

# Cryogenics at the Rutherford Appleton Laboratory



Space  
Coolers



Alma



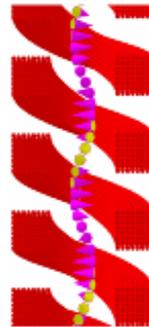
Neutrino



Materials  
Testing



Particle Physics



Superconducting  
Magnets



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# Space Coolers



- Developed long life refrigerators for space use
- Have demonstrated 16yrs continuous operation
- Licenses to Astrium and Ball Aerospace in the US
- Single stage Stirling - 80K, two stage - 10K, and 4K - Stirling + JT



# Life test and delivered Coolers

Name	Comments	Com p	Disp	Life
RAL 80K Lifetest	Failed after 7.5 years due to leak in feedthrough – started again and now run for 16 years Mar 2006			16 yrs
ESA 80K Lifetest				8.1 yrs
ATSR1	Launch June '91run until June '96still OK. Satellite failed	2	1	5 yrs
ATSR2	April '95- still running	2	1	5.7 yrs +
AATSR	Two coolers	2	2	
Bae DM1	Life test cooler later AIRS DM	1	1	
Bae DM2	Development models later ESA 65K DM's	2	2	
ISAMS	Launch Sep '91 (2 coolers) RAL/OU	2	2	1.8 yrs
NRL HTSSE1	Launch failure - Sea ?	1	1	
NRL HTSSE2	Spring '97 No failures	1	1	
JPL	Test cooler – extensively tested	1	1	
TRW	Evaluation cooler	1	1	
GSFC	Evaluation cooler	1	1	
ESA	Pre-qualification model	1	1	
Fujitsu	2 x “Evaluation” model	2	2	
French Military mission	2 x QM + 2 x FM	4	4	
MIPAS	4 built	4	4	
Moppit (Canada)	2 x evaluation cooler	2	2	
Toshiba	Evaluation cooler	1	1	
IMG (Toshiba)	FM + EM	2	2	
Rockwell	Four coolers delivered	4	4	
INTEGRAL	2 x FS + 4 FM Started operation with coolers 1 Nov 2002	6	6	2.5yrs
Odin	Swedish instrument	1	1	
Bae	Two-stage cooler pre-qual. model	2	1	
TRP Cooler	Two Stage Stirling + JT compressors (5 mechs.)	4	1	
FIRST	As above but two complete versions made. Compressors later used for Planck	8	2	
Totals		57	45	

It is quite difficult to track the fate of all the coolers of the "Oxford" type that have been manufactured and flown. Some have been sold to military programmes. A number of these coolers were sold into Japan and their fate is not known.

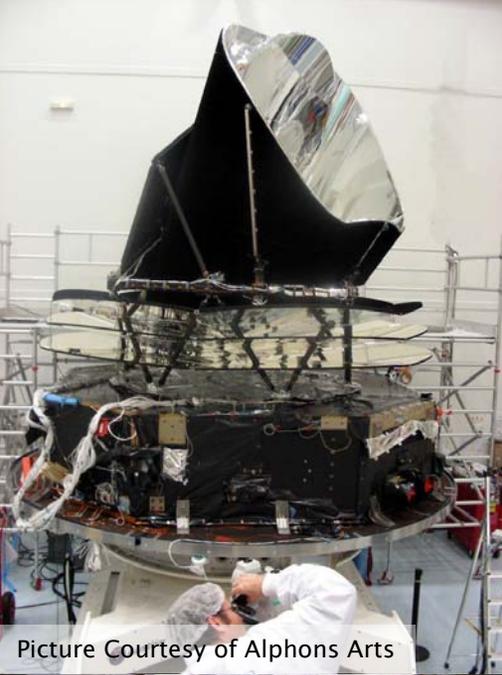
Included in this table are Astrium and RAL coolers



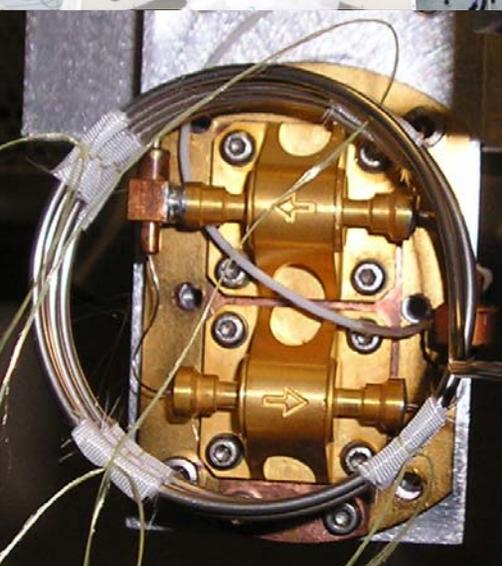
# Planck 4K Cooler

Integrated on spacecraft in 2007, cold tests completed August 2008.

