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undulator manufacture and measurement

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On behalf of the Helical collaboration

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Scope of presentation

- Introduction
  - Undulator specification
- Prototype design, manufacture, testing
  - 4m Module design
  - Magnet Testing and integration
  - Assembly of 4m module
  - First tests of the final prototype
- Current status
  - Where we are at the moment
  - Plans for the coming months

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Magnet manufacturing spec

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

Undulator Period			11.5 mm
Field on Axis			0.86 T
Peak field homogeneity		<1%	
Winding bore			>6mm
Undulator Length			147 m
Nominal current			215A
Critical current			~270A
Manufacturing tolerances			
	winding concentricity	20um	
	winding tolerances	100um	
	straightness	100um	
NbTi wire Cu:Sc ratio		0.9	
Winding blocck			9 layers
			7 wire ribbon

This defines the shortest period undulator we could build with a realistic operating margin.

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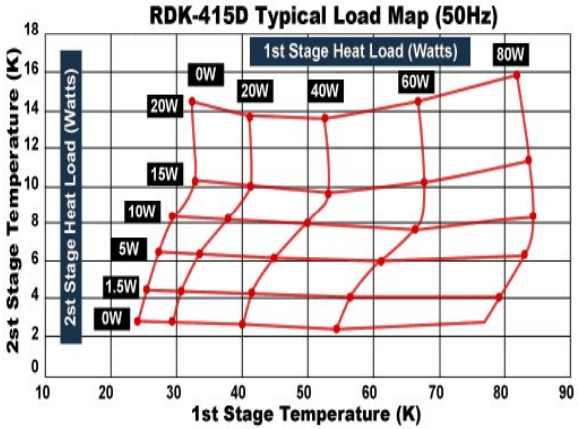
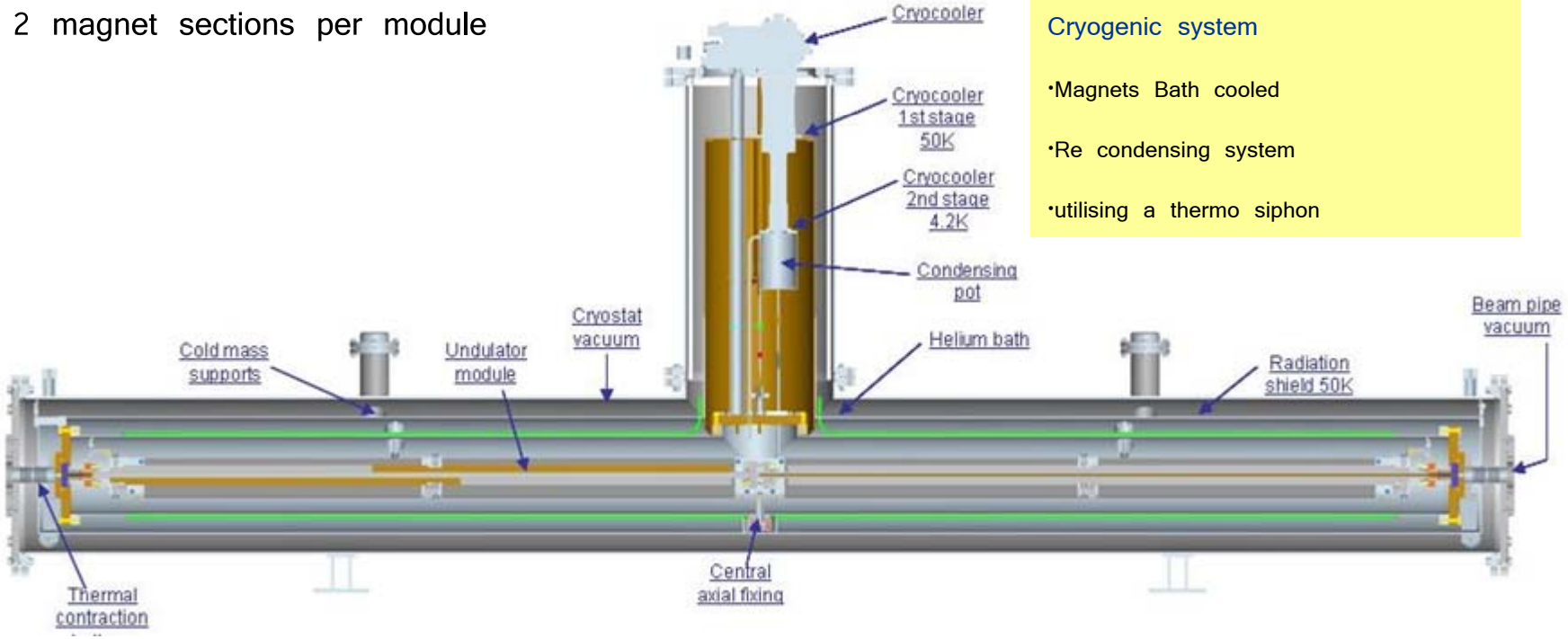
4m Prototype

