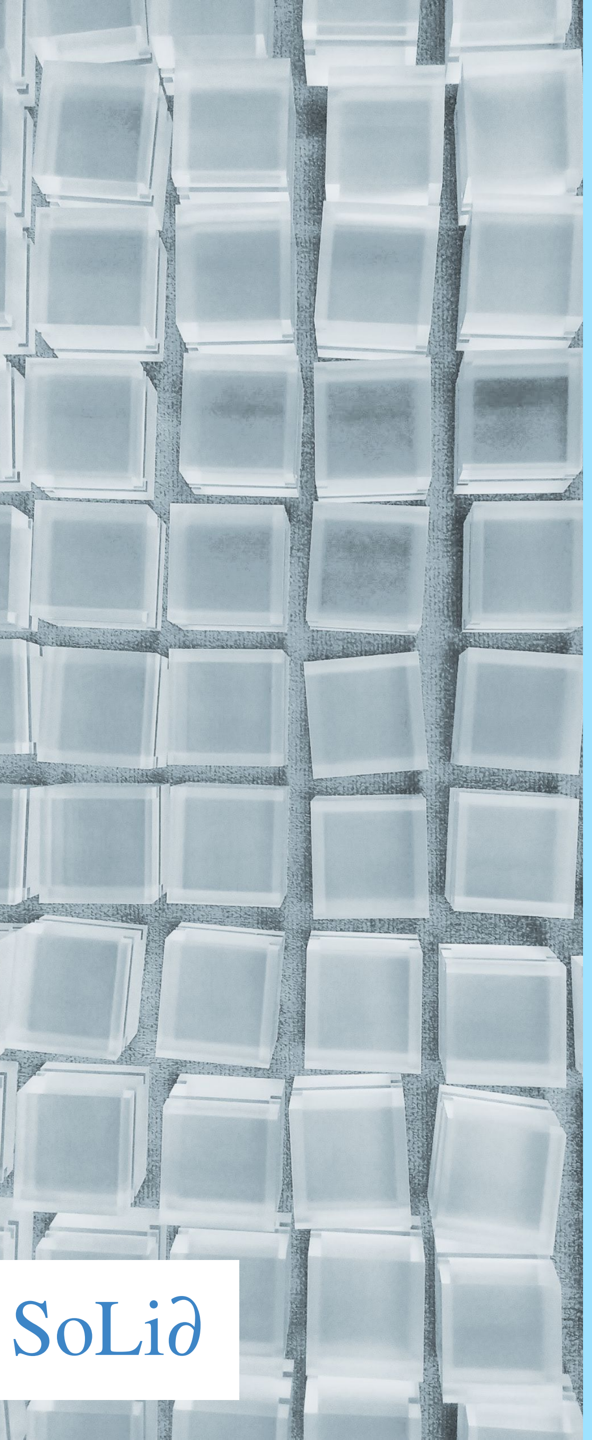
Neutrino Physics Session
ICNFP 2019 - Kolymbari, Crete

Status of the SoLid experiment at the BR2 reactor

Universiteit Antwerpen

SoLid

Simon Vercaemer
Ianthe Michiels (UGent)
for the SoLid Collaboration



Outline

1 The SoLid experiment

Experimental program
Reactor site
Detector technology

2 Data reconstruction and BGs

Energy scale calibration
Data reconstruction
Main backgrounds
Background data/MC

3 Antineutrino detection

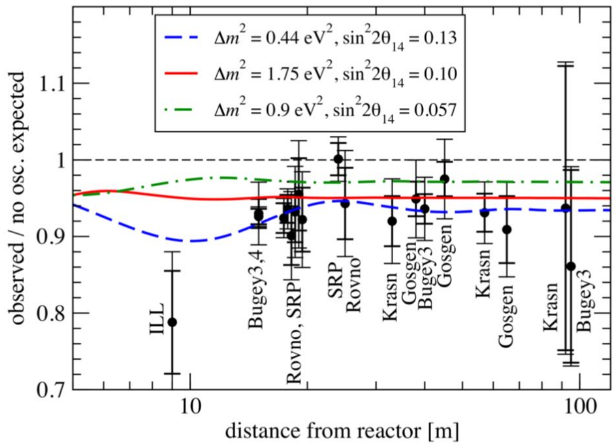
IBD selection cuts
Predicted S:B
Analysis status

