Larmor Labelling

Part 2: Further Details

Robert Dalgliesh

Summary of Part 2

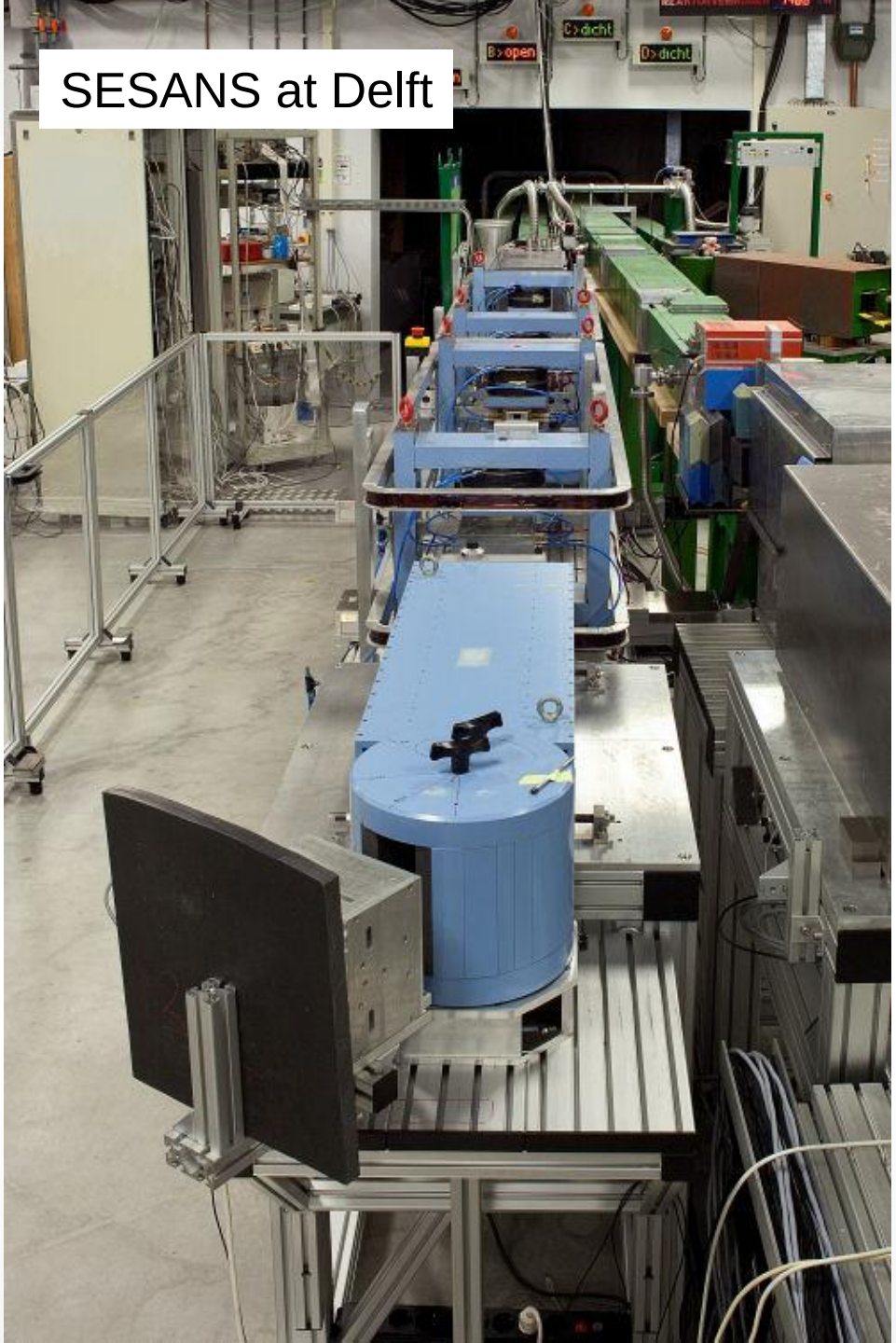
- Current Instrumentation
- SESANS at TU Delft
- OffSpec at ISIS
- SESAME
- ZETA
- Practical Issues
- Precession region options
- Future Developments

Current Instrumentation

Larmor Labelling

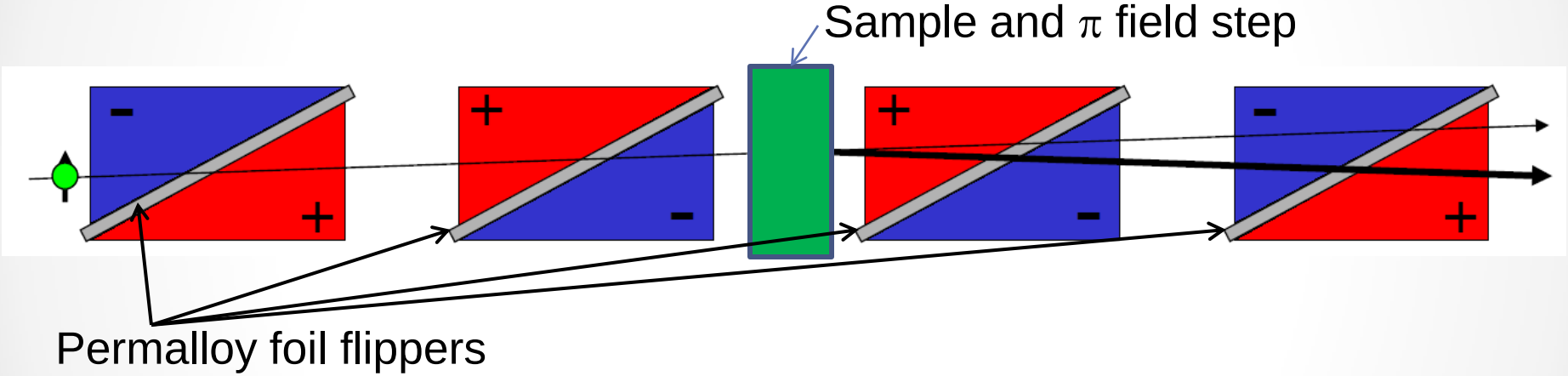
- Very few instruments world wide.
- Only 3 with permanently installed equipment
  - OffSpec at ISIS
  - SESANS at TU Delft
  - RESADA at FRM2
- One further installations that may be transported to an instrument and "rapidly" installed.
  - SESAME (Roger Pynn)
- This is indicative of the nature of the measurements and size of the current user community.

SESANS at Delft

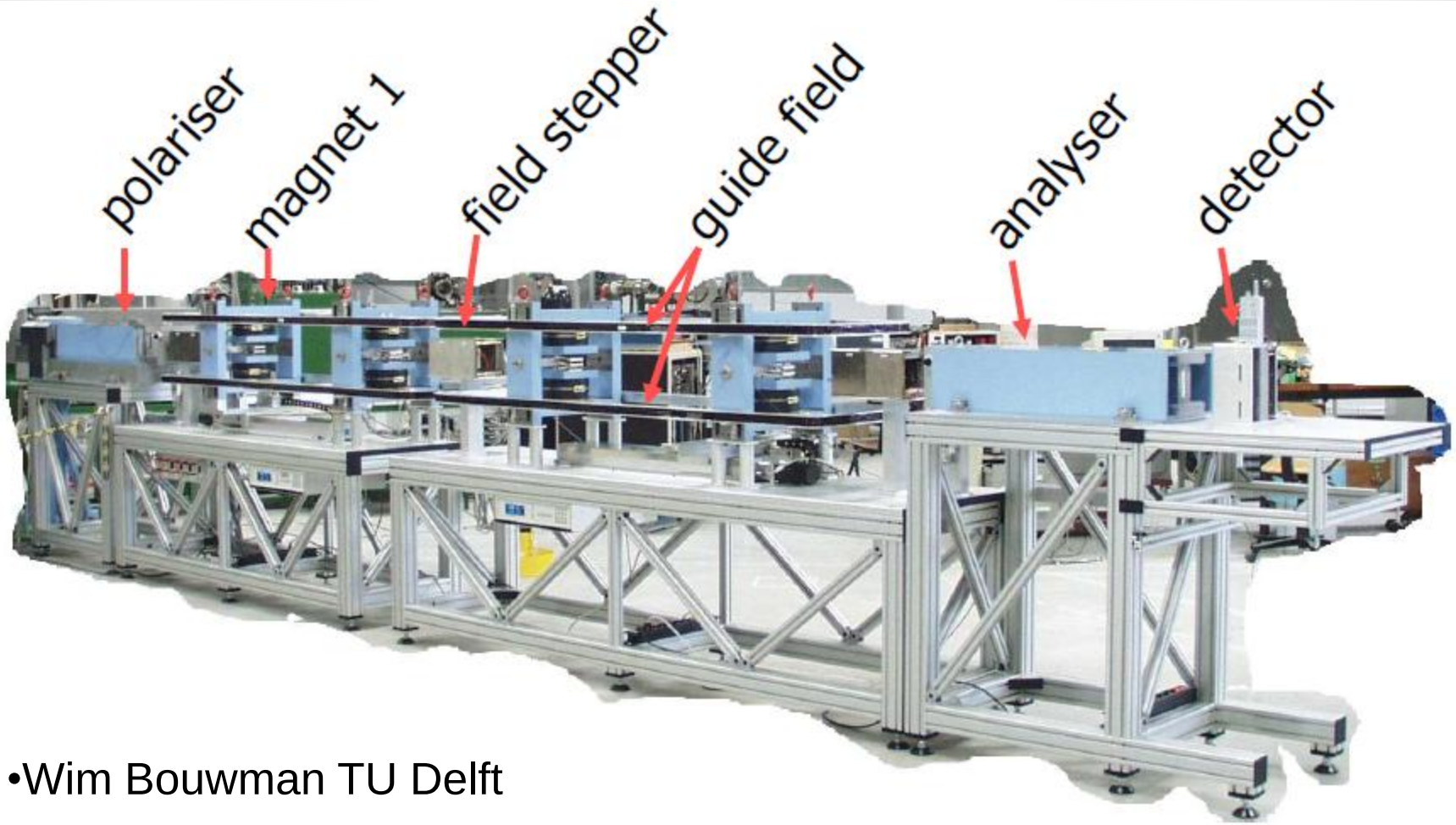


SESANS at Delft

- Monochromatic instrument ~2Å wavelength.
- Electromagnets provide the main precession field
- Thin permalloy films on silicon are used as flippers

