The Cockcroft Institute 20th Anniversary

Peter Ratoff

Director, 2014-2023

First Day

July 2014

Last Day

April 2023

CI Triple Celebration, April 2017

(1) New STFC core grant, (2) New home in A Block & (3) New full partner (U. Strathclyde)

The Cockcroft Institute (2004-)

The Cockcroft Institute of Accelerator Science and Technology

Align with STFC accelerator strategy & ESPP (future colliders & nu beams)

Sustainability

secondary applications

Global challenges in health, security, energy, manufacturing & environment

World class R&D & leadership in conventional RF based systems, novel methods of acceleration and underpinning basic science & technology

Engage with business & industry to develop disruptive technologies (economic & societal impact)

The *de-facto* UK centre for accelerator R&D

primary applications

Education, Training & Public Engagement

Maintain the skills & expertise that provides the UK with a broad & strong capability in the field

Contributing to construction of national & international accelerator facilities enabling PP/NP research & light source users

Equality, Diversity & Inclusivity

5 Partners

Lancaster University

University of Liverpool

Manchester 1824 The University of Manchester

University of Strathclyde

UKRI Science and Technology Facilities Council

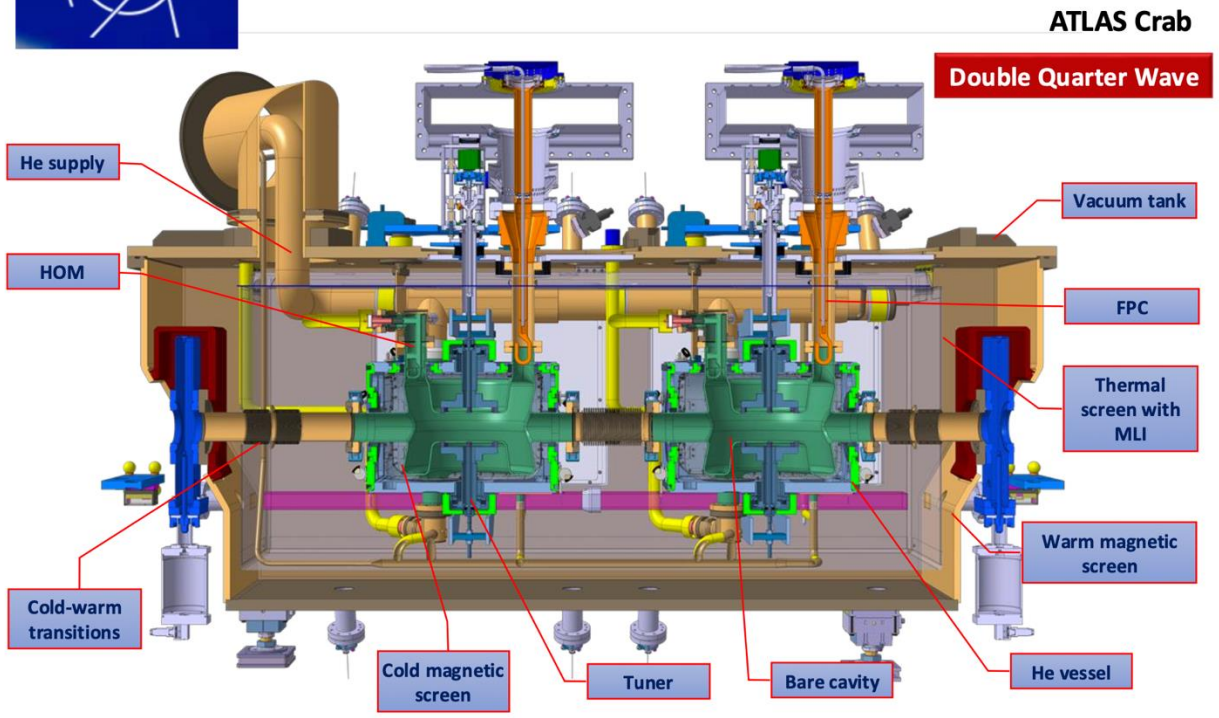
GOALS

Supporting Particle Physics

Enabling high energy proton collider physics

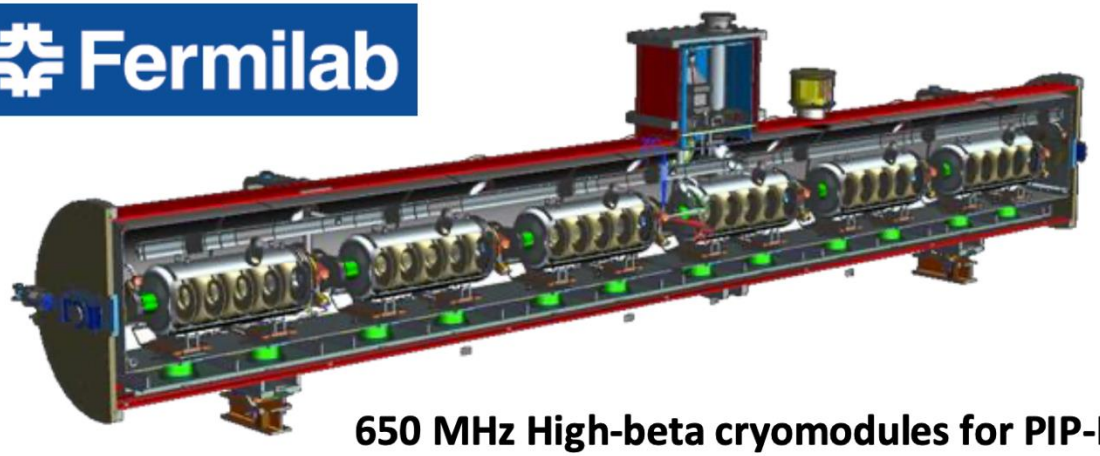
CERN

HL-LHC Crab Cryomodule



Enabling long baseline neutrino oscillation physics

Fermilab

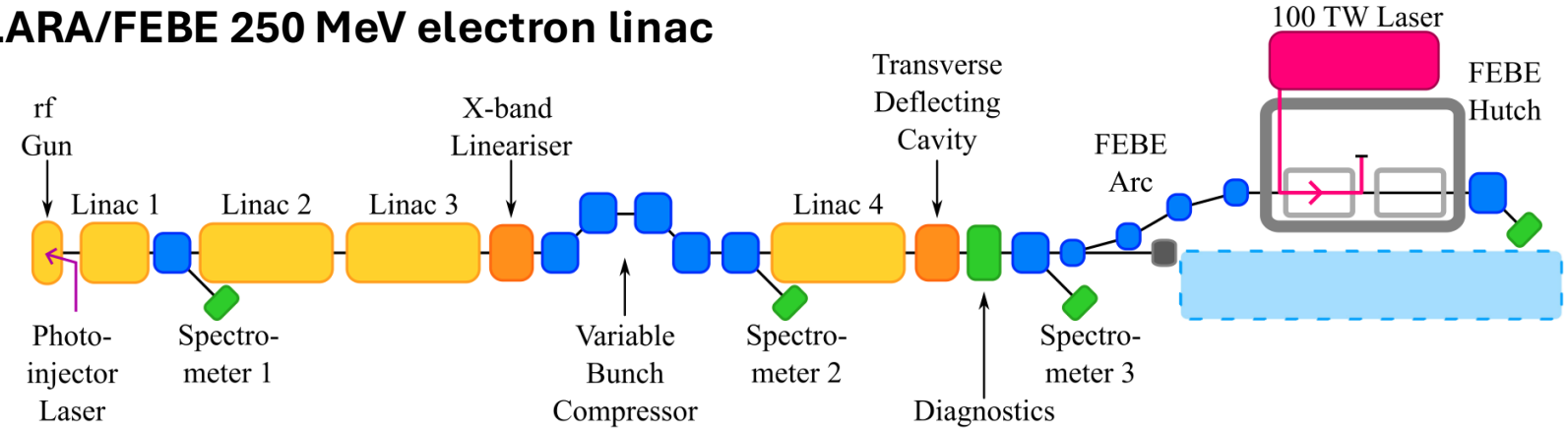


ASTeC

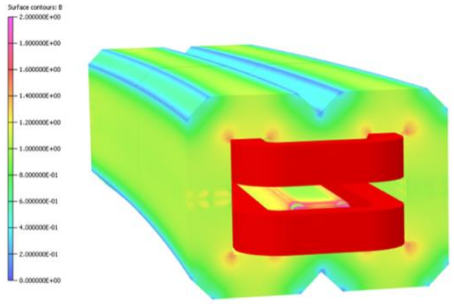
650 MHz High-beta cryomodules for PIP-II

Supporting the Users of Intense Photon/Electron Beams

CLARA/FEBE 250 MeV electron linac

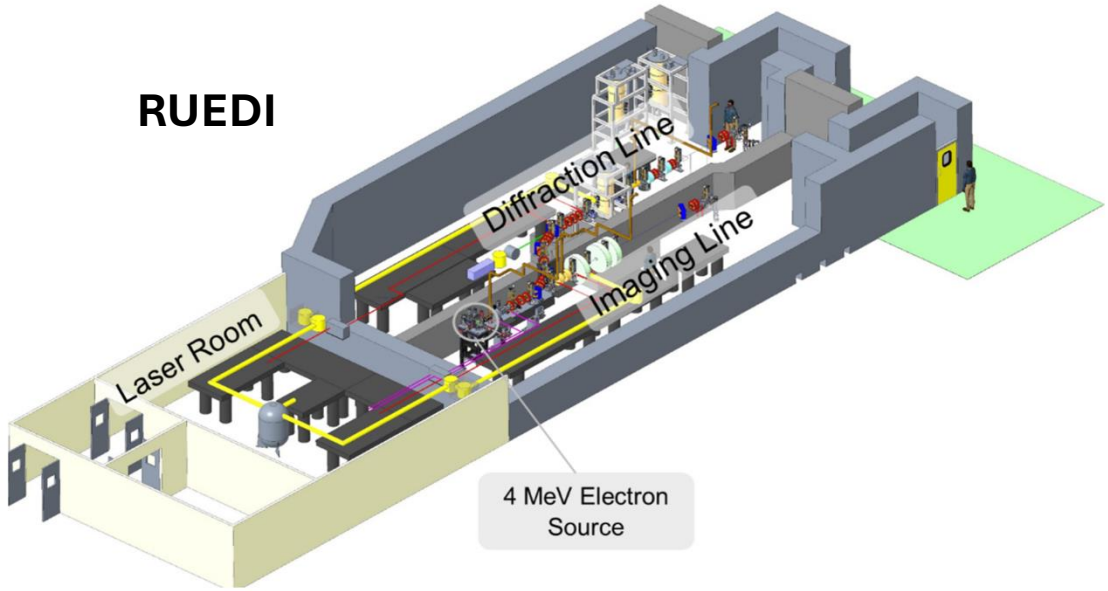


Diamond-2 Booster Magnets



3D field profile of one of the multifunction booster synchrotron dipole magnets. The magnet is used to bend, focus, and correct the beam as it is accelerated. The magnet is compact with a high peak field and small aberrations, allowing the booster to achieve very high performance.

RUEDI



RUEDI facility design showing the layout of the Diffraction and Imaging beamlines, flanked by the facility laser systems.

The three R's ...

- Reading
- wRiting
- aRithmetic

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The five R's ...

