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Technology

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

Magnet manufacturing spec

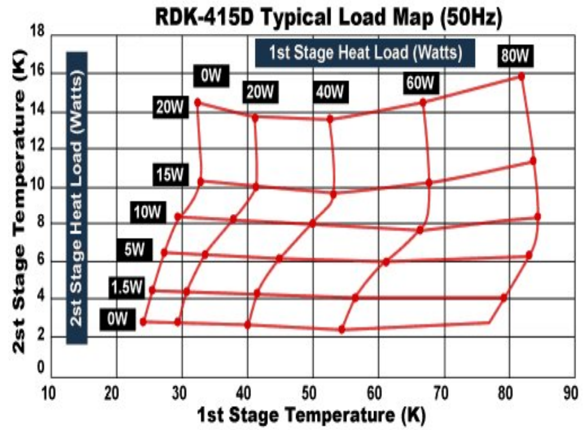
Following a pretty extensive R&D programme and modelling study the following specification was developed for the undulators:

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.

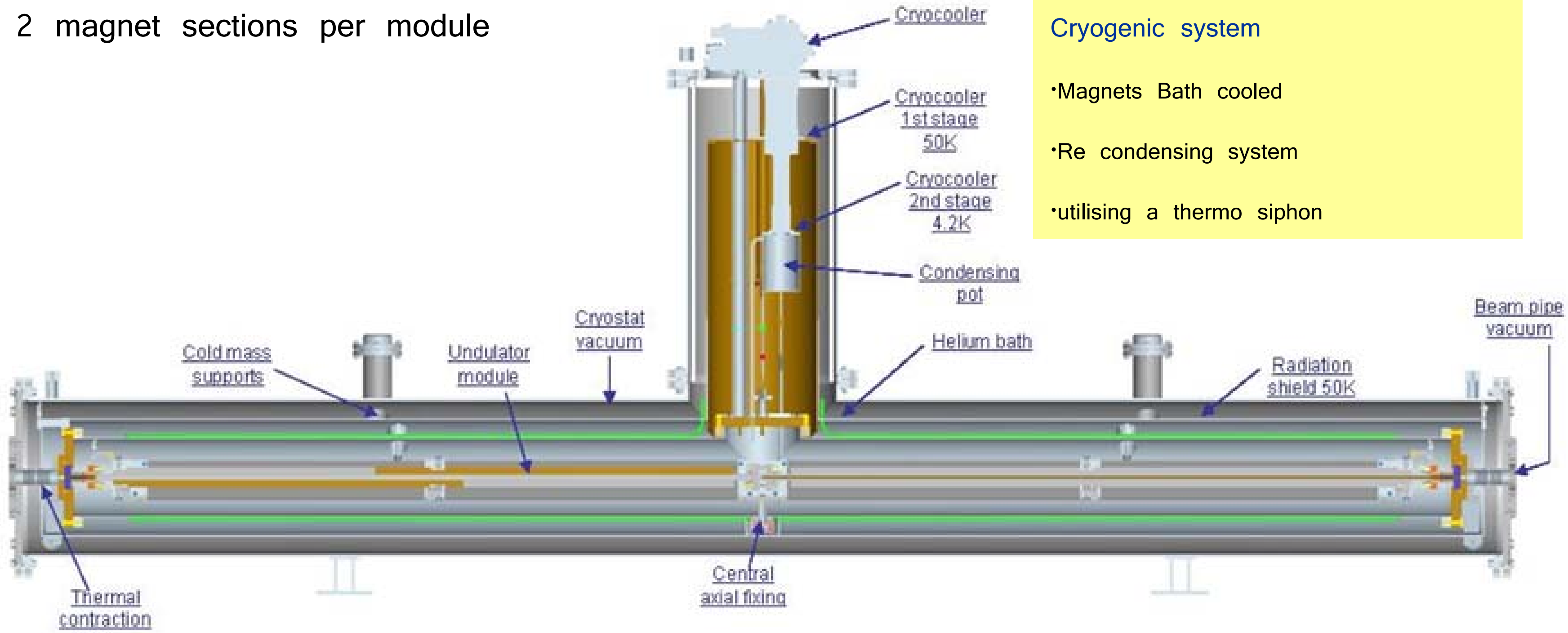
