CORNELL

Overview of WG2 (Optics and Beams)

CHESS & LEPP

Georg H. Hoffstaetter (Cornell University / Physics)

on behalf of WG2:

Co-conveners: Hywel Owen, Vladimir Litvinenko

Speakers: Dan Abell, Michael Boege, Michael Borland, Dave Douglas, Alexei Fedotov, Luca Giannessi, Ryoichi Hajima, Georg Hoffstaetter, David Holder, Andrew Hutton, Andreas Kabel, Joerg Kewisch, Gennady Kulipanov, Valeri Lebedev, Steve Lidia, Vladimir Litvinenko, Lia Merminga, Bruno Muratori, Sergei Nagaitsev, Hywel Owen, Phillip Piot, Eduard Pozdeyev, James Rosenzweig, David Sagan, Masaru Sawamura, Luca Serafini, Todd Smith, Chris Tennant, Marion White

1. Goal
2. Projects & Areas of Interest
3. Highlights
4. Reports
5. Important future issues

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Charge

Home Page of the ERL05 Working Group 2:

Optics and Beam Transport

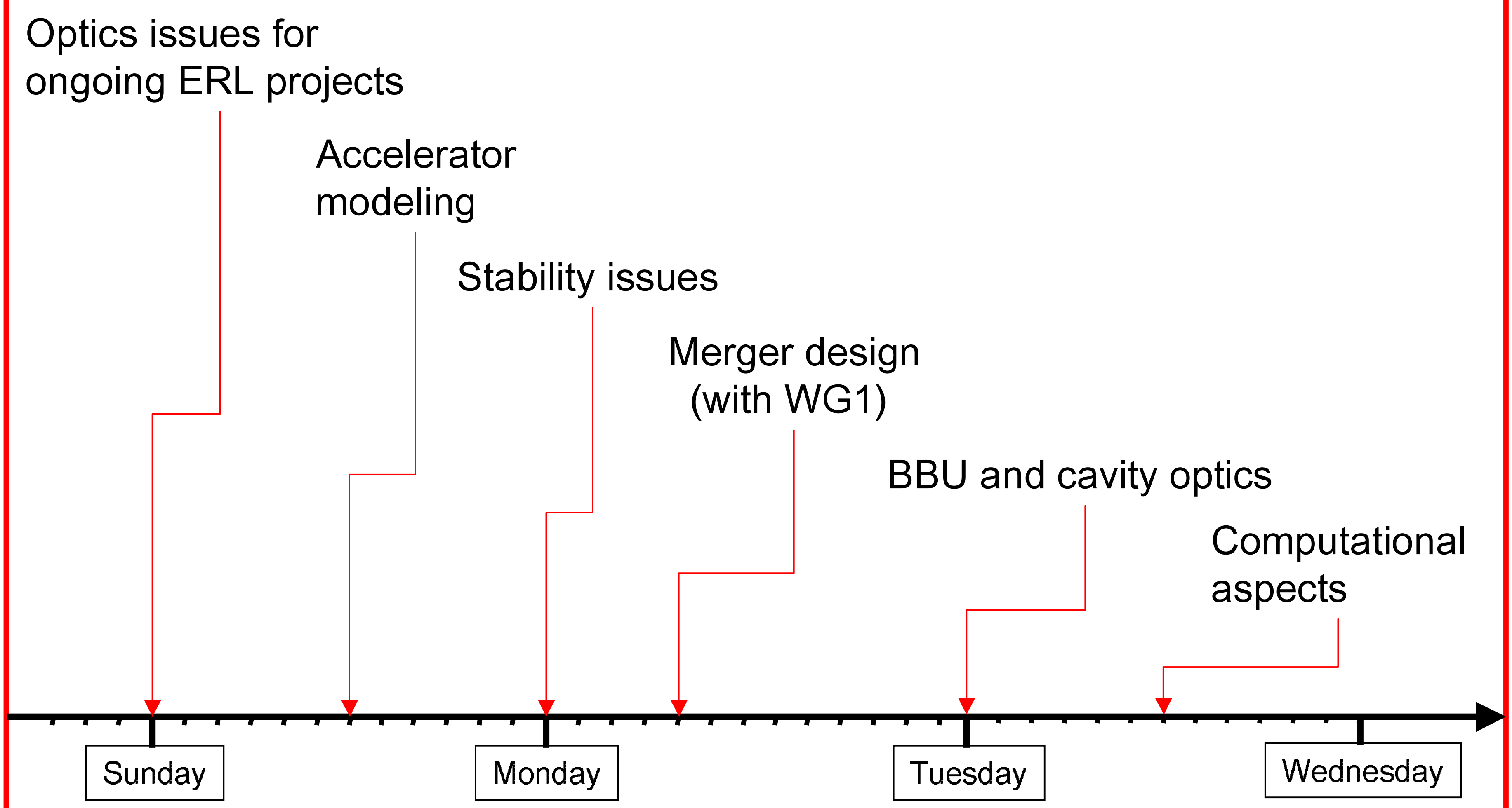
Working Group Conveners: Georg Hoffstaetter (Cornell), Vladimir Litvinenko (BNL), Hywel Owen (CCLRC)

Program Committee Contacts:Â M.Borland (APS), D.Douglas (JLAC), R.Hajima (JAERI), G.H.Hoffstaetter (Cornell), V.Litvinenko (BNL), A.Mosnier (Saclay), S.Smith (CCLRC), T.Suwada (KEK)

Charge

Perform a **survey of the present status** of optics and beam transport issues in ERLs and make a **list of unsolved problems**.The ERLs to be covered include those currently in operation, currently under construction, or envisioned as a possibility for the future anywhere in the world. Special emphasis should be placed on the clear identification of the **beam physics limits and accelerator technology limits** and an examination of the extent that they have been addressed by past research or **need to be addressed** by further research. These issues should include linear optics design for the main linac section, linear optics for different ERL applications, nonlinear optics, current dependent effects like BBU and CSR, other sources of emittance growth, halo development and collimation, instrumentation and commissioning techniques. Identify new and promising ideas even though they may need additional work. Finally, the group should summarize in a brief report (a few pages) the **highest priority research topics for beam transport in ERLs** and provide an approximate schedule for **key experiments and R&D developments**. The group is also asked to provide a comprehensive presentations in plenary sessions during this workshop.

WG2 Schedule



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Optics in ongoing ERL Projects

