Joint Universities Accelerator School

JUAS 2025

# Practical Work on Magnets
# Part 2: Magnetic Measurements

11th – 12th March 2025

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TE-MSC

CERN

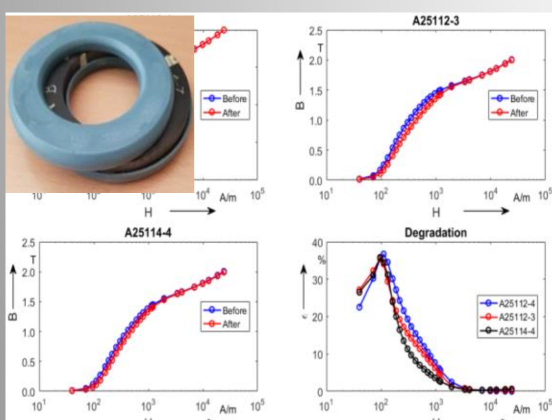
# Tour in one of our laboratory

b.311 lab built in 2017

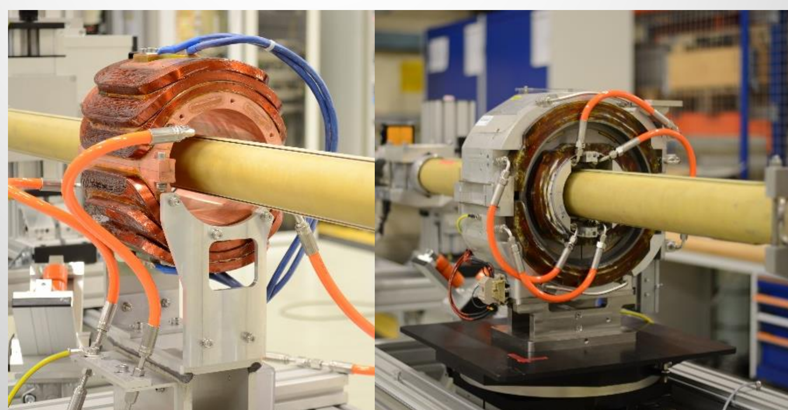
# Unterstand the motivation for MM

**Magnetic measurements (MM)** are performed to:

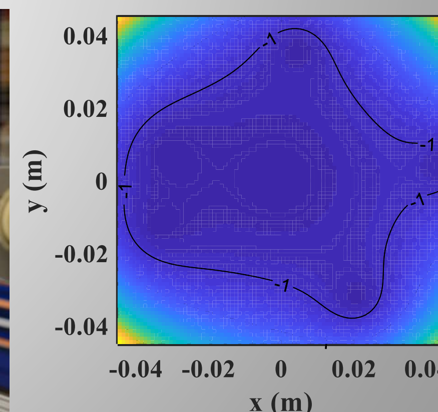
- Characterize soft (iron) and hard (permanent magnets) ferromagnetic **materials**
- Prove that the electro-magnetic **design** is correct
- Monitor production quality and steer **manufacturing**
- **Characterization** for **operations**: transfer function, field uniformity, magnetic axis, dynamic effects (eddy currents) and cycling effects (hysteresis)
- Provide **real-time** field measurements for **operations**
- Characterize magnets after **repairs** or for **changes** in the operation ranges




