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How is trapped flux affected by the cavity geometry

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Magnetic sensitivity

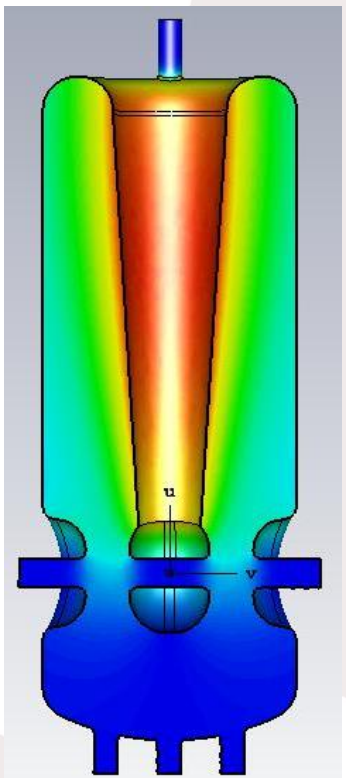
Experimental vs theoretical

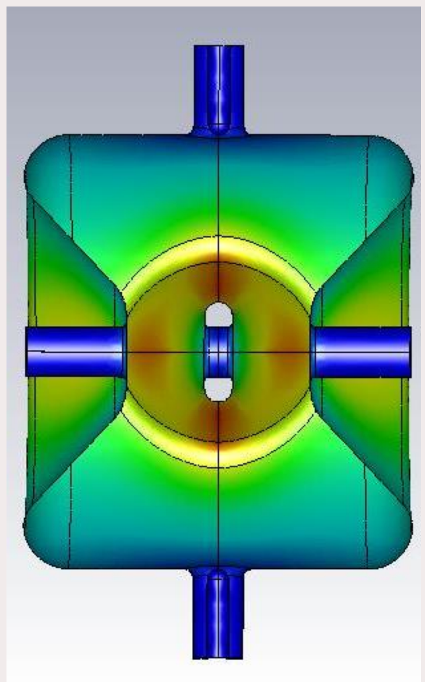
SPIRAL2 QWR
- ✓ F_0 = 88 MHz
- ✓ T = 4.2K
- ✓ Sv = 0.006 nΩ/mG
- ✓ St = 0.05 nΩ/mG
- ✓ $S_{théo}$ = 0.08 nΩ/mG

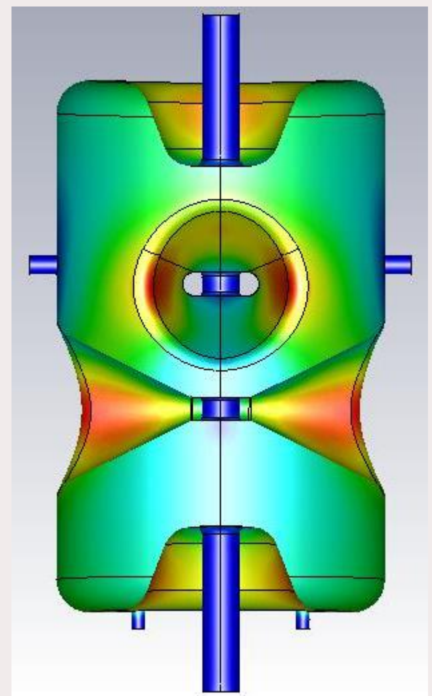
MYRRHA Spoke
- ✓ F_0 = 352 MHz
- ✓ T = 2K
- ✓ Sv = 0.04 nΩ/mG
- ✓ St = X
- ✓ $S_{théo}$ = 0.12 nΩ/mG

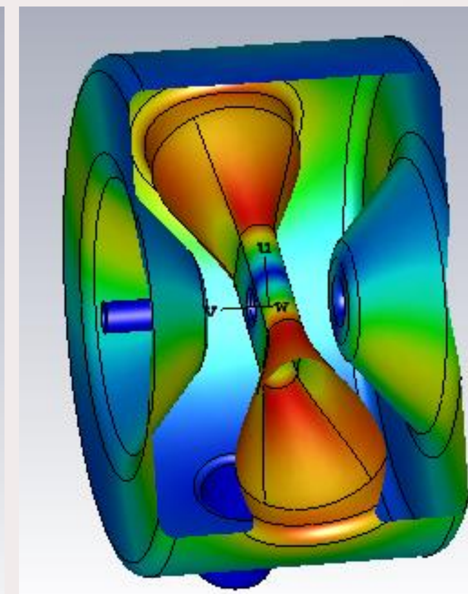
ESS Spoke
- ✓ F_0 = 352 MHz
- ✓ T = 2K
- ✓ Sv = 0.06 nΩ/mG
- ✓ St = X
- ✓ $S_{théo}$ = 0.12 nΩ/mG

SSR1 Spoke
- ✓ F_0 = 325 MHz
- ✓ T = 2K
- ✓ Sv = X
- ✓ St = 0.05 nΩ/mG
- ✓ $S_{théo}$ = 0.11 nΩ/mG







