Study of Cherenkov background in the DarkSide-50 experiment

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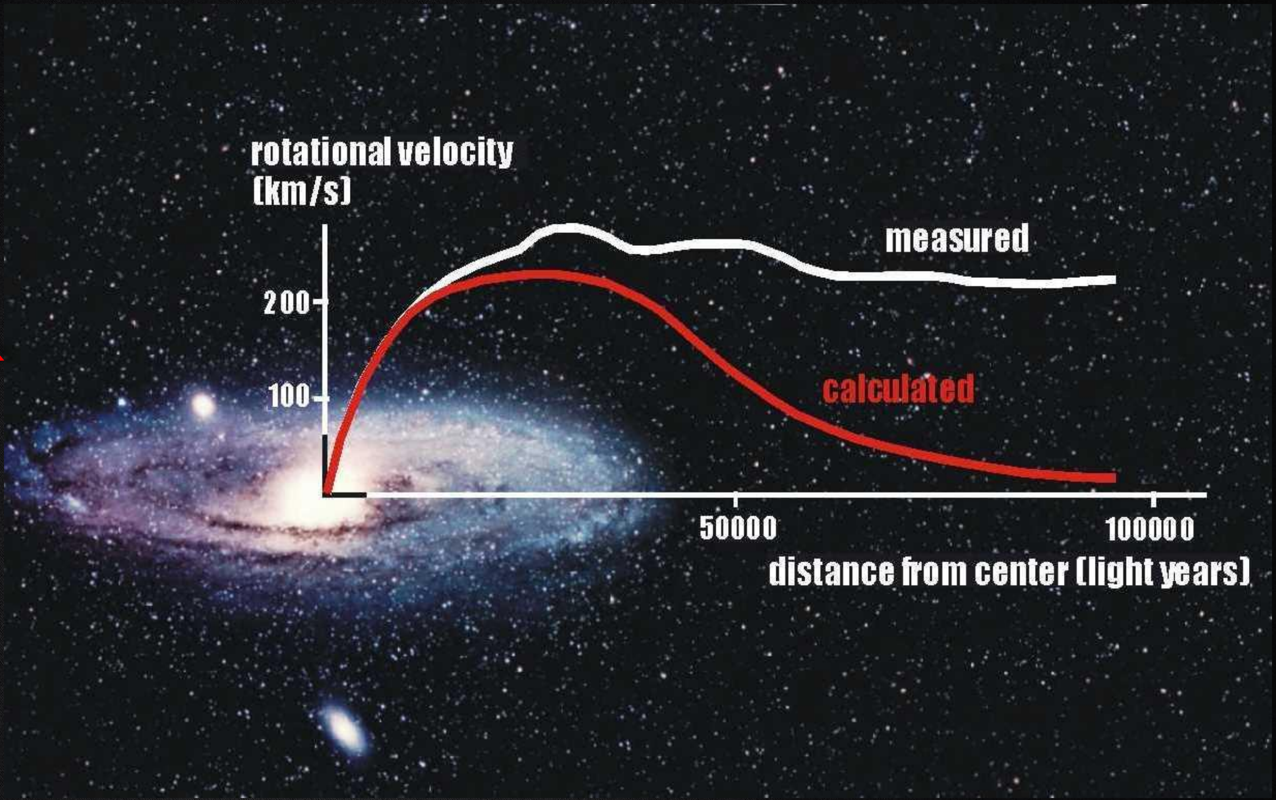
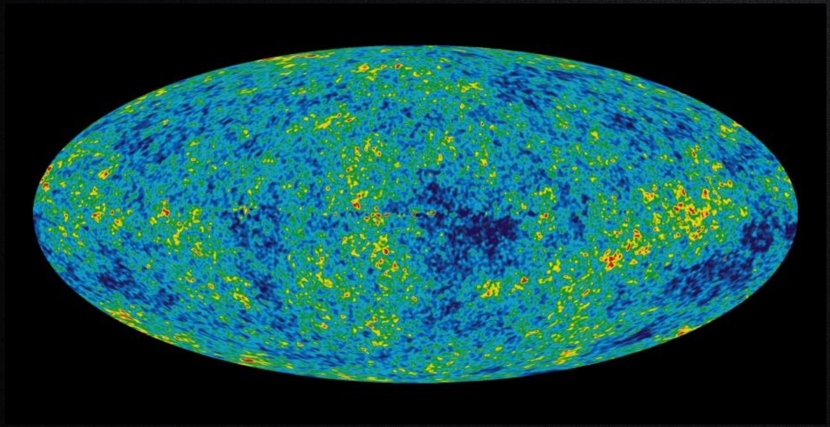
Evidence of Dark Matter presence in the Universe

Spiral Galaxies



WMAP-PLANCK



Cosmic Microwave Background Anisotropies

84.5% of matter in the Universe is Dark Matter

How to explain Dark Matter?

In the most favoured theories Dark Matter is composed of a massive particle not included in the Standard Model

Multiple candidates
(sterile neutrinos, axions, WIMPs...)

WIMPs = Weakly Interacting Massive Particles

Massive particles which interact through a force as weak as or weaker than the weak nuclear force

We can try to study WIMPs in different ways:

- Production
- Direct detection
- Indirect detection

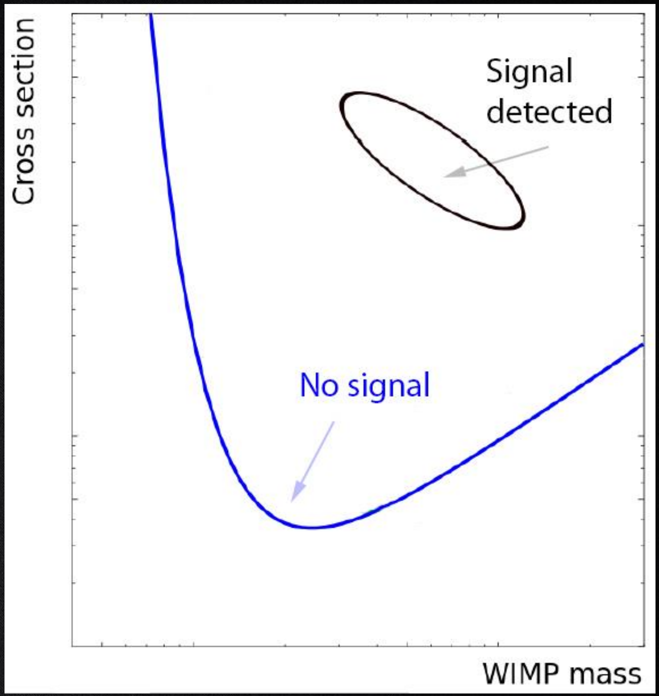
Direct detection of WIMPs

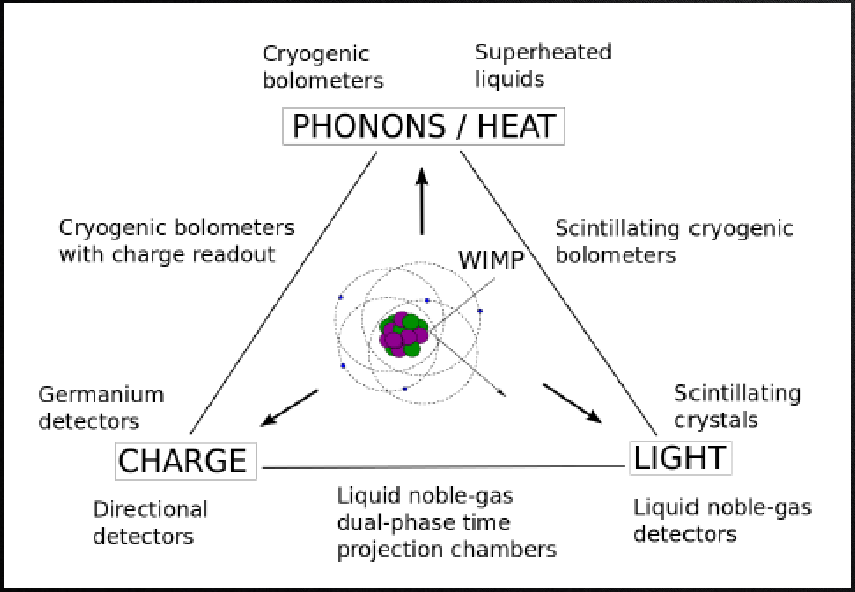
The goal is to measure the energy spectrum of WIMPs scattering against a target

$$\frac{dR(E,t)}{dE} = \frac{\rho_0}{m_A m_\chi} \int v\, f(\boldsymbol{v},t) \frac{d\sigma(E,v)}{dE} d^3v$$

Observables of the experiment are WIMP mass m_χ

and cross section σ





A scattering with the target causes:

- Heat production (phonons)
- Atoms excitation (light)
- Atoms ionization (charge)

DarkSide-50

Goal of the experiment: **direct detection of WIMPs**

- Since 2013 is acquiring data @Laboratori Nazionali del Gran Sasso (LNGS)

