5th International Particle Accelerator Conference
June 15 - 20, 2014 | Dresden, Germany
IPAC14

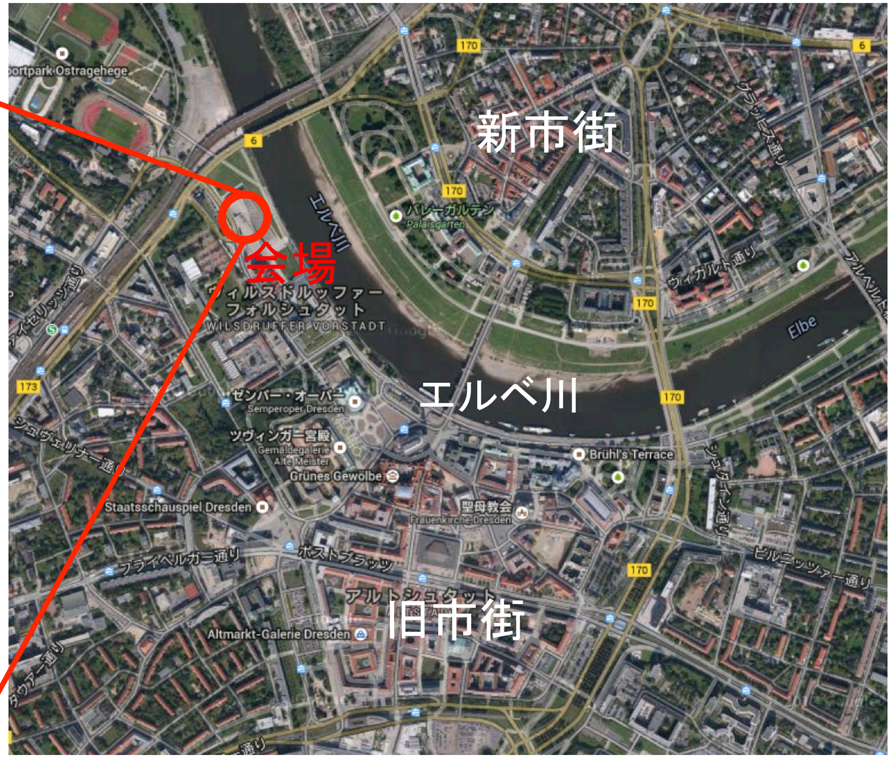
IPAC14参加とドイツ加速器施設見学の報告

加速器研究施設
中村 典雄、小林幸則、本田　融、島田 美帆
三浦 孝子、Olga Konstantinova

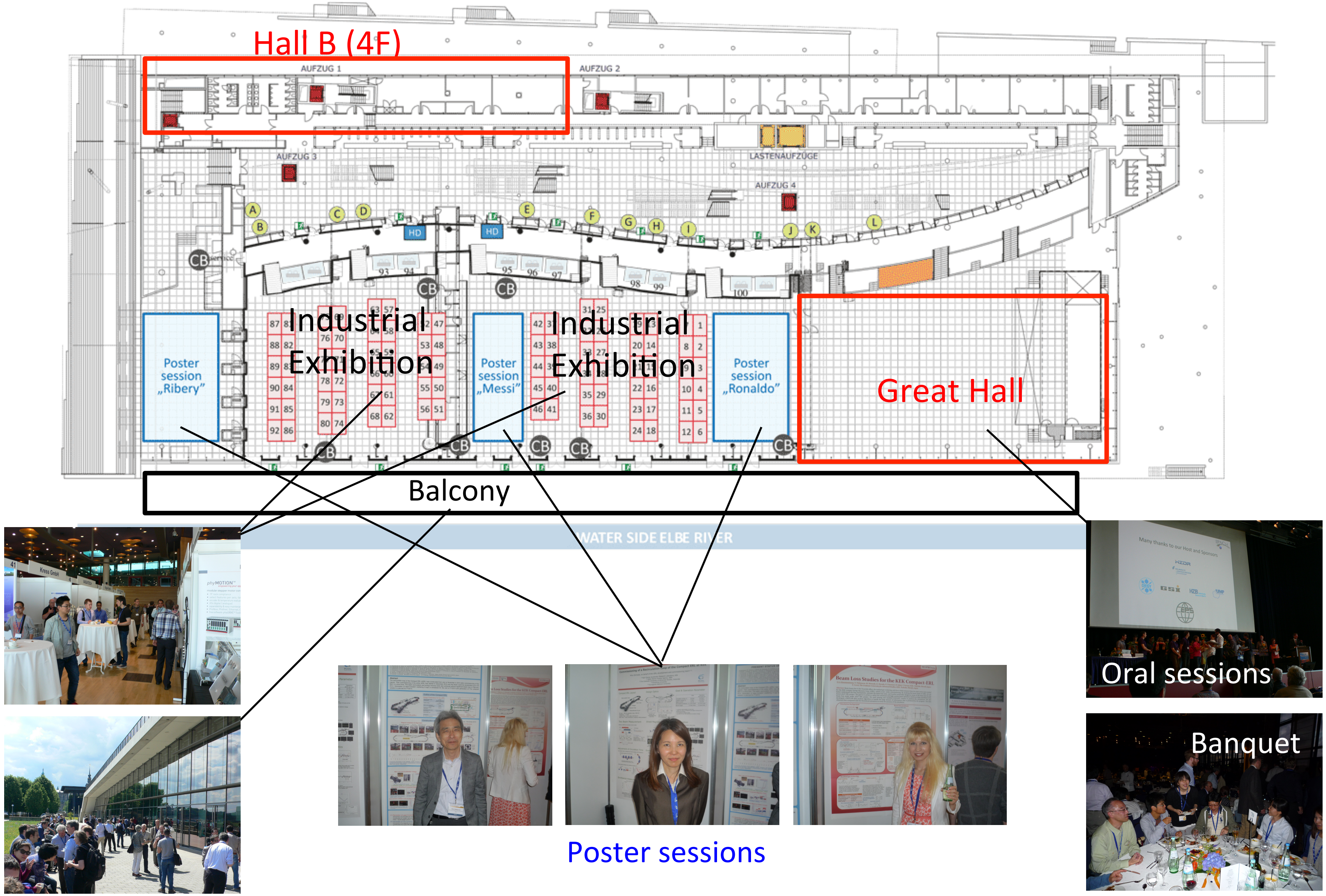
IPAC14報告

IPAC14の概要

- 開催日 : 2014年6月15日 - 20日
- 会場 : International Congress Center, Dresden, Germany
- 参加者数 : 1215名（日本 117名 / KEK 約30名）
- 企業展示数 : 100ブース（94社）



IPAC14会場


Hall B (4F)
AUFZUG 1
AUFZUG 2
AUFZUG 3
AUFZUG 4
LASTENAUFZÜGE
Industrial Exhibition
Industrial Exhibition
Poster session „Ribery"
Poster session „Messi"
Poster session „Ronaldo"
Great Hall
Balcony
WATER SIDE ELBE RIVER
Oral sessions
Banquet
Poster sessions

Oral Presentations

(*Monday, June 16*)

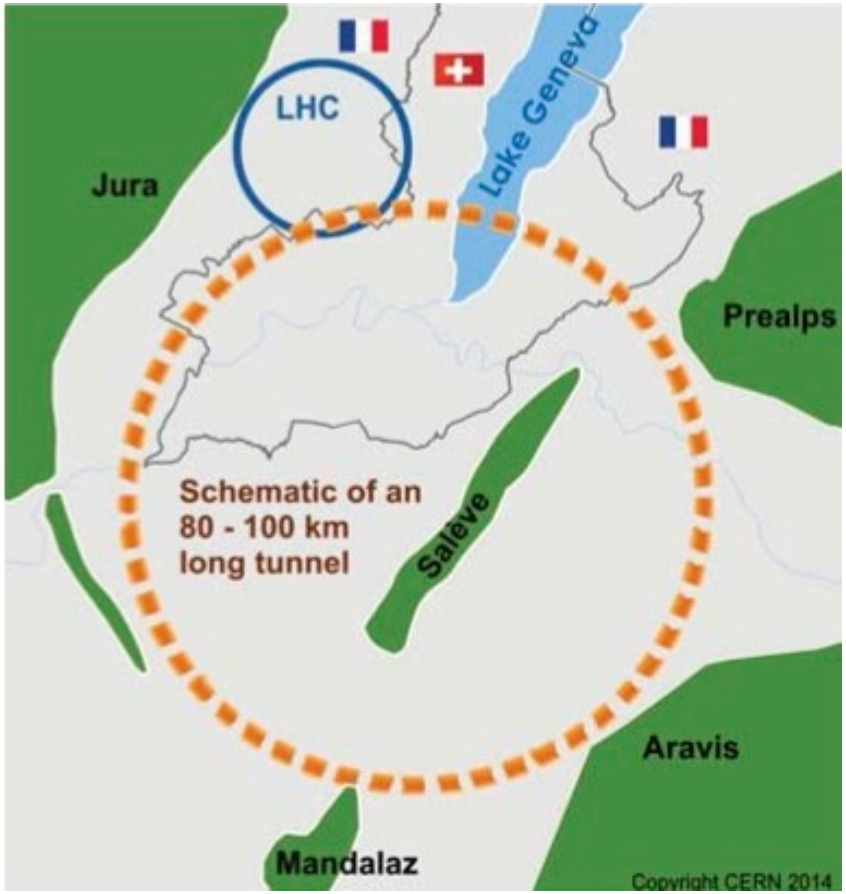
- *Challenges for Highest Energy Circular Colliders*
  Frank Zimmermann (CERN)
- *Challenges in the Design of Diffraction-limited Storage Rings*
  Robert Hettel (SLAC)
- *Innovative Ideas for FELs*
  Toru Hara (RIKEN/SPring-8)

⋮

(*Friday, June 20*)

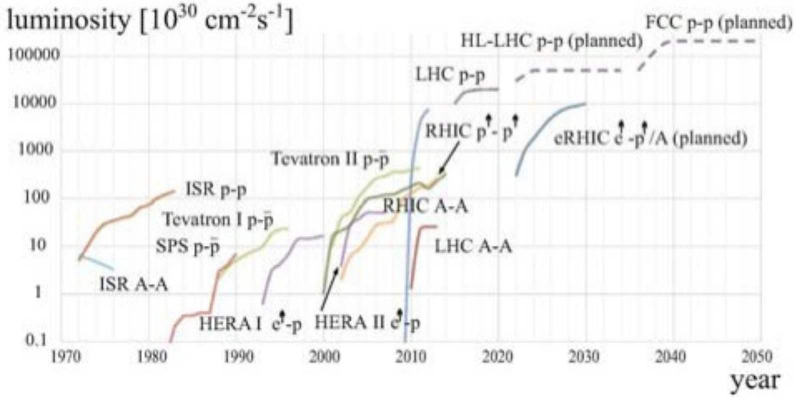
- *Options and Priorities for Accelerator-Based High-Energy Physics*
  Fabiola Gianotti, CERN

Challenges for Highest Energy Colliders

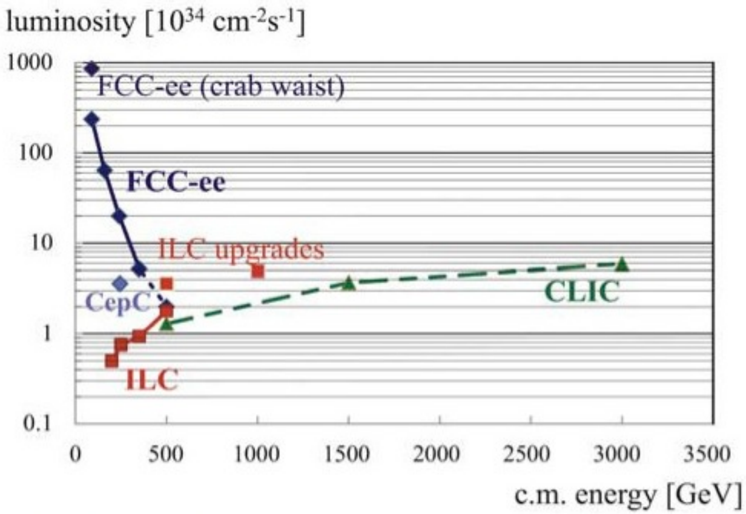


FCC (Future Circular Collider) Project

by F. Zimmermann (+ F. Gianotti)



Hadron-collider peak luminosity vs. year

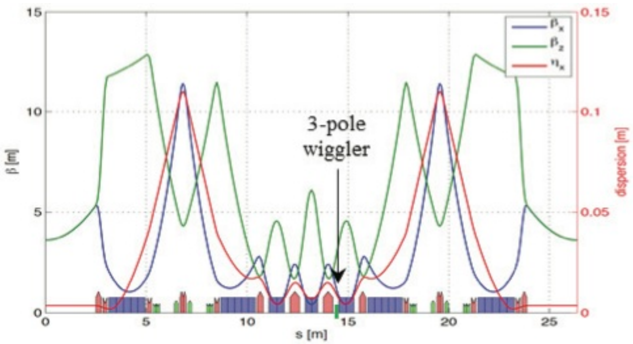


e^-e^+-collider luminosity vs. cm energy

4GSR&FEL Review

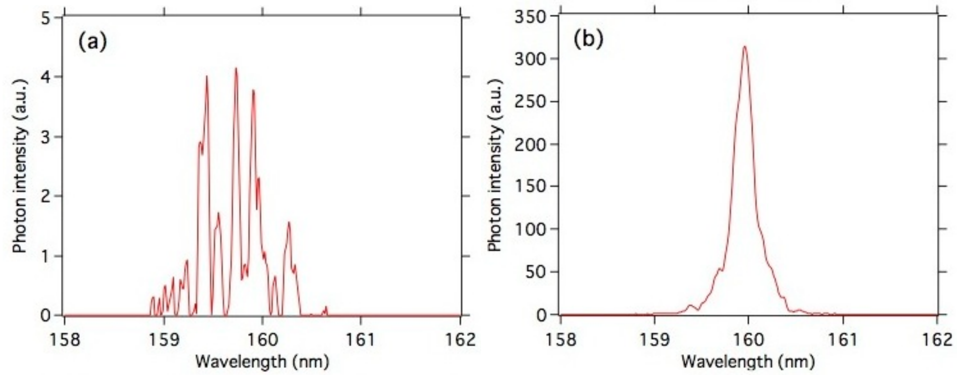
Table 1: Parameters for some low-emittance rings. (IC/IS = in construct/study; LGD = longitudinal gradient dipoles; SB = superbend insert; 3PW = 3-pole wiggler; DW = damping wiggler.)

Facility	E(GeV)/ I(A)	C (m)	ε_0 (pm)	Features
NSLS-II	3/0.5	792	600	2BA, DW, IC
MAX-IV	3/0.5	528	250	7BA, 100 MHz RF, IC
Sirius	3/0.5	518	280	Hybrid 5BA, SB, IC
ESRF-U	6/0.2	844	150	Hyb7BA ,LGD,3PW, IS
APS-U	6/0.2	1104	65	ESRF style, swap-out, IS
SPring8-2	6/0.2	1436	100	5BA, IS
ALS-U	1.9/0.5	200	100	9BA, SB, swap-out, IS
BAPS	5/0.2	1500	50-100	IS
SLAC	6/0.2	2.2	10	7BA, 90m DW, IS
TauUSR	9/0.2	6280	3	7BA, DW, IS

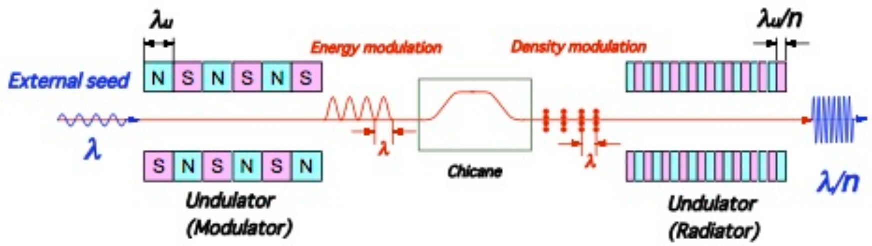


7BA lattice for ESRF-2

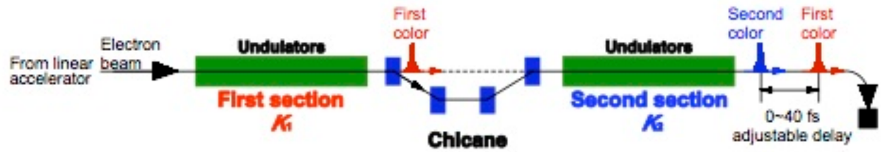
by R. Hettel



SASE and seeded SASE



Single-stage HGHG configuration



Undulator configuration for two-color FEL

by T. Hara

ERL関係のオーラル発表

- ***Recent Advances in Energy Recovery Linacs***
  Christopher Mayes (Cornell)
- ***Advances in Photocathodes for Accelerators***
  Luca Cultrera (Cornell)
- ***Large Dynamic Range Beam Diagnostics for High Average Current Electron LINACs***
  Pavel Evtushenko (JLAB)
- ***Design Study of an ERL Test Facility at CERN***
  Erk Jensen (CERN)

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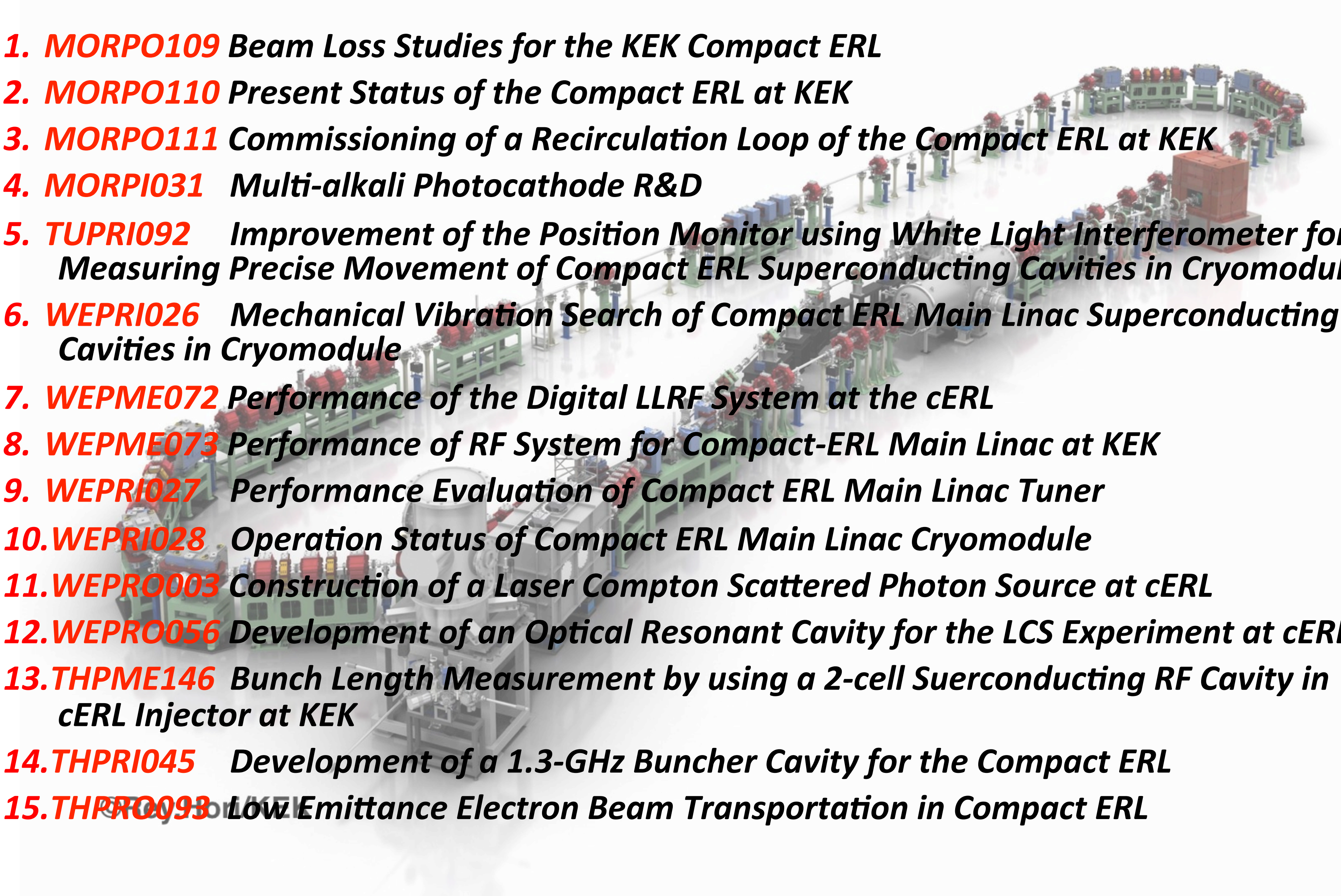
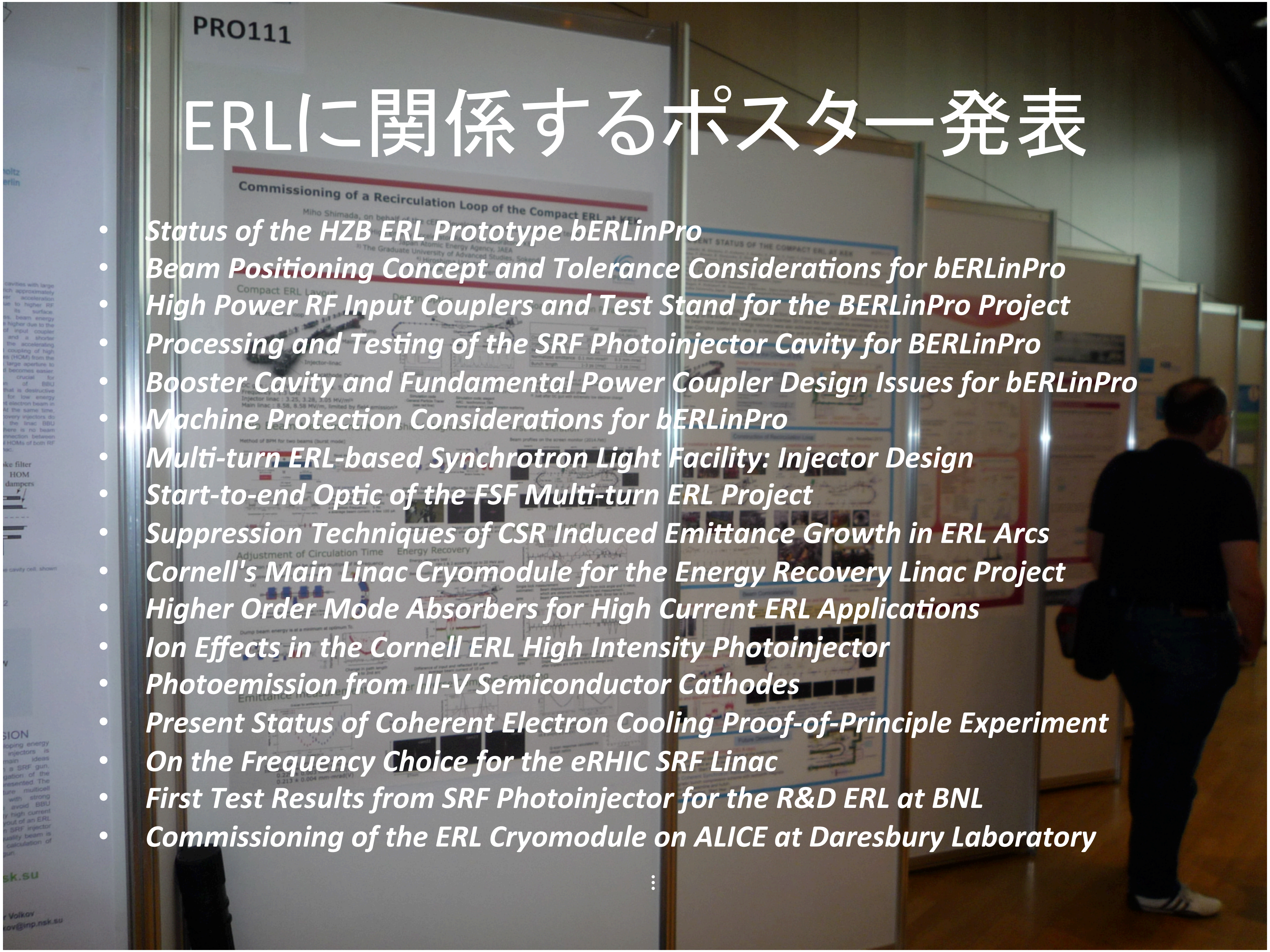
cERLに関する発表



