Working Group 2 Summary

Ion Beams from Plasmas

Alessandro Flacco (LOA/ENSTA)
Louise Willingale (University of Michigan)

WG2: ion beam presentation themes

Energy scaling and beam quality

High-rep-rate targets

TNSA for Applications

External transport and focusing for applications

Neutron generation

Novel / advanced mechanisms

Relativistically induced transparency

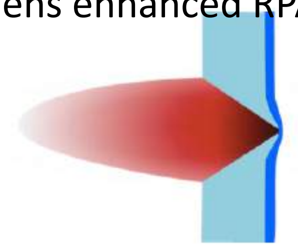
Near-critical targets

Novel / advanced ion acceleration mechanisms

Cascaded laser acceleration of carbon ions from double-layer nanotargets

Wenjun Ma (Peking University)

Near-critical plasma lens enhanced RPA



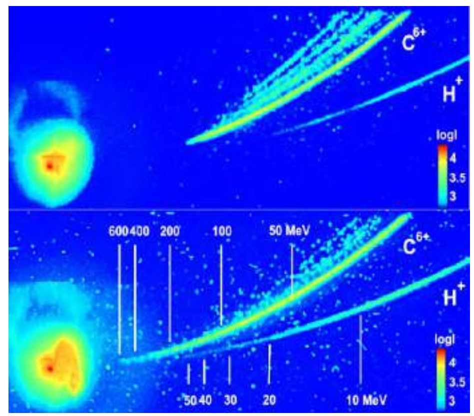
Single layer target

20 nm DLC

Double-layer target

20 nm DLC+80 um CNF

(optimal parameters)



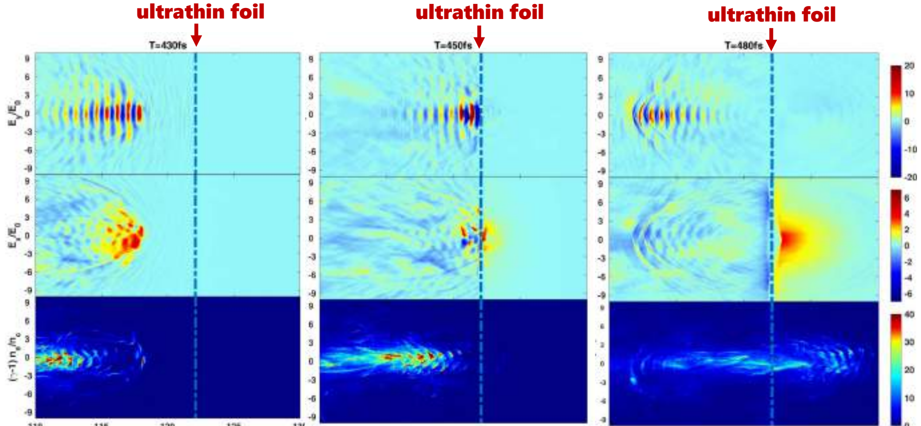
J.H.Bin*, W.J.Ma*, et. al. *Physical Review Letters 115, 064801 (2015).*

Cascaded acceleration

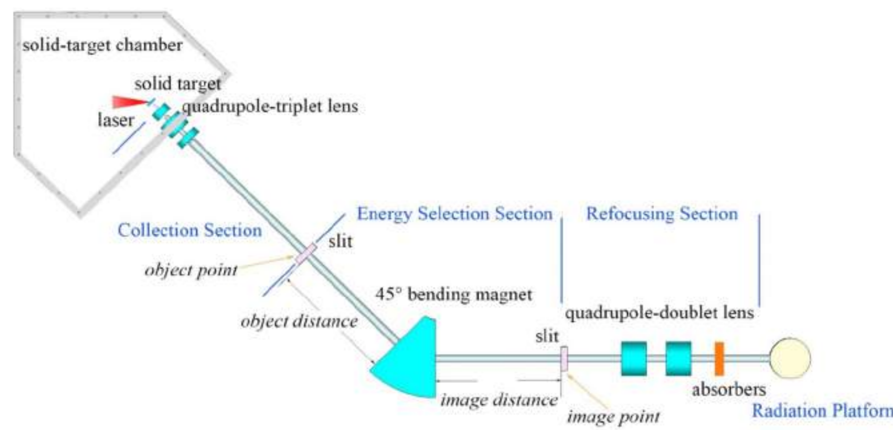
Laser shaping and electron flow generation

Stage 1 : Radiation pressure acceleration

Stage 2 : Sheath field acceleration



CLAPA laser

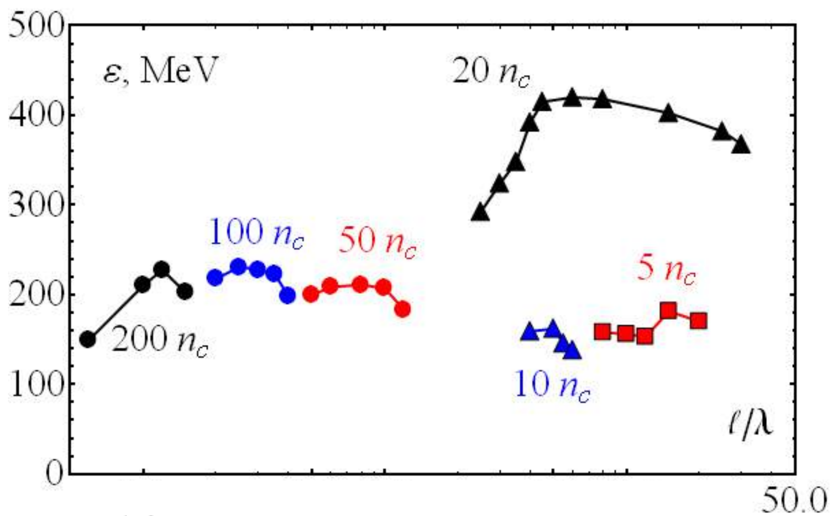


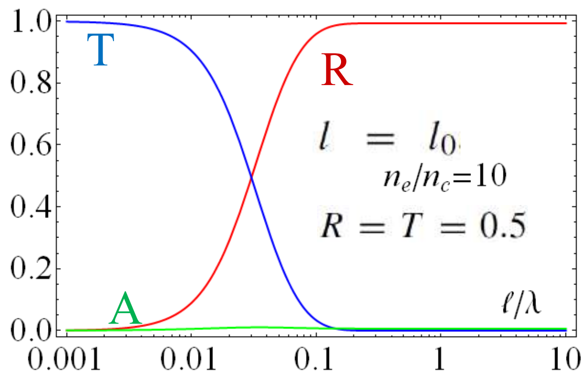
New concept of light ion acceleration from low-density target

A.V. Brantov, V. Yu. Bychenkov (P.N. Lebedev Physical Institute of the Russian Academy of Sciences)

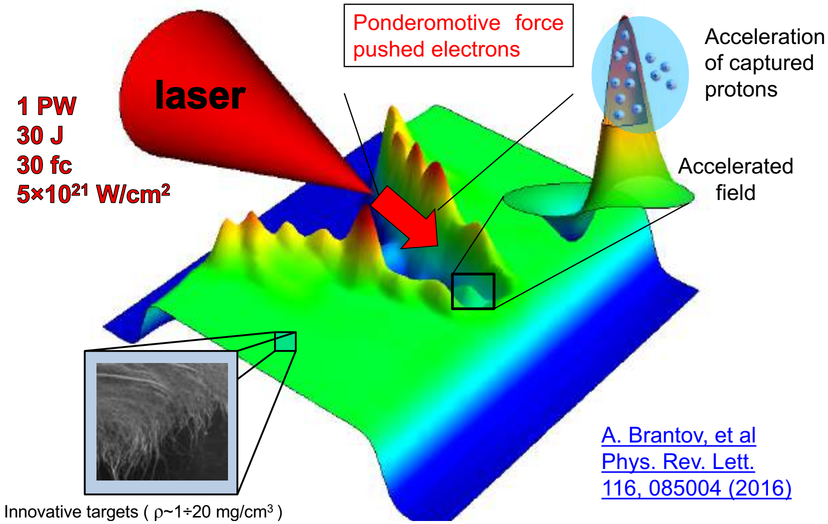
Synchronized proton Acceleration by ultraintense Slow Light (SASL)

Proton acceleration: maximum energy vs. thickness & density of the target.

