THE KLASH AXION CALLING

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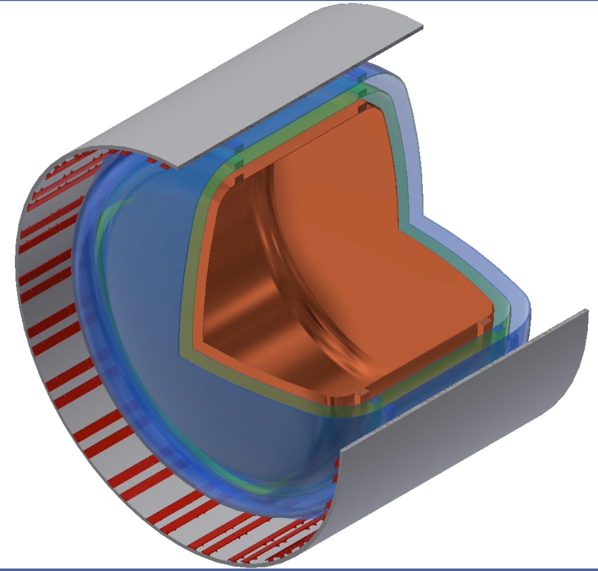
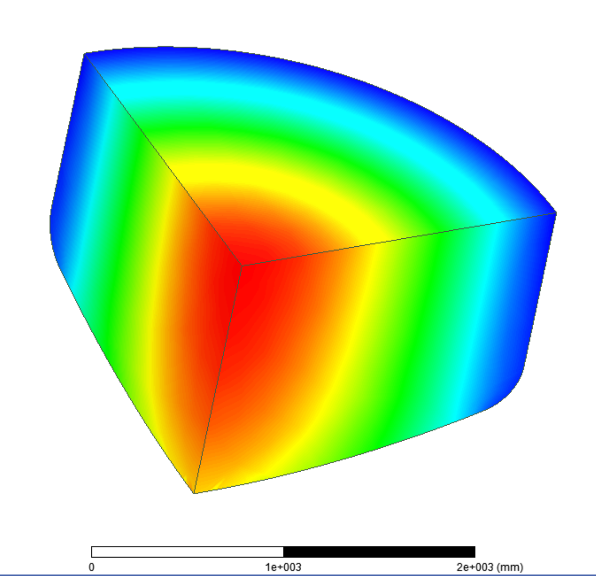




14^{th} AxionWIMP Conference – Hamburg June 2018

OUTLINE

- The Klash Proposal
- KLOE and the KLOE Magnet
- Cryoplant
- Cryostat
- SQUID
- RF Cavity
- Frequency tuning
- Expected sensitivity
- Conclusion

THE KLASH PROPOSAL

arXiv:1707.06010 (Alesini, Babusci, Di Gioacchino, Gatti, Lamanna, Ligi)

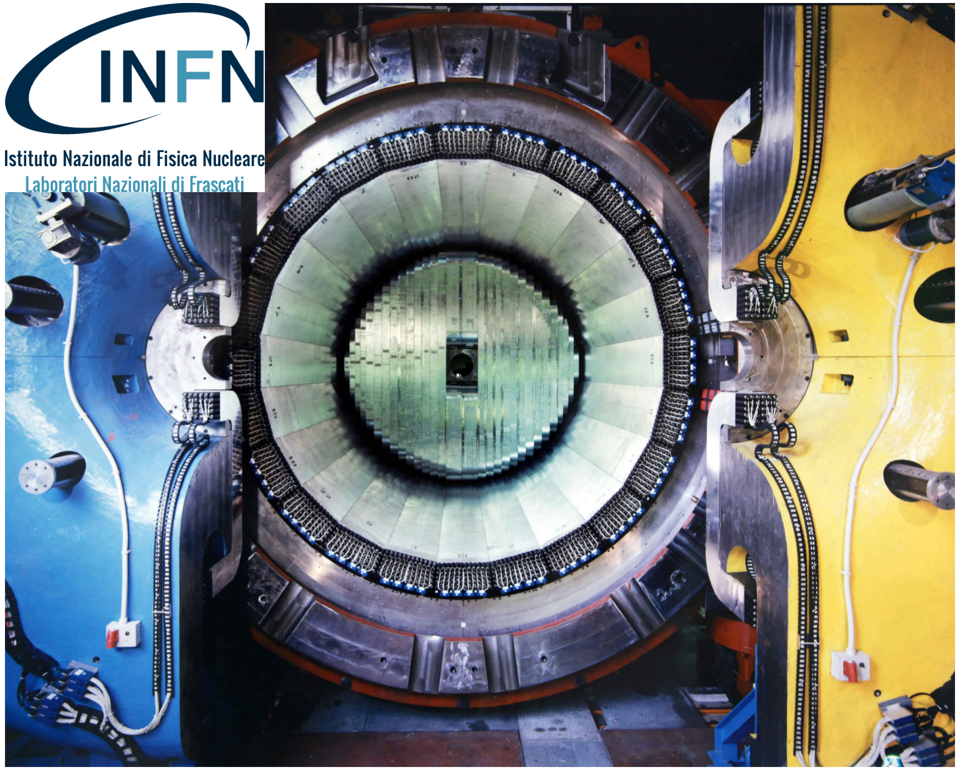
- KLASH - KLoe magnet for Axions SearcH
- Proposal of a large Haloscope
- Search of galactic axions in the mass range 0.3-1 μeV
- Large volume RF Cavity (35 m^3)
- Moderate magnetic field (0.6 T)
- Copper rf cavity Q~600,000
- T 4.2 K

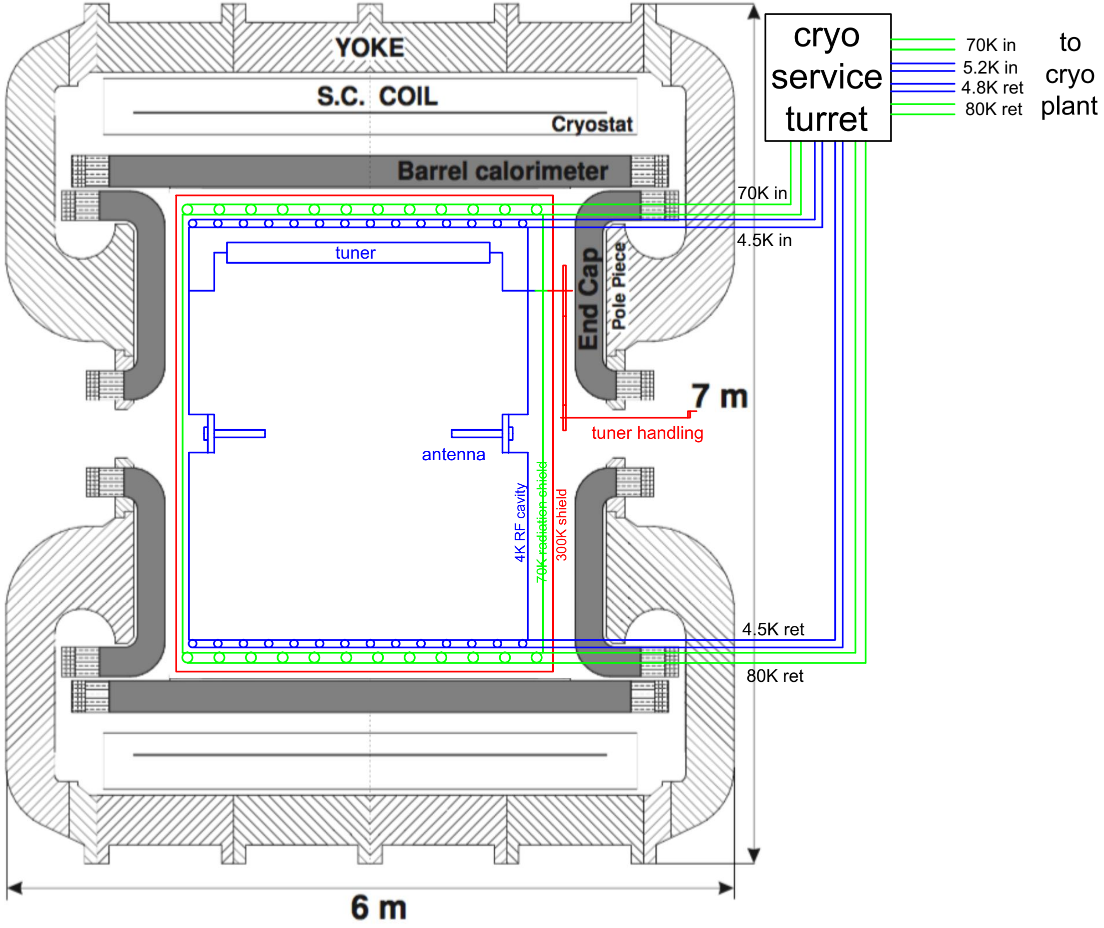
$$P_{\text{sig}} = \left(g_\gamma^2 \frac{\alpha^2}{\pi^2} \frac{\hbar^3 c^3 \rho_a}{\Lambda^4} \right) \times \left(\frac{\beta}{1+\beta} \omega_c \frac{1}{\mu_0} B_0^2 V C_{mnl} Q_L \right)$$

