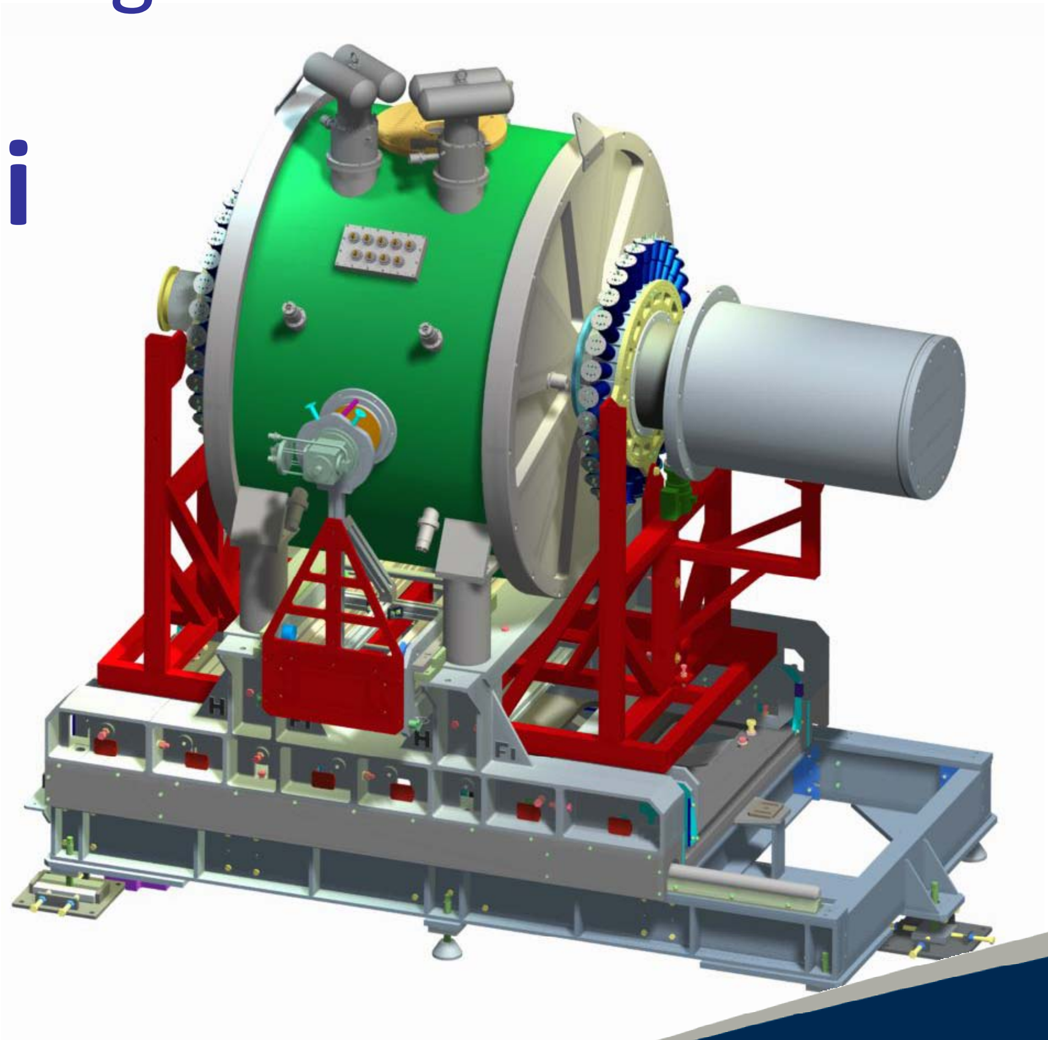
High Longitudinal Fields for Muons at ISIS:

HiFi



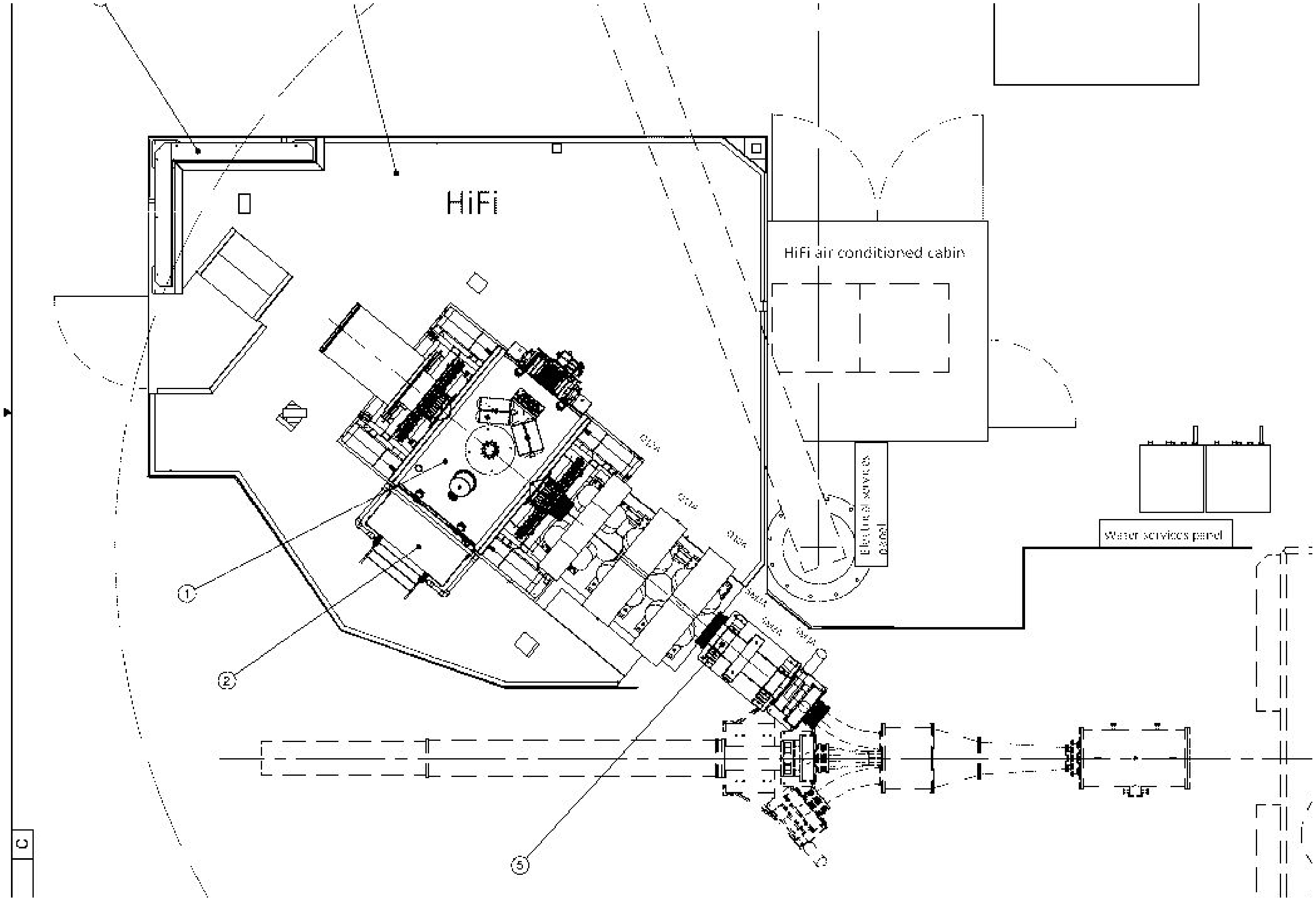
Muon JRA Collaboration Meeting
Barcelona, 11 May 2010

Science & Technology Facilities Council
ISIS

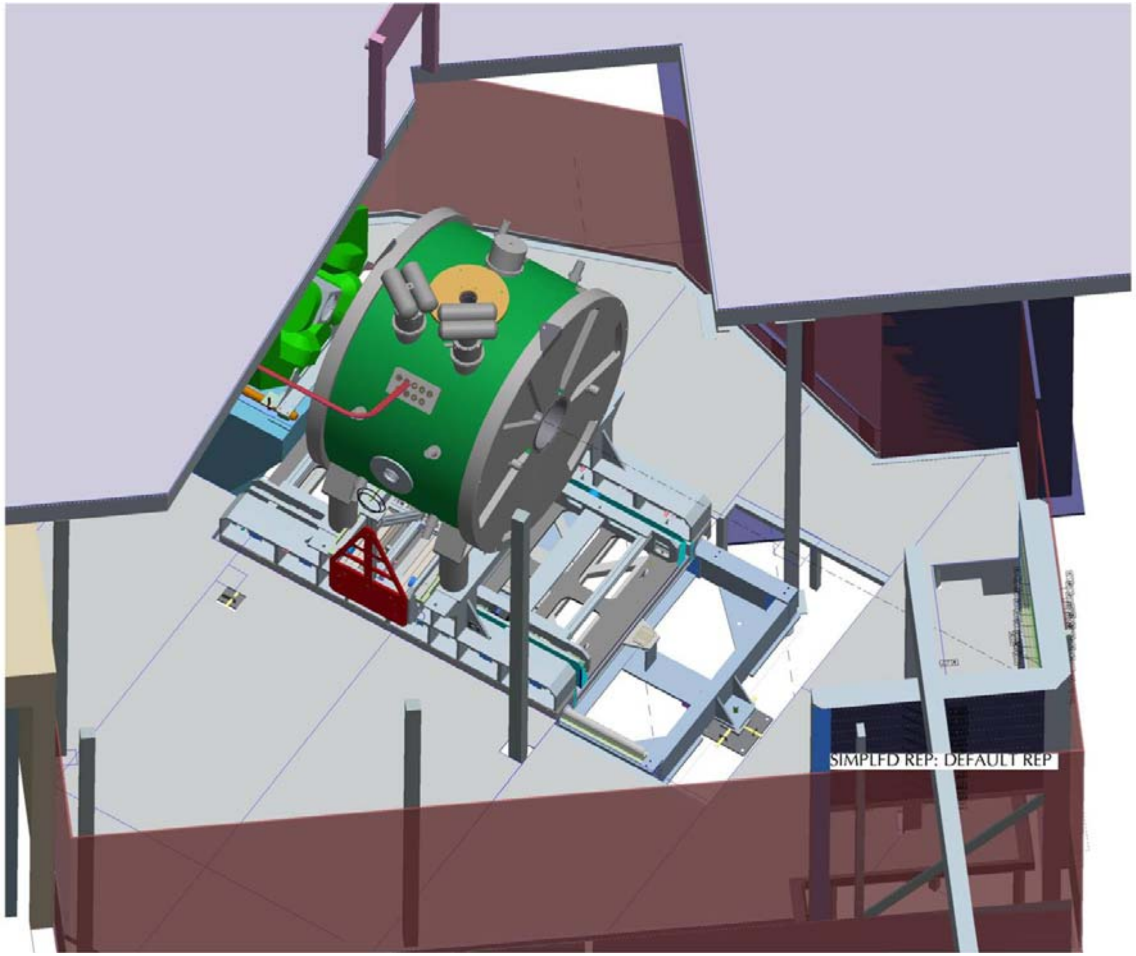
Instrument specs:

