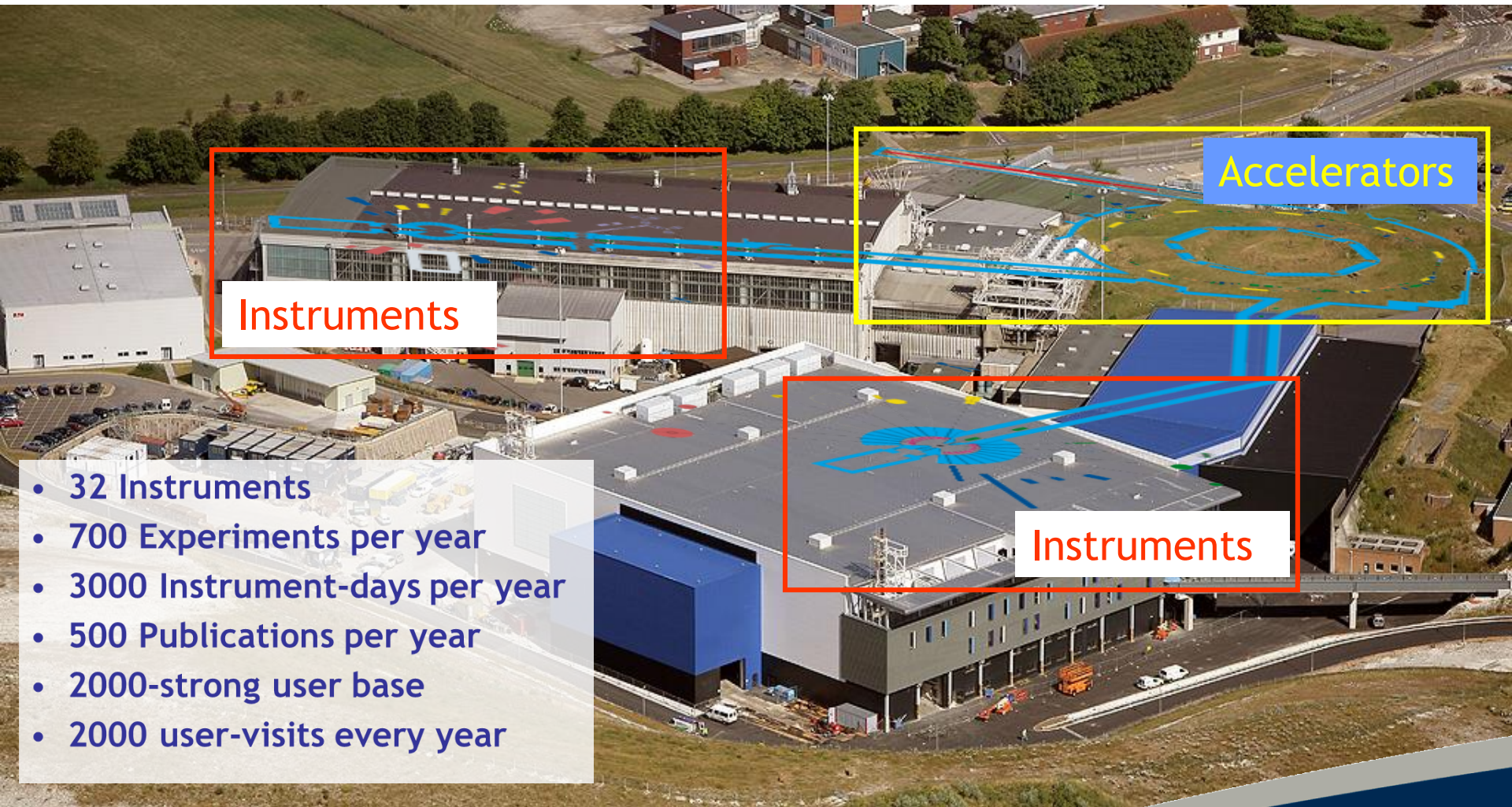


ISIS Muons

Adrian Hillier
ISIS Muons



The ISIS Pulsed Neutron and Muon Source



Instruments

Accelerators

Instruments

- 32 Instruments
- 700 Experiments per year
- 3000 Instrument-days per year
- 500 Publications per year
- 2000-strong user base
- 2000 user-visits every year

A World Centre for Condensed Matter
Science with Neutrons and Muons



Science & Technology Facilities Council

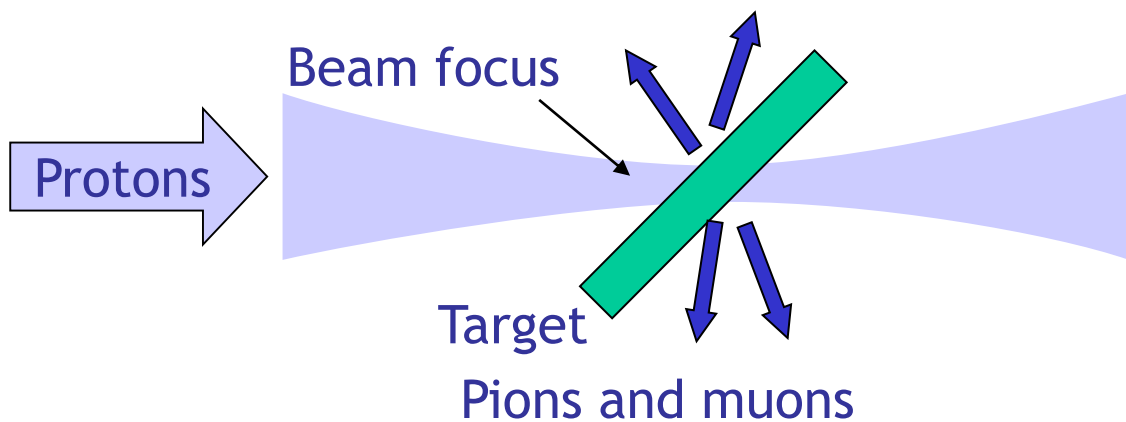
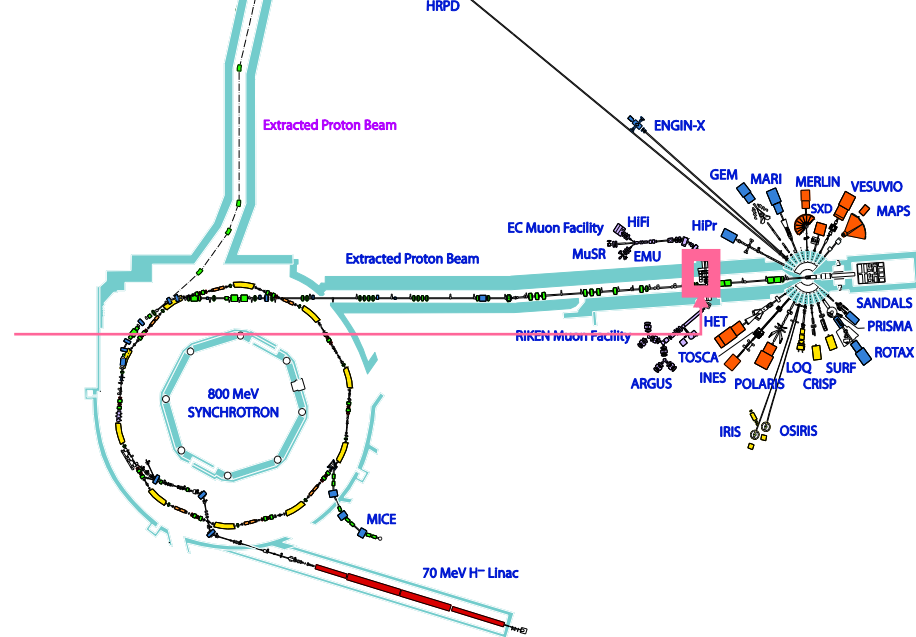
ISIS