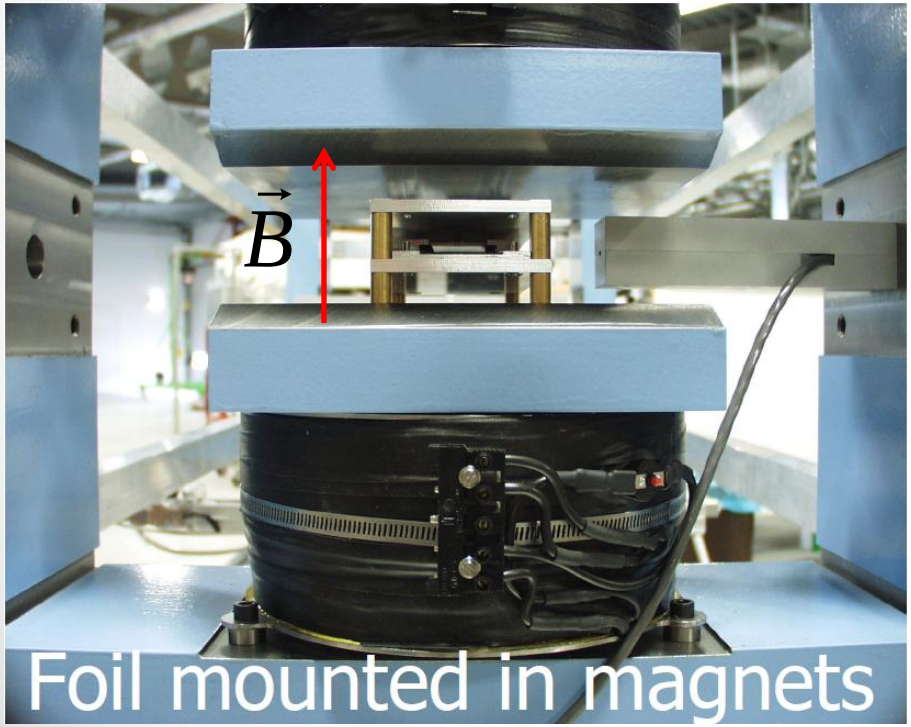


- Permanent installation used routinely to study a broad range of soft matter systems.
- Real space range 30nm-18μm



•Wim Bouwman TU Delft

- Vertical field maintained using a field probe with current feedback
- By flipping in the centre of the pole shoes some field aberrations are compensated



- Strong in-plane field within the permalloy.
- Thickness optimised to rotate the 2Å neutrons by 180°.
- Height of the beam is limited by the length and perfection of the foil.

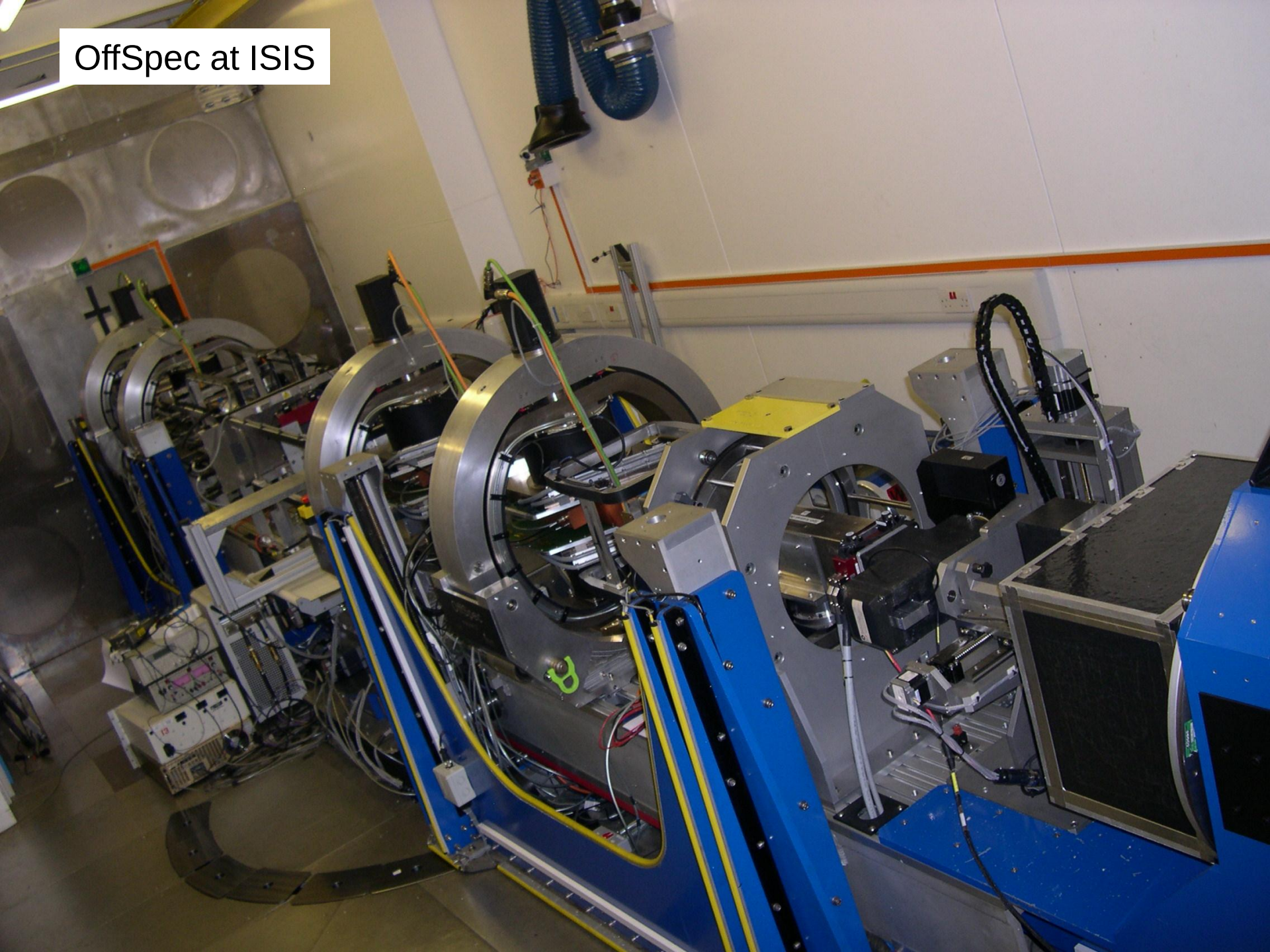
Instrument Advantages

- Low power reactor, instrument situated in guide hall with low backgrounds.
- Flexible set up mounted on optical benches.
- A wavelength of 2Å is not easily depolarised so field imhomogeneities are less of a problem.
- 2Å neutrons can travel through air without to great a flux penalty so complicated evacuated flight paths are not required.
- Delft is not currently a full time user facility so time is available to optimise and tune the setup.

