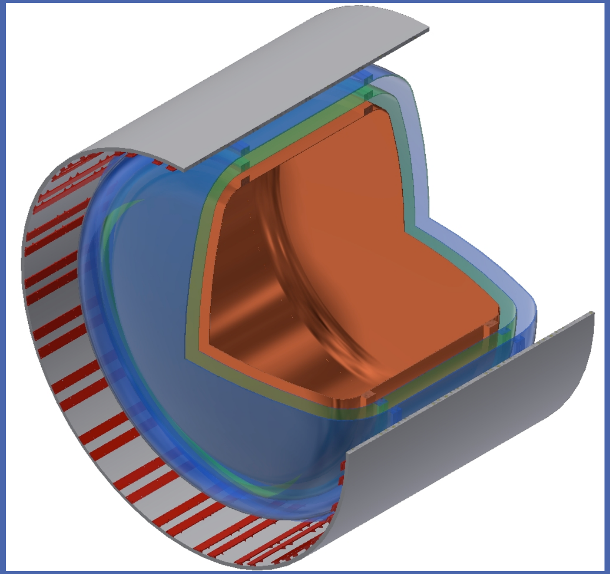
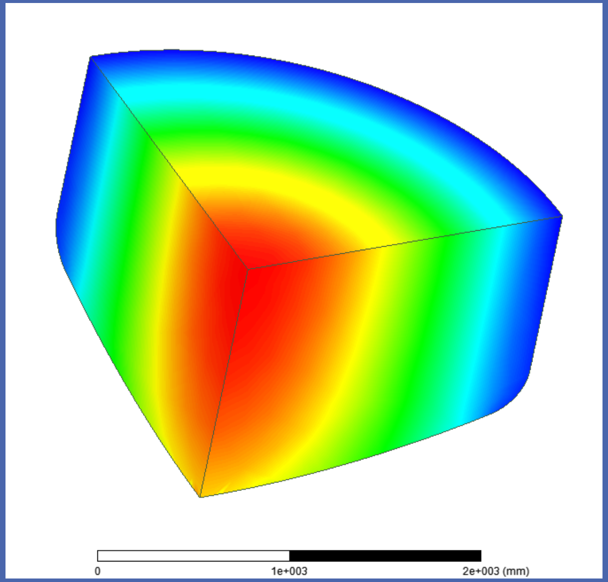
THE KLASH AXION CALLING

