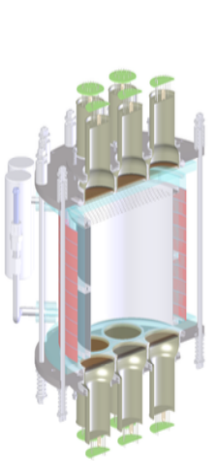




S.Albergo  
DarkSide @INFNCT  
Richieste 2025



# The DarkSide program

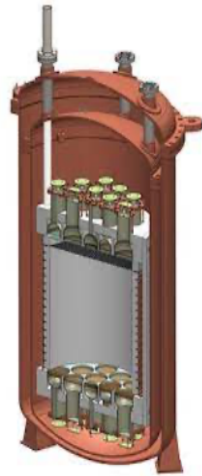


**DarkSide-10**

10 kg Ar




 2011 - 2013

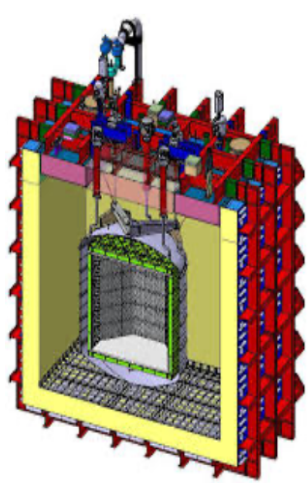


**DarkSide-50**

50 kg Ar




 2015 - 2019



**DarkSide-20k**

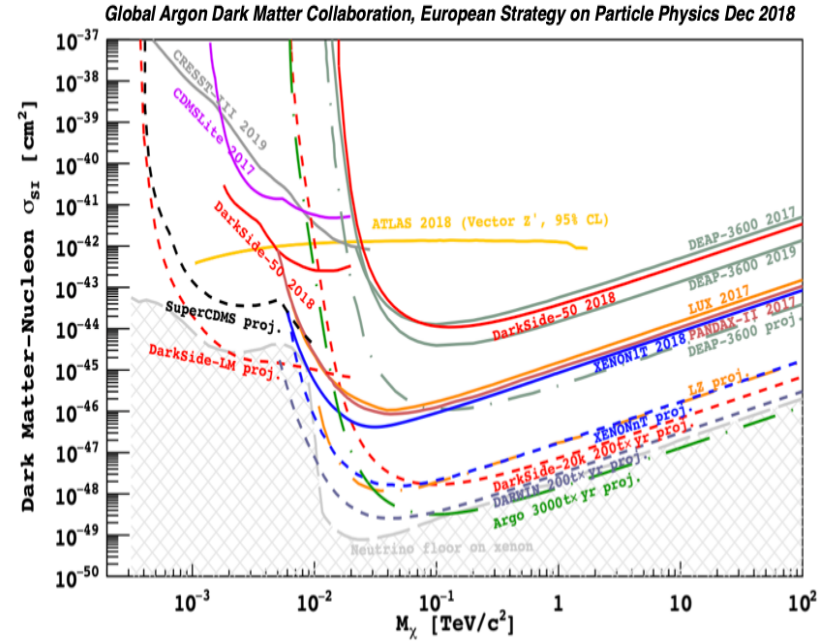
50 t Ar (20 t fiducial)