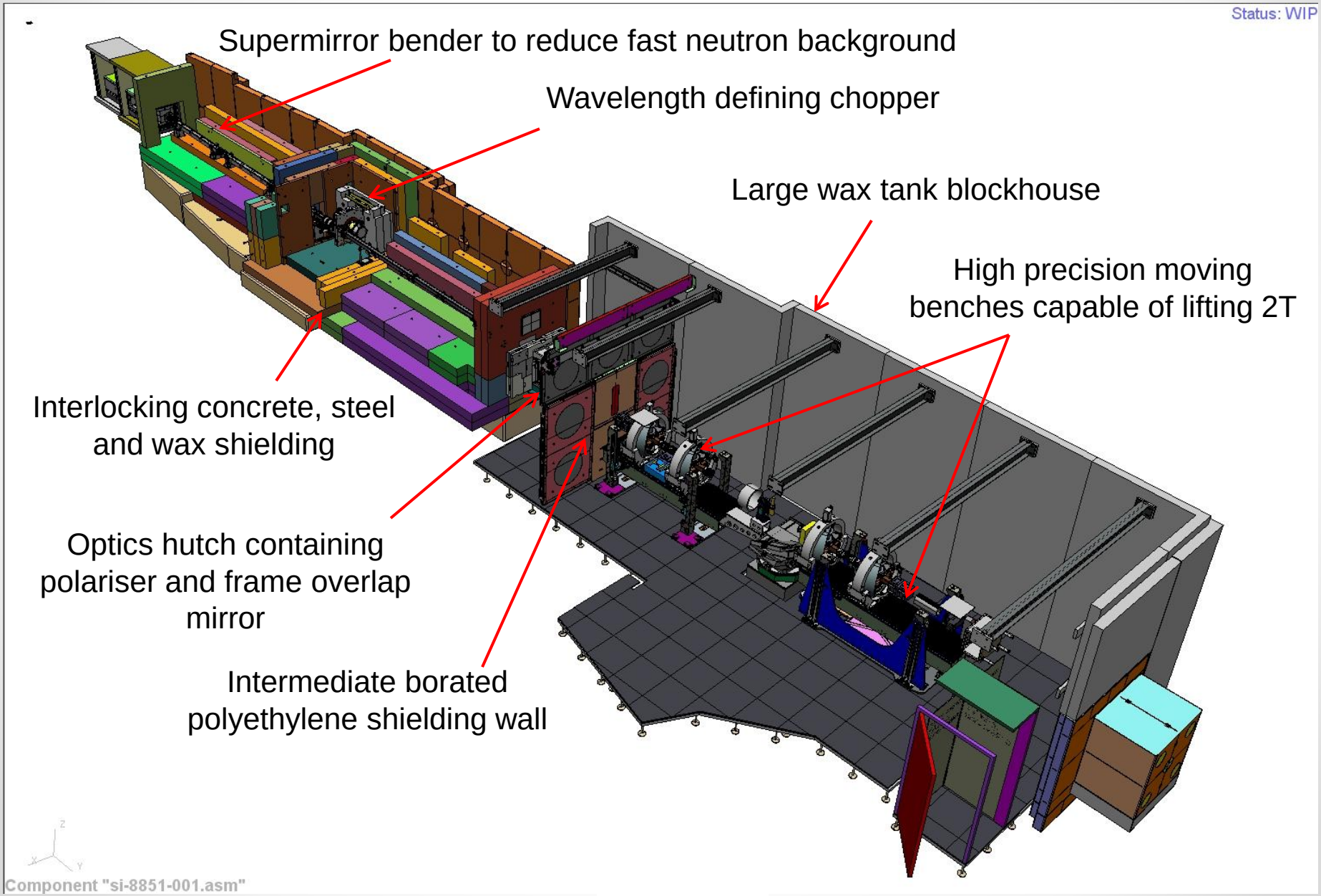
Instrument Disadvantages

- Low intensity source so samples must be stable.
- Monochromatic beam limits potential applications to the study of fast kinetic processes.
- Permalloy films are a potential source of scattering
- Permalloy films limit the maximum divergence.
- Instrument is in a large open hall which fluctuates in temperature.

OffSpec at ISIS



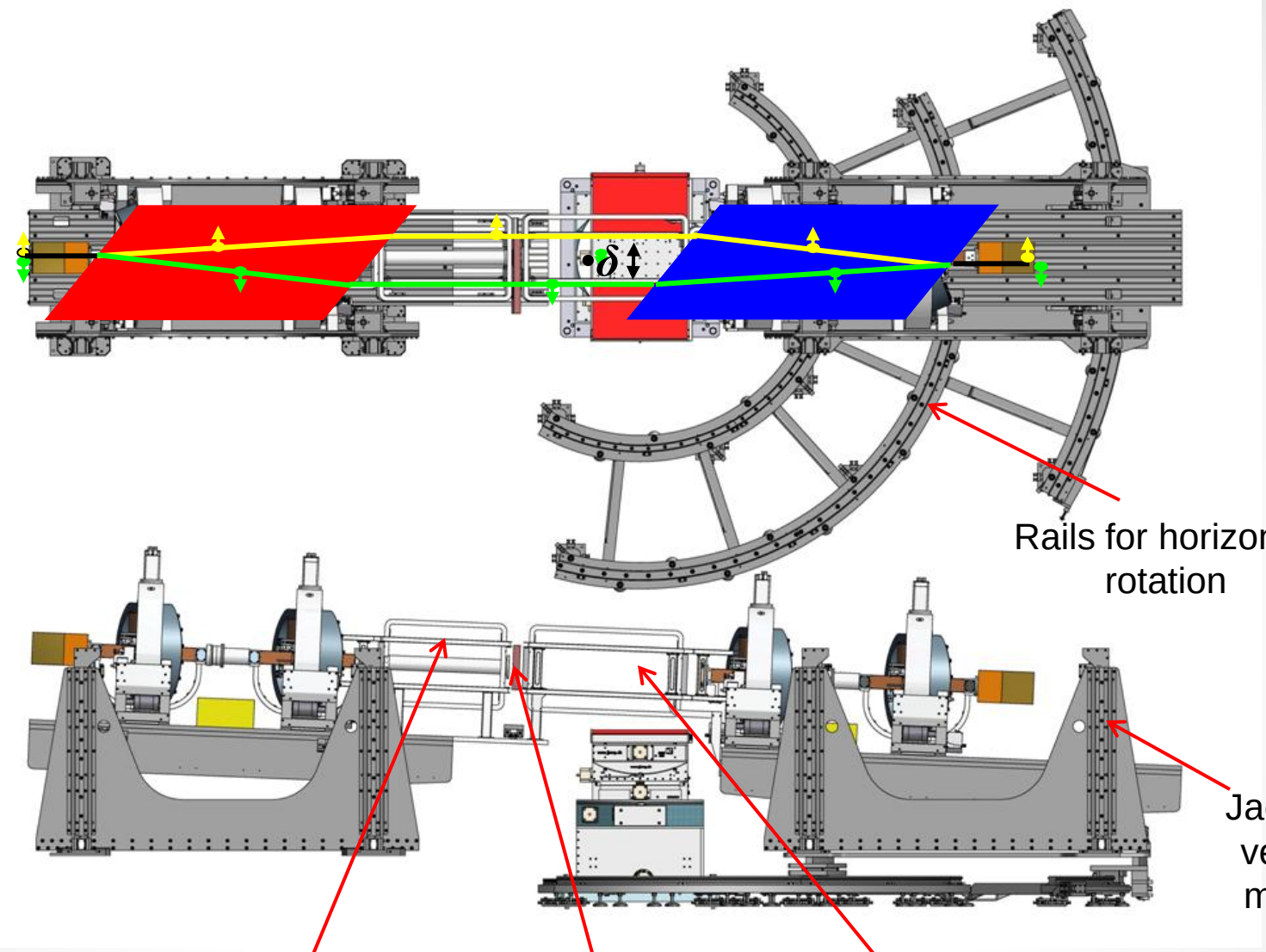
OffSpec at ISIS TS2



OffSpec at ISIS TS2

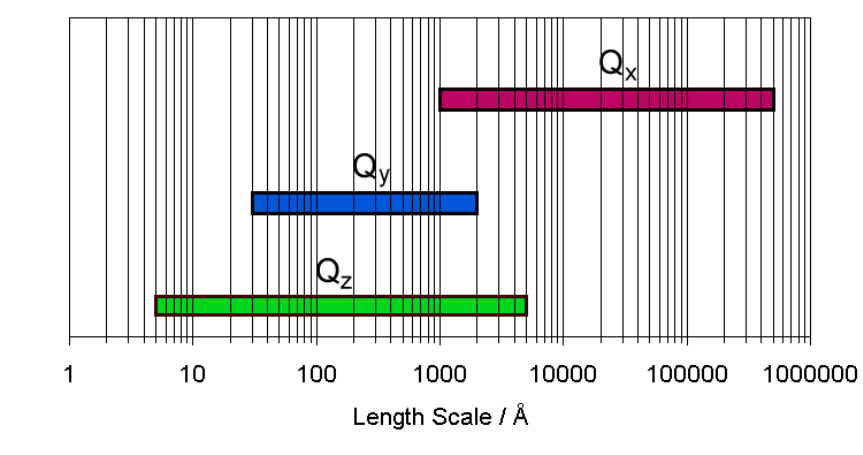
- Conceived as a low background reflectometer.
- Larmor labelling components developed in colaboration with TU Delft.

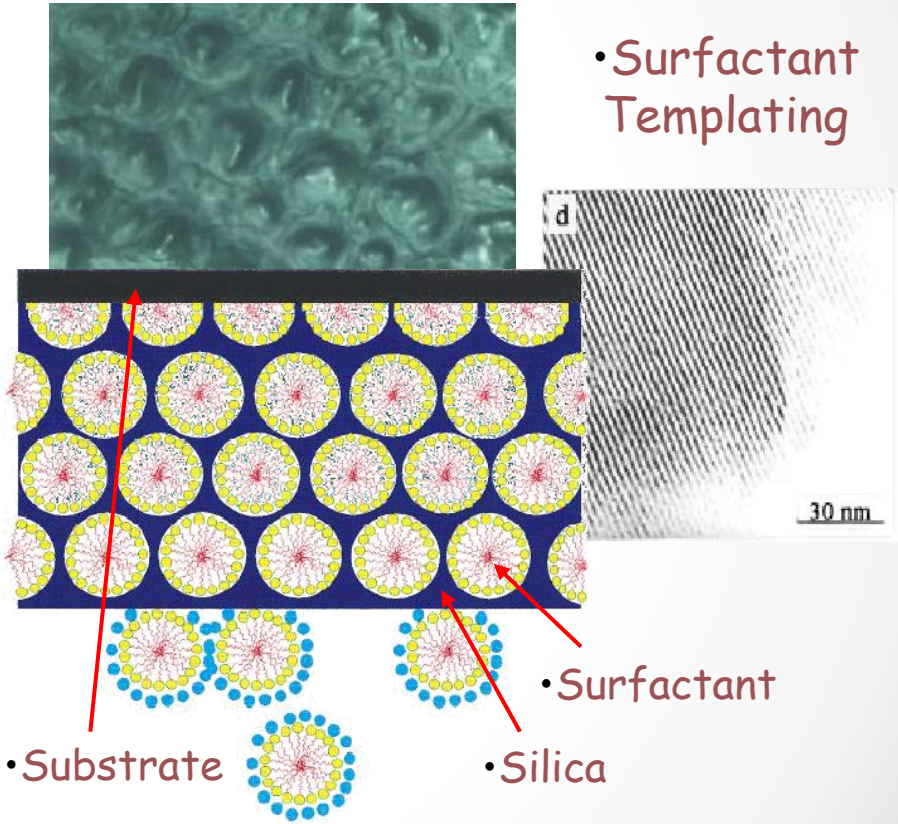
- Large RF gradient field flippers used to define precession regions.
- Magnets can be reproducibly rotated to 3 different positions
- V-coils as $\pi/2$ flippers to define the precession region.
- Stable echo for 48 hrs without retuning.


