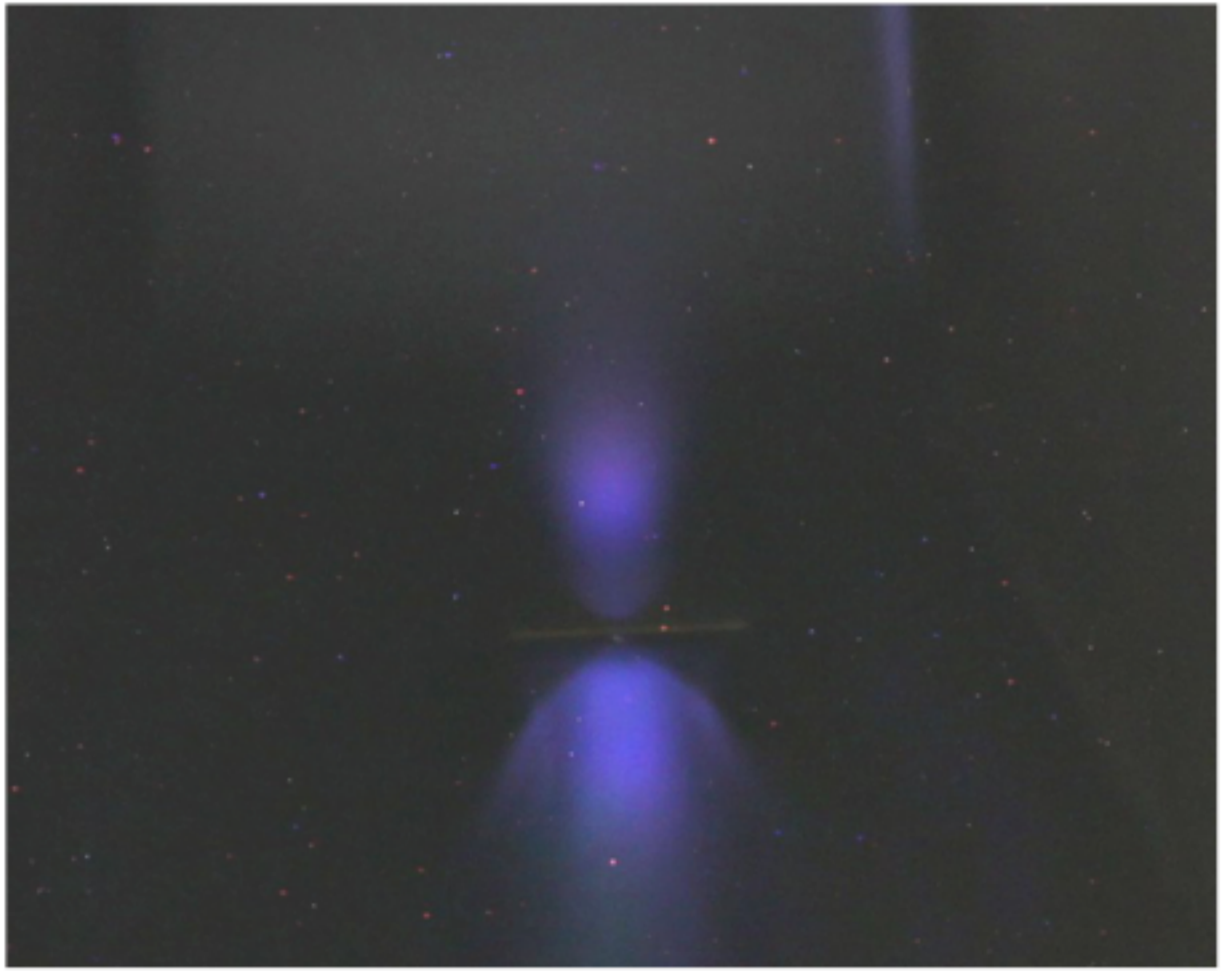
John Adams Institute for Accelerator Science

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.

