A Cryogenic Current Comparator for Absolute Ion Beam Current Measurement

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- Working principle of CCC
- Superconducting magnetic shielding
- Experimental determination of the attenuation factor
- Status of the CCC project

Measurement of low ion beam current in FAIR

FAIR: Production of unprecedented **high** intensity, **high** brightness beams of rare ions and antiprotons

Slow extraction channels - **online measurement** of very **low** ion current

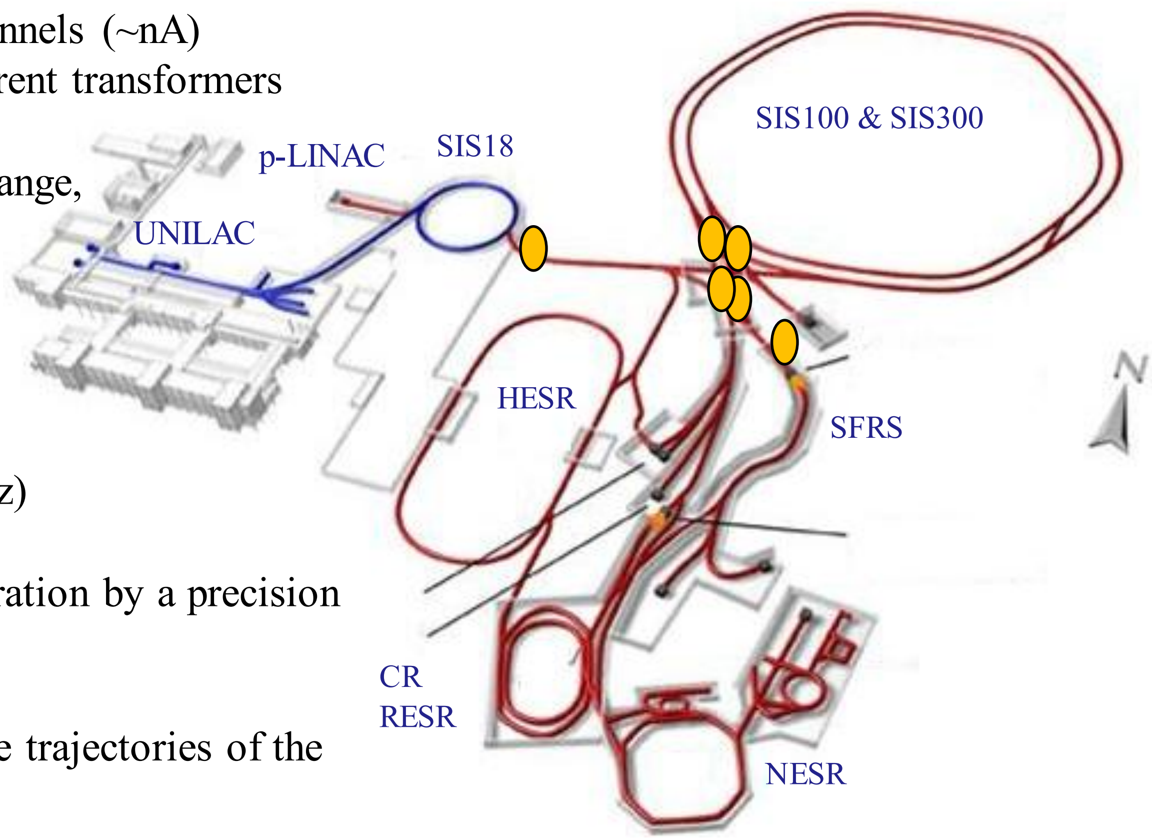
Typical currents in the slow extraction channels (~nA)

- Detection threshold of the dc current transformers (~µA)

Beam current measurements down to nA range,

Cryogenic Current Comparator

- Non-intercepting
- Highest resolution (< 100pA/√Hz)
- Absolute value of current- Calibration by a precision current source
- Independent of ion energy and the trajectories of the beam