- JLAB-FEL
- JAERI-FEL
- RECUPERATOR –FEL
- ERLplus

} ERL-FELs

- Cornell X-Ray ERL
- 4GLS
- MARS
- APS-ERL
- Arc en Ciel

} ERL-Light sources

- eCool-RHIC
- eRHIC-ERL
- ELIC
- …

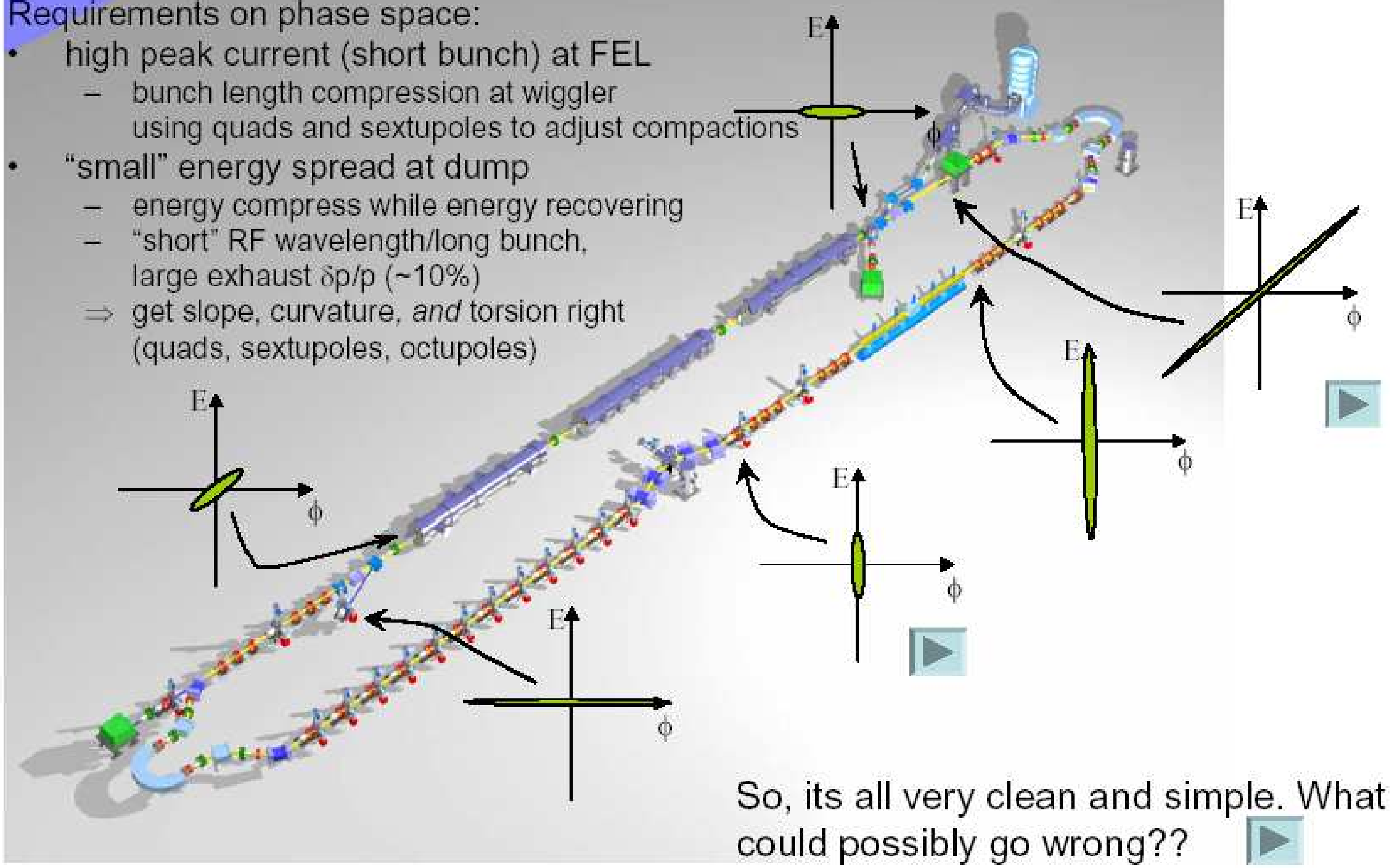
} Nuclear Physics ERLs

FEL-ERL operation experiences

Longitudinal Matching Scenario

Requirements on phase space:

- high peak current (short bunch) at FEL
  - bunch length compression at wiggler using quads and sextupoles to adjust compactions
- "small" energy spread at dump
  - energy compress while energy recovering
  - "short" RF wavelength/long bunch, large exhaust $\delta p/p$ (~10%)
  - ⇒ get slope, curvature, *and* torsion right (quads, sextupoles, octupoles)



So, its all very clean and simple. What could possibly go wrong??

WG2 Accelerator modeling (e.g. ERL-FEL)

FELV Fit

2) Simultaneously fit the data sets to get the actual quadrupole strengths.

Common variables:

- 54 Quadrupoles

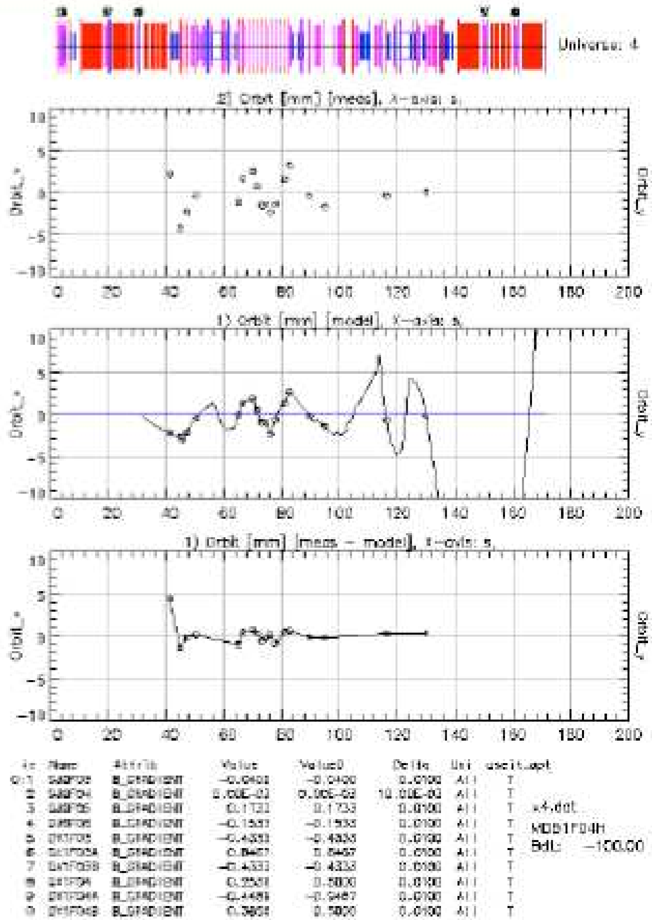
Individual variables:

- 20 Steerings

Data:

Final Model:

Data - Model:



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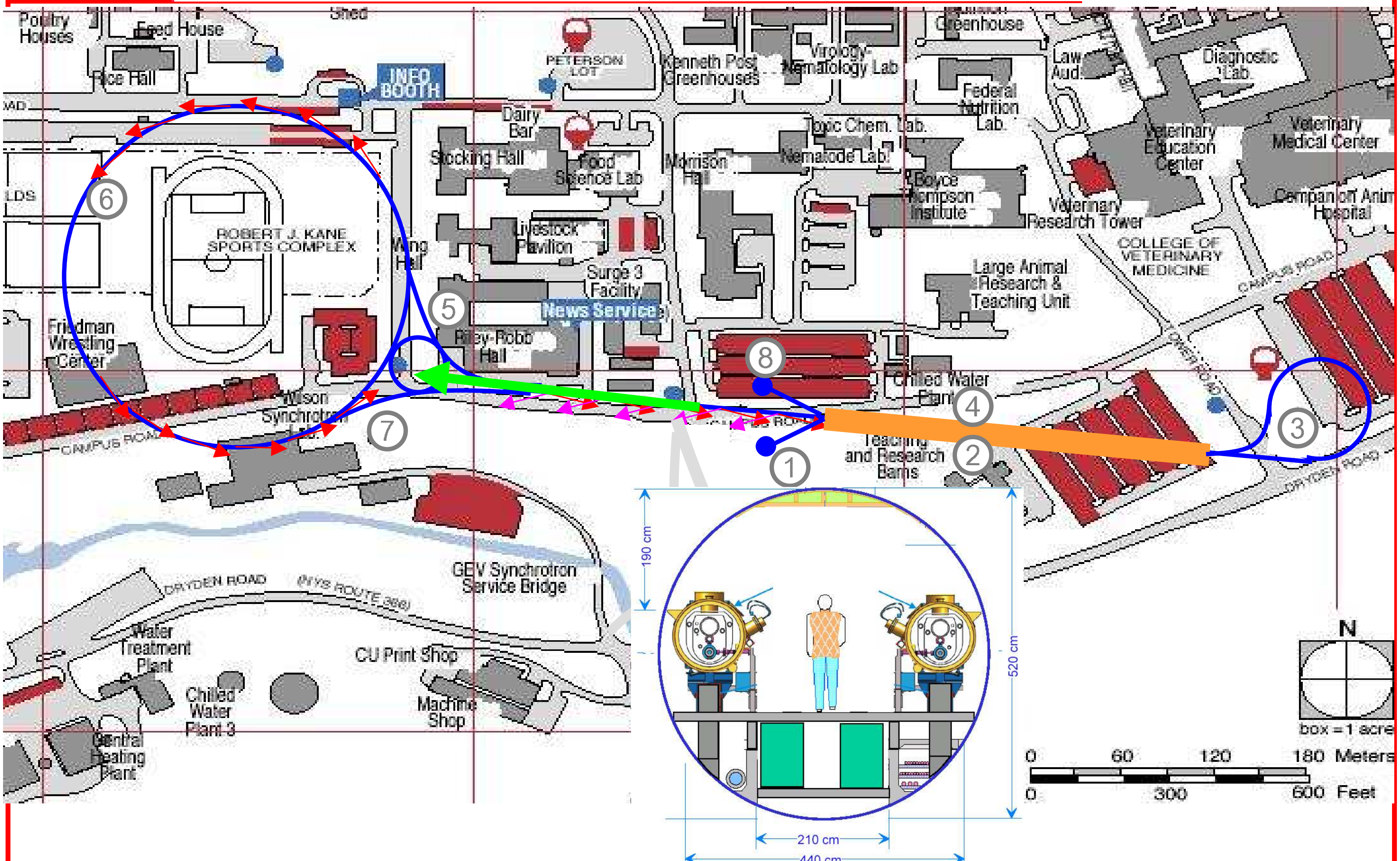
5GeV ERL Upgrade for CESR



