

Doing an Experiment



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Outline

- Muons and Spectrometers
 - Muon decay; timing; detection; setup
- Sample Environment
 - Choosing a cryostat; Special Equipment;
- Doing an Experiment
 - Sample mounting; beam collimation; dead time; beam steering; small samples; stopping muons; frequency response; determining alpha; data archiving



Muons and Spectrometers...

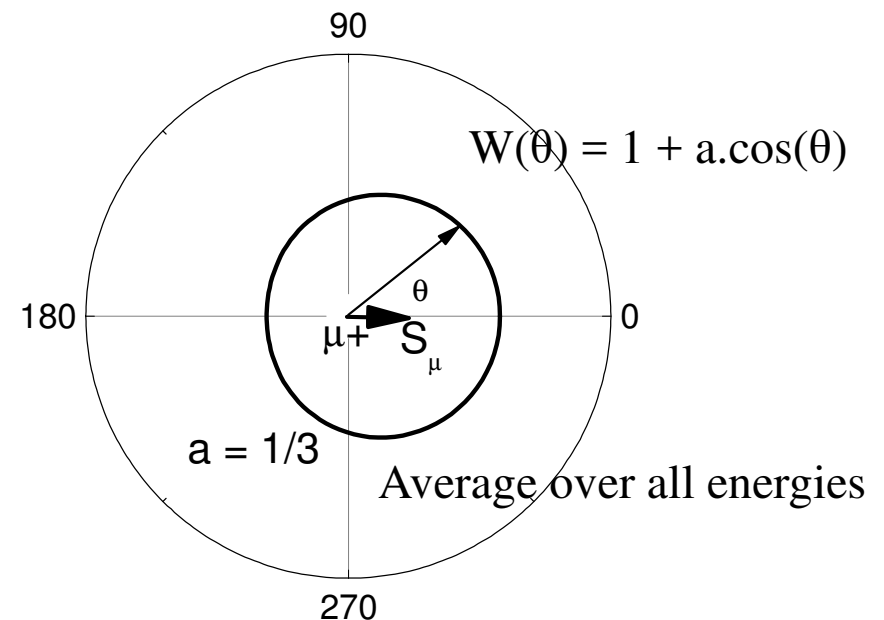


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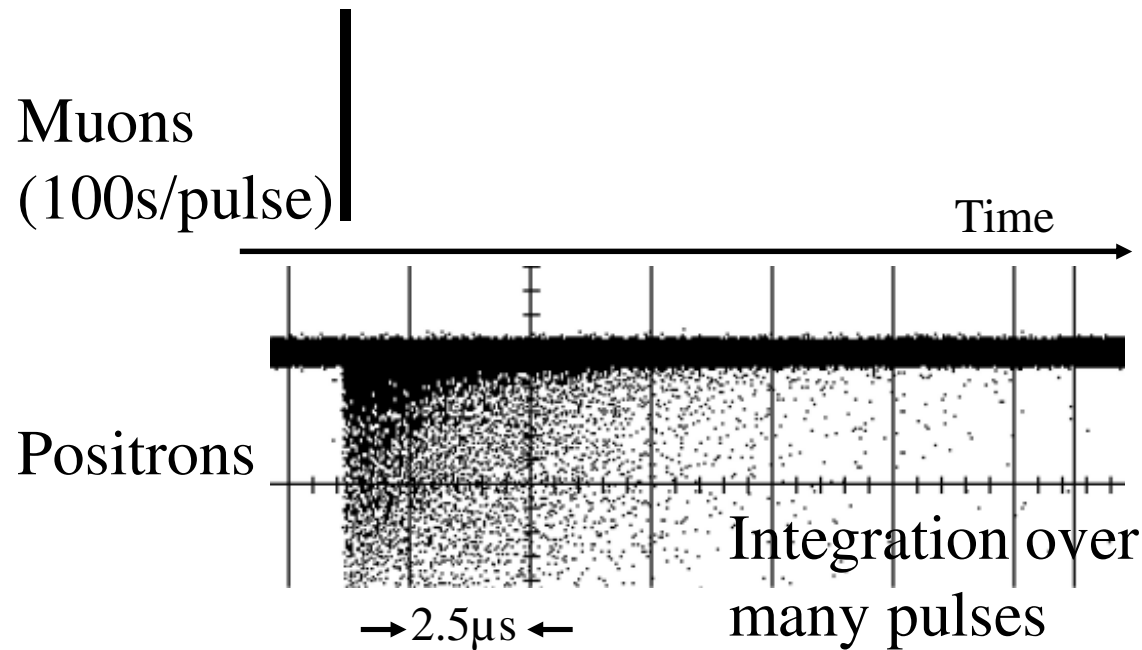
Muon Decay

- μ SR depends on **detecting positrons from implanted muons**
- Need **time of decay and direction** for time differential measurements
- Positron emitted **preferentially along S_μ**
- Positron **energies and asymmetry can be tuned** by degrader



Positron Detection

If NO time evolution of muon polarisation positron count rate is: $N(t) = N_0 \exp(-t / \tau_\mu) + B_g$



Usually, there is a time evolution of the muon polarisation. Studying this is where the physics lies.