Characterization of the BH-curve on samples of magnetic steel



Rotating coil measurement on a model and the final magnet



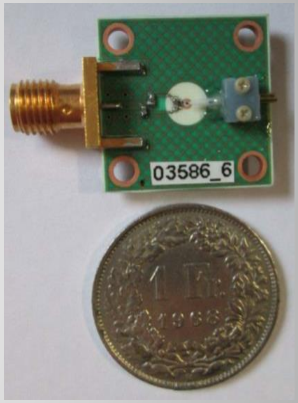

Field homogeneity reconstructed from rotating coils measurements

# Explore different MM sensors

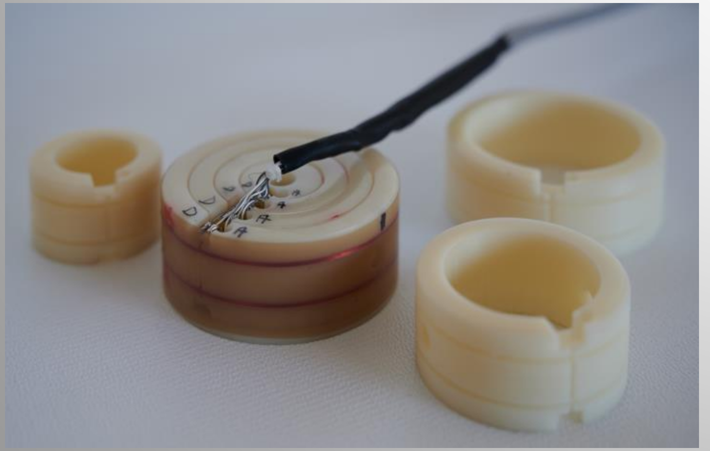
## Various instruments or methods to cover the requirements

- Multiple instruments are complementary
- Overlaps provide estimation of absolute uncertainty and error correction

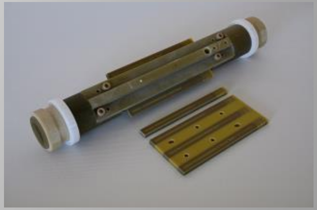
Commercial teslameters based on Hall sensors and NMR




