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ArDM

The Argon Dark Matter experiment

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With the collaboration of The Nuclear Innovation Unit (CIEMAT)

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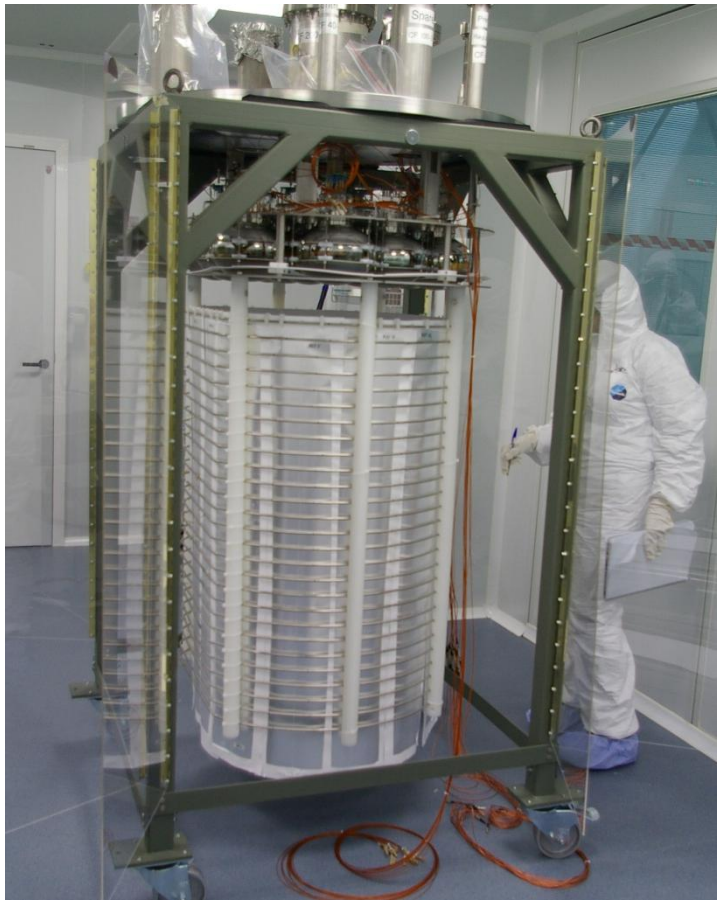
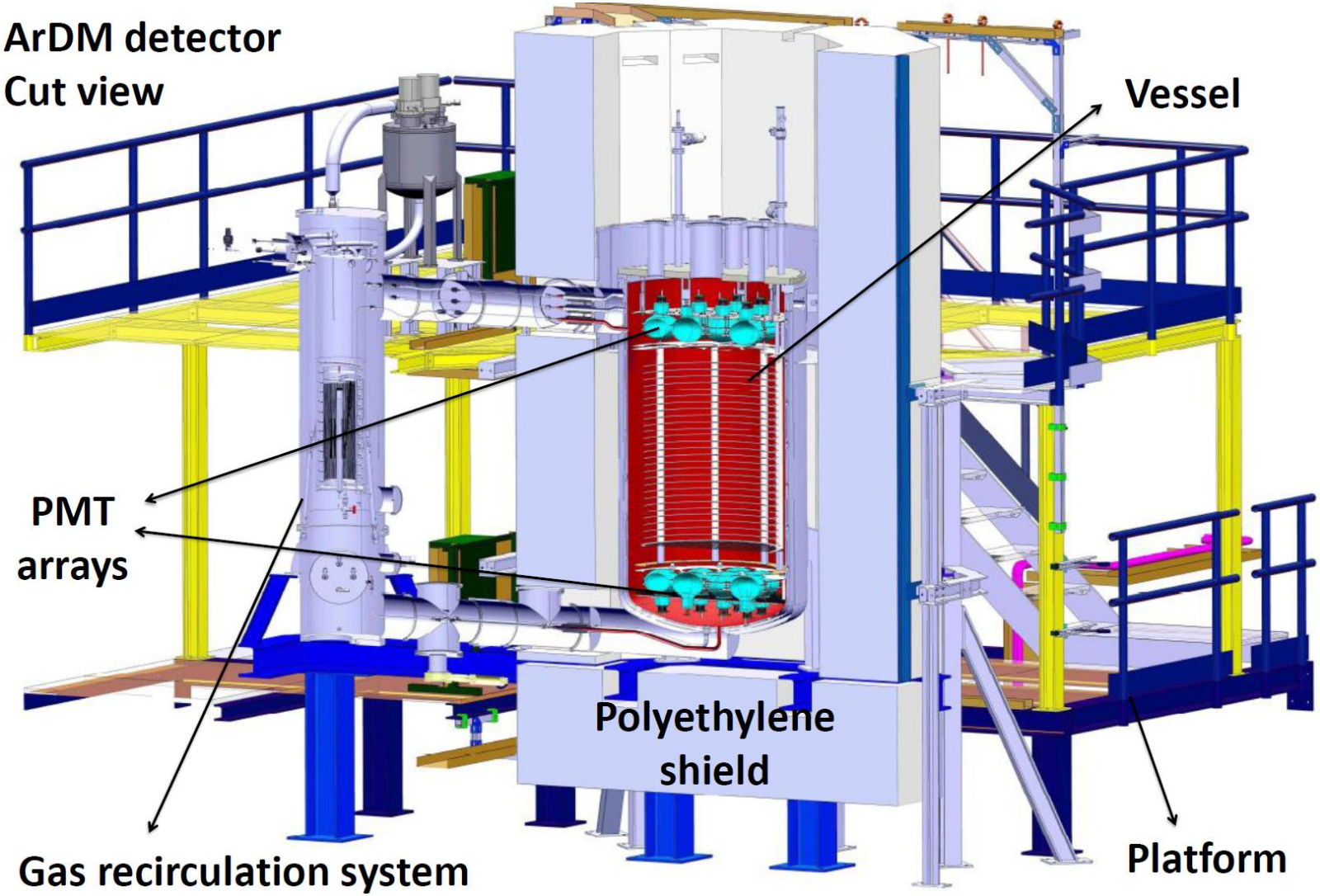
ISAPP