$$SNR = \frac{P_{\text{sig}}}{k_B T_{sys}} \sqrt{\frac{\tau}{\Delta \nu_a}}$$

Experiment	ω B^2 V Q (rad $T^2 m^3/s$) (×10^{15})
The KLASH	1
ADMX	4
HAYSTAC	0.5

THE KLOE DETECTOR

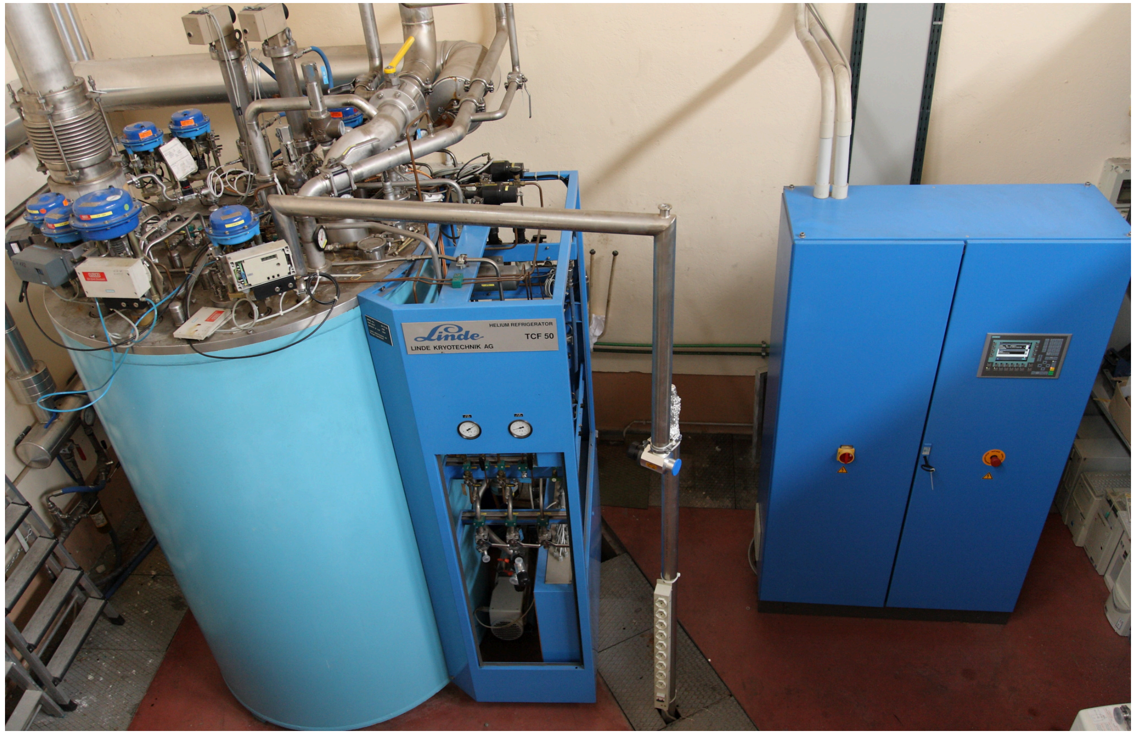




THE KLOE MAGNET

B(T)	**0.6**
R(m)	4.86
L(m)	4.4

THE DAFNE CRYOGENIC PLANT

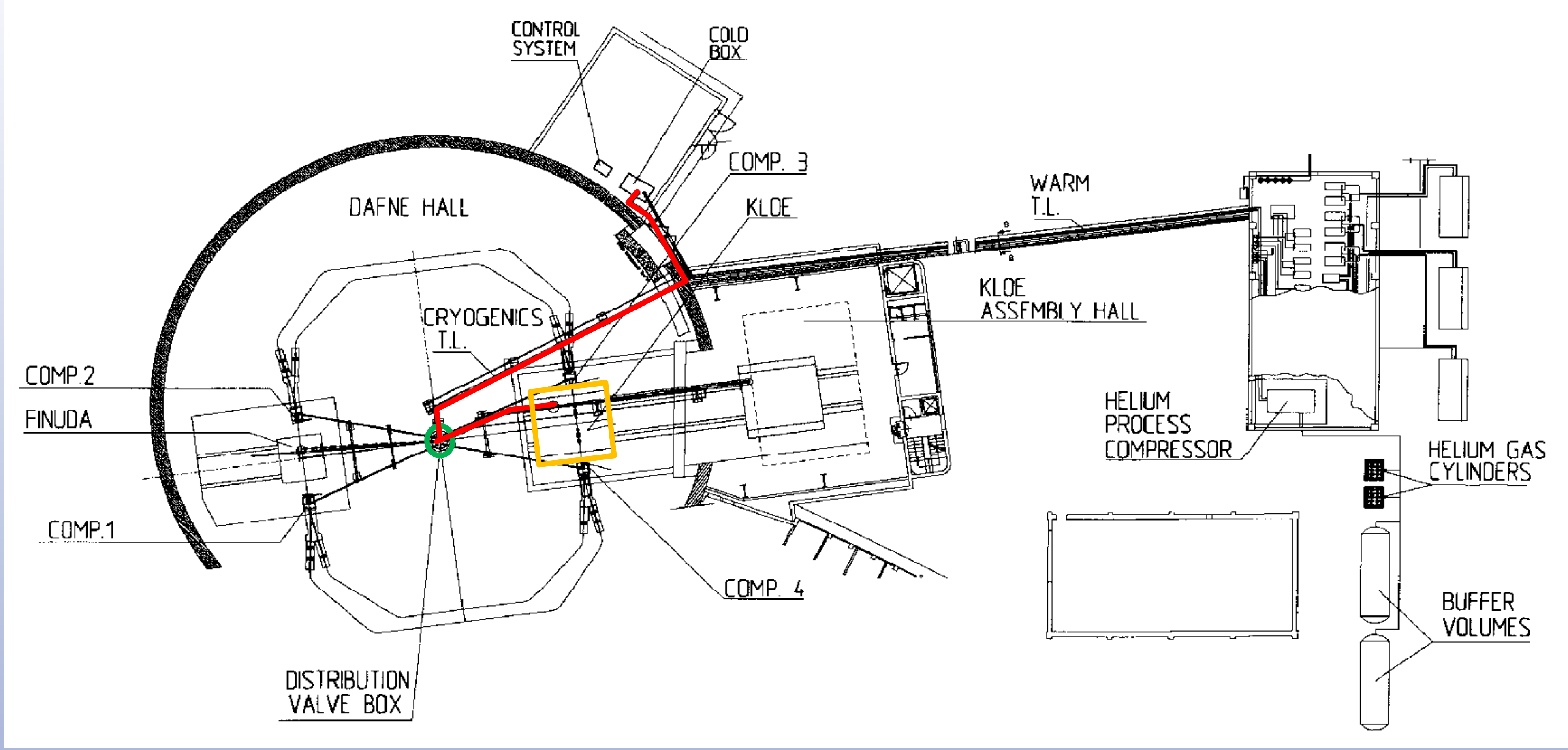


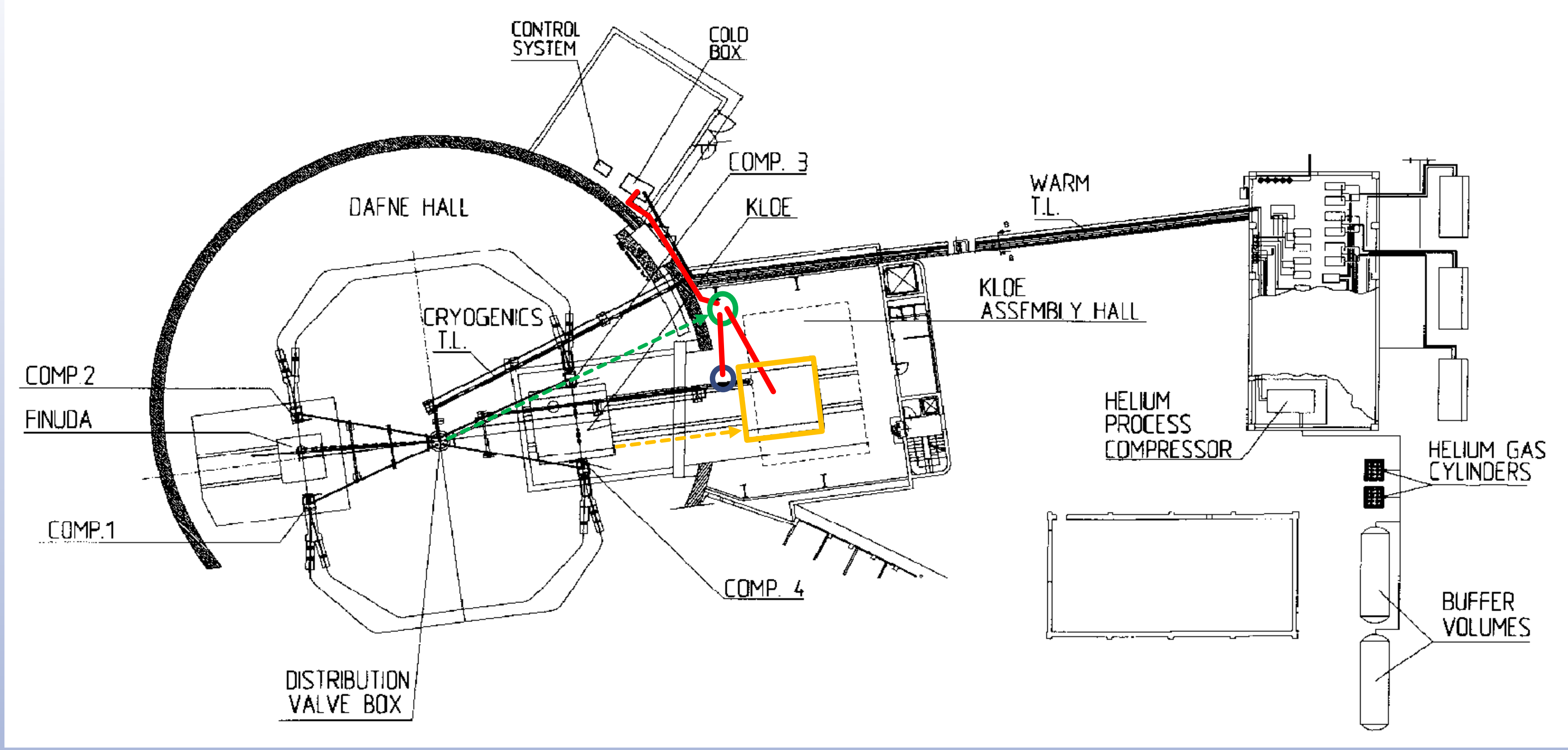
LINDE TCF 50 liquid He liquefaction/refrigeration plant

Running at DAFNE since 1996.
Perfectly working.
Located outside the DAFNE main ring.

4.5K refrigeration capacity	**99 W**
4.5K liquefaction capacity	1.14 g/s