CLAUDIO GATTI, LABORATORI NAZIONALI DI FRASCATI - INFN

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati





CdL Preventivi 2019 – LNF June 2018

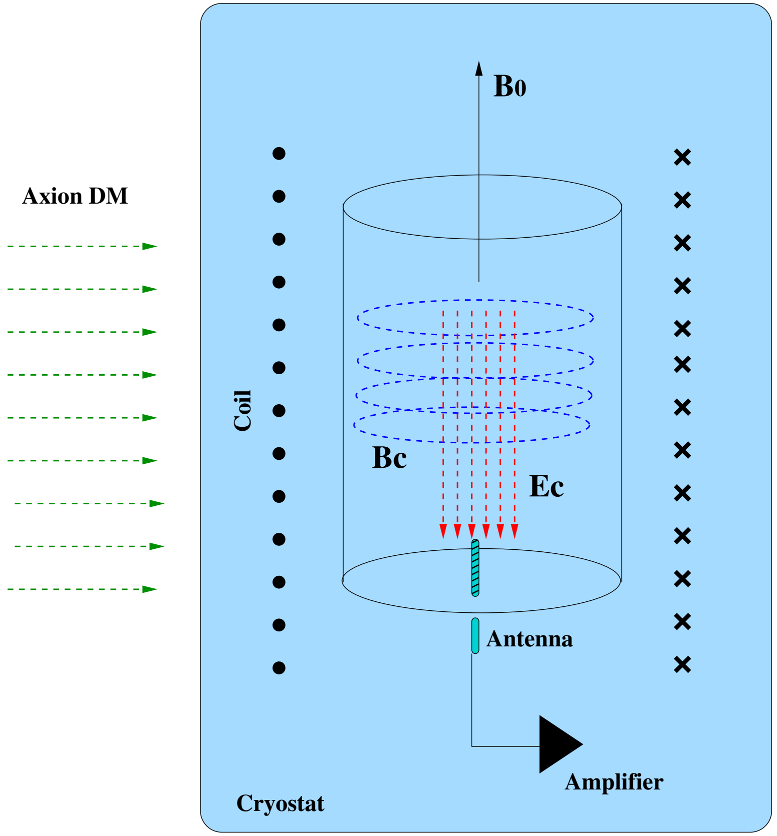
OUTLINE

- 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



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

THE KLASH PROPOSAL

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

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

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

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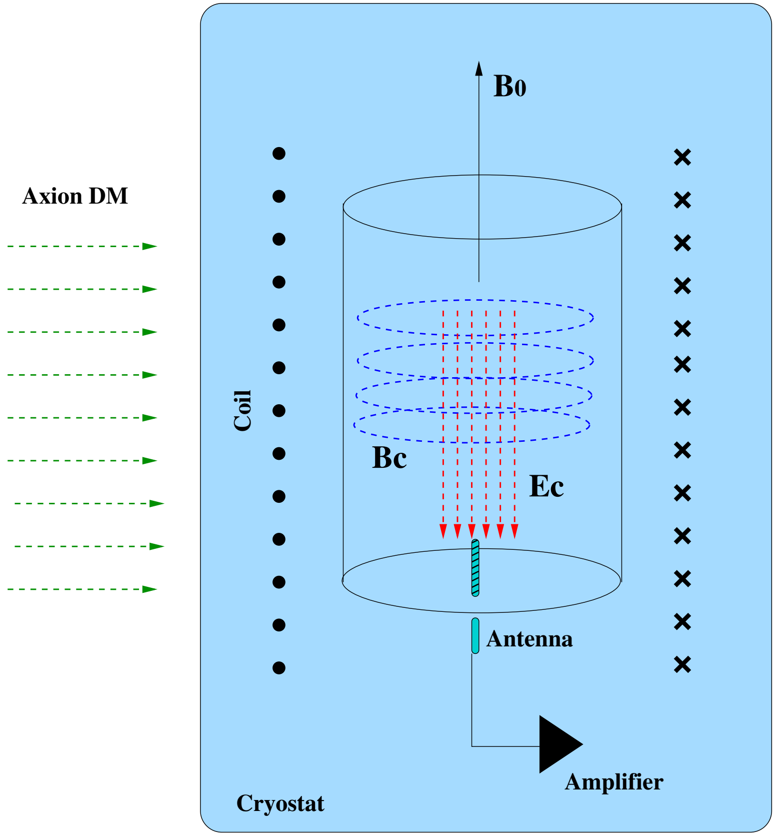
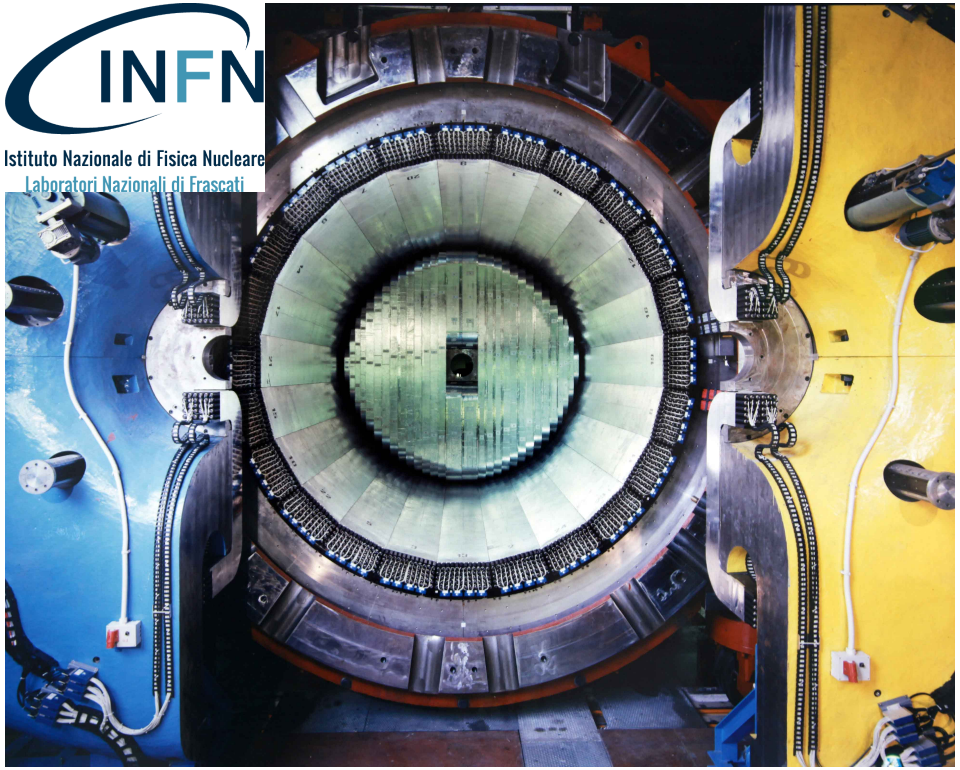
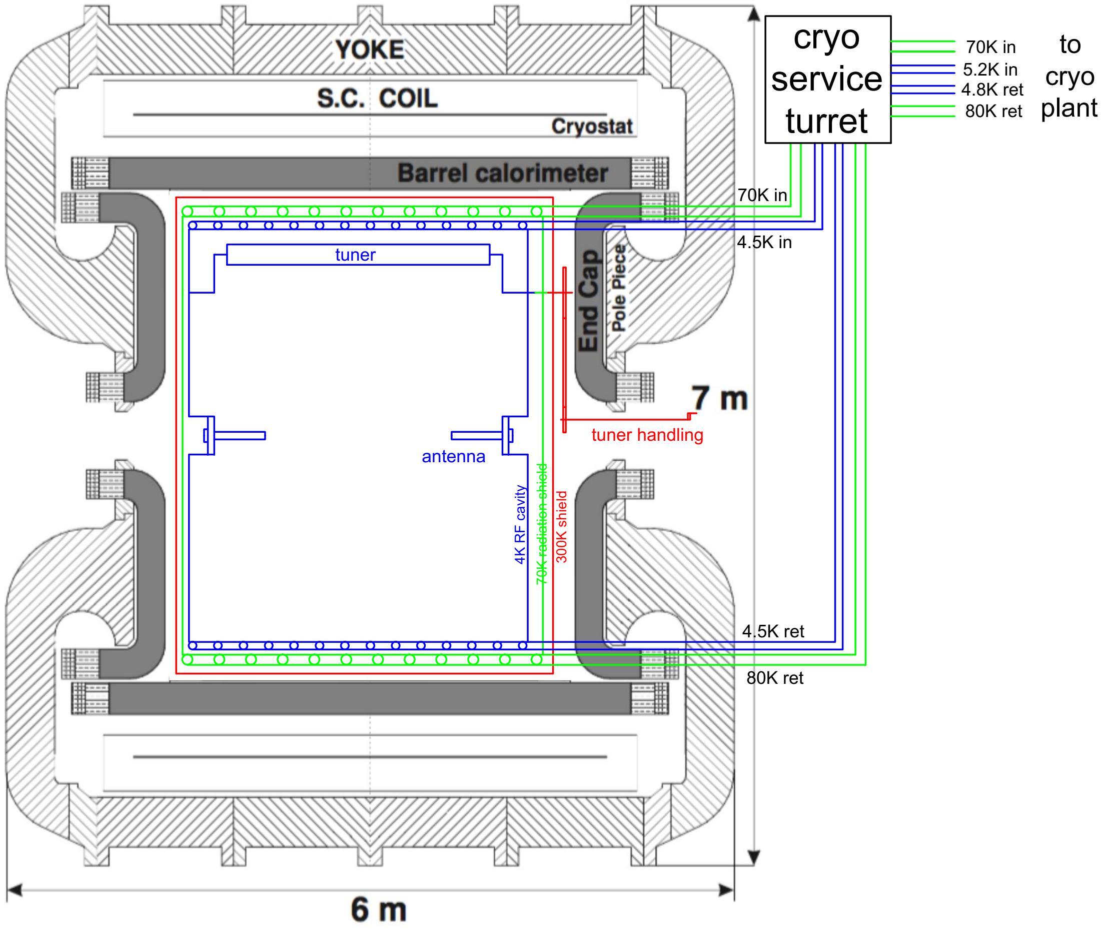


