WG2 on ERL light sources

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Charge:

Address and try to answer a list of critical questions for ERL light sources.
Session leaders can approach each question by means of
(a) (Very) short presentations
(b) Open discussions
(c) Panel discussions
(d) Distribution of problems to be solved, etc.

During the course of the workshop, the session leaders will formulate an answer to their question. This might require work and meetings of experts outside the workshop sessions.

Furthermore extra discussion time can be scheduled at the end of the second day. Some questions might require computer simulations, and (windos/linux) access is available in the meeting room.

Question to be addressed (Tuesday)

(1) Overview of critical ERL issues

(2) Project overviews

- (a) JLAB
- (b) Cornell
- (c) Daresbury
- (d) KEK / JAEA

(3) Particle transport

- (a) Are there optimal schemes to minimize bunch length and energy spread?
- (b) What is the optimal injector / linac merger design?
- (c) What should start to end simulations include?
- (d) What are beam abort strategies and beam loss tolerances?

(4) What are diagnostic needs?

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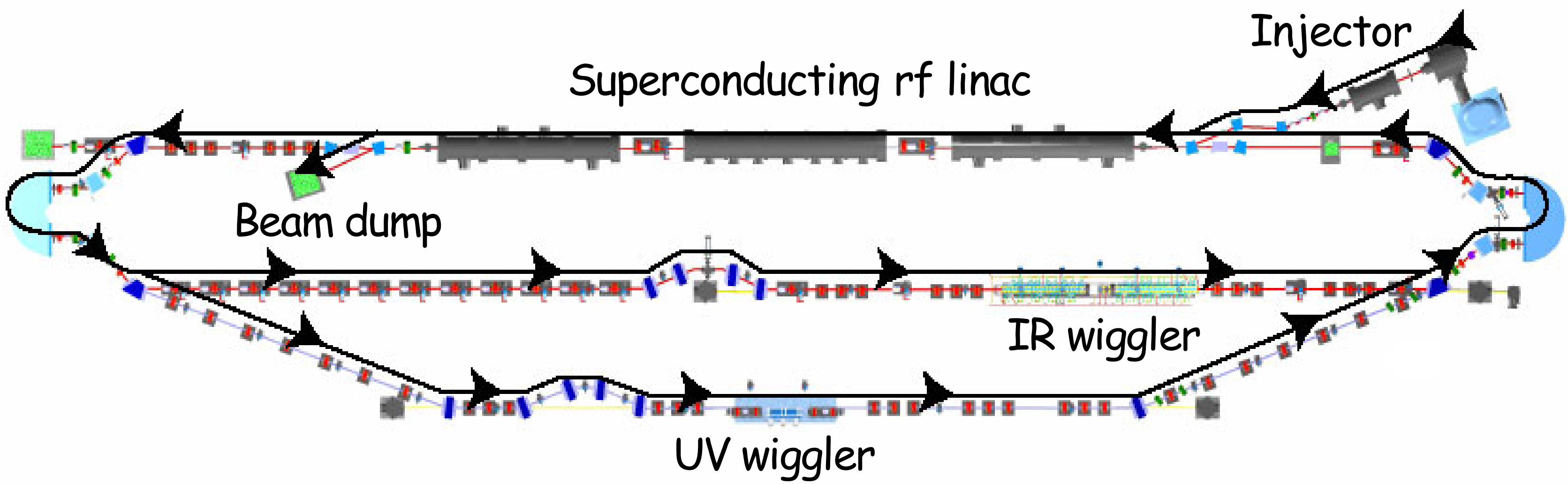
An existing ERL

Promise: High average laser power (~ 100 kW)
High overall system efficiency
Reduced beam dump activation

Reality: JLab 10kW IR FEL and 1 kW UV FEL
JAERI 2.3kW IR FEL
Novosibirsk NRF 180MHz recuperator



courtesy Lia Merminga

ERL Layout

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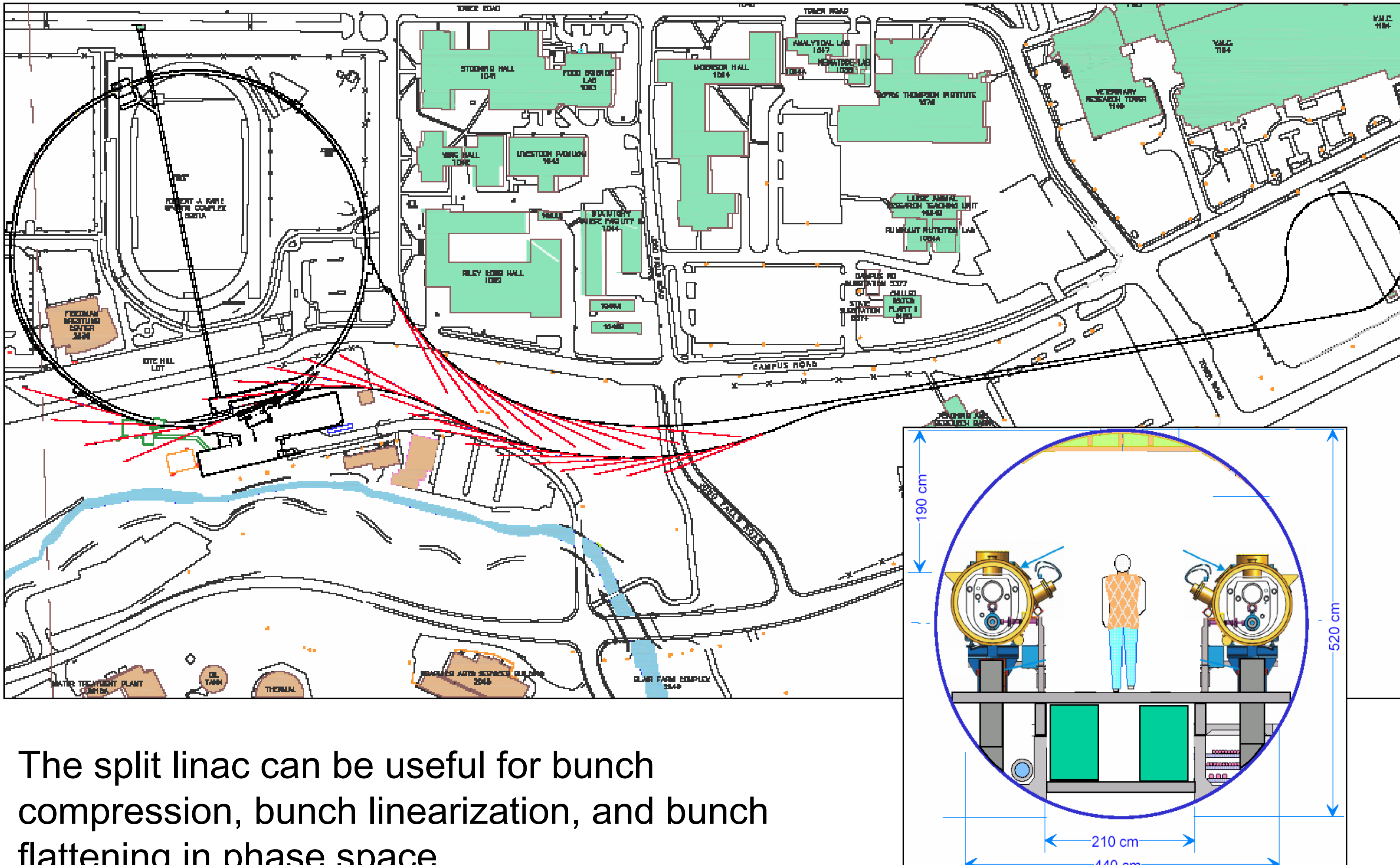

