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Helical Undulator Programme

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T Bradshaw

On behalf of the HeLiCal collaboration

Helical Collaboration

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Project Engineering - A Brummit, G Burton, C Dabinett
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ASTEC:
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I.R. Bailey, J.B. Dainton, P. Cooke, T. Greenshaw, L. Malysheva

DESY :
D.P. Barber

University of Durham :
G.A. Moortgat-Pick

Collaboration

RAL Cryogenics and Project Engineering

Magnetic modelling
Prototyping
Mechanical design
Manufacture

Astec

Impedance calculations
Wakefield heating
Vacuum considerations
Specification (plus Liverpool and Durham

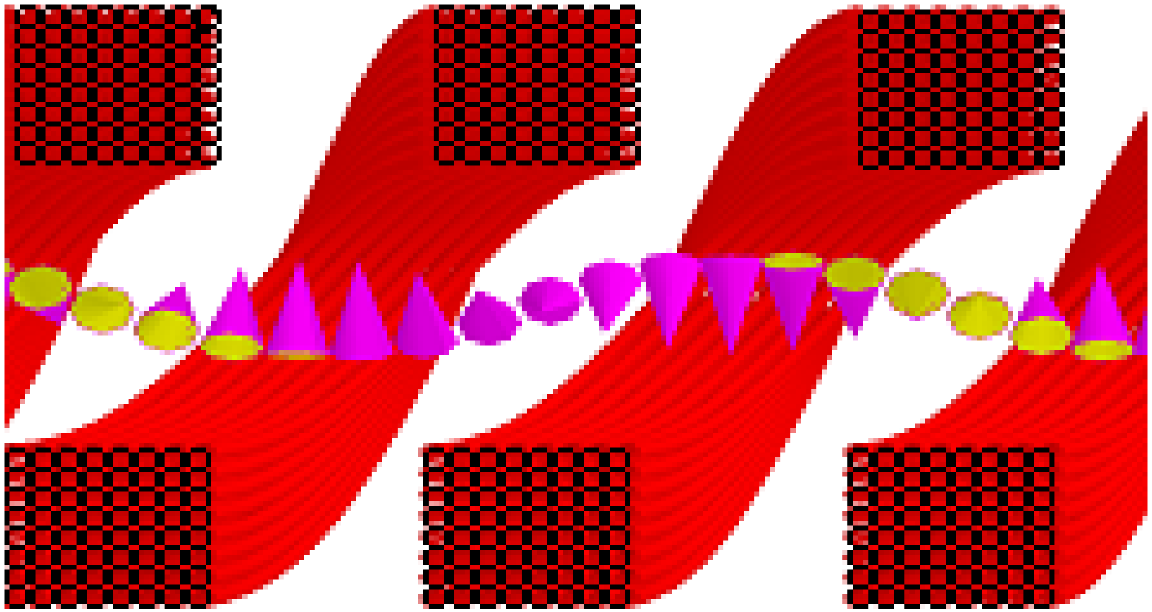
Joint work

Test programme
Data analysis

Talk

- Requirements - specification
- Feasibility – what are we able to make ? Design drivers
- Modelling and Prototypes
- Module design
- Testing
- Assembly of 4m module

Requirements



ILC requirement : To produce a circularly polarised positron beam

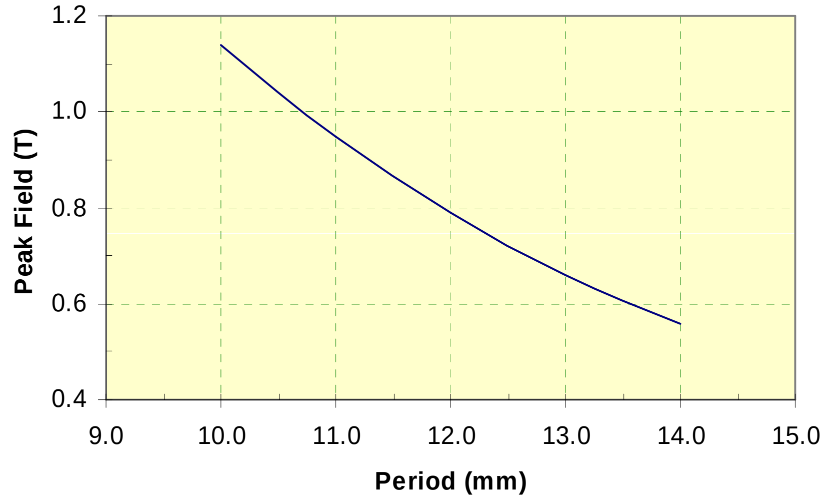
High energy electron beam through helical undulator produces polarised photons.

These hit a target which produces a polarised positron beam.

Requirements

- Shorter period – fewer magnets and shorter undulator – undulator could be 100-200m length
- Shorter period – manufacturing difficulties
- Need to maintain an adequate margin on the superconductor

We needed to assess what could be achieved ..



Electron energy: 150GeV
First harmonic photon energy: 10MeV

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Magnet modelling

Aim of the modelling was to assess parameters like

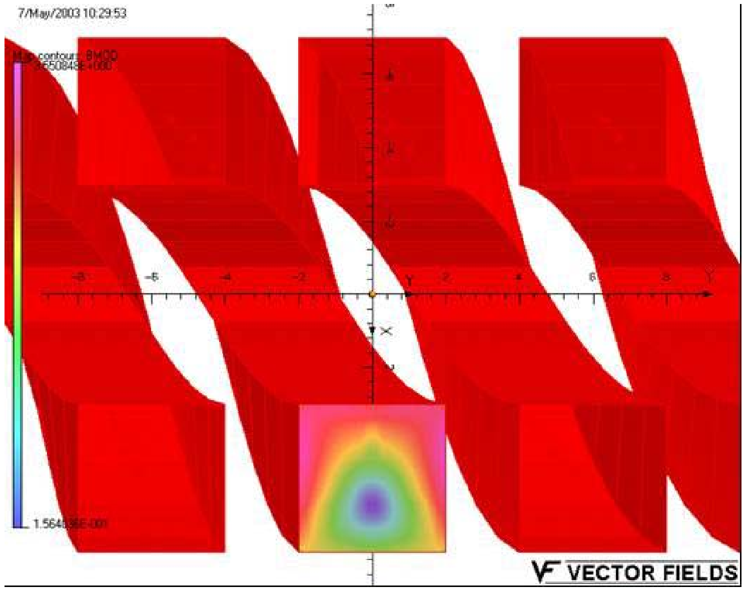
•Conductor aspect ratio
•Bore diameter
•Pitch
•Conductor working margin
•Would Iron help

