Evidence of reduced magnetic sensitivities in low beta SRF cavities

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OUTLINE

- *Definition of magnetic sensitivity*
- *How to measure magnetic sensitivity*
- *Measurements and observations :*
  - *On low-beta cavities at IJCLab*
  - *On samples*
- *Geometrical dependence : hypothesis and model*
- *Comparison between model predictions and measurements :*
  - *On elliptical cavities (AMR + T-MAP) at HZB*
  - *On low beta cavities*
- *Conclusion*

Magnetic sensitivity

- *Surface resistance of a superconductor in radio-frequency regim*

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$$0 < \eta_{mag} < 1$$

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- *Magnetic sensitivity :* $S_{mag} = \frac{R_n(f,T)}{2 \cdot H_{c2}(T)}$,

Normal resistance

How to measure magnetic sensitivity

- *Proceed with slow cool down to ensure μ ≈ 1*

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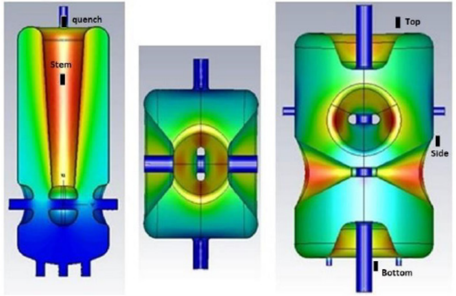
→ *Global sensitivity depends on geometry (RF field distribution)*

- *3 types of cavities studied : Spiral2 Quarter-Wave resonator (QWR), MYRRHA Single Spoke resonator (SSR), ESS Double Spoke resonator (DSR).*



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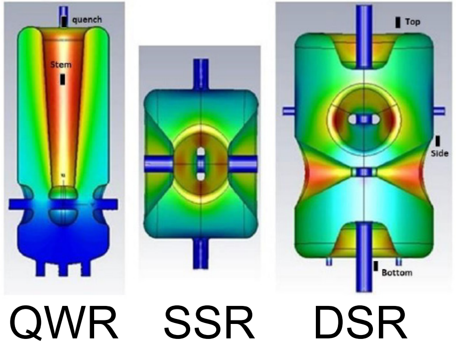

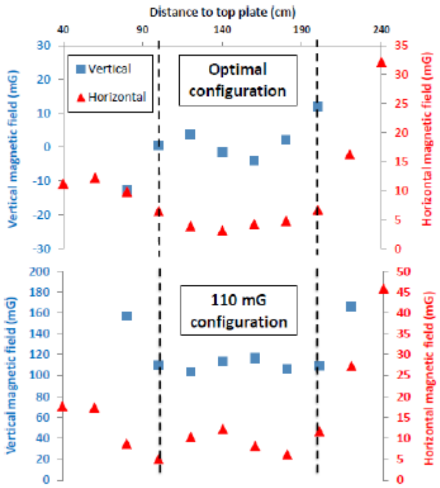

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QWR (88 MHz)	*Vertical*	**0.006**	*0.08*	**93**
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SSR (352 MHz)	*Vertical*	*0.04*	*0.12*	**64**
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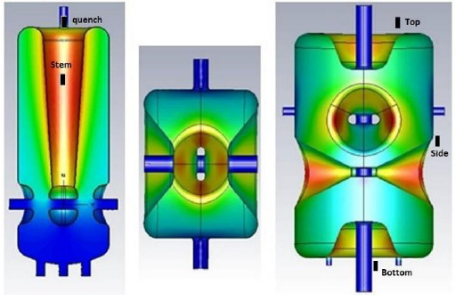

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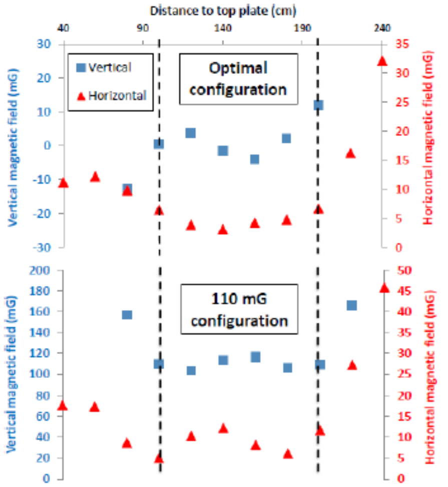