1. MORPO109 *Beam Loss Studies for the KEK Compact ERL*
2. MORPO110 *Present Status of the Compact ERL at KEK*
3. MORPO111 *Commissioning of a Recirculation Loop of the Compact ERL at KEK*
4. MORPI031 *Multi-alkali Photocathode R&D*
5. TUPRI092 *Improvement of the Position Monitor using White Light Interferometer for Measuring Precise Movement of Compact ERL Superconducting Cavities in Cryomodule*
6. WEPRI026 *Mechanical Vibration Search of Compact ERL Main Linac Superconducting Cavities in Cryomodule*
7. WEPME072 *Performance of the Digital LLRF System at the cERL*
8. WEPME073 *Performance of RF System for Compact-ERL Main Linac at KEK*
9. WEPRI027 *Performance Evaluation of Compact ERL Main Linac Tuner*
10. WEPRI028 *Operation Status of Compact ERL Main Linac Cryomodule*
11. WEPRO003 *Construction of a Laser Compton Scattered Photon Source at cERL*
12. WEPRO056 *Development of an Optical Resonant Cavity for the LCS Experiment at cERL*
13. THPME146 *Bunch Length Measurement by using a 2-cell Suerconducting RF Cavity in cERL Injector at KEK*
14. THPRI045 *Development of a 1.3-GHz Buncher Cavity for the Compact ERL*
15. THPRO093 *Low Emittance Electron Beam Transportation in Compact ERL*



ERLに関係するポスター発表

- *Status of the HZB ERL Prototype bERLinPro*
- *Beam Positioning Concept and Tolerance Considerations for bERLinPro*
- *High Power RF Input Couplers and Test Stand for the BERLinPro Project*
- *Processing and Testing of the SRF Photoinjector Cavity for BERLinPro*
- *Booster Cavity and Fundamental Power Coupler Design Issues for bERLinPro*
- *Machine Protection Considerations for bERLinPro*
- *Multi-turn ERL-based Synchrotron Light Facility: Injector Design*
- *Start-to-end Optic of the FSF Multi-turn ERL Project*
- *Suppression Techniques of CSR Induced Emittance Growth in ERL Arcs*
- *Cornell's Main Linac Cryomodule for the Energy Recovery Linac Project*
- *Higher Order Mode Absorbers for High Current ERL Applications*
- *Ion Effects in the Cornell ERL High Intensity Photoinjector*
- *Photoemission from III-V Semiconductor Cathodes*
- *Present Status of Coherent Electron Cooling Proof-of-Principle Experiment*
- *On the Frequency Choice for the eRHIC SRF Linac*
- *First Test Results from SRF Photoinjector for the R&D ERL at BNL*
- *Commissioning of the ERL Cryomodule on ALICE at Daresbury Laboratory*

⋮

ERL関係の発表数

- *cERL* *15件*
- *HZB* *12件 (bERLinPro, Multi-turn ERL etc.)*
- *Cornell U.* *8件 (Injector, Cryomodule etc.)*
- *BNL* *6件 (Coherent cooling, Test facility etc.)*
- *JLAB* *3件 (monitor, MEIC electron cooler)*
- *ALICE* *2件 (Cryomodule collaboration, FFAG)*
- *IKP* *2件 (MESA)*
- *BINP* *1件*
- *CERN* *1件*
- *General* *1件*

発表数合計 51件

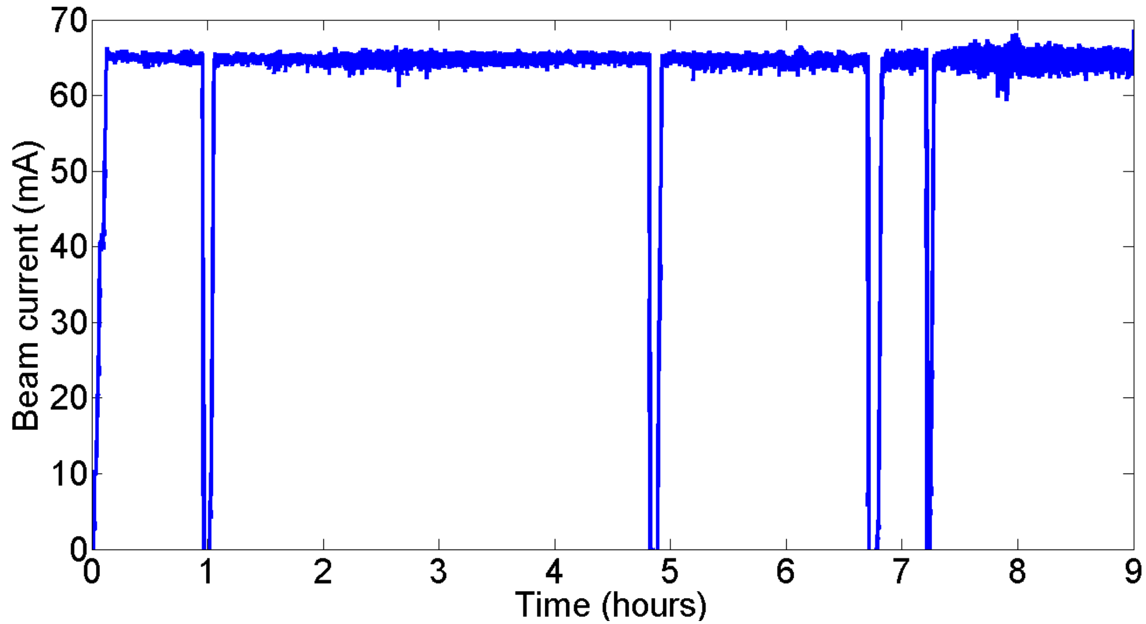
その他興味ある発表

- *The LCLS-II Project*
  John Galayda (SLAC)
- *Status of the Free Electron Laser User Facility FLASH*
  Mathias Vogt (DESY)
- *Control and Application of Beam Microbunching in High Brightness Linac-driven Free Electron Lasers*
  Gennady Stupakov (SLAC)
- *Superconducting RF Guns: Emerging Technology for Future Accelerators*
  Jochen Teichert (HZDR)
- *How to produce 100 Superconducting Modules for XFEL in Collaboration with Industry*
  Hans Weise (DESY)
- *Low Emittance Upgrade for Existing Mid-size Light Sources*
  Seunghwan Shin (PAL)
- *Longitudinal Top-up Injection for Small Aperture Storage Rings*
  Masamitsu Aiba (PSI)
- *First Cavity Design Studies for the BESSY-VSR Upgrade Proposal*
  Axel Neumann (HZB)
- *Update on Sirius, the New Brazilian Synchrotron Light Source*
  Lin Liu (LNLS)
- *ESRF Upgrade Phase II Status*
  Jean-Luc Revol (ESRF)

⋮

以下、主に下記の発表スライドからの抜粋

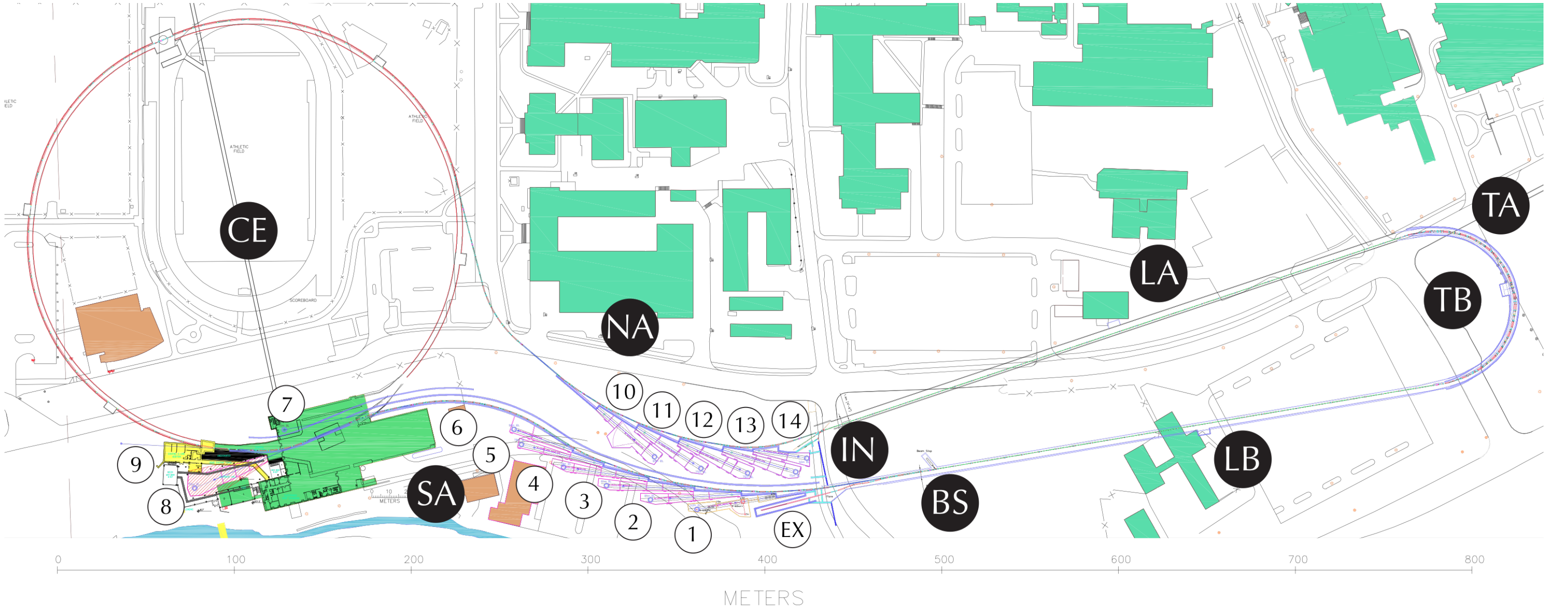
Recent advances in Energy Recovery Linacs

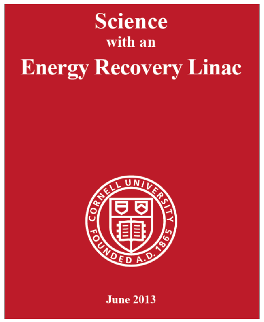


Christopher Mayes – June 20, 2014

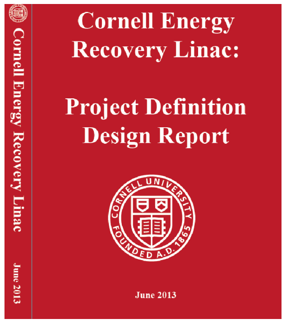
Large ERL Facilities

ERL lightsources: Cornell ERL





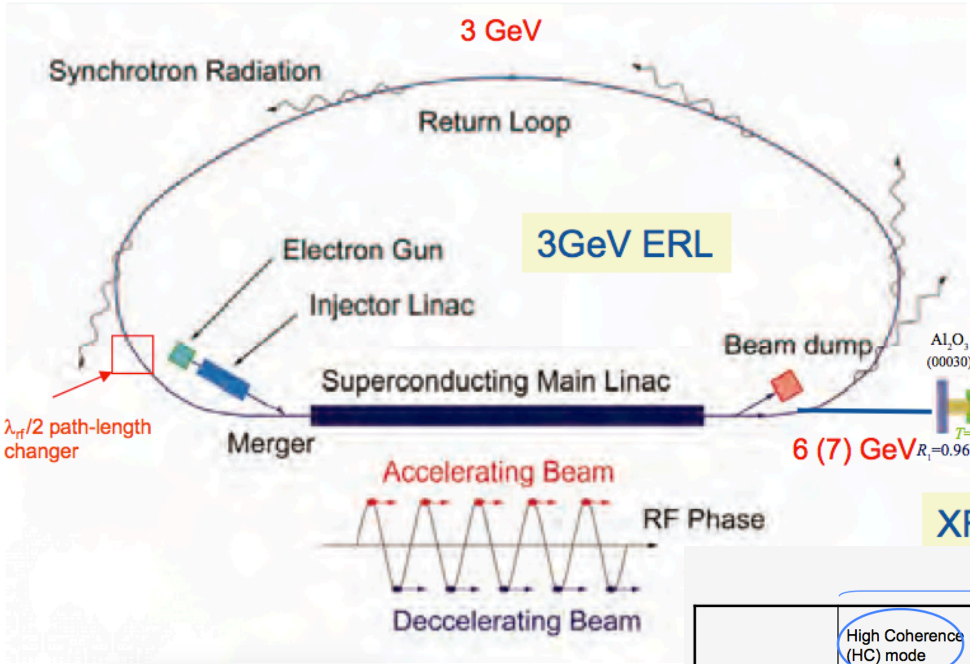
Science case gathered in international workshops

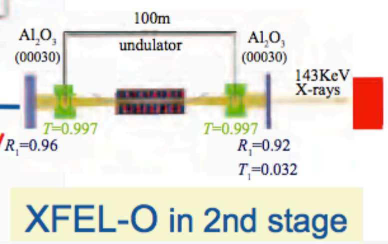


530 page PDDR

Cornell ERL
Project Definition Design Report
(PDDR)
http://www.classe.cornell.edu/ERL

ERL lightsources: KEK

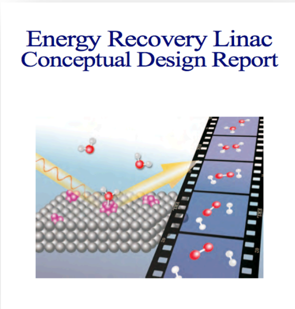




PEARL Photon Factory

次世代放射光源
Energy Recovery Linac

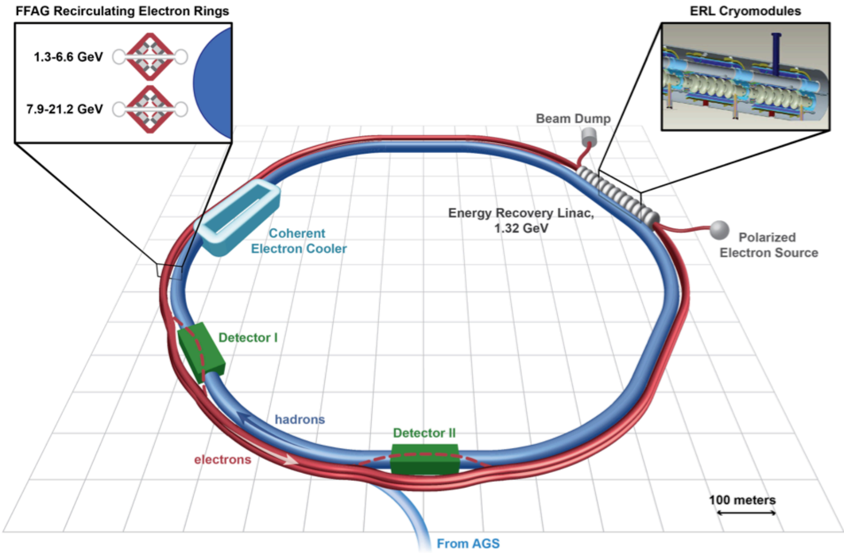
	3 GeV ERL				XFEL-O
	High Coherence (HC) mode	High Flux (HF) mode	Ultimate (UL) mode	Ultra-Short Pulse (US) mode	XFELO mode
Beam Energy	3 GeV				6 - 7 GeV
Beam Current	10 mA	100 mA	100 mA	77 μA (typ.)	10 μA
Bunch Charge	7.7 pC	77 pC	77 pC	77 pC	10 pC
Repetition Rate	1.3 GHz	1.3 GHz	1.3 GHz	1 MHz	1 MHz
Norm. Emittance	0.1 mm·mrad	1 mm·mrad	0.1 mm·mrad	-	0.2 mm·mrad
Emittance	17 pm·rad	170 pm·rad	17 pm·rad	-	15 pm·rad
Energy Spread	2×10^{-4}	2×10^{-4}	2×10^{-4}	-	5×10^{-5}
Bunch Length	2 ps	2 ps	2 ps	≤ 100 fs	1 ps



KEK ERL CDR (2012)

N. Nakamura IPAC12 talk

ERLs for Nuclear Physics - eRHIC



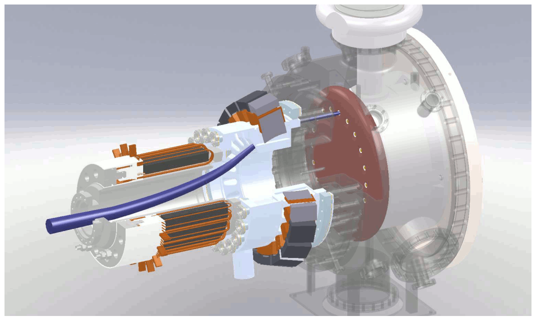
	e	p	$^{2}He^{3}$	$^{79}Au^{197}$
Energy, GeV	15.9	250	167	100
CM energy, GeV		122.5	81.7	63.2
Bunch frequency, MHz	9.4	9.4	9.4	9.4
Bunch intensity (nucleons), 10^{11}	0.33	0.3	0.6	0.6
Bunch charge, nC	5.3	4.8	6.4	3.9
Beam current, mA	50	42	55	33
Hadron rms normalized emittance, 10^{-6} m		0.27	0.20	0.20
Electron rms normalized emittance, 10^{-6} m		31.6	34.7	57.9
β^*, cm (both planes)	5	5	5	5
Hadron beam-beam parameter		0.015	0.014	0.008
Electron beam disruption		2.8	5.2	1.9
Space charge parameter		0.006	0.016	0.016
rms bunch length, cm	0.4	5	5	5
Polarization, %	70	70	70	none
Peak luminosity, 10^{33} cm^{-2}s^{-1}		1.5	2.8	1.7

21.2 GeV (16 passes) : 18 mA
15.9 GeV (12 passes) : 50 mA
=> 12 MW SR power

Linac: 1.32 GeV
422 MHz cavities
120 m cold length
no quadrupoles
1.2 A total current

Two FFAG arcs

Injection at 12 MeV



[courtesy of V. Litvinenko]

ERLs for High-Energy Physics - LHeC

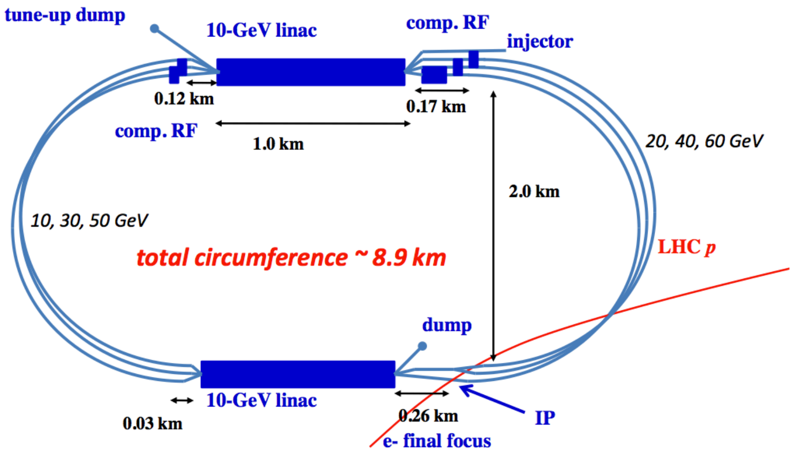
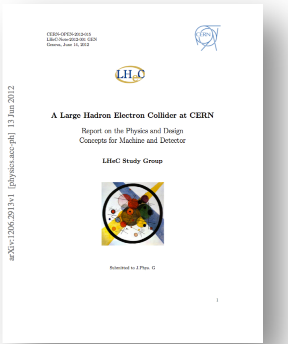


Figure 7.5: LHeC ERL layout including dimensions.

LINAC Parameters for the Linac-Ring Option		
Operation mode	**CW**	**Pulsed**
Beam Energy [GeV]	60	140
Peak Luminosity [$cm^{-2}s^{-1}$]	10^{33}	$4x10^{31}$
Cavity gradient [MV/m]	20	32
RF Power Loss [W/cavity]	13-37	11
W per W (1.8K to RT)	700	700
Cavity Q_0	$2.5x10^{10}$	$2.5x10^{10}$
Power loss/GeV	0.51-1.44	0.24
RF length [km]	2	7.9
Total length [km]	9	7.9
Beam current [mA]	6.4	0.27
Repetition rate	-	10 Hz
Pulse length	-	5ms

Bruening – IPAC13 MOZB201

Designed for 100 MW wall-plug power
6.4 mA, but could be raised 12+ mA



A Large Hadron Electron Collider at CERN: Report on the Physics and Design Concepts for Machine and Detector - J. L. Fernandez et al.