Working principle of CCC

Superconducting Pick up coil + High permeability ring core

- Detects the azimuthal component of the beam's magnetic field

SQUID

- Measure extremely small variation in the magnetic flux

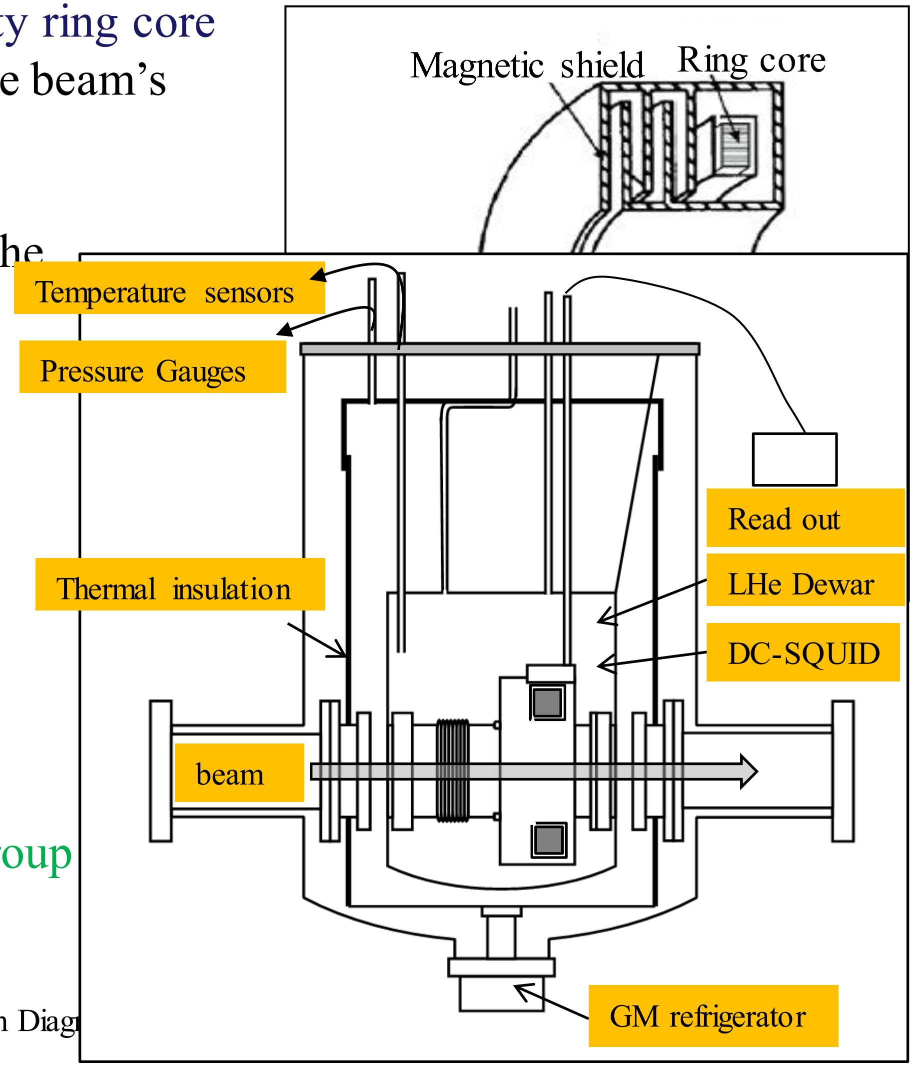
Read out electronics

External noise fields:

- Horizontal component of Earth's magnetic field » 50µT
- Field produced by a 100 nA beam at 10 cm from the beam tube » 0.2 pT !

Resolution of the CCC

Sensitivity of the SQUID system* } Jena group
High permeability ring core** } Jena group
Super conducting Magnetic shielding

