Development of 2 m long $Pr_2Fe_{14}B$ Cryogenic Permanent Magnet Undulator at SOLEIL

Synchrotron SOLEIL
Gif sur Yvette FRANCE

- Introduction
- Permanent magnet characterisation
- Four period cryogenic device
- Full scale $Pr_2Fe_{14}B$ cryogenic undulator
- Conclusion

Introduction

- CPMU (Proposed by Spring-8) takes benefit from improved magnetic properties of $RE_2Fe_{14}B$ at cryogenic temperatures.

- Cooling down permanent magnet increases the remnant magnetisation and the intrinsic coercivity

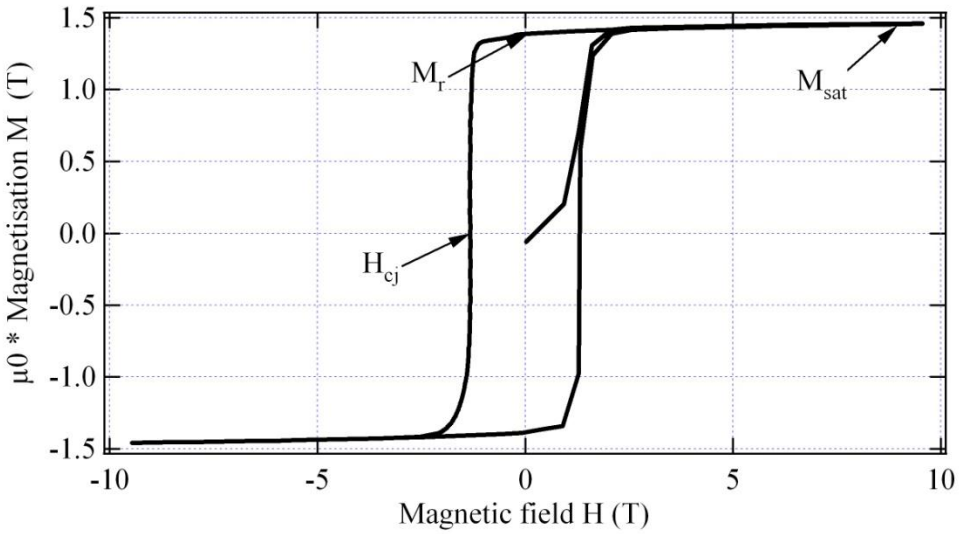
  - ✓ The increase of $Nd_2FE_{14}B$ remnant magnetisation is limited by the appearance of Spin Reorientation Transition phenomenon. CPMU working temperature is around 140 K (ESRF, Diamond, SLS)

  - ✓ The increase of $Pr_2FE_{14}B$ remnant magnetisation is not limited because of the absence of SRT phenomenon. CPMU working temperature is at liquid nitrogen one 77 K (SOLEIL). Development under progress (BESSY II and NSLS II)

- CPMU is an adaptation of an in vacuum undulator with a cooling system and a dedicated low temperature magnetic bench

Permanent Magnet characterisation

- Magnetometer of Louis NEEL institute at Grenoble
- Magnetic field ± 10 T
- Temperature rang 1.5 K to 300 K



