



FIRST HEAVY ION BEAM ACCELERATION WITH A SUPERCONDUCTING MULTI GAP CH-CAVITY

W. Barth^{1,2}, K. Aulenbacher^{1,3}, M. Basten⁴, M. Busch⁴, F. Dziuba¹, V. Gettmann¹, M. Heilmann²,
T. Kürzeder¹, M. Miski-Oglu¹, H. Podlech⁴, A. Rubin², A. Schnase², M. Schwarz⁴, S. Yaramyshev²

¹ Helmholtz Institut Mainz, Germany

² GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany

³ Johannes Gutenberg-Universität Mainz, Mainz, Germany

⁴ IAP Goethe-Universität Frankfurt, Frankfurt, Germany



FIRST HEAVY ION BEAM ACCELERATION WITH A SUPERCONDUCTING MULTI GAP CH-CAVITY

W. Barth^{1,2}, K. Aulenbacher^{1,3}, M. Basten⁴, M. Busch⁴, F. Dziuba¹, V. Gettmann¹, M. Heilmann², T. Kürzeder¹, M. Miski-Oglu¹, H. Podlech⁴, A. Rubin², A. Schnase², M. Schwarz⁴, S. Yaramyshev²

¹ Helmholtz Institut Mainz, Germany

² GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany

³ Johannes Gutenberg-Universität Mainz, Mainz, Germany

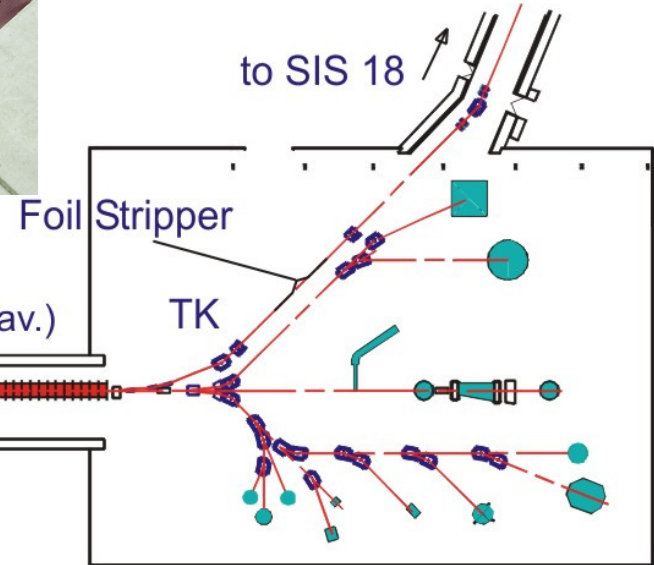
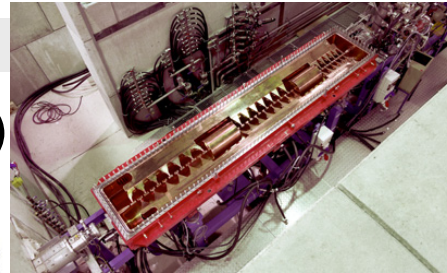
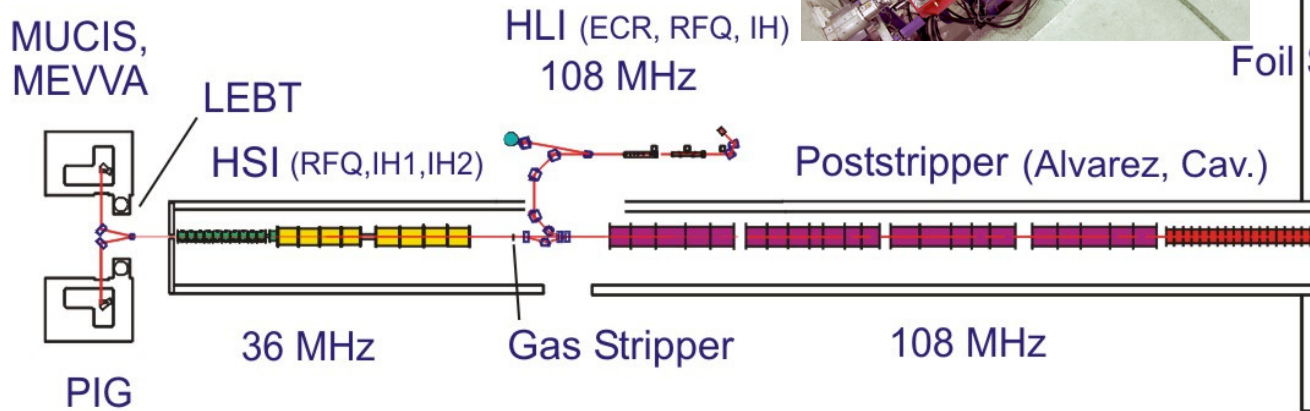
⁴ IAP Goethe-Universität Frankfurt, Frankfurt, Germany

1. Introduction
2. Cavity Development
3. CW-Linac layout
4. R&D activities
5. Heavy ion beam test at cw-Linac Demonstrator
6. Further R&D und Outlook

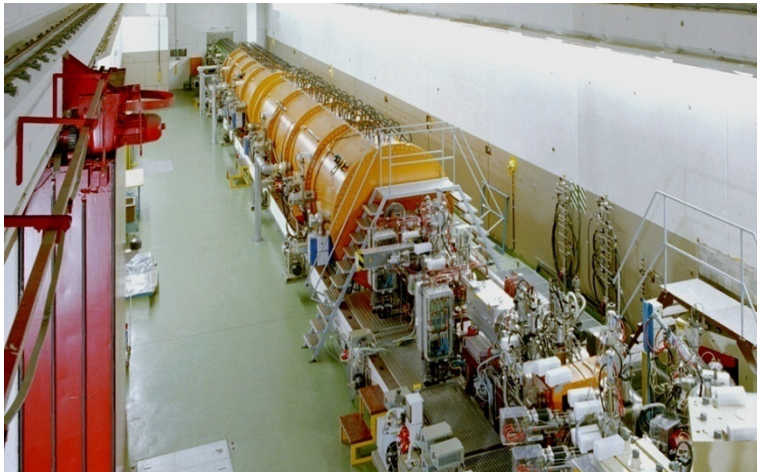
Introduction

GSI UNIversal Linear ACcelerator

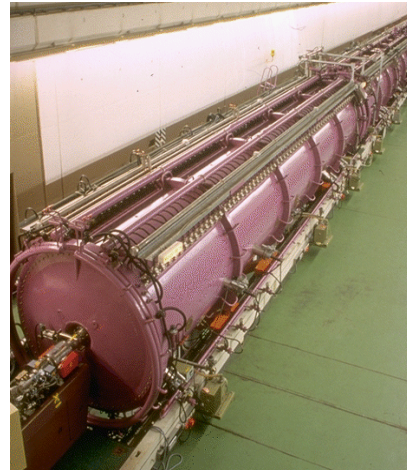
High Charge State Injector(1991)



High Current Injector (1999)



Alvarez (1975)



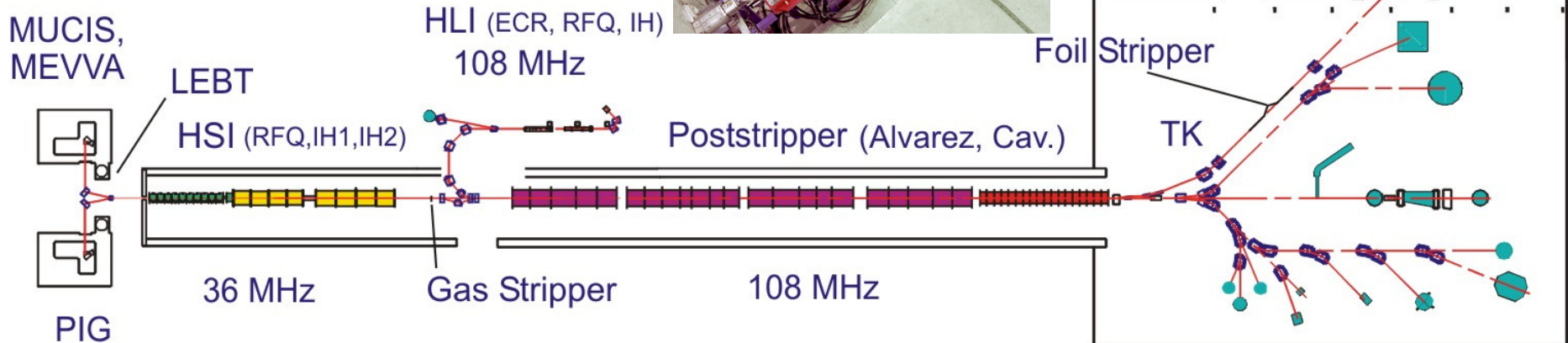
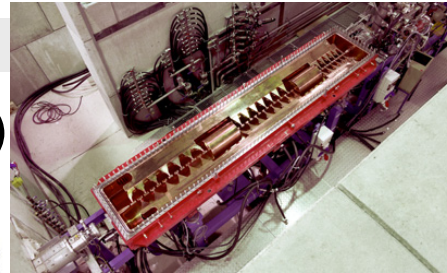
Single Gap Resonators (1975)



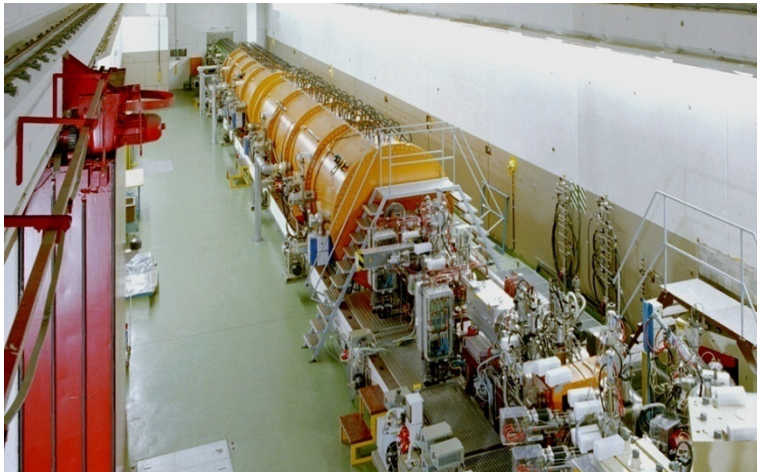
Introduction

GSI UNIversal Linear ACcelerator

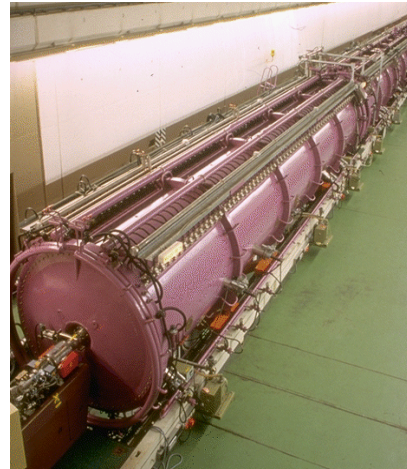
High Charge State Injector(1991)



High Current Injector (1999)



Alvarez (1975)



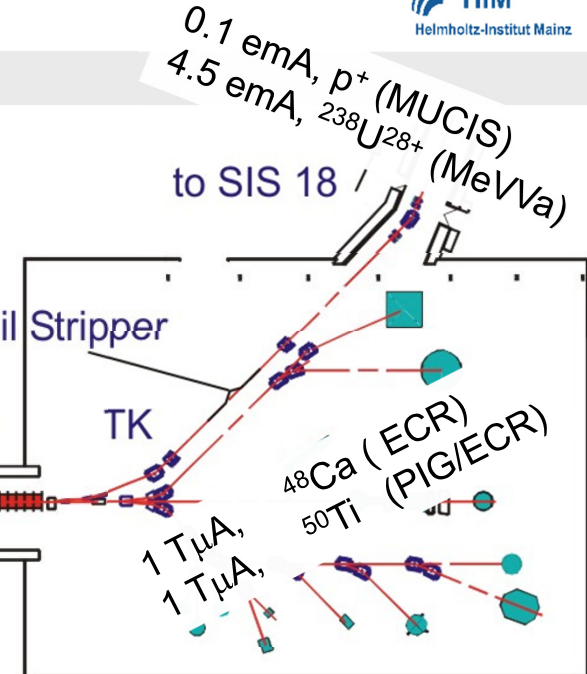
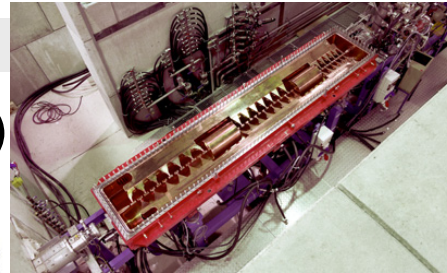
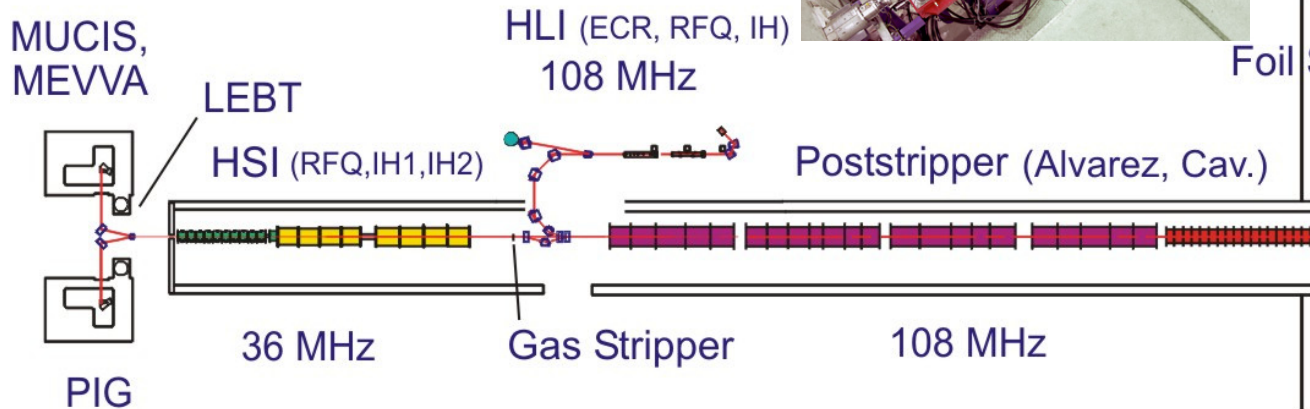
Single Gap Resonators (1975)



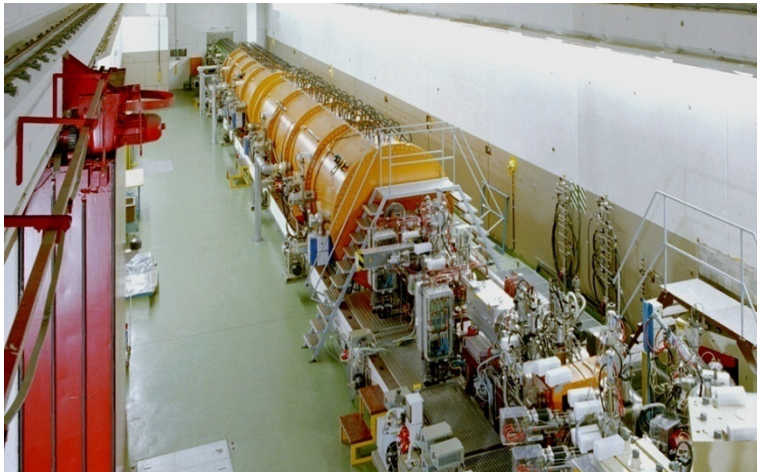
Introduction

GSI UNIversal Linear ACcelerator

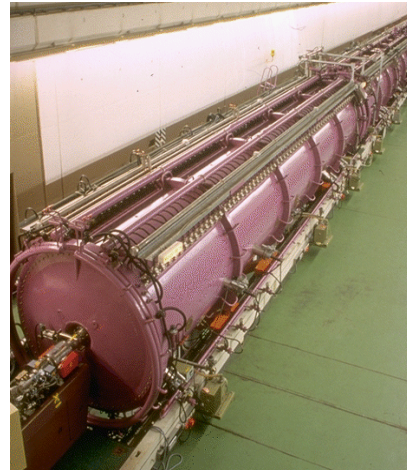
High Charge State Injector (1991)



High Current Injector (1999)



Alvarez (1975)

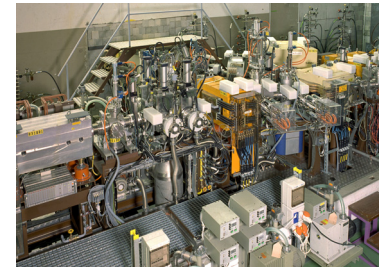
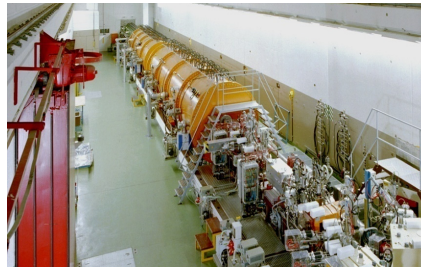
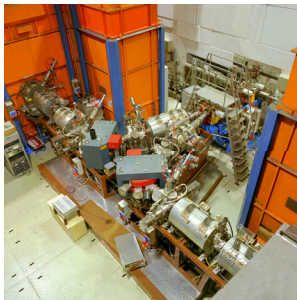


Single Gap Resonators (1975)

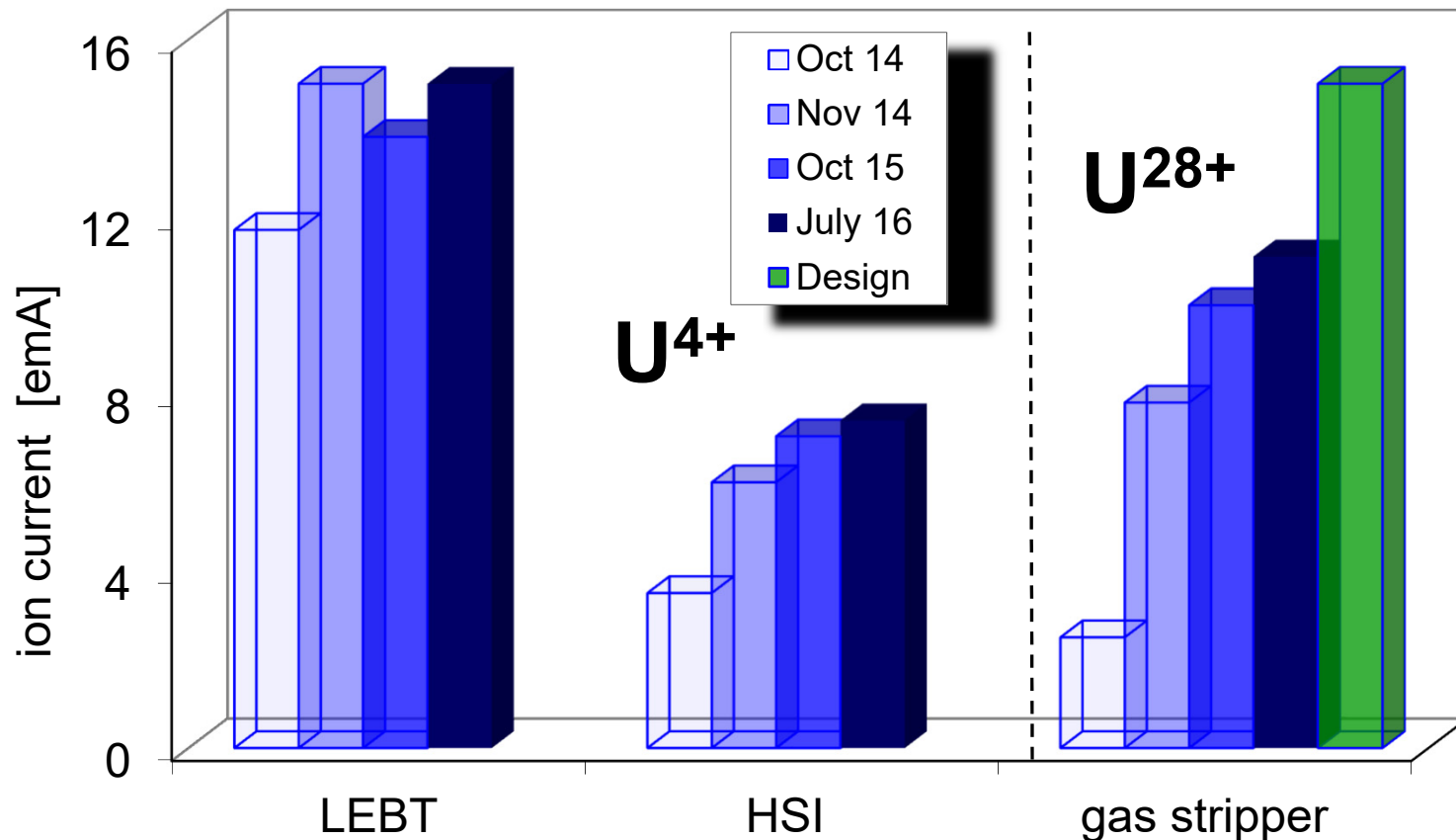


Status “UNILAC Uran-High Current”

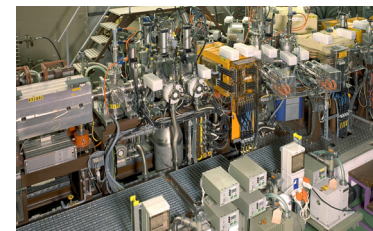
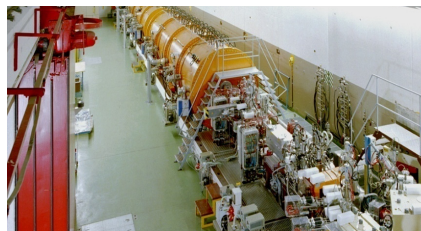
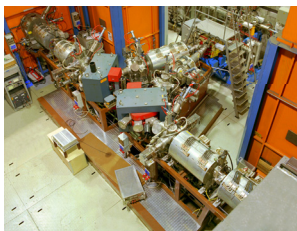
W. Barth, et al., Phys.
Rev. ST Accel. & Beams
20, 050101 (2017)



Status “UNILAC Uran-High Current”



W. Barth, et al., Phys.
Rev. ST Accel. & Beams
20, 050101 (2017)



FAIR:

- high beam currents
- low repetition rate (max. 3 Hz)
- low duty factor (0.1 %, pulse length for SIS18 only 100 μ s)



FAIR:

- high beam currents
- low repetition rate (max. 3 Hz)
- low duty factor (0.1 %, pulse length for SIS18 only 100 μ s)

“Super Heavy Element”:

- relatively low beam currents
- high repetition rate (50 Hz)
- high duty factor (100 %, pulse length up to 20 ms)



FAIR:

- high beam currents
- low repetition rate (max. 3 Hz)
- low duty factor (0.1 %, pulse length for SIS18 only 100 μ s)

“Super Heavy Element”:

- relatively low beam currents
- high repetition rate (50 Hz)
- high duty factor (100 %, pulse length up to 20 ms)

“Material Science”:

- Heavy Ions ($m \geq 200$)
- High Beam Energy (up to 10 MeV/u)
- Continuous Beam Energy Variation (1.5 – 10 MeV/u)



cw-LINAC-project: Motivation and Design-Parameter

- Nuclear reactions at the Coulomb-barrier → production of Super Heavy Elements (SHE)
- Operation mode cw
- Mass / Charge 6
- Beam current ≤ 1 emA
- Injection energy 1.4 MeV/u
- Output energy 3.5 - 7.3 MeV/u

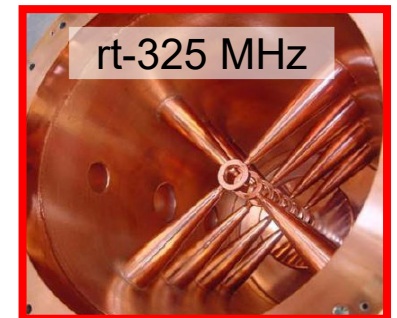
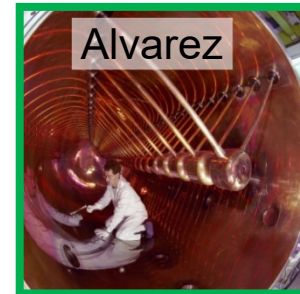
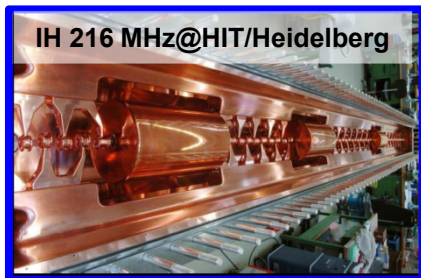
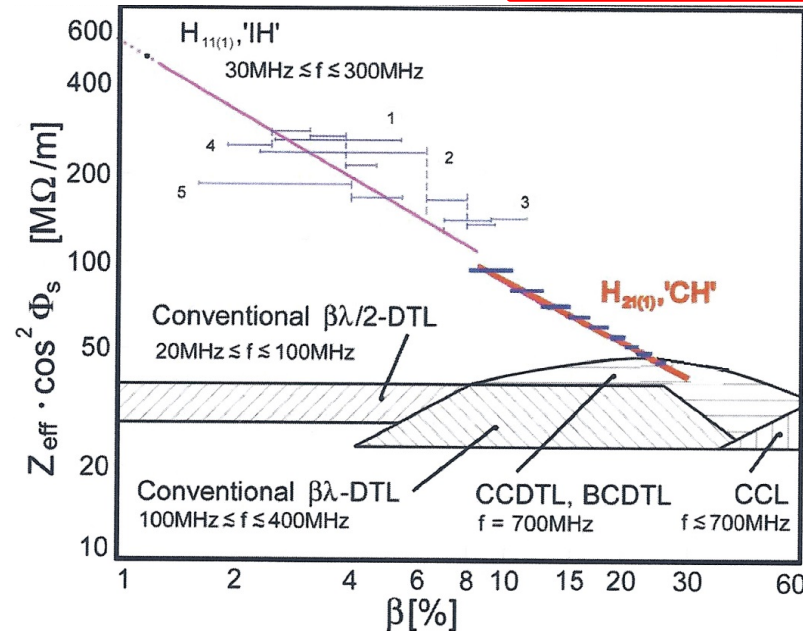
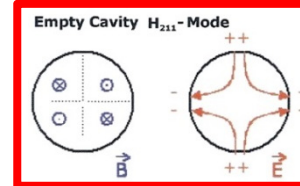
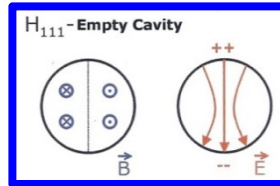
Production of Element ${}_{115}^{288}\text{uut}$, ${}_{115}^{289}\text{uut}$, 30 *events*

(D. Rudolph, Lund Univ., PRL 111, 112502 (2013))

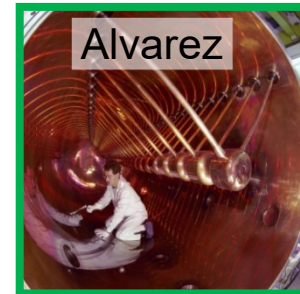
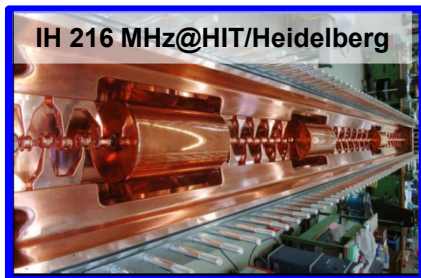
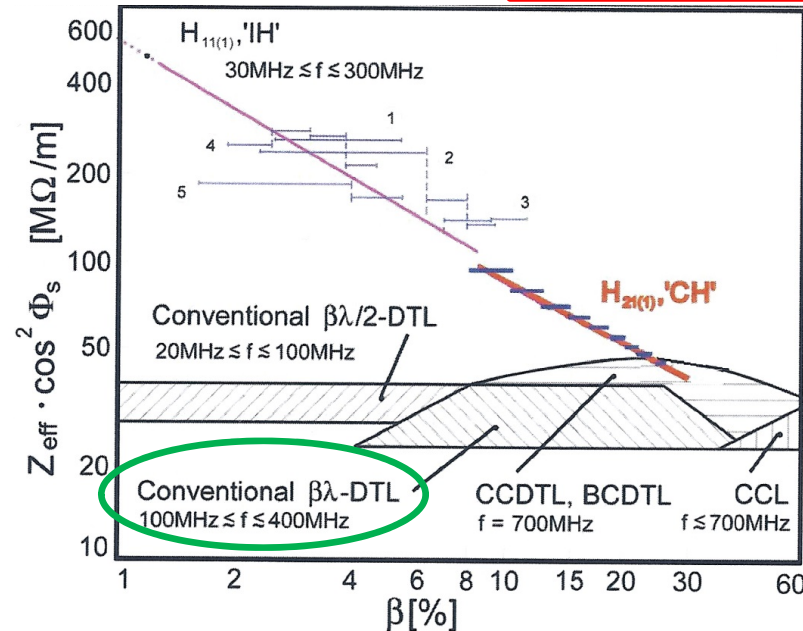
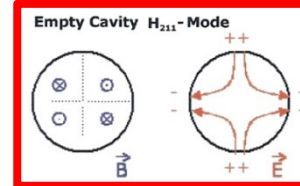
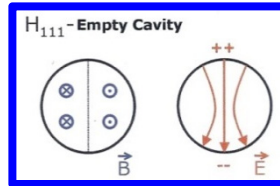
	GSI- Unilac	cw-Linac
Beam intensity (particle/s)	$6 \cdot 10^{12}$	$6 \cdot 10^{13}$
Beam on target	3 weeks	2 days



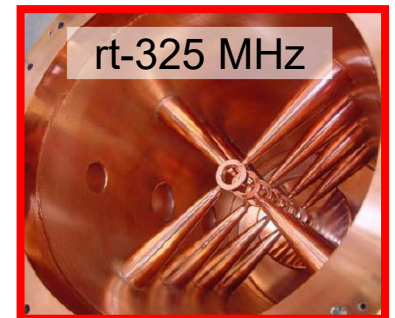
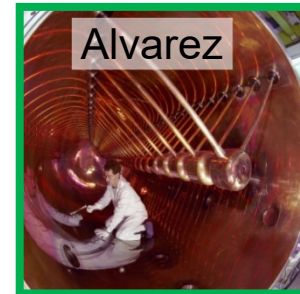
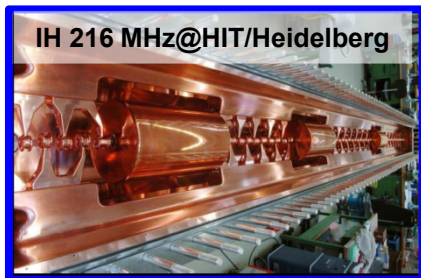
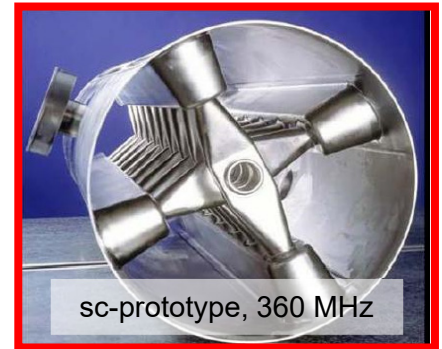
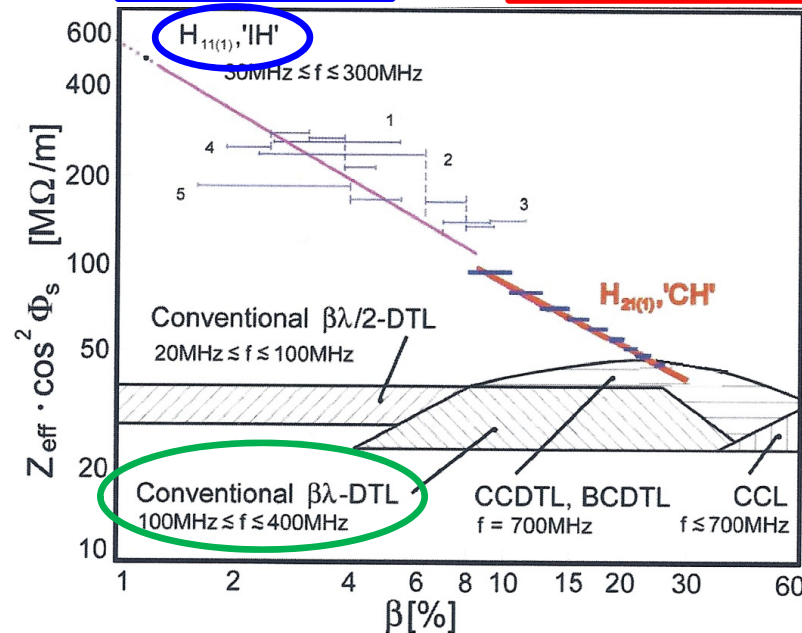
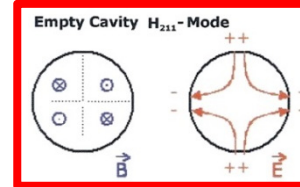
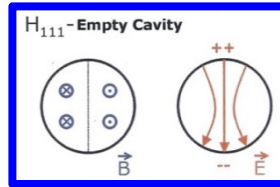
H-type Cavity developments



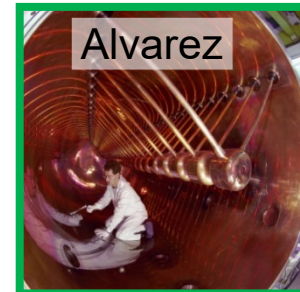
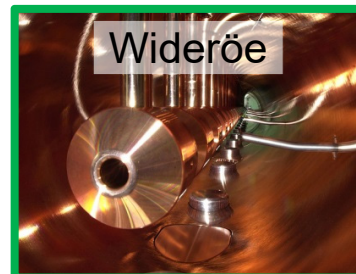
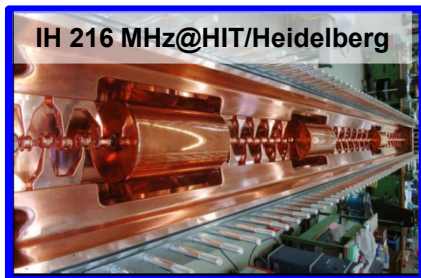
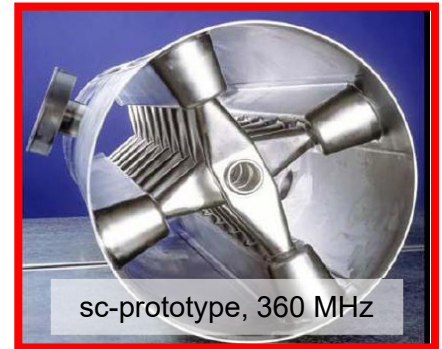
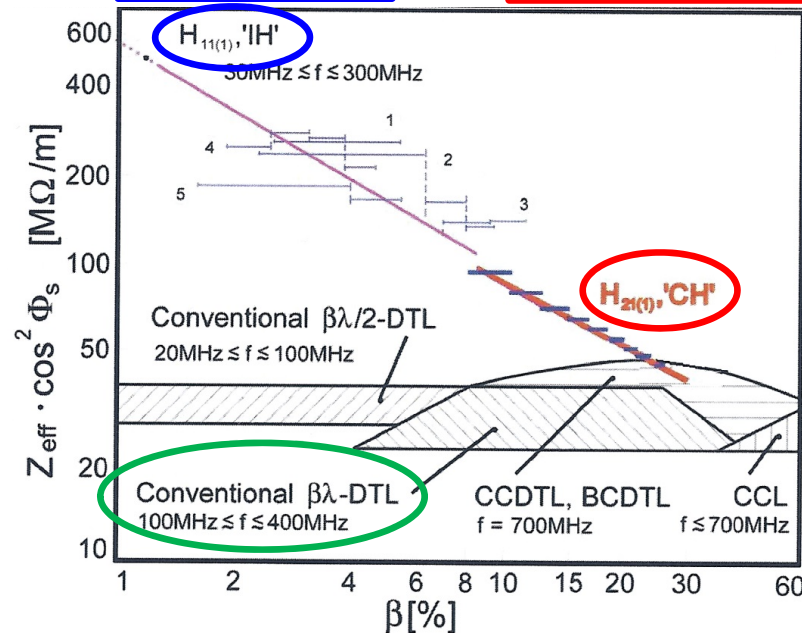
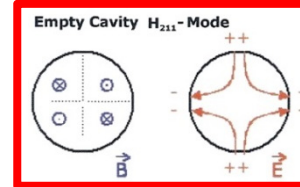
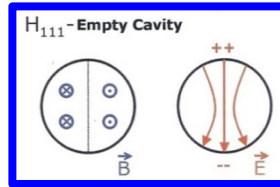
H-type Cavity developments



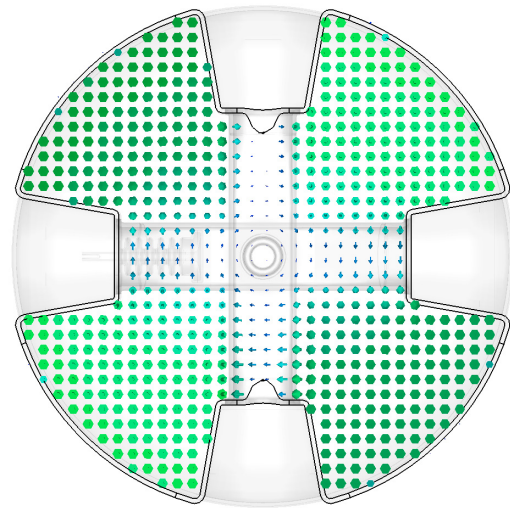
H-type Cavity developments



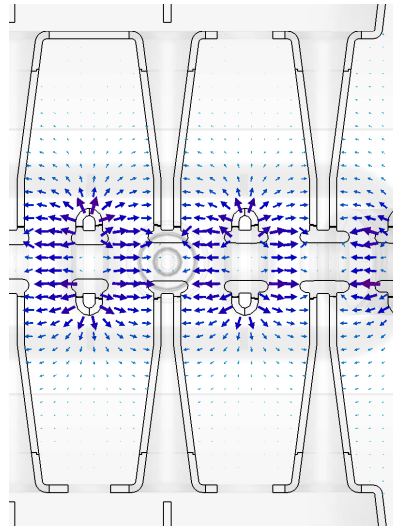
H-type Cavity developments



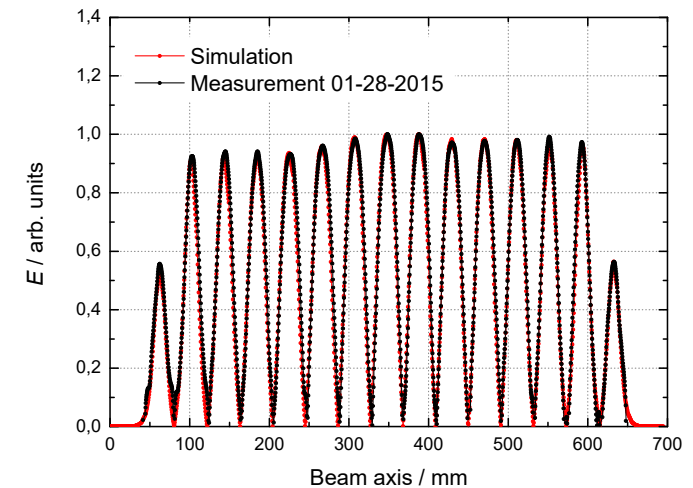
H field



E field



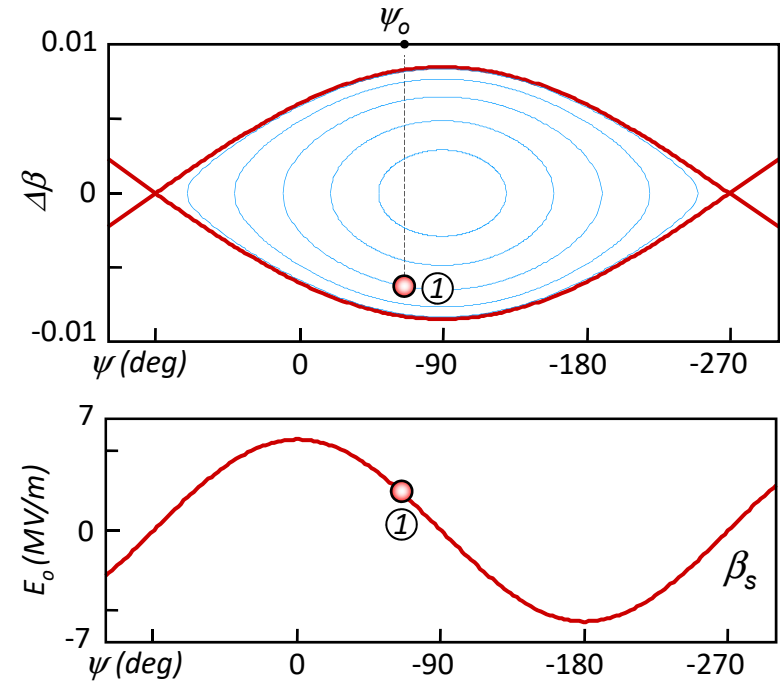
E field along beam axis



- Multigap drift tube cavity for the acceleration of protons and ions in the low and medium energy range
- Drift tubes are alternating connected to “+” and “-” potential
- **Cross-bar-H-mode** cavity → CH cavity
- Equidistant drift tubes length → special beam dynamics

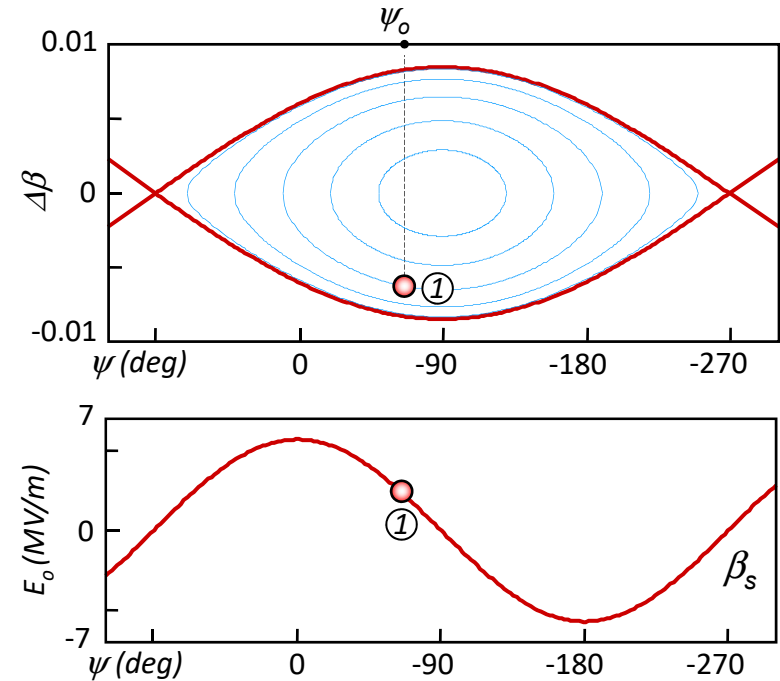
EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section



