$0\nu\beta\beta$: the CUPID-0 experiment

M. Pavan for the CUPID-0 Collaboration

Università di Milano Bicocca - INFN sez- di Milano Bicocca

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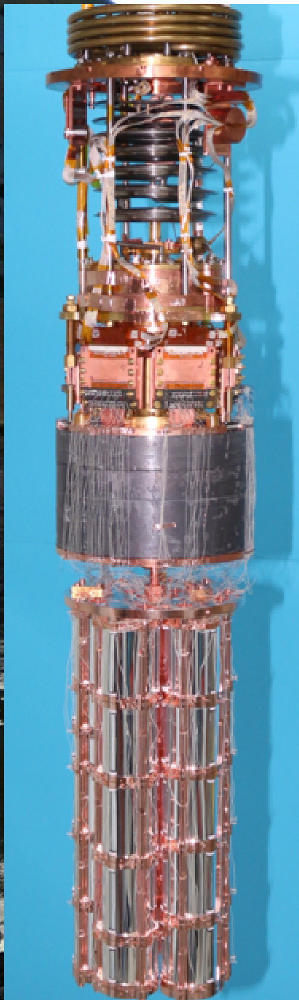
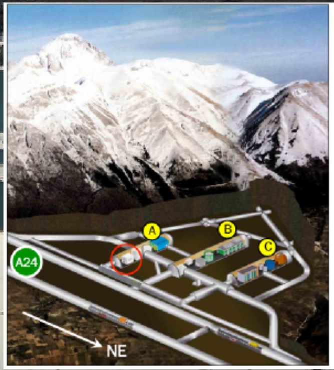
INFN – Laboratori Nazionali del Gran Sasso



CUPID-0

the first $\beta\beta0\nu$ experiment using double-read out bolometers

- an array of 26 ZnSe scintillating bolometer
- presently running at LNGS



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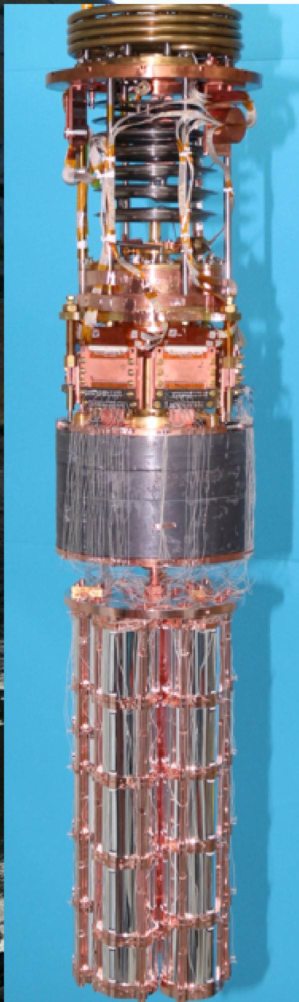

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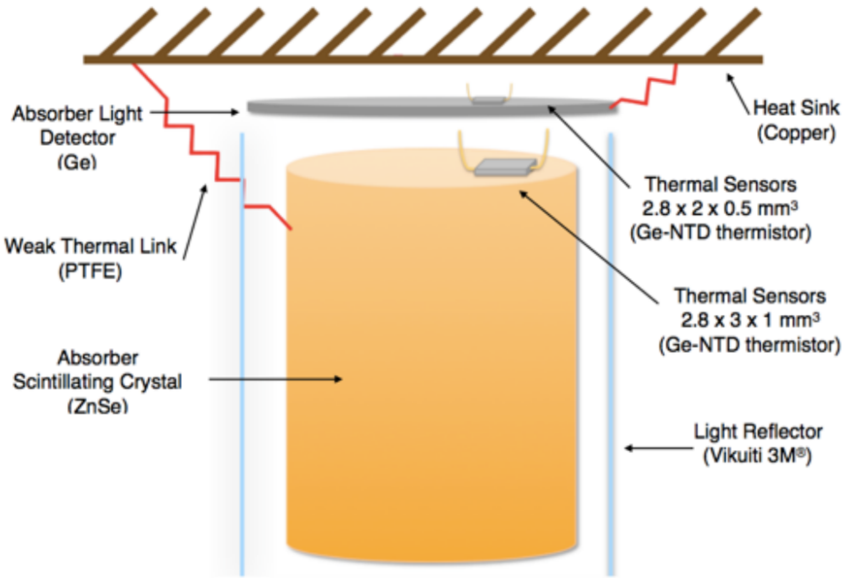
CUPID

CUORE (Cryogenic Underground Observatory for Rare Events) Upgrade with Particle IDentification

