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# Wide-Angle Solid State Polarization Analysis for MAGiC

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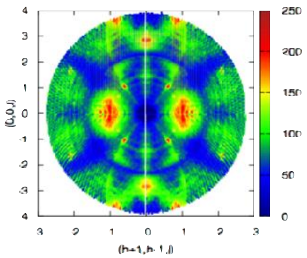
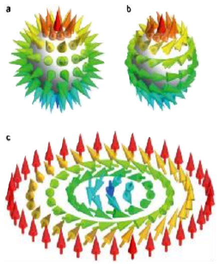
# MAGiC– Science and capabilities

## Science Case

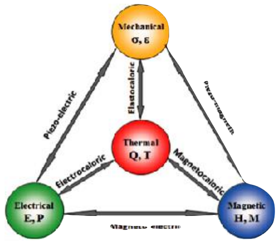
Quantum magnets



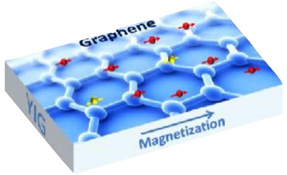
New exotic phases



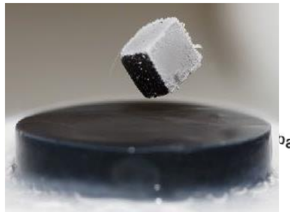
Multifunctional materials



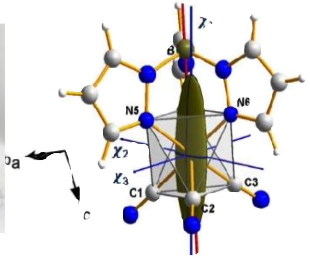

Thin-films




Superconductors



Molecular magnets



## Capabilities

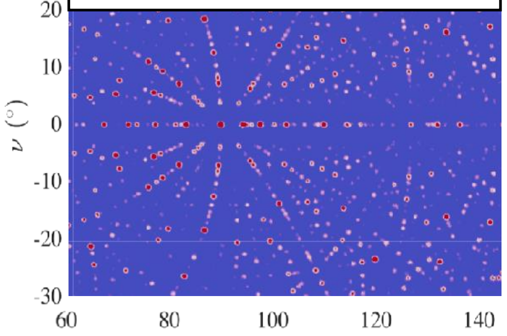
- High flux: up to $4 \times 10^9$ n/s/cm$^2$
- Polarised over $0.6 < \lambda < 6$ Å (>97%)
- Polarisation analysis for $\lambda > 2$ Å
- Flexible longitudinal and transverse resolutions
- Focusing capabilities: study of sub-mm$^3$ samples

Typical experiments:

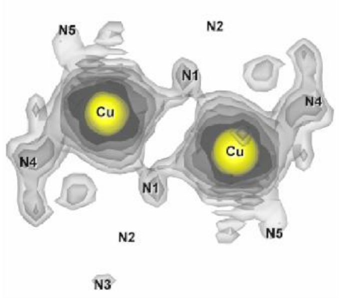
- data collection on 1mm$^3$ = 30 mn
- spin density on 0.05 μB = 2 hours
- local suscep. (SC&powder) = 1 hour
- diffuse scattering map = 1 hour

## Virtual Experiments

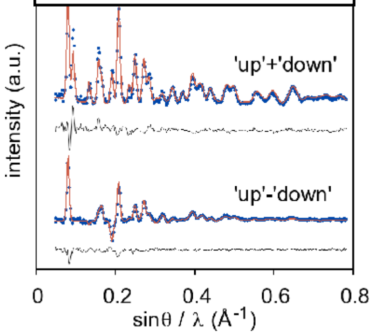
Data collection



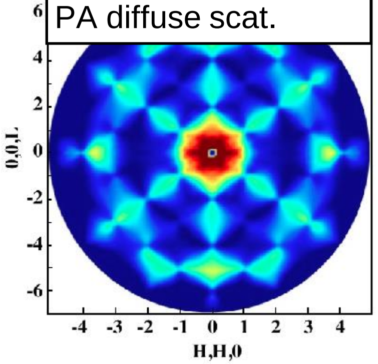

Spin density map




Local susceptibility




PA diffuse scat.



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# Virtual experiments using MAGiC: polarization analysis

Cases

HoMnO$_3$

**BiFeO$_3$**

**Spin ice**

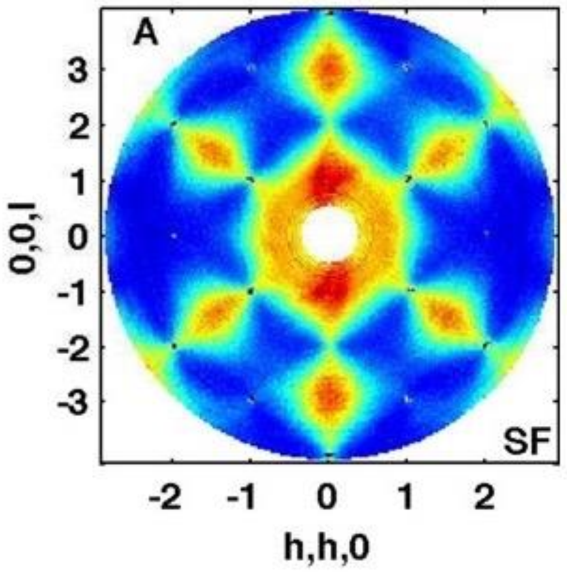
**Bucky ball**

Molecular magnets

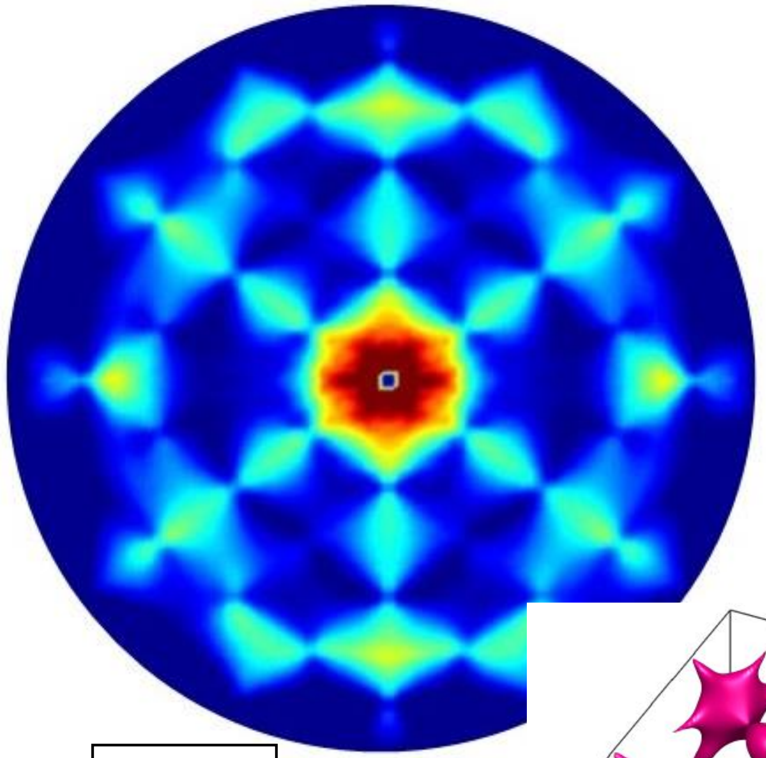
$Ho_2Ti_2O_7$

T. Fennell *et* al.
*Science* 2009

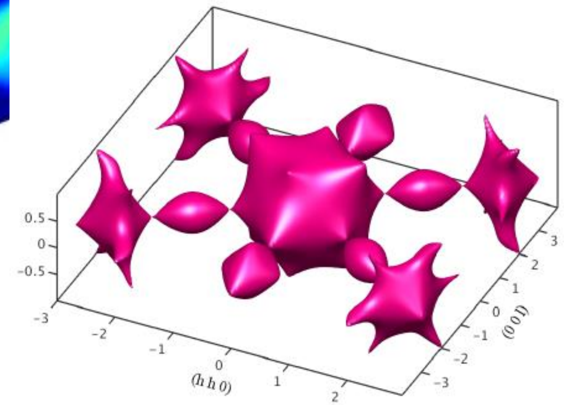
**D7**




**MAGiC:** ~$10^9$ n/s/cm$^2$

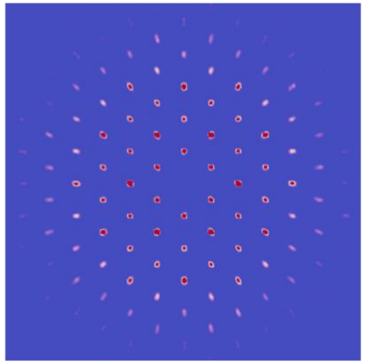


10 mm$^3$
10 min

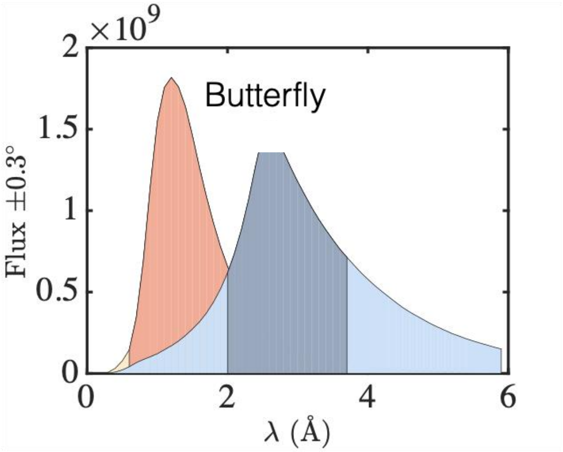


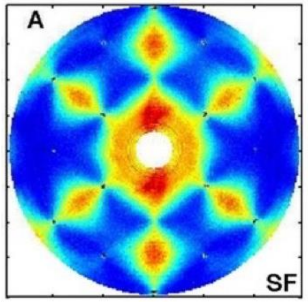
# MAGiC: functional requirements

**Spectrum:** thermal & cold



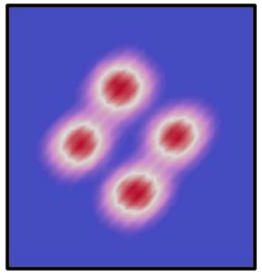
Crystal & magnetic structures
Spin-lattice coupling



