# New beam dynamics design for iLinac of HIAF

**Liu Shuhui**

**On behalf of Linac Center**

**Institute of Modern Physics (IMP) ,Chinese Academy of Sciences**
**Lanzhou, China**

# Outline

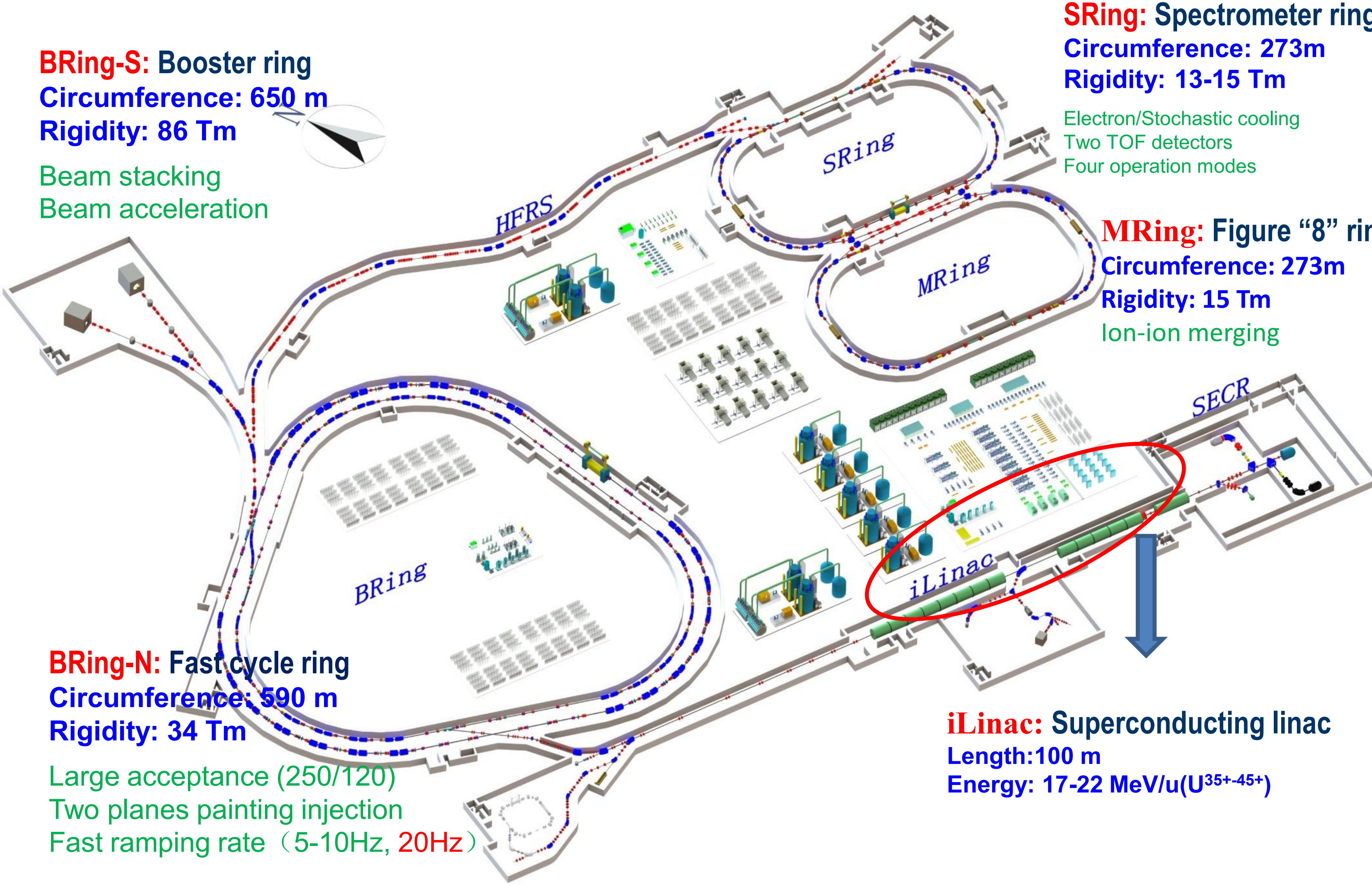
- General introduction
- Physics design of RFQ
- Physics design of SC section
- Summary

# HIAF Layout

**BRing-S: Booster ring**
**Circumference: 650 m**
**Rigidity: 86 Tm**
Beam stacking
Beam acceleration

**SRing: Spectrometer ring**
**Circumference: 273m**
**Rigidity: 13-15 Tm**
Electron/Stochastic cooling
Two TOF detectors
Four operation modes

