EUROPEAN UNION

Structural Instruments 2014-2020

Project co-financed by the European Regional Development Fund through the Competitiveness Operational Programme "Investing in Sustainable Development"

eli nuclear physics

Extreme Light Infrastructure-Nuclear Physics (ELI-NP) - Phase II

IFIN-HH

First results from 10 PW electron acceleration experiments at ELI-NP

Petru Ghenuche on behalf of the ELI-NP team and collaborators

ELI-NP, Bucharest - Magurele, Romania

petru.ghenuche@eli-np.ro

EAAC2025 7th European Advanced Accelerator Conference

Collaborators

V. Lelasseux, V. Phung, I. Dăncuş, F. D'Souza, M. Gugiu, A. Lazăr, C. A. Ur, D. Ursescu, L. Văsescu, V. Horny, P. Tomassini, D. Doria, V. Malka, P. Ghenuche

Y. Shou, S. Krishnamurthy, I. Kargapolov, E. Kroupp, A.-M. Talposi, S. Tata, V. Malka

A. Matheron, I. A. Andriyash, J. Gautier, A. Leblanc, S. Corde

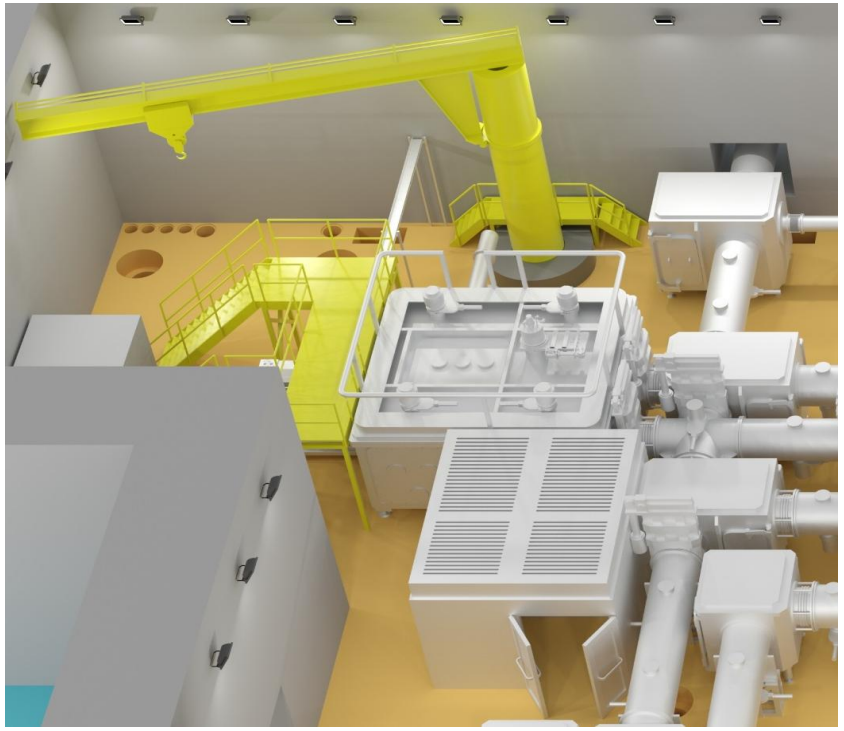
J.-R. Marquès, Y. Ayoul, A. Beluze, M. Dumergue, M. Frotin, F. Gobert, L. Lancia, M. Lo, D. Mataja, F. Mathieu, D. Papadopoulos

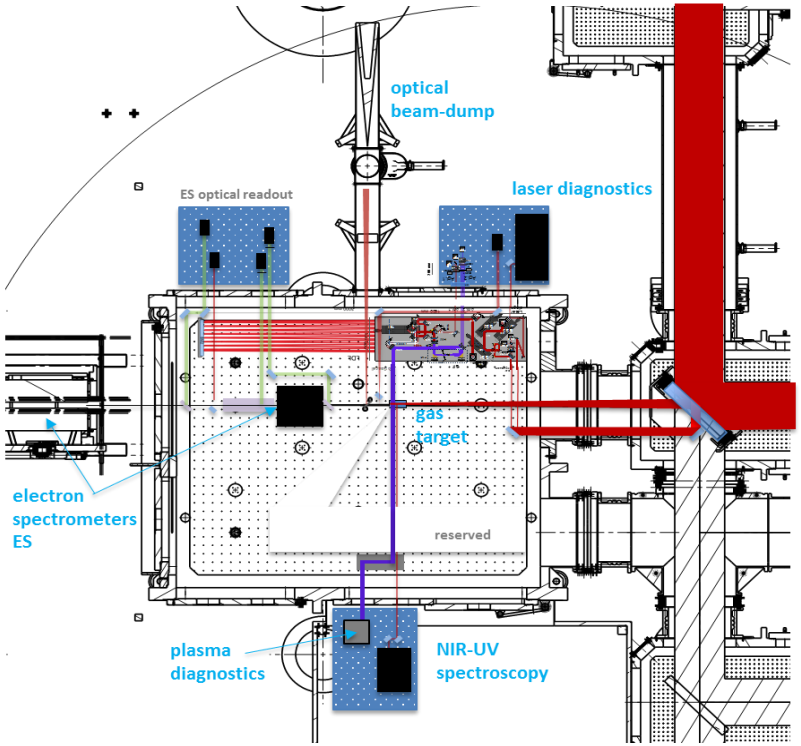
F. Dorchies, K. Ta Phuoc

G. Sarri

A. Saftoiu, M. Dobre,C. Vancea, A. Balaceanu

E6 Commissioning goals and long-term goals:





Single 10PW Laser Beam Experiments:

- ❑ **Stable multi-GeV electron acceleration at multi-PW**
- ❑ **Compton Scattering/Betatron**
- ❑ **Generation of muon/anti-muon beams**

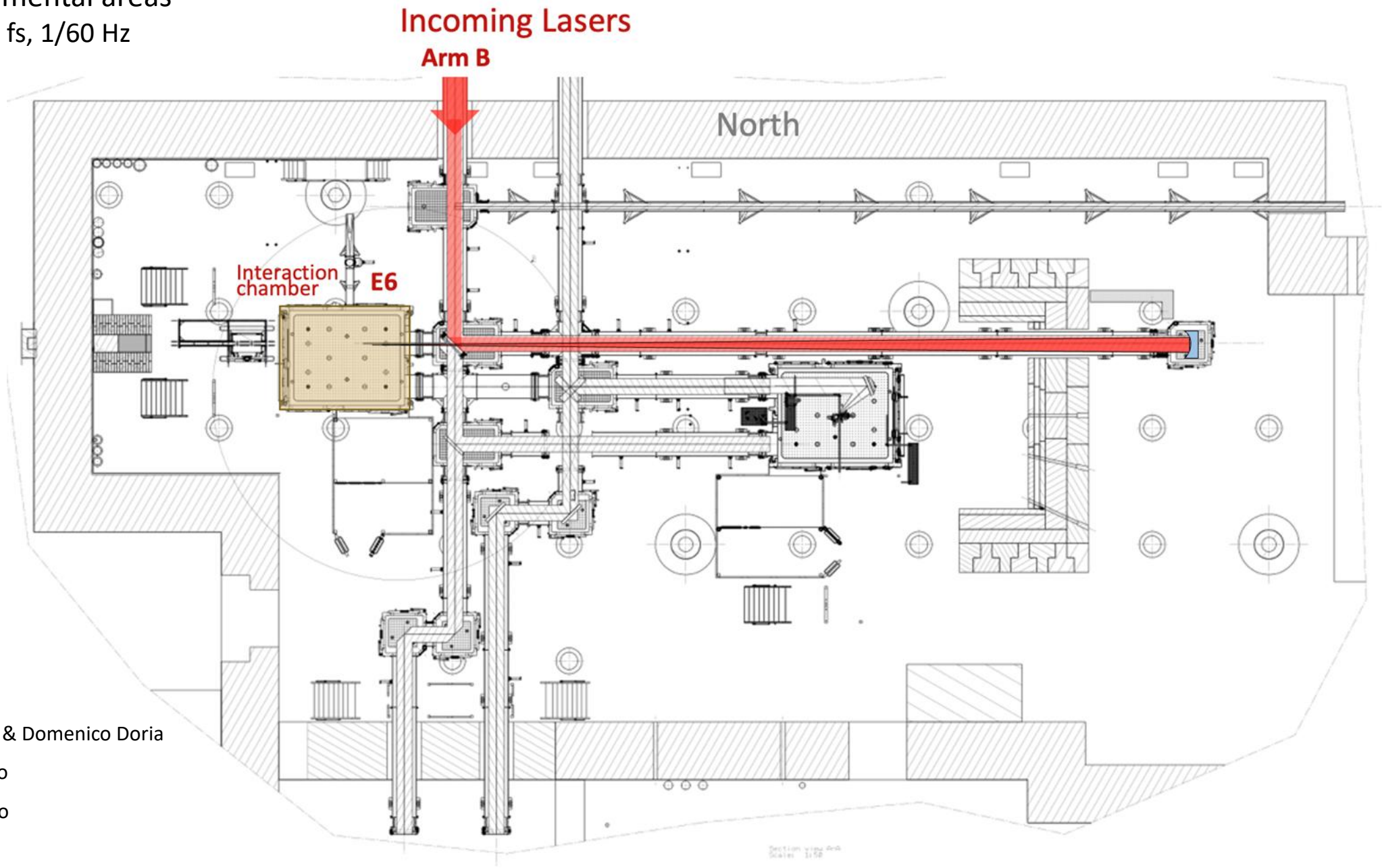
Dual 10PW laser Beams Experiments:

- ❑ **Collision of multi-GeV electron beam with $I>10^{22}$ W/cm^2 laser**
- ❑ **QED effects: RR, BW pairs, Inverse non-linear Thomson/Compton scattering**

The 10 PW experimental areas

E1 & E6: 10 PW experimental areas

HPLS: 2 arms of 240 J, 23 fs, 1/60 Hz



LDED department

Head of LDED: Domenico Doria

Contact Person: Petru Ghenuche & Domenico Doria

E-mail: domenico.doria@eli-np.ro

E-mail: petru.ghenuche@eli-np.ro

Laser specs for the 10 PW laser-driven electron acceleration

Spherical mirror: 30 m focal length (F# ~50)

Spot size diameter: ~ 60.0 ± 2 µm at FWHM

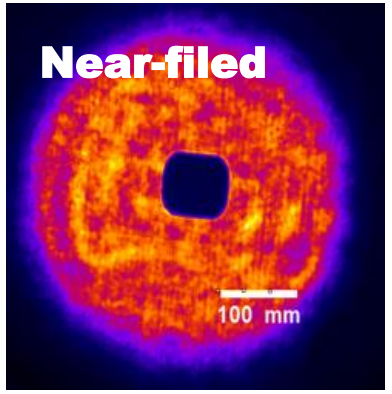
Laser max. energy: 185±1 J on target (Nominal 8PW)

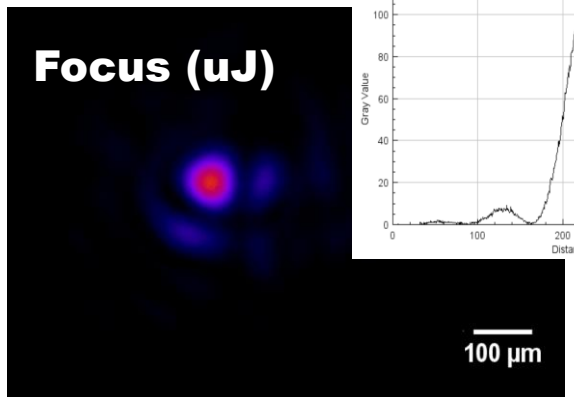
Encircled energy: ~ 40% @ $1/e^2$ (ideal Gaussian beam 86%)

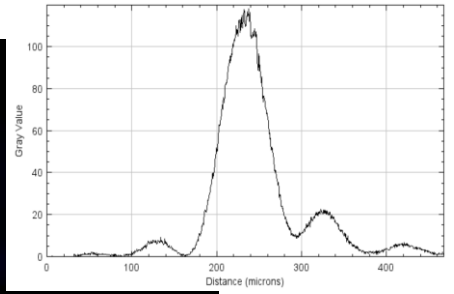
Pulse duration : 23±1 fs on target

Laser energy stability at full power: ±2%

Laser pointing stability on target: < 1 µrad

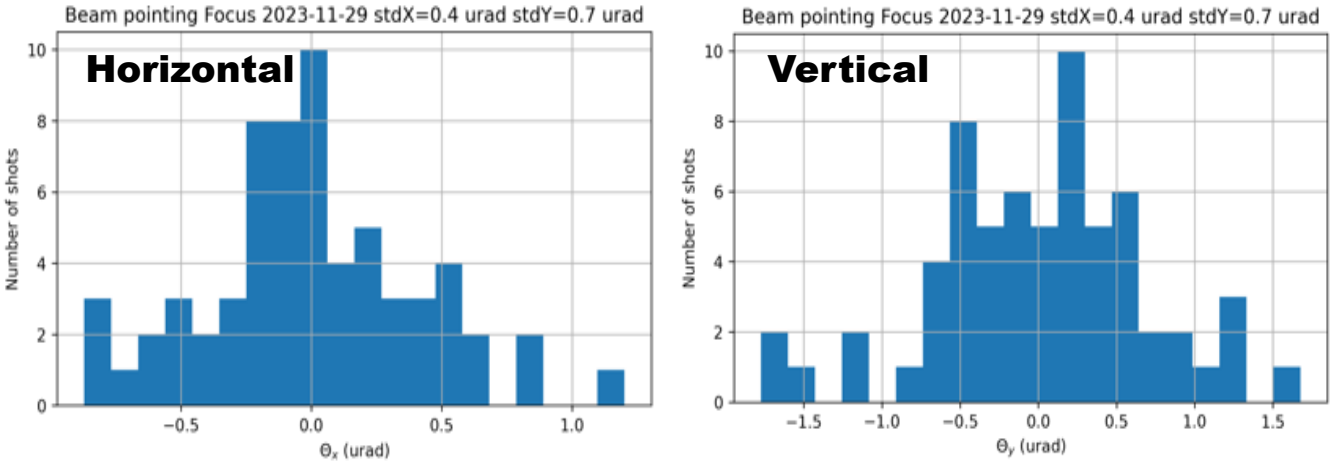




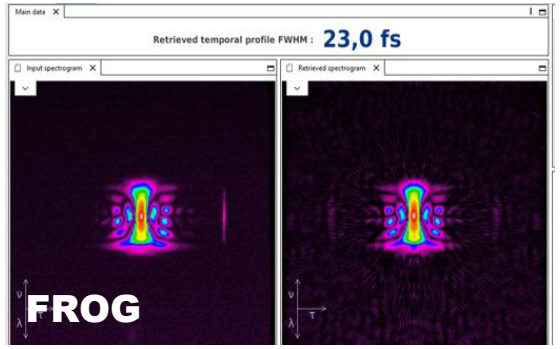


60um FWHM

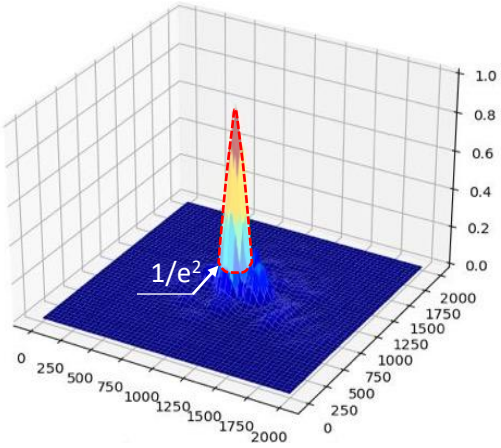
Laser pointing



Pulse duration measurement on shot



Estimated encircled energy ~40%



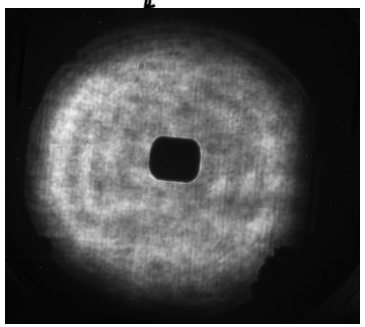
Approx 1 urad FWHM focus pointing (0.5 - 1 focal spot)