CUPID is a proposed future tonne-scale bolometric neutrinoless double beta decay ($0\nu\beta\beta$) experiment to probe the Majorana nature of neutrinos and discover Lepton Number Violation in the so-called inverted hierarchy region of the neutrino mass. CUPID will be built on experience, expertise and lessons learned in CUORE, and will exploit the current CUORE infrastructure as much as possible. In order to achieve its ambitious science goals, CUPID aims to increase the source mass and dramatically reduce the backgrounds in the region of interest. This requires isotopic en-

CUPID-0 Detectors: ZnSe scintillating bolometer

HEAT signal $\rightarrow$ phonons produced by energy deposition in the ZnSe crystal (with ^{82}Se being the source of $\beta\beta0\nu$ decay)



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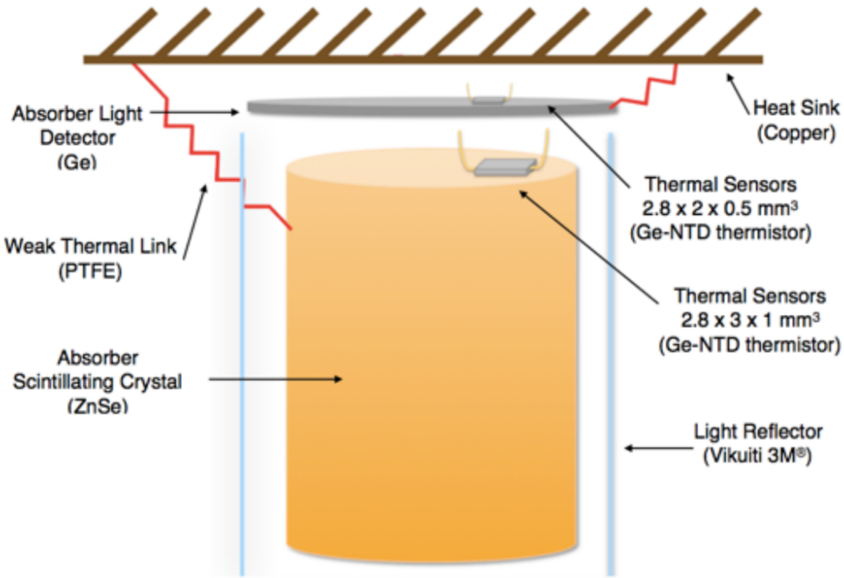

LIGHT signal $\rightarrow$ scintillation photons emitted by ZnSe and collected with a Ge bolometer (Light Detector LD)

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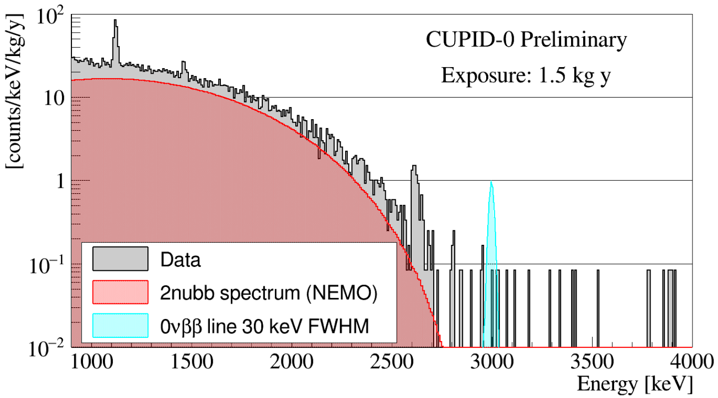

Figure 1: CUPID-0 (FWHM $\sim$ 30 keV): $\beta\beta2\nu$ is well separated from $\beta\beta0\nu$

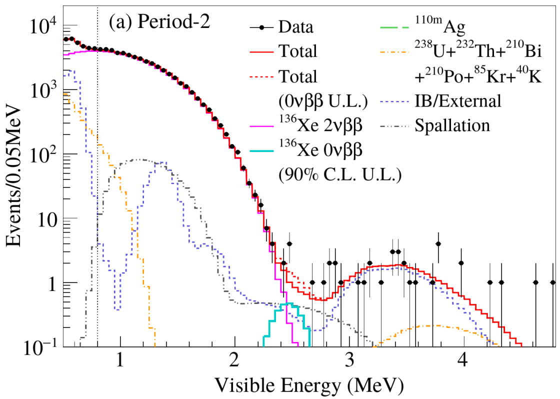

Figure 2: KamLand-ZEN (FWHM $\sim$ 250 keV):$\beta\beta0\nu$ and $\beta\beta0\nu$ mix (arXiv:1605.02889)

CUPID-0 Strategies (II)

LIGHT signal (scintillation) $\rightarrow$ active background rejection

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- particle identification $\rightarrow$ separates β/γ from α