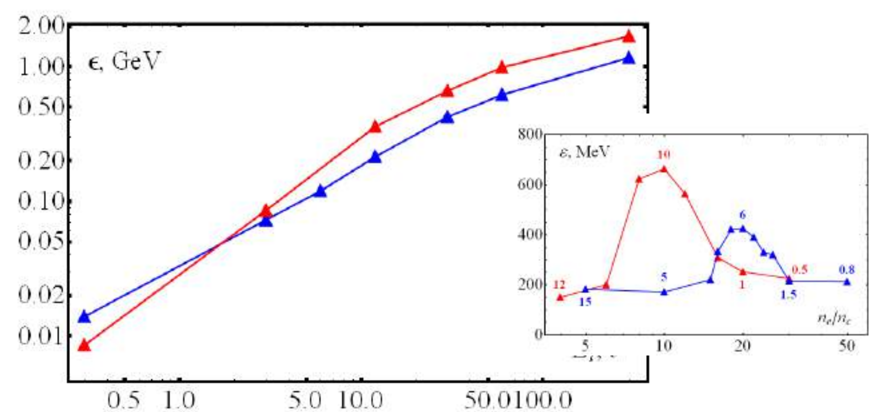




Proton acceleration by ponderomotive potential



A. Brantov, et al Phys. Rev. Lett. 116, 085004 (2016)

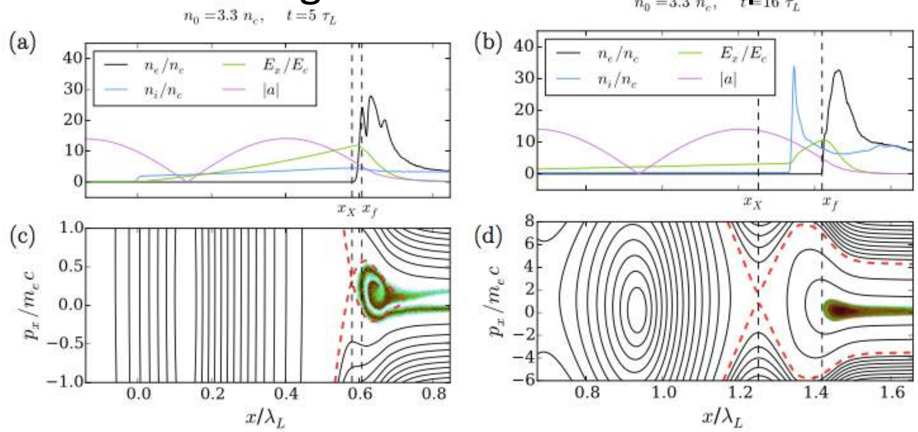


Kinetic and finite ion mass effects on the transition to relativistic self-induced transparency in laser-driven ion acceleration

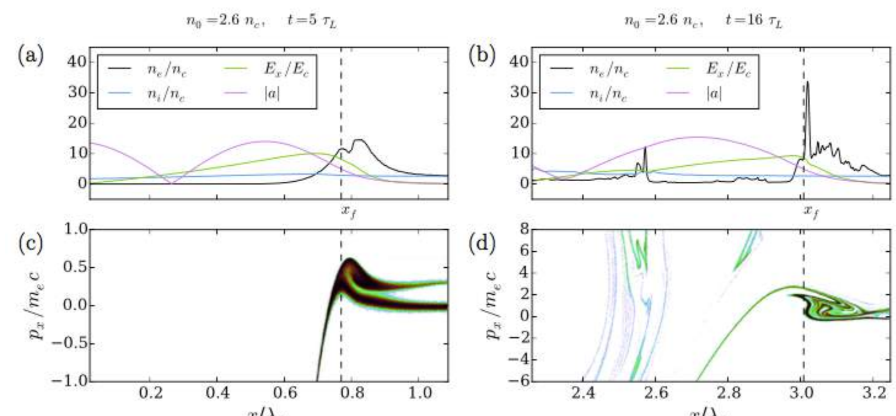
Evangelos Siminos (Chalmers University of Technology, Sweden)

- Complex transition physics
- Fast electron escape triggers propagation
- Ion motion mitigates electron escape by inducing widening of separatrix
- Dynamic transition: Short time transient → long time effect on ion spectra
- Transverse instabilities need to be controlled

In HB regime no electrons escape



In RSIT regime electrons escape continuously

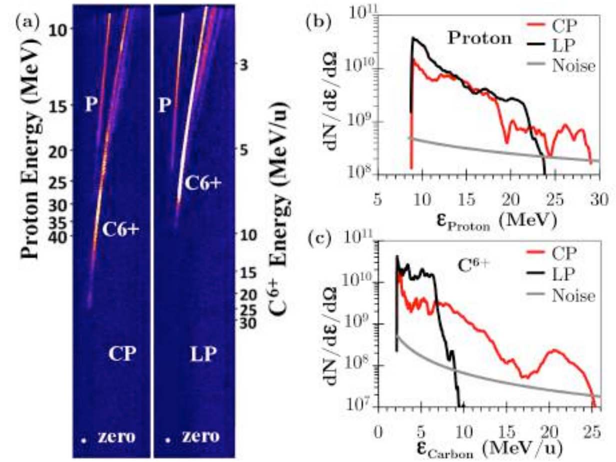


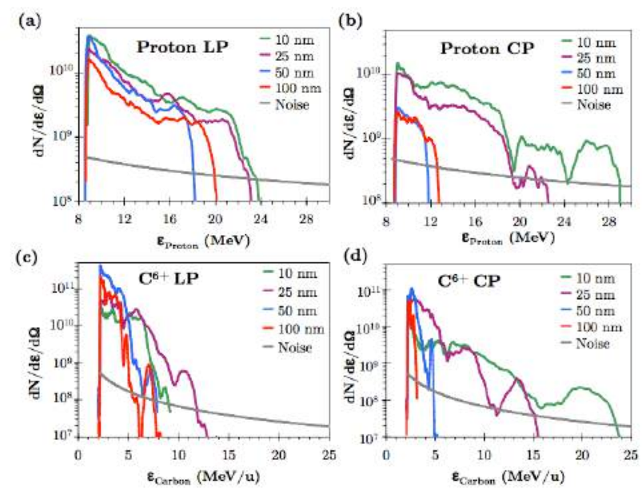
E. Siminos, M. Grech, B. Svedung Wettervik, T. Fülöp (2016), arXiv:1603.06436, to appear in NJP
E. Siminos, M. Grech, S. Skupin, T. Schlegel, V. Tikhonchuk, Phys Rev E **86** 056404 (2012)

Transition to Light Sail Acceleration from Ultrathin Foils

Aodhán McIlvenny (Queen's University Belfast U.K.)

- Linear polarisation produces higher energies for thicker targets – TNSA. Circular polarisation produces higher carbon and proton energies for targets thinner than 25nm indicative of a transition to radiation pressure acceleration
- Gemini laser (UK) campaigns produced a maximum of 25MeV/u C^{6+} (2013) on 10nm amorphous Carbon
- An optimum thickness of 15nm produced 33MeV/u C^{6+} (2017).
- Thinner targets produce lower energies as they become transparent and radiation pressure stops.
- Structure seen in proton beam profile shows how electron density is affected by transmitted laser pulse



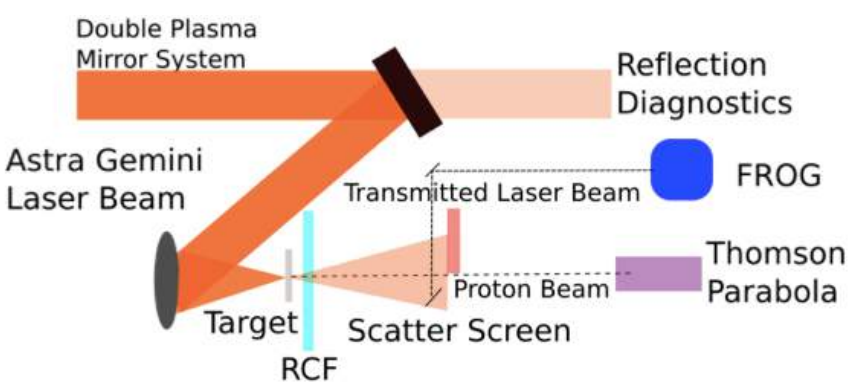


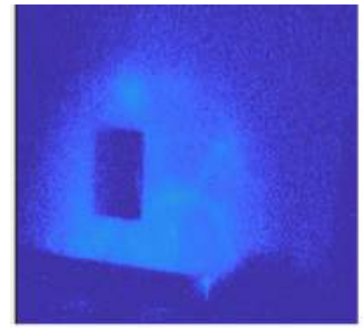
C. Scullion *et al* PRL **119**, 054801 (2017)

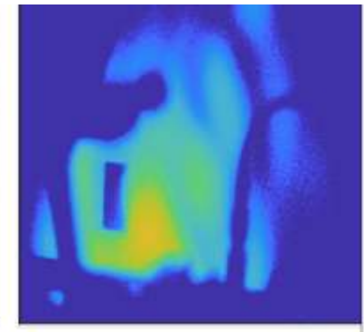
B. Gonzalez-Izquierdo *et al* Nat. Com. **7**:12891 (2016)