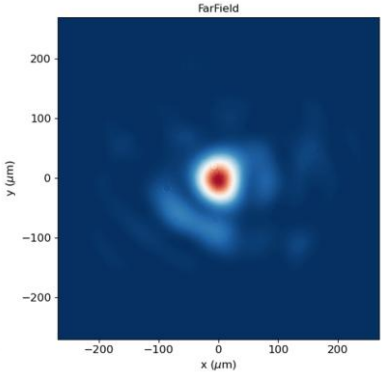
M. Talposi, V. Lelasseux, V. Nastasa, T. Asavei, D. Popescu, P. Ghenuche

High-fidelity q-3D PIC simulations with reconstructed pulses

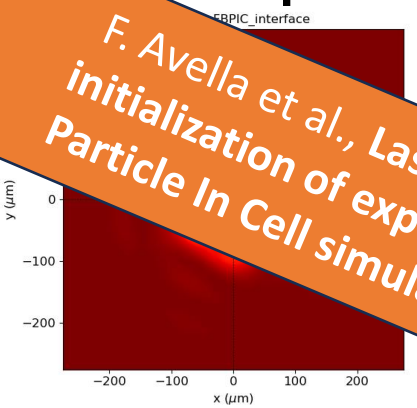
Theory @ LDED

Simulations with FB-PIC and LP4PIC package (Tomassini/Avella)





LP4PIC

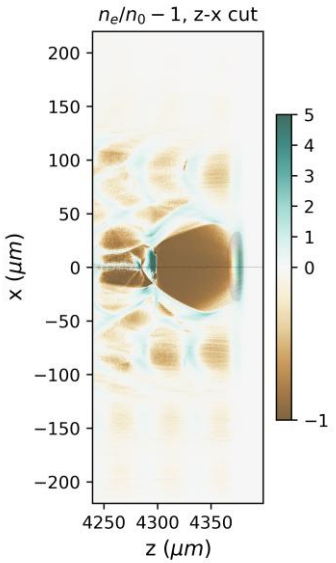


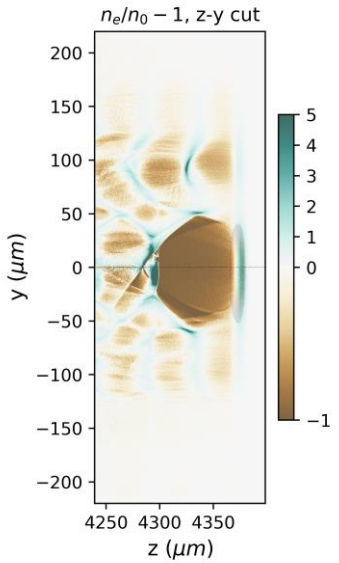
F. Avella et al., **Laser fields reconstructor for initialization of experimental laser profiles in Particle In Cell simulations**, Wed. 24th 7-9 PM

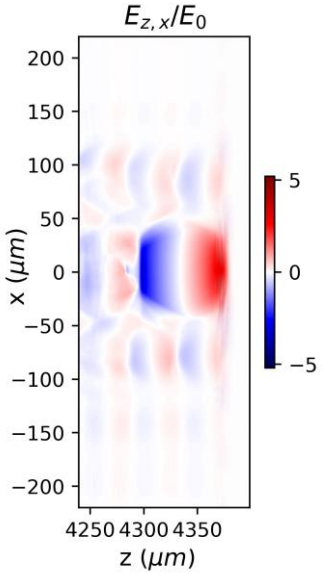
Federico Avella
Ph. D. student@CNR-INO
LA.Gizzi/P. Tomassini

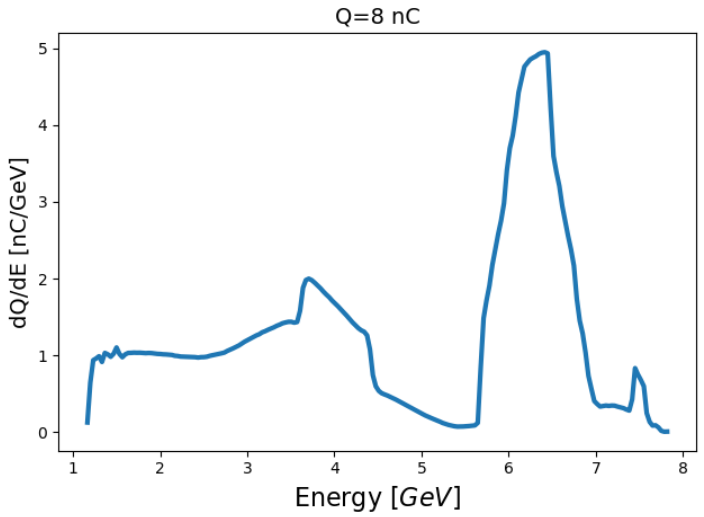
Exp. Near Field | **Exp. Far Field** | **Reconstructed**

FBPIC simulation (**Nm=5**), **reconstructed laser pulse**, ne=5e17/cm3, 8 cm long plasma, 10PW [run on ELI-N… ster]





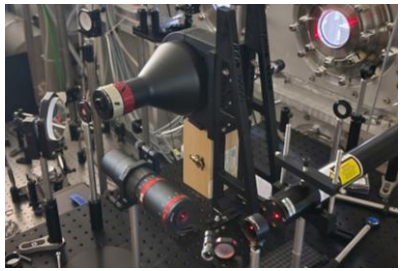


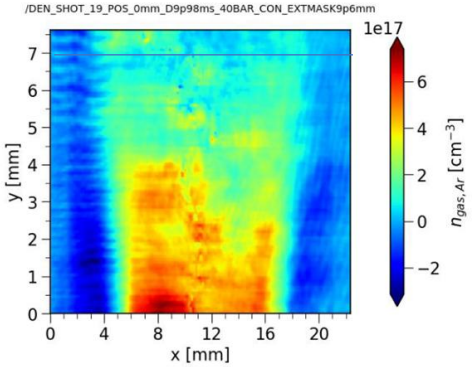


Slide by P. Tomassini/ELI-NP/LDED. LP4PIC is under testing and it is developed on collaboration with CNR-INO/La.Gizzi

10 PW multi-GeV electron acceleration: Target and Interaction

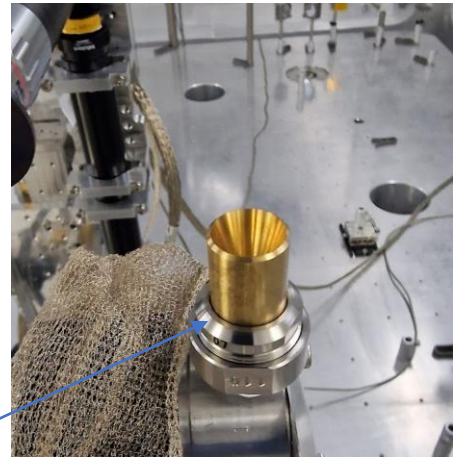
- Gas jet target
- 15 to 60 mm
- Up to 50bar backing pressure
- He with 2% N2

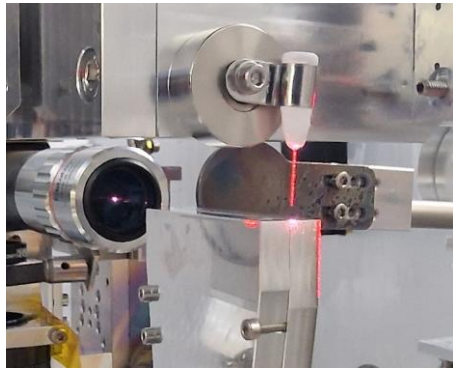




V. Phung, G. Ciubega, P. Ghenuche

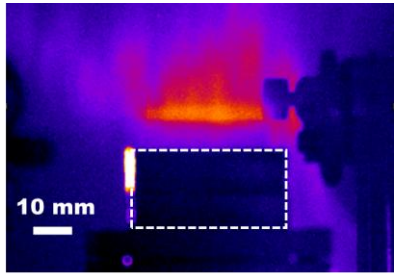
Targets

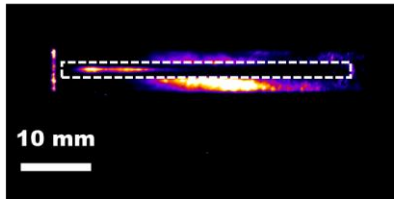




E. Kroupp, V. Malka, V. Phung, M. Gugiu, A. Mohanty, G.Sarri, M.Risca

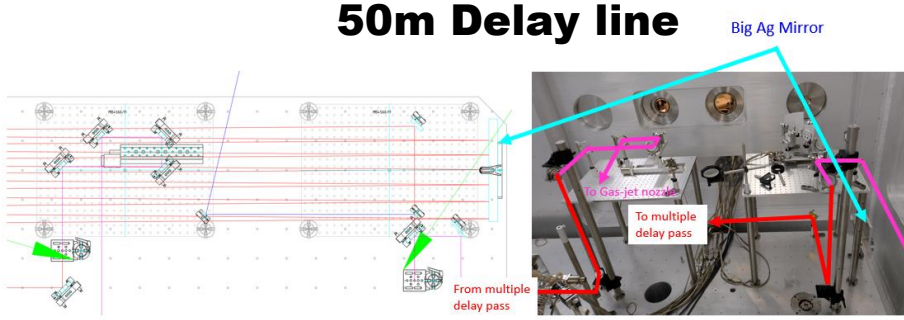
Side and top view at high power





V. Lelasseux, M. Talposi

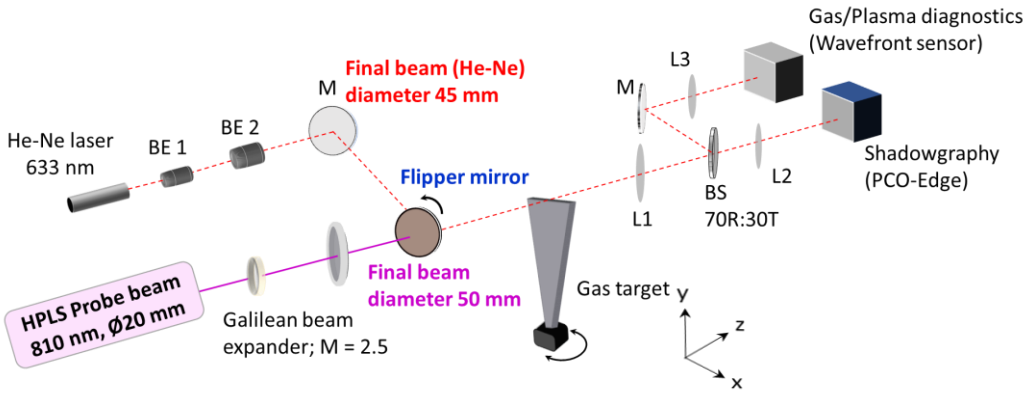
50m Delay line



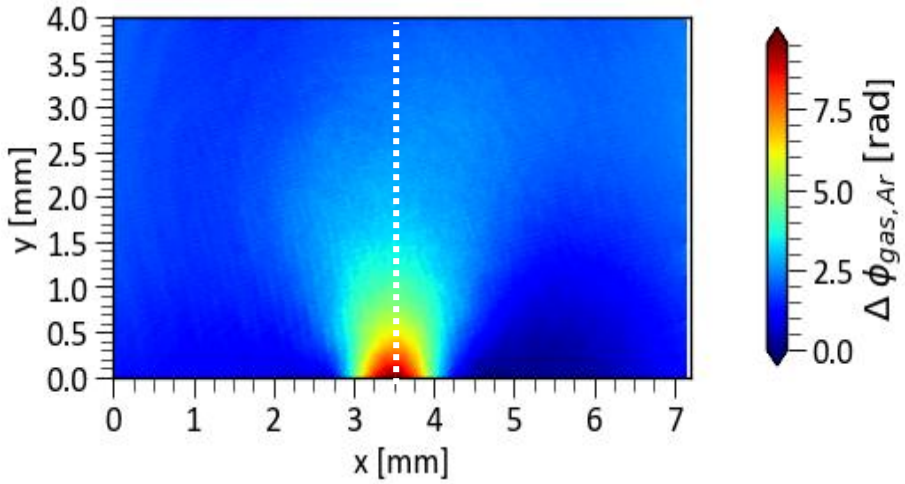
Y. Nakamiya, I. Slabu, V. Manjakotya, F. D'Souza, A. Mohanty, V. Phung, L.Neagu

