WG4 Summary
Application of compact and high-gradient accelerators

Stuart Mangles, Imperial College, London

Deepa Angal-Kalinin, STFC Daresbury Laboratory, Cockcroft Institute

24-30 September 2017, La Biodola, Isola d'Elba

6 Sessions : 22 talks , 15 posters

Three Themes:

1. Application of LWFA electrons and x-rays (6 talks)
2. Application of protons (+ions) (6 talks)
3. Electron delivery and Light Sources development (10 talks)

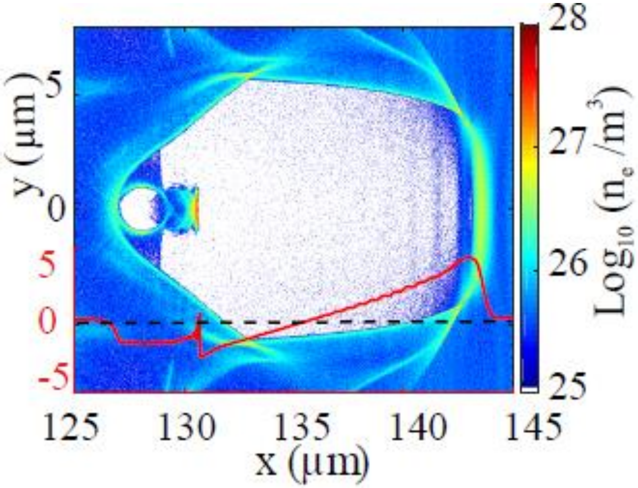
1. Application of LWFA electrons and x-rays

