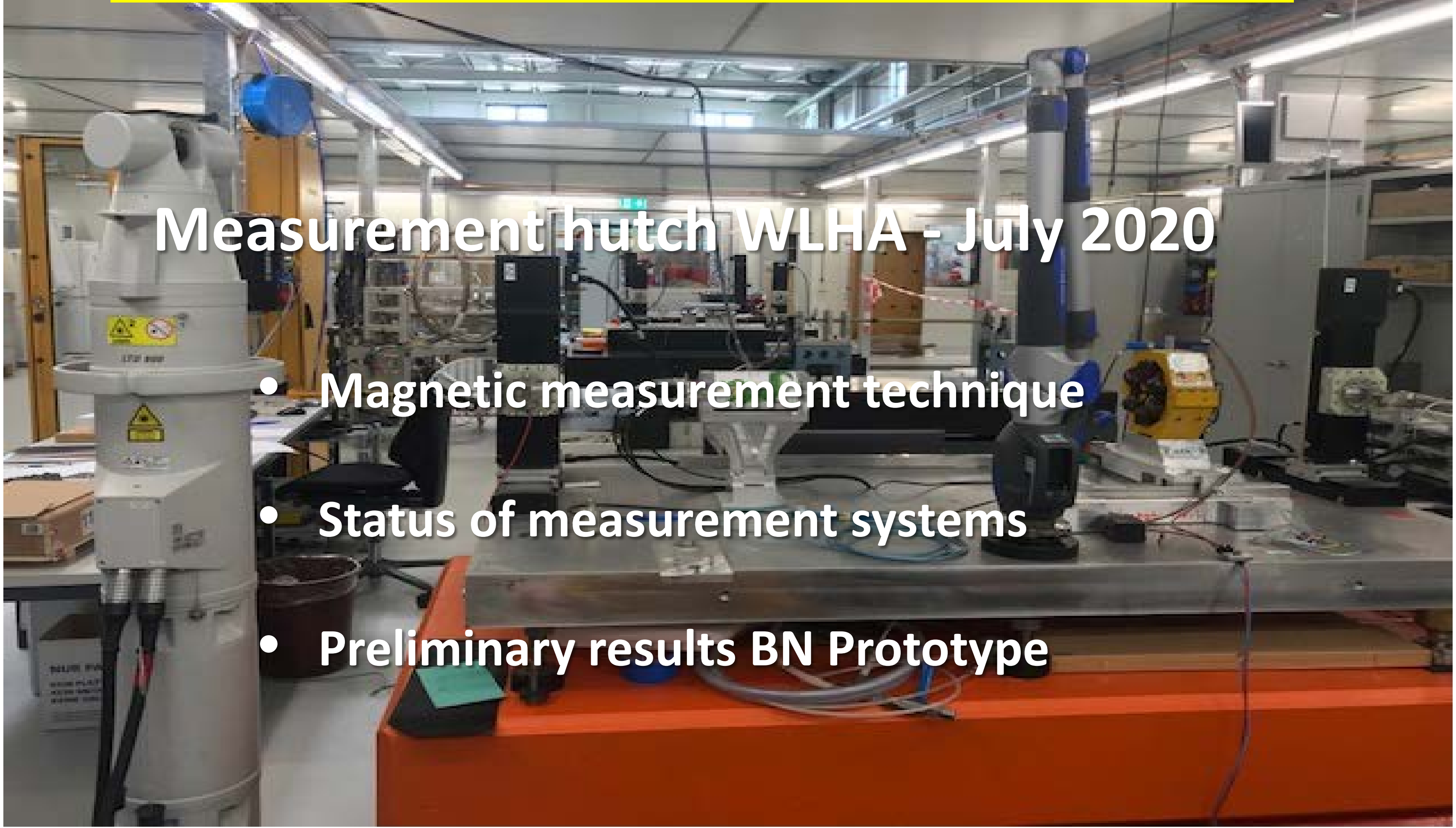
G. Montenero:: Magnets :: Paul Scherrer Institut

Magnetic Measurement for SLS 2.0 Magnets

DLS-2 / SLS 2.0 Information Exchange

12.10.2020

Magnetic Measurements



Measurement hutch WLHA - July 2020

- Magnetic measurement technique
- Status of measurement systems
- Preliminary results BN Prototype

