LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Laser-Ion Acceleration at the Centre for Advanced Laser Applications

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September 24, 2024

Chair of Experimental Physics – Medical Physics

Laser-Ion Acceleration Group, Prof. Dr. Jörg Schreiber

CALA

Laser-ion acceleration in a nutshell

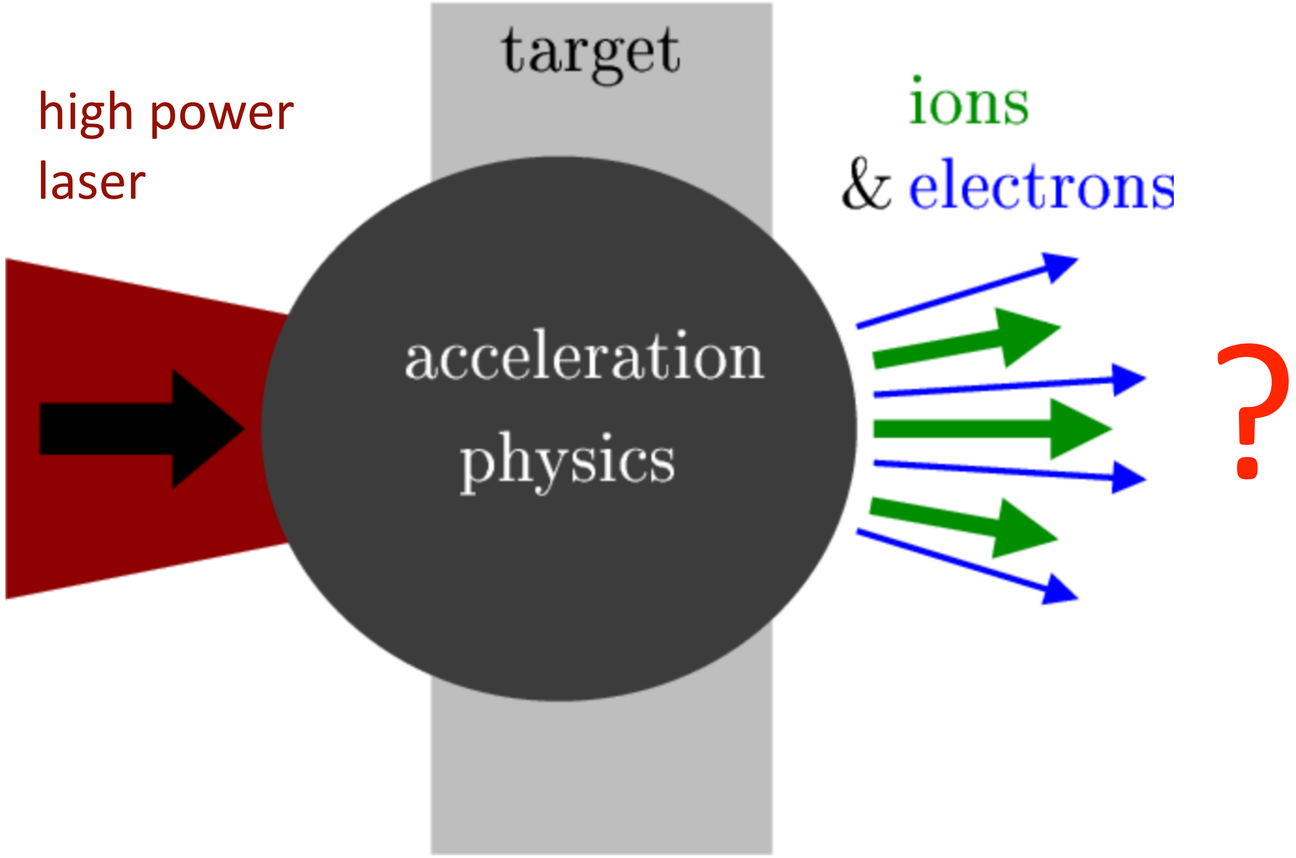


Fig: Macchi, 2017

Many interesting properties:

- Ultra-high peak currents
- Broad energy distribution
- multiple synchronous radiation modalities
- …