SoLid goals

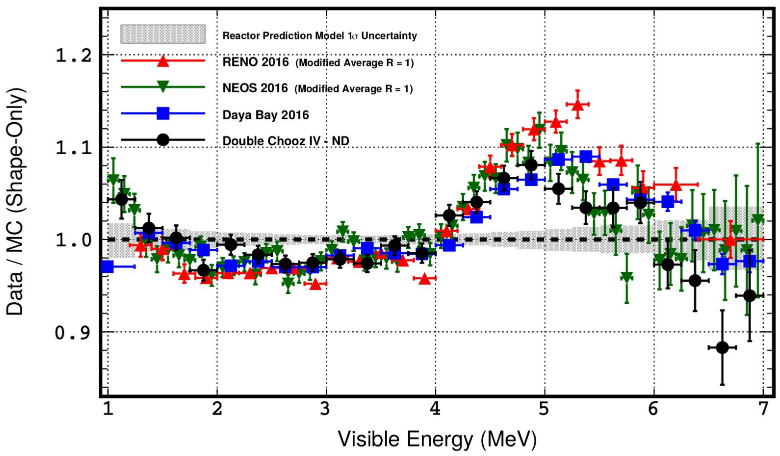
MOTIVATION

- Probe the reactor anomaly deficit and search for oscillation at very short baseline: L ≃ 10 m ↔ $\Delta m^2 \simeq 1\ eV^2$
- Resolve discussion on spectral features observed by previous reactor experiments

Kopp et al., JHEP 1305 (2013)



Double Chooz Collaboration, arXiv:1901.09445



SoLid goals

MOTIVATION

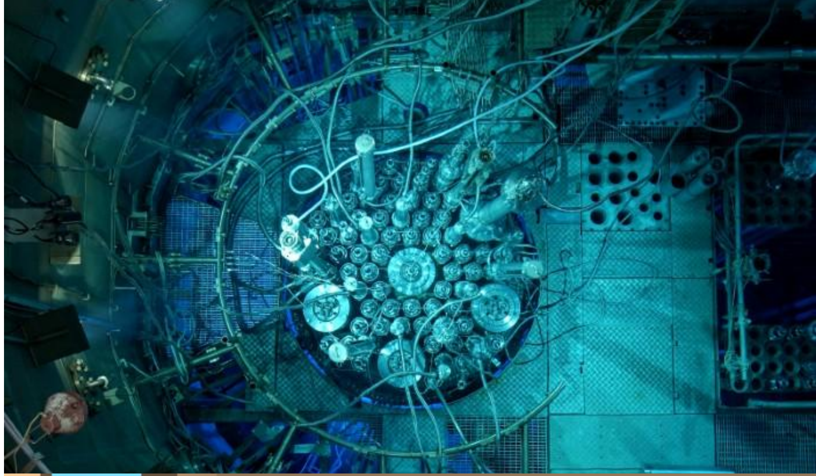
- Probe the reactor anomaly deficit and search for oscillation at very short baseline: $L \simeq 10$ m $\leftrightarrow$ $\Delta m^2 \simeq 1$ eV^2
- Resolve discussion on spectral features observed by previous reactor experiments