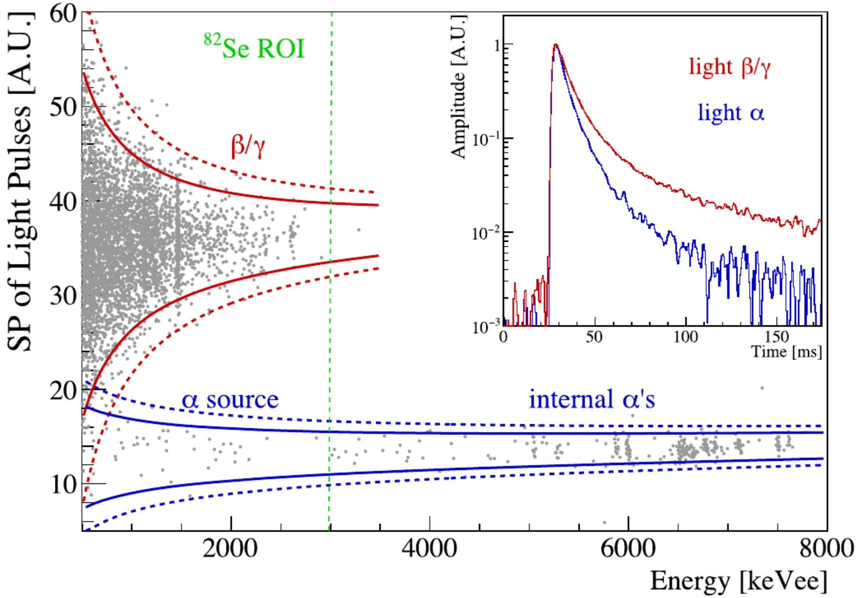


Figure 3: Particle identification in a ZnSe scintillating bolometer: LIGHT shape vs HEAT amplitude (EPJ C 76:364 (2016))

CUPID-0 Strategies (III)

HEAT+LIGHT allow particle discrimination.
Due to their fully active surface, bolometers show a large background component ascribed to **energy degraded** α **particles**

CUPID-0 Strategies (III)

In CUORE-0 and CUORE α background is sizeable and sums to the 2615 keV (^{208}Tl) multi-Compton.

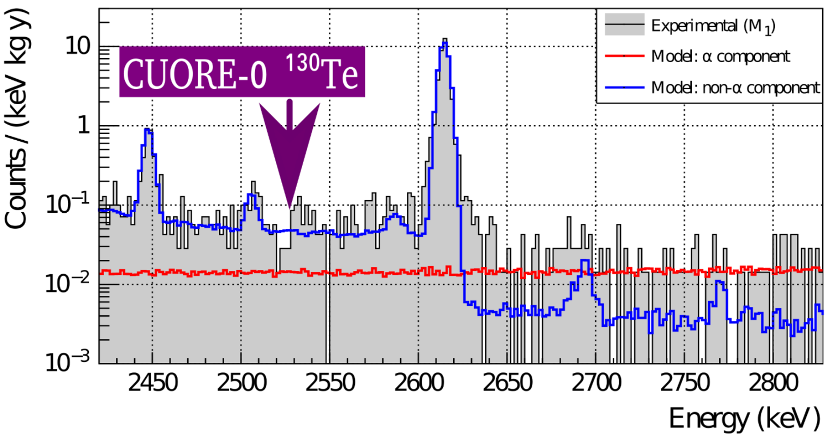
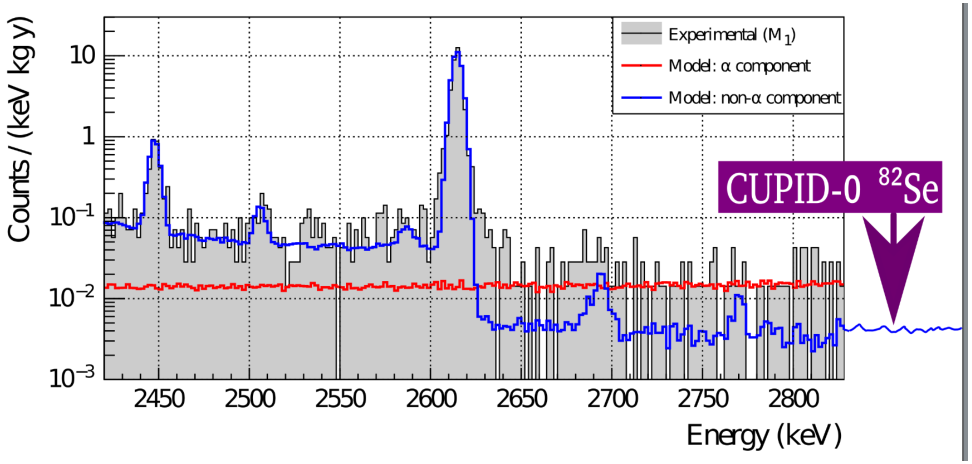


