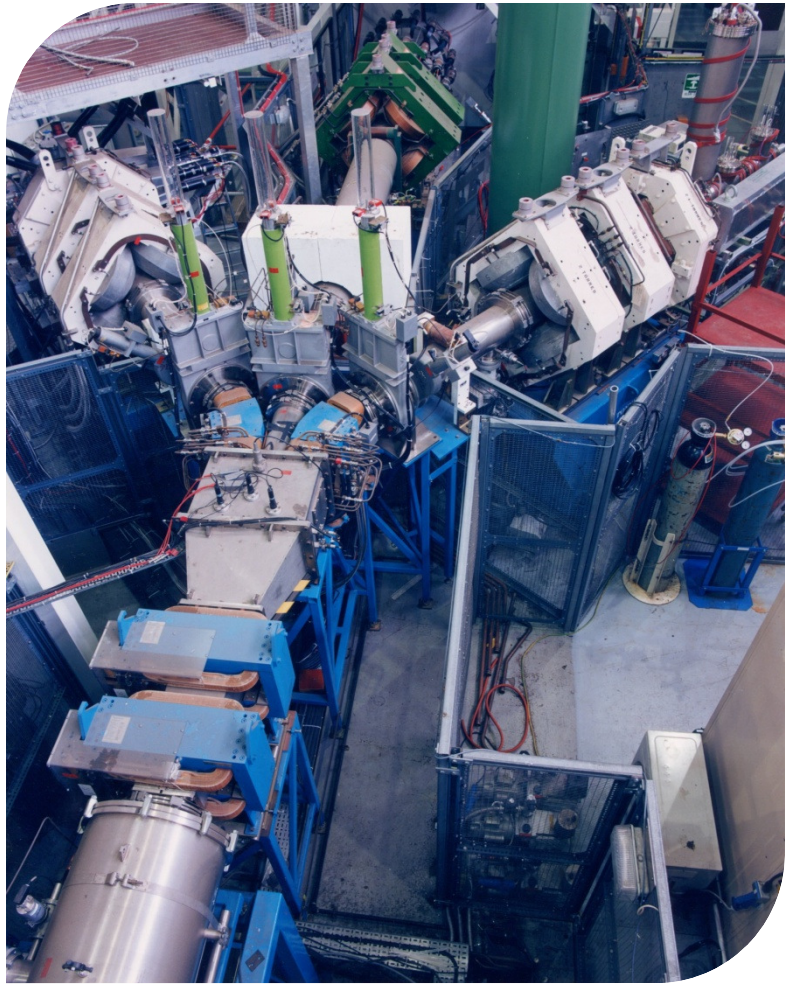
ISIS Muon Training School

19-23 March 2018



Welcome to the ISIS muon training course

Adrian Hillier

ISIS Muons

Science & Technology Facilities Council
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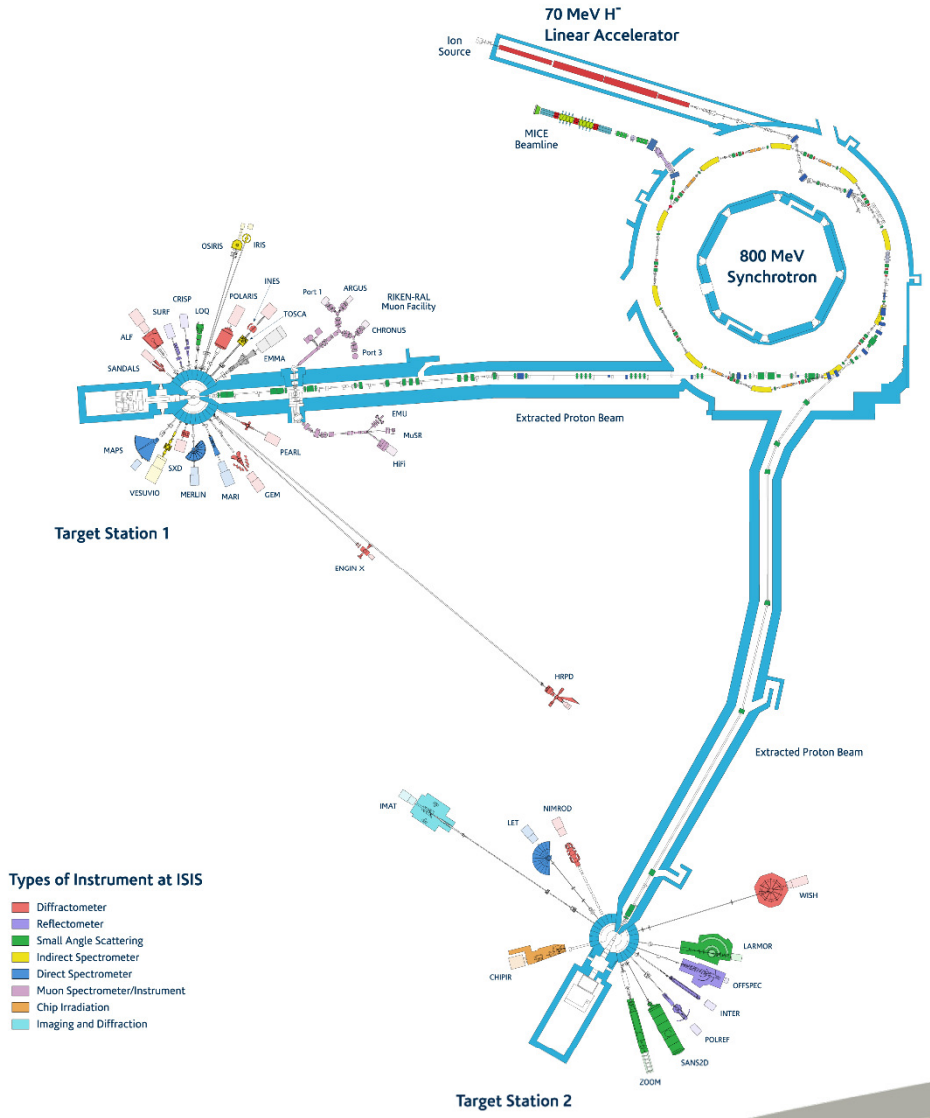
Outline

- Introduction to ISIS
- The ISIS accelerator
- Neutrons at ISIS
- Muons at ISIS



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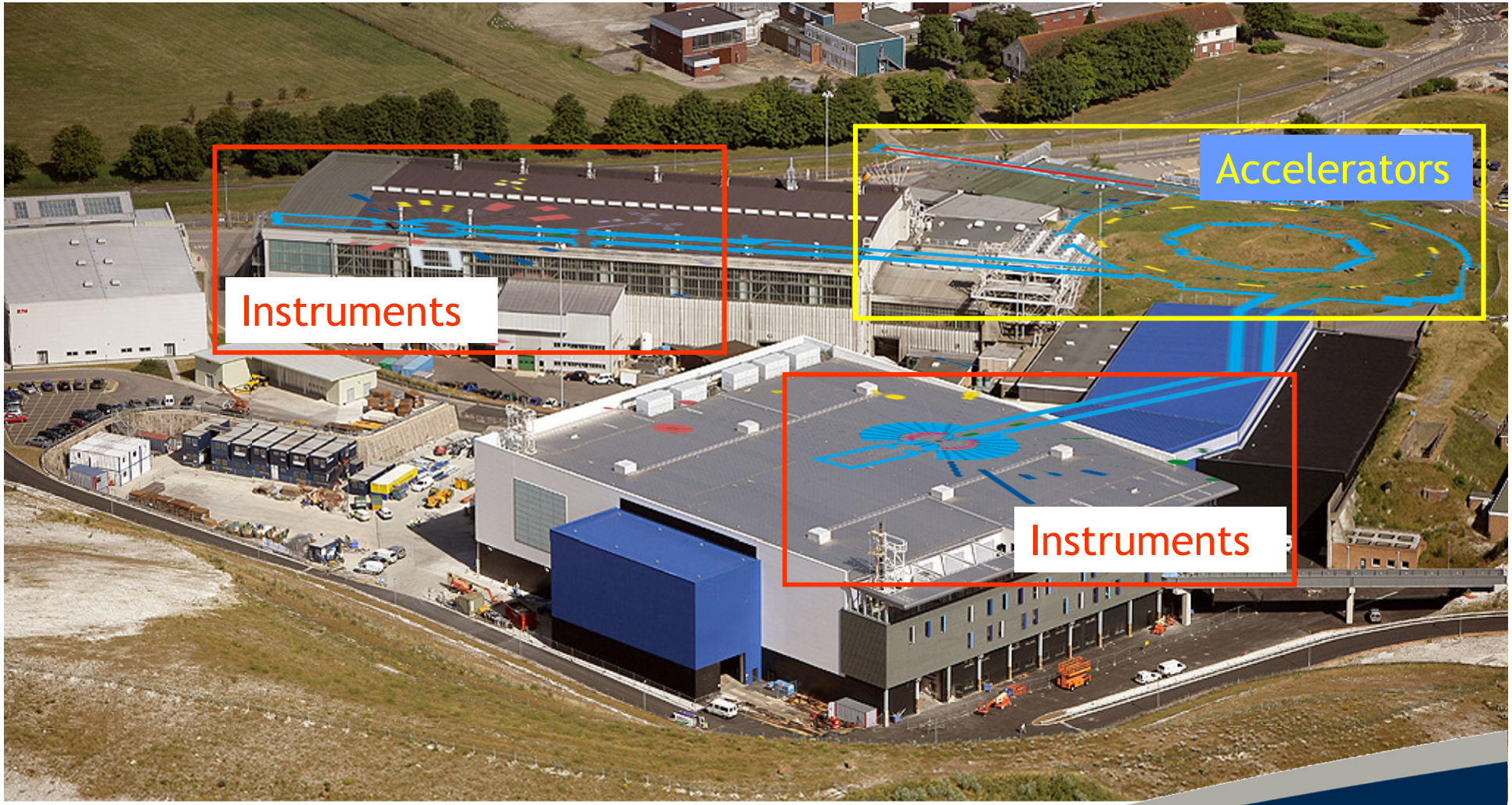
Introduction to ISIS

The ISIS Pulsed Neutron and Muon Source



A World Centre for Condensed Matter Science with Neutrons and Muons

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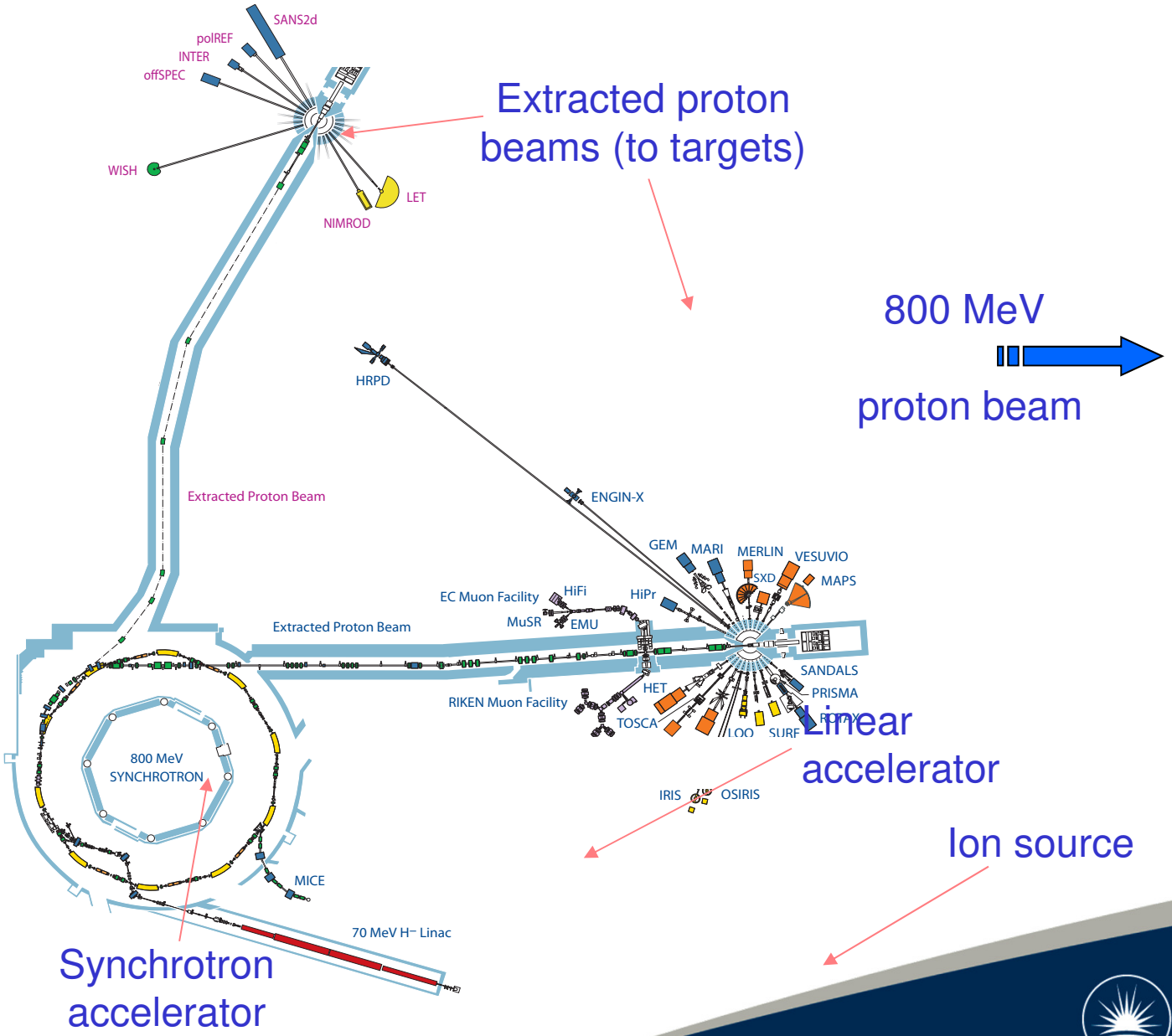
The ISIS Accelerators



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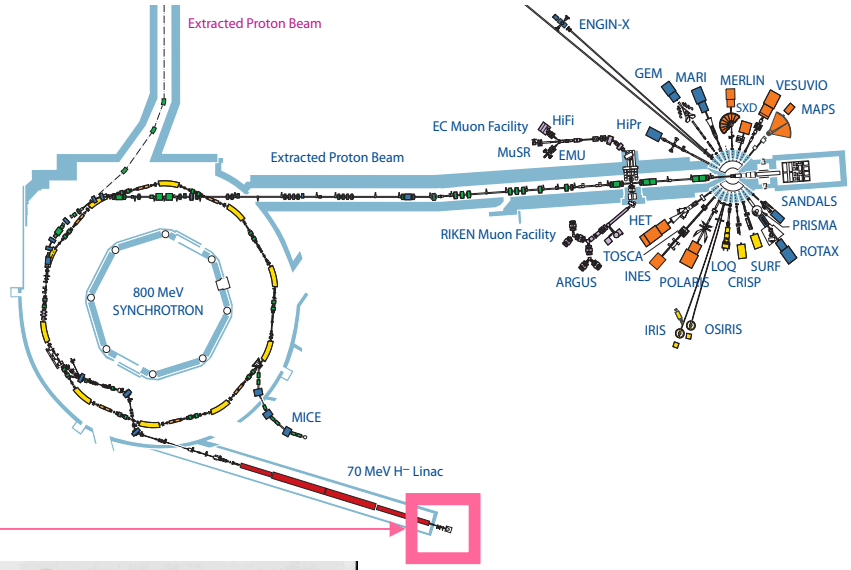
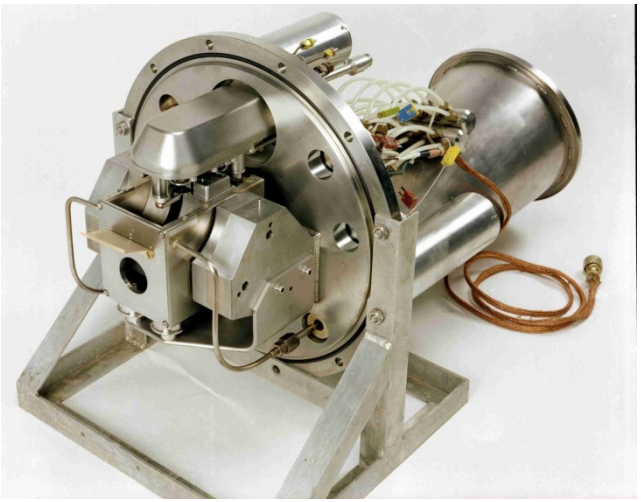
The ISIS Accelerators

The beginning - the
Ion Source





Produces H^- ions and accelerates them to 665 keV.

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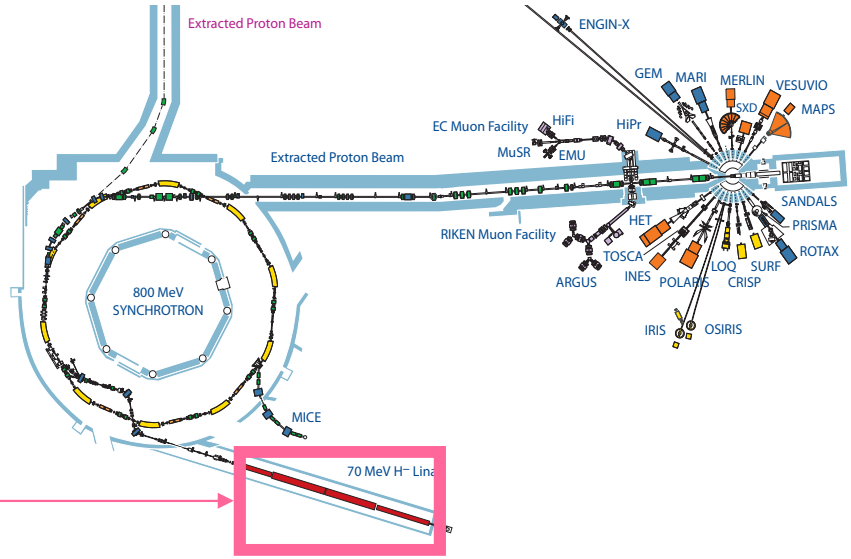
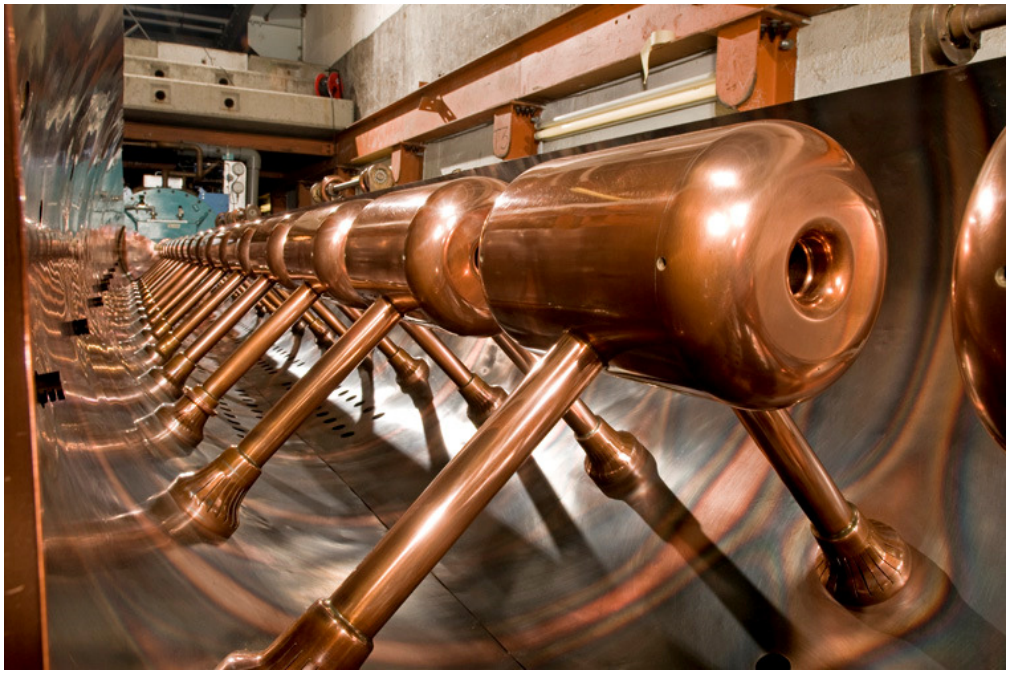
The ISIS Accelerators

The middle - the *Linear Accelerator*

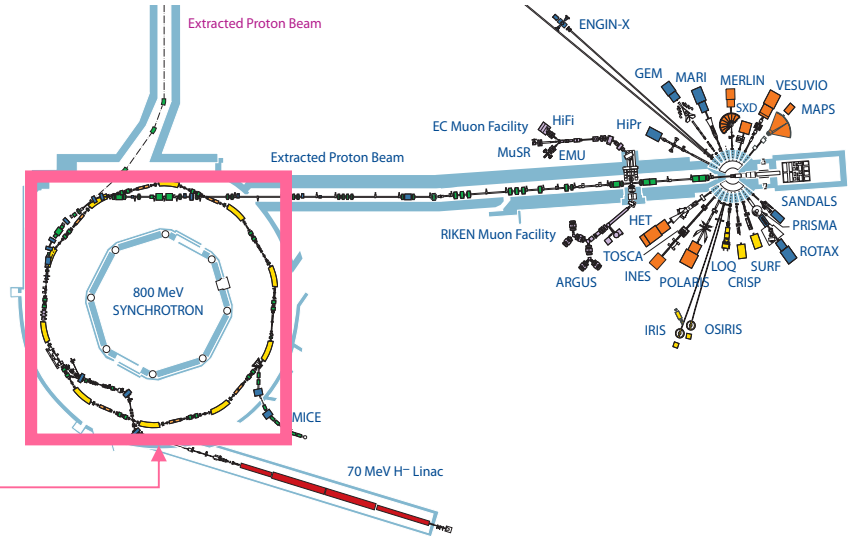




Accelerates the H^- ions to 70 MeV.

