

Attività iniziali su JJ in Lab COLD

SIMP LNF Group

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COLD LAB
29-11-2018



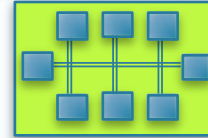
Istituto Nazionale di Fisica Nucleare
LABORATORI NAZIONALI DI FRASCATI

Primi passi: *prendere confidenza con JJ*

Dic 2018-Feb 2019

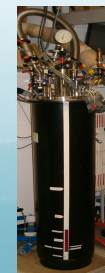
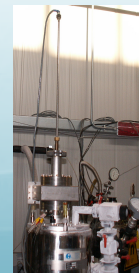
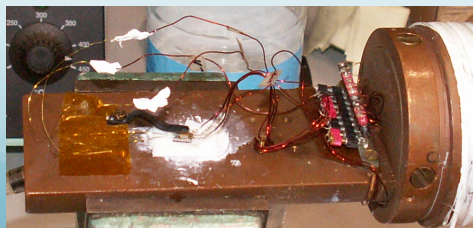
- Iniziare a T (4.2K) in LHe

➤ JJ realizzate con composti di Nb (**CNR-IFN**):



- Messa a punto inserto per I-V criostato ^4He ad immersione
 - ✓ Sample holder rame (LNF)
 - ✓ Bobina x campi B_{DC} (gauss) (LNF)
 - ✓ Riscaldatore (LNF)
 - ✓ Termometro cernox (LNF)
 - ✓ Cilindro x schermare campo magnetico terrestre (μ metal) (LNF)

- ☐ Cablaggio Inserto, realizzazione bobina (Dic 2018- Feb 2019)
- ☐ Flangia inserto-criostato ad immersione (Dic 2018- Feb 2019)
- ☐ Primi tests (Feb/Marz 2019)