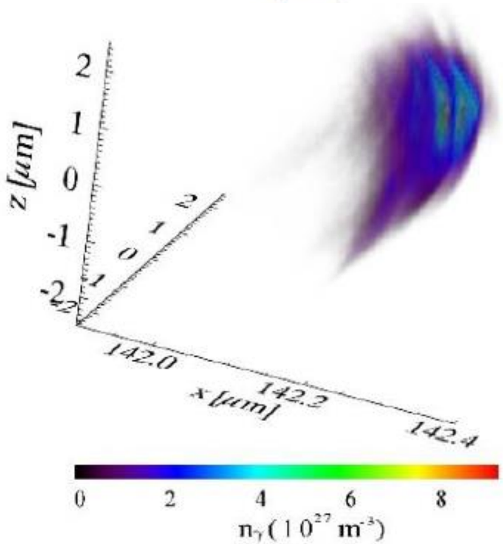
PEKING UNIVERSITY 北京大學

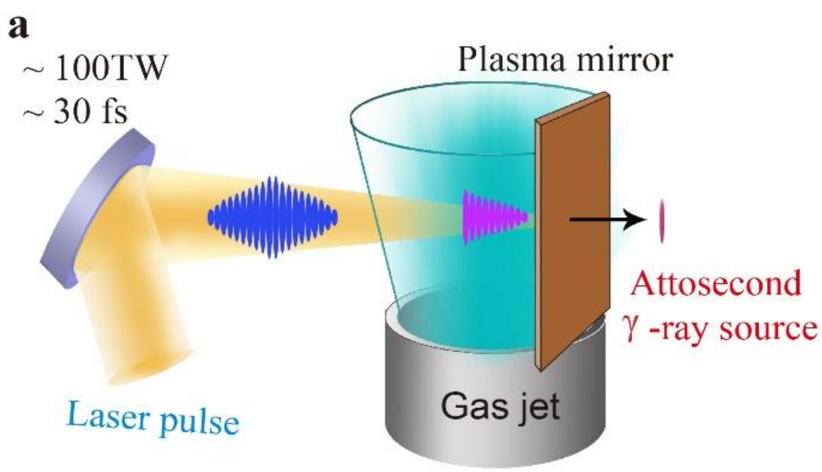
Imperial College London

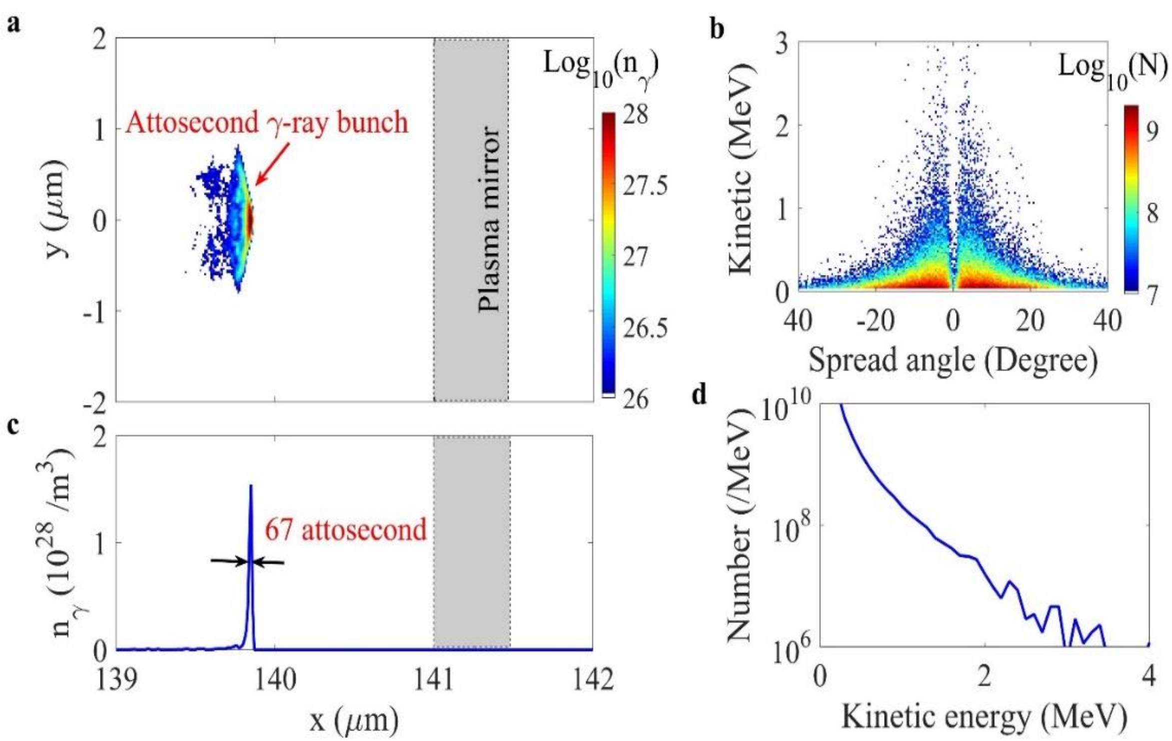
UCI University of California, Irvine

Ultra-brilliance isolated attosecond gamma-ray light source – Jinqing Yu



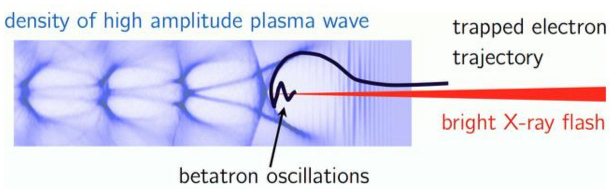


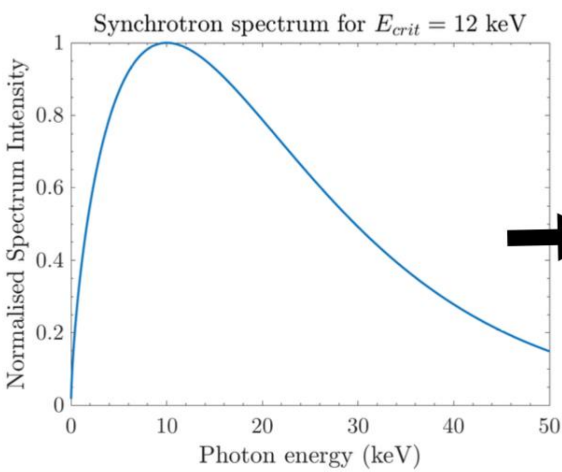


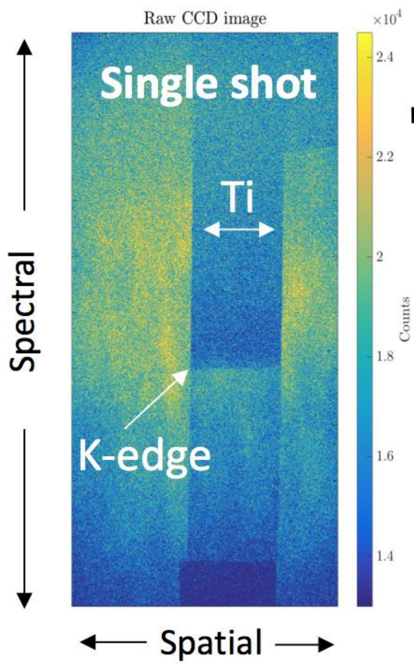


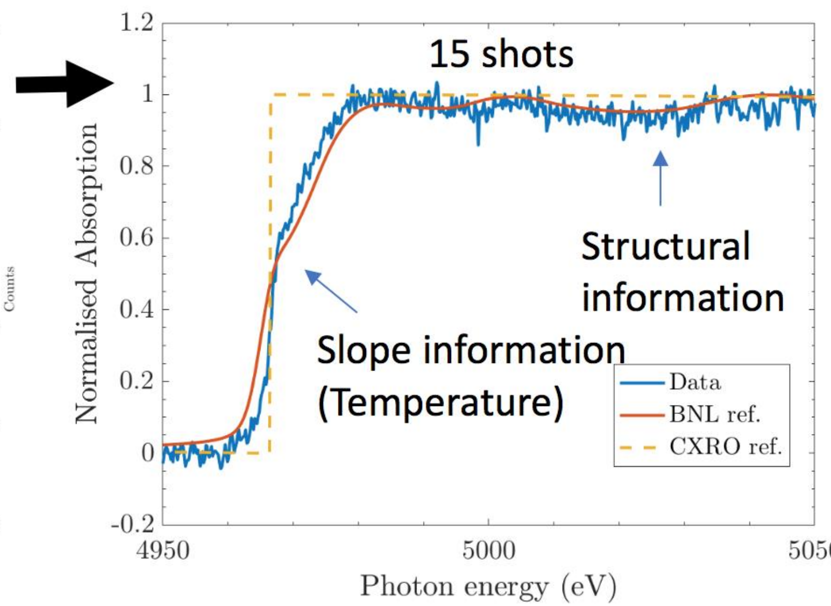
Ultrafast X-ray absorption measurements of high energy density matter using broadband X-rays from an electron beam

- Direct spectral measurement of LWFA X-rays over ≈150 eV range, on a single shot.
- Single shot XANES features from Cold Ti targets.
- Looking forward to **single shot, sub 100 fs, XANES and EXAFS measurements of High energy density matter**.



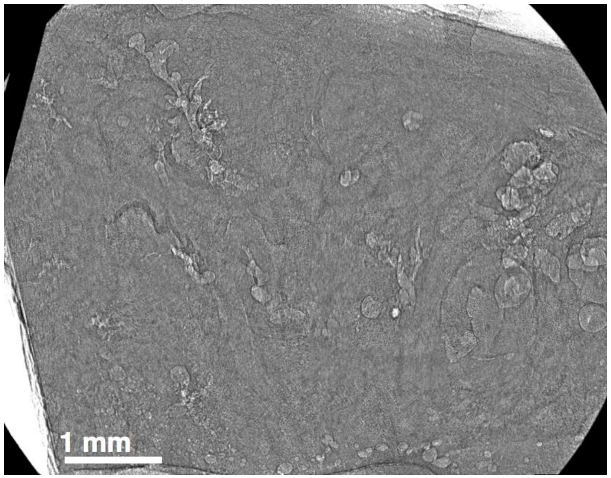




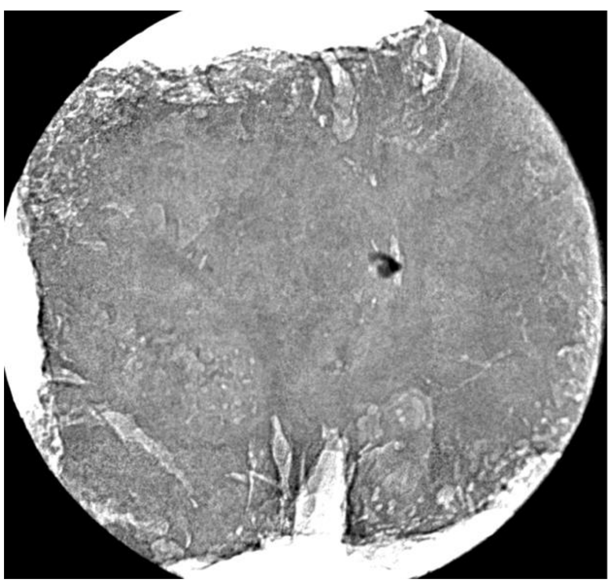


Laser wakefield accelerators as x-ray sources for biomedical imaging applications

Human prostate



Human breast



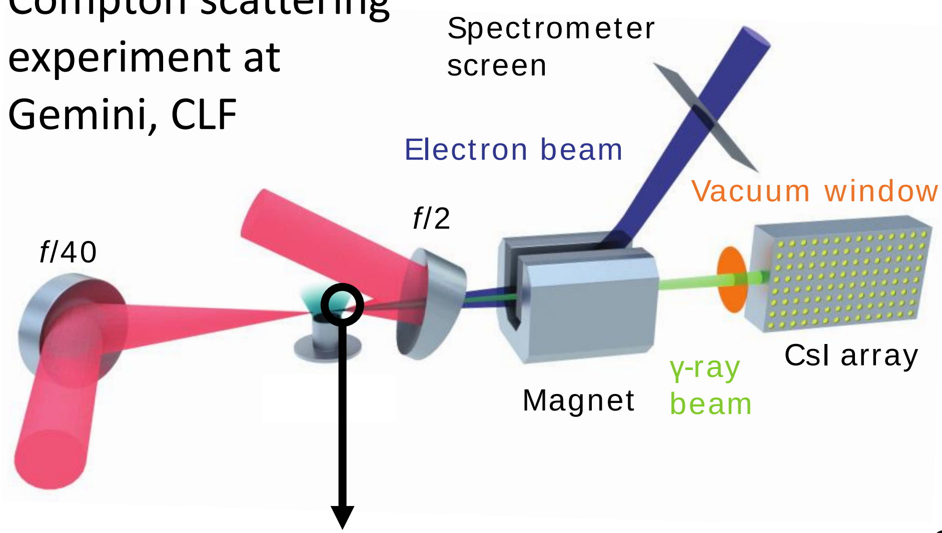
Murine embryo

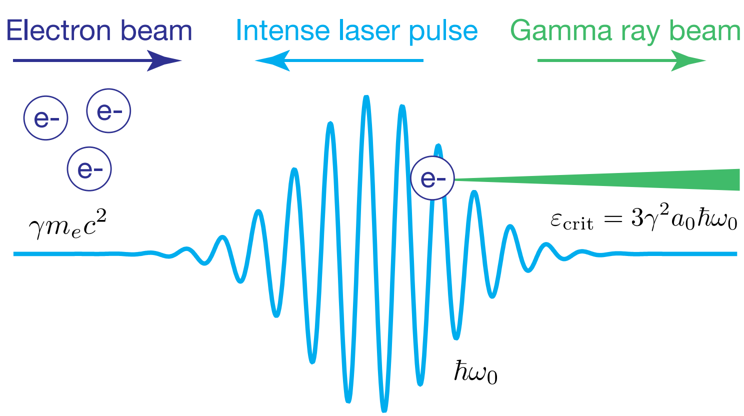
Human femur

Imaging samples

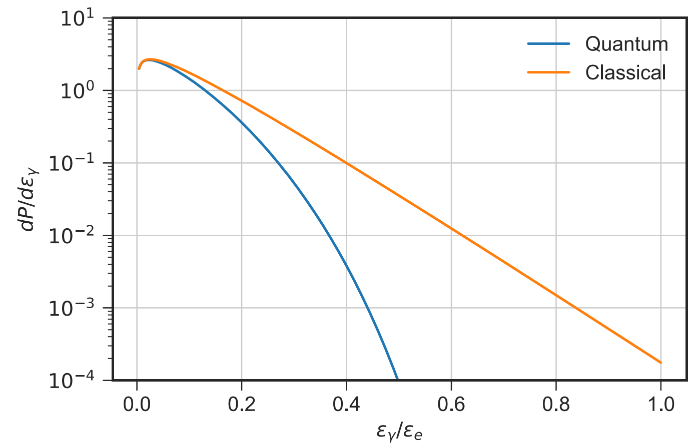
Experimental observation of radiation reaction in the collision of an intense laser pulse with a LWFA electron beam

LWFA inverse Compton scattering experiment at Gemini, CLF

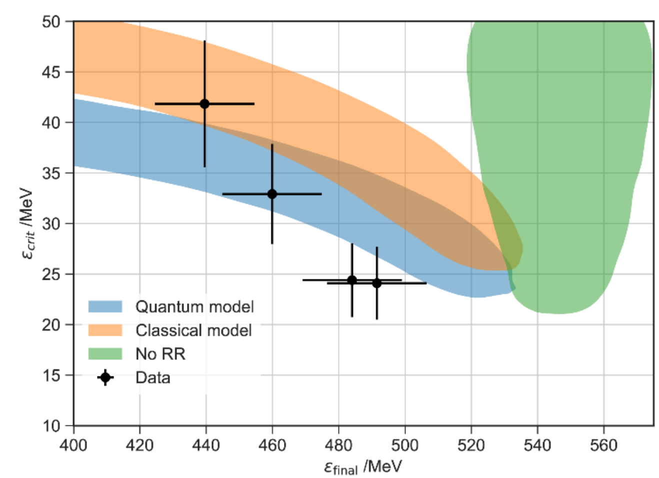




Broad spectrum of Compton-scattered gamma-rays



Observe electron energy loss, and gamma-ray energies consistent with radiation reaction

