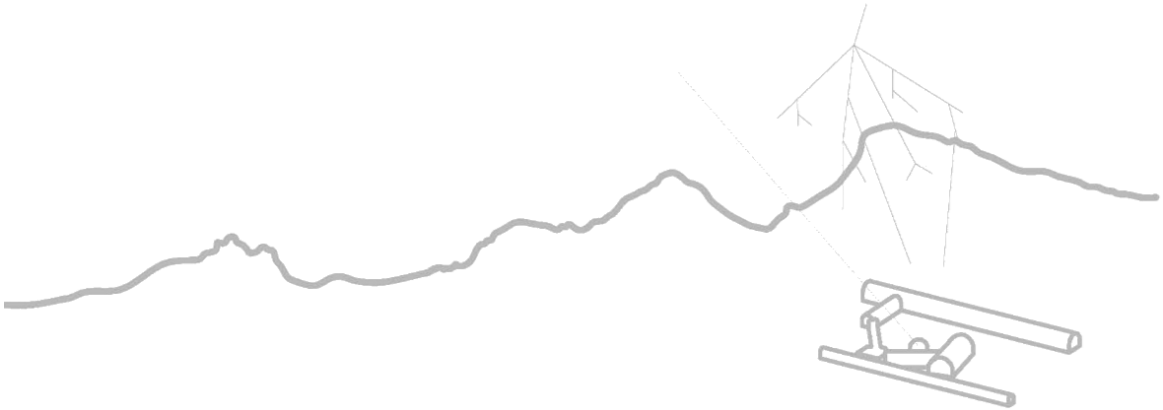
Status of the ANAIS experiment



J. Amaré, S. Cebrián, C. Cuesta, E. García, M. Martínez, M. A. Oliván, Y. Ortigoza, A. Ortiz de Solórzano, J. Puimedón, M. L. Sarsa , P. Villar and J. A. Villar.

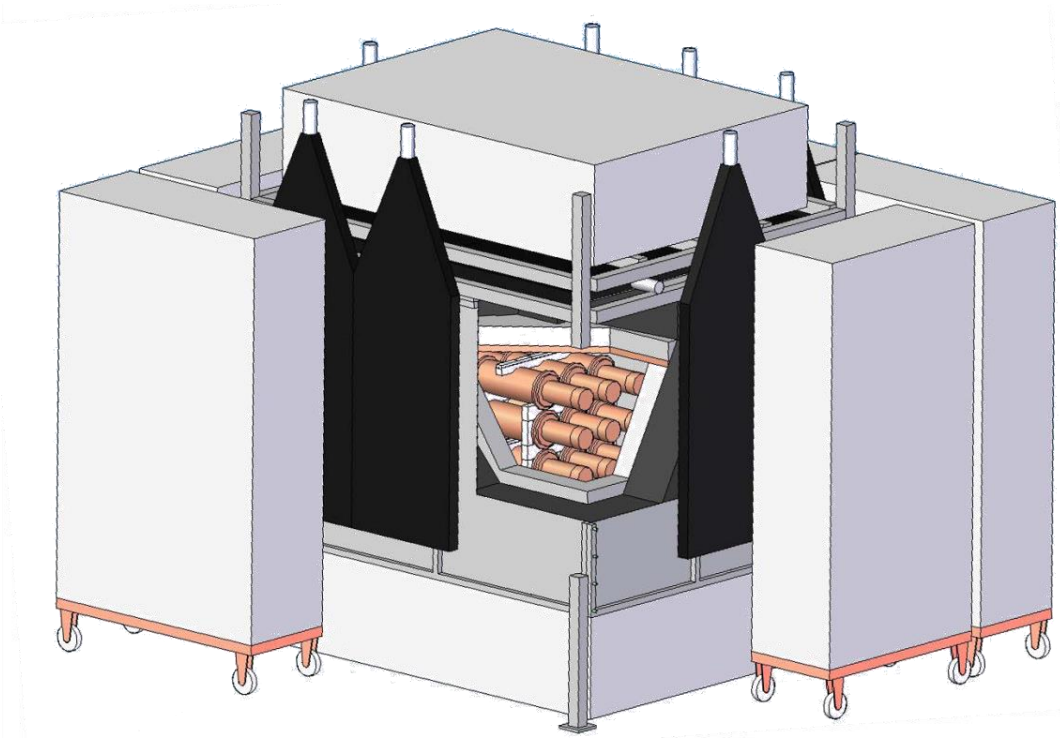
Universidad Zaragoza 1542

LSC Laboratorio Subterráneo de Canfranc

MultiDark Multimessenger Approach for Dark Matter Detection

ANAIS EXPERIMENT

ANAIS is a project aiming to set up, at the new facilities of the Canfranc Underground Laboratory (Spain), a potassium-purified NaI(Tl) experiment to look for dark matter.



Motivation

Study of the annual modulation DAMA/LIBRA positive signal.

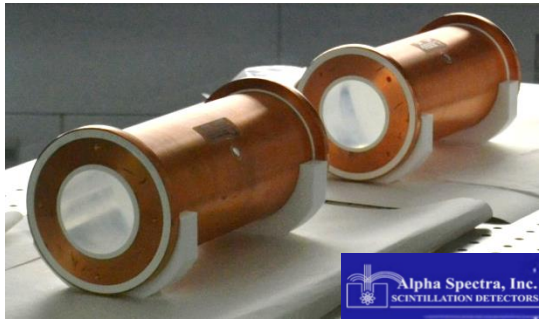
Technical aspects:

- 9 NaI(Tl) crystals of 12.5 kg.
- Coupled each one to 2 PMTs.
- Shielded from external radiation.

Experimental goals:

- Energy threshold < 2 keVee.
- Background at low energy as low as possible.
- Very stable operation conditions.

APPROACH

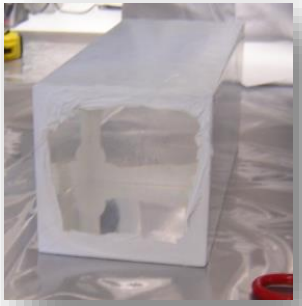


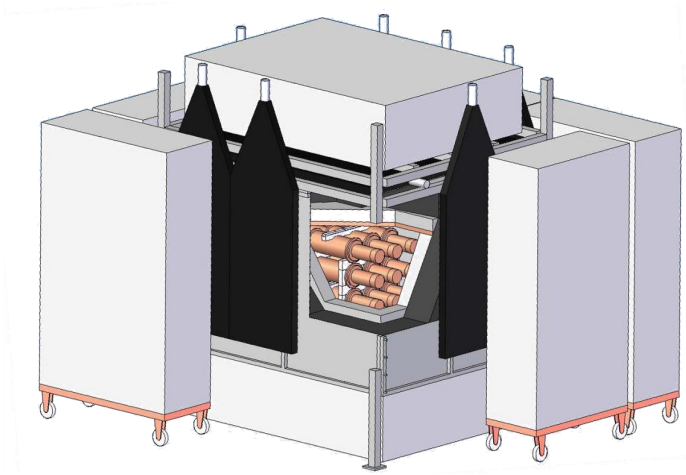
ANAIS-0

ANAIS-25

ANAIS-37

ANAIS-112

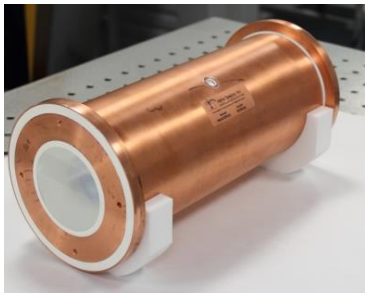




NaI(Tl) CRYSTALS

9 ultrapure NaI(Tl) crystals of 12.5 kg each.

Produced by Alpha Spectra Inc., CO following low radioactivity protocols.



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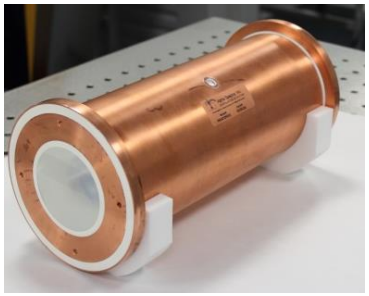

Produced by Alpha Spectra Inc., CO following low radioactivity protocols.