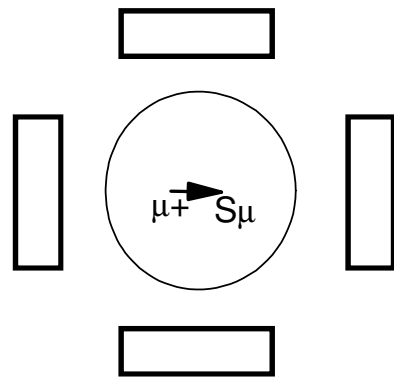
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Experiment Geometries

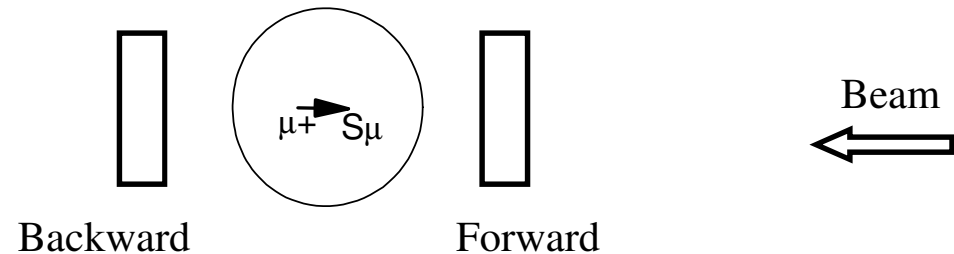
Decide on experiment, then position detectors to maximise asymmetry, count rate, etc

Transverse



Field out of screen

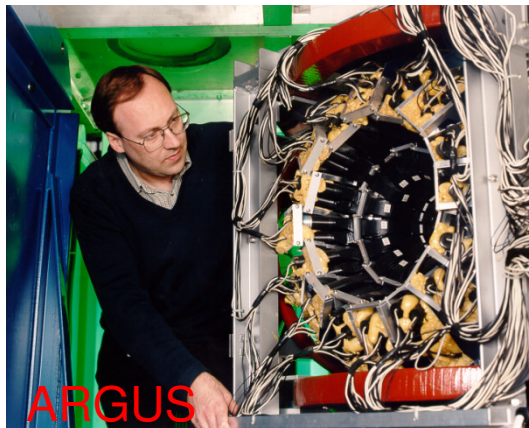
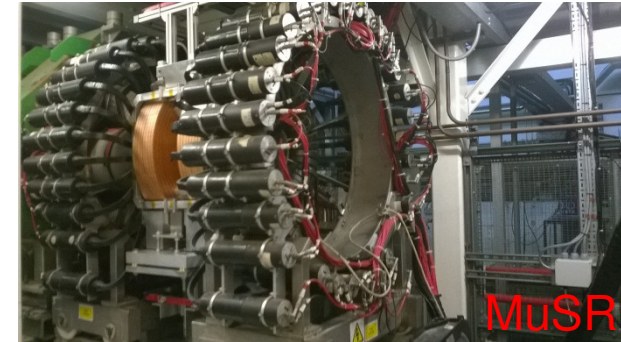
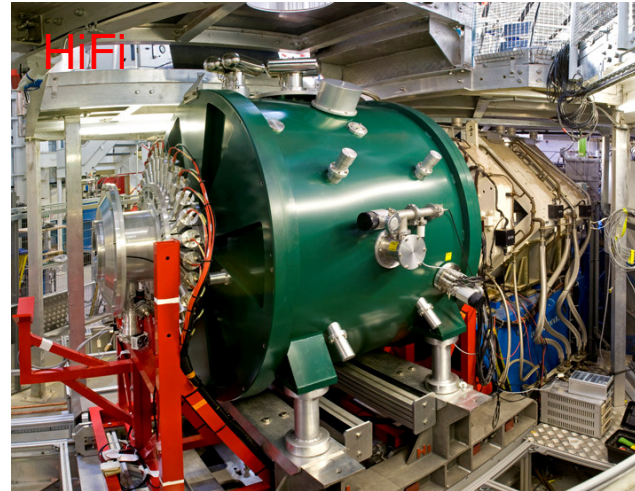
Longitudinal



Field parallel to beam



ISIS Instruments



EMU, HiFi, ARGUS (Longitudinal),
MuSR (Transverse) Instruments



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Sample Environment...