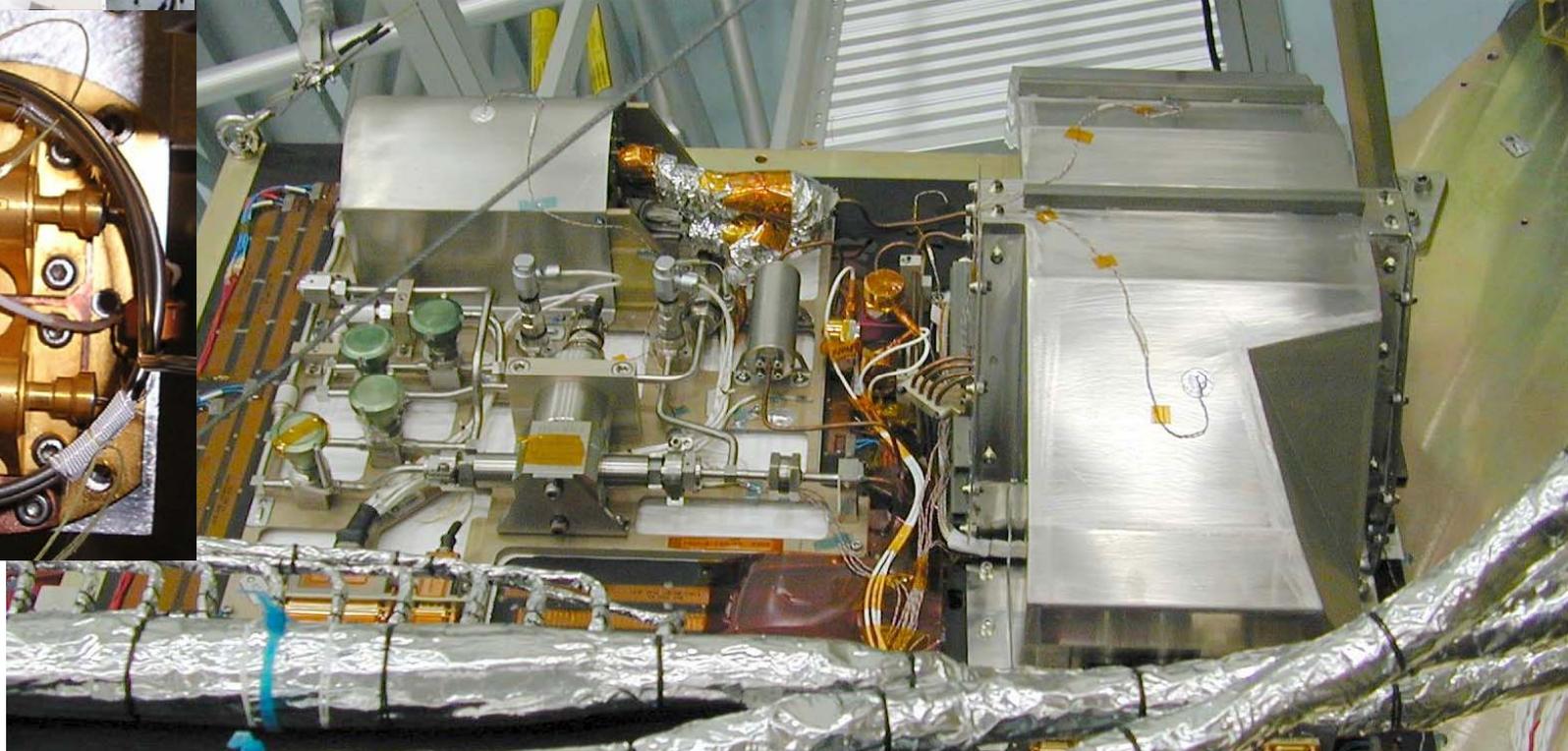
RAL is supplying the 4K cooler sub-system



