AstroCeNT

NICOLAUS COPERNICUS ASTRONOMICAL CENTER OF THE POLISH ACADEMY OF SCIENCES

Measurement of nuclear recoils in LAr TPC For Dark Matter Searches

Paul Zakhary (AstroCeNT, GADM Collaboration)

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National Science Centre Poland

European Funds

Republic of Poland

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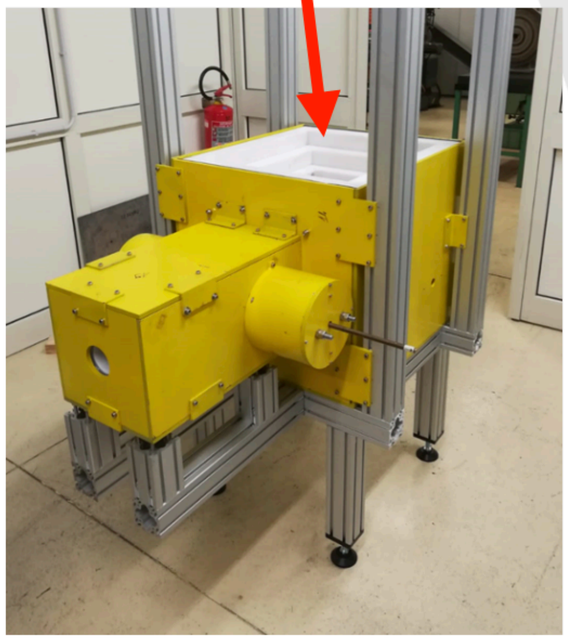
European Union

