FLS2010報告

中村典雄(ISSP)、羽島良一(JAEA)、西森信行(JAEA)、宮島司(KEK)

概要

- 名称

  48th ICFA Advanced Beam Dynamics Workshop on Future Light Source

- 開催日・場所

  March 1 – 5, 2010, SLAC National Accelerator Laboratory

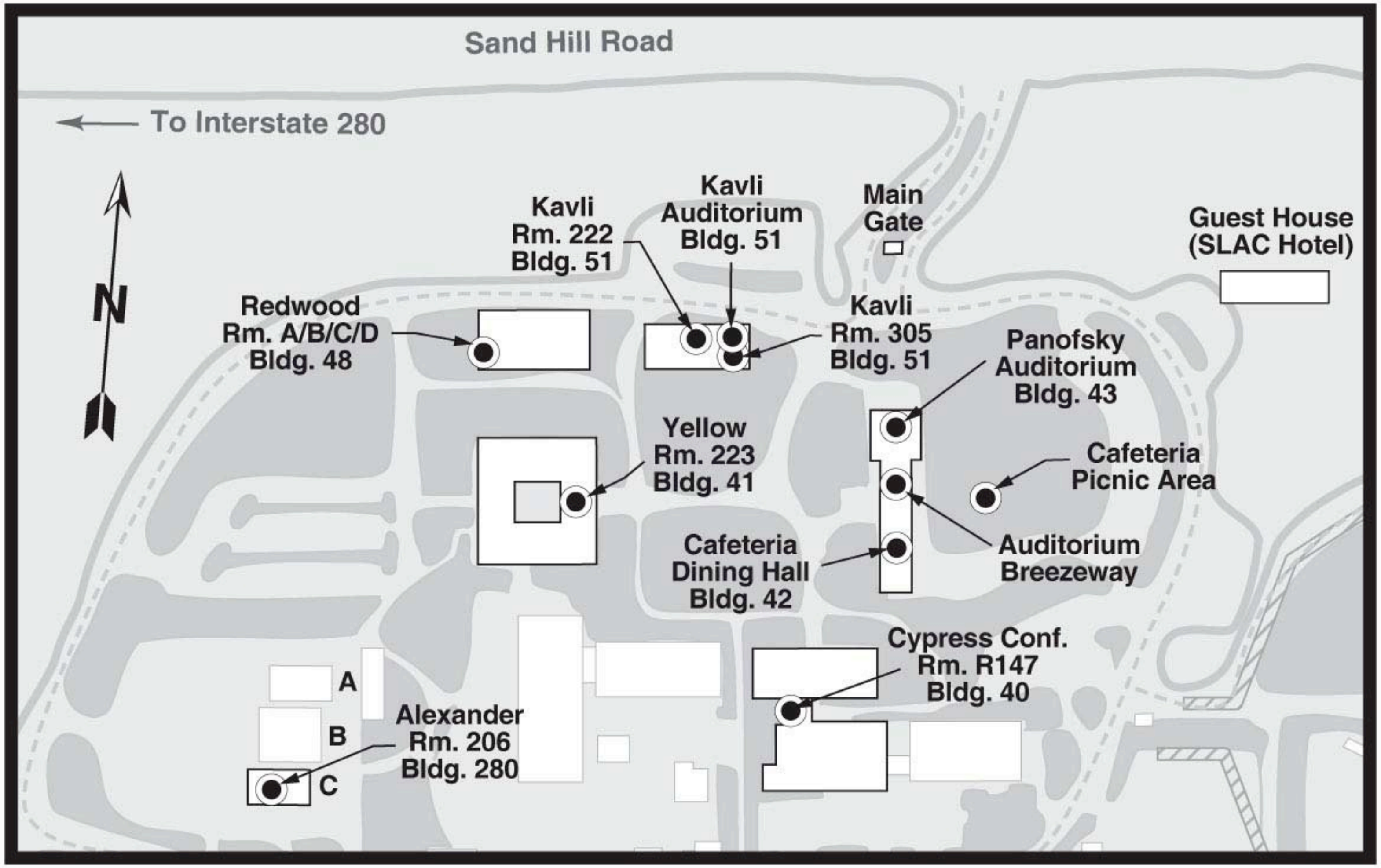
- 目的

  to review and discuss modern accelerator-based light sources for wavelengths ranging from the Infrared to X-rays.

- 参加人数

  総計225名（各WG内訳：Scientific needs 24名、Storage ring 31名、ERL 12名、FEL 51名、Gun 36名、Diagnostics 27名、Undulator&BL 18名、Novel source 26名）
  日本人 8名（KEK 2名, JAEA 2名, ISSP 1名, RIKEN 2名, JASRI 1名）

ワークショップ会場



Plenary talk: Panofsky Auditorium, ERL WG: Redwood Room C

ワークショップ写真

Panofsky Auditorium


Cafeteria


Stanford Guest House


Excursion

主催者側によるワークショプ関係の写真は、近々ウェブ上に掲載予定。

プログラム

	28 Sunday	1 Monday	2 Tuesday	3 Wednesday	4 Thursday	5 Friday	6
8 AM							
9		9:00 AM 9:00-Welcome-P.Drell (SLAC) || 9:15-Welcome-J.Galayda (SLAC)	9:00 AM Science with next-generation hard X-ray sources – S. Wakatsuki (KEK)	9:00 AM Report from the high brightness electron beams workshop – J. Rosenzweig (UCLA)	9:00 AM Working groups	9:00 AM Summary report – Working Group 1	
		9:30 AM Future performance of the LCLS – J. Welch (SLAC)	9:30 AM Science with next-generation soft X-ray sources – F. Parmigiani (ST)	9:30 AM Concepts for smaller, cheaper, better – C. Pellegrini (UCLA)	9:30 AM Working groups	9:30 AM Summary report – working group 2	
10		10:00 AM Progress at the XFELs in Europe and Japan – H. Braun (PSI)	10:00 AM X-Ray Detectors for Next-Generation X-Ray Sources-The Fine Art of High-Speed X-Ray Imaging--Daniel Rolles, CFEL	10:00 AM Advances in laser/plasma-based sources – W. Leemans (LBNL)	10:00 AM Working groups	10:00 AM Summary report – working group 3	
		10:30 AM Coffee break	10:30 AM Coffee break	10:30 AM Coffee break	10:30 AM Coffee break	10:30 AM Coffee break	
11		11:00 AM Progress in soft X-ray FELs – R. Bartolini (Diamond)	11:00 AM Ring-based sources overview – M. Borland (ANL)	11:00 AM Advanced insertion devices; practices and concepts – R. Schlueter (LBNL)	11:00 AM Working groups	11:00 AM Summary report – working group 4	
		11:30 AM Lessons from FLASH - S. Schreiber (DESY)	11:30 AM R&D towards an ERL – G. Hoffstaetter (Cornell U.)	11:30 AM Room temperature high rep-rate RF structures for light sources – S. Tantawi (SLAC)	11:30 AM Working groups	11:30 AM Summary report – working group 5	
12 PM		12:00 PM Performance Metrics of Future Light Sources – R. Hettel (SLAC)	12:00 PM Unassigned discussion time	12:00 PM Unassigned discussion time	12:00 PM Working groups	12:00 PM Summary report – working group 6	
		12:30 PM Lunch	12:30 PM Lunch	12:30 PM Lunch	12:30 PM Lunch	12:30 PM Lunch	
1		1:30 PM Working groups	1:30 PM Working groups	1:30 PM Excursion	1:30 PM Working groups	1:30 PM Summary report – working group 7	
2						2:00 PM Summary report – working group 8	
3							
4		4:00 PM Coffee Break	4:00 PM Coffee Break		4:00 PM Coffee Break		
		4:30 PM Working Groups	4:30 PM Working Groups		4:30 PM Working Groups		
5	5:00 PM Registration and Reception						

WG3プログラム(1)

Day : 1. Monday (11)

	3/1/2010 1:30 PM	04:00 PM	Working Group (Project Status Update)	
	3/1/2010 1:30 PM	01:55 PM	Project status updata (Cornell)	G. Hoffstaetter
	3/1/2010 1:55 PM	02:20 PM	Project status update (KEK/JAEA)	N. Nakamura
	3/1/2010 2:20 PM	02:45 PM	Project update (JLAB)	S. Benson
	3/1/2010 2:45 PM	03:10 PM	Project status update (Daresbury)	S. Smith
	3/1/2010 3:10 PM	03:35 PM	Project status update (Berlin)	Bettina Kuske
	3/1/2010 4:30 PM	06:00 PM	Working Group (ERL Performance)	
	3/1/2010 4:30 PM	04:50 PM	Performance evaluation of ERLs	J.D. Brock
	3/1/2010 4:50 PM	05:10 PM	ERL operation modes	G. Hoffstaetter
	3/1/2010 5:10 PM	05:30 PM	Performance comparison between APS-upgrades and an ERL@APS	M. Borland
	3/1/2010 5:30 PM	06:00 PM	Discussion	

Day : 2. Tuesday (12)

	3/2/2010 1:30 PM	06:15 PM	Working Group (High rep rate guns)	*** joint with Gun WG ***
	3/2/2010 1:30 PM	01:55PM	High rep rate guns: JAEA	N. Nishimori
	3/2/2010 1:55 PM	02:20 PM	High rep rate guns: JLAB	F. Hannon
	3/2/2010 2:20 PM	02:45 PM	High rep rate guns: Cornell University	C. Sinclair
	3/2/2010 2:45 PM	03:10 PM	High rep rate guns: KEK	T. Miyajima
	3/2/2010 3:10 PM	03:35 PM	High rep rate guns: BNL	I. Ben-Zvi
	3/2/2010 3:35 PM	04:00 PM	High rep rate guns: LBNL	F. Sannibale
	3/2/2010 4:30 PM	06:15 PM	Working Group (High rep rate guns)	*** joint with Gun WG ***
	3/2/2010 4:30 PM	04:55 PM	High rep guns: APS	A. Nasiri
	3/2/2010 4:55 PM	05:20 PM	High rep guns: NPS	J. Lewellen
	3/2/2010 5:20 PM	05:45 PM	High rep rate guns: FZD Rossendorf	J. Teichert
	3/2/2010 5:45 PM	06:15 PM	High rep rate gun discussion	*** ALL ***

WG3プログラム(2)

Day : 4. Thursday (17)

	3/4/2010 9:00 AM	09:30 AM	Working Gourp (FELs in ERLs)	*** joint with FEL WG ***
	3/4/2010 9:00 AM	09:30 AM	XFELO in an ERL	R. Hajima
	3/4/2010 9:30 AM	09:45 AM	Recirculation Design for FEL Driver	S. Smith
	3/4/2010 9:45 AM	10:00 AM	Recirculation Optics for XFEL-O	M. Borland
	3/4/2010 10:00 AM	10:30 AM	FELs in ERLs: general discussion	*** ALL ***
	3/4/2010 11:00 AM	12:30 PM	Working Group (Injector and SRF)	
	3/4/2010 11:00 AM	11:20 AM	Studies at KEK	T. Miyajima
	3/4/2010 11:20 AM	11:40 PM	Studies at Cornell	F. Loehl
	3/4/2010 11:40 AM	12:00 PM	Studies at JLAB	R. Rimmer
	3/4/2010 12:00 PM	12:30 PM	Discussion	
	3/4/2010 1:30 PM	04:00 PM	Working Group (Miscellaneous Topics)	
	3/4/2010 1:30 PM	01:50 PM	BBU	G. Hoffstaetter (discussion leader)
	3/4/2010 1:50 PM	02:10 PM	HOM absorber	R. Hajima (discussion leader)
	3/4/2010 2:30 PM	02:50 PM	Design of a 2-loop ERL at Cornell	G. Hoffstaetter
	3/4/2010 2:50 PM	04:30 PM	other topics	*** ALL ***
	3/4/2010 4:30 PM	06:00 PM	Working Group (New idea, cost/performance tradeoffs)	
	3/4/2010 4:30 PM	04:50 PM	Coherent Light Generation	A. Meseck

Day : 5. Friday (1)

	3/5/2010 10:00 AM	10:30 AM	Summary Report - Working Group 3	

ERL WG Summary

Summary of ERL WG

Conveners

Ryoichi Hajima

Georg Hoffstaetter

March 5, 2010.

Working Group Overview

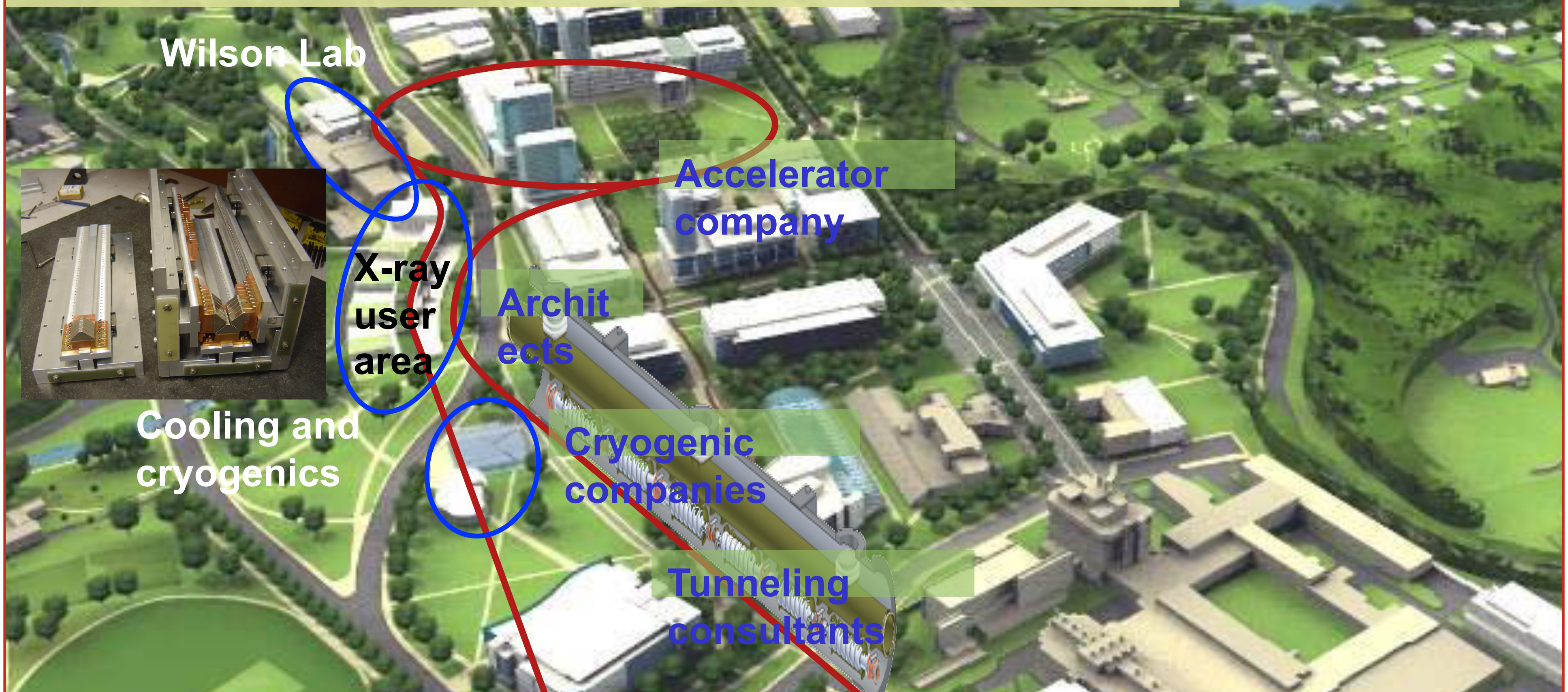
- Project Status Update
  - reports from 5 projects
- Performance & Operation modes
- High-rep. Guns (Joint Session with Gun WG)
- FEL in ERLs (Joint Session with FEL WG)
- Injector & SRF
- Miscellaneous Subjects

Status of Cornell's ERL Project

Working modes: current, emittances, energy spread, bunch length

A)	**100mA,**	**30/30pm,**	**2.e-4,**	**2ps**
B)	**25mA,**	**8/ 8pm,**	**2.e-4,**	**2ps**
C)	**25mA,**	**300/10pm,**	**2.e-3,**	**1ps in South, 100fs in North beamlines**

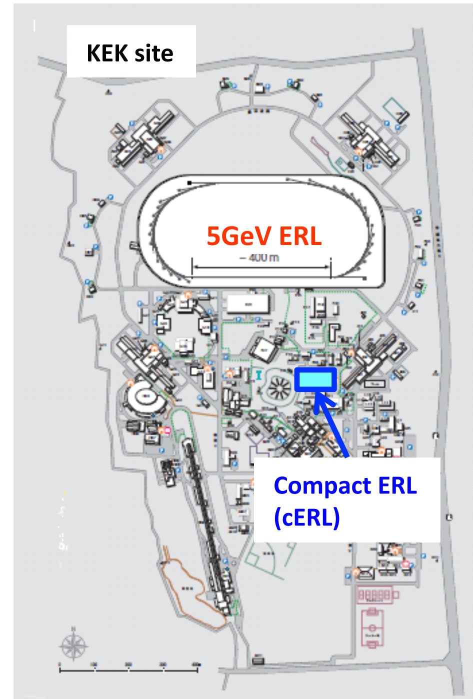
The option of large bunch charge (1nC) with low repetition rate (100kHz),
without energy recovery, up to 1nC for studying XFELO, HGHG FELs, etc.



Status of the ERL Project in Japan

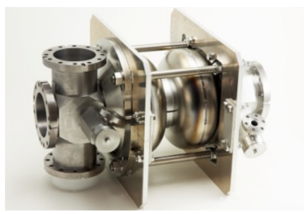
ERL Project

- Compact ERL (final version : 2 loop, 245 MeV, 100 mA)
- Two-loop 5-GeV ERL and 7.5-GeV XFEL-O



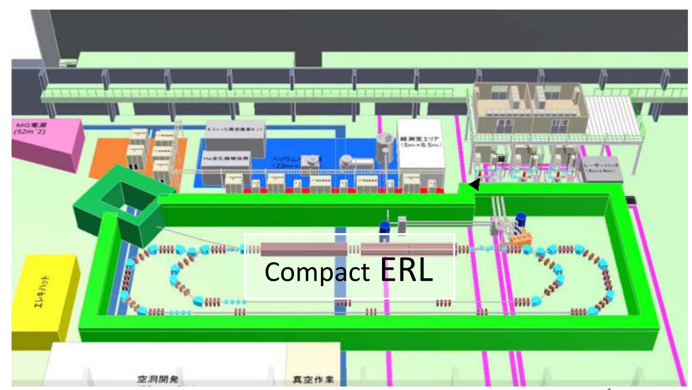
R&D on Key Components

- 500-kV DC photocathode gun with a segmented insulator
- Test injector beamline and drive laser system
- SC cavities for both injector and main linacs



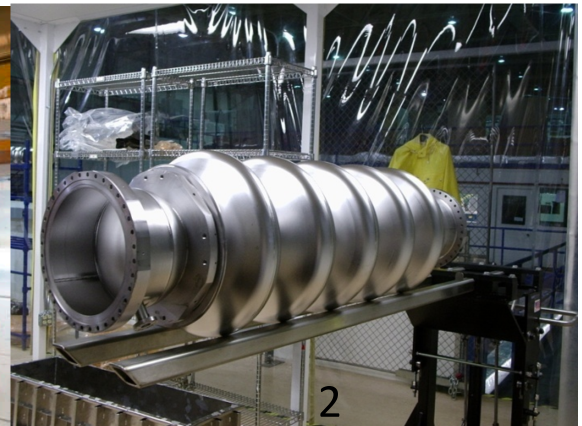
Compact ERL (cERL)

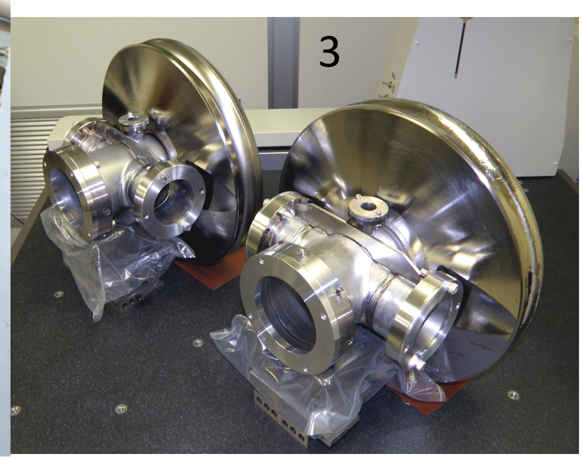
- Optics design and error effects of cERL studied
- East Counter Hall renewed as cERL building
- Commissioning (1 loop, 35MeV, 10mA) planned in FY2012

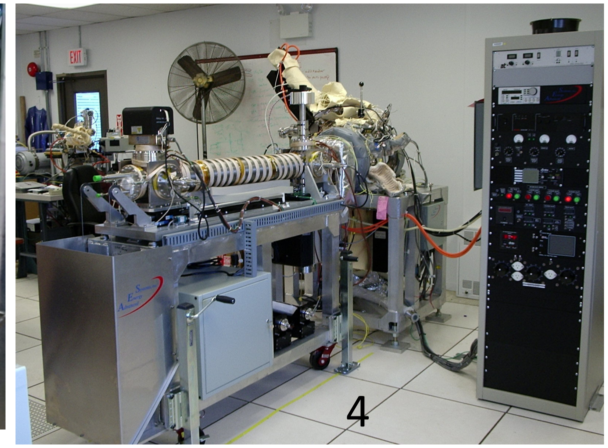


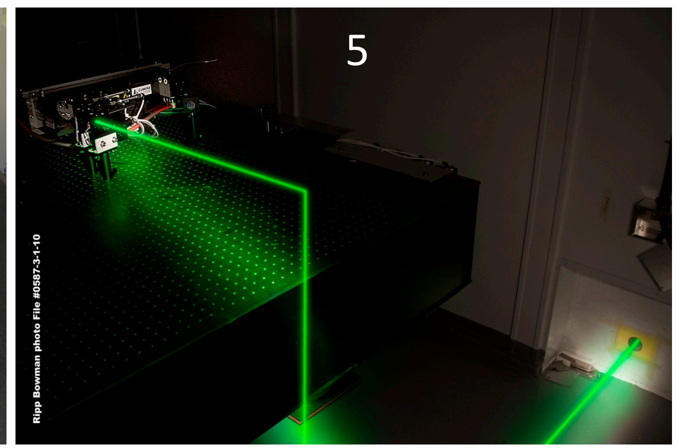
Status of the ERL Projects at BNL

R&D ERL at BNL: 500 mA, 20 MeV, SRF injector, advanced state of construction





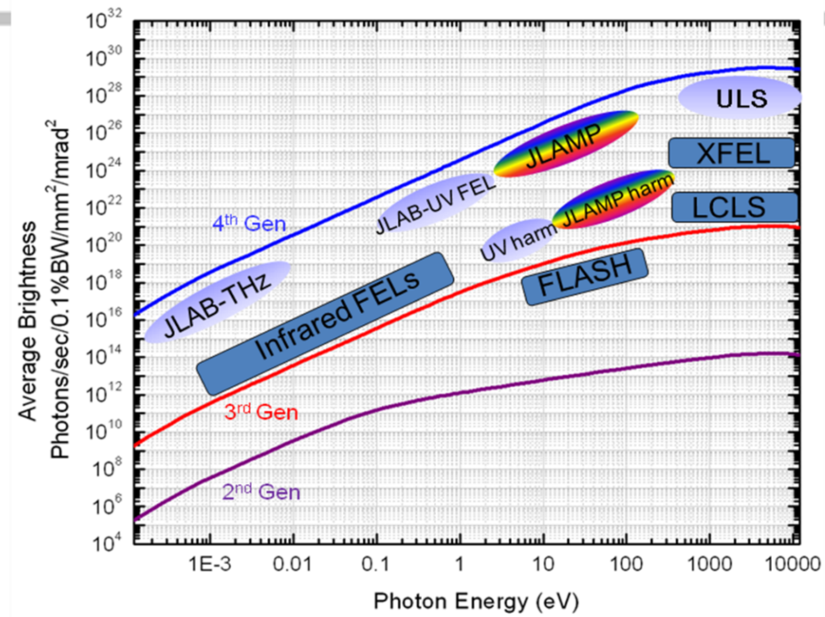


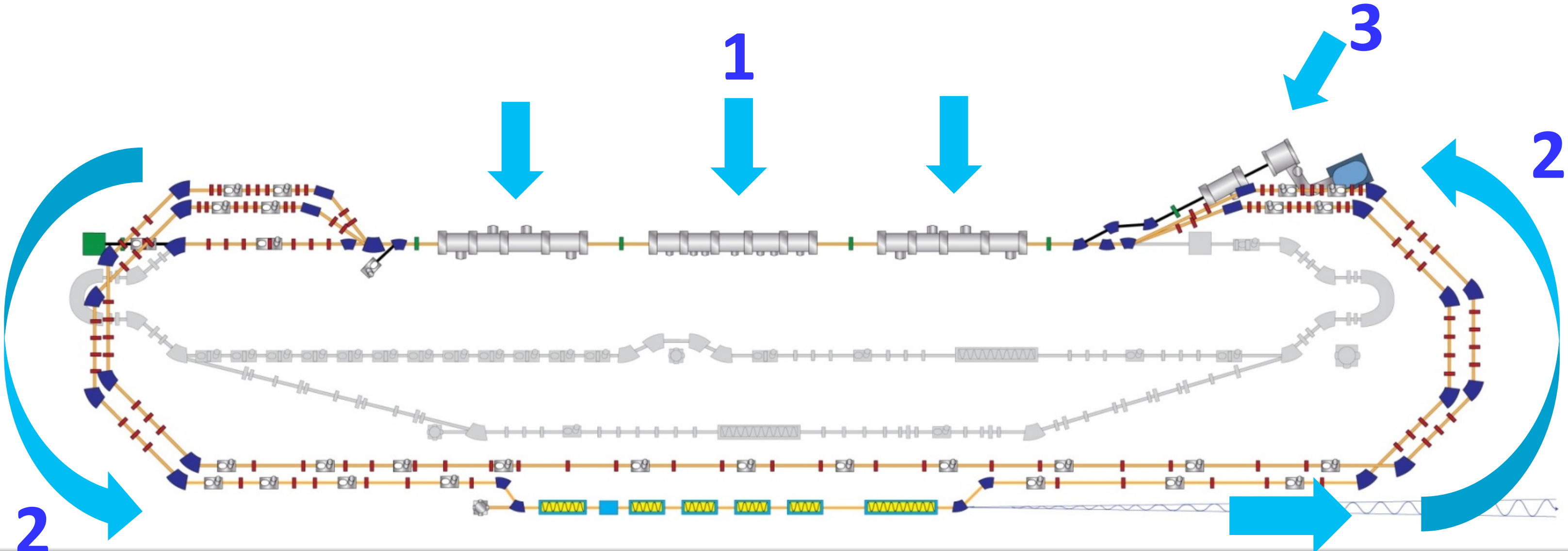


1. The ERL vault, showing the SRF cavity and some of the magnets. 2. The 704 MHz 5-cell 20 MeV cavity with single-mode properties. 3. The superconducting 2 MeV 500 mA guns. 4. The load-lock multialkaline photocathode system. 5. 6 watt green beam laser.

