The Muon JRA in FP7

Stephen Cottrell,
ISIS Facility

JRA presentation
General Assembly
Rome
2011, November 9

A broad collaboration

Partners:

- University of Parma, Italy
- University of Babes-Bolyai, Romania
- PSI Continuous Muon Facility, Switzerland
- ISIS Pulsed Muon Facility, UK (Coordinator)

Collaborators:

- Dubna, Russia
- University of East Anglia, UK
- RIKEN-RAL, Japan/UK
- University of British Columbia, Canada

Tasks in the JRA

1. (Management and dissemination)
2. Technologies for high-field instruments
3. Developing technologies for µSR at high pressures
4. Novel resonance techniques and simulation codes for complex experiments
5. Muon beamline control and modelling

Building on work started during FP6 …

JRA Tasks

Technologies for High Field Instruments

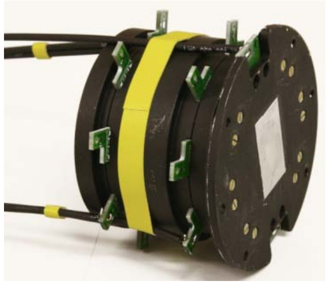
- Fast-timing detectors for high transverse field applications
- Design and simulation of a high field instrument for PSI
- Performance assessment of high-field operation at ISIS

Fast Timing Detectors for High Field Applications

Experiments in High Fields require detectors that provide:

- Fast timing
- Work in a High Magnetic Field

APD technologies have been investigated to build novel arrays



Prototype detector module (PSI)

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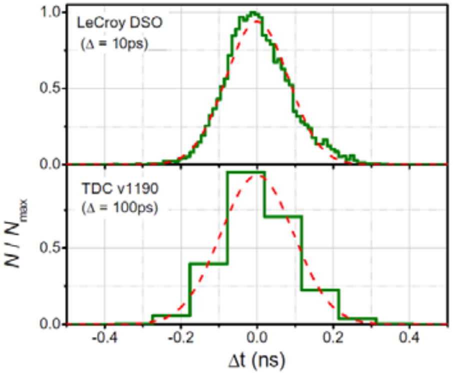
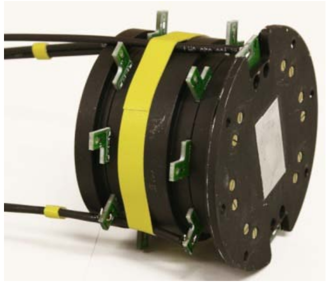


Detector resolution better than 100 ps



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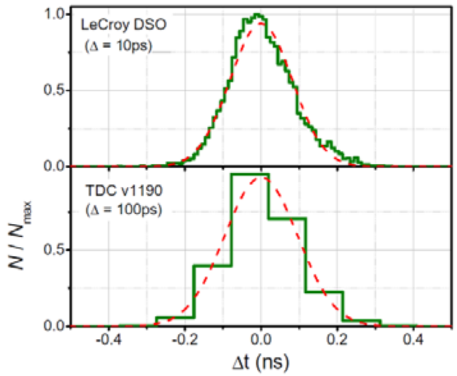

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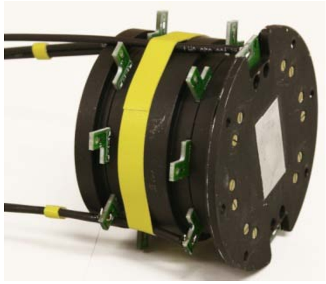

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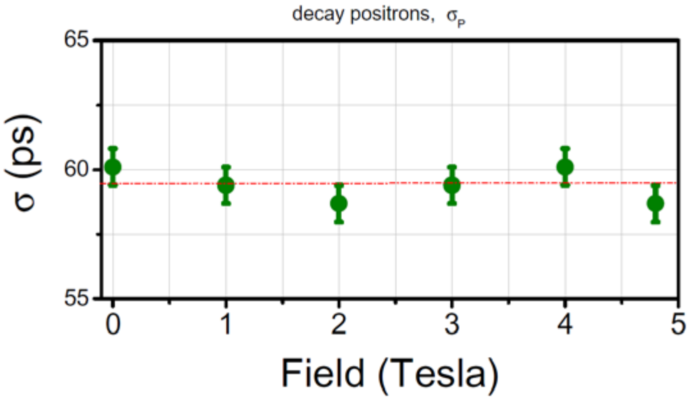