Conclusions of modelling

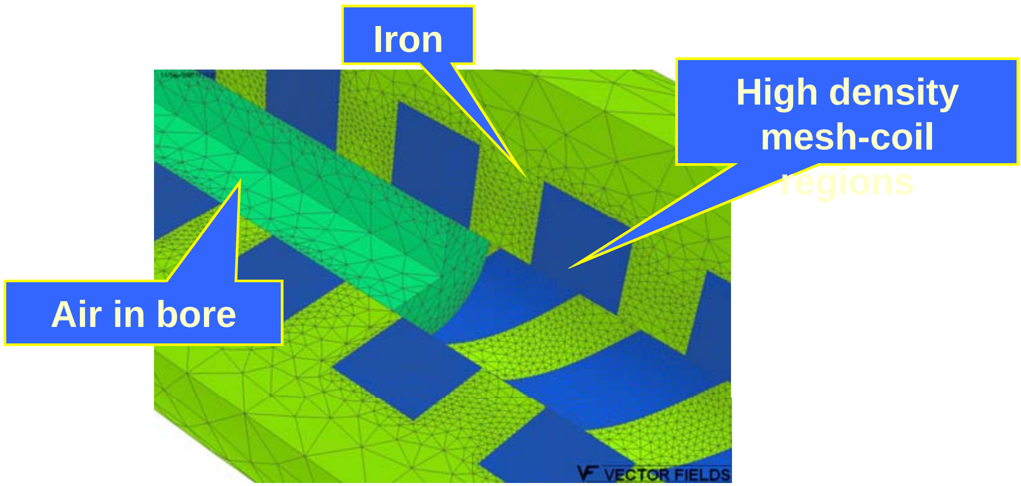
If NbTi was used

3d iron model-to achieve the required field

•Iron former and poles were necessary
•Realistically a minimum11.5mm was achievable
•With a winding bore of ~6mm
•Operating at 80% short sample