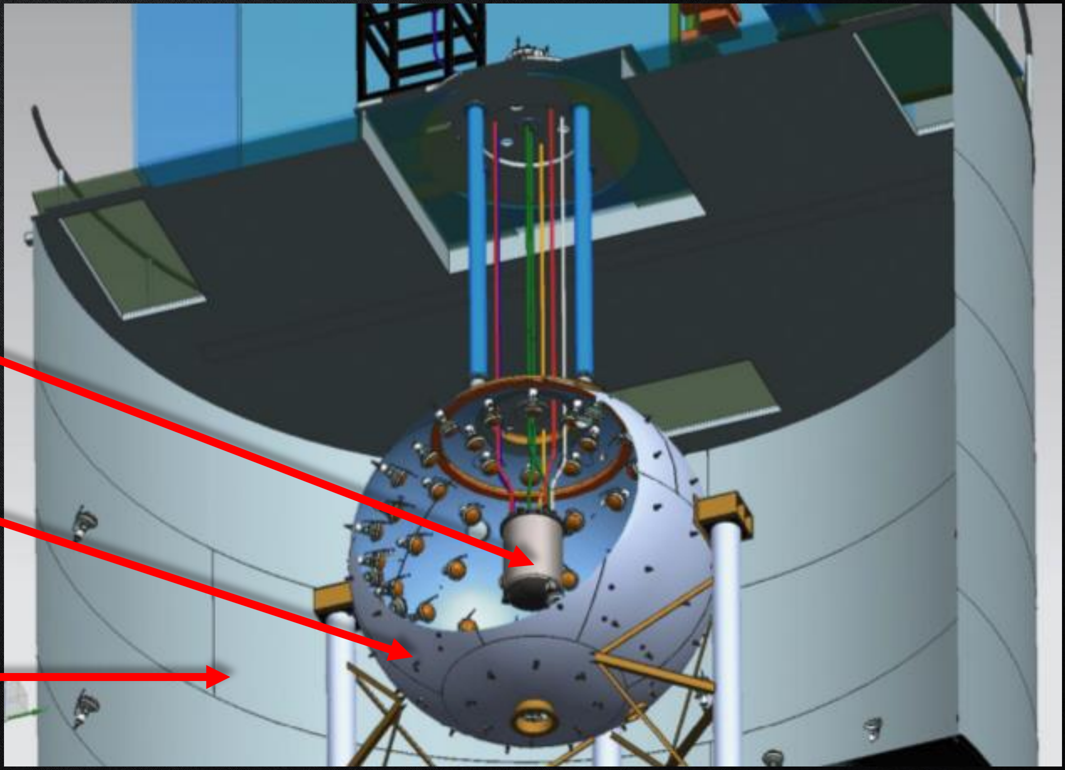
- Employs a 50 kg Liquid Argon target

3 DETECTORS

- Time Projection Chamber (TPC)
  WIMPs detector

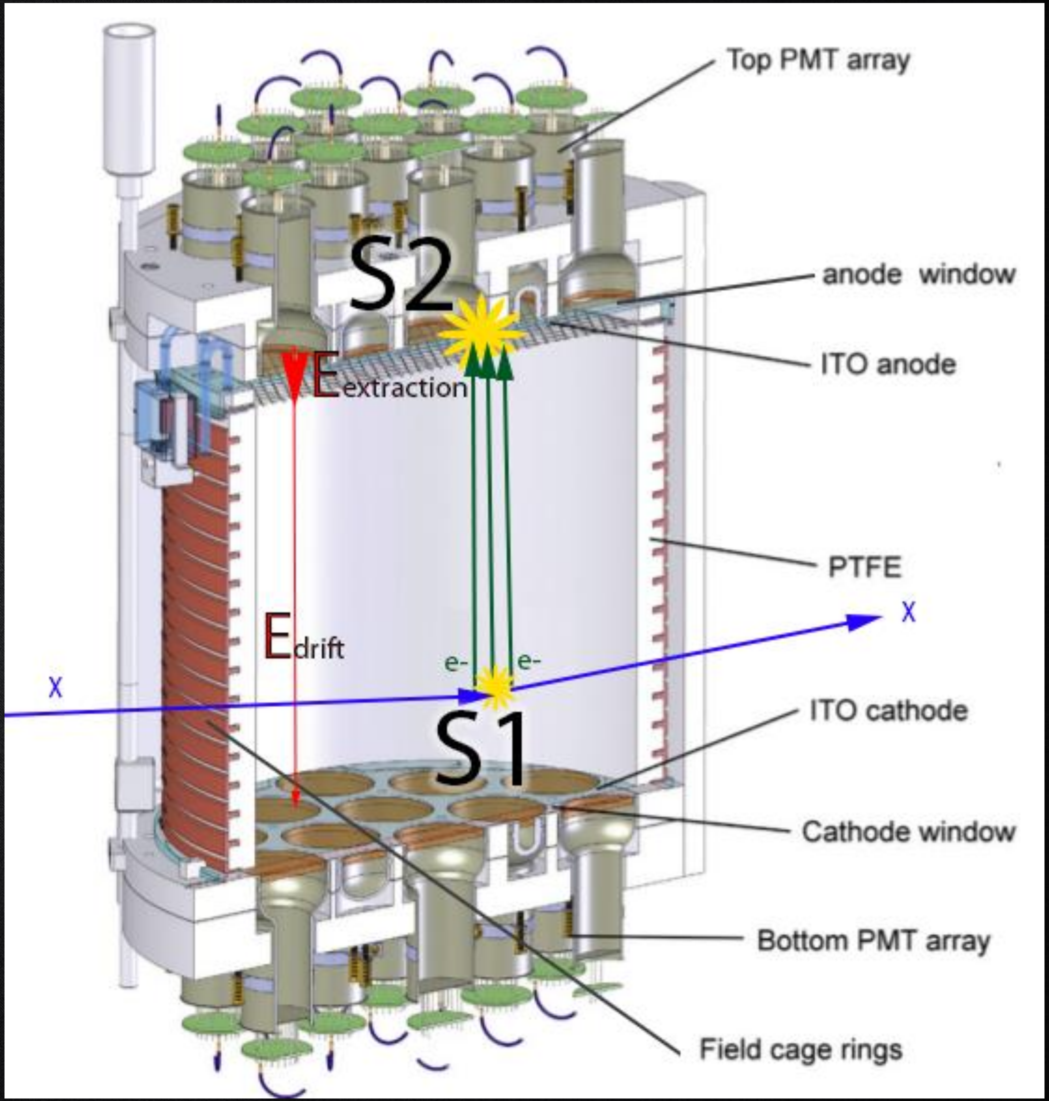
- Liquid Scintillator Veto (LSV)
  detects neutron-induced events

- Water Cherenkov Detector (WCD)
  detects muon-induced events



Liquid Argon (LAr) Time Projection Chamber (TPC)

WIMPs detector which takes advantage of scintillation (S1) and ionization (S2) in Liquid Argon



ER/NR discrimination with a LAr TPC

A particle interacting with Liquid Argon can create two excited states:

- Singlet (S), with mean lifetime $7 \pm 1\ ns$
- Triplet (T), with mean lifetime $1600 \pm 100\ ns$

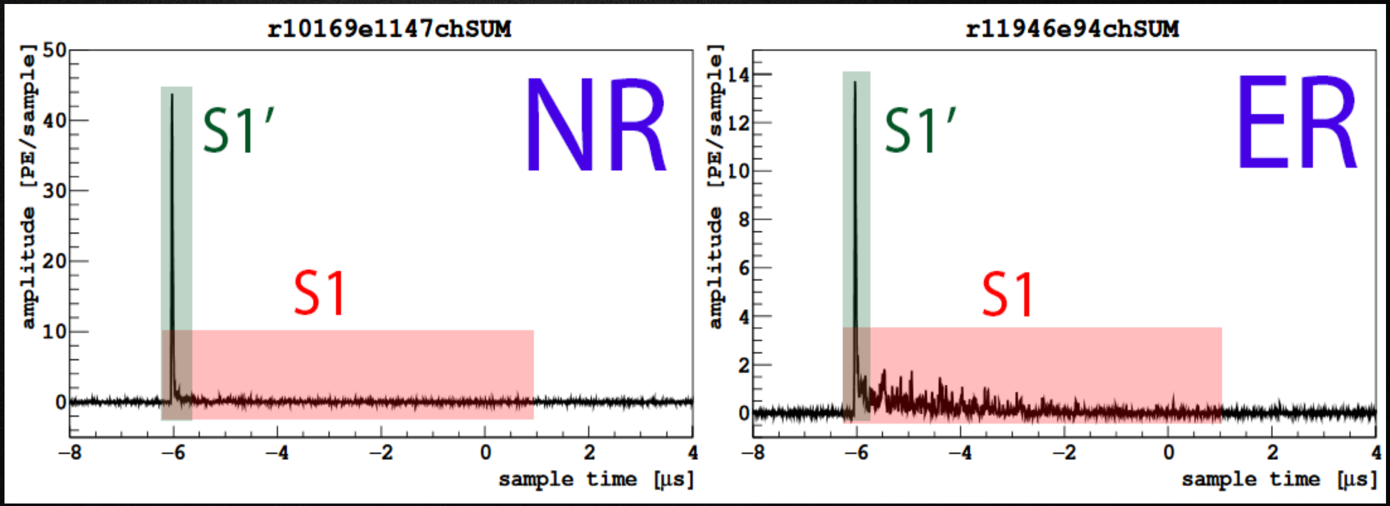
- α/neutrons/WIMPs (Nuclear Recoils) -> Light emission from S states is prevalent

- β (Electron Recoils) -> Light emission from T states is prevalent

To get rid of ER background we use:

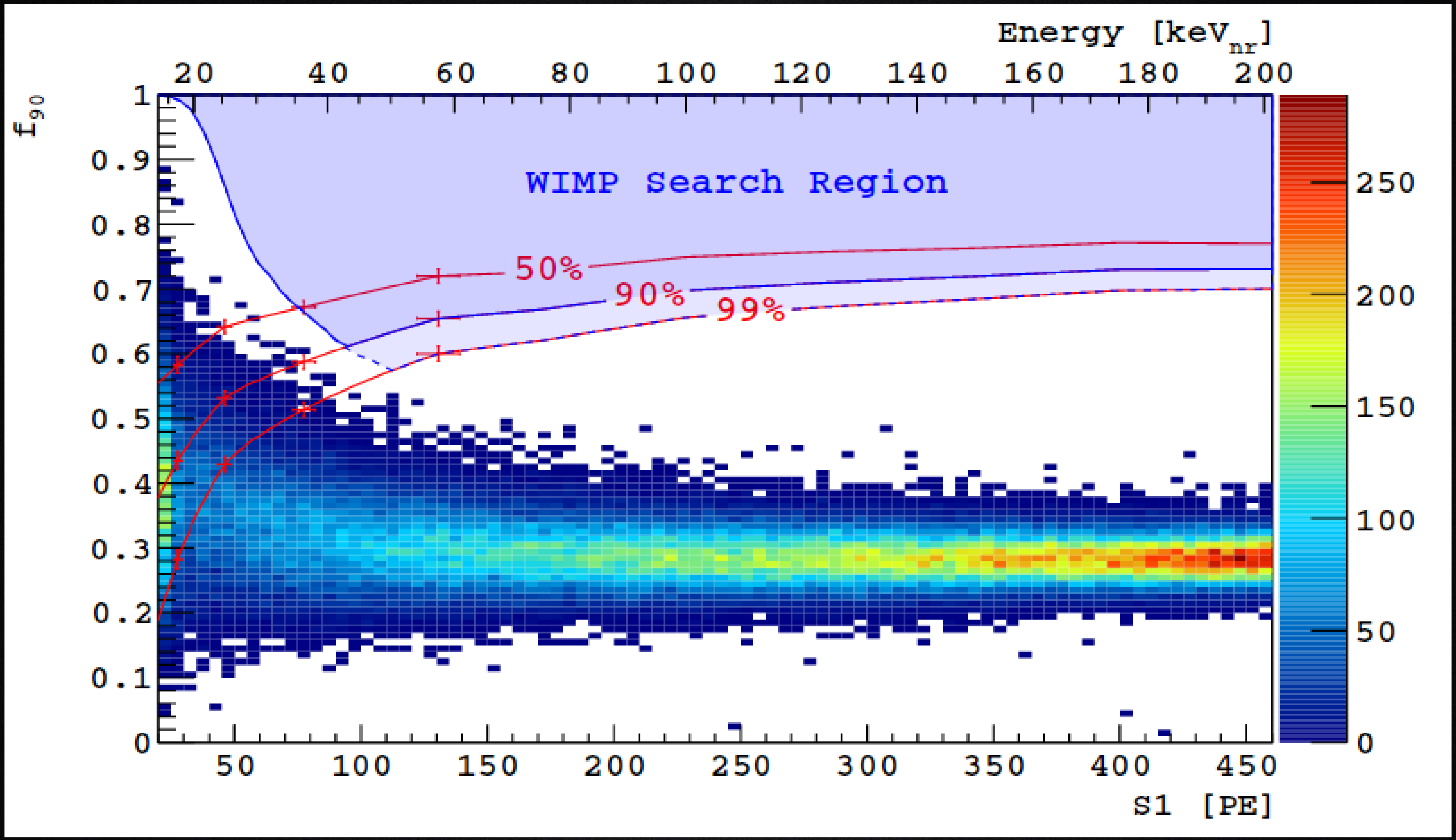
$$f90 = \frac{S1'\,(PE)}{S1\,(PE)}$$

$$f90\,(ER) < f90\,(NR)$$



First data collection

F90 VS S1

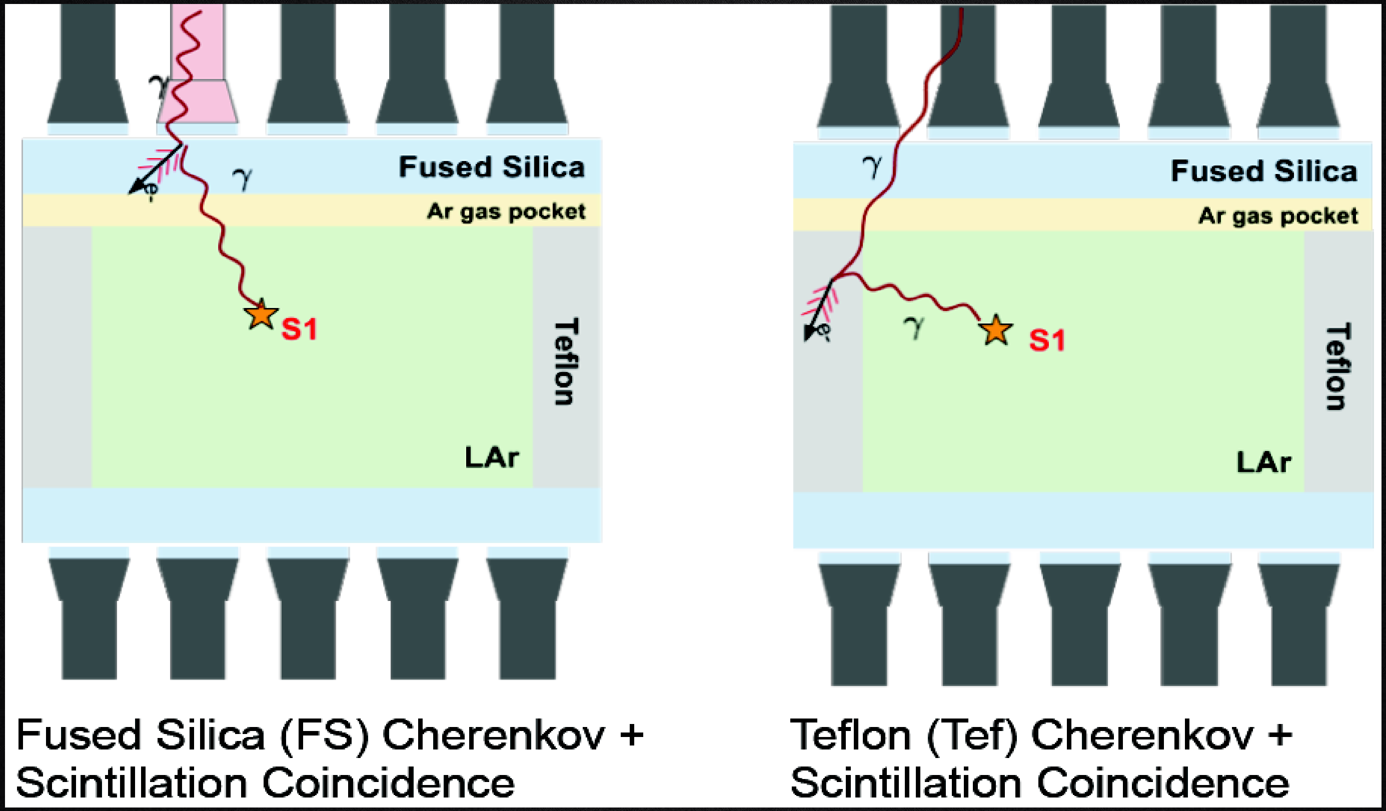


- 70 days of data
- 0 events in the WIMP Search Region after data analysis

Cherenkov+ER events

Cherenkov Radiation: is emitted when a charged particle passes through a dielectric medium at a speed greater than the speed of light in that medium

Cherenkov events alone are NOT a problem for the experiment (S2 is missing).