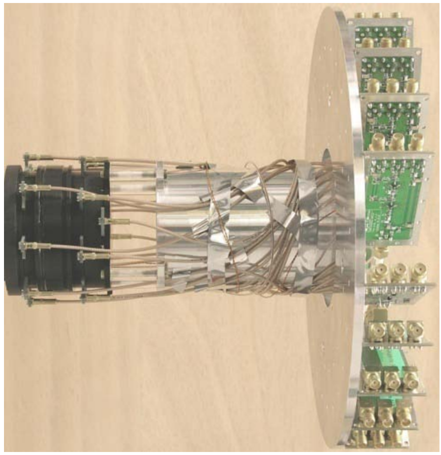
Resolution independent of field

Instrument Development – High Transverse Fields at PSI

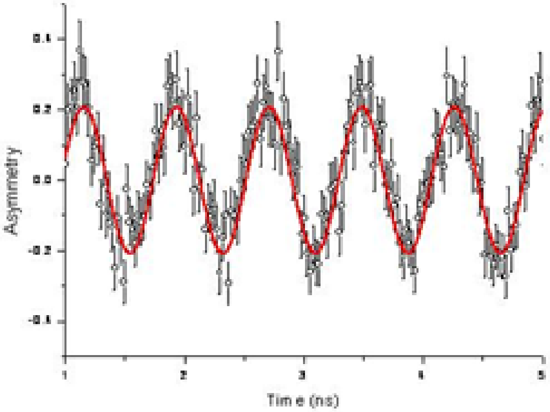
Challenging requirements:

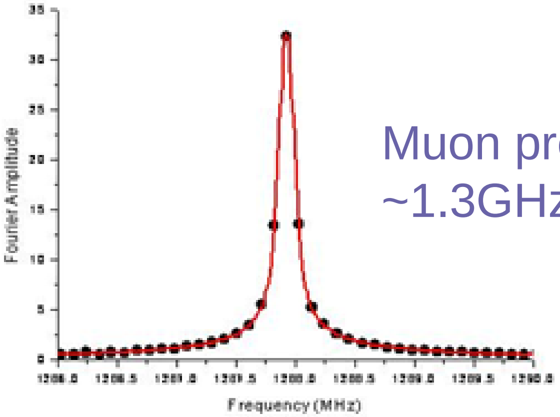
- Maximum field 9.5 T
- Field homogeneity 10 ppm
- Time resolution better than 140 ps
- Base temperature:15 mK

The development of new detector technologies and instrument simulation was essential



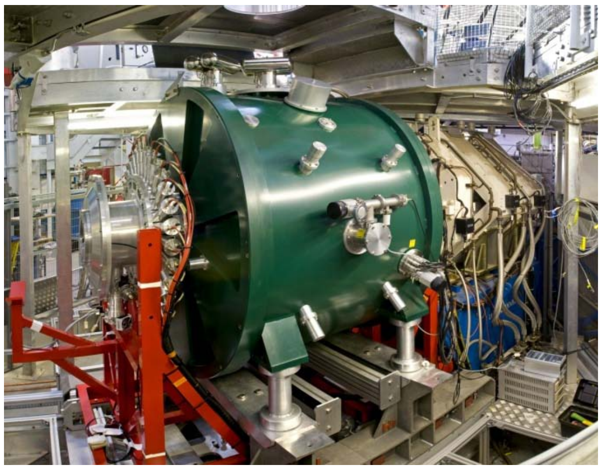
APD Detector array





Muon precession ~1.3GHz, 9.8T

Instrument Development – High Magnetic Fields at ISIS



Commissioned and evaluated during FP7

REVIEW OF SCIENTIFIC INSTRUMENTS 82, 073904 (2011)

Design and commissioning of a high magnetic field muon spin relaxation spectrometer at the ISIS pulsed neutron and muon source

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The high magnetic field (HiFi) muon instrument at the ISIS pulsed neutron and muon source is a state-of-the-art spectrometer designed to provide applied magnetic fields up to 5 T for muon studies of condensed matter and molecular systems. The spectrometer is optimized for time-differential muon spin relaxation studies at a pulsed muon source. We describe the challenges involved in its design and construction, detailing, in particular, the magnet and detector performance. Commissioning experiments have been conducted and the results are presented to demonstrate the scientific capabilities of the new instrument. © 2011 American Institute of Physics. [doi:10.1063/1.3608114]

I. INTRODUCTION

Rev. Sci. Instrum. 82, 073904 (2011)