δ
Rails for horizontal rotation
Jacks for vertical motion
Horizontal and vertical guide fields
Current Screen
Sample Position

Science Program

- Mixture of Larmor labelling and neutron reflection
  - Magnetic Materials
  - Polymers
  - Biological Systems
  - Electrochemistry
  - Surfactants
  - Mesoporous Films





Instrument Advantages

- Instrument situated on ISIS TS2 which has very low backgrounds.
- Broad simultaneous wavelength band (2-14Å) suitable for the study of kinetics.
- RF flippers do not place material in the beam.
- Highly flexible magnet configuration which is permanently installed.
- Steel and wax blockhouse magnetically isolates the instrument from the external crane
- Air conditioned blockhouse keeps temperature stable to ~1°C.

Instrument Disadvantages

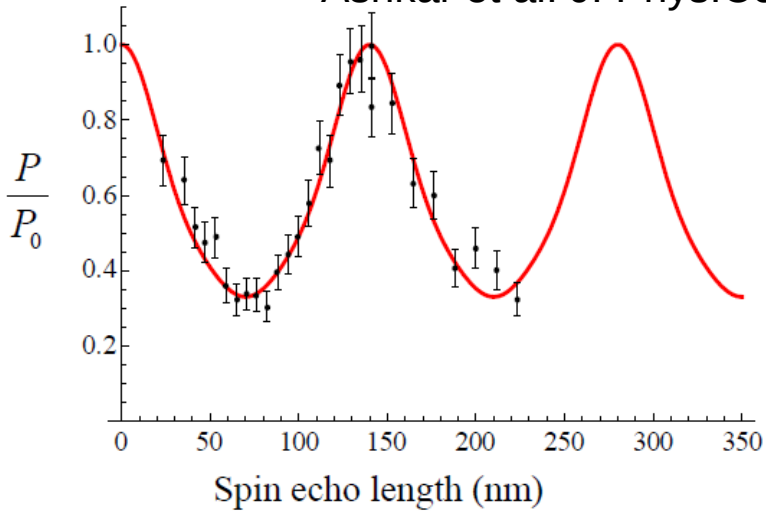
- Broad simultaneous bandwidth!
  - The wavelength dependence of the scattering process makes is difficult to optimise sample thickness with a white beam.
- The use if RF flippers and the long length of the instrument limits the divergence that can reach the detector to ~1°.
- Long wavelengths (>6Å) are more difficult to transport without polarisation losses.
- It is difficult to obtain a detector that can survive the high intensity of the peak of the ISIS TS2 pulse without saturation. Hence, the beam must be artificially collimated which increases count times.

SESAME Indiana University

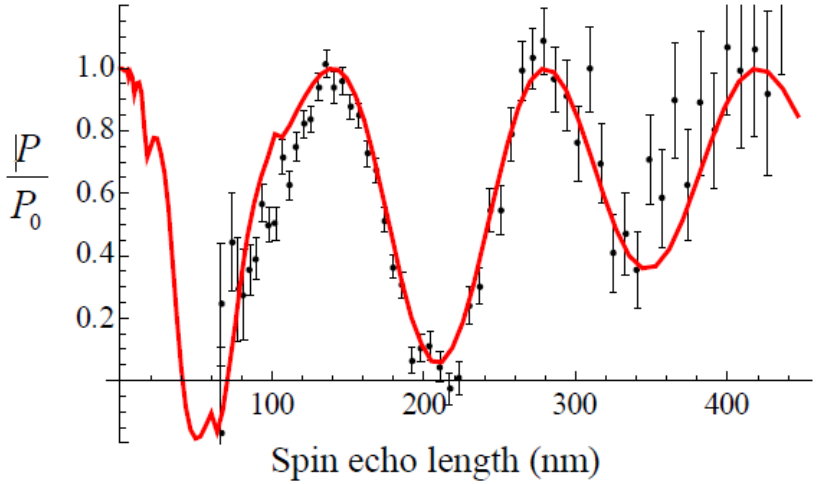
Science Program

- Used by R Pynn and his group at Indiana University to explore the practical capabilities of SESANS and SERGIS in both TOF and monochromatic modes.
- Gratings, model scattering systems used to develop new theoretical data analysis framework

•Ashkar et al. J. Phys:ConferenceSeries 251 (2010) 012066



NIST Monochromatic data



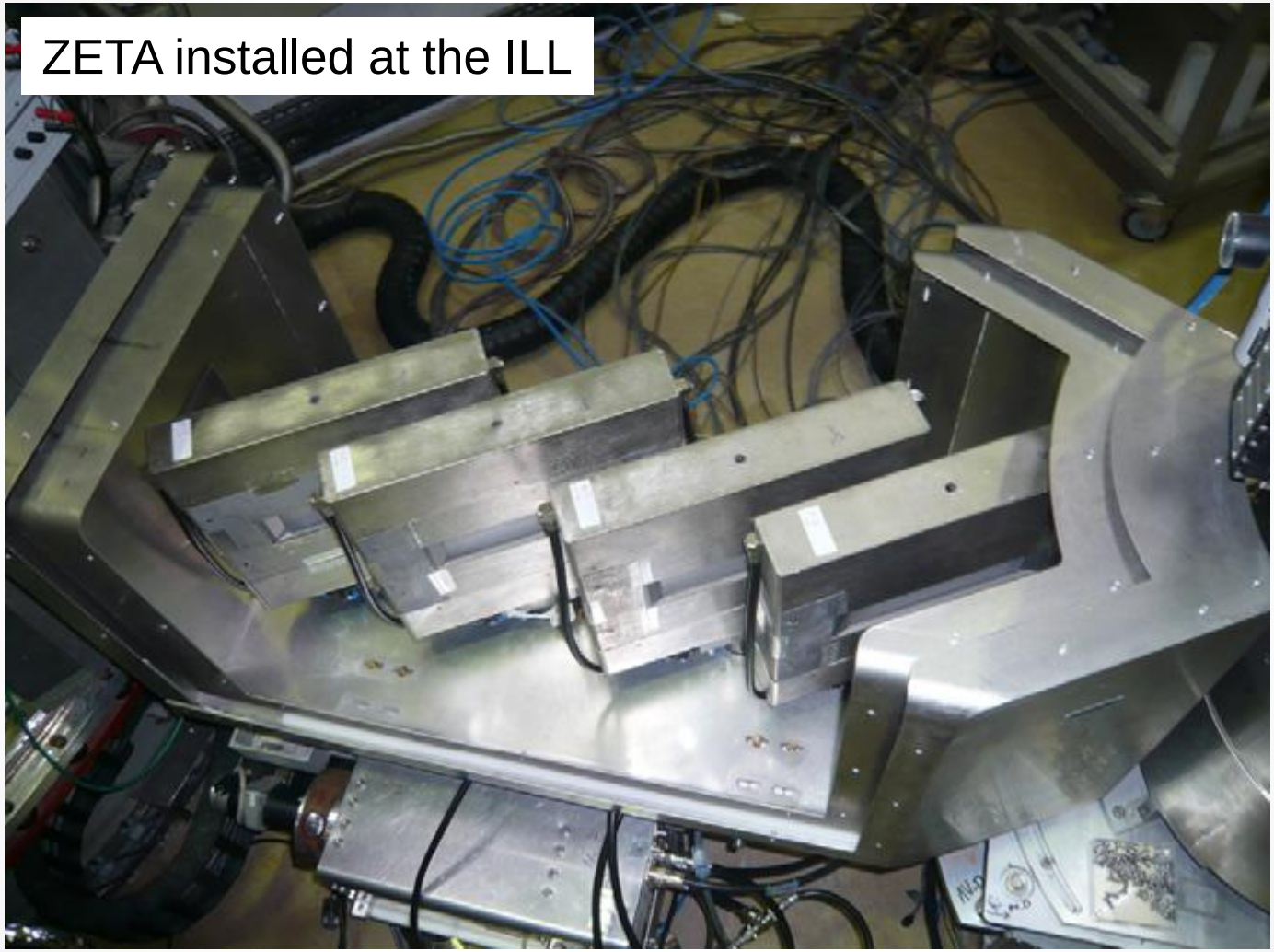
TOF Data LANSCE

Instrument Advantages

- Portable set up that can be installed on a reflectometer in a few hours.
- Can be used on both monochromatic and pulsed sources.
- The short length of the set up allows reasonable divergences to be transported.
- Triangular coils are optimised to produce a very uniform line integral.

Instrument Disadvantages

- The use of adapted solenoid coils to provide the magnetic field limits the maximum spin echo length because of thermal heating.
- The use of coils introduces significant amounts (several mm) of Aluminium into the beam which produces parasitic scatter.
- The set up is not yet fully optimised for reproducible installation and so requires significant calibration time to ensure that everything is working as expected.


