

# Energy response and position reconstruction at DEAP-3600

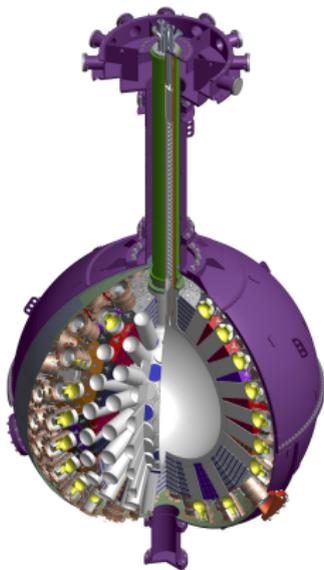
CAP 2017, Kingston

**Stefanie Langrock**  
on behalf of the DEAP-3600 collaboration  
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Laurentian University

01/06/2017



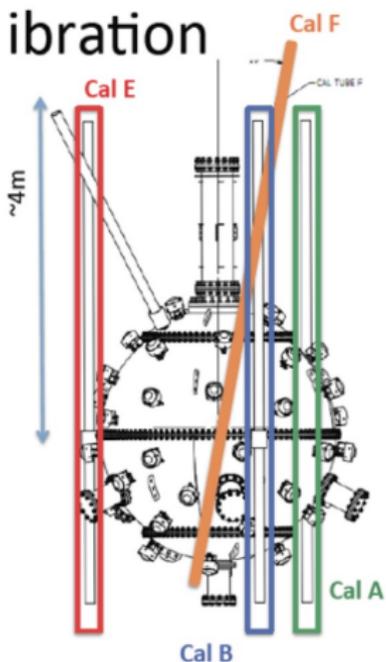


## The experiment:

- Pixelated detector
- Detection of WIMPs via nuclear recoils
- Designed for 3600 kg LAr
- 255 PMTs to measure energy and position of events in the LAr
- AV coated with wavelength shifter TPB
- Located at SNOLAB
- Taking physics data since 2016
- Target sensitivity to WIMP-nucleon cross section  $10^{-46} \text{ cm}^2$  at WIMP masses of 100 GeV



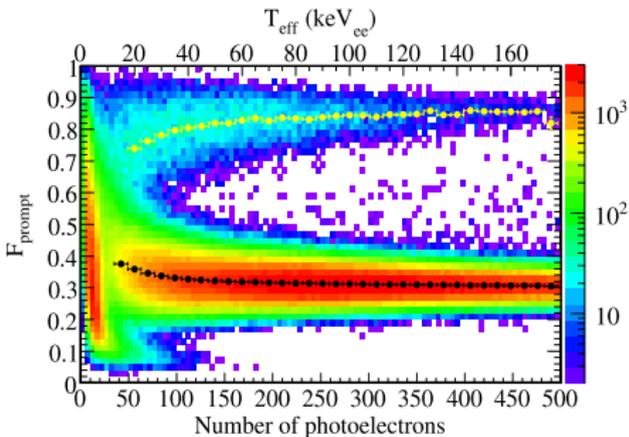
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## Discriminating the $^{39}\text{Ar}$ signal using PSD:



### DEAP-1 calibration data

Astroparticle Physics 85 (2016) 1-23

$$f_{\text{prompt}} = \frac{q_{\text{prompt}}}{q_{\text{event}}}$$

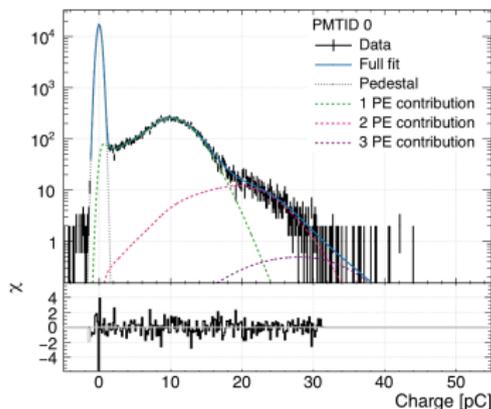
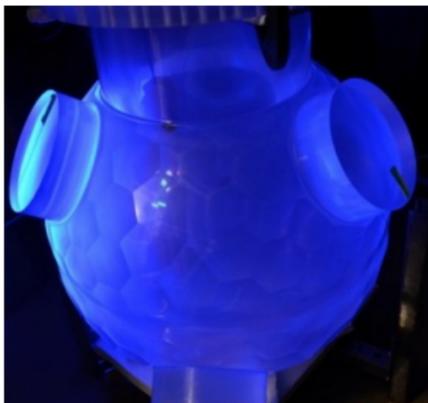
- Ar Dimer states with different life times:
  - Singlet  $\tau$  6 ns -predominantly nuclear recoils
  - Triplet  $\tau$  1500 ns -predominantly electromagnetic events
- $^{39}\text{Ar}$ :
  - $\beta^-$  emitter with  $Q = 565$  keV
  - From cosmic ray interaction on  $^{40}\text{Ar}$
  - Isotropically distributed in LAr