**MRing: Figure "8" ring**
**Circumference: 273m**
**Rigidity: 15 Tm**
Ion-ion merging



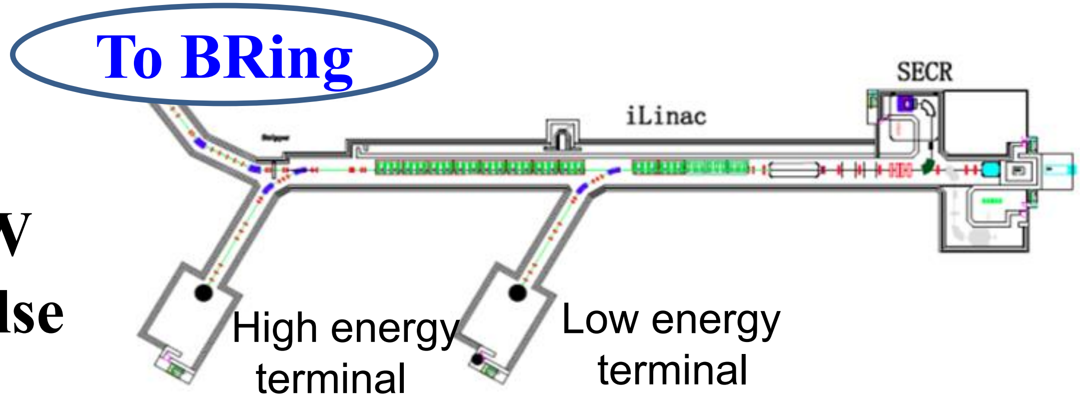

**BRing-N: Fast cycle ring**
**Circumference: 590 m**
**Rigidity: 34 Tm**
Large acceptance (250/120)
Two planes painting injection
Fast ramping rate（5-10Hz, 20Hz）

**iLinac: Superconducting linac**
**Length:100 m**
**Energy: 17-22 MeV/u($U^{35+-45+}$)**

## Energy & Mode:

22MeV/u（$^{238}U^{45+}$）@CW

17MeV/u（$^{238}U^{35+}$）@pulse




| CW mode<br>Independent machine | Pulsed mode<br>BRing injector only |
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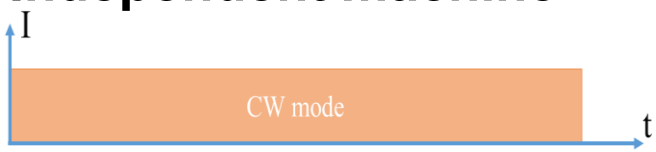
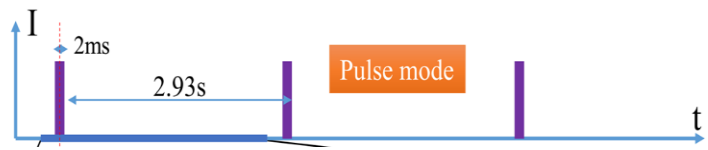
|  |  |





**CW mode**

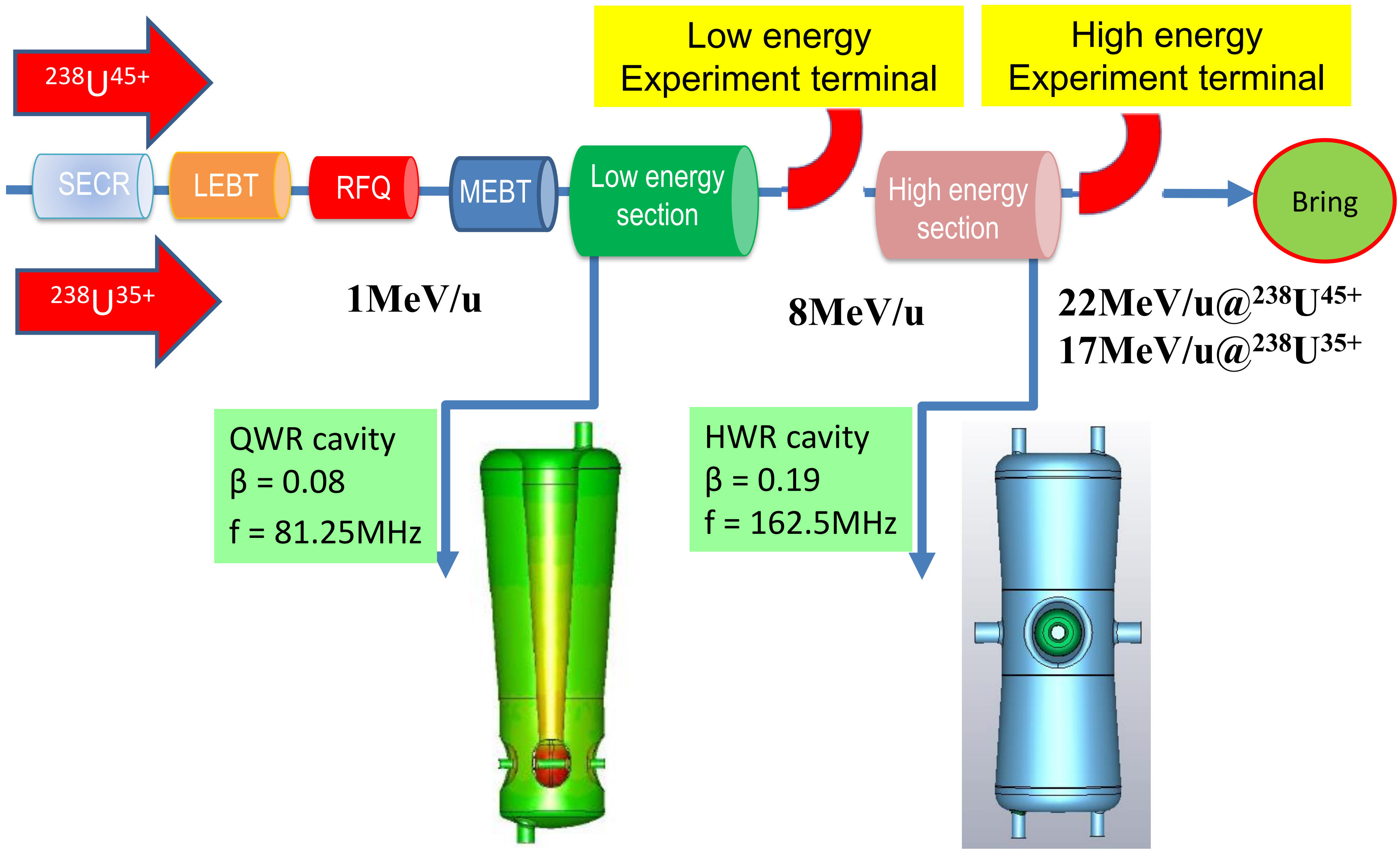
| | |
|---|---|
| $^{16}O^{6+}$ | 1 emA |
| $^{129}Xe^{27+}$ | 1 emA |
| $^{209}Bi^{31+}$ | 1 emA |
| $^{238}U^{45+}$ | 0.1 emA |

