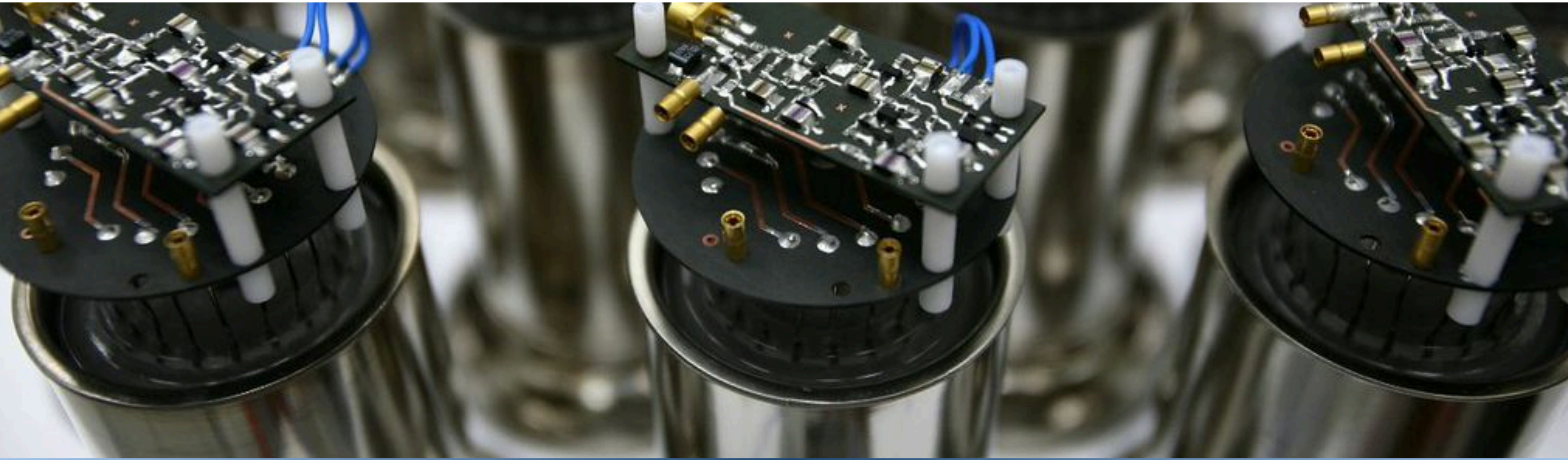


g4ds
the DarkSide simulation tool

Paolo Agnes
Laboratoire APC, Université Paris 7
on behalf of the DarkSide Collaboration

Dark Matter 2016
UCLA
17th - 19th February 2016

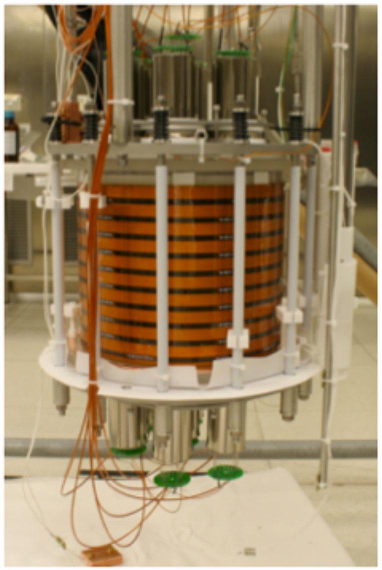
DARKSIDE

APC

The DarkSide program

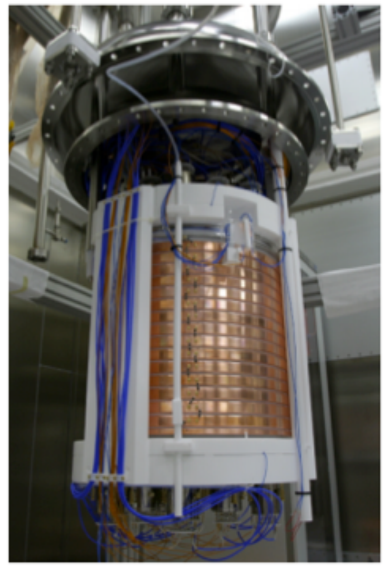
Double Phase Liquid Argon TPC, a staged approach:

