# MICE Alignment – Historical Perspective

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# Alignment

- 3 different parts in the MICE alignment
  - Surveys
  - Beam-based detector alignment
  - Magnetic field mapping
- These *should* all be wrapped into the MAUS model
  - Different parts interact with the model in different ways
  - May be tension between different procedures
- Beam-based magnetic alignment has not been done
  - It is hard!
- Also we have tracker Hall probes
  - Which do not agree with MAUS field model (at 1 % level)

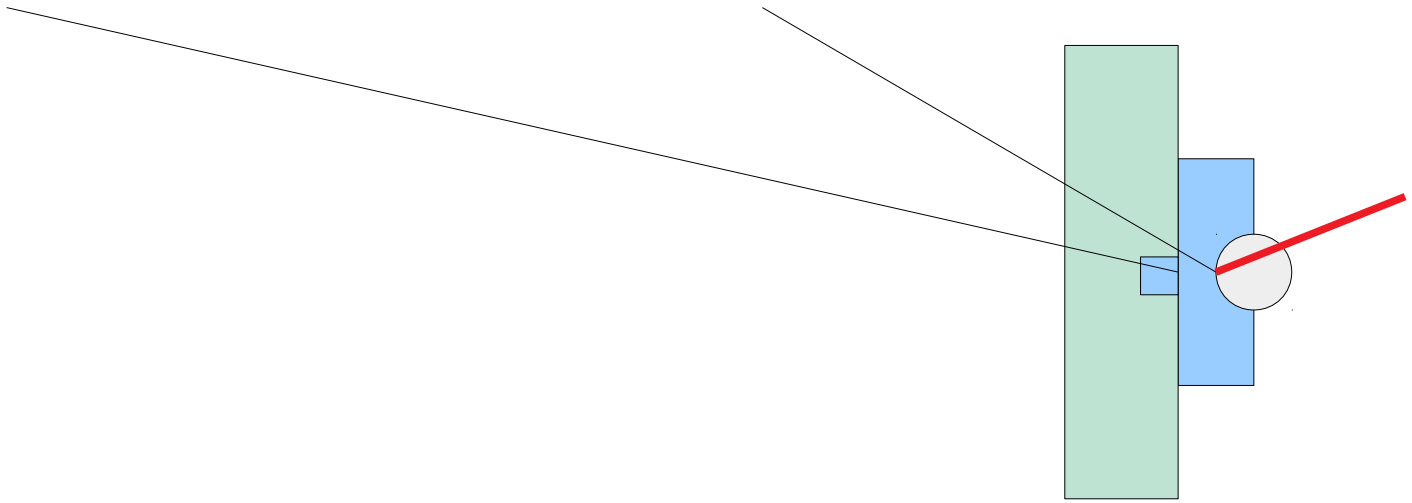
- “Accurate to 100 microns; errors O(cm)”

# Survey

- Survey was done with a laser tracking system
  - Laser tracker measures distance using time-of-flight method
  - Surveyor defines coordinate system
    - Define vertical axis using laser tracker inclination sensor and draw a line straight up from brass floor plate under Q9
    - Define beam axis by finding perpendicular to vertical axis that passes through centre of Q9
      - Found by placing a jig into the Q9 bore with a survey probe attached
    - Define horizontal axis as perpendicular to other two axes
    - Surveyors use x as the beam axis, z as vertical axis, y as horizontal axis
    - Physicists use z as the beam axis, x as horizontal axis, y as vertical axis
  - Place further fixed survey probes around the MICE hall
    - Measure distance to survey probes and build up a “survey network”
    - All survey measurements are related back to the survey network
  - Placed further survey probes on each piece of equipment
    - Used to measure the equipment position
- Reference https://micewww.pp.rl.ac.uk/projects/operations/wiki/2015-09-01_Survey

# Survey

- Note surveyor changed from Daresbury/TD to ISIS in Jan 2015
- We have access to all raw survey data files; but they are in a proprietary format
- Raw data files are processed and surveyor writes a survey note - placed on the MICE note server
- Survey is supposed to be redone every time there is a major operation in the hall e.g. detector reinstall, absorber change
- Open question – does surveyor report position of the back of the survey probe or to the back of the glass?