**Pulsed mode**

| | |
|---|---|
| $^{16}O^{6+}$ | 2 emA |
| $^{129}Xe^{27+}$ | 2 emA |
| $^{209}Bi^{31+}$ | 1.5 emA |
| $^{238}U^{35+}$ | 1 emA |

0.3-5 Hz/0.2-2 ms

# New Design of iLinac

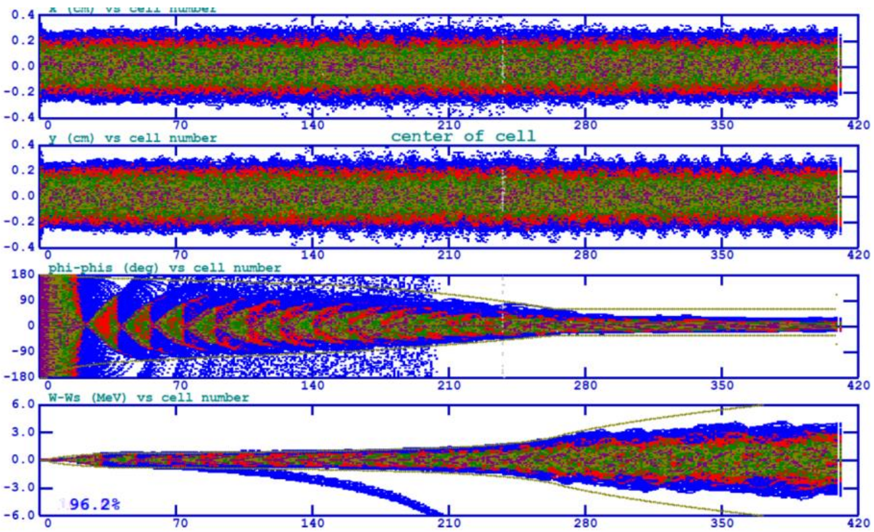


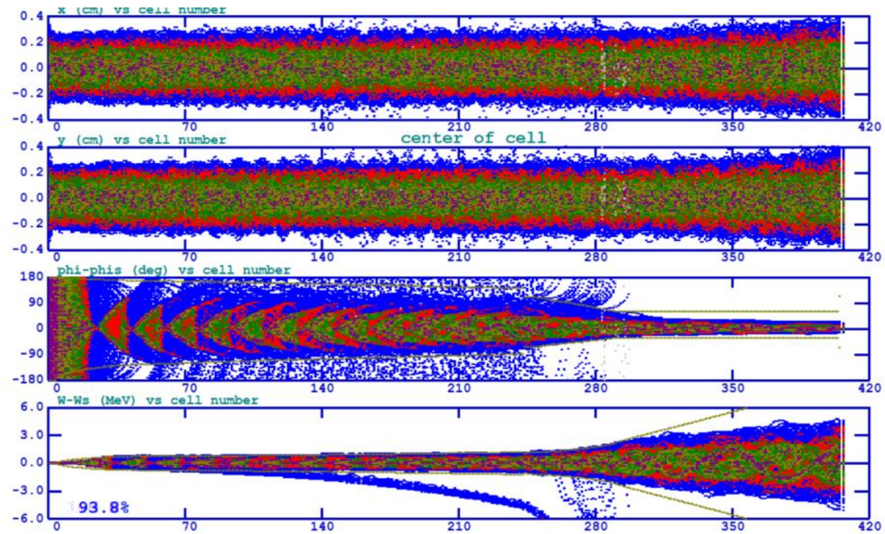
# Physics design of RFQ

- Kp<1.5 @ CW to keep operational stability and keep the Kp value not too high at pulse mode
- Optimize the design parameters to minimize the beam loss at high energy part to improve operational stability of RFQ and avoid the activation problem
- longitudinal emittance of RFQ / acceptance of SC section ＜1/5 —minimize the beam loss possibility at SC section
- The output energy of RFQ is 1 MeV/u—considering the difficulty of tuning the field and rf power & beta option of low energy SC section

| Parameter | Values |
|---|---|
| I/O energy(MeV/u) | 0.014 / 1 |
| Kilpatrick | <1.5 @cw |
| Design particle | $^{238}U^{45+}$@cw |
| Output99.9% longitudinal emit (pimm•mrad) | 3.5 |
| Length (m) | <10m |
| Transmission efficiency@pulse (%) | >95% |

# Physics design of RFQ




| Parameter | Voltage constant | Voltage ramp |
|---|---|---|
| Kilpatrick | 1.7pulse@1.48cw | 1.7pulse@1.48cw |
| Vane voltage (kV) | 67 | 67~120 |
| Length (m) | 13.02m | 10.74m |
| RMS Longitudinal emittance （πmmmrad） | 0.66 | 0.54 |
| 99.9% Longitudinal emittance （πmmmrad） | 5.57 | 4.58 |
| Transmission efficiency@pulse (%) | 96.2% | 93.8% |

# Physics design of RFQ

**For decreasing the longitudinal emittance**

**LEAF RFQ** —— scheme with three harmonic buncher + non - 90 ° synchronous phase are studied to reduce the longitudinal beam emittance.