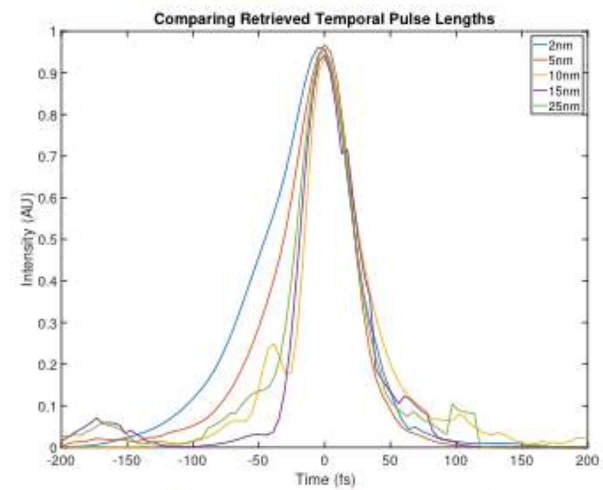
Exploring Energy Absorption in Ultra-Thin Targets

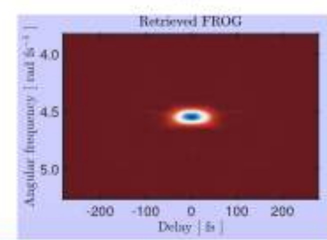
Emma-Jane Ditter (Imperial College London)









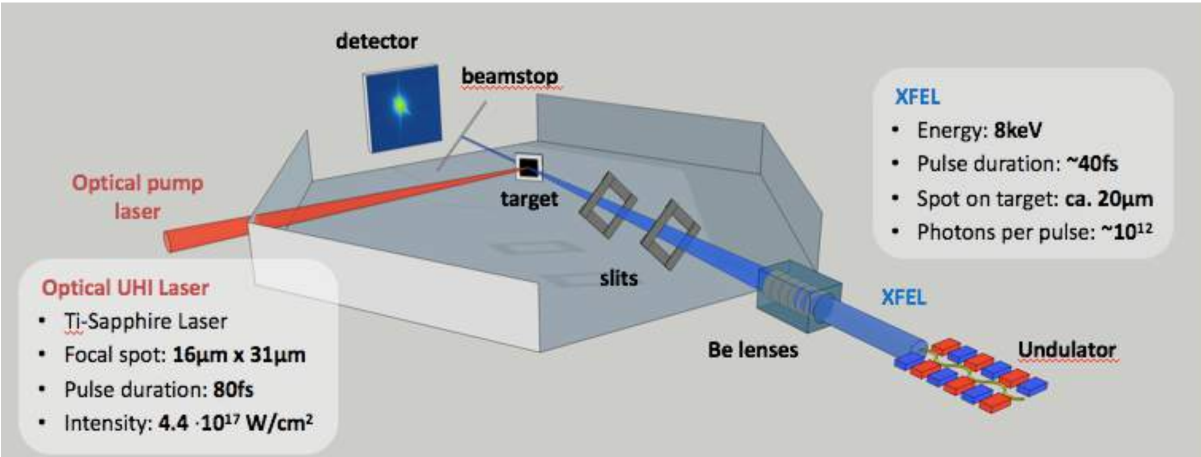


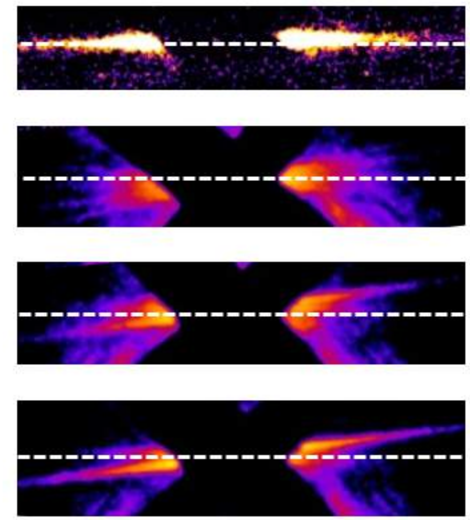
- Transmitted beam showed proof of RTA at 25nm, as confirmed through simulation
- Transmitted beam showed proof of pinhole effect as observed previously on the same laser system[1]
- FROG traces showed proof of optical shuttering for the thinner targets
- Temporal measurements of optical transition radiation for thick targets (50-100 nm) achieved

[1] Gonzalez-Izquierdo, B., Gray, R., King, M., Dance, R., Wilson, R., McCreadie, J., Butler, N., Capdessus, R., Hawkes, S., Green, J., Borghesi, M., Neely, D. and McKenna, P. (2016). Optically controlled dense current structures driven by relativistic plasma aperture-induced diffraction. *Nature Physics*, 12(5), pp.505-512.

Observation of ultrafast solid-density plasma dynamics using femtosecond X-ray pulses from a free-electron laser

Melanie Rödel (Institute for Radiation Physics, Helmholtz Zentrum Dresden-Rossendorf)

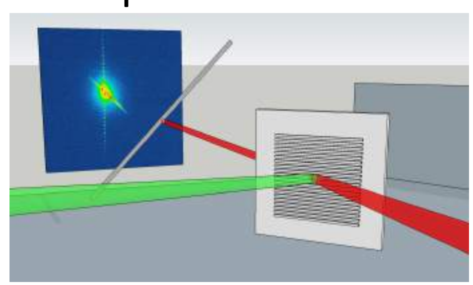


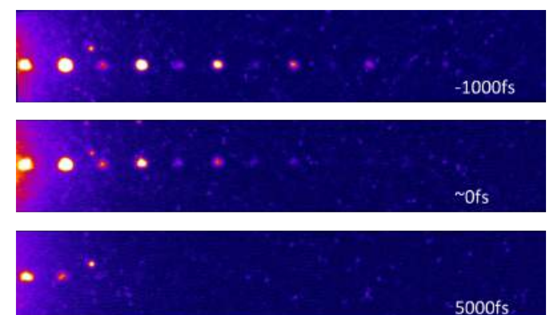


SAXS is a versatile tool to investigate laser target interaction on a few nm- to µm scale at a 10fs to ps temporal resolution

SAXS experiments help to understand:

- Instabilities
- Target front surface expansion
- Hole boring
- plasmons





HIBEF · European XFEL · LEIBNIZ-INSTITUT für PHOTONISCHE TECHNOLOGIEN ipht jena · UNIVERSITÄT SIEGEN · DESY · LCLS · SLAC NATIONAL ACCELERATOR LABORATORY · IBC. · TECHNISCHE UNIVERSITÄT DRESDEN · oncooptics

Target Normal Sheath Acceleration (TNSA)

Using PW, short laser pulse for ion acceleration in TNSA regime

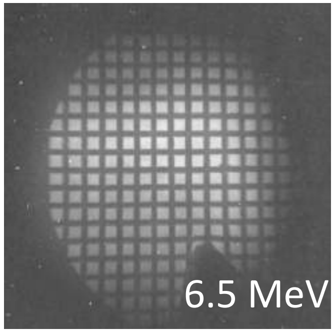
Sargis Ter-Avetisyan (ELI-ALPS)

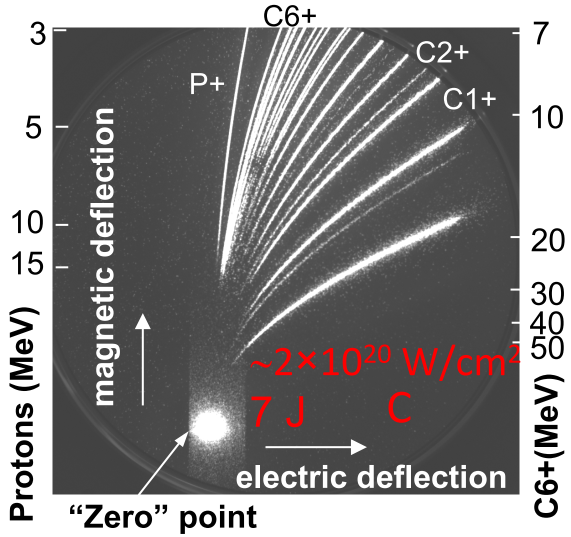
- ***The observed about 0.05 coefficient of back reflection is measured - it can have serious consequences when using PW laser systems in the interaction experiments.***

- **it is found:**
  - Rear side protons energy scaling $\sim I^{1}$
  - Front side energy scaling $\sim I^{0.5}$

- ***proton source and beam properties***

e.g., proton image of the mesh





- **It is demonstrated** that proton beam has distinct different emission characteristics along and perpendicular to the laser polarisation directions.