- 150m of undulator
- Module length
  - Vacuum considerations <4m
  - Collimation <4m
  - Magnet R&D 2m section realistic
- Minimise number of modules
  - 2 magnet sections per module





Cryogenic system

- Magnets Bath cooled
- Re condensing system
- utilising a thermo siphon

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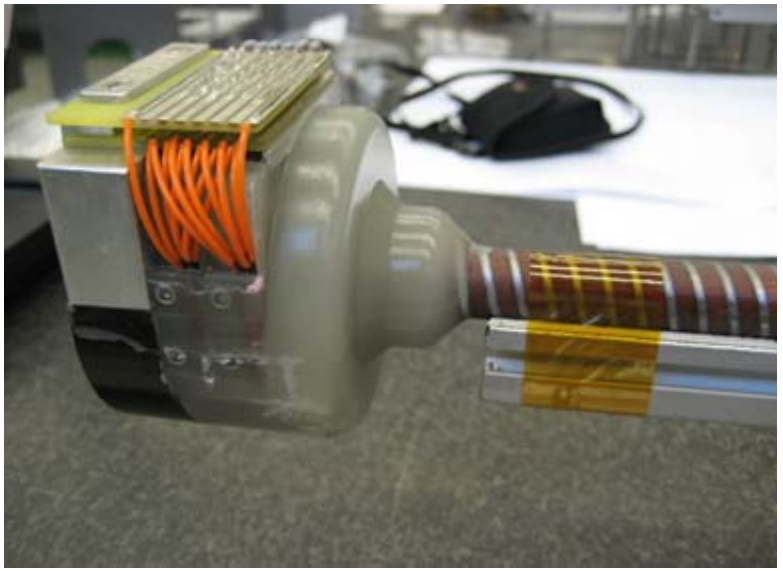
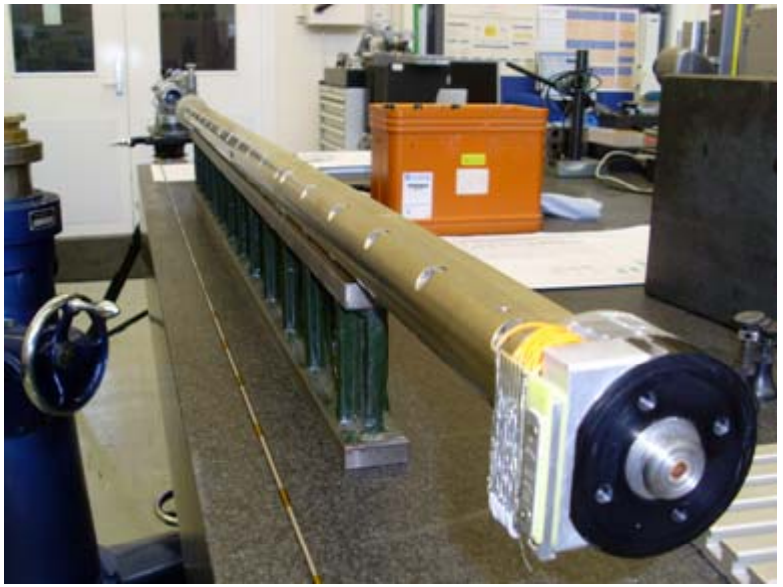
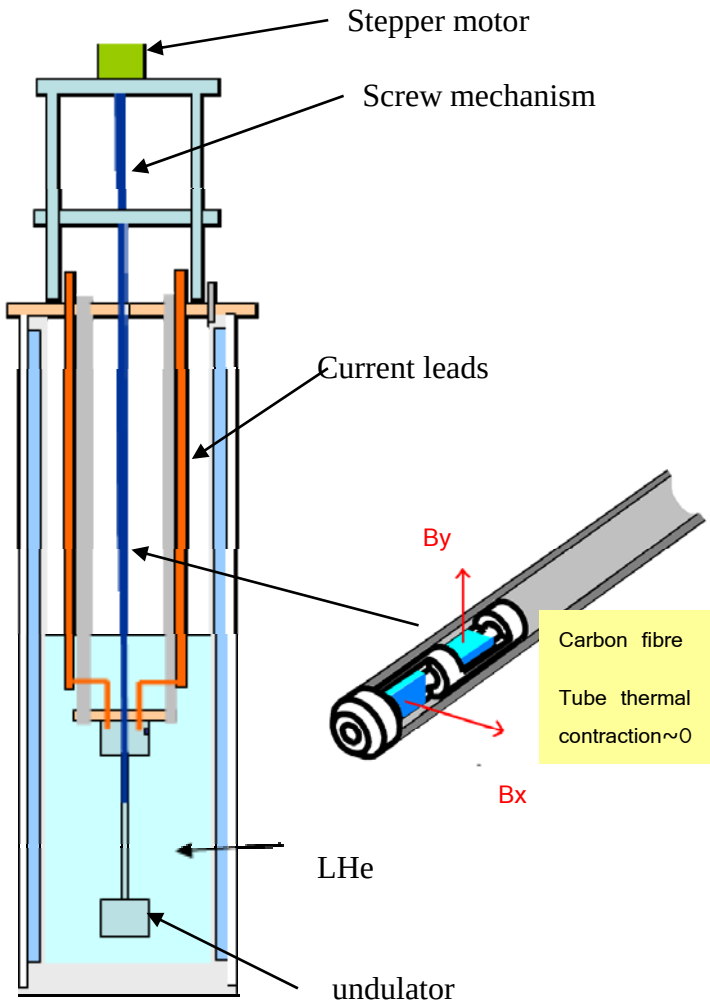
Magnet manufacture