The split linac can be useful for bunch compression, bunch linearization, and bunch flattening in phase space.

Energy Recovery Linac Prototype

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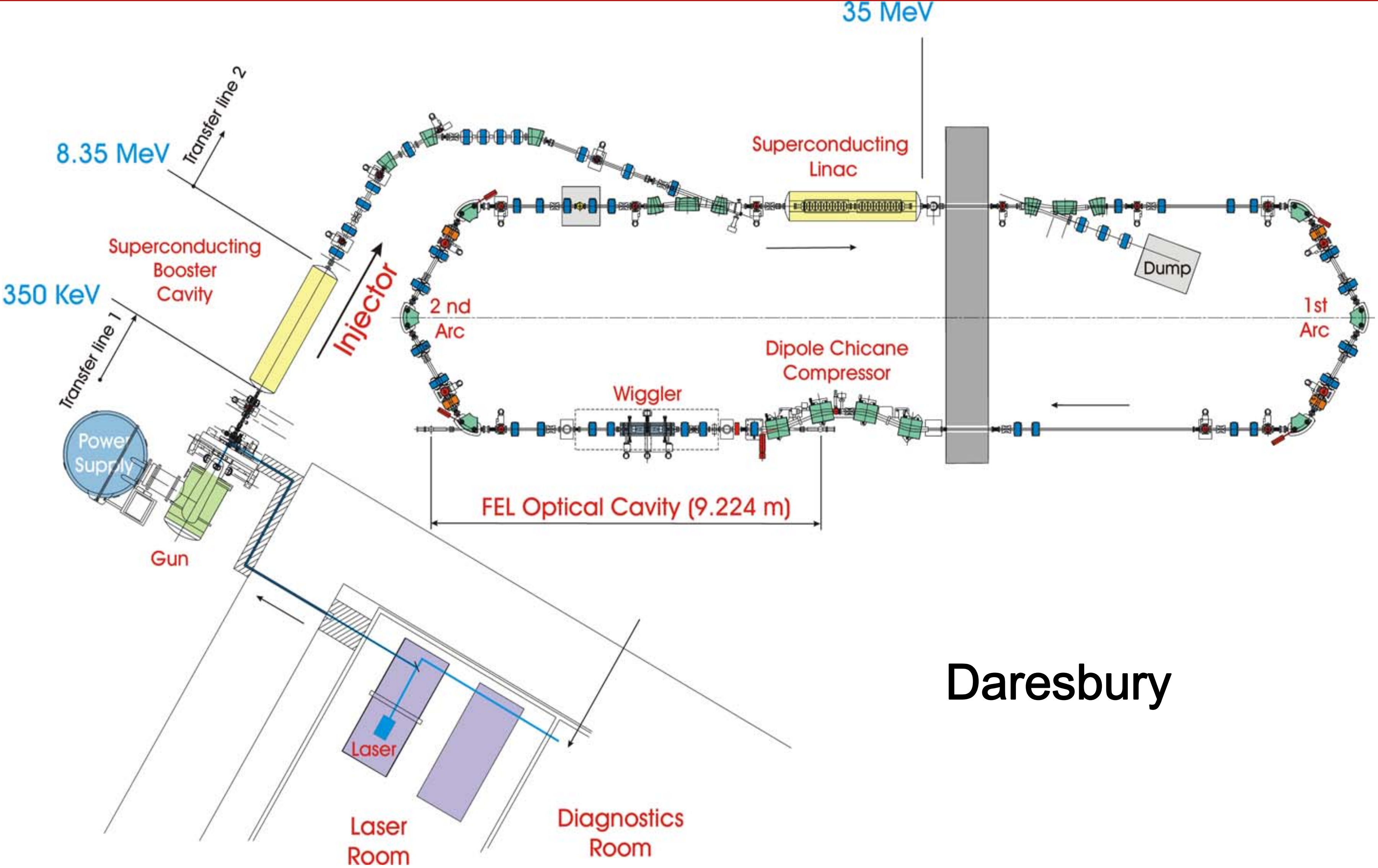

