SUPA Physics Scotland

SUPA IAC Meeting – 7th June 2018

Nuclear and Plasma Physics

Theme Leader: Professor Dave Ireland

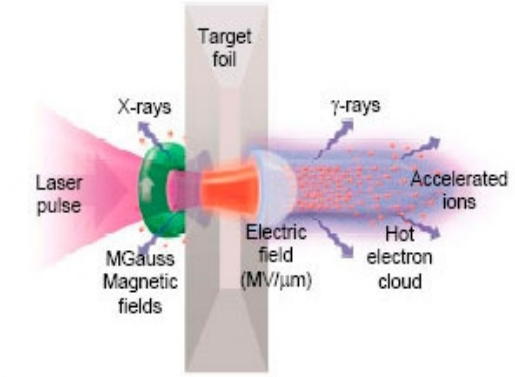
Theme: Edinburgh, Glasgow, Strathclyde, and UWS

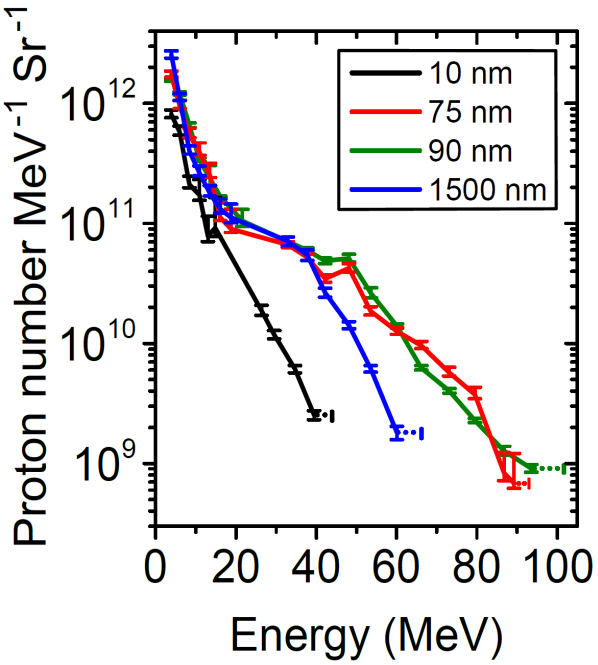
Existing Scope of Theme

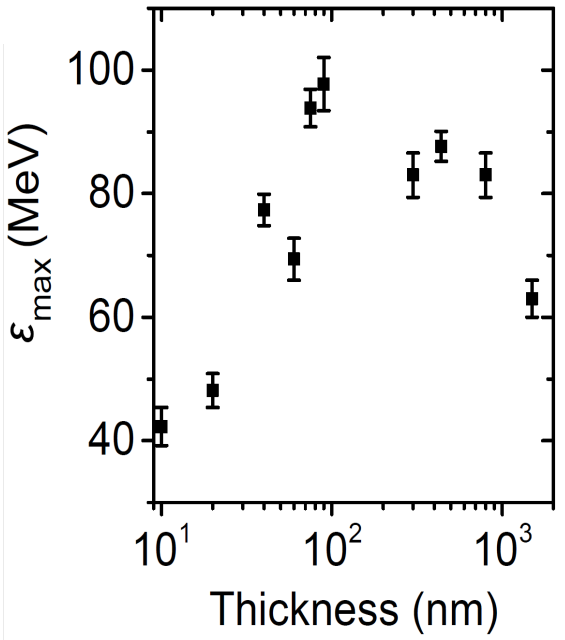
- **Plasma Physics**: high field physics, fusion related physics, laboratory astrophysics,
- **Laser-plasma based accelerators and radiation sources**: compact coherent X-ray, gamma-ray, THz & microwave sources, radiotherapy, imaging
- **Nuclear physics**: hadron structure, hadron spectroscopy, mesons, nucleons and nuclei, nuclear astrophysics, exotic nuclei
- **SCAPA: enabling facility** for cross-disciplinary research
- **Industry engagement**: radiotherapy, radiation damage and imaging for security, defence, health and the environment.
- **Spin-out companies**: Anacail, Lynkeos

Record high laser-driven proton energies

- Experiment performed using the Vulcan laser at the Central Laser Facility
- Near-100 MeV protons (between 94 MeV and 101 MeV) measured for an optimum target foil thickness of ~90 nm
- New hybrid laser radiation pressure-sheath acceleration mechanism demonstrated