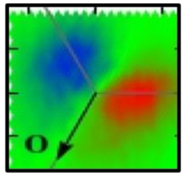

Fundamental magnetism
Diffuse scattering

**Flexible Q-resolution**

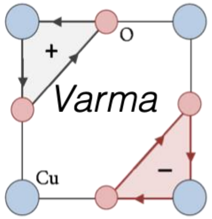


$\Delta Q \sim 10^{-2} \ldots 10^{-3} \text{Å}^{-1}$

**Polarised**

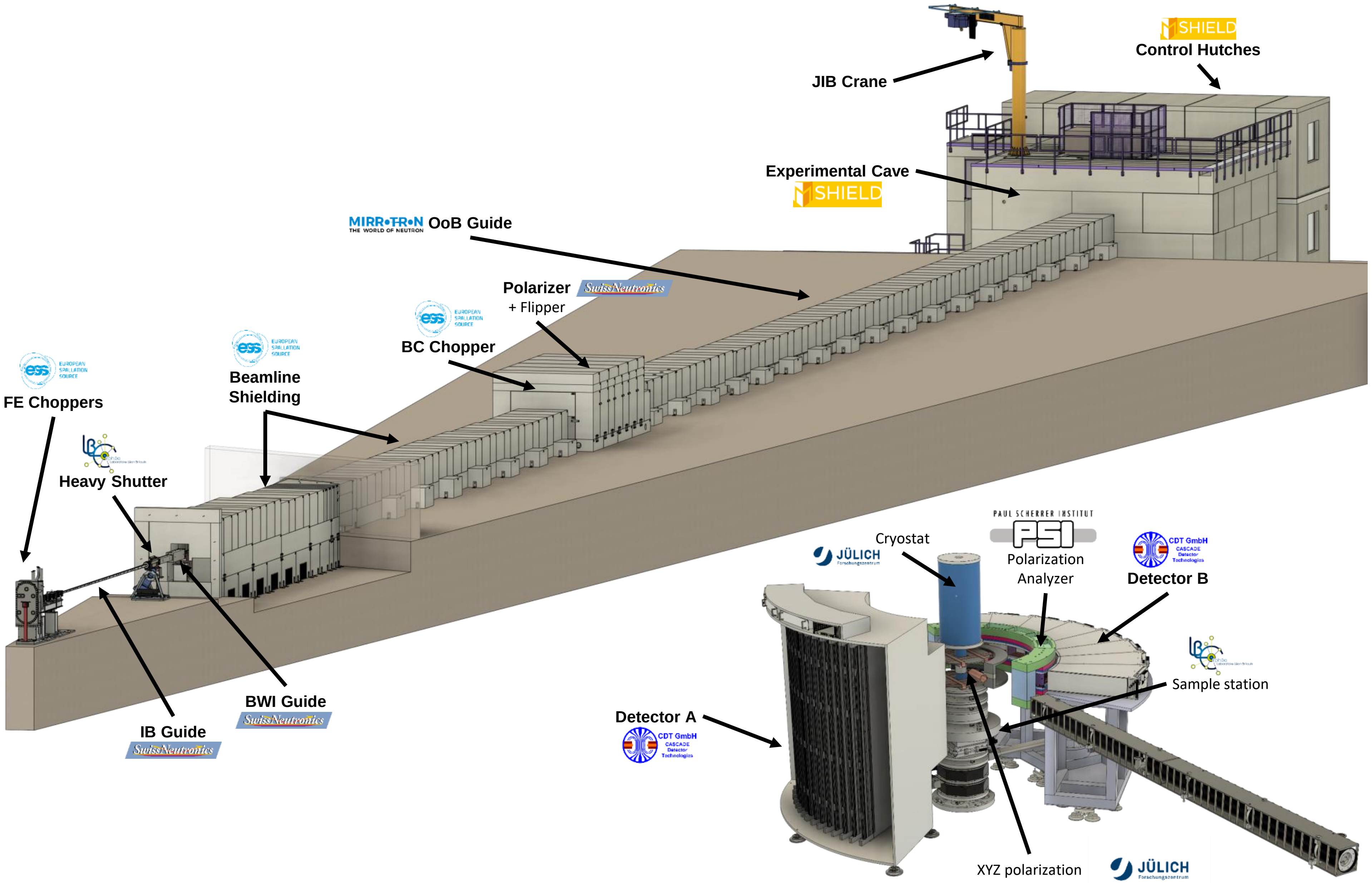



Vector properties
Chirality

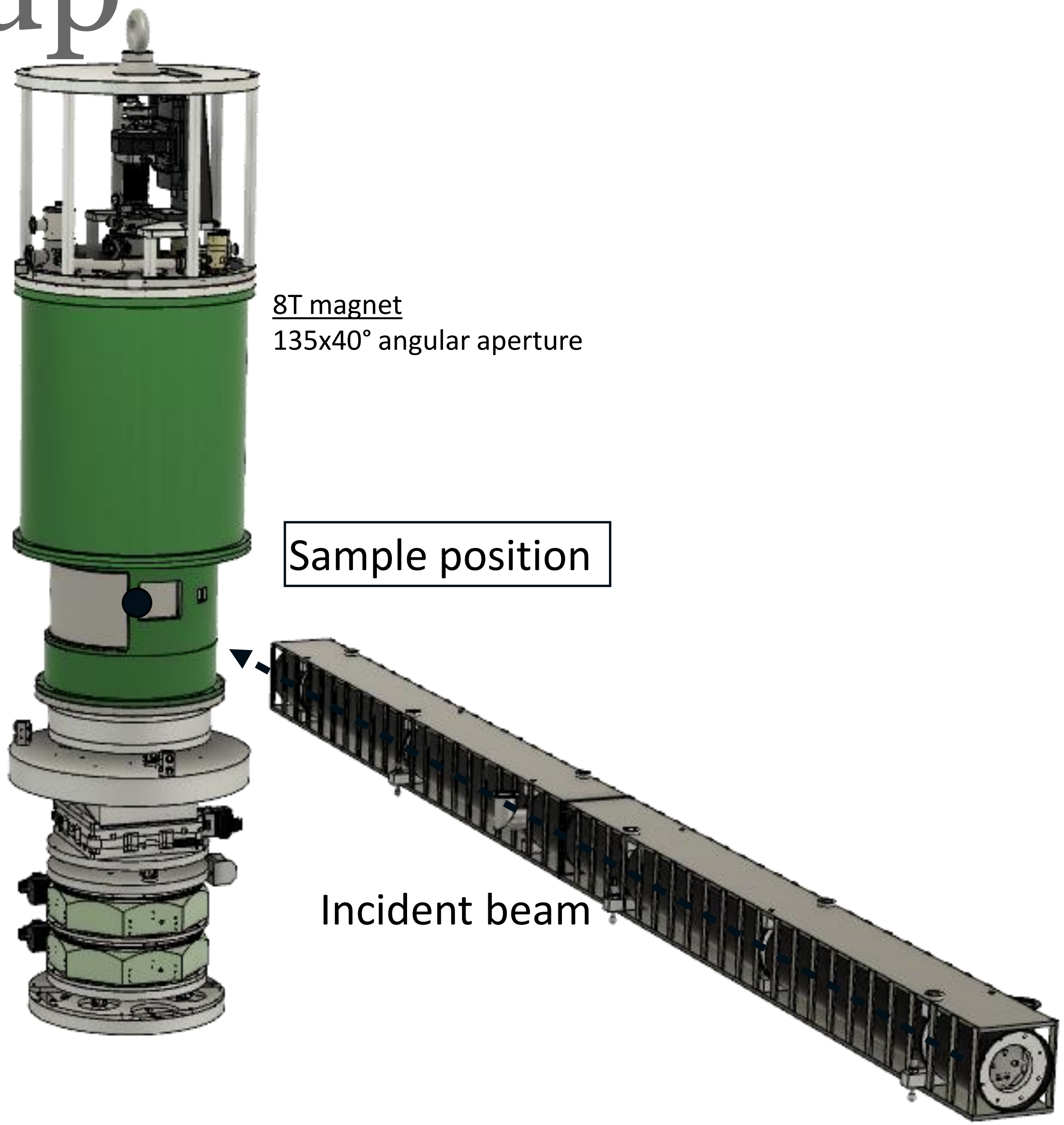



