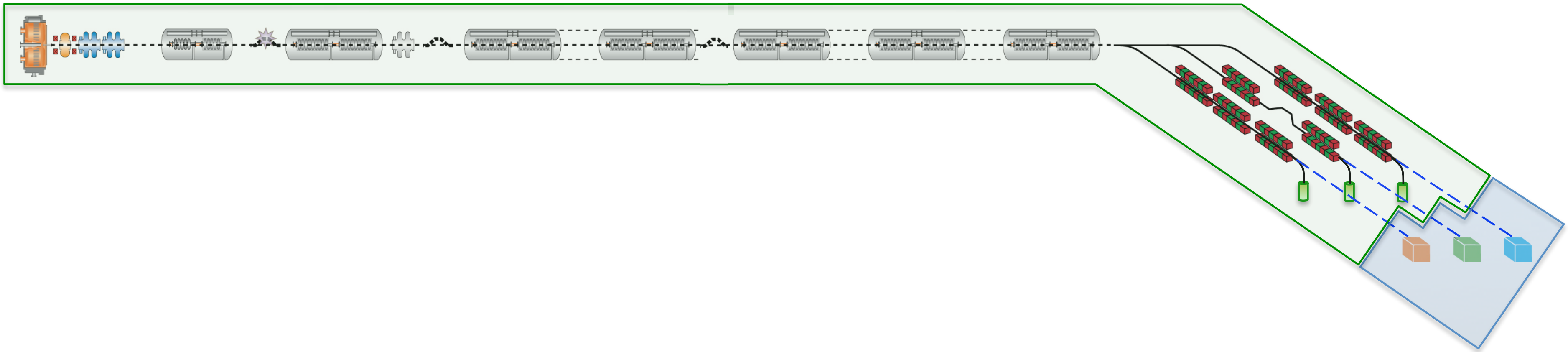


A Next Generation Light Source at LBNL

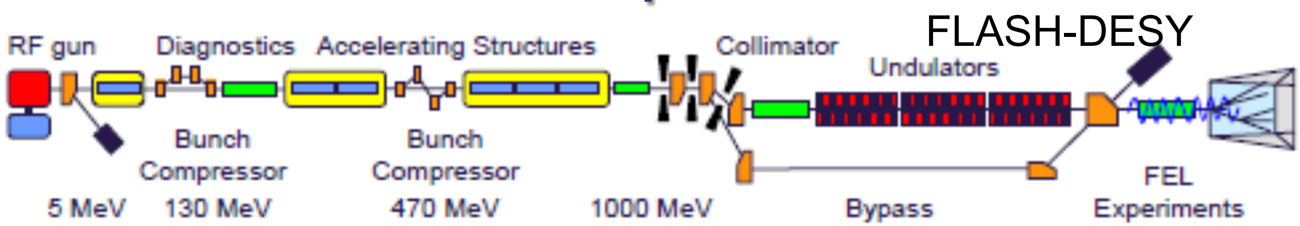
Fernando Sannibale
for the NGLS Accelerator Systems Team

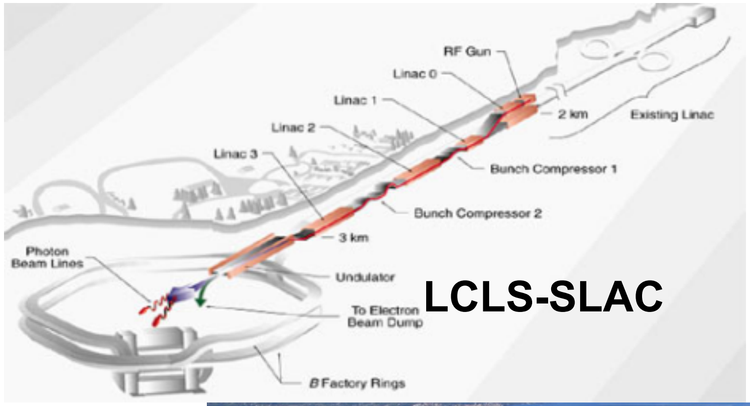
FEL2012, August 31, 2012

The X-FEL Revolution

NGLS next generation light source

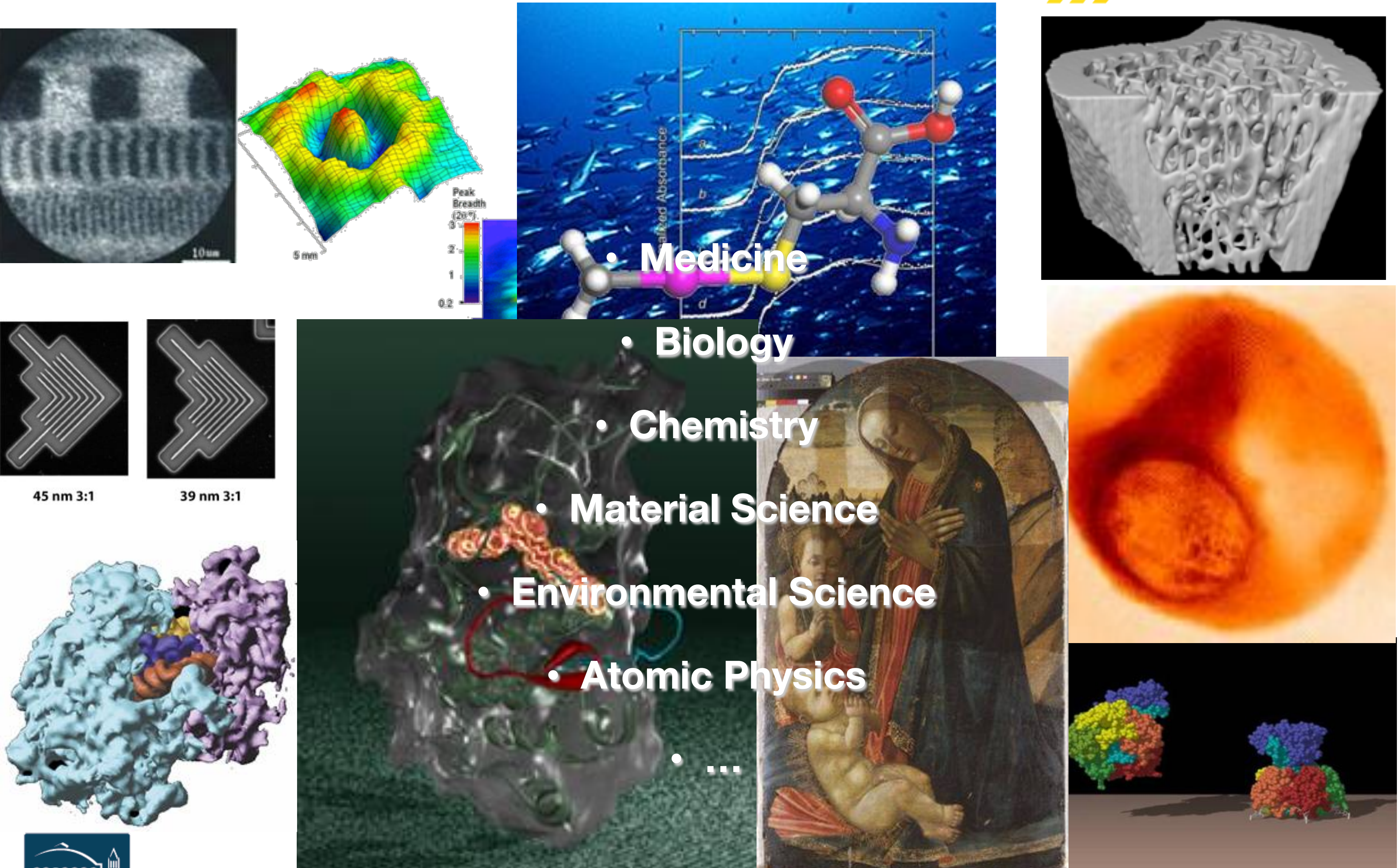
FLASH, LCLS and SACLA brought laser performance in the x-ray range. Extraordinary brightness, transverse coherence and time resolution are now available to experimenters





More recently, FERMI@TRIESTE, SFLASH and the self-seeding experiment at SLAC are demonstrating the capability of seeded schemes of a much improved control of the longitudinal characteristics of the photons!

A Revolution for Science



- Medicine
- Biology
- Chemistry
- Material Science
- Environmental Science
- Atomic Physics
- …

What Is Next?

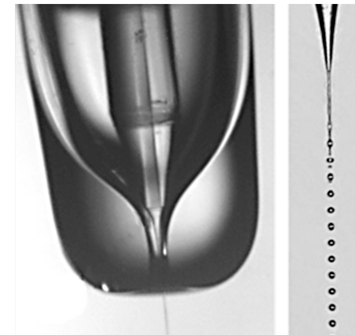
The natural next step forward would be to extend the extraordinary FEL performance at much higher repetition rates. From the present ~ 100 Hz to MHz.

This will represent the next revolution in terms of science opportunities, allowing for new classes of experiments presently not accessible.