- D0, D1 and D2 taking data at ANAIS-37.
  Radioactivity measured at LSC used to improve Alpha Spectra procedures:

	^{40}K	^{238}U	^{210}Pb	^{232}Th
D0	1.4 mBq/kg (45 ppb K)	10 μBq/kg	3.15 mBq/kg	3 μBq/kg
D1	1.1 mBq/kg (34 ppb K)	10 μBq/kg	3.15 mBq/kg	3 μBq/kg
D2	1.1 mBq/kg (34 ppb K)	3 μBq/kg (*)	0.7 mBq/kg	1 μBq/kg (^{220}Rn-^{216}Po) <0.5 μBq/kg (^{212}Bi-Po) (*)

(*) PRELIMINARY

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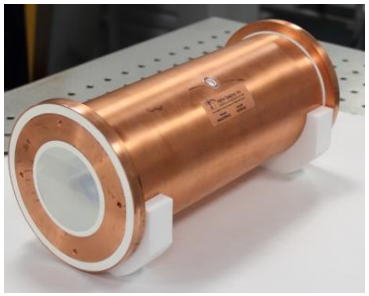

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(*) PRELIMINARY

- D3 travelling to LSC, will arrive in February 2016.
  Improvement in radiopurity expected (<20 ppb K measured in powder).
- D4, D5 and D6 under preparation at Alpha Spectra, will arrive to LSC in Spring 2016.
- D7 and D8 will be prepared next.

PHOTOMULTIPLIERS

- Ham R12669SEL2.
- Selected after R&D considering low background + quantum efficiency + dark current rate.

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M.A. Oliván PhD Thesis arXiv:1601.07312

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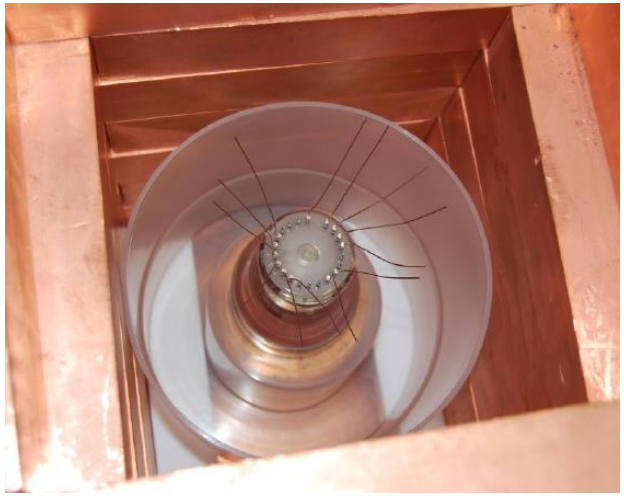
20.7 ± 0.8	157 ± 8	82.5 ± 0.8	111 ± 5



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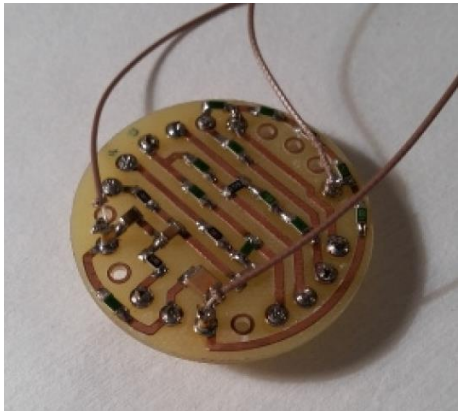

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- Light collection in ANAIS-37:

Detector	Phe$^-$/keV
D0	15.26 ± 0.10
D1	14.44 ± 0.09
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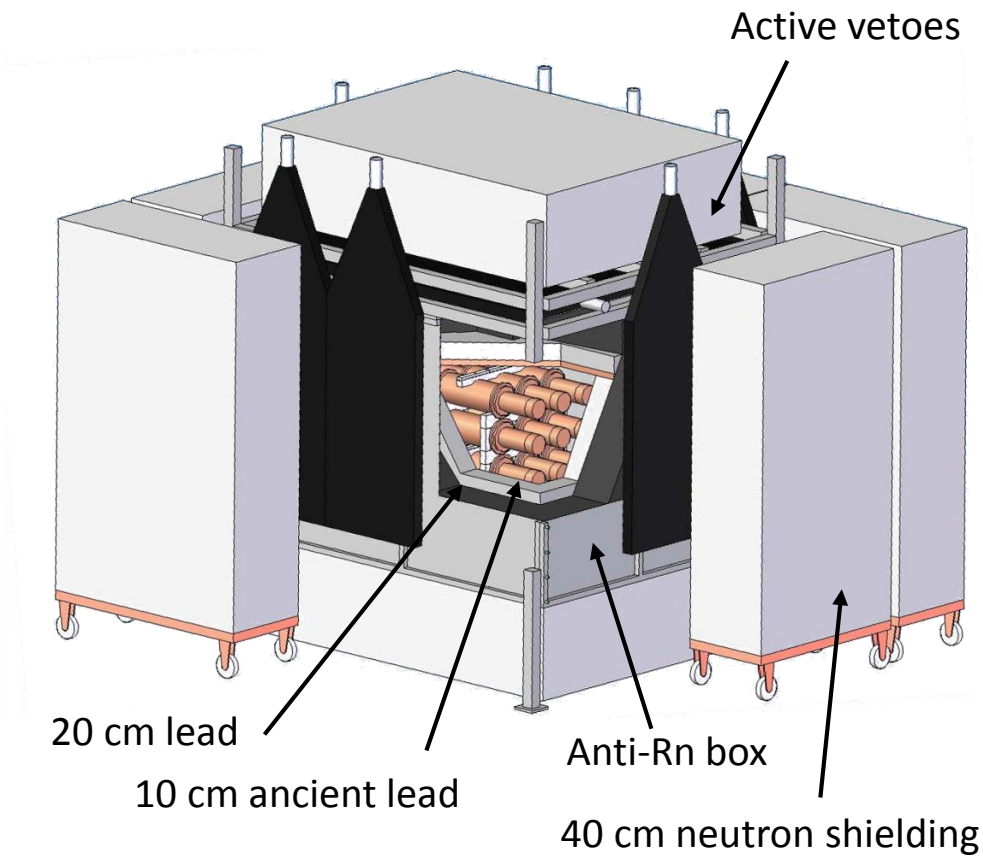
D2	16.31 ± 0.56

- Available at LSC.

SHIELDING

Shielding Materials for the full experiment available at LSC.



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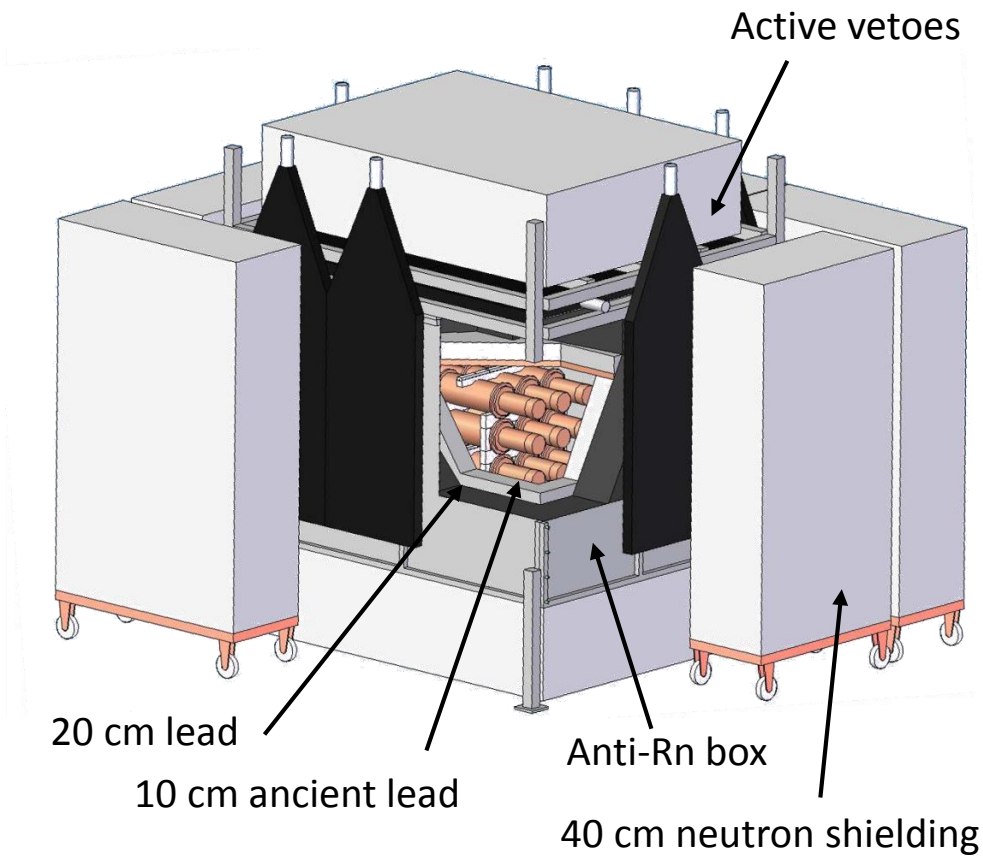
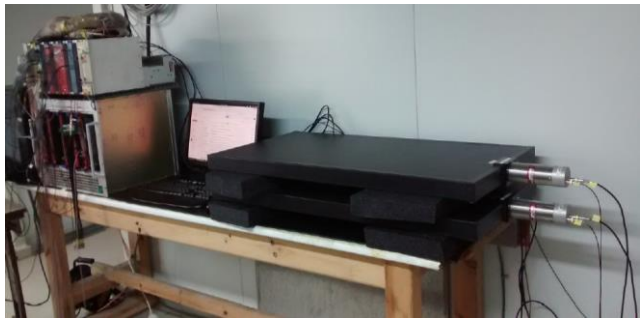
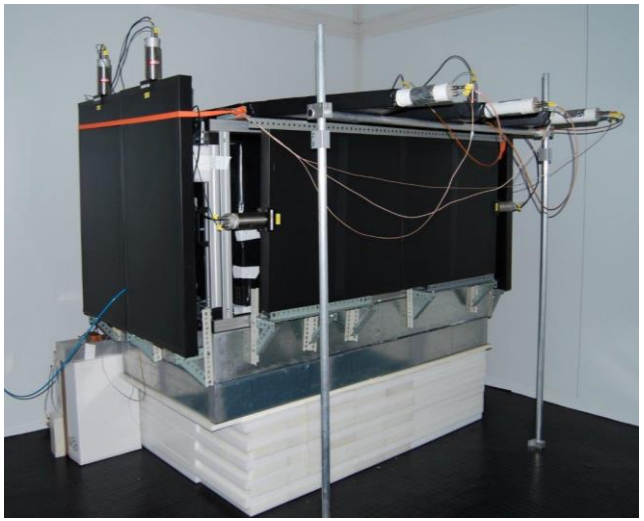