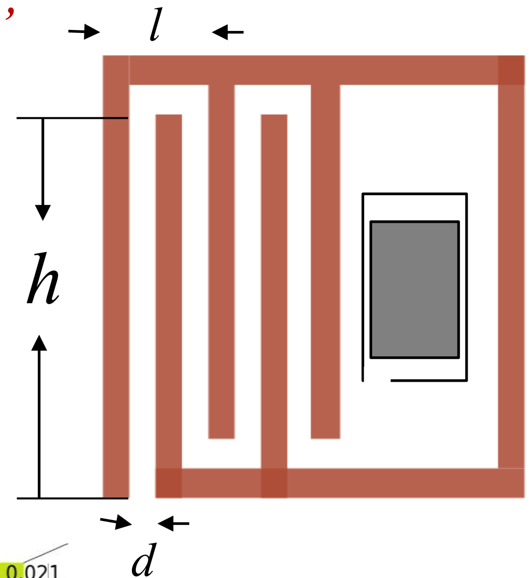


* W. Vodel, FSU Jena, Workshop on „Low Current, Low Energy Beam Diag

** Steppke, Geithner, Vodel et al., IEEE Transactions on Appl. Supercond., Vol. 19 No. 3, June 2009, p. 768)

Superconducting Magnetic Shielding

Attenuation as a function of *length 'l'*, *gap width 'd'* and *height 'h'*



Field attenuation through a superconducting coaxial cylinder

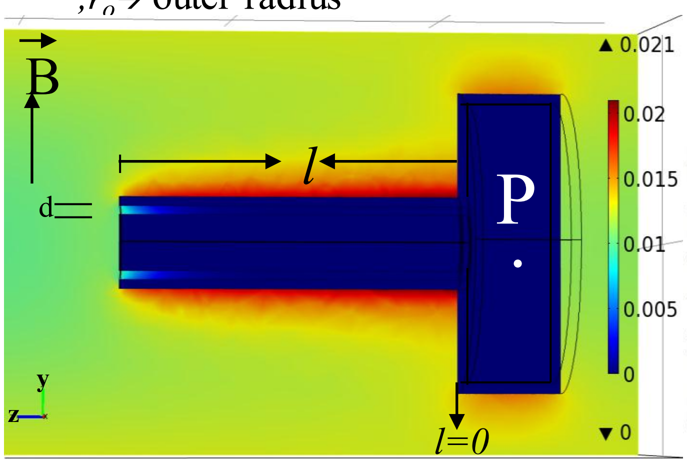
Longitudinal components are strongly attenuated*.

The magnetic scalar potential,

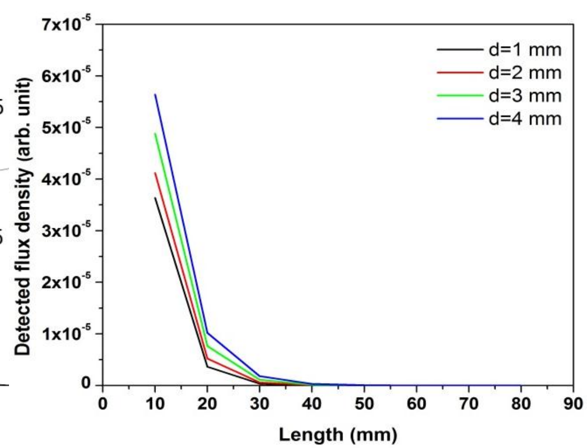
$$V(r,\varphi,z)=\sum_{m=1}^{\infty} V_m(r,\varphi)e^{-(z/r_0)}$$, $r_0 \rightarrow$ outer radius

For small gap width values,

$$V(r,\varphi,z)=V_1(r,\varphi)\, e^{-(z/r_0)}$$



Colour legend : Magnetic flux density (T)



* K.Grohmann D. Hechtfischer. Magnetic shielding by superconducting simple and coaxial cylinders: a comparison. Cryogenics, p.579, Oct. 1977.

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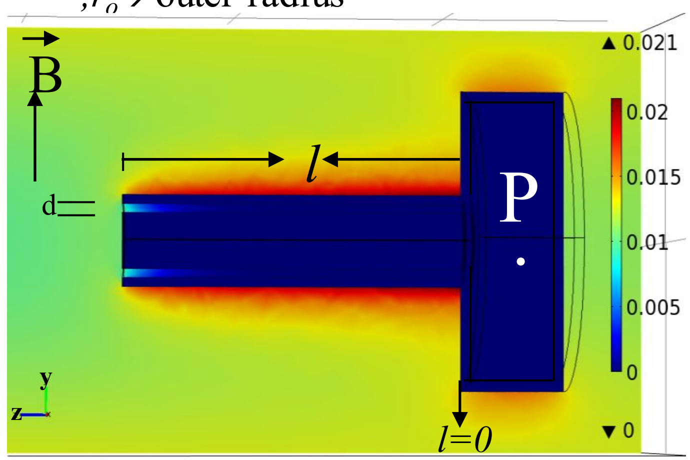