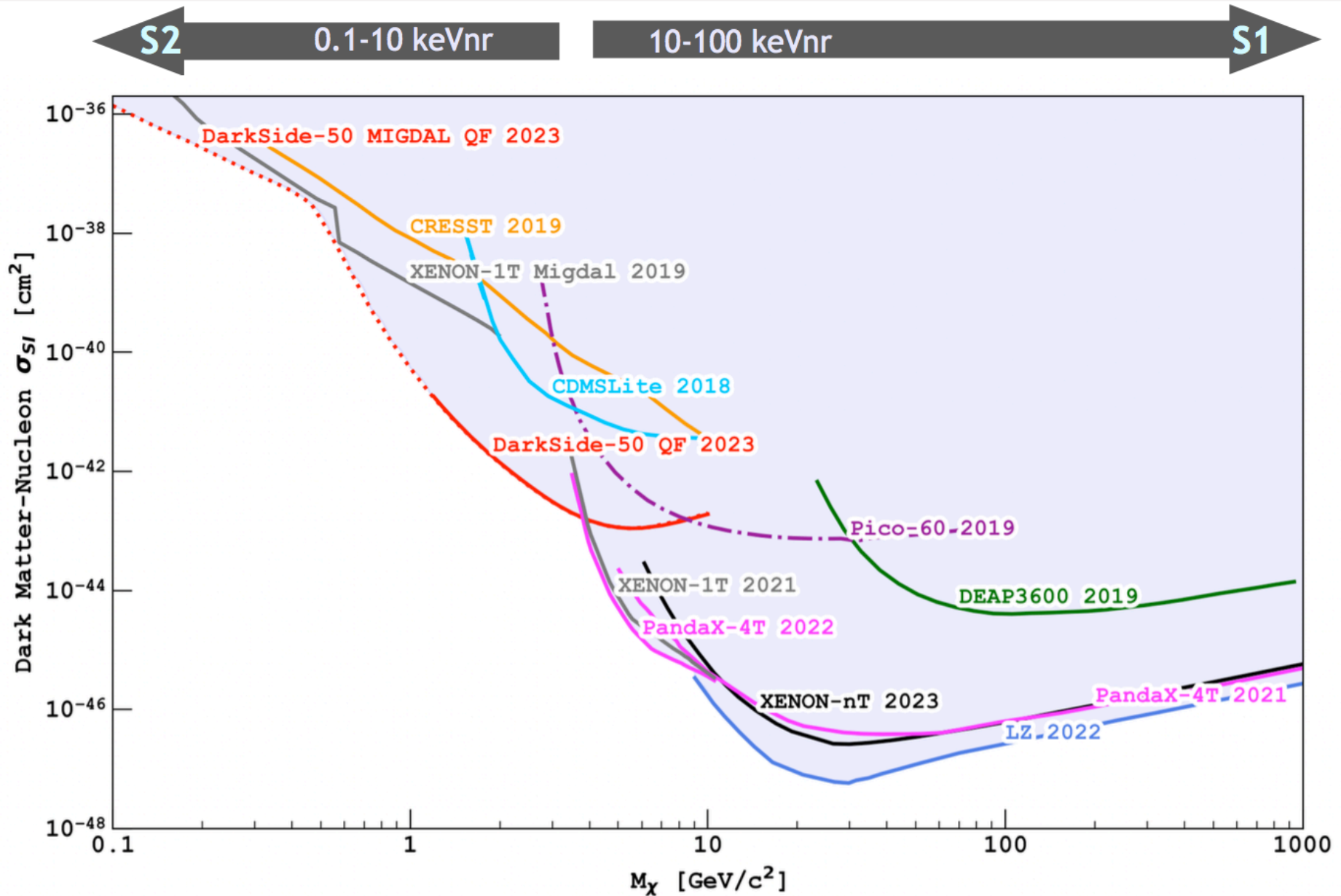
 2026 - ...

**Under construction  
@ INFN - LNGS**

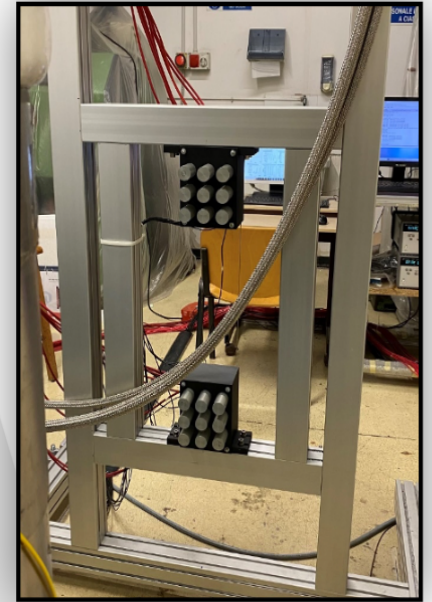
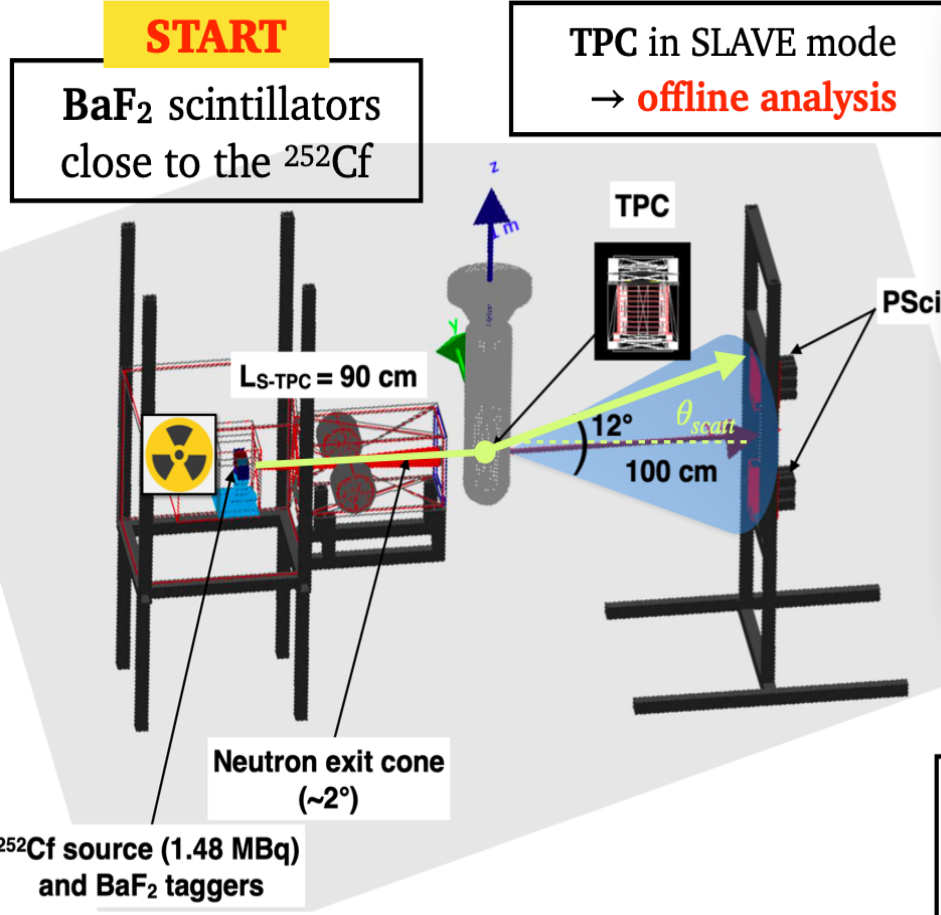
- DarkSide-20k : Near-future goal of *Global Argon Dark Matter Collaboration* [see talk by Andrea Zani]
- Liquid Argon TPC in dual phase
- Push sensitivity down to neutrino fog