Muon Production Target

- Made of graphite
- Takes ~5% of the proton beam
- 40 pulses per second



The *Muon Target*



Muon Production Target

- 40 pulses per second
 - (50 Hz one missing)
- Muon pulse width ~60 ns

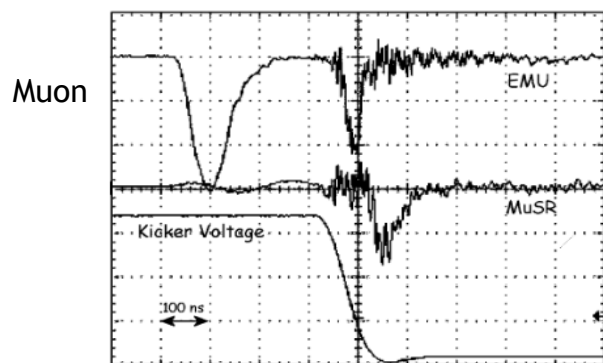
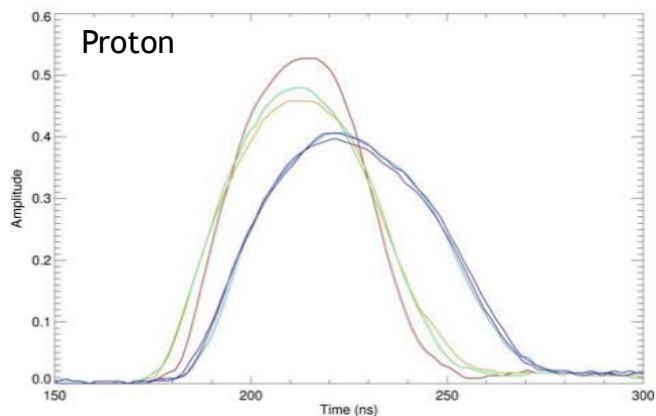
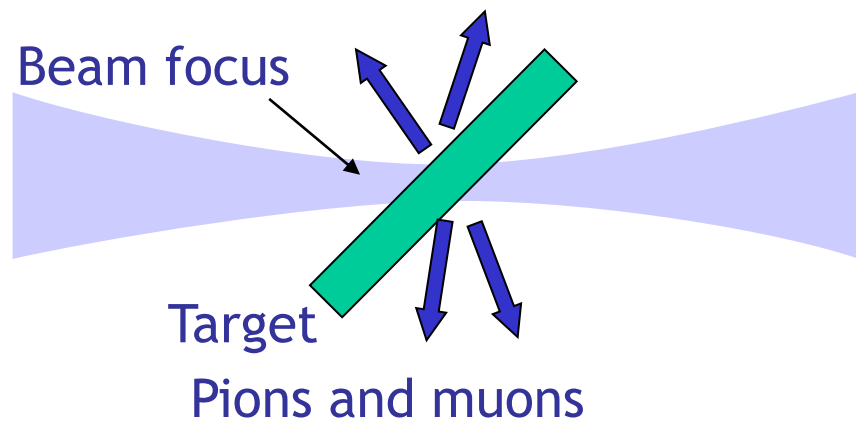
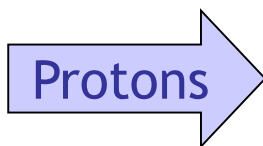
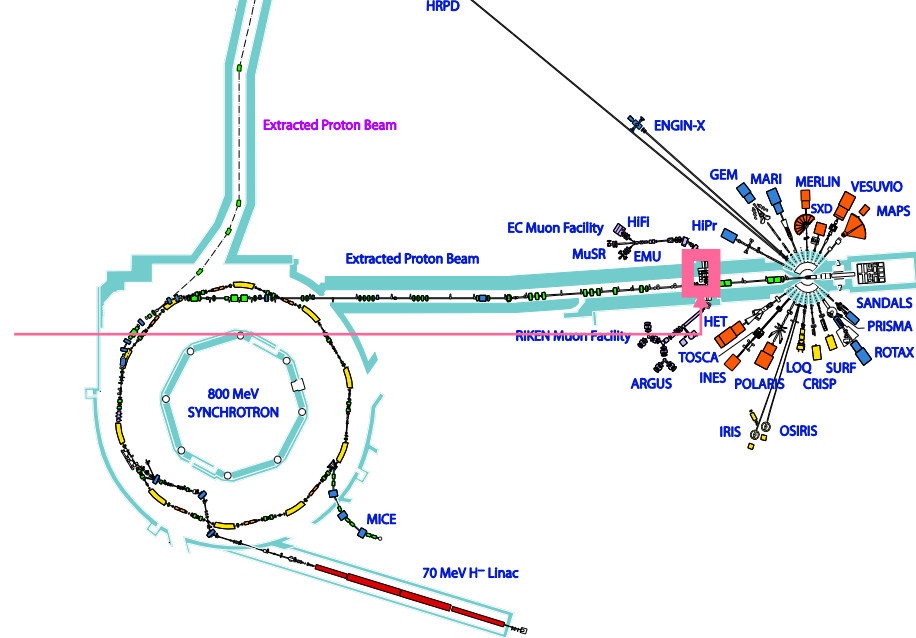
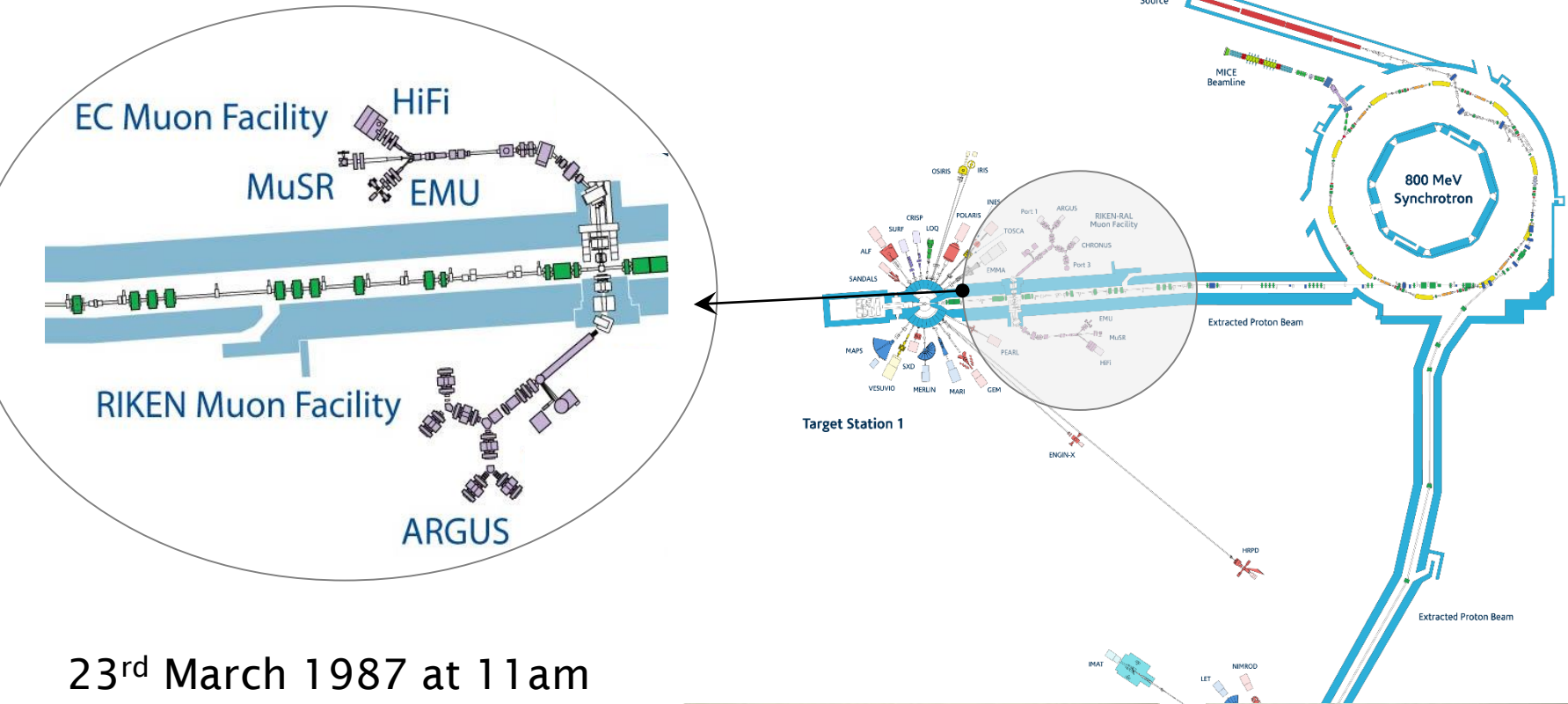


Fig. 1. EMU and the time-sliced μ SR pulses with the kicker voltage falling in the centre of the second pulse. The voltage fall-time of the kicker is artificially extended by the limited bandwidth of the measuring device.

The *Muon Target*



Muons at ISIS

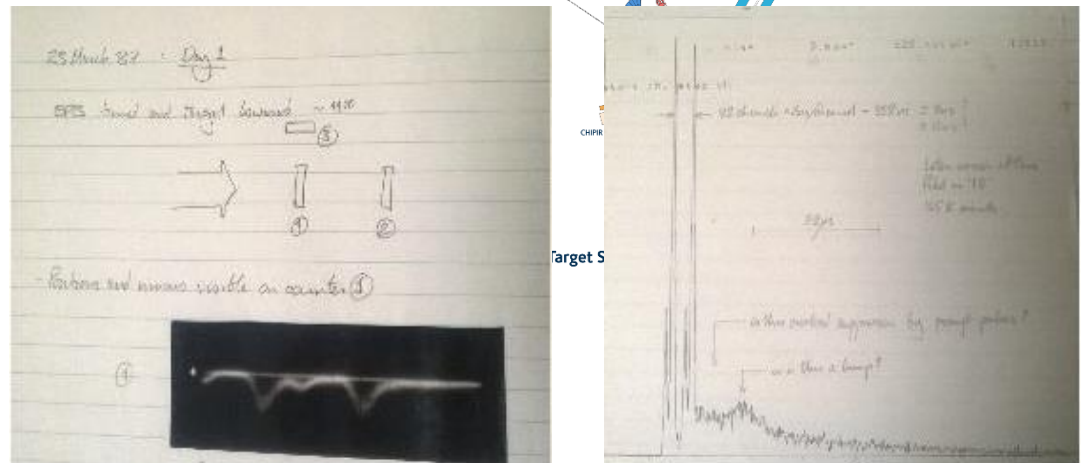


23rd March 1987 at 11am

Since then 3 ISIS Instruments
4 beam ports on RIKEN Side

Over 1200 publications

Cite this article: Hillier AD, Lord JS, Ishida K, Rogers C. 2019 Muons at ISIS. *Phil. Trans. R. Soc. A* **377**: 20180064. <http://dx.doi.org/10.1098/rsta.2018.0064>



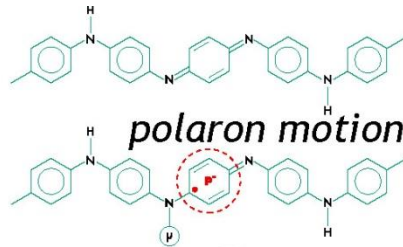
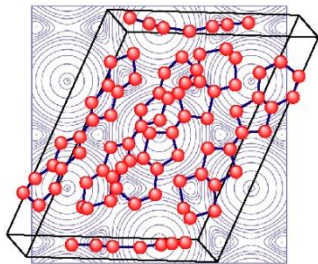
Target 5

Muons

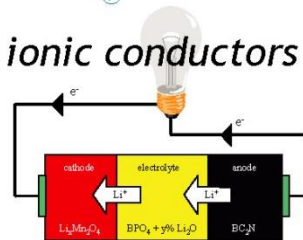
- Muons as passive probes in superconductivity, magnetism, molecular dynamics, charge transport.

- Muons as active probes: proton analogues in semiconductors, proton conductors, light particle diffusion, etc.