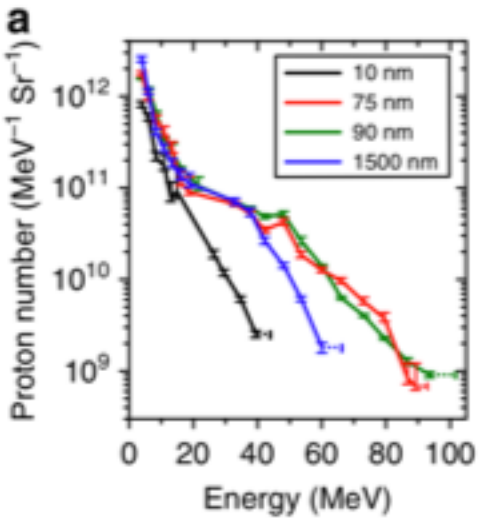
Current status of laser accelerators

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]

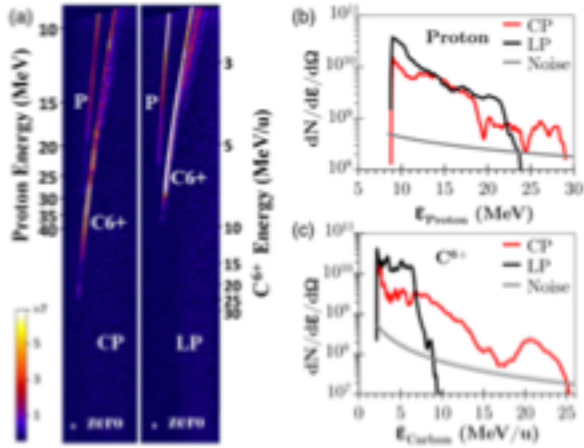


Carbon energies at nearly over 30MeV/u*

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

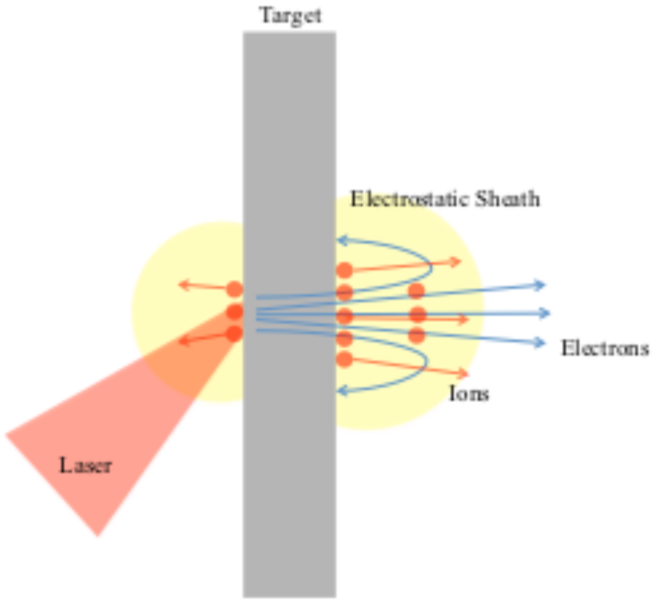
Polarization Dependence of Bulk Ion Acceleration from Ultrathin Foils Irradiated by High-Intensity Ultrashort Laser Pulses

