NTD-Ge development in the LUMINEU project for Rare Events searches with cryogenic detectors

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LUMINEU = Luminescent Underground Molybdenum Investigation for NEUtrino mass and nature

LTD16 – Grenoble - July the 22nd 2015

Why producing NTDs?

- NTDs are highly impedant semiconductors close to the Metal Insulating Transition (MIT)
- Robust, reproducible, reliable thermal sensors, easy to use over a large range of temperature and a large dynamic range in energy.
- For experiments in 0νDBD and Dark Matter search such as the LUMINEU and EURECA projects.
- Until now NTDs of many large experiments such as CUORE, EDELWEISS were produced at LBNL
- New solution to produce NTDs for long term and large scale experiment
- Reduce the energy resolution and energy threshold

Neutron Transmuted Doped Ge

$$^{70}_{32}Ge + n \rightarrow {}^{71}_{32}Ge \xrightarrow[T_{1/2} = 11.2\,d]{EC} {}^{71}_{31}Ga + \nu_e$$

$$^{74}_{32}Ge + n \rightarrow {}^{75}_{32}Ge \xrightarrow[T_{1/2} = 82.8\,min]{\beta^-} {}^{75}_{33}As + \bar{\nu}_e$$

$$^{76}_{32}Ge + n \rightarrow {}^{77}_{32}Ge \xrightarrow[T_{1/2} = 11.3\,hrs]{\beta^-} {}^{77}_{33}As + \bar{\nu}_e$$

$$\xrightarrow[T_{1/2} = 38.8\,hrs]{\beta^-} {}^{77}_{34}Se + \bar{\nu}_e$$

Isotope	Natural Abond.	Period
^{70}Ge	21,23%	Stable with 38 neutrons
^{72}Ge	27,66%	Stable with 40 neutrons
^{73}Ge	7,76%	$> 1{,}8 \cdot 10^{23}$ years
^{74}Ge	35,94%	Stable with 42 neutrons
^{75}Ge	7,61%	10^{21} years

- Neutron flux leads to germanium p-type doping
- Heavy dopings induce high densities of traps

=> **variable range hopping process at Metal Insulator Transition**

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30th ESLAB Symposium, "Submillimetre and Far-Infrared Space Instrumentation," Noordwijk, The Netherlands, Sept. 24-26, 1996

NEUTRON TRANSMUTATION DOPED (NTD) GERMANIUM THERMISTORS FOR SUB-MM BOLOMETER APPLICATIONS

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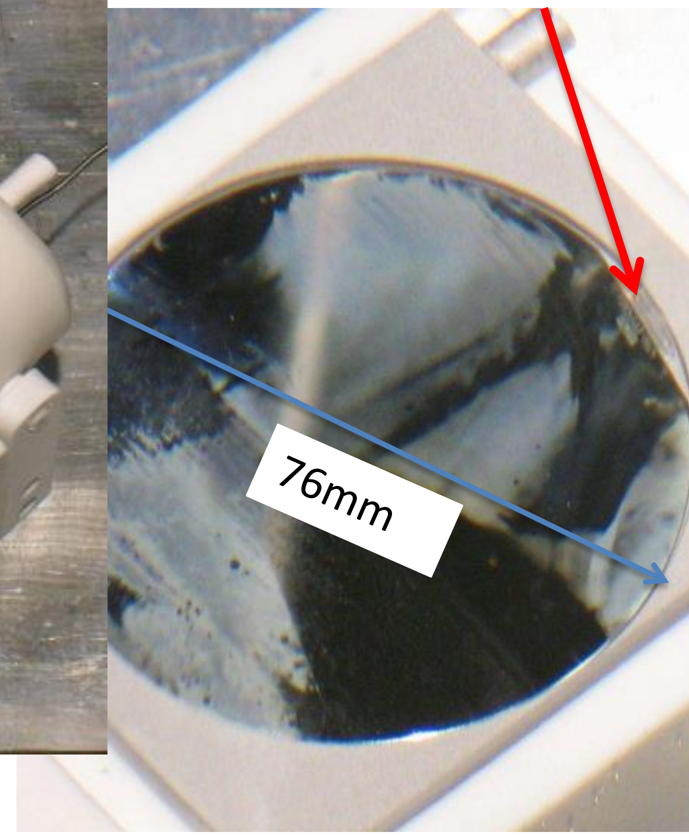
HPGe irradiation with thermal neutrons

