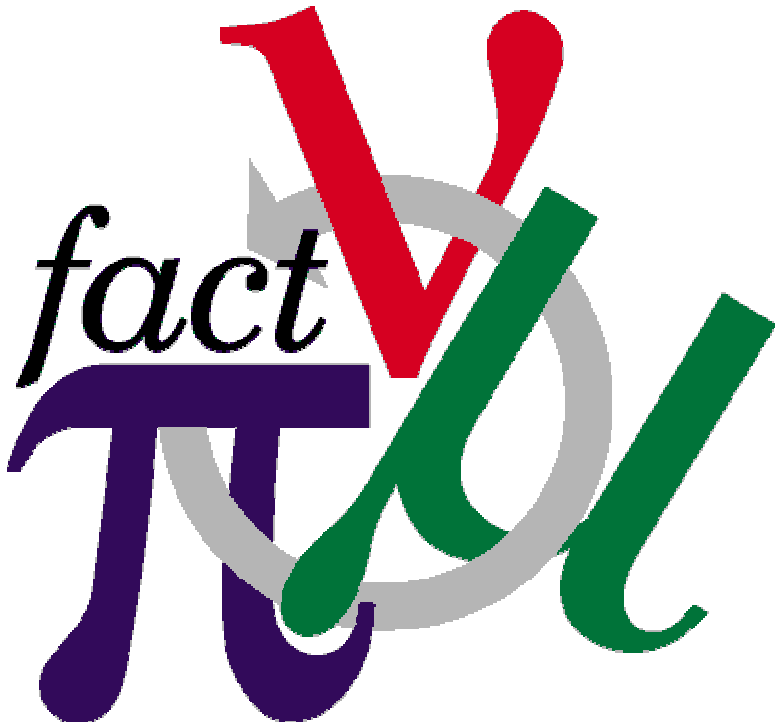
The Neutrino Factory & Synergy with Beta-beam

Rob Edgecock

CERN-AB/ABP & RAL



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Outline

- Some history vol. I
- Some history vol. II
- Neutrino Factory
- UK Neutrino Factory R&D projects:
  - Proton driver
  - Target
  - Cooling
  - Acceleration
- World Design Study
- Conclusions

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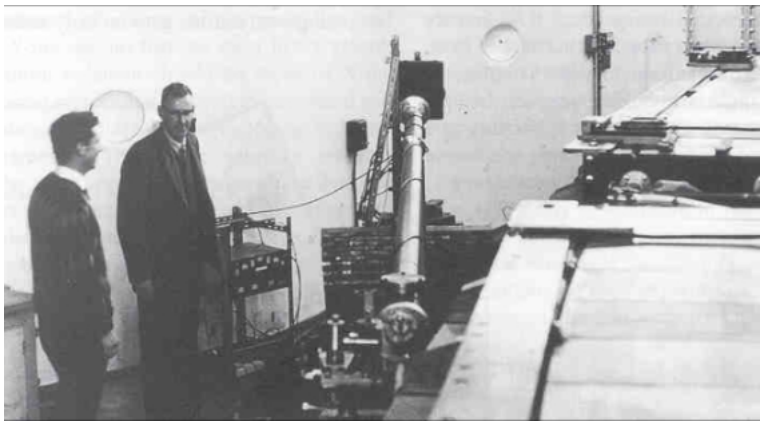
History Vol. II

- UK has a distinguished record in the design and construction of accelerators
- However, domestic machines closed in 1970s:

NINA - 5 GeV electron synchrotron



Closed: 1st April 1977

NIMROD - 7 GeV proton synchrotron

Closed: 6th June 1978

- Expertise ⇒ other areas - SRS, ISIS - countries

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History Vol. II

- 1999: restart accelerator R&D for PP
  - Most PP projects require *accelerators* and *detectors*
  - Can't assume that CERN will always provide former
  - Provide equipment rather than cash
  - Simulate UK industry involvement in accelerator construction
  - Possibility of large accelerator PP project in the UK
- Since then, much progress, particularly for NF
- Involved/leading most R&D in Europe

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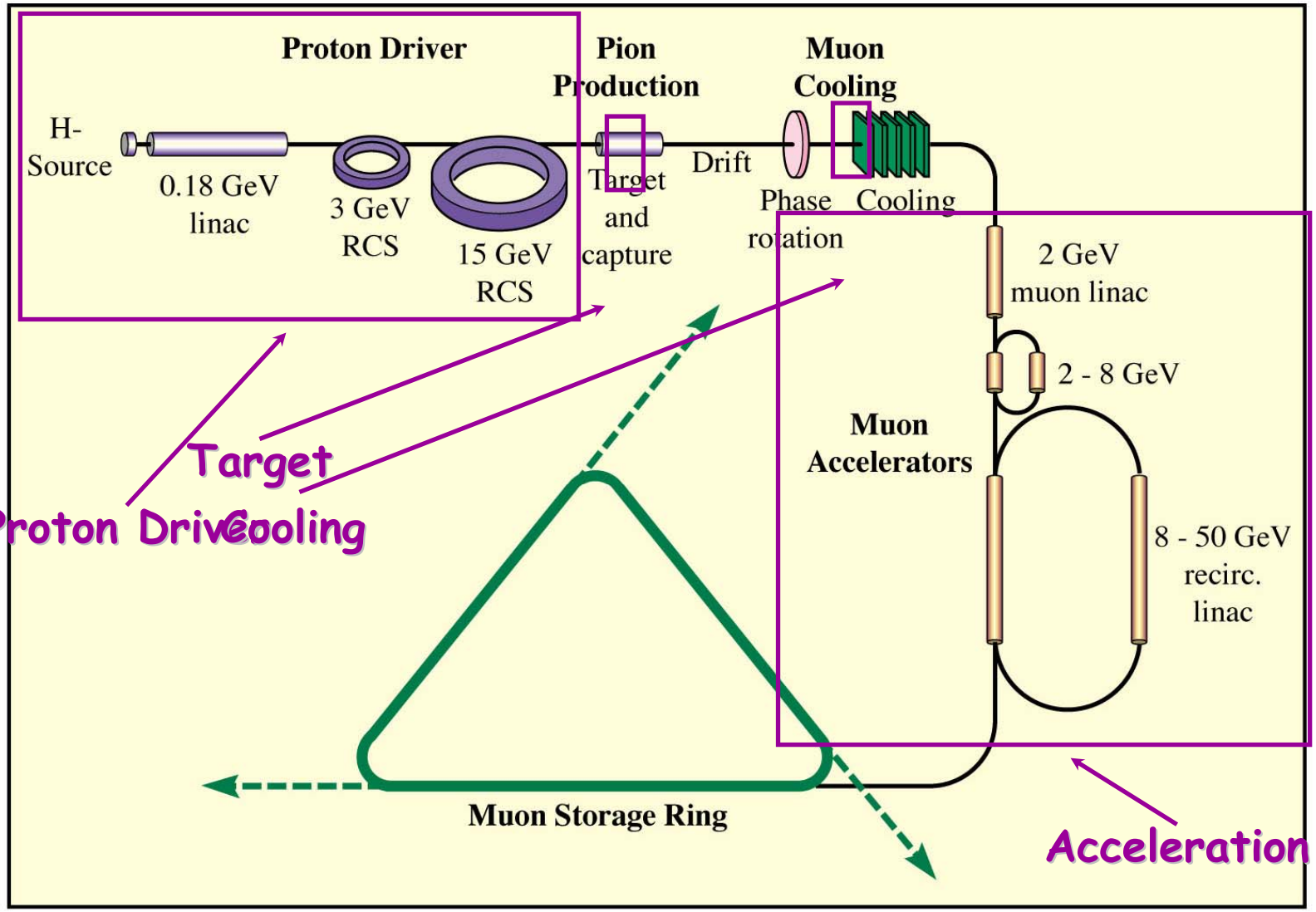
Neutrino Factory: R&D Required