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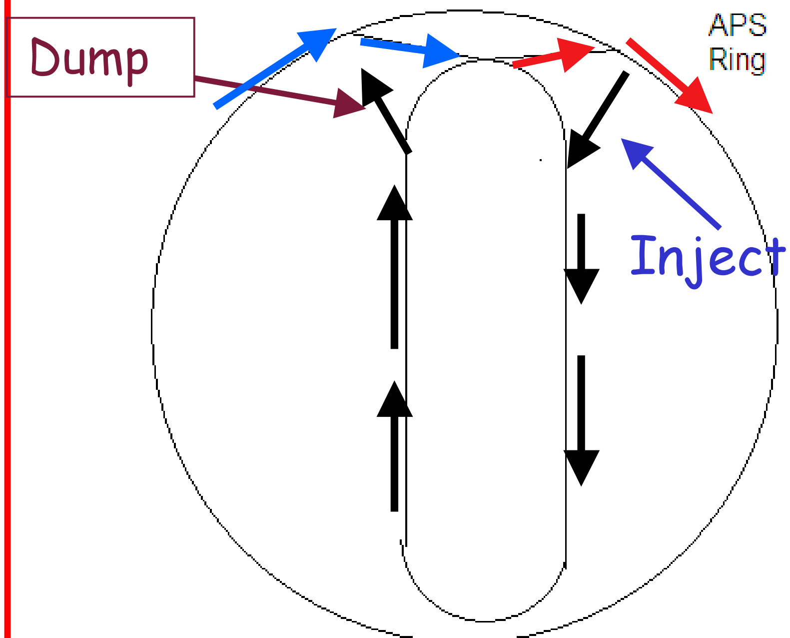
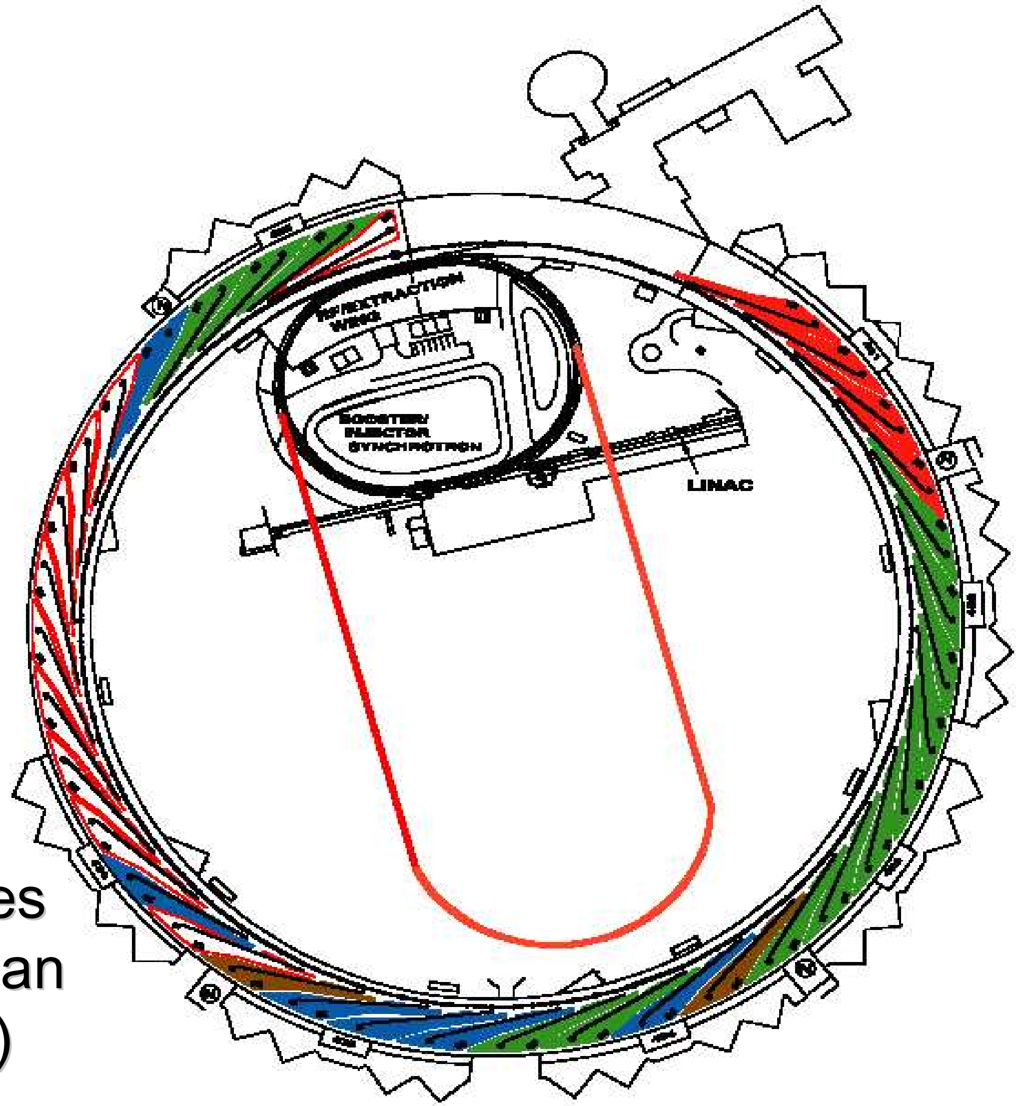
Upgrade for APS





Predictions for x-ray properties
Somewhat more optimistic than
At other designs (preliminary)

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Why X-ray ERLs ?

Simulated Injector Performance

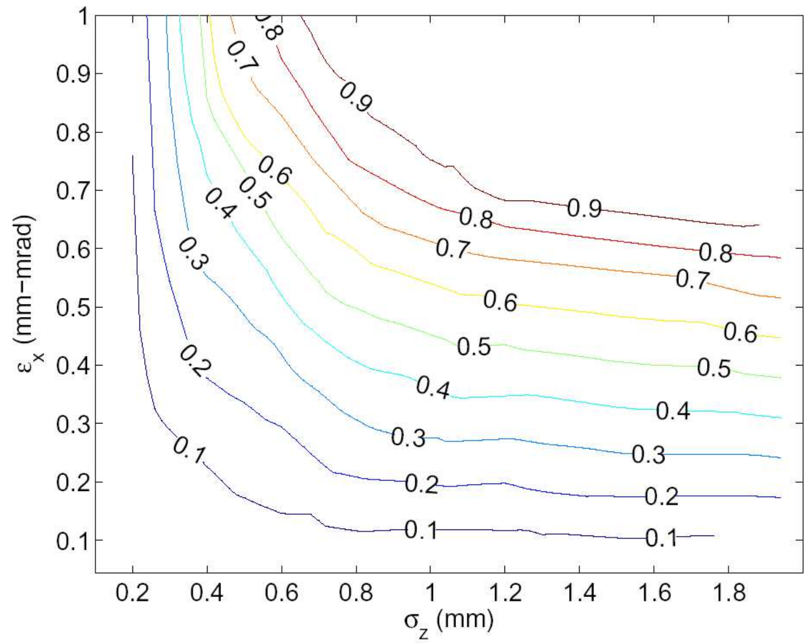


FIG. 10: Transverse emittance vs. bunch length for various charges in the injector (nC).