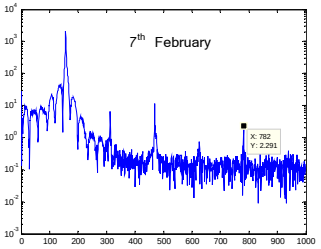




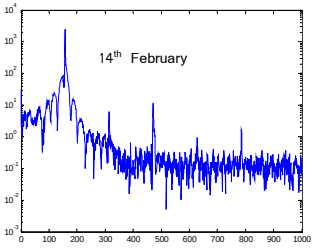
Magnet testing



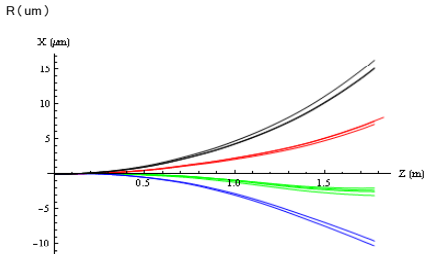
Field maps along the length of the undulator

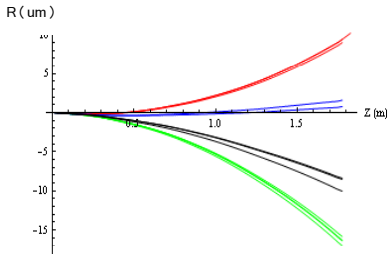


Consistency of logging system

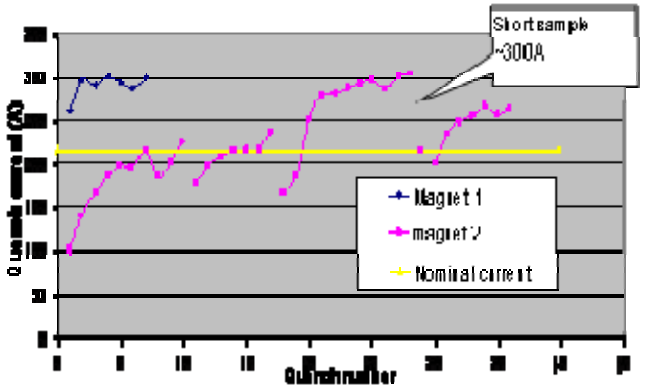


Sine wave pitch of – 11.492mm





Particle Trajectories analysis – SPECTRA within expectations



Quench testing both magnets deliver nominal field

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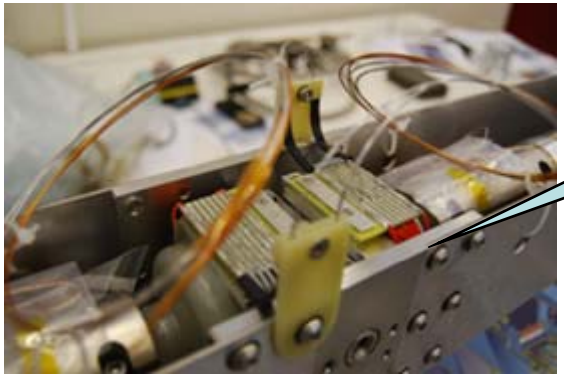
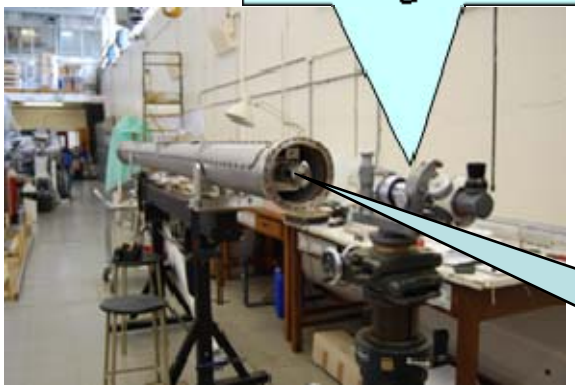
4m module assembly