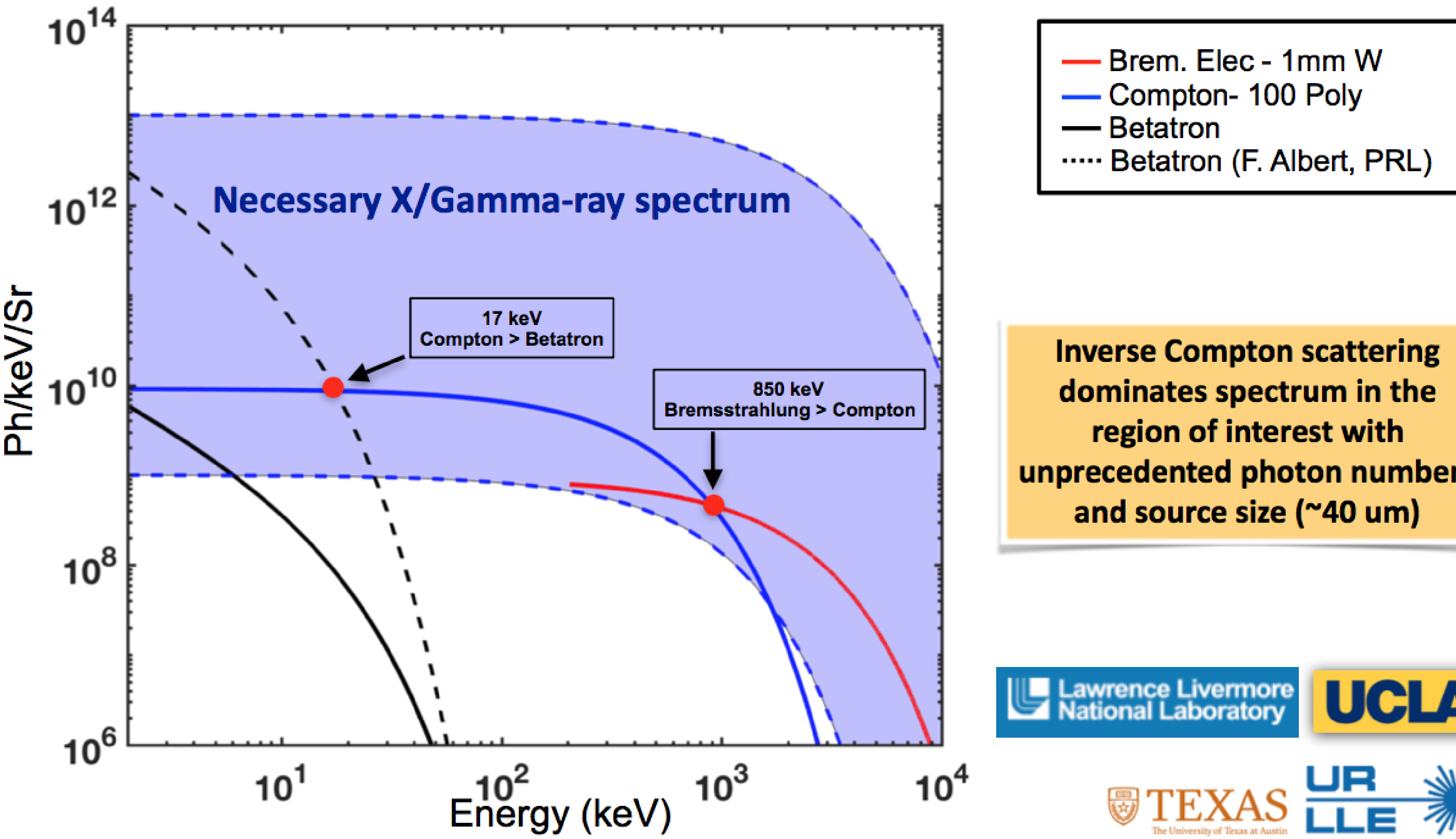


A Muon Source Based on Plasma Accelerators

Luca Serafini – INFN Milano
(A. Bacci, F. Broggi, C. Curatolo, I. Drebot, V. Petrillo, A. Rossi, M. Rossetti)

- **Why GeV-class Muons? Because they are keys to several strategic applications, in particular radiography of very thick objects (Volcanoes, Nuclear Power Plants, National Security) thanks to their high penetration/low stopping power (compared to photons/electrons…)**
- **Why Plasma Accelerator? Because of its compactness (ord. of magnitude cheaper and shorter than GeV-class muon section of a typical muon collider)**
- **The Challenge: run a 10^{31} $cm^{-2}s^{-1}$ luminosity (Lorentz Boosted) e-γ collider at E_{cm}=400 MeV to make a point-like, GeV-class, nsec synchronized, muon source at 1 μ_+^-/s with collimated emission (200 mrad)**
- **The requirement on plasma accelerator: a few nC at 2 GeV with 20% energy spread and 20 mm·mrad rms transv. emittance.**

X/Gamma-ray emission from self-modulated laser wakefield accelerators



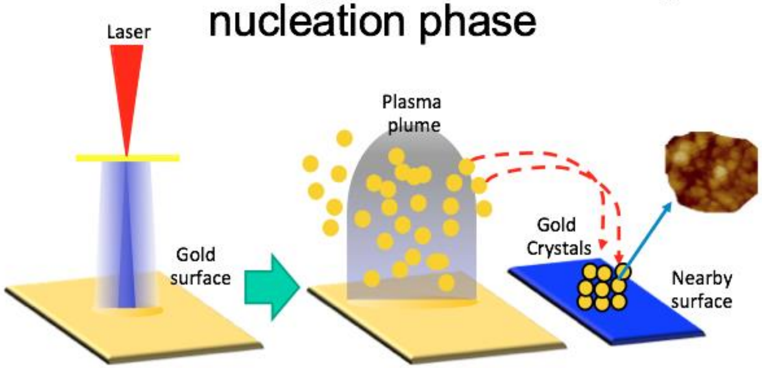
Inverse Compton scattering dominates spectrum in the region of interest with unprecedented photon numbers and source size (~40 um)

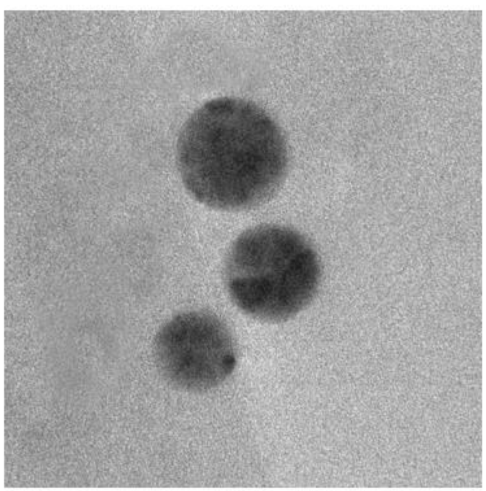
Lawrence Livermore National Laboratory
UCLA
TEXAS The University of Texas at Austin
UR LLE

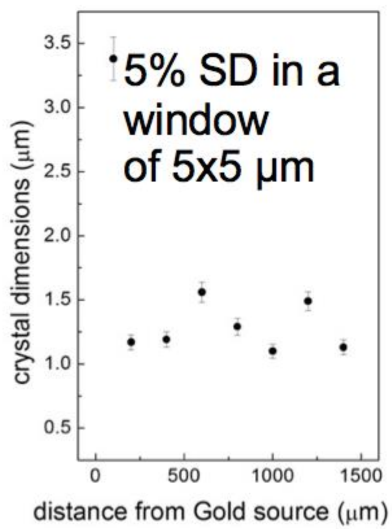
2. Application of protons

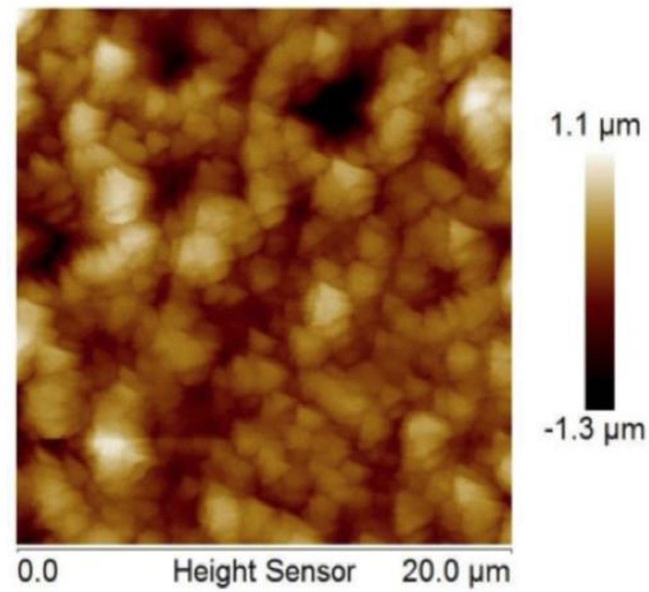
High-precision nanoparticle generation

Laser driven protons produce explosive boiling and allow for very short nucleation phase