Irradiation in Orphée reactor **2 to 4·10^{18}n/cm^2**

=> **8 months of decay**



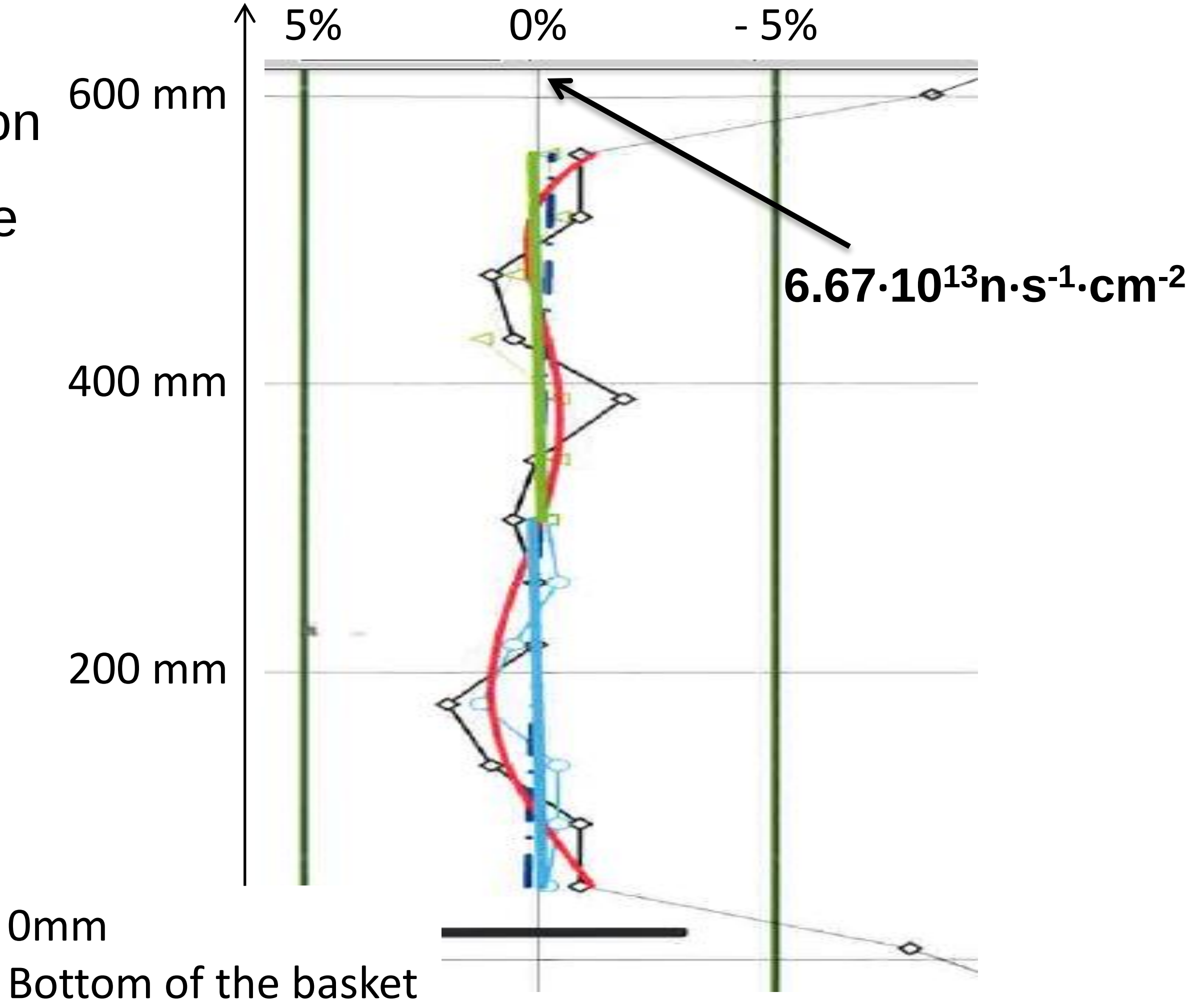
Direct contact with the water of the reactor => **surface contamination** removed by chemical etching at IAS.

