Doing an Experiment

Science & Technology Facilities Council
ISIS

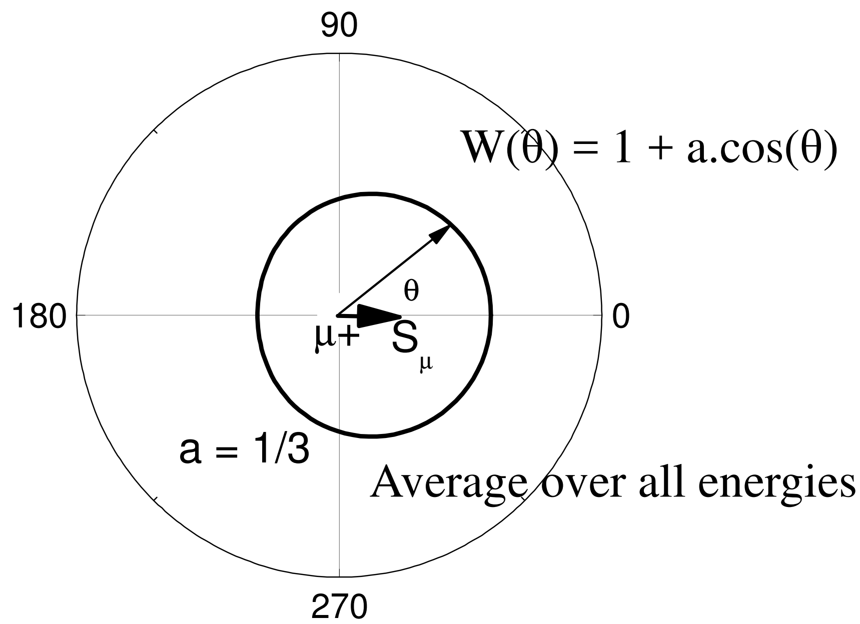
Outline

- 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…

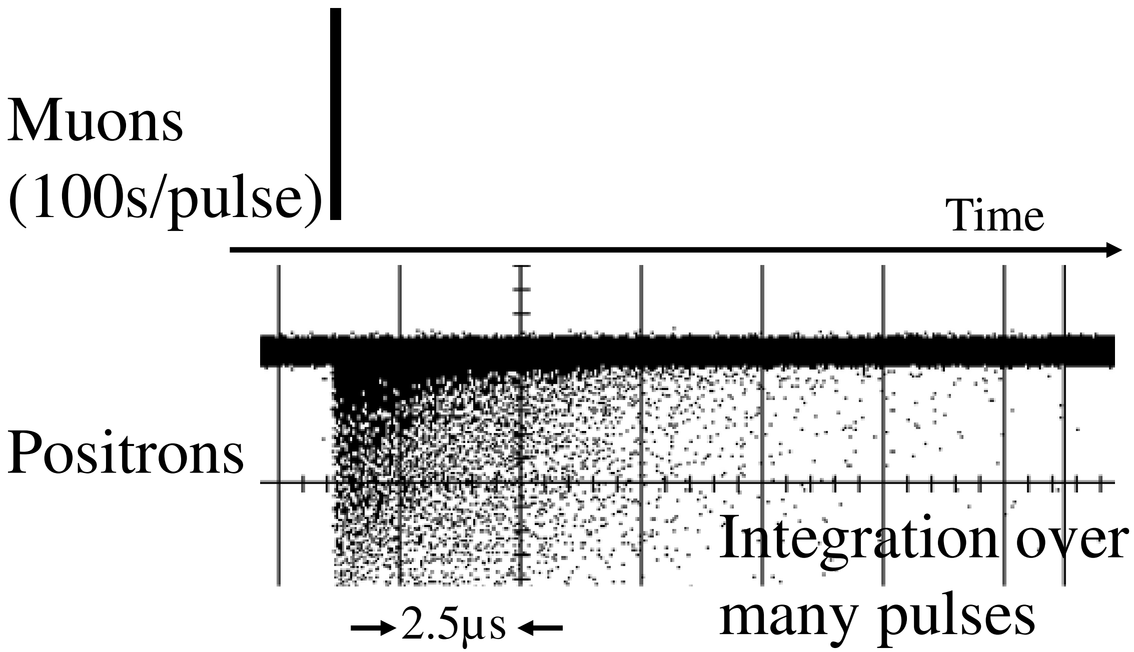
Muon Decay

- μSR 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: $N(t) = N_0 \exp(-t/\tau_\mu) + B_g$