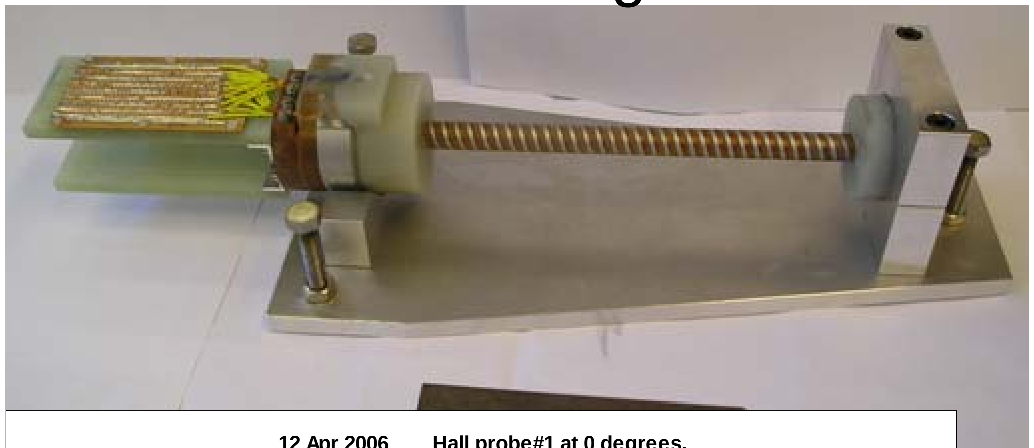
Peak field in an Air only model

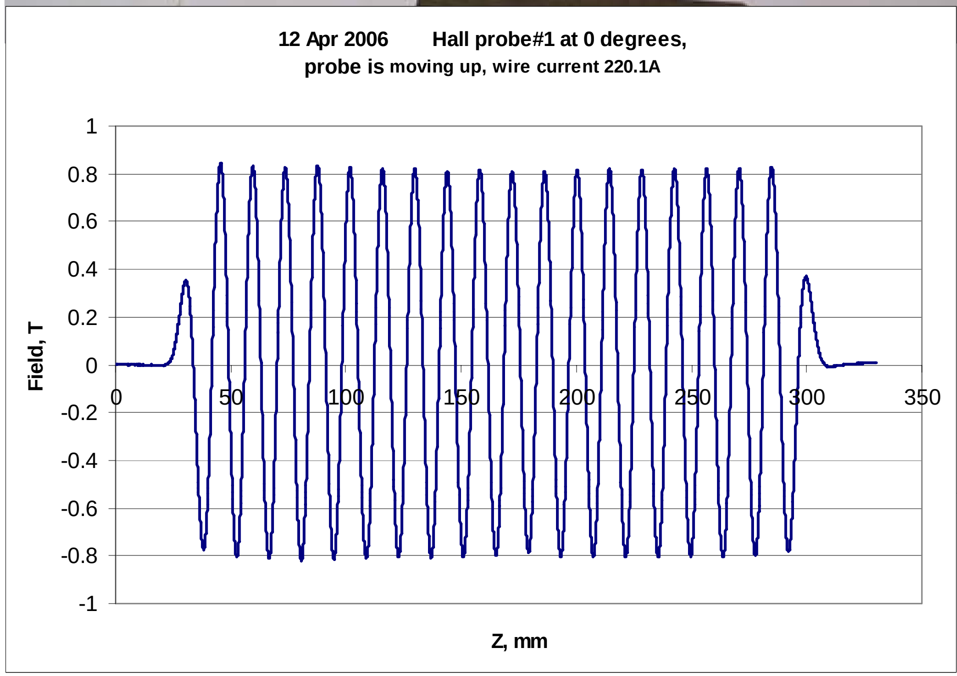


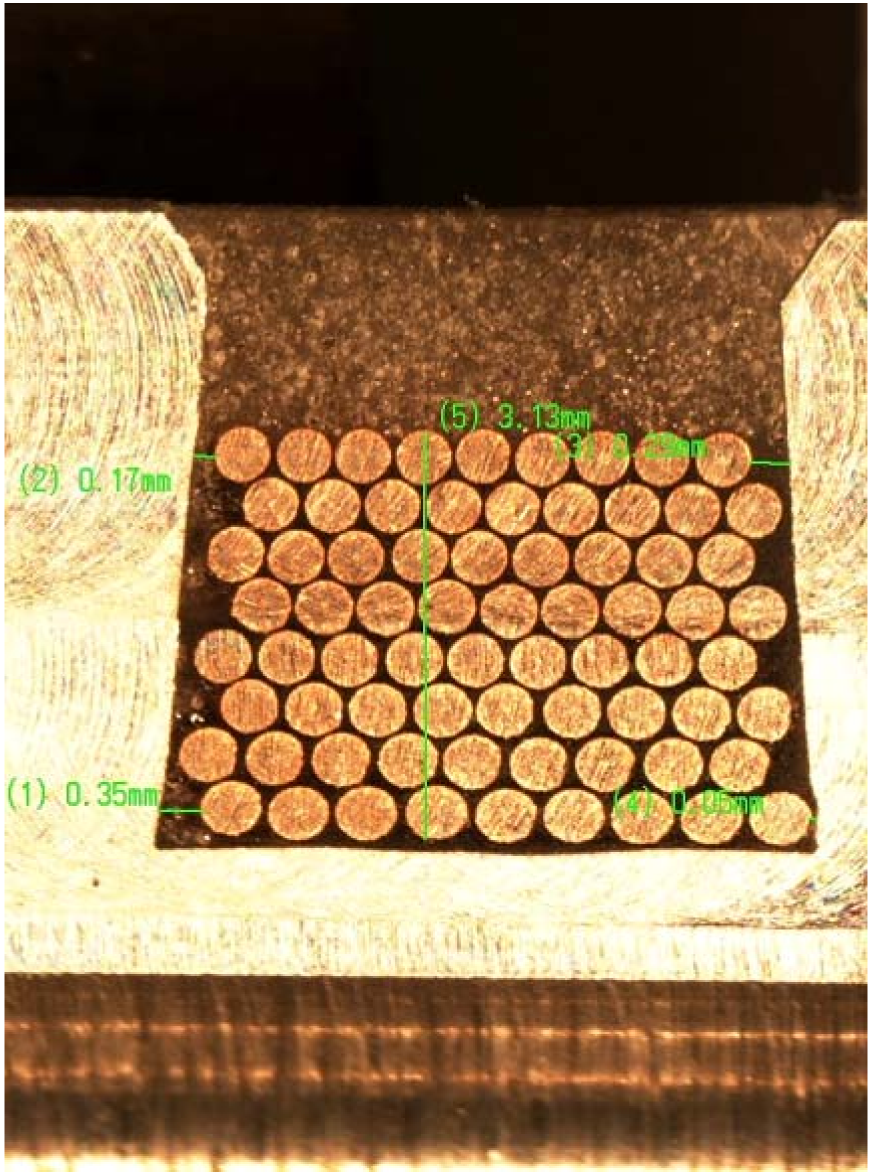
Mesh distribution in 3d iron model

R&D Prototypes

Short prototypes manufactured to assess manufacturing methods







R&D Prototypes

Parameter	Prototype 1	Prototype 2	Prototype 3	Prototype 4	Prototype 5	**Prototype 5’**
Prototype goal	Winding technique verification	Check effect of mechanical tolerances	Prototype with reduced period	Check effect of iron	Prototype with the final period	**Quench study with improved impregnation**
Length	300 mm	300 mm	300 mm	300 mm	500 mm	**500 mm**
Former material	Aluminium	Aluminium	Aluminium	Iron	Iron	**Iron**
Winding period	14 mm	14 mm	12 mm	12 mm	11.5 mm	**11.5 mm**
Winding bore	6 mm	6 mm	6 mm	6 mm	6.35 mm	**6.35 mm**
Magnet bore	4 mm	4 mm	4 mm	4.5 mm	5.23 mm	**5.23 mm**
Superconducting wire	Cu:SC 1.35:1	Cu:SC 1.35:1	Cu:SC 1.35:1	Cu:SC 1.35:1	Cu:SC 0.9:1	**Cu:SC 0.9:1**
Winding	8-wire ribbon, 8 layers	9-wire ribbon, 8 layers	7-wire ribbon, 8 layers	7-wire ribbon, 8 layers	7-wire ribbon, 8 layers	**7-wire ribbon, 8 layers**

Specification

Following a pretty extensive **R&D programme** and **modelling study** the following specification was developed :

Electron Drive Beam Energy	150 GeV
Photon Energy (*1st harmonic cutoff*)	10.06 MeV
Photon Beam Power	131 kW
Undulator Period	11.5 mm
Undulator Strength	0.92
Field on Axis	0.86 T
Beam Aperture	5.85 mm
Undulator Length	147 m

This specification defines the shortest period undulator we could reliably build as a prototype.

