Impressions from ERL2011

Stephen Benson and Kevin Jordan

Outline

- Workshop held at KEK in Tsukuba, Japan
- Five Working groups:
  - WG1 – Electron Sources
  - WG2 – Lattice Design and beam dynamics
  - WG3 – SRF progress
  - WG4 – Instrumentation and Control
  - WG5 – Unwanted beam loss
- ERL 2013 to be held at BINP, Novosibirsk, Russian (in summer)
- Conclusions

Working Group 1 – Electron Sources

Charge

Explore the progress in high average current, extremely bright sources for use in ERLs. The working group will explore the results and new technologies available in injectors since the previous ERL workshop.

Summary of HZDR – SRF- Gun (Andre Arnold)

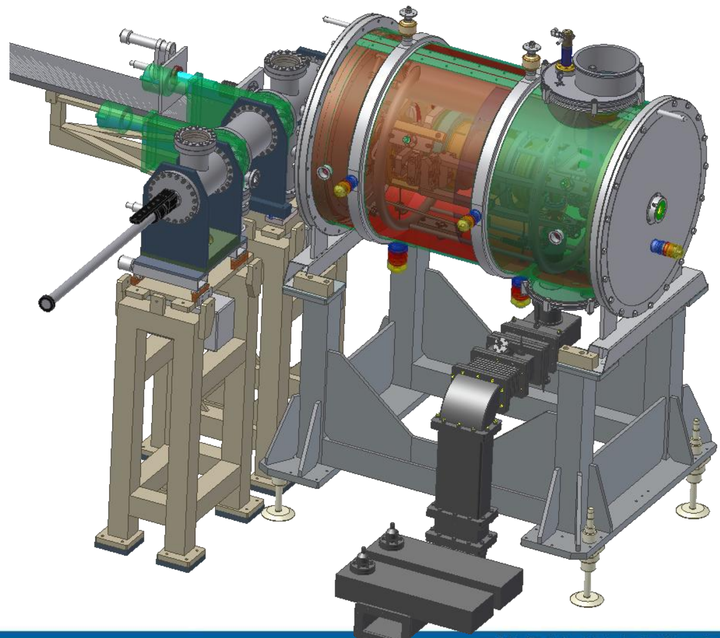
- Reliable operation of the SRF-Gun since 4 years with phase stability of $\Delta\phi$=0.04°
- No Q_0 degradation of cavity while operating 6 cathodes and performing about 20 cathode exchanges from warm to cold (RF operation ≈ 2500 h, beam time ≈ 1400 h)
- Long lifetime of CsTe cathodes in SRF-Gun (>1 yr, QE ≥ 1%, total charge 35 C in 1000h)
- Strong multipacting defeated by DC biasing and triangular grooving of the cathode
- First successful measurements using the **ELBE accelerator** (40 MeV, CW machine)

  - Inverse Compton backscattering (with laser group from HZDR)

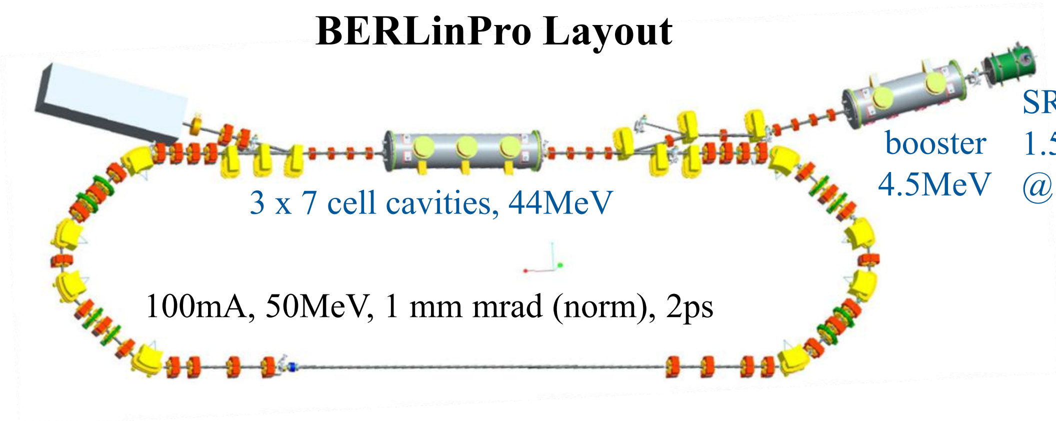
  - Slice emittance and longitudinal phase space measurements using zero phasing of one TESLA cavity

Outlook 2012

- Installation of upgrade cavity built by Peter Kneisel and the JLab to twice E_{pk}>35MV/m and beam energy to 6-7 MeV
- Installation of 13 MHz laser upgrade to start medium average current operation (1mA)

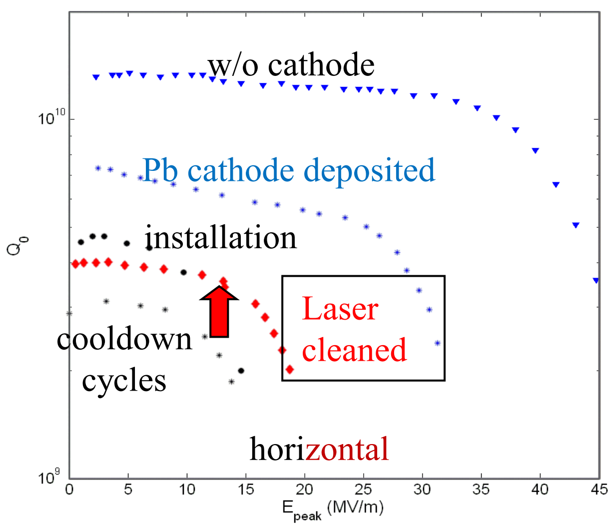


BERLinPro Layout

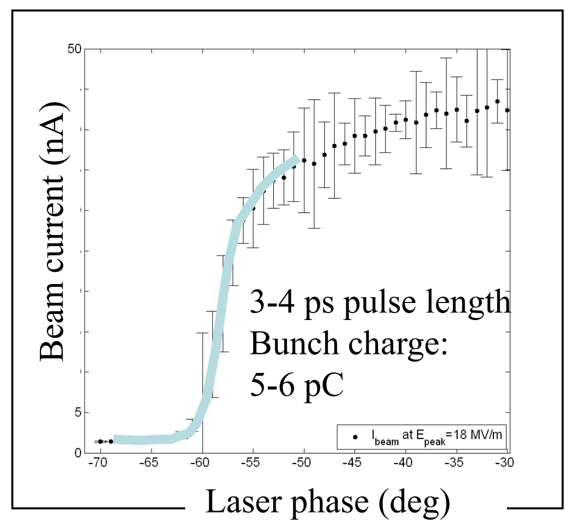


SRF Gun with stiffening spider

QE lowered by Pb deposition – partial recovered with laser cleaning

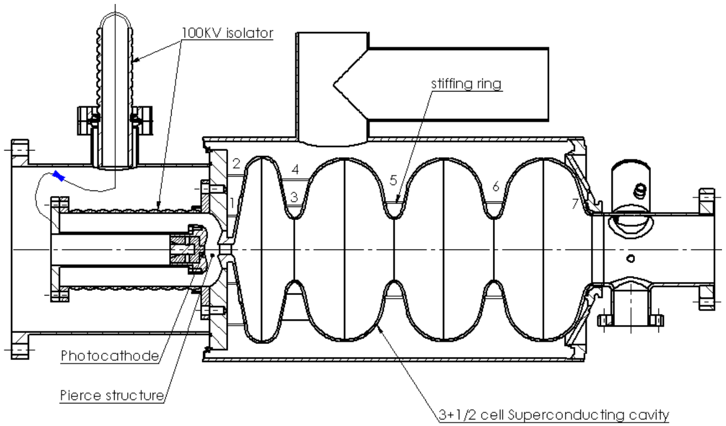


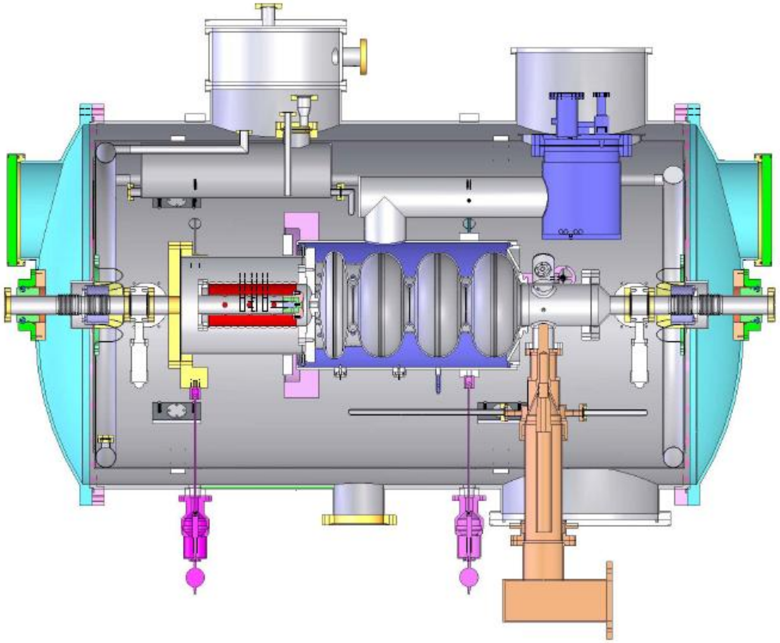
50nA@20MV/m with 1.8MeV reached

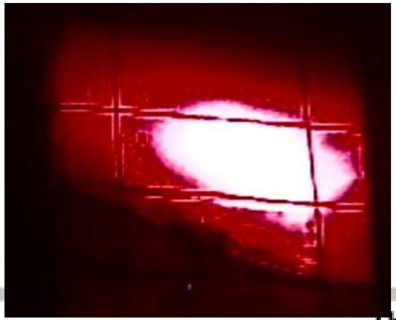


Next steps: **CsK$_2$Sb cathode in SC gun, high current + high power operation**

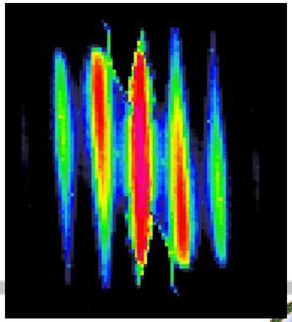
DC-SRF photocathode injector for ERL at Peking University, Kexin LIu





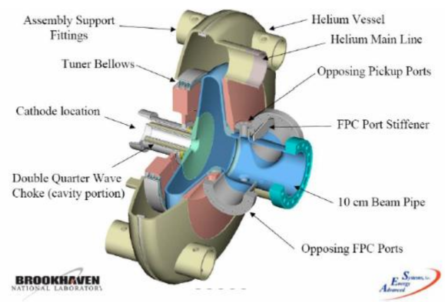


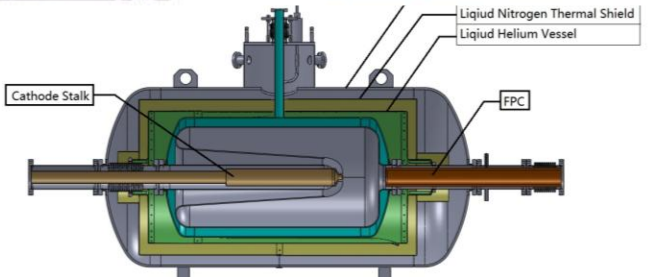
First beam, September, 2011
2.5 MeV, 50 uA



Status of BNL SRF guns

- Two SRF guns are under active development at BNL.
- The first gun, ½-cell elliptical shape, belongs to the first generation of SRF guns. It operates at 703.75 MHz and is designed to produce high average current (up to 500 mA), high bunch charge (up to 5 nC) electron beams for the R&D ERL at BNL.
- The gun cavity has been tested vertically several times and ins now in the process of being assembled into its cryomodule. The first cold test of the gun and subsequent beam generation are scheduled for 2012.
- The first test will be with a metal photocathode, which will eventually be replaced with a high-QE multi-alkali one.
- The second gun, of a Quarter-Wave Resonator (QWR) type, operates at 113 MHz. This gun is designed to generate high charge, low repetition rate beam for the Coherent electron Cooling (CeC) experiment as well as to be used for photocathodes studies.
- The gun has been cold tested successfully last year. It is now being modified to be compatible with use in the CeC proof-of-principle experiment. Multi-alkali cathodes will be used in this experiment.

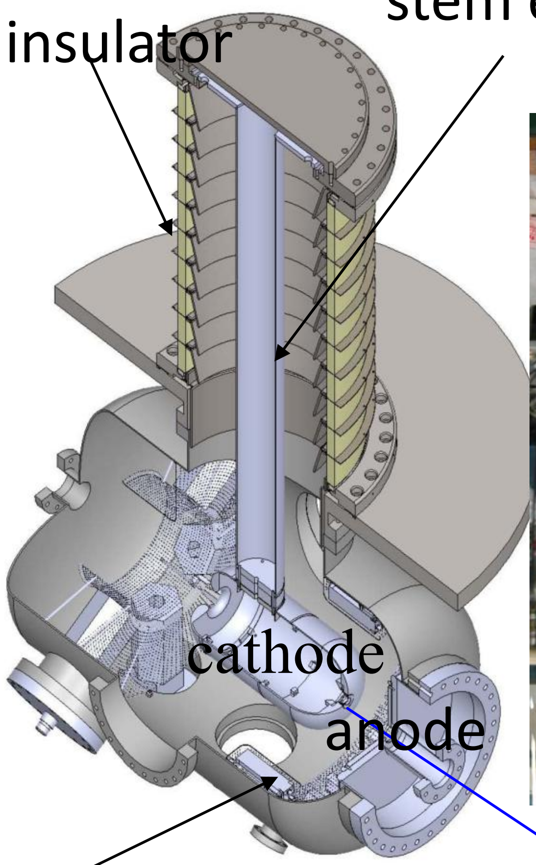


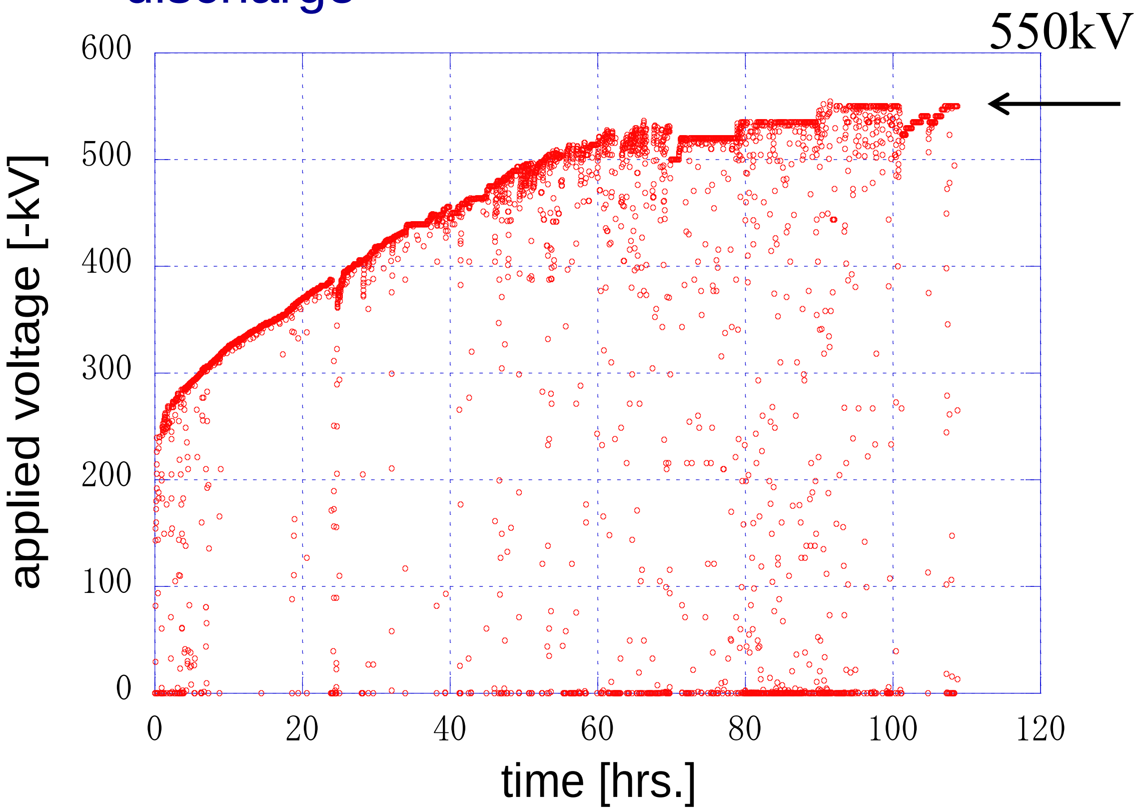


Status of 500kV DC gun at JAEA, N. Nishimori

HV testing of segmented ceramics with a stem electrode

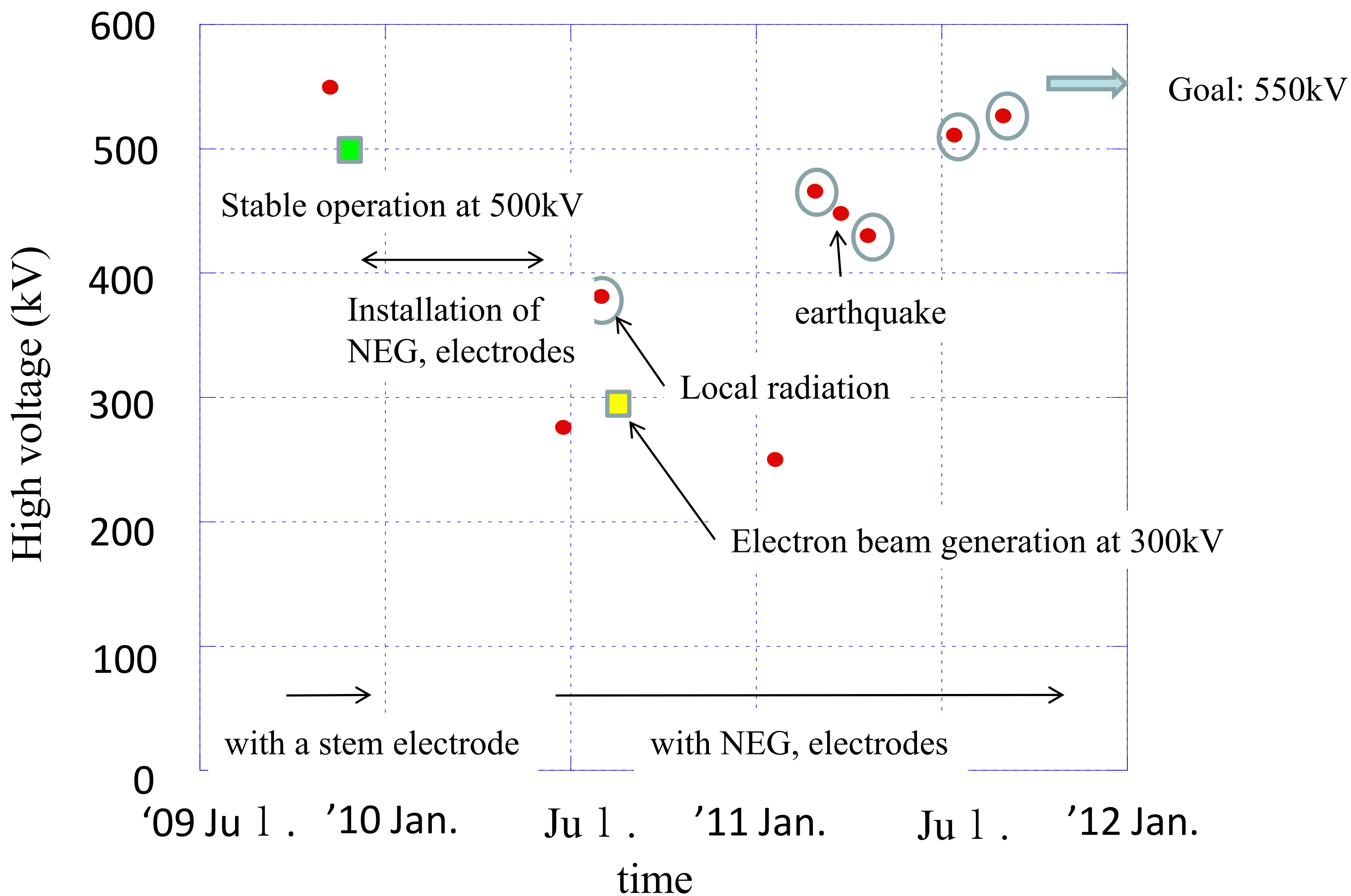
- HV processing up to 550 kV
- 500 kV for eight hours without any discharge