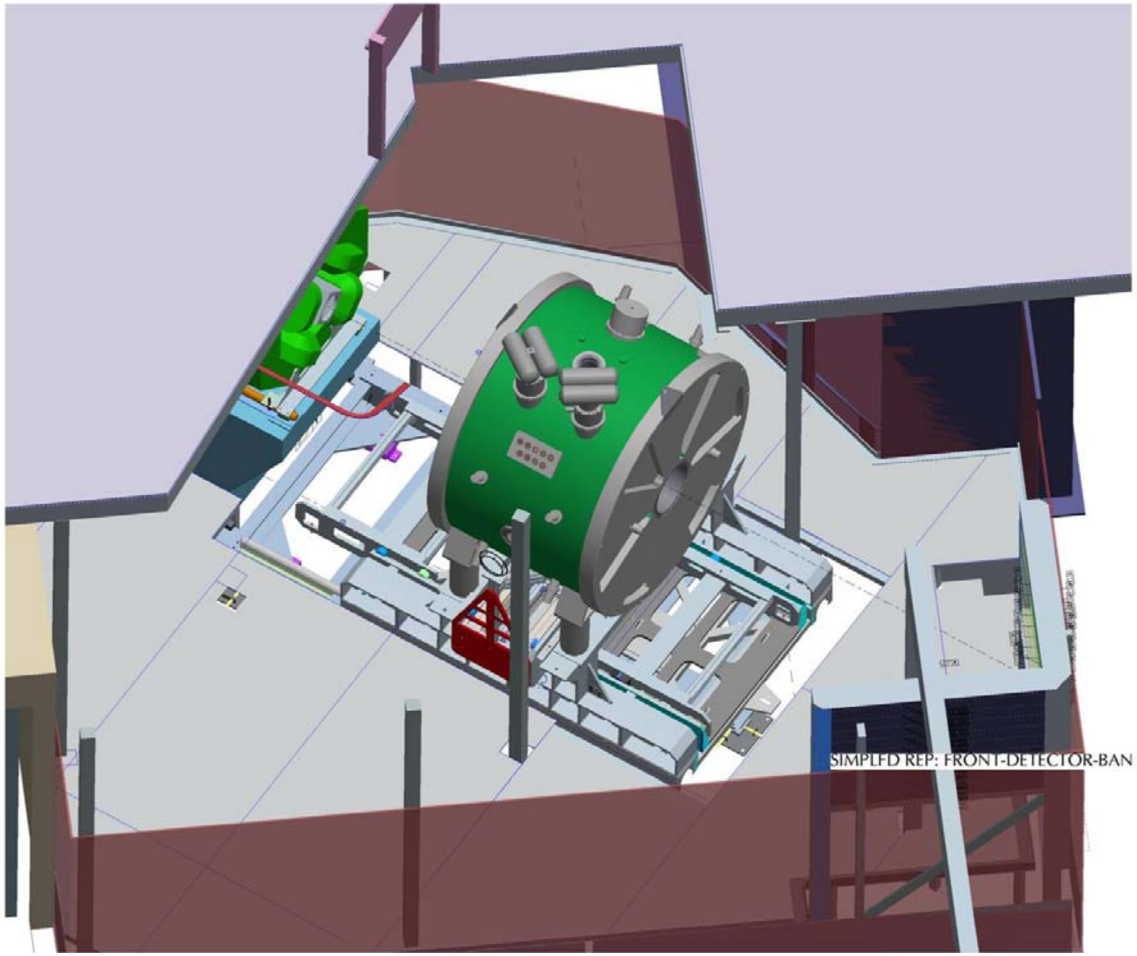
- 5 T main field, longitudinal
  - Stray field: 2 G at 3 m
  - Stability: 50ppm over 12 hours (persistent mode)
  - Ramp rate: 1T in 10 mins (full field in ~90 mins)
  - Homogeneity: 20 ppm over normal sample volume
  - Cool-down for system: ~7 days (cryogen-free)
- + 400 G auxiliary field (for field switching, e.g. ALC)
- + 2 x 100 G transverse fields
- Zero field compensation

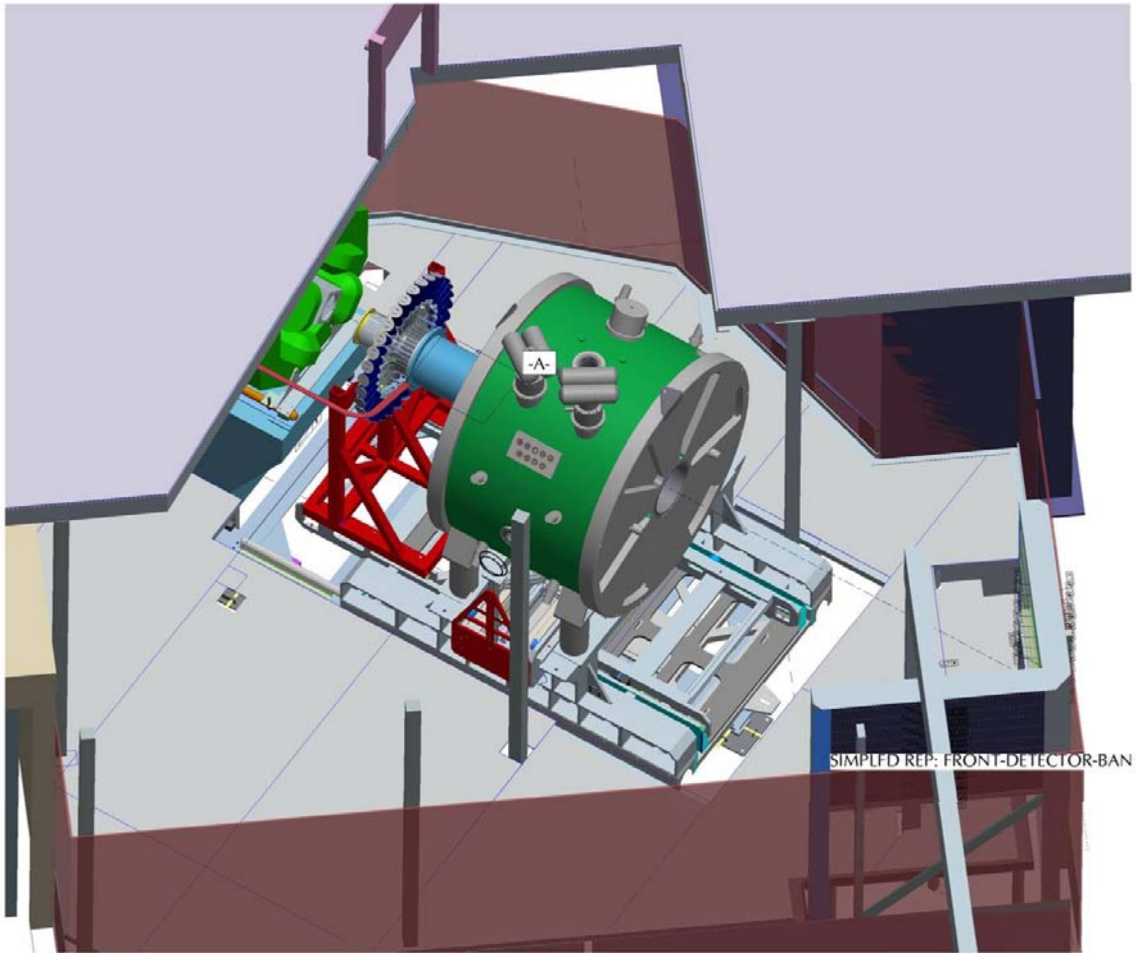
- 64 detectors
- Split pair to allow flexible SE access
- Temperature range: 30mK – 1500K
- Data rates ~50 MeV/hr
- ‘fly-past’ possible