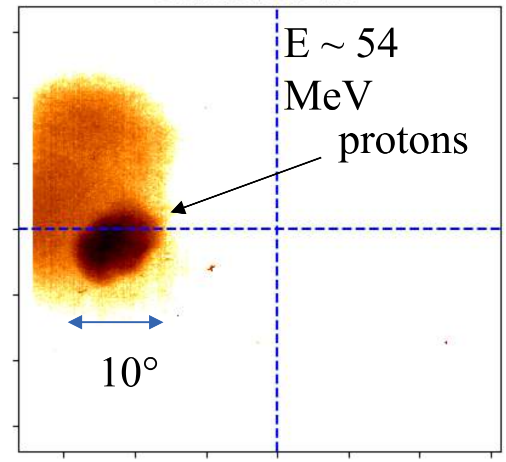
- **The normalized emittance** of 6.5 MeV proton beam:
  - 2.2 π mm mrad in laser polarisation direction
  - 1.6 π mm mrad perpendicular to laser polarisation direction

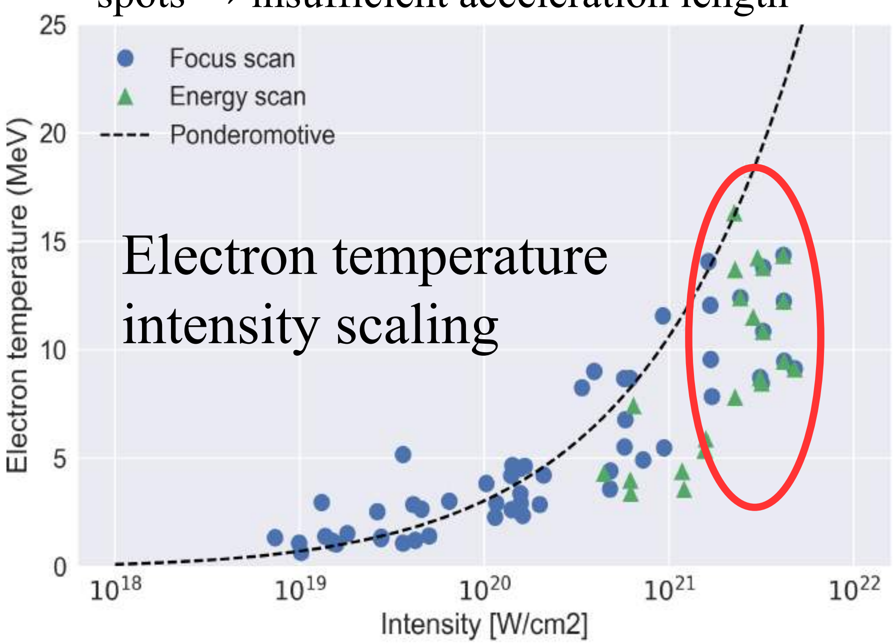
There is still life in the established TNSA mechanism

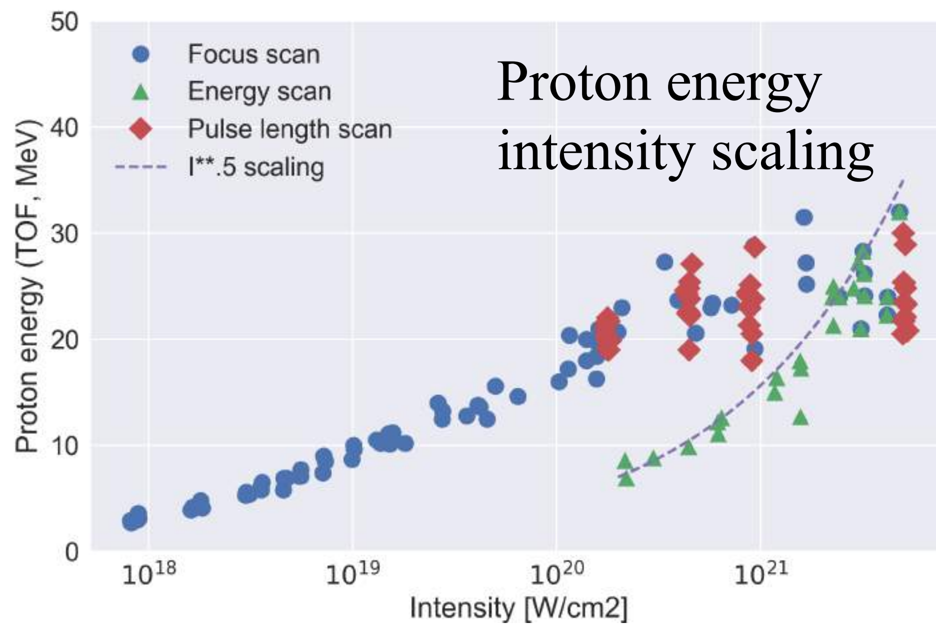
Sheath acceleration up to 5×10^{21} Wcm^{-2} @ Kansai Photon Science Institute

N. P. Dover, KPSI, QST, Japan

- Upgraded J-KAREN-P → ~PW (30 J, 30 fs) on target
  - Commissioning expt.: sheath acceleration 250 TW, 5×10^{21} Wcm^{-2}
- Max. proton energy regularly > 40 MeV, up to ~54 MeV @ 2 μm foil
- Measured *sheath intensity scaling* @ ~0.1 Hz – increasing energy gives $E_p \sim I_L^{1/2}$ scaling
- *Electron temperature saturates* at ultra-high intensity & small focal spots → insufficient acceleration length







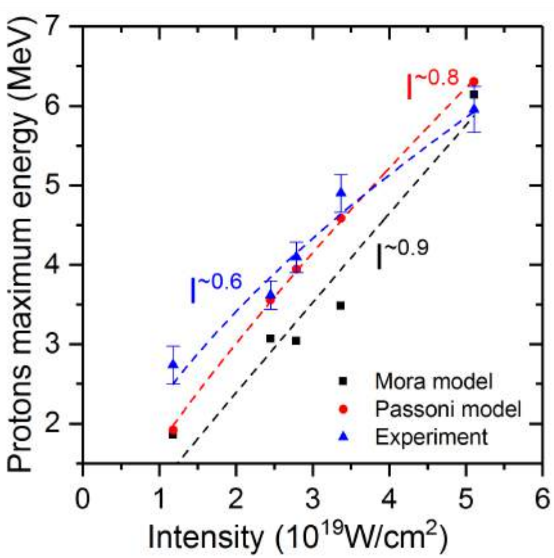
Parametric study of proton beams driven by 200 TW laser system using a tape driven target system

Muhammad Noaman-ul-Haq[1,2], Thomas Sokollik[1,2], Hamad Ahmad[3] , X.L. Ge[1,2], Fang Yuan[1,2], Xiaohui Yuan[1,2], Liming Chen[1,2], J. Zhang[1,2]

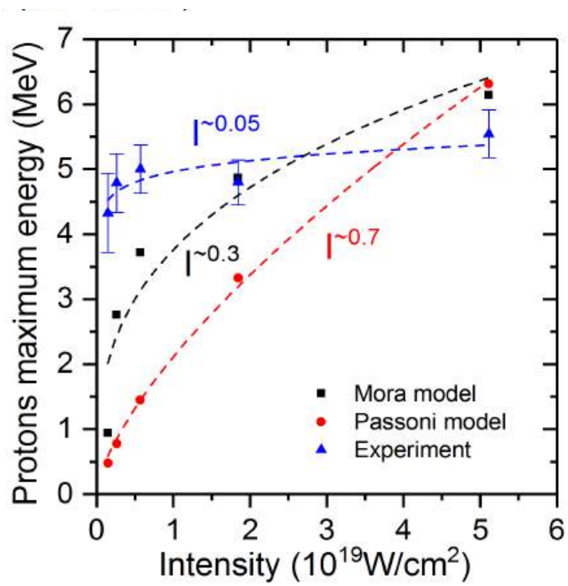
[1]*Key Laboratory for Laser Plasmas (Ministry of Education) and School of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai, 200240, China*

[2]*Collaborative Innovation Center of IFSA (CICIFSA), Shanghai Jiao Tong University, Shanghai 200240, China*

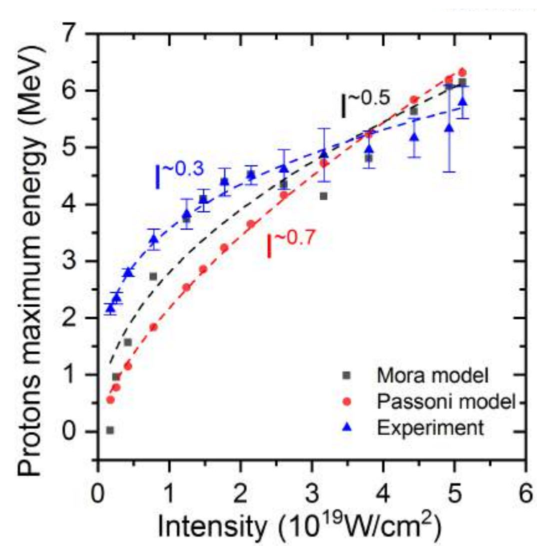
[3]*School of Mathematics and Physics, Queen's University Belfast, Belfast, BT71NN, UK*



For laser energy variation



For pulse duration variation



For focal spot variation

激光等离子体教育部重点实验室
Key Laboratory for Laser Plasmas , SJTU

CICIFSA
IFSA协同创新中心
Collaborative Innovation Center of IFSA

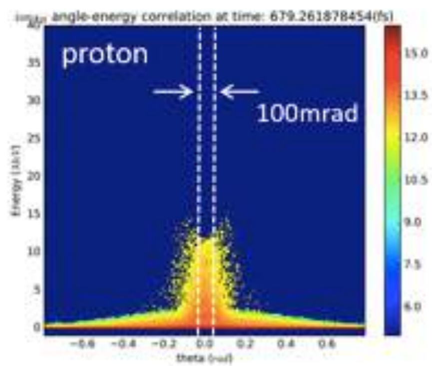
上海交通大學
SHANGHAI JIAO TONG UNIVERSITY

Isochoric heating of solid gold targets with the PW-laser-driven ion beams

Sven Steinke (LBNL)