FMR marker



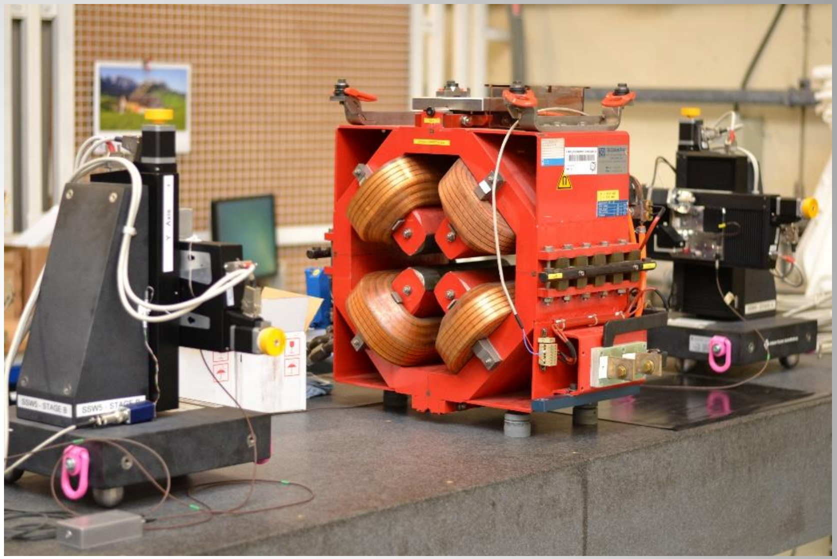
Concentric induction coils


Rotating coils with various diameters, lengths, and coil arrangement

# Discover the different MM techniques


3D mapper

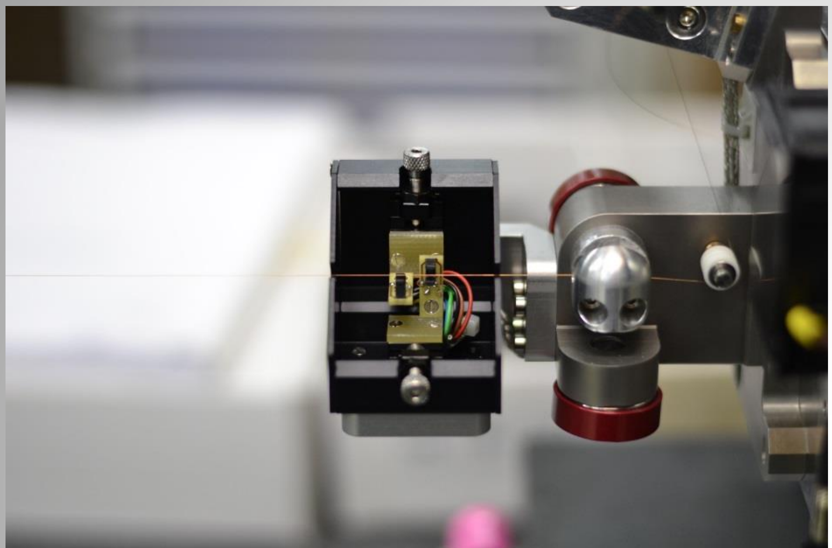


Single stretched wire bench

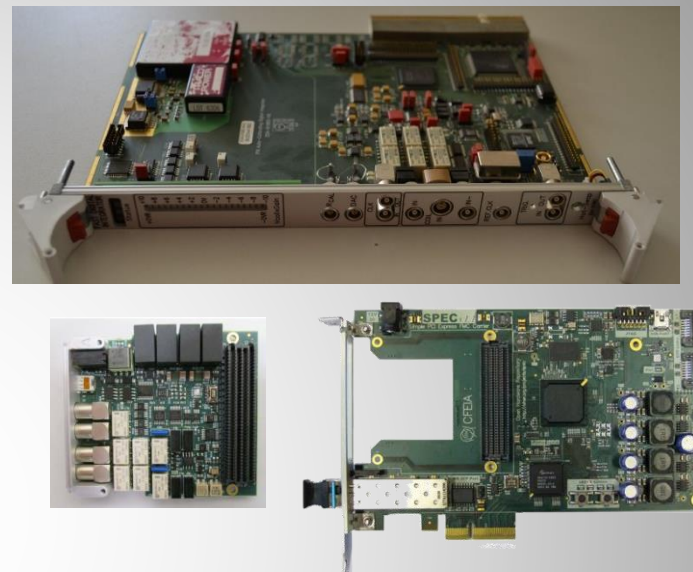

Induction coil magnetometer (“fluxmeter”)

Rotating coil magnetometer

# Find out about latest developments



Photodetectors in the vibrating wire system



Digital integrator modules

Multi-coil fluxmeter for the ELENA curved dipoles

Rotating-coil scanner for HL-LHC magnets

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# Find out about latest developments