The experiment

- The Argon Dark Matter (ArDM) detector is a double-phase (liquid-gas) argon time projection chamber for direct dark matter searches. It is currently installed in the Laboratorio Subterráneo de Canfranc in Spain.



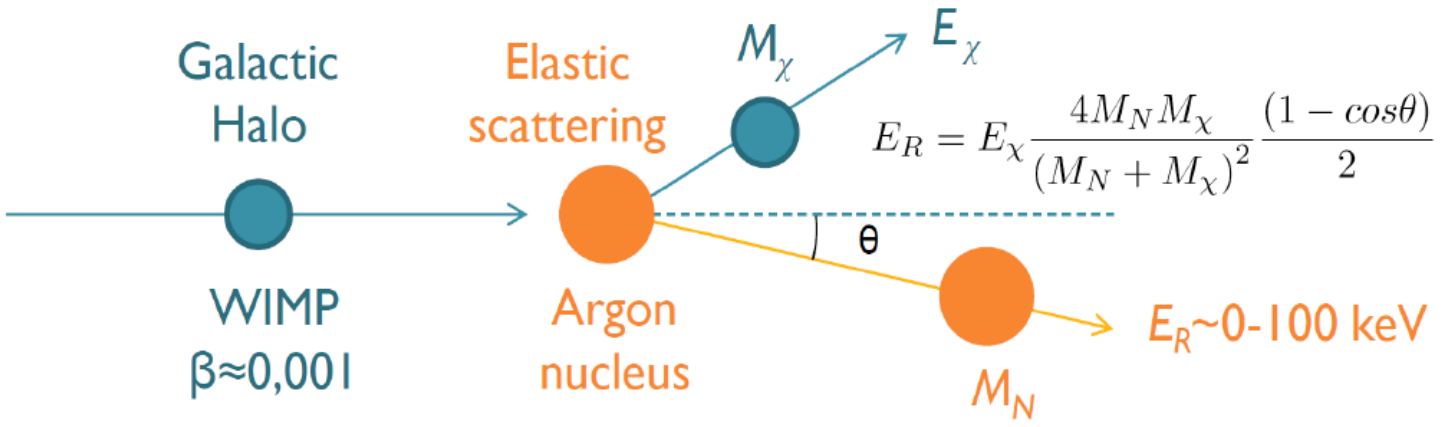
The detector



Elastic scattering

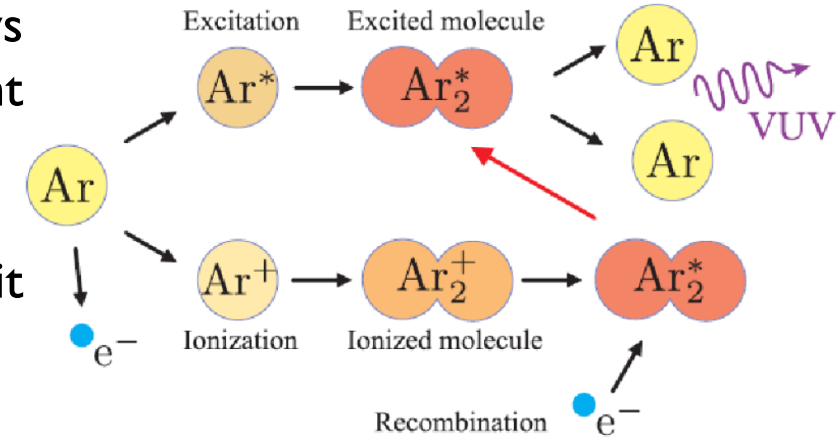