Figure 4: CUORE-0 reconstructed background shows a clear component coming from degraded α particles Eur. Phys. J. C 77 (2017) 77:13

CUPID-0 Strategies (III)

CUPID-0 use a higher $Q_{\beta\beta}$ isotope and rejects α signals using the scintillation LIGHT



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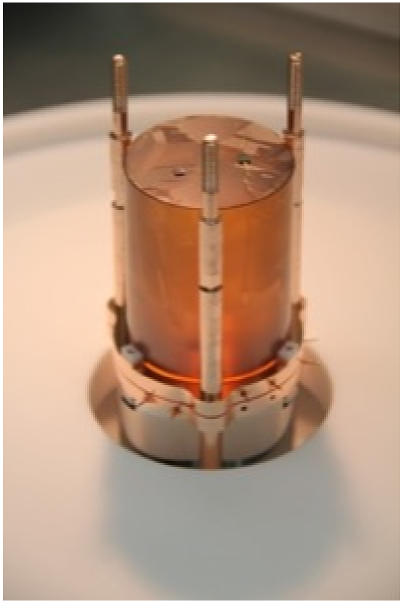
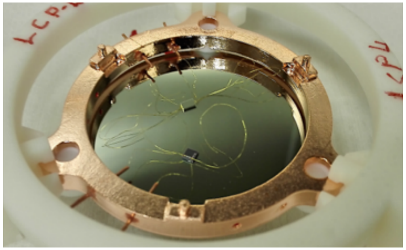
The Detectors





24 $Zn^{82}Se$ CRYSTALS

Mass = 9.65 kg
Se enrichment in ^{82}Se at 96%
^{82}**Se** Mass = 5.17 kg $N_{\beta\beta} = 3.8\ 10^{25}$

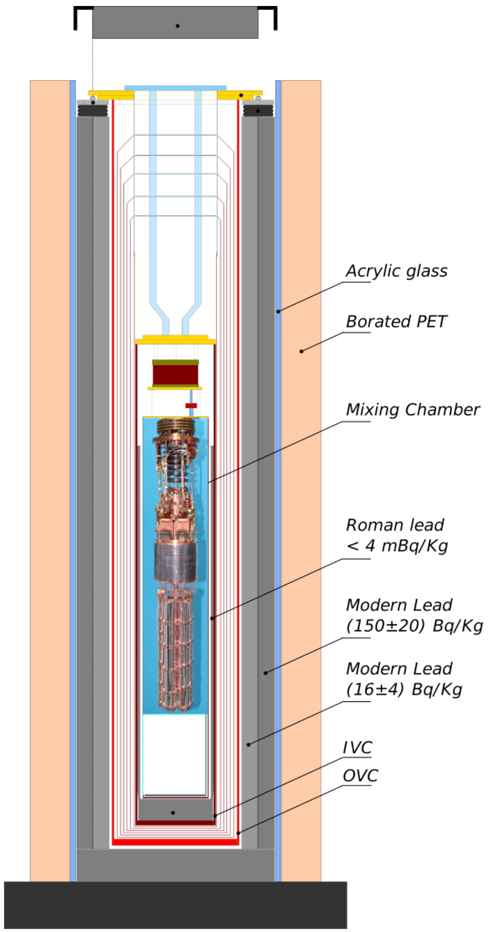
2 $ZnSe$ CRYSTALS

Mass = 0.85 kg
Se natural ^{82}Se at 8.7%

31 Ge LIGHT DETECTORS

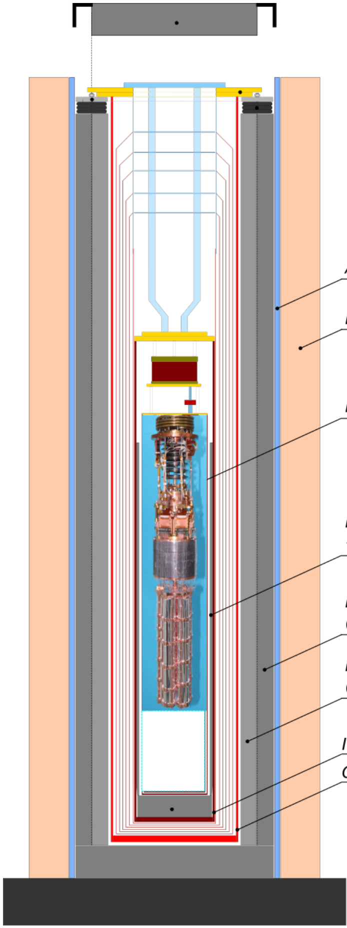
hyperpure Ge wafers
diameter = 44.5 mm ($\simeq$ ZnSe crystals)
thickness = 0.17 mm

The array



Detectors arranged in 5 columns held by a Cu+PTFE structure. Mounted in the dilution refrigerator formerly used for CUORE-0.