Dynamic fields in the partial magnetization plateau of $Ca_3Co_2O_6$

Muonium chemistry and spin dynamics in sulphur, modelling interstitial hydrogen

FAST TRACK COMMUNICATION

Observation of a level crossing in a molecular nanomagnet using implanted muons

New instrument (HiFi) funded by STFC (UK)

Using technologies developed during FP6

Fully integrated into the ISIS User Programme

Developing technologies for μSR at high pressures

- Development of a solid-sample pressure cell
- Development of gas-phase sample cell with RF coils

Pressure measurements

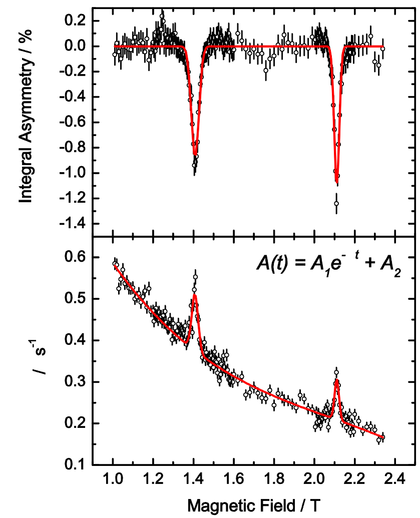
First Data!

Develop 50 bar Gas Sample cells:

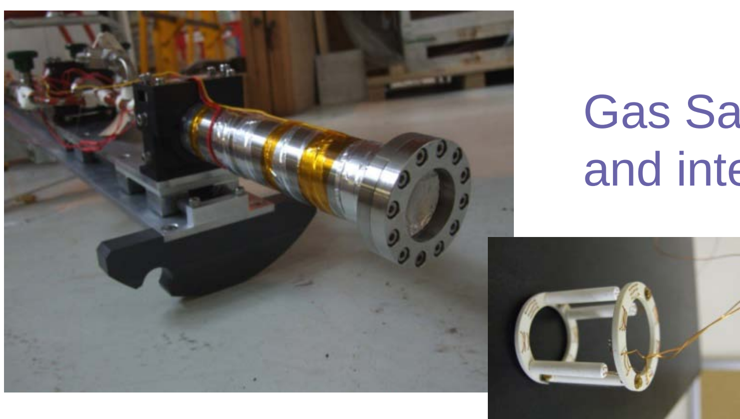
- for the ISIS High Field spectrometer
- provide capability for RF excitation

Experiment requirements make it tough:

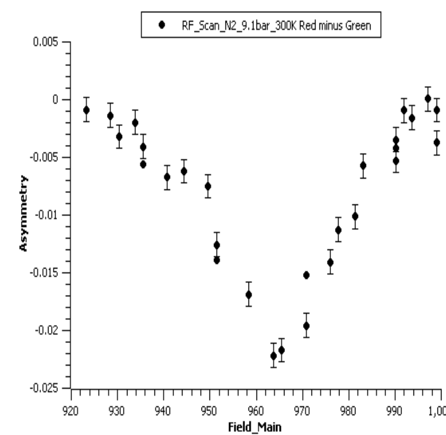
- thin window to admit muons
- RF feed into high pressure cell
- large (3cmx2cm) RF coil



ALC of the Mu-ethyl radical



Gas Sample pressure cell and integral RF coil



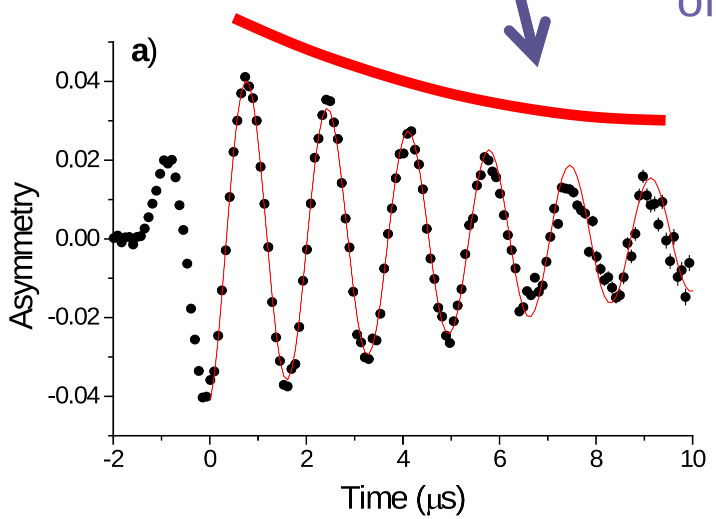
RF scan, N_2

Novel Resonance Techniques
and
Simulation codes for Complex Experiments

- RF μSR experiments using NMR style pulsed techniques
- Development of an in-situ NMR spectrometer
- Simulation codes to support μSR experiment analysis