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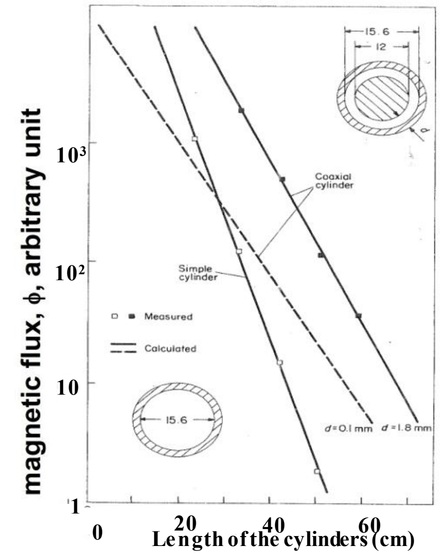

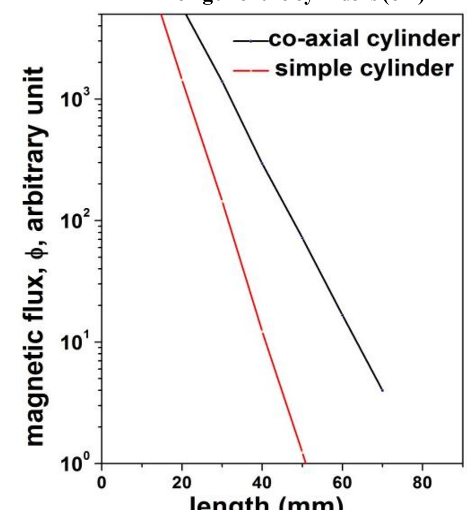

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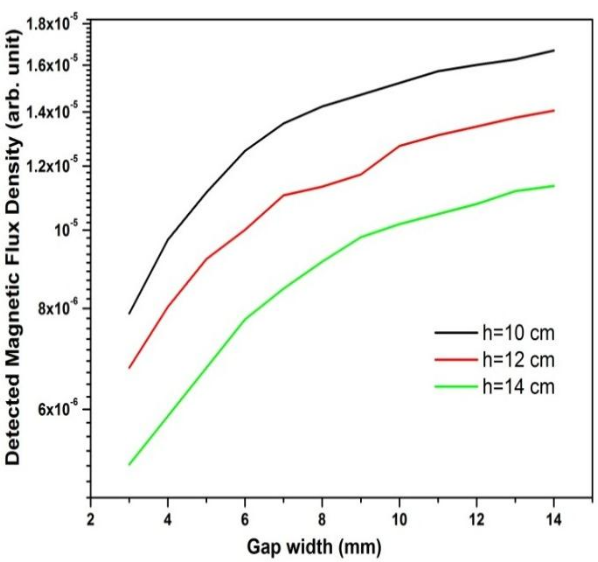
Superconducting Magnetic Shielding

Field attenuation versus height and gap width

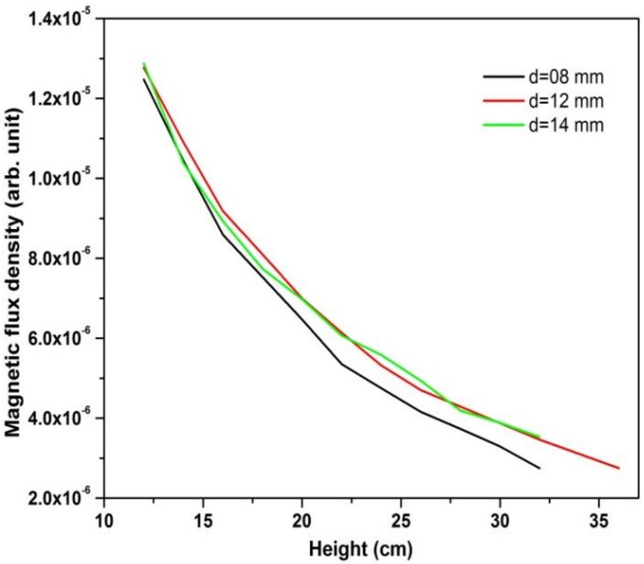
Field strength measured at the point P

- An asymptotic behavior in the field strength as the gap width increases
- Exponential decay as *h* increases