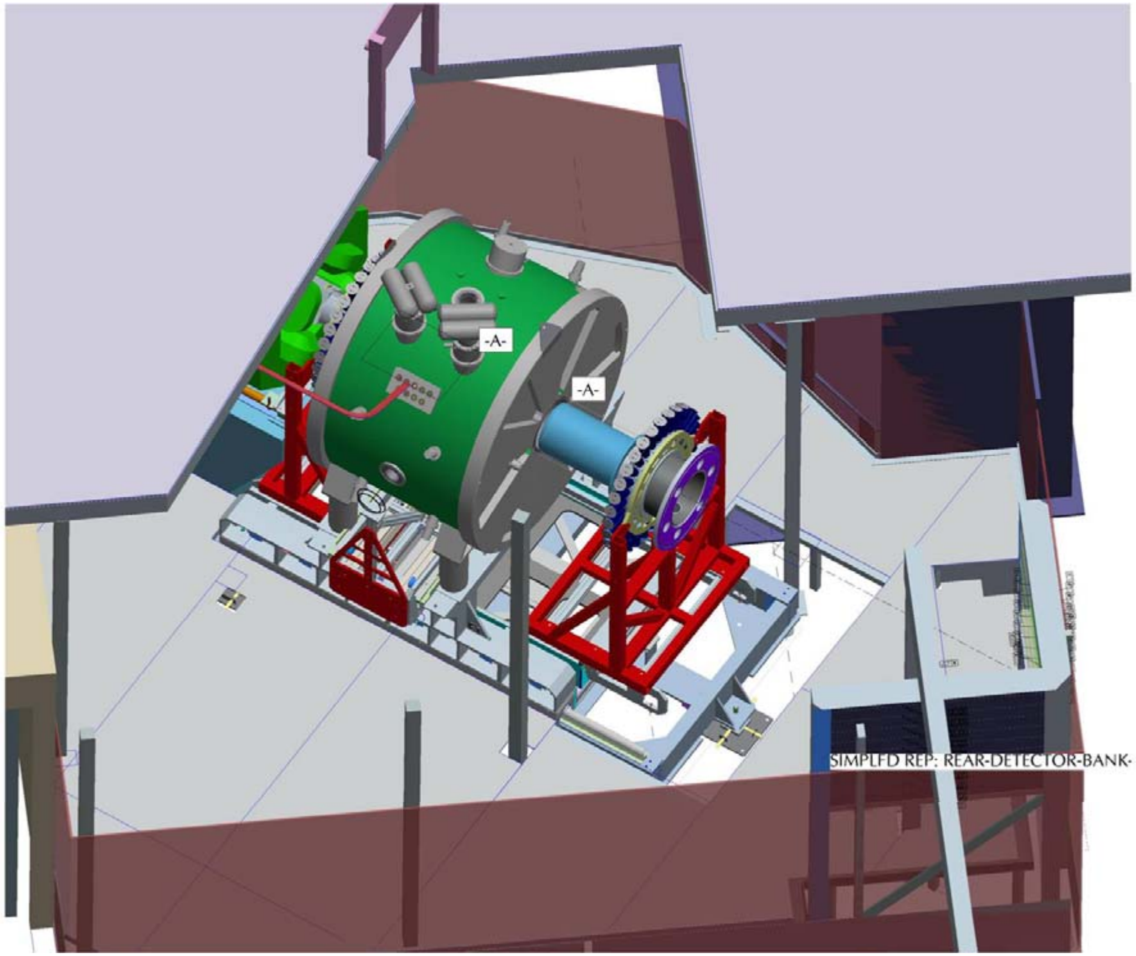

HiFi
HiFi air conditioned cabin
Electrical services panel
Water services panel
1
2
5
C