The ISIS Accelerators

The final stage - the *Synchrotron Accelerator*



- H^- ions stripped to protons
- Protons travel ~10,000 times round
- Accelerated to 800 MeV (84% light speed)

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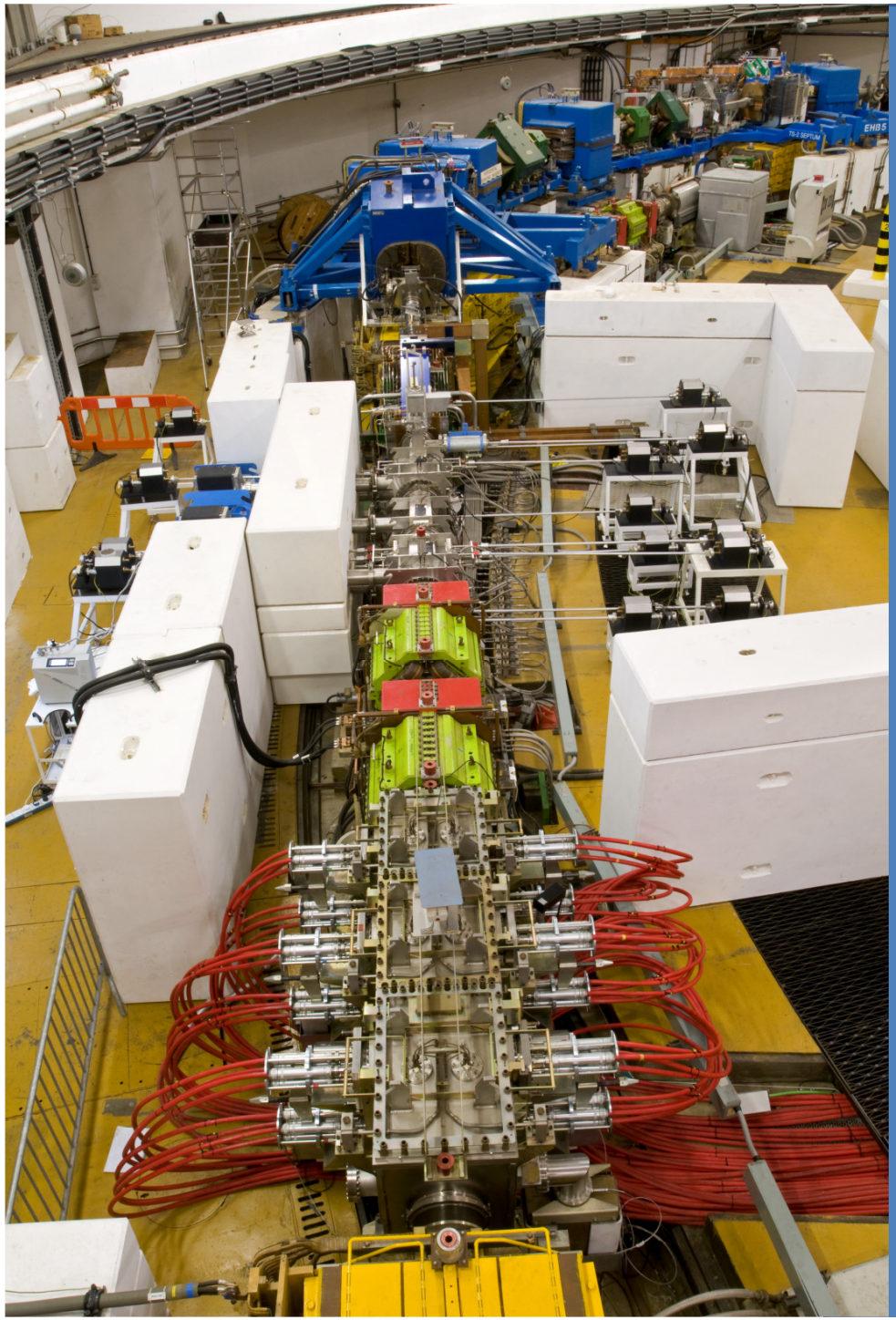
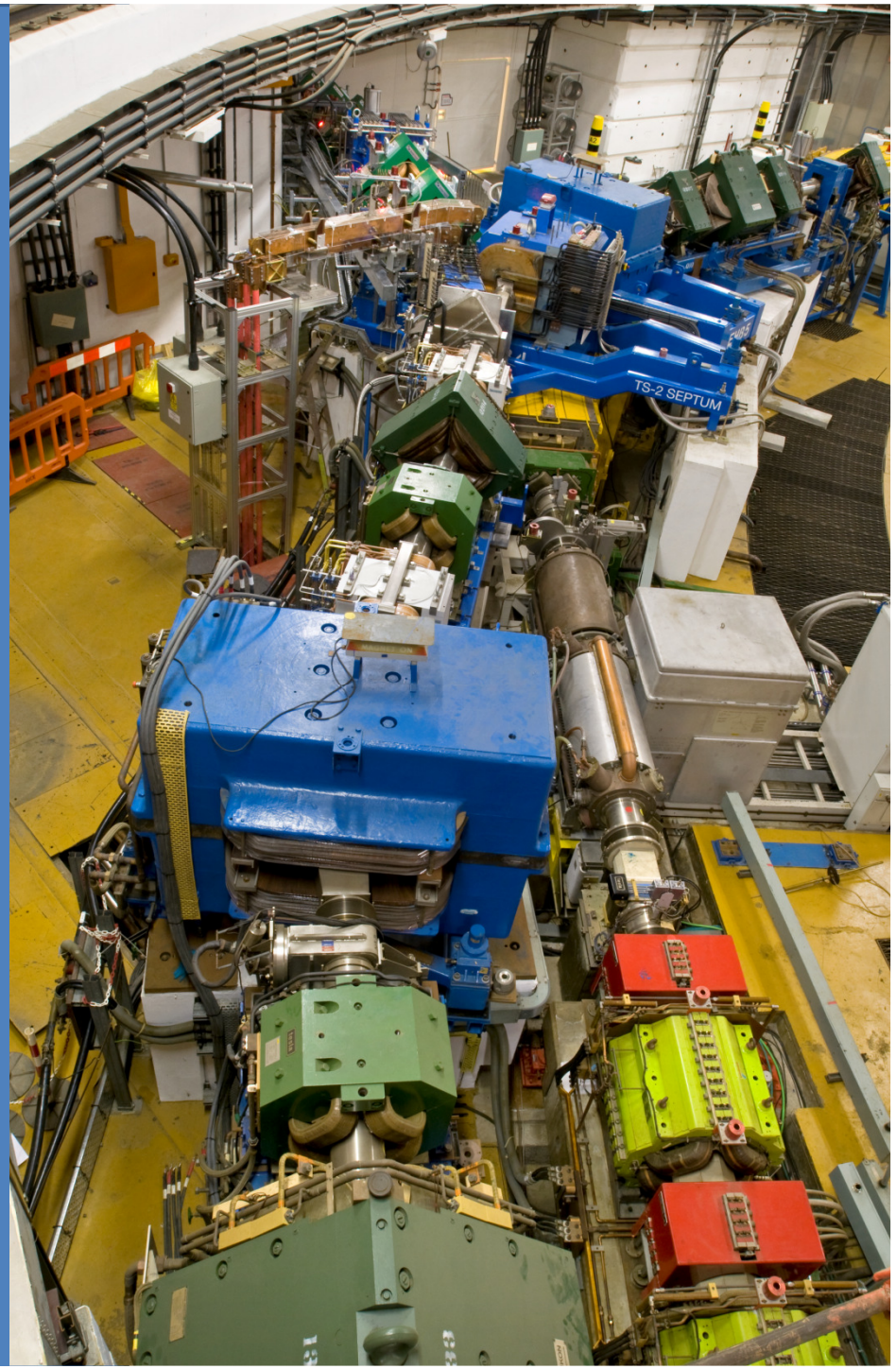
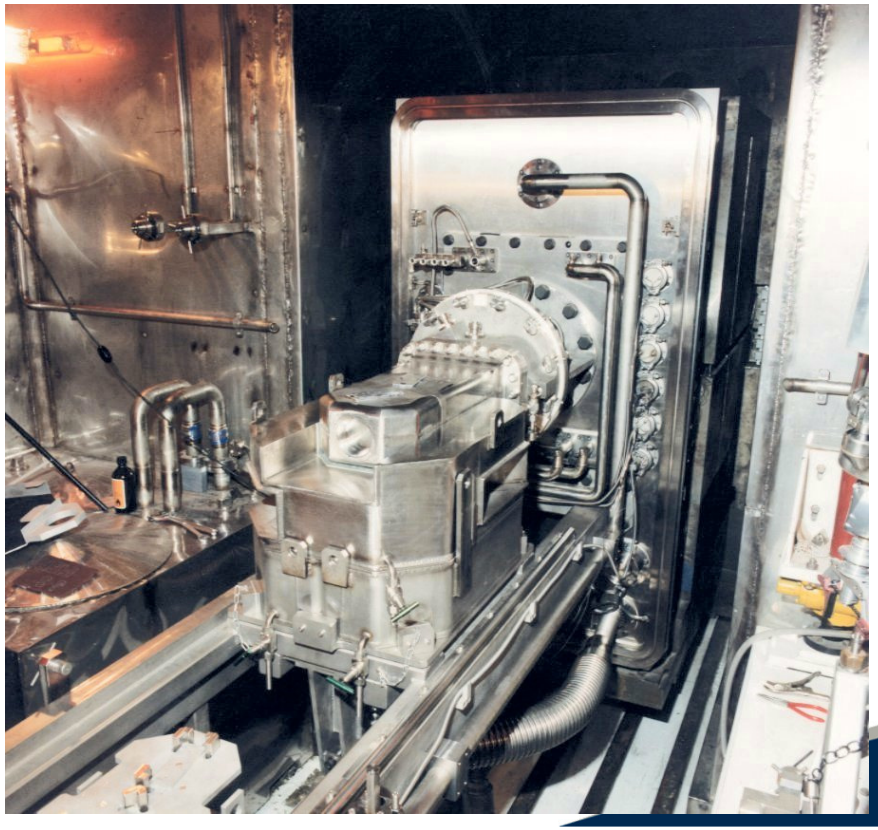

TS-2 SEPTUM
EH3.5

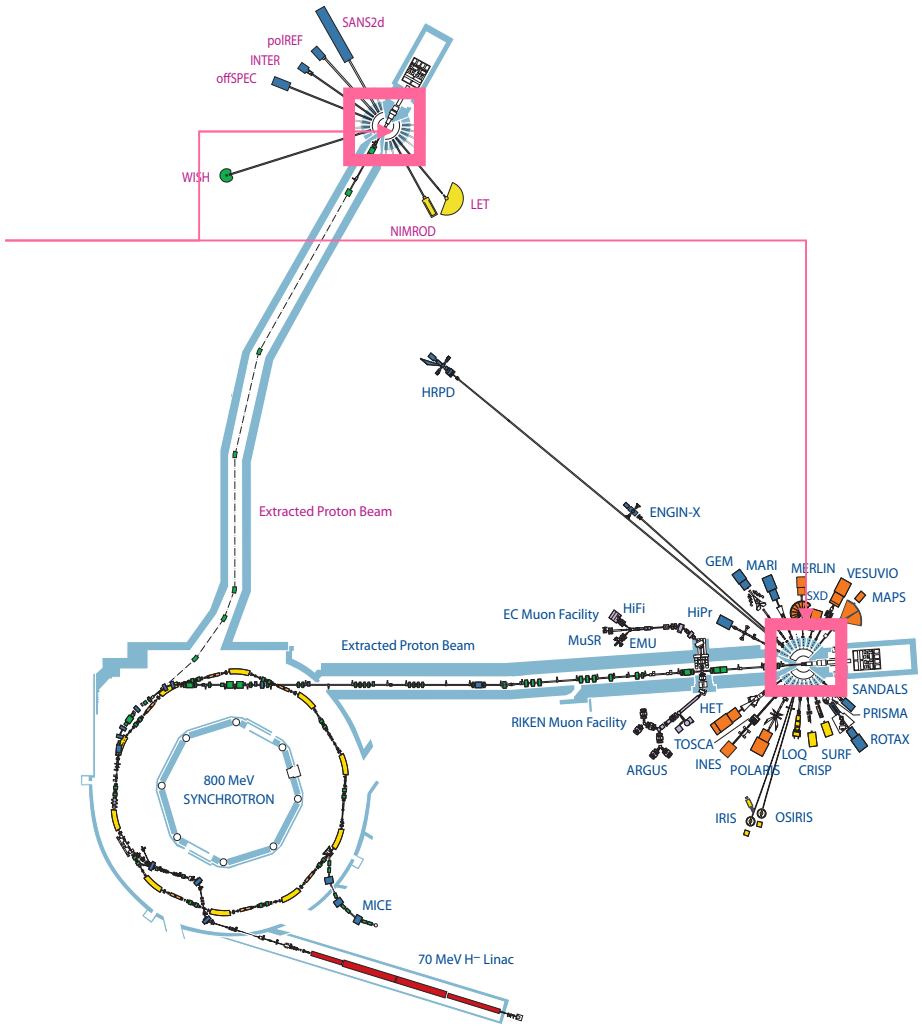

TS-2 SEPTUM

The ISIS Targets

- Tantalum targets
- Neutrons produced by ‘spallation’
- Heat dissipation is 160 kW TS1, 40kW TS2

The *Neutron Targets*





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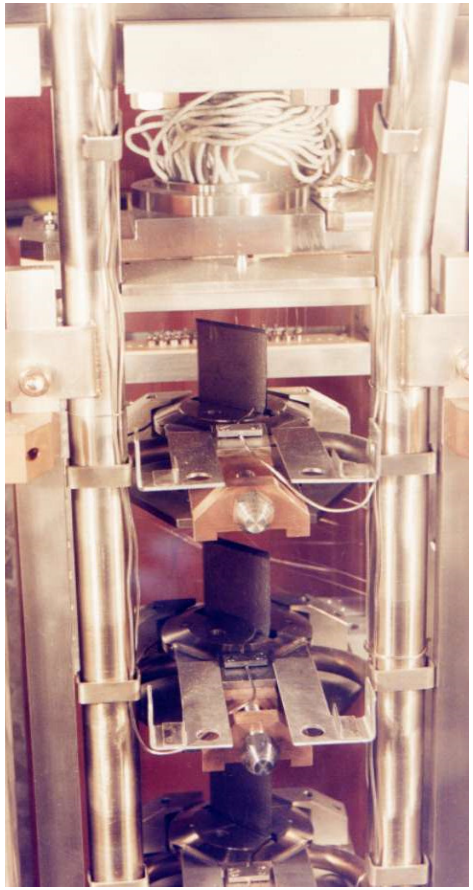
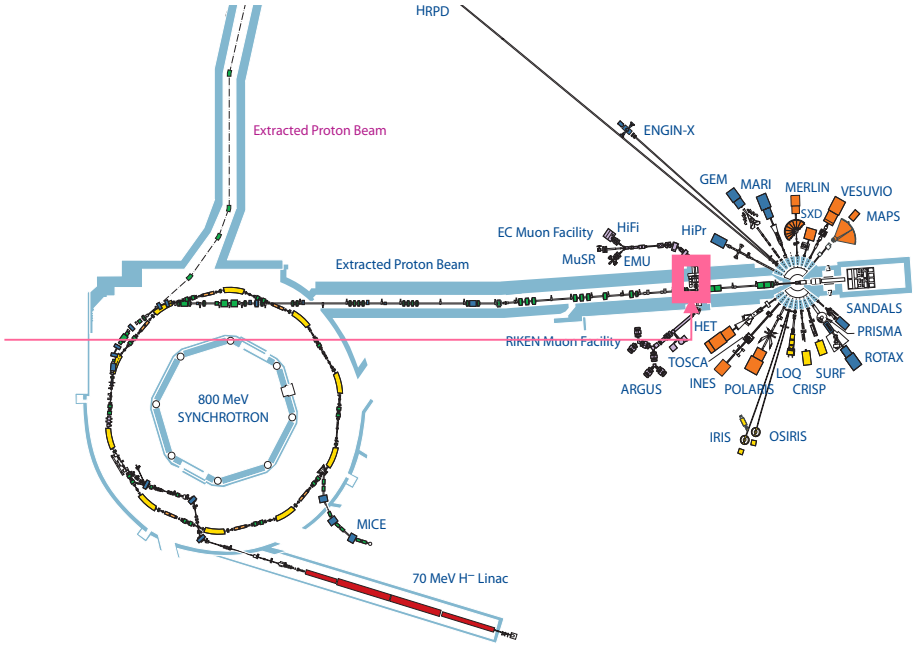
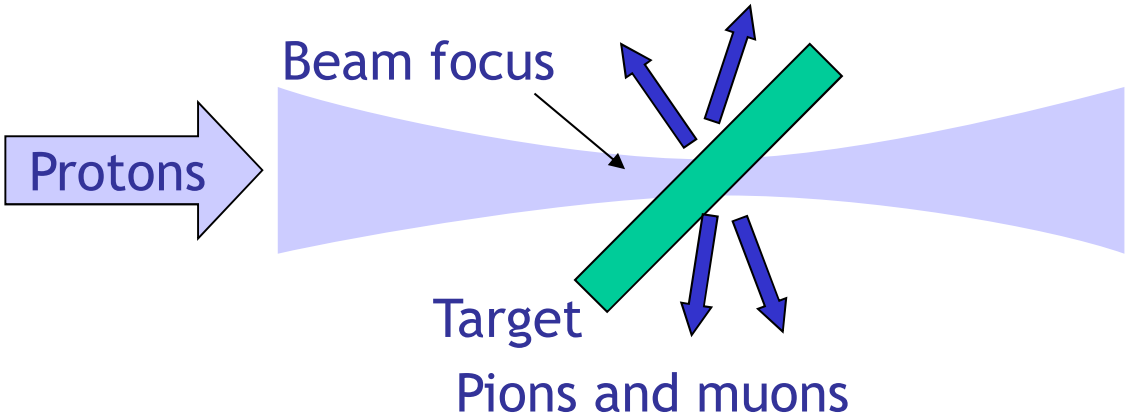
Muon Production Target