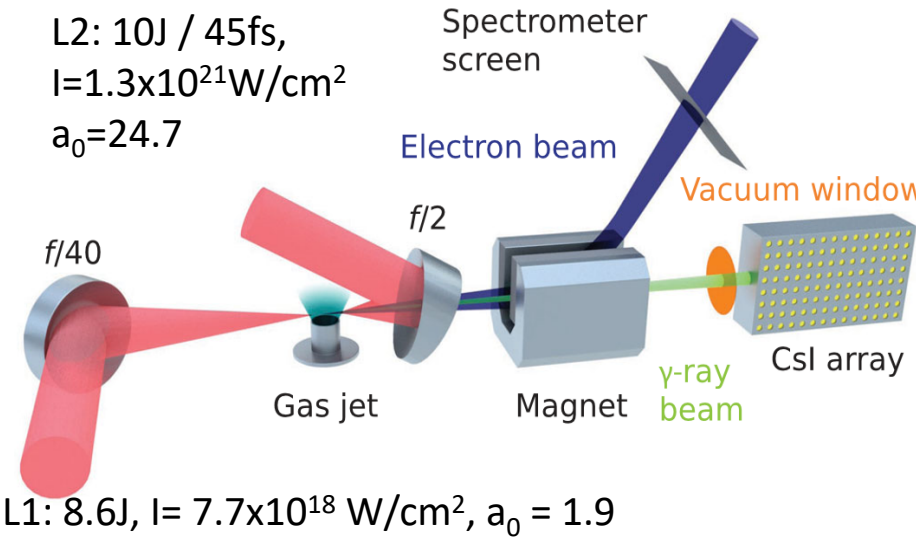
A Higginson,…P McKenna, Nature Communications, 9, 724 (2018)

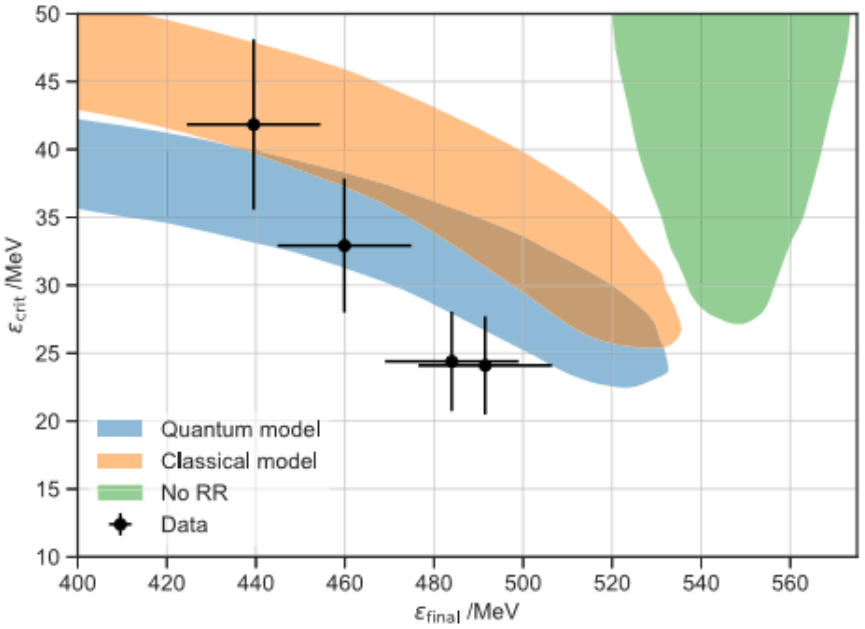
International collaborative experiment, led by University of Strathclyde

For further information: paul.mckenna@strath.ac.uk

Experimental evidence of radiation reaction

- Laser-accelerated electrons radiate energy as γ-rays in high laser field
- Correlation between electron energy reduction and γ-ray energy measured
- Evidence of the onset of radiation reaction detected experimentally for the first time
- Further investigation required to determine of the results are consistent with a quantum radiation reaction model