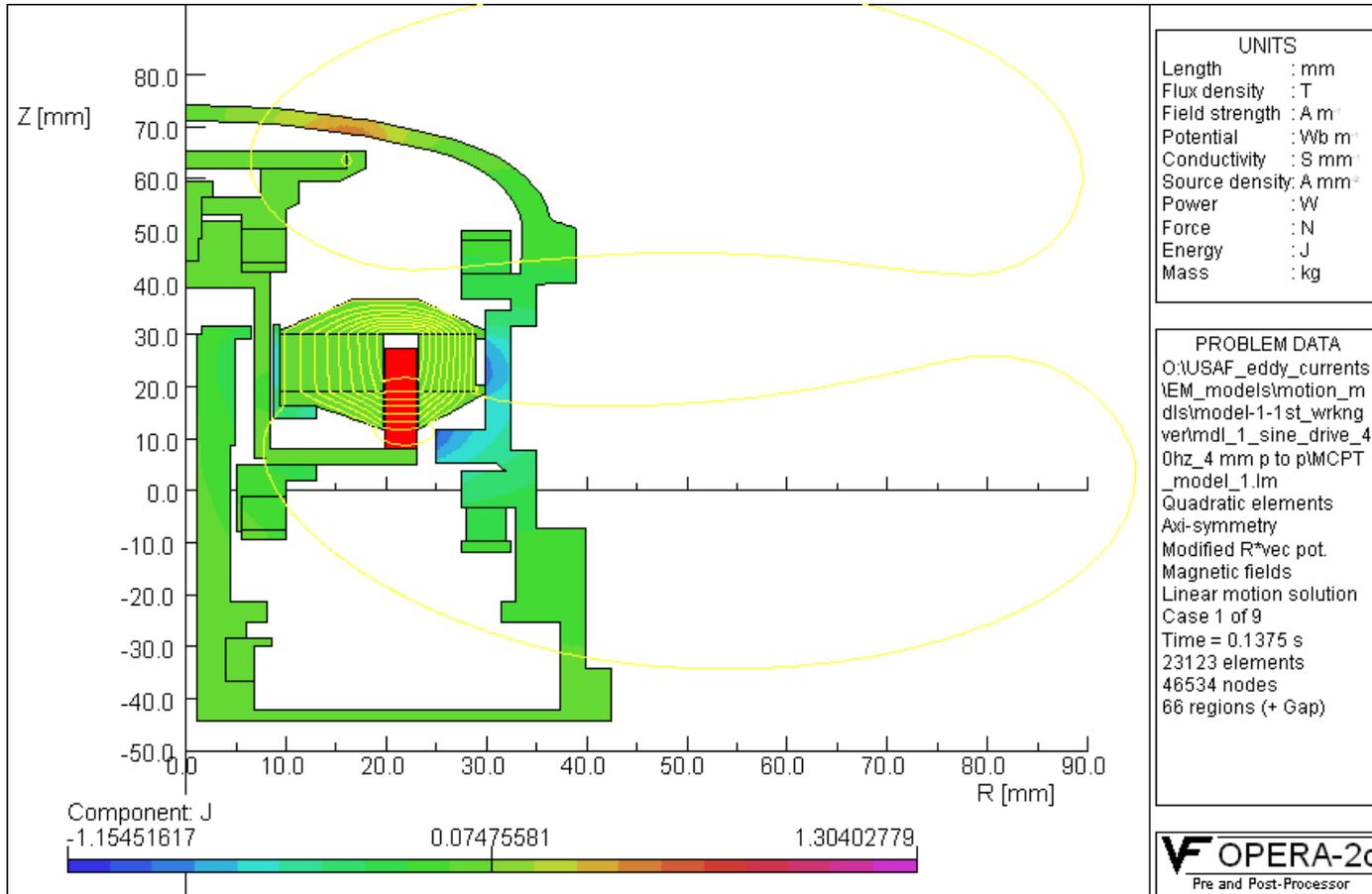
Picture Courtesy of Alphonse Arts



4K Stage



# Compressor Development - Analysis



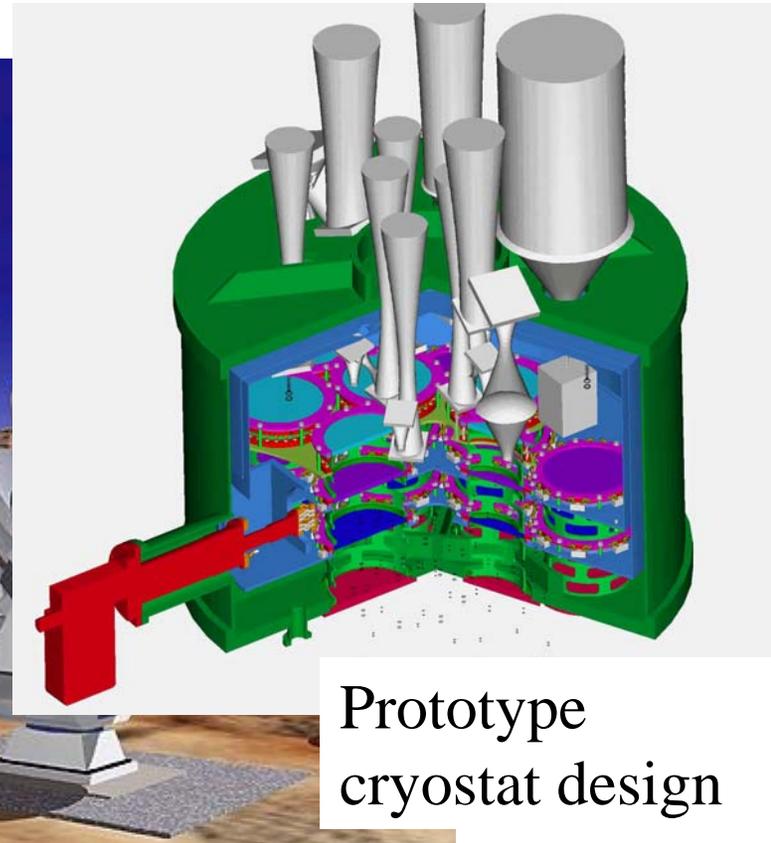
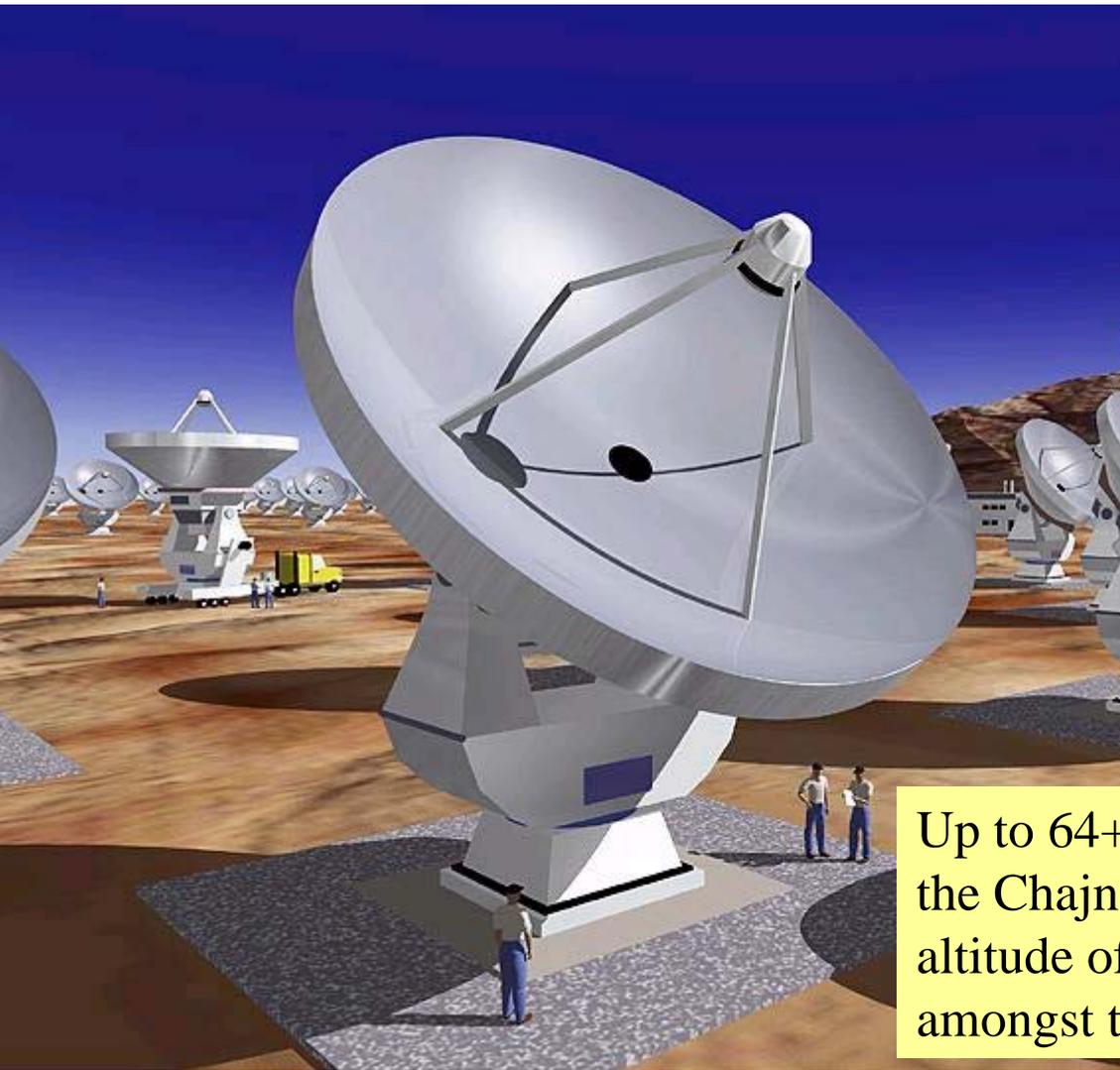
An example of the recent modelling work – eddy current analysis.



## Atacama Large Millimetre Array

64+ x 12m telescopes in Chile - all need long life high reliability systems

## Atacama Large Millimetre Array



Prototype  
cryostat design

Up to 64+ 12-m antennas will be placed on the Chajnantor site, a high plateau at an altitude of about 5000 meters (15,000 ft) amongst the Andean mountains in Chile.