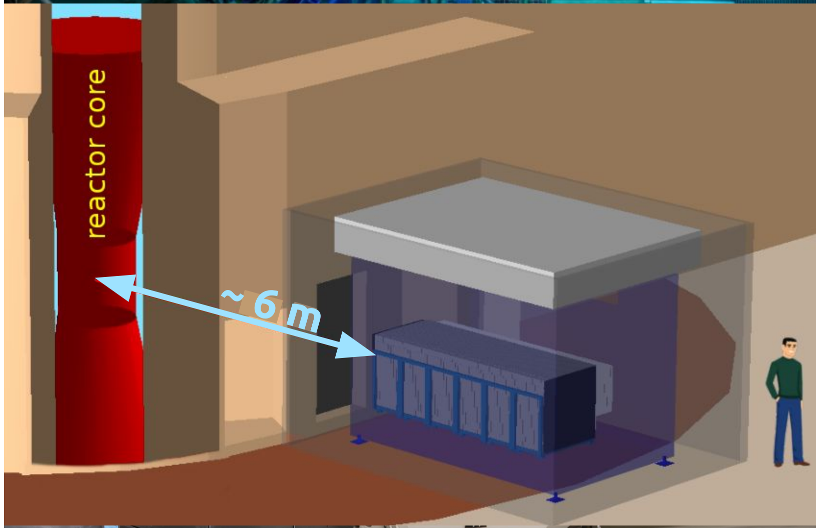
APPROACH

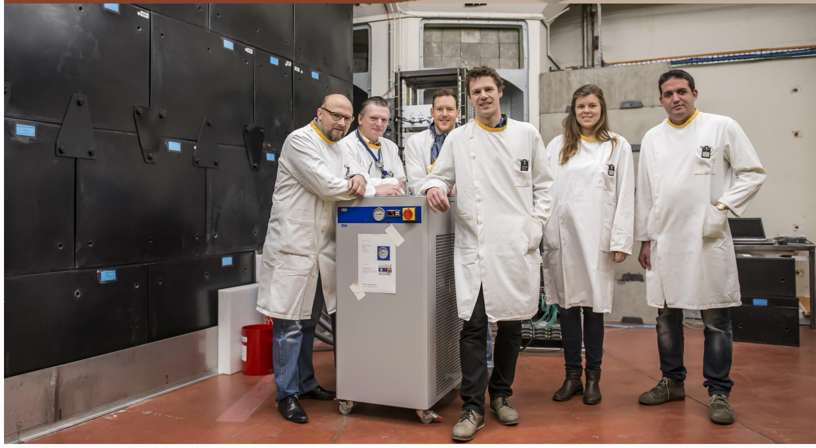
- Using plastic scintillator with linear energy response
- Use of segmentation to allow for topological event information (BG reduction) and measurement of potential oscillations in E and L
- Using a compact core with highly enriched ^{235}U fuel

BR2 reactor site

- Compact research reactor at SCK•CEN: ⌀ **50 cm - H 90 cm**
- Highly enriched fuel: **93.5% ^{235}U**
- Operating power at **50-80 MW**
- 6 cycles of ~1 month each: **~ 150 days per year**
- SoLid baseline at **6-9 m from core**
- At ground level → low overburden