Separation of weak
Magnetic from nuclear
contributions

# MAGiC– Overview



# FR setup


8T magnet
135x40° angular aperture
Sample position
Incident beam

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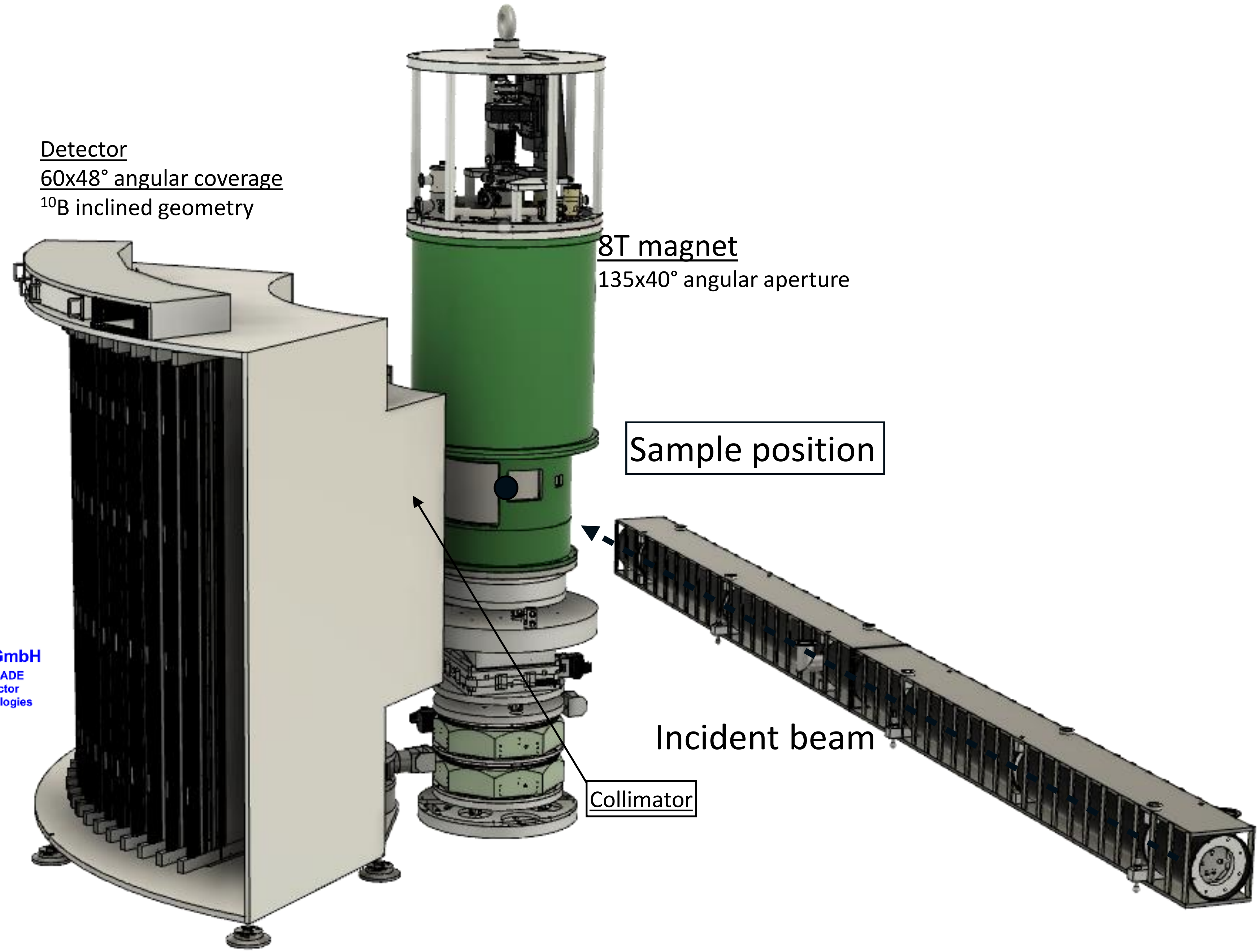
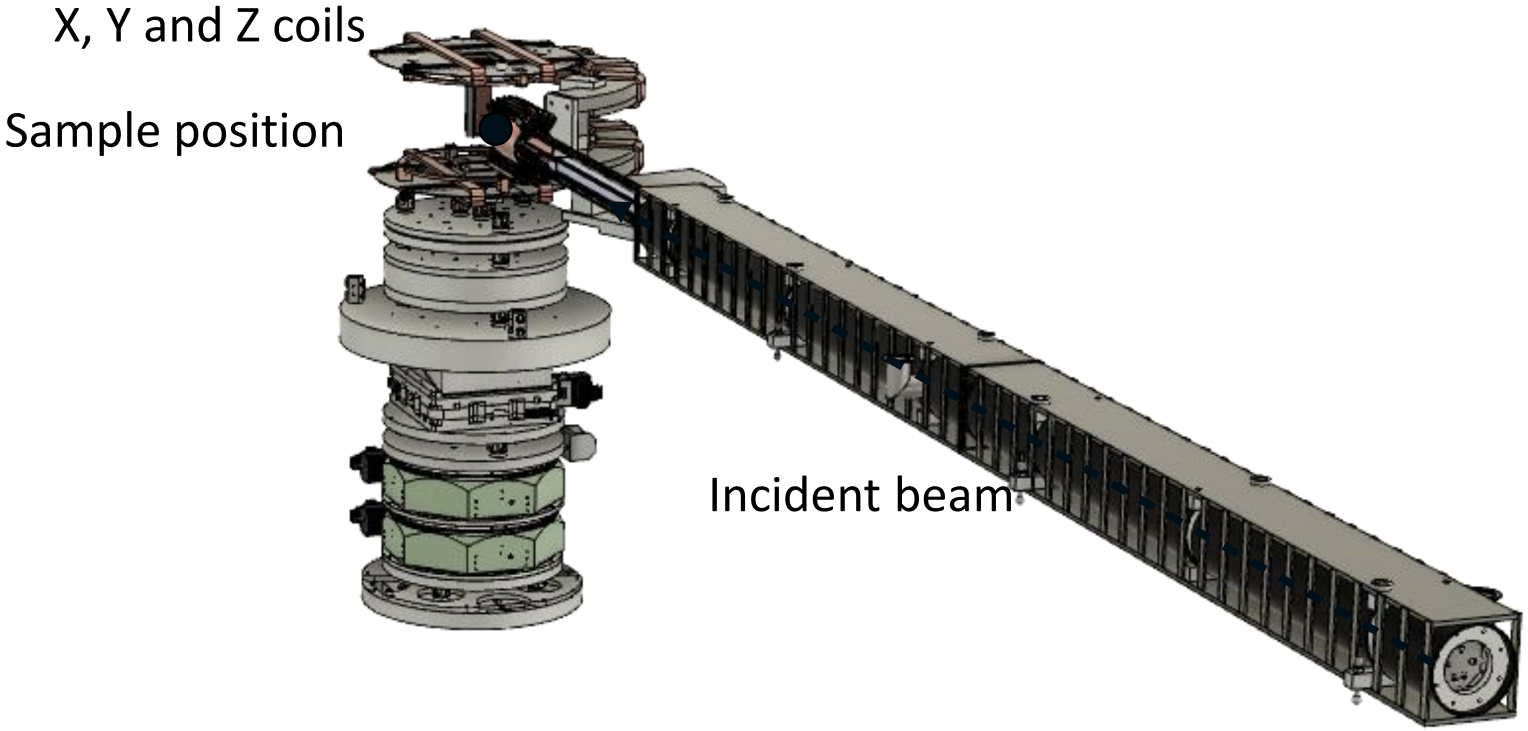
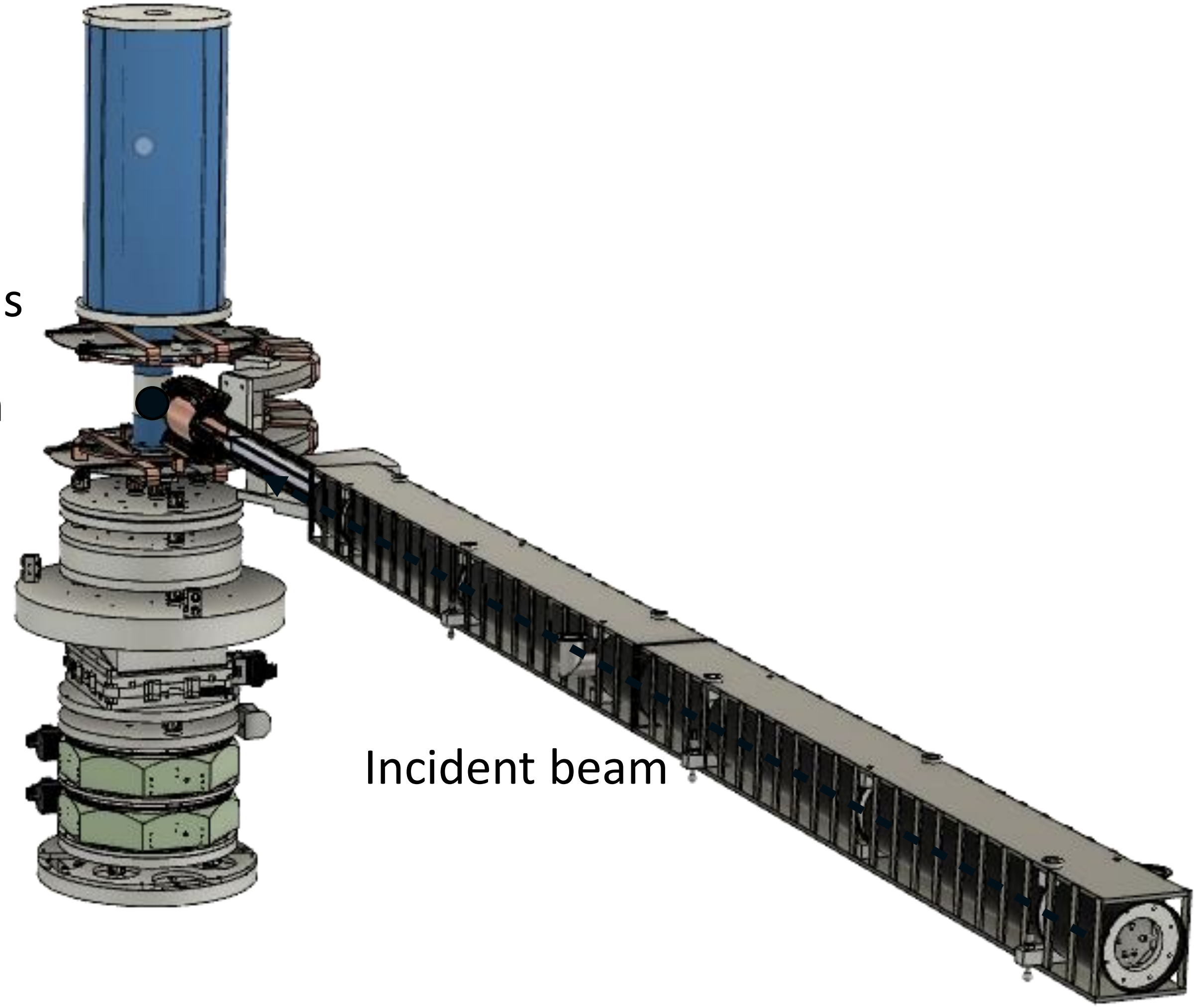