4 meter module assembly

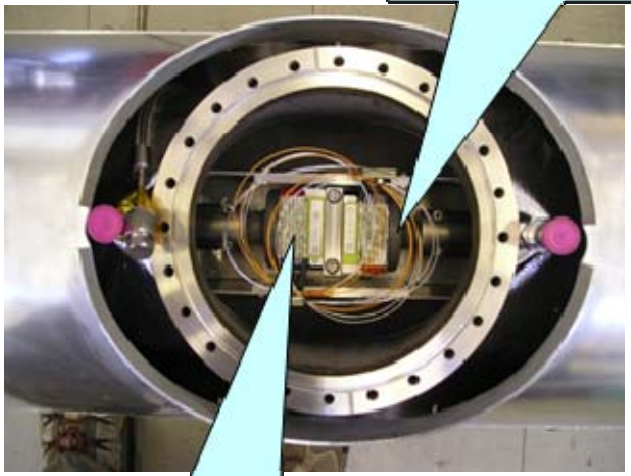


Straightness
250um



Alignment scope

Axis
alignment 1mm



Mag 2 connection

Mag 1 connection

Current leads

Condensing pot

HTS leads

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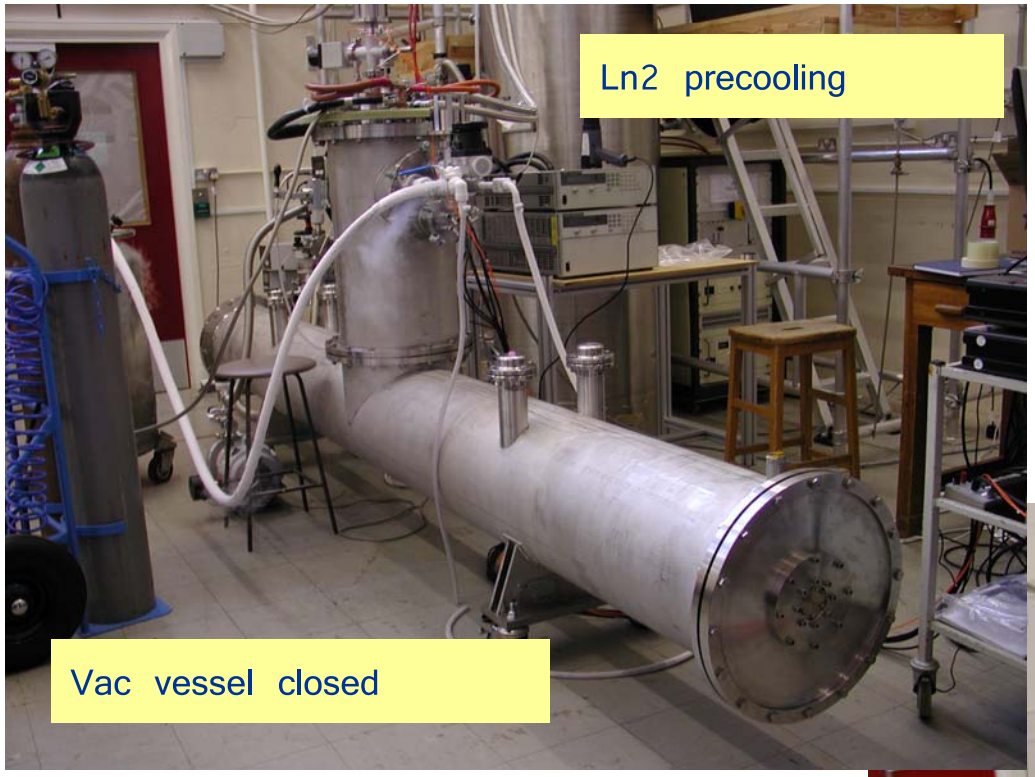
4m module testing 1