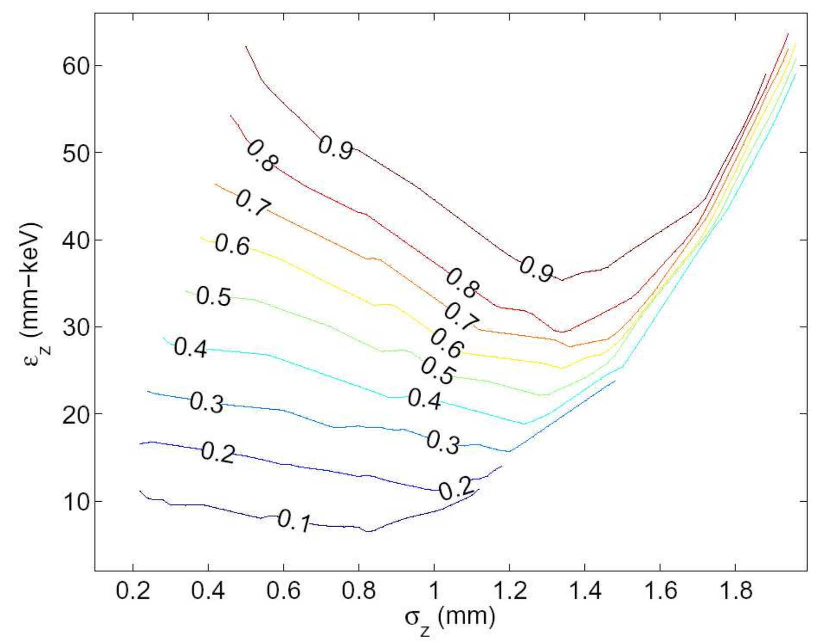


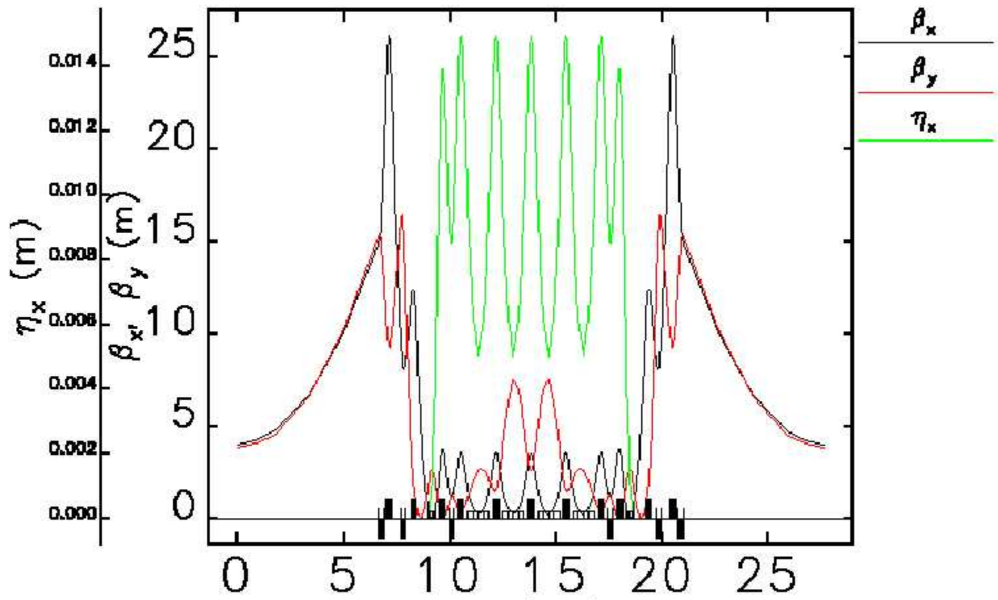
FIG. 11: Longitudinal emittance vs. bunch length for various charges in the injector (nC).

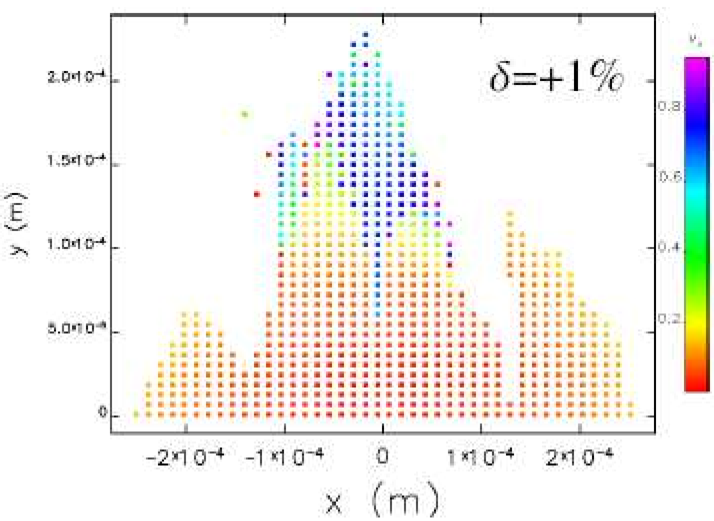
Takes several 10^5 simulations

$$\varepsilon_\perp[\text{mm-mrad}] \approx q[\text{nC}]\ (0.73 + 0.15/\sigma_z[\text{mm}]^{2.3})$$

WG2 Why X-ray ERLs ?

- Original XPS design[1] had an error.
- New design is based on similar concepts
- Use combined function magnets
  - Dipole with fixed gradient and sextupole
  - 12 pole magnets for combined quadrupoles
- Use variable permanent magnets
  - Only way to get the strengths required
  - Need the stability for ultra-low emittance
  - Need electromagnetic trims for correctors





Color code shows horizontal tune.

Momentum aperture too small: +/- 1%

DA is much too small:
0.1mm x 0.05mm or 7σ x 3.5σ

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Stability issues (Rings)

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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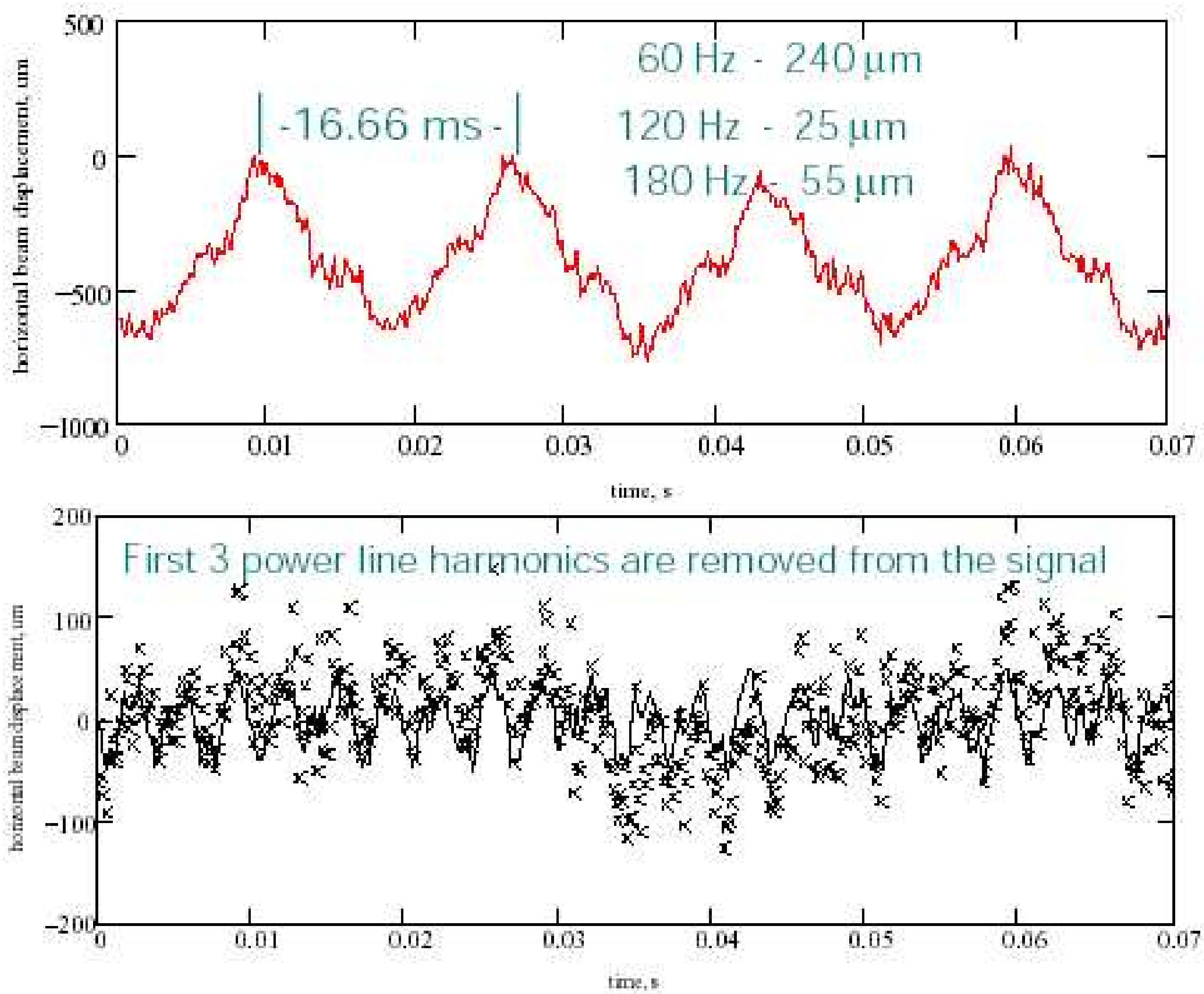
Stability issues (Linacs)



