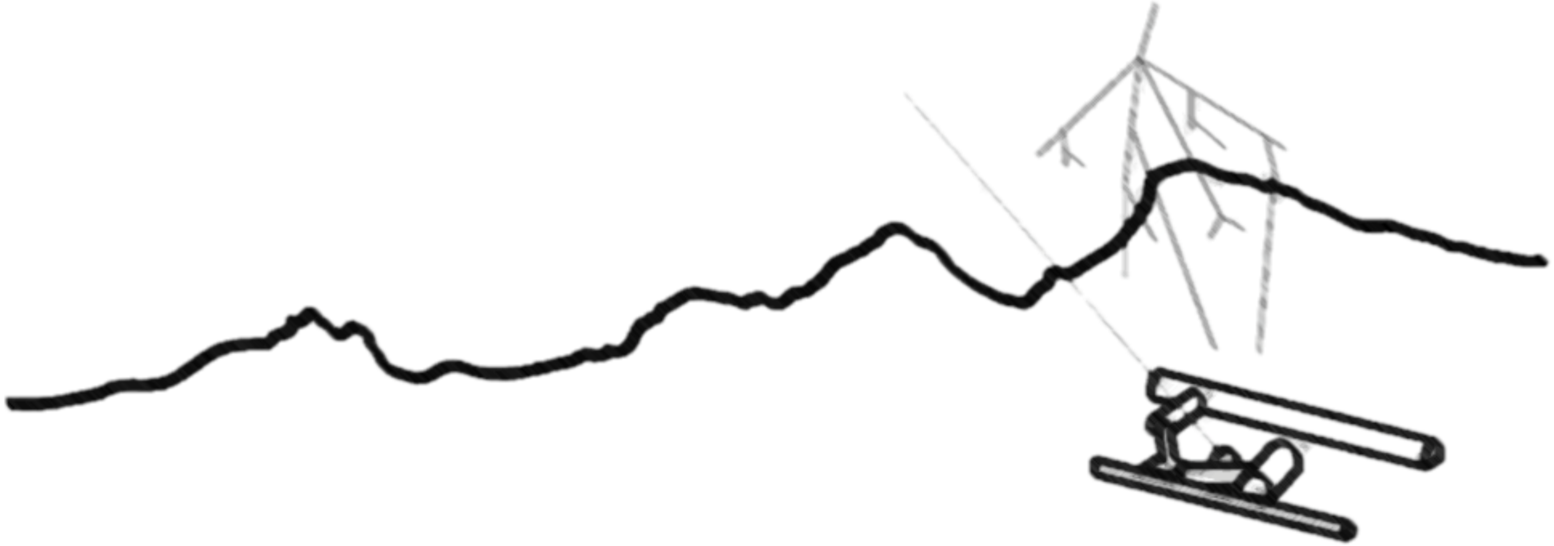
TESTING DAMA/LIBRA RESULT WITH ANAIS-112 EXPERIMENT

MultiDark
Multimessenger Approach for Dark Matter Detection

Universidad Zaragoza

LSC
Laboratorio Subterráneo de Canfranc

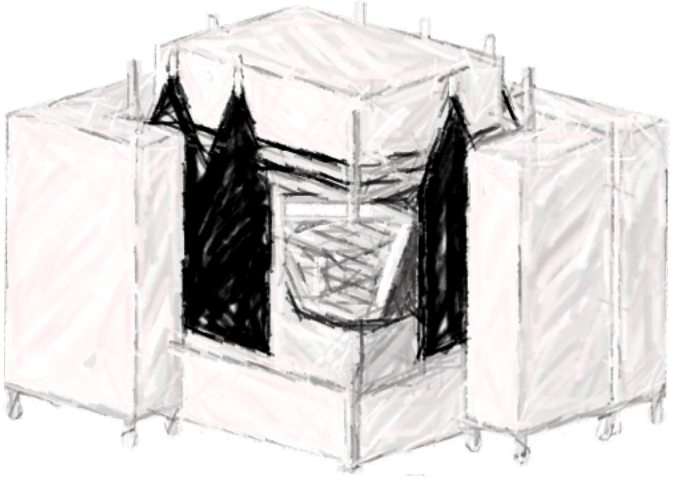


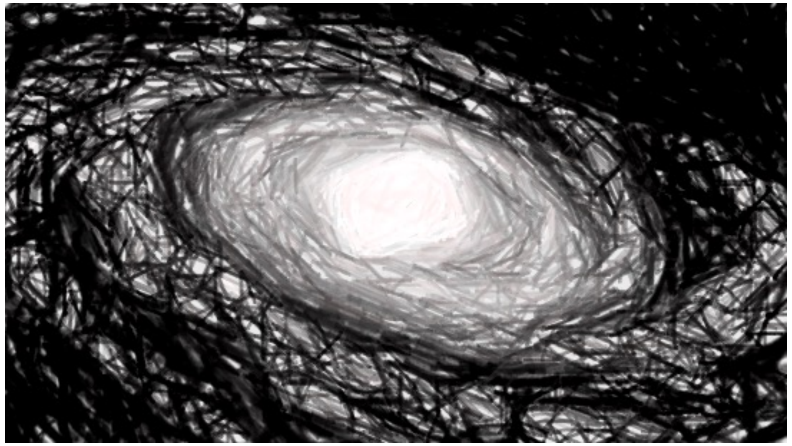
J. Amaré, I. Coarasa, S. Cebrián, E. García, M. Martínez, M.A. Oliván, Y. Ortigoza, A. Ortiz de Solórzano, J. Puimedón, A. Salinas, **M.L. Sarsa**, J.A. Villar †, P. Villar

Dark Matter 2018

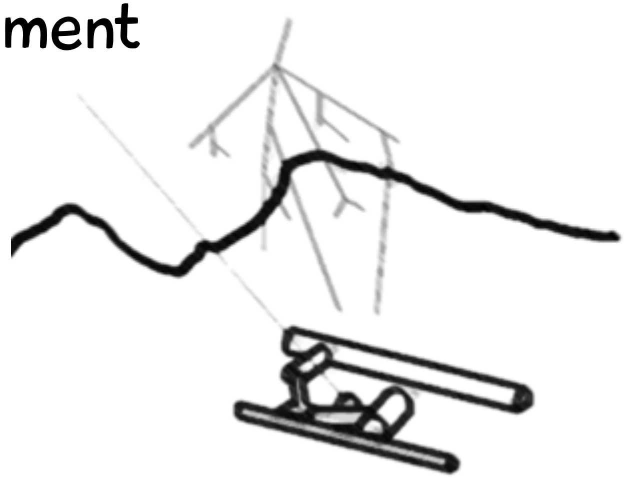
Coming to UCLA February 21-23, 2018

Outline



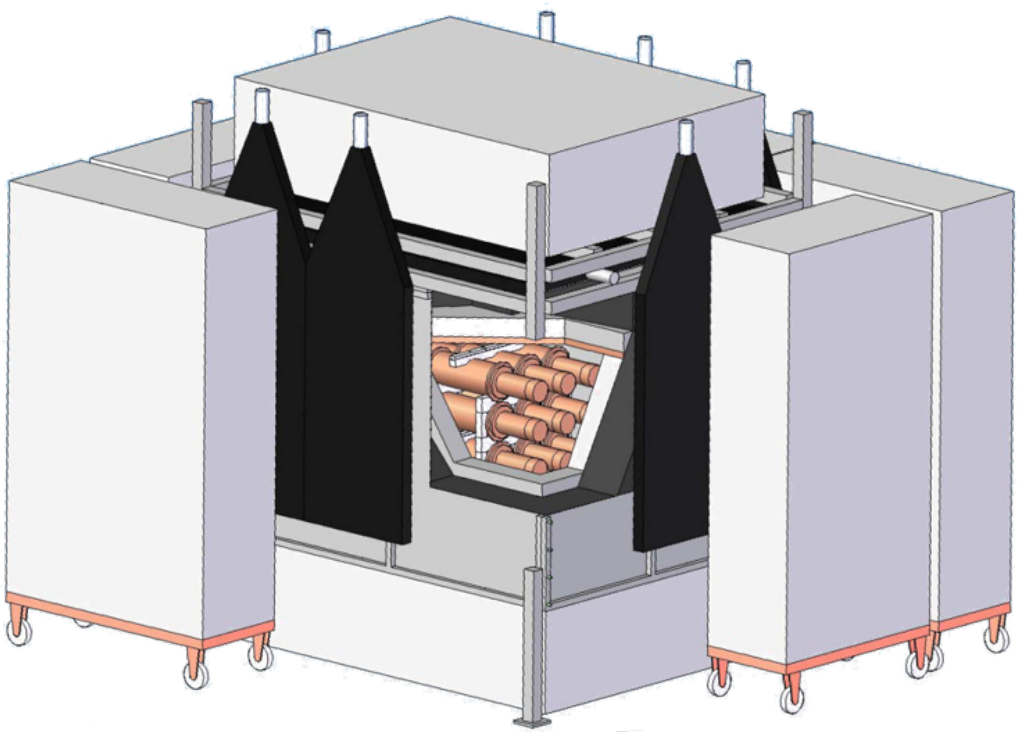


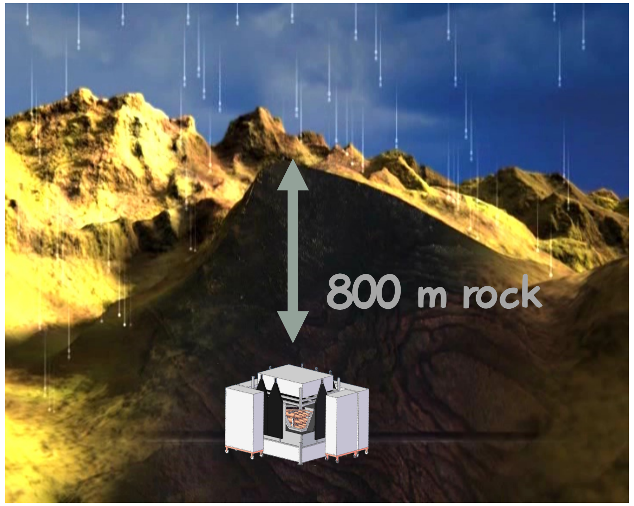
- ANAIS scientific case
- ANAIS status
  - Detectors performance
  - ANAIS-112 set-up accomplishment
- ANAIS sensitivity prospects
- Summary and outlook

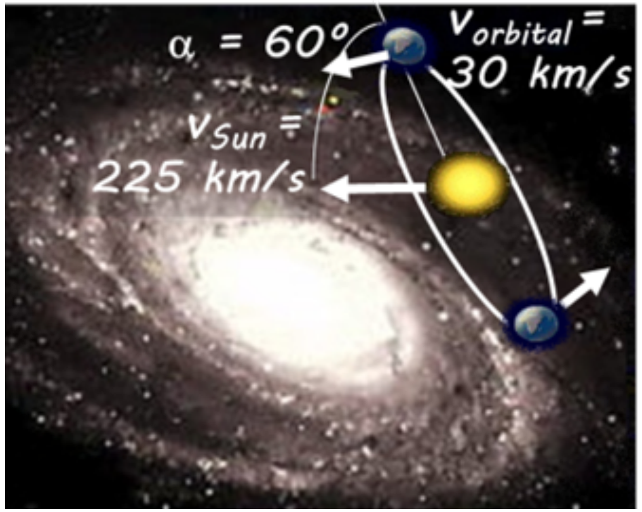


ANAIS experiment at LSC

Annual modulation with NAI Scintillators



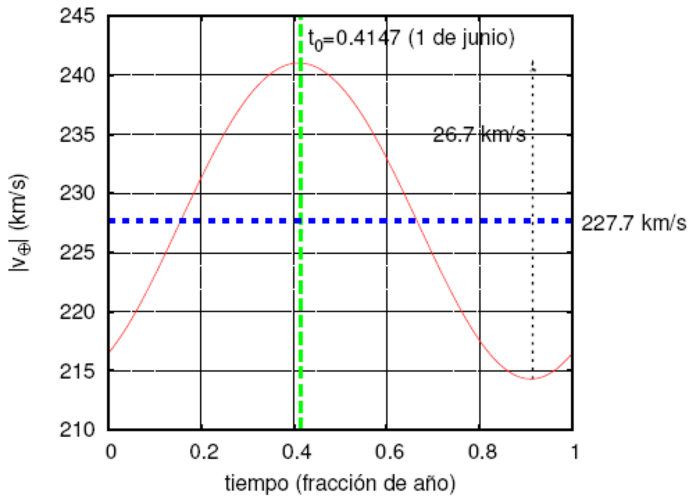


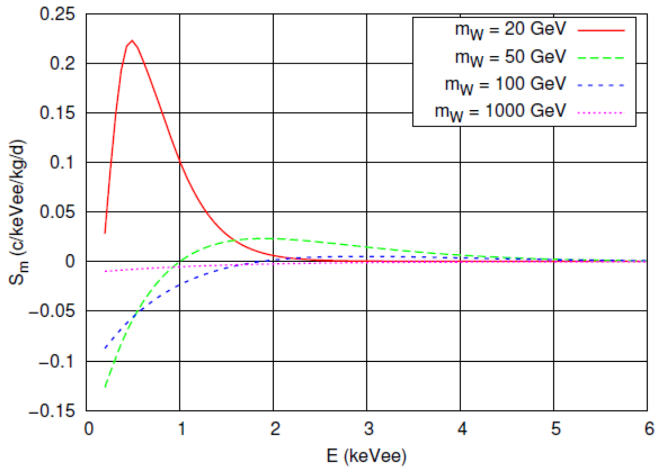


- Confirmation of DAMA-LIBRA modulation signal -> **same target and technique** / **different** experimental approach / **different** environmental conditions affecting **systematics**
- At Canfranc Underground Laboratory @ **SPAIN** (under **2450 m.w.e.**)
- 3x3 matrix of 12.5 kg cylindrical modules = **112.5 kg** of active mass

Dark Matter Annual Modulation

Annual modulation in the DM detection rate is produced by the change on the relative velocity WIMP-detector along the year



