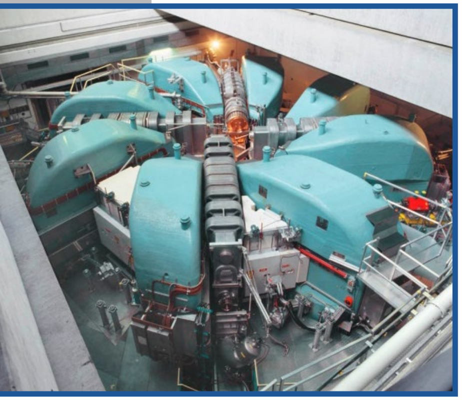
Ciro Calzolaio on behalf of the Magnet Section & MagDev Team :: Paul Scherrer Institut

HTS Magnet Development at PSI

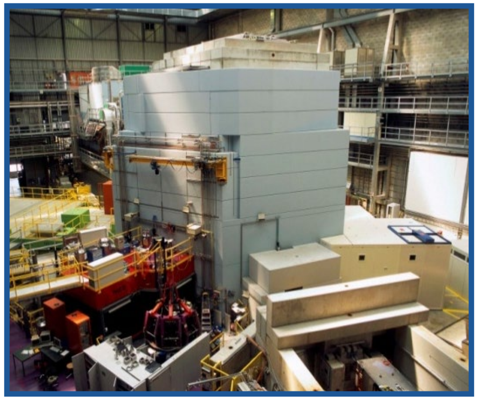
Large Research facilities & CPT at PSI

High Intensity Proton Accelerator Complex

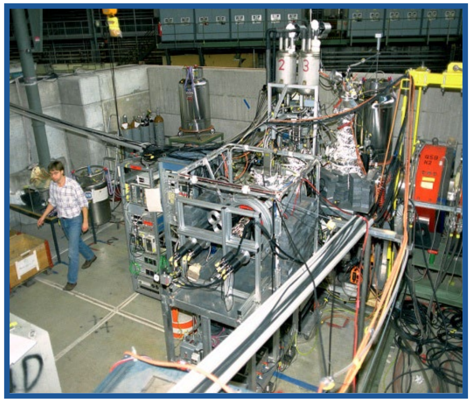
Proton Accelerator



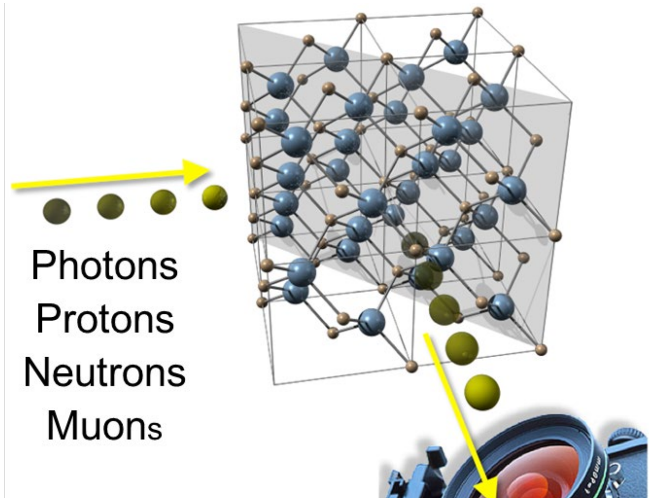
Spallation Neutron Source (SINQ)



Swiss Muon Source (SμS)



Swiss Light Source (SLS)



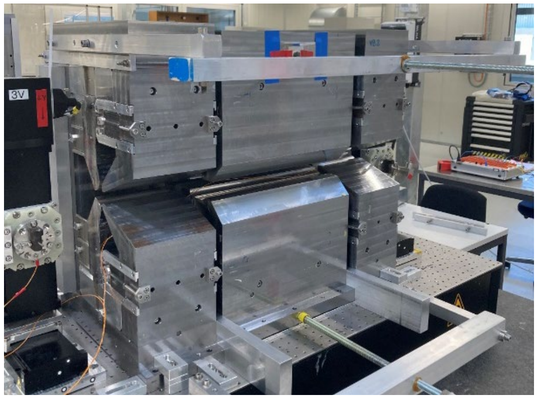
Microscopic insights into materials

Protons beam therapy

Swiss Free Electron Laser (SwissFEL)

SLS 2.0 vs SLS : Energy savings (dipoles)

SLS2.0 Triplet = VB-BN-VB



Total number of triplets: 60

BN: By=1.35 T; VB: GdL=-40.64 T/m

Total Weight=1250 kg

60 Triplets ~Total P=<u>0 W</u>

SLS BX Dipole

Total number of BXs:12
By=1.39 T ; I=407 A; R= 58 mΩ;
Weight=2950 kg
Cooling= 16 l/min
BX: P= 58 mΩ x (407 A)^2= <u>~9.6 kW</u>

