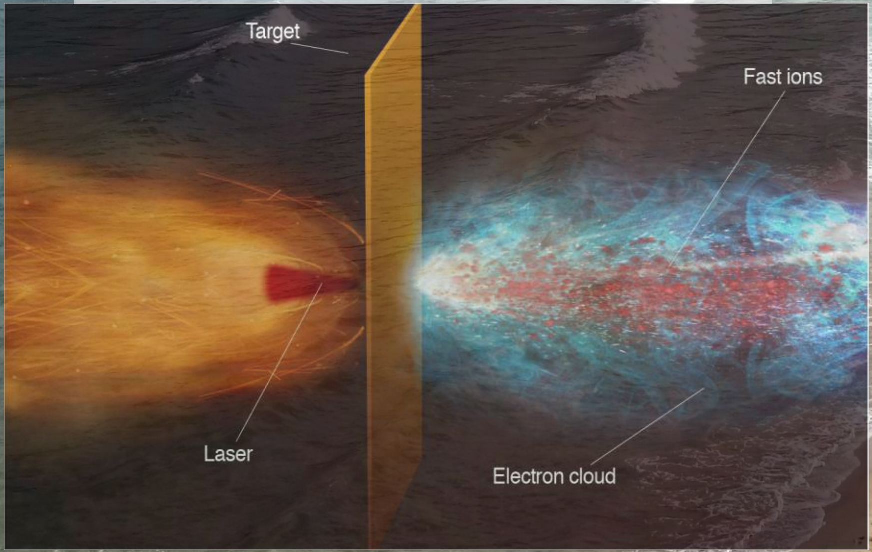
WG2 Summary: Ion acceleration

M.Borghesi

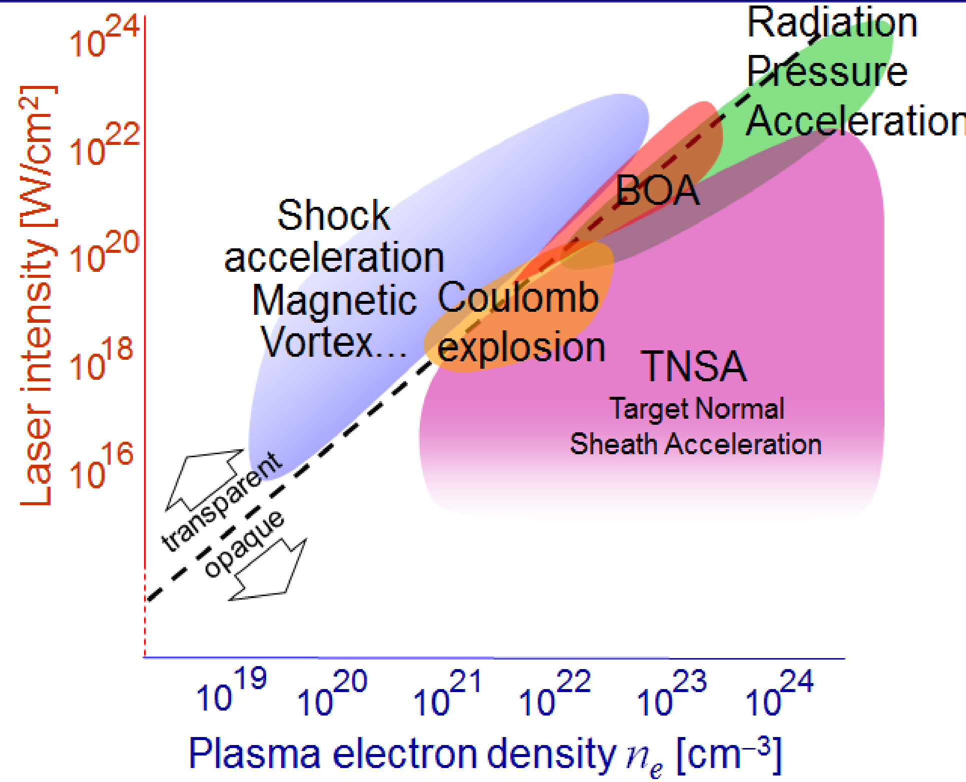
Queen's University Belfast

U. Schramm

Helmholtz-Zentrum Dresden-Rossendorf

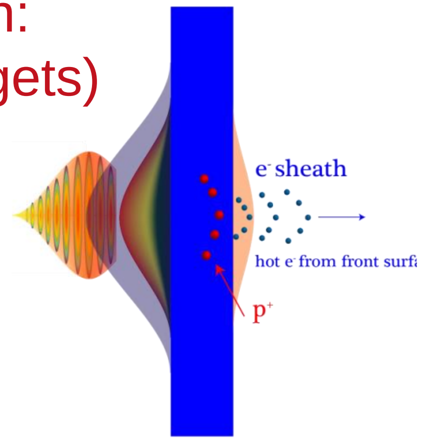


Ion acceleration mechanisms



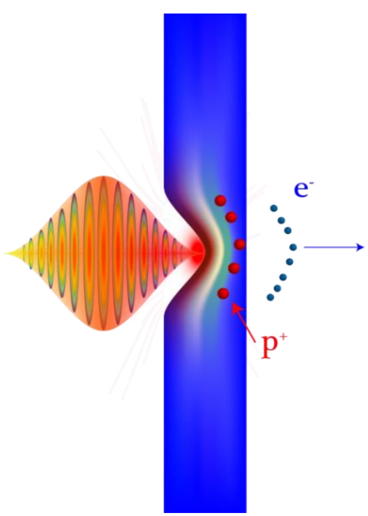
Sheath acceleration:
(in micron-thick targets)

TNSA

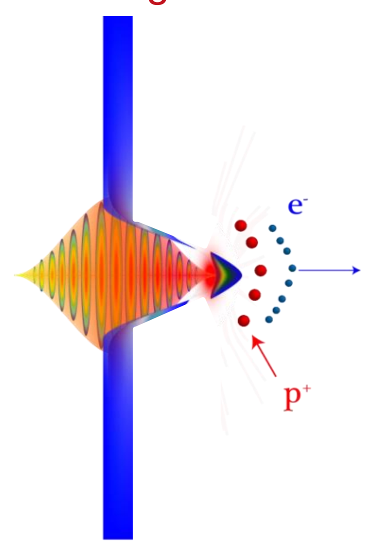


Volumetric acceleration:
(in nanometre-thick targets)

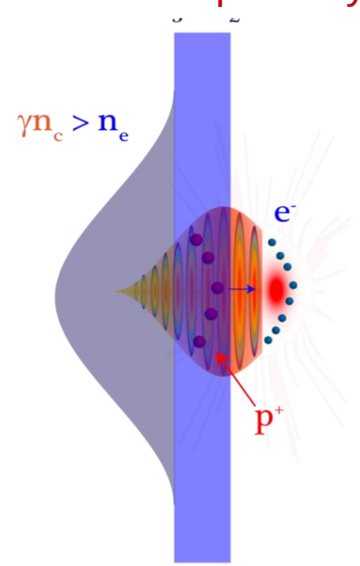
RPA – Hole Boring



RPA – Light Sail



Relativistic transparency regime



State of the art – and some considerations

Maximum proton energies (published):

60-70 MeV on ~ ps systems

(NOVA PW, Trident)

30-40 MeV on fs systems

(GEMINI, PULSAR, J-KAREN)

+ Several unconfirmed/unpublished results

- Publication via peer-review is a necessary condition for validating scientific results
- Emphasis on record energies over physical understanding is impacting the credibility of our field

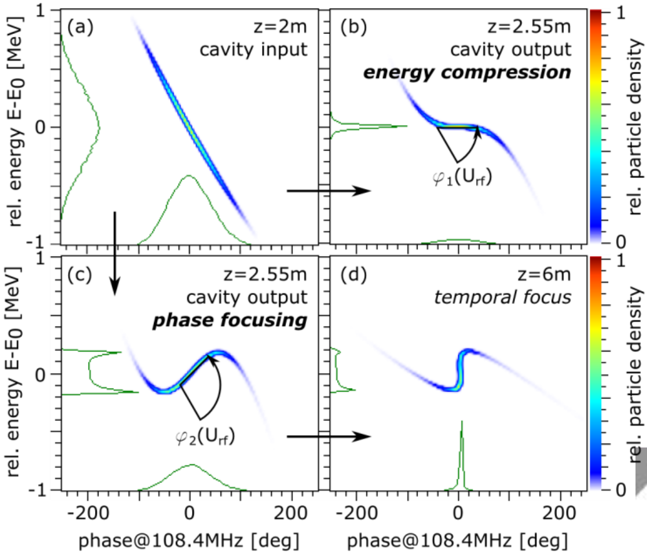
- Need for the establishment of community-accepted standards in diagnostic and analysis approaches as well as agreed practices in reporting results:

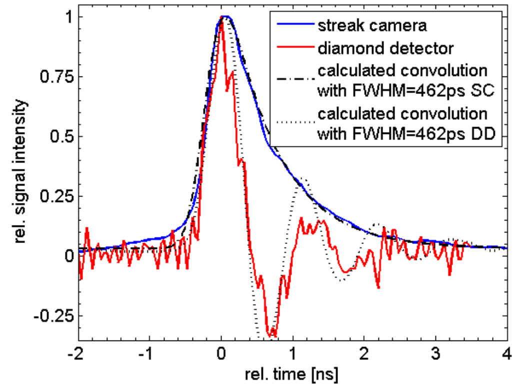
  e.g. separation of signal from spurious noise

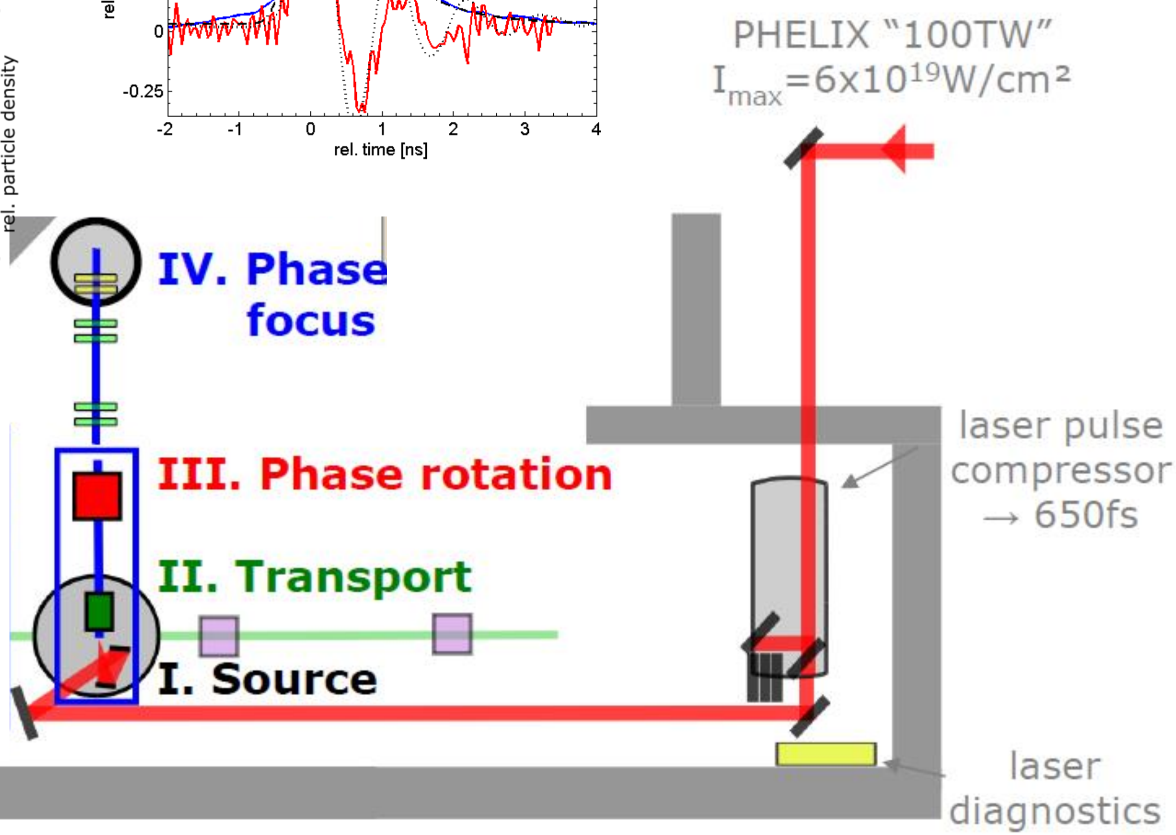
  end point of an exponential spectrum ?