70K refrigeration capacity	800 W
KLOE 4.5K refrig. load	55 W
KLOE 4.5K liquef. load	0.6 g/s
KLOE 70K refrig. load	530 W
cavity 4.5K refrig. availability	44 W
cavity 70K refrig. availability	270 W

M. Modena LNF–97/046 (IR)


CONTROL SYSTEM
COLD BOX
COMP. 3
KLOE
WARM T.L.
DAFNE HALL
KLOE ASSEMBLY HALL
CRYOGENICS T.L.
COMP.2
FINUDA
COMP.1
HELIUM PROCESS COMPRESSOR
HELIUM GAS CYLINDERS
COMP. 4
BUFFER VOLUMES
DISTRIBUTION VALVE BOX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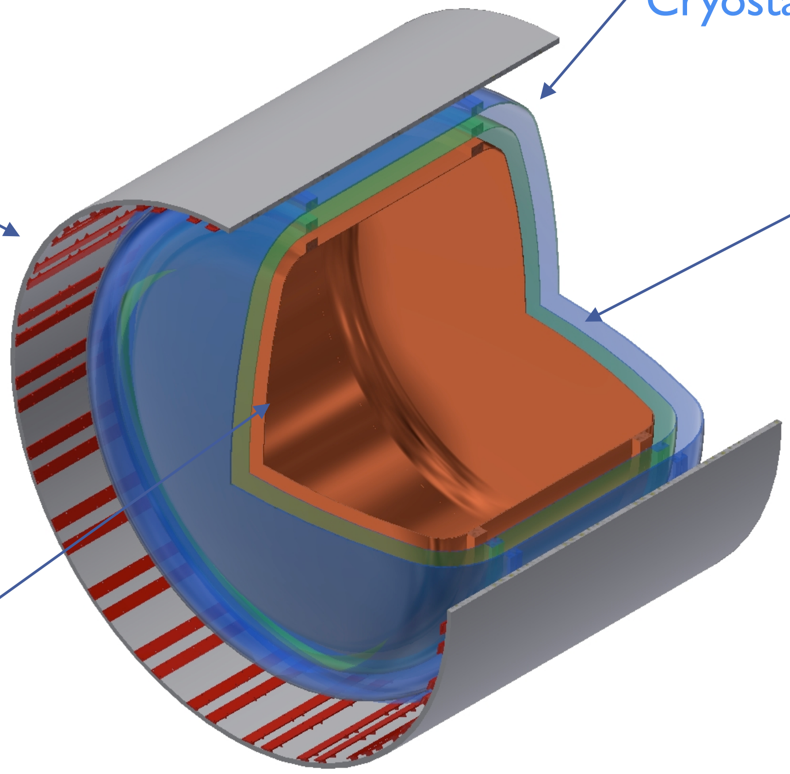
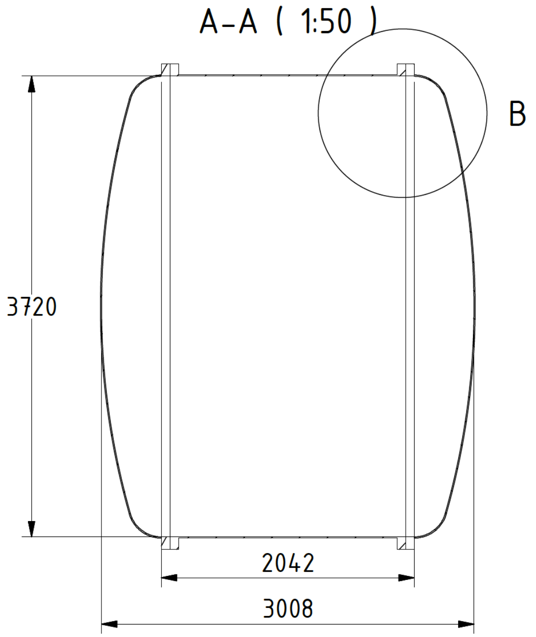
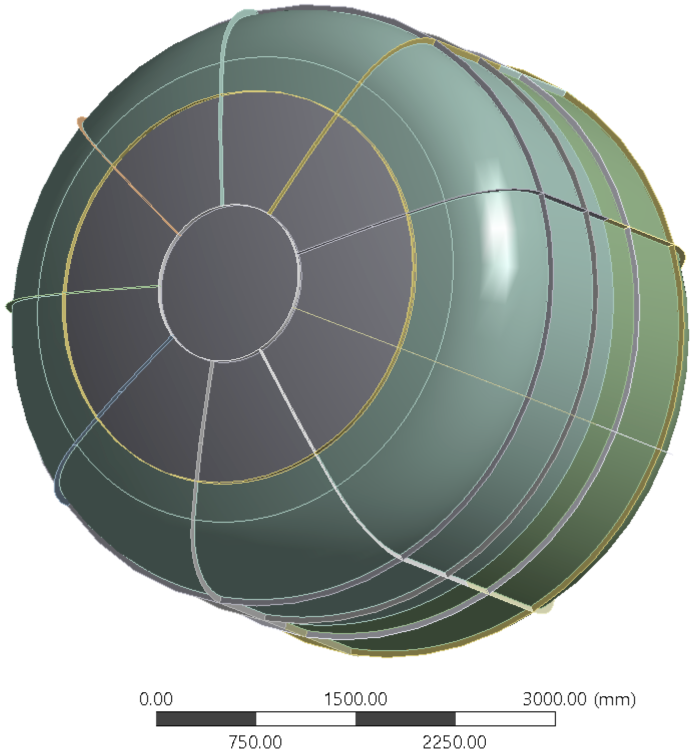
CRYOSTAT