Daresbury

Split Linac Bunch Flattening

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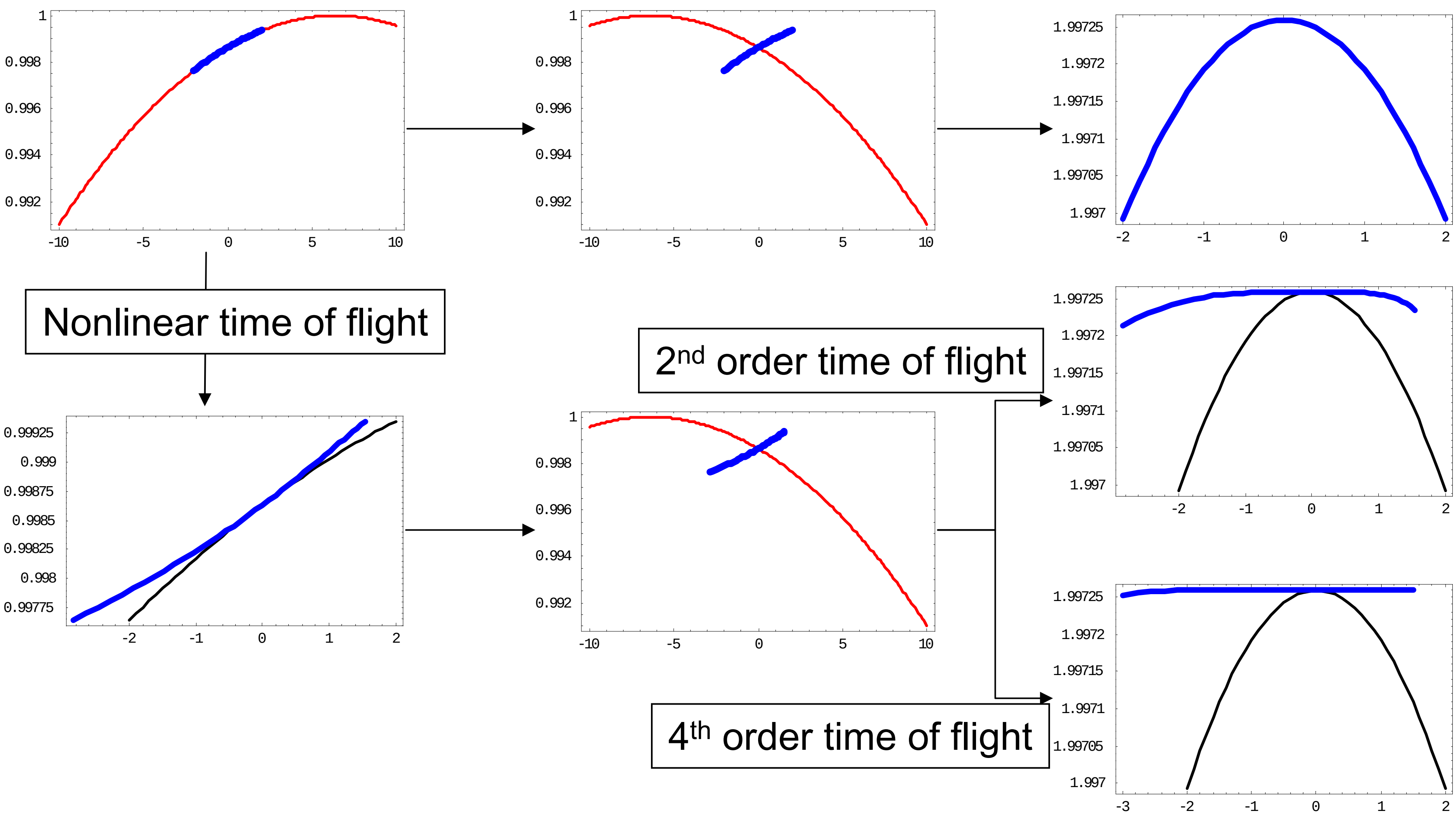
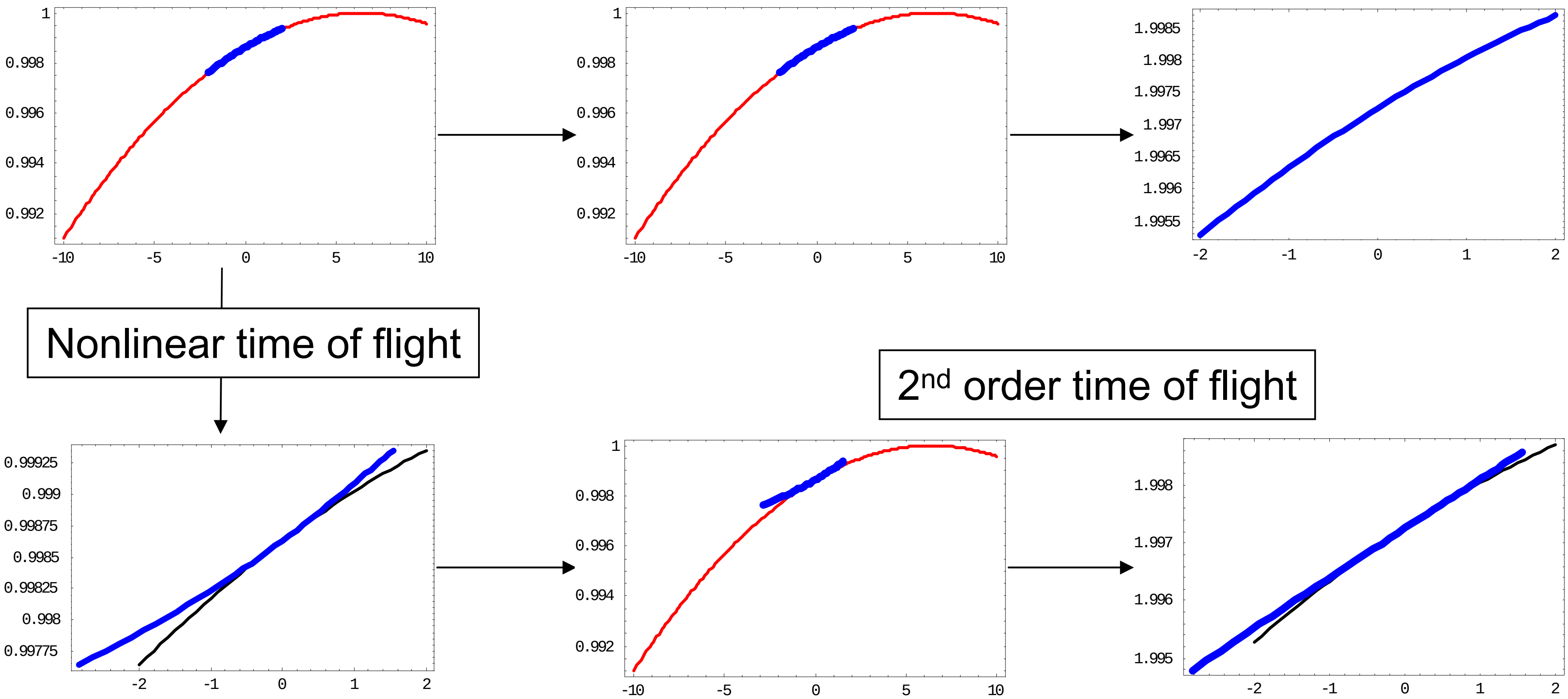