Neutrino Factory at RAL

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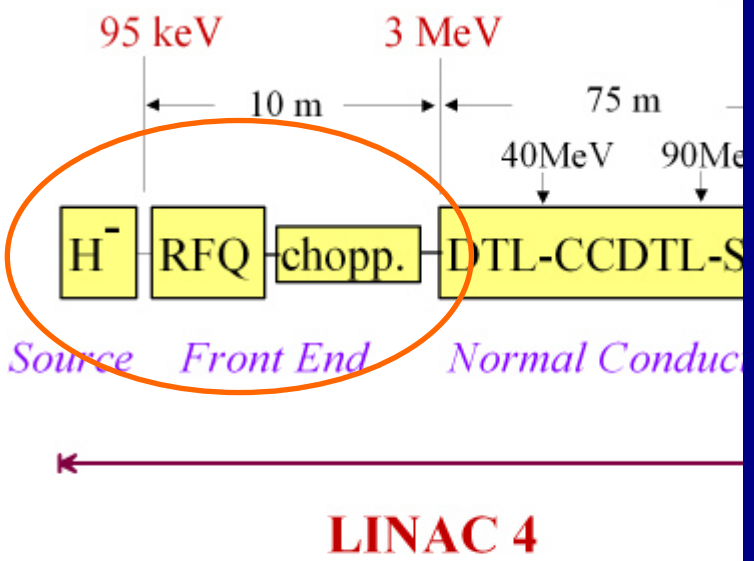
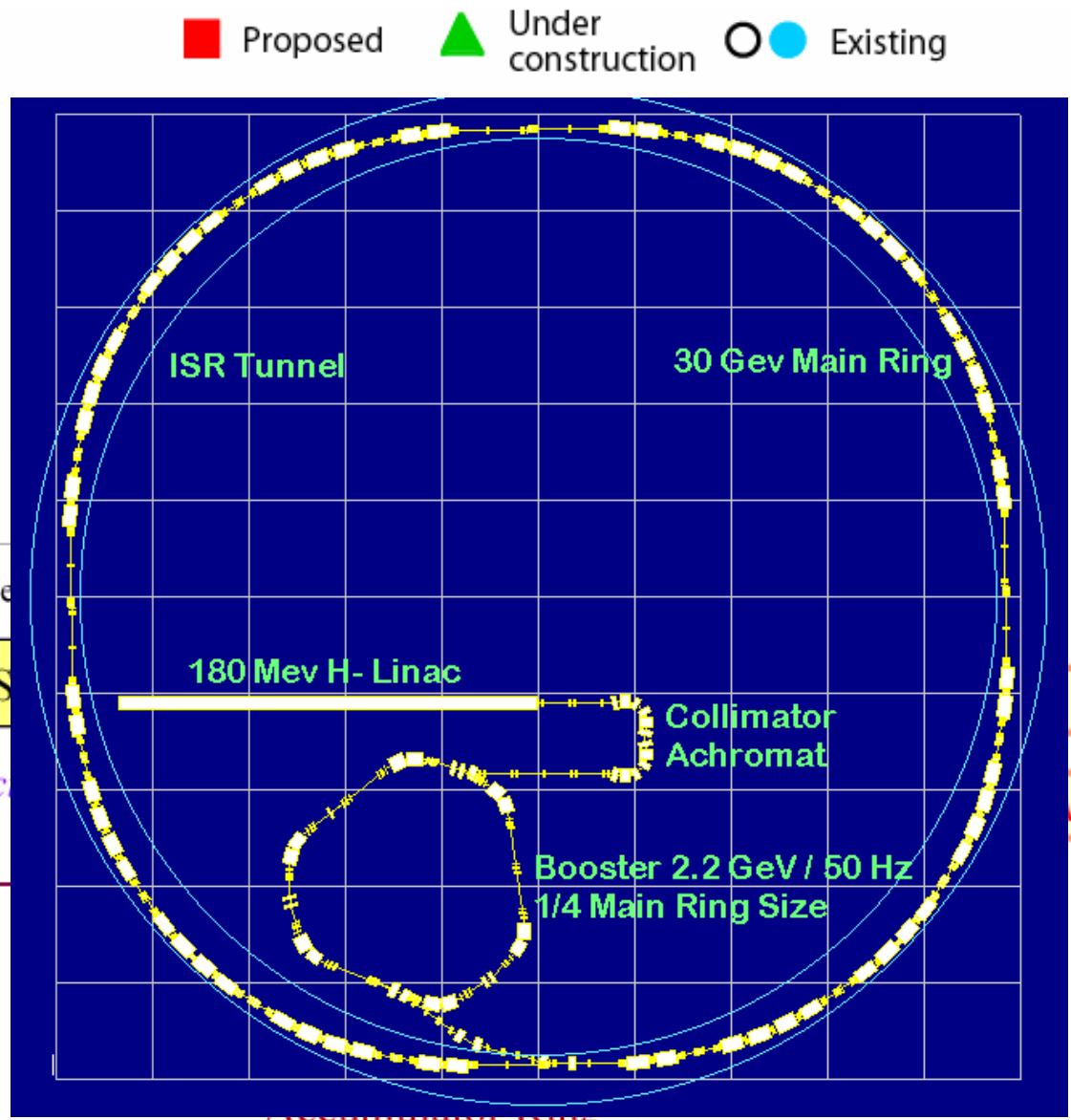
Proton Driver

- Main requirements:
  - 4 MW beam power
  - 50Hz
  - 1 ns bunch length





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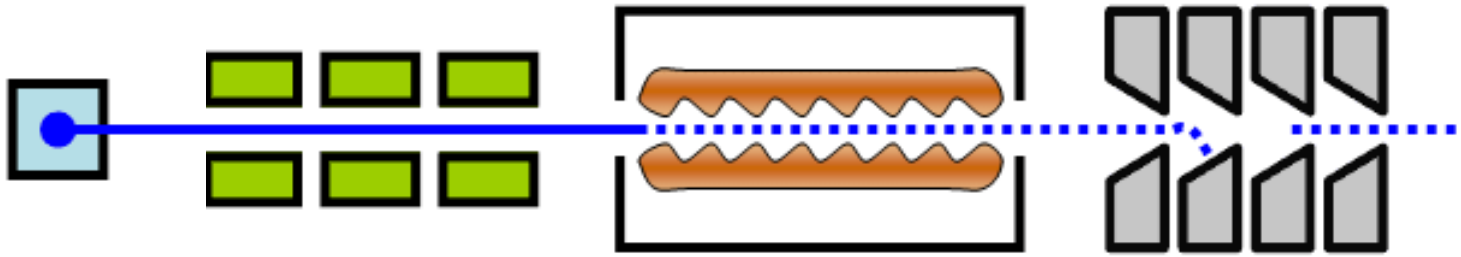
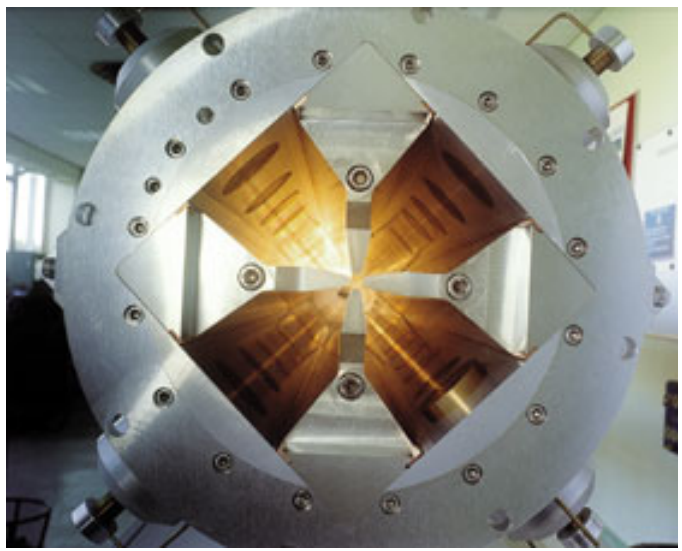
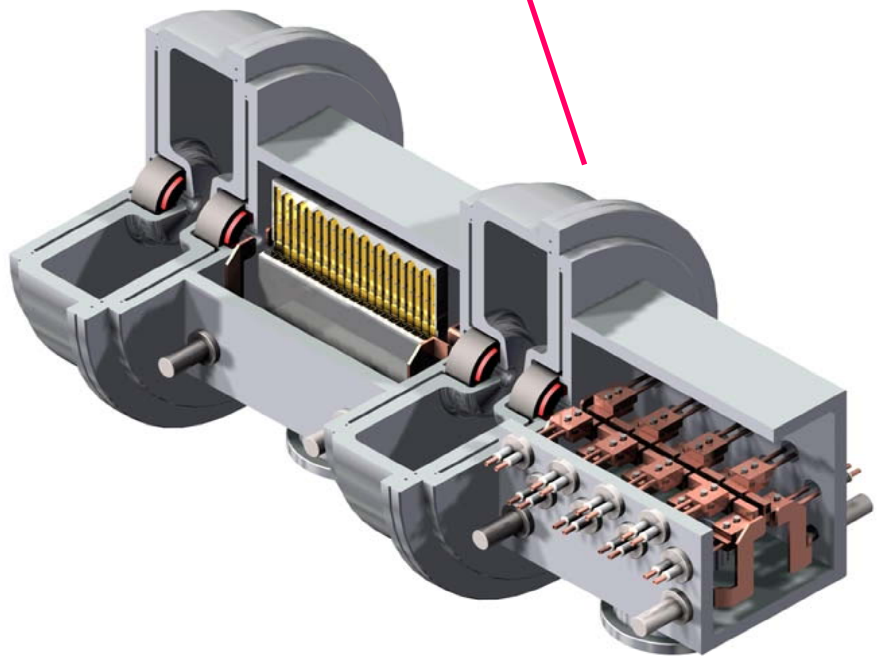
Proton Driver

Two test stands under construction:

- CERN mainly for Neutrino Factory
- RAL mainly for ISIS upgrade, but generic







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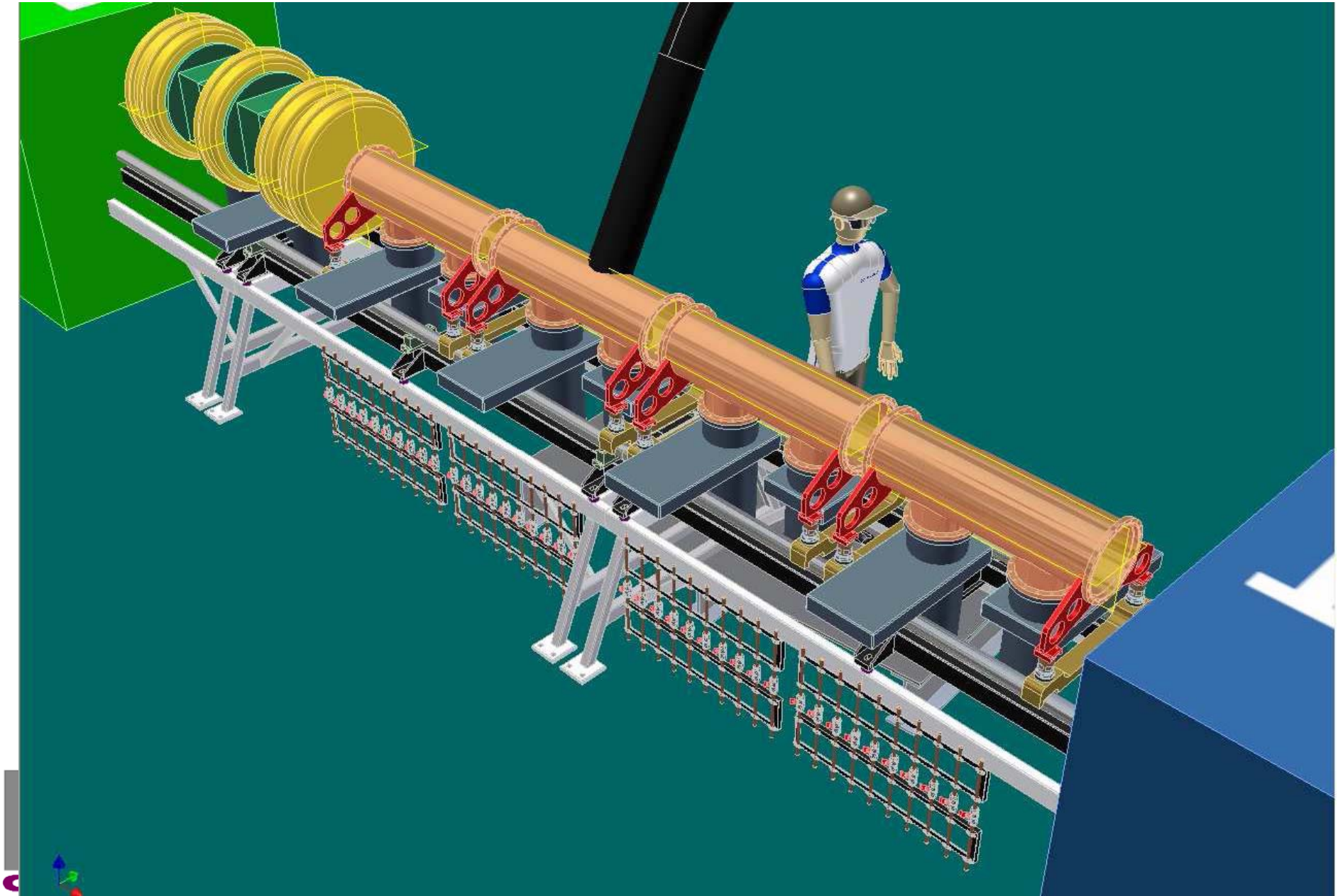
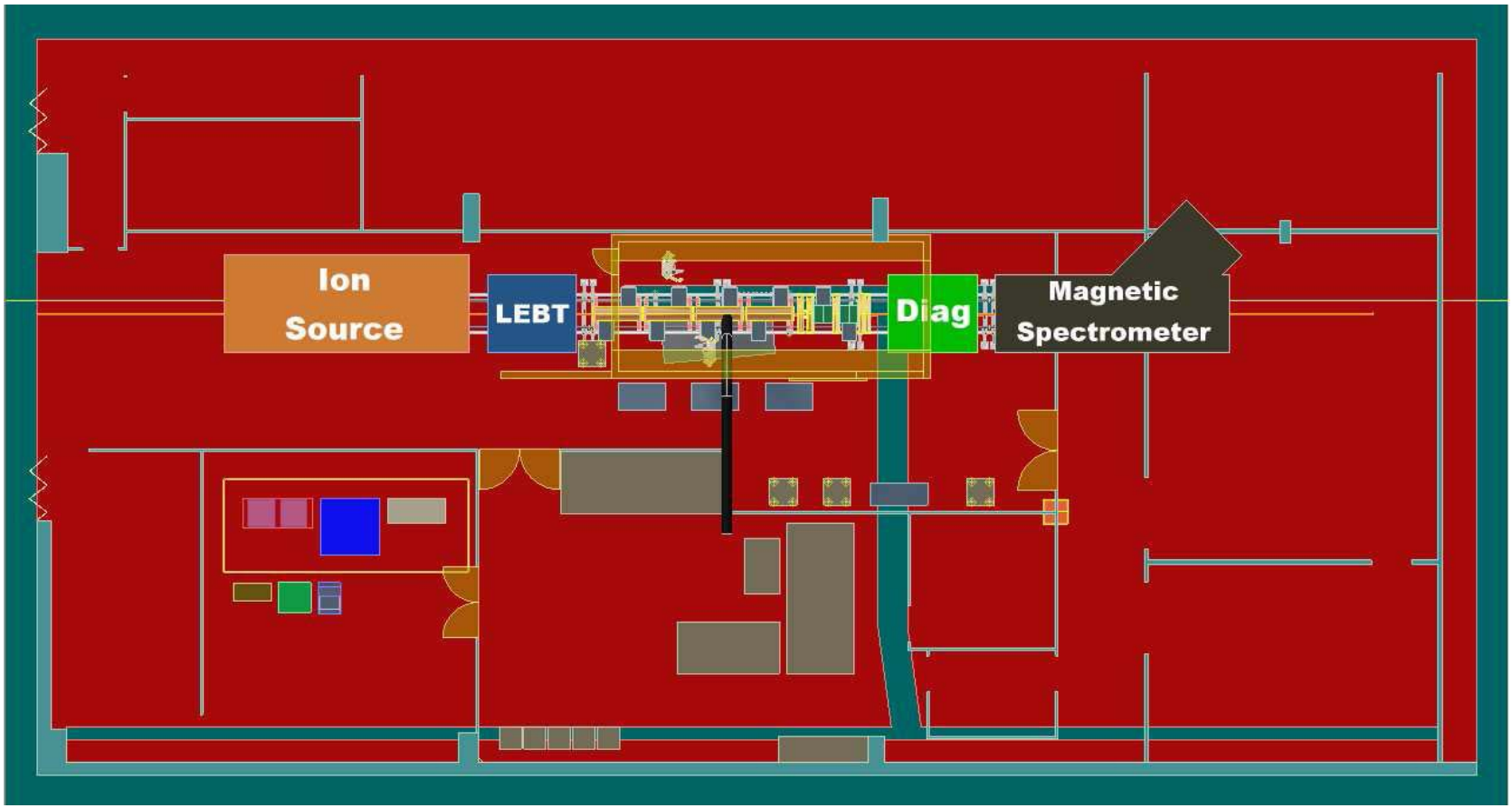
RAL Test Stand



RAL Test Stand

Test Stand in R8



Aim: “4MW” operation before 2009

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Target

4 MW beam → 1 MW dumped in target → 20 kW/cm^3

⇒ Sudden temperature rise

⇒ “Shock”

⇒ Activation

No proven target technology

In fact, no target technology above 1MW

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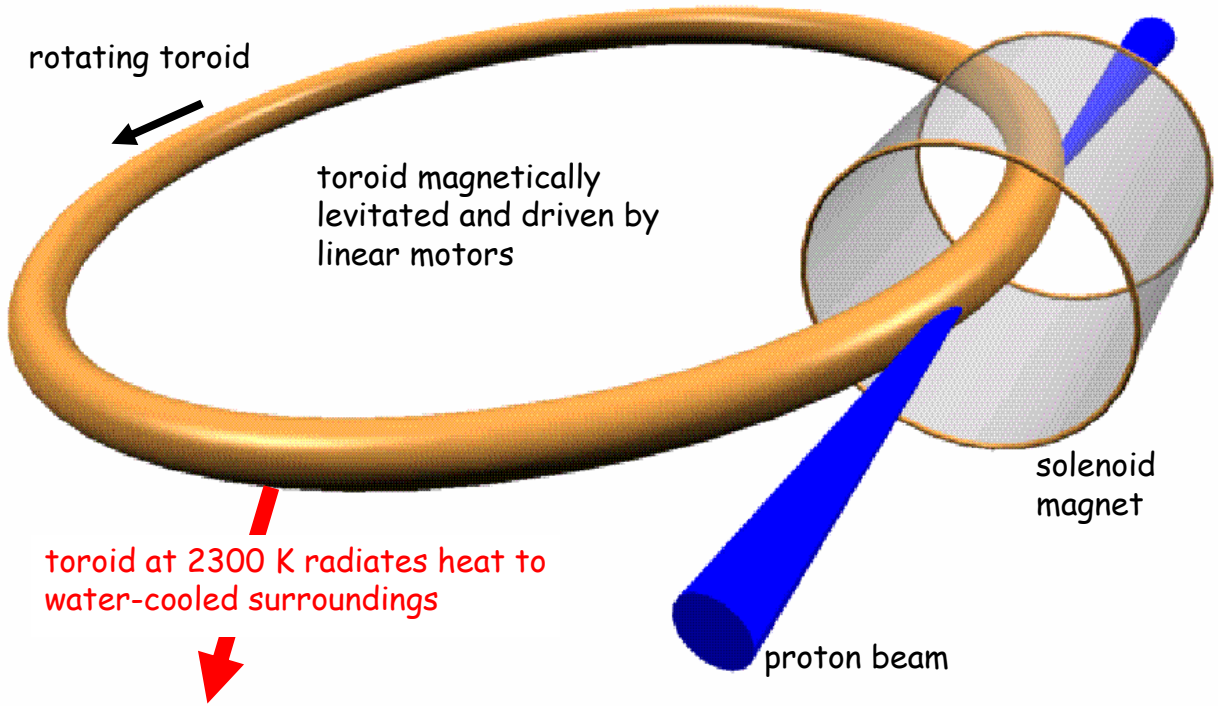
Solid Target R&D