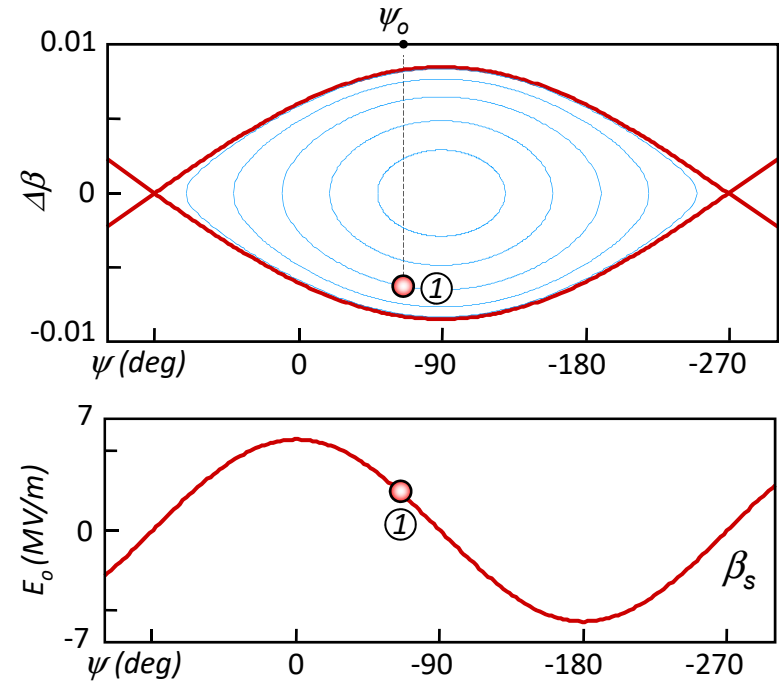
EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section



EQUUS - EQUidistant mUltigap Structure

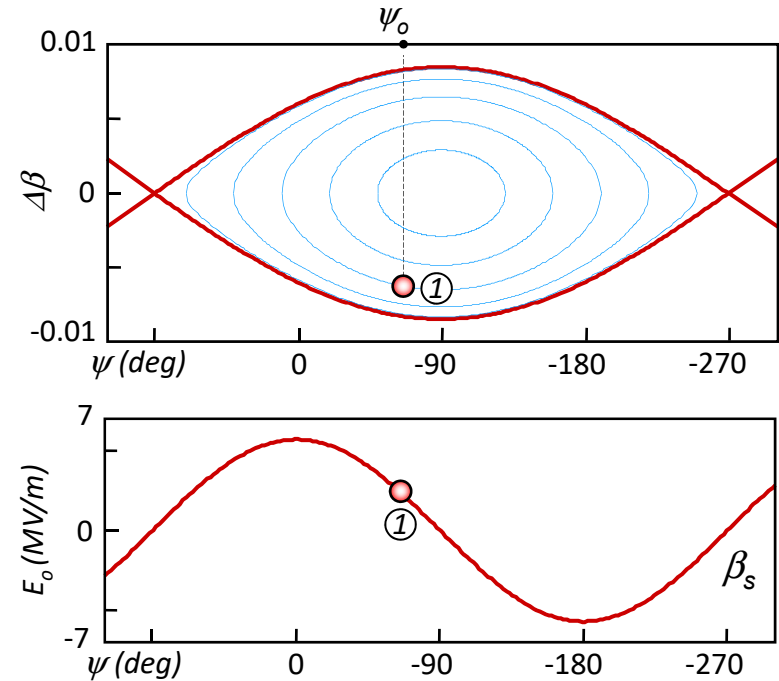
Longitudinal motion of an accelerated bunch in the constant- β -section



EQUUS

EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

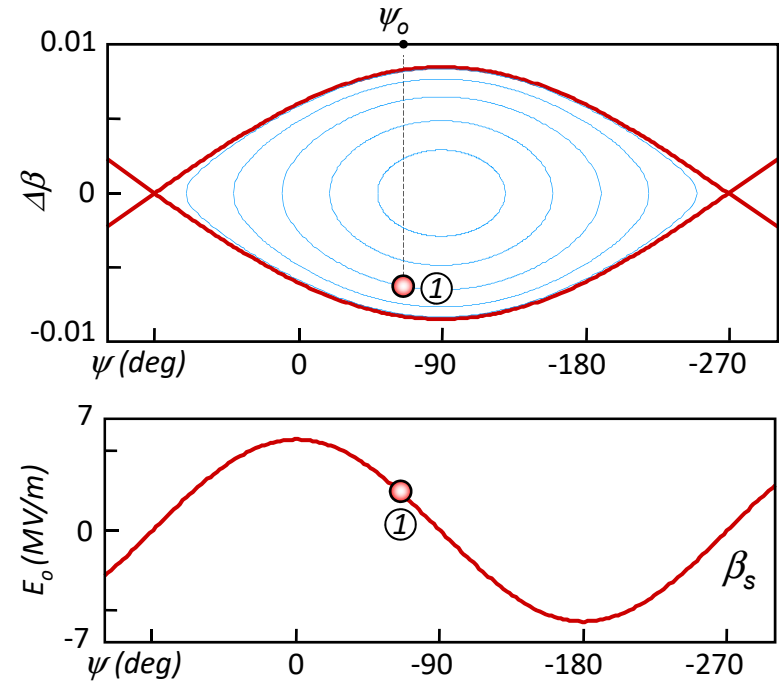


EQUUS



EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

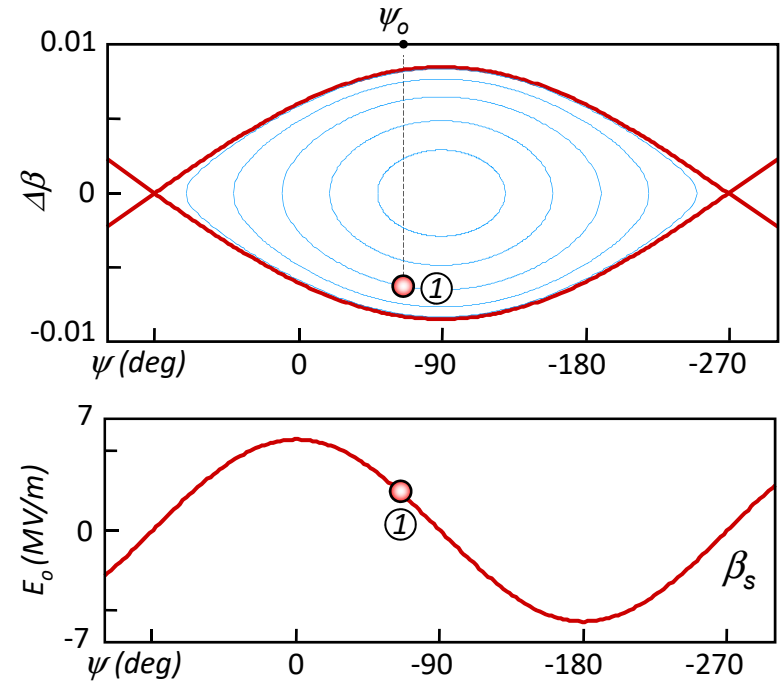


EQUUS



EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section



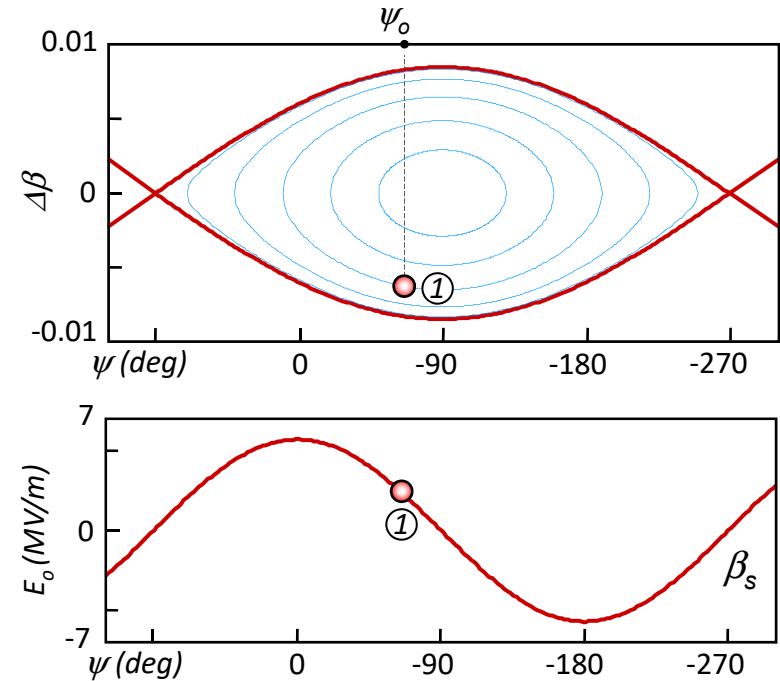
EQUUS

①

○

EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section



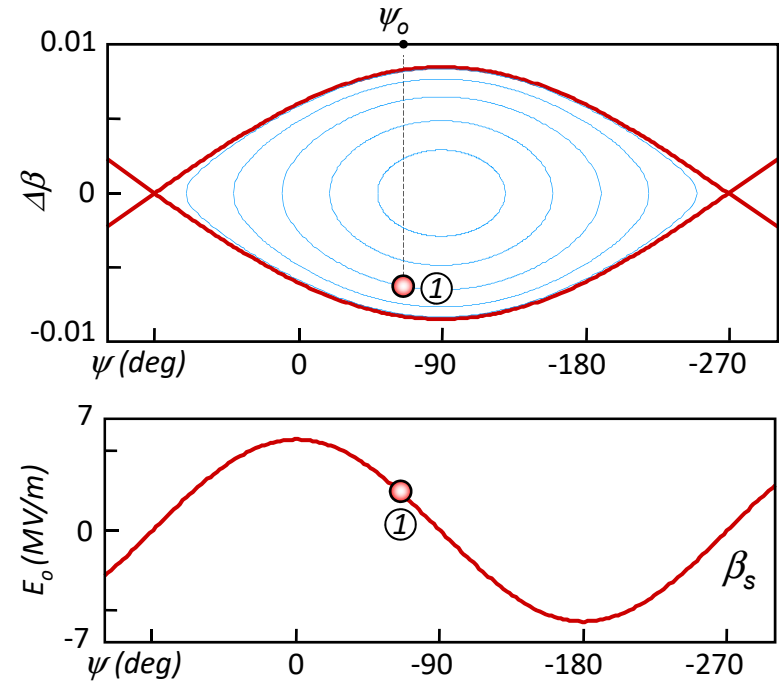
EQUUS

①

○

EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section



EQUUS

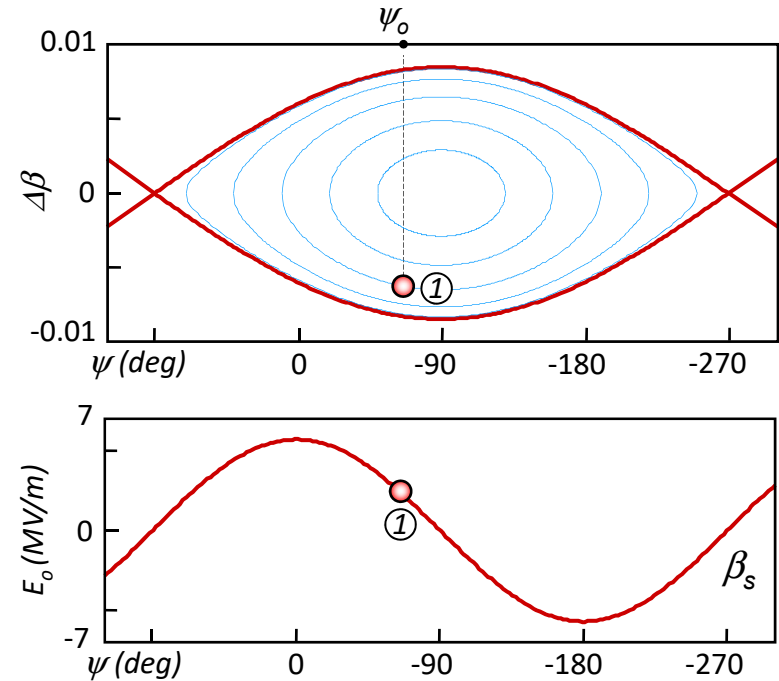
①

○



EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section



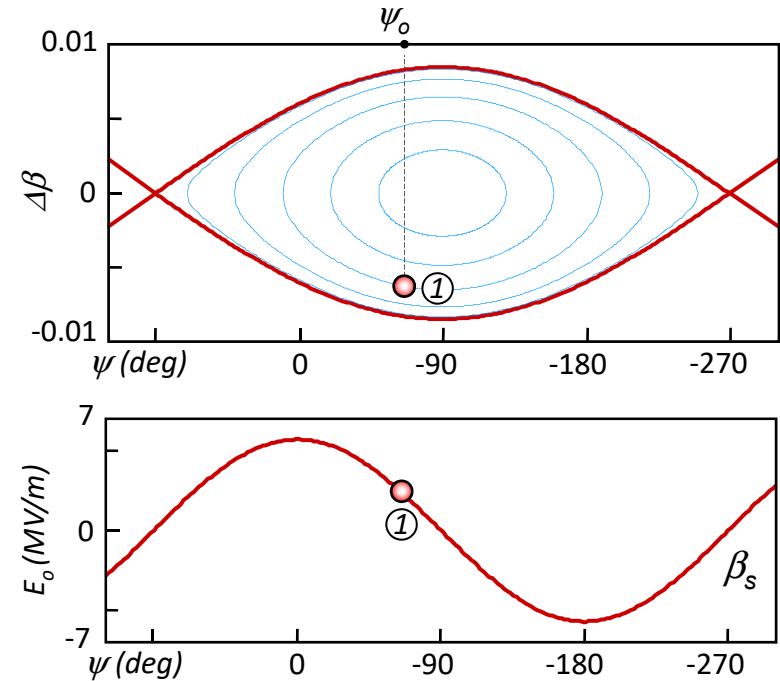
EQUUS

①



EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section



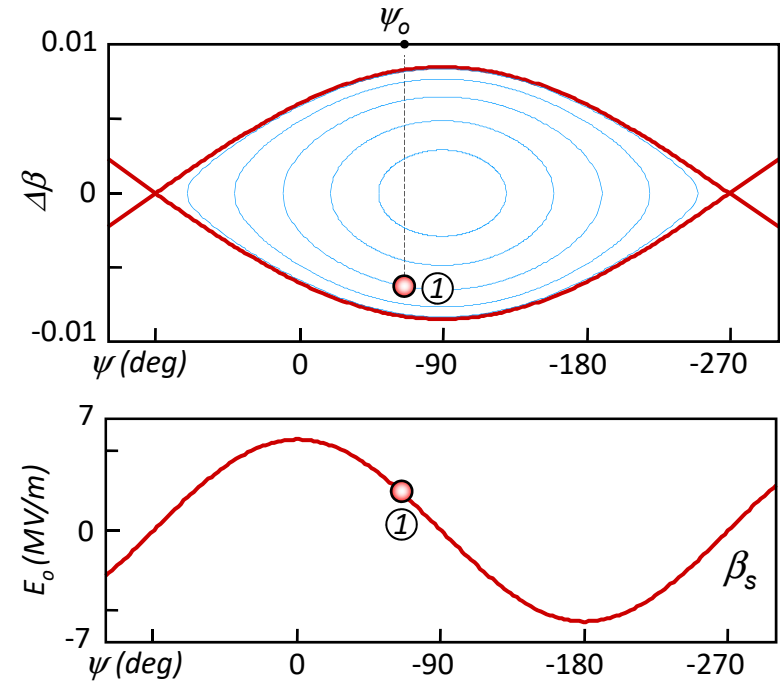
EQUUS

①

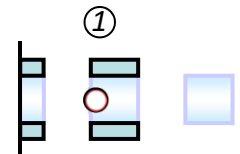


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

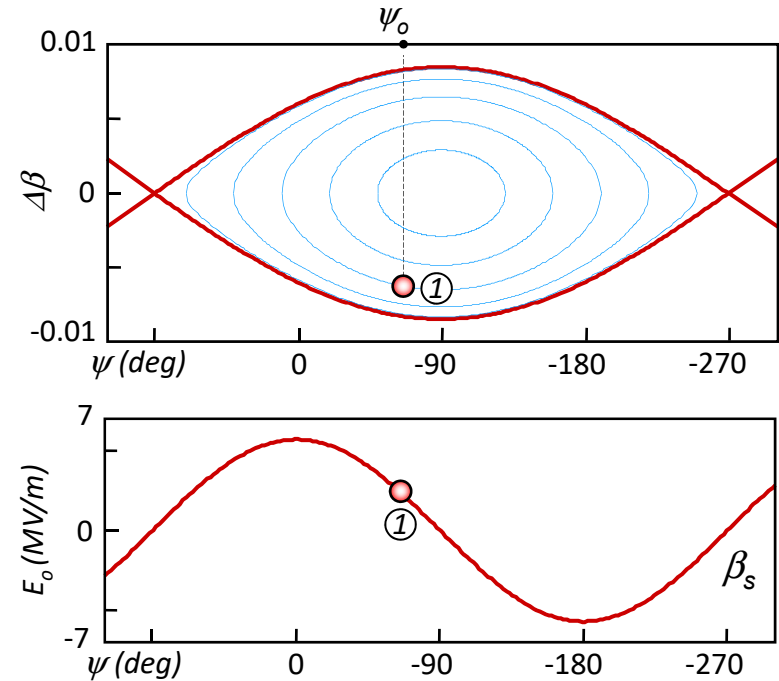


EQUUS



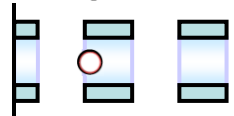
EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section



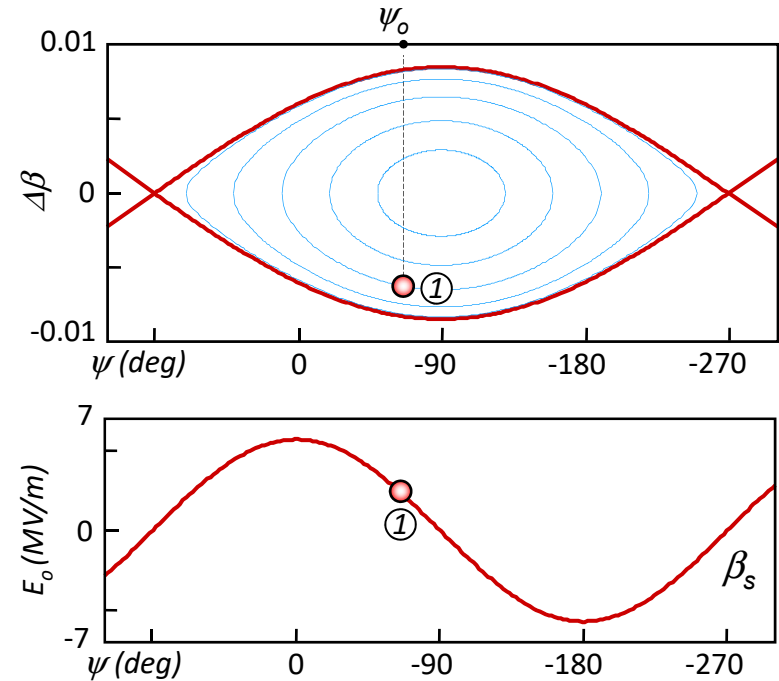
EQUUS

①

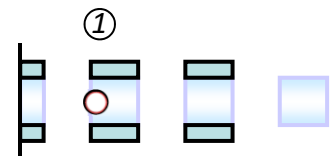


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

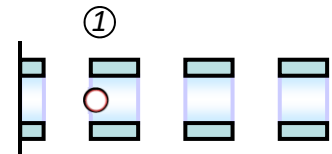


EQUUS

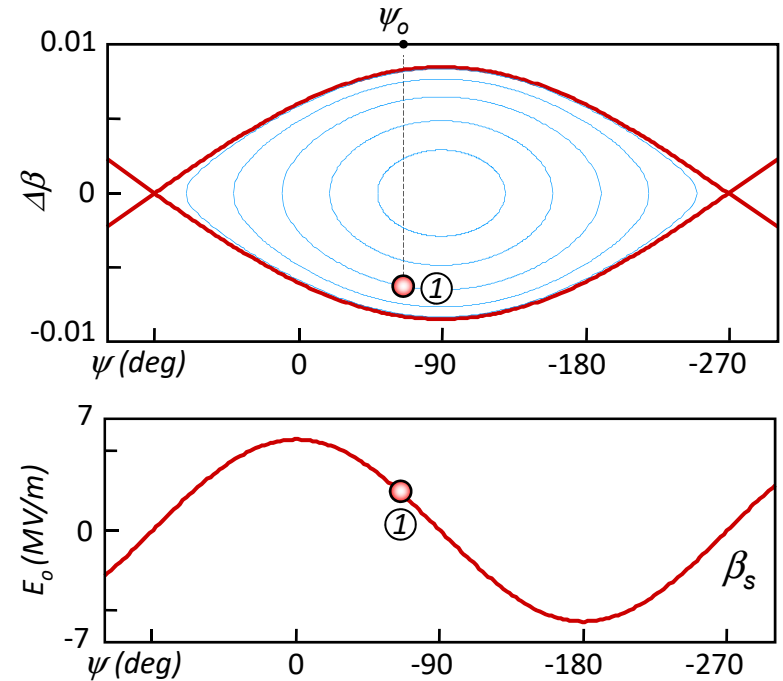


EQUUS - EQUidistant mUltigap Structure

EQUUS

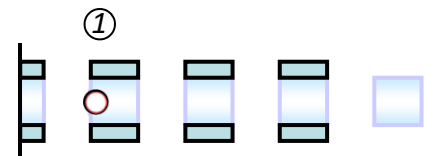


Longitudinal motion of an accelerated bunch in the constant- β -section

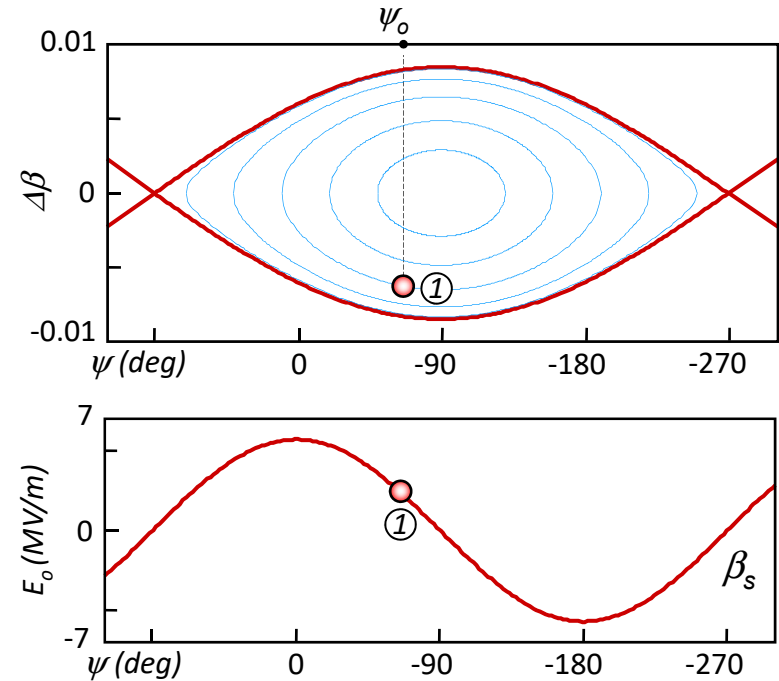


EQUUS - EQUidistant mUltigap Structure

EQUUS

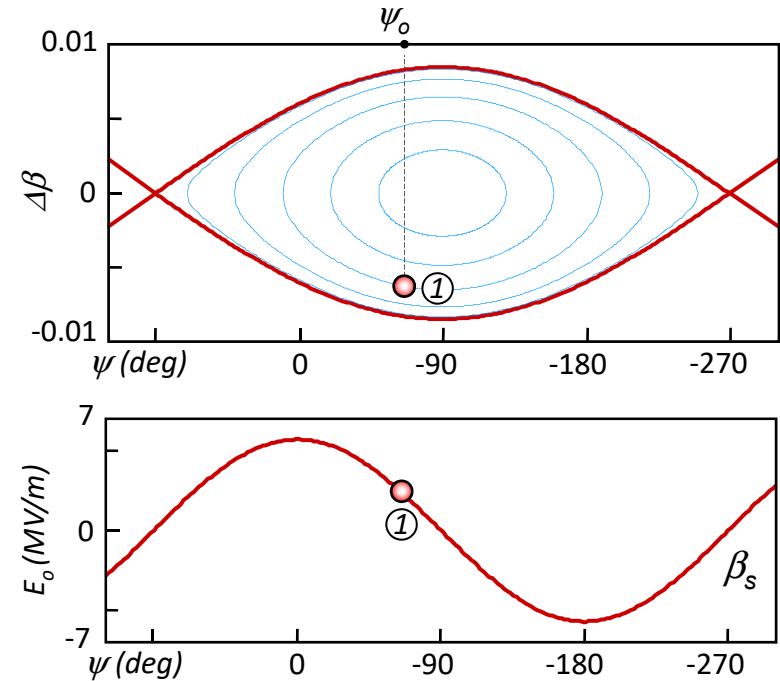


Longitudinal motion of an accelerated bunch in the constant- β -section



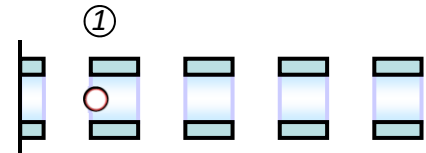
EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section



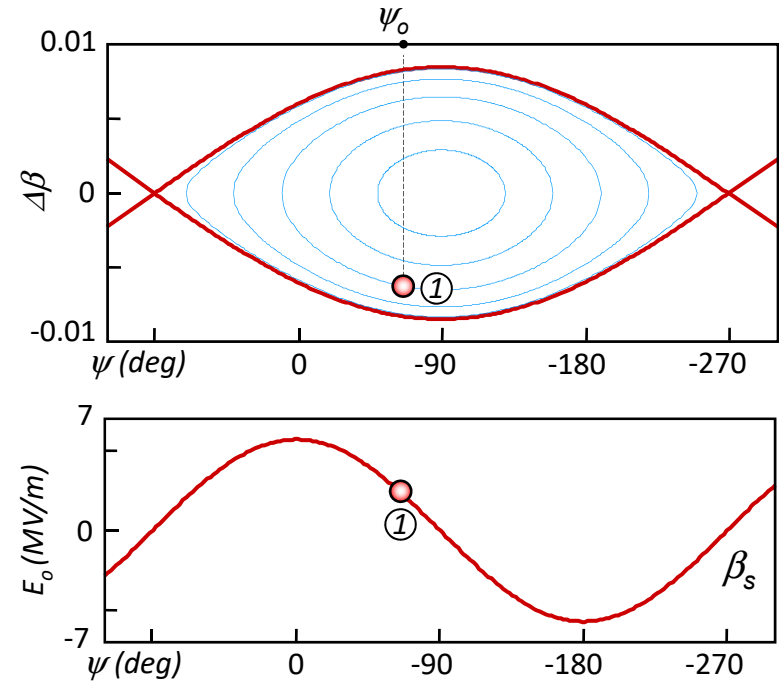
EQUUS

①

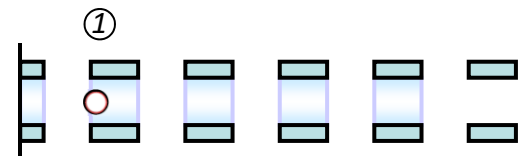


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

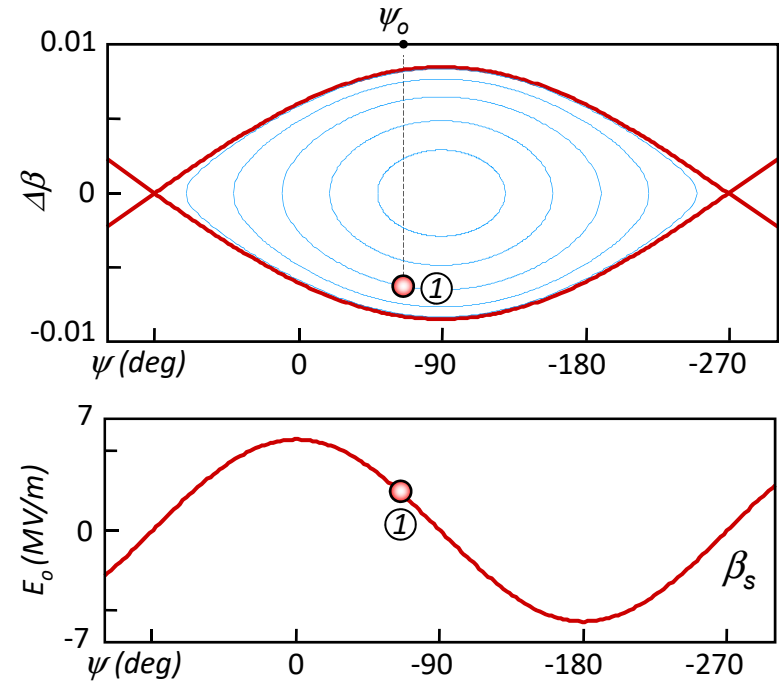


EQUUS

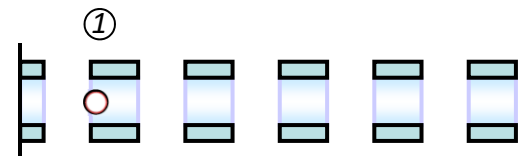


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

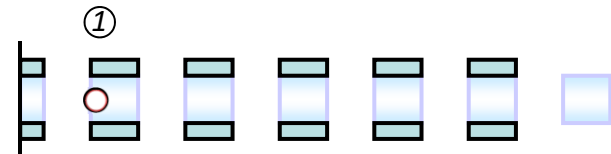


EQUUS

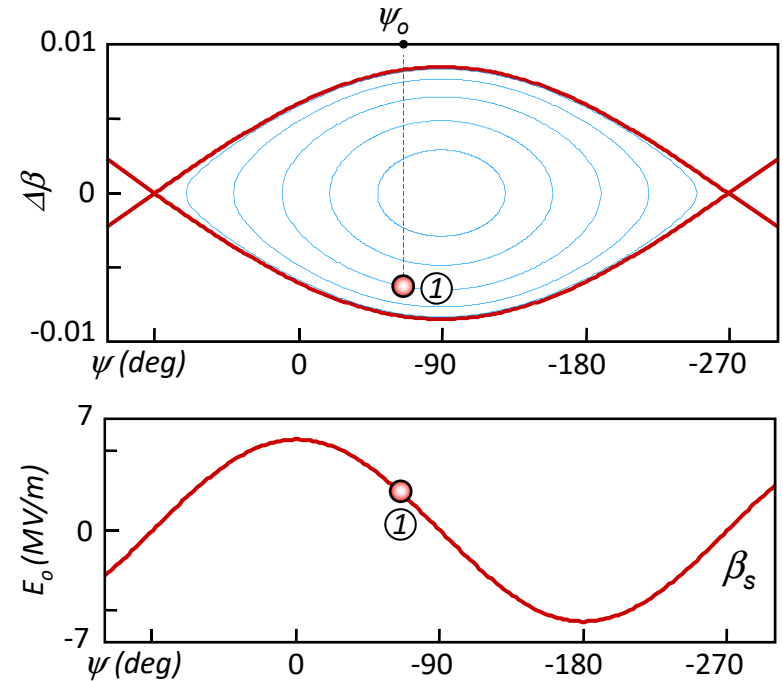


EQUUS - EQUidistant mUltigap Structure

EQUUS

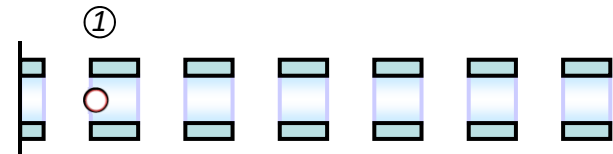


Longitudinal motion of an accelerated bunch in the constant- β -section

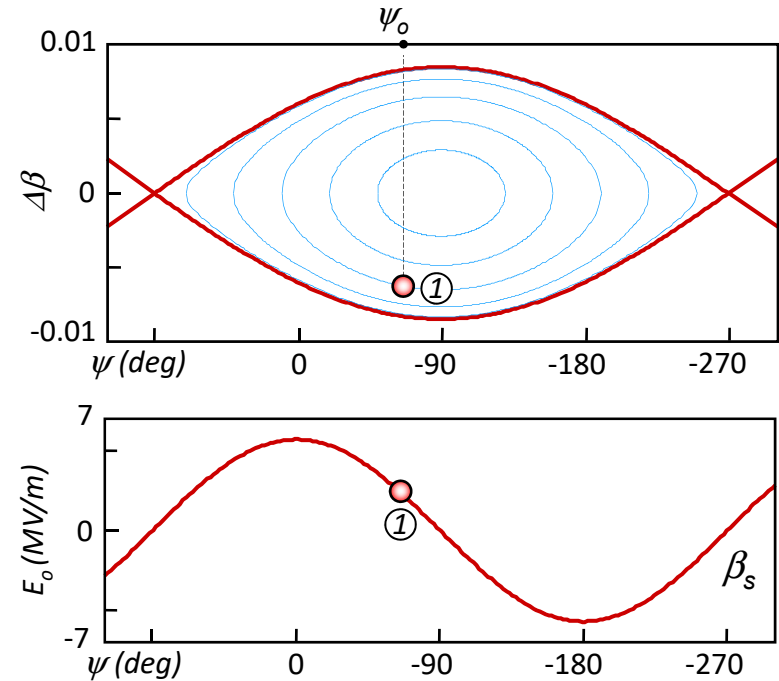


EQUUS - EQuidistant mUltigap Structure

EQUUS

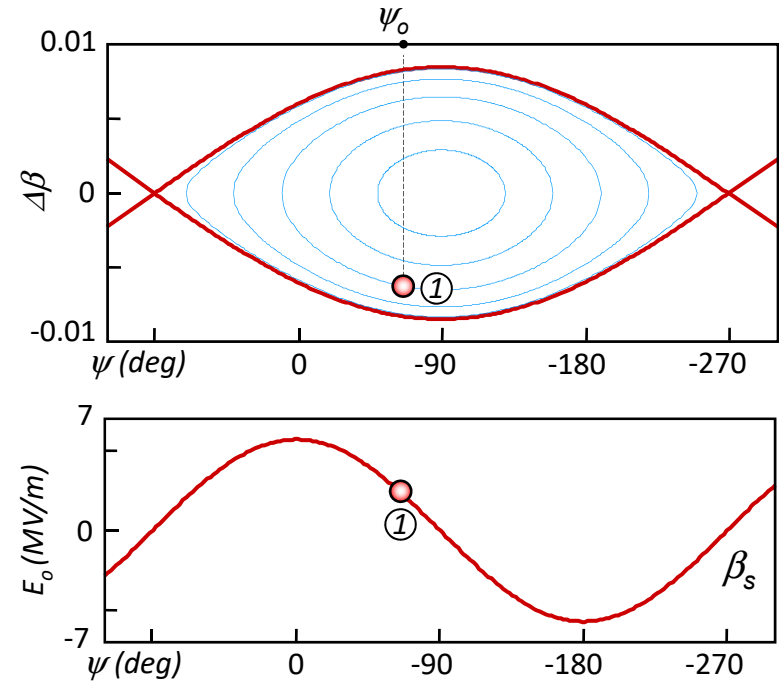


Longitudinal motion of an accelerated bunch in the constant- β -section

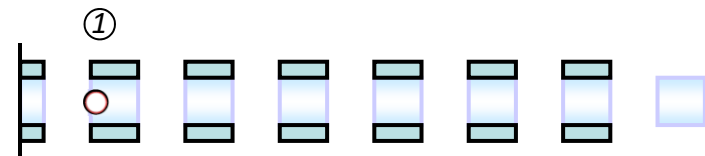


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

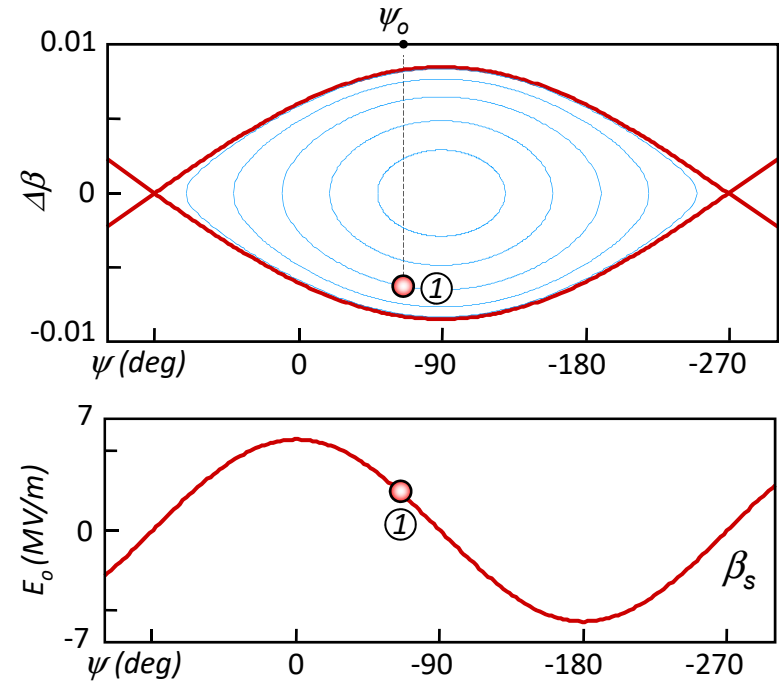


EQUUS



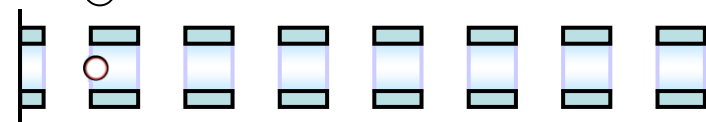
EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section



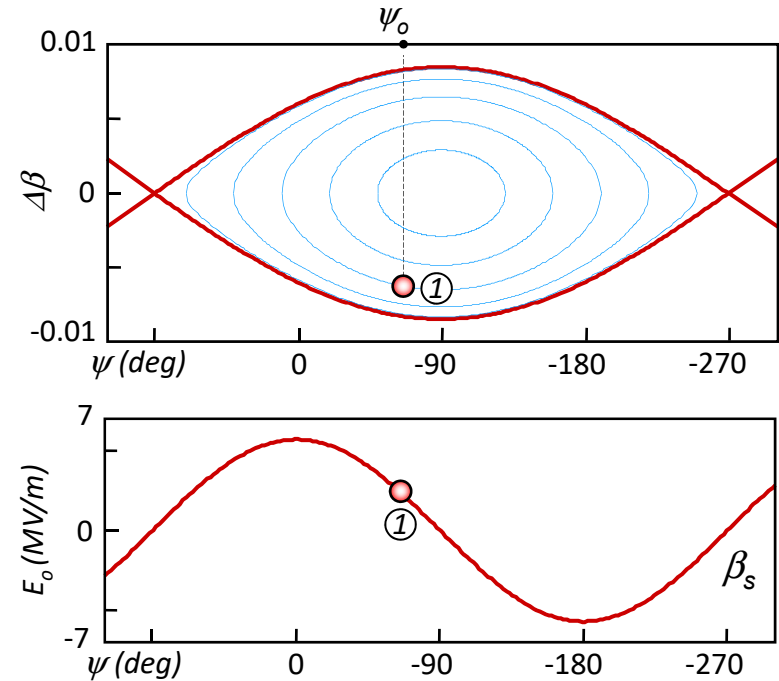
EQUUS

①

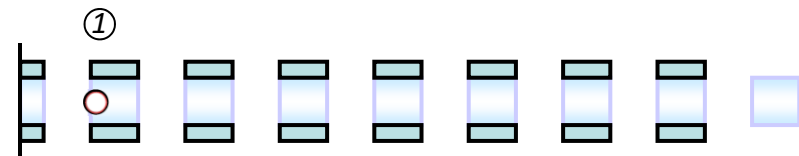


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

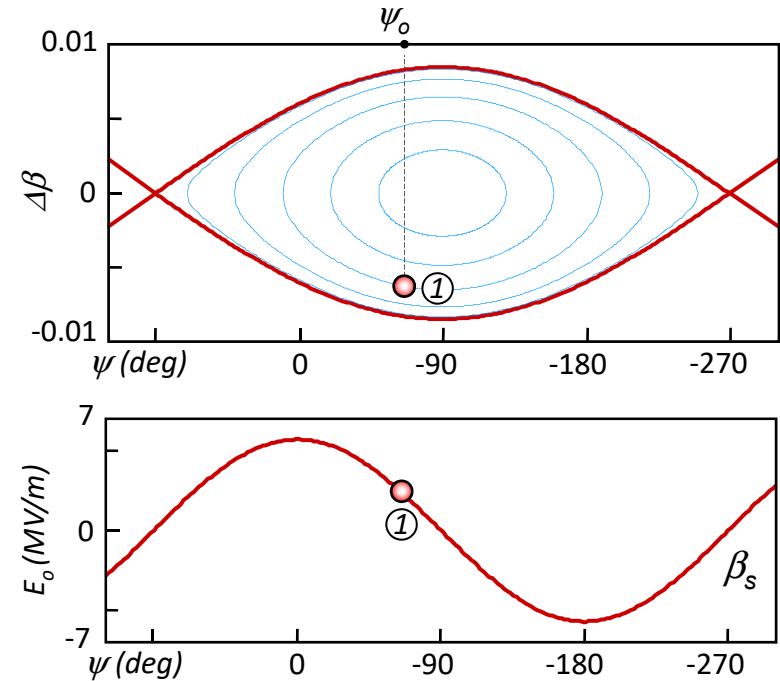


EQUUS



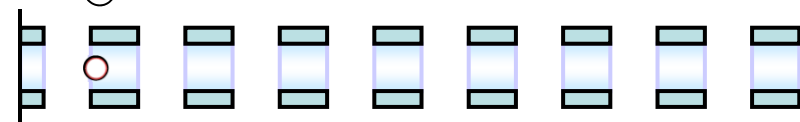
EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section