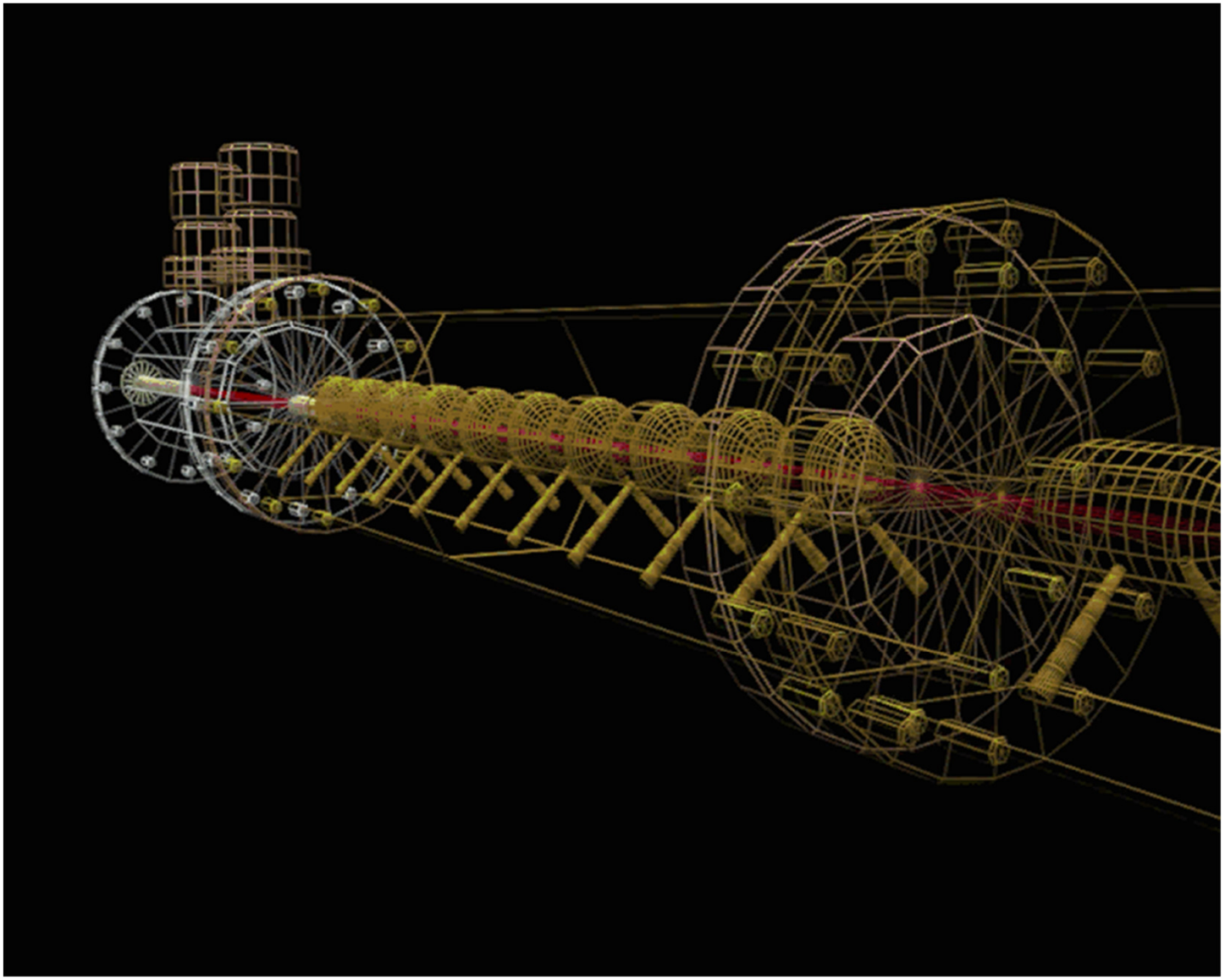
- Made of graphite
- Gets to perhaps 900K
- Takes ~5% of the proton beam



The *Muon Target*







The ISIS Pulsed Neutron and Muon Source

- ISIS runs ~150 days per year
- It runs in ‘cycles’ of 30-40 days each
- ISIS is controlled from the Main Control Room – which is always staffed

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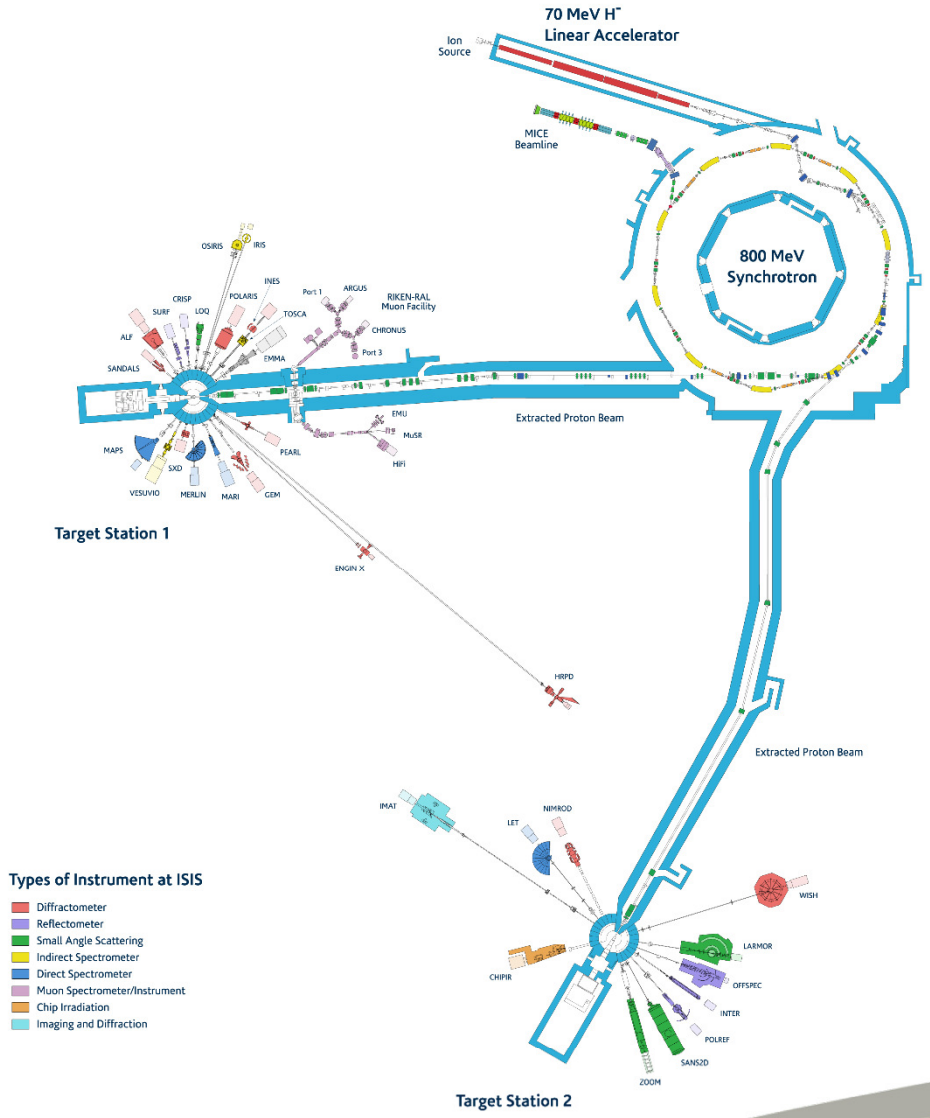
Neutrons at ISIS

30 neutron instruments



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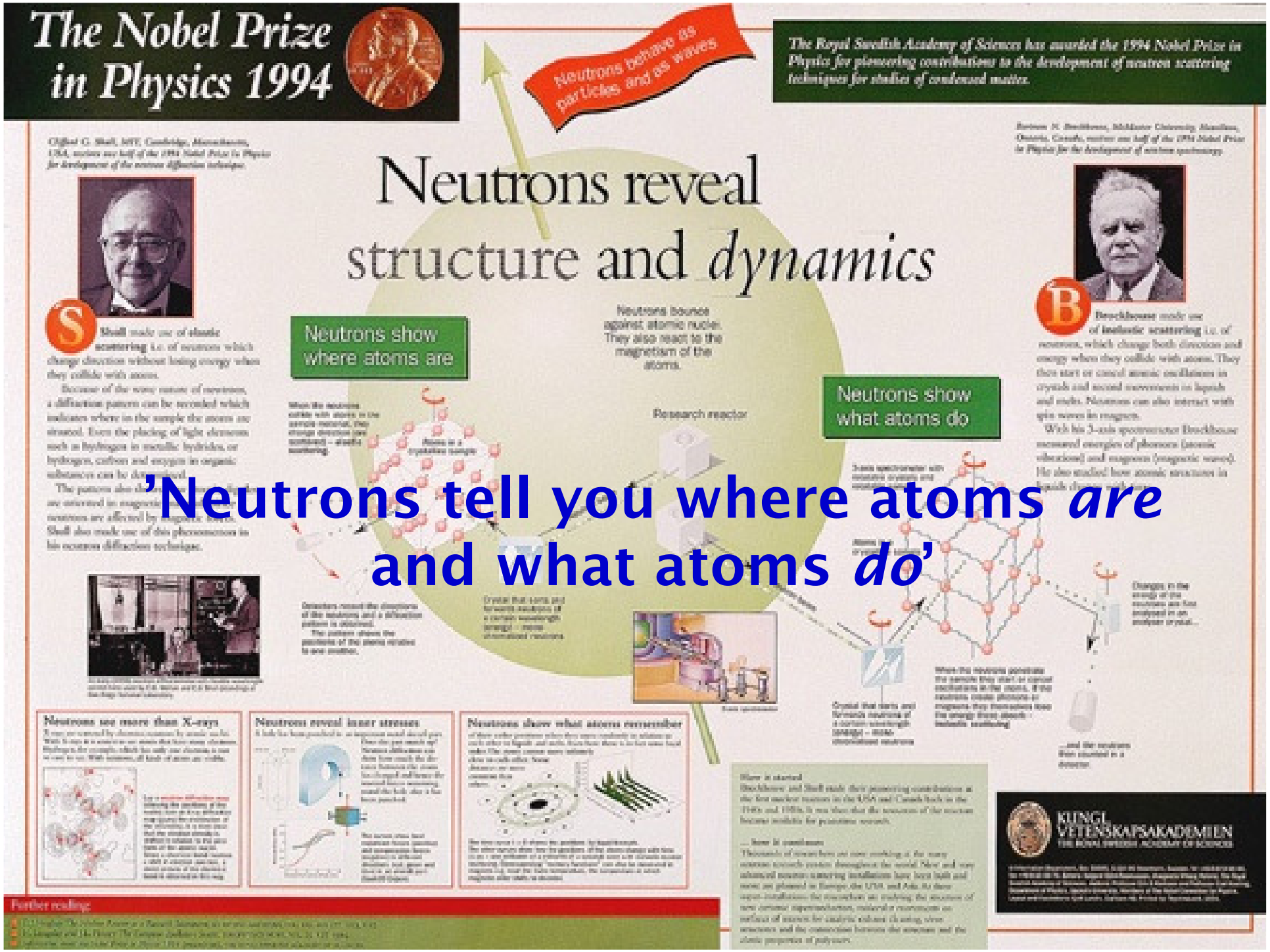
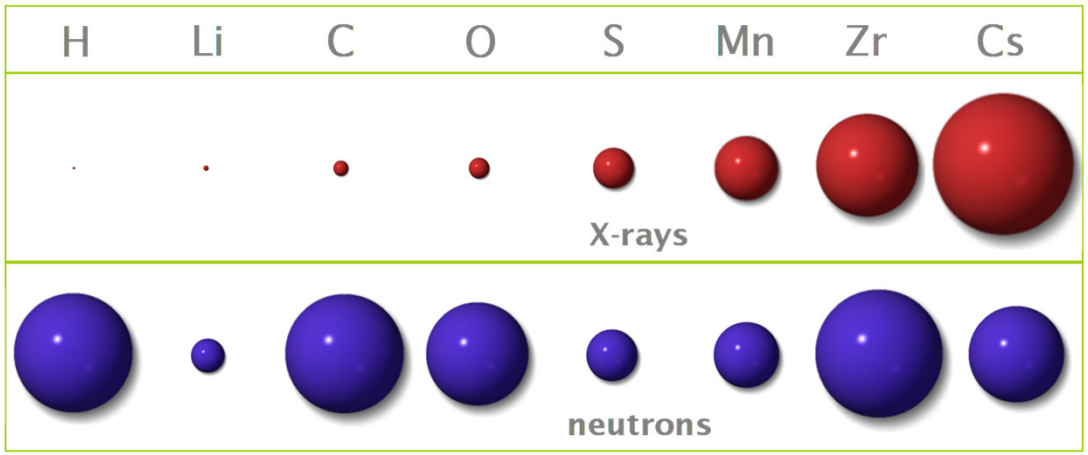
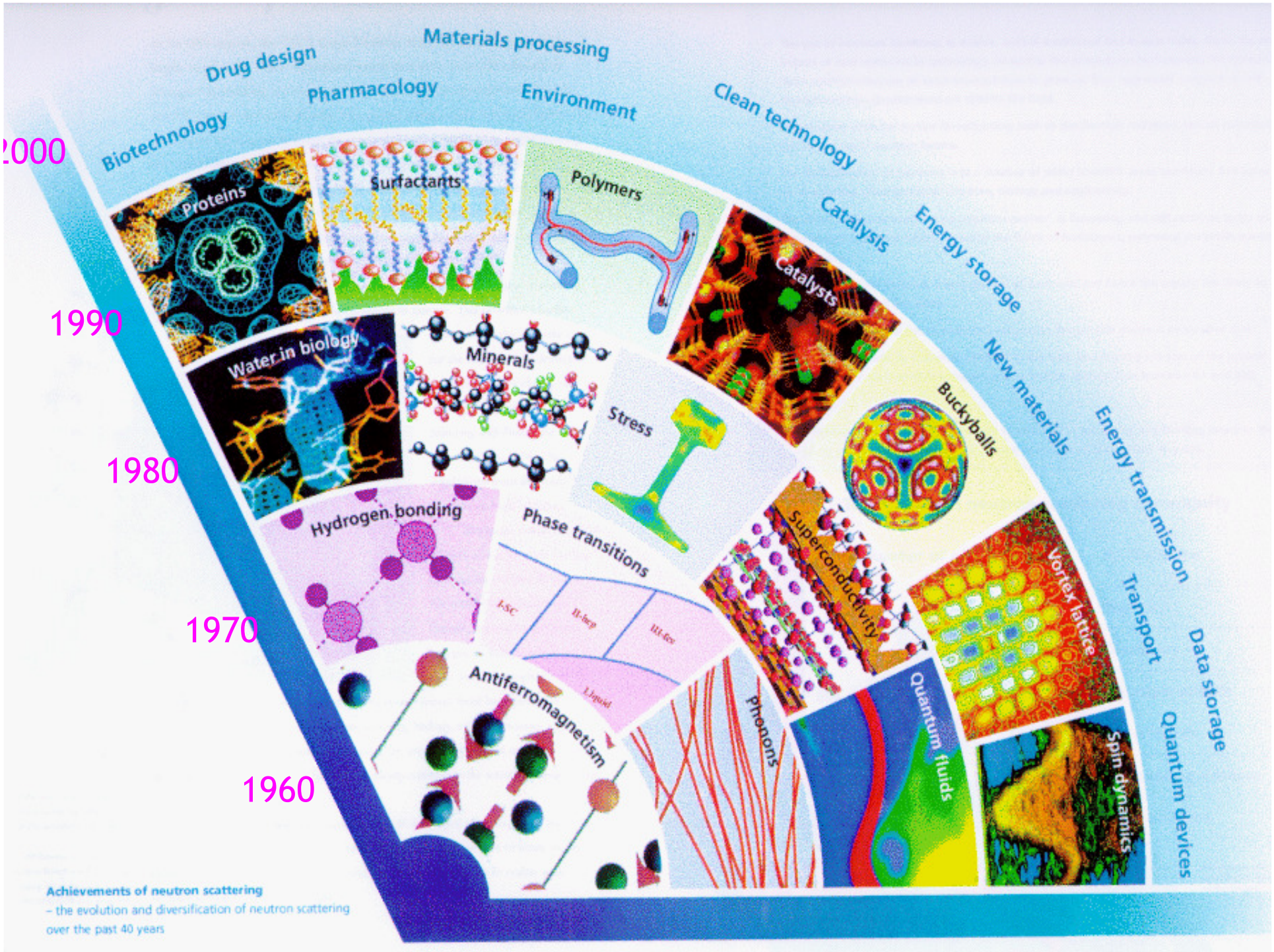


'Neutrons tell you where atoms *are* and what atoms *do*'

Neutrons - a tailor-made probe

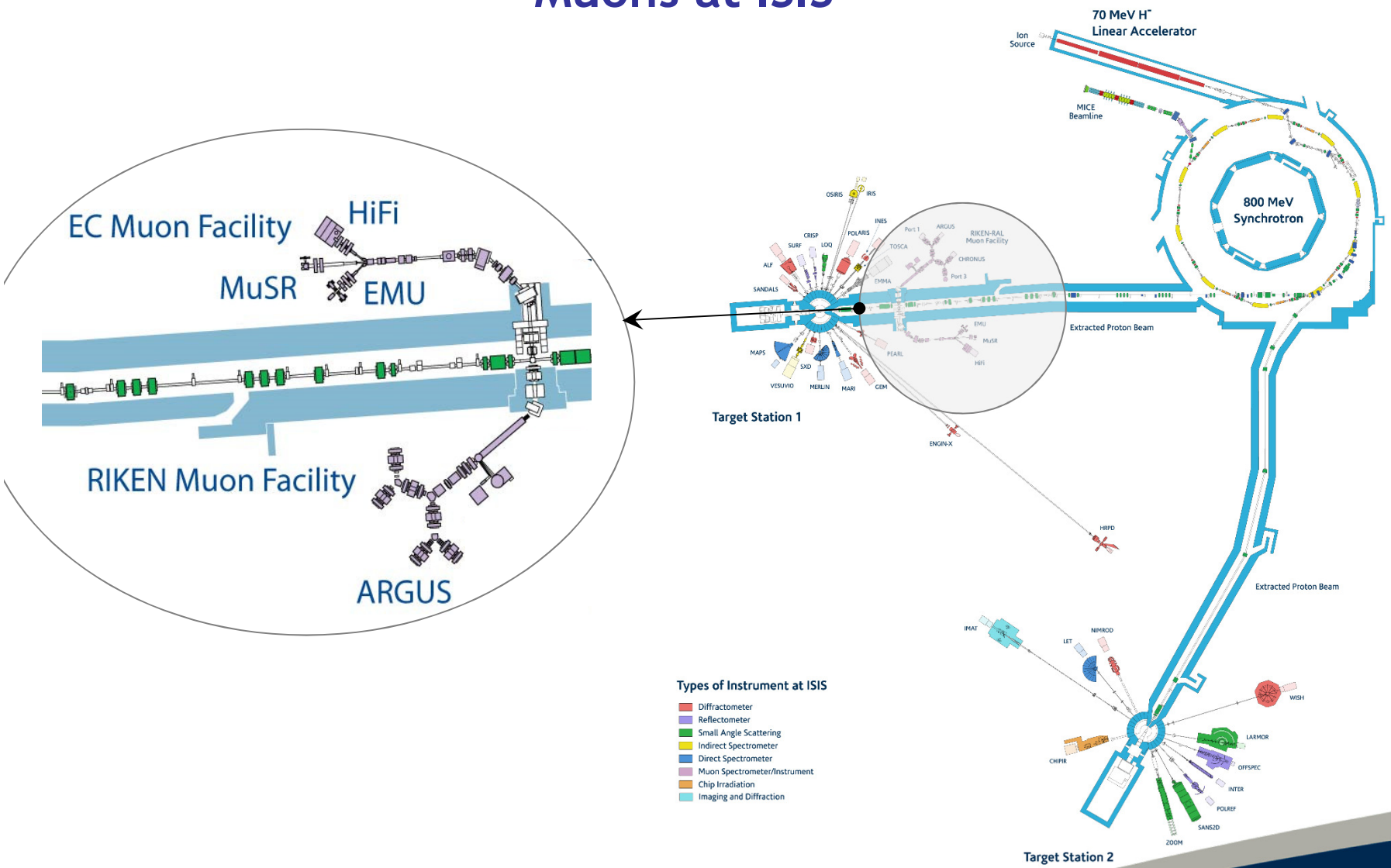
- Neutron wavelength and energy 'just right' (25meV ~ 1.8 Å)
  - *structure and dynamics*
- Neutron cross-section
  - *isotopic dependence*
- H / D contrast
  - *nuclear form factor*
- Magnetic Moment
  - *magnetic order & excitations*
- Weak probe
  - *theoretical interpretation*
- Highly penetrating
  - *bulk probe*
  - *complex SE*





Achievements of neutron scattering
– the evolution and diversification of neutron scattering over the past 40 years