Many useful applications:

- Radiobiological experiments
- Probing of ultrafast processes
- Research in astrophysics
- …

Centre for Advanced Laser Applications (CALA)

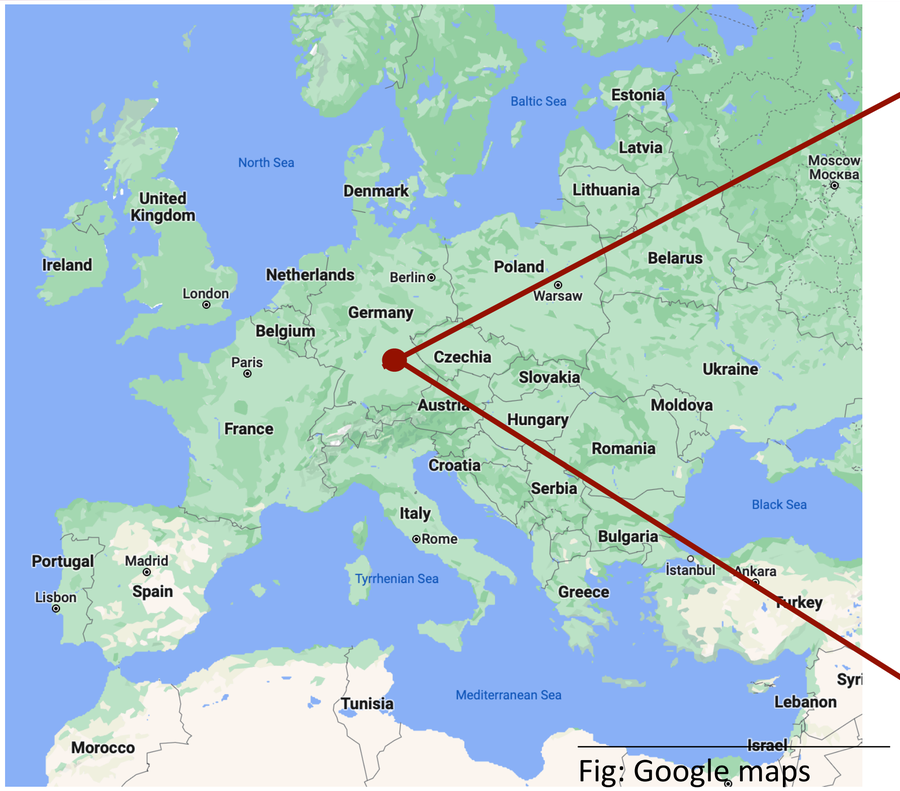
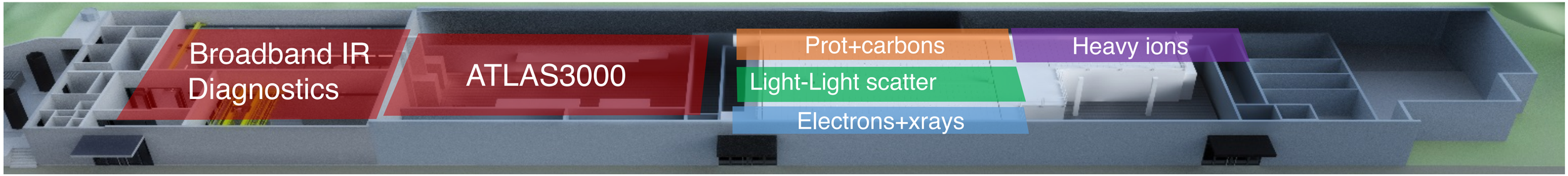
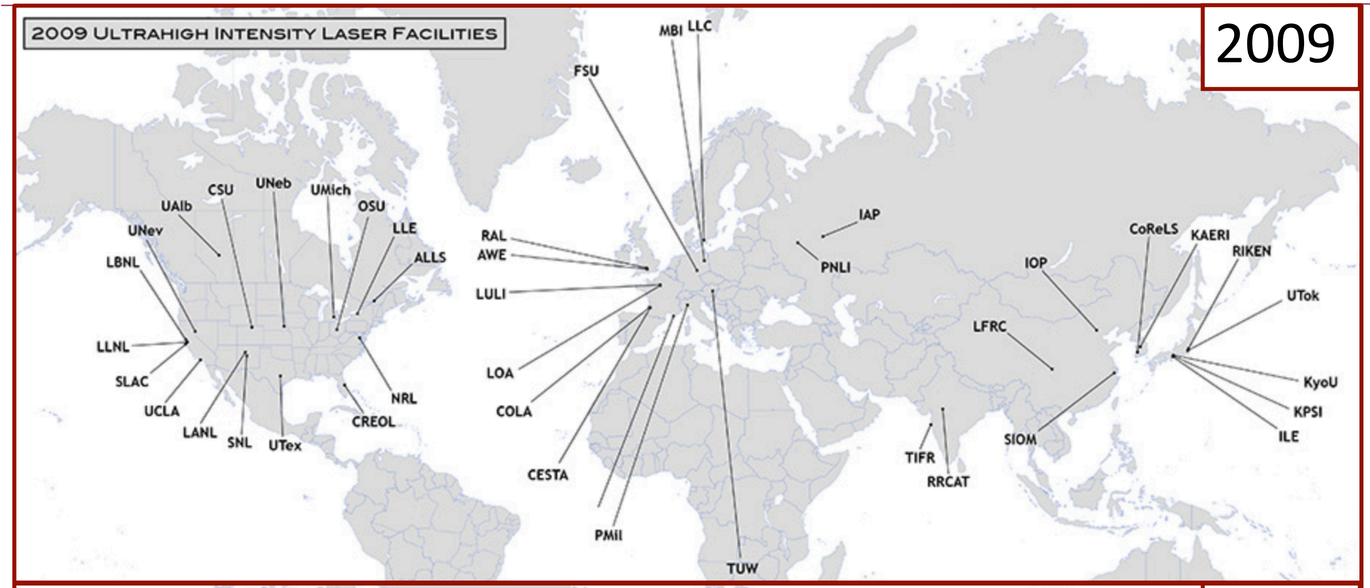
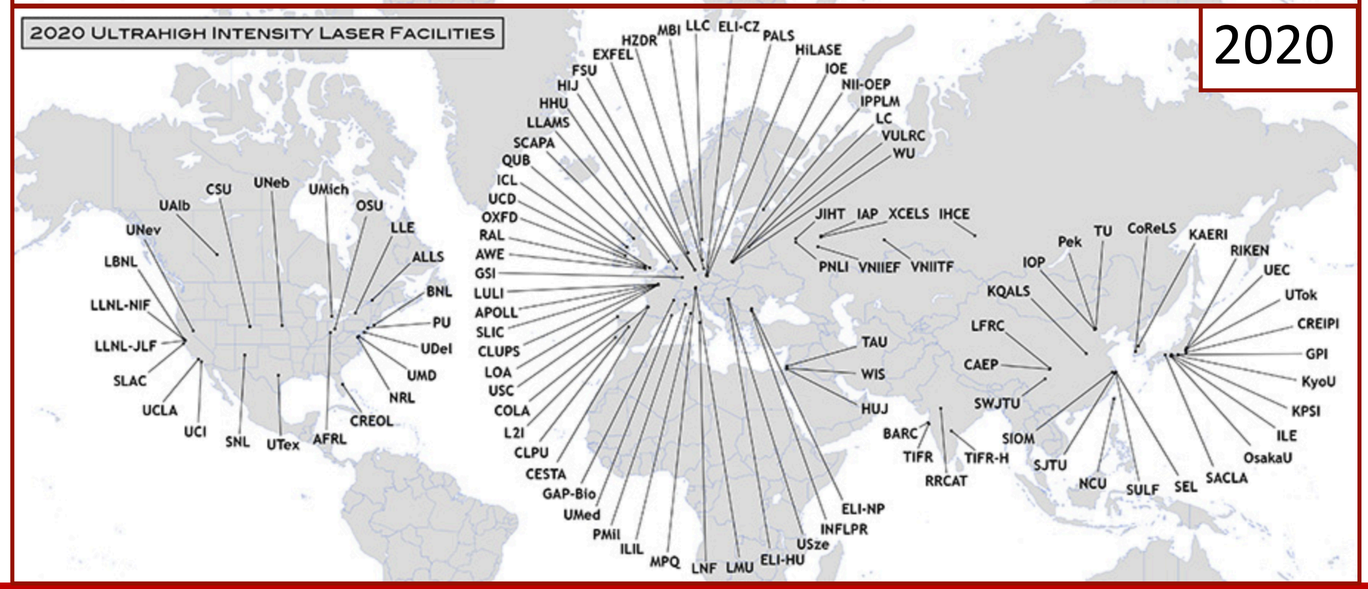