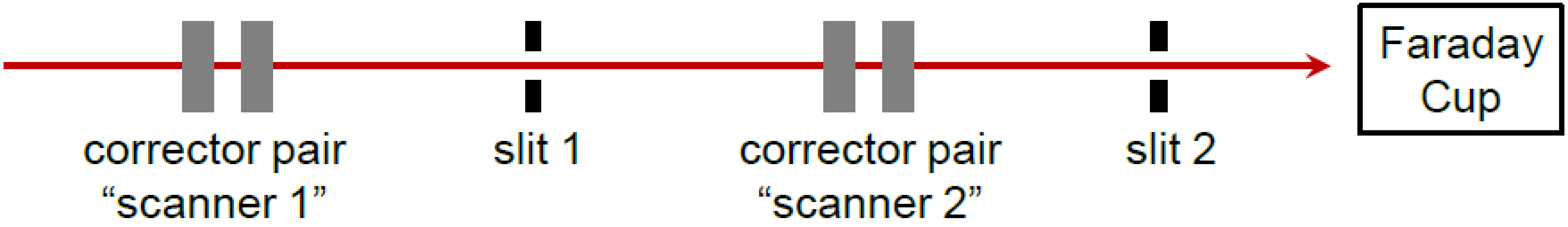


R. Nagai et al., RSI 81 033304 (2010).

History of HV processing



New way to use 2 slits



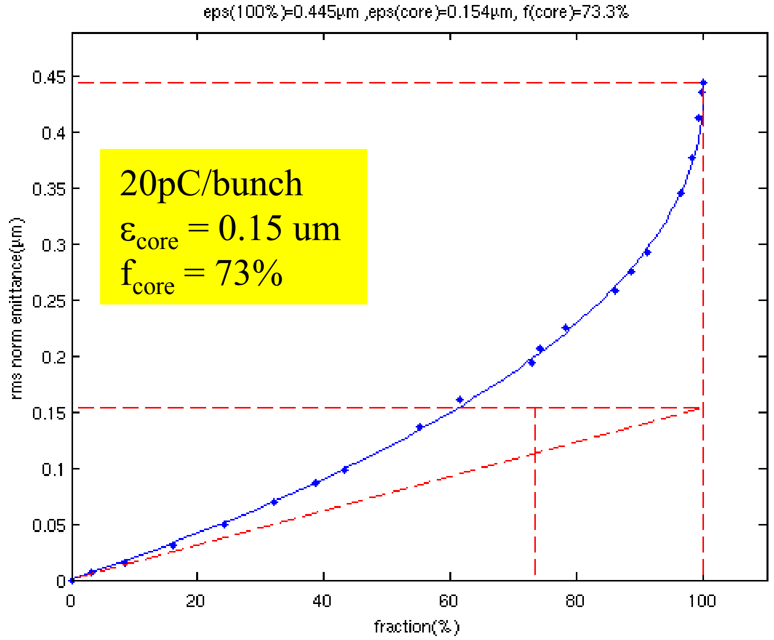
Leave the slits stationary and scan the beam across them. Using a faraday cup gives very wide dynamic range, no concerns about saturation.

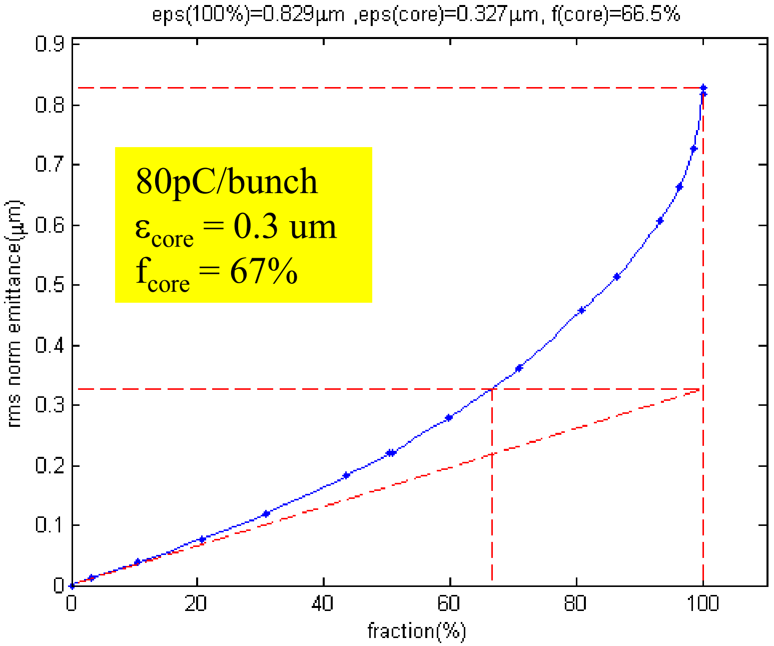
We scan the correctors at several kHz rates and can get a good measurements in a few seconds.

This turns our injector into an analog computer for performing multi-parameters optimizations.

Cornell Emittance Measurements

- Single RMS emittance definition is inadequate for linacs
  - Beams are not Gaussian
  - Various groups report 95% emittance or 90% emittance (or don't specify what exactly they report)
- The right approach
  - Measure the entire phase space, then obtain emittance of the beam vs. fraction (0 to 100%)





Photocathode Development at Cornell - Bruce Dunham

Highlights

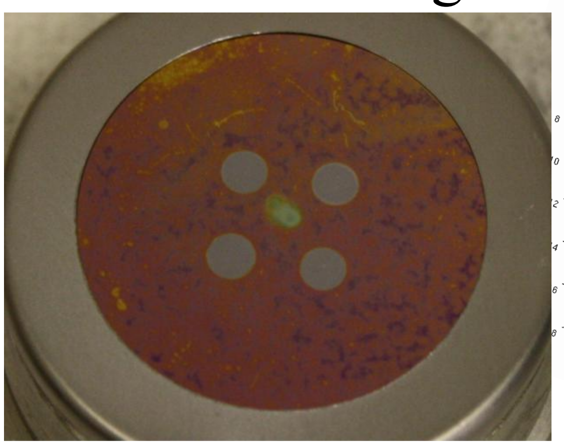
20 mA CW at 5 MeV for 8 hours using CsK_2Sb cathodes

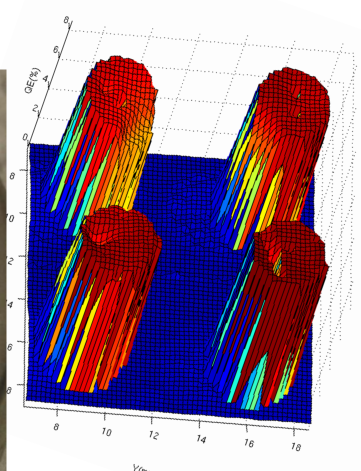
25 mA CW at 5 MeV from GaAs (for minutes)

Measured thermal emittance and time response for:

GaAs, GaN, GaAsP, CsK_2Sb, Cs_3Sb

GaAs damage

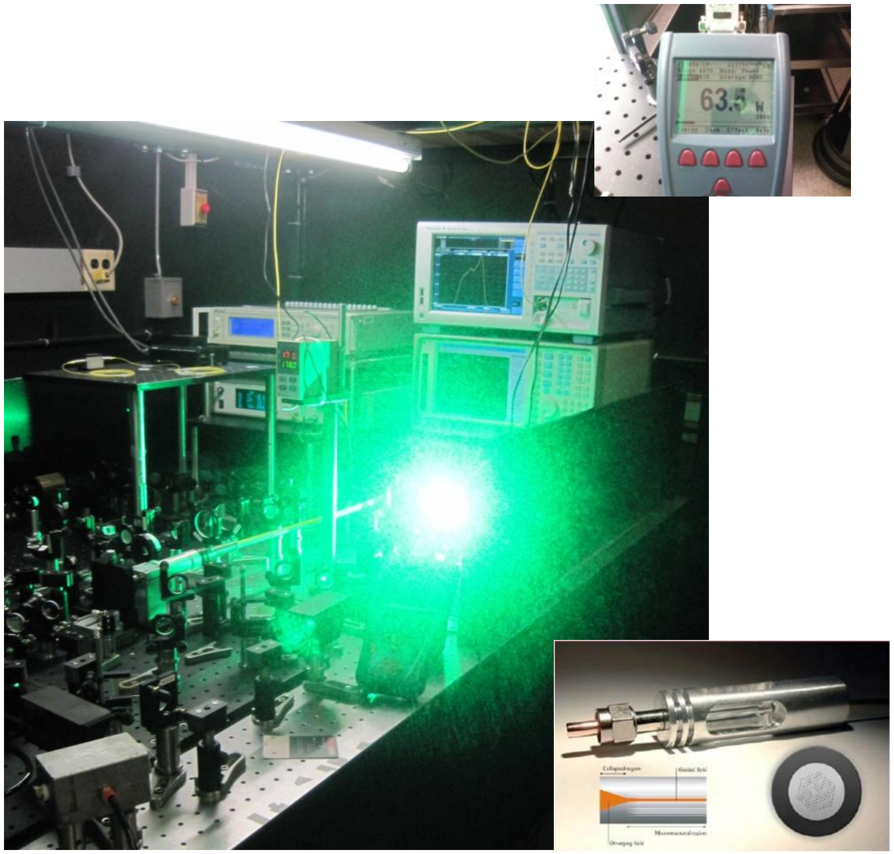




QE map

CsK_2Sb damage after 20mA run

Cornell 1300 MHz, High-power Fiber Drive Laser - Bruce Dunham



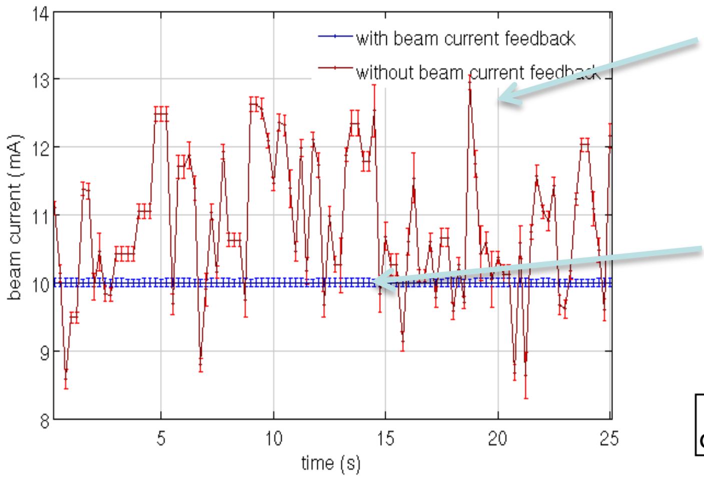
Commercial fiber terminator

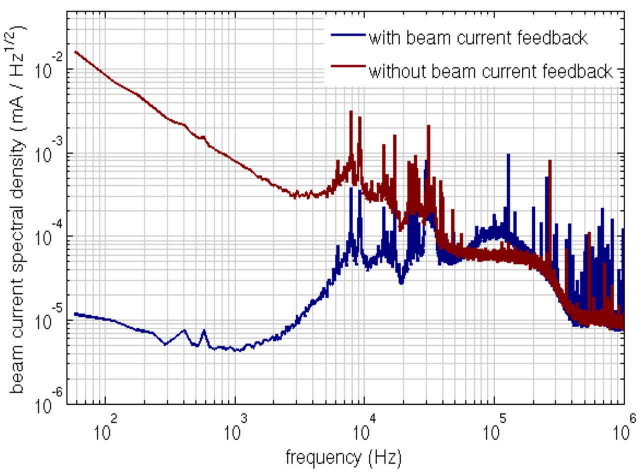
After recent improvements, we increased the average power from < 15 W at 520 nm to over 60 Watts!

Added a second pre-amp, compressed the pulse after the amplifier to reduce non-linearities instead of before it, and starting using commercial, high-power fiber terminators.

Now, we have more headroom for dealing with cathode lifetime, and shaping and transport losses

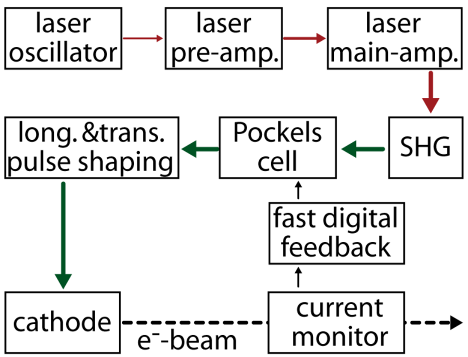
Learning New Things about High Current Operations





Beam current fluctuations made the RF unstable during high current operations. Due to laser intensity and position changes.

A fast-feedback system was installed, using a BPM as the sensor. This dramatically reduced the RF trip level.



We also need the laser position stabilized to 10 µm. This feedback system is being designed, but is more difficult due to the large dynamic range needed

Working Group 2 – Lattices and Beam Dynamics

General Observation

People are now looking at ERLs for applications other than light sources.

- Electron cooling source at Brookhaven
- Electron-ion collider at RHIC
- Electron-ion collider at LHC (60 GeV)
- Dark Matter detection at Mainz and Jlab

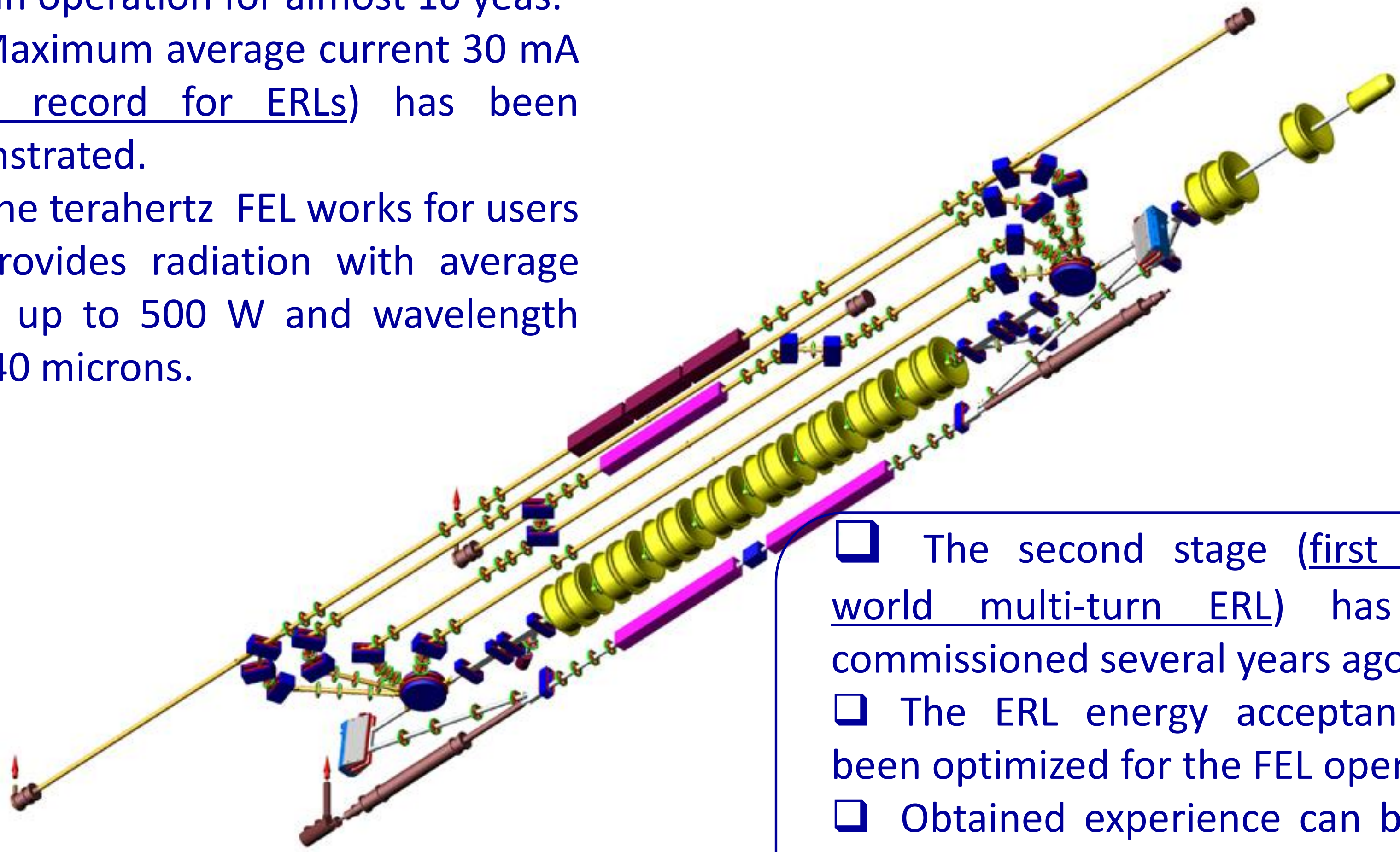
These new applications have to look at new effects like beam disruption, scatter, and ISR.

Lot of Test ERLs under construction – KEK, Berlin Pro, Peking University, Beijing IHEP

Lattice of the Novosibirsk ERL

Oleg Schevchenko (BINP)

- ❑ The first stage of the Novosibirsk ERL is in operation for almost 10 yeas.
- ❑ Maximum average current 30 mA (<u>world record for ERLs</u>) has been demonstrated.
- ❑ The terahertz FEL works for users and provides radiation with average power up to 500 W and wavelength 120-240 microns.

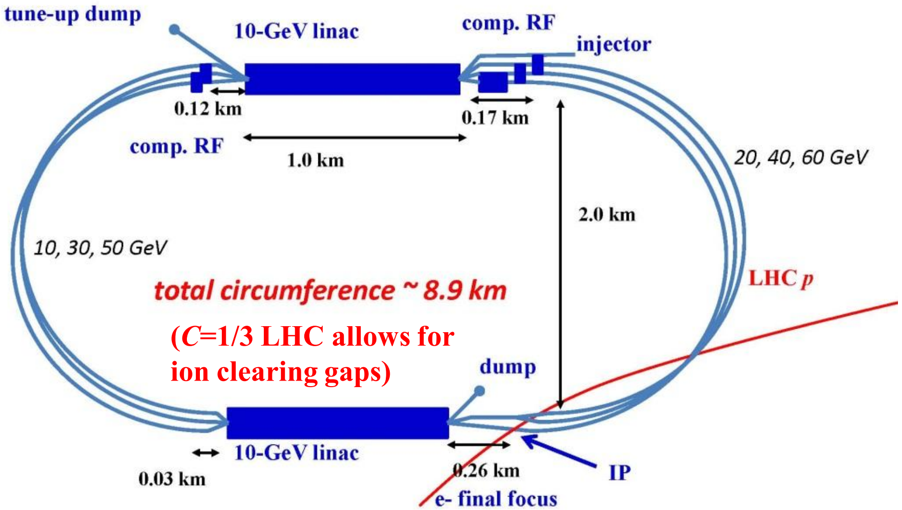


- ❑ The second stage (<u>first in the world multi-turn ERL</u>) has been commissioned several years ago.
- ❑ The ERL energy acceptance has been optimized for the FEL operation.
- ❑ Obtained experience can be used in the design of future machines.