The array



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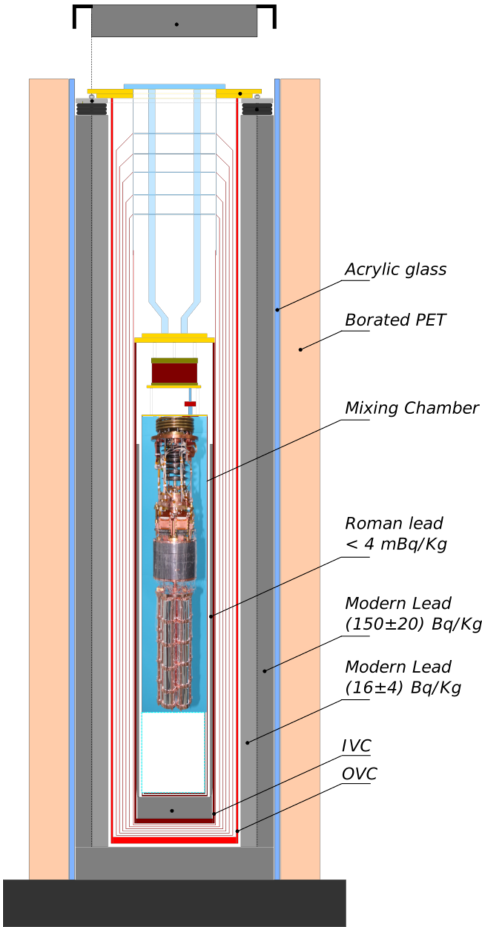
Light collection is optimized with:

- a reflecting foil (VIKUITI 3M) surrounding each crystal
- a SiO anti-reflective coating (60 nm) on one face of LD

The array



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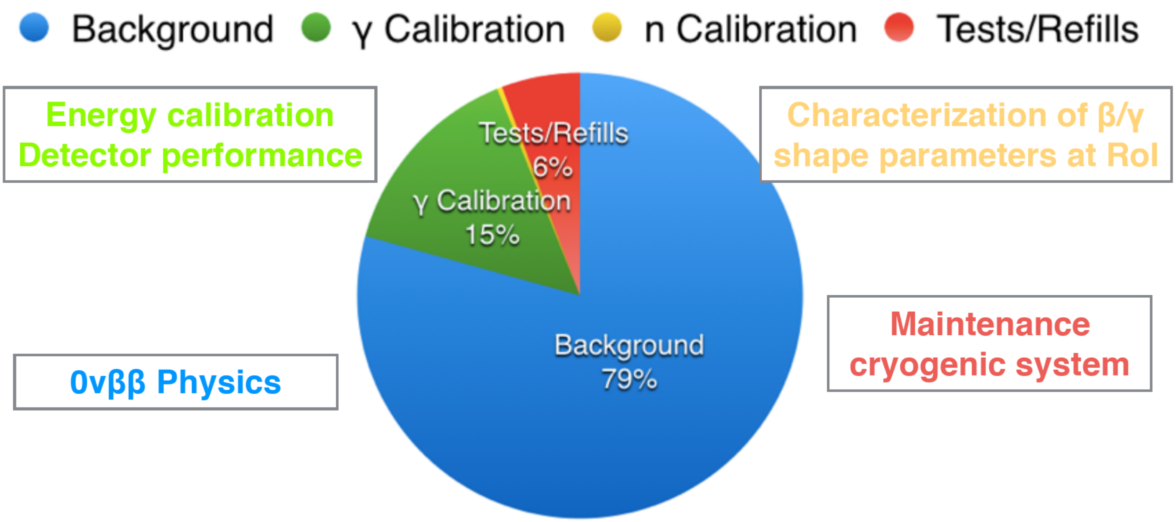
Materials and surface treatments as far as possible similar to those adopted for CUORE.

Data Taking: started on March 17, 2017



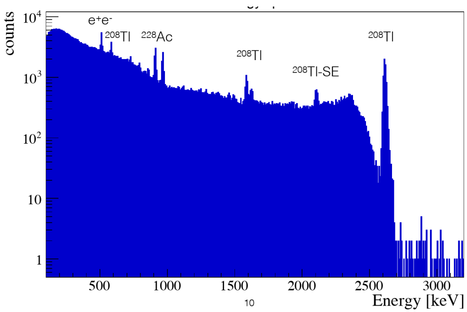
Science Runs (SR)