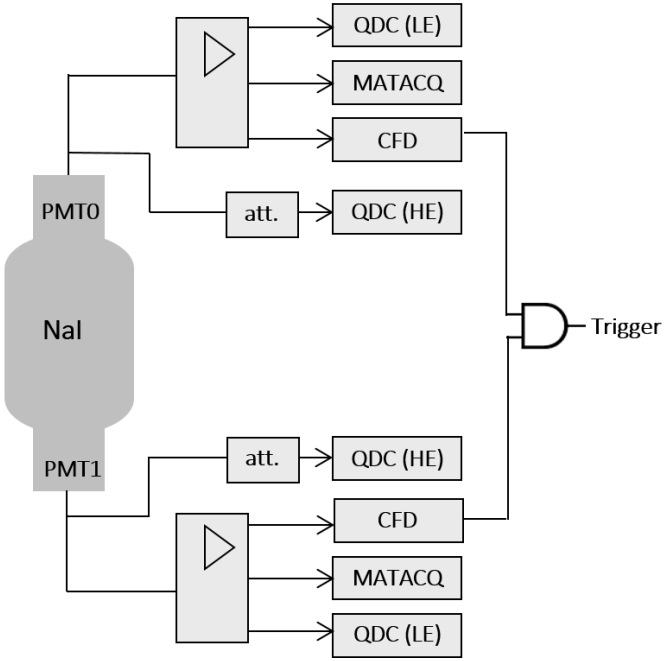




Muon-tagging system on-site and tested.

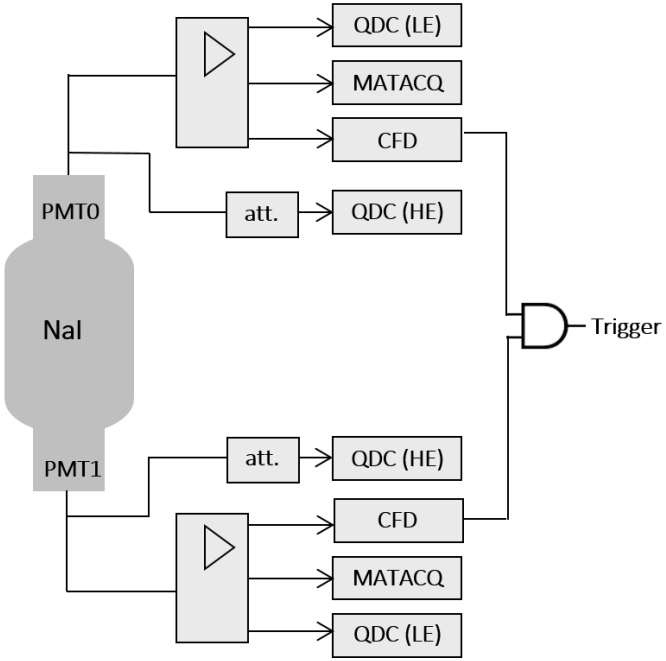
DATA ACQUISITION

- DAQ system:
  - Individual PMT signals fully processed.
  - Trigger at phe level each PMT signal.
  - AND coincidence in 200 ns window.
  - Redundant energy conversion by QDC in different ranges.
  - Trigger in OR logical mode among modules.



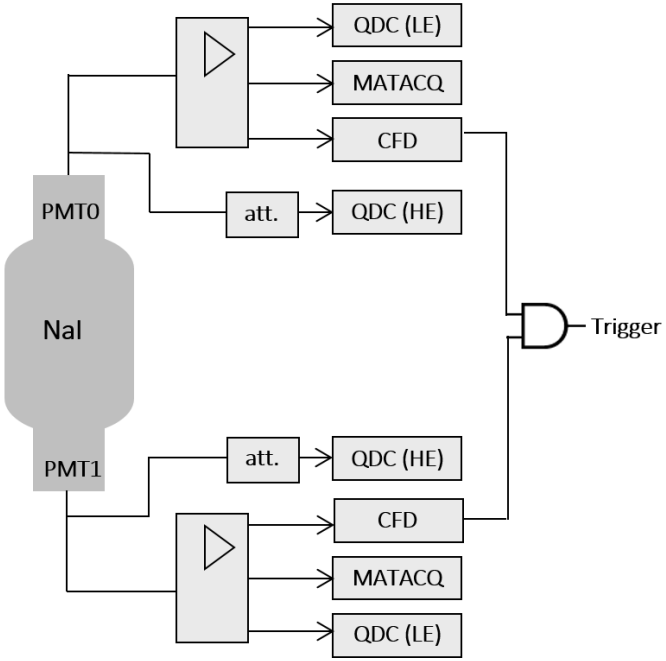
DATA ACQUISITION

- DAQ system:
  - Individual PMT signals fully processed.
  - Trigger at phe level each PMT signal.
  - AND coincidence in 200 ns window.
  - Redundant energy conversion by QDC in different ranges.
  - Trigger in OR logical mode among modules.
- Front-end modules available.
- DAQ software designed and tested.

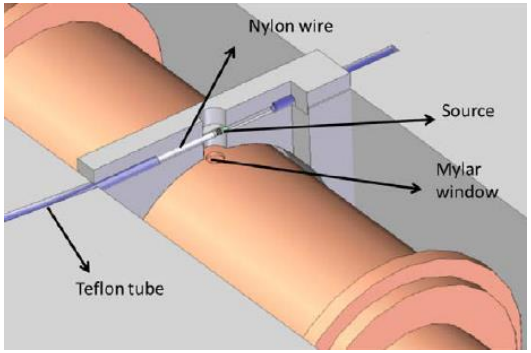


DATA ACQUISITION

- DAQ system:
  - Individual PMT signals fully processed.
  - Trigger at phe level each PMT signal.
  - AND coincidence in 200 ns window.
  - Redundant energy conversion by QDC in different ranges.
  - Trigger in OR logical mode among modules.
- Front-end modules available.
- DAQ software designed and tested.
- Slow control system operative:
  - Monitoring:
    - External Rn, H, P, T
    - T inside the shielding
    - N_2 flux and PMT HV.
  - Stability checks: gain, trigger level, coincidence window, trigger rate.