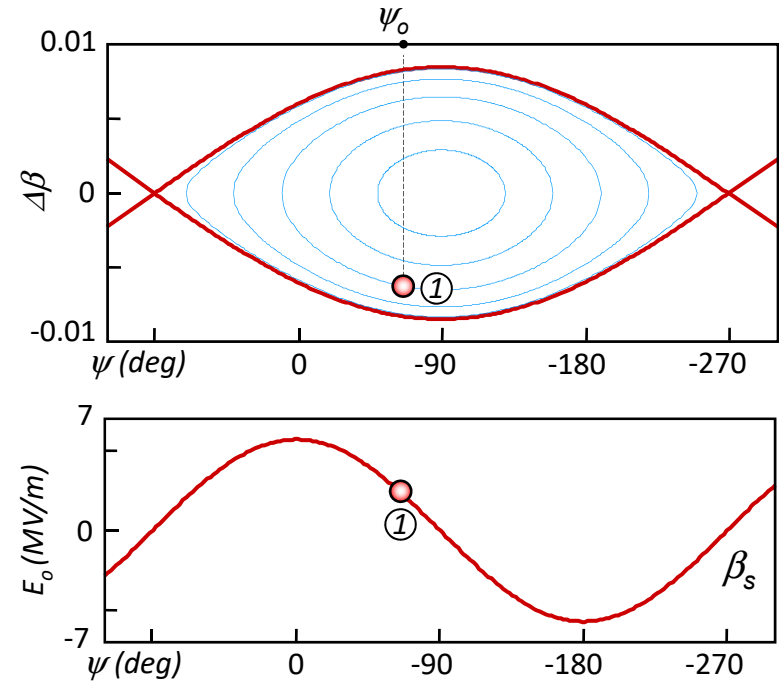
EQUUS

①

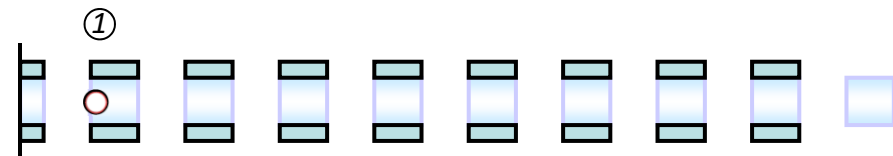


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

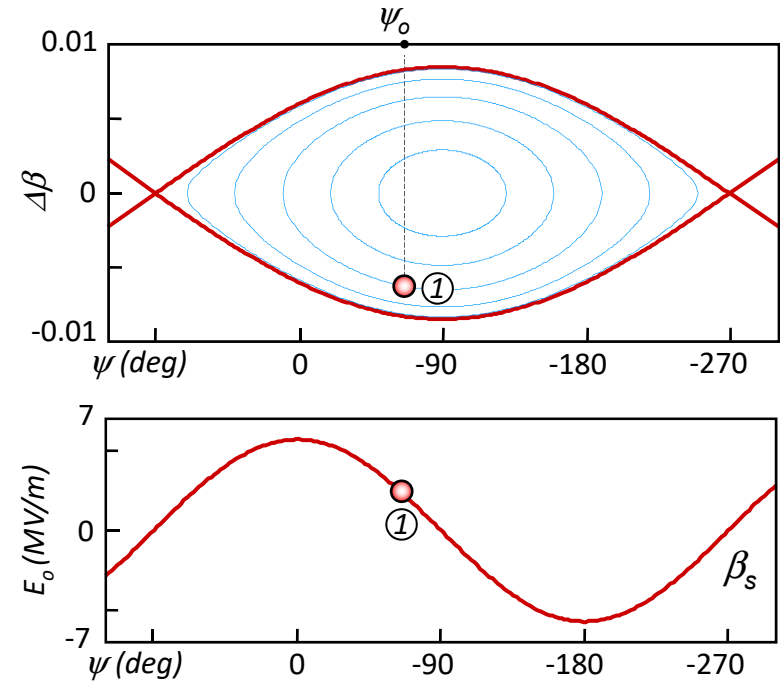


EQUUS



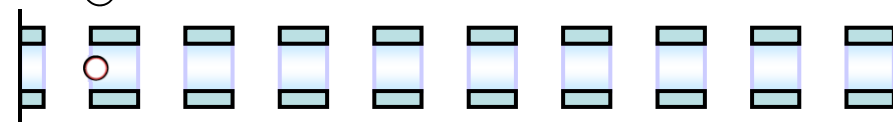
EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section



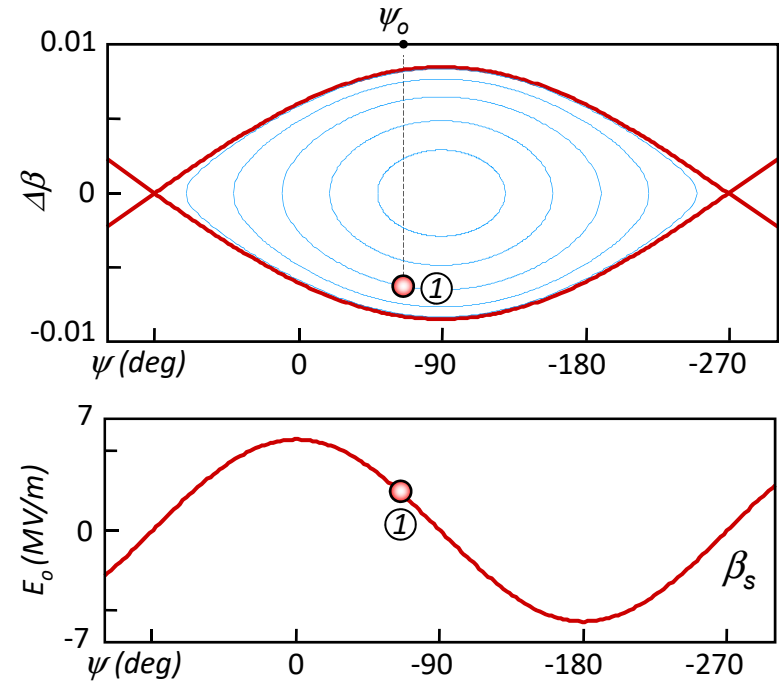
EQUUS

①

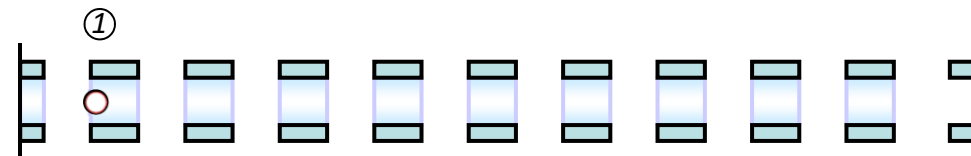


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

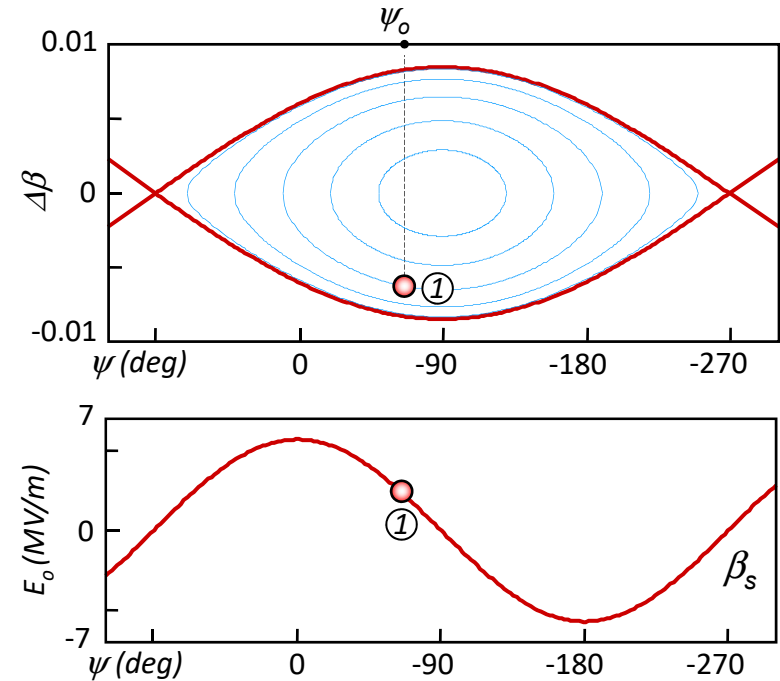


EQUUS



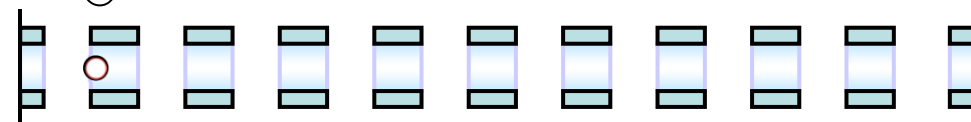
EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section



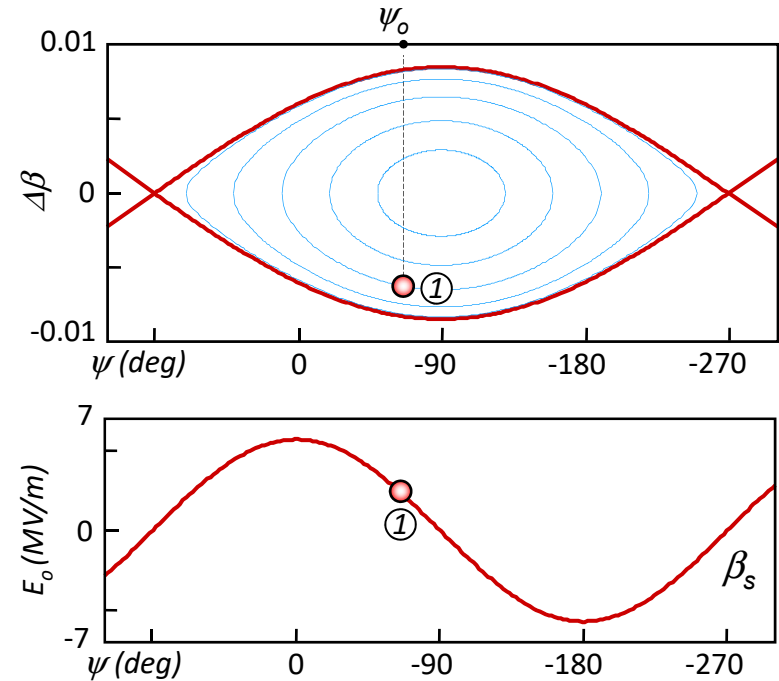
EQUUS

①

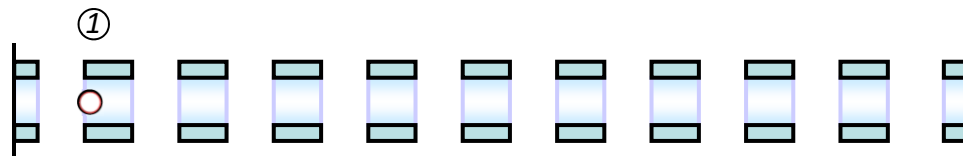


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

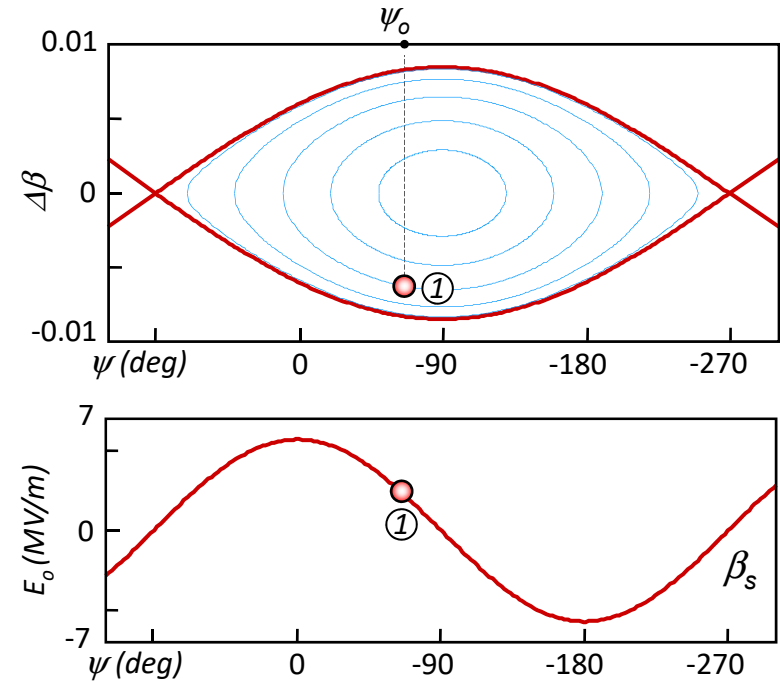


EQUUS

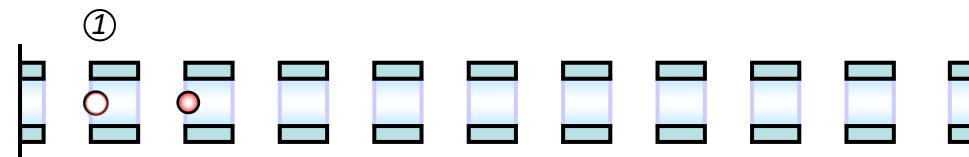


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

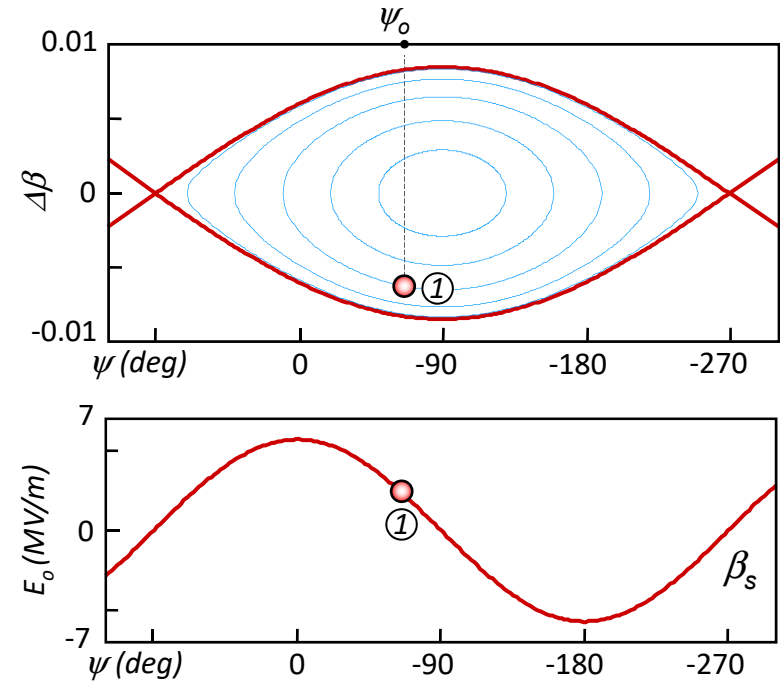


EQUUS

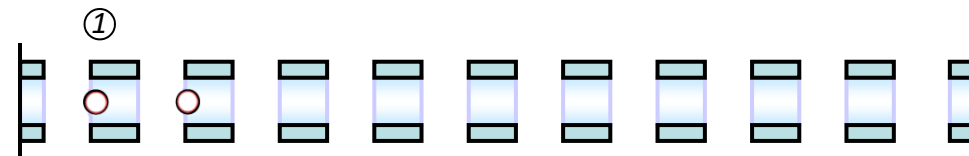


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

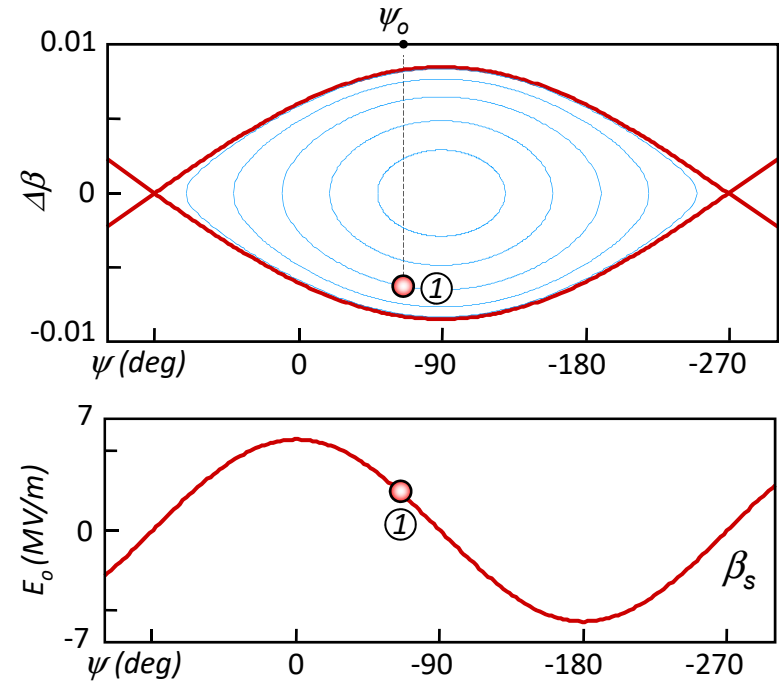


EQUUS

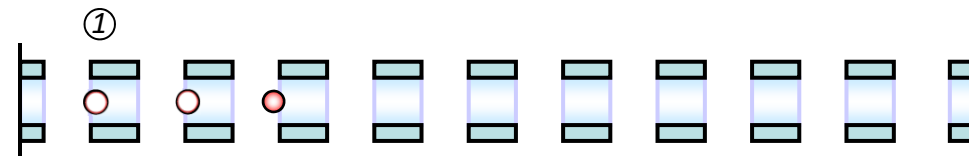


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

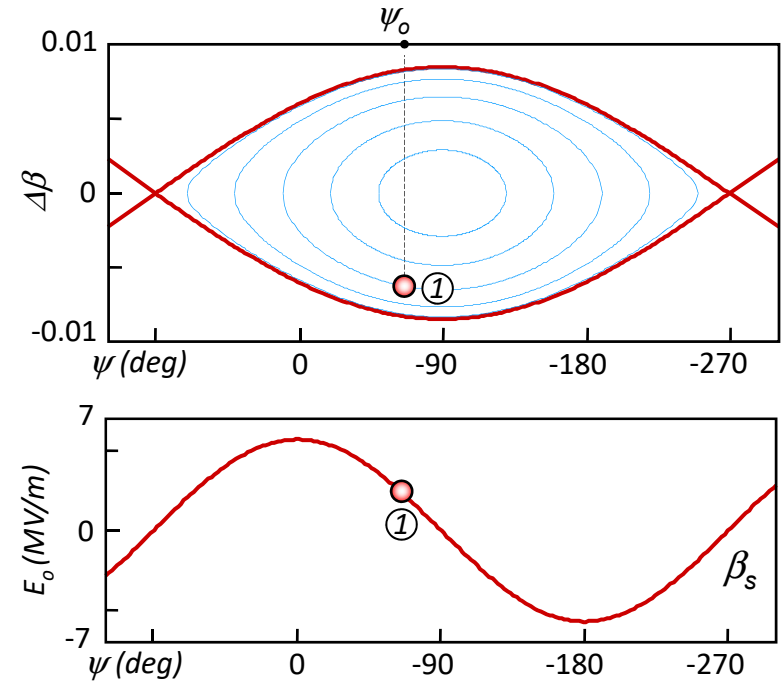


EQUUS

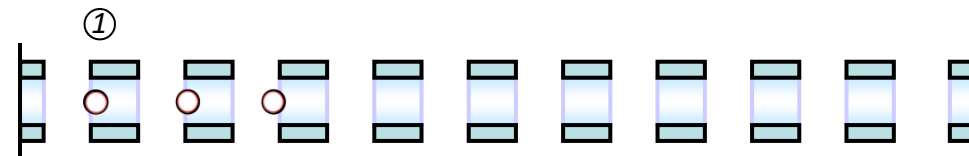


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

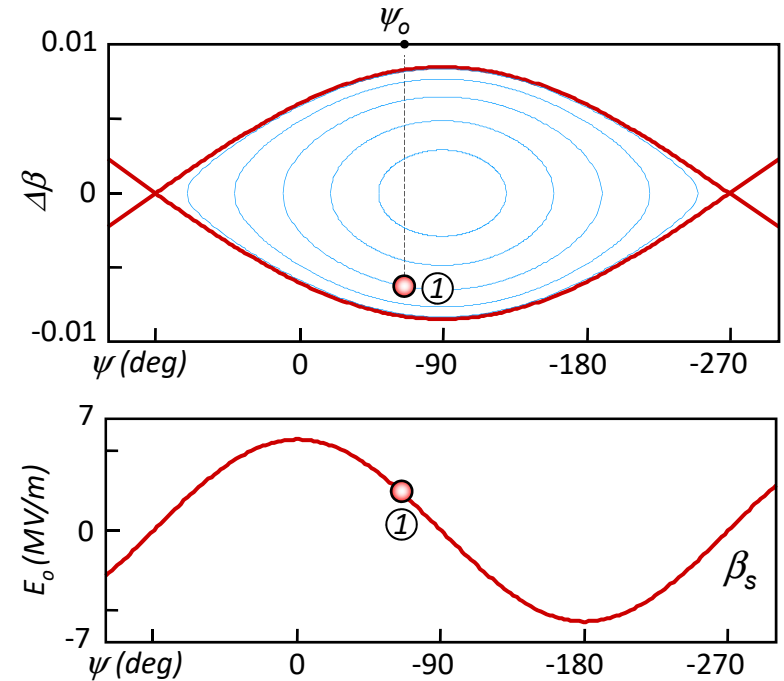


EQUUS

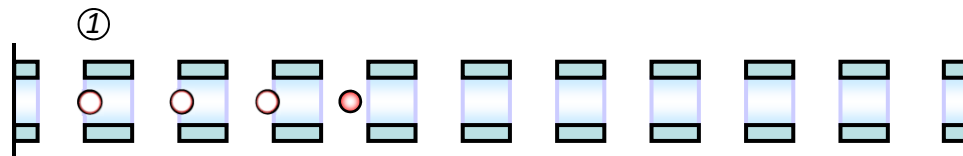


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

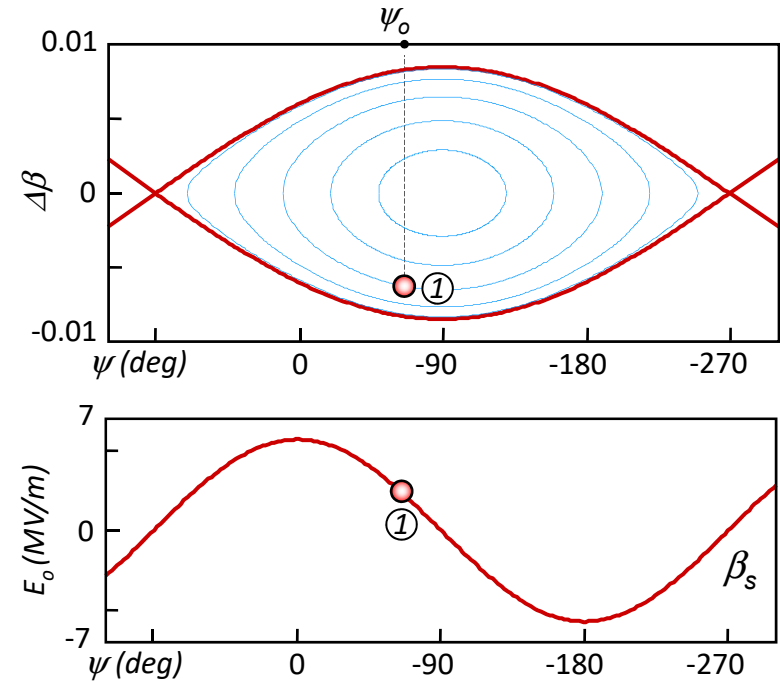


EQUUS

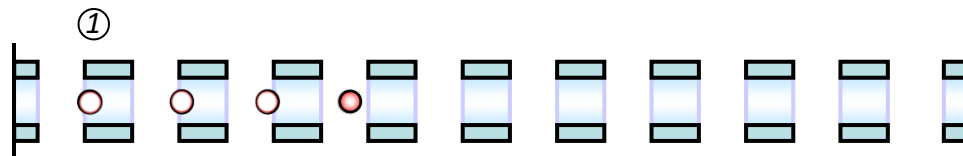


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

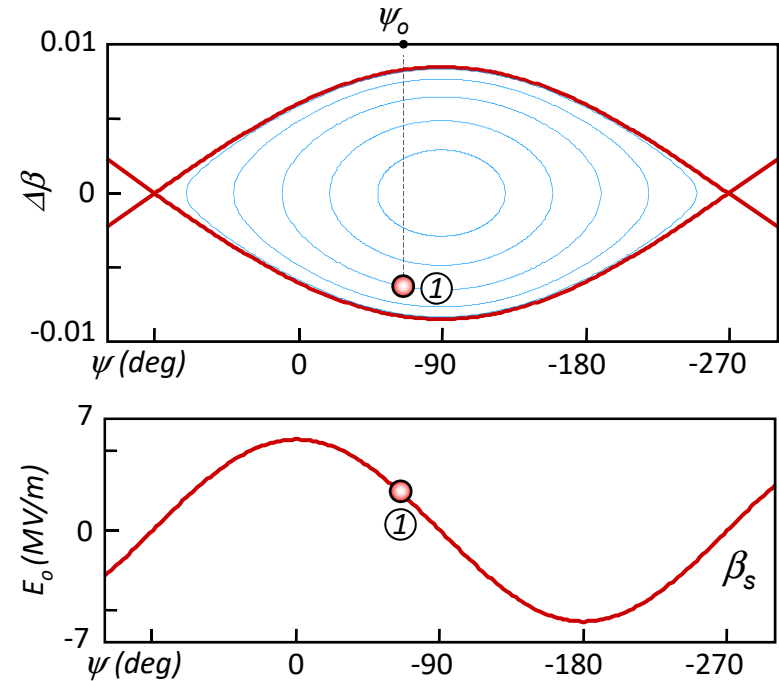


EQUUS



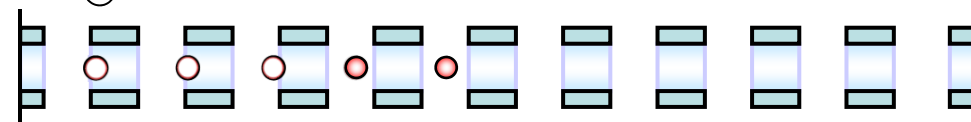
EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section