<u>However, they might be problematic if:</u>

γ -> scatters in glass/teflon-> e- emits Cherenkov light + γ causes ER in Ar

Cherenkov + ER events background

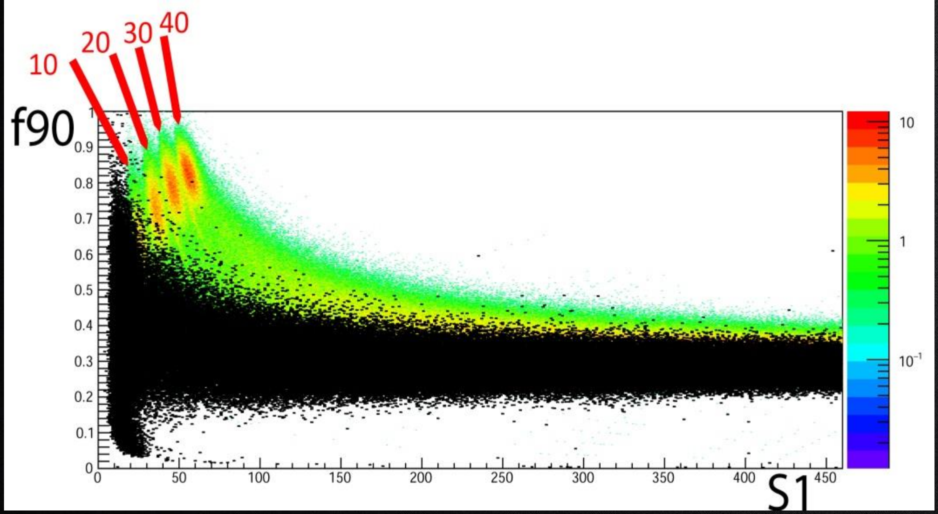
Cherenkov (teflon) + ER events create an extremely dangerous background

prompt light coming from Cherenkov radiation adds up to an ER event

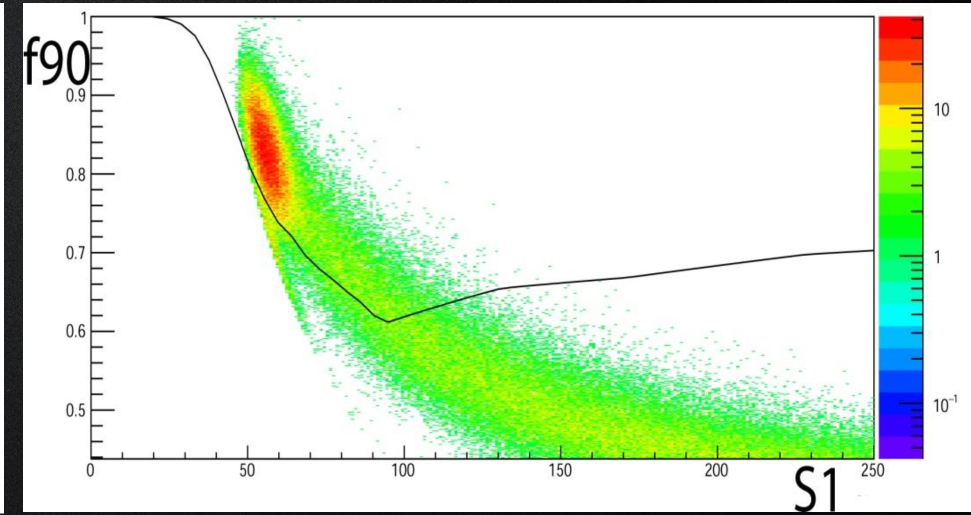
↓

f90 increases

I tried to visualize this effect:



Black: ER events
Colors: ER events adding 10-40 prompt Photoelectrons (PE)



Black line: DM search box
Colors: ER events adding 40 prompt Photoelectrons (PE)

Sample of Cherenkov + ER events

I found 8 Cherenkov+ER events inside the DM search box in the UAr campaign:

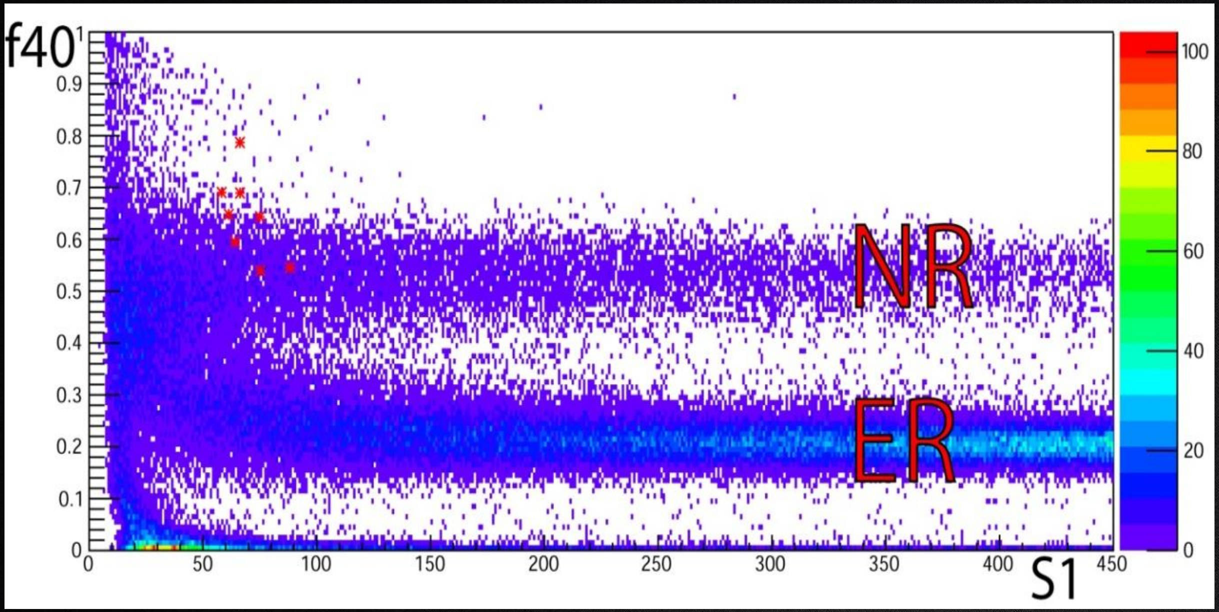
- We can get rid of 5 events using standard cuts
- Remaining 3 events can be eliminated using the veto system (risky)

Run	Event Number	f90	S1 (PE)
12025	05493	0.720	75.26
12084	08968	0.654	88.44
12535	13798	0.730	64.96
12538	20056	0.845	66.19
12897	17647	0.809	66.16
13004	05043	0.744	61.15
13020	08024	0.670	75.92
13143	01927	0.802	58.55

For the upcoming campaigns (longer data collection) a specific cut for this type of events would be much more reliable: veto system may fail to detect the gamma ray causing the event

Specific cut for Cherenkov + ER events?