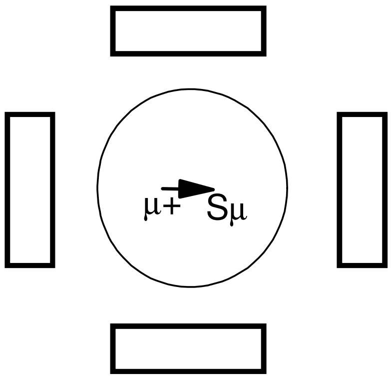


Usually, there is a time evolution of the muon polarisation.
Studying this is where the physics lies.

Experiment Geometries

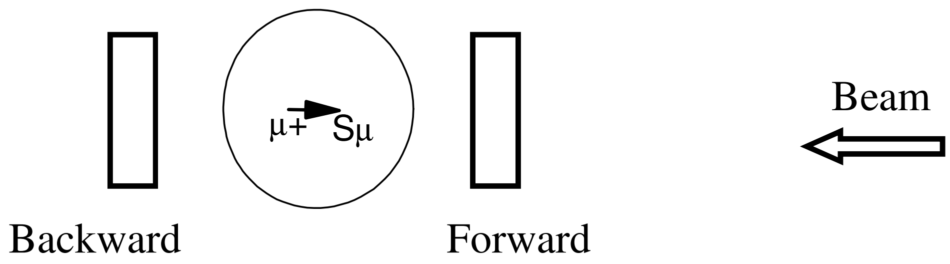
Decide on experiment, then position detectors to maximise asymmetry, count rate, etc