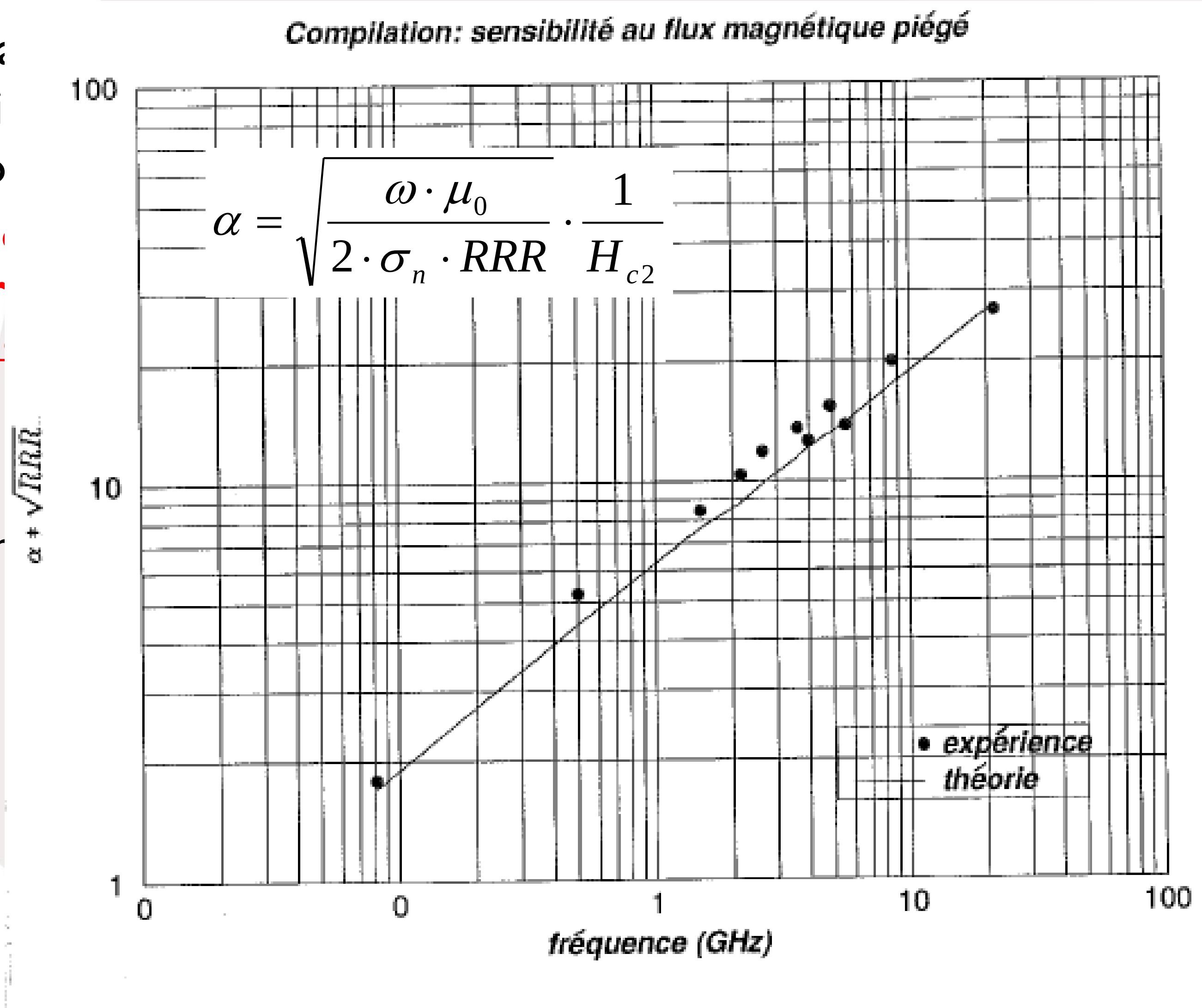


Magnetic sensitivity is way less than theoretical value and depend on field direction!

How is flux trapped ?

In the literature

- “Angul… …tors : which i… …ci. Techno…
  - **“Du… …tion Mirr… …fields and…**
- “Etude… fréquer… …y.



$$\alpha = \sqrt{\frac{\omega \cdot \mu_0}{2 \cdot \sigma_n \cdot RRR} \cdot \frac{1}{H_{c2}}}$$

Figure 38 $\alpha * \sqrt{RRR}$ versus la fréquence

How to apply corrections ?

Geometrical effect

- The calculation of the real sensitivity especially for complex geometries can't be analytic!
- How to calculate magnetic sensitivity of a structure with simulation code :
  - Evaluate the surface normal component and the additional resistance

$$R_{mag} = \sqrt{\frac{\omega \cdot \mu_0}{2 \cdot \sigma_n \cdot RRR}} \cdot \frac{H_{\perp}}{H_{c2}}$$

⇒ This gives the amount of trapped flux… but not the sensitivity!