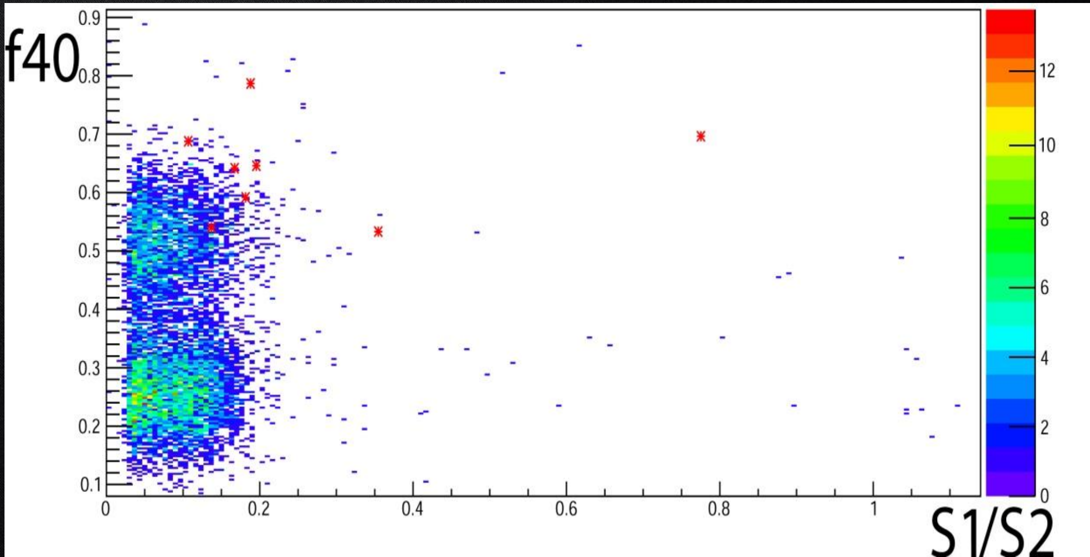
We can try to use a new variable: f40 (similar to f90, but for the first 40 ns)



Colors: events from an AmBe campaign

Red: sample of Cherenkov+ER events

we can also try to use f40 & S1/S2: in this case there is a partial separation between the two families, <u>but not enough to design a new cut</u>



CONCLUSIONS

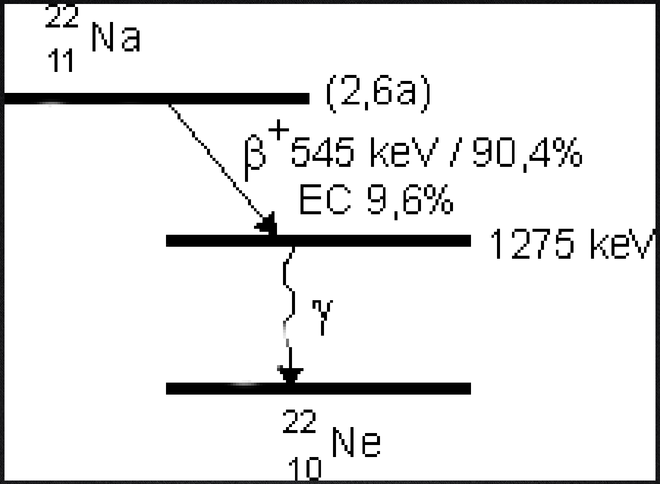
- At the current day there isn’t a specific cut for this background, which is the most problematic one for the experiments.
  - Attempt to better undestand this background through simulations
- The DarkSide Collaboration plans to replace DarkSide-50 with a new experiment: DarkSide-20k
  - Cherenkov+ER events could still be a problem in the new experiment, but fiducial cuts might solve it

"I can't tell you what's in the dark matter sandwich. No one knows what's in the dark matter sandwich."