**CMIF RFQ** —— scheme with internal buncher is used to reduce the longitudinal beam emittance.

**CiADS RFQ** —— scheme with small energy acceptance to reduce longitudinal emittance

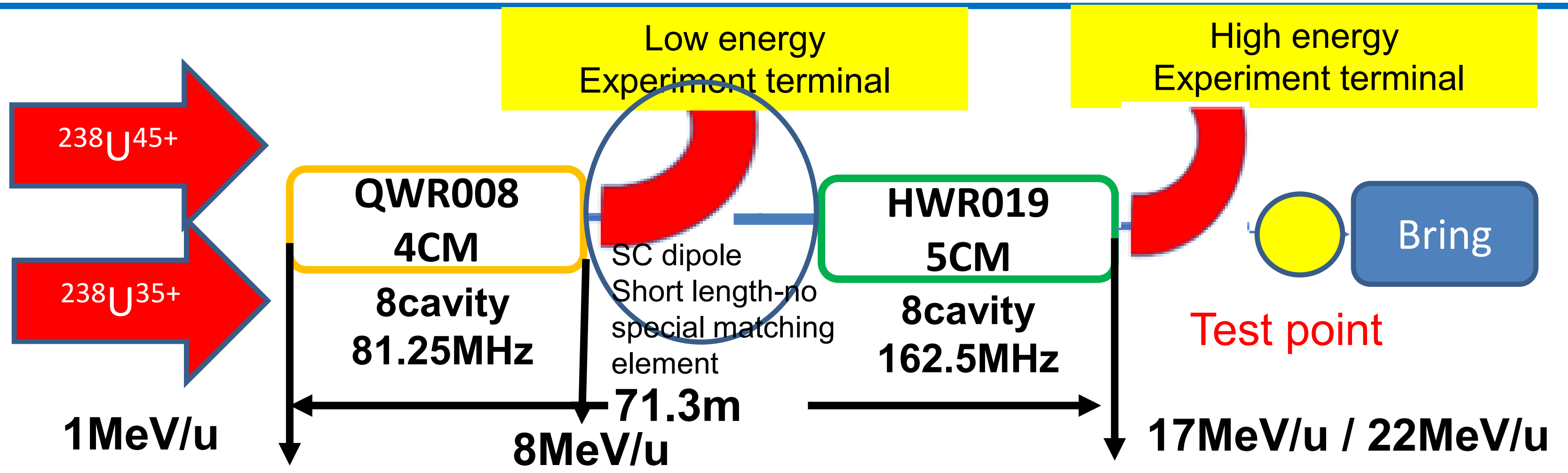
**For shortening the total length**

**Separated RFQ** —— External harmonic buncher + non - 90 ° synchronous phase injection. The length can be shortened by about 25% in the Leaf project

**Voltage ramp** —— High acceleration efficiency in the high energy part of RFQ. The length of the RFQ was shortened by about 30% in CPHS (IPAC' 10,MOPEC071).