Layout, optics and beam dynamics for the LHeC ERL

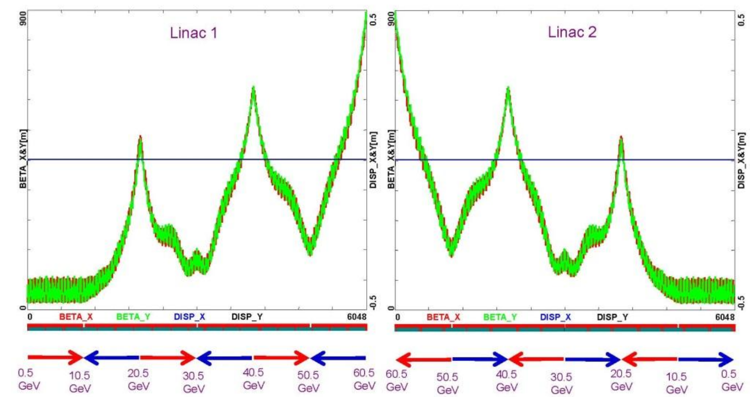
F. Zimmermann (CERN)

two 10-GeV SC linacs, 3-pass up, 3-pass down;
6.4 mA, 60 GeV e-'s collide w. LHC protons/ions



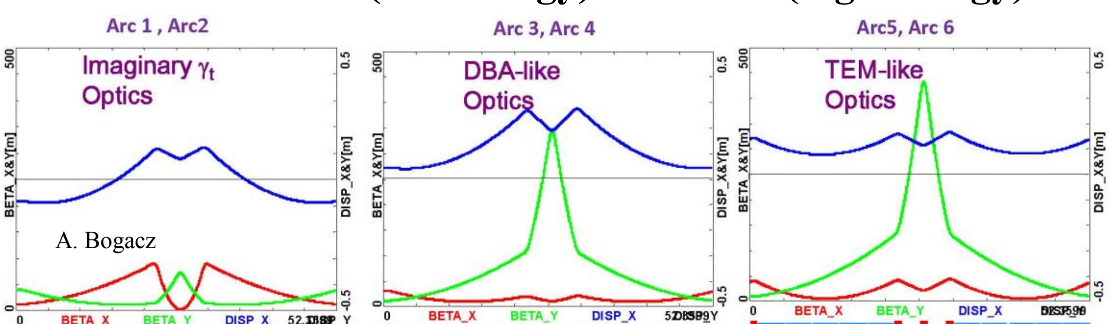
integral $\int_0^L \frac{\beta}{E}\,ds$ minimized; Linac1&2symmetric

Linac 1 and 2 – Multi-pass ER Optics



Alex Bogacz

arc optics: flexible momentum compaction cell; tuned for small beam size (low energy) or low Δε (high energy)



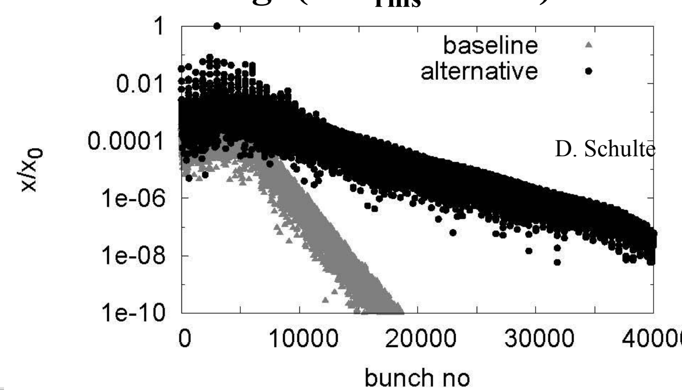
$\langle H \rangle = 8.8 \times 10^{-3}\ m$ | $\langle H \rangle = 2.2 \times 10^{-3}\ m$ | $\langle H \rangle = 1.2 \times 10^{-3}\ m$

factor of 18 smaller than FODO

limit chamber size (>12 σ at 25 mm diameter)

limit emittance growth

BBU: beam stability requires both damping (Q~10^5) & detuning ($\Delta f/f_{rms}$~0.1%)

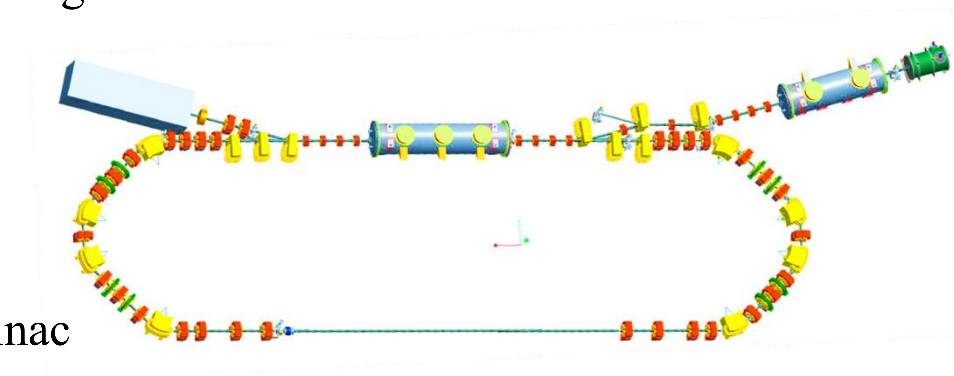


draft LHeC CDR exists, TDR by 2014, expect first beam by 2022

Status of the Optics for BerLinPro

B. Kuske for BERLinPro Theory Group

Redesign of BERLinPro optics after down grading of project parameters almost complete



Layout has to cope with

- No pulse shaping of cathode laser
- Open cavity decision of gun project
- Stronger RF focusing in booster and linac
- Conditions set by BBU

=> 100mA / 2ps / 1mm mrad still within reach

Cathode Laser Profile – Gauss versus Flat Top

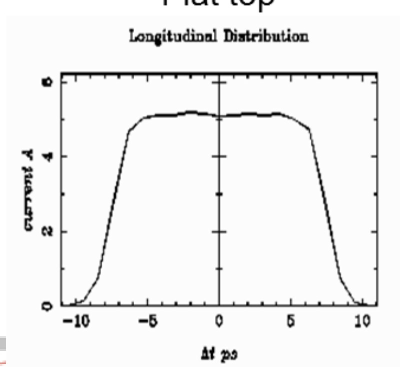
Same hardware, same phases, fields

Bunch current profiles at 8cm (behind cathode)

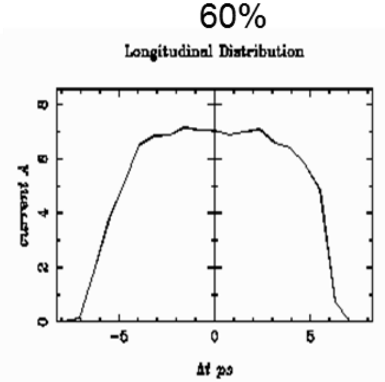
Difference in sliced Emittance

Laser profile

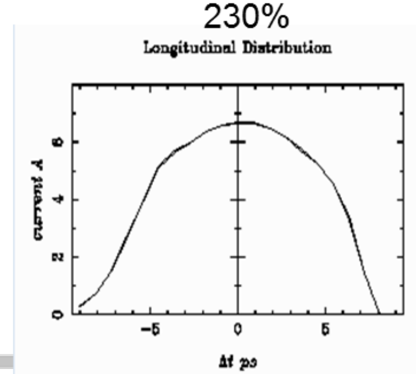
Flat top



60%

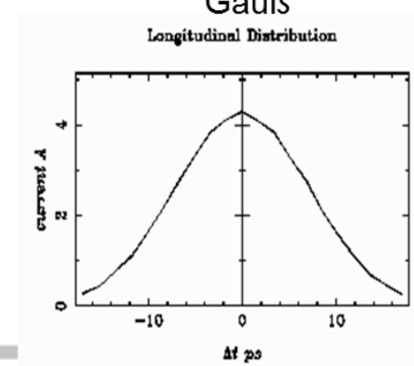


230%



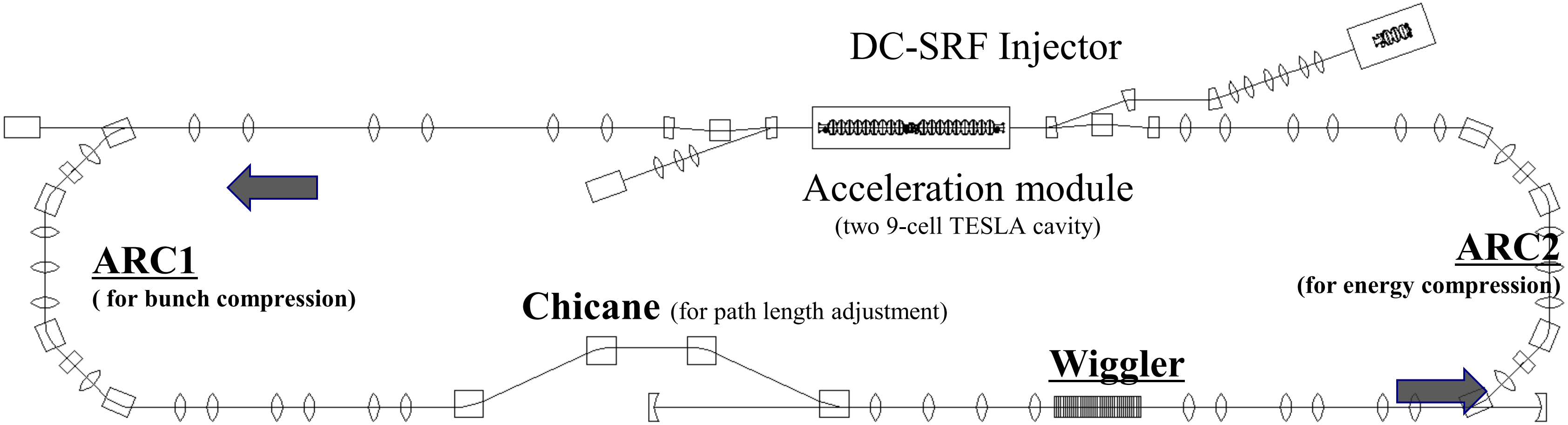
Laser profile

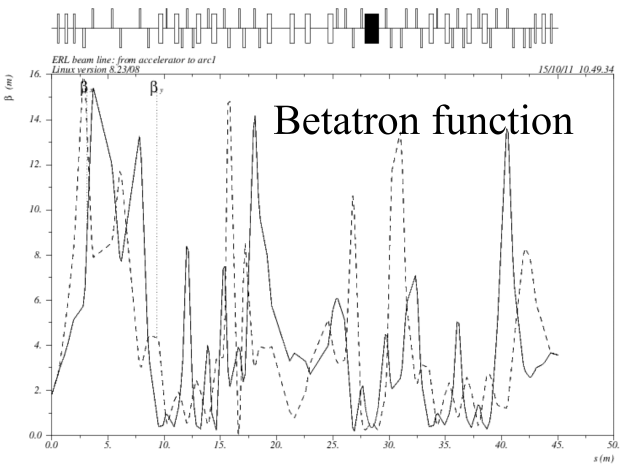
Gauß

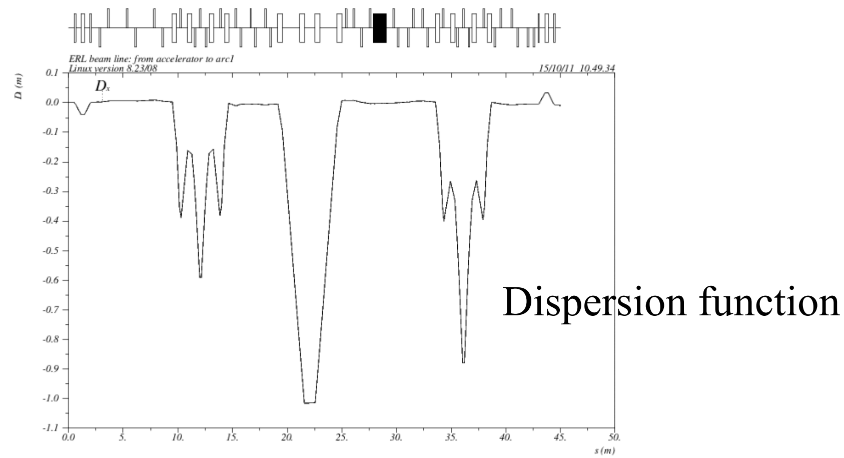


Optics Layout for the ERL Test Facility at Peking University

Senlin Huang (PKU)







- The optics design has been updated according to the expected characteristics of DC-SC photoinjector and accelerating module.
- The optics design gives enough flexibility for ERL and ERL-based FEL experiments.
- Further study on beam dynamics is on-going.

Design Studies on the ERL Test Facility at IHEP-Beijing

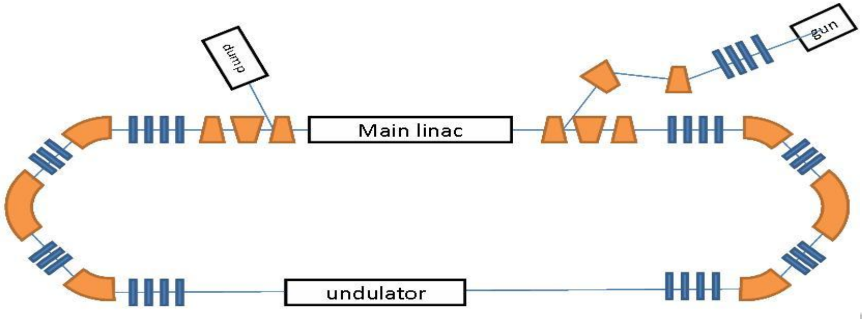
Jiuqing Wang (IHEP)

1) A 5 GeV small emittance synchrotron radiation facility is planed @ IHEP, and may be further upgraded to an 5 GeV ERL-FEL facility.

2) A (35 MeV-10 mA) ERL TF is proposed @ IHEP, its beam dynamics design and the key components design were preliminary done：

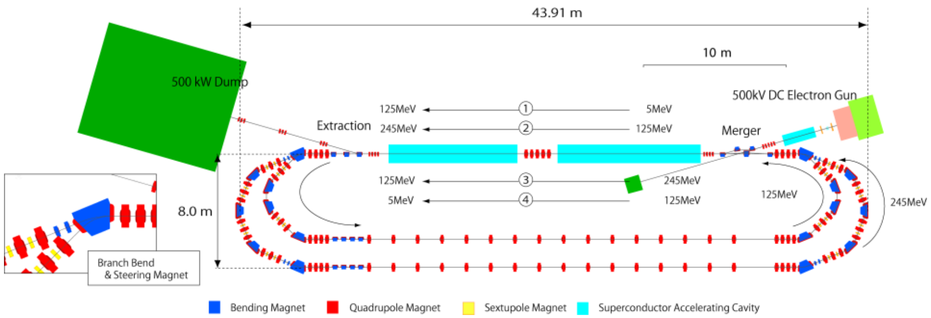
- ✓ **Beam dynamics design of the 5 MeV injector and the injection system.**
- ✓ **A lattice with 2 TBAs and 2 straight sections for the ERL-TF.**
- ✓ **A bunch compression (from 2 ps to 0.25 ps, 77 pC) with the 1st TBA arc is studied, cost by the nor. emittance growth of ~30% due to the CSR effect, even the CSR induced emittance growth suppression is employed. Further study to optimize this issue is under way.**
- ✓ **The BBU current limitation is about 260 mA as preliminary studied.**

3) A 500 keV DC-gun will be constructed soon for the ERL TF, funded (~2M USD) by IHEP. Its design and optimization are being done.

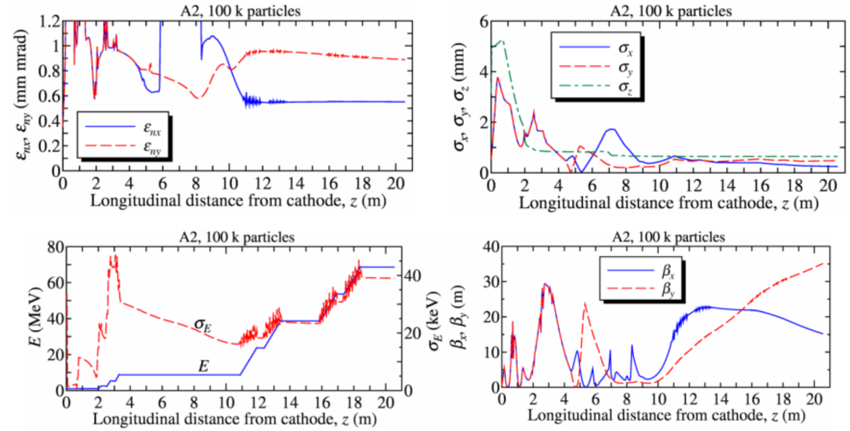


Strategy of the Lattice and Optics of 2-loop Compact ERL and Multi-GeV ERL

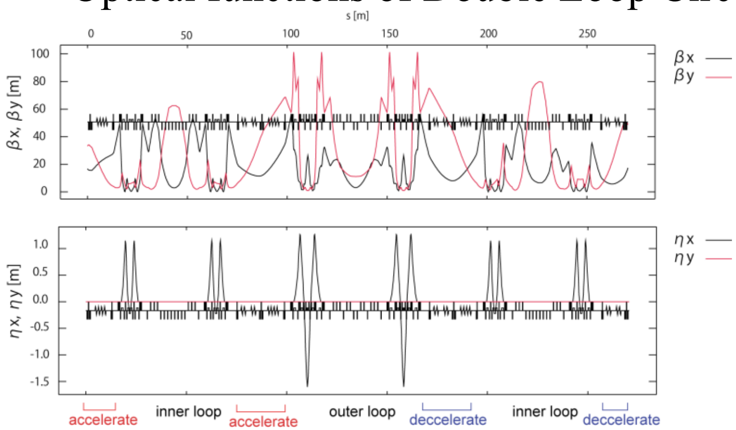
Miho Shimada (KEK)

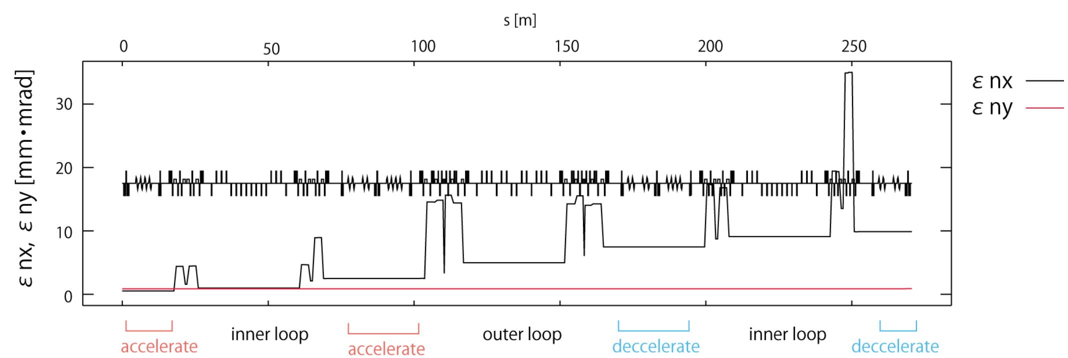


Optical functions of Injector



Optical functions of Double Loop Circulator





Developments of transverse emittance in 2 loop.

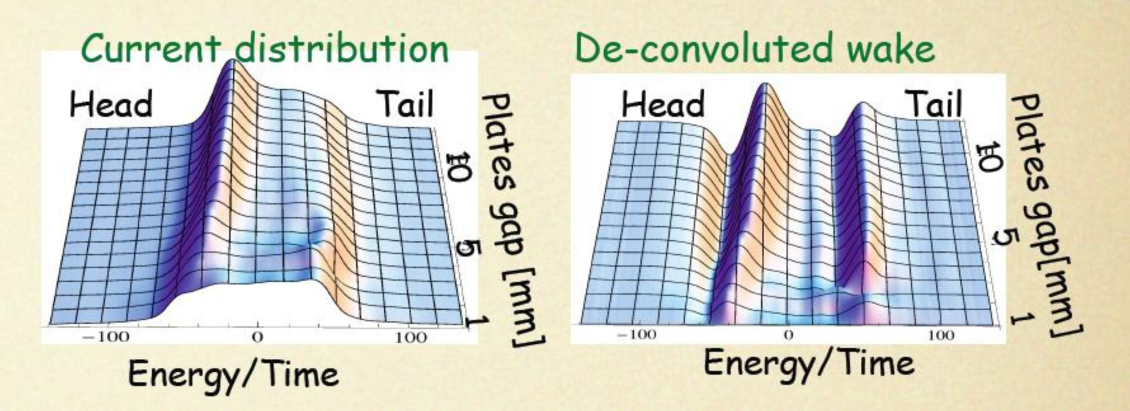
The first trial of S2E simulation for the 2 loop cERL.

ε_{nx} increases step by step at every each arc.