JLab Conversion to JLAMP

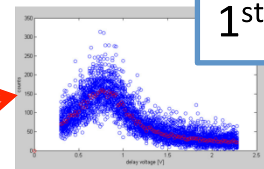
- 4 steps
- 600 MeV, 2 pass acceleration
- 200 pC, 1 mm mrad injector
- Up to 4.68 MHz CW repetition rate
- Recirculation and energy recovery
- 10 eV – 100 eV fundamental output, harmonics to 2nm
- Pulse widths down to 50 fs



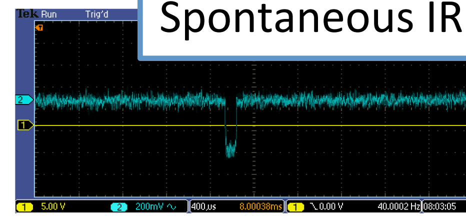


ALICE Project Status Update

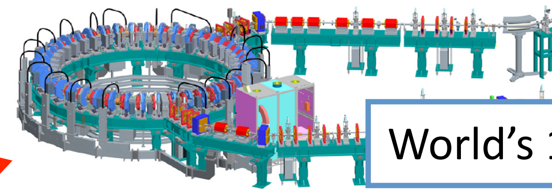
- Commissioning 2009/10
  - Achieved 1st THz in Diagnostics Room
  - 1st Compton Scattering
  - Characterisation of beam
  - Some RF conditioning & optimisation
- **FEL commissioning Feb 10**
- Future experiments
  - Accelerator science R&D
    - FEL lasing
    - EMMA etc...
  - Photon science R&D
    - THz tissue culture lab
    - IR and THz pump probe etc...
  - Technology development
    - International cryomodule
    - Gun upgrade etc......



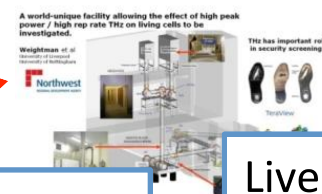
1st Compton X-rays



Spontaneous IR

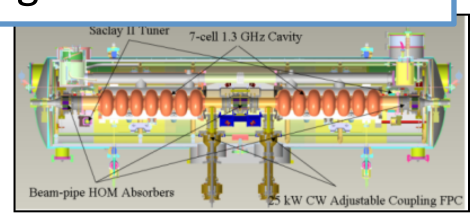


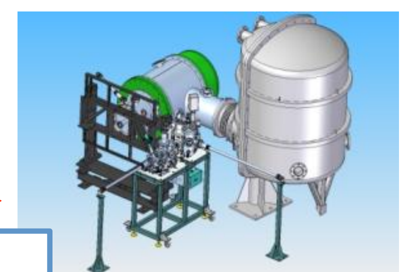
World's 1st ns-FFAG



Live tissue exp.

CW high current module

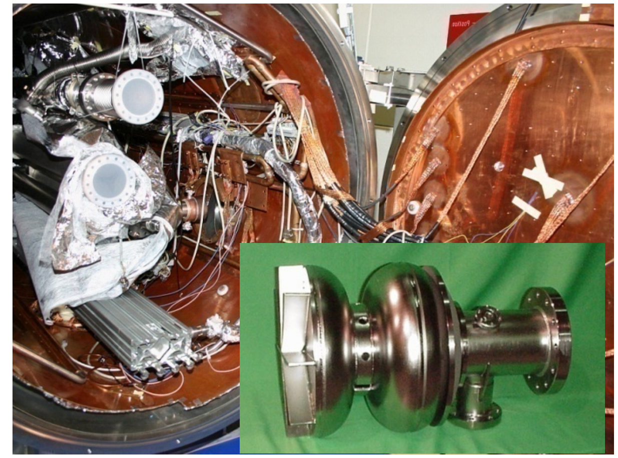




Load lock cathode exp.

HELMHOLTZ ZENTRUM BERLIN für Materialien und Energie

BERLinPro: ERL demonstration facility @ Berlin-Adlershof

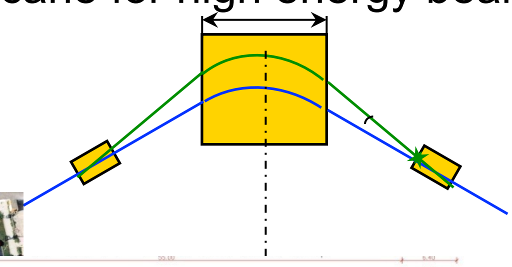


Goal: 1.3GeV, 100MeV, 100mA, small emittance, short bunches
Explore limits of ERL, show different operational modes

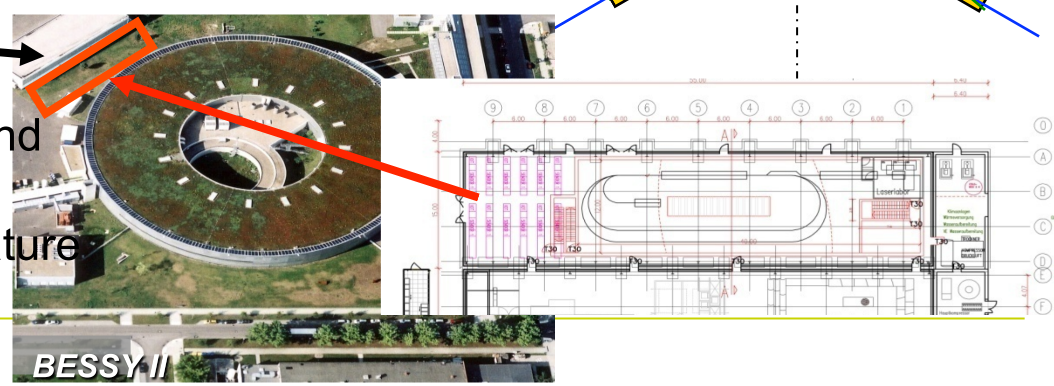
Gun: Funded, staged approach
Beam dynamics → Cathode infrastructure → High current

Merger: Studies show: C-chicane does the job
- Higher order dispersion is an issue
- Lower limit on bunch length after merger depends on current and energy spread
- Emittance depends on bunch length: Remaining compression factors in recirculator < 10
- Lambertson Magnet considered as last merger dipole: saves chicane for high energy beam

Path length control:
Most probably in arc, trajectory elongation in central dipole by outside deflection of the beam



Cryogenic plant

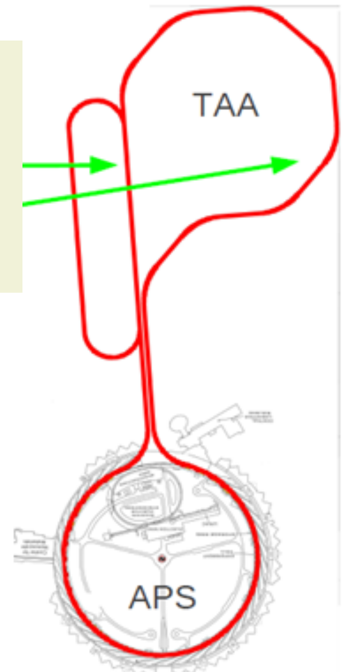


Too little space for shielding above ground
Consider construction underground
Benefit: reduced vibrations and temperature fluctuations at comparable costs

Comparison of APS-upgrade to ERL@APS

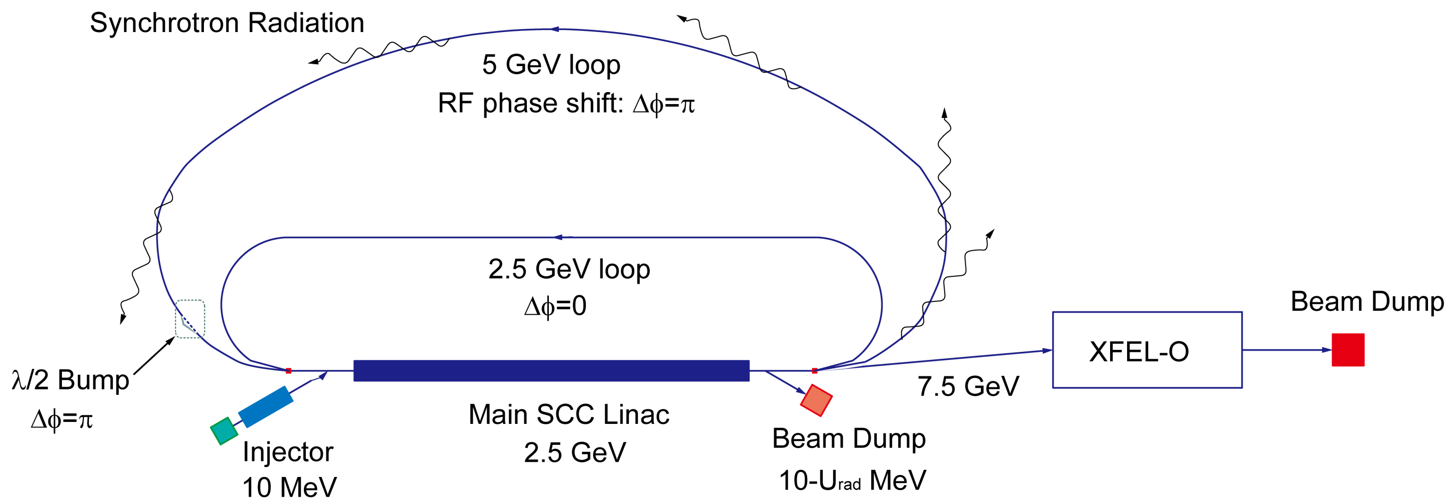
APS-upgrade may include
- 2ps X-ray by crab cavity
- short-period SC undulators
- long straights (7.7m)
- higher current (150 mA)
- lower coupling (8 pm)

ERL@APS
- 2-pass 7-GeV linac
- 50-m straights at TAA
- 0.1 mm-mrad, 25 mA



- APS-U is a cost-effective approach
  - shorter pulse, higher flux and brightness
  - relative low risk
- ERL@APS makes spectacular promises, but
  - multiple show-stoppers → significant R&D required
  - not much enthusiasm from APS users
- APS-U does nothing to preclude ERL@APS
- ANL also keeping XFELO and USR in mind

XFELO in ERL

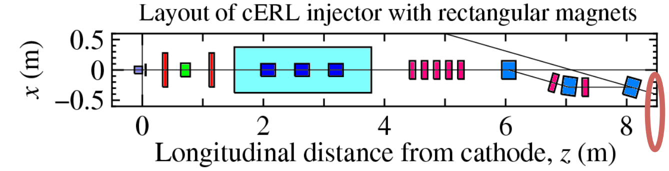


- Hard X-ray ERL can accommodate XFELO.
- 0.1nm-XFELO is feasibly realized at
  - 5-GeV ERL with velocity bunching
  - 7.5-GeV beam from a 2-loop 5-GeV ERL
- In the Japanese collaboration, XFELO is considered as a part of 5-GeV hard X-ray ERL.

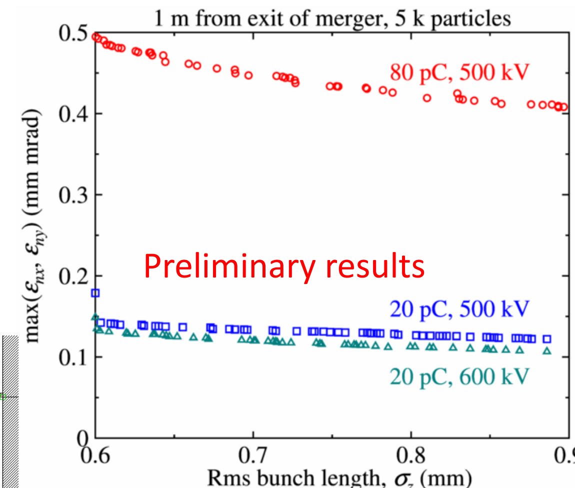
Studies of compact ERL injector in Japan

- Beam dynamics simulation for the compact ERL (cERL) has been carried out using 3D space charge particle tracking code.
  - For high current mode with 80 pC/bunch, we obtained the minimum emittance of 0.56 mm mrad with the bunch length of 0.63 mm. with the gun voltage of 500 kV.
  - For XFEL-O with 20 pC/bunch, so far, we have obtained the minimum emittance of 0.13 mm mrad with the bunch length of 0.6 mm and the gun voltage of 600 kV.
- To evaluate performance of the DC guns, we are developing the gun test beamline in the PF-AR south experimental hall, KEK.
- From the early part of March, we are going to start beam running in the gun test beamline using NPES3 200kV DC photo cathode gun.

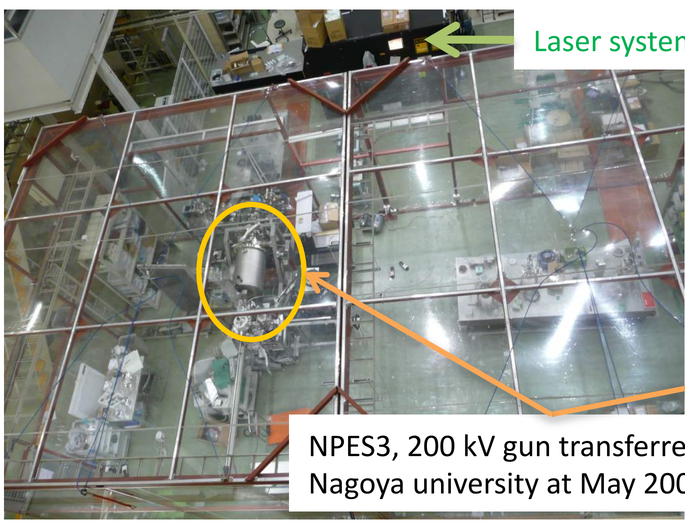
Layout of cERL injector beamline



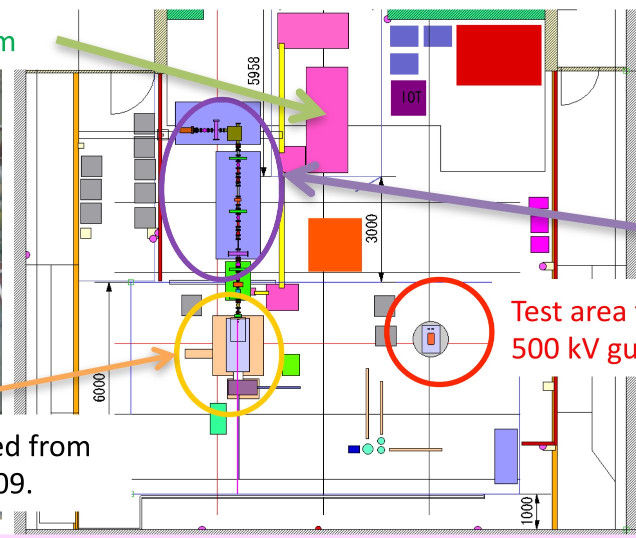
Bunch length vs. emittance



Gun test area in PF-AR south hall, KEK



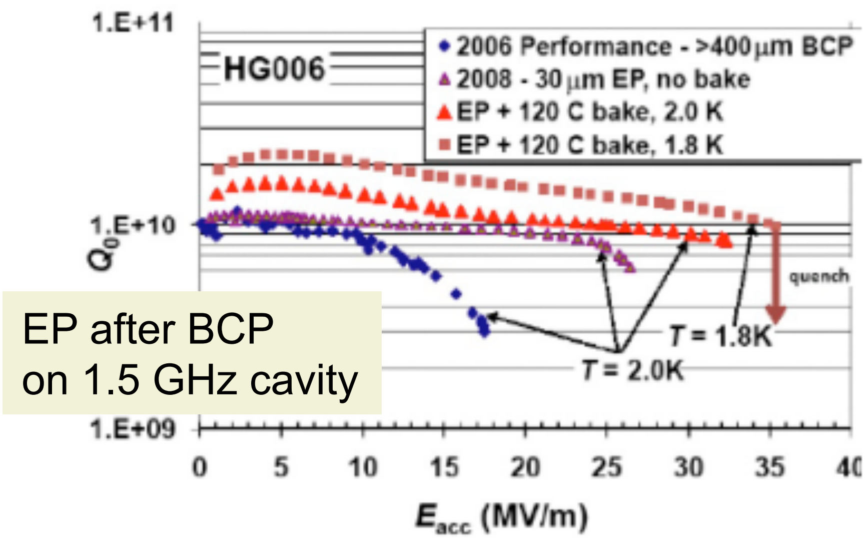
Layout of gun test beamline

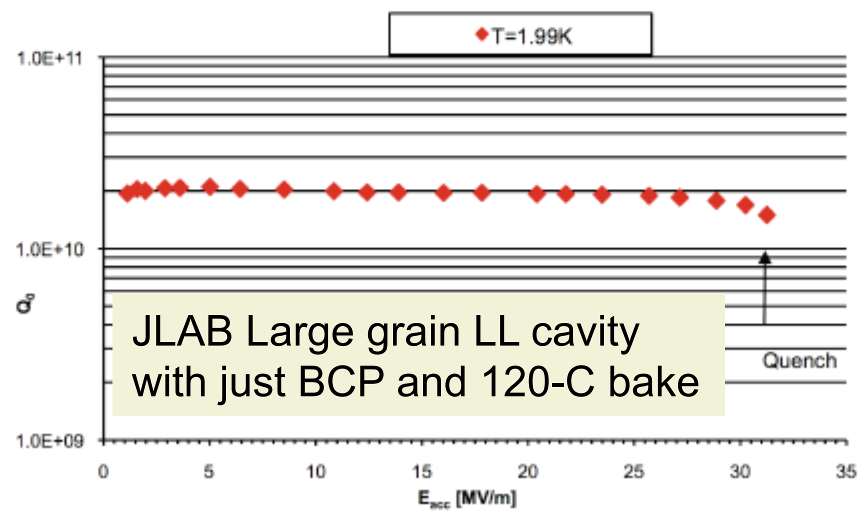


Beam line to develop diagnostics system with emittance and bunch length measurement systems

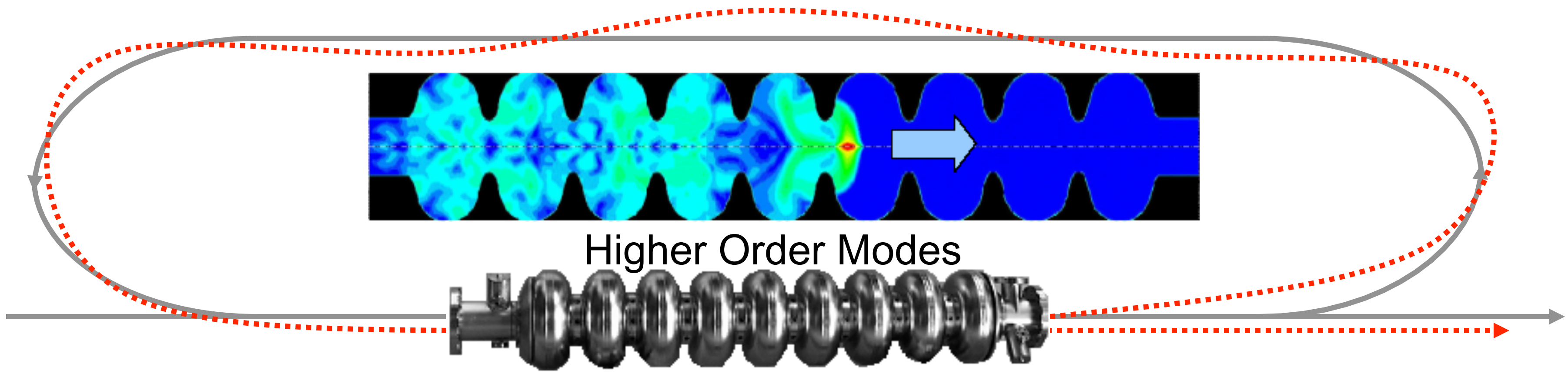
Update on CW SRF at JLAB

- CEBAF 12 GeV upgrade ramping up (10 CM's in 2 years)
- Cavity performance encouraging with EP or large grain
- better Q0 pulls down ERL cost
- JLAMP/FEL, SRF guns, high-current cavity.
- Large 2K cryogenic plant are getting more efficient





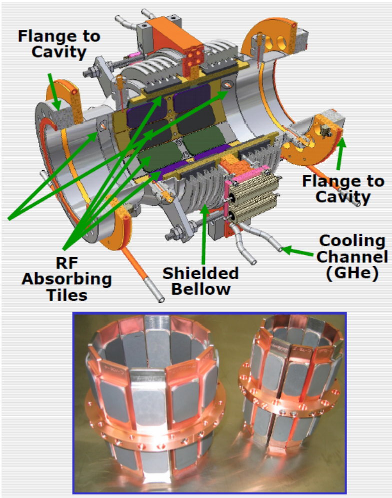
BBU: Collective Instabilities

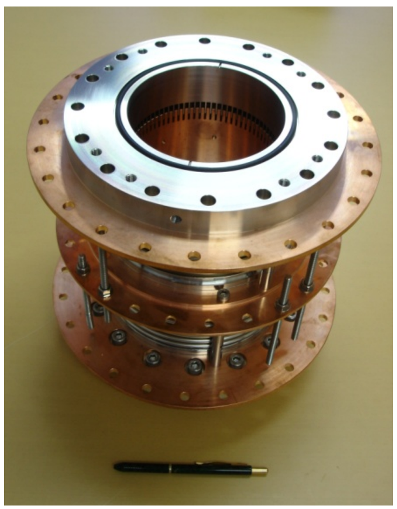


- Beam-Breakup instability is well understood and simulations corrspond to measurements at the JLAB ERL. BBU studies therefore do not require another test ERL.

- Cavity shapes can and have to be optimized so that the BBU threshold becomes insensitive to cavity construction errors.