# DARK MATTER 90% CL EXCLUSION LIMIT



# Laboratorio ReD presso INFNCT



**STOP**

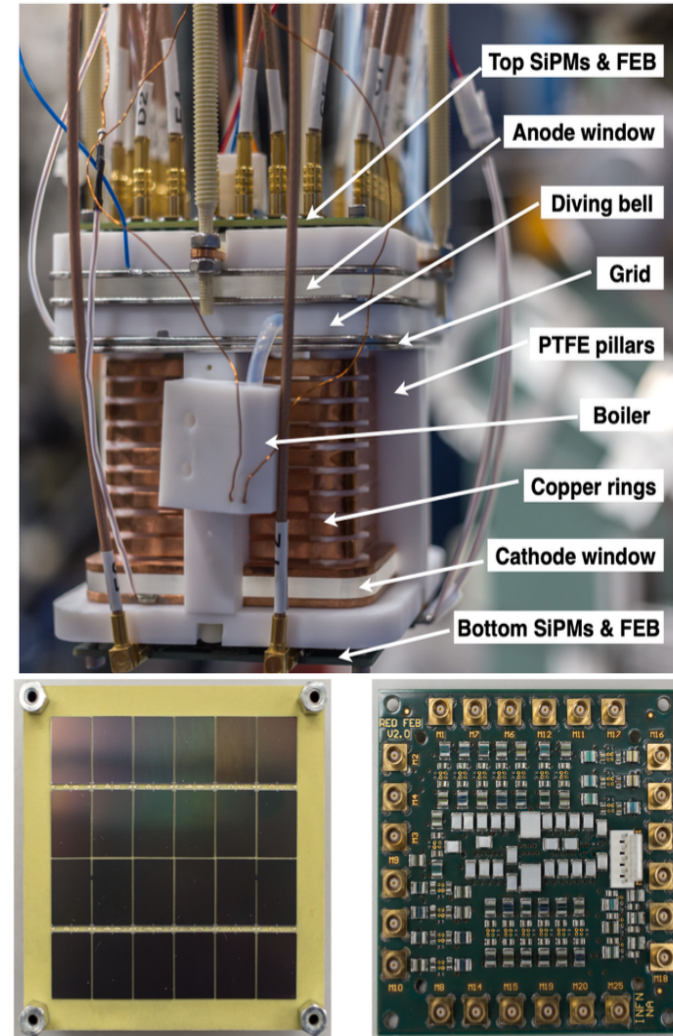
Neutron spectrometer:  
18 Plastic Scintillators  
(PScis)