Ln2 precooling

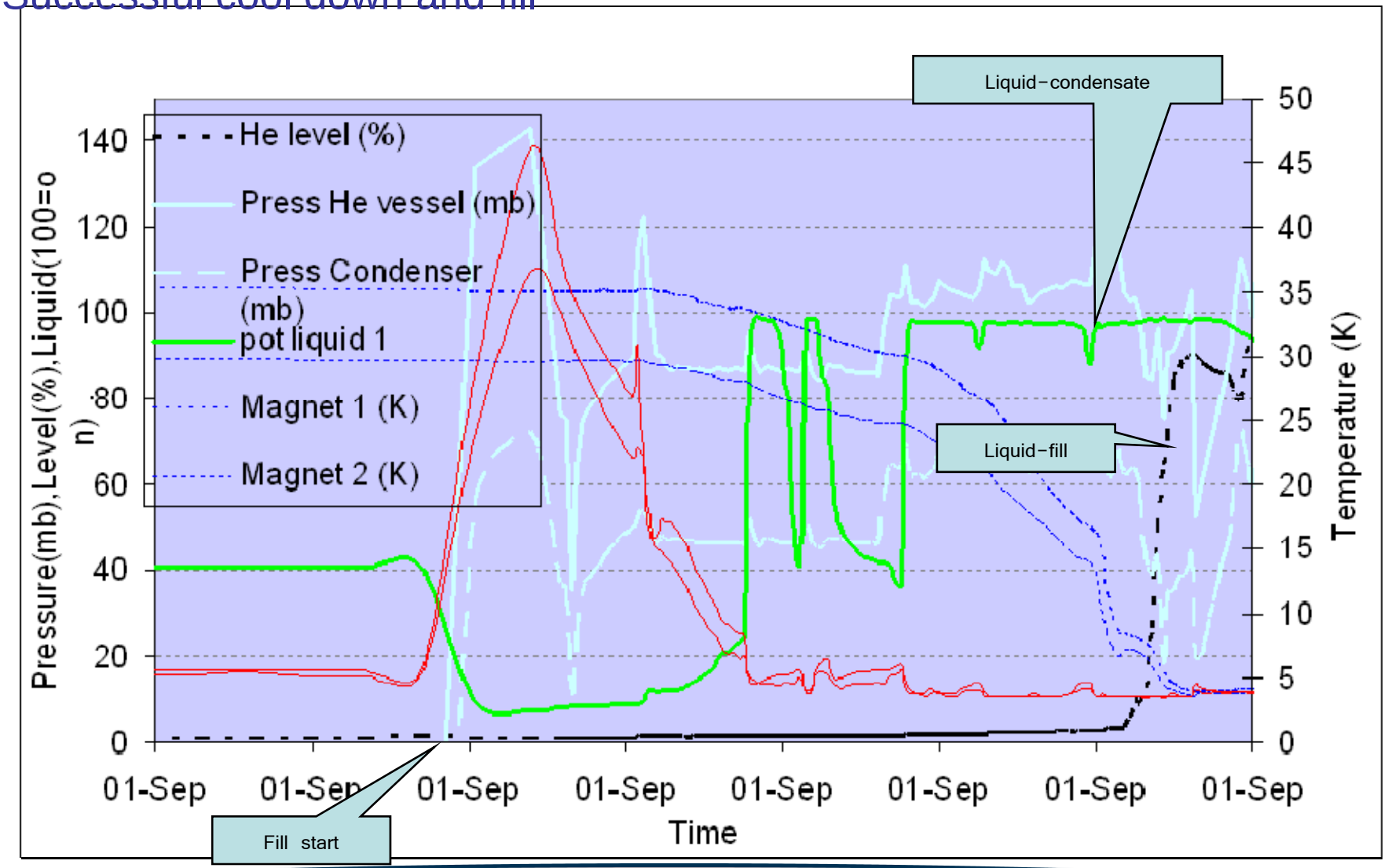
Vac vessel closed

First run of complete system early Sept.

Logging system connected

4m module testing 2

Successful cool down and fill



4m module testing 3

The 1st cool down was successful

- Filled system successfully
- Siphon operation seems good

However had serious problem

- Large heat leak evident
- Rapid boil off of liquid
- Loss of vacuum in magnet bore （Beam tube）
- Liquid helium leak into magnet bore
- System not stable enough to put current into the magnets