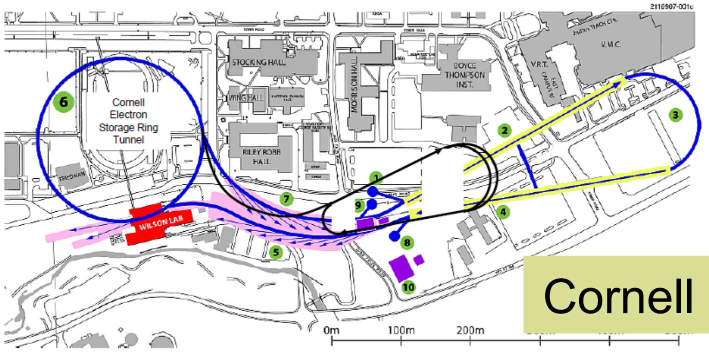
HOM Absorber

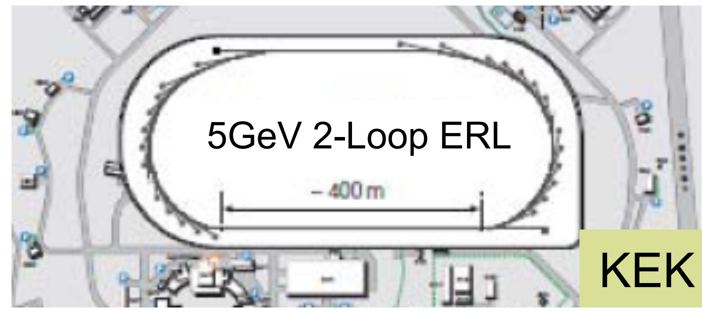




- Material of absorber
  - ferrite (New IB004-1) for KEK/JAEA main linac
  - Carbon nanotube for Cornell main linac
- Frequency range to be covered
  - We need to manage high-frequency component (>100GHz)
  - additional installation of XFEL-type HOM absorber may help
- Manufacturing
  - Study needed
  - Effects of thermal cycle and design to avoid cracking
  - hot isostatic press seems promising
- Magnetization
  - No problem, so far.
- Conductivity to avoid charge up
  - Carbon nanotube seems to be conductive in low temp.

2-Loop ERL Concerns: OK, Challenge





1. Space charge forces for superimposed beams and emittance growth.
2. Intra beam scattering between superimposed beams and halo/background creation.
3. Increasing Higher Order Mode (HOM) power for separated bunches.
4. More sophisticated Beam spectrum and RF control.
5. Tighter orbit and return time tolerances.
6. Limits of orbit corrections for 4 simultaneous beams.
7. Linac optics for 4 simultaneous beams.
8. Reduced Beam-Breakup (BBU) tolerances, esp. with cavity errors.
9. Reduced effectiveness of polarized cavities and coupled optics for fighting the BBU instability.
10. Impedance budget and increased energy spread.

Depending on environment, the challenges can be worth the potential savings or not.

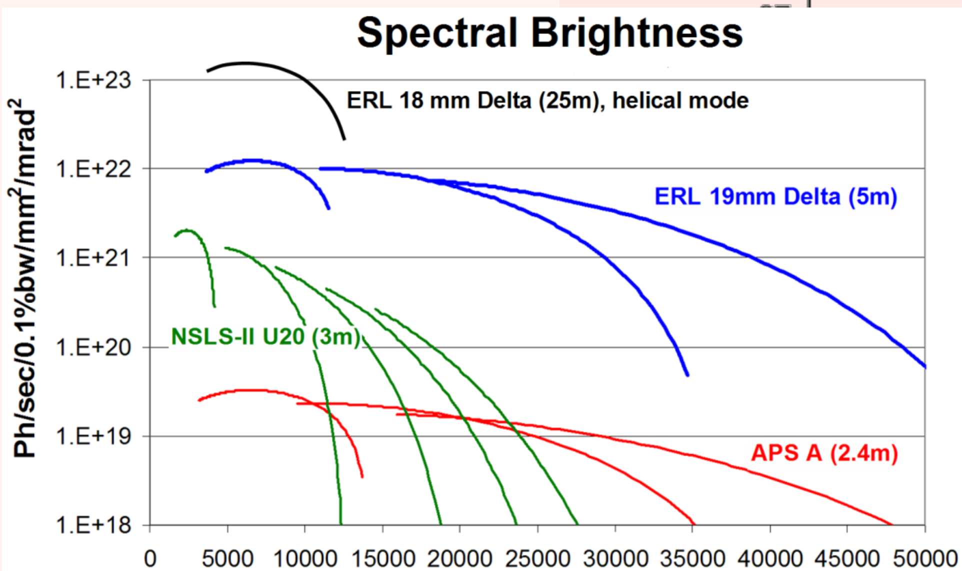
Cornell: increased tunnel and building needs for two turns make risk not worth taking.

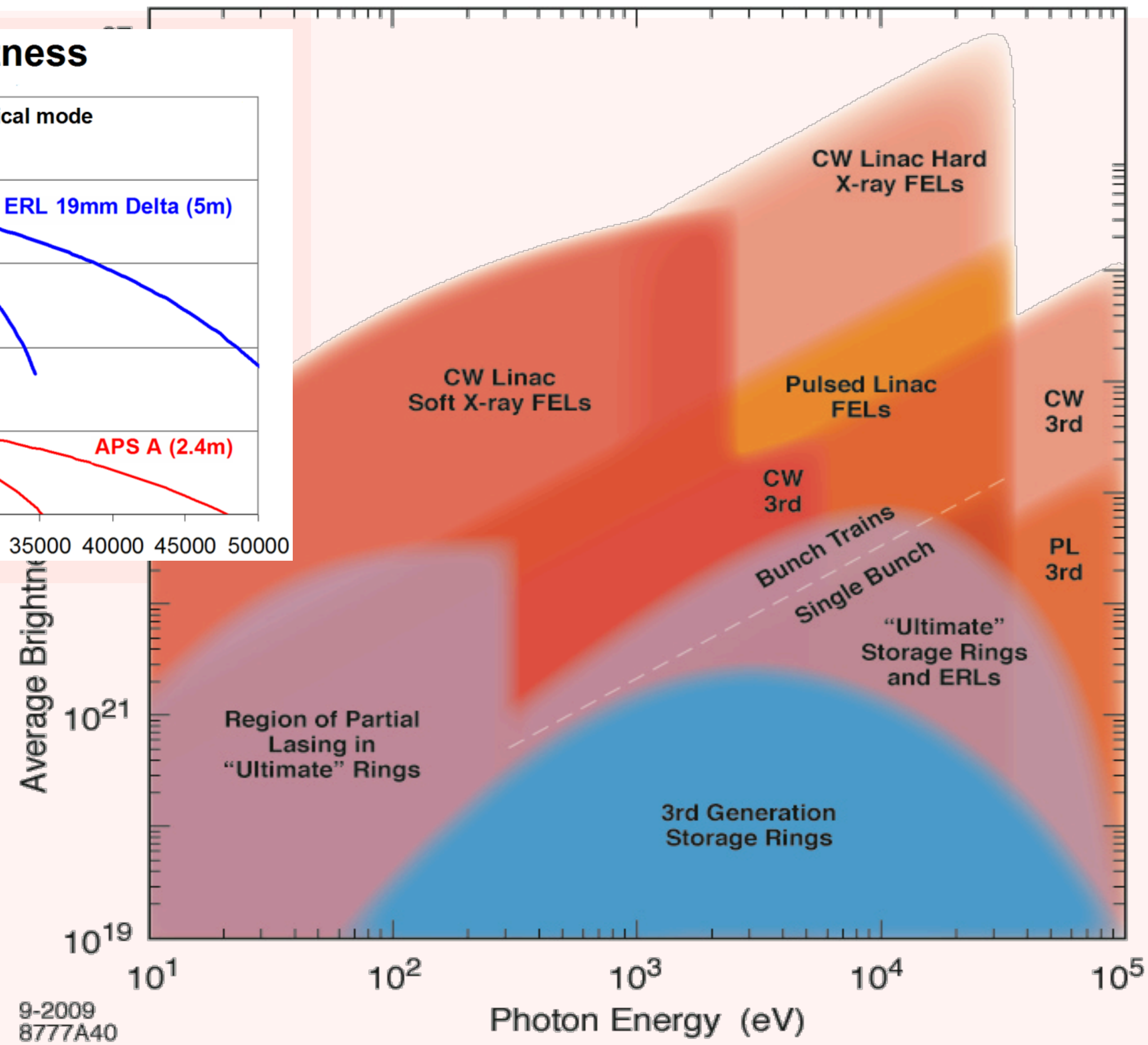
KEK: because of space limitations, a two turn ERL seems to have a benefit.

Operation Modes for Hard X-ray ERL (Cornell)

	Energy recovered modes			One pass	
Modes:	(A) Flux	(B) Coherence	(C) Short-Pulse	(D) High charge	Units
Energy	5	5	5	5	GeV
Current	100	25	100	0.1	mA
Bunch charge	77	19	77	1000	pC
Repetition rate	1300	1300	1300	0.1	MHz
Norm. emittance	0.3	0.08	1	5.0	mm mrad
Geom. emittance	31	8.2	103	1022	pm
Rms bunch length	2000	2000	100	50	fs
Relative energy spread	0.2	0.2	1	3	10^{-3}
Beam power	500	125	500	0.5	MW

Average Spectral Brightness for Hard X-ray ERL





Exceedingly large average spectral brightness is one large advantage for ERLs, but by far not the only one.

Summary of Advantages for ERLs

ERLs have unique capabilities and many advantages over rings:

a) Large currents for Linac quality beams

b) Continuous beams with flexible bunch structure

c) Small emittances for round beams

[similar transverse properties have recently been proposed for 3km long rings]

d) Openness to future improvements

[today's rings can also be improved, improvements bejond ring performances mentioned under c) may be harder to imagine]

e) Small energy spread

a) Variable Optics

b) Short bunches, synchronized and simultaneous with small emittances

The breadth of science and technology enabled is consequently very large and the ERL will be a resource for a very broad scientific community.

X-ray ERLs are at the beginning of a development sequence, whereas decades have brought x-ray rings to the end of their development.

Operation Modes for Other Types of ERLs

Modes:	THz	Compton gamma	Compton x-ray	Seeding FEL
Energy	100MeV<E<1GeV	>300MeV	>25MeV for IR laser for 10keV	>2GeV HHG for Sxr >5GeV for selfseeding Hxr ?
Current	>1mA	>1mA	Large?	kA peak
Bunch charge		Cavity length as long as possible	As large as pos	As high as pos
Repetition rate	for 75MHz	Therefore as low as possible	As low as pos for given current	<1MHz if echo enhanced
Norm. emittance	$\gamma\lambda/4\pi$	$\lambda_{Laser}/4\pi$	$\gamma\lambda/4\pi$ for beam matching	
Geom. emittance	$\lambda/4\pi$	$\lambda_{Laser}/4\pi/\gamma$		
Rms bunch length	<100fs	< hourglass > Energy spread if applicable	< hourglass	Somewhat > 30fs +- 20fs jitter laser length
Relative energy spread	To recover	1.e-9, thus as small as possible or corresponding to emittance		Slice over 30fs seed as small as possible.

We appreciate all the contributions to the ERL WG, and the arrangement by WS Organizers.

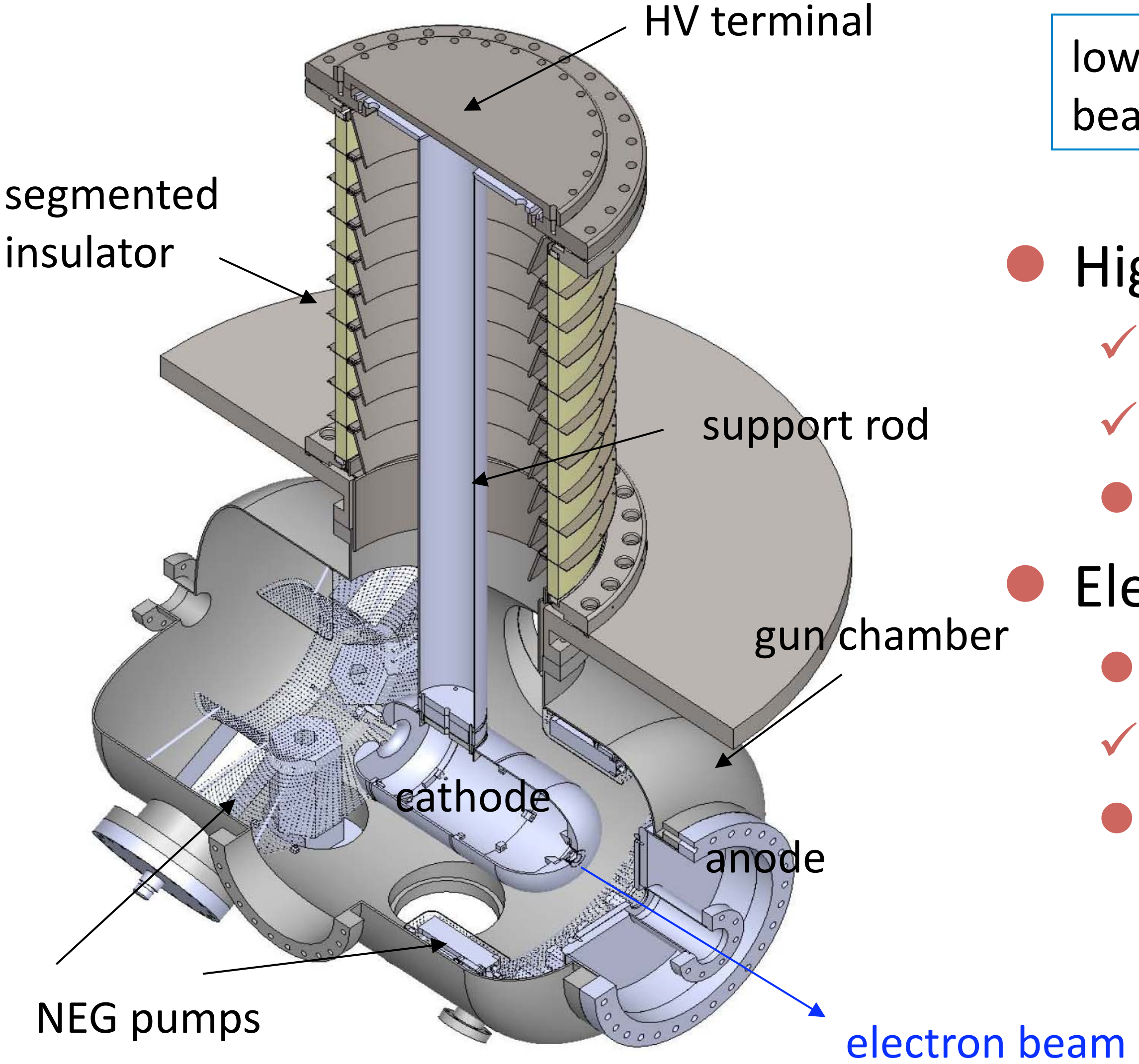
ICFA have approved ERL-11 WS. See you at Tsukuba Japan in fall 2011.

Joint Sessions
（抜粋）

JAEA/KEK DC gun for ERLs

N. Nishimori, R. Nagai, R. Hajima
Japan Atomic Energy Agency (JAEA)
M. Yamamoto, T. Miyajima, T. Muto, Y. Honda
KEK
H. Iijima, M. Kuriki
Hiroshima University
M. Kuwahara, S. Okumi, T. Nakanishi
Nagoya Univiersity

Development of a 500 kV photocathode DC gun at JAEA



low emittance: <=1 mm-mrad (normalized)
beam current: >=10 mA

- High DC voltage >= 500kV
  - ✓ CockCroft Walton power supply
  - ✓ Segmented insulator with guard rings
  - High voltage testing
- Electrodes and vacuum
  - Cathode and anode electrodes
  - ✓ Low outgassing material (titanium)
  - NEG pumps

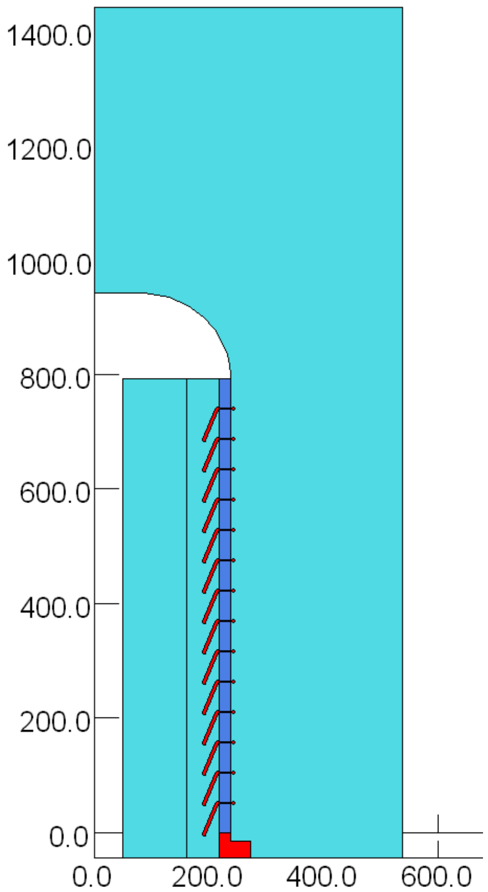
High Brightness, HVDC, Photoemission Electron Gun Development at Cornell

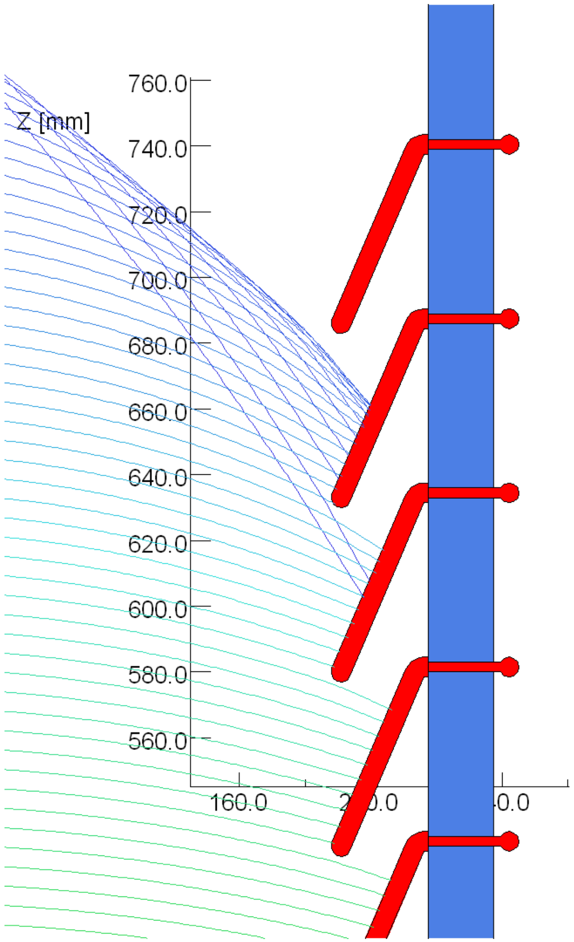
Charlie Sinclair

Cornell University

Segmented Ceramic

750 kV terminal

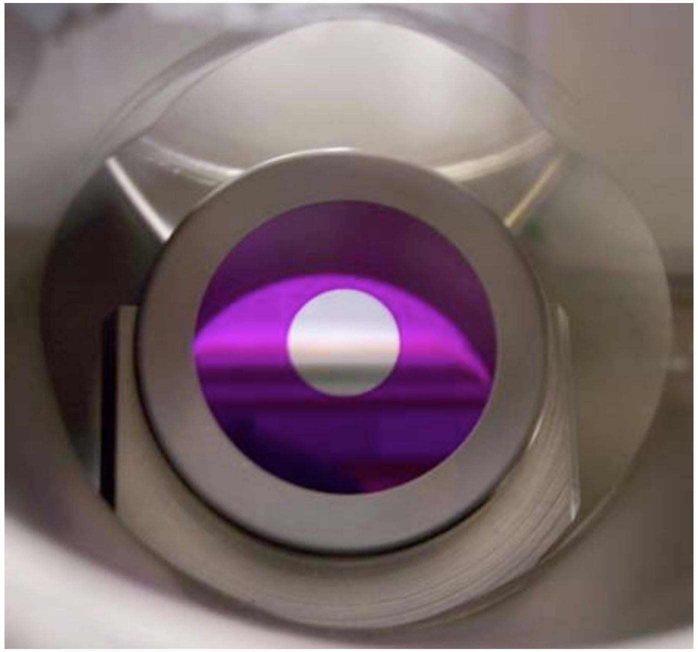




750 kV, 100 mA HVPS

- Insulating core transformer technology
- 62 circuit boards, each delivering 100 mA at 12.5 kV, stacked in series – 24 pf total capacitance
- Pressurized SF_6 insulation
- External high power, high frequency (~ 100 kHz) drive and control circuitry

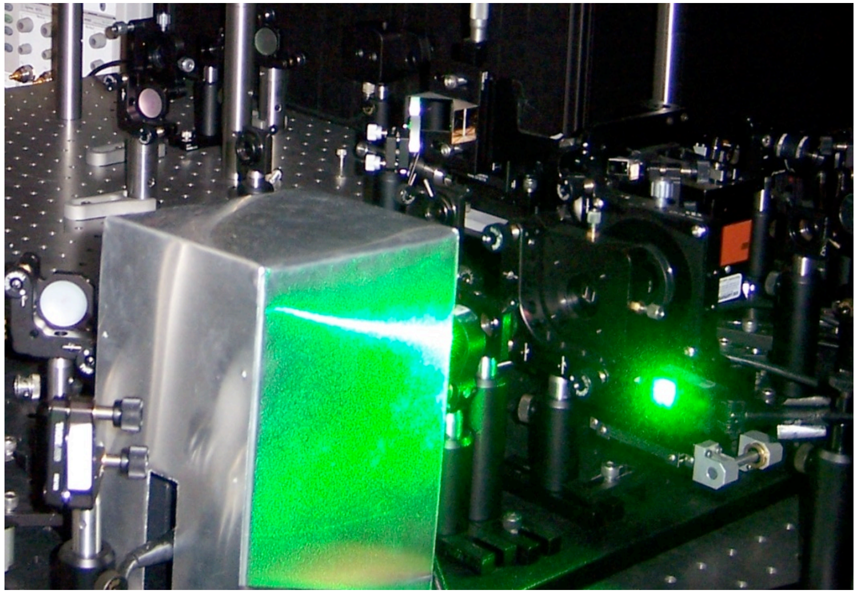
Photocathode Performance



GaAs wafer, anodized at large radius, indium soldered to Mo Puck

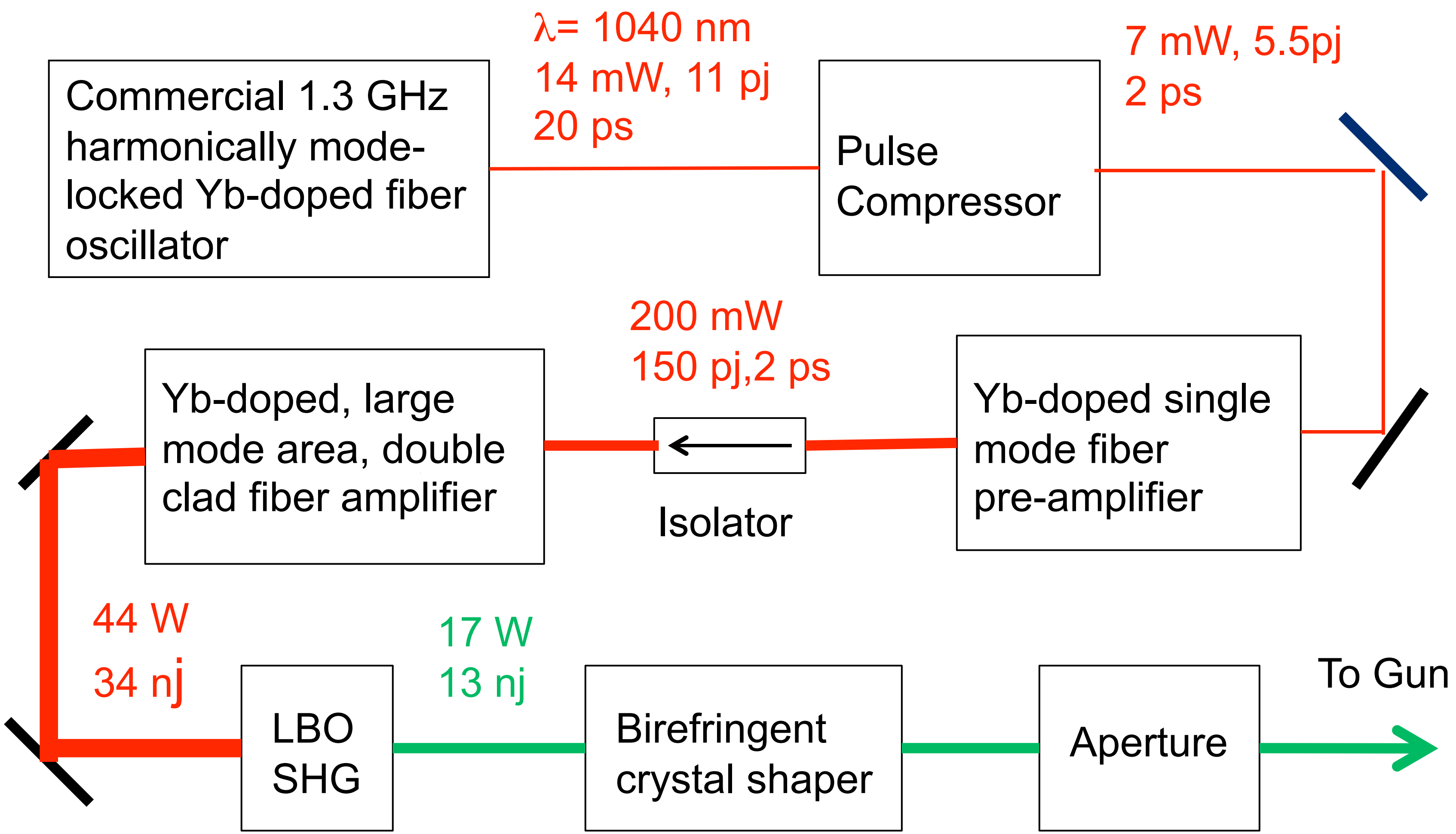
- Cathodes to date have been GaAs, cleaned by atomic hydrogen and heating, and activated with Cs and NF_3
- Initial QEs of 12-15% at 520 nm, with lifetime limited only by ion back bombardment
- Cathode changes, every several weeks, take about ½ hour, with no dropped pucks
- Maximum current to date 20 mA DC in test lab, 8 mA with 1.3 GHz RF structure