THE KLOE DETECTOR

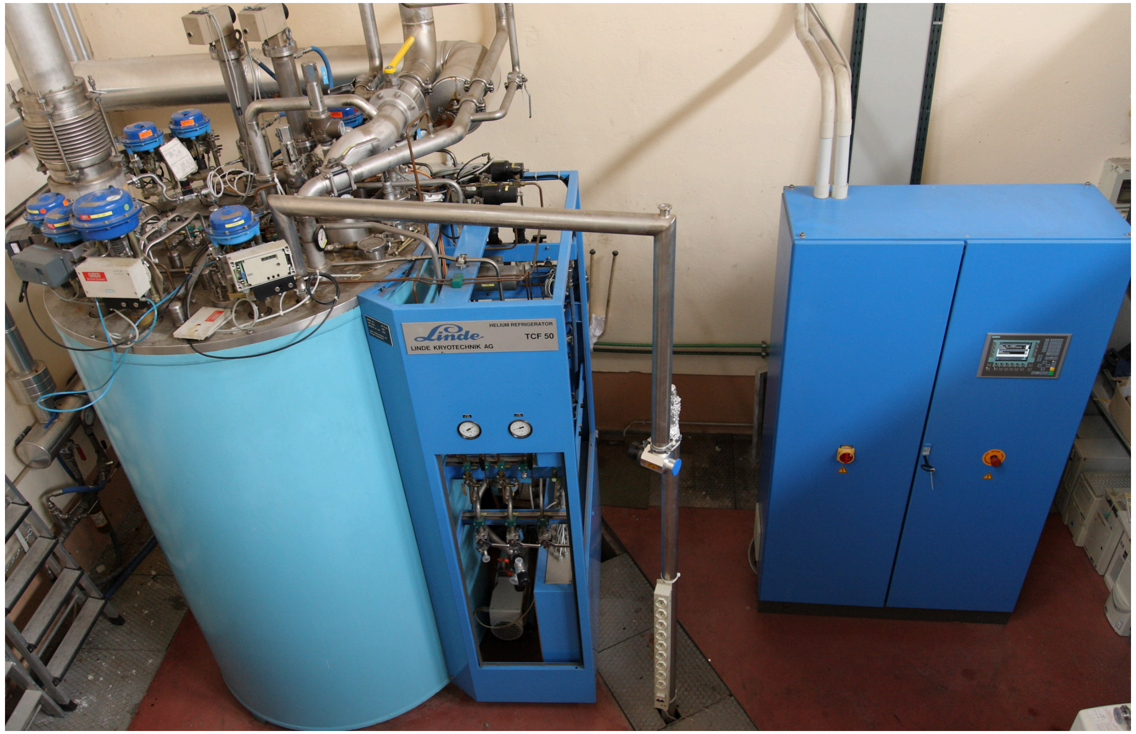




THE KLOE MAGNET

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

THE DAFNE CRYOGENIC PLANT

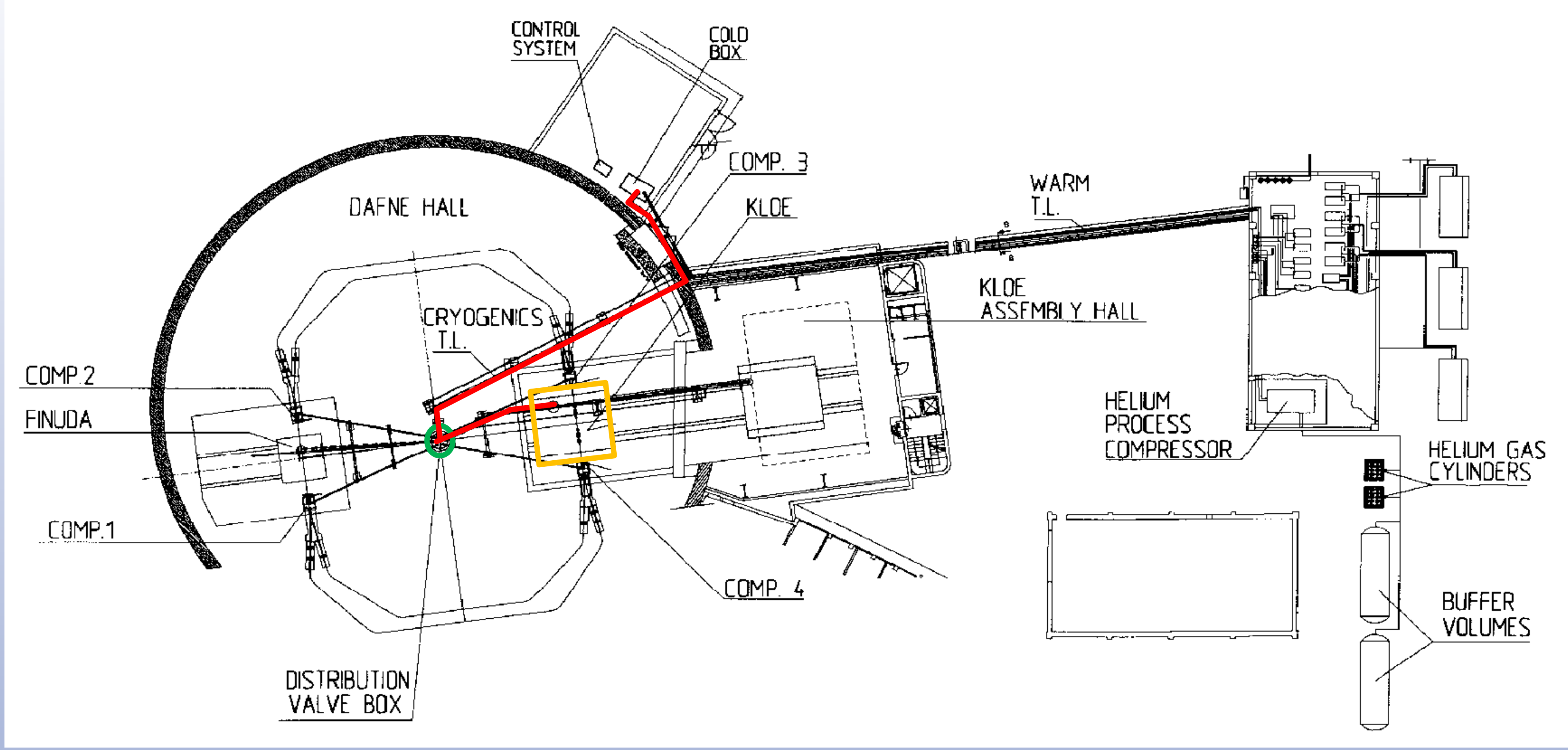


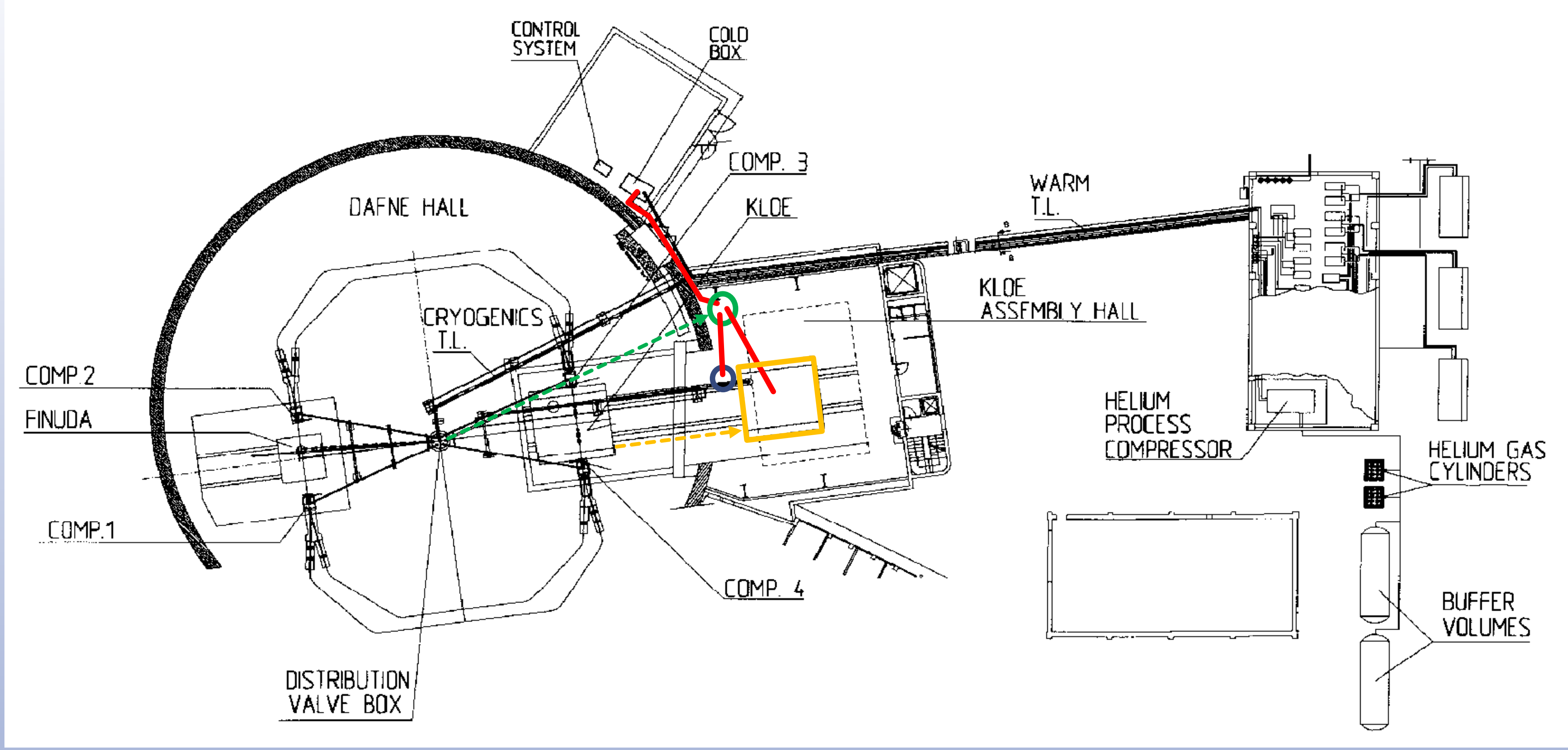
LINDE TCF 50 liquid He liquefaction/refrigeration plant