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Choosing a Cryostat: Temperature

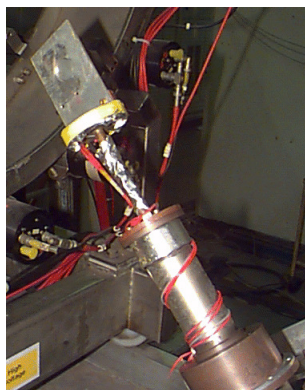


Variox
1.5K – 300K

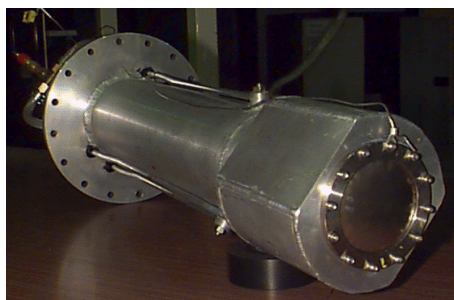


Sorb
300mK – 50K

Dilution Fridge
40mK – 4K



CCR
4K (10K) – 750K



Furnace
300K – 1500K

Choosing a Cryostat: Cooling Method

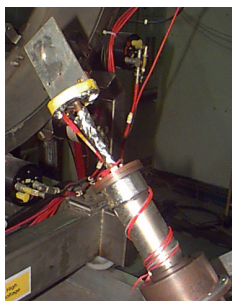


Fridge

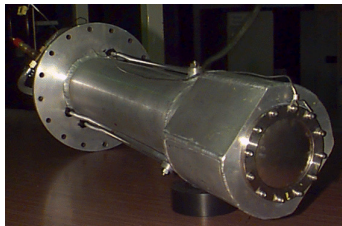
Cold Finger



Sorb



CCR



Furnace

- Fast response
- Temperature gradients
- Sample mounting needs care and additional heat shields

Exchange Gas



Variox

Flow
Cryostats

- Slow response
- Good thermal equilibrium
- Easy sample mounting

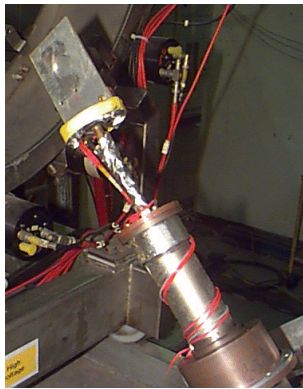


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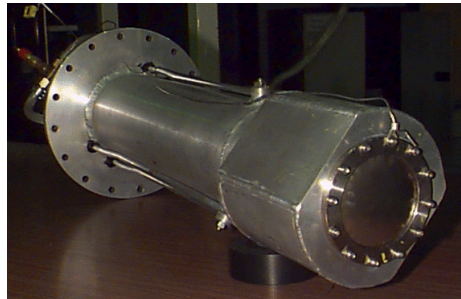
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Choosing a Cryostat: Ease Of Use

'Plug & Play'!



CCR



Furnace

Intermediate



Variox

Flow
Cryostats

Lots of Work!



Sorb

Fridge



Sci

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Choosing a Cryostat: Special Kit

Special equipment is sometimes used for experiments:

- RF
- Current (80A, 1 μ s)
- Light / Laser
- Switched E-Fields (\pm 5kV)
- Gas condensation cells
- In-situ liquid handling



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Doing an Experiment...

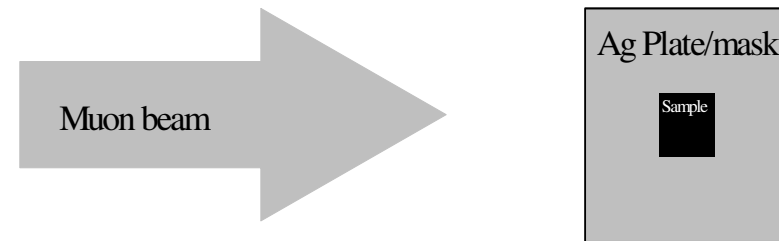


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Sample Mounting

Usual sample mounting:



The beam spot is frequently larger than the sample. Silver masks or plates are used to catch muons stopping outside the sample (silver has a very small nuclear moment).