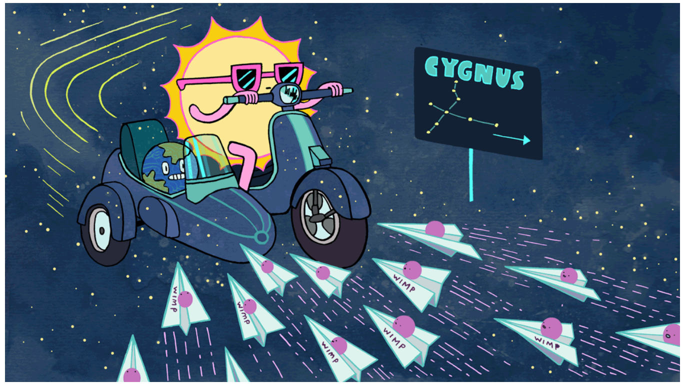


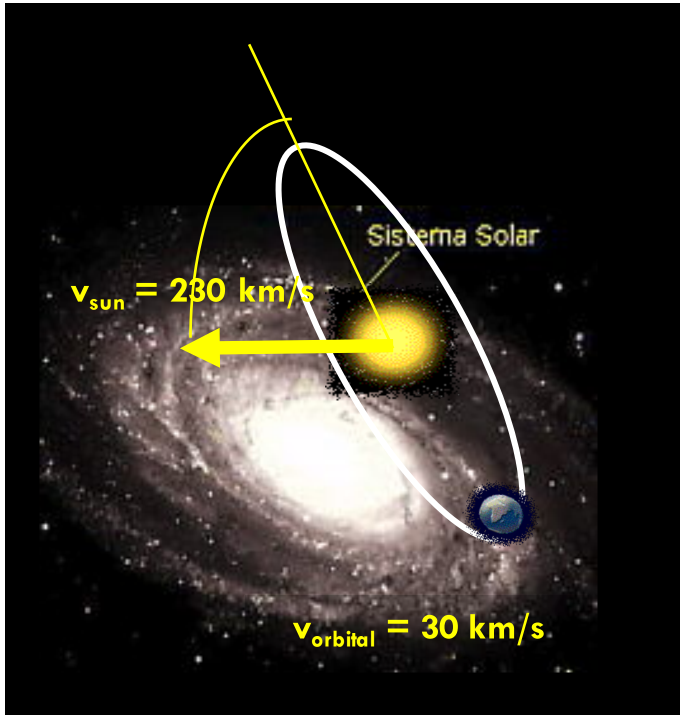
$$\eta(t) = v_\oplus(t)/v_0 = \eta_0 + \Delta\eta cos\omega(t - t_0)$$

$$\boxed{S_k(t) = S_{0,k} + S_{m,k} cos\omega(t - t_0)}$$

Small effect (<7% of S_0)

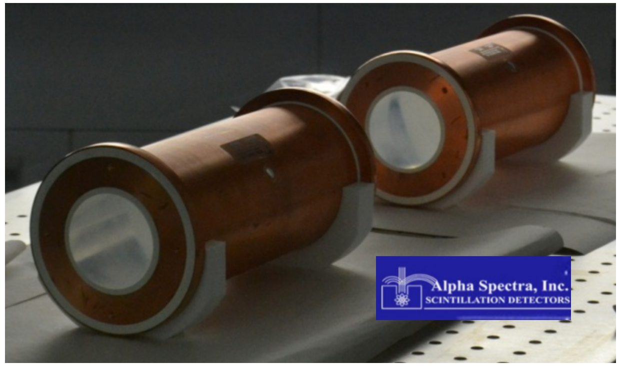
Inverse modulation at very low energies



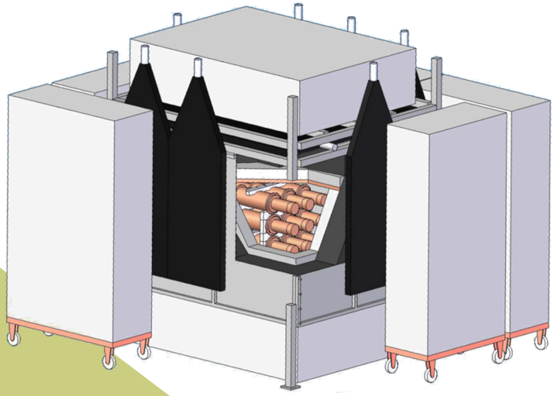


DAMA/LIBRA modulation result is highly significant, but difficult to reconcile with other experiments. We need model independent confirmation or refutation

Experimental Approach

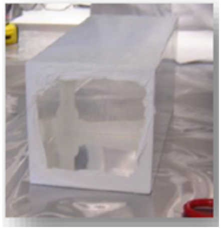


ANAIS-112



12.5 kg
Alpha Spectra Inc.

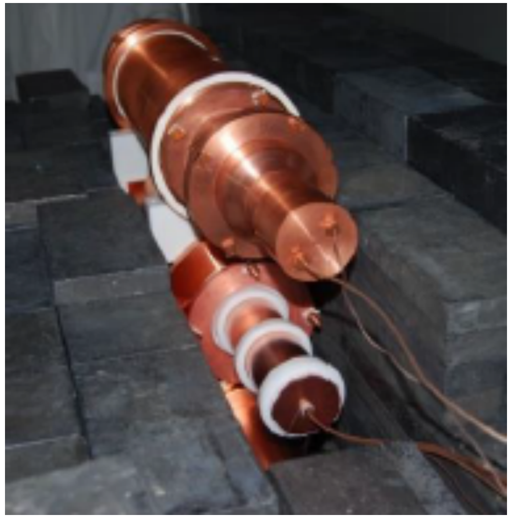
ANAIS-25



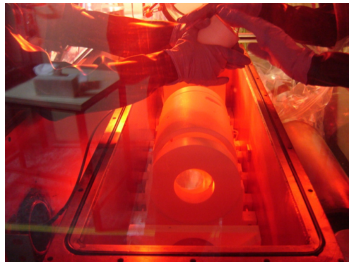
9.6 kg
Saint-Gobain

10.7 kg
BICRON

ANAIS-37



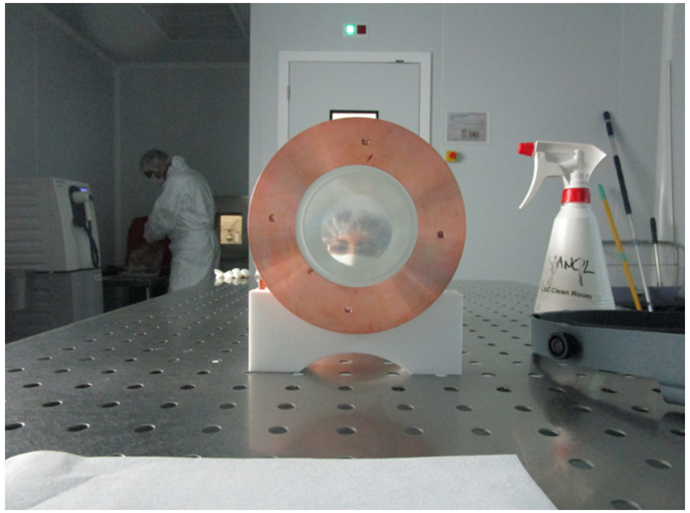
ANAIS-0



DM-32

ANAIS Detectors

- 12.5 kg cylindrical NaI(Tl) detectors built @ Alpha Spectra, Co (US) from NaI selected powder & developing specific radiopurity protocols with them
- Housed in OFE copper @ AS
- Mylar windows allow for LE calibration
- HQE PMTs Ham12669SEL2 coupled at LSC clean room
- Electroformed copper PMT housing prepared at LSC electroforming facility

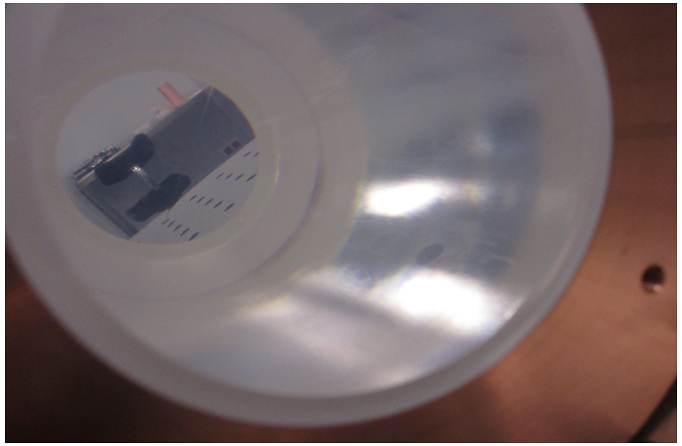


Last three modules received at LSC in March 2017

ANAIS Detectors

Excellent light collection

A factor of 2 larger than the published light collection for DAMA/LIBRA detectors

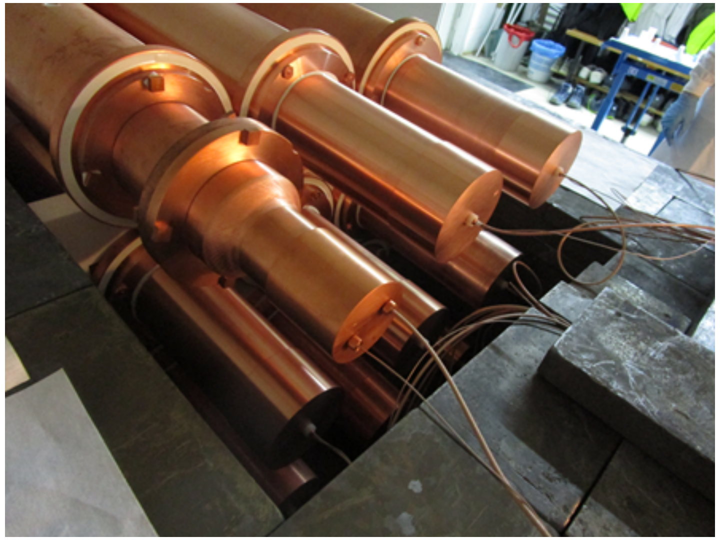


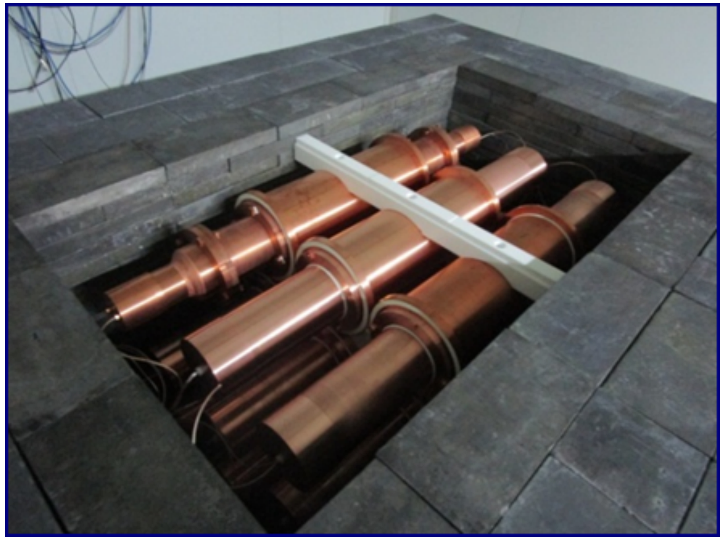
Detector	PMT/set-up	Total Light Collection (phe/keV)
D0	Ham R12669 / ANAIS25	15.6 ± 0.2
	Ham R12669 / ANAIS37	15.3 ± 0.1
	Ham R12669 / A37D3	15.1 ± 0.1
	Ham R12669 /ANAIS112	14.6± 0.1
D1	Ham R11065 / ANAIS25	12.6 ± 0.1
	Ham R12669 / ANAIS25-III	15.2 ± 0.1
	Ham R12669 / ANAIS37	14.4 ± 0.1
	Ham R12669 /ANAIS112	14.7 ± 0.1
D2	Ham R12669 / ANAIS37	15.4 ± 0.1
	Ham R12669 /ANAIS112	14.6 ± 0.1
D3	Ham R12669 / A37D3	15.2 ± 0.5
	Ham R12669 /ANAIS112	14.6 ± 0.1
D4	Ham R12669 / A37D5	14 ± 1
	Ham R12669 /ANAIS112	14.5 ± 0.1
D5	Ham R12669 / A37D5	15 ± 1
	Ham R12669 /ANAIS112	14.3 ± 0.1
D6	Ham R12669 /ANAIS112	12.7 ± 0.1
D7	Ham R12669 /ANAIS112	14.9 ± 0.1
D8	Ham R12669 /ANAIS112	16.0 ± 0.1

M.A. Oliván et al.
Astroparticle Physics 93 (2017) 86-95

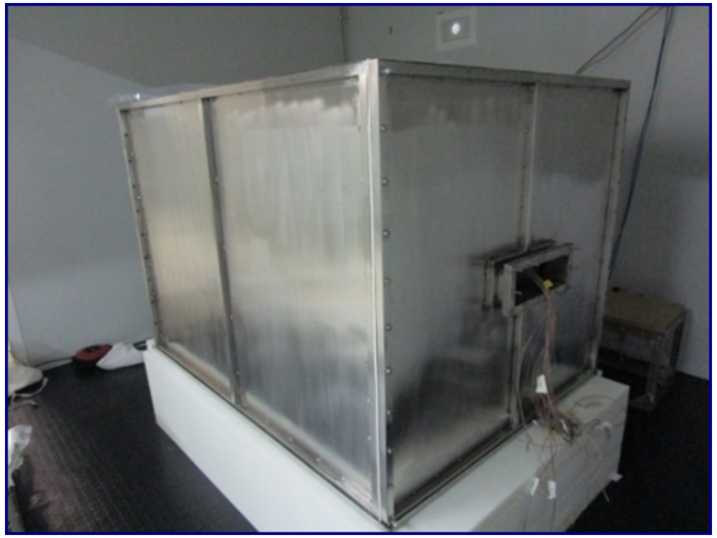
ANAIS-112 Set-up

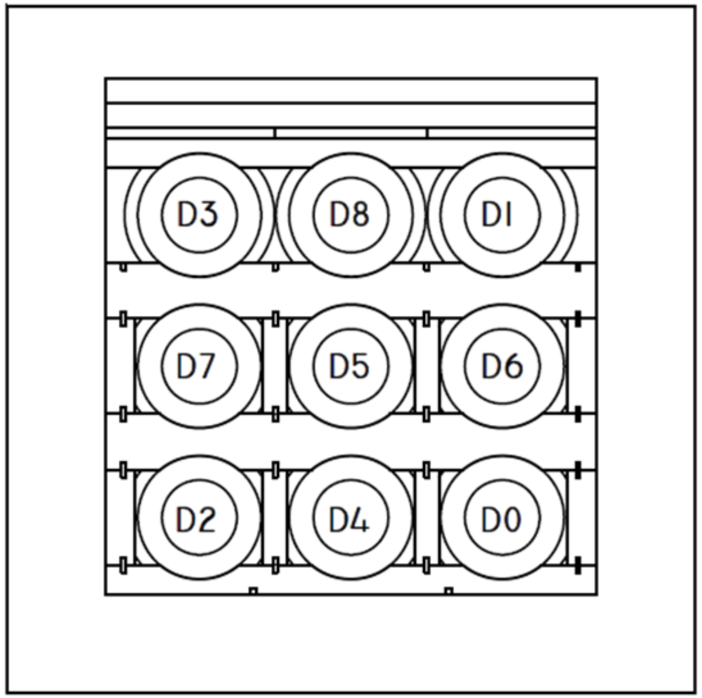
ANAIS-112 consists of a matrix of 3x3 modules and was installed in March 2017