DarkSide-10
2011-2013



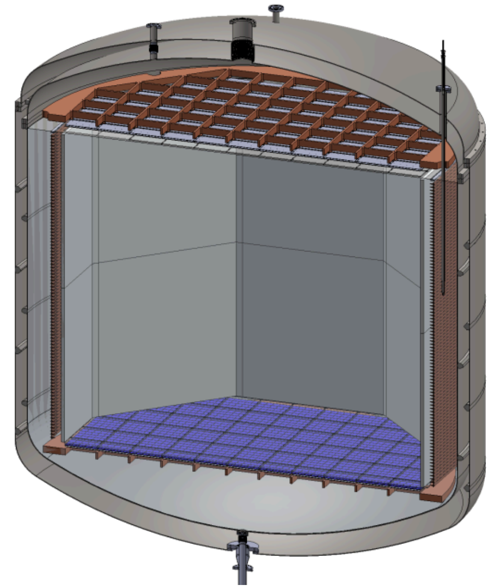
Princeton /LNGS

DarkSide-50
2013-201X



~10^{-45} cm^2

DarkSide-20k
2016-202x



~10^{-47} cm^2

2013 — 2015 — 2017 — 2019

Software development started

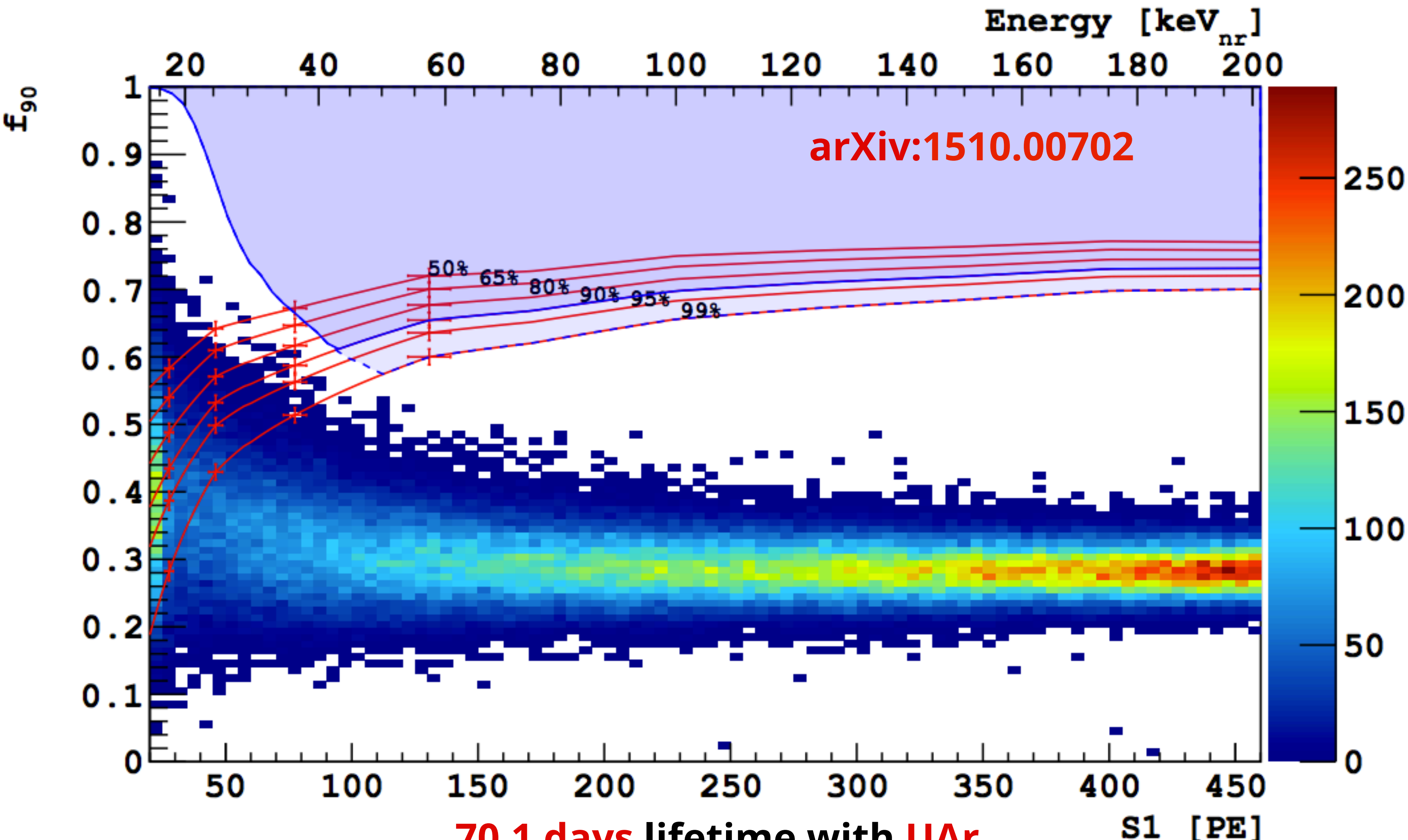
DS50 data taking started

DS20k –proposal: detector design finalized

Software tuning completed

The UAr result

PSD parameter: f90 = fraction of S1 in the first 90 ns



70.1 days lifetime with UAr

Background free search. (No S2/S1 cut applied)

g4ds overview

- **GEANT-4** based simulation
- All the **detectors** included, **additional geometries**
- **Electronics** simulation

1. **Full optics** description
2. **TPC energy scale** (**S1 done, S2 underway**)
   - ER and NR
   - **Recombination** probability
   - Calibration sources
3. **Pulse shape discrimination parameter**
4. Calibration of the vetoes

- **Applications**
  - Reconstruction software validation
  - Validation of position reconstruction algorithms
  - **Neutron background estimation**
  - **Spectral fit**
  - Design of DS20k phase
  - True shape of ^{39}Ar beta spectrum

DS50 detector design

At *Laboratori Nazionali del Gran Sasso*, Italy

LAr TPC

- 36 cm x 18 cm radius
- 50 kg LAr (**36.9 kg fiducial mass**)
- 19 + 19 3" PMTs
- Uniform Electric Field (200 V/cm)
- ~ 1 cm Gas Pocket
- Extraction Electric Field (2.8 kV/cm)
- Reflectors and TPB coating

Outer neutron veto

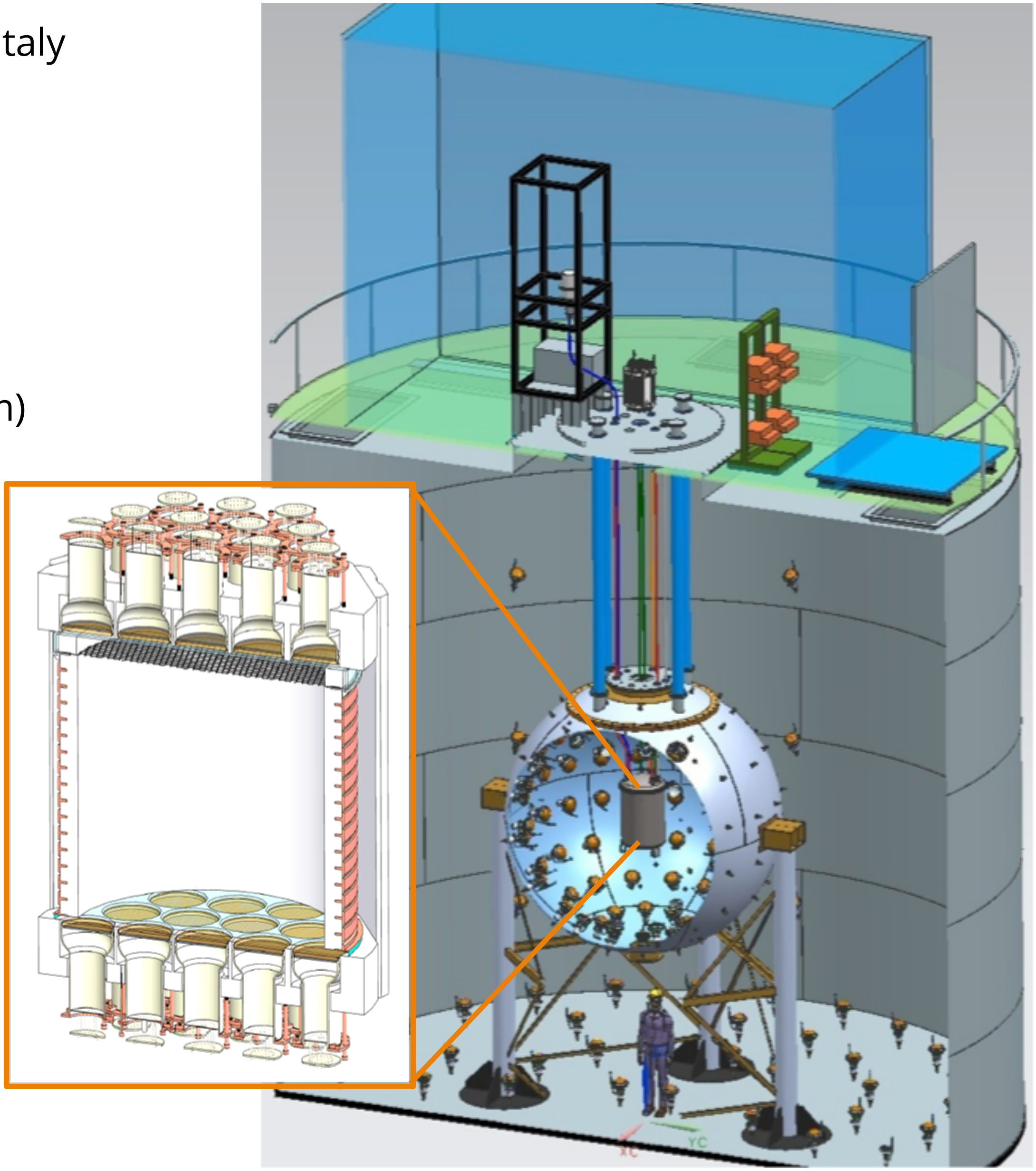
- 30 tons, 2 m radius
- Liquid Scintillator (1:1 TMB + PC)
- 110 PMTs (LY = 0.5 pe/keV)