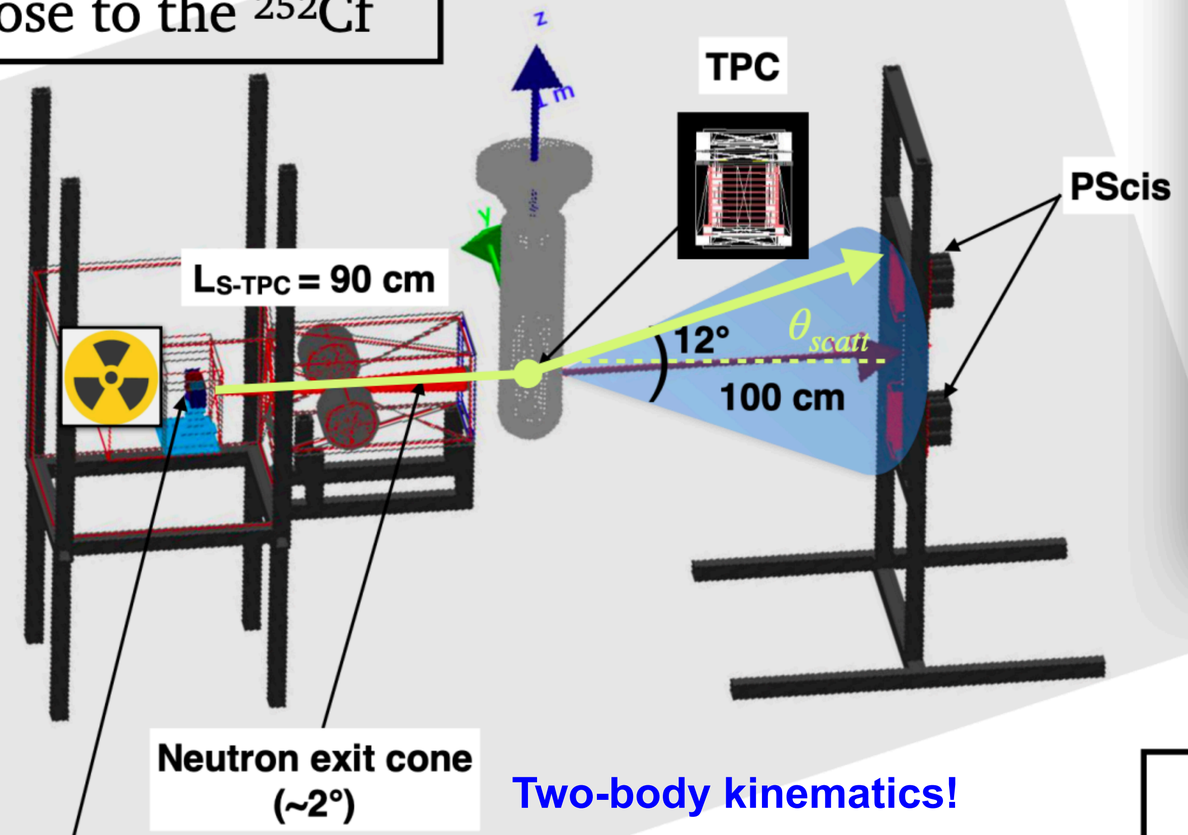
ReD Experimental Layout

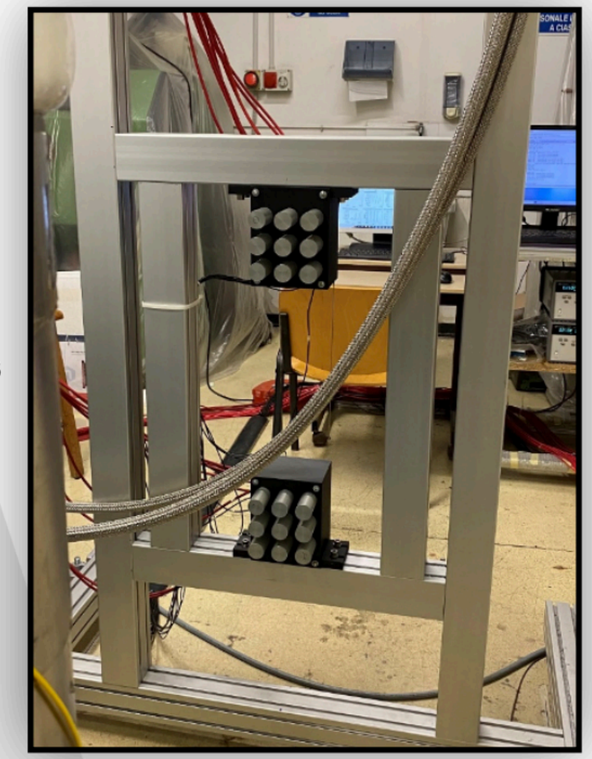


START

BaF_2 scintillators close to the ^{252}Cf

TPC in SLAVE mode → **offline analysis**





Two-body kinematics!

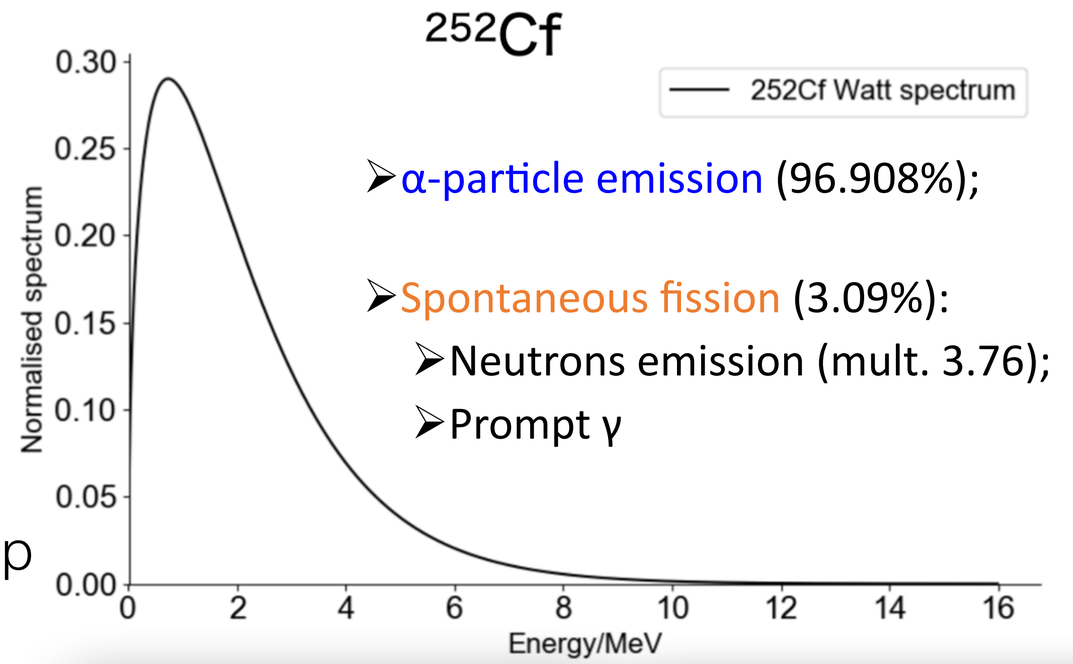
$$E_{NR} = 2KE_{neutron}\frac{m_n m_{Ar}}{(m_n + m_{Ar})^2}(1 - cos\theta_{scatt})$$