Other factors to consider include:

- **Powders** must be contained in a recessed holders or foil packets. **Solids** can be varnished to a silver plate. **Liquids/gases** need special holders.
- Minimise thickness and maximise area.
- For cold-finger cryostats the joint to the finger and thermal shielding are crucial. Powders can be difficult to use.
- Keep in mind material properties (for the mount) – unwanted superconductivity and magnetism can play havoc with results.



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Collimating the Beam

The uncollimated muon spot is elliptical with the major axis in the horizontal direction. Horizontal collimation is achieved using slits.

The slits enable the spot to be adjusted to better match the sample size:

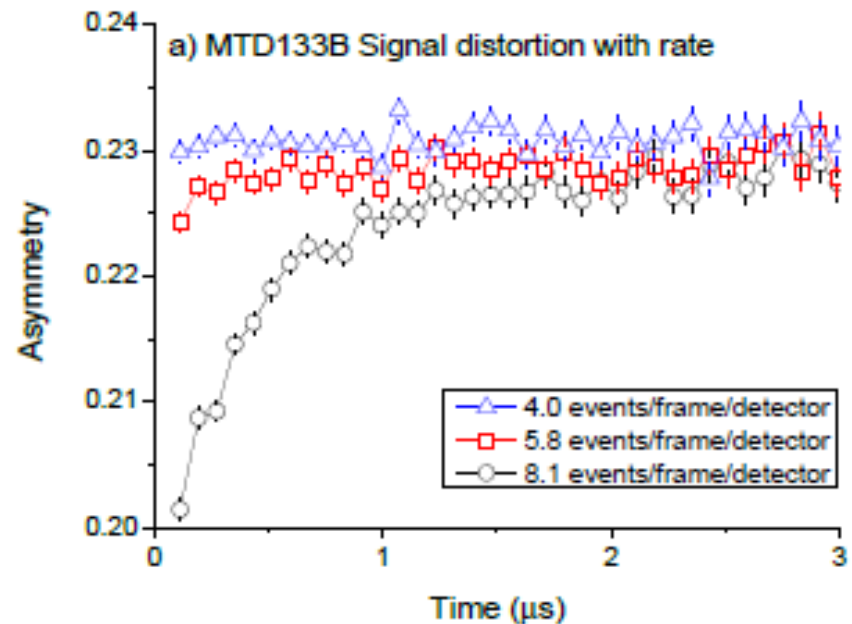
	Slit setting					
	4	8	12	16	20	30
% of beam on a 20mm mask	23%	25%	28%	31%	35%	45%
% of beam on a 24mm mask			15%		21%	
% of beam on a 28.5mm mask			8%		13%	
% of beam on a 38mm mask			2%		4%	

and the count rate to be adjusted to minimize deadtime distortion ...
(a compromise is usually necessary!)



Deciding the counting rate (considering Dead Time)

- Parts of the detector have limitations on the speed with which they can respond
- There is a ‘dead time’, τ_d , after each event during which counts are missed ... leads to distortion
- Can be modelled, calibrated and corrected for each detector
- Mantid and Wimda contain code to carry out this correction



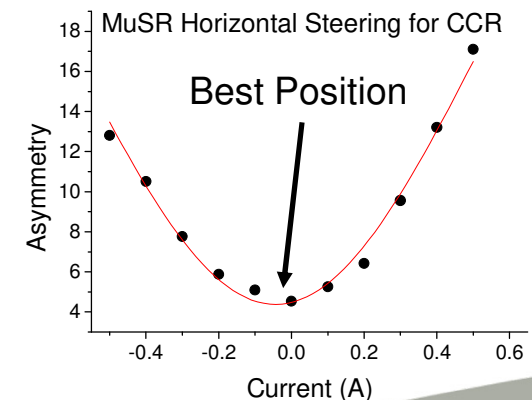
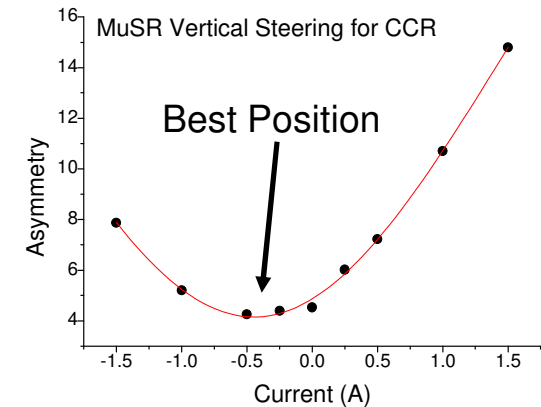
Steering the Beam

Magnets are incorporated in the beamline to adjust the position of the beam spot to ensure it is centred on the sample.