Example: Time to do Experiments - Photosynthesis

Required	**10^{17}**	photons
Damage Limit	**10^{8}**	ph/pulse
Max Rep. Rate	**10^{5}**	Hz

Sample Replacement:
10^{5} Hz



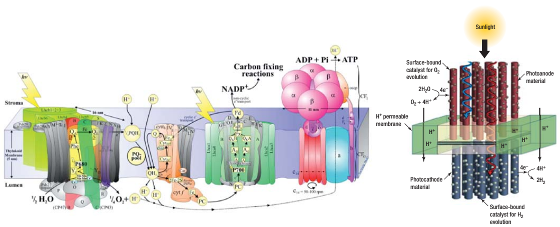
Time to do experiment:
Photons Required / (Photons/Pulse x Rep. Rate)

	Source (*intrinsic*)				
	Max. ph/pulse	Max. Rep. rate [Hz]	**Time to do experiment**		Time resolution
Storage Ring	10^{5}	$5\text{x}10^{8}$	**10^{17}**/10^{5}/**10^{5}**	**100 days**	100 ps
Pulsed FEL	10^{10}	10^{2}	**10^{17}**/**10^{8}**/10^{2}	**100 days**	~fs
NGLS	10^{9}	10^{6}	**10^{17}**/**10^{8}**/**10^{5}**	**3 hours**	~fs

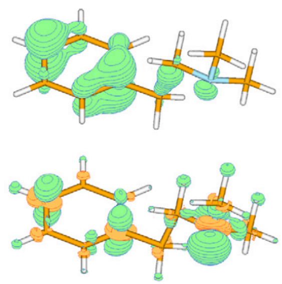
NGLS
next generation light source

Broad Range of Science Uniquely Enabled by the High Repetition Rate

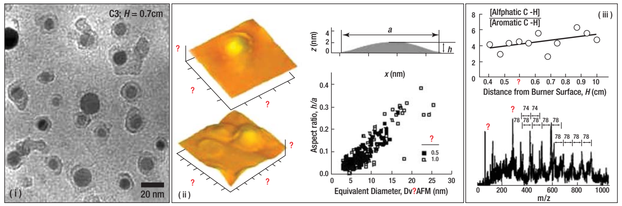
Natural and Artificial Photosynthesis



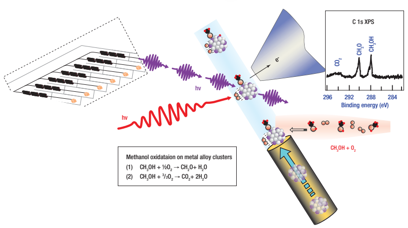
Fundamental Charge Dynamics



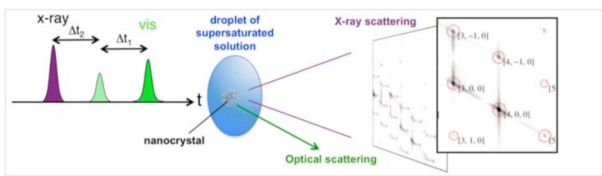
Advanced Combustion Science



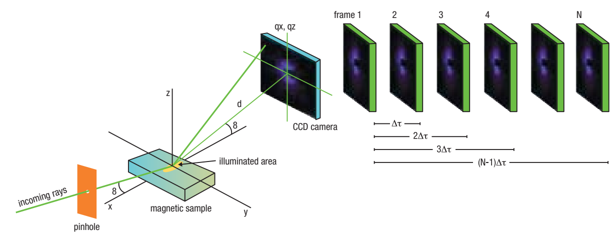
Catalysis



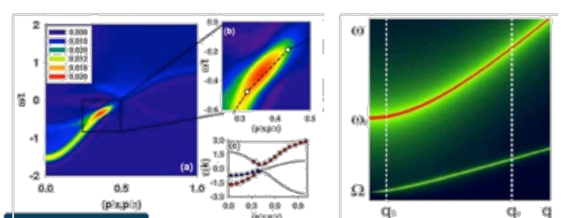
Nanoscale Materials Nucleation



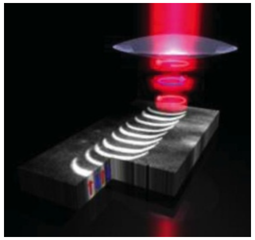
Dynamic Nanoscale Heterogeneity

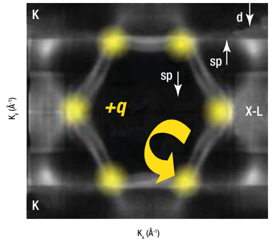


Quantum Materials

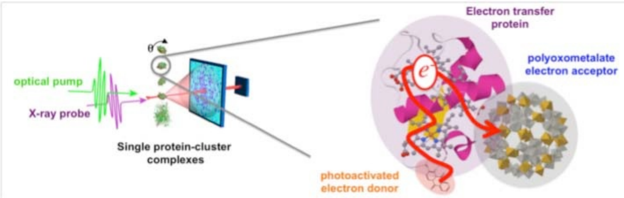


Nanoscale Spin and Magnetization





Bioimaging: Structure-to-Function



A CD0 Proposal to DOE for a Next Generation Light Source (NGLS)

The Deputy Secretary of Energy
Washington, DC 20585

April 5, 2011

MEMORANDUM FOR WILLIAM F. BRINKMAN
DIRECTOR
OFFICE OF SCIENCE

FROM: DANIEL B. PONEM...

SUBJECT: Approval of Cr... ...ecision-0 for the Next Generation Light Source

In accordance with Department of E... Order 413.3B, *Program and Project Management for the Acquisiti... ...ital Assets,* the Next Generation Light Source project has met Critical Decis... ...)-0 (Approve Mission Need) requirements. As the Secretarial Acquisition E... ...ive ...ased on the recommendation of the Energy Systems Acquisition Advisory B... I approve CD-0. The rough order of magnitude cost range is $0.9 billion to $1.... ...llion.

Please continue to w... ...ith the Office of Engineering and Construction Management as you progress t... ...Critical Decision-1 (Alternative Selection and Cost Range).

cc:
Steven E. Koonin, S-4
Ingrid Kolb, MA-1
Paul Bosco, MA-50
Sean Lev GC-1
Associate Director, Office of Basic Energy Sciences, SC-22
Director, Office of Project Assessment, SC-28

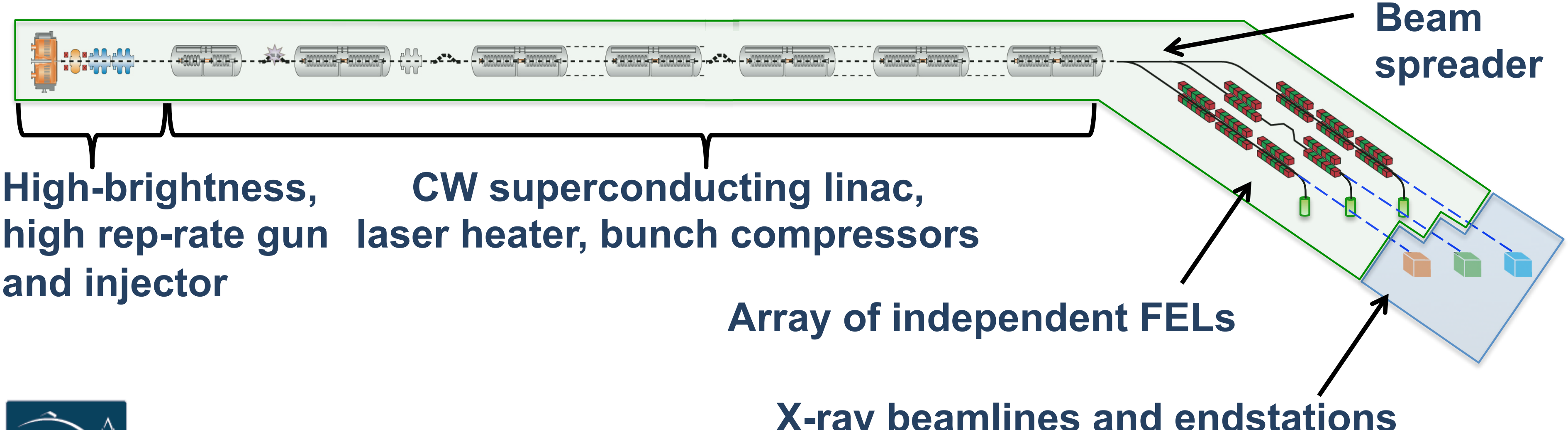
- Submitted December 2010
- More than 150 contributors
- Representing >40 national and international research institutions

CD0 recognizes the validity of the scientific case and the need of building a facility in US to pursuit it.

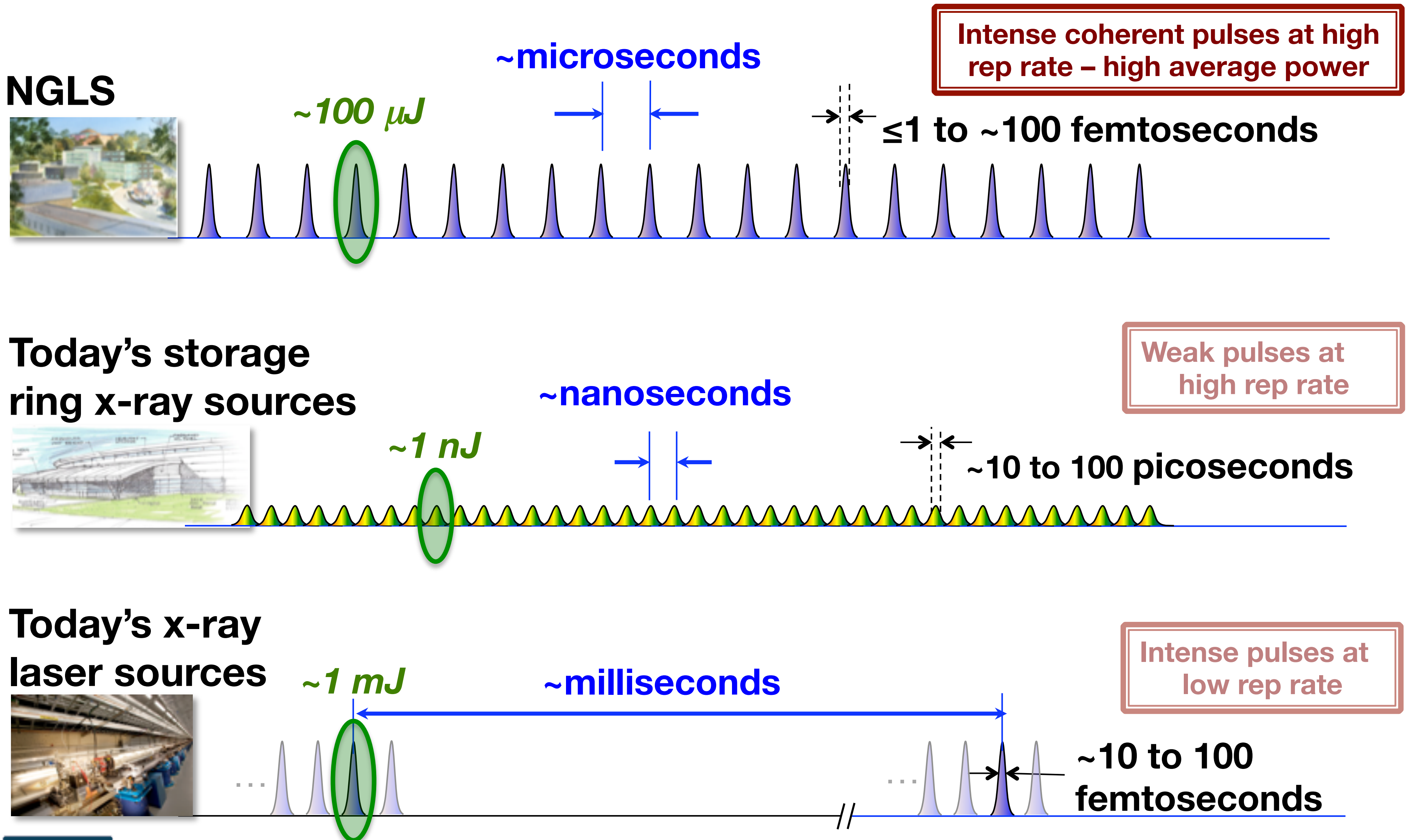
CD0 Science Requirements Drive LBNL NGLS Proposal Design