# The LAr TPC

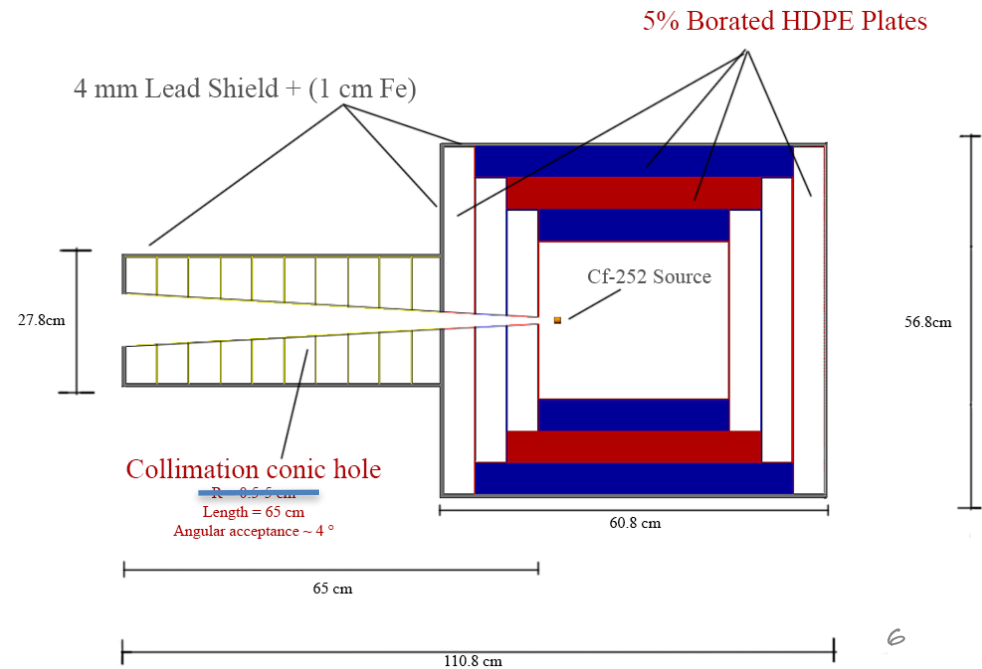
- Active volume: 5(L) x 5 (W) x 6 (H) cm<sup>3</sup>
- 7 mm-thick gas pocket
- TPB coating for wavelength shifting
- Light readout: 5x5 cm<sup>2</sup> DarkSide tiles, each made by 24 SiPMs
  - 24 ch readout (*top*) → *increased (x, y) resolution*
  - 4 ch readout (*bottom*)
- 3D event reconstruction:
  - (x, y) from *S2 pattern* on the top SiPMs
  - z from *drift time* (up to ~55 μs)
- In this data taking campaign:
  - S2 gain  $g_2 = \sim 17 \text{ PE/e}^-$  ( $E_{\text{drift}} = 200 \text{ V/cm}$ ,  $E_{\text{el}} = 5.79 \text{ kV/cm}$ )
  - Electron lifetime > 1 ms

Agnes et al. EPJ C **81** (2021) 1014



# $^{252}\text{Cf}$ collimator

- Hardware:
  - 400 kg of B-loaded HDPE
  - $^{252}\text{Cf}$  (~1.5 MBq)
  - Fission taggers: BaF detectors



# The source and tagger detectors

## $^{252}\text{Cf}$ source

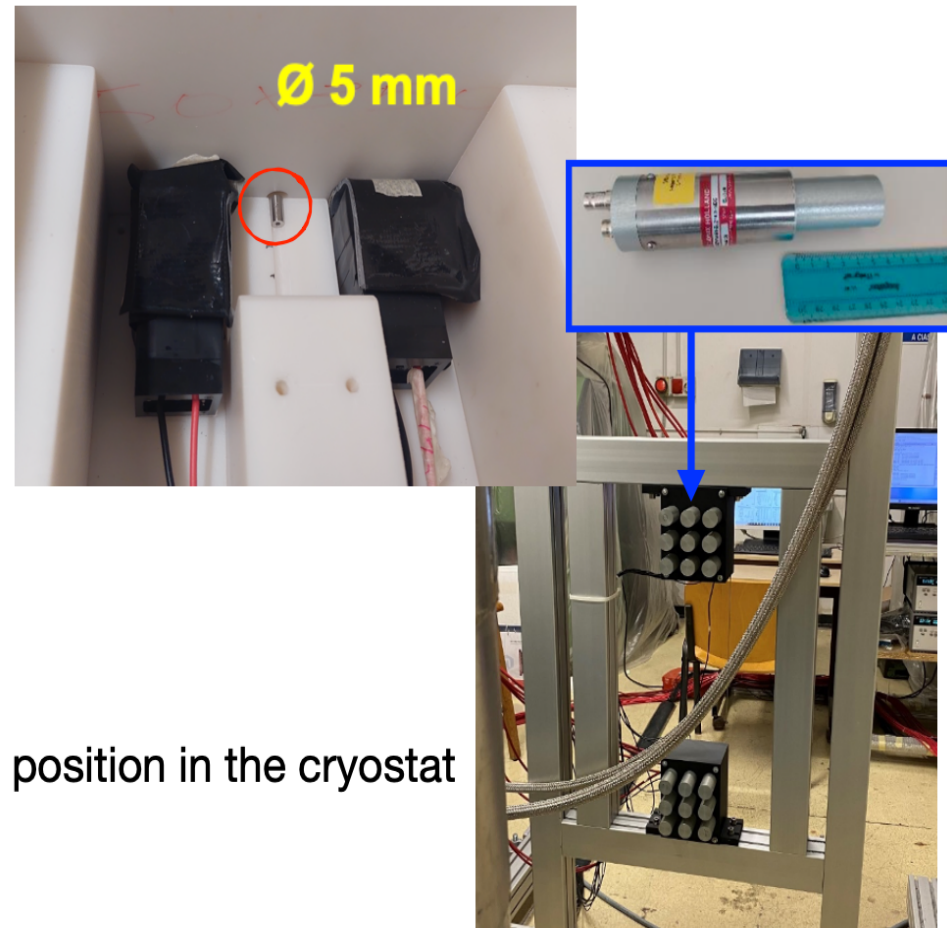
- 26 kBq SF
- Shield in a Collimator made of B-loaded PE (15 cm), Fe and Pb, opening angle  $\sim 2^\circ$