The 'best' values are determined for each cryostat and frequent checks are made.

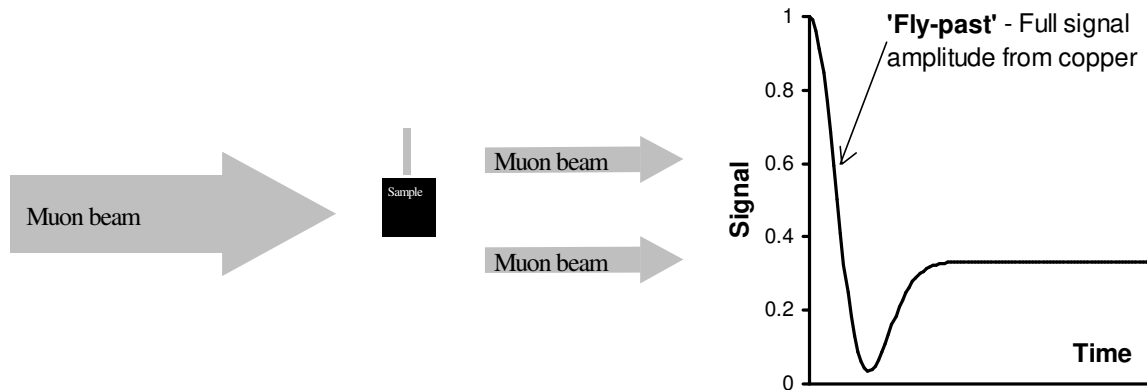
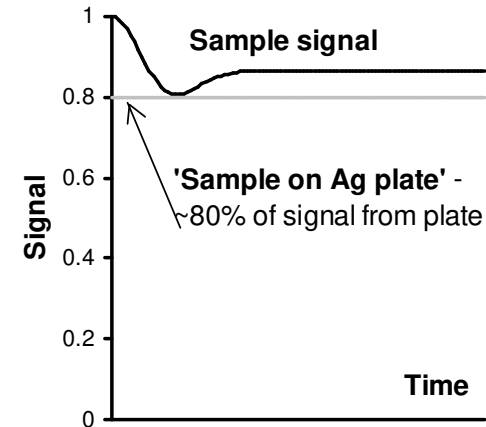
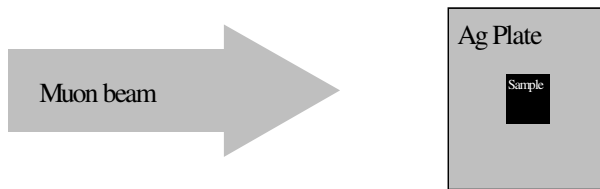
Beam steering during the experiment may be required if unusual samples are used or Transverse Fields are applied on MuSR.

The MuSR Transverse Field deflects the beam vertically and compensation must be made to ensure the beam continues to hit the sample.



Dealing with Small Samples

Usual sample mounting:



Suspending the sample allows beam not falling on the sample to 'fly-past', signal is measured only from the sample



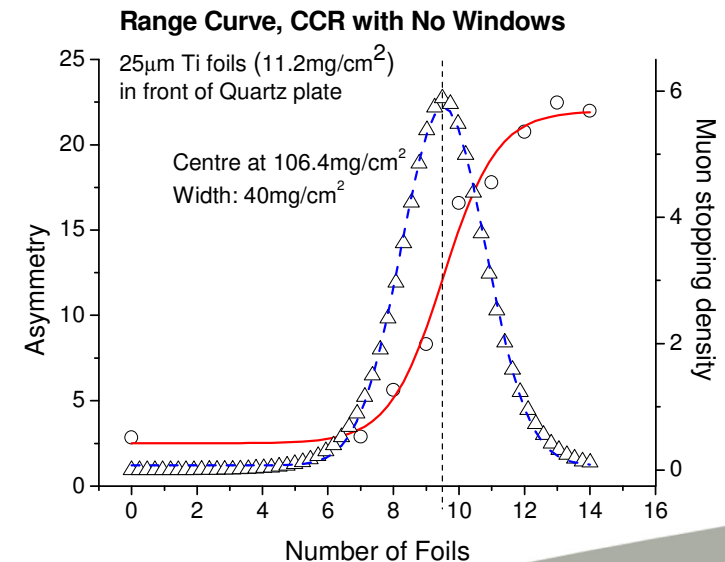
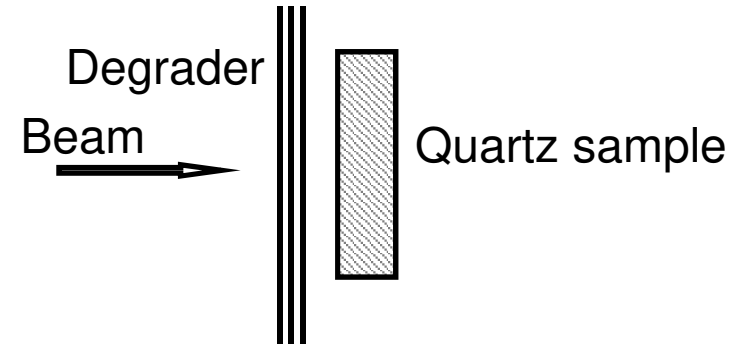
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Stopping the Muons