Hysteresis cycle measurements

- Remnant magnetisation M_r
- Intrinsic Coercivity H_{cj}

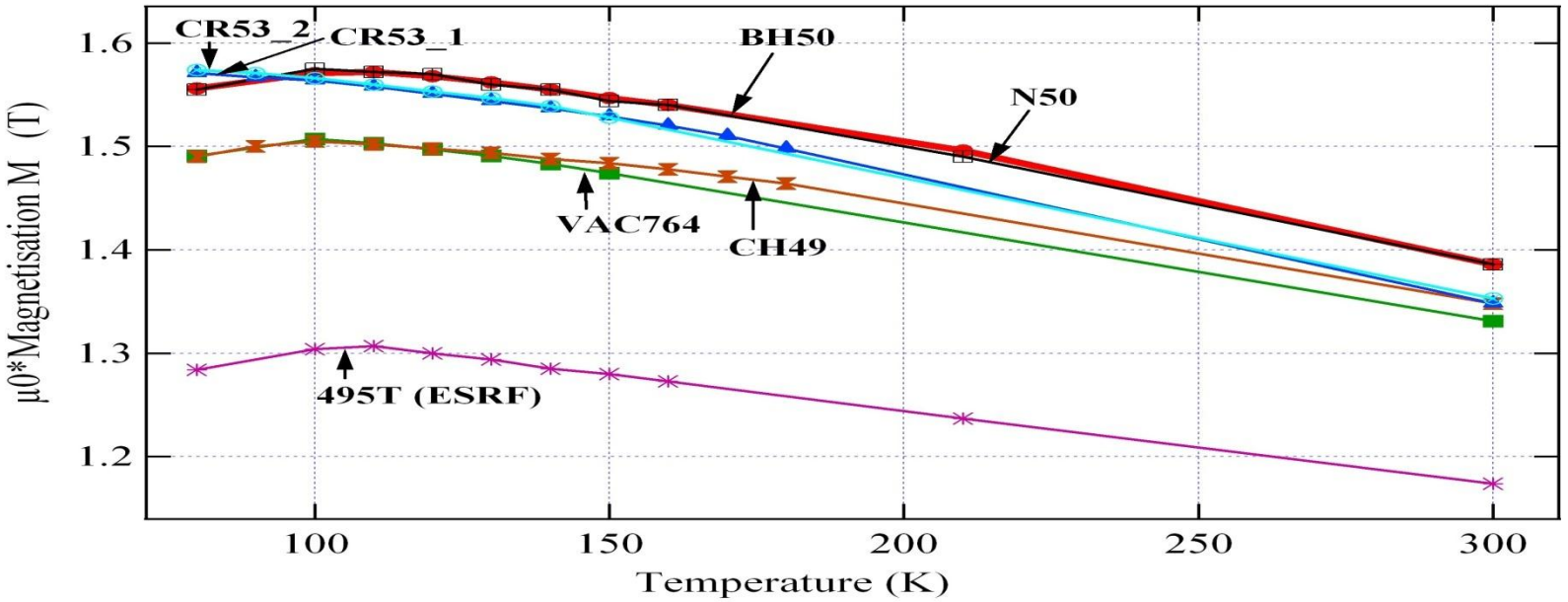
Permanent Magnet characterisation

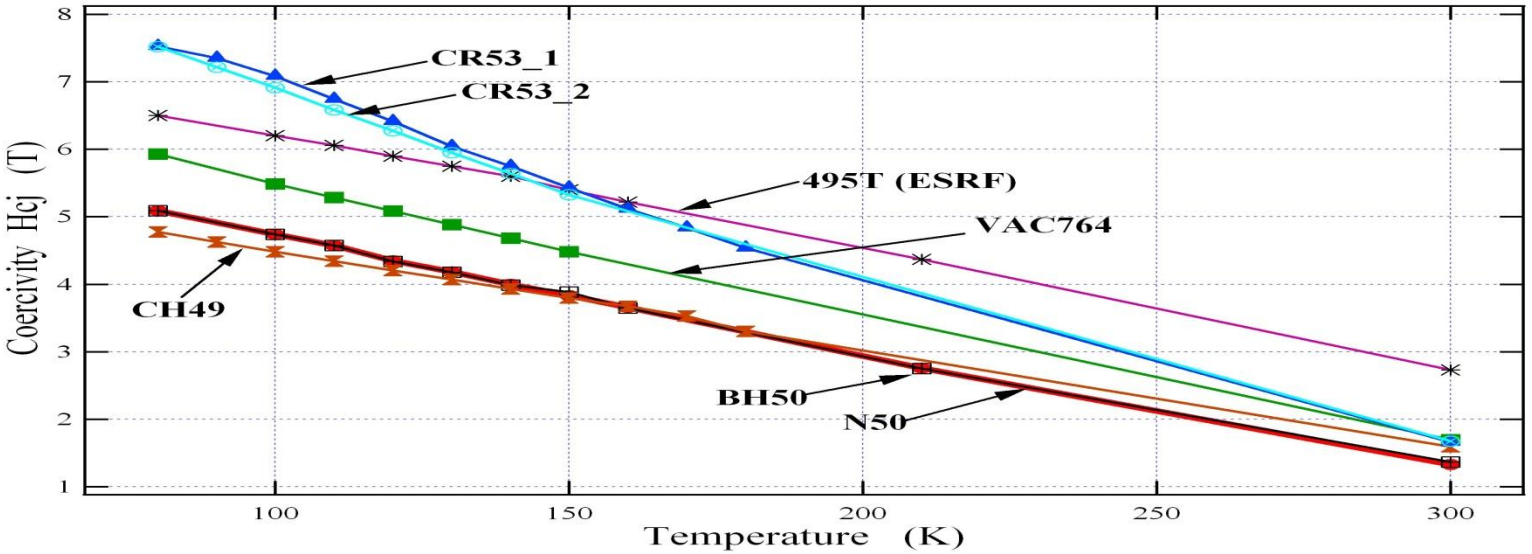
Five samples have been characterised at different temperature between 300 and 80 K

Characteristics	CR53	BH50	CH49	VAC764	N50
Company	Hitach-Neomax			VAC	Atlas-Yunshen
Type of magnet	$Pr_2Fe_{14}B$	$Nd_2Fe_{14}B$	$Nd_2Fe_{14}B$	$Nd_2Fe_{14}B$	$Nd_2Fe_{14}B$
Remanence Br (T)	1.35	1.40	1.39	1.37	1.40
Coercivity Hcj (T)	1.65	1.39	1.63	1.63	1.38
Temp. Coef ΔBr (%/°C)	0.11	0.11	0.11	0.12	0.11
Temp. Coef ΔHcj (%/°C)	0.58	0.58	0.58	0.70	0.60
Dimensions (mm^3)	4x4x4	4x4x4	4x4x4	4x4x4	4x4x4

High remanence samples can not be used for the construction of room temperature in vacuum undulators because of the week coercivity