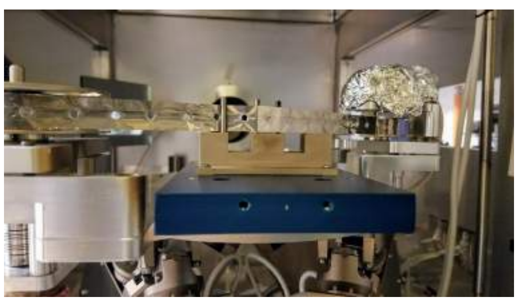
Larger spot sizes to increase number of particles and reduce divergence

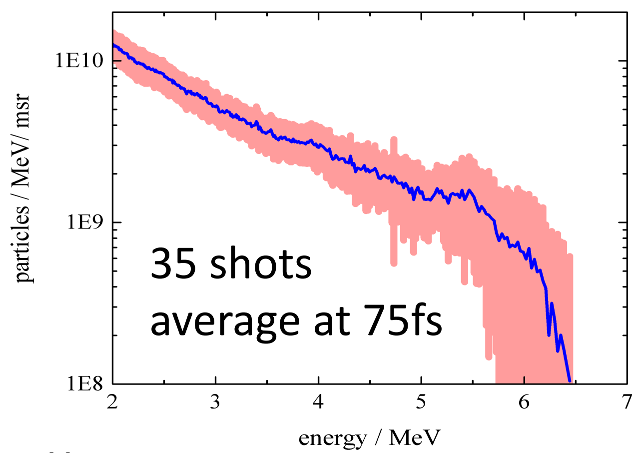
TNSA: 100 micron spot, CE=1%:
10^{12} protons, <250 mrad



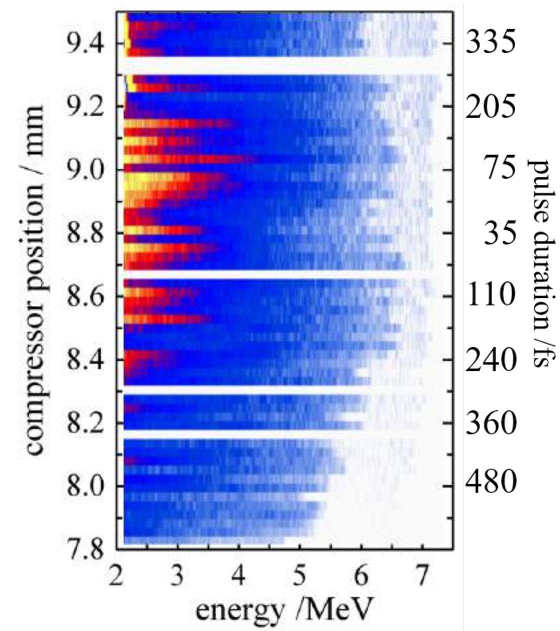
- **Advanced understanding of different states of matter- ion heating of matter (WDM)**
- **Radiation damage studies; radiography and fast ignition studies**

First study at 1PW with statistical significance- Large laser spot size (f\65) yields ions beams with reduced divergence and unprecedented charge densities





~10^{11} protons total with energies up to (6.2 ± 0.4) MeV



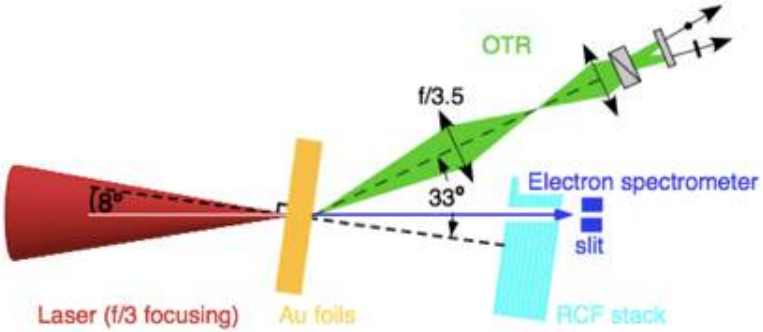
70 shots, 5 micron Ti tape target

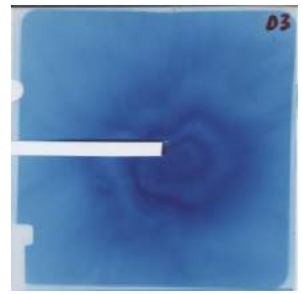
Features within sheath accelerated proton beams

C. A. J. Palmer, C. Bellei, R. J. Clarke, A. E. Dangor, R. Heathecote, A. Henig, M. C. Kaluza, S. Kneip, S. P. D. Mangles, S. R. Nagel, M. P. Read, C. R. Ridgers, A. Sävert, J. Schreiber, M. J. V. Streeter, L. Willingale and Z. Najmudin

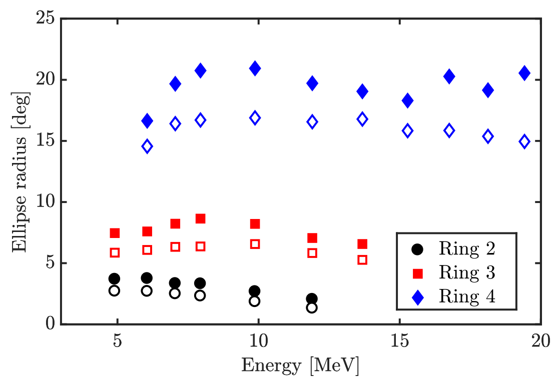
Lancaster University

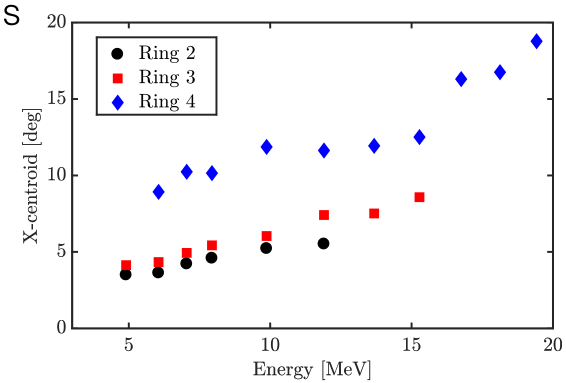
The Cockcroft Institute of Accelerator Science and Technology





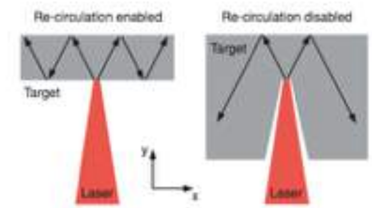
- Interaction of $a_0 \sim 10$ laser with 10 micron thick Au foil produced a sheath accelerated proton beam with ring-ed structure
- Concentric rings persist over broad energy range with little change in divergence.
- While broadly centred around rear surface target normal, the ring centroid drifts *away* from laser axis at high energy.
- Results do not seem consistent with filamentation, beam hollowing, magnetic fields at the rear surface or in the bulk.
- Hot electron recirculation under investigation as a possible explanation.

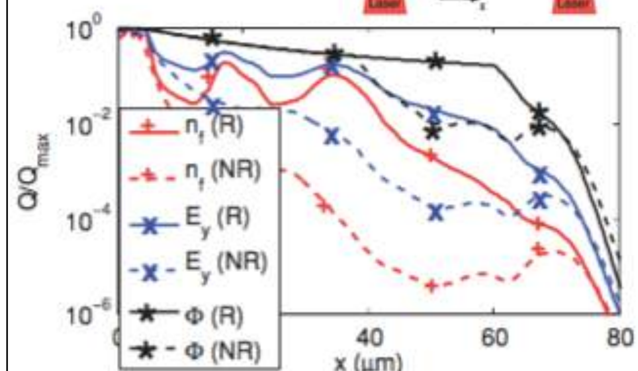




Hot electron recirculation:

- Modification of electron density at the target rear surface observed in simulations of planar foils.
- Modulations suppressed by use of cone target design which prevents recirculation of hot electrons inside the target.
- Simulations to study temporal evolution and influence of target thickness on the modulations are ongoing.