NGLS next generation light source

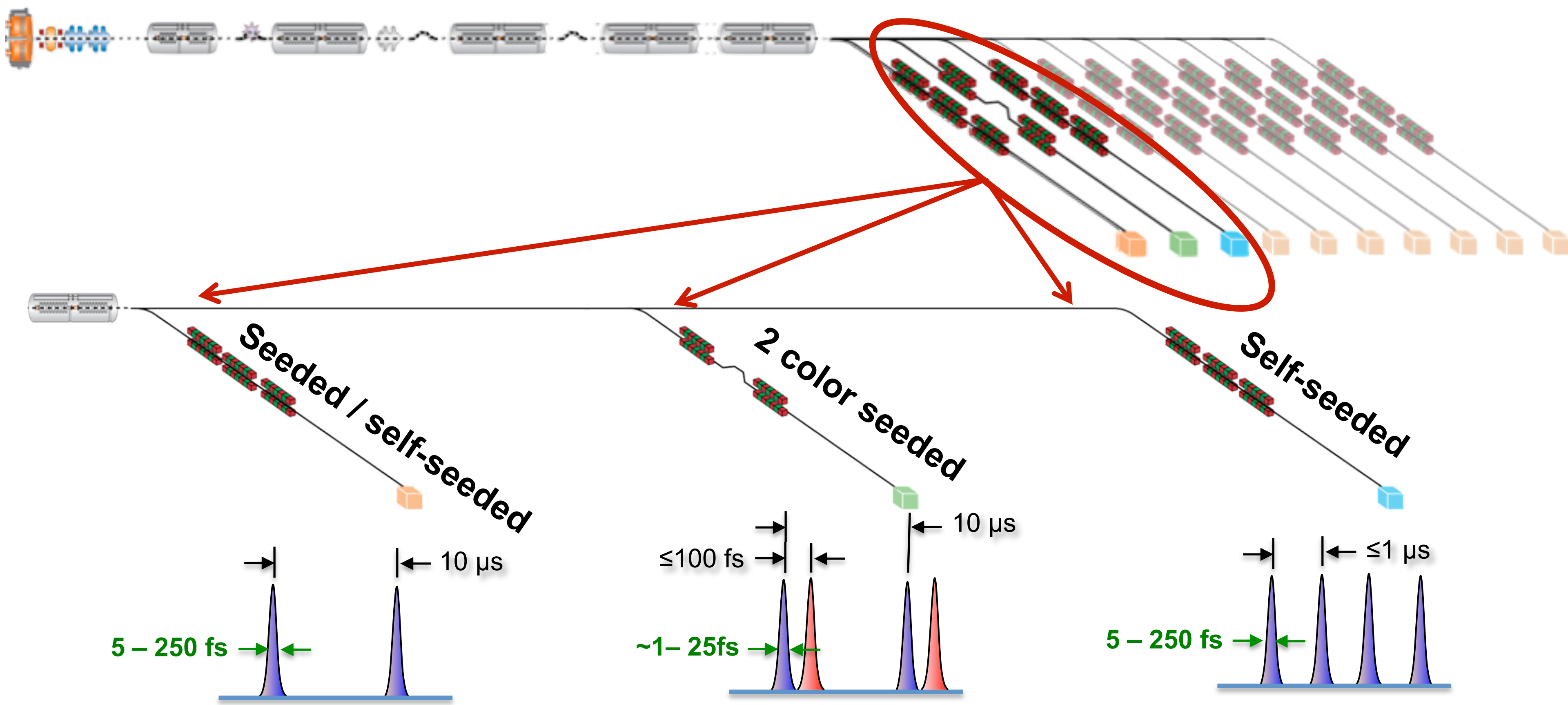
Parameter	Range	Independence of Control
Pulse Energy (μJ)	0 - 200	attenuation available per beamline
Photon Energy (keV)	0.27 - 1.2 (+)	selectable per beamline
Pulse Length (fs)	≤1 - 300	some independence if laser seeded
Bandwidth (%)	0.005 - 1	depends on individual FEL config.
Polarization	linear-circular	selectable per beamline
Pulse Rate (MHz)	0 - 1 (+)	1 FEL near 1 MHz (others at 0.1 MHz)



NGLS X-ray Pulse Time Structure



Initial and Upgraded NGLS Layout

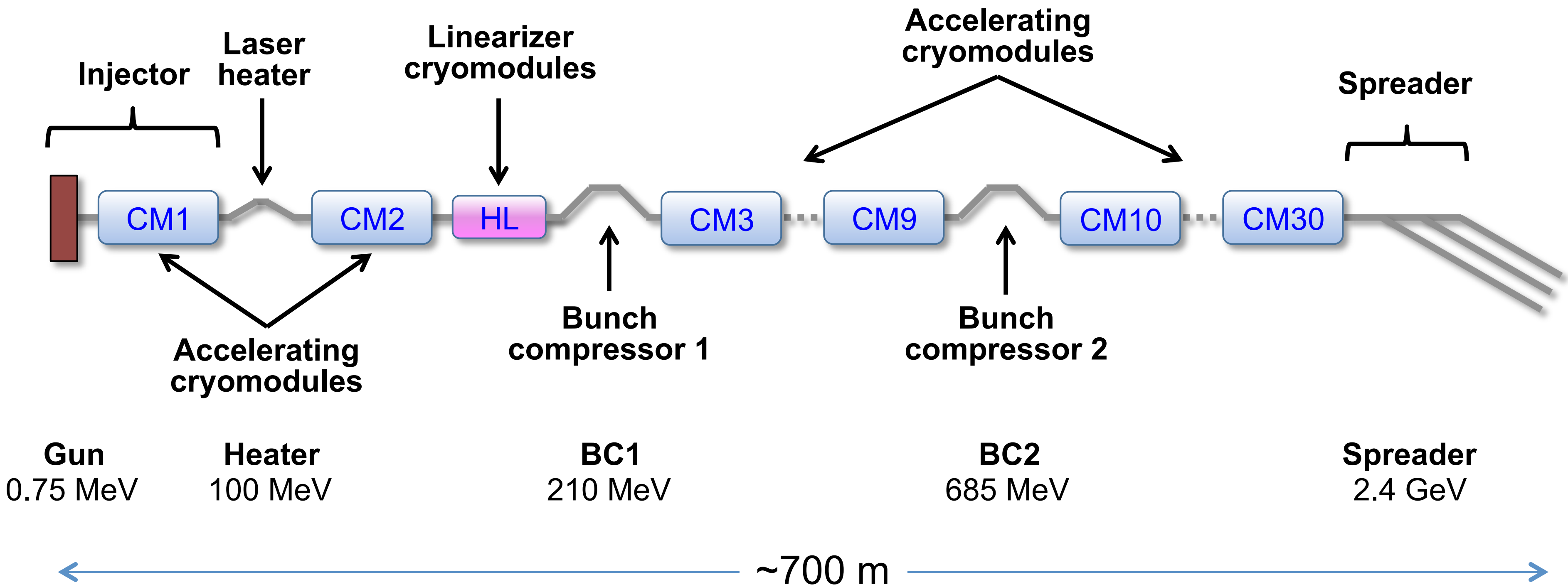


- High resolution
- Trade-off time/energy resolution
- 10^{11} – 10^{12} ph/pulse
- 10^{-3} – 5×10^{-5} bandwidth