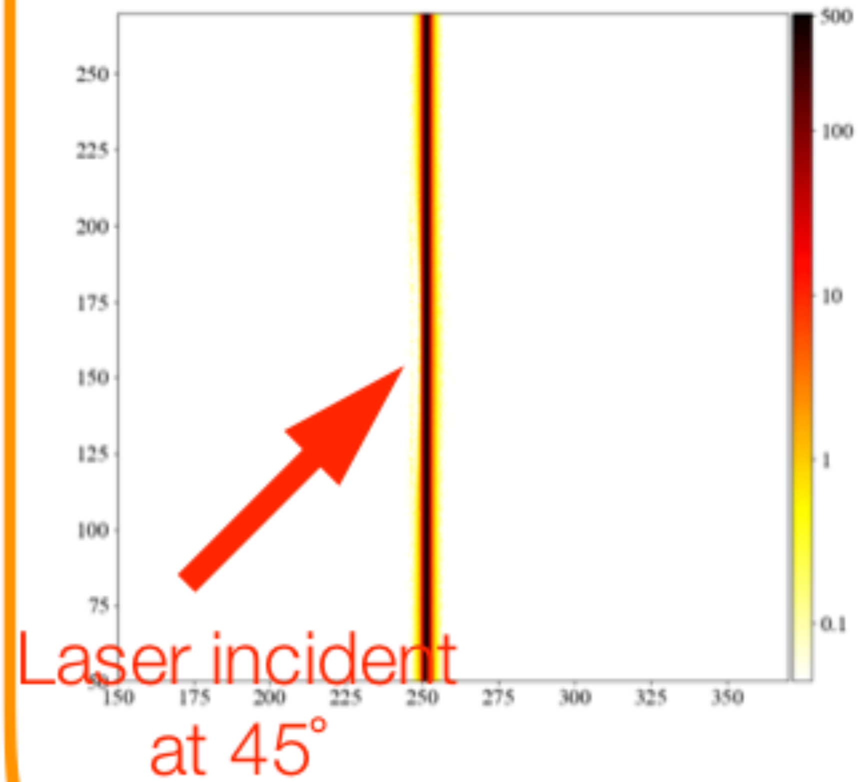
C. Scullion,[1] D. Doria,[1,2] L. Romagnani,[2] A. Sgattoni,[3,2] K. Naughton,[1] D.R. Symes,[4] P. McKenna,[5] A. Macchi,[3,6] M. Zepf,[1,7] S. Kar,[1] and M. Borghesi[1,3]
[1]Centre for Plasma Physics, School of Mathematics and Physics, Queen's University Belfast, Belfast BT7 1NN, United Kingdom
[2]LULI, 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





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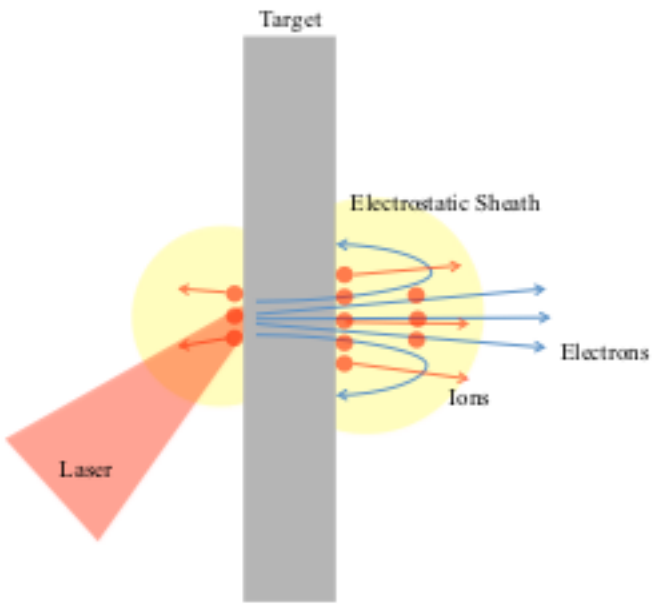