- gRadients
- Radiotherapy
- Resources
- Resilience
- Reviews

Higher accelerating field gradients → more compact accelerators

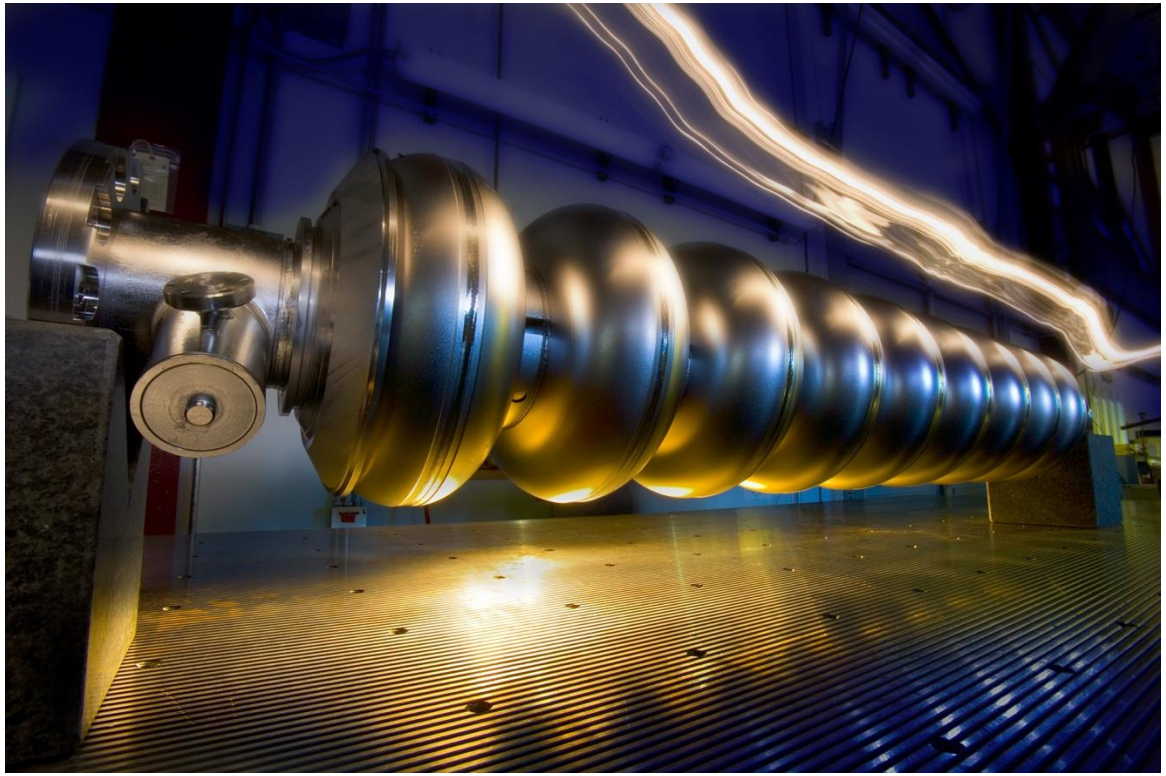
Conventional RF Acceleration

~ 100 MV/m

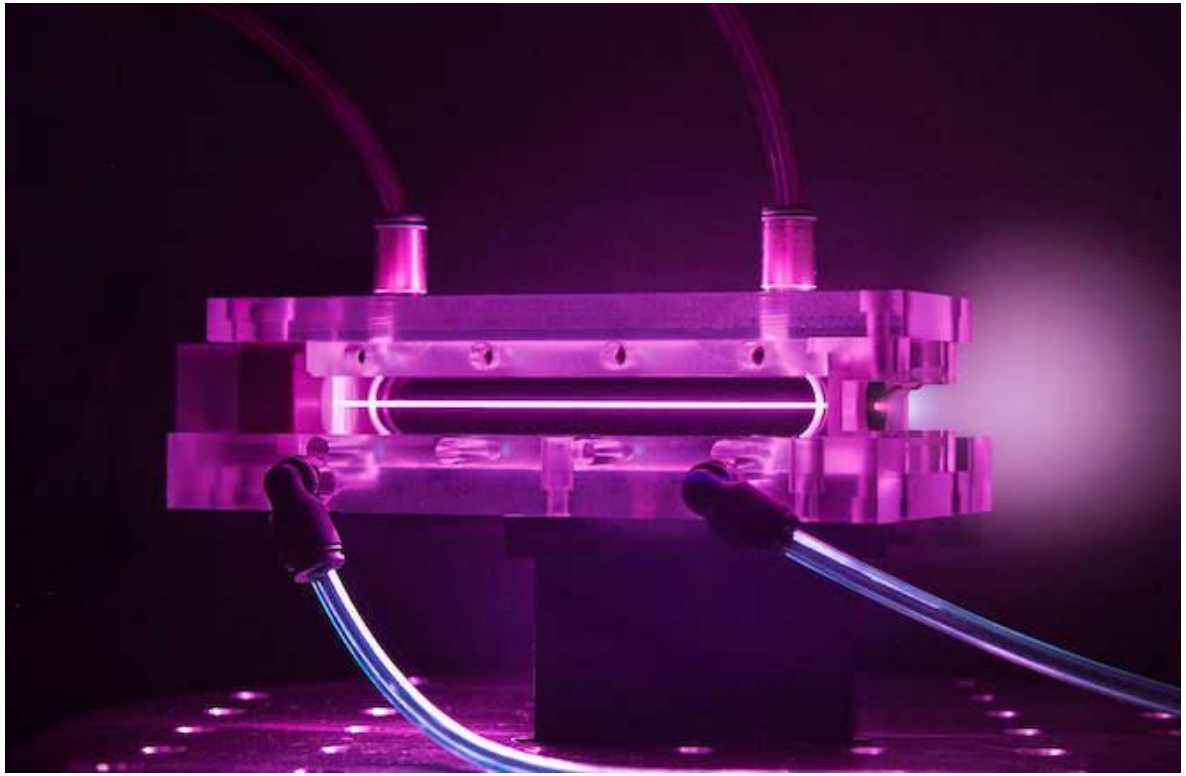
gRadients

Novel Plasma Wakefield Acceleration

~ 10 GV/m



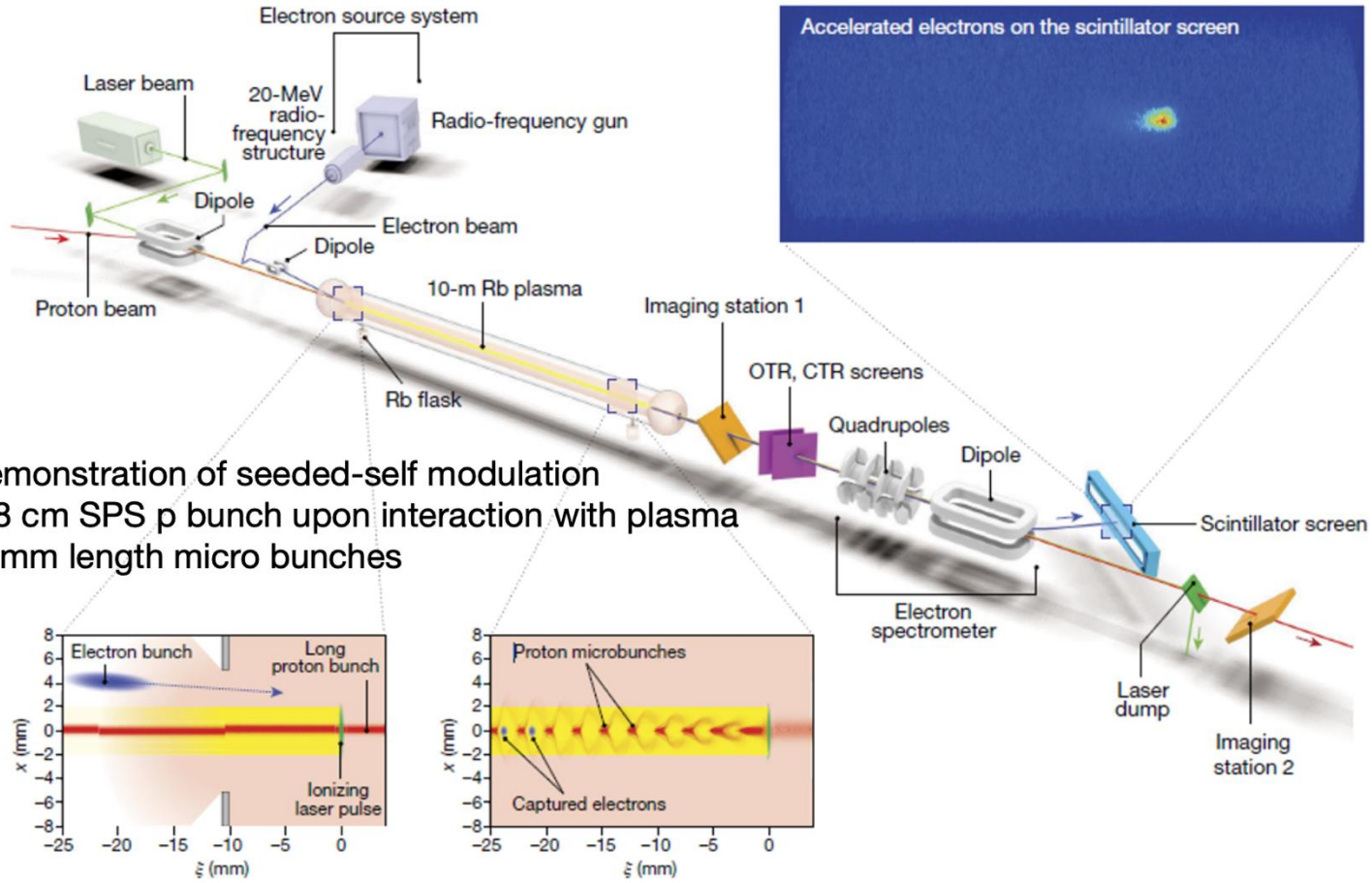
100 cm



10 cm

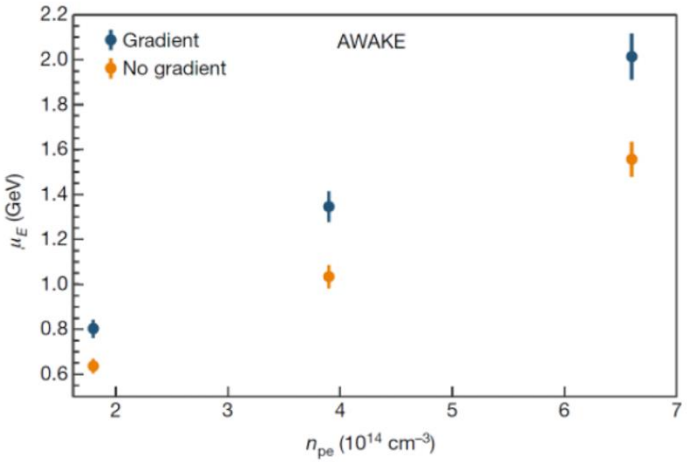