Estimation of the neutron flux

Measurement of the neutron flux with a collectron before and after the irradiation

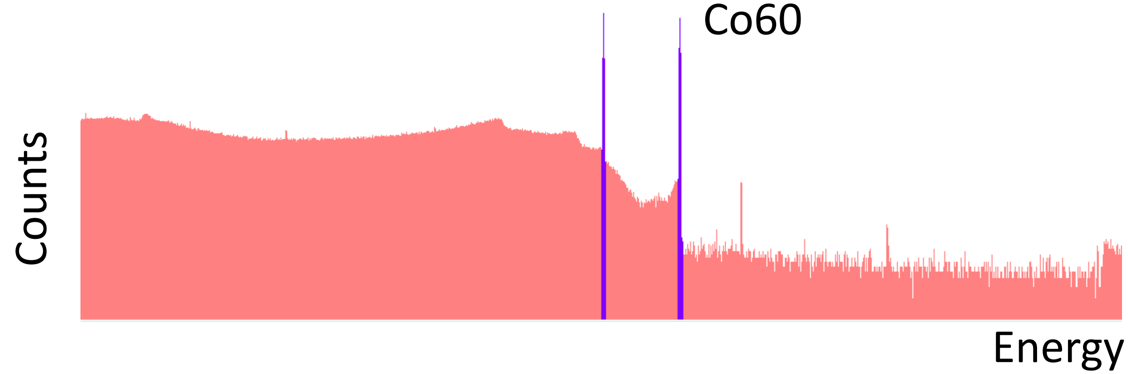
⇒ Mean flux

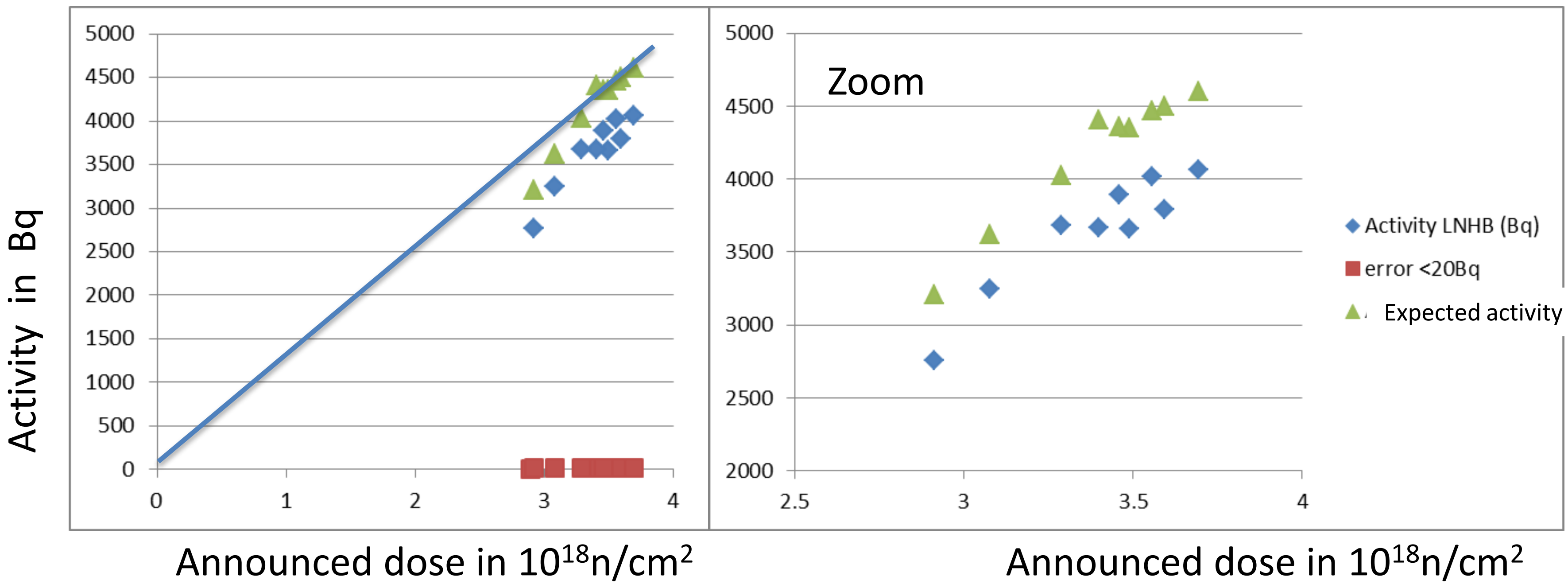
⇒ Irradiation time



Dosimeter measurement at LNHB (CEA)