4m Prototype

- 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

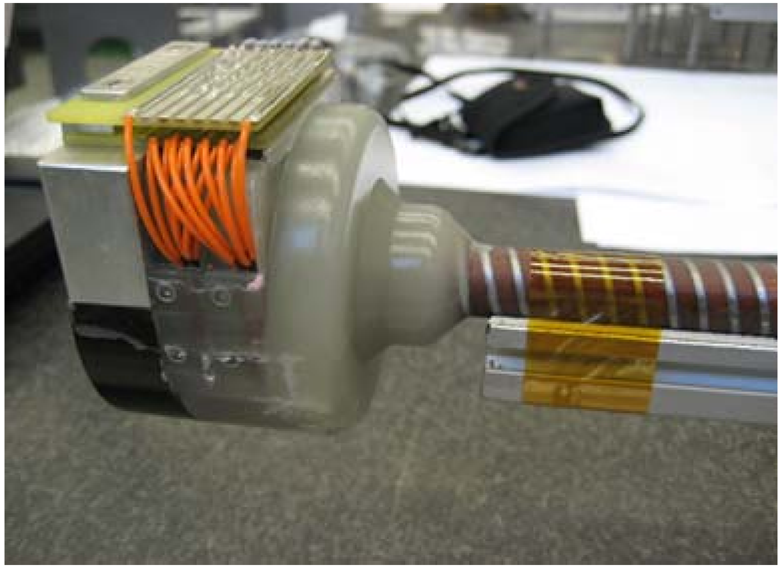


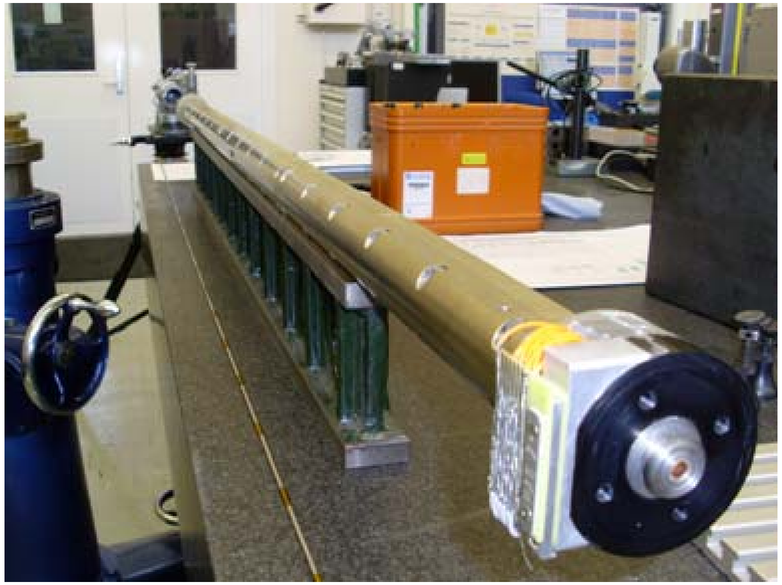
Cryogenic system

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

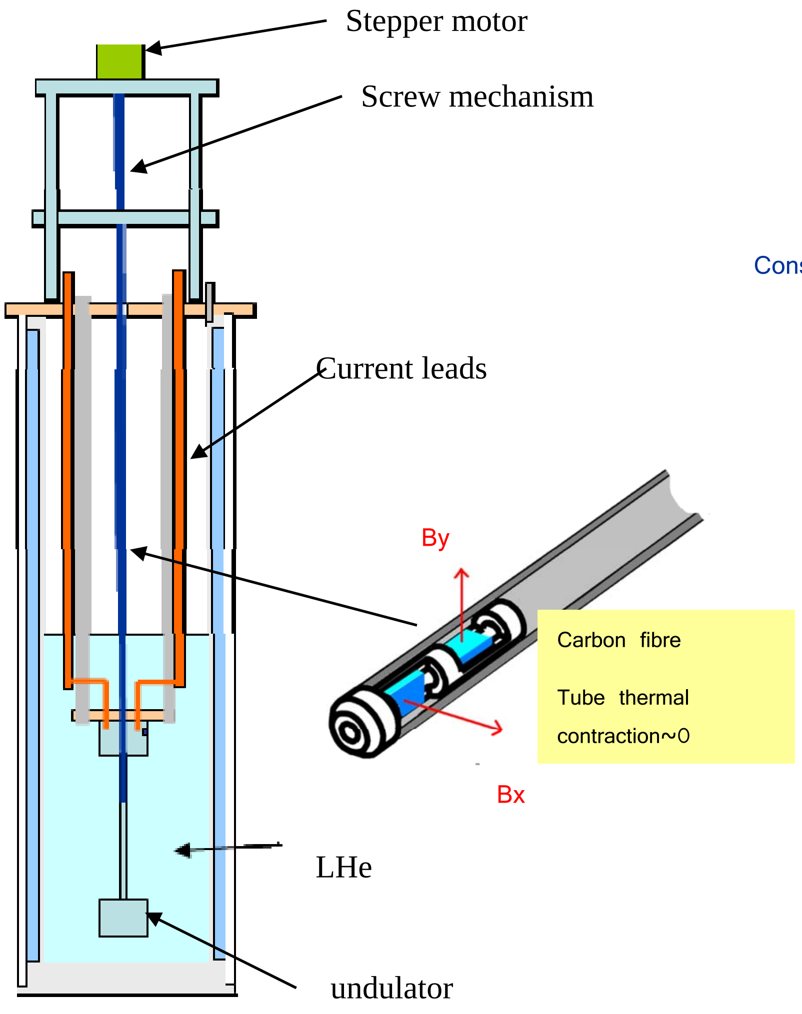


Magnet manufacture

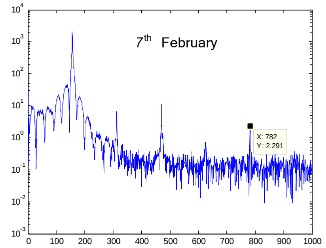




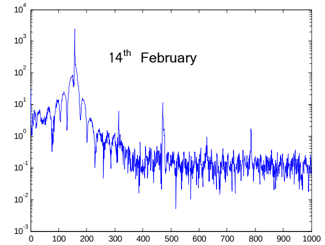
Magnet testing



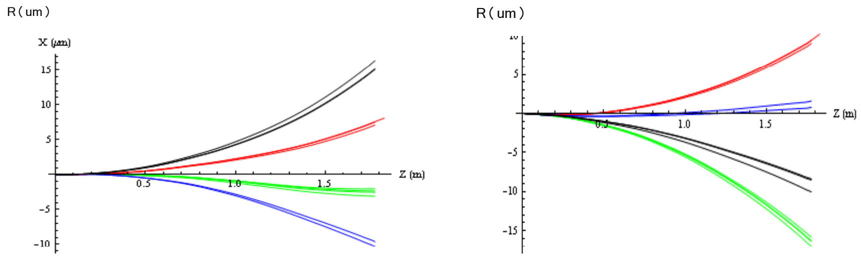
