Background model for a NaI(Tl) detector in the frame of the ANAIS experiment

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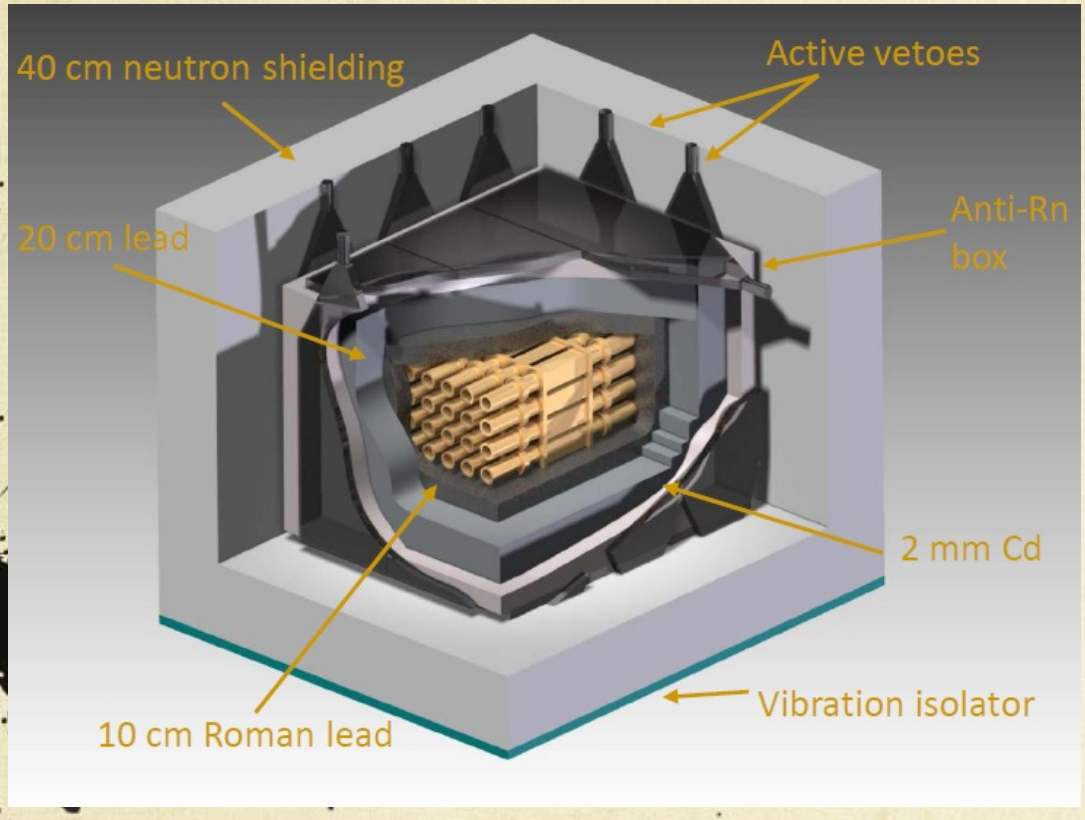
OUTLINE

- *Brief Introduction and Present Status of the ANAIS Experiment*
- *Filtering of low energy events*
- *BACKGROUND MODEL FOR THE ANAIS-0 PROTOTYPE*
- CONCLUSIONS AND PROSPECTS

The ANAIS Experiment



250 kg of ultrapure NaI(Tl) detectors at Canfranc Underground Lab.

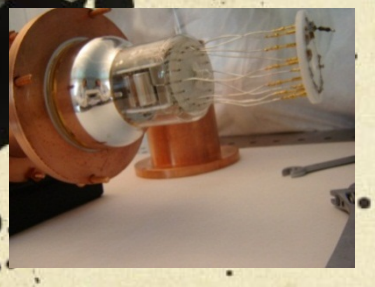
Goal: study the annual modulation in the dark matter signal

SAME TARGET AND TECHNIQUE AS DAMA/LIBRA

The ANAIS Experiment

Long effort in R+D at the University of Zaragoza

- HPGe radiopurity test bench for material selection
- PMT Testing
- Background understanding
- Optimization of data analysis and readout



New radiopure NaI(Tl) crystals

HPGe spectrometry screening of K content in NaI powder from different providers.

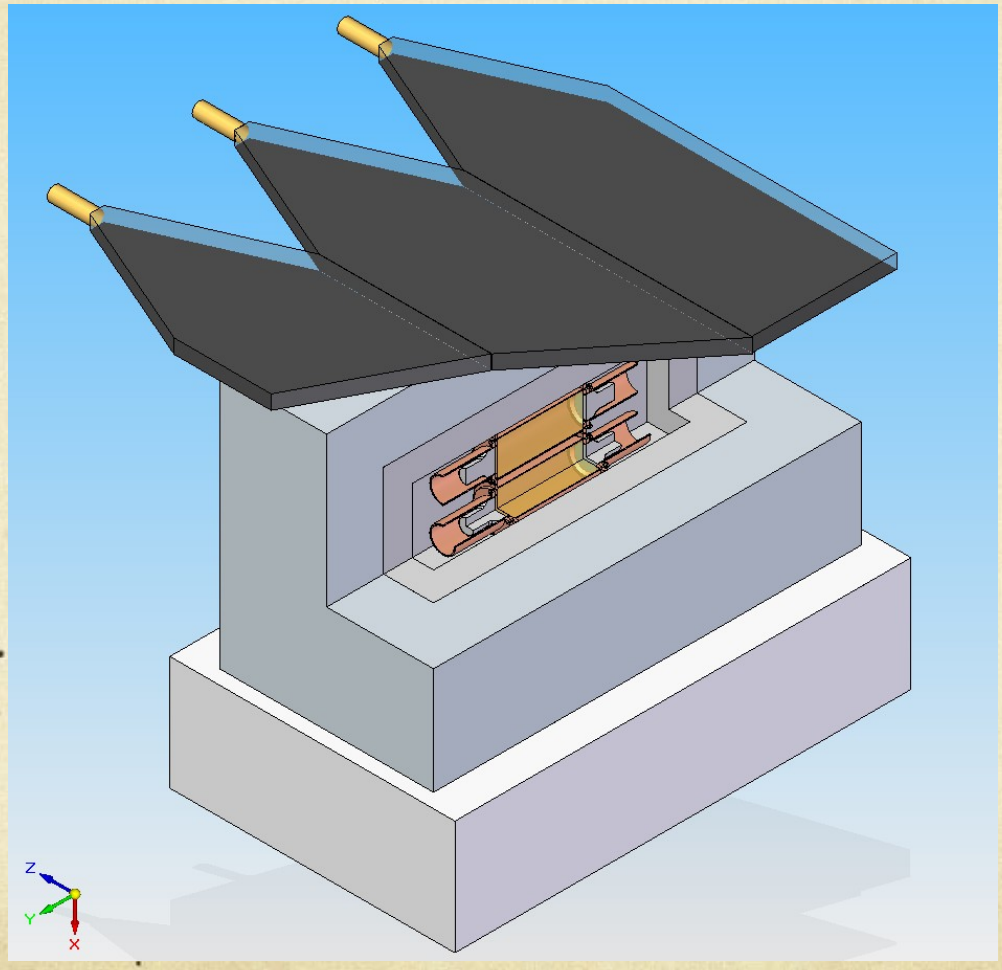
Two 12.5 kg cylindrical crystals have been grown by AS with the best raw powder and are being encapsulated.

They should be received this summer for final background assessment at LSC. **We require no more than 0.02 ppm Potassium.**

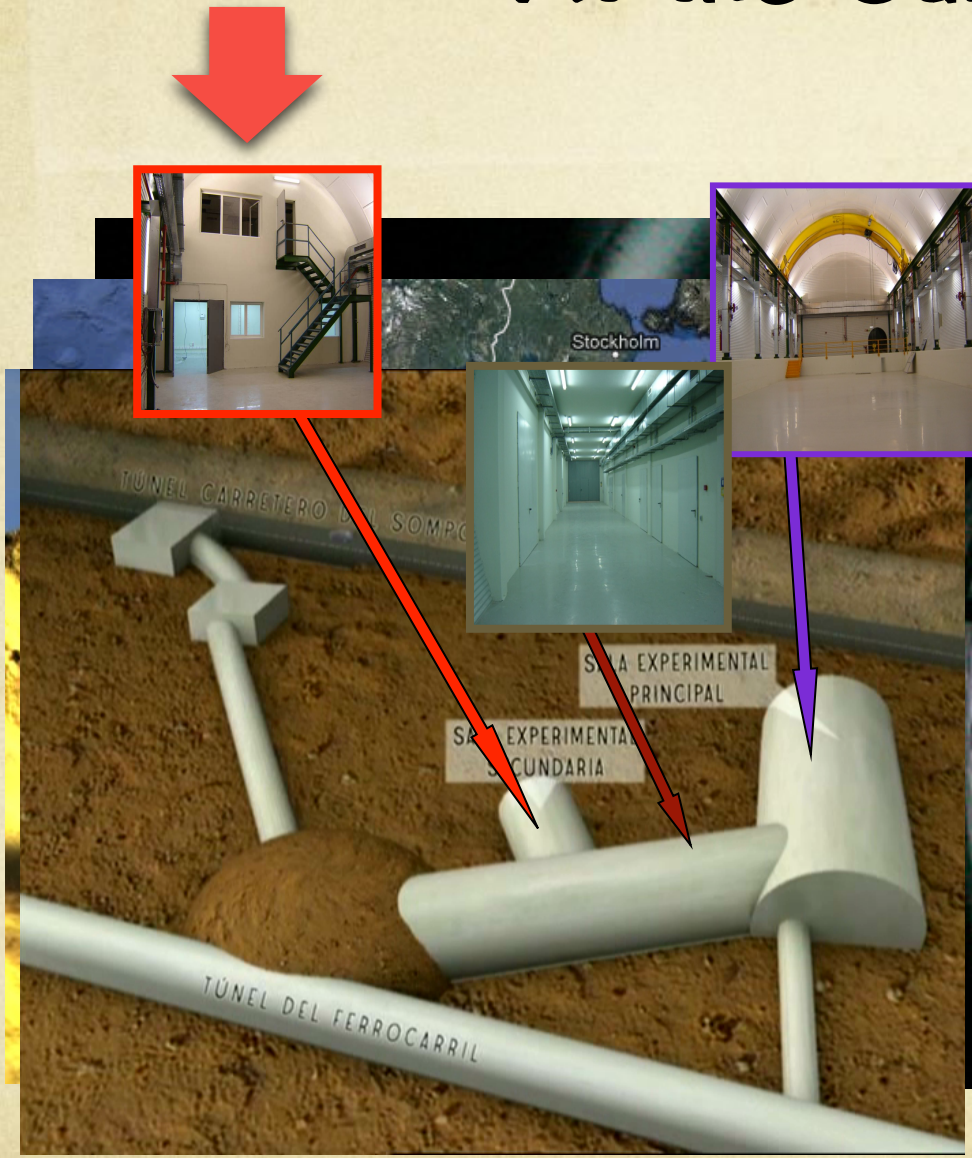
4,75" ϕ x 11.75"length cylindrical shape