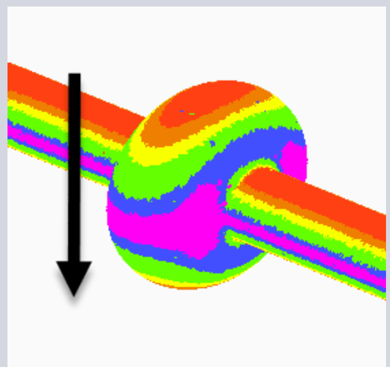
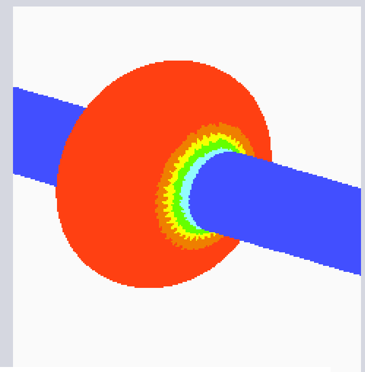
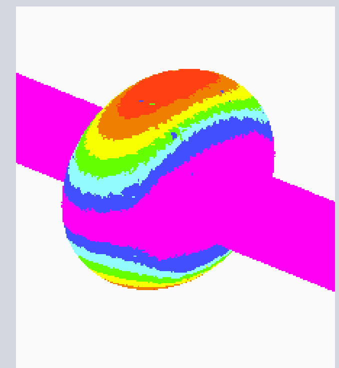
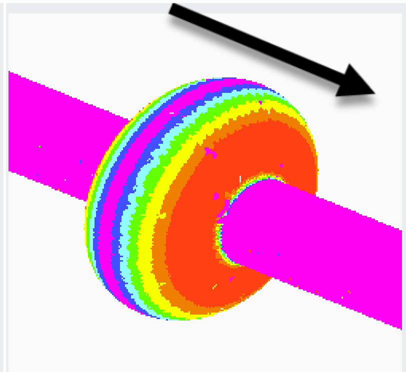
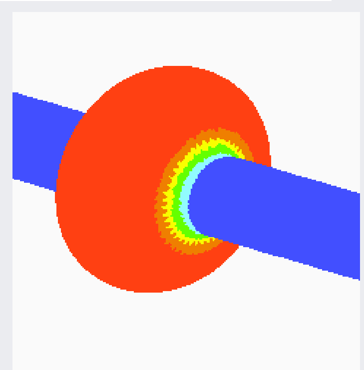
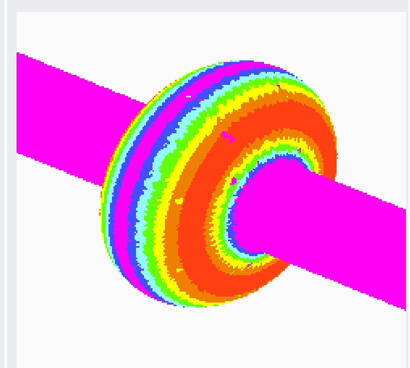
⇒ Trapped flux has to be subject to RF magnetic field

  - Evaluate local power dissipations and integrate all over the geometry

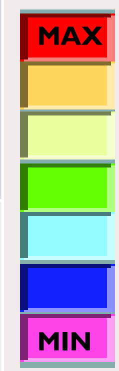
$$S_{mag} = \frac{\iint_S R_{mag} \cdot H_{RF}^2 \cdot dS}{B_{res} \cdot \iint_S H_{RF}^2 \cdot dS}$$

ANALYSIS

TESLA 1.3 GHz

Theoretical : 0.22 nΩ/mG @2K	Trapped flux regions	RF surface currents	Sensitive regions to magnetic field
Vertical field			 0.092 nΩ/mG
Horizontal field (beam axis)			 0.137 nΩ/mG

Are there some data showing this difference of sensitivity on 1.3 GHz cavities ?



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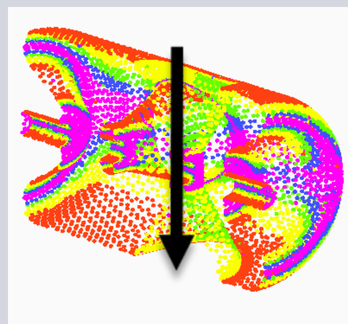
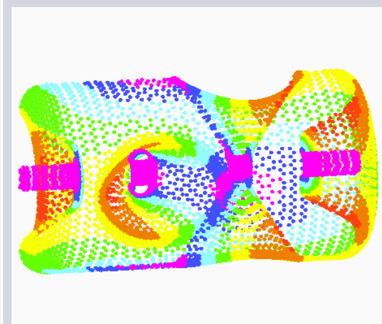
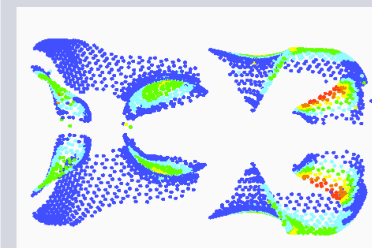
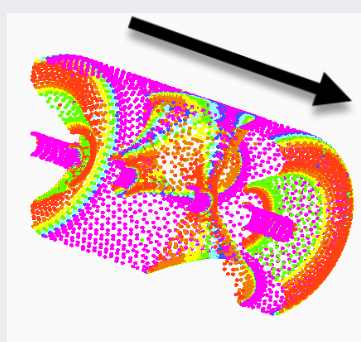
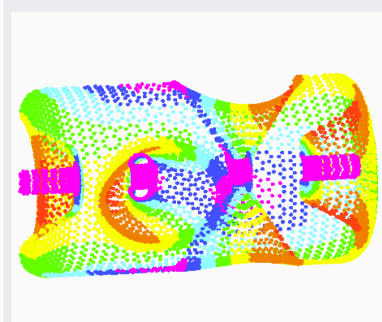
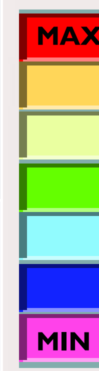
ANALYSIS