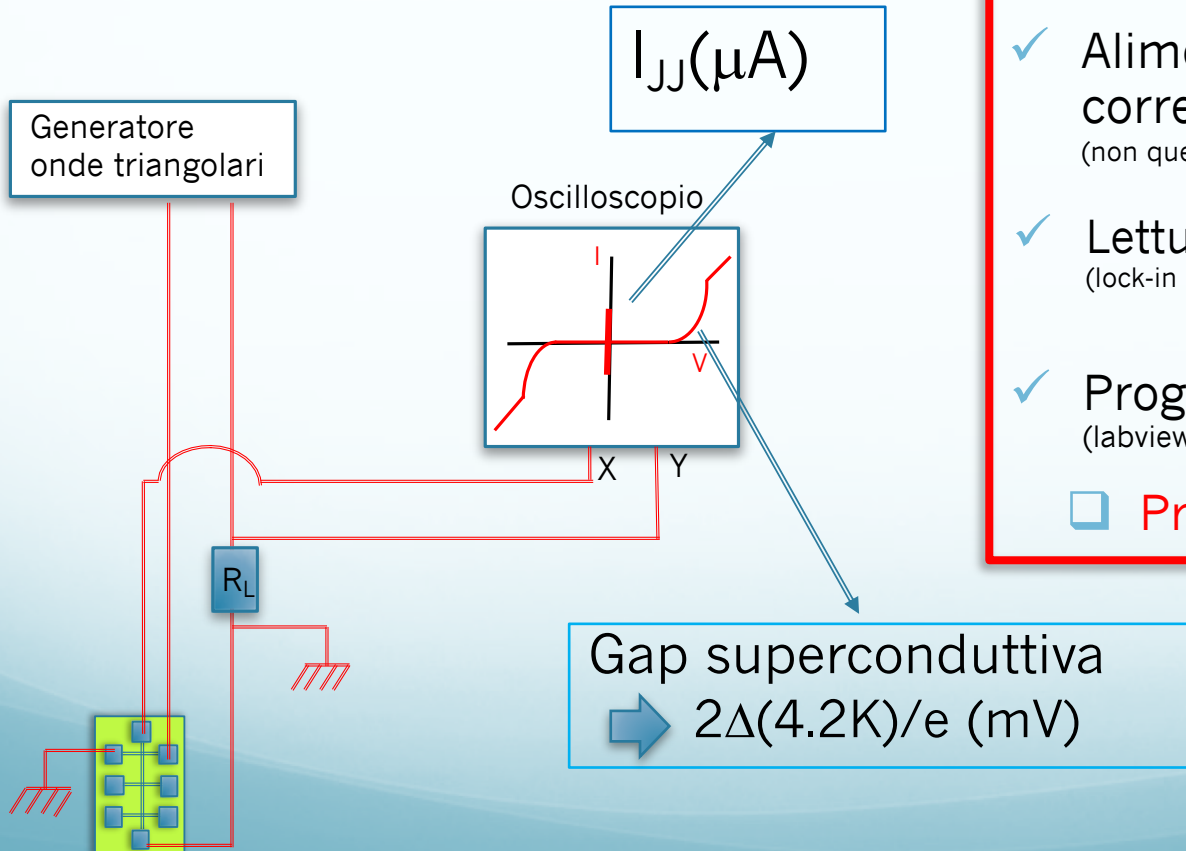


Primi passi: *prendere confidenza con JJ*

Febbraio/Marzo 2019

- Approntare una I-V con JJ di composti Nb : I_{jj} , Δ

T=4.2K



- ✓ Inserto x I-V con JJ(Nb based)
LNF (CNR-IFN) (Dic 2018-Gen2019)
 - ✓ Alimentatore denti di sega in corrente (μA) basso rumore
(non quella definitiva: tipo HP33120A? ...da una tesi)
 - ✓ Lettura V (mV)
(lock-in o simile amplificatore)
 - ✓ Programma di acquisizione
(labview)
- ☐ Primi tests (Feb 2019)?

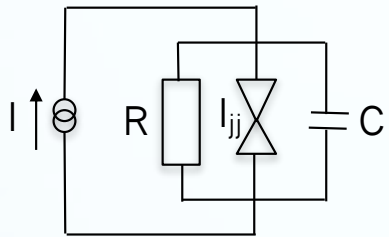
Primi passi: *prendere confidenza con JJ*

- Un test x studio distribuzione switch I_{jj} : uscita dallo stato metastabile $V=0 \rightarrow V \neq 0$

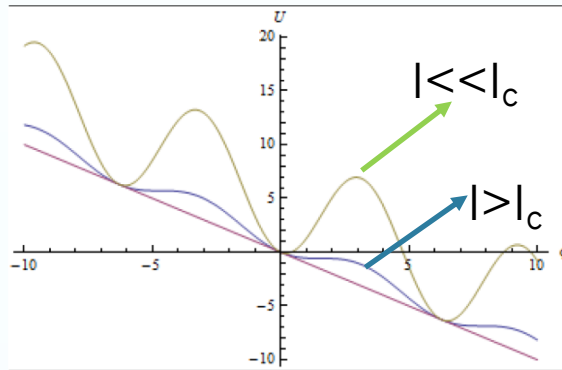
T=4.2K

(Marzo 2019 ?)

✓ RCSJ model



$$U = I_c \left[1 - \cos \phi - \phi \frac{I}{I_c} \right]$$



$$\omega_p = \sqrt{2eI_c / \hbar C} \quad \omega_p / 2\pi \text{ è la Frequenza di plasma Josephson}$$

