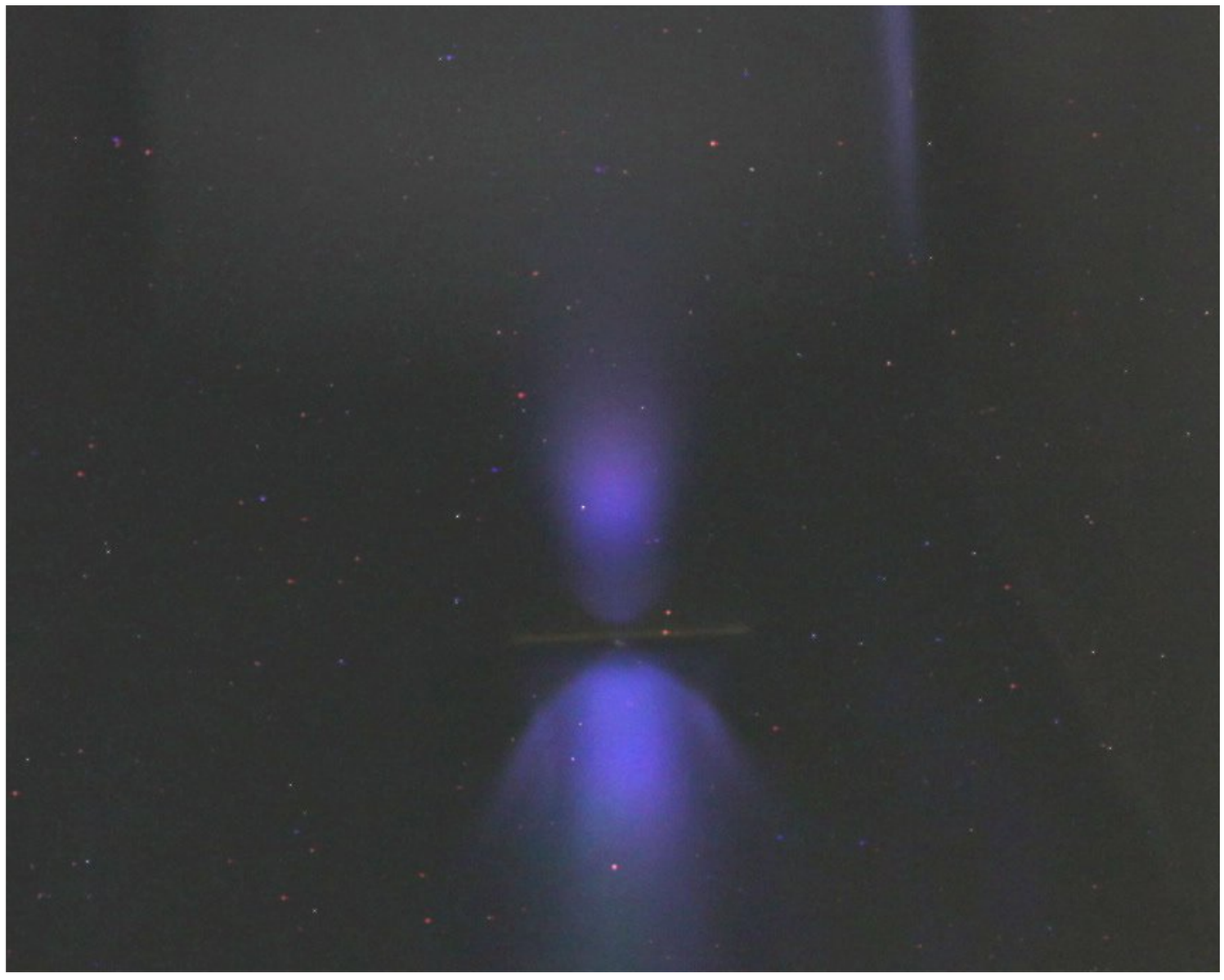
John Adams Institute for Accelerator Science

Imperial College London

CCAP Centre for the Clinical Application of Particles



LhARA Pre-CDR: Laser and Proton/Ion Source

Zulfikar Najmudin, Oliver Ettlinger

31/03/2020

Motivation for a laser-driven ion source

- What are the benefits for a laser driven proton/ion source?
  - High instantaneous dose rates - full treatment doses possible in a single shot?
  - Flash dosing with ultra-short particle beams - sub ps duration.
  - Source flexibility - simple switching of ion species.
  - More compact (cheaper) accelerators - higher accelerating gradients.

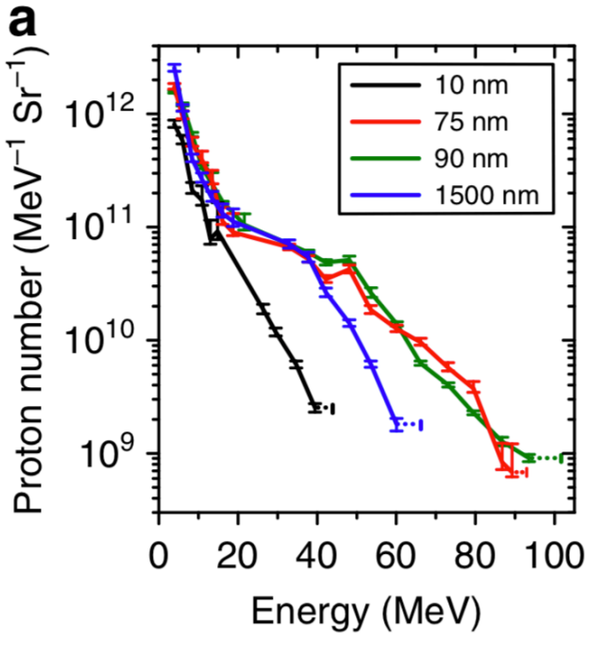
Current status of laser accelerators

Proton energies at nearly 100MeV

DOI: 10.1038/s41467-018-03063-9 OPEN

Near-100 MeV protons via a laser-driven transparency-enhanced hybrid acceleration scheme