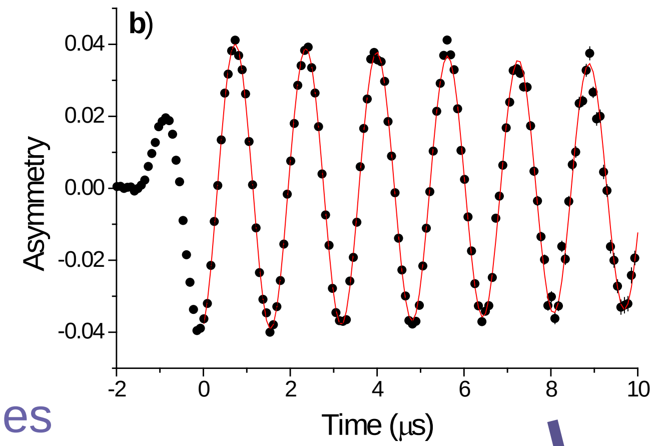
Pulsed RF Techniques – RF Decoupling

Decay envelope tells us about the environment the muon is probing



RF irradiation of nuclei

modifies environment



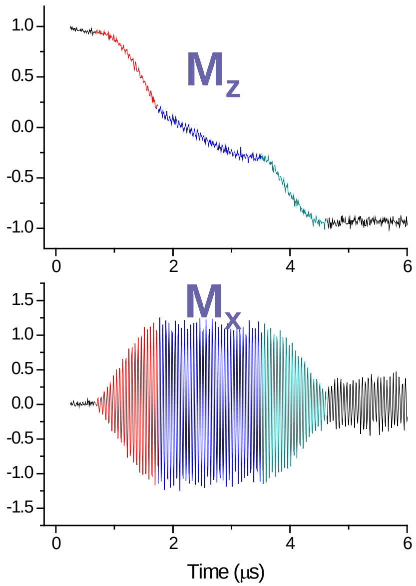
New information about muon coupling and dynamics – a model for proton behaviour

Pulsed RF Techniques – Composite Pulse

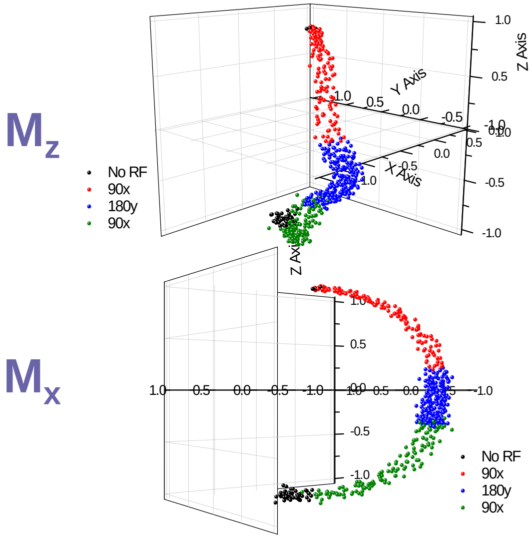
Composite pulses are often used in magnetic resonance to correct for pulse artefacts (a particular problem with pulsed RF μSR)

The composite inversion sequence $\pi/2_x\ \pi_y\ \pi/2_x$ demonstrates this:

Composite pulse : ΔM_z = 100%



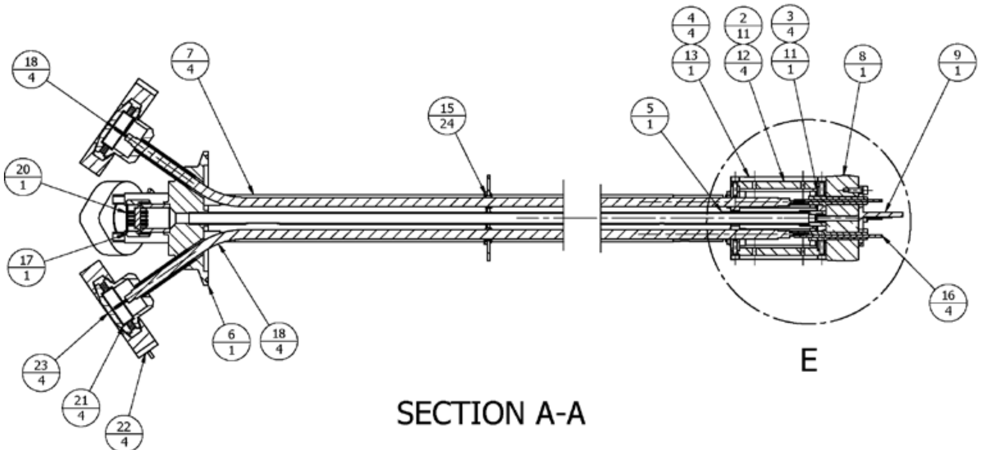
μSR can look inside the RF pulse!