Permanent Magnet characterisation





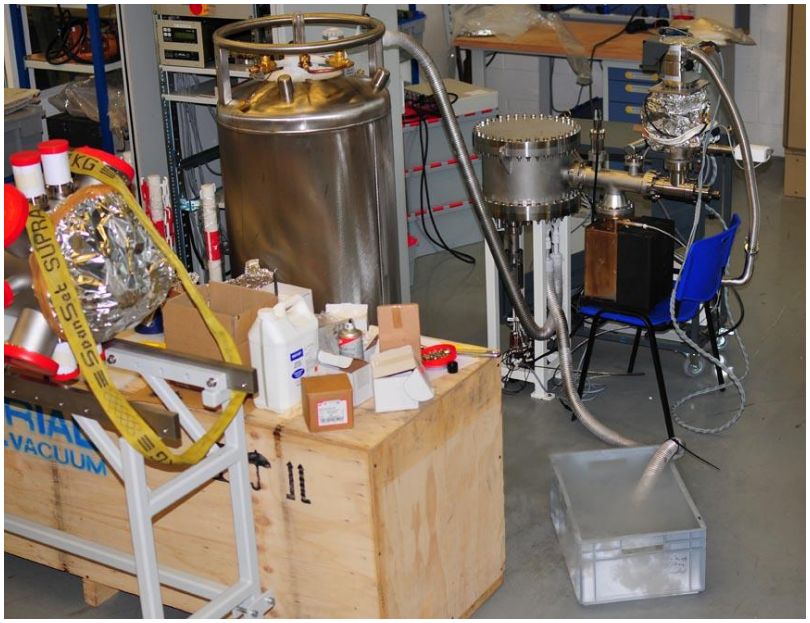
Four period cryogenic device

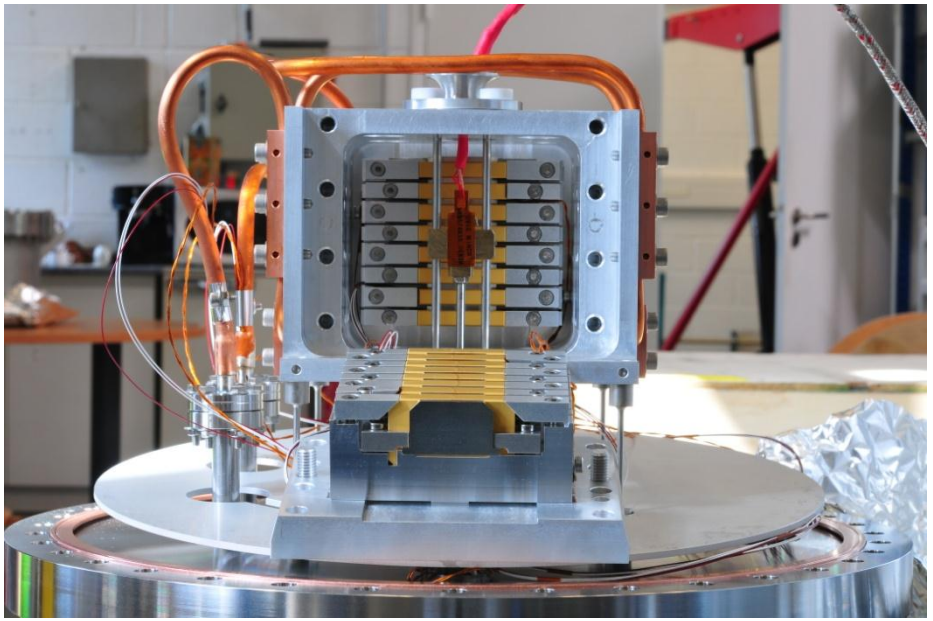
Two cryogenic devices have been designed and assembled at SOLEIL

Undulator type	Hybrid	Hybrid
Magnet material	$Nd_2Fe_{14}B$ (BH50)	$Pr_2Fe_{14}B$ (CR53)
Magnet size (mm^3)	50 x 30 x 7.5	50 x 30 x 6.5
Pole material	Vanadium P	Vanadium P
Pole size (mm^3)	33 x 22 x 2.5	33 x 22 x 2.5
Period (mm)	20	18
Gap (mm)	10	10
Number of periods	4	4
Cooling system	Liquid Nitrogen	Liquid Nitrogen