**Trapezoidal modulation** ——The shunt impedance is increased by 60% at ATLAS (PRST, 15,110101,2012)

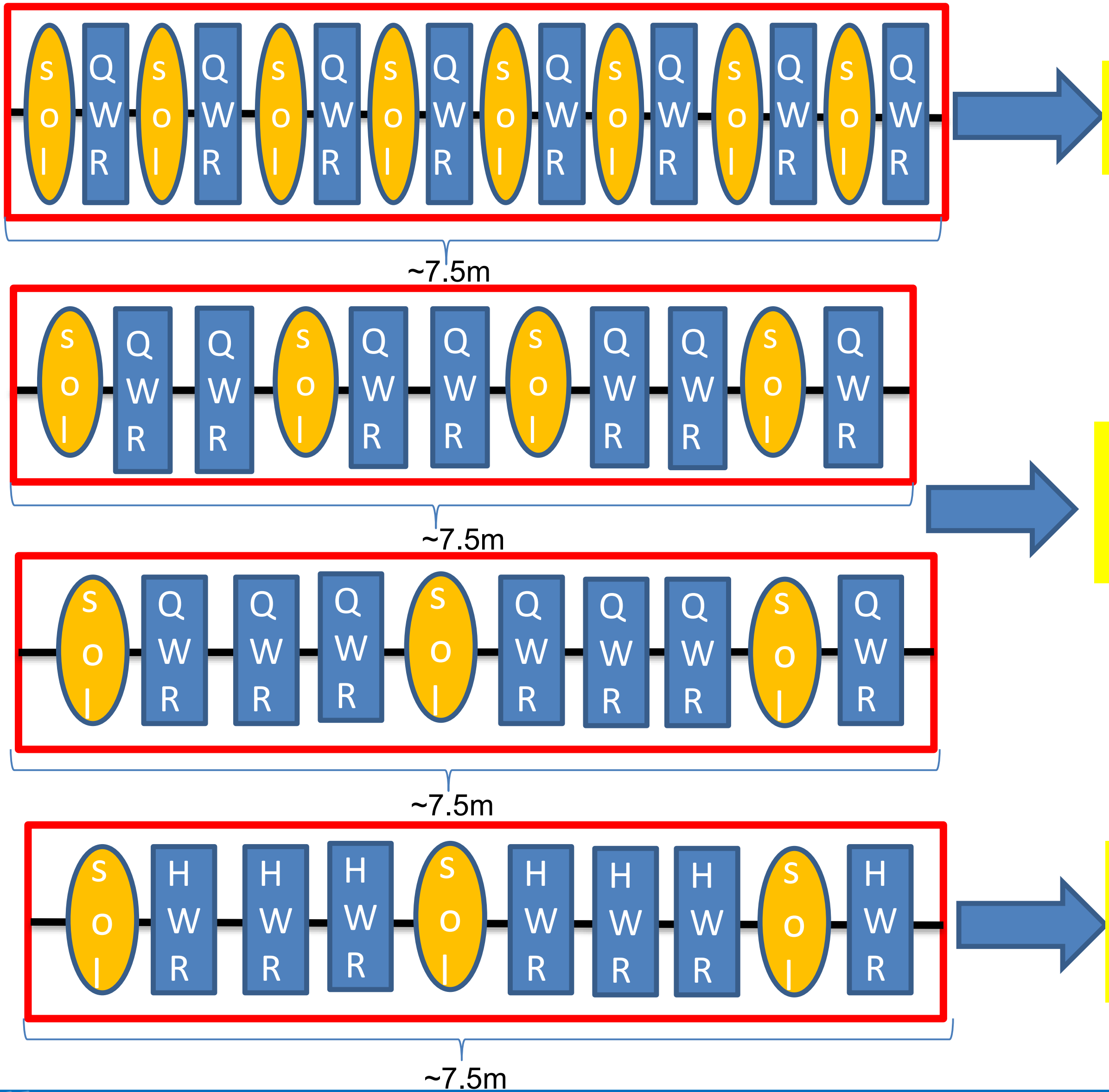
# Physics design of SC section




| | Unit | QWR008 | HWR019 |
|---|---|---|---|
| f | MHz | 81.25 | 162.5 |
| Vmax | MV | 2.0 | 2.5 |
| Ep | MV/m | 32 | 32 |
| Q0 | E+09 | 8.00 | 5.00 |
| M/C | | 8/8&4/7&3/8 | 3/8 |
| CM | m/number | 7/4 | 7/5 |