Water Cherenkov detector

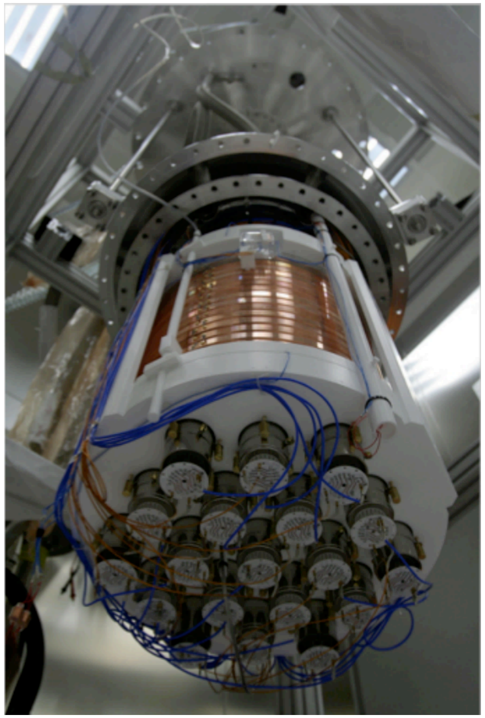
- 1 kt water, 5.5 m radius
- 80 PMTs

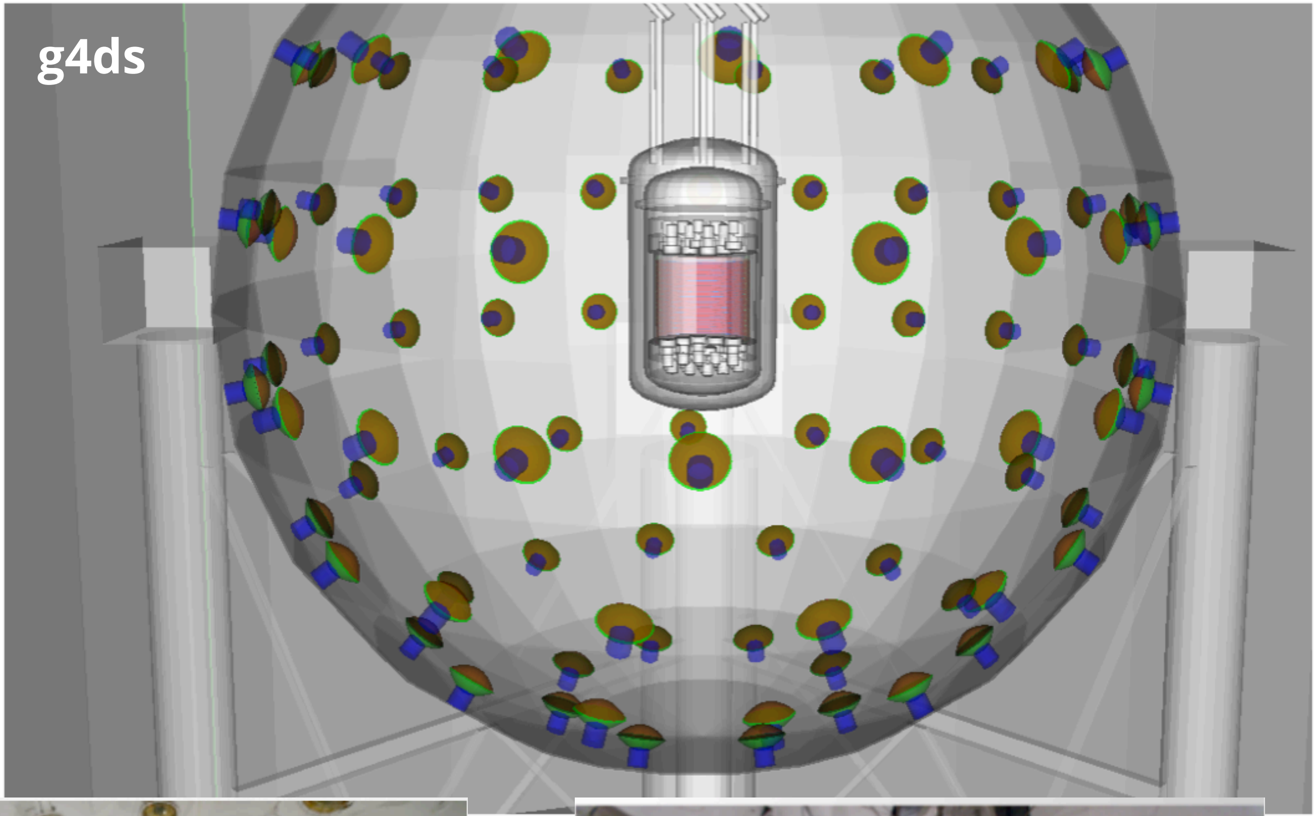
Veto's Rejection Efficiencies:

> 99% against Radiogenic neutrons



DS50 geometry

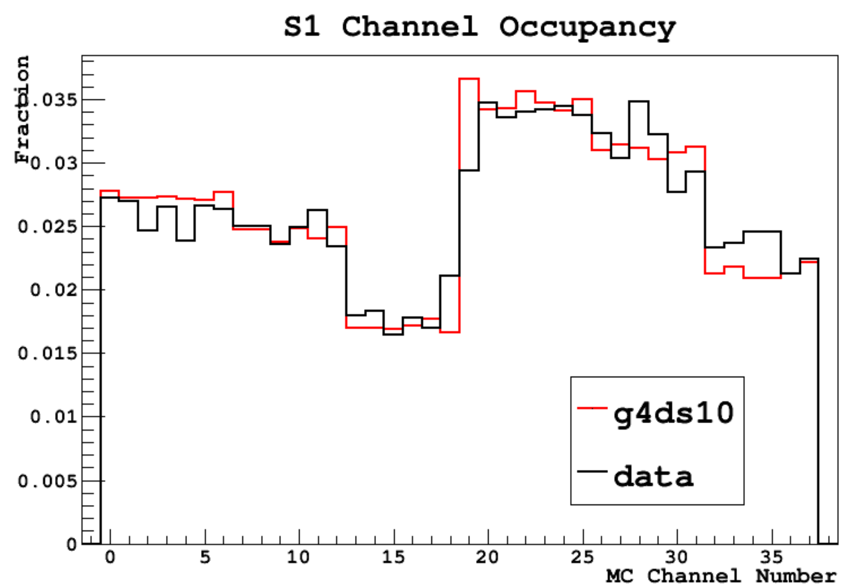


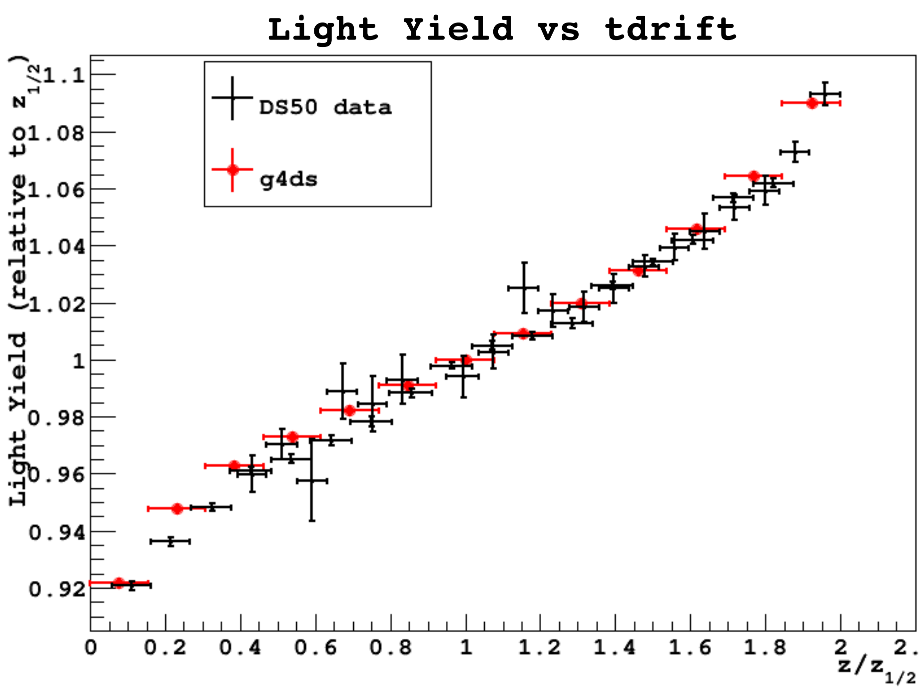


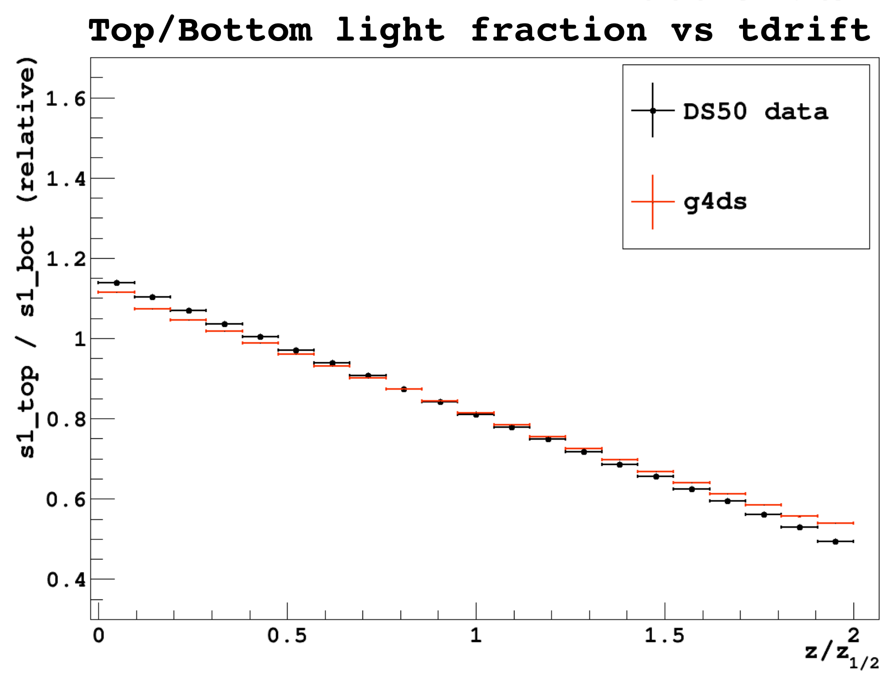
1. g4ds optical tuning

- 38 (3 in.) PMTs, two arrays
- Description of the internal optics
- **Tuning** of several parameters (RIndex, absorption lengths, WLS…) + condensed Ar layer found/WLS defects

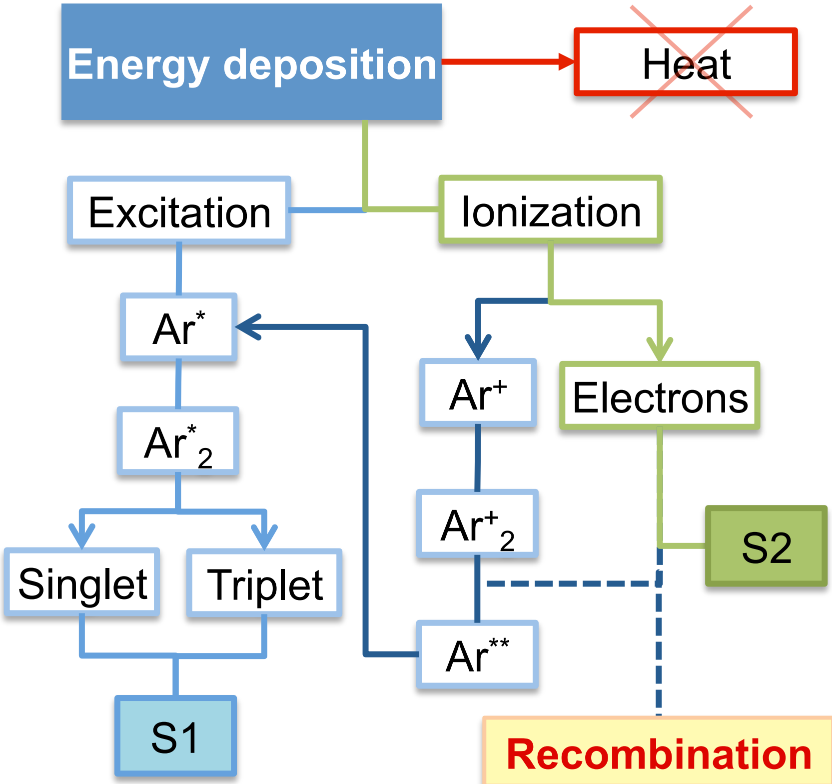
Relative quantities:
no assumption on energy







2. The Energy calibration



$$N_q = E / W$$
$$N_i = N_q / (1+\alpha)$$
$$N_{ex} = N_q - N_i$$

$$\mathbf{N_q^{S1} = N_{ex} + R N_i}$$
$$\mathbf{N_q^{S2} = N_i(1 - R)}$$

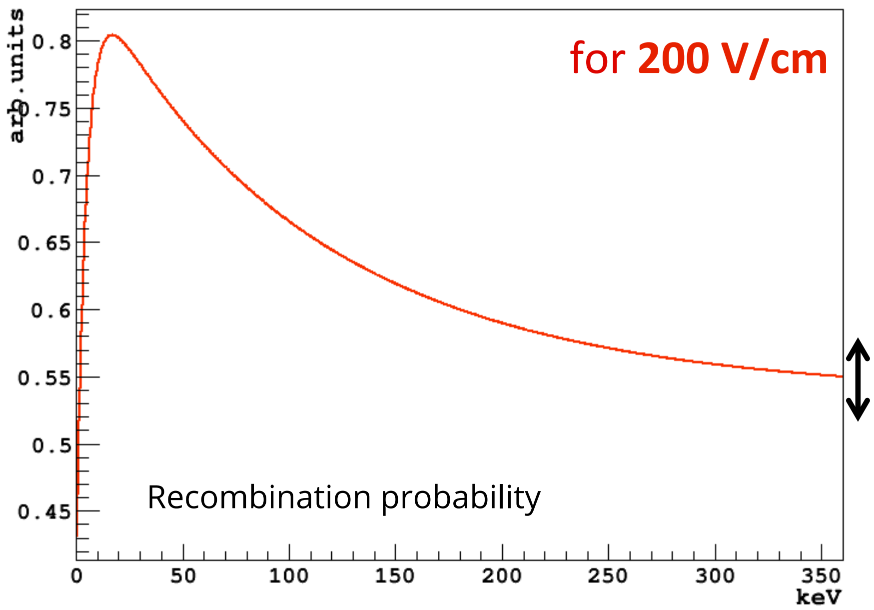
$$\mathbf{S1 = Y_{S1}\ N_q^{S1}}$$
$$\mathbf{S2 = Y_{S2}\ N_q^{S2}}$$