Transverse



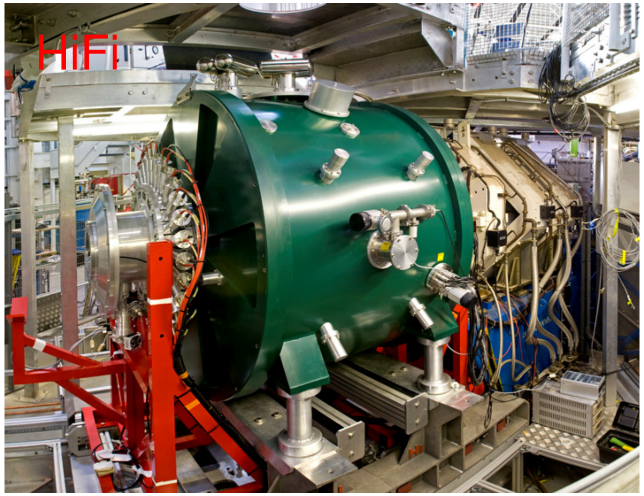
Field out of screen

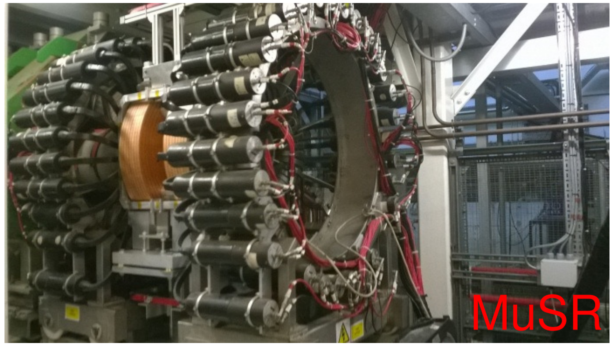
Longitudinal

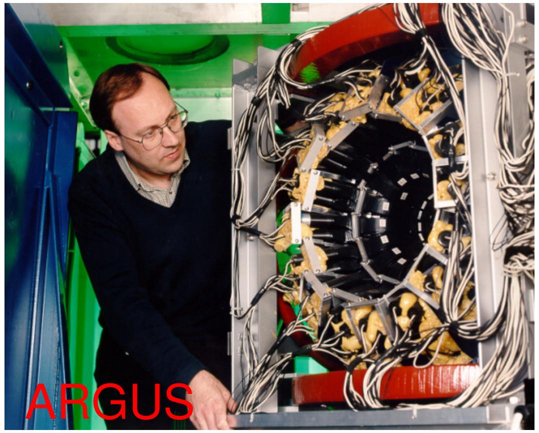


Field parallel to beam

ISIS Instruments







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

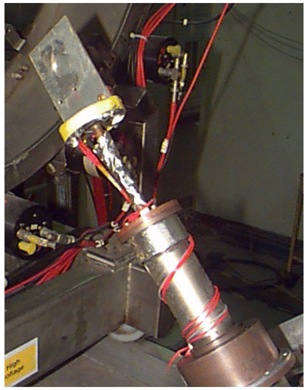
Sample Environment…

Choosing a Cryostat: Temperature

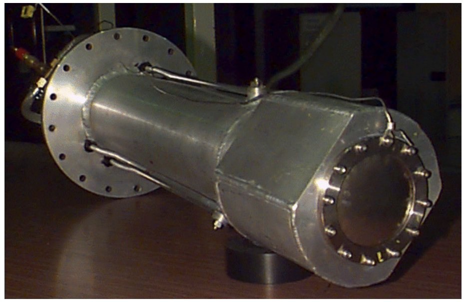
Variox
1.5K – 300K

Sorb
300mK – 50K

Dilution Fridge
40mK – 4K

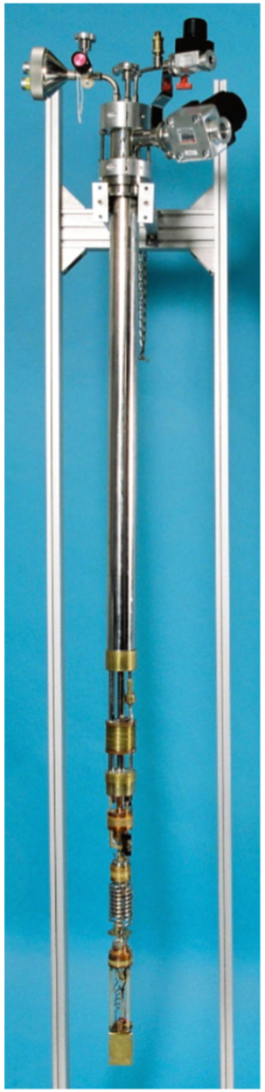


CCR
4K (10K) – 750K



Furnace
300K – 1500K

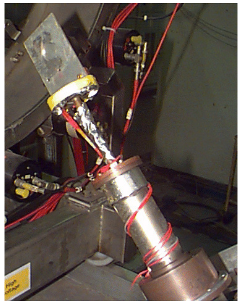
Choosing a Cryostat: Cooling Method



Fridge

Cold Finger

Sorb



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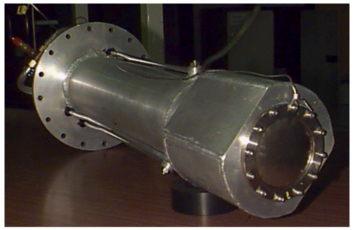


Furnace

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

Exchange Gas

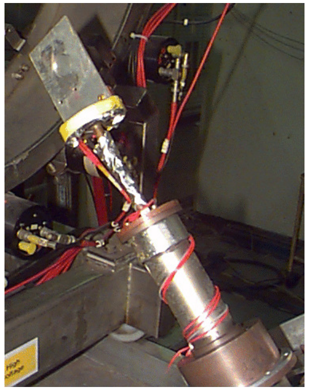
Variox

Flow Cryostats

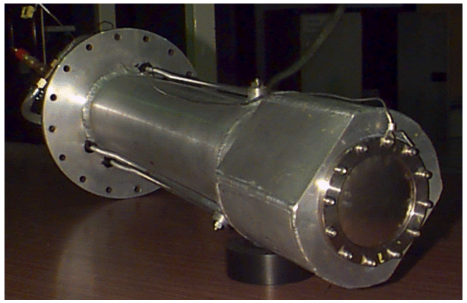
- Slow response
- Good thermal equilibrium
- Easy sample mounting

Choosing a Cryostat: Ease Of Use

‘Plug & Play’!



CCR



Furnace

Intermediate

Variox

Flow Cryostats

Lots of Work!