- Ultra-fast
- ≤ fs pulse capability
- 2 color
- 10^{8} ph/pulse

- Highest rep rate
- High flux
- 10^{11} - 10^{12} ph/pulse
- 100 W

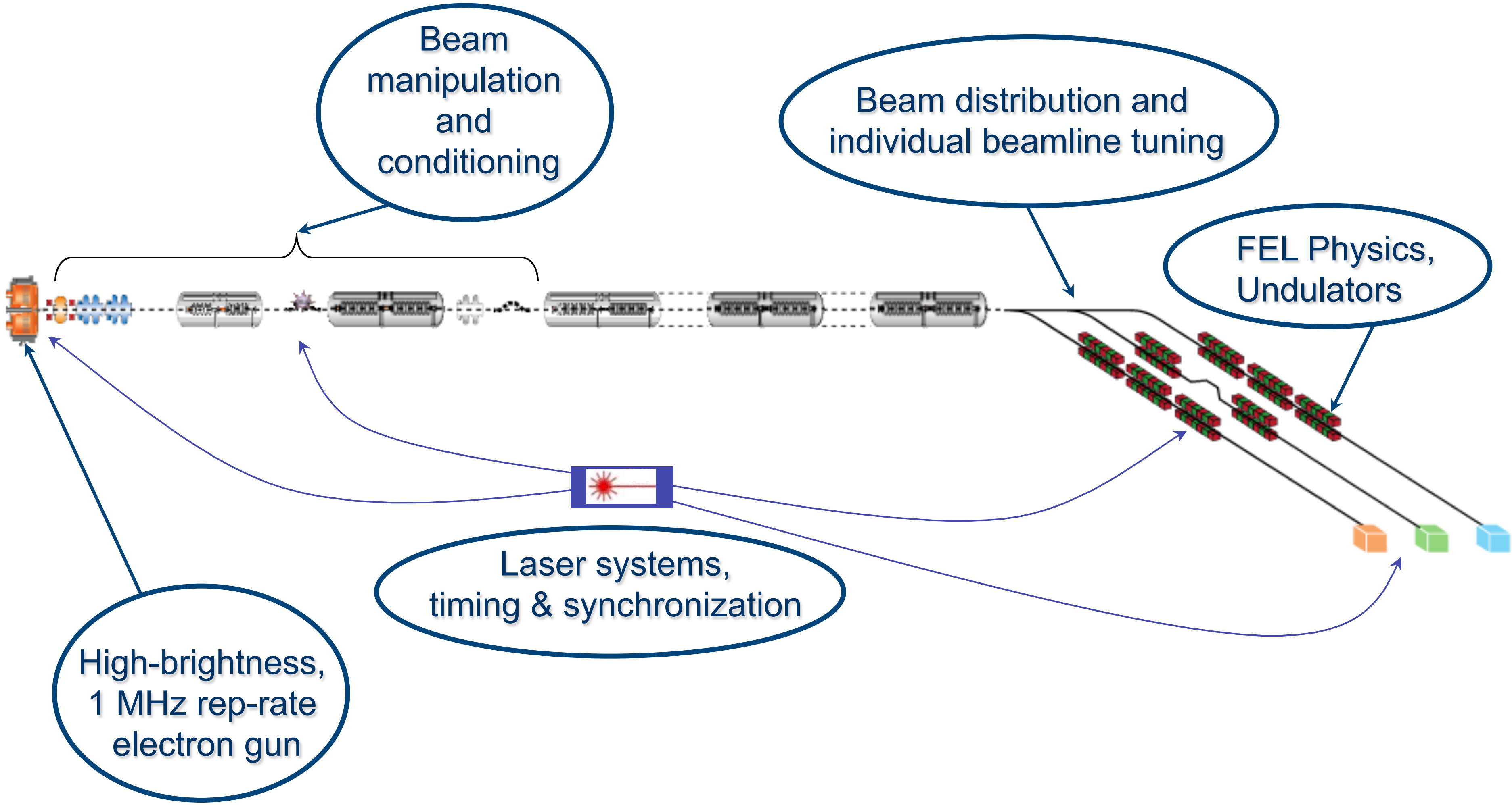
Accelerator Schematic Layout



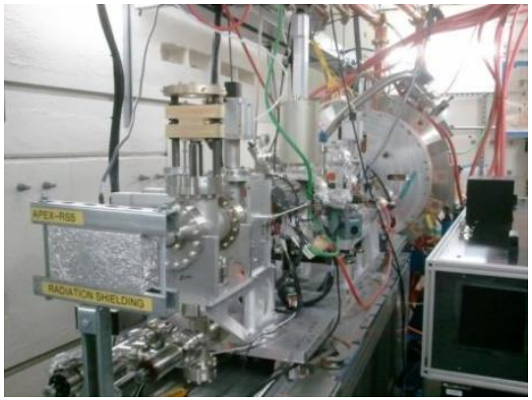
- 30–300 pC bunches
- 1 MHz rep-rate (+)
- 2.4 GeV
- ~16 MV/m gradient
- ~27 cryomodules

- 2 bunch compressors
- 1 laser heater
- 3 initial identical spreader beamlines

R&D and Collaboration Areas for NGLS



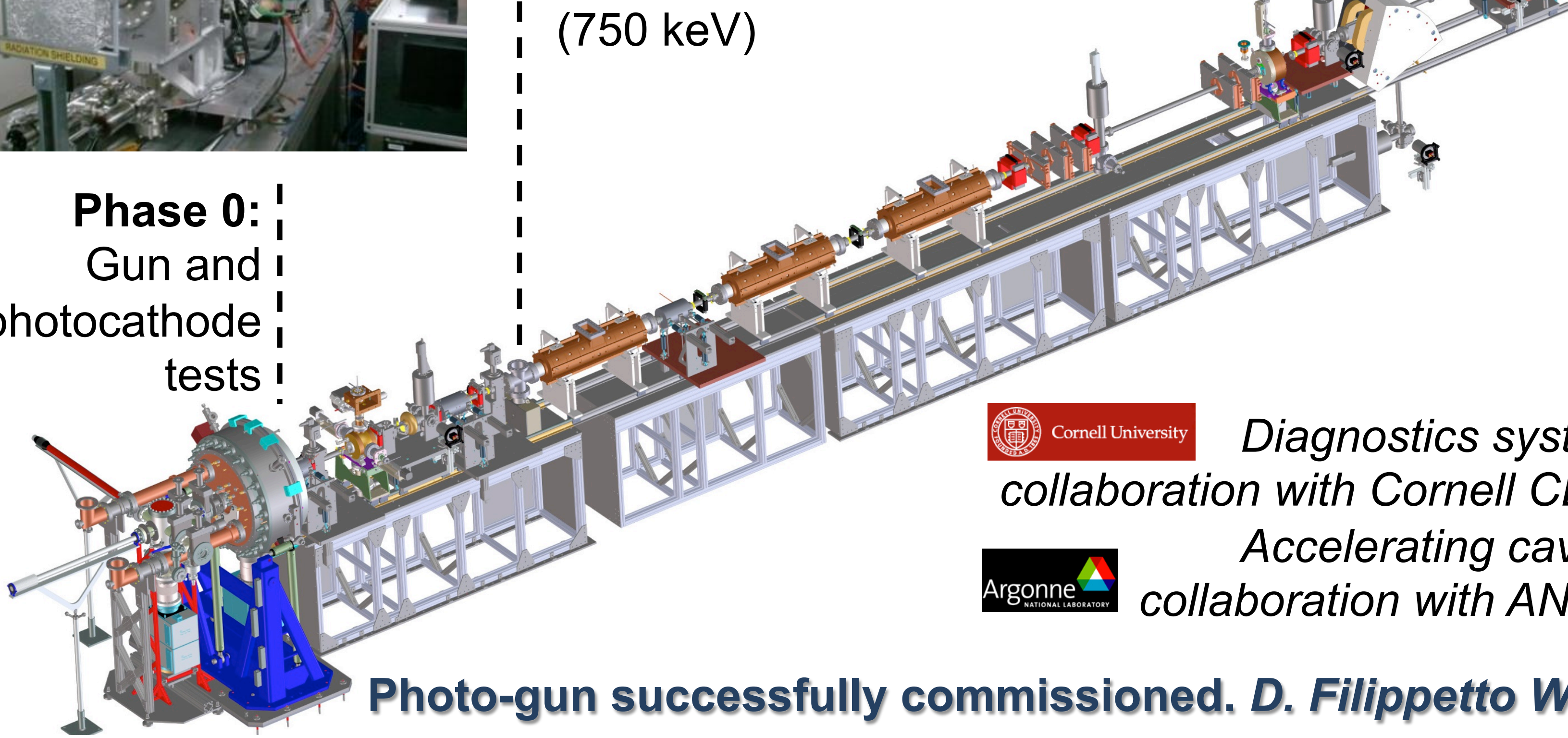
APEX (頂点): the Advanced Photo-injector EXperiment



Phase I:
Beam characterization at gun energy (750 keV)

Phase-II:
Beam characterization at 15–30 MeV
6-D brightness measurements

Phase 0:
Gun and photocathode tests



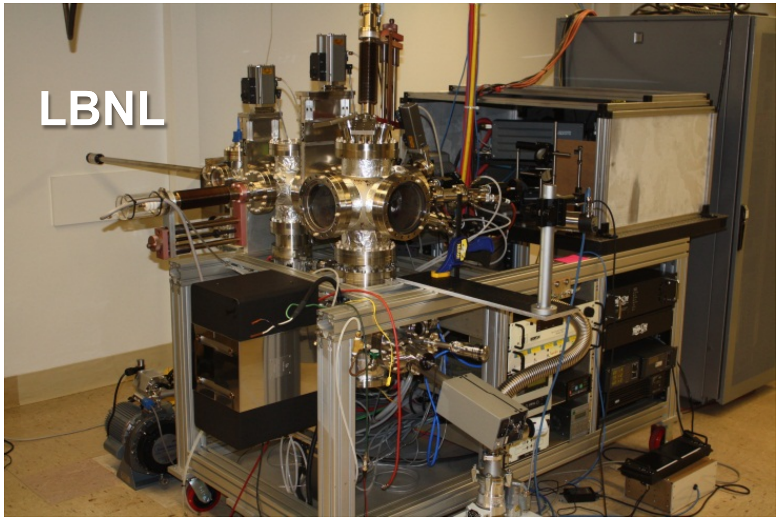
Diagnostics systems in collaboration with Cornell CLASSE

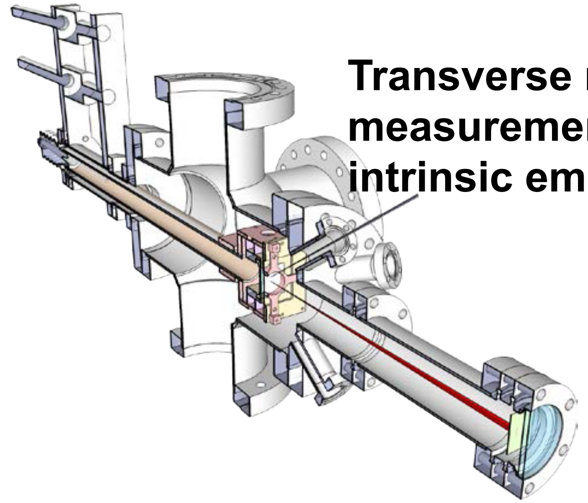
Accelerating cavities in collaboration with ANL AWA

Photo-gun successfully commissioned. *D. Filippetto WEOAI01*

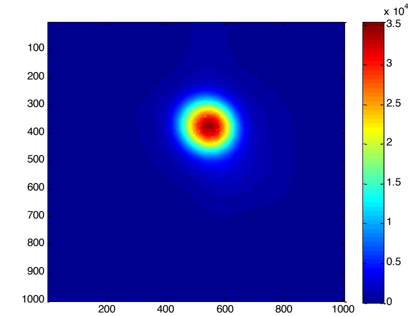
Phase II completed in summer 2014

Photocathode Materials R&D





Transverse momentum measurement yields intrinsic emittance



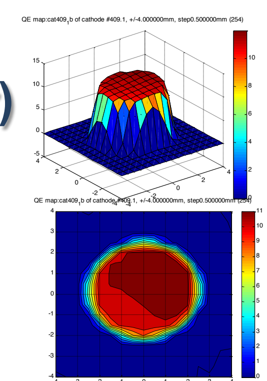
K_2CsSb:
6% QE at 532 nm
0.36 microns / mm rms ε_n
>> 1 week lifetime