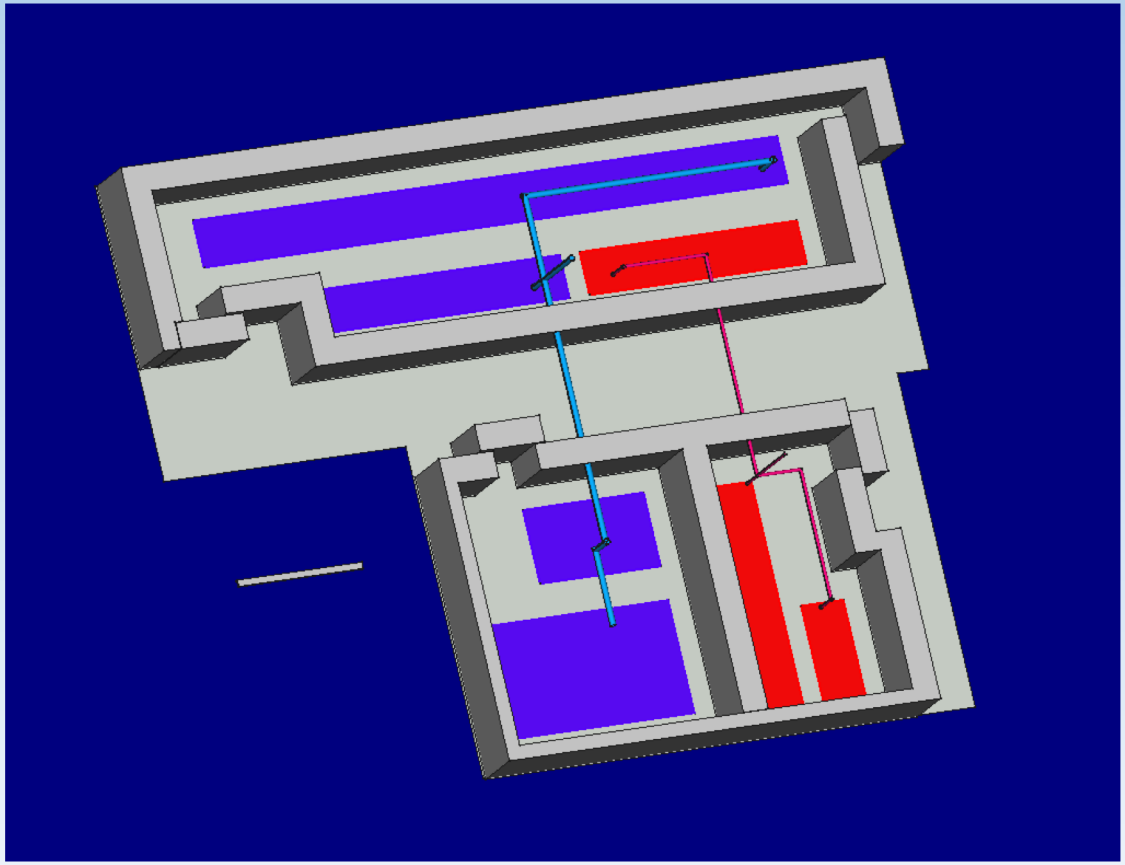


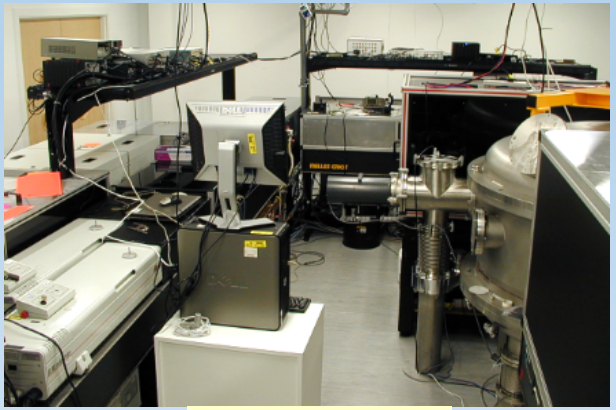


JM Cole,…P McKenna *et al*, Phys. Rev. X, 8, 011020 (2018)

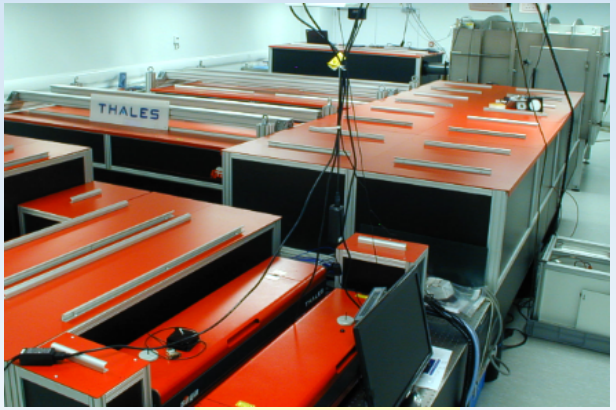
International collaborative experiment, led by Imperial College London