Split Linac Bunch Linerizing



Subsequent bunch compression is linearlized and relatively simple

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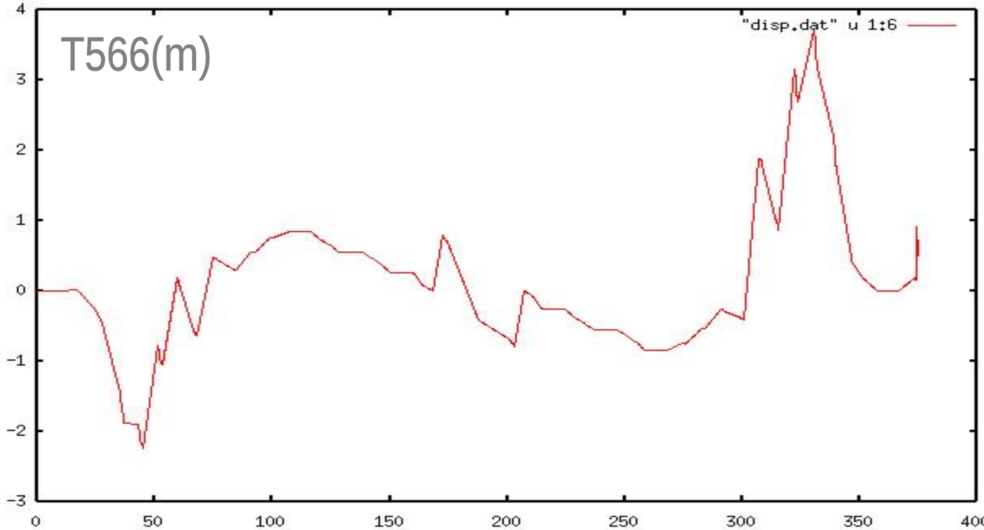
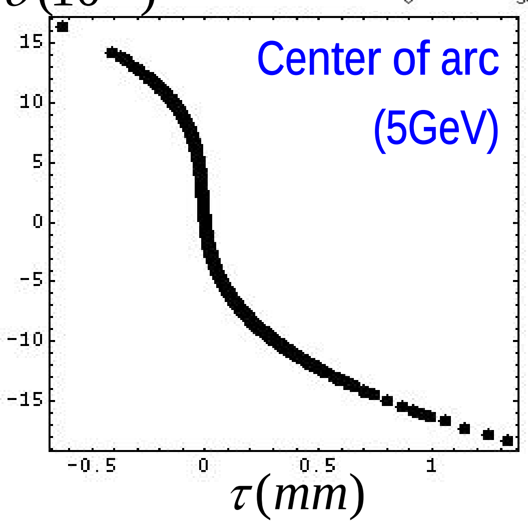
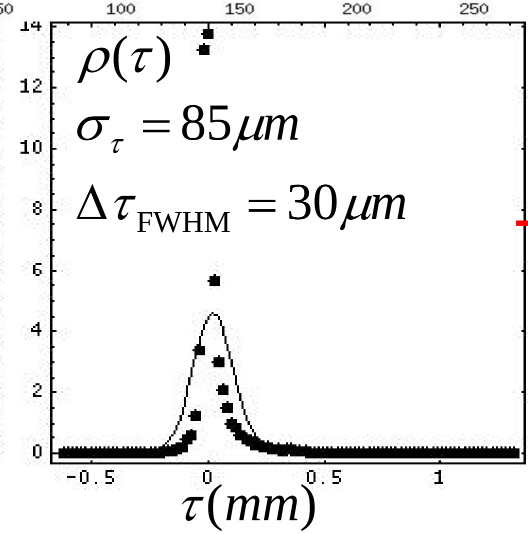
Second Order Time of flight

$\Delta\varphi = 15^0$ RF

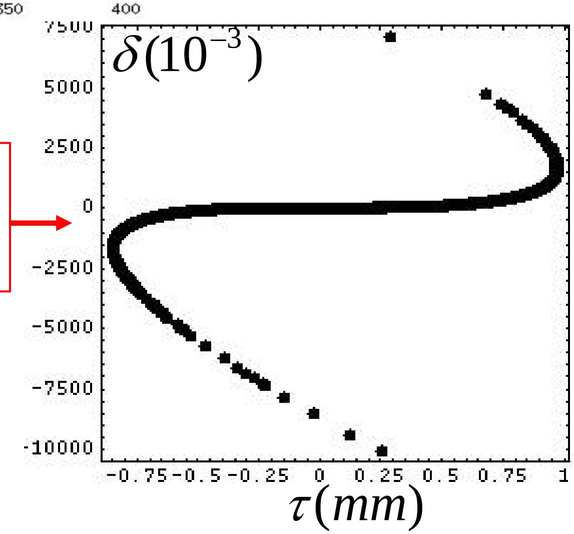
0.44% energy spread







After ERL



- The energy spread is too large

Undercompression

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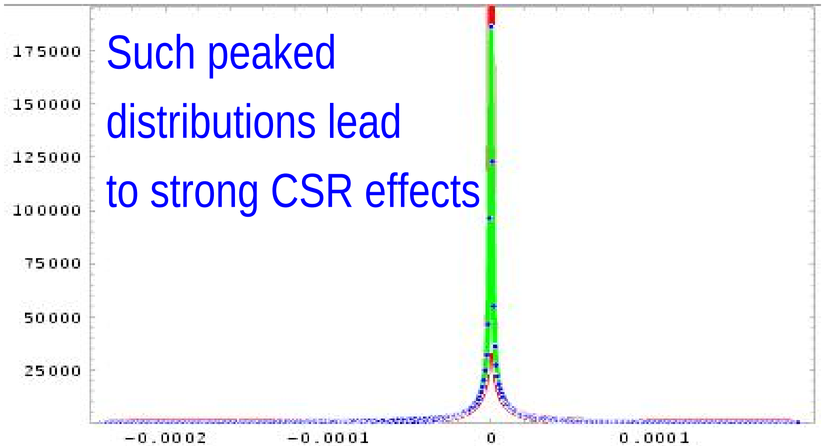
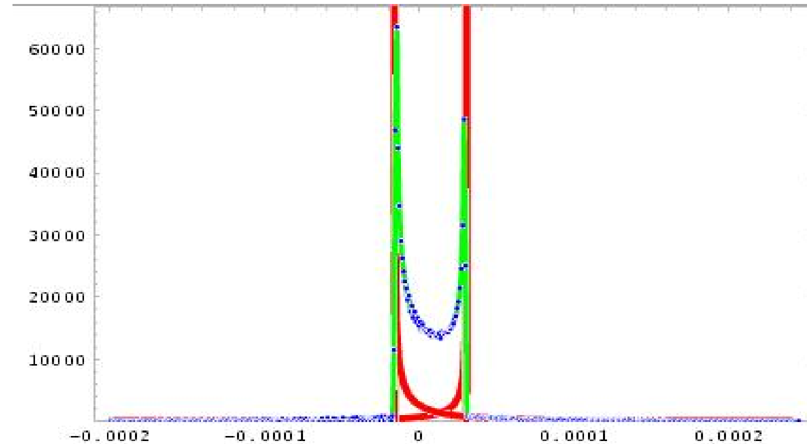
Peak at 6^0 RF phase