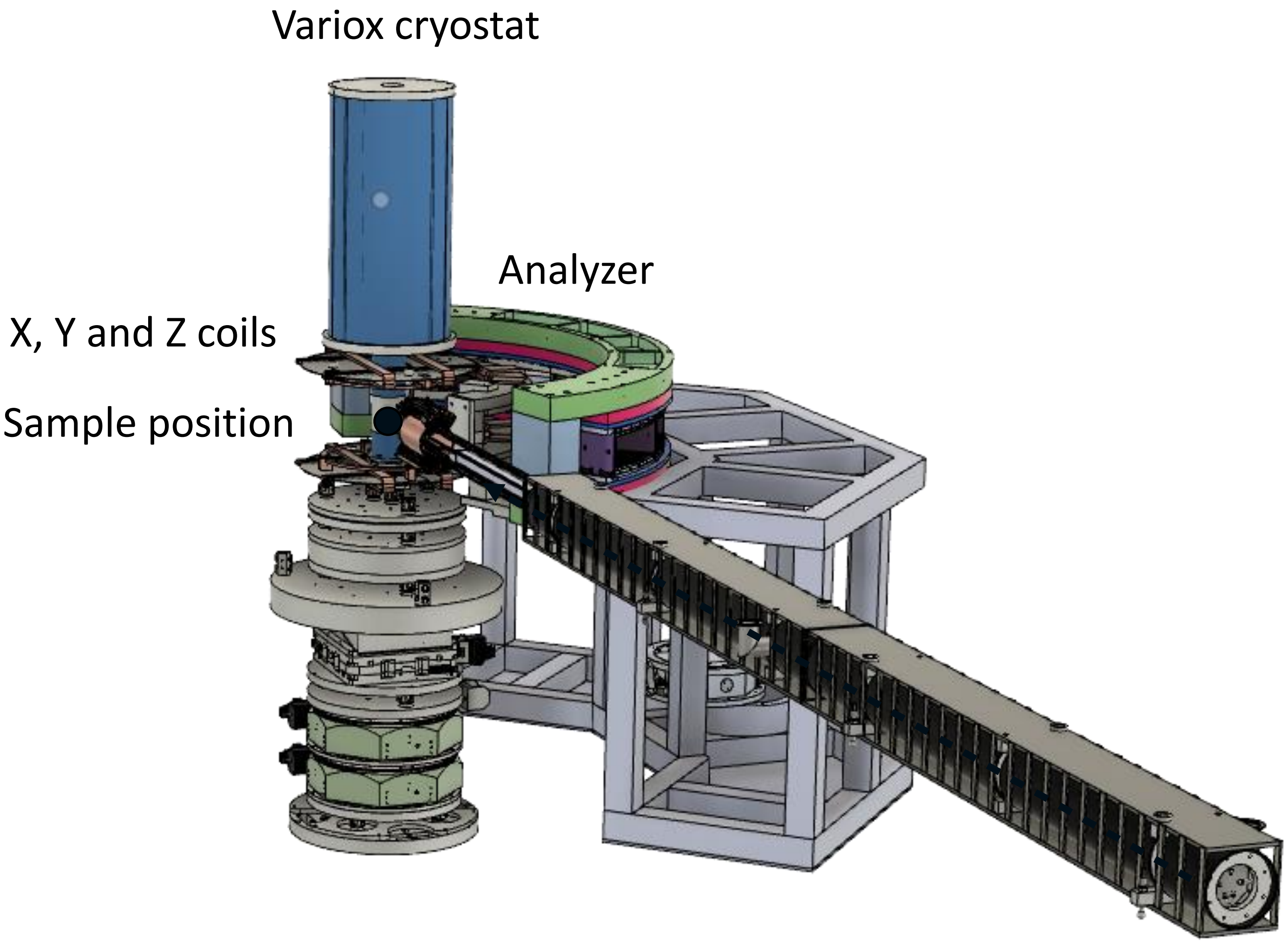
# PA setup



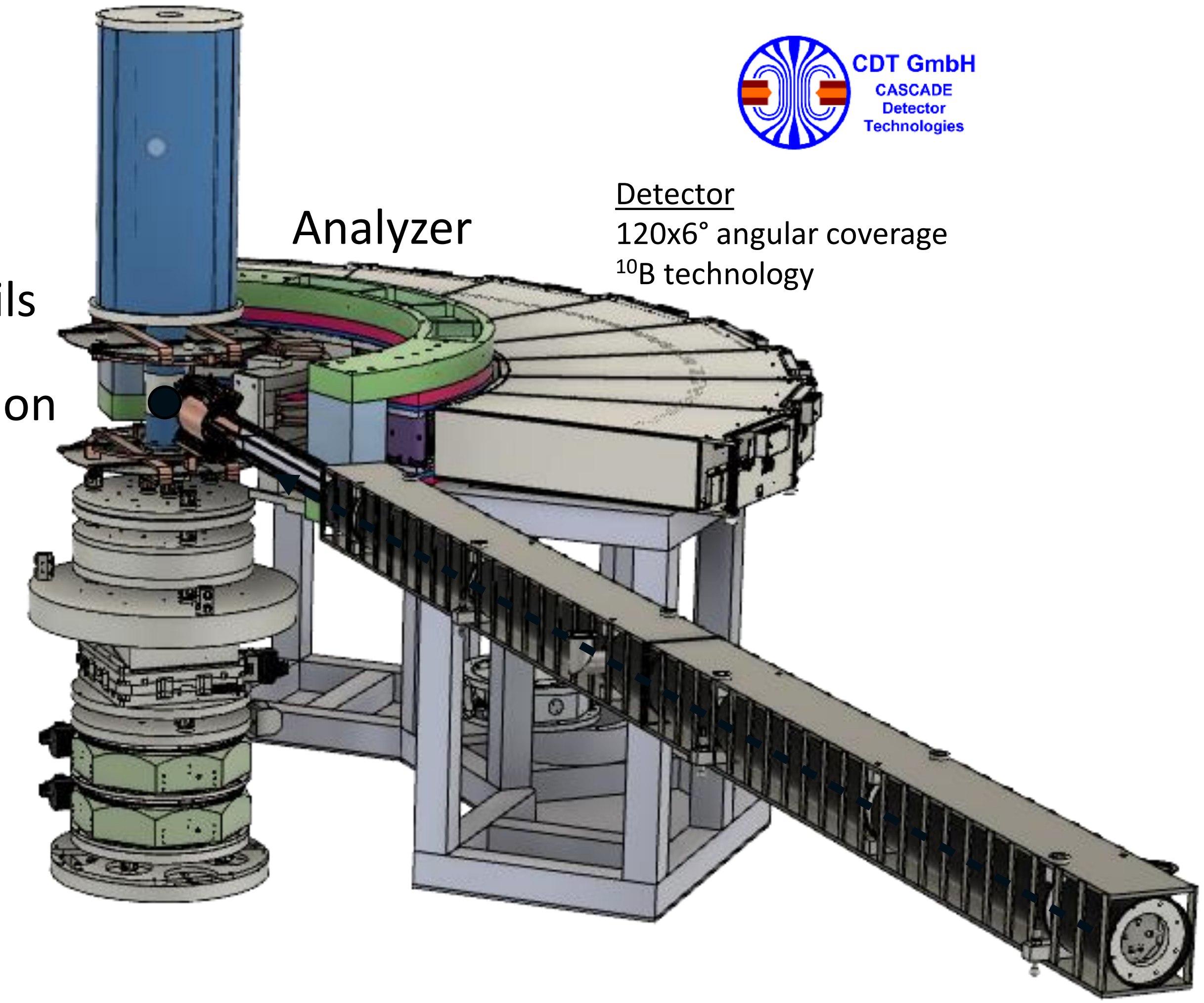
# PA setup


Variox cryostat
X, Y and Z coils
Sample position
Incident beam

# PA setup



# PA setup

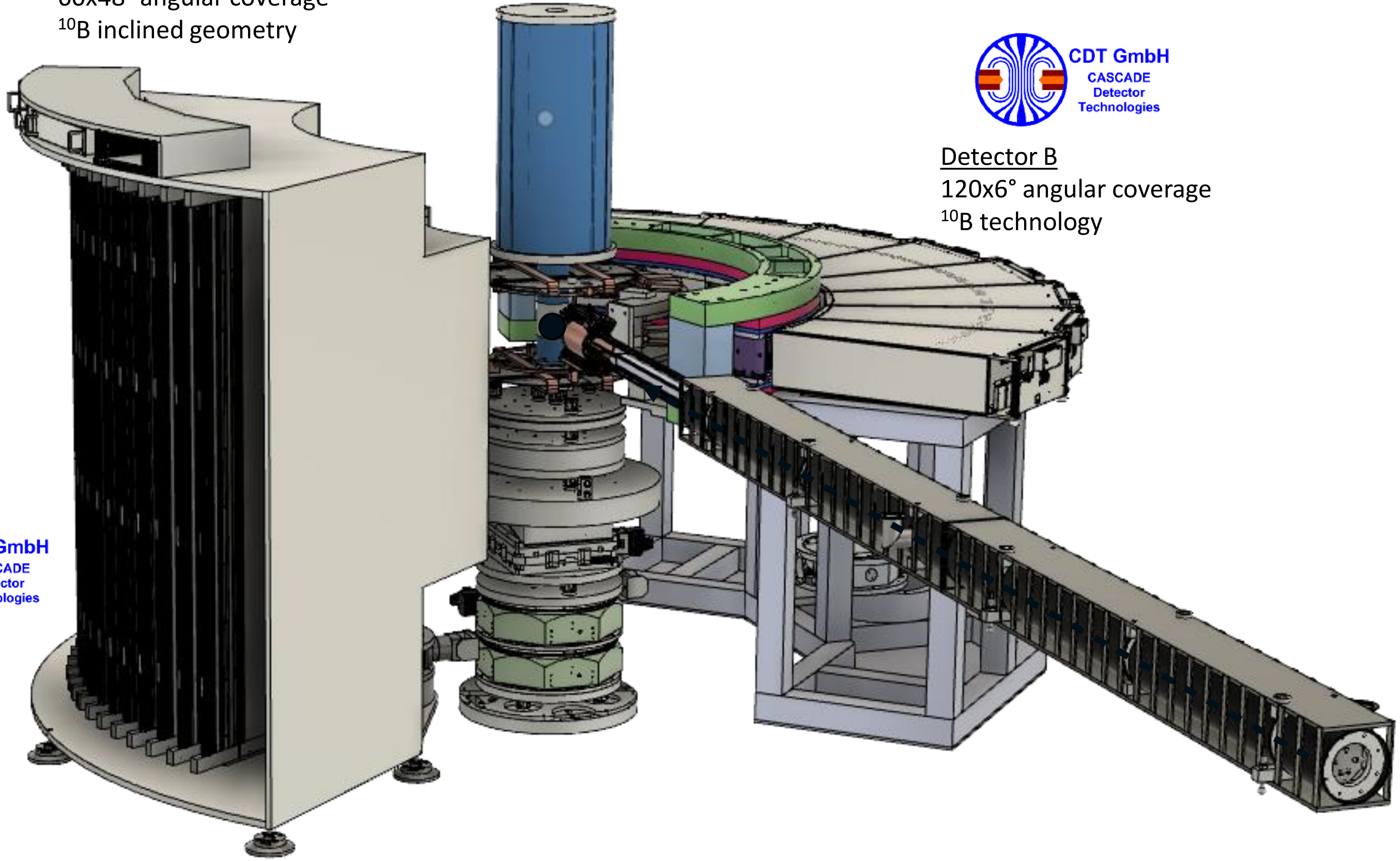



CDT GmbH
CASCADE
Detector
Technologies

<u>Detector</u>
120x6° angular coverage
$^{10}$B technology

# Full setup

<u>Detector A</u>
60x48° angular coverage
$^{10}$B inclined geometry

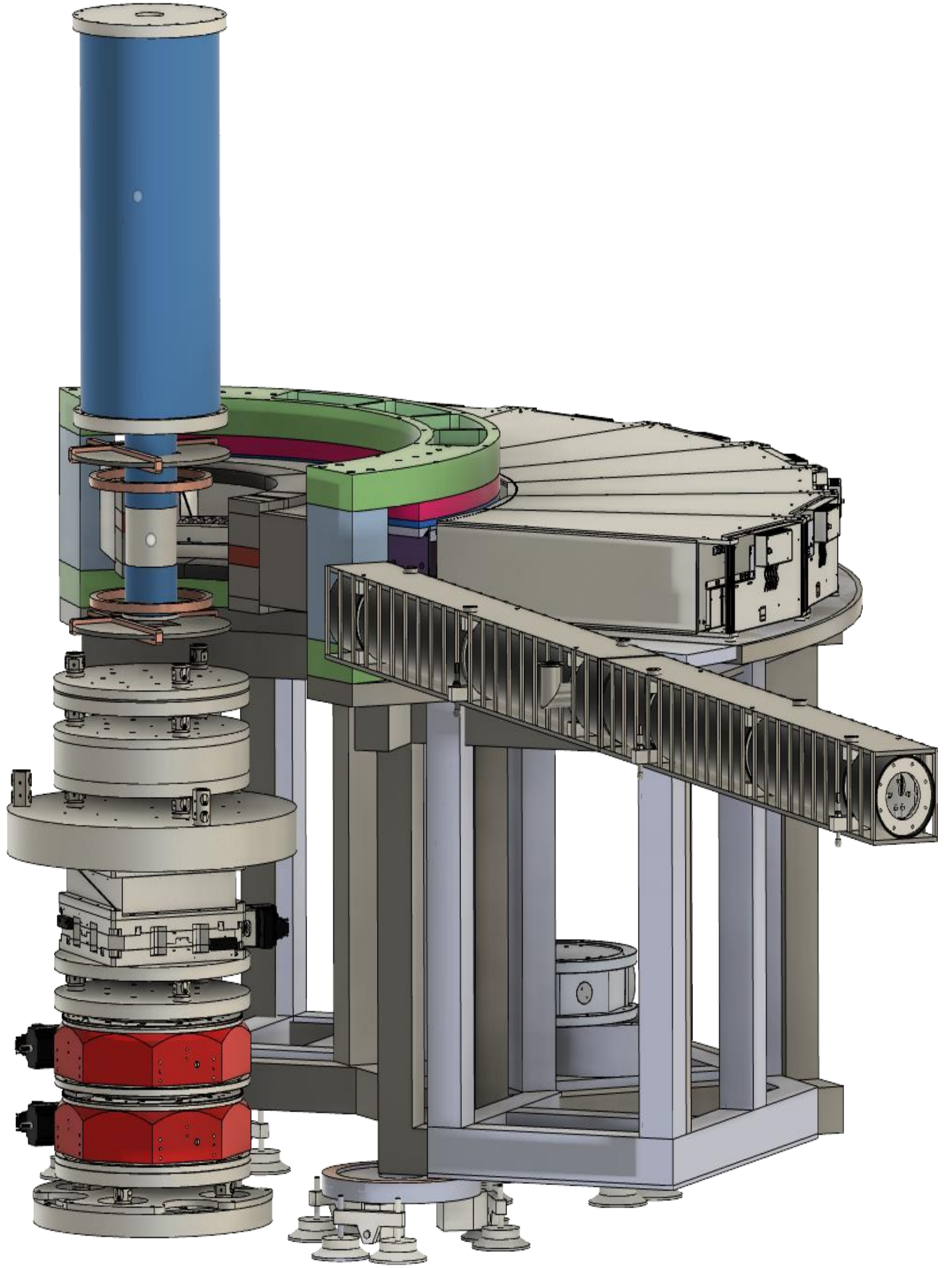


<u>Detector B</u>
120x6° angular coverage