High Power 1.3 GHz Laser

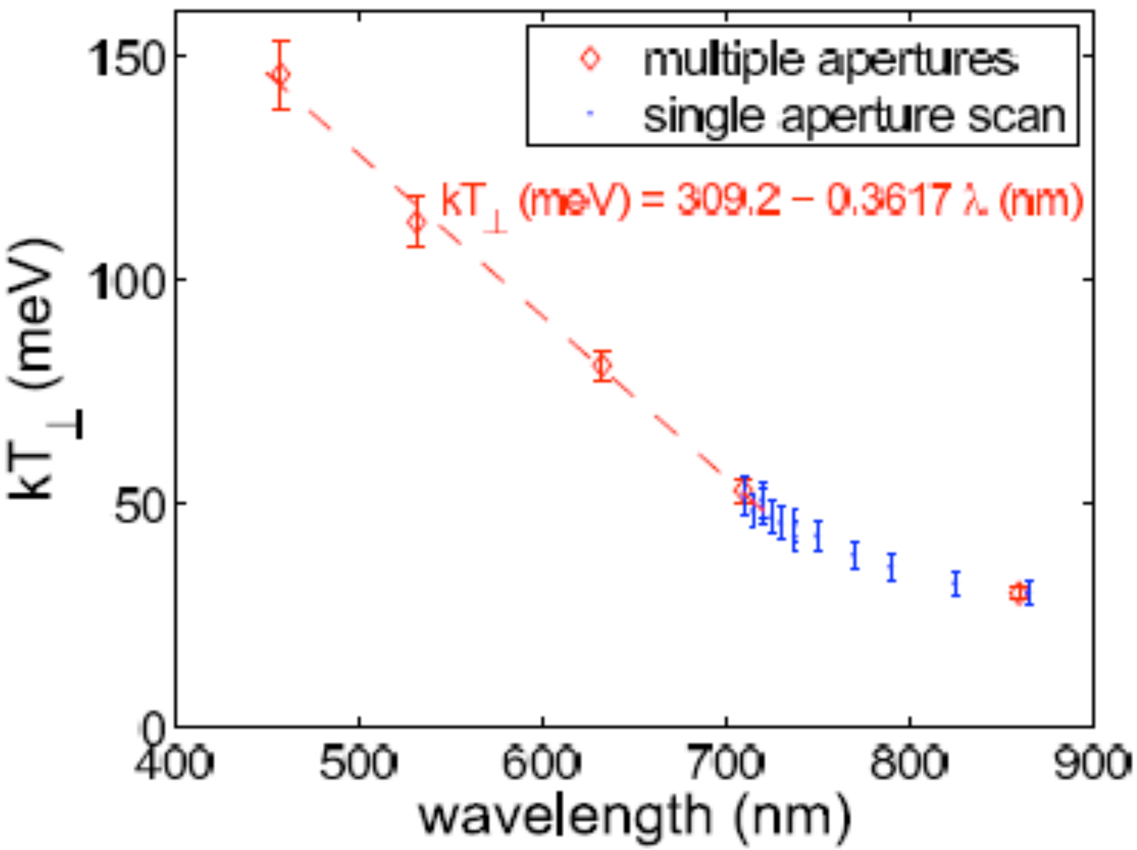


- Operated for ~ 5 hours at 20 W green, and for very extended times at 15 W green
- Measured 53% transmission from laser output to gun entrance window

ACTUAL 1.3 GHz Green Laser



Measured GaAs Thermal Emittance vs. Wavelength



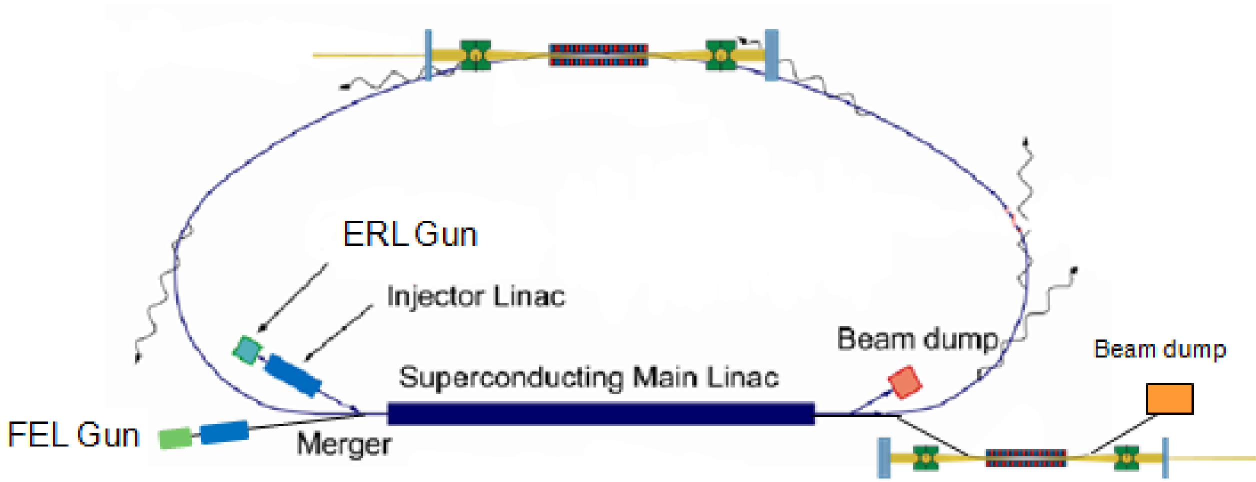
GaAs Temporal Response vs. Wavelength

Wavelength (nm)		Gun Voltage (kV)		Temporal Response (ps)
860		200		76 +/- 26
		250		69 +/- 22
785		200		11.5 +/- 1.2
		250		9.3 +/- 1.1
710		200		5.8 +/- 0.5
		250		5.2 +/- 0.5
520		250		< 1
460		250		<0.14

Summary
FLS2010 FEL Working Group
Part II

Joe Bisognano/Kwang-Je Kim

Integration of XFELO and ERL



Location
- straight section of the loop
- additional branch

Operation mode
- independent
- concurrent

Injector
- share an ERL injector
- use a FEL injector

From the ERL side,

XFELO adds a new feature with minor modification
ERL and XFELO provides complimentary X-rays

Conclusions

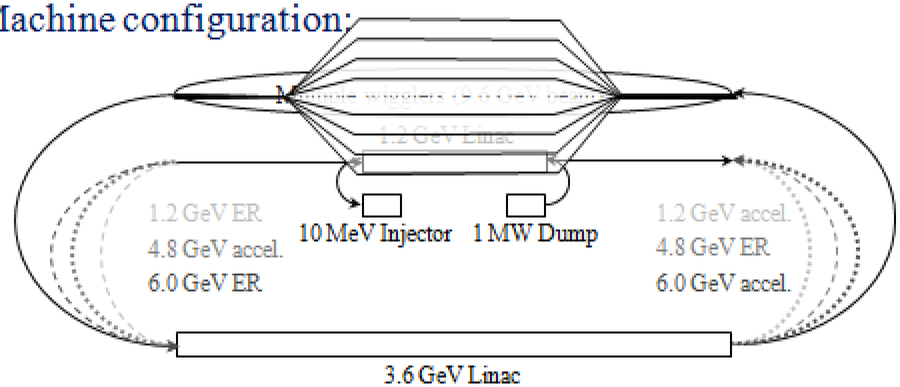
- Hard X-ray ERL can accommodate XFELO.
  - we can extend the frontier of X-ray beam parameters
- 0.1nm-XFELO is feasibly realized at
  - 5-GeV ERL with velocity bunching
  - 7.5-GeV beam from a 2-loop 5-GeV ERL
  - an ERL injector is shared, no major modification is needed
- XFELO can be installed either at a loop or a branch.
  - however, beam loss in a long narrow duct might be a problem for a XFELO in a loop
- In the Japanese collaboration, At KEK XFELO is considered as a part of 5-GeV hard X-ray ERL.

Hajima

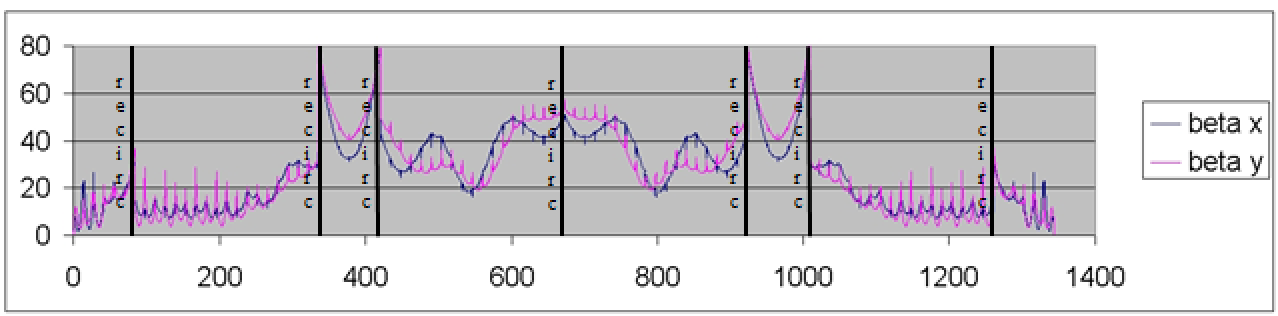
Many FELs in an ERL

GERBAL

– Machine configuration:



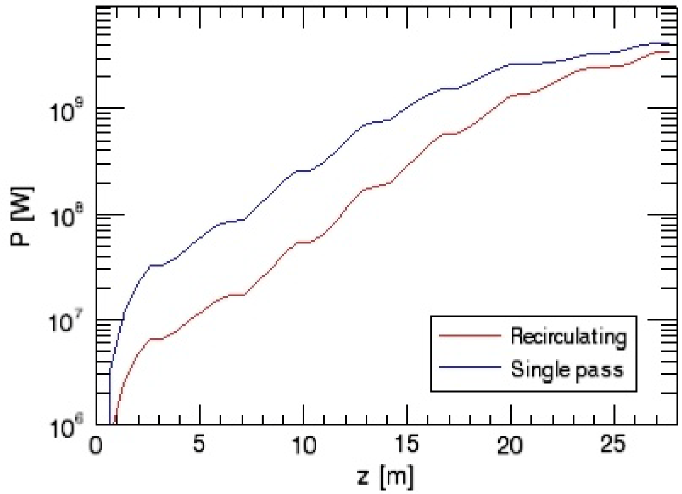
– Transverse optics

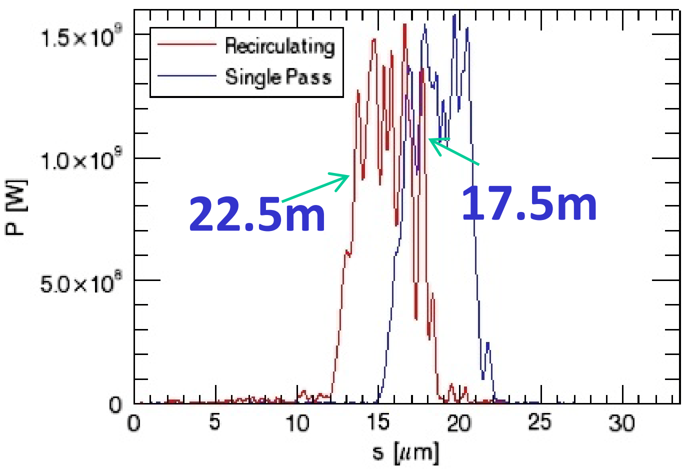


Or subharmonic seeding

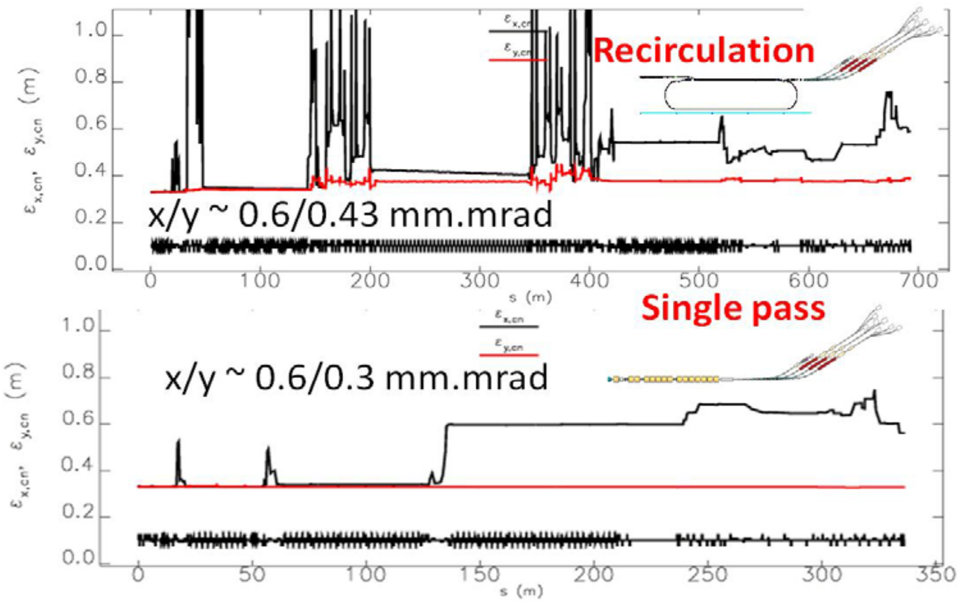
Recirculation in NLS Summary

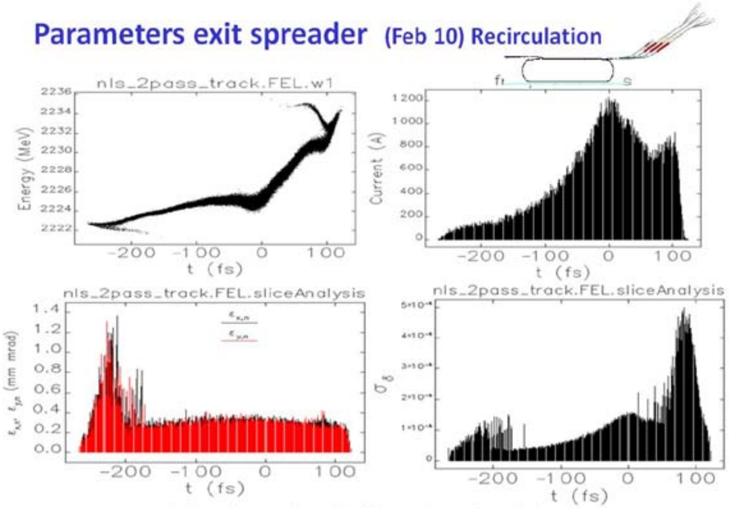
Seeded FEL Output
Single pass V Recirc.



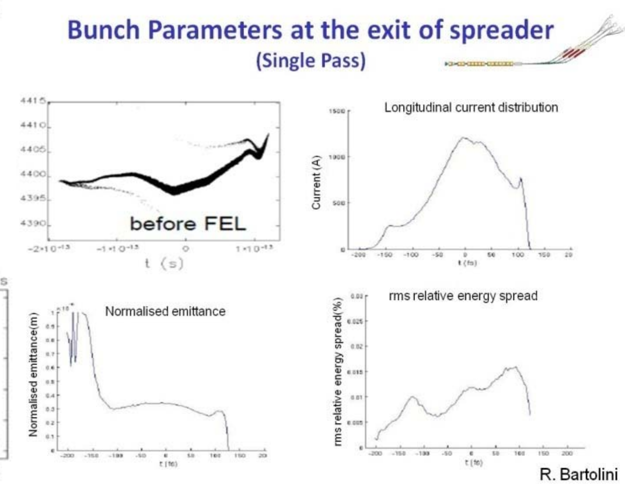


Emittance Start to end of Spreader





Tracked 100k particles. The data is binned in 1fs slices.



Also a presentation from M Borland

Personal Highlights/Biases

- FELs in ERLs
  - Workable but not necessary for FELs, since average current low
  - RF separation or seeding at subharmonic frequency to allow several FELs
  - Layout of user experiments needs to be better considered
  - Low power beam dumps an attraction
  - Simultaneous incoherent ERLing with FEL operation an open question
- Recirculation to save costs
  - Two pass recirculation seems to survive CSR and beam quality preserved well enough
  - Bunch compression harder, doesn't look as good as single pass and may be problematic (but looks good enough to lase)
  - Cost savings of ~30 % for linac; 10 % for facility; is this worth it? (on the other hand 10 % of $1 billion is nontrivial)

XFEL-O
（抜粋）

Argonne NATIONAL LABORATORY

... for a brighter future

U.S. Department of Energy

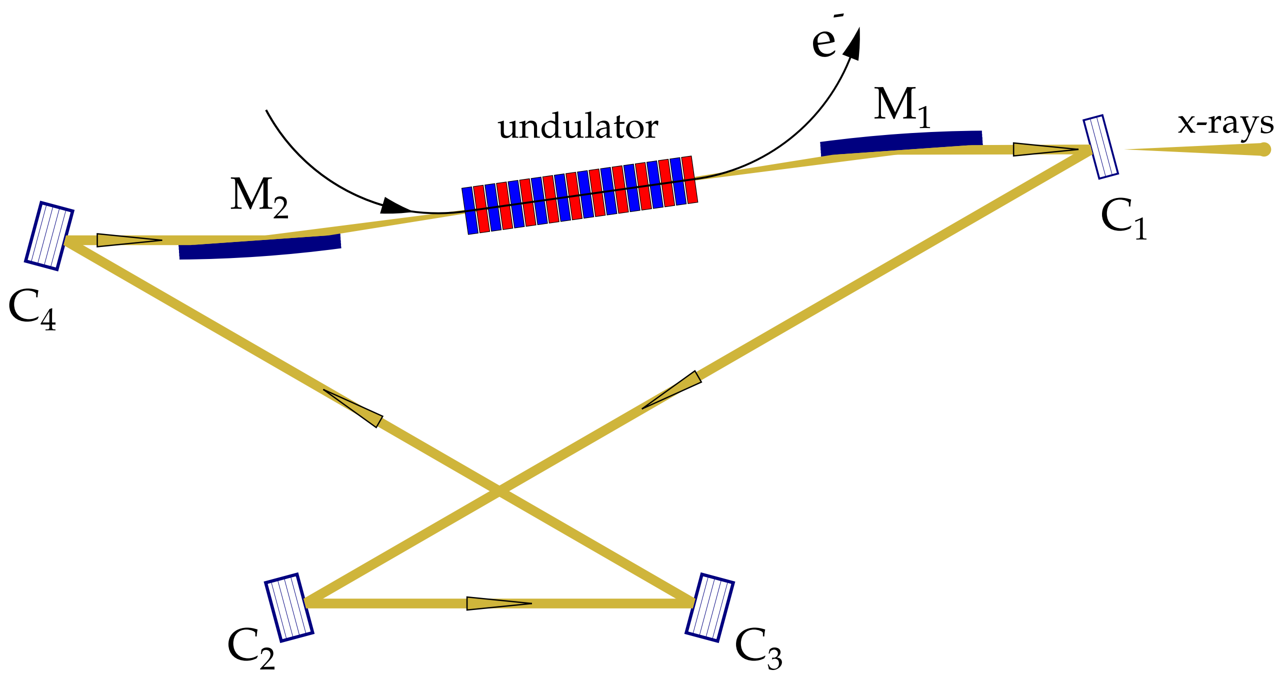
UChicago Argonne LLC

Office of Science
U.S. DEPARTMENT OF ENERGY

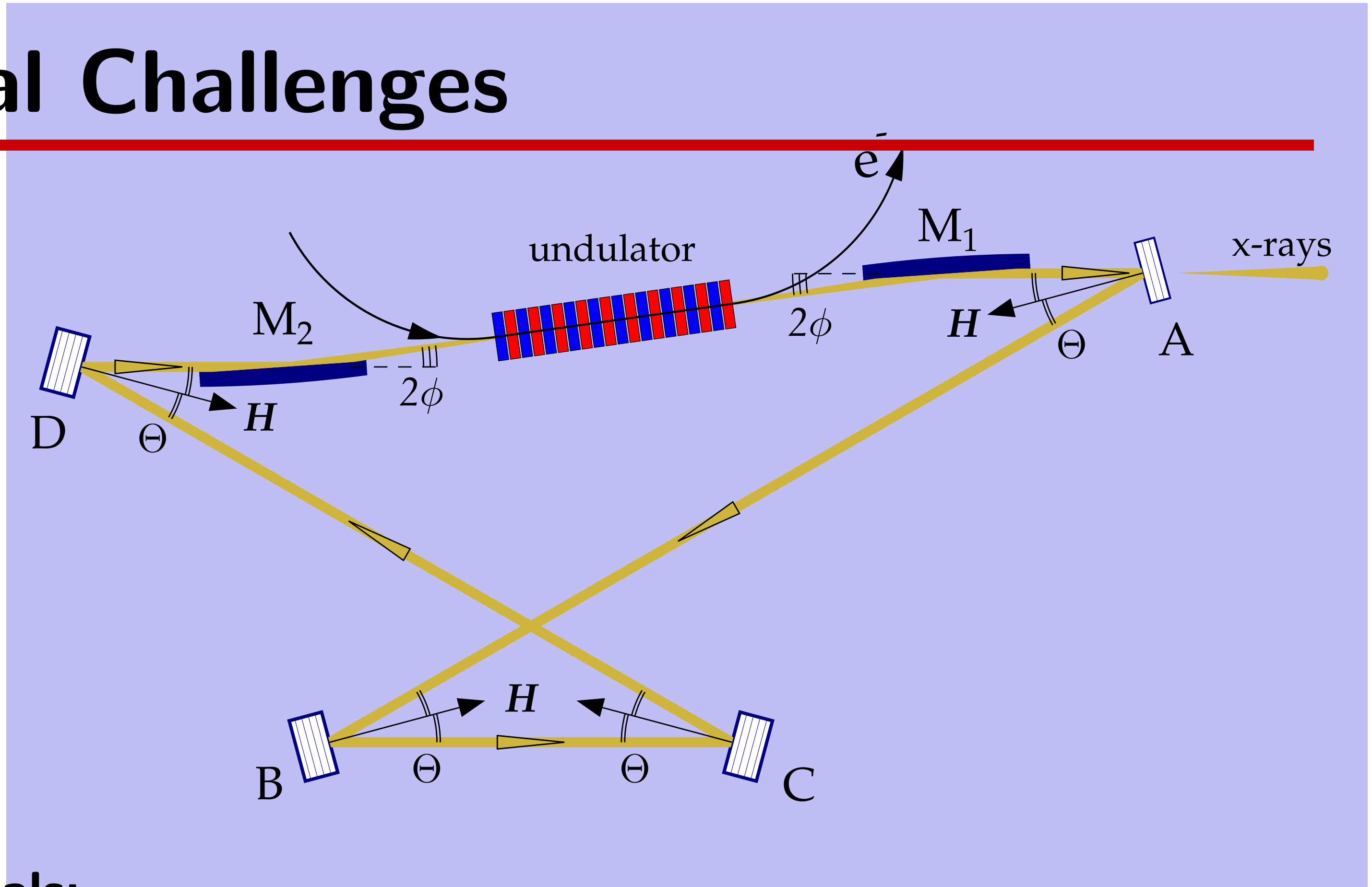
A U.S. Department of Energy laboratory
managed by UChicago Argonne, LLC

XFELO X-ray Cavity Feasibility Studies

Yuri Shvyd'ko



XFELO Technical Challenges



X-ray Optics:

- **Quality of diamond crystals:**
  is the theoretical reflectivity achievable? ✓
- **Heat load problem: reflection region variations $\lesssim 1$ meV.** ✓
- **Angular stability: $\delta\theta \lesssim 10$ nrad (rms)** ✓
  Spatial stability: $\delta L \lesssim 3\ \mu$m (rms) $\quad\rightarrow\quad \delta L/L \lesssim 3\times 10^{-8}$
- **Radiation damage** ?