Field maps along the length of the undulator



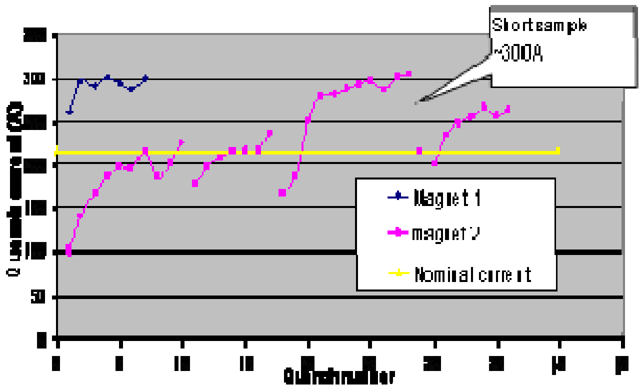
Consistency of logging system



Sine wave pitch of – 11.492mm



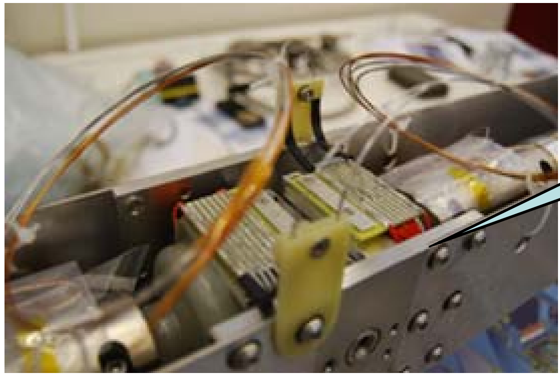
Particle Trajectories analysis – SPECTRA within expectations

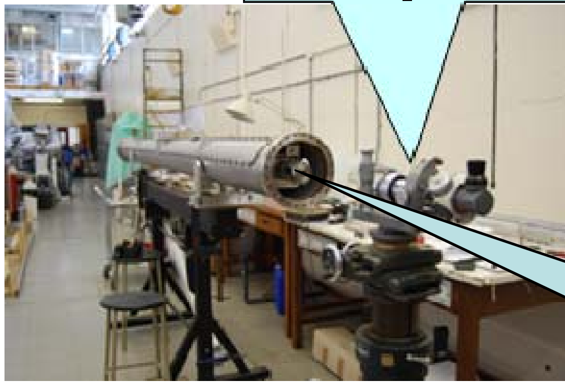


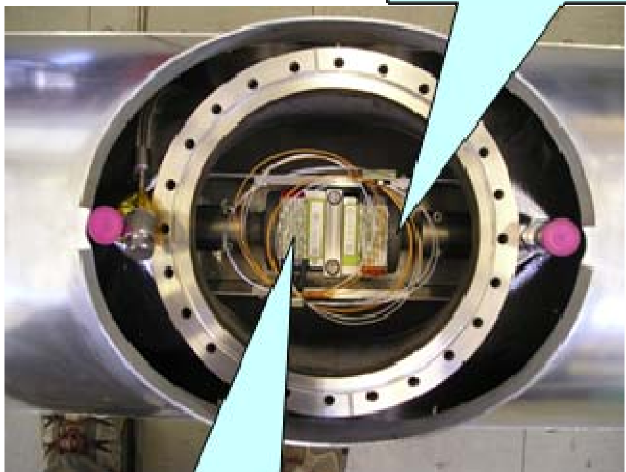
Quench testing both magnets deliver nominal field