Gas target (slit 60 mm x 1 mm) characterisation

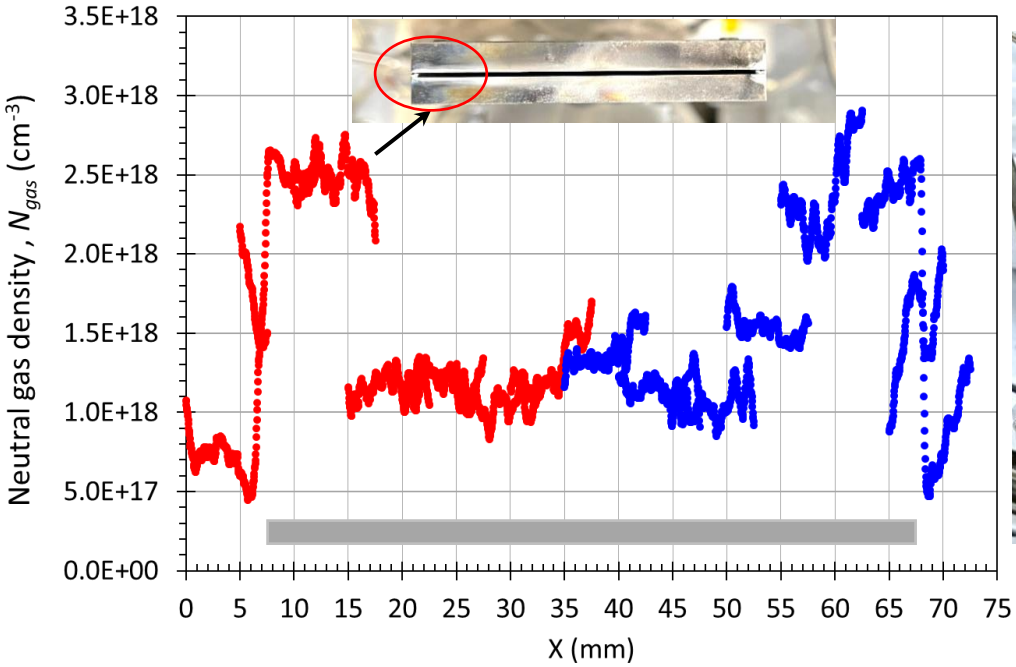
V. Phung

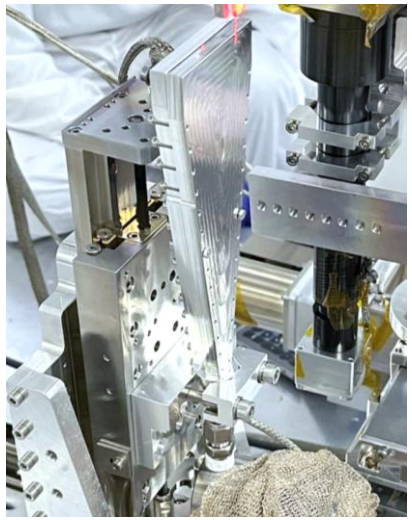


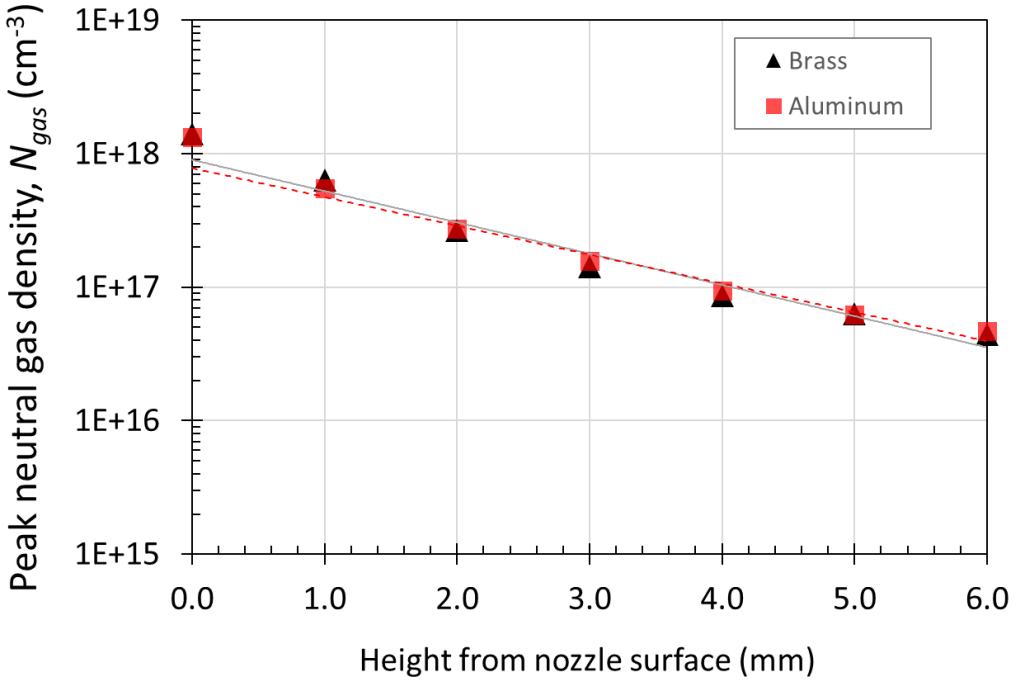
Transverse gas phase shift at various height from nozzle surface



Gas density profile at height 0 mm from nozzle surface





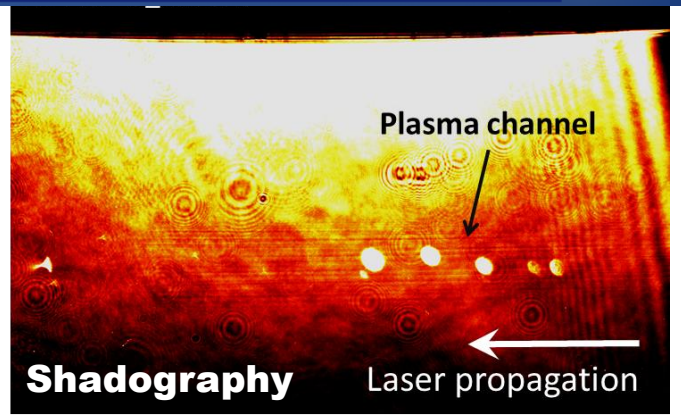


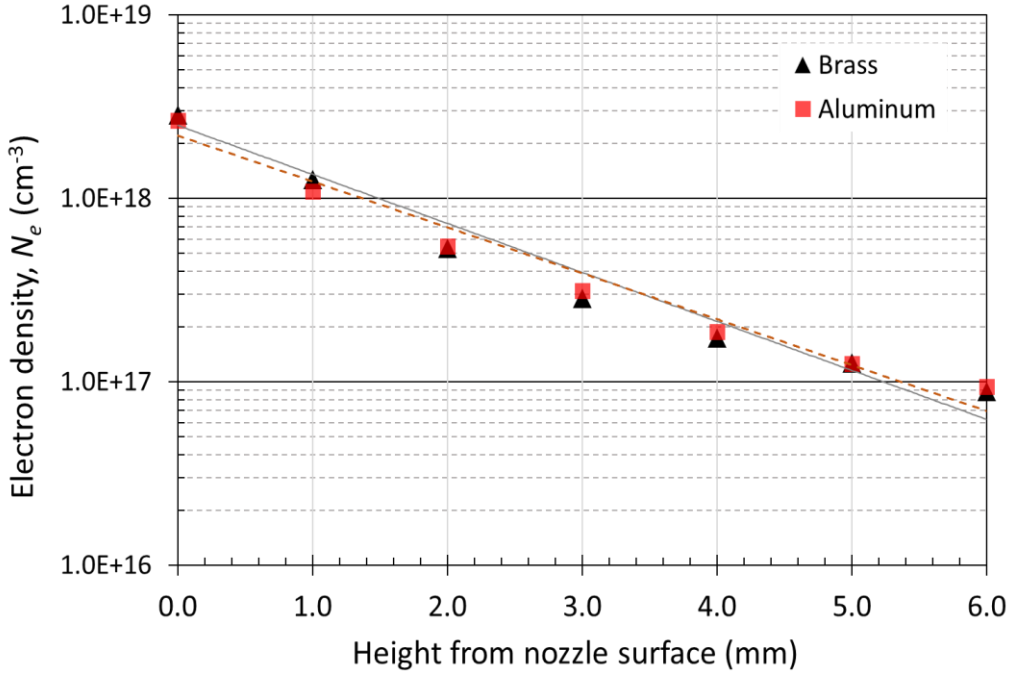
Measured electron density ~ to neutral gas density after ionisation.

Y. Nakamiya

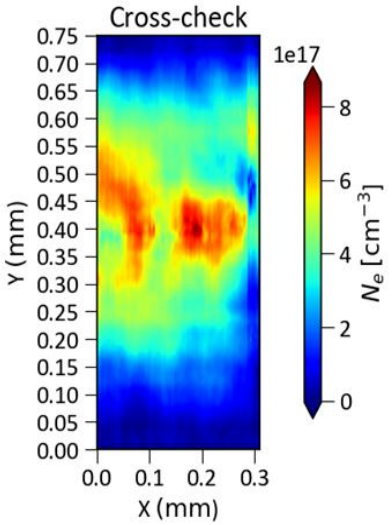
I. Slabu

E_{laser} = 180 J at 6 mm from nozzle surface

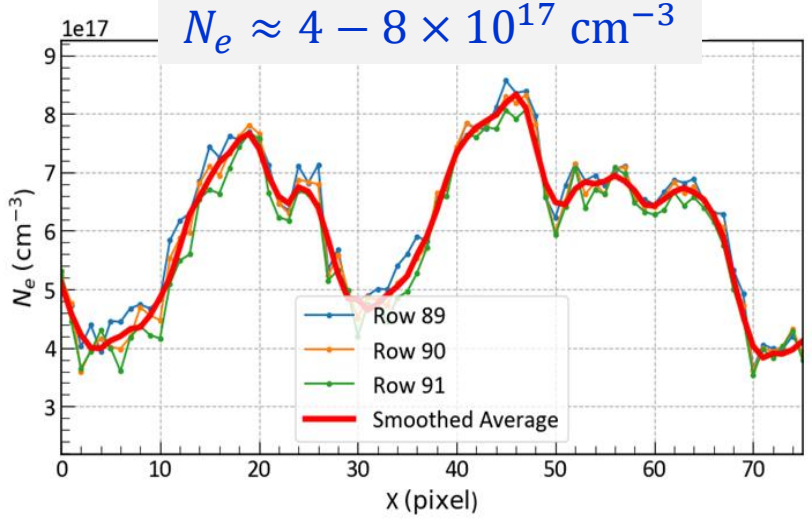




Electron density at front edge of the nozzle

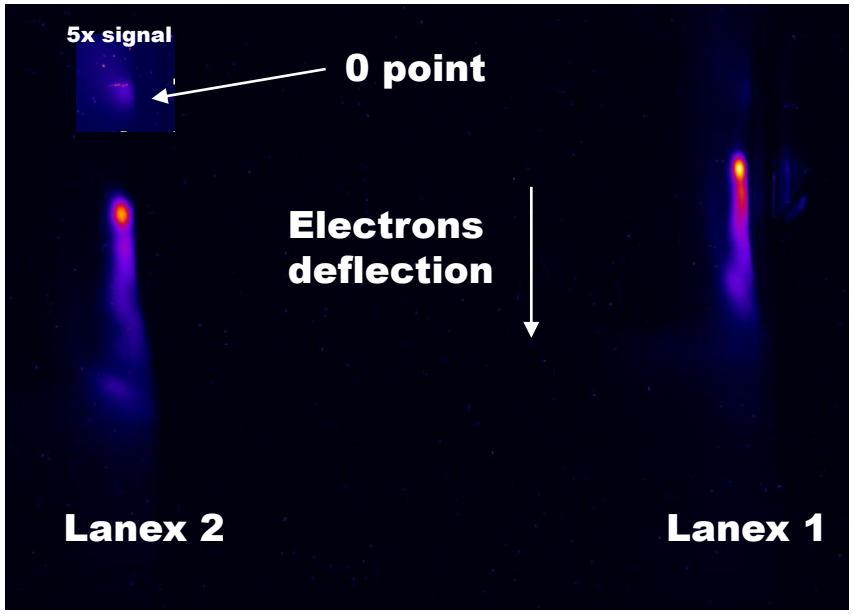


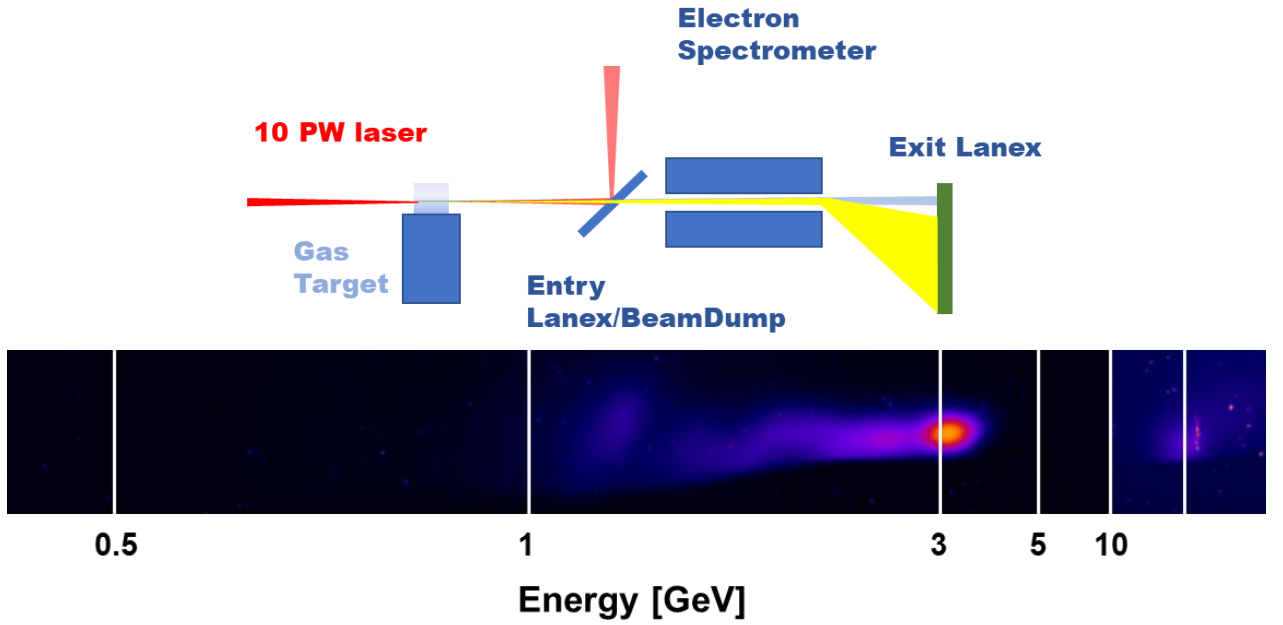
$N_e \approx 4 - 8 \times 10^{17}$ cm^{-3}