ERL vs Ultimate Ring
（抜粋）

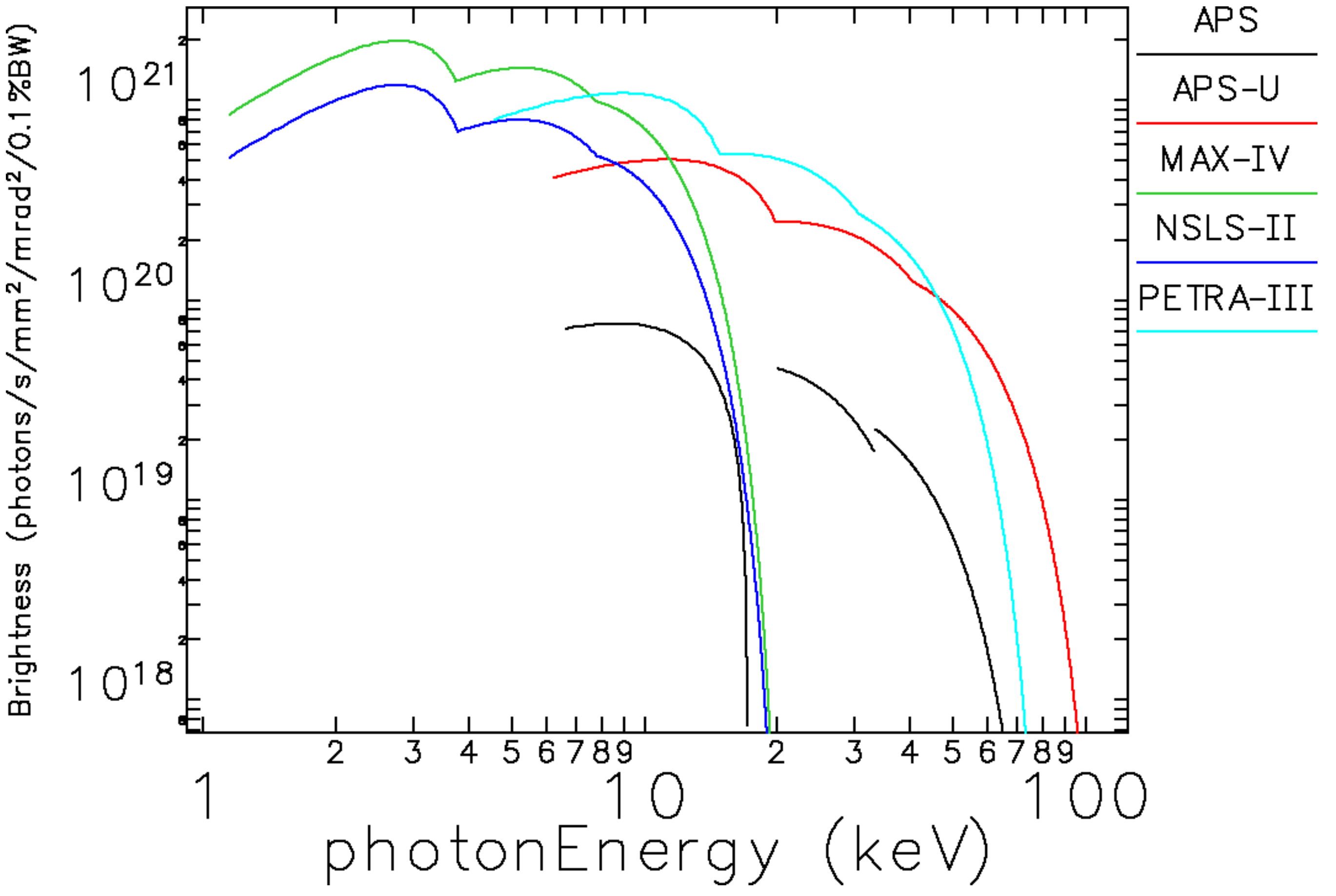
Overview of Ring-Based X-ray Sources

Michael Borland

Argonne National Laboratory

March 2010

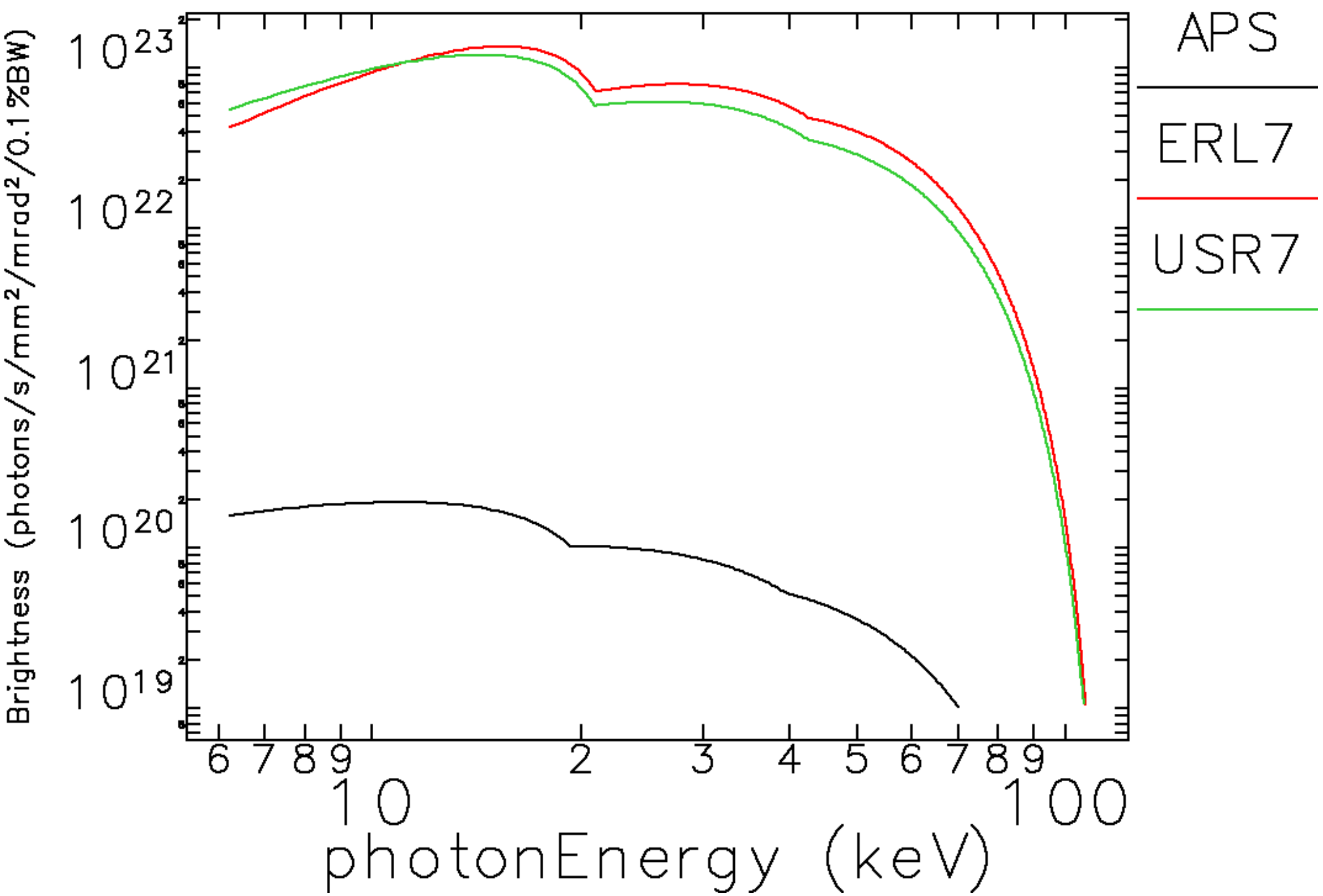
Brightness of a Few Present and Planned Rings



- APS curve assumes existing 2.4m long U27
- Assume maximum length SCU20 (future 1.25T device[1])
- Used best published electron beam parameters, with 1% coupling
- First three harmonics shown only

[1]R. Dejus, private communication.

Brightness Comparison

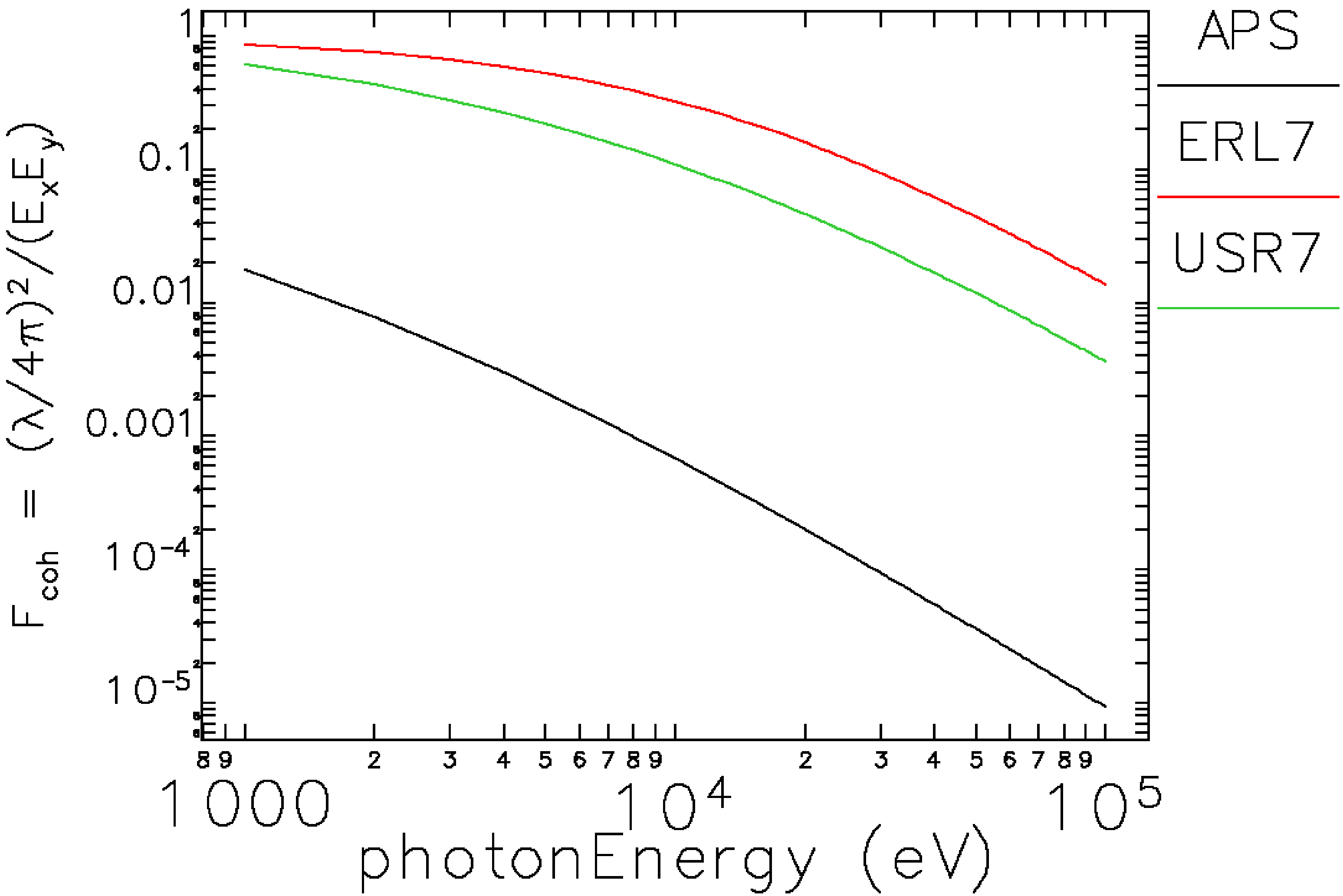


Maximum-length SCU20 (Nb_3Sn wire)

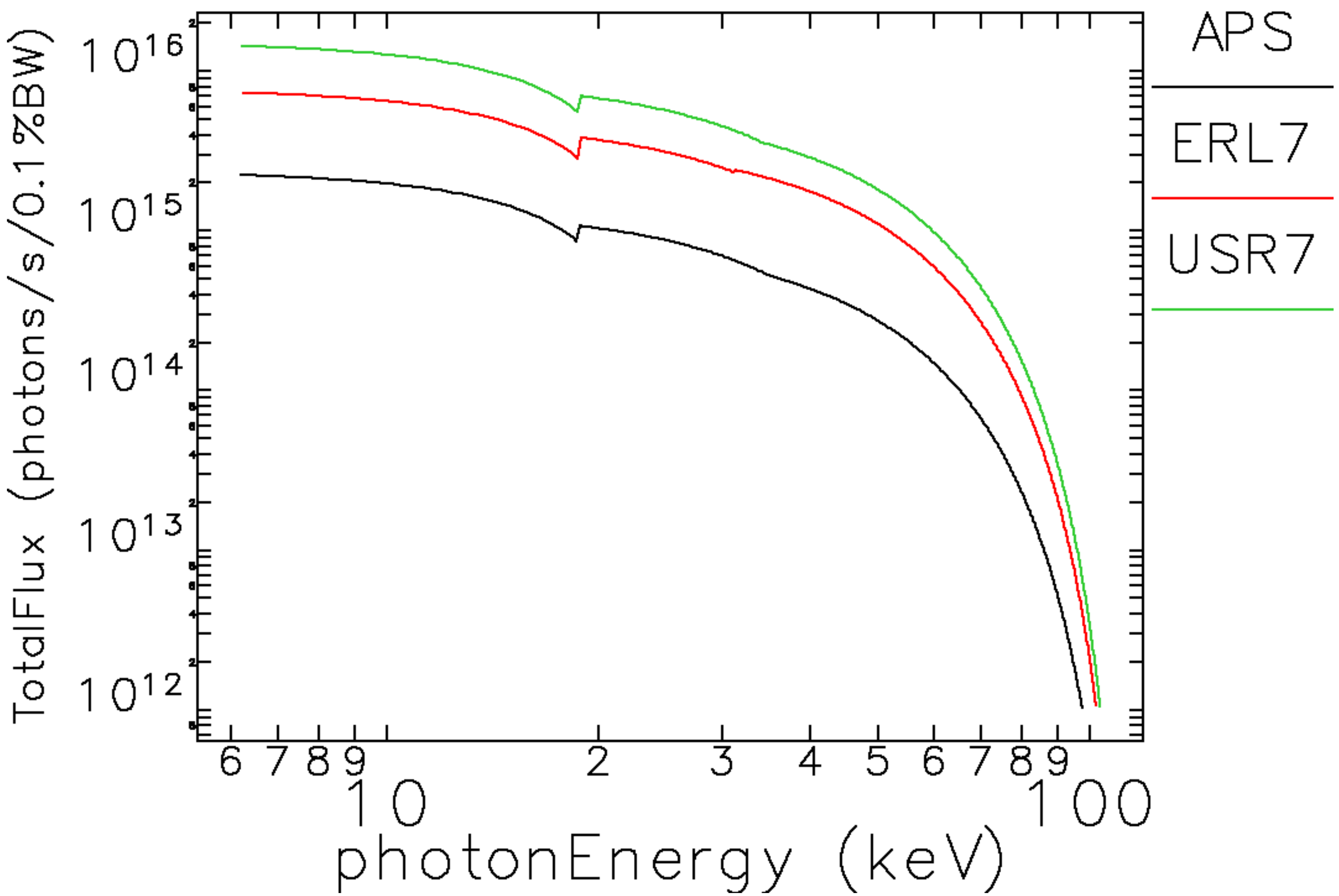
APS: 100mA, 1.3% coupling, 3.8 m device
USR7: 300mA, 100% coupling, 8.0 m device
ERL7: 25mA, “high-coherence” parameters, 48m device

Computed with **sddsbrightness** (H. Shang, R. Dejus, M. Borland)

Transverse Coherence Comparison



Flux Comparison



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ERL7: 25mA, “high-coherence” parameters, 48m device

Computed with **sddsfluxcurve** (M. Borland, R. Dejus, H. Shang)

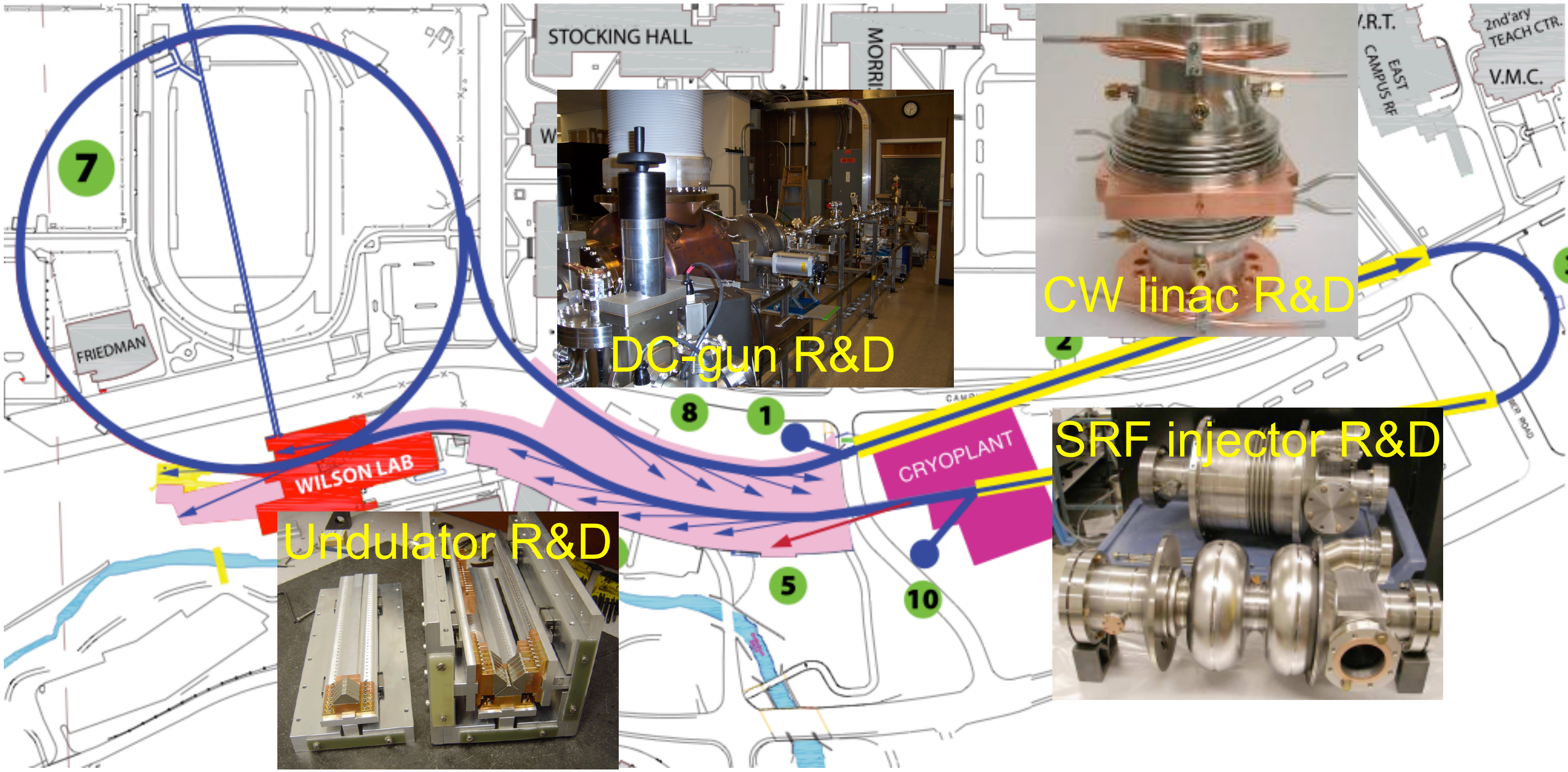
Isn't an ERL Better?

Performance Measure	Advantage	Comment
High transverse coherence	ERL	ERL has emittance and matching advantage
High average flux	USR7	ERL needs very long undulators and high current, not very plausible
High average brightness	Similar	Assuming 48m undulators in ERL, extremely small emittances
Wide tunability	ERL?	Can gaps really be smaller in ERL (impedance)?
Short bunch length	ERL++	Who cares at 1.3 GHz?
Useful repetition rate	Similar	USR7 slightly more flexible
High stability	USR7	ERL has additional sources of jitter
Less R&D	USR7++	
Less risk	USR7++	
Lower construction cost	USR7	For same number of beamlines
Lower operating cost	USR7+	Large cryoplant for ERL
Higher reliability	USR7++	Large cryoplant, many rf systems for ERL

USR+FELs is a better strategy than ERL+FELs

R&D toward an ERL

Georg Hoffstaetter
Cornell Physics Dept. / CLASSE
Cornell's ERL team



Summary of Advantages for Hard X-Ray ERLs

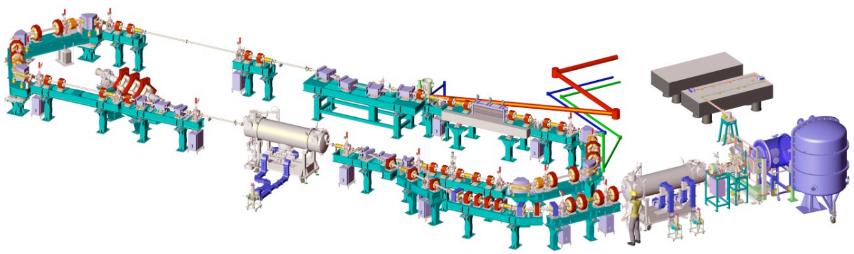
X-ray ERLs have unique capabilities and many advantages over rings:

a) Large currents for Linac quality beams
b) Continuous beams with flexible bunch structure
c) Small emittances for round beams
d) Openness to future improvements
e) Small energy spread
f) Variable Optics
g) Short bunches, synchronized and simultaneous with small emittances

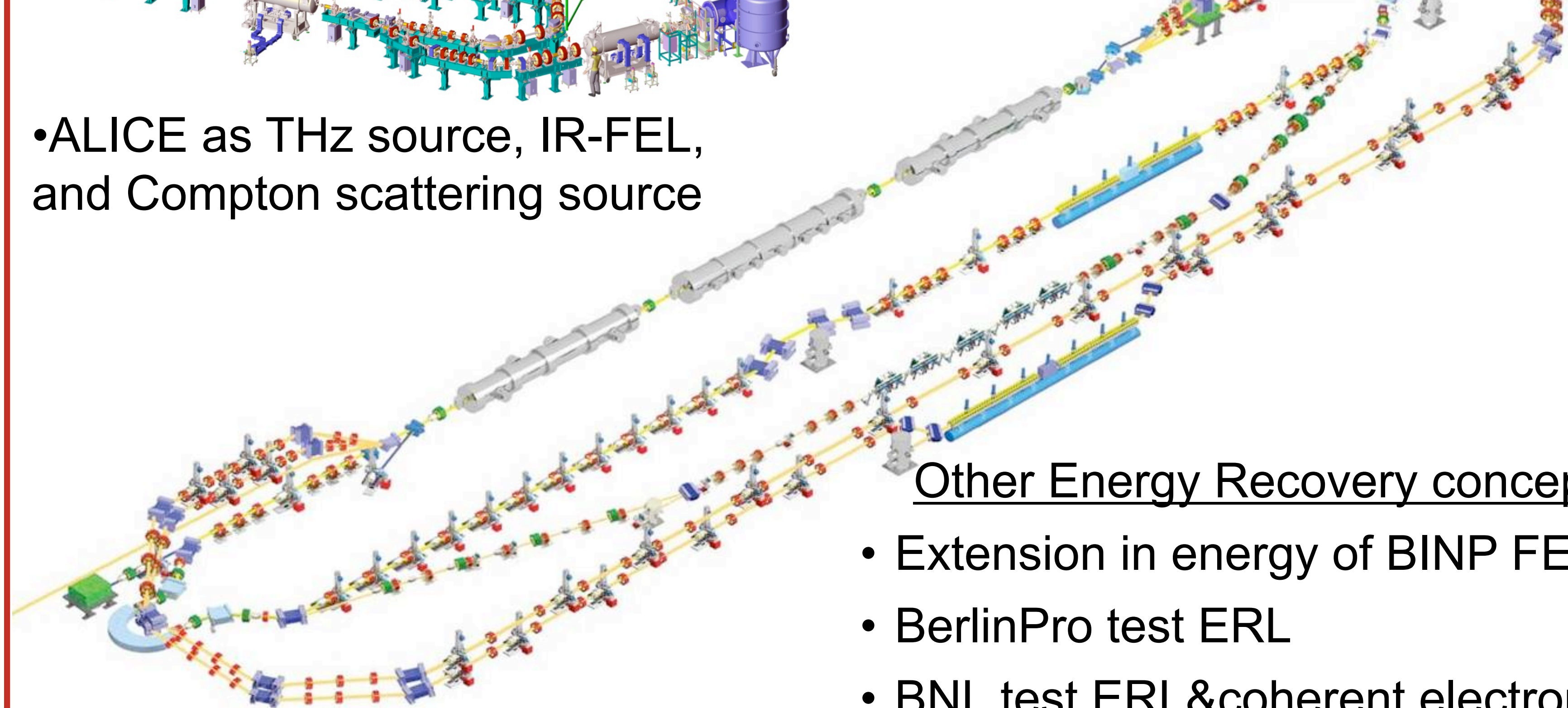
The breadth of science and technology enabled is consequently very large and the ERL will be a resource for a very broad scientific community.