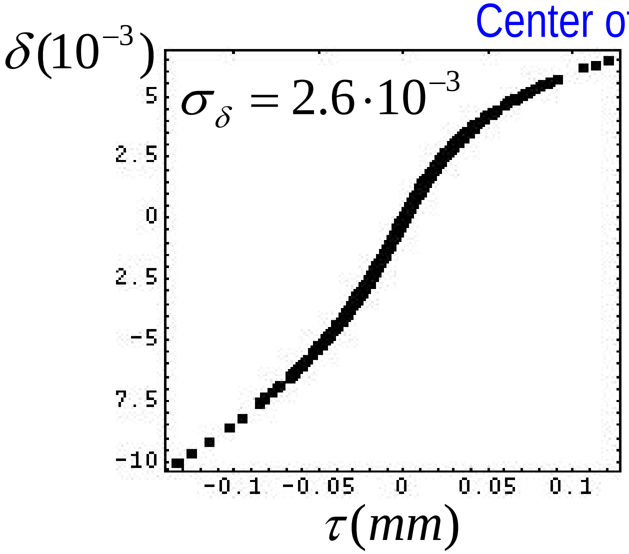
Overfocused peaks

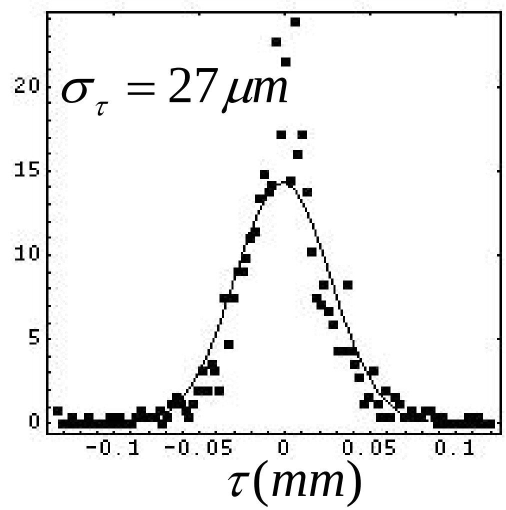


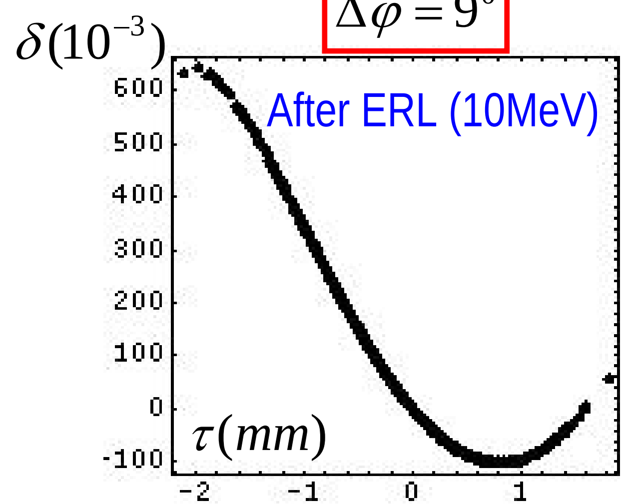
With second order optimization: 9^0 RF phase and undercompression

Center of arc (5GeV)

$\Delta\varphi = 9^0$







CSR microbunching

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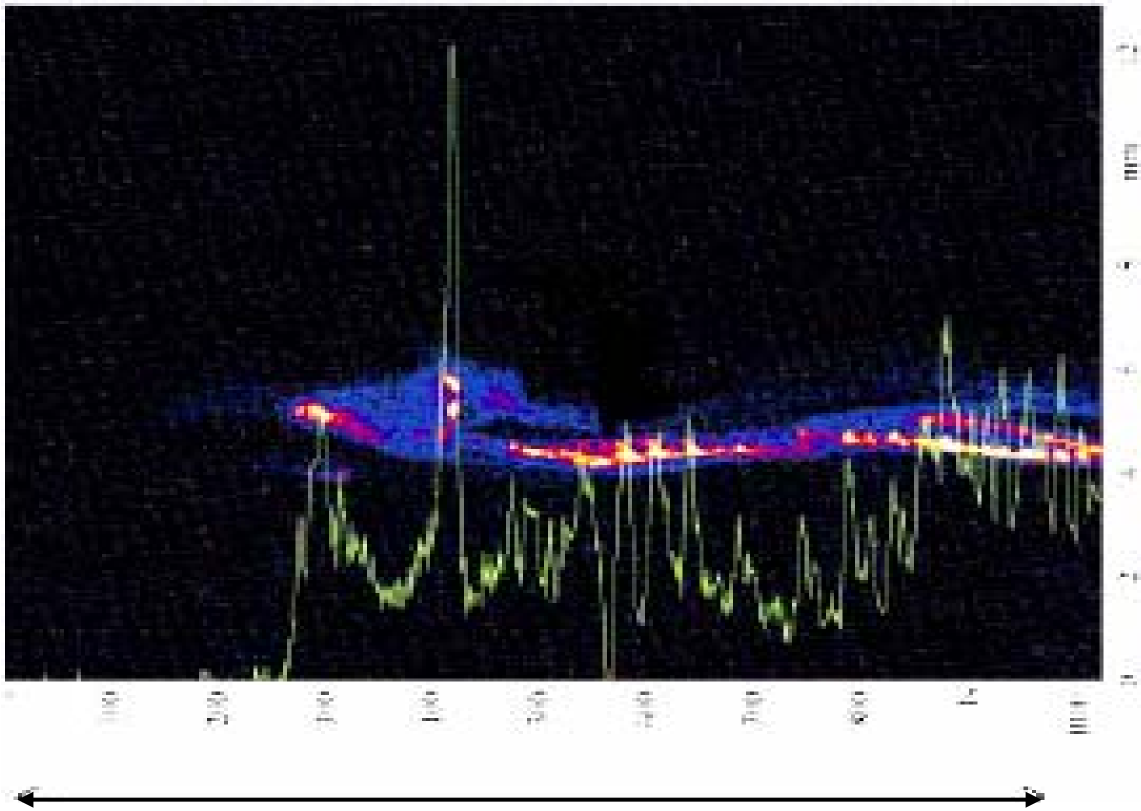