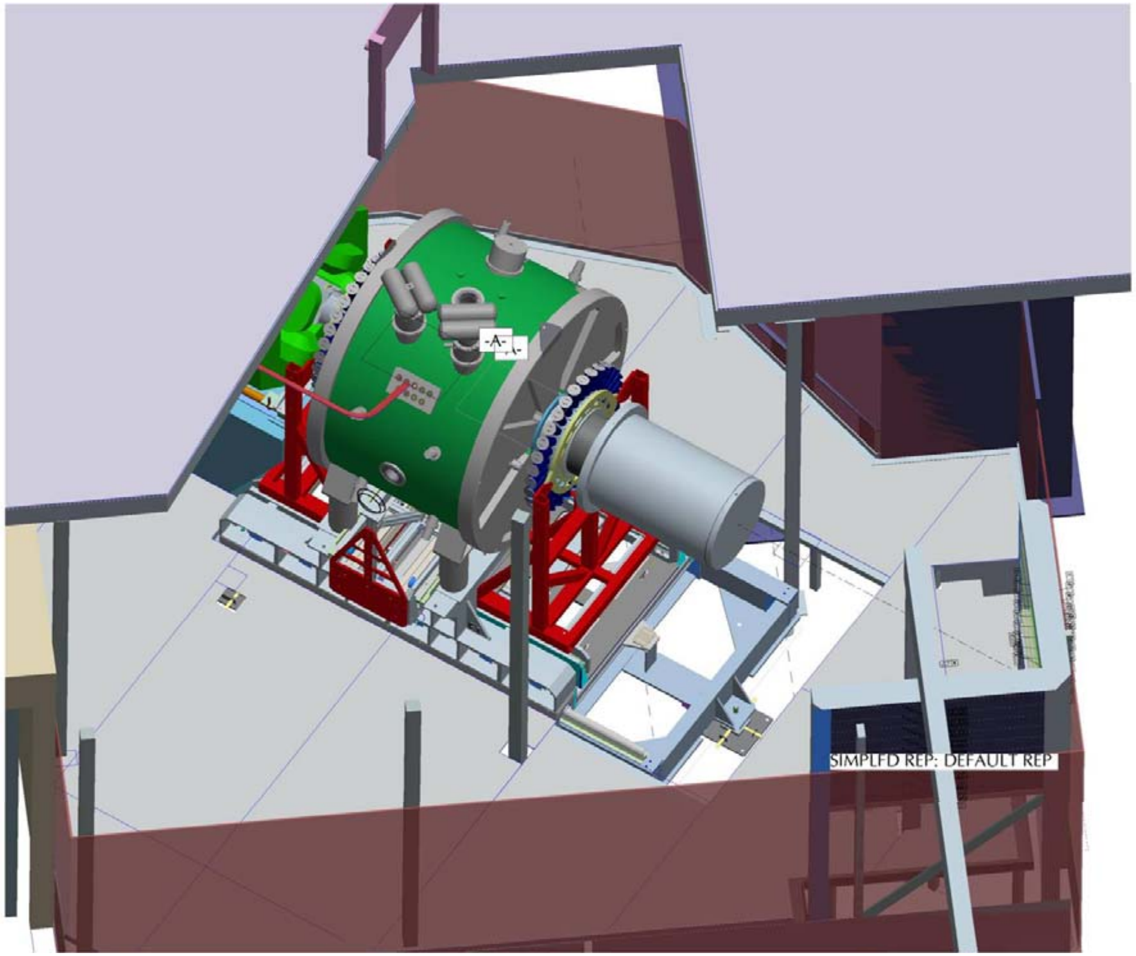

SIMPLFD REP: DEFAULT REP

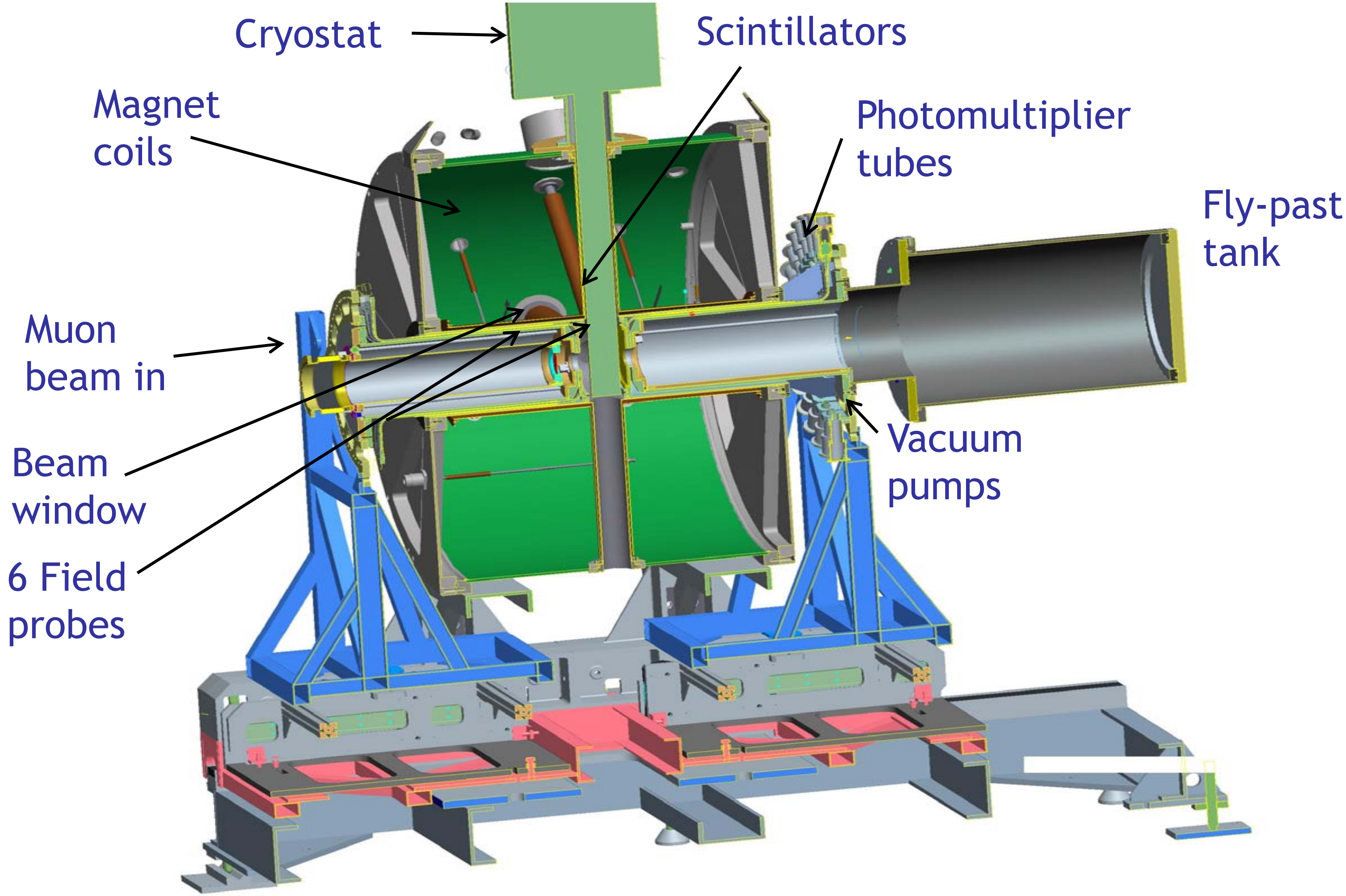

SIMPLFD REP: DEFAULT REP

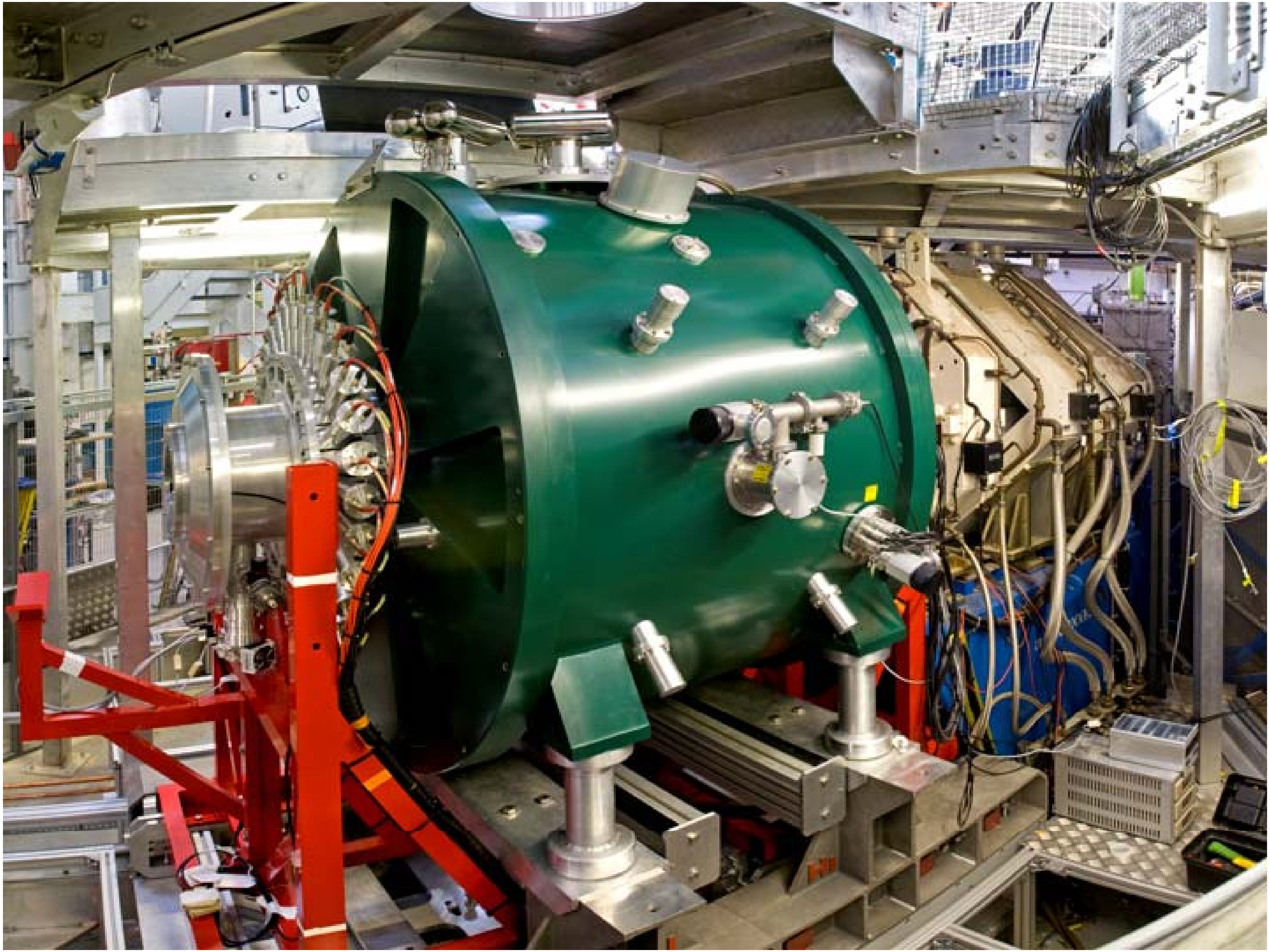

SIMPLFD REP: FRONT-DETECTOR-BAN


-A-
SIMPLFD REP: FRONT-DETECTOR-BAN

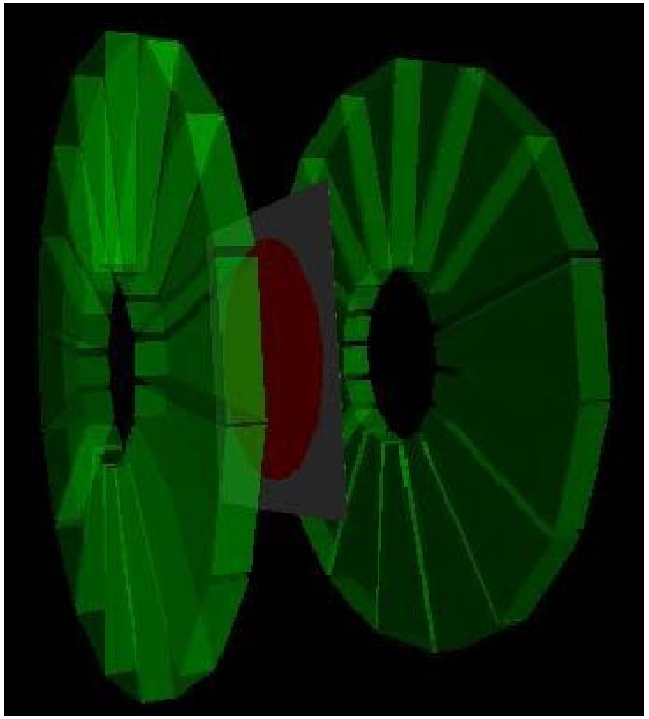