ZETA installed at the ILL

Instrument Advantages

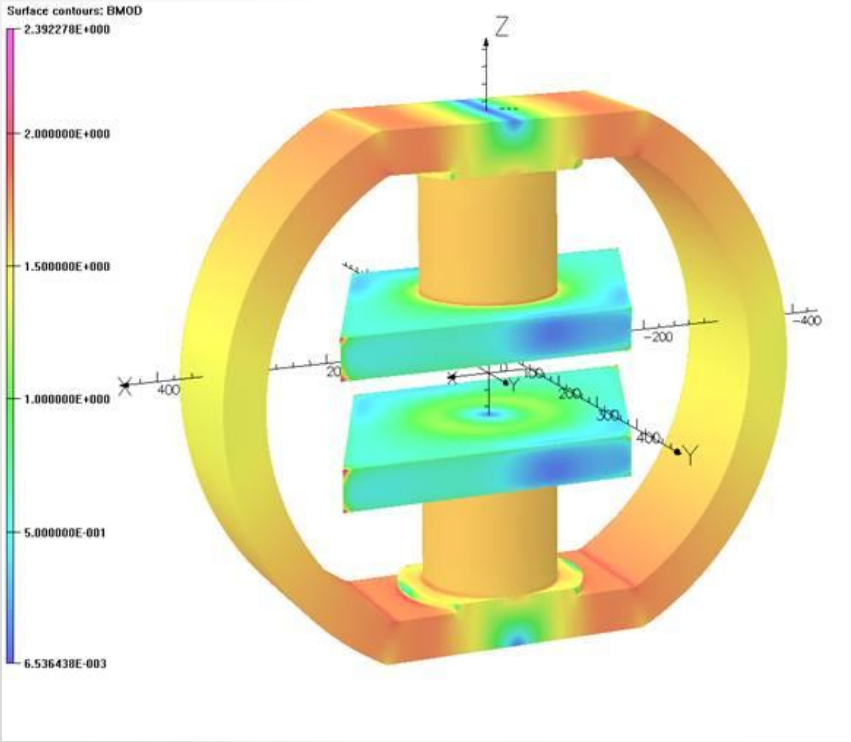
- Neutron resonant spin echo device designed with a high degree of flexibilty.
- M-metal shielded flight paths provide a very well controlled field environment that protects against changes in external field environment.
- Transportable set up. (If you have a large enough crate and space on an instrument)

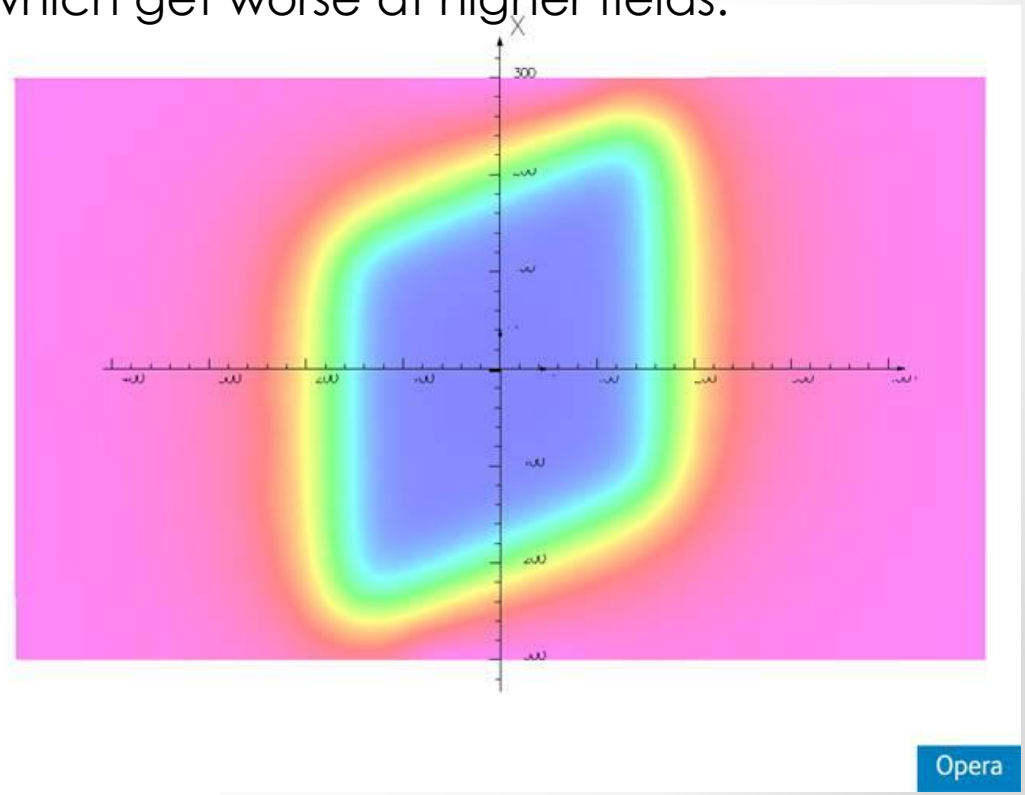
Practical Issues

- Several key components must be though about carefully.
- Precession Regions
  - Line integral aberrations must be minimised if a significant divergence is to be transported
- Flippers
  - Efficient flipping over a large beam size is essential. It is not necessarily easy to combine flexibility of setup with this requirement.
- Non-magnetic beamline components
  - Standard beamline components such as diaphragms are not necessarily easy to obtain with low magnetic effects. Stepper drives, encoders and lead screws can all cause problems.
- Guide fields
  - Careful design of guide fields around the beam and sample position are important for day to day use.
- Make sure you have enough space!

Precession Regions

- OffSpec and SESANS-Delft
  - Unenclosed edges of the electromagnet poles lead to uncorrected aberrations.
  - Gets worse the closer to sharp corners you go
  - Cannot use current elements to compensate as they introduce other uncompensated fields.
  - Solution is to flip in the middle and to use symmetry.
  - There are still aberrations which get worse at higher fields.

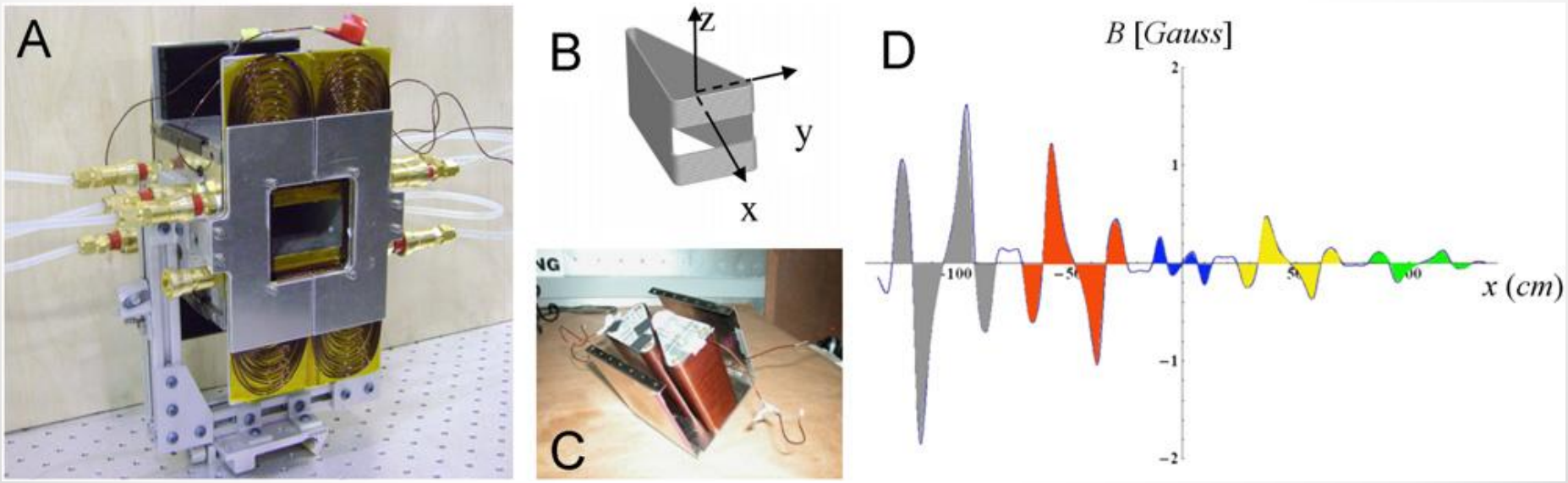




Precession Regions

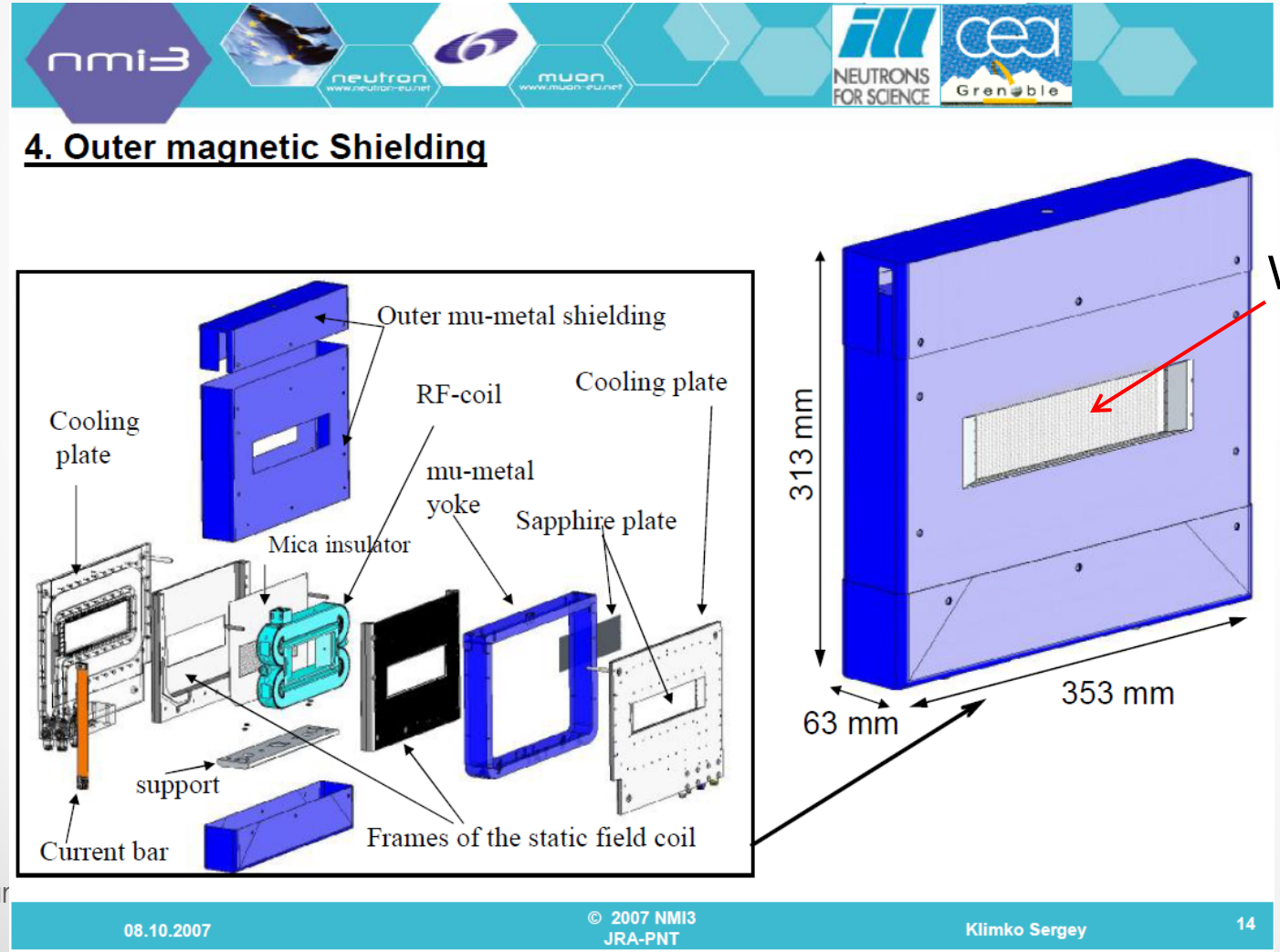
- SESAME set up.
  - Carefully optimised solenoids to remove aberration by symmetry.
  - Hole in side of coil allows for a continuous guide field and removes some aluminium from the beam
  - Ultimate polarisation limited by edge effects from the wires.