M:magnet C:cavity CM:croymodule

# Lattice design




Compact design for good control of beam

QWR008 section

quasi-period for good matching and compact structure

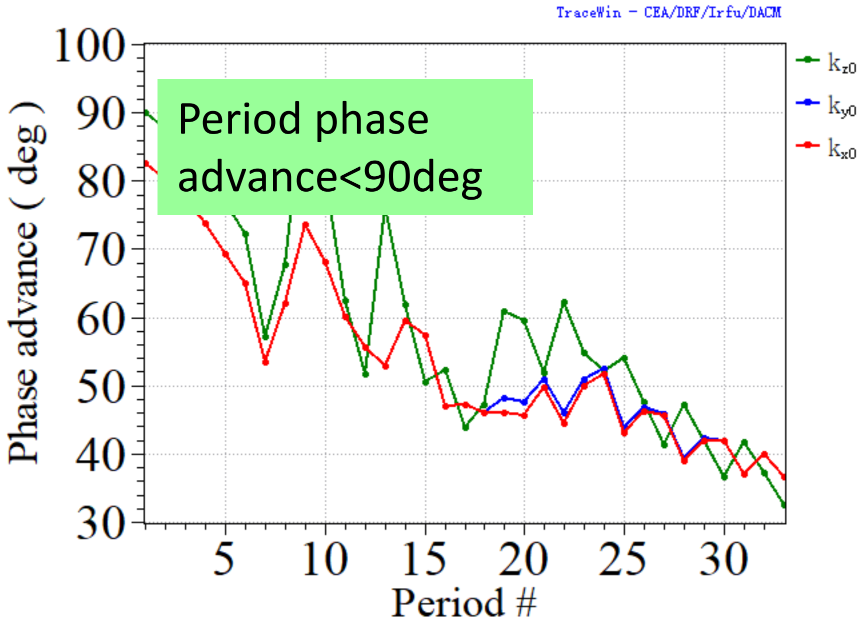
HWR019 section

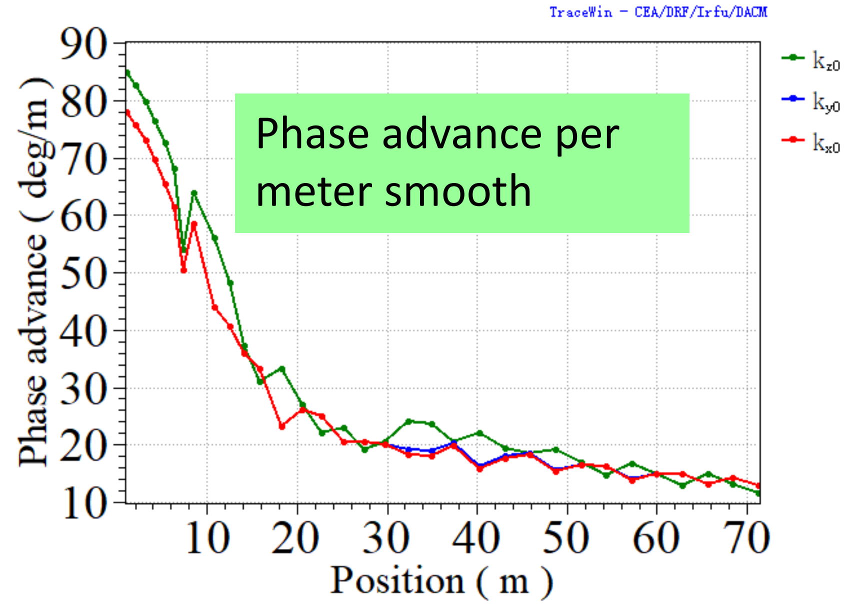
quasi-period for good matching and compact structure

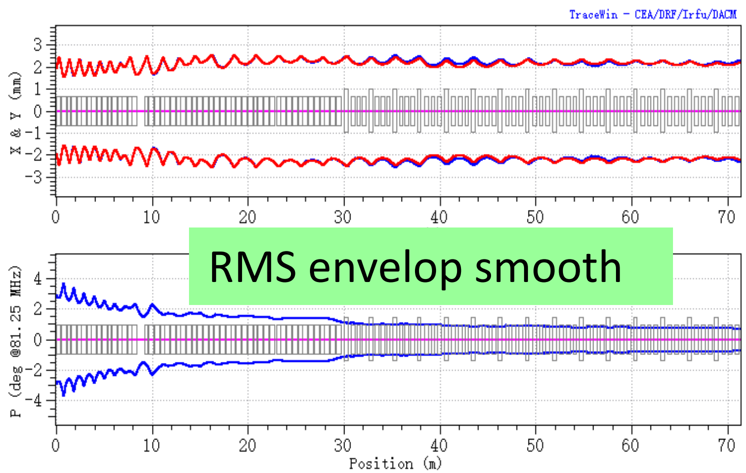
# Lattice design

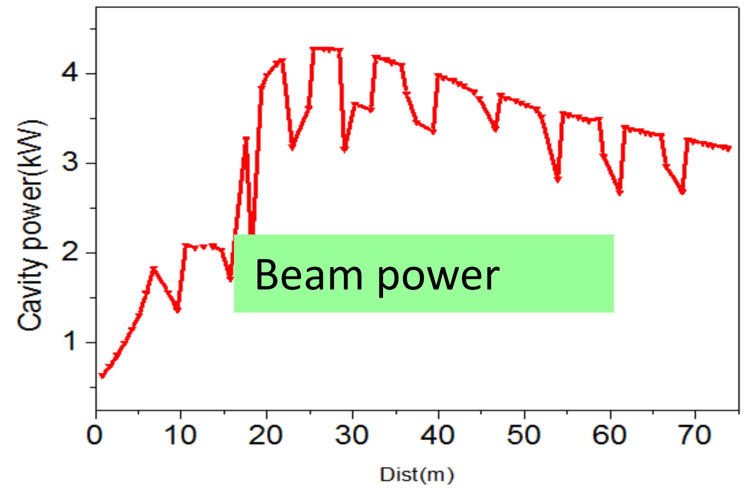
- TraceWin program is used for beam dynamics
- Beam current is 1mA, and the initial beam energy is 1MeV/u
- Solenoid is 3D field ,cavity is 1D field
- Using Gaussian  distribution
  - 6d Gaussian  with100000 macroparticles for the entrance.
  - Normalized rms emittance in x/y/z: 0.2π.mm.mrad / 0.2π.mm.mrad / 0.13π.mm.mrad.