Very-fast (1 shot), high-precision (5% SD), tunable nanoparticle generation on neighbor surface

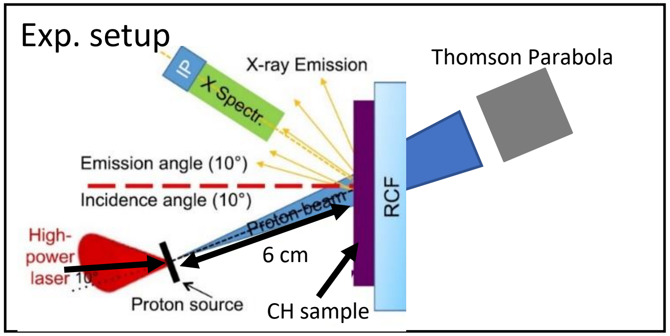
iPAT-LAB
Innovative Particle Acceleration Technologies
Lasers • Applications • Beamlines

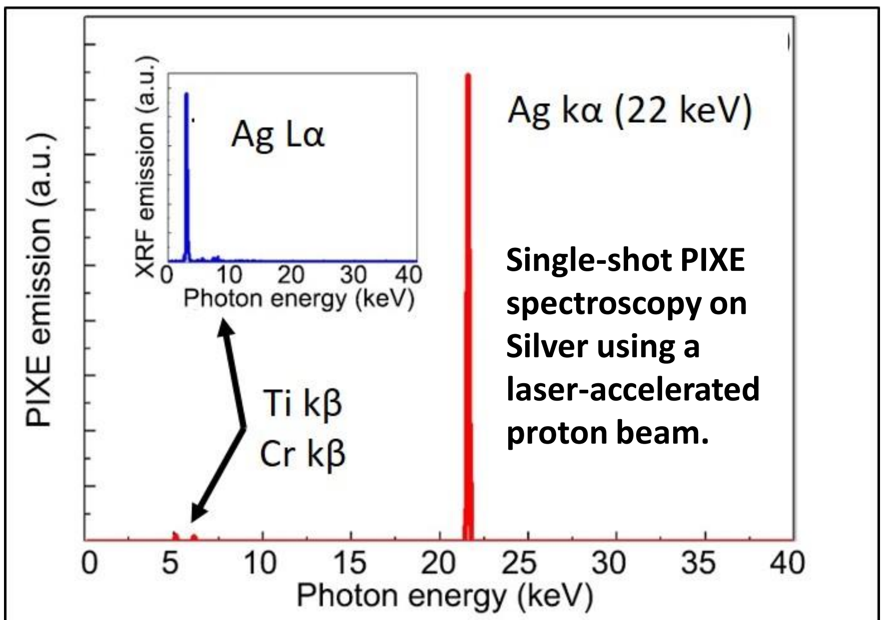
M. Barberio, M. Barberio, M. Scisciò, S. Vallières, S. Veltri, A. Morabito, P. Antici, Scientific Report (published online 2 Oct 2017)
P. Antici, M. Barberio, Patent Pending US 14448.128

Laser-accelerated proton beams as diagnostics for Cultural Heritage

M. Barberio, S. Veltri, M. Sciscìò, A. Morabito, S. Vallieres and P. Antici

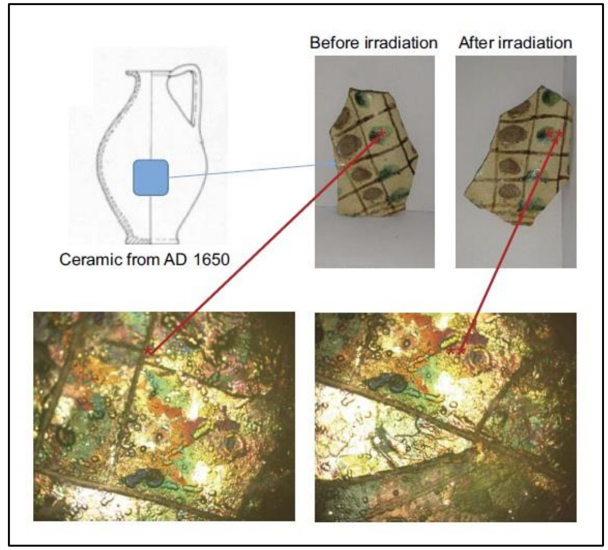
Laser-accelerated proton beams potentially enable a quicker and less invasive Proton Induced X-ray Emission spectroscopy on Cultural Heritage artifacts.

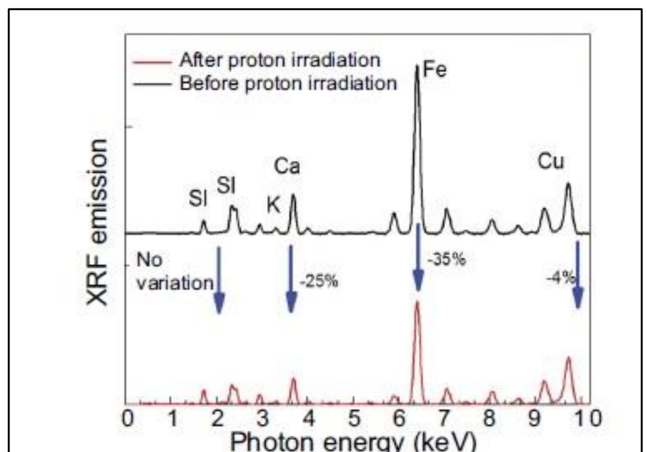




Damage analysis of a proton-irradiated CH artifact (ceramic) shows no aesthetical or chemical changes.