High gRadients

AWAKE Run 1 (2016-2018)



- Demonstration of seeded-self modulation
- 6-8 cm SPS p bunch upon interaction with plasma
- <1mm length micro bunches

Witness e-beam energy gain



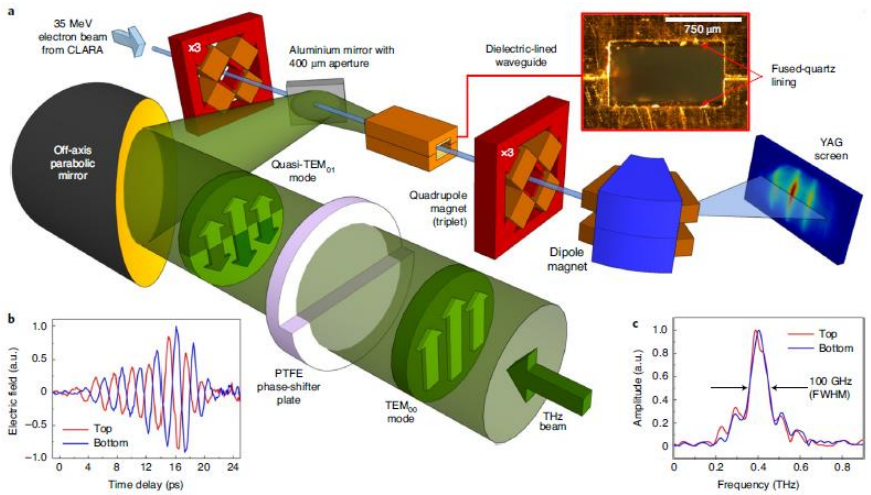
- Acceleration from 20 MeV to 2.0±0.1 GeV was achieved
- with a plasma density of 6.6 x 10^{14} cm^{-3} over 10 m.
- Avg. acceleration gradient ~200 MV/m.