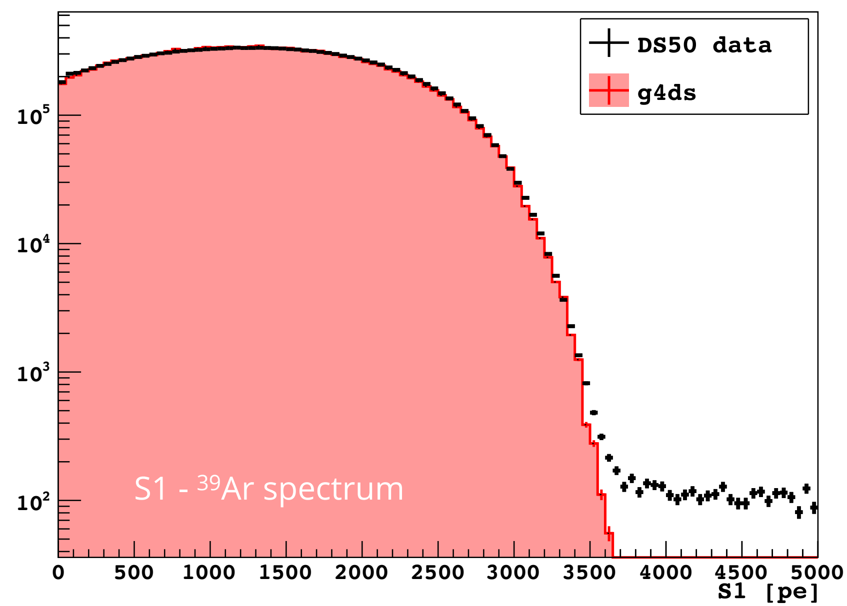
Assumptions:
W = 19.5 eV
α = 0.21
Constant Y_{S1} and Y_{S2}

The goal is to model **R**
(the **recombination probability**)
as a function of the **recoil energy**

An effective parameterization (6 degrees of freedom)

Fit of the
- endpoint of ^{39}**Ar** spectrum (565 keV),
- ^{83m}**Kr** (9.4 keV + 32.1 keV) peak
- ^{37}**Ar** peak (2.7 keV) peak



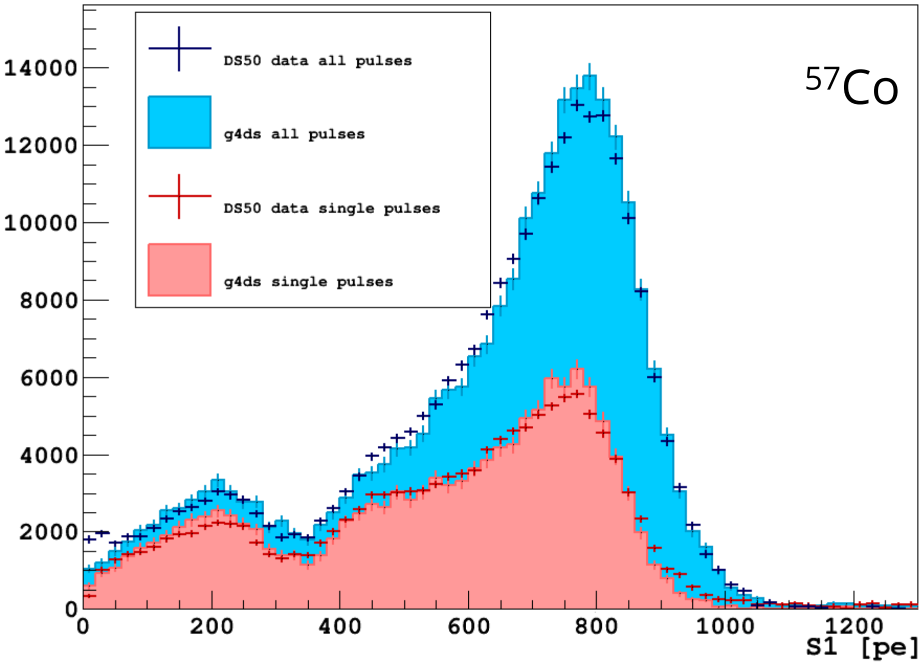


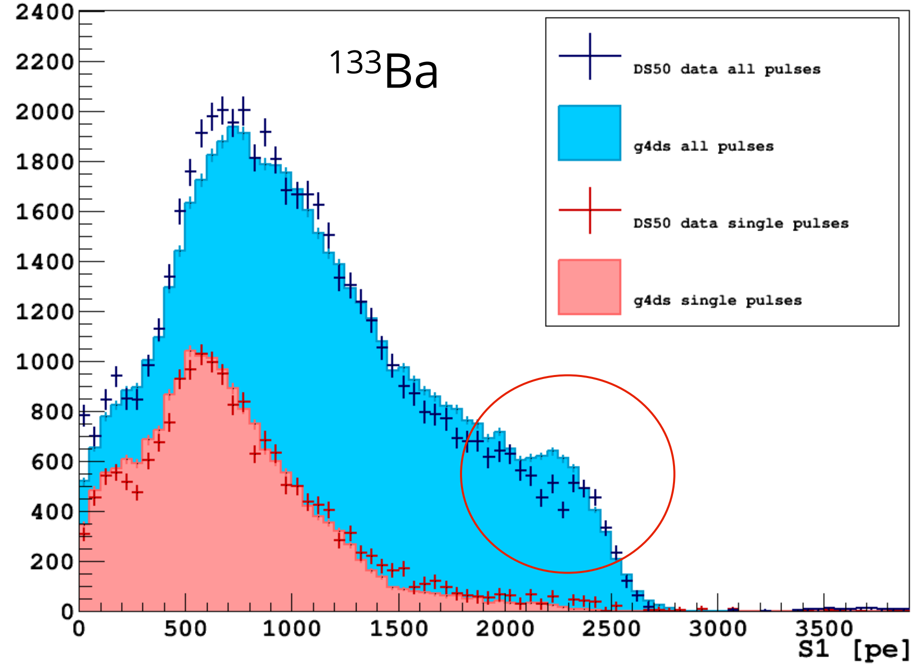
No additional smearing required!