- 0.54 mm-mrad (merger), 1 mm-mrad (Inner Loop), 5 mm-mrad (Outer loop)

Rms beam size of σ_x and σ_y are just before the extraction chicane : (σ_x , σ_y) =(4.1 mm, 0.68 mm)

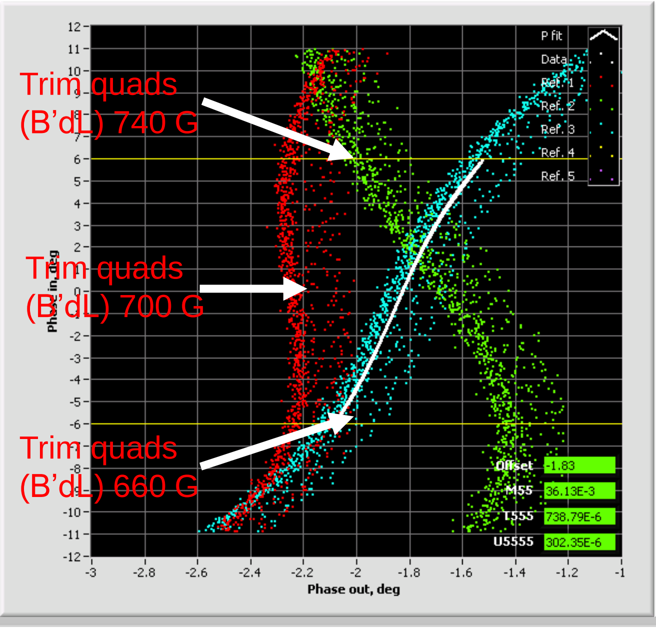
- Small gap vacuum chamber eliminates both average energy loss from CSR as well as RMS energy spread
  (in contrast to predictions in some papers and previous presentations on CSR!)
- New type of experiments with focus on the f(E) modification were performed at ATF and demonstrated excellent sensitivity to short-range wake-fields (better than 1 keV for 60 MeV beam)
- Exact analytical theory for the case of parallel plates is developed and is in good agreements with the measurement
- Detailed analysis is under way
- We'll present poster and paper at PAC'11 with detail of the experiments, simulations and comparison

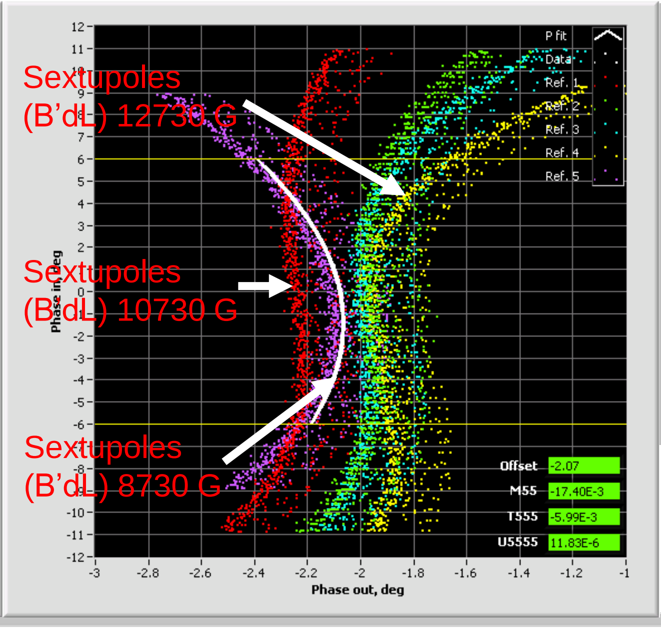


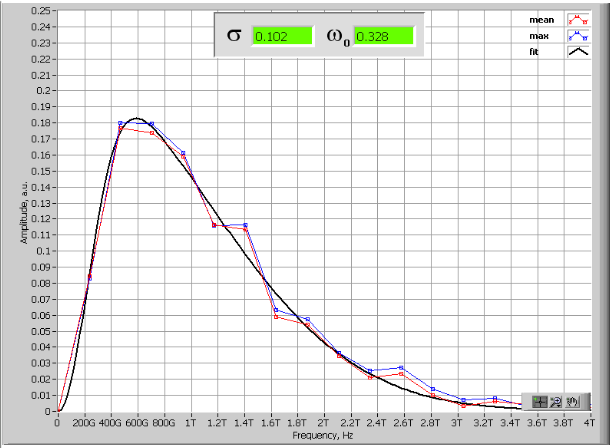
JLab FEL bunch compression and diagnostics

courtesy Pavel Evtushenko

- JLab IR/UV Upgrade FEL operates with bunch compression ration of 90-135 (cathode to wiggler); 17-25 (LINAC entrance to wiggler).
- To achieve this compression ratio nonlinear compression is used – compensating for LINAC RF curvature (up to 2nd order).
- The RF curvature compensation is made with multipoles installed in dispersive locations of 180° Bates bend with separate function magnets - D. Douglas design (no harmonic RF)
- Operationally longitudinal match relies on:
  - a. Bunch length measurements at full compression (Martin-Puplett Interferometer)
  - b. Longitudinal transfer function measurements R_{55}, T_{555}, U_{5555}
  - c. Energy spread measurements in injector and exit of the LINAC







Martin-Puplett Interferometer data in frequency domain – give upper limit on the RMS bunch length

Magnet Field Quality

Provides significant obstacle to ERL performance:

- differential field error =>
- differential angular kick =>
- differential betatron oscillation =>
- accumulated path length error=phase error=>
- energy error=>
- failure of energy compression/beam loss at dump

May have been source of performance-limiting loss in CEBAF-ER during operation with 20 MeV injection

Sets limits on tolerable field errors

CSR Force Representations

Can improve 1-D model (Mayes, Sagan), but here we instead look at how accurate it is for the idealized case (the Goldreich solution).

We use Ryne's code LW3D – an exact Lienard-Weichert solver with 6B source electrons, solving (up to quad precision):

$$\vec{E} = e\left(\frac{\hat{n}-\vec{\beta}}{\gamma^2(1-\vec{\beta}\cdot\hat{n})^3R^2}\right)_{ret} + \frac{e}{c}\left(\frac{\hat{n}\times\left((\hat{n}-\vec{\beta})\times\dot{\vec{\beta}}\right)}{(1-\vec{\beta}\cdot\hat{n})^3R^2}\right)_{ret}$$

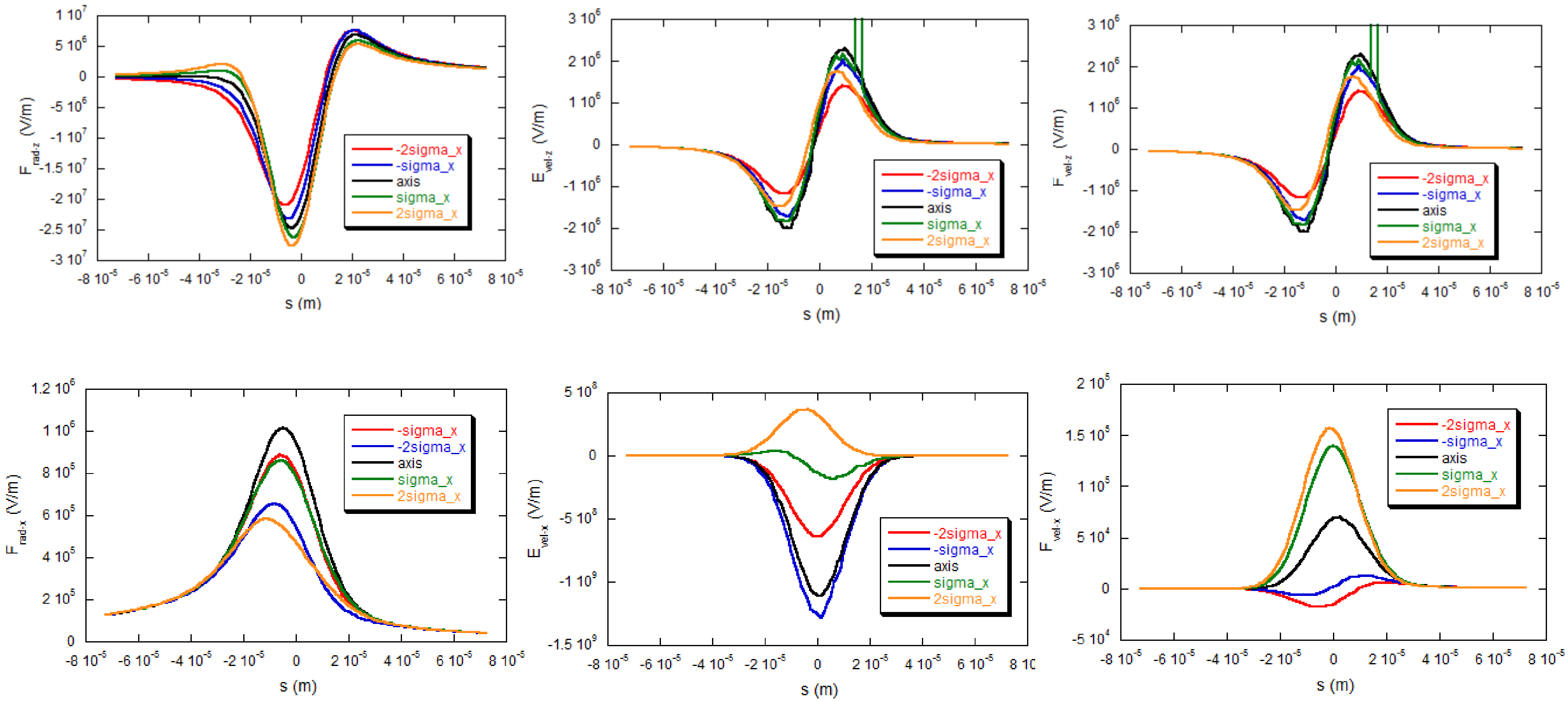
$$\vec{B} = \hat{n}\times\vec{E}$$

velocity field

radiation field

Needs ~ 50k processors for 1/3 hour for 1 time step (NERSC). This is not a good tool for design work, but provides a benchmark to check the physics, the 1-D model, and other effects.

LW3D Results – 100-MeV Disk (100x10 microns)

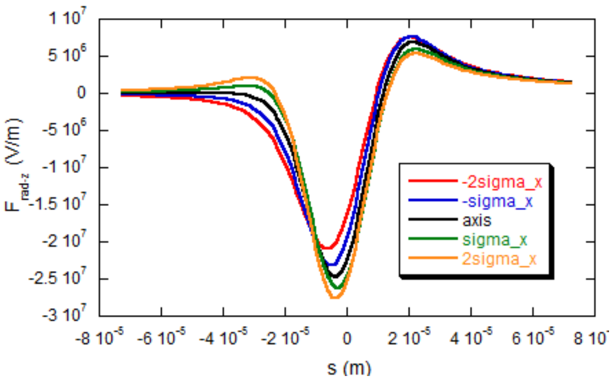


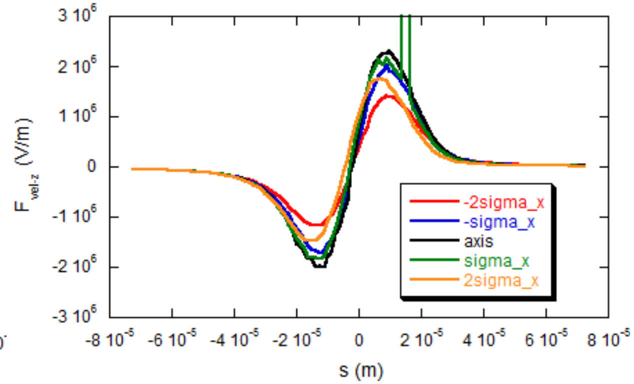
F_x-rad E_x-vel F_x-vel

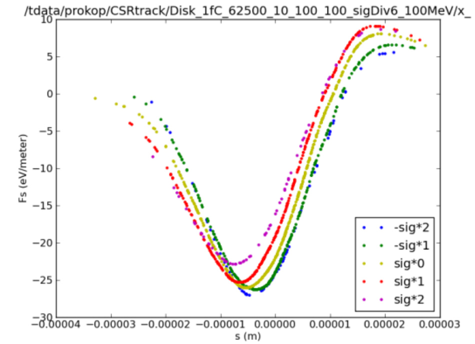
Some radial spread, see expected cancelations

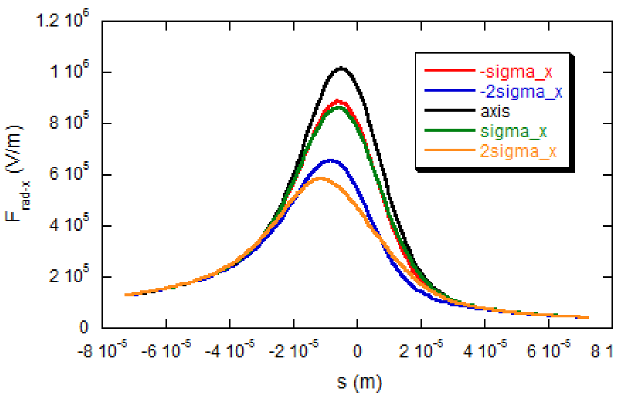
Plots are longitudinal cuts at different beam radii

CSRTrack Has Good Agreement with LW3D

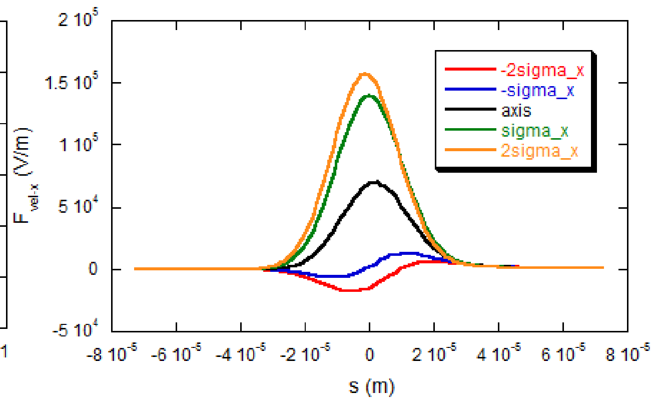




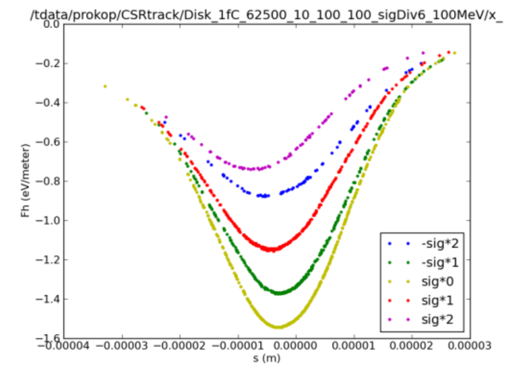




F_x-rad



F_x-vel



Different sign for the transverse force, but magnitude comparison is good

Working Group 3 – SRF Advances

Charge

- Parameter search of ERLs and status
- Cavity technology:
  cavity design, treatment,
  performance, diagnostics
- Cryogenics for 2K
- Microphonics and frequency tuning
- Power coupler
  Power capacity and limitations
- Cryo-module design

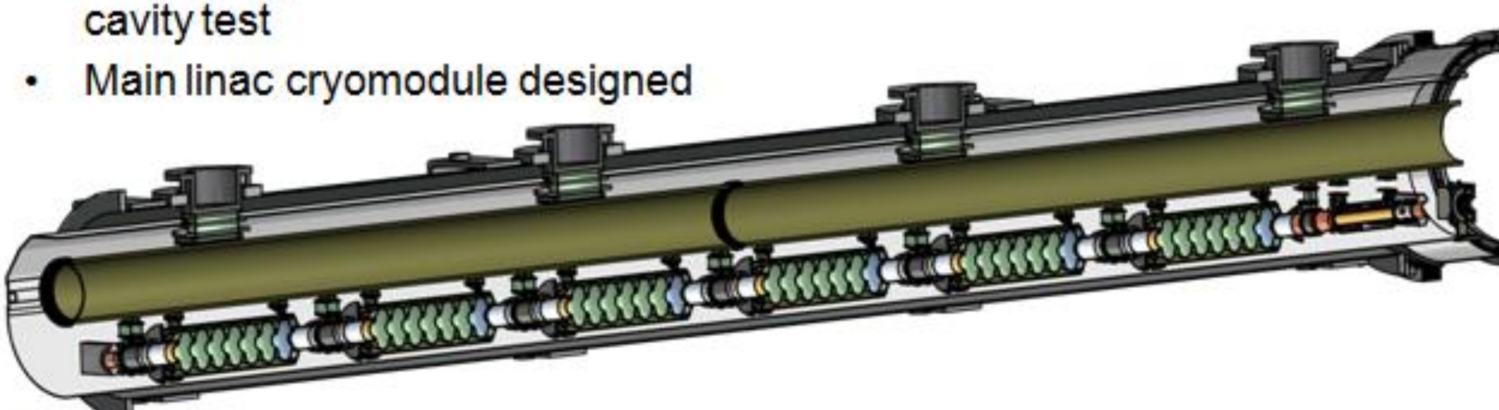
ERL SRF Injector construction and operation

- Successful construction
- HOM spectrum and heating ok
- Alignment ok
- Operation ok to 25mA, 5MeV

ERL SRF main linac construction

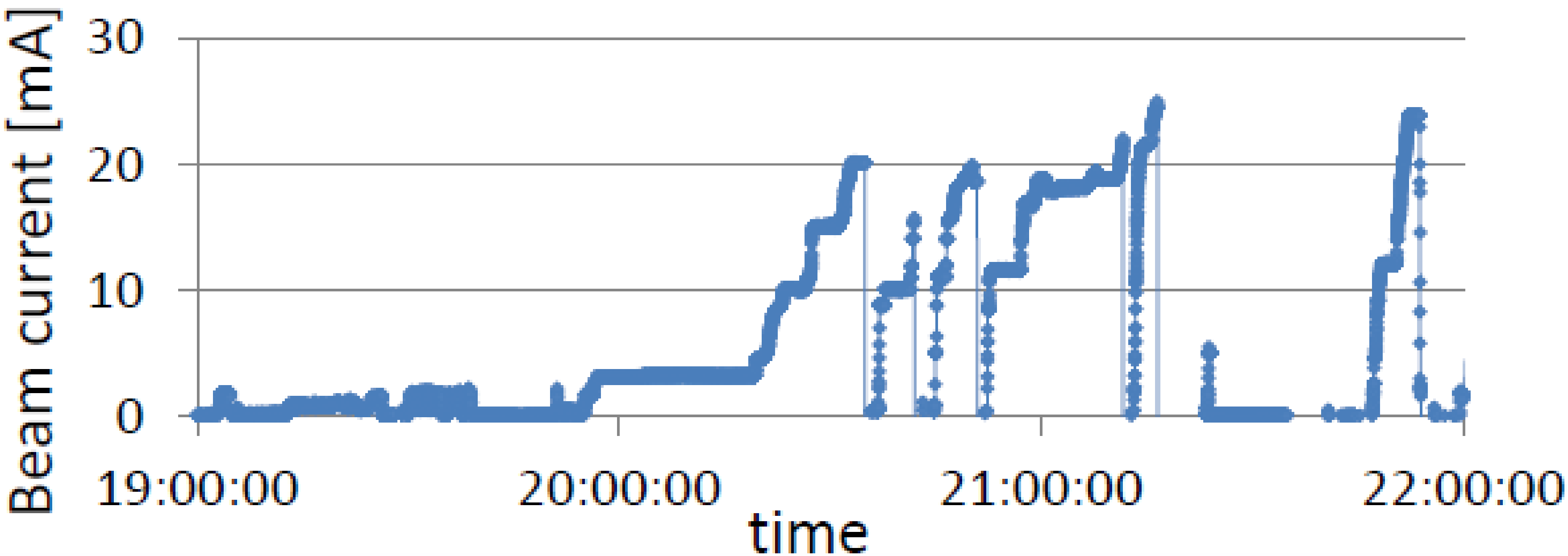
Finished main linac cavity with ±0.25 mm shape precision

- Successful cavity desing
- Successful cavity construction
- ERL SRF specs reached in vertical cavity test
- Main linac cryomodule designed