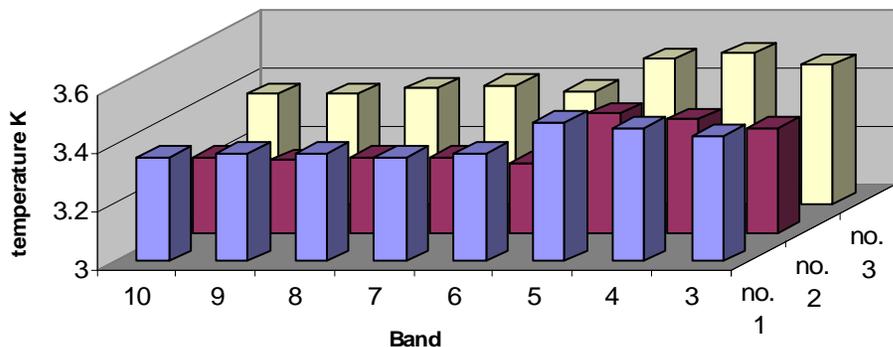
# ALMA - Atacama Large Millimetre Array



- 4K Plate  
Concentricity to Datum = 202.35  $\mu\text{m}$   
Parallelism to Datum = 29.65  $\mu\text{m}$
- 12K Plate  
Concentricity to Datum = 182.95  $\mu\text{m}$
- 90K Plate  
Concentricity to Datum = 126.4  $\mu\text{m}$
- DATUM  
Flatness of Datum = 30.40  $\mu\text{m}$