$^{10}$B technology

CDT GmbH
CASCADE Detector Technologies

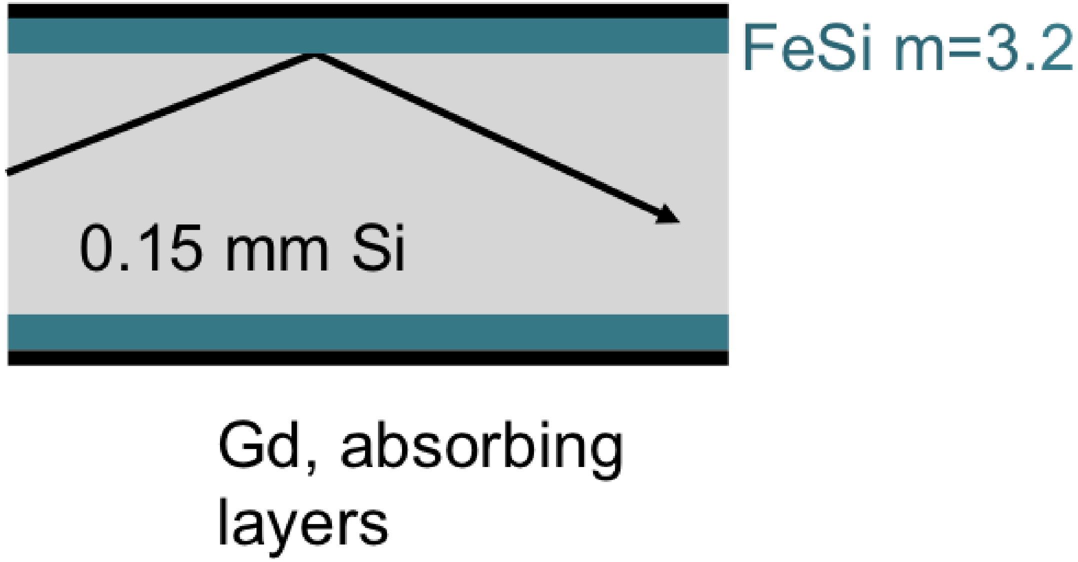
# Requirements

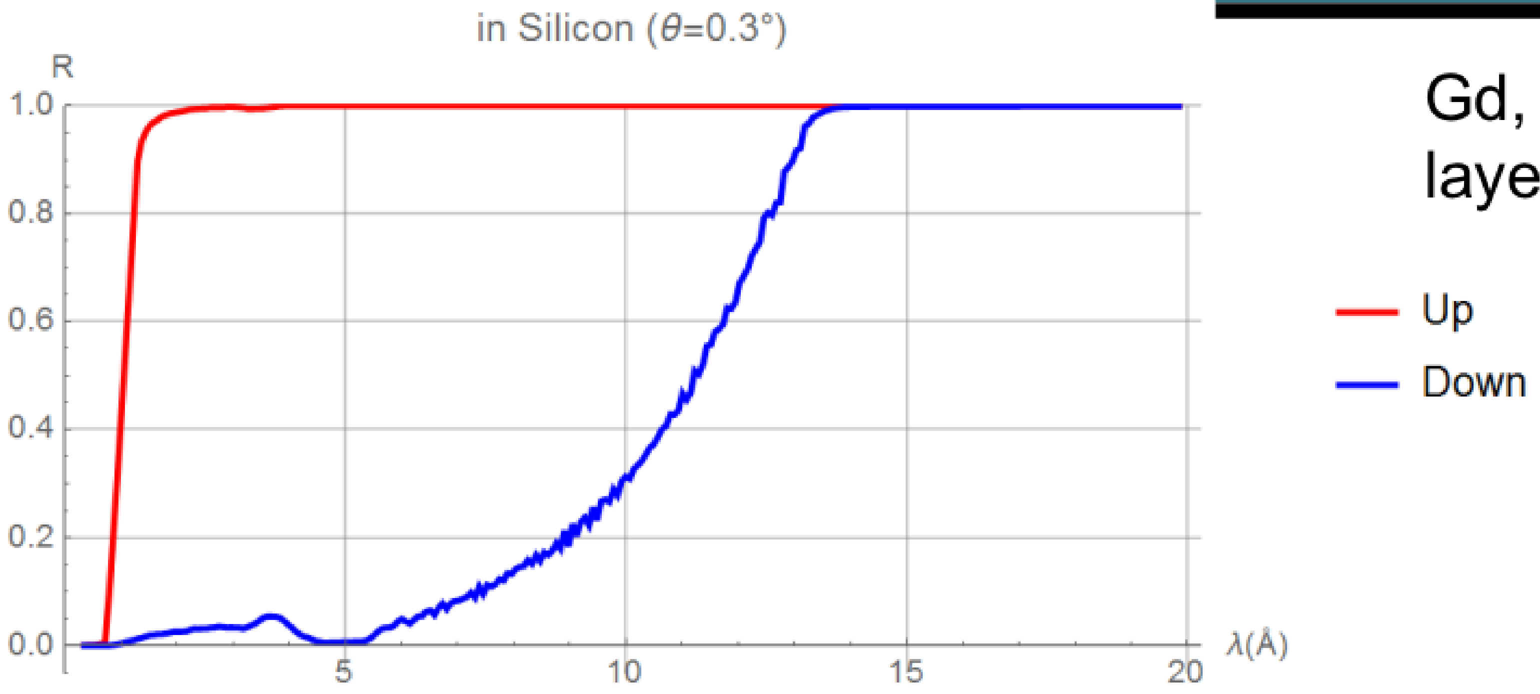
- High polarization, ~99%
- High transmission
- 2 Å – 6 Å
- Angle covered: 120 °
- no blind spots
- Sample size up to 4 mm diameter



# The Solution: Solid State Analyzer

- Neutron travels in Si channel
- Polarizing&absorbing coating on both sides



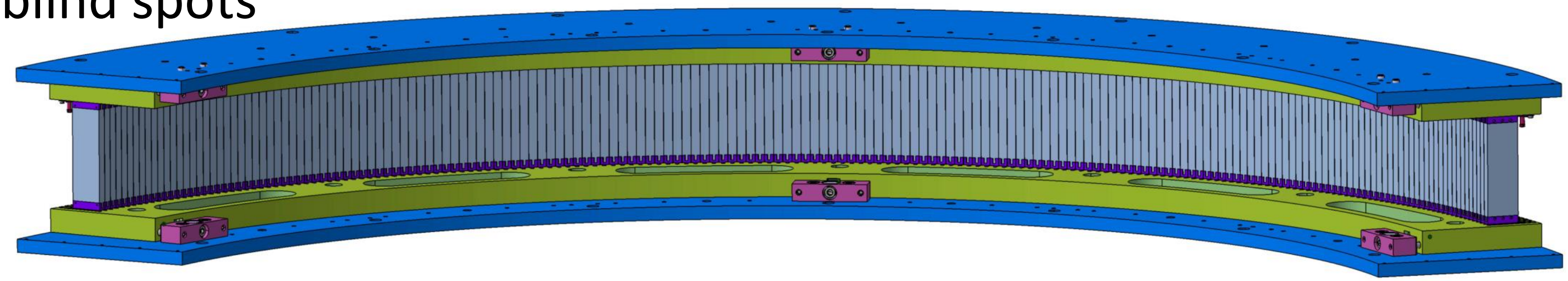




*Reflectivity on Fe/Si in Si, graphics from T. Bigault*