→ Percentage of light signal in prompt light as indication of singlet state population



## Single Photon counting:

Ideal measurement: single photon counting correcting for PMT effects  
 De-excitation photons (128 nm) →  
 TPB (420 nm) → Photoelectron  
 cascades in PMTs

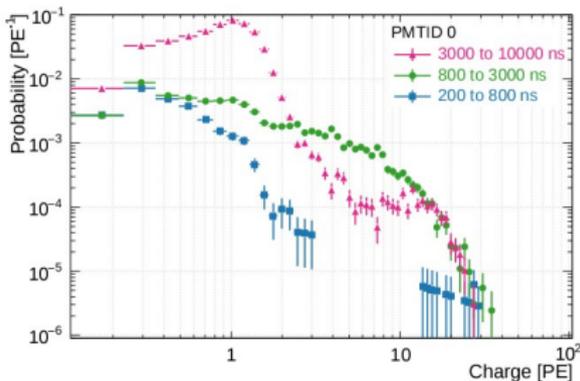


arXiv:1705.10183

- Translation of PMT pulses to number of photoelectrons observed using charge division (qPE)



## Correction of different effects necessary:



### Effects to correct on PE estimator:

#### ● PMT effects:

- After-pulse (AP): caused by back-scatter of electrons on PMT dynodes
- Saturation of PMTs
- Dark noise

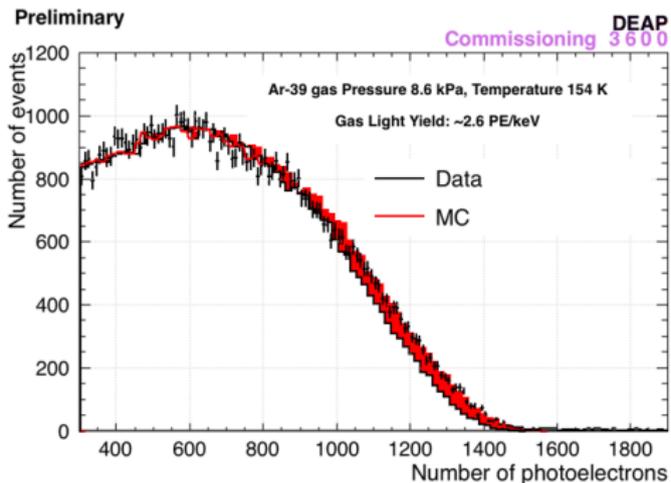
#### ● Other effects:

- Pile-up of two or more events in same event window

arXiv:1705.10183



## Understanding the energy response using $^{39}\text{Ar}$ :



- Light yield uniformly scaled to match the simulation to data

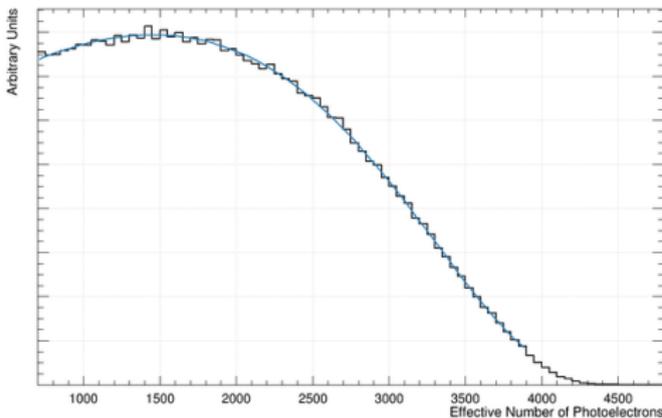
Cool down phase, before fill

Gas phase calibration with  $^{39}\text{Ar}$



## Understanding the energy response using $^{39}\text{Ar}$ :

Preliminary - Fit to Simulated  $^{39}\text{Ar}$  Spectrum



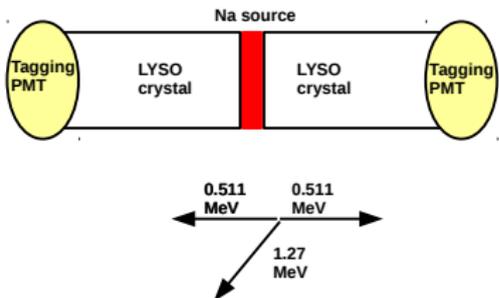
- Light yield uniformly scaled to match the simulation to data