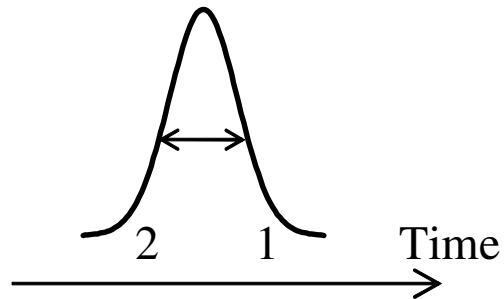
- Muons strike sample at 0.25c and are slowed by interactions with the material.
- Range is about $110\text{mg}/\text{cm}^2$ (1mm water).
- For thinner samples, degraders must be used.

Muon signal in degrader should contrast with that in the sample.



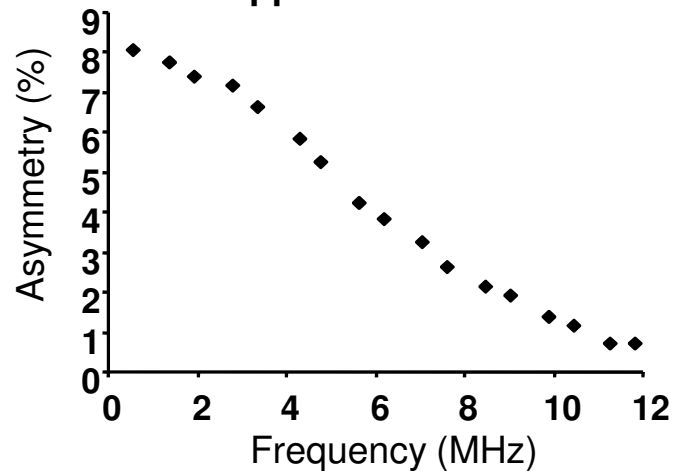
Frequency Response

Muon Pulse 80ns FWHM



In a transverse field, a phase difference will develop between muons implanted at the start ('1') and end of the pulse ('2').

Frequency response of the μ SR signal in an applied Transverse Field



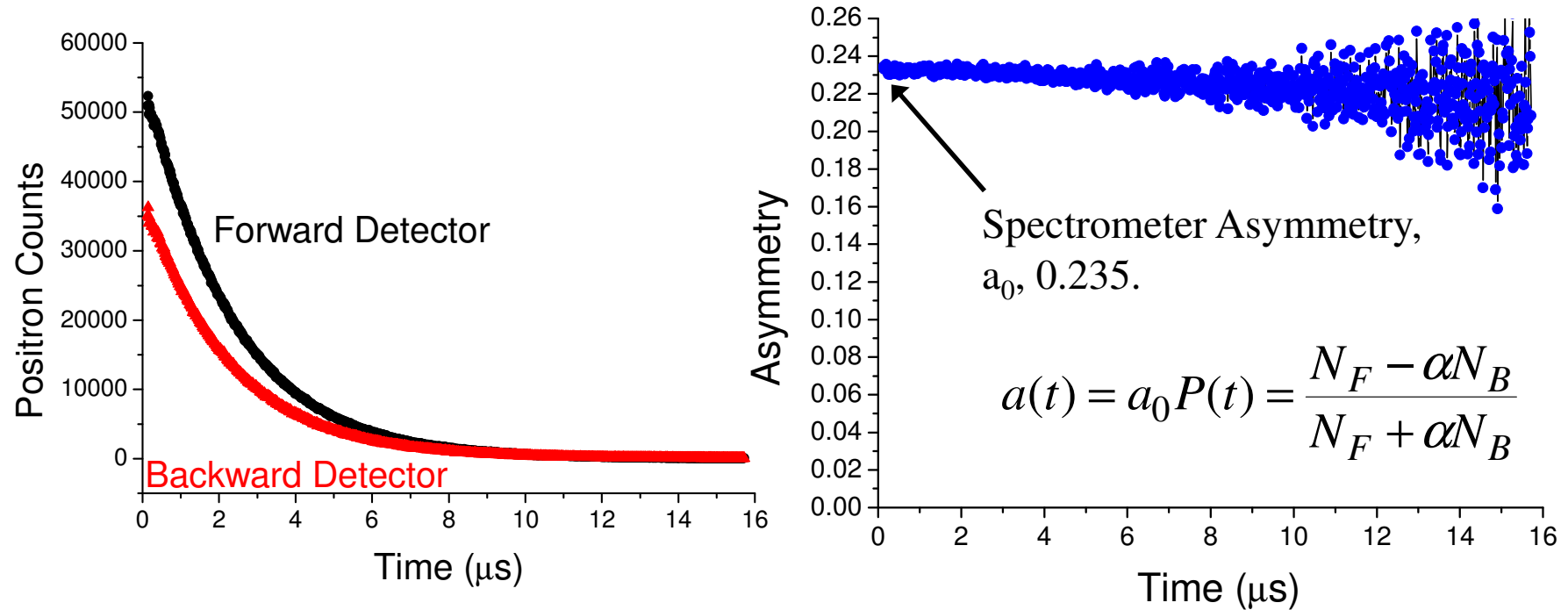
From this, about 10MHz (or $10\mu\text{s}^{-1}$ for relaxation measurements) is the limit for ISIS.