12 BX →Total P: <u>116 kW</u>

SLS dipoles : 116 kW x 6800 operating hours ; 789 MWh per year

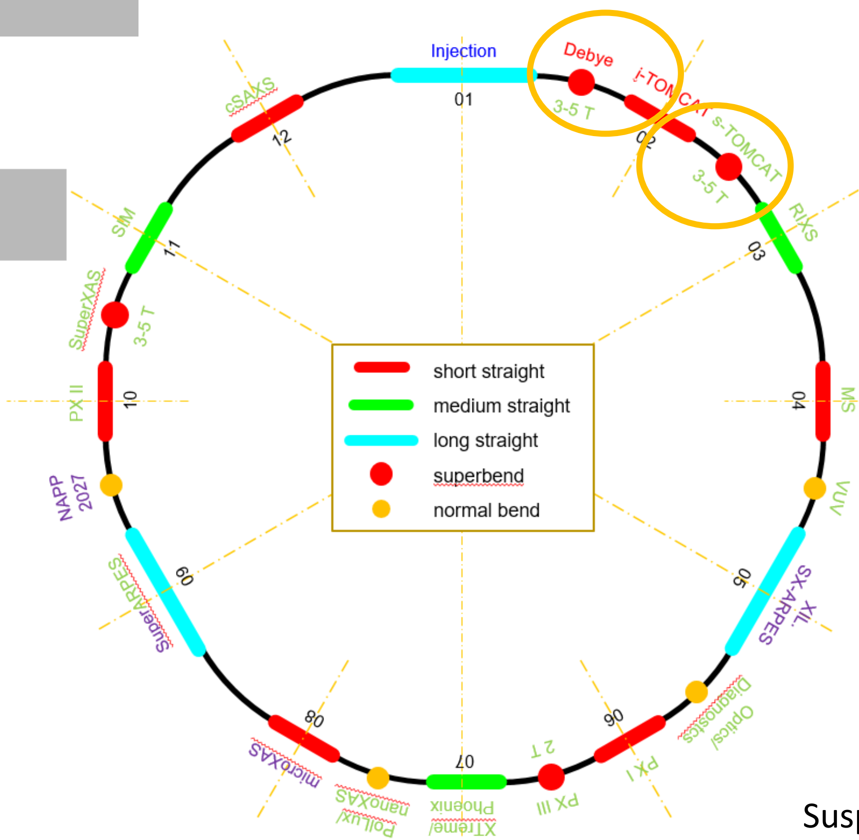
Savings for 15 Years : 11.83 GWh

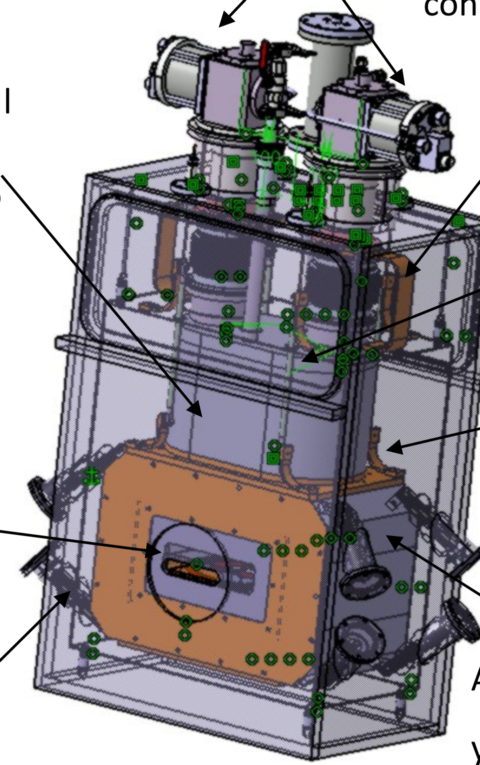
Same considerations apply for the dipoles in the dispersion suppressor: BE magnets

24 permanent magnets based BE magnets.

24 BE electromagnets magnets: P_{tot}=199 kW

5 T superbends: maybe more interesting to compare….



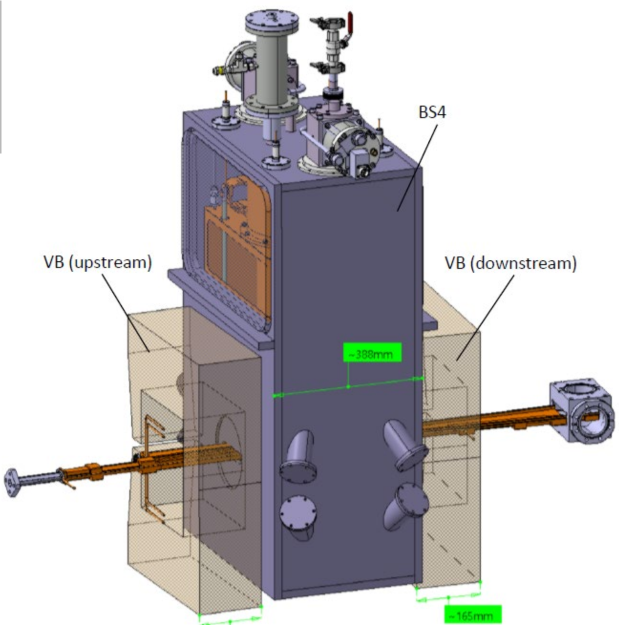


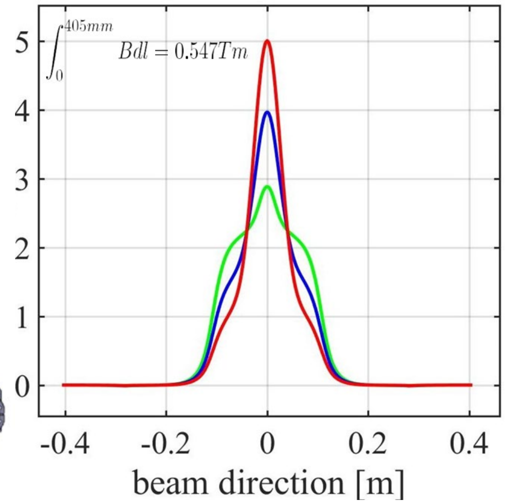
2 x F50 H compressors:

- Steady state power: 6.5 kW each;
- Peak power: 7.2 kW each.