Sorb

Fridge

Choosing a Cryostat: Special Kit

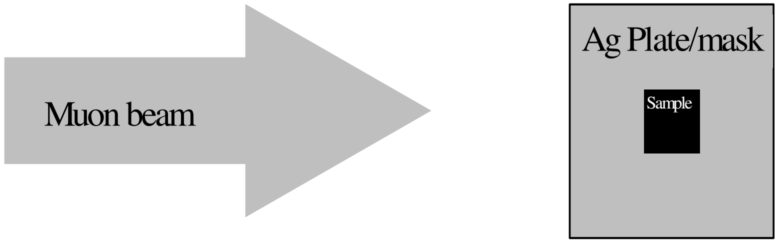
Special equipment is sometimes used for experiments:

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

Doing an Experiment...

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.

Collimating the Beam

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

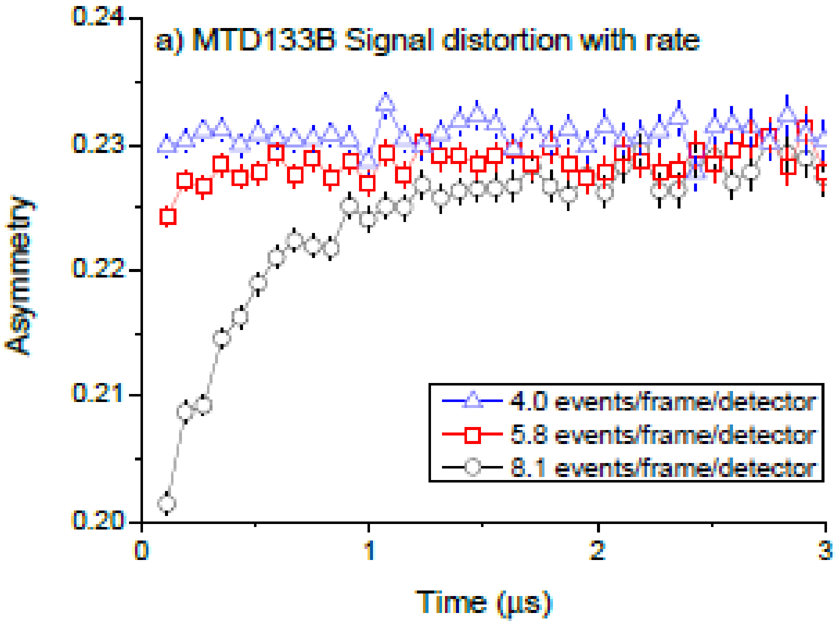
The slits enable the spot to be adjusted to better match the sample size:

	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



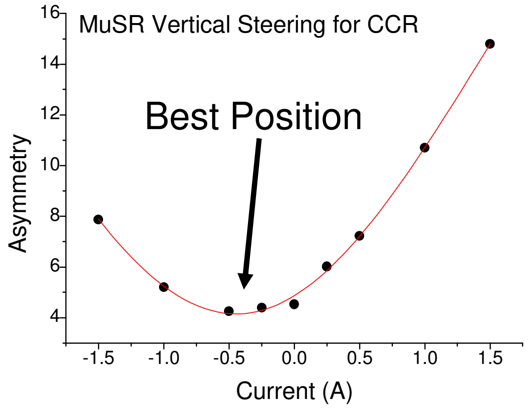
Steering the Beam

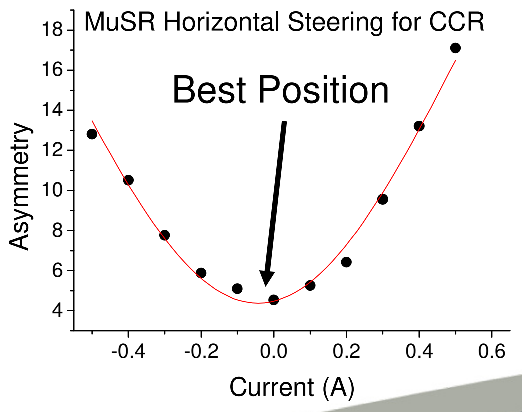
Magnets are incorporated in the beamline to adjust the position of the beam spot to ensure it is centred on the sample.

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.