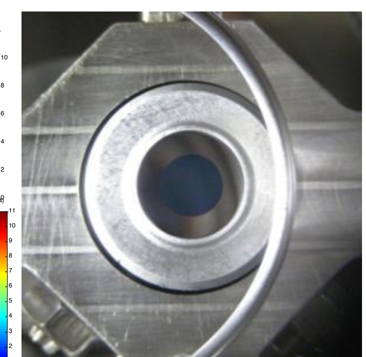
T. Vecchione, et al., Appl. Phys. Letters 99, 034103, (2011)

BROOKHAVEN NATIONAL LABORATORY

Cesium Telluride Cs_2Te

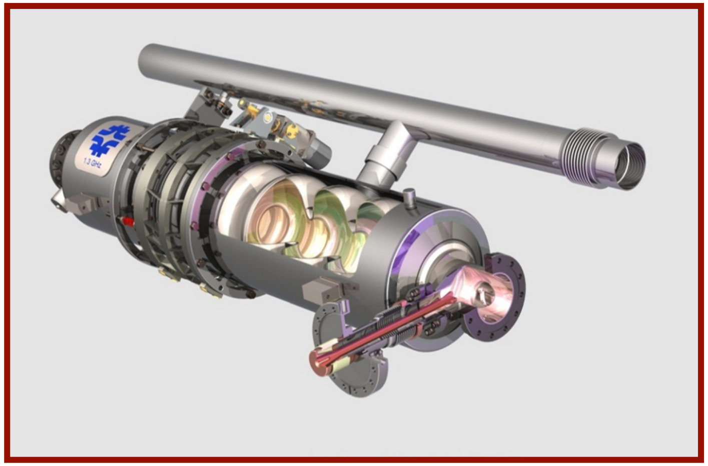
relatively robust and un-reactive (operates at ~ 10^{-9} Torr)
high QE > 1% - ε_n ~ 0.8 μm/mm rms
photo-emits in the UV (~250 nm)





INFN - LASA
Istituto Nazionale di Fisica Nucleare

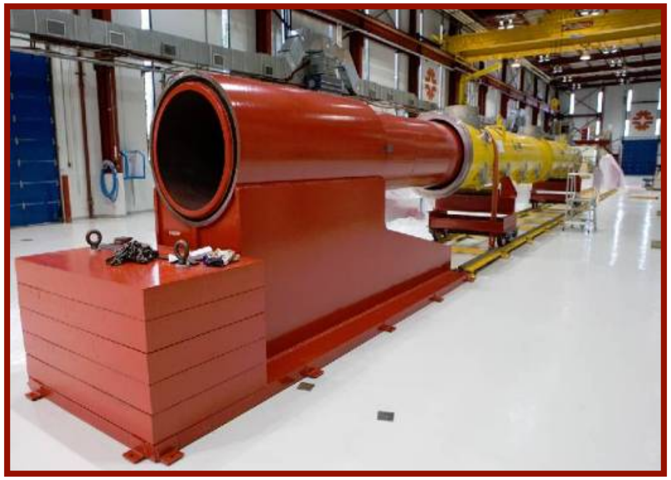
Superconducting Linac and RF Power Source



Fermilab

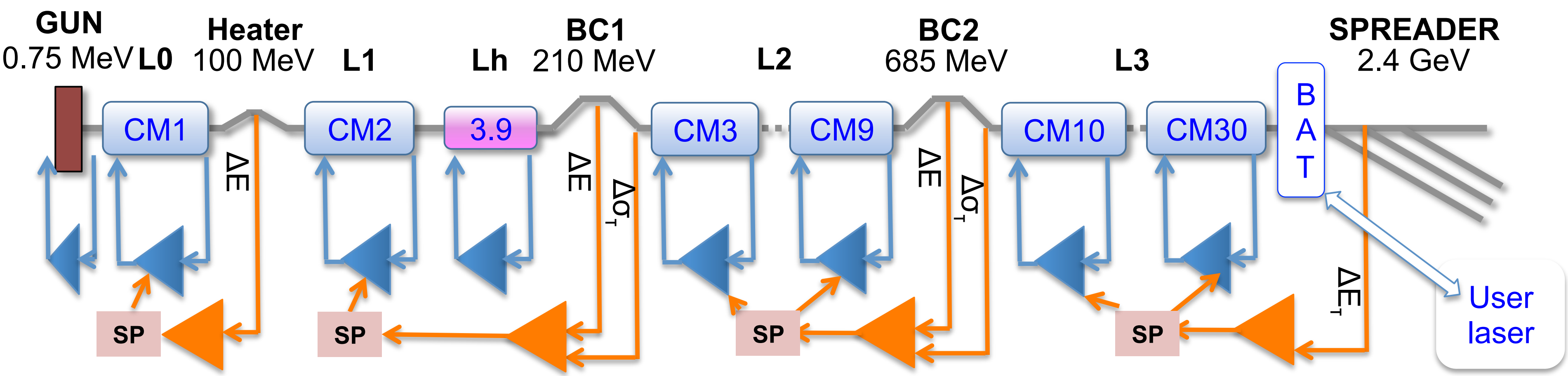
Jefferson Lab

SLAC



- Cryomodule concept: "TESLA/XFEL" cavities in JLAB-style housing
  - ~16 MV/m as goal for CW operation (CEBAF 12 GeV upgrade)

RF & Beam-Based Feedback



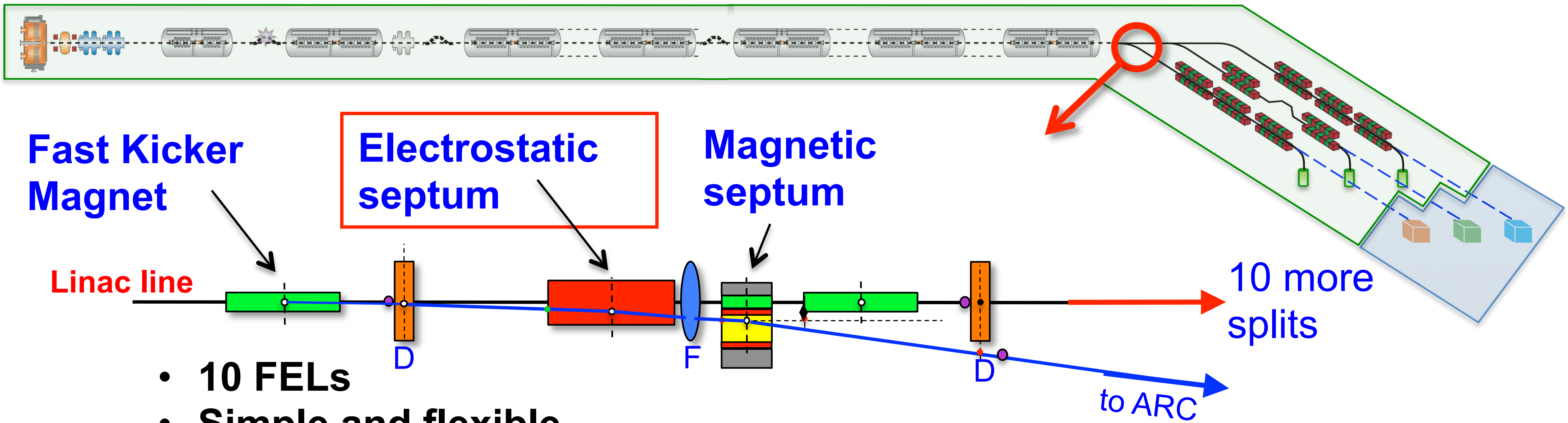
CW SRF provides potential for highly stable beams (important for users!)

- Measure beam energy (4 locations), bunch length (2 locations), bunch arrival time (1 location)
  - Feedback to RF phase & amplitude, external lasers
- Stabilize beam energy, (~10^{-5}), peak current (few %), arrival time (<20 fs)

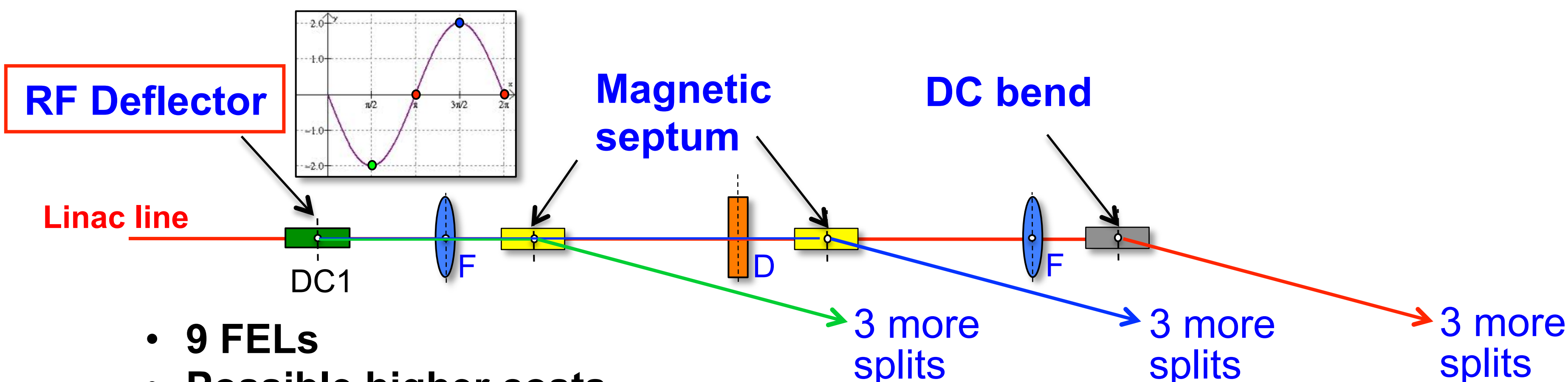
J. Byrd - TUPD29 A Dynamic Fdbck Model For High Rep. Rate Linac-driven FELs

R. Wilcox - THOAI01 Strategies for achieving sub-10fs timing in large-scale FELs

Beam Spreader Options (Kickers or RF)