Design 4m module

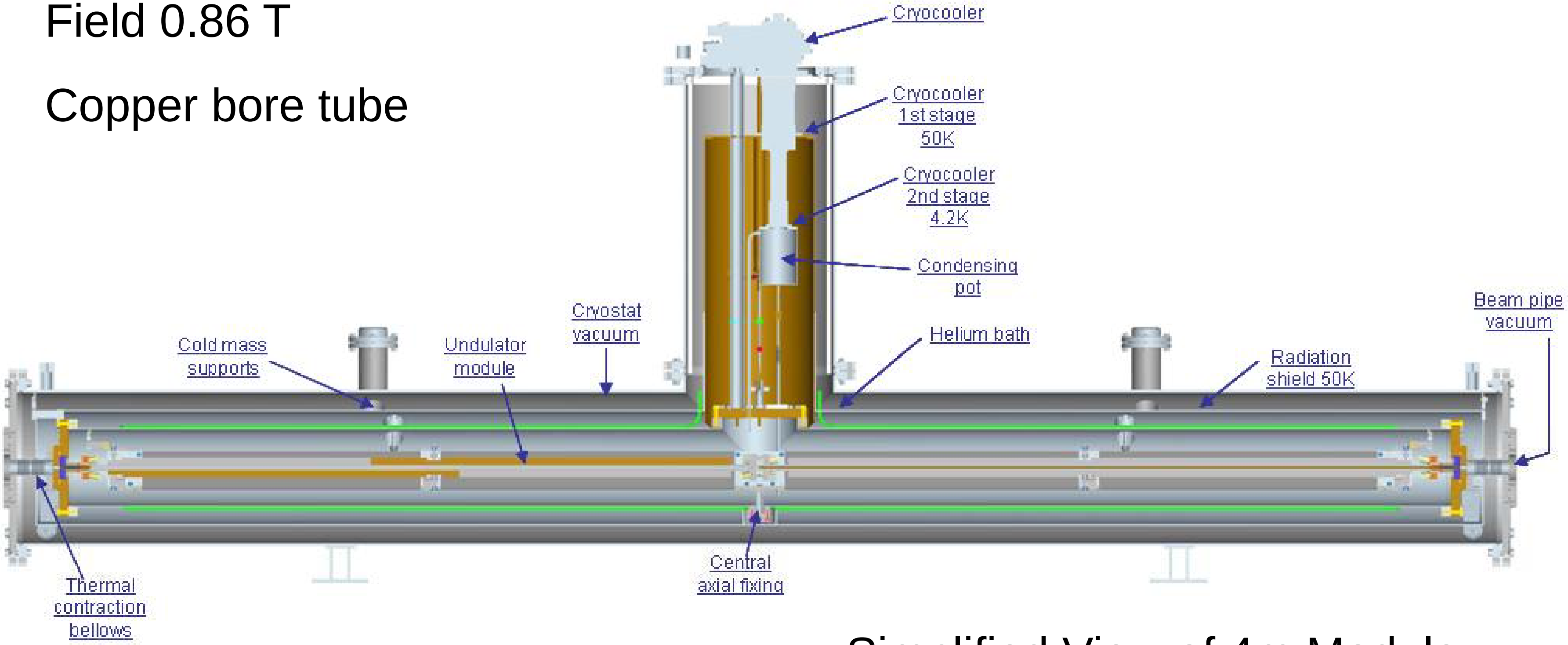
With the magnets defined, the design of a stand alone prototype section for the ILC was started.

The goal was to have 2 x 2m undulator sections in each module

Period 11.5mm

Field 0.86 T

Copper bore tube



Simplified View of 4m Module

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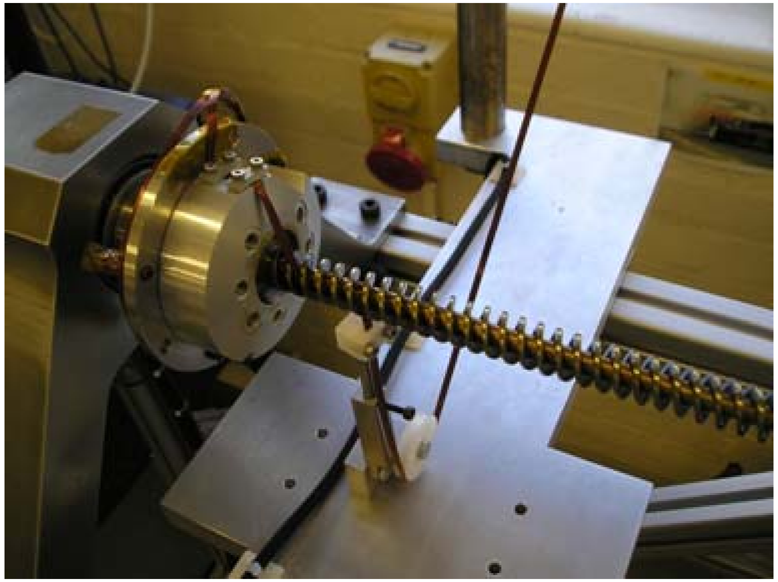
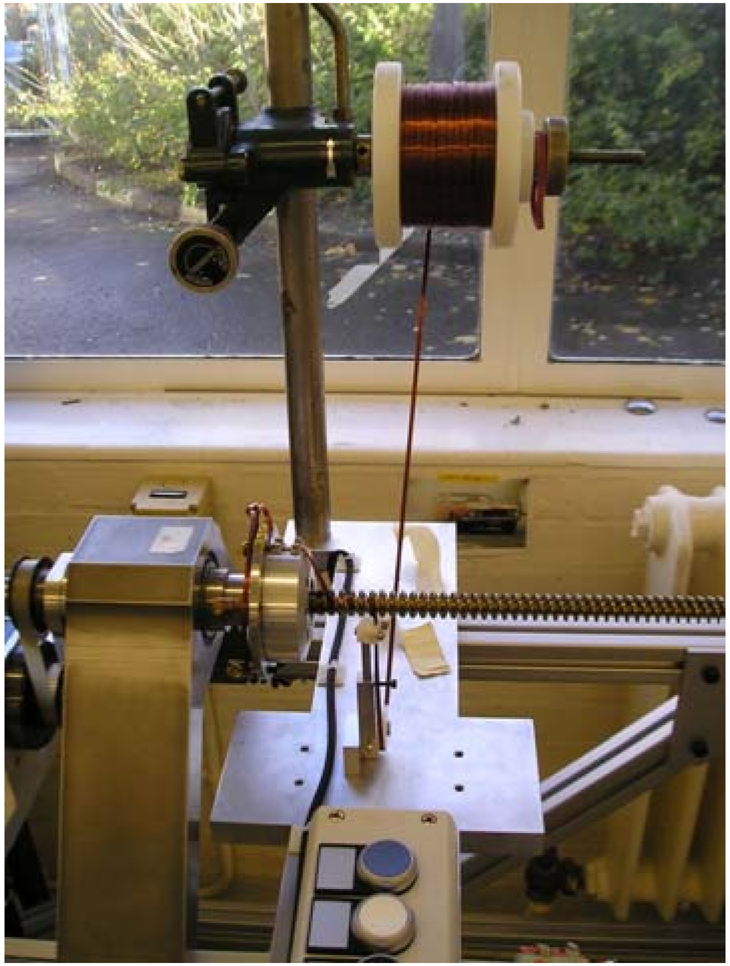
2m magnet sections

Undulator Period	11.5 mm
Undulator Strength	0.92
Field on Axis	0.86 T
Beam Aperture	5.85 mm
Undulator Length	147 m