Dosimeters:
AlCo (0.1%) wires

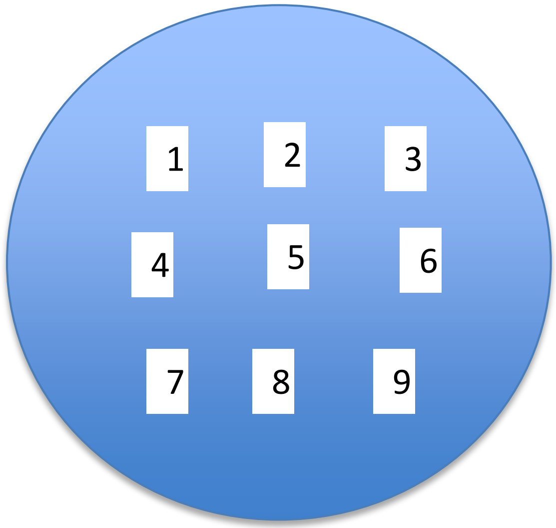


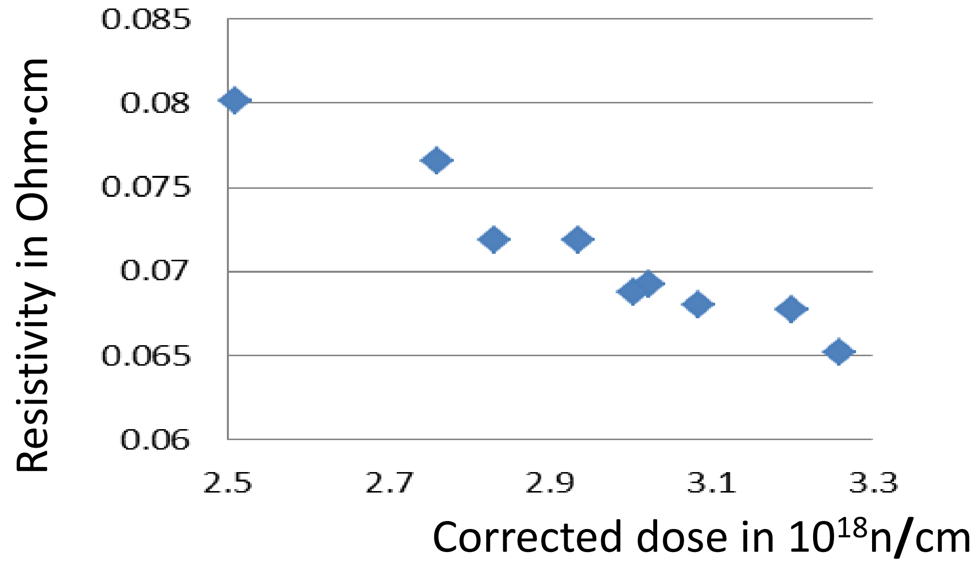


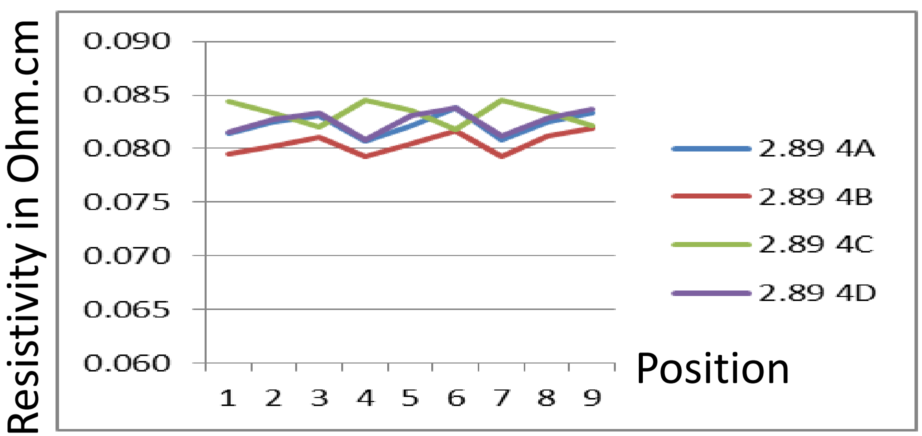
Effect of the Ge on the neutron flux in the dosimeter ?