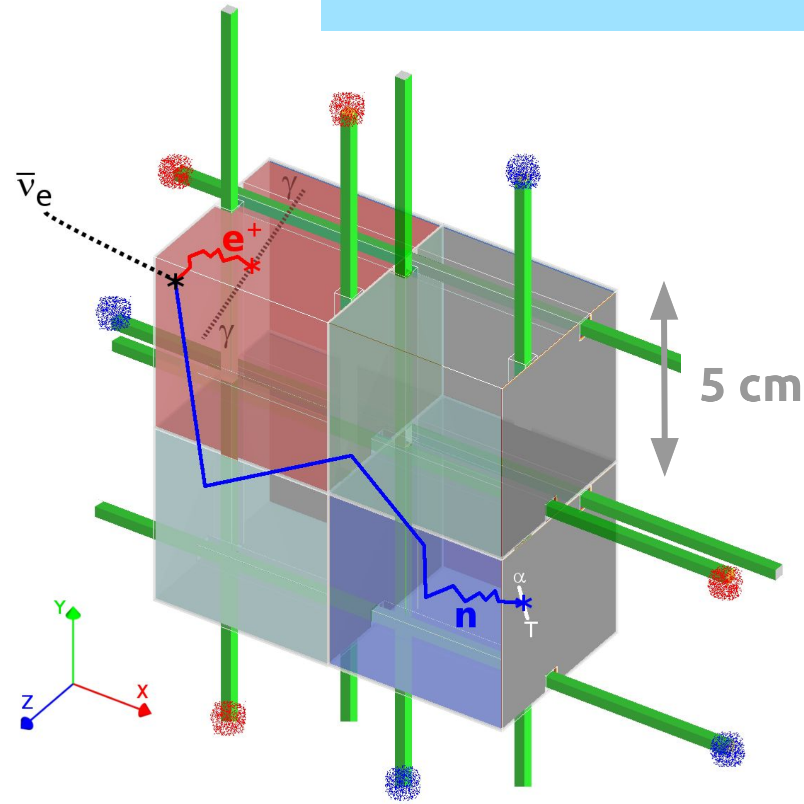


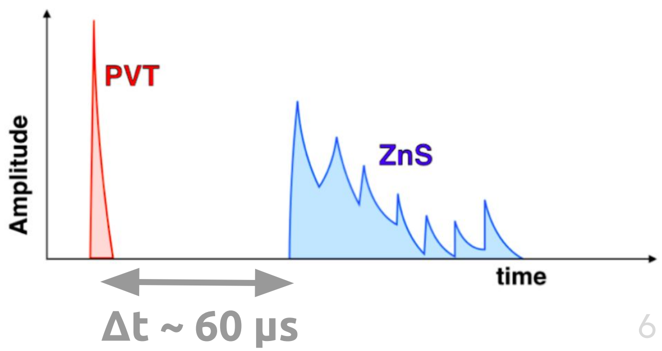
$$\bar{\nu}_e + p \rightarrow e^+ + n$$

SoLid detector technology

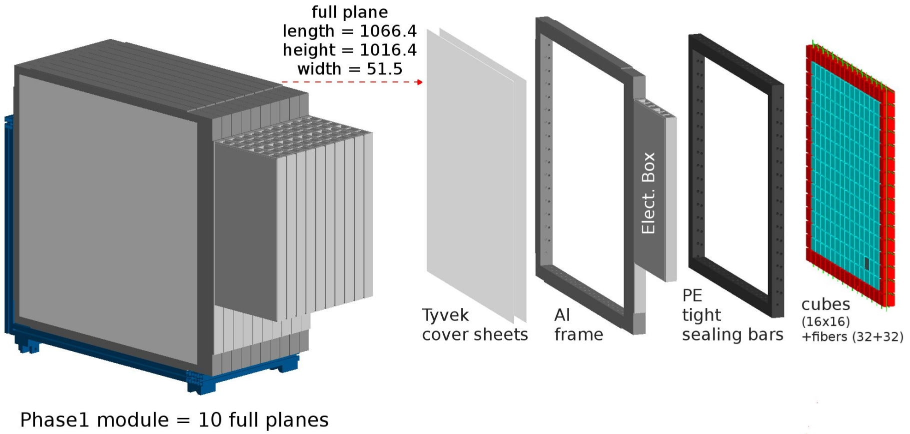
- Stacked **PVT** cubes of (5x5x5) cm^3 for **electromagnetic signal** (ES) detection
- Each covered with two ^{6}**Li**F:ZnS(Ag) screens for **nuclear signal** (NS) detection
- Wrapped in reflective Tyvek paper
- X/Y wavelength shifting fibre arrays, read out by SiPMs