SLS 2.0 vs SLS : Energy savings (superbends)

SLS2.0 Triplet = VB-BS5-VB





Total number of triplets: 2

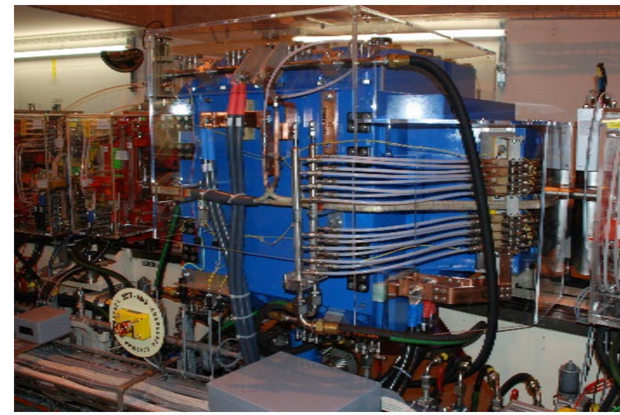
BS5: By=3-5 T; VB: GdL=-40.64 T/m

Total Weight=1200 kg

2 Triplets → maxP<29 kW →

→197 MWh (6800 h/year)

SLS BS Dipole

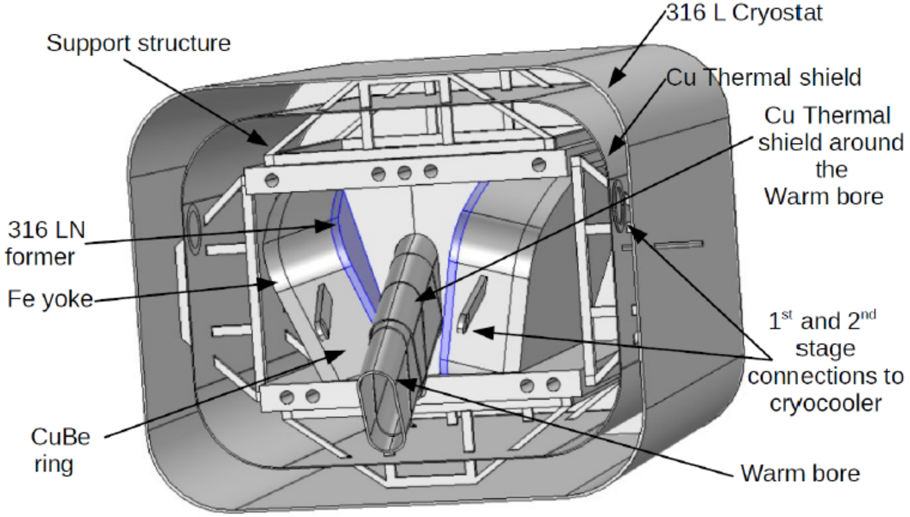


Total number of BSs:3
By=2.9 T ; I=500 A; V=170 V;
Weight=6000 kg
Cooling= 16 l/min
BS: P= = 85 kW

2 BS →Total P: 170 kW →

→ 1.16 GWh (6800 h/year)

Gantry magnets



Magnet weight: 45000 kg

B_{GFR}=1.6 T

P_{el}=85 kW

Magnet weight: 2300 kg

B_{GFR}=3.5 T;

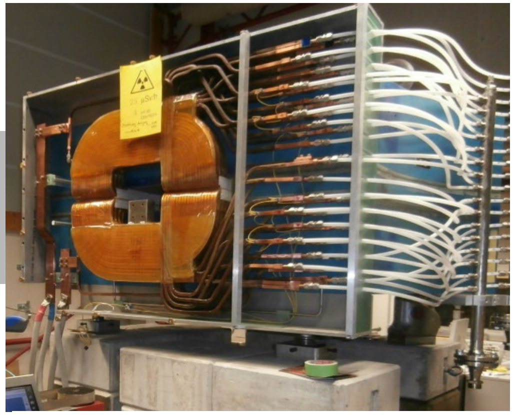
$P_{el,cryo}$<28.5kW

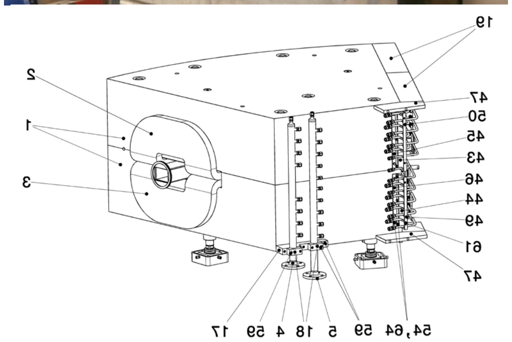
$P_{peak, AC}$=36.5 kW (peak power during the current sweep: 2700A, 27A/s, ~0.5 H.)

Challenge: superconducting magnet used in AC mode.

Proton accelerator

AHC





B_{nom}=1.64 T;

$R_{bending}$=2.451 m;

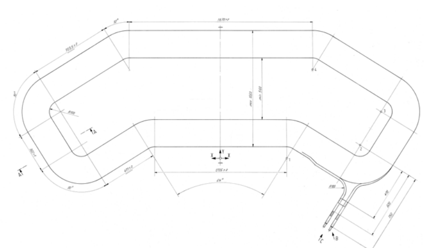
α_bending=37.4° at 590 MeV

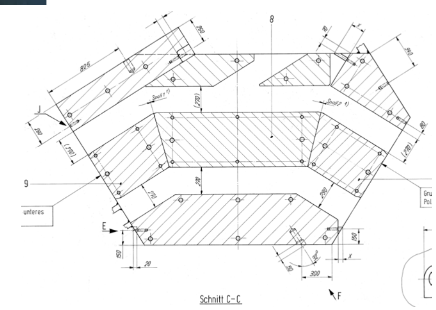
M ~ 13000 kg

I_{op}=850 A; V_{op}=129 V → P_{op}= 109.65 kW →

→E~560 MWh (24/7, from May to December)

AHO





B_{nom}=1.45 T;

$R_{bending}$=2.780 m;

α_bending=64.0° at 590 MeV

M ~ 47600 kg

I_{op}=921 A; V_{op}=155 V → P_{op}= 142.755 kW →

→E~715 MWh (24/7, from May to December)