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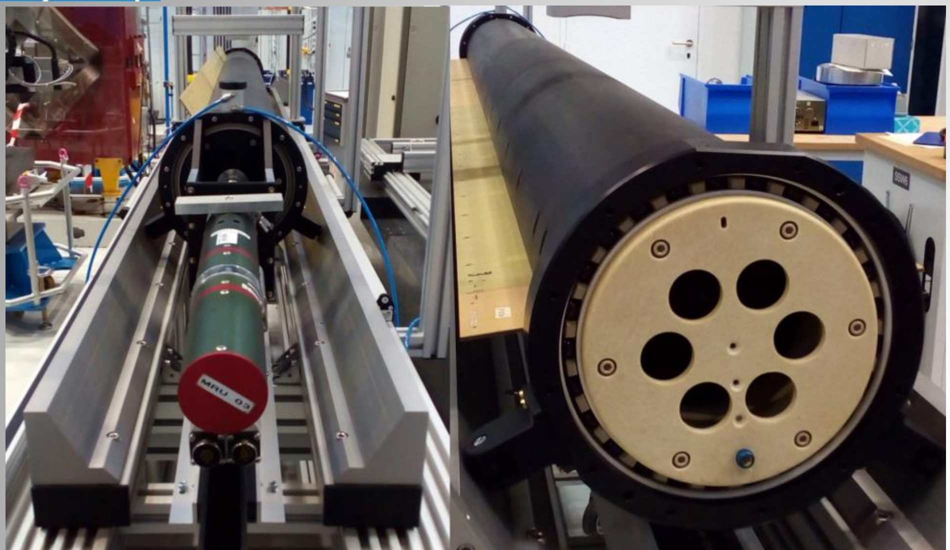
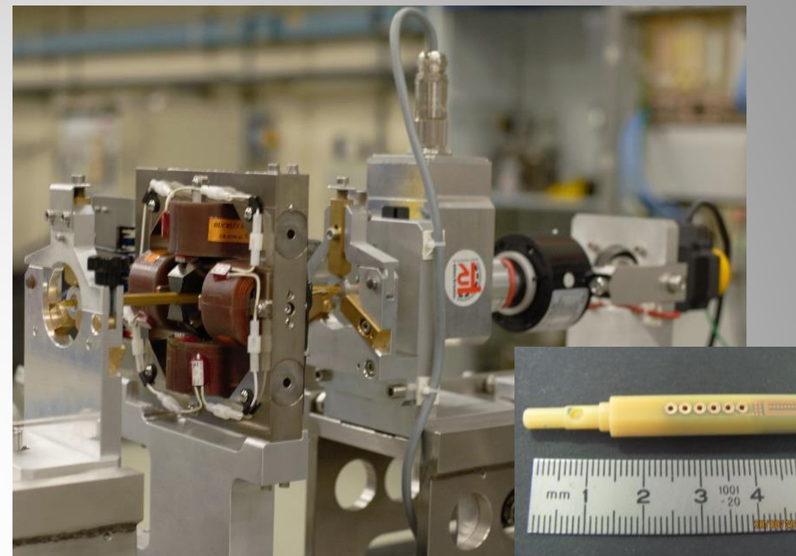
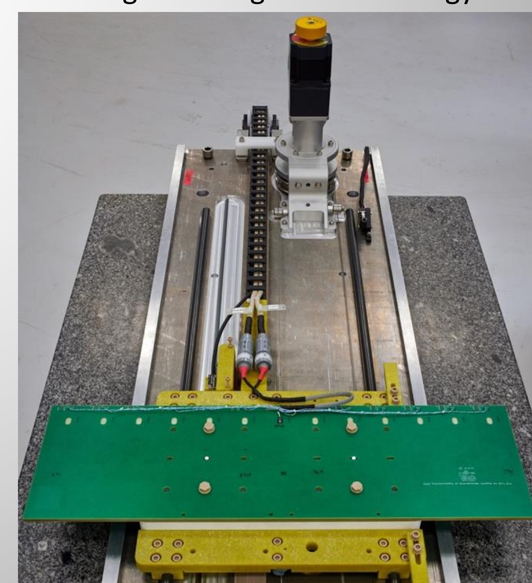