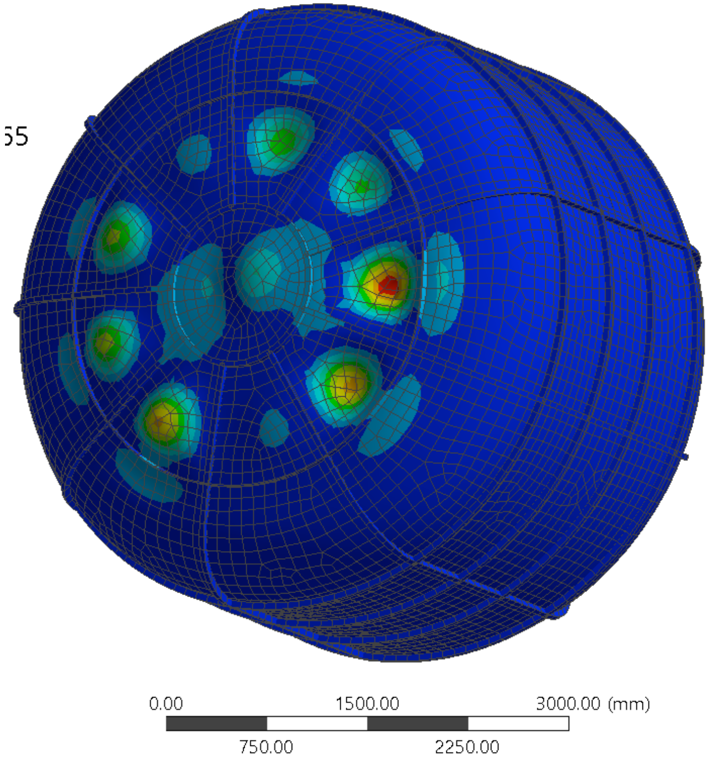




Cryostat Total Weight	12 Ton
RF Cavity diameter (mm)	3720
RF Cavity length (mm)	3008
RF Cavity Volume (m^3)	~33

CRYOSTAT

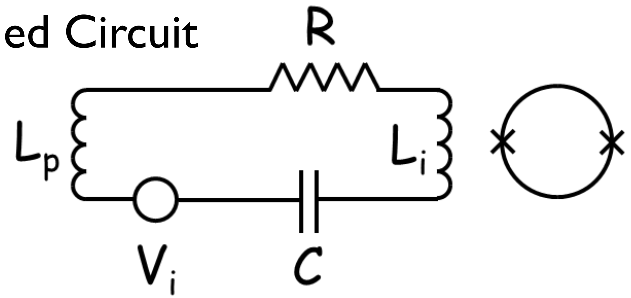




The external wall of the cryostat must withstand a pressure of 1 bar: ongoing calculations to balance mechanical resistance and weight.

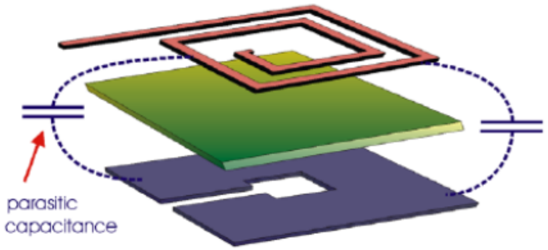
THE DC SQUID AS A RADIOFREQUENCY AMPLIFIER

Tuned Circuit



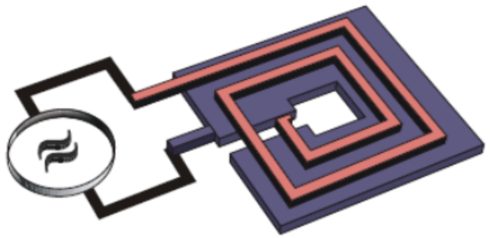
At frequencies higher than a few MHz it is convenient to use a tuned circuit:
e.g. Noise Temperature T_N=1.7K @93MHz and @4.2K
C. Hilbert and J. Clarke, J. Low Temp. Phys. **61**, 263 (1985).

but



In a conventional square-washer SQUID the parasitic capacitance between the input coil and the square washer can lower the gain to useless levels at frequencies around 100 MHz