DATA ANALYSIS

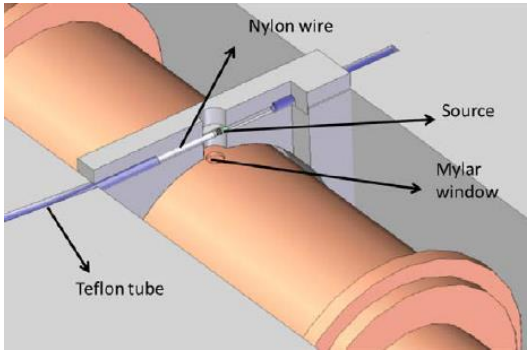


External calibration source data (^{109}Cd / ^{57}Co)

→ Energy calibration

→ Determination of cut efficiency

DATA ANALYSIS



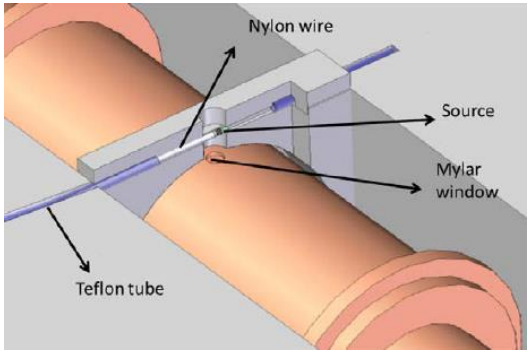
External calibration source data (^{109}Cd / ^{57}Co)

- Energy calibration
- Determination of cut efficiency

Background data

- Coincidences with HE γ
  - Energy Calibration
  - Determination of trigger efficiency
  - Checking cut efficiency

DATA ANALYSIS



External calibration source data (^{109}Cd / ^{57}Co)

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Background data

- Coincidences with HE γ
  - Energy Calibration
  - Determination of trigger efficiency
  - Checking cut efficiency

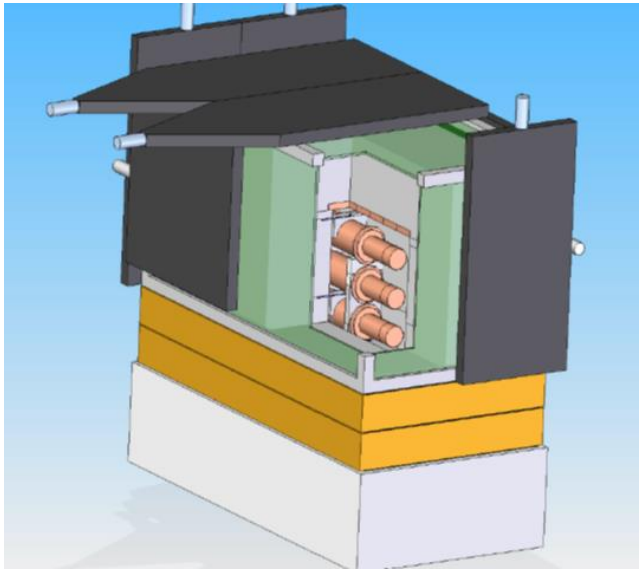
- Application of cuts
- Efficiency correction

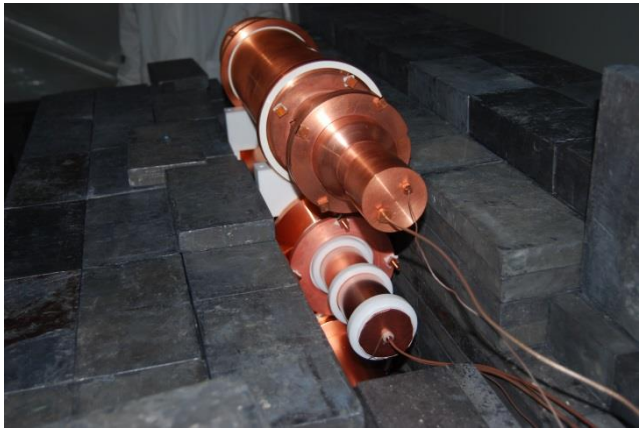
Building filtered background

ANAIS-37 DATA ANALYSIS

PRELIMINARY

- New AS improved module 12.5 kg – D2 installed together to D0/D1 (ANAIS-25 ones).





ANAIS-37 DATA ANALYSIS

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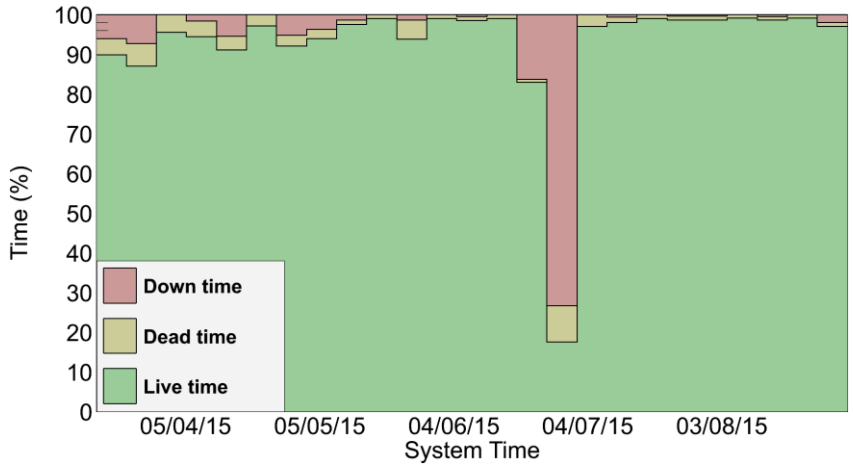
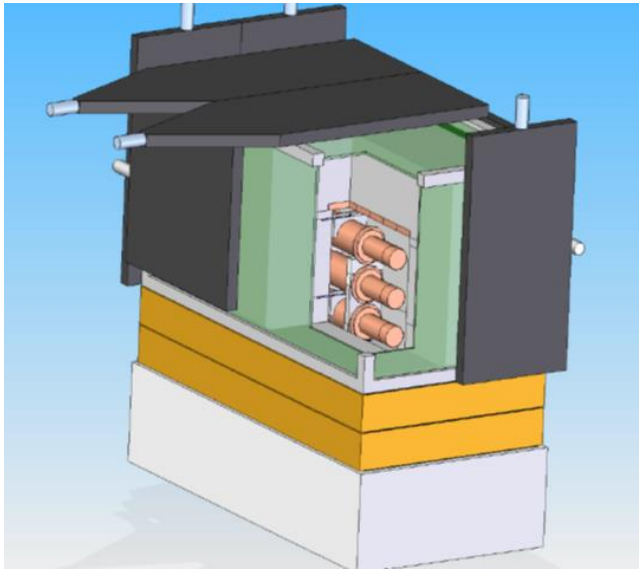
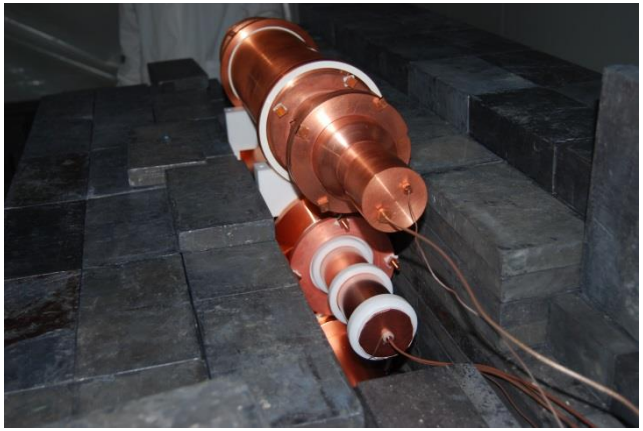
- New AS improved module 12.5 kg – D2 installed together to D0/D1 (ANAIS-25 ones).
- Data taking since March 2015.