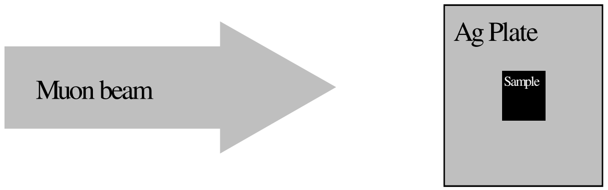
The MuSR Transverse Field deflects the beam vertically and compensation must be made to ensure the beam continues to hit the sample.

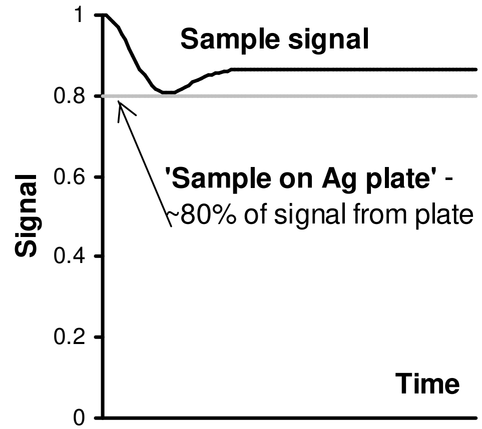


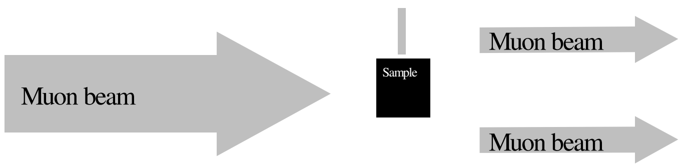


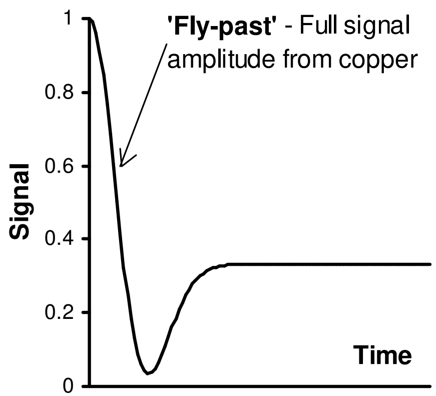
Dealing with Small Samples

Usual sample mounting:





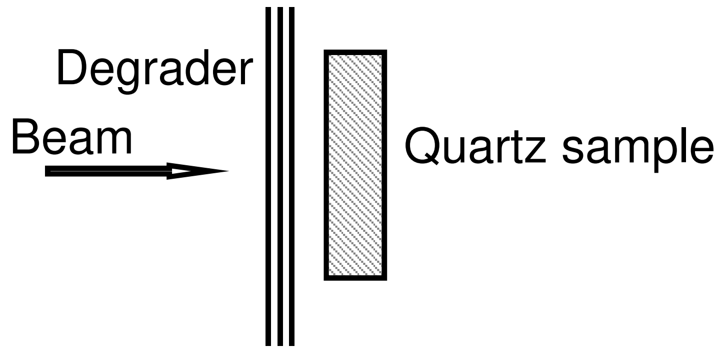


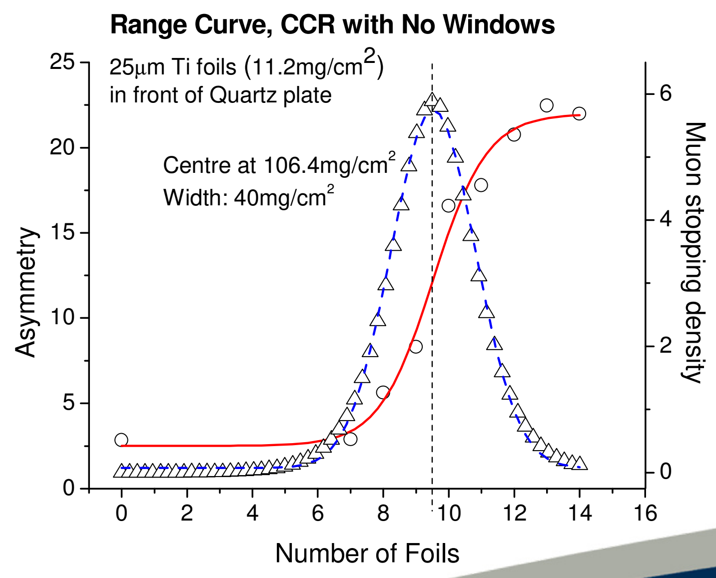


Suspending the sample allows beam not falling on the sample to 'fly-past', signal is measured only from the sample