New radiopure NaI(Tl) crystals

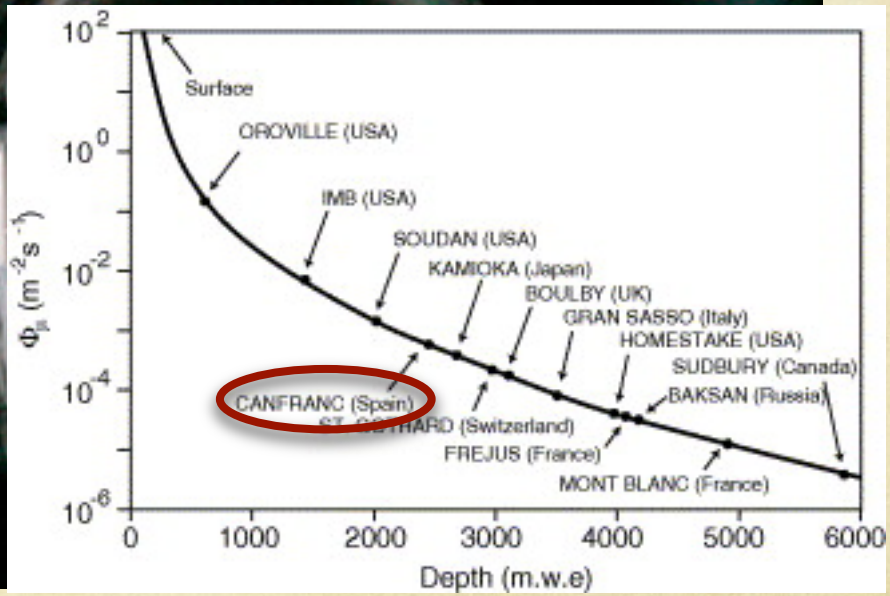
EVERYTHING AT LSC IS READY FOR THE MOUNTING



At the Canfranc Underground Laboratory



About 850 m rock



At the Canfranc Underground Laboratory – HALL B

Lead and polyethylene ready for the shielding of ANAIS

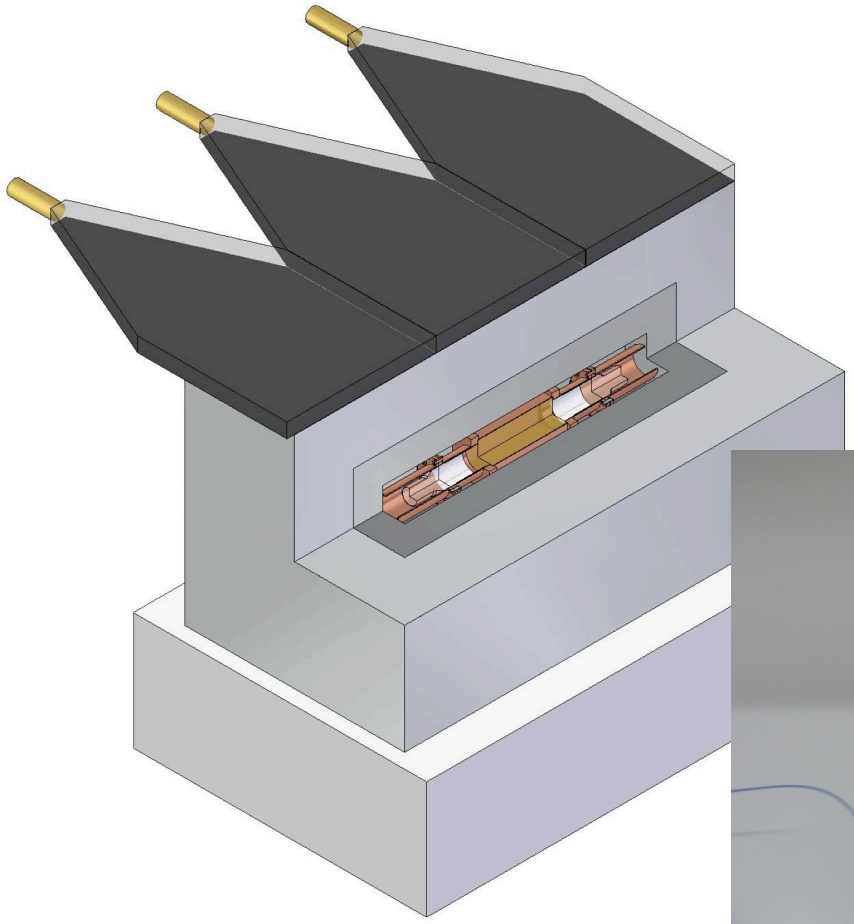
ANAIS control room

ANAIS experimental room

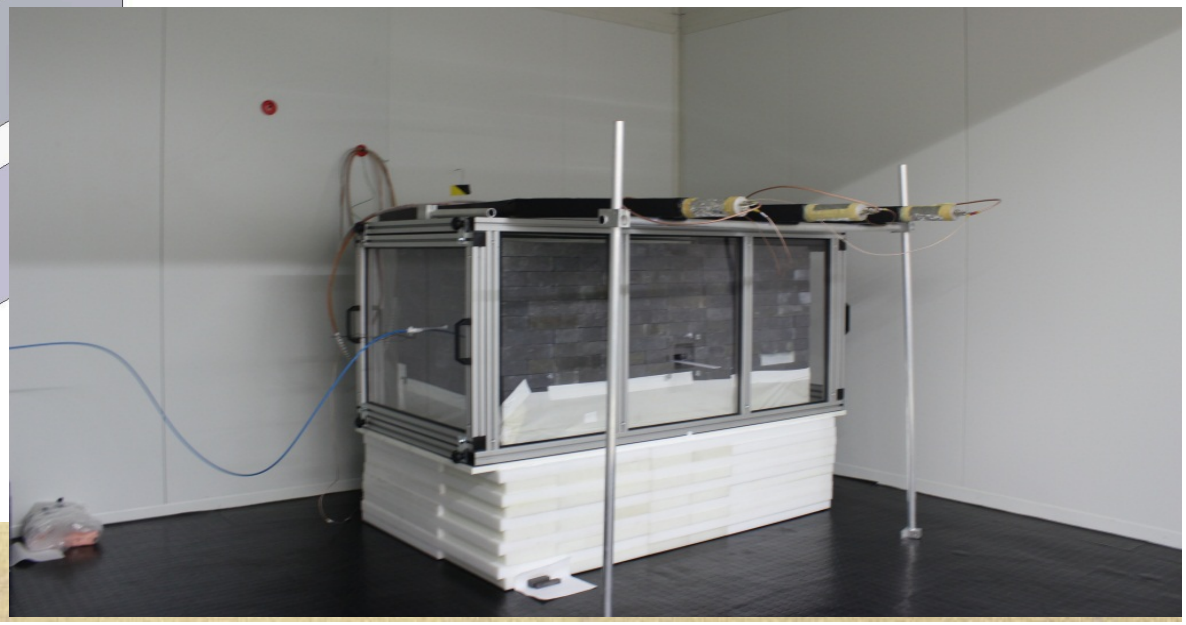
Access to ANAIS control room

Removable walls allow for convenient access to the experimental space

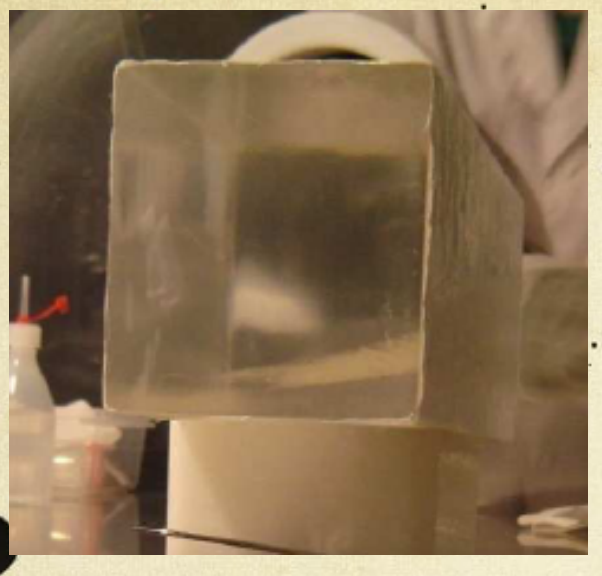
At the Canfranc Underground Laboratory – SHIELDING of ANAIS-0

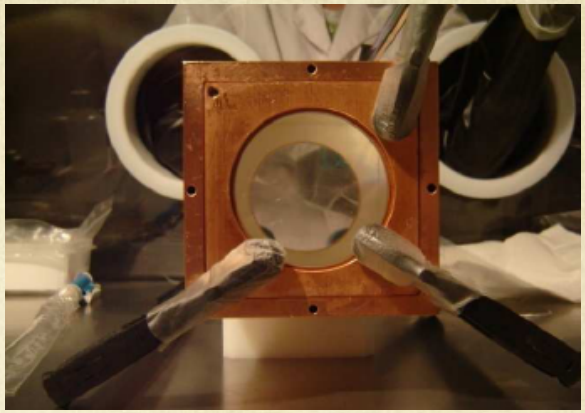


- 10 cm archaeological lead
- 20 cm low activity lead
- Tightly closed box kept with boil-off nitrogen overpressure
- Three plastic scintillators as muon vetoes