Increase particle energy, spectral control, reliability and repetition rate
target shape and density
engineer plasma gradient
micro/nano-manipulation
advance power,
pulse shape control,
wavelength (?)

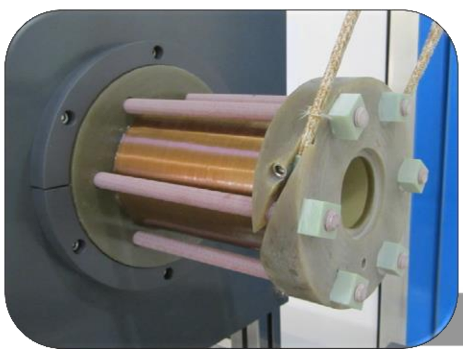
Phase rotation and pulse compression





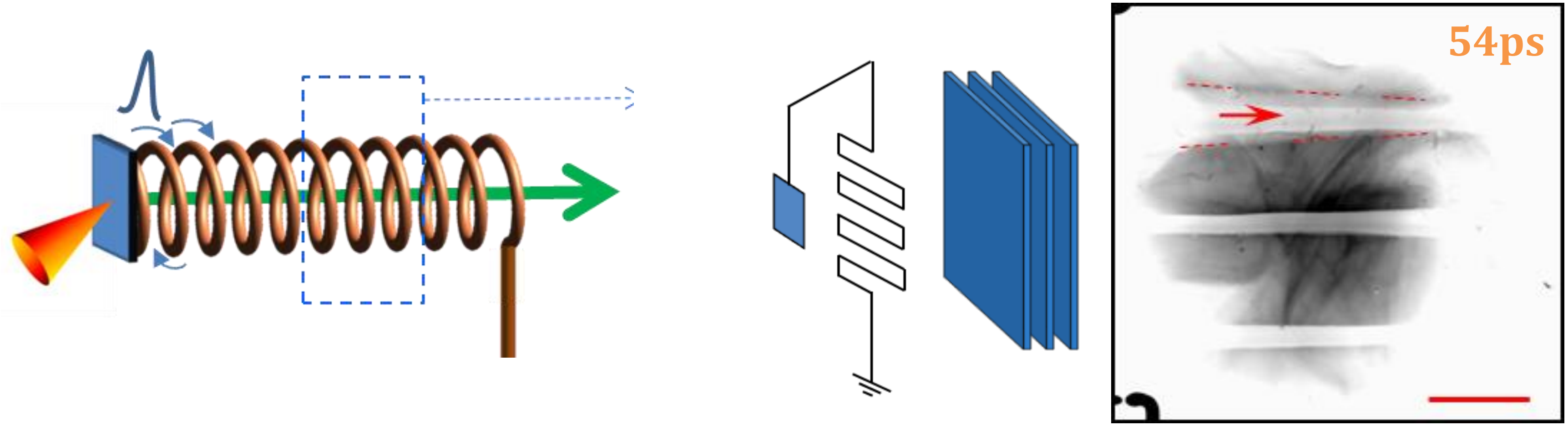


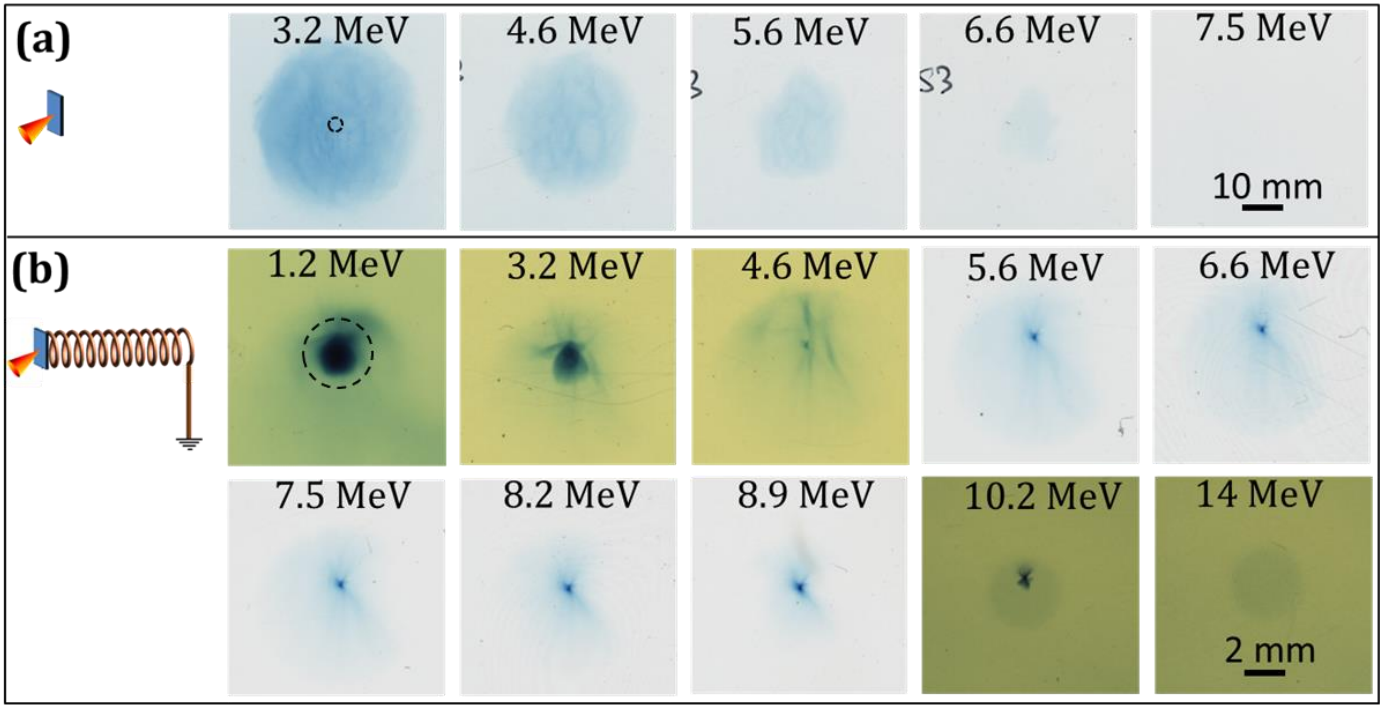
Pulsed solenoid focusing



S. Kar, Traveling wave ion accelerator

A-SAIL
ADVANCED STRATEGIES FOR ACCELERATING IONS WITH LASERS

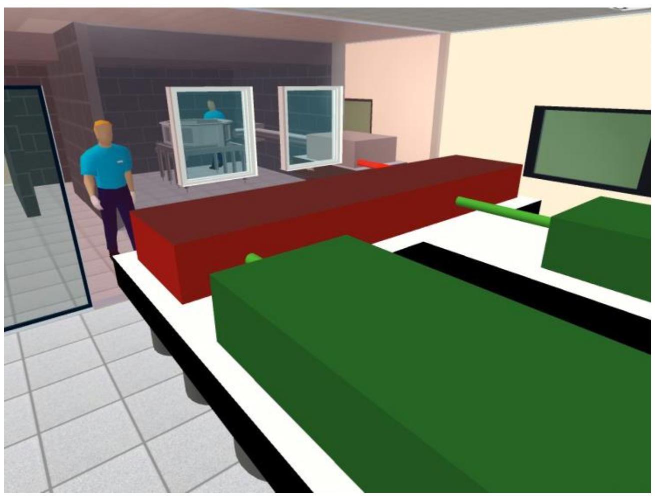


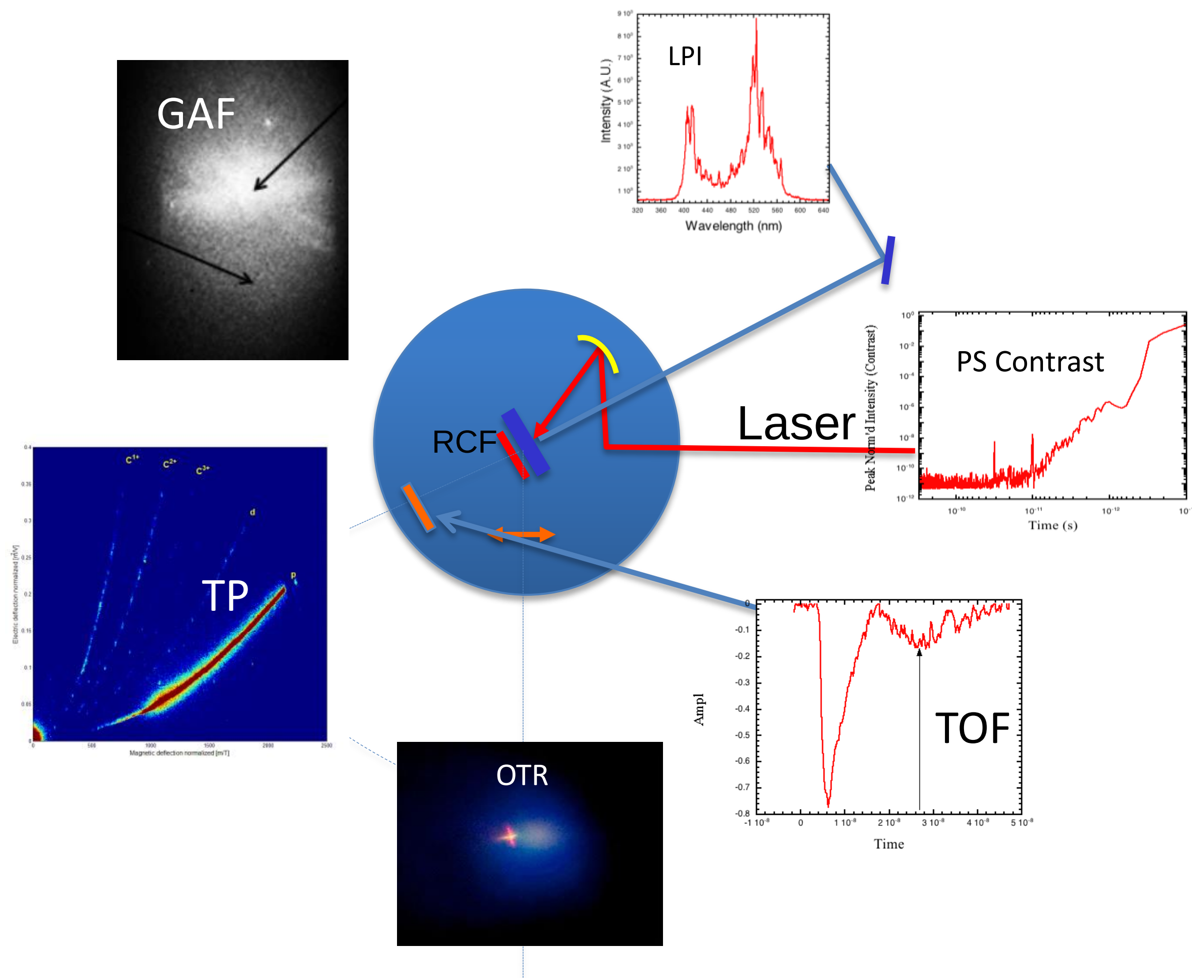


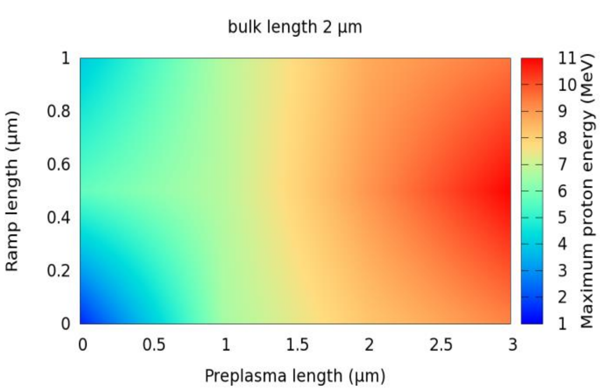
Towards a TNSA-based proton-beamline in Italy

L3IA An INFN-CNR National initiative based at ILIL (Pisa) and involving groups from Milan, Naples, Catania, Frascati, Florence and Bologna,