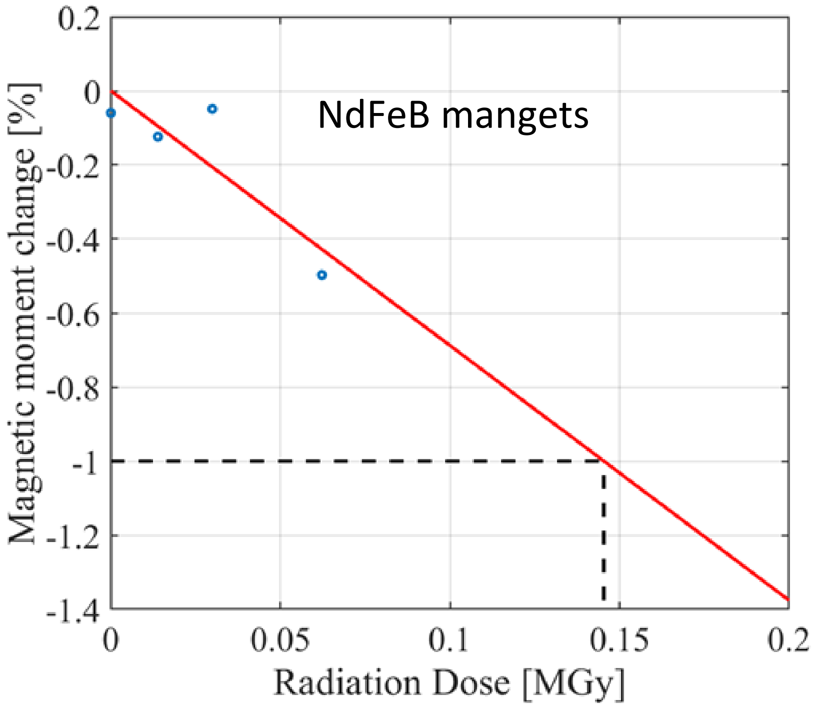
Proton accelerator, radiation resistant magnets

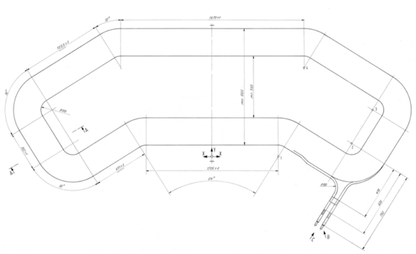
AHO

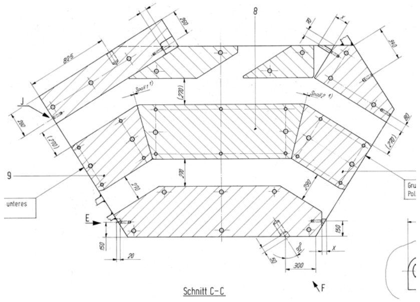
AHO is epoxy impregnated.

Limit for epoxy impregnation ~ 10MGy (*)

Radiation damage with time
(A. Temnykh)







B_{nom}=1.45 T;

$R_{bending}$=2.780 m;

α_bending=64.0° at 590 MeV

M ~ 47600 kg

I_{op}=921 A; V_{op}=155 V → P_{op}= 142.755 kW →

→E~715 MWh (24/7, from May to December)

(*) A. Gabard et al., RADIATION HARD MAGNETS AT THE PAUL SCHERRER INSTITUTE

A. F. Zeller et al., RADIATION RESISTANT MAGNET R&D AT THE NSCL

PAUL SCHERRER INSTITUT PSI

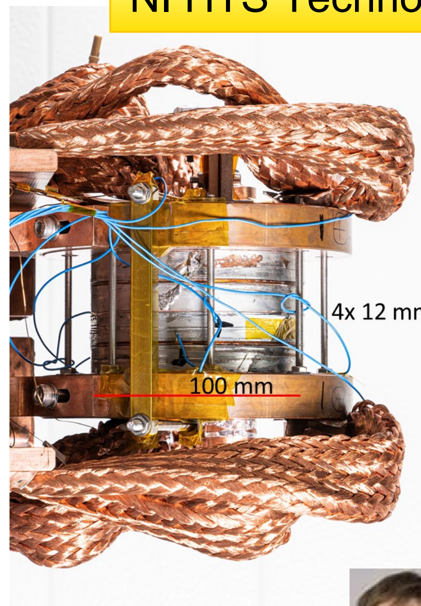
Some achievements in magnets and measurement systems

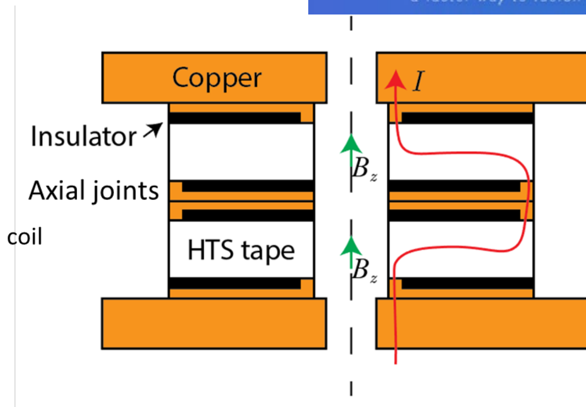
CHART Swiss Accelerator Research and Technology

PSI CCT magnet

NI HTS Technology Solenoid

tokamak energy
a faster way to fusion





18 T at 12 K, 2 kA

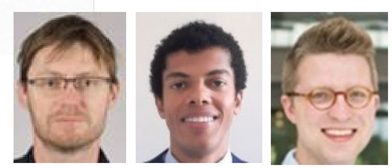


CHART HTS

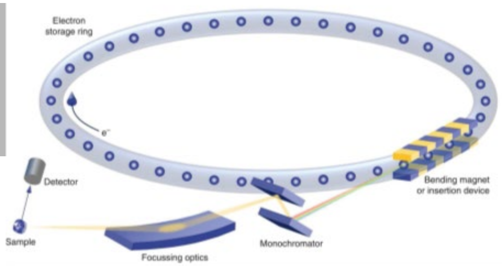
HTS Bulk Undulator Project (SLS2.0)