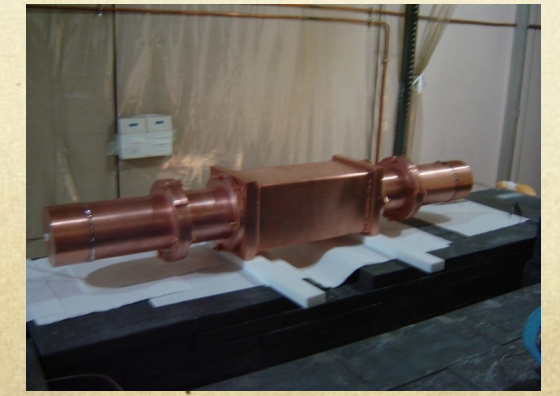


ANAIS-0 Prototype



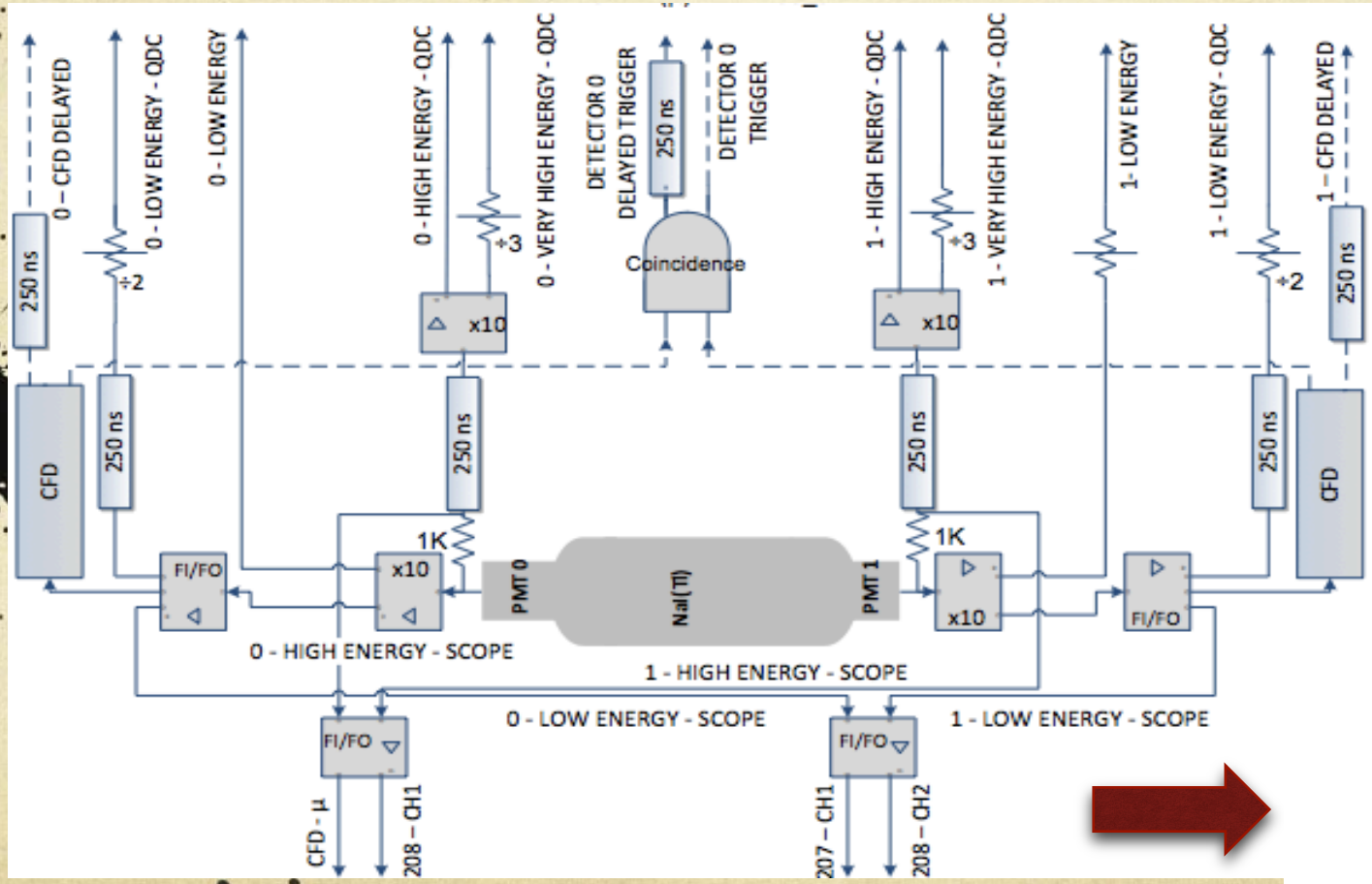


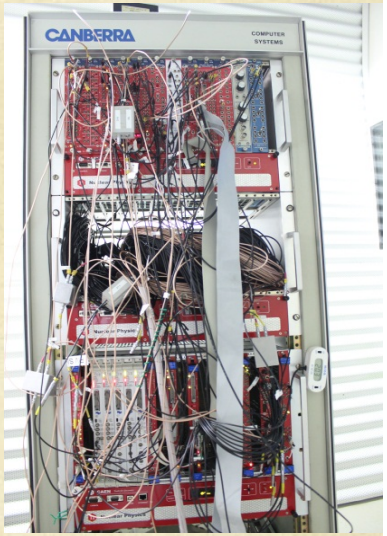
ANAIS-0 module consists of a 9,6 kg NaI(Tl)
made by Saint Gobain
4"x4"x10"
Encapsulated at the UZ using ETP Copper
Choice of using LG and test different PMTs



ANAIS-0-DATA READOUT

TRIGGER AT PHOTOELECTRON LEVEL
LOGICAL AND COINCIDENCE IN A 200ns WINDOW
2 PMT SIGNALS ARE DIGITIZED – CAEN V1729 MATACQ (2GS/s, 12 bits resolution, 1.25 μs window)





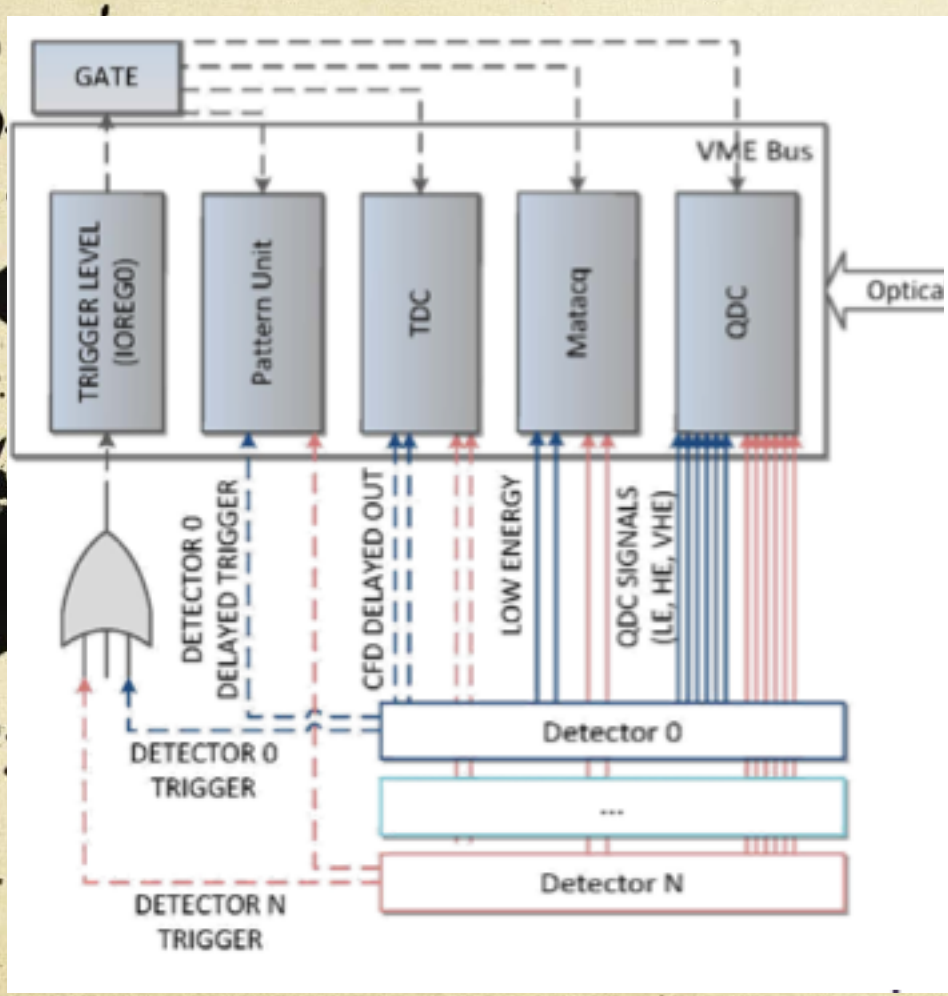
INDEPENDENT ACQUISITION OF VERY ENERGETIC EVENTS IN LONG TIMESCALE

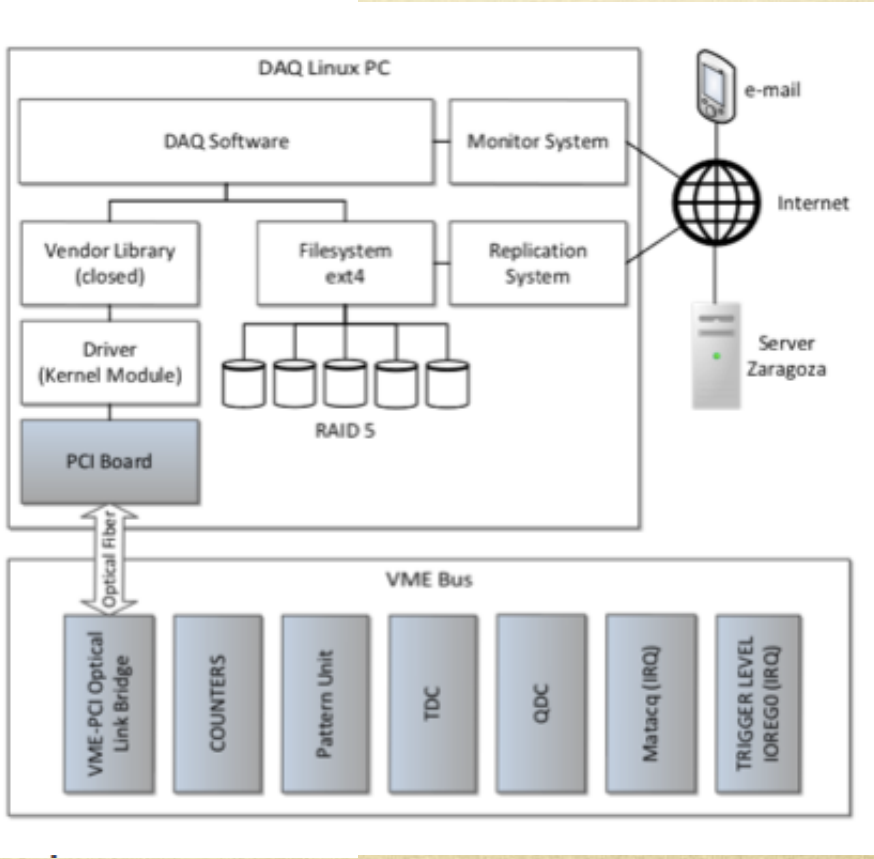
M.L. Sarsa, IDM 2012

ANAIS-ELECTRONIC CHAIN

ALMOST FULLY COMMISSIONED

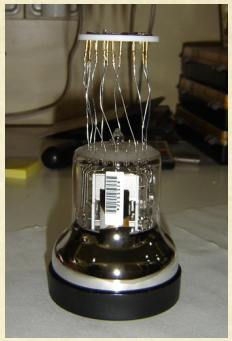
BUS VME/NIM
LINUX-ROOT





PMT Testing

HP Ge spectrometry at Canfranc



Ham LB

Ham ULB

Ham VLB

Model	^{40}K (mBq/PMT)	^{232}Th (mBq/PMT)	^{2328}U (mBq/PMT)
HAM - R6233-100 HAM-LB	678 ± 42	68 ± 3	100 ± 3
HAM - R11065SEL HAM-ULB	12 ± 7	3.6 ± 1.2	^{238}U: 47 ± 28 ^{226}Ra: 8.0 ± 1.2
HAM - R6956MOD HAM-VLB	97± 18	20 ± 2	^{238}U: 128 ± 38 ^{226}Ra: 84 ± 3

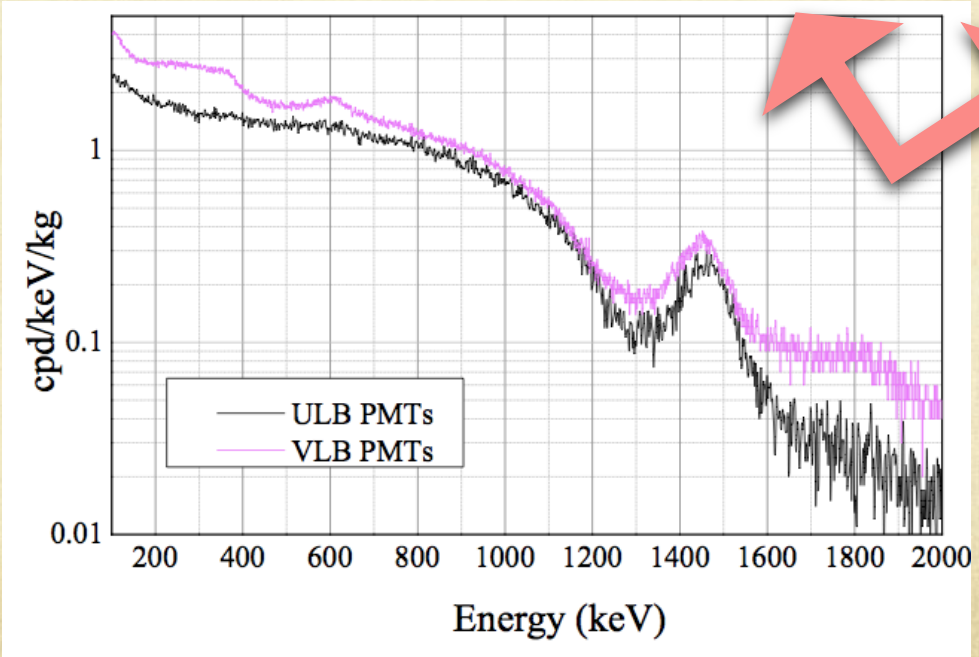
PMT Testing

We would like to avoid *LG* ...