- Mainly focussing on target feasibility
- Shock and lifetime studies of tantalum planned



Main problem: *SHOCK!*

→ yield strength exceeded by single pulse

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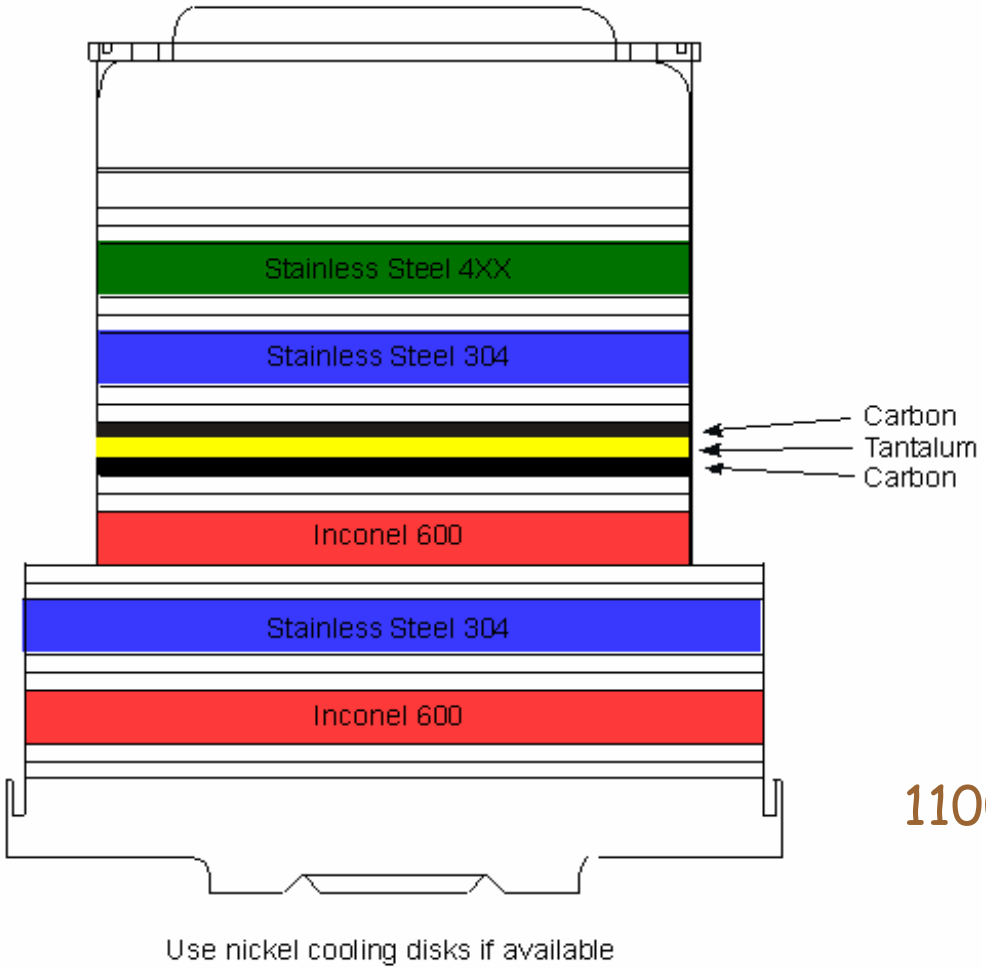
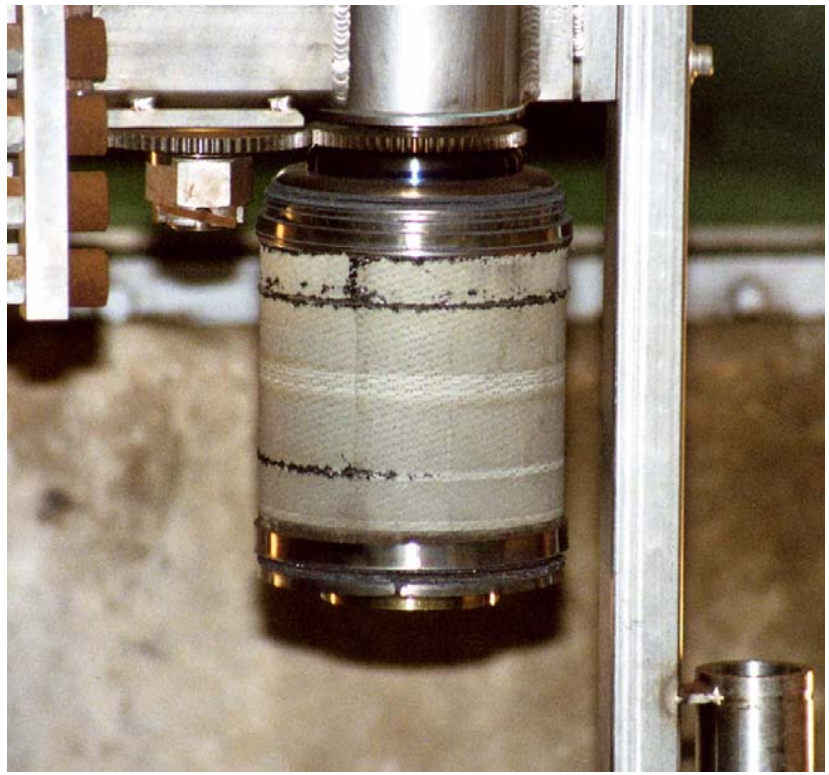
Solid Target R&D

- Tests at ISOLDE, FNAL pbar, etc: does not happen





1100 pulses at 30000 J/cm^3
⇒ no damage!

Solid Target R&D

Two experiments planned:

- Pulsed heating with large current
  - current ~8kA
  - voltage ~40kV
  - rise time ~30ns
  - wire diameter 0.4mm
  - 50 or 100Hz

  $\Rightarrow$ lifetime test!
- Proton beam at ISOLDE, LANL, etc
  - measure effect of 0.1k, 1k, 10k, 100k pulses
  - determine effect of real proton beam
- Measurements made with a VISAR
  - laser based interferometer
  - high resolution measurement of surface velocity
  - interpretation of what is happening inside

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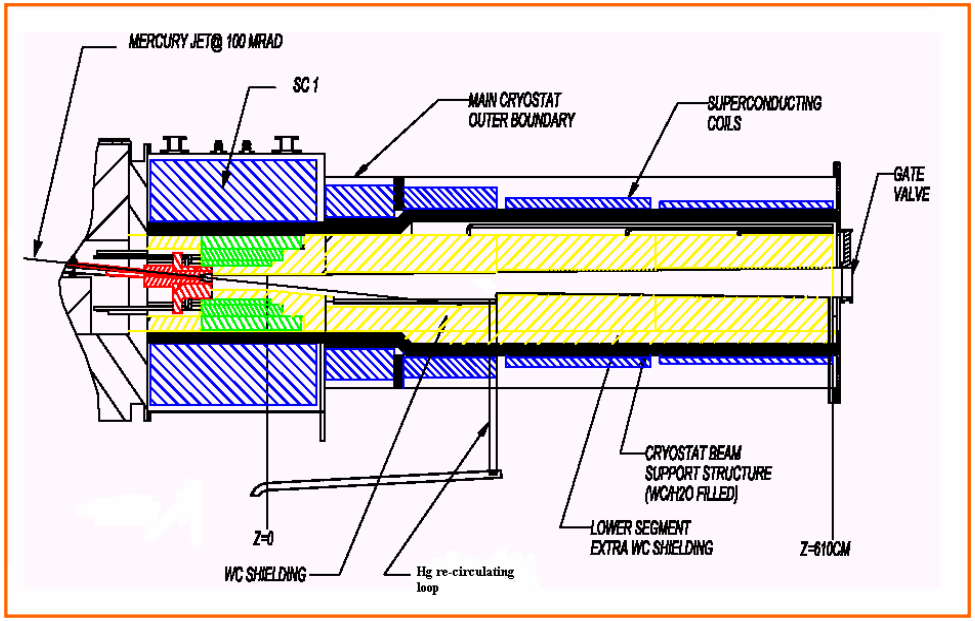
Liquid Target R&D

Baseline target technology for NF: liquid mercury jet

- jet carries away heat
- each pulse independent

However must study:



- Near proto-type configuration
- Jet entry into magnetic field and effect of field
- Jet dispersal by proton impact
- Duration of effects
- Longitudinal effects

⇒ Aims of the TT2A experiment

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Liquid Target R&D

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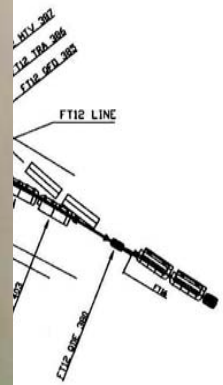