CEBAF with adaptive feed forward at 60, 120, and 180Hz.

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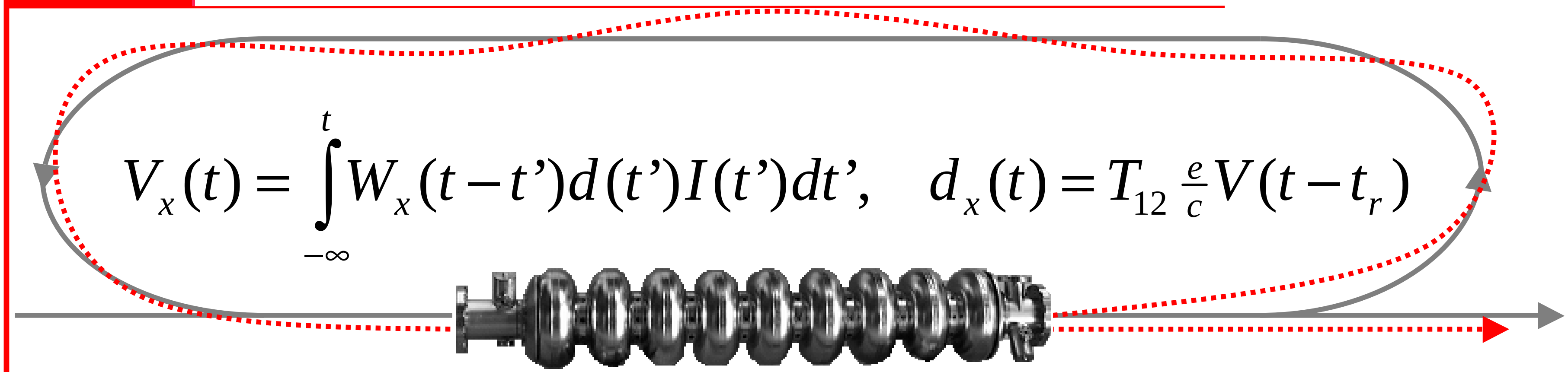
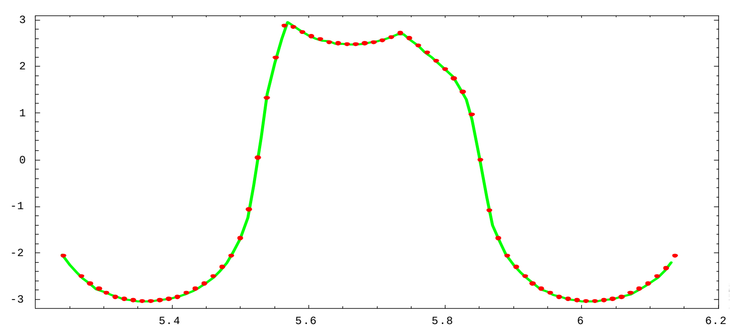
BBU codes



$$V_x(t) = \int_{-\infty}^{t} W_x(t-t')d(t')I(t')dt', \quad d_x(t) = T_{12}\,\tfrac{e}{c}V(t-t_r)$$

$$V_x(t) = T_{12}\,\tfrac{e}{c}\int_{-\infty}^{t} W_x(t-t')V(t'-t_r)I(t')dt'$$

How to Solve



- Beam Tracking (Beam position vs. Time)
  - BBU-R (JAERI)
  - TDBBU (JLab)
  - bi (Cornell Univ.)
  - new code (JLab)
- Eigenvalue Solution (Current vs. Frequency)
  - MATBBU (JLab)

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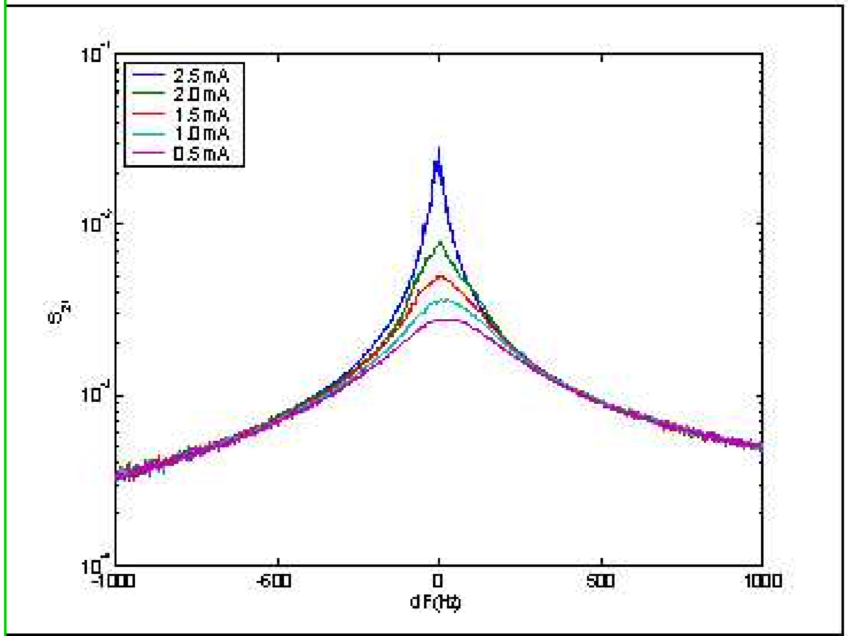
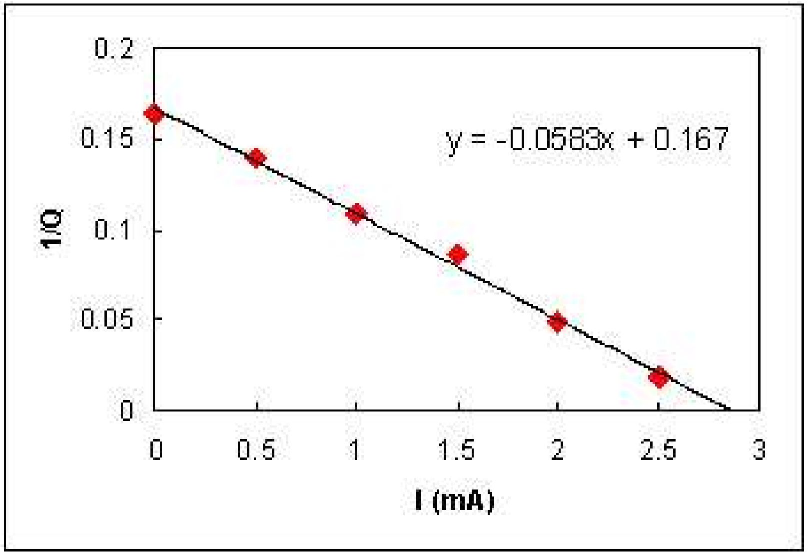
BBU measurements