ERL-Ring and Ring-Ring studies - 600 pages
http://arxiv.org/abs/1206.2913

January 2014 workshop

Critical Components

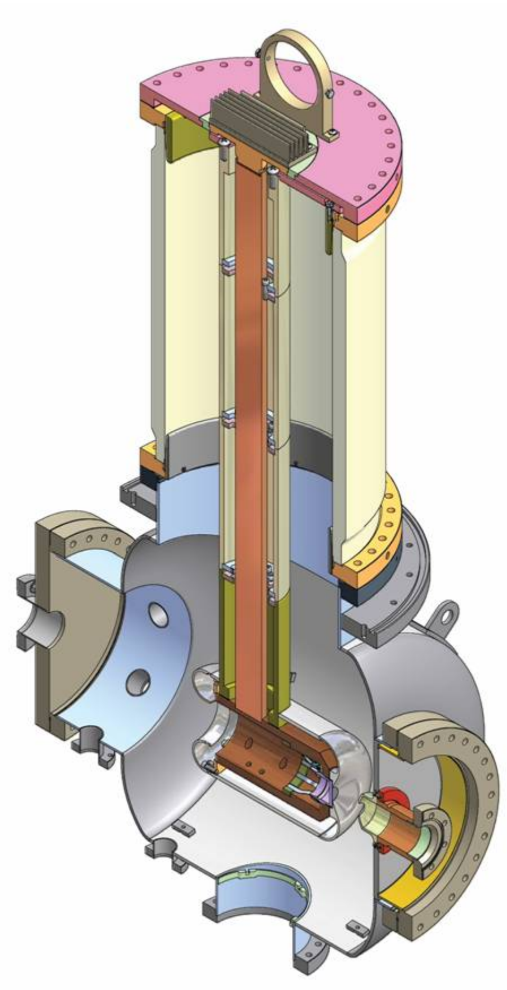
Source

Injector

Linac

Beam Transport

Insertion Devices



Cathode Engineering

L. Cultrerea, IPAC14: MOZB02

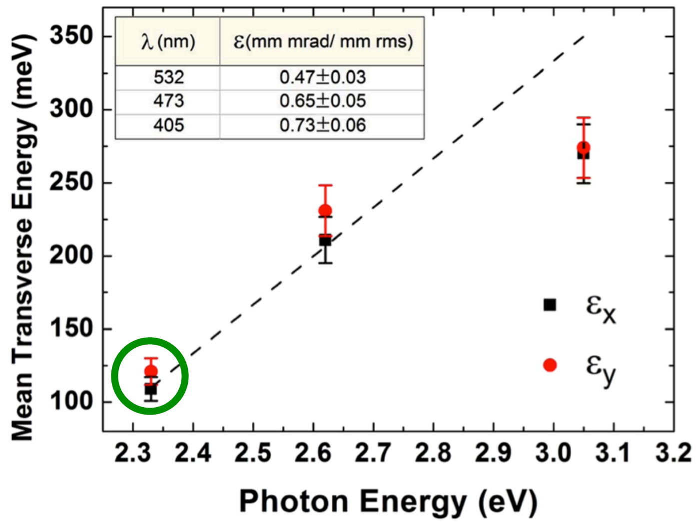
Want:
Low $\mathcal{E}_{\text{thermal}}$
Good Quantum Efficiency (> 1%)
(QE: electron yield per photon)
Long lifetime (many hours)

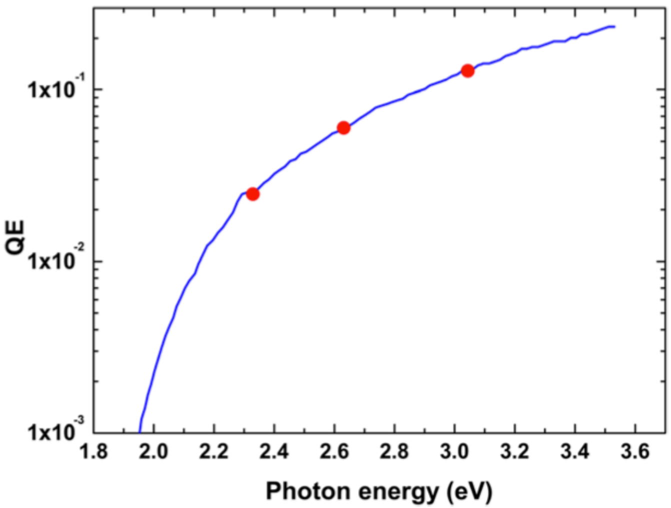
<u>GaAs</u>
lowest thermal energy of any known cathode
25 meV at 800 nm (IR), QE 1%
120 meV at 520 nm (green), QE 10%
(also can produce polarized electrons)

Alkalai antimonide: <u>CsK_2Sb</u>, <u>NaKSb</u>
widely used in photomultiplier devices
100's meV in visible, QE of a few %
Robust
Record sustained currents (65 mA)

<u>NaKSb Measurement</u>

$\mathcal{E}_{\text{thermal}}$



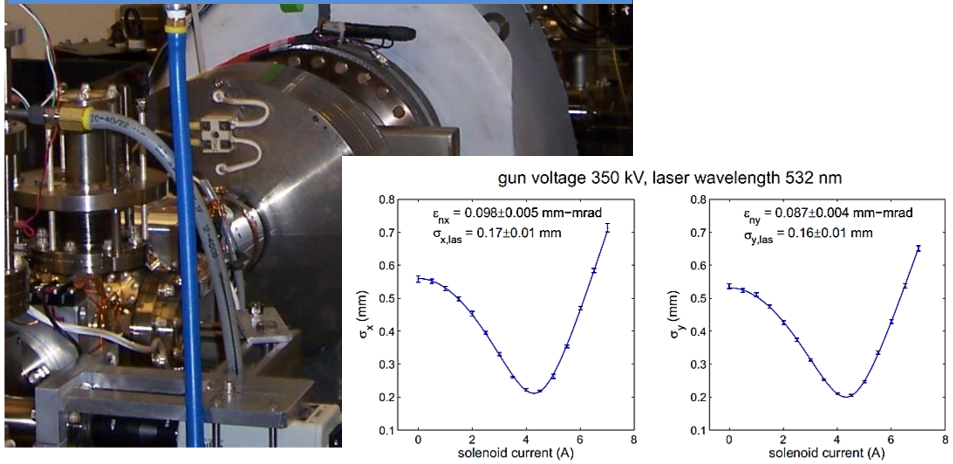


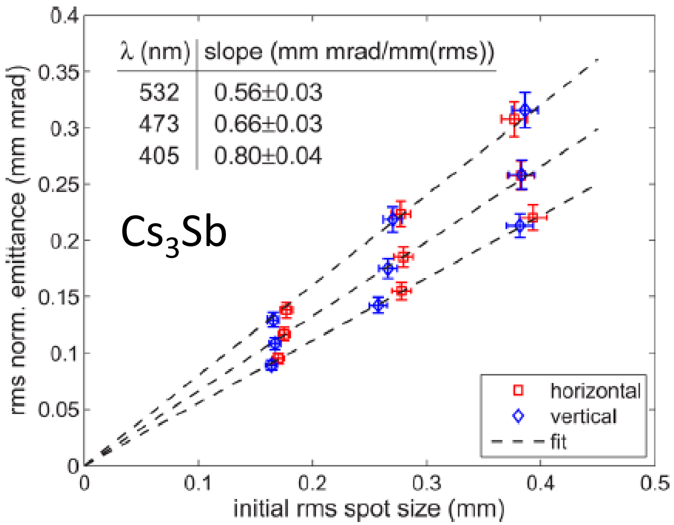
Cultrera et al., Appl. Phys. Lett. **103**, 103504 (2013)

Antimonides MTEs

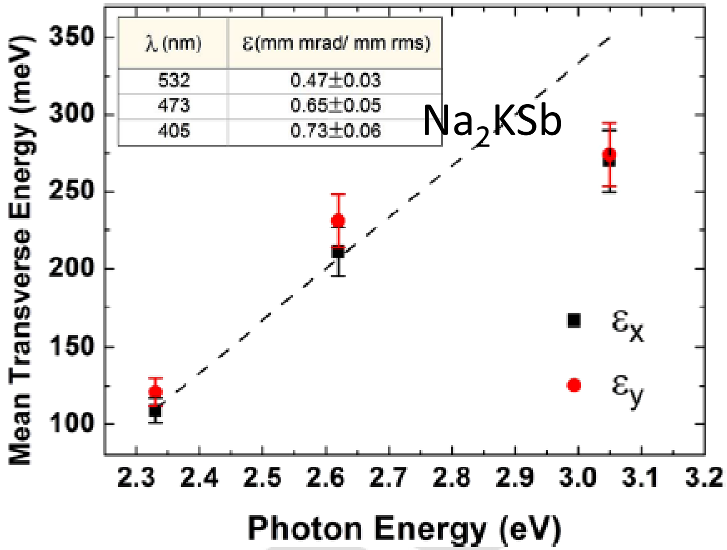
onference
, Germany

Measured in HV DC gun using solenoid scan

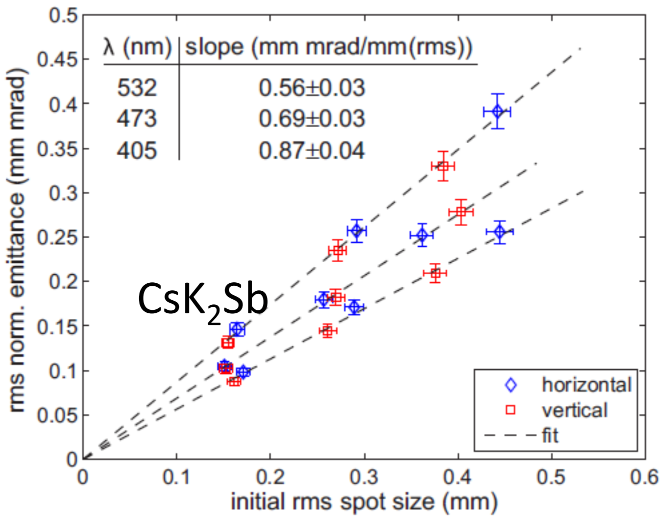




L. Cultrera et al., *Appl. Phys. Lett.* 99 (2011) 152110

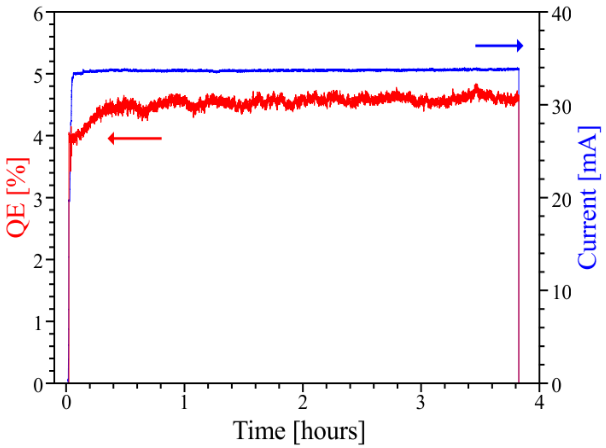


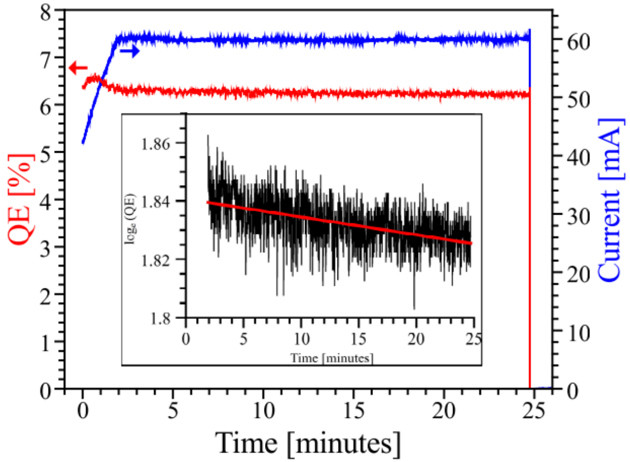
L. Cultrera et al., *Appl. Phys. Lett.* 103 (2013) 103504

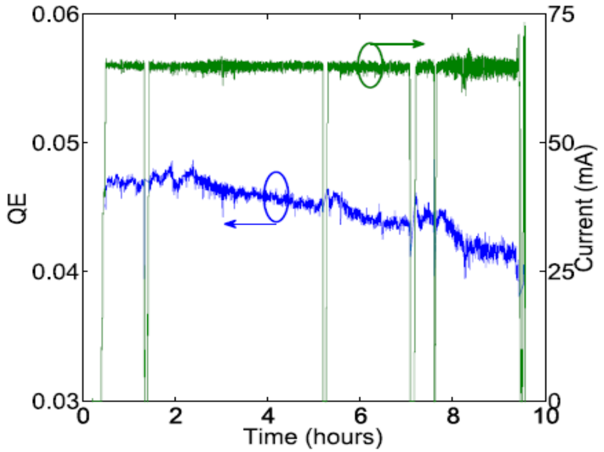


I. Bazarov et al., *Appl. Phys. Lett.* 98 (2011) 224101

High current lifetime







Cs_3Sb
QE @ 520 nm 4%
Max AVG current **33 mA**
Lifetime >> 500 C
NO QE DECAY

Cs_2KSb
QE @ 520 nm 6.5%
Max AVG current **60 mA**
Lifetime >> 2000 C
1/e QE 30 hr

Na_2KSb
QE @ 520 nm 4.5%
Max AVG current **65 mA**
Lifetime >> 2000 C
1/e QE 66 hr

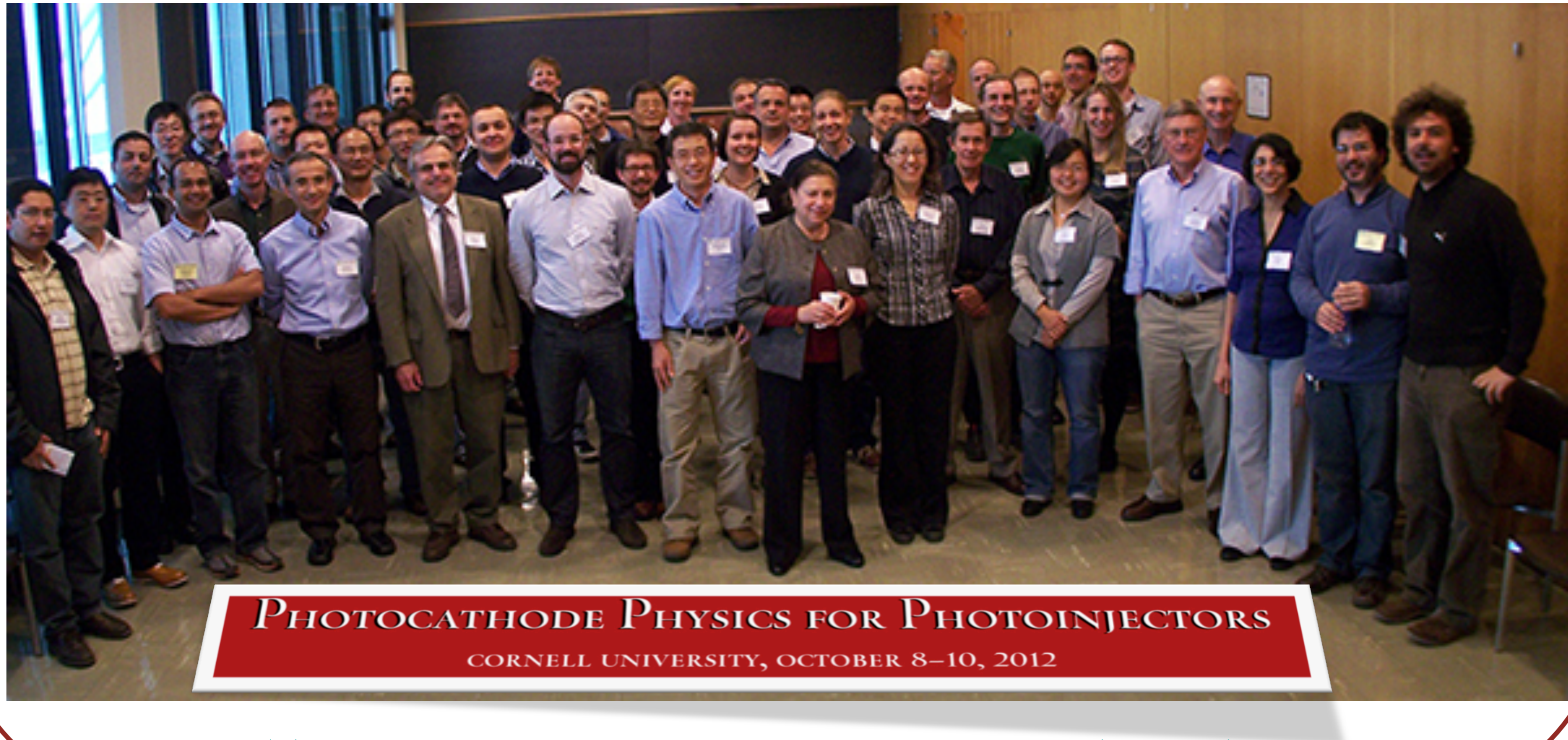
Alklai antimonide based photocathode have been extensively tested in DC gun of the ERL injector prototype at Cornell University. MTEs, response time, QEs and lifetimes at high current are **compatible with the operation of an ERL user facility.**

B. Dunham et al., *Appl. Phys. Lett.* 102 (2013) 034105

L. Cultrera et al., *Appl. Phys. Lett.* 103 (2013) 103504

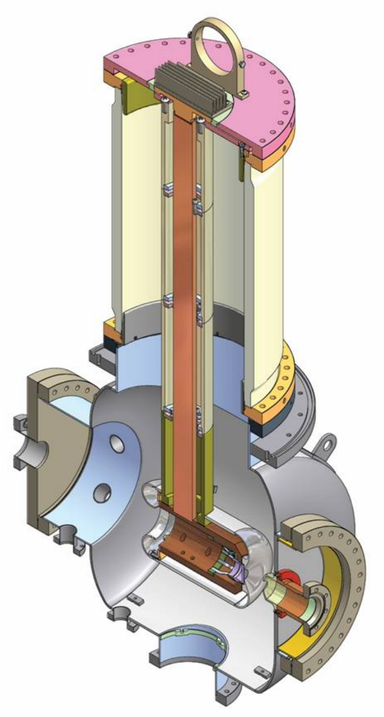
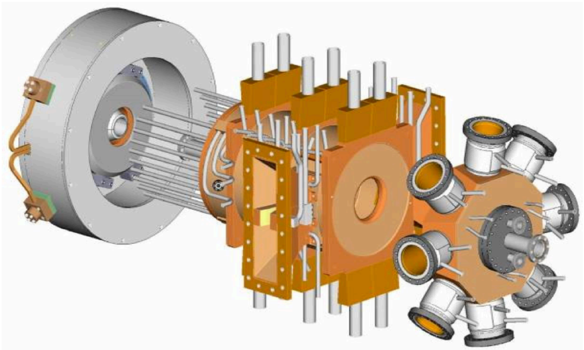
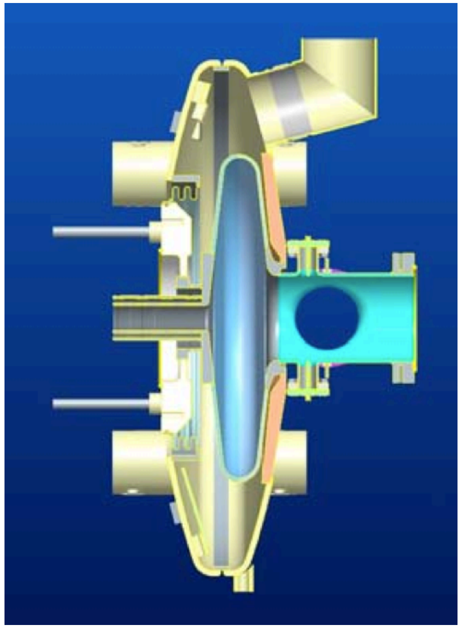
Photocathode Wiki

P3 workshop at Cornell (Oct 2012), wiki website for photocathodes, fostering national and international collaborations on theory/modeling and MBE grown samples, and more…



http://photocathodes.chess.cornell.edu/wiki/Main_Page

High-Current, low emittance Guns

DC	NCRF	SRF
		
Cornell 500 kV DC Gun	LANL 700 MHz NCRF Gun	BNL 704 MHz SRF Gun

Superconducting RF (SRF) Guns

J. Teichert, IPAC14: MOZB01

SRF

High fields on cathode (10-20 MV/m)
(but bunch must be accelerated off-crest, 30 degrees)
-> higher charge/area

High net accelerating voltage
(+2 to +9 MeV, dependent on the number of cells)

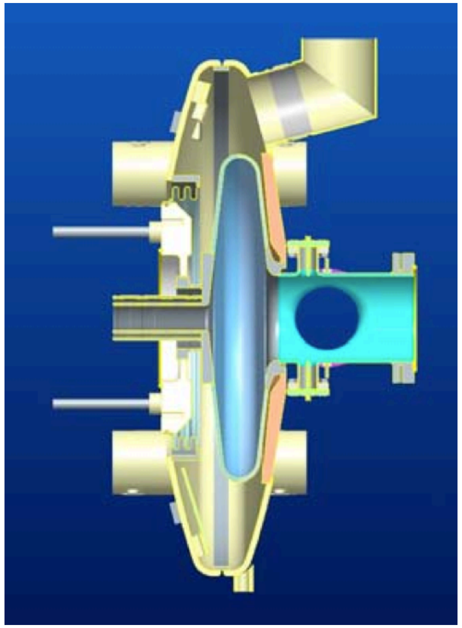
Can suffer from field emission
(contamination from cathode insertion)

Difficulty pumping in RF power for high currents

Record: 0.4 mA at Rossendorf

Developed for:

- eRHIC (BNL) (300 mA)
- BERlinPro (HZB) (100 mA)
- ELBA (Rossendorf) (<10 mA)
- PKU (8 mA)



BNL 704 MHz SRF Gun

Normal-Conducting RF Guns (NCRF)

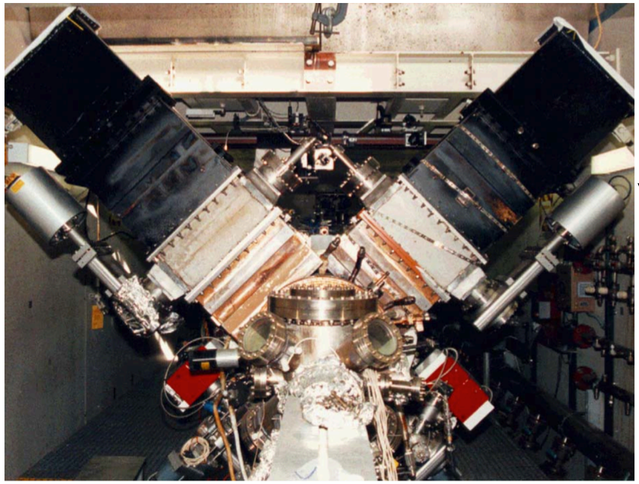
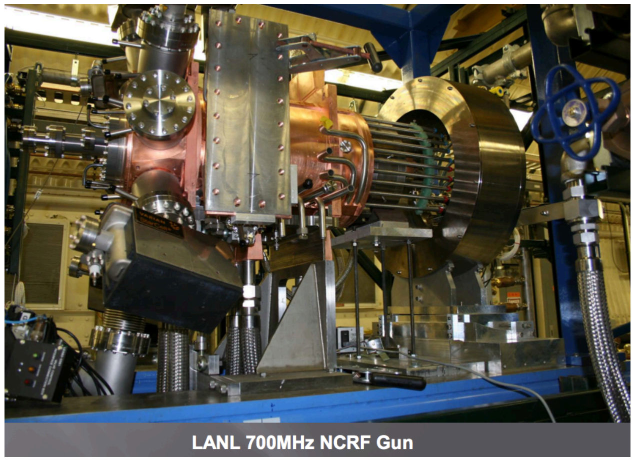


Fig. 1. Photograph of the Boeing/LANL 433 MHz NCRF gun in the test vault.