## $\text{BaF}_2$ scintillators

- Fast scintillation (0.8 ns but @220 nm)
- Detect  $\gamma$ s from SF

## Neutron Spectrometer

- 18 1-in EJ-276 **Plastic Scintillators** + PMTs
- 2 matrices 3x3 placed at  $12^\circ$ - $17^\circ$  wrt the TPC position in the cryostat and out from the direct collimation cone
- Featuring  $n/\gamma$  discrimination



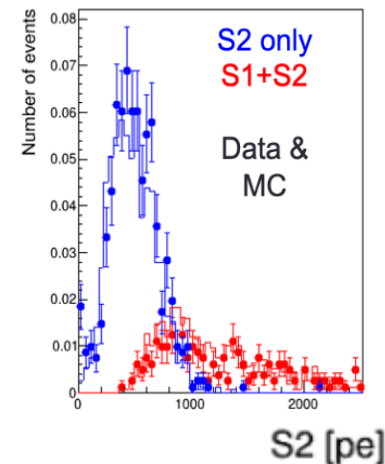
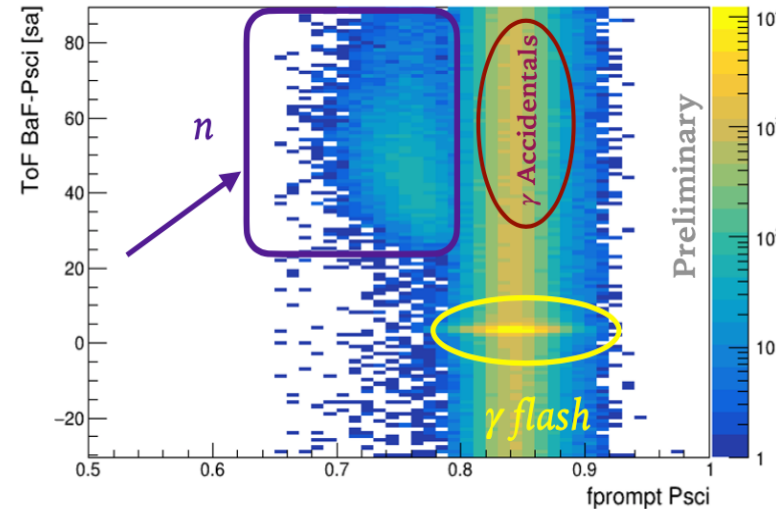
# Selezione degli eventi

## 1 - Tagger detectors

- Selection of candidate **neutrons** by ToF BaF<sub>2</sub>-PSci and PSD from the PSci (  $\sim 28$  events/h  $\rightarrow$  0.3% )
  - ToF resolution  $\sim 0.7$  ns
  - Event-by-event  $E_n$  at  $< 5\%$