- ArDM, with a ton-scale sensitive volume, has been conceived to detect nuclear recoils produced by dark matter particles scattering off target nuclei.

- The elastic scattering of a WIMP with mass M_χ produces the recoil of the argon nucleus of a mass M_N with an energy E_R and an angle θ:



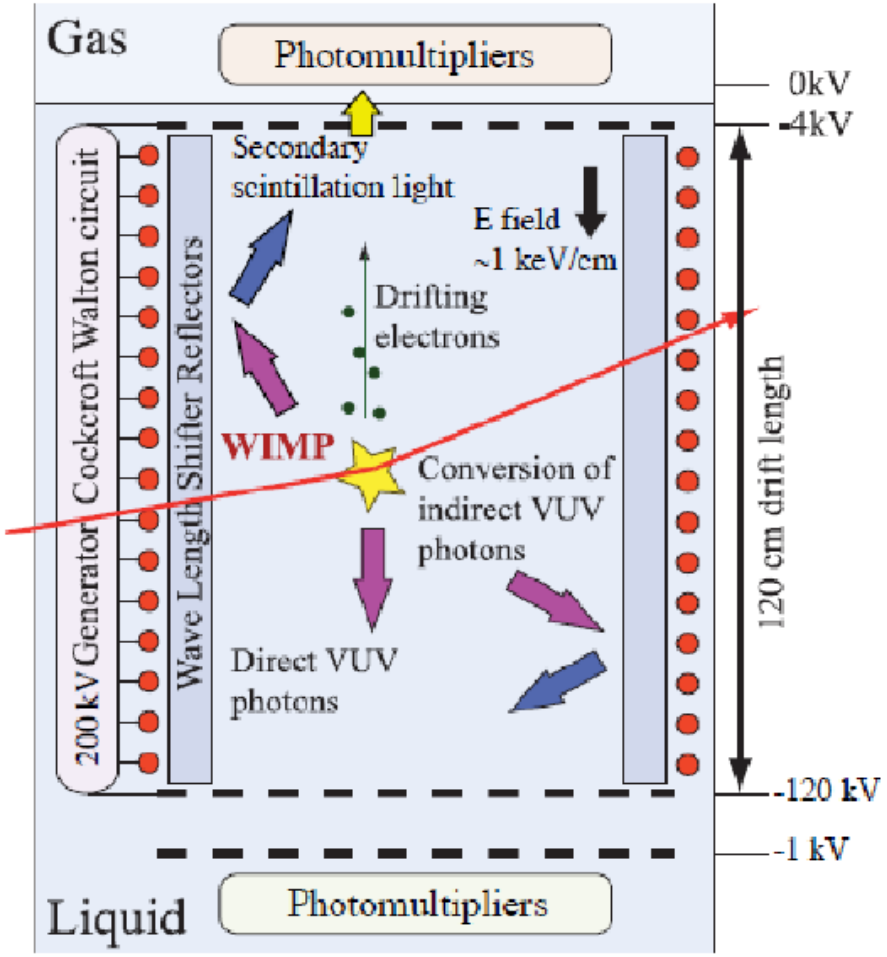
Elastic scattering and primary scintillation