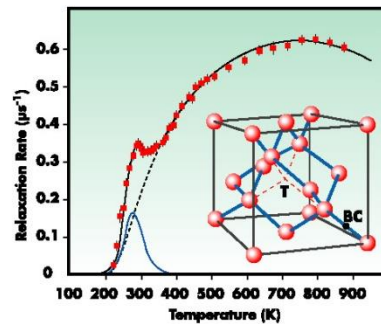
superconductors



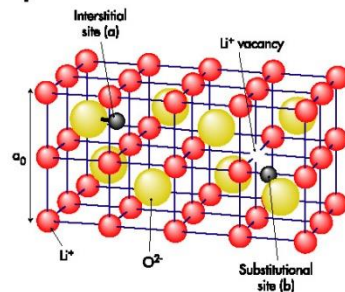
ionic conductors



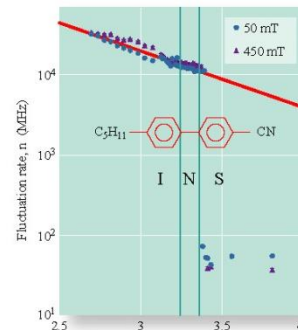
semiconductors



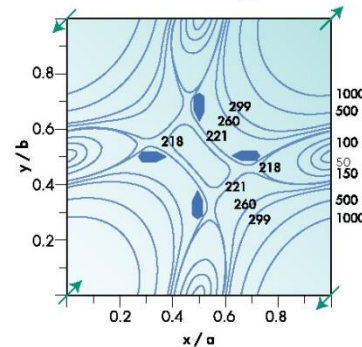
proton conductors



molecular dynamics



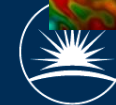
magnetism

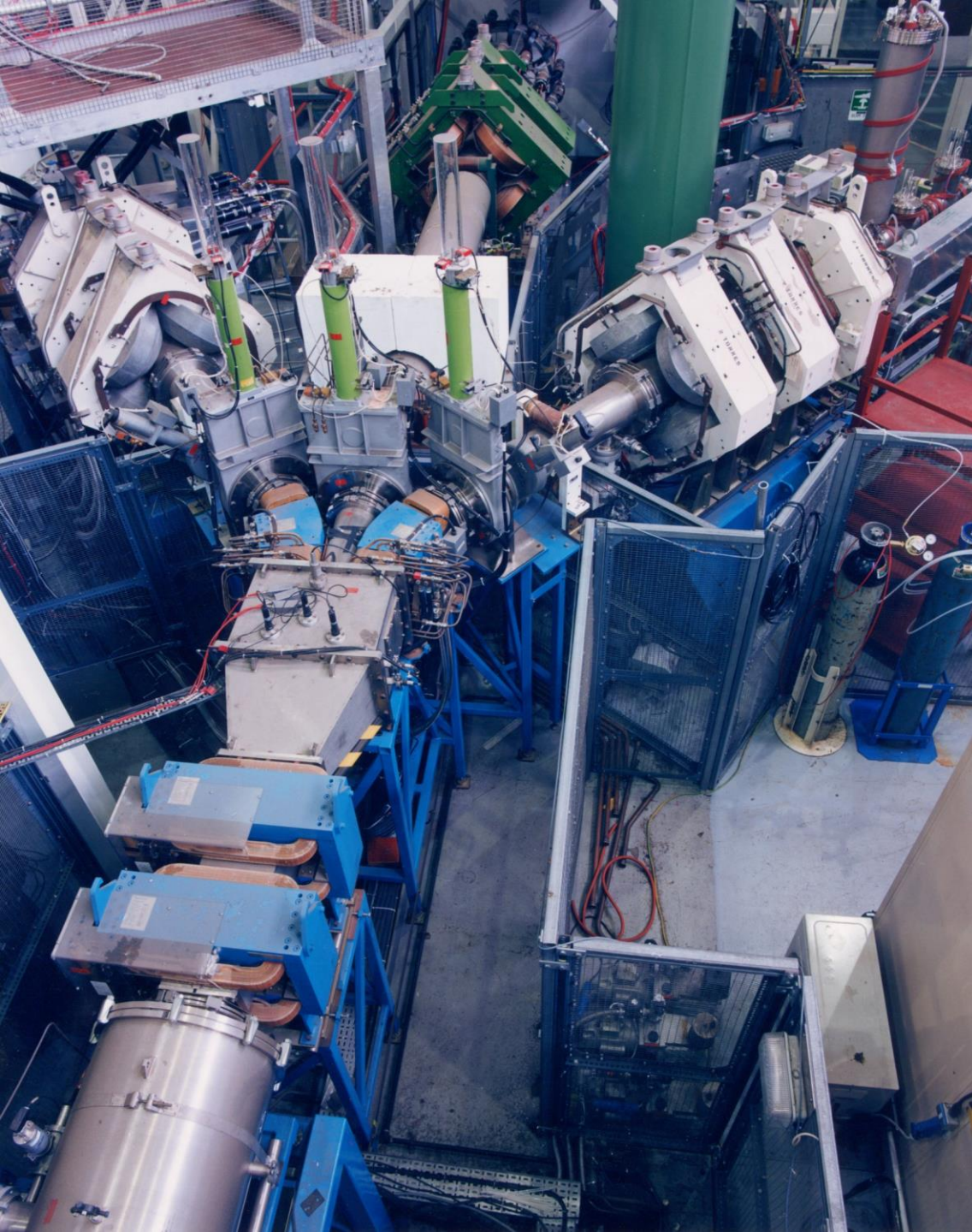


Electronic irradiation



Elemental Analysis





The European Muon Facility

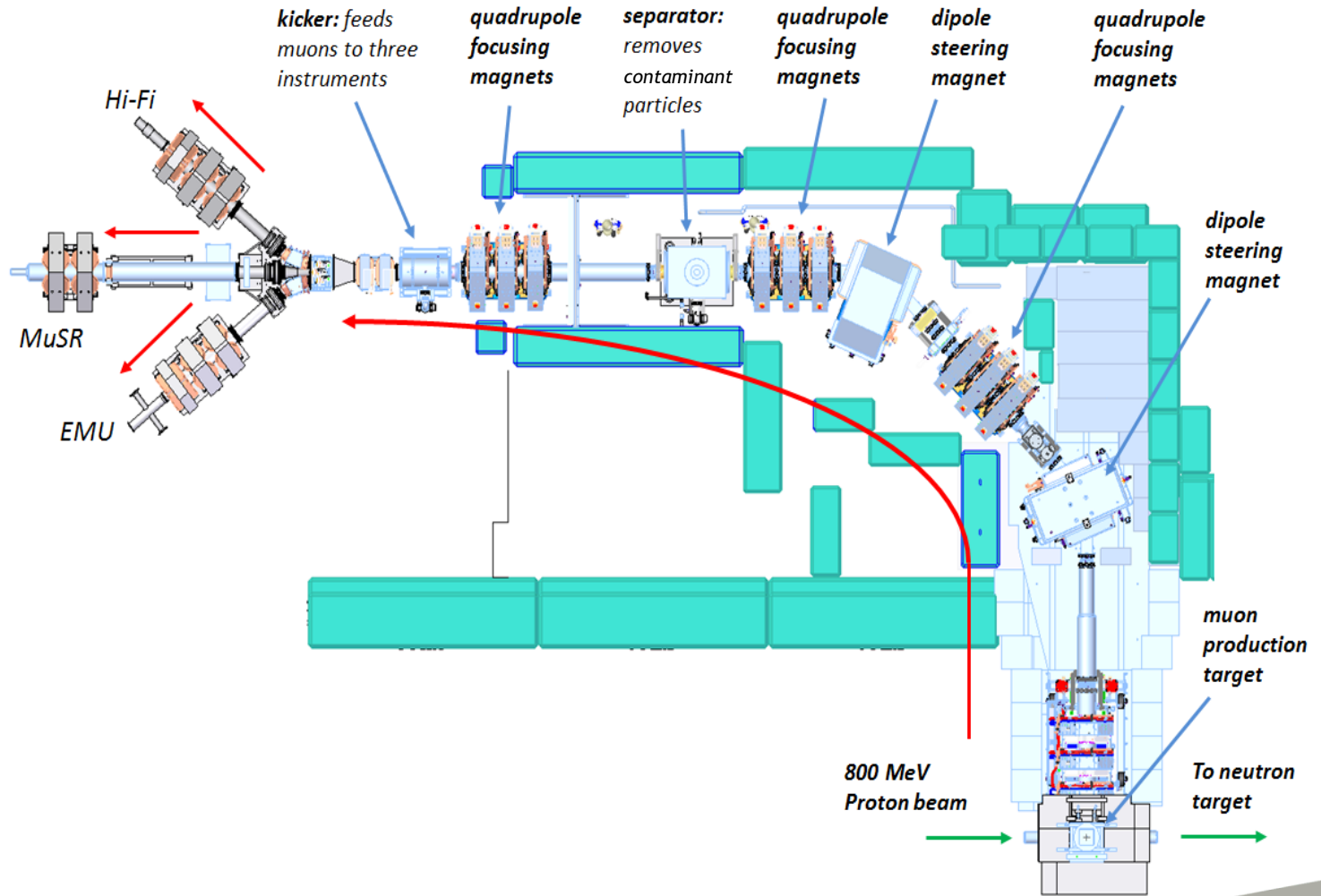
Surface muon channel



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The EC Muon Facility



Muon Characteristics

Positive Muons

Muon Energy fixed at 4.1 MeV (~28 MeV/c)
set for peak flux

2% momentum bite

MuSR:

4×10^6 muons per second
 $\sim 1 \times 10^5$ per pulse

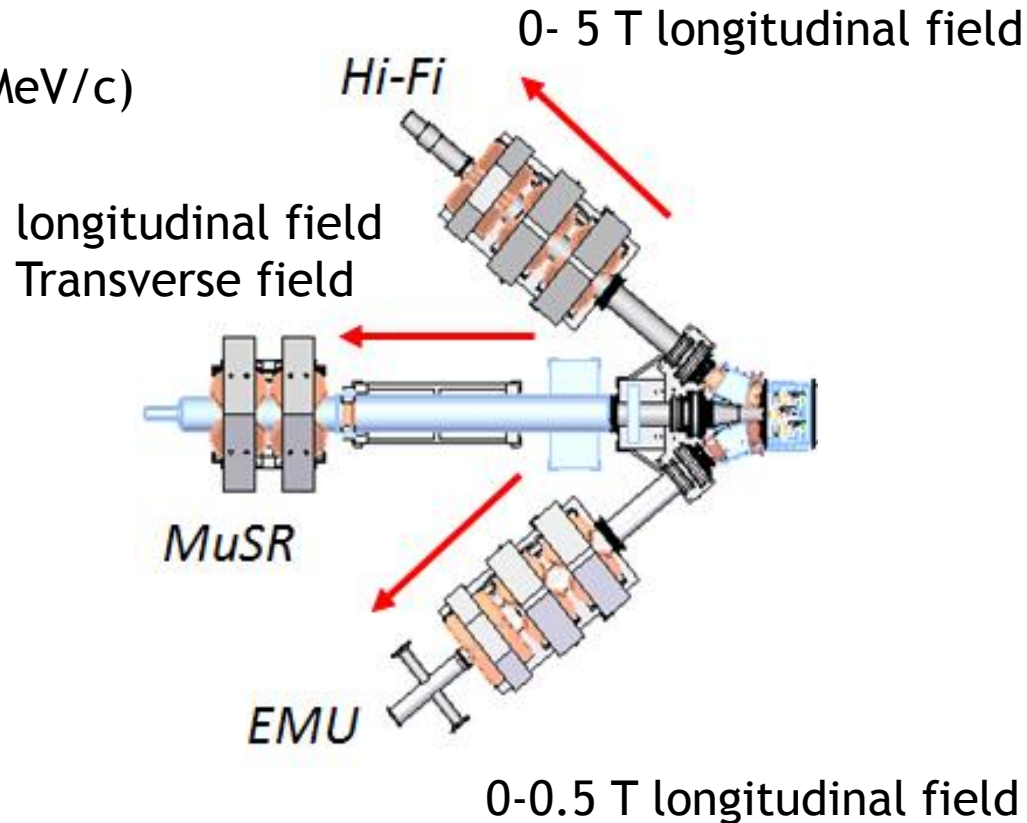
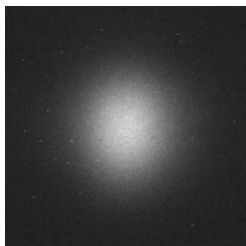
EMU/Hi-Fi