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Magnetic Measurements Techniques for SLS2.0 Magnets

- 100 % of the magnets measured at PSI
- And cross check between measuramtn systems for magnets subsets

Moving Wire

Integral Field measurements, adjustment, and alignment of permanent magnets:
- Main arc dipoles (BN and BE)
- Vertical focusing combined function quadrupoles (VB, VBX, and BEV)
- Horizontal focusing combined function quadrupoles (AN and ANM)

Vibrating Wire

Magnetic axis and relative alignment of electro magnets:
- Sextupole (SX-W) and Octupole (OC-W) magnets in the assembly SOQ
- Stand alone sextupoles SXQ
- Cross calibration of matching section quadrupoles' magnetic axis

PCB Rotating Coils

Field quality, transfer function, and magnetic axis of:
- Matching section quadrupoles (QP and QPH)
- Horizontal and Vertical correctors (CHV)
- Sample measurements of the sextupole and octupole magnets

Compact Field Mapper

3D Field maps and integrals for a sample of:
- Assembled triplets
- On the magnets pre-series to assess effective lengths

3D Helmholtz Coils

Magnetization and angle measurements of permanent magnet blocks in order to cross check (randomly) the production of the supplier/s

Status of Measurement Systems

PSI Measurement Benches

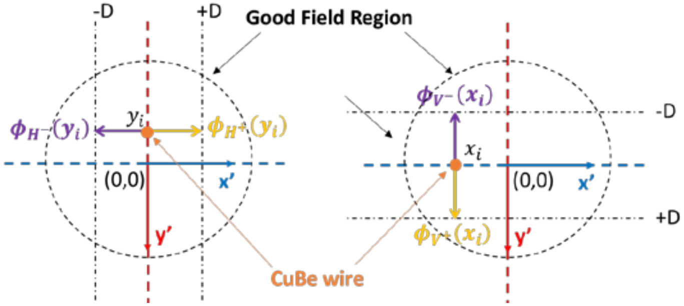
1. Moving Wire
2. Vibrating Wire
3. Rotating Coil
4. Compact Field Mapper
5. Helmholtz coils

1. Moving Wire System (MV_W)

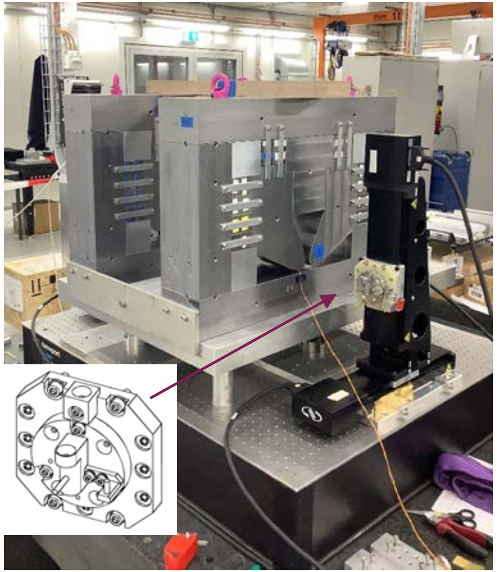
Moving Wire Benches (PSI-2019/2020)

- Bench 1: X,Y linear stages with stroke of 200 mm
- Bench 2: X,Y linear stages with stroke of 150 mm
  - Relative alignment of stages better than 30 μm
  - CuBe wire with φ=0.125 mm and length of up to 1.0 m
  - Acquisition system: 4.5 digits at 50 kS/s
  - Fiducialisation cones for φ=12.7 mm tooling ball reflector
  - **1-σ repeatability ~ 0.01 % at 1 T field**
  - **Accuracy on integral field ~ 0.1 %**

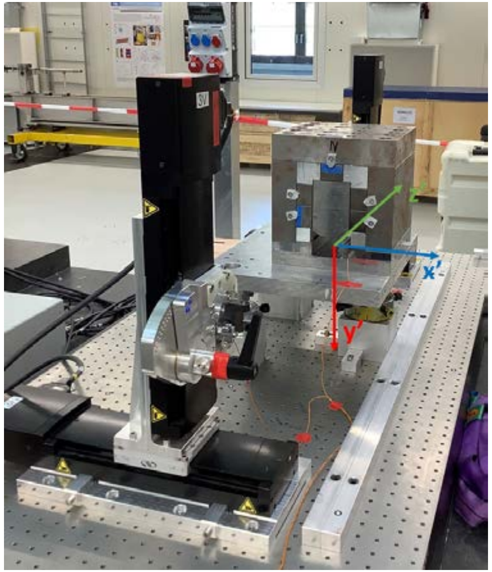
Next Steps	Till May 2021
2 MV_W benches for series meas.	WLHA - Installation of a SwissFEL girder
	New stages supports
	Commissioning with triplet prototype



Measurement Bench 1.