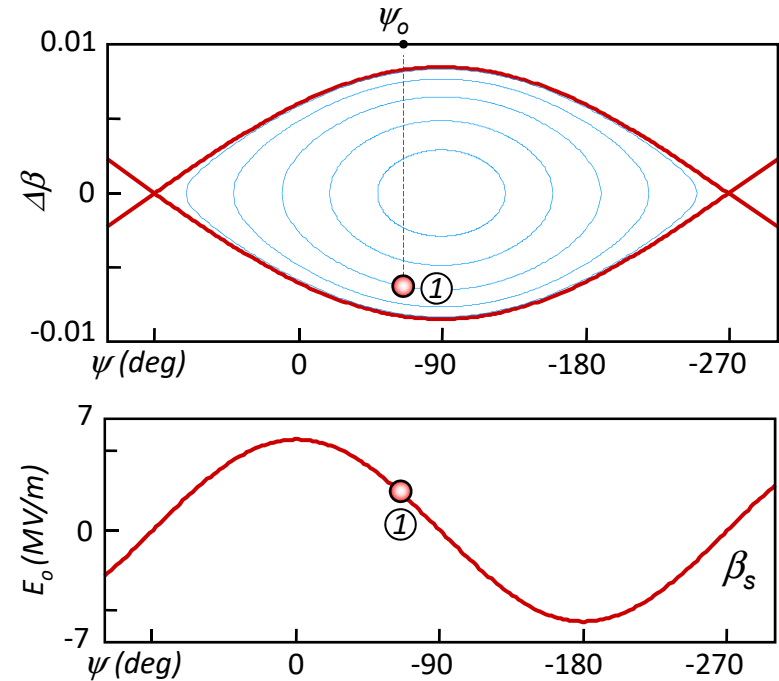
EQUUS

①

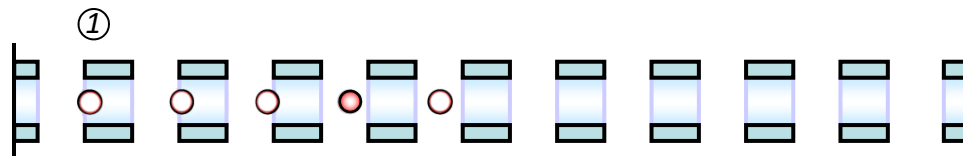


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

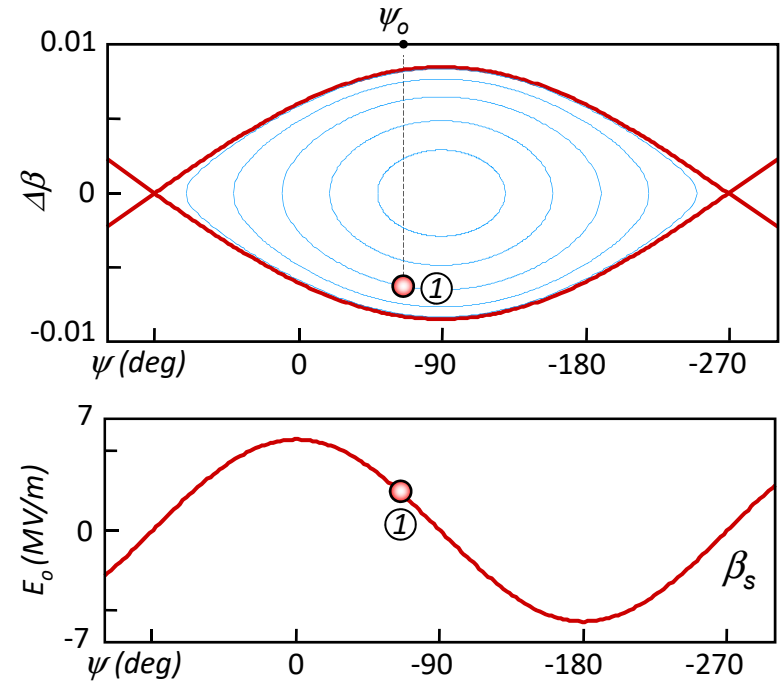


EQUUS

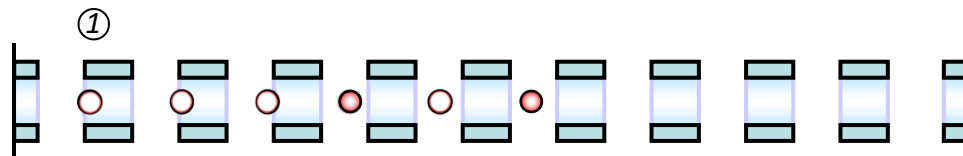


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

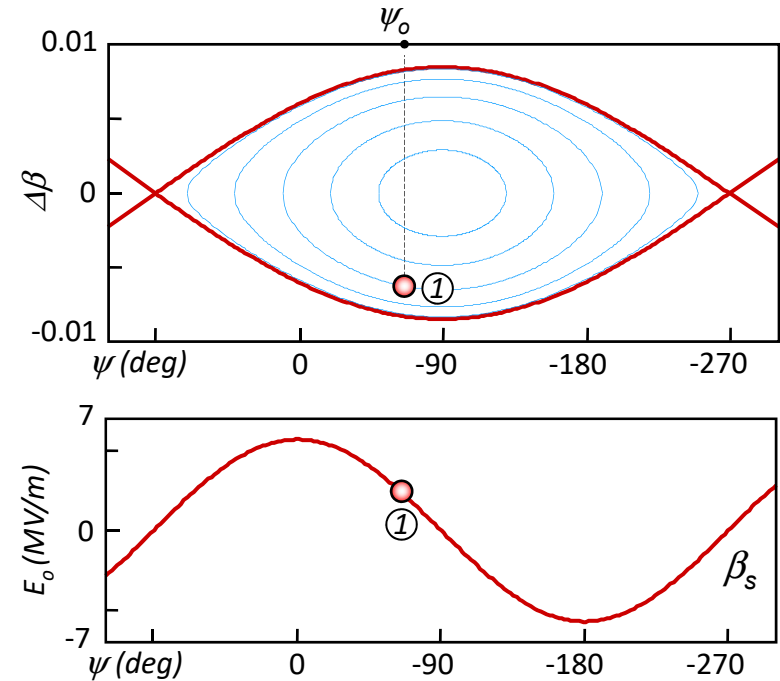


EQUUS

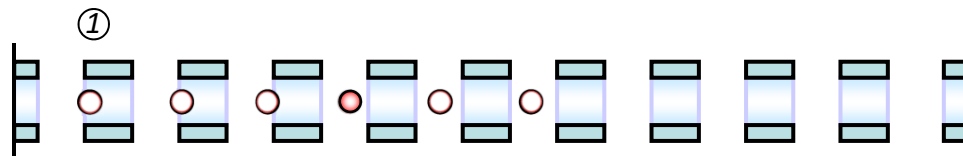


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

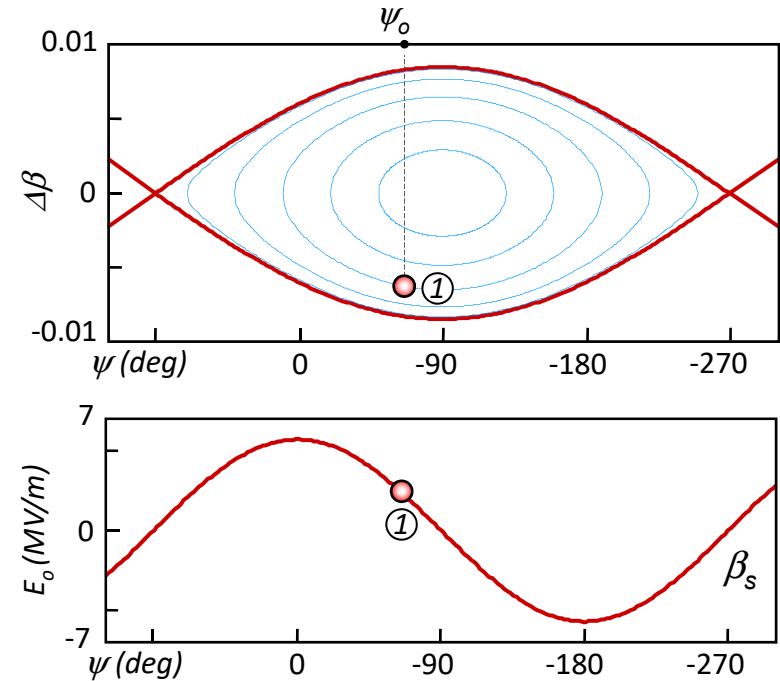


EQUUS

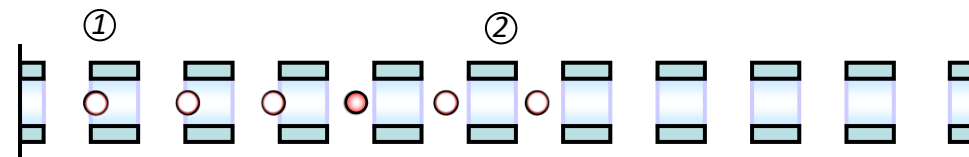


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

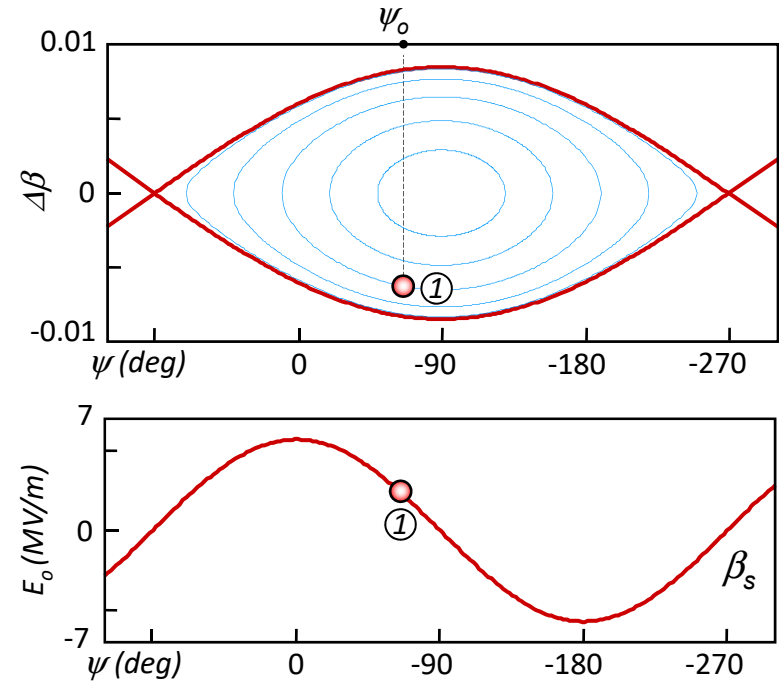


EQUUS

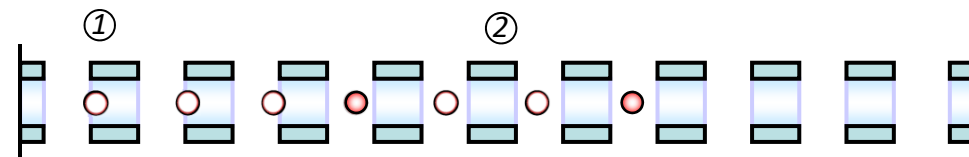


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

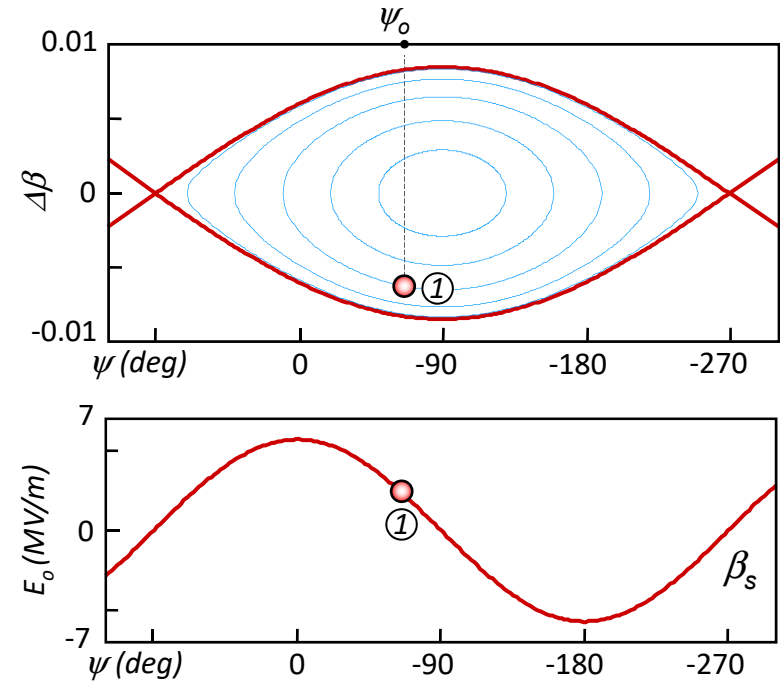


EQUUS

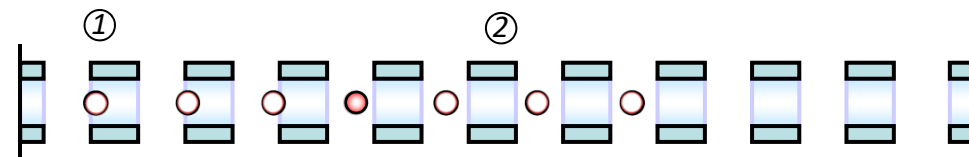


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

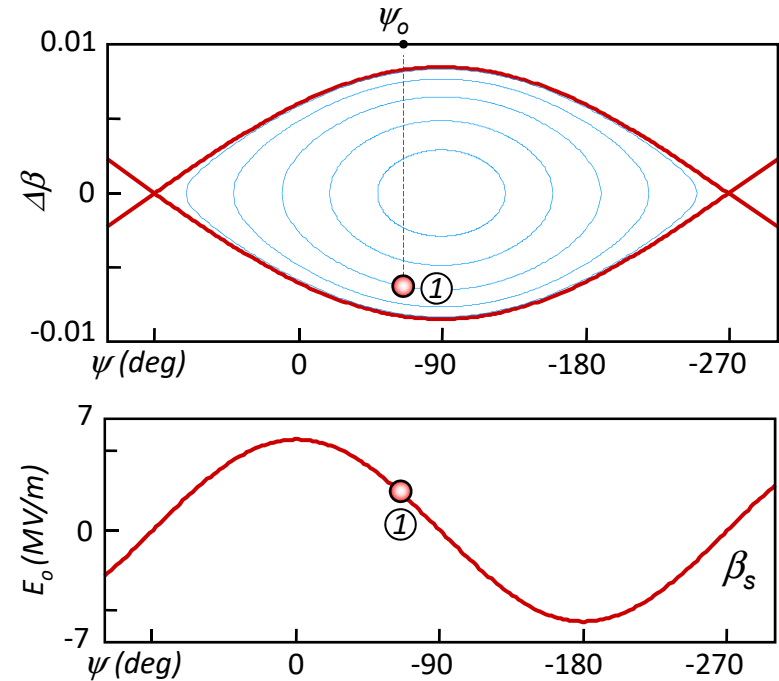


EQUUS

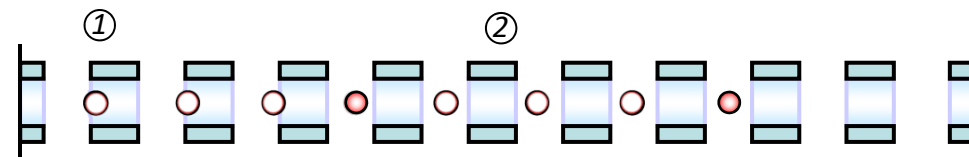


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

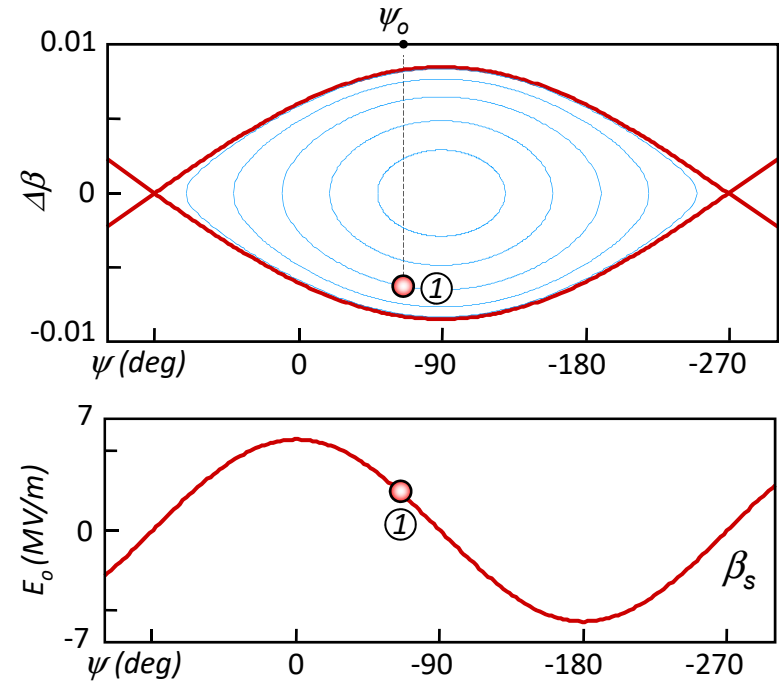


EQUUS

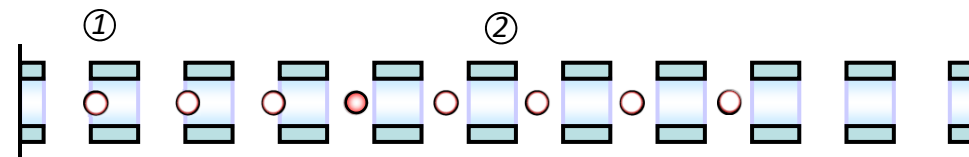


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

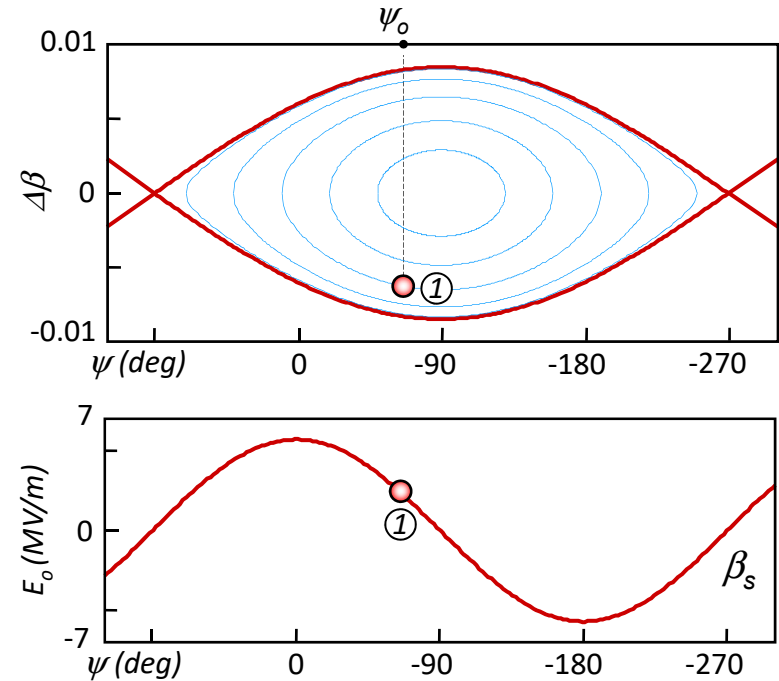


EQUUS

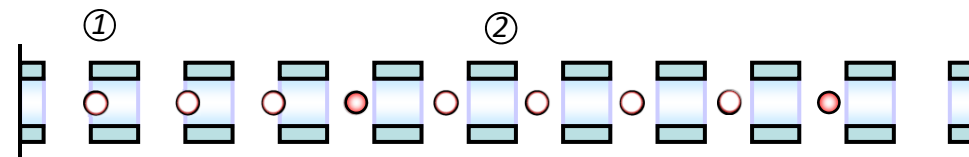


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

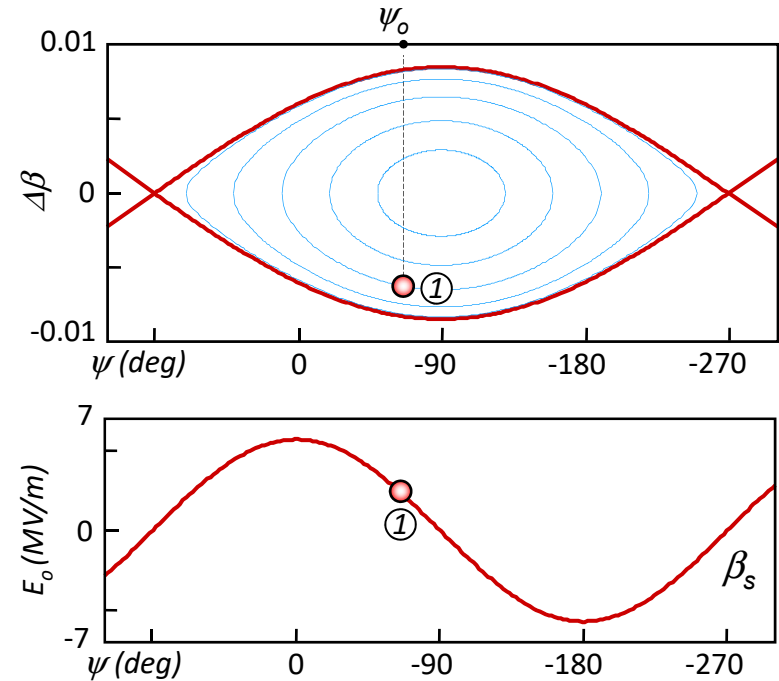


EQUUS

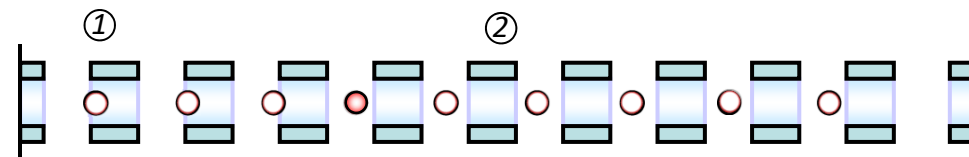


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

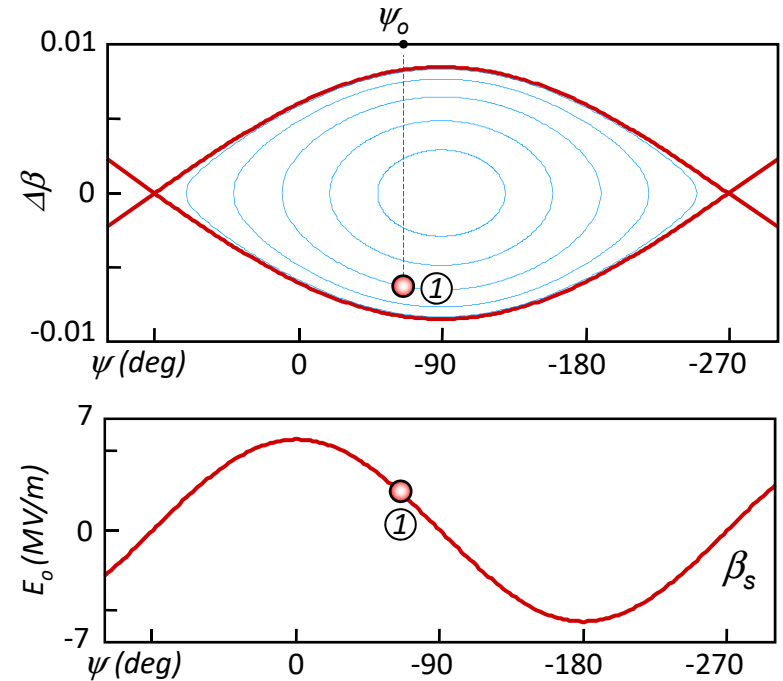


EQUUS

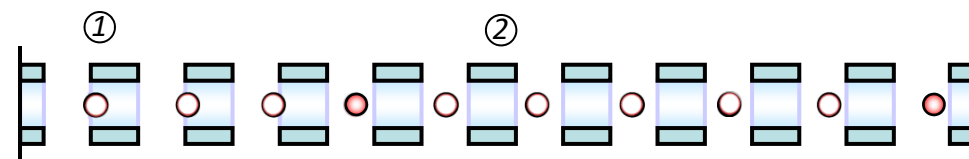


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

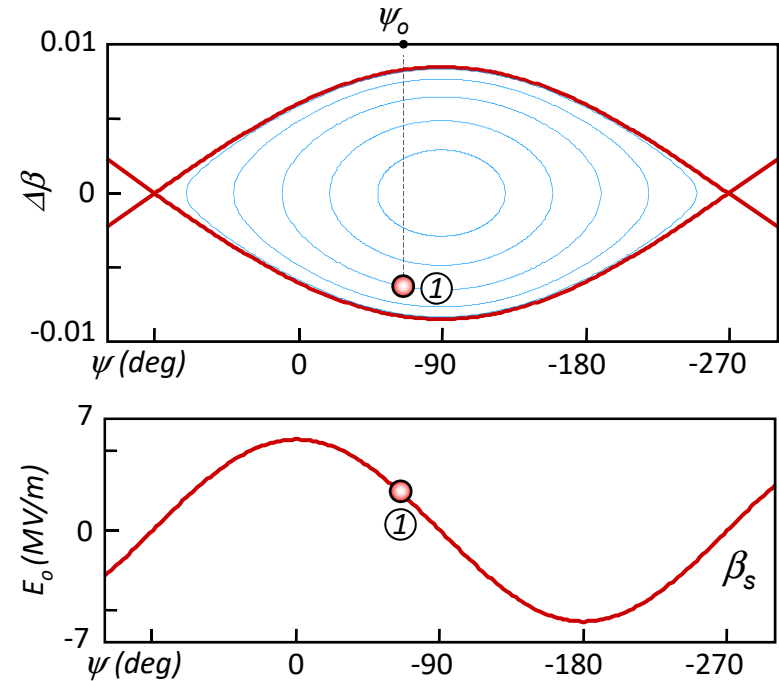


EQUUS

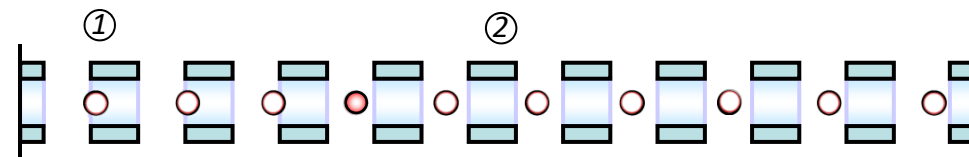


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section

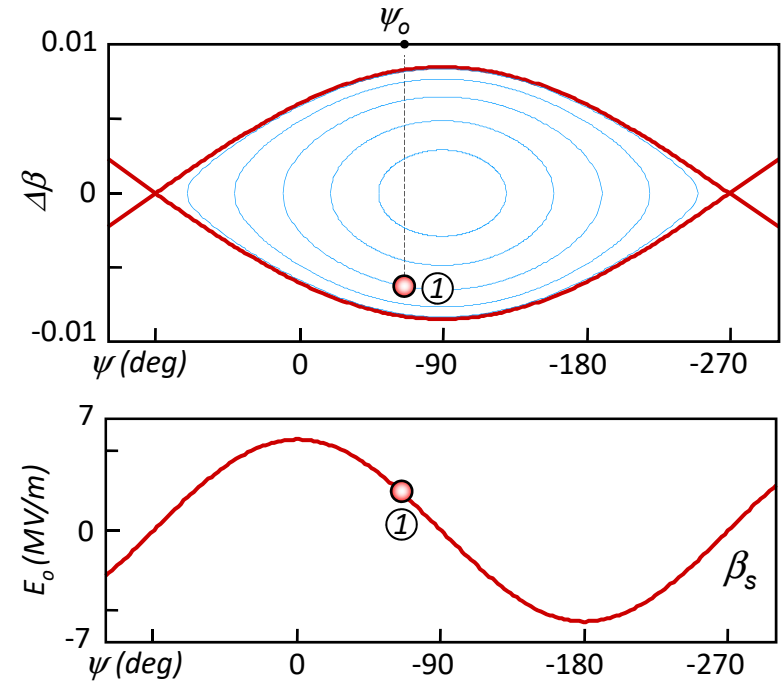


EQUUS

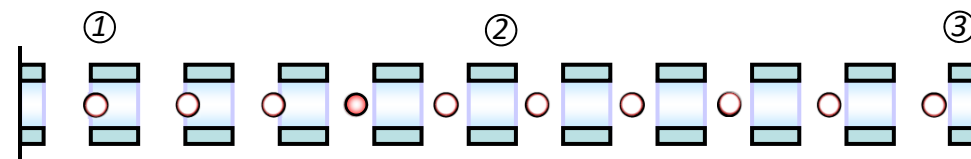


EQUUS - EQUidistant mUltigap Structure

Longitudinal motion of an accelerated bunch in the constant- β -section



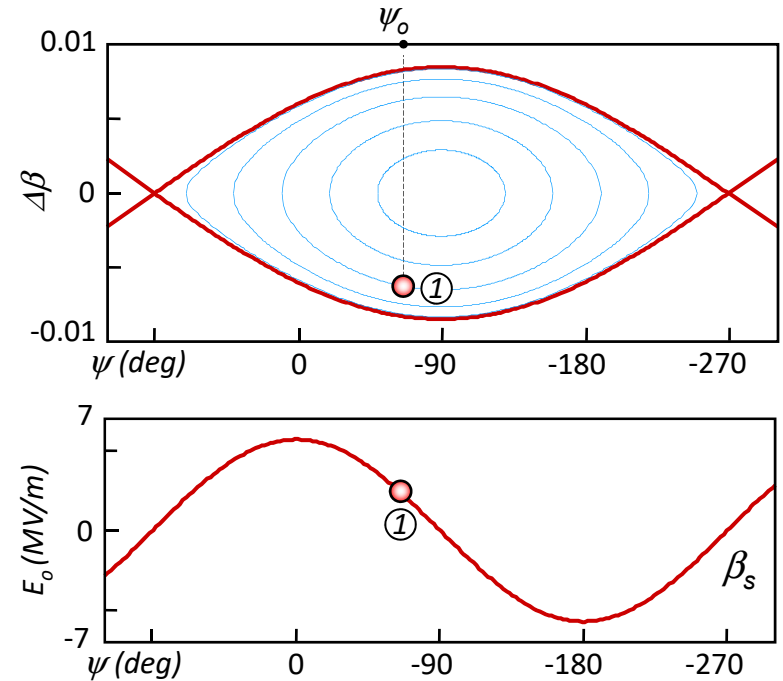
EQUUS



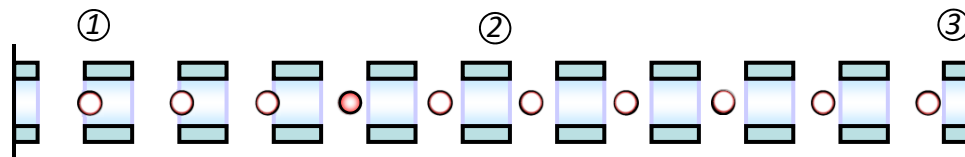
EQUUS - EQUidistant mUltigap Structure

①

Longitudinal motion of an accelerated bunch in the constant- β -section



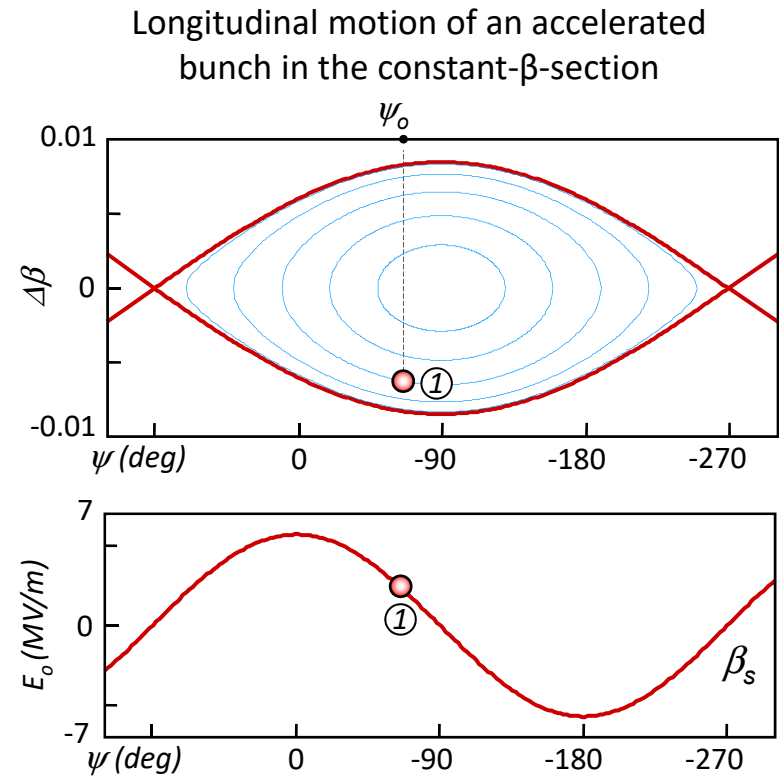
EQUUS



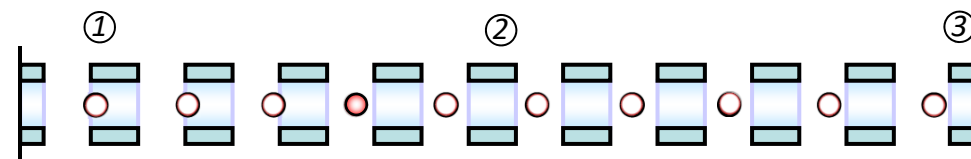
EQUUS - EQUidistant mUltigap Structure

① Particles too early

obtain less acceleration
longitudinal focussing



EQUUS



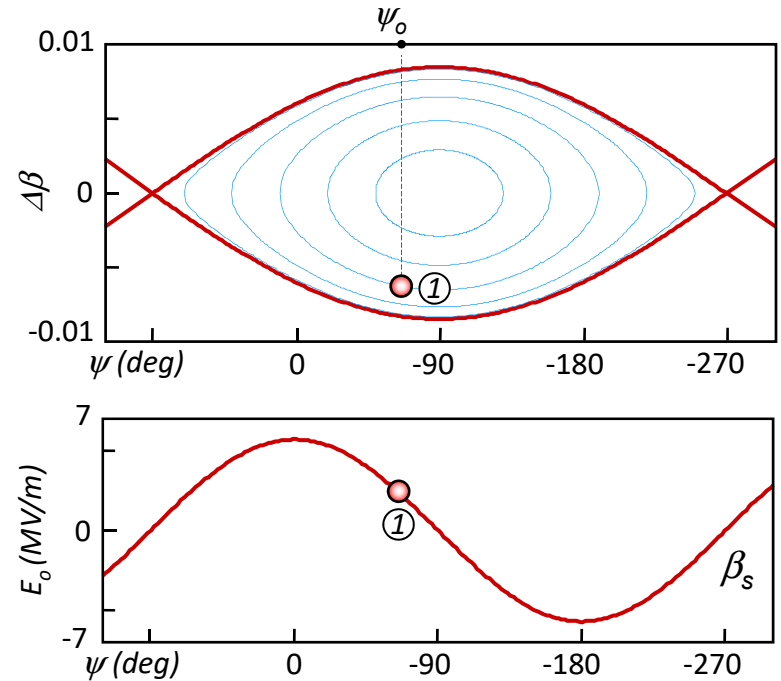
EQUUS - EQUidistant mUltigap Structure

① Particles too early

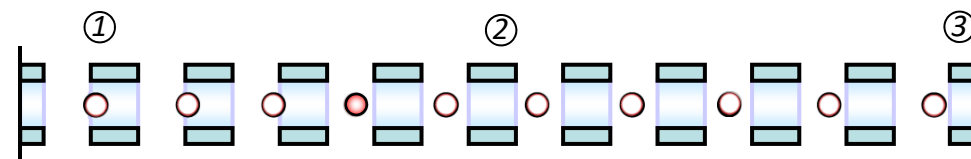


obtain less acceleration
longitudinal focussing

Longitudinal motion of an accelerated
bunch in the constant- β -section



EQUUS

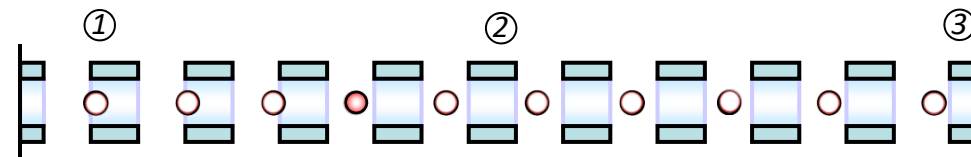


EQUUS - EQUidistant mUltigap Structure

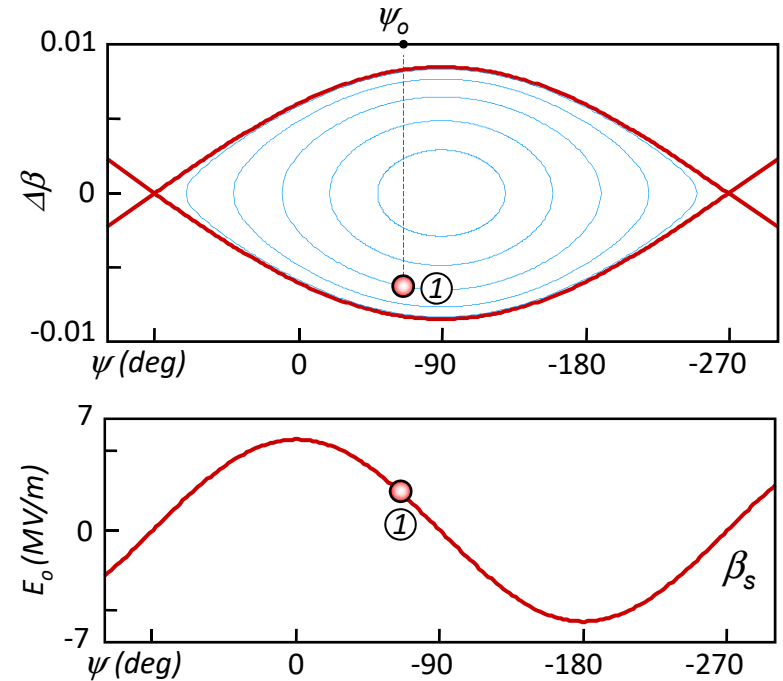
① Particles too early

- ➡ obtain less acceleration
- ➡ longitudinal focussing

EQUUS



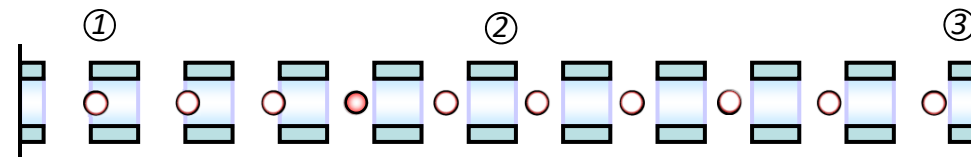
Longitudinal motion of an accelerated bunch in the constant- β -section



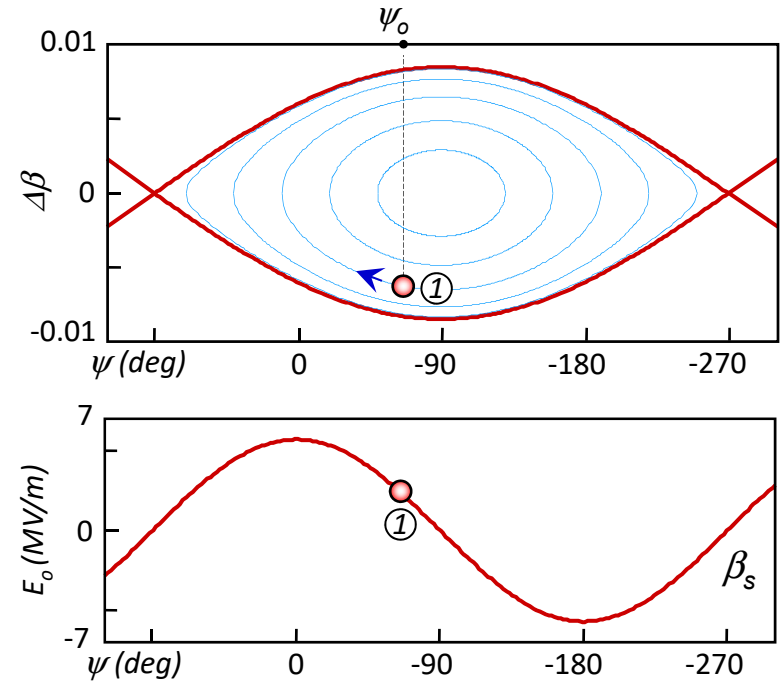
EQUUS - EQUidistant mUltigap Structure

- ① Particles too early
- ➡ obtain less acceleration
 - ➡ longitudinal focussing

EQUUS



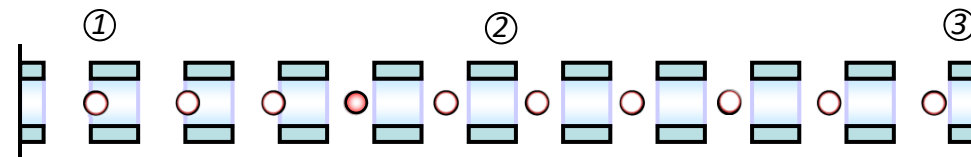
Longitudinal motion of an accelerated bunch in the constant- β -section



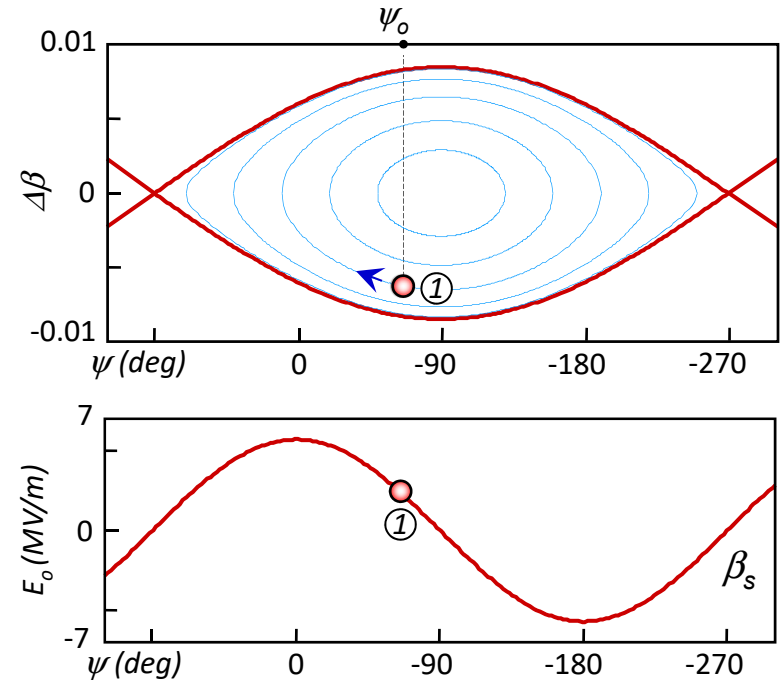
EQUUS - EQUidistant mUltigap Structure

- ① Particles too early
- ➡ obtain less acceleration
 - ➡ longitudinal focussing

EQUUS



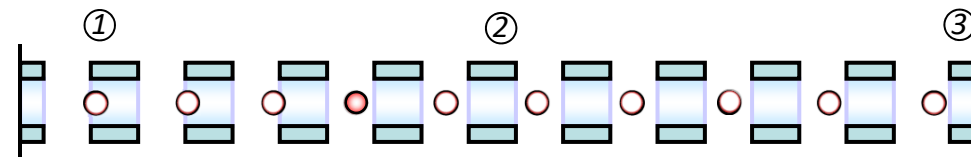
Longitudinal motion of an accelerated bunch in the constant- β -section



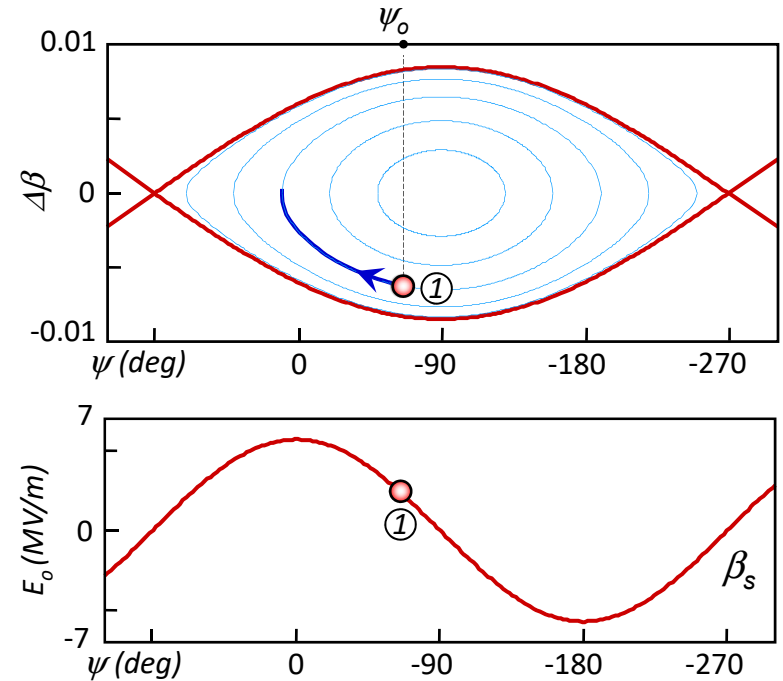
EQUUS - EQUidistant mUltigap Structure

- ① Particles too early
- ➡ obtain less acceleration
 - ➡ longitudinal focussing

EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section

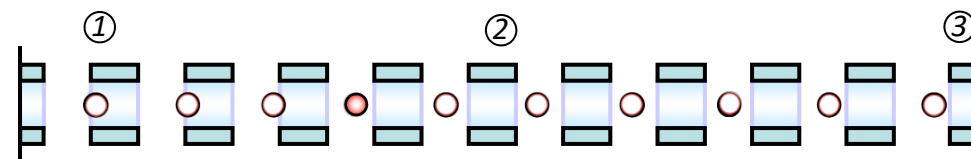


EQUUS - EQUidistant mUltigap Structure

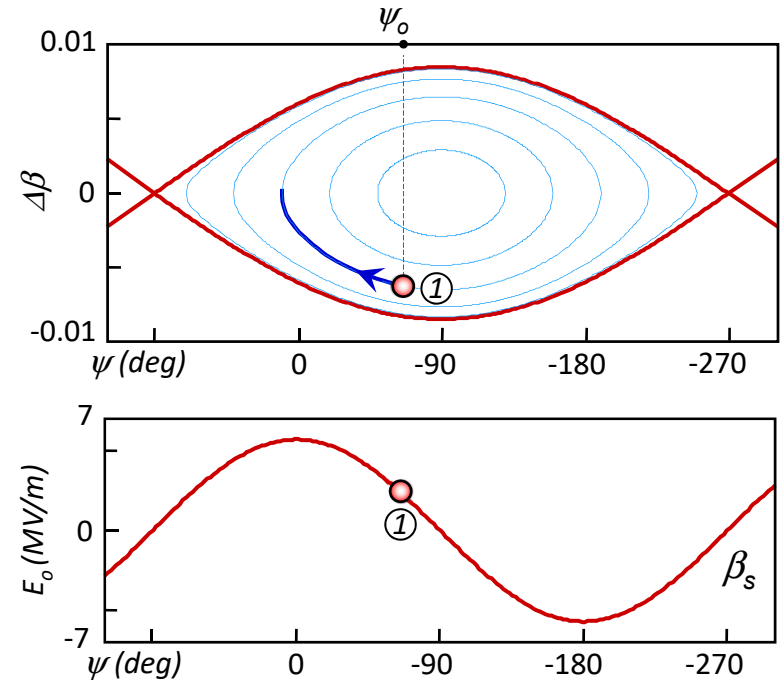
① Particles too early

- ➡ obtain less acceleration
- ➡ longitudinal focussing

EQUUS



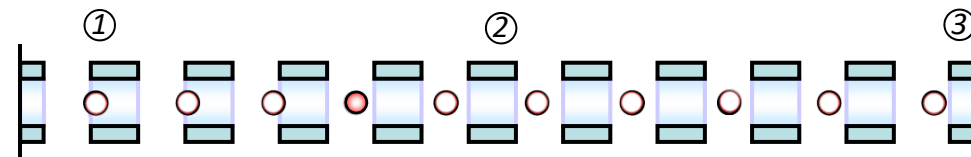
Longitudinal motion of an accelerated bunch in the constant- β -section



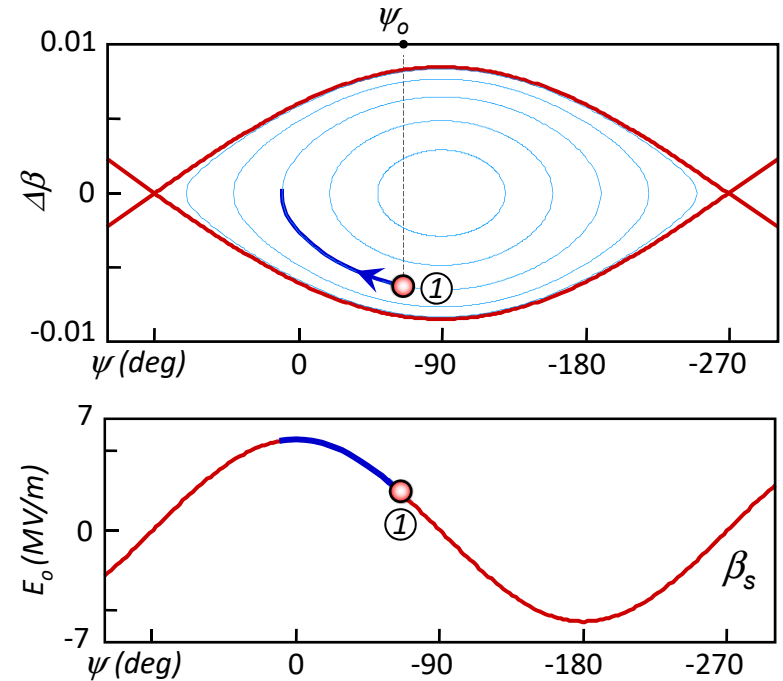
EQUUS - EQUidistant mUltigap Structure

- ① Particles too early
- ➡ obtain less acceleration
 - ➡ longitudinal focussing

EQUUS



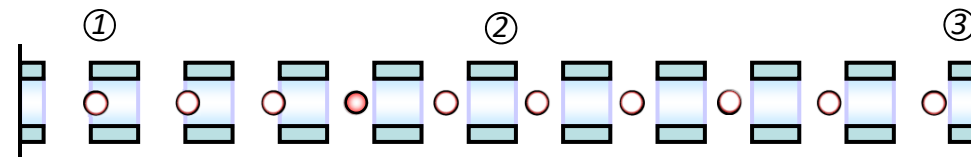
Longitudinal motion of an accelerated bunch in the constant- β -section



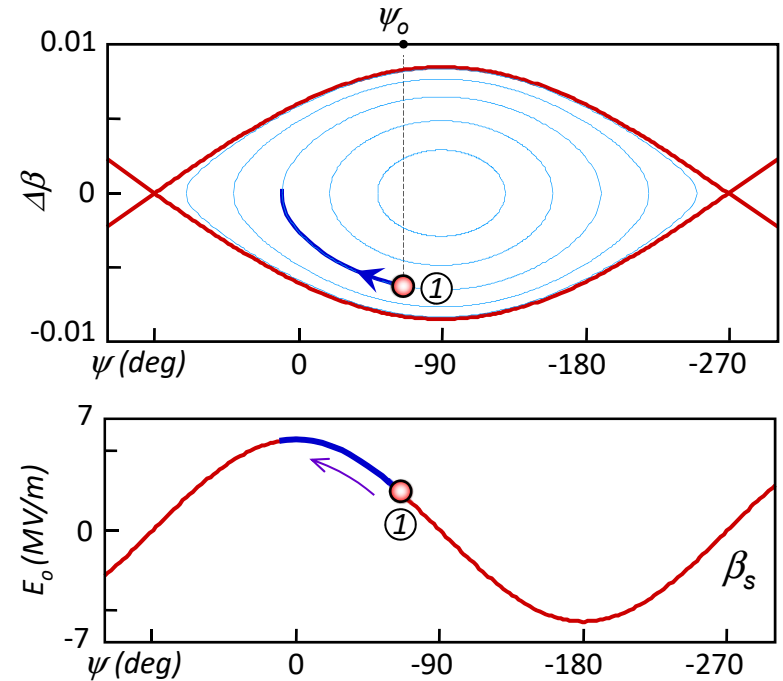
EQUUS - EQUidistant mUltigap Structure

- ① Particles too early
- ➡ obtain less acceleration
 - ➡ longitudinal focussing

EQUUS



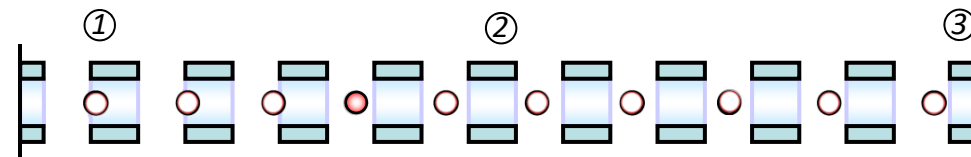
Longitudinal motion of an accelerated bunch in the constant- β -section



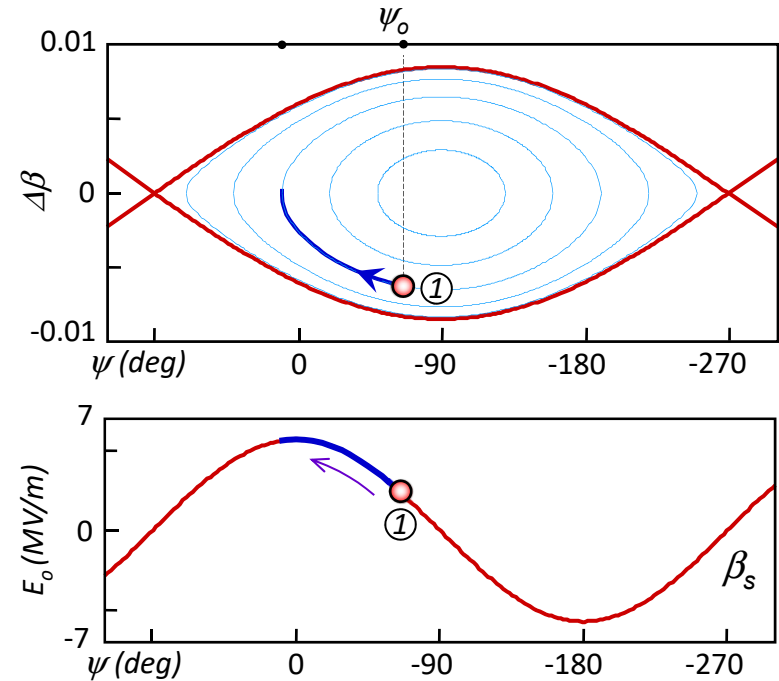
EQUUS - EQUidistant mUltigap Structure

- ① Particles too early
- ➡ obtain less acceleration
 - ➡ longitudinal focussing

EQUUS



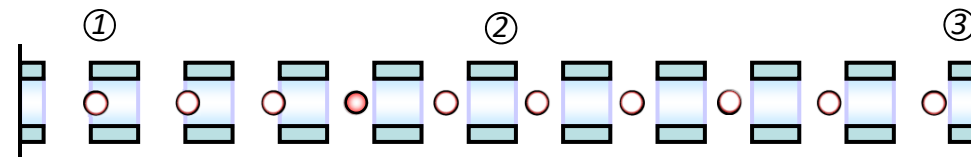
Longitudinal motion of an accelerated bunch in the constant- β -section



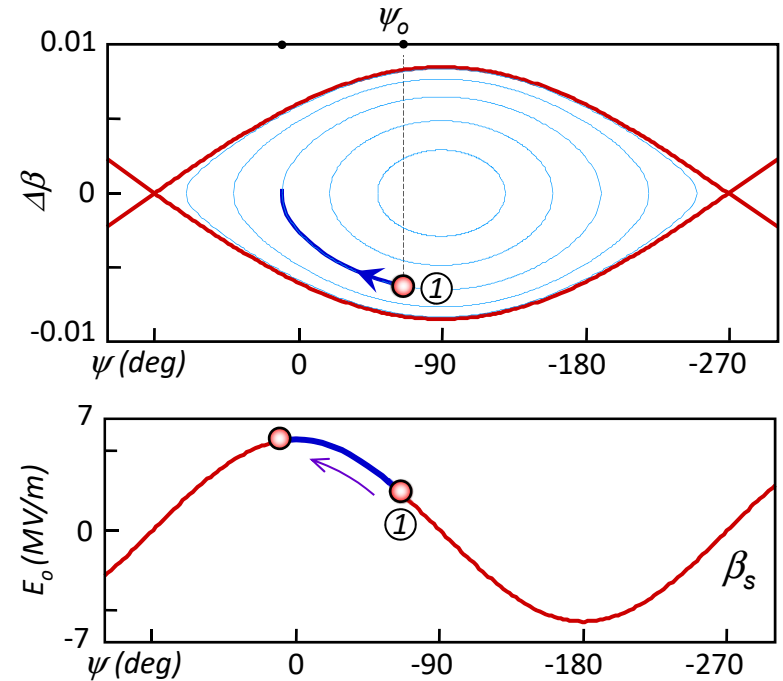
EQUUS - EQUidistant mUltigap Structure

- ① Particles too early
- obtain less acceleration
 - longitudinal focussing

EQUUS



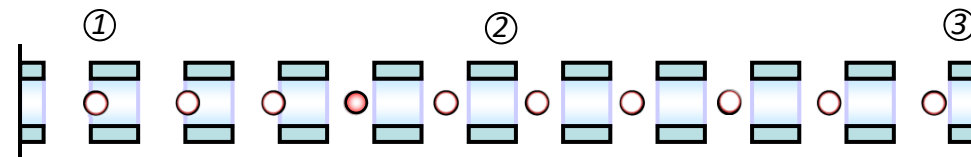
Longitudinal motion of an accelerated bunch in the constant- β -section