10 cm archaeological lead + 20 cm low activity lead

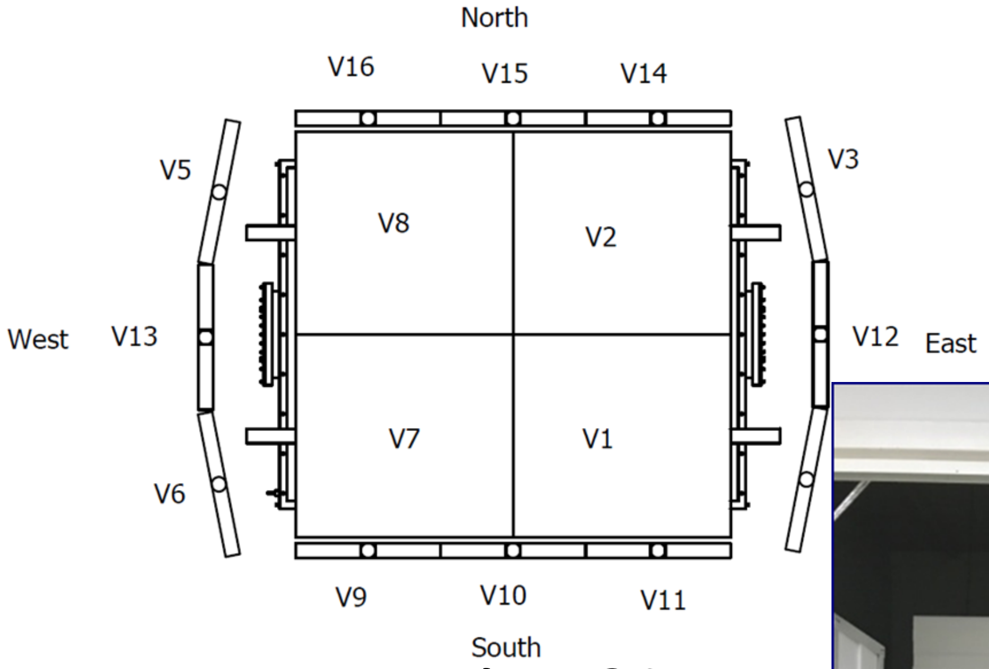




ANAIS-112 detectors testing and commissioning run started immediately and was fully operative by June-July 2017 for detector calibration and general assessment

ANAIS-112 Set-up

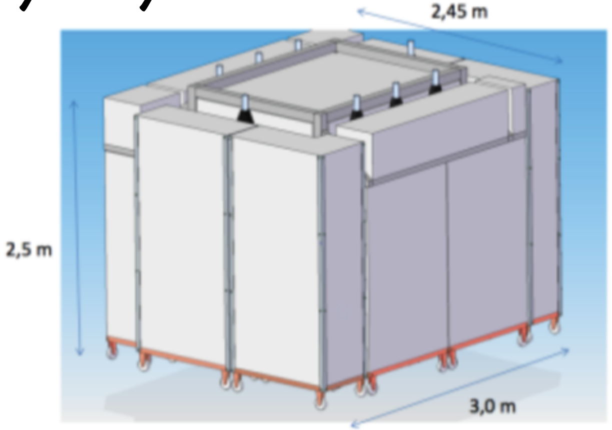
ANAIS-112 scintillators veto system was installed in May 2017



ANAIS-112 neutron shielding was installed in July 2017.

It consists of water tanks and polyethylene (40 cm)

It allows partial periodic opening for calibrations

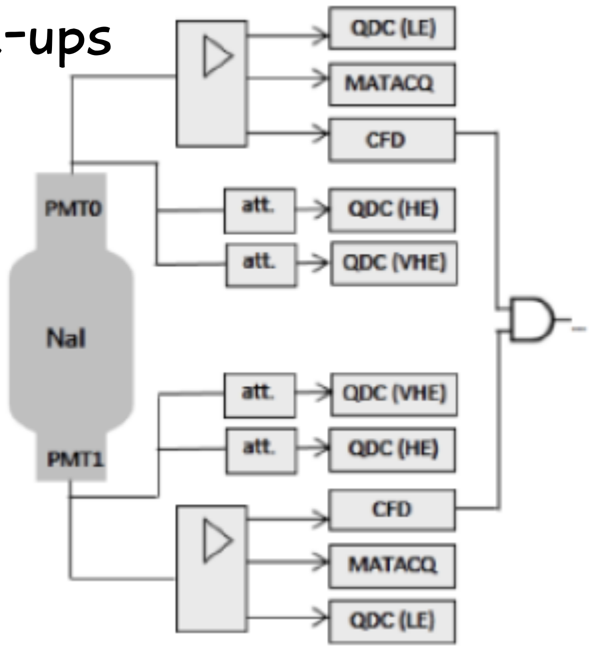


ANAIS-112 DM run started on August 3, 2017

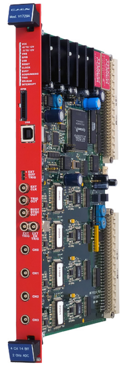
ANAIS-112 Set-up

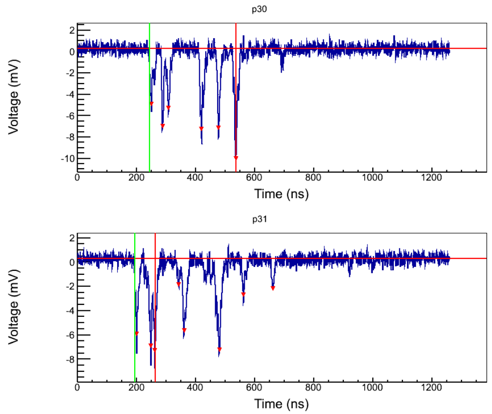
- DAQ hardware and software designed and tested with previous set-ups
  -> ROBUST & SCALABLE
    - Individual PMT signals digitized * and fully processed
    - Trigger at phe level for each PMT
    - Logical AND coincidence in 200ns window for each module triggering
    - Redundant energy conversion

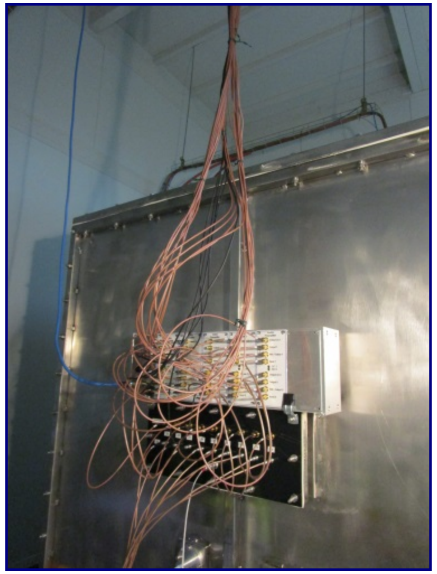
    - Preamplifiers designed at UZ
    - Electronics at air-conditioned-room to decouple from Hall B temperature fluctuations



* CAEN V1729A – VME 6U board – MATACQ chip
14 bits / 2 GS/s





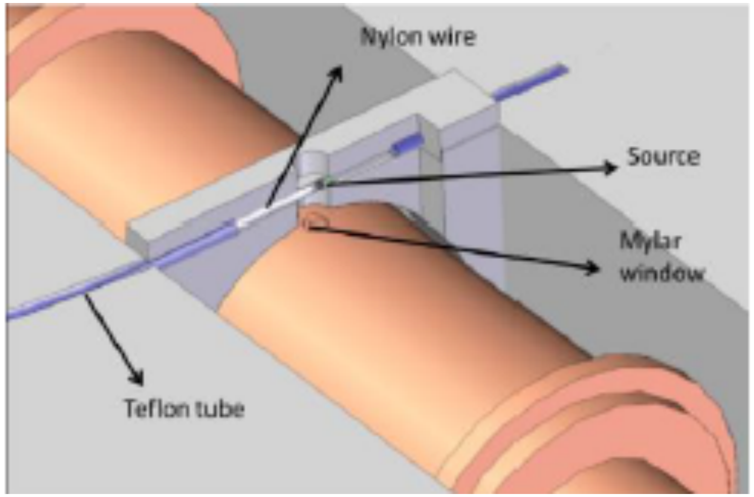


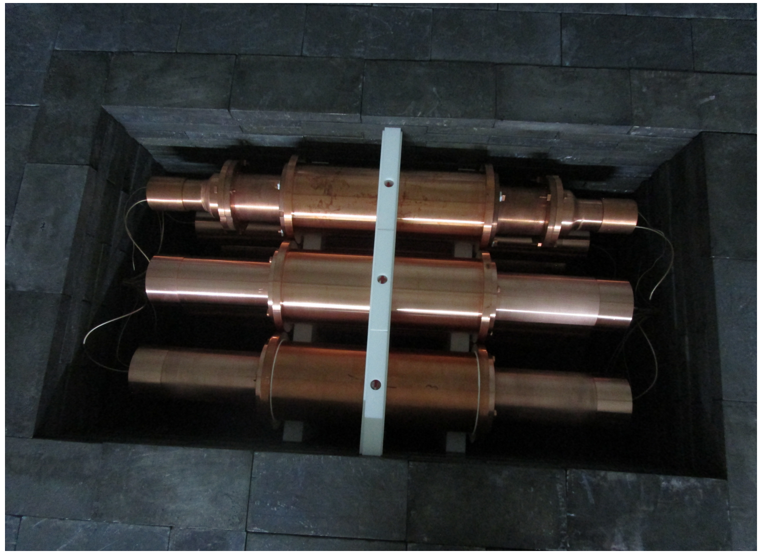
ANAIS-112 Performance

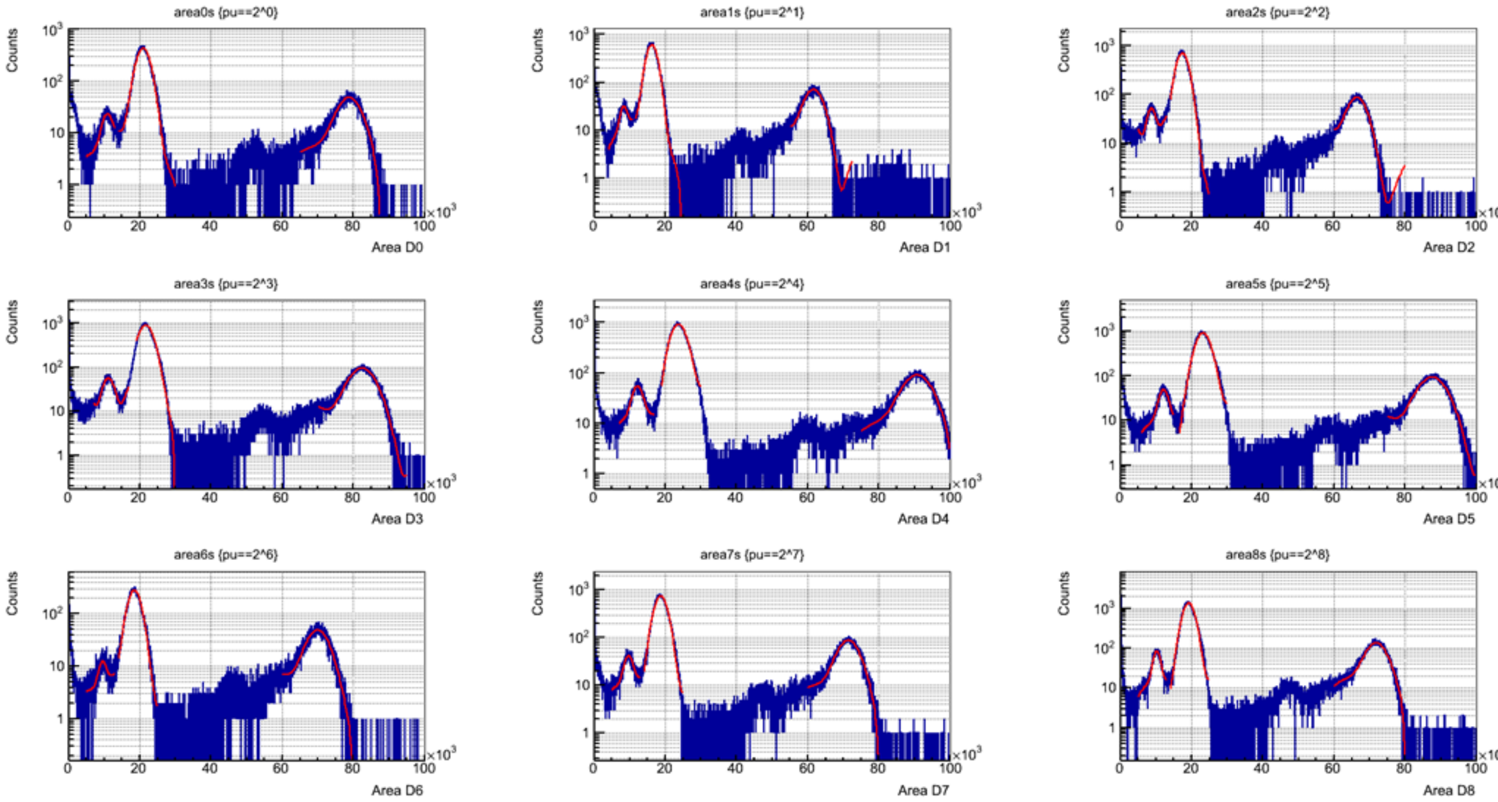
Calibrations every 2 weeks at low energy

^{109}Cd sources on flexible wires allowing the simultaneous calibration of the 9 modules