Cav 7, F_{hom}=2106 MHz





Projected threshold current is 2.86 mA

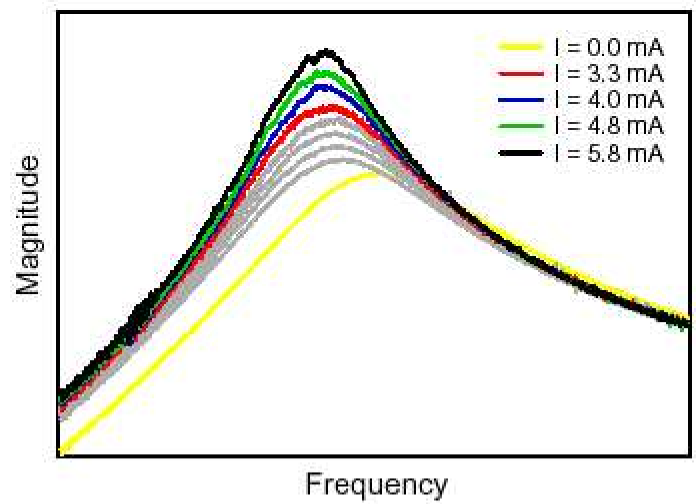
WG2 BBU passive feedback

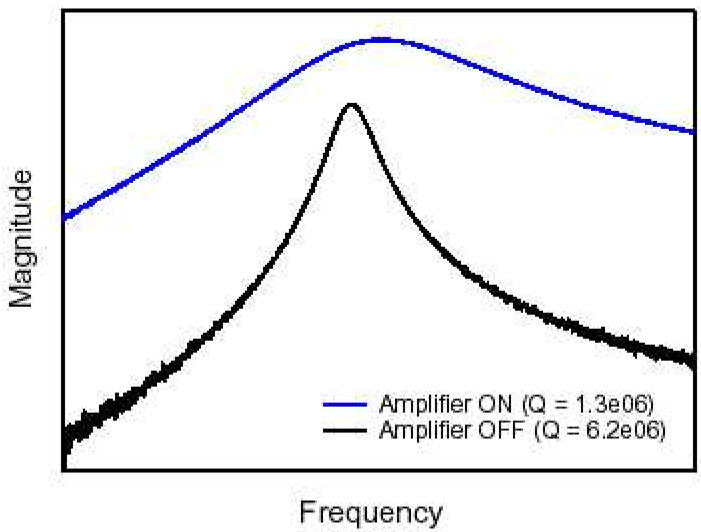
Recall… $I_{threshold} \propto \frac{1}{Q_{HOM}}$

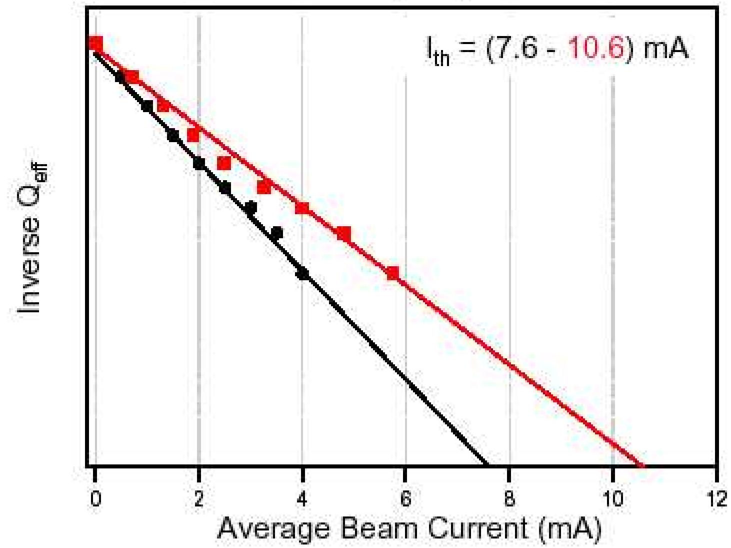
- Damping circuit easily reduced the *Q* of the 2106 MHz mode by a factor of 5

  (Above a factor of about 10, the system becomes sensitive to external disturbances)

- The threshold is increased accordingly: from 2 mA to ~10 mA







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BBU stabilization

		Effect on 2106 MHz HOM	Considerations for Implementation
Q-Damping	**Damping Circuit**	5 × I_{th}	• Works for only *1 mode per cavity* • Not as effective at raising the threshold as beam optical methods • Long term stability of system • Does **not** effect beam optics
	3-Stub Tuner	1.5 × I_{th}	
Beam Optics	**Phase Trombone**	*Stabilized*	• Can *stabilize* the mode against BBU • What are the effects on other HOMs? • Do they prevent reaching the requirements needed for a suitable lasing configuration?
	Pseudo-Reflector	*Stabilized*	

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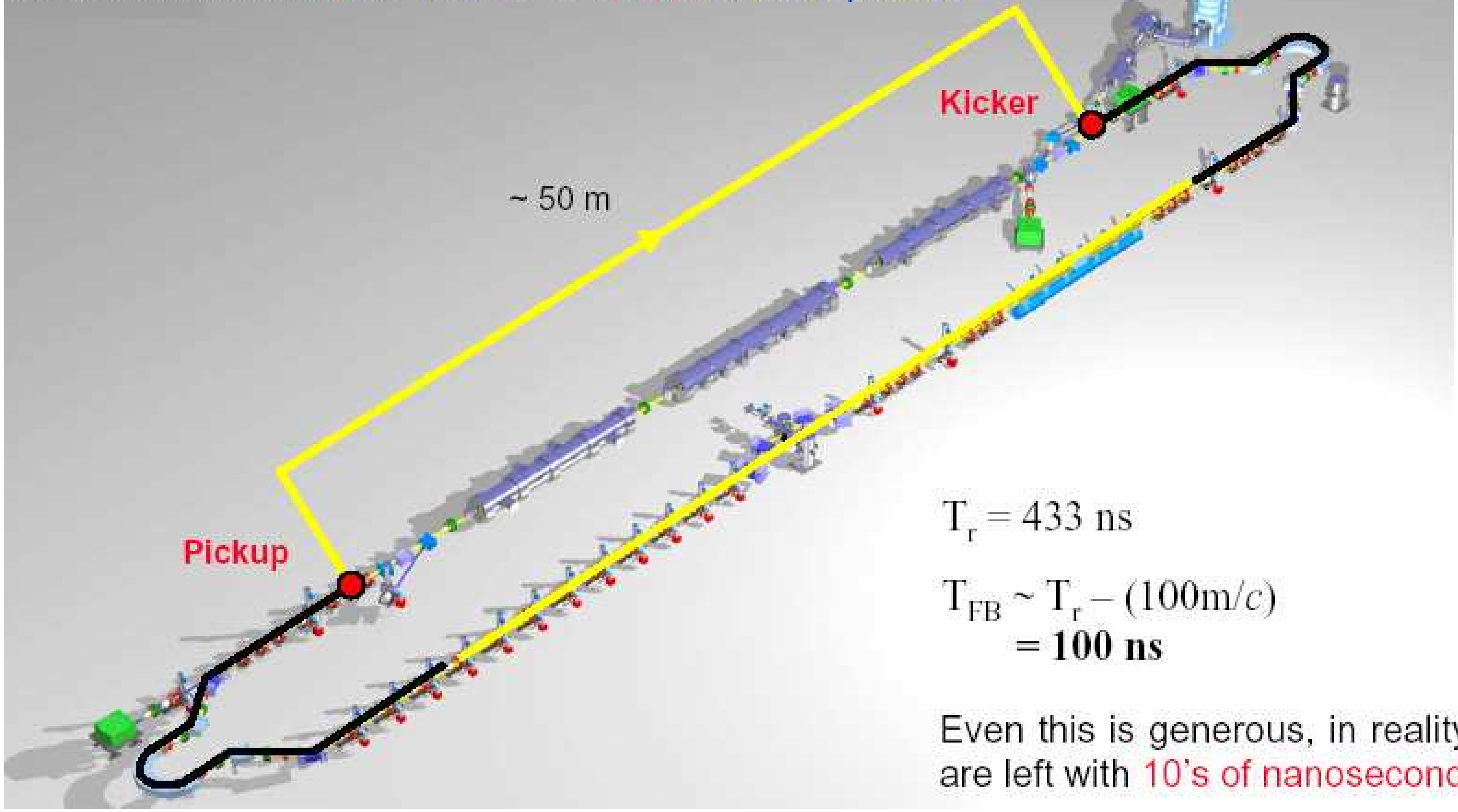
BBU active feedback