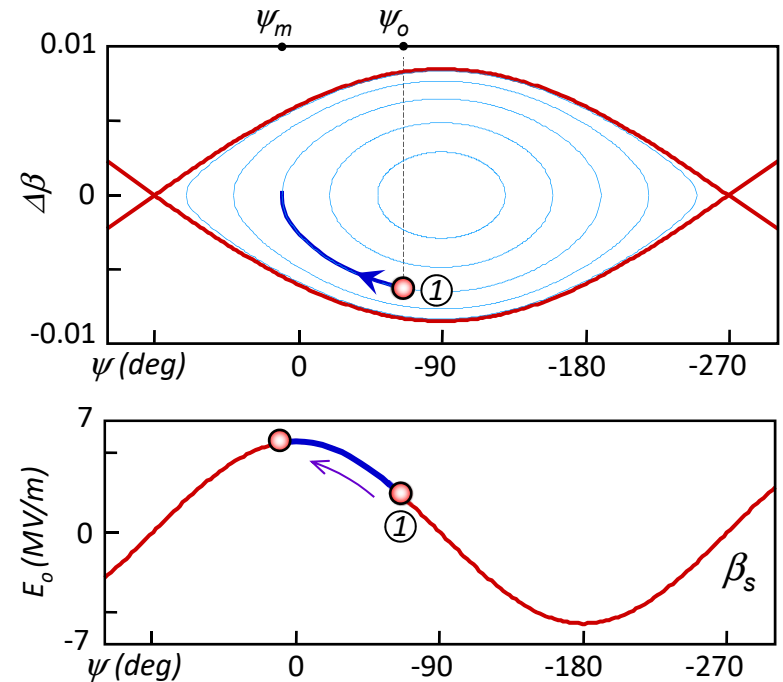
EQUUS - EQUidistant mUltigap Structure

- ① Particles too early
- obtain less acceleration
 - longitudinal focussing

EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section

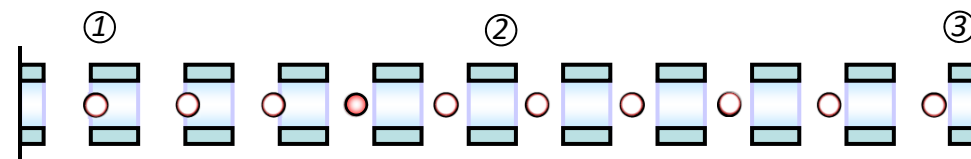


EQUUS - EQUidistant mUltigap Structure

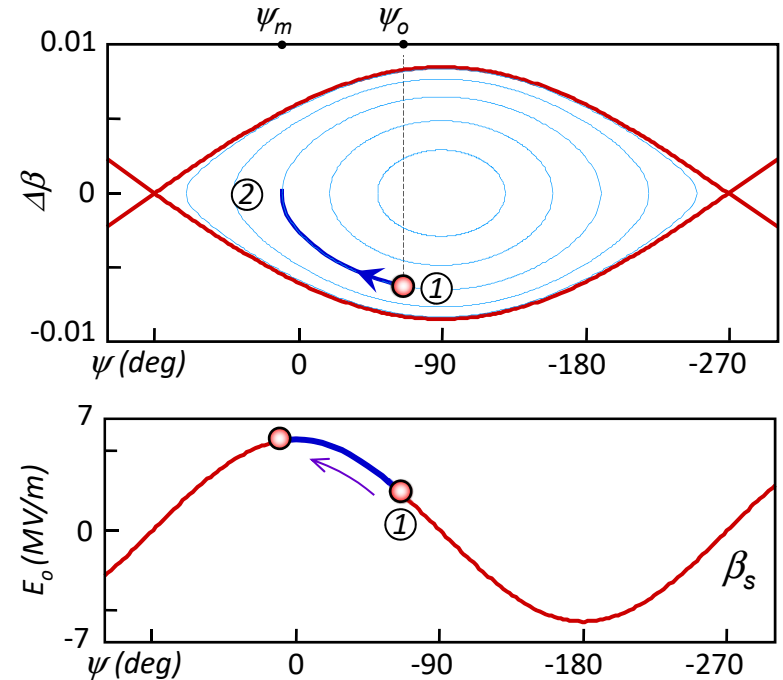
① Particles too early

- ➡ obtain less acceleration
- ➡ longitudinal focussing

EQUUS



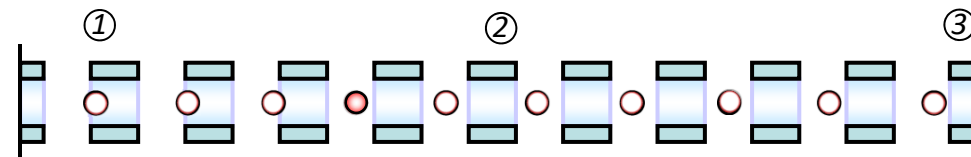
Longitudinal motion of an accelerated bunch in the constant- β -section



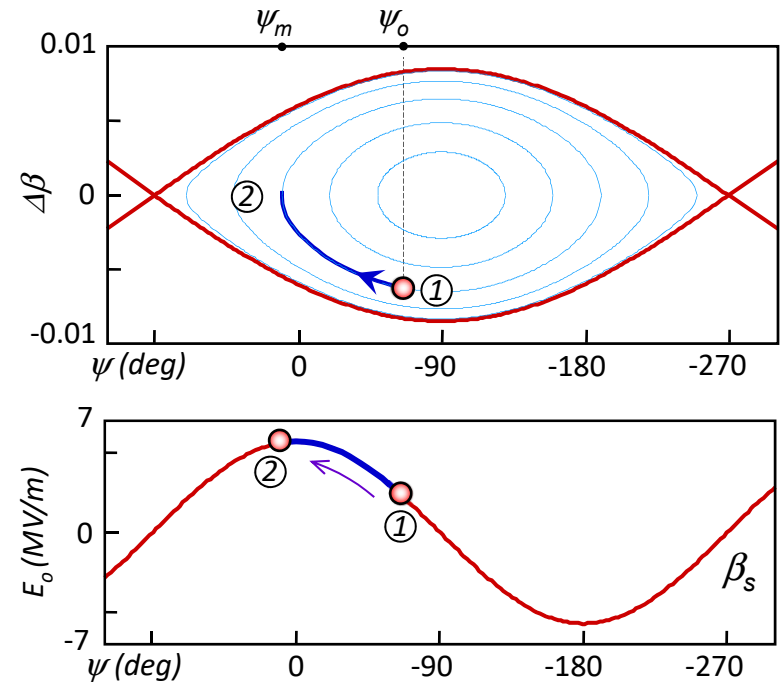
EQUUS - EQUidistant mUltigap Structure

- ① Particles too early
- ➡ obtain less acceleration
 - ➡ longitudinal focussing

EQUUS



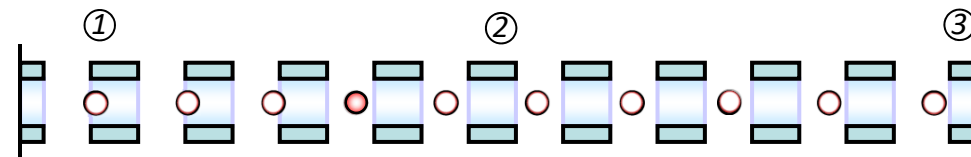
Longitudinal motion of an accelerated bunch in the constant- β -section



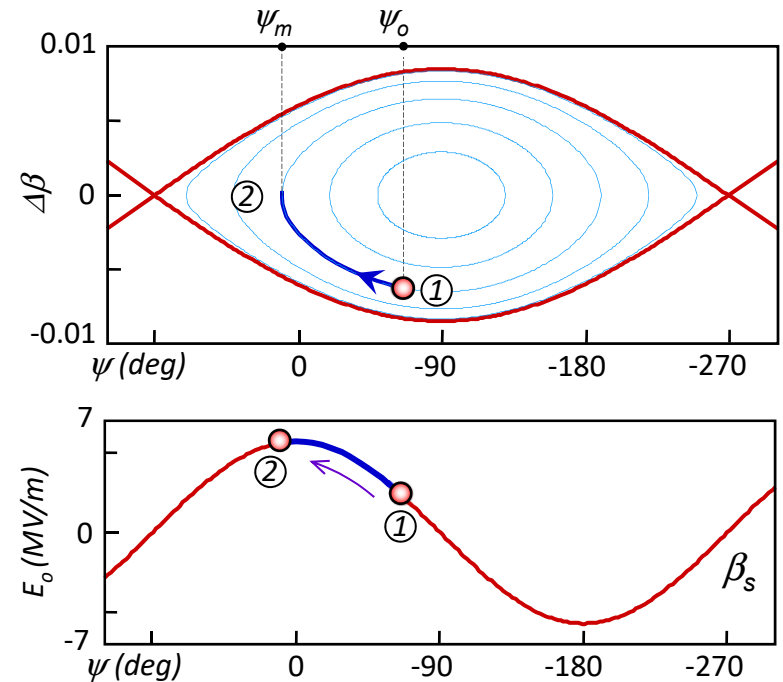
EQUUS - EQUidistant mUltigap Structure

- ① Particles too early
- ➡ obtain less acceleration
 - ➡ longitudinal focussing

EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section

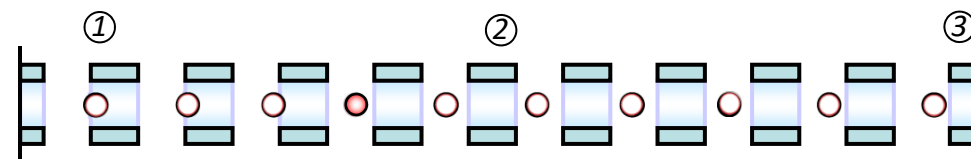


EQUUS - EQUidistant mUltigap Structure

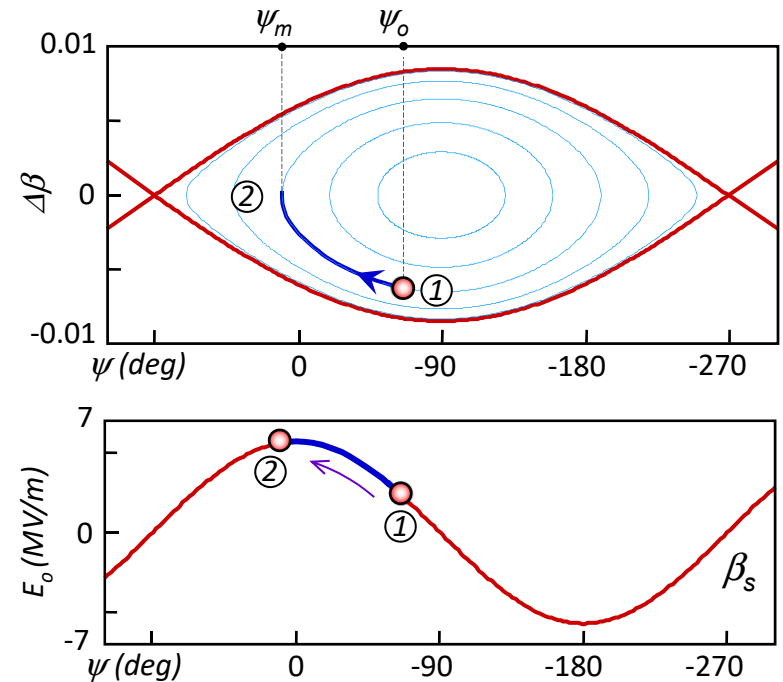
- ① Particles too early
- ➔ obtain less acceleration
 - ➔ longitudinal focussing

②

EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section

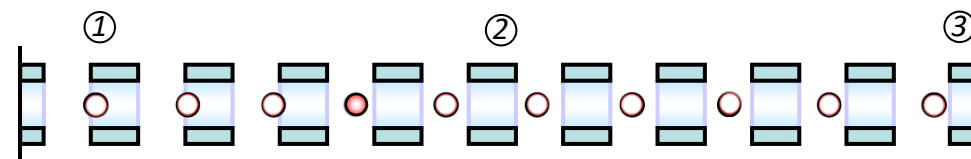


EQUUS - EQUidistant mUltigap Structure

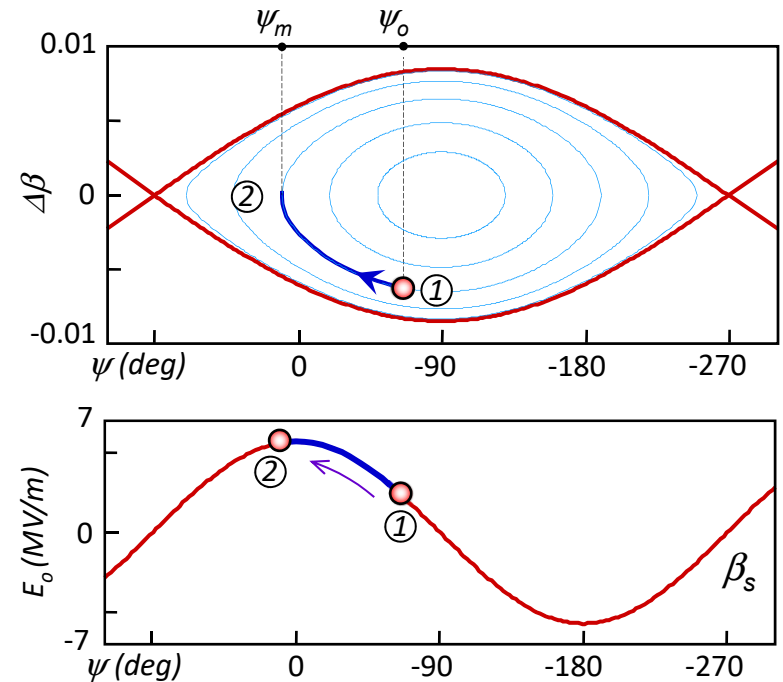
- ① Particles too early
- obtain less acceleration
→ longitudinal focussing

- ②
-

EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section

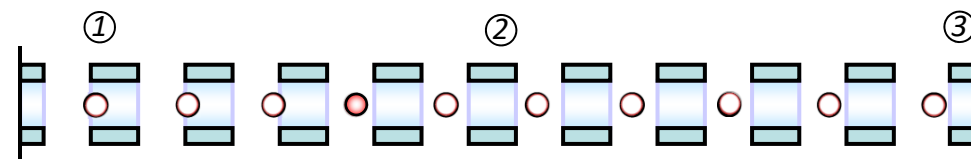


EQUUS - EQUidistant mUltigap Structure

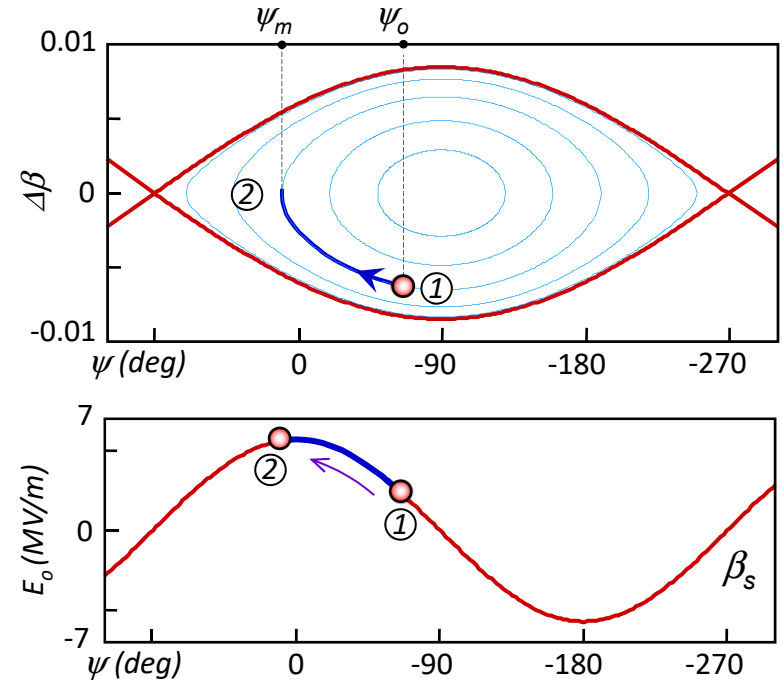
① Particles too early
 → obtain less acceleration
 → longitudinal focussing

②
 →
 →

EQUUS



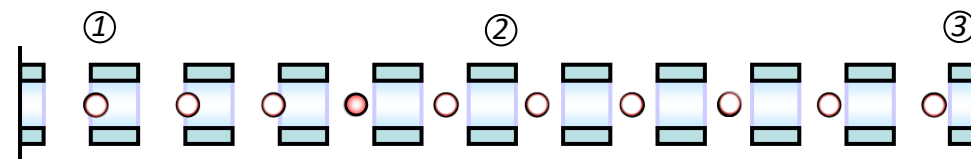
Longitudinal motion of an accelerated bunch in the constant- β -section



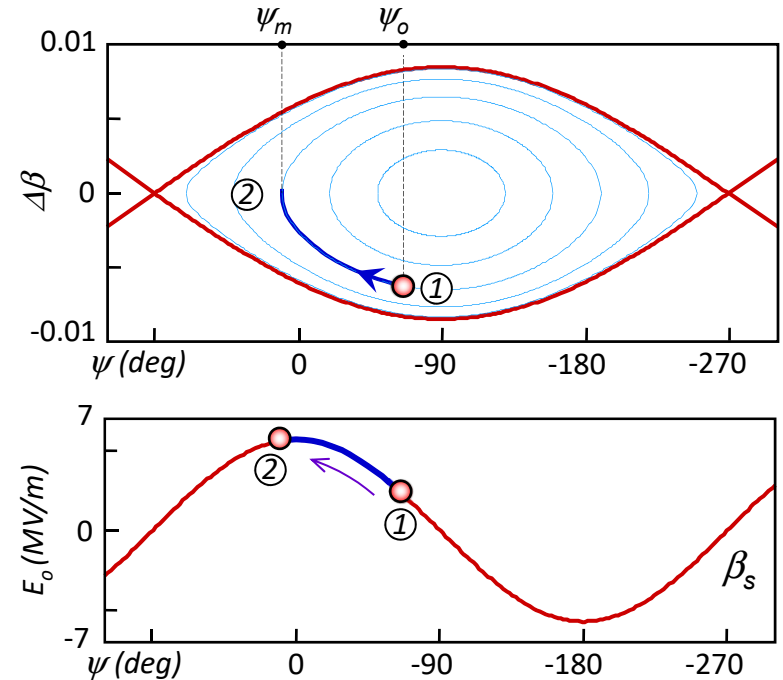
EQUUS - EQUidistant mUltigap Structure

- ① Particles too early
 - ➡ obtain less acceleration
 - ➡ longitudinal focussing
- ② Particles synchr.
 - ➡ reach max. acceleration
 - ➡ longitudinal defocussing

EQUUS



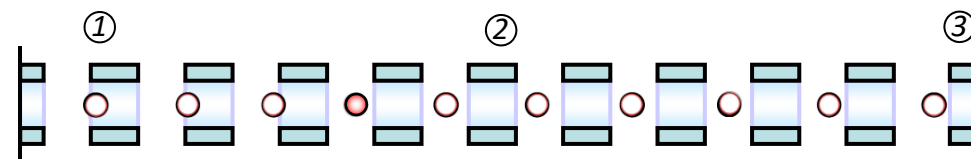
Longitudinal motion of an accelerated bunch in the constant- β -section



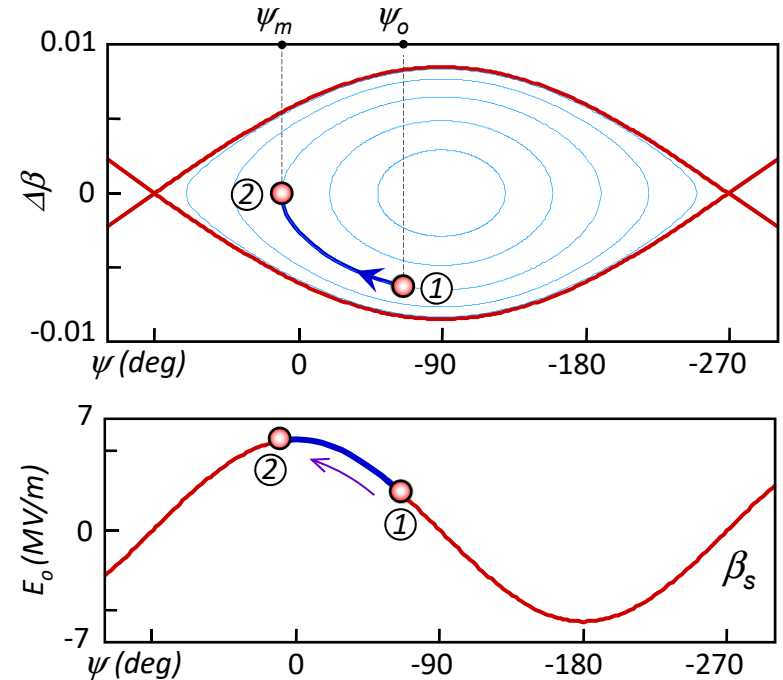
EQUUS - EQUidistant mUltigap Structure

- ① Particles too early
 - ➡ obtain less acceleration
 - ➡ longitudinal focussing
- ② Particles synchr.
 - ➡ reach max. acceleration
 - ➡ longitudinal defocussing

EQUUS



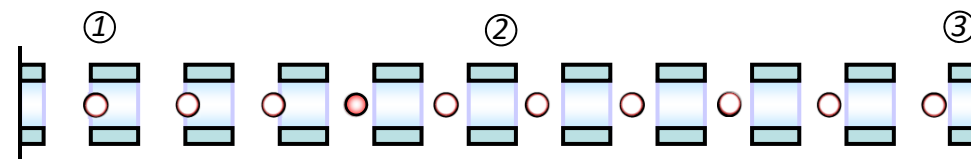
Longitudinal motion of an accelerated bunch in the constant- β -section



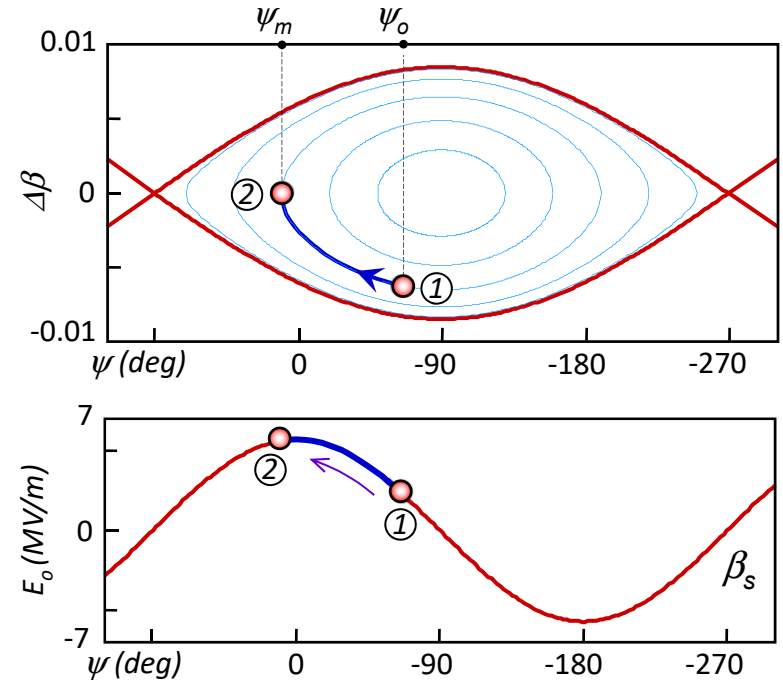
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|---|
| ① Particles too early | <div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> obtain less acceleration
<div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> longitudinal focussing |
| ② Particles synchr. | <div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> reach max. acceleration
<div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> longitudinal defocussing |

EQUUS



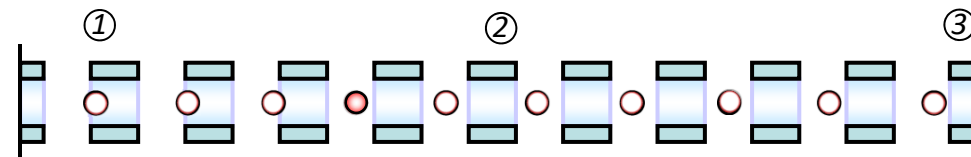
Longitudinal motion of an accelerated bunch in the constant- β -section



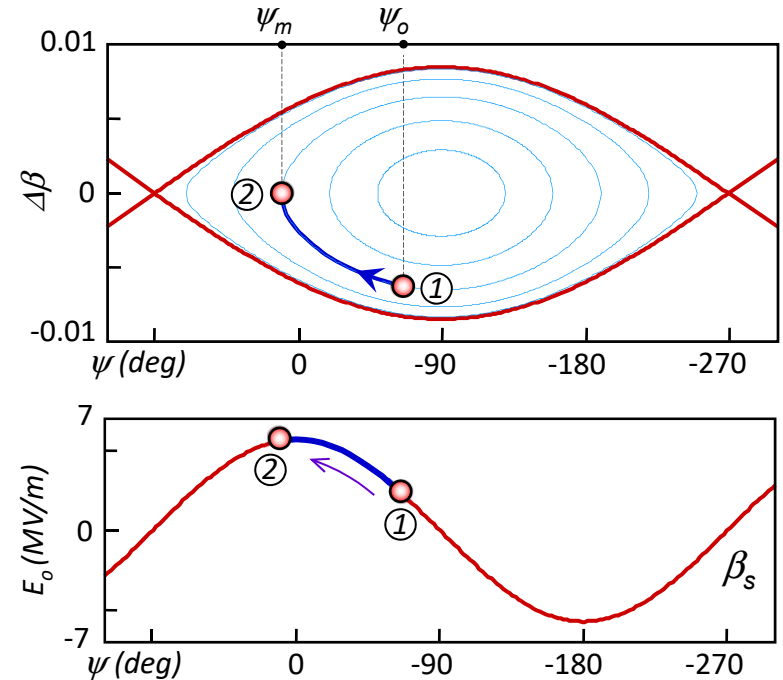
EQUUS - EQUidistant mUltigap Structure

- ① Particles too early
 - ➡ obtain less acceleration
 - ➡ longitudinal focussing
- ② Particles synchr.
 - ➡ reach max. acceleration
 - ➡ longitudinal defocussing

EQUUS



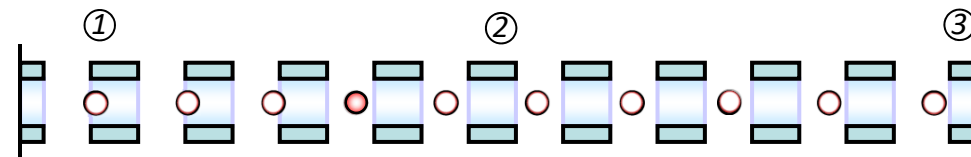
Longitudinal motion of an accelerated bunch in the constant- β -section



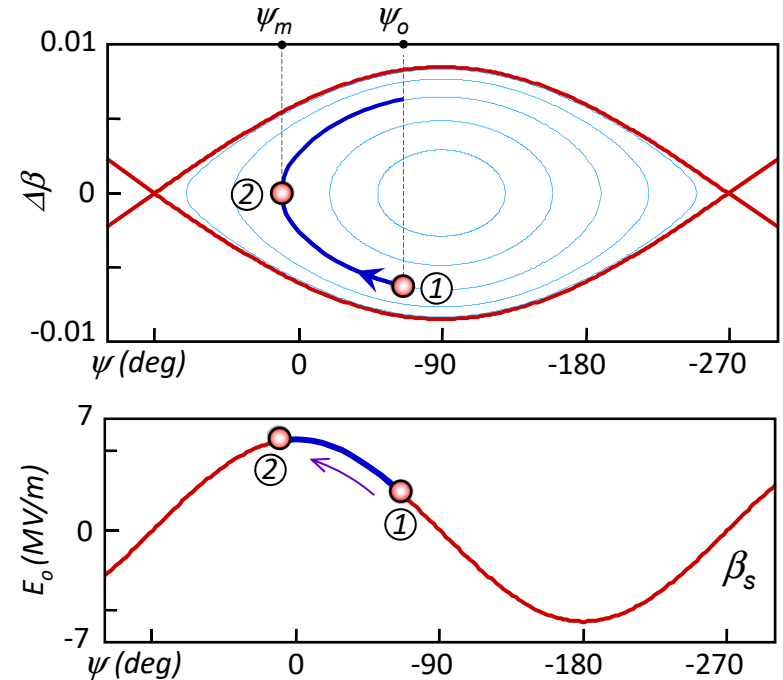
EQUUS - EQUidistant mUltigap Structure

- ① Particles too early
 - ➡ obtain less acceleration
 - ➡ longitudinal focussing
- ② Particles synchr.
 - ➡ reach max. acceleration
 - ➡ longitudinal defocussing

EQUUS



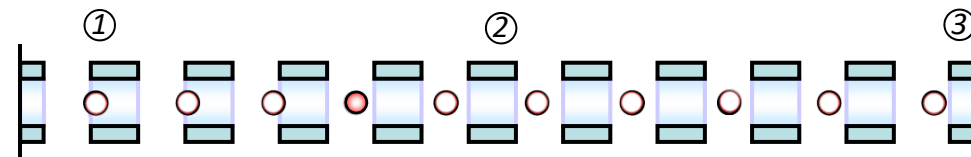
Longitudinal motion of an accelerated bunch in the constant- β -section



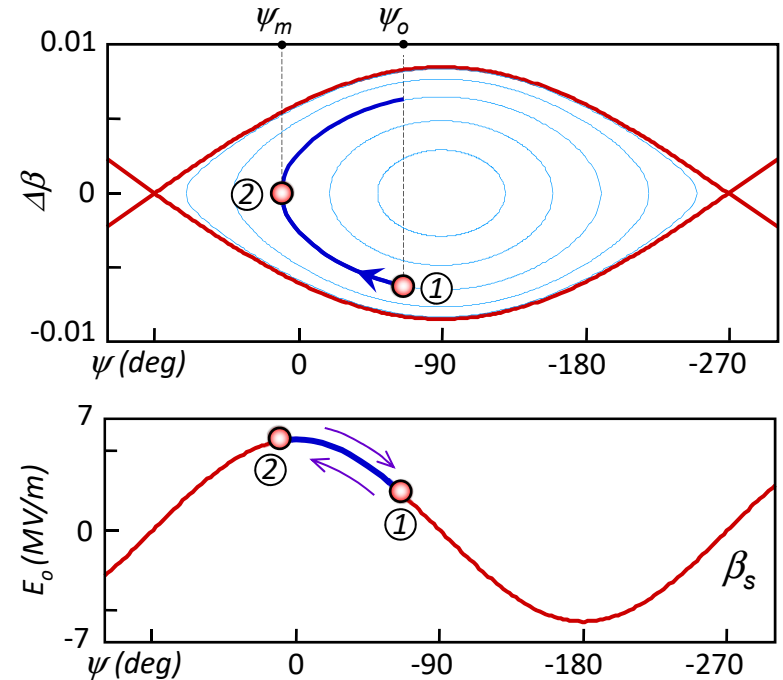
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|---|
| ① Particles too early | <div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> obtain less acceleration
<div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> longitudinal focussing |
| ② Particles synchr. | <div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> reach max. acceleration
<div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> longitudinal defocussing |

EQUUS



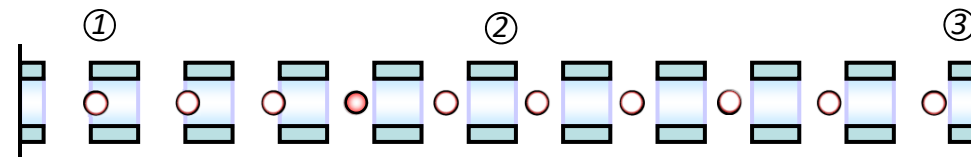
Longitudinal motion of an accelerated bunch in the constant- β -section



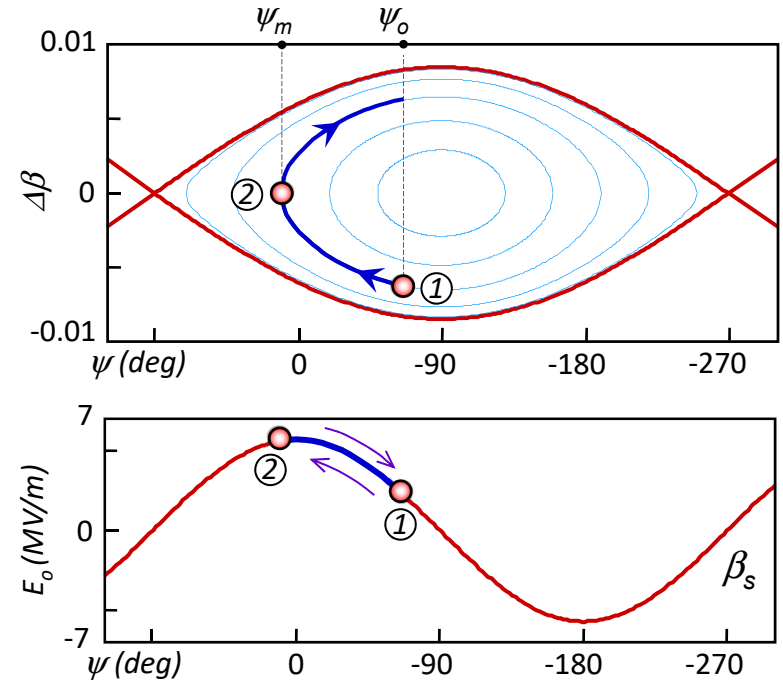
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|---|
| ① Particles too early | <div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> obtain less acceleration
<div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> longitudinal focussing |
| ② Particles synchr. | <div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> reach max. acceleration
<div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> longitudinal defocussing |

EQUUS



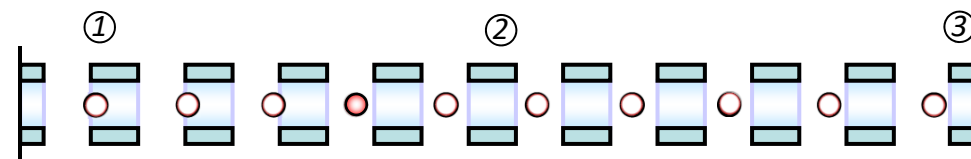
Longitudinal motion of an accelerated bunch in the constant- β -section



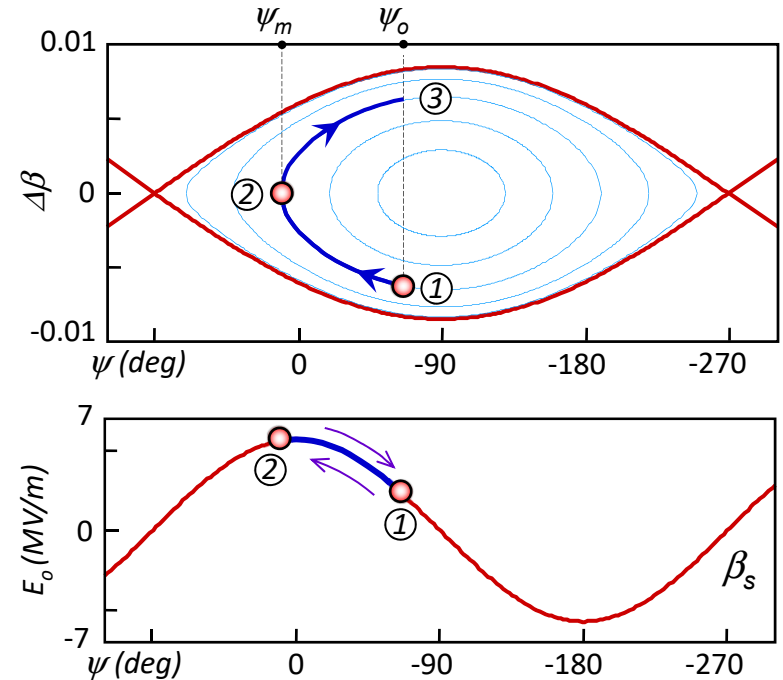
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|---|
| ① Particles too early | <div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> obtain less acceleration
<div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> longitudinal focussing |
| ② Particles synchr. | <div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> reach max. acceleration
<div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> longitudinal defocussing |

EQUUS



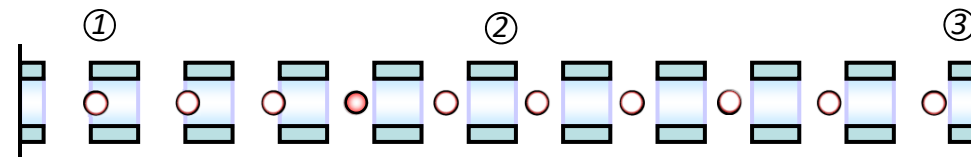
Longitudinal motion of an accelerated bunch in the constant- β -section



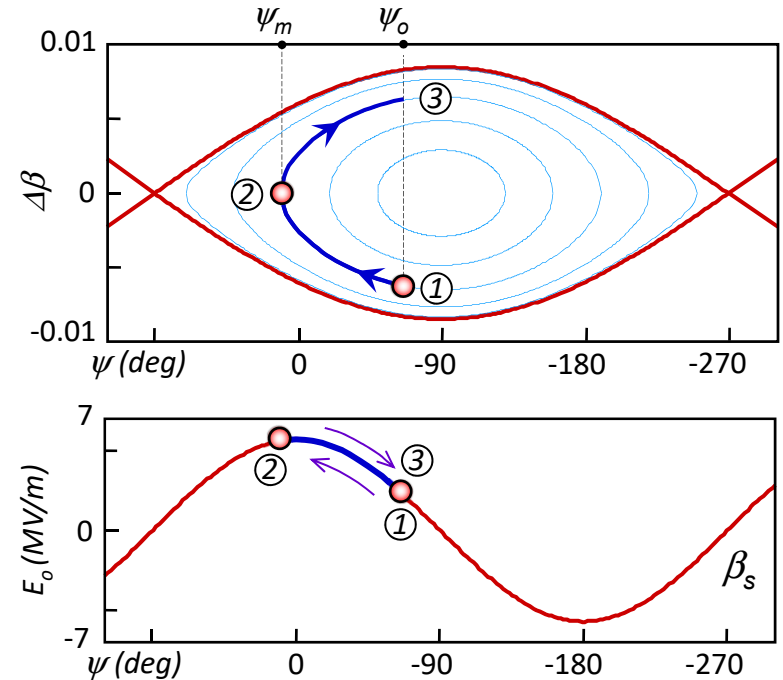
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|---|
| ① Particles too early | <div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> obtain less acceleration
<div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> longitudinal focussing |
| ② Particles synchr. | <div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> reach max. acceleration
<div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> longitudinal defocussing |

EQUUS



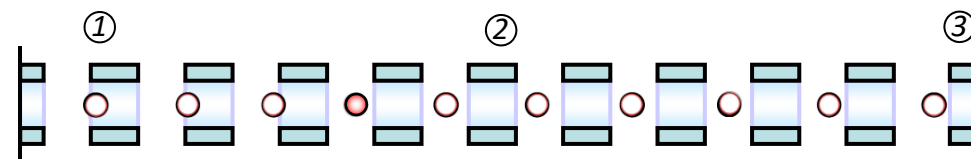
Longitudinal motion of an accelerated bunch in the constant- β -section



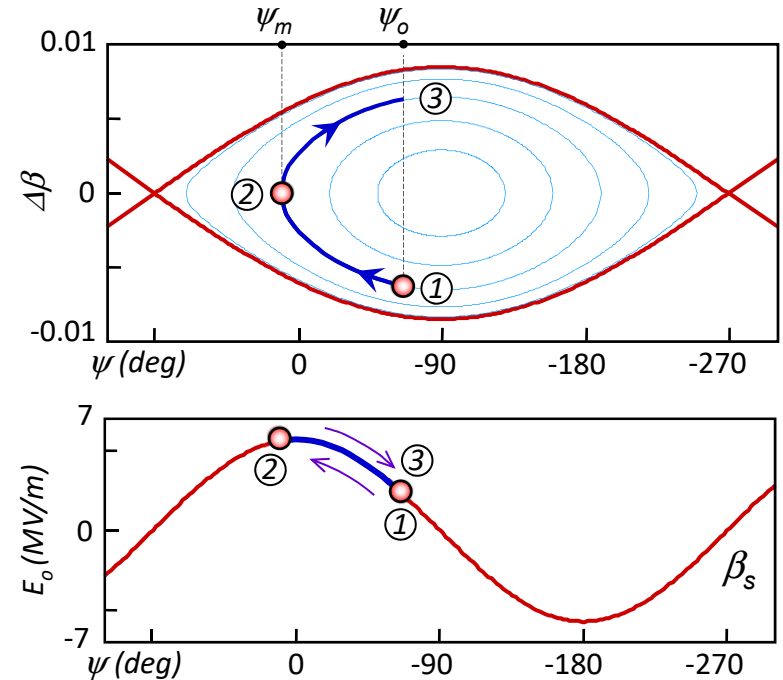
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|---|
| ① Particles too early | <div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> obtain less acceleration
<div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> longitudinal focussing |
| ② Particles synchr. | <div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> reach max. acceleration
<div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> longitudinal defocussing |
| ③ | |

EQUUS



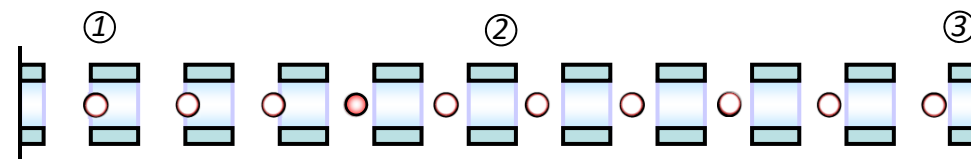
Longitudinal motion of an accelerated bunch in the constant- β -section



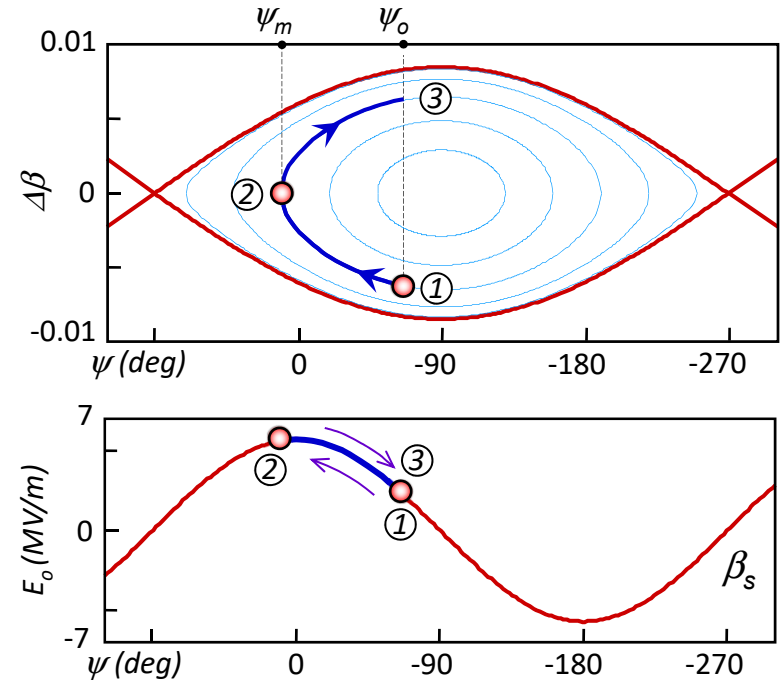
EQUUS - EQUidistant mUltigap Structure

- ① Particles too early
 - ➡ obtain less acceleration
 - ➡ longitudinal focussing
- ② Particles synchr.
 - ➡ reach max. acceleration
 - ➡ longitudinal defocussing
- ③
 - ➡

EQUUS



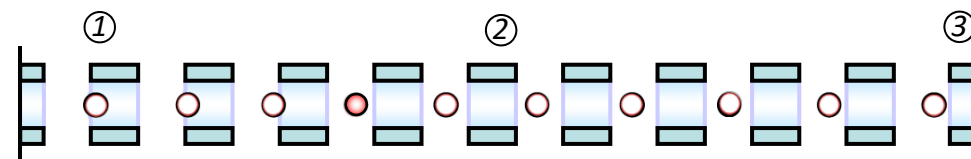
Longitudinal motion of an accelerated bunch in the constant- β -section