4m module assembly

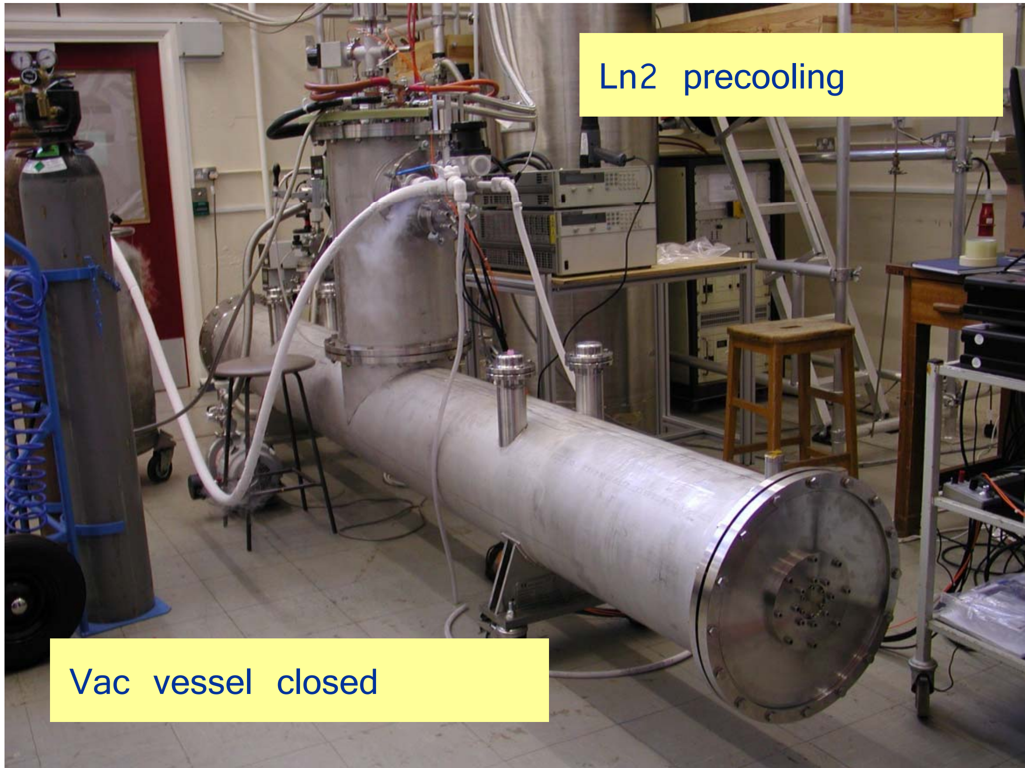
4 meter module assembly





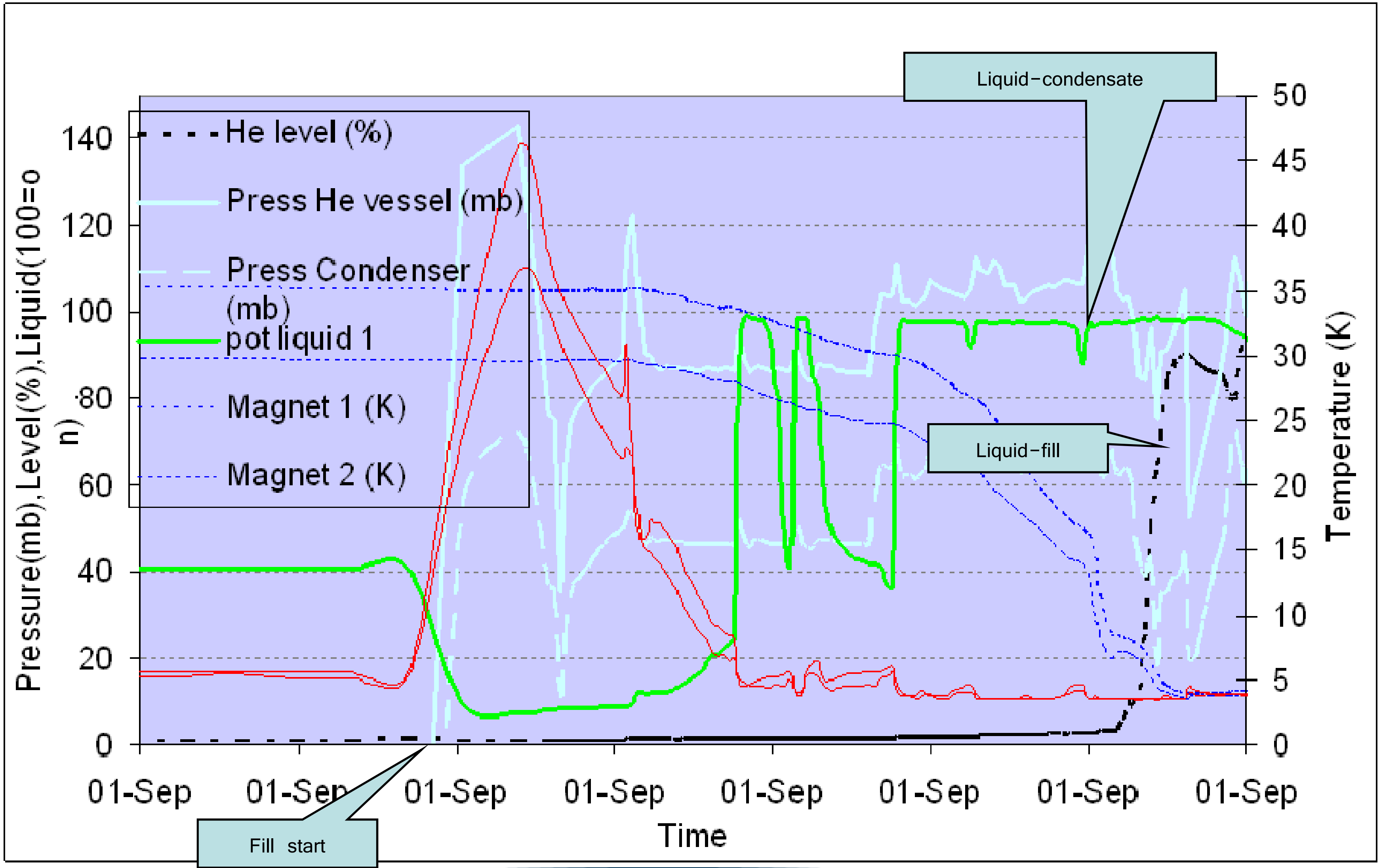


4m module testing 1



First run of complete system early Sept.

Successful cool down and fill



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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