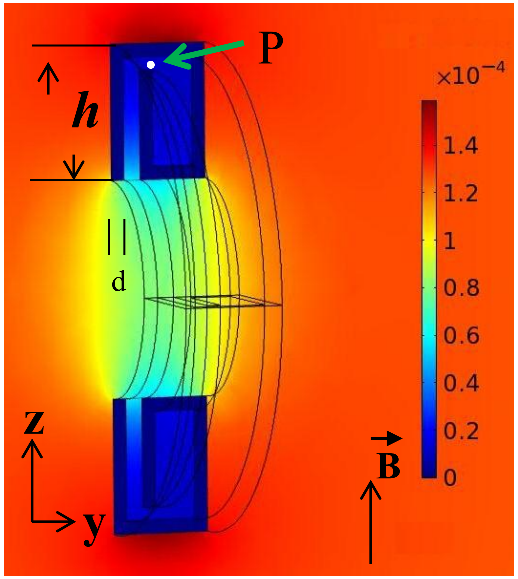
(Further investigations on the exponential fit has to be carried out)



Variation of the field strength with d



Variation of the field strength with h



Colour legend : Magnetic flux density (T)

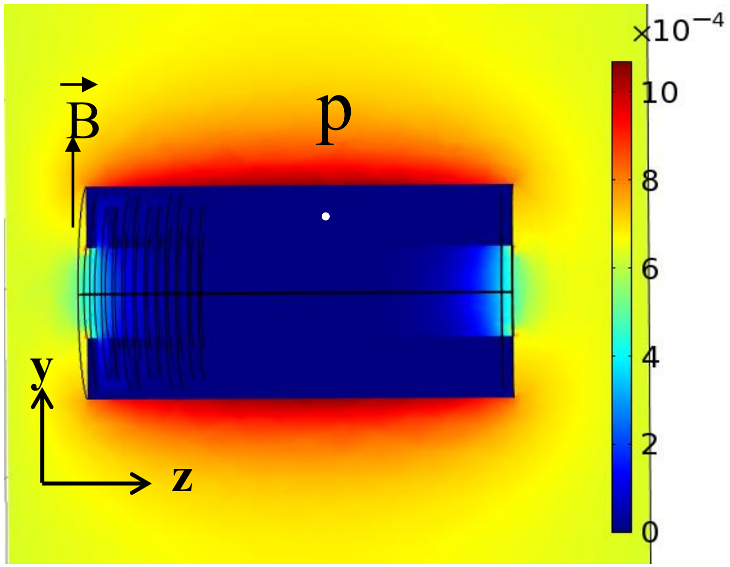
Applied field: 1.256×10^{-4} T

Attenuation versus number of meanders

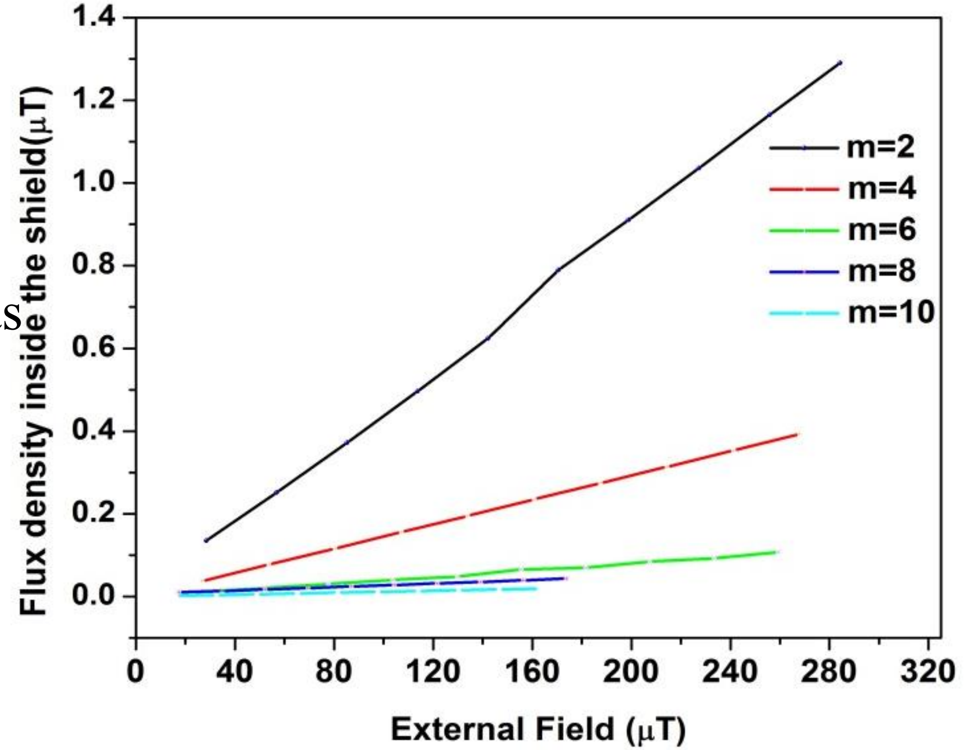
Attenuation factor,