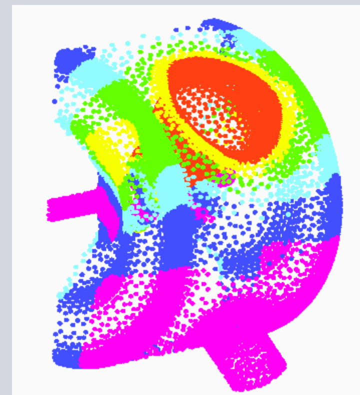
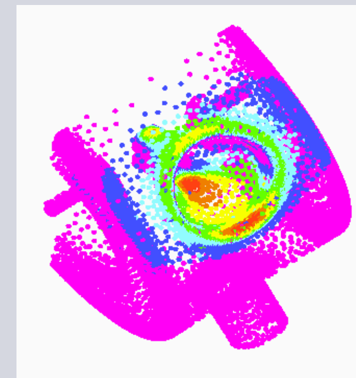
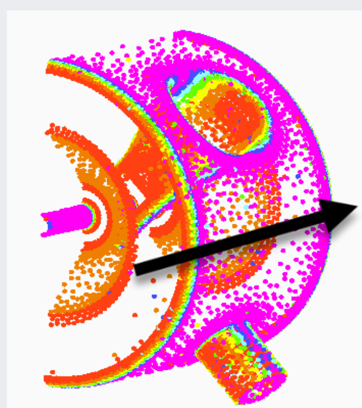
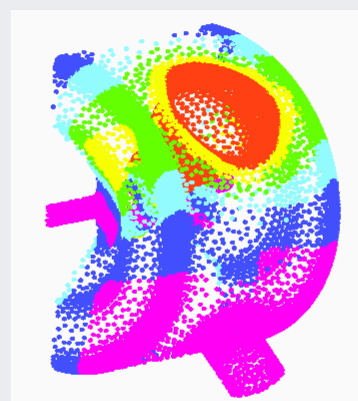
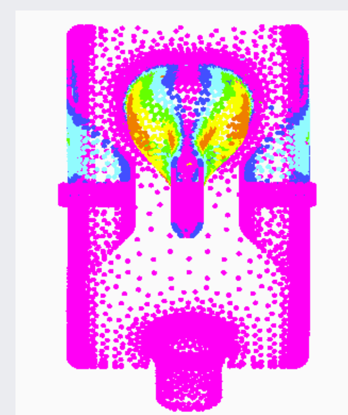
DSR (ESS) 352 MHz

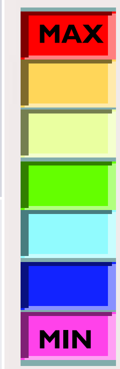
Theoretical : 0.11 nΩ/mG @2K	Trapped flux regions	RF surface currents	Sensitive regions to magnetic field
Vertical field			 0.057 nΩ/mG
Horizontal field (beam axis)			 0.055 nΩ/mG



ANALYSIS

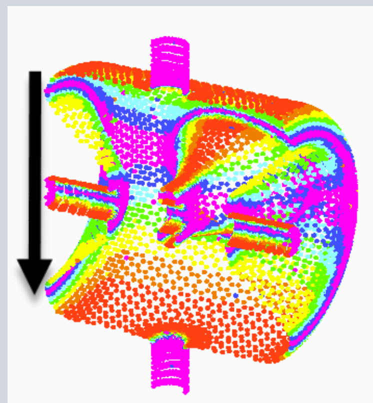
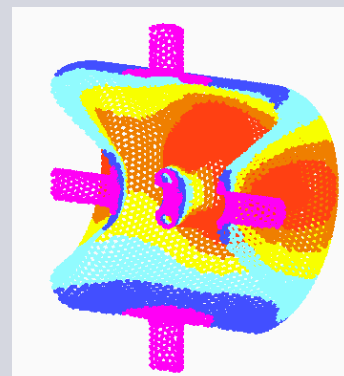
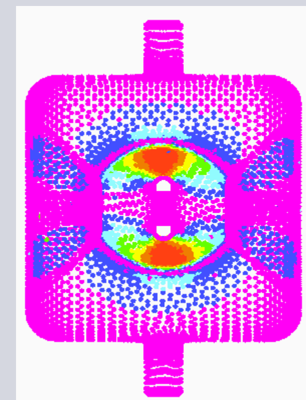
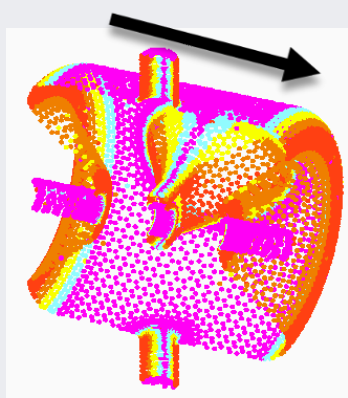
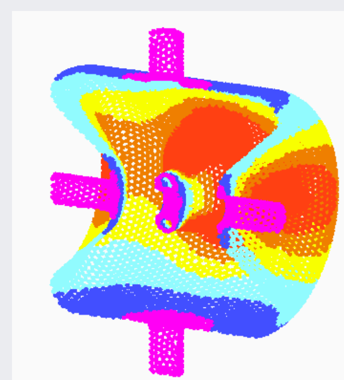
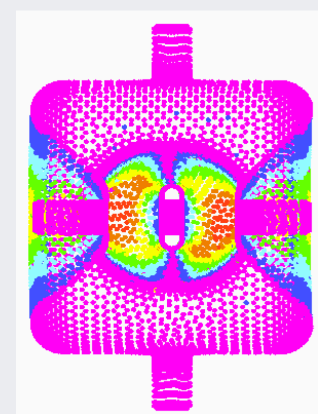
SSR1 (PIP-II) 325 MHz

