Physics and Applications of High Brightness Beams

San Sebastian, Spain - June 19-23, 2023

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(http://pbpl.physics.ucla.edu/index.html)

UCLA Particle Beam Physics Laboratory

pbpl.physics.ucla.edu (http://pbpl.physics.ucla.edu/index.html)

(https://w3.lnf.infn.it/?lang=en)

(https://www.mi.infn.it/it/#randomSmart)

INFN-Milano

www.mi.infn.it (https://www.mi.infn.it/it/#randomSmart)

National Science Foundation

(https://www.nsf.gov)

(https://cbb.cornell.edu)

Center for Bright Beams

(https://psti.ucla.edu)

UCLA Plasma Science and Technology Institute

psti.ucla.edu (https://psti.ucla.edu)

(https://www.mdpi.com/journal/instruments)

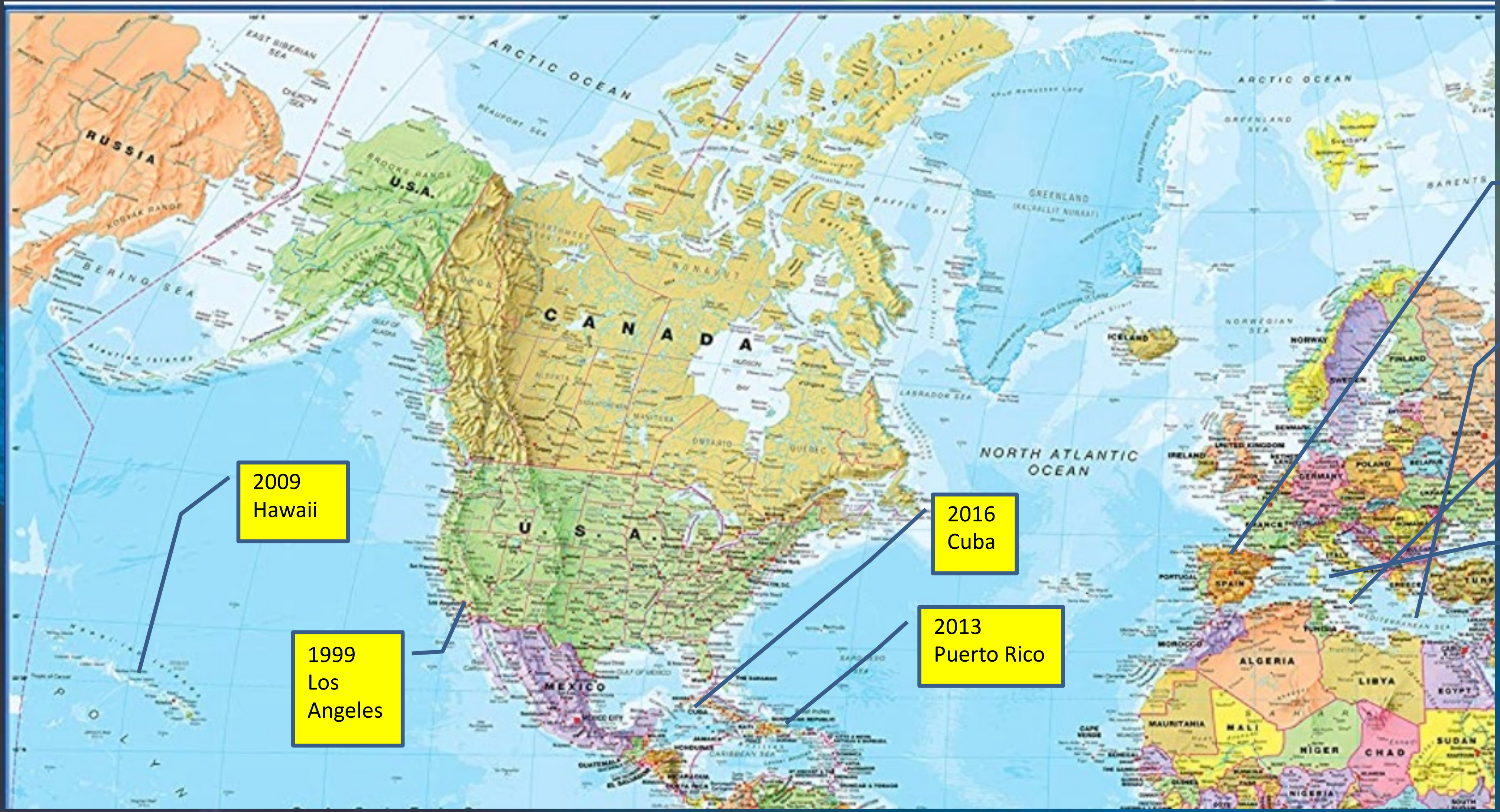
Instruments

(https://www.lpgp.u-psud.fr/icfaana)