- Elastic scattering WIMP-argon nucleus → nuclear recoil.
- Ionization and excitation of surrounding argon atoms form dimers and excimers, Ar_2^+ y Ar_2^* .
- By recombination with free e^- coming from ionization of atomic argon, Ar_2^+ → excimer Ar_2^*.
- Ar_2^* can be in singlet or triplet states and radiatively decays producing primary scintillation light (VUV).
- S1 cannot be reabsorbed, so it propagates within the detector.



Secondary scintillation and detection

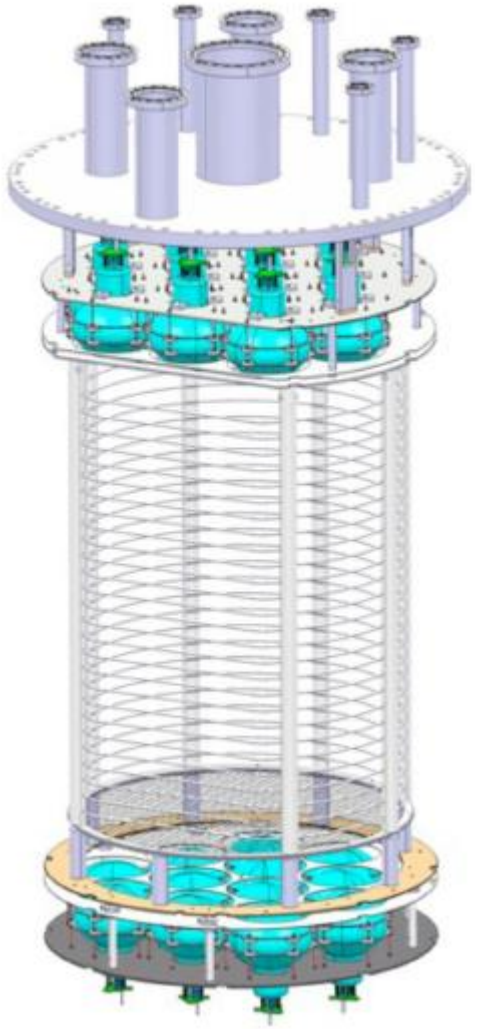
- Ionization
  - e^- that do not recombine are drifted towards the interface liquid-gas by an electric field.
  - They are extracted and accelerated from liquid into gas phase, producing secondary electroluminescence scintillation (S2), which is proportional to the amount of charge reaching the gas phase.



Light detection and position reconstruction

- Wavelength conversion 128 nm (VUV) —› ~420 nm, optimal for detection on the photomultipliers (PMTs), using the wavelenth shifter tetraphenyl butadiene (TPB).