Talks by: Antonio Gizzi, Carmen Altana, Annamarie Muoio, Stefano Sinigardi

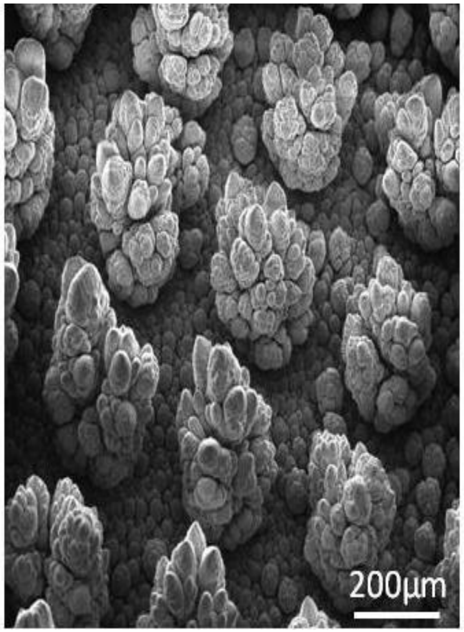


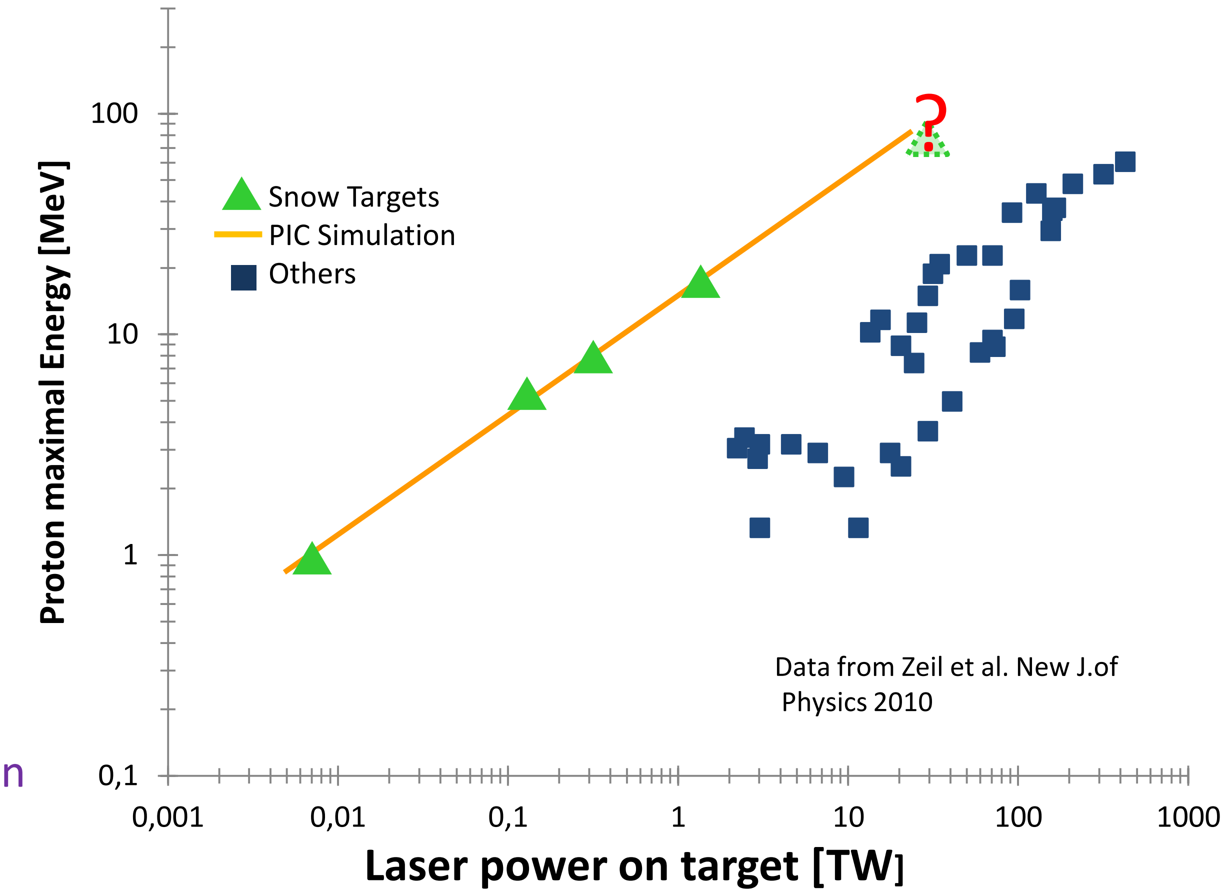


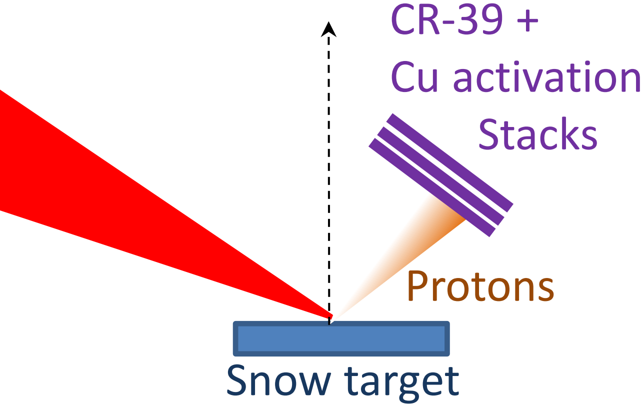


STRUCTURED SNOW TARGETS

A.Zigler, Hebrew University of Jerusalem

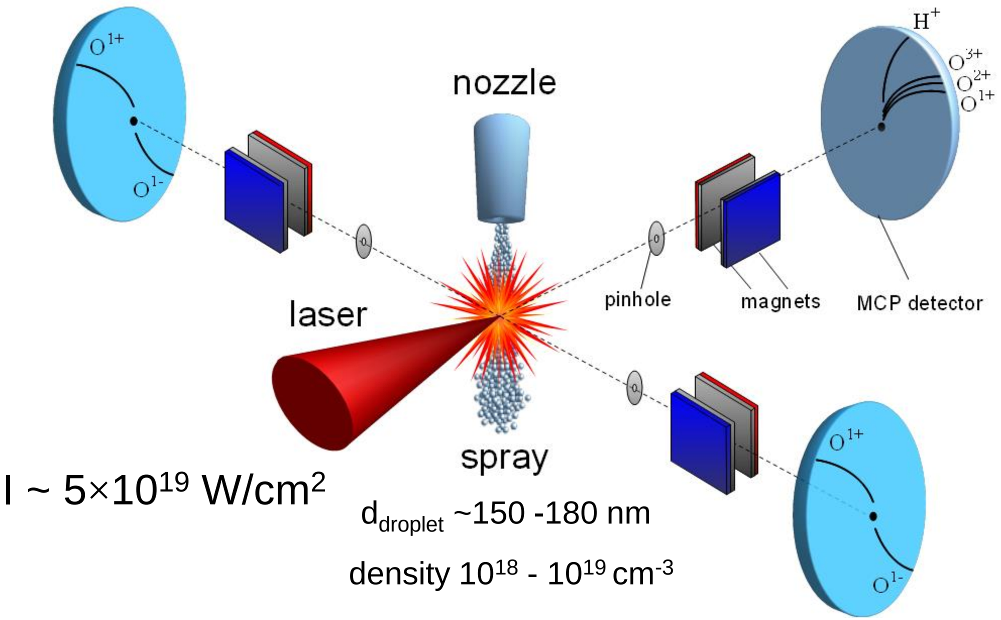




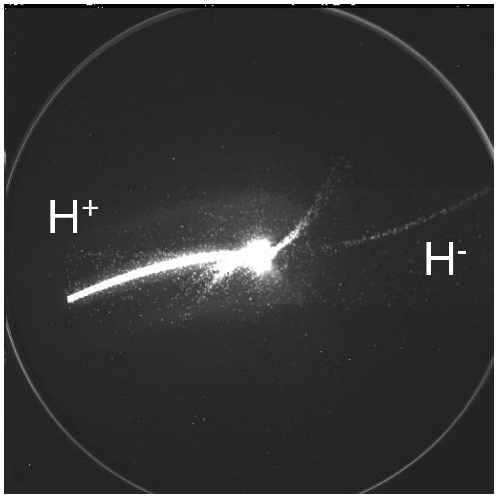


Energetic negative ion and neutral atom beams

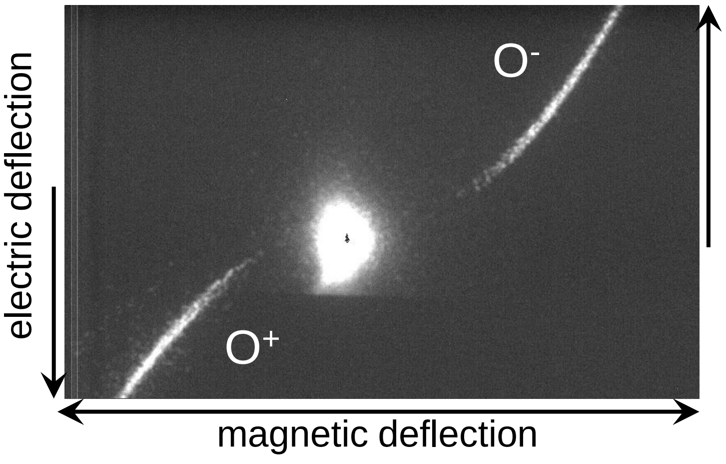
Ter-Avetisyan Sargis



***H^-* ~ 300 keV**



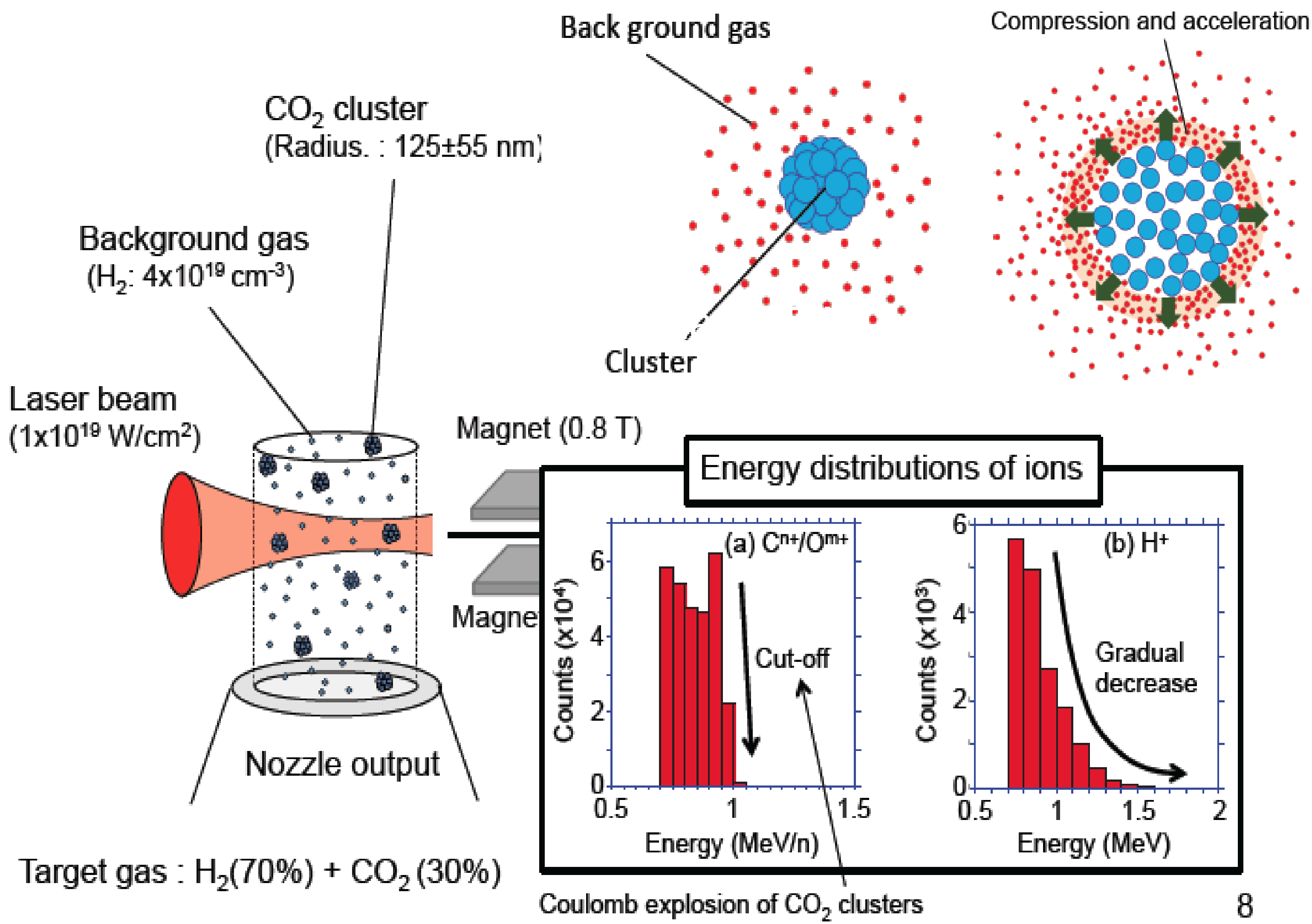
water spray



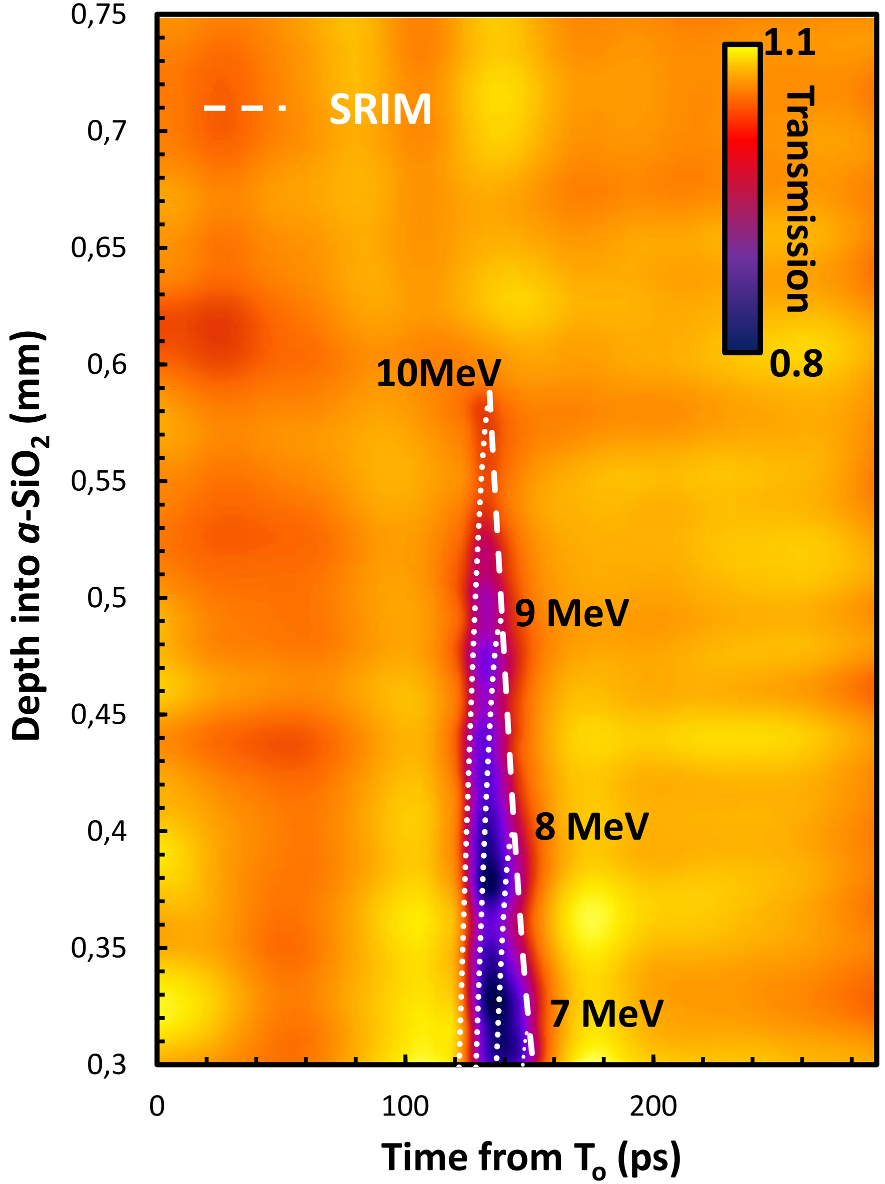
- negative ions are generated in near-elastic electron–capture and –loss processes

Ion acceleration from clusters

Y. Fukuda, KPSI JAEA



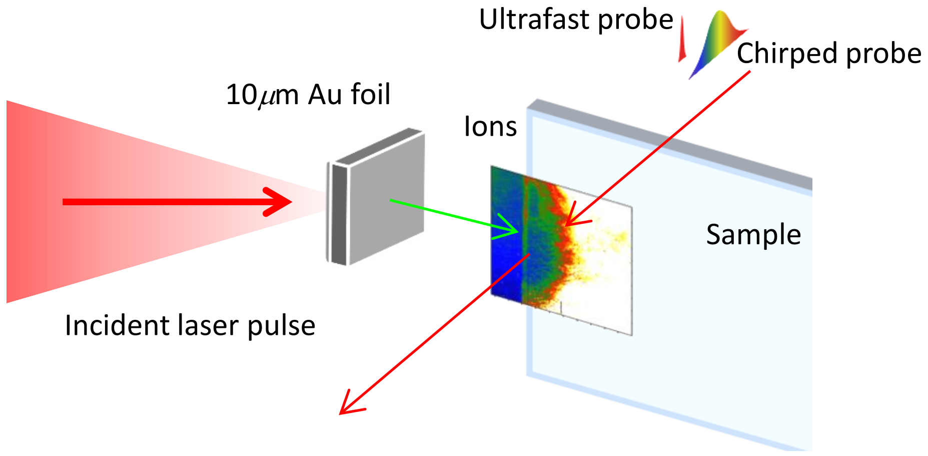
Metrology of picosecond laser driven ion bursts



Brendan Dromey