Energies 11.9 keV, 22.6 keV and 88.0 keV



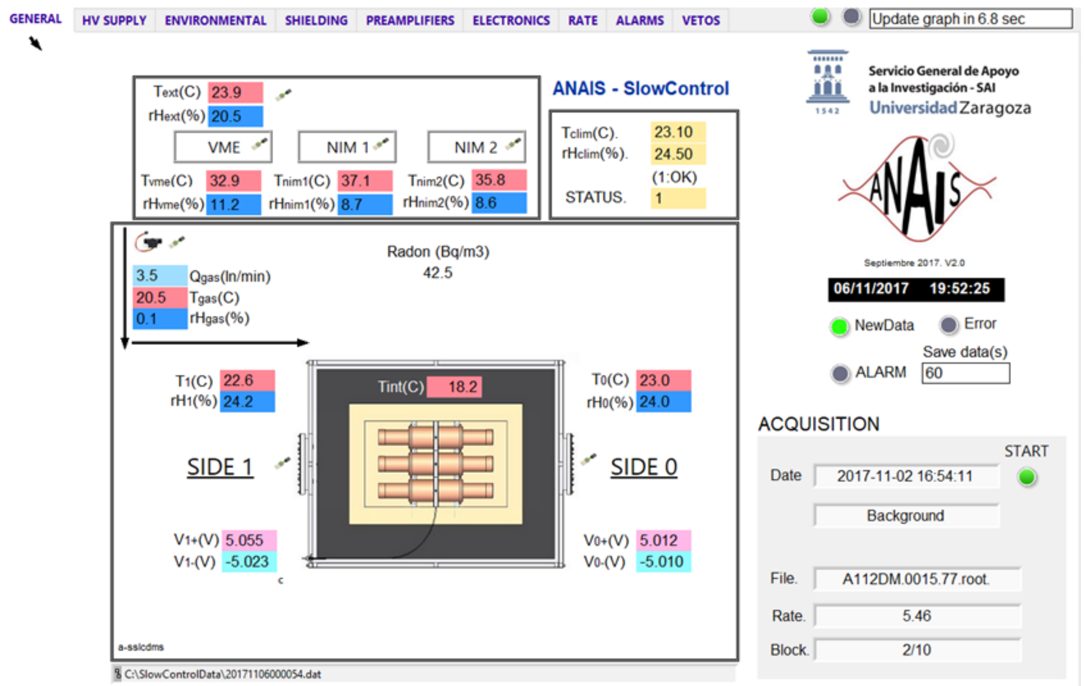


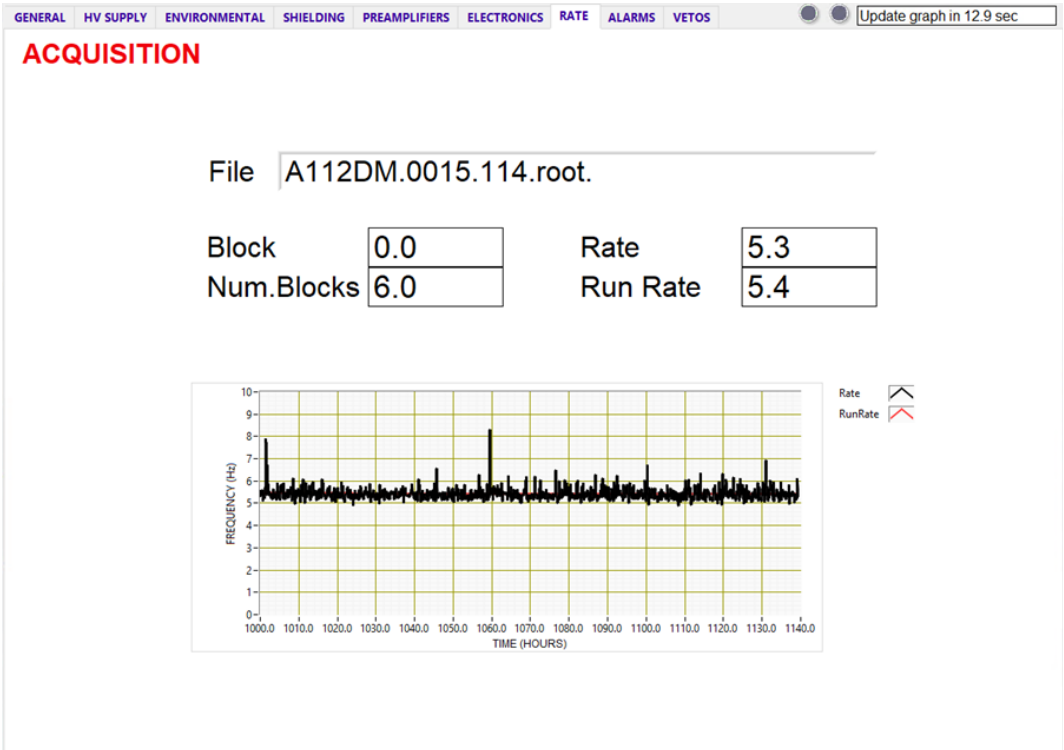


Monitoring of environmental parameters

It consists of several windows for monitoring LN2 flux; temperatures at electronics, inner shielding, laboratory, preamplifiers, etc.; radon content in laboratory air; relative humidity; HV supply to every PMT; muon rates; etc.

All the data are saved every few minutes and alarms have been set on the most relevant parameters sending an alarm message to ANAIS GLIMOS through Telegram.





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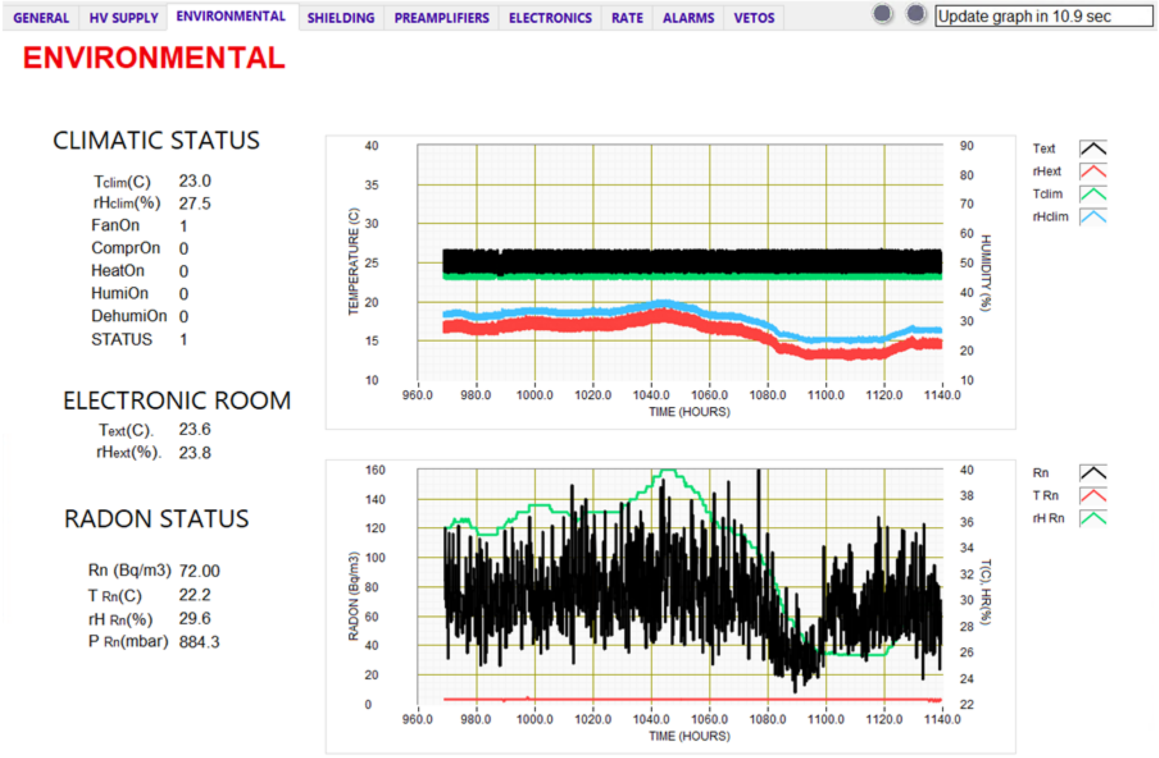
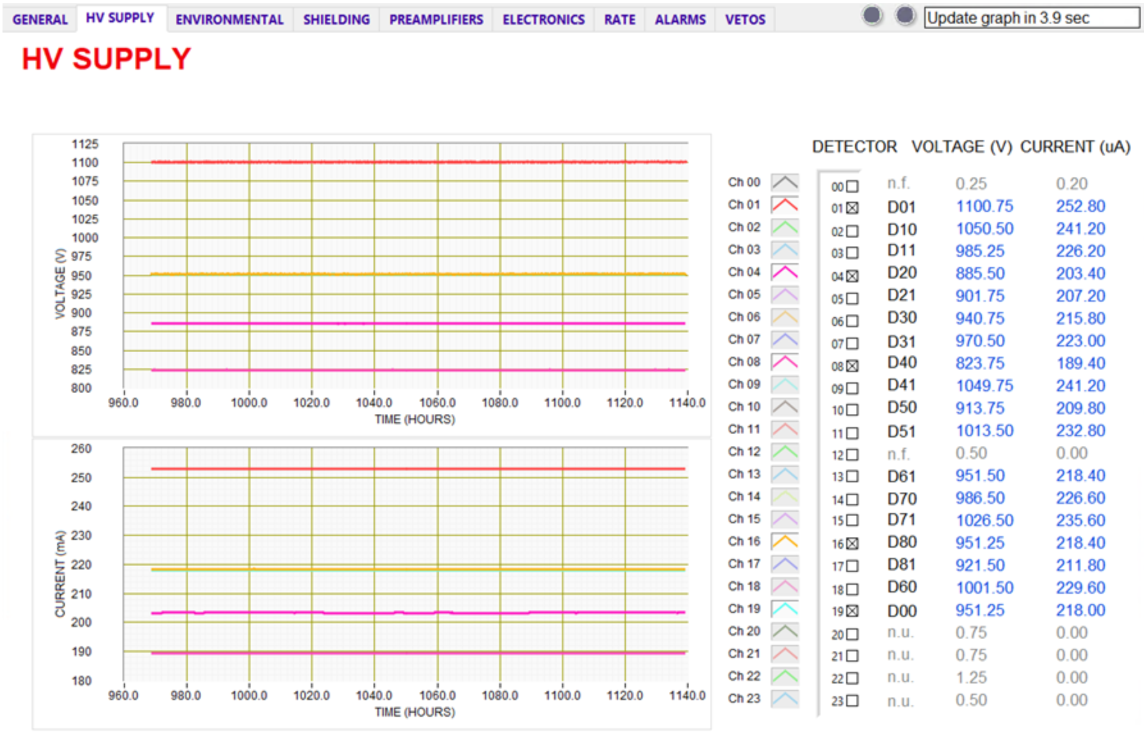
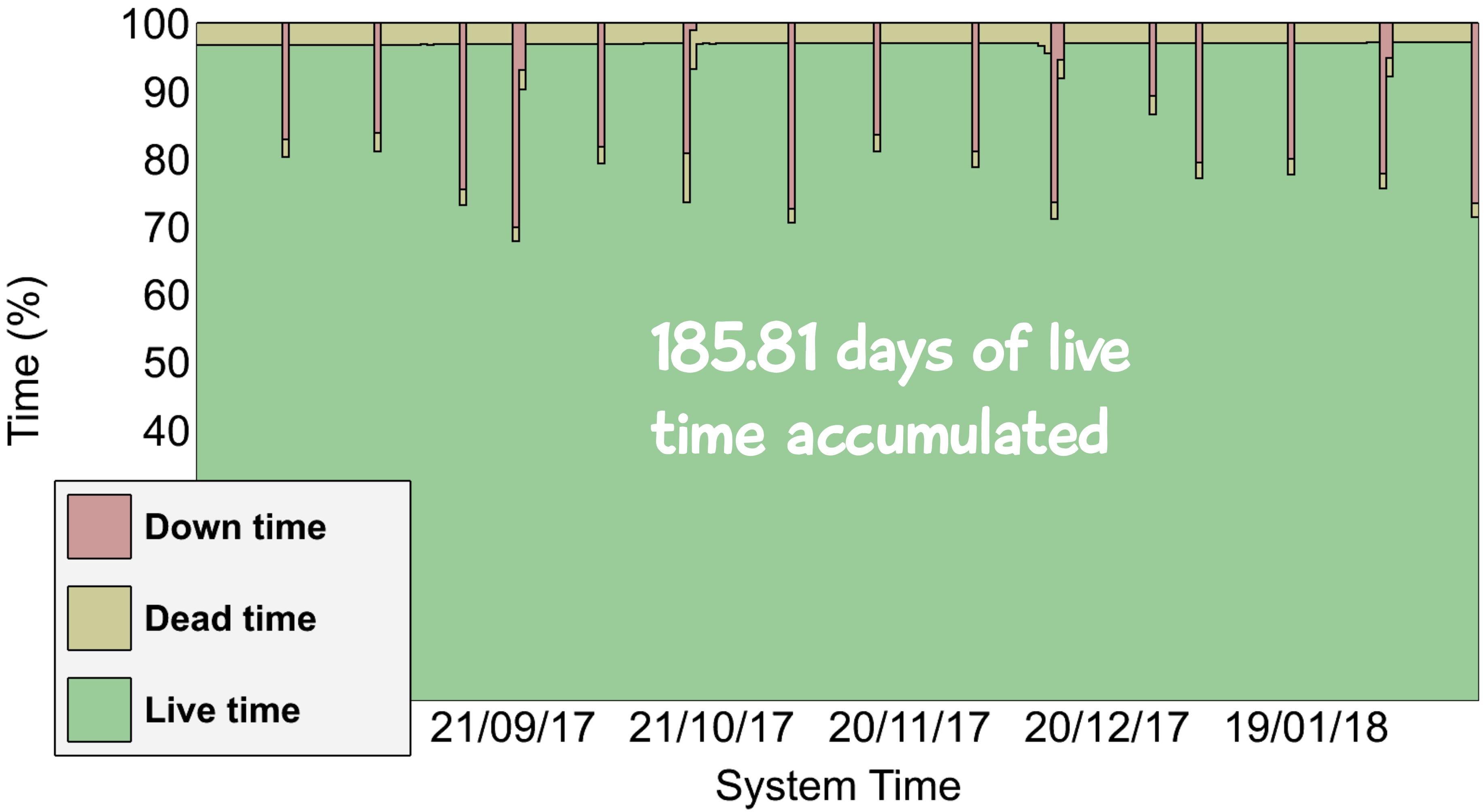