Ham ULB

Ham VLB

Direct measurement in ANAIS-0 prototype



PMT Testing

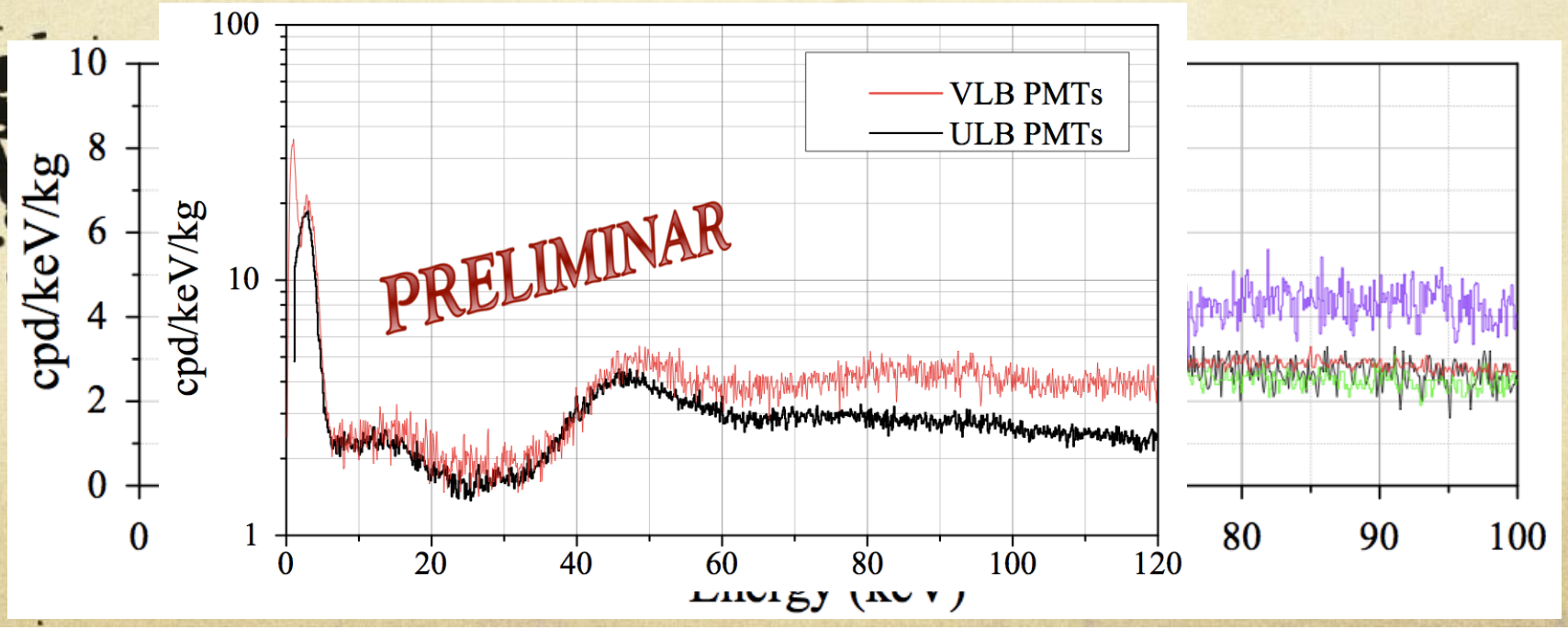
We would like to avoid *LG* ...

We need FILTER events below 20 keV (no electronic noise)

Rely on SIMULATIONS

Ham ULB

Ham VLB



Events FILTERING with ANAIS-0

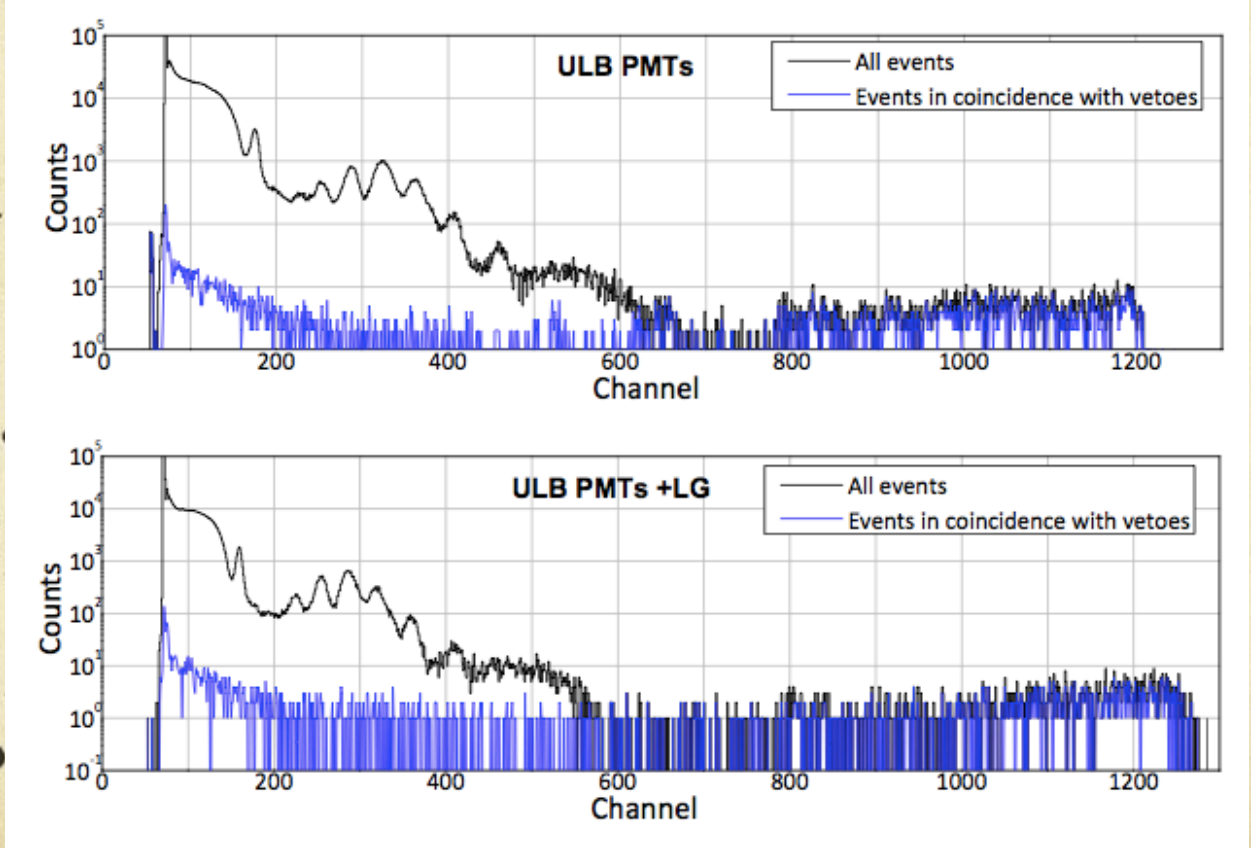
We want to select **real bulk NaI scintillation events**

CUTS have been developed for:

1. Periods of high rate (f.i. periods after calibrations or electronically noisy)
2. Events coincident with a muon on plastic vetoes.
3. Events after a muon (Very High Energy event) in the NaI crystal in a 0.5 s-window.
4. Events having in total no more than 4 photoelectrons (n0s≤4 p.e.)
5. Anomalous fast events

Muon related events in ANAIS-0

We have studied events coincident with a VETO SIGNAL in the plastic scintillators (partially covering the shielding)



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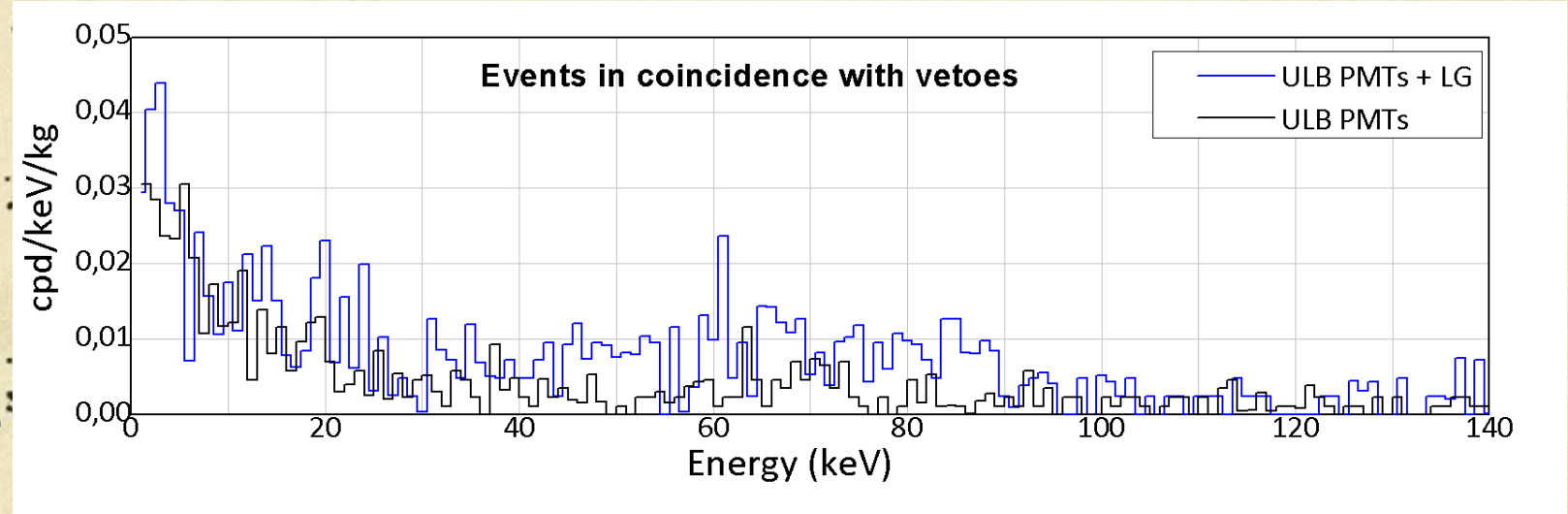
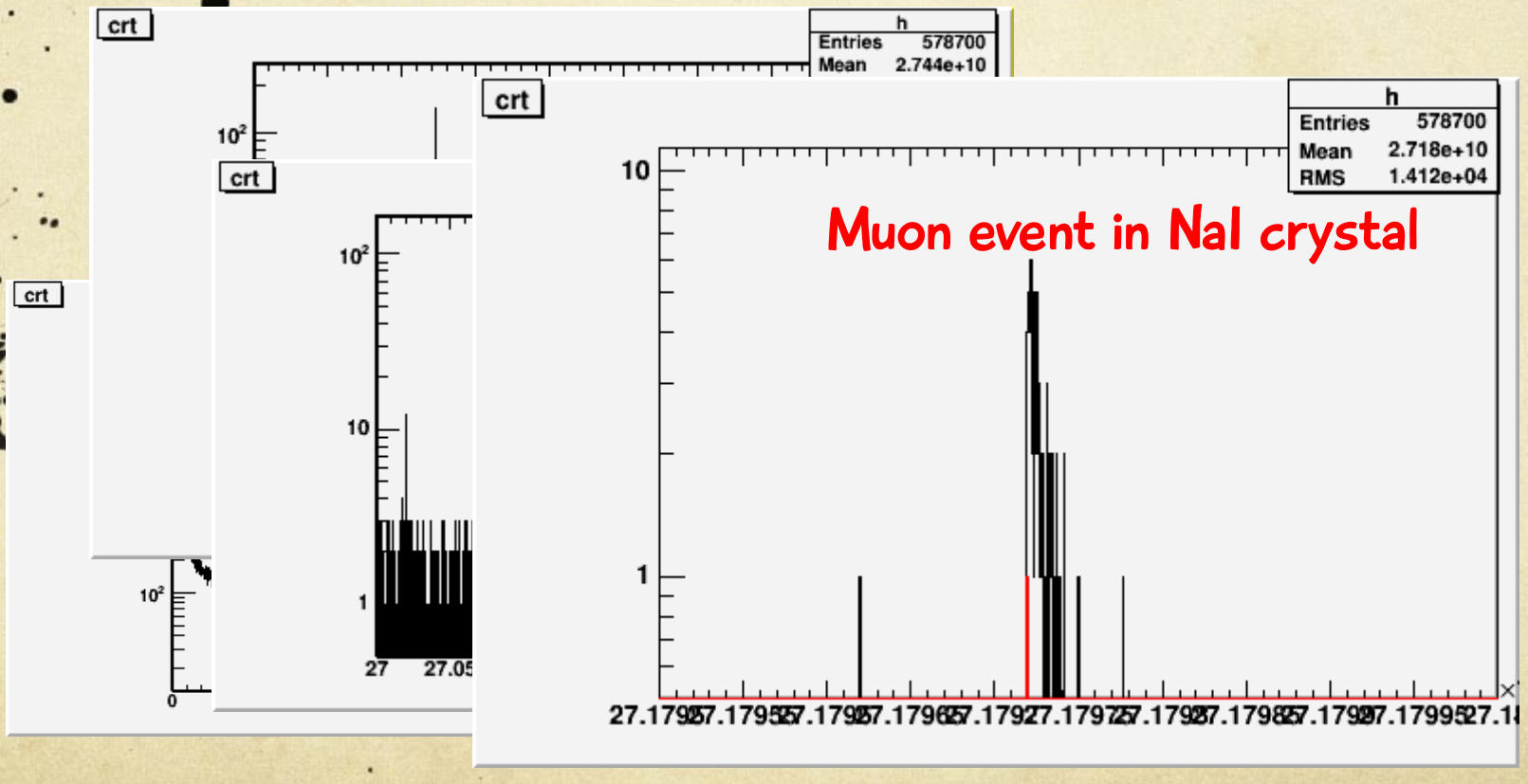