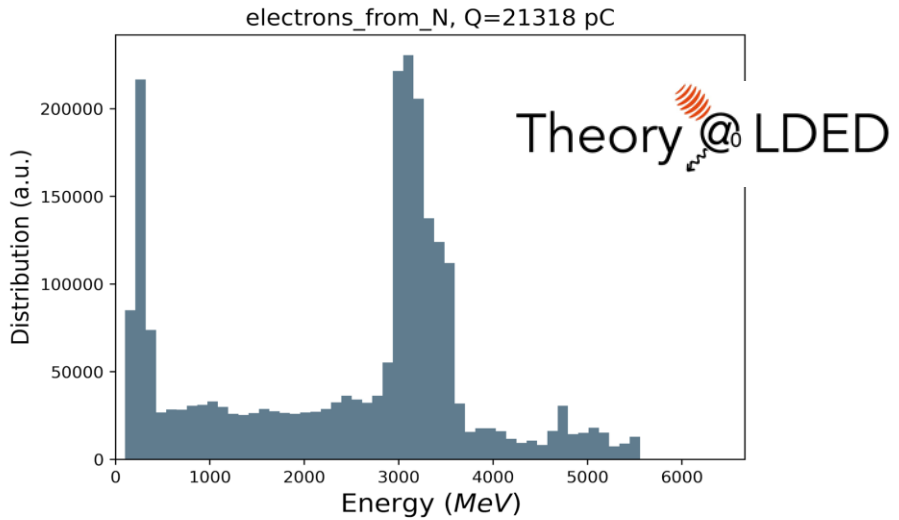


First Multi-GeV beams at E6

800mm Electron Spectrometer





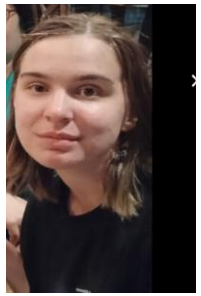


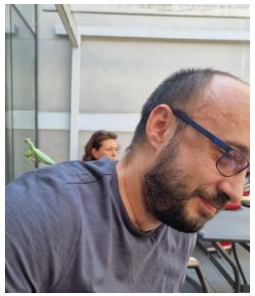
Theory @ LDED

- ❑ Good Charge and Divergence (mrad/nC)
- ❑ Multi-GeV at nominal 4-8PW
- ❑ Good agreement with PIC simulations (P. Tomassini) and scaling laws (V. Phung)

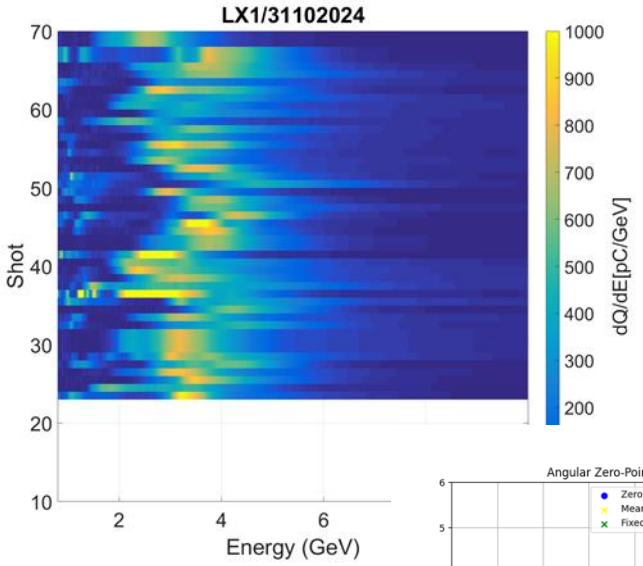
F. D'Souza, B. Diaconescu, S. Balascuta, P. Tomassini, V. Phung, C.Ticos, D. Ghita, S. Ter-Avetisyan

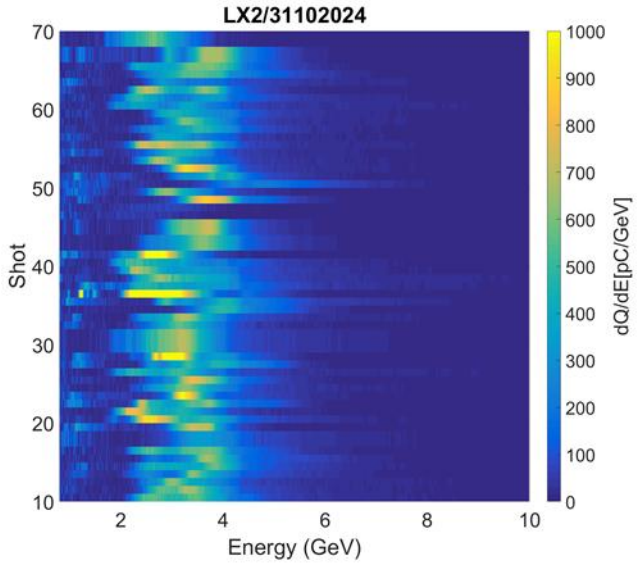
First Multi-GeV beams at E6

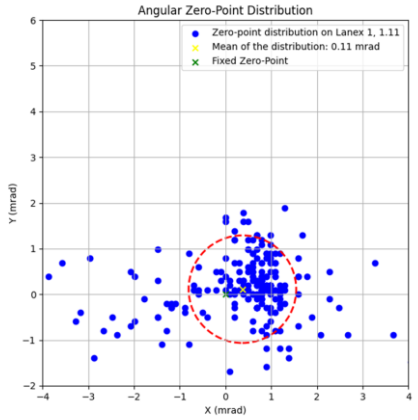




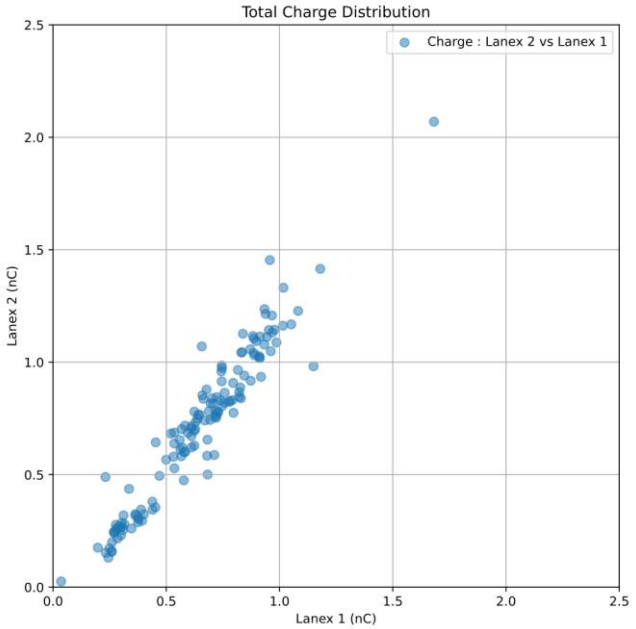
D. Catana **V. Lelasseux** **D. Doria**

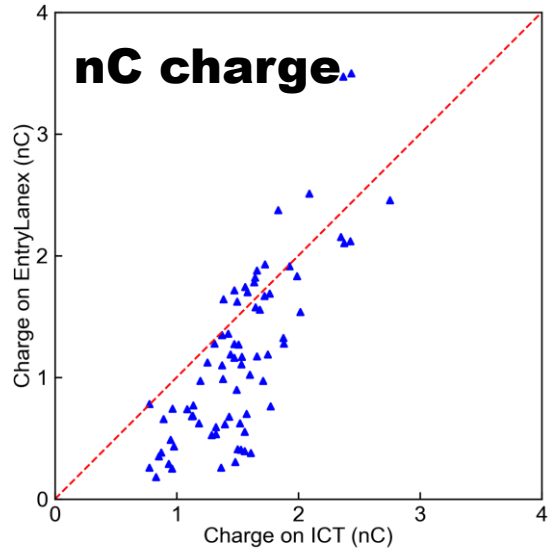






mrad pointing and divergence



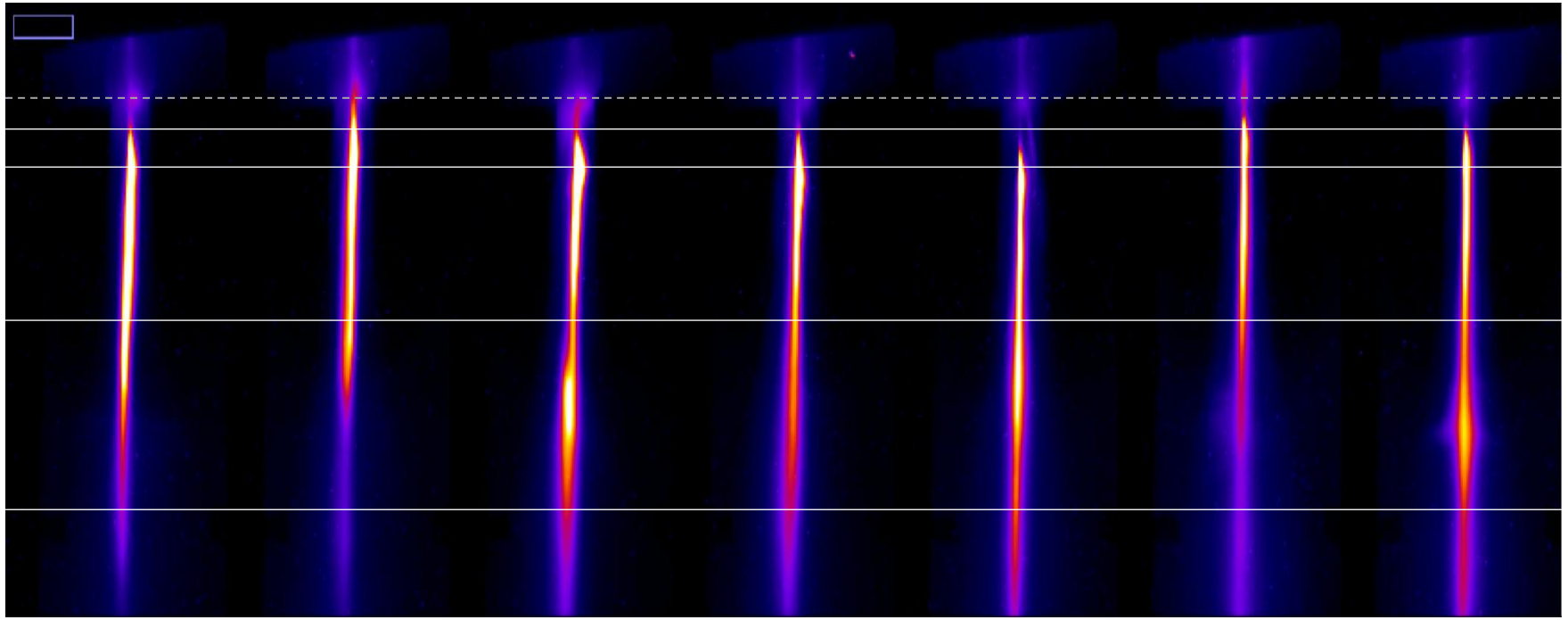


V. Phung, Y. Shou

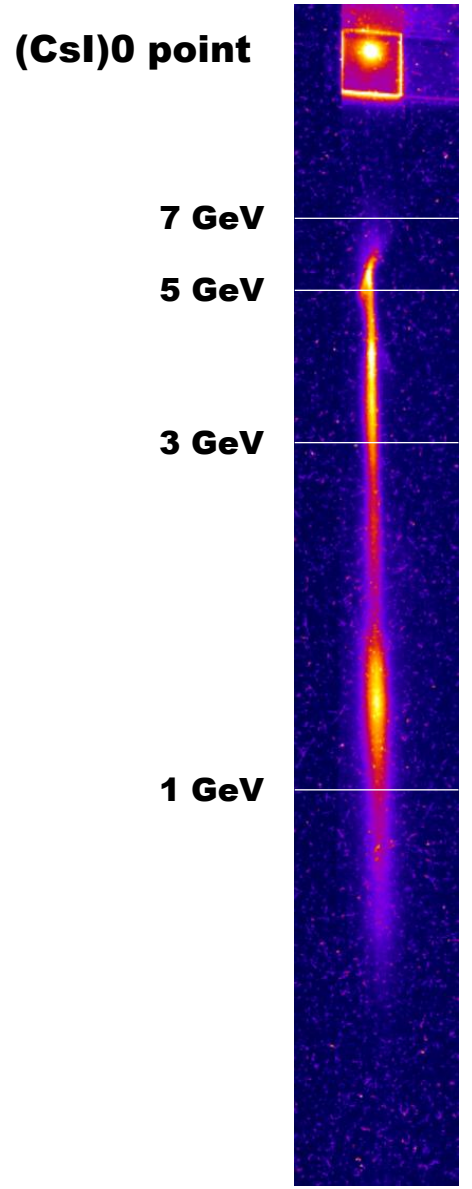
Multi-GeV e-beams at E6

- Series of high power shots @ 8 PW nominal
- 60 mm target, electron density 5E17 cm-3