For further information: paul.mckenna@strath.ac.uk



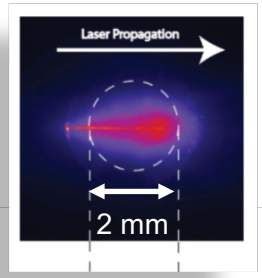


40 TW laser



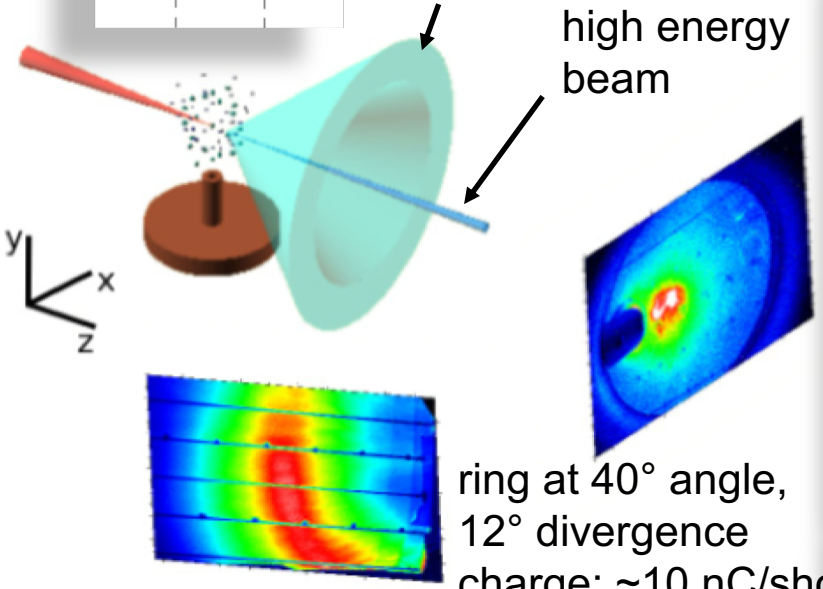
350 TW laser

High-charge beams from a LWFA



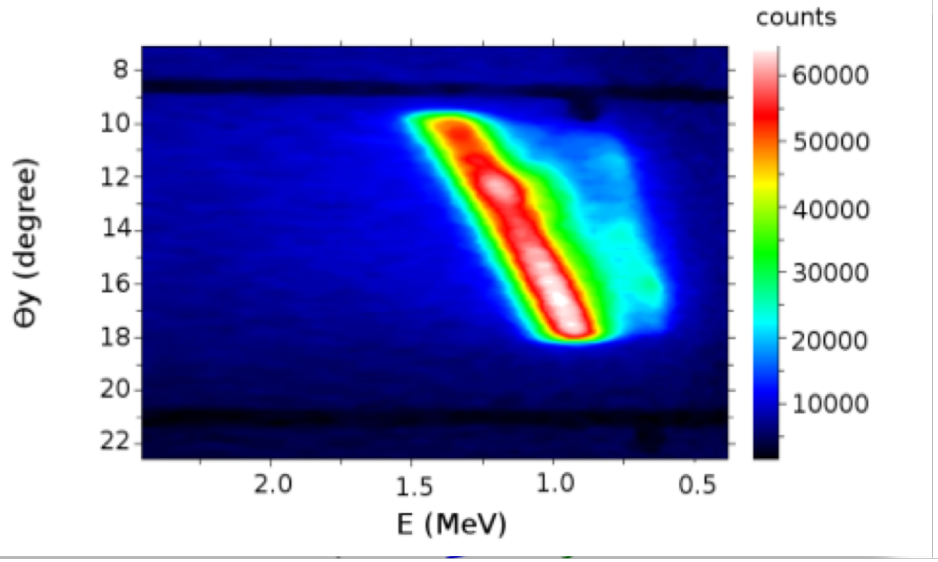
low energy beam

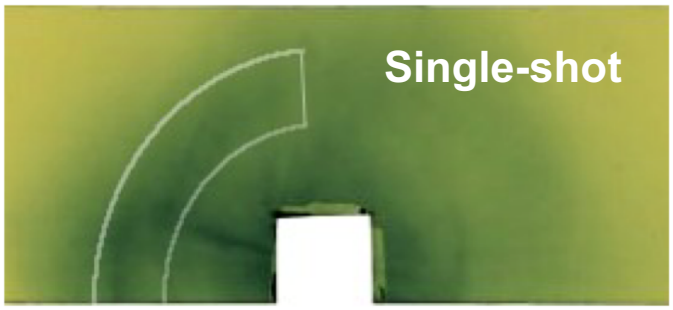
high energy beam

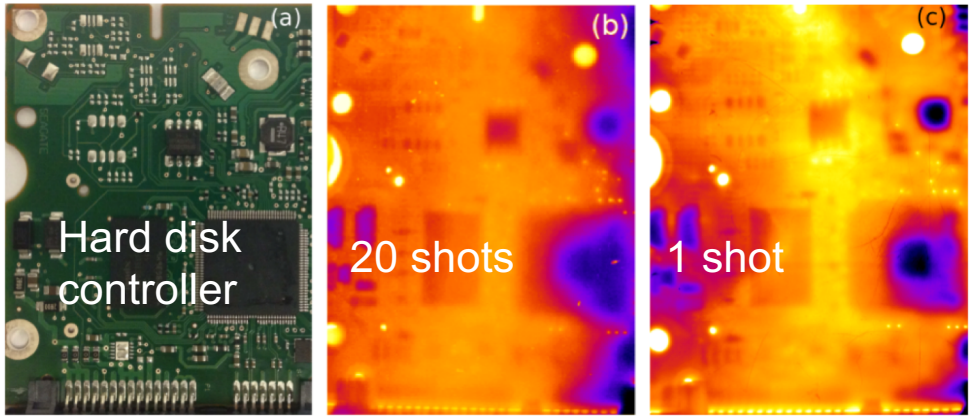


ring at 40° angle,
12° divergence
charge: ~10 nC/shot

X. Yang, E. Brunetti et al., Scientific Reports 2017







In selection:

- maximum dose: 5.6 Gy
- average dose: 3.2 Gy
- charge: 7.5 nC in 1 ps – ultra-high dose rates

mJ, THz pulse generation: X Yang, E Brunetti, DA Jaroszynski, NJP 2018

dino@phys.strath.ac.uk SUPA 2018

Plasma Physics

Plasma Research (Declan Diver, Glasgow):
Current EPSRC funded:

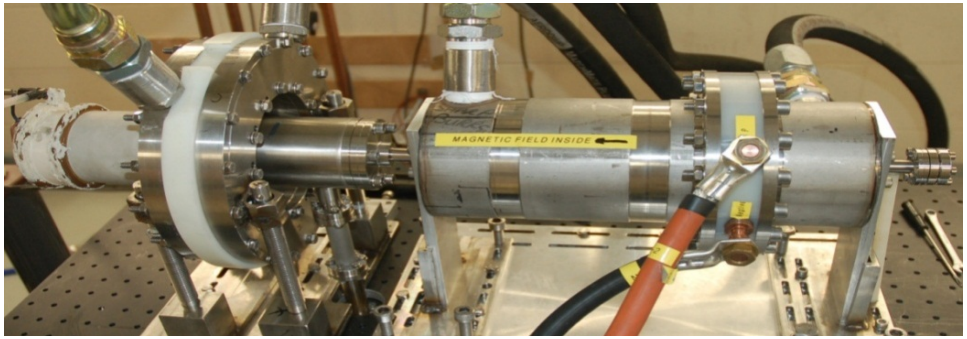
- dynamics and evolution of pellets injected into tokamaks (in partnership with CCFE)
- STFC IAA funded: Plasma Agriculture investigation and funding preparation (using cold plasmas to reduce pesticide use)

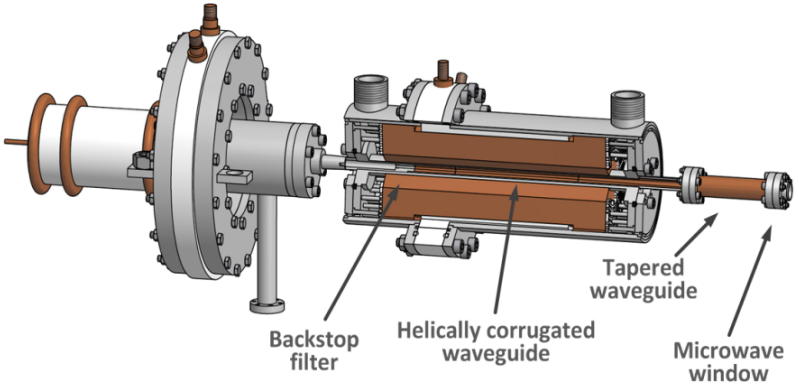
Other research work:

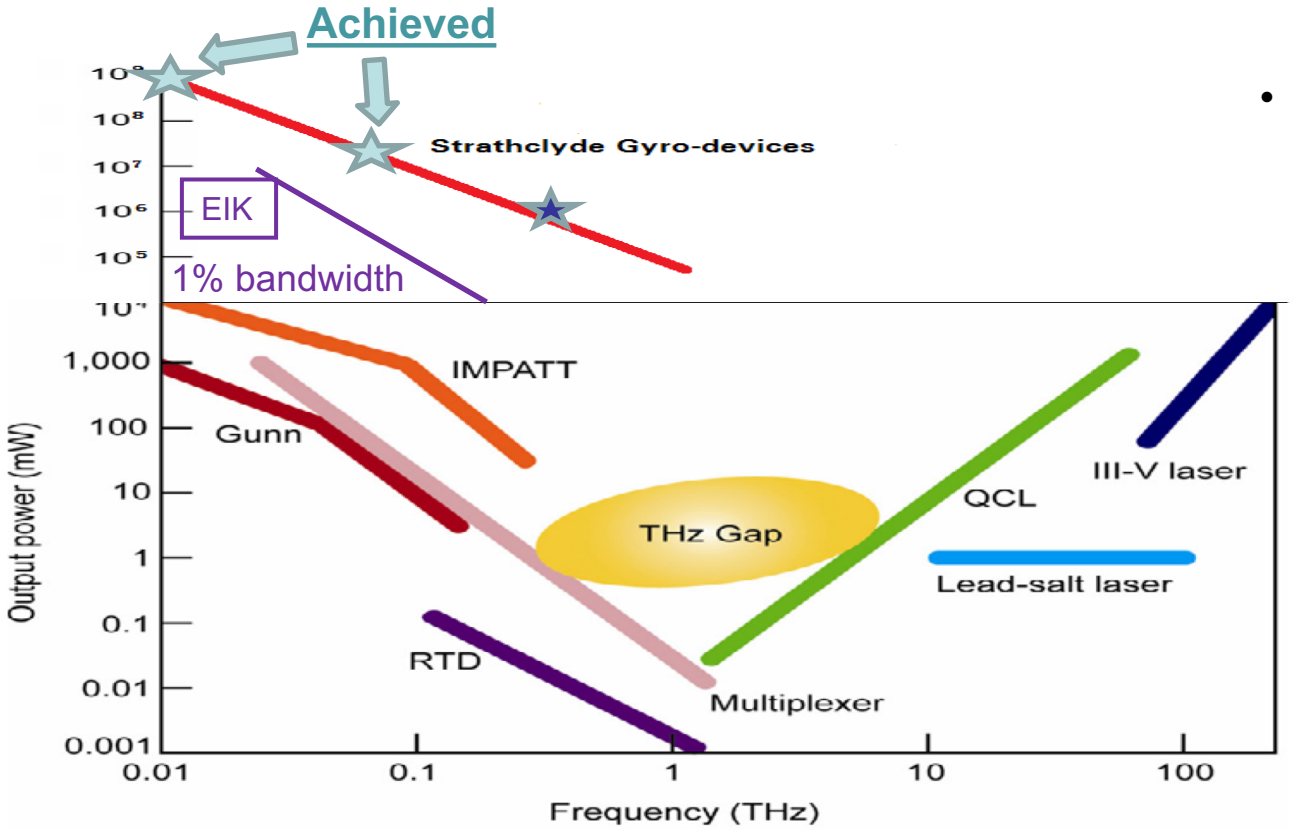
- evolution of dust (accretion, etching, coulomb explosion) of dust in planetary atmospheres in presence of transient plasmas (with Abertay)
- pulsar radiation processes: ultra-relativistic gamma-B to e+e- near pulsar surface, focusing on cross-section sensitivity to transient localised pair-plasma disturbances, relevant to intermittent pulsar behaviour
- non-maxwellian influences in plasma chemistry rate equations affecting yields and simulation accuracy