Events at low energy coincident with a veto signal are present in our data and scintillation in the LG is confirmed

Muon related events in the crystal

High energy depositions excite very slow scintillation component in NaI(Tl), producing a strong increase in rate after each muon event (very low energy events):

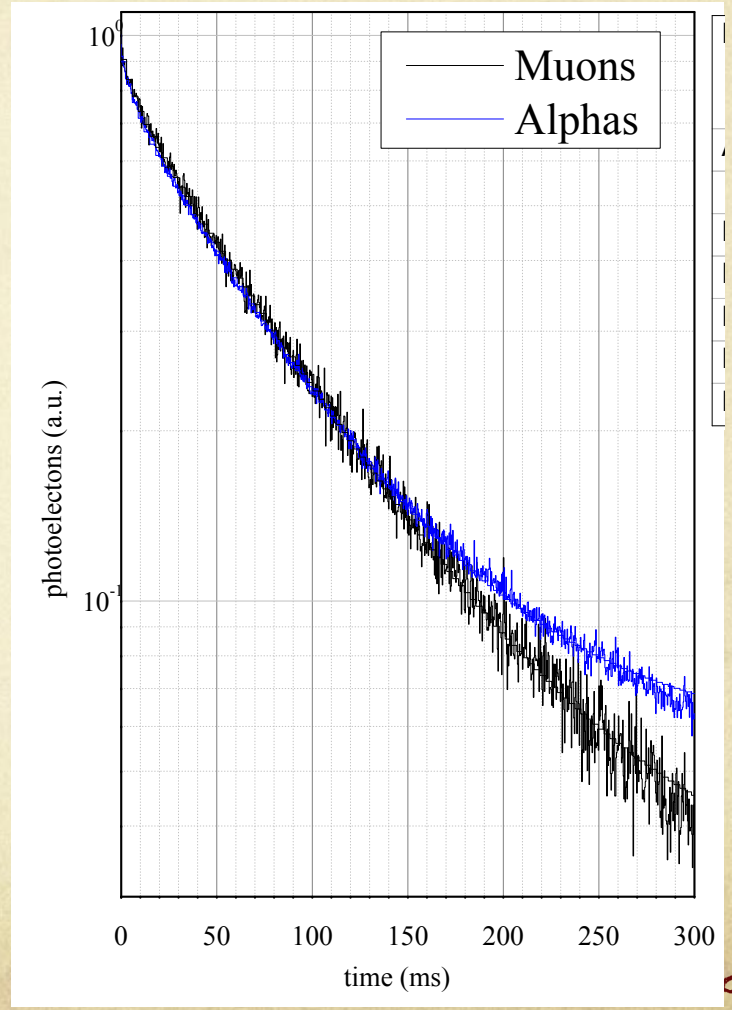


Determination of the very slow scintillation time constants

We have determined in a precise way the time constants of the NaI(Tl) phosphorescence