Ceramic from 1650 AD





M. Barberio et al., Sci. Rep. 7, 40415 (2017)

The ELIMED application

J. Pipek, F. Romano, G. Milluzzo et al.,, Journal of Instrumentation, Volume 12, March 2017

INFN LNS

Geant 4

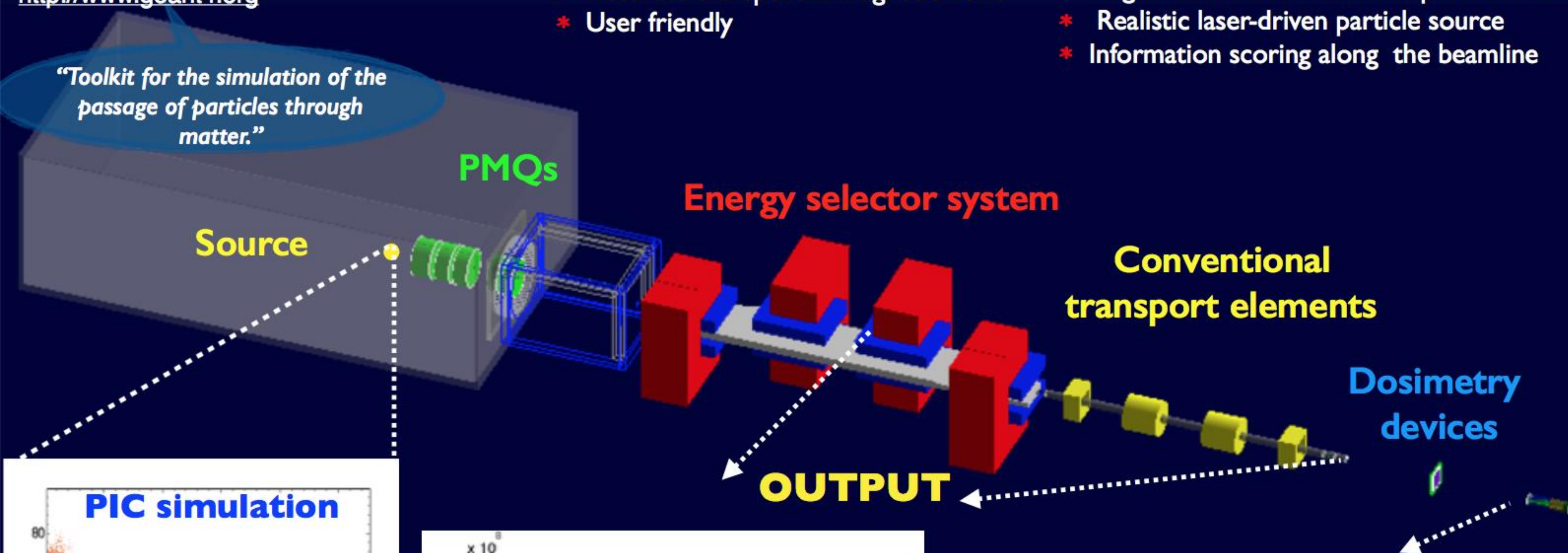
http://www.geant4.org

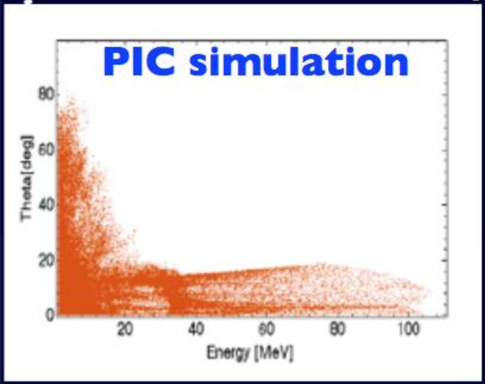
Requirements from ELI

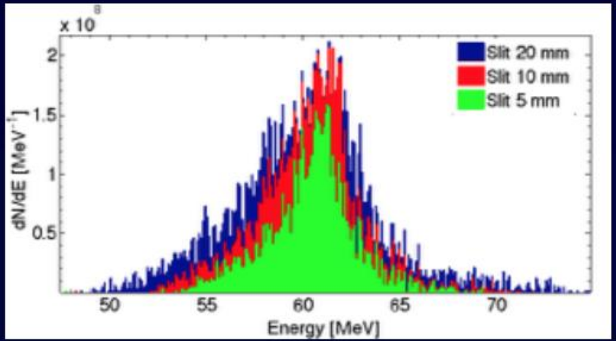
* Easily modify geometrical configurations
* Accurate transport in magnetic fields
* User friendly

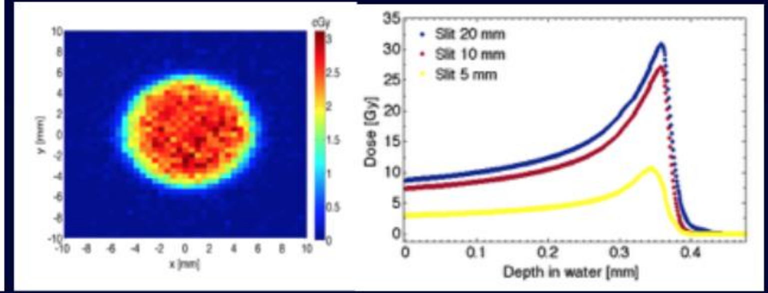
Application structure

* Component realistic model
* Magnetic and electric field implementation
* Realistic laser-driven particle source
* Information scoring along the beamline







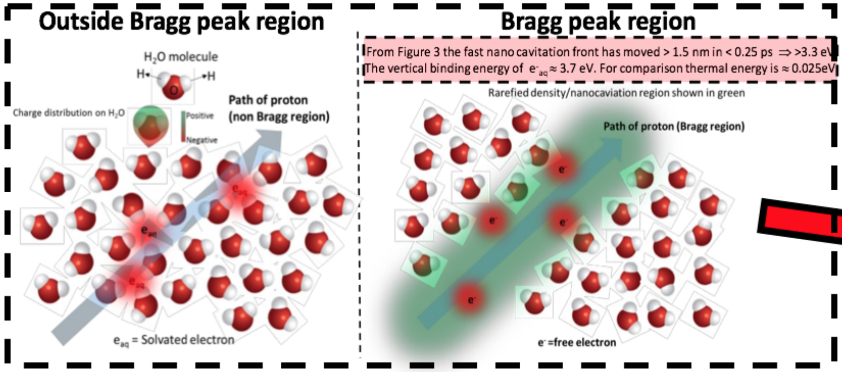


Compact laser based neutron source

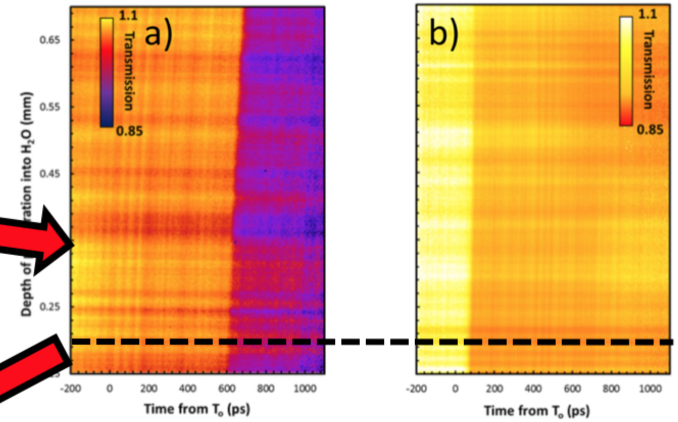
- **Complementary** to other radiation sources, like FEL, Compton, THz, already available in the project of large plasma based infrastructure
- Great interest in having at the <u>same</u> place all of these radiation sources especially for cultural heritage studies
- We are going to investigate the use of high energy electrons produced by self-injection to produce neutrons instead of protons/ions from TNSA or similar mechanism

Ultrafast pulsed proton radiolysis in water
Delayed solvation time of electron

Nanocavitation



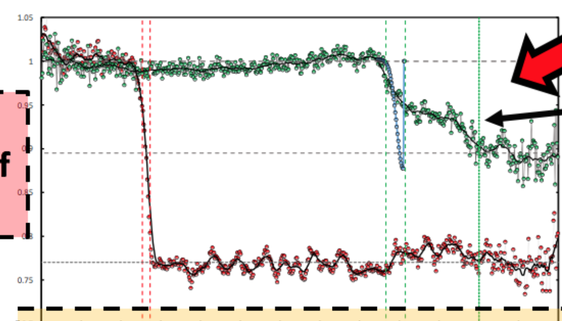
Optical steaking of both protons and electrons/x-rays



Ions

Electrons /X-rays

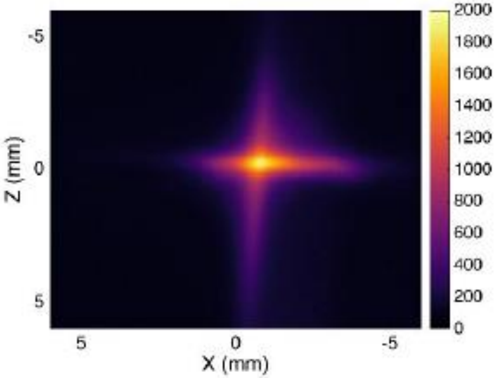
Temporal evolution of photoabsorption band of solvated electron