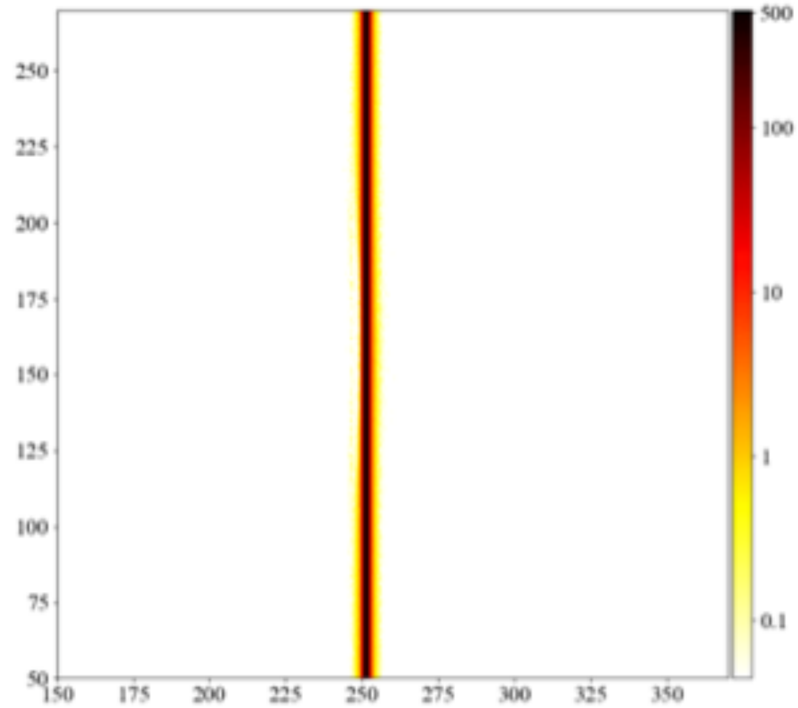

Courtesy of G. Hicks

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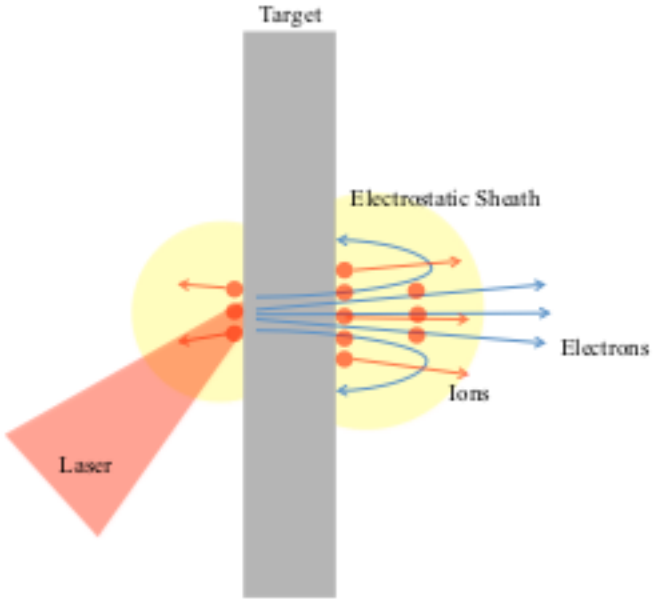
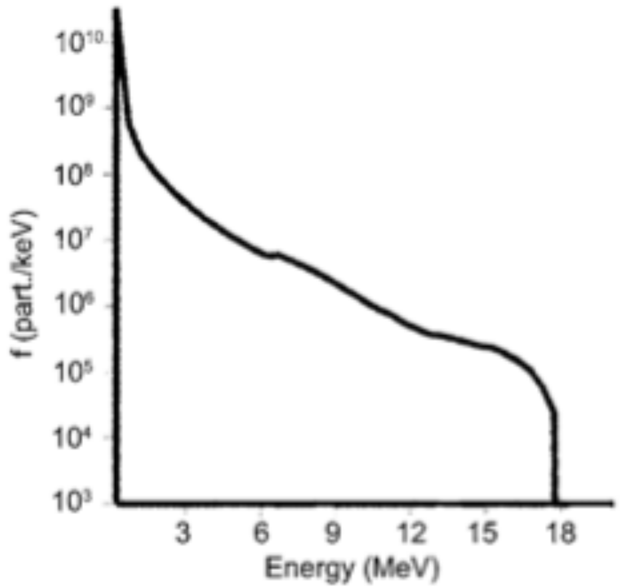


15MeV energies for LhARA injection achievable as part of thermal particle distribution



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:

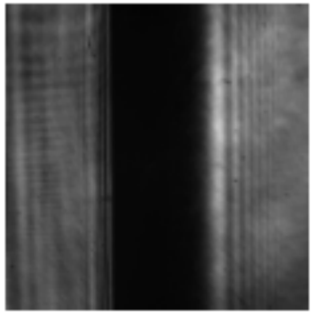
	Pulsar 60	Pulsar 140
Rep. rate		5 Hz [1]
Pulse Duration		< 25 fs [2]
Peak Power [3]	> 60 TW	> 140 TW
Contrast [4]		> 1: 10^{10}
Energy Compressed	1.5 J	> 3.5 J
Energy shot-to-shot Stability		< 1% RMS
Strehl ratio [5]		> 0.85