$$Q = \omega_p RC$$

$$Q^{-1} = \text{damping}$$

➤ **attivazione termica**
→ escape process $\Gamma(I)$

➤ $\frac{dI}{dt}$ sweep rate

$P(I)$
Switching probability

SET-UP

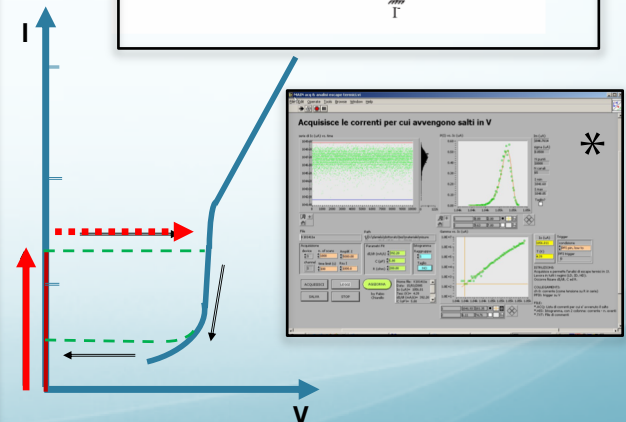
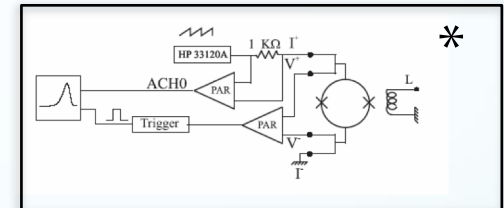
➤ T (4.2K)

➤ V=0volt

➤ Generatore dente
(...tipo HP33120A? ...da una tesi)

➤ rampa: $dI/dt = 1 \text{ mA/s}$

➤ eventi = 10^4



* Cap.2 Simeone 2005, tesi
(.....Fabio Chiarello CNR?)

I-V JJ nel criostato a diluizione CNR

Dic 2018-Febbraio/Marzo 2019

- Ripristino criogenico criostato a diluizione con test (LNF)

- Messa a punto inserto I-V (LNF) mK

- ✓ Sample holder rame
- ✓ Termometri
- ✓ Riscaldatore ?
- ✓ Gabbia schermata magnetica (μ metal?)

- Sviluppo Elettronica per I-V (LNF)

- ✓ Alimentatore denti di sega in corrente (mA) basso rumore
- ✓ Lettura V (μ V)
- ✓ Programma di acquisizione

- Realizzazione JJ basata su Al (CNR)
(..o primo test con JJ Nb studiate in LHe?)

- ☐ Primi tests (mK):
(da Marz 2019 ?)

- ✓ I-V JJ
- ✓ Switch current distribution (mK)