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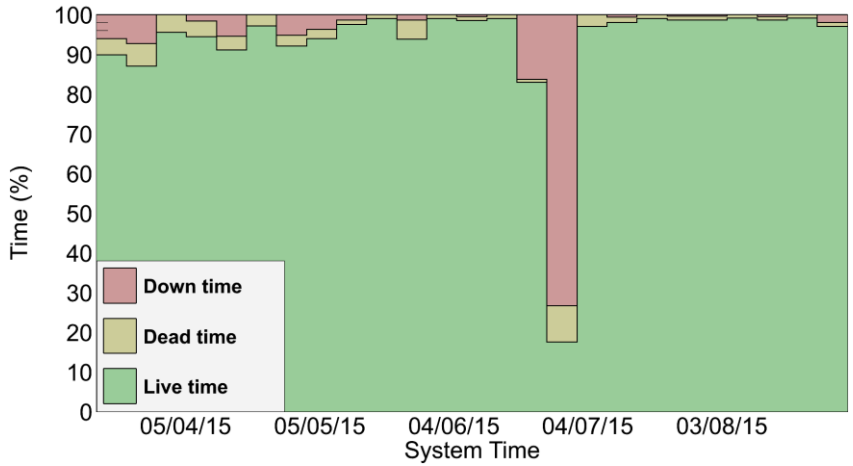
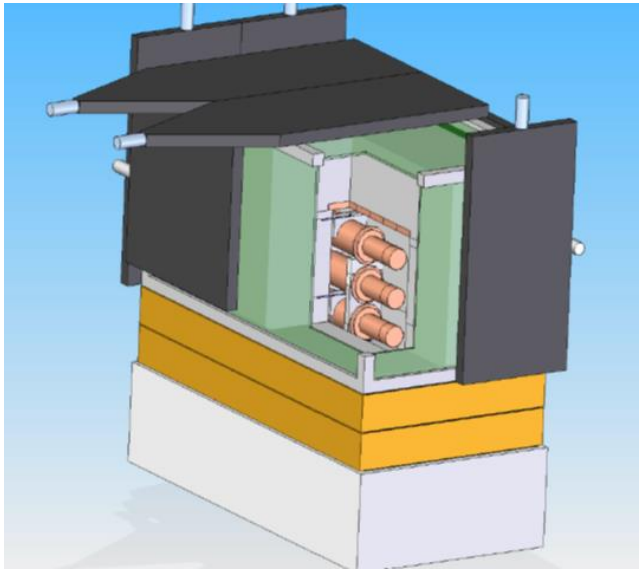
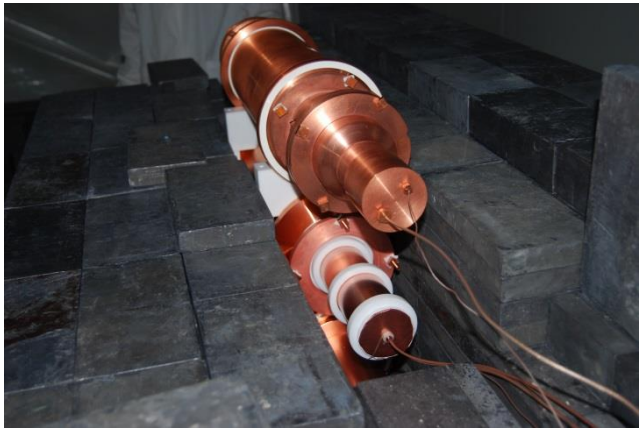


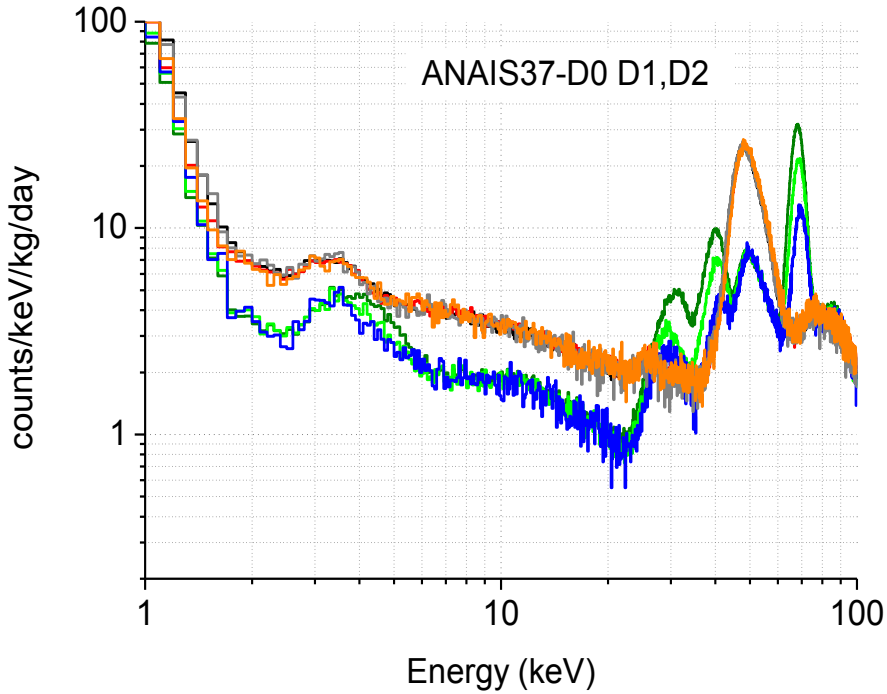




- Goals:
  - Evaluate background after implementation of improvements at AS procedures.
  - Confirm threshold below 2 keVee.

ANAIS-37 DATA ANALYSIS

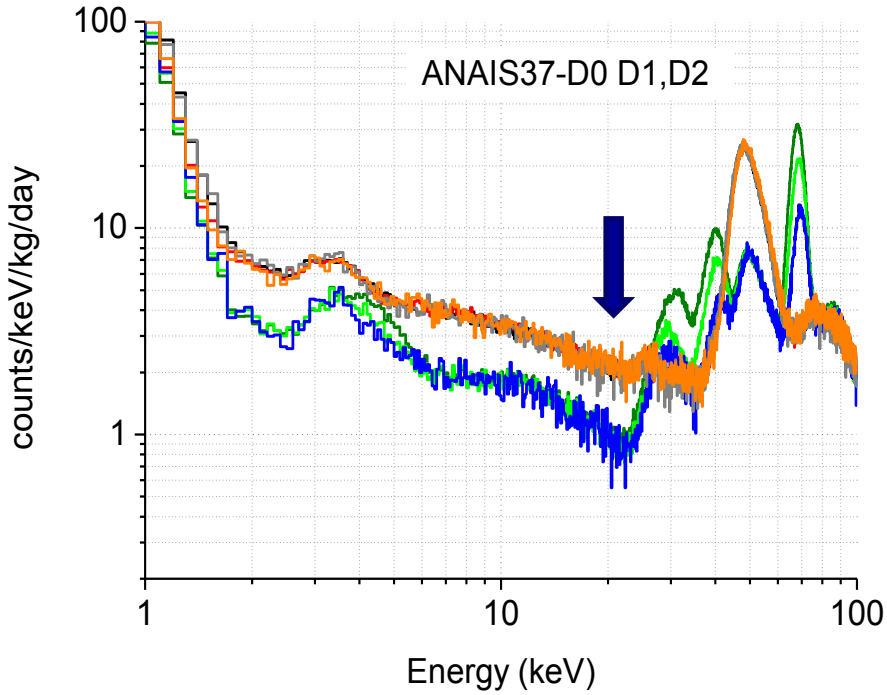
PRELIMINARY



D0 (total)
D1 (total)
D2 (cosm. activated)
D2 (after 3 month underground)
D2 (after 5 month underground)

ANAIS-37 DATA ANALYSIS

PRELIMINARY



➡ Very promising reduction under 20 keV.

D0 (total)
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D2 (after 3 month underground)
D2 (after 5 month underground)

ANAIS-37 DATA ANALYSIS

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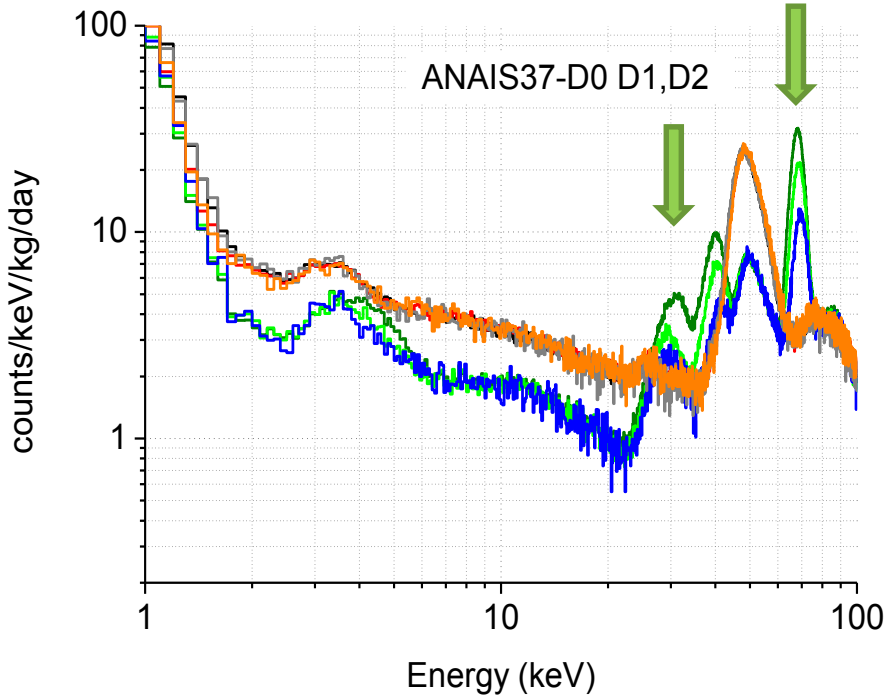
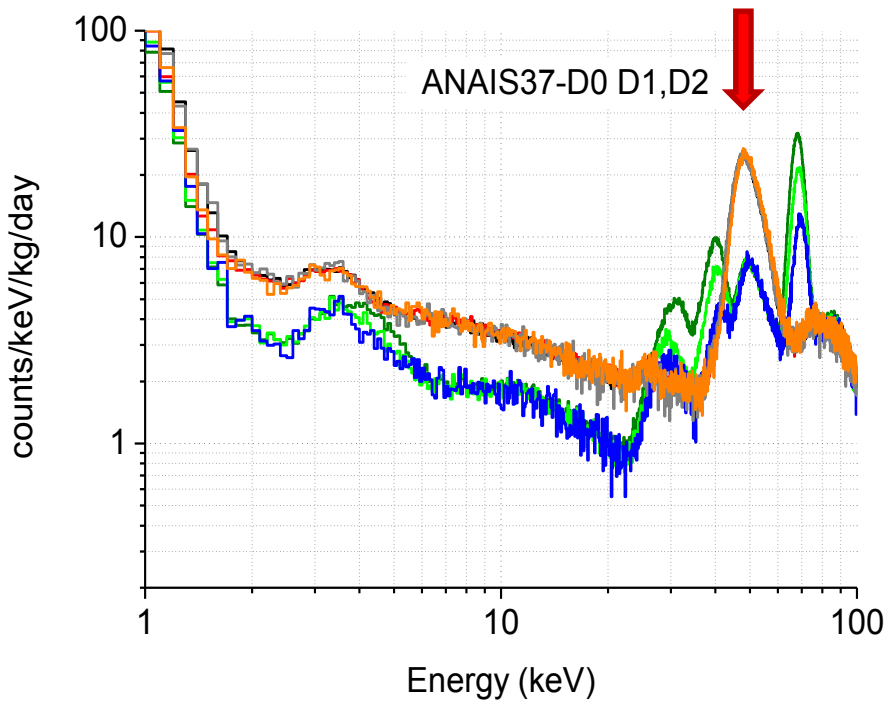