X-ray ERLs are at the beginning of a development sequence, whereas decades have brought x-ray rings to the end of their development.

Energy Recovery Projects: (A) low energy



•ALICE as THz source, IR-FEL, and Compton scattering source



- JLAMP: unparalleled average brightness for 10-100eV photons. 600MeV by 2 pass ERL, pulses of 50fs, 200pC/1μm for HHG-FEL

<u>Other Energy Recovery concepts</u>

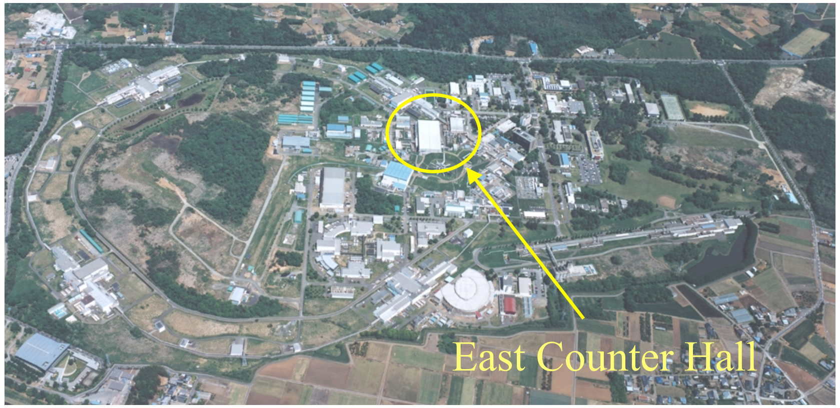
- Extension in energy of BINP FEL/ERL
- BerlinPro test ERL
- BNL test ERL&coherent electron colling
- Medium Energy Electrion Ion Collider
- ERL for eRHIC Electrion Ion Collider
- ERL for LHeC

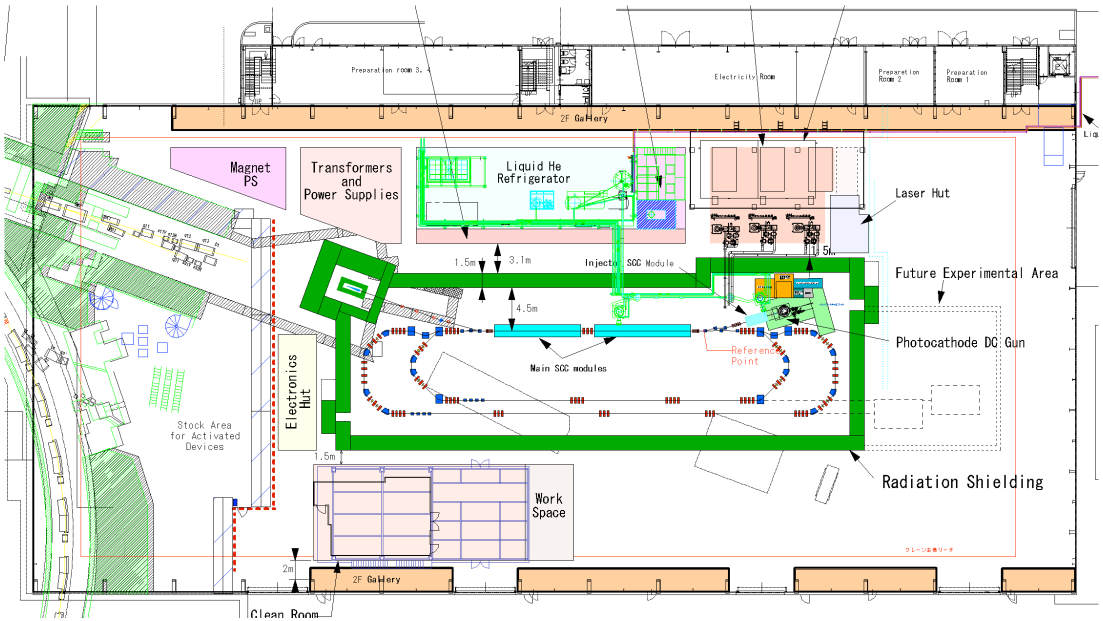
The Compact ERL for Demonstrating ERL Technologies at KEK

Before constructing large-scale ERL facility, we need to demonstrate the generation of ultra-low emittance beams using developed key devices. → **Compact ERL**

Parameters of the Compact ERL

	Parameters
Beam energy	35 - 245 MeV
Average current	10 - 100 mA
Normalized emittance	0.1 - 1 mm·mrad
Bunch length (rms)	1 - 3 ps (usual) ~ 100 fs (with B.C.)
RF frequency	1.3 GHz



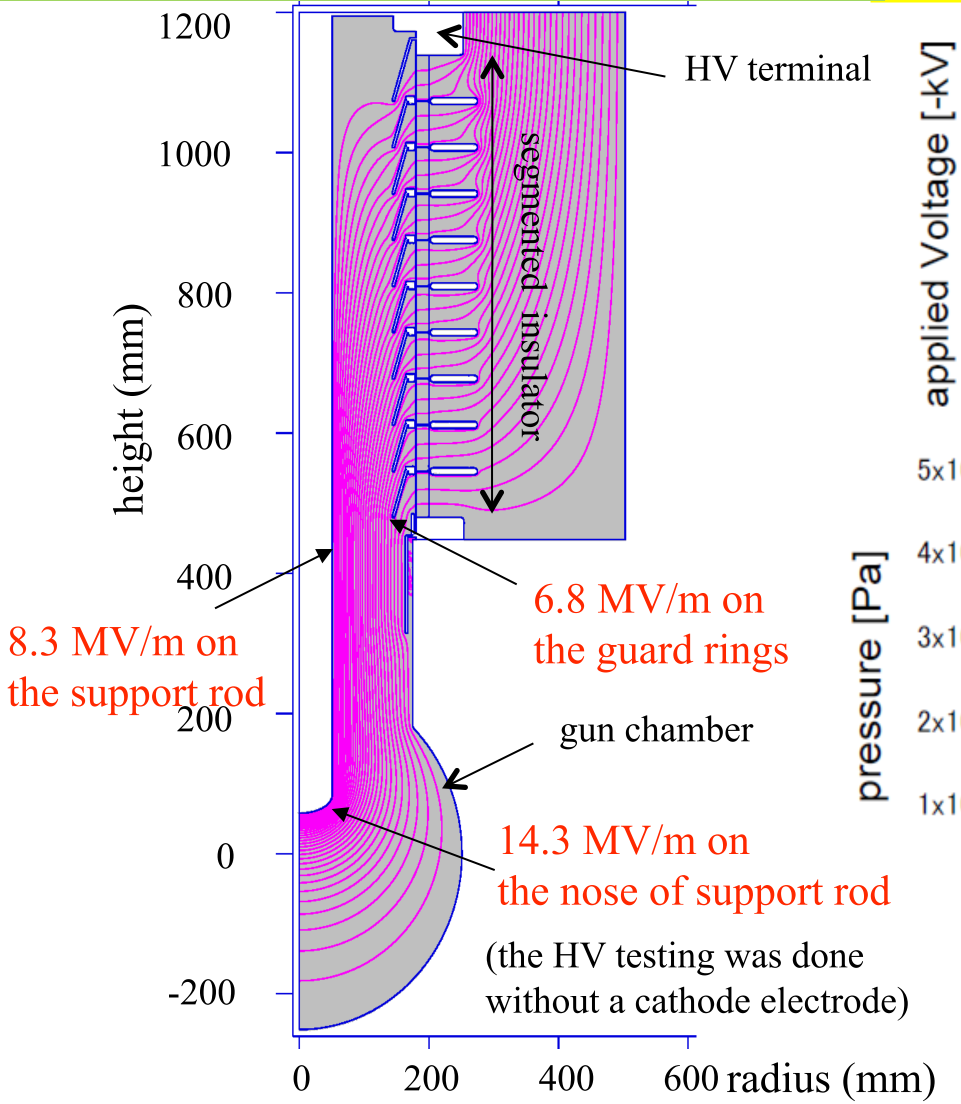


Status:

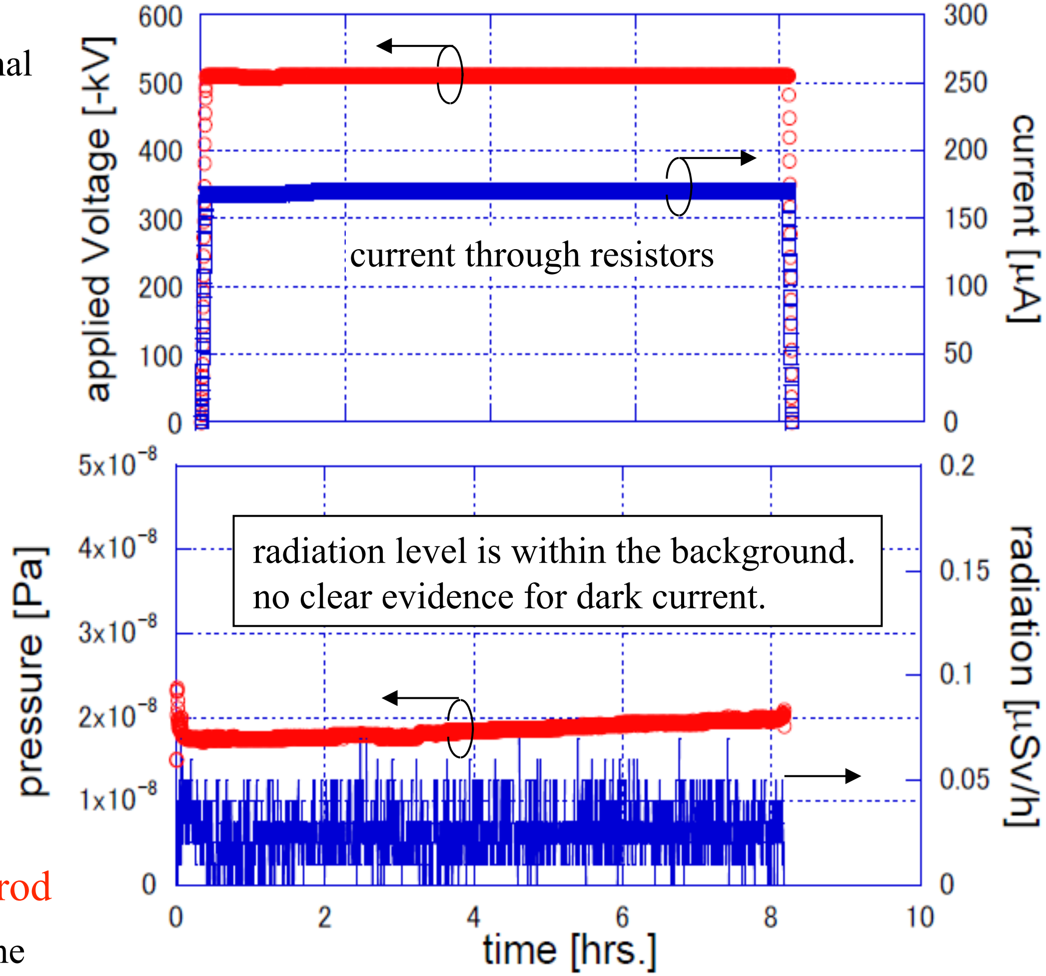
- Clearing 10,000 tons of concrete shields in the East Counter Hall has almost been finished.
- Refurbishments of the building, cooling-water plant, and electric substation have almost been finished.
- Installation of liquid-Helium refrigerator (cooling capacity: 600 W) has almost been finished.
- Installations of rf source (single station) and clean room for SCC development have almost been finished.

JAEA / HV testing of a 500-kV DC gun

Field distribution of the 500-kV gun



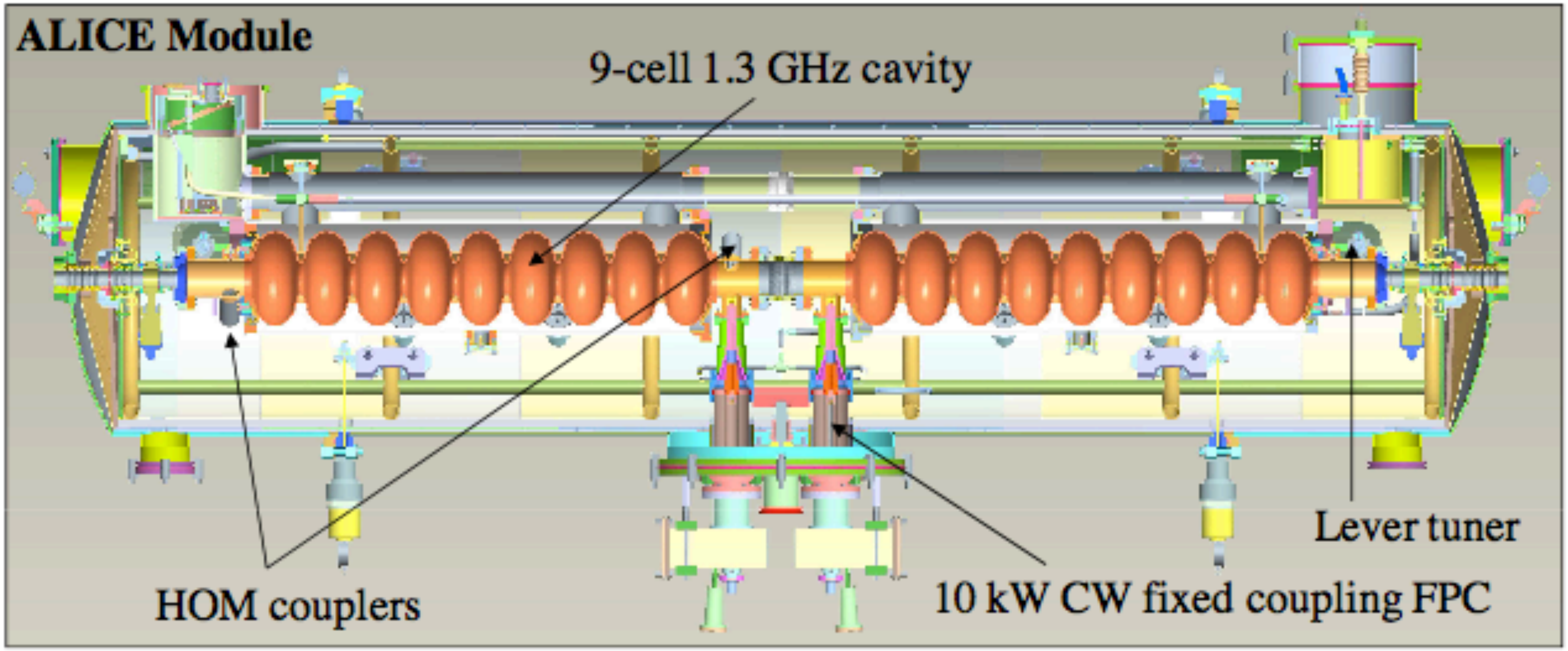
500 kV for 8 hours without any discharge



R. Nagai et al., to be published in Rev. Sci. Instr.

Talk by N. Nishimori for more details.

Technical challenges of CW linacs: International CW cryomodule collaboration



- Stanford has provided a 2-cavity cryomodule (incl. some internals).
- Cornell provides two modified and vertically tested 7-cell cavities (original superstructure cavities were supplied by DESY); design of HOM absorbers and input couplers; overall expertise.
- DL provides the HOM absorbers and couplers; modification of the CM; other new components (thermal and magnetic shields, tuners, end caps, ...); facilities for CM assembly and tests.
- FZD have provided the 3D cryomodule drawings.
- LBNL have provided electromagnetic cavity design expertise.
- Engineering and design effort split across institutes (mostly DL and Cornell).

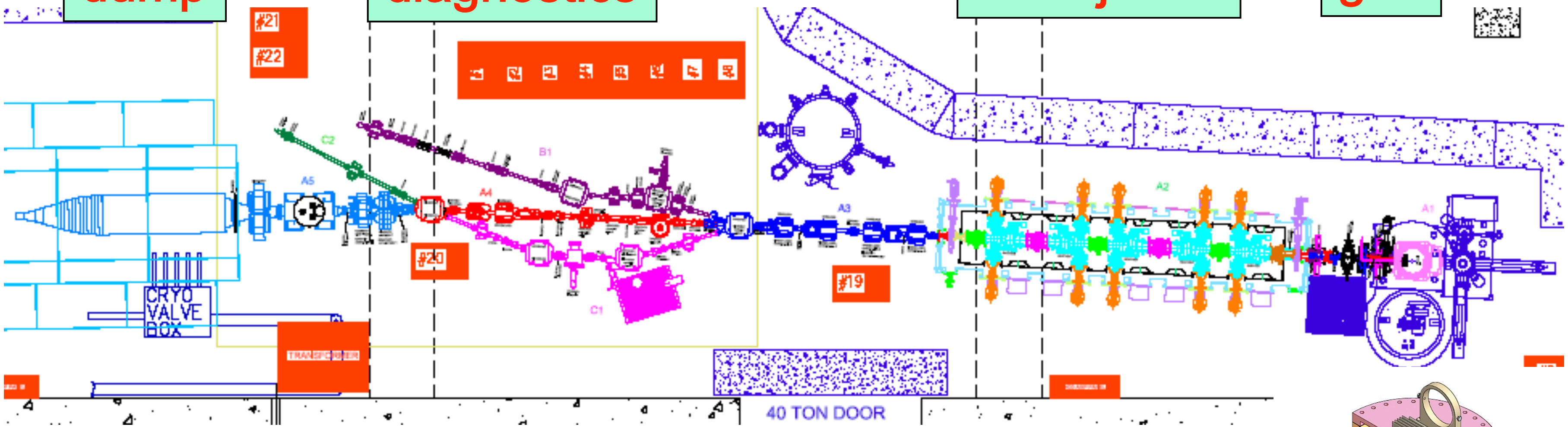
Cornell Injector prototype: Verification of beam production

dump

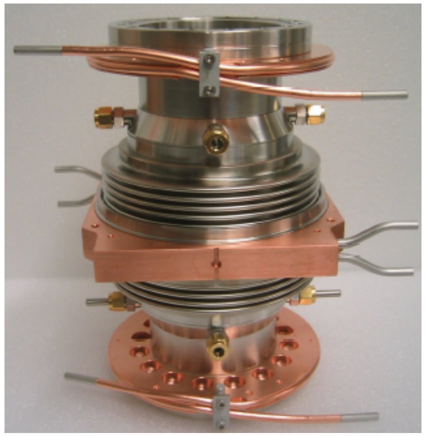
diagnostics

SC injector

gun

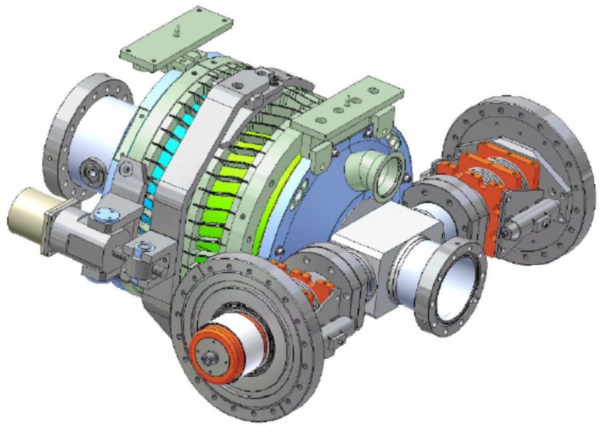


HOM absorb.

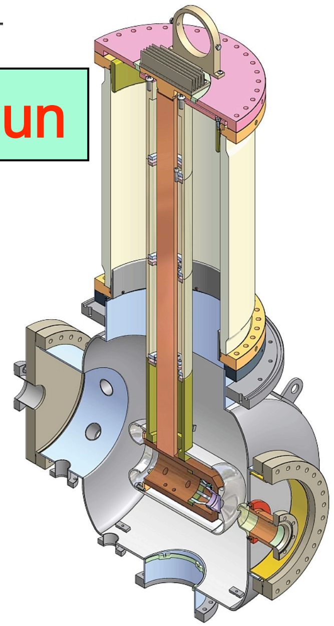


CW coupler

Dressed cavity

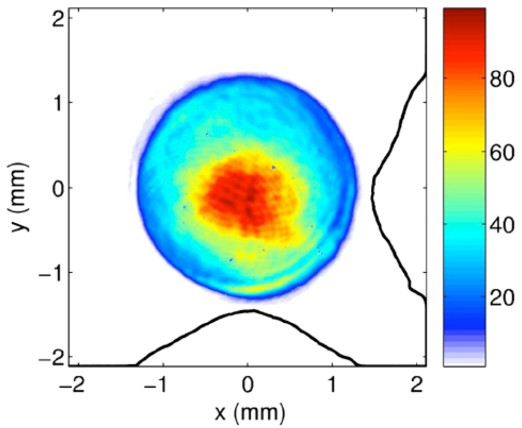


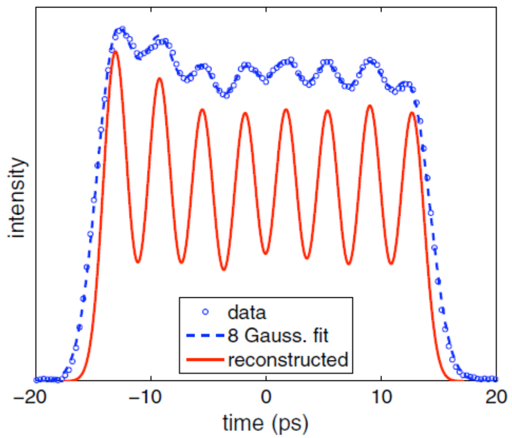
gun



Understanding of emittances

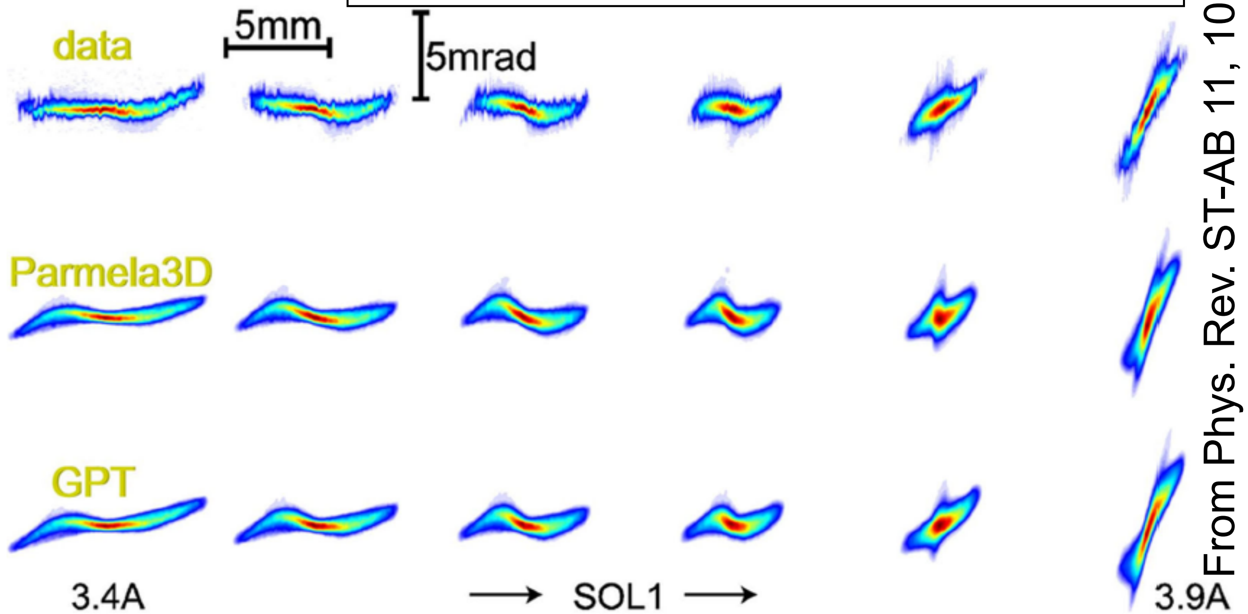
Beam properties at the cathode





Fixed slits phase space measurements

- Corrector coils for beam scanning
- 10 micron precision slits
- 1 kW beam power handling



From Phys. Rev. ST-AB 11, 100703 (2008)

Are transported through the accelerator, measured in a fixed slit phase space measuring system, and compared with simulations.