ICFA Panel on Advanced and Novel Accelerators

(https://www.sirepo.com)

Sirepo by RadioSoft



2023 San Sebastian
2019 Crete
2005 Erice
2002 Chia Laguna
2009 Hawaii
2016 Cuba
2013 Puerto Rico
1999 Los Angeles
ARCTIC OCEAN
RUSSIA
U.S.A.
CANADA
GREENLAND
NORTH ATLANTIC OCEAN
MEXICO
ALGERIA
LIBYA

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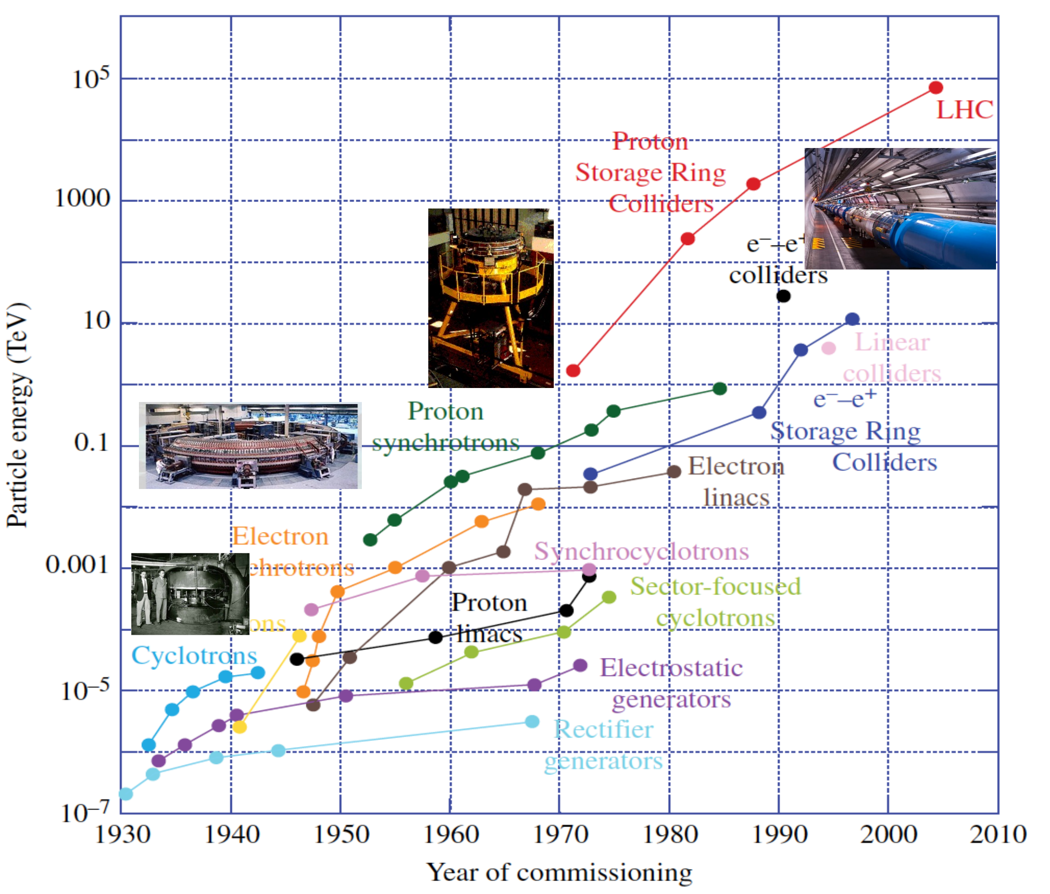
- **The Mission**

- Meeting ground for discussion of high brightness beam production, manipulation, and acceleration in state-of-the-art systems ranging from cutting-edge RF accelerators, to very high-field plasma-based schemes.