D0 (total)
D1 (total)
D2 (cosm. activated)
D2 (after 3 month underground)
D2 (after 5 month underground)

- Very promising reduction under 20 keV.
- ➡ D2 cosmogenic lines still decaying.

ANAIS-37 DATA ANALYSIS

PRELIMINARY



D0 (total)
D1 (total)
D2 (cosm. activated)
D2 (after 3 month underground)
D2 (after 5 month underground)

- Very promising reduction under 20 keV.
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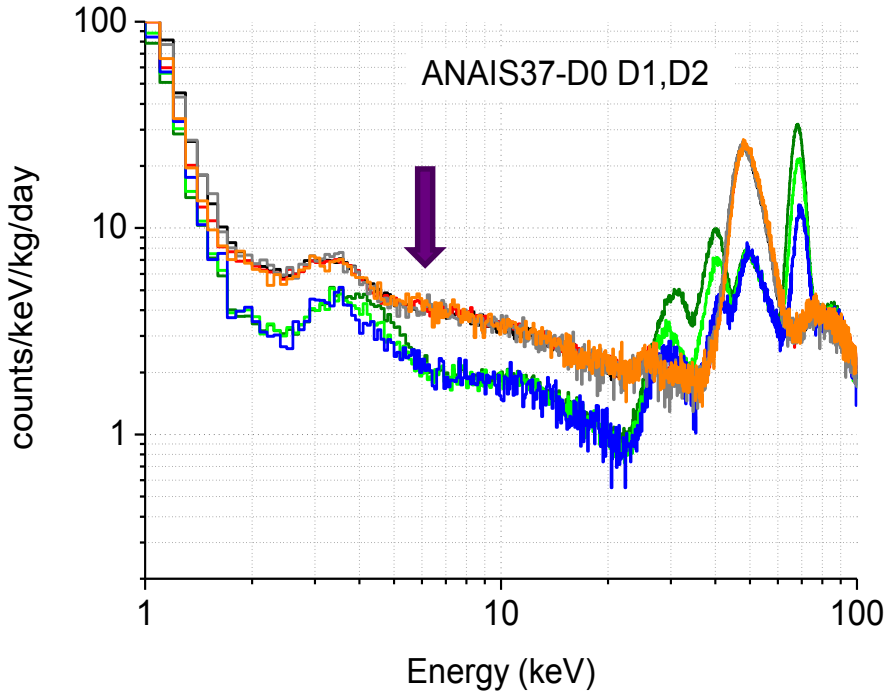
➡ ^{210}Pb clear reduction with respect to ANAIS-25 modules.

ANAIS-37 DATA ANALYSIS

PRELIMINARY



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D2 (after 3 month underground)
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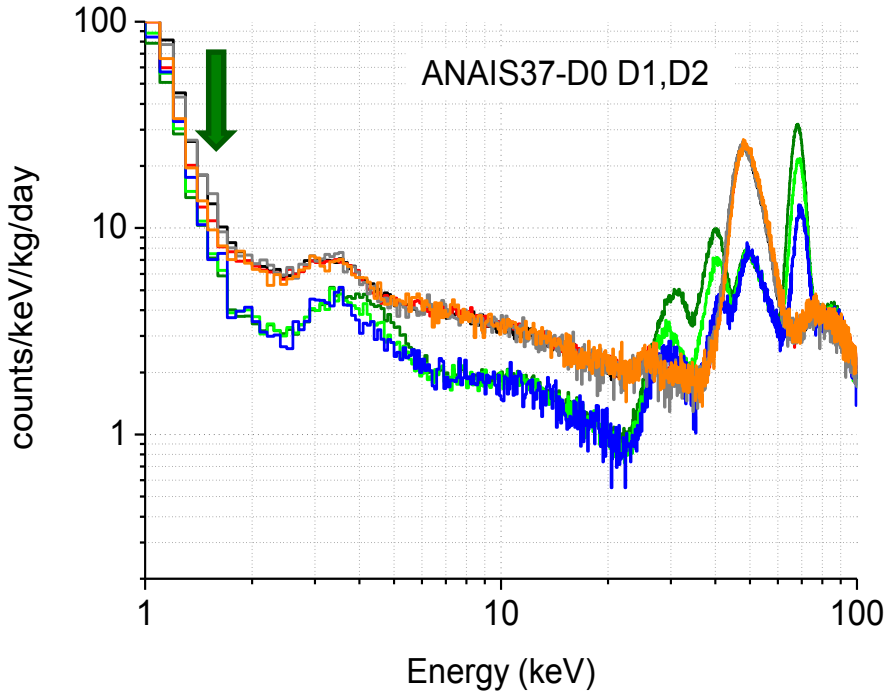
- Very promising reduction under 20 keV.
- D2 cosmogenic lines still decaying.
- ^{210}Pb clear reduction with respect to ANAIS-25 modules.

➡ Background below 2 counts/keV/kg/day down to 6 keV.

ANAIS-37 DATA ANALYSIS

PRELIMINARY



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D2 (cosm. activated)
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D2 (after 5 month underground)

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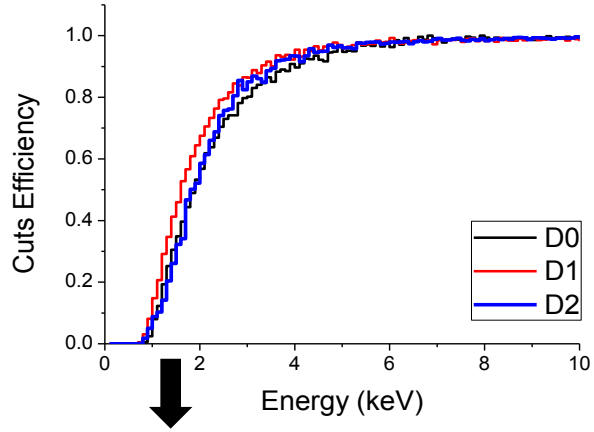
- D2 cosmogenic lines still decaying.
- ^{210}Pb clear reduction with respect to ANAIS-25 modules.
- Background below 2 counts/keV/kg/day down to 6 keV.

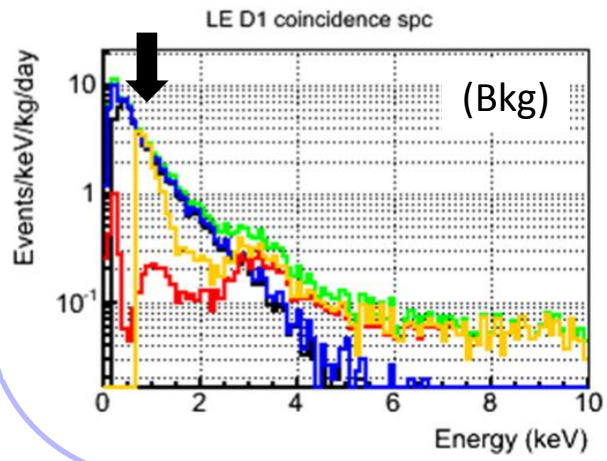
➡ Background below 10 counts/keV/kg/day down to 1.5 keV:
- Filtering protocols still under optimization.
- Limited by acceptance below 2 keVee → still working to understand PMT origin events (**Blank Module measurements ongoing**).