A. Higginson[1], R.J. Gray[1], M. King[1], R.J. Dance[1], S.D.R. Williamson[1], N.M.H. Butler[1], R. Wilson[1], R. Capdessus[1], C. Armstrong[1,2], J.S. Green[2], S.J. Hawkes[1,2], P. Martin[3], W.Q. Wei[4], S.R. Mirfayzi[3], X.H. Yuan[4], S. Kar[2,3], M. Borghesi[3], R.J. Clarke[2], D. Neely[1,2] & P. McKenna[1]



Carbon energies at nearly over 30MeV/u*

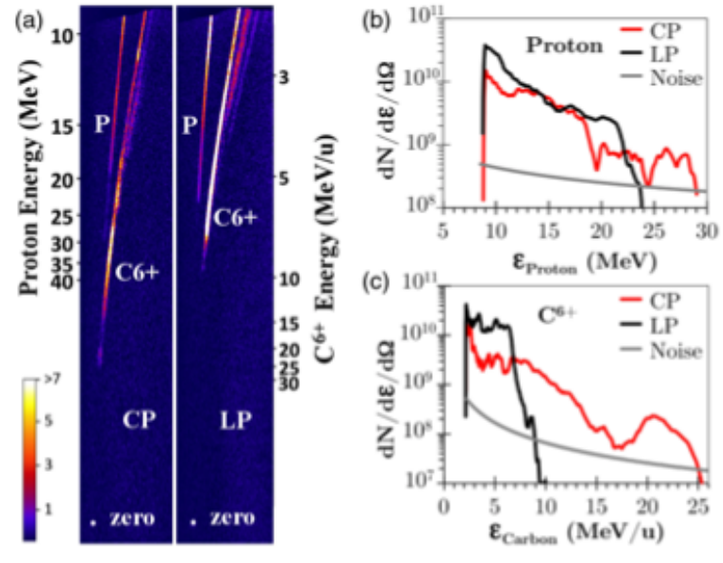
PRL 119, 054801 (2017) PHYSICAL REVIEW LETTERS week ending 4 AUGUST 2017

Polarization Dependence of Bulk Ion Acceleration from Ultrathin Foils Irradiated by High-Intensity Ultrashort Laser Pulses

C. Scullion,[1] D. Doria,[1,*] L. Romagnani,[2] A. Sgattoni,[3,†] K. Naughton,[1] D. R. Symes,[4] P. McKenna,[5] A. Macchi,[3,6] M. Zepf,[1,7] S. Kar,[1] and M. Borghesi[1,‡]

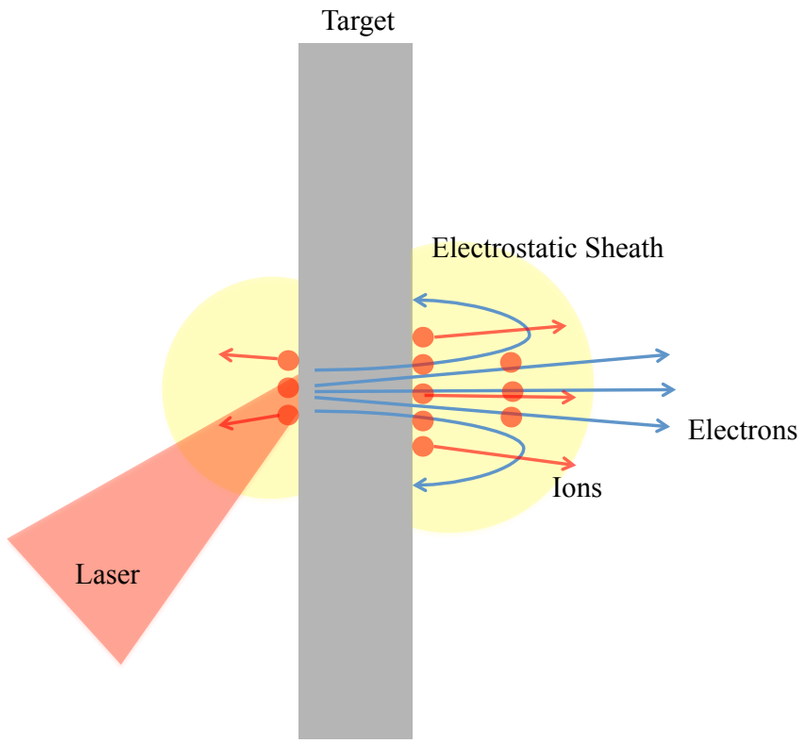
[1]*Centre for Plasma Physics, School of Mathematics and Physics, Queen's University Belfast, Belfast BT7 1NN, United Kingdom*
[2]*LULI, École Polytechnique, CNRS, Route de Saclay, 91128 Palaiseau Cedex, France*
[3]*Istituto Nazionale di Ottica, Consiglio Nazionale delle Ricerche (CNR/INO), Laboratorio Adriano Gozzini, 56124 Pisa, Italy*
[4]*Central Laser Facility, Rutherford Appleton Laboratory, Oxfordshire OX11 0QX, United Kingdom*
[5]*SUPA, Department of Physics, University of Strathclyde, Glasgow G4 0NG, United Kingdom*
[6]*Dipartimento di Fisica Enrico Fermi, Università di Pisa, 56127 Pisa, Italy*
[7]*Helmholtz Institute Jena, 07743 Jena, Germany*