Stopping the Muons

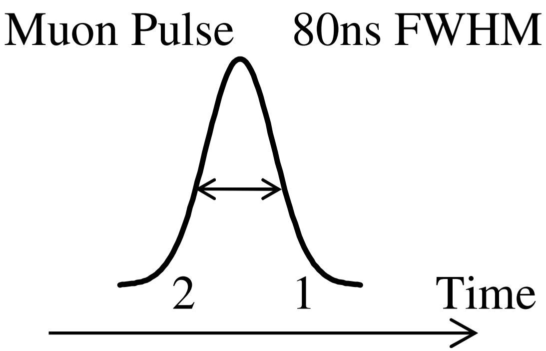
- Muons strike sample at 0.25c and are slowed by interactions with the material.
- Range is about 110mg/cm^2 (1mm water).
- For thinner samples, degraders must be used.



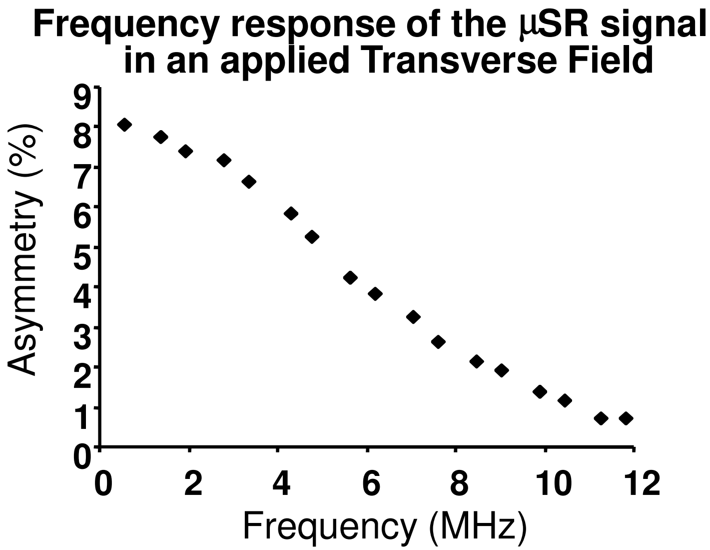


Muon signal in degrader should contrast with that in the sample.