An open liquid nitrogen loop was used to cool down the devices

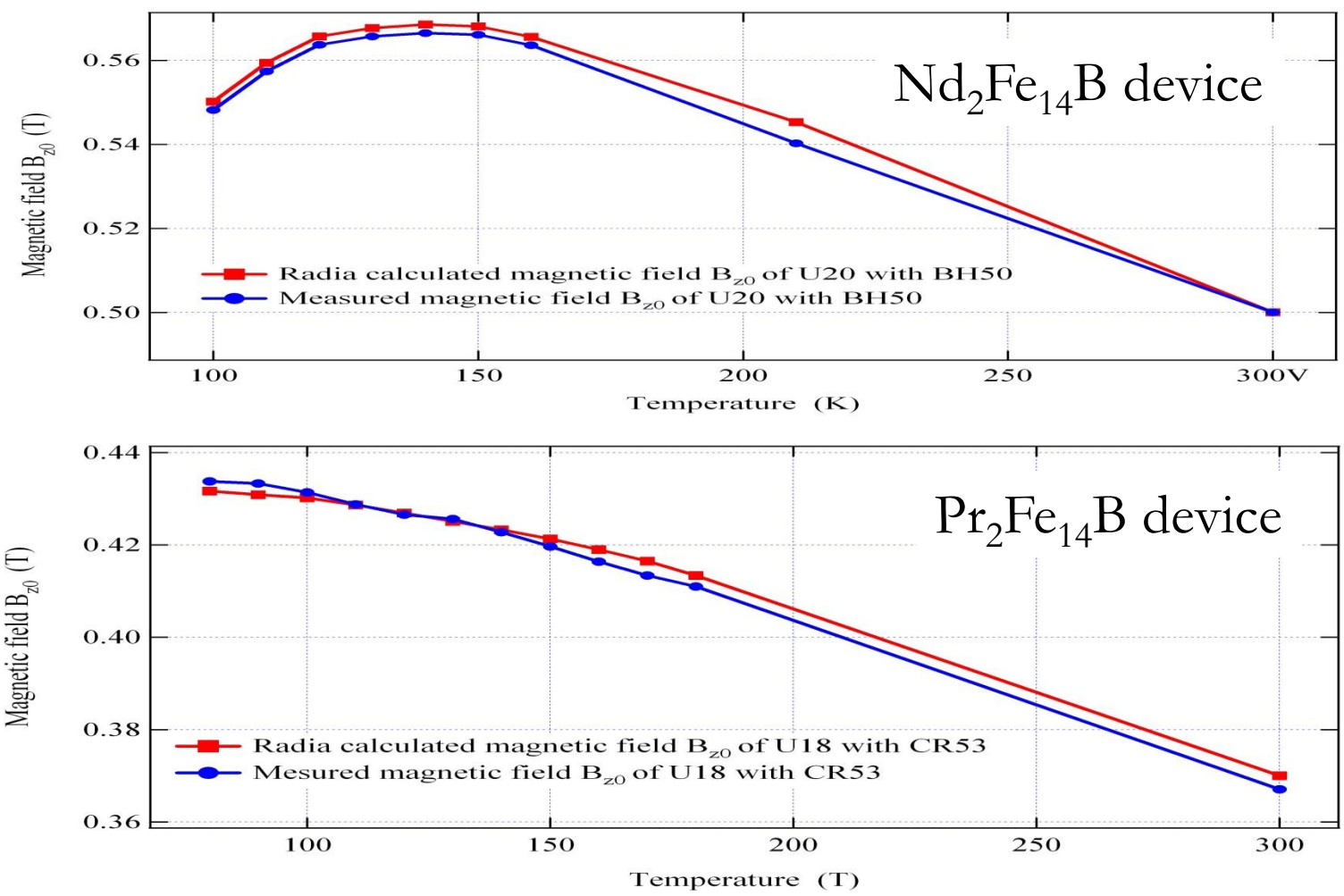
Four period cryogenic device





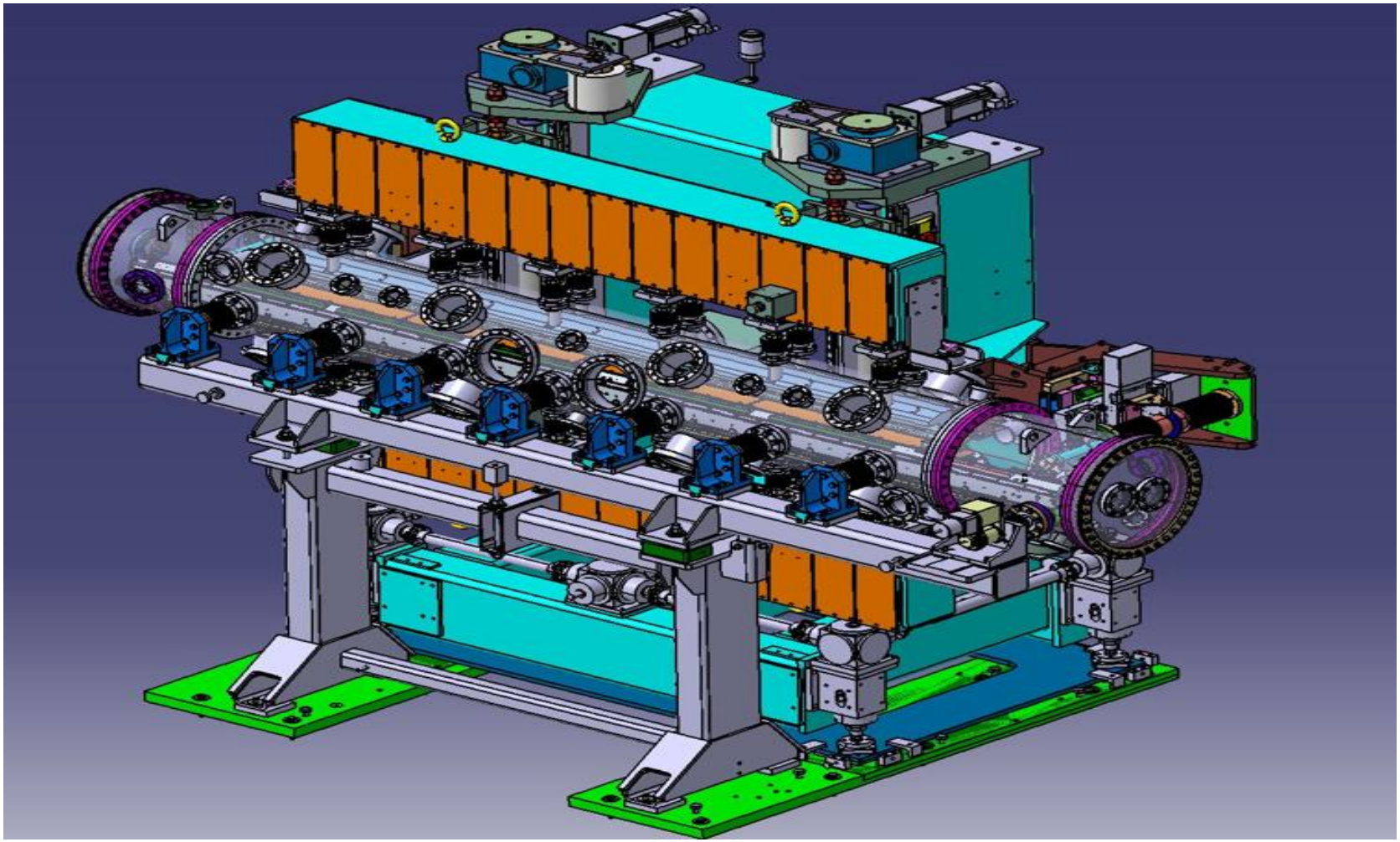
- The magnetic field is measured by a Hall probe maintained at room temperature
- Hal probe handled from air side using a vacuum feed-through equipped with a motor.
- Temperature sensors (TC and PT100) are fixed on different parts of the test bench.