Cross check with external calibration sources (^{57}Co and ^{133}Ba)

CALIS (calibration insertion system)

S1 after statistical background (^{39}Ar) subtraction:



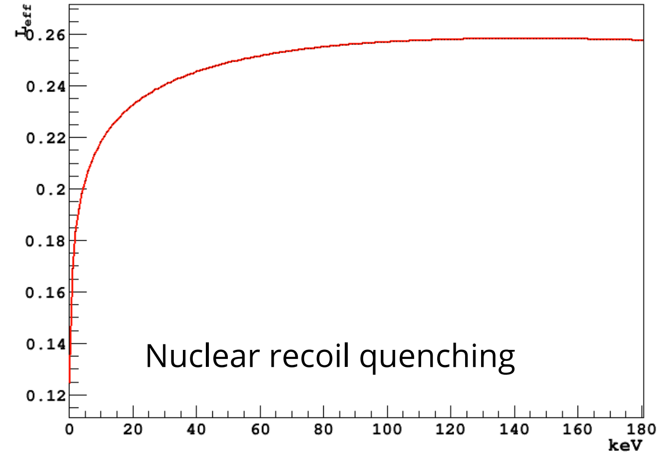


Same agreement for number of pulses, tdrift vs x-y distribution...

No additional smearing required!

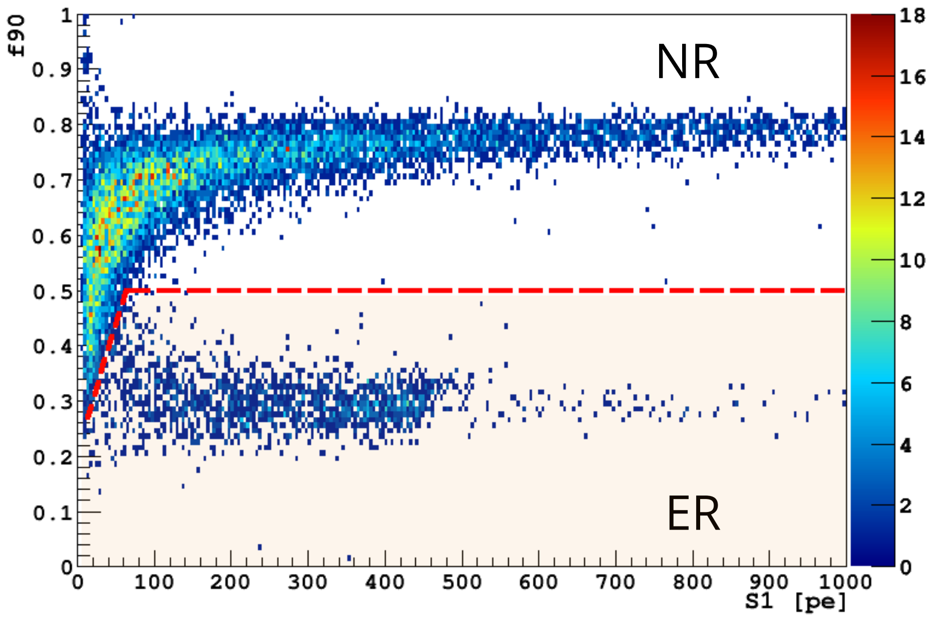
2. Nuclear recoils calibration

Addition of **Mei model** for NR quenching
(arXiv:0712.2470)

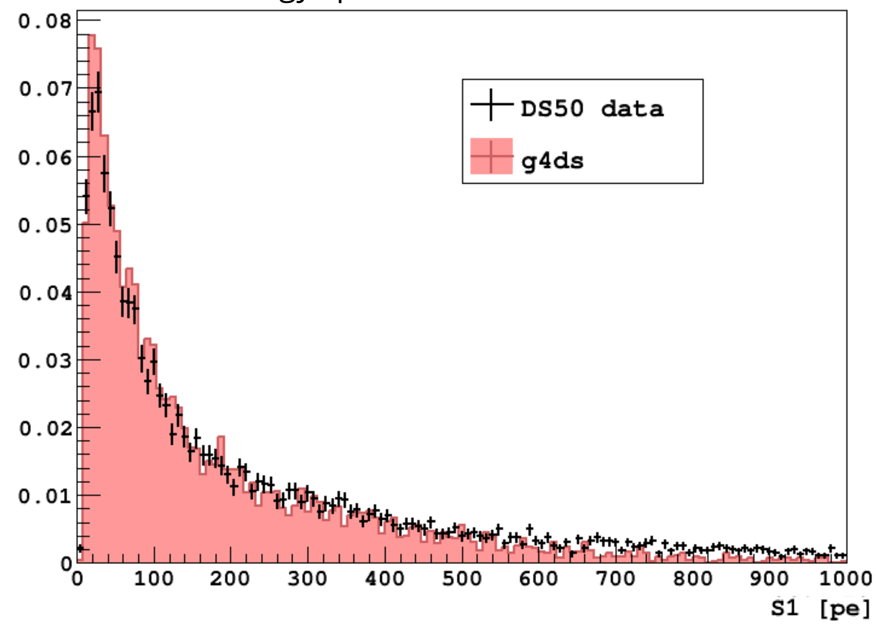


AmBe source, strong data selection cuts
(4.4 MeV coincidence in the LSV, f90)