Ground breaking performance of high power millimetre wave source

- **Tuneable oscillator** (W. He. C.R. Donaldson, L. Zhang, K. Ronald, P. McElhinney and A.W. Cross, PRL 110, 165101, 2013
  http://prl.aps.org/abstract/PRL/v110/i16/e165101





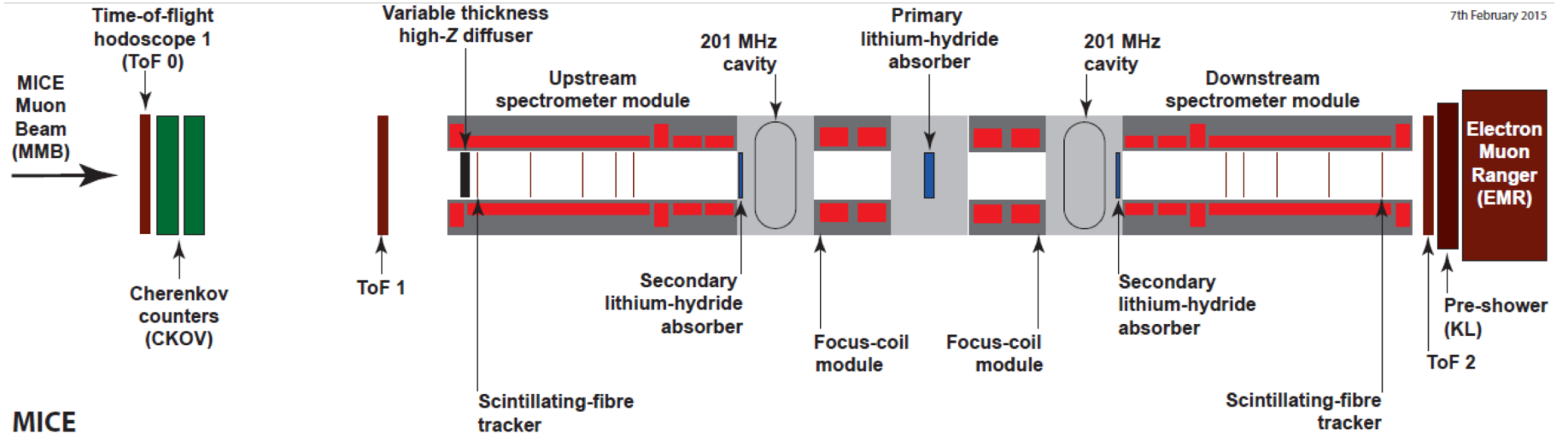


- **Turned into a high power amplifier**
  - 3.4kW, gain 37dB, bandwidth (91 – 96.5)GHz
  - W. He, C. R. Donaldson, L. Zhang, K. Ronald, A. D. R. Phelps and A. W. Cross, Phys. Rev. Lett. 119, 184801 31 October 2017
  - https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.119.18480101

MICE

Muon Ionisation Cooling Experiment [MICE]:

- **Major accelerator science project**
- **UK hosted, International team**
- **Demonstrate the principle of ionisation cooling**
  - Reduce emittance of synthesised muon beams by low Z absorber materials
- **Validate models for interaction of muon beams with matter**
- **Show route to neutrino factory/muon collider**
- **Collaborators include:**
  - UK: Brunel, Glasgow, Imperial, Strathclyde. Liverpool, Oxford, Sheffield, Warwick, Daresbury & RAL
  - International: US; FNAL,LBNL, BNL, IIT, Iowa, Mississippi, UC Riverside: Swiss; Geneva, CERN: Italy; Milano, Napoli, Pavia, Roma III: Serbia; Belgrade: Bulgaria; Sofia: China; IHEP, Sichuan
- Enable next generation fundamental physics experiments through future circular particle colliders



SUPA participants: Dr. Colin G. Whyte, Chair, MICE International Project Office, Dr. Alan R. Young,