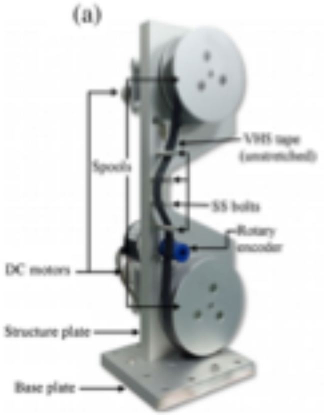
Would aim for ~100TW system

Targetry

Requirement for 10Hz operation:

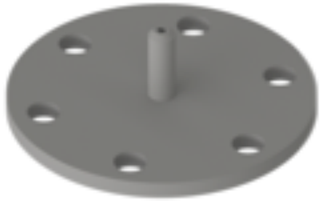
Tape targets:

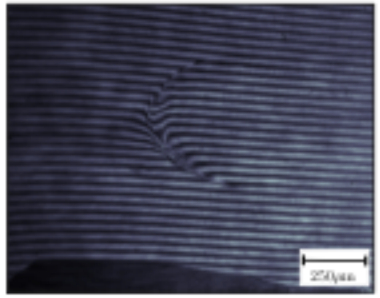




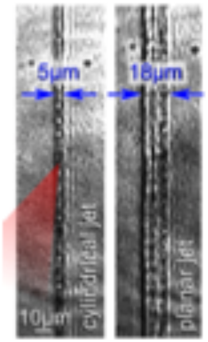
Noaman-ul-Haq et al. PRAB (2017)

Gas jets:



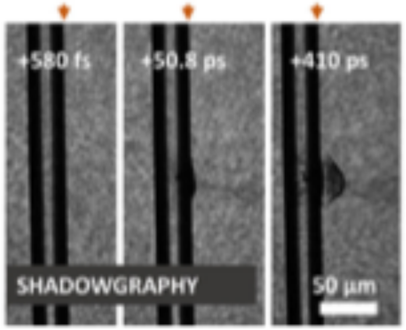


Cryogenic targets:



L Obst et al. Sci. Rep. 2017

Liquid sheets:



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

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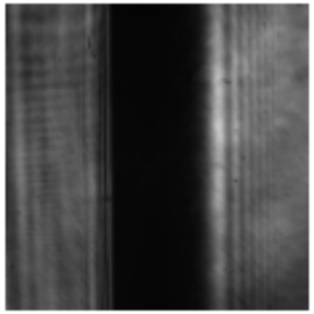

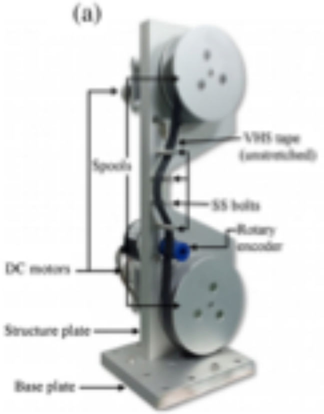

Noaman-ul-Haq et al. PRAB (2017)

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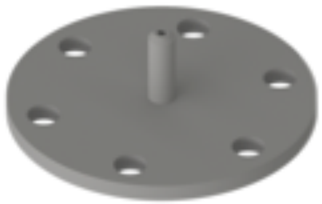

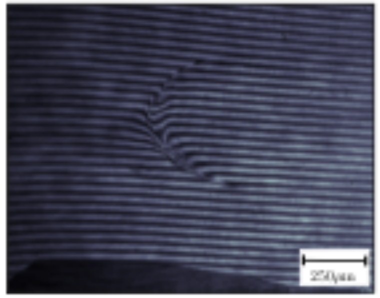

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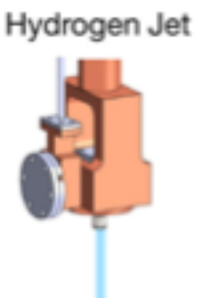