Pynn et. al., Physica B 406 (2011) 2350–2353



Precession Regions

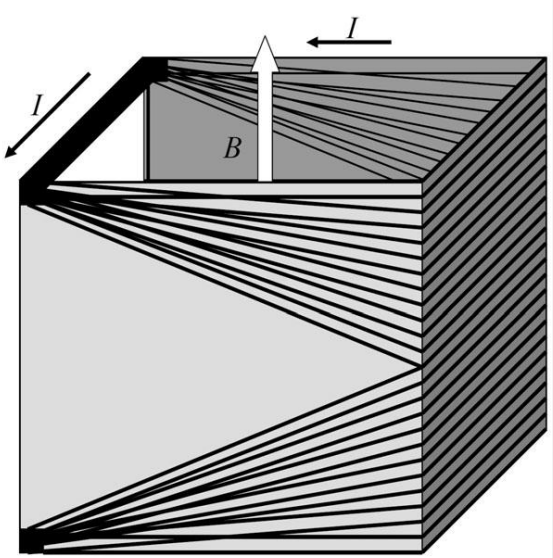
- Bootstrap Coils
  - Large amount of work in recent years to increase window size and remove second order effects
  - E.g. http://jra4.neutron-eu.net/FILES/PNT-CEA.pdf



Flippers

- Numerous designs exist.
  - Don't over complicate things.
  - If a simple well characterised design will do the job make use of it. This is particularly true for monochromatic instruments where there is a larger range of choices.
  - Take care to minimise the amount of material in the beam particularly if long wavelengths are required.

- OffSpec V-coils
  - A necessary complication that resulted from running out of room! and the instrument complexity. (5 modes)
  - The stray fields form the analyser and polariser would have spoiled the performance of other devices
  - Compromise means that it is difficult to achieve >95% polarisation.



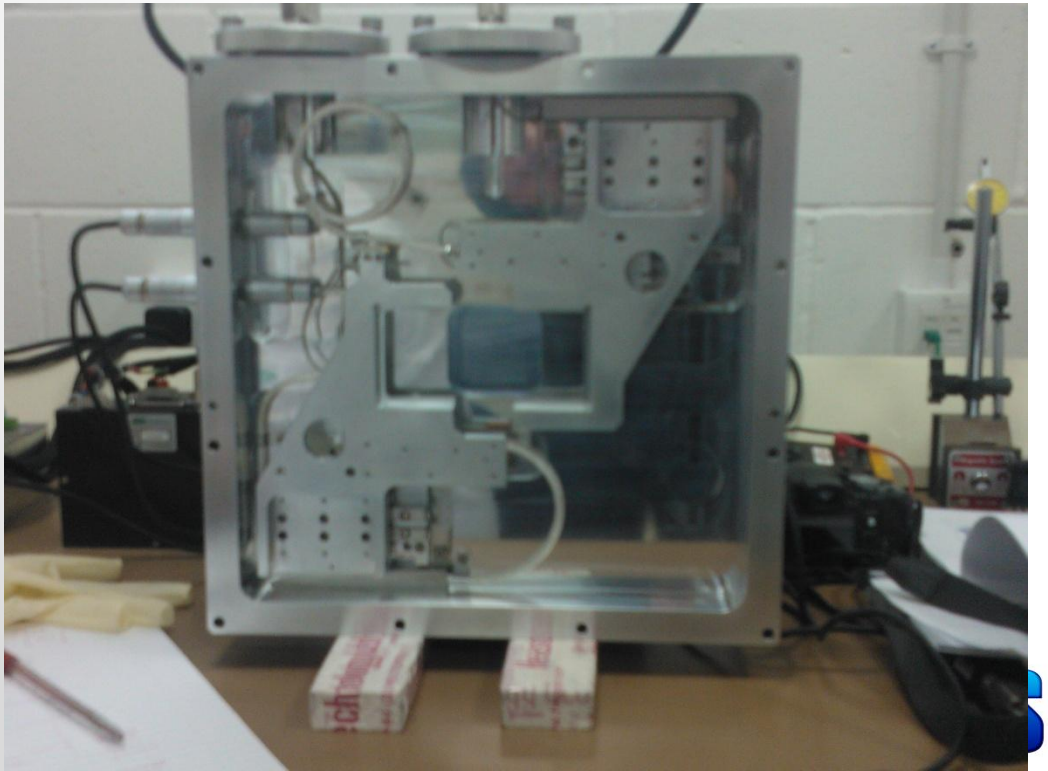
Vcoil

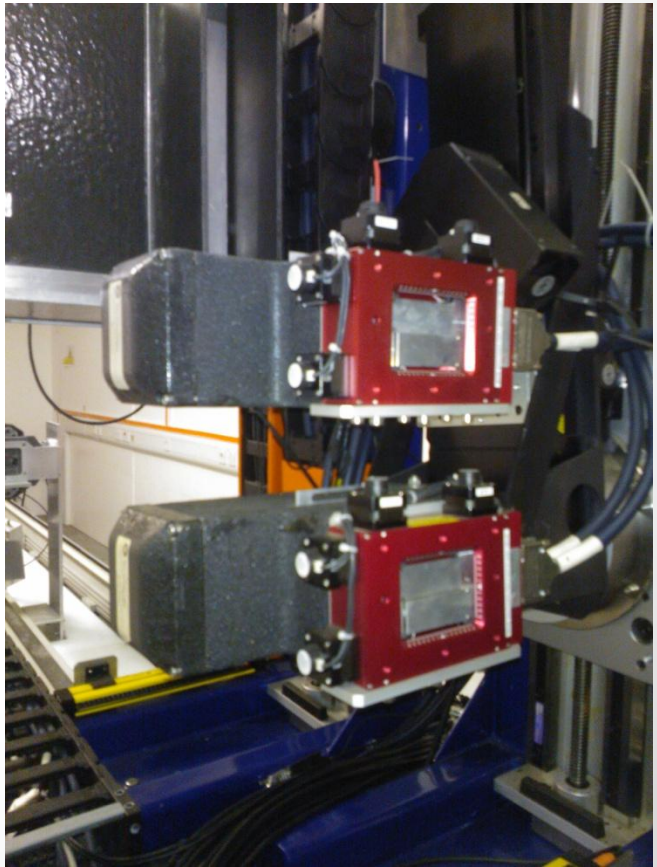
Collimation

- Magnetic components are a significant problem as they are close to the beam
- High precision is difficult to achieve with long lead screws and no encoders.
- The red jaws shown shift the echo tuning position on OffSpec by 1Amp.

Lead screw driven stepper drives

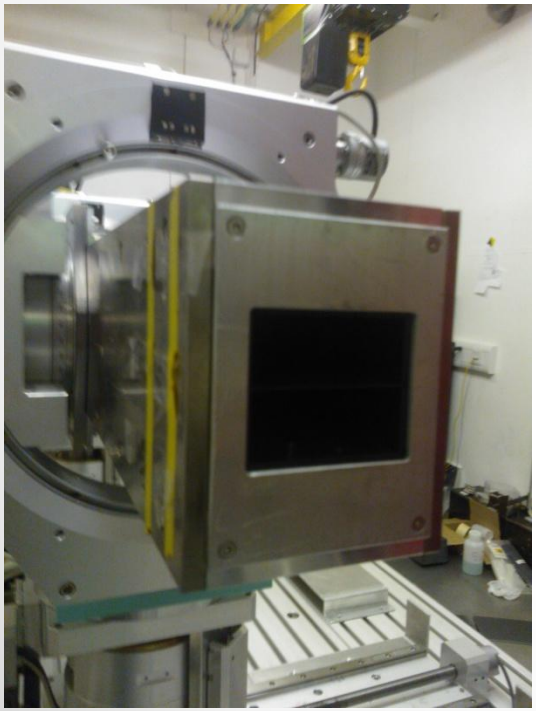
Piezo electric drive with glass encoders