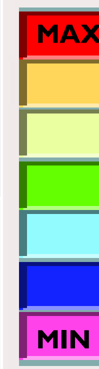
Theoretical : 0.11 nΩ/mG @ 2K	Trapped flux regions	RF surface currents	Sensitive regions to magnetic field
Vertical field			 0.046 nΩ/mG
Horizontal field (beam axis)			 0.064 nΩ/mG



ANALYSIS

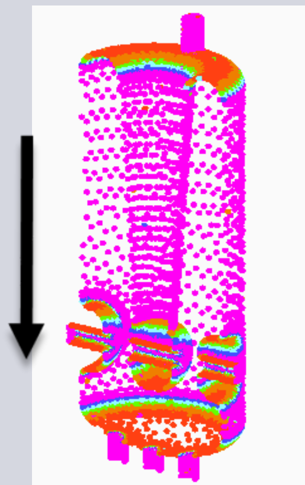
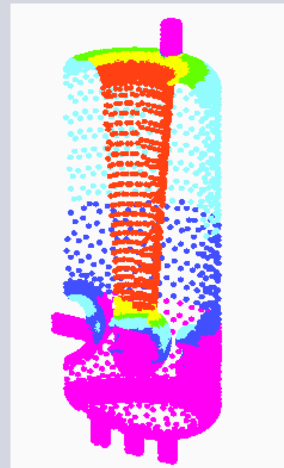
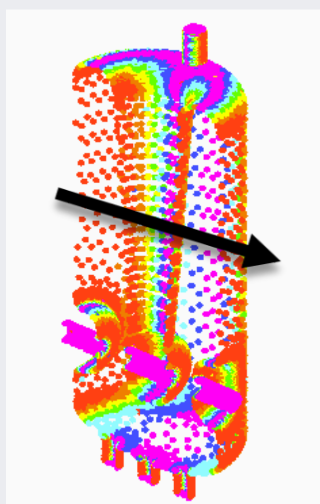
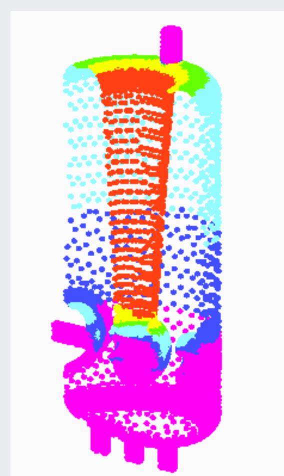
SSR (MYRRHA) 352 MHz

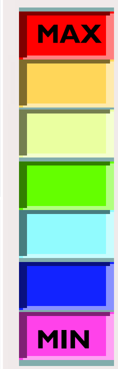
Theoretical : 0.11 nΩ/mG @ 2K	Trapped flux regions	RF surface currents	Sensitive regions to magnetic field
Vertical field			 0.047 nΩ/mG
Horizontal field (beam axis)			 0.062 nΩ/mG



ANALYSIS

QWR (Spiral2)

Theoretical : 0.08 nΩ/mG @ 4.2K	Trapped flux	RF surface currents	Sensitive regions to magnetic field
vertical field			 0.011 nΩ/mG
Horizontal field (beam axis)			 0.048 nΩ/mG



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SUMMARY

Geometrical effect

nΩ/mG		Transverse sensitivity	Beam axis sensitivity	Vertical sensitivity	
SPIRAL2 QWR @ 4.2K @ 88 MHz	Calculated	0.048	0.048	0.011	
	Measured	0.05 (IPNO)		0.006 (IPNO	Theoretical 0.08 nΩ/mG
	Error (%)	4 (-38)		-45 (-93)	
MYRRHA SPOKE @ 2K @352 MHz	Calculated	0.061	0.062	0.047	
	Measured			0.043 (IPNO	Theoretical 0.12 nΩ/mG
	Error (%)			-8.5 (-64)	
ESS SPOKE @ 2K @352 MHz	Calculated	0.057	0.055	0.057	
	Measured		0.06 (IPNO)		Theoretical 0.12 nΩ/mG
	Error (%)		9 (-50)		
PIP-II SSR1 @ 2K @ 325 MHz	Calculated	0.046	0.064	0.046	
	Measured		0.05 (FNAL)		Theoretical 0.11 nΩ/mG
	Error (%)		-22 (-55)		

Error : relative error between measurement and calculations
(Error) : relative error between measurement and theoretical value

CONCLUSION

- **Systematic error from theoretical values : measured sensitivities are always a lot less!**