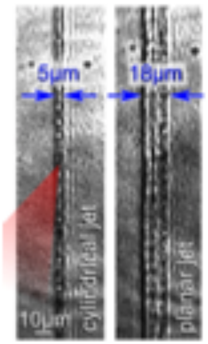

L Obst et al.
Sci. Rep. 2017

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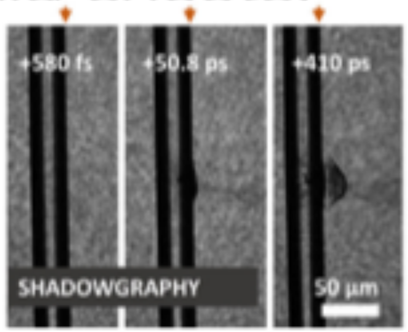
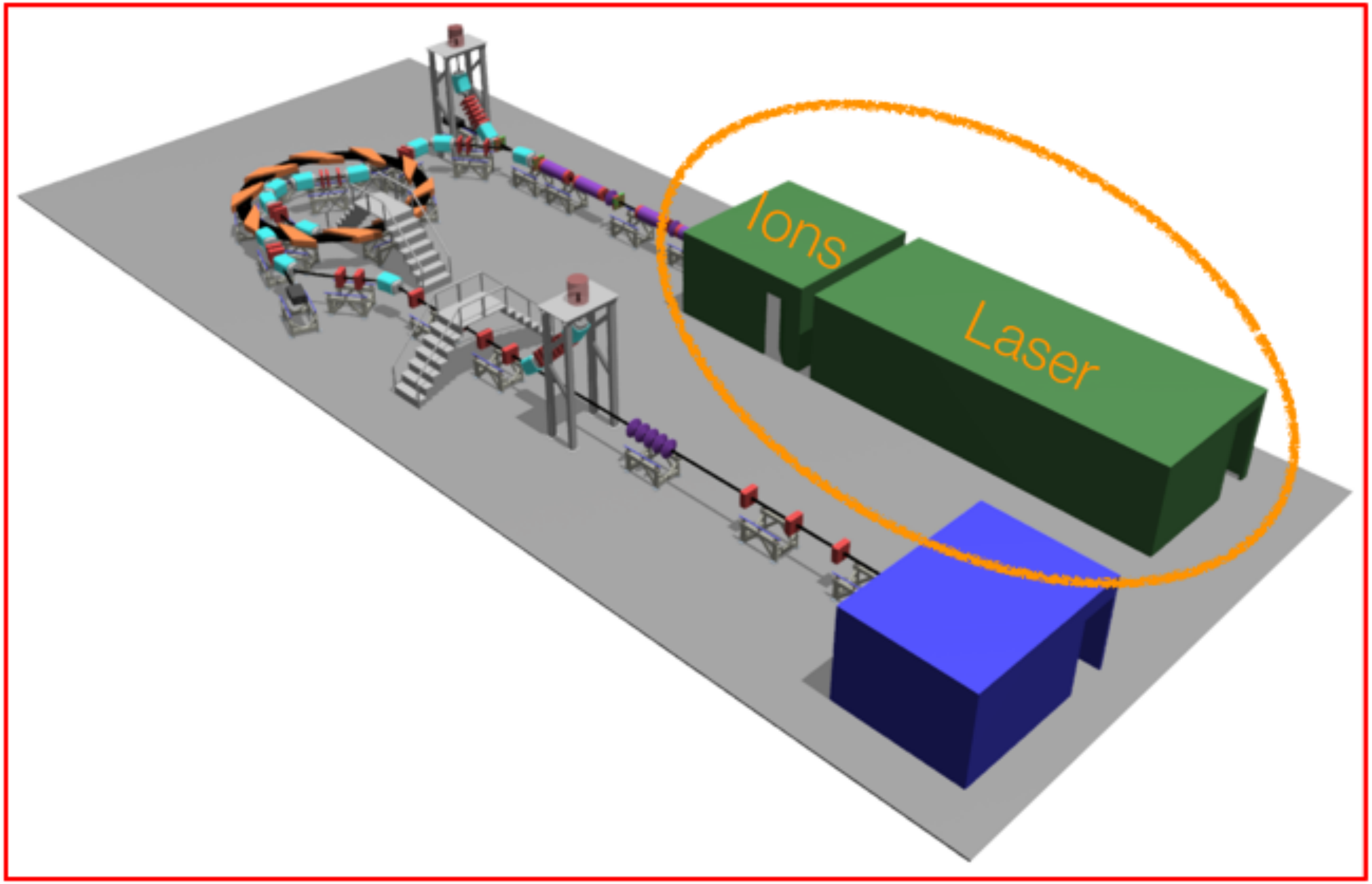