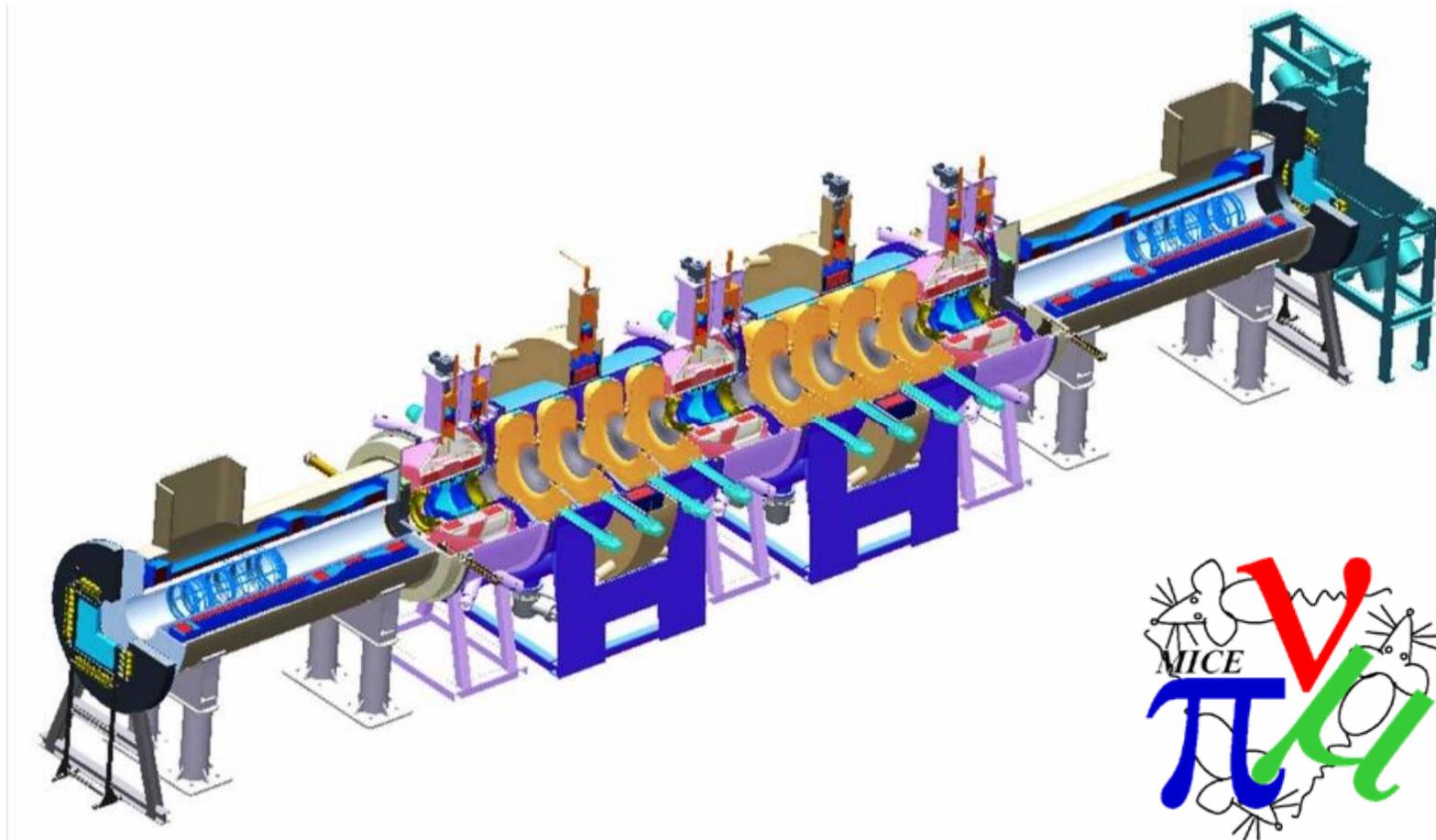


4 K temperatures with full operating heat loads

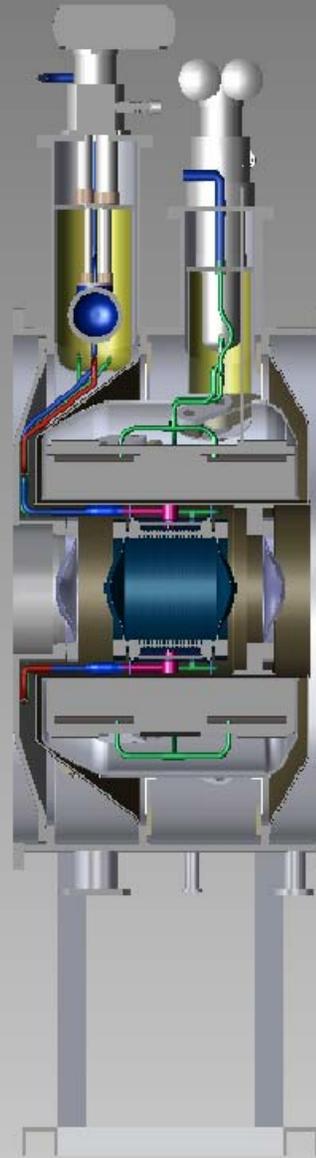


# MICE

Muon Ionisation Cooling Experiment ( MICE ) – precursor to a neutrino factory



# Muon Ionisation Cooling Experiment

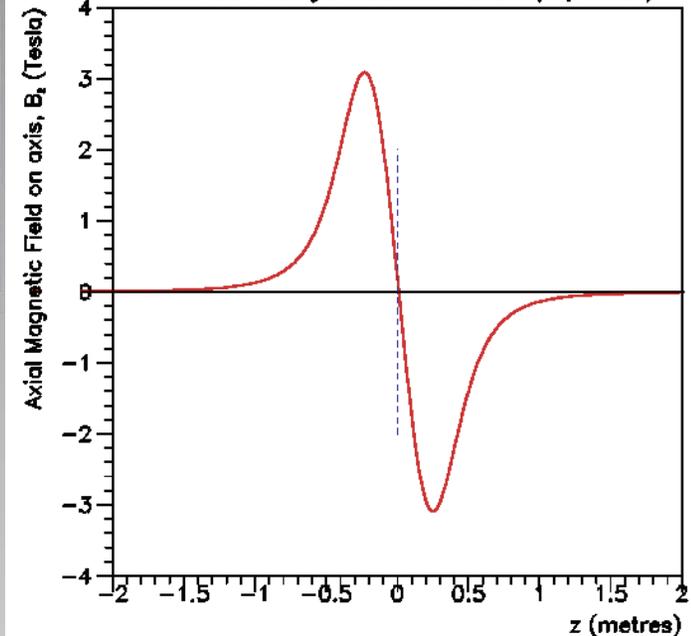


AFC Module for MICE –  
being produced with  