-A-
-A-
SIMPLFD REP: REAR-DETECTOR-BANK-

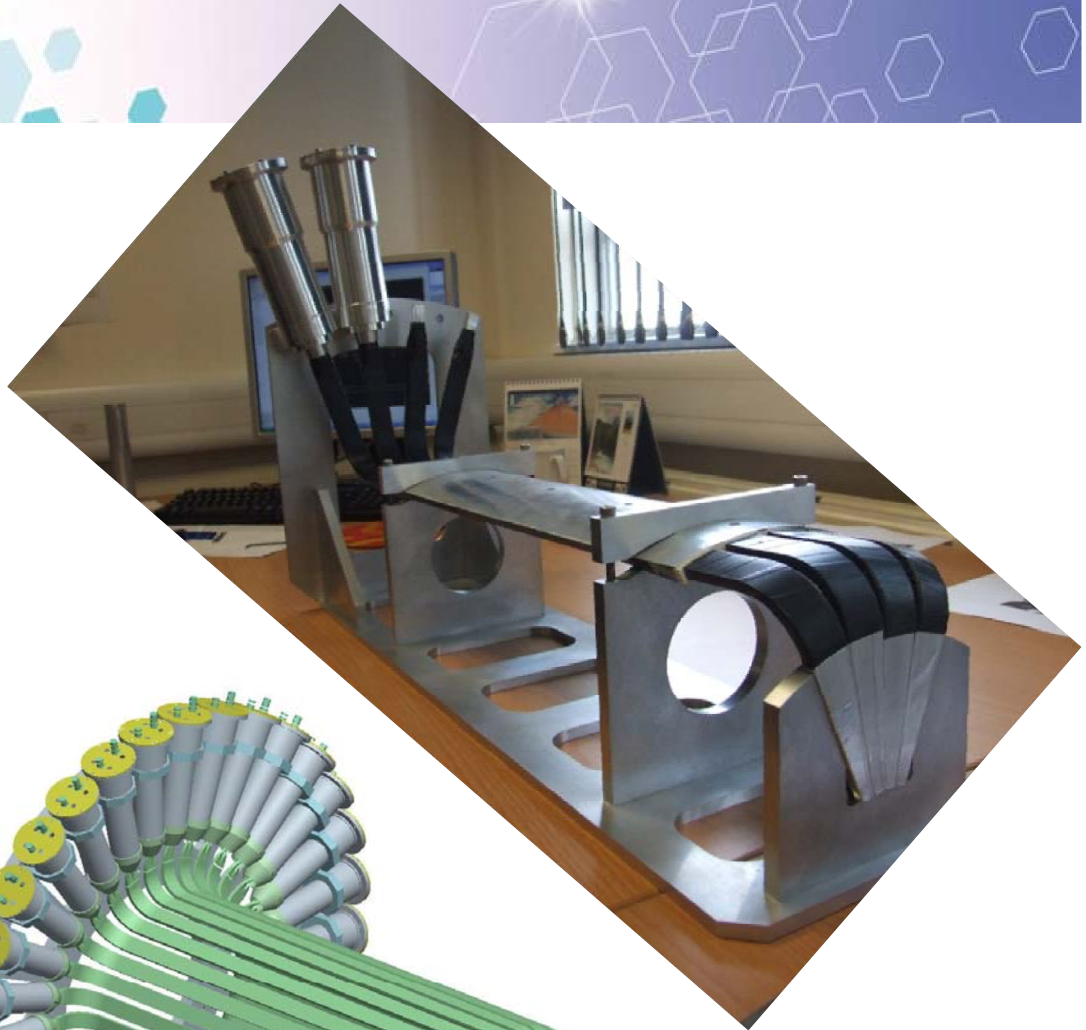

-A-
SIMPLFD REP: DEFAULT REP

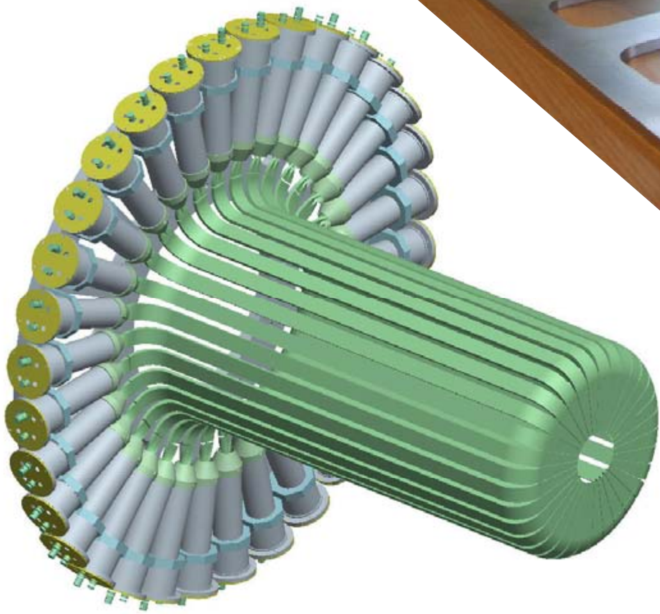

Cryostat
Scintillators
Magnet coils
Photomultiplier tubes
Fly-past tank
Muon beam in
Beam window
6 Field probes
Vacuum pumps