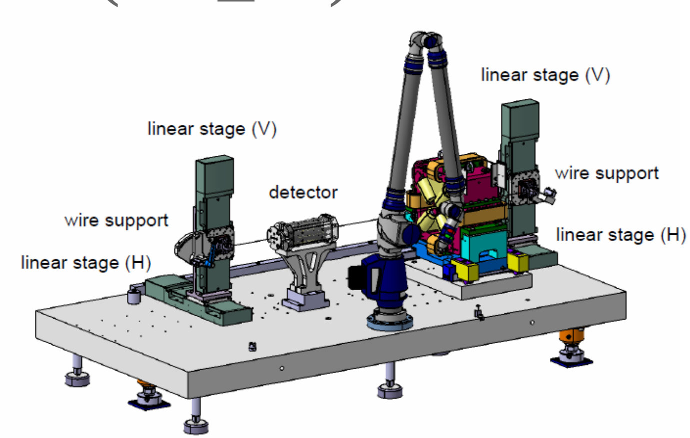
Measurement Bench 2.

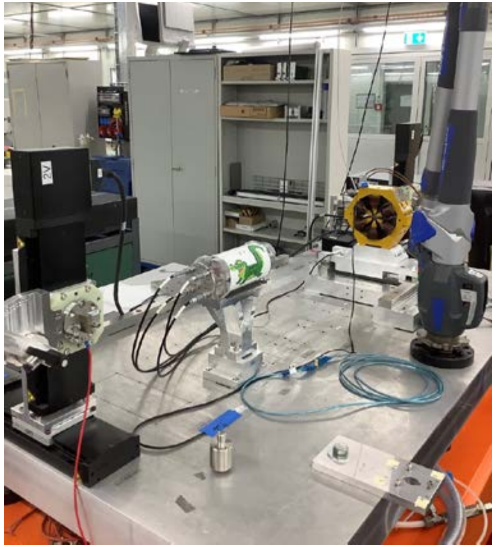


2. Vibrating Wire System (VB_W)

Vibrating Wire Bench (end of development 2014)

- X,Y linear stages with stroke of 150 mm
- For magnets of few hundreds of kg, ~0.5 m
- CuBe wire with φ=0.125 mm and length of up to 1.6 m
- Vibration detection : inductive method with 2 sets of coil pairs for wire position and horizontal and vertical vibration detection
- Lock-in amplifier to detect the voltage drops and measure the change of phase + PLL to compensate the change of resonance frequency during the movement
- **Axis to sensor accuracy ~1 µm**
- **Sensor to fiducial transfer uncertainty ~ 25 µm**





Next Steps	Mid 2021
Existing bench upgrade	for laser tracker fiducialisation
Second bench for series measurements	starting from next October

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3. Rotating Coil System (RC)

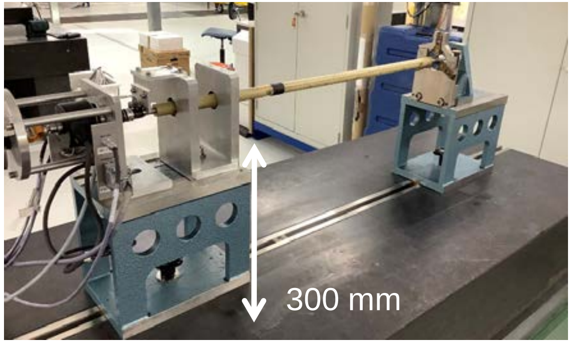
Rotating Coil Bench (to be upgraded this year)