Oxford University for the  
MICE experiment

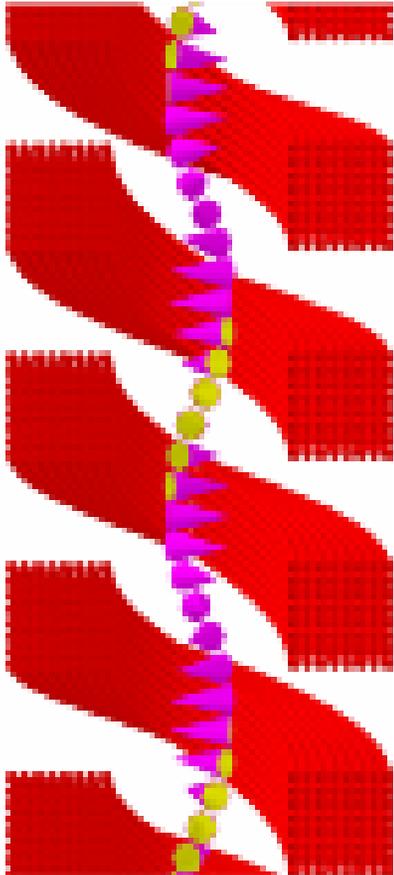
This is a superconducting  
magnet with a 22litre  
liquid hydrogen absorber  
in the centre

Group is responsible for  
the hydrogen delivery  
system

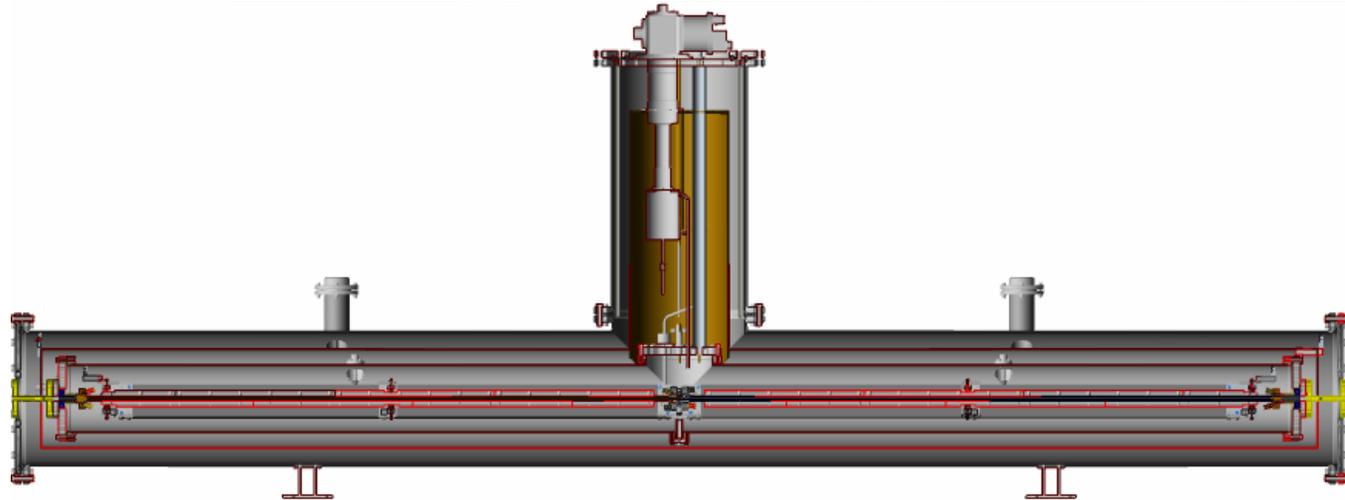
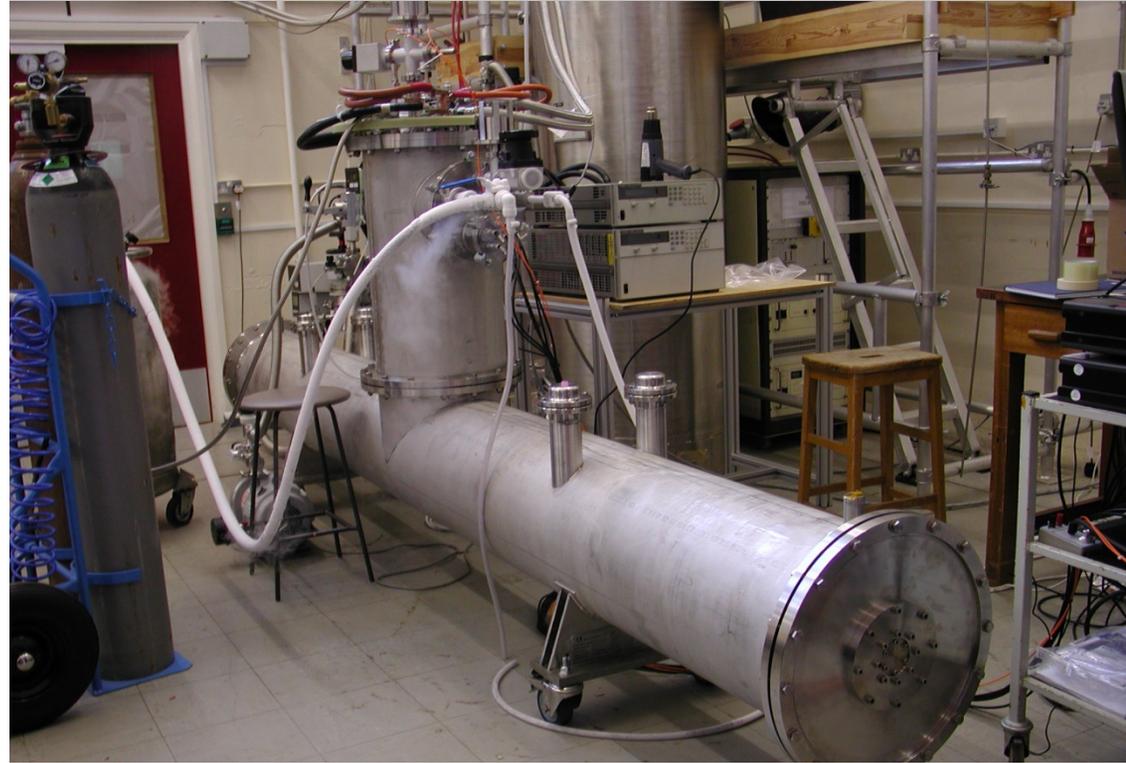
Axial Field in single MICE AFC module (Flip mode)