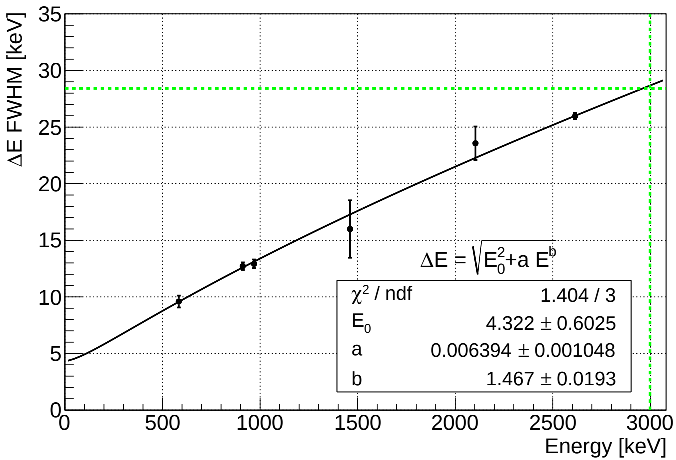
SR1+SR2+SR3+SR4 collected exposure → 2.4 $kg(ZnSe) \cdot y$

SR1+SR2 analysed, preliminary results → 1.5 $kg(ZnSe) \cdot y$

Performances: HEAT Signale ^{232}Th calibration

sum calibration spectrum





$\langle$FWHM$\rangle$

noise $\rightarrow \sim 0.4$ *keV*
2615 *keV* $\rightarrow \sim 25$ *keV*

major contribution from crystal quality

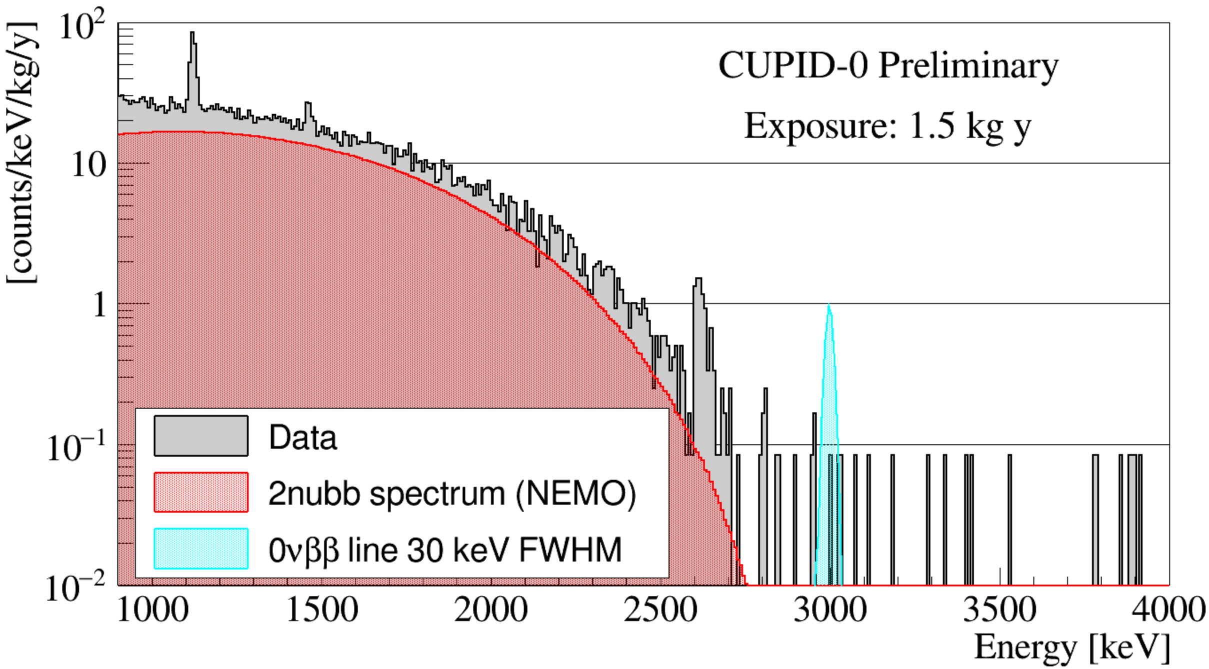
at ^{82}Se $Q_{\beta\beta} = 2998$ *keV* resolution is extrapolated

$\langle$FWHM$\rangle$ at $Q_{\beta\beta}$

SR1 $\rightarrow 29.2 \pm 2.0$ *keV*
SR2 $\rightarrow 27.0 \pm 1.0$ *keV*

1.5 $kg \cdot y$ EXPOSURE

- M1 (only single hit events) + PSA on HEAT
- $\beta\beta 2\nu$ spectrum normalized to NEMO [1]