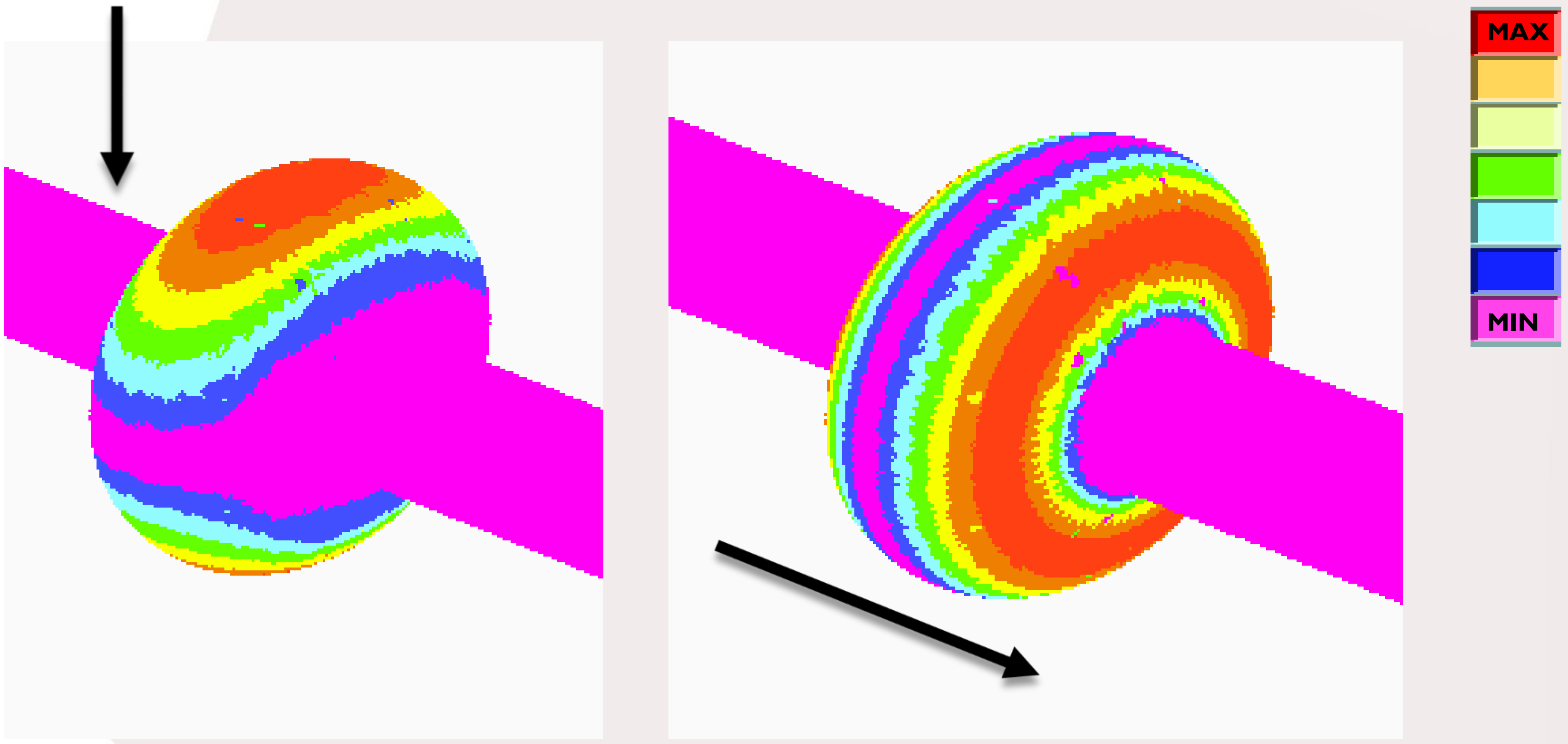
  =>Sensitivity does not only depend on material!

- **Considering only the normal component seems to be a good approximation:**
  - No systematic error between calculated and measured sensitivities
  - Explains difference between theoretical and measured sensitivities on several geometries
  - Explains difference of sensitivity depending on the orientation of residual field (SPIRAL2)