Very difficult to measure at sea level

PRELIMINAR



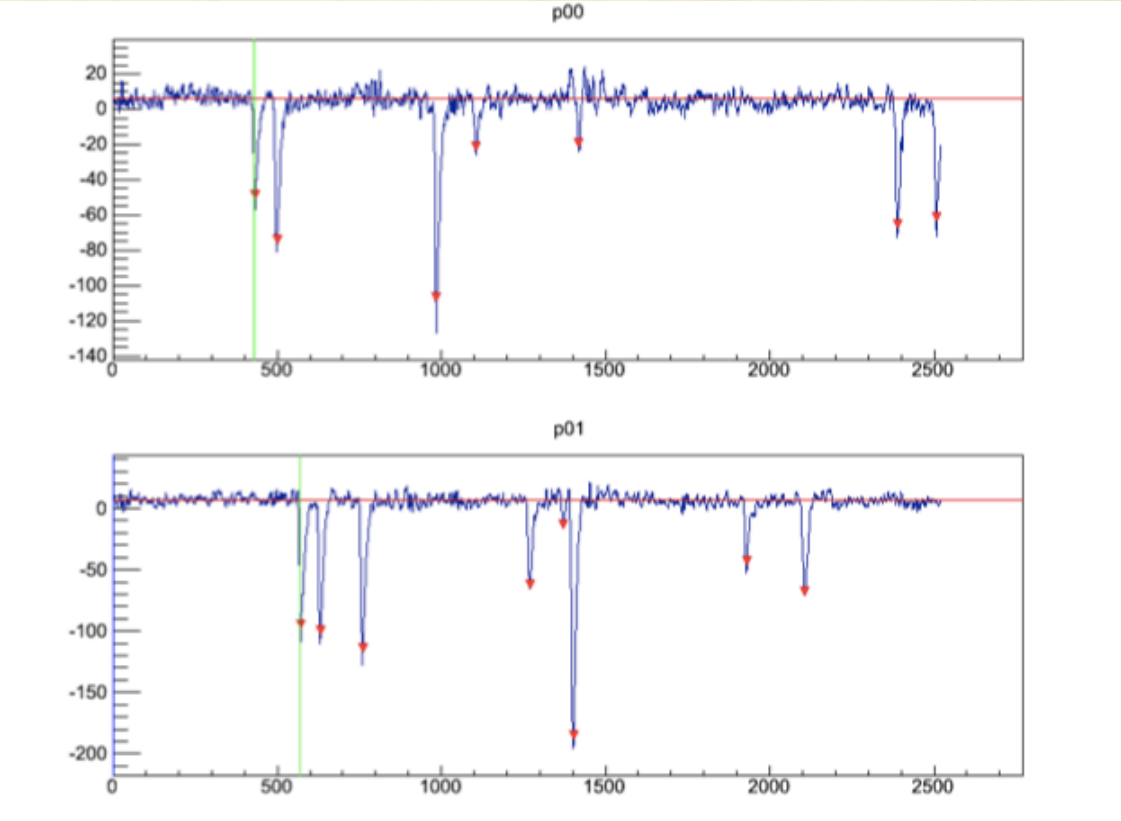
Events FILTERING with ANAIS-0

We count the total number of photoelectrons in every low energy event

Same event

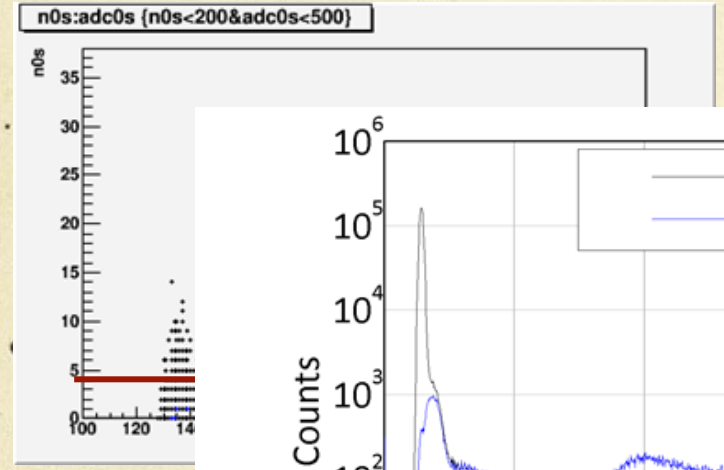
PMT 1

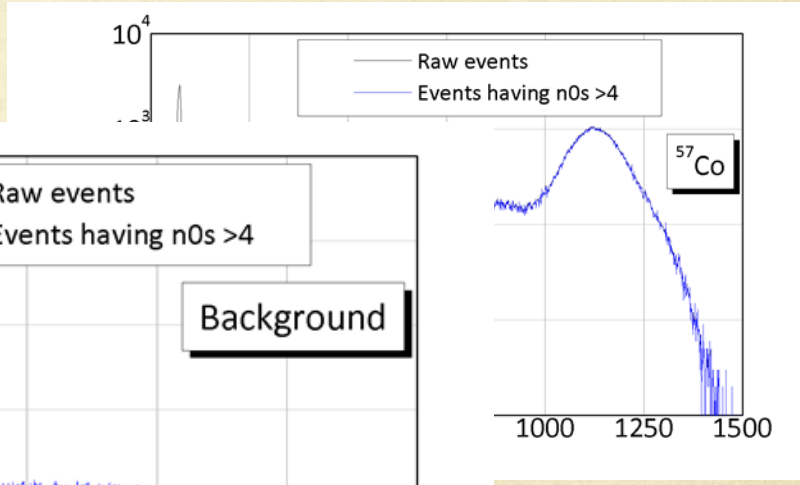
PMT2



Events FILTERING with ANAIS-0

We count the total number of photoelectrons in every low energy event



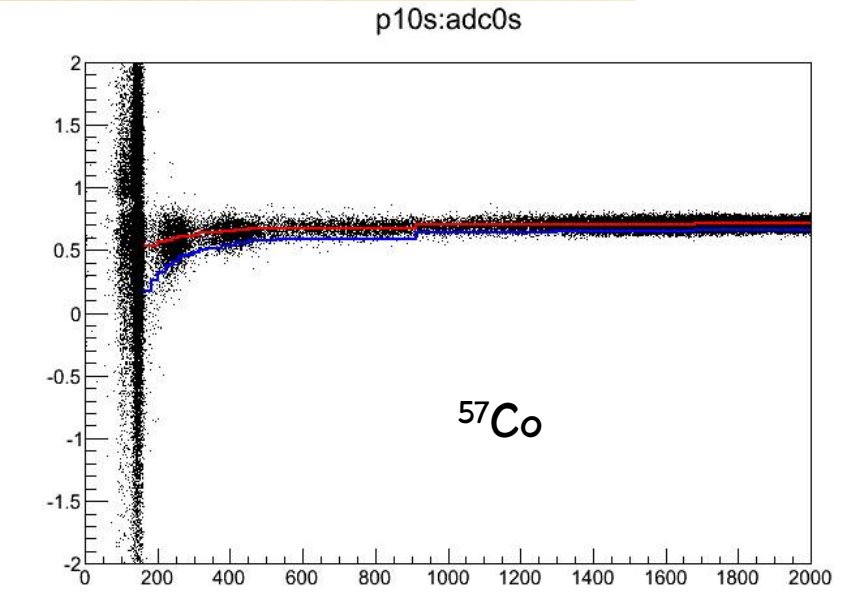


Effect of r … e n0s>4 3.2keV co … ation data events

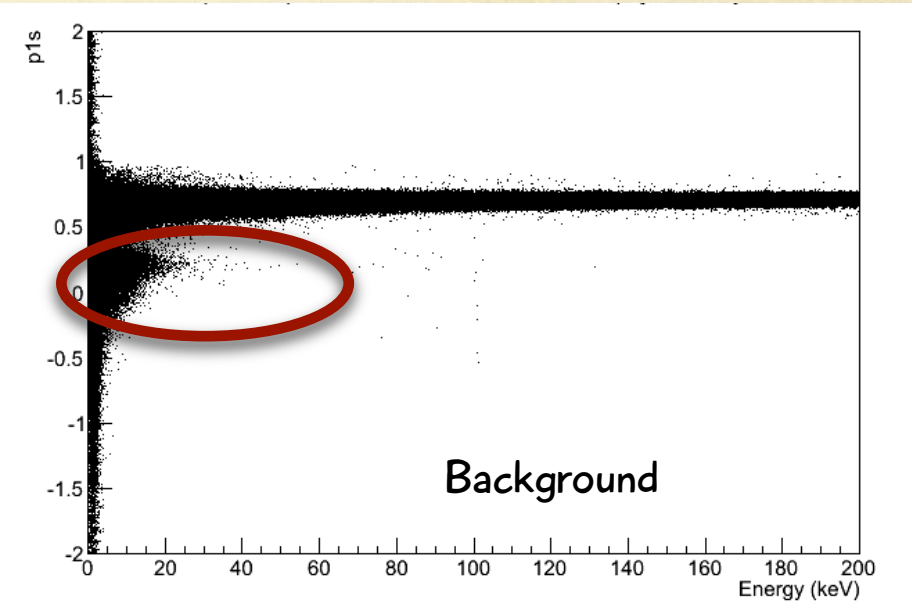
Events FILTERING with ANAIS-0

We filter the fast anomalous event population

$$P1s = \frac{area1(100-600\,ns) + area2(100-600\,ns)}{area1(0-600\,ns) + area2(0-600\,ns)}$$



Alpha events in the surface?
(see results from KIMs on CsI)

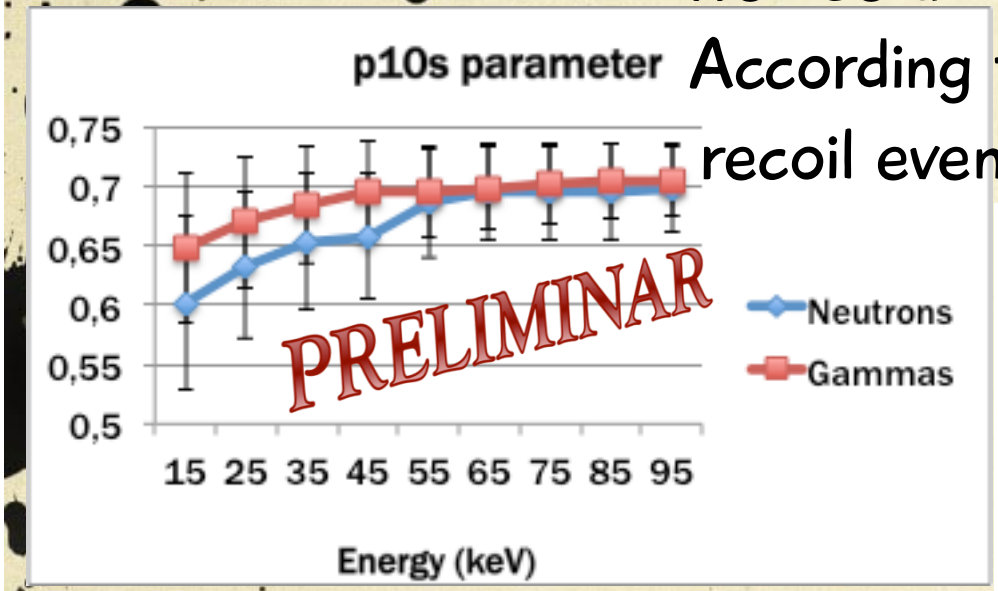


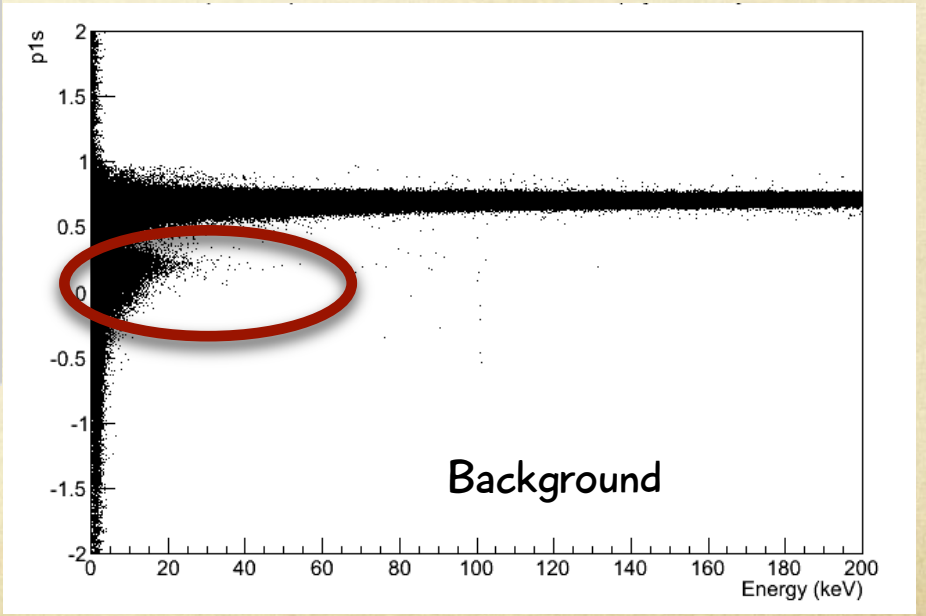
Events FILTERING with ANAIS-0

We filter the fast anomalous event population

We use a ^{252}Cf source with other crystal

According to Geant4 simulations, nuclear recoil events are dominant below 50 keV

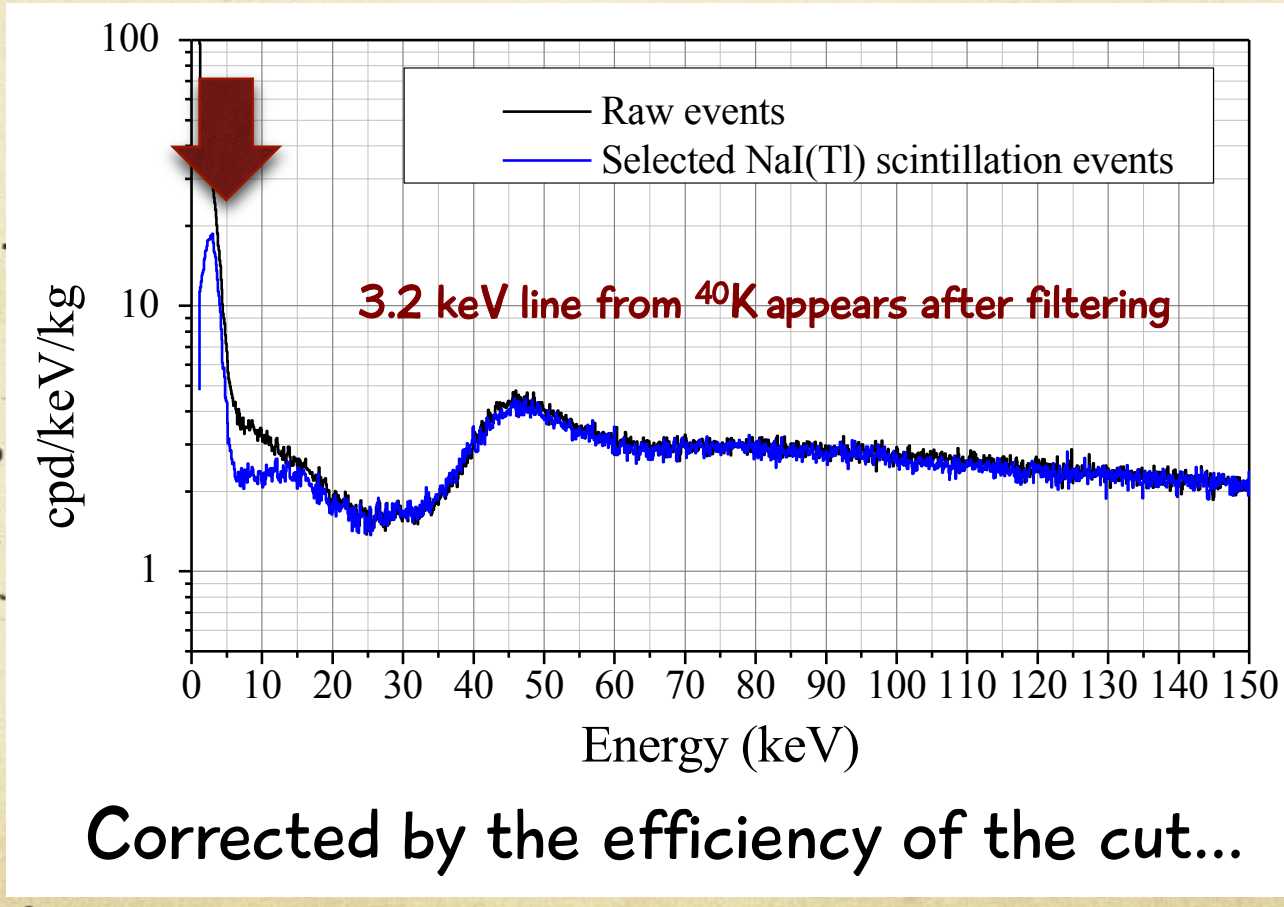




Alpha events in the surface?
(see results from KIMs on CsI)