- The resultant beams provide the underpinnings of new scientific instruments such as X-ray free-electron lasers (XFELs) and TeV-class linear colliders.

- This edition of the workshop will emphasize two emerging trends: first, the vital involvement in the development of the field through student and post-doctoral training through a dedicated half-day session sponsored by the NSF STC Center for Bright Beams); and the key involvement in the future user communities of 5th generation light sources.

The Livingstone Plot



(Energy of colliders is plotted in terms of the laboratory energy of particles colliding with a proton at rest to reach the same center of mass energy.)

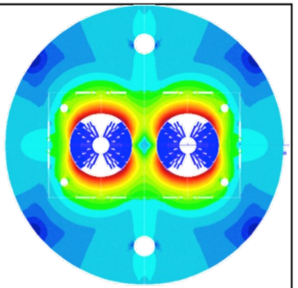
Options towards higher energies

Hadron (p) circular collider

$$p = e \cdot R \cdot B_y$$

Increase bending field
SC bend magnet work (FCC-hh)

Increase radius = size (FCC-hh)



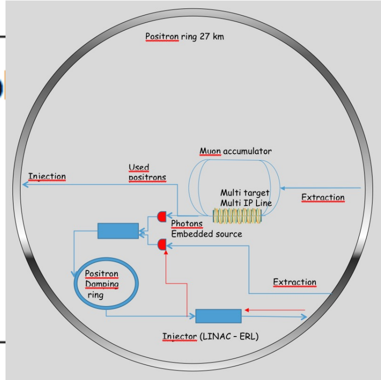
Lepton (e-,e+) circular collider

$$p \propto E_0 \cdot \sqrt[4]{\rho \cdot U_0}$$

Increase supplied RF vo
(FCC-ee)

Increase mass of acc. particle (muon)

Increase radius = size (FCC-ee)



Lepton (e-,e+) linear collider

$$p = L \cdot G_{acc}$$

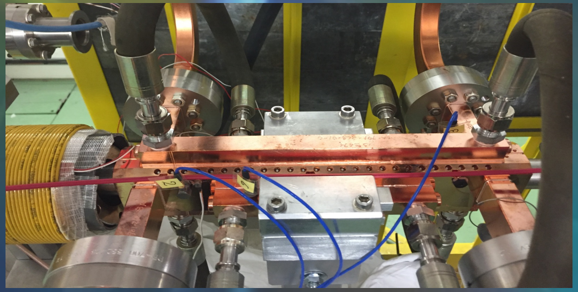
Increase length (ILC, CLIC)

Compact and Cost Effective....

High Gradient Options

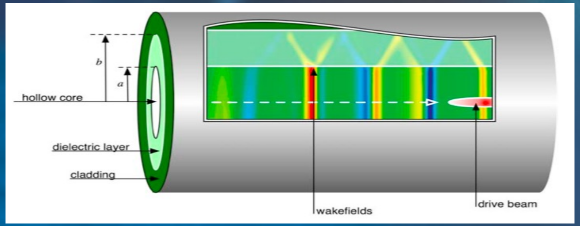
Metallic accelerating structures =>

100 MV/m < E_{acc} < 1 GV/m



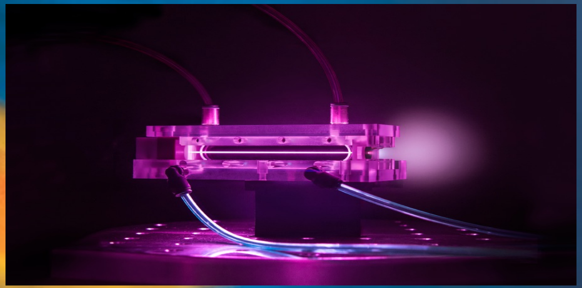
Dielectrict structures, laser or particle driven =>

E_{acc} < 10 GV/m



Plasma accelerator, laser or particle driven =>

E_{acc} < 100 GV/m



Related Issues: Power Sources and Efficiency, Stability, Reliability, Staging, Synchronization, Rep. Rate and short (fs) bunches with small (μm) spot to match high gradients