➔ **Pulse shape discrimination**
➔ **Time and spatial event signature**



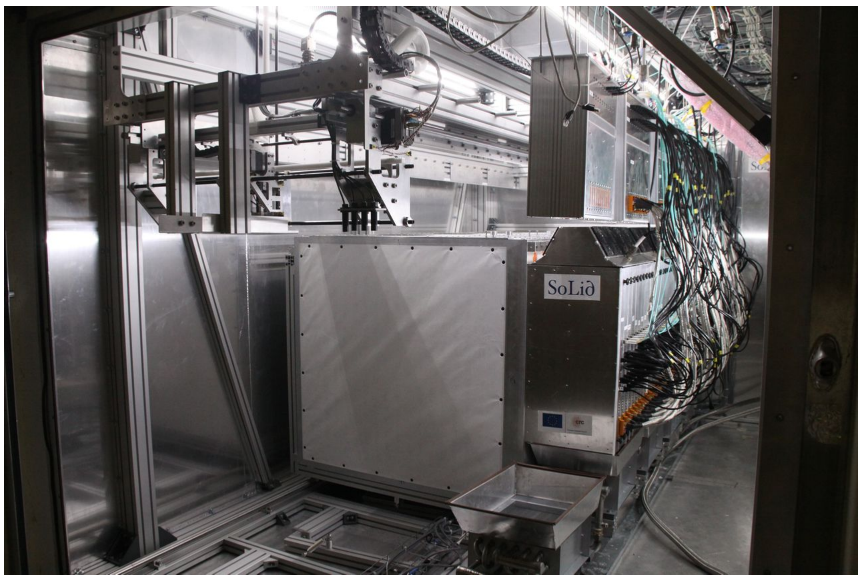


SoLid Phase I detector

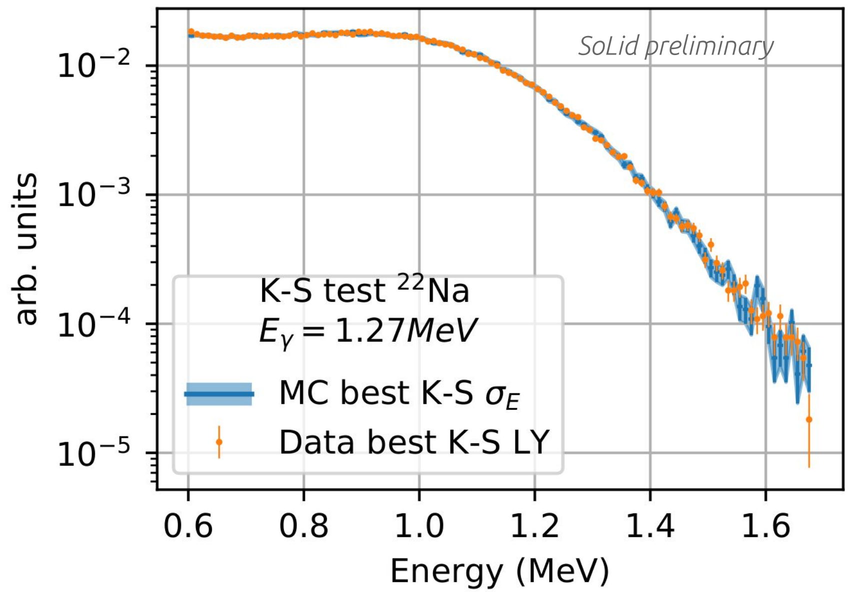


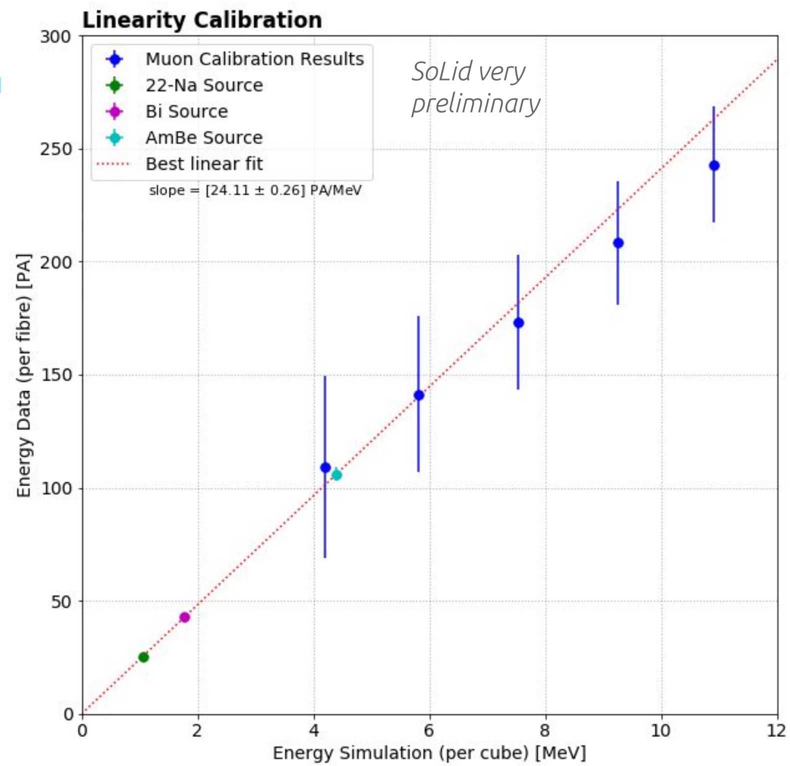
- Planes are filled with 16x16 detection cells
- Planes are grouped per 10 in a module
- 5 movable modules on rail system
- ➔ **1.6 tonnes sensitive mass**
- ➔ **Closest approach to core of 6.2m**
- Housed in container, cooled to 10°C
- Instrumented with remotely operated calibration system (CROSS)
- Passive shielding (50 cm):
  - Sides: water bricks
  - Roof: HDPE slabs

SoLid Phase I detector



Energy scale calibration



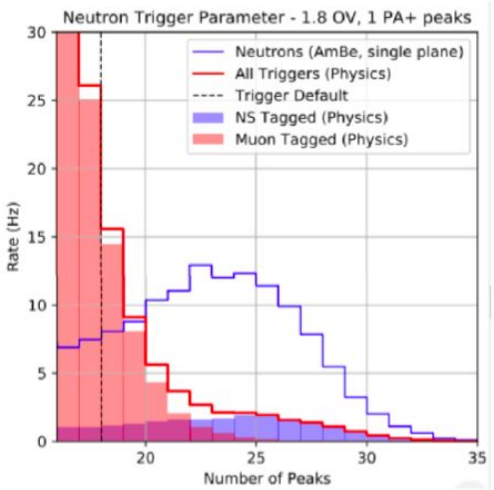


- Calibration with crossing muons (*wip*)
- Calibration with sources using CROSS
  - Very good data/MC agreement
  - Energy scale determination using two methods:
    - Kolmogorov-Smirnov test
    - Klein-Nishina analytical fit

- Consistent results over large energy range
- Light yield of 96 PA/MeV (12% at 1 MeV stochastic term)

Data reconstruction

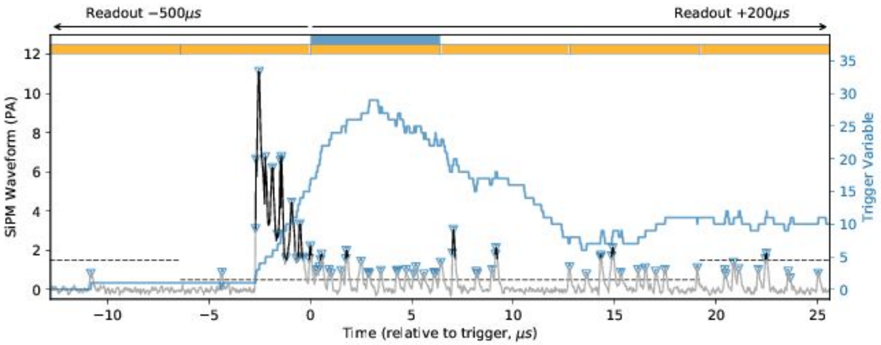
0. Different trigger types for first selection
- ➔ **Threshold:** *XY coincidence > 2 MeV*
- ➔ **Neutron:** *PSD algorithm for neutrons*
- ➔ **Random:** *Full detector readout at 1 Hz*