Marco Calvi for the Insertion Device Group

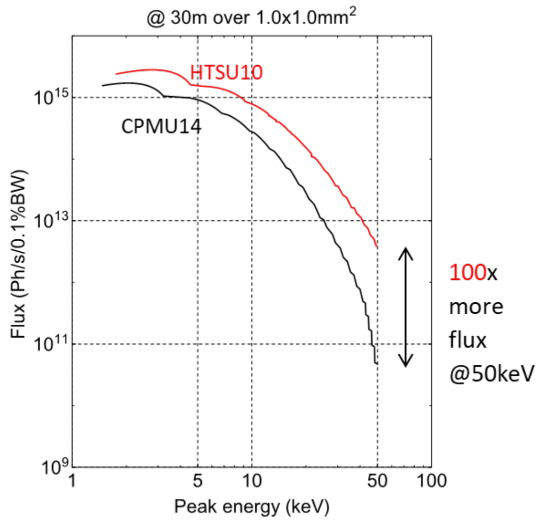
M. Calvi, PSI

LEAPS INNOVATION · CHART Swiss Accelerator Research and Technology · SLS 2.0

UNIVERSITY OF CAMBRIDGE · Fermilab · Kyoto University · SPring-8 · ESRF



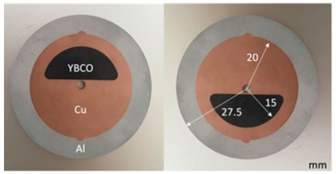
Calculations done for the future iTOMCAT beamline, dedicated to tomographic microscopy

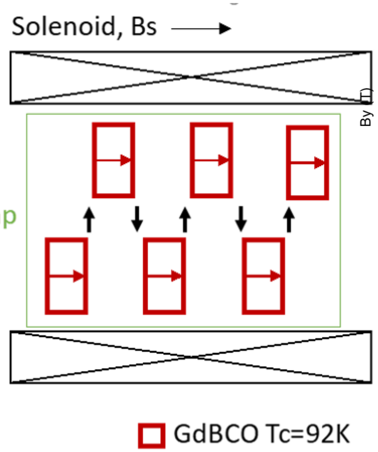


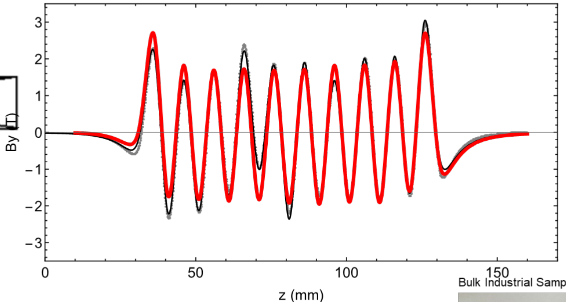
Bulk HTS sample : Cambridge
Ø : 30 mm; Thickness : 4 mm

10 mm period, 4 mm gap, 2 T
Tmag~10 K

Nb_3Sn solenoid (10T): Fermilab



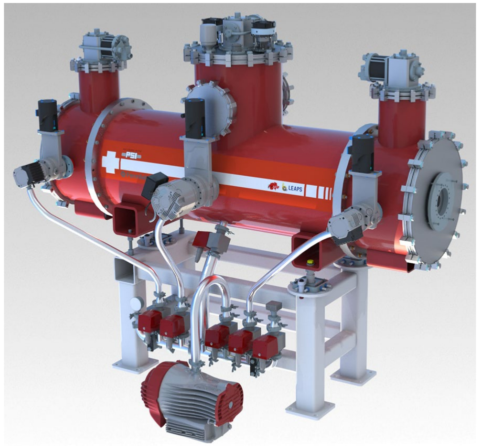




B (z) for a prototype

(FC @ 10T to 0)

Bulk Industrial Sample



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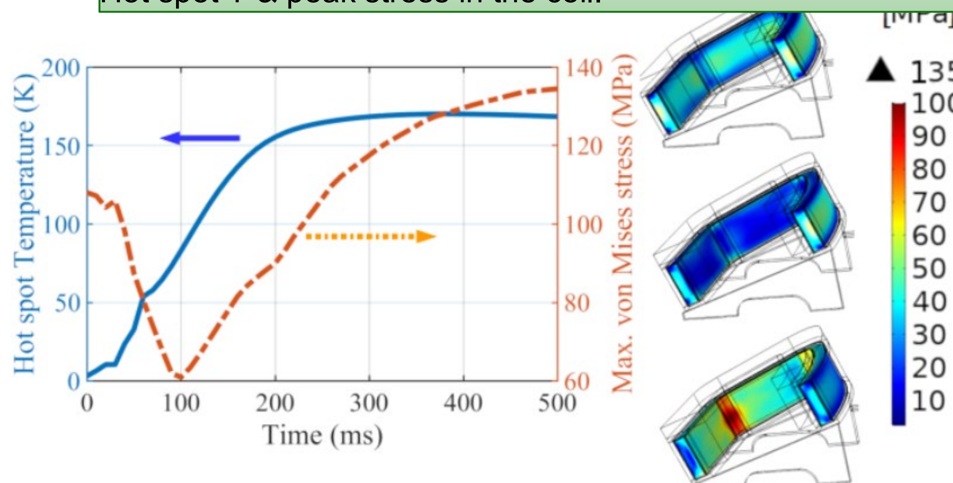
Thank you

for your attention

Multiphysics ….