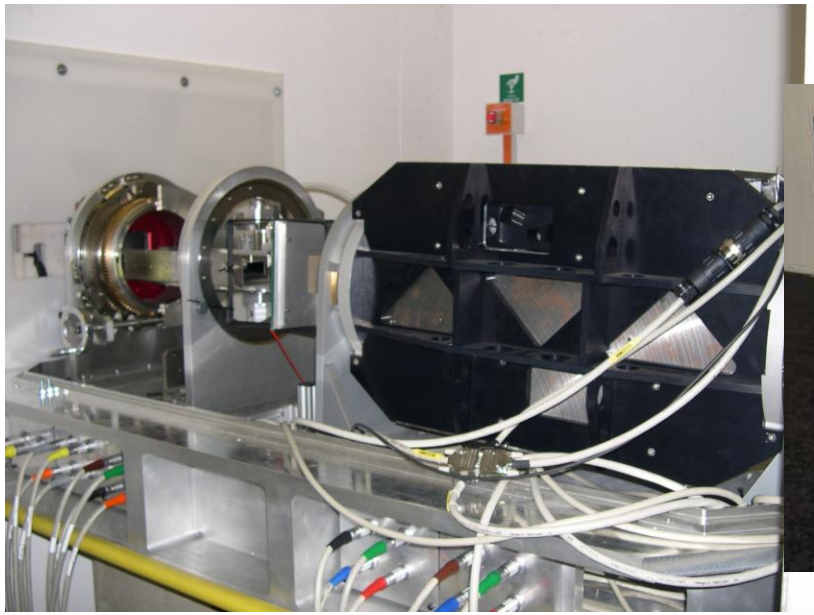


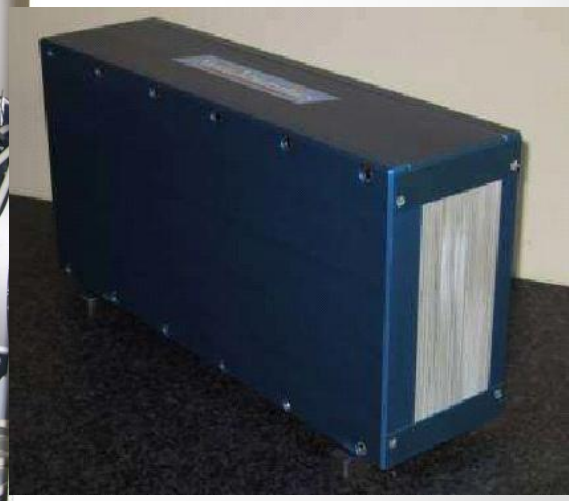


Polariser and Analyser Stray Field

- Manufacturers will not make an effort to contain the stray field used to maintain polarisation unless you ask!
- >600G is needed to polarise an FeSi mirror
- Leave space or be careful to specify