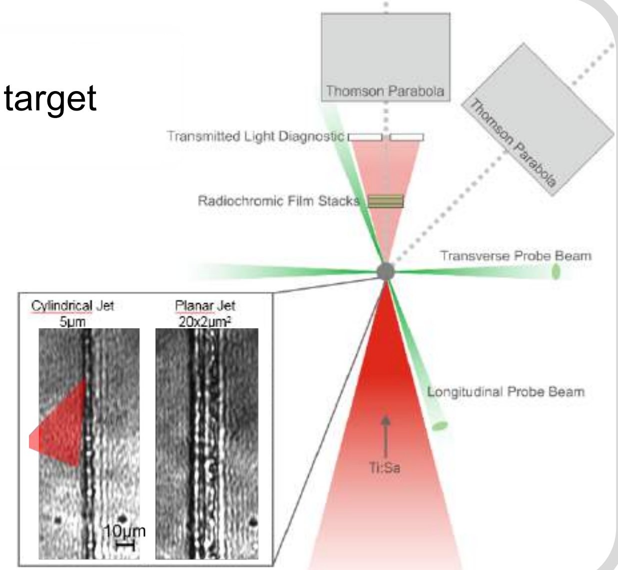
C. Ridgers et al. PRE 83, 036404 (2011)

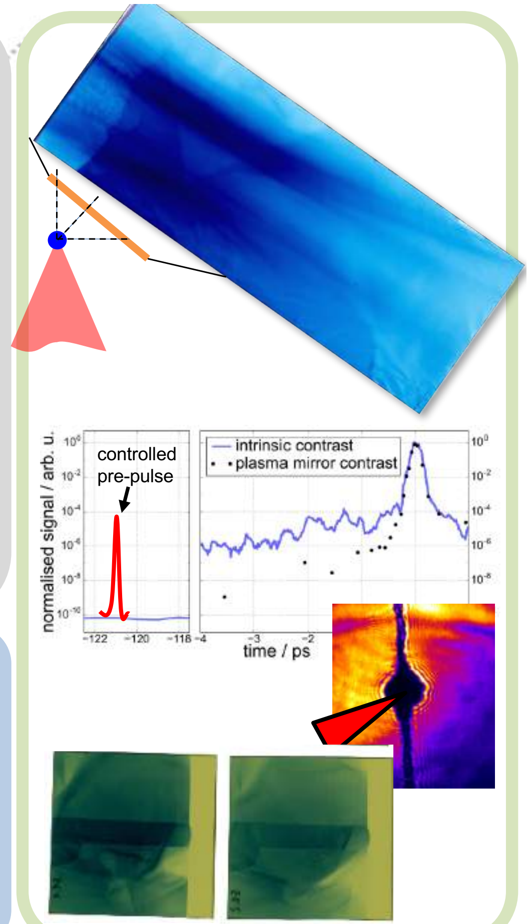
TNSA beam transport and focusing… … towards applications

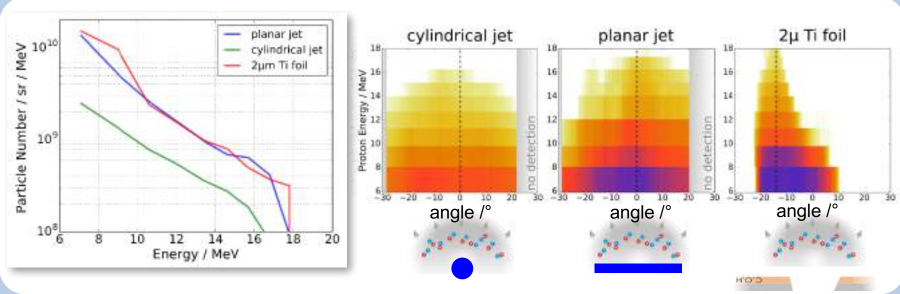
High-performance proton acceleration from a renewable cryogenic hydrogen target

L. Obst, S. Göde, M. Rehwald, F.-E. Brack, J. Branco, S. Bock, M. Bussmann, T. E. Cowan C. B. Curry, F. Fiuza, M. Gauthier, R. Gebhardt, U. Helbig, A. Huebl, U. Hübner, A. Irman, L. Kazak, J. B. Kim, T. Kluge, S. Kraft, M. Loeser, J. , R. Mishra, C. Rödel, H.-P. Schlenvoigt, M. Siebold, J. Tiggesbäumker, S. Wolter, T. Ziegler, U. Schramm, S. H. Glenzer and K. Zeil

- debris-free
- pure proton target
- renewable



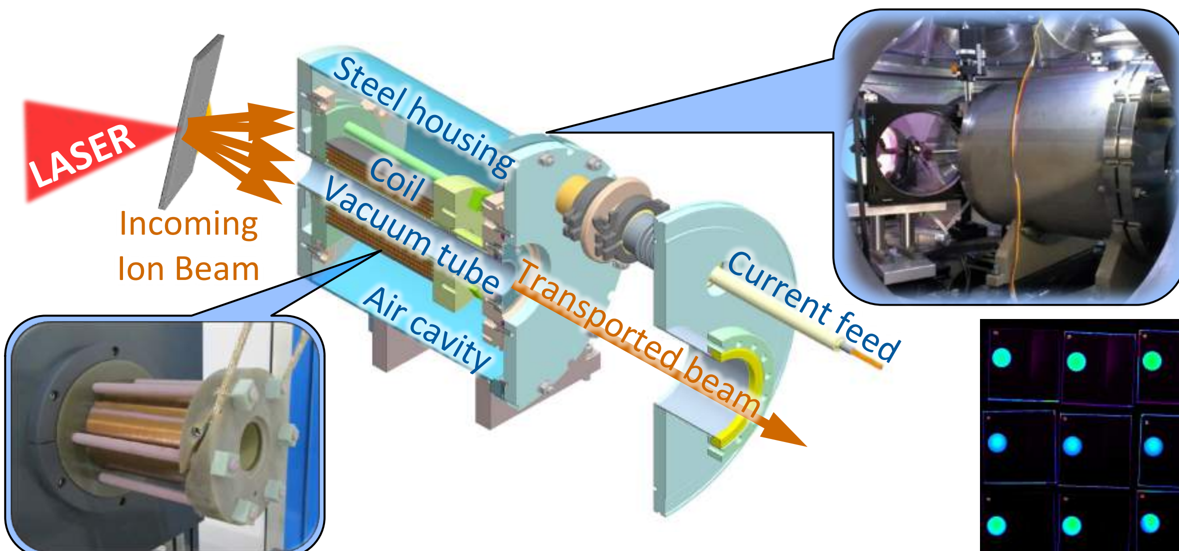


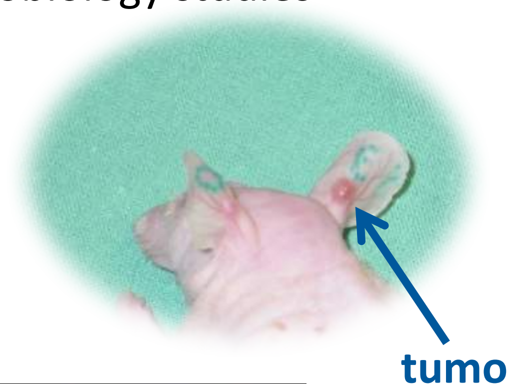


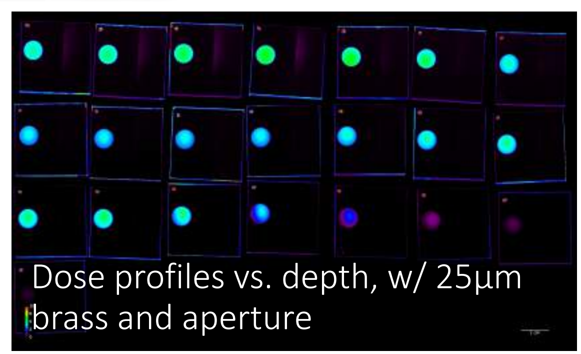
Proton acceleration studies with ultrashort PW pulses at DRACO

F.-E. Brack, L. Gaus, A. Jahn, S. Kraft, F. Kroll, J. Metzkes, L. Obst, M. Rehwald, **H.-P. Schlenvoigt**, K. Zeil, T. Ziegler, U. Schramm, T. Cowan, S. Bock, C. Eisenmann, R. Gebhardt, U. Helbig, D. Möller, E. Beyreuther, L. Karsch, M. Schürer, J. Pawelke, T. Herrmannsdörfer, S. Zherlitsyn, S. Goede, M. Gauthier, W. Shoemaker, S. Glenzer, P. Poole, G. Cochran, D. Schumacher

- DRACO: a 150 TW / 1 PW dual beam laser facility
- Status of proton acceleration at DRACO
- Highly efficient proton beam transport with pulsed solenoid coils
- Spectral and spatial beam shaping for in-vivo radiobiology studies







HLD. OncoRay SLAC The Ohio State University HZDR

Generation of highest peak intensities of ultrashort MeV proton bunches and going towards applications

D. Jahn, D. Schumacher, C. Brabetz, J. Ding, S. Weih, A. Blazevic, V. Bagnoud, F. Kroll, F.-E. Brack, T. Cowan, U. Schramm, M. Roth