ANAIS-37 DATA ANALYSIS

PRELIMINARY



Underestimate of acceptance efficiencies is suggested by the study of coincident events among detectors



Raw coinc. spc.
After cuts
After cuts eff. corr.
Rejected by cut (I)
Rejected by cut (II)

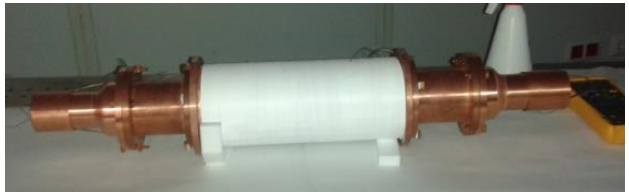
- Very promising reduction under 20 keV.
- D2 cosmogenic lines still decaying.
- ^{210}Pb clear reduction with respect to ANAIS-25 modules.
- Background below 2 counts/keV/kg/day down to 6 keV.
- Background below 10 counts/keV/kg/day down to 1.5 keV:
  - Filtering protocols still under optimization.
  - Limited by acceptance below 2 keVee → still working to understand PMT origin events (**Blank Module measurements ongoing**).

ANAIS-37 DATA ANALYSIS

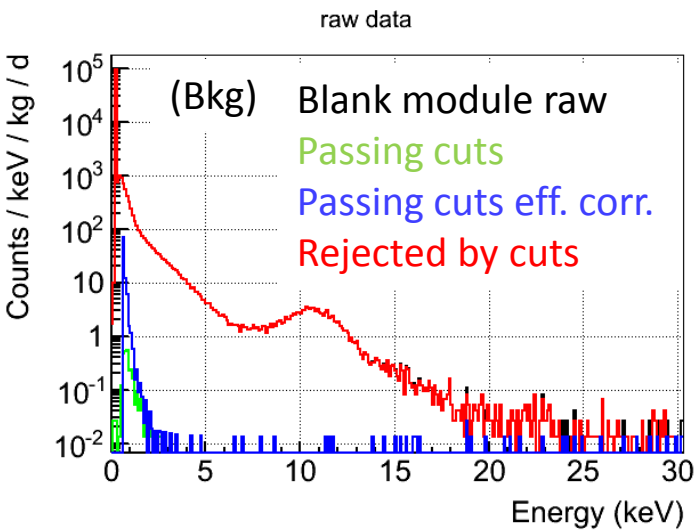
PRELIMINARY

Blank Module measurements

Goal: accumulate a population of pure PMT events and testing the filtering protocols

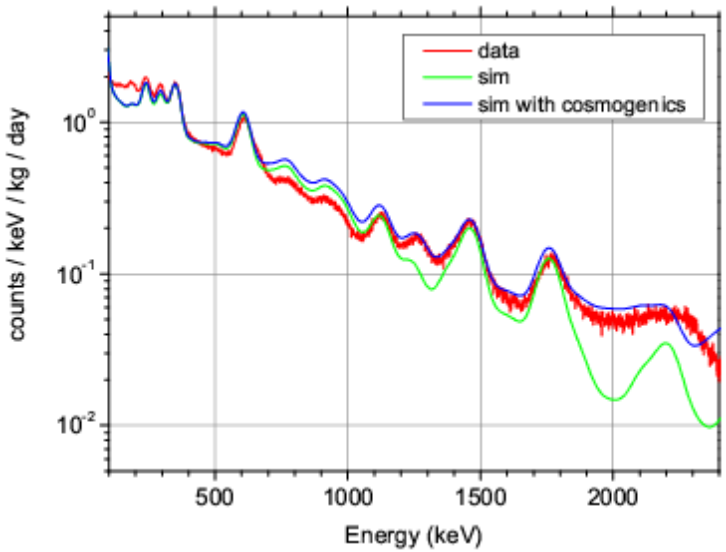


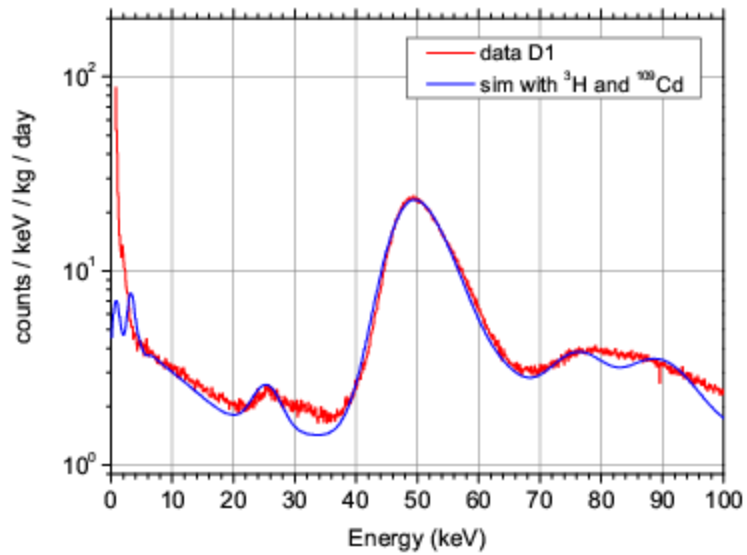
Filtering protocols seem to reject most of the PMT events

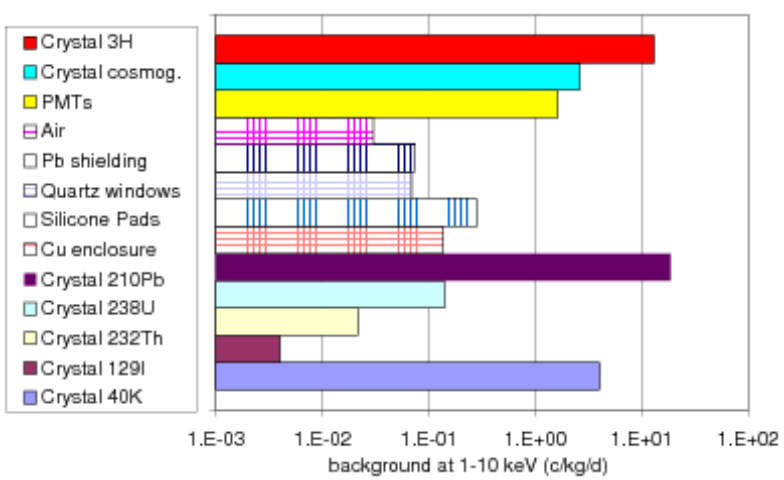


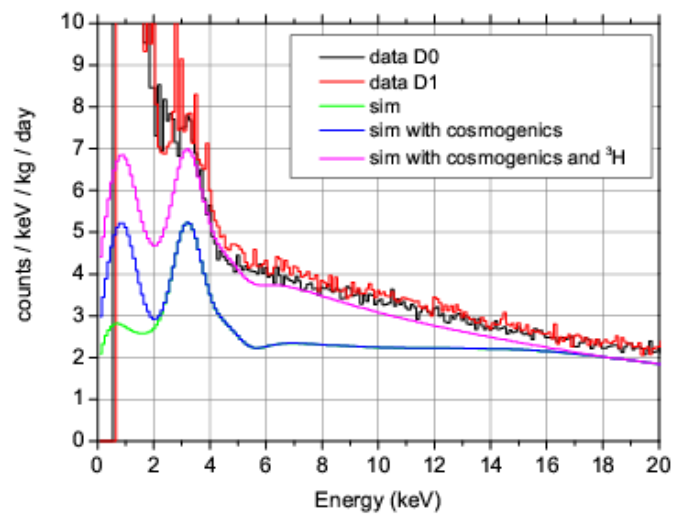
- Very promising reduction under 20 keV.
- D2 cosmogenic lines still decaying.
- ^{210}Pb clear reduction with respect to ANAIS-25 modules.
- Background below 2 counts/keV/kg/day down to 6 keV.
- Background below 10 counts/keV/kg/day down to 1.5 keV:
  - Filtering protocols still under optimization.
  - Limited by acceptance below 2 keVee → still working to understand PMT origin events (**Blank Module measurements ongoing**).