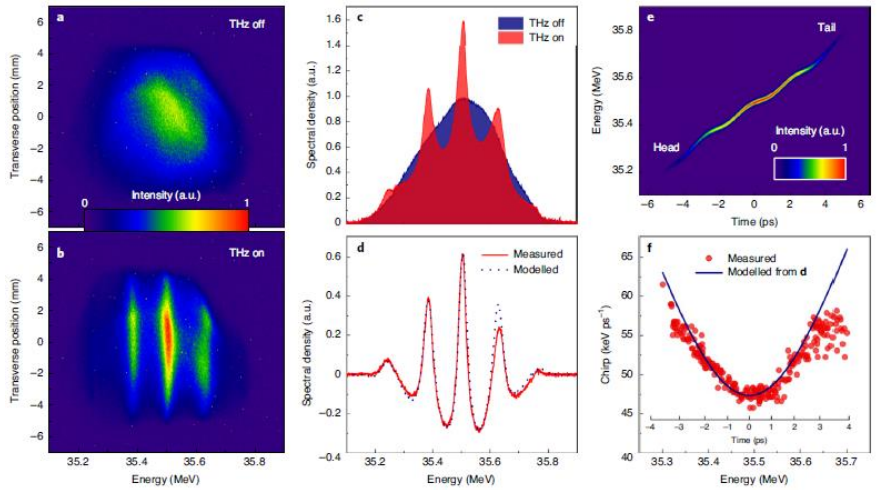
CLARA Run 1 – THz acceleration of relativistic electrons

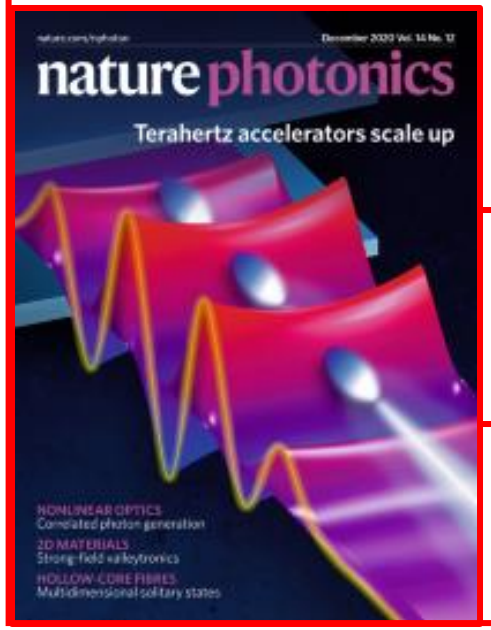
M.T. Hibberd *et al. Nat. Photon.* **14,** 755-759 (2020)

First THz-driven linear acceleration of a relativistic electron beam

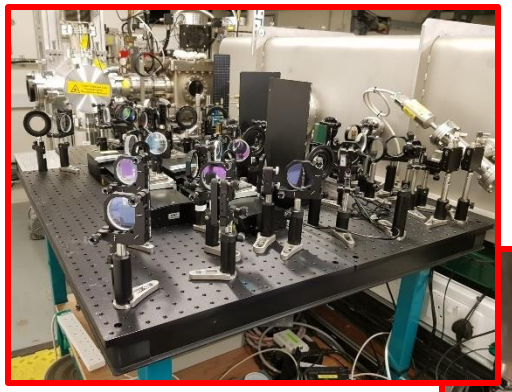
Narrowband THz pulse in dielectric-lined waveguide
10 keV peak energy gain







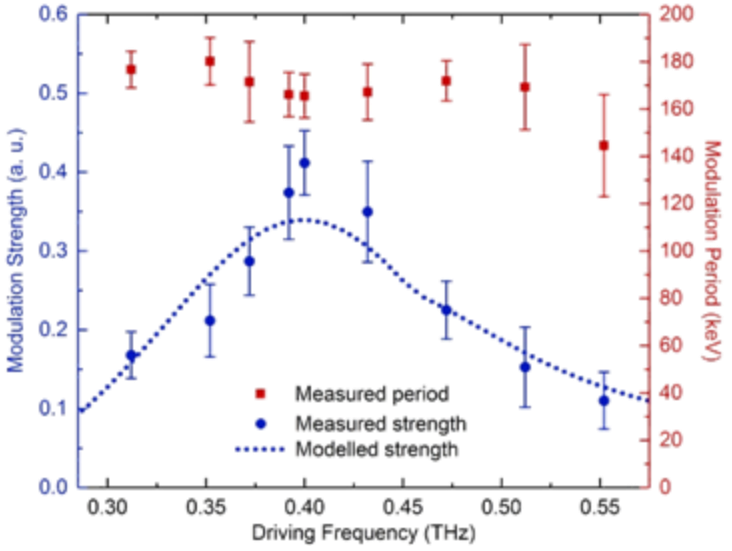
Our group's front-cover publication in Nature Photonics