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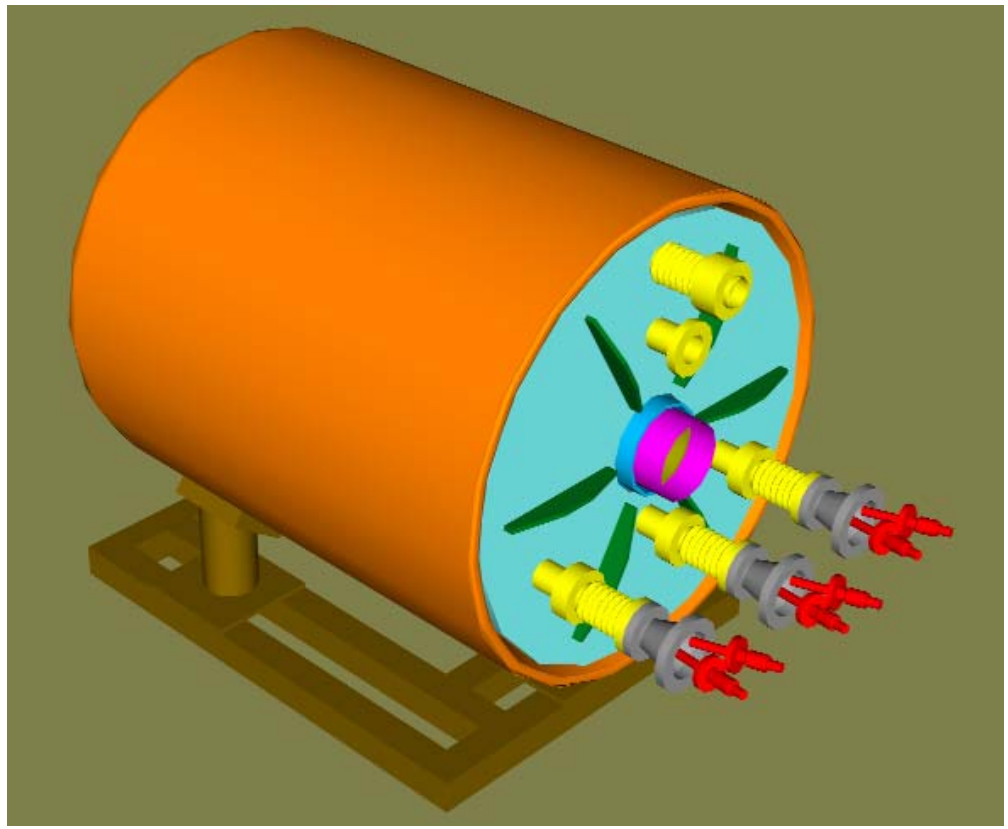
Liquid Target R&D

- 15T magnet being built
- Cooled with LN2
- Pulsed every 30mins
- 24GeV PS beam used
- Correct energy density
- Optical diagnostics
- 60 photos with beam
- 1-2k total
- Two weeks running
- Proposal for UK participation last Friday



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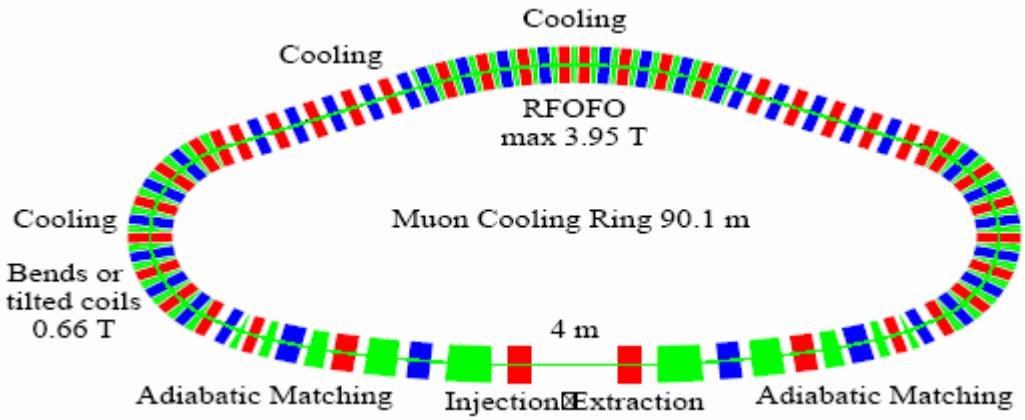
Muon Cooling

- Cooling ⇒ needs to be fast (muon lifetime)
- Existing techniques can't be used ⇒ ionisation cooling



- Cooling is delicate balance:

$$\frac{d\varepsilon_{\perp,\mathrm{N}}}{dz} = -\frac{\varepsilon_{\mathrm{N}}}{\beta^2 E}\frac{dE}{dz} + \frac{\beta_\chi (13.6\mathrm{MeV/c})^2}{2\beta^3 E m_\mu L_R}$$

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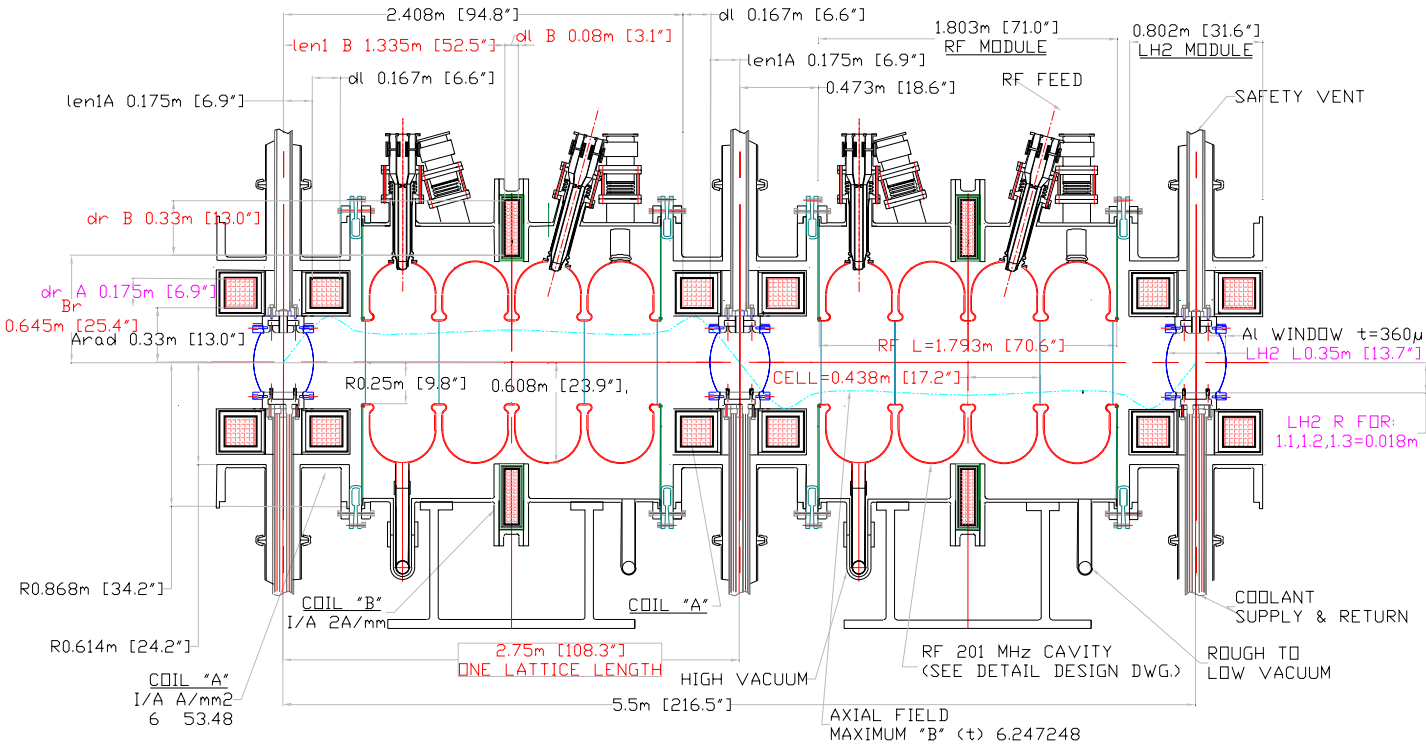
Transverse Cooling