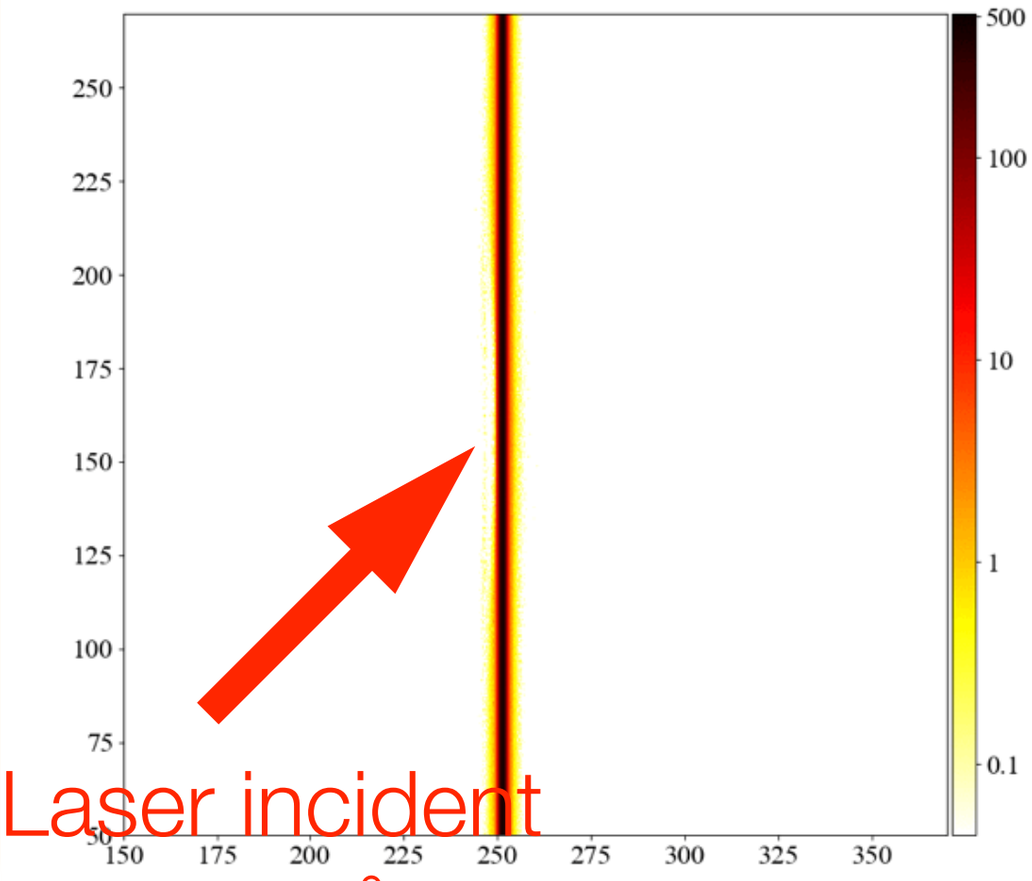
(Received 23 May 2016; published 2 August 2017)



Current status of laser accelerators

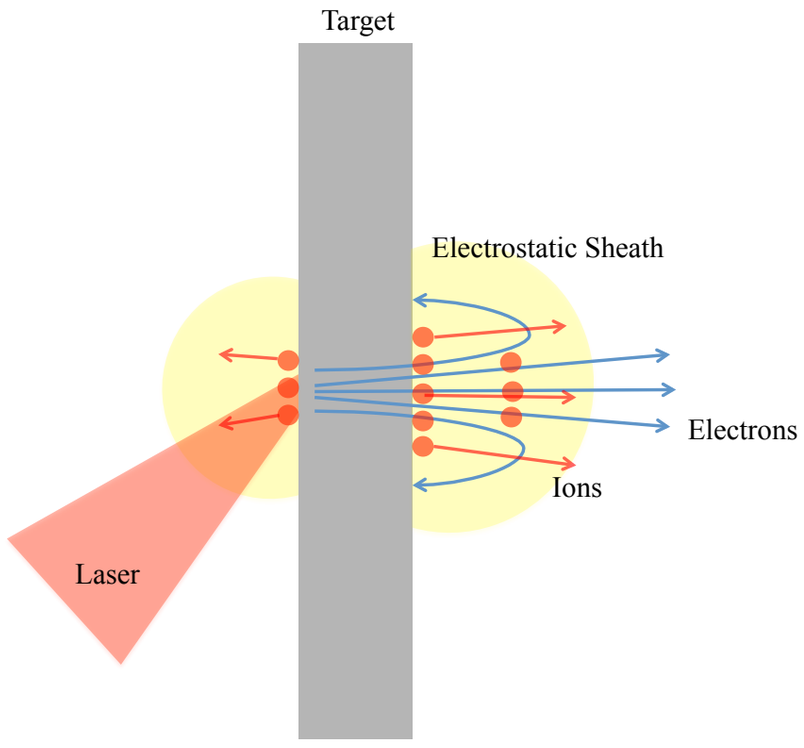
Many acceleration methodologies, but most studied and best characterised is sheath acceleration