1 picosecond

Micro-bunching: Longitudinal Bunch Profile Measurements at TTF

Emittance with CSR and nonlinear optics

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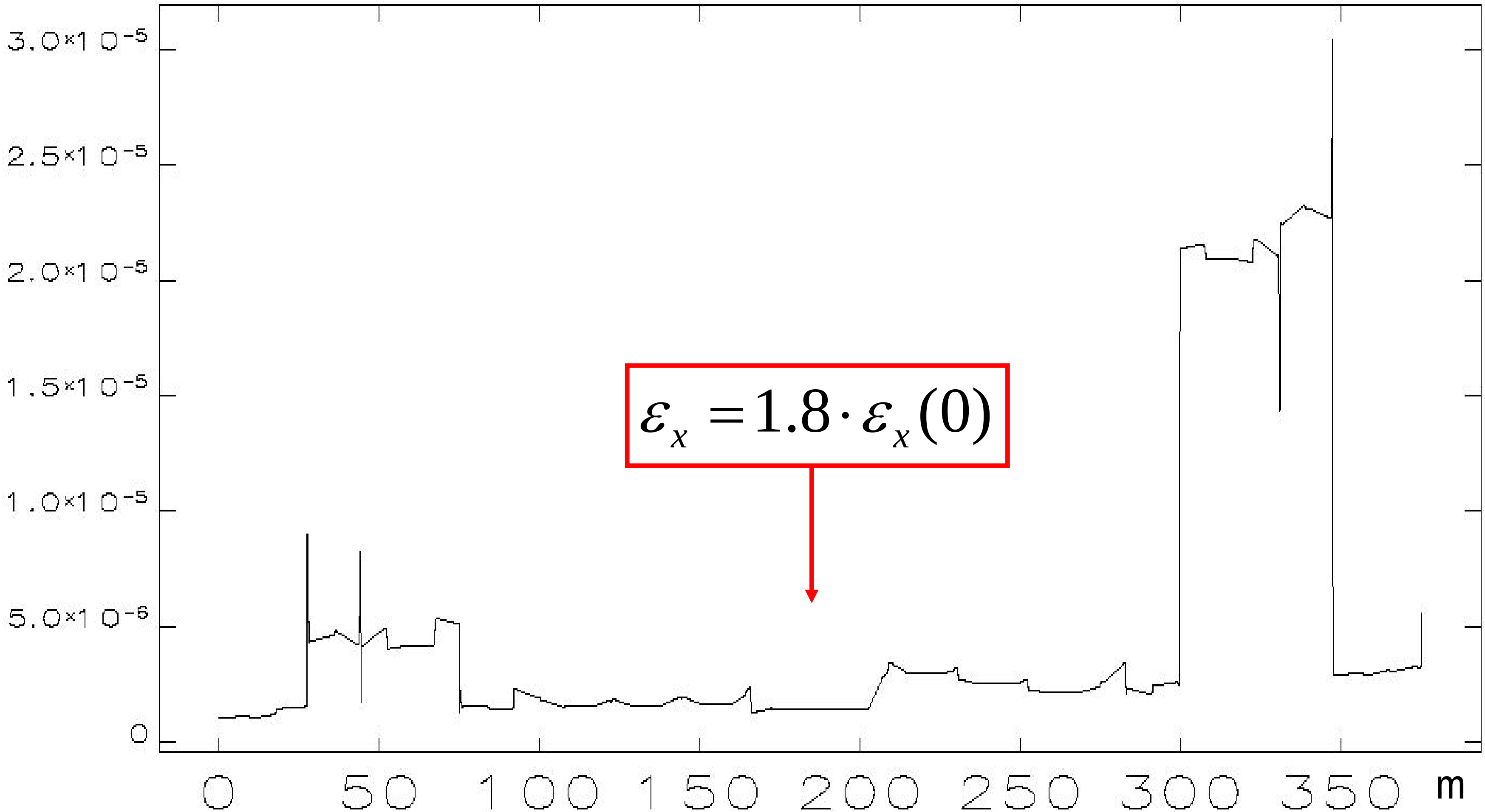
Horizontal emittance with coherent synchrotron radiation



Result: After suitable nonlinear bunch length manipulation, the emittance growth can be controlled in all undulators.

Question to be addressed (Thursday)

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(5) What are vacuum and aperture needs for ERL light sources?

(6) What are advantages and limits of multi-turn ERLs?

(7) RF issues

 (a) What is the maximum Q_L possible, and what stabilization is needed?

 (b) What are optimal cavity parameters?

(8) What are good beam stabilization strategies and their limits?

(9) What are undulator issues that are specific to ERLs?

(10) What issues are critical for all proposed ERLs?

Reports (drafts) for each question should be finished by Friday morning !

Ion accumulation in the beam potential

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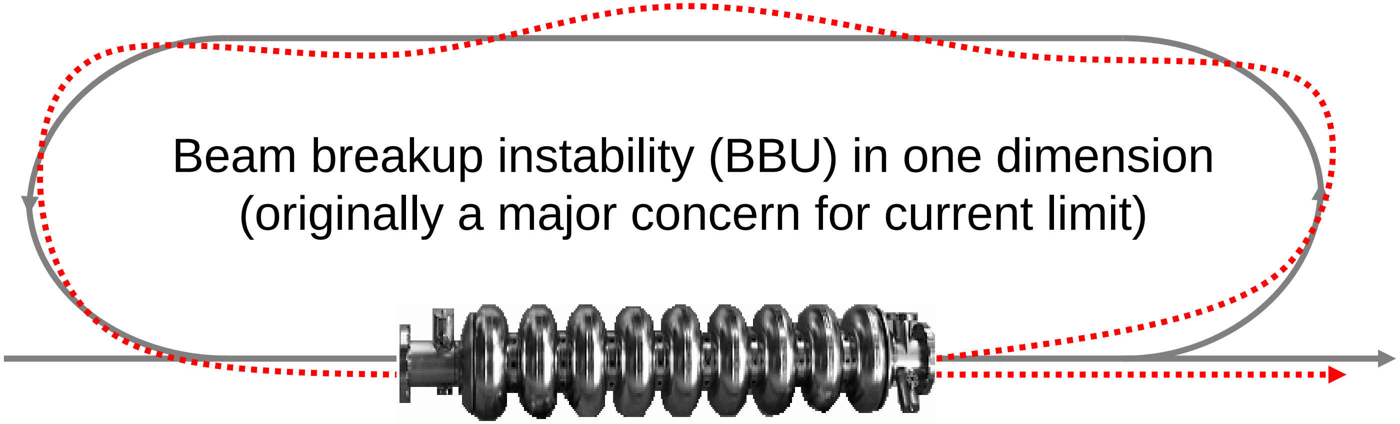
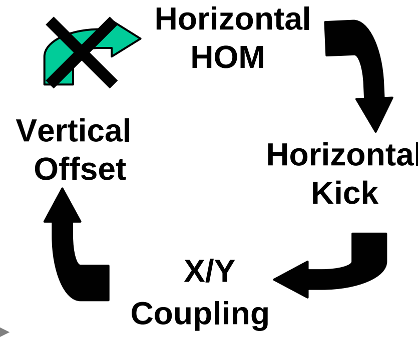
Ion are quickly produced due to high beam density

Ion	σ_{col}, 10MeV	σ_{col}, 5GeV	τ_{col}, 5GeV
H_2	$2.0 \cdot 10^{-23}\mathrm{m}^2$	$3.1 \cdot 10^{-23}\mathrm{m}^2$	5.6s
CO	$1.0 \cdot 10^{-22}\mathrm{m}^2$	$1.9 \cdot 10^{-22}\mathrm{m}^2$	92.7s
CH_4	$1.2 \cdot 10^{-22}\mathrm{m}^2$	$2.0 \cdot 10^{-22}\mathrm{m}^2$	85.2s

- Ion accumulate in the beam potential. Since the beam is very narrow, ions produce an extremely steep potential – they have to be eliminated.
- Conventional ion clearing techniques can most likely not be used:
  1) Long clearing gaps have transient RF effects in the ERL.
  2) Short clearing gaps have transient effects in injector and gun.
- DC fields of about 150kV/m have to be applied to appropriate places of the along the accelerator, without disturbing the electron beam.