Muons at ISIS



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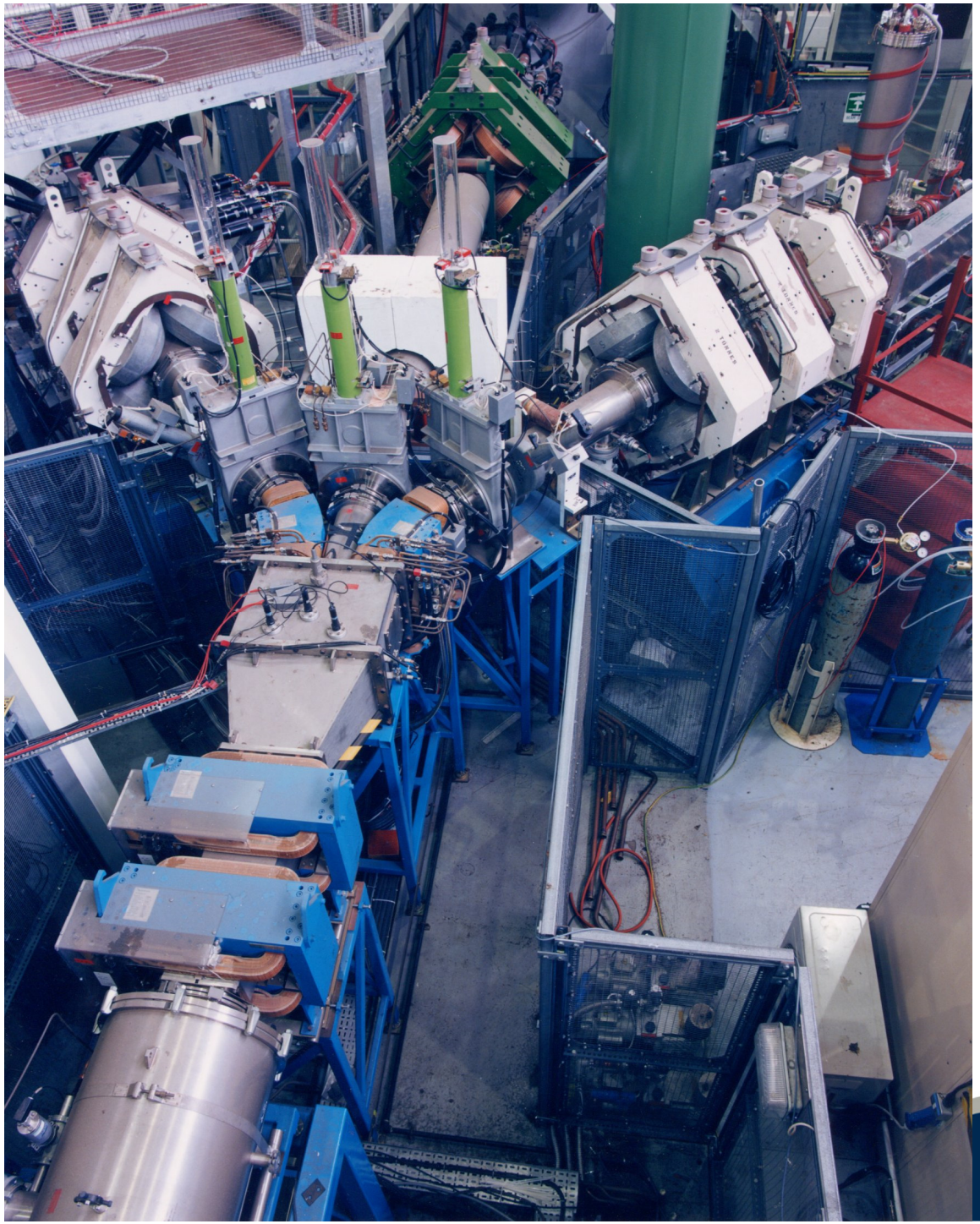

The European Muon Facility

Science & Technology Facilities Council
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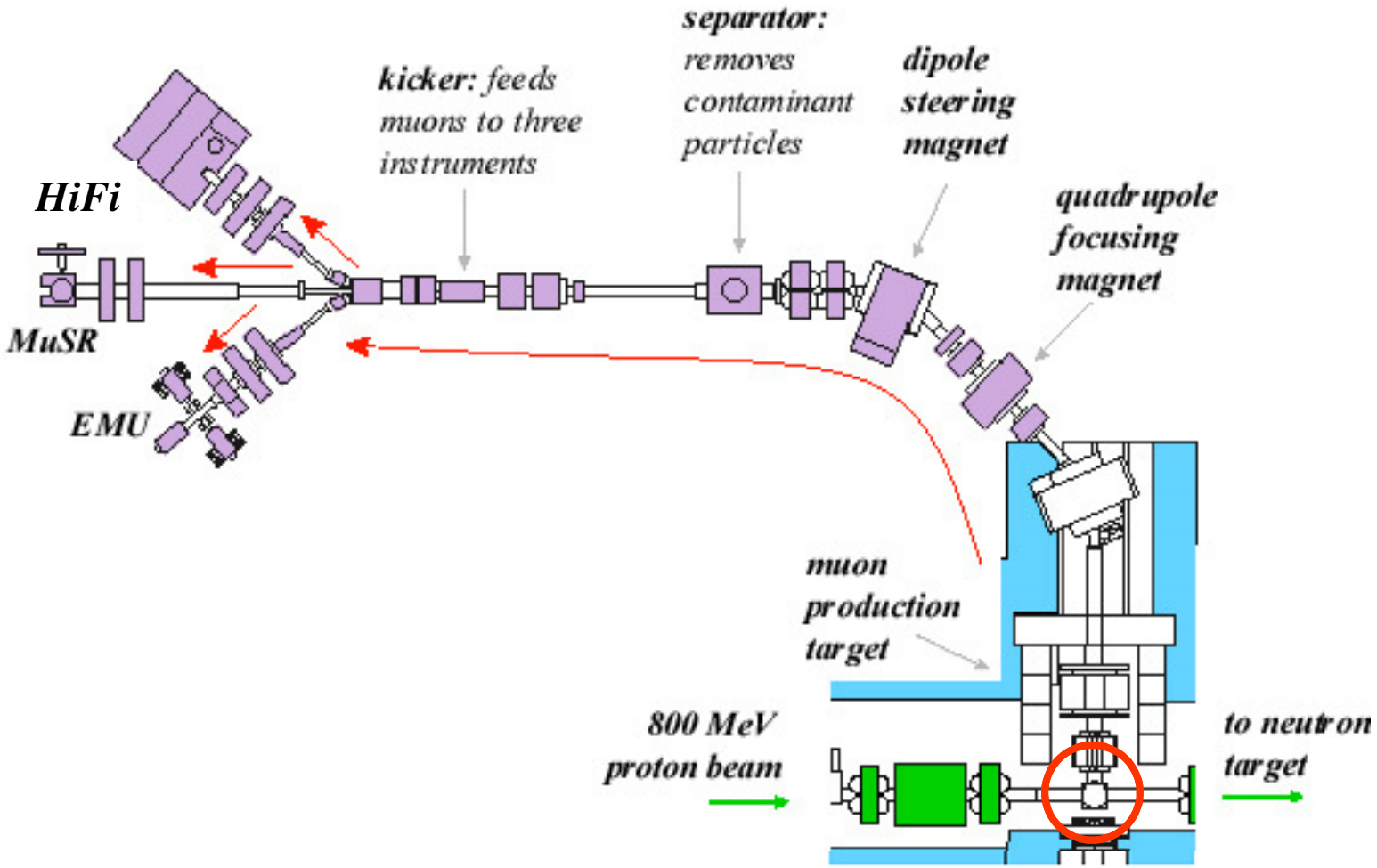
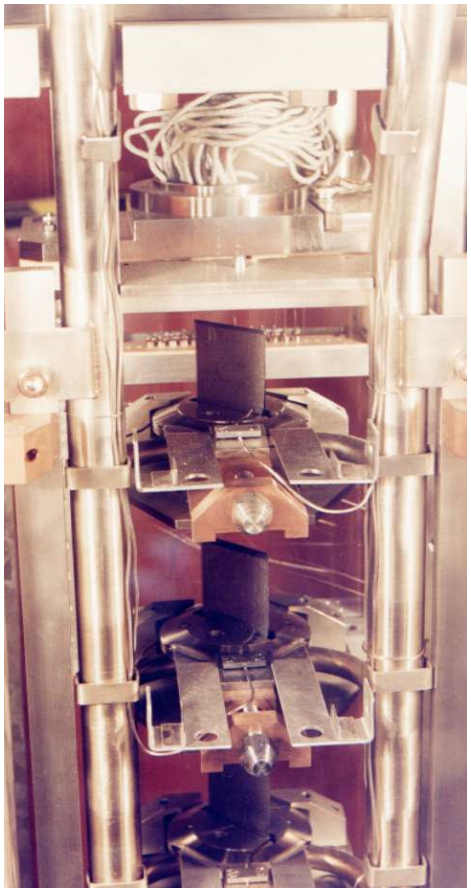
The EC Muon Facility

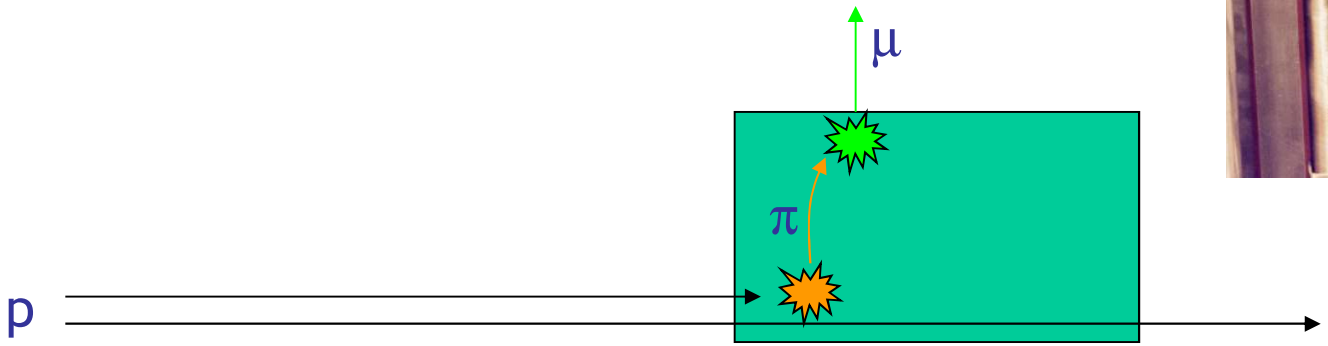


‘Surface’ muons

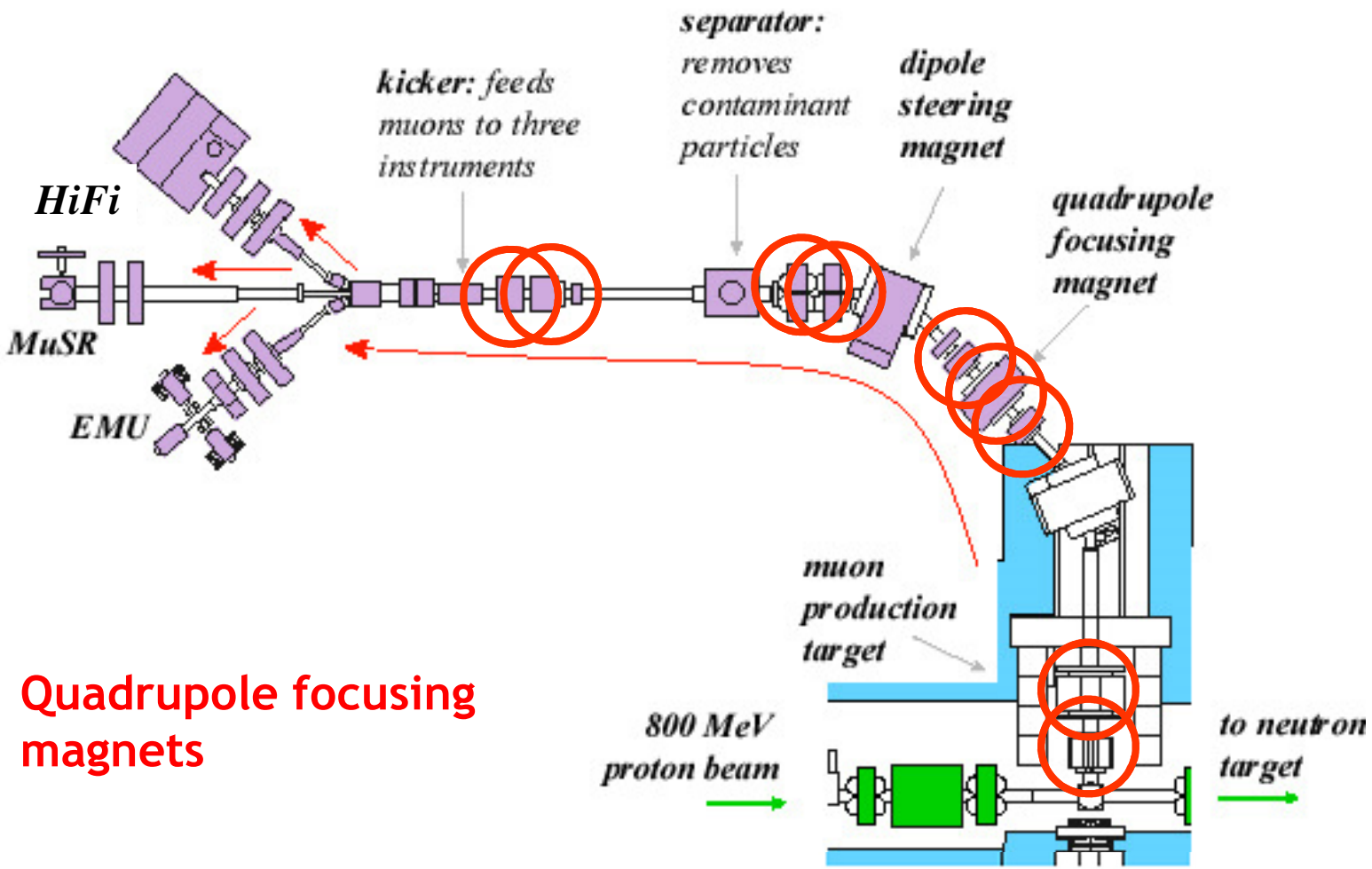
- Proton collisions produce ***pions***, e.g.

  $p + p \rightarrow p + n + \pi$
- Some pions ***stop*** in the target
- They decay to muons, which escape if formed near the target surface
- Muons collected into the beam line
- Polarisation 100%





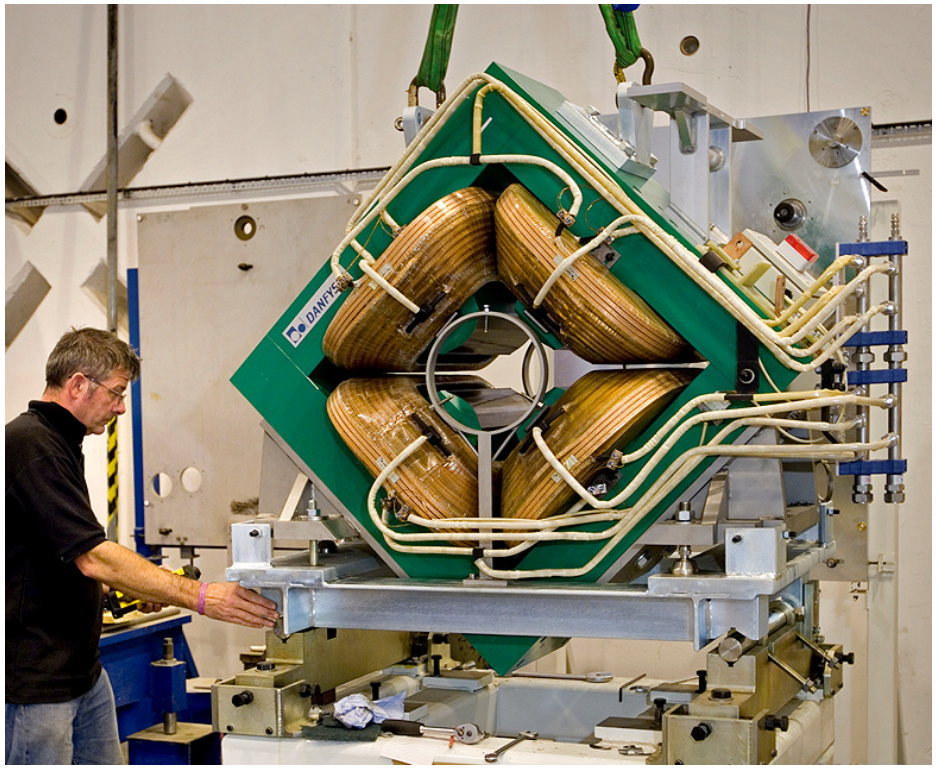
The EC Muon Facility

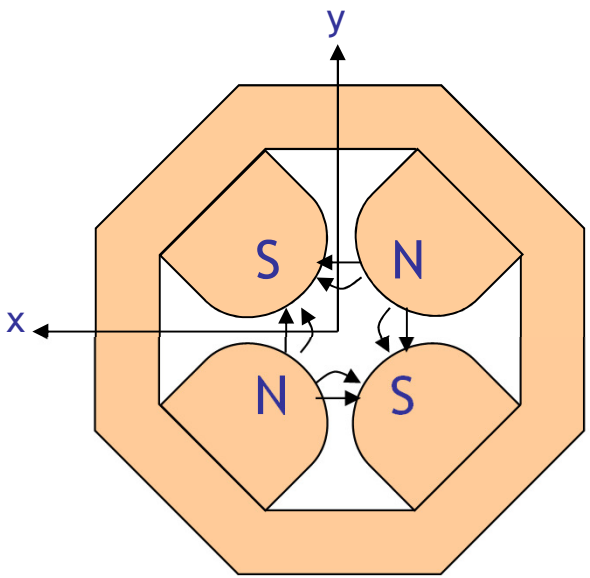


Quadrupole focusing magnets

Focusing the beam - quadrupole magnets

- Quadrupole magnets focus in one direction, defocus in the other.
- So they appear in our beamline in 2's or 3's
- Allow tuning of the beam by varying the current





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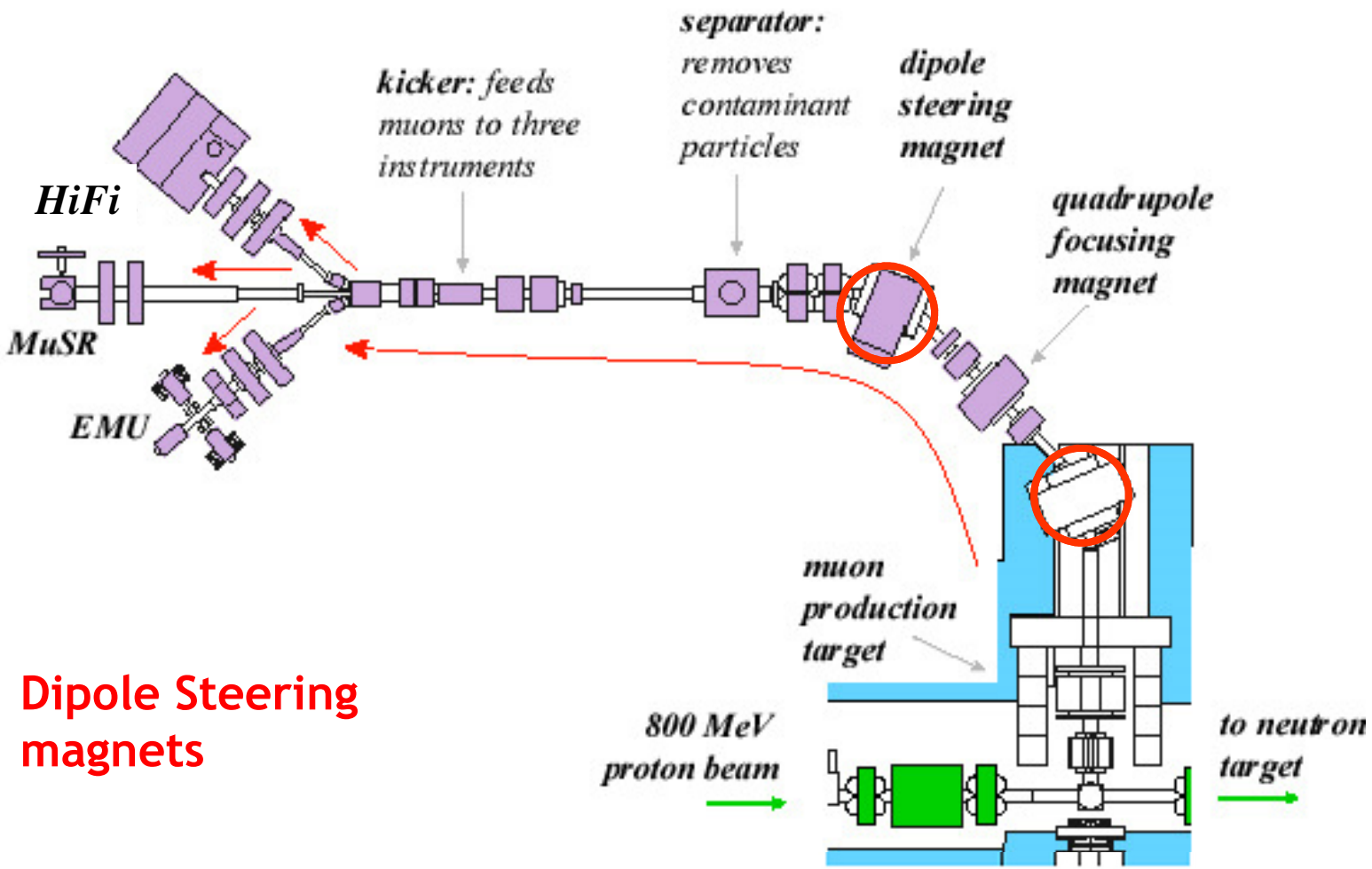
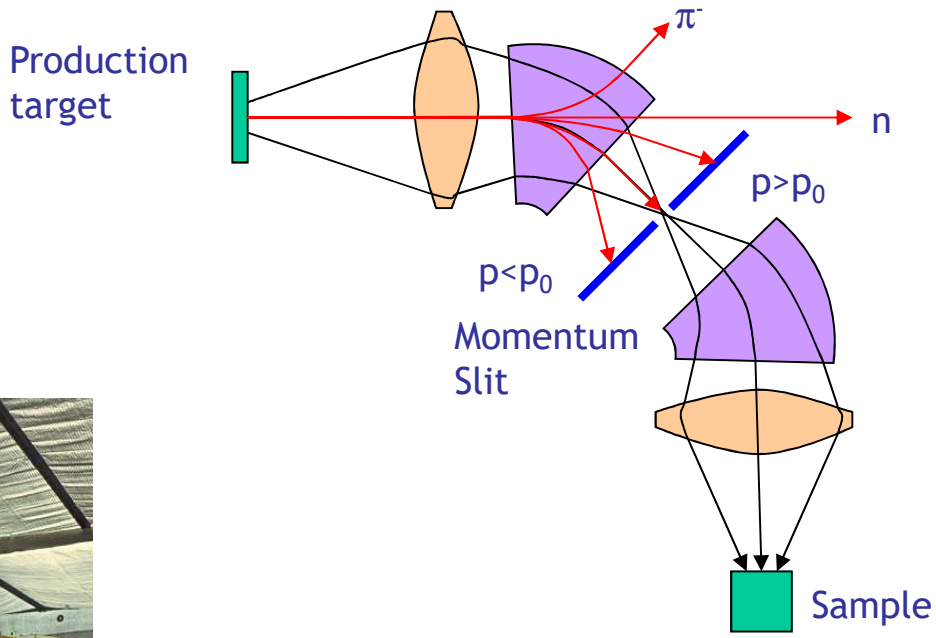