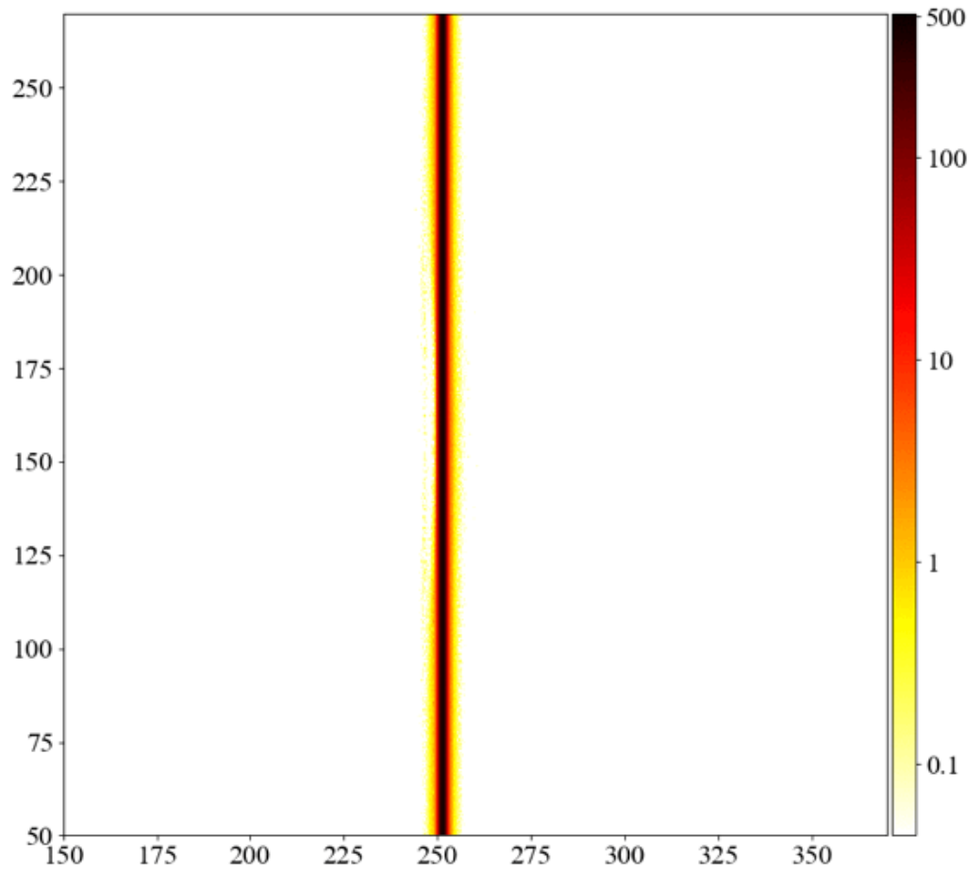




Current status of laser accelerators

Many acceleration methodologies, but most studied and best characterised is sheath acceleration