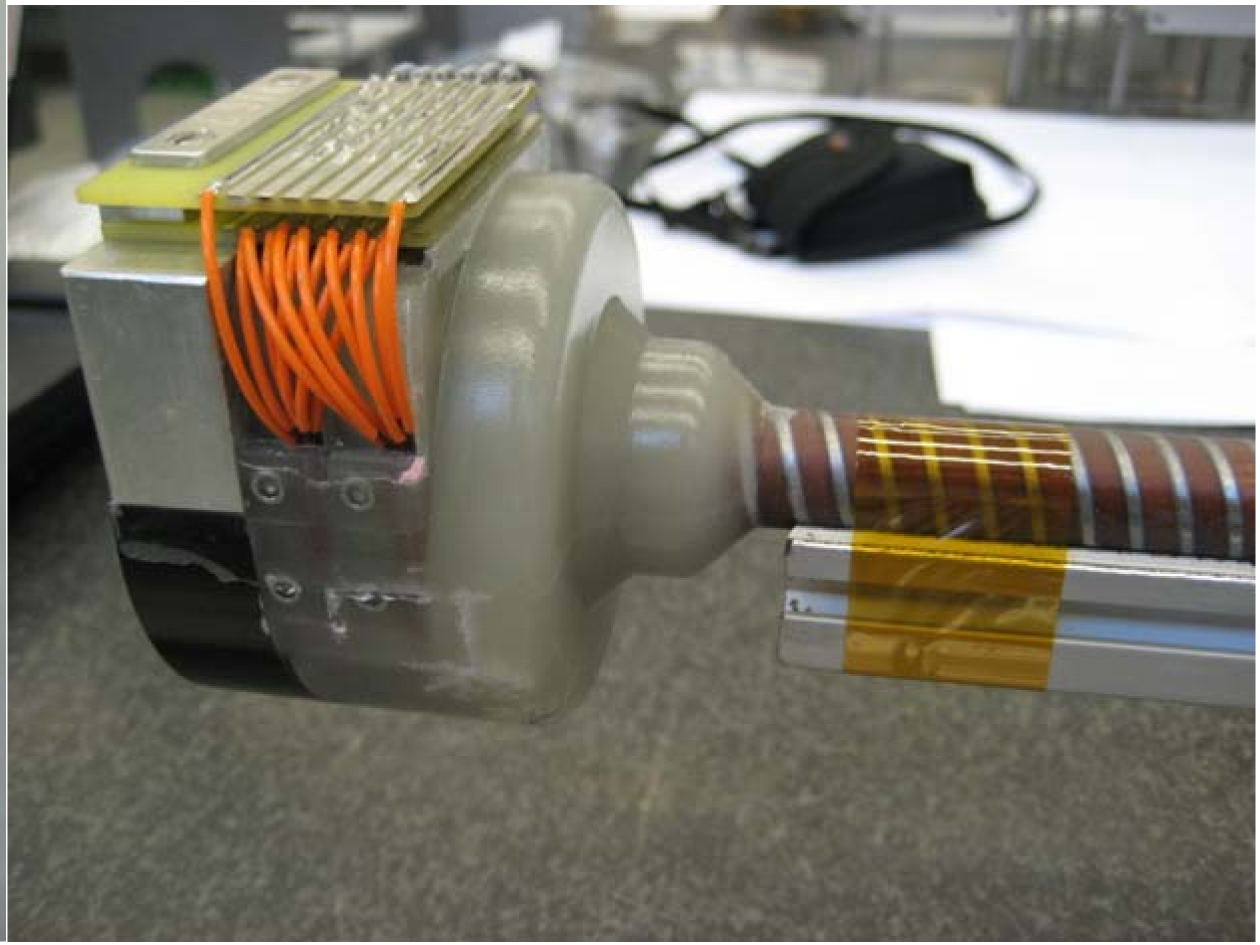


Coil winding

2m magnet sections

Following winding each coil is potted

And end connections

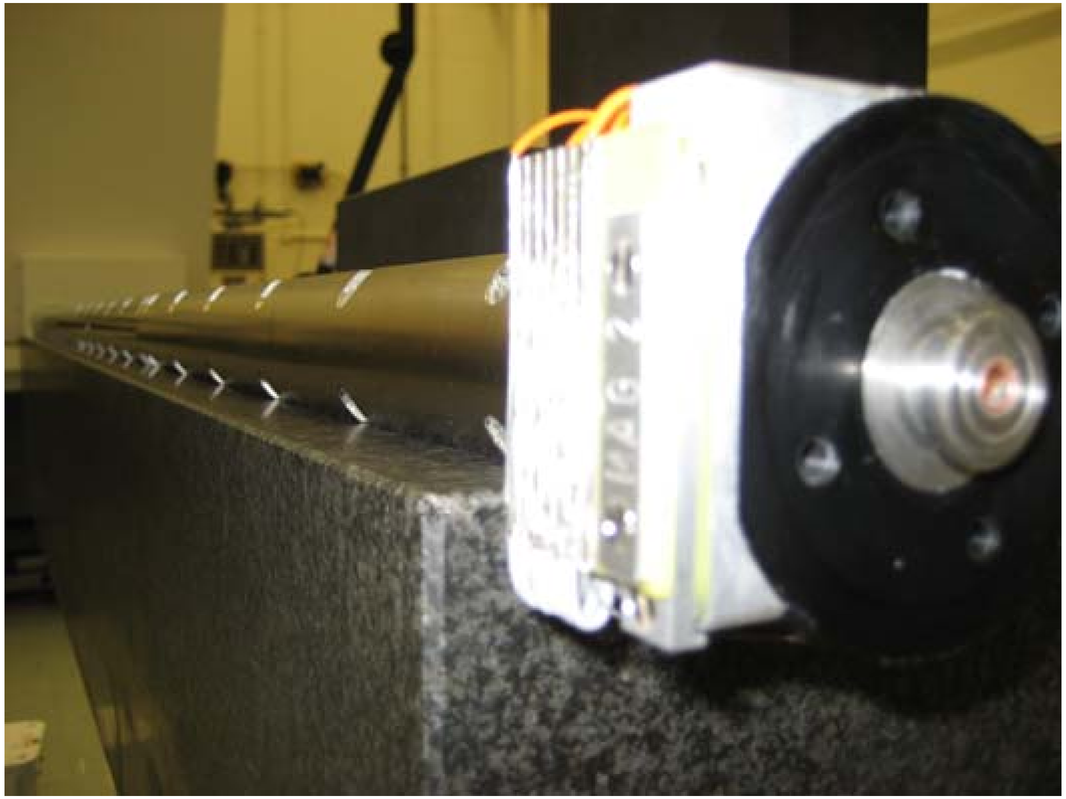


Iron yoke

R&D and modelling has shown that it is not possible to deliver a realistic operating margin without the addition of iron poles