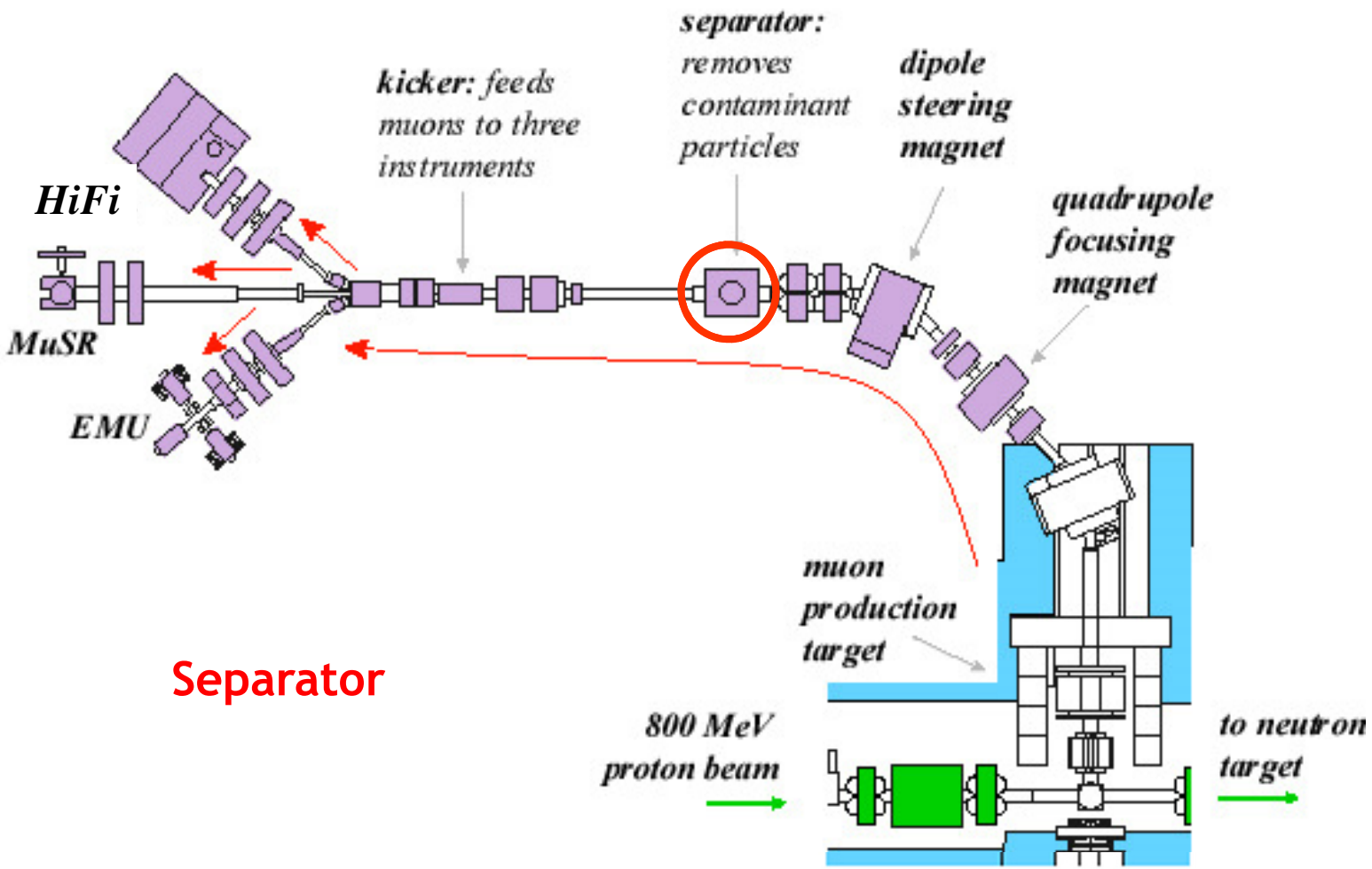
Dipole Steering magnets

Bending the beam - dipole magnets

- Get the beam round corners!
- Also exclude neutral particles or those of the wrong charge
- Act as a momentum filter



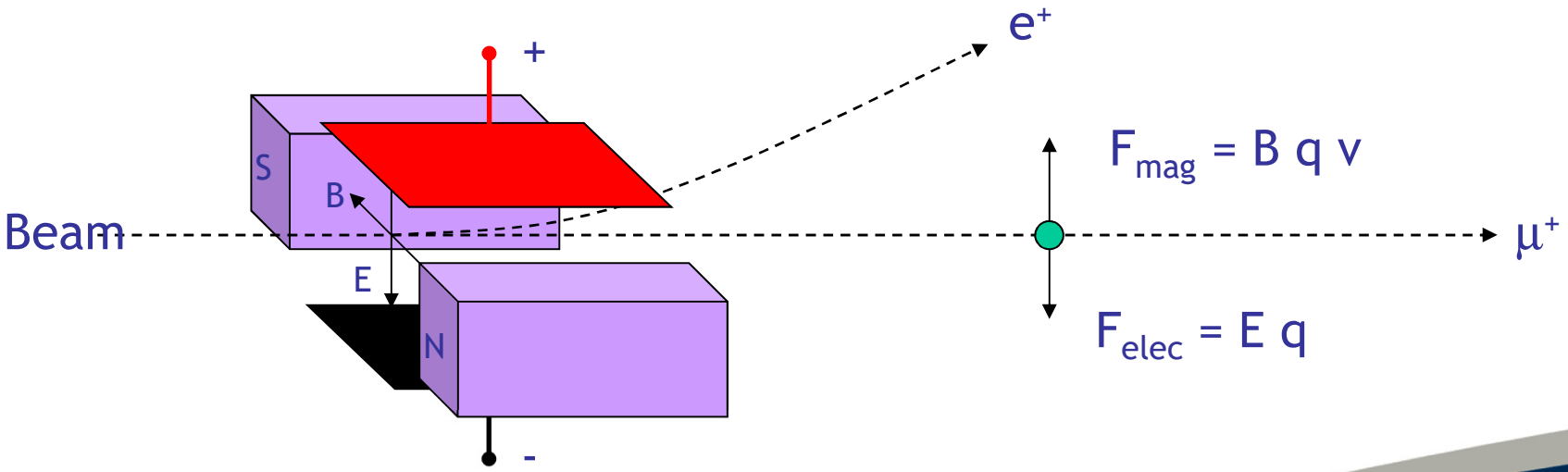
The EC Muon Facility



Separator

Cleaning the beam - the separator

- E and B fields, mutually perpendicular
- Acts as a velocity filter
- E and B field forces cancel for particles of the correct velocity
- Gives a 6º spin rotation



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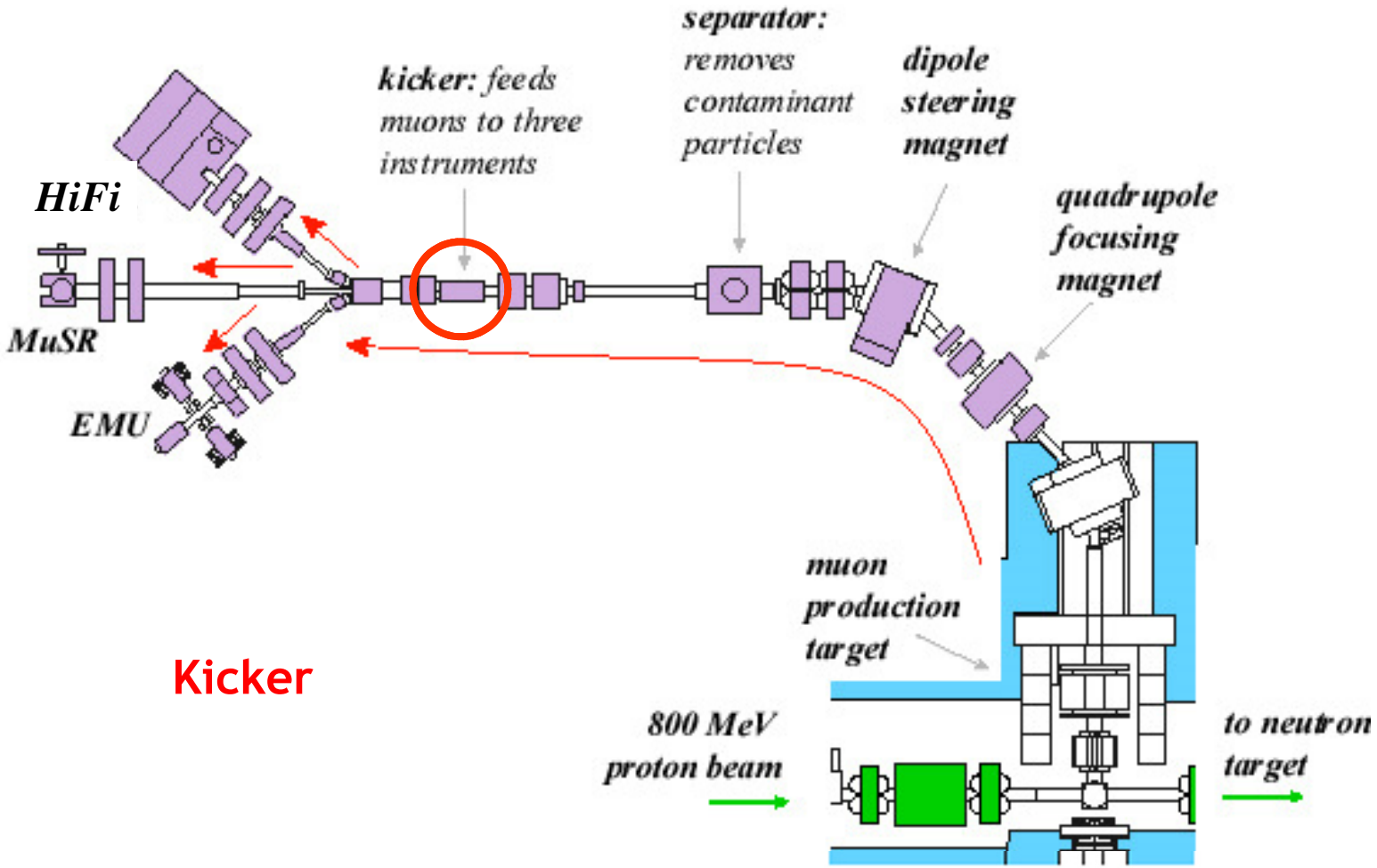
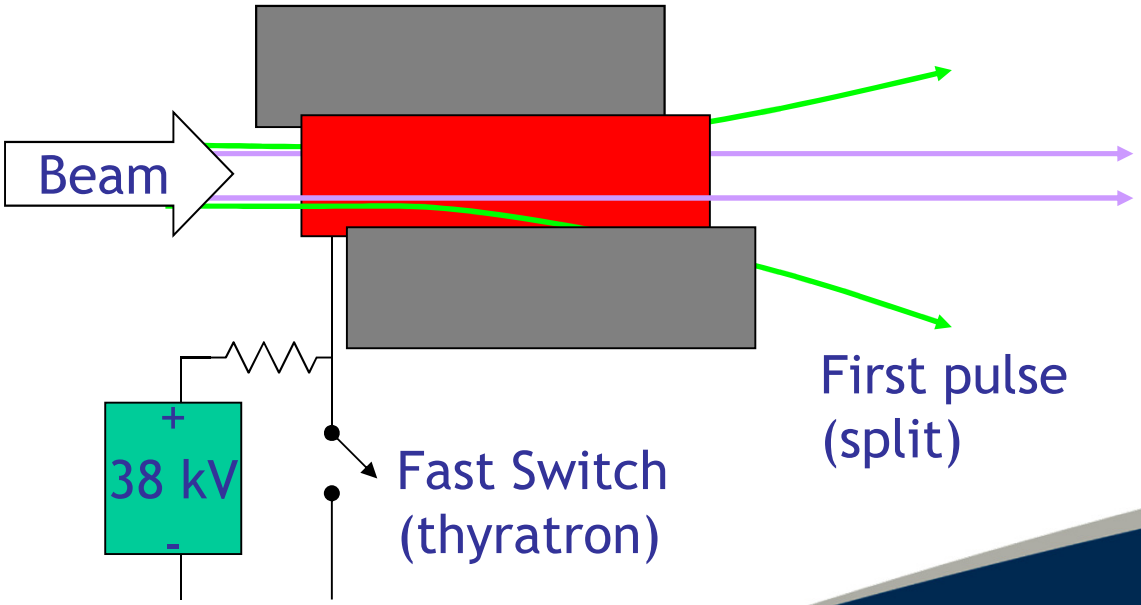
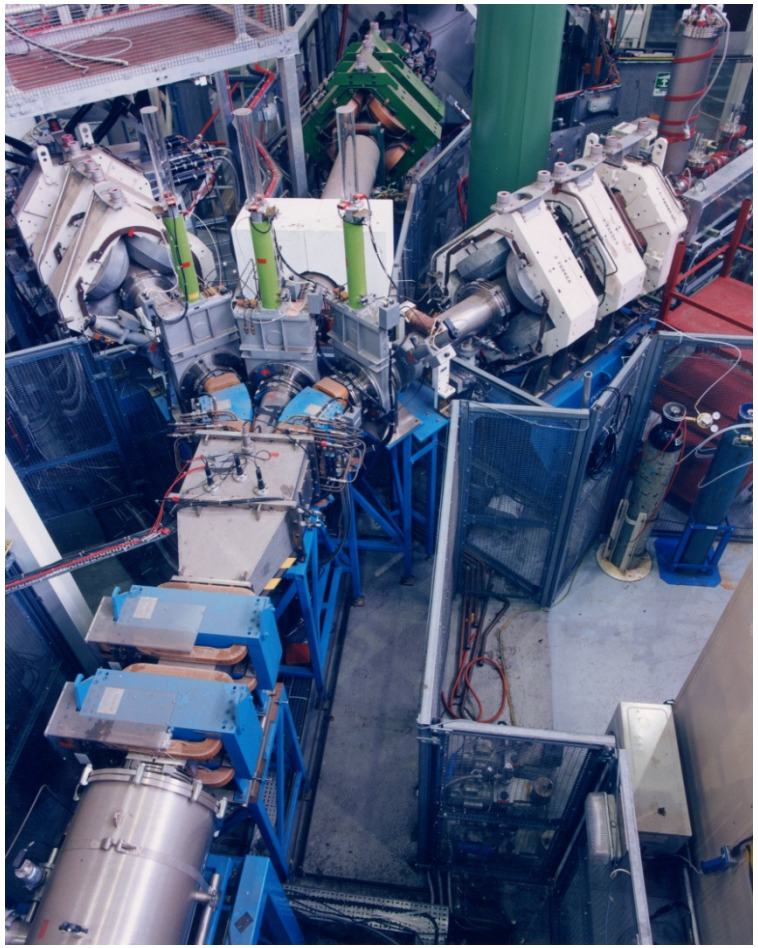


Kicker

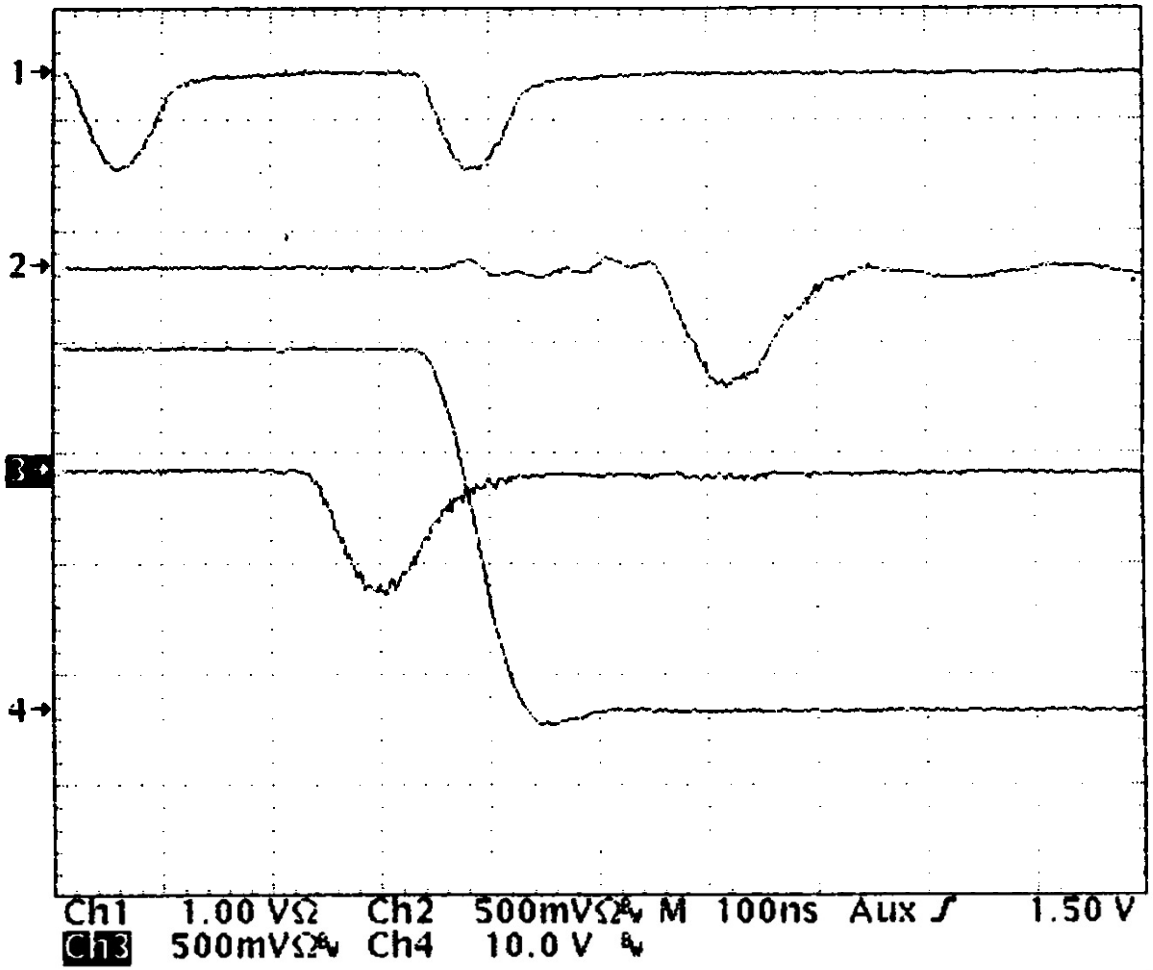
Splitting the beam - the kicker

- Central electrode
- Charged positively for first muon pulse
- Splits the first pulse in two
- No voltage for second muon pulse
- Second pulse goes straight through