2×10^6 muons per second
 $\sim 0.5 \times 10^5$ per pulse

Spot size ~ FWHM

vertical ~8 mm

horizontal ~8 mm+



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RIKEN-RAL Muon Facility

Decay muon Channel

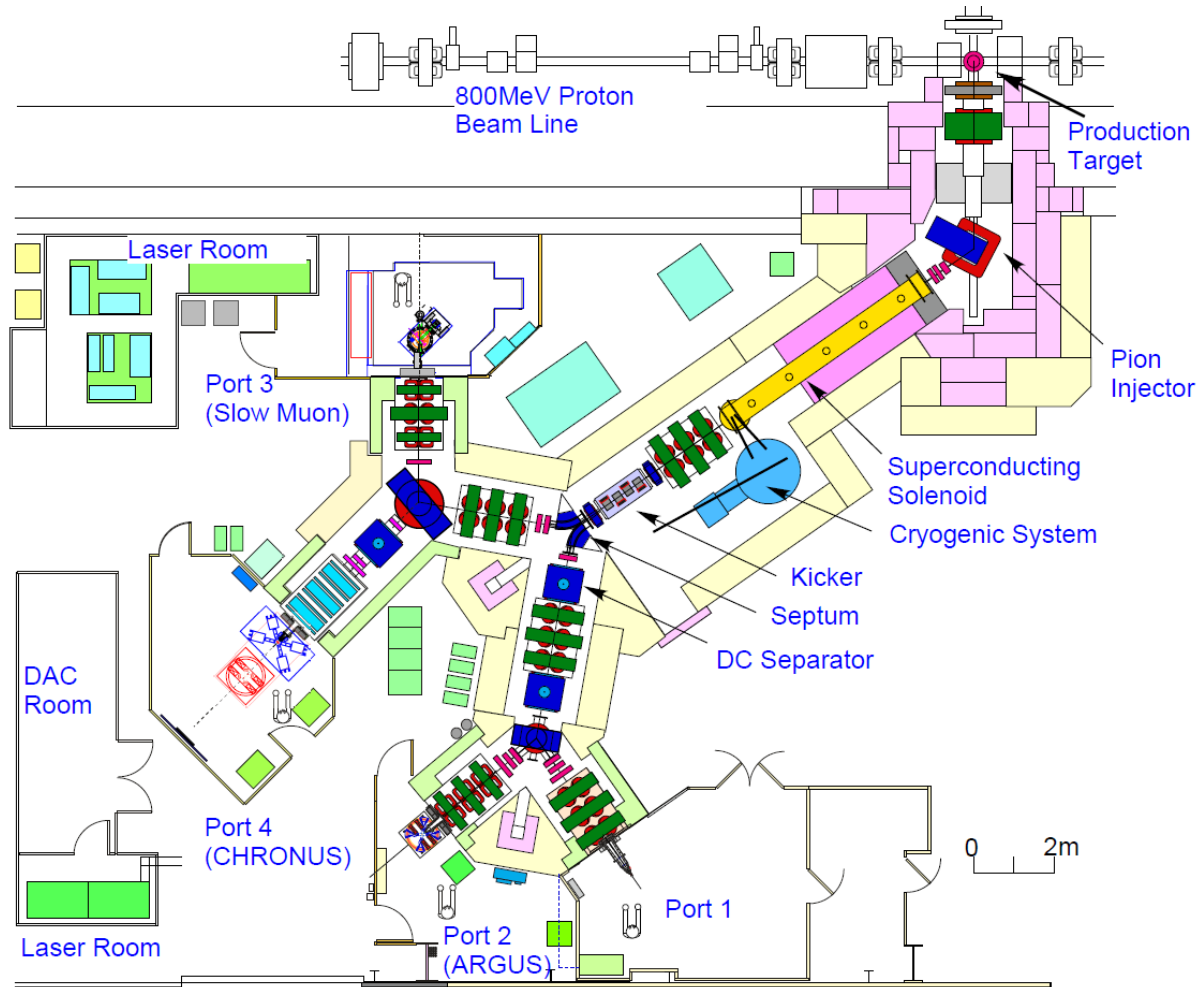
Long UK-Japan science
collaboration

First muons 1994

4 experimental areas

- condensed matter
- other uses of muons
 - Muon catalysed fusion
 - Ultra Slow Muons (g-2)
 - Proton Radius Puzzle
 - Transmutation
 - Effects of muons on electronics
 - Muonic atoms