BACK UP

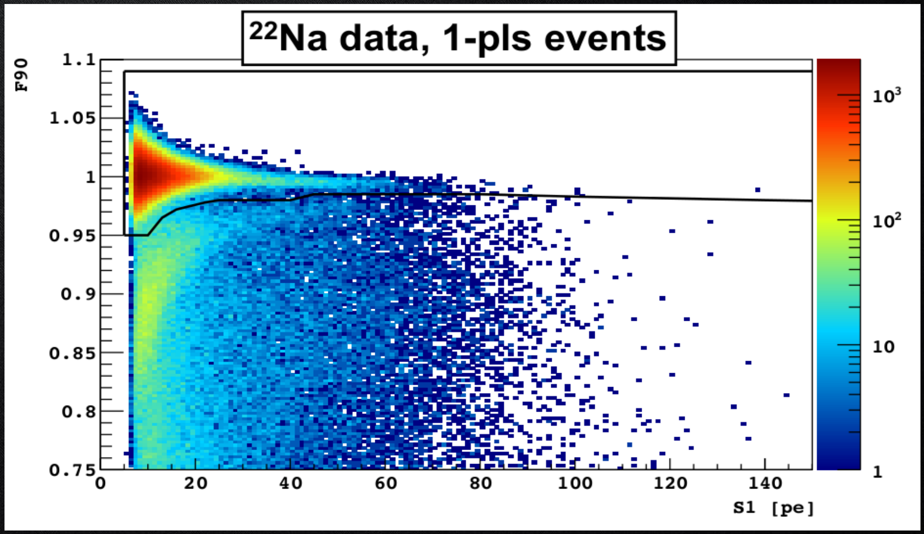
22Na CAMPAIGN

22Na source placed inside the LSV



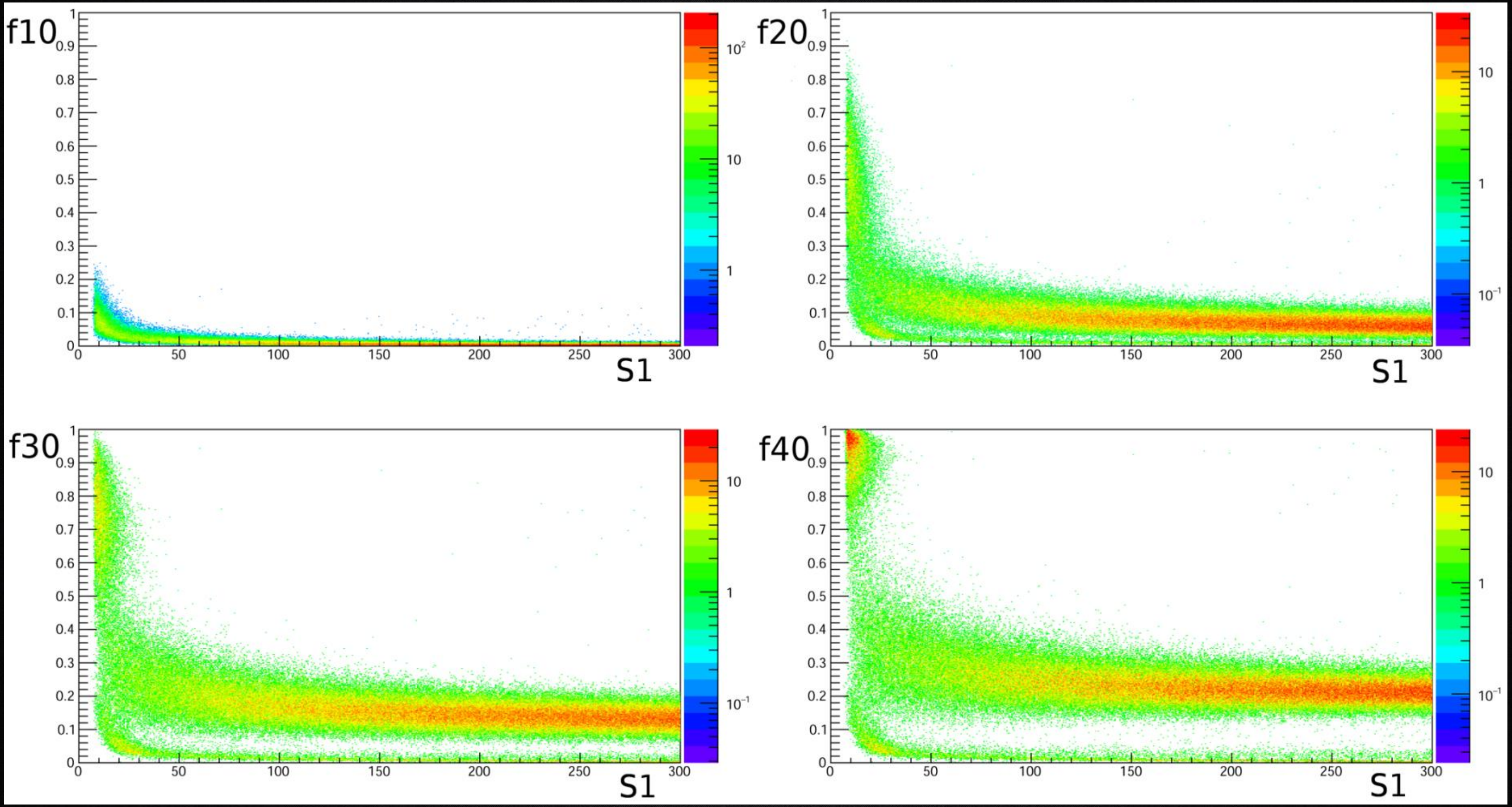
A family of the events appear: caused by Cherenkov radiation (high f90, low S1).

Cherenkov light is all prompt, instead light coming from LAr is not all prompt



fXX

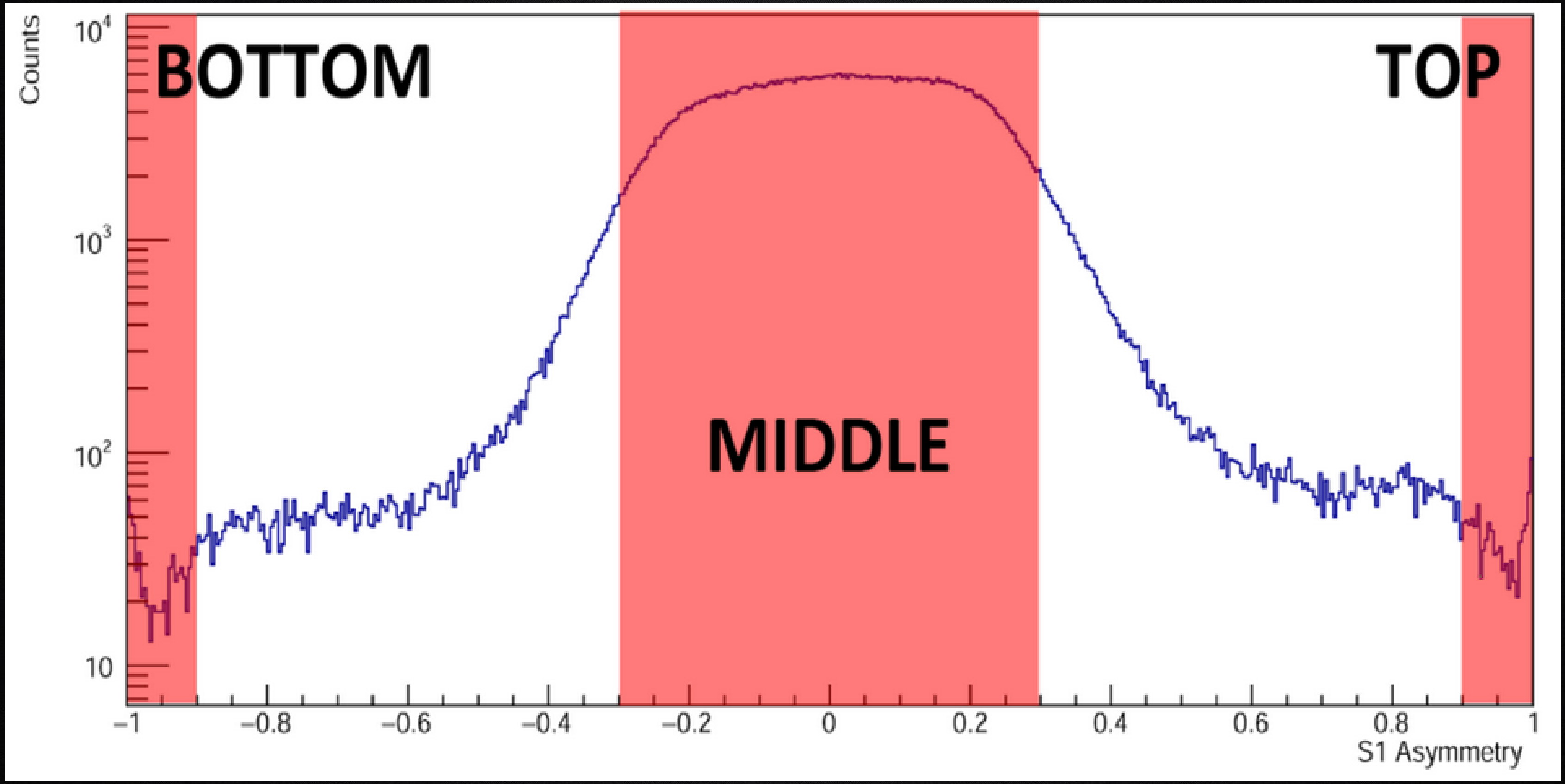
New variables developed in attempt to study the Cherenkov background