$$A = 20 \log(B_{out}/B_{in})$$

Exponential decay of the field inside as the number of meanders are increased



Magnetic field distribution inside the shield geometry



Number of meanders, (m)	Attenuation factor A (dB)
2	47
4	57
6	68
8	74
10	79

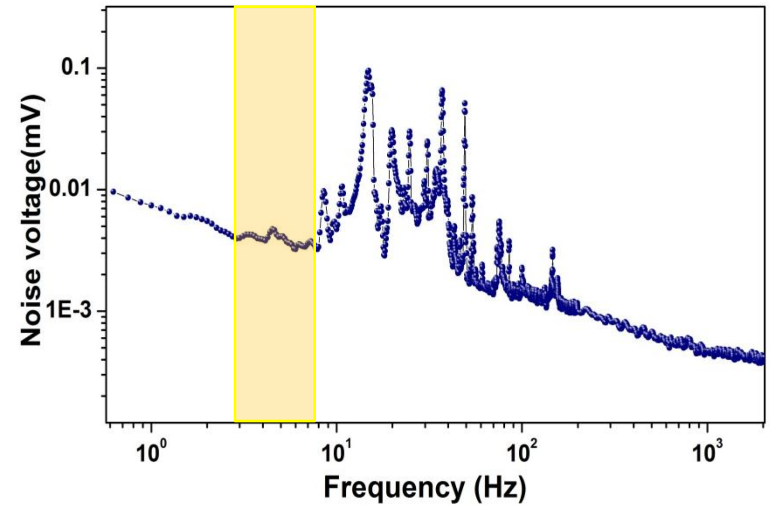
Experimental determination of attenuation factor

CCC developed for the dark current measurement in the TESLA cavities of DESY accelerator facility