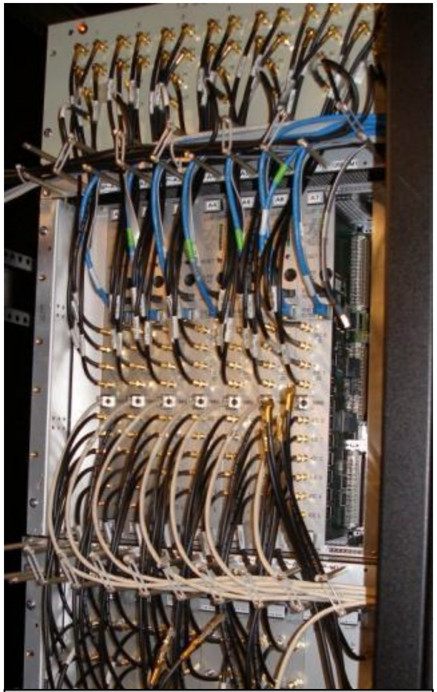


High Current Cryomodule Operation

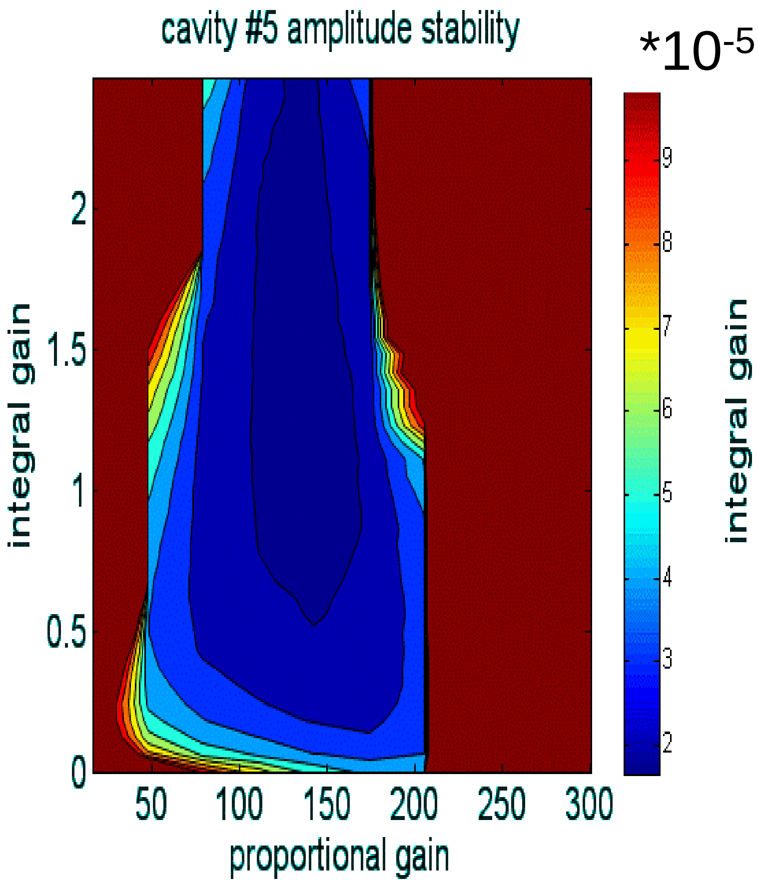
- Successfully operated injector SRF module with **beam currents of 25 mA**
  - No increase in 1.8K dynamic load observed
  - ΔT of HOM absorbers small (<0.5K). **Module should easily handle operation at >100 mA.**

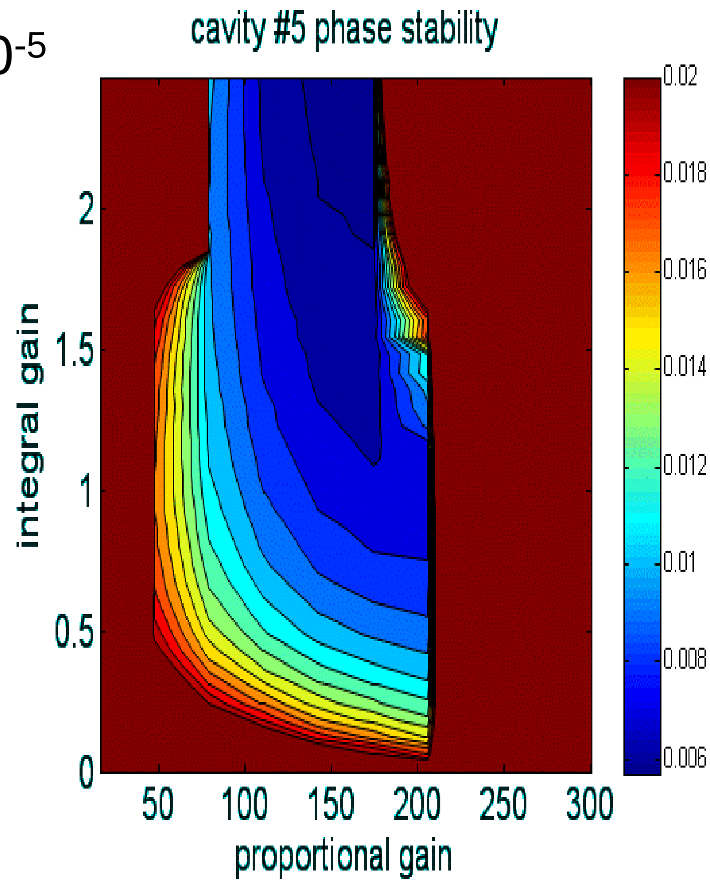


LLRF Field Control and Field Stability



Cornell digital LLRF control system





Excellent field stability achieved: amplitude: $\sigma_A/A < 2\cdot10^{-5}$

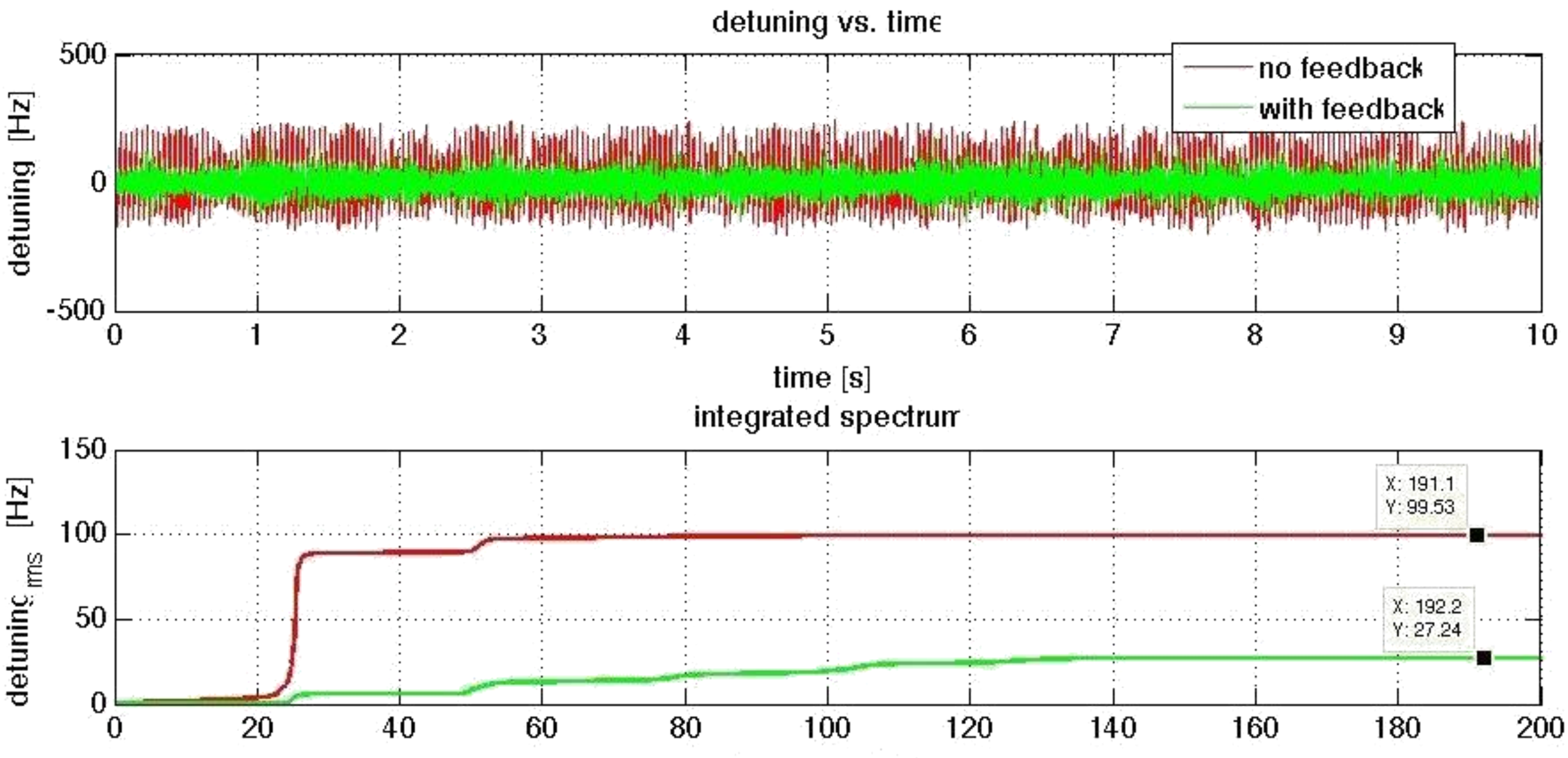
(in loop measurements) **phase: $\sigma_P < 0.01$ deg**

Highlight: Active Microphonics Control

Piezo Feedback on Tuning Angle/Cavity Frequency:

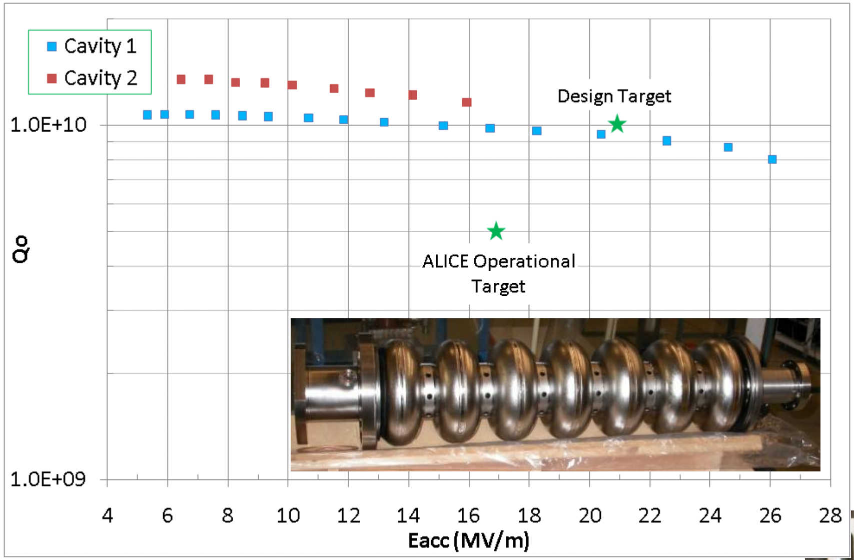
⇒ Reduces rms microphonics by up to 70%!

⇒ Important for ERL main linac, where $Q_L > 5 \cdot 10^7$ and $P_{RF} \propto \Delta f$!

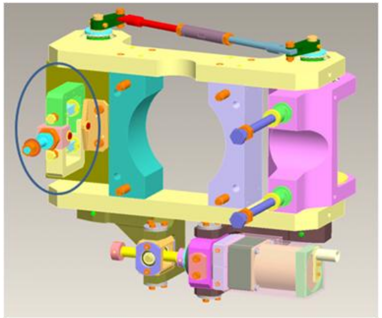


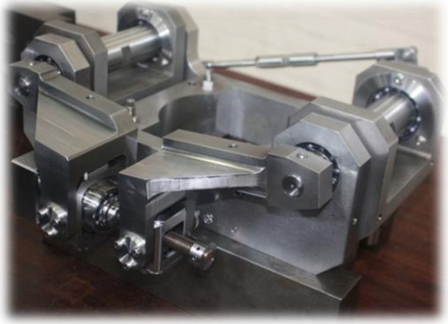
Assembly preparations at Daresbury for the intern. CW cryomodule

DESY superstructures modified, changed to optimised end groups by Cornell

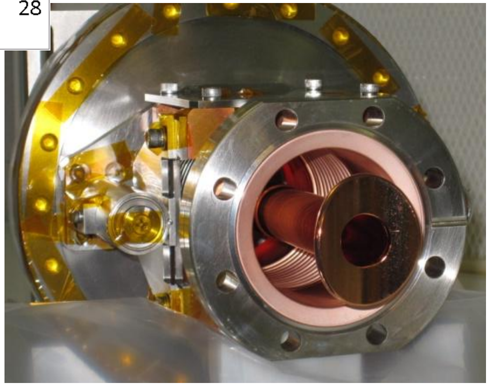


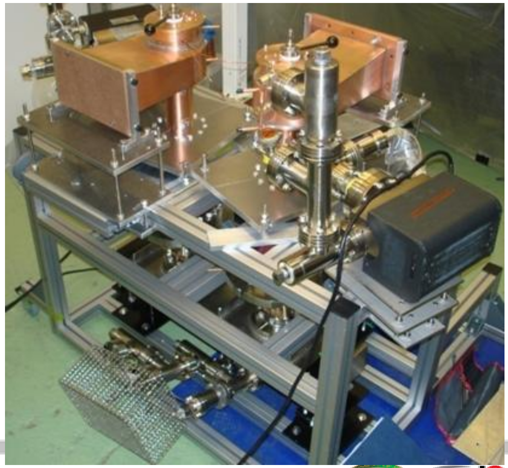
Modified Saclay-II tuner with wider aperture and low voltage piezo cartridges.





Modified Cornell ERL injector coupler with a shortened cold section.



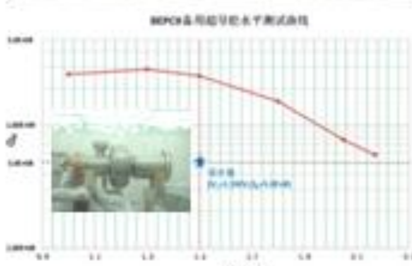


Cold couplers installed ⇒ awaiting HOM absorbers.

Cryomodule to be ready later this year.

IHEP (China) SCRF Activities

- **IHEP SCRF key components R&D and integration test**
  - 500 MHz BEPCII spare cavity module test (2MV, 7.7E8) meet specs
  - 1.3 GHz 9-cell cavity 20MV/m, short cryomodule integration next year
  - SCRF infrastructures established, EBW & EP facility planned
  - China ADS (325 MHz spoke cavities, 650 MHz elliptical cavities)
- **35 MeV, 10 mA ERL test facility SCRF design study**
  - components prototyping in 2012-2014





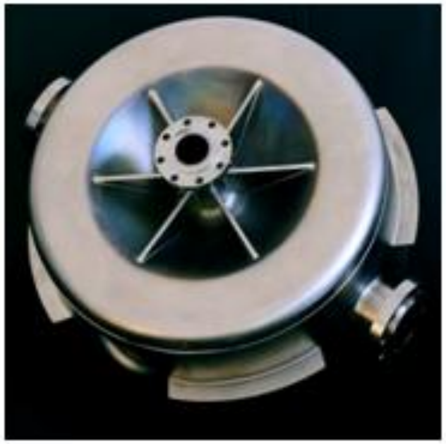
SRF cavities at Peking University

Progresses on SRF cavity have been made at Peking University in recent two years:

- A 9-cell TESLA type cavity has the gradient of 28.6 MV/m. A large grain 9-cell cavity has Q_0 higher than 2×10^{-10} at the gradient of 22MV/m.

- A 5-cell high current prototype cavity has been fabricated for ANL.

- A single-spoke cavity for proton acceleration has been fabricated too.

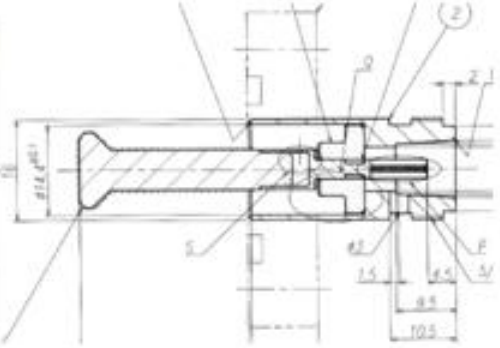


Promote the industrialization process in China by establishing a new company for cavity fabrication cooperated with OTIC in Ningxia province of China.

More cavities include high current type, high gradient type and low β will be made for several projects.

SRF cavities for KEK cERL

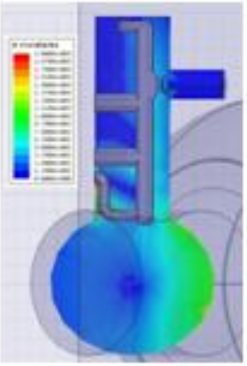
2-cell injector cavities
9-cell main linac cavities
Reached the specification



RF parameter of input coupler

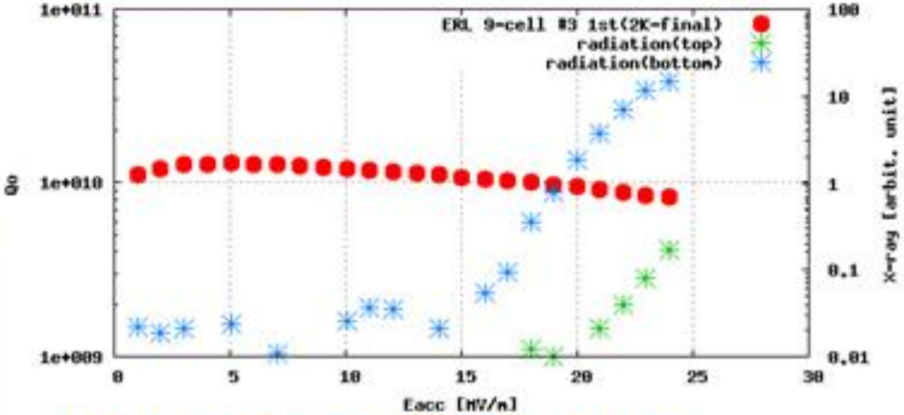
	V_{acc} [MV]	Q_L [x10^5]	P_{rf} [kW]
Cavity-1	1.5	10.	10
Cavity-2	2.5	4.	25
Cavity-3	2.5	4.	25

(Q_L/coupler, P_{rf}/coupler, I_{beam} = 10 mA)



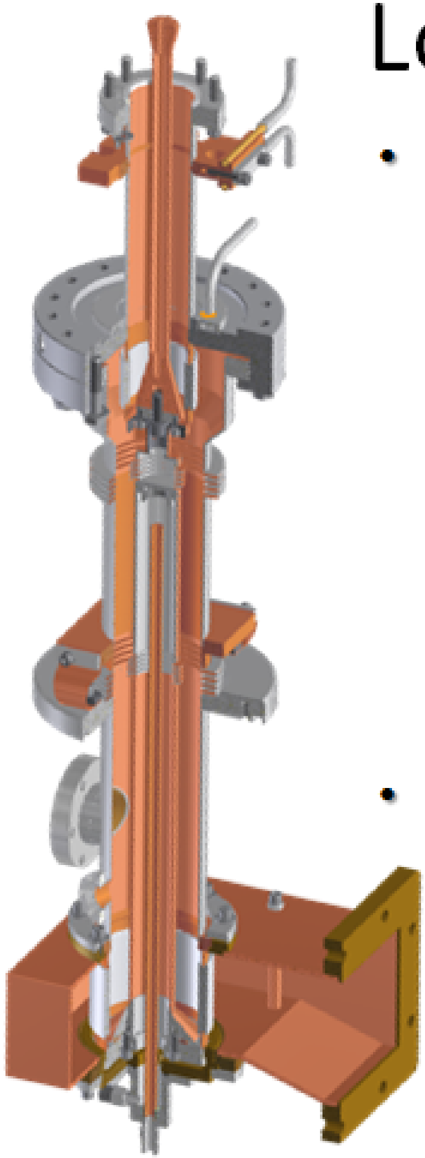
3 x 2-cell cavity with 5 coaxial HOM couplers in the injector cryomodule.