Splitting the beam – the kicker



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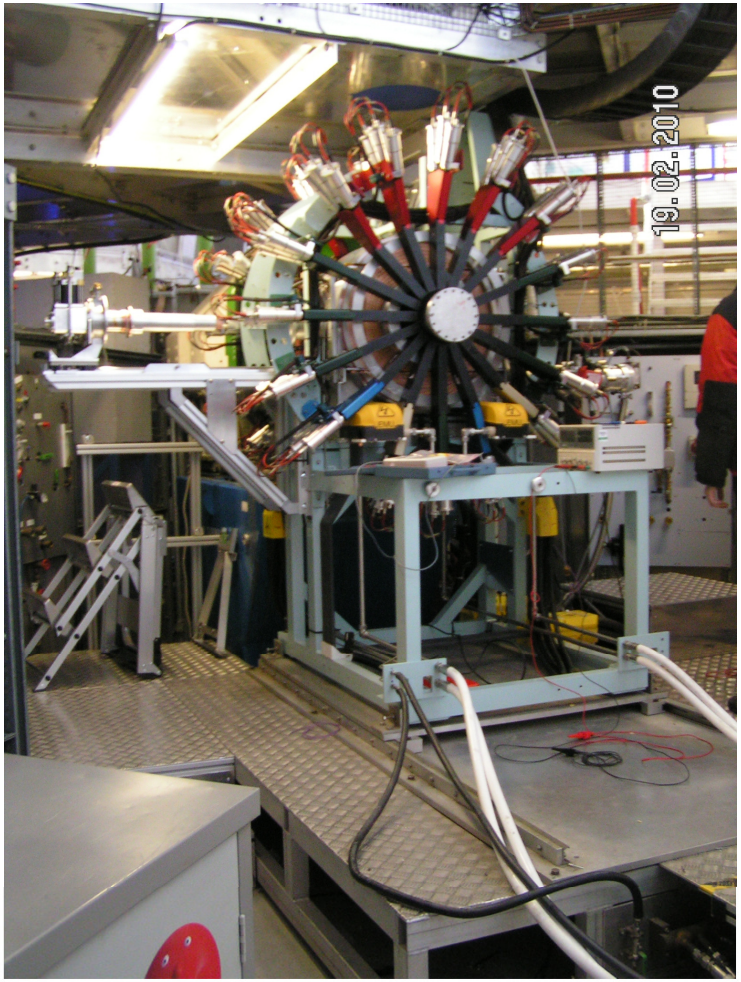
EMU



0.5 T main field, longitudinal

+ 150 G transverse fields

+ Stray field compensation

96 Detectors

Data Rates –
single pulse
120MeV/hr

Fly-past

Temperature range of 40 mK- 2000 K

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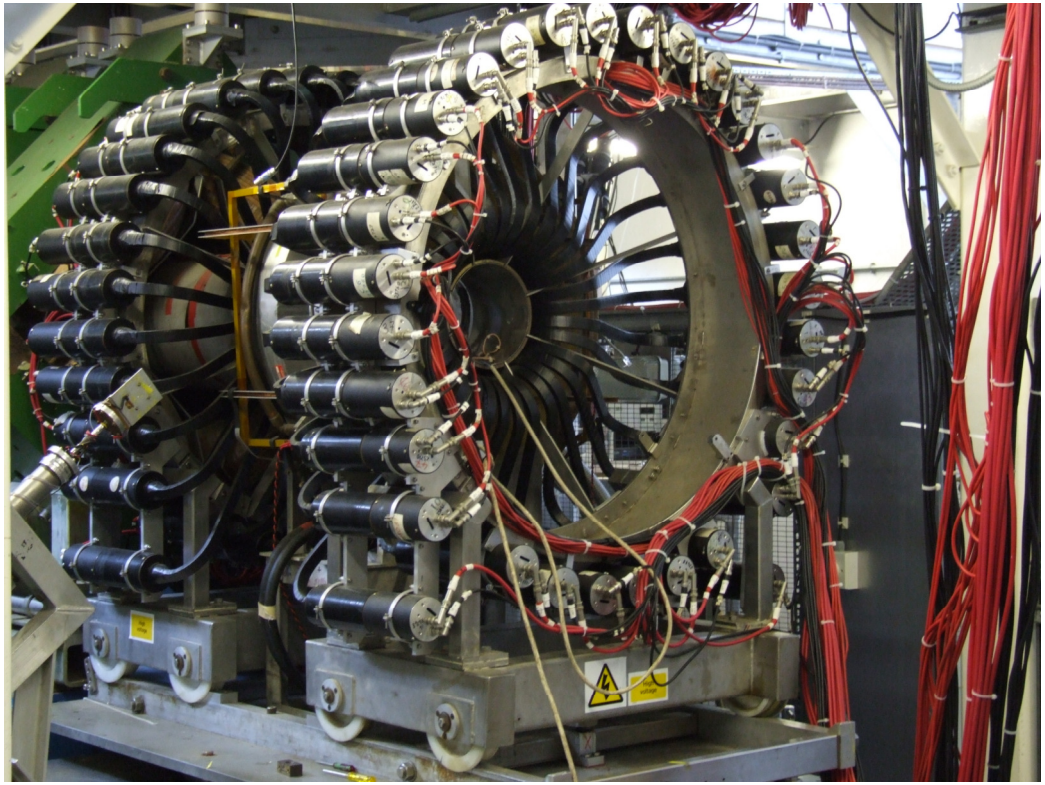
MuSR



0.3 T main field, longitudinal

+ 20 G transverse fields

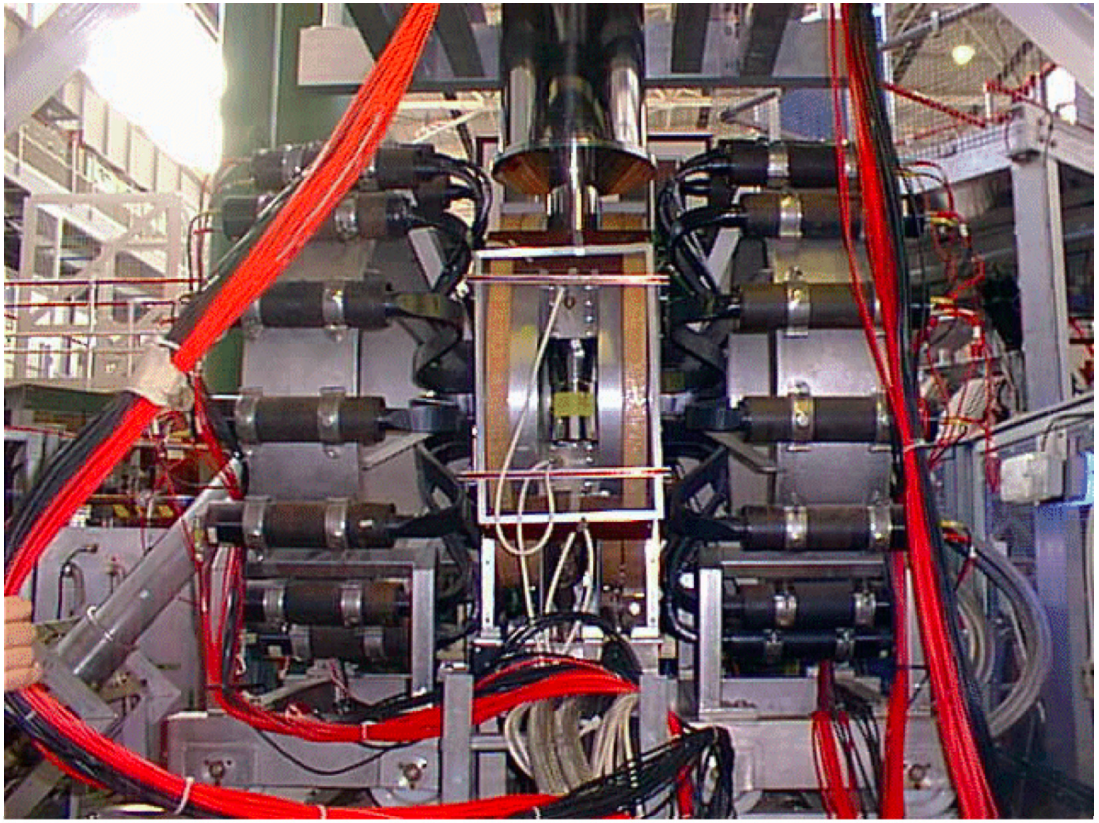
+ Stray field compensation

64 Detectors

Data Rates –
single pulse 45 MeV/hr

Temperature range of 40 mK- 1000 K

MuSR



0.07 T main field, transverse

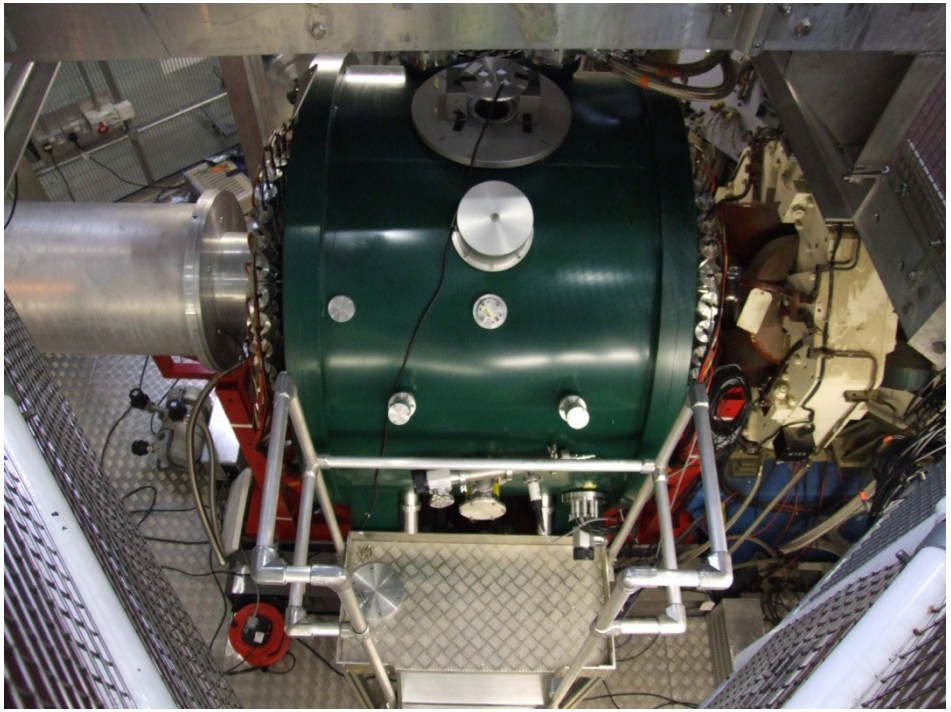
+ Stray field compensation

64 Detectors

Data Rates –
single pulse 45 MeV/hr

Temperature range of 40 mK- 1000 K

HiFi



5 T main field, longitudinal

+ 400 G auxiliary field (for field switching, e.g. ALC)

+ 2 x 100 G transverse fields

+ Stray field compensation

Data Rates upto 200Mev/hr

Temperature range of 40 mK- 2000 K

RIKEN-RAL Muon Facility

Largest UK-Japan science collaboration

First muons 1994

4 experimental areas
- condensed matter
- other ‘exotic’ uses of muons

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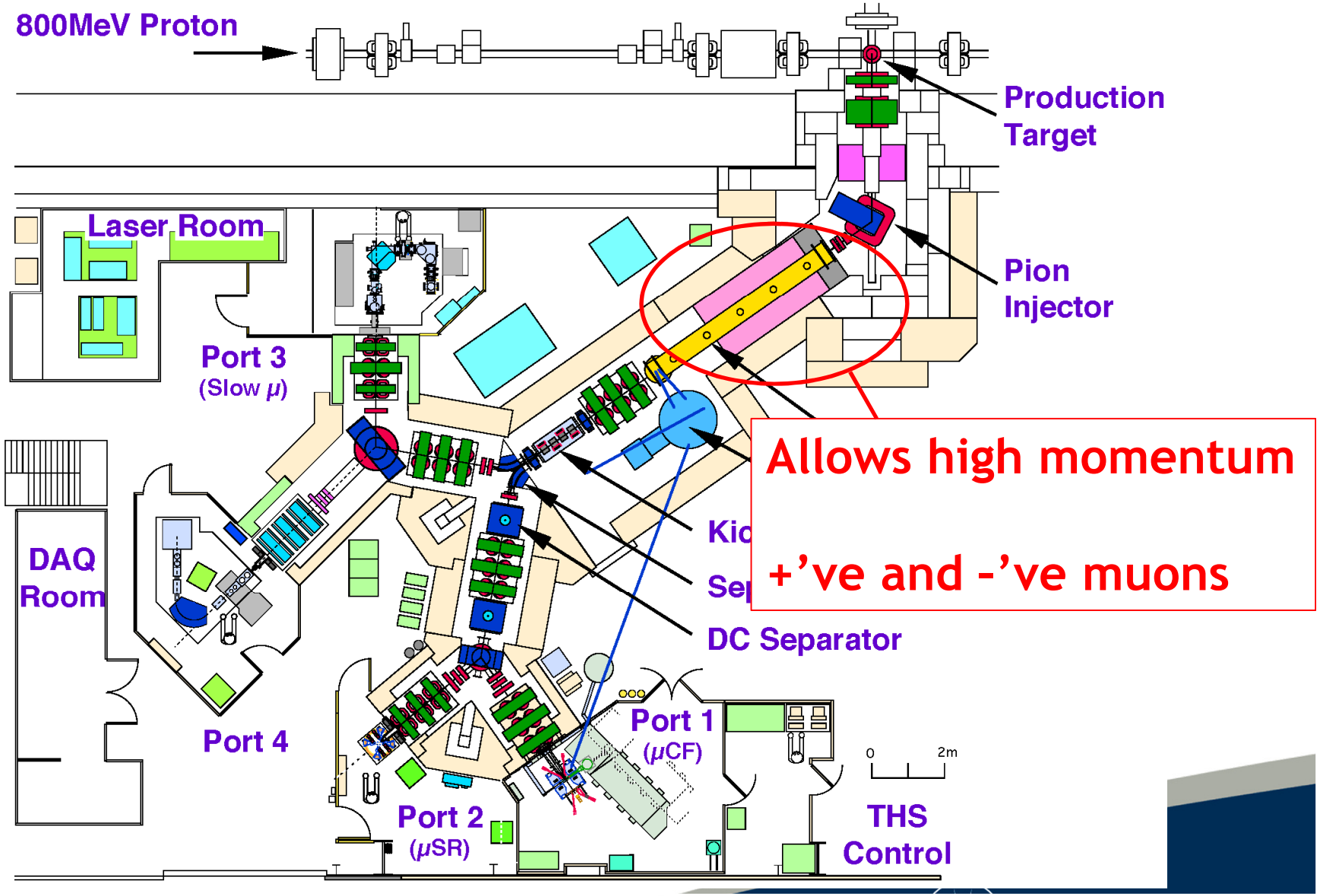

Allows high momentum

+'ve and -'ve muons

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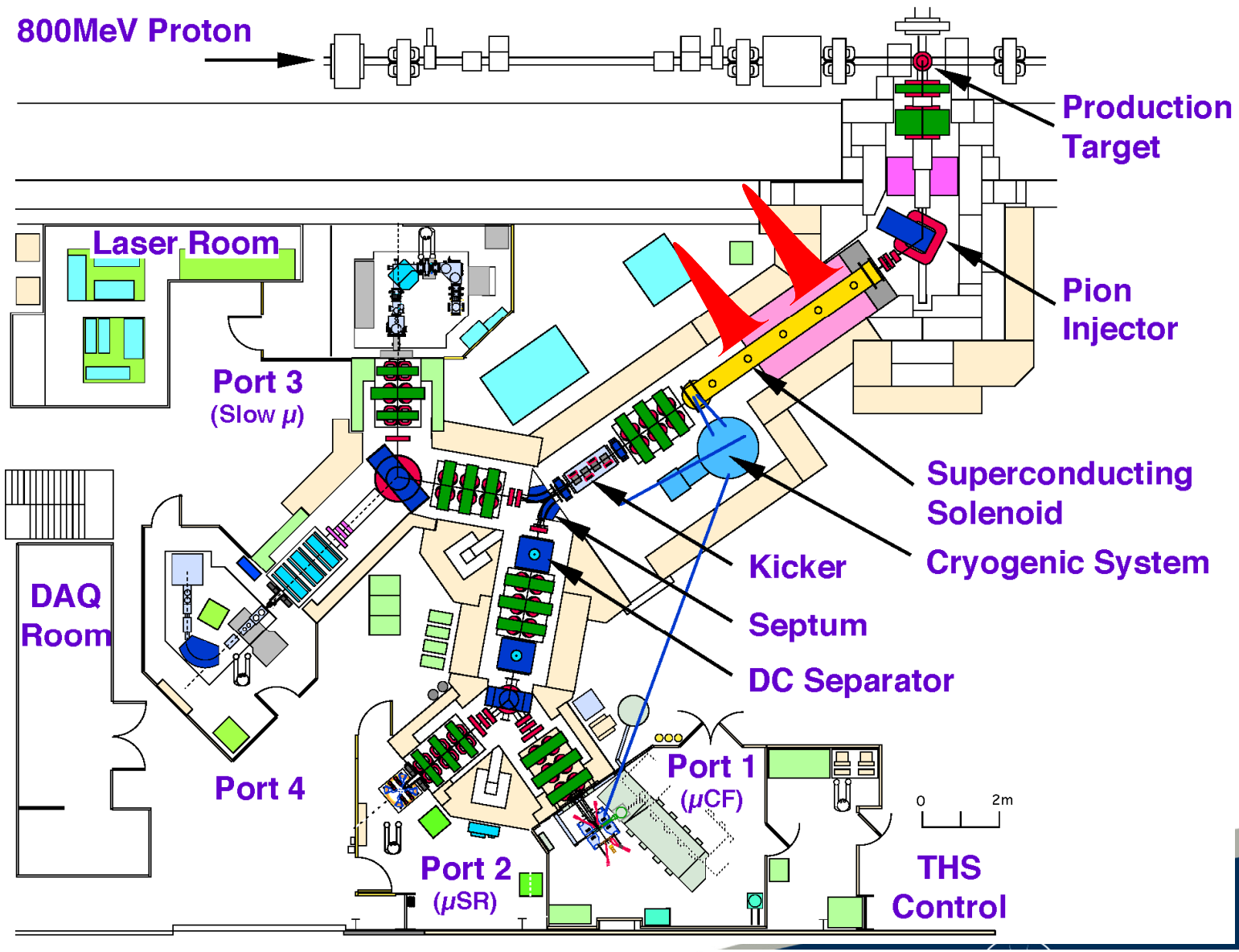

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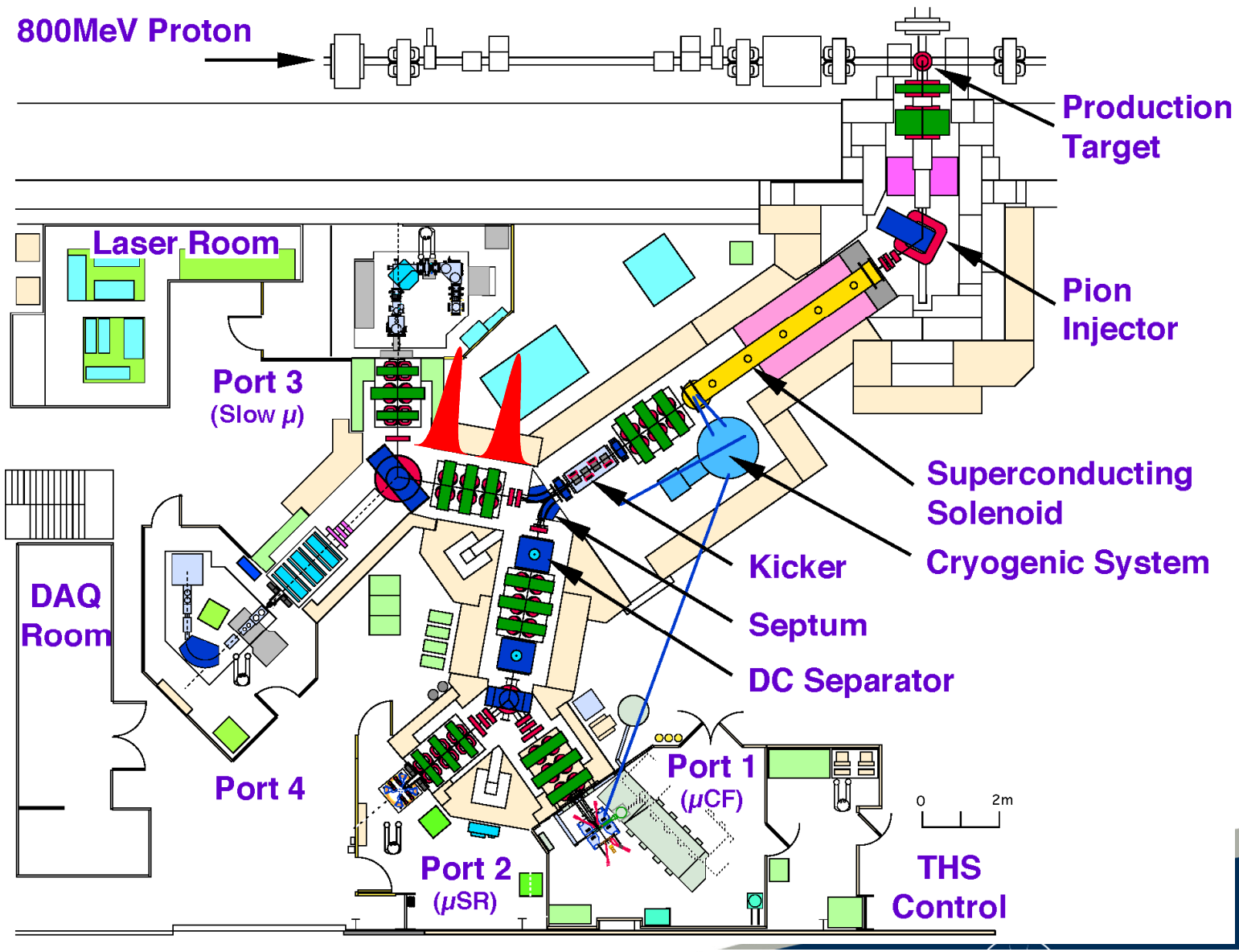