Beam Quality Requirements

Future accelerators will require also high quality beams :

==> High Luminosity & High Brightness,

==> High Energy & Low Energy Spread

$$L = \frac{N_{e+} N_{e-} f_r}{4\pi\sigma_x\sigma_y}$$

- –N of particles per pulse => 10^9
- –High rep. rate f_r=> bunch trains
- –Small spot size => low emittance

$$B_n \approx \frac{2I}{\varepsilon_n^2}$$

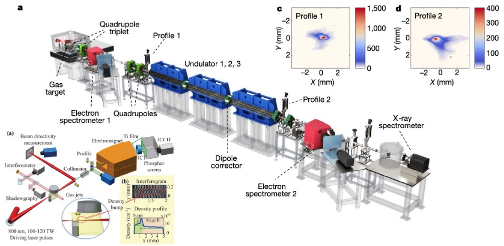
- –Short pulse (ps => fs)
- –Little spread in transverse momentum and angle => low emittance

Basic beam quality achieved in pilot FEL experiments

2021 Plasma FEL Feasibility Proven: Laser-driven

Horizon Europe

W. T. Wang, K. Feng, *et al.*, *Nature*, **595**, 561 (2021).



Recent ground-breaking result in China

500 MeV electron beam from a laser wakefield accelerator

FEL lasing **amplification of 100** reached at 27 nm wavelength (average radiation energy 70 nJ, peak up to 150 nJ)

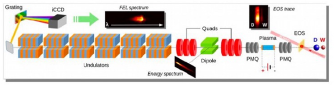
2021 Plasma FEL Feasibility Proven: Electron-driven

Horizon Europe

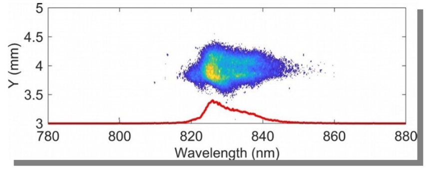
Recent ground-breaking results in Frascati:

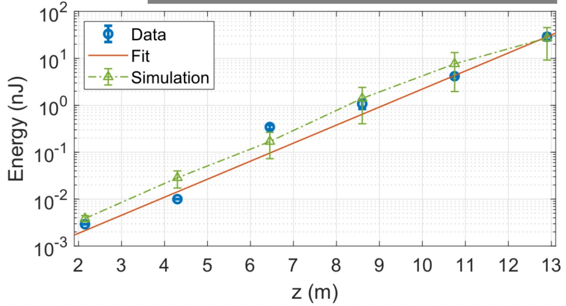
First FEL lasing from a beam-driven plasma accelerator

Pompili et al., Nature **605**, 659–662 (2022)

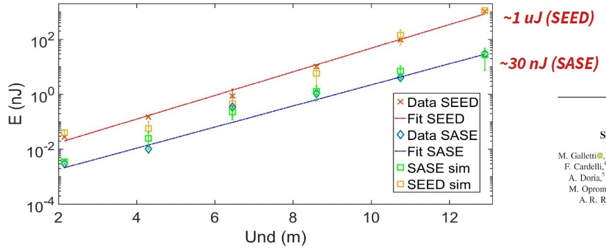


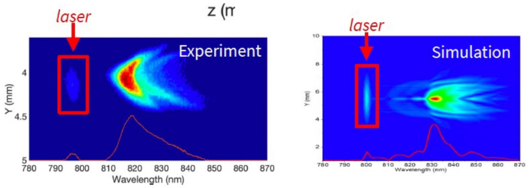
Single Spike SASE spectrum





First Beam Driven SEEDED - FEL Lasing at SPARC_LAB (June 2021)





PHYSICAL REVIEW LETTERS **129**, 234801 (2022)