Frequency Response

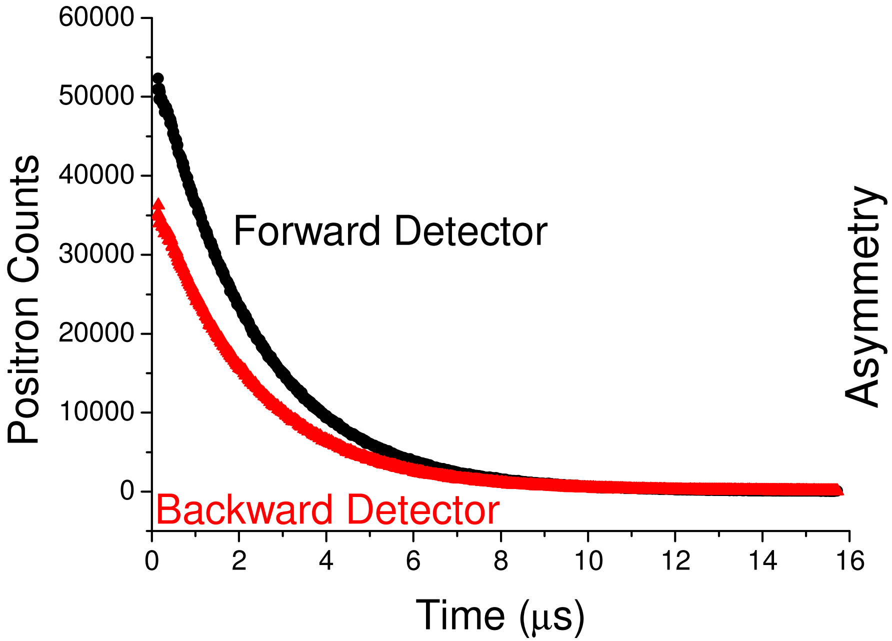


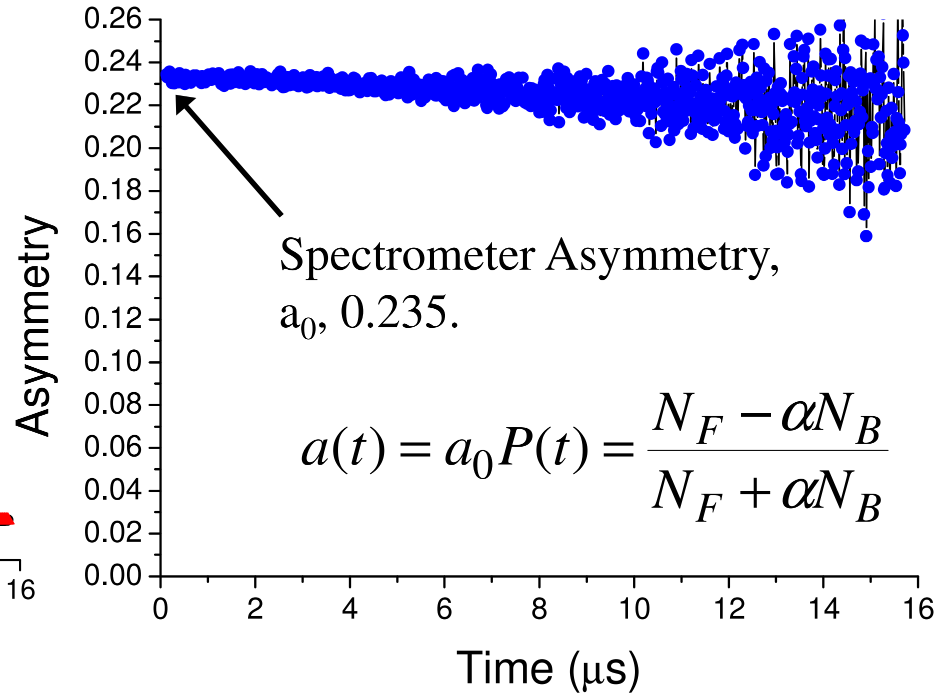
In a transverse field, a phase difference will develop between muons implanted at the start ('1') and end of the pulse ('2').