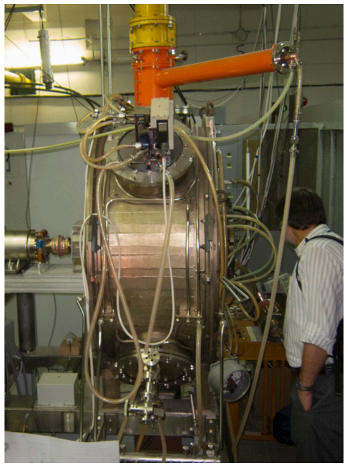
Dowell et al., Appl. Phys. Lett. 63, 2035 (1993)

Boeing/LANL 433 MHz gun held
record 32 mA at 5 MeV in 1993

Very high-field on cathode for pulsed operation:
>100 MV/m LCLS gun
Moderate fields for CW operation:
10 MV/m for the LANL/AES gun
Difficulty cooling at CW
Limited to alkali cathodes because of poor vacuum



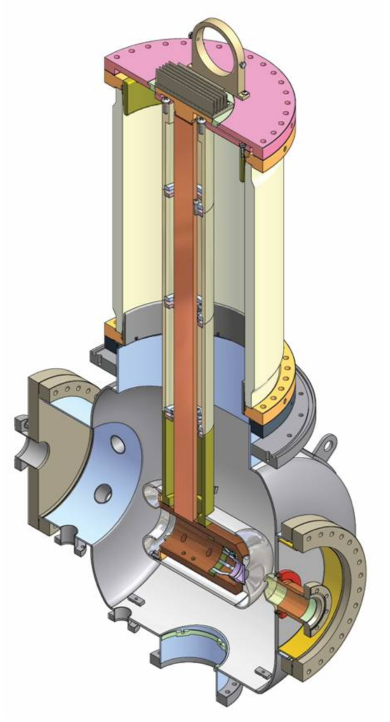
LANL 700 MHz NCRF Gun



BINP (Novosibirsk) 130 MHz Gun

Developed at:
- BINP (30 mA)
- LANL
- Berkeley (1 mA)

Direct-Current (DC) Guns



Moderate fields on cathode (4-7 MV/m)
Compatible with any type of cathode
Any repetition rate
Any average current
Bunch charges < a few hundred pC
Reliable, proven design (developed at SLAC, Jlab)

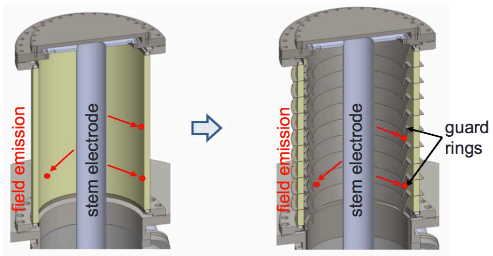
Relatively inexpensive

Potential problems with insulator at high voltages
newer guns use guard rings

New current record-holder …

Used and developed at:
Cornell
JLab
KEK
JAEA
ALICE (Daresbury)
IHEP (Beijing)

Improvements



Critical Components

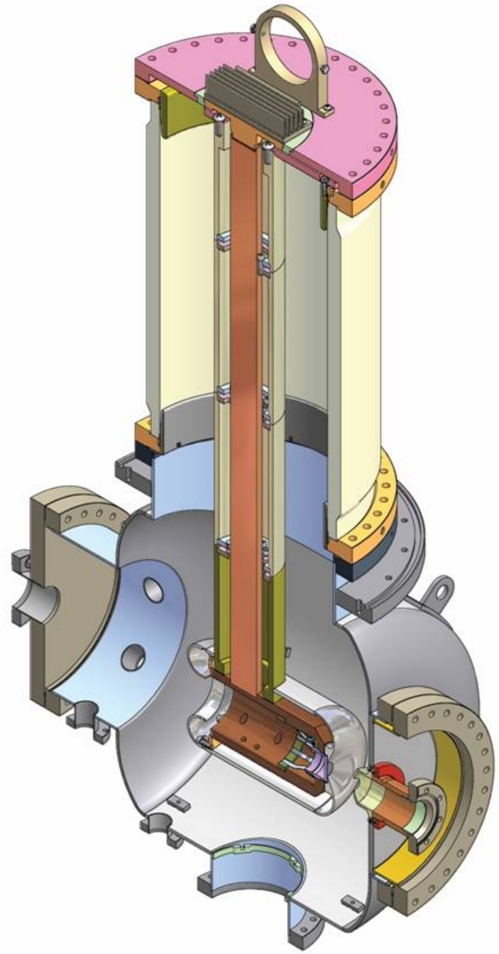
Source

Injector

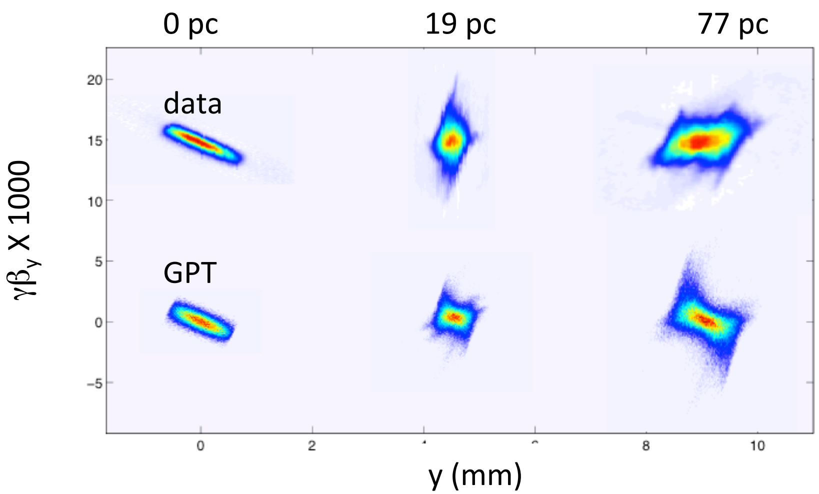
Linac

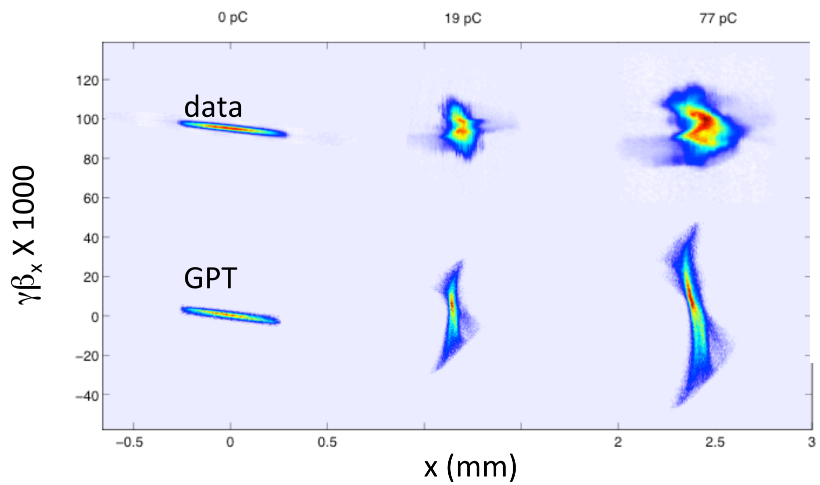
Beam Transport

Insertion Devices



Phase space measurements and simulation





Projected Emittance for 19 (77) pC at 8 MeV:

$$(y, p_y)$$

Data Type	enorm(100%) [mm-mrad]	enorm(90%) [mm-mrad]
Projected (EMS)	0.20 (0.40)	0.14 (0.29)
GPT	0.16 (0.37)	0.11 (0.25)

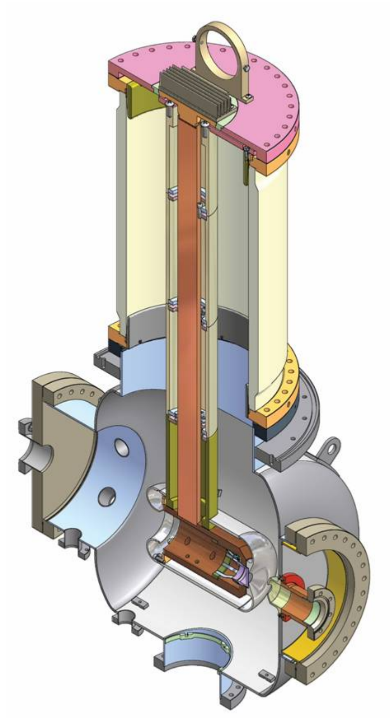
$$(x, p_x)$$

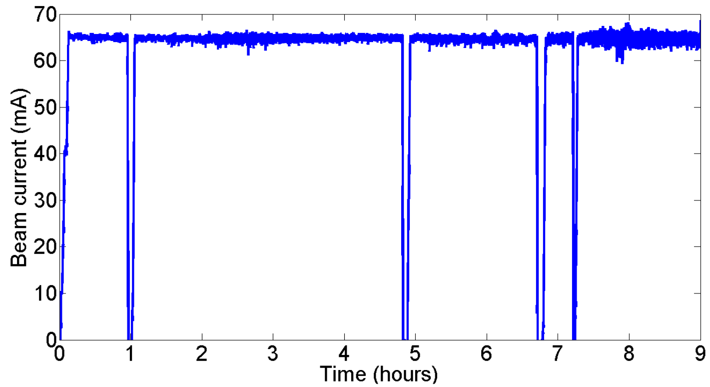
Data Type	enorm(100%) [mm-mrad]	enorm(90%) [mm-mrad]
Projected (EMS)	0.33 (0.69)	0.23 (0.51)
GPT	0.31 (0.72)	0.19 (0.44)

Gulliford et al., Phys. Rev. ST Accel. Beams 16, 073401 (2013)

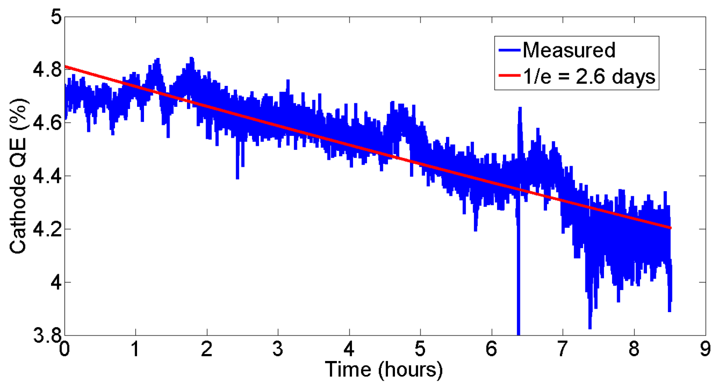
Cornell Injector Record Current at 4 MeV

Highest current ever NaK_2Sb Cathode: 75 mA, 65 mA sustained





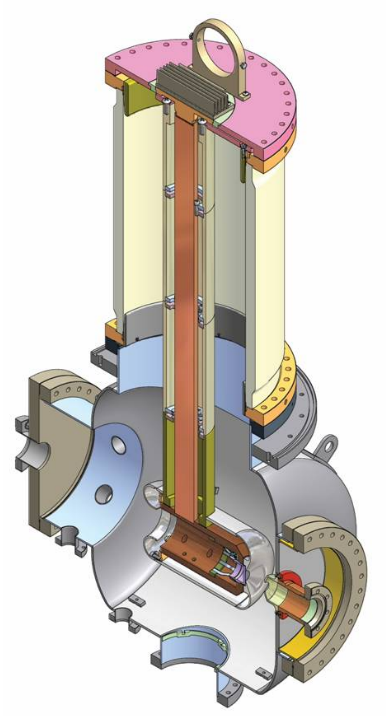
May 24, 2013



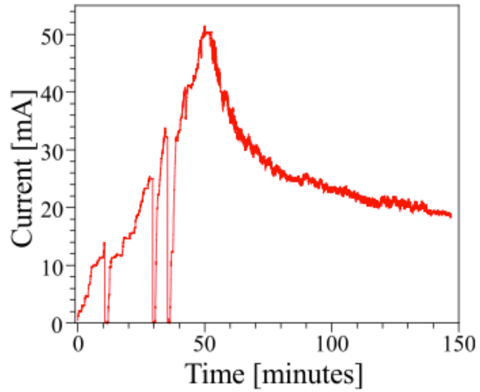
Dunham et al., Appl. Phys. Lett., 102, 034105 (2013)

Cornell Injector Record Current at 4 MeV

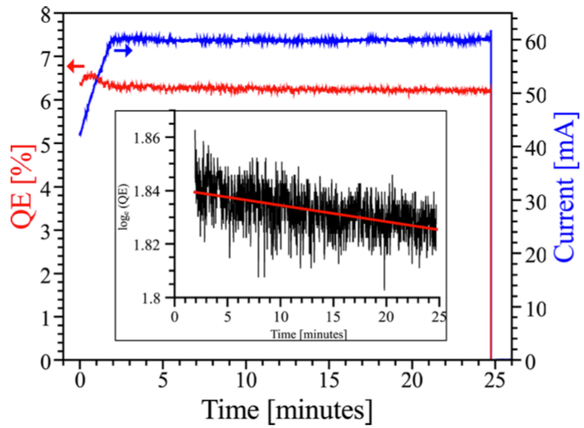
More records:



GaAs: 52 mA



CsK_2Sb: 60 mA



Dunham et al., Appl. Phys. Lett., 102, 034105 (2013)

Critical Components

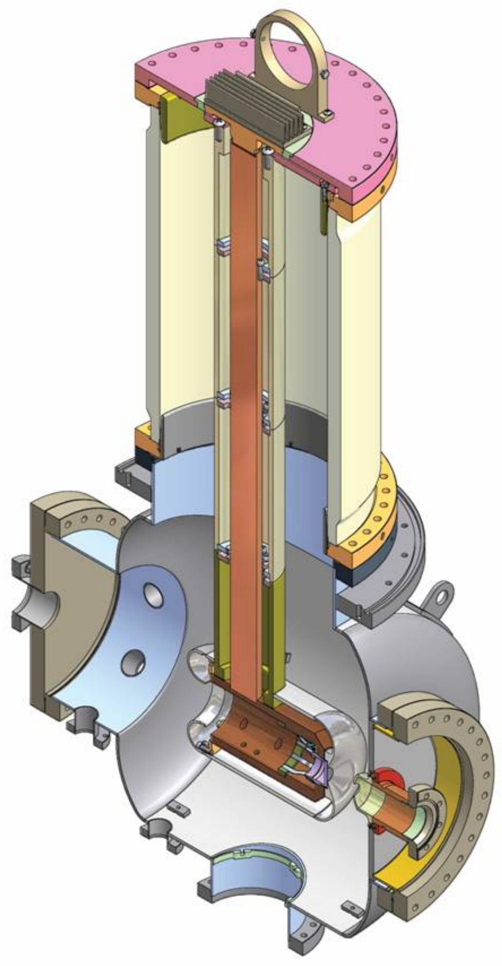
Source

Injector

Linac

Beam Transport

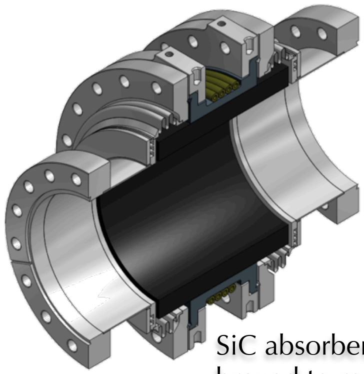
Insertion Devices



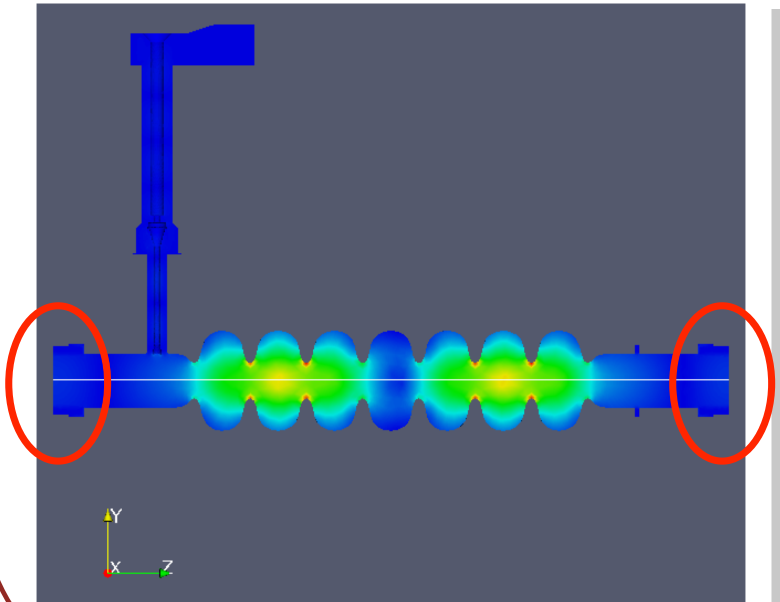
Add HOM Absorbers

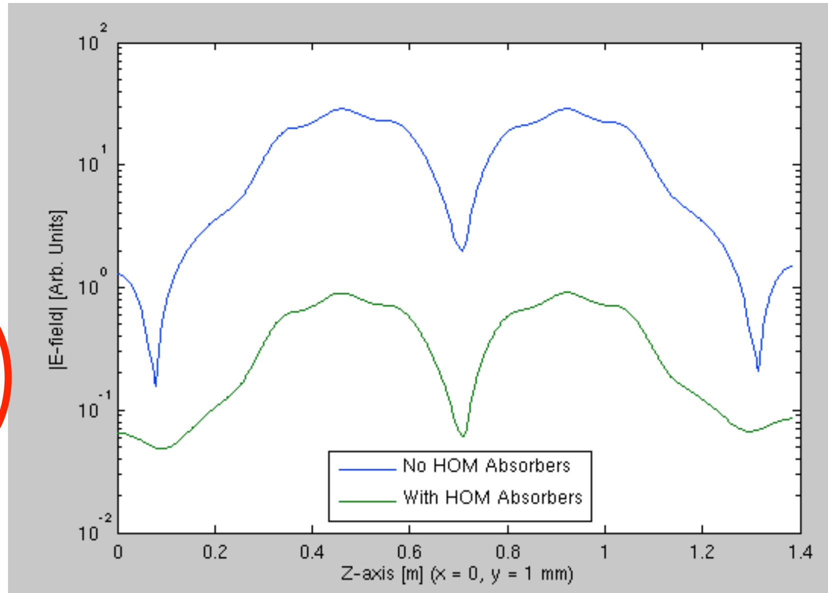
Example HOM at 1612.4604 Hz
Q without absorber: $Q = 5.49 \times 10^6$
Q with absorber: 5.38×10^3

Other methods: HOM antennas
(BNL, KEK)



SiC absorber ring
brazed to metal ring

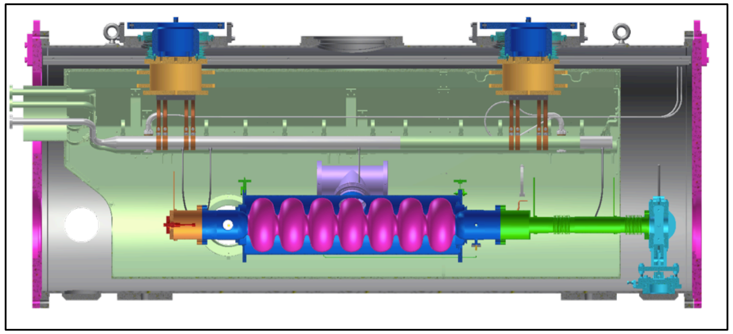




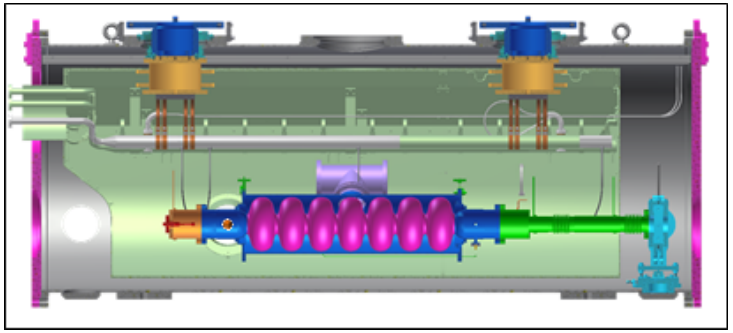
[Courtesy of N. Valles]

Cornell Horizontal Test Cryomodule (HTC)

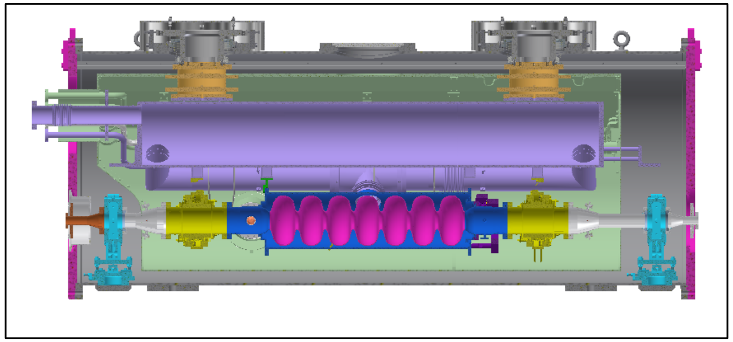
- HTC-1: Follow vertical assembly procedure as closely as possible



- HTC-2: Include side mounted, High-power input coupler

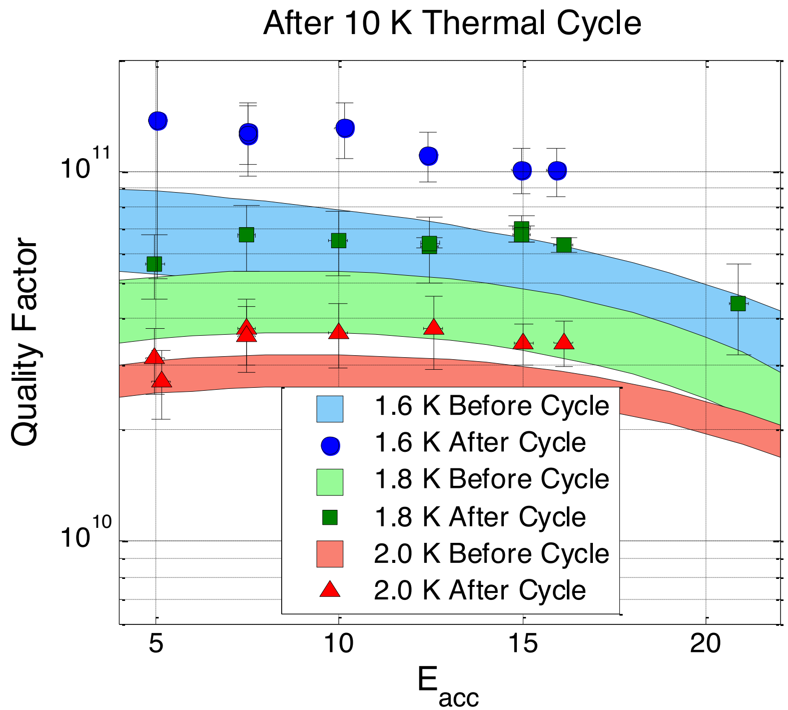


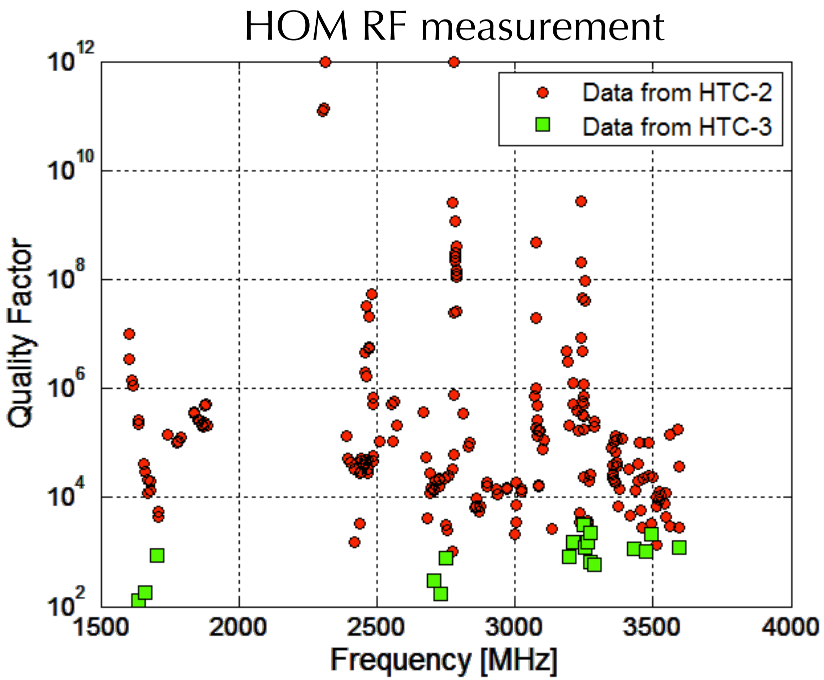
- HTC-3: Full cryomodule assembly-high power RF input coupler and HOM absorbers