# The Solution: Solid State Analyzer

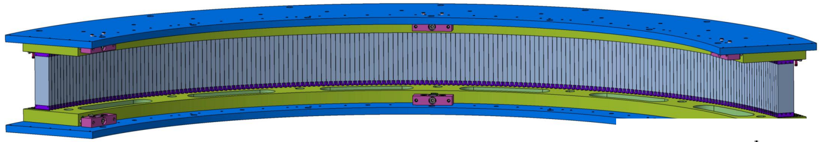
- Neutron travels in Si channel
- Polarizing&absorbing coating on both sides


- Short (37 mm length) & straight (0.5° inclined)
- 0.38 ° acceptance/ channels (0.15mm)
- 12000 substrates
- Glued stacks of ca 1 cm width
- No blind spots

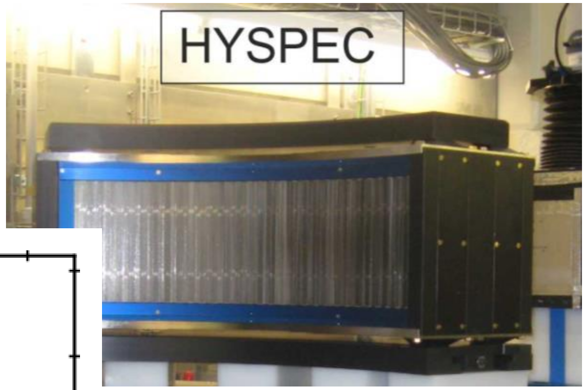


# Benchmark Against state-of-the-art Airgap

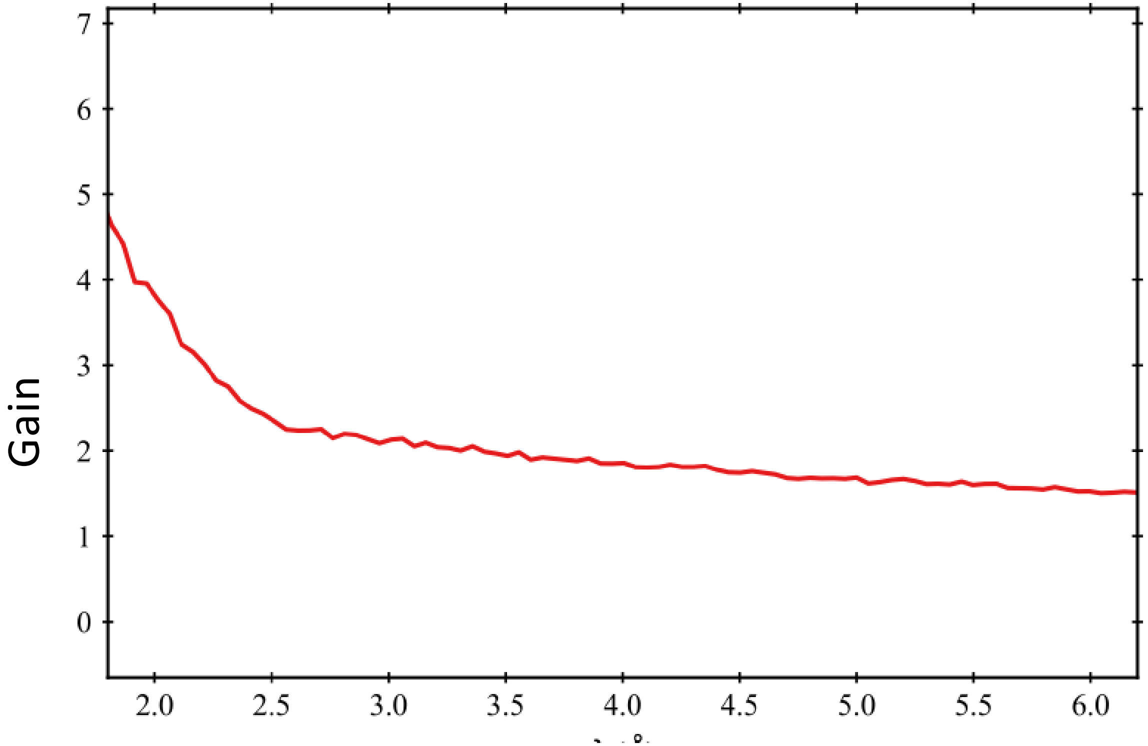
MAGiC



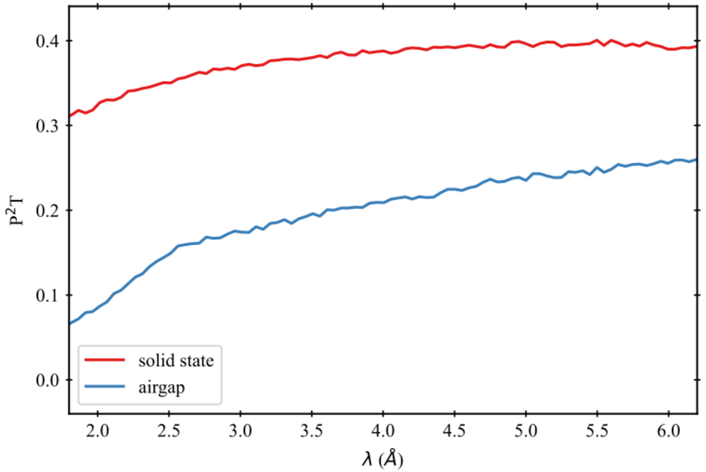
VS.