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

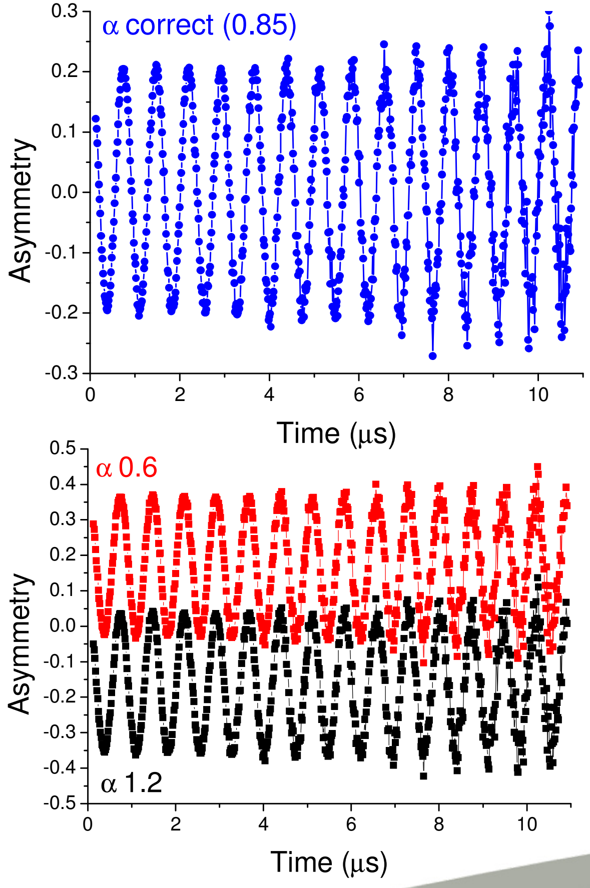
Counts and Asymmetry



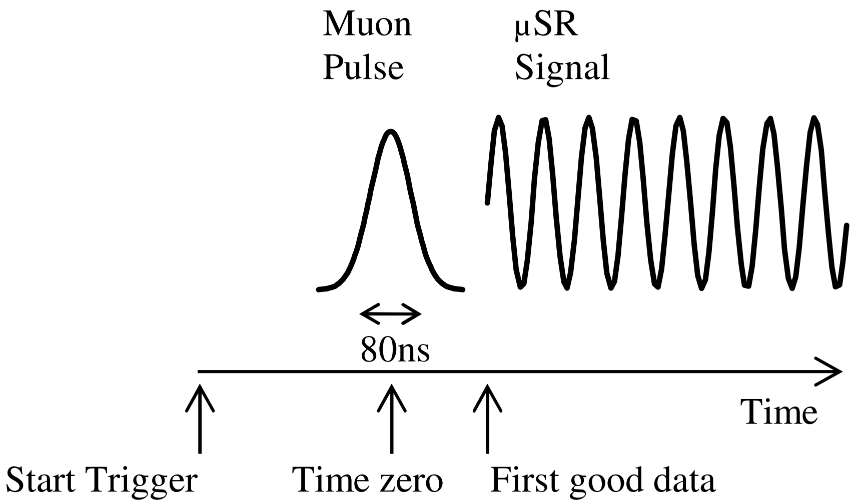


Determining Alpha

- 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.

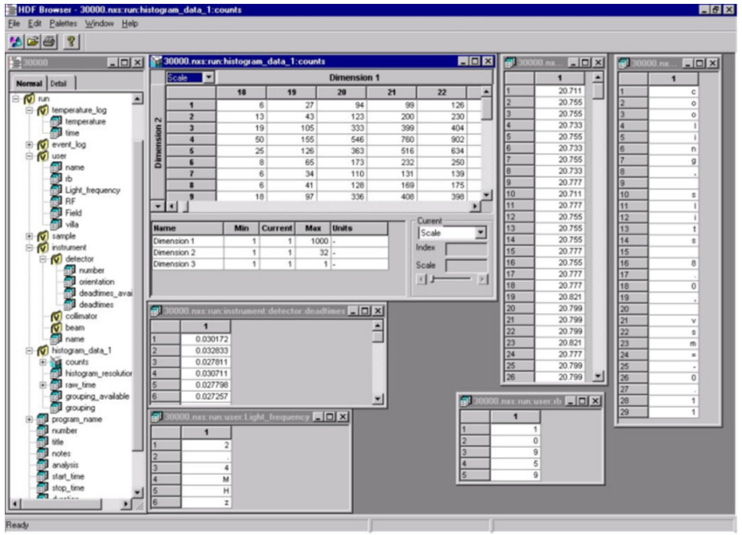
Getting the Data

Storage for analysis …

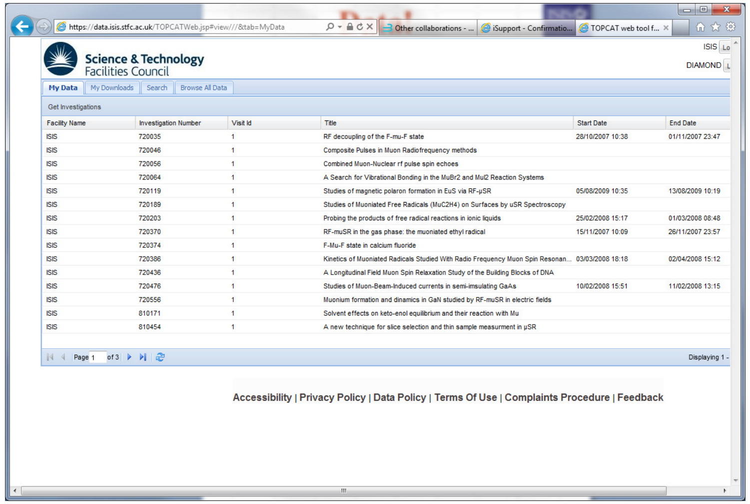
Self describing, extensible, portable …

Storage for archiving …

Searching and retrieving your data …



NeXus file in HDFView



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

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.