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- *Main conclusions :*
  - *Measured sensitivities are systematically lower than expected*
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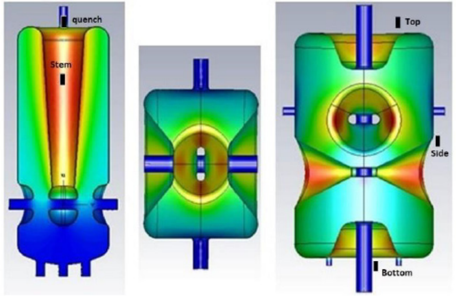

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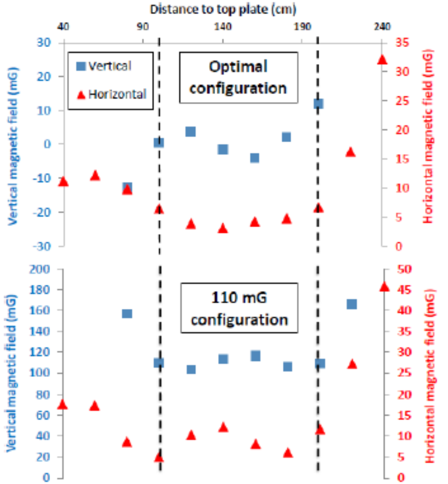

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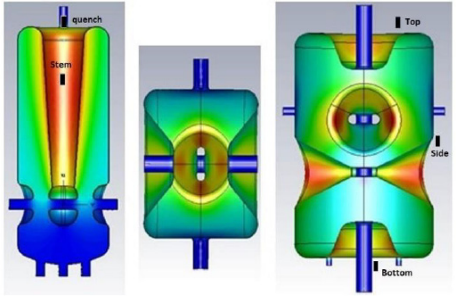

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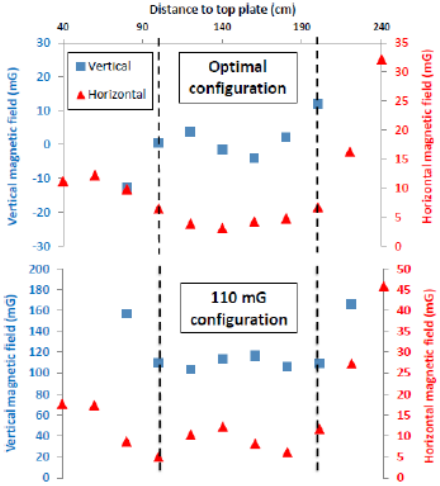

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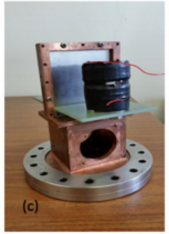
→ Preferential trapping or parrallel trapped flux induces less dissipation ?

Measurements on samples

- *In the literature, several sample studies have been performed :*
  - *<u>On Niobium</u> : R. Eichhorn, J. Hoke, and Z. Mayle, On Magnetic Flux Trapping in Superconductors, in 28th International Linear Accelerator Conference (2017).*



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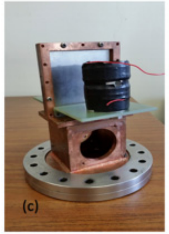

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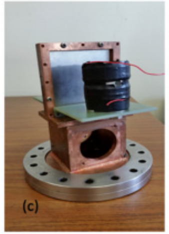

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→ Sample studies tend to suggest preferential trapping of perpendicular field