1th exit Lanex



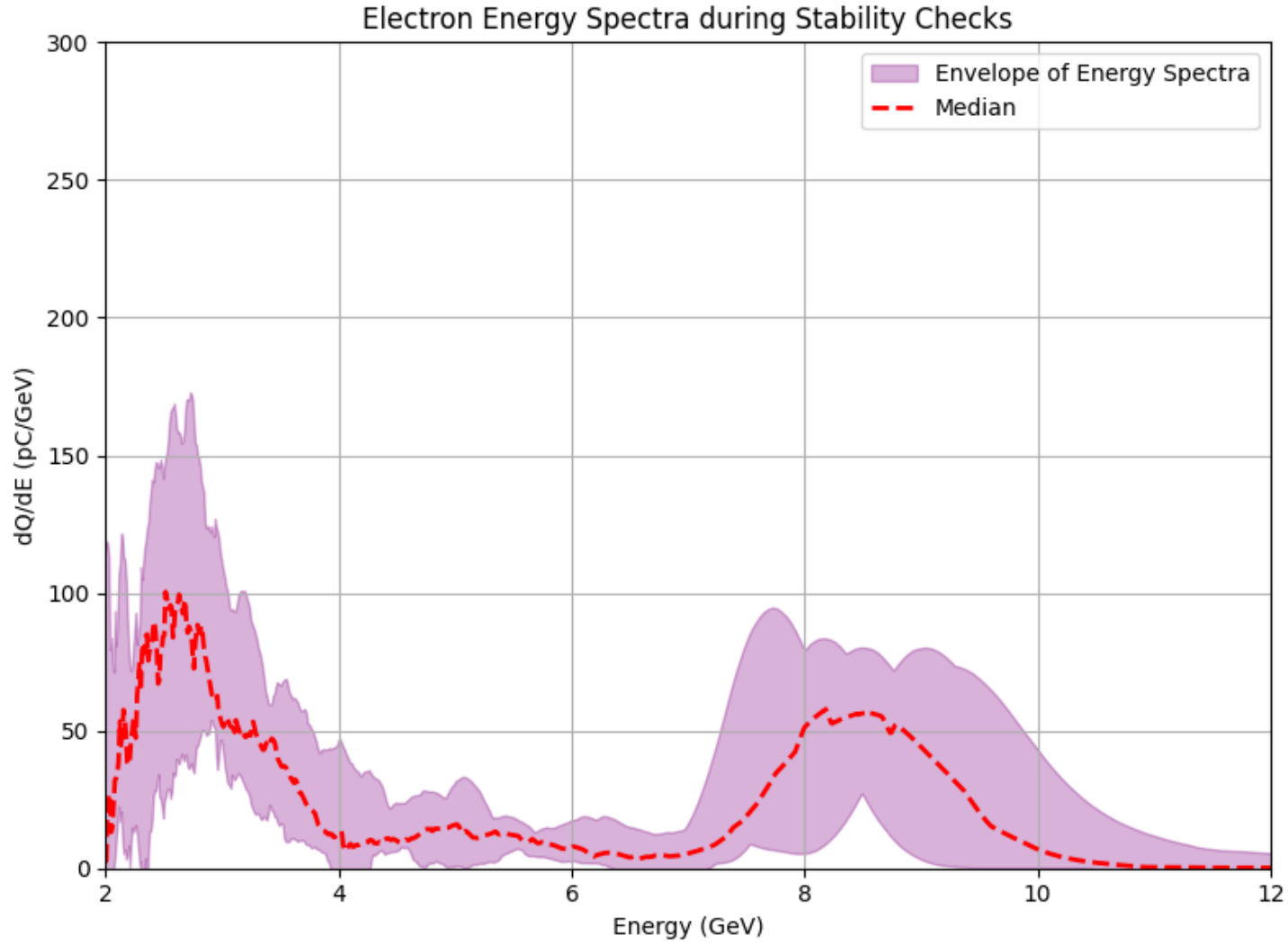
2th exit Lanex



P. Ghenuche et al. in preparation

Multi-GeV e-beams at E6 favoring high-energy

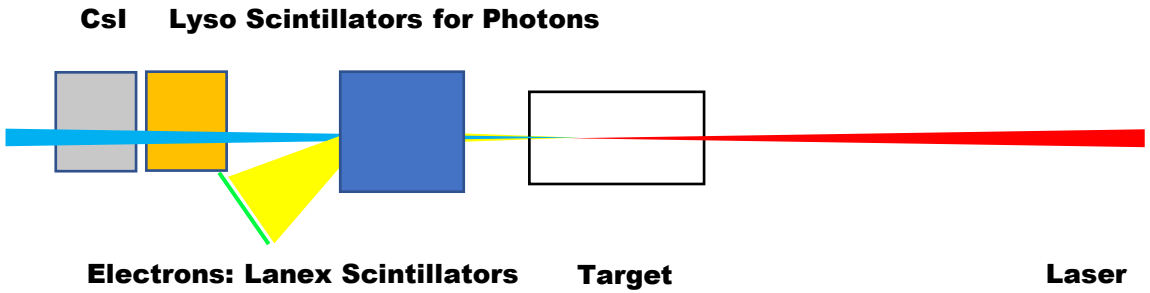
- Series of high power shots @ 10 PW nominal
- 60 mm target, electron density 5E17 cm-3



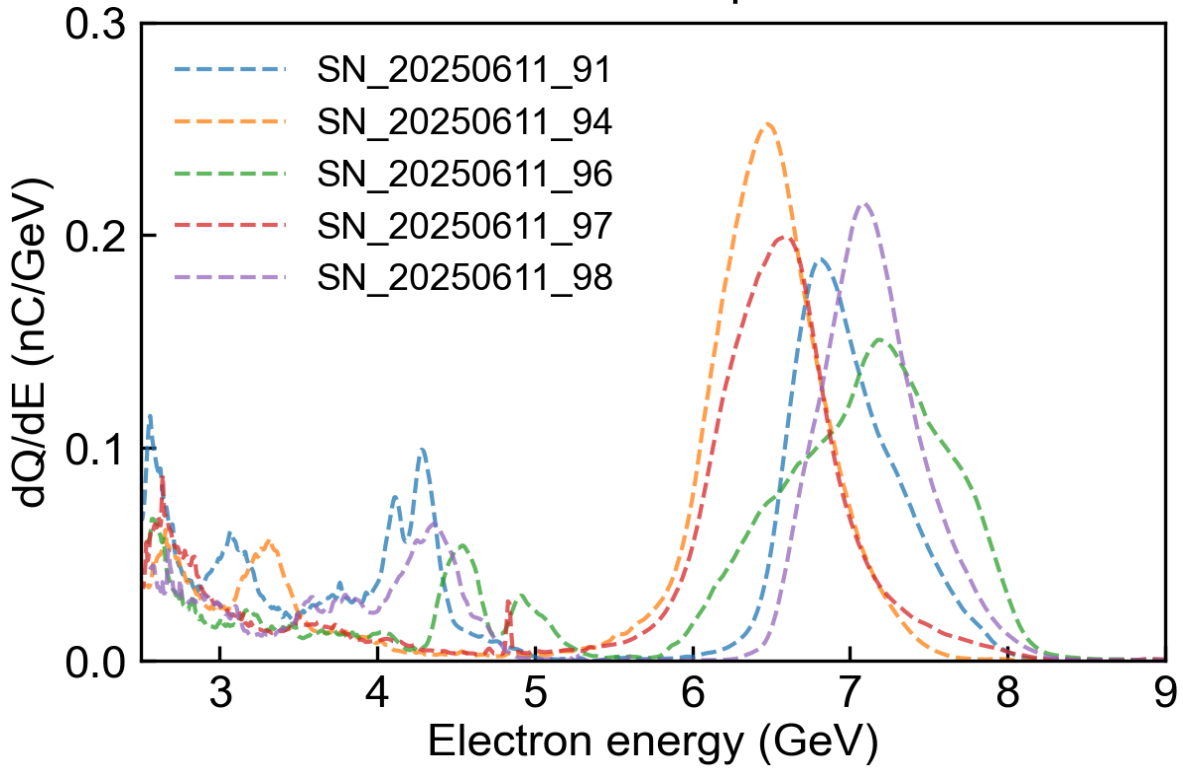
Recent betatron generation at the 10PW station/2025 Preliminary analysis