HTC-3: Cavity + Coupler + HOM Absorbers

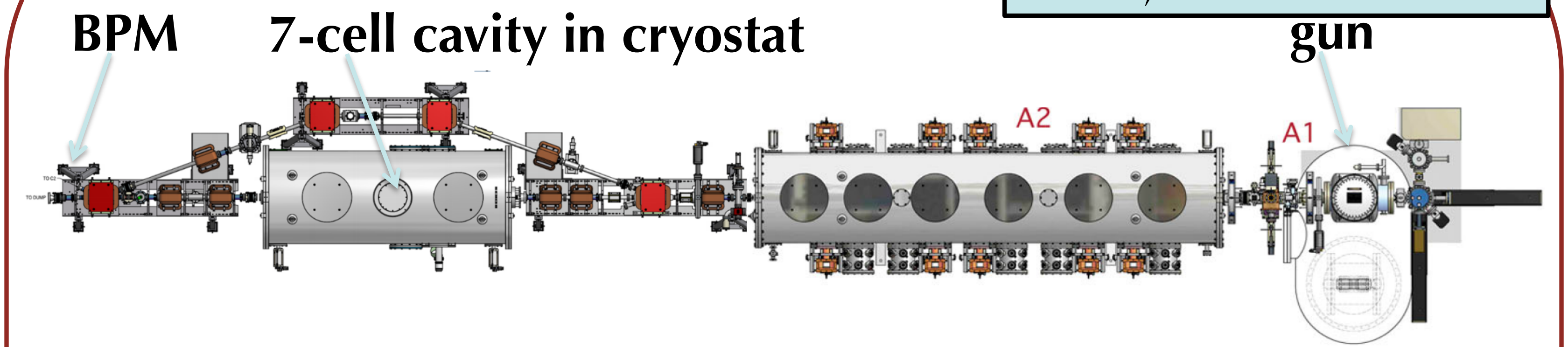
New Record in a horizontal cryomodule:
$\mathbf{Q_0 > 10^{11}}$ (at 16.2 MV/m, 1.6 K)

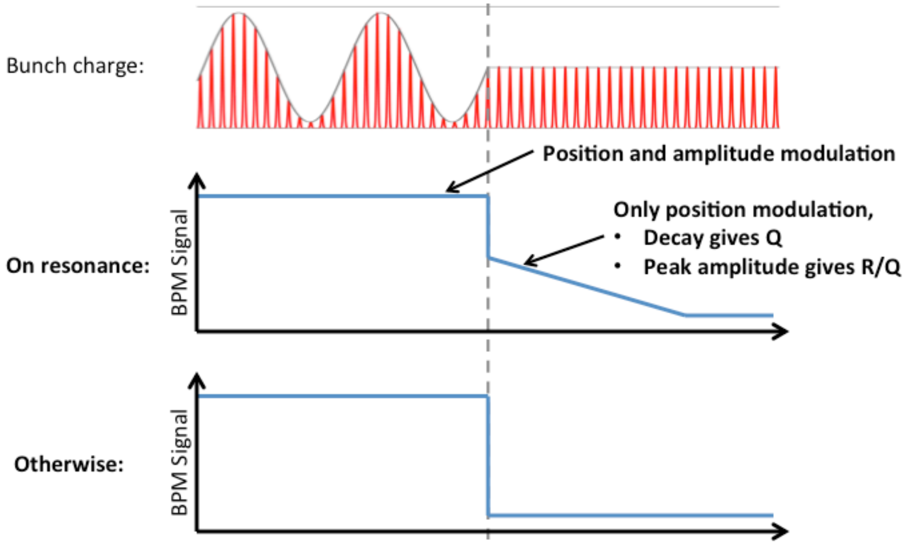


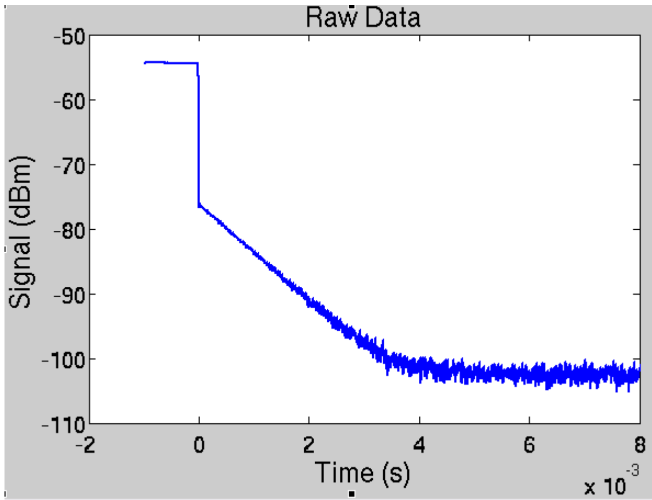


HTC HOM measurement with beam

D. Hall, IPAC14: MOPRO113



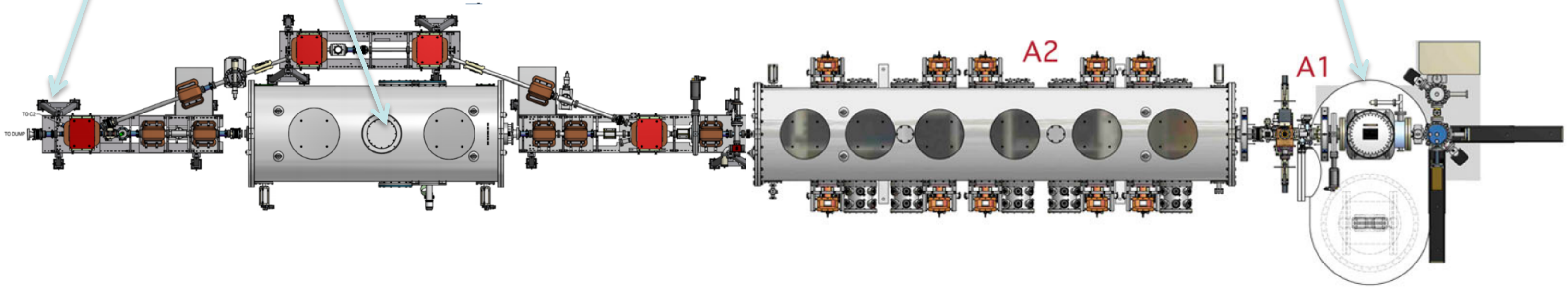




Data was taken December 2013, currently being analyzed…

HTC High current tests with beam (40 mA)

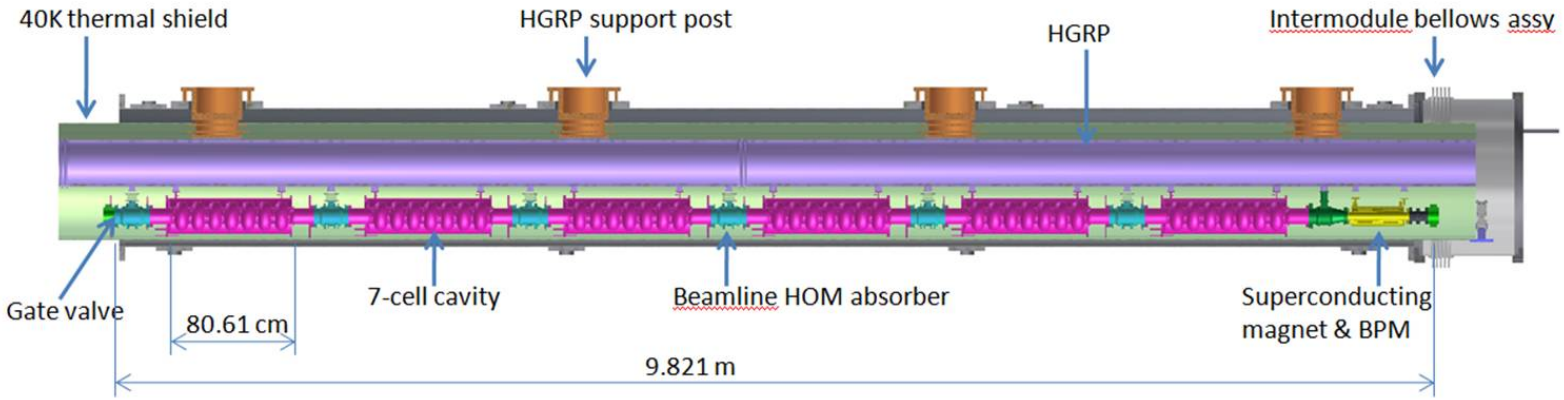
R. Eichhorn IPAC14: THPRI111



Current, bunch length	ΔT (beam pipe behind Abs.) coated/uncoated	ΔT (80K gas temp) coated/uncoated	ΔT (80K absorber temp) coated/uncoated	ΔT (5K flange next to cavity) coated	ΔT, beam pipe to cavity coated/uncoated
25 mA, 3.0 ps	0.075/0.075	1.14/0.82	1.02/0.975	0.007	0.076/-.005
40 mA, 3.4 ps	0.2475/0.335	2.95/2.16	2.72/2.53	0.021	0.179/0.009
40 mA, 2.7 ps	0.2975/0.425	3.00/2.22	2.772/2.63	0.027	0.203/0.014

- No charge-up of the HOM ceramics observed
- HOM heating was less than expected

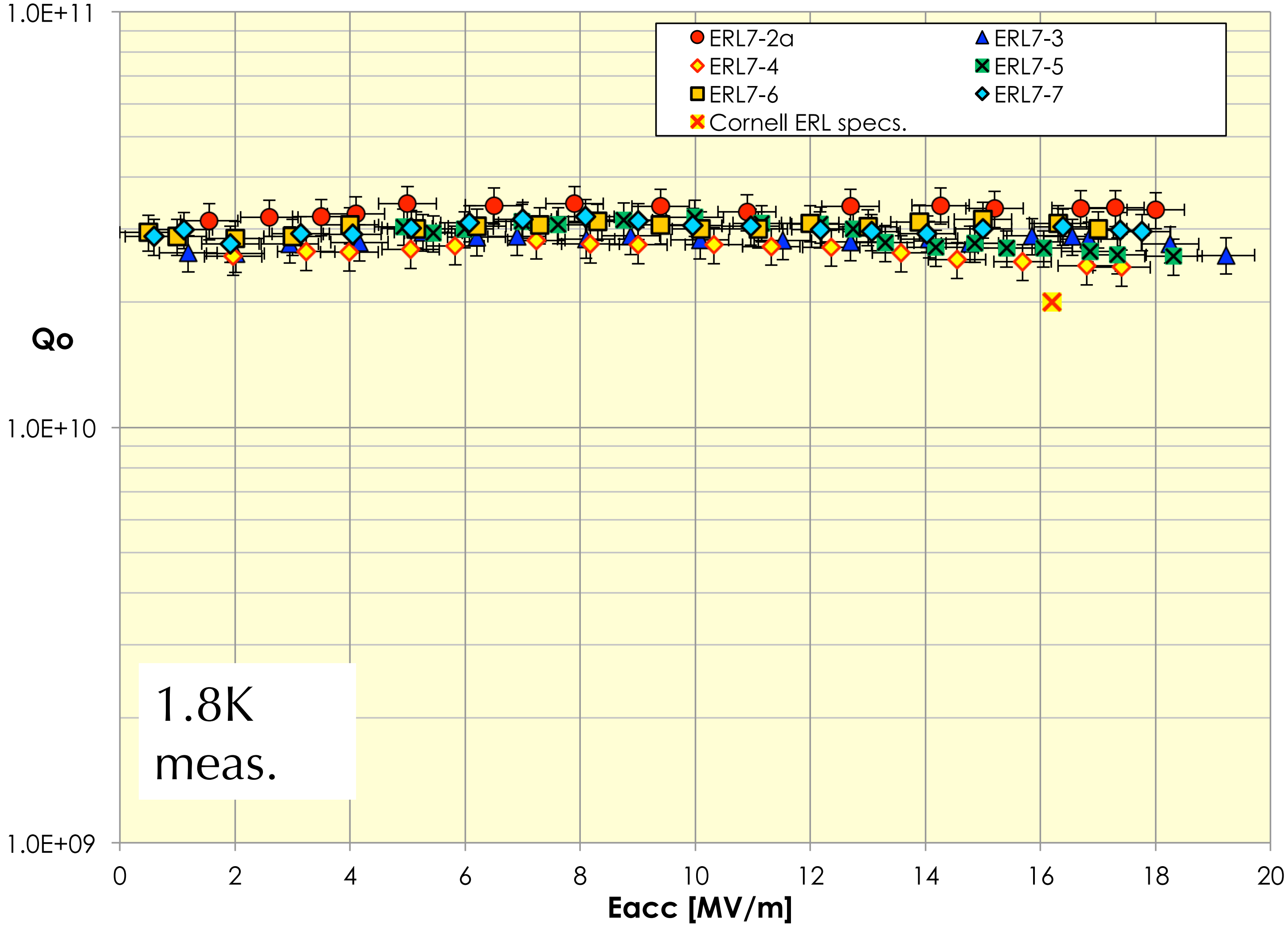
Cornell ERL Main Linac Cryomodule (MLC) Prototype



- Completed fabrication and RF test of 6 main linac SRF cavities
  - Statistics of high Q_0 cavity preparation
- Fabrication of full ERL main linac prototype cryomodule
  - Fabrication of input couplers, tuners, beamline HOM absorbers, cryomodule components…
  - January 2014: Started string assembly
  - June 2014: Start cold mass assembly June
  - End 2014: completion

First high current (>100 mA), CW SRF linac cryomodule worldwide!

Cornell Main Cryomodule cavity tests (Vertical)



Existing ERL Facilities

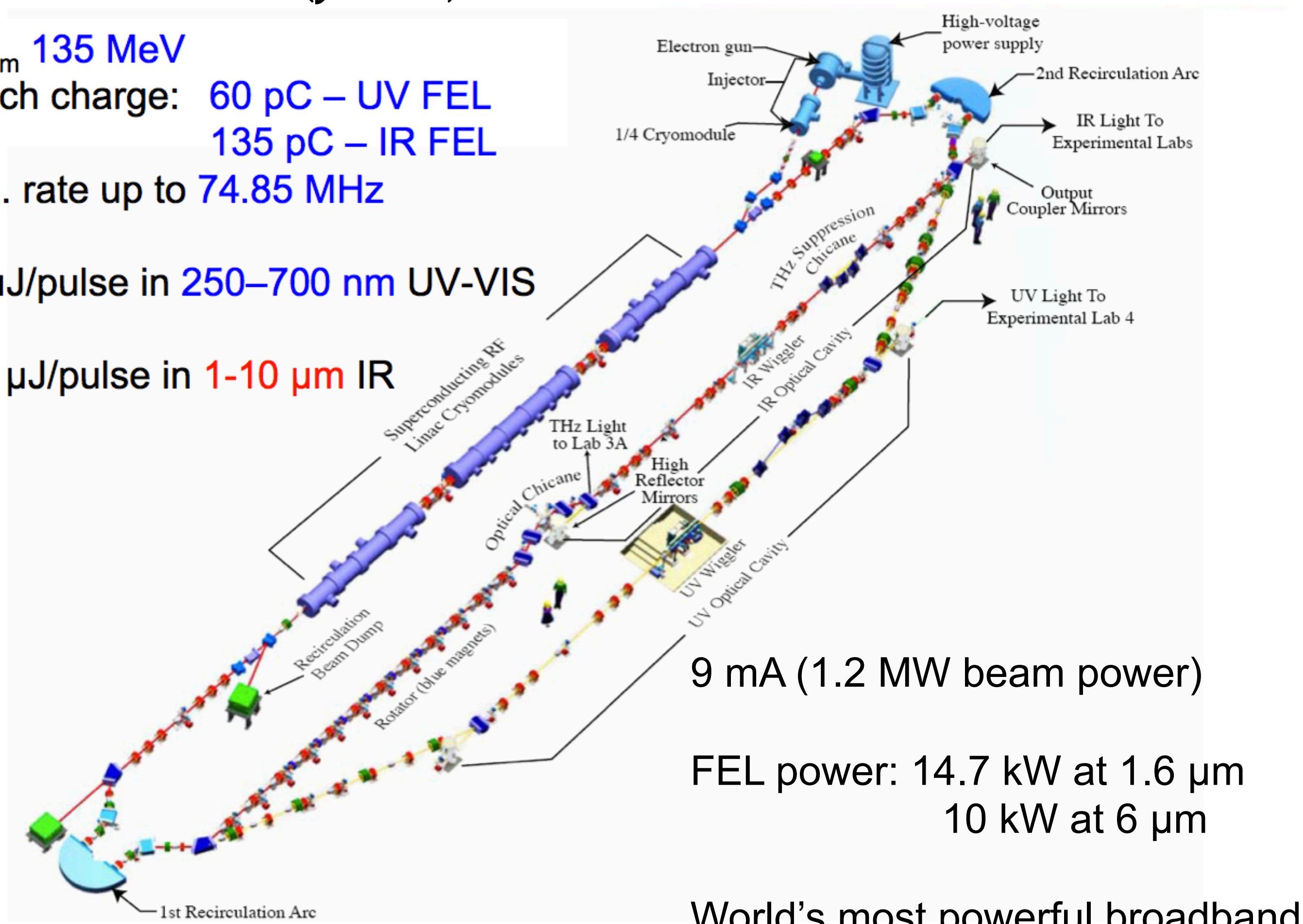
UV / IR FEL (JLab)

E_{beam} 135 MeV
Bunch charge: 60 pC – UV FEL
135 pC – IR FEL

Rep. rate up to 74.85 MHz

25 µJ/pulse in 250–700 nm UV-VIS

120 µJ/pulse in 1-10 µm IR



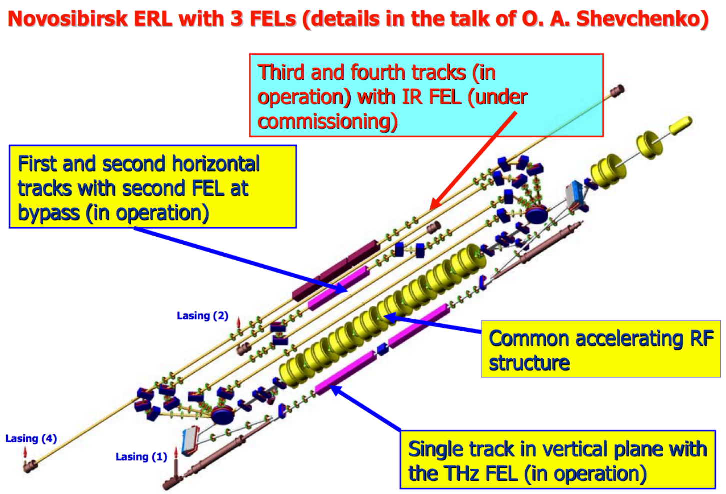
9 mA (1.2 MW beam power)

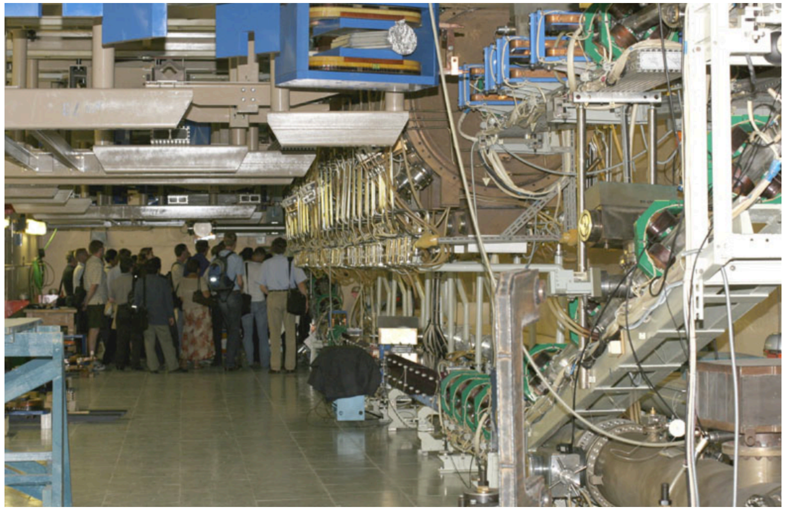
FEL power: 14.7 kW at 1.6 µm
10 kW at 6 µm

World's most powerful broadband THz source, 100 W

Neil et al., NIM-A 557 1 9–15 (2006)

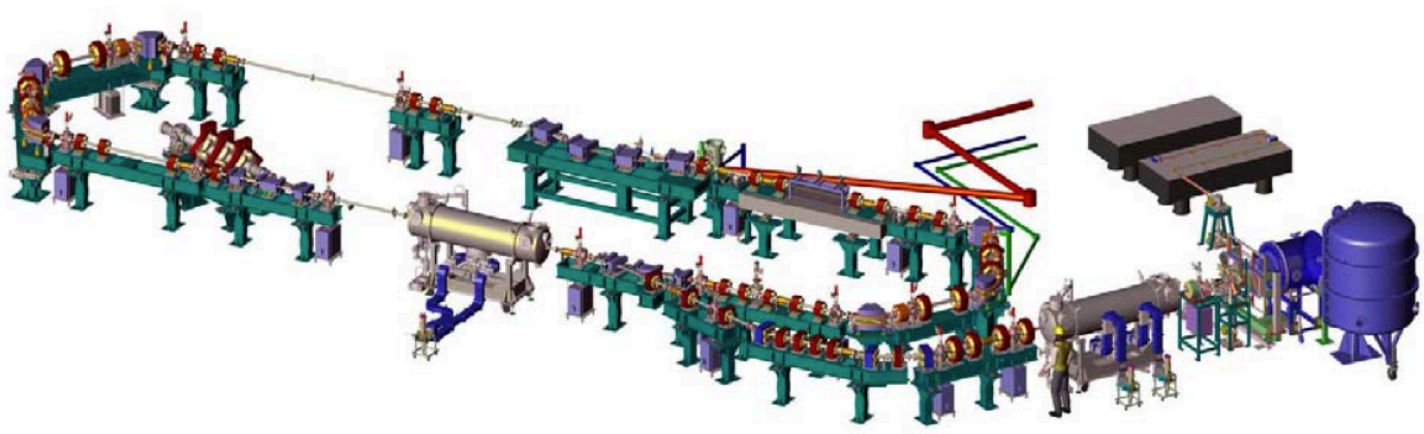
Novosibirsk ERL-FEL

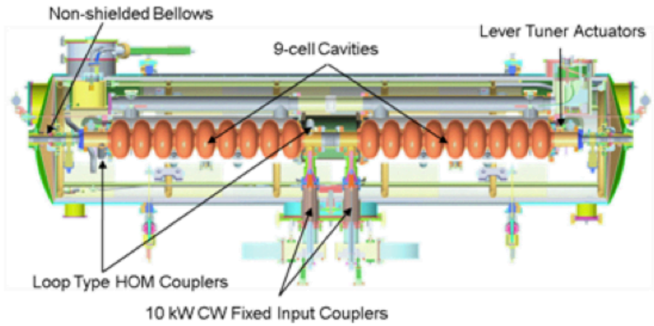




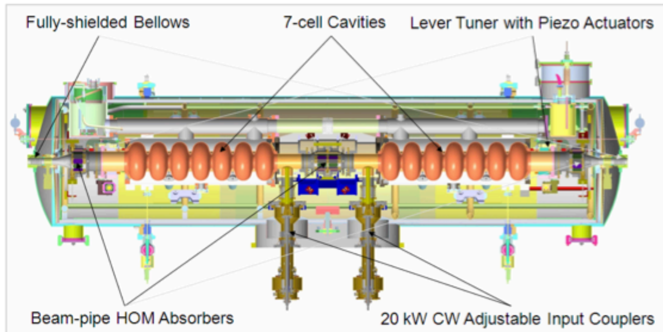
NovoFEL ERL13 presentation

ALICE (Daresbury)