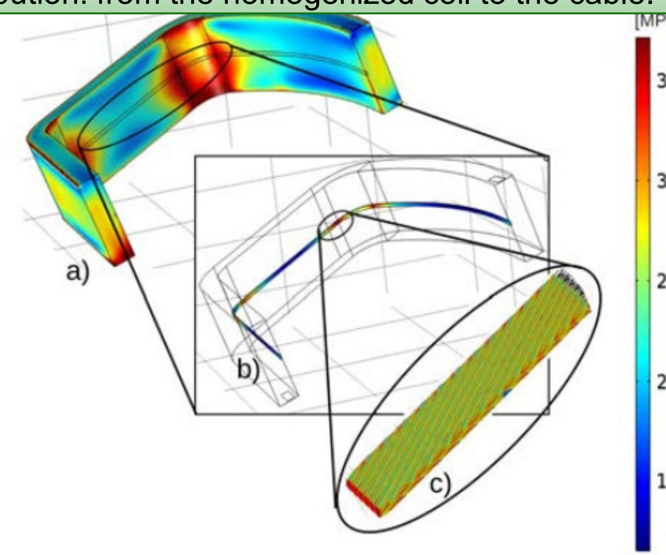
Quench model, superconducting magnet for gantry.

Hot spot T & peak stress in the coil.



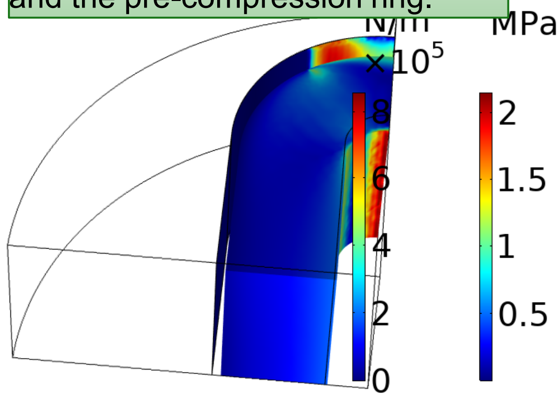
Superconducting magnet for gantry: multi-scale approach.

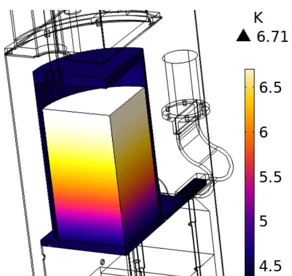
Stress distribution: from the homogenized coil to the cable.



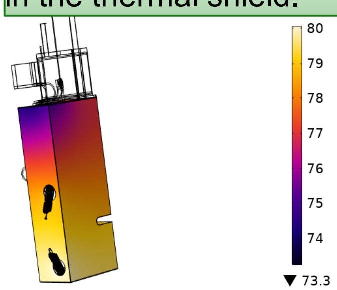
Superbend for SLS2.0

Contact pressure between the coil and the pre-compression ring.





T distribution in the LHe vessel and in the thermal shield.

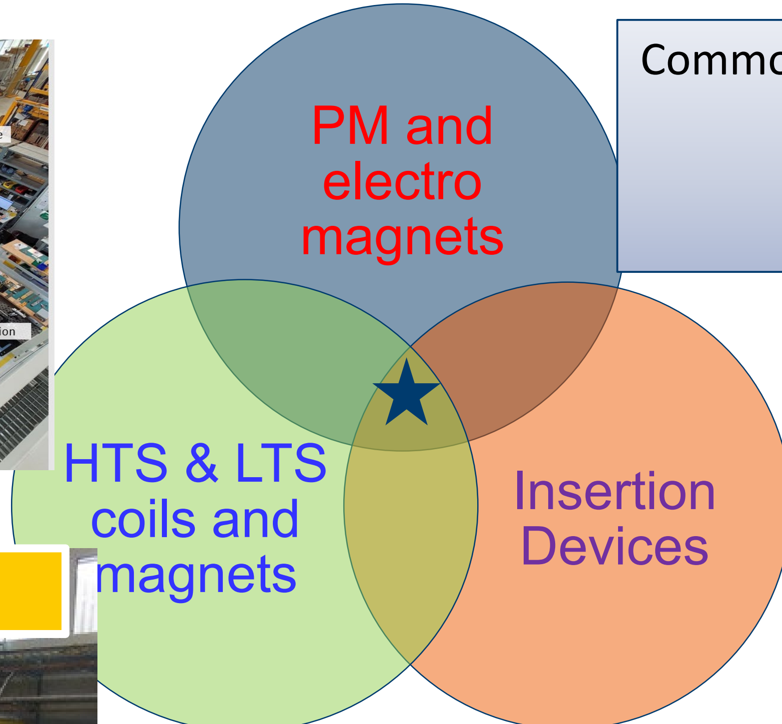


Infrastructure for Magnets & Insertion Devices

PAUL SCHERRER INSTITUT

SC magnets

Know-how



Resource

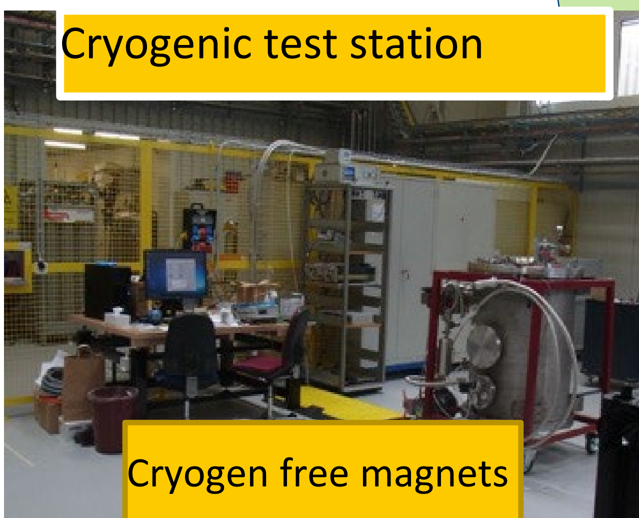
Infrastructure

Common workshop, production tools
Winding machines
Impregnation oven
Measurement systems