RIKEN



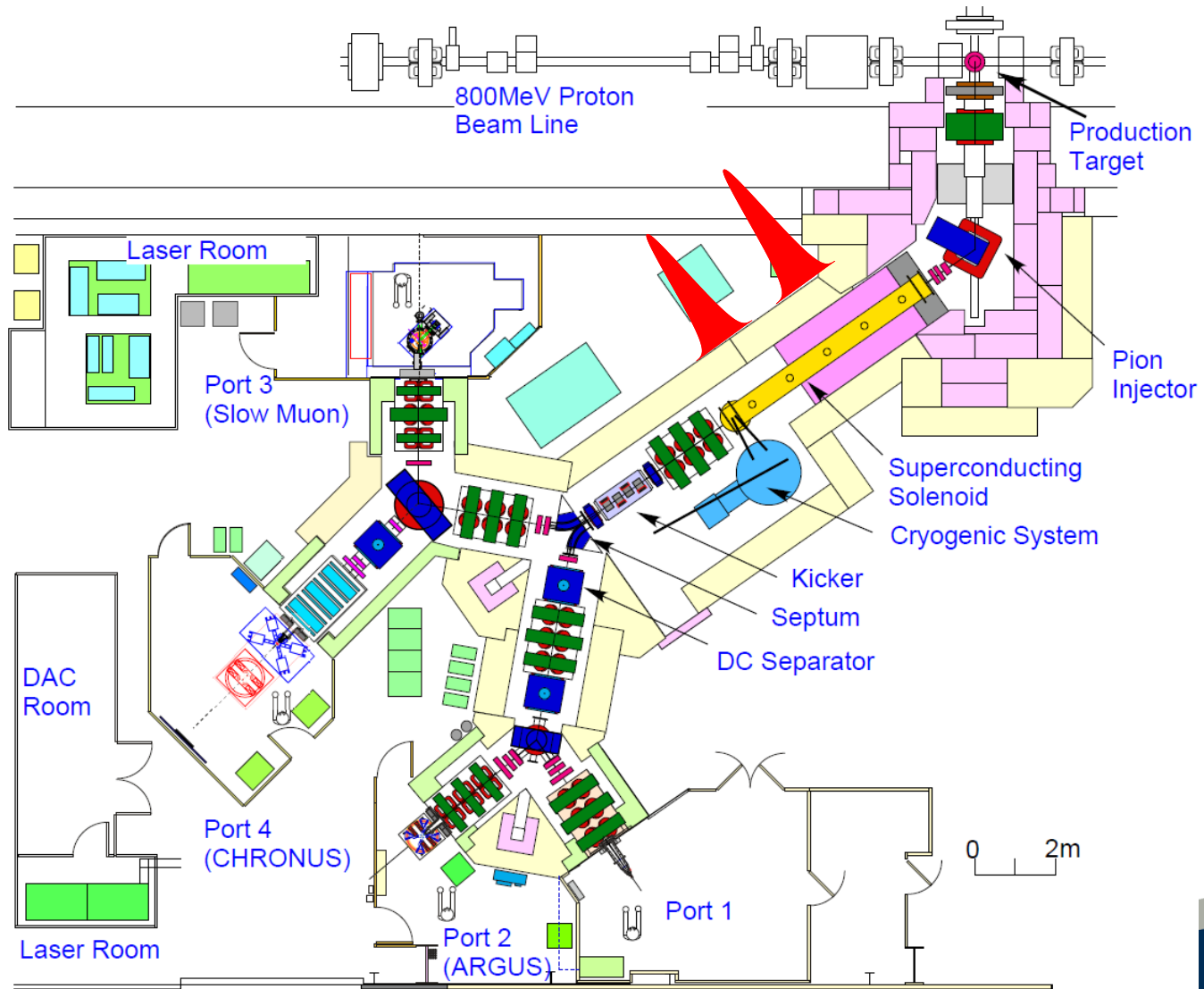
Science & Technology Facilities Council

ISIS



RIKEN

RIKEN



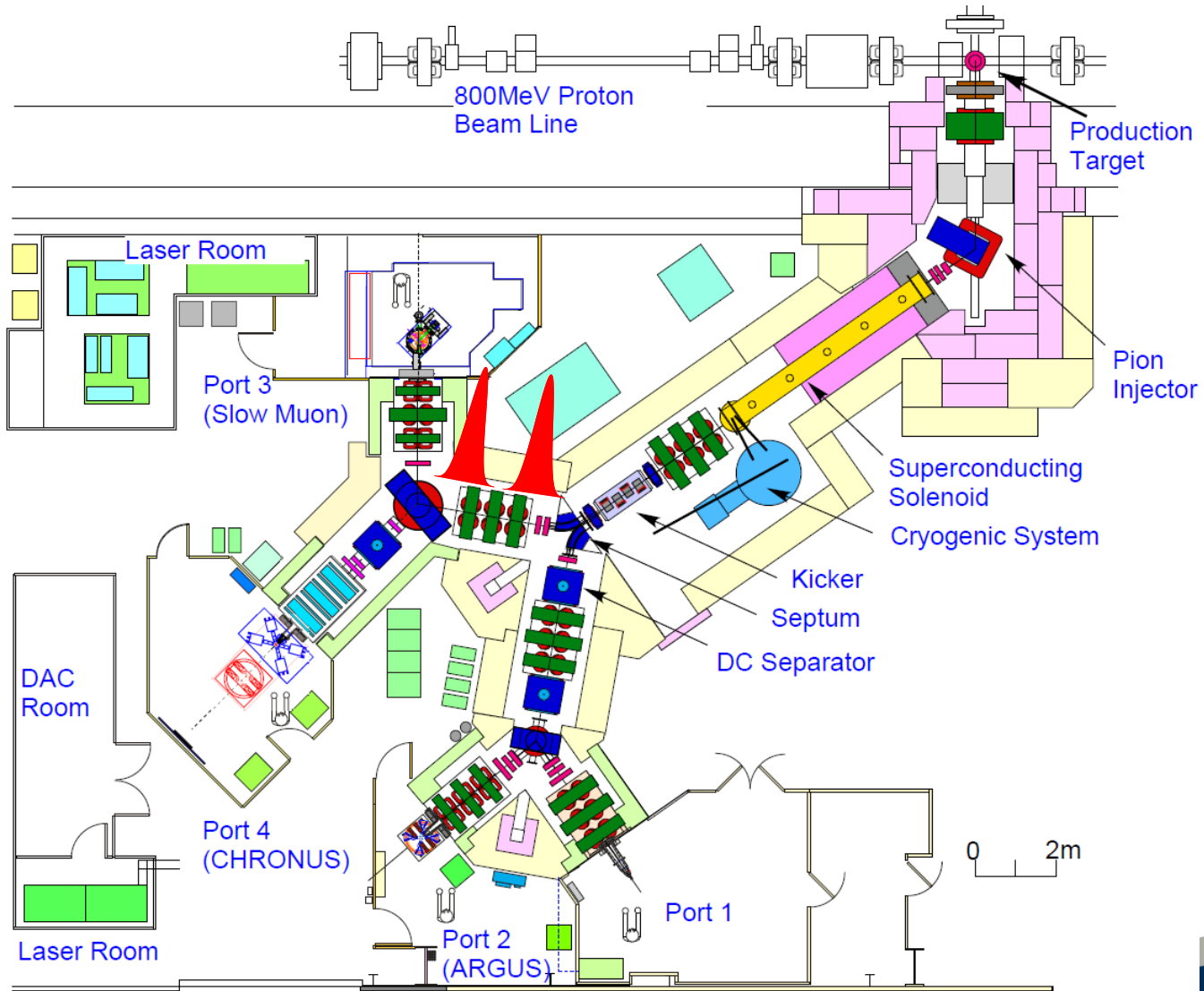
Science & Technology Facilities Council

ISIS



RIKEN

RIKEN



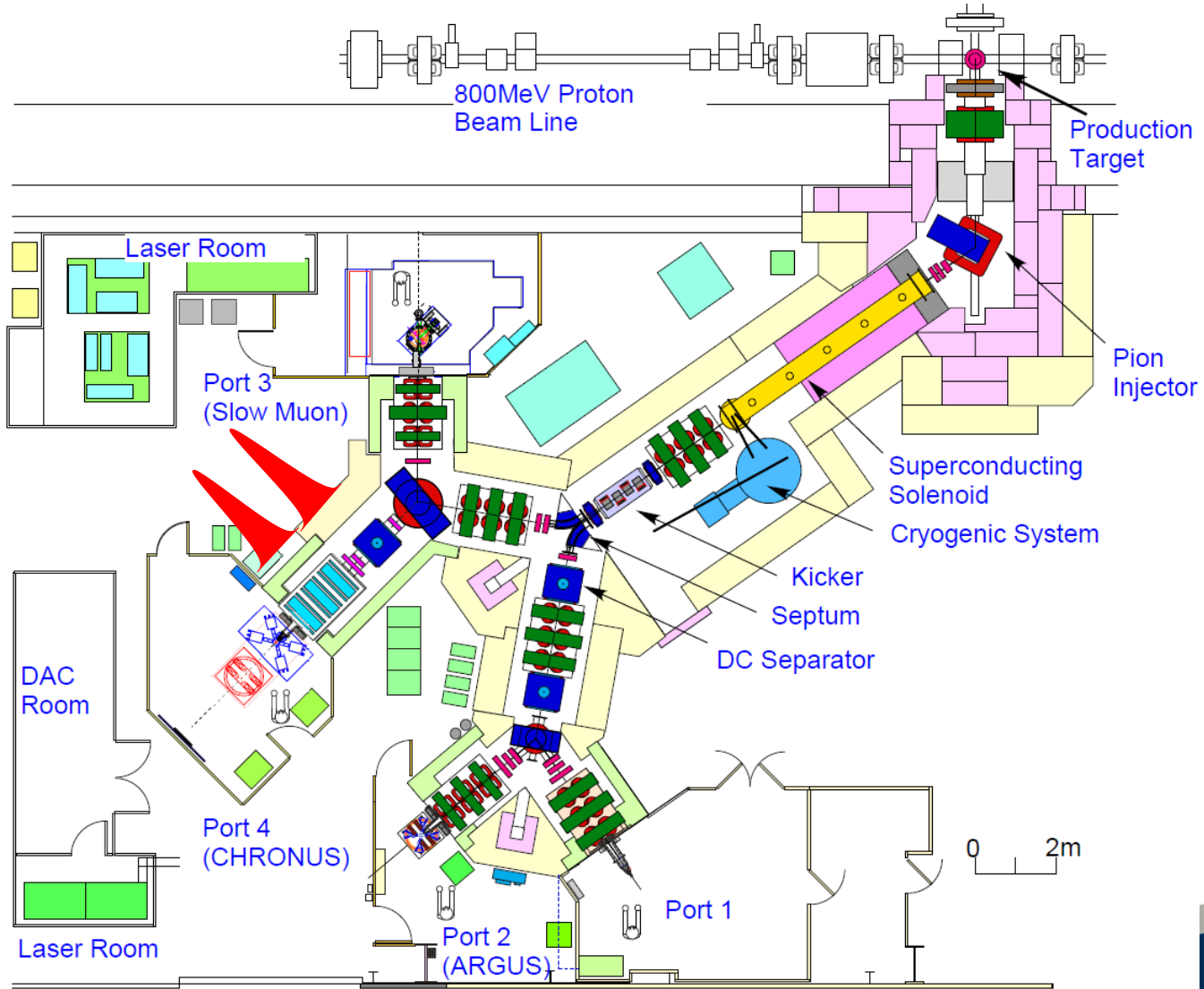
Science & Technology Facilities Council

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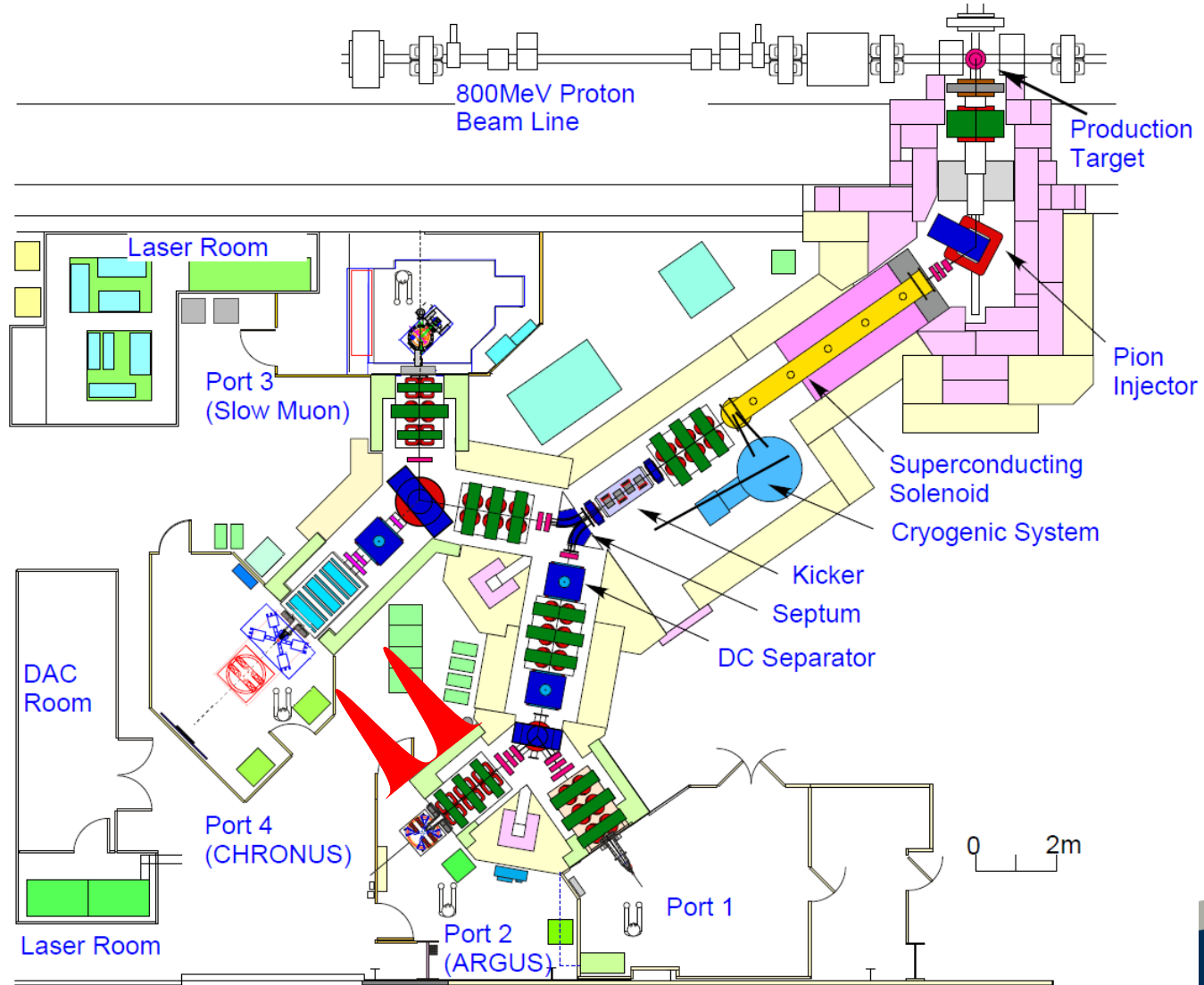
Science & Technology Facilities Council

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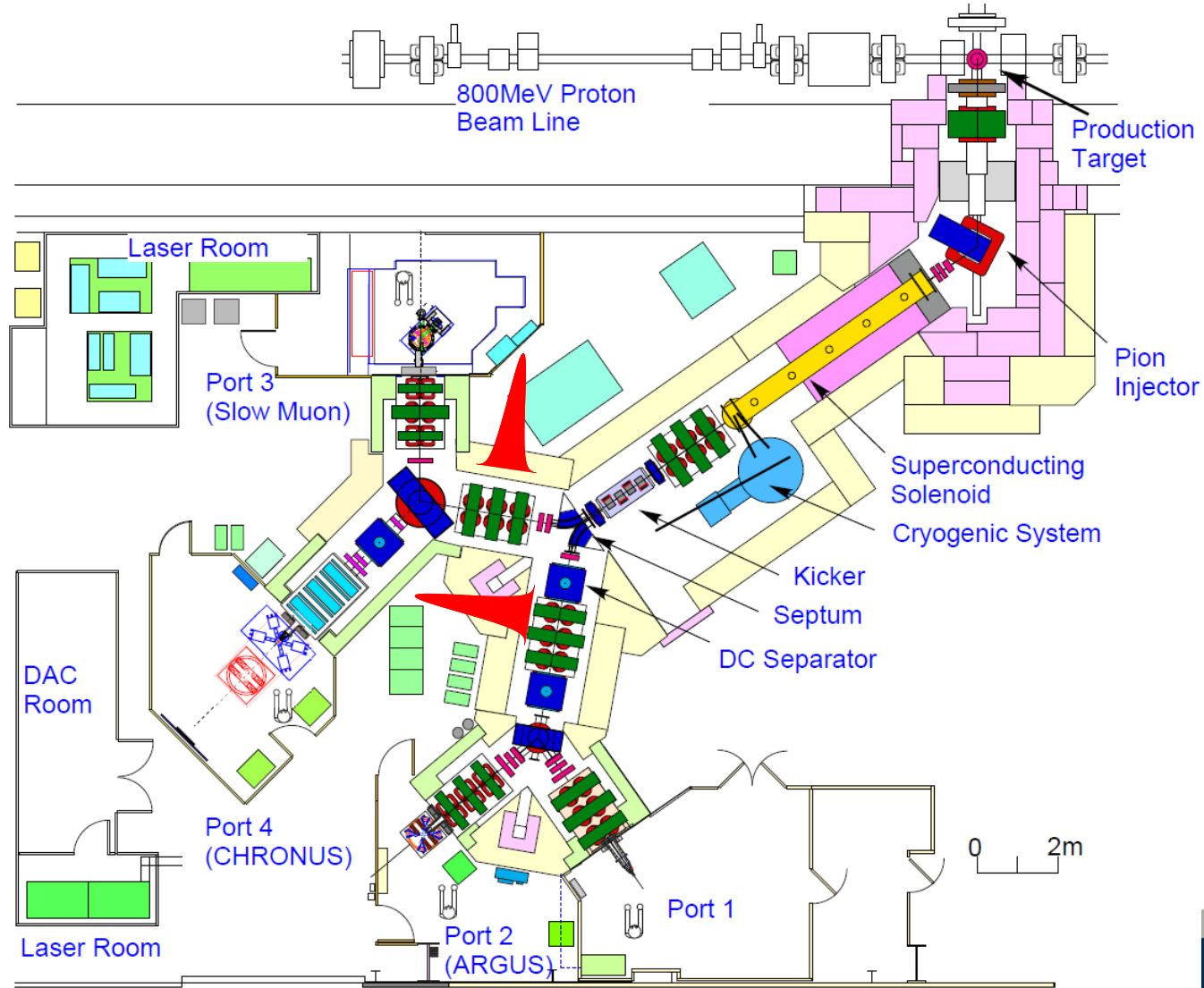
Science & Technology Facilities Council