# Tracker – a special case

- Tracker installation was tricky and tracker is a sensitive equipment
- Tracker internal alignment was done using CMM
- Tracker then installed into the solenoids
  - Once installed, tracker was no longer visible!
- Alignment was done by first installing a dummy tracker mounted with survey probes and alignment feet on the solenoid bore
  - Survey probes used to measure alignment
  - Feet adjusted to get the tracker straight
- Then “real” tracker was installed – by placing on the previously aligned feet

# Tracker – Hall probes

- Hall probes were placed on the tracker
  - These had been carefully calibrated at Nikhef (IIRC)
  - The hall probes were attached to the tracker using glue
  - Several hall probes failed during operations
- Of the hall probes that remained, none agreed with the MAUS magnetic model
  - This is not surprising, MAUS does not have proper model for iron
  - However, it was the hall probes that were furthest from the end plates that were worst!
  - During decommissioning it was discovered that the hall probes closest to the He window had crashed into the He window, presumably during installation, and broken off
  - Hall probes still disagree with MAUS model, but now a simple scaling of the MAUS coil current (~1 %) recovers the measured field; note only hall probes at one z-position
    - Is this an effect of iron? Or something else?

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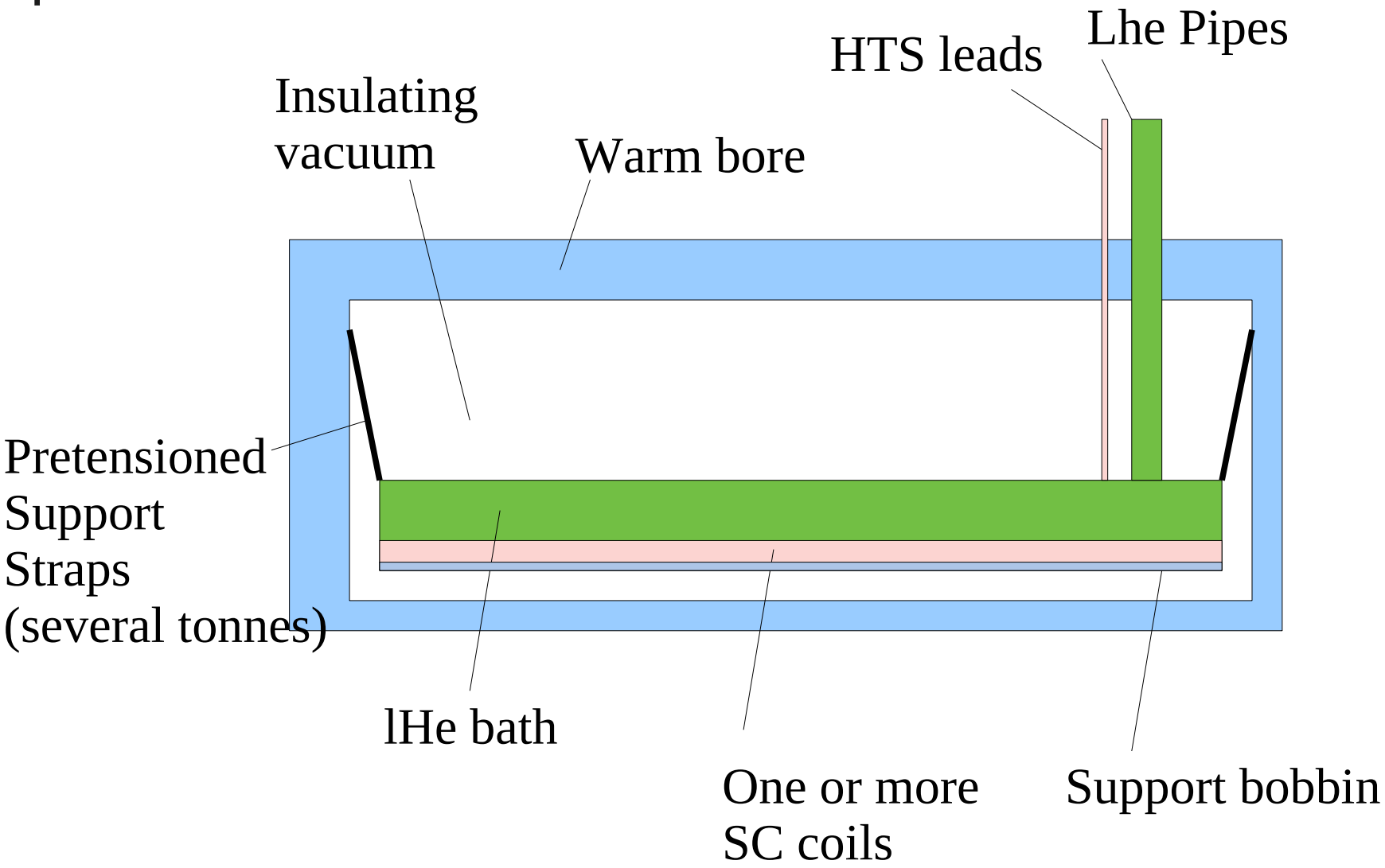
# Beam-based tracker alignment