Measurement hutch

Workshop

Cryogenic test station

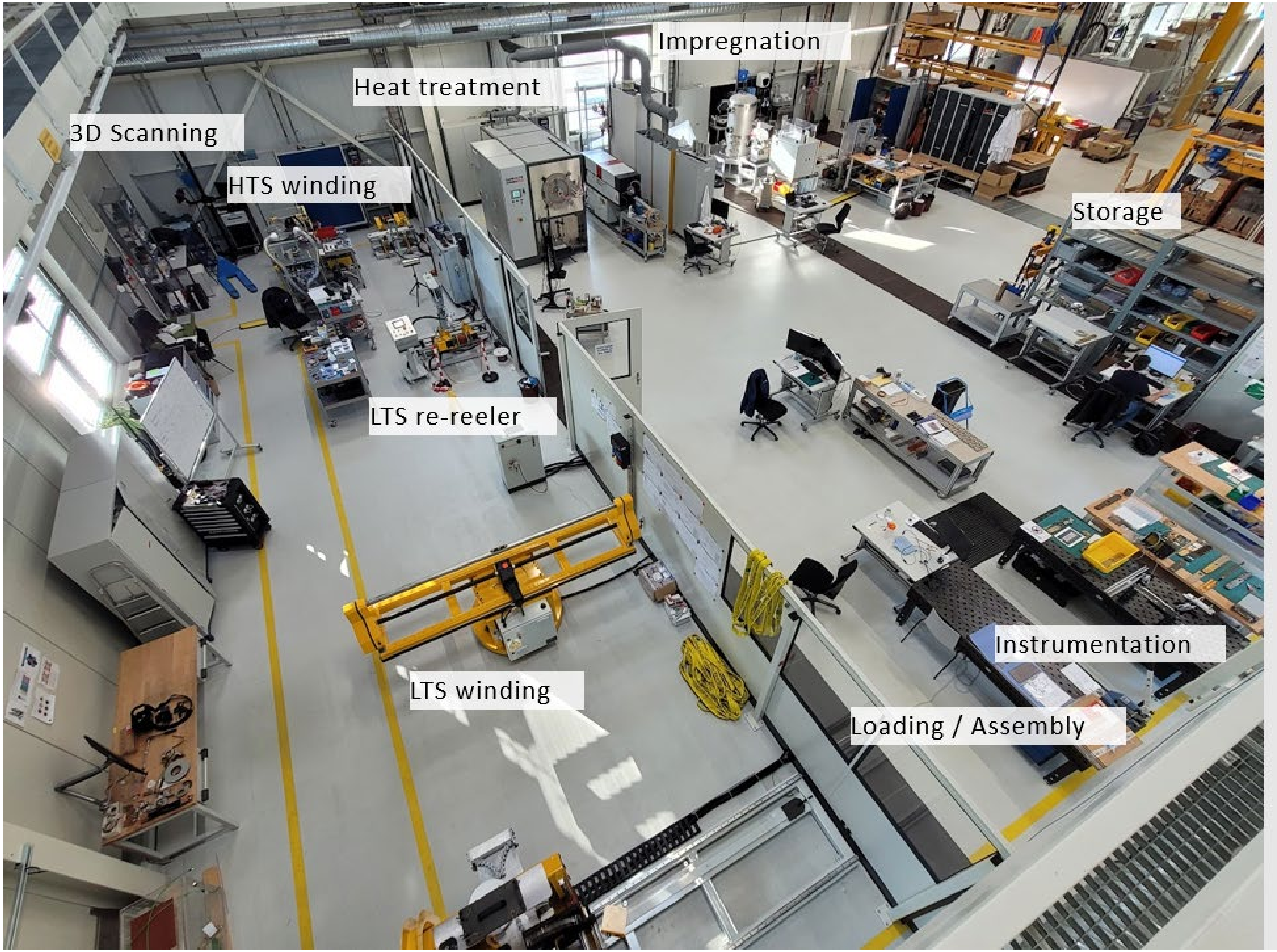


Cryogen free magnets and undulator

PM based undulator magnetic test

1100 m² for Insertion Devices & Magnets

MagDev Laboratory (applied superconductivity)



2 kA cryogen-free test station at PSI

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Swiss Accelerator Research and Technology

Electronic rack

- vacuum control
- temperature monitoring
- voltage signals recording
- quench detection system

Vacuum chamber

with pumps (not visible)

Radiation shield with MLI

2kA power converter

Water chillers

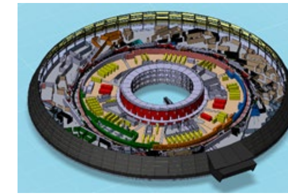
(for compressors and power converter)

Cryostat insert with two cryocoolers

Power cables

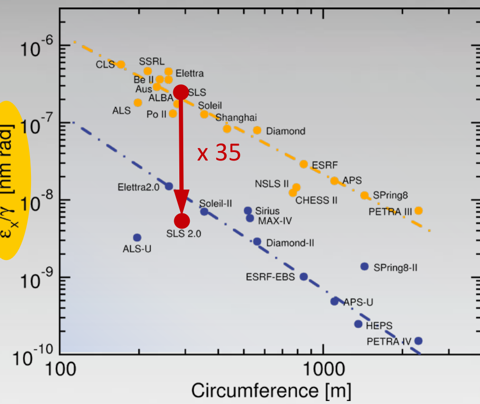
(500A single cable)