S. Feister et al. Rev. Sci. Inst. (2014)

Proposed Layout



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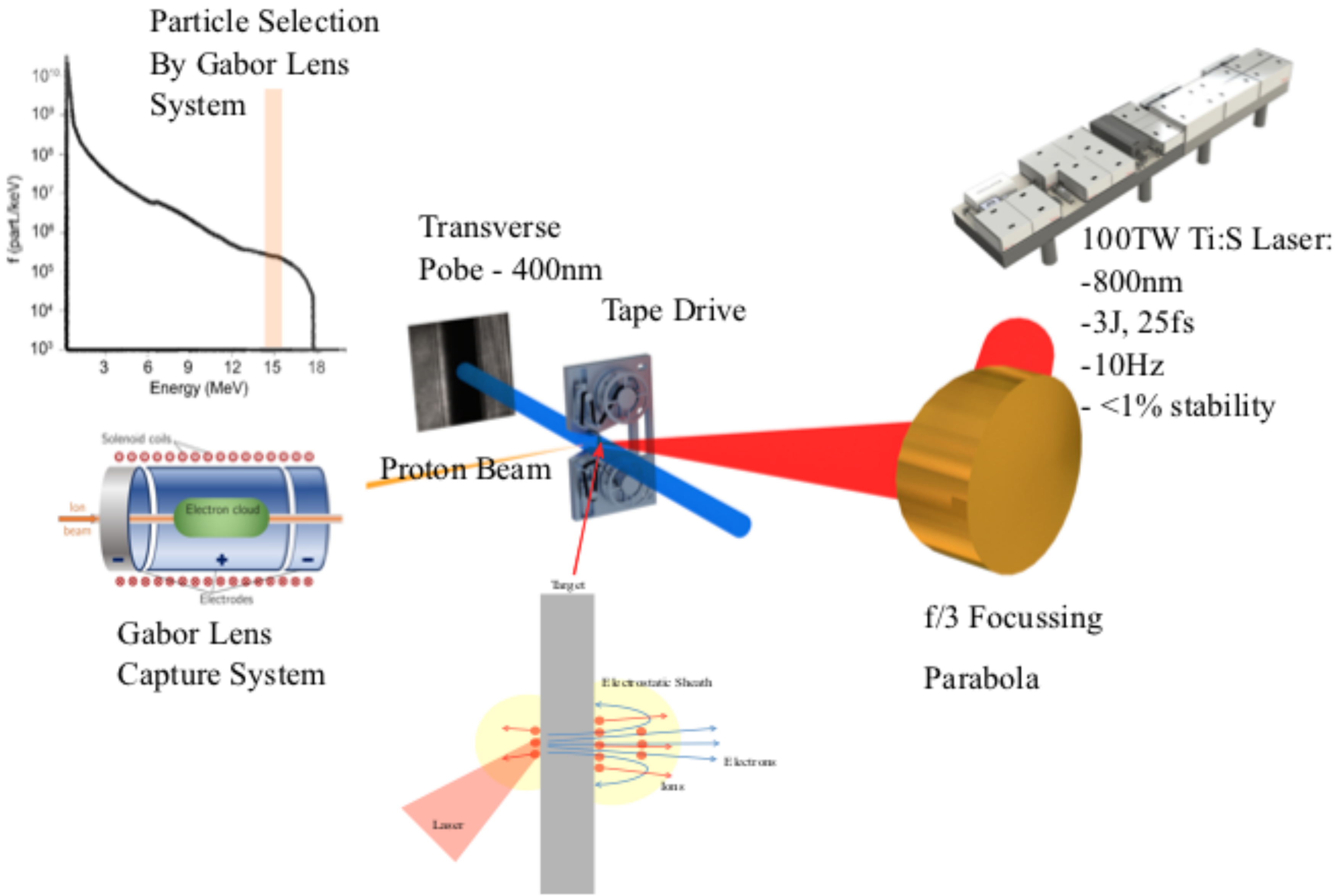

R&D Effort Requirements

- 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.