Existing Cryomodule on ALICE



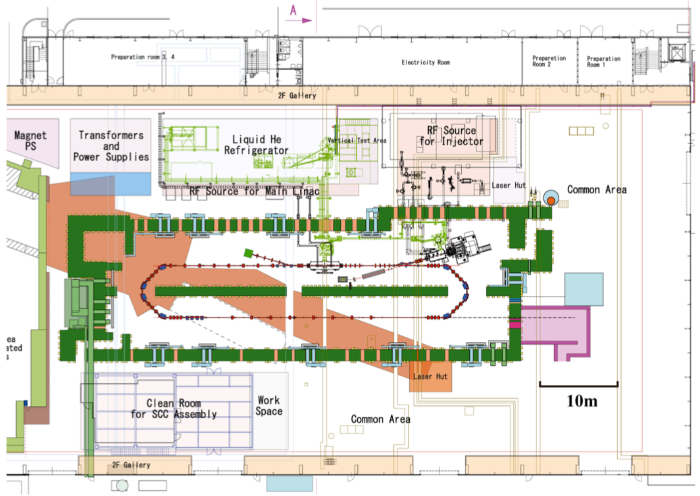
CW-ERL Cryomodule

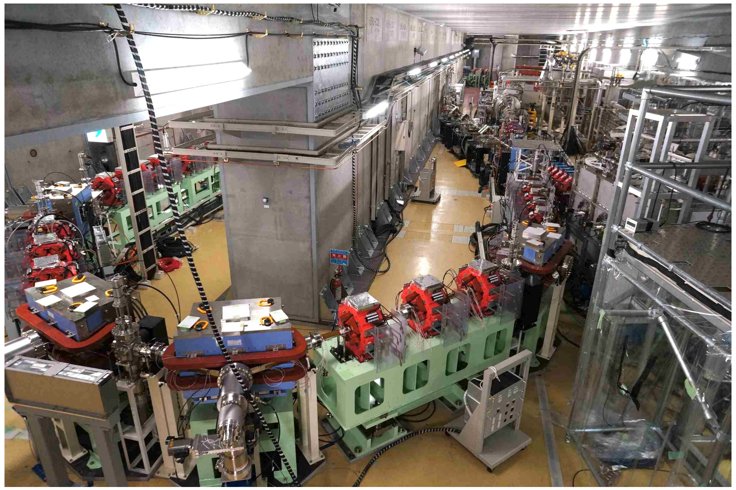
Jones et al., AIP Conf. Proc. 1149, 1084 (2009)

New ERL Facilities

Compact ERL (KEK)

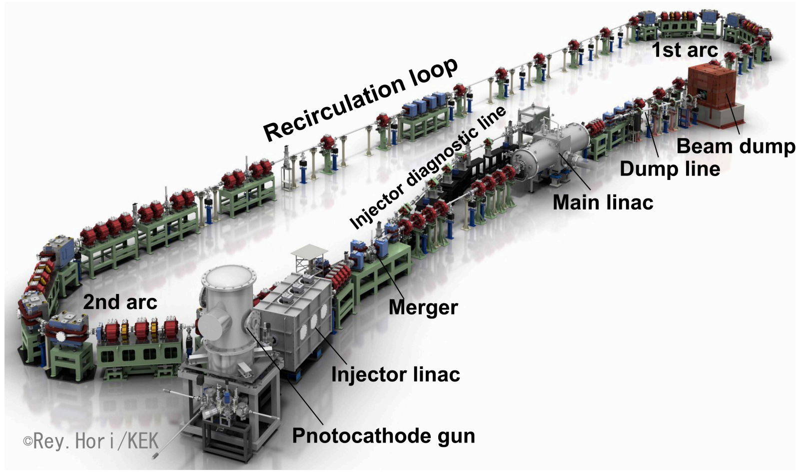
Beam energy	35 - 125 MeV (single loop) 245 MeV (double loop)
Injection energy	5 MeV
Average current	10 mA (100 mA in future)
Acc. gradient	15 MV/m
Normalized emittance	0.1 mm·mrad (7.7 pC) 1 mm·mrad (77 pC)
Bunch length	1 - 3 ps 100 fs (with bunch compression)
RF frequency	1.3 GHz





Nakamura IPAC12 - TUXB02

Compact ERL (KEK)



Purpose

- Demonstrate the generation and recirculation of ultra-low emittance beams
- Demonstrate reliable operations of ERL components (photocathode gun, SC cavities, ...)
- Initial goal: 1 mm·mrad @7.7pC/bunch (10 mA with improved localized and dump shielding)

Achievements

Commissioning of the entire cERL was started in Dec. 16, 2013.

So far achieved:

acceleration of beams up to 20 MeV

beam recirculation and energy recovery without significant beam loss

maximum current of 6.5 μA in CW operation

Optics tuning and beam quality improvement are in progress.

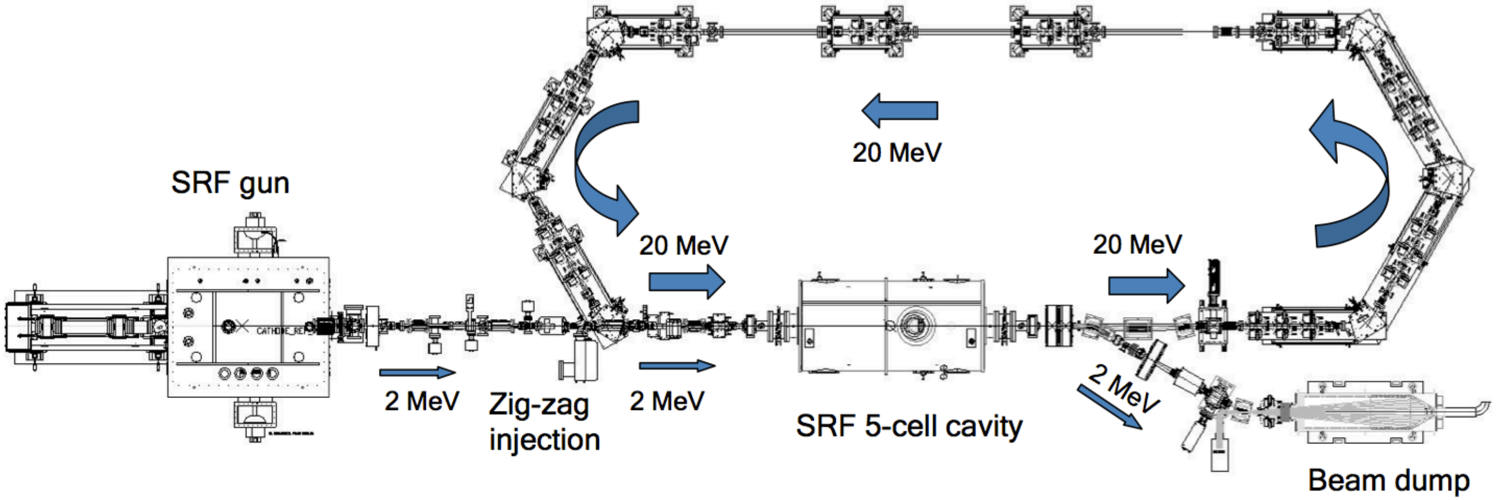
Future developments

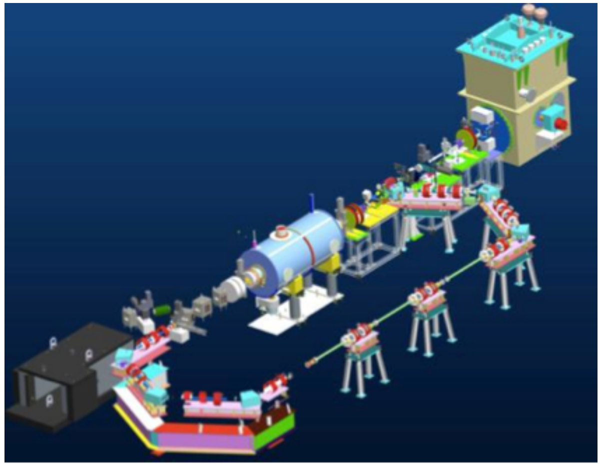
Generation of Laser Compton Scattering (LCS) X-rays is scheduled at the end of FY2014.

Generation of THz coherent radiation is planned in FY2015.

[Slide courtesy of N. Nakamura]

BNL Test ERL





✓The main goal of BNL R&D ERL project is to serve as a test-bed to demonstrate the main electron beam parameters for future RHIC upgrade projects:

- ERL-based coherent electron cooling;
- 10-to-20 GeV ERL for lepton-ion collider eRHIC.

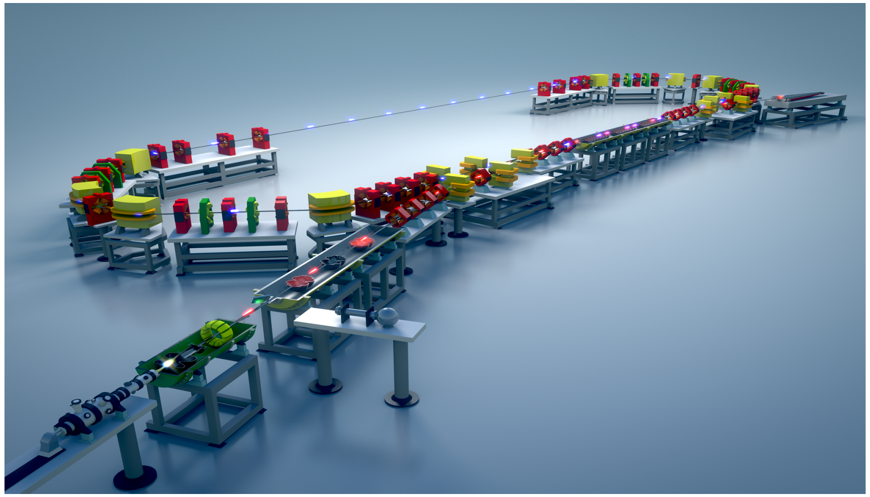
✓Test the key components of a high current ERL based solely on SRF technology

- SRF photoinjector test with 300 mA: preservation of high-charge, low emittance beam;
- High current 5-cell SRF linac test with HOM absorbers: single turn, 300 mA;
- Stability criteria for CW beam current;
- Attainable ranges of electron beam parameters in an SRF ERL.

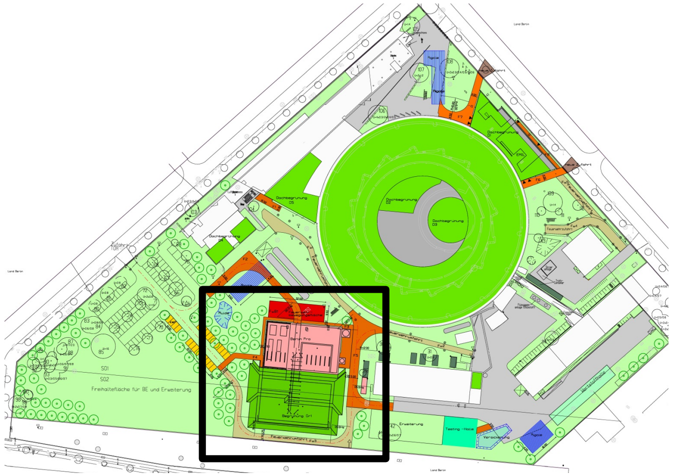
9/10/13 Wencan Xu: SRF system for BNL's R&D ERL 5

ERL13 Presentation

bERLinPro - Helmholtz Zentrum Berlin (HZB)



Parameter	Value	Unit
Beam energy	50	MeV
Beam current @ 1.3 GHz	100	mA
Bunch charge	77	pC
Bunch length	< 2	ps
Energy spread	0.5%	-
Emittance	< 1	mm mrad
Beam loss	$< 10^{-5}$	-



Groundbreaking late 2014

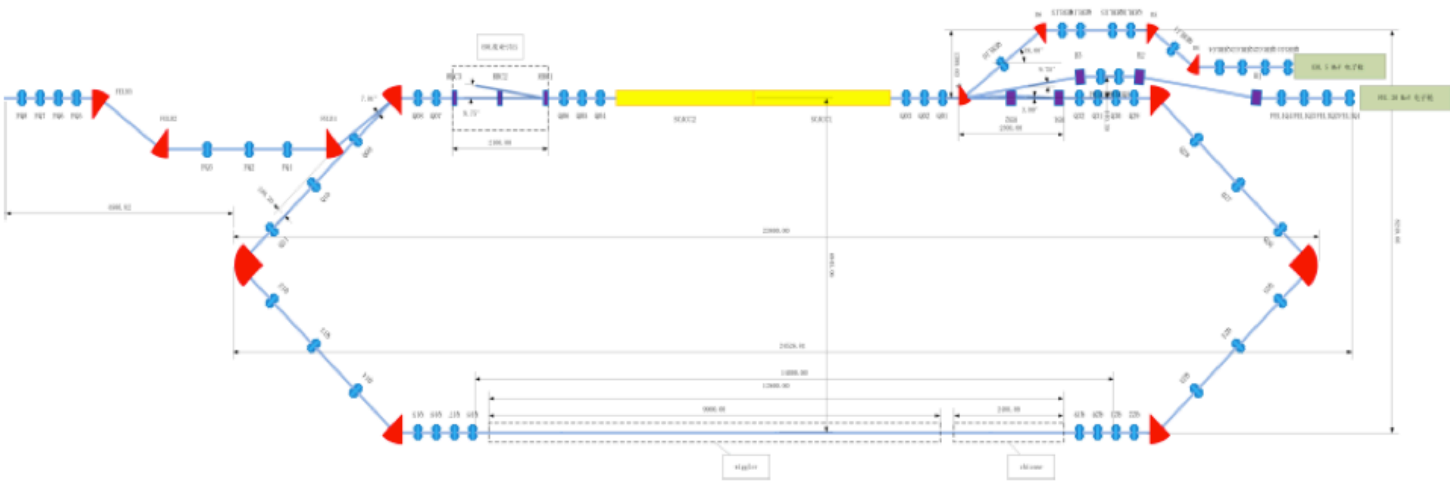
Operational
Cathode prep system

Fabricated
SRF gun
SRF booster cavities (in fabrication)

Ordered
All magnets
Gun cryomodule parts (some delivered)
Klystrons and SS amplifiers
Beam stop

Designed
Vacuum components
Linac (being designed)

IHEP ERL Test Facility (Beijing)

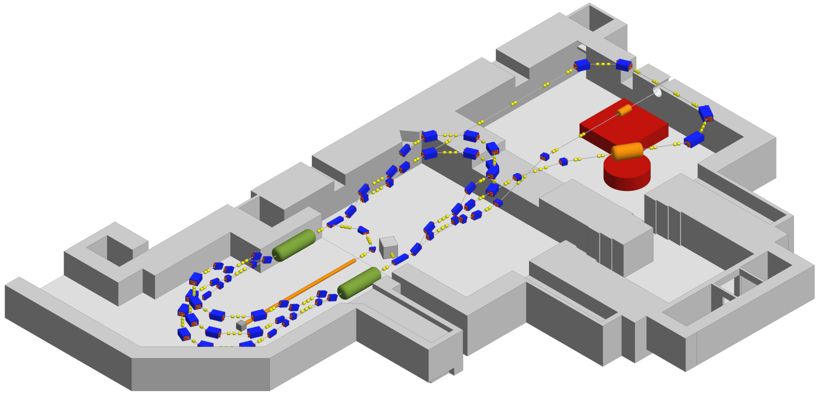


Parameter	Value
Beam energy (MeV)	35
Beam current (mA)	10
Bunch charge (pC)	77 (or 7.7)
Normalized emittance (mm.mrad)	1.0-2.0
Rms bunch length (ps)	2.0-4.0
Rms energy spread (%)	0.2-1.0
Bunch frequency (MHz)	130 (or 1300)
RF frequency (MHz)	1300

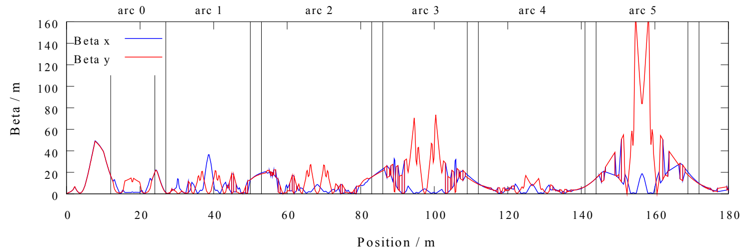
Yi and Ou-Zheng - Beam dynamics studies of the photo-injector in low-charge operation mode for the ERL test facility at IHEP
http://arxiv.org/abs/1308.0383

MESA (Mainz)

R. Heine, IPAC14: MOPRO108



Parameter	stage-1 (EB/ERL)	stage-2 (EB/ERL)
Beam energy, MeV	155/105	205/105
Bunch charge, pC	0.15/0.77	0.15/7.7
norm. emittance, μm	0.1 / <1	0.2/< 1
Beam polarization, %	>0.85/n.a.	>0.85/n.a.
Recirculations	2	3
Beam power at exp., kW	22.5/100	31/1000

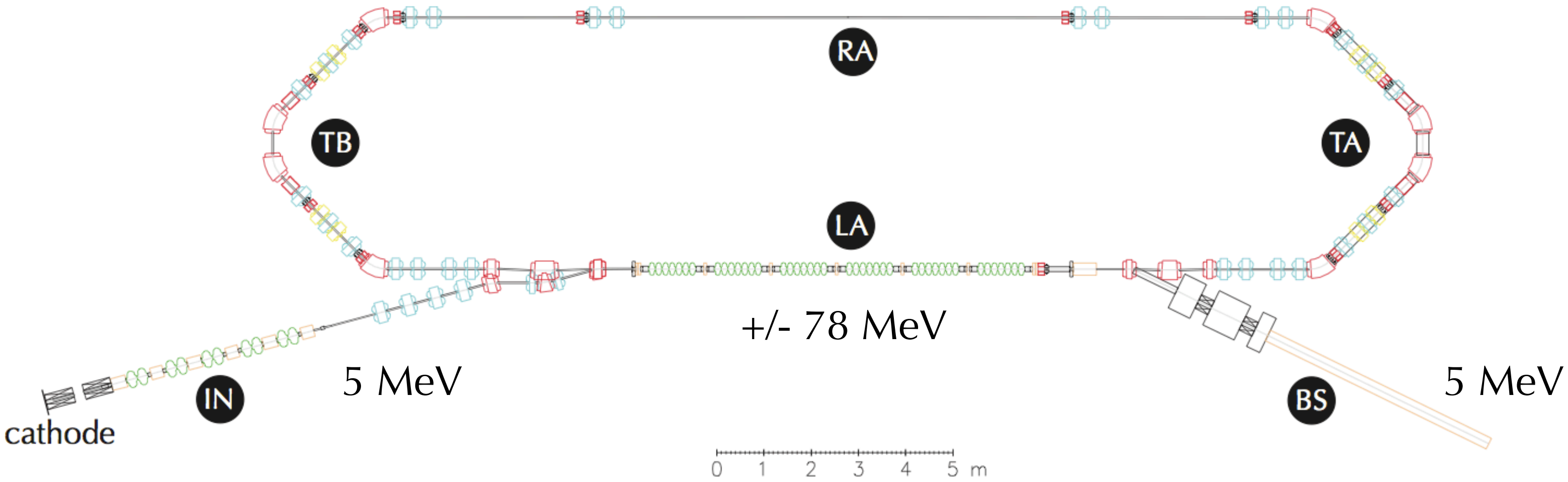


- one normal conducting injector linac with an extraction energy of 5 MeV
- two superconducting linac modules with an energy gain of 25 MeV each
- four spreader sections for vertically separating and recombining the beam
- five 180° arcs for the beam recirculation
- two chicanes for the injection and extraction of the 5 MeV beam
- one 180° bypass arc for energy recovery mode incorporating the internal experiment
- one beam line to the external experiment

Aiming for beam in 2017

[K. Aulenbacher, AIP Conf. Proc. 1563, 5-12 (2013)]

Cornell High-power recirculation loop (preliminary design)

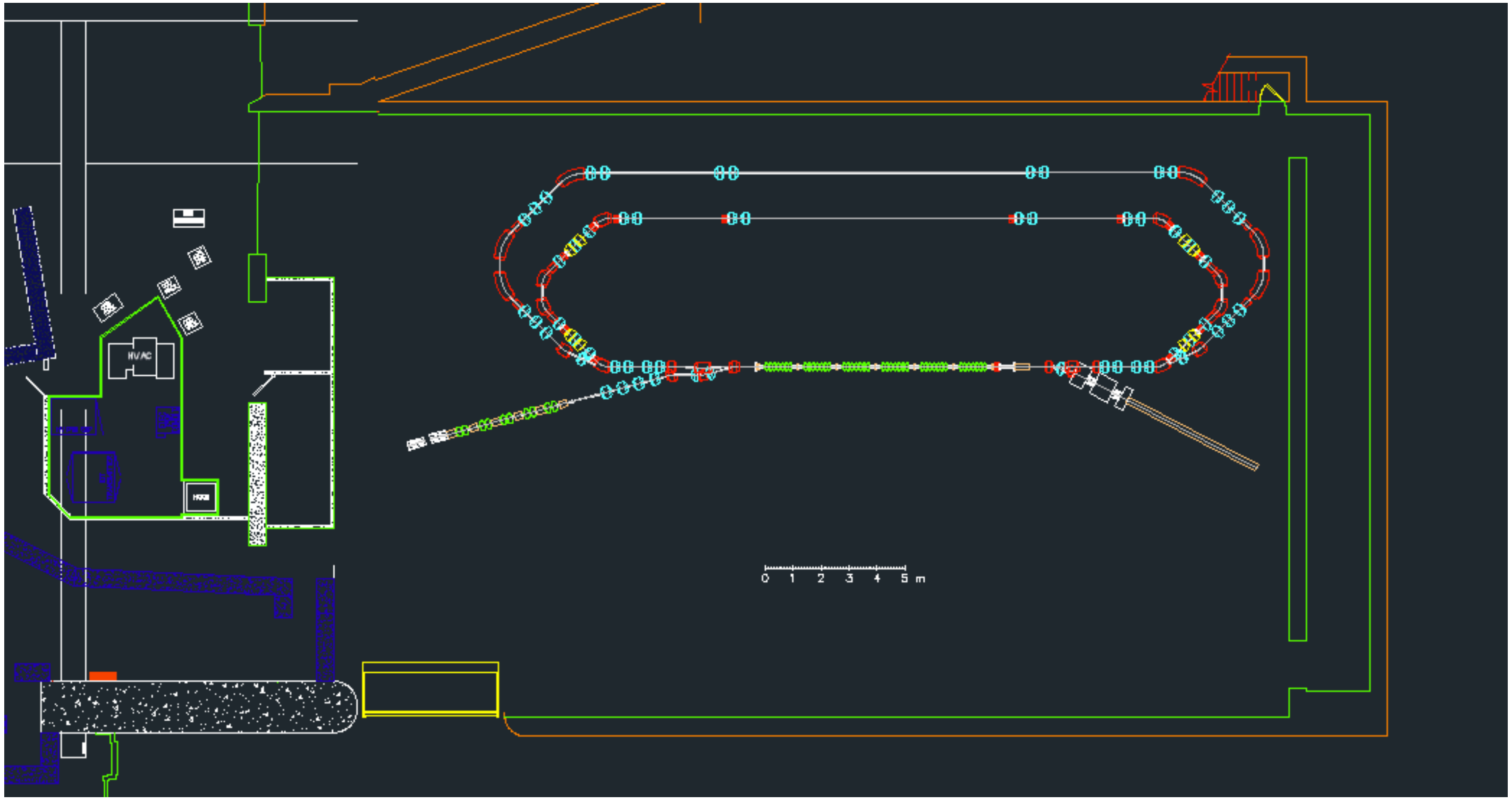


Energy	83	MeV
Current	100	mA
Emittance x, y	0.3	mm-mrad
Frequency	1.3	GHz
Bunch charge	77	pC

Mayes ERL13 Presentation

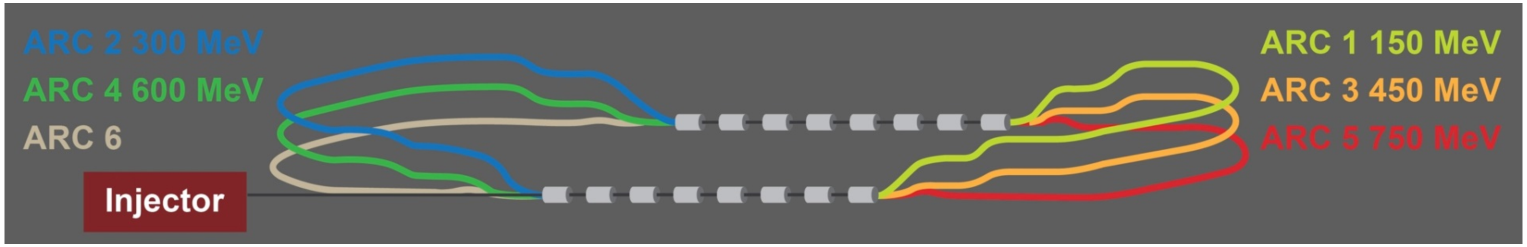
Cornell High-power recirculation loop

CESR's L0E hall



CERN ERL Test Facility

E. Jensen IPAC14: TUOBA02



Parameter	Value	
injection energy	5 *MeV*	
RF *f*	801.59 *MHz*	
acc. voltage per cavity	18.7 *MV*	
# cells per cavity	5	
cavity length	≈1.2 *m*	
# cavities per cryomodule	4	
RF power per cryomodule	≤50 *kW*	
# cryomodules	4 *)	
acceleration per pass	299.4 *MeV* *)	
bunch repetition *f*	40.079 *MHz*	
Normalized emittance	50 μm	
injected beam current	<13 *mA*	
nominal bunch charge	320 *pC*=$2 \cdot 10^9$ *e*	
number of passes *)	2	3
top energy *)	604 *MeV*	903 *MeV*
total circulating current *)	52 *mA*	78 *mA*
duty factor	CW	

CERN Mandate: 5 main points

LHeC

The mandate for the technology development **includes studies and prototyping of the following key technical components**:

- Superconducting RF system for CW operation in an Energy Recovery Linac (high Q_0 for efficient energy recovery) S
- Superconducting magnet development of the insertion regions of the LHeC with three beams. The studies require the design and construction of short magnet models
- Studies related to the experimental beam pipes with large beam acceptance in a high synchrotron radiation environment
- The design and specification of an ERL test facility for the LHeC.
- The finalization of the ERL design for the LHeC including a finalization of the optics design, beam dynamics studies and identificationof potential performance limitations

The above technological developments require close collaboration between the relevant technical groups at CERN and external collaborators.