- Beam based alignment done by Francois
  - Ref MICE note 500
  - Use surveyed TOF1/2 position
  - Draw track between TOF1 and TOF2
  - Check that tracks in the tracker and other detectors, on average, line up with the track between TOF1 and TOF2
- Main bias is asymmetric scraping if the beam is asymmetric
- Other things that could contribute:
  - ToF inefficiency
  - ToF measurement errors (e.g. tracks crossing between bars etc)
  - Earth’s magnetic field?
- Validated in MC
- Consistency between several beam line settings and momenta

# Typical Coil Construction

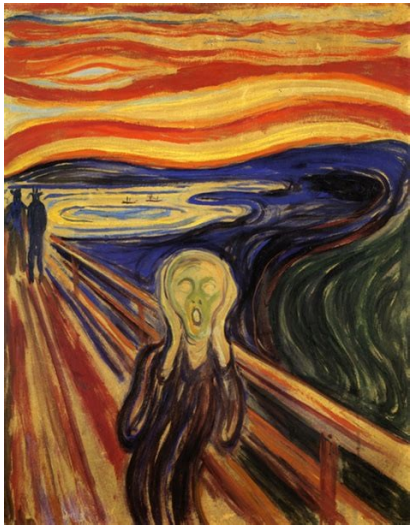


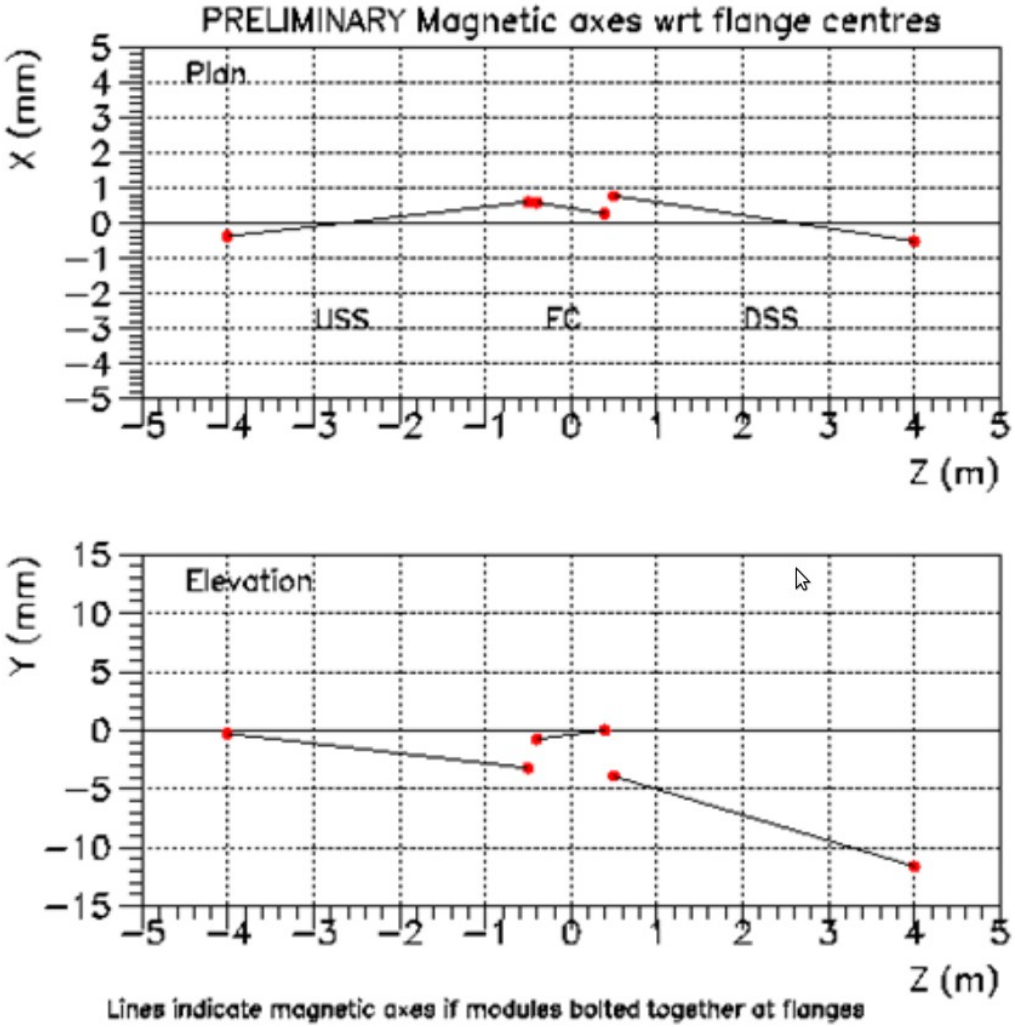
# Field Measurement

- Field was measured by CERN colleagues
  - Automated field measurement jig traversed the solenoid bores on rails
  - Survey probe mounted to measure position of the jig (and hence associated hall probes)
    - Note rails are not totally straight
  - Survey probe was related to the solenoid bore
    - **Not** the survey fiducials
  - Solenoid bore was related then to the survey fiducials
  - Nb: Tolerance was O(1 mm, 1 mrad)
- MICE note 481, 496
- https://indico.cern.ch/event/374187/contributions/888672/attachments/745674/1022924/Mapping-CM42s.pdf

# Field Measurement

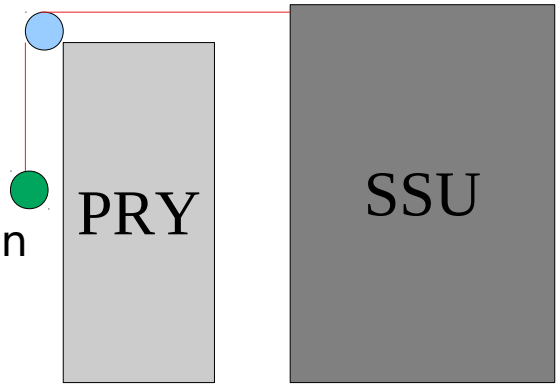
John Cobb, Victoria Blackmore