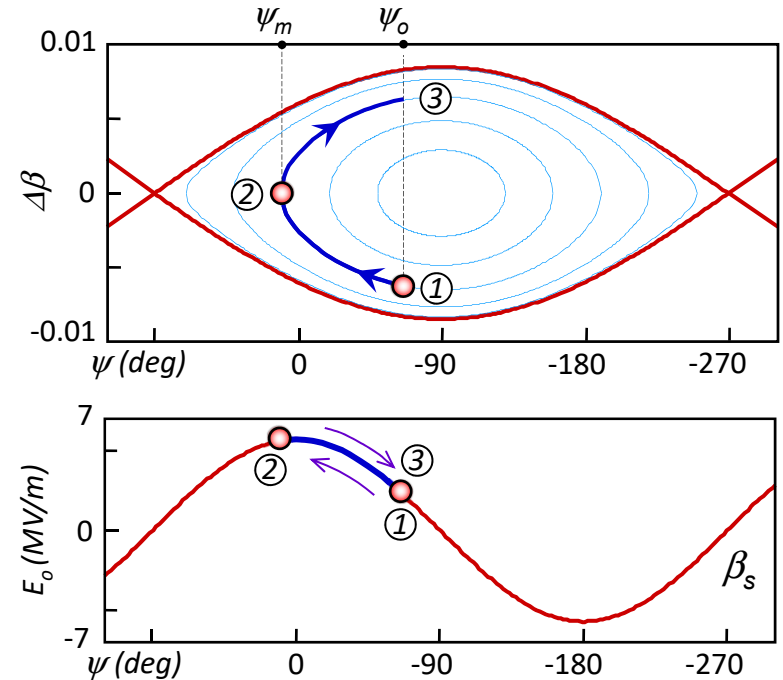
EQUUS - EQUidistant mUltigap Structure

- | | | |
|-----------------------|---|---|
| ① Particles too early | <div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> <div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> | obtain less acceleration
longitudinal focussing |
| ② Particles synchr. | <div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> <div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> | reach max. acceleration
longitudinal defocussing |
| ③ | <div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> <div style="display: inline-block; width: 20px; height: 10px; background-color: blue; margin-right: 5px;"></div> | |

EQUUS



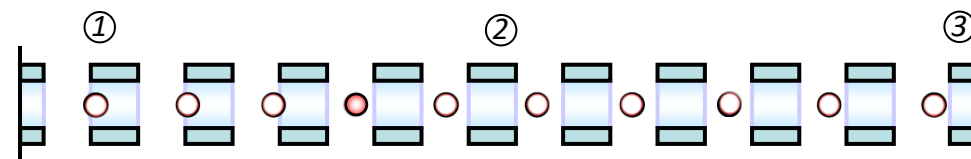
Longitudinal motion of an accelerated bunch in the constant- β -section



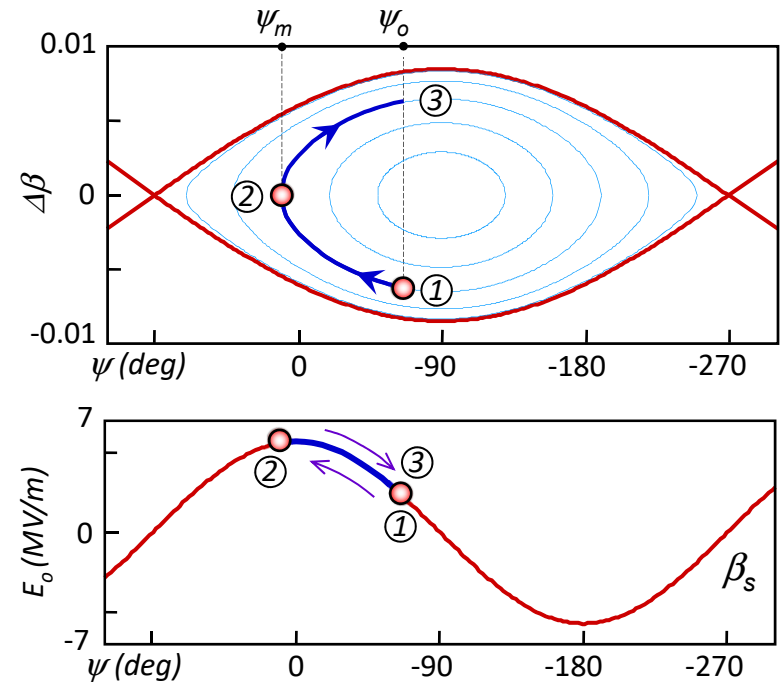
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

EQUUS



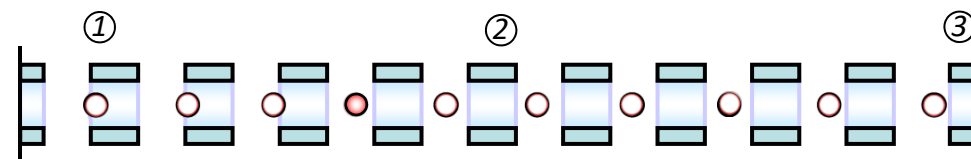
Longitudinal motion of an accelerated bunch in the constant- β -section



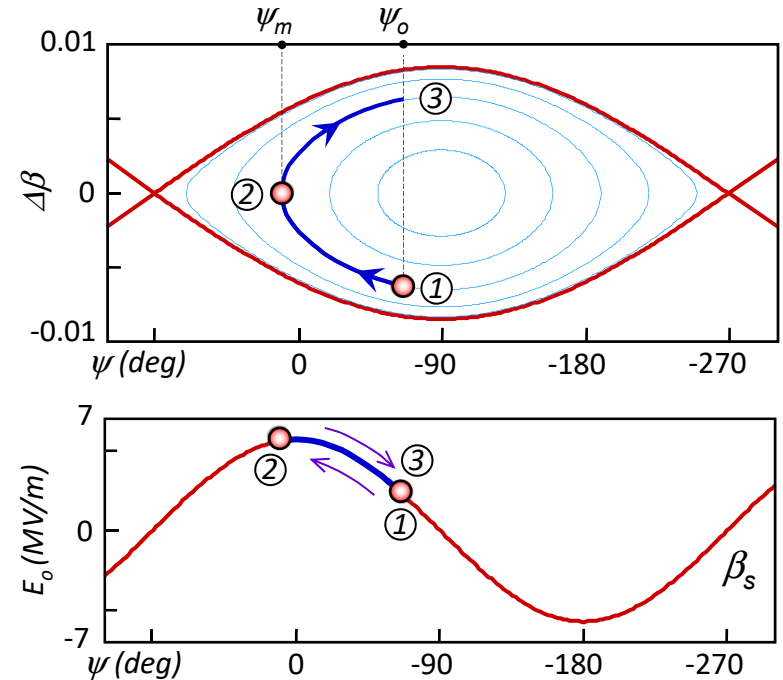
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

EQUUS



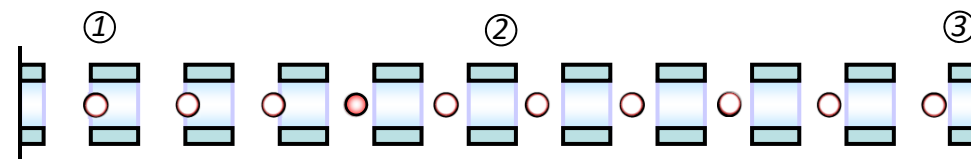
Longitudinal motion of an accelerated bunch in the constant- β -section



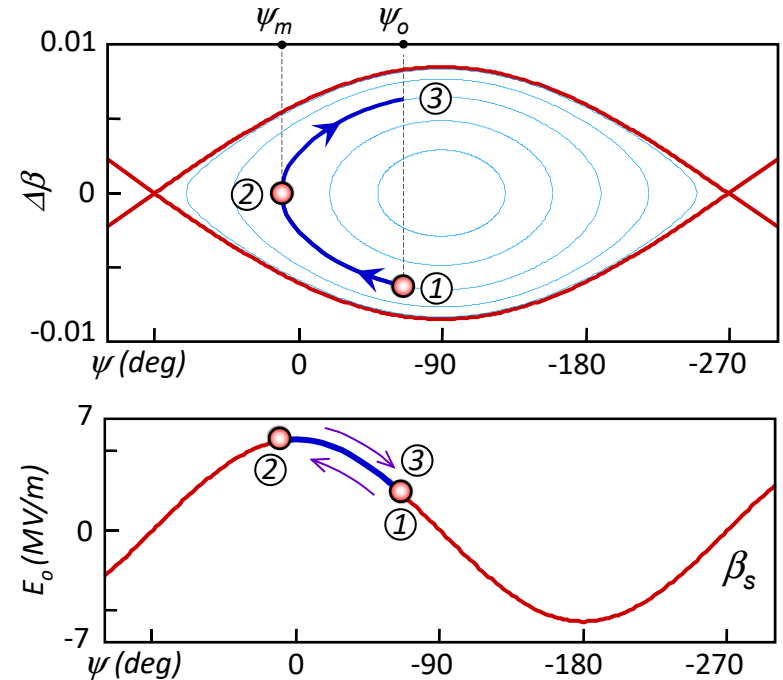
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section

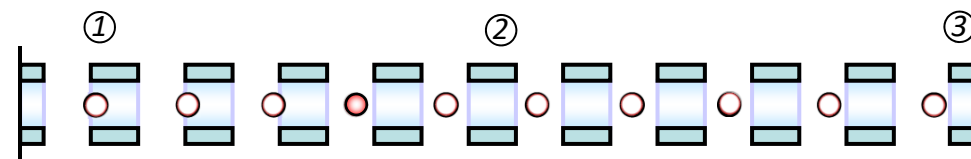


Resonant acceleration at $\phi = -30$

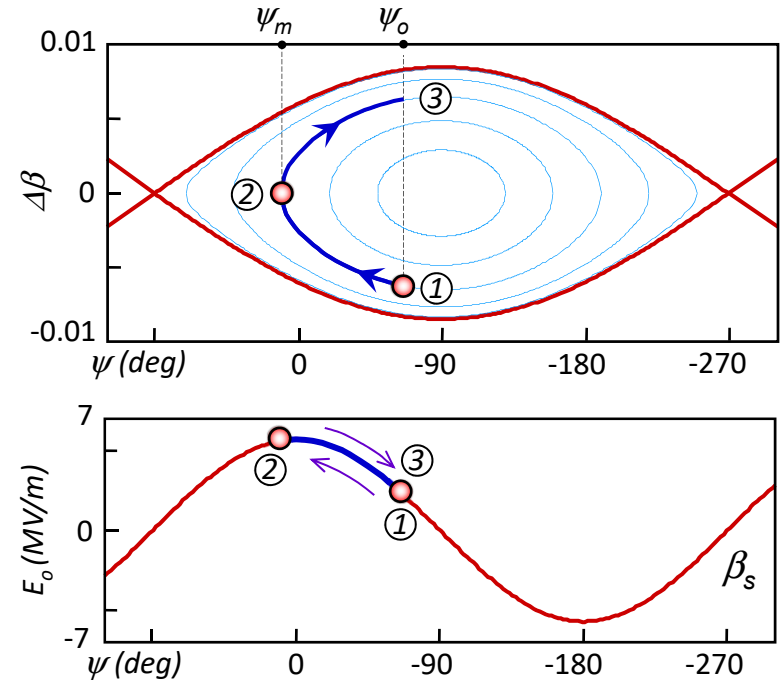
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



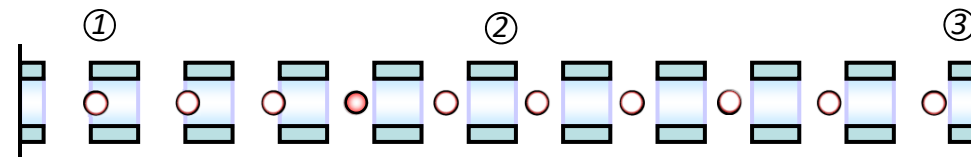
Resonant acceleration at $\varphi = -30$



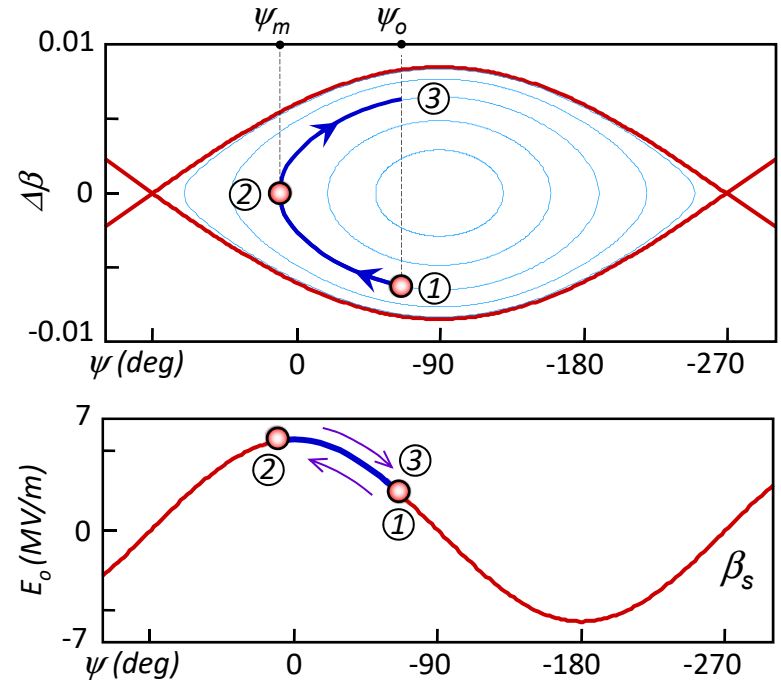
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



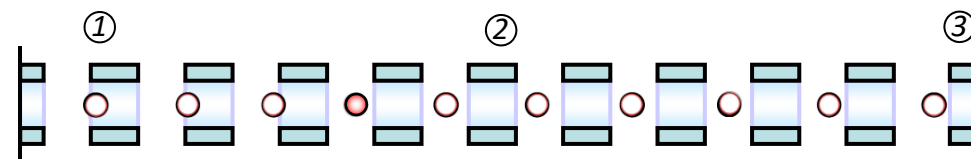
Resonant acceleration at $\varphi = -30$



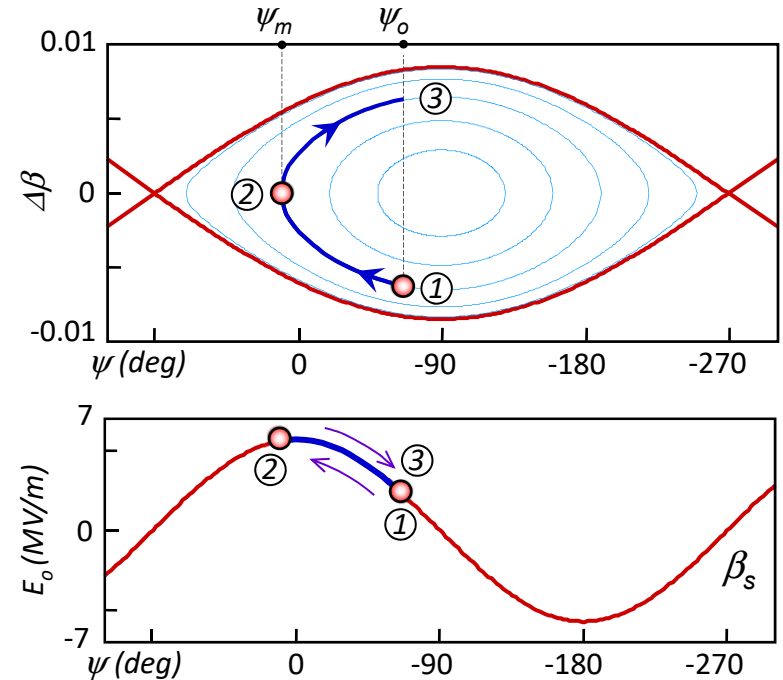
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



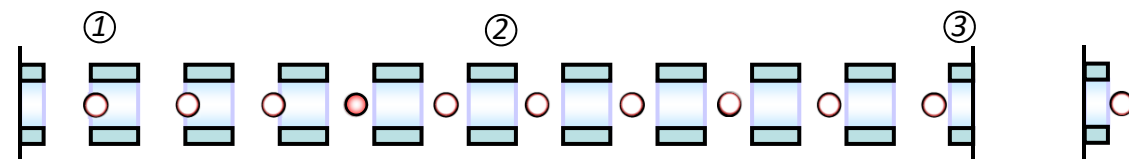
Resonant acceleration at $\varphi = -30$



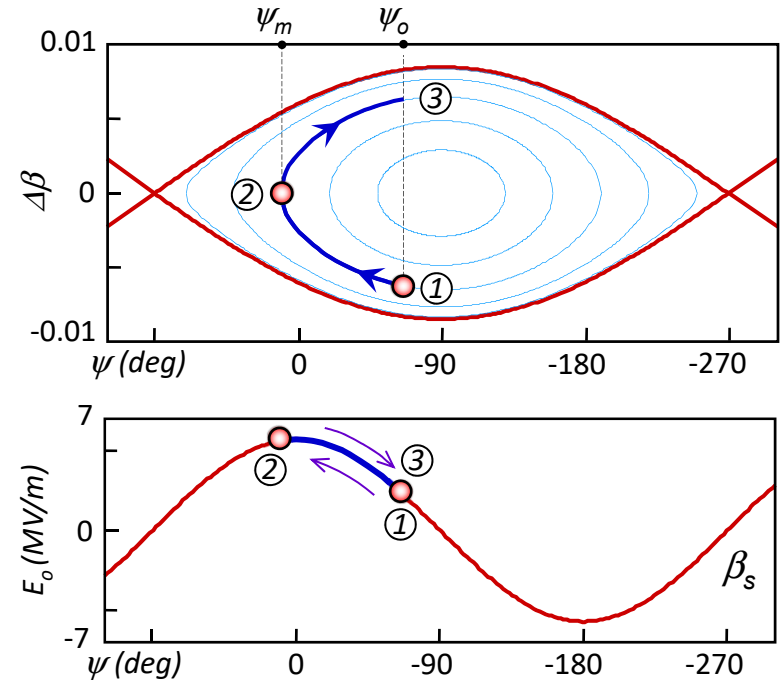
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section

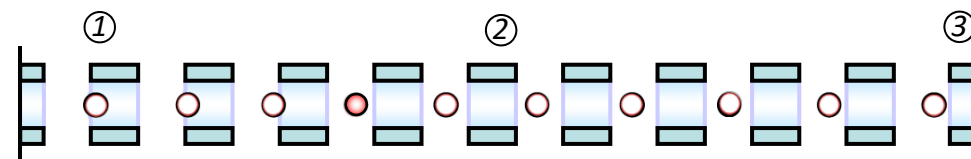


Resonant acceleration at $\phi = -30$

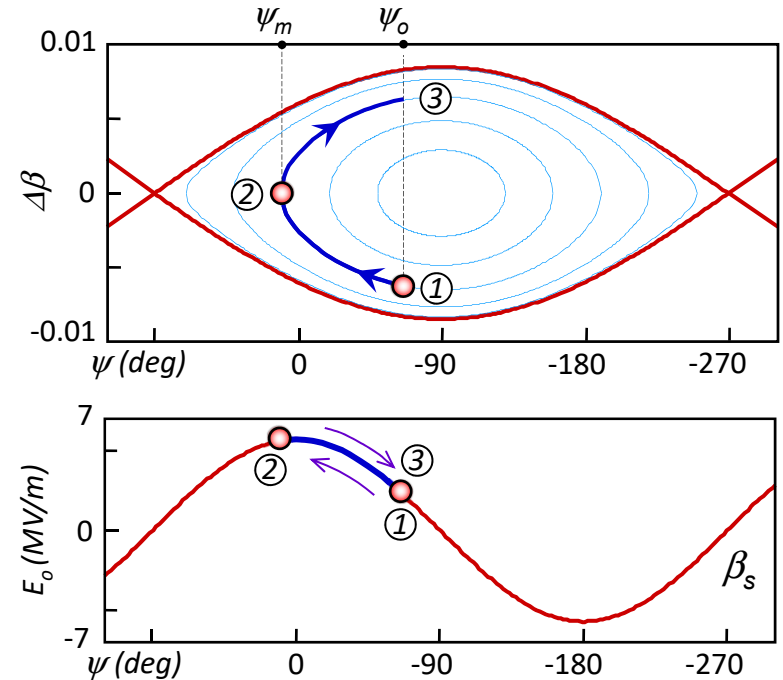
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

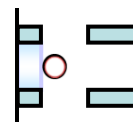
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



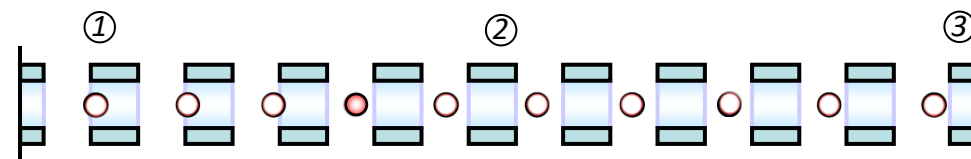
Resonant acceleration at $\varphi = -30$



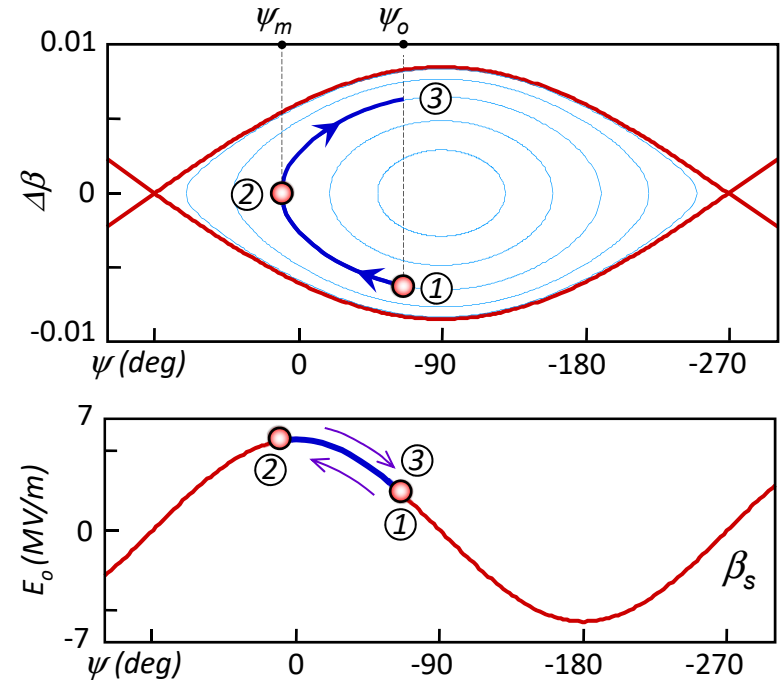
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

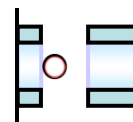
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



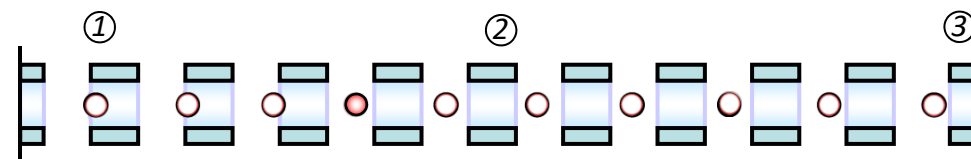
Resonant acceleration at $\varphi = -30$



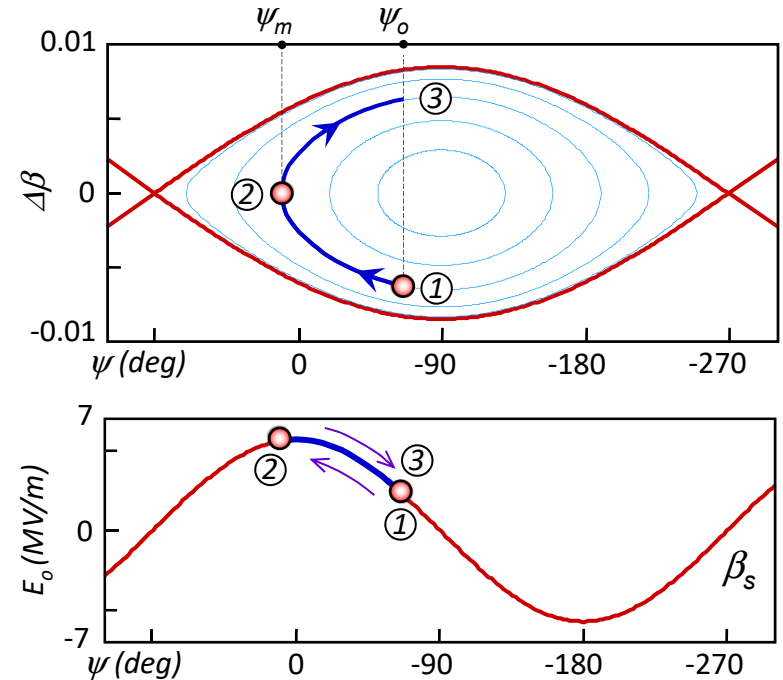
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

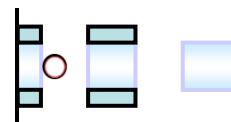
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



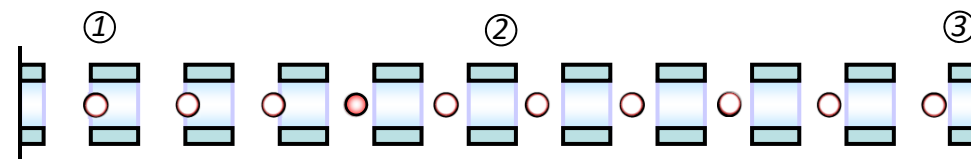
Resonant acceleration at $\phi = -30$



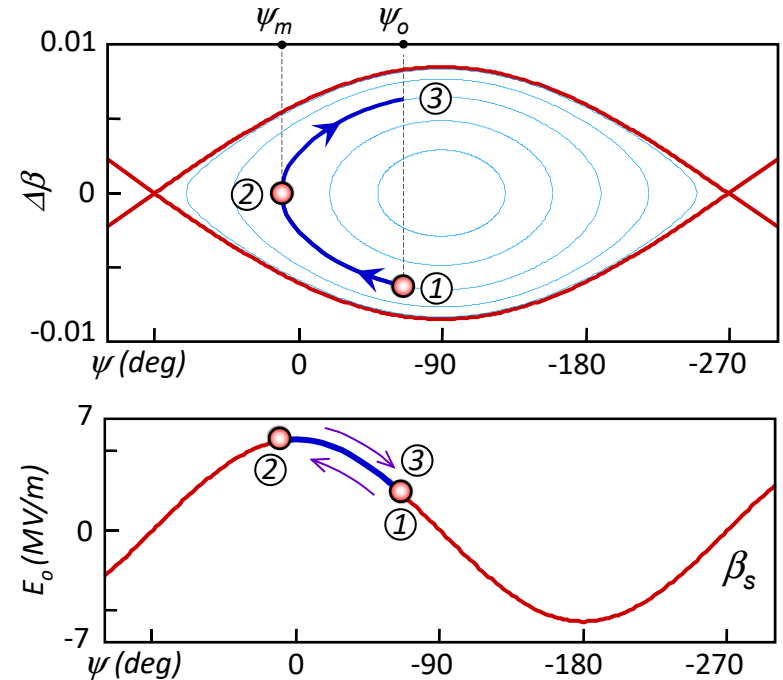
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

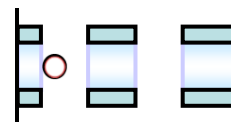
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



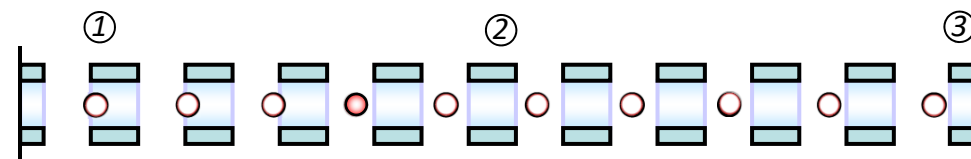
Resonant acceleration at $\varphi = -30$



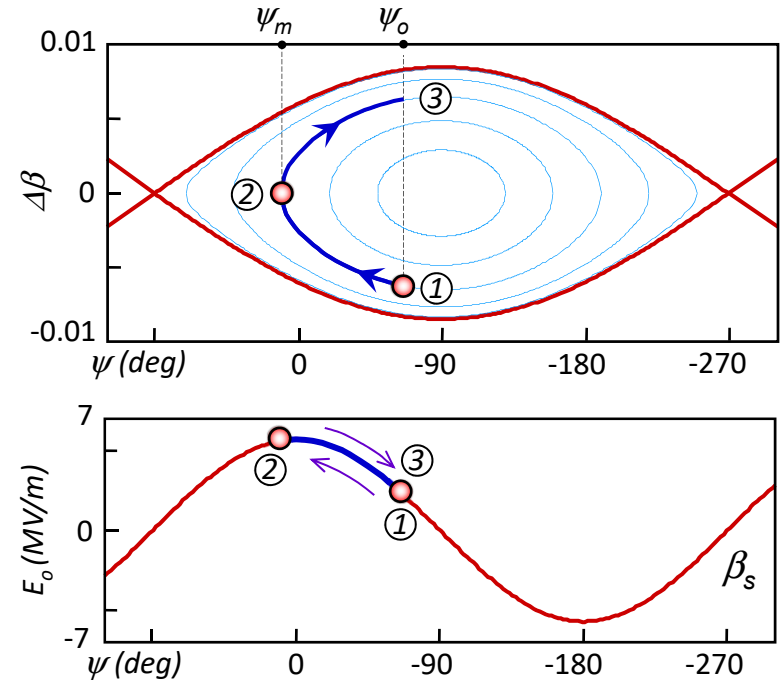
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

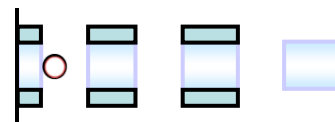
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



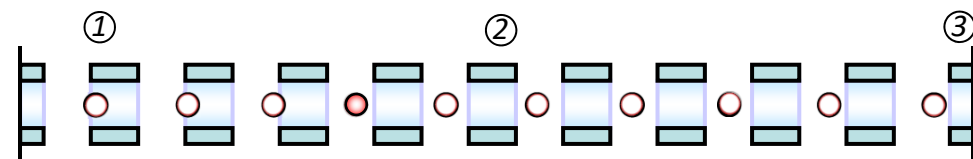
Resonant acceleration at $\varphi = -30$



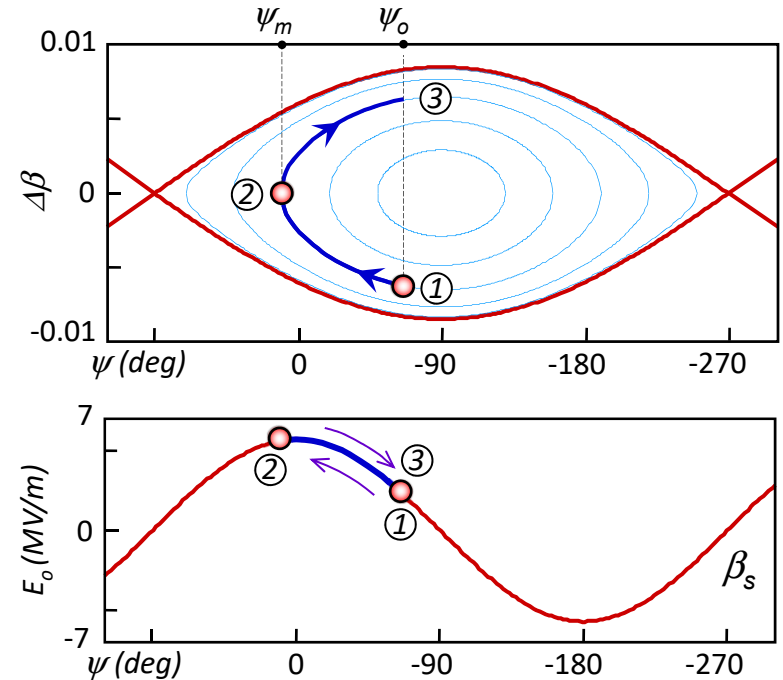
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

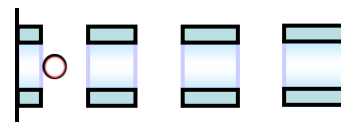
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



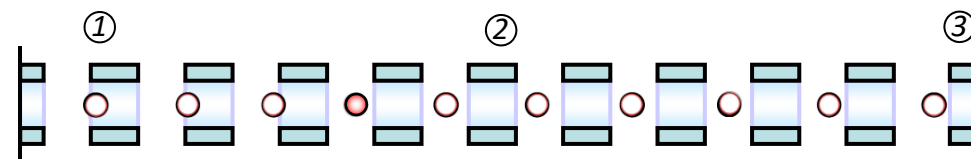
Resonant acceleration at $\varphi = -30$



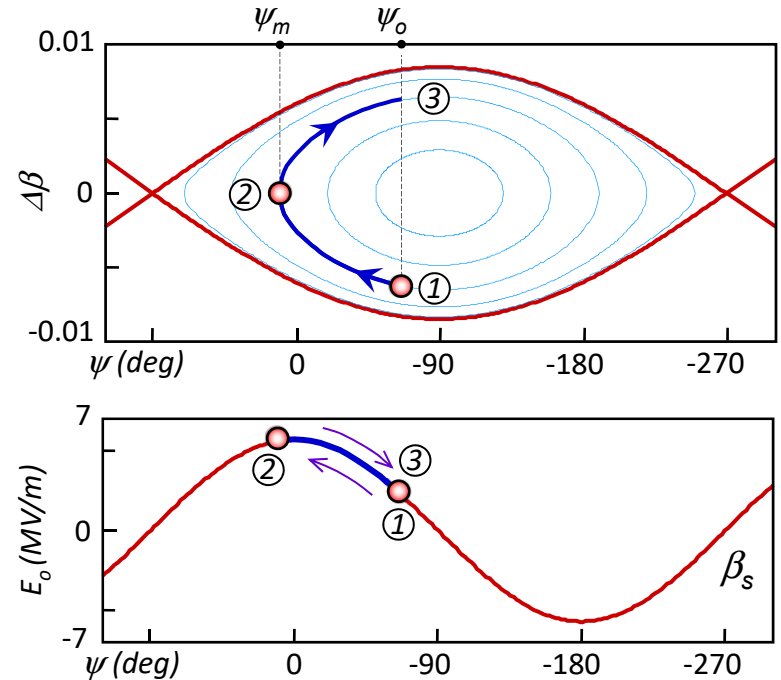
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

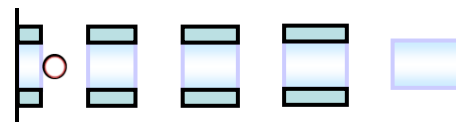
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



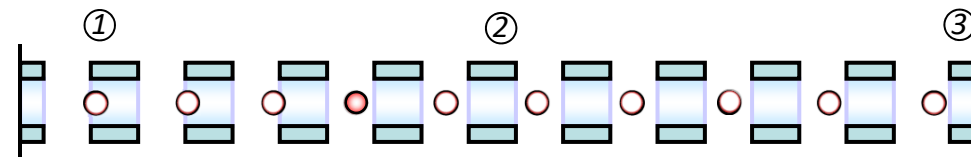
Resonant acceleration at $\phi = -30$



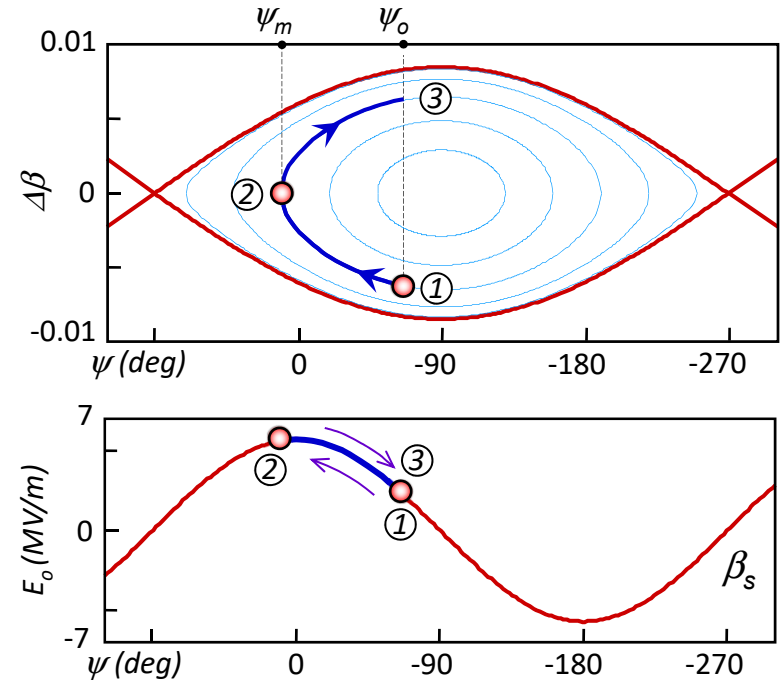
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

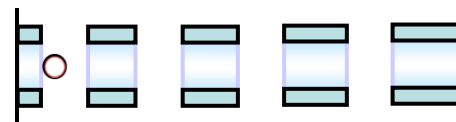
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



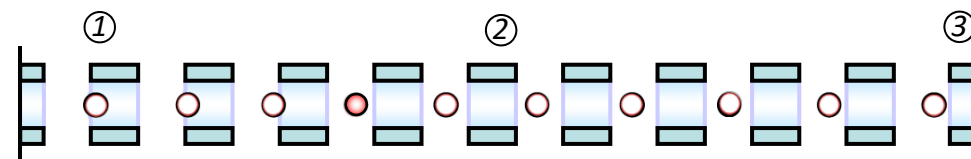
Resonant acceleration at $\varphi = -30$



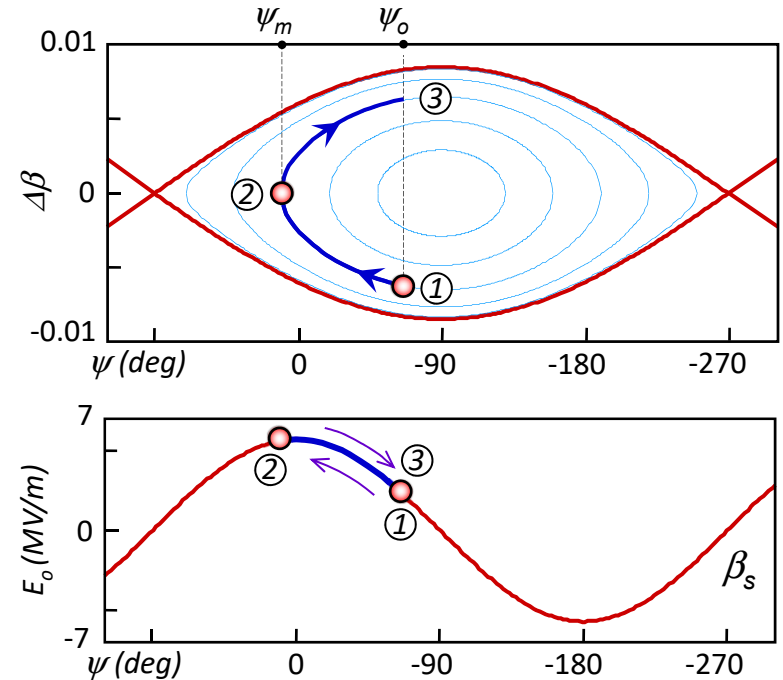
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

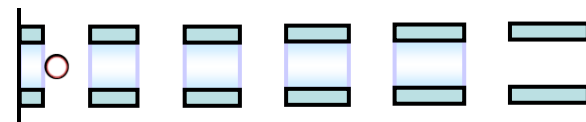
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



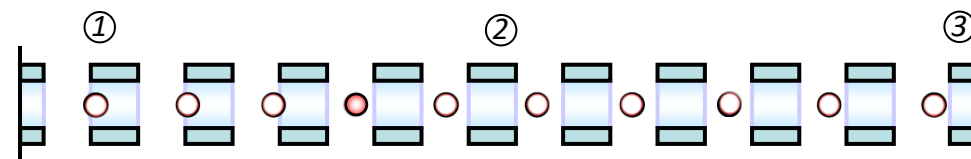
Resonant acceleration at $\phi = -30$



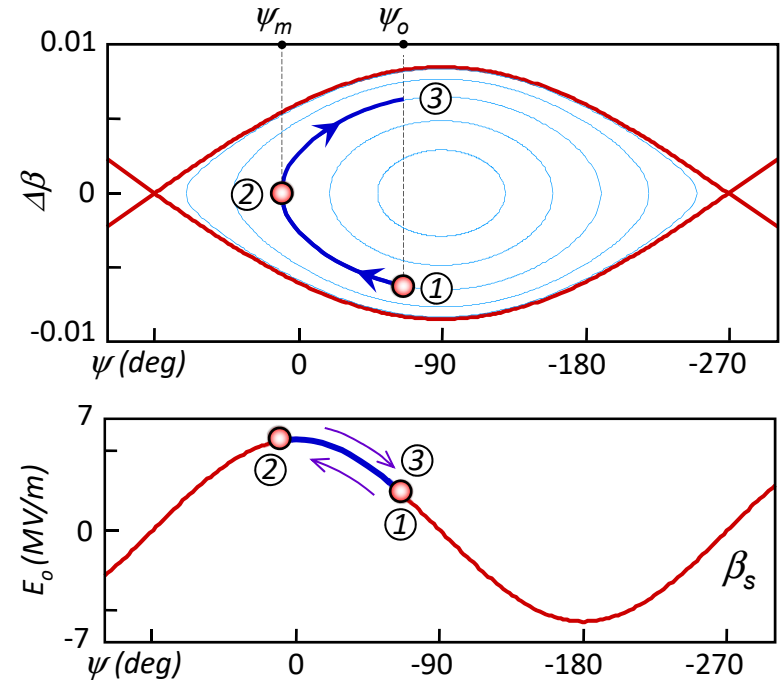
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

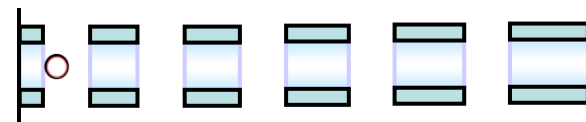
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



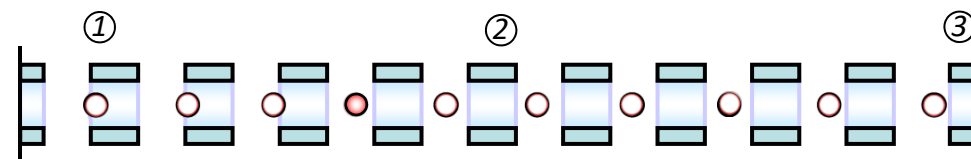
Resonant acceleration at $\phi = -30$



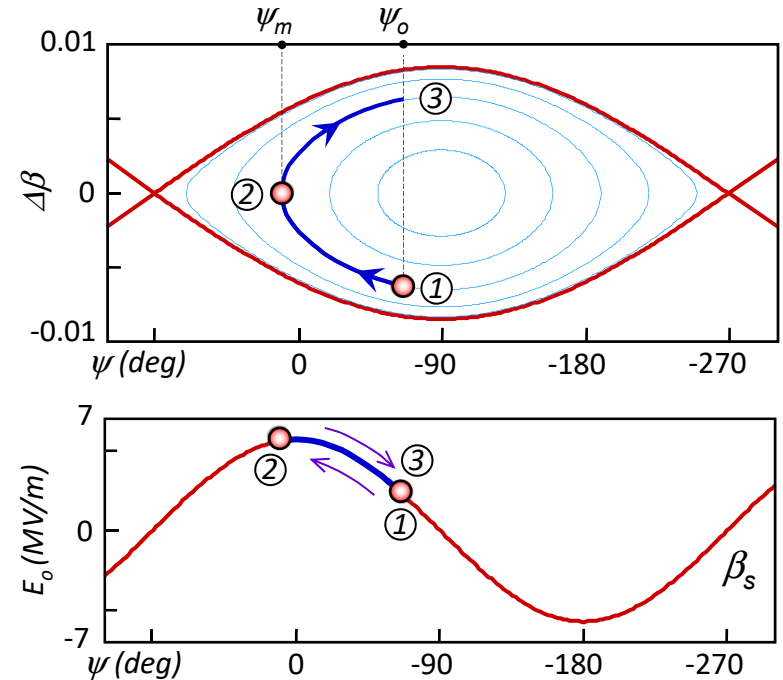
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