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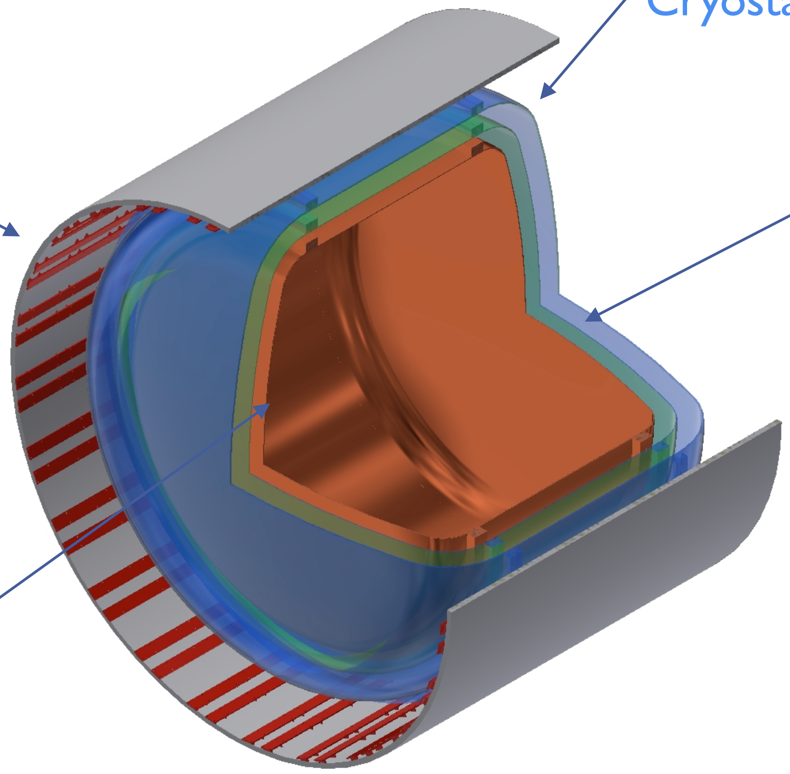
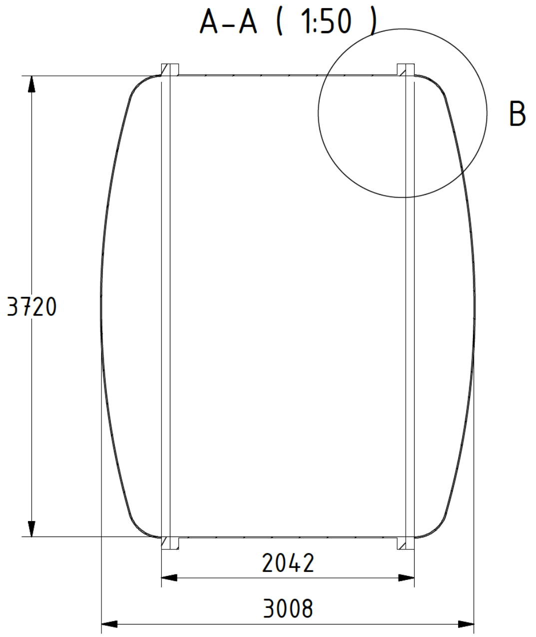
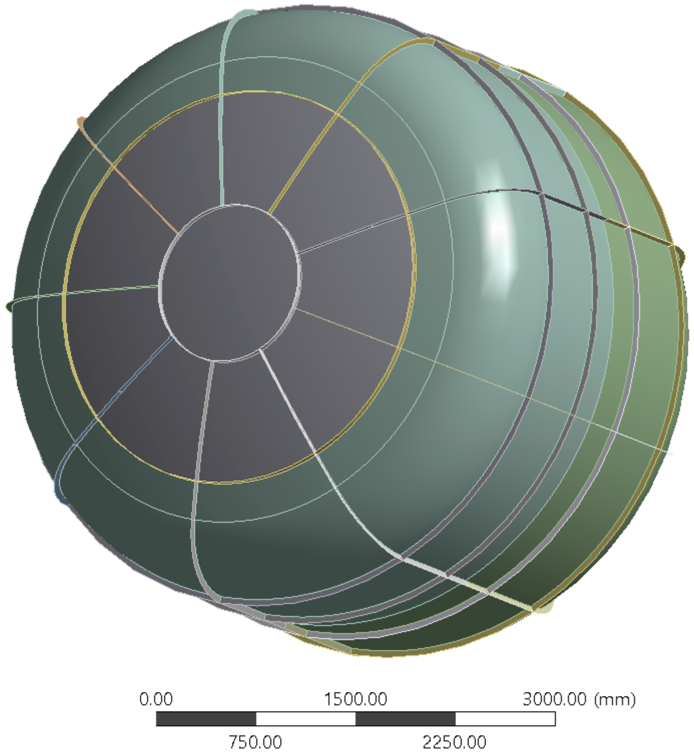
CRYOSTAT

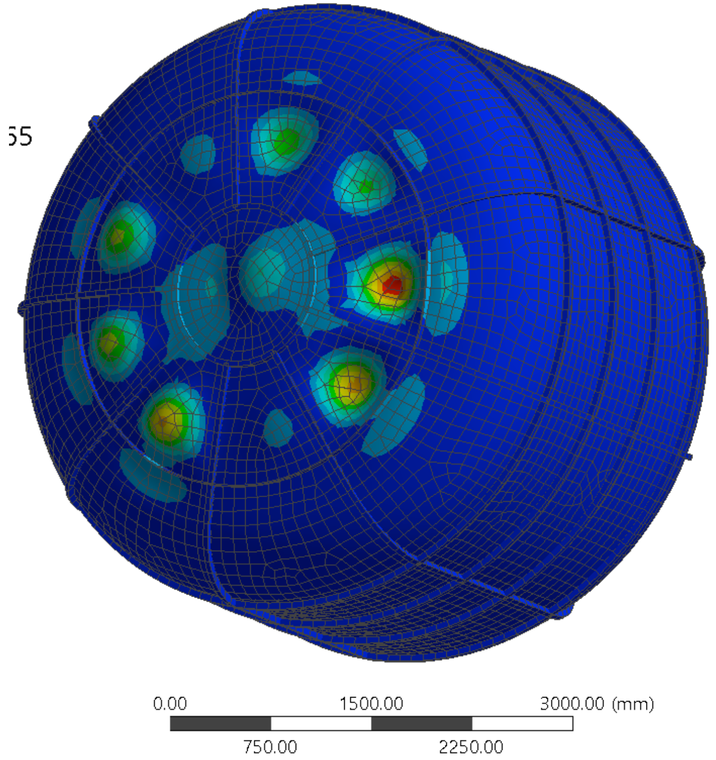




Cryostat Total Weight	~15 Ton
RF Cavity diameter (mm)	3720
RF Cavity length (mm)	3008
RF Cavity Volume (m^3)	~33

CRYOSTAT

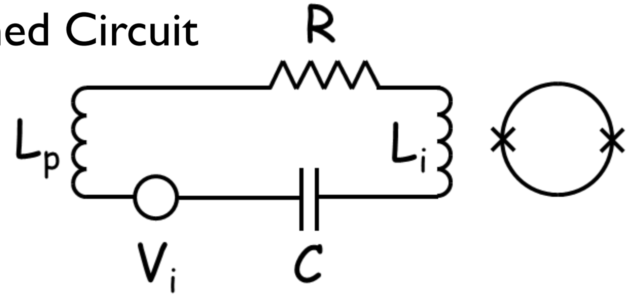




The external wall of the cryostat must withstand a pressure of 1 bar: ongoing calculations to balance mechanical resistance and weight.

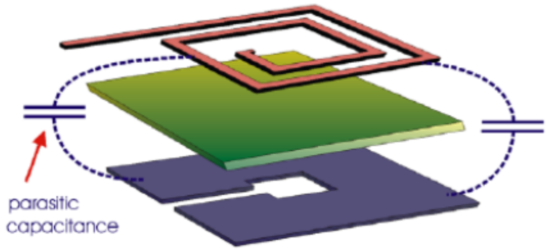
THE DC SQUID AS A RADIOFREQUENCY AMPLIFIER

Tuned Circuit



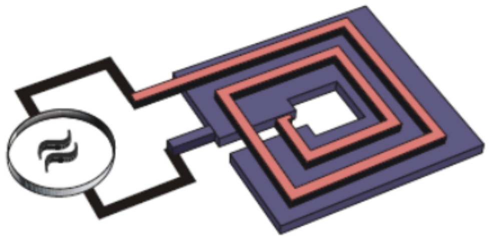
At frequencies higher than a few MHz it is convenient to use a tuned circuit:
e.g. Noise Temperature T_N=1.7K @93MHz and @4.2K
C. Hilbert and J. Clarke, J. Low Temp. Phys. **61**, 263 (1985).