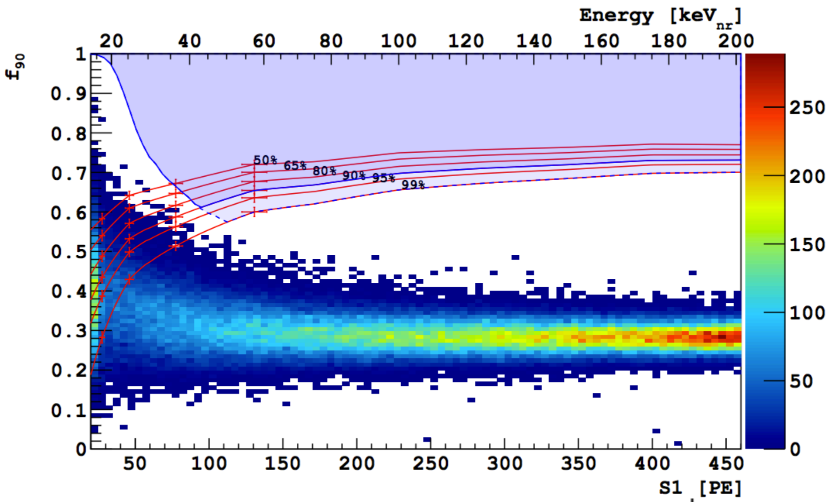
Data selection

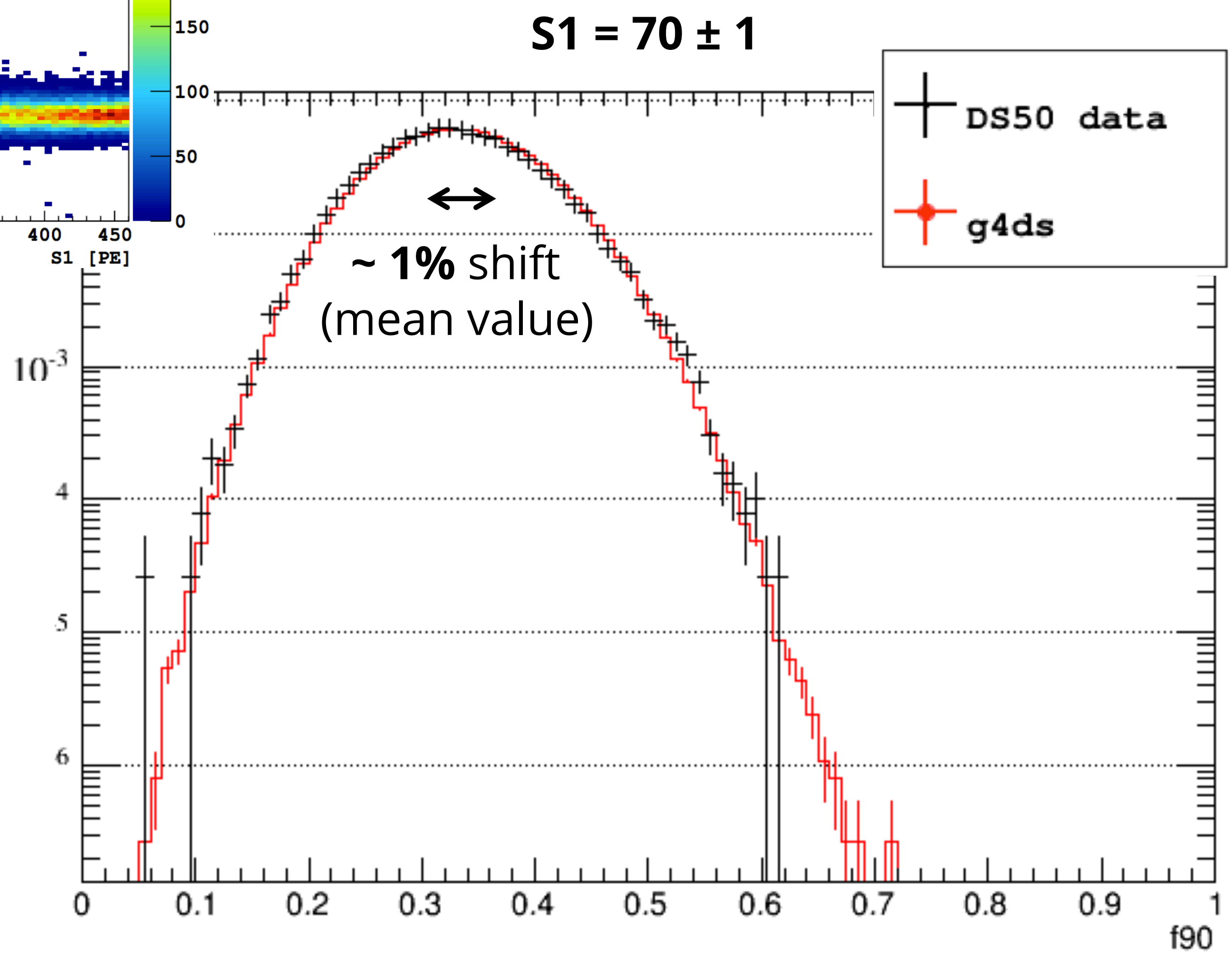


Energy spectrum of selected events



3. Pulse shape discrimination





Leakages prediction

Tuning ongoing:

τ_{fast} = 6 ns

τ_{slow} = 1600 ns

Prompt fraction

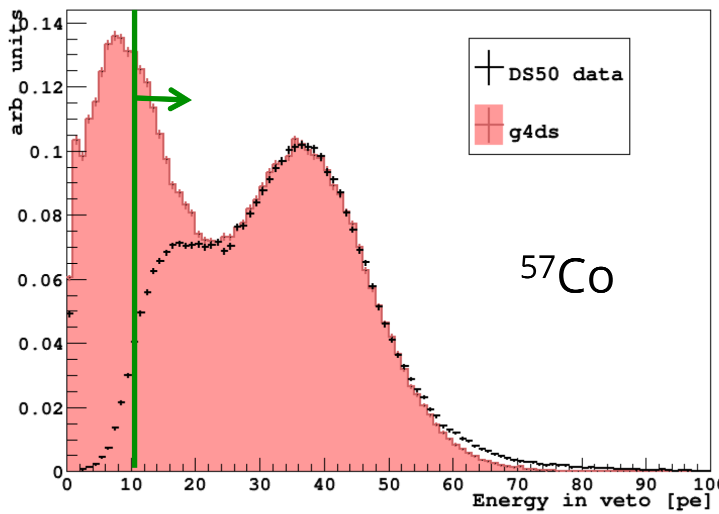
(from data)

Cerenkov in the water (muons)

Focus on the **LSV**

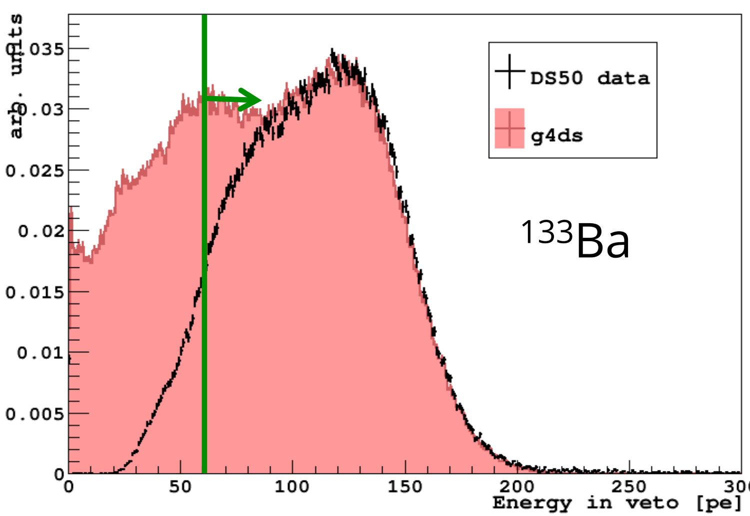
LY ~ 0.5 pe/keV from calibration sources

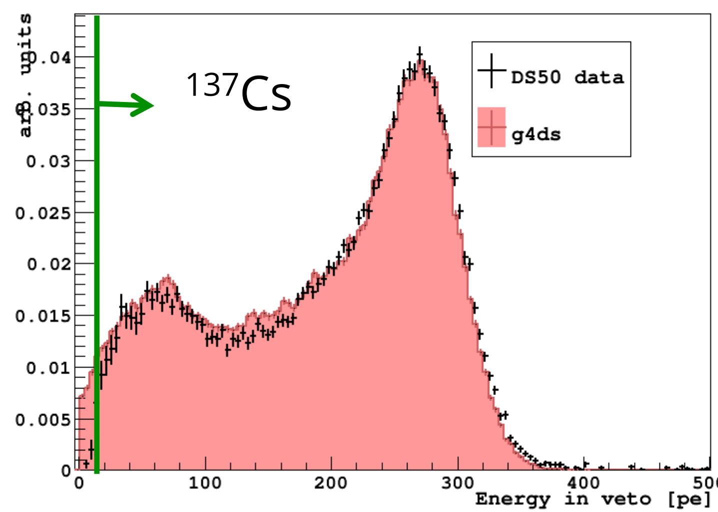
$$^{10}B + n \rightarrow \begin{cases} ^{7}Li\ (1015\ keV) + \alpha\ (1775\ keV) & (6.4\%) \\ ^{7}Li^{*} + \alpha\ (1471\ keV), ^{7}Li^{*} \rightarrow ^{7}Li\ (839\ keV) + \gamma\ (478\ keV) & (93.6\%) \end{cases}$$