- ➢ Upgrade of the present RC for the SLS2.0 magnets
  - Coil axis at 400 mm from the granite support
  - Rref =18 mm, compensation of B1 and B2
  - Active coil length of 500 mm
- ➢ Coil Design using PCB technology (collaboration with Elettra)
  - 5 radial coil (1 spare)
  - Single coil= 24 layers (12 doubles) with 5 turns each -> 120 turns
- ➢ Shaft
  - Hexagonal cross section (simplify metrology process)
  - Macor -> increased stiffness and rigidity
- ➢ Performance targets:

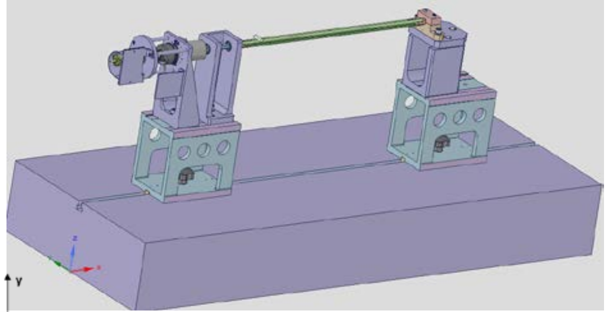
1-σ repeatability < 0.05 %, accuracy ~0.1 %

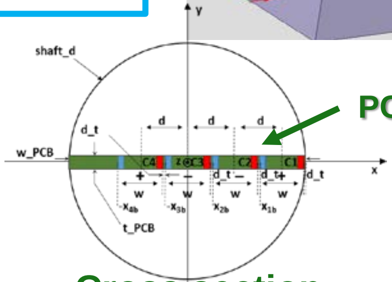
Next Steps	
Assembly of the new bench	End of October 2020
Calibration of PCB coil at CERN	End of November 2020
Commissioning (SwissFEL quad) measurements of AN prototype	December 2020 Beginning 2021

Available rotating coil bench (φ=19 mm)



Upgrade for SLS2.0 magnets

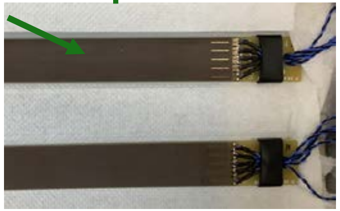




PCB coil

Cross section

Top view



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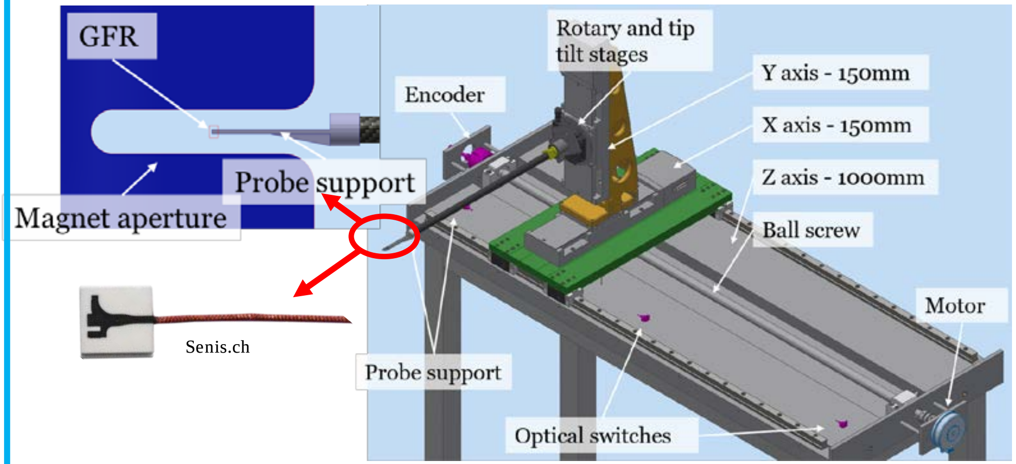
4. Compact Field Mapper (CFM)