## 2 - TPC offline analysis

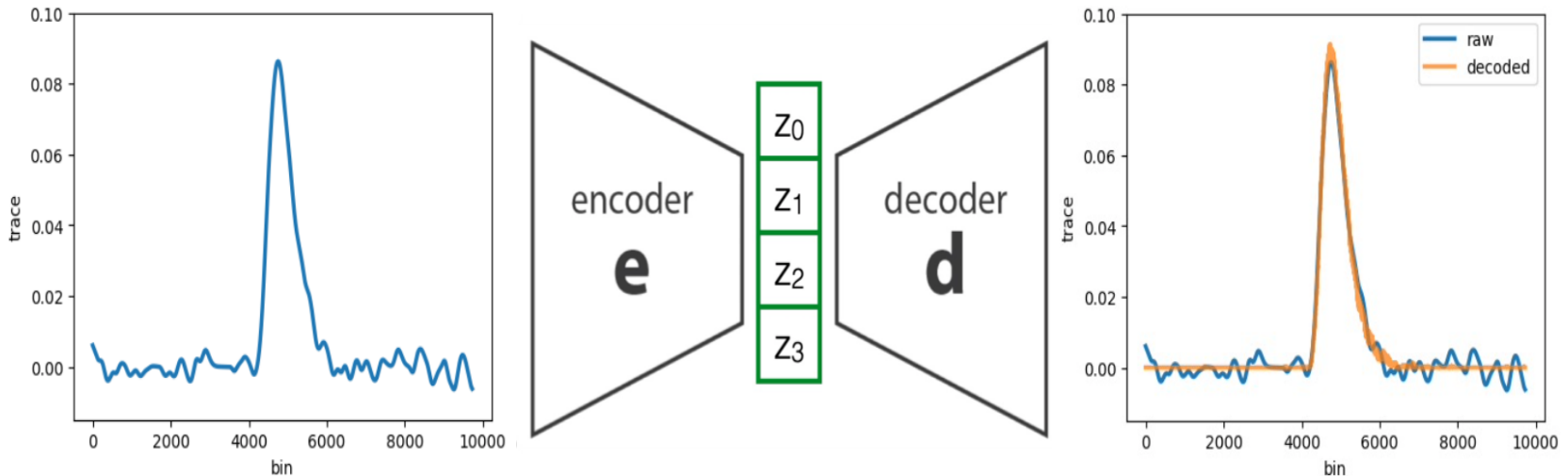
- Pulse finder and selection cuts:
  - One S2 within 65  $\mu$ s from BaF<sub>2</sub> and optionally, an S1 ( $< 100$  PE)
  - If S1 available, consistent BaF-TPC ToF
  - No tails of previous S2 pulses
  - FIDUCIALIZATION:  $(x, y)$  in the central 4x4 cm region
- **Final sample**:  $\sim 820$  passing all cuts, out of 2300 candidate neutron events w/ TPC signal
  - 75% are **S2-only** ( $\sim$  as in MC)



# Convolutional AutoEncoders and their application

**Self-supervised neural network** architecture where data are compressed into a low dimensionality *latent space*, then reconstructed minimizing differences between original and output.

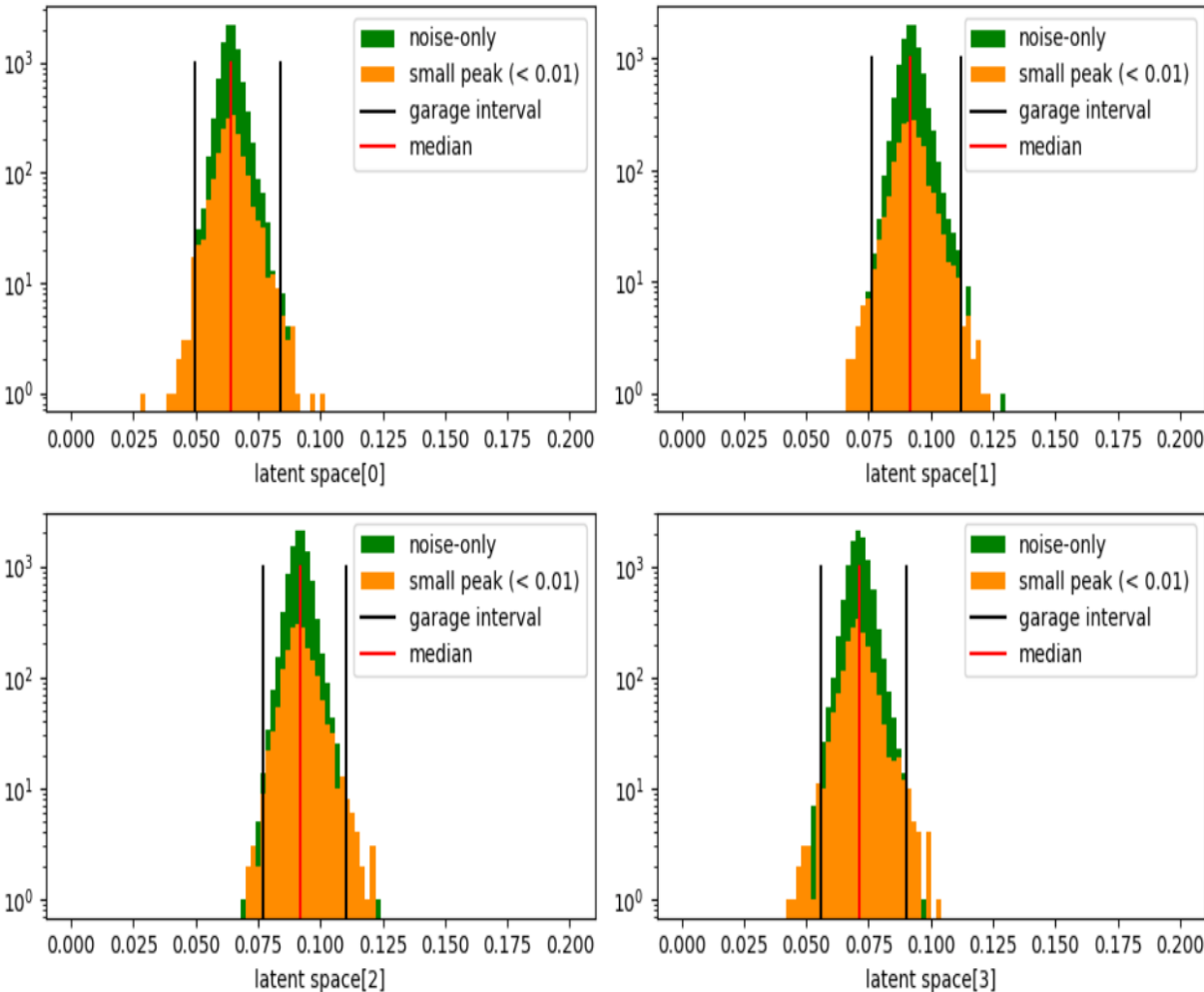
**Implicitly highlighting features of a dataset, while disregarding noise and redundancies**