Leak checking 1

Upon warming

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

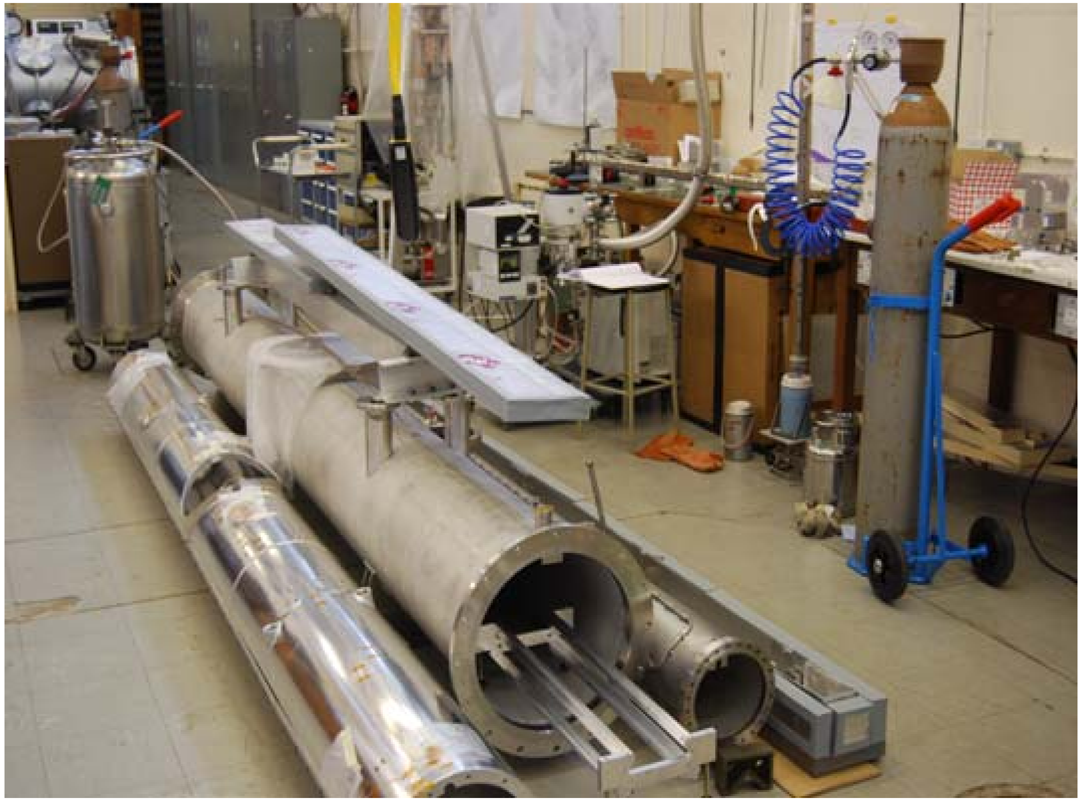
Found very small leaks between He vessel

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

Clear we had a cryogenic leak !