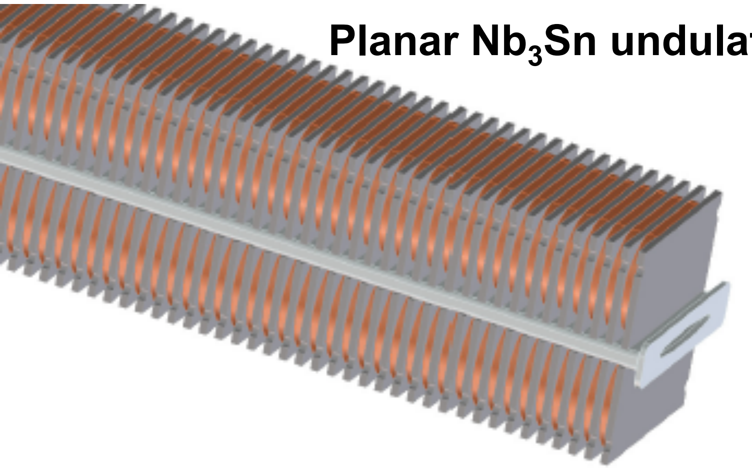
- **10 FELs**
- **Simple and flexible**
- **Repetition rate < 1 MHz (one FEL near 1 MHz?)**



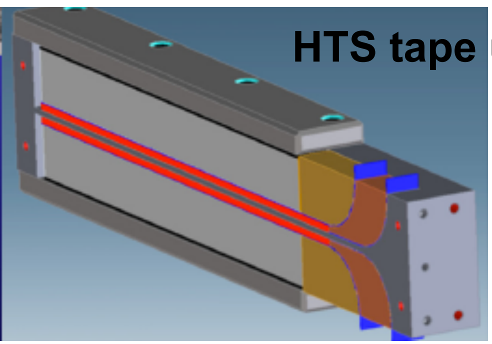
- **9 FELs**
- **Possible higher costs**
- **Repetition rate > 1 MHz (>1 FEL near 1 MHz)**

Superconducting Undulator R&D

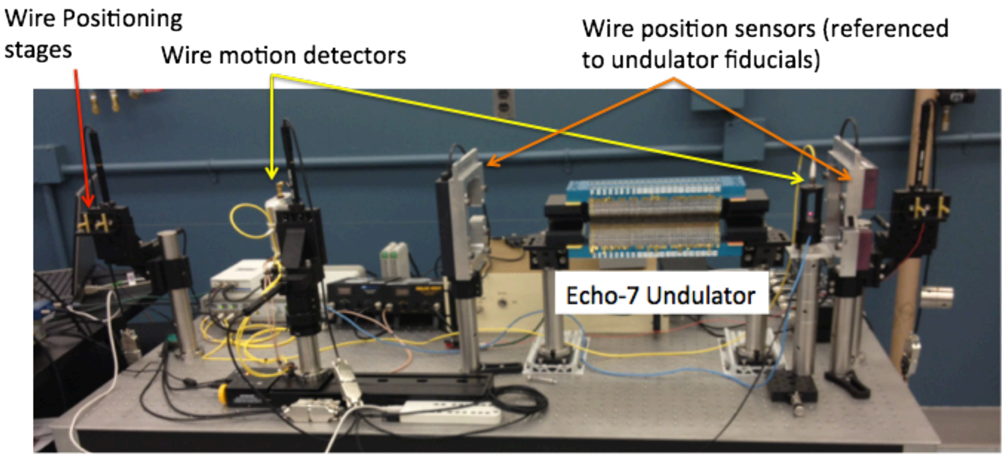
Planar Nb_3Sn undulator

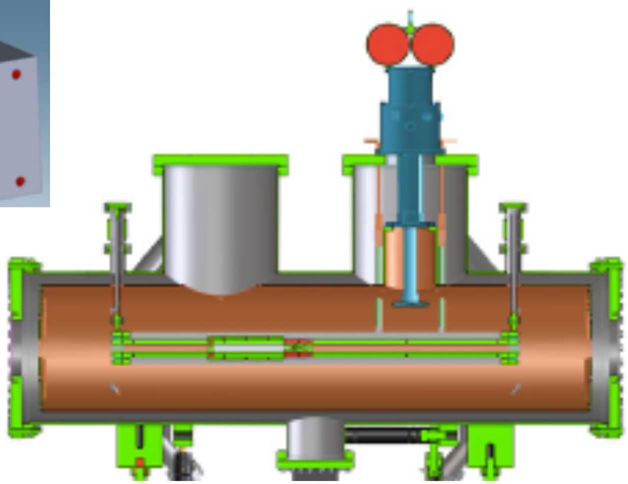


HTS tape undulator



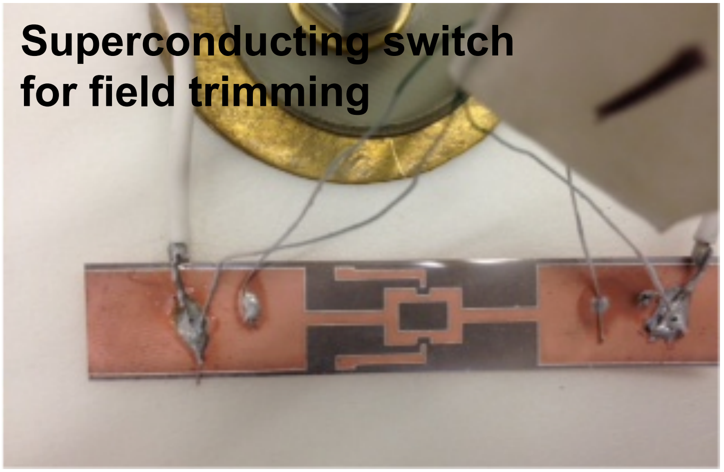
Stretched wire magnetic field measurement