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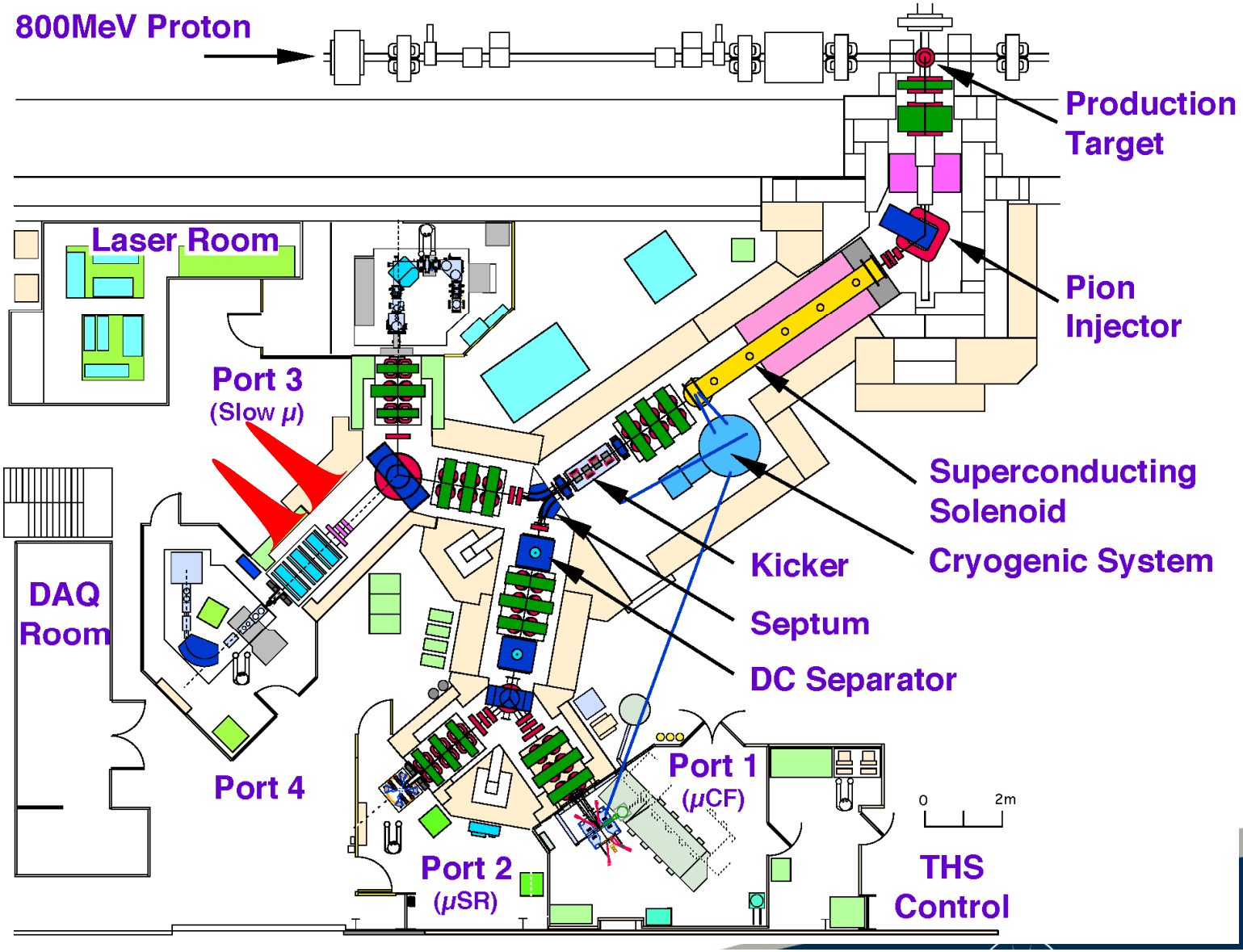

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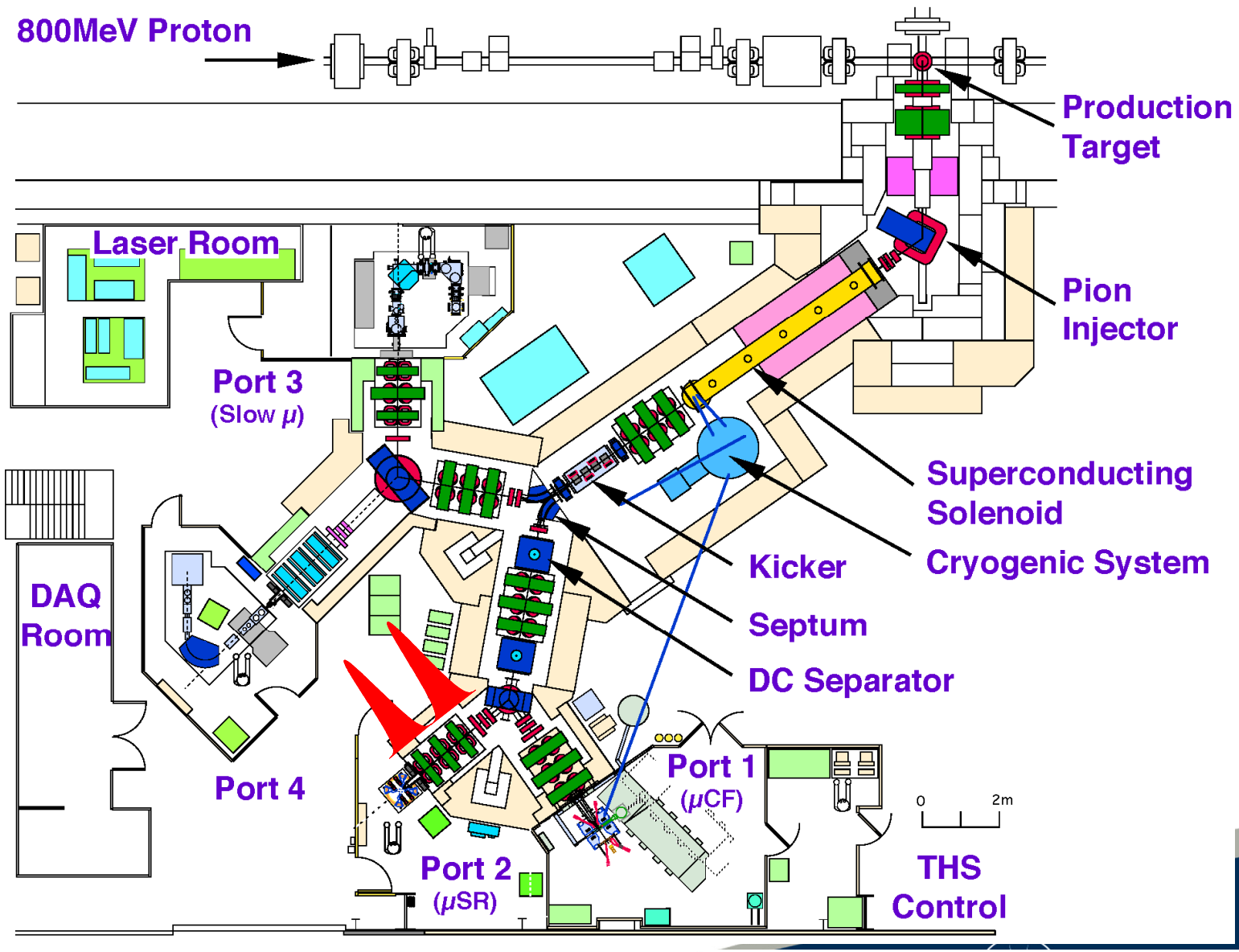

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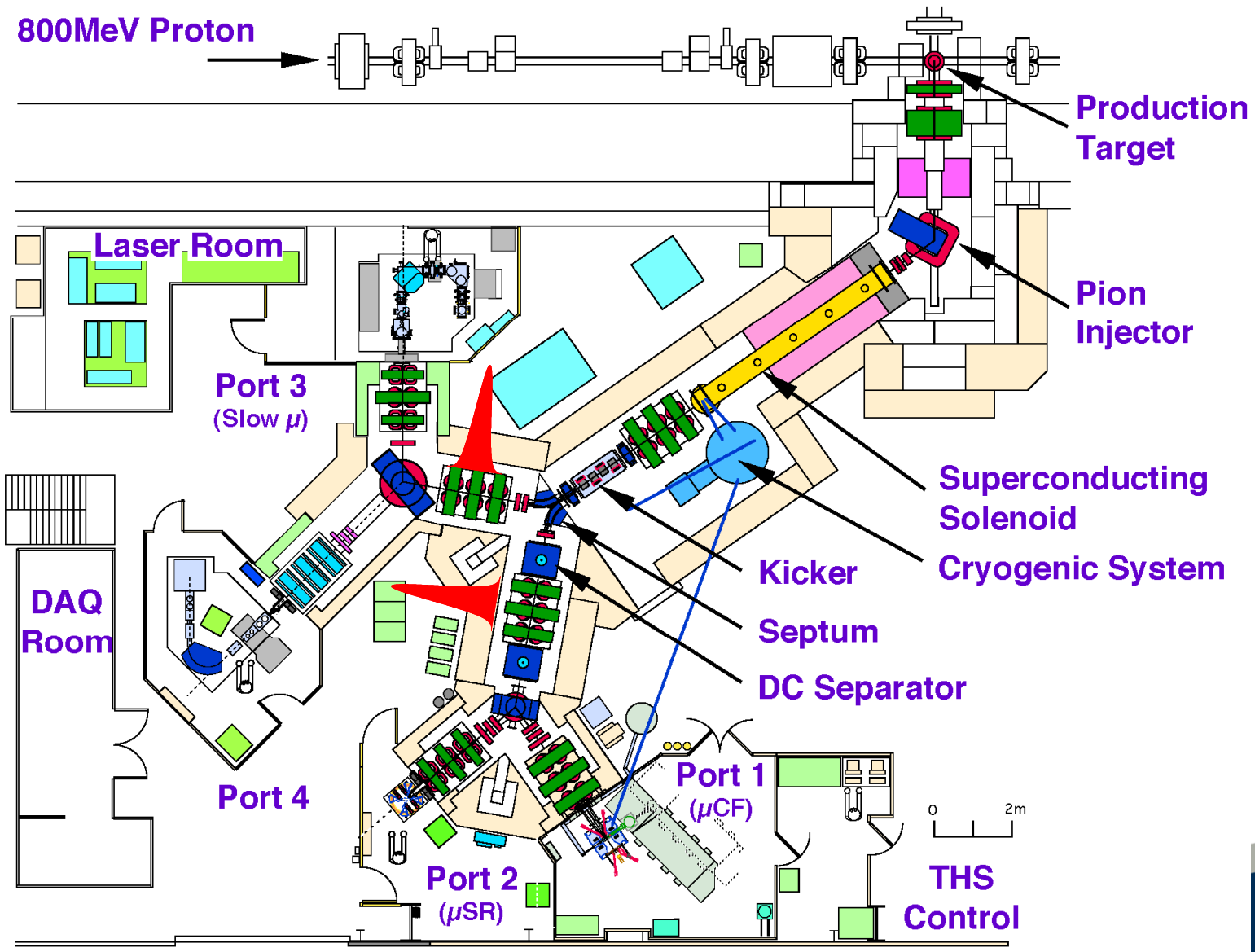

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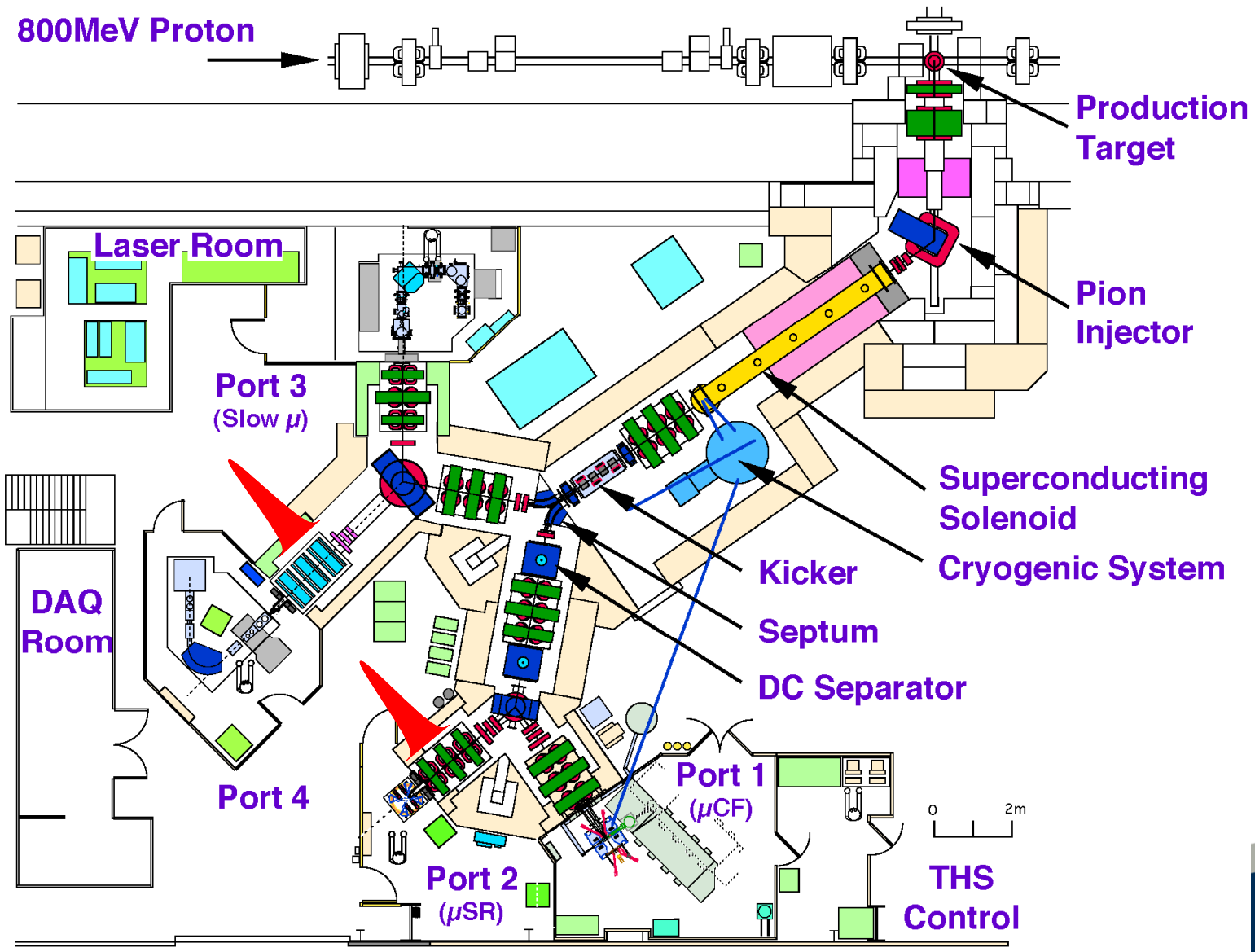

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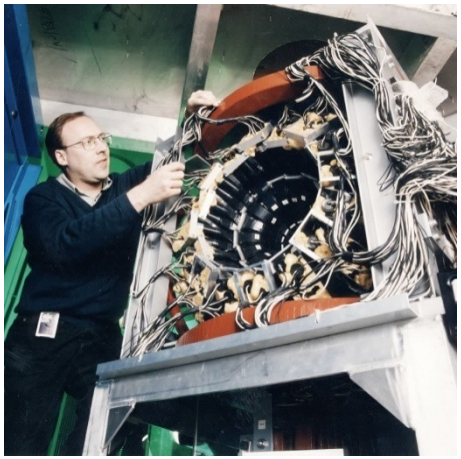
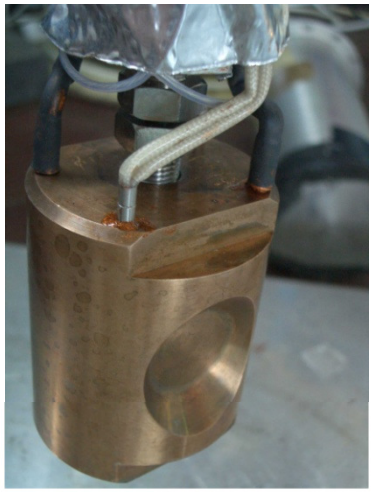
RIKEN-RAL Muon Facility

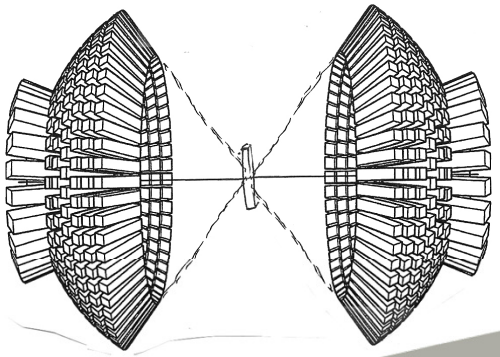
ARGUS (Port 2)





- pressure studies
- laser stimulation

New spectrometer - Chronus (Port 4)



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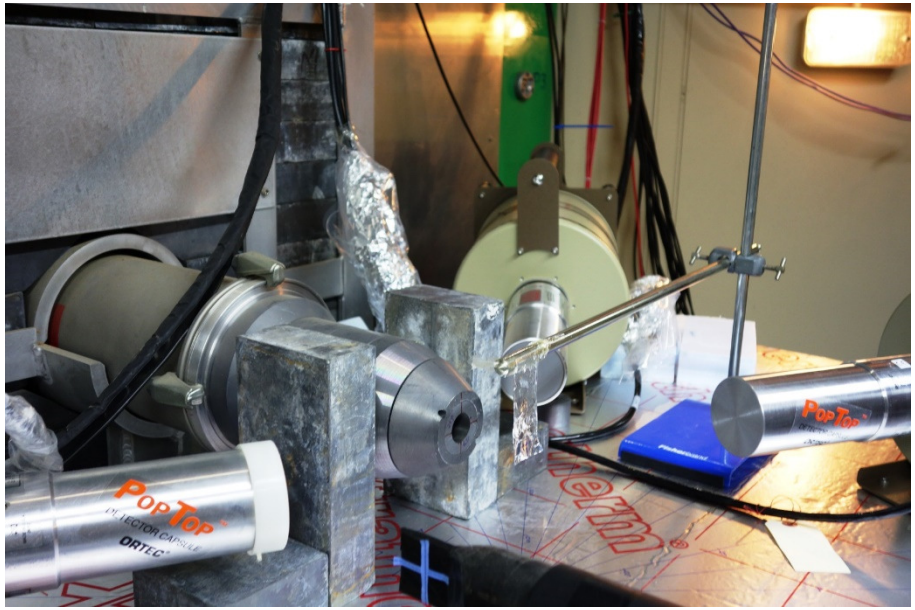
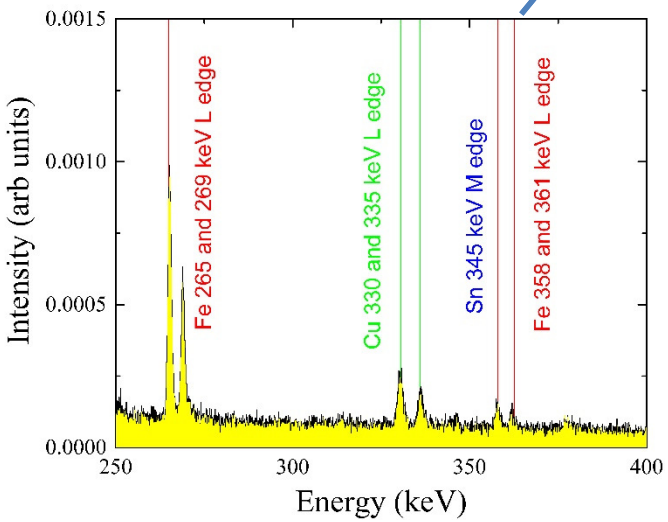
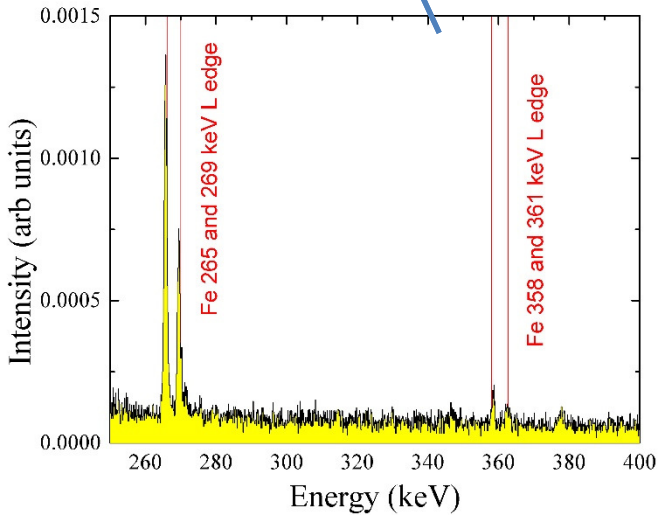
Negative muons