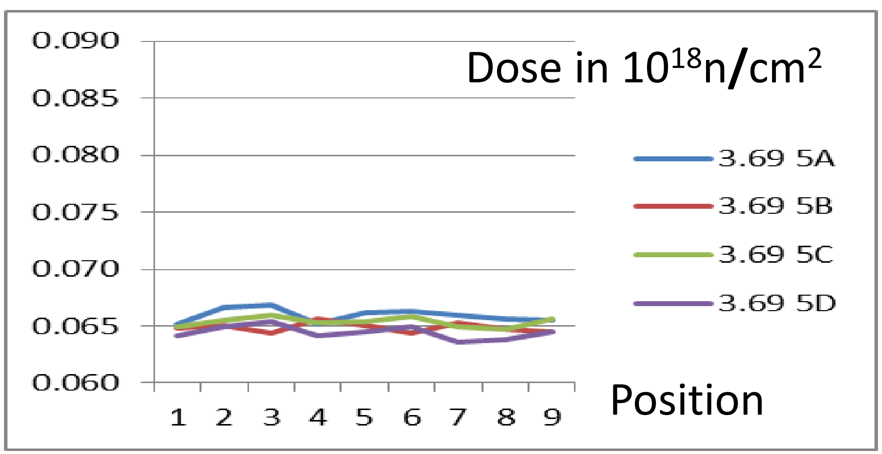
4 point measurement at IAS

on wafers at 300K before annealing.





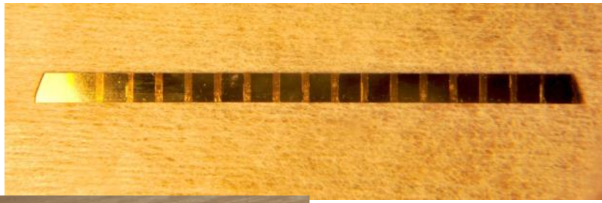




4 point measurement at CEA

Production of NTD samples :

<ins>Extraction</ins> of a band from 20 different wafers at IEF

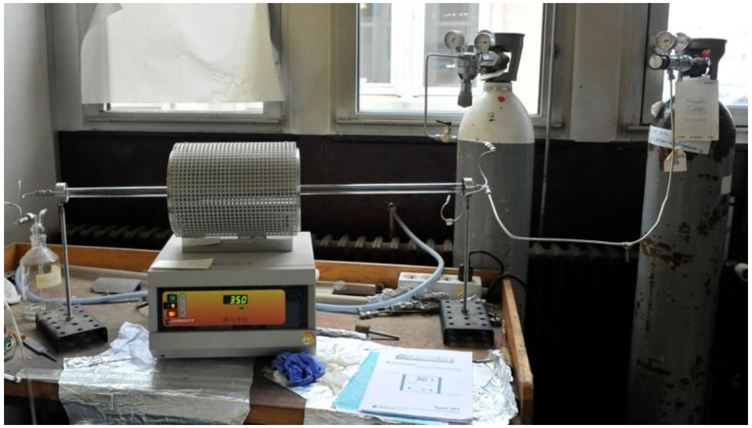


<ins>Metallization</ins>:

- Implantation of boron at CSNSM (5, 15 and 25 keV)
- Pd + Au evaporation at Minerve technological platform (IEF)

<ins>Annealing</ins> at SPEC (CEA)