Fig: Google maps



High power lasers around the world:





Map:

High power lasers with Intensities > 10^{19} W/cm^2

ATLAS 3000 @ CALA:

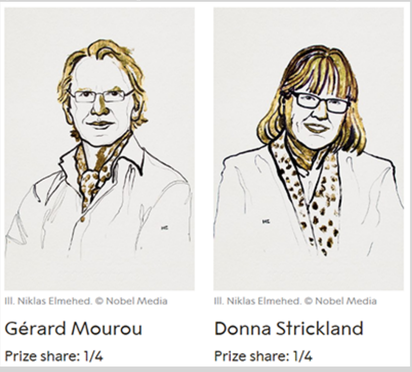
Nominal power: 60 J, 25 fs -> 2.5 Petawatt
Current power: 10 J, 25 fs -> 0.4 Petawatt
Current Intensity: approx. 10^{21} W/cm^2

Why high Intensities?:

$$E_{\text{ions}} \propto \sqrt{I_{\text{Laser}}}$$

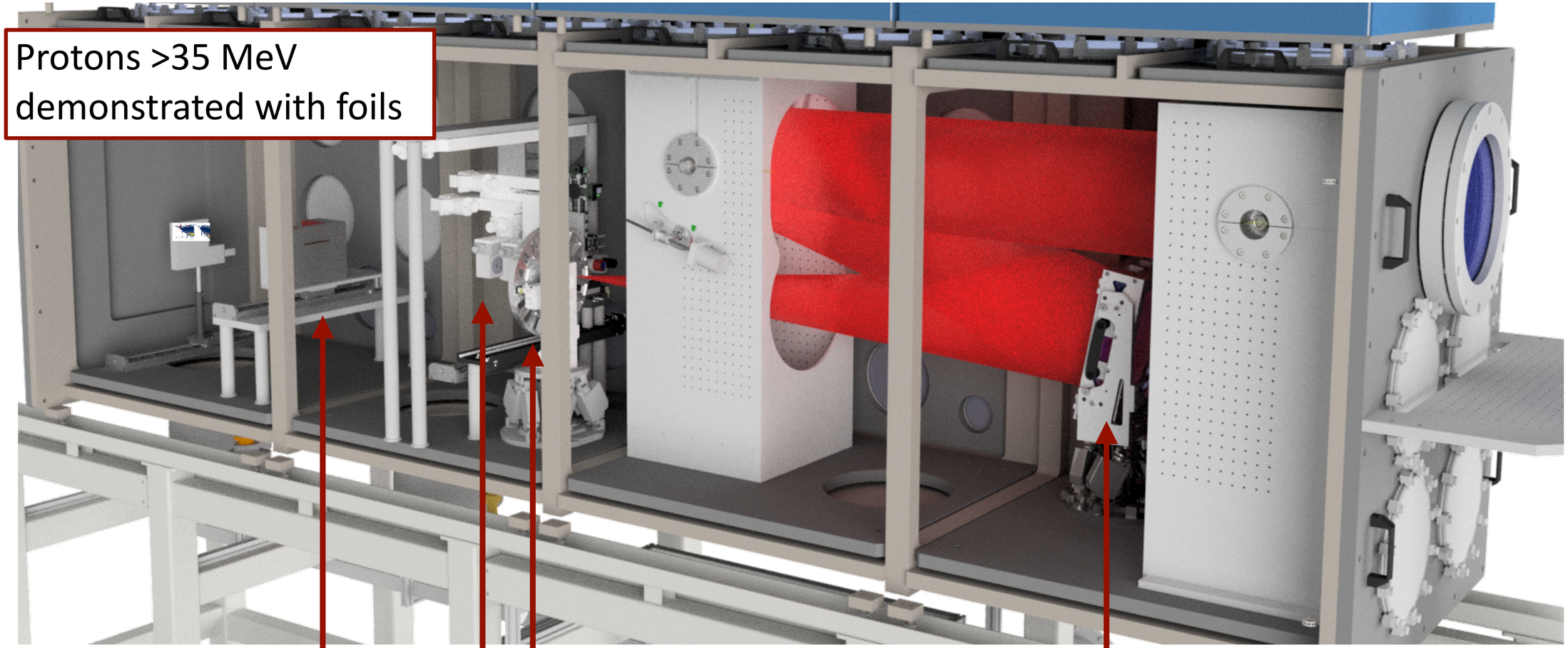
Fields: ≈100 MV / µm

Trick:
Chirped **P**ulse **A**mplification
(Nobel prize 2018)



Map: Courtesy of the International Committee on Ultrahigh Intensity Lasers - www.icuil.org

LION: Laser-ION acceleration at CALA



Protons >35 MeV demonstrated with foils

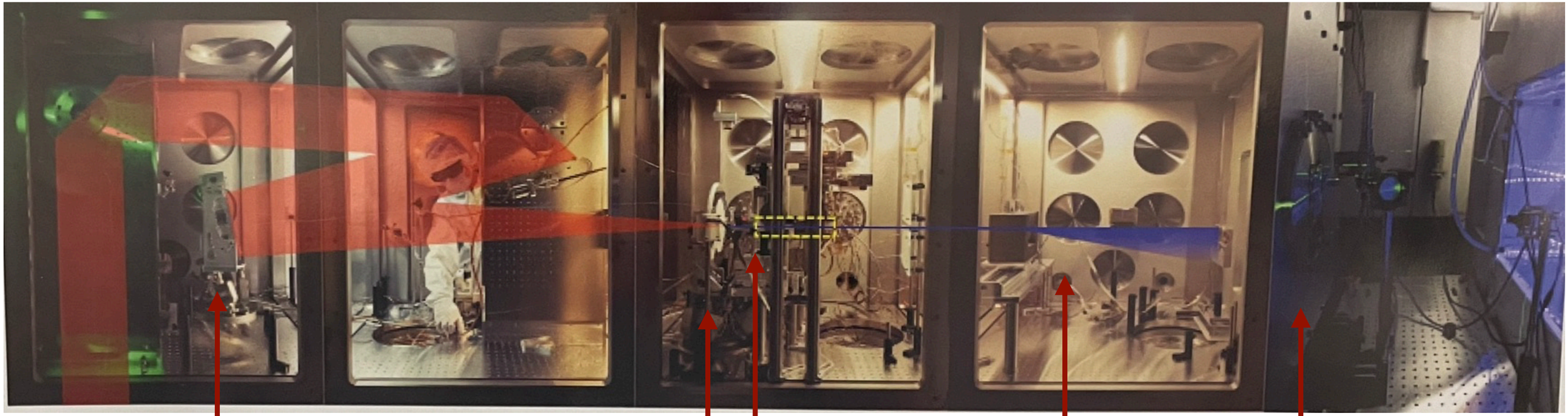
Wide-angle spectrometer with CMOS detector & calibration mask