Simulation, after finishing fill

LAr phase calibration with  $^{39}\text{Ar}$

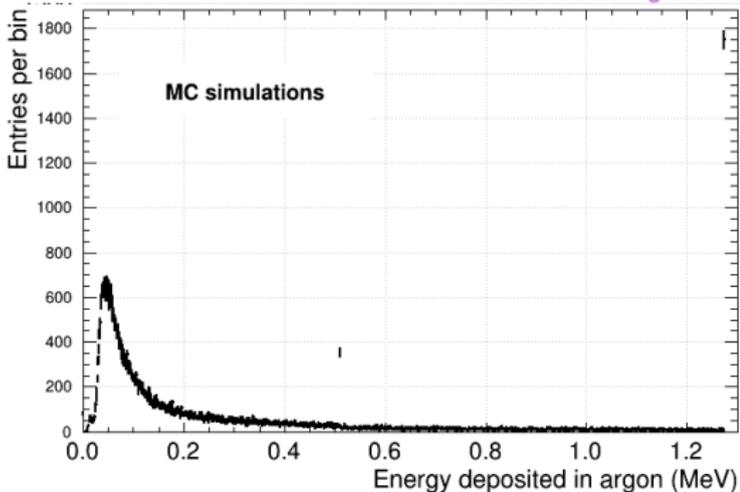


## External $^{22}\text{Na}$ source allows tagged gamma rays:



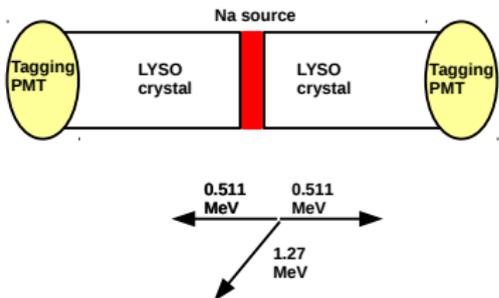
Preliminary

DEAP  
Commissioning 3600



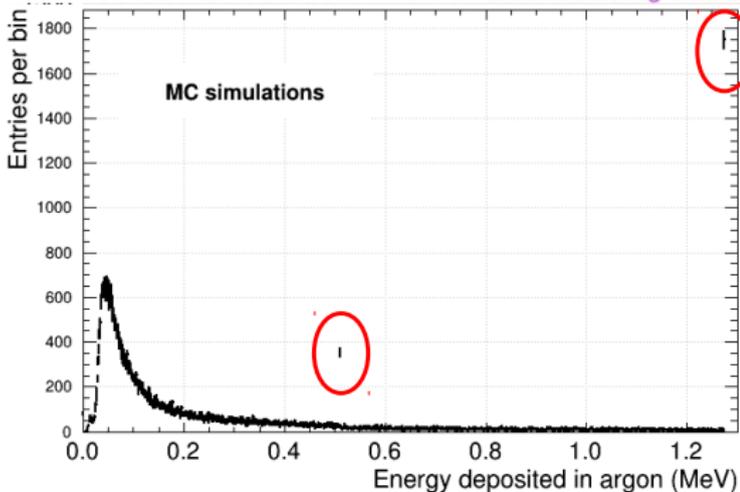


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Preliminary

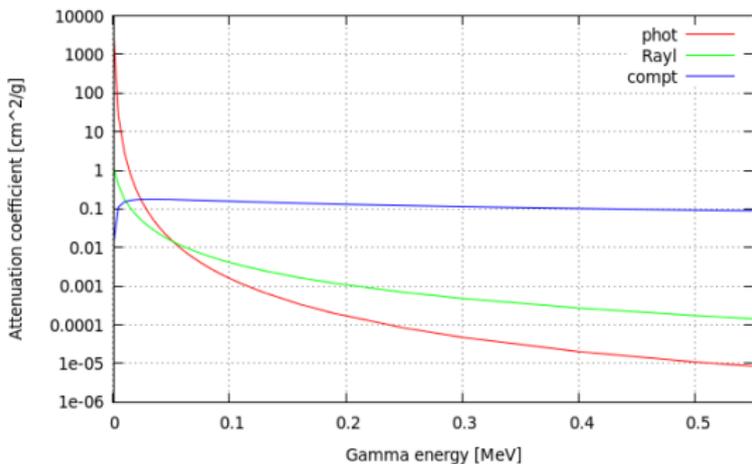
Commissioning 3600 DEAP





## Photoconversion of incoming $\gamma$ on the acrylic:

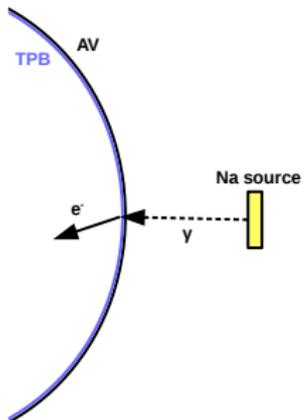
- at few tens of keV photoelectric effect dominant effect over Rayleigh and Compton scattering
- Once gammas are degraded to a few tens of keV, they travel very short distance before being photoabsorbed



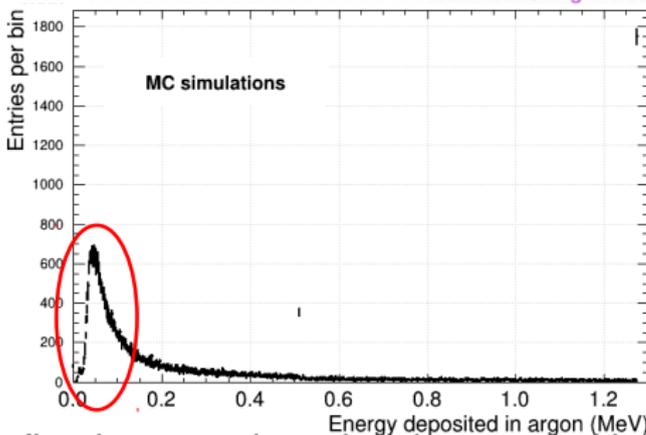


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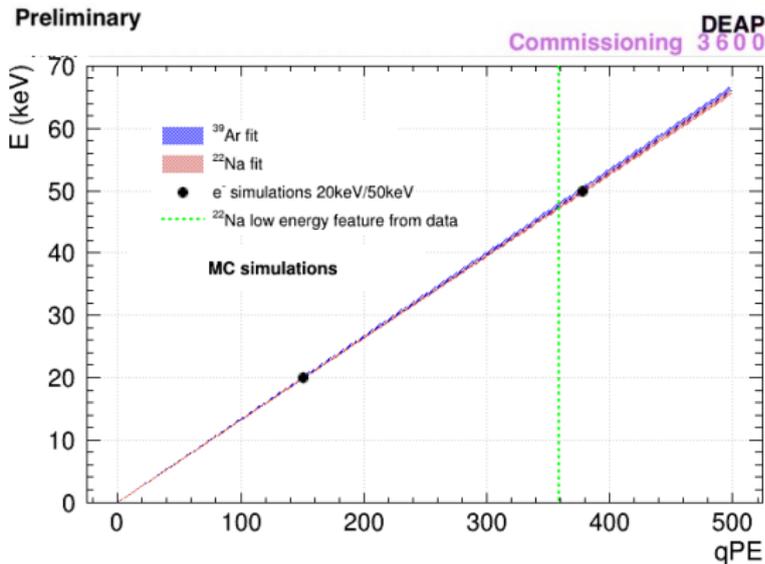
DEAP  
Commissioning 3600