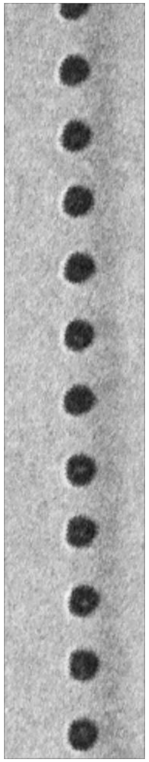
Queen's University Belfast

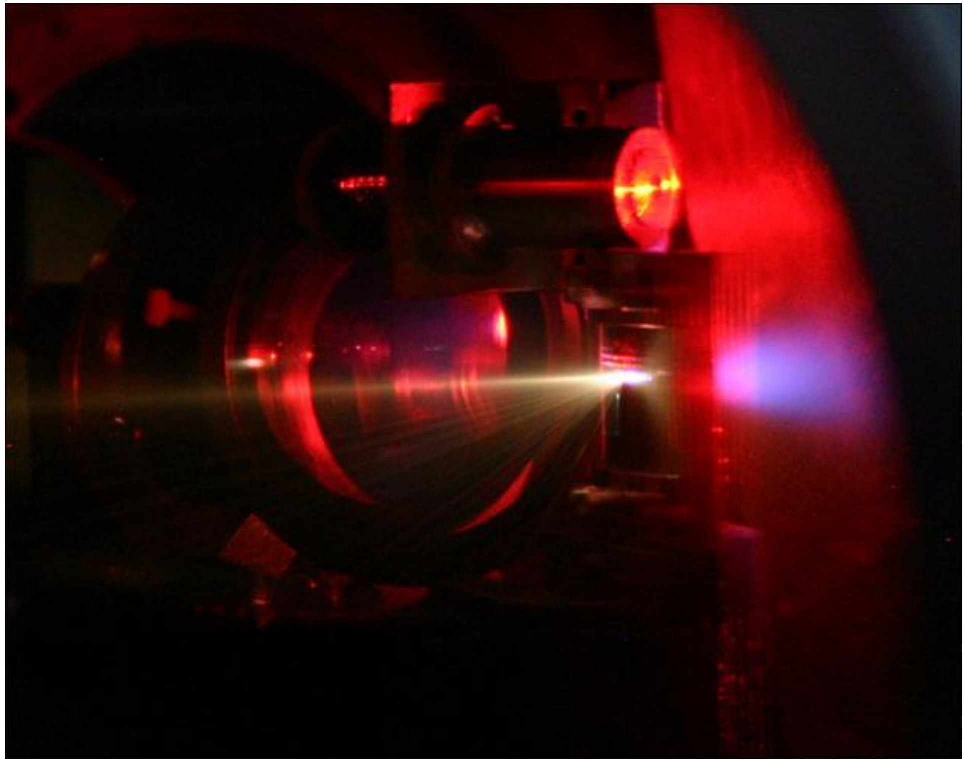
- Temporally resolved ion induced damage (opacity) – optical streaking method

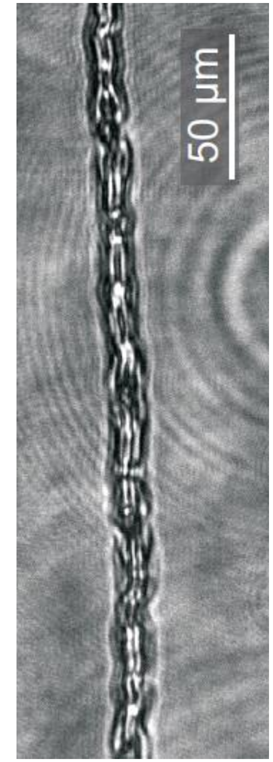


b.dromey@qub.ac.uk

Laser-ion acceleration using truly mass-limited targets







Malte C. Kaluza

Institute of Optics and Quantum Electronics and Helmholtz-Institute Jena
Friedrich-Schiller-University Jena, Germany

TR 18

ultra optics

Bundesministerium für Bildung und Forschung

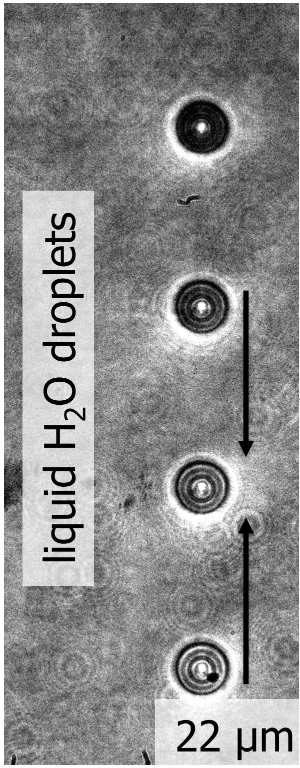
oncooptics

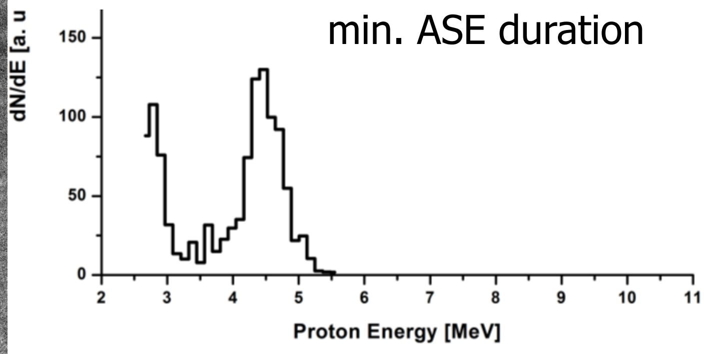
seit 1558

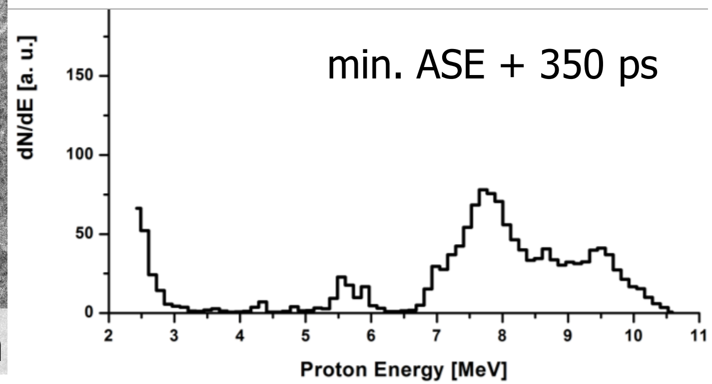
HELMHOLTZ GEMEINSCHAFT

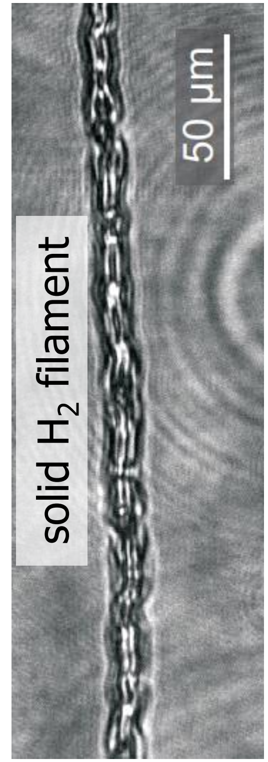
Helmholtz-Institut Jena

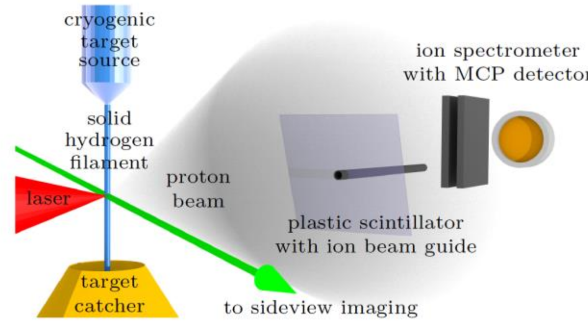
Proton acceleration from H_2O droplets and solid H_2 filaments