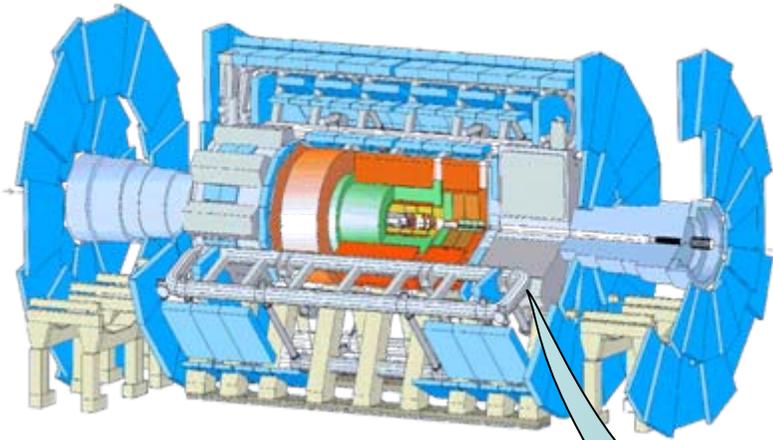
- Helical Undulator
- 4m long prototype made in 2 x 2m sections



# Undulators



# ATLAS End Cap Toroids



The ATLAS Detector

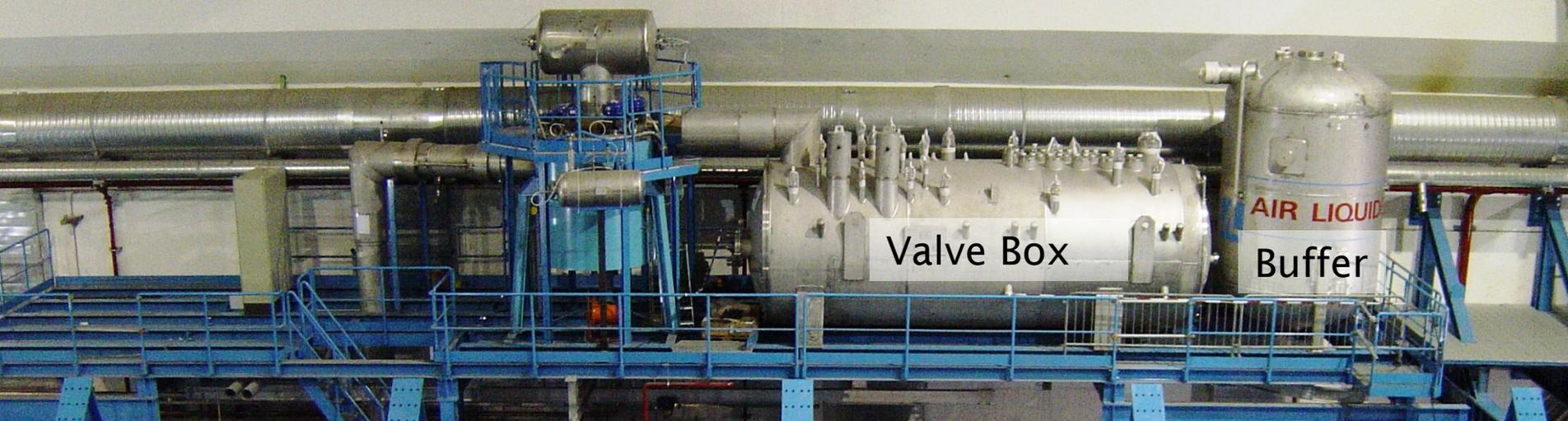
20,000 Amps

Field radially from 1.5 to 5 m

4 Tesla field

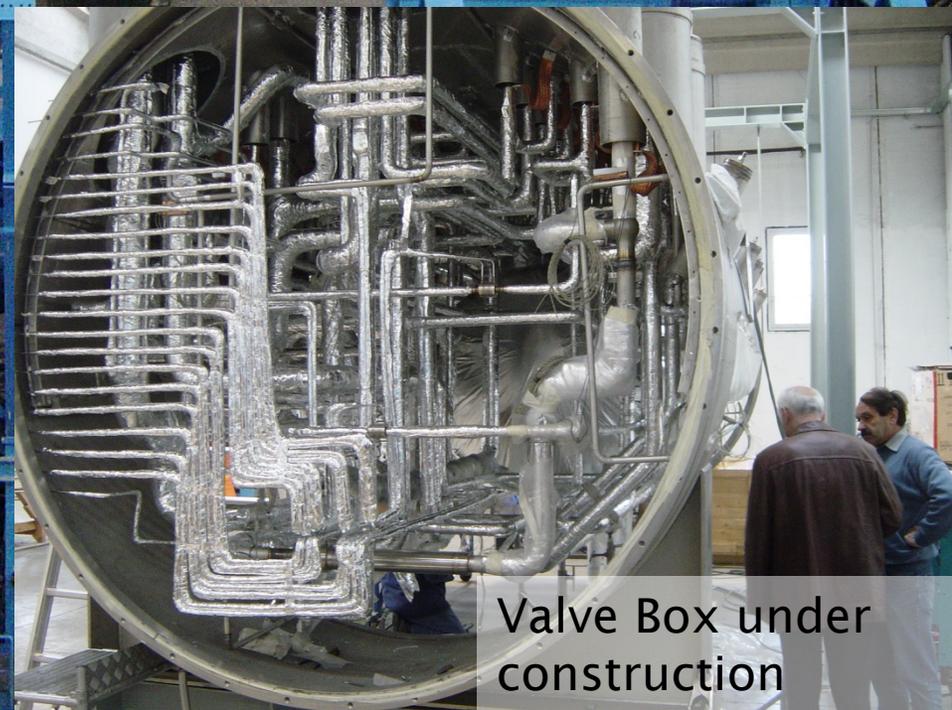
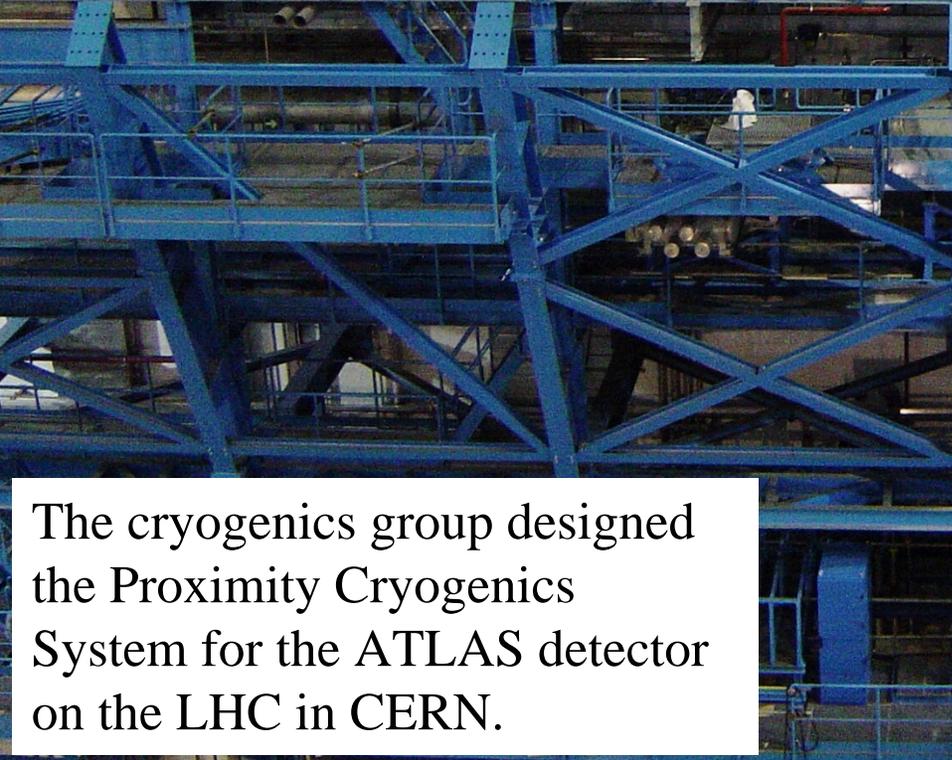


# ATLAS Proximity Cryogenics



Valve Box

AIR LIQUID  
Buffer



Valve Box under construction

The cryogenics group designed the Proximity Cryogenics System for the ATLAS detector on the LHC in CERN.

## Material testing

Together with our partner organisation, the Astronomy Technology Centre in Edinburgh, the Advanced Materials Group can offer a comprehensive materials testing facility down to low temperatures.

Property	Temperature Range
Thermal conductivity	4-300K
Specific Heat	4-300K
UTS and Young's modulus	4K, 77K and 300K
CTE and contraction integrals	4-300K



# Advanced Materials Group – Material Testing

Current materials characterisation equipment includes:

- Servo-hydraulic universal testing machine to 100kN, operating at 4K, 77K and ambient temperatures.
- Strain measurement using an optical system, clip-gauges and strain gauges
- Screw-driven Universal testing machine to 77K, up to 50kN
- Thermal analysis suite including a DMA, TGA and DSC.
- FT-IR with an ATR stage.
- CTE measurement system operating at liquid helium and nitrogen temperatures, a variable temperature test cryostat for thermal conductivity and specific heat measurements