Large-diameter carbon fibre shaft for FAIR



Miniature rotating coil using PCB technology for CLIC

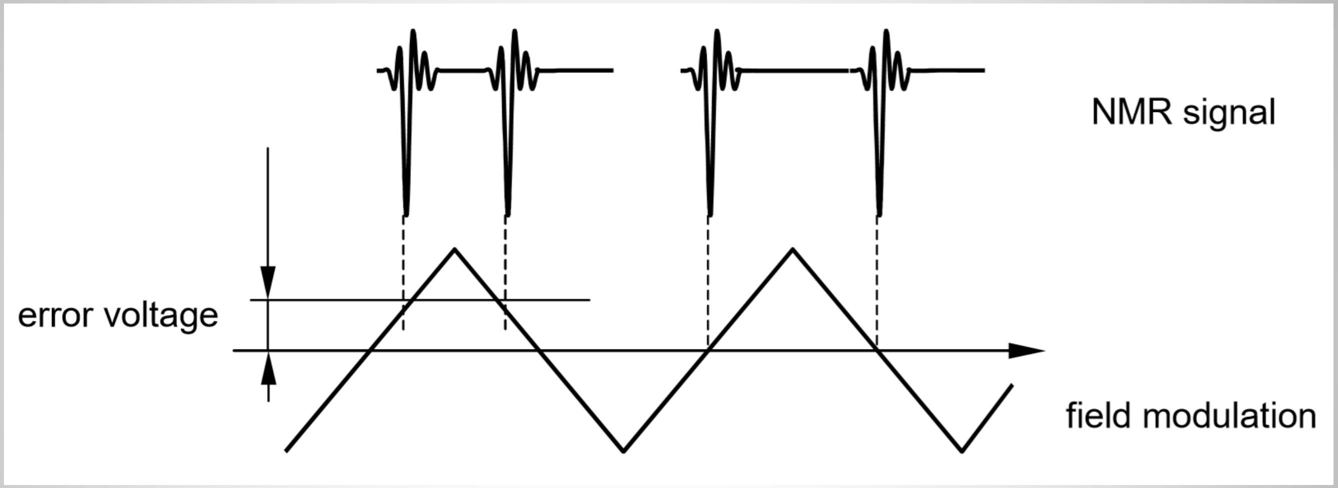
Compass-laser probe for solenoids



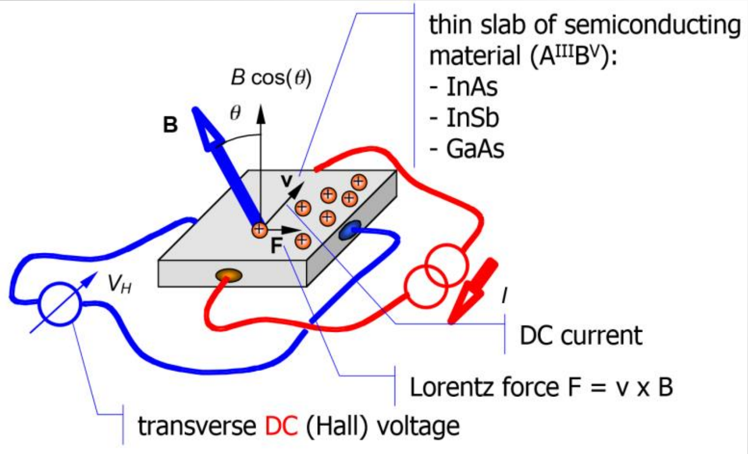
Translating fluxmeter for FAIR dipoles

# And learn…

## … how the sensors work and how to chose the right one




NMR

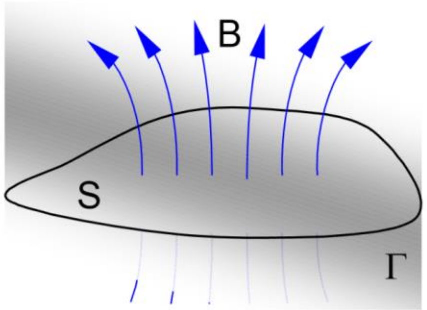



Hall sensors

Magnetic flux: $\varphi = \int_S \mathbf{B} d\mathbf{S}$

Induction law: $V = -\frac{d\varphi}{dt}$

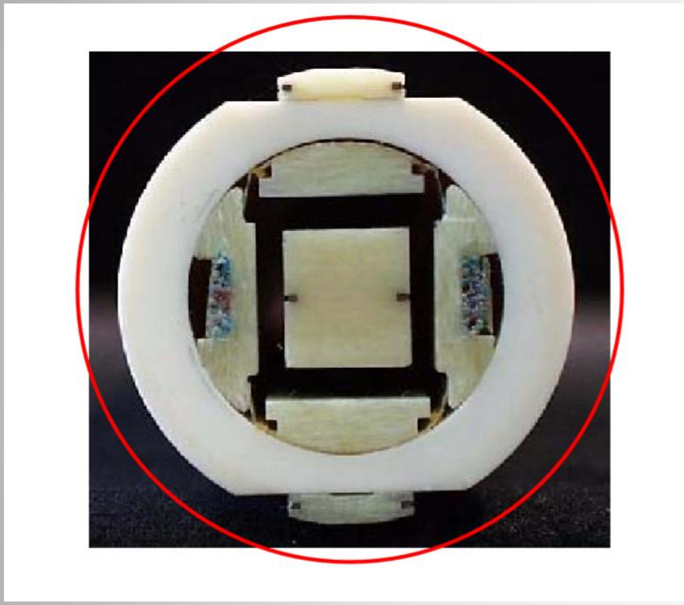
$$\varphi_{end} - \varphi_{start} = -\int_{t_{start}}^{t_{end}} V\, dt$$