- **input:** time series (~ 10,000 bins) resembling waveforms measured by the ReD TPC
- **architecture:** 3 Conv1D + avg. pooling layers, followed by 1 flattened dense layer (*details in backup*)
- **4-dimensional latent space** ( i.e. each trace is compacted into only 4 values, named  $z_i$ )



# Application to a synthetic dataset - results



Garage defined as the combination of the  $3\sigma$ -intervals around median calculated for each  $z_i$  distribution using "noise-only" waveforms

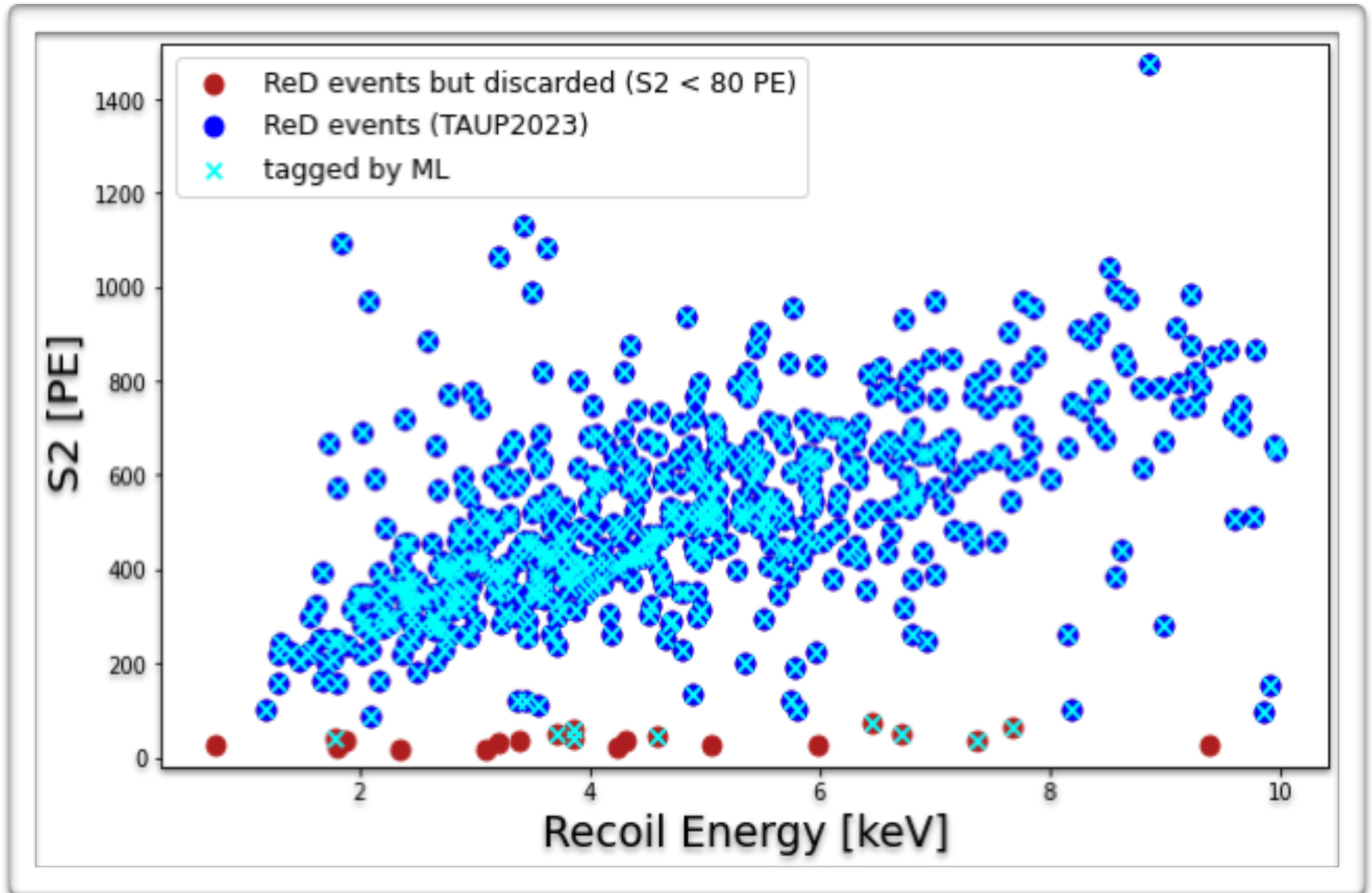
**False positives fraction < 1%**

## Labelling of events :

- if the 4  $z_i$  fall simultaneously in the "garage", tag as noise-only;
- if not, tag as signal.

**True positives fraction > 99%**  
**down to signal amplitudes ~ 0.015**

# Confronto risultati ML e non ML



# Completamento ReD e avvio ReD+

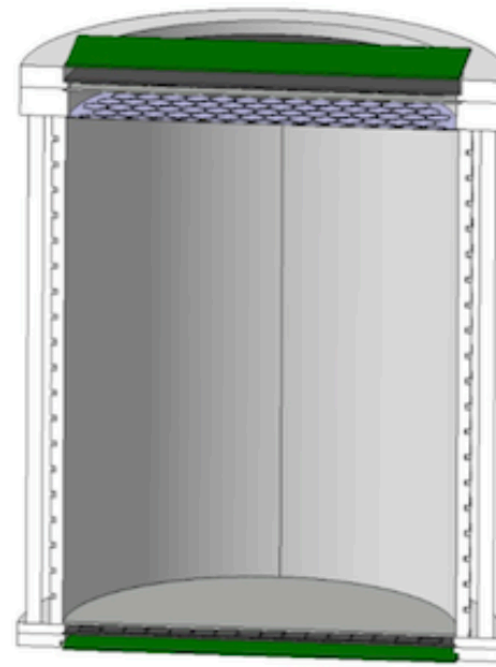
Al di fuori dei finanziamenti INFN è stato approvato un PRIN 2022:

ReD+, a low-energy characterization for low-mass Dark Matter searches with Argon

Future perspectives: ReD+, to cover down to  $0.4 \text{ keV}_{nr}$



TPC exterior



TPC interior

# Conferenze ultimo anno

- N.Pino “CHARACTERIZATION OF LOW-ENERGY RECOILS WITH THE RED EXPERIMENT”, Majorana International workshop, Modica 12–14 lug 2023