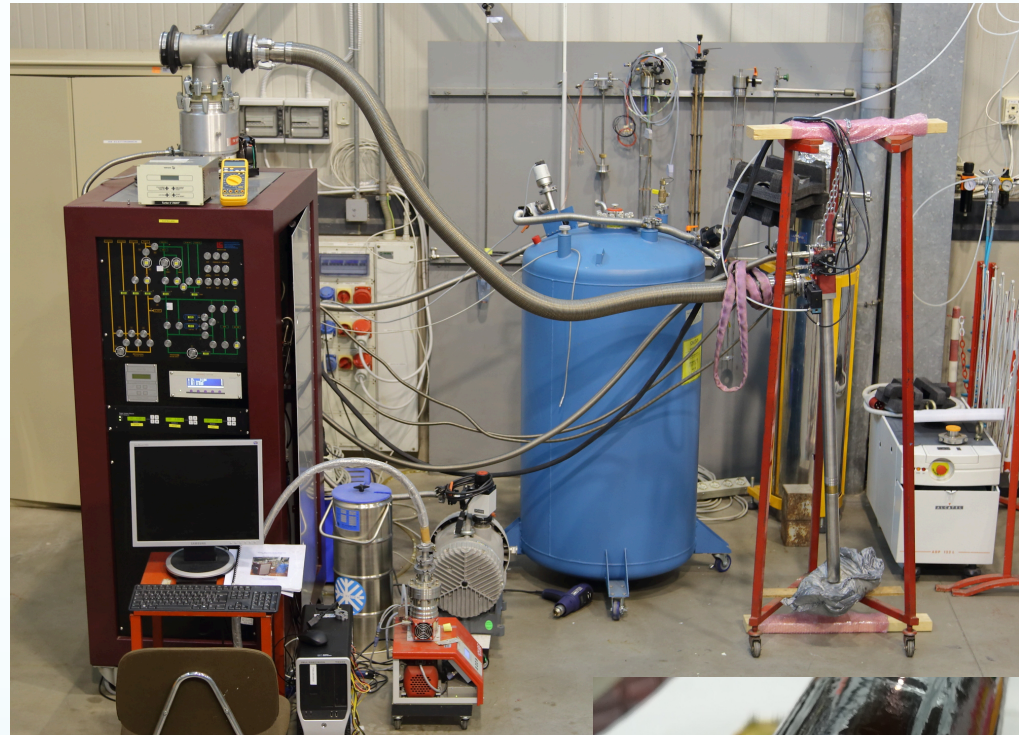
Lab COLD / CNR fridge



Lab COLD / CNR fridge

- *Leiden Cryogenics MCK50/100 Dilution Refrigerator*
- $T_{\text{base}} \approx 25 \text{ mK}$
- $\dot{Q} \approx 100 \mu\text{W} @ 120 \text{ mK}$
- Plastic MC
- wet exp. volume $\phi=24, h=40$
- Optional cold finger
- 24+12 available wires
- Liquid He/N₂ cryostat
- No magnetic field
- ~ ready to be tested @ LNF
- (needs: Control Sys. / LHe / ³He)

...Qui ci stà aiutando Carlo anche **Luca Foggetta (LNF)**...



Milestone SIMP

Milestone September 2019: DC measurements step 0 device

1 Milestone :

✓ Design and setup of AI JJ (CNR)

- Low noise DC generator (10 ns ramps, nA)
- electronics for trigger circuit
Noise level: 0.1 nA

➤ amplification



Amplifier
Stanford
Research
SR560

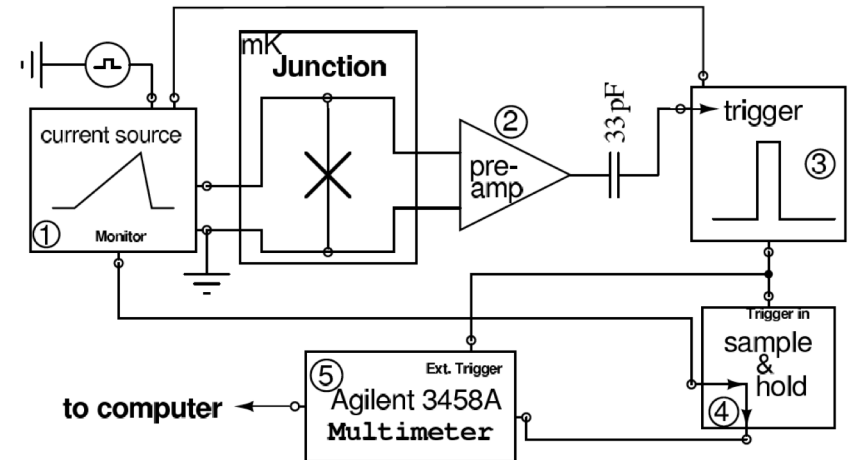
➤ filtering of the lines*

- * Filtering must be compatible with signal speed (>MHz) for time coincidence studies



NI ADC

➤ acquisition



Milestone SIMP

Milestone September 2019: DC measurements step 0 device

2 Milestone :

✓ AI JJ DC characterization at mK

➤ Switching current probability density

$$P(I) = \frac{\Gamma(I)}{dI/dt} \exp \left[- \int_0^I \frac{\Gamma(I')}{dI'/dt} dI' \right]$$