40% of the field generated by the iron poles

Similarly by including a return yoke adds ~ 10% to the margin



2m magnet testing

The 2m sections were tested in a large modified cryostat

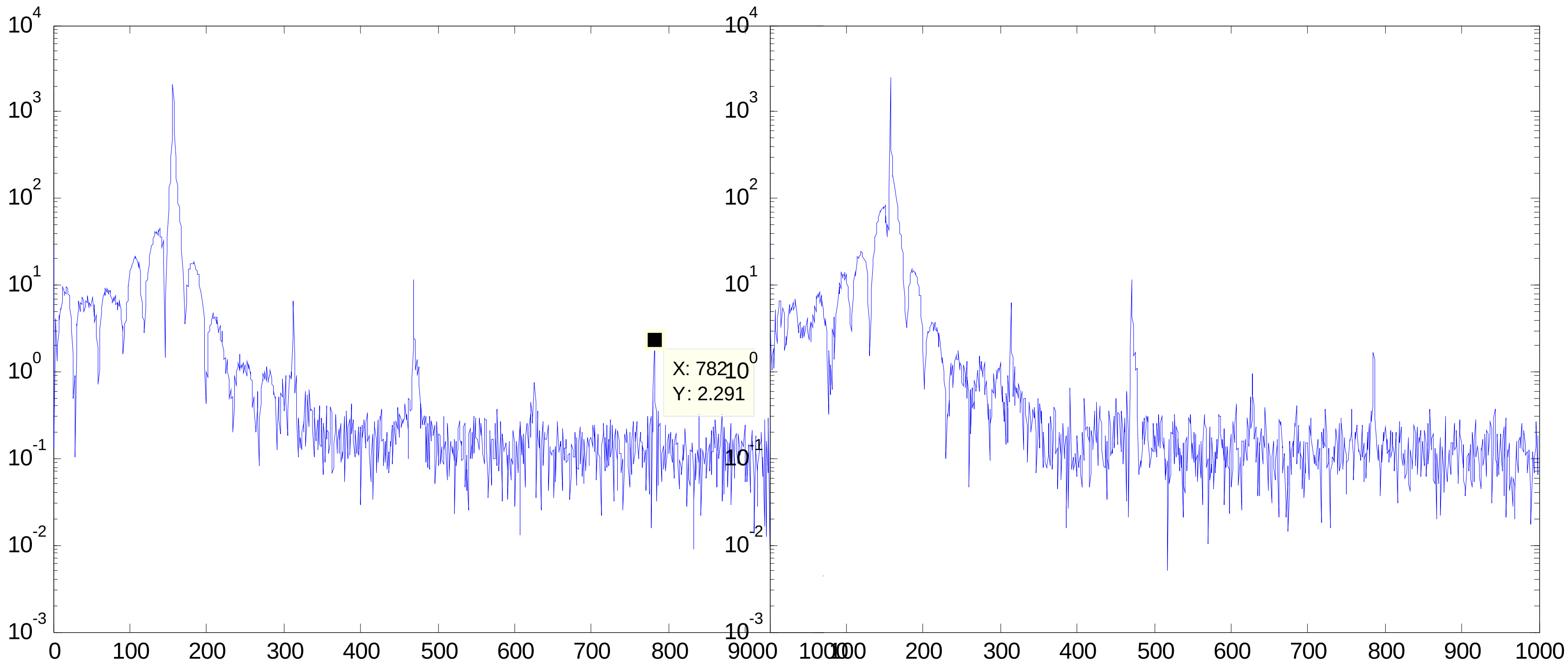
Undulator in the test cryostat

Test Programme

Field maps along the length of the undulator

- Mapping Br along the axis
- At 4 points around the azimuth; 0, 90, 180 & 270 degrees
- At magnet ends (200mm along Z) carried out more detailed maps at 45^{O} intervals around the azimuth
- All readings were repeated at least twice with different hall probes to check repeatability of the logging system
- Also carried out a Quench data study