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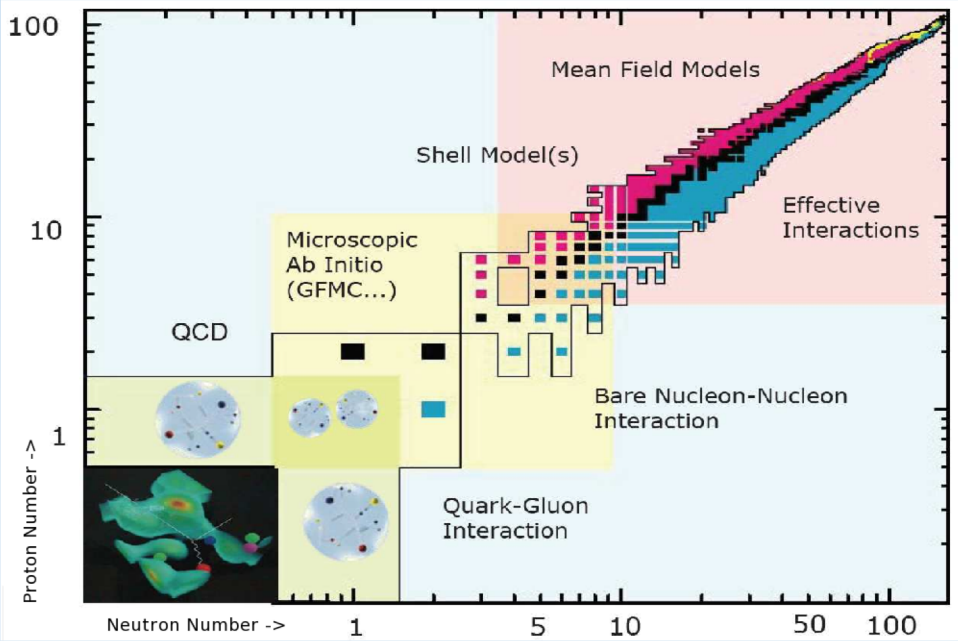
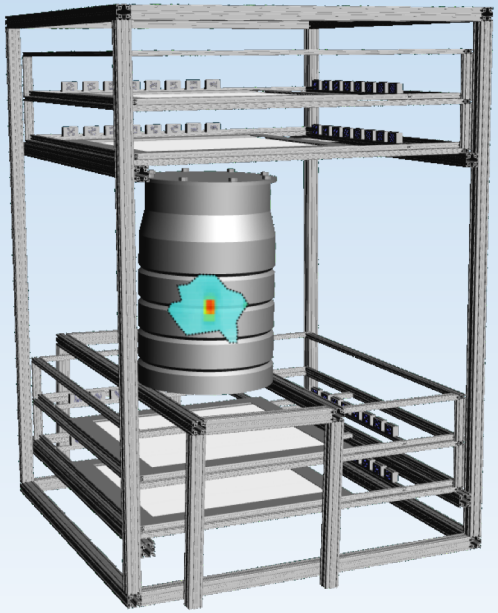
Nuclear Physics