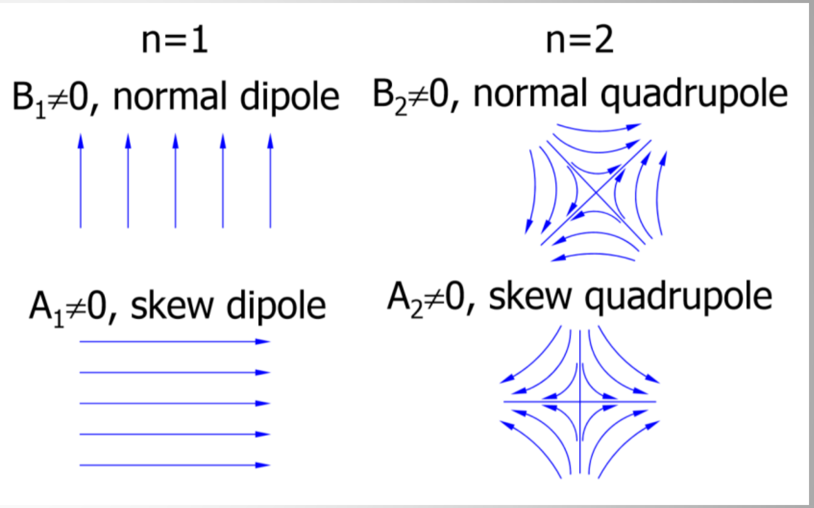


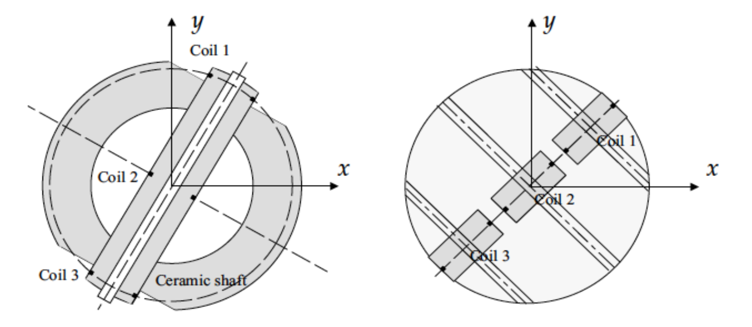

Induction coils

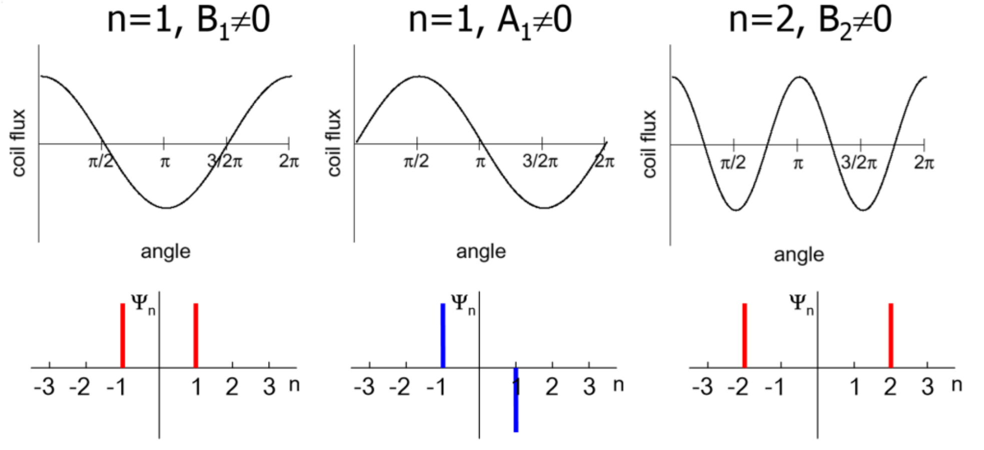
# And learn…

## … how a rotating-coil system works



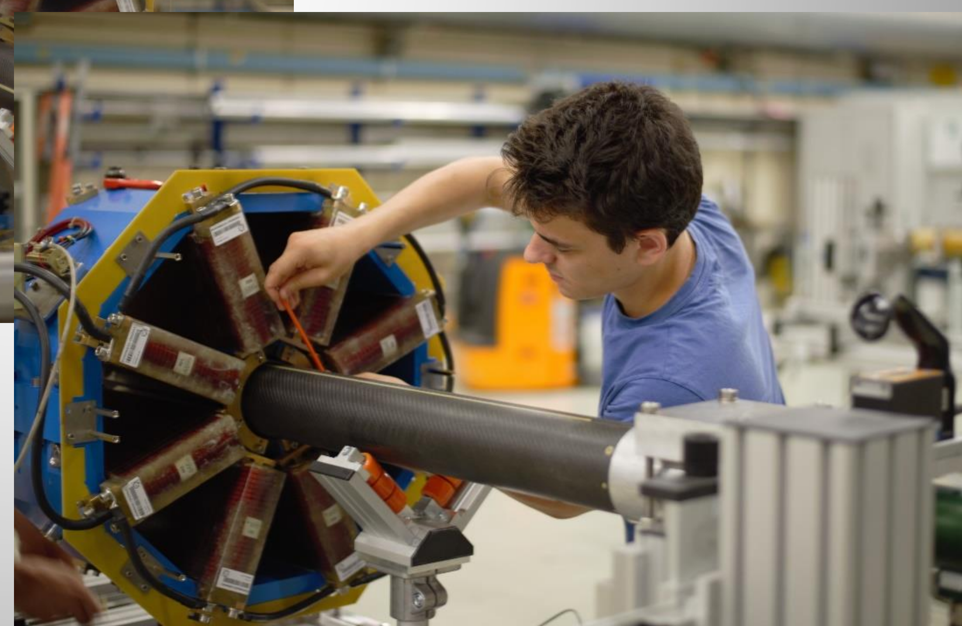