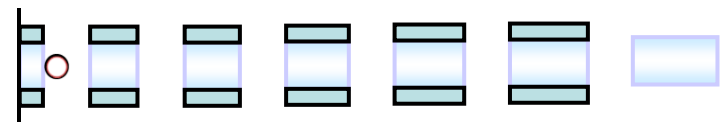
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



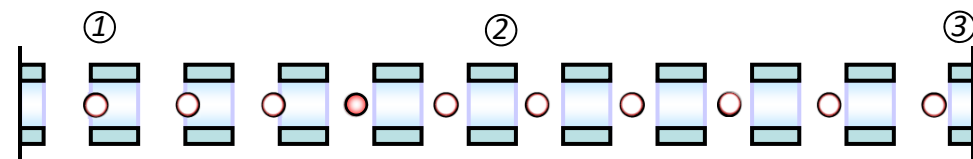
Resonant acceleration at $\phi = -30$



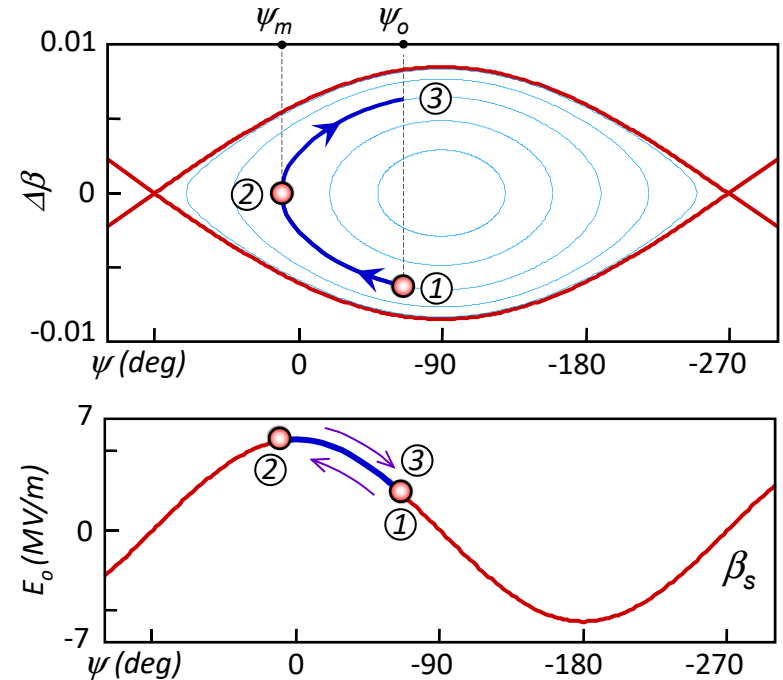
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

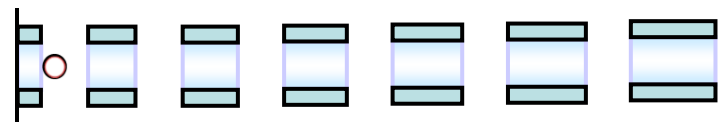
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



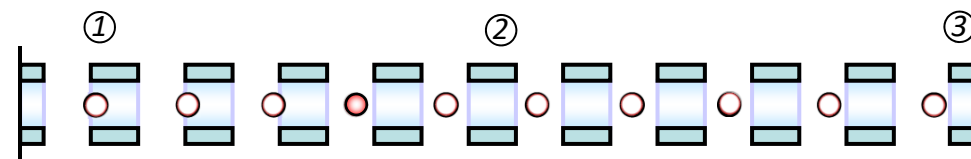
Resonant acceleration at $\phi = -30$



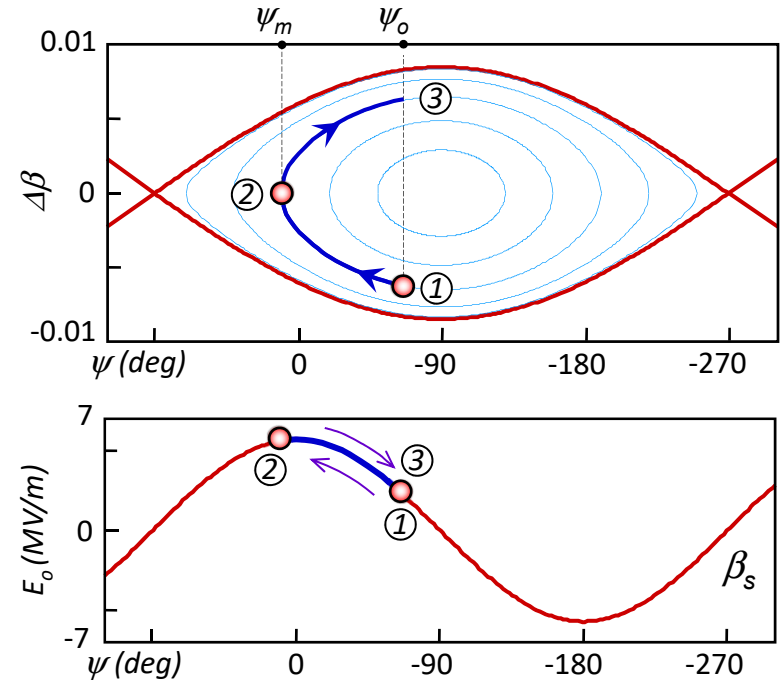
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

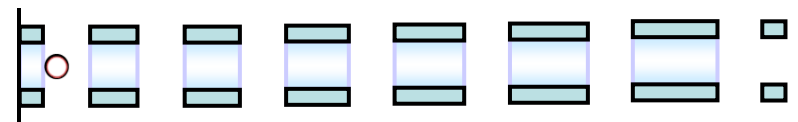
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



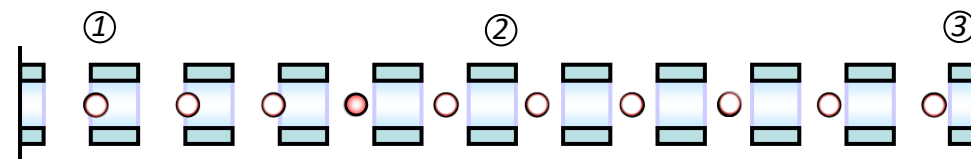
Resonant acceleration at $\phi = -30^\circ$



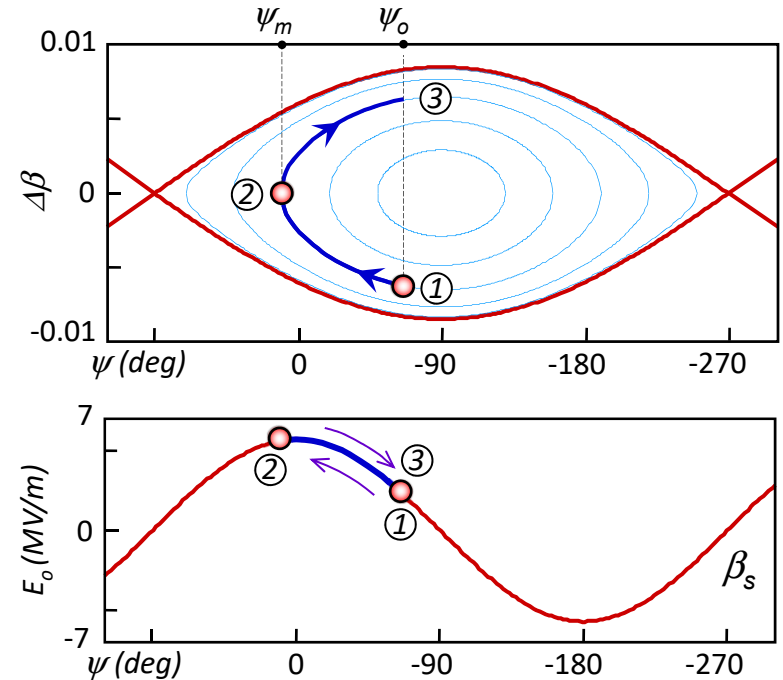
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

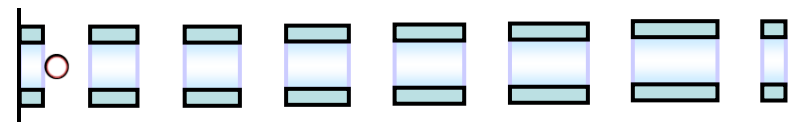
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



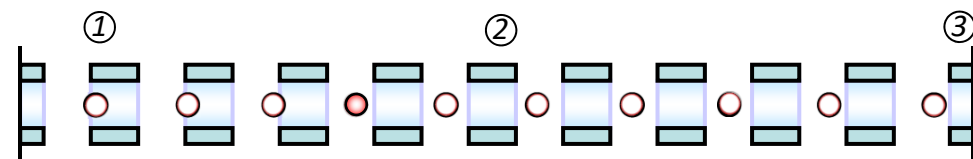
Resonant acceleration at $\varphi = -30$



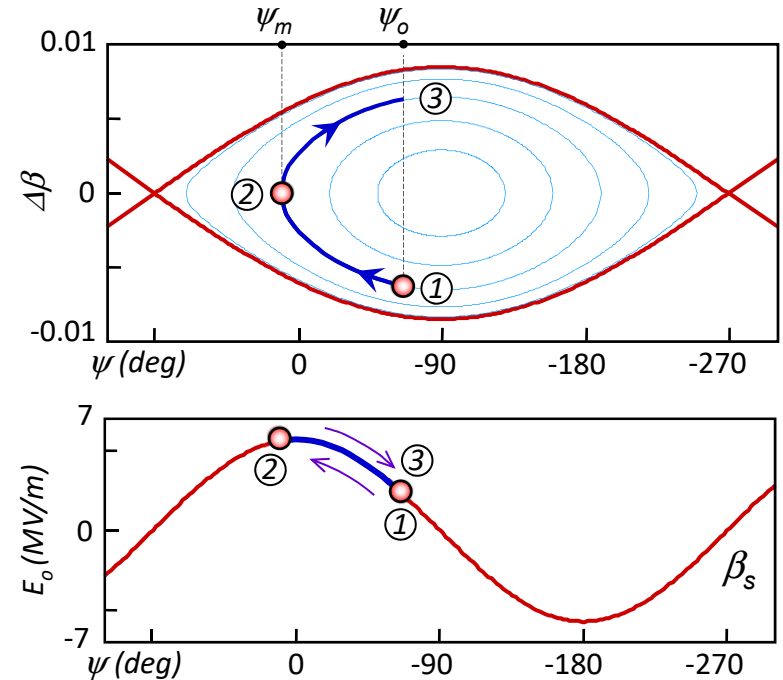
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

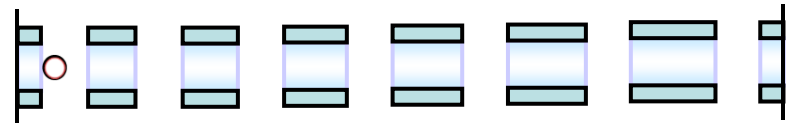
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



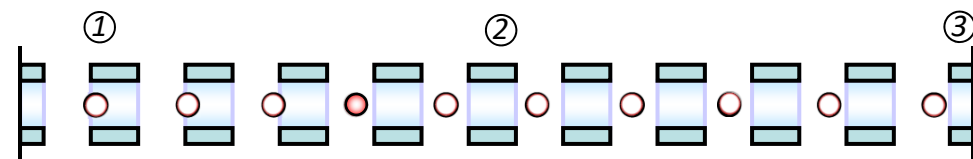
Resonant acceleration at $\phi = -30$



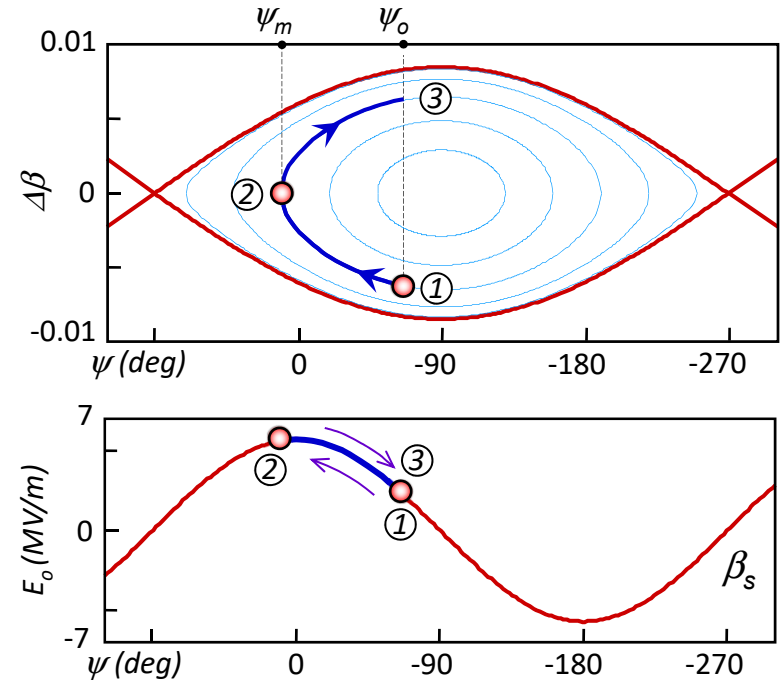
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

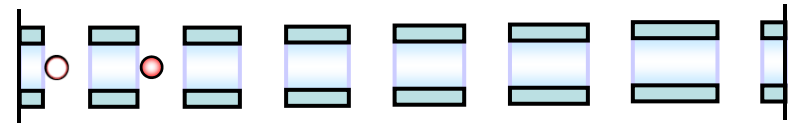
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



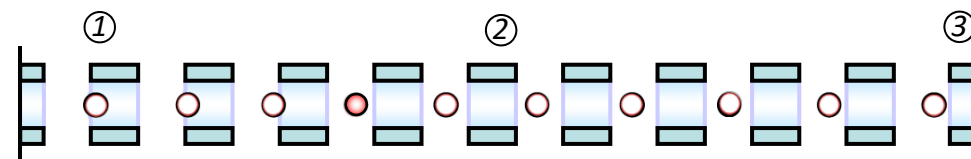
Resonant acceleration at $\phi = -30$



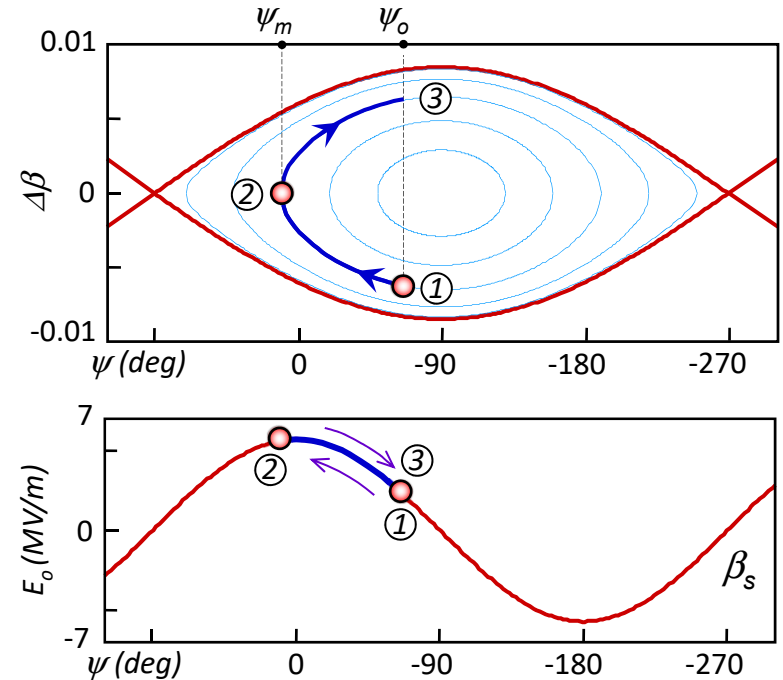
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

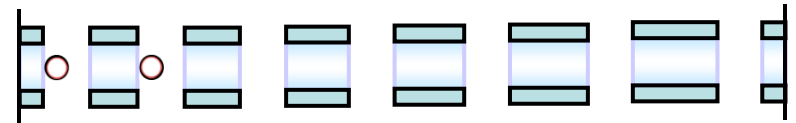
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



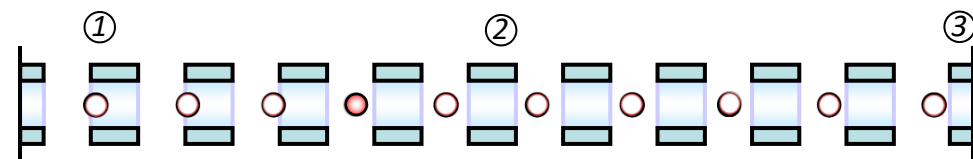
Resonant acceleration at $\phi = -30^\circ$



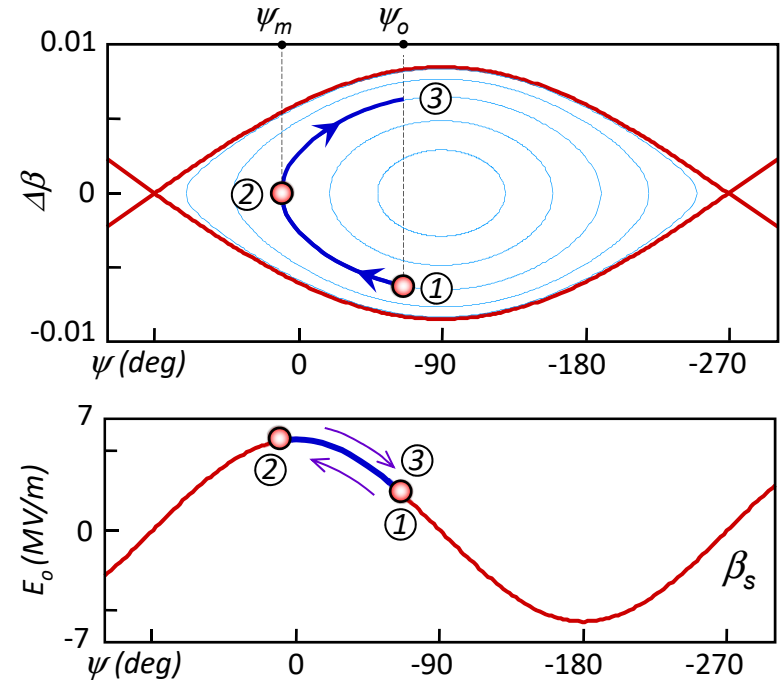
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

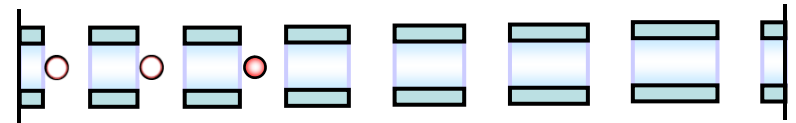
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



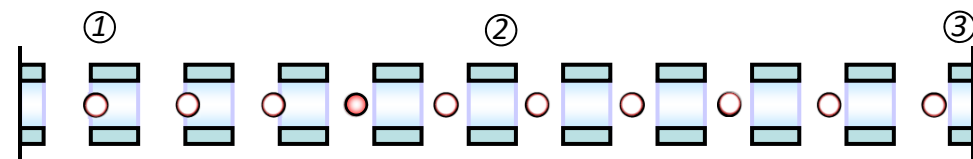
Resonant acceleration at $\phi = -30$



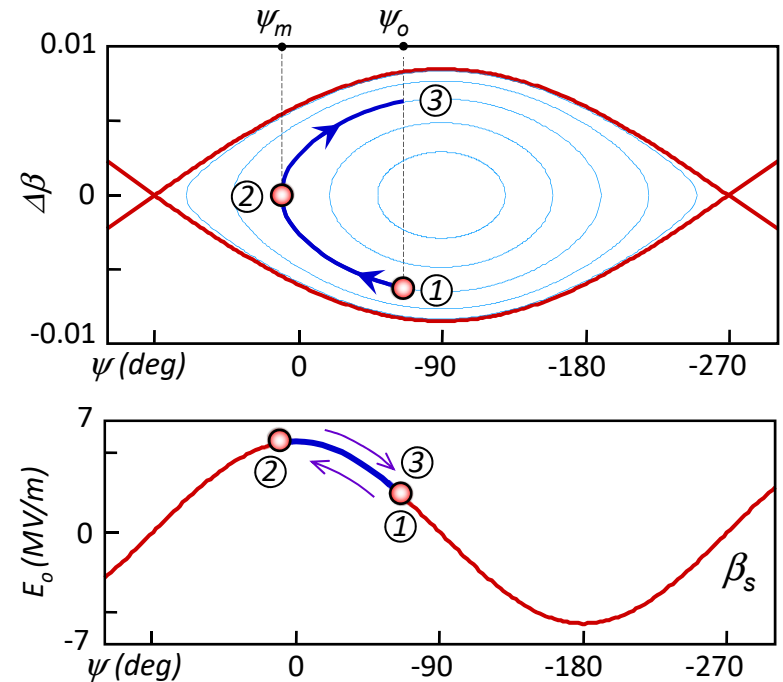
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

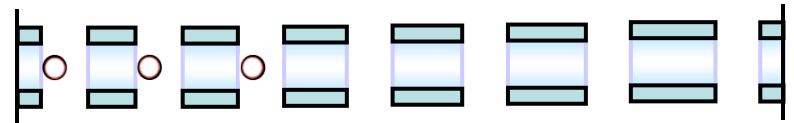
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



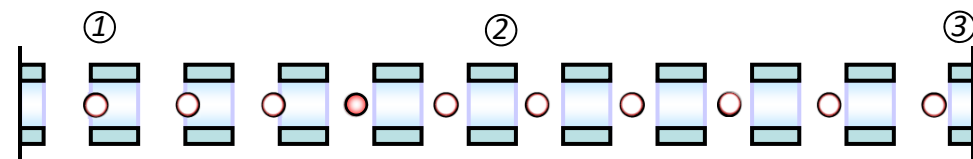
Resonant acceleration at $\phi = -30$



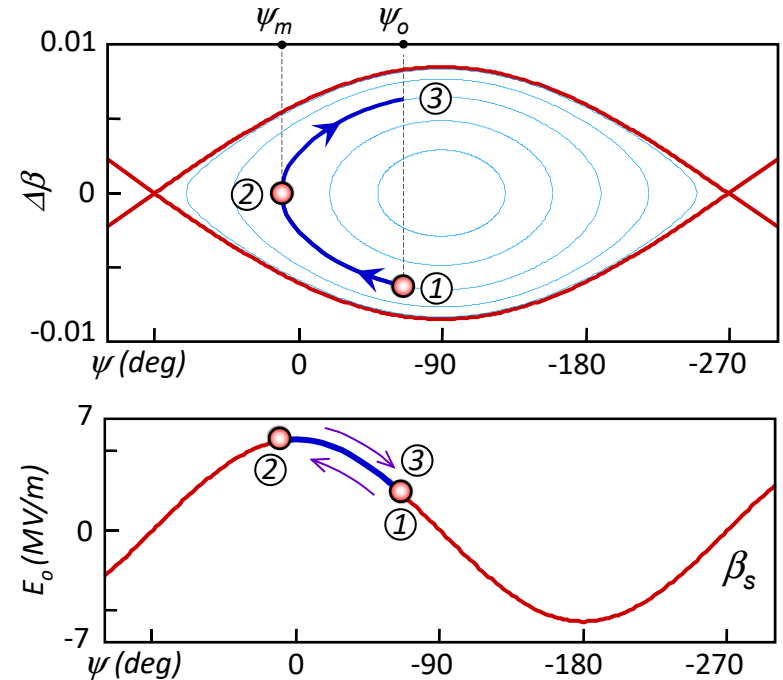
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

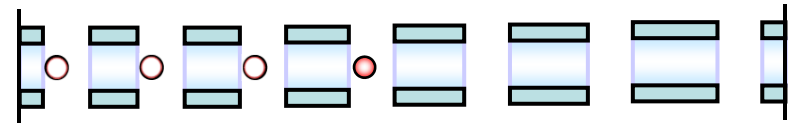
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



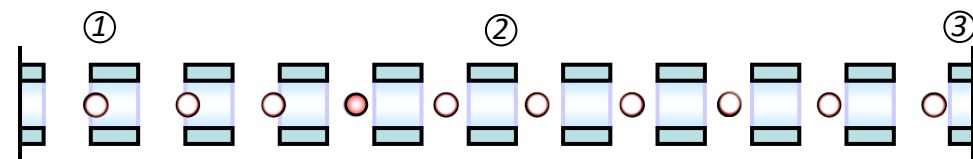
Resonant acceleration at $\phi = -30$



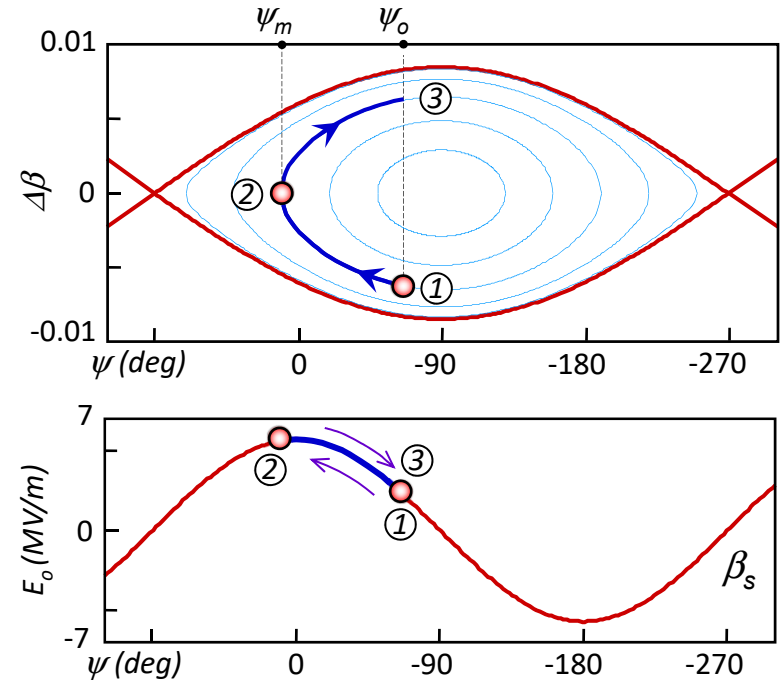
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

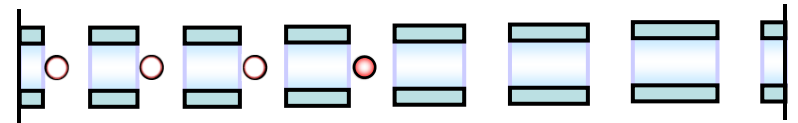
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



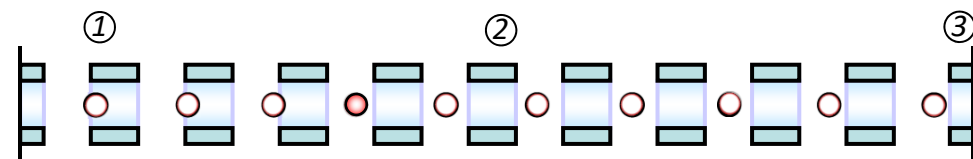
Resonant acceleration at $\phi = -30$



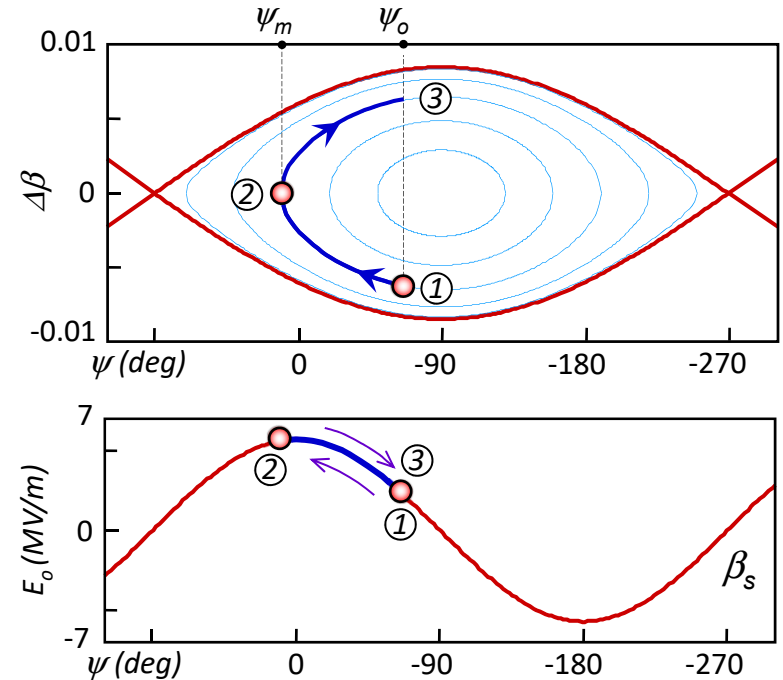
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

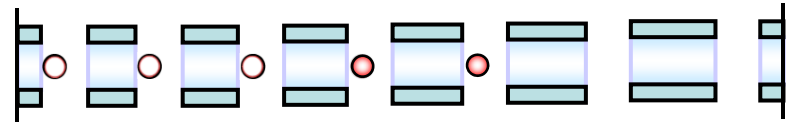
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



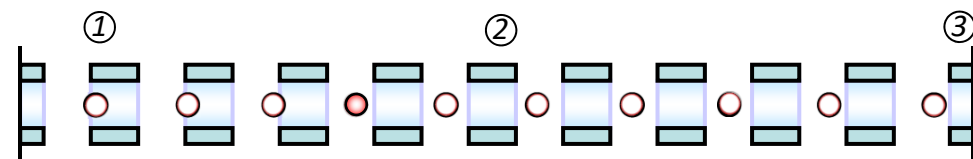
Resonant acceleration at $\phi = -30$



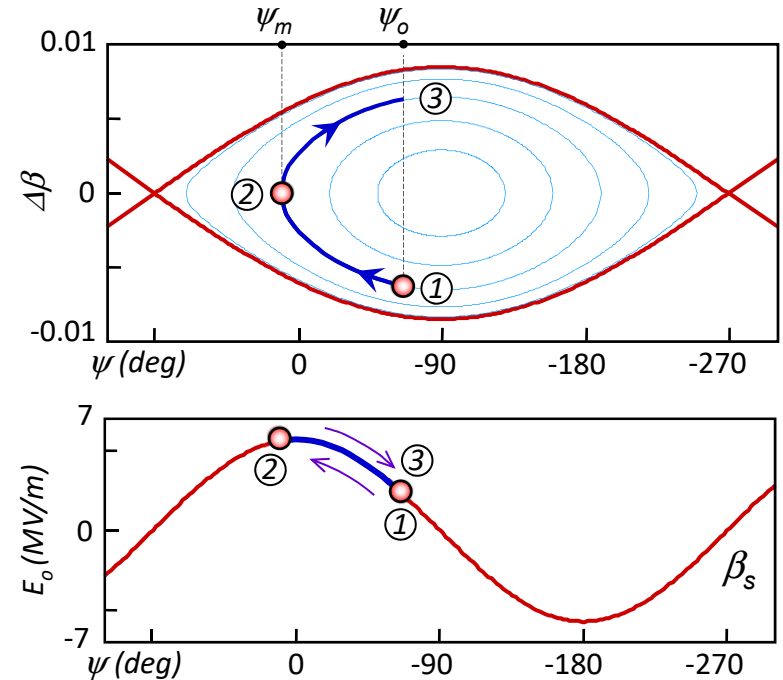
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

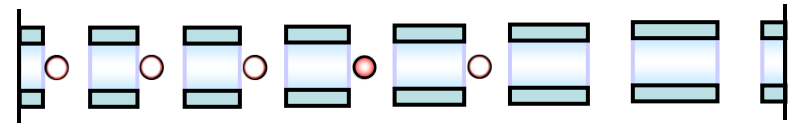
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



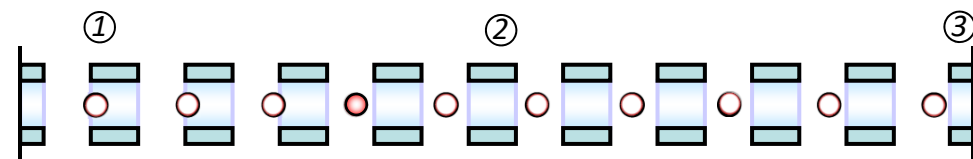
Resonant acceleration at $\varphi = -30$



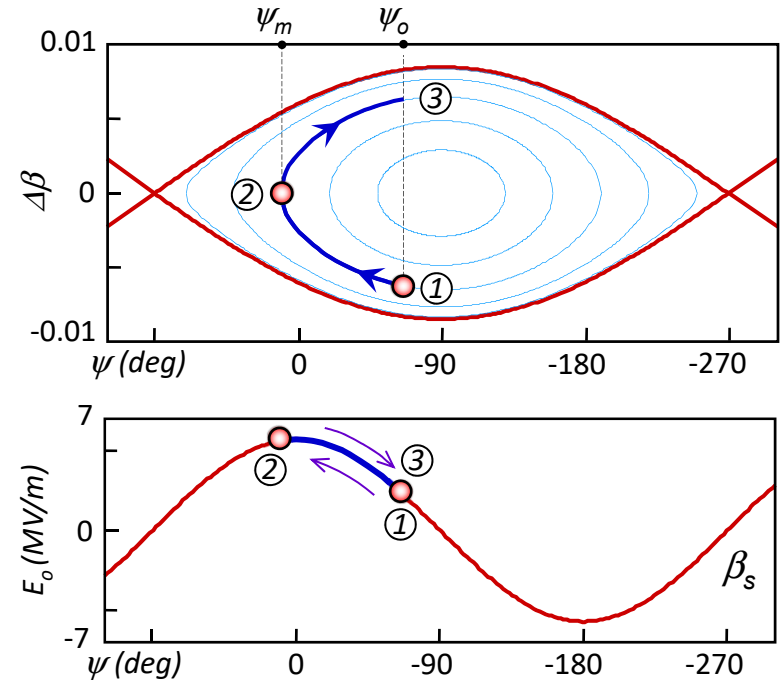
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

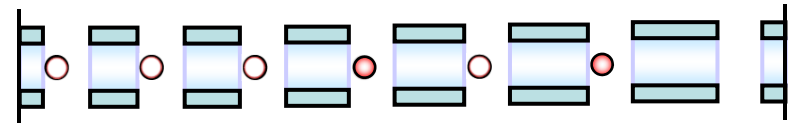
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



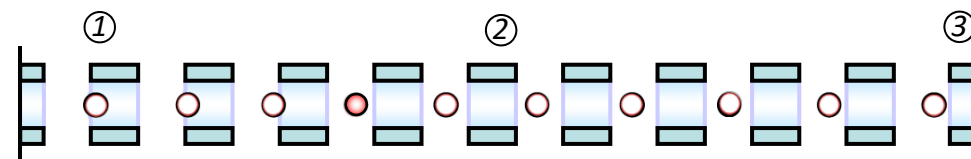
Resonant acceleration at $\phi = -30^\circ$



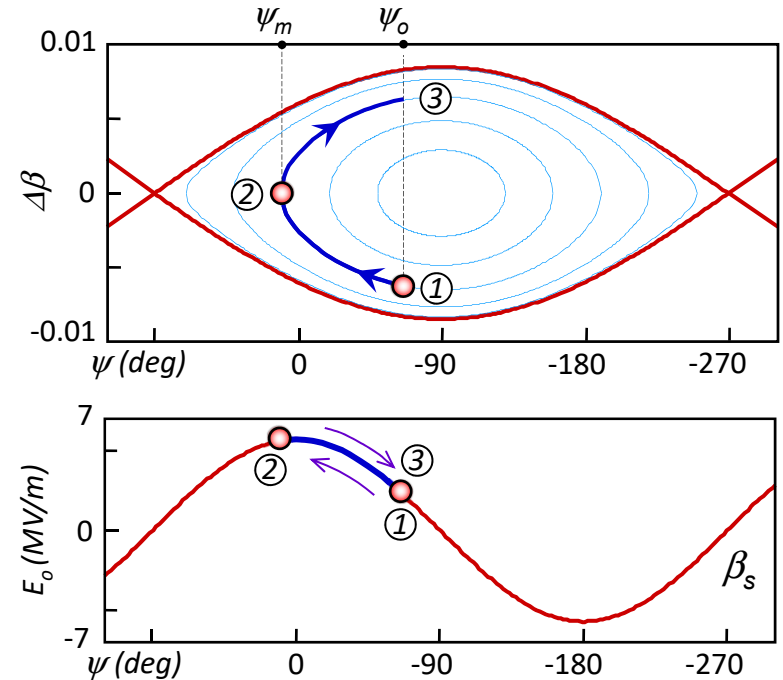
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

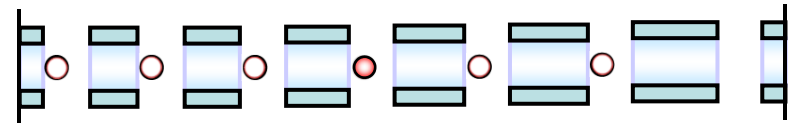
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



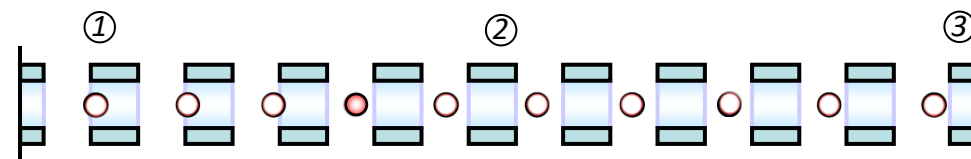
Resonant acceleration at $\phi = -30^\circ$



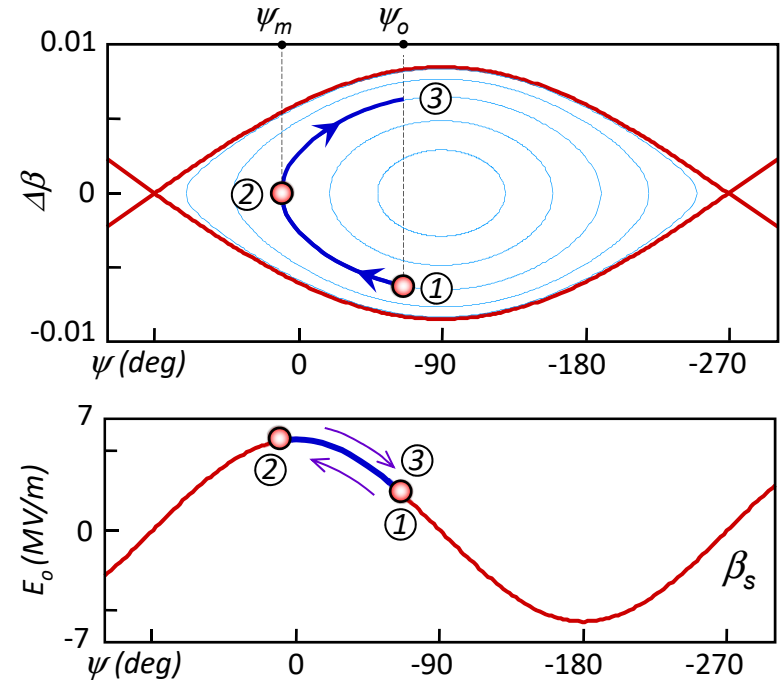
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

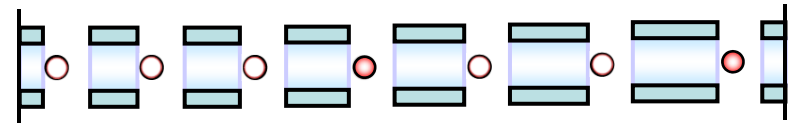
EQUUS



Longitudinal motion of an accelerated bunch in the constant- β -section



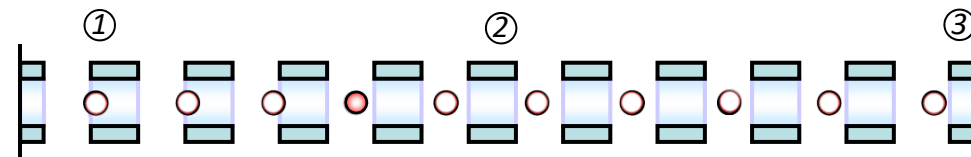
Resonant acceleration at $\phi = -30$



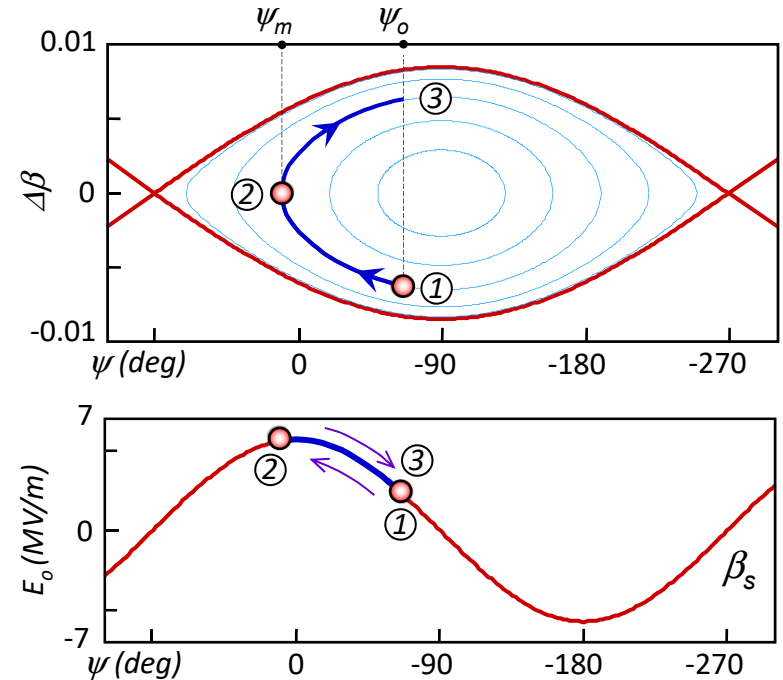
EQUUS - EQUidistant mUltigap Structure

- | | |
|-----------------------|----------------------------|
| ① Particles too early | → obtain less acceleration |
| | → longitudinal focussing |
| ② Particles synchr. | → reach max. acceleration |
| | → longitudinal defocussing |
| ③ Particles too early | → obtain less acceleration |
| | → longitudinal focussing |