Had to remove magnets

Complete strip down of the prototype



Leak checking 2

Cryogenic leak testing

Created a large open Liquid nitrogen bath

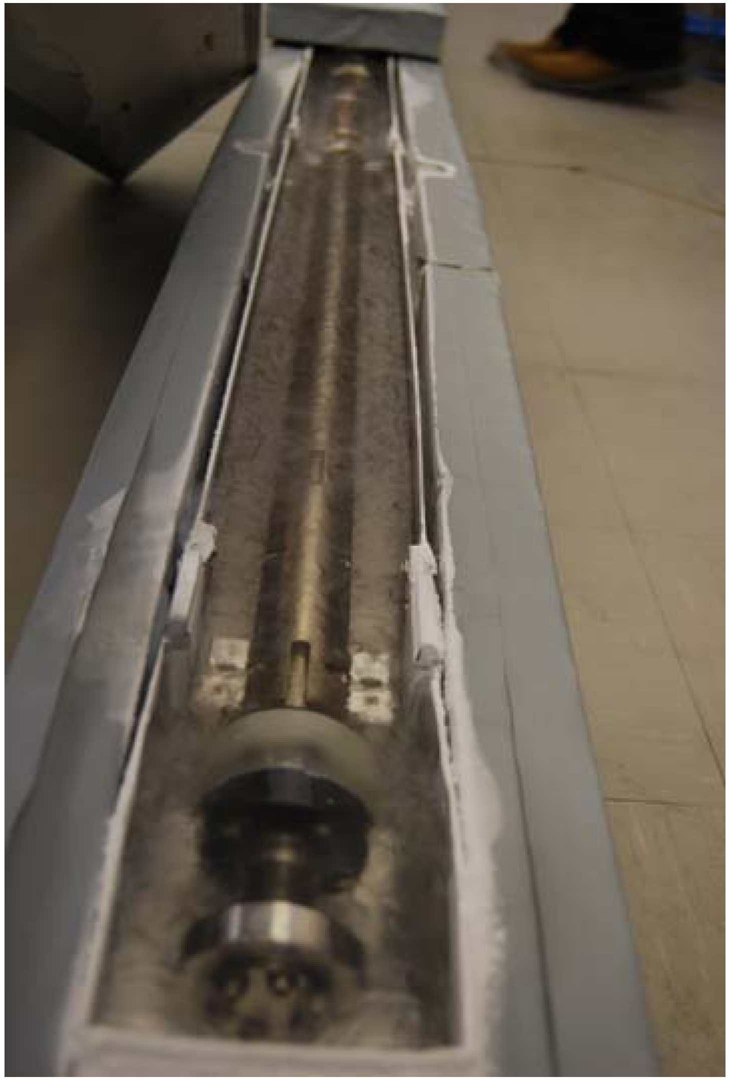
To immerse magnets whilst leak testing

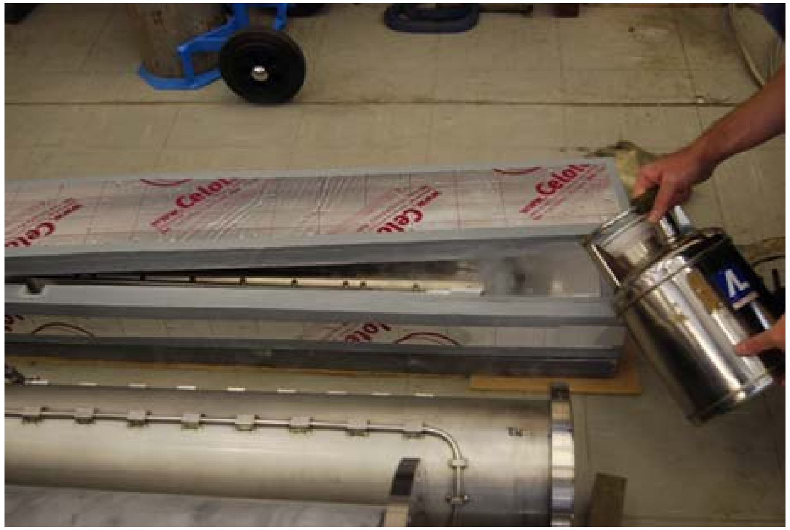
Initially found a leak at the indium seal between magnets