System had to be warmed

Current status

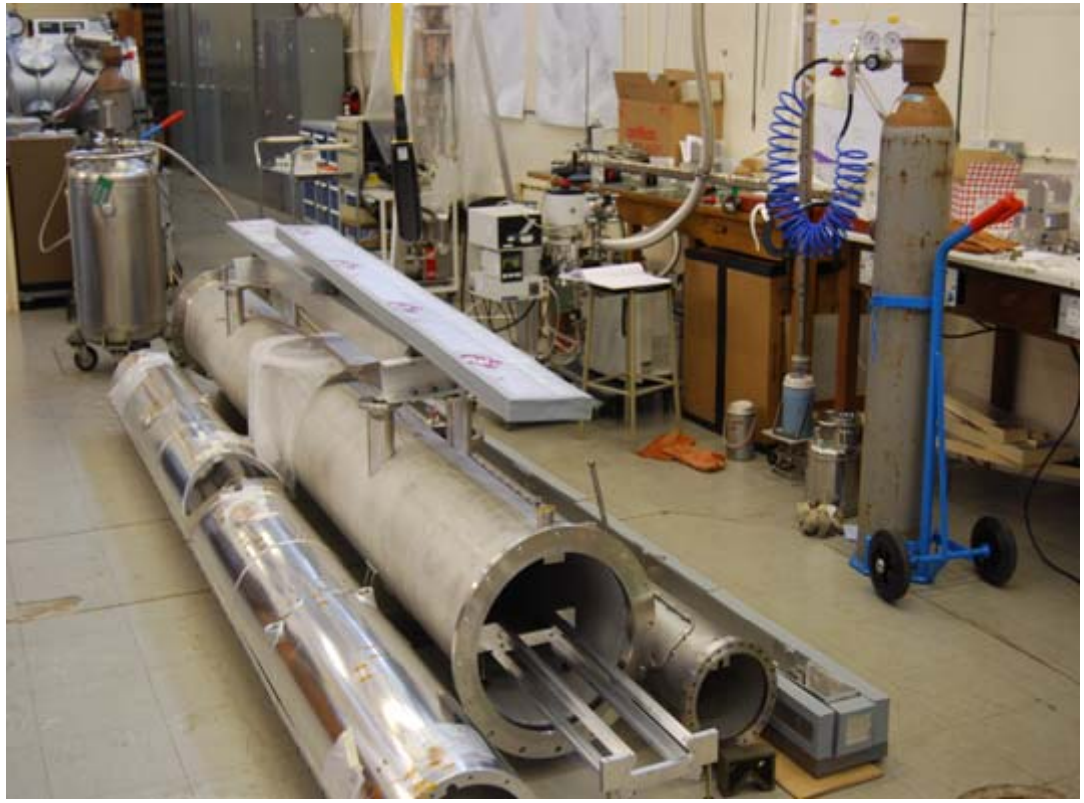
Upon warming

Found no leaks at 300K all <10e-10 into magnet bore

Found very small leaks between He vessel

–insulating vacuum <1e-8 – copper conflate seals

Clear we had a cryogenic leak !