Very different temporal response

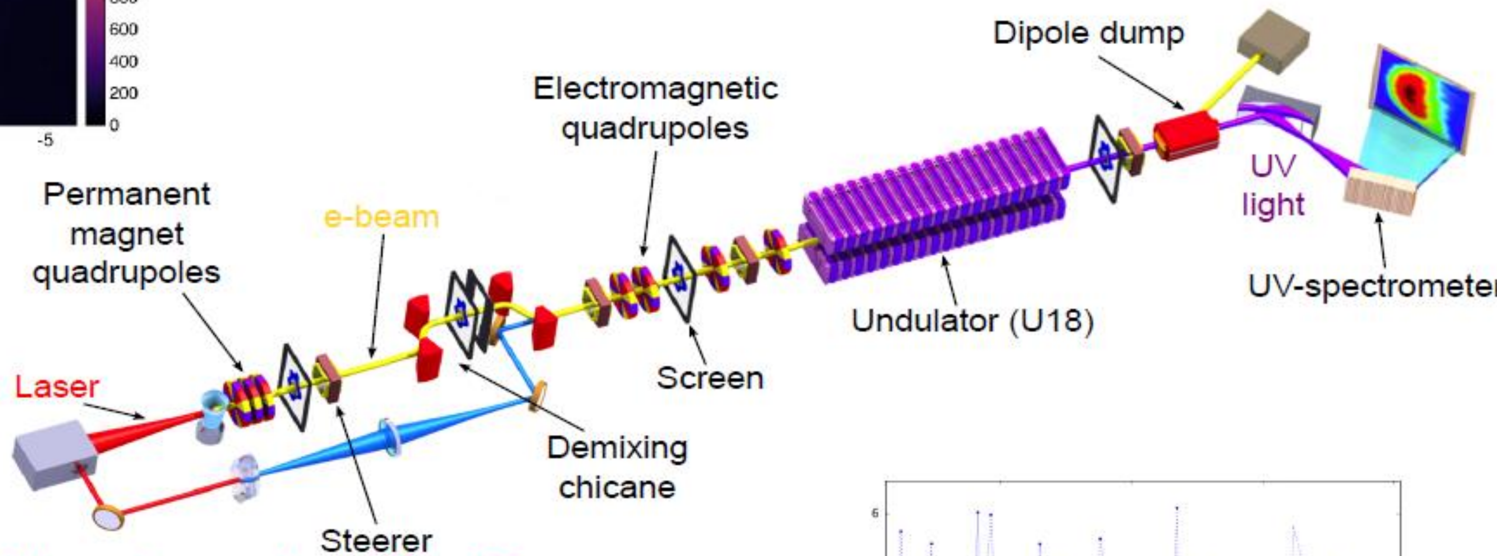
b.dromey@qub.ac.uk

3. Electron delivery and Light Sources development

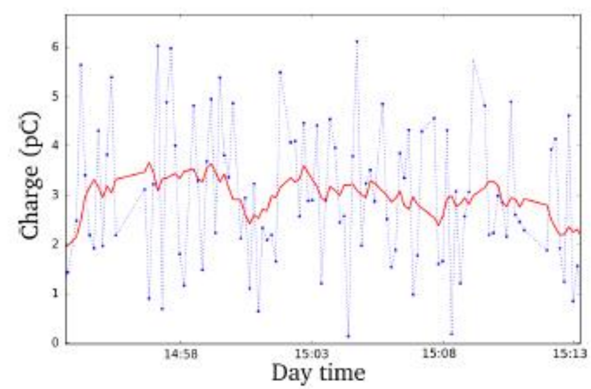


COXINEL beam line (EAAC September 27th 2017)

T. Andre

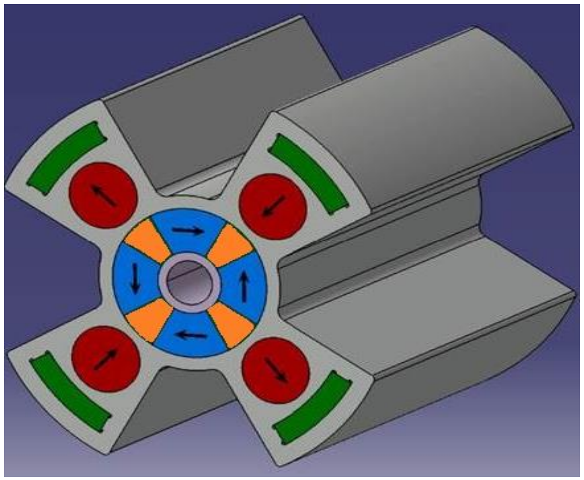


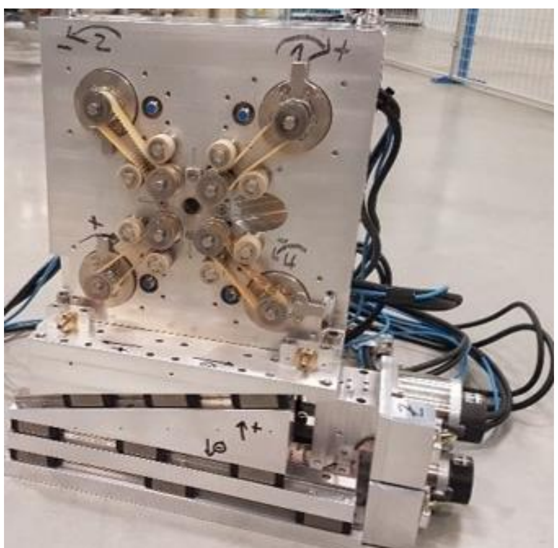
- **Total control of LPA beam transport** over 10 m (7 quadrupoles + 4 dipoles + undulator)
- Excellent agreement with the measurement numerical simulations
- Observation of the spontaneous emission of the undulator



Tunable High Gradient Quadrupoles , A. Ghaith

Concept was patented (QUAPEVA program-Triangle de la Physique, SOLEIL/Sigmaphi collaboration)

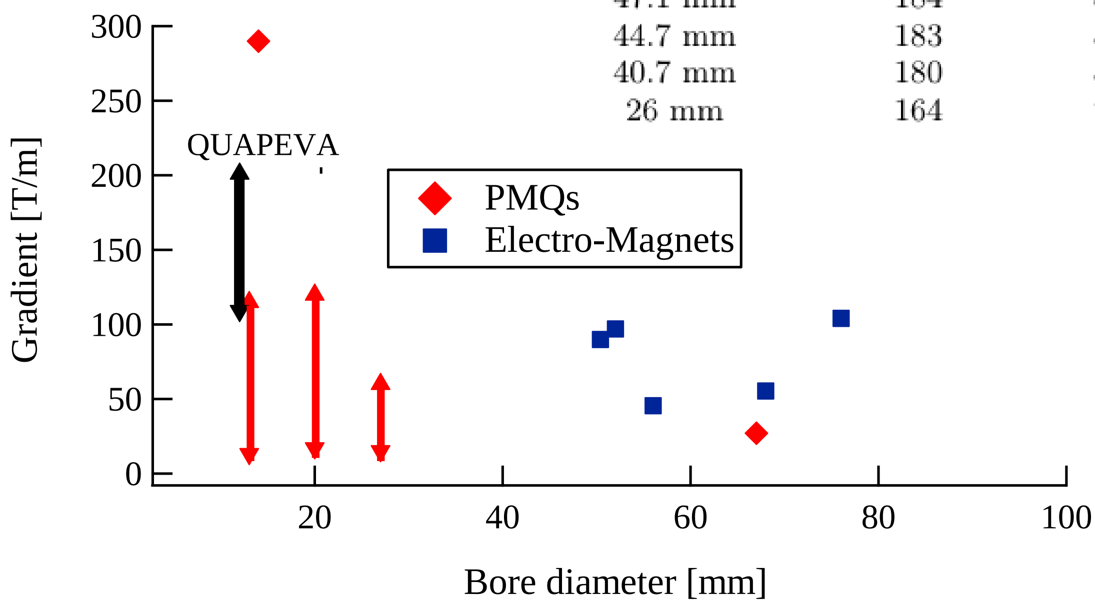




7 systems :

- First triplet to focus a 180 MeV beam
- Second triplet to focus a 400 MeV beam
- A prototype

Magnetic length	G_{max} [T/m]	ΔG [T/m]
100 mm	201	92
81.1 mm	195	89
61 mm	190	88
47.1 mm	184	86
44.7 mm	183	86
40.7 mm	180	85
26 mm	164	78

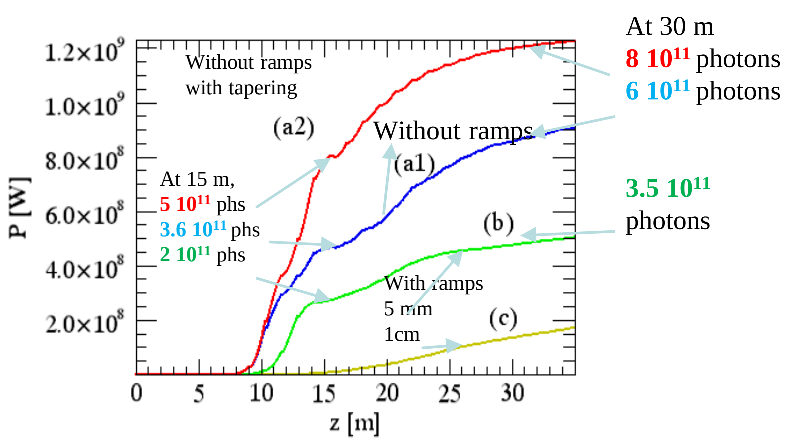


Magnetic center excursion in both planes (x, z) is about ± 10 µm

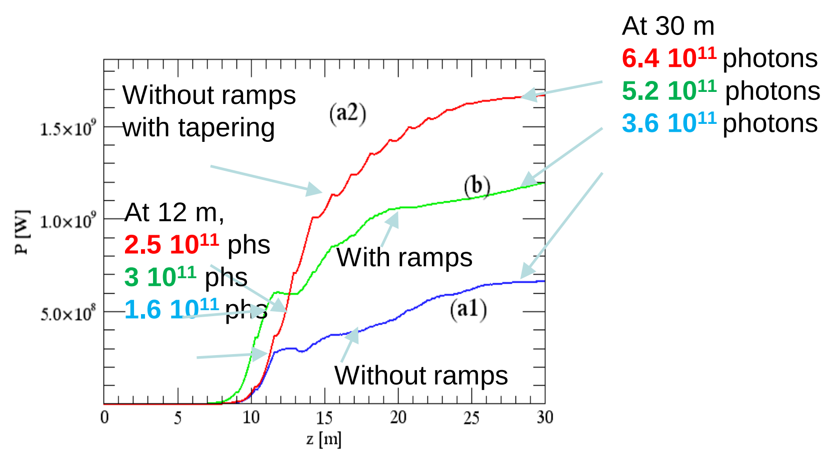
BD studies in the X-band Linac of EuPraxia@SPARC_LAB

C. Vaccarezza

- Three WP's under study:
- **WP1**: Low Charge-High Current **30 pC-3KA** (FWHM) per bunch from Photoinjector with only velocity bunching, suitable both for Beam Driven and Laser driven acceleration in Plasma
- **WP2**: Low Charge-Low Current **30 pC-100A** per bunch from Photoinjector with velocity bunching coupled with a magnetic compression (**R_{56}=9 mm**), in the chicane to reach I = 3kA (Hybrid scheme), suitable both for Beam Driven and Laser driven acceleration in Plasma
- **WP3**: High charge-Very Low Currrent **200 pC-70 A** per bunch from Photoinjector with velocity bunching coupled with a magnetic compression (**R_{56}=16 mm**) in the chicane to serve the SASE-FEL, with peak current Ipk=2kA, and the Compton Source in the high flux operation scheme.