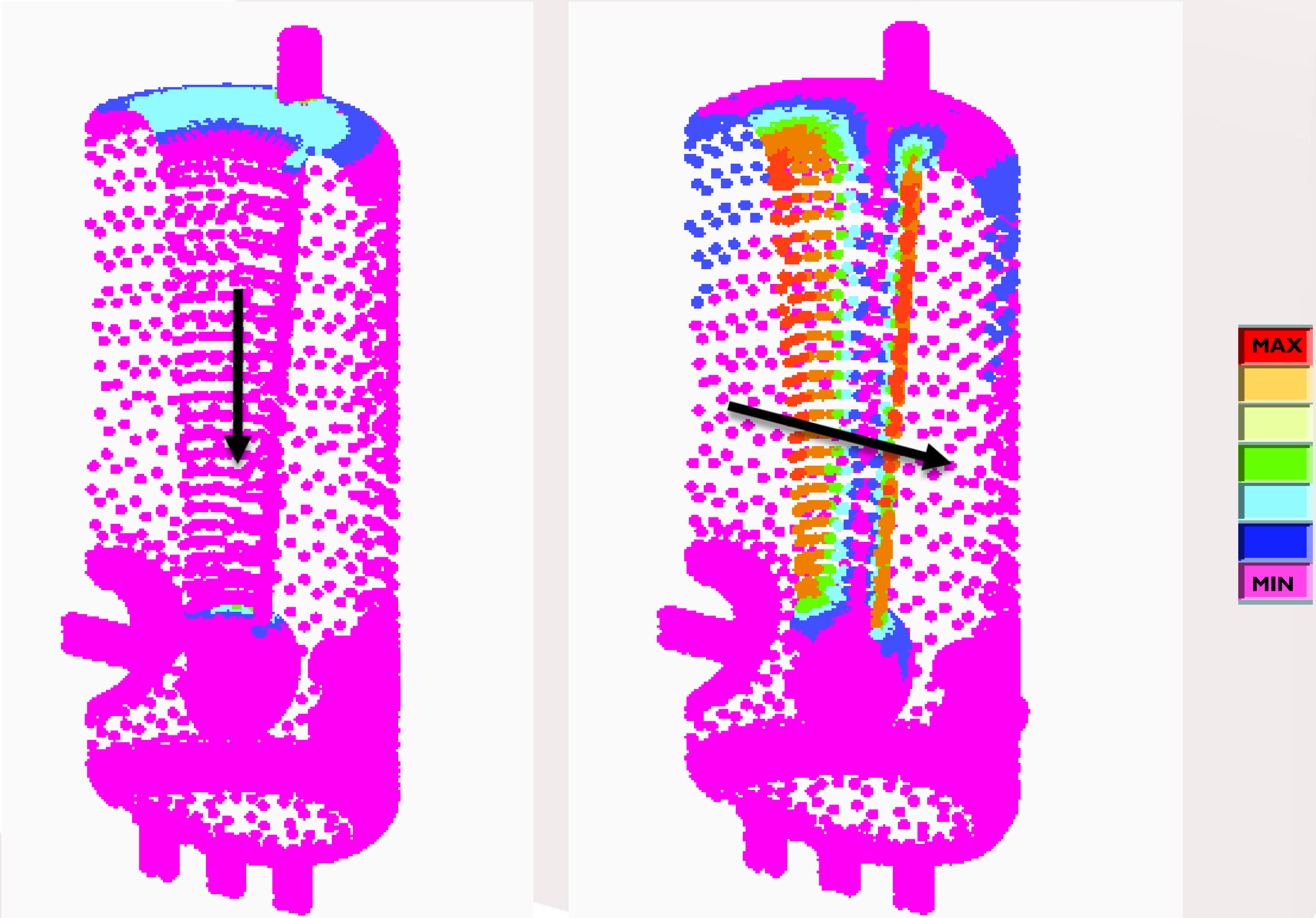
- Trapping flux is not enough to explain magnetic sensitivity, it has to happen in a RF magentic field region