- Cooling cells are complex



- R&D essential: MuCool, MuScat and MICE

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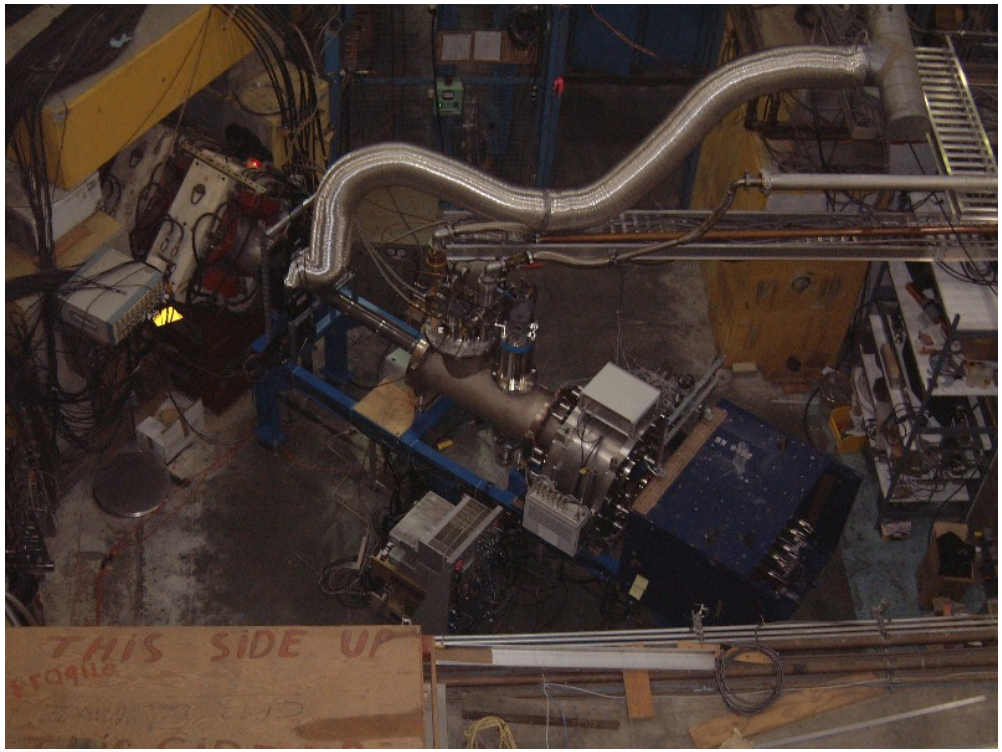
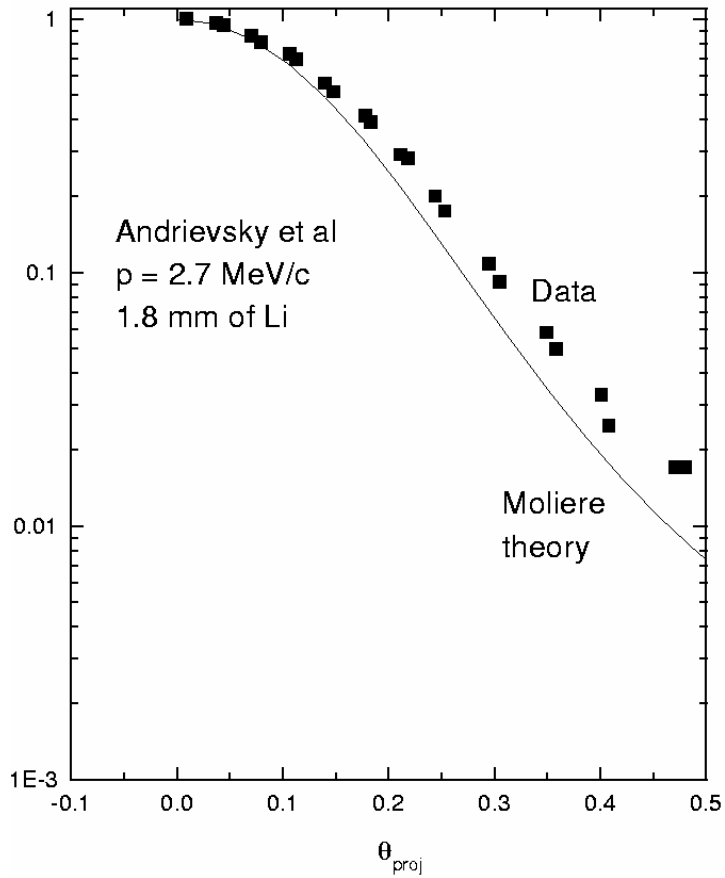
MuScat

- Measurement of muon multiple scattering:
  only relevant data – e^- scattering, Russia, 1942
- Input for cooling simulations and MICE
- First (technical) run at TRIUMF summer 2000, M11 beam





- Run2: April-May 2003
- Data being analysed

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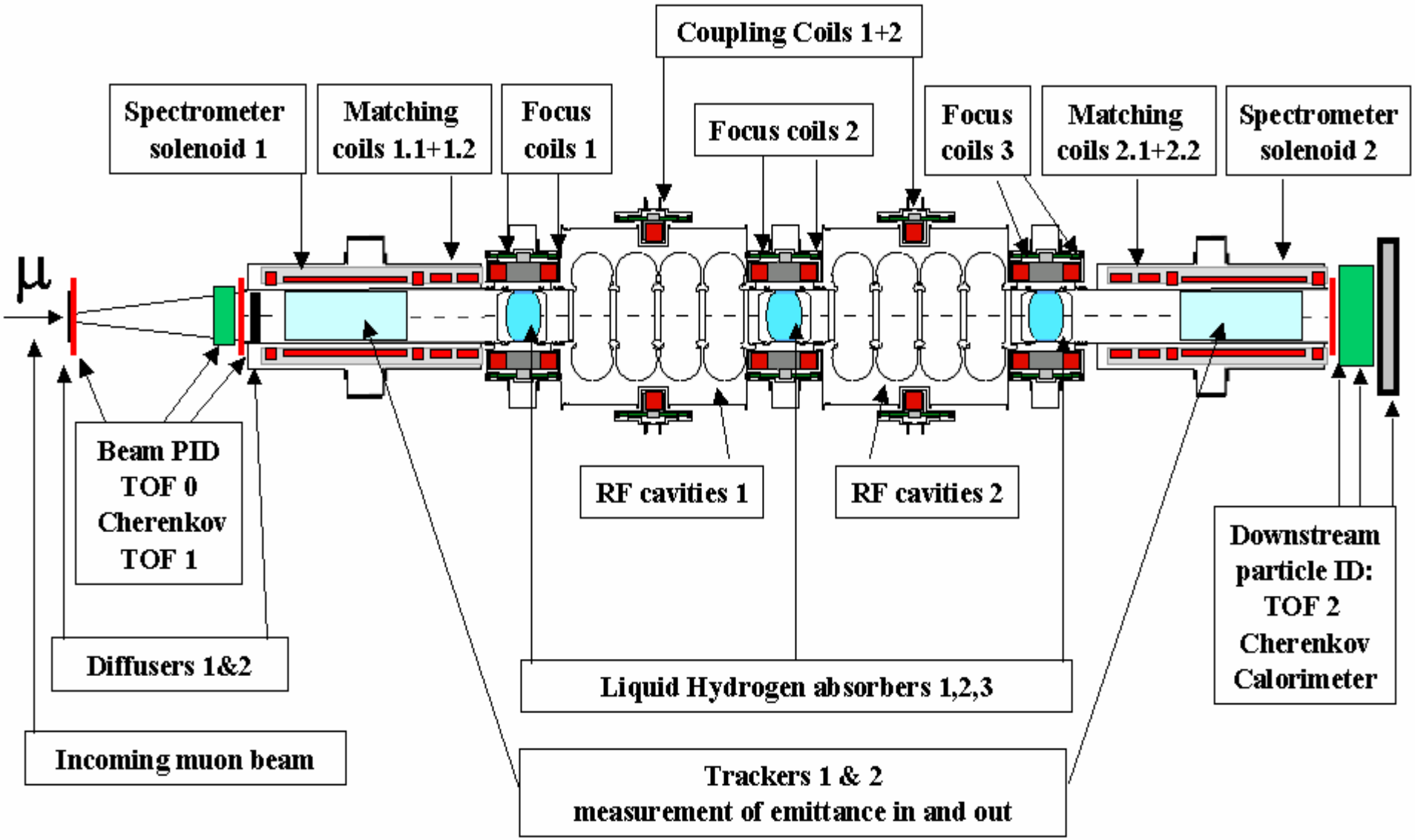
MICE

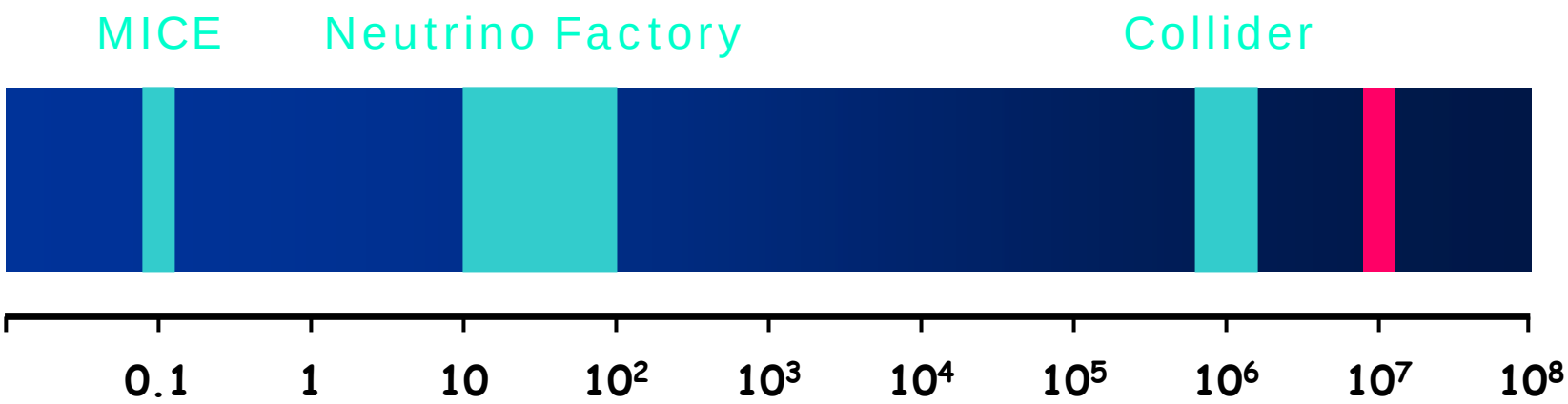
Muon Ionisation Cooling Experiment



MICE

- Biggest Neutrino Factory R&D project
- Collaboration of 40 institutes from Europe, US and Japan
- Selected HEP test beam hall at RAL as location!
- First time for the UK
- Major UK responsibilities for:
  - beam line and infrastructure
  - tracking detectors
  - cooling cell
- Progress in all areas
- First beam ~2006
- But funding difficulties
- Good news recently!