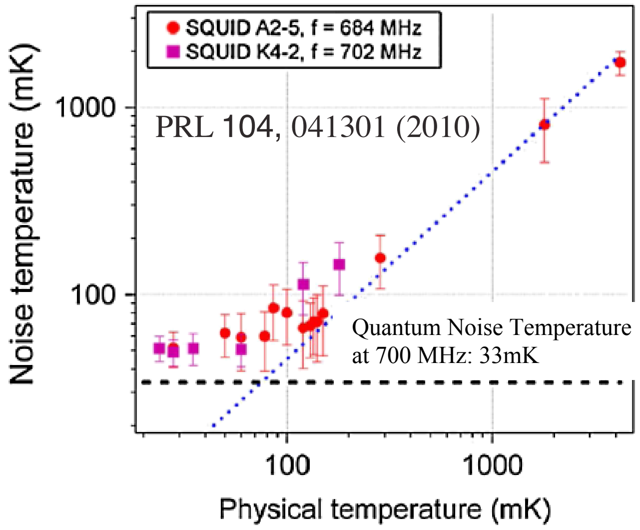
then

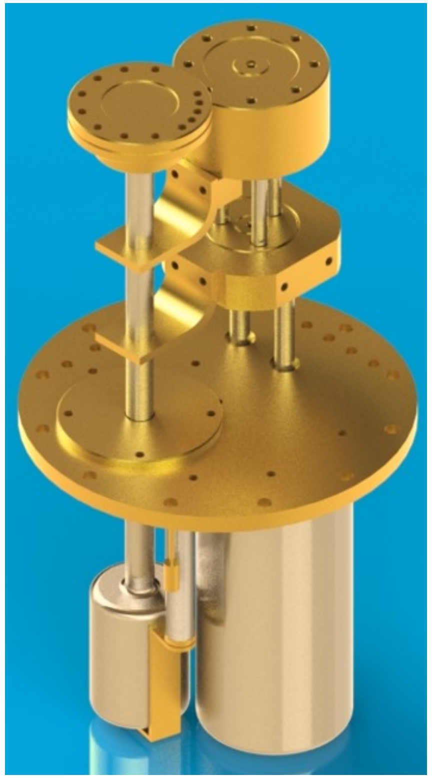


Possible solution: in contrast to the conventional input scheme the signal is applied between one end of the coil and the washer (the other end of the coil is left open).
e.g. T_N=52mK @538MHz and @0.1K (Quantum Limited T_N=26mK) M. Muck et al. Appl. Phys. Lett **78,** 967, (2001)

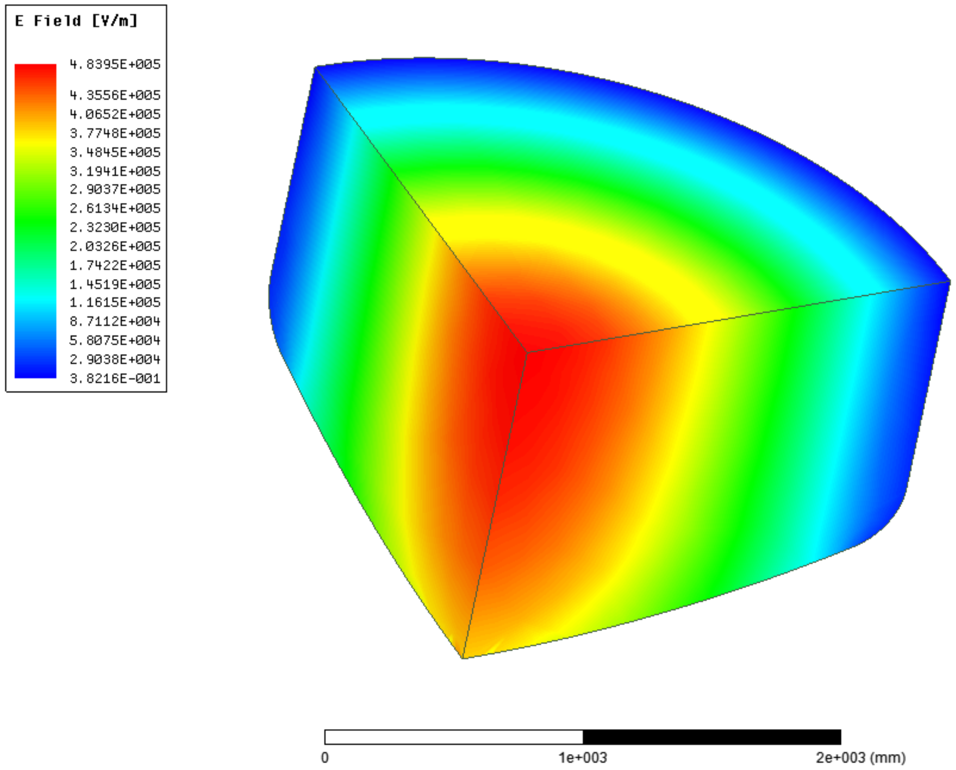
300 mK COOLING FOR SQUID

- SQUID can be cooled at about 0.3 K using a ^3He fridge
- The simplest solution foresees a coupled $^4He/^3He$ fridges
- Compact and quite easy to operate
- T_{base} ≈ 300 mK, cooling power ≈ few tens of μW
- Single shot condensation allows a 80÷90% duty cycle operation
- Two ^3He fridges and a thermal switch allow continuous operation, but requires developement

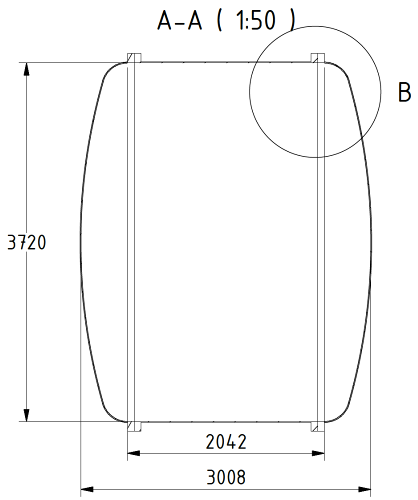




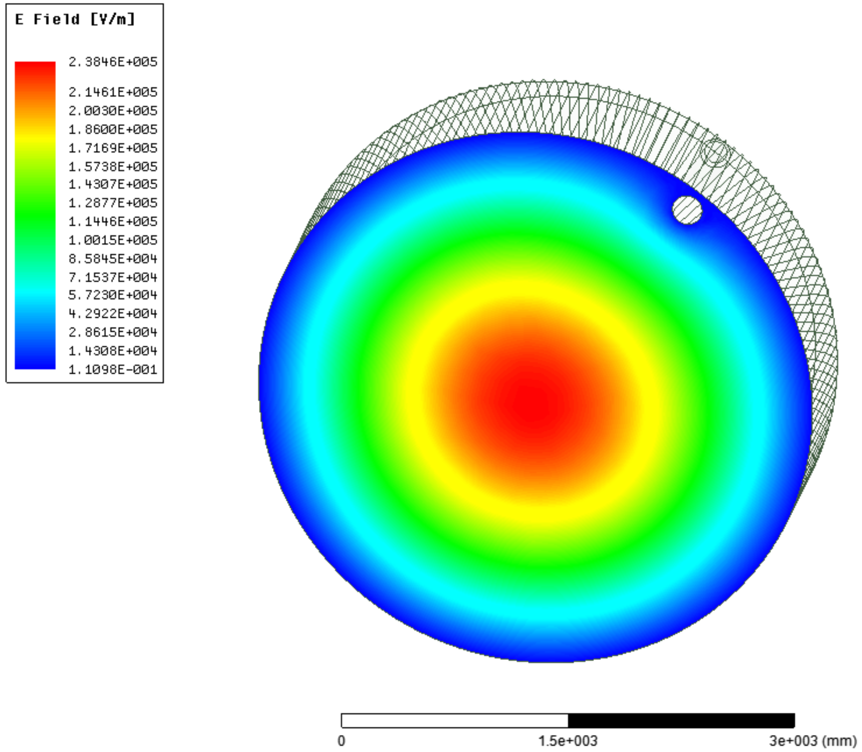
RESONANT CAVITY: RF SIMULATION



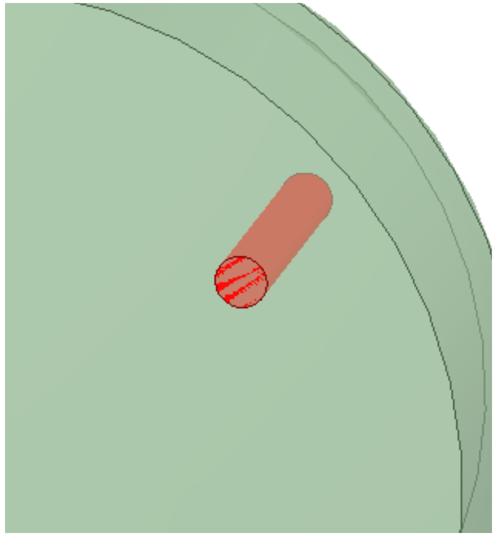
Mode	TM010
Frequency [MHz]	64
Q @ T=4K (RRR=25)	746,000
C_{010}	0.71