Fixed this by modifying the clamp arrangement

Much more worryingly was we seemed to have a leak through

the magnet structure, on magnet 1 and magnet 2



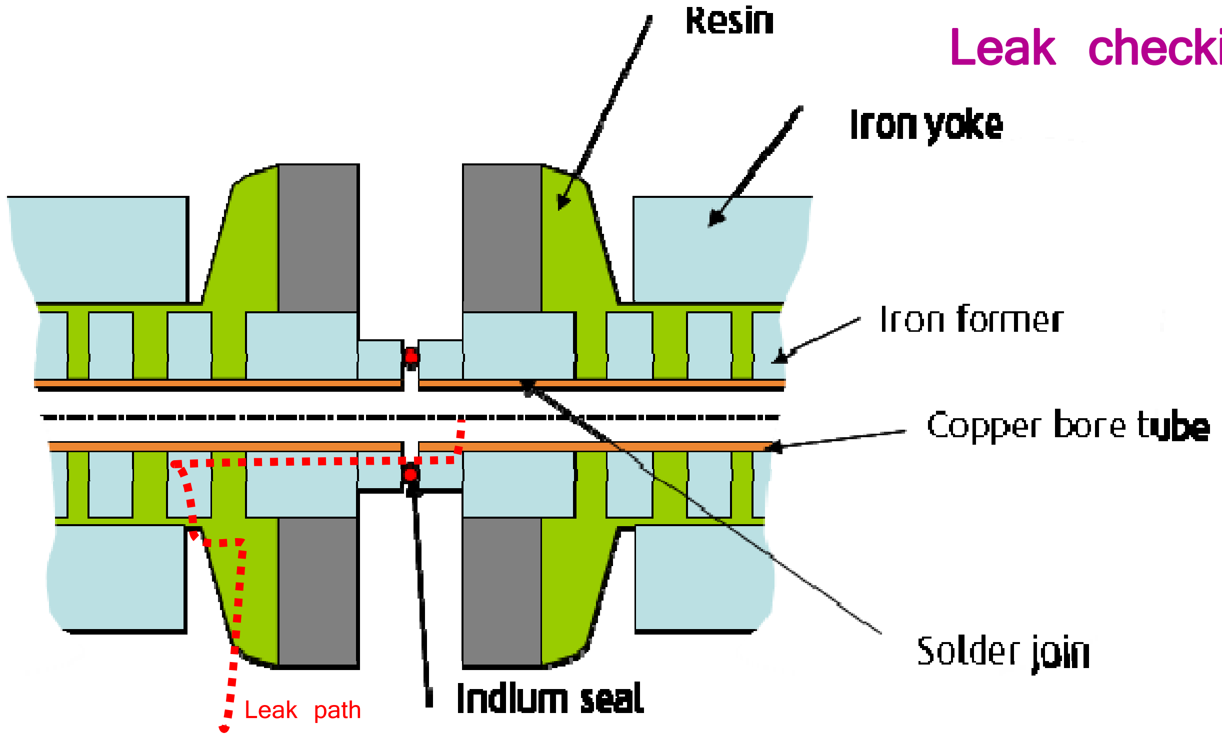


Leak checking 3

The 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

Leak rate 2e-4 level on magnet 1

There is a small possibility that the bore tube has ruptured somewhere this is really bad news! , unfortunately we cannot differentiate clearly between these, but the delay times in the leak response indicate the solder leak is much more probable