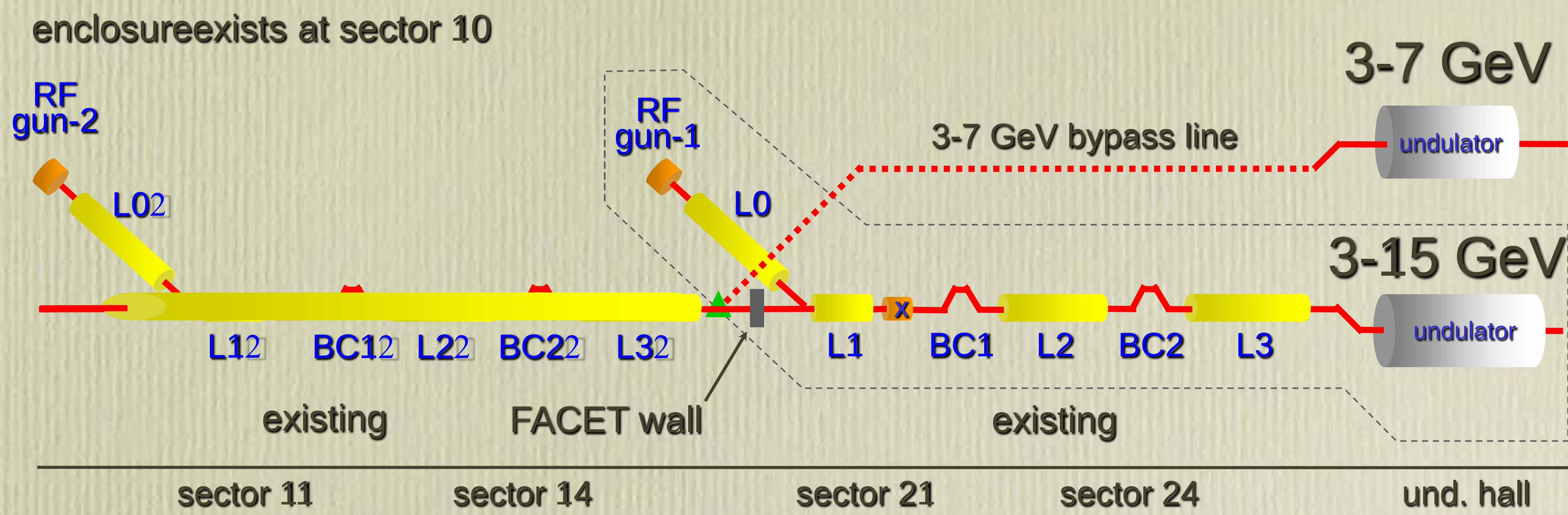
Good agreement with theory gives confidence that the very small simulated emittances can be achieved.

FEL
（抜粋）

Future Performance of the LCLS

J. Welch for many*
SLAC National Accelerator Laboratory

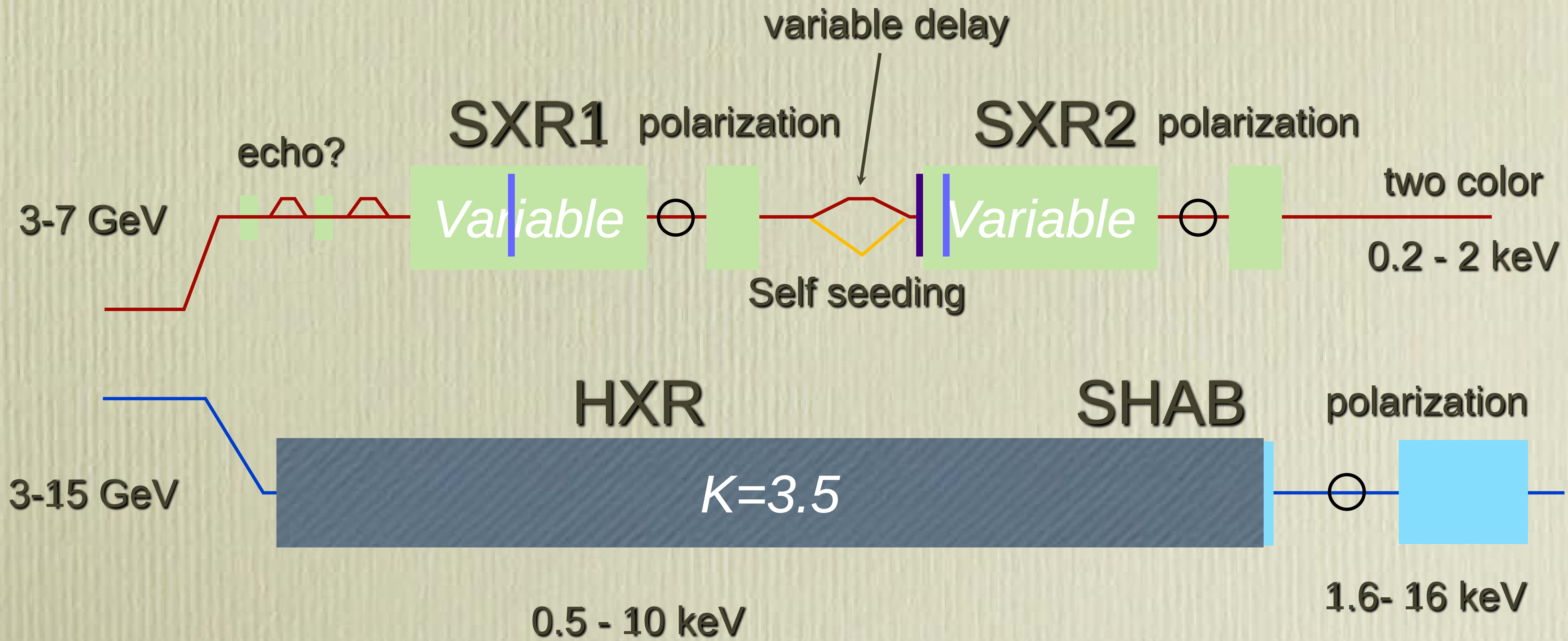
Injector concept



- A second injector provides for two simultaneous FEL beams with <u>independently adjustable parameters</u>
- Two independent e- beams allows x-ray pump, x-ray probe with decoupled wavelength, pulse width, energy and timing constraints

FEL Concept

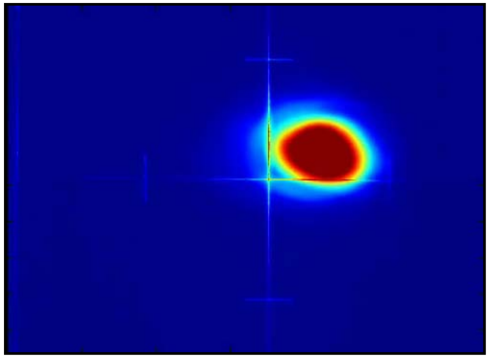
- Baseline: One hard xray beam and one two-color, two-pulse, variable delay beam; e- beam lases twice.



J. Wu, Self Seeding
H.D. Nuhn, Undulator parameters

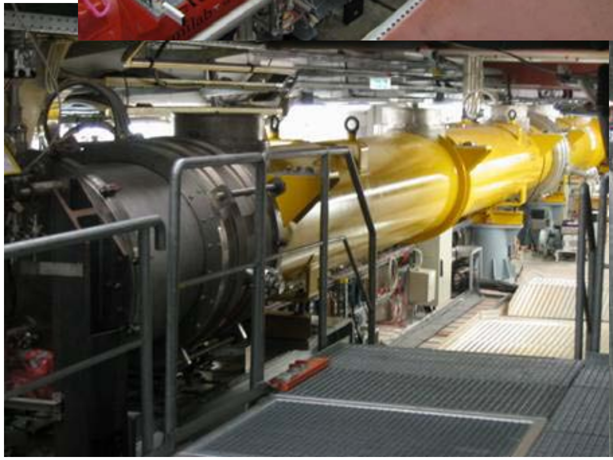
Lessons from FLASH

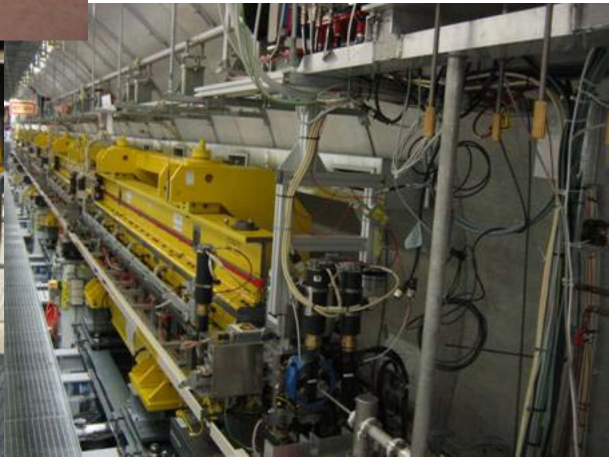
FLASH.
Free-Electron Laser in Hamburg



- FLASH
- Upgrade
- FLASH II
- Lessons

Siegfried Schreiber
DESY





FLS 2010
SLAC
1-6 March 2010

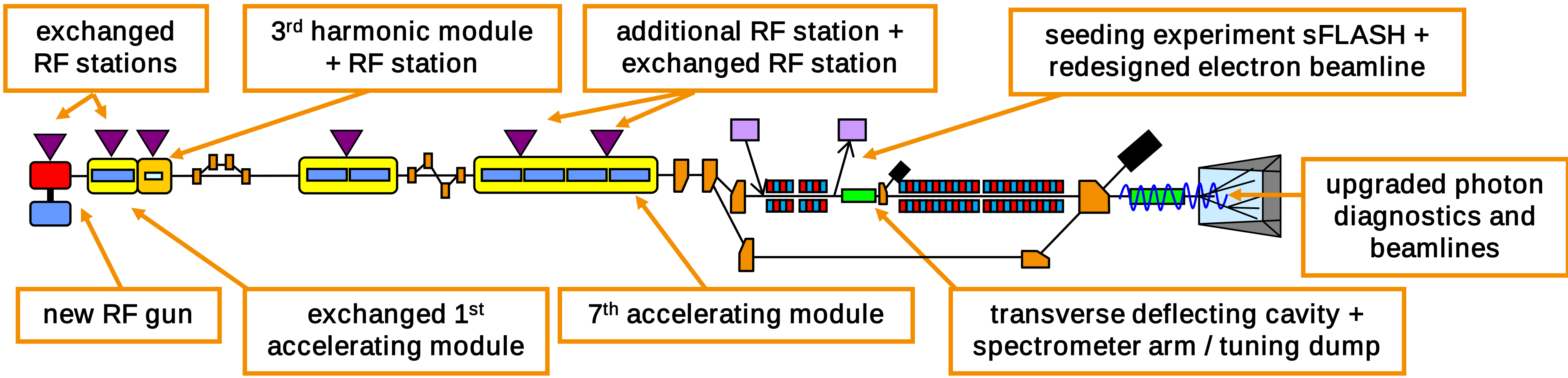
HELMHOLTZ GEMEINSCHAFT

DESY

Summary Upgrade 2009 / 2010

FLASH.
Free-Electron Laser in Hamburg

- Upgrade shutdown started September-21, 2009
- Technical commissioning started February-15, 2010
- First beam expected in April, user runs to be started in late summer 2010



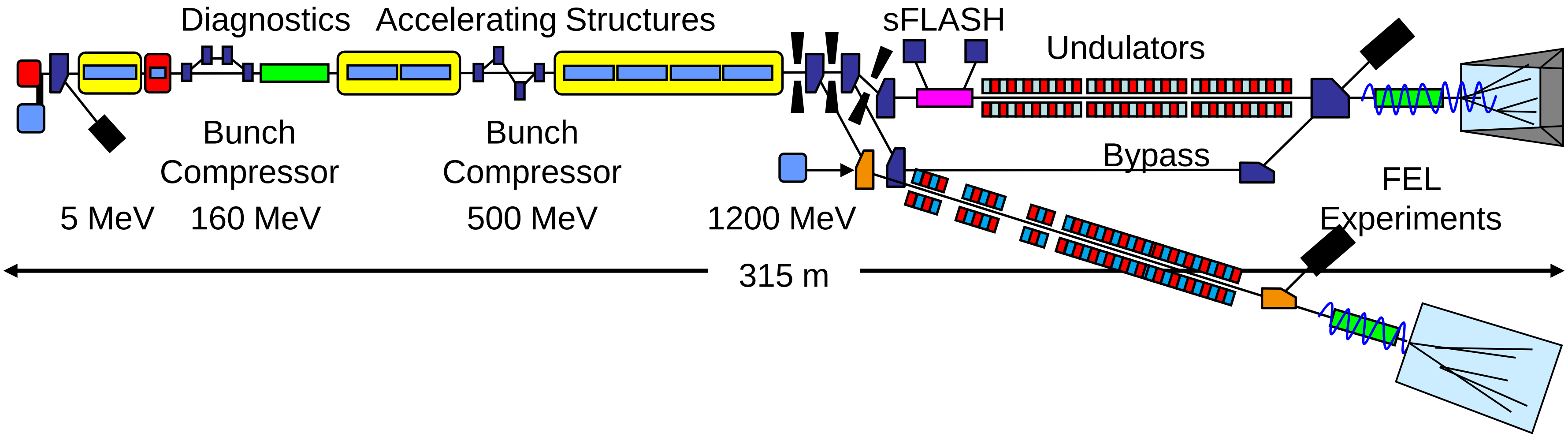
- new diode pumped photocathode laser; upgraded old laser system
- new cabling/layout injector llrf electronics
- installation of a second master oscillator (as backup)
- exchanged injector steerers
- new synchronization and feedback systems
- upgraded magnet controls
- optimized llrf controls
- upgraded and optimized waveguide distribution
- maintenance of infrastructure: water supplies, cryogenics
- improved survey and alignment of accelerator components (incl. SASE undulators)
- upgraded personnel interlock und radiation safety systems

DESY

FLASH II layout

FLASH. Free-Electron Laser in Hamburg

- Main features: Seeding and polarized radiation
- Extend user capacity with SASE and HHG/HGHG seeding
- Tunability of FLASH II by moveable undulator gap
- Using existing infrastructure
- Separation FLASH and FLASH II behind last accelerator module



DESY

SLAC NATIONAL ACCELERATOR LABORATORY

PAUL SCHERRER INSTITUT PSI

Progress at the XFELs in Europe and Japan

Hans-H. Braun, PSI

48th ICFA Advanced Beam Dynamics Workshop on Future Light Sources
March 1-5, 2010
SLAC National Accelerator Laboratory

XFELs overview

Project	Status	First Lasing	T_{e-}	λ_{min}	Driver technology (main linac)	Overall length
FLASH	running	2005 (2000 TTF)	1.2 GeV	50 Å	Pulsed SC 1.3 GHz	315 m
FERMI@ELETTRA	construction	2010	1.8 GeV	30 Å	Pulsed NC 3.0 GHz	375 m
SCSS	construction	2011	8 GeV	1 Å	Pulsed NC 5.7 GHz	750 m
European XFEL	construction	2015	17.5 GeV	1 Å	Pulsed SC 1.3 GHz	3400 m
SPARX	Waiting for approval	2015 ?	2.4 GeV	5 Å	Pulsed NC 2.85 GHz	500 m
SwissFEL	Waiting for approval	2016 ?	5.8 GeV	1 Å	Pulsed NC 5.7 GHz	715 m
NLS	Waiting for approval	?	2.25 GeV	12 Å	C.W. SC 1.3 GHz	660 m

Novel Sources
（抜粋）

Prospects for Laser Plasma Accelerator Driven Light Sources

Wim Leemans
and members and collaborators of the LOASIS Program

Lawrence Berkeley National Laboratory

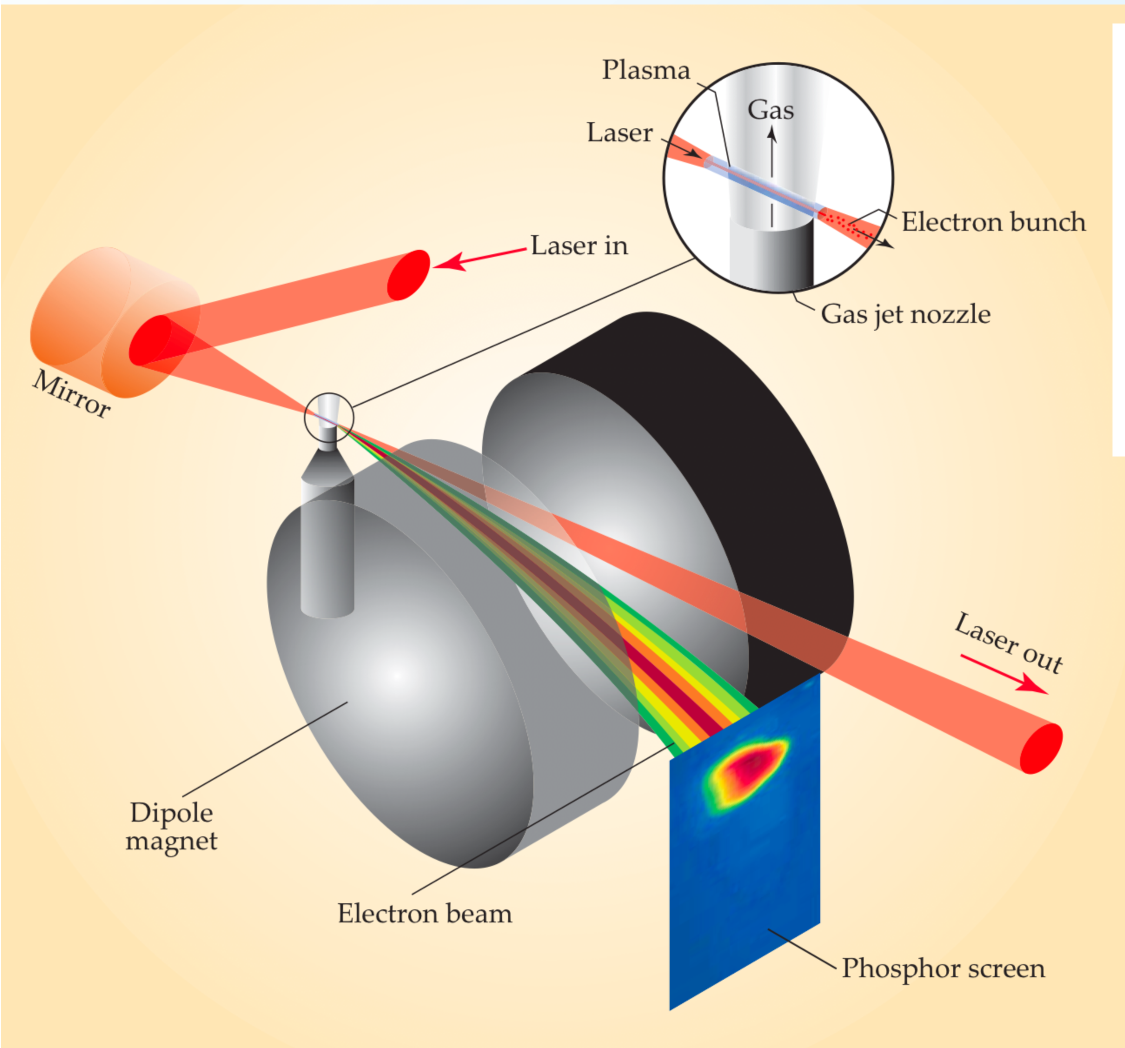
FLS2010
SLAC
March 1 – 5, 2010

http://loasis.lbl.gov/

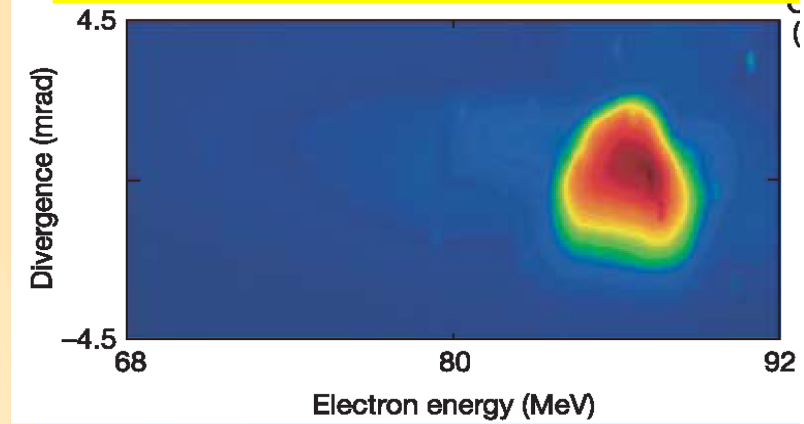
National Nuclear Security Administration

U.S. DEPARTMENT OF ENERGY | Office of Science

Typical experimental set-up for gas jet experiments: ~ 100 MeV beams



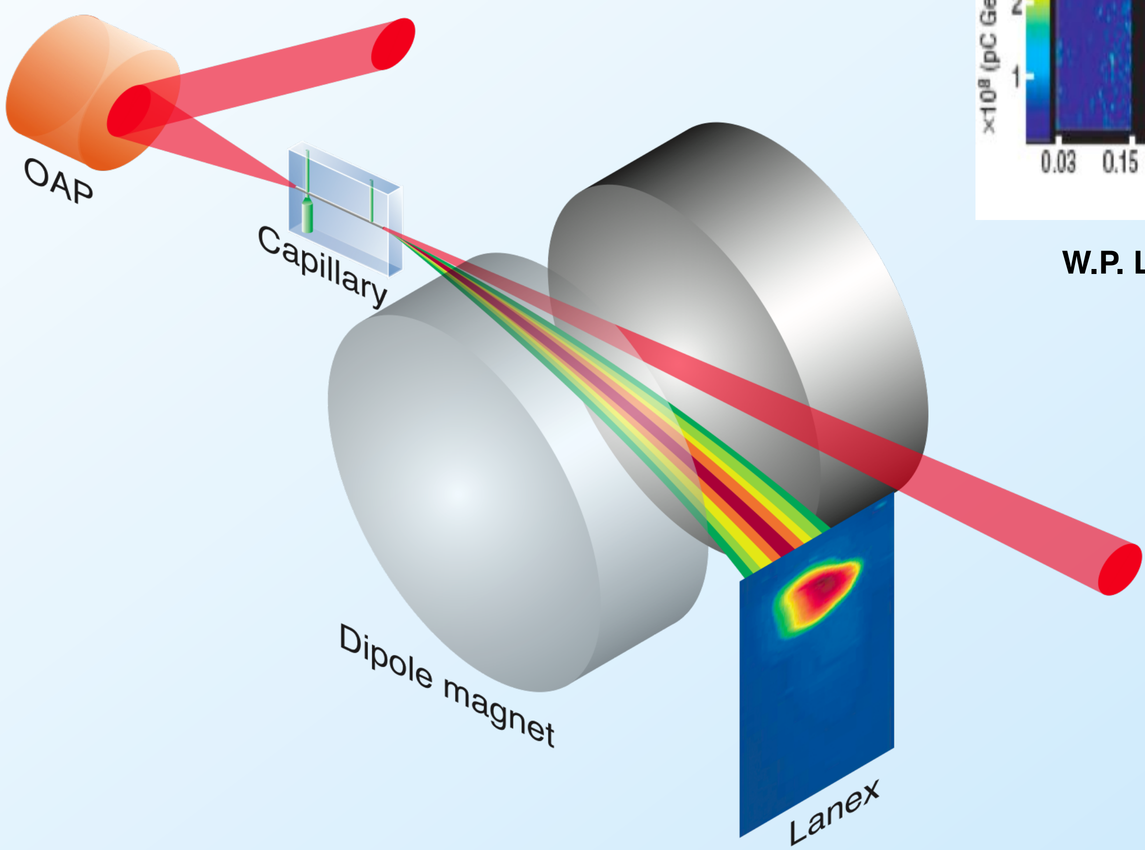
10 TW laser => 100 MeV e-beam



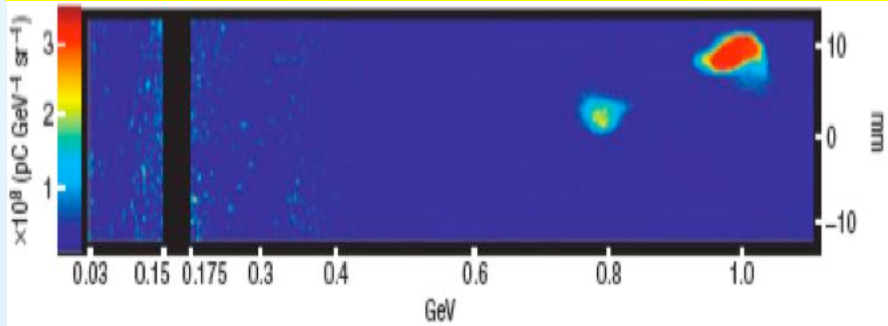
C. G. R. Geddes et al, Nature,431, p538 (2004); S.P.D. Mangles et al,; J. Faure et al., ibid