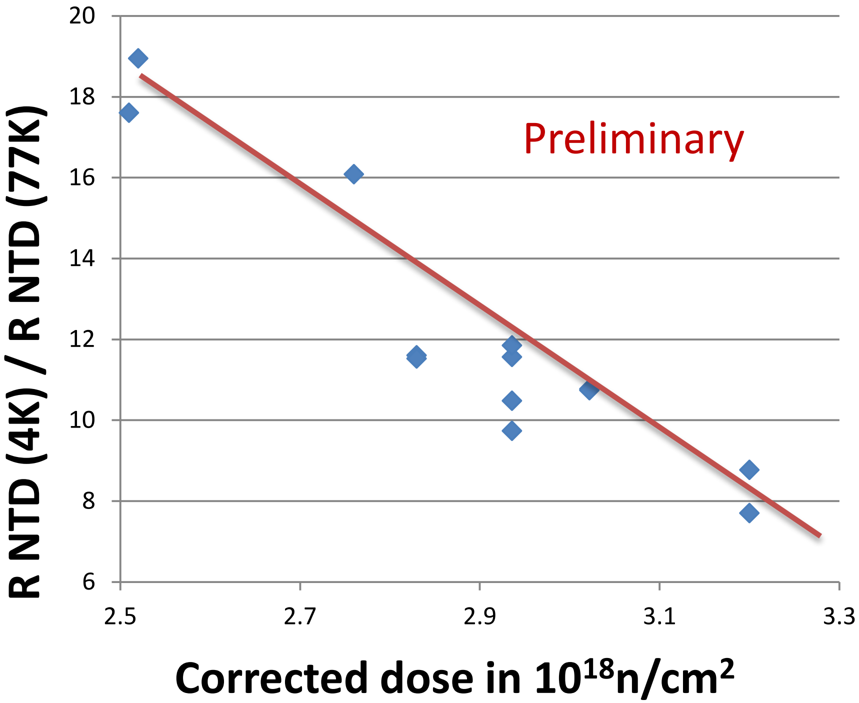
Different annealing temperatures (from 350° to 600°C)

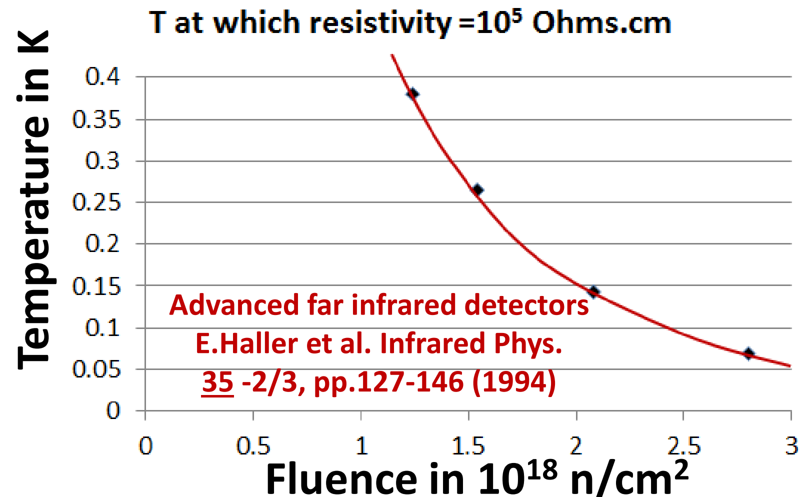


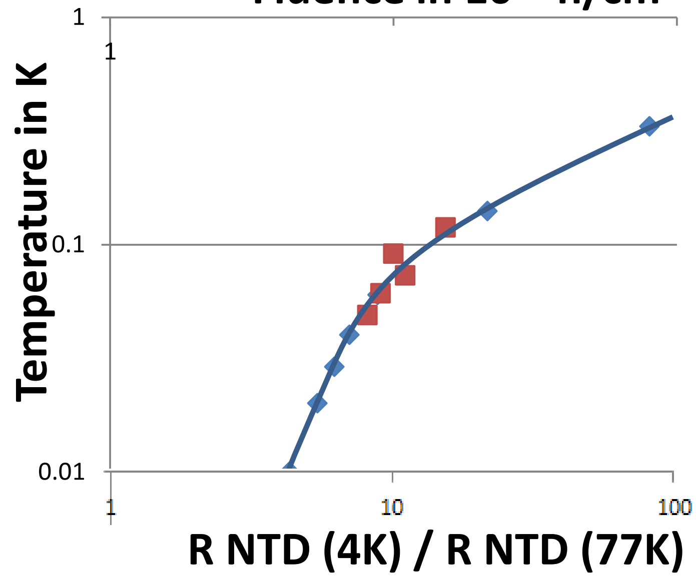
4 point measurement at CEA

Comparison of the resistance at 4K and 77K in a dip stick :