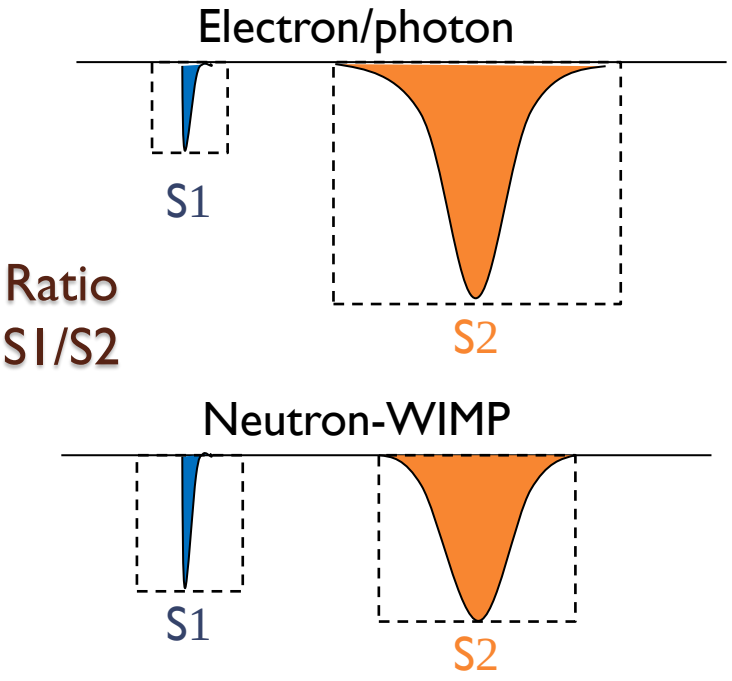
- 3D interaction position
  - xy coordinates are preserved and reconstructed using the light pattern from the top PMT array.
  - z coordinate is reconstructed considering the drift time as the delay between S2 with respect to S1.

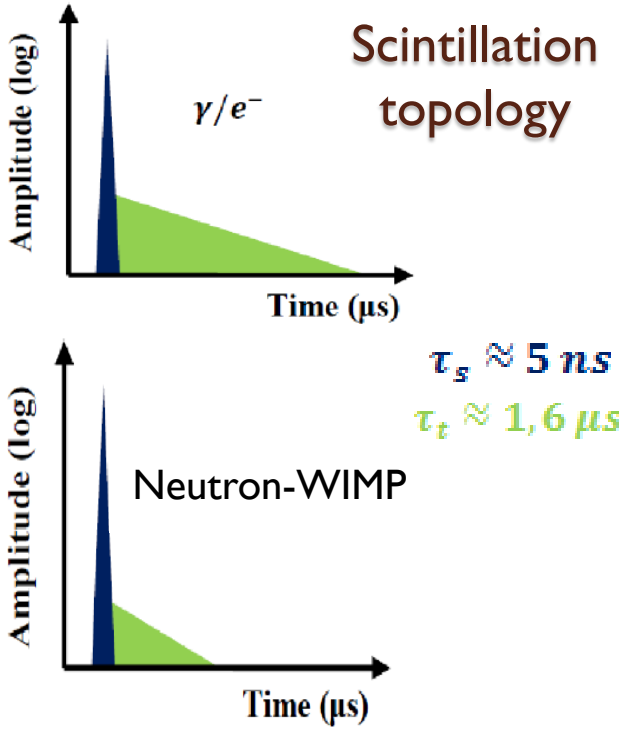


Background discrimination

- Background contributions, mainly: electrons and photons (beta decay ^{39}Ar, radioactive decay of the detector and laboratory materials) and neutrons (U/Th decay chains).

- Two different methods:



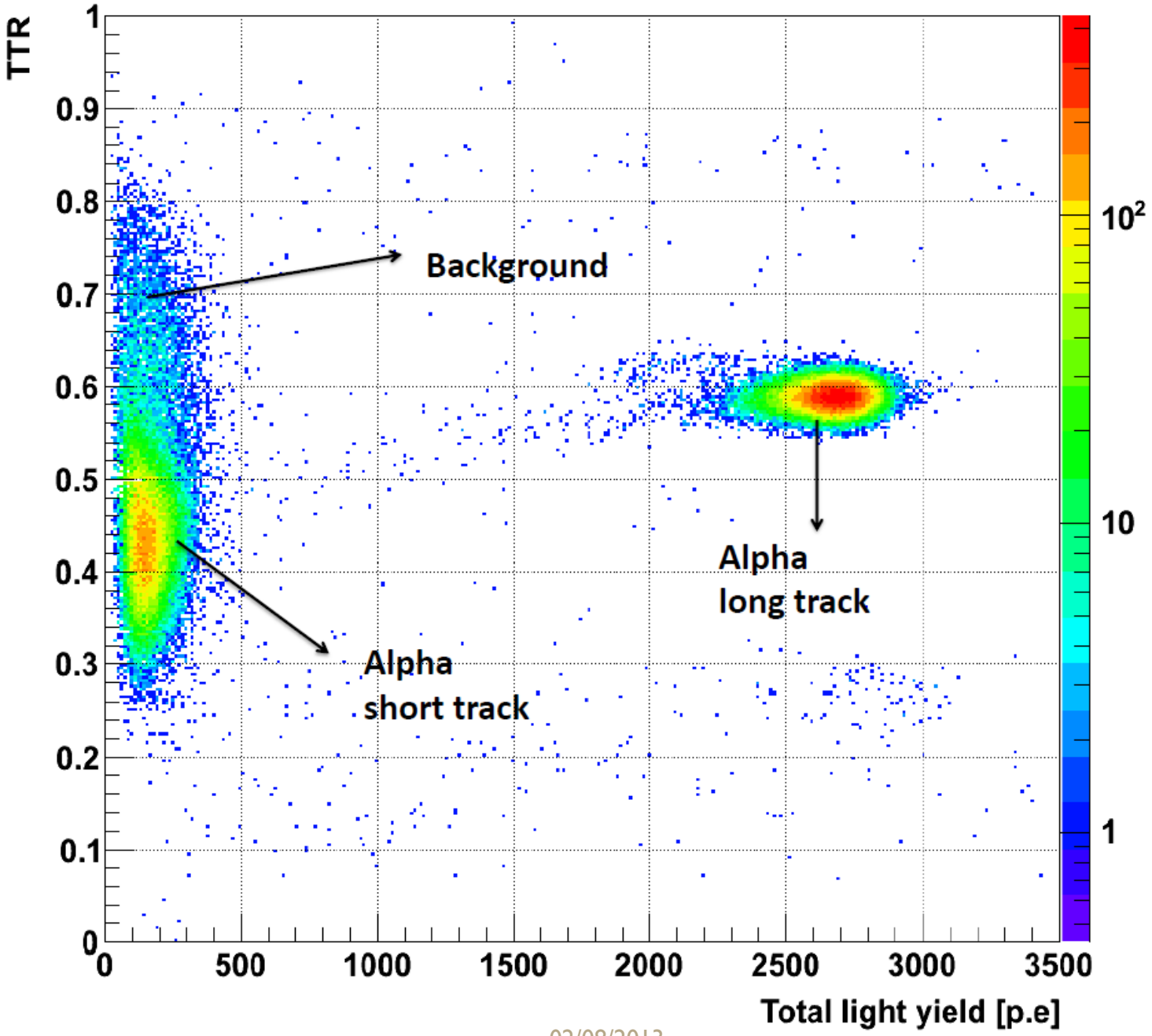


Gas argon measurements

- First data taking at LSC was carried out for two weeks in April 2013 with warm pure gas argon and a low-activity ^{241}Am source installed inside the detector vessel.

- The top-to-total ratio of the signals is defined as TTR = LY_{TOP} / LY_{TOTAL} , where LY_{TOP} and LY_{TOTAL} are the integrated signals for top and top+bottom PMT arrays respectively.

- There are two types of alpha tracks:
  - long tracks (LY_{TOT}~2500 p.e.) correspond to full energy deposition in gas argon
  - short tracks (LY_{TOT} < 500 p.e., TTR < 0.6) are produced by partial energy deposit of the alpha due to interaction with the source holder.