#3 cavity 1st vertical test



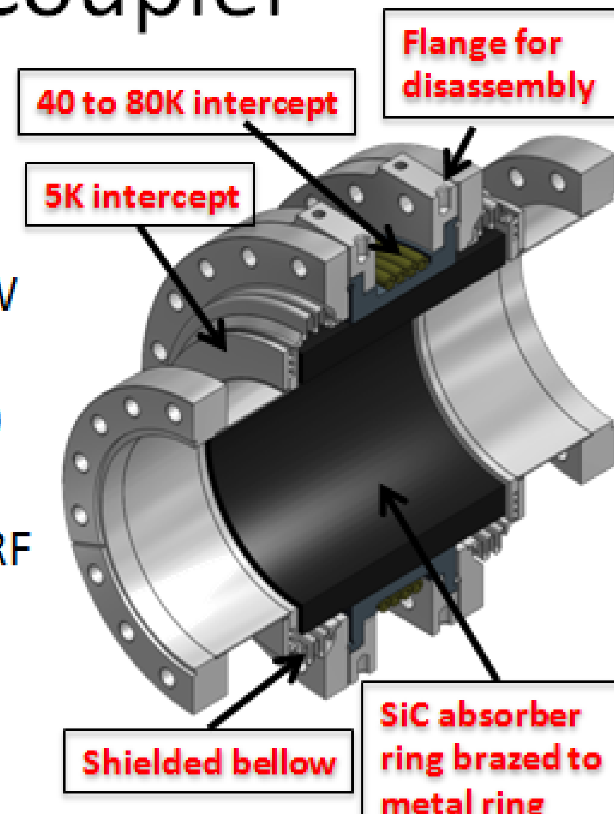
- Field reached to 25 MV/m
- No limitation up to 25 MV/m
- Q > 1e10@15MV/m
- X-ray on-set around 15 MV/m
- Satisfied cERL specification

Cornell ERL Main Linac: HOM Beamline Load and RF Input Coupler



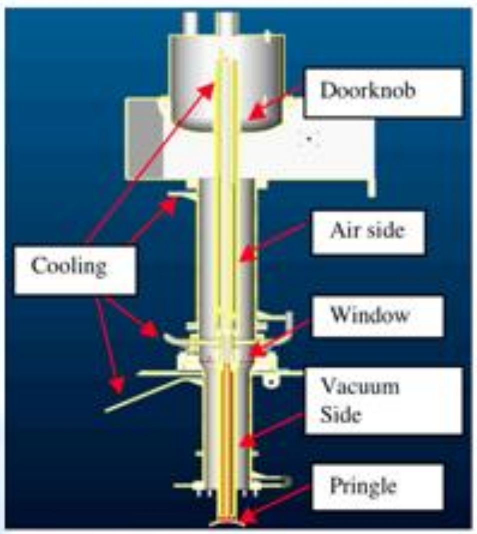
- **Input coupler:**
  - Based on TTF III coupler
  - Fixed coupling to reduce cost
  - Increased cooling for higher CW power (5 kW)
  - Large transverse flexibility (>10 mm)
  - Prototypes under fabrication; RF test early 2012

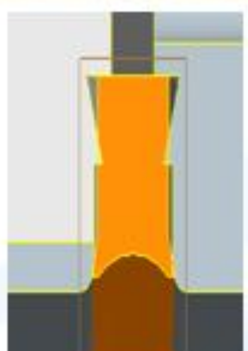
- **HOM Beamline Absorber:**
  - Simple design with SiC ring absorber
  - Strong, broadband RF absorption
  - Cleanable

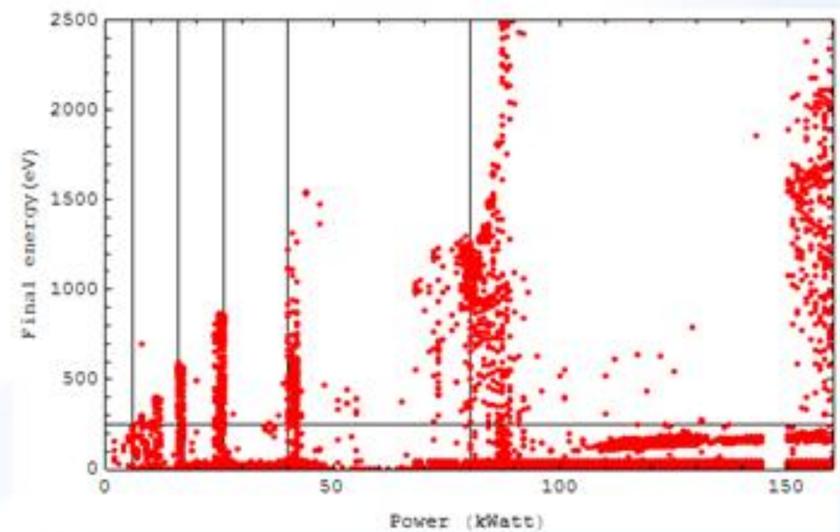


Fundamental power couplers for the ERL prototype SRF gun at BNL

- We have successfully tested 500-kW FPCs for the R&D ERL SRF gun.
- The test was in a standing wave mode with full reflection.
- Maximum power was set to 250 kW in pulse mode (limited by klystron collector) and 125 kW in CW (administrative limit).
- Observed MP barriers were in very good agreement with those predicted by simulations with Track3P.
- A modified Conflat gasket with RF contact was designed and may be useful for beam pipe seals.







High Power Input Couplers for cERL injector

E. Kako and S. Noguchi
(KEK, Japan)

Injector coupler for cERL

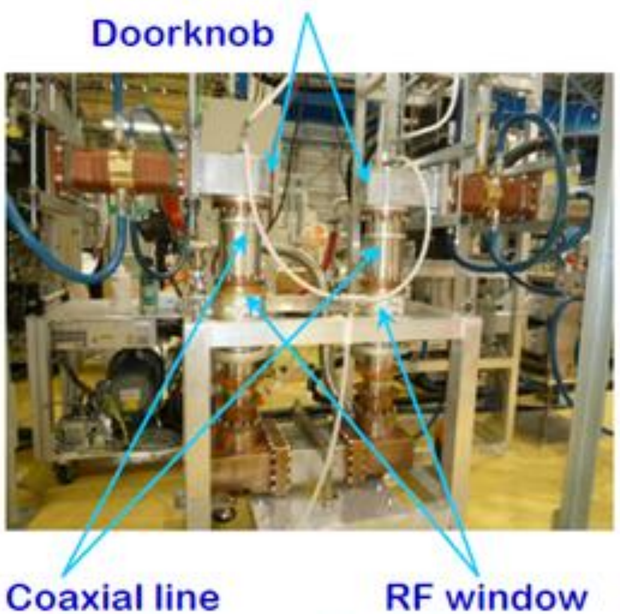
Two prototype input couplers

(completed in 2009, Oct.)
(finished conditioning in 2010)

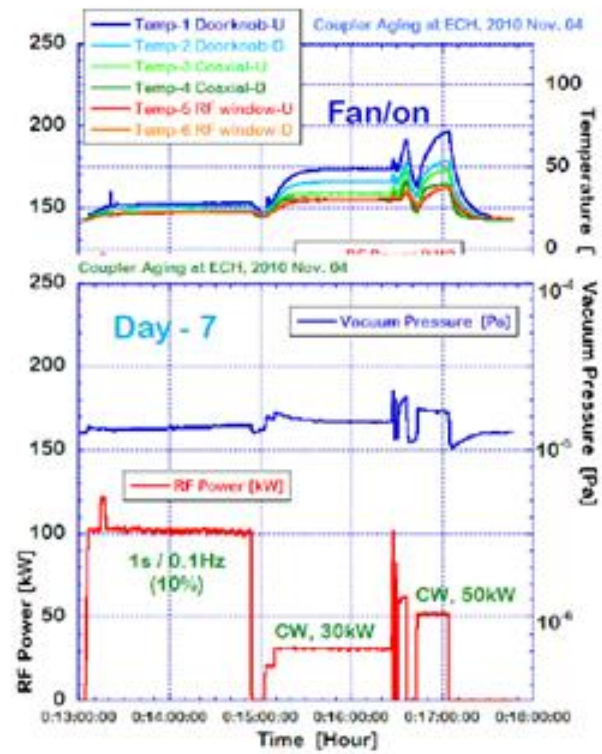
Six input couplers for cERL injector

(completed in 2011, June)
(scheduled conditioning in 2011, Dec.)

Location of Temperature Sensors



High power test stand



Conditioning Results

- 1s, 0.1Hz, 100kW for 2h
- cw 30kW for 1.5h
- cw 50kW for 0.5h
- cw 100kW for 1 min

WG-3 Conclusions

- Development of components:

  Cavity performance has reached to the ERL level.

  The main linac cavities are now staring to meet both gradient and Q0 spec.

  Large grain cavity has a potential to improve the residual resistance.

  CW-power test of couplers has advanced:

  60kW (Cornell, at cold test), 125kW(BNL), 50kW(KEK)

  New design of cavity, HOM damper was proposed (Cornell).

  Calculated BBU current > 100 mA (JLAB, BNL, Cornell)

- What's next;

  Demonstration of full ML module, including operation at >100mA.

  All key components are in the level of practical use.

Working Group 4 Report
Instrumentation & Controls

ERL Experience – Plenary - 7

Operations, Controls and Diagnostics for High Power Electron Injectors

Bruce Dunham (Cornell)

Related topics that can be applied to ERL's

Turn-by-Turn Monitor Using Fast Gate Switch - Makoto Tobiyama (*KEK*)

Beam Diagnostic Instruments for SACLA - Hirokazu Maesaka (*RIKEN/SPring-8*)

Design and Performance of the Synchronization System - Hirokazu Maesaka

Development of Femto-second Timing Distribution System - Takashi Naito (*KEK*)

Diagnostics unique to ERLs

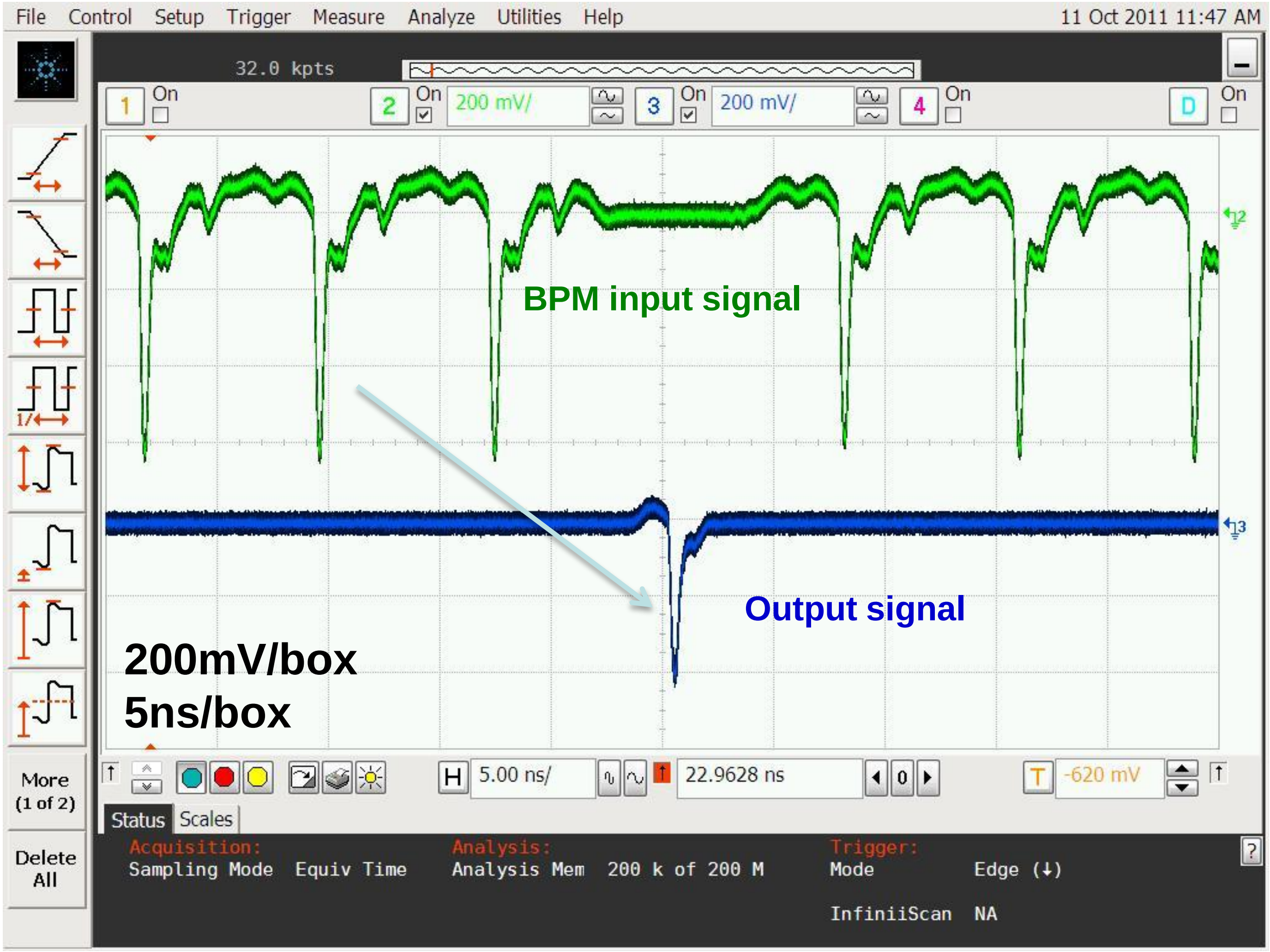
Halo monitor

Two-pass BPM

High resolution BAMs

Beam dump monitors

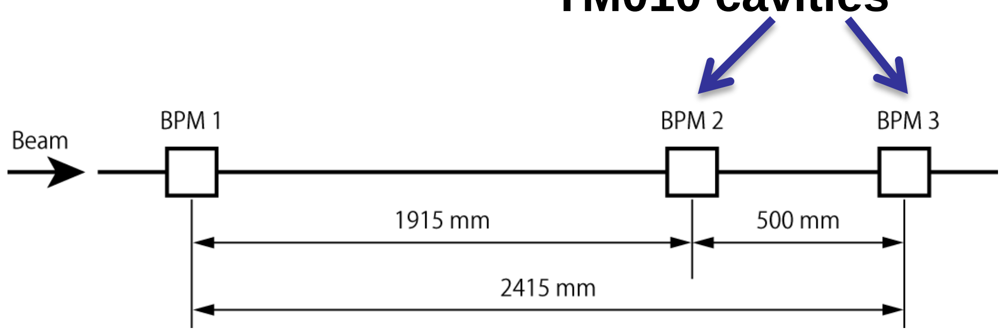
Fast Switch used to Gate BPM Signal

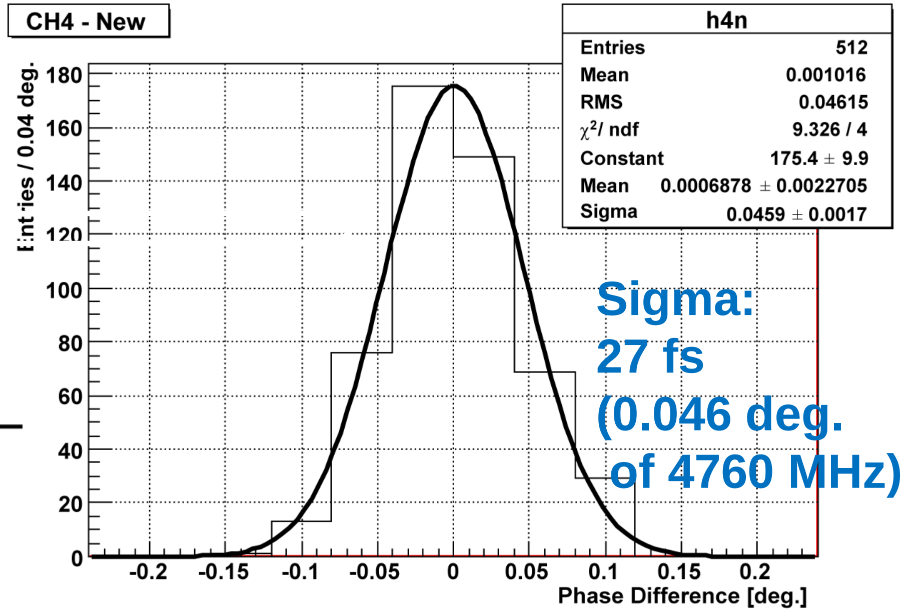


RF-BPM Beam Arrival Timing Resolution

- Beam arrival timing can be measured by the phase of the reference cavity (TM010).
  - Useful to monitor the timing drift of the machine
  - Required temporal resolution: < 50 fs
- **Arrival timing resolution: 27fs**
  - Measured by the reference cavities of two neighboring BPMs in the SCSS test accelerator.

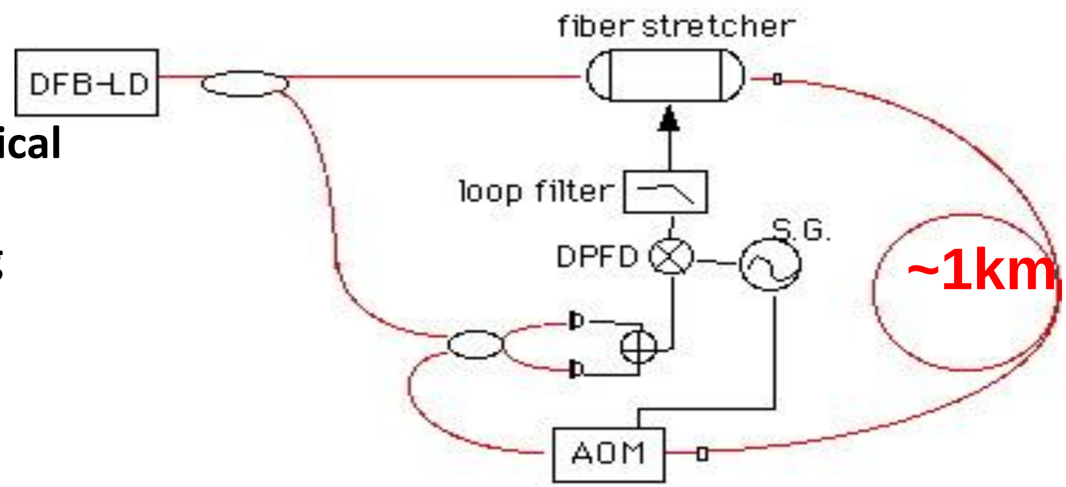
Phase Difference of TM010 cavities

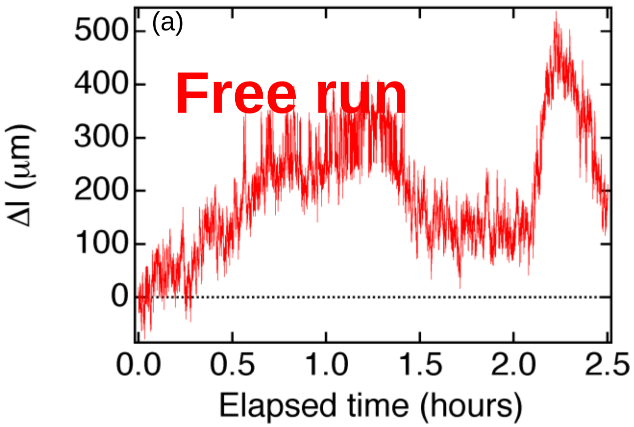


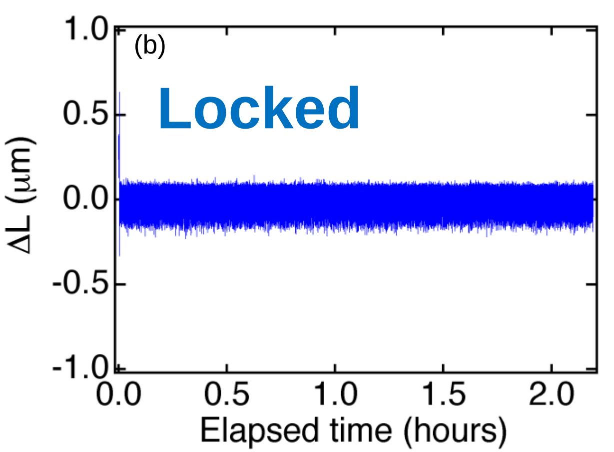


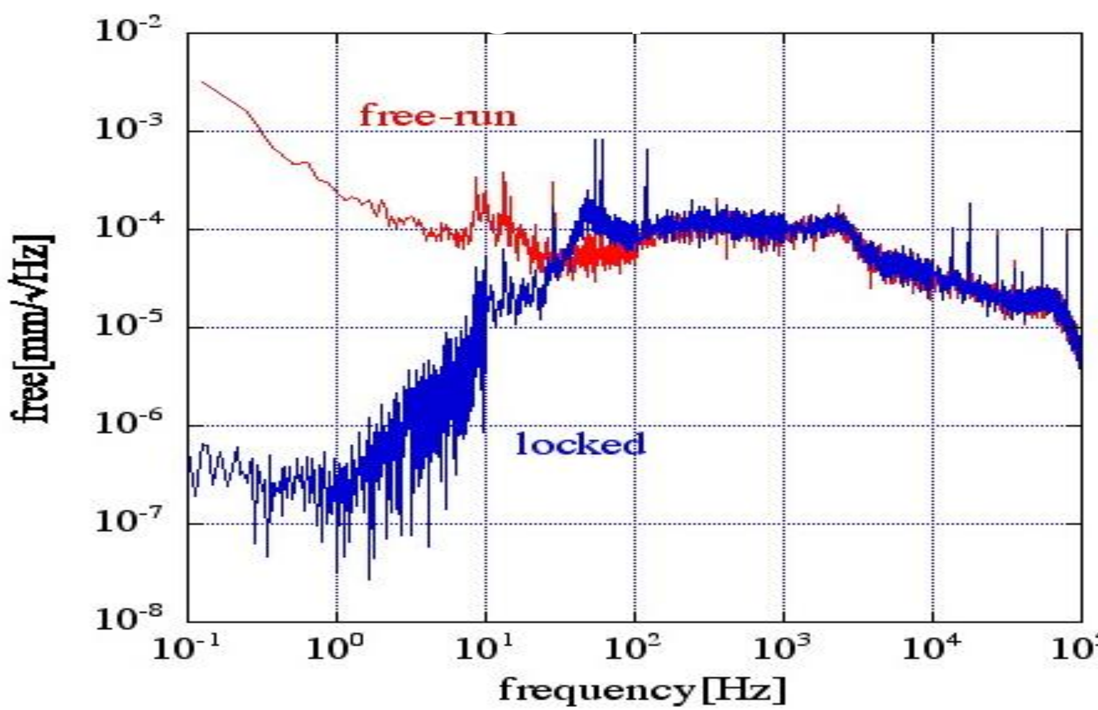
Experiment of Fiber Length Control

Use the 1 km phase stabilized optical fiber cable settled along the circumference of the SPring-8 ring