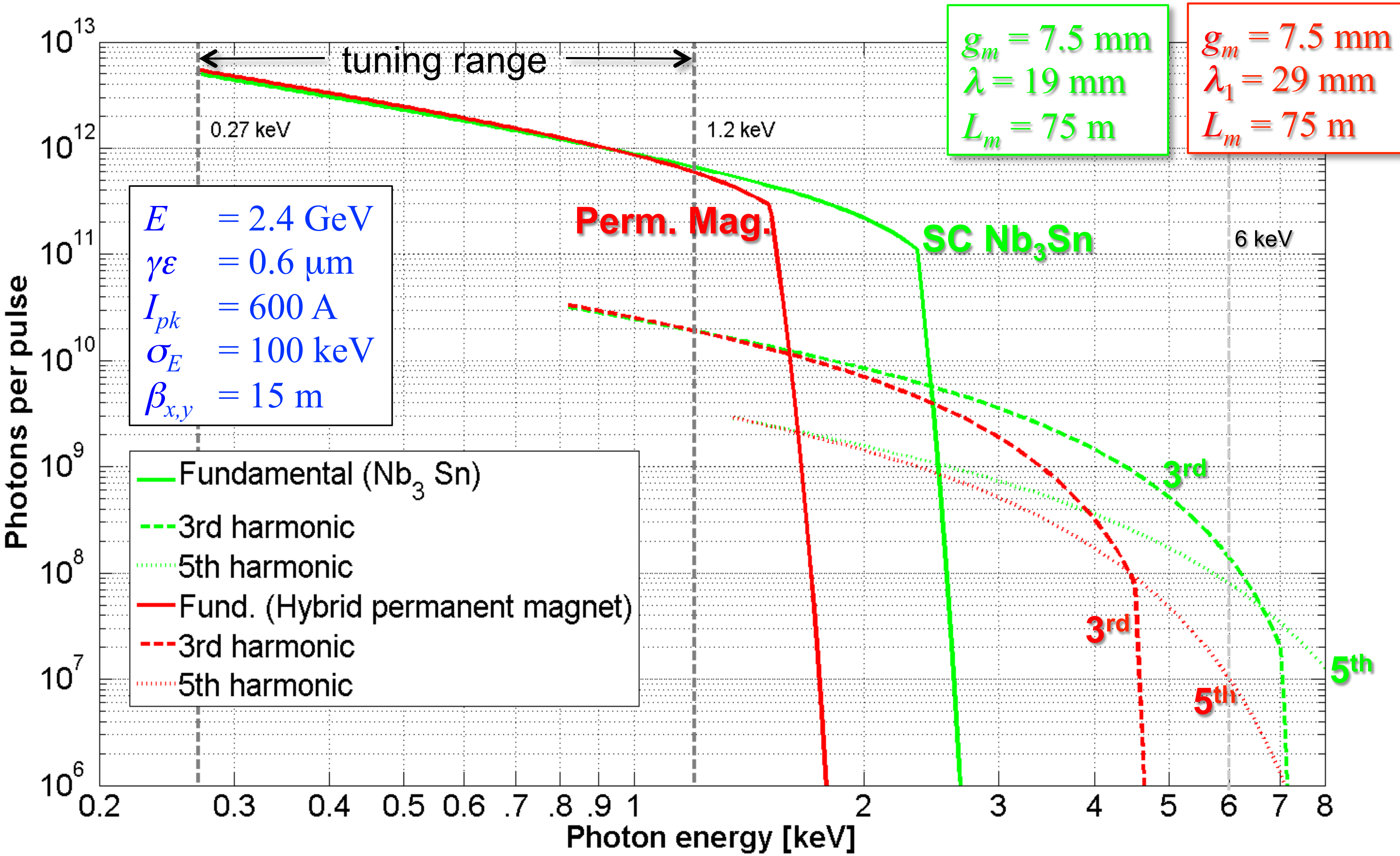


Cryostat for test and measurement

Superconducting switch for field trimming



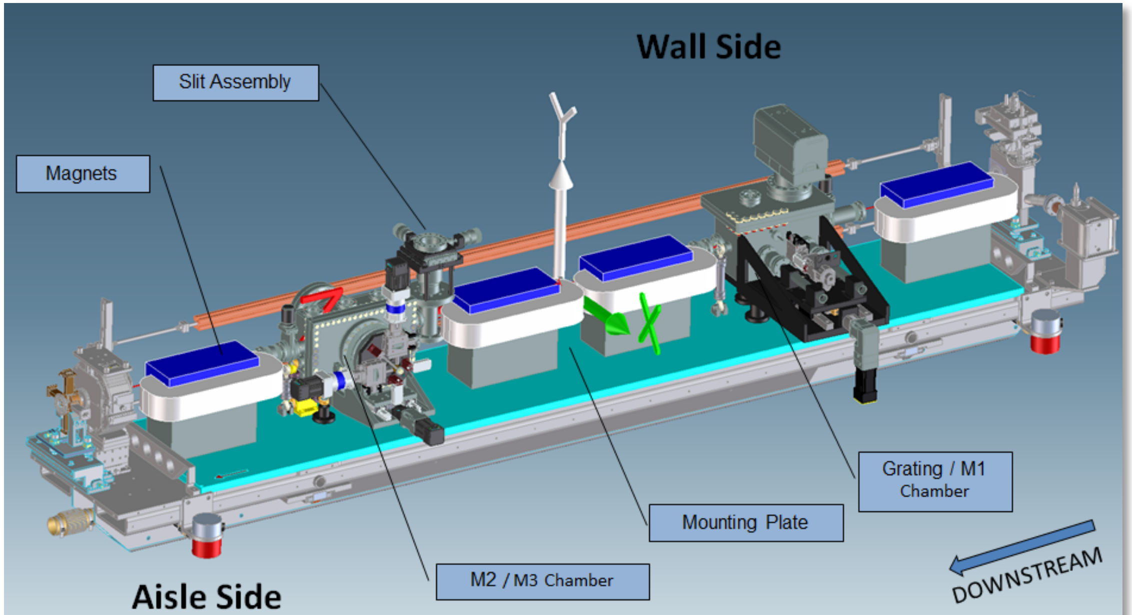
SC & PM Planar Undulators

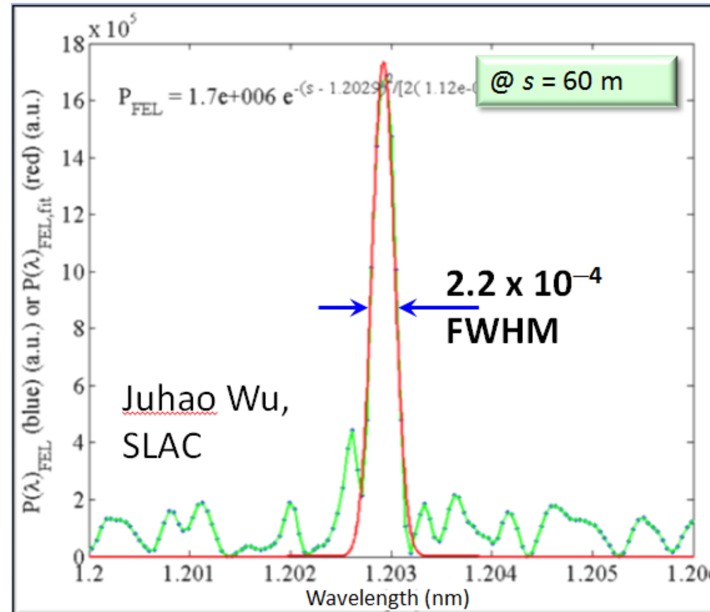


Actual performance will likely be *reduced* with real errors (start-2-end simulations)

Soft X-Ray Self-Seeding R&D (SXRSS)

NGLS
next generation light source





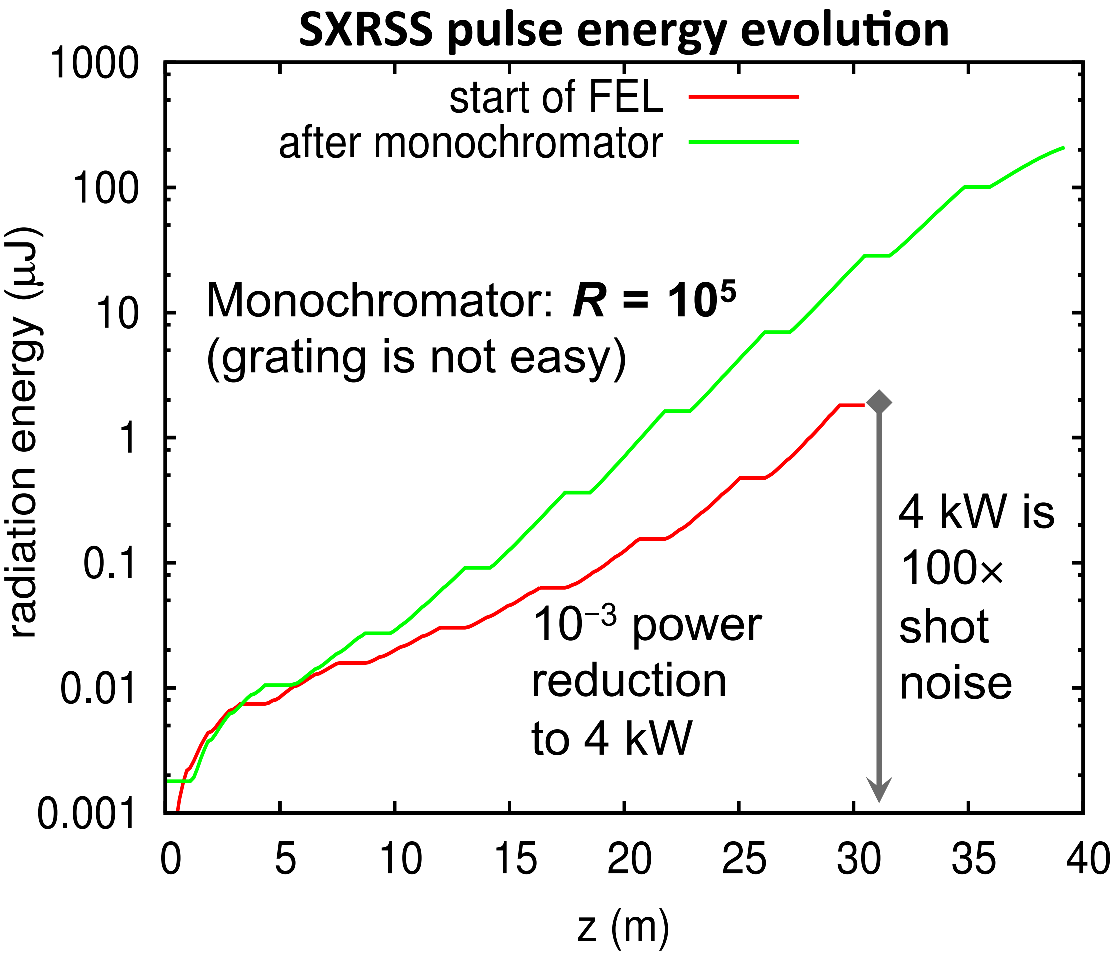
simulation

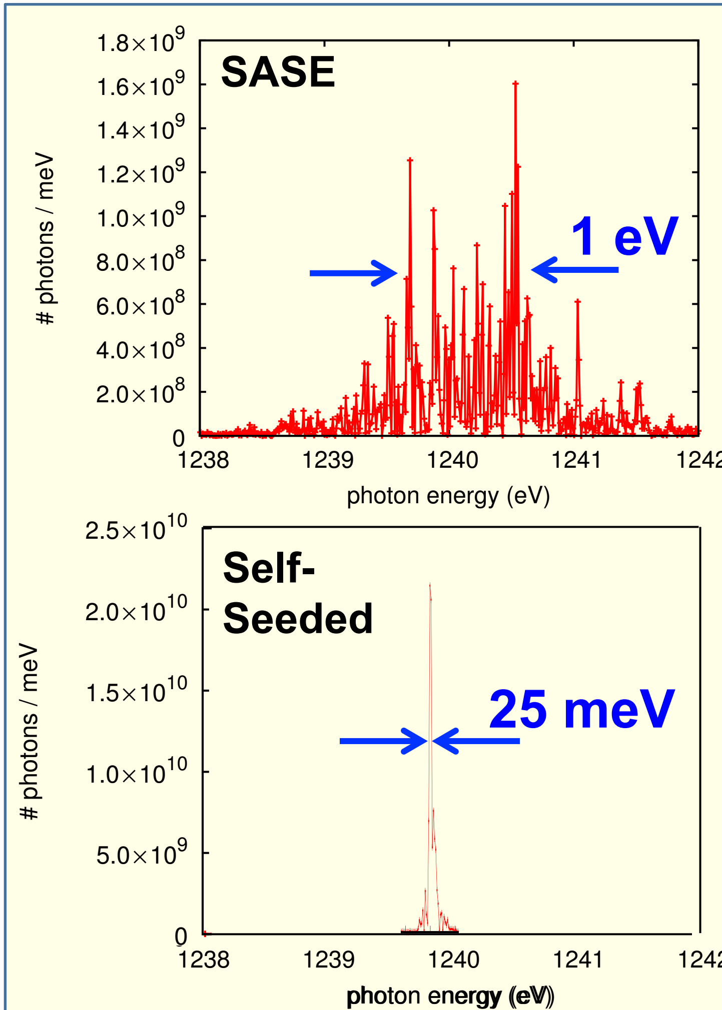
- *LBNL* in collaboration with *SLAC*
- Replace *LCLS* undulator #9 (of 33) with grating-based monochromator and 4-dipole chicane
- **0.3-1.2 keV** seeding (**0.02% FWHM BW**) - transform limited pulse (**~10 fs**)
- Possibility for strong taper and 10-times FEL power
- **Goal:** Installed and commissioned by end of 2013 (NGLS R&D)