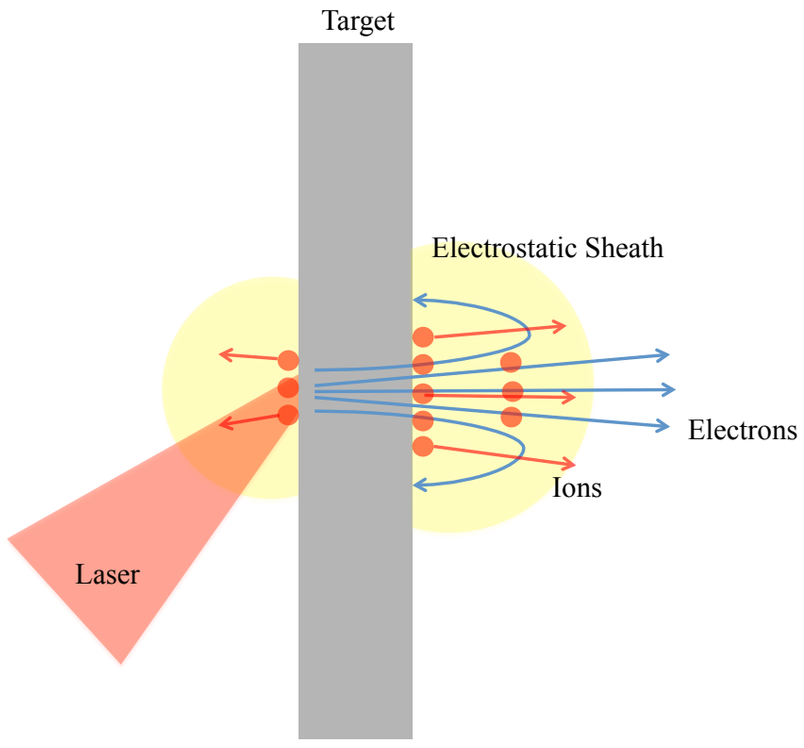




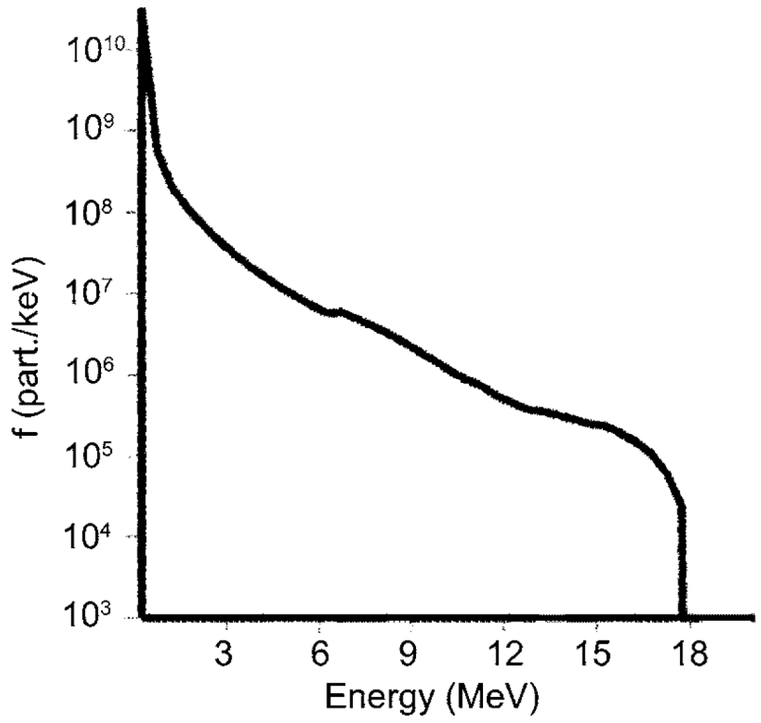
Courtesy of G. Hicks

Current status of laser accelerators

Many acceleration methodologies, but most studied and best characterised is sheath acceleration



15MeV energies for LhARA injection achievable as part of thermal particle distribution



How to achieve these particle beams

A number of commercial laser systems are available to purchase of the order 100TW which should be capable of producing stable, >15MeV peak energy beams.

Example of laser options from Amplitude:

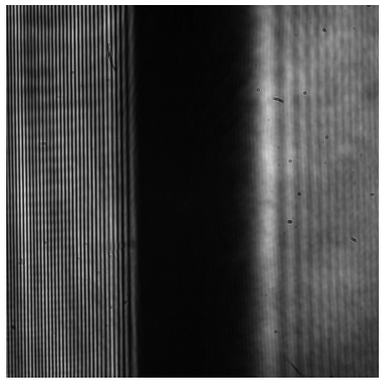
	Pulsar 60	Pulsar 140
Rep. rate		5 Hz (1)
Pulse Duration		< 25 fs (2)
Peak Power (3)	> 60 TW	> 140 TW
Contrast (4)		> 1: 10^{10}
Energy Compressed	1.5 J	> 3.5 J
Energy shot-to-shot Stability		< 1% RMS
Strehl ratio (5)		> 0.85

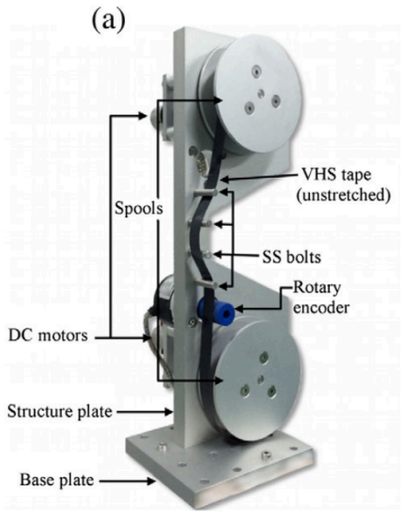
Would aim for ~100TW system

Targetry

Requirement for 10Hz operation:

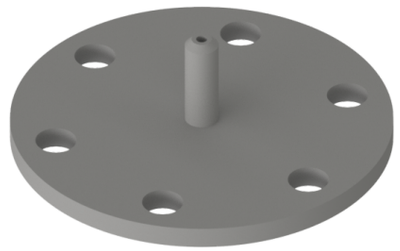
Tape targets:

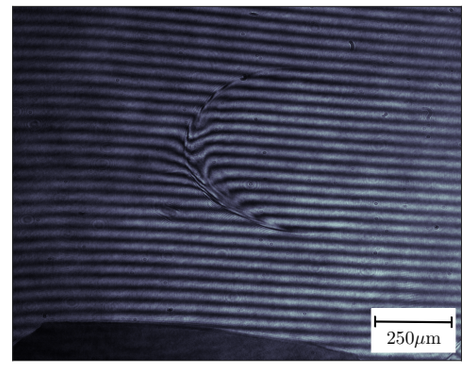




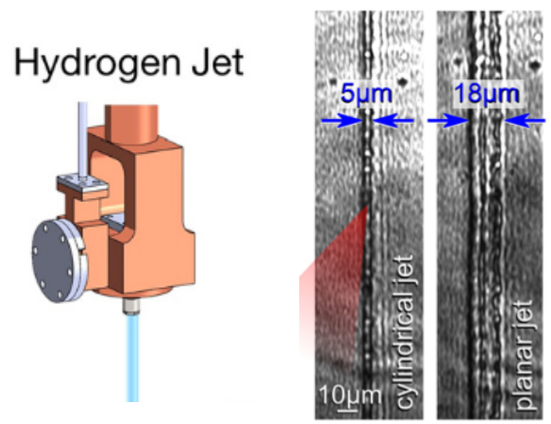
Noaman-ul-Haq et al. PRAB (2017)