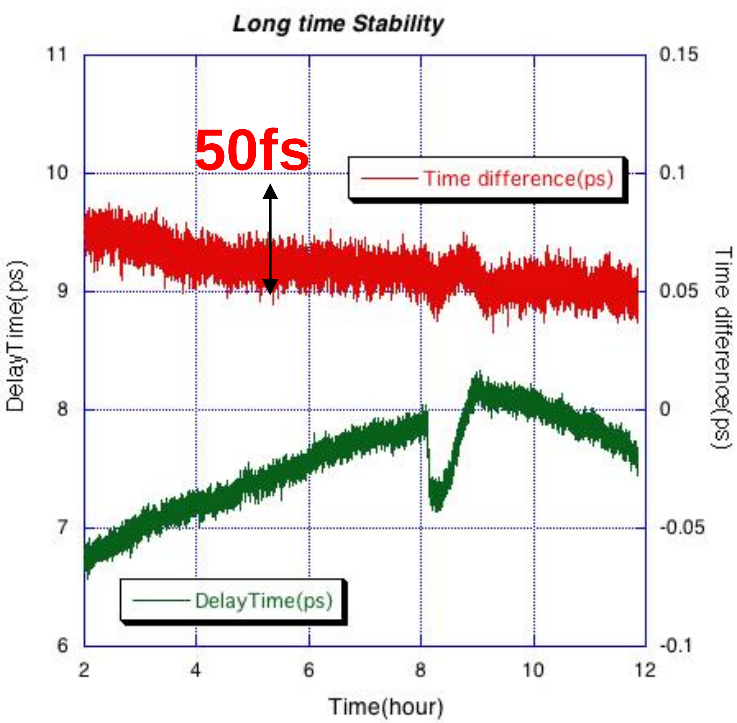


Summary SACLA Synchronization

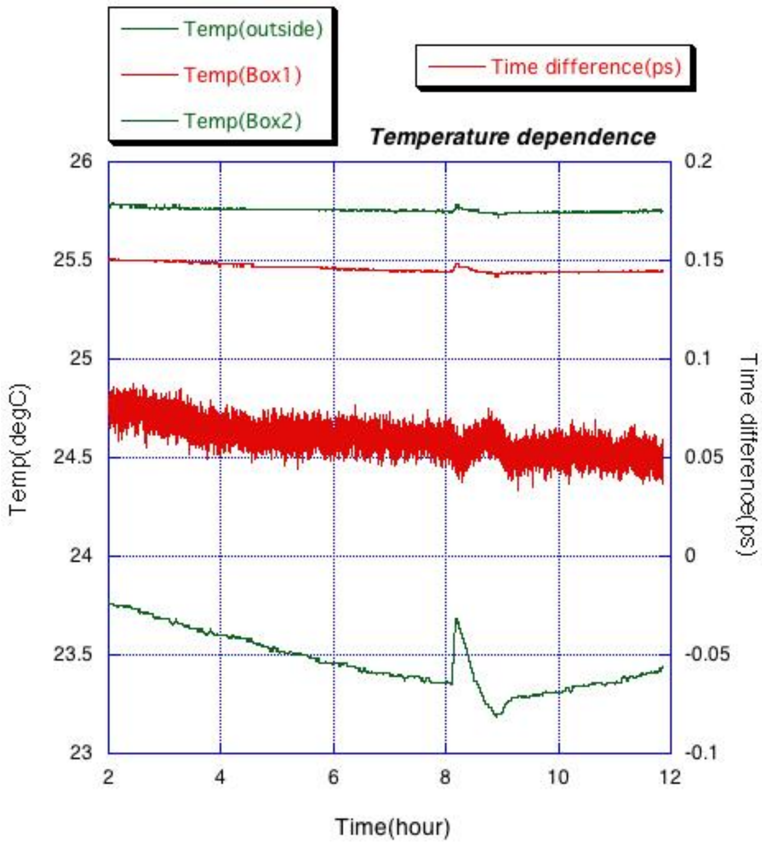
- Optical RF and Timing Distribution
  - Jitter: ~ 10 fs (from phase noise measurement)
  - Drift: 750 fs (pk-pk) for 400m cable → Fiber length controller will be installed to improve towards goal of 100fs (5.7GHz).

- Low-level RF System
  - Difficult.
  - Our IQ-mod/demod system is intended for pulsed RF signals and for normal conducting accelerators.
  - Need considerable modification for CW signal or super-conducting accelerator.
    - Vector sum
    - Intra-pulse feedback

Long time stability(1)

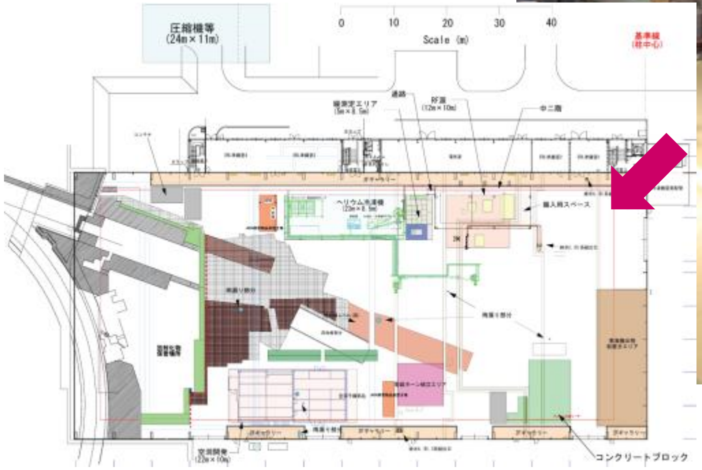


10hour trend ~50fsp-p

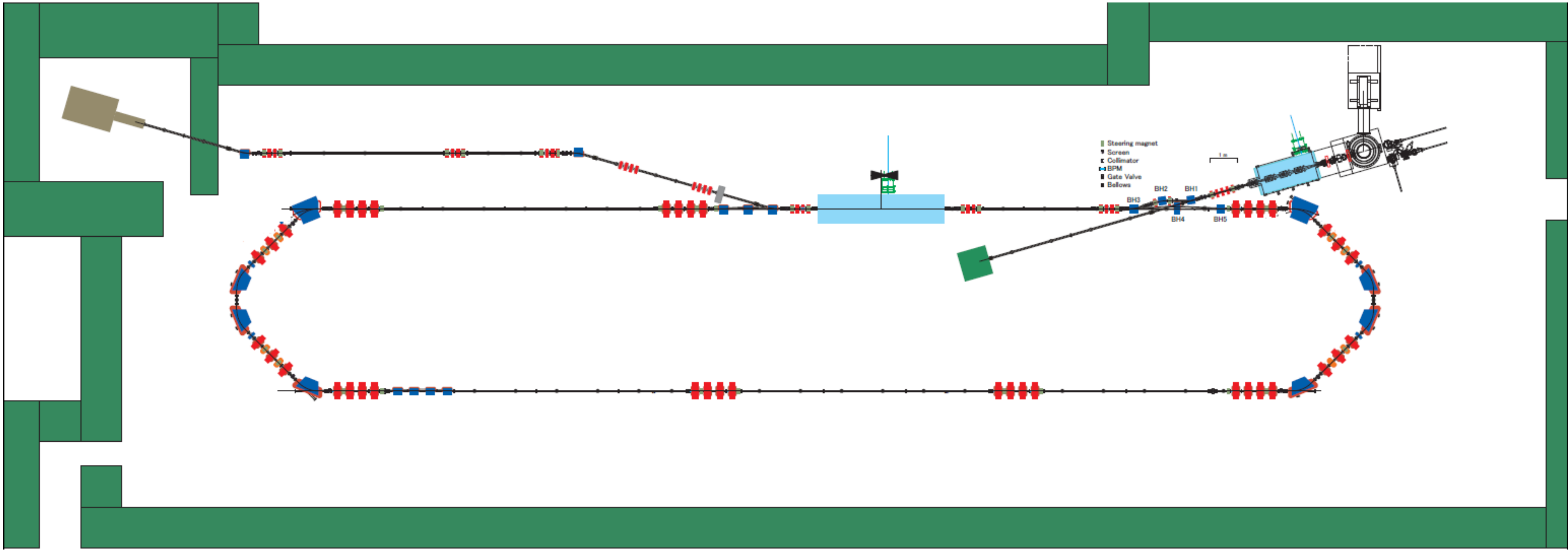


Comparison with the temperature

Present Status : Photo



cERL at the end of FY2012



Start operations under 35MeV, 10mA (begin with reduced current).

The compact ERL will demonstrate:

- **ERL accelerator technologies**
- **Experimental possibilities based on CSR of THz radiation**
- **Laser driven inversed Compton X-ray source**

Beam Halo Imaging using an Adaptive Optical Mask*

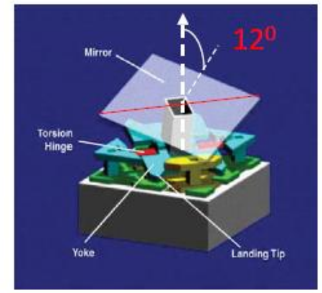
R. Fiorito, H. Zhang, A. Shkvarunets, I. Haber, S. Bernal, R. Kishek, P. O'Shea
Institute for Research in Electronics and Applied Physics
University of Maryland

S. Artikova
MPI- Heidelberg

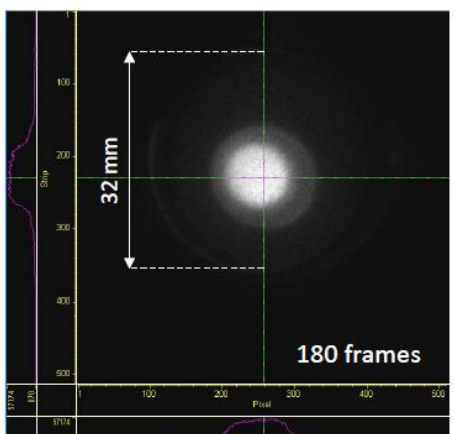
C. Welsch
Cockcroft Institute, University of Liverpool

Presented at Beam Instrumentation Workshop, Santa Fe, NM May 3-6, 2010
*Work Funded by US ONR, DOD JTO and DOE Office of HEP

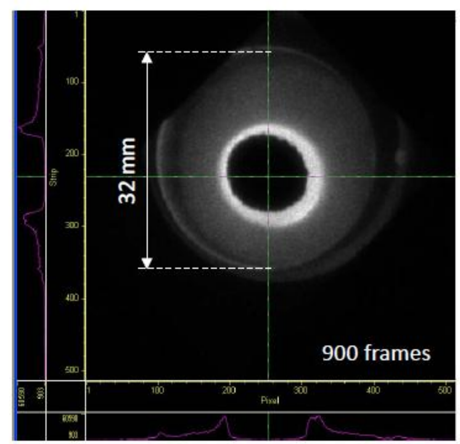
Micro mirror architecture:



Whole Beam shows halo +core

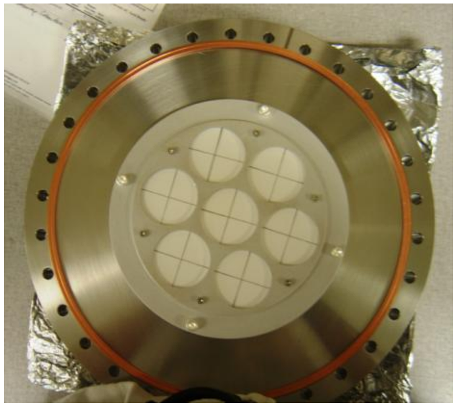


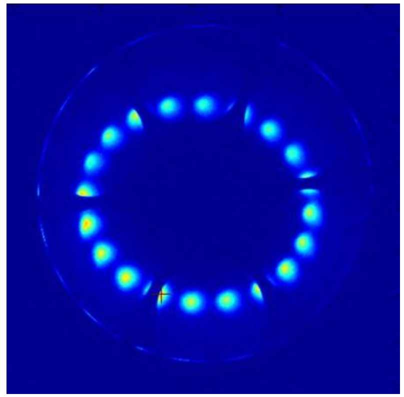
Masked Beam shows Halo Alone



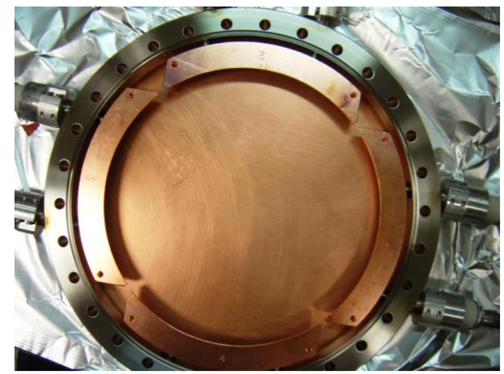
Beam Dump Monitoring

Large BeO viewscreen at the dump location



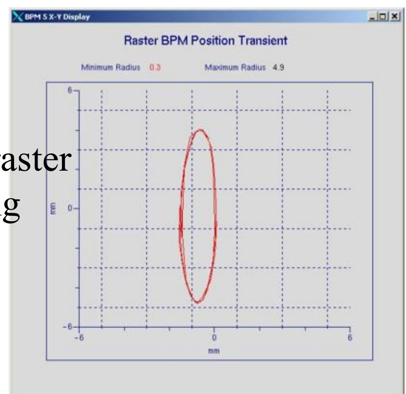


Beam image beyond the raster during calibration



A large quadrant detector before the dump ensures that the beam cannot get too big

A bpm located after the raster for continuous monitoring



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- The defocusing/rastering system is calibrated using the large viewscreen (shown above) before installing the dump.
- A bpm will be used for continuous monitoring, and an array of 80 thermocouples around the dump will monitor hot spots.

WG 5; Unwanted Beam Loss Talks

- Proposal of a Diamond-based Beam Halo Monitor for an Energy Recovery Linac; Hideki Aoyagi (*JASRI/SPring-8*)
- Beam Loss Monitoring and Machine Protection at the ELBE CW Accelerator; Jochen Teichert (*HZDR*)
- NSLS-II Beam Loss Monitor System; Stephen Kramer (*BNL)*
- ALICE Beam Loss Monitoring System; by Susan Smith for Steve Buckley, (Daresbury Lab)
- Brief Review of the Approaches to Elucidate the Mechanism of the Radiation-induced Demagnetization;Teruhiko Bizen (*JASRI/SPring-8*)
- Availability of Optical Fiber Based Beam Loss Monitor at SACLA XFEL Facility; Toshiro Itoga (*JASRI/SPring-8*)
- Operational Experience with Jefferson Lab ERL/FEL Machine Protection System (MPS); Kevin Jordan (*JLAB*)
- Development of Optical-Fiber Beam Loss Monitor at KEK Linac; Yoshiharu Yano (*KEK*)

Key Points

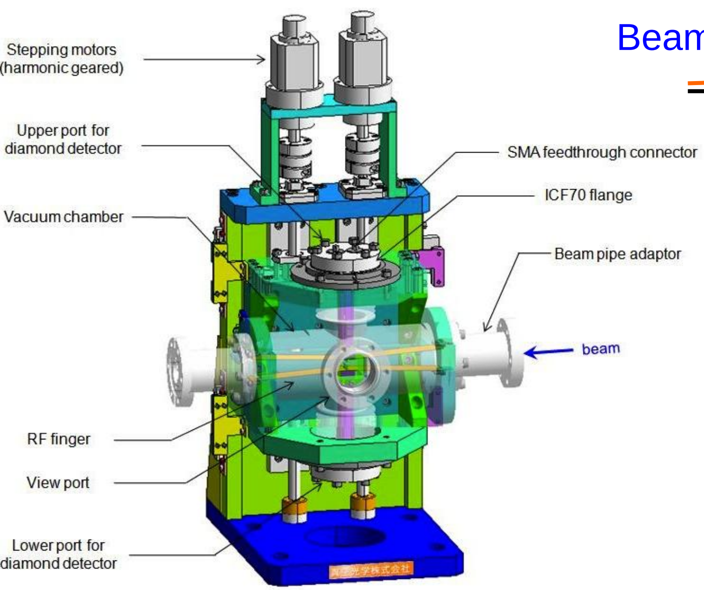
- Unwanted beam loss is either Chronic or Acute
- Detectors & Machine Protection Systems have no problem w/Acute losses
  - Chronic losses lead to activation & degradation of components
    - Permanent magnets, vacuum valve seals…
- Better understand sources of *chronic* losses and PREVENT them
  - Continue to understand & reduce the sources of Halo
- One has to pay special attention to proper shielding of insertion devices and cryo sections

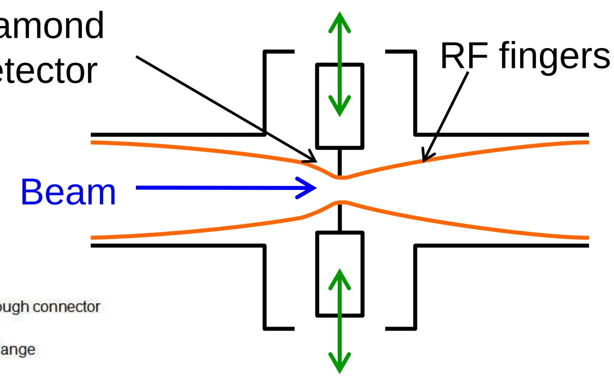
Proposal of a Diamond-based Beam Halo Monitor for an Energy Recovery Linac

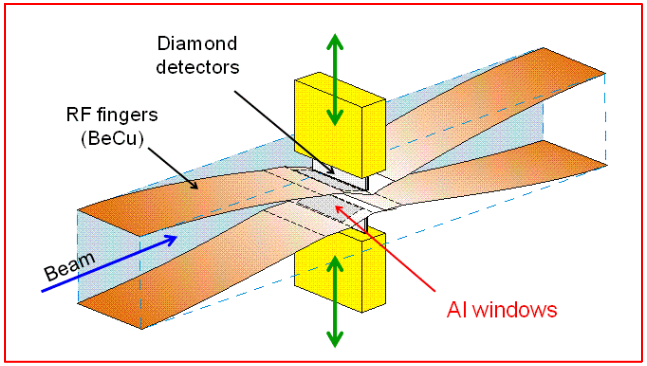
Hideki Aoyagi, T. Bizen , T. Itoga, N. Nariyama, *JASRI / SPring-8*
Y. Asano, T. Tanaka, H. Kitamura, *RIKEN/ SPring-8*

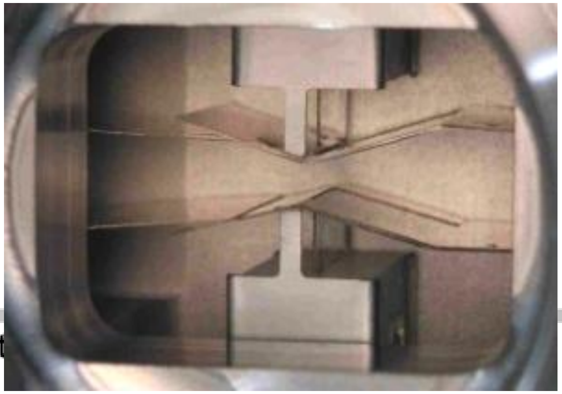
Purpose : To protect undulator magnets against radiation damage

Structure: Diamond detectors are inserted into a beam duct directly, and covered by RF fingers with Al windows.