THANKS FOR YOUR ATTENTION

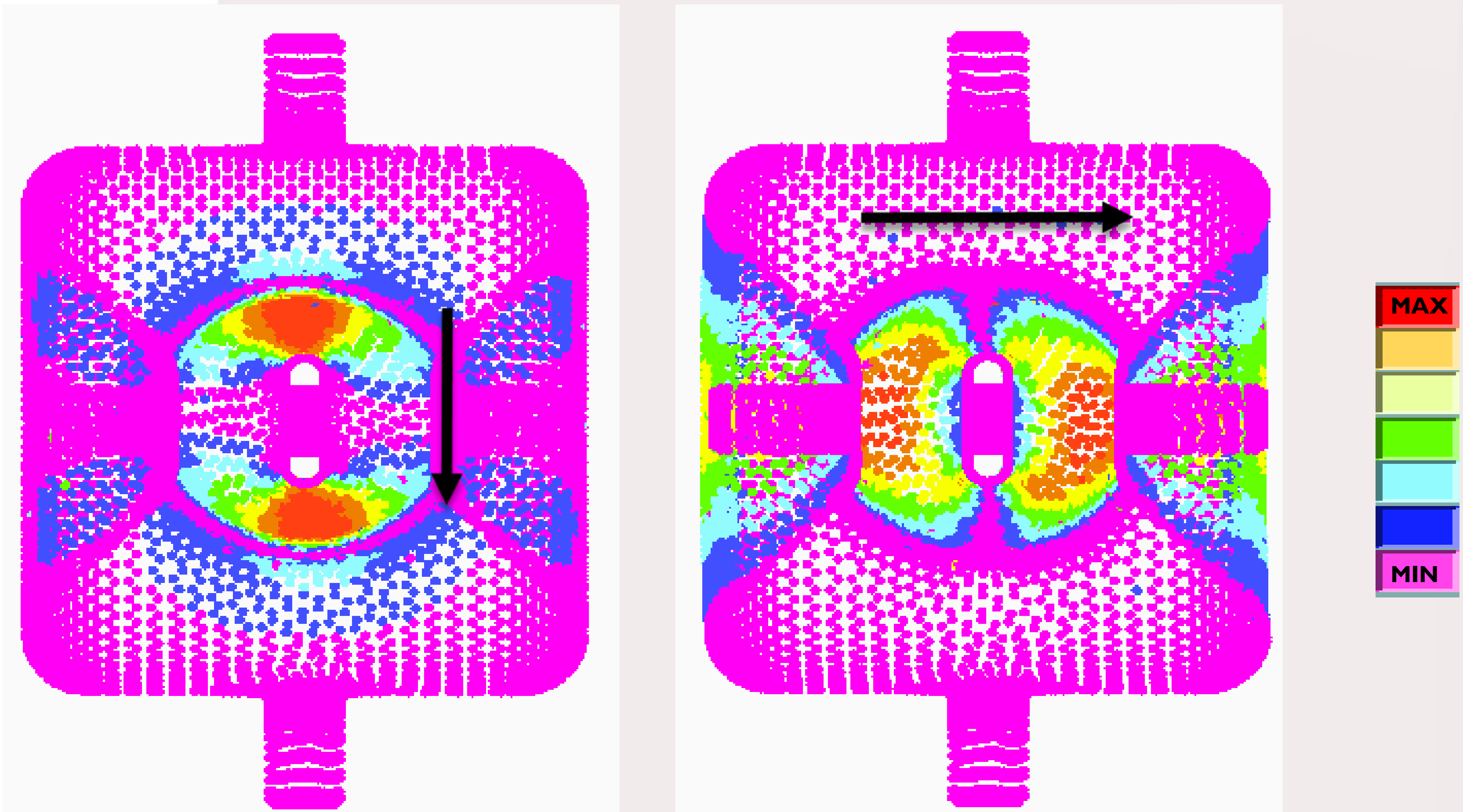
ELLIPTICAL



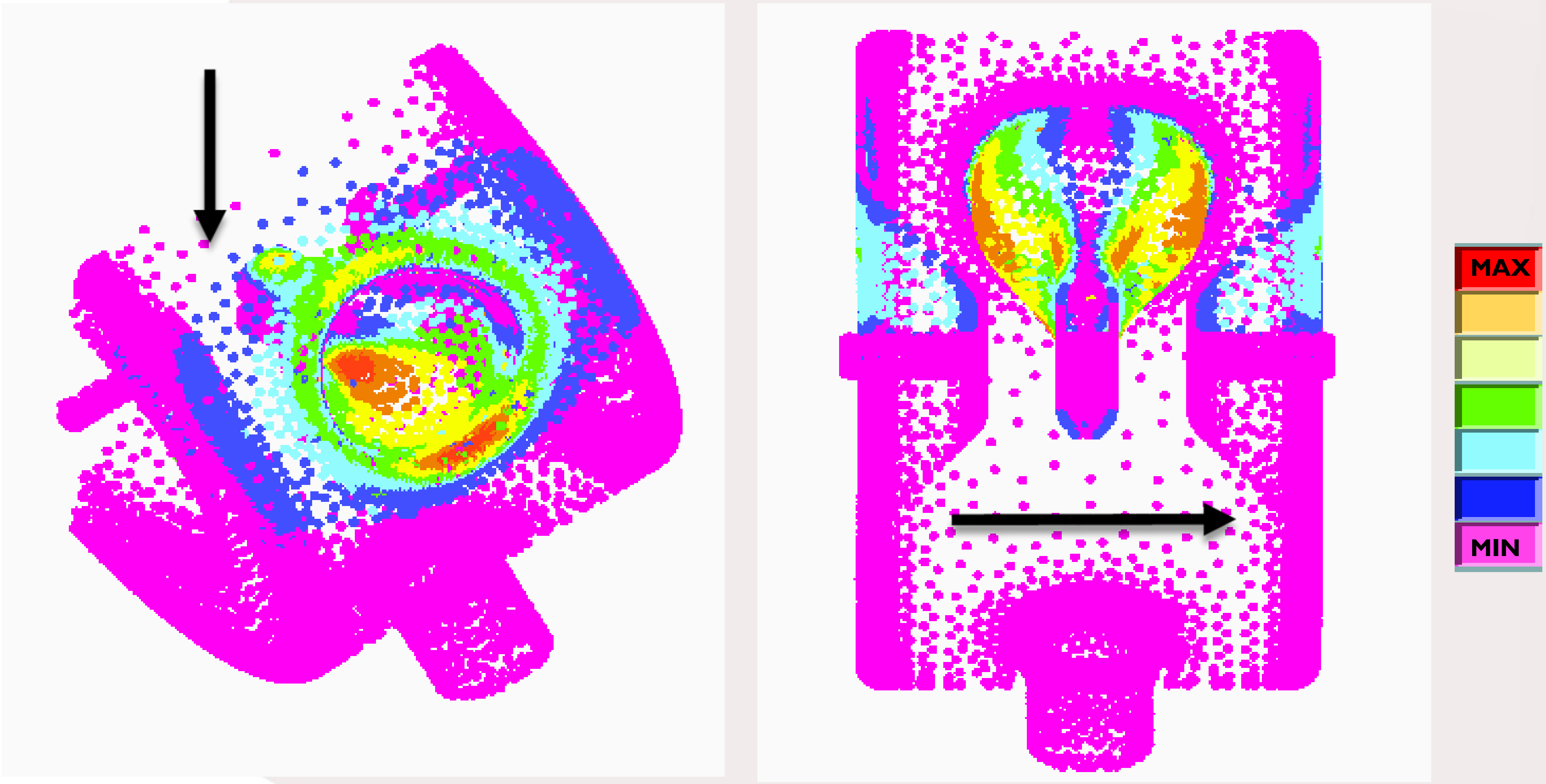
SPIRAL2



MYRRHA



SSR1 (PIP-II)



ESS