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

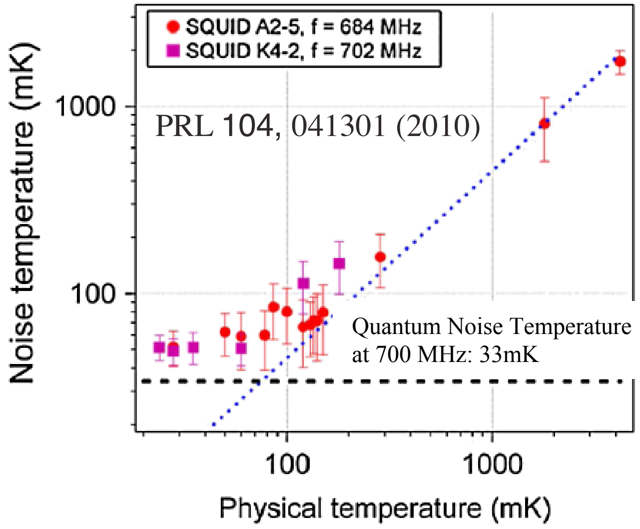
then

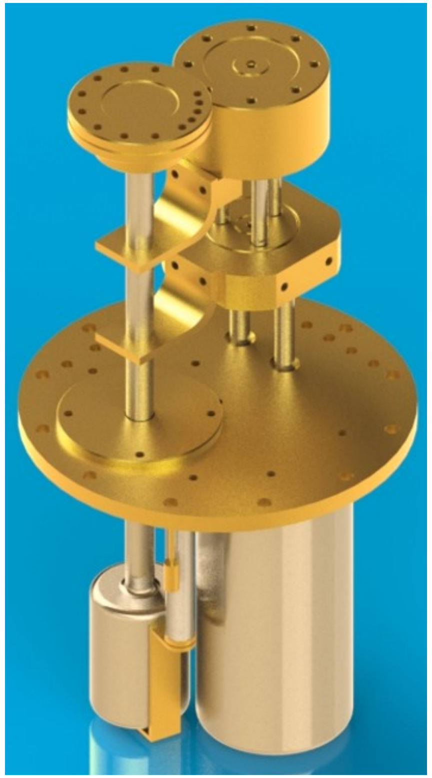


Possible solution: in contrast to the conventional input scheme the signal is applied between one end of the coil and the washer (the other end of the coil is left open).
e.g. T_N=52mK @538MHz and @0.1K (Quantum Limited T_N=26mK) M. Muck et al. Appl. Phys. Lett **78,** 967, (2001)

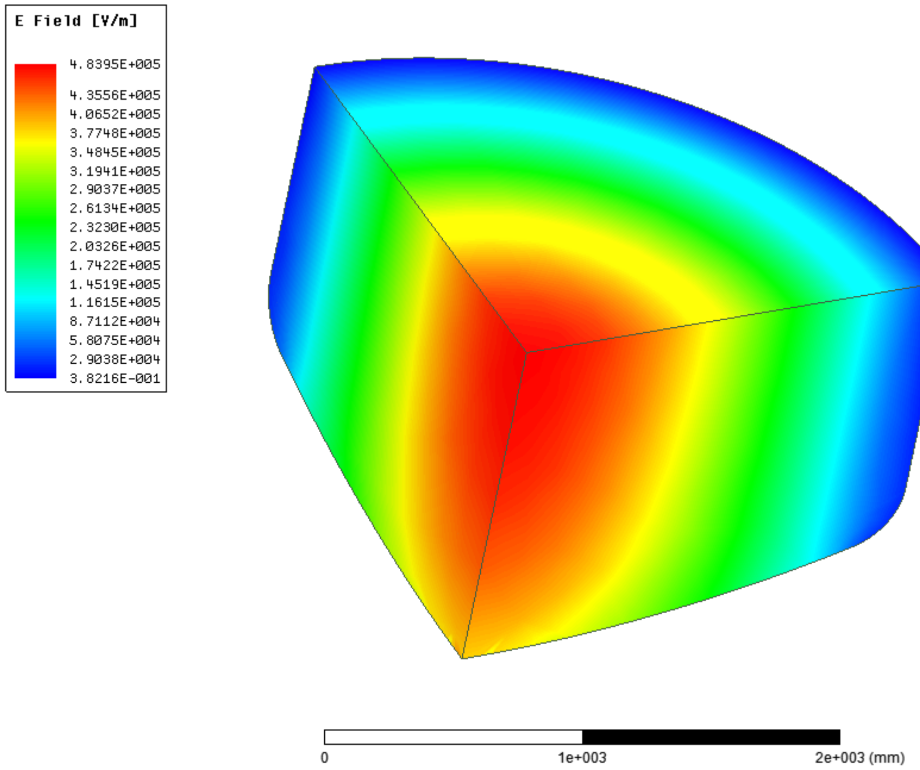
300 mK COOLING FOR SQUID

- 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

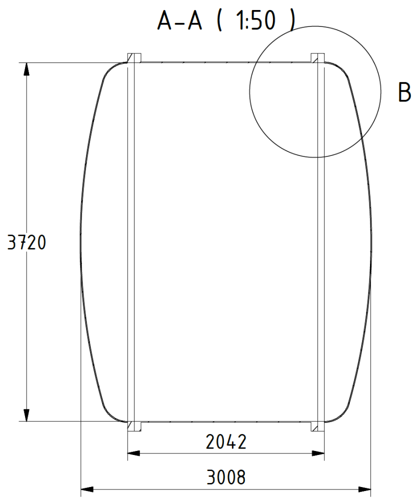




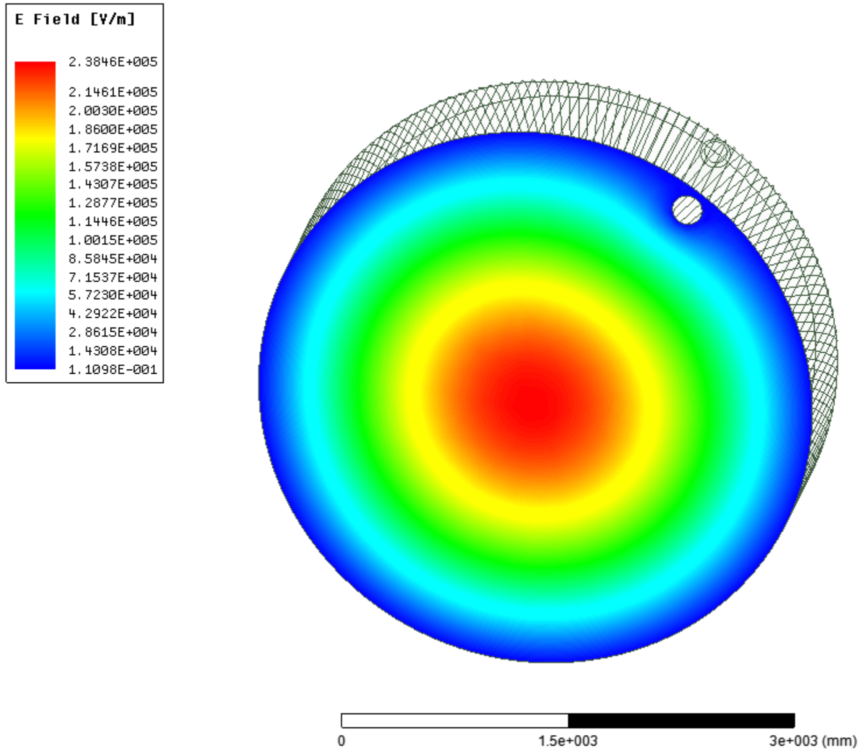
RESONANT CAVITY: RF SIMULATION



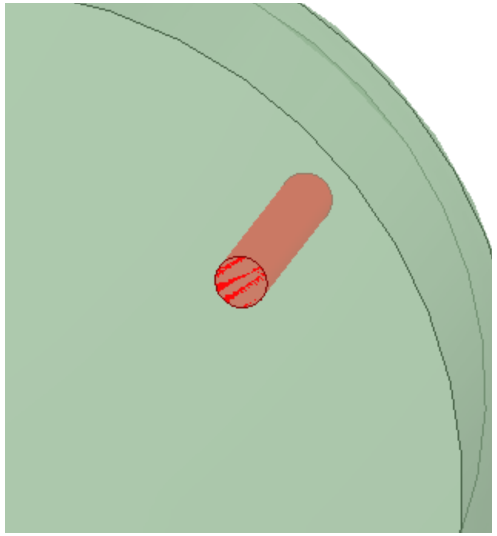
Mode	TM010
Frequency [MHz]	64
Q @ T=4K (RRR=25)	746,000
C_{010}	0.71