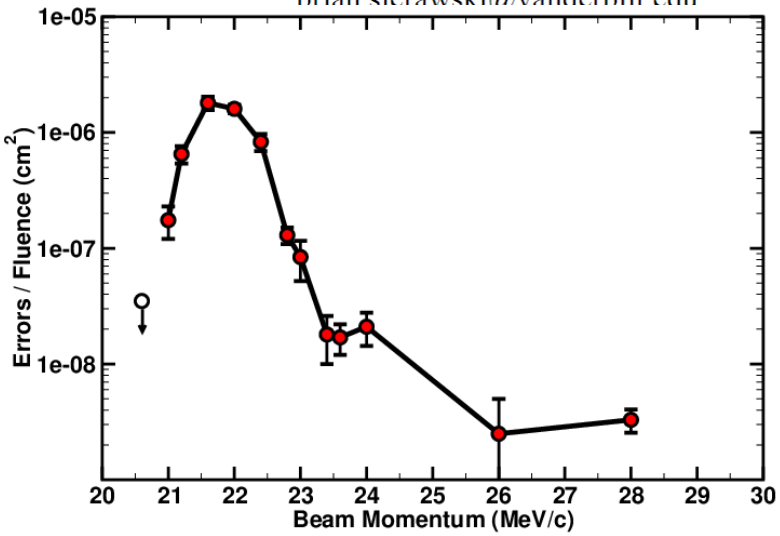




Effects of muons on electronics

Bias Dependence of Muon-Induced Single Event Upsets in 28 nm Static Random Access Memories

Brian D. Sierawski, Bharat Bhuva, Robert Reed
Institute for Space and Defense Electronics
Vanderbilt University
Nashville, TN 37212
brian.sierawski@vanderbilt.edu

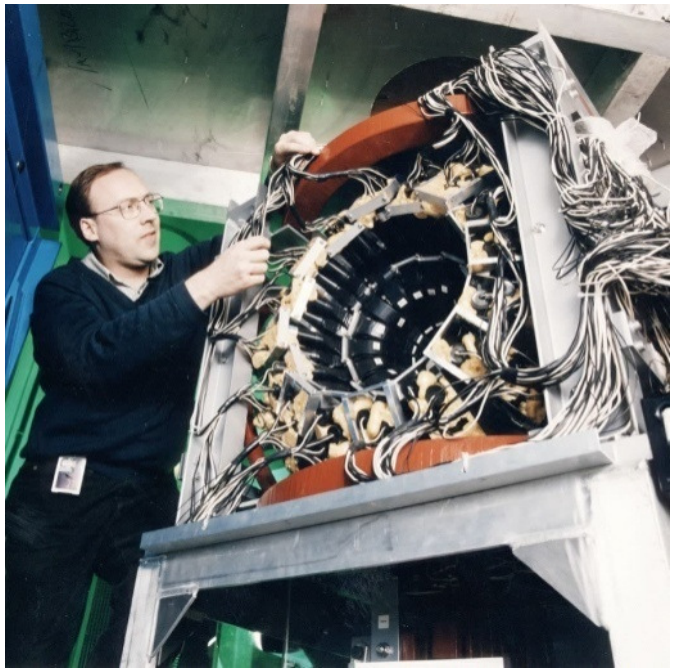


Katsuhiko Ishida
RIKEN Nishina Center, RIKEN

- Researchers at Vanderbilt University used RIKEN-RAL facility to investigate effects of muons on state-of-the-art microelectronic memories
- Collaborators from industry including Marvell Semiconductors, Cisco Systems, and Texas Instruments
- Muon-induced data errors clearly observed in multiple devices
- Results will support investigation into error rates of commercial electronics and have just been

Published in 2014 IEEE International Reliability Physics

ARGUS



0.4 T main field, longitudinal

+ 100 G transverse fields

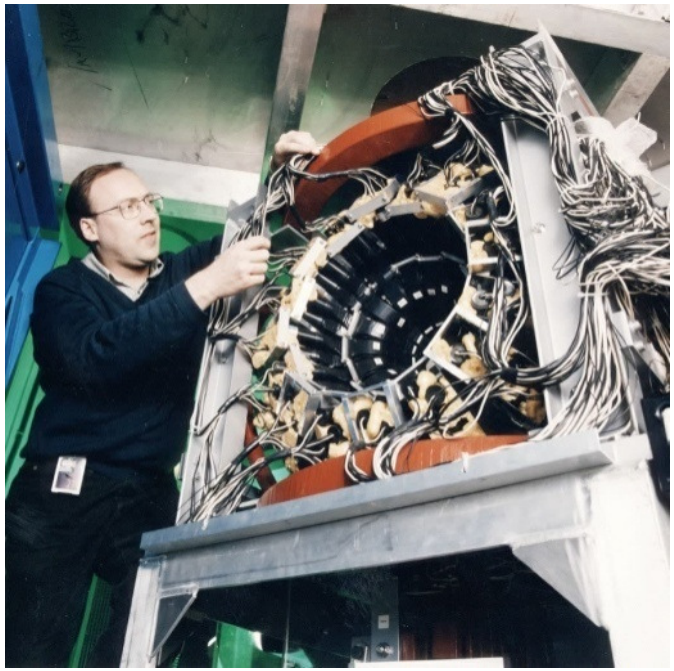
+ Stray field compensation

Data Rates (single pulse)
upto 50 Mev/hr

Temperature range of 25 mK- 600 K

Pressure Cell 0-6.4 kbar (2 – 300 K)

CHRONUS



0.4 T main field, longitudinal

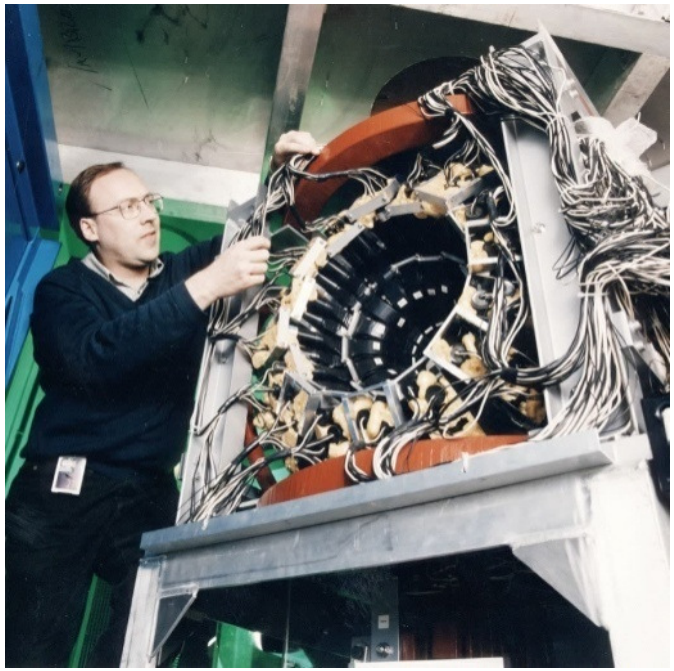
+ 100 G transverse fields

+ Stray field compensation

Data Rates (single pulse)
upto 50 Mev/hr

Temperature range of 300 mK- 600 K

CHRONUS



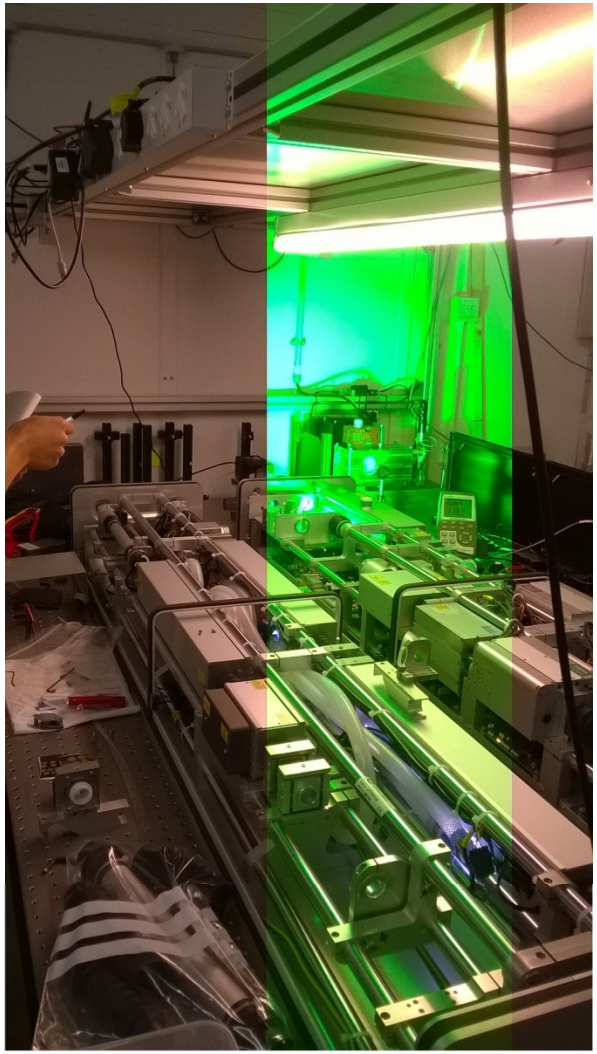
600 G main field, transverse

+ Stray field compensation

Data Rates (single pulse)
upto 50 Mev/hr

Temperature range of 300 mK- 600 K

Exciting muons



Stimulation of your sample and muons is possible

Light (HiFi)

RF techniques

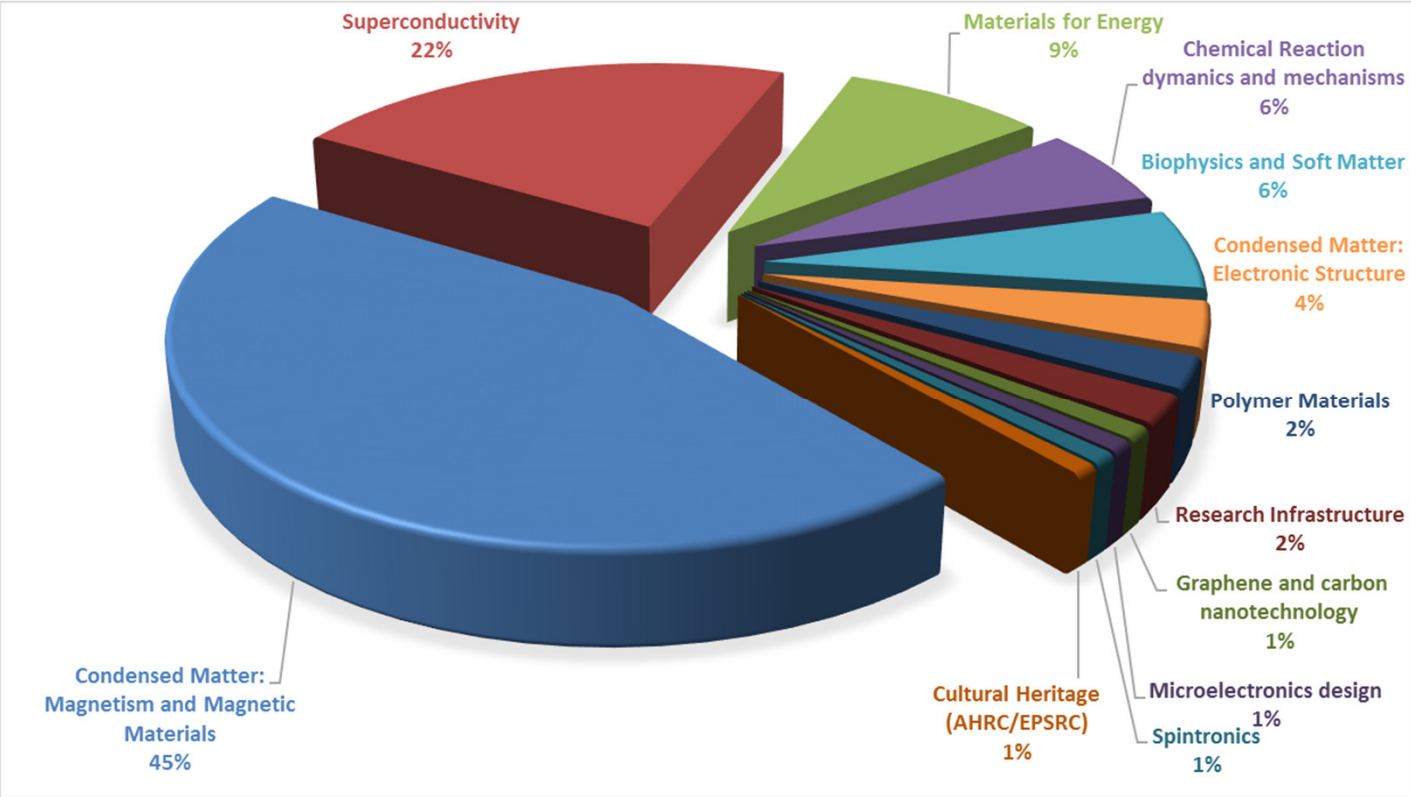
Electric field

Microwaves

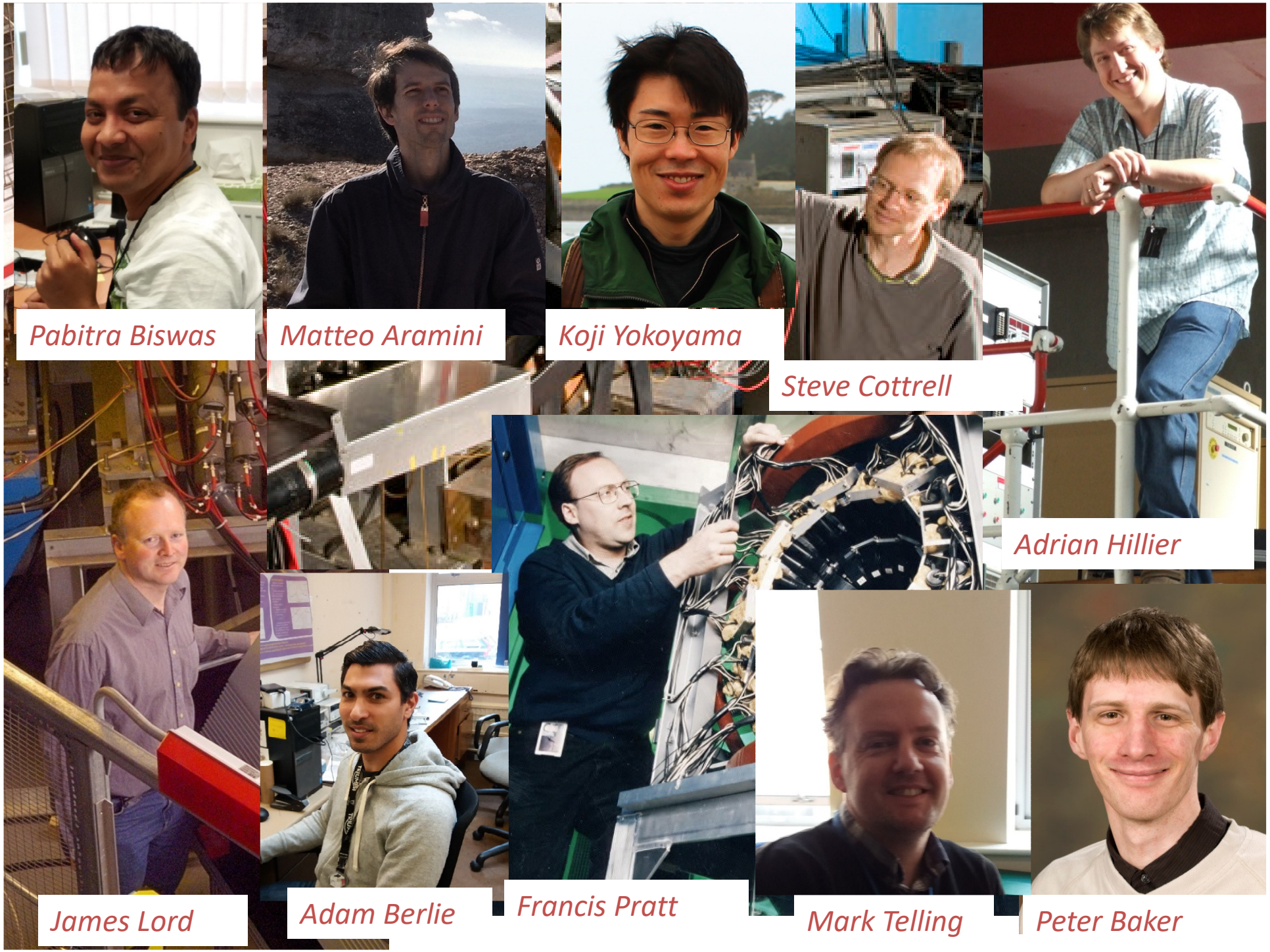
Pulsed Currents

Usage of EC ISIS Muons

Over 1000 publications many in high impact publications, such as Nature, Nature family, Science PRL.



Science & Technology Facilities Council
ISIS


Pabitra Biswas
Matteo Aramini
Koji Yokoyama
Steve Cottrell
Adrian Hillier
James Lord
Adam Berlie
Francis Pratt
Mark Telling
Peter Baker

Time	Monday 19/03/18	Tuesday 20/03/18	Wednesday 21/03/18	Thursday 22/03/18	Friday 23/03/18
08:30			Practical Session 1 and Building a Spectrometer	Practical Session 2 and Building a Spectrometer	Practical Session 3 and Building a Spectrometer
08:45	START				
09:00	Welcome and Introduction	Applications of µSR - Magnetism			
09:15	Adrian Hillier	Tom Lancaster			
09:30	Tour of ISIS		Data Analysis and Presentation writing	Data Analysis and Presentation writing	Presentation Writing
09:45		Applications of			
10:00					
10:15	G				
10:30					
10:45					
11:00	Intro				or
11:15	Step				sis
11:30					
11:45	Analyz				
12:00	Step				a
12:15					
12:30					
12:45					
13:00					
13:15					
13:30	Ap				ments
13:45	µSR - S				
14:00	Rob				
14:15	U				g
14:30	Roberto De Renzi	Spectrometer	Spectrometer	Spectrometer	Adrian Hillier
14:45					Student Presentations
15:00					
15:15					
15:30	TEA	TEA	TEA	TEA	TEA
15:45					
16:00	Data analysis workshop	Practical Session 1	Practical Session 2	Practical Session 3	Student Presentations
16:30					
17:00	Social Evening and Dinner				
18:00		DINNER	DINNER	DINNER	DINNER
19:00		Practical Session 1 and Presentation Writing	Practical Session 2 and Presentation Writing	Practical Session 3 and Presentation Writing	Farewell/ Prize Giving Adrian Hillier
	CR12, R68				
	CR16/17, R80				
	Muon area, R55				

- A 3.5 minute presentation (no more than 3.5 minutes!)
- On one of the practicals that you have done during the week
- e.g.
  - what you were studying and why
  - what measurements you made and why
  - how you analysed the data
  - what results you got

Please give us your talks by Friday coffee break