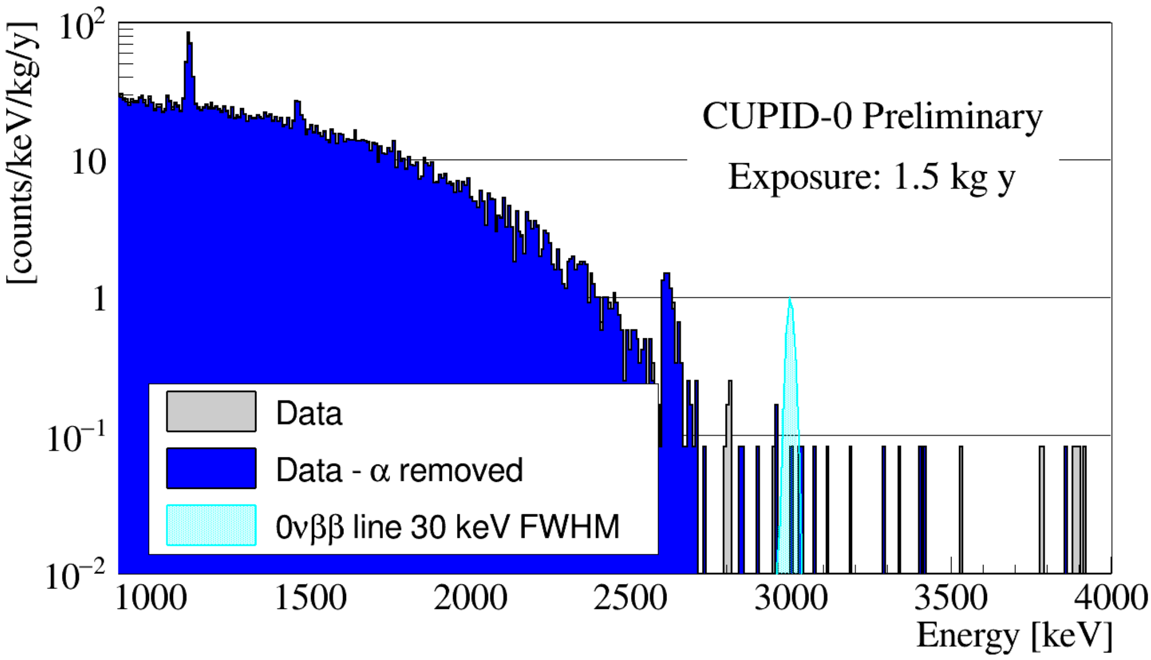


[1] NEMO measurement of ^{82}Se $\beta\beta 2\nu$ half-life (arXiv:1105.2435 [hep-ex])

1.5 $kg \cdot y$ EXPOSURE - α REMOVED

- M1 + PSA on HEAT signal (removes pile-up, noisy events ...)
- ... + α removed (PSA on LIGHT)

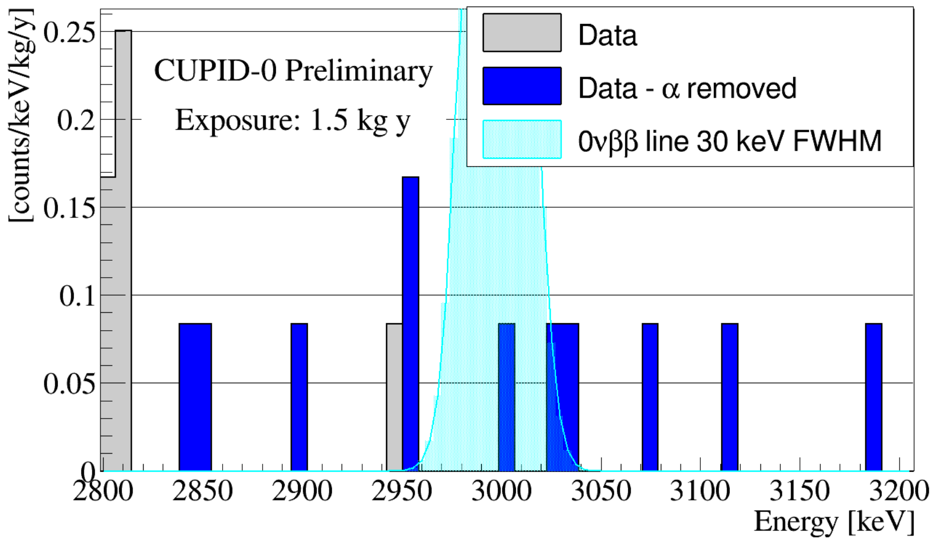
-



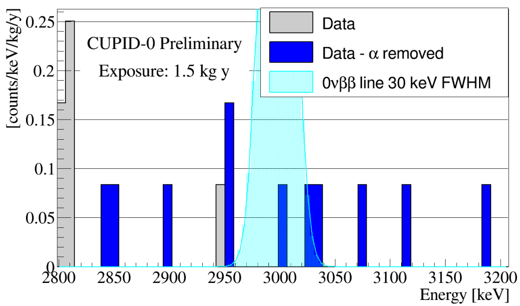
1.5 $kg \cdot y$ EXPOSURE - α REMOVED - ROI

Same plot in the [2800-3200] keV Region of Interest.