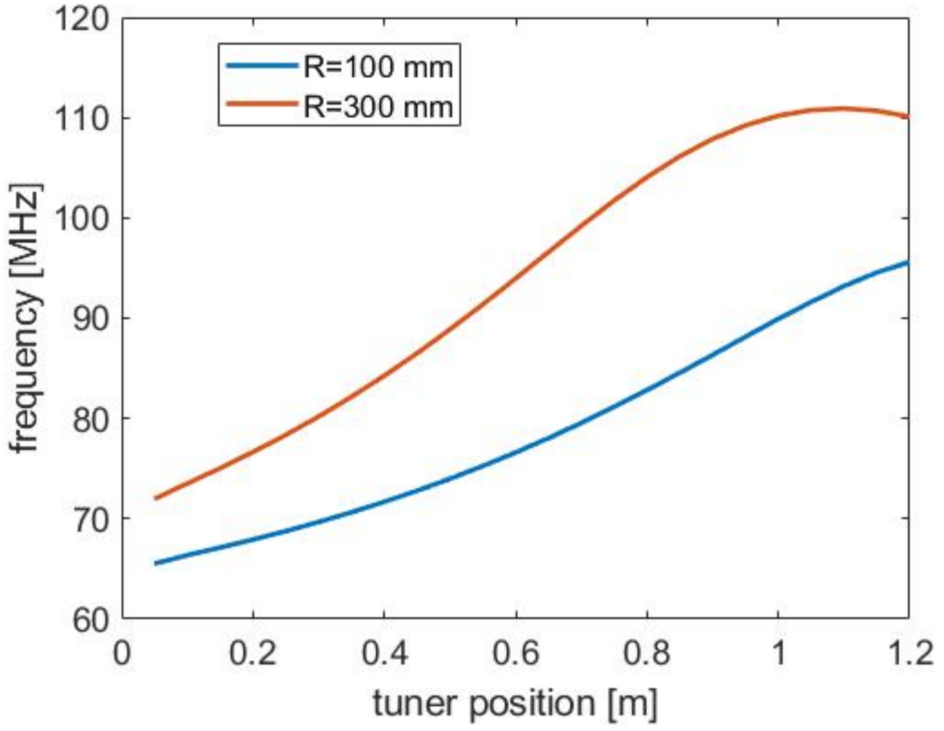
TUNING

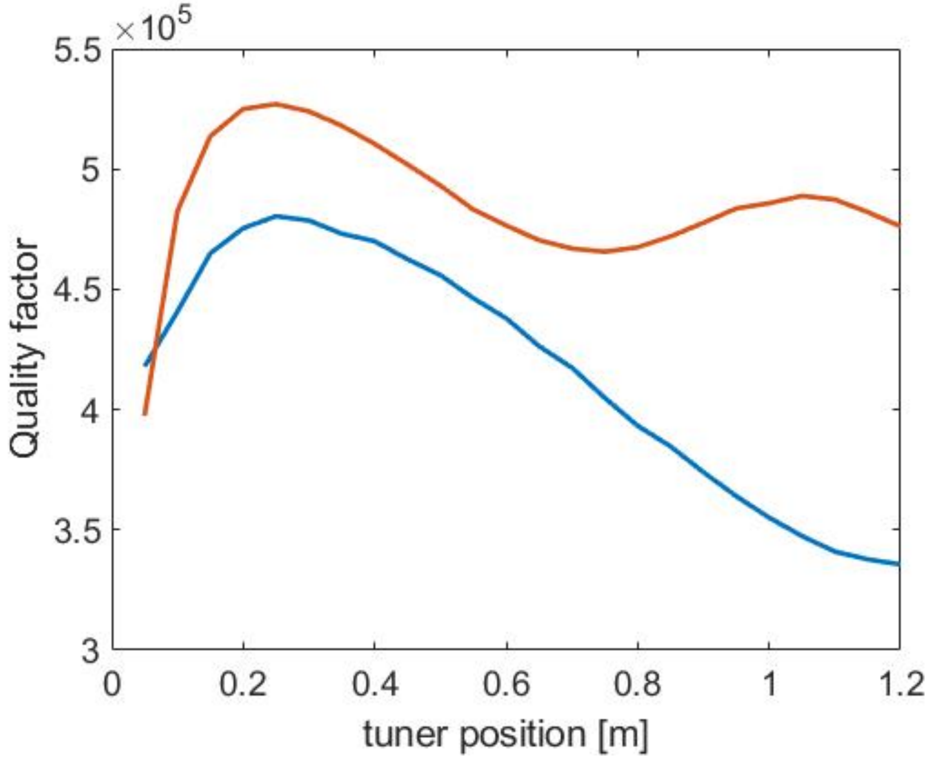


Simulation with tuning rods of different radii (100-300 mm) and with different numbers of rods.