Four period cryogenic device



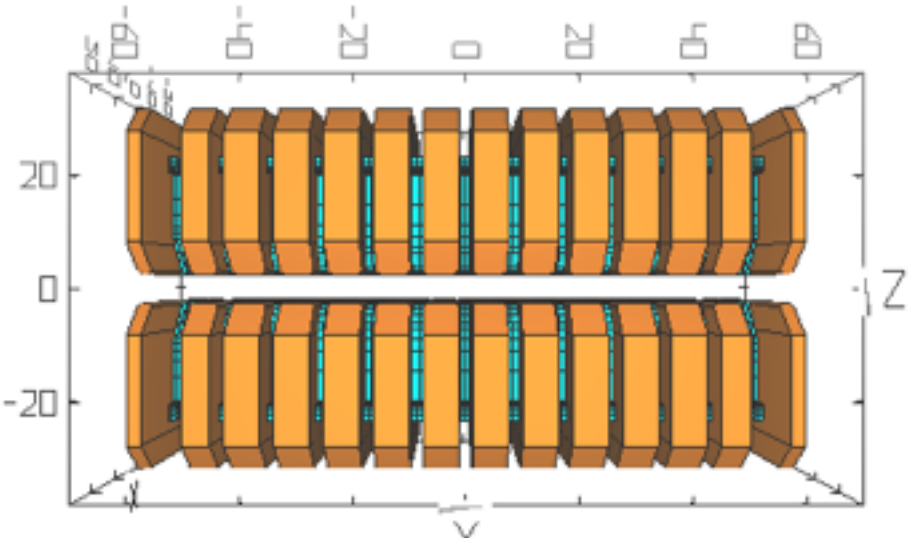
$Nd_2Fe_{14}B$ and $Pr_2Fe_{14}B$ magnets characterisation and modelling for Cryogenic Permanent Magnet Undulator applications
C. Benabderrahmane et al, Submitted to Nucl. Inst. Meth. A

2 m $Pr_2Fe_{14}B$ cryogenic undulator

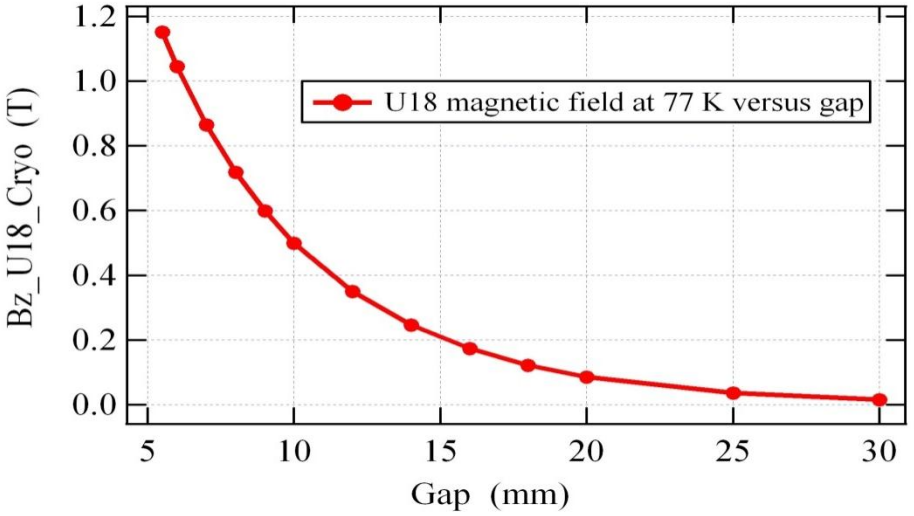


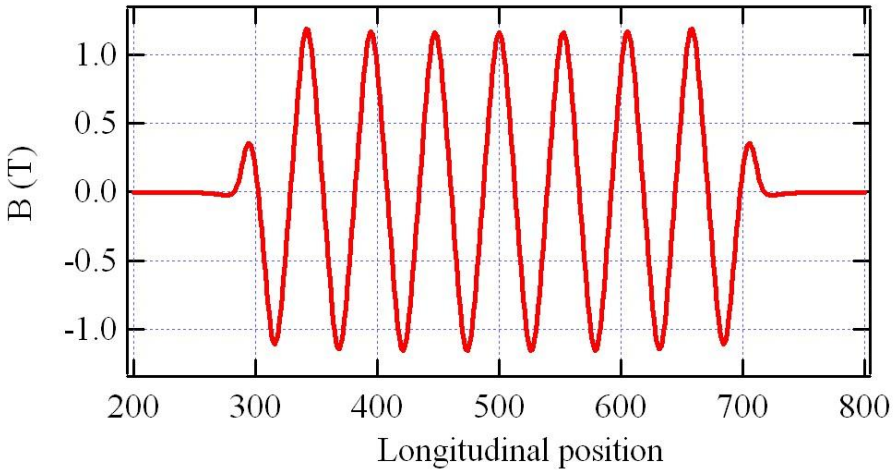
Cryogenic undulator of SOLEIL (3D Catia)