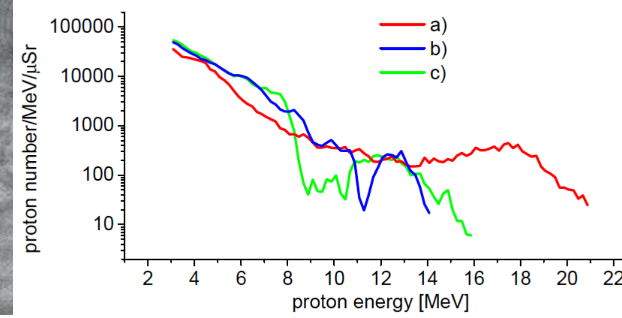












@ JETI-laser (750 mJ, 25fs)

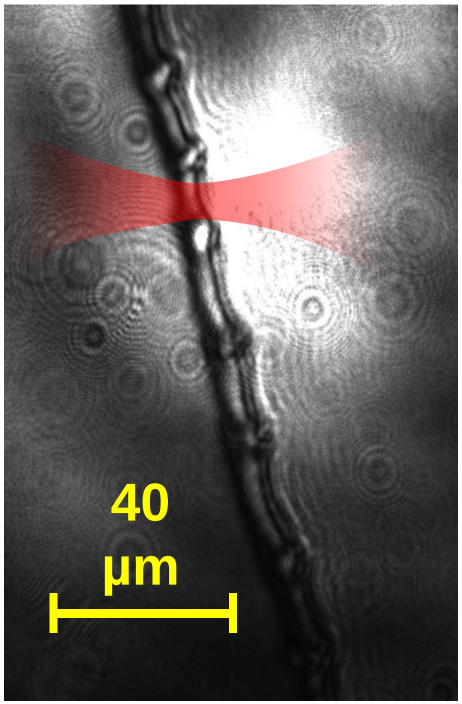
- quasi-monoenergetic p^+-spectra
- highest E_{max} for mid. ASE-duration (prepulse-dependent e-heating)

@ POLARIS-laser (2.5 J, 215fs)

- modulated p^+-spectra
- conversion efficiency > 10%

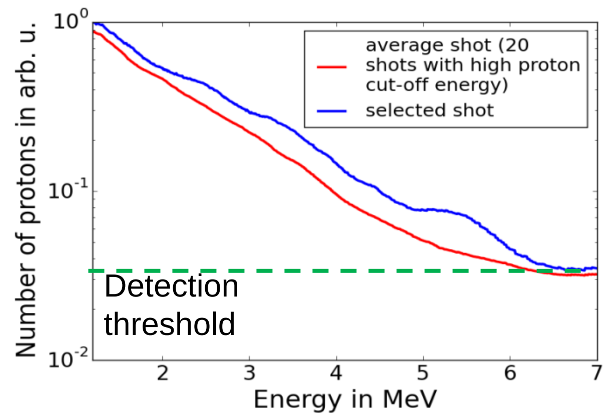
J. Polz *et al.,* submitted (2015)

Cryogenic Hydrogen jet



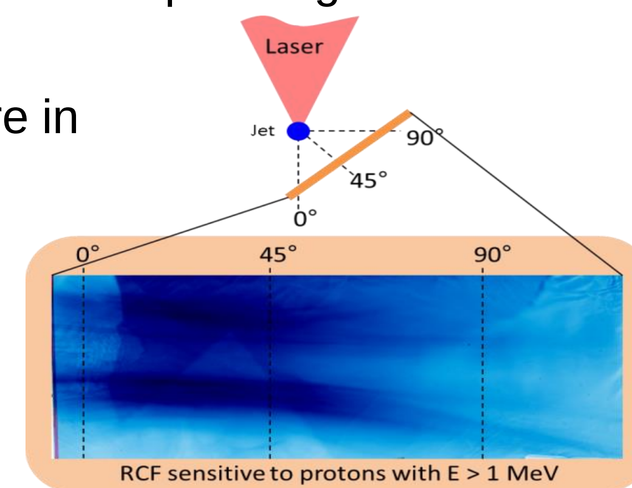
- Regenerative high repetition rate target (2-10 micron)
- Low density (40 n_c @ 800nm)

- Exponential proton spectra with cut-off energies of several MeV (similar to ref. foil)



- 1 Hz repetition rate proton generation

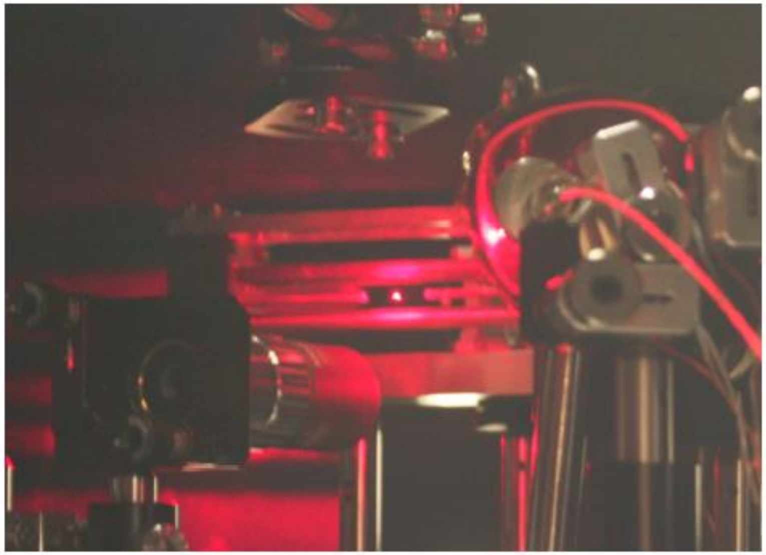
- Wire-like structure in spatial proton emission



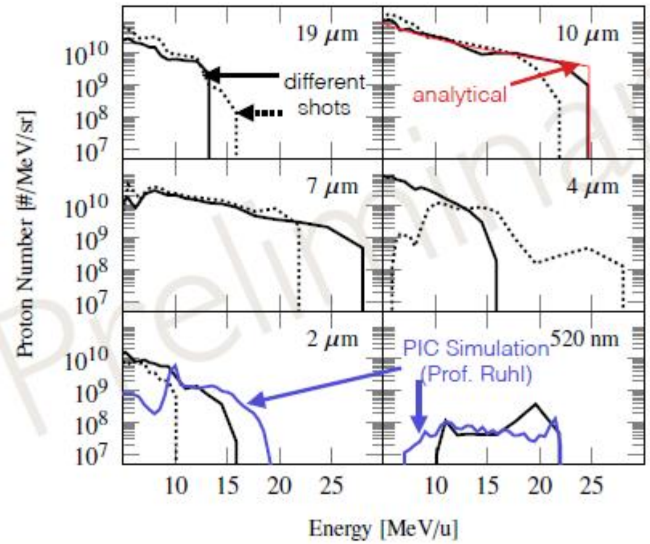
Levitating targets for laser ion acceleration

T. Ostermayr. P. Hilz, D. Haffa, J. Gebhard, J. Schreiber

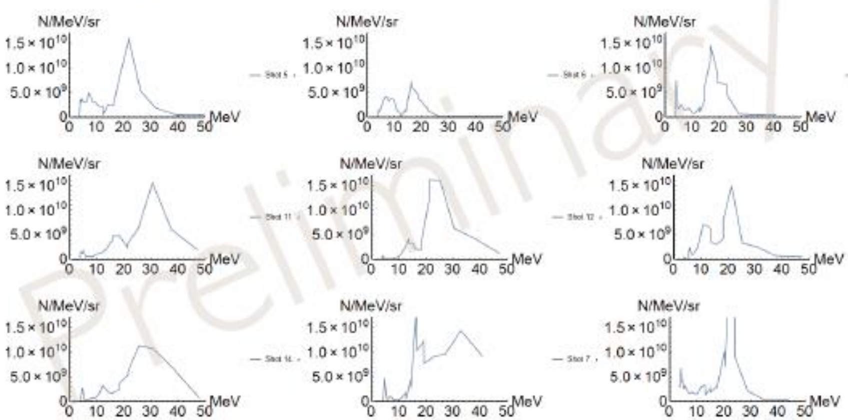
Paul trap with levitating target



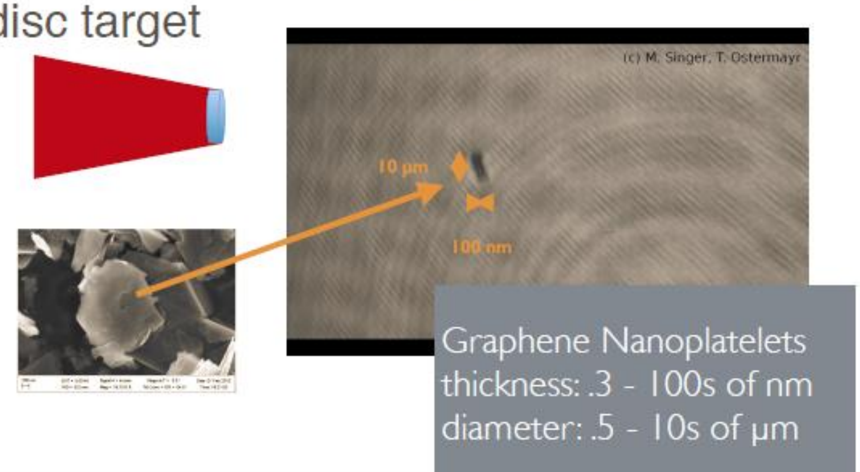
TPW experiment proton spectra target size scan



PHELIX, different proton spectra (all targets 1 μm)

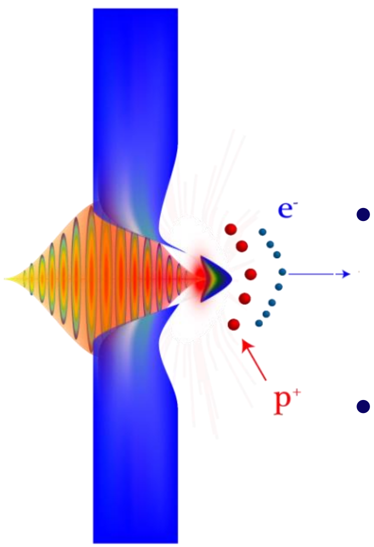


soon: isolated (levitating) disc target



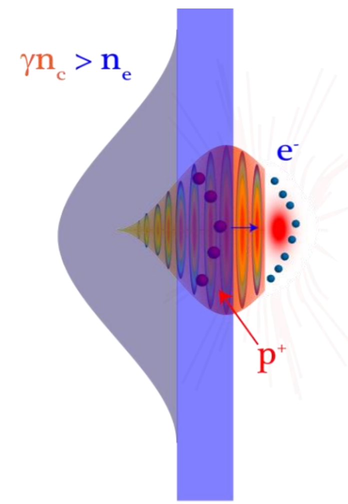
Ultrathin (nm) foils experiments

RPA – Light Sail



- **GEMINI**
  C. Scullion, QUB
  M. Zepf, QUB, Jena
- **PULSER, GIST**
  W. Ma, LMU
- **POLARIS**
  G. A. Becker, Jena
- **VULCAN**
  A. Alejo, QUB