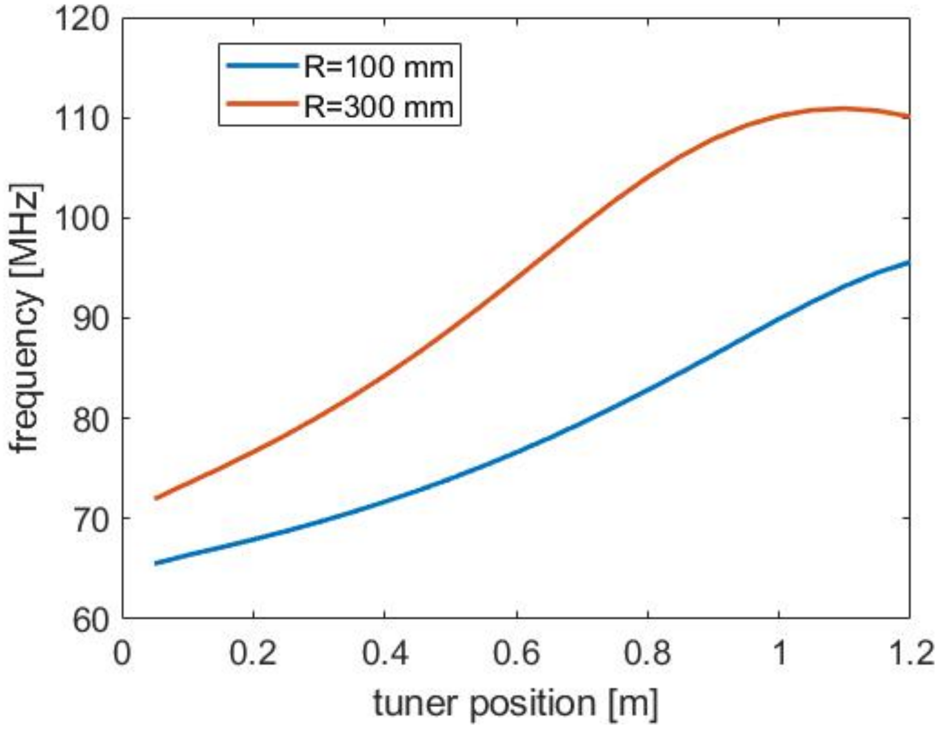
TUNING

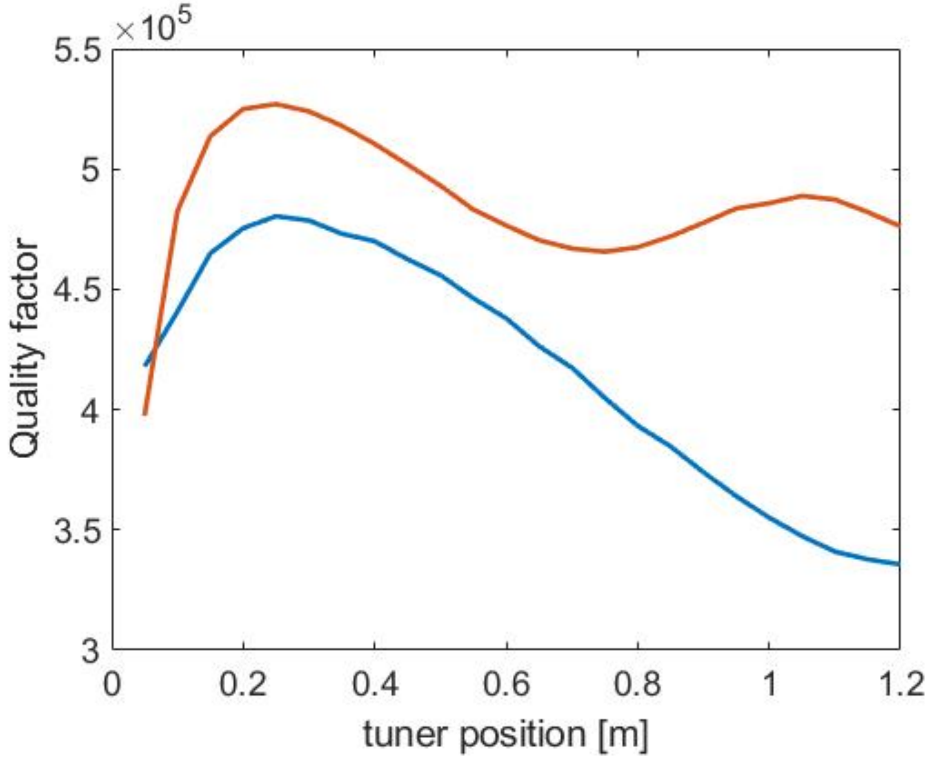


Simulation with tuning rods of different radii (100-300 mm) and with different numbers of rods.