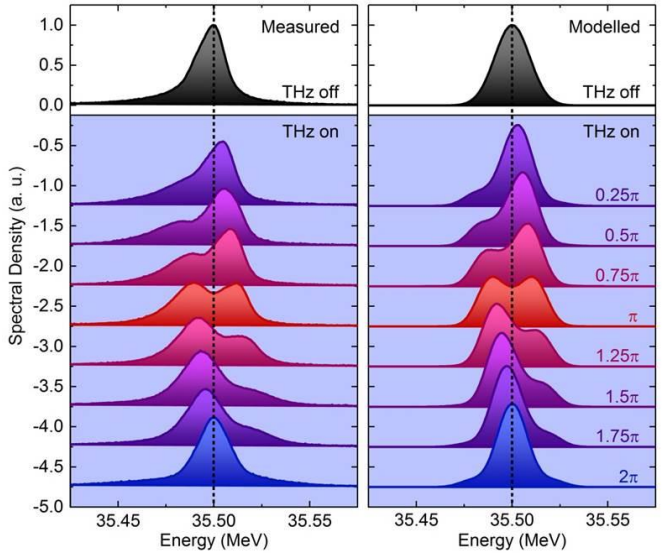
THz optics including source generation, timing overlap and electro-optic detection

Arrangement inside interaction chamber including waveguide and THz transport

Demonstrated phase-velocity matched interaction and capability for longitudinal phase space diagnostic

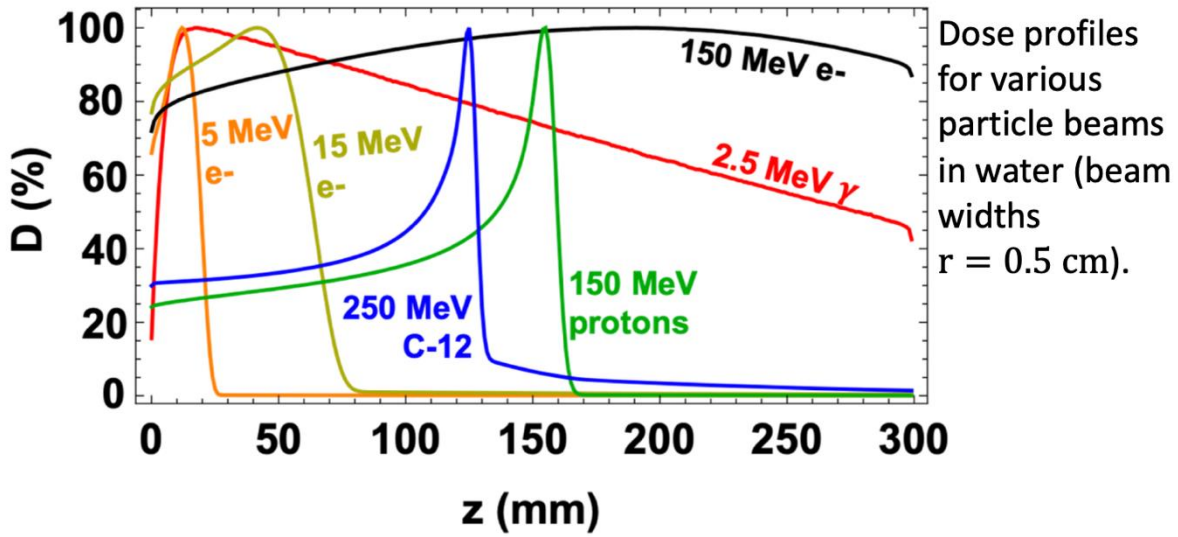


Near-whole bunch acceleration limited by the CLARA bunch length



Radiotherapy

Very High Energy Electron (VHEE) Therapy



Dose profiles for various particle beams in water (beam widths r = 0.5 cm).

- **Photons:** The *most commonly used*, peak dose deposited close to the skin surface
- **Protons:** *High cost* and *limited availability*, *Well-defined finite range* in matter
- ***Electrons:*** Used for treating *superficial tumours*. *Lateral scattering.*
- **VHEE:** Higher dose range, less lateral scattering