ANAIS-112 Performance

First six and a half months of ANAIS-112DM run, from 03-08-17 until 15-02-18



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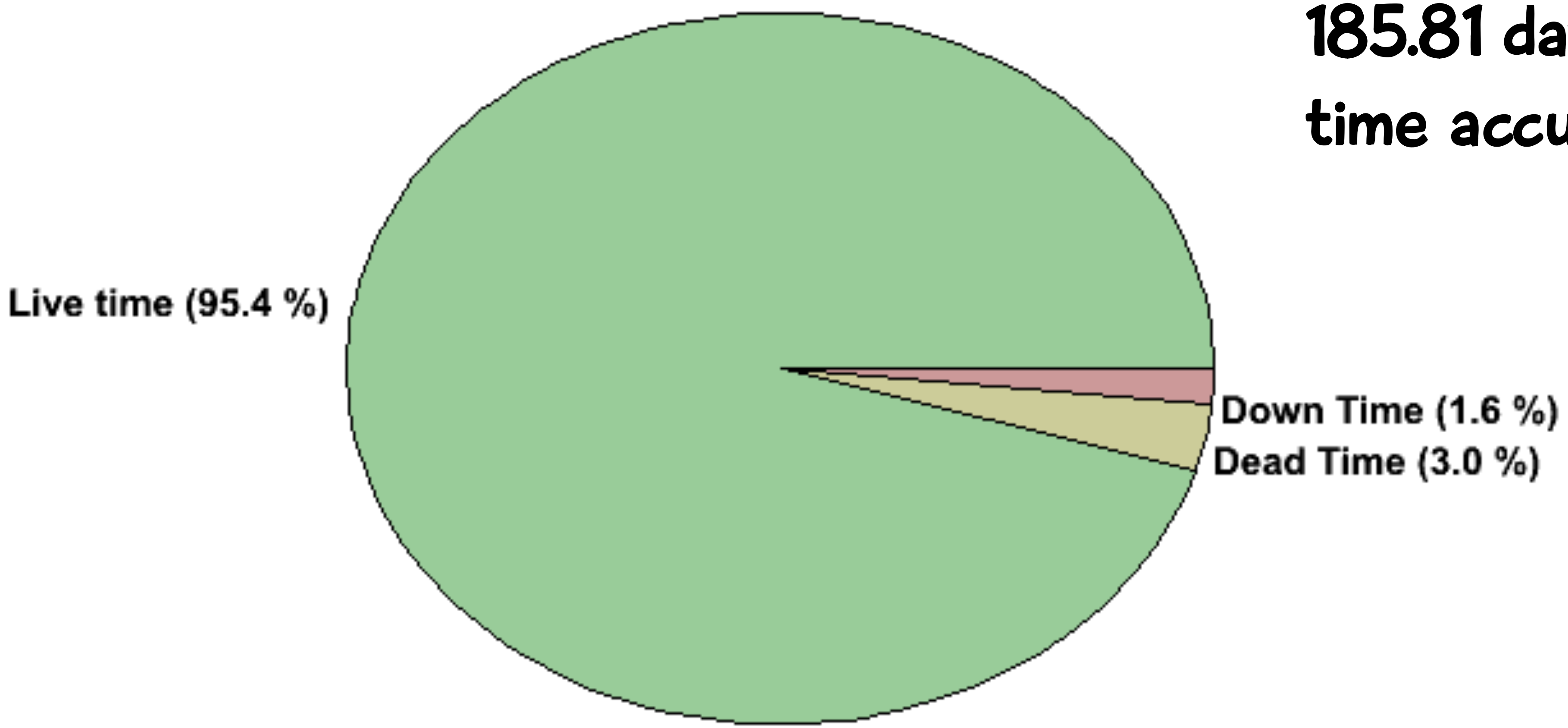

185.81 days of live time accumulated

ANAIS-112 Performance

First six and a half months of ANAIS-112DM run, from 03-08-17 until 15-02-18

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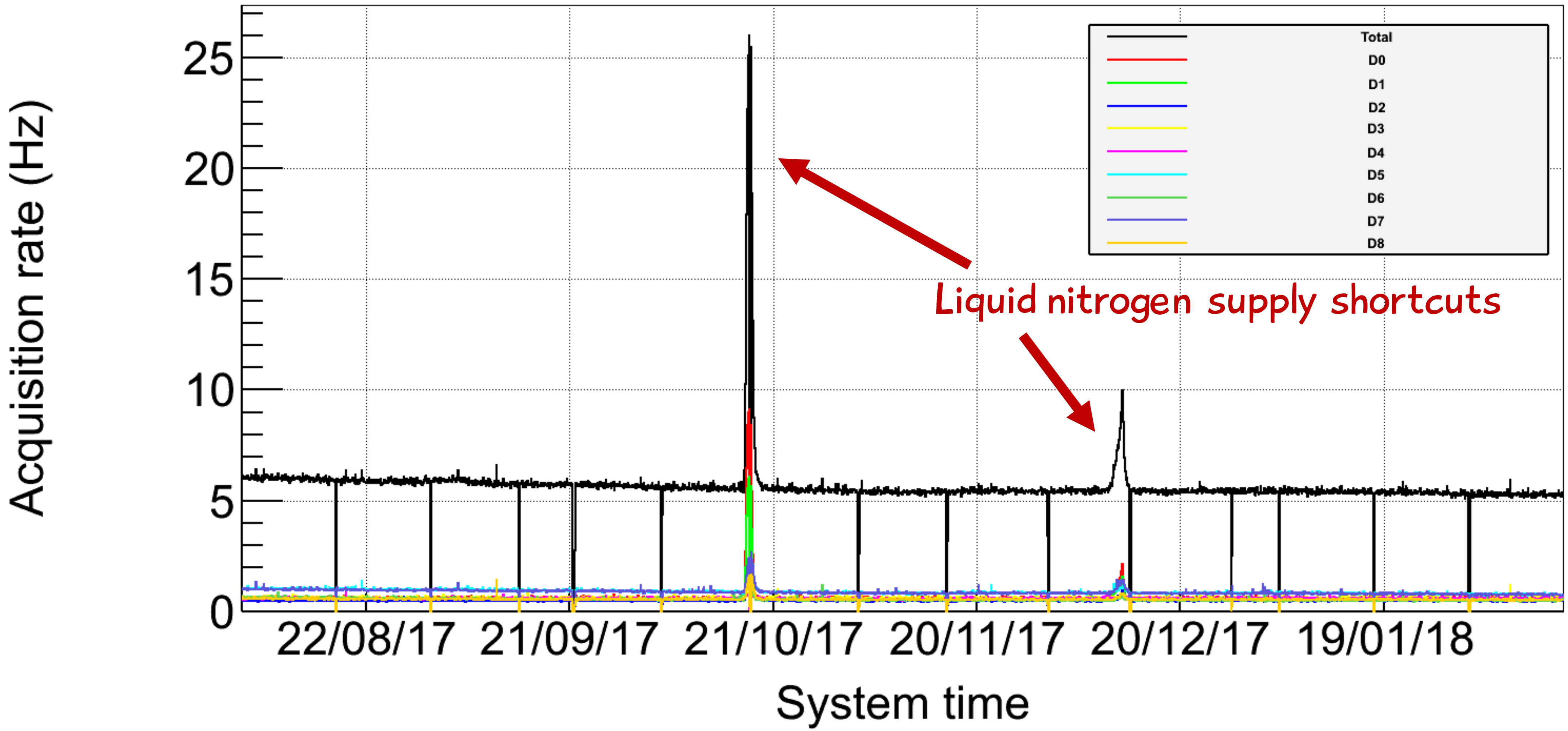
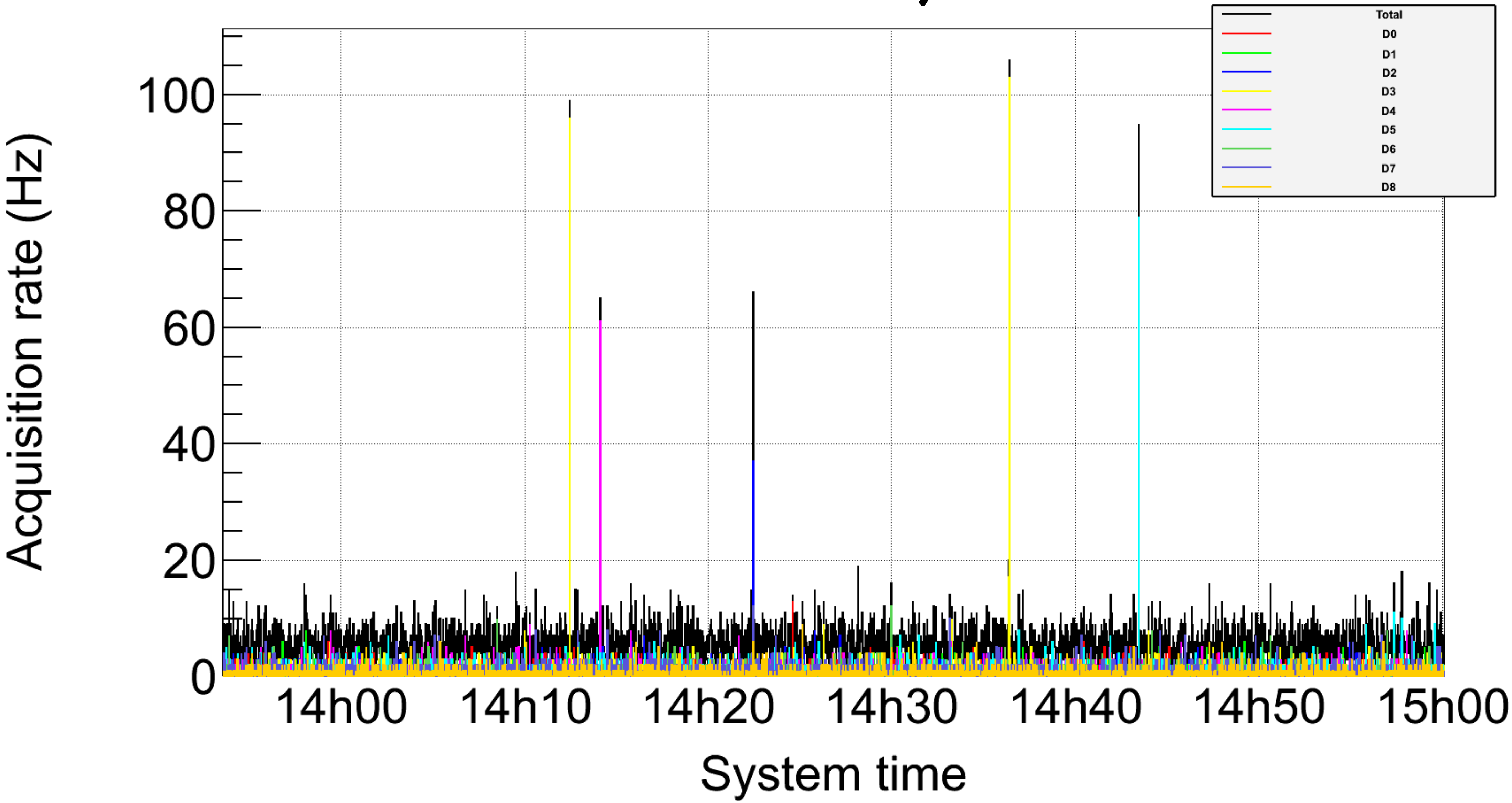


First six and a half months of ANAIS-112DM run, from 03-08-17 until 15-02-18

1 hour with rate calculated every second



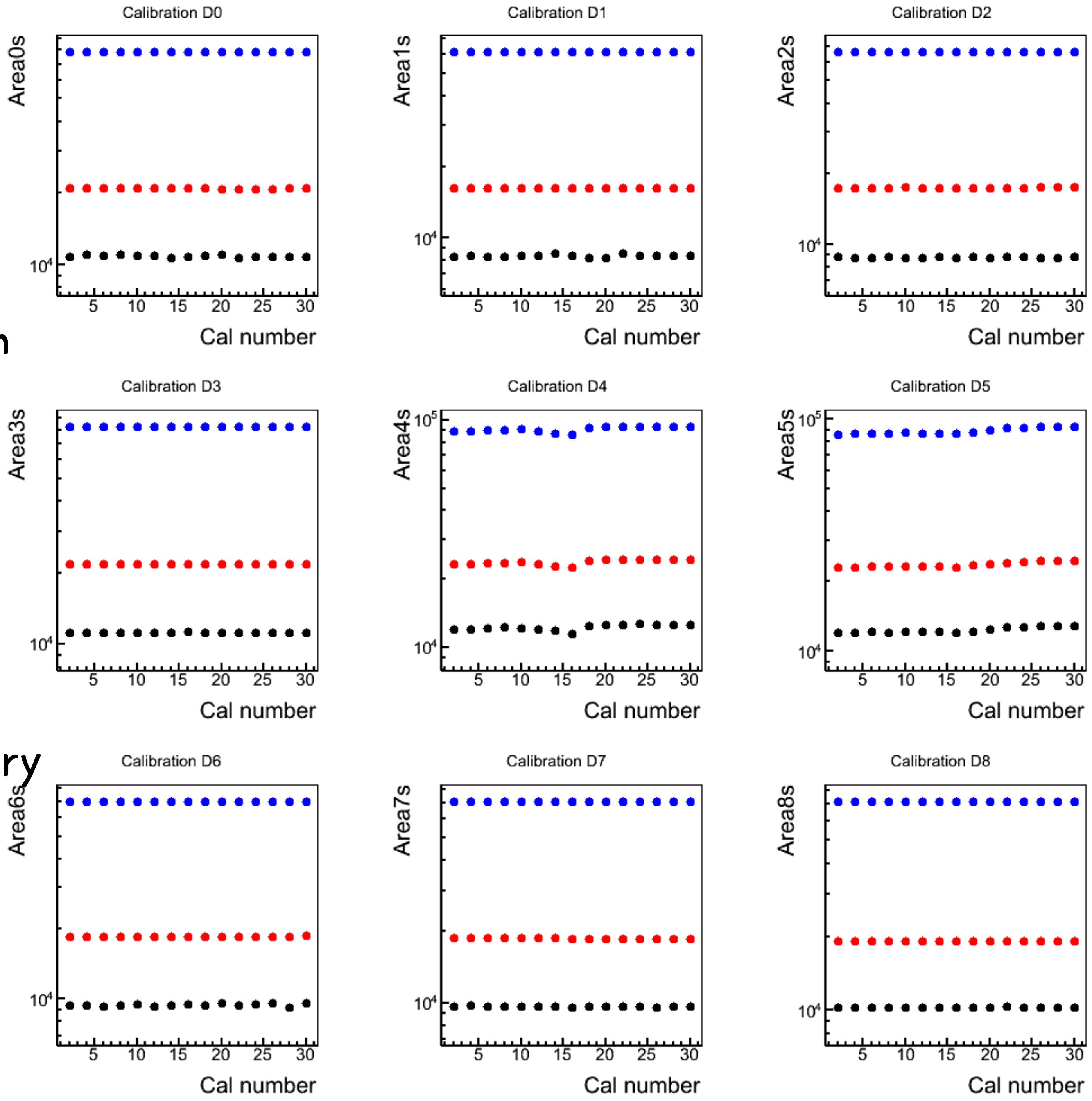
ANAIS-112 Performance

Periodic ^{109}Cd calibrations

They allow monitoring (and if necessary correcting) possible gain drifts in the modules.

Evolution of the positions of ^{109}Cd lines along the six months of measurement.

Most of the modules have been very stable during this period of data taking.