Storage Rings...finite number of bunches, infinite passes

ERLs................infinite number of bunches, finite passes



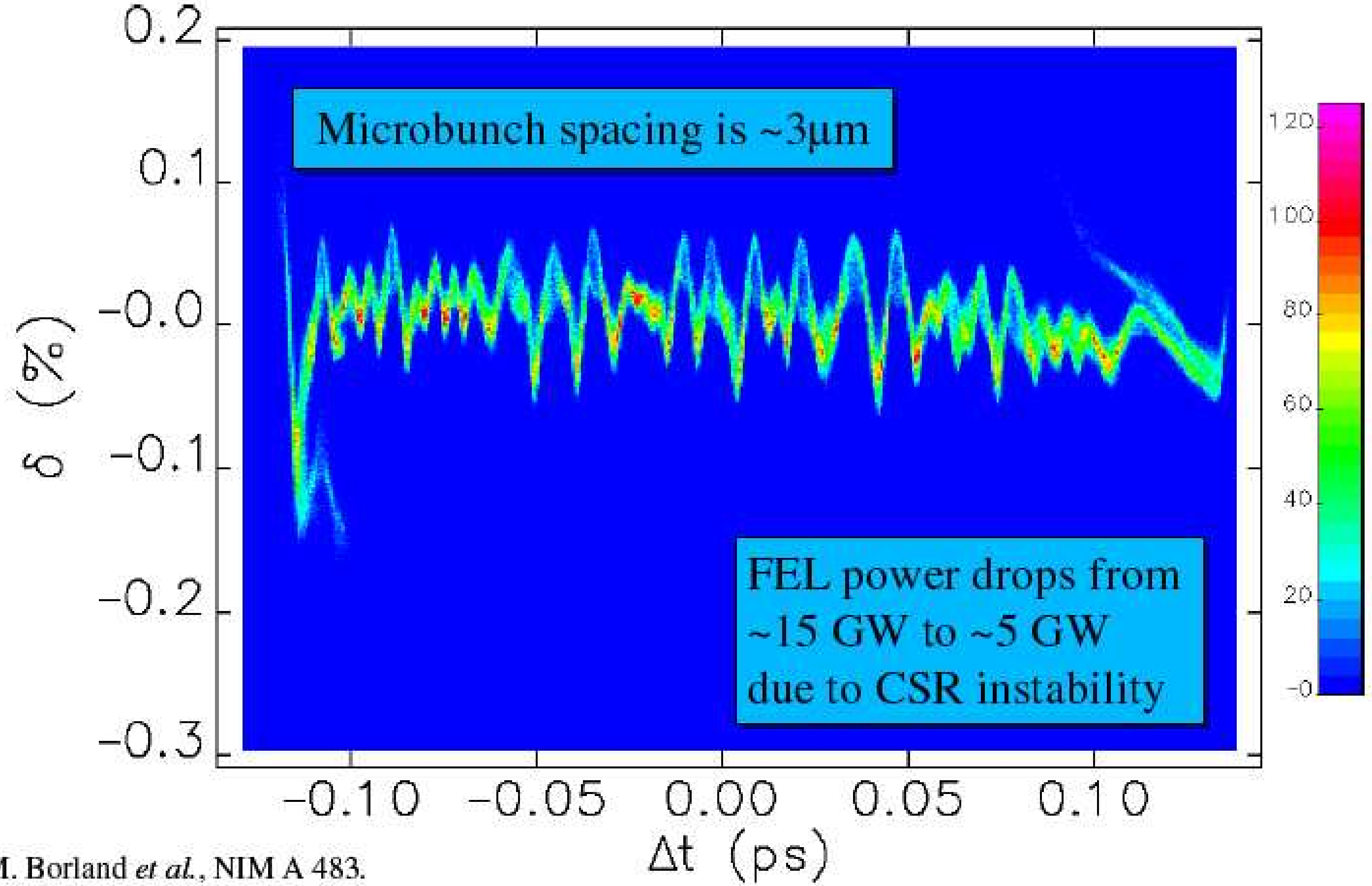
$T_r = 433$ ns

$T_{FB} \sim T_r - (100\text{m}/c)$
$= \mathbf{100\ ns}$

Even this is generous, in reality you are left with 10's of nanoseconds

WG2 Accelerator modeling (S2E simulations)

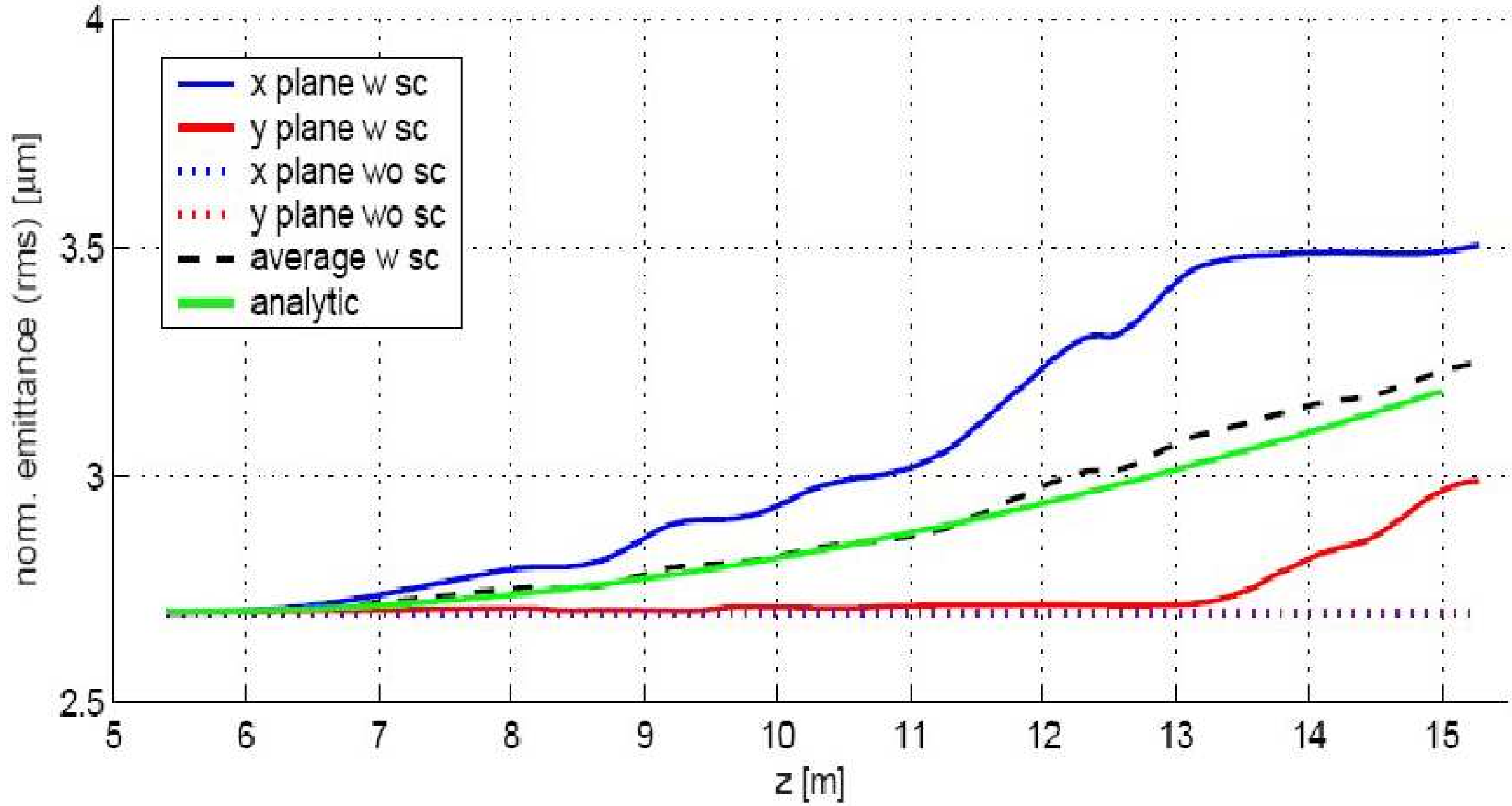
CSR Microbunching Instability in LCLS



M. Borland *et al.*, NIM A 483.

WG2 Computational aspects

Need for fast, open source, parallel 3D space charge codes:



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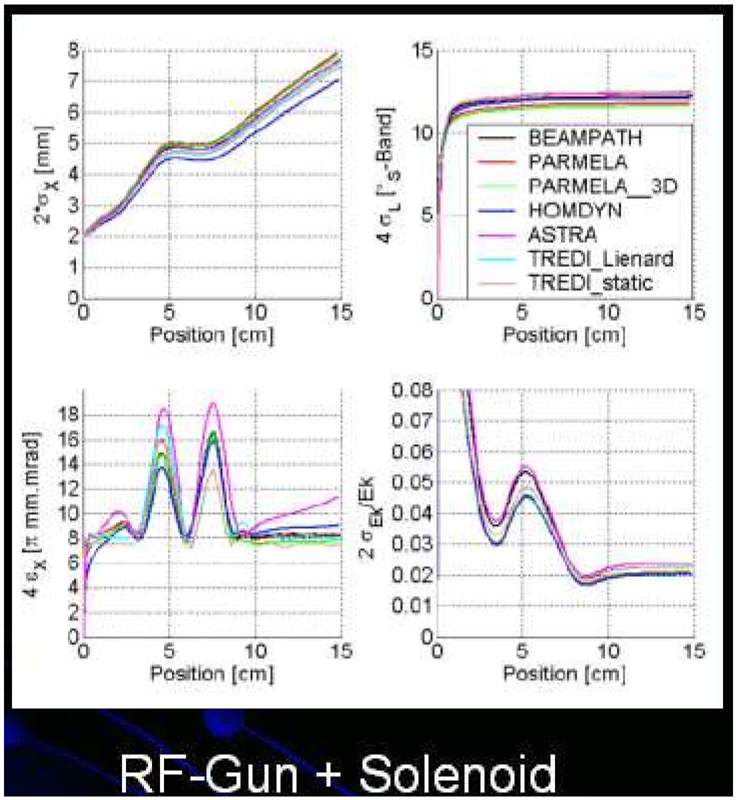
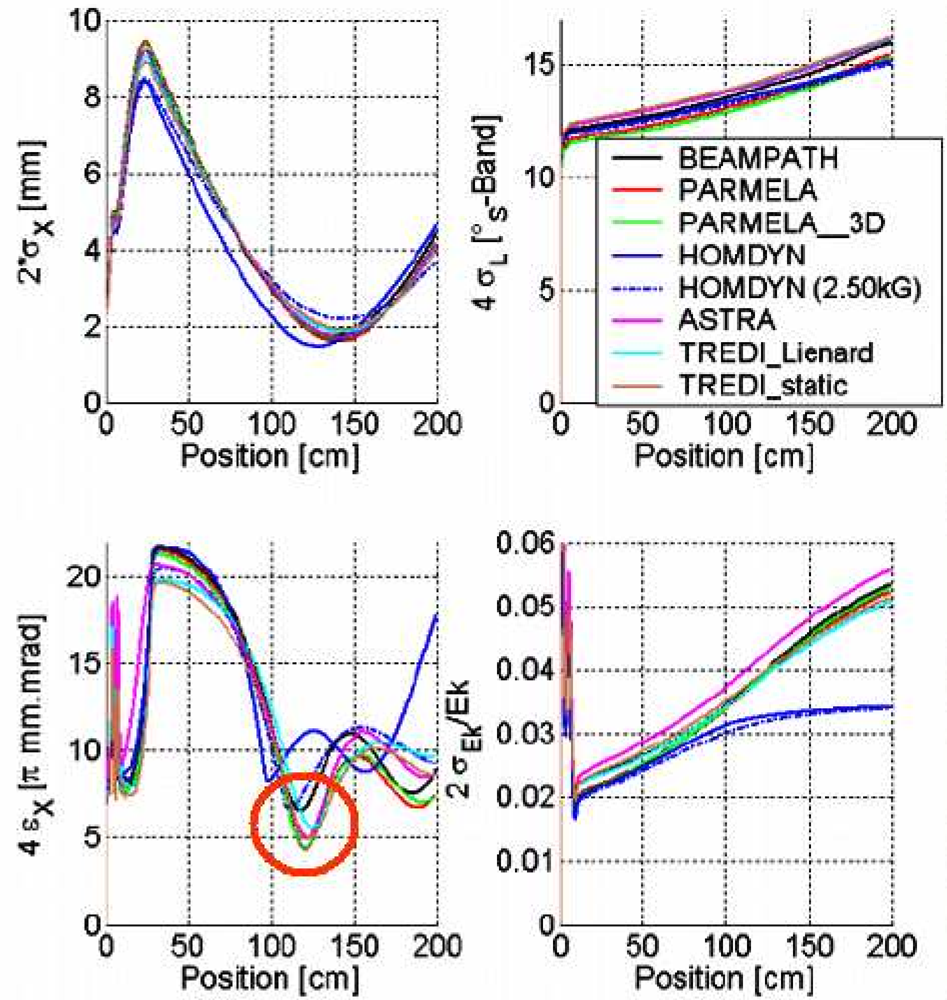
Space charge and CSR





RF-Gun + Solenoid + Drift

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Space charge and CSR

A Taxonomy of Codes

Nameless (R. Li)	FMM32
ELEGANT (Borland)	AMV31
TraFiC4 (Dohlus, Limberg, A.K.)	FMM33
CSRTrack (Dohlus, Limberg)	MMV33
TREDI (Giannessi and Quattromini)	FMM33
Nameless (P. Emma)	FMV31

Recent approaches:

- Agoh and Yokoya: Grid calculations of field
- Warnock, Ellison, Bassi: PF, new field integration scheme
- Talman: string charges

	3D	δE	σE	ε
3D	TRAFIC4	-0.058	-0.002	1.4
	TREDI	-0.018	-0.001	1.85
2D	Program by R.LI	-0.056	-0.006	1.32
1D	Elegant	-0.045	-0.0043	1.55
	CSR_CALC	-0.043	-0.004	1.52
	Program by M. Dohlus	-0.045	-0.011	1.62

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Collaboration (EuroFEL)

Example: European FEL design study (EuroFEL)

18 European laboratories, lead by DESY-Hamburg
Collaborating on several different FEL projects

- DS 1 Photo-Guns & Injectors (Massimo Ferrario, INFN);
- DS 2 Beam Dynamics (Hywel Owen, CCLRC);
- DS 3 Synchronisation (Mario Ferianis, ELETTRA);
- DS 4 Seeding and Harmonic Generation (Sverker Werin, MAX-lab);
- DS 5 Superconducting CW and Near-CW Linacs (Jens Knobloch, BESSY);
- DS 6 Cryomodules Technology Transfer (Bernd Petersen, DESY);

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Collaborations

- Joint proceedings writing:

Optics issues for ongoing ERL projects	(Susan Smith)
Stability issues	(Michael Boege)
Merger design	(Vladimir Litvinenko)
BBU issues	(Eduard Pozdeyev)
RF optics	(Phillip Piot)
Space charge and CSR	(Gabriele Bassi)
Push-Pull FEL	(Andrew Hutton)
Multi turn ERL issues	(Gennady Kulipanov)
Ion clearing	(Georg Hoffstaetter)

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Instrumentation

Discussions on diagnostic necessities:

a) Number and location of BPMs
b) BPMs for two beams
c) Number and location of beam size measurements
d) Longitudinal beam profile measurements
e) Longitudinal tomography
f) Optic measurement procedures
g) Beam based alignment procedures
h) Commissioning strategies
i) Emittance control
j) Phase space tomography

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Conclusion

- Most important things to address:

Stability issues

Beam loss and halos in ERLs

CSR and LSC suppressing designs

Completion of BBU test

Experimental verification of RF optics

Clarification of Multi turn ERL issues