- M1 + PSA on HEAT signal (removes pile-up, noisy events ...) $\rightarrow (30 \pm 7)\, 10^{-3} c/(keV\ y\ kg)$
- ... + α removed (PSA on LIGHT) $\rightarrow (18 \pm 6)\, 10^{-3} c/(keV\ y\ kg)$

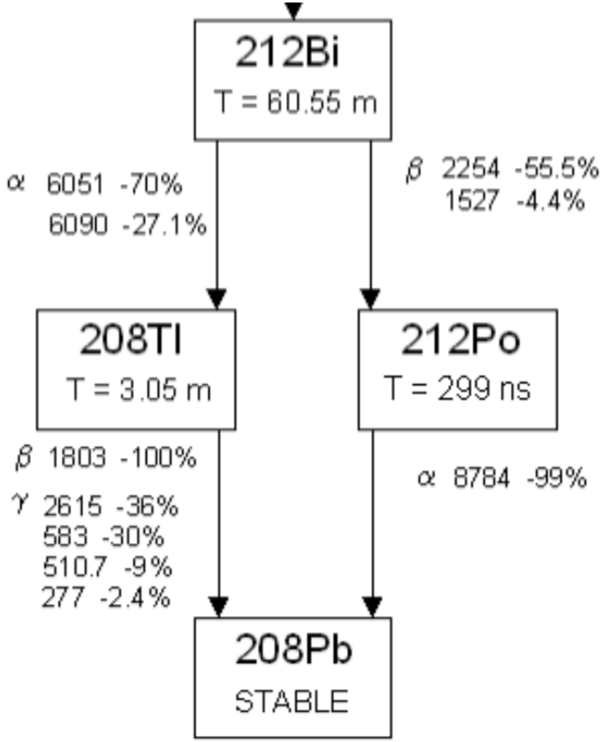


Residual background

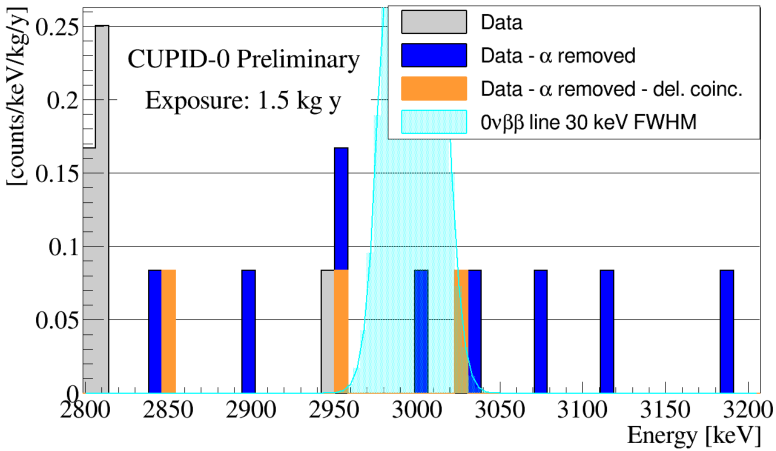


sizable β/γ residual rate likely due to ^{232}Th ZnSe crystal contaminations

$\rightarrow$ can be reduced applying a Delayed Coincidence cut



ALL CUTS + DELAYED COINCIDENCES - ROI



only 3 events survive !!!
(the ROI is $\simeq$ 13 FWHM)

CUTS summary

M1 (single hit cut)
PSA on HEAT
PSA on LIGHT (remove α)
Delayed Coinc.

ROI = [2800, 3200] keV

N. of Events = 3
$[2.2\text{-}8.6]\cdot 10^{-3} c/(keV\ y\ kg)$
$\epsilon_{0\nu\beta\beta} \sim 80\%$
$\epsilon_{cuts} > 85\%$

CONCLUSIONS and PERSPECTIVES

CUPID-0 is running, all the results here presented are preliminary, the analysis procedure is still to be finalized.

CONCLUSIONS and PERSPECTIVES

Science: final goal is to improve by more than 1 order magnitude the present $\beta\beta0\nu$ limit on ^{82}Se half-life $\tau_{1/2} = 3.2 \cdot 10^{23} y$ [2] (requires about $1y$ data)

- With particle identification we will be able to have a better insight in background sources.
- First publication on $\beta\beta0\nu$ result and background model will come soon.

[2] NEMO measurement of ^{82}Se $\beta\beta2\nu$ half-life (arXiv:1105.2435 [hep-ex])

CONCLUSIONS and PERSPECTIVES

Technique: operation of a medium size array, where bolometers are instrumented with light detector, is successful.

- an important milestone for the 1-ton Cuore Upgrade with Particle IDentification