SLAC

Y. Feng - TUOBI01 System Design for Self-Seeding the LCLS at Soft X-ray Energies

SXRSS Might Reach 200 μJ/Pulse



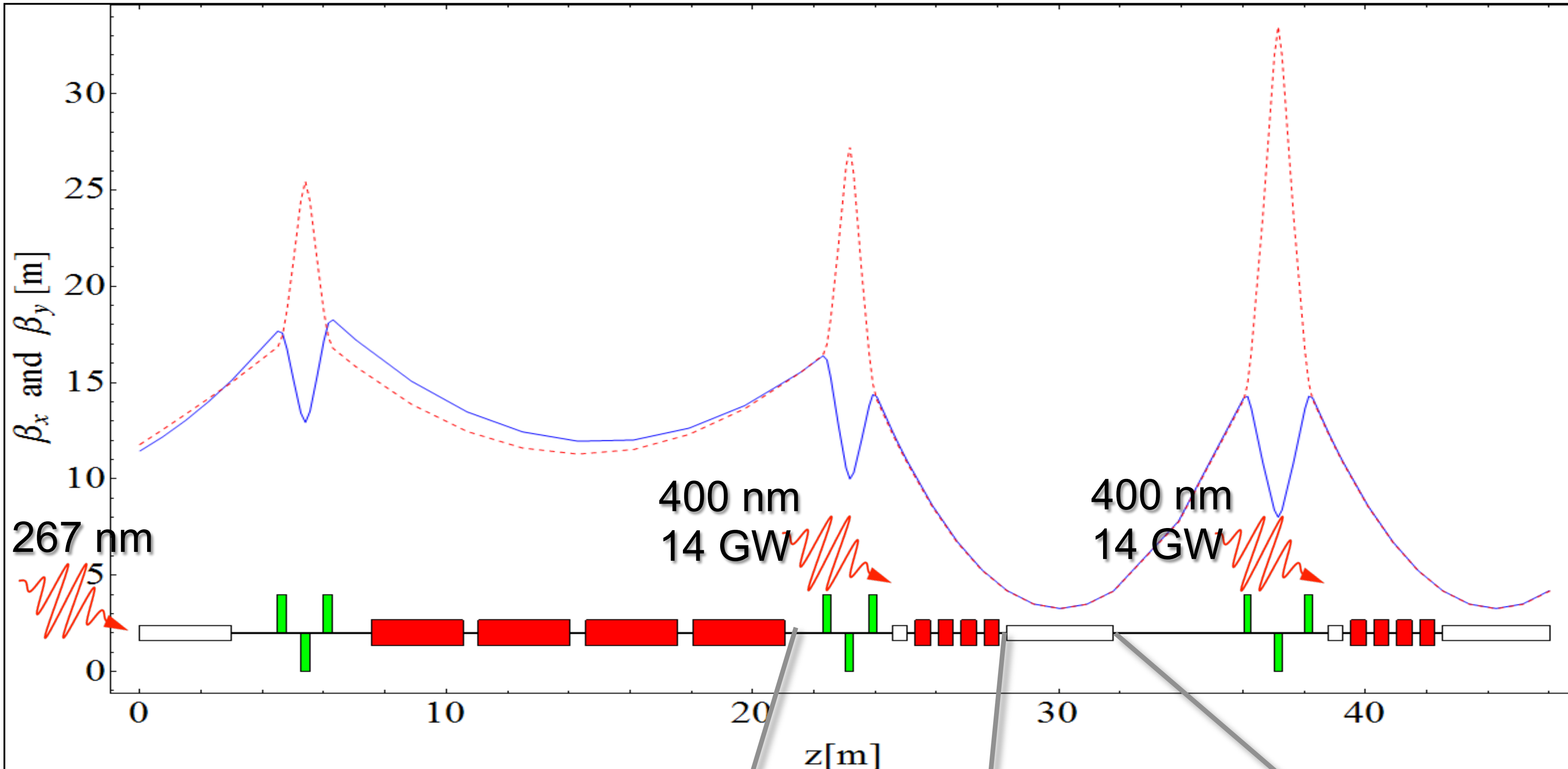


200 μJ per pulse is similar to SASE, but in ~25 meV BW instead of 2000 meV

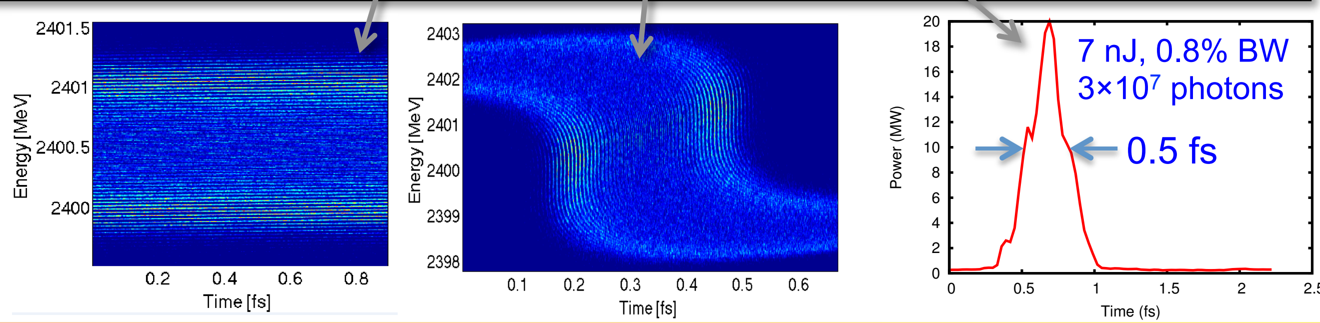
G. Penn - TUPD20

Laser Seeded FELs – ECHO

NGLS
next generation light source

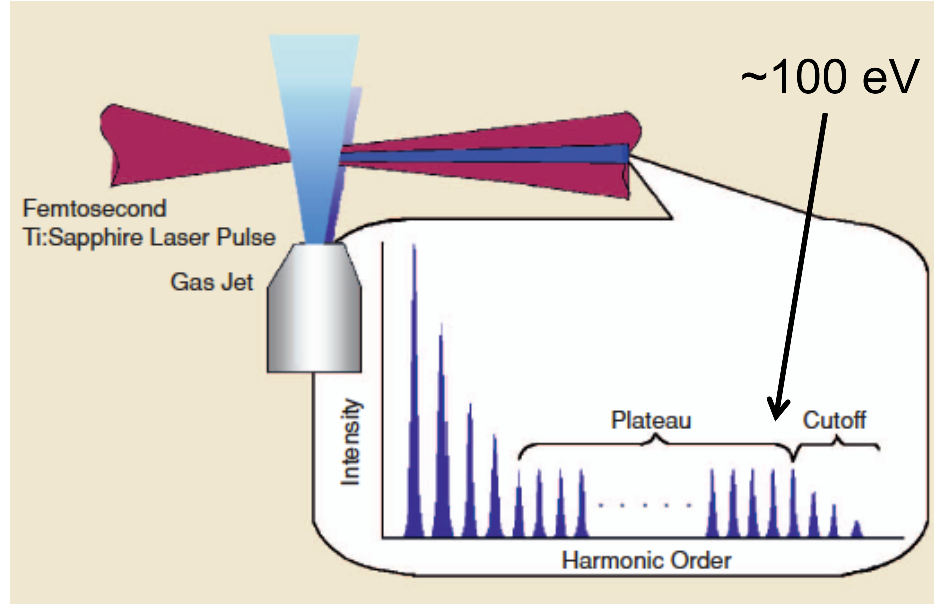


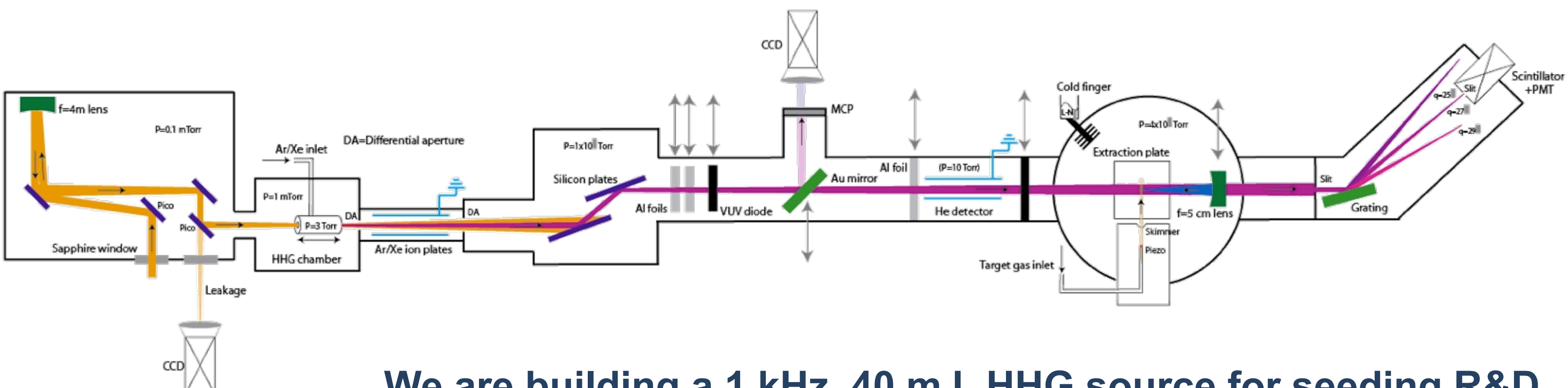
- **Developing R&D plans**
  - **Beam experiments**
  - **Laser developments**



HHG seeded FEL R&D

- **HHG seeding at 50 – 100 eV**
- **HHG seeding demonstrated at 61.5 nm (SCSS)**
- **Harmonic generation in FEL to reach 1 nm**





We are building a 1 kHz, 40 mJ, HHG source for seeding R&D

Summary

- NGLS is a soft x-ray FEL with multiple FEL beamlines operating at MHz-class repetition rate.
- The high repetition rate opens to a complete new class of experiments.
- NGLS has “CD-0” or “Approval of Mission Need” from the U.S. Department of Energy
- At LBNL, we are
  - Optimizing machine design to best meet science needs
    - High repetition rate
    - CW time structure
    - High average power soft x-ray lasers
  - Executing and developing R&D plans
  - Strengthening and building collaborations

NGLS DESIGN STUDY AND ACCELERATOR R&D TEAM

アリガトウ！
(Thank you!)

K.M. Baptiste, D. Bowring, J.M. Byrd, J.N. Corlett, P. Denes, S. DeSantis, R. Donahue, L. Doolittle, P. Emma, D. Filippetto, J. Floyd, J. Harkins, G. Huang, T. Koettig, S. Kwiatkowski, D. Li, H. Nishimura, T.P. Lou, H.A. Padmore, C. Papadopoulos, C. Pappas, G. Penn, M. Placidi, S. Prestemon, D. Prosnitz, J. Qiang, A. Ratti, M. Reinsch, D.S. Robin, F. Sannibale, R. Schlueter, R.W. Schoenlein, A. Sessler, J.W. Staples, C. Steier, C. Sun, T. Vecchione, M. Venturini, W. Wan, R. Wells, R. Wilcox, J. Wurtele