Had to remove magnets

Complete strip down of the prototype

Current status

Cryogenic leak testing

Created a large open Liquid nitrogen bath

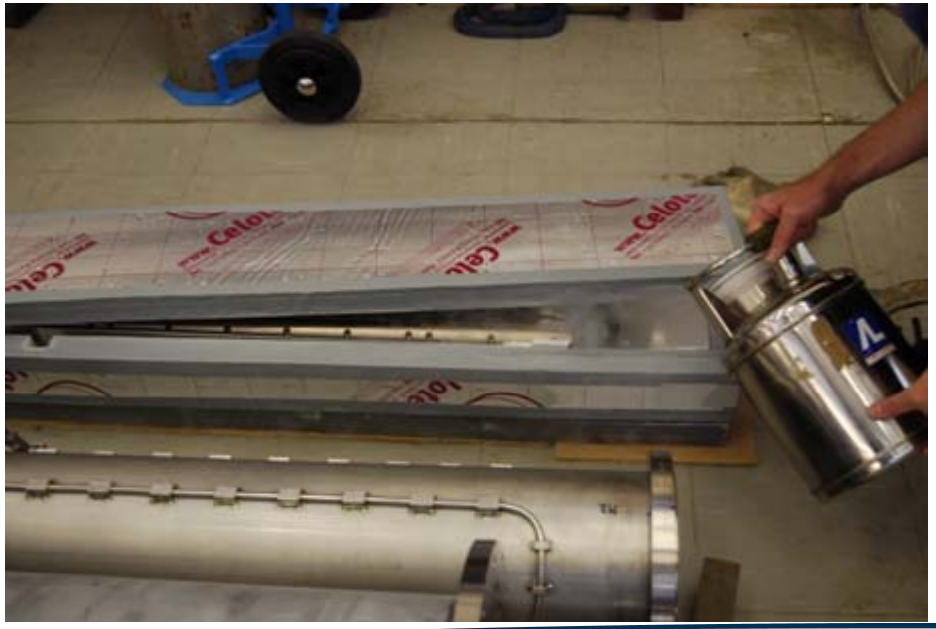
To immerse magnets whilst leak testing

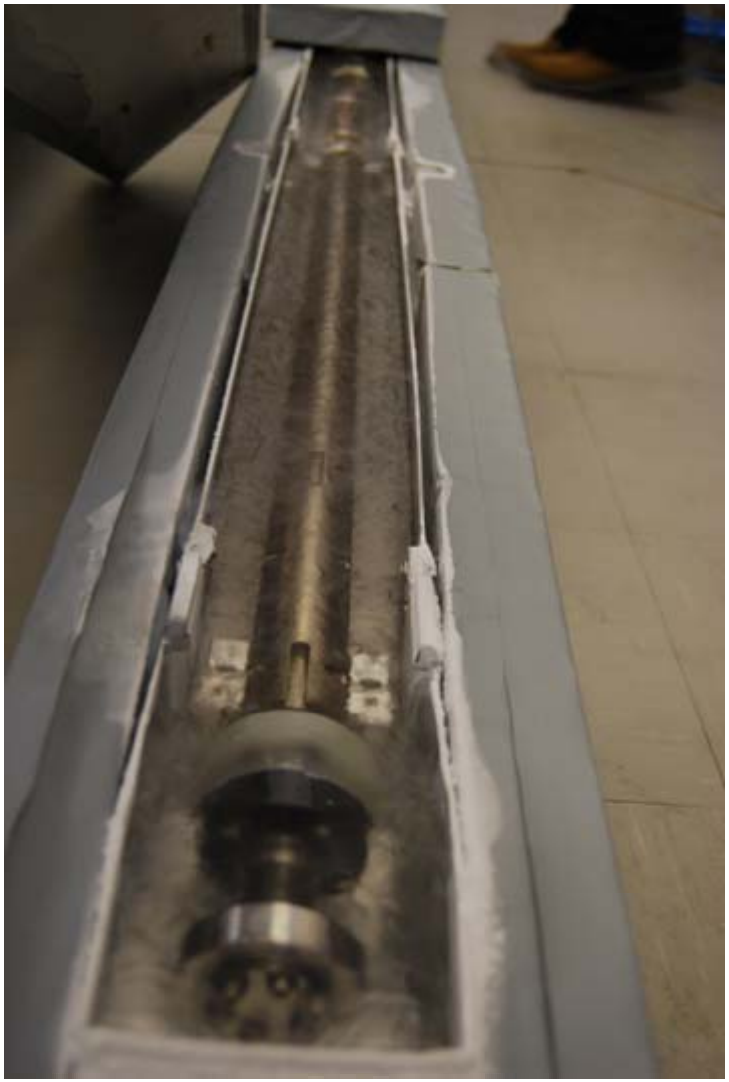
Initially found a leak at the indium seal between magnets

Fixed this by modifying the clamp arrangement

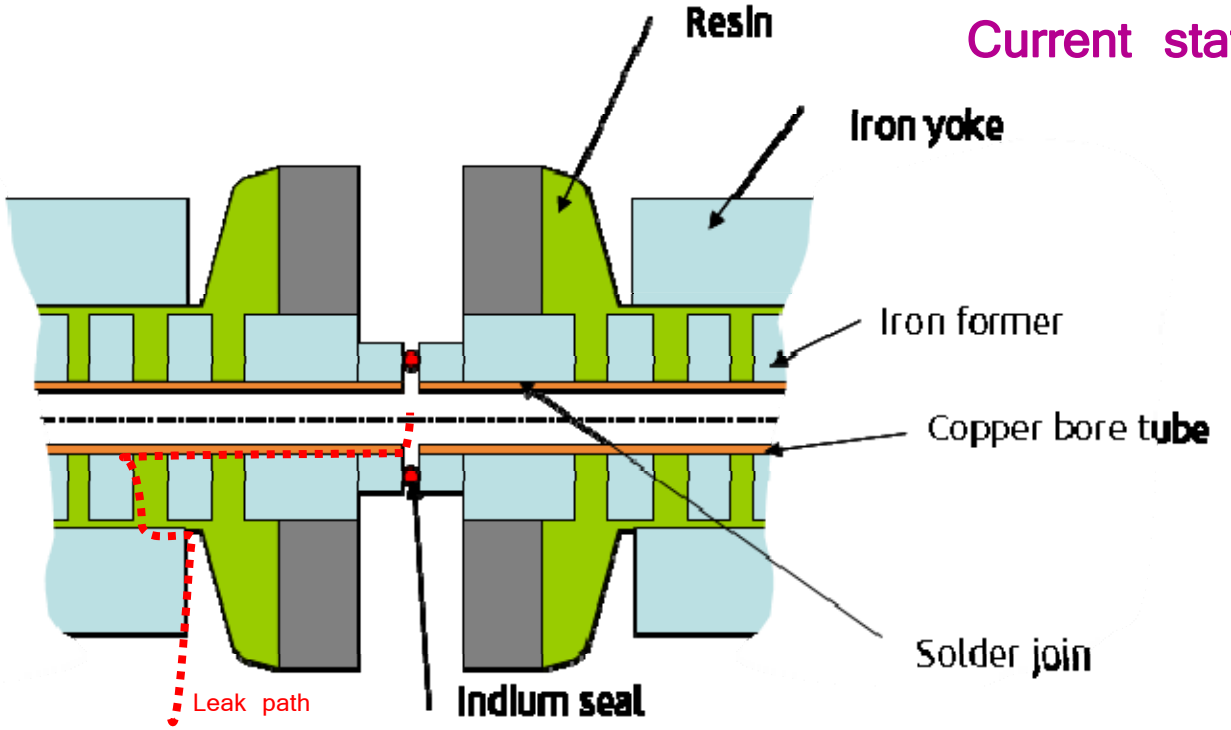
Much more worryingly seem to have a leak through