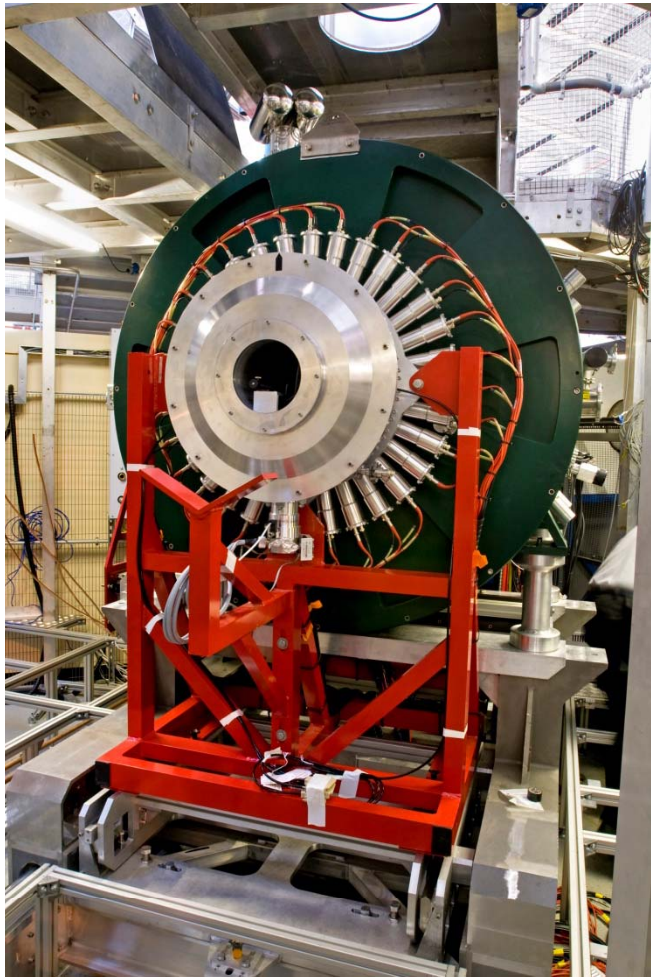
Detector arrays







Detector arrays



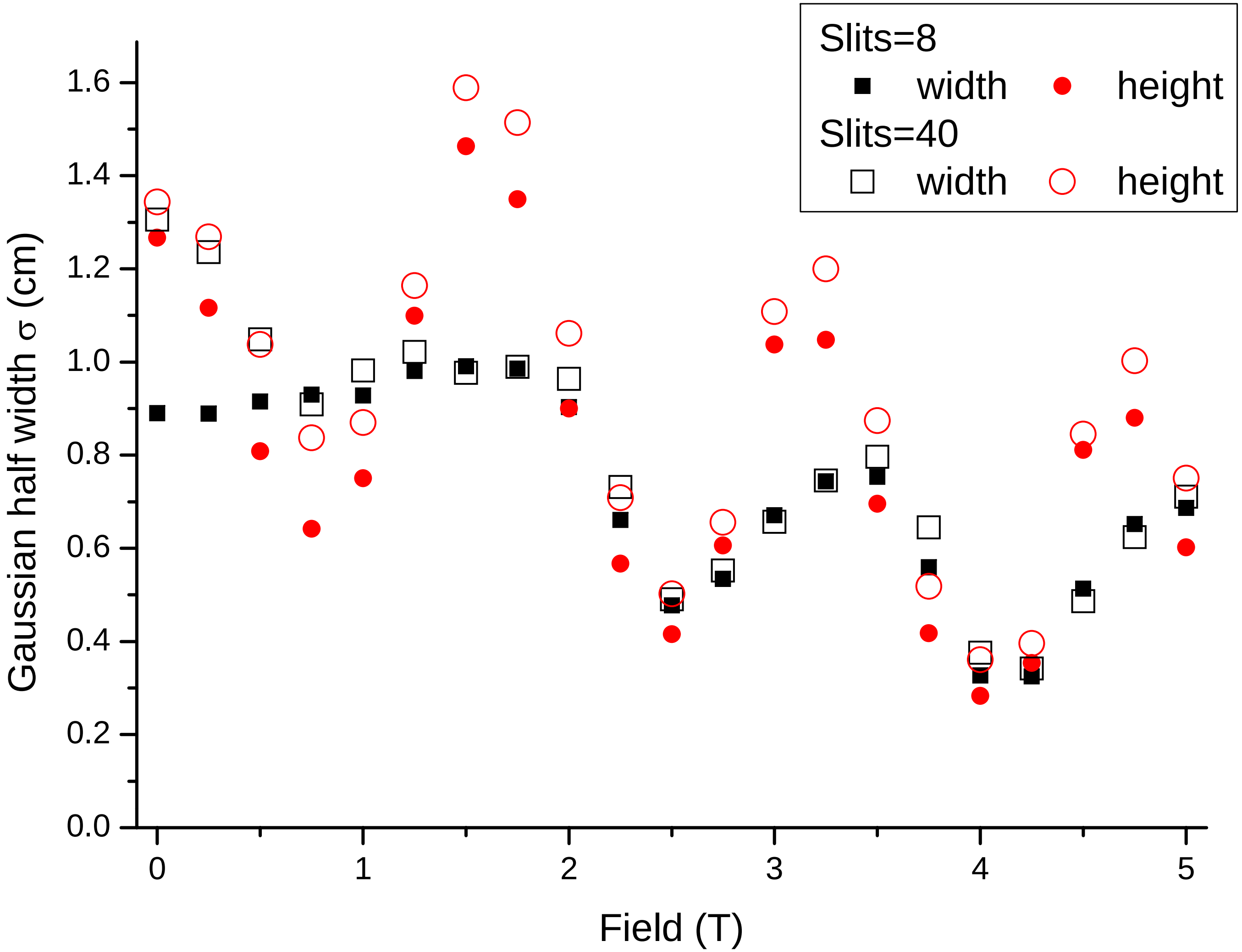

OXFORD
INSTRUMENTS

Instrument status

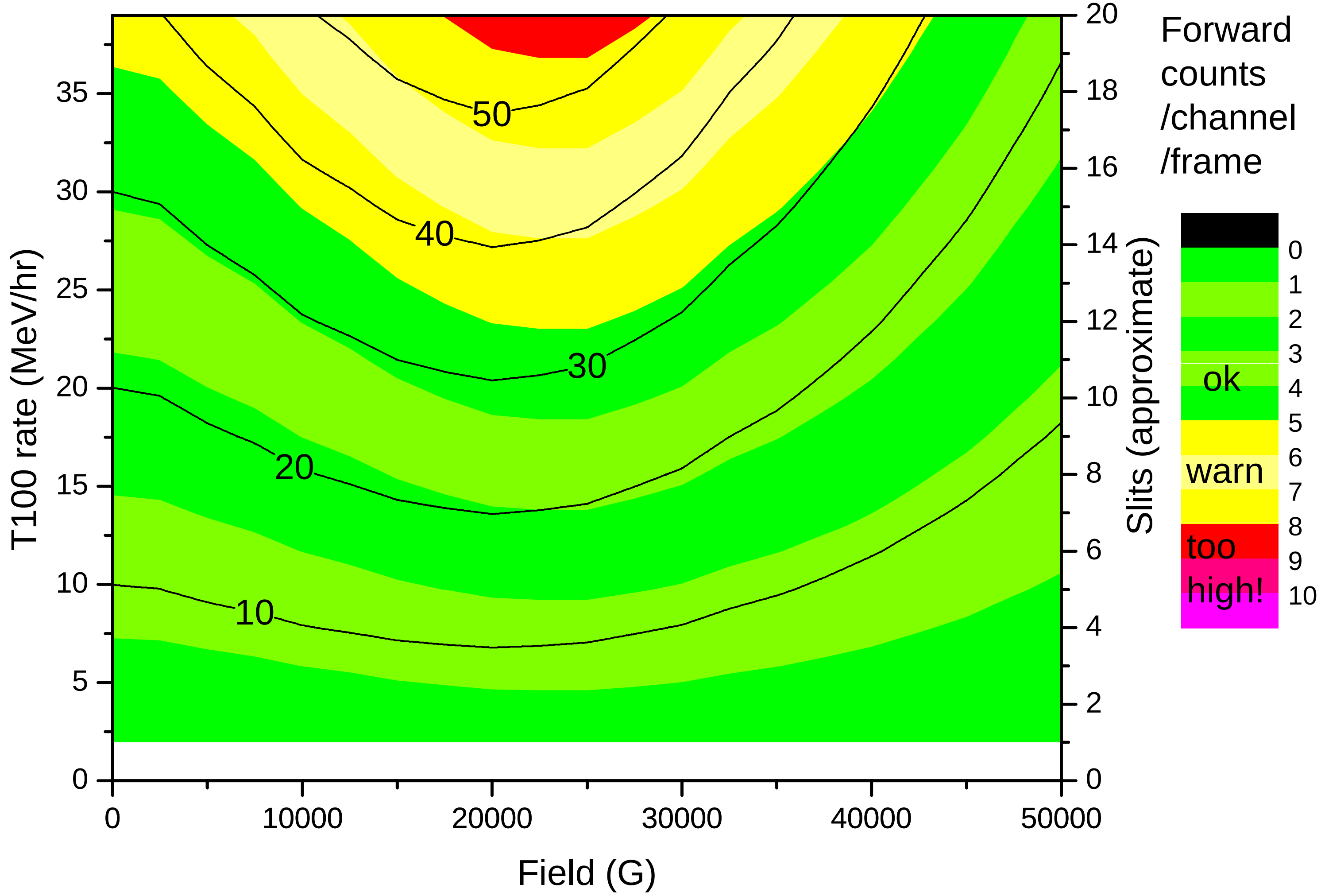
- Instrument completed late 2009
- Commissioning began early 2010, now completed
- Some SE equipment commissioning still to do
- HiFi now a full part of the ISIS user programme
- 23 approved experiments, 7 of which have been completed

First HiFi users: Alan Drew and co-workers, Iain McKenzie.