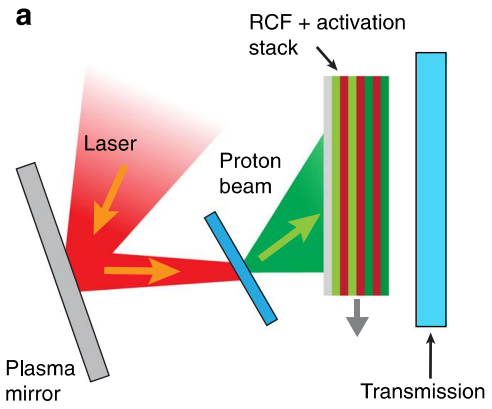
Proton Beam Therapy

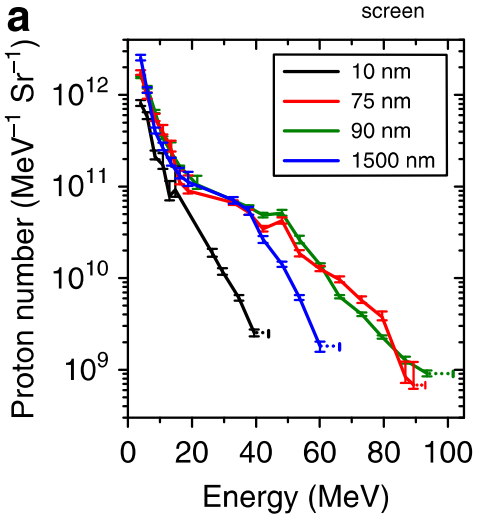
NHS
The Christie
NHS Foundation Trust

NHS/Christie PBT Centre opened at end of 2018 with dedicated Research Room

gRadients + Radiotherapy

Synthesis of high-gRadient (plasma) acceleration & Radiotherapy



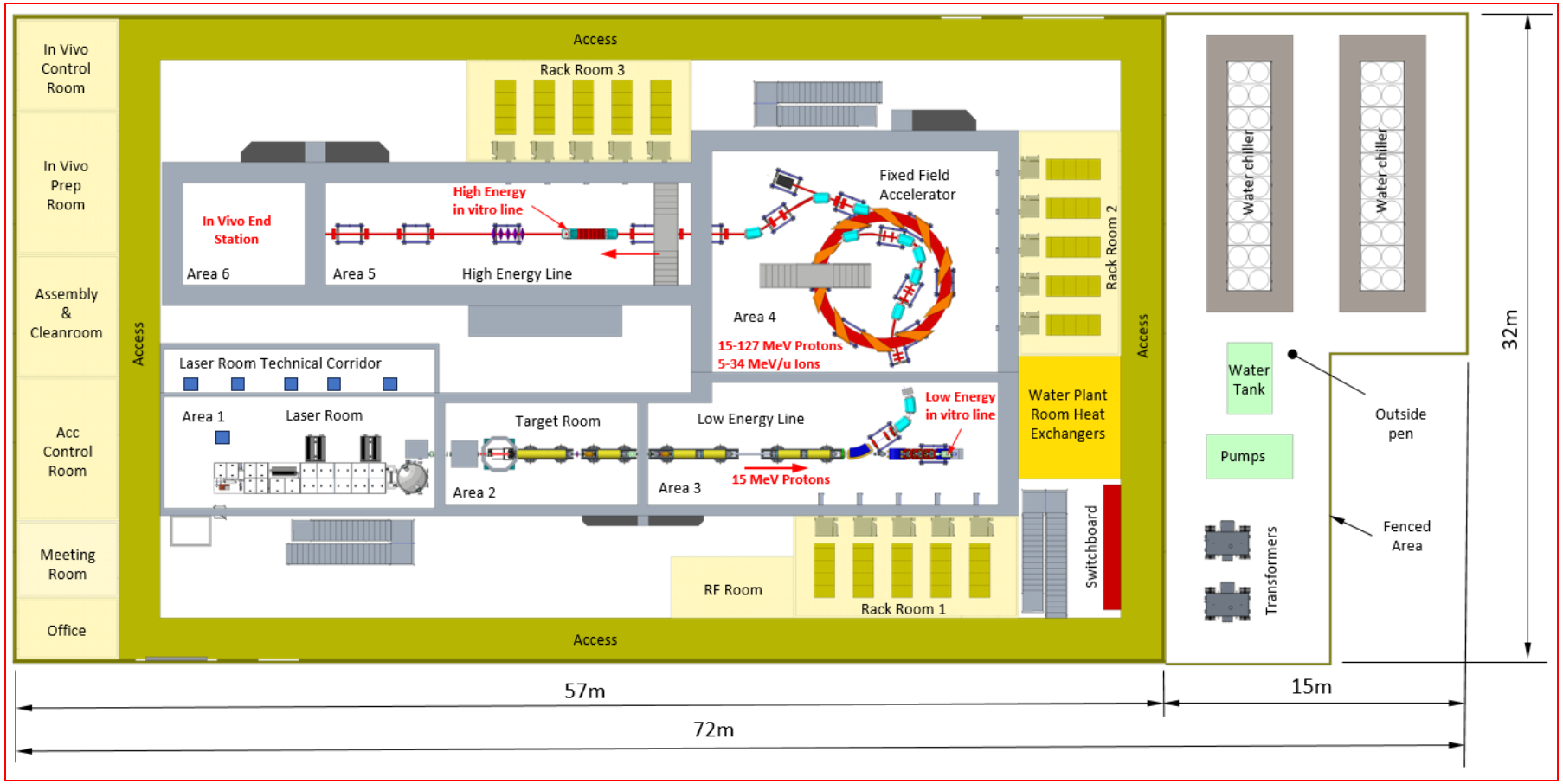


100 MeV protons from thin metal foils @ CLF

Nature Comms. (2018) 9:724

Strathclyde/CI/QUB/CLF

Ion Therapy Research Facility (ITRF) Conceptual Design Study (2022-2024)