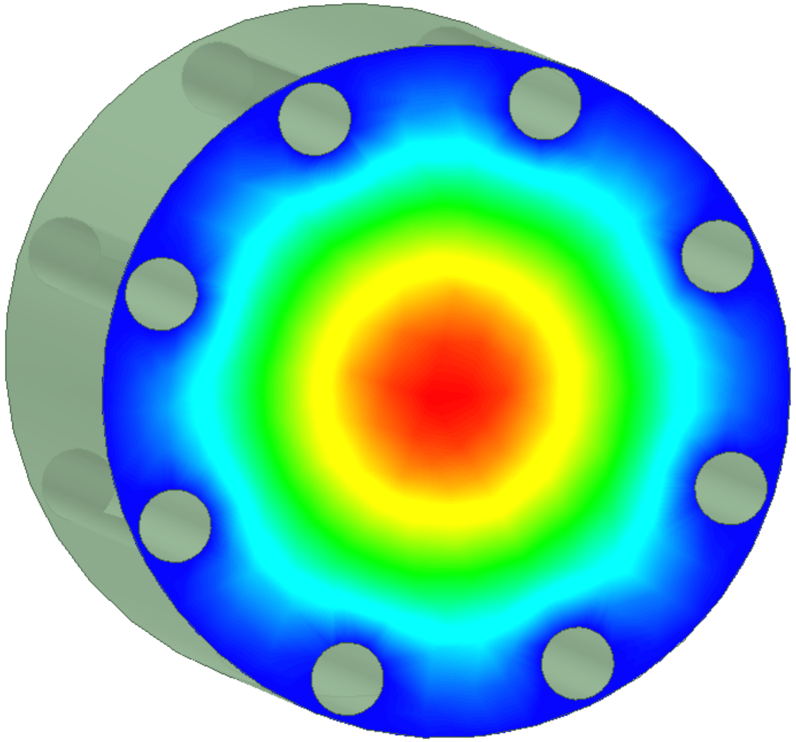


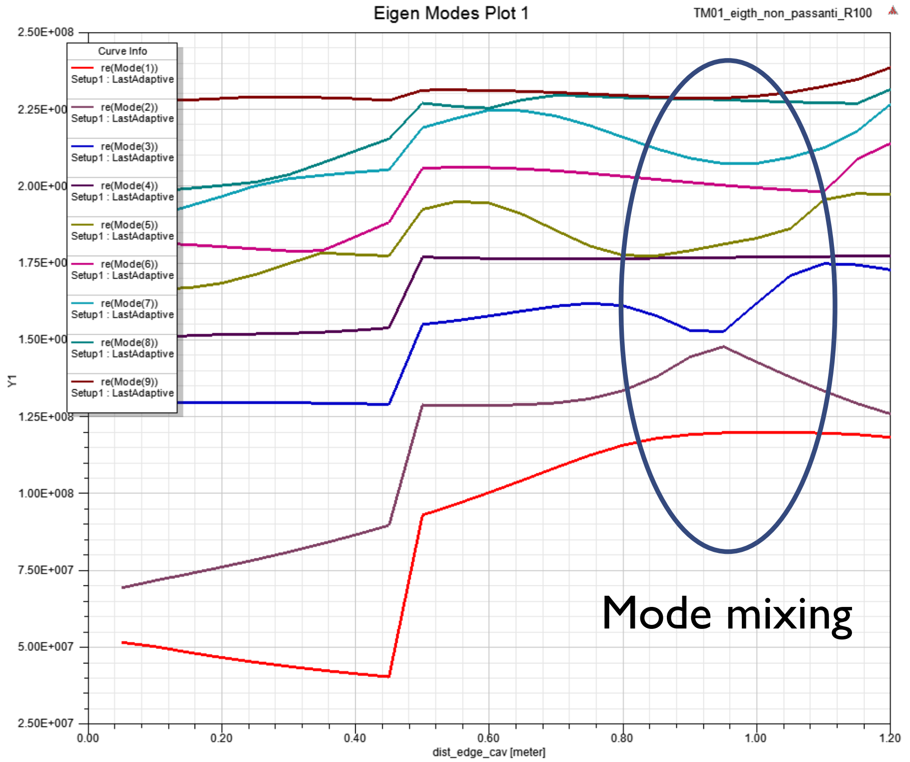
TUNING: TWO TUNING RODS





MORE RODS: MODE MIXING

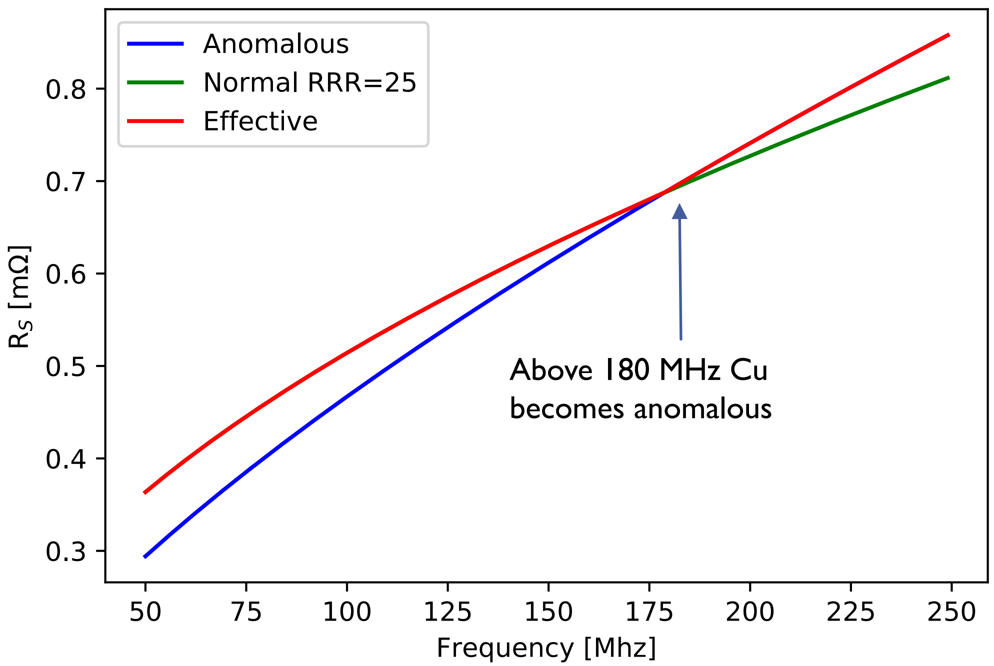




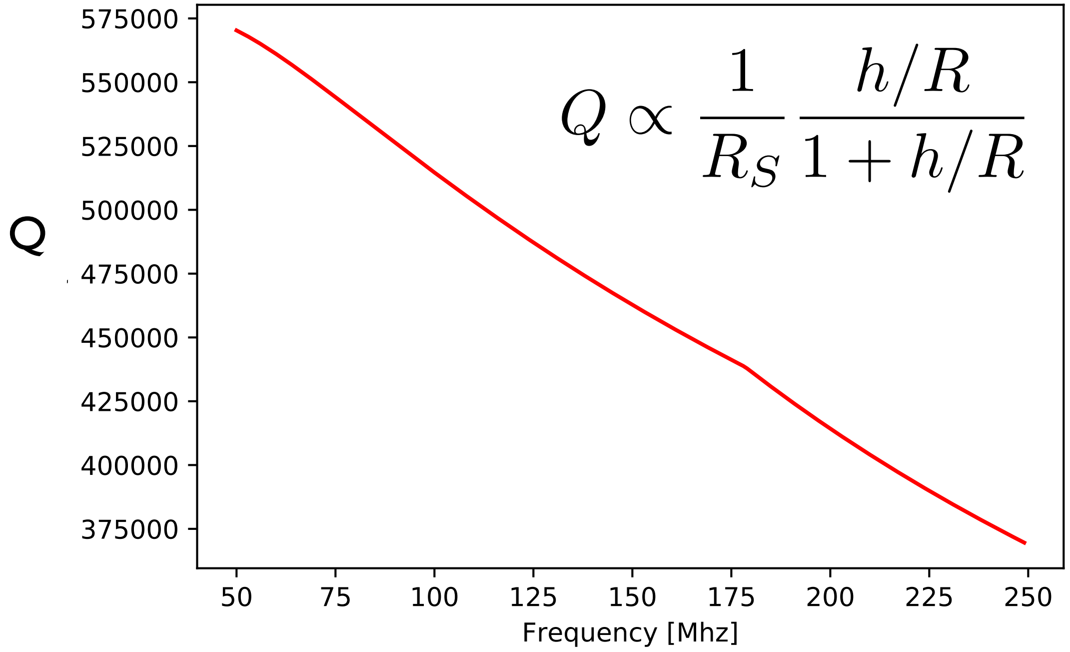
Investigating up to 8 rod.s Mode mixing becomes a problem.
In the following, we assume only 2 tuning rods with R=300mm.