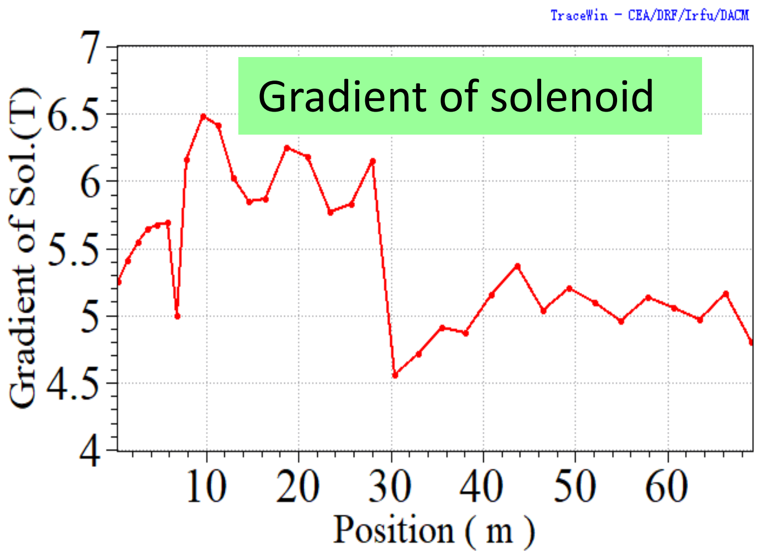
# Lattice design

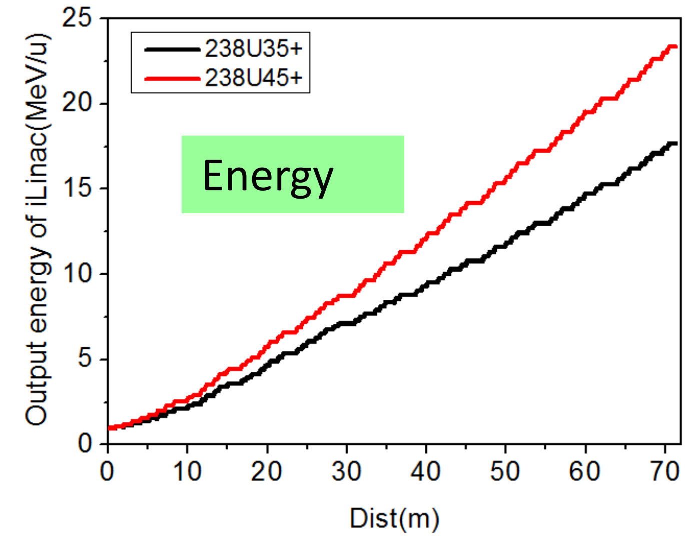


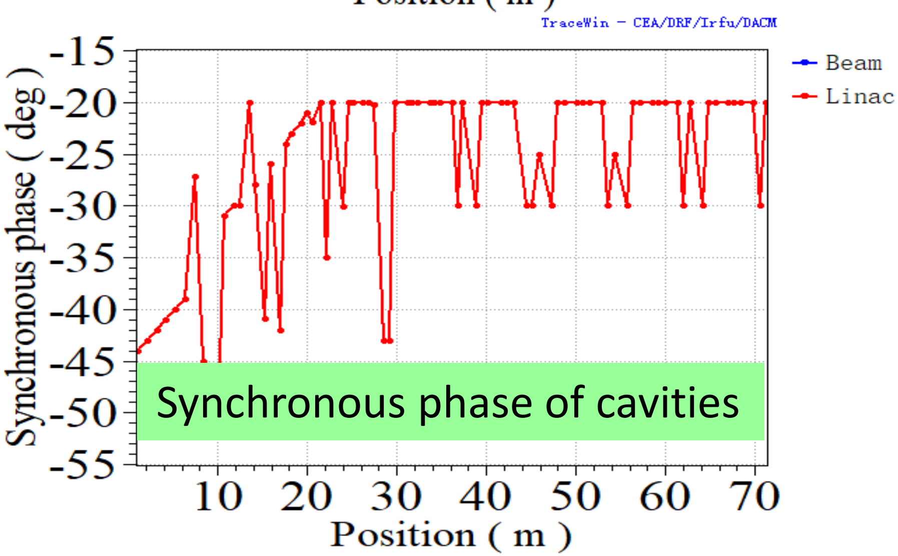



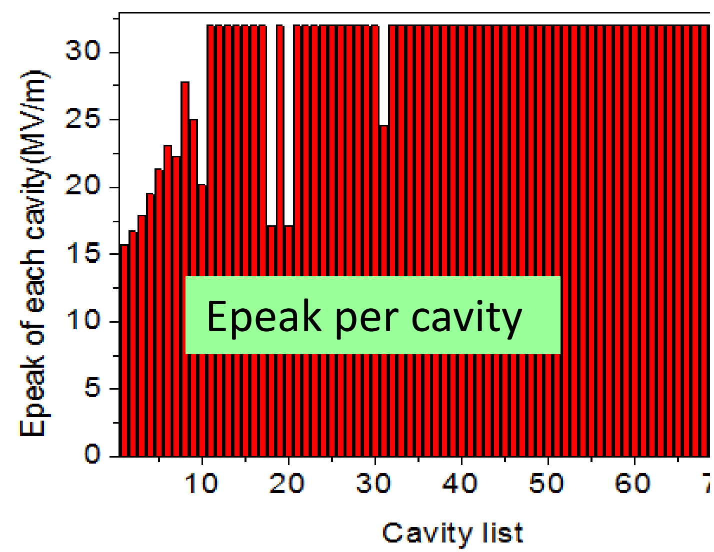



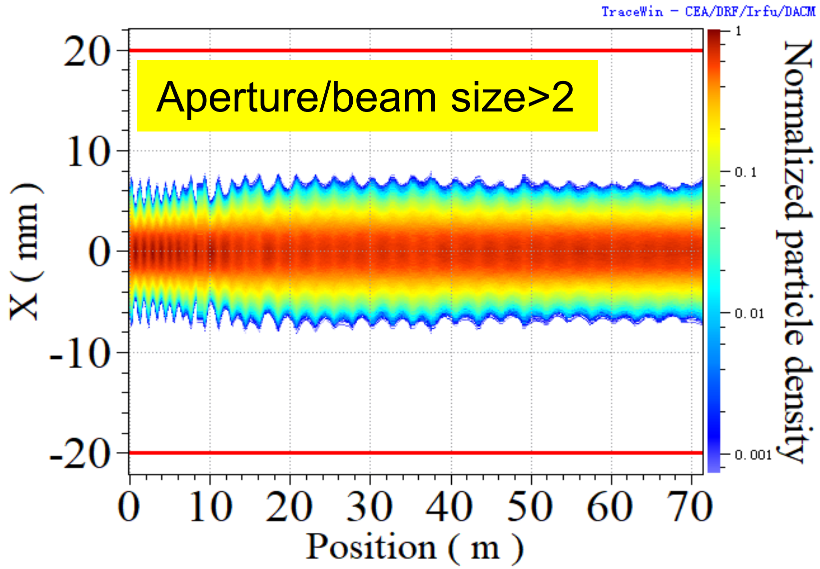

TraceWin - CEA/DRF/Irfu/DACM
Gradient of solenoid
Gradient of Sol.(T)
Position ( m )