Geometrical dependence : hypothesis and model

- *Samples measurements tend to show that trapped flux is preferentially normal to the surface*
- *What could explain preferential trapping ?*
  - *Surface currents are constrained by geometry to flow parallel to the surface*
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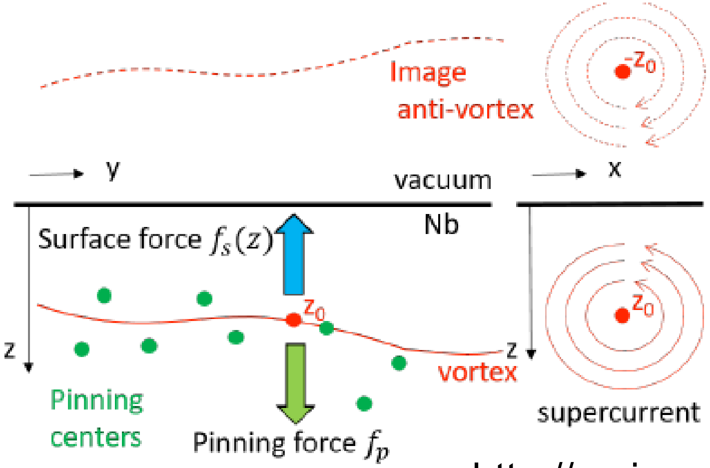
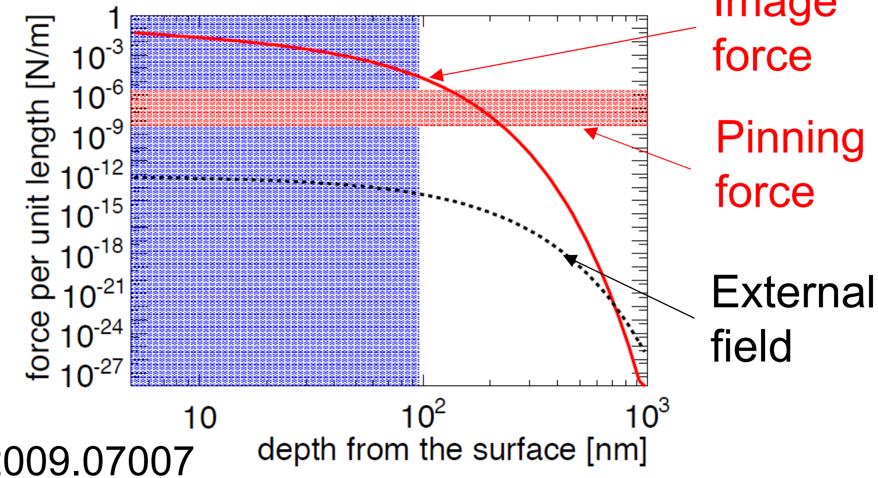
    → *parallel flux can't be trapped close to the surface (< 200 nm)*





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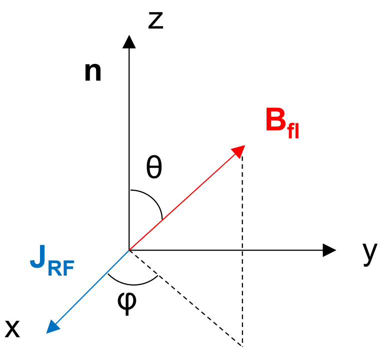

Homogeneous trapping

$$f_L = J_{RF} \times B_{fl}$$

$$= \begin{pmatrix} J_0 \\ 0 \\ 0 \end{pmatrix} \times \begin{pmatrix} \phi_0 \cos\varphi \sin\theta \\ \phi_0 \sin\varphi \sin\theta \\ \phi_0 \cos\theta \end{pmatrix} = \begin{pmatrix} 0 \\ -J_0\phi_0 \cos\theta \\ J_0\phi_0 \sin\varphi \sin\theta \end{pmatrix}$$

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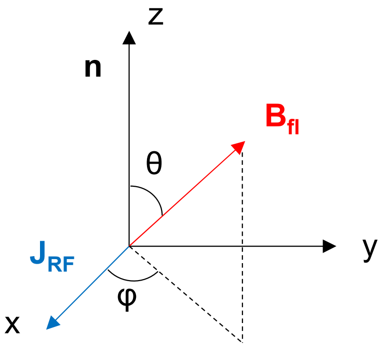

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Preferential normal trapping

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ArxiV : http://arxiv.org/abs/2009.07007

Geometrical dependence : hypothesis and model

- *Convolution of geometrical effect and local sensitivity*

  - *Determine $H_\perp$ everywhere on the geometry :*

$$H_\perp = H_{res} \cdot \cos(\theta)$$

  - *Evaluate local resistance R_{mag}*

$$R_{mag} = R_n \cdot \frac{H_\perp}{2 \cdot H_{c2}}$$

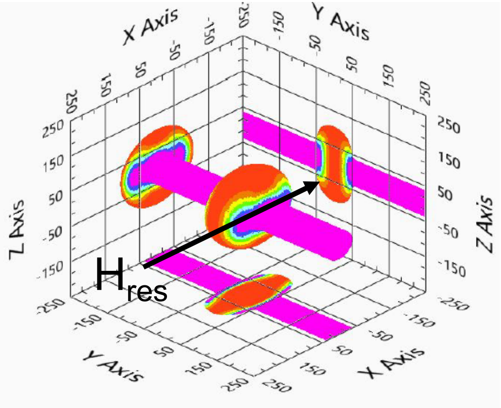
- *Calculation of global sensitivity : R_{mag} impacts Q_0 if RF currents*