1. Time clustering to group signals from different fibres

2. Pulse shape discrimination used in offline reconstruction to divide signals in 3 streams: NS - ES - Tracks

3. Make correlations between prompt ES and delayed NS signals



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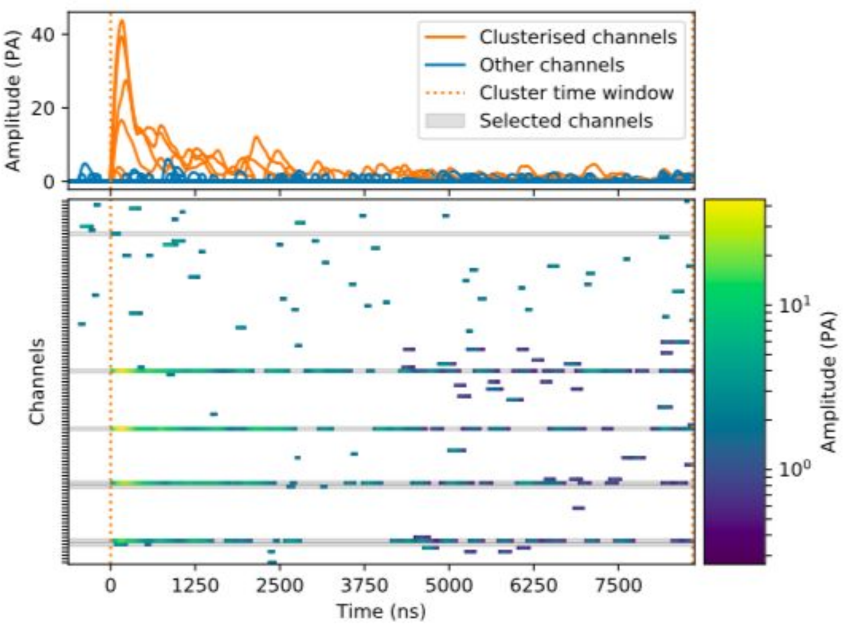

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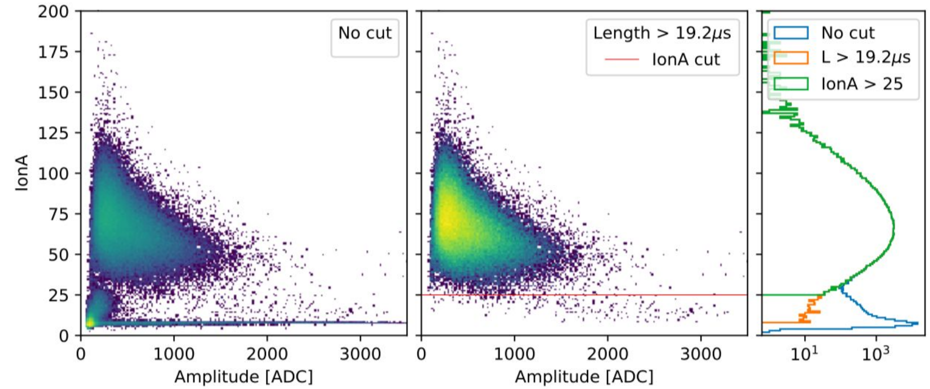
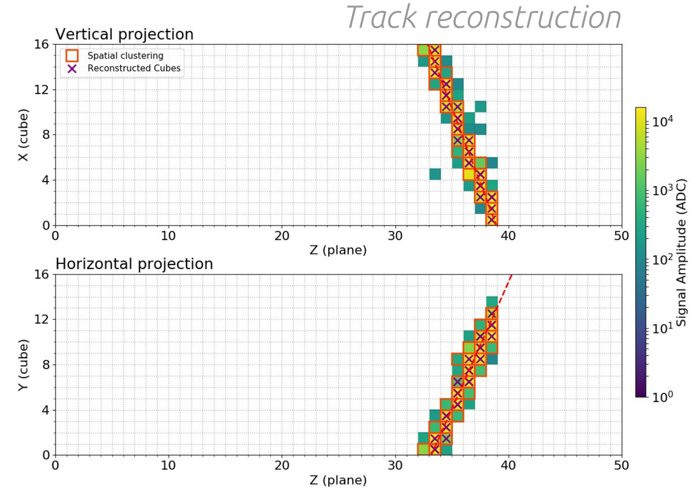
NS selection cuts



1. Time clustering to group signals from different fibres

Track reconstruction



2. Offline reconstruction uses cluster lengths and integral/amplitude ratio to divide signals in 3 streams: NS - ES - Tracks