# Magnets (cont)

- After this mapping was done
  - Added in iron shielding
  - Installed in hall
- Note that flanges were an issue
  - Needed special flexible flanges
  - Not possible to move the magnets as much as desired
- “Draw wires” were installed on the PRY/SSU and SSD
  - Measure motion of SSU vs PRY
  - Few mm movement longitudinal
    - In EPICS somewhere
  - Note this is movement of warm bore
    - Cold mass movement may be different
    - Serious concern that the pretensioning on SSs was not sufficient to prevent “swinging”



# Final field mapping

- We did a further field mapping exercise just before decommissioning
  - Analysed for Joe Langlands thesis
  - Never incorporated into MAUS
  - But did include e.g. PRY
  - Alignment parameters below
  - Also full fit done
    - Residuals at level of 20 mT (e.g. 1%) just 30 mm from axis

| $\theta_x$ [mrad] | $\theta_y$ [mrad] | $p_x$ [mm] | $p_y$ [mm] |
|---|---|---|---|
| -0.61 $\pm$ 0.03 | 0.90 $\pm$ 0.03 | -13.05 $\pm$ 0.44 | -7.64 $\pm$ 0.44 |

Table 3.11 Estimated rotation angles and offsets of SSU.

| $\theta_x$ [mrad] | $\theta_y$ [mrad] | $p_x$ [mm] | $p_y$ [mm] |
|---|---|---|---|
| 0.26 $\pm$ 0.02 | 1.12 $\pm$ 0.02 | -17.40 $\pm$ 0.43 | -8.43 $\pm$ 0.43 |

Table 3.12 Estimated rotation angles and offsets of SSD.