  - *Integration of local resistance*

$$S_{mag} = \frac{\iint_S R_{mag} \cdot H_{RF}^2 \cdot dS}{H_{res} \cdot \iint_S H_{RF}^2 \cdot dS}$$

- *Case of elliptical cavity (Horizontal testing)*
- *Transverse residual field*

Homogeneous trapping



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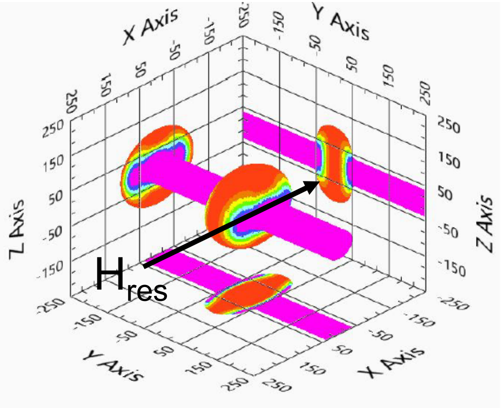
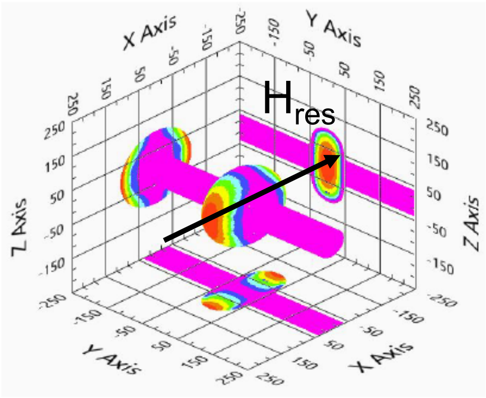


Model prediction



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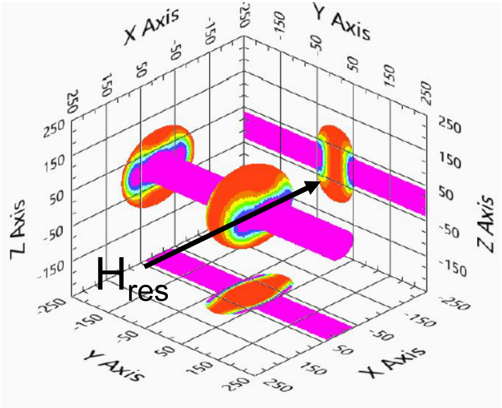

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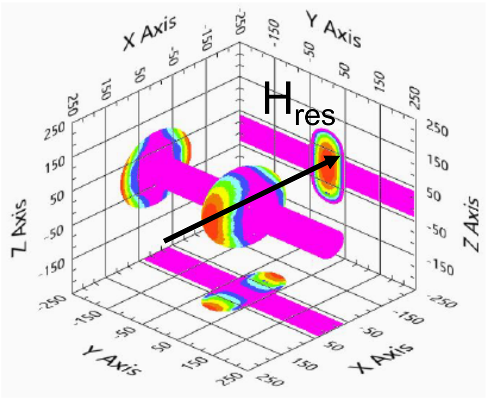
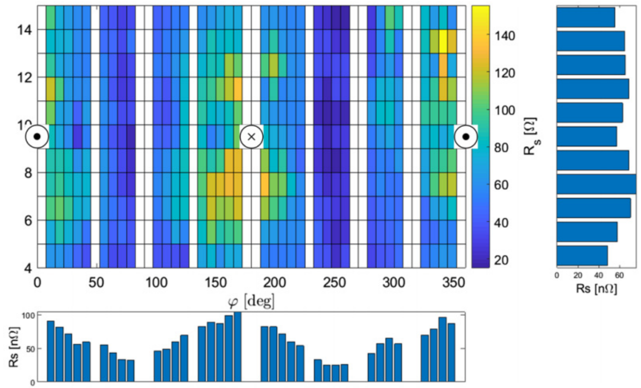


T-MAP data (Kramer, HZB)