3. Make correlations between prompt ES and delayed NS signals

Data reconstruction

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Threshold: *XY coincidence > 2 MeV*
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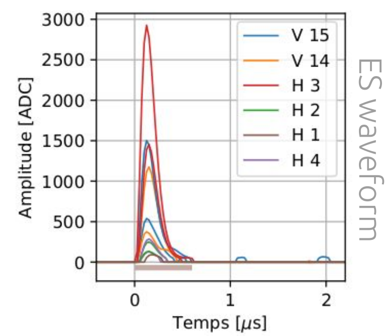
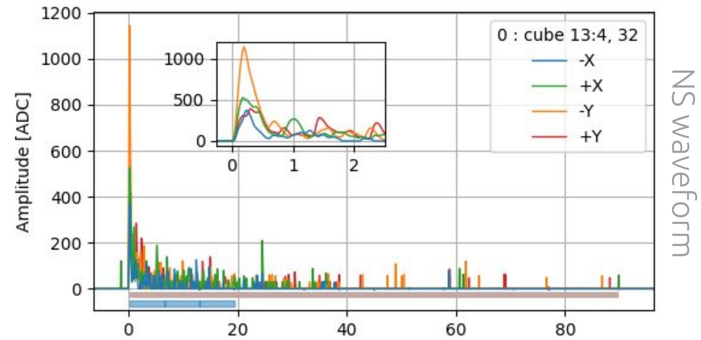
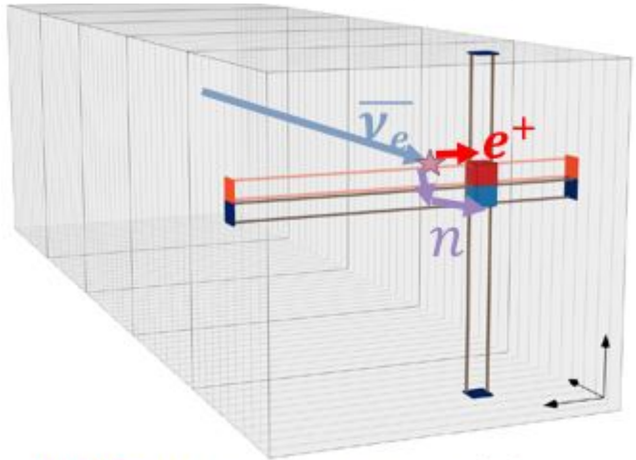






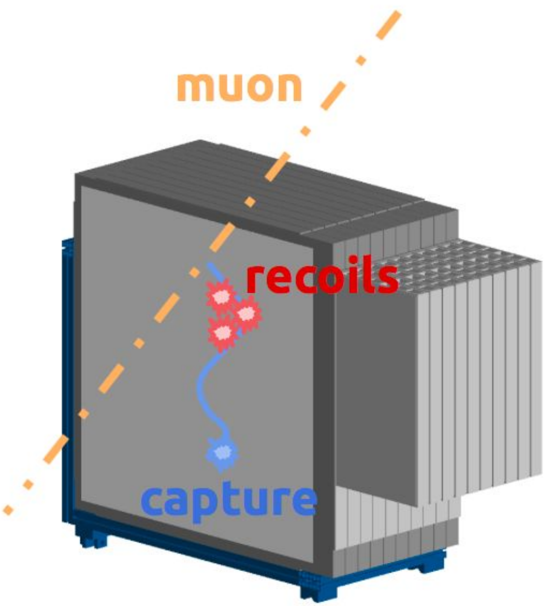
Prompt-Delayed Coincidence Candidate - 2017/12/05, 00:07:26

Main backgrounds

Fast Neutrons

Muon spallation and/or cosmic ray air showers create fast neutrons

➔ neutron recoil mimics 'prompt ES'
➔ neutron capture is 'delayed NS'