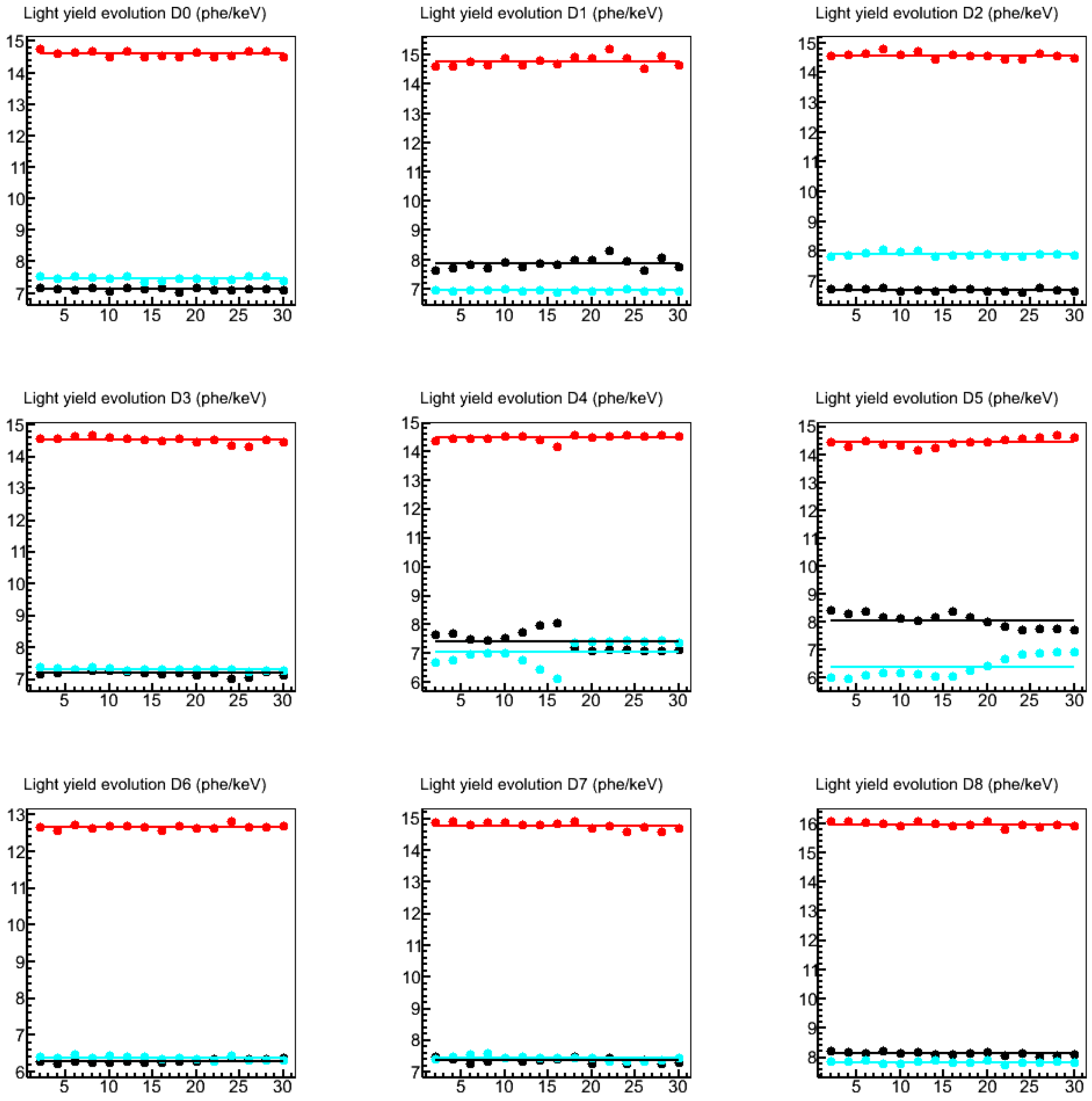
88.0 keV
22.6 keV
11.9 keV

ANAIS-112 Performance

Periodic monitoring of light collection along ANAIS-112 DM run.

Evolution of the light collection estimates per PMT and per module, using the periodic Cd-109 calibration (22.6 keV line) and the photoelectron area distribution derived from background runs.

It is to remark the stability of the total light collection per module along the data taking.

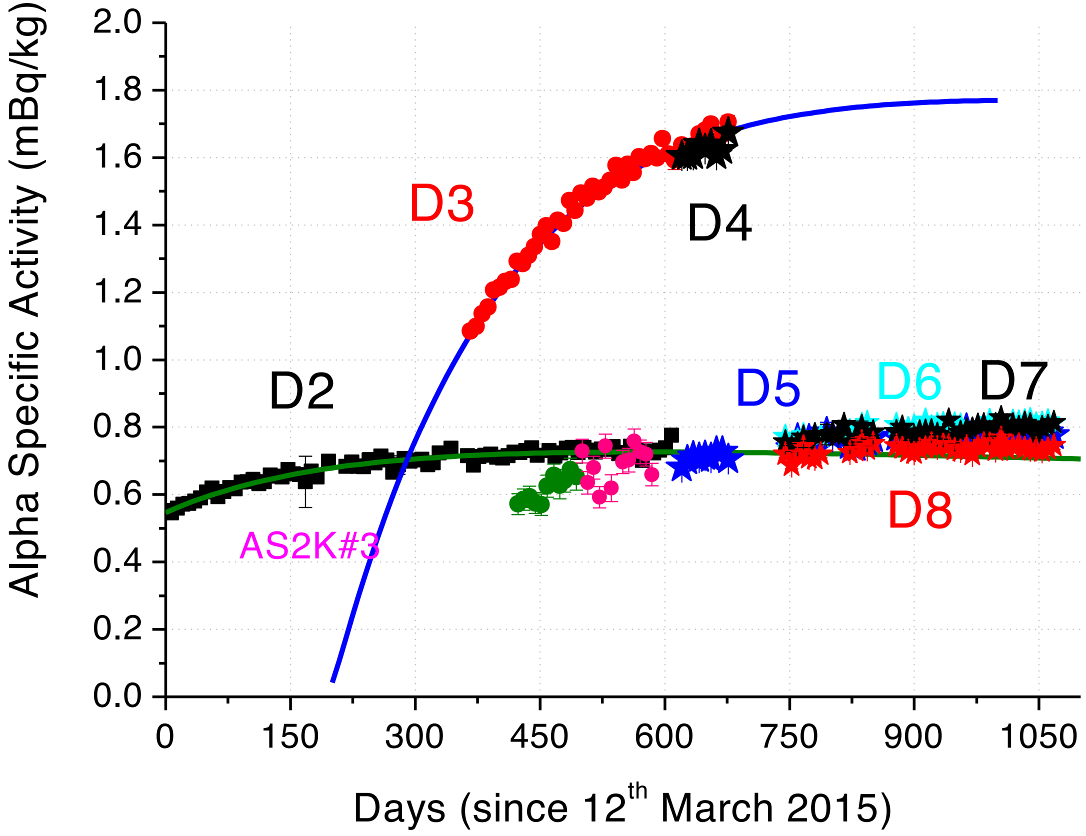


PMT0
PMT1
PMT0+PMT1

ANAIS-112 Performance

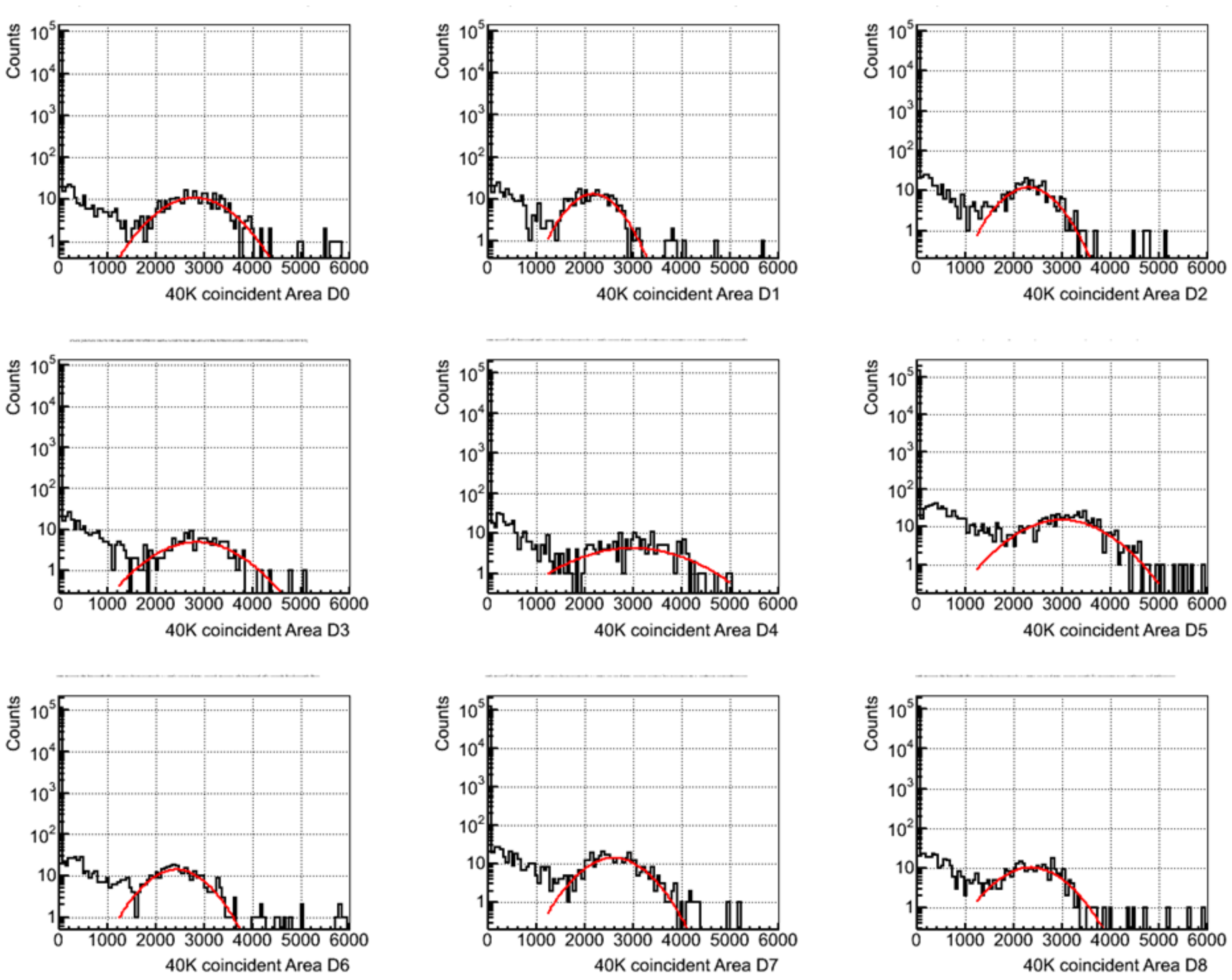
Monitoring of alpha decay rate in D5-D8 in ANAIS-112

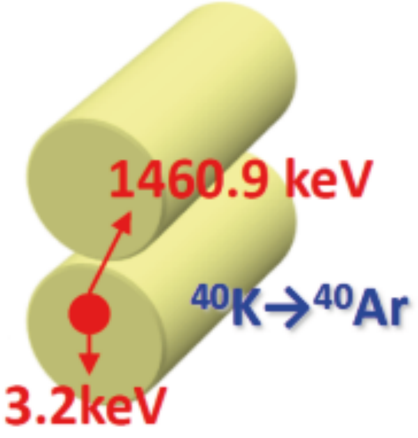
Alpha events rate is dominated by ^{210}Po decay, allowing to characterize the ^{210}Pb content in all the crystals



Module	^{210}Pb content
D0	3,15 mBq/kg
D1	3,15 mBq/kg
D2	0,75 m Bq/kg
D3	1,8 mBq/kg
D4	1,8 mBq/kg
D5	0,78 mBq/kg
D6	0,81 mBq/kg
D7	0,80 mBq/kg
D8	0,73 mBq/kg

Potassium content in all the AS modules: obtained by using coincidences with all the modules





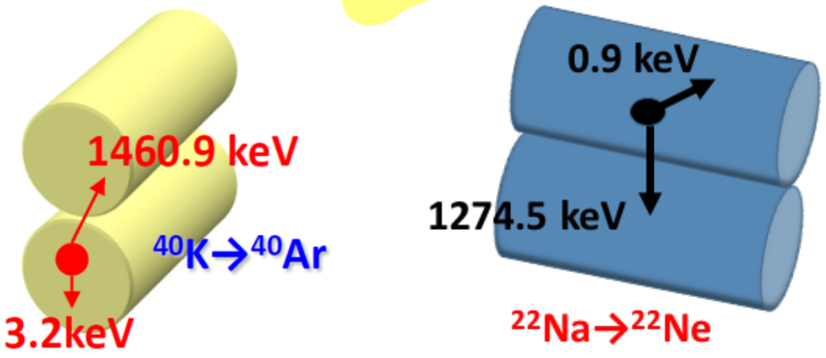
Module	Potassium content
D0	43 ppb
D1	35 ppb
D2	39 ppb
D3	21 ppb
D4	18 ppb
D5	30 ppb
D6	28 ppb
D7	31 ppb
D8	22 ppb