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Comparison between model predictions and experimental data

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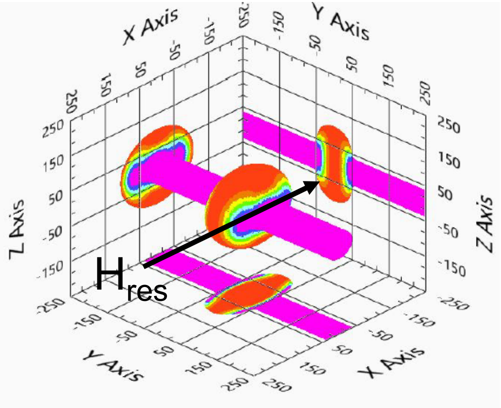

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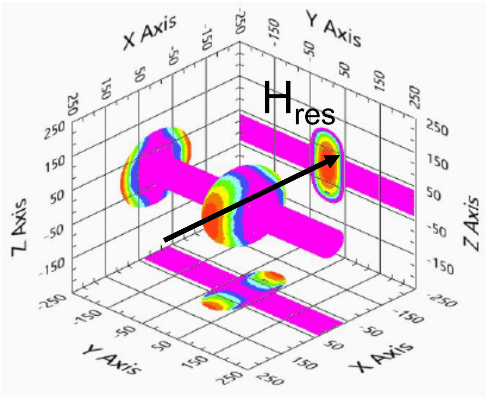

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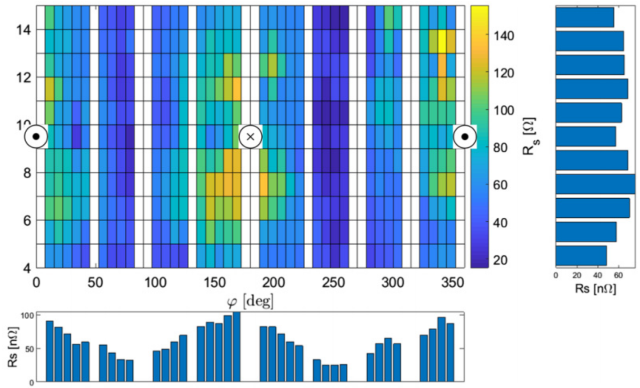

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➔ *T-MAP data in agreement with model prediction*

Comparison between model predictions and experimental data

- *Case of low beta cavities (QWR)*

Type of cavity	Hres orientation	Measured sensitivity (nΩ/mG)	Predicted sensitivity (nΩ/mG)	Relative error (%)
QWR (88 MHz)	*Vertical*	*0.006*	*0.011*	*45*
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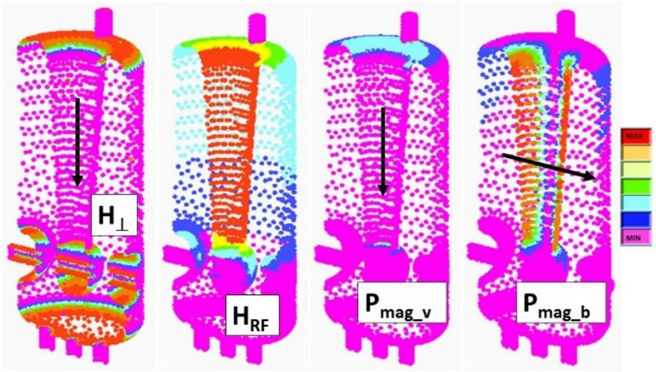

➔ *Good agreement between predicted and measured sensitivity*

Conclusion

- *Measurements of magnetic sensitivity have been performed at IJCLab unveiling geometrical effect*
  - *Sensitivities are systematically lower than expected for several type of cavities*
  - *Vertical sensitivity is significantly lower than transverse sensitivity*
- *Dedicated sample studies highlighted preferential trapping of perpendicular field*
- *Image force on a parallel vortex to the surface surpasses pinning forces within several London penetration depth (< 200 nm)*
- *A numerical model has been build to take into account :*
  - *Preferential trapping*
  - *Integration of local resistance weighted by RF currents : Higher resistance measured if power is dissipated!*
- *Predicted sensitivities are in agreement with experimental data on elliptical cavities*
- *Predicted sensitivities are in agreement with experimental data on low beta cavities*

THANK YOU FOR YOUR ATTENTION