FEL Genesis simulation with **particle driven plasma accelerated electron beams (WP1)**

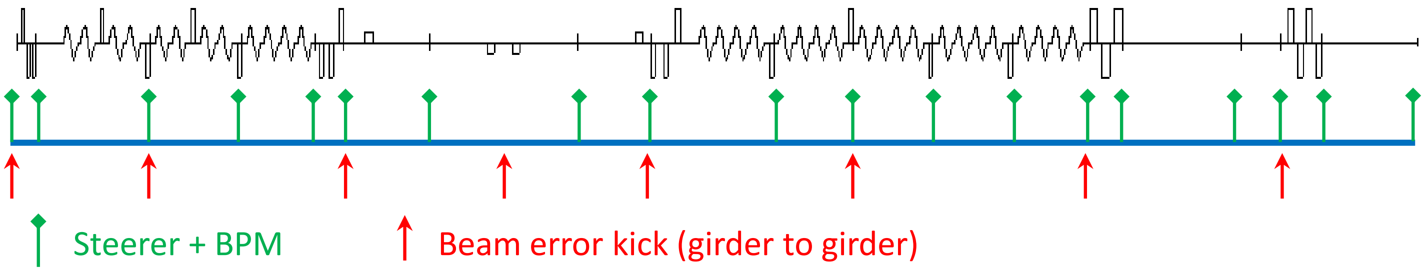


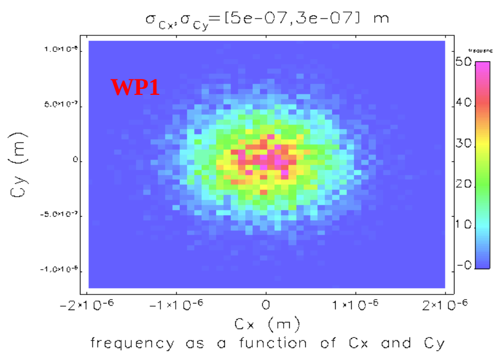
FEL Genesis simulation with **laser driven plasma accelerated electron beams (WP1)**

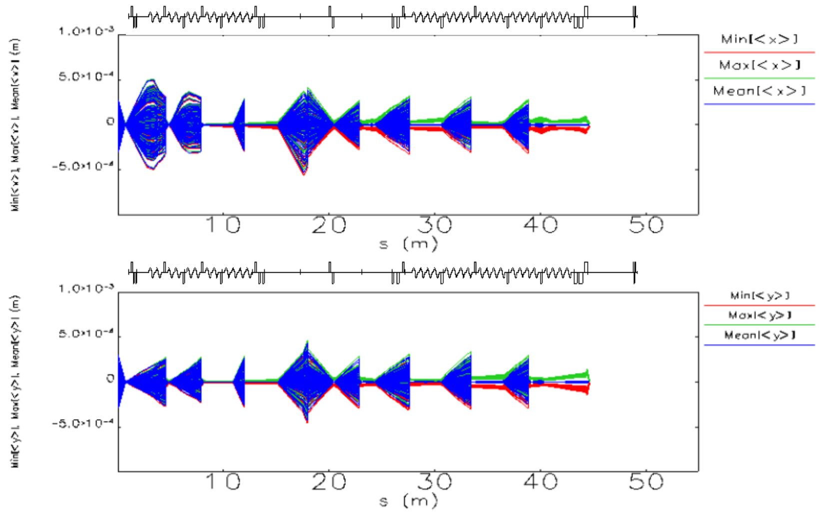
SPARC LAB

Static and dynamic error studies in the X-band Linac of EuPraxia@SPARC_LAB : misalignements & quad/steerers jitters

C. Vaccarezza







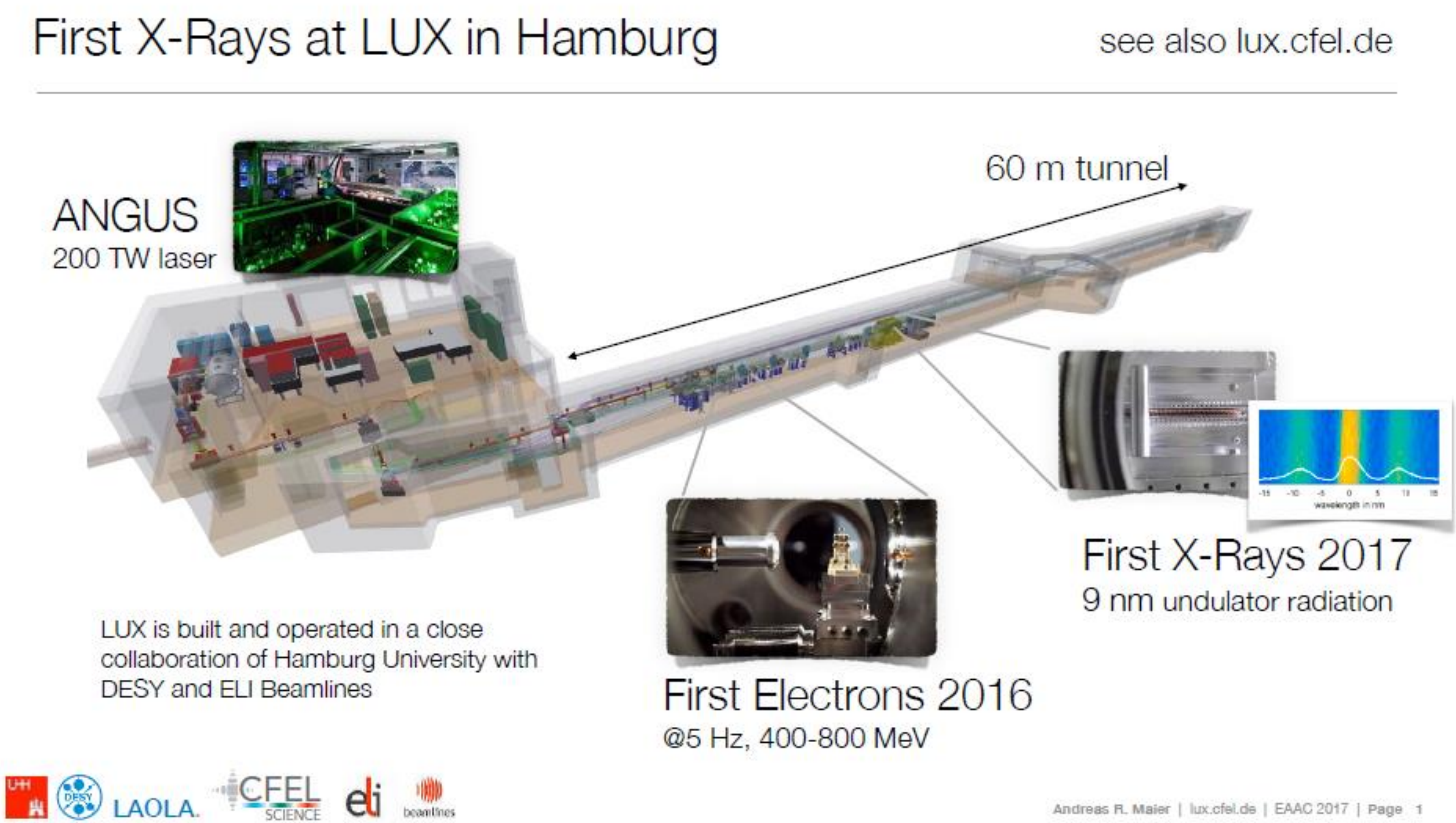
WP1 results: Centroid distribution at the capillary entrance (above) and trajectory envelope (right) for 70μm misalignment on RF and magnetic elements, 150 μm girder to girder, and 0.1% jitter on quadrupole strength and steerer kick after trajectory correction.

Next steps:

- RF phase and amplitude jitters
- Photocathode laser energy and pointing jitters.