Target positioning system

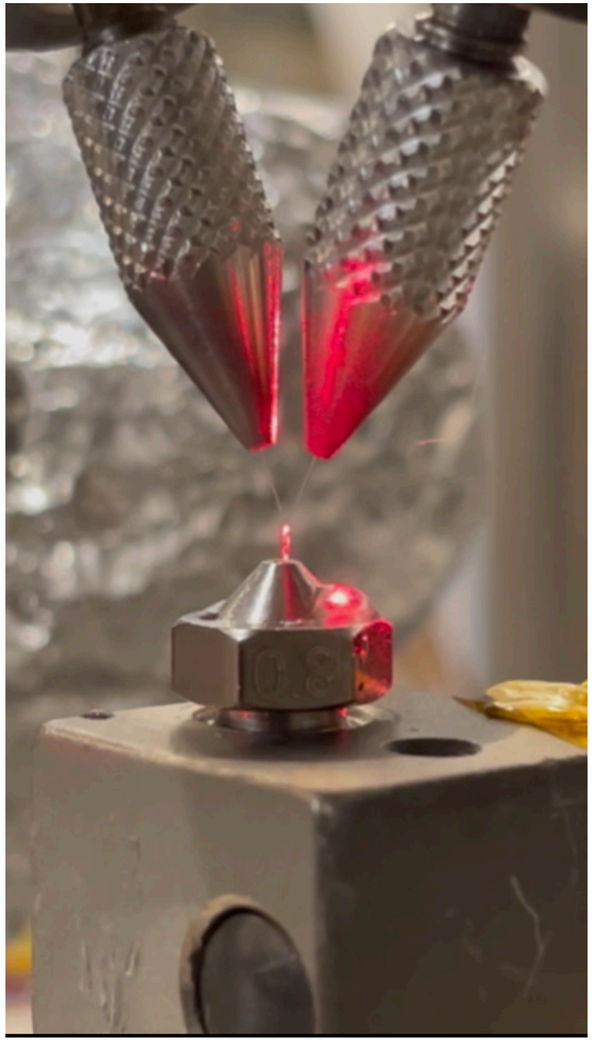
Permanent magnet quadrupoles

f/5 off-axis parabola

LION: Laser-ION acceleration at CALA



LION: Water leaf target



Two colliding jets form a water leaf, thickness: approx. 1 um

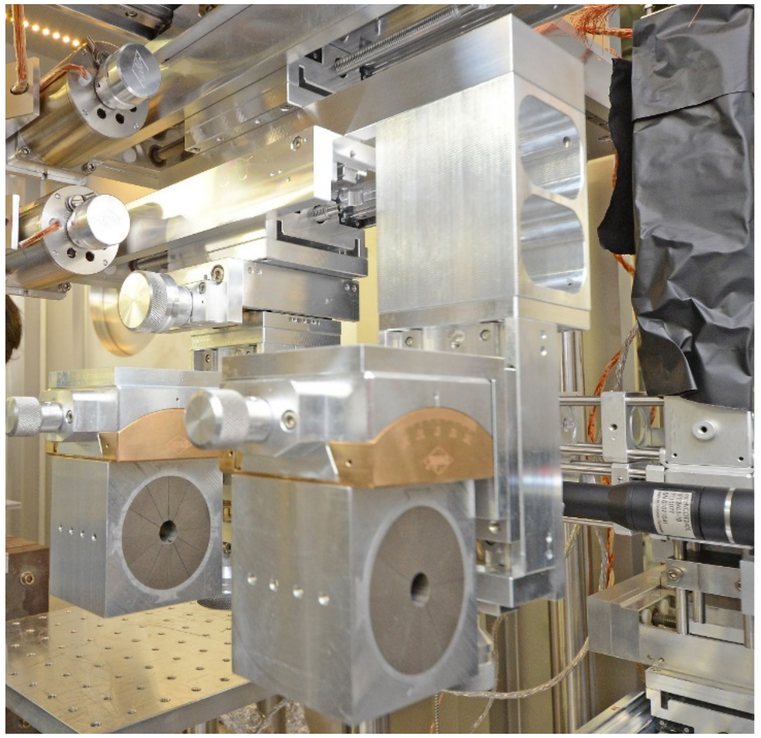
- + More stable ion bunch properties
- + Higher amount of shots possible
- - More challenging to operate

Beam parameters Lhara:

- **10-15 J on target, 28 fs**
  -> 0.4 - 0.6 Petawatt
- **Intensity: approx. 10^{21} W/cm²**
- **Rep rate: Shot on demand mode, up to approx. 0.1 Hz**
- **Proton cutoff Energy: 12-25 MeV**