Given the rather tight personnel resource conditions at CERN **the above studies should exploit where possible synergies with existing CERN studies.**

Jensen – IPAC14 Presentation

Bruening - ERL13 Presentation

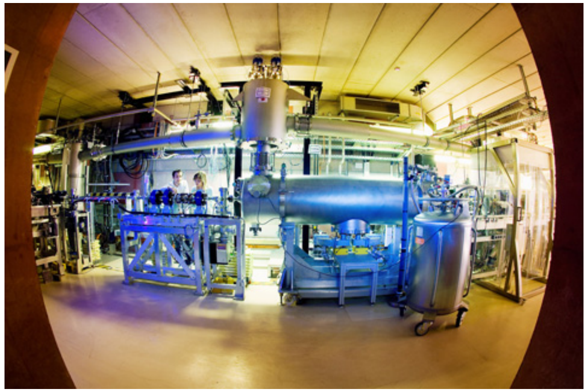
ERL Technology Readiness

Shovel Ready

Key ERL challenges have been overcome

- Photocathode lifetime
- High current
- Low emittance
- Emittance preservation through merger between photoinjector and linac
- High Q_0 superconducting RF accelerating structures

Large-scale ERL construction could begin soon



ドイツ加速器施設見学

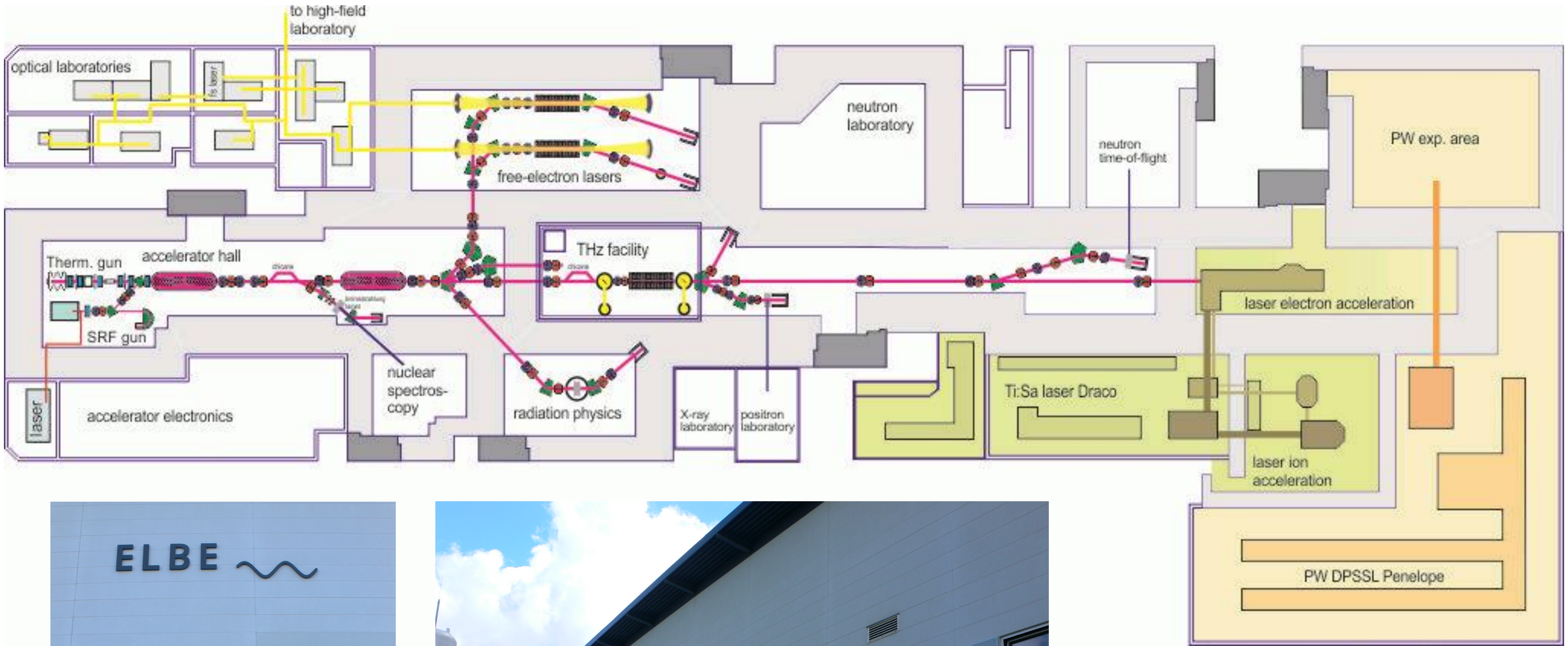
IPAC14 Technical Tours

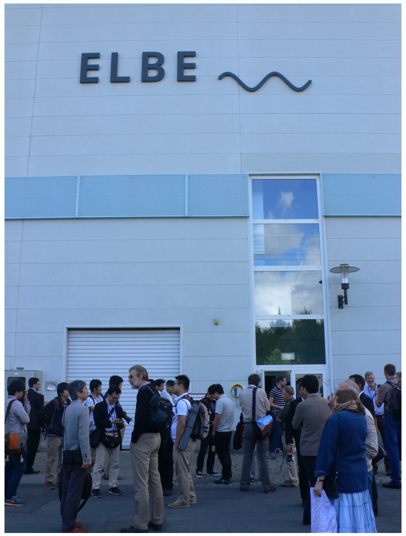
1) HZDR 6/20 13:30-16:00
   ELBE

2) HZB 6/21 13:30-16:00
   BESSY-II, bERLinPro, MLS

3) DESY 6/23 10:30-13:30
   HERA, FLASH, PETRA-III

ELBE訪問（1）

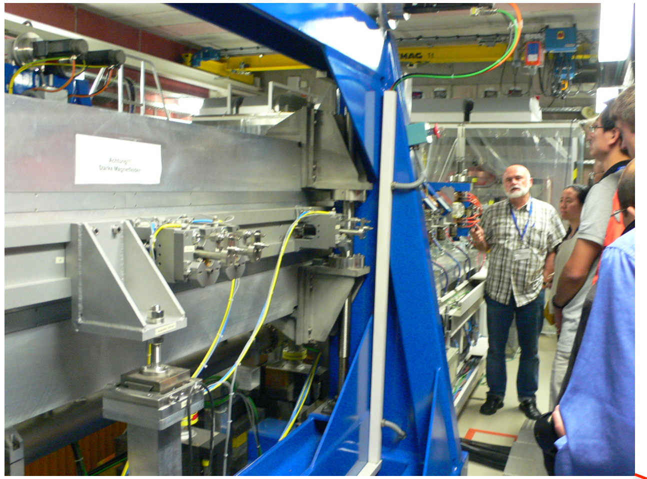

to high-field laboratory
optical laboratories
fs laser
free-electron lasers
neutron laboratory
neutron time-of-flight
PW exp. area
Therm. gun
accelerator hall
SRF gun
THz facility
laser electron acceleration
laser
accelerator electronics
nuclear spectros-copy
radiation physics
X-ray laboratory
positron laboratory
Ti:Sa laser Draco
laser ion acceleration
PW DPSSL Penelope

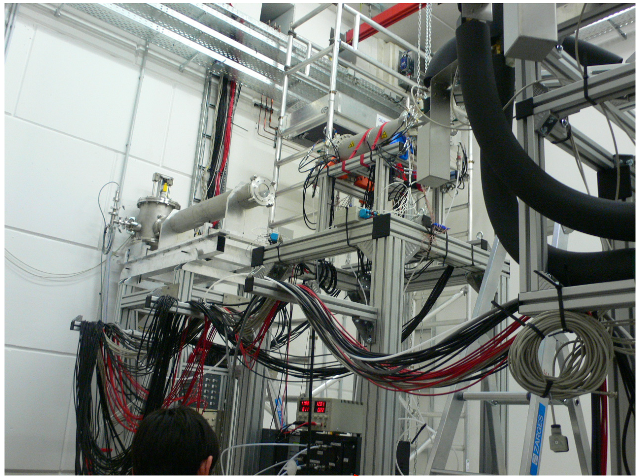

ELBE

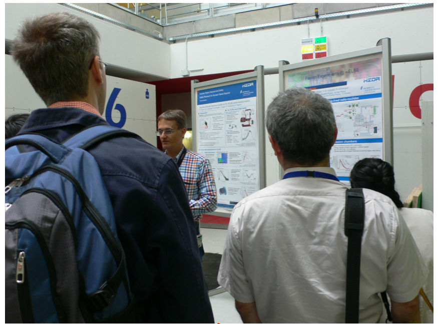
ELBE訪問(2)

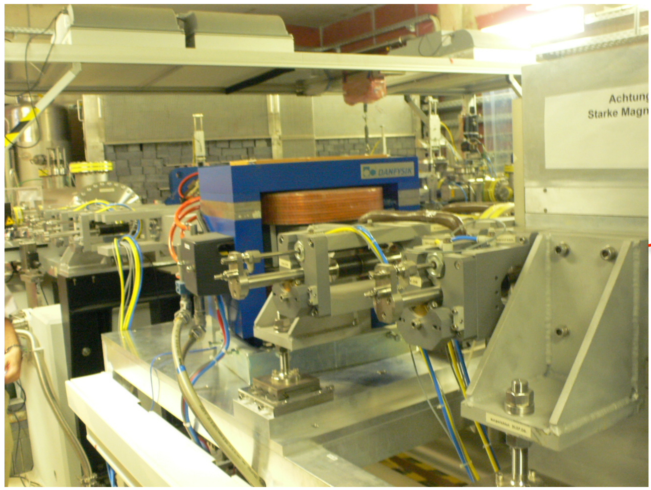
赤外自由電子レーザー

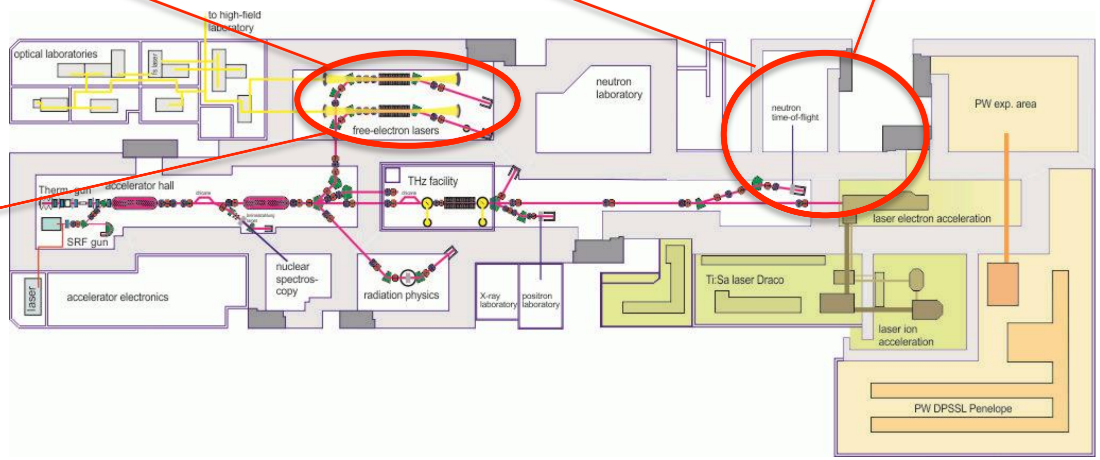
中性子実験





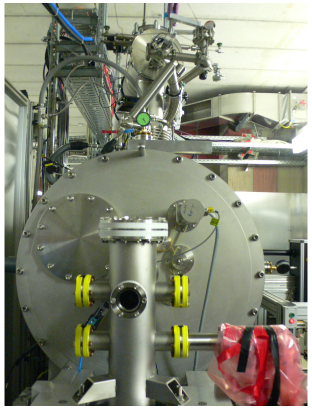


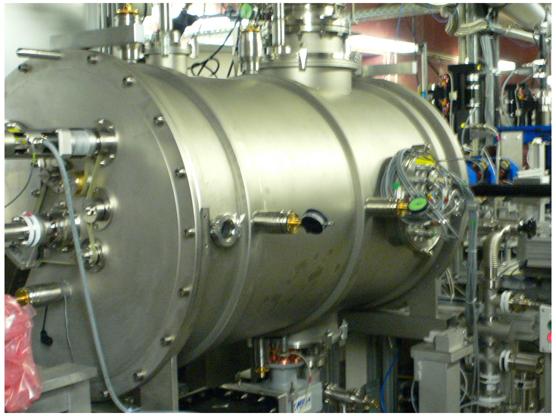




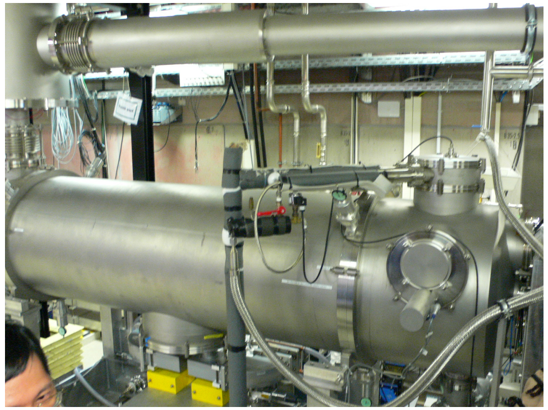
ELBE訪問(3)

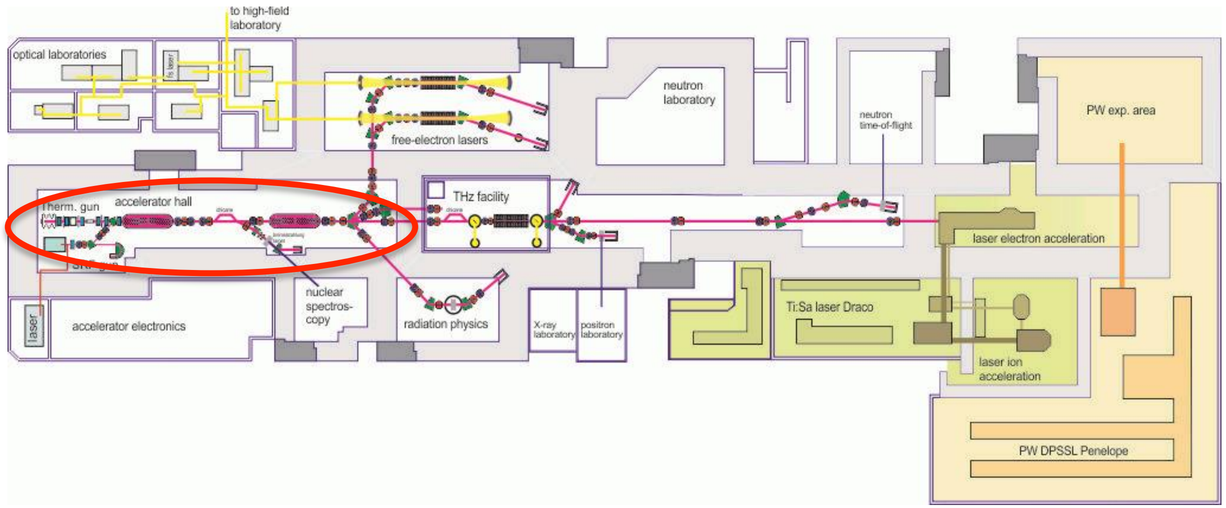
超伝導RF電子銃

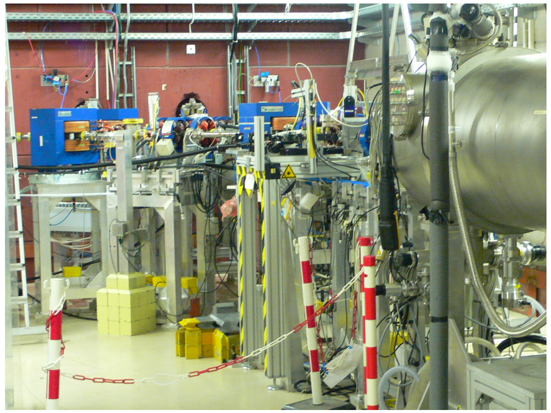




超伝導加速空洞

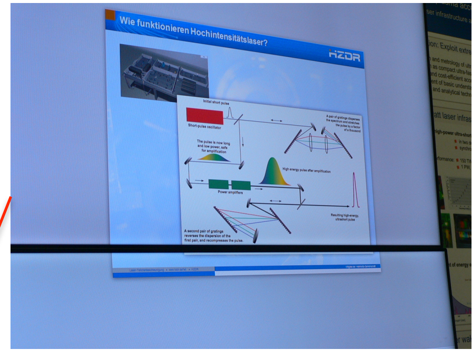




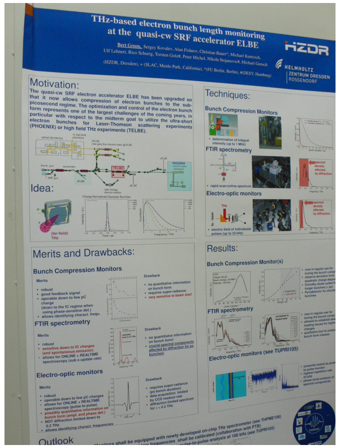


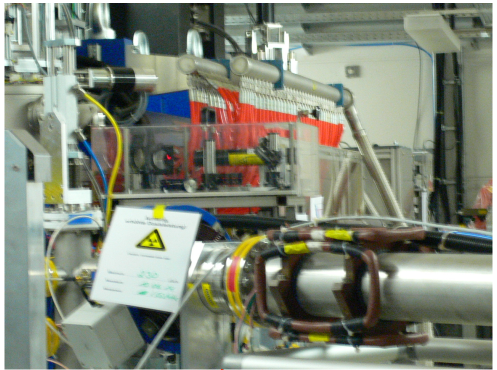
ELBE訪問（4）

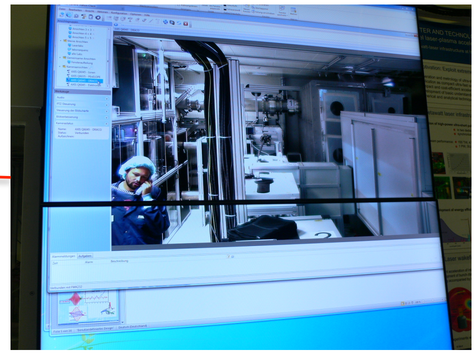
レーザー加速

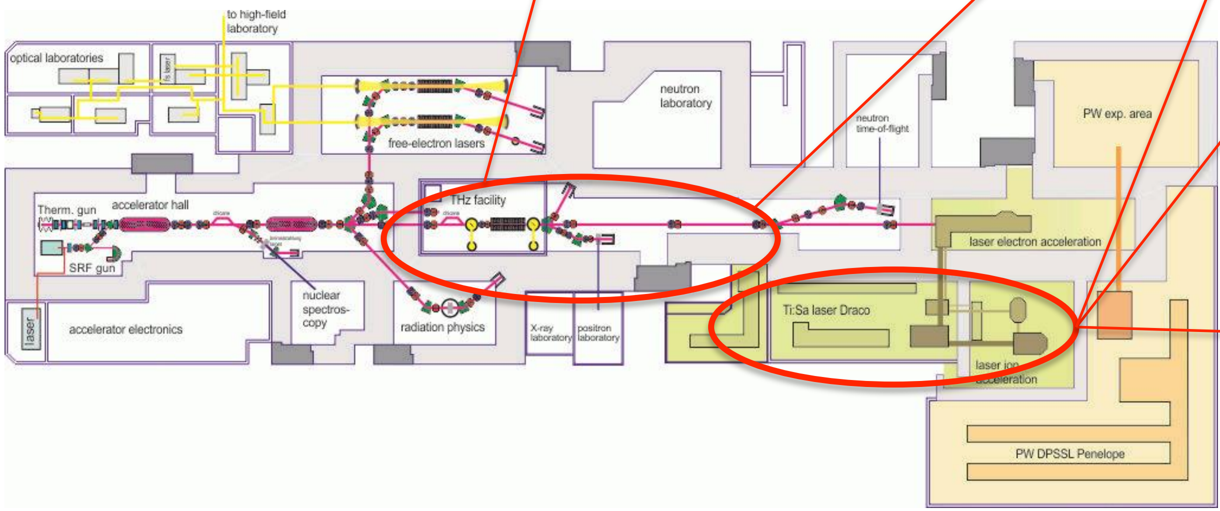


テラヘルツ光発生用
電磁石アンジュレータ





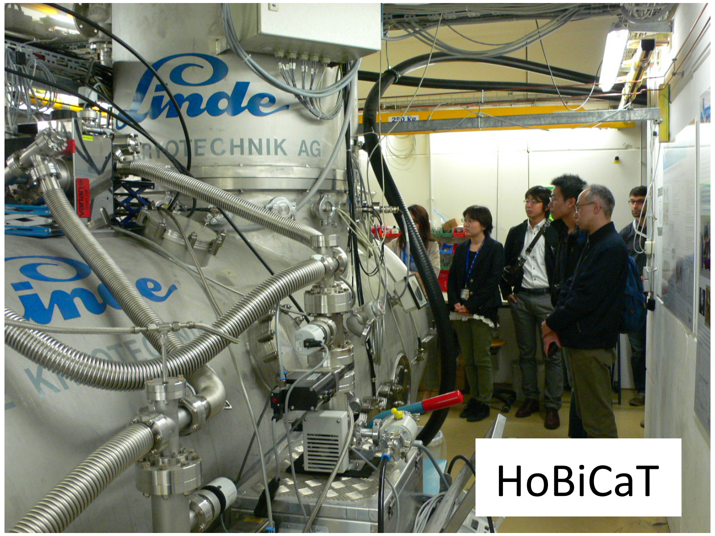




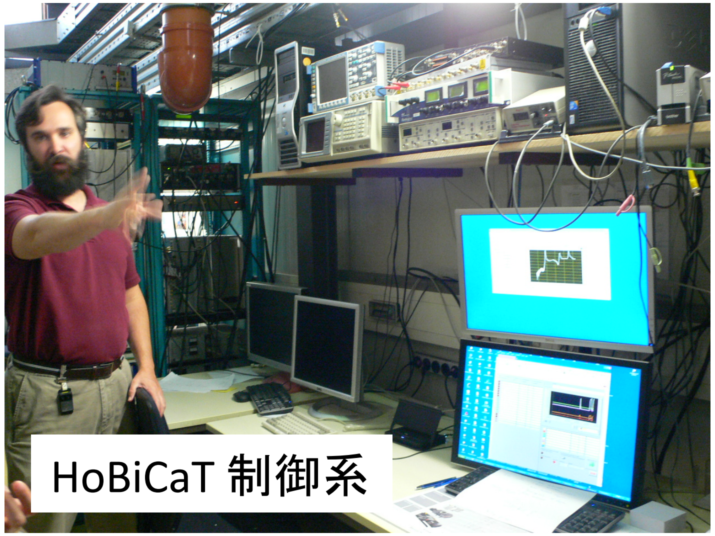
HZB訪問（1）

HoBiCaT (Horizontal bi-cavity testing facility)