Stable Operation of a Free-Electron Laser Driven by a Plasma Accelerator

M. Galletti,[1,2,3,*] D. Alesini,[4] M. P. Anania,[4] S. Arjmand,[4] M. Behtouei,[4] M. Bellaveglia,[4] A. Biagioni,[4] B. Buonomo,[4] F. Cardelli,[4] M. Carpanese,[5] E. Chiadroni,[4,6] A. Cianchi,[1,2,3] G. Costa,[4] A. Del Dotto,[7] M. Del Giorno,[4] F. Dipace,[4] A. Doria,[5] F. Filippi,[5] G. Franzini,[4] L. Giannessi,[4] A. Giribono,[4] P. Iovine,[8] V. Lollo,[4] A. Mostacci,[6] F. Nguyen,[5] M. Opromolla,[9,10] L. Pellegrino,[4] A. Petralia,[5] V. Petrillo,[9,10] L. Piersanti,[4] G. Di Pirro,[4] R. Pompili,[4] S. Romeo,[4] A. R. Rossi,[10] A. Selce,[5,11] V. Shpakov,[4] A. Stella,[4] C. Vaccarezza,[4] F. Villa,[4] A. Zigler,[4,12] and M. Ferrario[4]

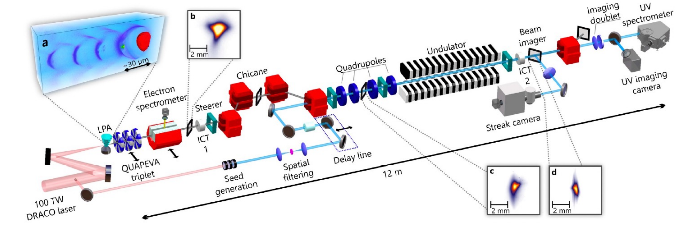
Seeded FEL radiation

- ✓ Pulse energy increased 2 order of magnitude respect to SASE radiation
- ✓ 6% pulse energy RMS fluctuations over 90% of successful shot respect to 17% over 30% of shot for SASE

Seeded UV free-electron laser driven by LWFA

Horizon Europe

Collaboration Soleil/HZ Dresden, published on *Nat. Photon.* (2022). https://doi.org/10.1038/s41566-022-01104-w



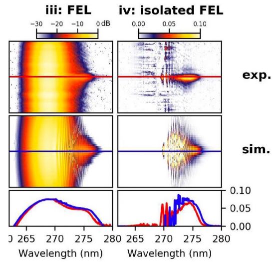


FIG. 1. **Experimental layout.** The electron beam generated in the LPA is first characterized using a removable electron spectrometer and then sent through a triplet of quadrupoles (QUAPEVAs) for beam transport to the undulator and FEL radiation generation. ICTs: Integrated Current Transformers. Non-labelled elements: dipoles (*red blocks*), optical lenses (*blue*), mirrors (*grey circled black disks*). Inset **a**: Particle-in-Cell simulation renders of the accelerating structure driven by the laser pulse (*red*), the electron cavity sheet formed from the plasma medium (*light blue*) is visible in *purple* and the accelerated electron bunch visible in *green*. Insets **b,c,d**: Electron beam transverse distribution measured at LPA exit (**b**), at undulator entrance (**c**) and at undulator exit (**d**).

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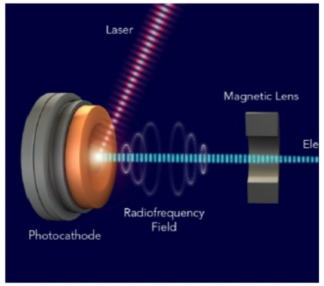
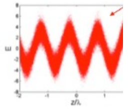
Photoinjectors
Photoemission DC and RF guns, S/TEM, UED, Accelerators…