Effects of field on muon spot

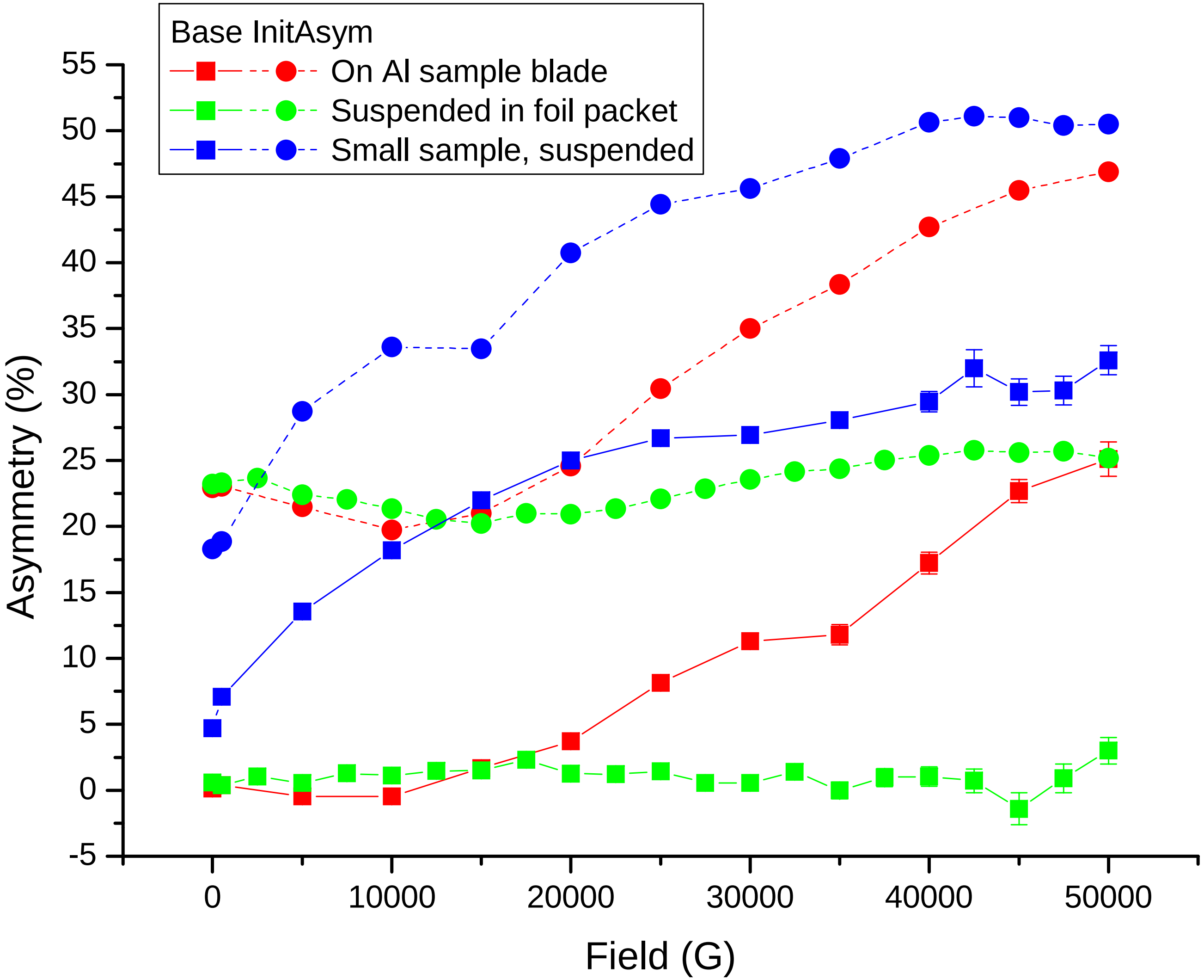


Effects of field on data rate

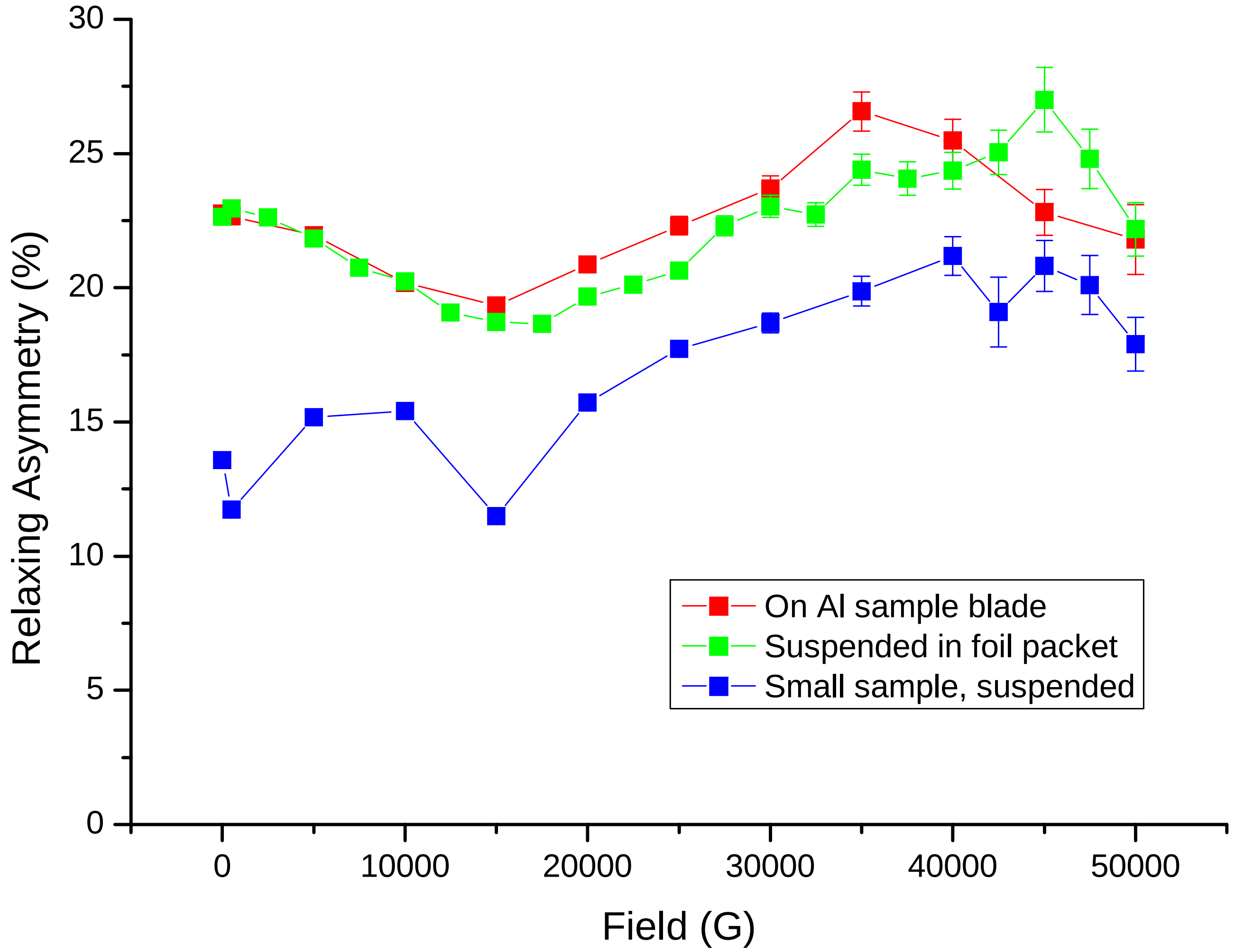


Double counting: negligible in 0T, Increases linearly to 25% in 5T

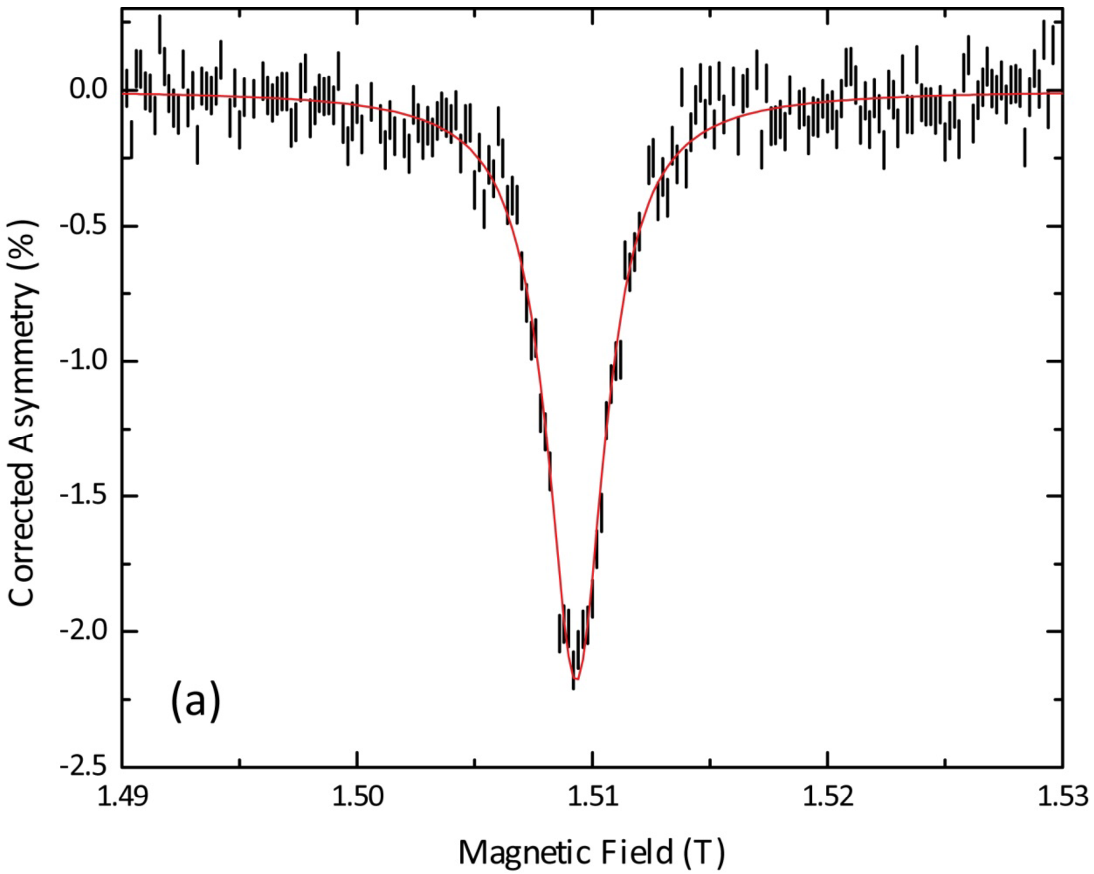
Effects of field on asymmetry



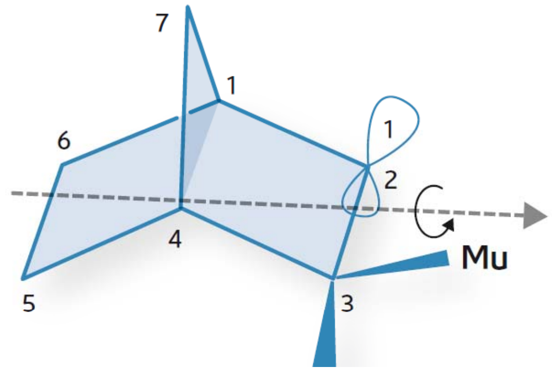
Effects of field on asymmetry



Results

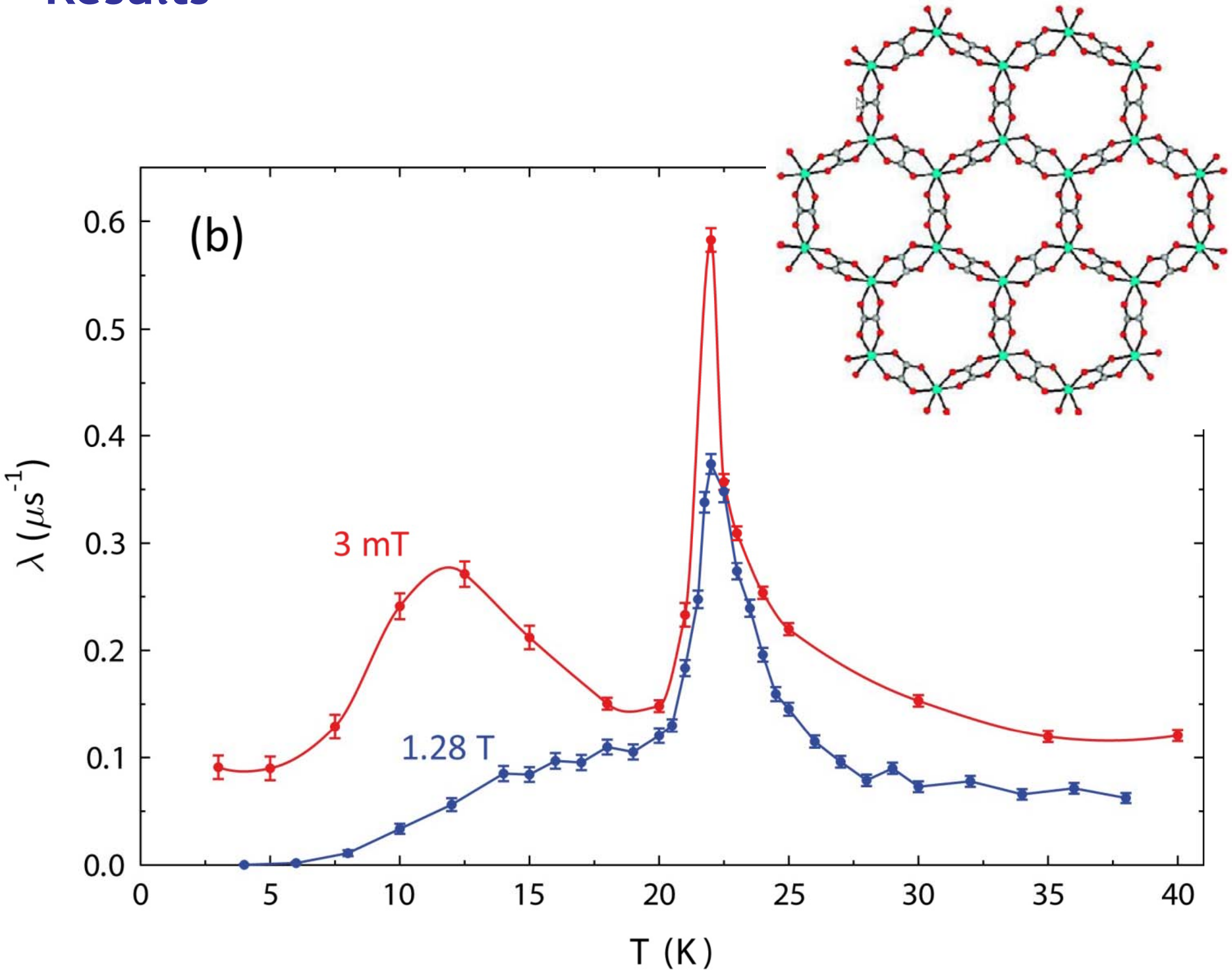


Norbornene LCR



Resonance shape informs on molecular dynamics (rotations) in the plastic phase

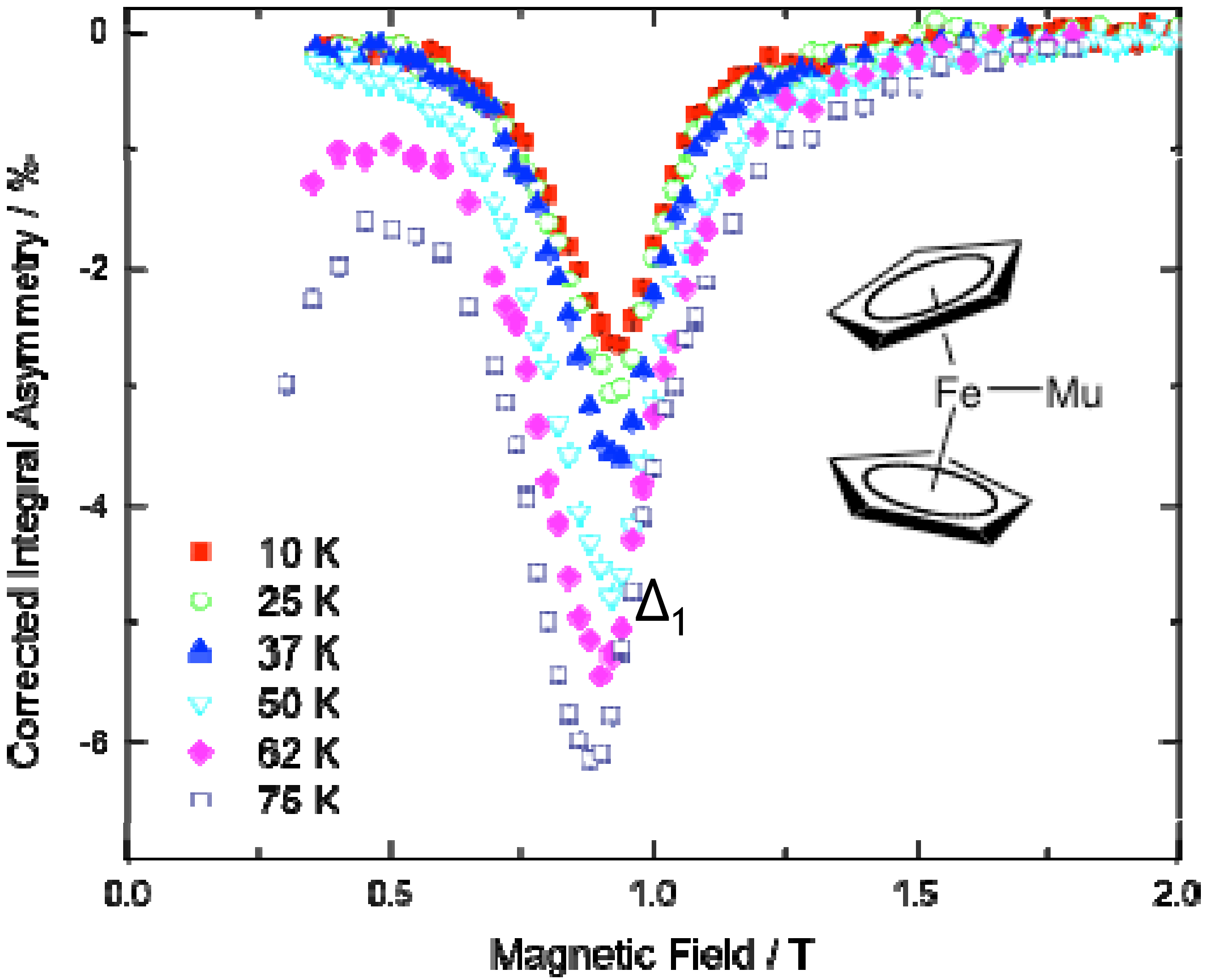
Results



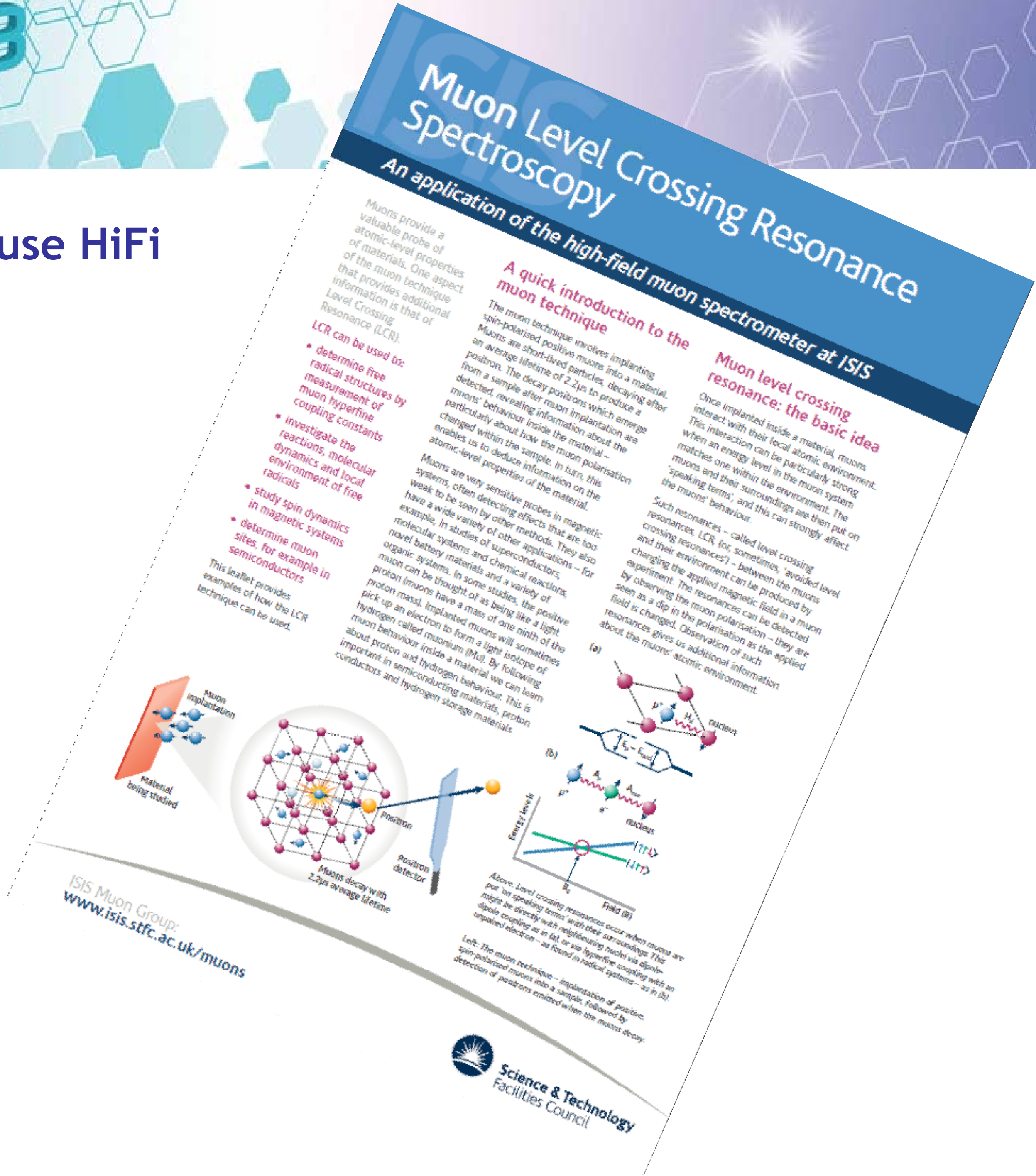
- Studies of organic magnetic systems based on oxalate-bridged transition metal ions
- New field-dependent magnetic transition in layered cobaltate compound below 22K

Results

ALC-µSR of an Organometallic Radical



Helping our users use HiFi



Muon Level Crossing Resonance Spectroscopy

An application of the high-field muon spectrometer at ISIS

Muons provide a valuable probe of atomic-level properties of materials. One aspect of the muon technique that provides additional information is that of Level Crossing Resonance (LCR).

LCR can be used to:

- determine free radical structures by measurement of muon hyperfine coupling constants
- investigate the reactions, molecular dynamics and local environment of free radicals
- study spin dynamics in magnetic systems
- determine muon sites, for example in semiconductors

This leaflet provides examples of how the LCR technique can be used.

A quick introduction to the muon technique

The muon technique involves implanting spin-polarised positive muons into a material. Muons are short-lived particles, decaying after an average lifetime of 2.2μs to produce a positron. The decay positrons which emerge from a sample after muon implantation are detected, revealing information about the muons' behaviour inside the material – particularly about how the muon polarisation changed within the sample. In turn, this enables us to deduce information on the atomic-level properties of the material.

Muons are very sensitive probes in magnetic systems, often detecting effects that are too weak to be seen by other methods. They also have a wide variety of other applications – for example, in studies of superconductors, molecular systems and chemical reactions, novel battery materials and a variety of organic systems. In some studies, the positive muon can be thought of