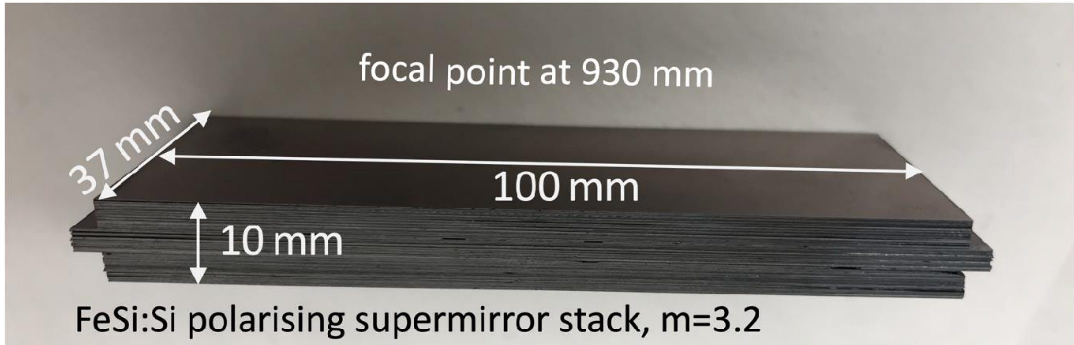

Neutron in Si
Straight channels
Short

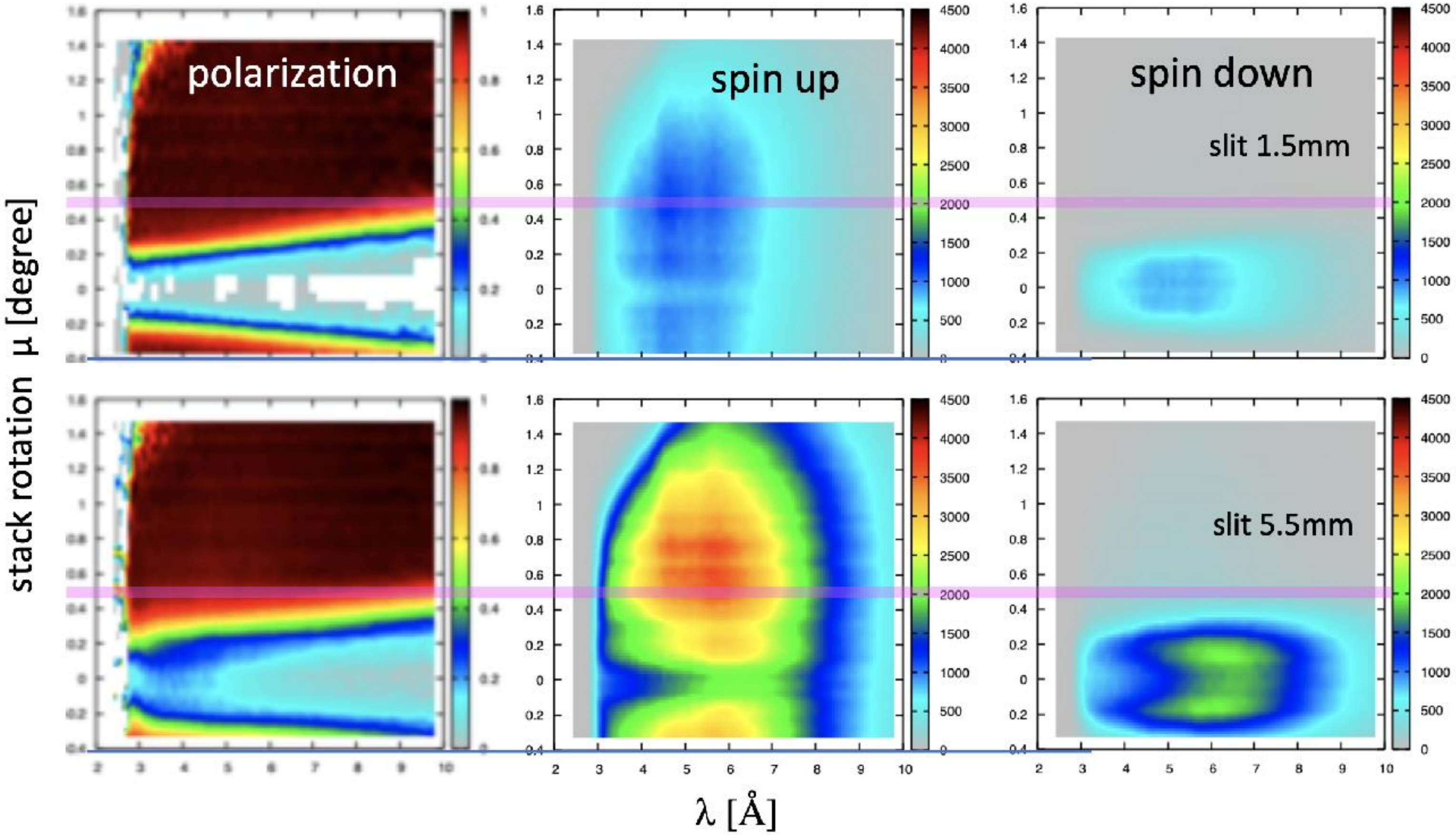



Neutron in air
Bent glass substrates
long

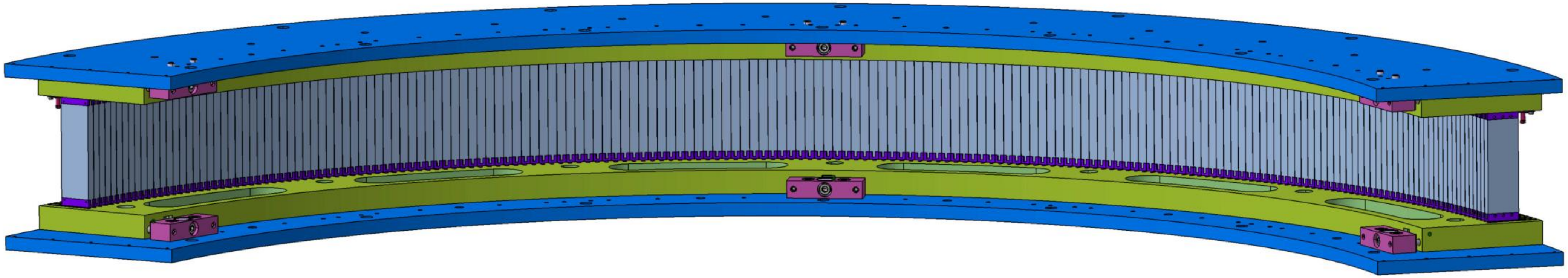


# Prototyping

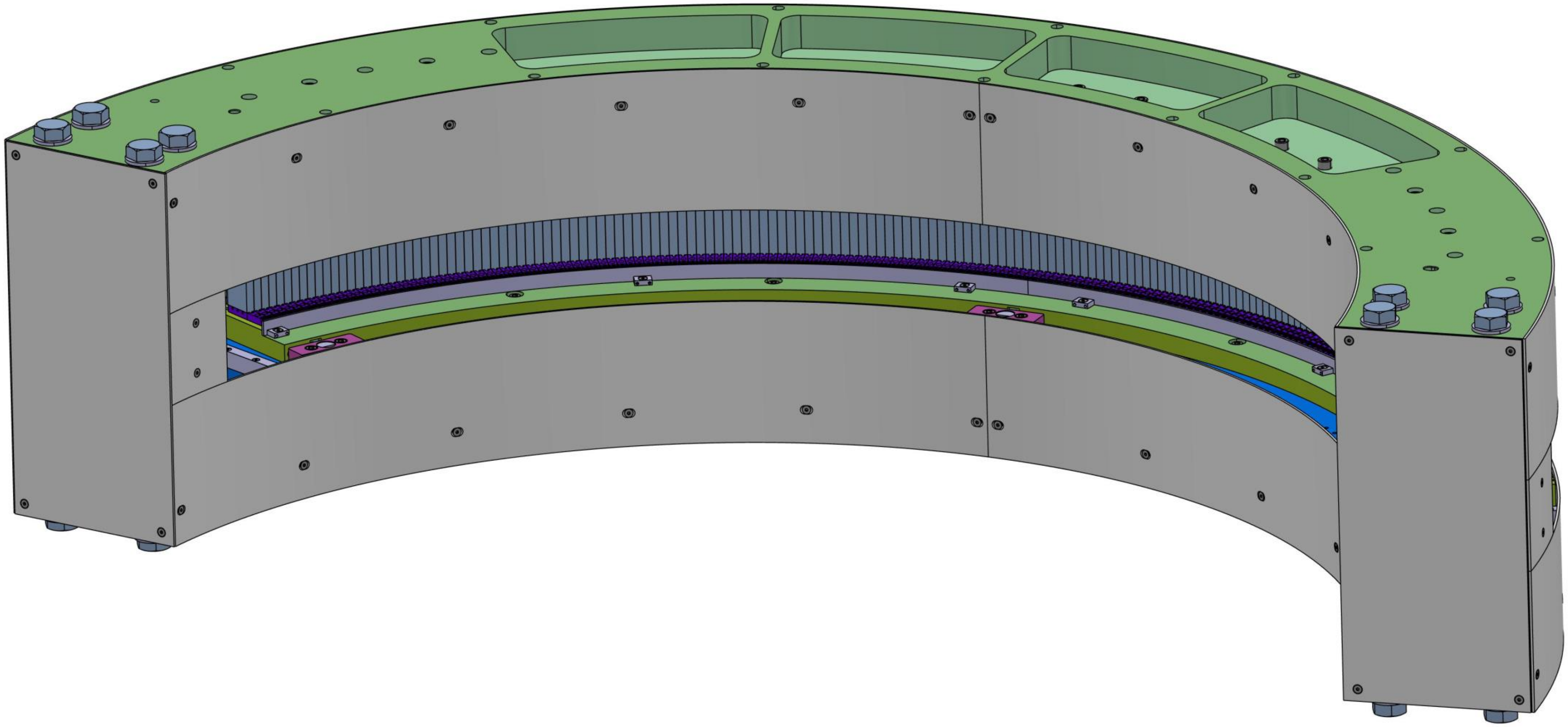


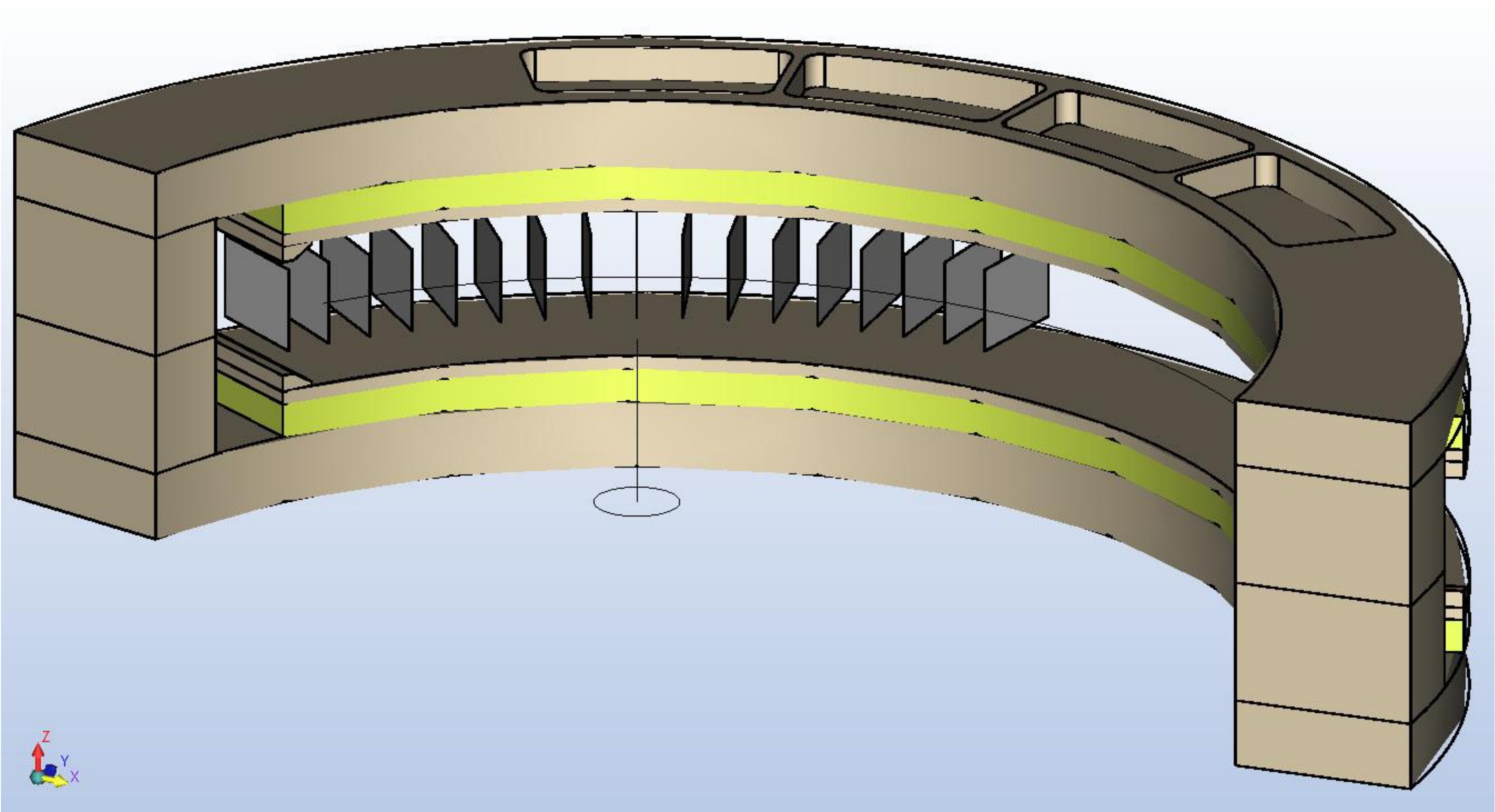

- Test@AMOR
- Excellent polarization over the whole wavelength range
- Good agreement with mcstas simulations
- Validates the gain factors calculated



- 1 segment done
- 188 to be made
- 1.9 m width
- Total of 12000 individual channels
- Production kicked-off in 2023



# A MAGiC Magnetic Field




- Permanent Magnet (6000 individual magnets)
- High magnitude: >0.1 T
- Uniformity <5% in plane

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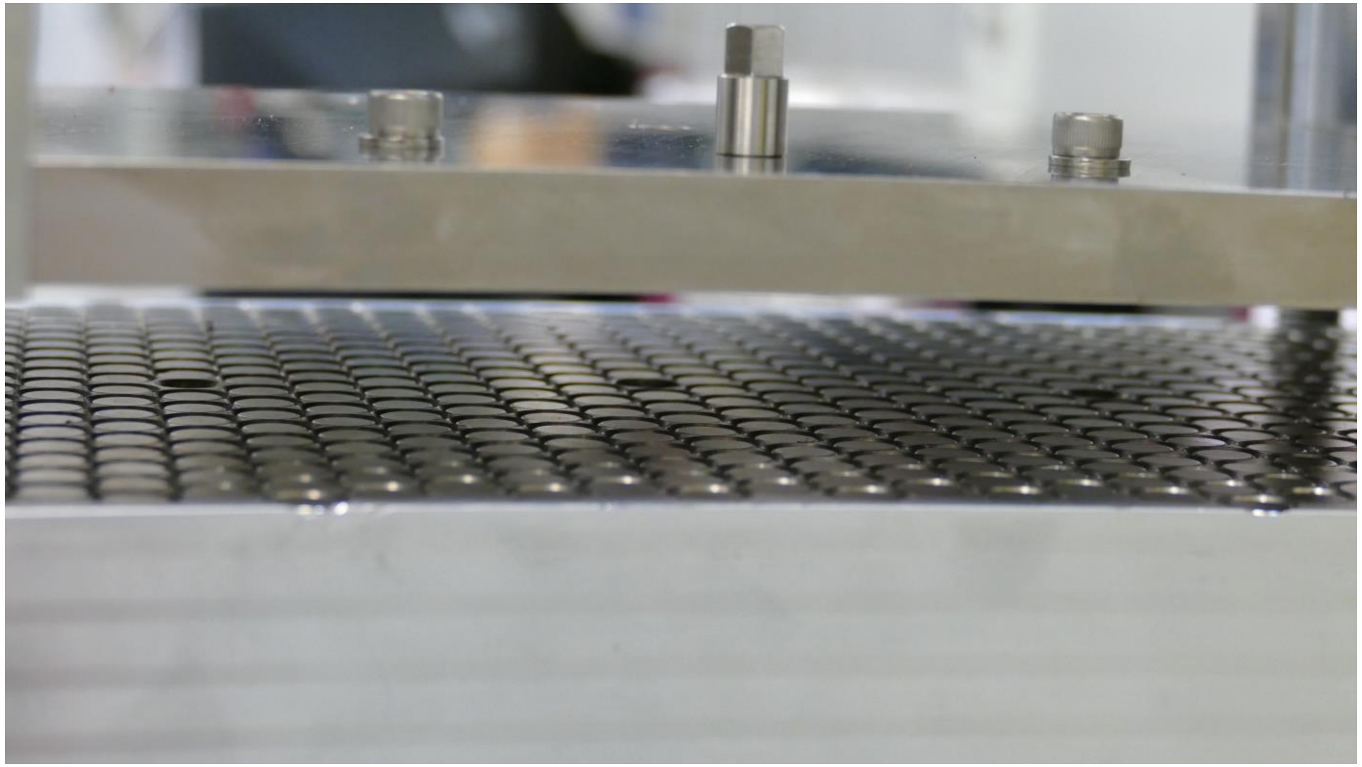