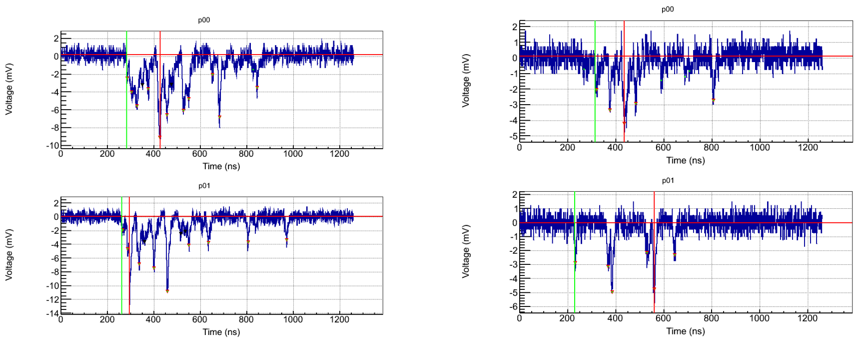
ANAIS-112 Performance

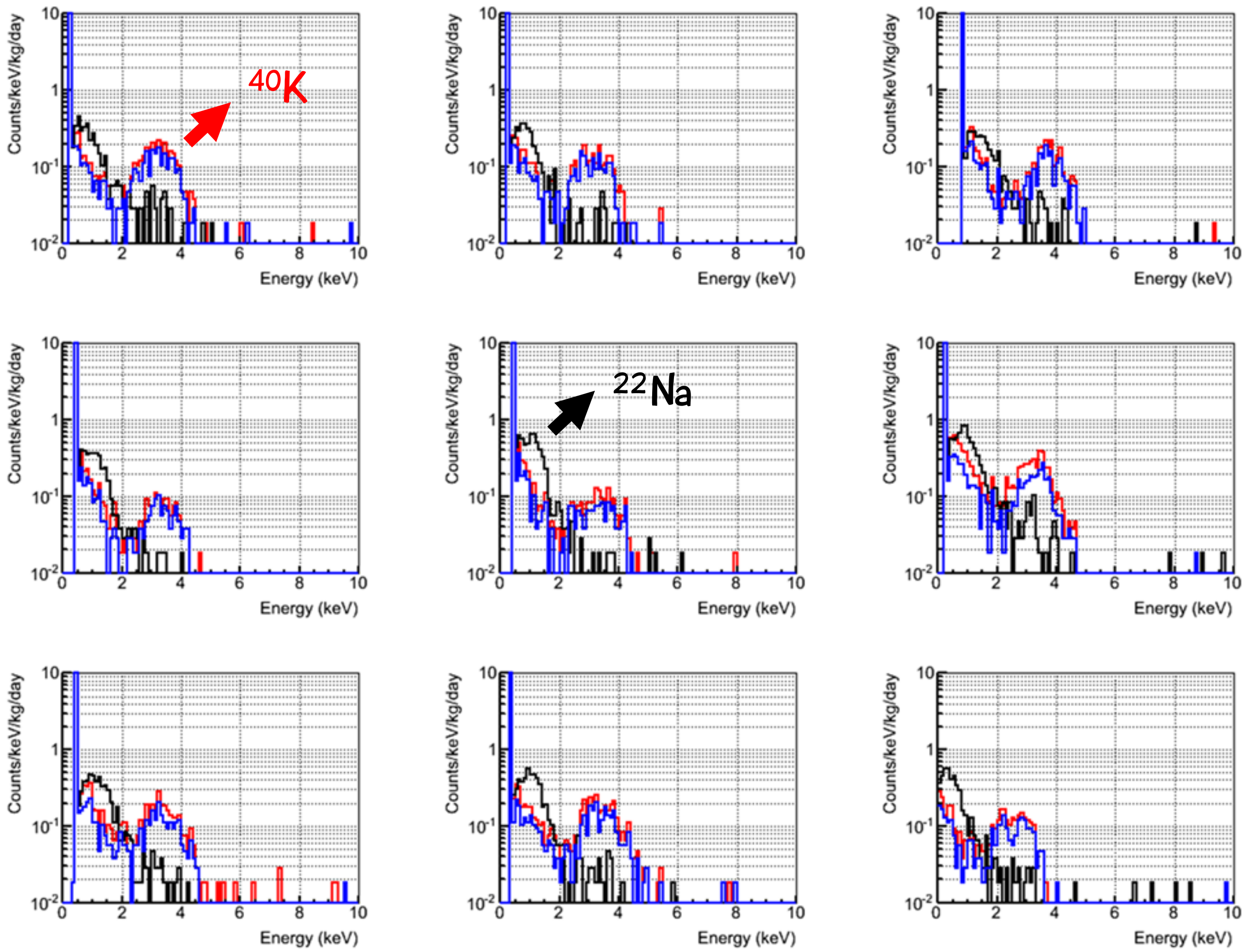
Spectra at low energy in coincidence with a high-energy gamma at 1460.5 keV (1274.5 keV) in another module for all the modules in the ANAIS-112 set-up.

These spectra have been used for the determination of the potassium contents, but also for calibrating down to the threshold our experiment.

We are triggering down to 1 keVee







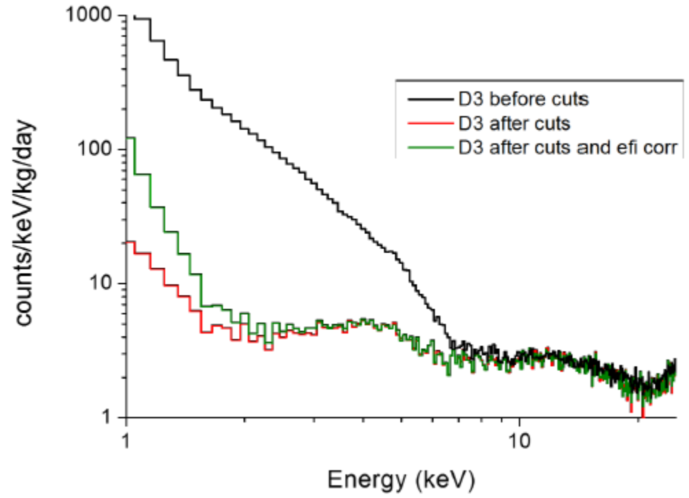
ANAIS-112 Performance

PMT events filtering (no electronic noise):

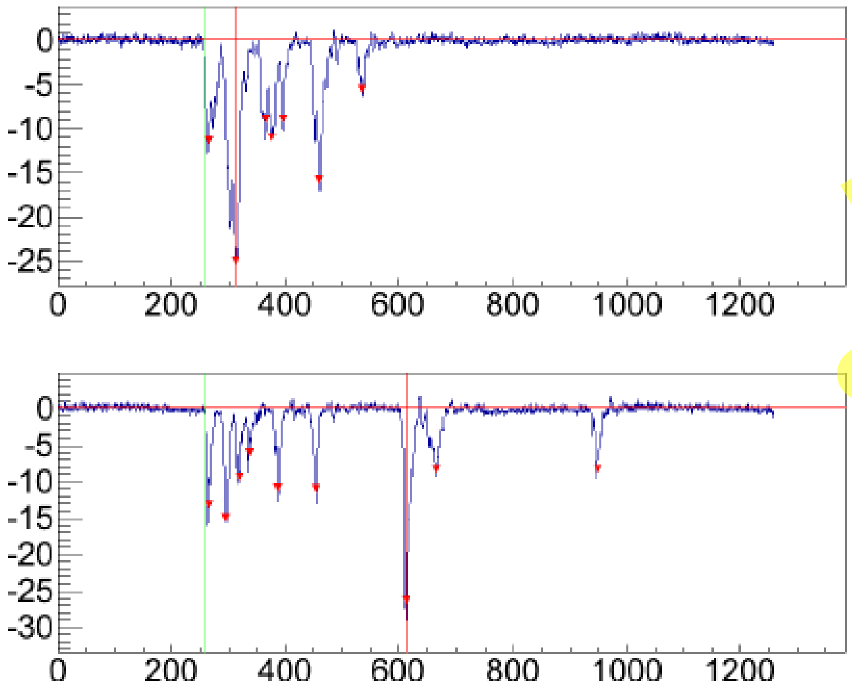
Multiparametric cuts on:

- Number of peaks in the pulse (n>2 in each PMT)
- Temporal parameters of the pulse
- Time after muon veto trigger

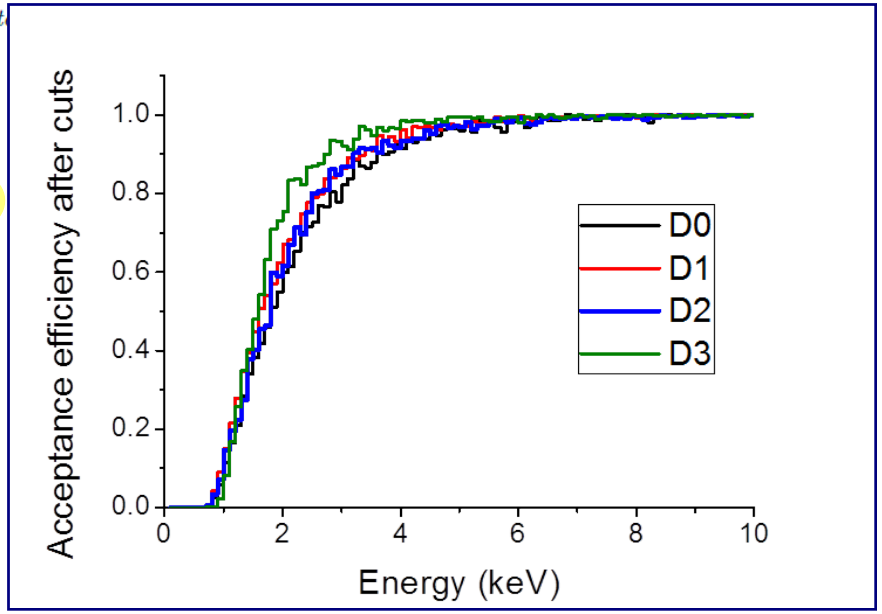
(Asymmetry in light sharing)



C. Cuesta et al., EPJ C 74 (2014) 3150

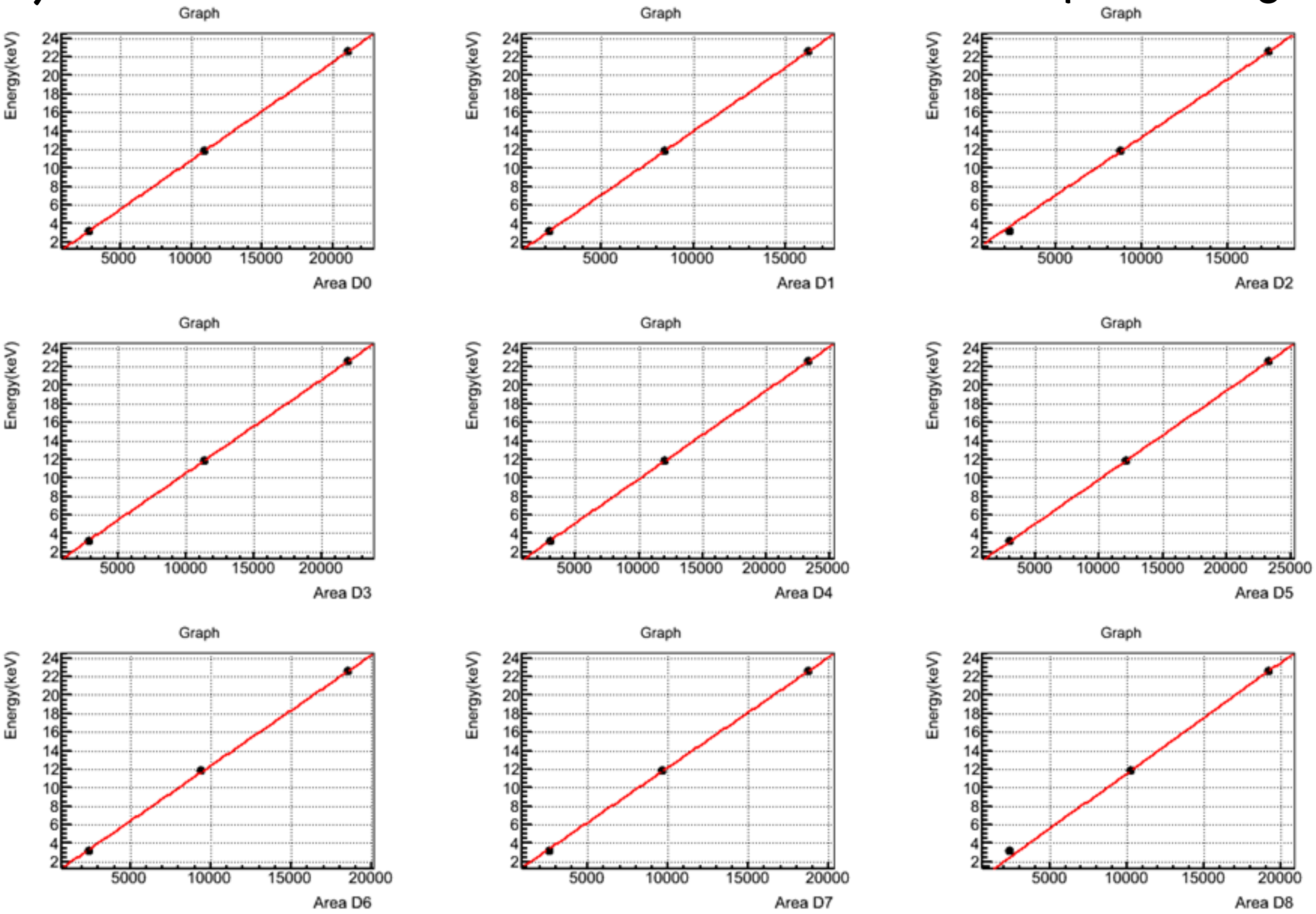


Analysis threshold is limited by efficiency of this filtering

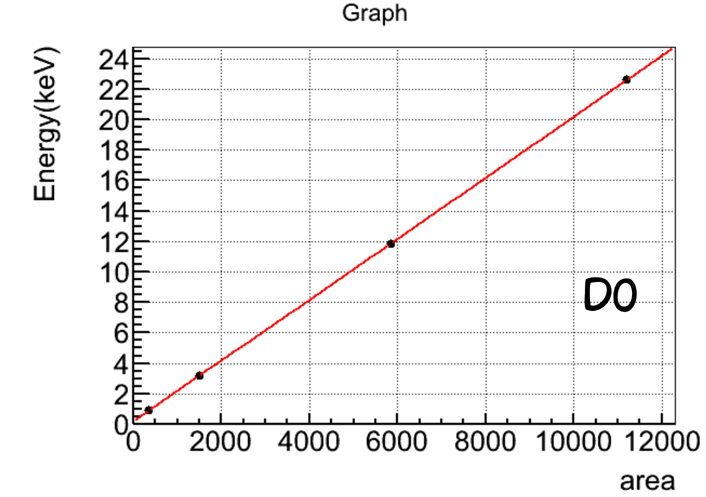


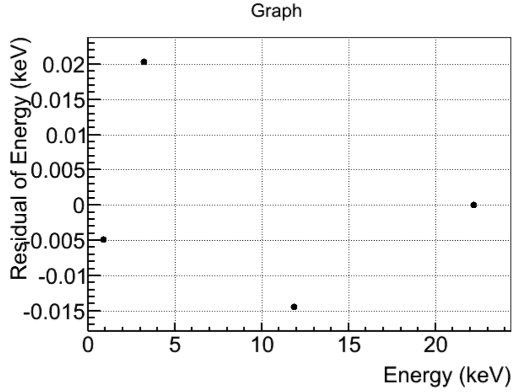
Acceptance efficiency curves from external calibration data

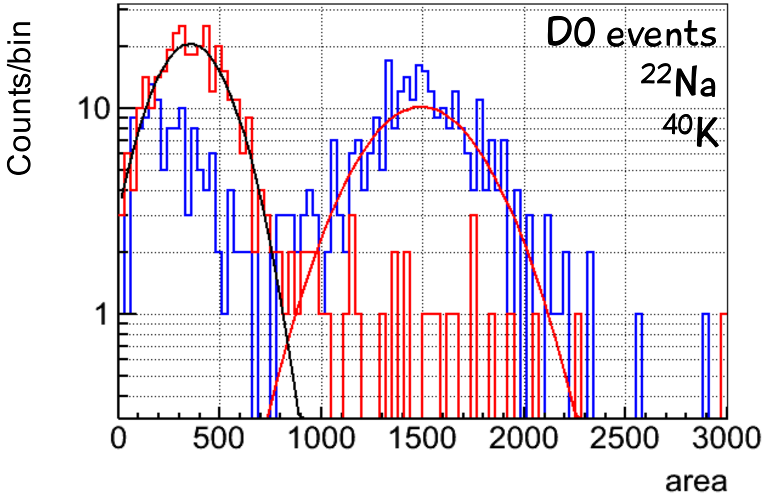
Calibration in energy in two steps-> EXTERNAL ^{109}Cd sources allow to calibrate every two weeks below 100 keV and to correct for possible gain drifts