HZB


HoBiCaT

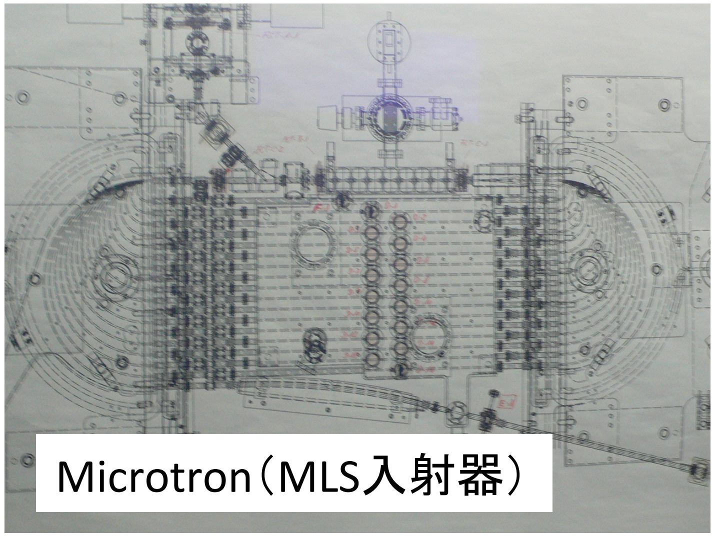

BESSY-II
bERLinPro site

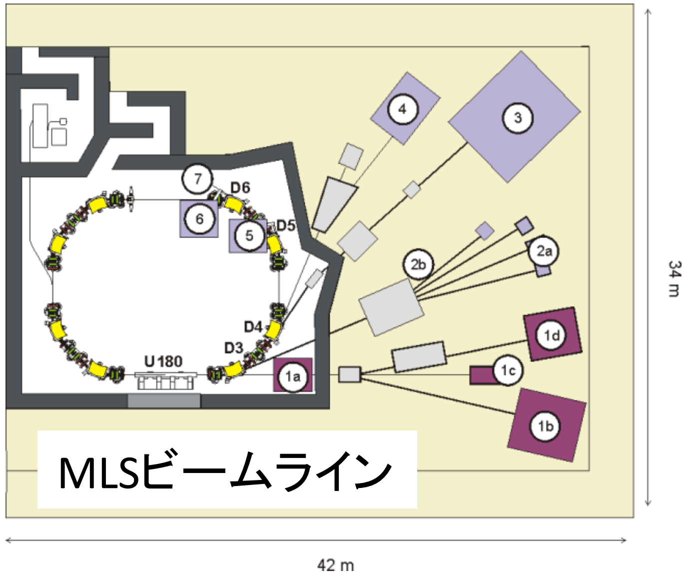

HoBiCaT 制御系

HZB訪問（2）

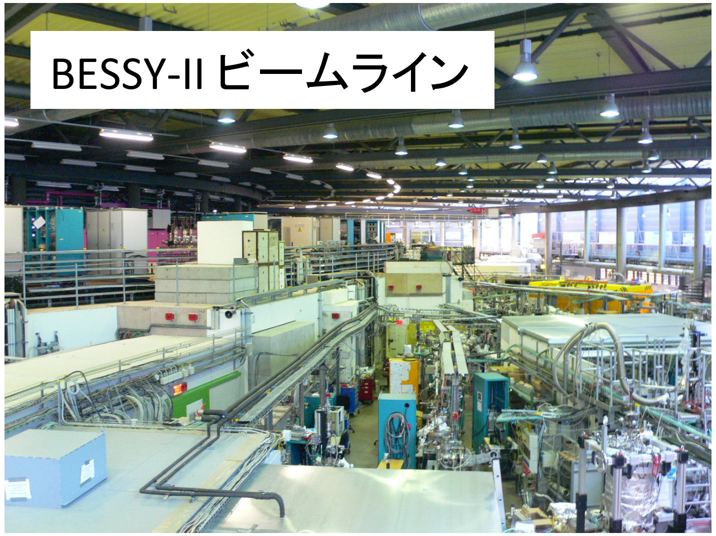

MLS: Metrology Light Source


MLS制御室

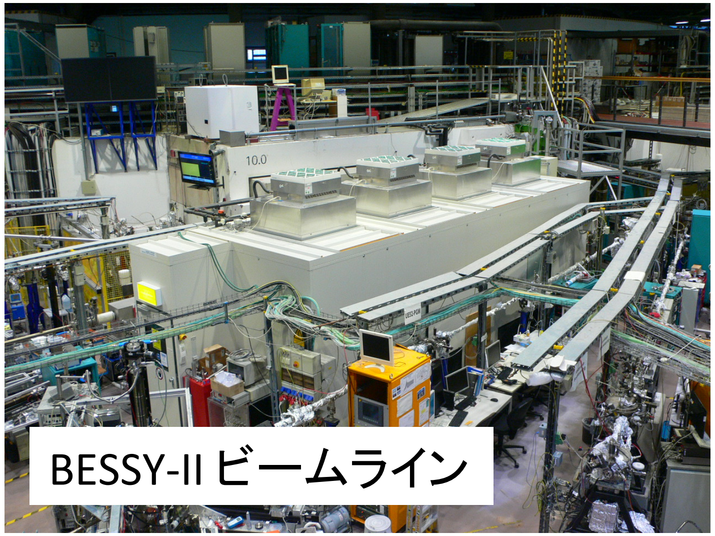

Microtron（MLS入射器）


4
3
7
D6
6
5
D5
2b
2a
D4
D3
U 180
1a
1d
1c
1b
34 m
42 m
MLSビームライン

HZB訪問（3）

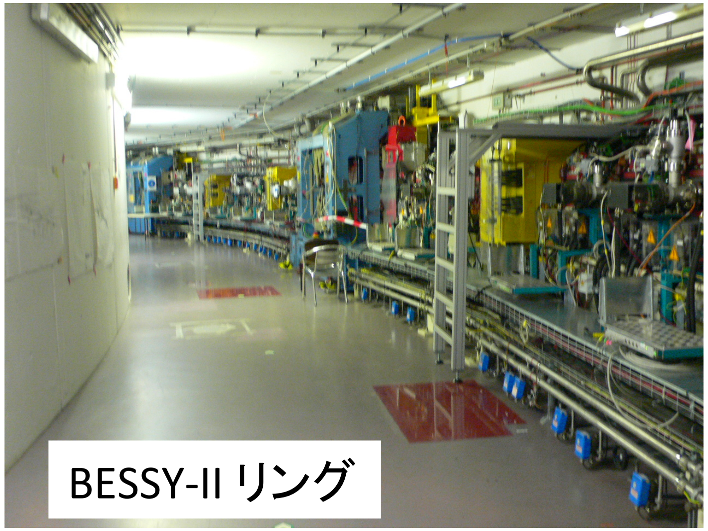

BESSY-II ビームライン

BESSY-II制御室

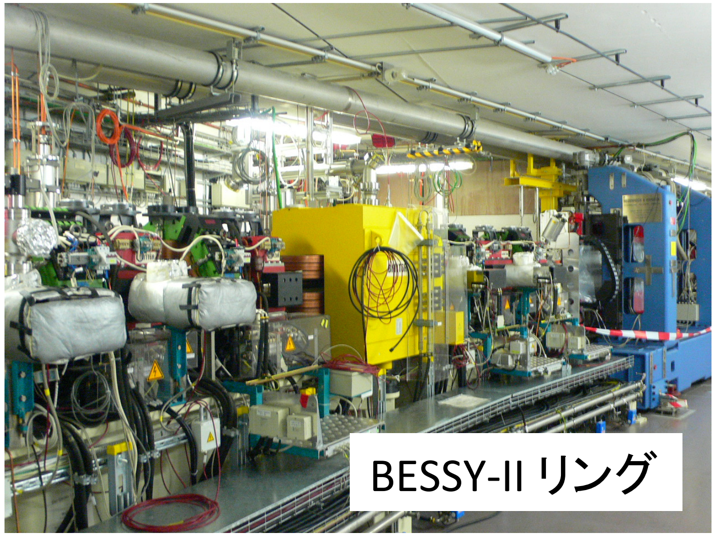

BESSY-II ビームライン


BESSY-II制御室

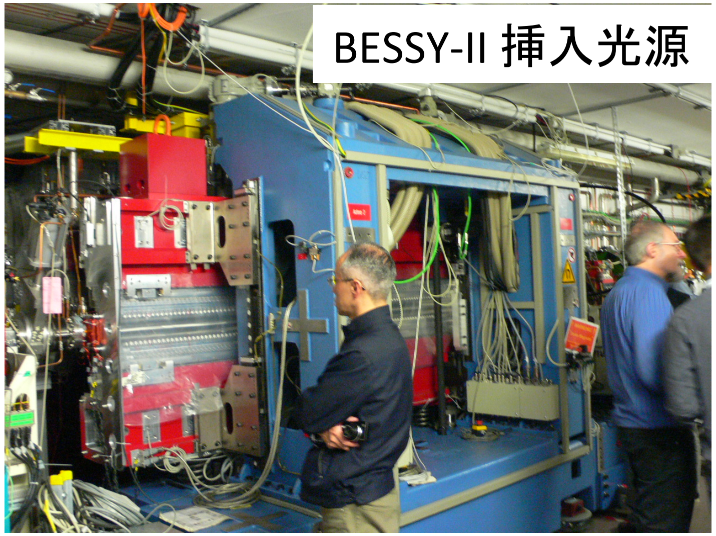
HZB訪問（4）



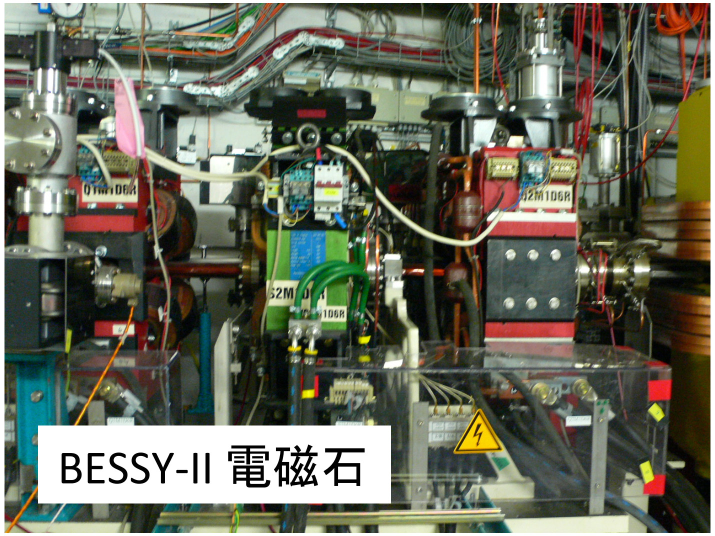
BESSY-II リング



BESSY-II リング



BESSY-II 挿入光源



BESSY-II 電磁石

HZB訪問（5）

DESY訪問（1）


DESY正門付近

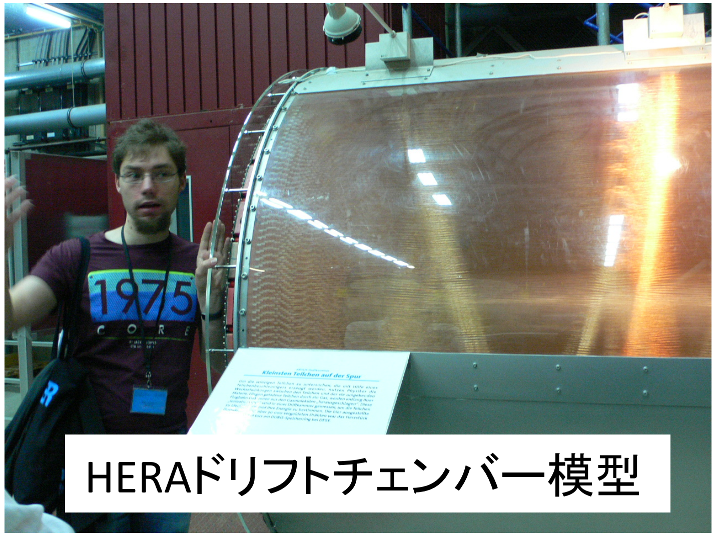

DESY見学者集合場所


レクチャーホール（外観）

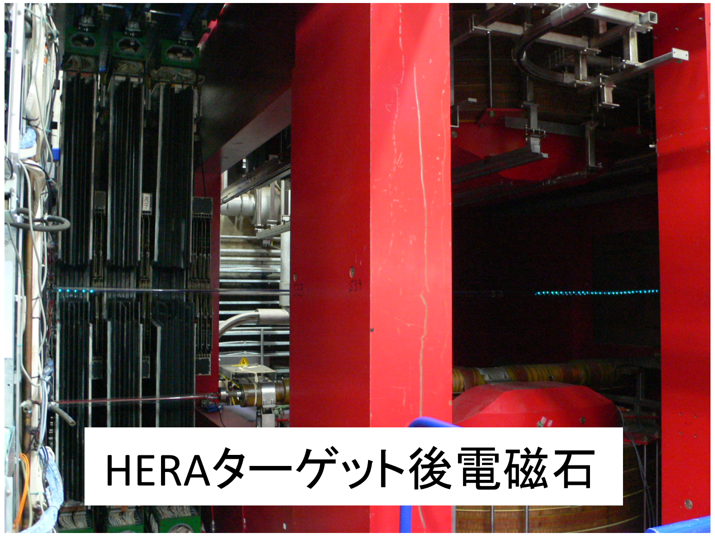
レクチャーホール（内）

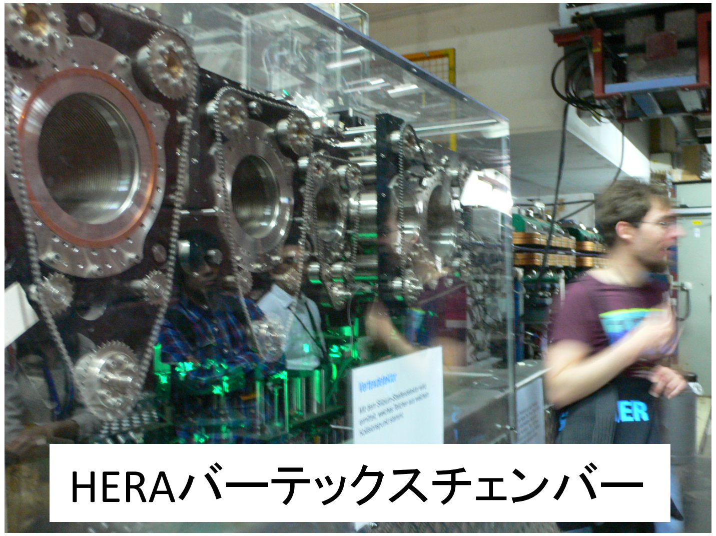
DESY訪問（2）


旧冷凍設備

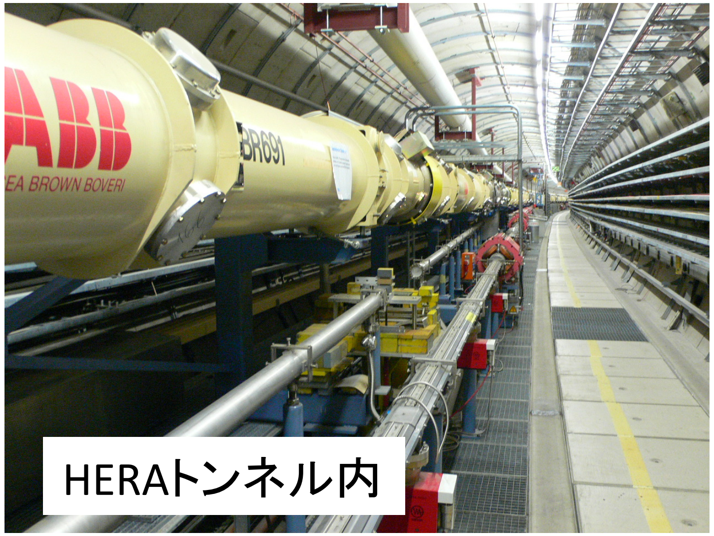


HERAドリフトチェンバー模型

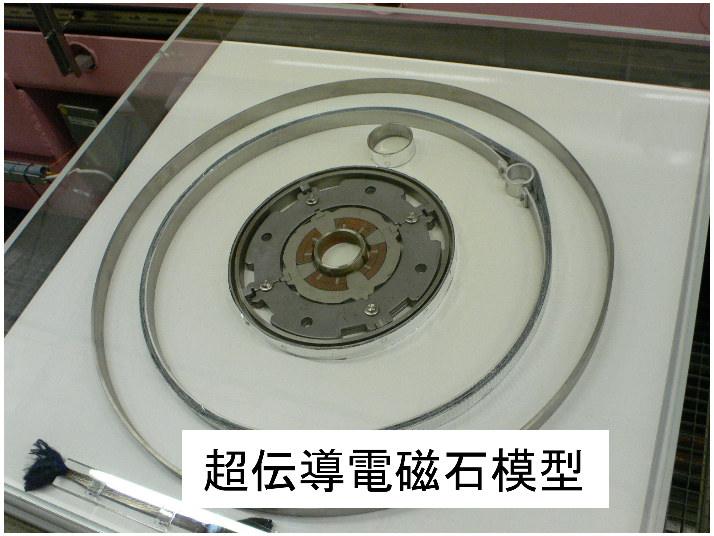

HERAターゲット後電磁石

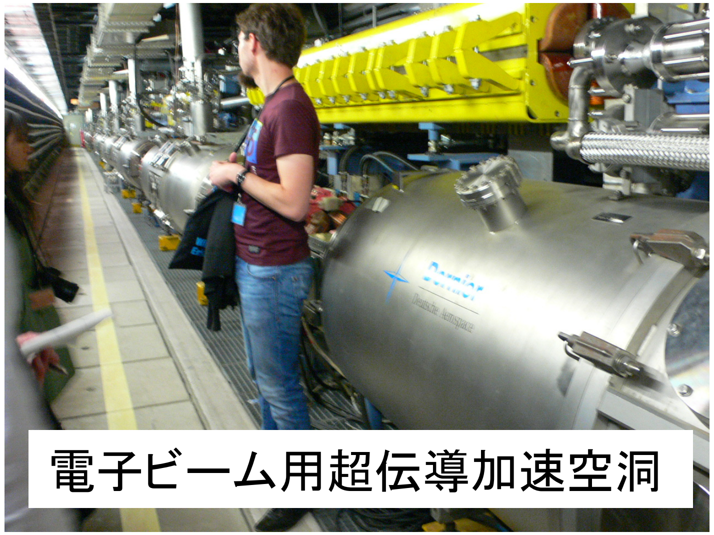

HERAバーテックスチェンバー

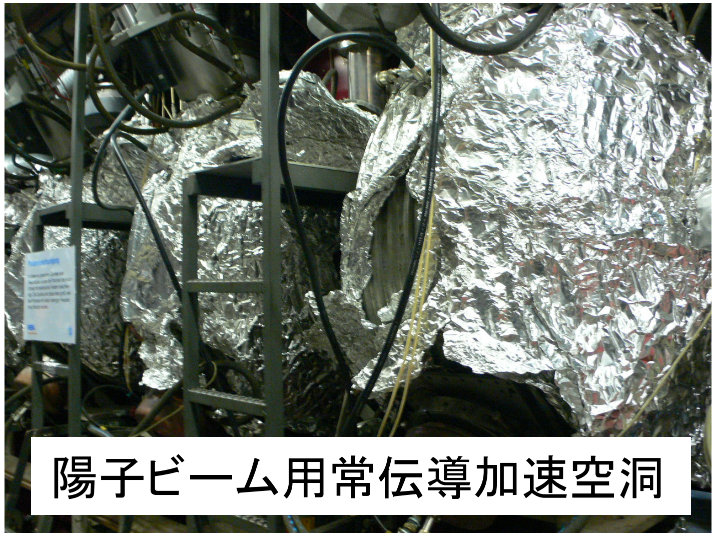
DESY訪問（3）



HERAトンネル内


超伝導電磁石模型


電子ビーム用超伝導加速空洞


陽子ビーム用常伝導加速空洞

DESY訪問（4）


FLASH超伝導空洞模型


FLASHシールド前

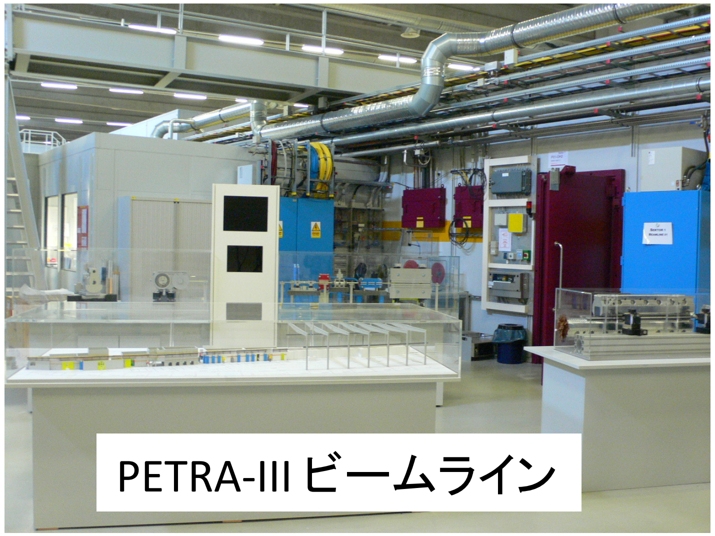

FLASHクライオモジュール


クリーンルーム

DESY訪問（5）

PETRA-III放射光施設

PETRA-III シールド



PETRA-III ビームライン

挿入光源模型

ご清聴ありがとうございました。