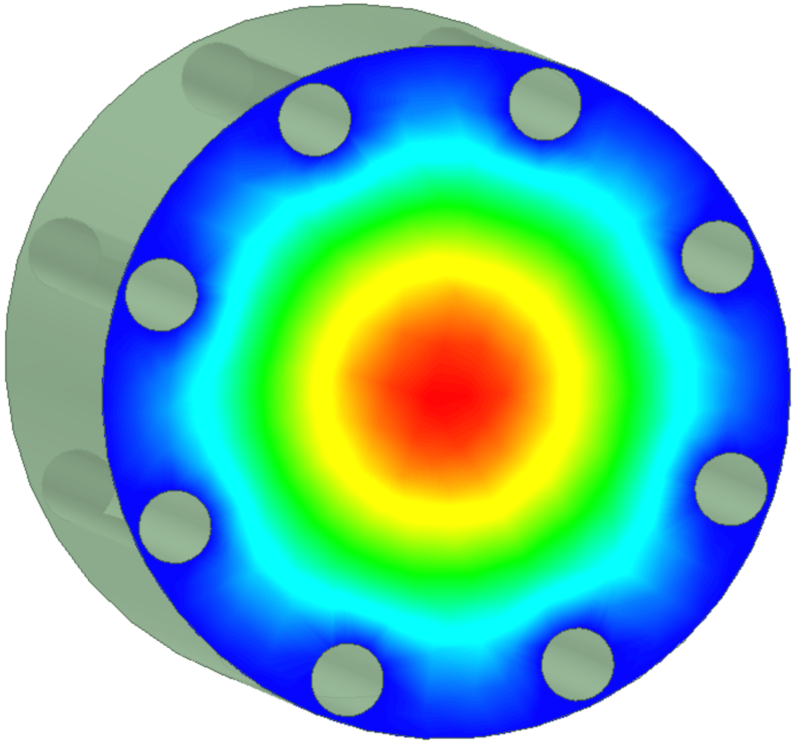


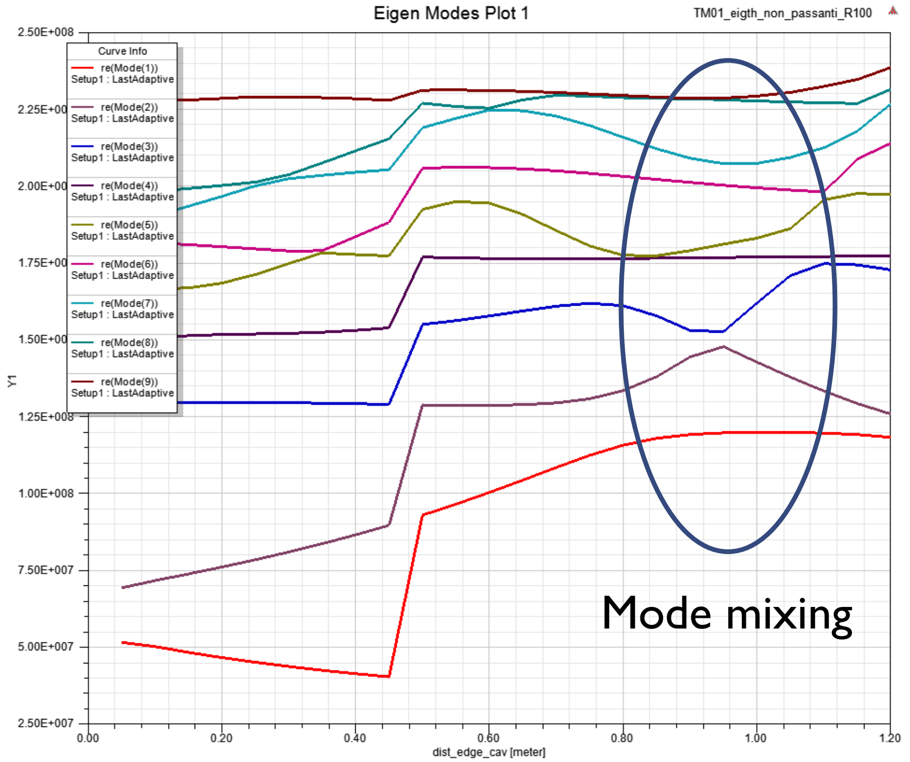
TUNING: TWO TUNING RODS





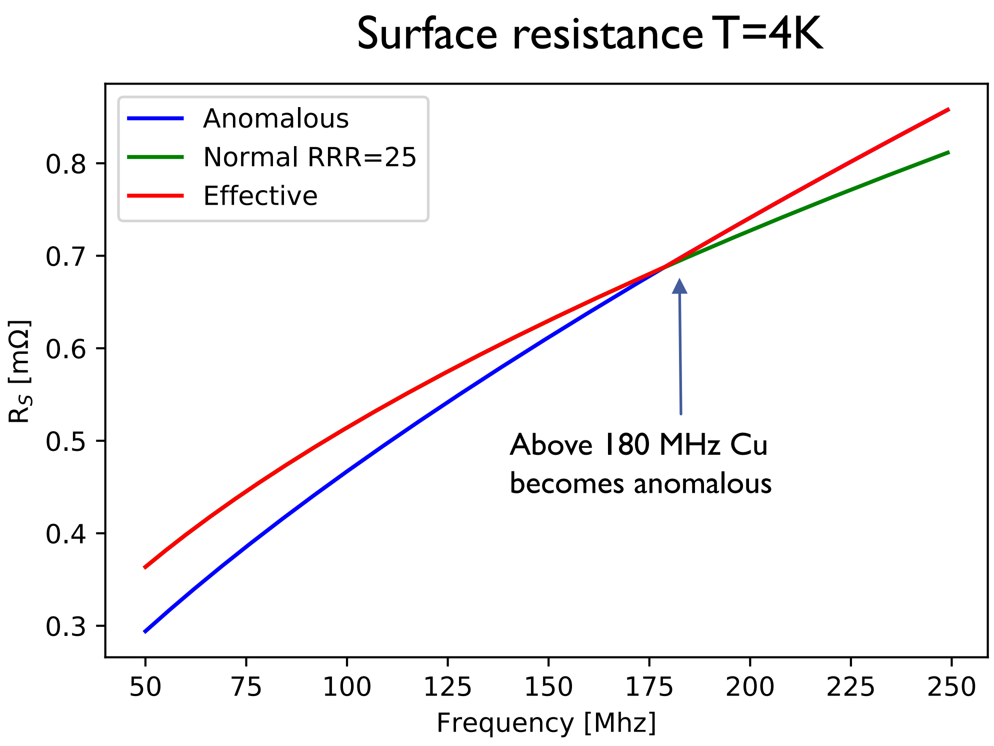
MORE RODS: MODE MIXING

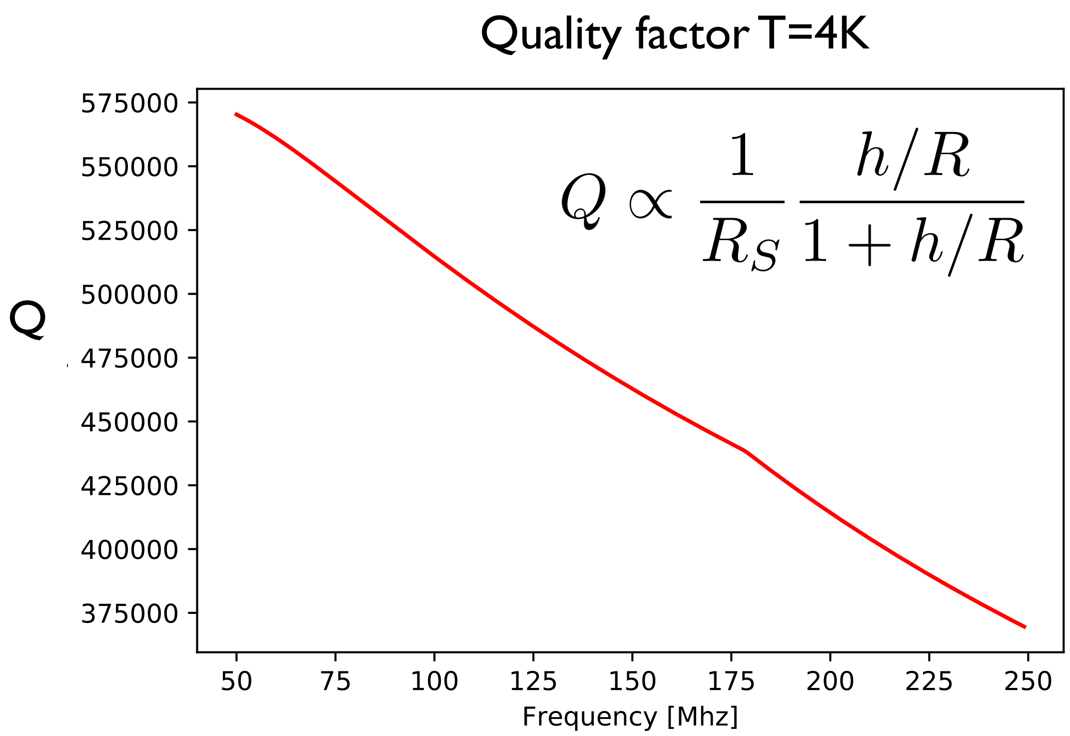




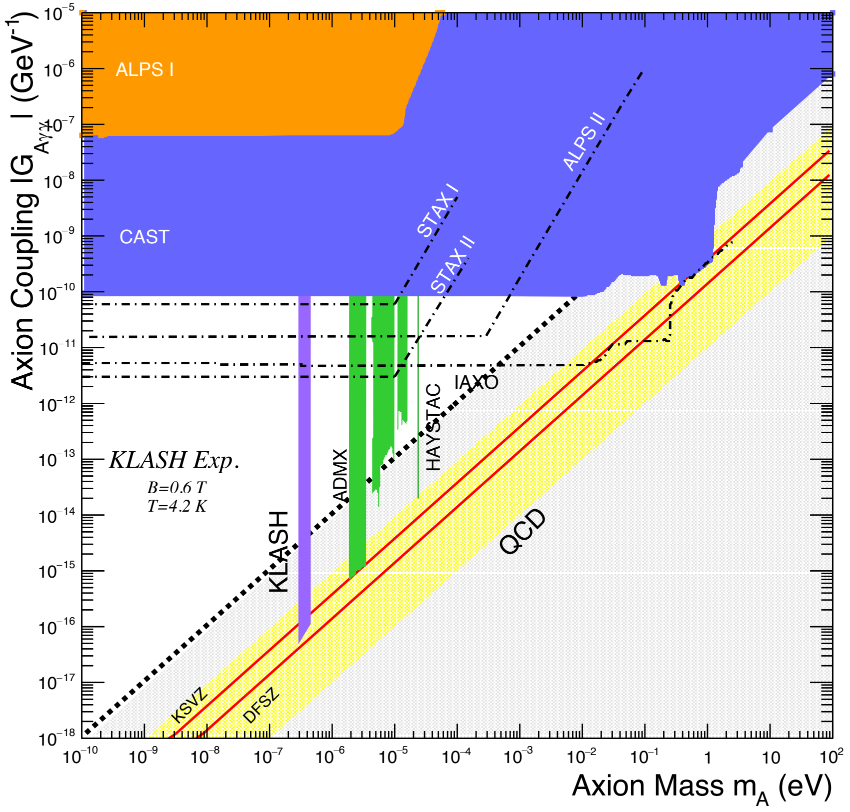
Investigating up to 8 rod.s Mode mixing becomes a problem.
In the following, we assume only 2 tuning rods with R=300mm.