SQUID >> 1 Φ_0 → 10V

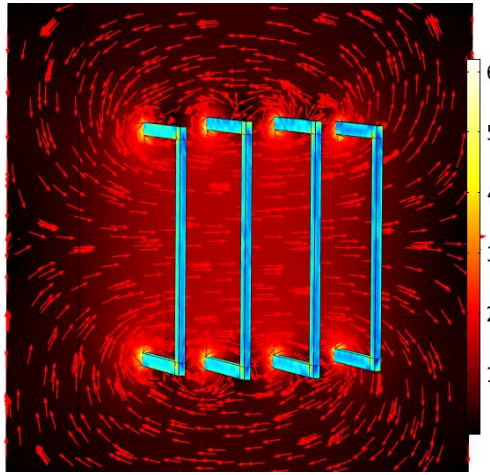
1 Φ_0 →183.3nA

Noise limited current sensitivity of the CCC → 52 pA/√Hz

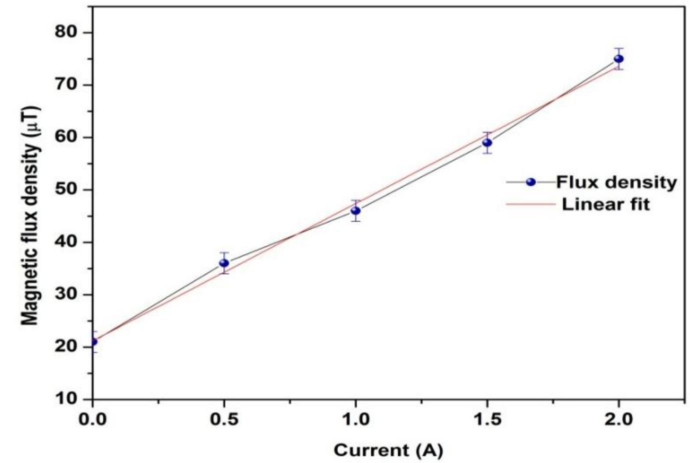


Helmholtz coil :

Uniform magnetic field of 20µT/A perpendicular to the axis of the shield and 40 µT/A parallel to the axis of the shield



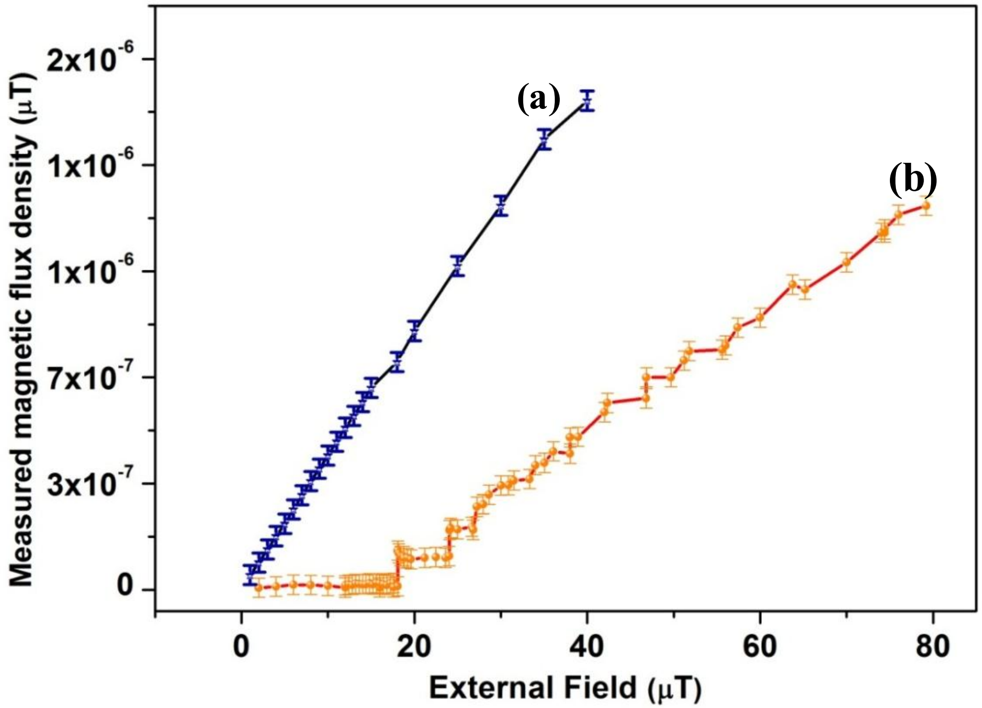
Field produced by a Helmholtz coil



Field measured by Hall probe

Experimental determination of attenuation factor

For the shield under investigation consists of,
Gap width between two consecutive meander plates = 0.5 mm
Number of meanders = 14
Outer radius=103.25mm
Inner radius = 76.8mm



(a): A slope of 3.7×10^{-8} gives an attenuation factor for transverse magnetic field:
A =148dB

(b): Longitudinal Magnetic field
Attenuation factor, A ~176dB

Transverse field components are dominant inside the shield

Status report on the CCC project

- Certain components of the CCC has been optimized for better performance compared to the previous CCC installation in GSI
- Re-commissioning of a previously installed CCC unit is under development
- Design of cryostat with optimized parameters

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A. Peters, HIT, Heidelberg

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Thank you for your attention