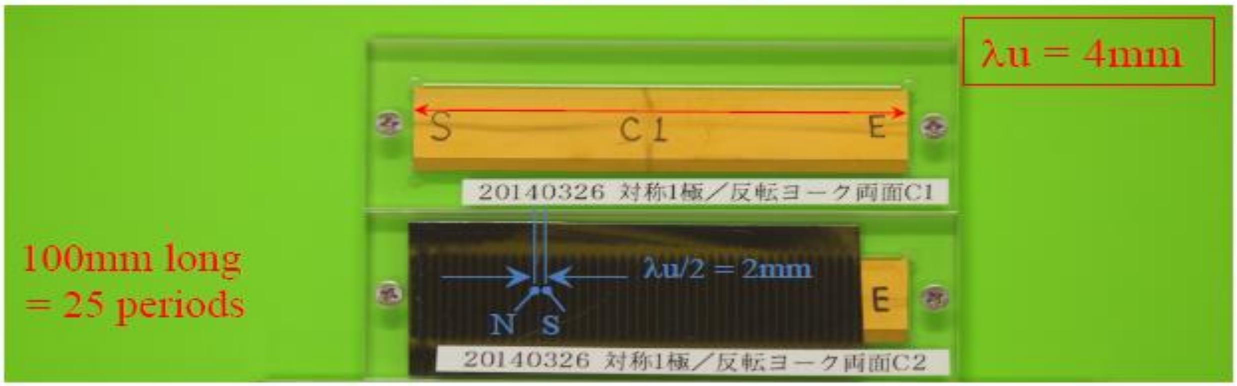
Commissioning Results From The LUX Beamline For Plasma-Driven Undulator Radiation. A. MAIER

Undulator Upgrade for the LUX Beamline. C. WERLE



Summary of
Development of a Novel Undulator with a Very Short Period Length
@ 3rd EAAC WS WG4 (Sept./27/2017): Shigeru Yamamoto, KEK-PF

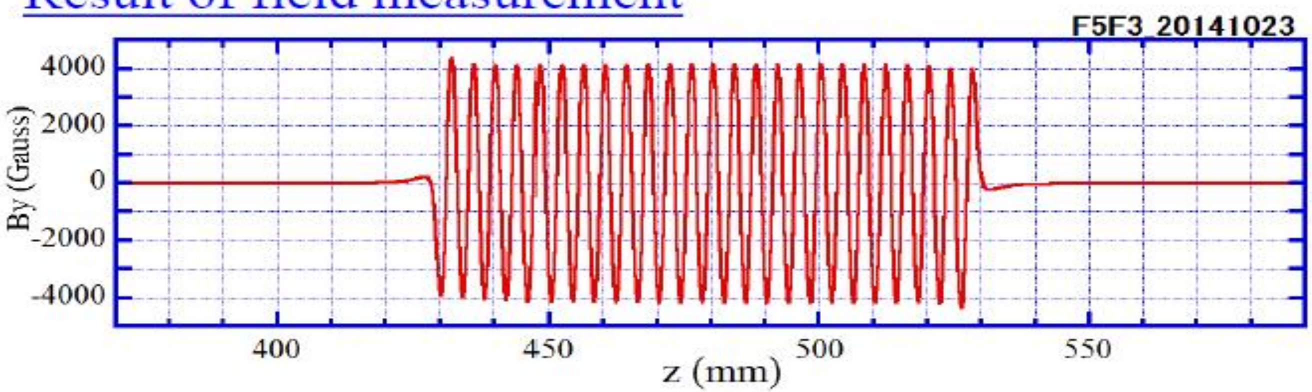
Plate type undulator magnets with a very-short-period undulator field



NMX-39EH TiN coated
20mm wide, 2mm thick

Field pattern seen through a magnetic viewer sheet

Result of field measurement



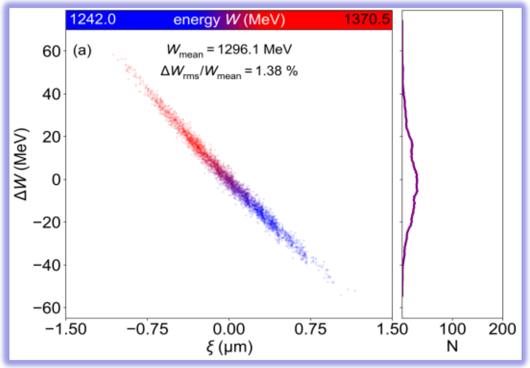
Ultrahigh 6D brightness electron beams from a single plasma acceleration stage

A. Fahim Habib et. al

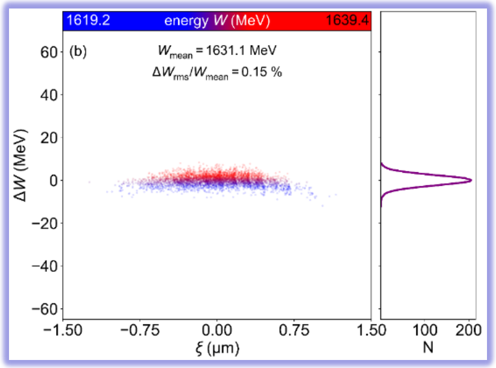
Nat. Commun. 8, 15705 doi: 10.1038/ncomms15705 (2017)

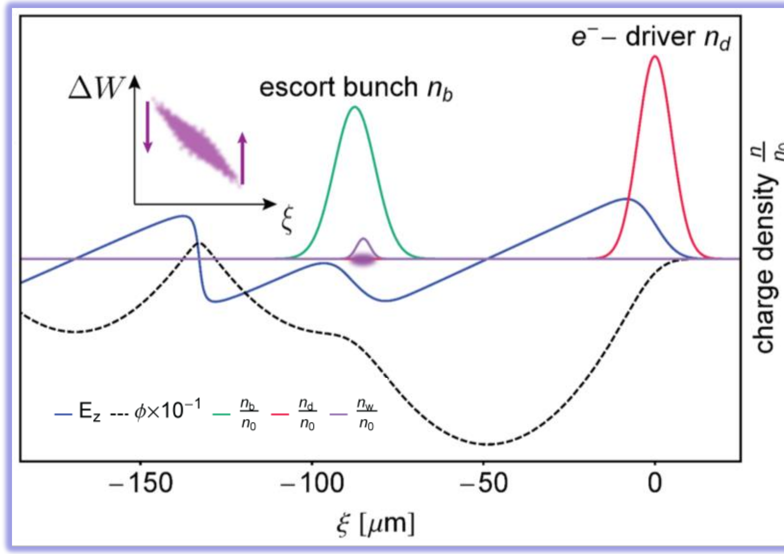
SCAPA
University of Strathclyde Glasgow

Before escort release

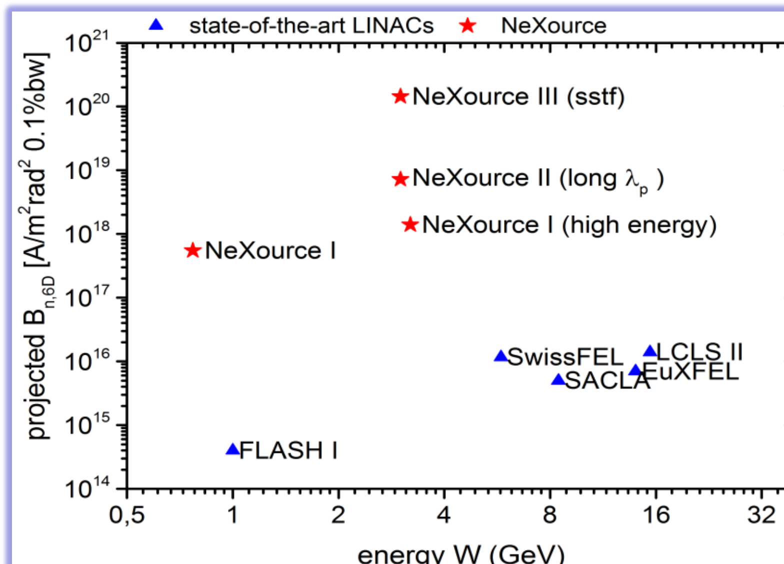


After dechirping





- A tuneable and flexible scheme for minimization of energy chirp in a single plasma acceleration stage
- Utilizing tailored beam loading by a second high charge bunch
- Relative energy spread is minimized by one order of magnitude
- Ultrahigh 5D brightness + minimized energy spread leads to unprecedented ultrahigh 6D brightness
  $\boldsymbol{B_{6D} \approx 5.5 \times 10^{17}\,\mathrm{A/m^2\ rad^2/0.1\%BW}}$
- Energy spread scaling law predicts $\Delta W_{rms}/W <$ 0.01 % for longer plasma wavelength
- Potentially game-changing for applications, e.g. ICS, XFEL and HEP



Transverse electron beam dynamics in a nanocoloumb-class laser wakefield accelerator. A. Koehler