Leak rate 2e-7 level on magnet 2

Leak checking 4

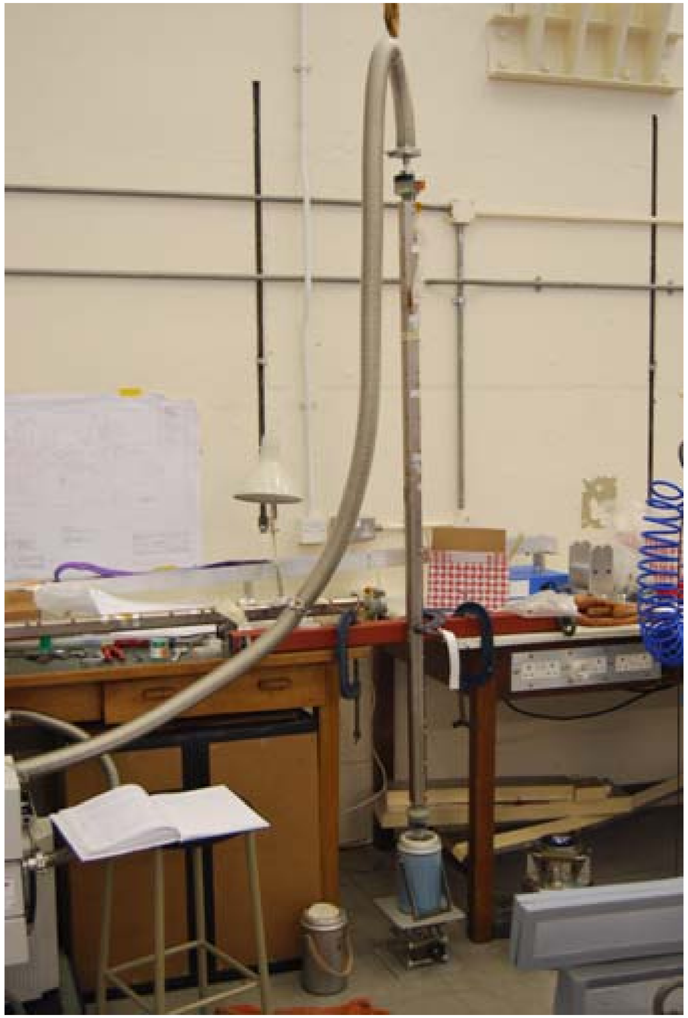
Further leak tests

Aim: Isolate leaks, difficult in composite structure

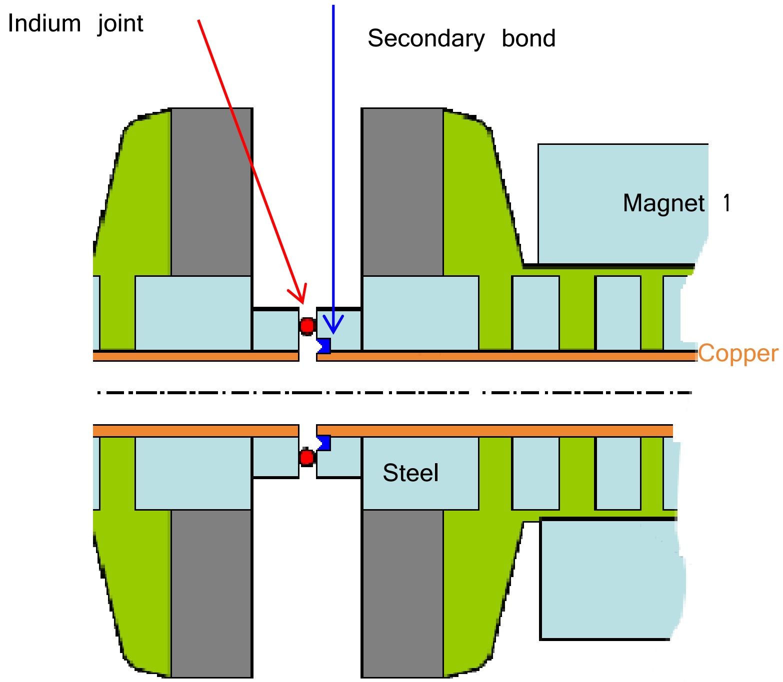
Tested magnets independantly

Are now confident only magnet 1 leaks

Original leak seen on magnet 2 – leak on magnet 1 close by



Fixing the leak 1



Leak fix R&D

Limited options here, magnet is delicate.

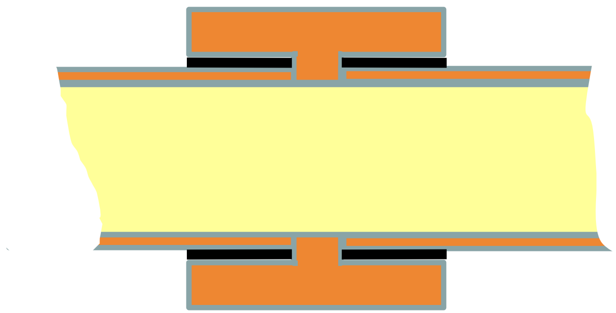
Cant simply rerun solder joint

Main ideas centre on creating a secondary seal.

Number or small R&D samples

Find the best method to fix it

- 1 keep existing structure machine in a small groove to fill
  - *need material to cope with differential contraction*
- 2 machine away steel flange leaving only the copper tube
  - *Sleeve and stycast (fall back solution)*



Stycasted Cu\Cu sleeve

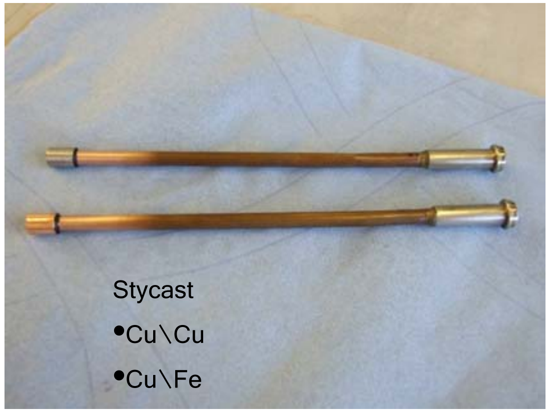
Fixing the leak 2

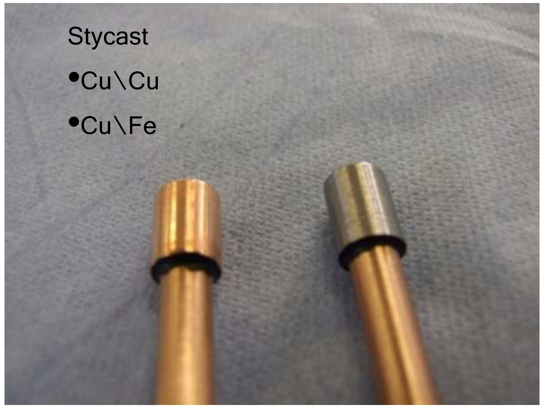
R&D Samples

Different epoxies
All fail under repeated cycling for Cu|Fe combination
Problem seems to be the differential contraction

Stycast with a Cu\Cu Joint works-implication need to machine away Steel flange

More samples to test using woods metal.
Have some ideas to inset a Steel\Cu ring to act as a filler which can better match the conductivities





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Future plans

Following leak fix

Check magnet 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

Rebuild of prototype

Should have system closed by Christmas （Aggressive schedule）

Next cool down

Power magnets to nominal current

1st week of the new year