Relativistic transparency regime



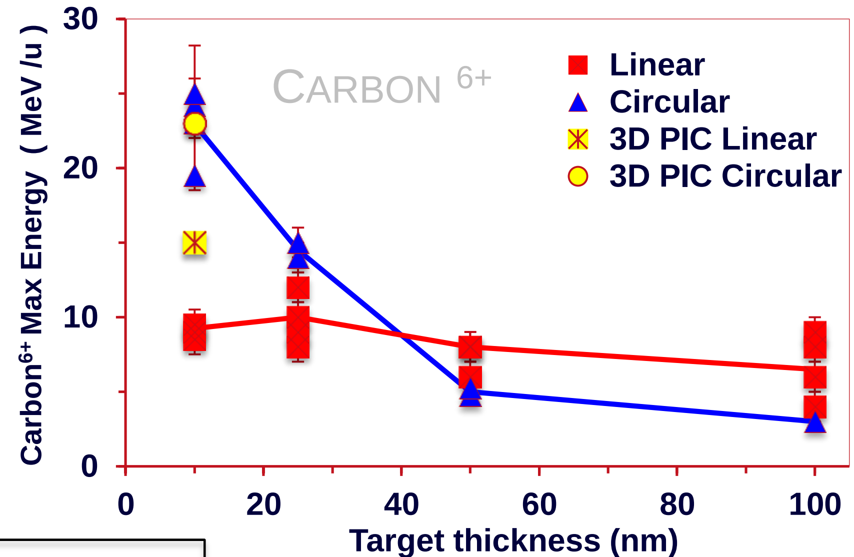
VULCAN
N. Dover (G. Hicks), IC

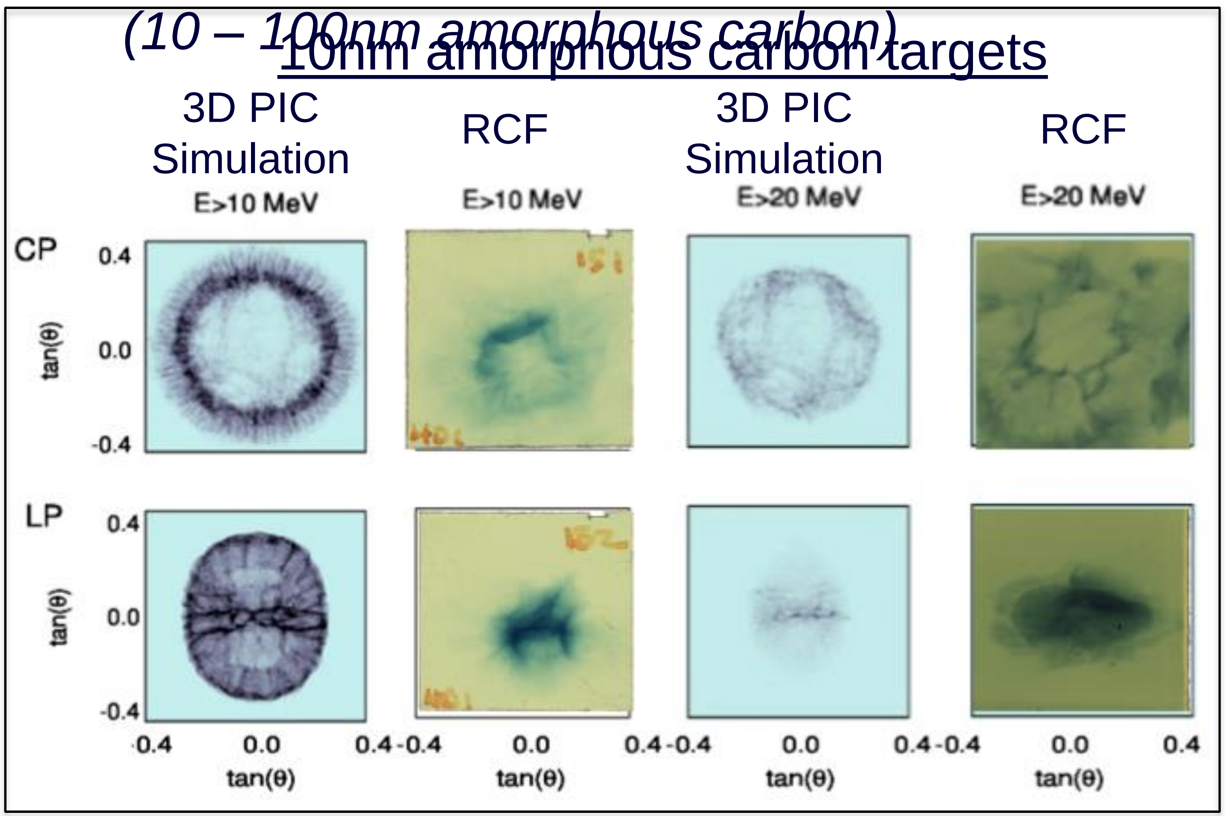
Also plenaries: P. McKenna (Strathclyde), A. Sgattoni (Pisa), V. Bagnoud (GSI
WG2 talks by R. Prasad, Dusseldorf

Clare Scullion - csculllion57@qub.ac.uk - Queen's University Belfast – EAAC September 2015

Optimising Ion Acceleration from Ultra Thin Foils on the Astra Gemini Laser Facility

Investigating the effects on ion acceleration when varying laser pulse polarisation and target thickness
(10 – 100nm amorphous carbon)



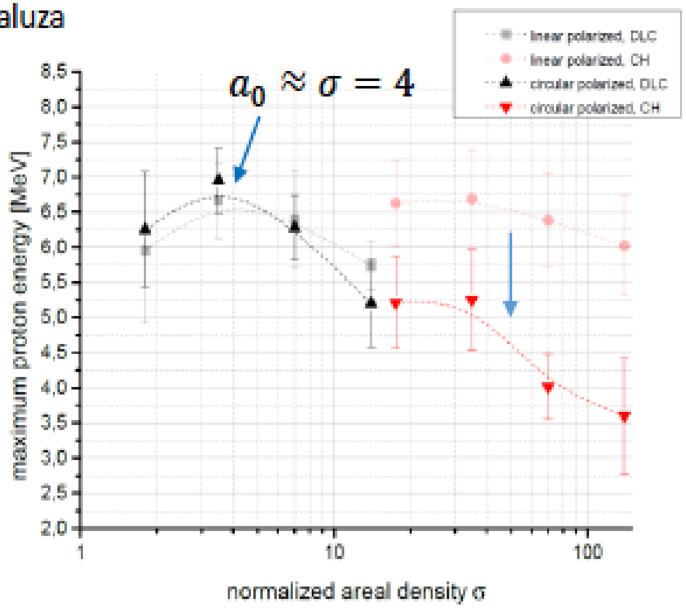


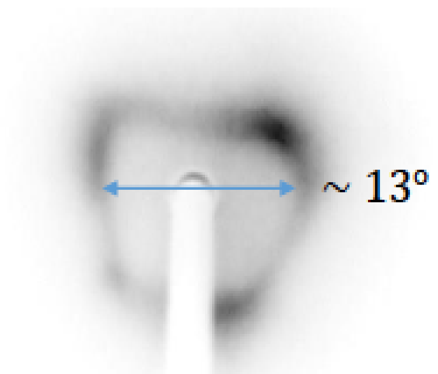
- 3D PIC simulations reproduce beam profile and match maximum carbon and proton energies
- Results from CP laser pulse and thin targets (10nm) indicate onset of light sail RPA
- Rayleigh-Taylor-like instabilities are evident in RCF and 3D simulations for

Laser-Driven Proton Acceleration at POLARIS with SHG and nm thin Foils

G. A. Becker, J. Reislöhner, M. Hornung, A. Seidel, J. Bin, L. Bock, F. Brack, M. Hellwing, P. Hilz, S. Keppler, A. Kessler, S. Kraft, S. Kuschel, H. Liebetrau, J. Polz, H-P. Schlenvoigt, F. Schorcht, H. Wang, K. Zeil, U. Schramm, M. Zepf, J. Schreiber and M. C. Kaluza

- using ultra-high contrast laser pulses via second-harmonic-generation
  - ➢ verification of $a_0 \approx \sigma$ (10 nm DLC-foil) and circular polarization as optimal for ion acceleration → Light-Sail (laser pulse energy for circ. pol. was ~80% of pulse energy for lin. pol.)
  - ➢ reduction of max. proton energy for circ. pol. for plastic foils (100 nm – 800 nm) → TNSA dominated
- very stable ring-like proton beam profile for plastic foils
  - ➢ less energetic protons in ring
  - ➢ emission normal to target rear surface
  - ➢ ring-like deflection probably caused by $B \gtrsim 10$ kT magnetic field behind target





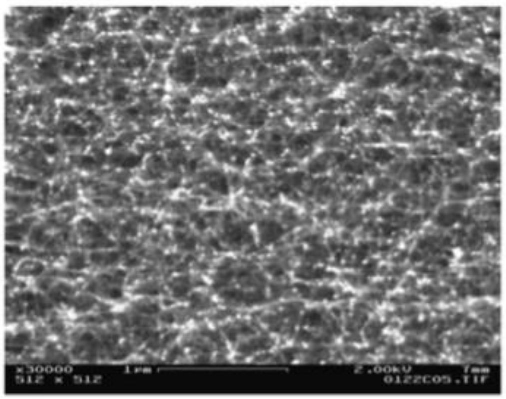
proton beam profile
for 100 nm thick plastic foils

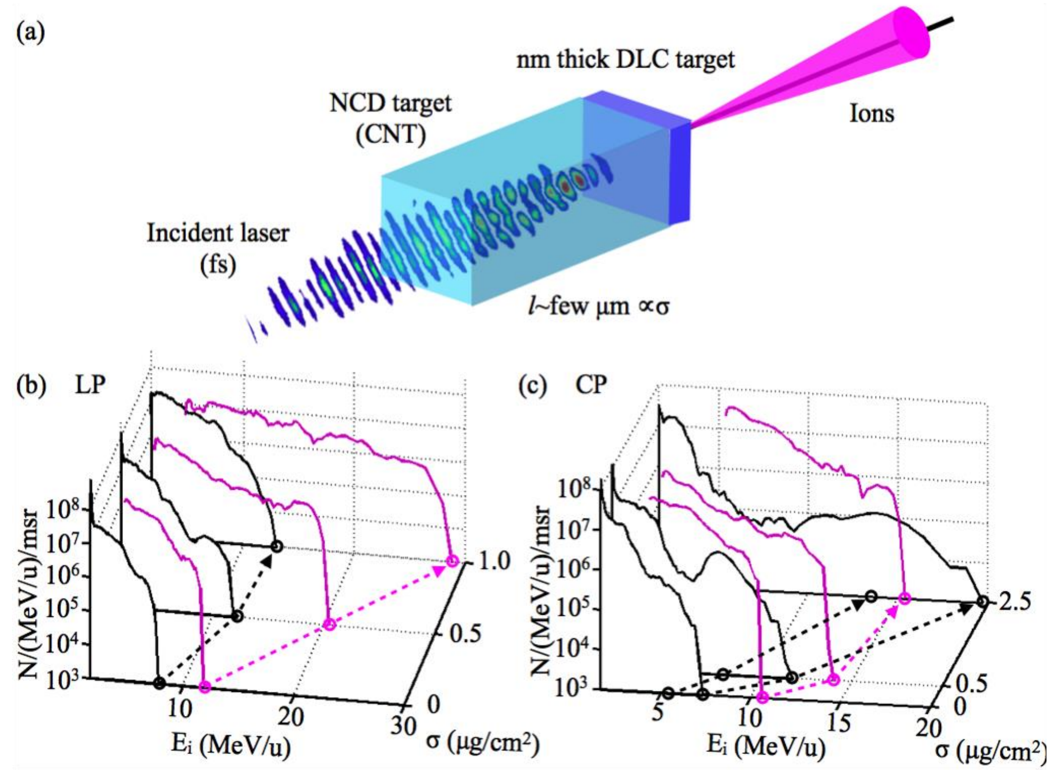
MAX-PLANCK-INSTITUTE OF QUANTUM OPTICS GARCHING · MPQ · LMU · TR 18 · HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