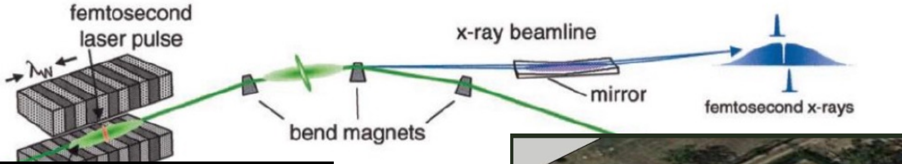


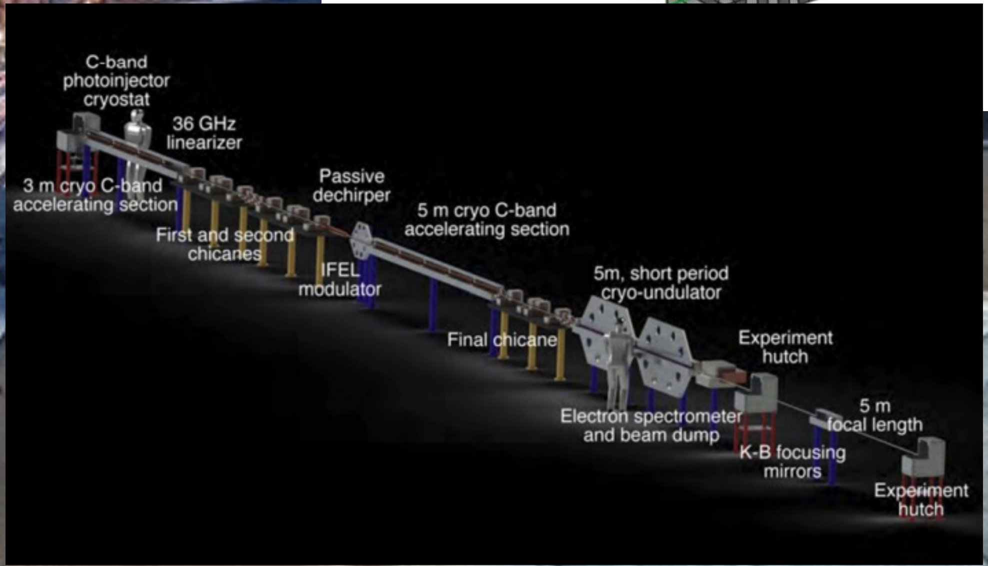
Seeded or Harmonic FEL emission
HHG seeded (instead of SASE) or Echo-Enabled Harmonic Generation

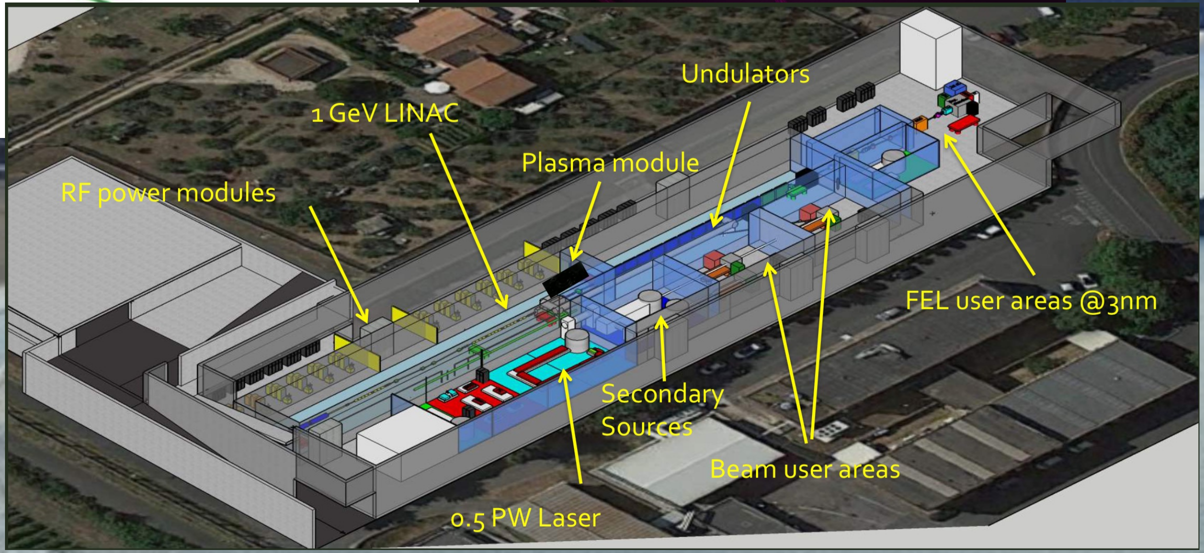


Stupakov, I
Hemsing, I

Beam Conditioning
Bunch slicing, a short laser pulse modulates a slice of the e-beam to provide separate emission peaks