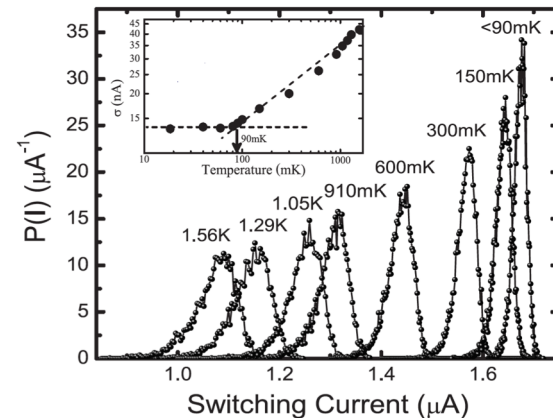
Total escape rate

$$\Gamma(I) \simeq \Gamma_T(I) + \Gamma_q(I)$$

Thermal activation

Macroscopic Quantum Tunneling

- Determine ω_p , Q and I_c from fit to data
- Determine L , R and C



Physics Procedia 36 (2012) 110 – 115

$$\begin{aligned} I &= I_c \sin \varphi \\ V &= \frac{\hbar}{2e} \frac{d\varphi}{dt} \\ \Phi_0 &= \frac{h}{2e} \\ \Phi &= \frac{\Phi_0}{2\pi} \varphi \\ E_j &= \frac{\Phi_0 I_c}{2\pi} \\ E_c &= \frac{2e^2}{C_j} \\ L_j &= \frac{\Phi_0}{2\pi I_c} \\ \omega_p &= \sqrt{2E_j E_c} / \hbar = \frac{1}{\sqrt{L_j C_j}} \end{aligned}$$

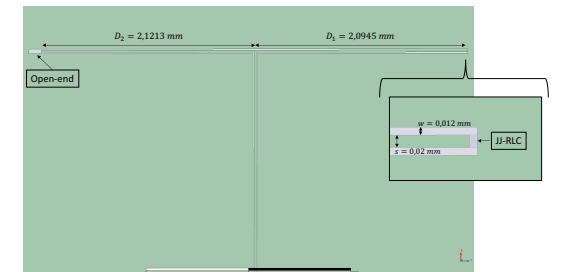
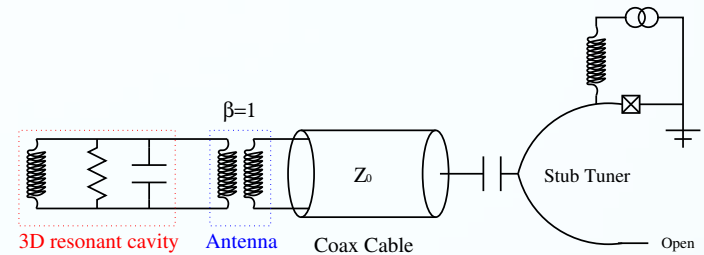
Milestone SIMP

Milestone September 2019: AC measurements step 1 device
Test “caldo” del chip costruito da CNR (no JJ)

3 Milestone:

✓ **Tests of Stub Tuner (ST), misura S11**

- First Test AI ST with VNA at 4 K
(Terminate ST with 500 k Ω resistor)