2 m $Pr_2Fe_{14}B$ cryogenic undulator

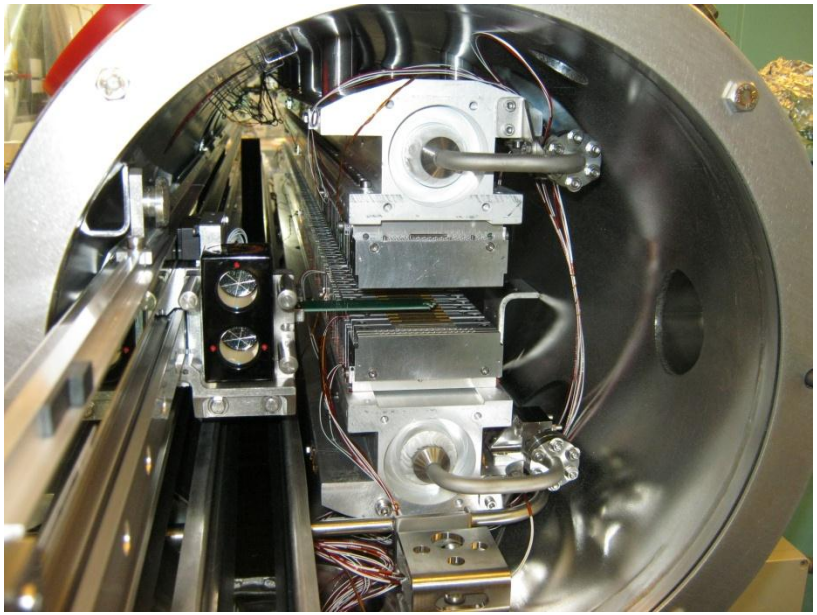


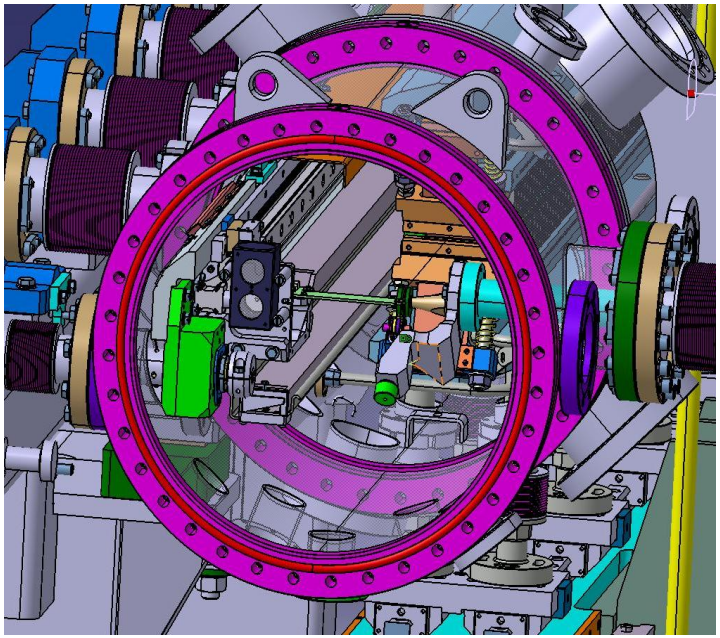
PM	$Pr_2Fe_{14}B$
Pole	Vanadium P
Period:	18 mm
N° periods:	107
Bz_0:	1.15 T à 77 K
K:	1.9
Gap min:	5.5 mm





2 m $Pr_2Fe_{14}B$ cryogenic undulator





- Dedicated low temperature magnetic measurement bench
- Hall probe bench for local magnetic field measurement
- Stepper motor from air side for longitudinal Hall probe displacement
- Measurement bench Installed in the vacuum chamber