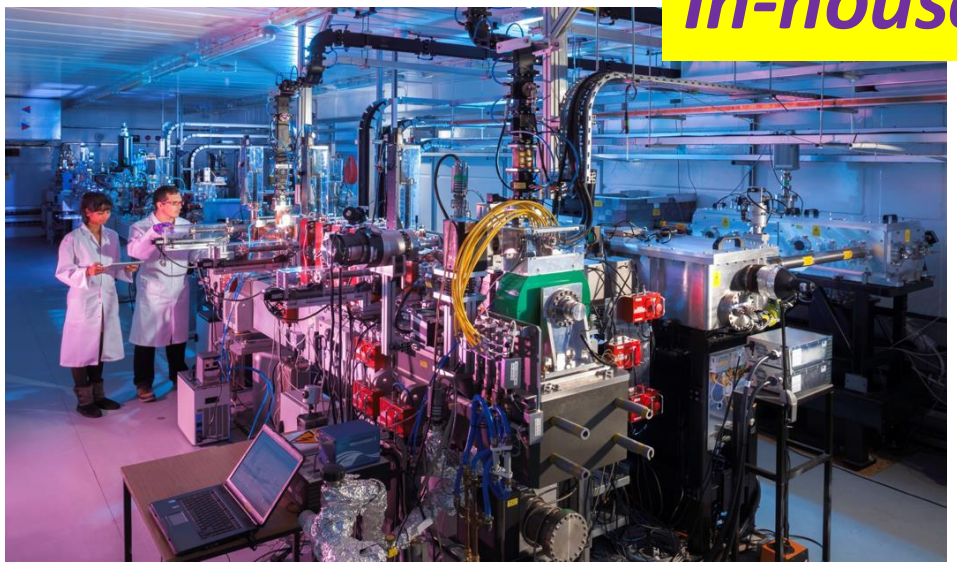
Daresbury Laboratory

RF, Cryo, Diagnostics, Laser & Vacuum labs

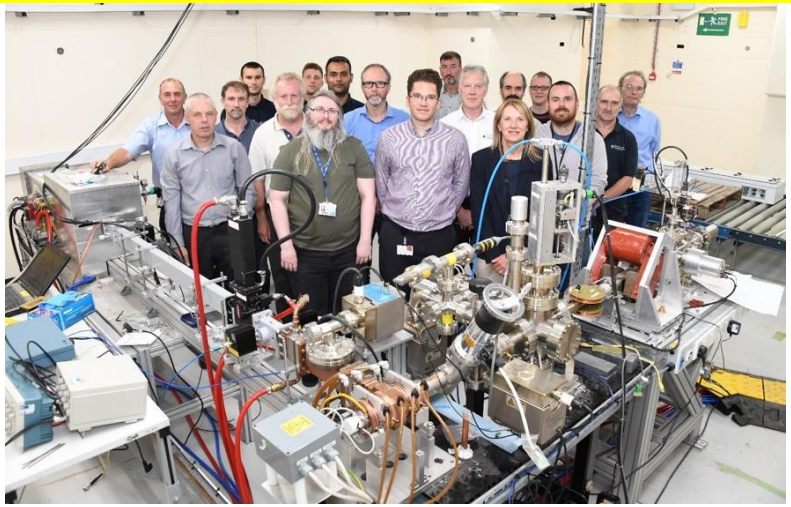
University of Strathclyde

Resources

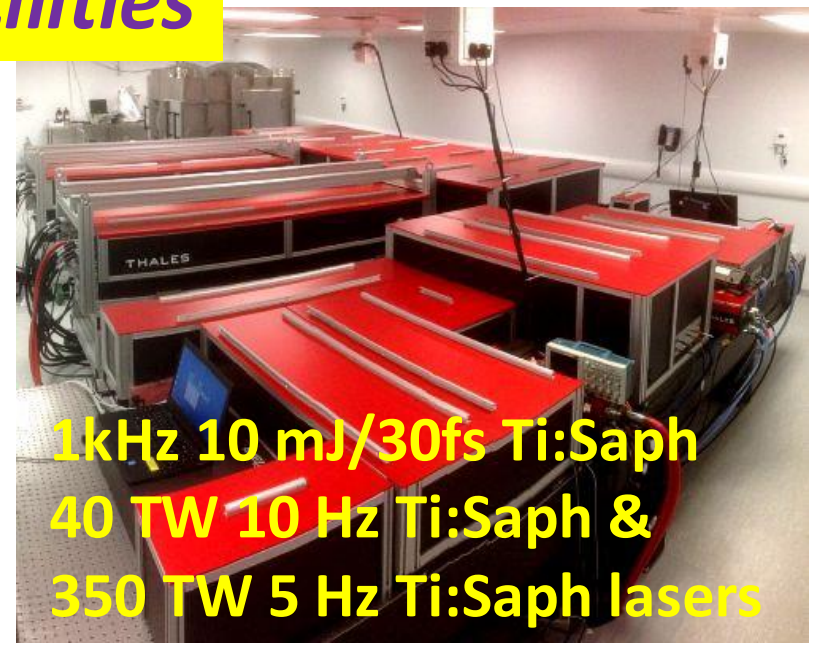
In-house developed labs & facilities



CLARA/VELA (4-250 MeV)



3.5 MeV Compact Linac



The 2019/20 Calendar & the impact of Covid-19

20–23 Oct. 2019	Oct. 2019 – Mar. 2020	Oct 2019 – Mar. 2020	16 Mar. 2020	19 Mar. 2020	Mar.–July 2020	June–July 2020	July–Oct. 2020	1–4 Sep. 2020	7–9 Oct. 2020
SAC2019 Review	Preparation of STFC Core Grant Application (2021-2025)	Announcement of STFC continued funding for HL-LHC & AWAKE	Daresbury Lab lockdown commenced	Submission of Core Grant Application to STFC	Working from home (almost all staff & students) FEBE design completed ESPP published UK XFEL Science Case published	Review of Core Grant (3 online meetings with panel)	Cautious return to on-site working at Daresbury Lab (very limited numbers, slow ramp-up) ESS cavity tests CLARA e^- gun conditioning	Hosted virtual Linac2020 Conference 790 registered	Hosted virtual EIC Workshop: "Promoting Collaboration on the EIC" 360 registered

Resilience

"Coming out of two years of severe COVID-19 related restrictions, CI appears to have weathered the storm well and has ramped up activities to (or even beyond) pre-pandemic levels.

CI is clearly a sought-after partner in accelerator physics and enters 2023 in a much stronger position than some five to eight years back.

The many students and postdocs attracted by CI to the science and technology of accelerators ensures the next generation of practitioners and underscores CIs strength. CI is positioned well to face the future!"

Jerry Blazey	(NIU)	Stephen Gibson	(RHUL/JAI)	Jens Knobloch, Chair	(HZB/Universität Siegen)
Ulrich Dorda	(SCK CEN/MYRRHA)	Anna Grassilino (remote)	(FNAL)	Wim Leemans	(DESY)
Angeles Faus-Golfe	(IJCLab)	Ryoichi Hajima	(QST)	Eduard Prat	(PSI)
Massimo Ferrario (remote)	(INFN Frascati)	Mark Hogan	(SLAC)	Frank Zimmermann	(CERN)

The Cockcroft Institute @20

- The Cockcroft Institute has existed for just over 20 years & acquired a global reputation
- Builds on 60 years of accelerator operations at Daresbury Laboratory
- Established a strong education/training programme (>300 PhDs) & award-winning public engagement
- Partnership of 4 universities & STFC accelerator department – 250+ staff & students
- Contributing to local, national & international accelerator facilities, basic R&D, technology transfer
- Past highlights – ALICE ERL (1st in Europe) and EMMA NS-FFA (World's 1st)
- Recent highlights – ESS SCRF cavities, CLARA, HL-LHC crab cavities, AWAKE p-PWFA, Muon g-2, ZEPTO magnets, high efficiency klystrons, thin film SCRF
- Bright (near) future: PIP-II cryomodules; CLARA/FEBE & SCAPA exploitation (THz & plasma acceleration)
- Supporting NWE radiotherapy hub including VHEE, PBT (Christie) & Ion Therapy Research Facility/LhARA
- Longer term future: RUEDI (£125M), Electron-Ion Collider, UK XFEL design study, FCC, PWFA user facilities