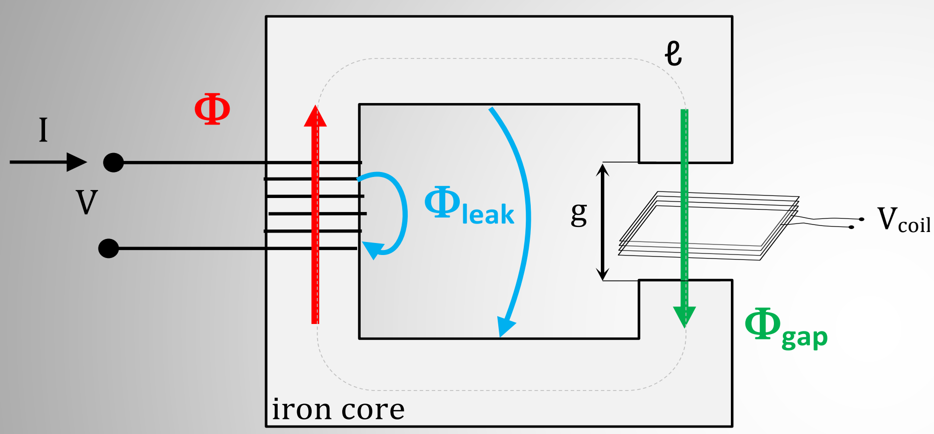
# And learn…

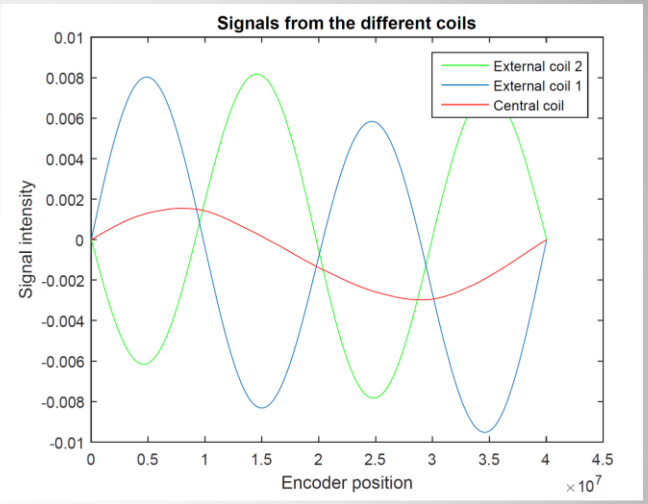
… how to measure a real magnet “hands-on”

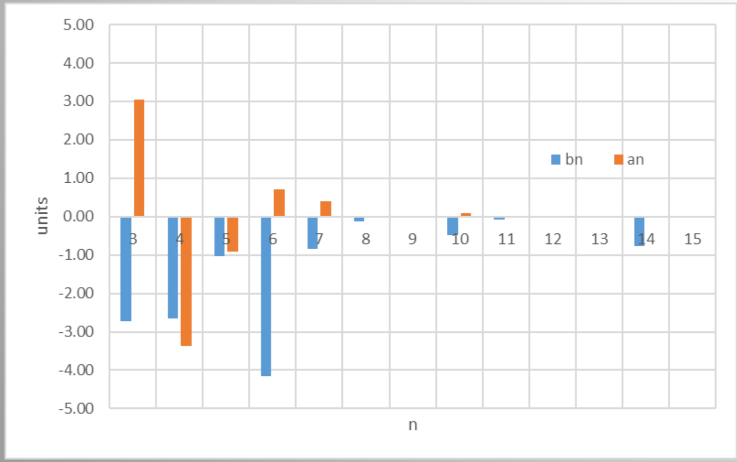


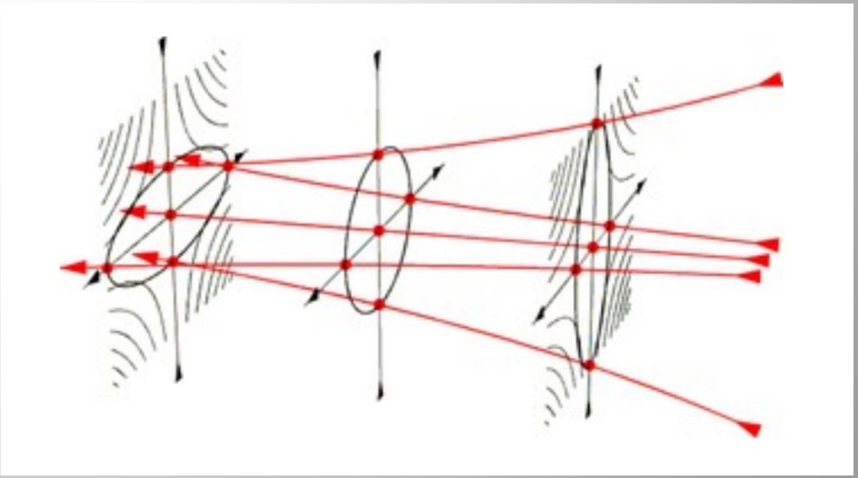
# And learn…

## … how to analyse and interpret the results



# We are looking forward to meet you!

Special thanks to the colleagues for providing the material and pictures

# Additional references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