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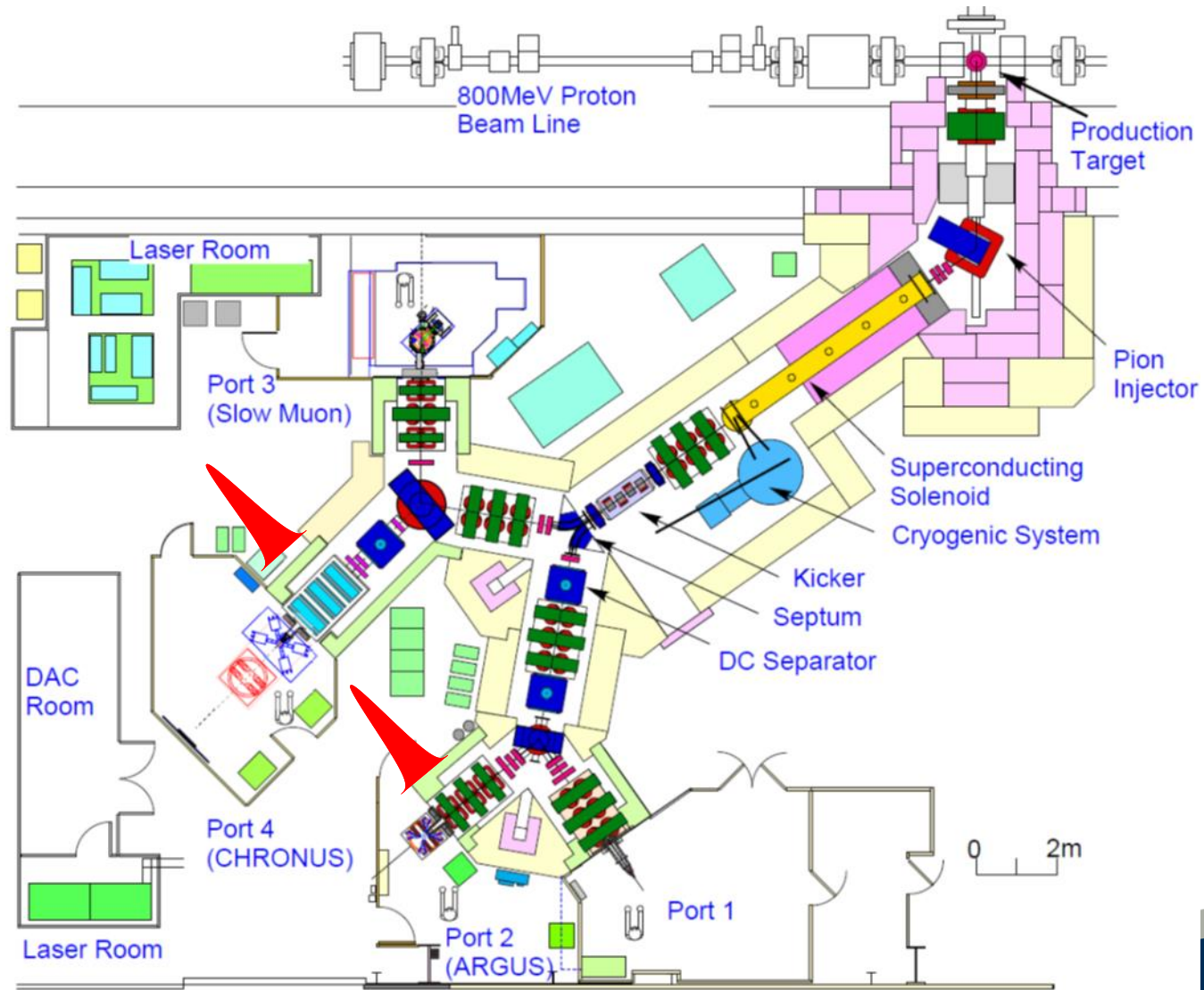
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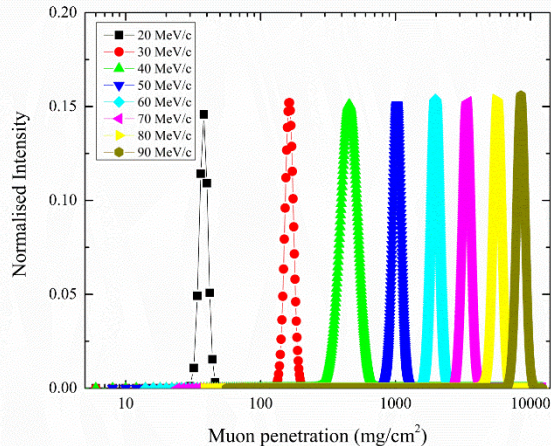
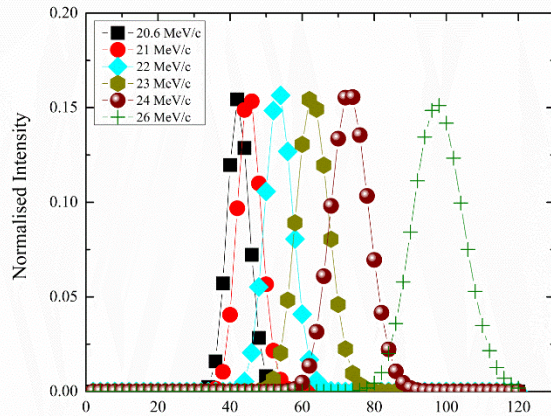
Muon Characteristics

Positive and Negative Muons

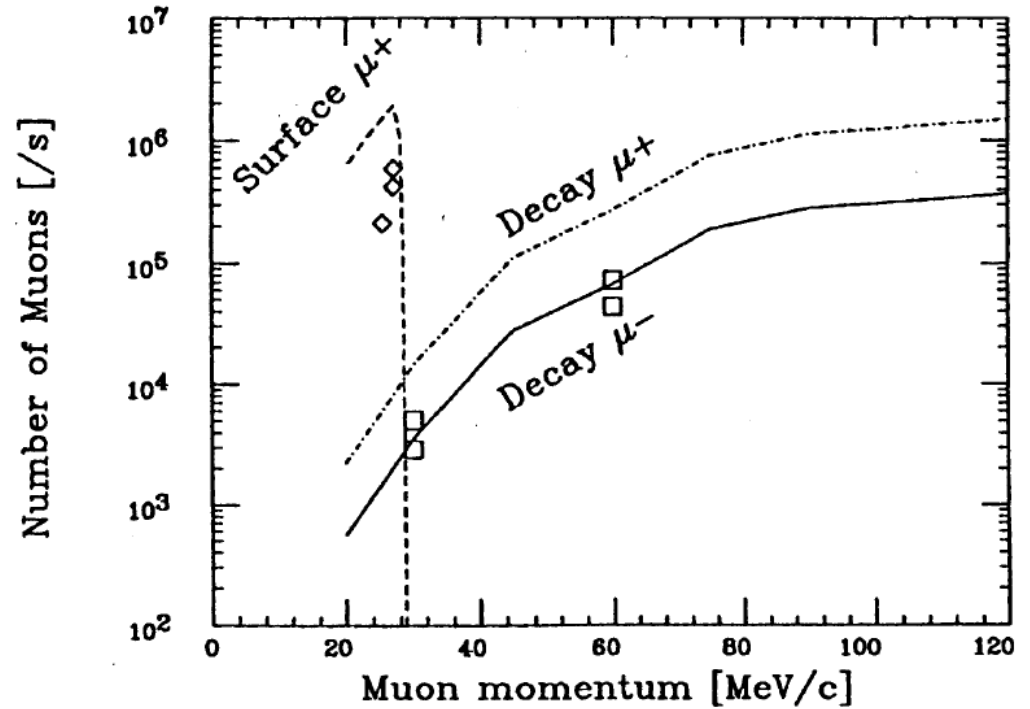
Energy Range at 1.5 to 33 MeV

4% momentum bite

Range of collimators 10 - 40 mm



Estimated muon intensity in 4cmx4cm



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Current Projects

Super-MuSR: a new instrument for muon spectroscopy

- Muon pulse slicer
- Large area detector array
- spin rotator

MuX: a new instrument for muonic X-ray measurements

- Large area HPGe detector array

FAMU experiment:

- muonic hydrogen high precision spectroscopy

Future Projects:

- smaller spot focusing
- superconducting solenoid replacement



MuSR Upgrade: Super-MuSR

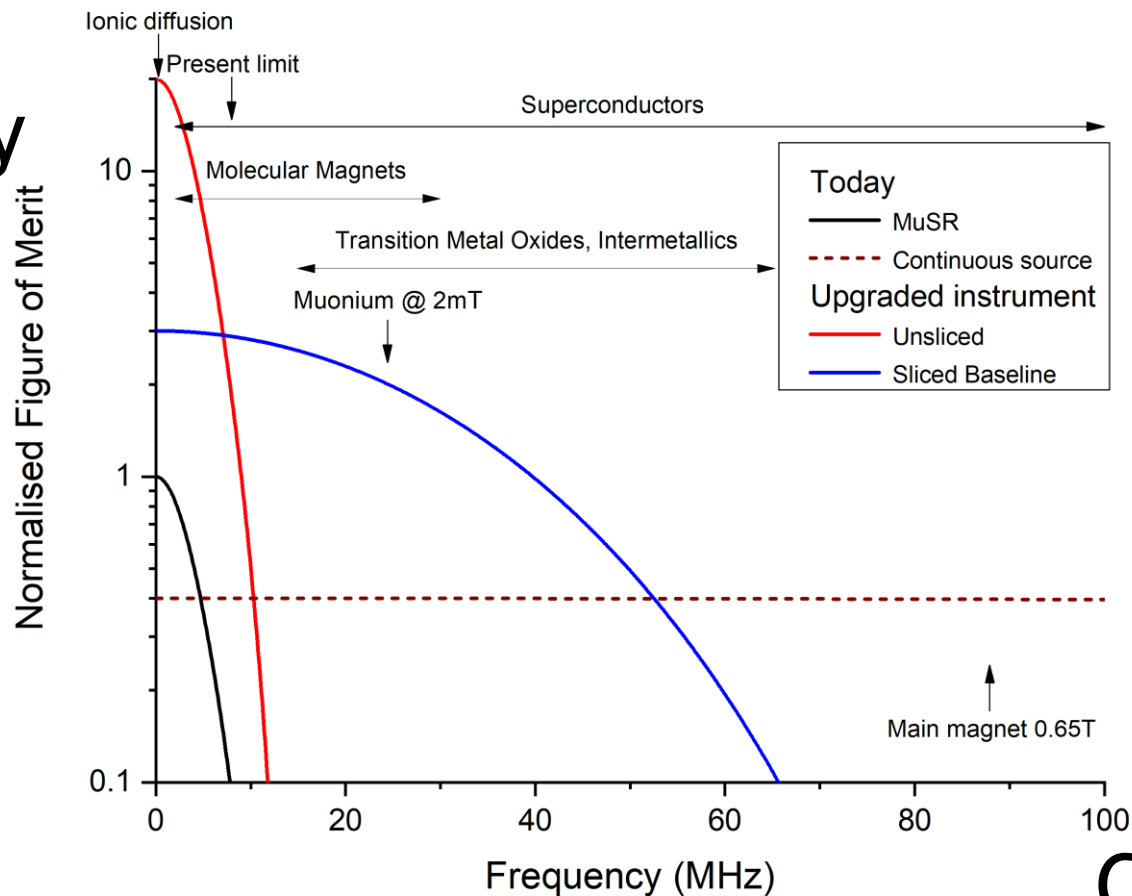
Beamline improvements

- ~10x increase in frequency resolution
- Access higher magnetic fields

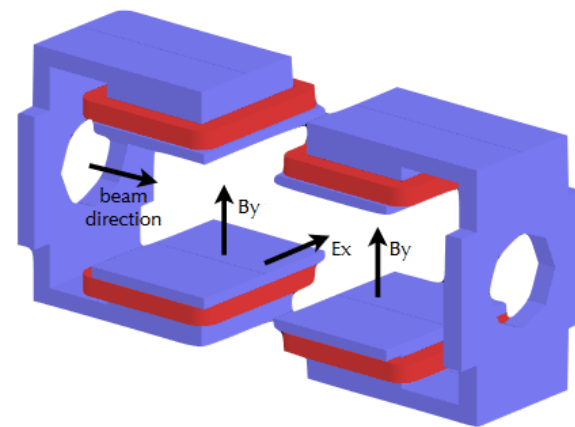
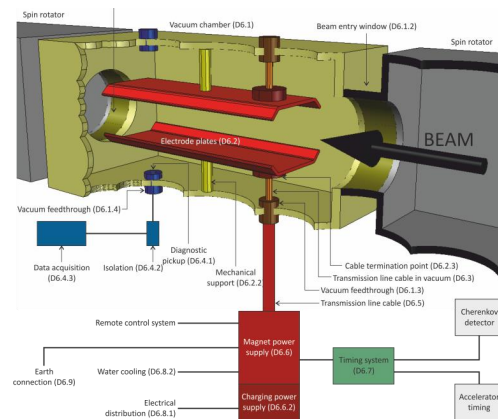
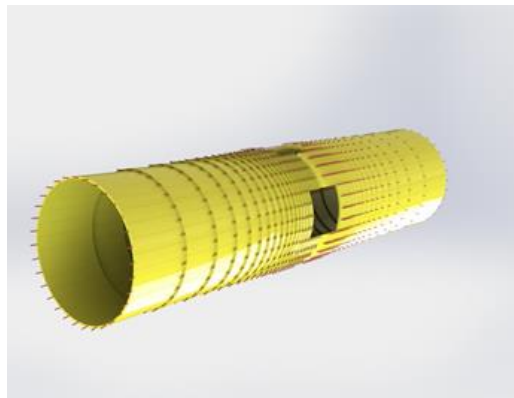
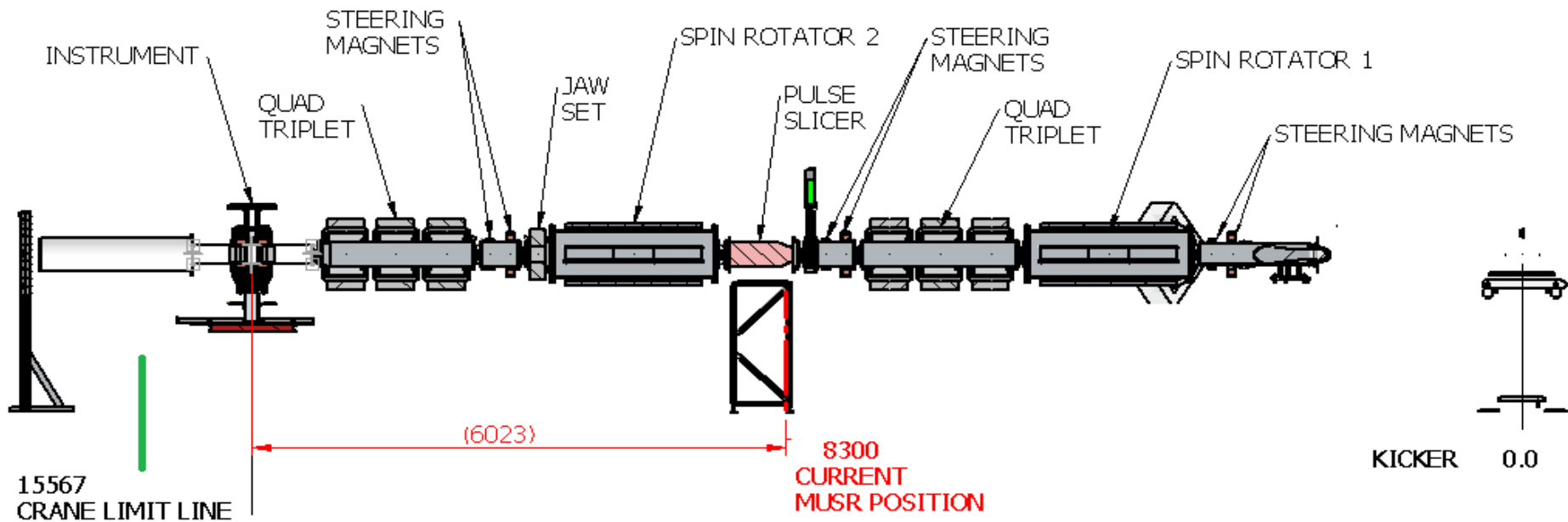
Detector Improvements

- 15-20x increase in count rate
- ~2.5x more information per muon

↑
Capacity



Capability →

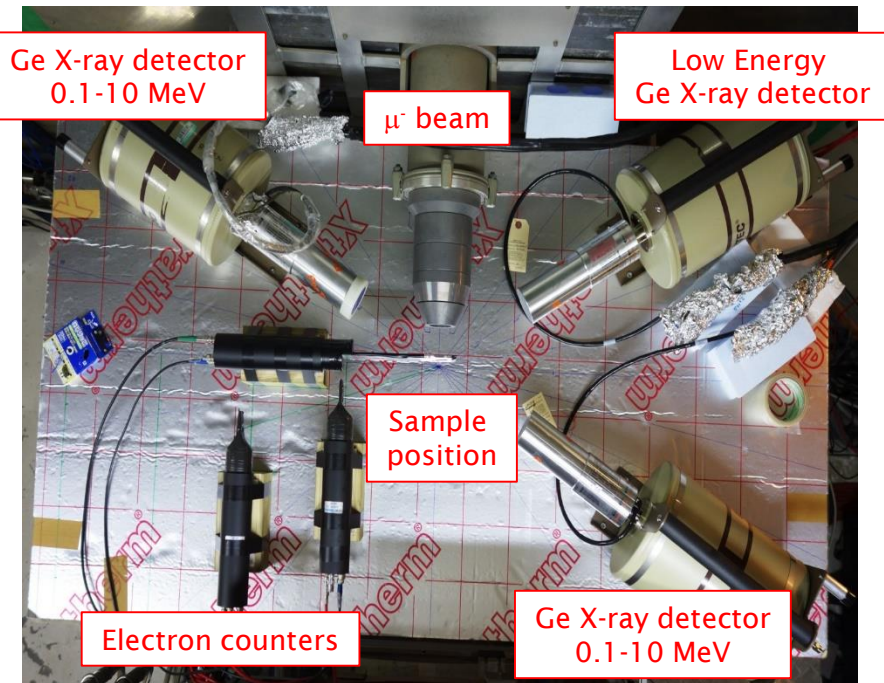


- 20x data rate
- High density array (for muons)
- Increases data quality

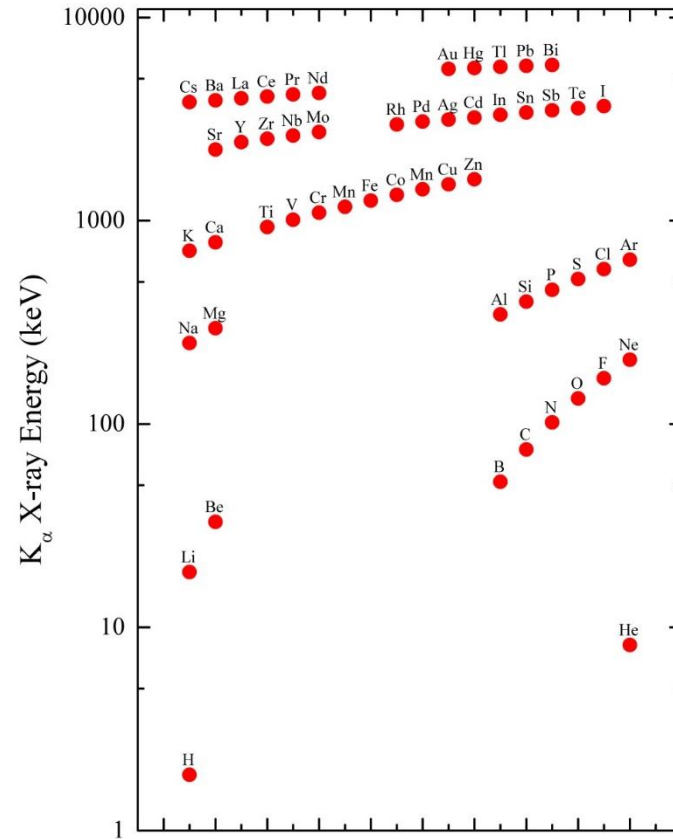
➤ 10x resolution

➤ Extends TF measurements

Current Projects - MuX



- High Energy X-rays emitted
- Energy dependent of the atom which captures the muon
- 0.1-10MeV – mass of the muon is 200x that of the electron
- Real space imaging demonstrated
- Larger solid angle coverage required



Current Projects - FAMU experiment muonic hydrogen high precision spectroscopy studies

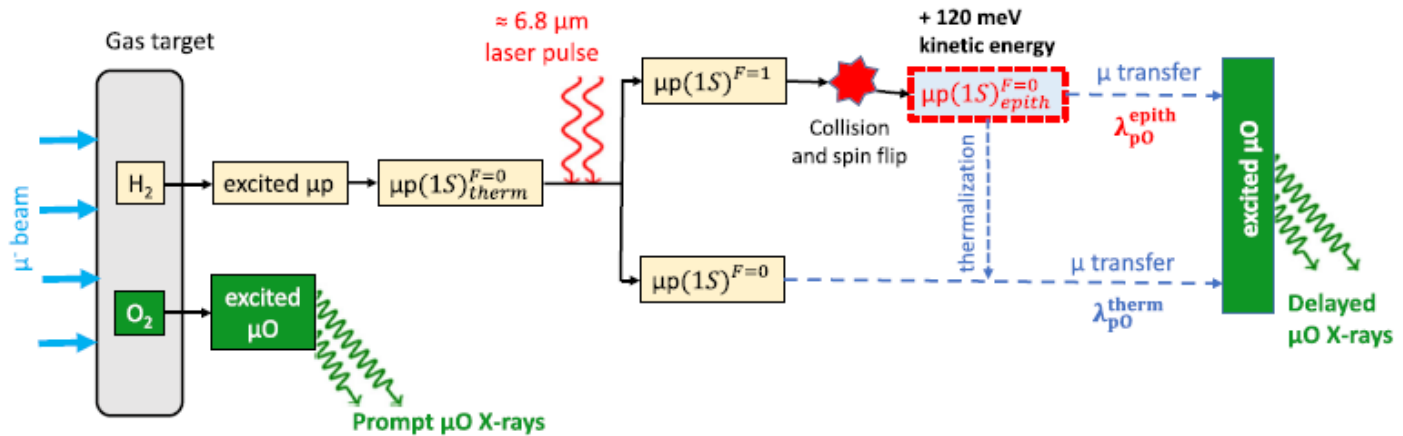


Fig. 1 Schematic representation of the FAMU experimental method. In this left-to-right time progression: muons stop in the gas target and subsequently de-excite and thermalize. At a latter time, the laser excita-

tion prompts the formation of the $F = 1$ state. This will cause a sizeable change in the time distribution of the delayed X-rays coming from muon transfer to oxygen