Y. Shou

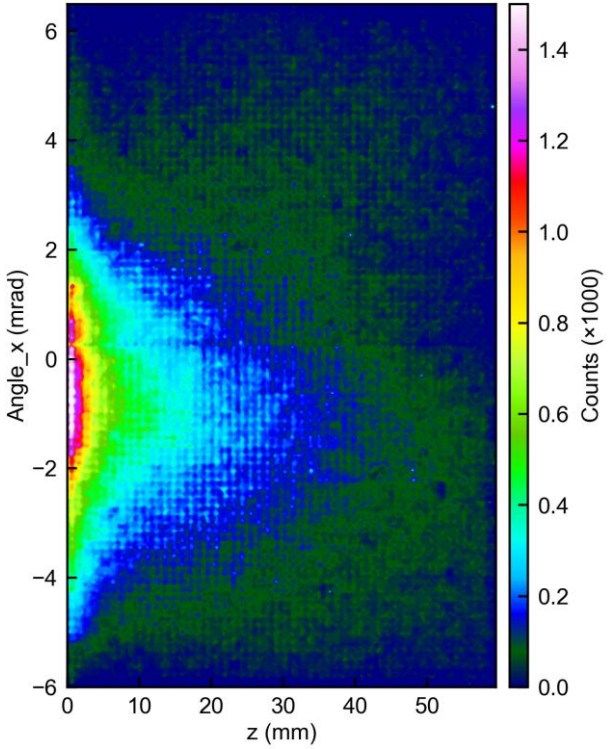
WEIZMANN INSTITUTE OF SCIENCE



Measured Electron spectra

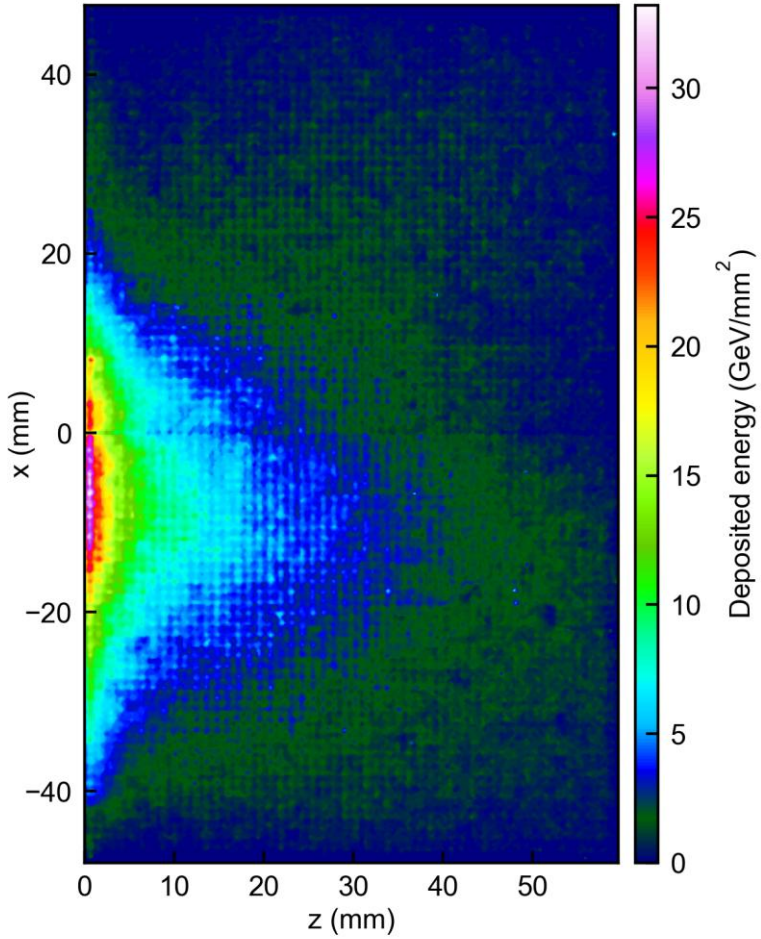


Measured results on LYSO

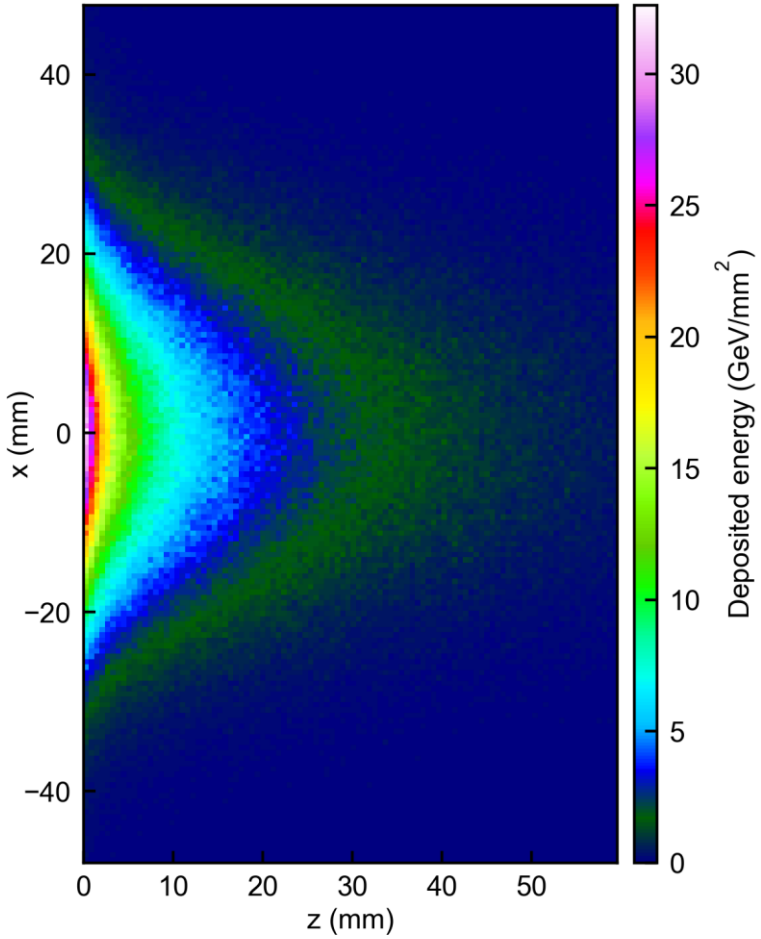


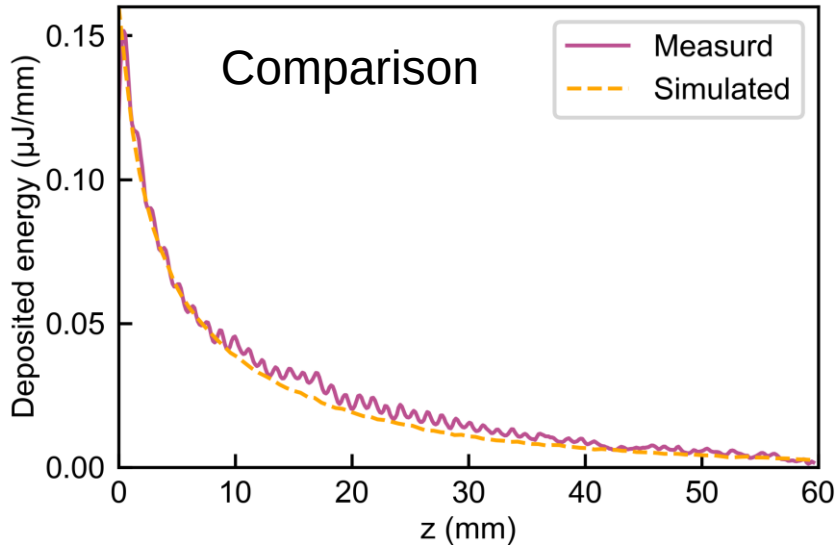
Betatron spectrum

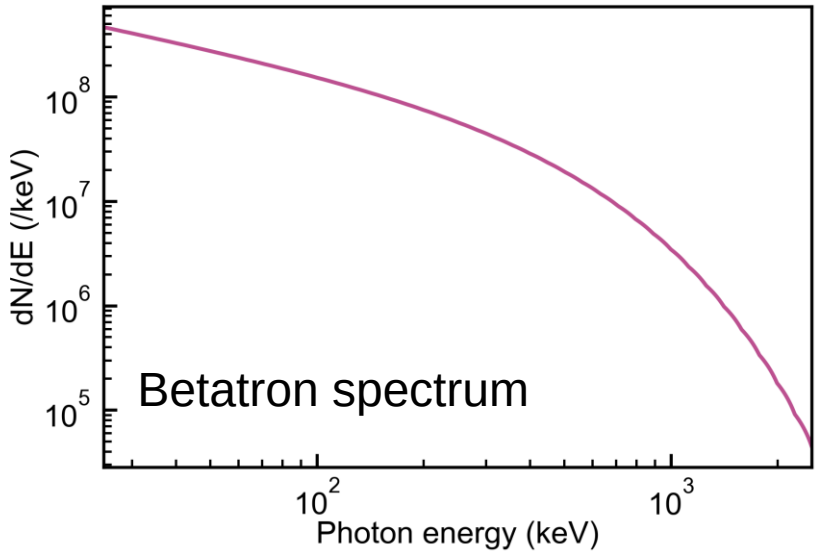
Measured results on LYSO



FLUKA simulation results

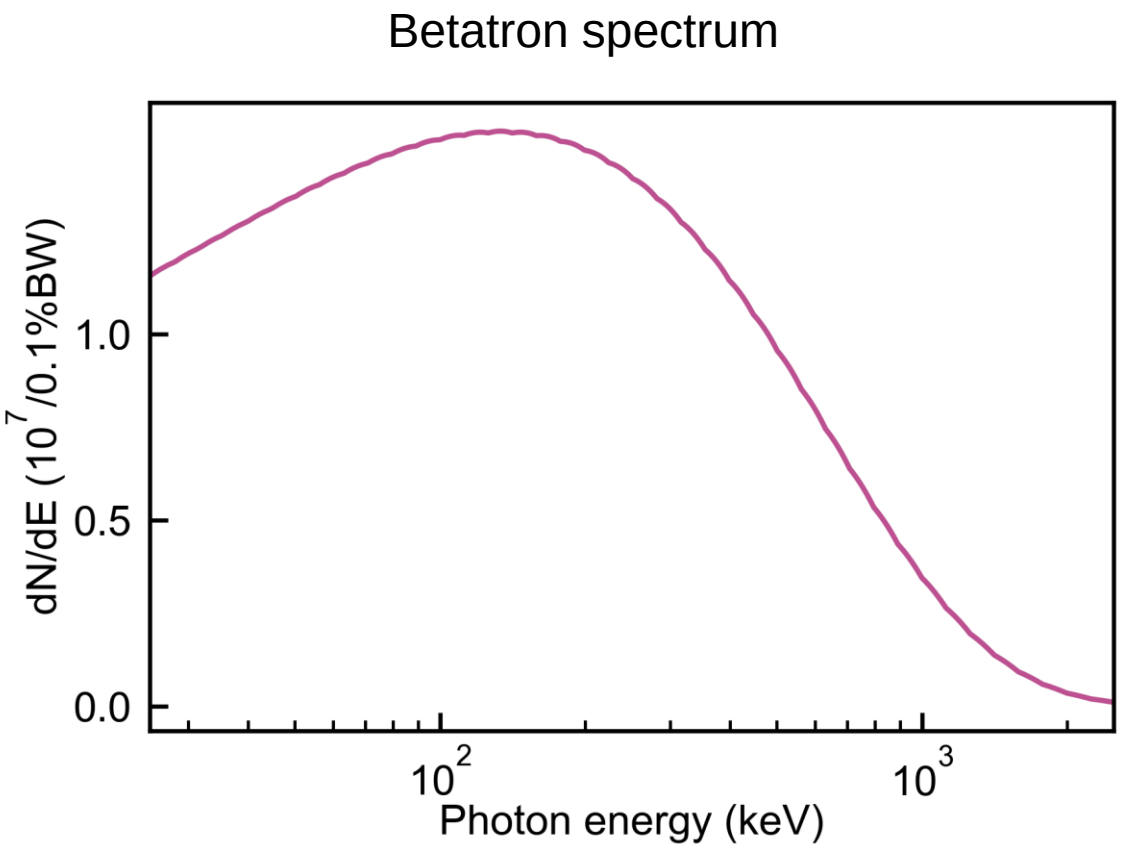






Nat. Phys. 7, 867–871 (2011).

Betatron spectrum



- Critical energy: 400 keV
- Peak energy: 140 keV
- Photon number: 5×10^{10} (>25 keV)
- Conversion efficiency: 10^{-5}
- At nominal rep rate (1/minute)

Calculated critical energy

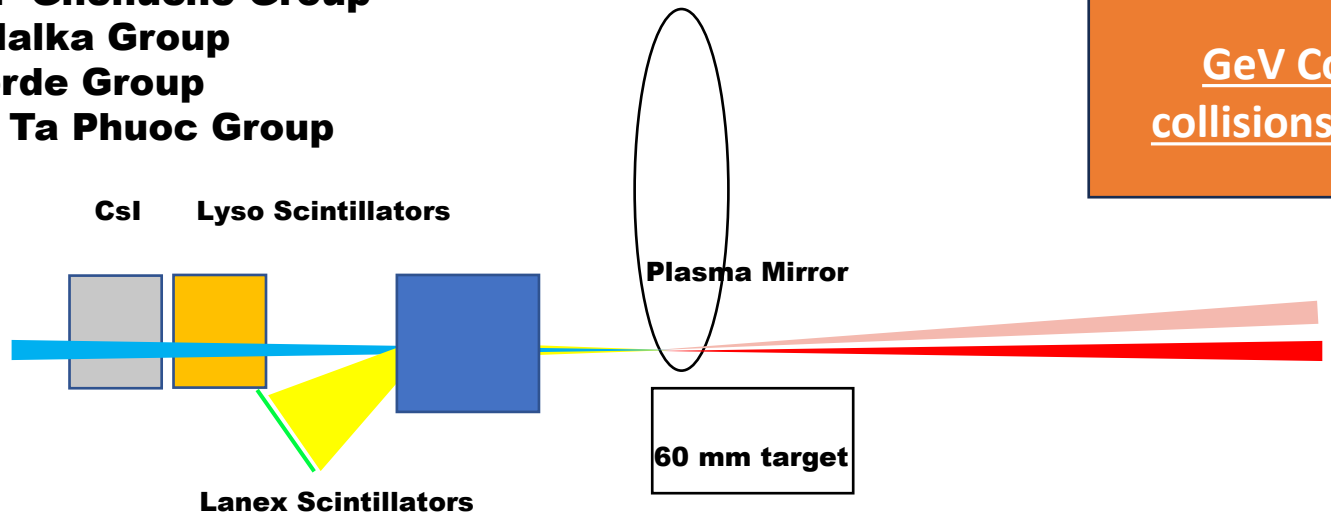
$K \ll 1 \quad \hbar\omega[\mathrm{eV}] = 5.25 \times 10^{-11}\gamma^{1.5}\sqrt{n_e[\mathrm{cm}^{-3}]}$ → 50 keV

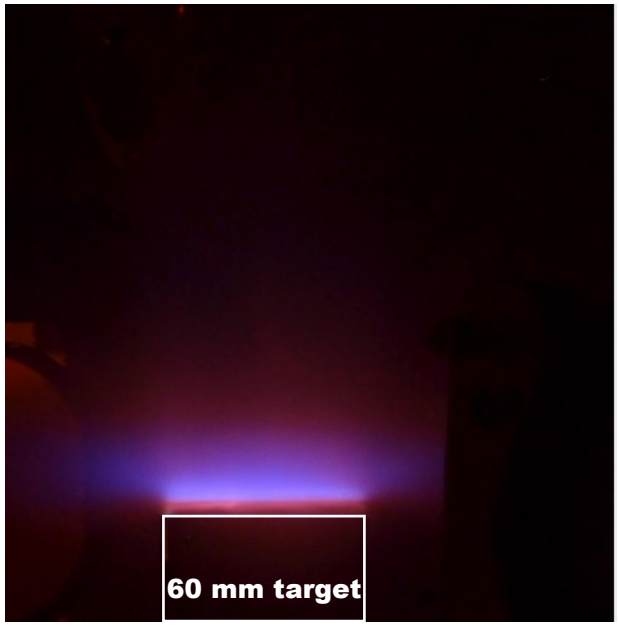
$K \gg 1 \quad \hbar\omega_c[\mathrm{eV}] = 5.24 \times 10^{-21}\gamma^2 n_e[\mathrm{cm}^{-3}] r_\beta[\mu\mathrm{m}]$ → 400 keV for $r_\beta = 1\ \mu\mathrm{m}$

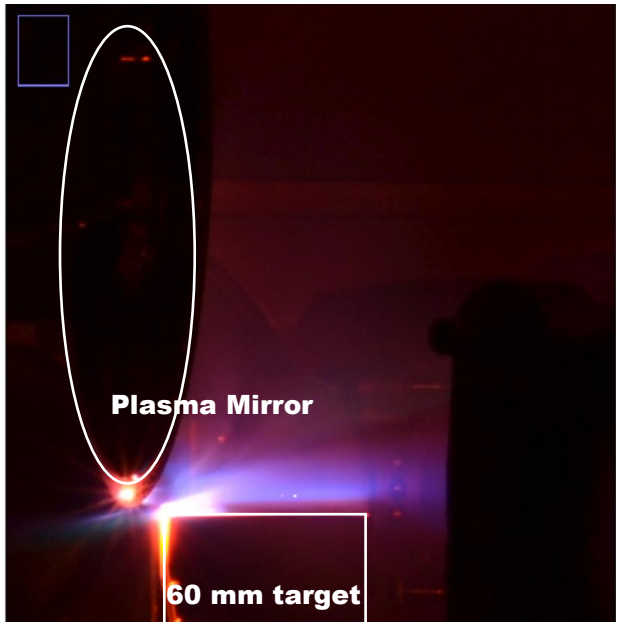
Rev. Mod. Phys. 85, 1–48 (2013).

Compton photons at the GeV scale

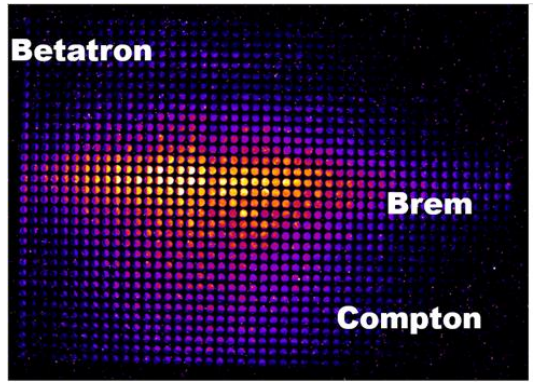
ELI-NP Ghenuche Group
WIS Malka Group
EP Corde Group
CNRS Ta Phuoc Group



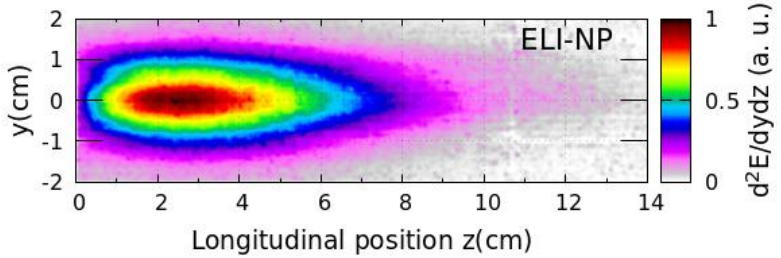




GeV Compton photons generated by self-aligned collisions with a plasma mirror, Sep 25, 2025, 5:20 PM



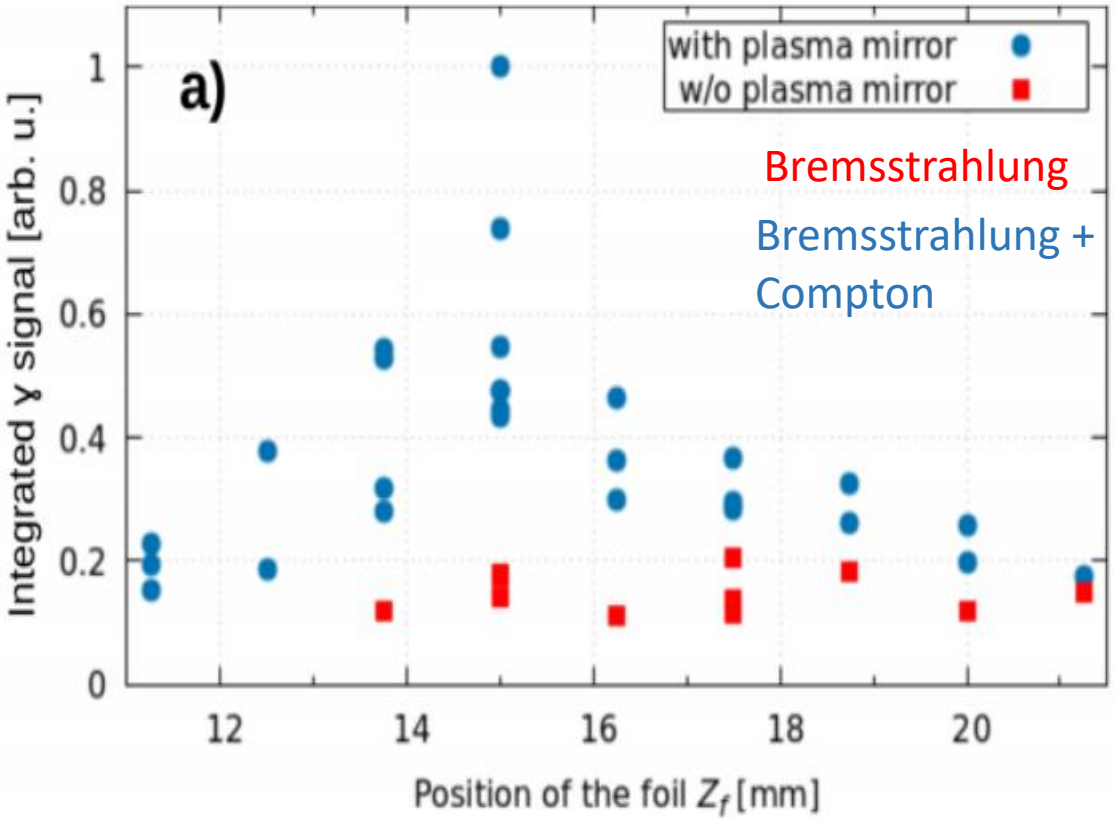
CsI pixelated Scintillator (RAL,UK)



