Doing an Experiment
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

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

\[
W(\theta) = 1 + a.\cos(\theta)
\]
Positron Detection

If NO time evolution of muon polarisation positron count rate is:

\[ N(t) = N_0 \exp\left(-\frac{t}{\tau_\mu}\right) + B_g \]

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

Beam
ISIS Instruments

EMU, HiFi, ARGUS (Longitudinal), MuSR (Transverse) Instruments
Sample Environment...
Choosing a Cryostat: Temperature

- Variox
  1.5K – 300K

- Sorb
  300mK – 50K

- CCR
  4K (10K) – 750K

- Dilution Fridge
  40mK – 4K

- Furnace
  300K – 1500K
Choosing a Cryostat: Cooling Method

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

**Exchange Gas**
- Slow response
- Good thermal equilibrium
- Easy sample mounting

**Fridge**
- Sorb
- Furnace

**CCR**

**Variox**

**Flow Cryostats**
Choosing a Cryostat: Ease Of Use

'Plug & Play'!
- CCR
- Furnace

Intermediate
- Variox

Lots of Work!
- Sorb
- Fridge

Flow Cryostats
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:

<table>
<thead>
<tr>
<th>Slit setting</th>
<th>4</th>
<th>8</th>
<th>12</th>
<th>16</th>
<th>20</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of beam on a 20mm mask</td>
<td>23%</td>
<td>25%</td>
<td>28%</td>
<td>31%</td>
<td>35%</td>
<td>45%</td>
</tr>
<tr>
<td>% of beam on a 24mm mask</td>
<td></td>
<td></td>
<td>15%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of beam on a 28.5mm mask</td>
<td></td>
<td></td>
<td></td>
<td>8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of beam on a 38mm mask</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2%</td>
<td></td>
</tr>
</tbody>
</table>

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’, $\tau_d$, 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:

- Muon beam
- Ag Plate
- Sample

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

Sample signal

'Sample on Ag plate' - 80% of signal from plate

'Fly-past' - Full signal amplitude from copper
Muons strike sample at 0.25c and are slowed by interactions with the material.

Range is about 110mg/cm² (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

Spectrometer Asymmetry, $a_0$, 0.235.

\[
a(t) = a_0 P(t) = \frac{N_F - \alpha N_B}{N_F + \alpha N_B}
\]
Determining Alpha

- The parameter $\alpha$ 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.

- $\alpha$ is adjusted such that the signal oscillates symmetrically about the time axis.
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.