- First time measuring the hyperfine splitting of the muonic hydrogen ground state
- The proton Zemach radius can be derived
- Shed light on the determination of the proton charge radius

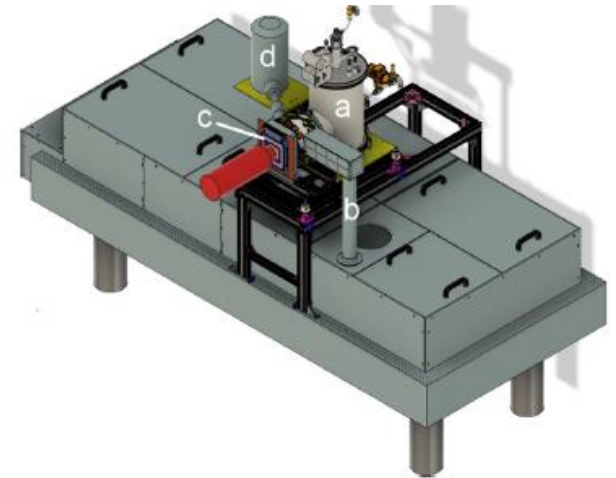


Fig. 4 CAD representation of the full FAMU system. Letters indicate some of the elements: a cryostat; b laser optical path; c hodoscope; d nitrogen tank for the germanium detector. Description in the text



Surface and decay muon beams are available

Pabitra Biswas

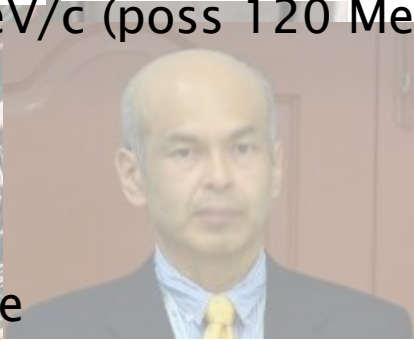
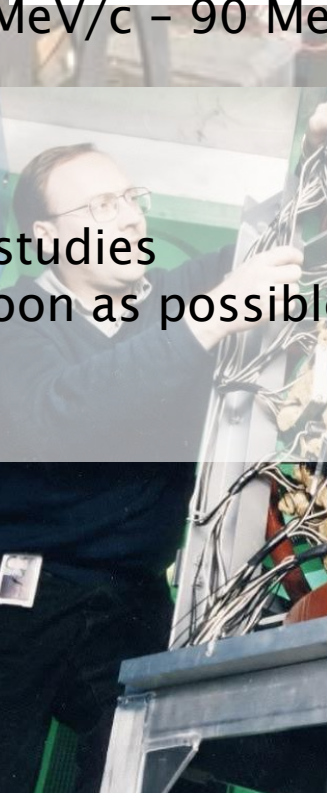
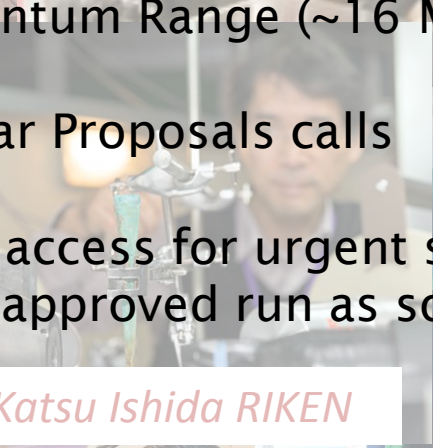
Koji Yokoyama

Steve Cottrell

Momentum Range (~16 MeV/c - 90 MeV/c (poss 120 MeV/c)

Regular Proposals calls

Rapid access for urgent studies
if approved run as soon as possible



Adrian Hillier

Katsu Ishida RIKEN

Isao Watanabe RIKEN



James Lord

Adam Berlie

Francis Pratt

Mark Telling

Peter Baker



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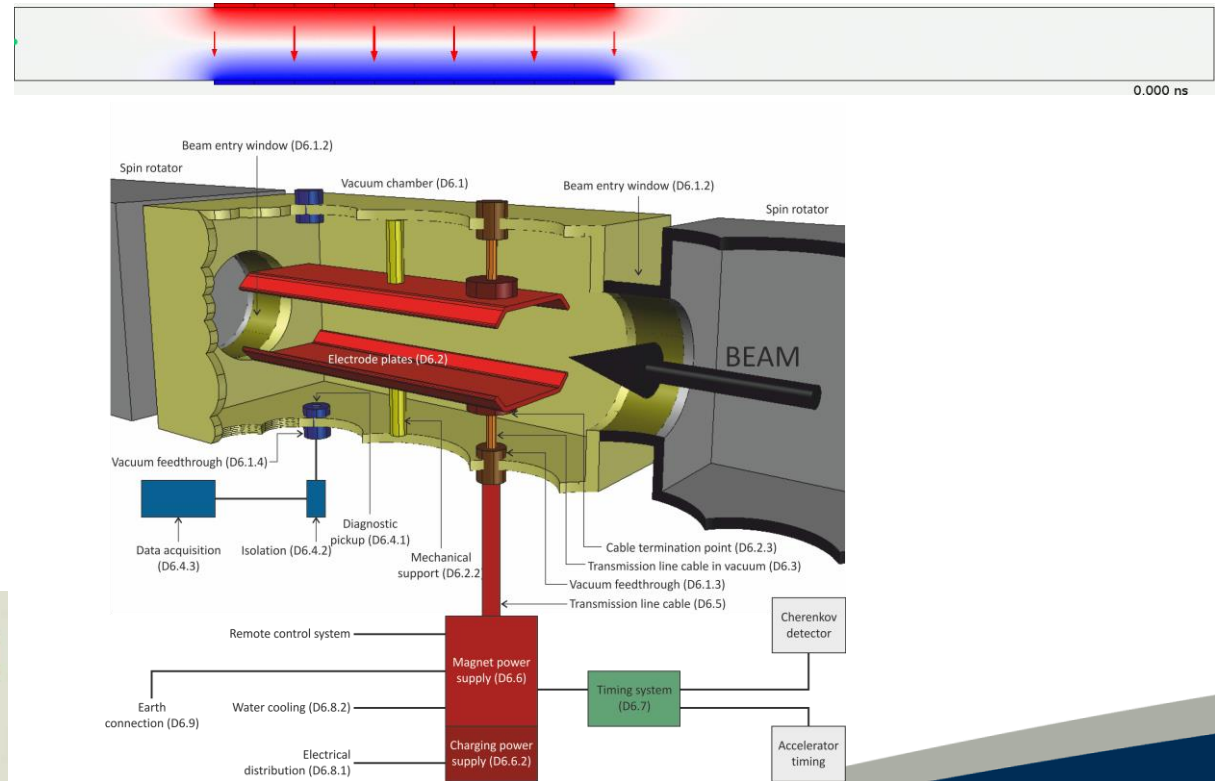
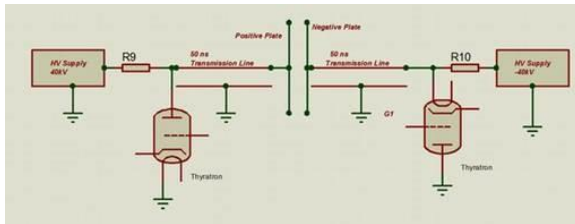
ISIS

Three main work packages

Pulse Slicer

Priority 1

- 10x resolution
- Builds on experience of existing muon kicker
- Increases range of superconducting, magnetic, and chemical samples that can be studied at ISIS

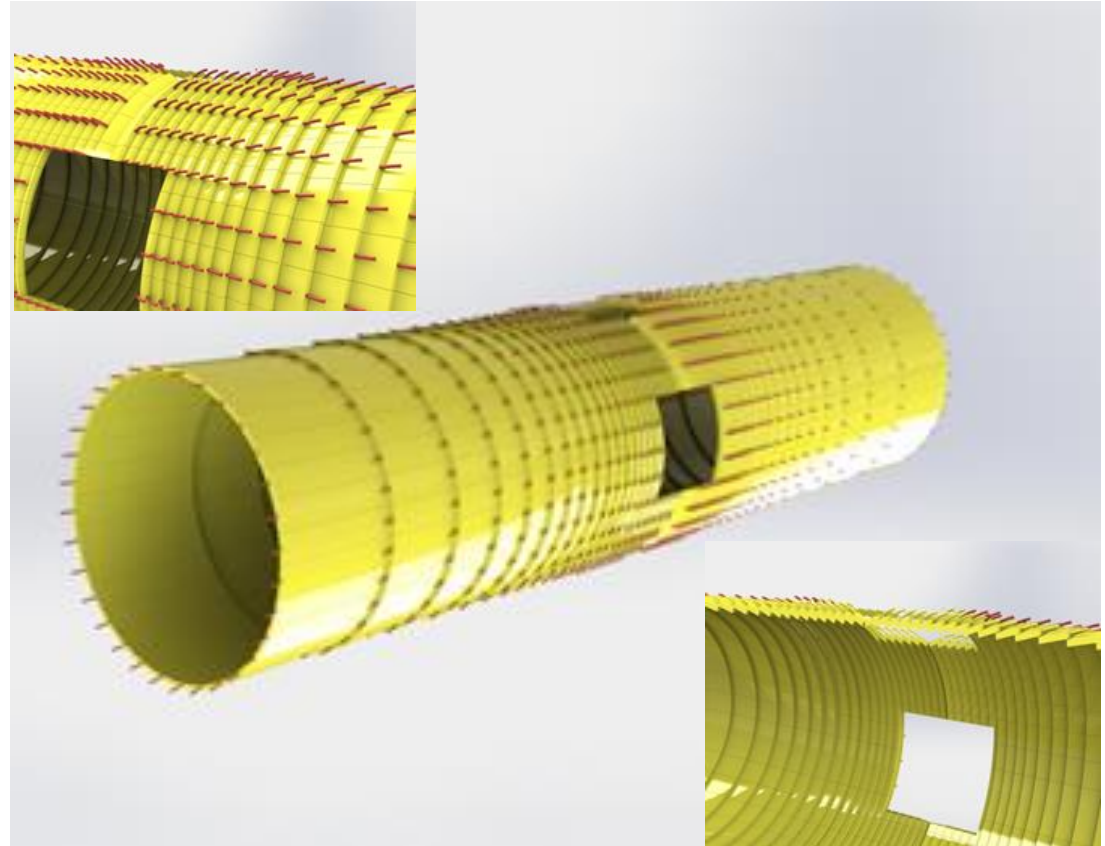


Three main work packages

Detectors

Priority 2

- 20x data rate
- High density array (for muons)
- Increases data quality
- New experiments such as cycling battery cells on the beamline



Three main work packages

Spin Rotators

Priority 3

- Extends measurements of superconductors and chemical reactions to higher magnetic fields
- Need two in series to generate necessary rotation with feasible voltages