Gas jets:



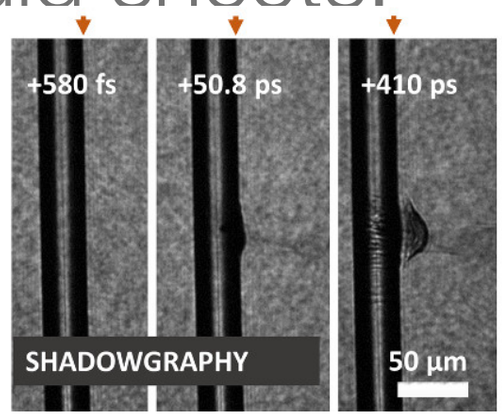


Cryogenic targets:



L Obst et al.
Sci. Rep. 2017

Liquid sheets:

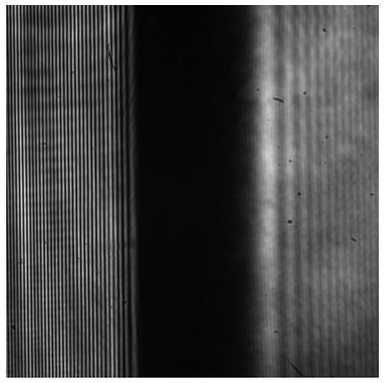


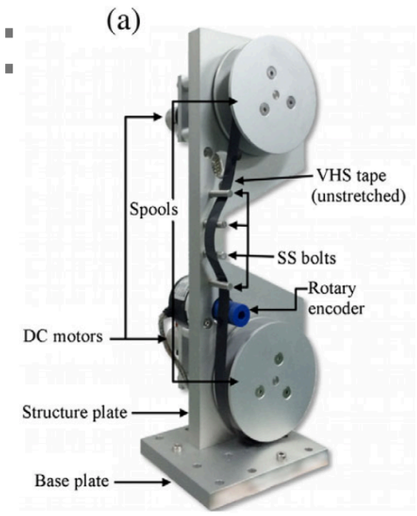
S. Feister et al. Rev. Sci. Inst. (2014)

Targetry

Requirement for 10Hz operation:

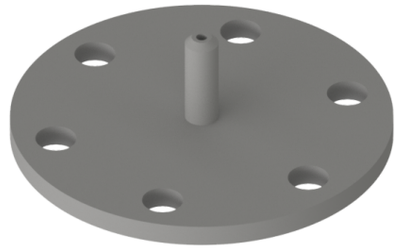
Tape targets:

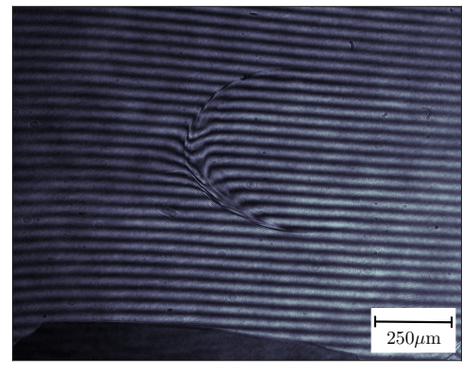




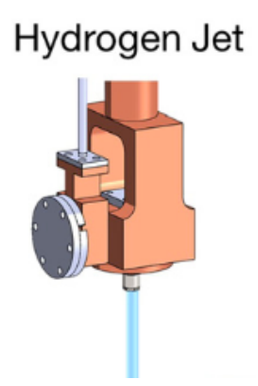
Noaman-ul-Haq et al. PRAB (2017)

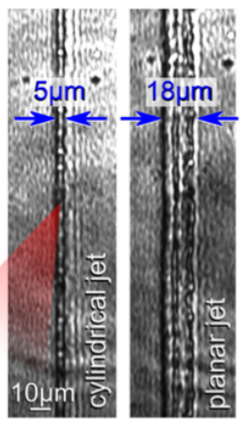
Gas jets:





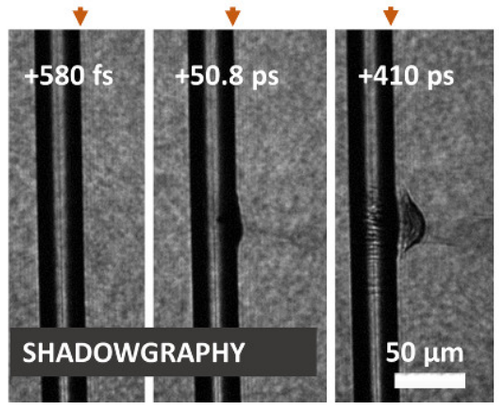
Cryogenic targets:





L Obst et al.
Sci. Rep. 2017

Liquid sheets:



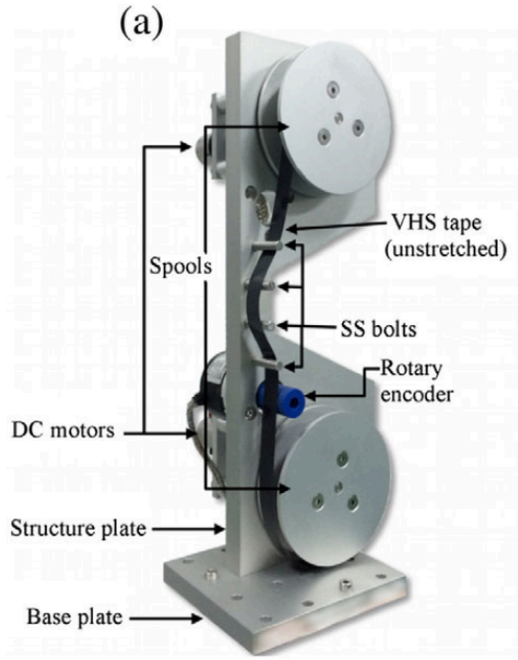
S. Feister et al. Rev. Sci. Inst. (2014)

Targetry

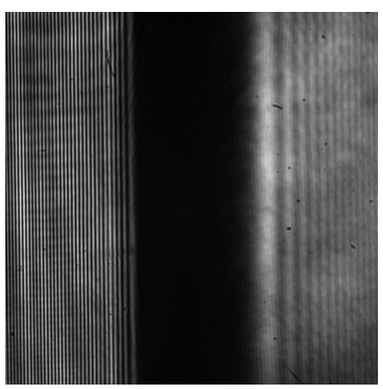
Requirement for 10Hz operation:

Tape targets:

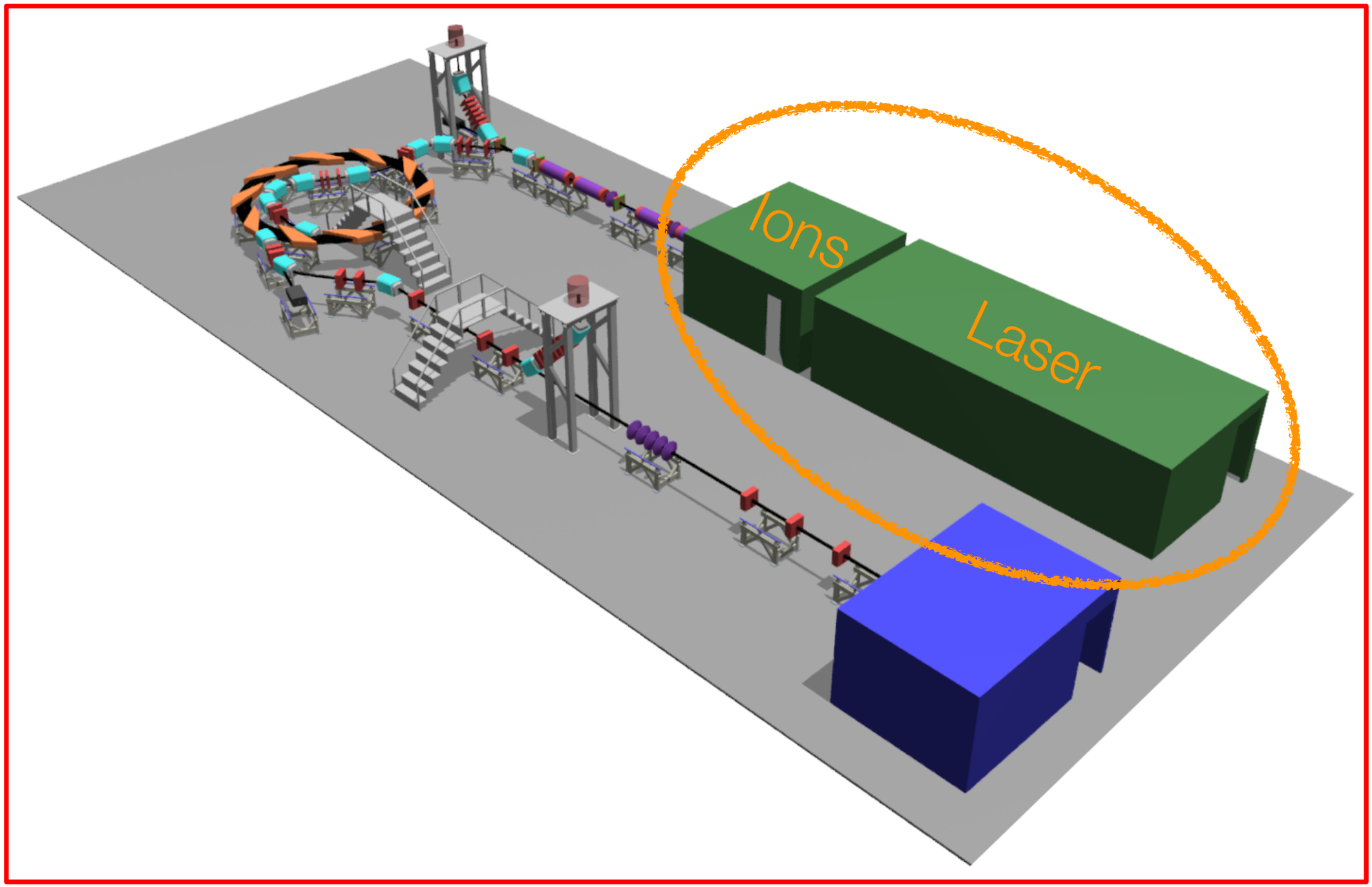
- Well established technology - relatively simple & IC experience
- Selection of tape materials available - **Mylar**, Kapton, Ti…
- 10Hz repetition rate or higher
- More advanced, etched targets possible - enhanced acceleration?