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	Monday 6/19	Tuesday 6/20	Wednesday 6/21	Thursday 6/22	Friday 6/23
9:30 AM	*M. Ferrario (INFN-LNF)* PAHBB intro	*J. Power (ANL)* Sub-GV/m X-Band Photocathode Gun at AWA	*P. Hommelhoff (FAU Erlangen)* Ebeam stat correlations	*X. Xu (Bejing University)* PWFA density downramp injection	*A. Curcio (INFN-LNF)* EuPRAXIA Advanced Photon Sources (Eu
	J. B. Rosenzweig (UCLA) UCXFEL	*T. G. Lucas(PSI)* Traveling wave high gradient photoinjector	*C. Duncan (EPFL)* Medusa UED	*A. Fahim Habib (Strathclyde)* Towards PWFA-X-FEL	*A. Giribono (INFN-LNF)* Stable, reliable and reproducible PWF
	A. Johnson (IMDEA) Dynamics of quantum materials with XFELs	*A. Galdi (UniSa)* CsSb atomically smooth thin film photocathodes	*T. De Raadt (Tech. Univ. Eindhoven)* Sub-picosecond ultracold electron bunches	*P. Tomassini (ELI NP)* Resonant Multi Pulse Ionization injection	*B. Gunther (LMU)* Munich Compact Light Source
			B. Alberdi-Esuain (Helmotz) Novel approaches and modalities in UED	*S. Barber (LBNL)* Reliable test bed for LWFA compact light sources	*M. Litos (Boulder)*
11:00 AM	Coffee	Coffee	Coffee	Coffee	Coffee
11:30 AM	*Z. Huang / R. Robles (SLAC)* Hard X-ray RAFEL	*H. Zhang (USTC)* Generation of sub-fs beams in RF Gun	*K. Chirvi (ICFO)* High temporal resolution in gas-phase ED	*M. Labat (SOLEIL)* LWFA Seeded FEL	*R. Lemons (SLAC)* Laser-based manipulation
	S. Reiche (PSI) Advanced concepts in FELs	*E. Simakov (LANL)* LANL cryogun	*D. Cesar (SLAC)* Collective interaction with matter	*M. Galletti (INFN-LNF)* SASE and Seeded FEL driven by a PWFA	*F. Lemery (DESY)* Laser driven hollow core fibers
	V. Petrillo/ A. Rossi (INFN-MI) Brixsino	*X. Li (DESY)* Status of PITZ photoinjector and applications	*J. McKenzie (Daresbury)* RUEDI	*N. Vafaei-Najafabadi (Stonybrook)* Probing of LWFA fields using relativistic electrons	*W. Li (BNL)* Sub-ps long-wave infrared lasers
		P. Garcia Vidal (U. Roma - La Sapienza) Effect of Mo coatings on RF cavity quality factor	*R. J. England (SLAC)* MeV UED facility at SLAC	*S. Antipov (DESY)* Laser-Plasma Injector for PETRA IV	*B. Hidding (Dusserdolf)* LWFA-PWFA hybrid
1:00 PM	Lunch break	Lunch break	Free Half Day	Lunch break	Adjourn
		CBB-sponsored student session (20 mins)			
3:00 PM	*M. Ferrario (DESY)* Eupraxia	*R. Robles (Stanford University)* Spectrotemporal shaping of attosecond XFELs		*E. Prat (PSI)* Intrabeam scattering in FEL injectors	
	P. Franz (Stanford University) TW-class Attosec X-ray Pulses from FEL Cascade	*W. Lynn (UCLA)* DWFA		*J. Maxson (Cornell)* Non linear emittance compensation	
	R. Hessami (Stanford University) PAX Experiment at FACET-II	*J. P. Aguilera (U. Chicago)* 4D Phase space reconstruction		*P. Anisimov (LANL)* Top gun beam dynamics	
		C. Hansen (Boulder) Ion Channel Laser		*S. Kim (ANL)* Update on Electron Beam Manipulation at AWA	
4:30 PM	coffee	Poster Session		Coffee	
5:00 PM	*A. Fisher (UCLA)* High efficiency FELs			*A. Edelen (SLAC)* Virtual diagnostics review	
	B. Schaap (Tech. Univ. Eindhoven) Superradiant Compton			*F. Mayet (DESY)* NN-Phase advance emittance measurements	
	D. Bruwihler (Radiasoft) Design and control of compact sources			*C. Pierce (Chicago)* Physics-based priors for modeling beam dynamics	
	A. Gover (Tel Aviv) First Light at the Israeli THz Superradiant FEL				


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Have a nice and fruitfull workshop !