as being like a light proton (muons have a mass of one ninth of the proton mass). Implanted muons will sometimes pick up an electron to form a light isotope of hydrogen called muonium (Mu). By following muon behaviour inside a material we can learn about proton and hydrogen behaviour. This is important in semiconducting materials, proton conductors and hydrogen storage materials.

Muon level crossing resonance: the basic idea

Once implanted inside a material, muons interact with their local atomic environment. This interaction can be particularly strong when an energy level in the muon system matches one within the environment. The muons and their surroundings are then put on 'speaking terms', and this can strongly affect the muons' behaviour.

Such resonances – called level crossing resonances, LCR, (or, sometimes, 'avoided level crossing resonances') – between the muons and their environment can be produced by changing the applied magnetic field in a muon experiment. The resonances can be detected by observing the muon polarisation – they are seen as a dip in the polarisation as the applied field is changed. Observation of such resonances gives us additional information about the muons' atomic environment.

Above: Level crossing resonances occur when muons are put 'on speaking terms' with their surroundings. This might be directly with neighbouring nuclei via dipole-dipole coupling as in (a), or via hyperfine coupling with an unpaired electron – as found in radical systems – as in (b).

Left: The muon technique – implantation of positive spin-polarised muons into a sample, followed by detection of positrons emitted when the muons decay.

ISIS Muon Group:
www.isis.stfc.ac.uk/muons

Science & Technology Facilities Council

JRA

JRA Task 20.2: Technologies for high field instruments

Development of detector technologies and array designs, supporting the ongoing programme at both STFC and PSI to develop new muon instruments operating at magnetic fields of up to 10T.

D 20.2.1.1	Demonstration of fast timing detector (PSI)	20
D 20.2.1.2	Report summarising detector performance (PSI)	35
D 20.2.2.1	Design document for a 10 T transverse field instrument detector array (PSI)	28
D 20.2.3.1	Document describing the performance of the 5 T longitudinal field spectrometer at currently in development (ISIS)	22
D 20.2.3.2	Publication of instrument performance and test results in scientific journal (ISIS)	26