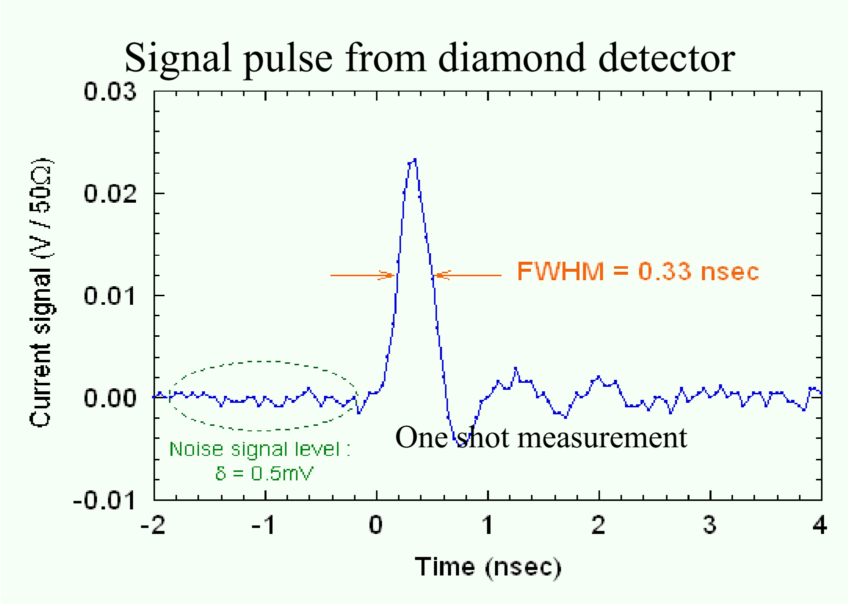




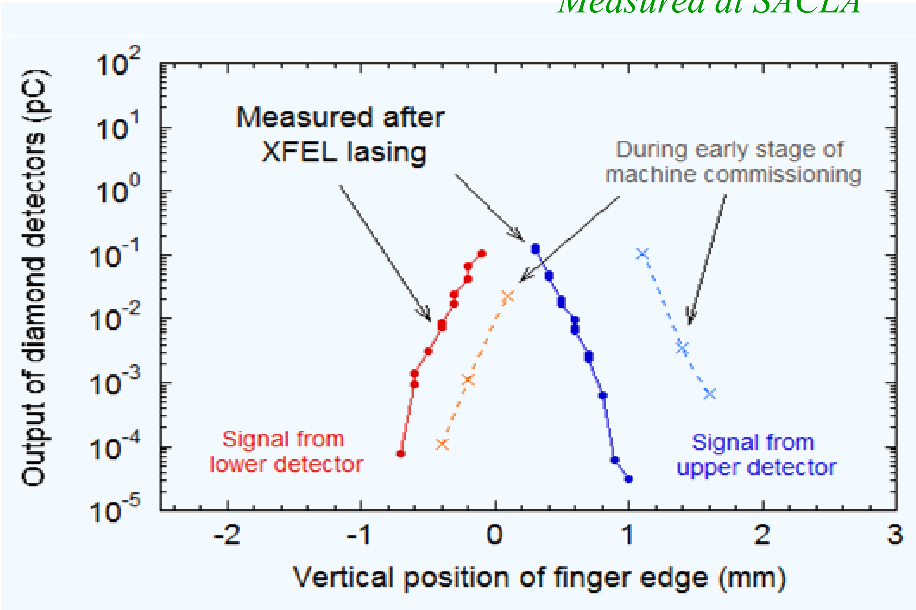


2. Performances of the Halo Monitor

- Practical detection limit is about 2×10^3 e/pulse. *(up to about 10^7 e/pulse)*
- Feasibility had been demonstrated. (see below)
- Commissioning at SACLA has been successfully carried out.



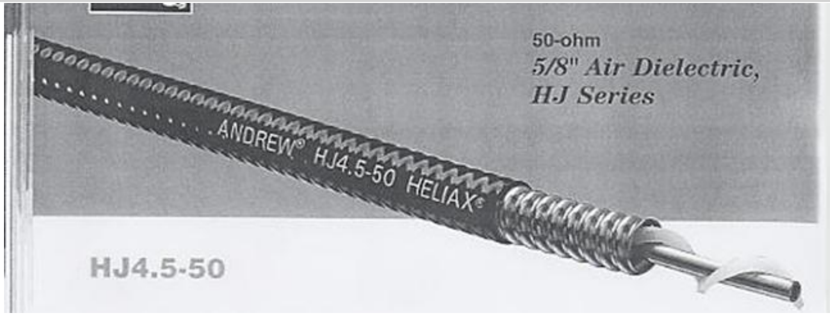
Measured at SACLA



3. Things to do toward ERLs,

- Improvement of lower/upper detection limit.
- Refinement of RF finger structure (reduce gap between a finger and a detector)
- Equipment with a cooling mechanism.

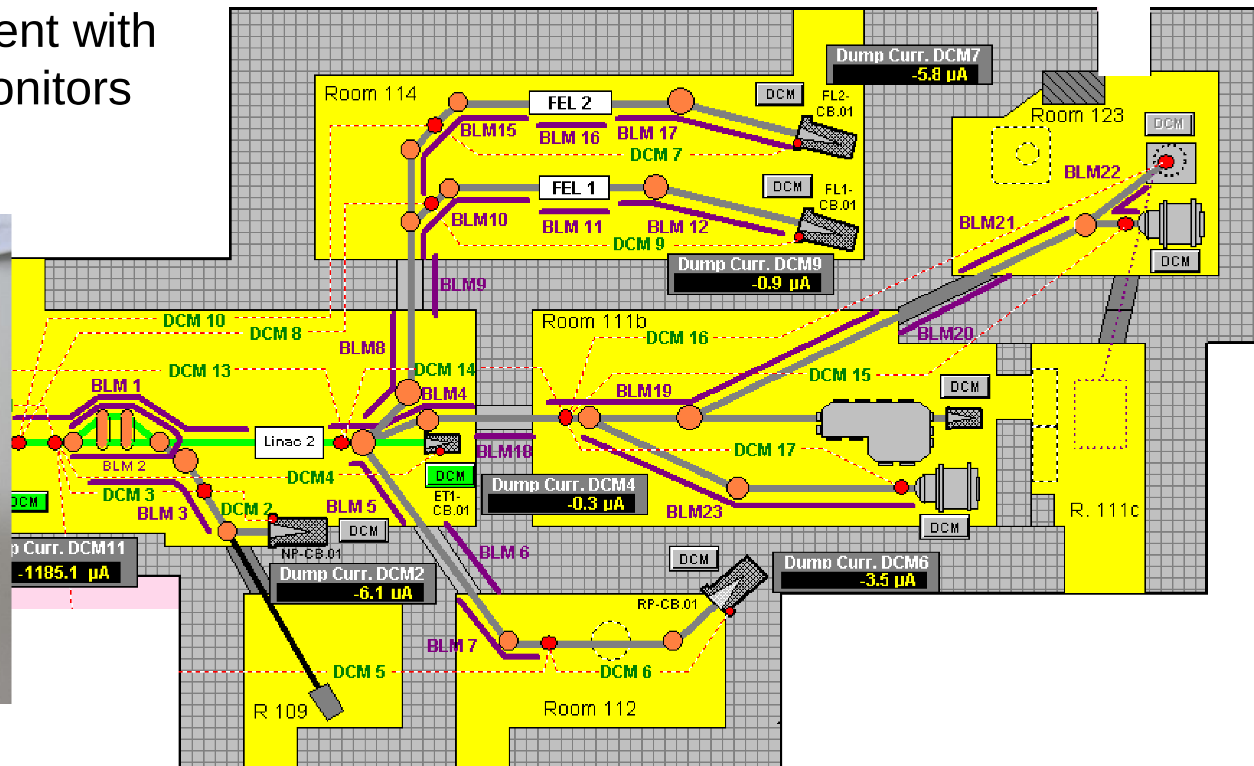
Radiation Source ELBE at Dresden-Rossendorf



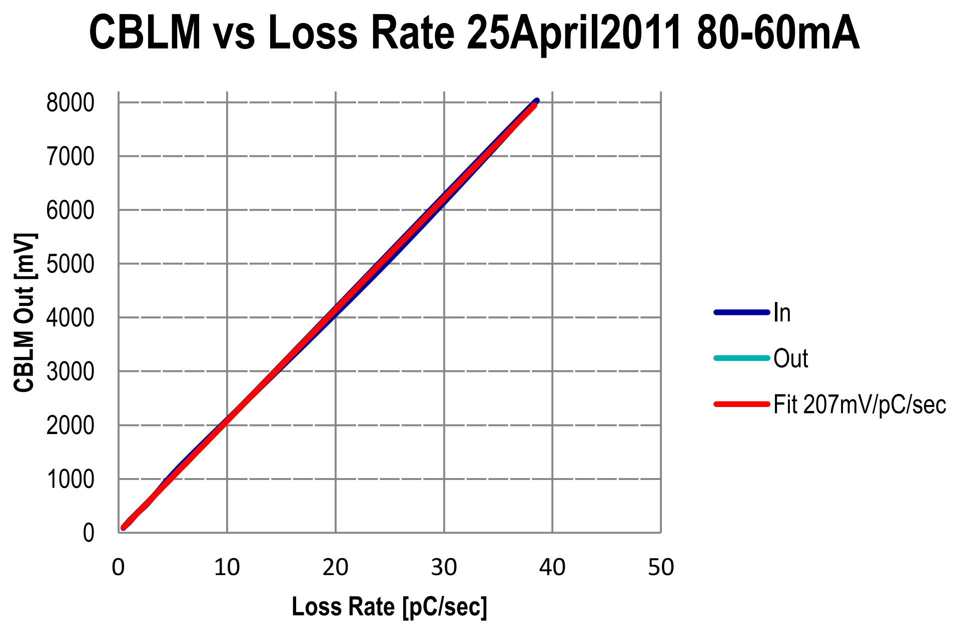
long ionization chambers

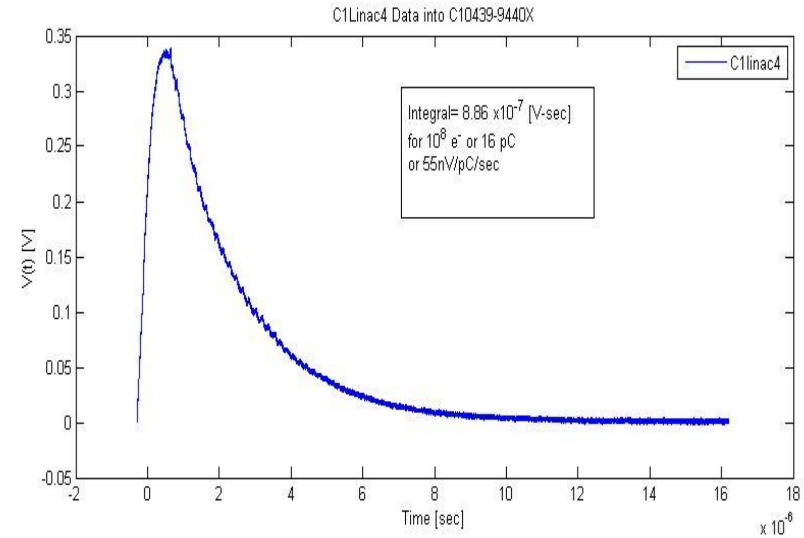
- based on air-filled coaxial cables
- segmented 3 -5 m, along beam lines
- sensitivity 0.5 µA beam loss
- response time of monitors 0.6 ms
- switch-off time : 2 ms

second redundant system:
different current measurement with stripe line beam position monitors and beam dump current



Fused Silica CBLM with Photodiode Detector





Large diameter rods yield large signals couple to Photodiodes

Scrapers can calibrate loss rate to DCCTs

CBLM signal scales linearly with local loss rate Io/τ over >40dB

Zero current level is 0.5 -0.7mV or

Noise level ~2-3 fC/sec (0.2-0.3)

Lower gain ~10^{-6} V/A of PDM can have BW=64KHz or 2.4μsec

Testing in Linac with 120MeV e^- beam at normal incidence with 10^8 (~16 pC) e^-/pulse (2nsec long)

Integral or DC term 55nV/pC/sec

Beam-Beam Effects in an ERL-based Electron-Ion Collider

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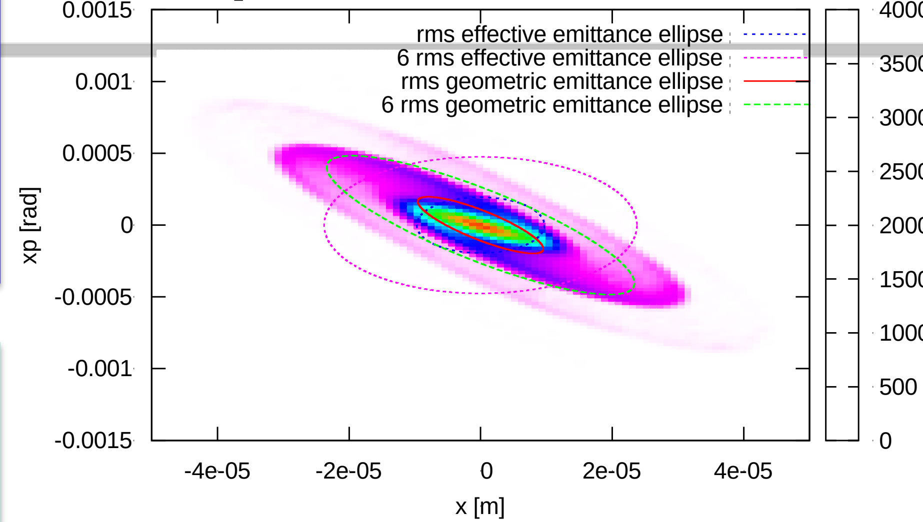
- Beam-beam effects are important R&D item for the ERL-based electron-hadron colliders.

- The electron transverse distribution is considerably modified by the beam-beam interactions. The emittance is increased due to both the linear mismatch and non-linear disruption.

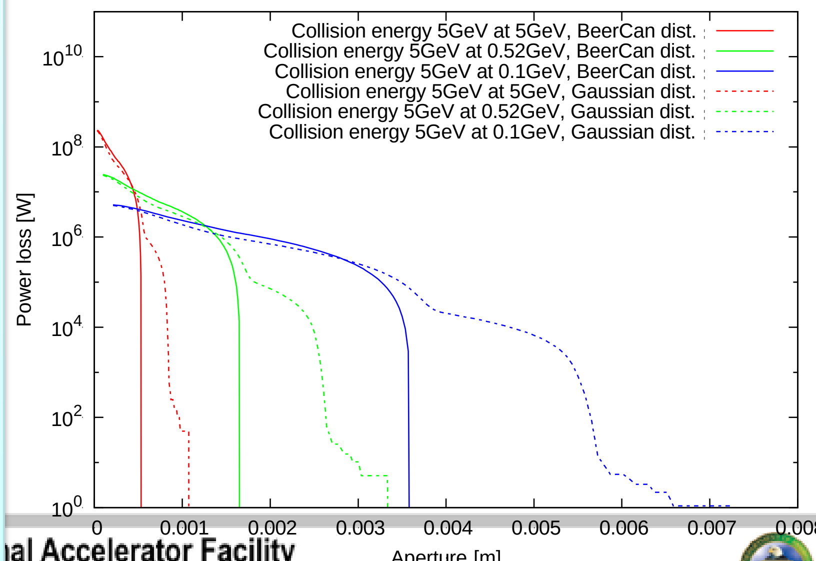
- Tails of the electron transverse distribution define the aperture requirements for the magnets of lower energy recirculation passes in eRHIC

- A correct choice of the interaction region optics electron can minimize both the mismatch and the disruption.

Modification of electron beam distribution at disruption d=100



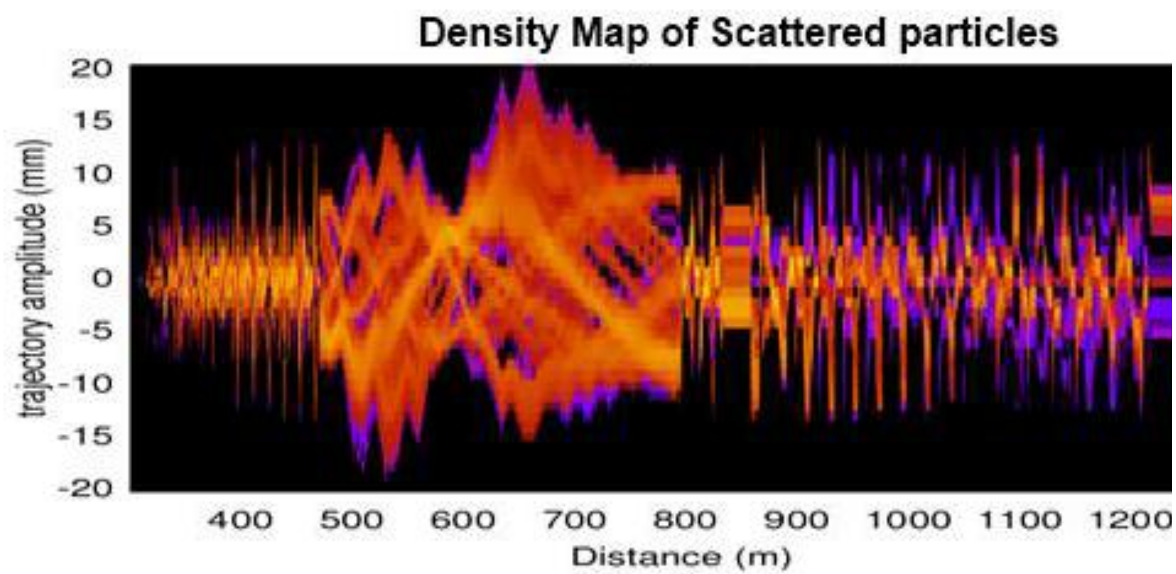
Beam power loss in dependence on the beam pipe aperture in eRHIC recirculation passes

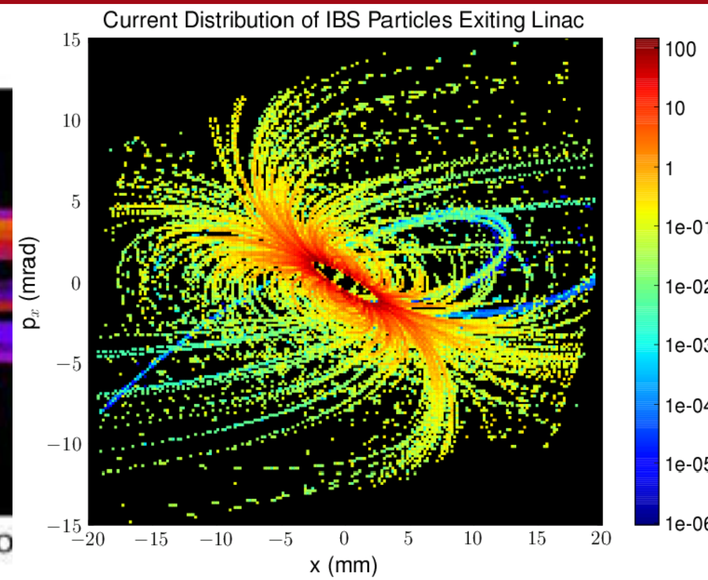


Discussion points came up during the workshop

- Does any of collimation scheme work (besides of simulations)? Or makes things worse? There one can put them on way up and on way down? Any first hands experience is needed. The experimentally proving collimation system at low and at high energy is necessary.
- Some chronic losses are unavoidable. The shielding of the ERL may rise the cost of the facility significantly. ERLers have to remember about that.
- For large circumference machine (eRHIC~ 50km total 6 pass up 6 pass down) the proper abort kicking/dumping systems has to be considered

Creation of Touschek particles for linac beams and placement of collimators





1. Once one knows the creation and propagation of Touschek particles, one can optimize the placement of collimators.
2. Choice: No collimator should take more than 1nA
3. Choice: No section in the user region should take significantly more than 3pA/m
4. Once can then simulate the x-ray and neutron background in collimation regions and design effective shielding for personnel and electronics.
5. The beam halo that leaves the Linac is computed to optimize the transport to the beam dump.
6. The optics is optimized so that beam halo from Touschek scattering fits through undulators.