Veto efficiency study

(LSV preferred solution for DS20k)



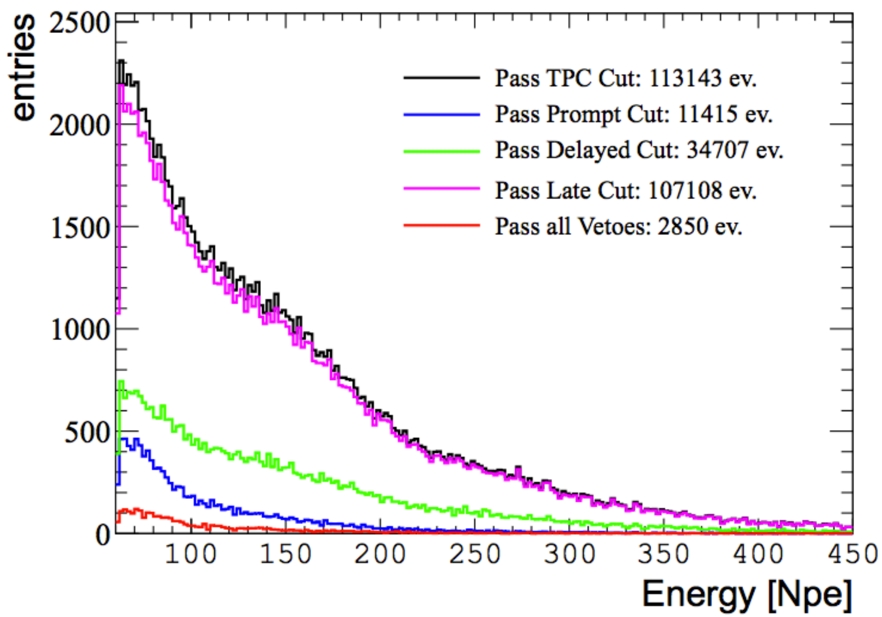


Neutron bg and veto efficiency

Radiogenic neutron background requirement: **<0.1 n/5y**

Neutrons from different materials (cryostats, PMTs, internal components).
Energy spectra from **TALYS**, activities from material screening.
Neutrons propagated through the g4ds geometry

TPC cuts to select WIMP-like events:
Single scattering
10 keV < E < 70 keV
FV cut
PSD cut



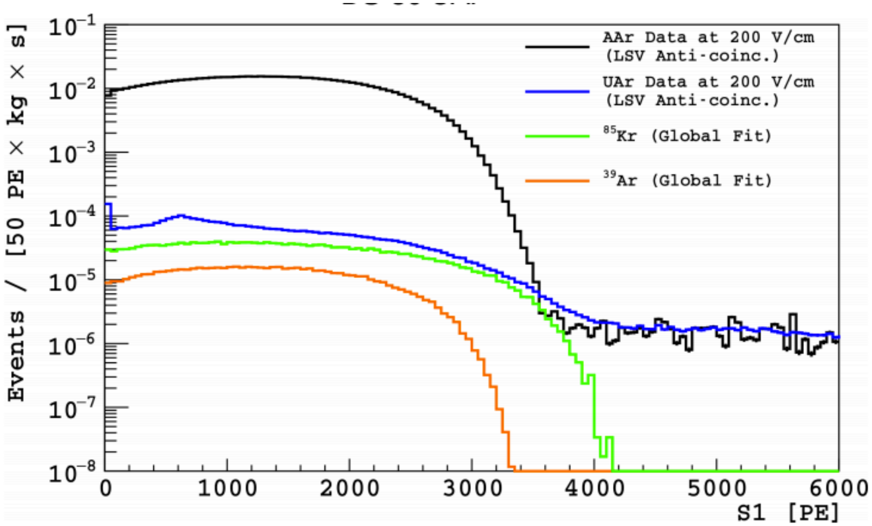
Different veto compositions
50% TMB (DS50-Phase I)
10% TMB
5% TMB (DS50-Phase II)

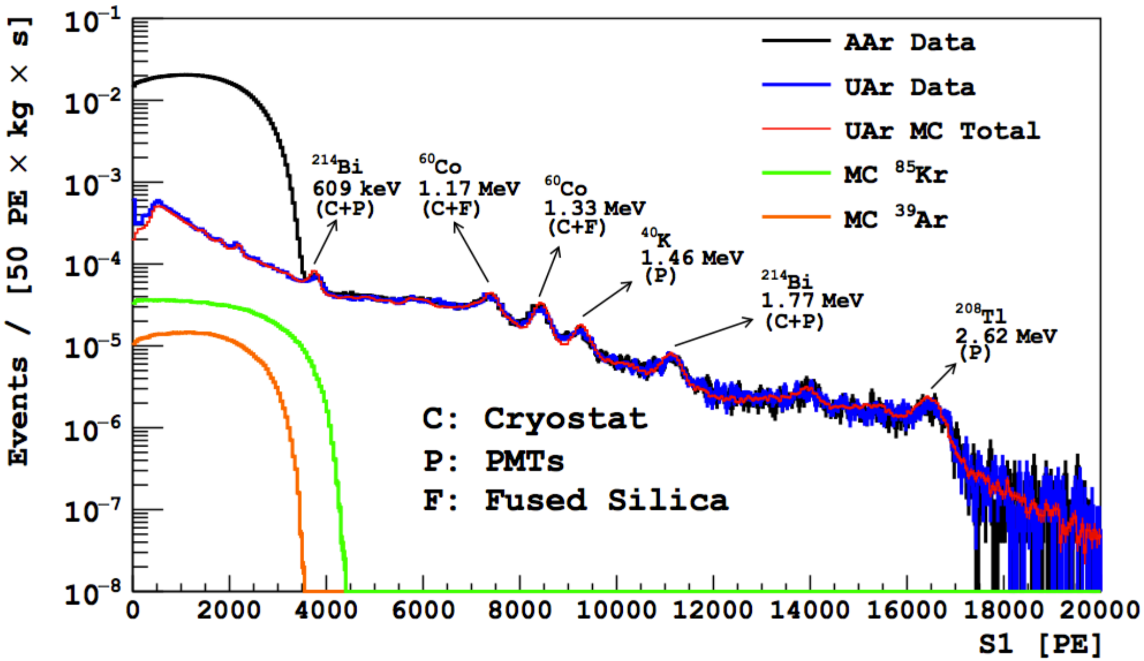
DS50 veto efficiency (capture only) from AmBe: **> 99.1% (current phase)**
see arXiv:1512.07896

Extension to DS20k: **design study**

A multidimensional spectral fit

- ^{39}Ar is first forbidden decay
- Multidimensional spectral fit: **field on** (tdrift) and **field off** data (full absorption peaks). MC spectra (gamma from materials).
- ^{85}Kr contamination found
- Fi the UAr data (better resolution) and subtract gamma contribution from AAr data (larger ^{39}Ar)





Conclusions

The g4ds **ready** and intensively used within the collaboration

Effective model for the **recombination probability**.
- It allows **energy** calibration (S1 done for ER and NR, S2 almost done).
- **Field dependence**: DS50 collected data for different drift field

Paper in preparation (full description of the g4ds code)