4 Milestone:

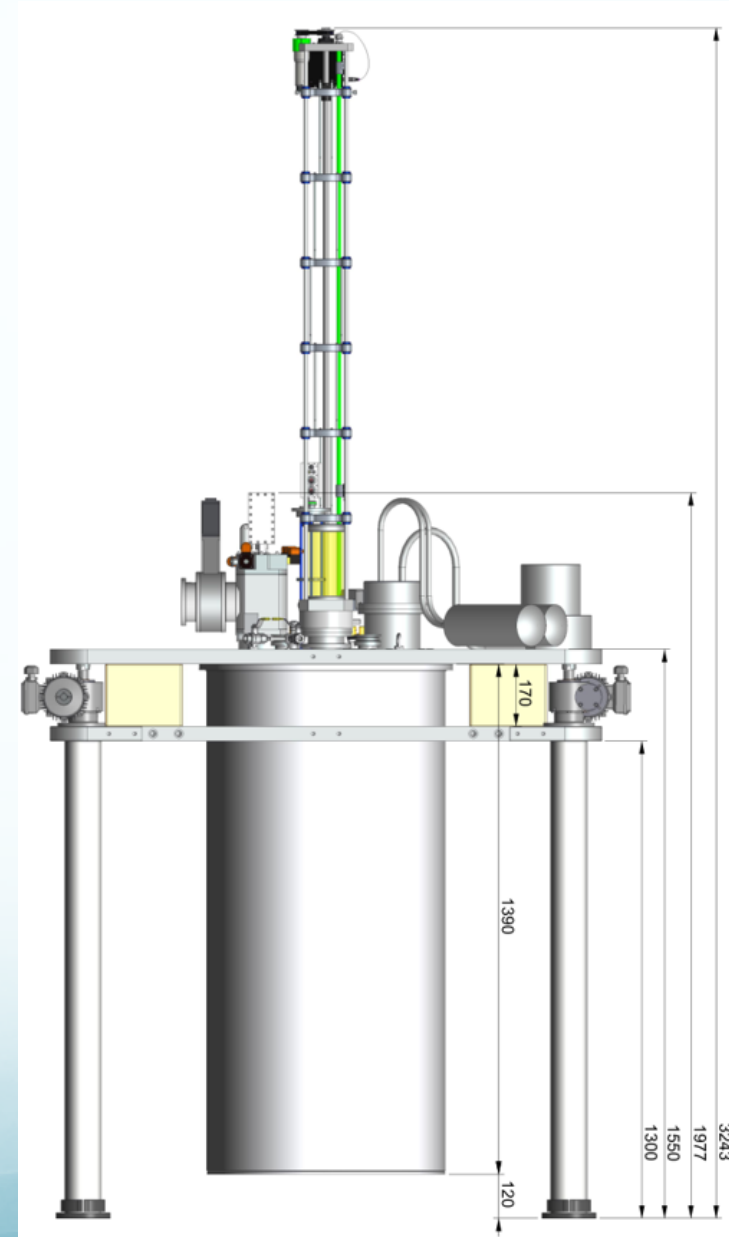
✓ **Screening (already in program for Quax)**

- μ Metal and Cryoperm screening
(Shielding box for JJ at 4K)

I-V JJ nel criostato a diluizione LNF

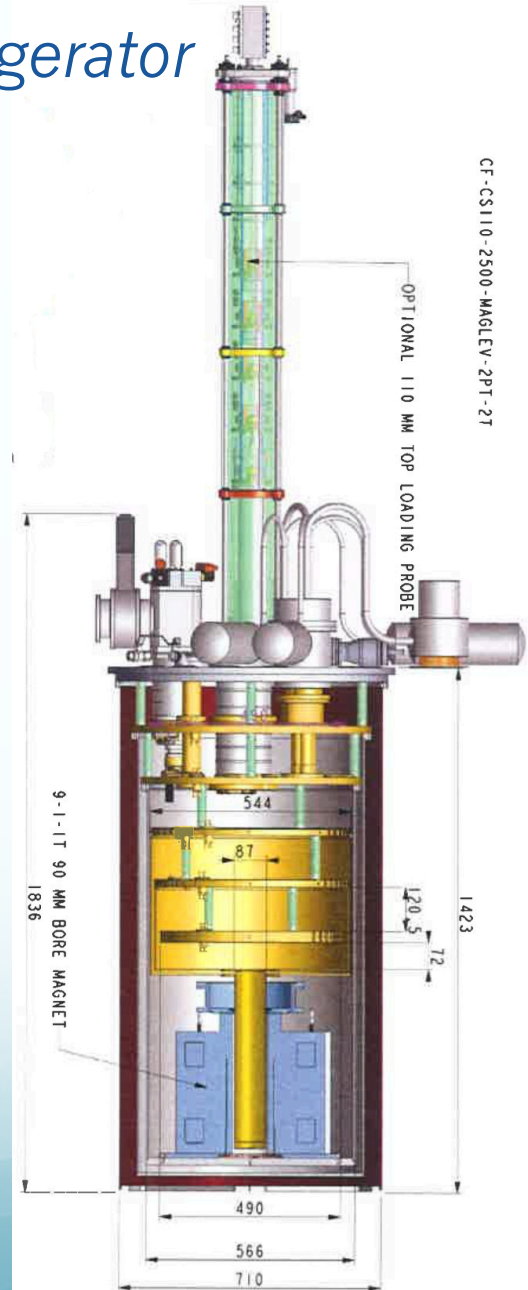
2019

- Arrivo presso lab COLD (LNF)
- Tests criogenici (LNF)
- Messa a punto inserto I-V (LNF)
- Test Elettronica per I-V sviluppata x criostato CNR (LNF)