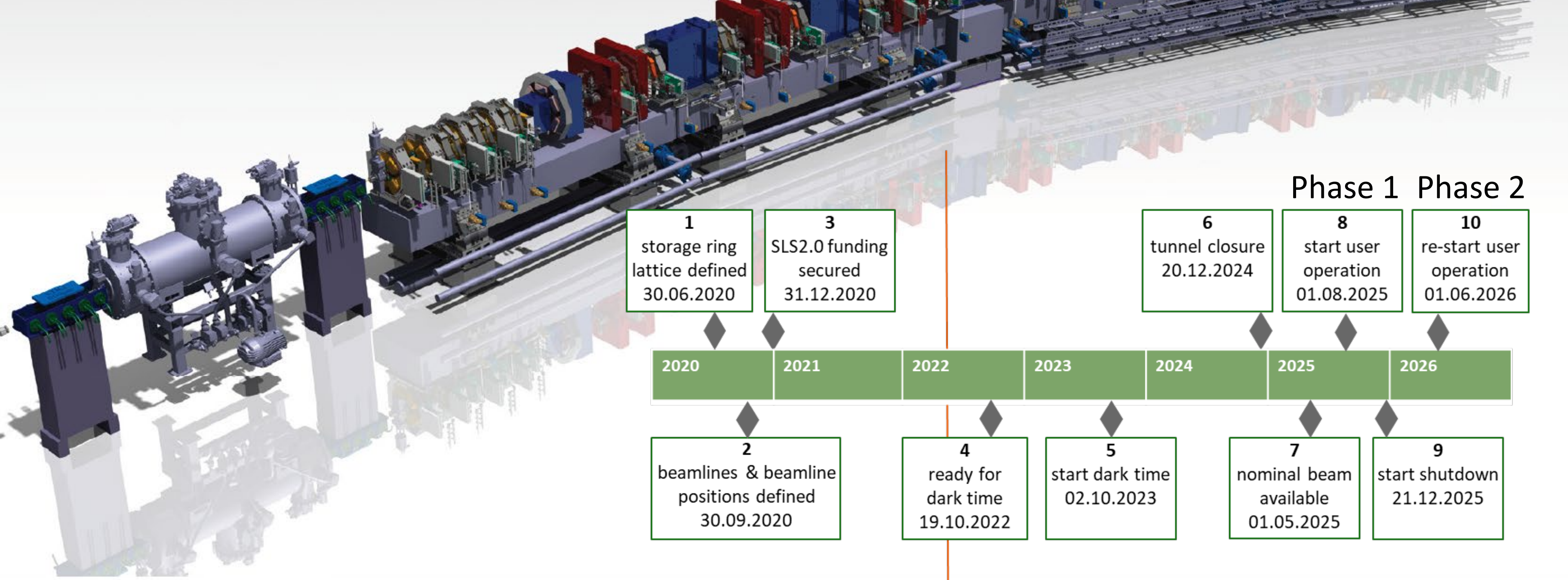
What 's next (2) : Upgrade of SLS SLS2.0



$$\mathcal{B} = \frac{\text{flux}}{\text{emittance}}$$

Brilliance





Phase 1	Phase 2

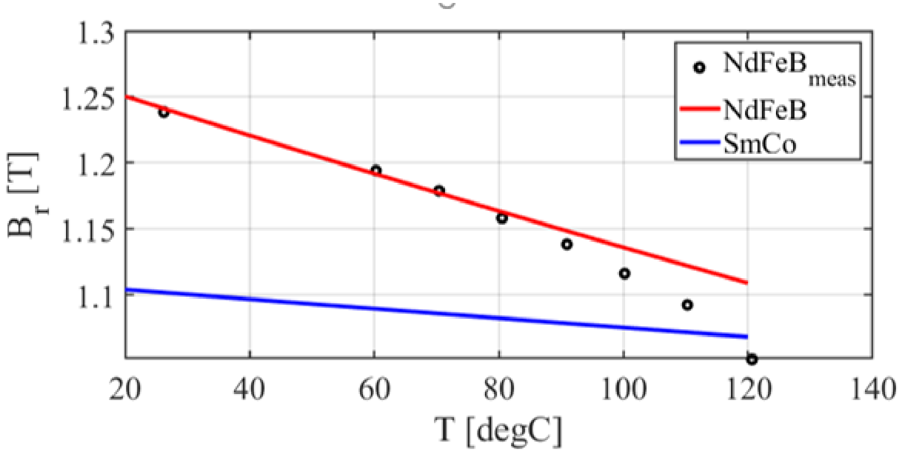
No.	Milestone	Date
1	storage ring lattice defined	30.06.2020
2	beamlines & beamline positions defined	30.09.2020
3	SLS2.0 funding secured	31.12.2020
4	ready for dark time	19.10.2022
5	start dark time	02.10.2023
6	tunnel closure	20.12.2024
7	nominal beam available	01.05.2025
8	start user operation	01.08.2025
9	start shutdown	21.12.2025
10	re-start user operation	01.06.2026

2020 2021 2022 2023 2024 2025 2026

12.4.2022

Permanent magnet blocks-magnetisation control

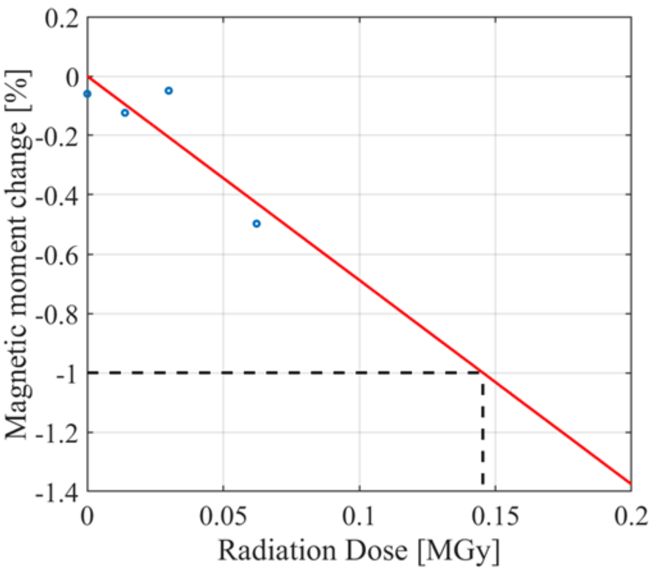
Temperature stability :
dominated by PM material
temperature coefficient (dB/B)/dT



(Linear) reduction of B_r: -0.12 %/°C

Temperature stabilisation with **passive NiFe shunts** for a relative field integral variation ~ **0.010%/°C**

Radiation damage with time (A. Temnykh)



Problem after a cumulative dose of **0.15 MGy**?

But : PM blocks are not close to the beam pipe

the dose is mostly onto the iron poles