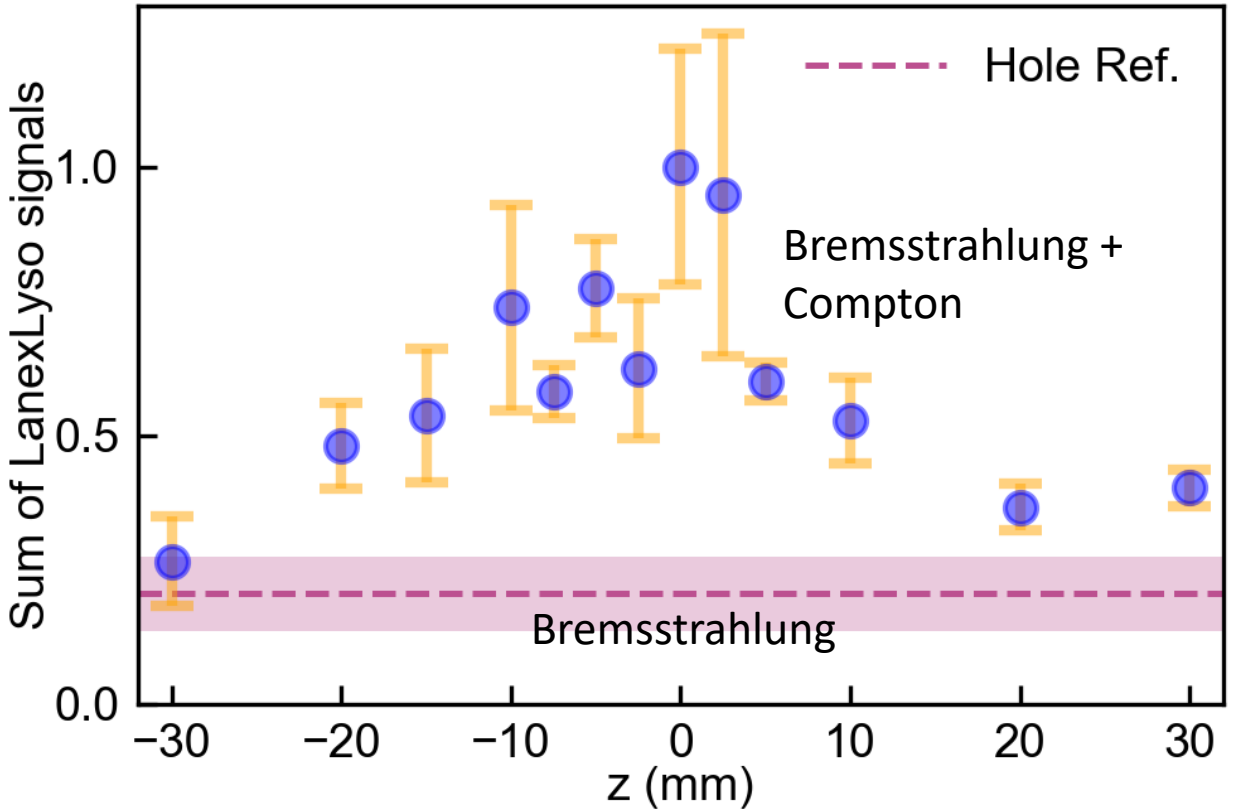
Lyso Scintillator (LULI, France)

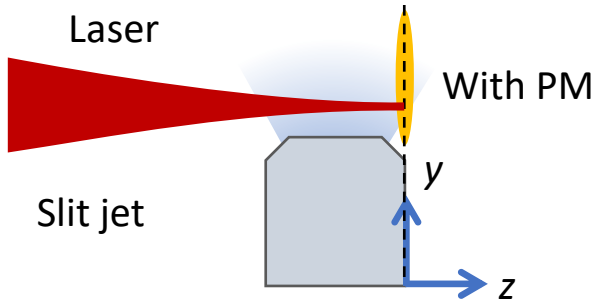
Scan of PM position and Integrated gamma signals

Results at Apollon



Results at ELI-NP





A. Matheron et al., submitted

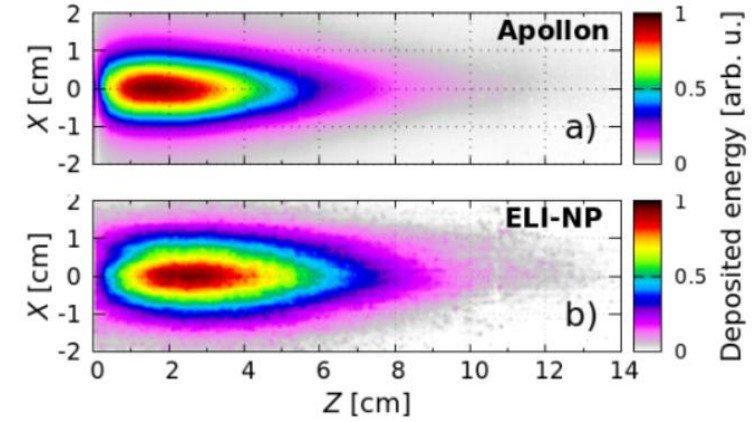
ELI-NP and Apollon laser results

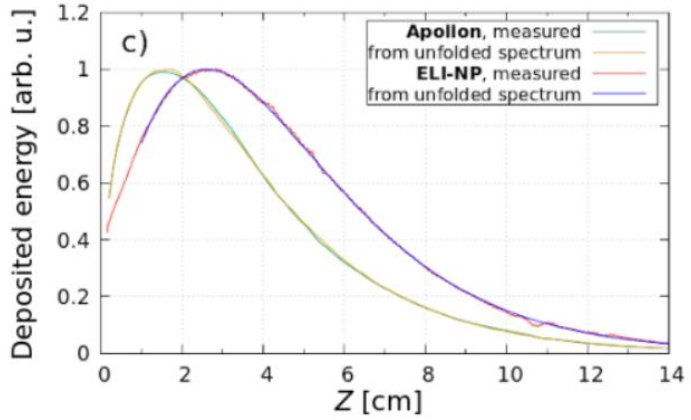
A. Matheron

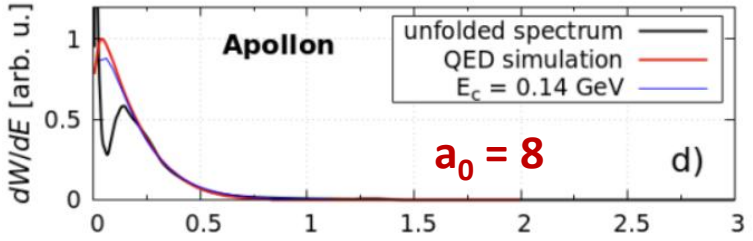
J-R Marquès

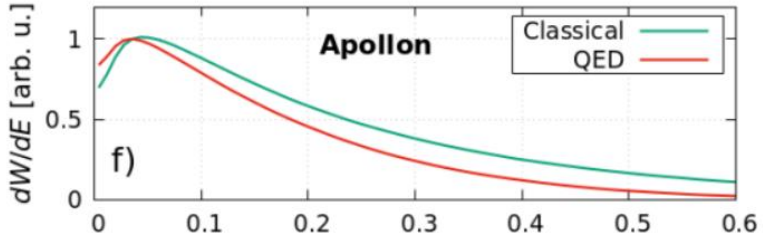
Spherical mirror: 6 m focal length (F#40)
Spot size diameter: 40 µm at FWHM
Laser max. energy: 15 J on target
Pulse duration: 25 fs on target
Laser strength a_0: ~ 3
Gas target: He + 1%N_2

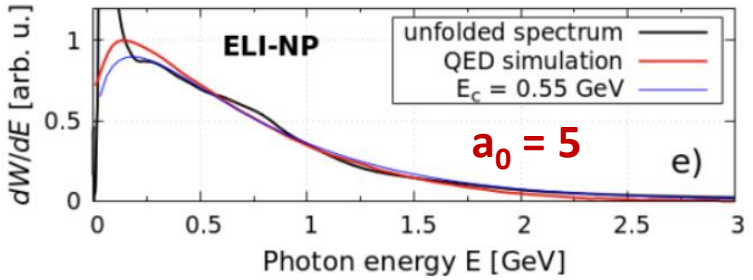
Spherical mirror: 30 m focal length (F#60)
Spot size diameter: 58.0 ± 2 µm at FWHM
Laser max. energy: 185 J on target
Pulse duration : 24±2 fs on target
Laser strength a_0: ~ 6
Gas target: He + 2%N_2