Fourier Analysis



7th Februrary   14th Februrary

Plot on a semi-logarithmic scale – sinewave is very pure

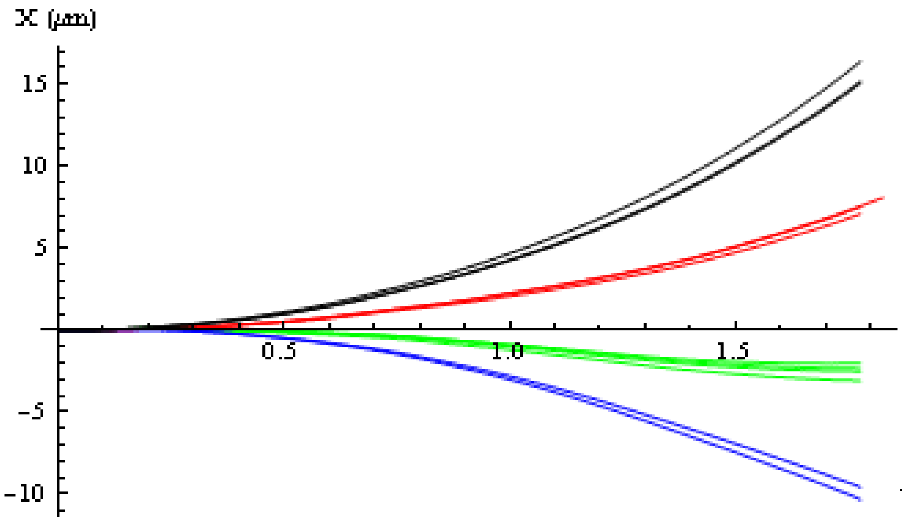
Results are repeatable

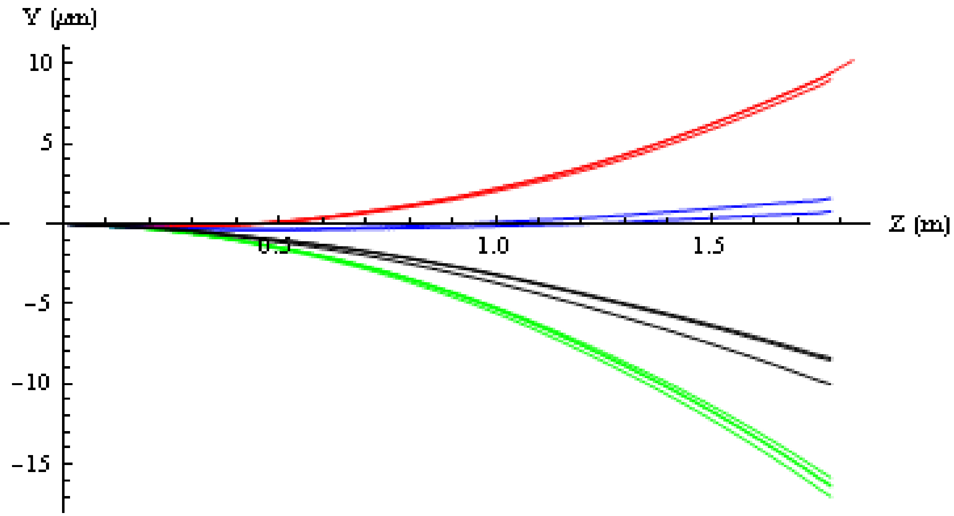
Conclusion good undulator with a pitch of – 11.492mm !

Trajectories

Colours refer to different probe orientations

Corrected x and y data





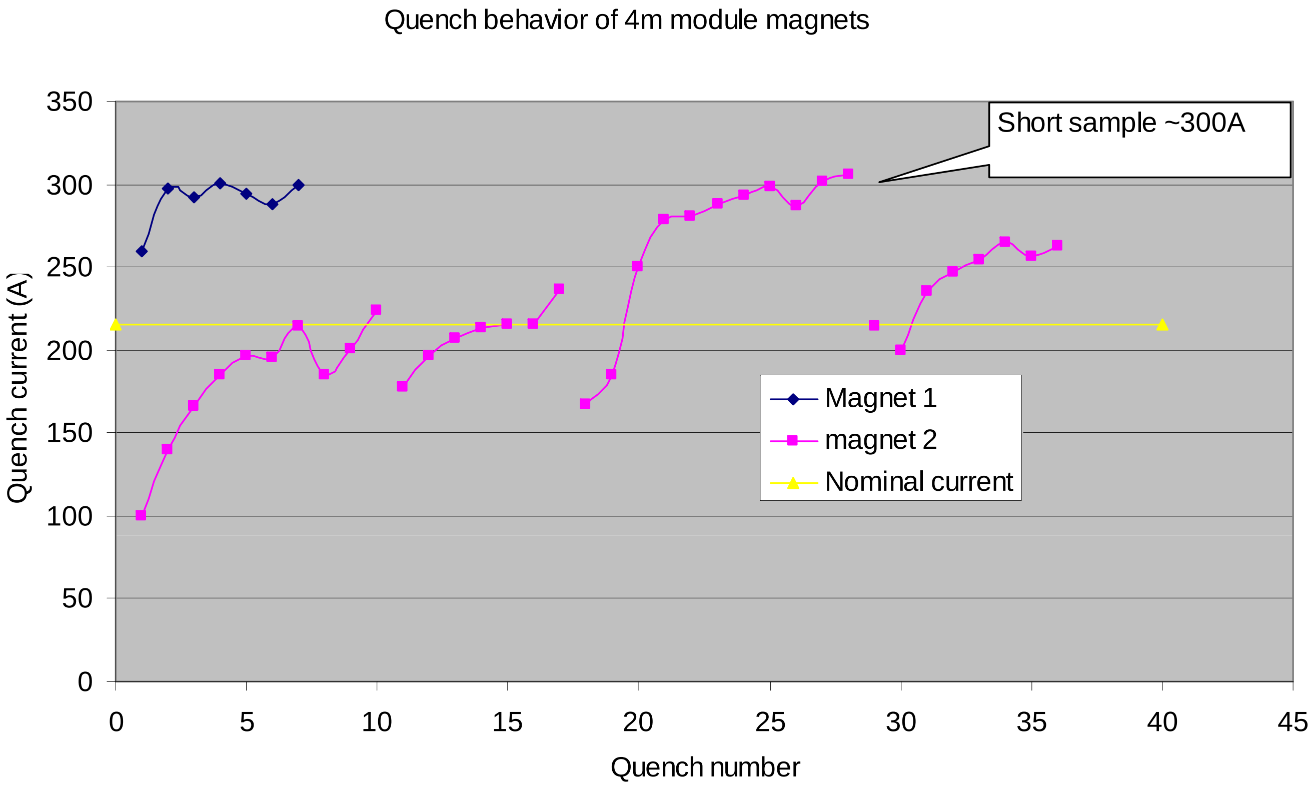
The particle trajectories were calculated from the measured fields in SPECTRA

Corrections made for the Hall probe offsets

Trajectories are well within expectations !