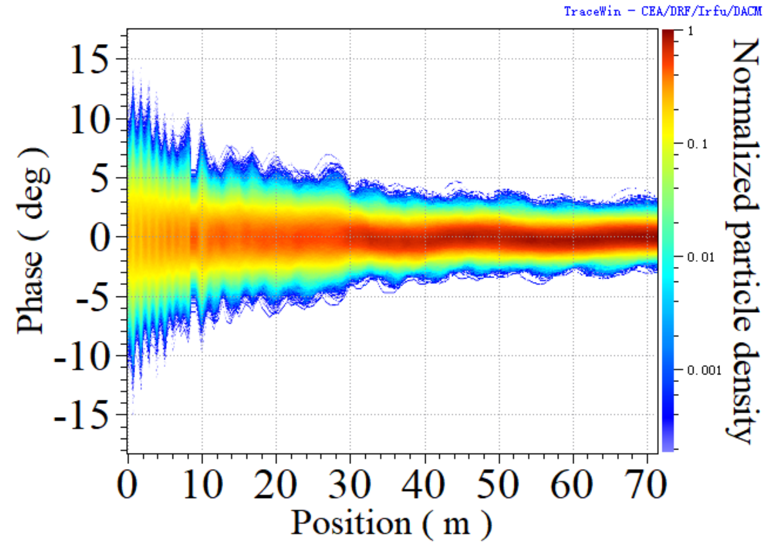

238U35+
238U45+
Energy
Output energy of iLinac(MeV/u)
Dist(m)

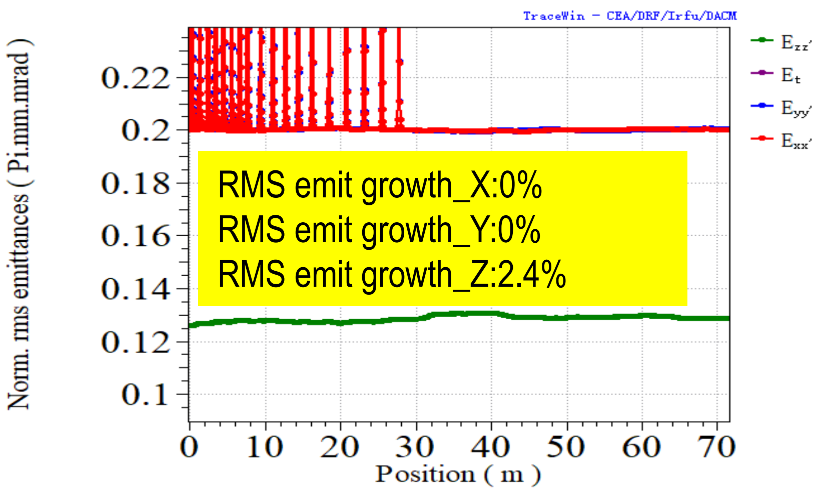

TraceWin - CEA/DRF/Irfu/DACM
Beam
Linac
Synchronous phase of cavities
Synchronous phase ( deg )
Position ( m )

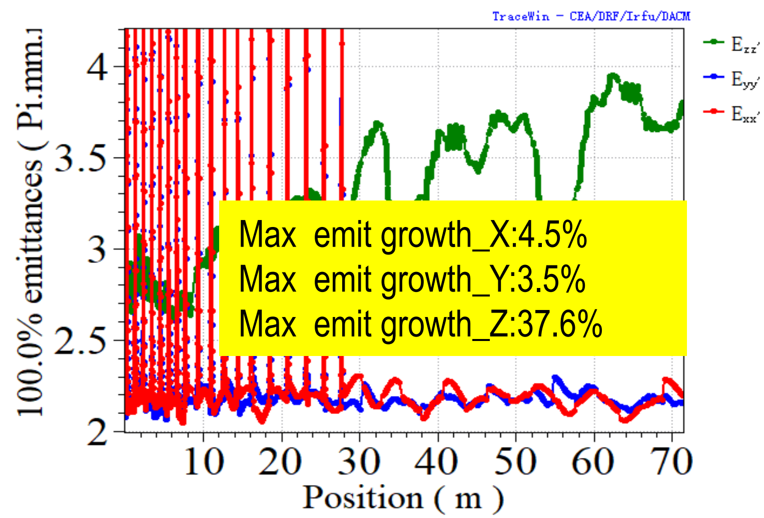

Epeak per cavity
Epeak of each cavity(MV/m)
Cavity list

# Multiparticle simulation



# Summary

- A new proposal for iLinac of HIAF is presented
- A new RFQ with 1MeV/u are proposed, and the preliminary results of beam dynamics design is presented, and the further optimization is on the way
- The preliminary beam dynamics design of SC section with QWR and HWR cavity was carried out which has good beam quality.
- More work will be done for the physics design based on the actual engineering

***Thanks for your attention!***