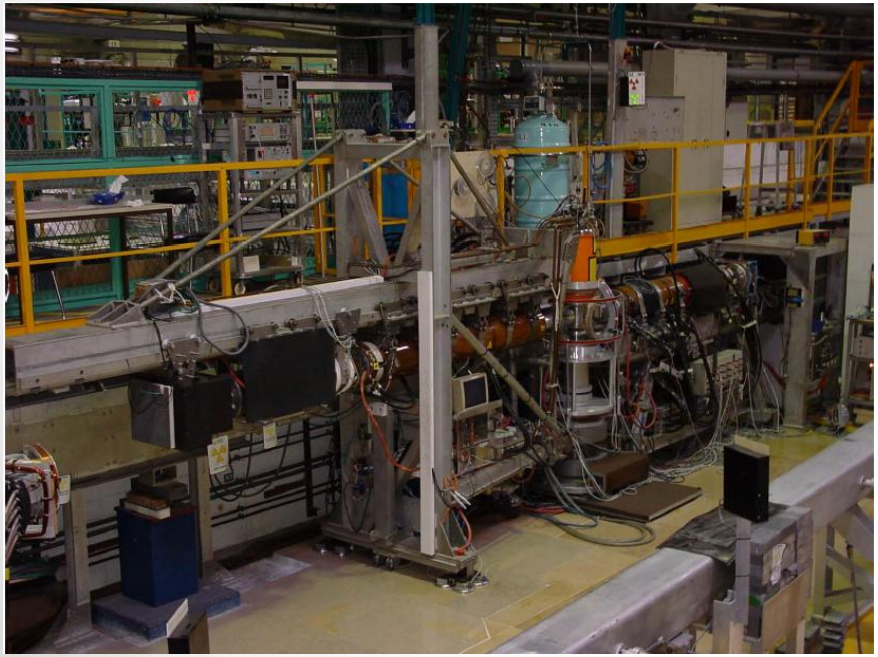


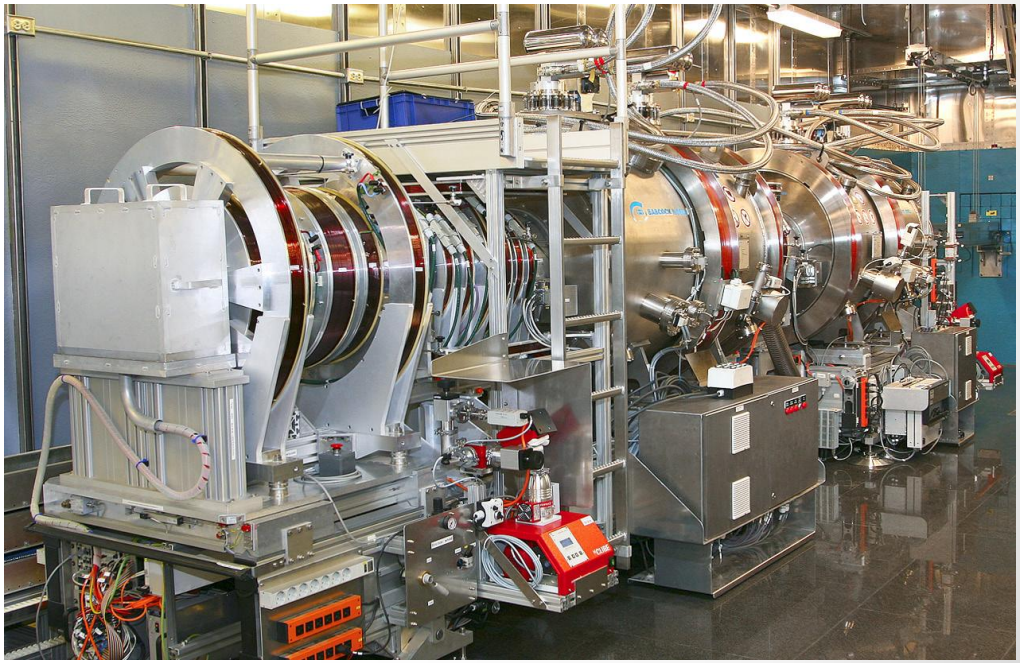




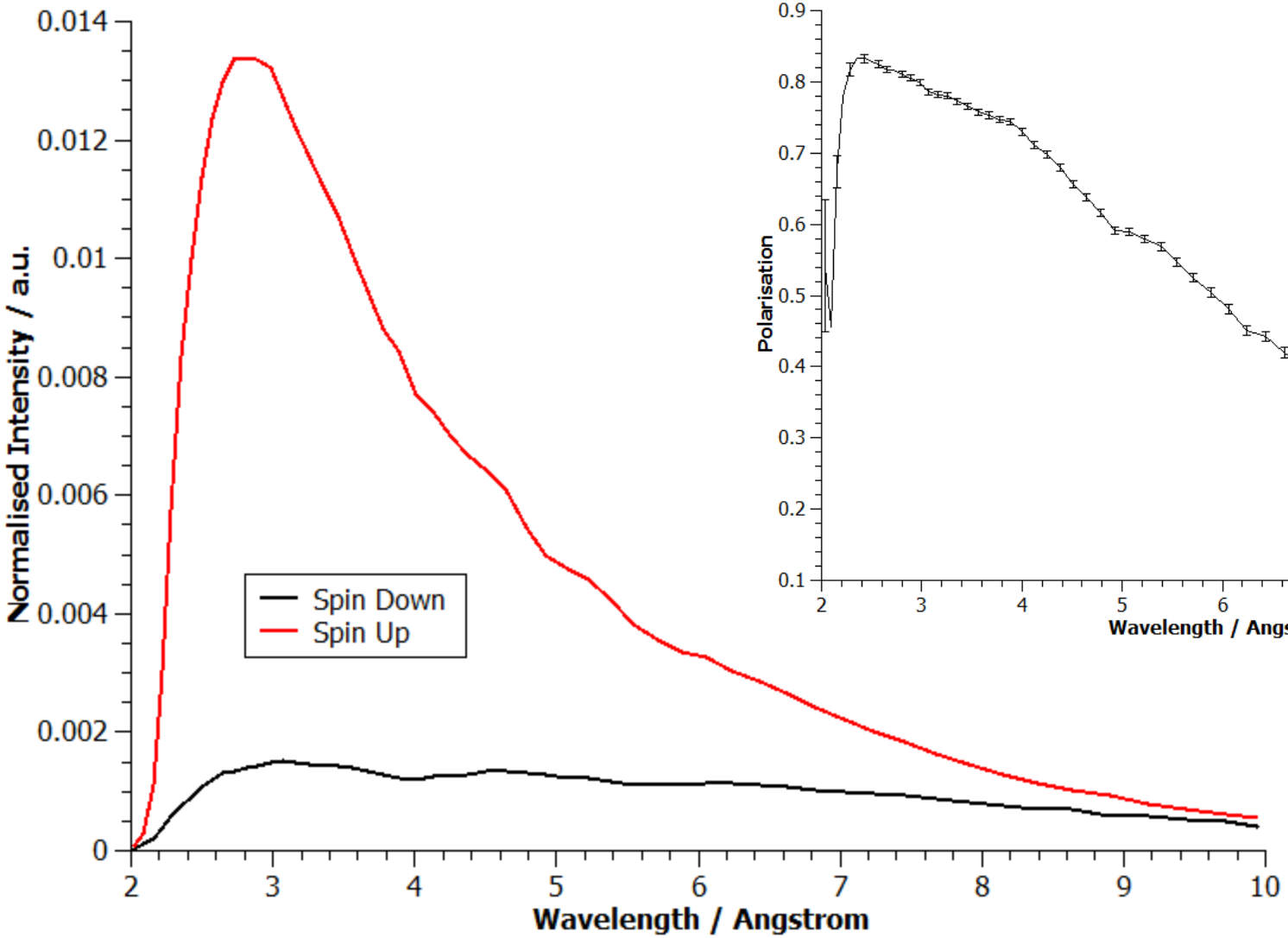
Instrument Stability

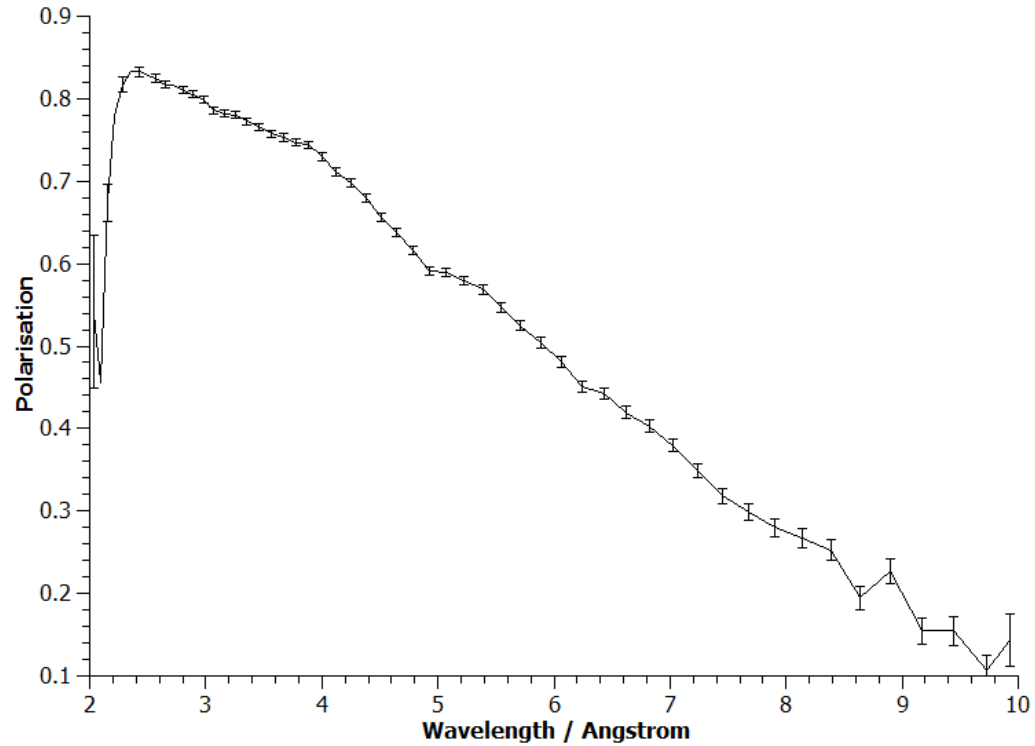
- Field stability is critical to performance as measurements can take days.
- ILL instruments are interlocked to the gantry crane as movement of large blocks of ferrous material are enough to effect measurement.
- SNS instrument is housed in a screened room





Wavelength dependent polarisation

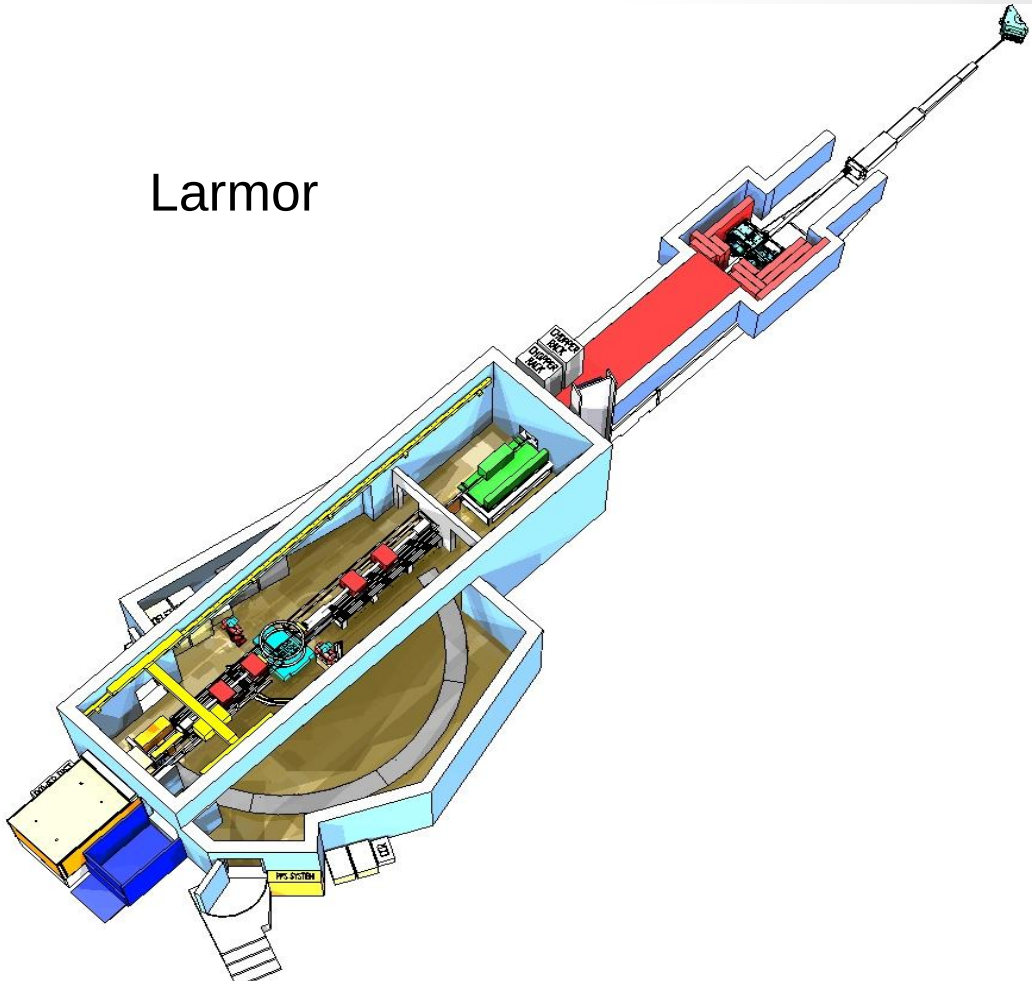




Future Instrumentation

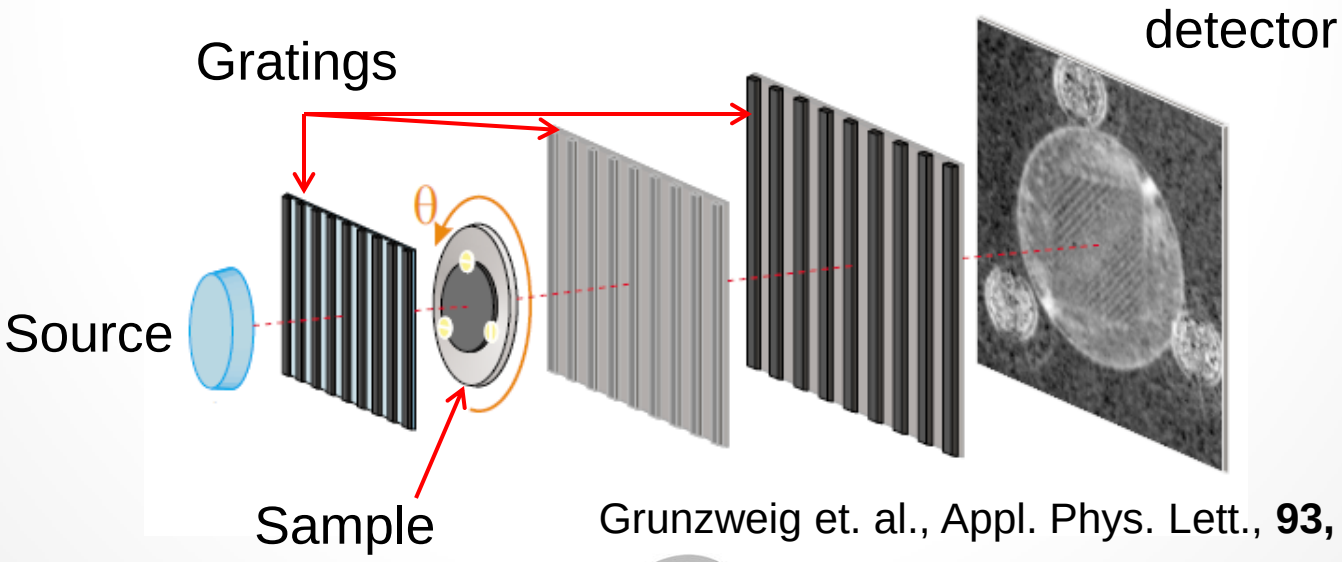
- Any new instrument at a user facility should (for now) still be constructed to perform an established technique such as reflection, SANS or NSE.
- Consider "bolt on" options in detail.
- Optimise the set up carefully to the source characteristics.
- Ensure repeatable installation with a minimum of calibration measurements

Larmor



Dark Field SESANS

- Attempt to overcome the problem of differentiating the SESANS signal from the un-scattered direct beam.
- Use a tomography technique on a monochromatic source.
- Gratings are used to block neutrons that are not scattered by the sample from reaching the detector.



Grunzweig et. al., Appl. Phys. Lett., **93, 112504 2008**

Conclusions

- Larmor Labelling is still a developing technique.
- Low magnetic and neutron backgrounds are essential to performance.
- Temperature control is also important.
- More flux will always be useful.
- TOF and broad bandwidth are not necessarily easy to exploit.
- The design of flippers and precession regions is critical to the eventual polarisation performance.