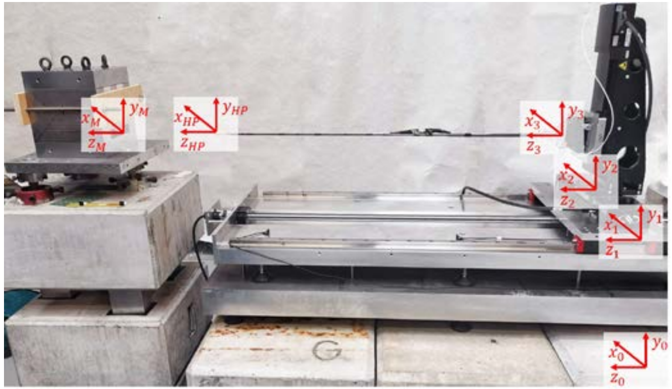
Hall Probe (PhD, PSI-PoliMi , 2018-2020)

- S type Hall probe by Senis
  - 3D Hall probe with 150x150x1 μm³ sensitive volume on each direction
  - Temperature compensated and spinning current technique implemented
- Performance
  - Positioning experimental uncertainty (2-σ) ~ 25 μm
  - **~0.1% accuracy along 3 axis at 1 T**
  - **1-σ repeatability ~0.05 %**

Next Steps	
Commissioning with prototypes	2020-2021

3D CAD model view





5. 3D Helmholtz Coils

The 3D Helmholtz coils system

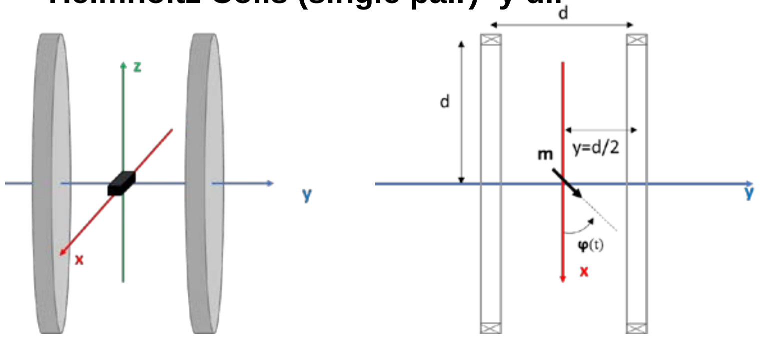
- First version developed by the PSI Insertion Device Group
- Main usage at magnet section
  - Assessment of angle deviation for PM blocks

$$\Delta\theta = arctan\left(\frac{\sqrt{m_x^2 + m_y^2}}{m_z}\right)$$

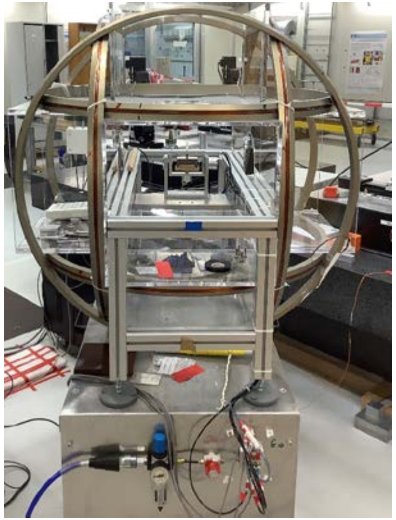
  - Cross check magnetization data from suppliers
- Target performance
  - **angular resolution ~3 mrad**
  - **1-σ repeatability <0.1 % for magnetization**

Next Steps	
Improve mechanics acquisition system	August 2020
Uncertainty sources evaluation	September 2020
Measurements PM blocks for prototypes	Till October 2020