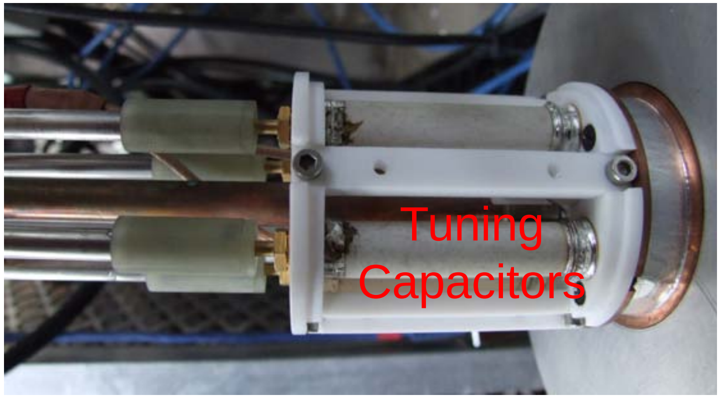


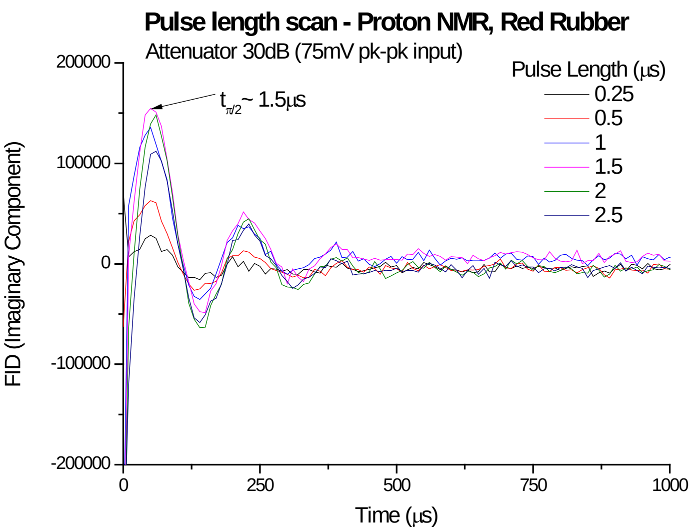
Impossible with NMR

New Equipment for RF Techniques

Pulsed RF techniques require very large RF powers.
To improve reliability we have developed a dedicated RF cryogenic insert







In-situ NMR used to commission the insert

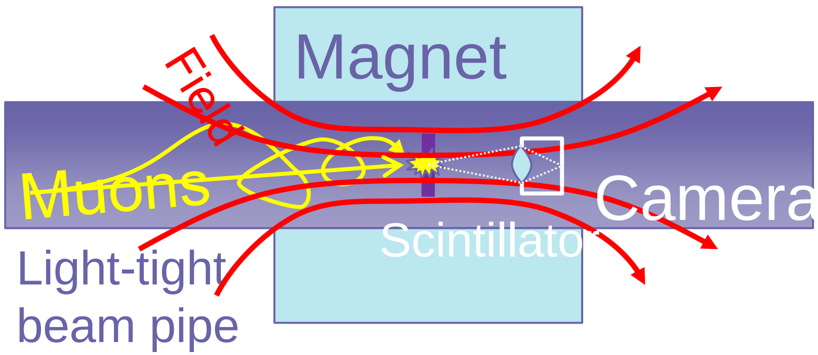
Muon Beamline Control and Modelling

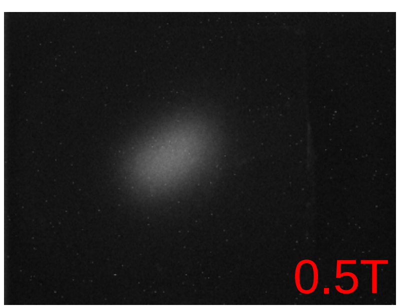
- Development of techniques for beamline diagnostics
- Instrument simulation code to allow full instrument modelling
- Extension of Nexus file format to capture full parameters