SIMULATIONS – D0 and D1 in ANAIS-25

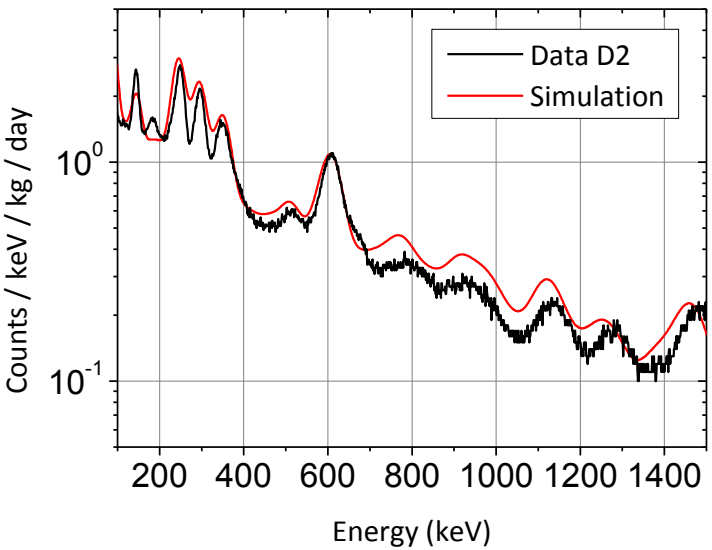


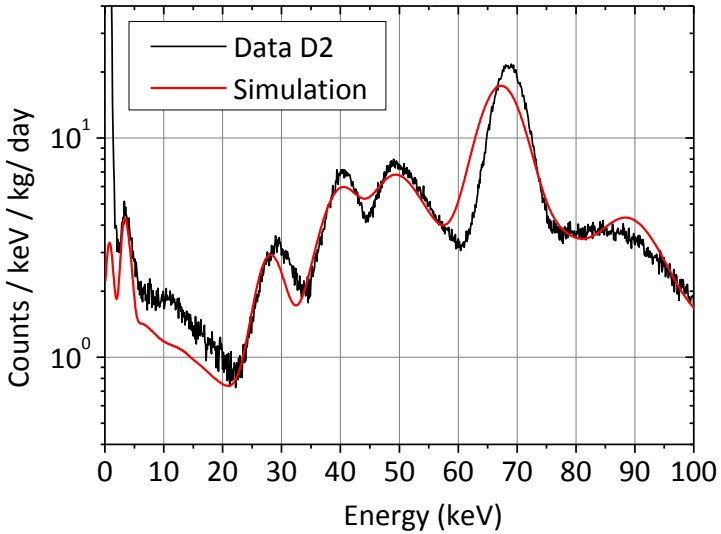


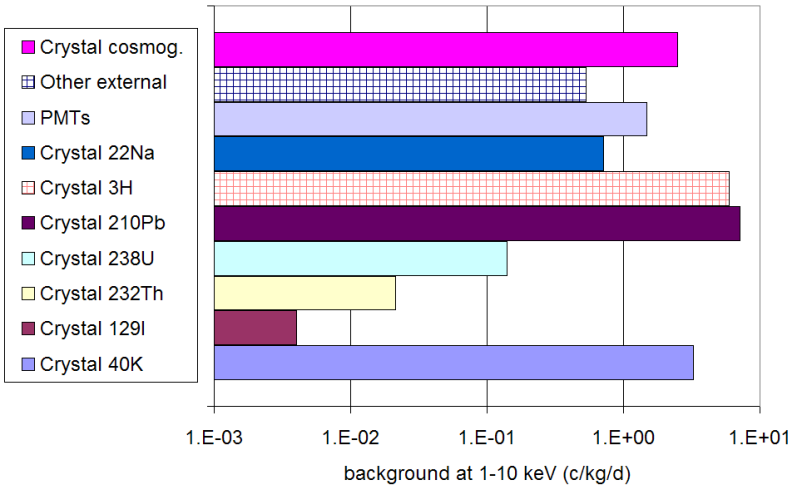


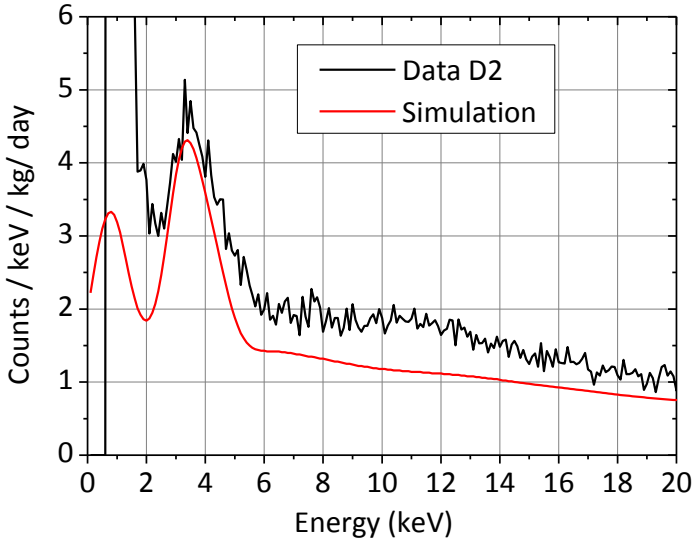


SIMULATIONS – D2 in ANAIS-37



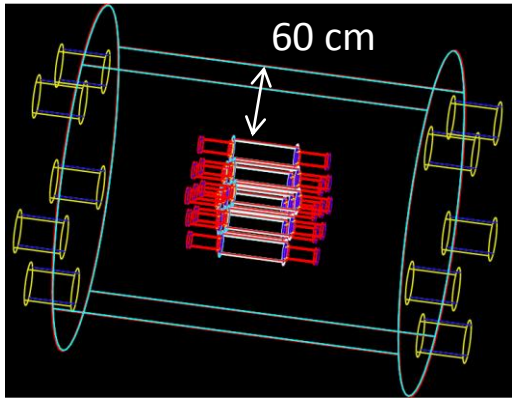






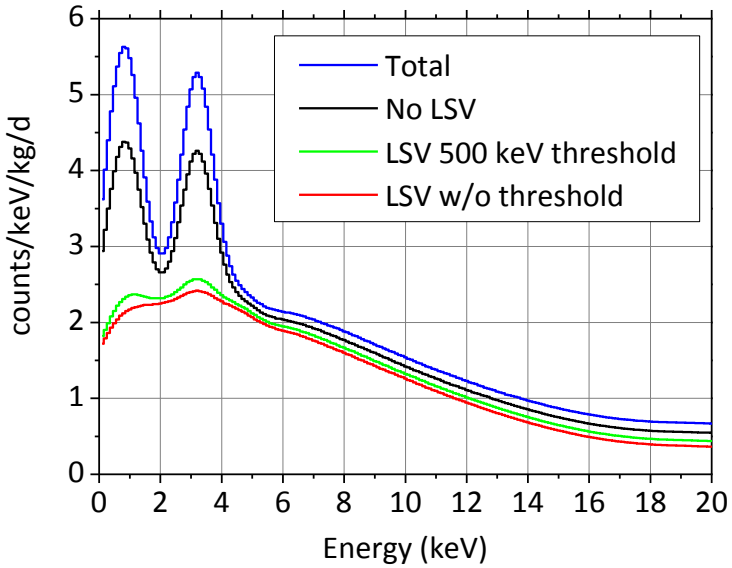
SIMULATIONS – ANAIS with liquid scintillator veto (LSV)

PRELIMINARY



3x3 detectors with ANAIS-25 features inside the LSV:

- Vessel: stainless steel cylinder, 5-mm-thick.
- Reflector: 0.5 mm reflector Lumirror.
- Liquid scintillator medium: Linear AlkylBenzene(LAB).
- PMTs: Ham. R5912, 8'' diameter borosilicate glass



Background reduction in the 1-10 keV region (Anticoincidence among cristals):

	^{40}K from crystals	^{22}Na from crystals	PMTs	all
No LSV (%)	70.3	60.2	64.2	89.1
LSV 500 keV th. (%)	19.1	5.5	31.3	73.9
LSV w/o th. (%)	15.5	1.1	9.1	71.0

CONCLUSIONS

- ANAIS experimental proposal:
  - 112.5 kg (3×3 crystal matrix) of NaI(Tl) taking data along 2016.
  - Shielding, electronic front-end, DAQ and software, slow control ready for the full experiment.

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- Good quality NaI(Tl) detectors from Alpha Spectra have been fully characterized:
  - Outstanding light collection improving energy resolution and triggering $\leq$ 1 keVee.
  - D2 background: 34 ppb K and 0.7 mBq/kg ^{210}Pb, next modules should be better in both isotopes.

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- Good sensitivity prospects for exploring the DAMA/LIBRA signal in a model independent way.

1-6 keVee region / 100 kg / 5 years

ANAIS-25 bkg with ^{210}Pb observed in D2

90% CL positive signal in 90% of the carried out experiments

Discovery potential!