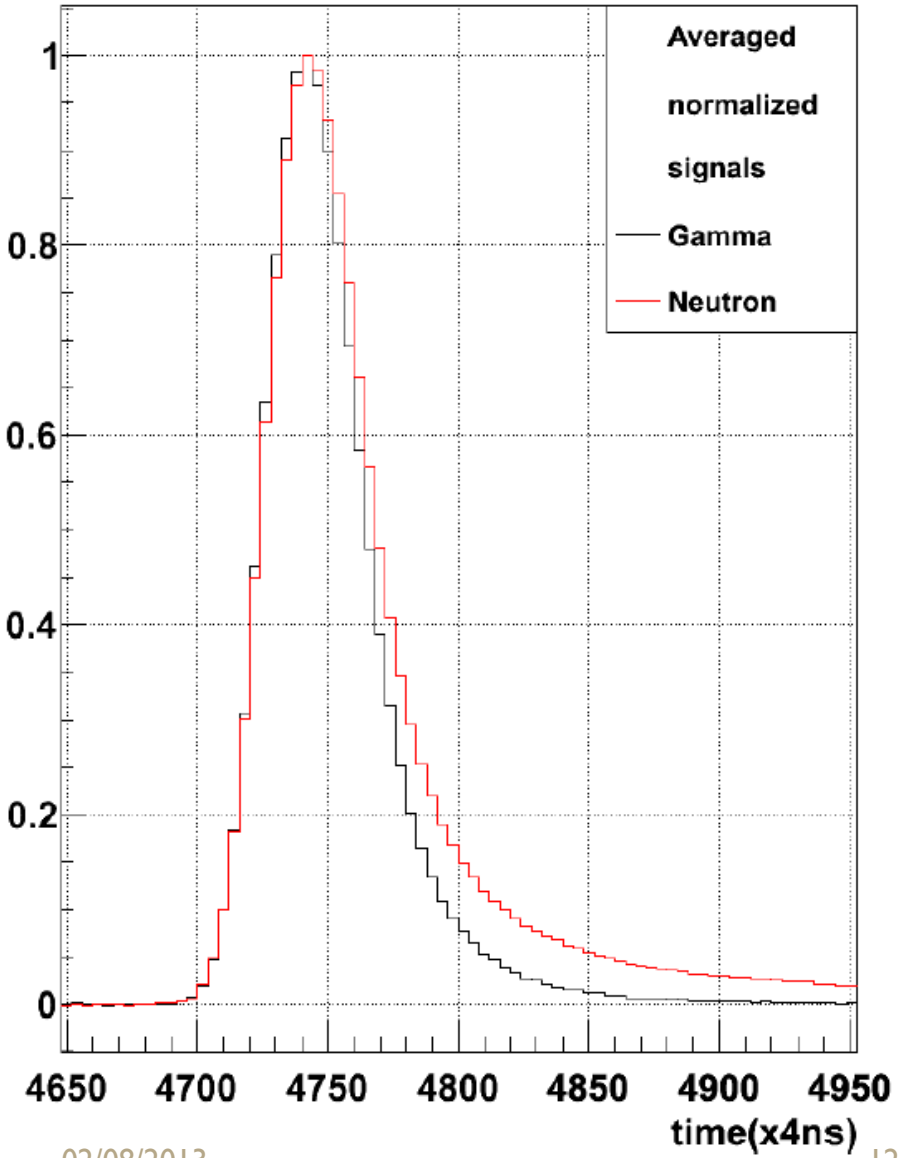

TTR
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
500
1000
1500
2000
2500
3000
3500
Total light yield [p.e]
Background
Alpha
long track
Alpha
short track
10^2
10
1