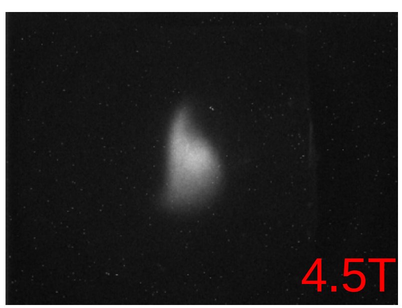
Beamline Diagnostics

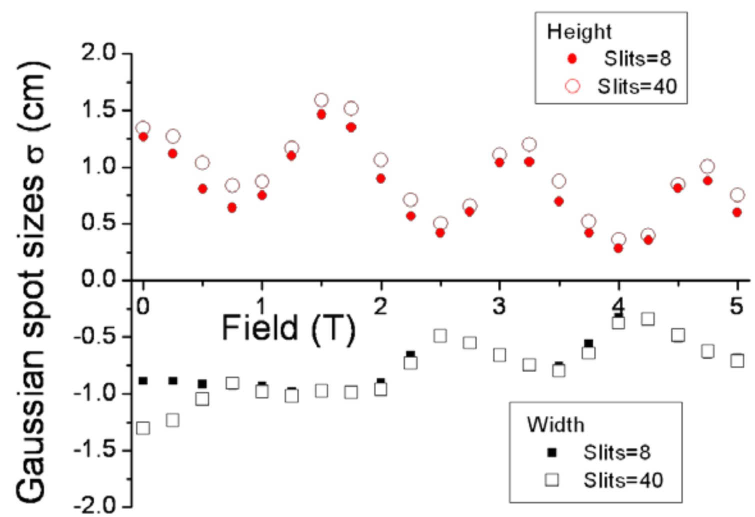
Muon beamlines are complex and tuning can take many hours. In FP7 we are:

- Investigating methods for providing beamline diagnostics
- Extending final beam spot imaging to work in High Magnetic Fields









Evolution of muon spot with field
(HiFi commissioning)

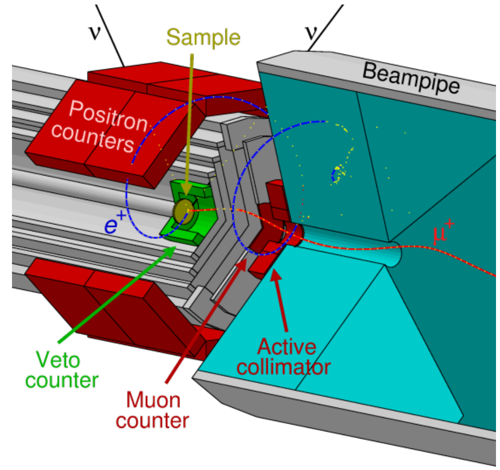
Instrument Modelling

Simulation codes have been developed to model both the *muon beam* and *positron track*

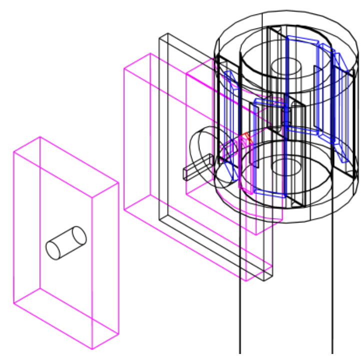
Based on GEANT4, *musrSIM* enables the instrument geometry, materials and fields to be defined

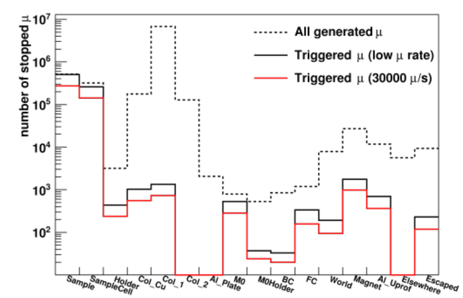
The output can be analysed for various acquisition modes using the *musrSimAna* software

Proved essential for the design of the high field instruments at PSI and ISIS



Simulation of PSI High Field spectrometer





GPD (PSI) modelled and location of muon stops investigated

and Finally ...

Thanks to the many people
who have contributed to the work of the JRA

Check out…

http://muons.neutron-eu.net/MuonsHome/

where we are posting project news and results