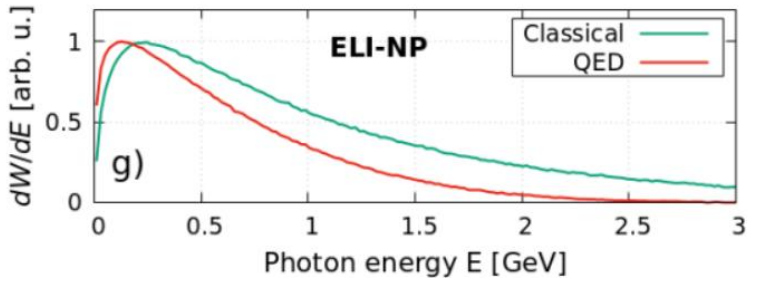






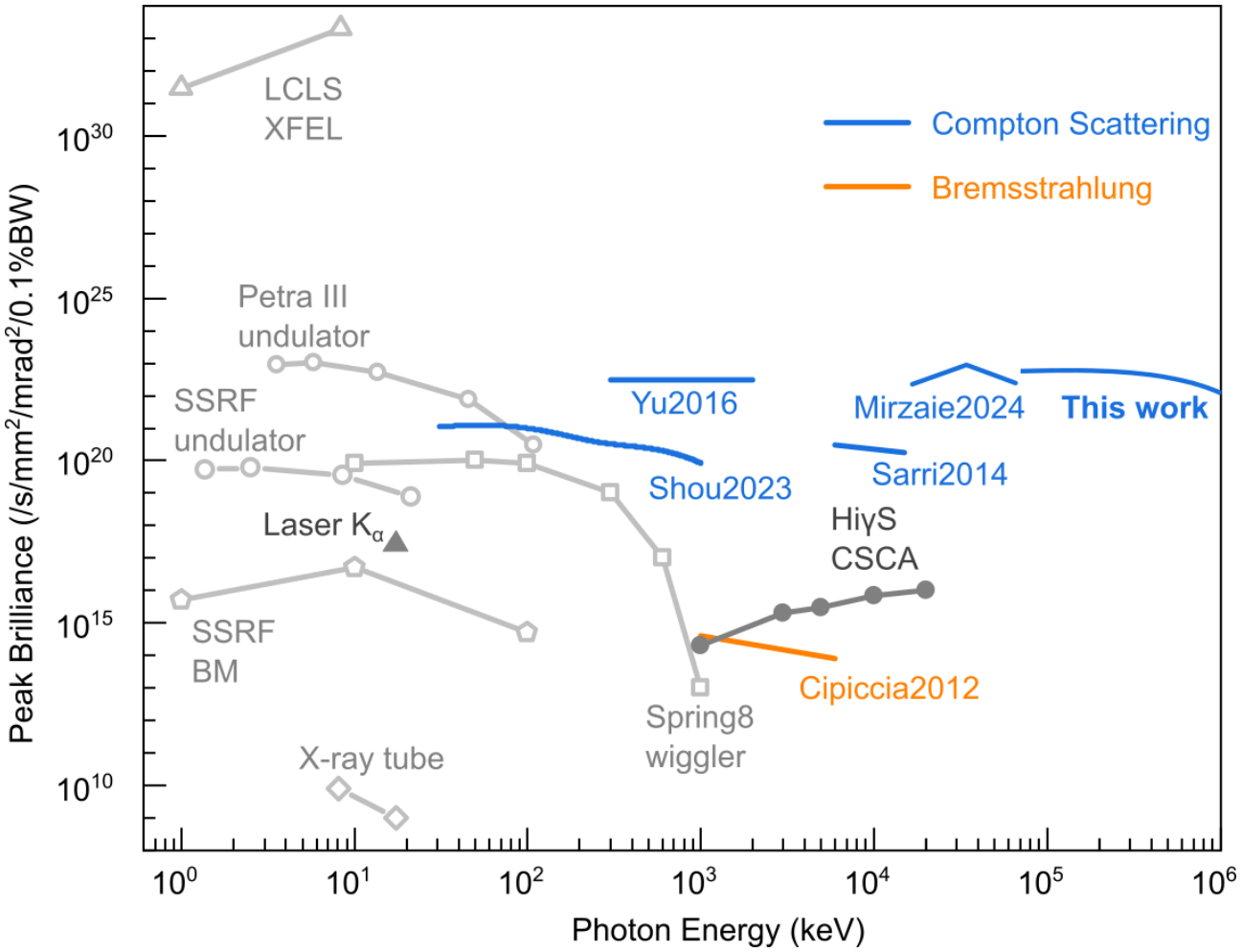


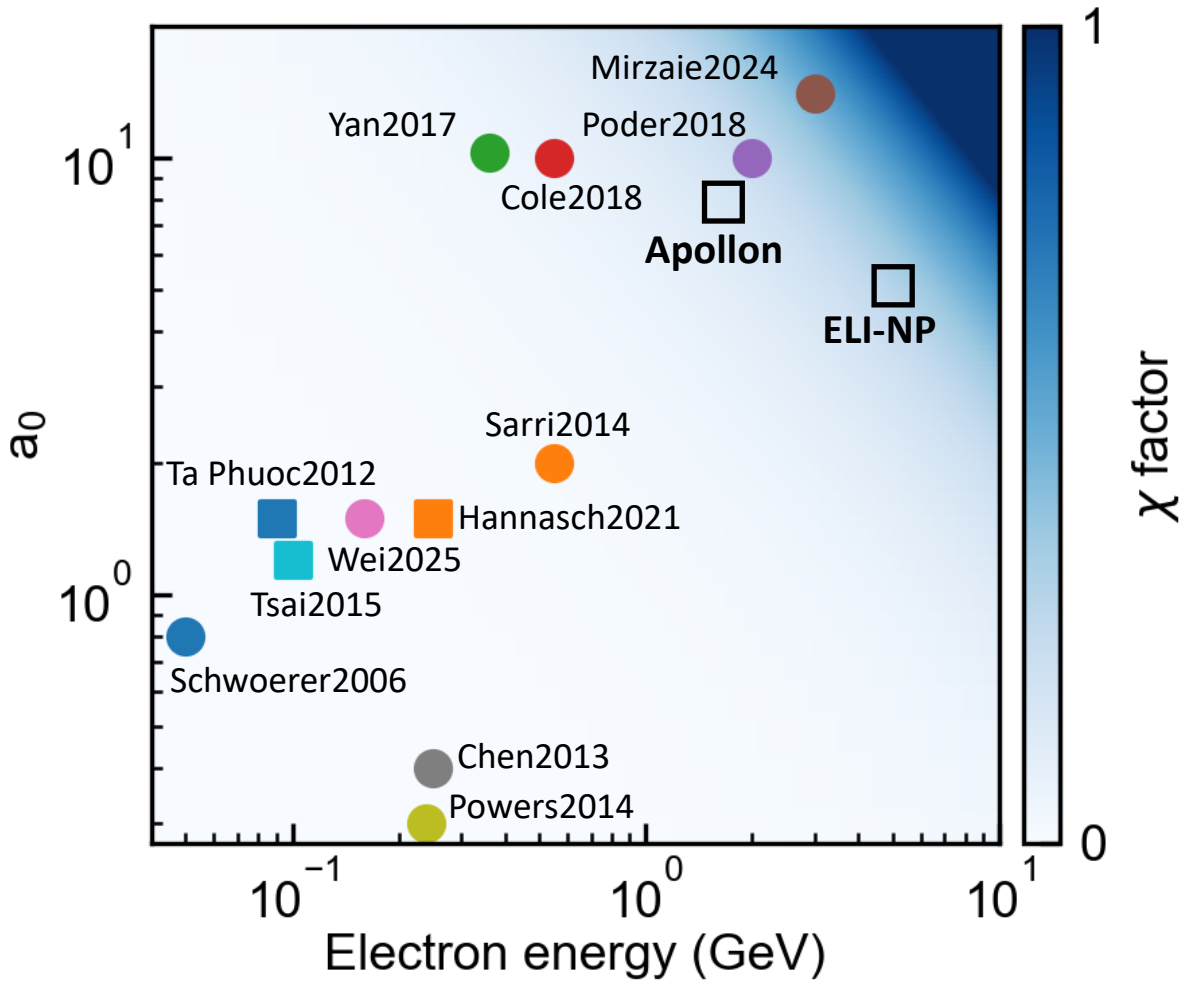




A. Matheron et al., submitted

Results: Brightness of the GeV gamma-rays





The experimental setup for muon generation and detection

Muon generation via the Bethe-Heitler process by LWFA electrons interacting with a Lead converter

Inside experimental area

- 2 x Scintillator PMT probes
- Neutron monitor **(n)**
- Electron spectrometer
  (**Lanex, magnet (M**))
- Lead Converter electrons to muons **(C)**

In the corridor

- **µ36** detector 3 m away
- Scintillator plates:
  - SiPM read bars **(2)**
  - PMT read continuous plate **(3)**
- Gamma monitors
- Neutron monitor

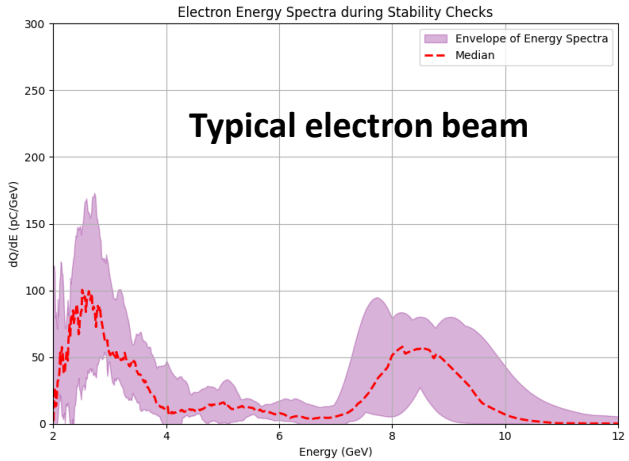
Outside the experimental building

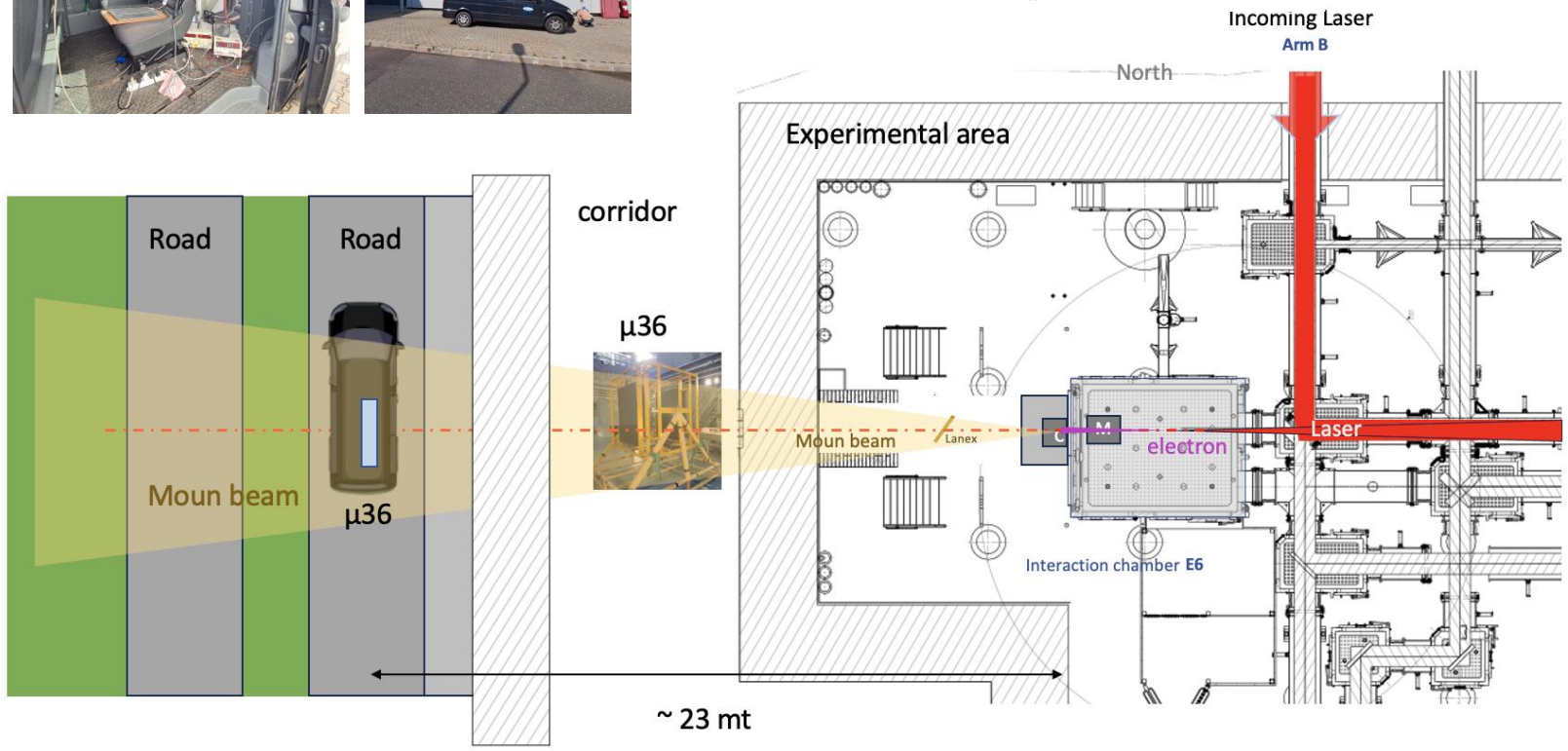
µ36 detector on a van to scan the muon beam

Detector on the Van

Pic of electronics inside the van

Pic of the van outside





The μ36 detector and the results

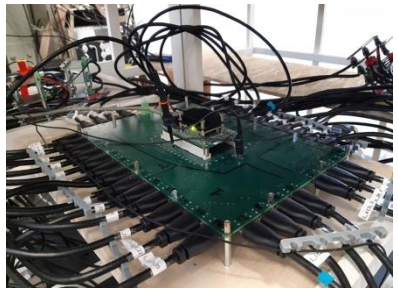
The μ36 detector characteristics

(it is designed for cosmic muons)

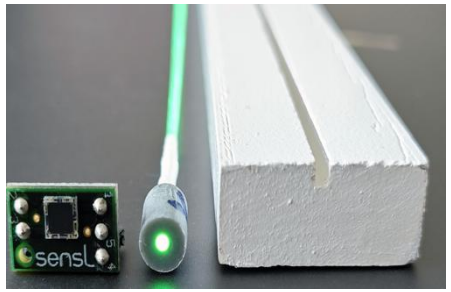
Consists of:

- 36 scintillator bars/layer 2.5x1x100 cm^3
- 4 detection layers
- BCF-91A light guides
- MicroFC-30035 SiPMs capable of detecting single muons
- FPGA-based acquisition

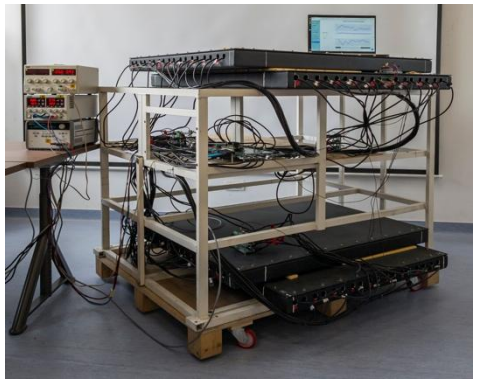
FPGA, motherboard



SiPM, Fiber, Bar

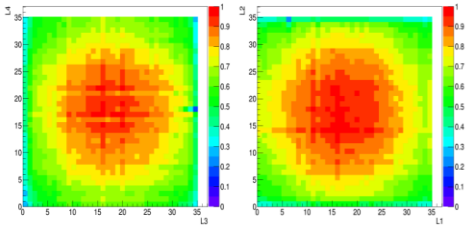


JINST article accepted for publication



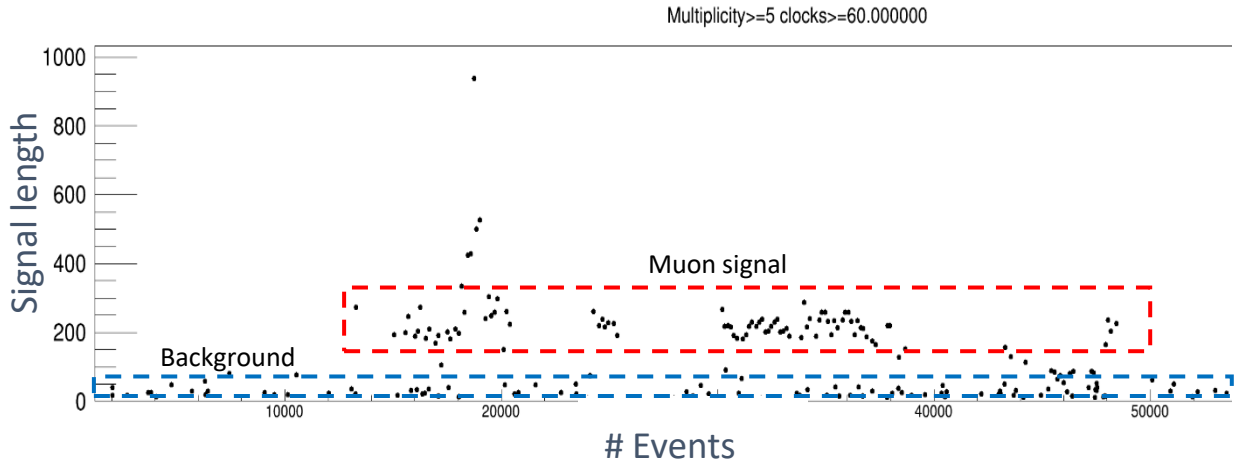
Pic of the μ36 detector

Detector response to cosmic background - horizontal



Preliminary experimental results

μ36 detection from the corridor



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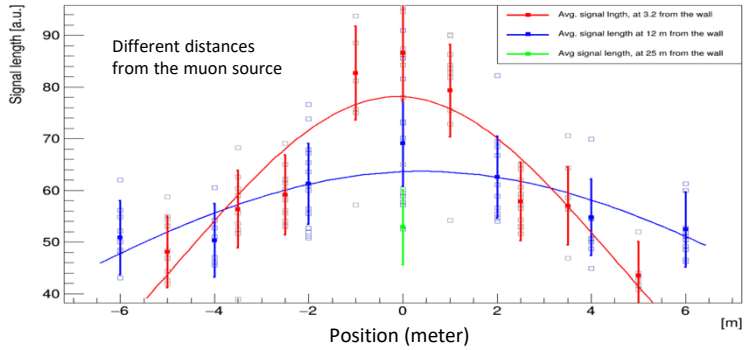
Detection of beam size using the van

Map of the Muon beam obtained by moving the van and taking several shots per position



Conclusions

- We commissioned the E6 experimental area of ELI-NP and is now opened to the community
- First 2 user runs in 2025
- Single beam experiments with multi-GeV electron beam and GeV photon beams
- Developed a series of tools and diagnostics for the area
- We continue the developments towards dual beam QED experiments

Thanks to the ELI-NP all staff, and special thanks go to

All Laser Driven Experiments Department (**LDED**) team and in particular
M. O. Cernaianu, F. Rotaru, P. Tomassini, B. Diaconescu, V. Nastasa, L. Tudor

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Thanks to the **Technical Department**

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Thanks to our collaborators

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ELI - RO

NUCLEU and IOSIN programs

eli
nuclear physics

Thank you!

Plasma Physics, Optics, Nuclear Physics, Material Science

1PW and 10PW laser beams available for the community

https://up.eli-laser.eu/calls

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http://www.eli-np.ro/jobs.php