Current limit due to BBU



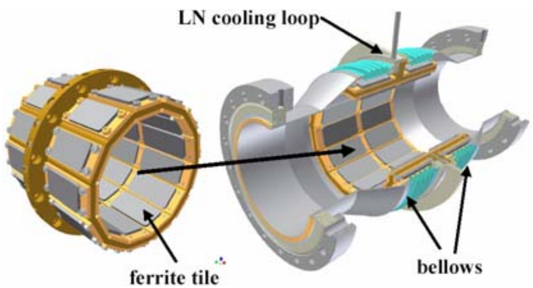


320 identical cavities → **Current limited to 25mA**

Randomized frequencies with rms of 10MHz → **Current limited to 500mA**

Polarized Cavities and x to y coupling → **Current limited to 2000mA >> required 100mA**

Now the current limited by a technical choice:
Cooling capacity of the HOM Dampers



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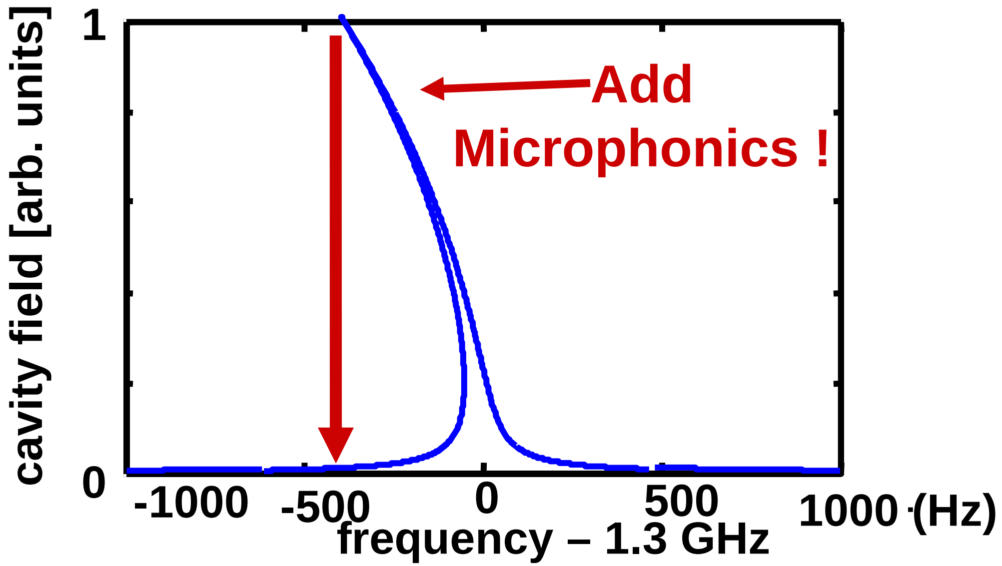
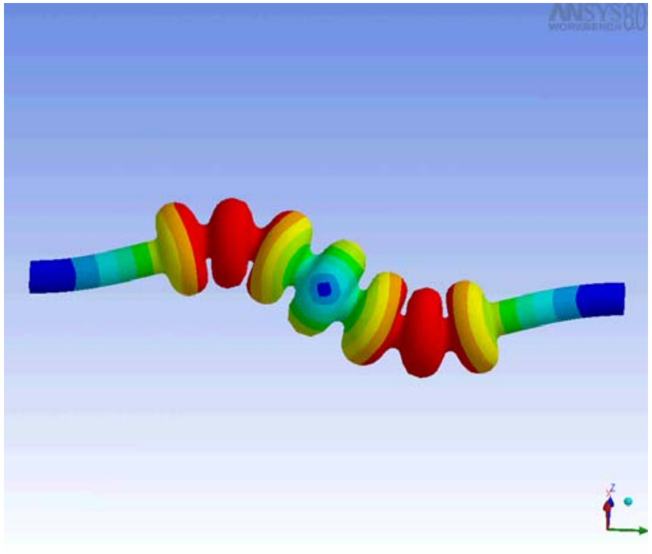
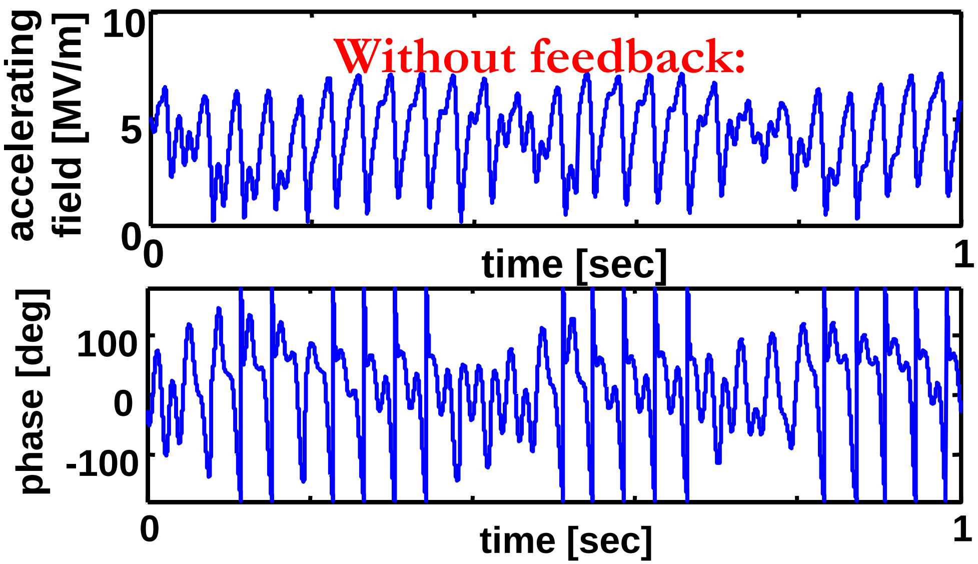
High loaded Q cavity control







- Run cavity at highest possible loaded Q for Energy recovery linac mode, i.e. without beam loading

- But: The higher the loaded Q, the maller the cavity bandwidth!