2 m $Pr_2Fe_{14}B$ cryogenic undulator

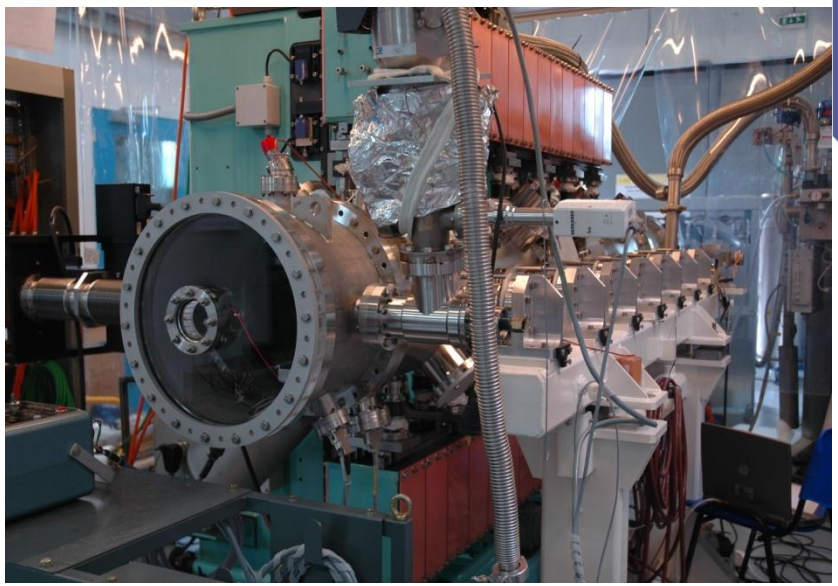
Cryo Cooler

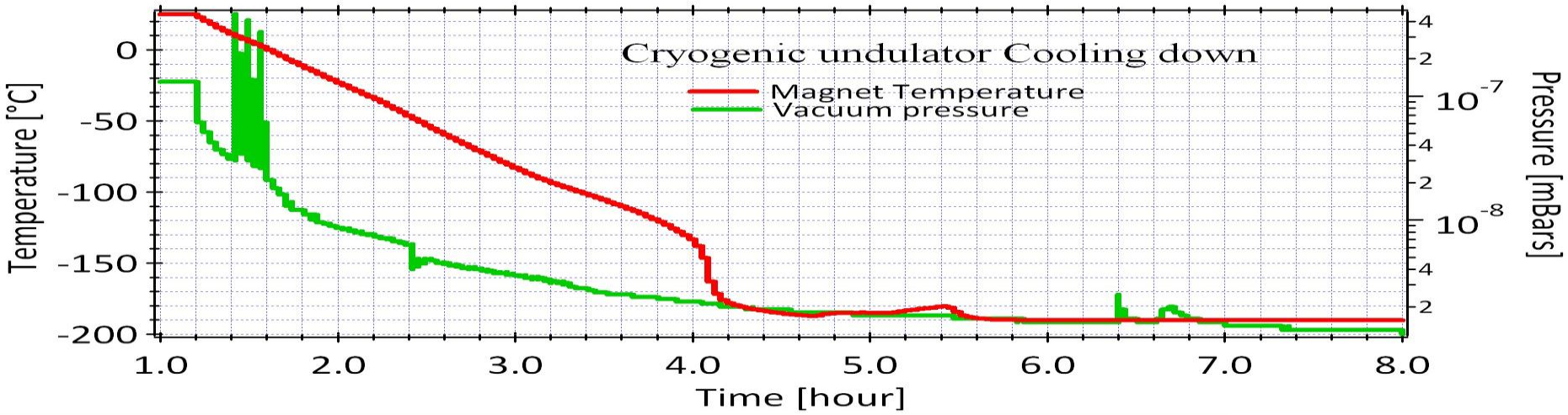
Power 2000 W (<300 W)

Liquid LN2

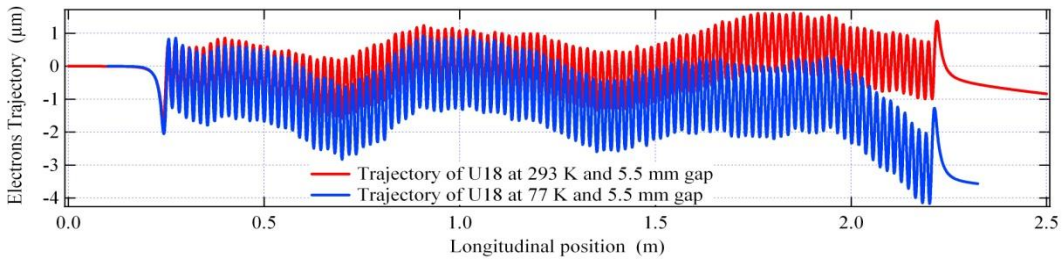
Pump 30 to 90 Hz (40 Hz)

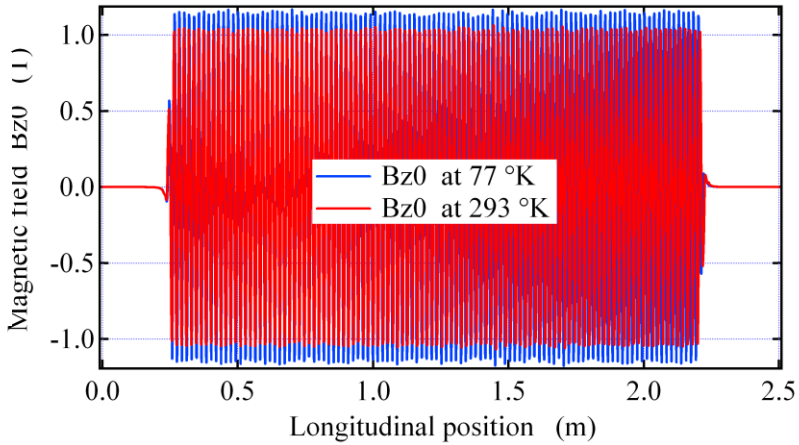
Flow 1 to 30 l/mn (5 l/mn)