Q VS FREQUENCY

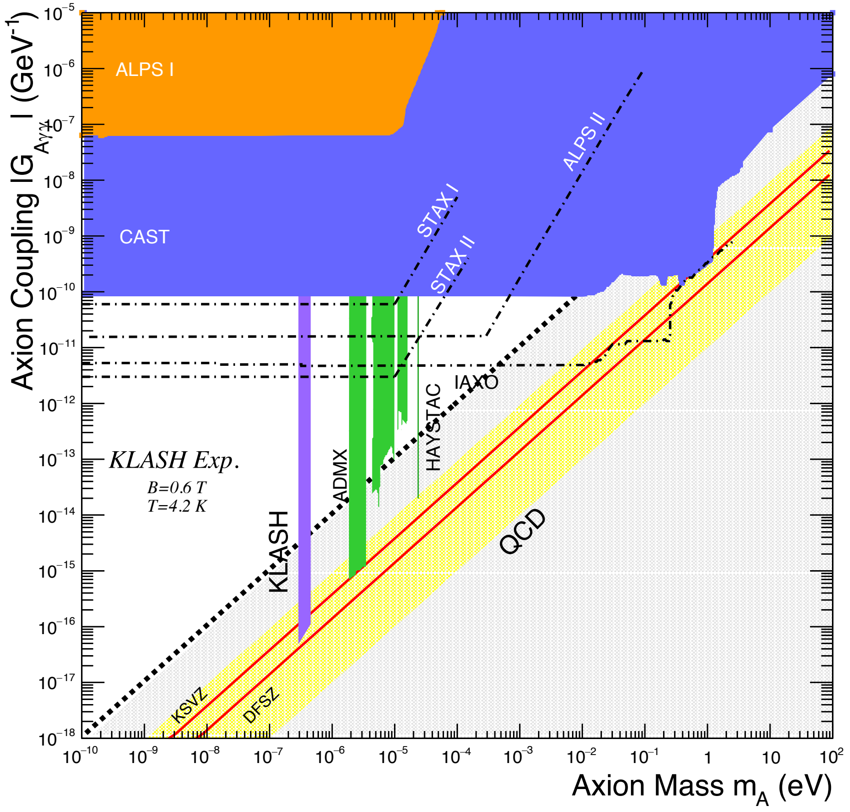
Surface resistance T=4K



Quality factor T=4K



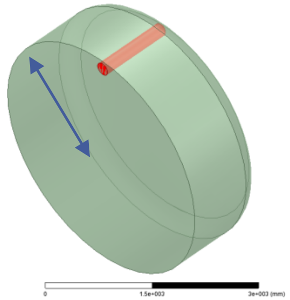
EXPECTED SENSITIVITY: PHASE I



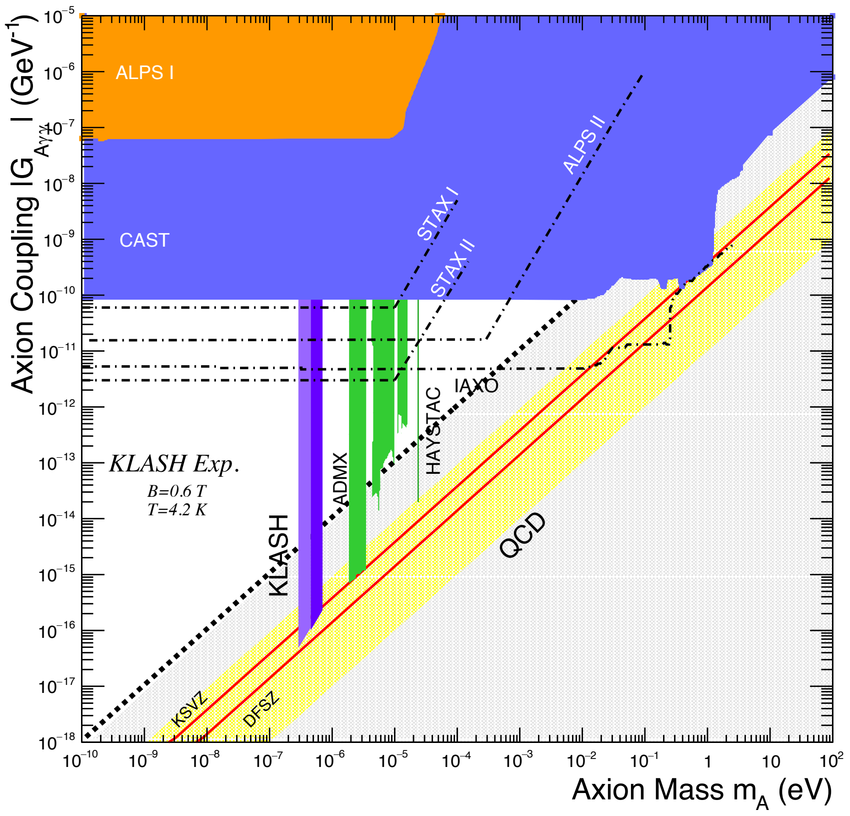
*Gray band PRL **118**, 031801 (2017)

Phase I	1 year data taking
Radius [m]	1.9
Frequencies [MHz]	70-110
Q (70MHz)	550,000
Power [W] (KSVZ)	1.3×10^{-22}
Rate [kHz] (KSVZ)	2.8
Integration time (min)	10

R=1.9m



EXPECTED SENSITIVITY: PHASE II

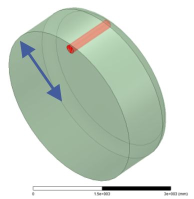


*Gray band PRL 118, 031801 (2017)

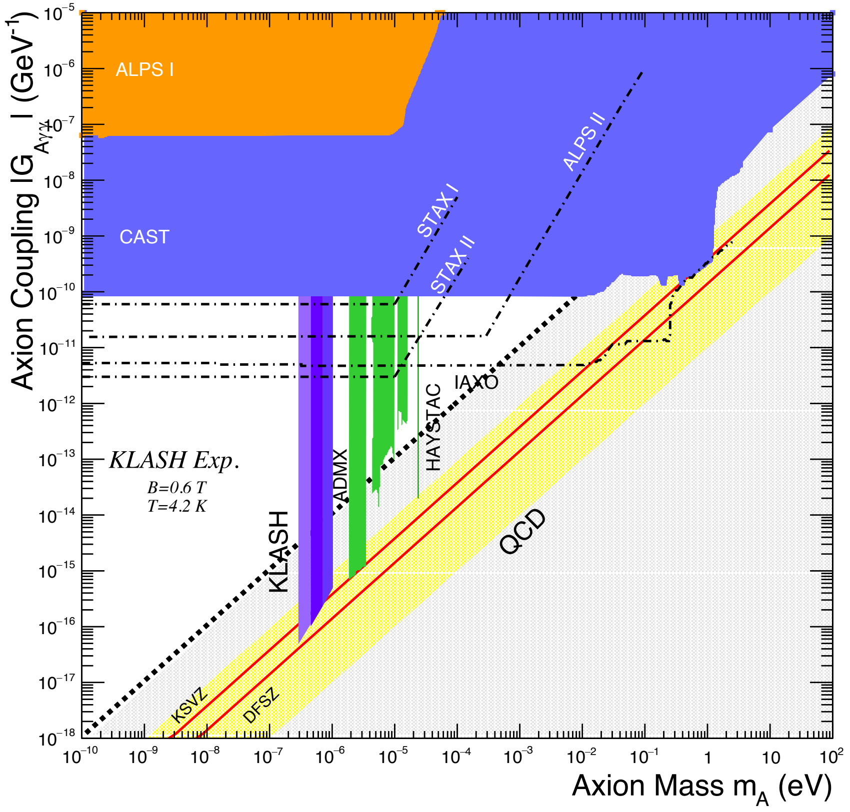
Phase II	1 year data taking
Radius [m]	1.2
Frequencies [MHz]	110-170
Q (110MHz)	500,000
Power [W] (KSVZ)	7.5×10^{-23}
Rate [kHz] (KSVZ)	1
Integration time (min)	15

1st RF Cavity Replacement

R=1.2m



EXPECTED SENSITIVITY: PHASE III

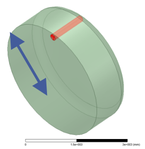


*Gray band PRL 118, 031801 (2017)

Phase III	1 year data taking
Radius [m]	0.9
Frequencies [MHz]	170-250
Q (170MHz)	445,000
Power [W] (KSVZ)	4.3×10^{-23}
Rate [kHz] (KSVZ)	0.38
Integration time (min)	15

2nd RF Cavity Replacement

R=0.9m



CONCLUSION

- We propose a large haloscope with the sensitivity to find galactic axions in the mass window 0.3-1 μeV.
- The project will be submitted to INFN Commission this summer for funding a TDR.
- The TDR is expected in summer 2019 for the final funding request.
- Interested groups: LNF, Pisa INFN and Univ., LNL, Padova INFN, TIFPA.


LNF - ADONE Cavity
Winter 2017-2019

Thanks to L.Pellegrino, S.Lauciani and P.Falferi for their contributions to this work.

FLASH

If KLOE magnet used for DUNE Near Detector:

- FLASH: Finuda magnet for Light Axion SearcH
- SC magnet built by Ansaldo Italia (ASG Supeconductors) for FINUDA experiment
- Similar sensitivity to galactic axions of KLASH

B(T)	1.1
R(m)	2.77
L(m)	2.52