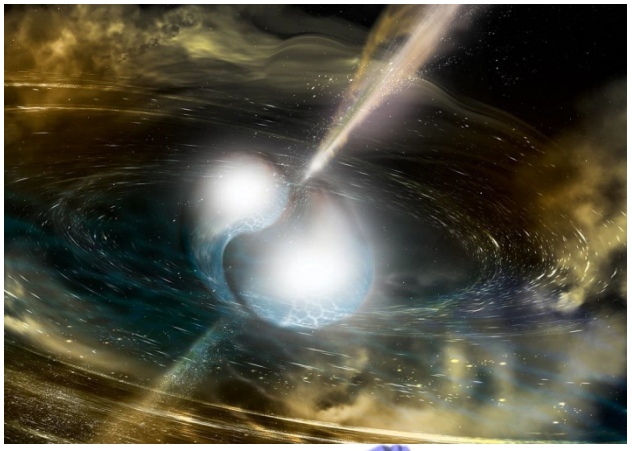
University of Glasgow



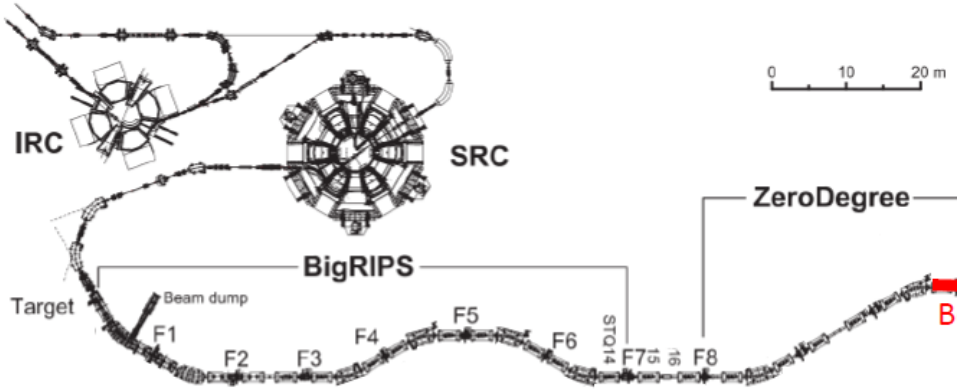
THE UNIVERSITY OF EDINBURGH

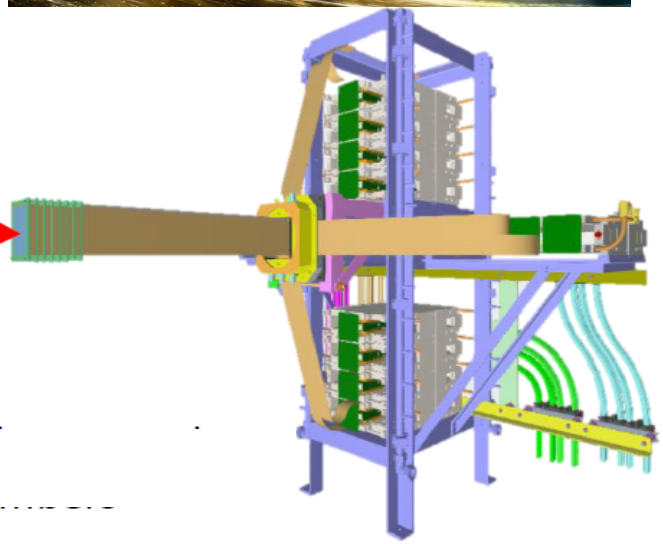
UNIVERSITY OF THE WEST of SCOTLAND
UWS

Studying heavy elements produced in neutron star mergers and supernovae (in Japan)



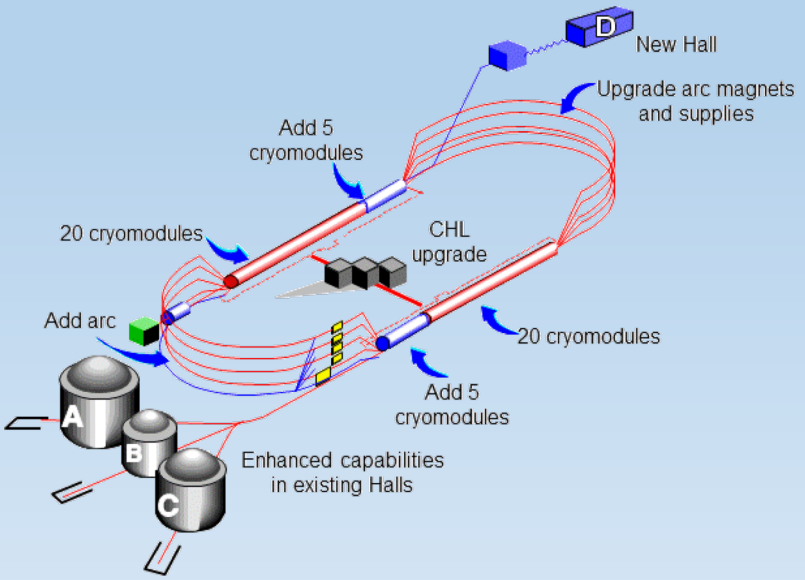
AIDA with BigRIPS



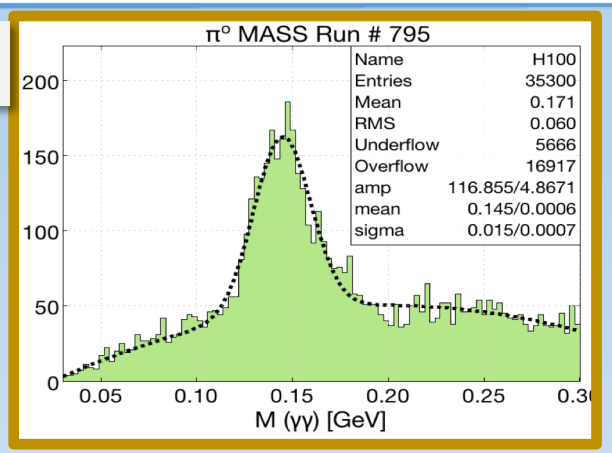


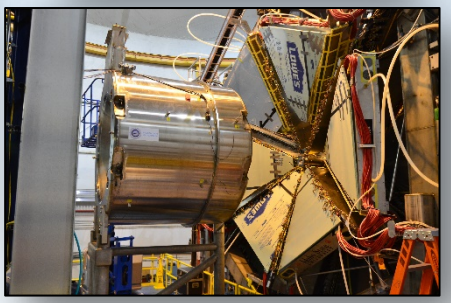
- Fragmentation products are transported to the recoil ion particle separator

Jefferson Lab Upgrade



$e\ ^{12}C \rightarrow \gamma\gamma X$





Project Status:

- **Complete!**
- Total Project Cost = $338M
- All Key Performance Parameters demonstrated
- All Level 2 milestones complete
- All project scope has been delivered
- Final task completed: cool down of last superconducting magnet with energization test

Spin-out Companies

Anacail

Food preservation

Berry Gardens

LINKEOS TECHNOLOGY LTD

Inspection of Nuclear Waste

NPP - Outlook

- **SCAPA:** planned operations this year
- **Basic laser-plasma:** Experimental campaigns and theoretical work to continue
- **Industrial Engagement:** spin-out companies with further prospects
- **FAIR and Jlab Upgrade:** nuclear physics groups to exploit investment
- **International Nuclear Physics Conference:** to take place in Glasgow, 2019 (associated SUSSP school)

SCAPA

INPC 2019 Glasgow, UK