Measurement of well defined energy deposit at known position





## Comparing $^{39}\text{Ar}$ and low energy $^{22}\text{Na}$ :



# Very preliminary results!



## Measurement of event position:

Two main approaches possible:

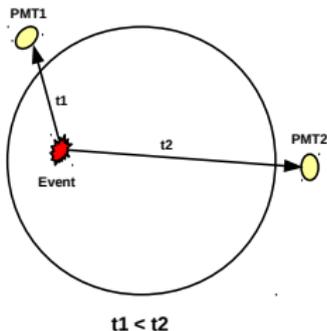
- Time-based
- Charge-based



## Measurement of event position:

Two main approaches possible:

- Time-based



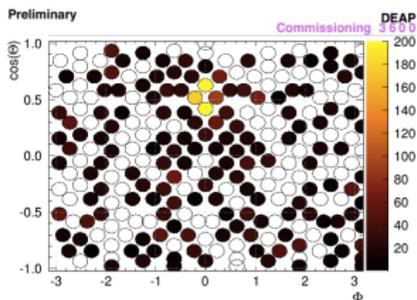
- Finite speed of light
- PMT hit time proportional to source distance from PMT
- Absolute vertex resolution uniform across volume
- Dependent on scintillator response times, PMT transit time, DAQ quality



## Measurement of event position:

Two main approaches possible:

- Charge-based



- Charge patterns of the PMTs
- Point-like source: closer PMTs expected to have more photon hits and charges
- Pattern detector dependent
- Vertex resolution improved towards the edge of the detector



## Measurement of event position:

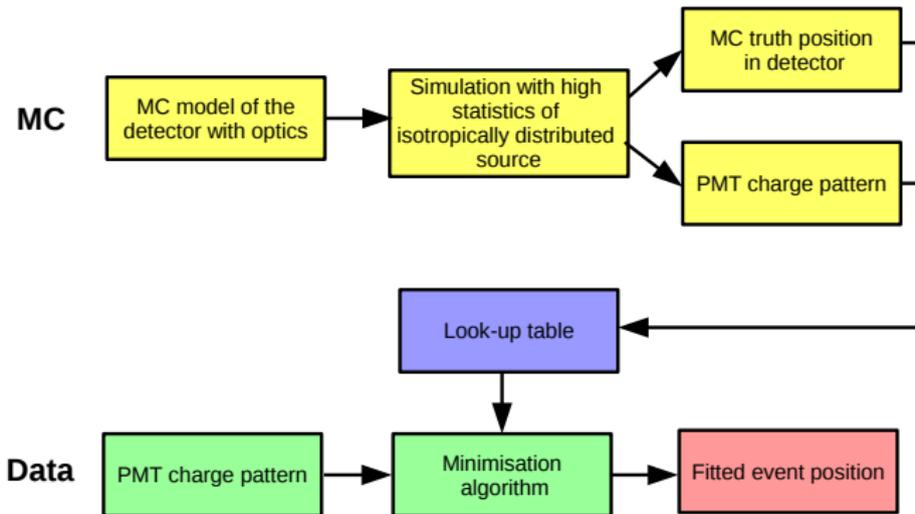
Two main approaches possible:

- Time-based
- Charge-based

DEAP-3600 small enough for charge-based vertex reconstruction to deliver the better position resolution



## How it is done:

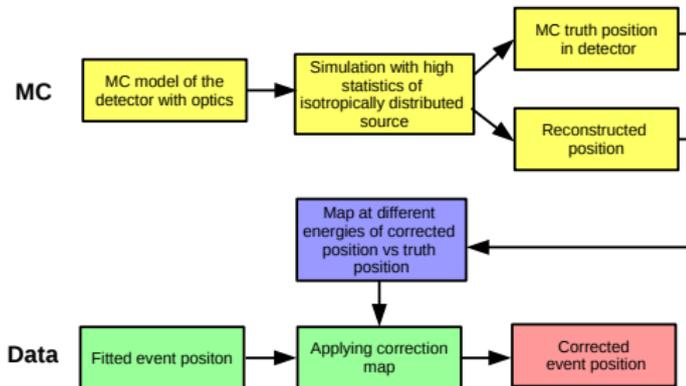


Work in progress!