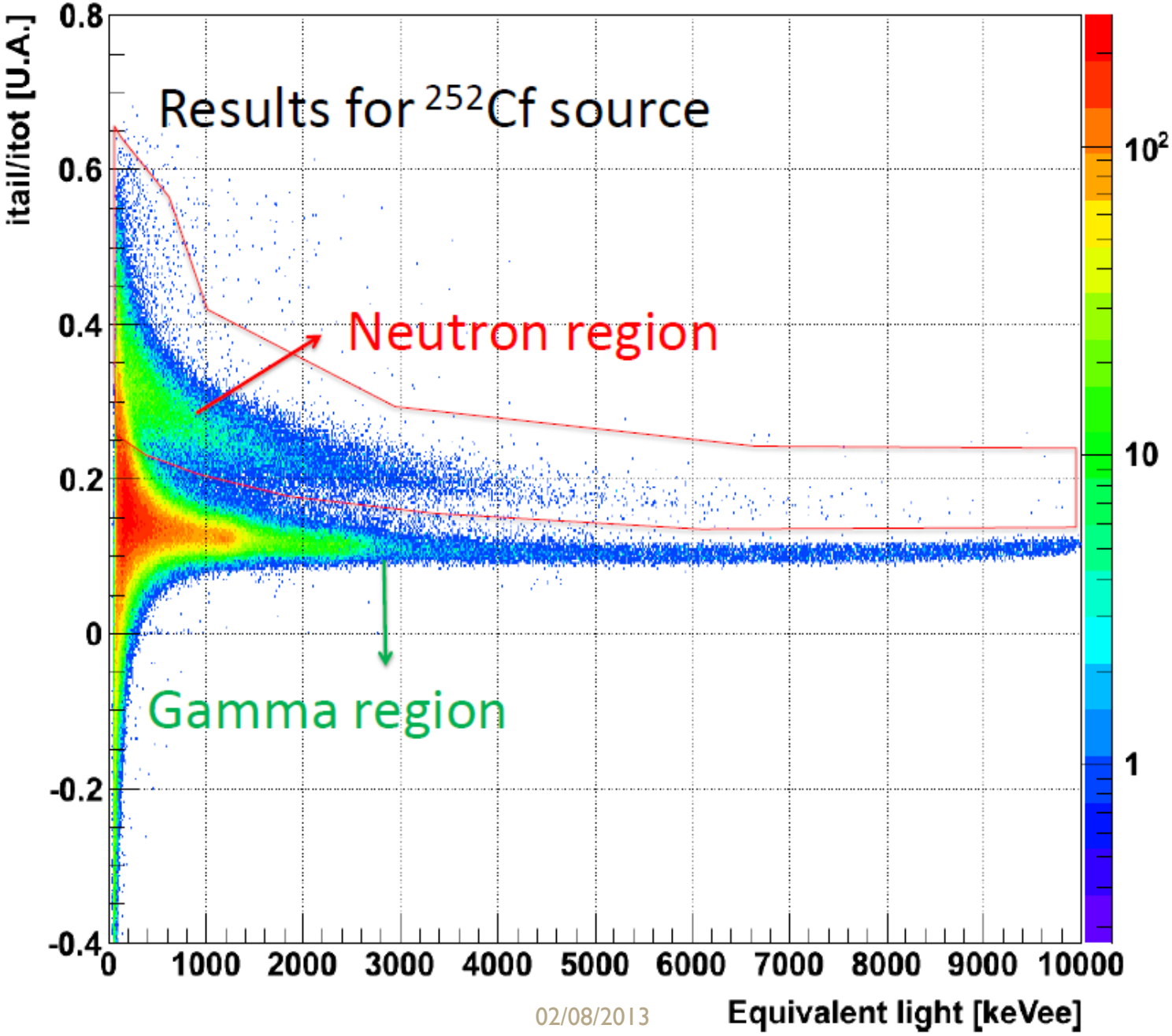
Neutron background measurements

- Neutrons coming from natural radioactivity can produce single scattering nuclear recoils in the energy region of interest, thus becoming an irreducible background.
- ArDM underground operation at LSC needs to be completed with site-specific neutron background measurements.
- Some tests have been done with a ^{252}Cf source and a BC501A liquid scintillator detector at CIEMAT.
- Digital charge integration discrimination method: distinguish between signals produced by neutrons and gammas.

Signals

- We obtain an averaged normalized signal from a specific energy region.
- Neutron signals show a longer tail than the gamma ones.
- The ratio between the tail integral and the total integral is larger for neutrons than for gammas.




Results for ^{252}Cf source
Neutron region
Gamma region
itail/itot [U.A.]
Equivalent light [keVee]
0.8
0.6
0.4
0.2
0
-0.2
-0.4
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
10^2
10
1

References

- ArDM Collaboration, "First results on light readout from the 1-ton ArDM liquid argon detector for dark matter searches", 2010 *JINST* 5 P11003.

- ArDM collaboration, "Status of the ArDM Experiment: First results from gaseous argon operation in deep underground environment", arXiv:1307.0117.

- C. Guerrero, D. Cano-Ott, M. Fernández-Ordóñez, E. González-Romero, T. Martínez, D. Villamarín, "Analysis of the BC501A neutron detector signals using the true pulse shape", Nuclear Instruments and Methods in Physics Research NIM A597 (2008) 212–218.