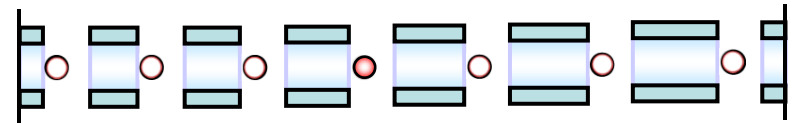
EQUUS



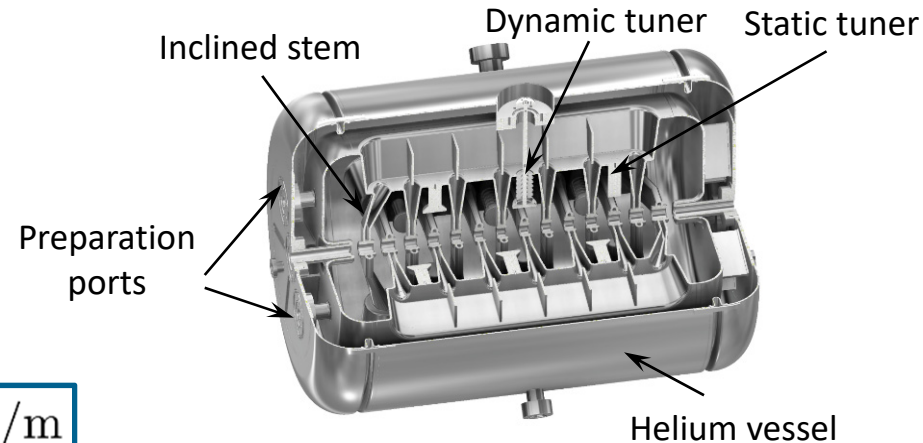
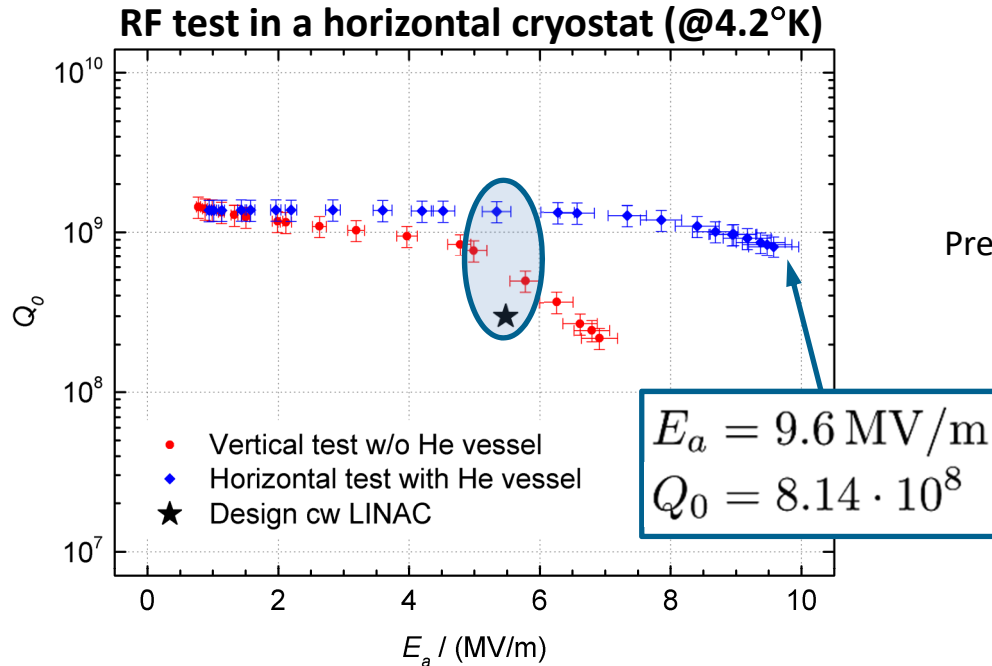
Longitudinal motion of an accelerated bunch in the constant- β -section



Resonant acceleration at $\phi = -30$



RF Testing of the CH-Cavity (10/2016)

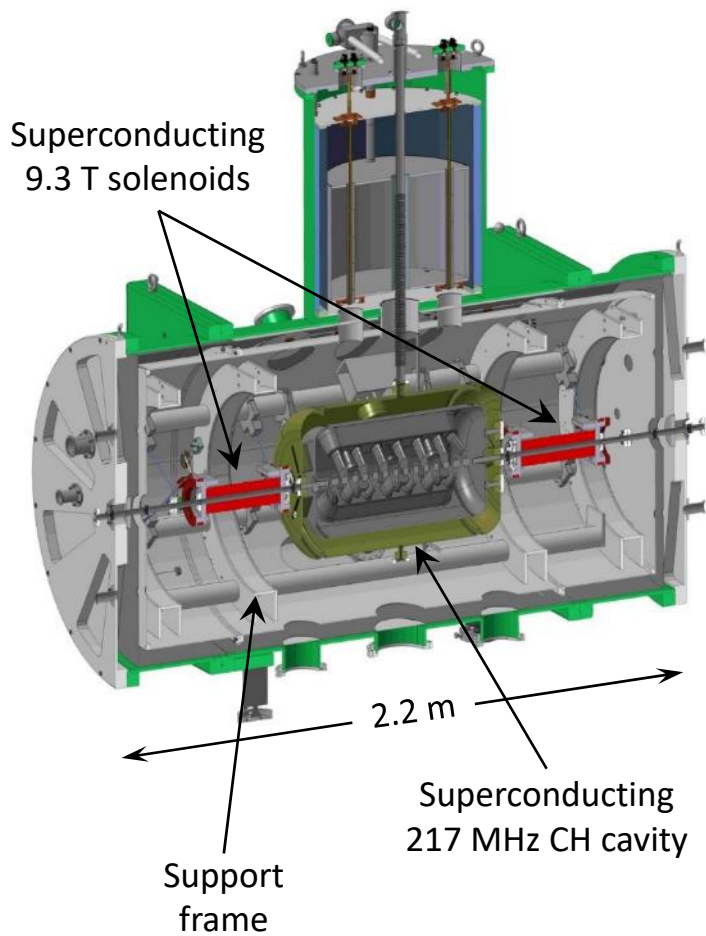


- ➡ Improved performance (add. HPR)
- ➡ Low field emission rate
- ➡ High field gradient
- ➡ Therm. quenching beyond 9.6 MV/m

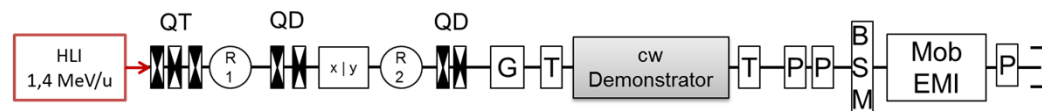
		Vertical test w/o He vessel	Horizontal test with He vessel
Q_0^{low}		$1.44 \cdot 10^9$	$1.37 \cdot 10^9$
R_S	nΩ	36	38
R_{BCS}	nΩ	15	15
R_{mag}	nΩ	9	12
R_0	nΩ	12	11
E_a	MV/m	6.9	9.6
Q_0		$2.19 \cdot 10^8$	$8.14 \cdot 10^8$
V_a	MV	4.2	5.9
E_p	MV/m	43	60
B_p	mT	39	55

Experimental setup of the demonstrator at GSI

Layout of the horizontal cryomodule



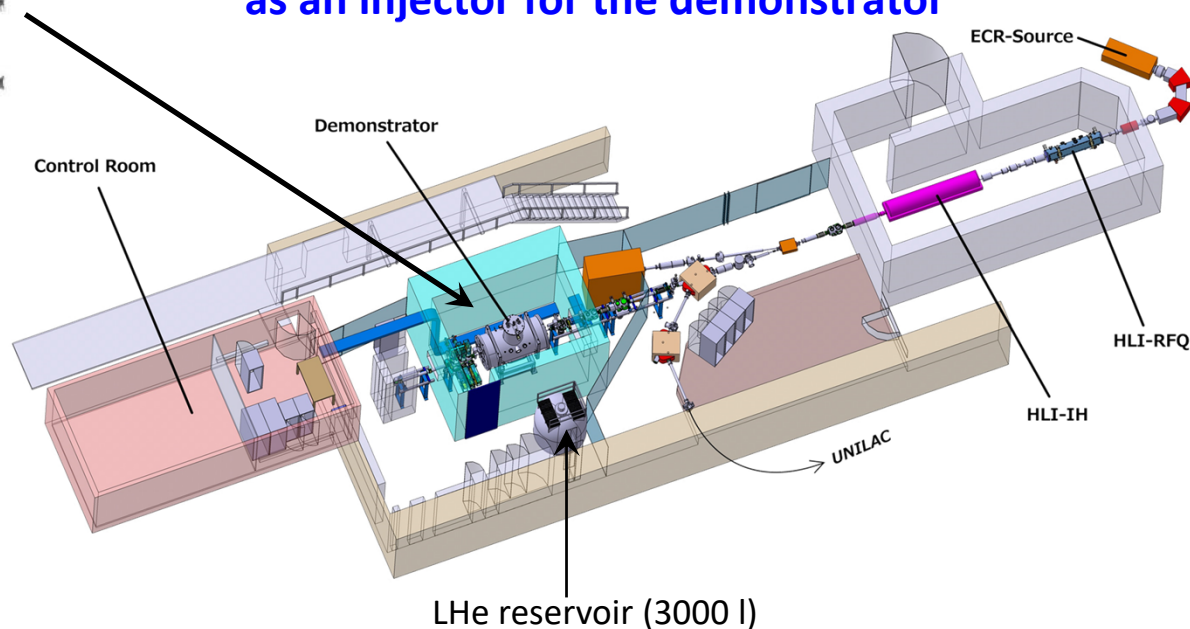
Matching line - demonstrator – test bench



- Steering magnets
- Rebuncher
- Quadrupole doublet
- Profile grids

- Phase probes for TOF measurement
- Beam current transformers
- Bunch shape monitor (Feschenko)
- Emittance measurement

The High Charge State Injector (HLI) at GSI serves as an injector for the demonstrator

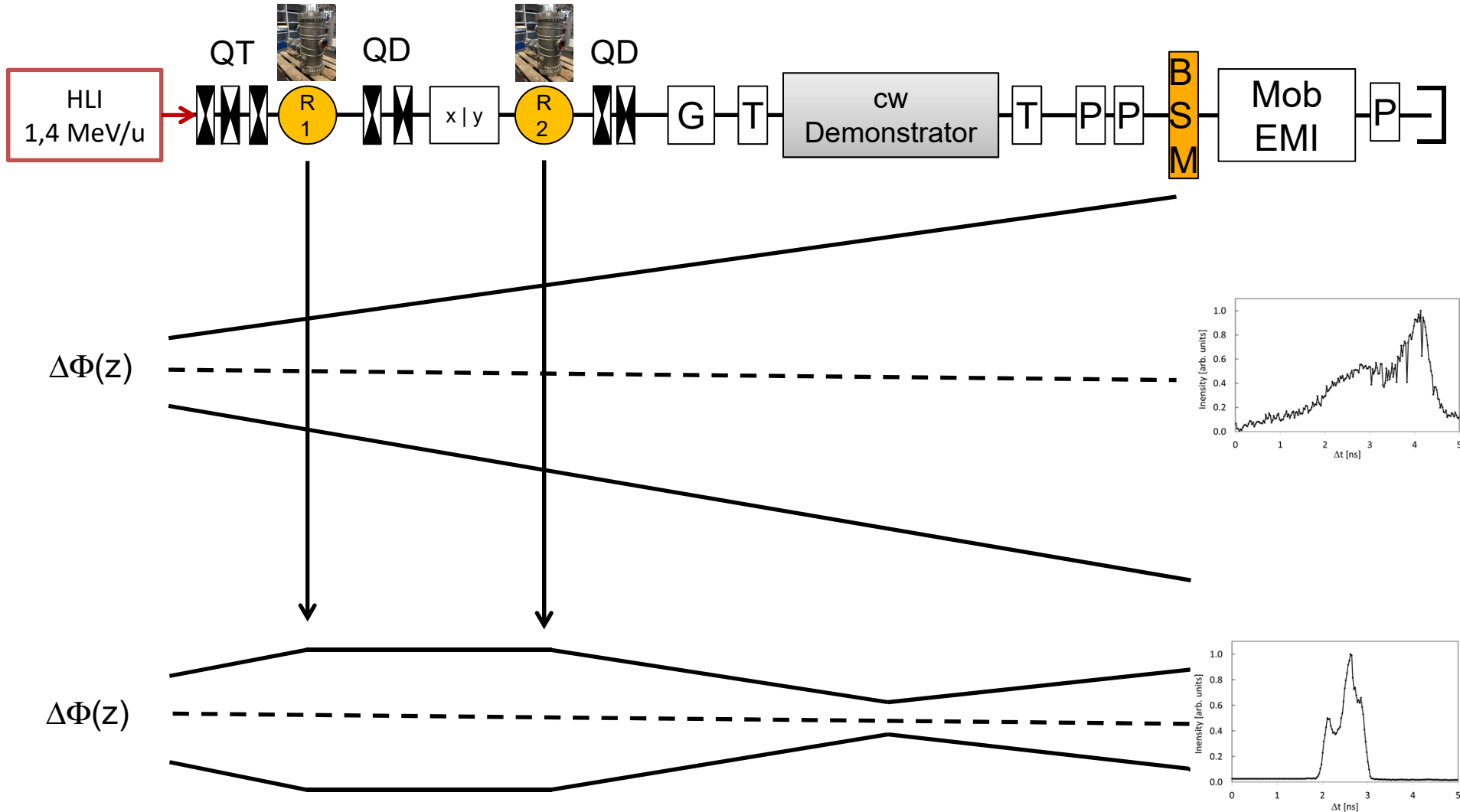




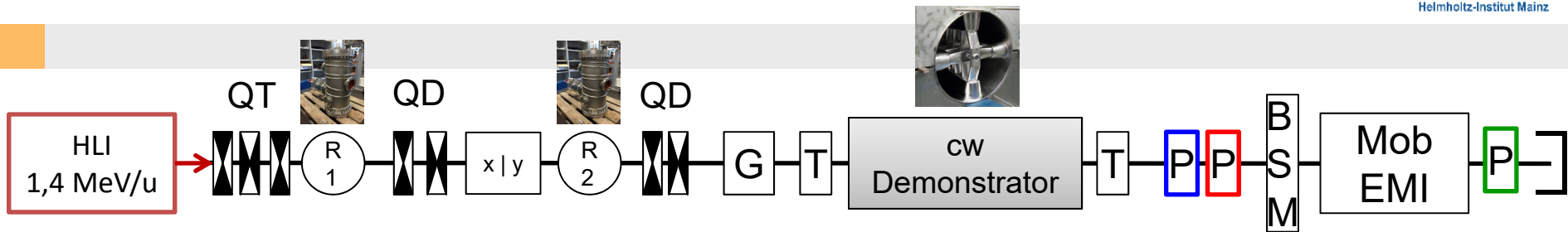
June 2017
First beam test



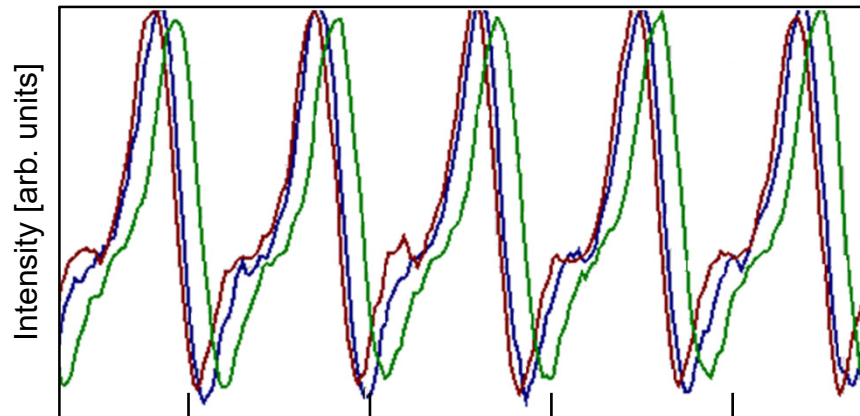
Longitudinal matching



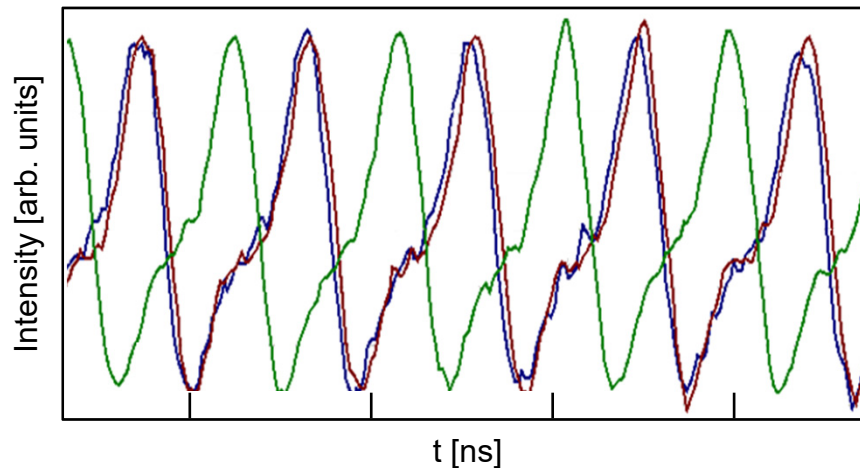
First Acceleration



cavity off

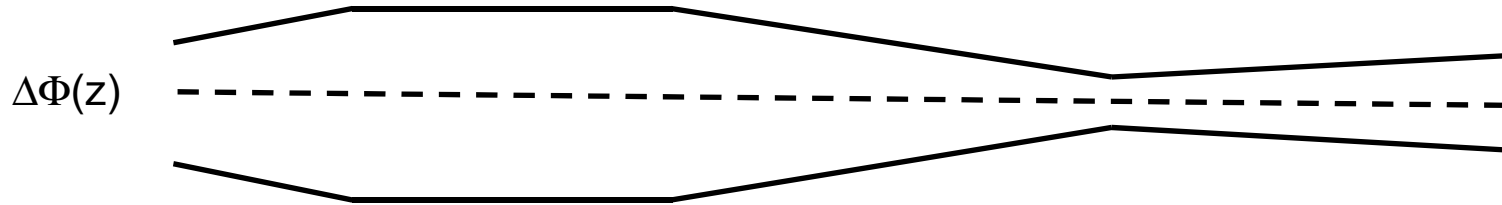
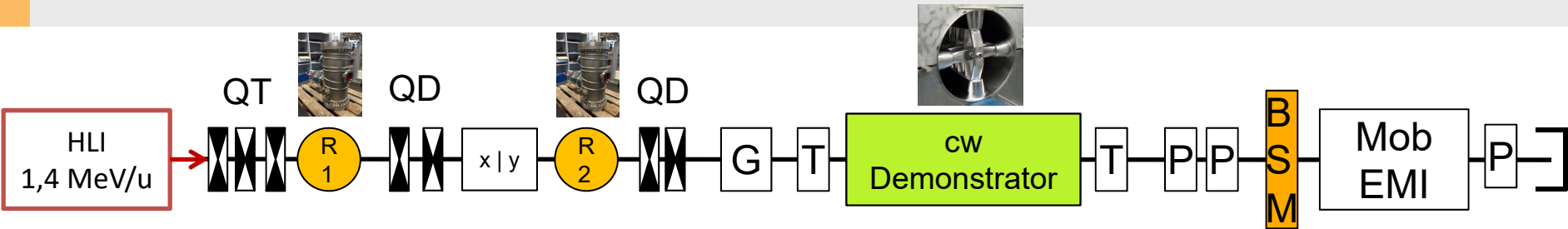


cavity on

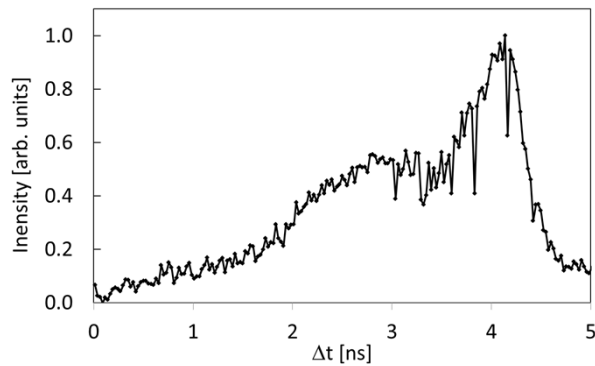


- Measurement of transient signal induced by traveling bunch
- **Acceleration! Energy gain of 0.5 MeV/u**
- → systematic scan of rf-phase and amplitude

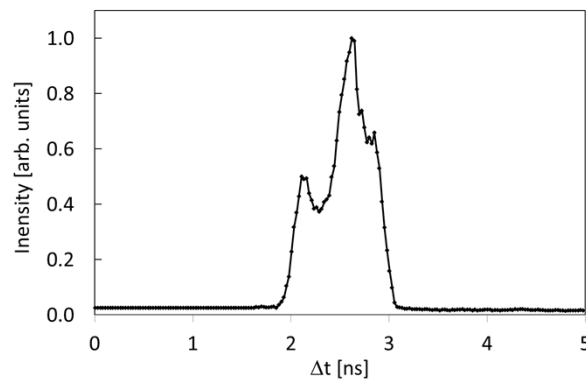
Bunch structure measurement



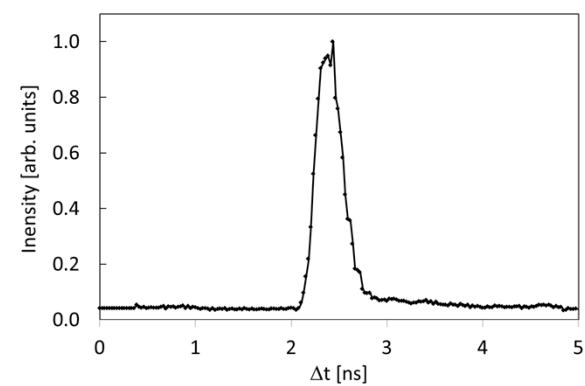
cavities off



R1 + R2



R1 + R2 + CH0



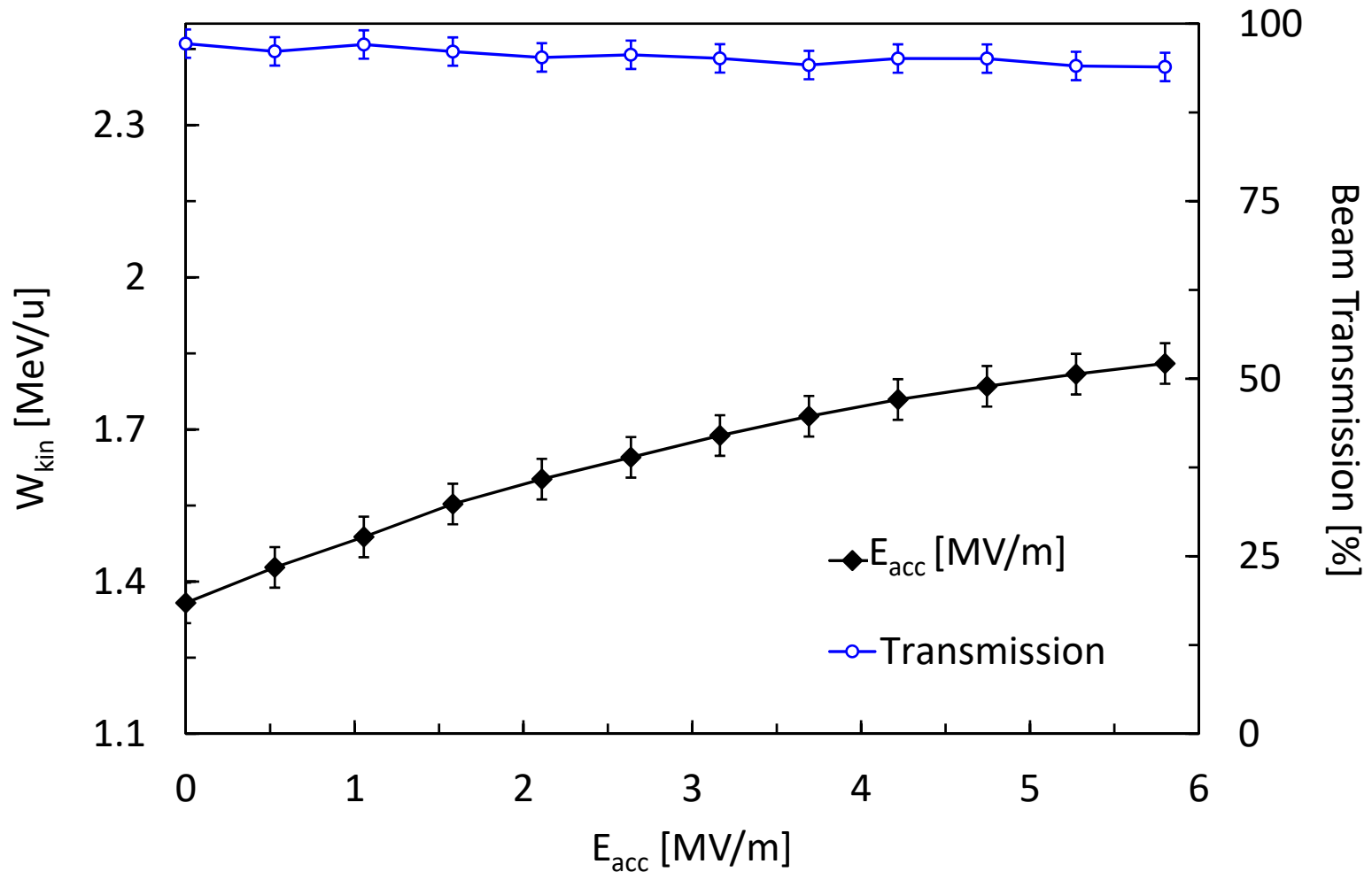
RF-parameter (matched case)

	He²⁺	Ar¹¹⁺	Ar⁹⁺	Ar⁶⁺
<i>A/q</i>	<i>2.0</i>	<i>3.6</i>	<i>4.4</i>	<i>6.7</i>
U _{Reb1,eff.} [kV]	8.3	15.0	18.3	27.9
U _{Reb2,eff.} [kV]	22.7	40.8	49.9	75.9
E _{acc,CH} *[MV/m]	1.8	3.2	3.9	5.9
U ₀ [MV]	1.2	2.2	2.7	4.0

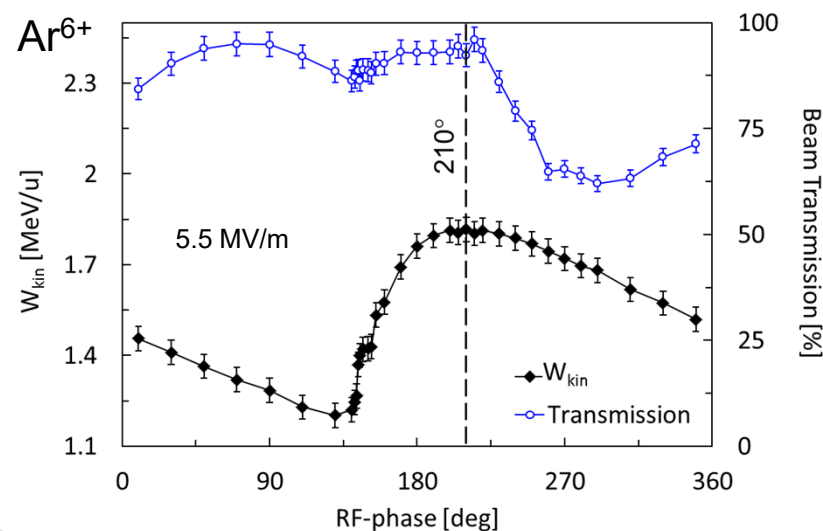
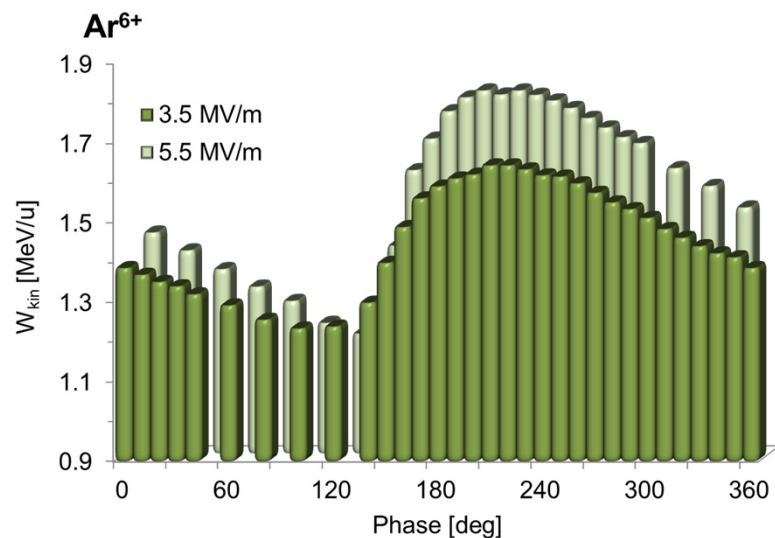
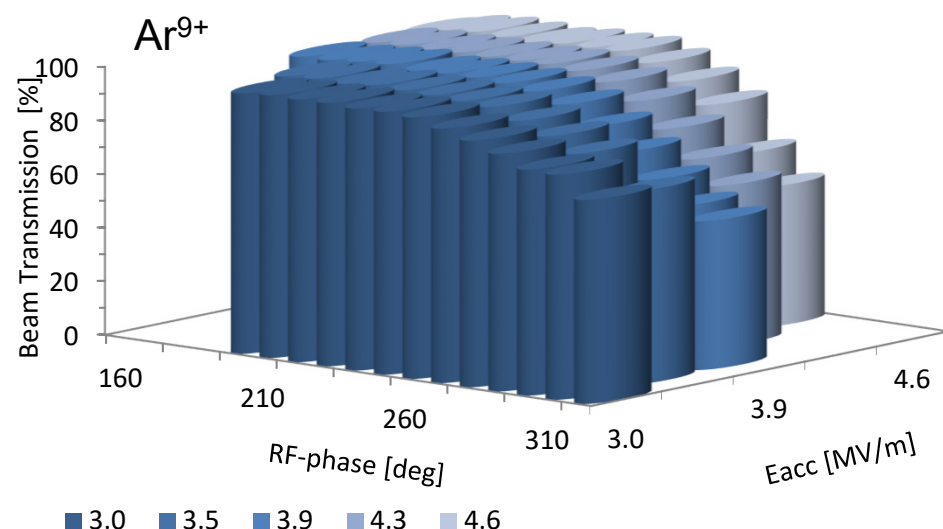
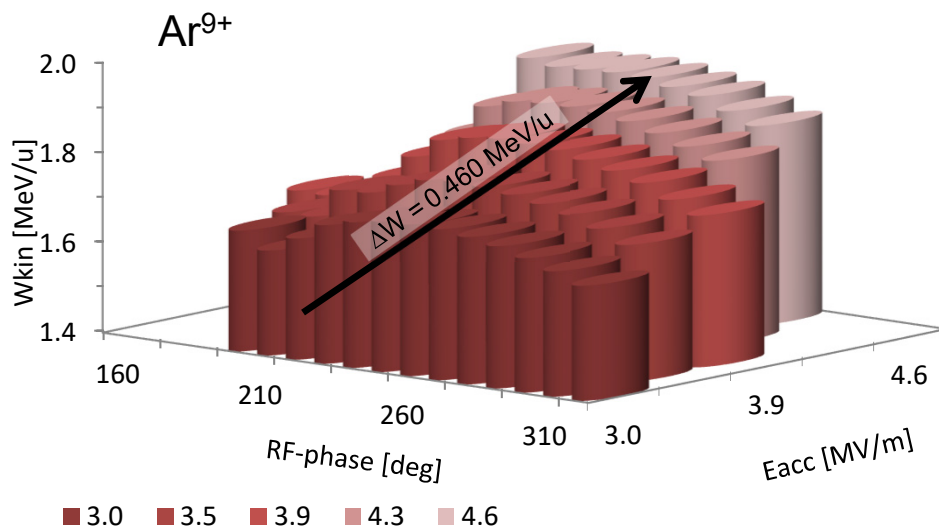
* $E_{acc} = \text{transit time factor} \times \text{total accelerating voltage} / (n \times 0.5 \times \beta \lambda)$



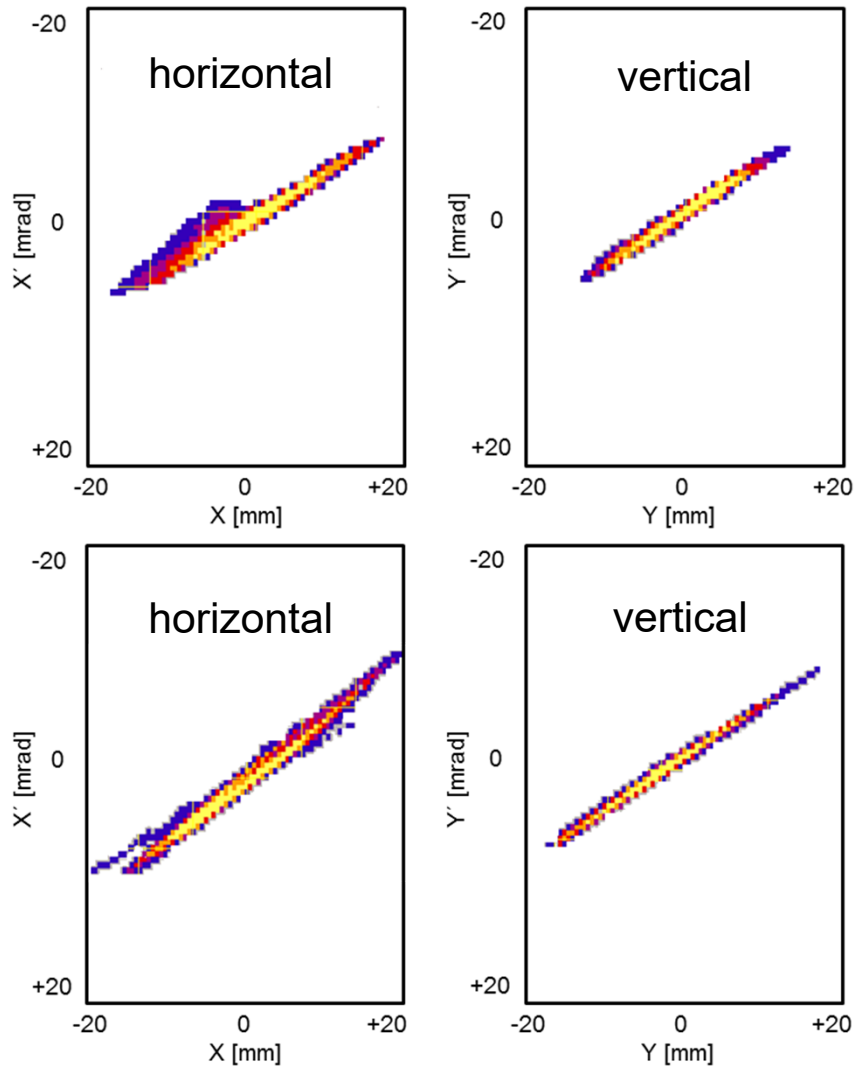
Amplituden-scan



Systematic Scans (RF-phase/-amplitude)



Emittance measurement



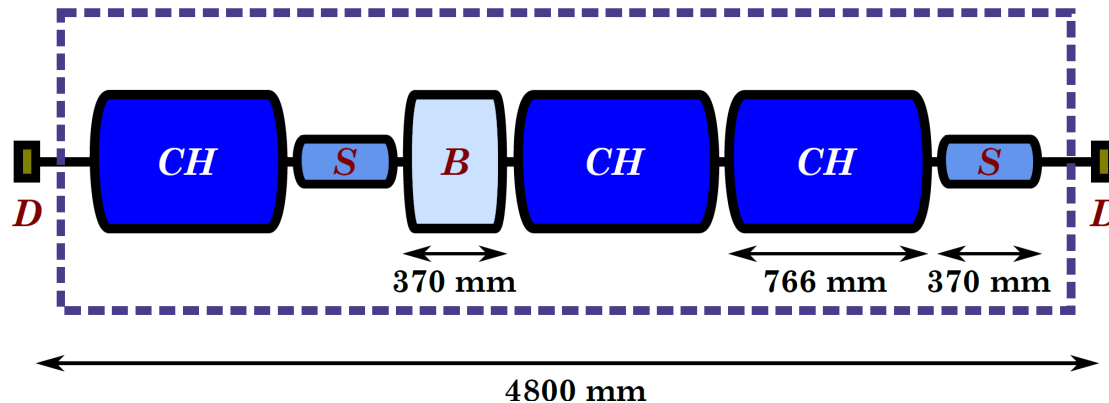
1.40 MeV/u

Ion species: $^{40}\text{Ar}^{11+}$, $^{40}\text{Ar}^{9+}$, $^{40}\text{Ar}^{6+}$ ($A/q=6.7$),
50 Hz, 5ms, 25% beam duty, cw (rf duty), $1.5\text{p}\mu\text{A}$
(particle current),
 $\approx 95\%$ (beam transmission), 0.460 MeV/u (ΔW),
transv. emittance growth $\approx 12\%$

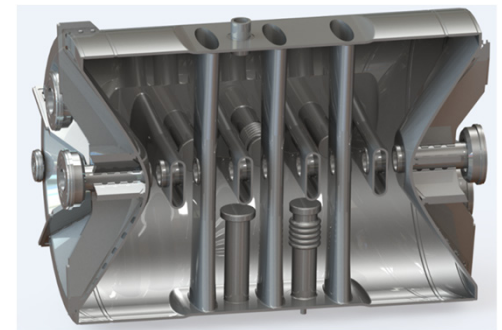
1.86 MeV/u



Standard cryomodule layout

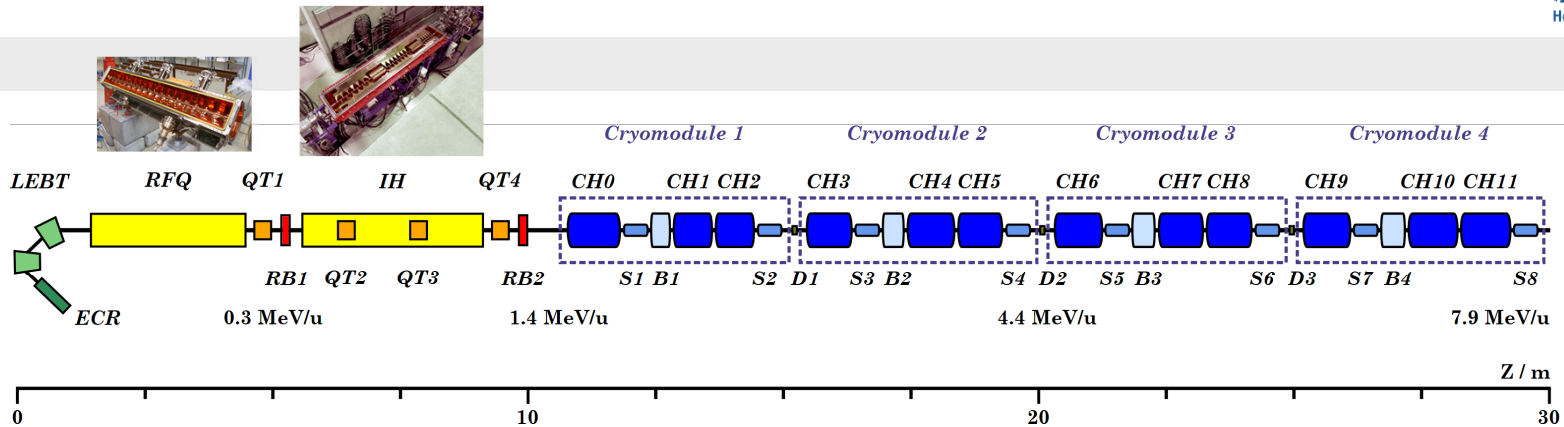


(8 gap)-CH-cavity

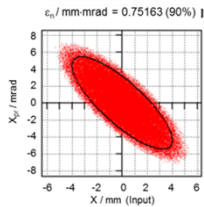


- New cryo module layout containing demonstrator CH cavity, 2 short CH cavities, 1 buncher and 2 solenoids
- Simplified cavity design (easier manufacturing & surface processing)
- CH1 & CH2 are already in production (delivery at 4th quarter of 2018)
- Tendering for cryostat at 3rd quarter of 2018
- Moderate increase of design gradient → more compact linac design or higher A/q

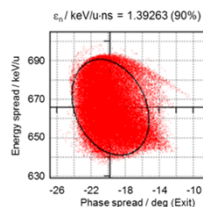
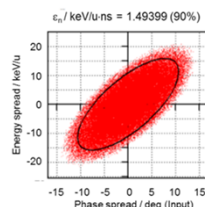
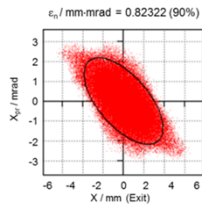
Current cw-Linac Layout



Input CM1



Output CM4



- Total of 12 CH cavities
- Each cryo module contains 3 CH cavities + 1 rebuncher + 2 solenoids
- Variable beam energy 3.6-7.5 MeV/u

Cryo Module	Cavity	Output energy (MeV/u)		
		<i>A/Z=6</i>	<i>A/Z=3</i>	<i>A/Z=1</i>
CM1	<i>HLI</i>	1.4	1.4	1.4
	CH0	2.1	2.2	3.0
	CH1	2.6	3.0	4.2
CM2	CH2	2.9	3.6	4.6
	CH3	3.4	4.3	5.7
	CH4	3.8	4.8	6.3
CM3	CH5	4.2	5.5	7.7
	CH6	4.7	6.2	8.6
	CH7	5.2	7.0	9.9
CM4	CH8	5.8	7.8	10.9
	CH9	6.4	8.7	12.3
	CH10	7.0	9.5	13.2
	CH11	7.6	10.5	14.6

Summary&Outlook



Summary&Outlook

- Demonstrator beam commissioning is a major milestone paving the way to the GSI/HIM-cw-Linac
- Design acceleration gain was achieved with heavy ion beams even above the design mass to charge ratio at full transmission and maximum available beam intensity
- Beam quality was measured as excellent in a wide range of different beam energies, confirming EQUUS beam dynamics design
- Advanced cw-Linac layout based on four cryomodules, each equipped with three CH-cavities and a sc-rebuncher, demonstrates the high capabilities due to energy variation preserving the beam quality
- New design could provide beam acceleration for a wide range of different ions (protons to uranium) above the design beam energy, featuring the ambitious GSI-user program, while the GSI-UNILAC is upgraded for short pulse high current FAIR-operation



Thank You for Your attention!