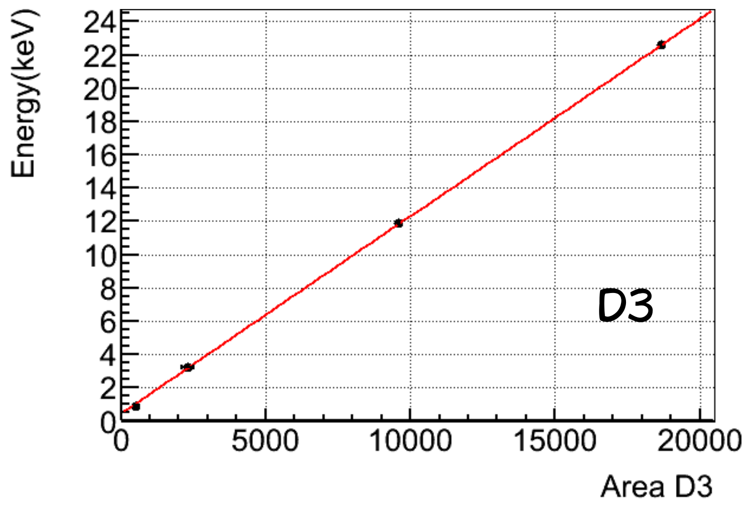


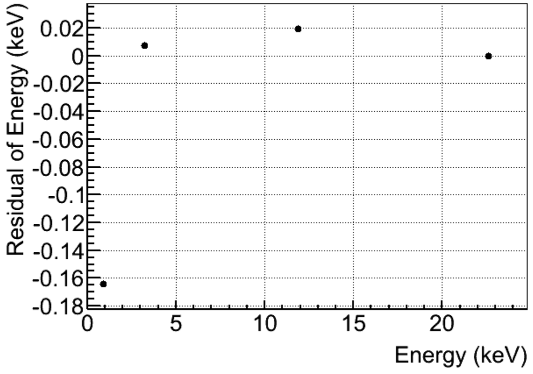
Final calibration will use both external sources at LE (^{109}Cd) and internal emissions (from ^{40}K and ^{22}Na in the bulk) in the range 0.9 to 22 keV

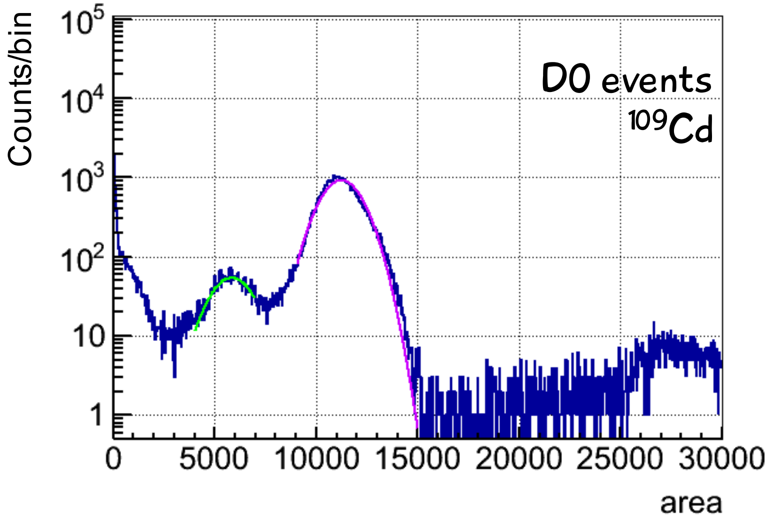








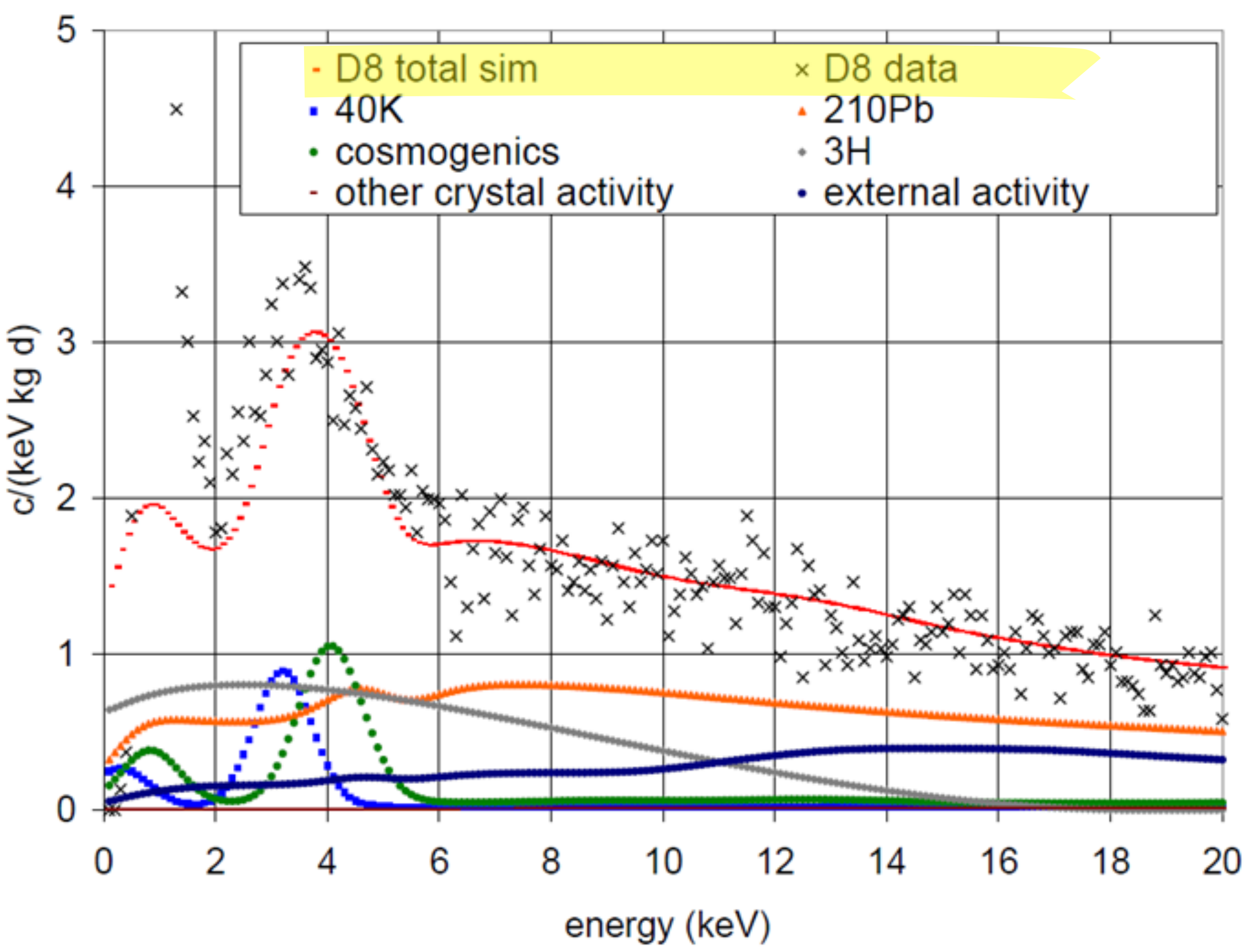




ANAIS-112 Background Model

Background model considering the measured crystal activities and the ANAIS-112 configuration, point to equivalent relevant background sources in the very low energy region:

Background sources well understood in all the modules



S. Cebrián et al, Astrop. Phys. 37 (2012) 60-69

J. Amaré et al. JCAP02 (2015) 046

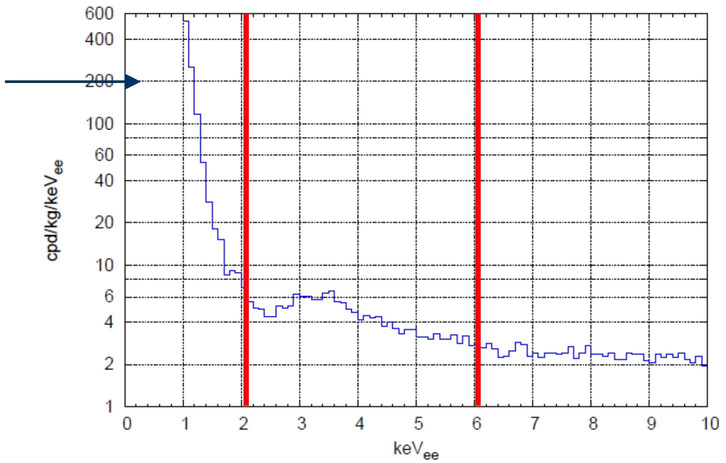
J. Amaré et al. Eur. Phys. Journal C 76 (2016) 1-15

J. Amaré et al. Astrop. Phys. 97 (2018) 96-105

^{40}K and ^{22}Na peaks and ^{210}Pb (bulk+surface) and ^{3}H continua are the most significant contributions in the very low energy region

ANAIS-112 Sensitivity

https://arxiv.org/pdf/1704.06861.pdf /



Annual modulation of dark matter:
The ANAIS–112 case

I. Coarasa[a,b], J. Amaré[a,b], S. Cebrián[a,b], C. Cuesta[a,b,c], E. García[a,b], M. Martínez[a,b,d], M.A. Oliván[a,b], Y. Ortigoza[a,b], A. Ortiz de Solórzano[a,b], J. Puimedón[a,b,1], M.L. Sarsa[a,b], J.A. Villar[a,b], P. Villar[a,b]

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[c] *Present Address: Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, CIEMAT, 28040, Madrid, SPAIN*

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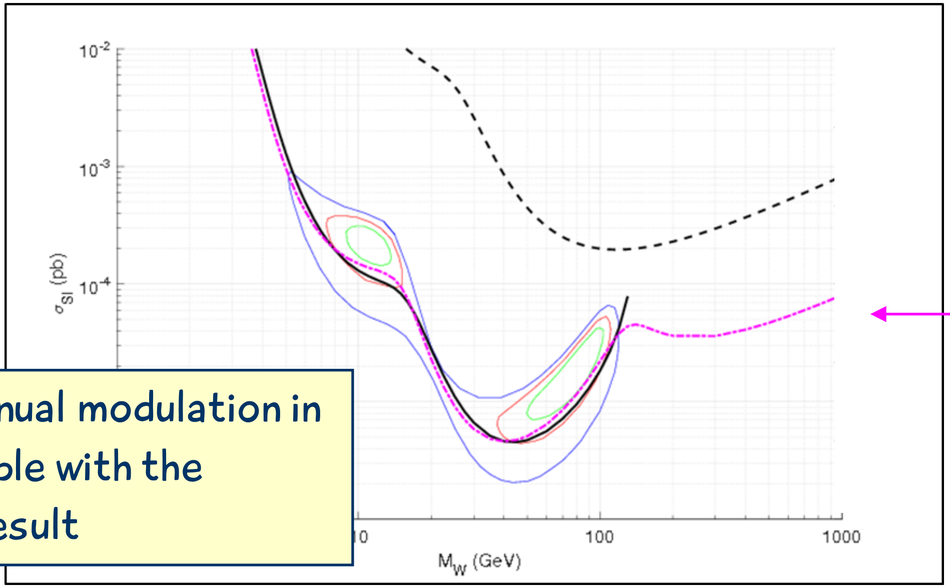
Detection limit at 90% C.L. for a critical limit at 90% C.L. for **ANAIS-112**

- Estimated **average background** from **D0-D5 measured levels** (corrected for cut efficiency)
- 2-6 keV$_{ee}$ region
- 5 years

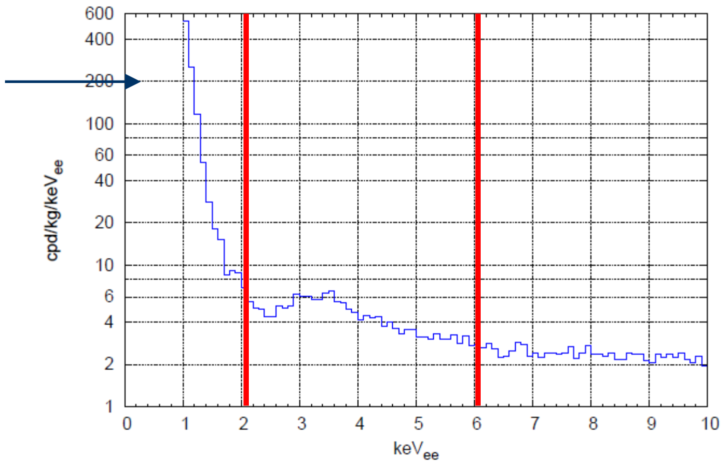


Dark matter hypothesis

90% probability of detecting an annual modulation signal at 90% C.L.

ANAIS-112 can detect the annual modulation in the 3σ region compatible with the DAMA/LIBRA result https://arxiv.org/pdf/1704.06861.pdf /

ANAIS-112 Sensitivity



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Detection limit at 90% C.L. for a critical limit at 90% C.L. for ANAIS-112

- Estimated **average background** from **D0-D5 measured levels** (corrected for cut efficiency)
- 2-6 keV$_{ee}$ region
- 5 years

ANAIS-112 has a detection limit for annual modulation lower than the measured amplitude by DAMA/LIBRA: 0.0112 ± 0.0012 cpd/kg/keV$_{ee}$

Model-independent annual modulation

Factor of Merit: from the variance of the estimator of the modulated amplitude

$$FOM = \left(\frac{2 \cdot B}{\Delta E \cdot M \cdot T_M \cdot \varepsilon}\right)^{\frac{1}{2}}$$

Detection Limit for annual modulation amplitude: for ANAIS-112 parameters

$$L_D = (8.40 \pm 0.25) \cdot 10^{-3} \text{ cpd/kg/keV}_{ee} \quad (90\% \text{ C.L.})$$

SUMMARY AND OUTLOOK

ANAIS-112 has been installed successfully at LSC:

112.5 kg (3x3 crystals matrix) of NaI(Tl) built at AS

-outstanding light collection

-good background understanding

Electronics/Acquisition has been fine-tuned

Dark matter run started data taking by August, 3rd, 2017

Data taking expected to go on in these conditions during the next two years (first phase):

Control populations in preparation

Blind annual modulation analysis foreseen

Good sensitivity prospects for exploring the DAMA/LIBRA signal:

5 years data taking needed for a 3 sigma significant result

SUMMARY AND OUTLOOK

Scintillation Quenching Factor measurement for nuclear recoils @ TUNL laboratories is in preparation

Combining data with COSINE-100 experiment is under discussion

Installation of a blank module before the summer -> control population is under consideration

For the second phase of measurement (last 2 years) we are considering possible experiment upgrades:

- Application of Si PMs to the light readout of NaI(Tl)
- LSV System

Making ANAIS data public after use to allow for independent analysis

Thank you for your attention

ANAIS

MultiDark
Multimessenger Approach
for Dark Matter Detection

LSC
Laboratorio Subterráneo de Canfranc

Universidad Zaragoza