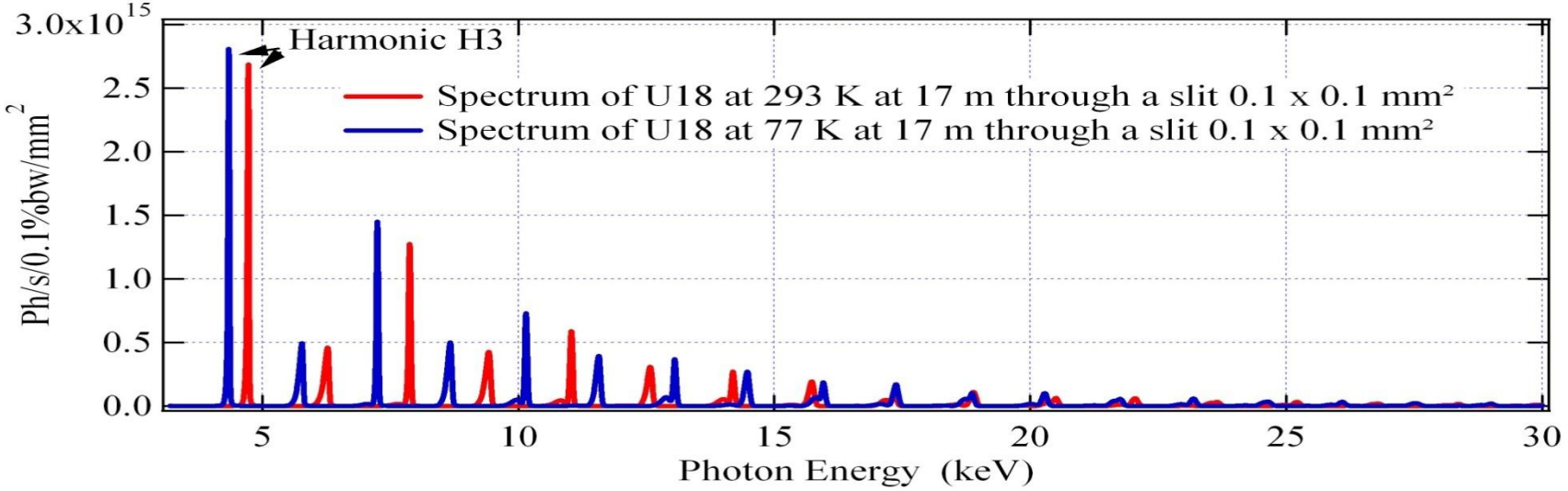
2 m $Pr_2Fe_{14}B$ cryogenic undulator



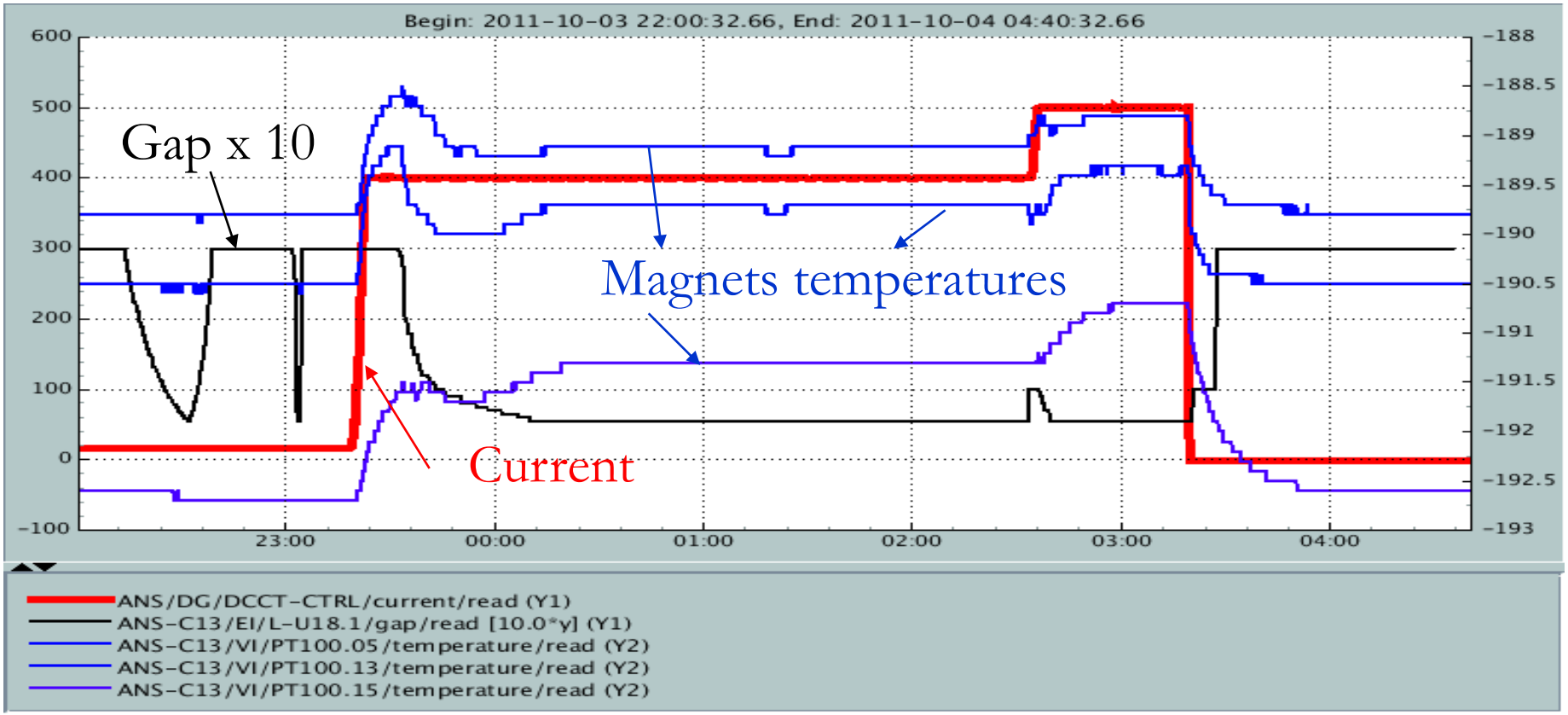


Gain of 10% on the peak field

Phase error at 77 °K is < 3.5° Rms



Commissioning



Thermal gradient on the magnetic system **< 1.5 K/m**

Total temperature variation du to electron beam (400 mA) and gap variation **< 2.5 K**

Conclusion

- Different permanent magnets samples have been characterised
- Two cryogenic devices with four period have been tested
- A 2 m $Pr_2Fe_{14}B$ CPMU has been designed and assembled
- CPMU was measured at low temperature with a dedicated bench
- CPMU installed in the storage ring and it is under commissioning

Thank you for your attention