Q VS FREQUENCY





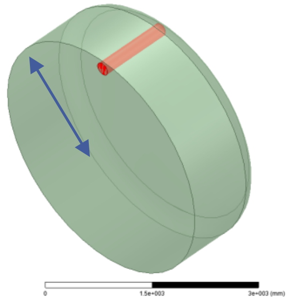
EXPECTED SENSITIVITY: PHASE I



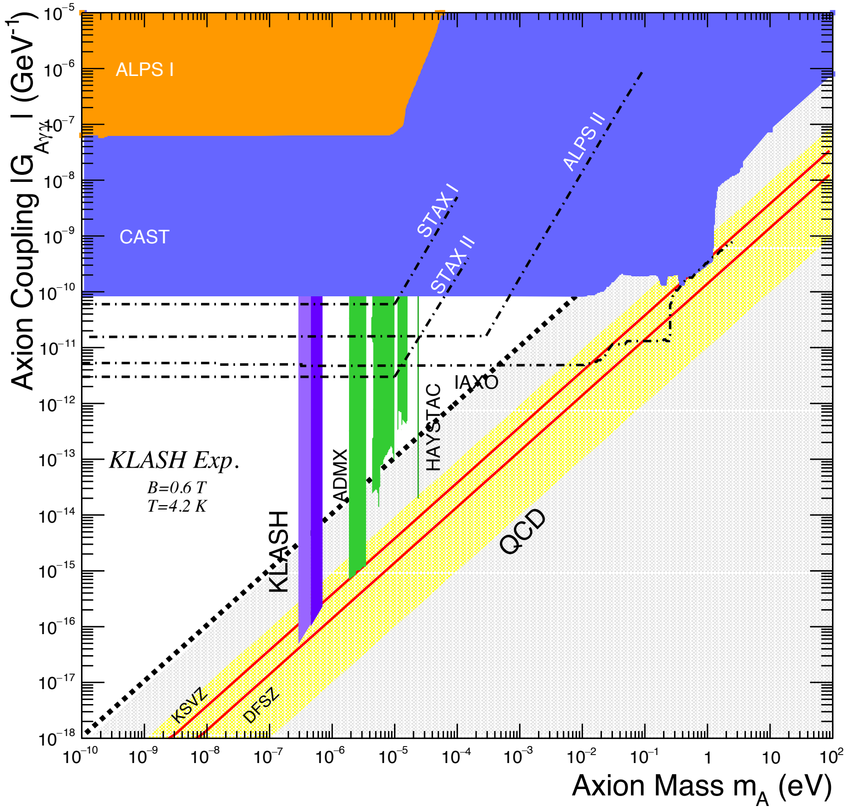
*Gray band PRL **118**, 031801 (2017)

Phase I	I 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

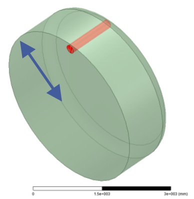


*Gray band PRL **118**, 031801 (2017)

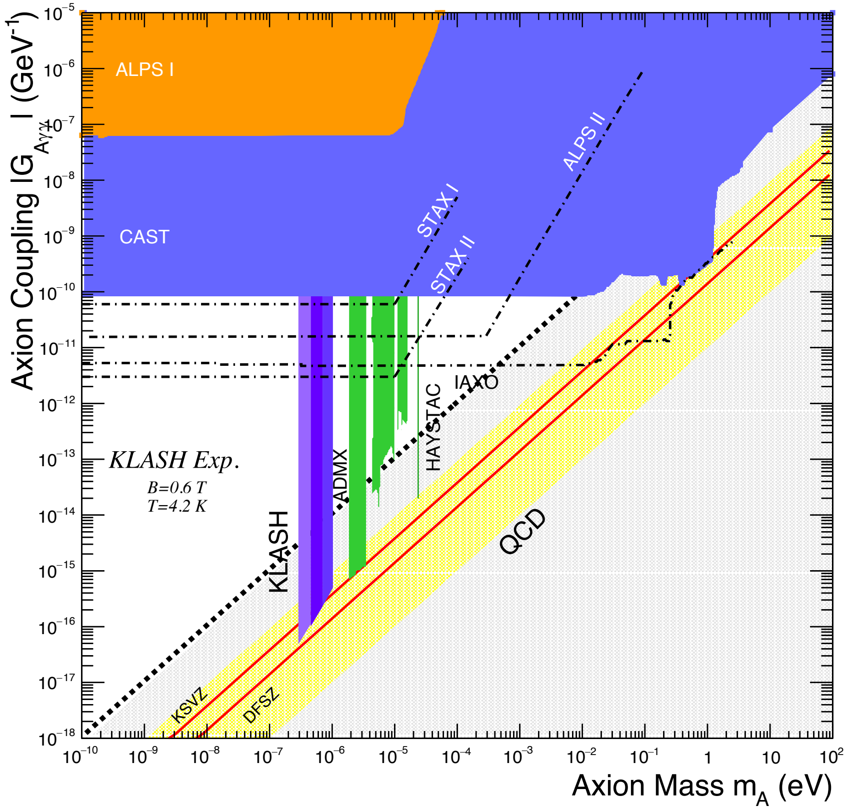
Phase II	1 year data taking
Radius [m]	1.2
Frequencies [MHz]	110-170
Q (110MHz)	500,000
Power [W] (KSVZ)	7.5×10^{-23}
Rate [kHz] (KSVZ)	1
Integration time (min)	15

1st RF Cavity Replacement

R=1.2m



EXPECTED SENSITIVITY: PHASE III

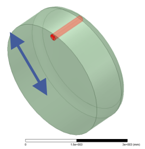


*Gray band PRL 118, 031801 (2017)

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



LOI

The KLASH – Letter Of Intent DRAFT

Introduzione

Con questo documento proponiamo di effettuare una ricerca di assioni galattici nell'intervallo di massa tra 0.3 e 1 μeV usando una cavità risonante con un volume di circa 33 m^3 raffreddata a circa 4 K ed immersa in un campo magnetico di 0.6T generato dal magnete superconduttore costruito per l'esperimento KLOE situato ai Laboratori Nazionali di Frascati. Questo esperimento, chiamato KLASH (KLoe magnet for Axion SearcH), avrebbe la sensibilità necessaria ad osservare assioni QCD predetti dal modello KSVZ [1]. Nel seguito descriviamo brevemente il caso scientifico, l'apparato sperimentale e diamo una stima dei costi e dei tempi necessari alla realizzazione del progetto.

Draft of LoI sent to M.Pallavicini to start the discussion in CSN2 and requests for TDR/CDR preparation.

REQUESTS FOR TDR

WP	FTE (x1 anno)	R&D	Persone
Fisica	0.2	No	A.Mirizzi (Ba), D. Babusci, D.Montanino (Le)
Progetto meccanico	0.5	No	L.Pellegrino + Servizio Div.Acc. LNF
Criogenia	0.5	Si	C.Ligi, G.Ceccarelli
Automazione	0.1	No	Ditta per dettagli+ Servizi Div. Acc. + R.Ricci con Servizio Impianti Elettrici LNF
Infrastruttura	0.1	No	R.Ricci con Servizio Impianti Elettrici LNF
Cavità risonante	0.5	Si	D.Alesini + Servizio RF Div.Acc. LNF
Amplificazione segnale	1	Si	P.Falferi (Tn), D.Di Gioacchino, C.Gatti
DAQ (ed elettronica 300k)	0.2	No	D.Moricciani (Rm2), G.Lamanna (Pi)

R&D	Costo (k€)
Progetto esecutivo (Ditta esterna)	10-20
Prototipo refrigeratore 300 mK	5
Modello cavità e tuners (5GHz)	5
Squid 100 MHz	30

Costo costruzione: stimato grossolanamente intorno a 1-2 M€

CONCLUSION

- We propose a large haloscope with the sensitivity to find galactic axions in the mass window 0.3-1μeV.
- LoI submitted to INFN Commission II for funding a CDR/TDR. Discussion ongoing.

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