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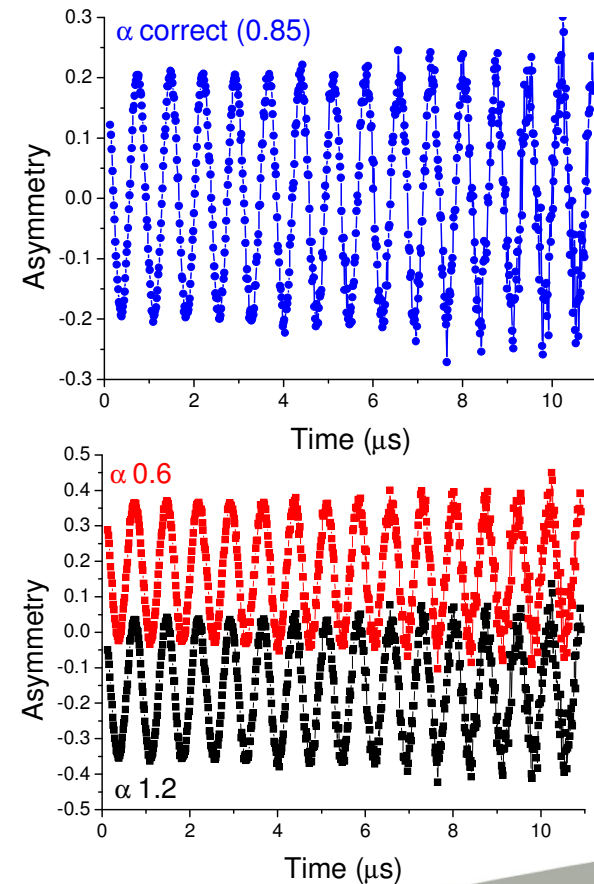
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Counts and Asymmetry

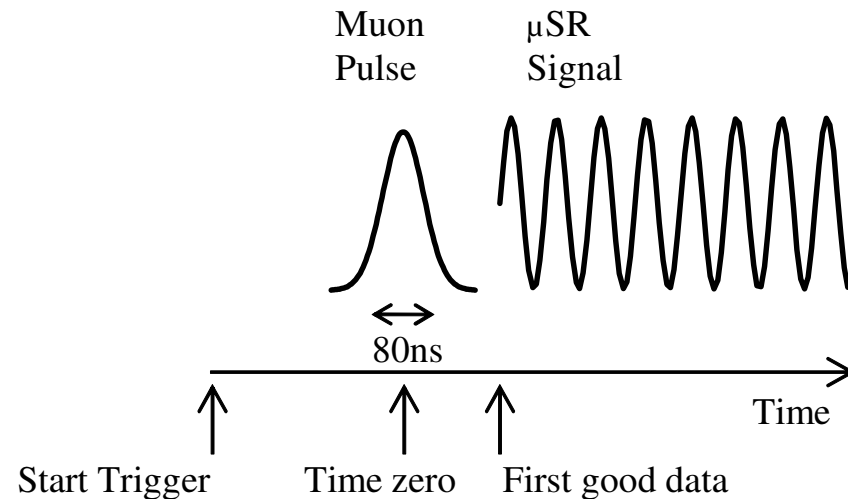


Determining Alpha

- The parameter α is dependent on sample position and detector efficiencies. It needs to be determined for each sample.
- This commonly done by applying a small field perpendicular to the initial muon polarisation.
- The muon polarisation rotates about the applied field, pointing first towards the forward detector and then towards the backward detector.
- α is adjusted such that the signal oscillates symmetrically about the time axis.