the magnet structure, on magnet 1 and magnet 2





Current status



Suspected leak path

The leak is strange

Not at a normal interface

Seems to be through the magnet torturous path through resin along copper bore to point where the magnets join

Have some ideas on how to fix this

There is a possibility that the bore tube has ruptured somewhere, this is really bad news! but the delay times in the leak response indicate the solder leak is much more probable

Leak rate 2e-4
level on magnet 1

Leak rate 2e-7
level on magnet 2

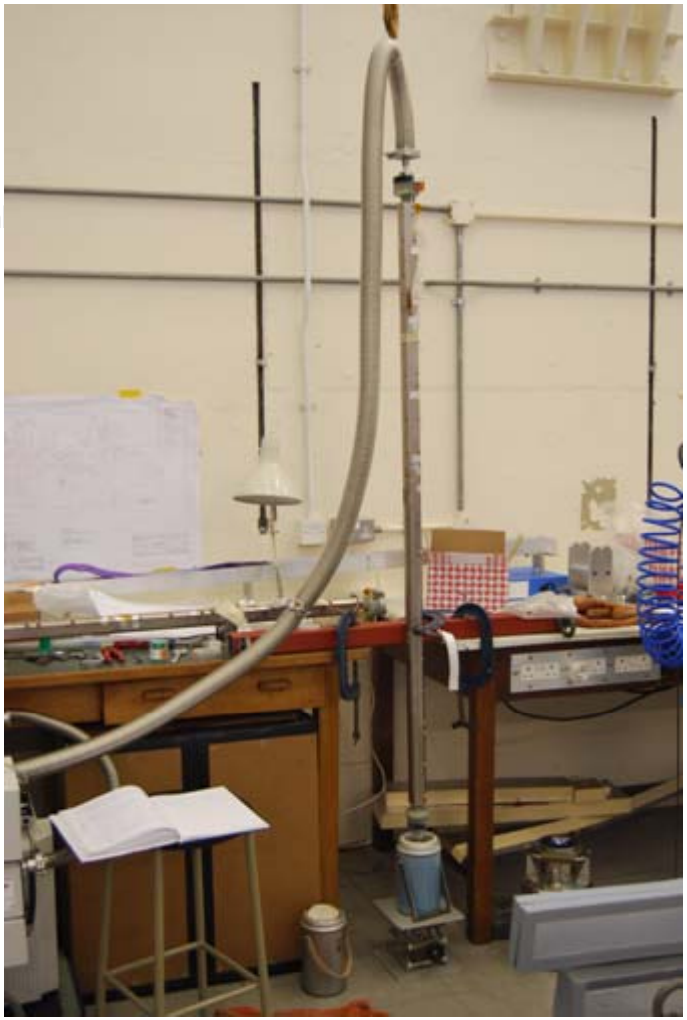
Current status

Further tests

Tests are hard to perform

Difficult to localise leak seen on magnet 2 may just be presence of lea on magnet 1 close by

More tests planned to try to isolate leaks



Future plans

Confirm leaks

Confident we can fix the leak with sty cast

Will check this by cooling with LN2 as for leak tests described earlier

Repeat prototype build with an additional step

Once the magnets are integrated in the vac vessel

We will cool using the LN2 circuit and leak check

prior to connecting the turret

If ok we will proceed with the build

Finish Rebuild of prototype

Hopefully by Christmas

Next cool down

Power magnets to nominal current

This will probably be in the new year

Stability tests

Warm up

Bore heater tests

More quench tests of magnet 2