Helmholtz Coils (single pair)- y dir



3D Helmholtz coil system at WLHA

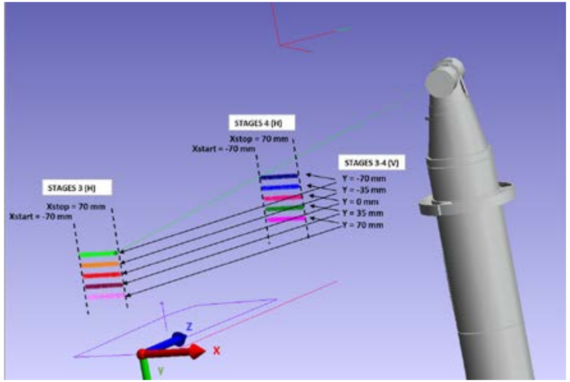


Preliminary Results BN Prototype

1. **Measurement Setup**
2. **Integral Measurements Results: A preview**

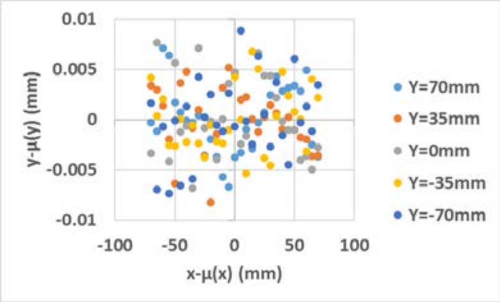
Measurement Setup

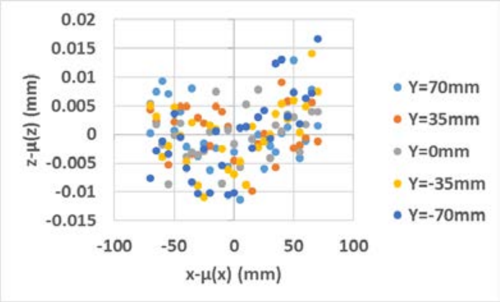
Precise Assembly of linear stages



Laser Tracker Measurements For Alignment

ASSEMBLY DEVIATIONS (XY and XZ planes)

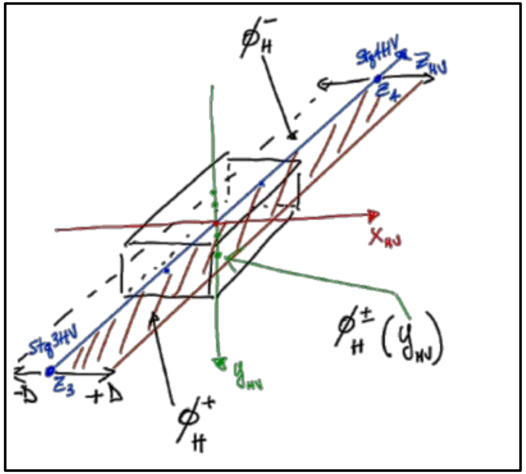


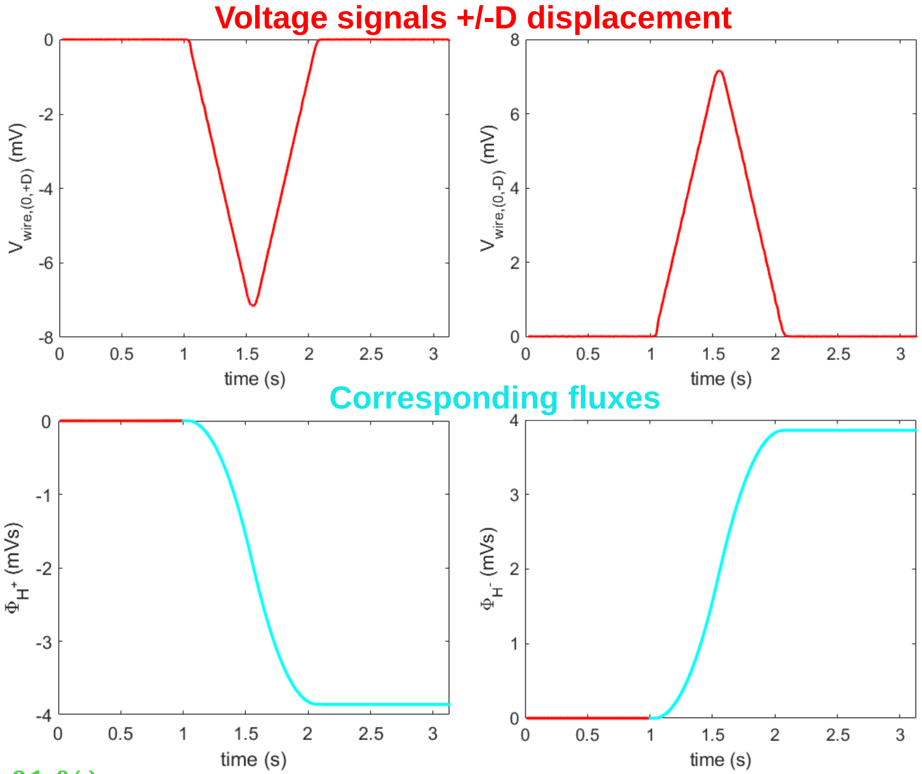


BN (Main Dipole) MV_W Bench

Integral Measurements Results: A preview

$$\int B_y\,dl = \frac{\phi_{H^+}(0) - \phi_{H^-}(0)}{2D}$$





- **Typical 1-σ repeatability better than 100 ppm (< 0.01 %)**
- **Measured ∫Bydl : 0.6071 (Tm) @ 23.4 °C, SLS 2.0 requirement 0.5471 (Tm) @ 24 °C**