STOP

Neutron spectrometer:
18 Plastic Scintillators
(PScis)

Experiment Components

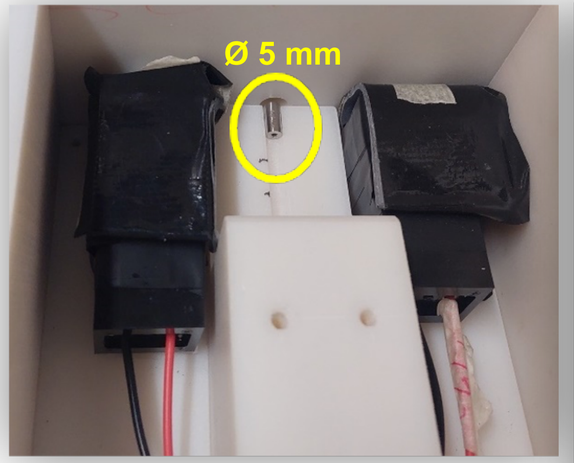
- **^{252}Cf source** (26 kBq fission)
  - Hosted inside a B-loaded PE, Fe, and Pb shields.
  - The shield features a 2° collimator for even TPC illumination at a 1 m distance

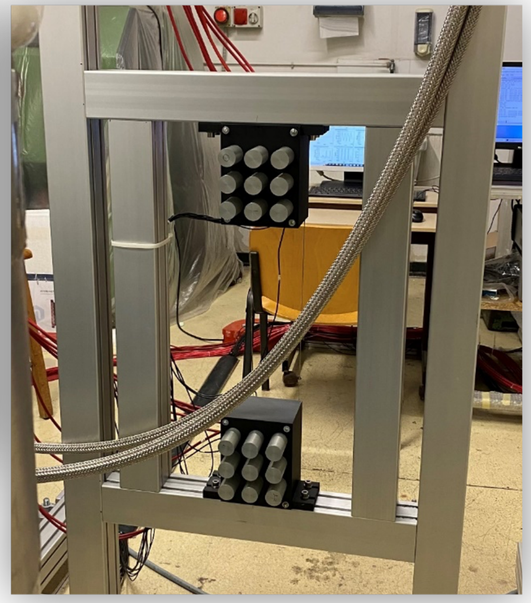


- ^{252}Cf → α-particle emission (96.908%);
- ^{252}Cf → Spontaneous fission (3.09%):
  - Neutrons emission (mult. 3.76);
  - Prompt γ

- Two **BaF_2 detectors** to tag fission products
  - Fast scintillation (0.8 ns decay constant)
  - Capable to withstand the source rate, without pileup
  - **START** for the time of flight measurement

- **Neutron Spectrometer**:
  - Two 3x3 arrays of EJ276 **plastic scintillators**
  - **1"-Diameter** —> Better 3D neutron reconstruction
  - **Time Resolution < 1 ns**
  - **STOP** for the time of flight measurement
  - Features **n/γ discrimination**
  - **θ ~ 12°-17°** to avoid direct neutrons from the source
  - **Symmetric** deployment to **control systematics** due to alignment