Cooling for a Muon Collider



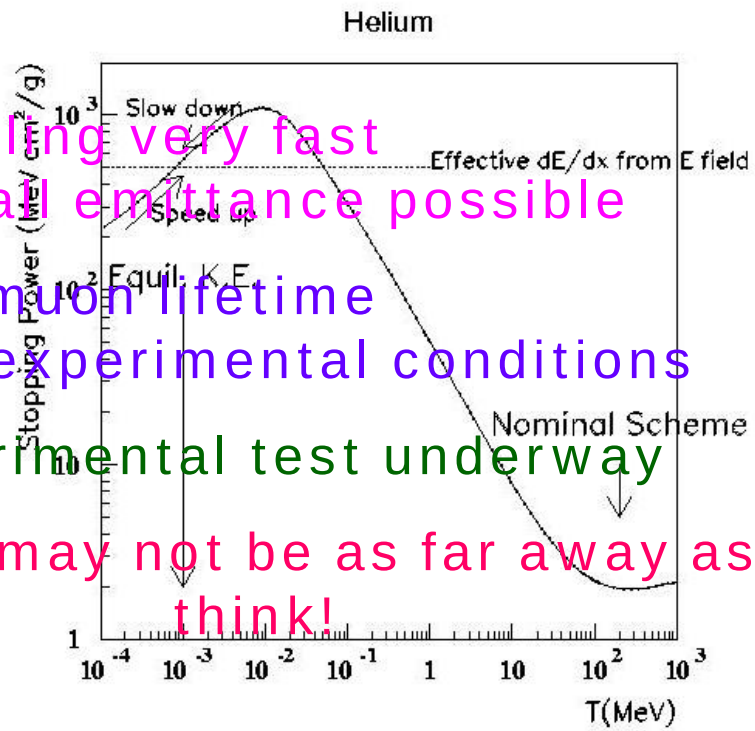
Frictional cooling:

Advantages: cooling very fast
small emittance possible

Disadvantages: muon lifetime
experimental conditions

Experimental test underway

Muon Collider may not be as far away as some think!



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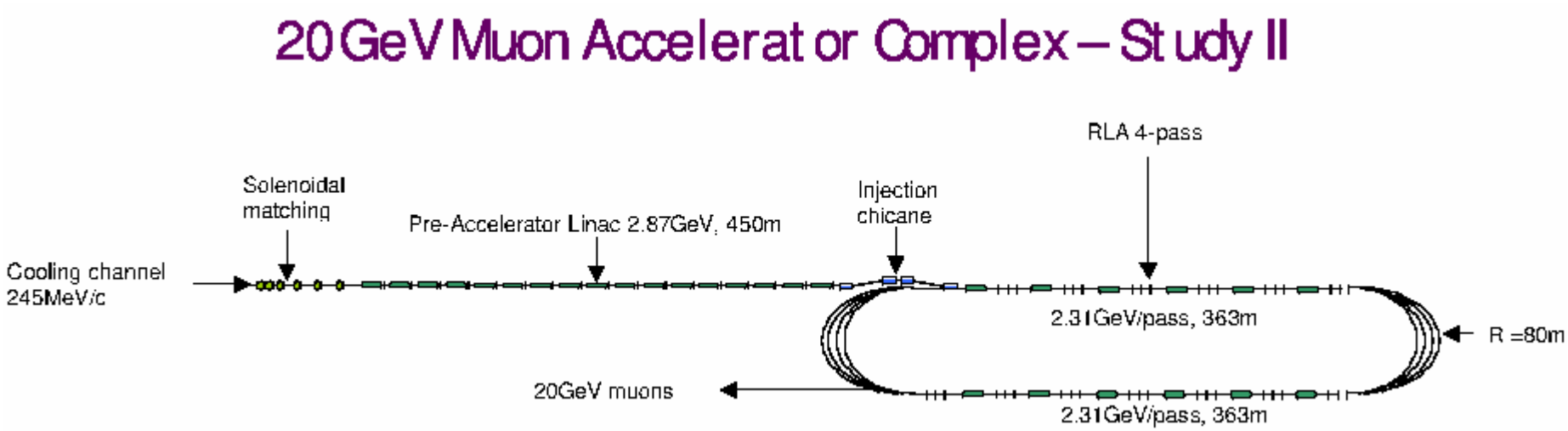
Muon Acceleration

- Needs to be fast – muon lifetime
- Needs to be a reasonable cost – not linacs all the way
- Baseline: Recirculating Linear Accelerators



- Other possibilities.....FFAGs

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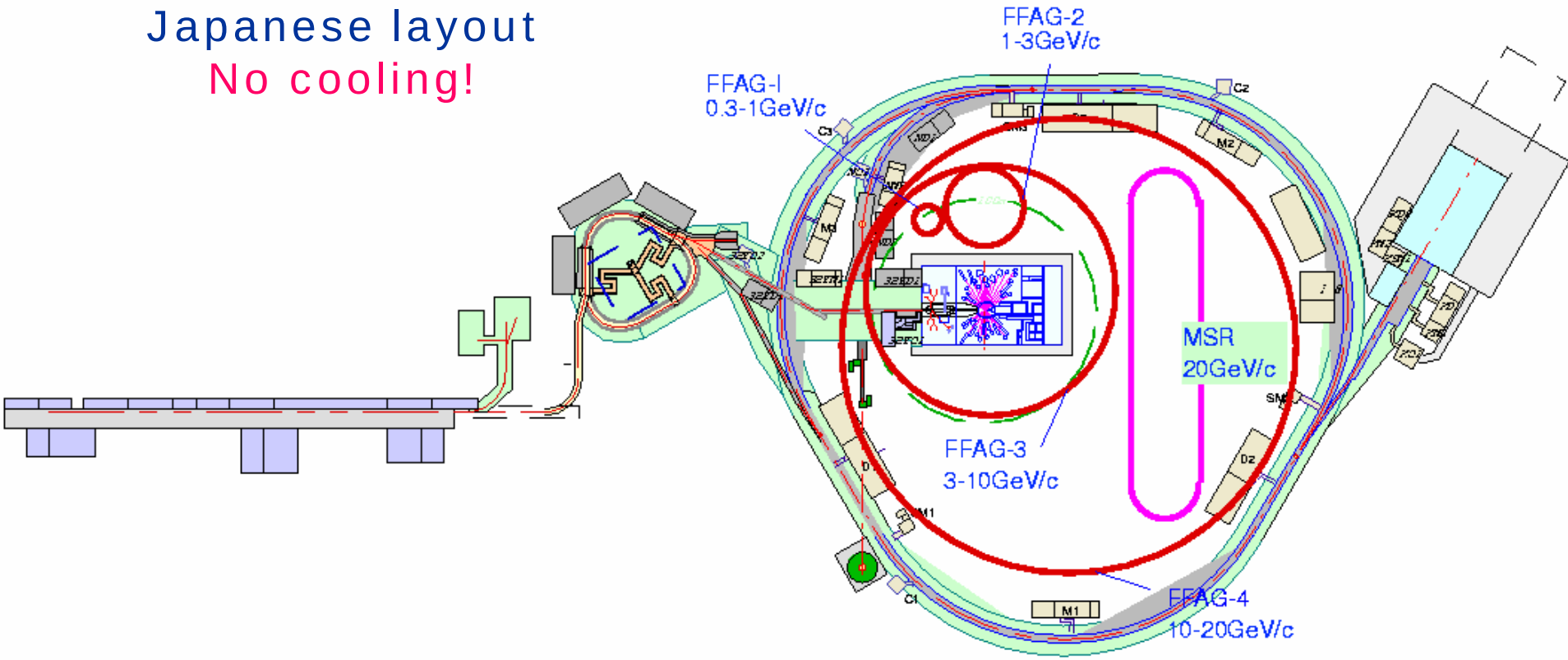
Layouts with FFAGs

FFAG based neutrino factory

Japanese layout

No cooling!