LNF Cryostat w/ Dilution Refrigerator

- *Leiden Cryogenics CF-CS110 Dilution Refrigerator*
- $T_{\text{base}} \approx 8 \text{ mK}$
- $\dot{Q} \approx 1 \text{ mW @ } 120 \text{ mK}$
- Dry cryostat (PT 1.8 W @ 4.2 K)
- $\phi=110 \text{ mm}$ clear shots tube
- Ready to host a SC Magnet
- In construction @ Leiden



Milestone SIMP: tempistica ragionevole...

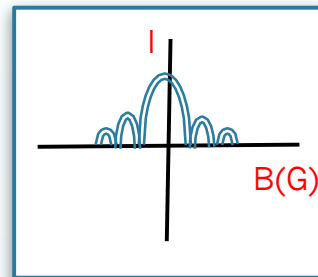
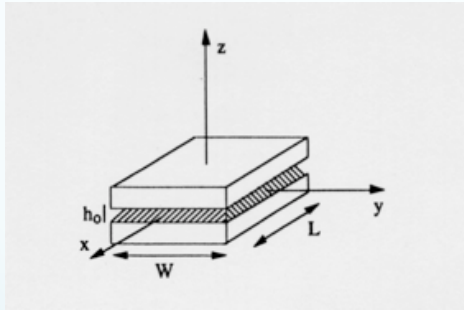
Task	1 trimestre	2 trimestre	3 trimestre	4 trimestre
Setup CNR refrigerator				
Setup LNF refrigerator				
Bias and daq electronics				
JJ 4 K DC test				
JJ @ mK DC test				
Shield test				

Altri possibili items: *per prendere confidenza con JJ*

Da Marzo 2019 ?????

- I_{JJ} vs $B(\text{gauss})$: misura di λ_L

$$\triangleright I_c(B) = I_c(0) \left[\frac{\sin \pi \phi / \phi_0}{\pi (\phi / \phi_0)} \right]$$



➤ Periodicità: $H^* = \phi_0 / L * d$

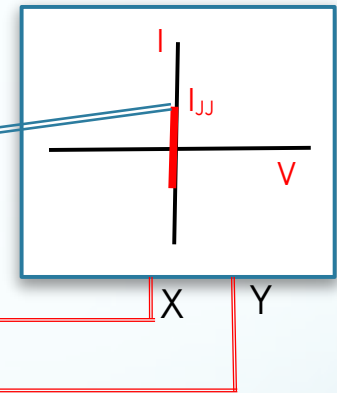
$$d = 2\lambda_L + h_0 \approx 2\lambda_L$$

$$\lambda_L = \frac{\phi_0}{2LH^*}$$

Generatore
onde triangolari

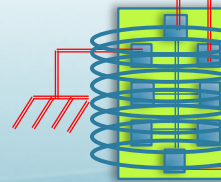
➤ **T (4.2K)**

Oscilloscopio



R_L

Alimentatore
DC



Altri possibili items : *per prendere confidenza con JJ*

Da Marzo 2019 ?????

- Fiske steps: misura del fattore di qualità Q di una JJ

- T (4.2K)
- I-V In campo $B \approx$ gauss
- I_{jj} presenta singolarità: Fiske steps
- interazione I_{jj} (a.c.) con modi risonanti cavità a dati valori di V
- I-V presenta singolarità: Fiske steps
 $\omega_n = 4\pi e V_n / h$

- Teoria Kulik
connette risonanze
I-V con Q_{JJ}