Quench Data

Quench Data for both Magnets

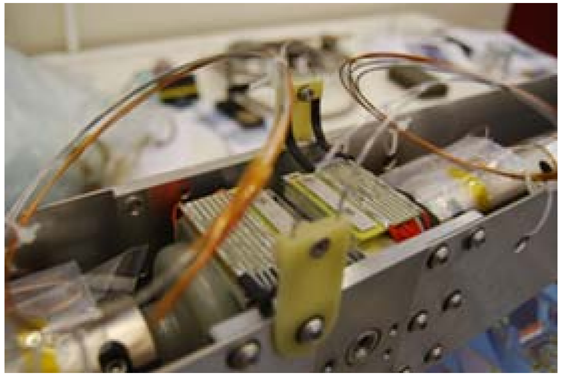


Both magnets can deliver nominal field

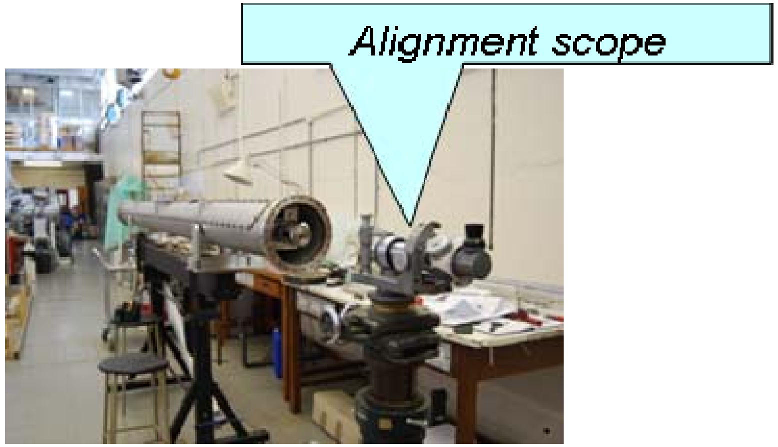
with a healthy margin!

4m Module

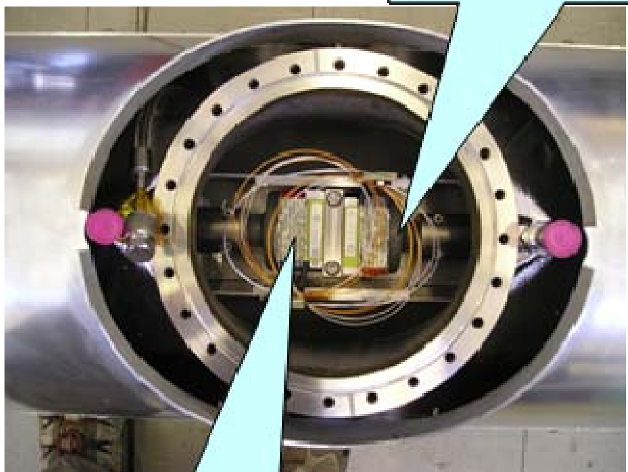
4 meter module assembly



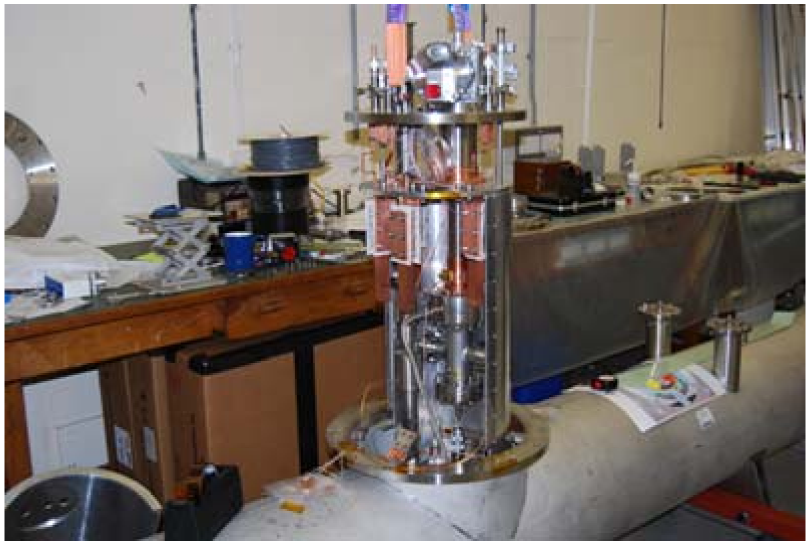
Magnet cold mass



alignment



radshield



Turret assembly

4m Module

4m module assembly

The 4m module was closed 2 weeks ago !

- All leak tests of vacuum and helium vessels were good
- However have problems with a current lead short
- Also had problems with the cryo cooler
- Sumitomo engineer has just visited on Tuesday
- Switched over the cold head
- Cooler is now running and the magnet is cooling

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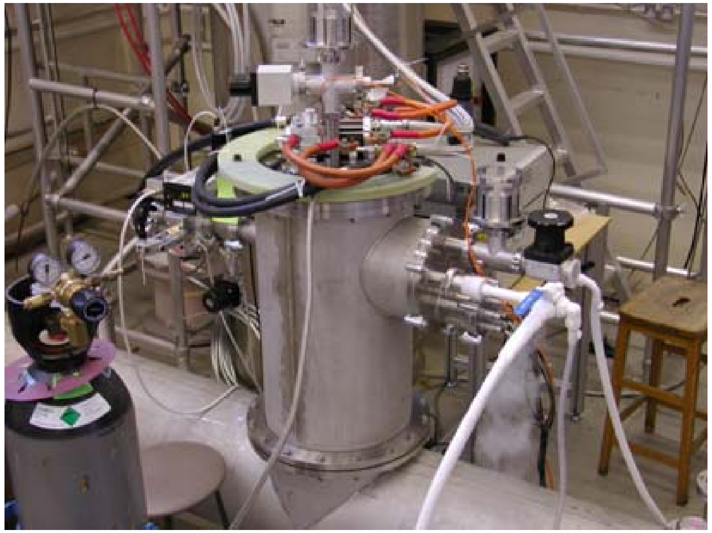
4m Module

4m module testing

Currently we are well into the first cool down !

The 2nd stage of the cooler is at 6K
The 1st stage of the cooler is at ~80K
The magnets are at 100-150K
Pressure in the helium vessel is ~1b
Liquid He delivery on Friday
ready to fill magnet
Proposed tests once cold



<u>Initial tests</u>
- check of logging-instrumentation
- Electrical checks on solenoid
- Functional test of cryocooler

<u>Magnet test</u>
- Power magnet 1, check C-leads.
- Power magnet 2, check C-leads.
- Power both magnets

<u>Longer term stability</u>
- Run both magnets 24 hrs – check stability
- Run both magnets several days, logging system

Current Status

Magnet sections

Both 2m sections have been manufactured and tested at 4K

Both magnets exhibited some training but both have met the field requirement

Vacuum Vessel and Helium Bath

The 2m sections have been incorporated into the vacuum vessel.

The vessel is complete and is now being tested.

Currently the magnet is under vacuum and we have begun testing.

Currently finalising the configuration of the instrumentation system.

After some initial problems we are making good progress with the initial cool down

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END