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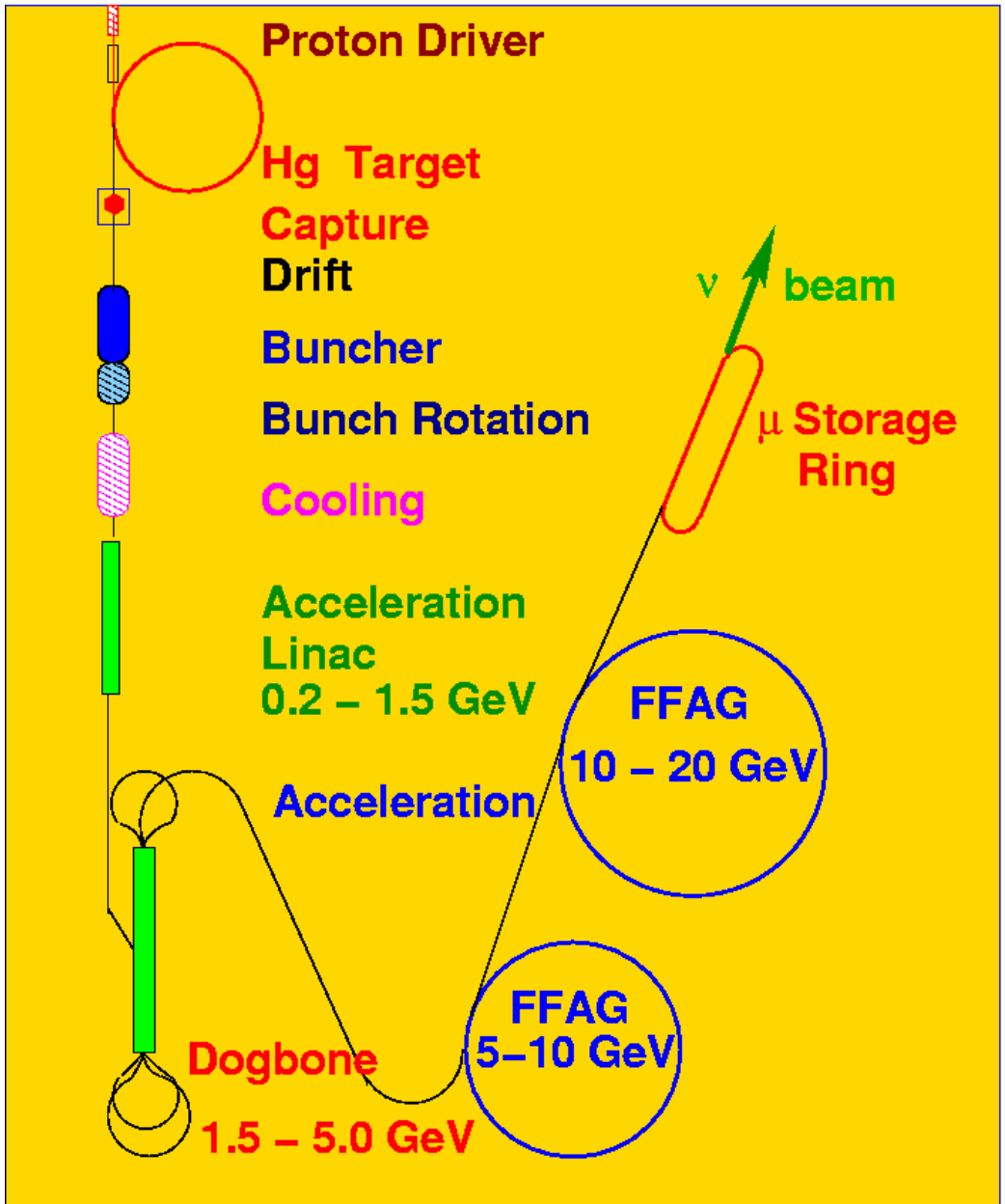
Layouts with FFAGs



US layout

Much reduced cooling!

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What is an FFAG?

Fixed Field Alternating Gradient synchrotron

- Rapid cycling: ideal for muons
- Large acceptance: no (little) need for cooling
- Large number of other applications:
  - proton/carbon cancer therapy
  - ADS
  - boron neutron capture therapy
  - ion implantation
  - scanning
  - proton, ion, electron acceleration

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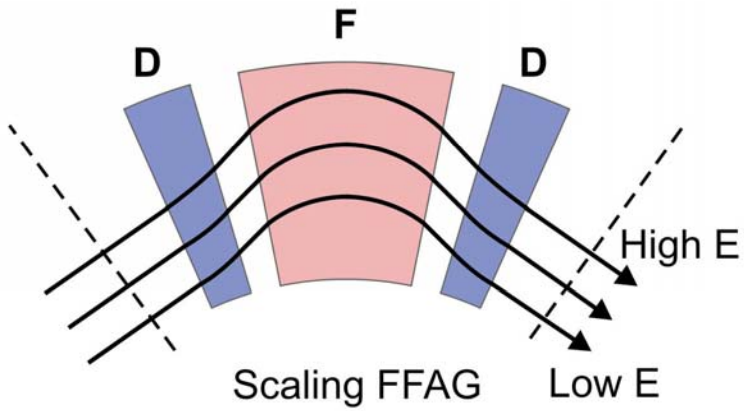
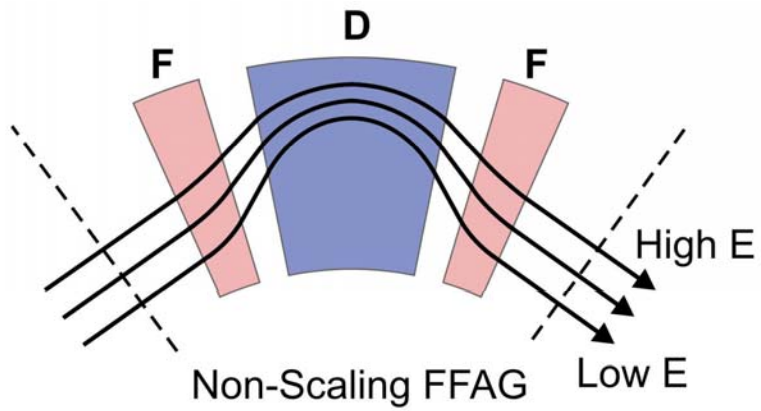
Non-scaling FFAGs

- Two types of FFAG: scaling and non-scaling



Japan



US

- Plan: build electron model non-scaling FFAG
  - ~10 to ~20 MeV
  - 15-20m circumference
- If successful ⇒ major impact on accelerator physics
- Proposed location: Daresbury Laboratory

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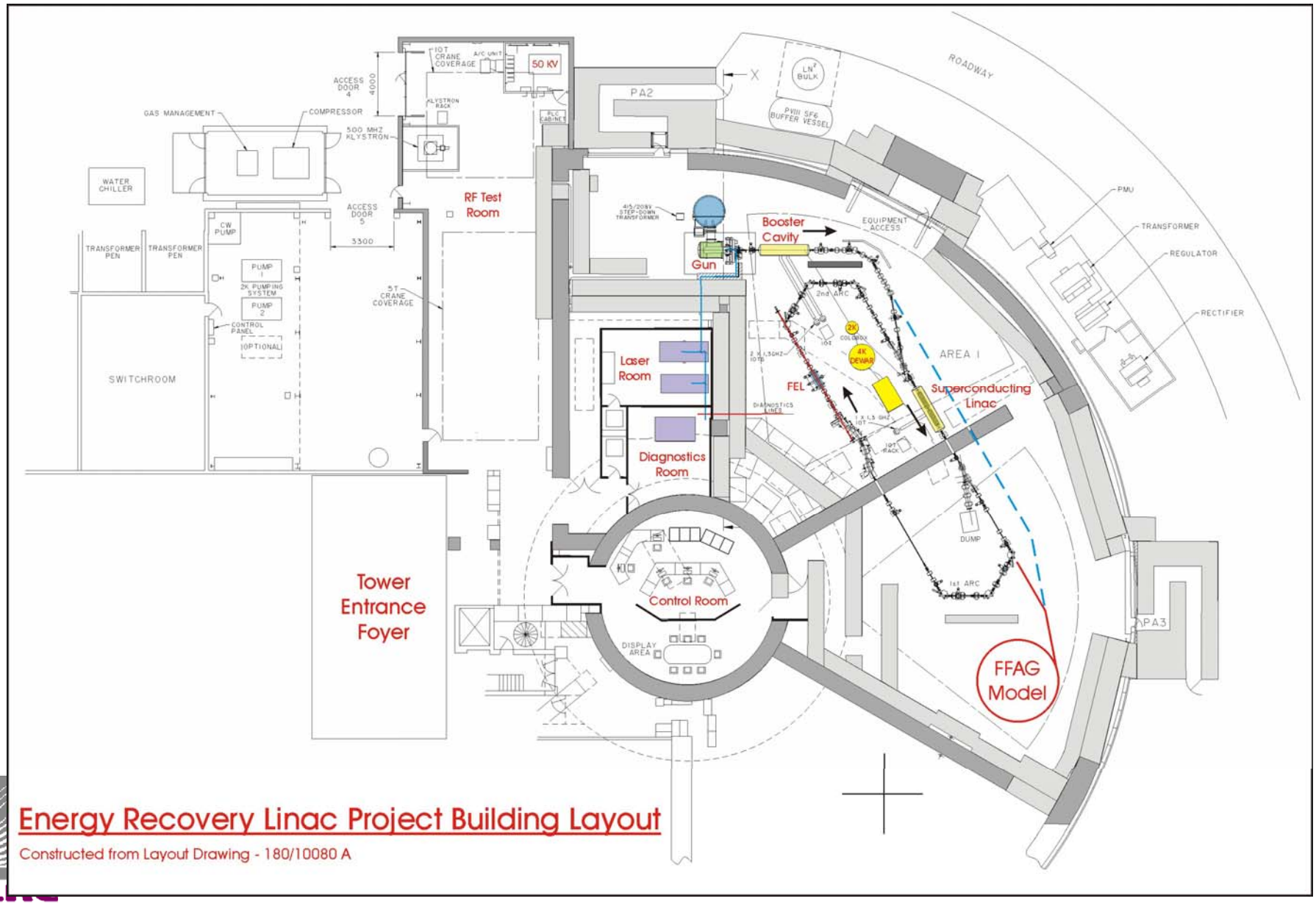
Non-scaling FFAGs



Design Studies

- In parallel to R&D, design and engineering studies
- Produced 5 NF layouts, 2 ~ costed
- Allowed focus on most expensive parts
- Study 2a → ~$1B

Next steps.....

- Compare ideas for the machine
- Produced cost optimised layout with detector(s)
- Start detailed engineering

World Design Study

- Design Study proposal to FP7
- Hosted by RAL

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Conclusions

- Neutrino Factory: ultimate oscillation facility
- UK participation began in 1999
- Much progress since then
- Major contributions to many important R&D projects
- Synergy with beta-beam in a number:
  - proton driver
  - target
  - FFAGs
- World Design Studied planned soon
- FP7 Design Study bid expected next year
- Hosted by RAL

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