Channel Guided Laser Plasma Accelerators – 2006 result

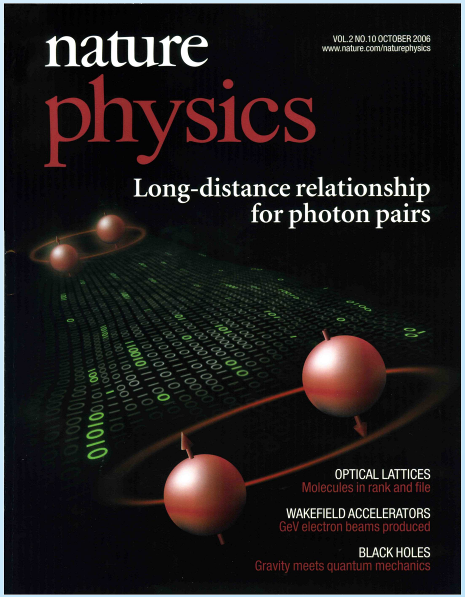
Experimental set-up



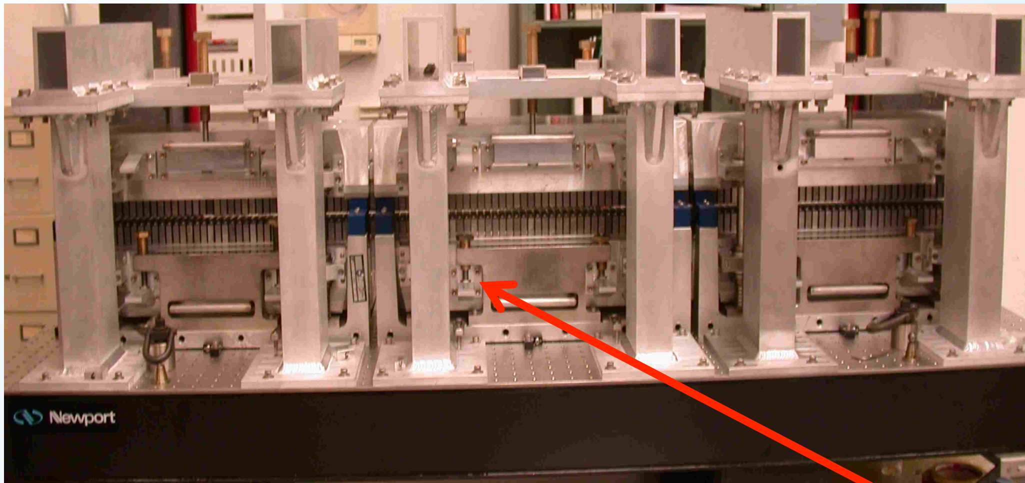
40 TW laser => 1 GeV e-beam

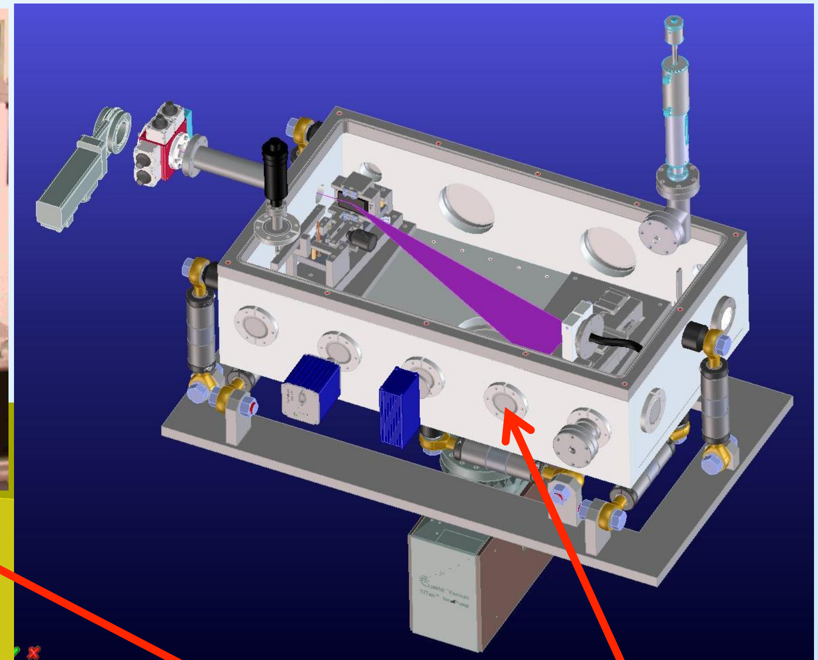


W.P. Leemans et. al, *Nature Physics* 2, p696 (2006)

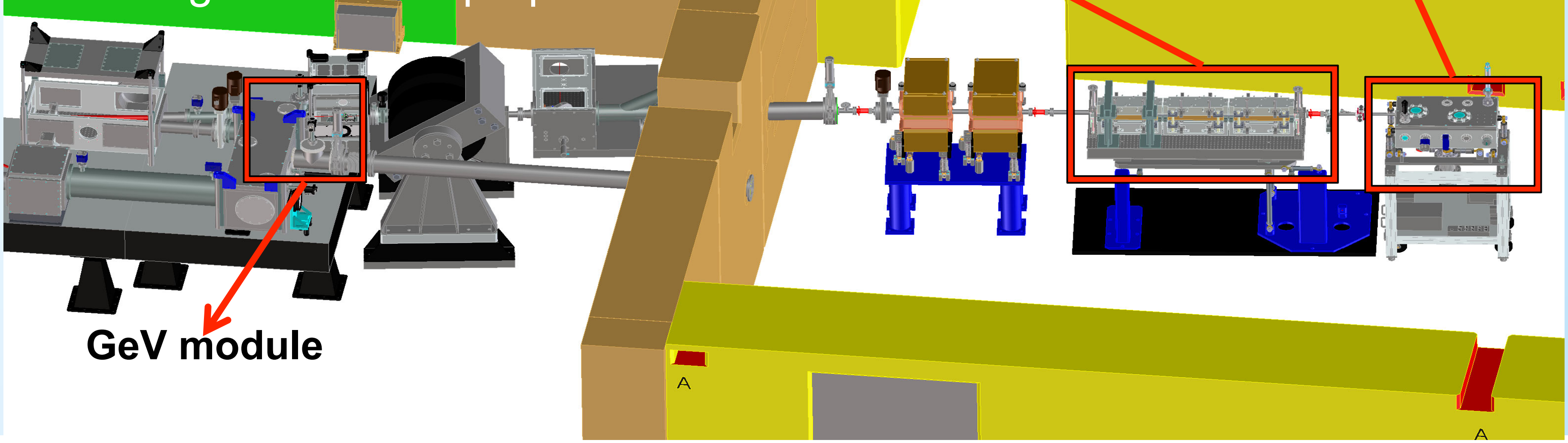


Undulator based diagnostic under development





- Undulator from Boeing corp.
- Measure beam properties by looking at radiation properties



Areas of improvement in LPA performance for various applications

	THz	X-rays (betatron)	FEL (XUV)	Gamma-rays	FEL (X-rays)	Collider
Energy	✓	✓	✓	✓	↑	↑↑
ΔE/E	✓	✓	↓	↓	↓↓	↓↓
ε	✓	✓	✓	✓	✓	↓↓
Charge	✓	✓	✓	↑	✓	↑
Bunch duration	✓	✓	✓	✓	✓	✓
Avg. power	↑	↑	↑	↑	↑	↑↑

✓: OK as is
↑: increase needed
↓: decrease needed

Performance Metrics
（抜粋）

Performance Metrics of Future Light Sources

Robert Hettel, SLAC

ICFA FLS 2010

March 1, 2010

NATIONAL ACCELERATOR LABORATORY

Science and Technology of Future Light Sources

A White Paper

Report prepared by scientists from ANL, BNL, LBNL and SLAC. The coordinating team consisted of Uwe Bergmann, John Corlett, Steve Dierker, Roger Falcone, John Galayda, Murray Gibson, Jerry Hastings, Bob Hettel, John Hill, Zahid Hussain, Chi-Chang Kao, Janos Kirz, Gabrielle Long, Bill McCurdy, Tor Raubenheimer, Fernando Sannibale, John Seeman, Z.-X. Shen, Gopal Shenoy, Bob Schoenlein, Qun Shen, Brian Stephenson, Joachim Stöhr, and Alexander Zholents. Other contributors are listed at the end of the document.

http://www-ssrl.slac.stanford.edu/aboutssrl/documents/future-x-rays-09.pdf

Argonne National Laboratory

Brookhaven National Laboratory

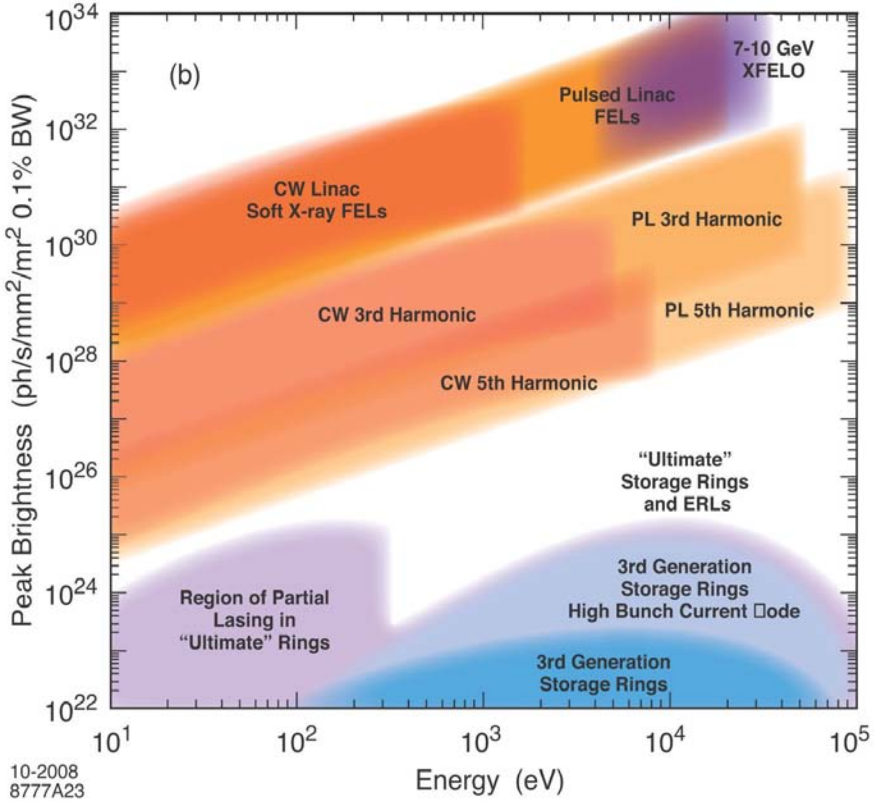
Lawrence Berkeley National Laboratory

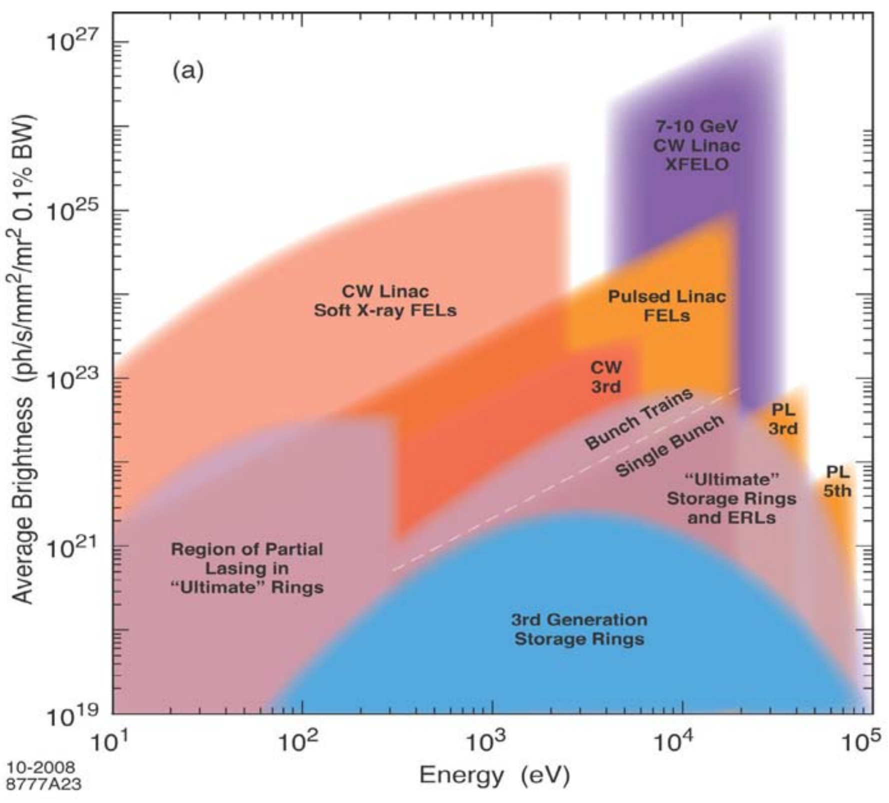
SLAC National Accelerator Laboratory

special acknowledgment to John Corlett, LBNL, and Terry Anderson, SLAC

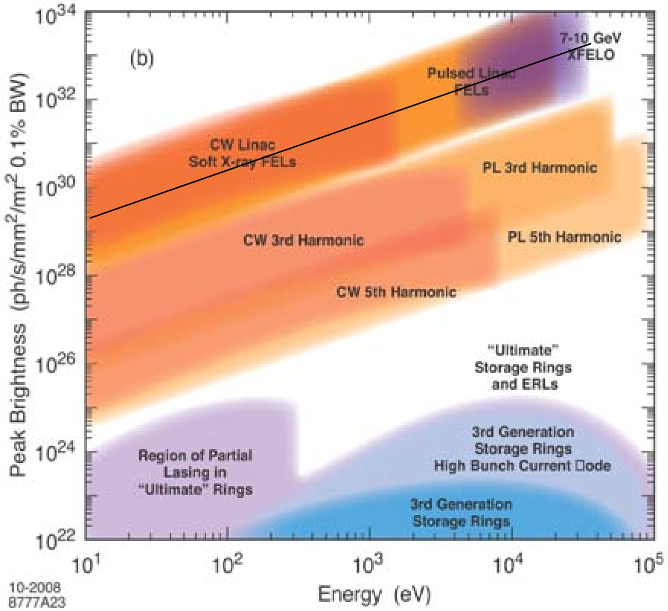
December 2008

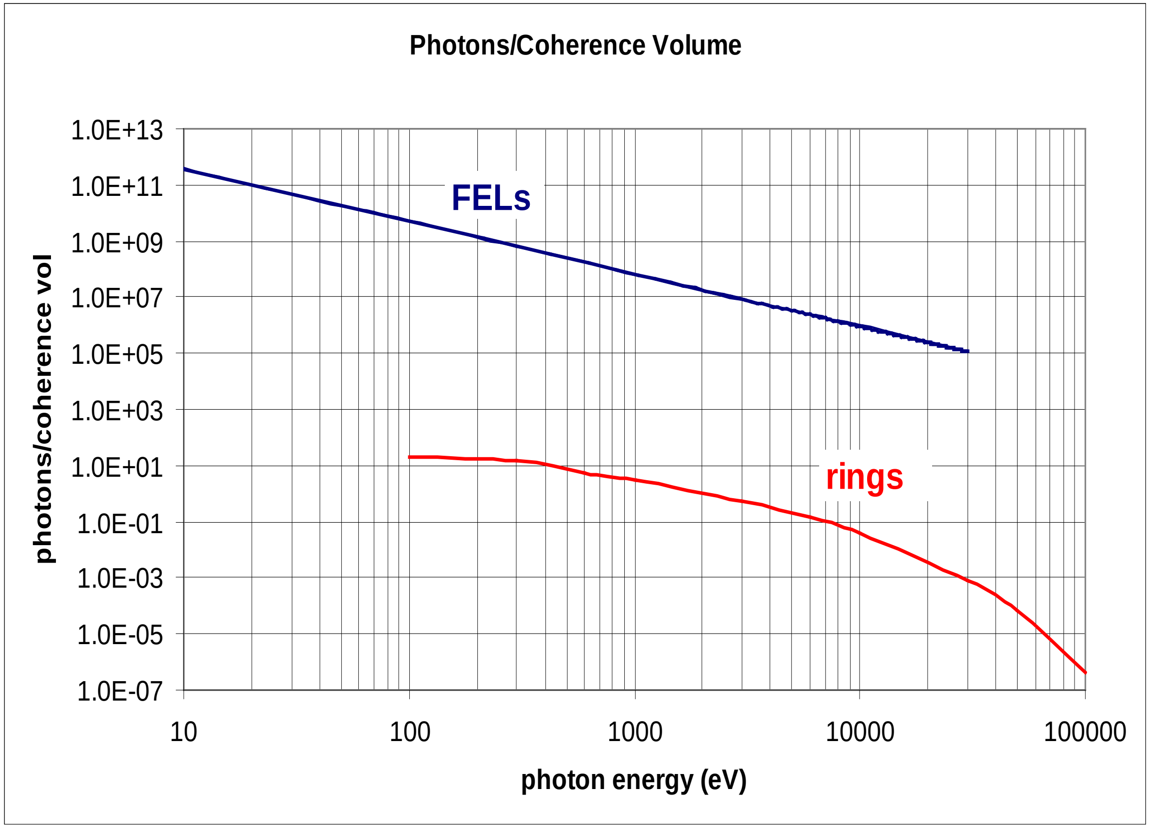
Spectral Brightness



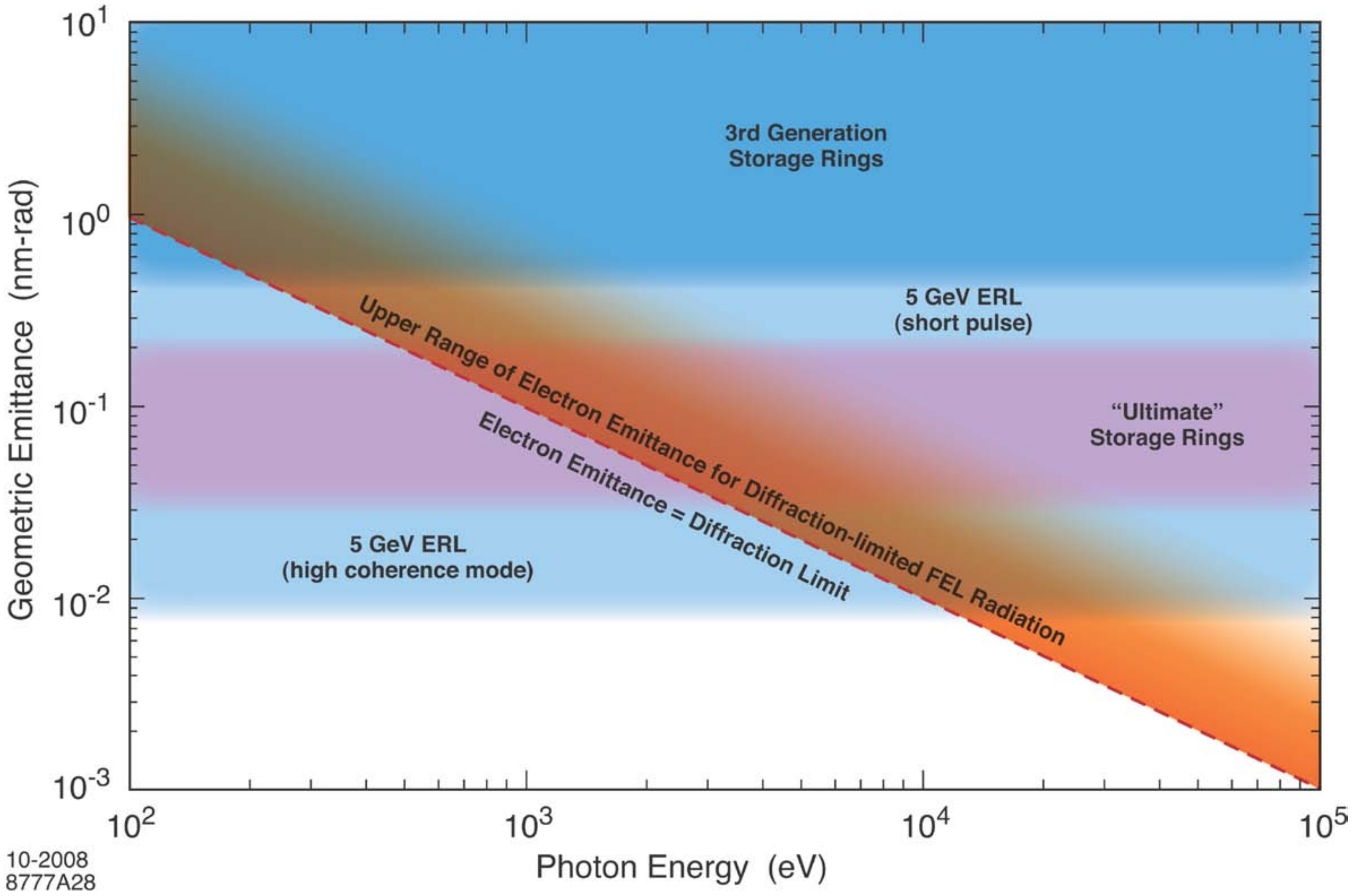


Photons per “Coherence Volume”



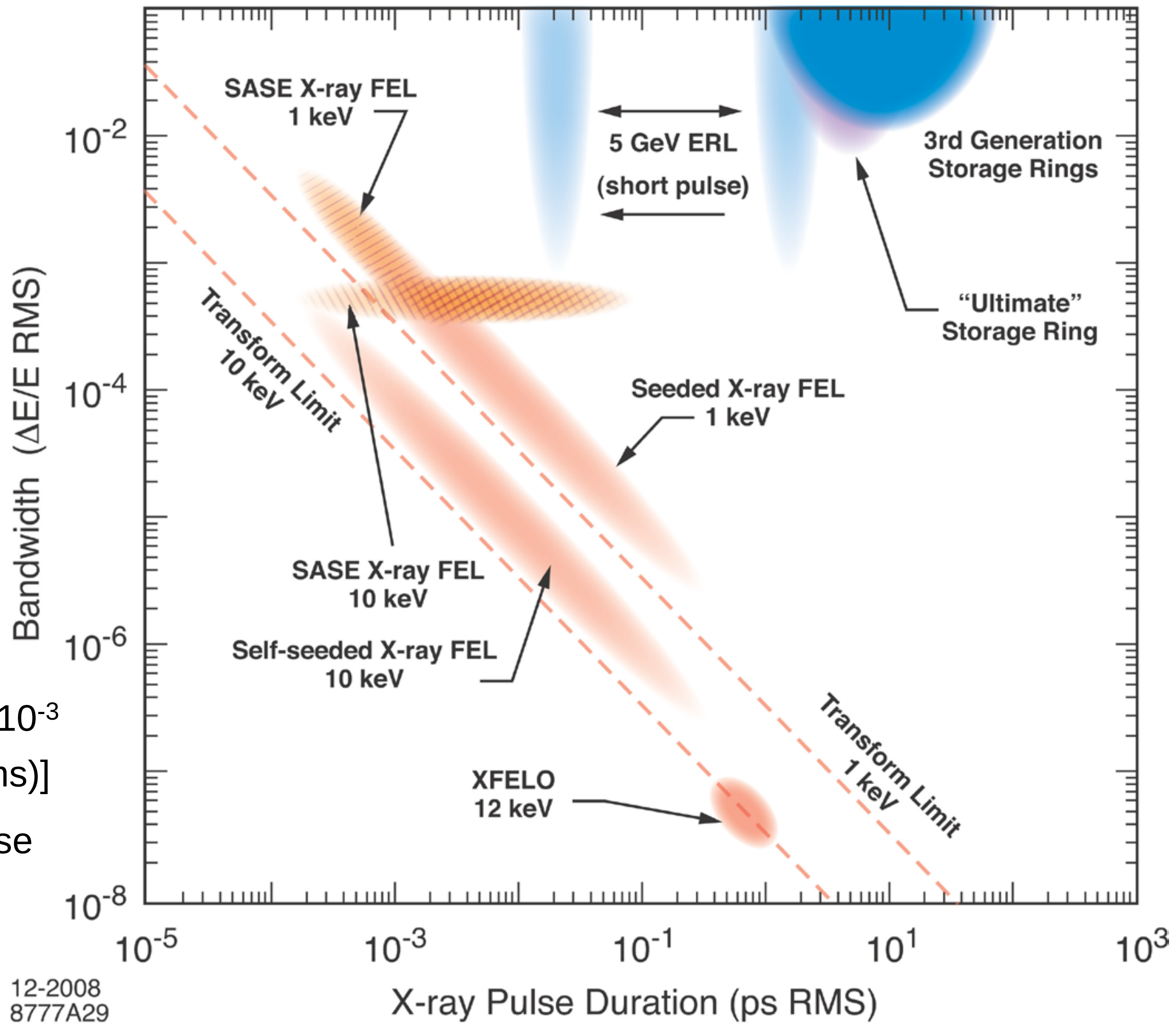


Diffraction-Limited Emittance



Diffraction limit: $\varepsilon_{ph} = \lambda/4\pi$

Energy Bandwidth vs. Pulse Length



$\Delta t \cdot \Delta E = 0.33 \times 10^{-3}$

[ps(rms)·eV (rms)]

for aussian pulse