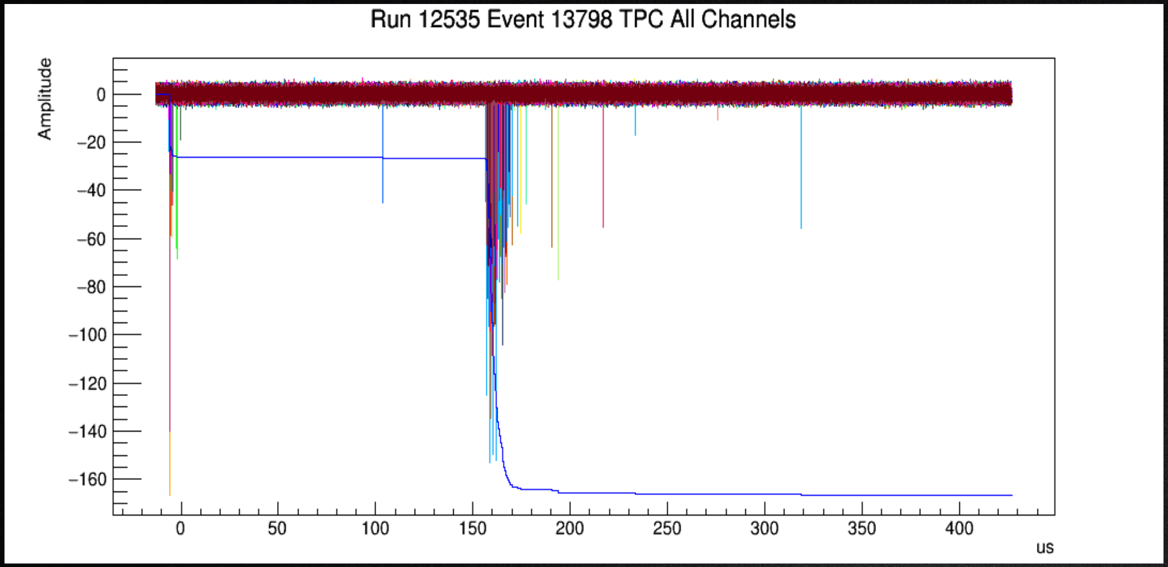
Pure Cherenkov events show f40 ~1 (22Na campaign)

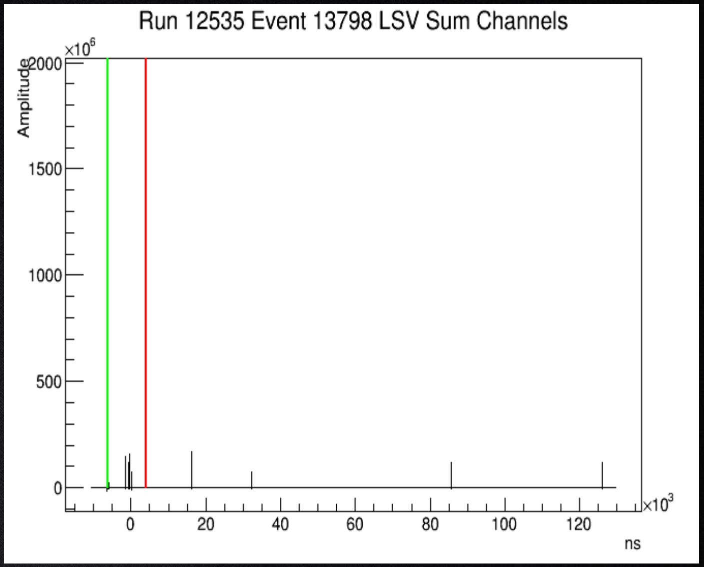
S1 ASYMMETRY IN 22NA

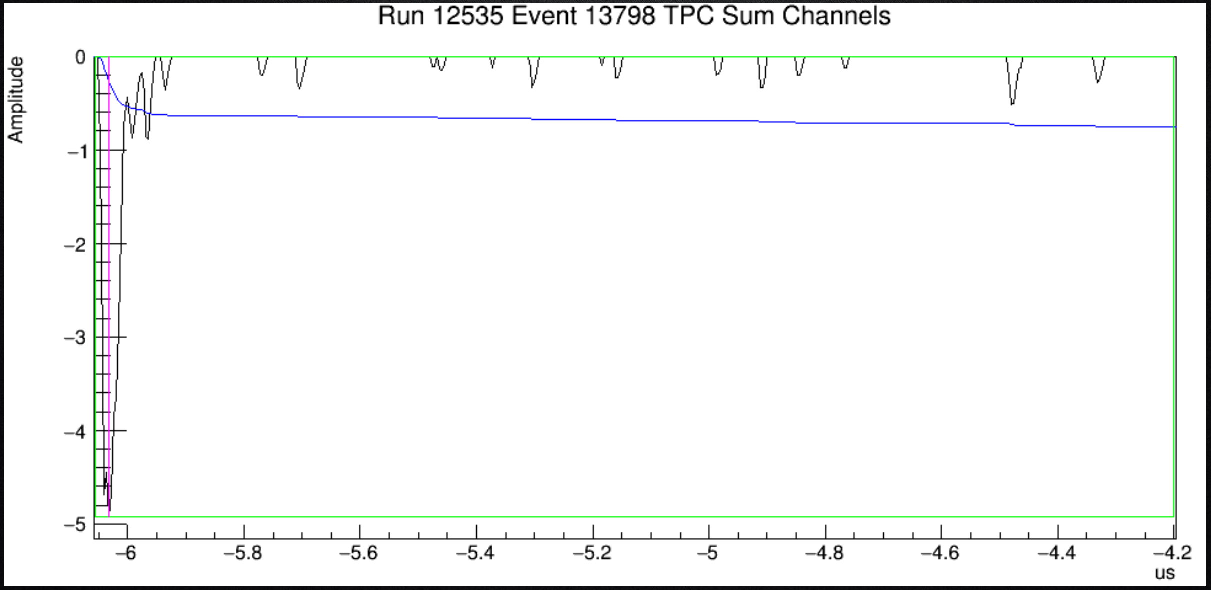
Could be used to see if Cherenkov events are coming from glass or teflon



CHERENKOV+ER EVENT







DARKSIDE-50 EXCLUSION CURVES