## Fiducialisation and de-biasing using $^{39}\text{Ar}$ :

- Isotropic  $^{39}\text{Ar}$  distribution
- Map true radius to reconstructed radius
- Account for energy dependence
- Determine fiducial mass by determining  $^{39}\text{Ar}$  rate

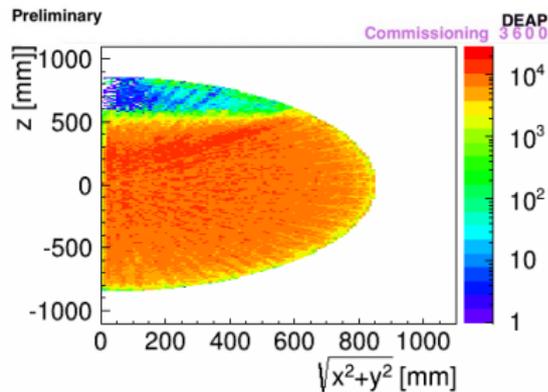
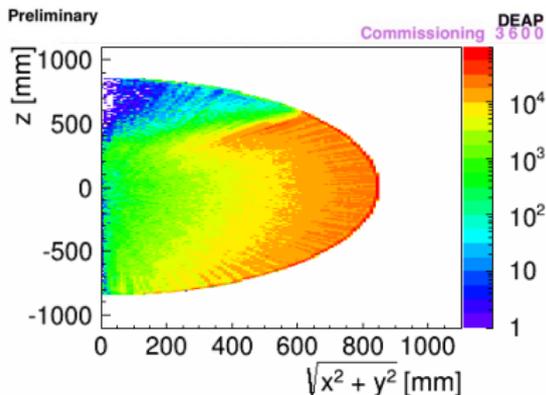


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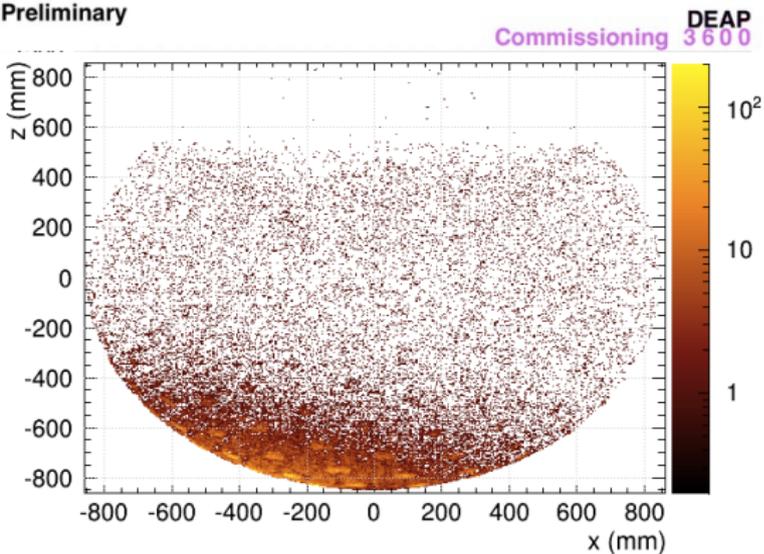


Work in progress!



## $^{22}\text{Na}$ studies to understand surface backgrounds:

Preliminary



Work in progress



## The Deap-3600 collaboration:

around 60 collaborators in Canada, the UK and Mexico



The speakers operational support was provided by NSERC



# Back Up



## DEAP-3600 calibration program:

Calibration Source	Calibration goal	Notes
Laserball	Optical (PMT) calibration	vacuum runs only
LED Light Injection	Optical (PMT) calibration, monitoring	used in all run phases
$^{22}\text{Na}$	Energy and position reconstruction, gamma response	Argon phase
AmBe	Energy calibration, gamma and neutron response	Argon phase
$^{39}\text{Ar}$	Intrinsic, energy and position reconstruction	Argon phase

- Argon phase: gas phase (GAR), partial fill phase, liquid argon phase (LAr)
- LED Light Injection system with fibres installed on PMTs
- External calibration sources:  $^{22}\text{Na}$  (1 MBq) and AmBe (74 MBq)
- Intrinsic calibration source:  $^{39}\text{Ar}$  (expected 1.01 Bq/kg)