Analysing the Data



Values for ‘Time zero’ (centre of the muon pulse) and ‘First good data’ (where clean data is available) are needed for analysis.

These will have been determined in advance during instrument calibration time.



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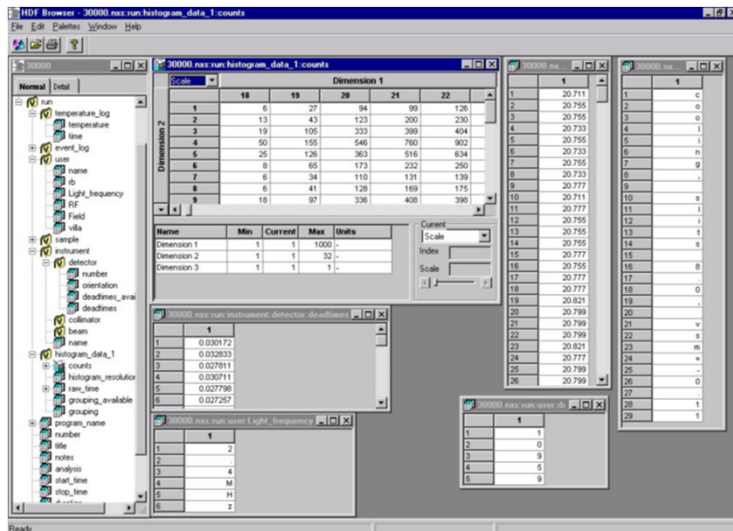
Getting the Data

Storage for analysis ...

Self describing, extensible,
portable ...

Storage for archiving ...

Searching and retrieving
your data ...



NeXus file in HDFView

The screenshot shows the STFC data portal website. The URL is <https://data.isis.stfc.ac.uk/TOPCATWeb.jsp?view//StatusMyData>. The page title is 'Science & Technology Facilities Council'. Below the header, there is a search bar and a 'My Data' section. The main content is a table of 'Get Investigations' with columns: Facility Name, Investigation Number, Visit Id, Title, Start Date, and End Date. The table contains several rows of investigation data.

Facility Name	Investigation Number	Visit Id	Title	Start Date	End Date
ISIS	720035	1	RF decoupling of the F-mu-F state	26/10/2007 10:38	01/11/2007 23:47
ISIS	720046	1	Composite Pulses in Muon Radio-frequency methods		
ISIS	720056	1	Combined Muon-Nuclear rf pulse spin echoes		
ISIS	720064	1	A Search for Vibrational Bonding in the MuD2 and MuD Reaction Systems		
ISIS	720119	1	Studies of magnetic polaron formation in EuS via RF- μ SR	05/08/2009 10:35	13/08/2009 10:19
ISIS	720189	1	Studies of Muoniated Free Radicals (MuC2H4) on Surfaces by μ SR Spectroscopy		
ISIS	720203	1	Probing the products of free radical reactions in ionic liquids	25/03/2008 15:17	01/03/2008 00:48
ISIS	720370	1	RF- μ SR in the gas phase: the muoniated ethyl radical	15/11/2007 10:09	26/11/2007 23:57
ISIS	720374	1	F-Mu-F state in calcium fluoride		
ISIS	720388	1	Kinetics of Muoniated Radicals Studied With Radio Frequency Muon Spin Resonance	03/03/2008 18:18	02/04/2008 15:12
ISIS	720436	1	A Longitudinal Field Muon Spin Relaxation Study of the Building Blocks of DNA		
ISIS	720476	1	Studies of Muon-Beam-Induced currents in semi-insulating GaAs	10/02/2008 10:51	11/02/2008 13:15
ISIS	720596	1	Muonium formation and dynamics in GaAs studied by RF- μ SR in electric fields		
ISIS	818171	1	Solvent effects on rate and equilibrium and their reaction with H ₂		
ISIS	818454	1	A new technique for slice selection and thin sample measurement in μ SR		

<https://data.isis.stfc.ac.uk/>



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Wrap Up

This lecture will hopefully have given you an insight as to the many things that need to be considered as you prepare for an experiment.

When you're running experiments later in the week use these notes as a checklist as you set things up for the measurements.



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