Noaman-ul-Haq et al. PRAB (2017)

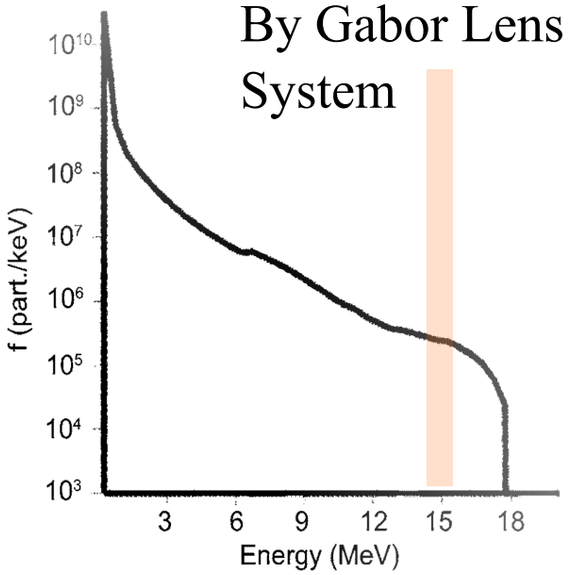


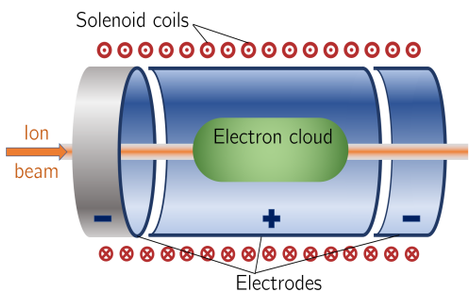
Proposed Layout



Proposed Layout

Particle Selection
By Gabor Lens
System

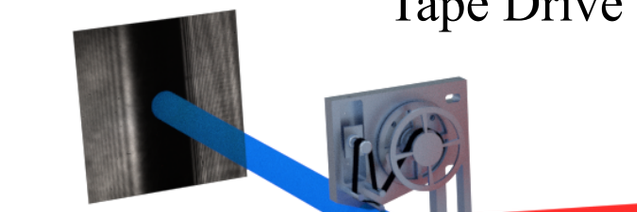




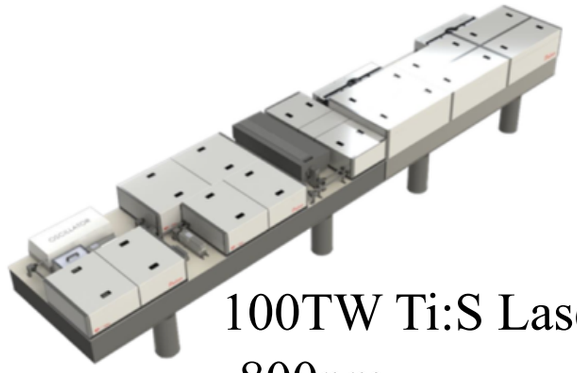
Gabor Lens
Capture System

Transverse
Probe - 400nm

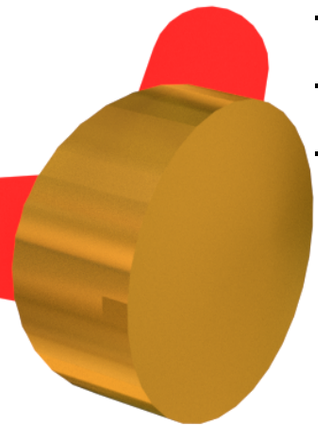
Tape Drive



Proton Beam

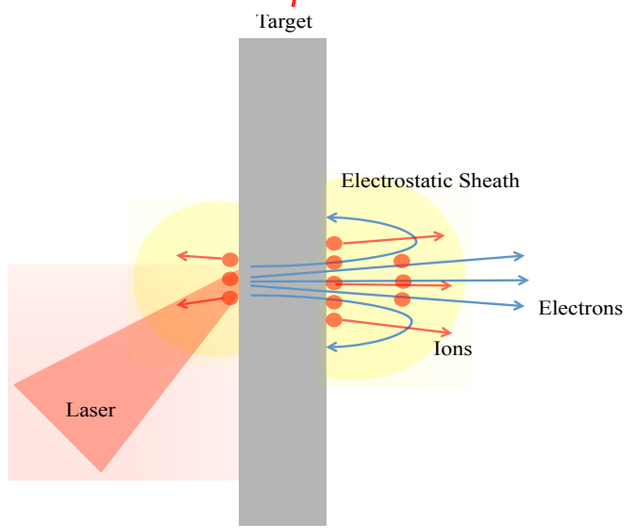


100TW Ti:S Laser:
-800nm
-3J, 25fs
-10Hz
- <1% stability



f/3 Focussing

Parabola



R&D Effort Requirements

- Continued development of tape drives to minimise the shot to shot variation in focal plane position and to ensure surface flatness - ongoing now.

- Adoption of machine learning and genetic algorithms for proton/ion source optimisation at 10Hz - beam charge, peak energy, beam divergence.

- On shot, passive diagnostics for ion beam characterisation - needed?

Summary

- Laser driven source offers unique properties which might be desirable for particle therapy.
- Sheath acceleration is well understood and offers appropriate beam parameters for LhARA.
- R&D requirements ongoing and manageable.