He et al submitted to PRX

LION: Ion Focusing lens

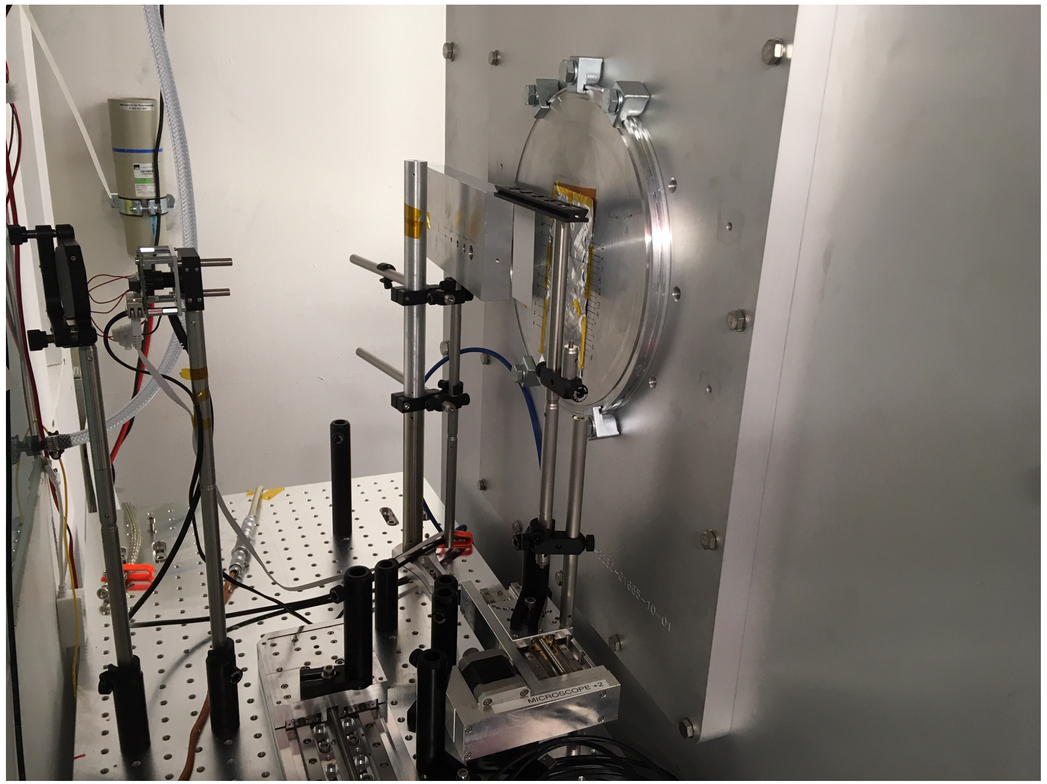


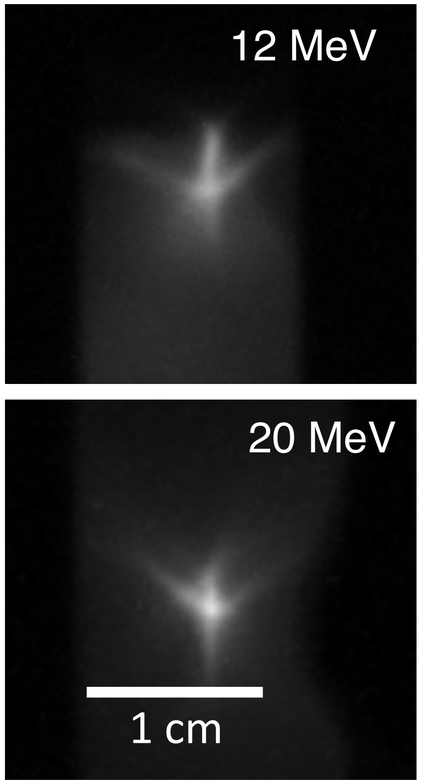
Application plattform

- 1.8 m downstream in air
- <1 mm proton foci
- Detection: Scintillator

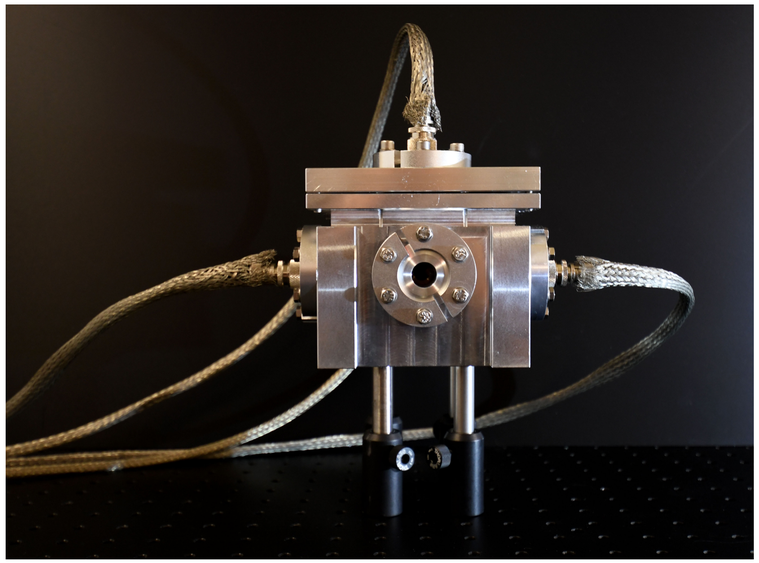
Permanent magnet quadrupoles

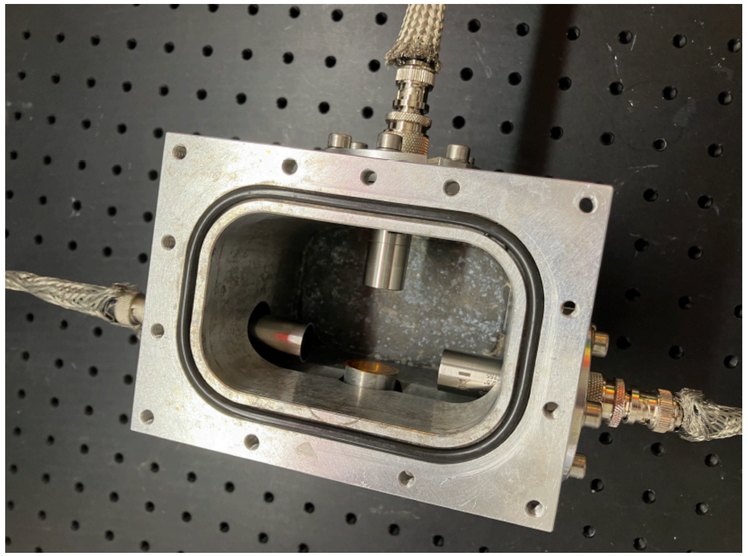
- Duplet / quadruplet available
- Magnets motorized in x/y position & rotation
- PMQ position defines transported proton energies





Ion detection: Ionoacoustics





I-BEAT 3D: Measures 3D particle bunch properties

- Energy & energy spread:
  5 MeV - 1 GeV per nucleon, sub-MeV resolution
- Lateral position and size:
  sub-mm resolution
- Particle number:
  10^6-10^9 per bunch

Experimentally confirmed, but not the limit…

Additional properties:

- Radiation hard & electromagnetic pulse resistant
- Simple & cheap set-up
- Online readout & fast data analysis available

Gerlach et al HPLSE 11 (2023)

Acknowledgements

Ludwig Maximilians University Munich:

AG Schreiber, AG Karsch, AG Thirolf

K. Parodi+, P.R. Bolton, J. Bortfeldt, G.Dedes, W. Assmann, F. Krausz+, H. Ruhl+, A. Friedl, M. Groß, J. Szerypo, H. Wirth, O. Gosau, N. Gjotev, F. Saran, G. Schilling

Recent and ongoing collaborations:
Queens University Belfast (UK): B. Dromey+
Texas University at Austin (US): M. Hegelich+
GSI Darmstadt (Germany): B. Zielbauer, V. Bagnoud+
TU Darmstadt (Germany): M. Roth+, G. Schaumann,
HZDR Dresden (Germany): U. Schramm, M. Bussmann+
FSU Jena (Germany): M. Zepf, P. Hilz, +
Peking University (China): W. Ma+
SIOM (China): J. Bin