- **Next steps:**
  - **Field vs. temperature studies**
  - **Insertion of flux shuts (thermal stabilization)**
  - **Introduction of shims for filed tuning**

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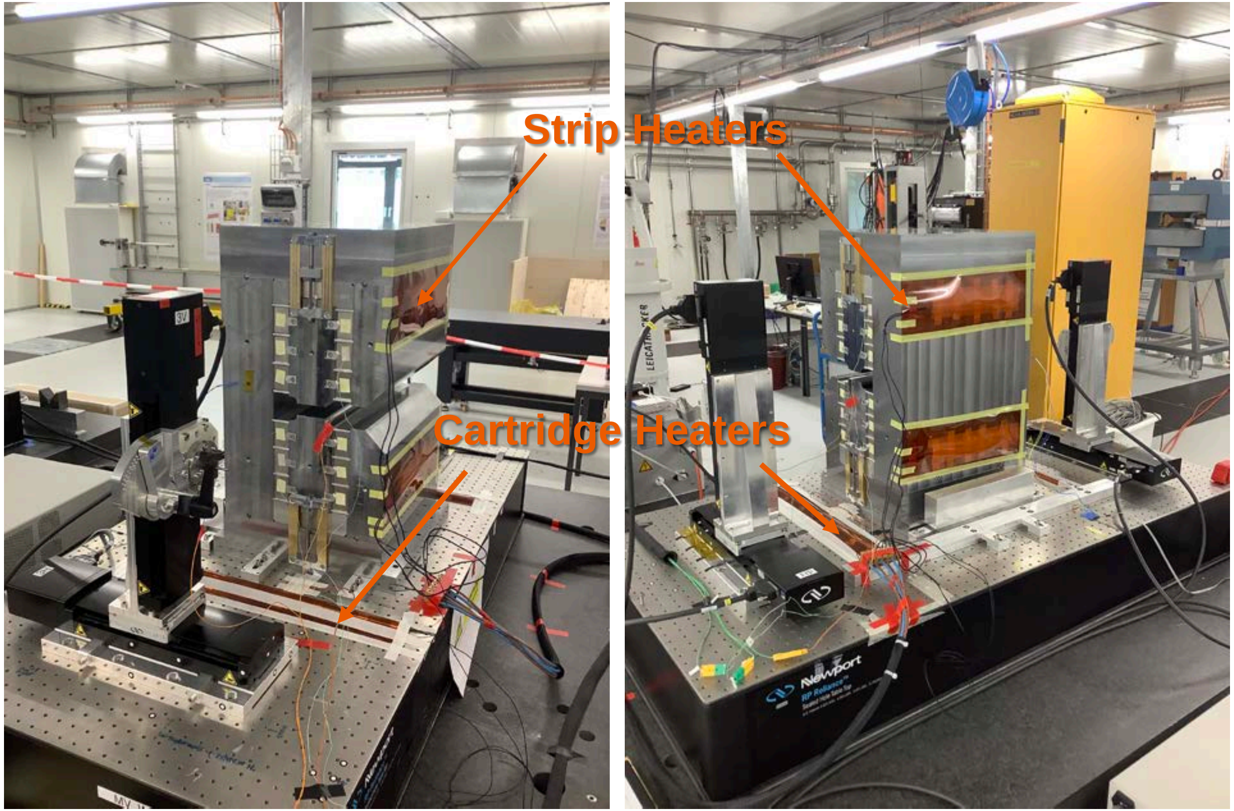
Being Ready for Temperature Studies

Setup for filed vs. temperature studies



- Field vs. temperature studies (up to 30 °C)
  - 2 sets of heaters:
  - 4 x Streep Heaters on the magnet (4 x 50 W)

  - 2 x Cartridge Heaters on the base table (2 x 400 W)

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Thank you for the attention

What about questions?

Many thanks to:

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