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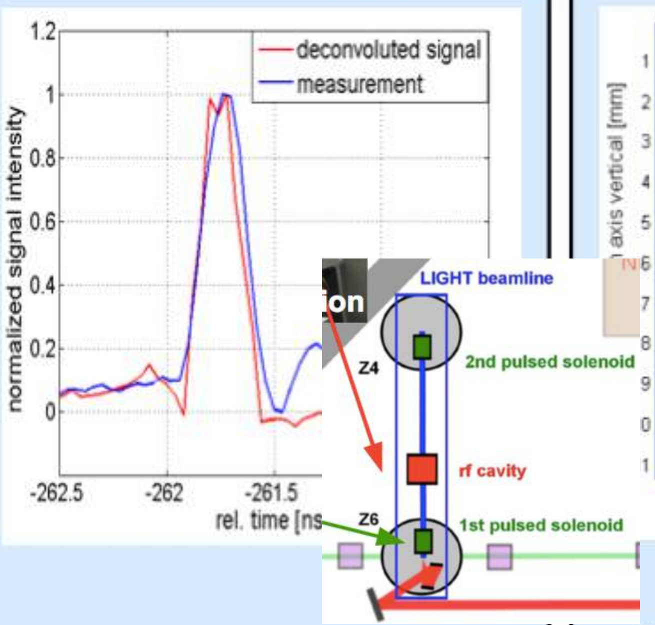
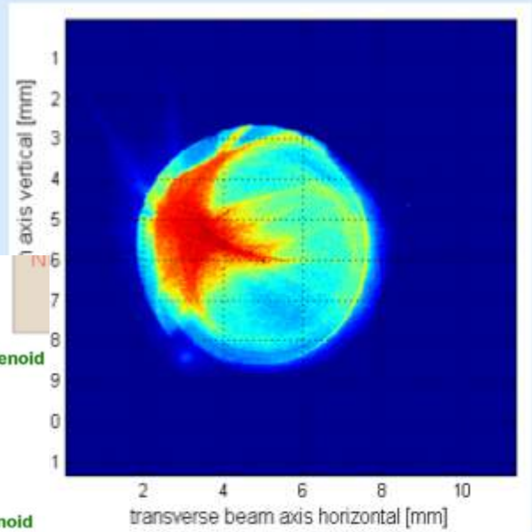
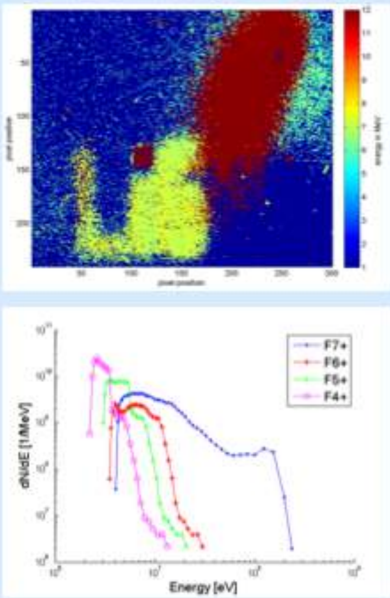


- time compression
- beam transport to 6 m
- bunch FWHM= 209 ps



- focal spot: 2.5 x 3 mm^2
- N_p = 6.8x10^8
- I = 520 mA

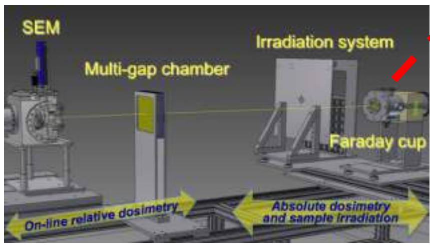


- ultrashort sub-ns pulses are useful imaging
- mid-Z ion acceleration
- going towards energy loss

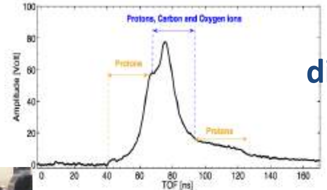
Laser driven ion beam for multidisciplinary applications at ELIMAIA beamline

Valentina Scuderi

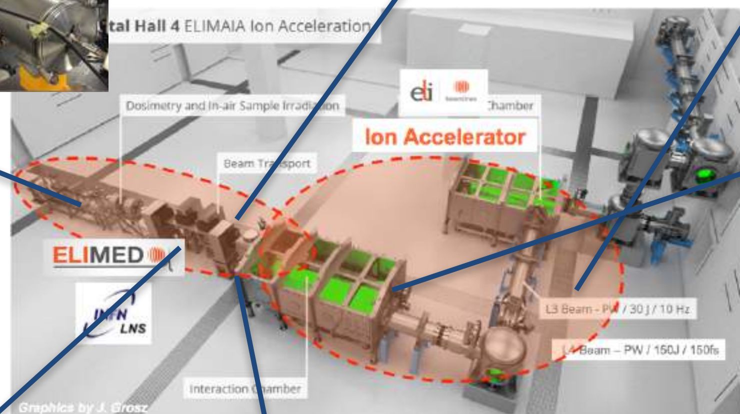
ELIMED dosimetry section



Successful dosimeter test (SEM, IC and FC) with laser-driven protons @ LOA: High rep-rate



On line TOF based diagnostics for high energy ion beam successfully tested @ PW class laser facility



High-Repetition-Rate Advanced Petawatt Laser System, 1 PW, 10 Hz delivered by LLNL installed this week at ELI

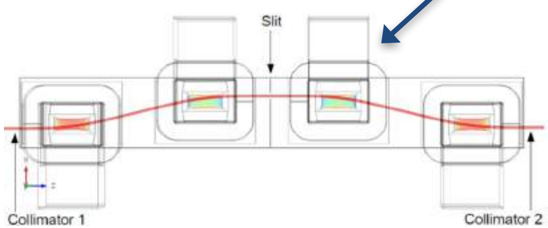
Advanced targetry for ELIMAIA: p acc. From cryogenic solid-H2 ribbon (ELISE) at PW class laser facility.

Vacuum, EMP: OK

Stability: to be improved

Pure proton beam (no contaminants): OK

Max proton energy: ~55 MeV



Expected delivery @ INFN-LNS December 2017

PMQ delivered last July @ INFN-LNS Optics study performed with 60 MeV p beam @ INFN-LNS

Fyzikální ústav Akademie věd ČR, v. v. i.

esf evropský sociální fond v ČR

EVROPSKÁ UNIE

MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

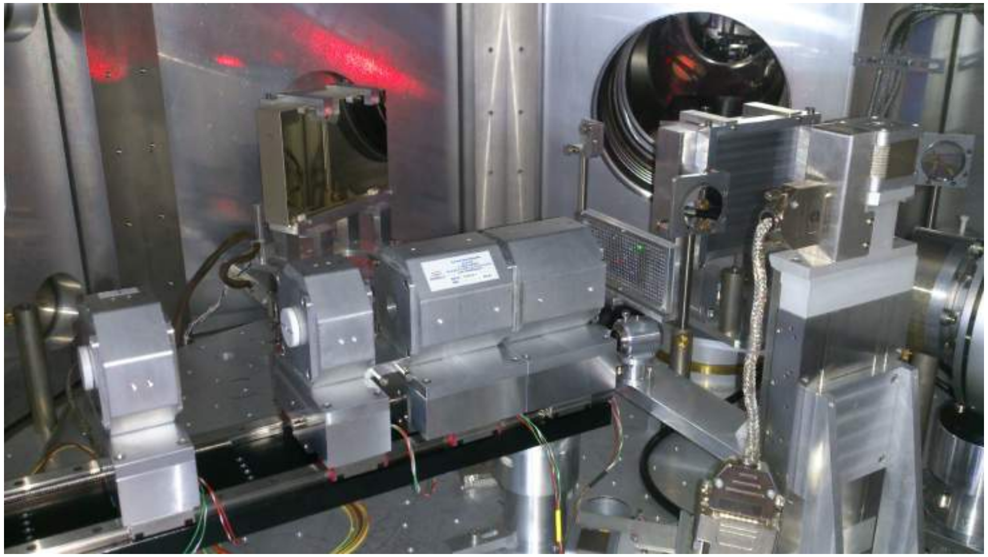
OP Vzdělávání pro konkurenceschopnost

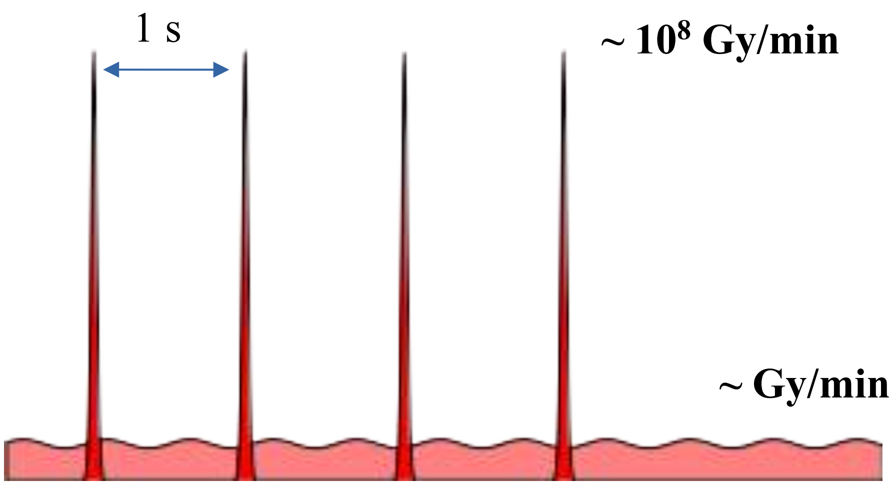
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