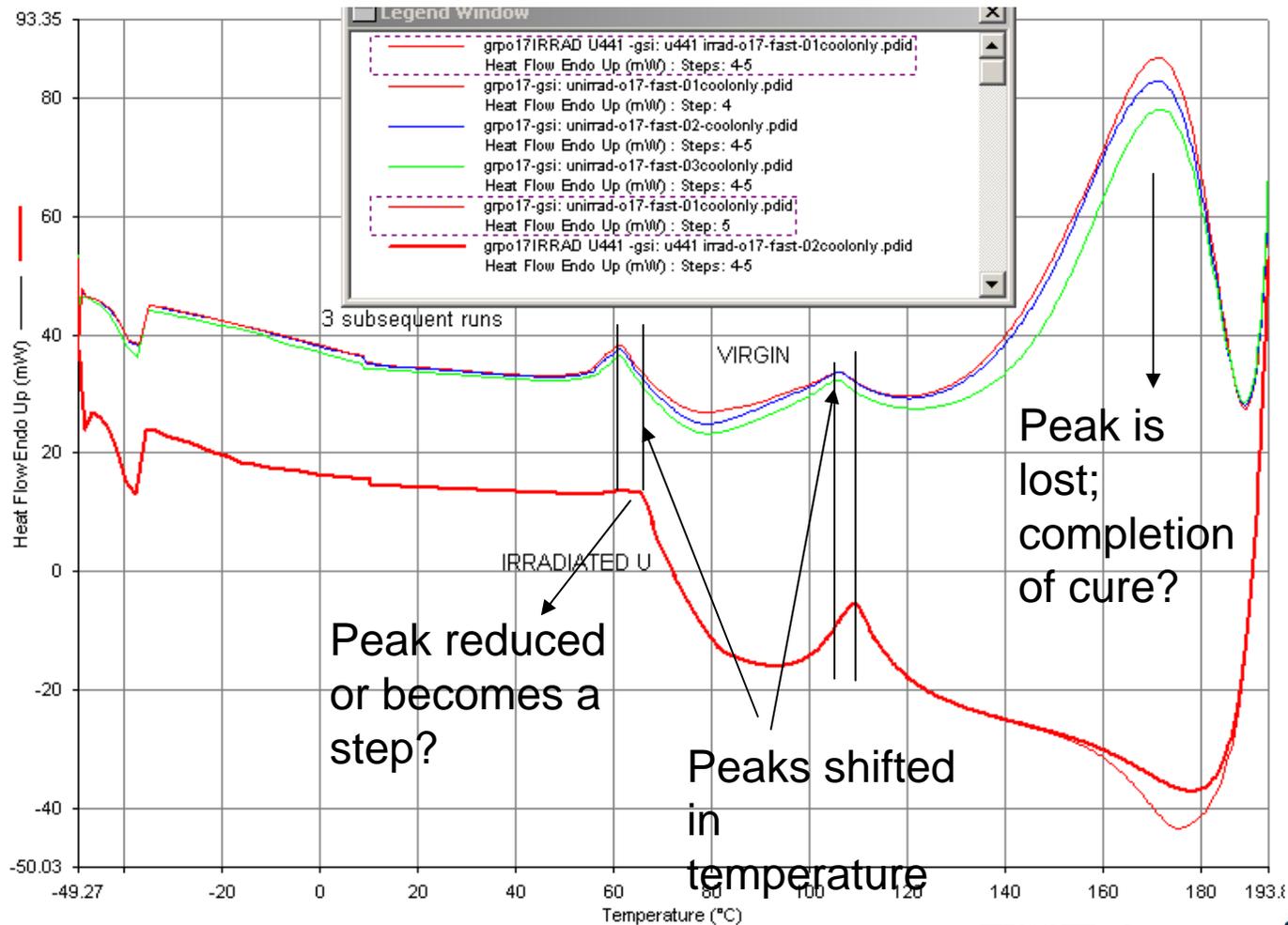


DSC: GRP virgin  
(top)

U-238 irradiated  
(bottom)

# Irradiated Materials

Programme with GSI for FAIR





Short beam shear testing at 77K

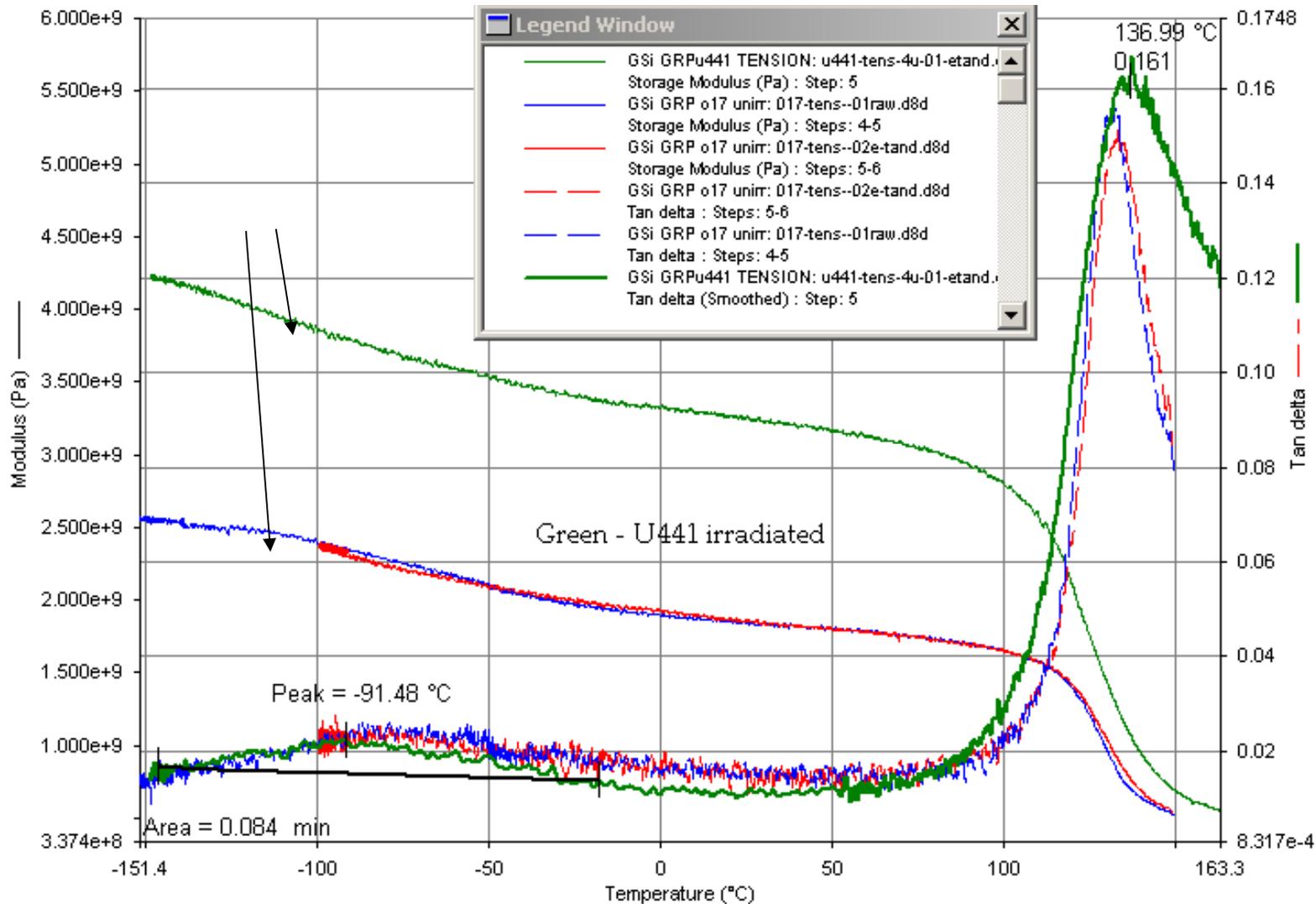
Dynamic Mechanical Analyser – 3 point bending test of GRP sample



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# DMA - irradiated U441 and unirradiated 017

NOTE Absolute modulus varies randomly, possibly related to sample length and positioning in the grips



# Expertise that we can bring

- Hydrogen safety and handling systems
- Materials in high radiation  
Environments  
(With Advanced materials and High Power Targets Group)
- Analysis of Cryogenics, Shock, Fluids  
(With High Power Targets Group)
- High Precision, Low temperature  
mechanisms
- General cryogenics Large and Small



END



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