after annealing

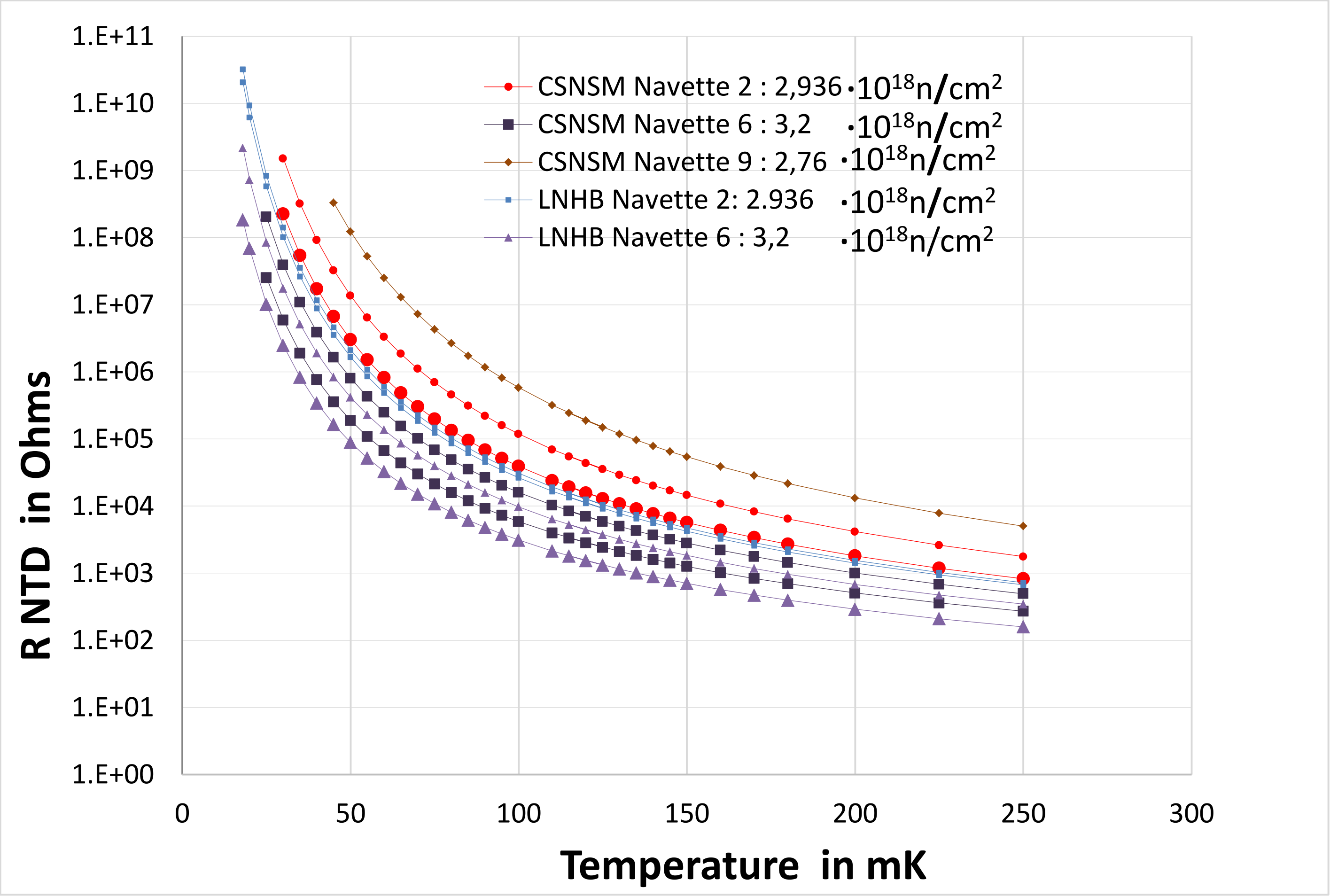






R measurement at TBT

2 and 4 point measurements at CEA-IRFU, CEA-LNHB and CSNSM



Status of NTD production

- **For LUMINEU, the target is a T0 of the order of 3 to 4K.**
  This is the range used in CUORE, EDELWEISS and LUCIFER.
- **T0 achieved of the order of 6K to 17K.**
- **R-T behavior of the characterized NTDs is satisfactory :**
  the correct VRH behavior and the contact fabrication was successful.
- **We are able to deduce the additional dose required to match the target.**

More details?
Please come
to my poster

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