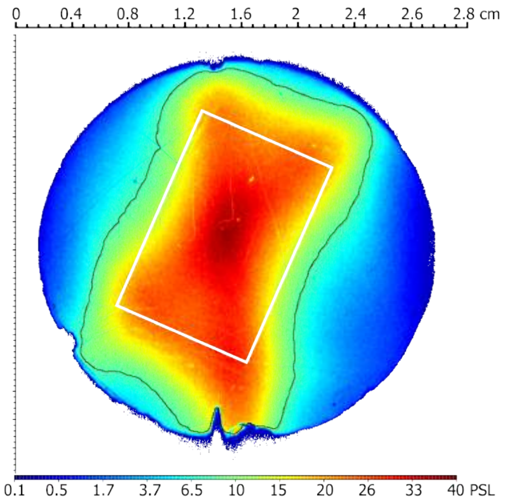
OP Výzkum a vývoj pro inovace

Spectral and spatial shaping of a laser-accelerated proton beam for radiation biology applications

Alessandro Flacco (LOA / ENSTA)

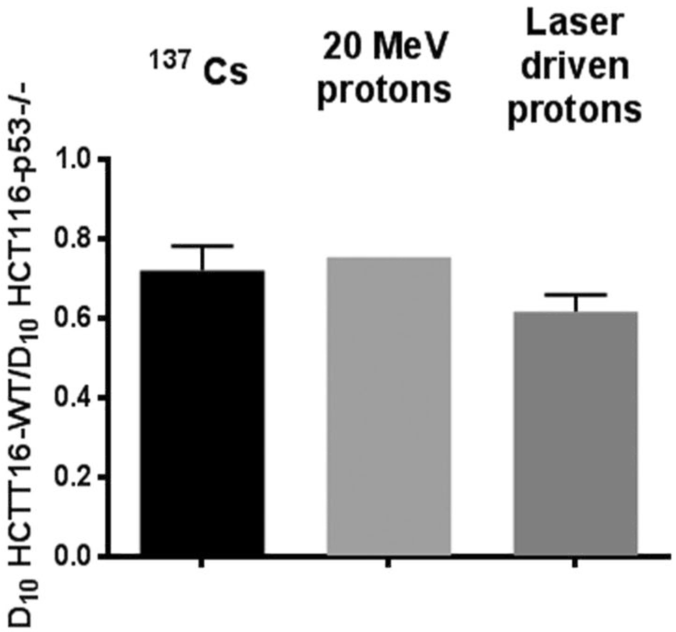






Stable irradiation conditions

- 0.7Gy/shot for *in vitro* 2D
- stability : 6 % rms
- uniformity : 20 % rms
- duration : ~ns
- peak dose rate : **10^8 Gy/min**
- repetition rate : 1/1.5s (*quasi*-automated)

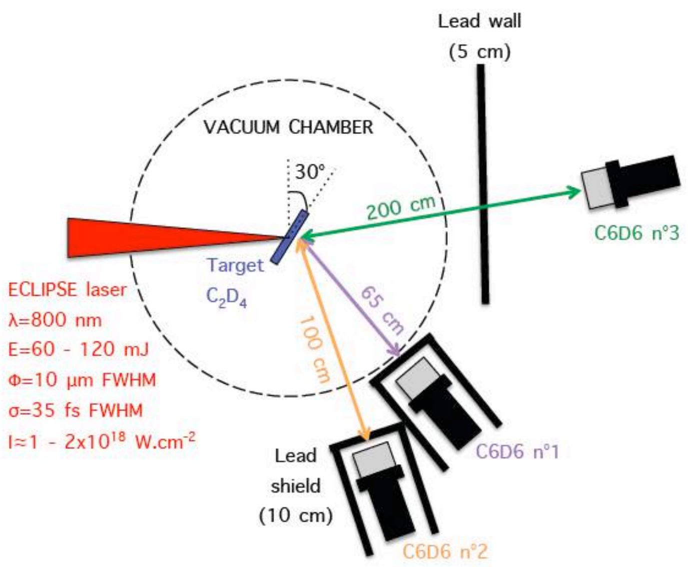


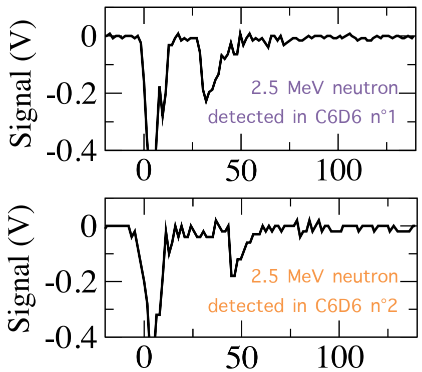
Neutron generation

Laser-plasma acceleration inducing nuclear fusion reactions

Danilo Giulietti [a, b], D.Batani [c], G. Boutoux [c], F. Burgy [c], M. Cipriani [b], F. Consoli [b], R. De Angelis [b], J.E. Ducret [c], F. Ingenito [b], K. Jakubowska [d, c], C. Verona[e], G. Verona-Rinati[e]

This experiment shows how it is possible, with a small size, a few TW Ti:Sapphire laser, to induce fusion processes and to study them in detail, making to glimpse the possibility of creating an unique, high-repetition-rate source of mono-energetic, high-energy neutrons.





$$ {}^2_1D + {}^2_1D \rightarrow {}^3_1T\ (1.01MeV) + p\ (3.02MeV) \qquad 50\% $$

$$ {}^2_1D + {}^2_1D \rightarrow {}^3_2He\ (0.82MeV) + n\ (2.45MeV) \qquad 50\% $$

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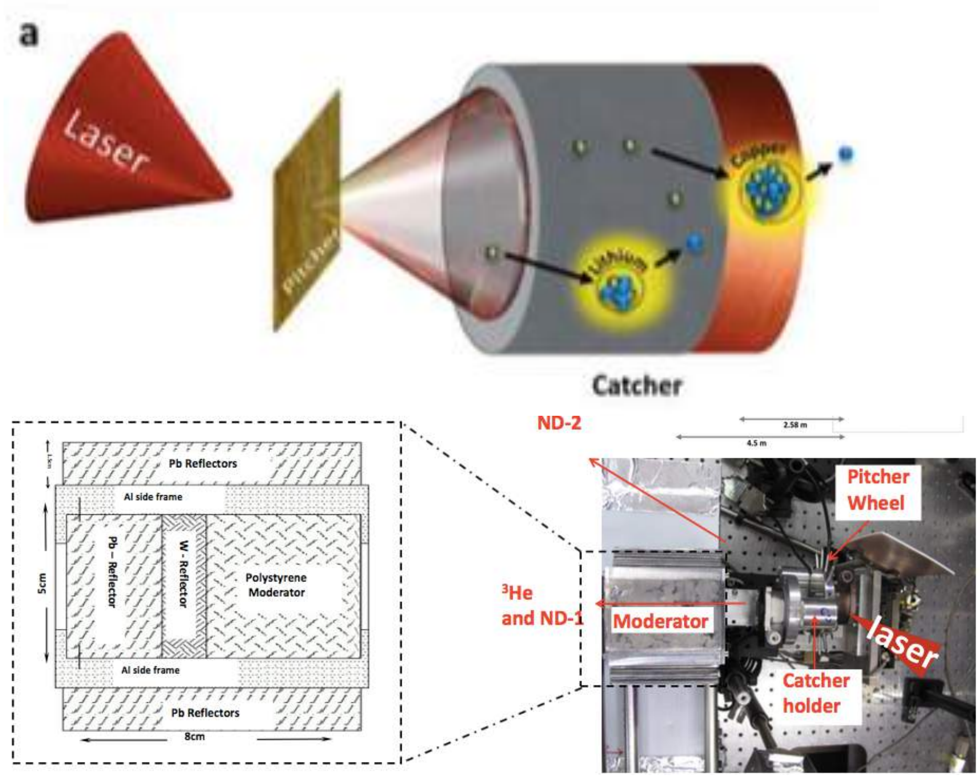
Laser-driven neutron sources and their applications

Seyed Reza Mirfayzi (Queen's University Belfast)

- Laser-based sources are fast approaching a crucial stage in their development for neutron science and applications to complement large-scale facilities.
- The current flux is adequate for many applications such as eV neutron spectroscopy, activation, BNCT in a closely coupled beam line.
- Development in laser facilities around the glob such as ELI, can lead to higher neutron fluxes.
- The future of a laser-based approach would be reliant on the progress in diode-pumped technologies, such as the DiPOLE and HAPLS projects, aiming towards developing 10 Hz, Petawatt-class laser systems.



Epithermal Neutron Source

Queen's University Belfast | European Spallation Source | STFC Central Laser Facility | Science & Technology Facilities Council ISIS | University of Strathclyde Glasgow

WG2: ion beam presentation themes