Stability issues (Rings)

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SR - Stability - Requirements

- $\beta_x = 1.4$ m, $\beta_y = 0.9$ m at **ID** position of section nS $\rightarrow$
  $\sigma_x = 84\ \mu$m, $\sigma_y = 7\ \mu$m assuming emittance coupling $\epsilon_y/\epsilon_x = 1$ %
- With stability requirement $\Delta\sigma = 0.1 \times \sigma \rightarrow$

Requirement: Orbit jitter < 1 µm at insertion devices

Noise Scenario from 1998 before SLS construction

	Worst case Noise estimate	30	60	Hz
	Seismic measurements	300	30	nm
	Damping by hall's concrete slab	neglected		
	Girder resonance max amplification	< 10	< 10	
	Closed orbit amplification hor./vert.	8/5	25/5	
→	Maximum Orbit jitter hor./vert	24/15	7.5/1.5	µm
	Attenuation by orbit feedback	−55	−35	dB
→	**Maximum Orbit jitter hor. /vert.**	**40/30**	**130/30**	**nm**

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Goals

	Short-Term Goals			Long-Term Goals		
Modes:	**(A) Flux**	**(B) High-Coherence**	**(C) Short-Pulse**	**(D) Ultra High-Coherence**	**(E) Ultra Short-Pulse**	**Units**
Energy	5	5	5	5	5	GeV
Current	100	25	1	100	1	mA
Bunch charge	77	19	1000	77	10000	pC
Repetition rate	1300	1300	1	1300	0.1	MHz
Norm. emittance	0.3	0.08	5.0	0.06	5.0	mm mrad
Geom. emittance	31	8.2	511	5.1	511	pm
Rms bunch length	2000	2000	50	2000	20	fs
Relative energy spread	2 10-4	2 10-4	3 10-3	2 10-4	3 10-3	
Beam power	500	125	5	500	5	MW
Beam loss	< 1	< 1	< 1	< 1	< 1	micro A

Non Light Source ERLs

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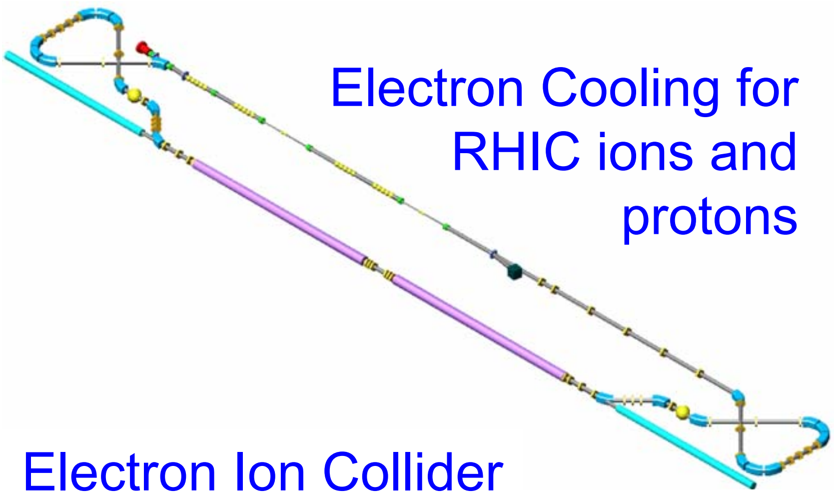
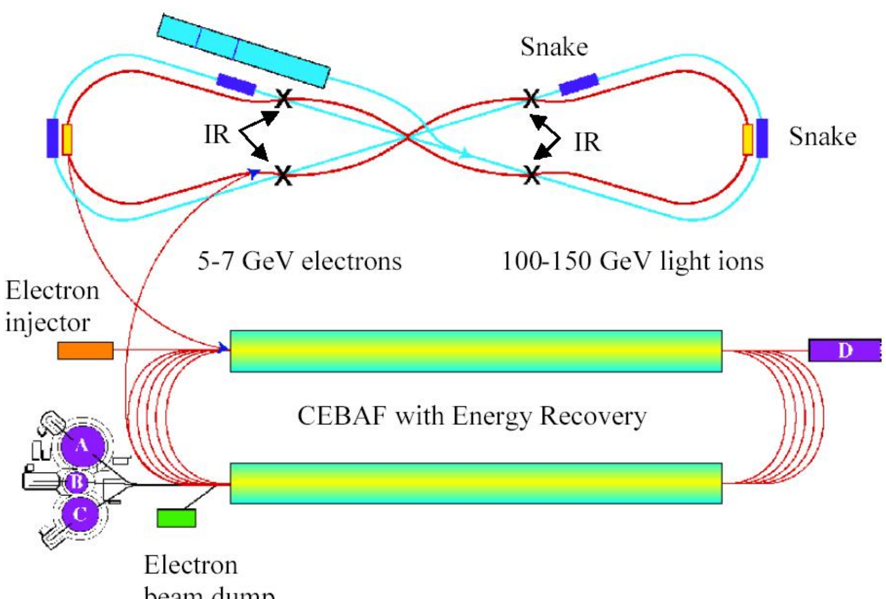
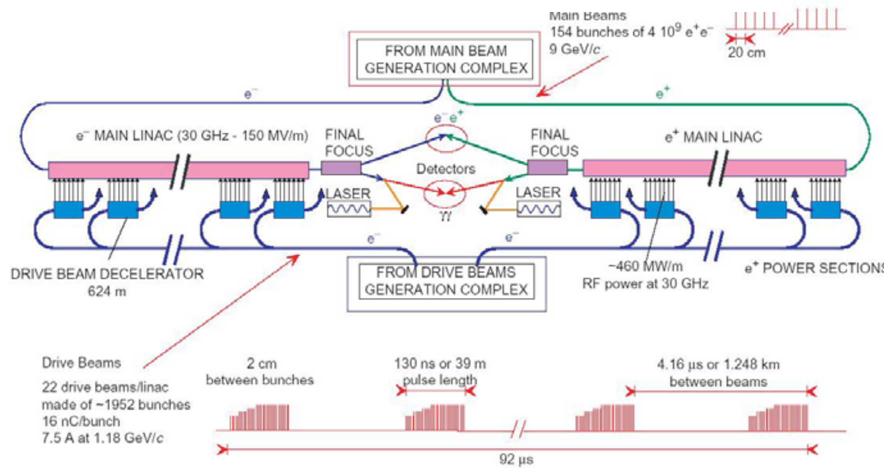


Electron Cooling for RHIC ions and protons

Electron Ion Collider



CLIC-like drive beam ERL



A low emittance RF source Could save the electron damping ring in a LC