Events FILTERING with ANAIS-0

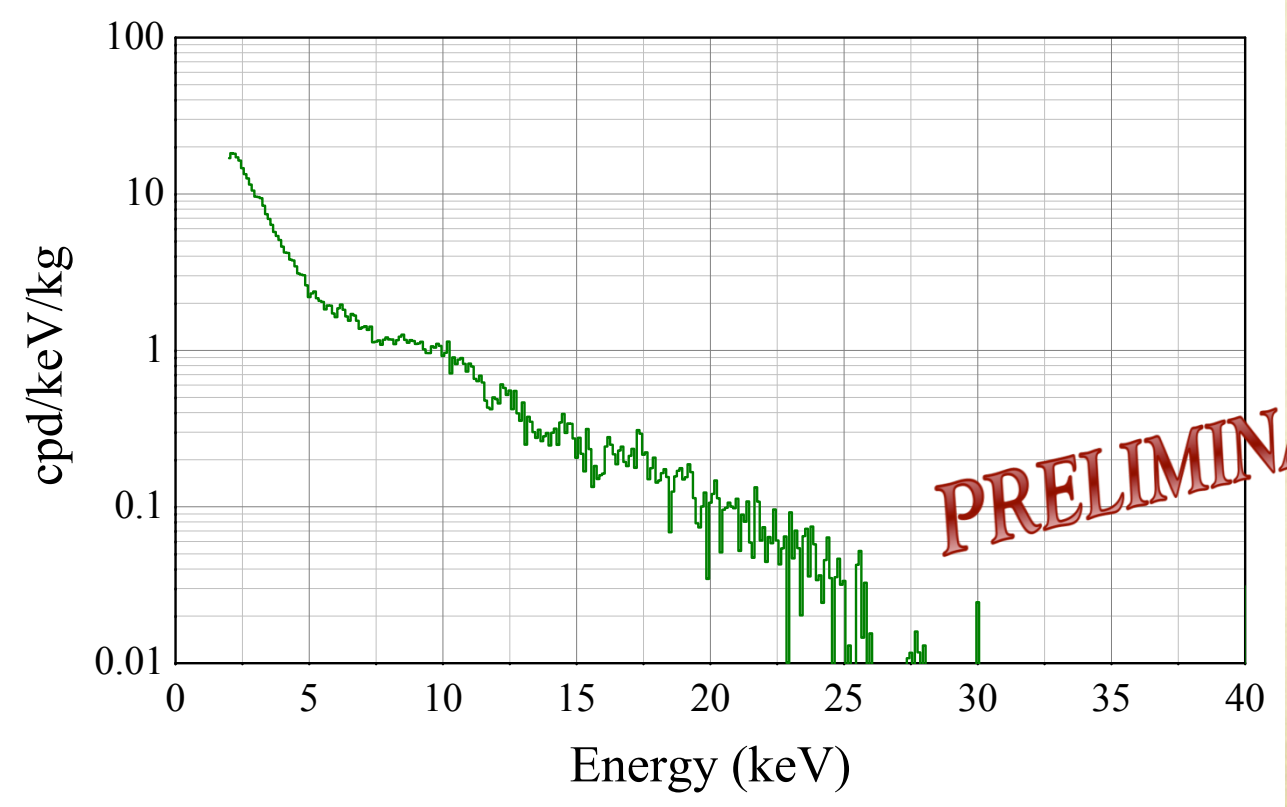
We filter the fast anomalous event population



Corrected by the efficiency of the cut...

Events FILTERING with ANAIS-0

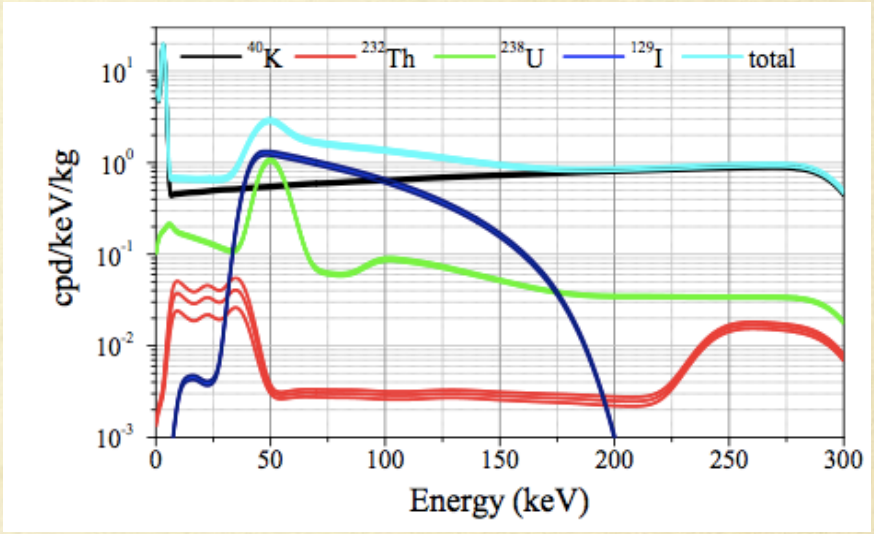
We filter the fast anomalous event population



Background model for ANAIS-0

We have built a background model for the ANAIS-0 module, based on radiopurity input data for the different detector and shielding components + Géant 4 code

Isotope	NaI crystal bulk activity mBq/kg
^{40}K	12.7 ± 0.5
^{129}I	0.96 ± 0.06
^{238}U/^{234}U	0.075 ± 0.005
^{230}Th	0.023 ± 0.007
^{226}Ra	0.098 ± 0.004
^{210}Pb	0.188 ± 0.005
^{232}Th	0.013 ± 0.005
^{228}Th	0.035 ± 0.003

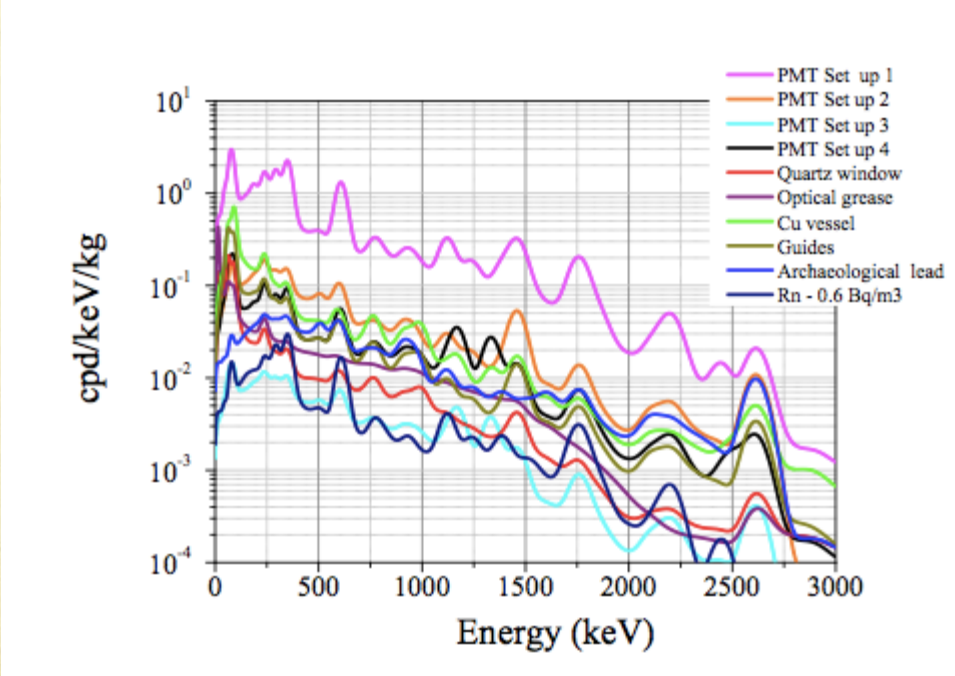


Background contribution from bulk crystal contaminations

Background model for ANAIS-0

Simulated component	Isotope	Activity
Copper encapsulation	^{40}K	< 11 mBq
	^{232}Th	< 4.1 mBq
	^{238}U	< 140 mBq
	^{226}Ra	< 2 mBq
	^{60}Co	< 0.94 mBq
Quartz optical window	^{40}K	< 12 mBq/kg
	^{232}Th	< 2.2 mBq/kg
	^{238}U	< 100 mBq/kg
	^{226}Ra	< 1.9 mBq/kg
Light guides	^{40}K	< 21 mBq/guide
	^{232}Th	< 4.1 mBq/guide
	^{238}U	< 120 mBq/guide
	^{226}Ra	< 4.7 mBq/guide
Optical coupling grease	^{40}K	< 200 mBq/kg
	^{232}Th	< 200 mBq/kg
	^{238}U	< 2000 mBq/kg
	^{226}Ra	< 30 mBq/kg
Archaeological Lead	^{210}Pb	< 20 mBq/kg
	^{232}Th	< 0.3 mBq/kg
	^{238}U	< 0.2 mBq/kg
Inner volume air	^{222}Rn	< 0.6 Bq/m^3

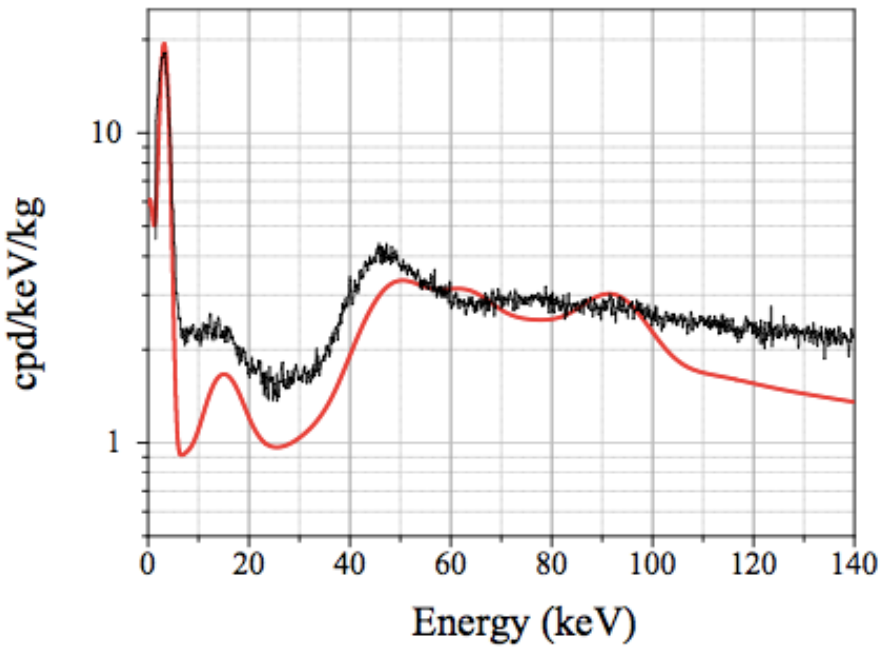
nd model for the ANAIS-0 module, based on data for the different detector and shielding components