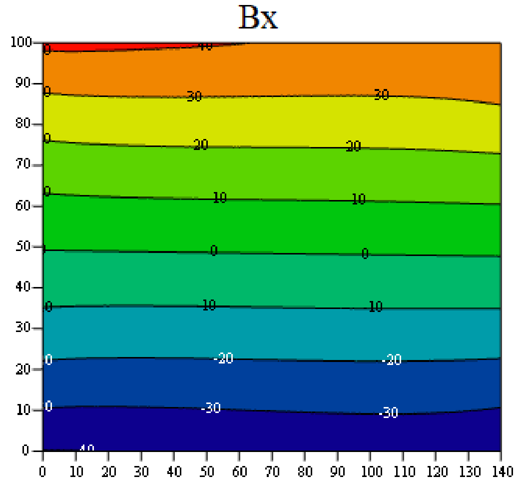
# A MAGiC Magnetic Field: Prototyping



- Permanent Magnet (6000 individual magnets)
- High magnitude: >0.1 T
- Uniformity <5%

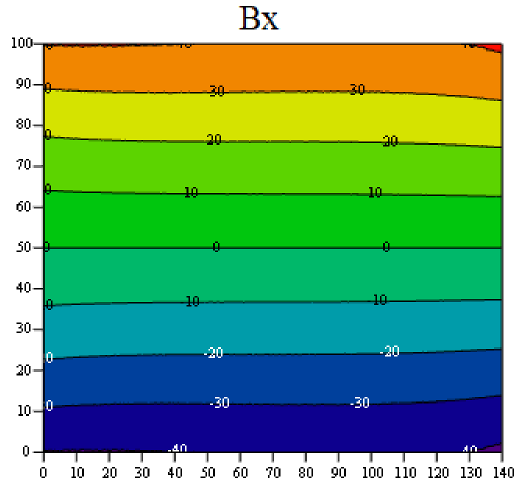
- Prototype agrees very well with simulation

**Measured values**




K-min(Bx) = −42.112 K-max(Bx) = 40.297

**Simulated values**




K-min(BBx) = −41.601 K-max(BBx) = 41.601

# Building The Big B-Field


# Summary

- MAGiC diffractometer will have solid-state analyzer covering 120 degrees at once
- Most suited for thermal-cold beam spectrum at MAGiC
- No blind spots
- Prototyping successful
- Large window frame magnet with highly uniform and strong field

- Production of full analyzer will started this year (2023)
- Delivery of analyzer @ ESS: 2026 –> ready for neutrons! ☺