- N.Pino “Characterization of low-energy nuclear recoils in the LAr TPC of the ReD experiment” 109<sup>o</sup> Congresso Nazionale SIF - 15th Sept. 2023 Salerno
- N.Pino “Study of low-energy nuclear recoils in liquid argon with the ReD experiment” Idding Conference, 20-22 Sep 2023 Madrid
- G.A. Anastasi “The Spoke 2 of the ICSC National Centre, with a focus on deep learning applications in astroparticle physics and satellite imagery” 213th CRIS-MAC, Trapani, 17-21 June 2024

# Composizione e percentuali 2024

Sebastiano Albergo	60%	PO Responsabile locale
Gioacchino Anastasi	0%	RTDA HPC
Noemi Pino	100%	Dottoranda
Sebastiana Puglia	80%	RTDA
Alessia Tricomi	10%	PO

Ringraziamenti a

N.Guardone,

N.Giudice

A.Rapicavoli,

M.Salemi



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Sebastiana Puglia	80%	RTDA
<b>Alessia Tricomi</b>	<b>10%</b>	<b>PO</b>
<b>Assegno Ricerca</b>	<b>100%</b>	

Contributo tecnico da

**Elettronica**

**Tecnologie avanzate**

**Officina**

# Impegni di attività nel 2024

- Implementazione analisi Machine Learning ReD&DS-50
- Attività su PROTO e test beam
- Collegata (extra INFN) attività su ReD+

## RICHIESTE 2025

<b>Consumo</b>	Metabolismo	2. k€
<b>Missioni</b>	- Meeting di collaborazione	2. k€
	- Partecipazione a test beam	2.0
	- Turni test PROTO Napoli	5.0