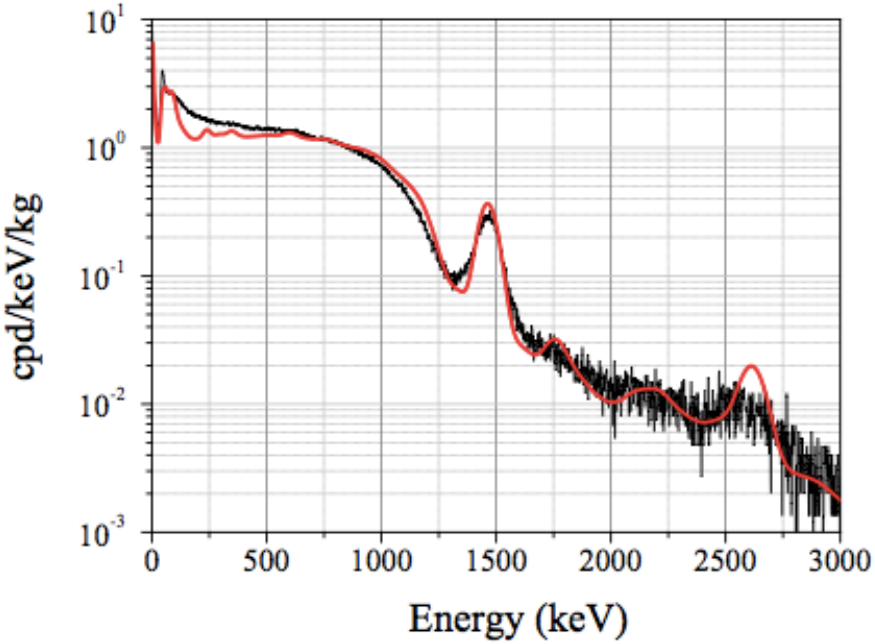


Background contribution from other detector components, shielding and Rn

Background model for ANAIS-0

We have built a background model for the ANAIS-0 module, based on radiopurity input data for the different detector and shielding components





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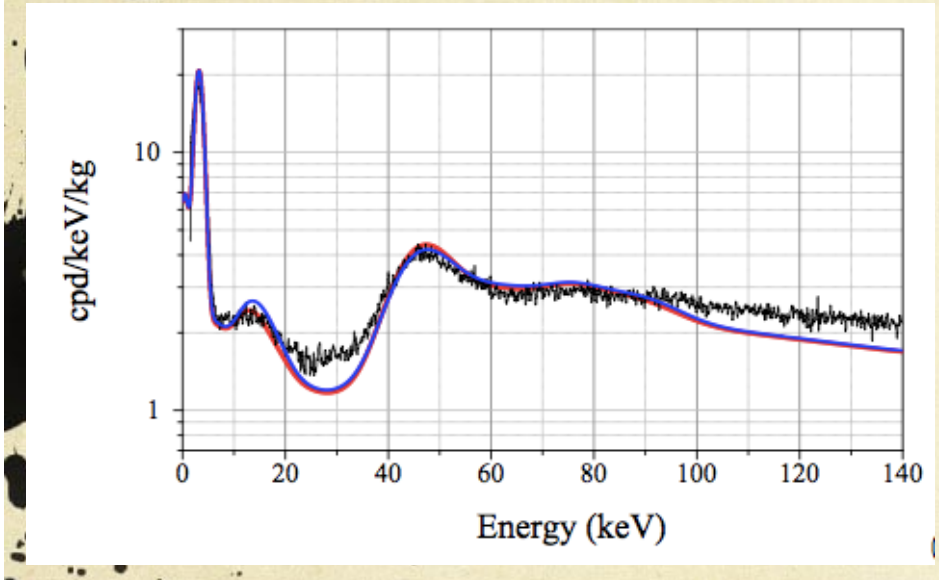
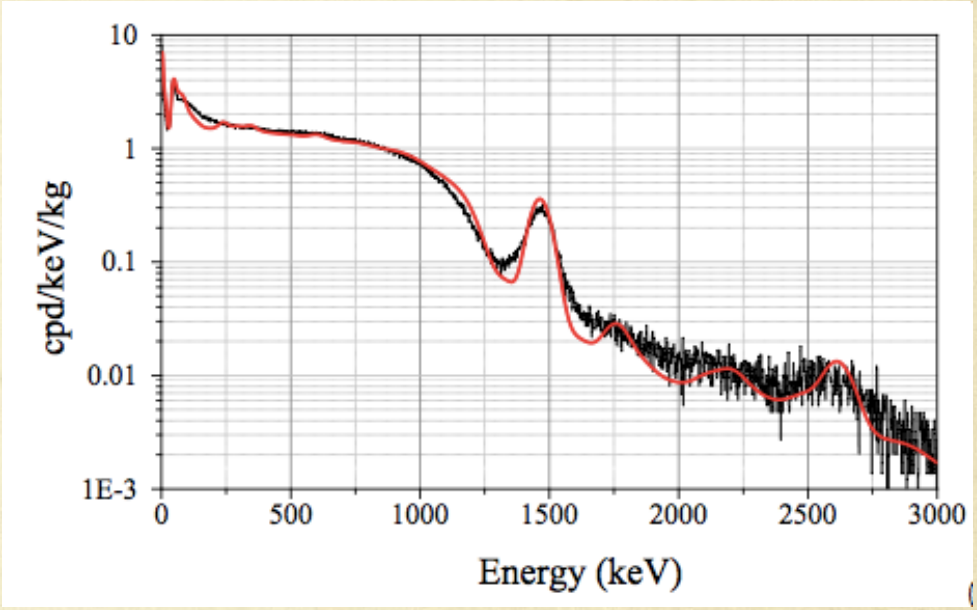
Background model for ANAIS-0

Introducing some small modifications: reducing some contaminations below the upper limits, adding some surface components, ...





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Background model for ANAIS-0

Simulated component	Background contribution 150 - 3000 keV	
	counts/kg/day	%
Crystal	1000.2 (1002.7)	77.5 (77.7)
Copper encapsulation	67.8 (47.5)	5.3 (3.7)
Quartz window	13.5 (6.6)	1.0 (0.5)
Optical coupling grease	21.4 (7.2)	1.7 (0.6)
Ham ULB PMT	47.2	3.7
Lead shielding	36.0 (145.0)	2.8 (11.2)
Inner volume air	9.1	0.7
Total	1195.2 (1265.3)	92.6 (98.1)

Table 6
Contribution to the background of ANAIS-0 module in set-up 4 from the different simulated set-up components: total rate derived from simulation from 150 keV to 3000 keV and corresponding percentage of the measured background. Rates and percentages shown in parentheses correspond to the simulation including extra hypotheses (see text).

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Background model for ANAIS-0

Simulated component	Background contribution			
	5 - 150 keV		2 - 20 keV	
	counts/kg/day	%	counts/kg/day	%
Crystal	196.0 (255.0)	53.0 (68.8)	49.6 (65.0)	64.8 (84.8)
Copper encapsulation	46.1 (31.4)	12.5 (8.5)	1.4 (8.0)	1.8 (10.5)
Quartz window	15.5 (2.5)	4.2 (0.7)	1.8 (0.2)	2.4 (0.3)
Optical coupling grease	15.7 (3.3)	4.2 (0.9)	5.8 (0.9)	7.6 (1.2)
Ham ULB PMT	15.4	4.2	0.5	0.7
Lead shielding	3.2 (33.7)	0.9 (9.1)	0.3 (1.3)	0.3 (1.8)
Inner volume air	1.2	0.3	0.1	0.1
Total	293.2 (342.1)	79.3 (92.5)	59.5 (76.0)	77.7 (99.3)

Table 7
Contribution to the background of ANAIS-0 module in set-up 4 from the different simulated set-up components: total rate derived from simulation from 5 keV to 150 keV and corresponding percentage of the measured background, total rate derived from simulation from 2 keV to 20 keV and corresponding percentage of the measured background. Rates and percentages shown in parentheses correspond to the simulation including extra hypotheses (see text).

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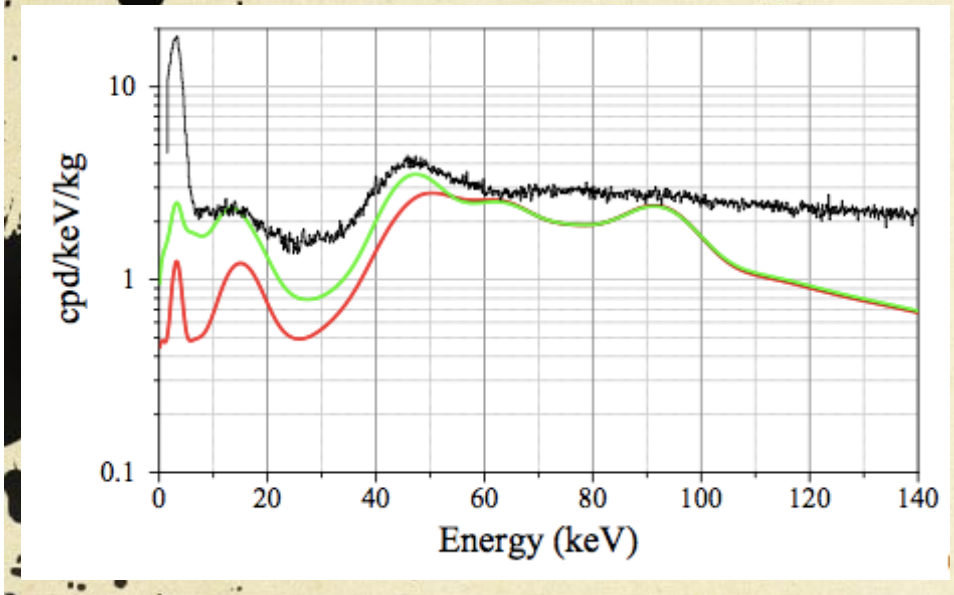
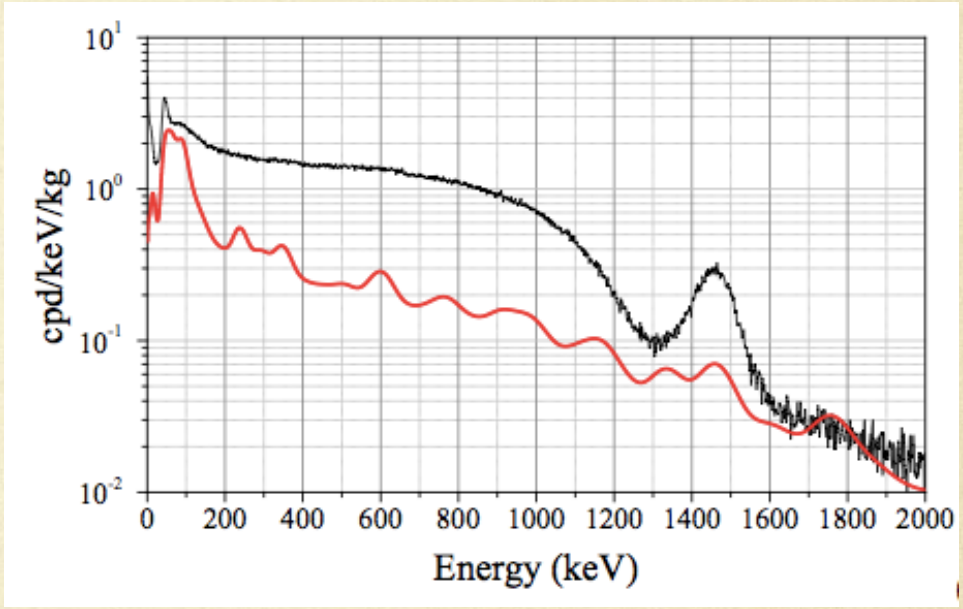
Background model for the new crystals

Applying the same background model, assuming the only improvement is the ^{40}K reduction down to 20 ppb level:





And without profit from coincidence between modules rejection factor...

Conclusions and Prospects

- Radiopure NaI powder (<90 ppb potassium) has been found and two 12.5 kg prototypes are almost ready to final background asessment at LSC
- If potassium content is below 20 ppb, 250 kg NaI (20 x 12,5 kg) will be mounted at LSC along 2013
- Electronic chain and readout is almost ready and the lead and polyethylene for the shielding are at LSC waiting to be mounted
- We understand quite well our present backgrounds: simulations and filtering protocols seem to work well