Preliminary Analysis Results

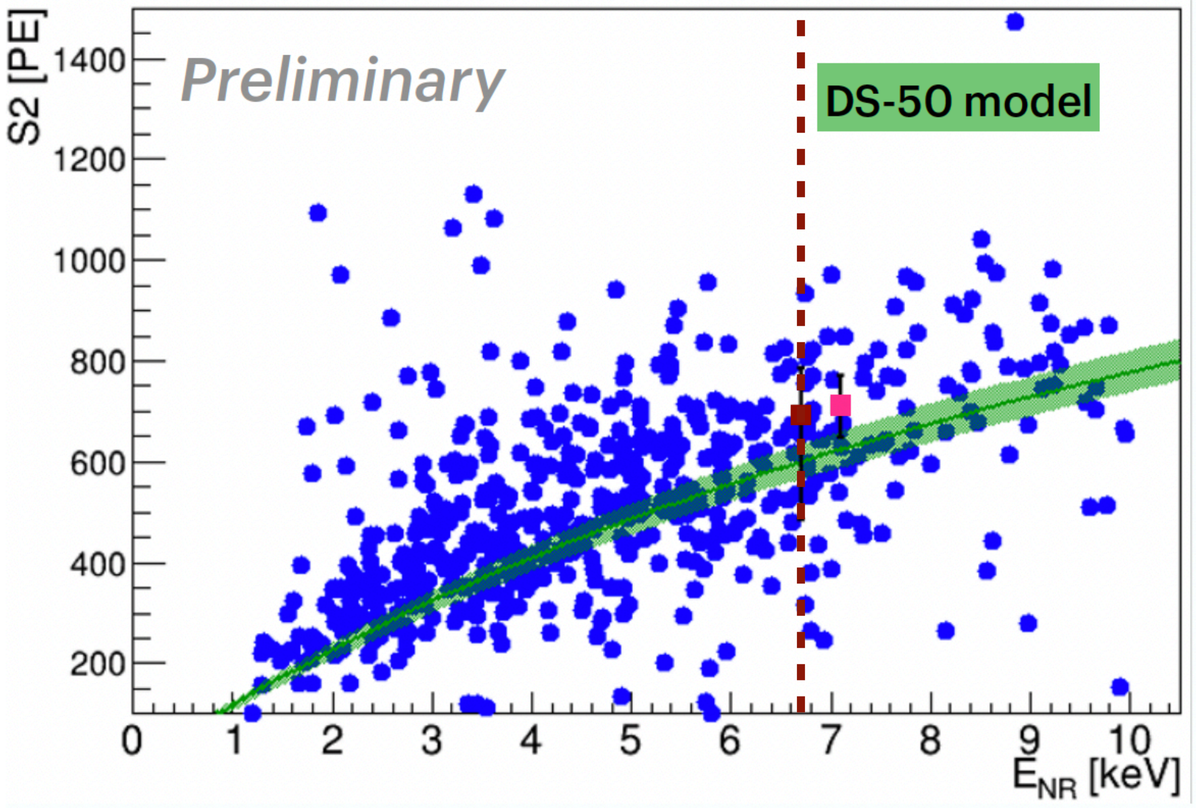
- ~ **820 passing all cuts**, out of 2300 candidate neutrons with a trace in the TPC
- 75% are S2-only (as expected from MC)
- Recoil energy was calculated on an event-by-event basis (uncertainty ± 5%)

Two-body kinematics!

$$E_{NR} = 2KE_{neutron}\frac{m_n m_{Ar}}{(m_n + m_{Ar})^2}(1 - cos\theta_{scatt})$$

- S2-only events: E_{NR} down to 1-2 keV_{nr}
- Compare against the prediction of the DS-50 model and literature data, using

  a preliminary value of **g_2 = 17.2 PE/e⁻**



Joshi et al. PRL **112** (2014) 171303

Agnes et al. PRD **97** (2018) 112005

Summary

- The ReD experiment aim is to characterize the response of LAr to low-energy O(keV) NRs
- I joined the local team on site @ INFN-LNS Italy for over 7 months thanks to DarkWave
- We successfully took enough ^{252}Cf data (Jan-Mar 2023) and the analysis is ongoing
- Design sensitivity met: down to 1-2 keV_{nr}
- This information is crucial for "low-mass WIMP" analyses of current DM experiments and for the design of the next-generation detectors.

- **Work in progress:**
  - Refine the Analysis: Infer g_2 directly from the ReD experimental data to constrain the parameters in the DS-50 ionization model (fit of data against MC distributions)
  - **Write the Thesis**

Conferences & Schools

- LIDINE 2023 - Madrid, Spain. - "^{37}Ar source on-demand production & deployment for low-energy NR calibration in ReD"
- CYGNUS 2023 - Sydney, Australia. - " Characterization of low-energy Ar recoils with the ReD experiment"
- Gran Sasso 2023Hands-on PhD autumn school on Experimental Astroparticle Physics


Stay Safe
Thank you!
The Future is Dark