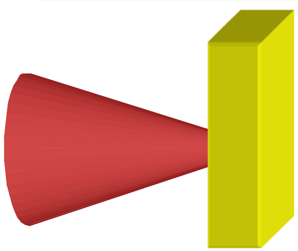
M. Zepf, QUB/Jena
W. Ma (LMU)

Carbon Nanotube enhanced laser interactions

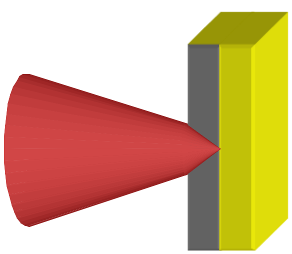
Strong relativistic non-linearity in CNT foam @ ~critical density







Single foil



CNT+Foil

- Up to Factor 8 intensity enhancement,
- Carbon ion energy enhanced up to 3x
- Carbon preferentially enhanced for Circ Pol

ASTRA GEMINI (J.Bin *et al*, PRL, 2015) + PULSAR, IBS - GI

Bulk Deuterium Acceleration in the Light Sail Regime

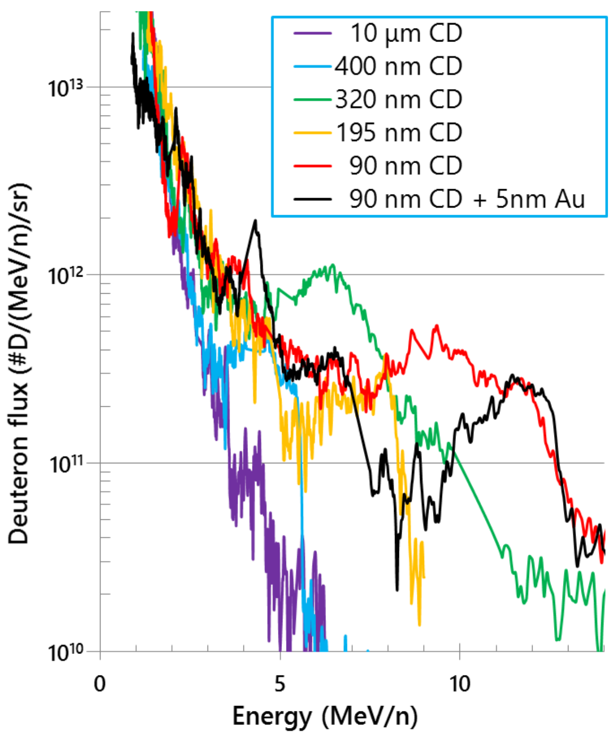
A-SAIL
ADVANCED STRATEGIES FOR ACCELERATING IONS WITH LASERS

A. Alejo, QUB

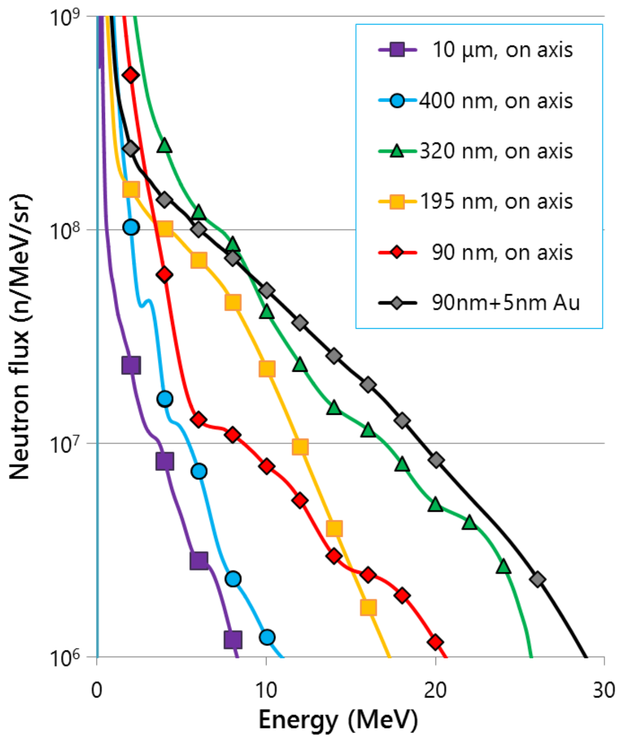
Queen's University Belfast

eutron spectroscopy assists in the characterization of the ion acceleration process

deuterons



neutrons

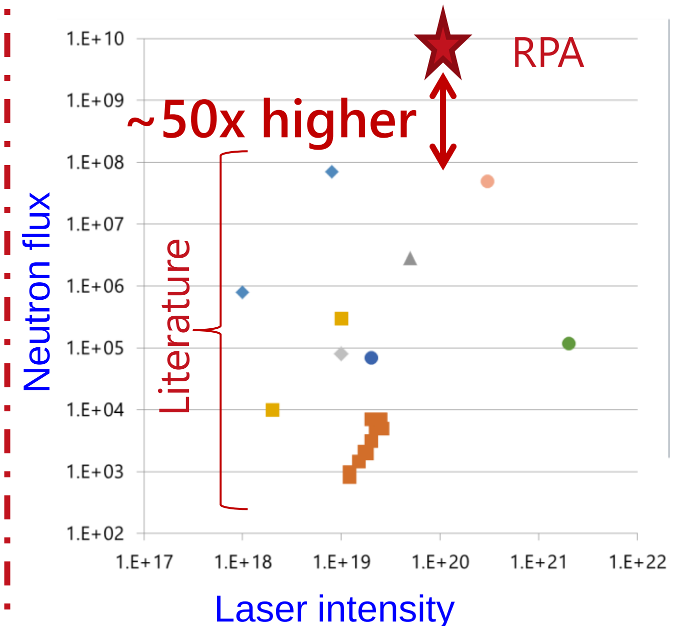


TNSA → Low flux, isotropic neutron emission

RPA bunches → Increase in neutron generation

Transparency → Drop of efficiency

Strong correlation between RPA-type bunching and in-flight neutron production from D-D reactions



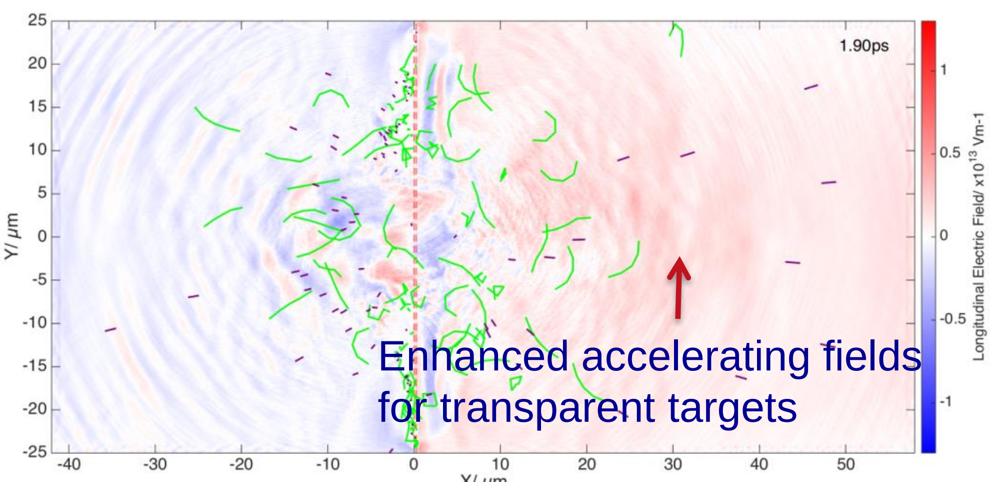
Single target neutron data (no catcher)

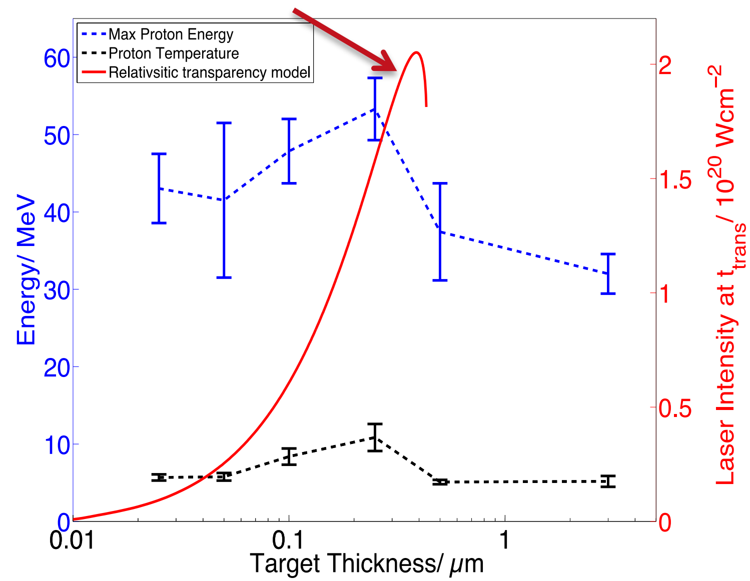
Energetic ion beams from relativistically transparent ultra-thin foils using Vulcan PW laser

G. Hicks – Imperial College London

Proton beam from 250 nm target:

- 25 nm to 3 um thickness plastic foils expand and become transparent during laser interaction
- Beams optimal when transparency occurs at peak laser intensity
- Protons accelerated up to ~60 MeV

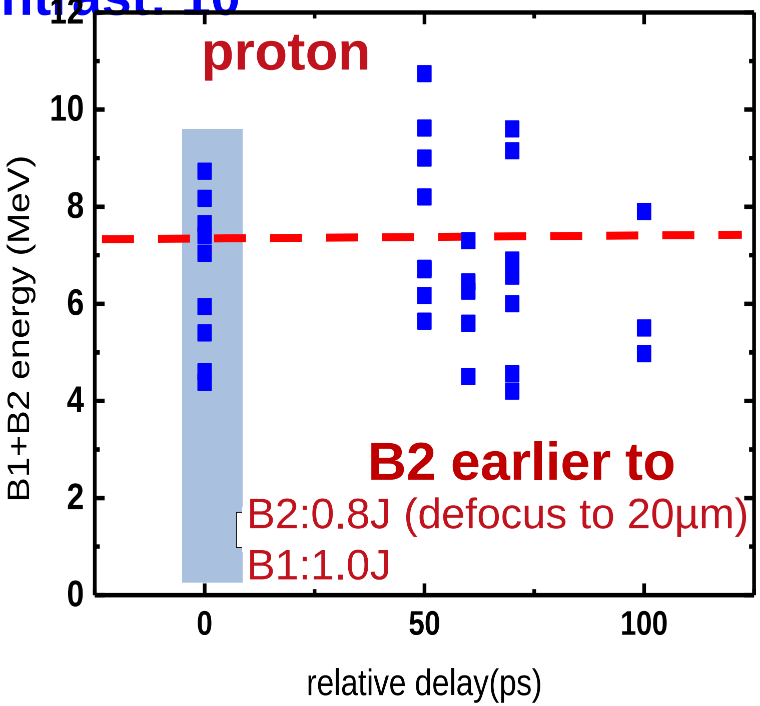


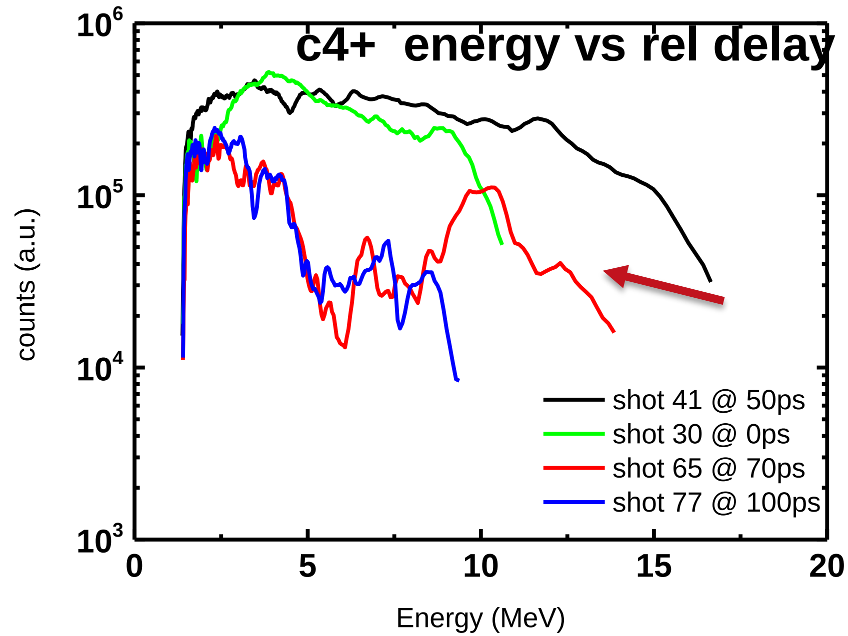


Enhancement in proton/ion energy and spectral modulation by varying relative delay of

HEINRICH HEINE UNIVERSITÄT DÜSSELDORF

2x200TW Laser system, Intensity on target: 2×10^{20} W/cm^2, pulse: 30fs, contrast: 10^{10}





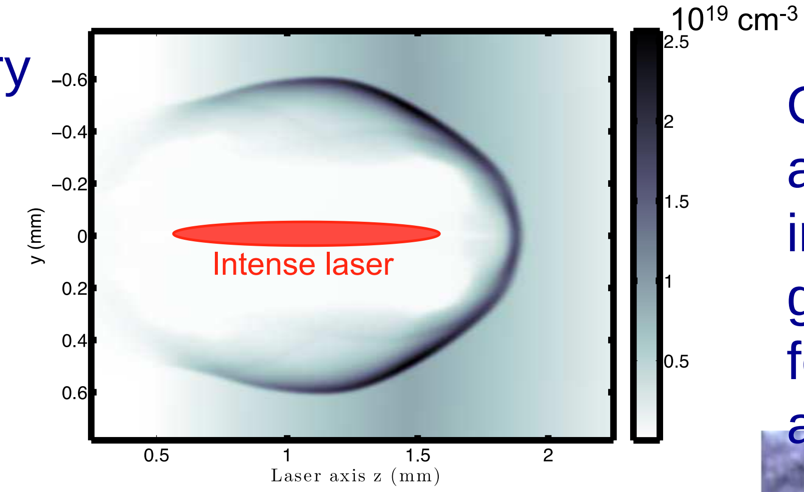
- ➢ **Optimum proton energy gain at 50ps delay (red line marks the max cut off energy for individual beams)**
- ➢ **About 50% enhancement in proton energy compared to individual beam energies**

- ➢ **C^{4+} ion follow the same trend**
- ➢ **Strong modulation (shown by arrow) appears at later delay than the optimum proton delay**
- ➢ **Presents possibilty of controlled spectral tailoring**

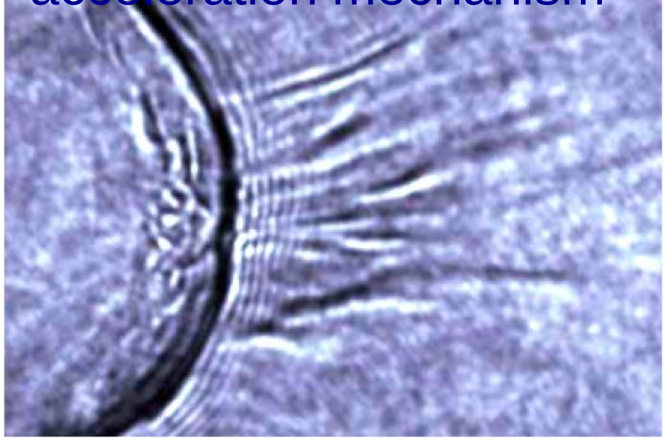
Ion acceleration from laser driven collisionless shockwaves in optically shaped gas targets

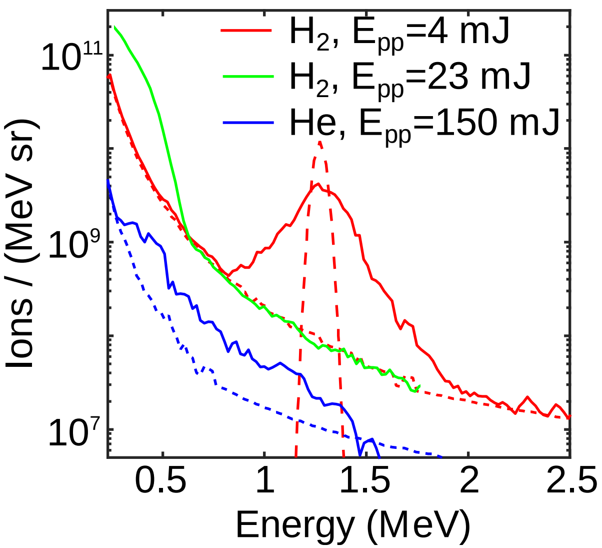
N.P. Dover et al., Imperial College London, Stony Brook University, ATF Brookhaven National Lab

Used secondary pulse to drive blastwaves, providing short scale length density gradients:



Observe filamentation and beam-plasma instabilities from laser generated electrons, feeding back into ion acceleration mechanism



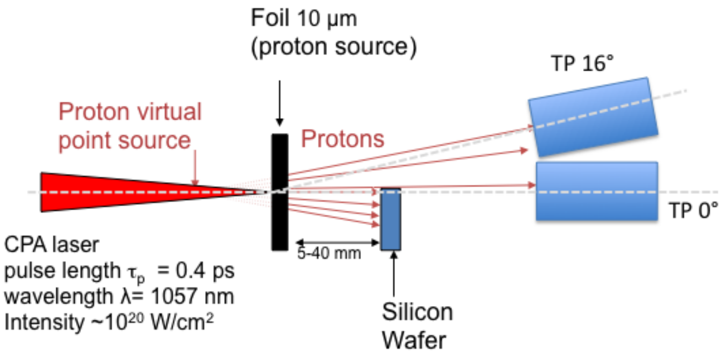


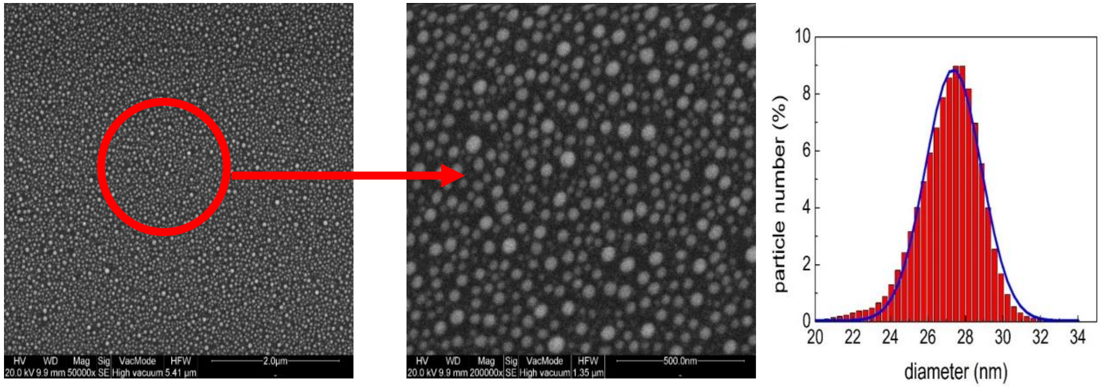
Generated broadband He and H beams, spectrally peaked H beams using this technique

Tresca, Dover, et al., PRL ***115*** *(2015)*

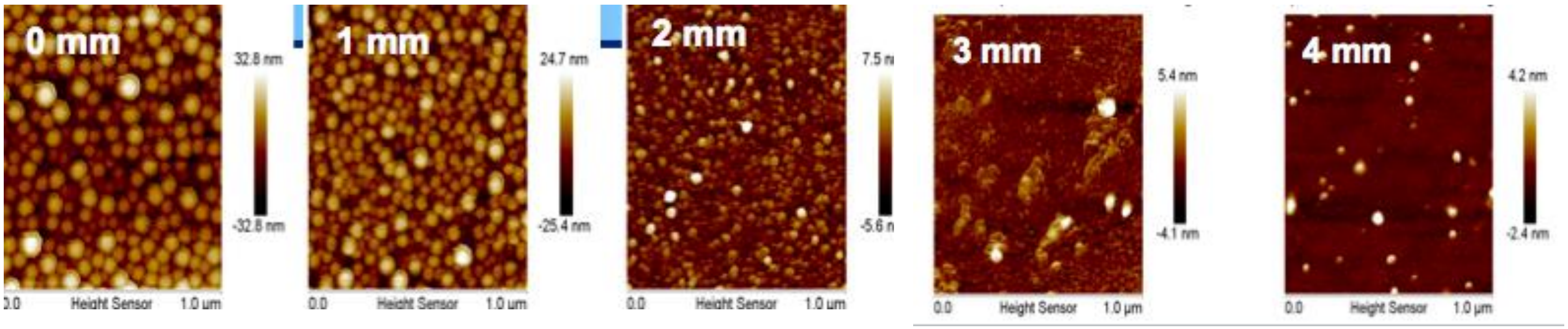
Applications:
Laser-driven Proton Beam for nanoparticle production

P.Antici, INRS





We obtain NP with a SD<6 % over very large surfaces (SEM images)



NP characteristics change with increasing distance from the beam center

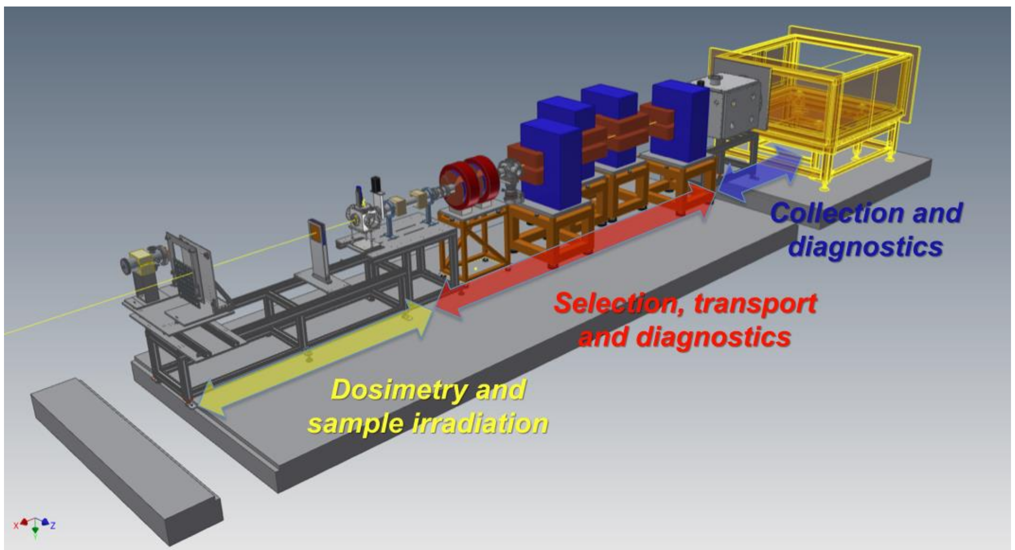
Patent US 62/158,704 (Goudreau Gage Dubuc S.E.N.C.R.L. - L.L.P.)

The ELIMED transport and dosimetry beamline for laser-driven ion beams

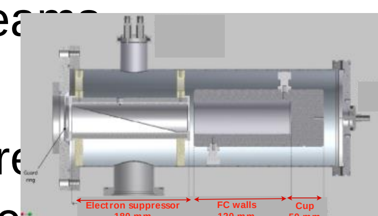
Francesco Romano , Giuliana Milluzzo - INFN-LNS, Catania, Italy

ELIMED (ELI MEDical applications)

to demonstrate that laser accelerated high energy ion beams can be potentially used for multidisciplinary applications, including the medical one.



- **Collection and focusing**
  - set of PMQ in Halbach array
- **Selection and transport**
  - 4 C-shaped resistive magnets
- **Dosimetry and sample irradiation**
  - SEM, multi-gap chamber, **Faraday cup**
- **Diagnostics with TOF detectors**



- Prototypes tested with conventional accelerated and laser-driven beams
- Feasibility studies of final transport elements completed
- Development of the detectors for diagnostics and dosimetry in progress
- ELIMED beam line delivered and assembled @ ELI-Beamlines in 2017

Summary WG2

- Investigations reported covered a broad range of mechanisms and target media

- There is still life in the established TNSA mechanism – with novel optimizati and characterization techniques, as well novel applications

- Significant amount of work on ultrathin foil acceleration, with signatures of Radiation Pressure Acceleration (LS) or Relativistic Transparency enhancem depending on the target opacity

- Significant technological innovation in targetry (droplets, levitating spheres, cryogenic jets, composite materials) with new features emerging in the accelerated beams

- First laser-driven beamlines are being developed (LIGHT, ELIMED)