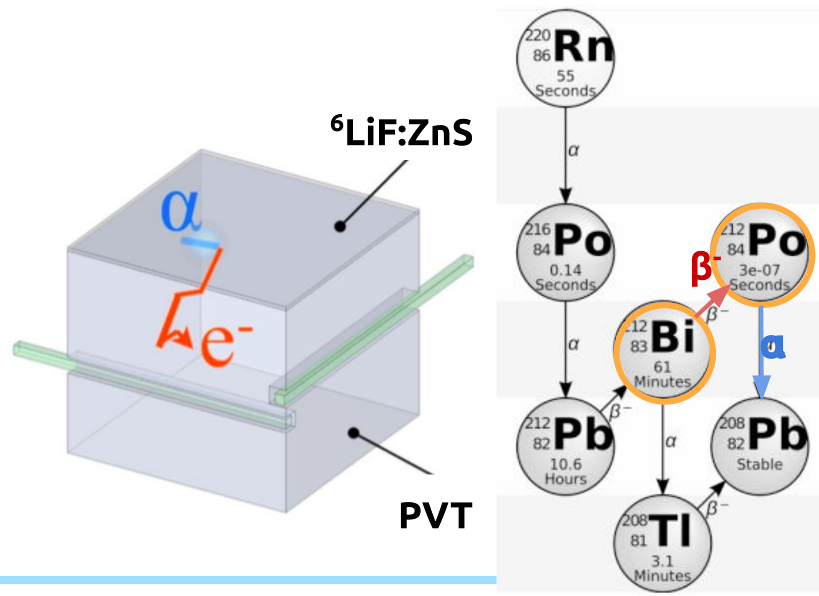


BiPo

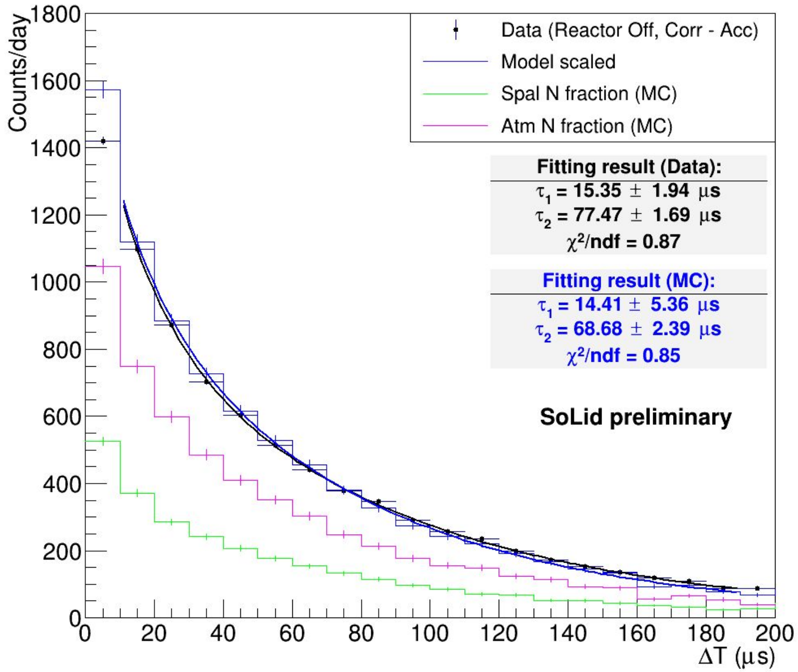
Contamination from $^{238}U/^{230}Th$ series in $^{6}LiF:ZnS(Ag)$ screens and in the air:

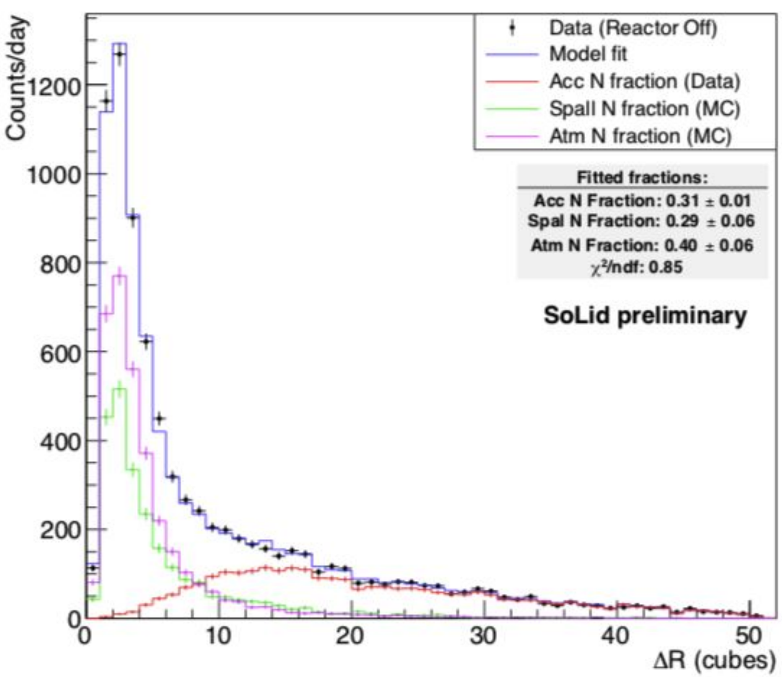
$^{214}Bi \rightarrow ^{214}Po \rightarrow ^{210}Pb$, with $T_{1/2}(Po) = 164\ \mu s$

➔ e^- from ^{214}Bi mimics 'prompt ES'
➔ α from ^{214}Po mimics 'delayed NS'



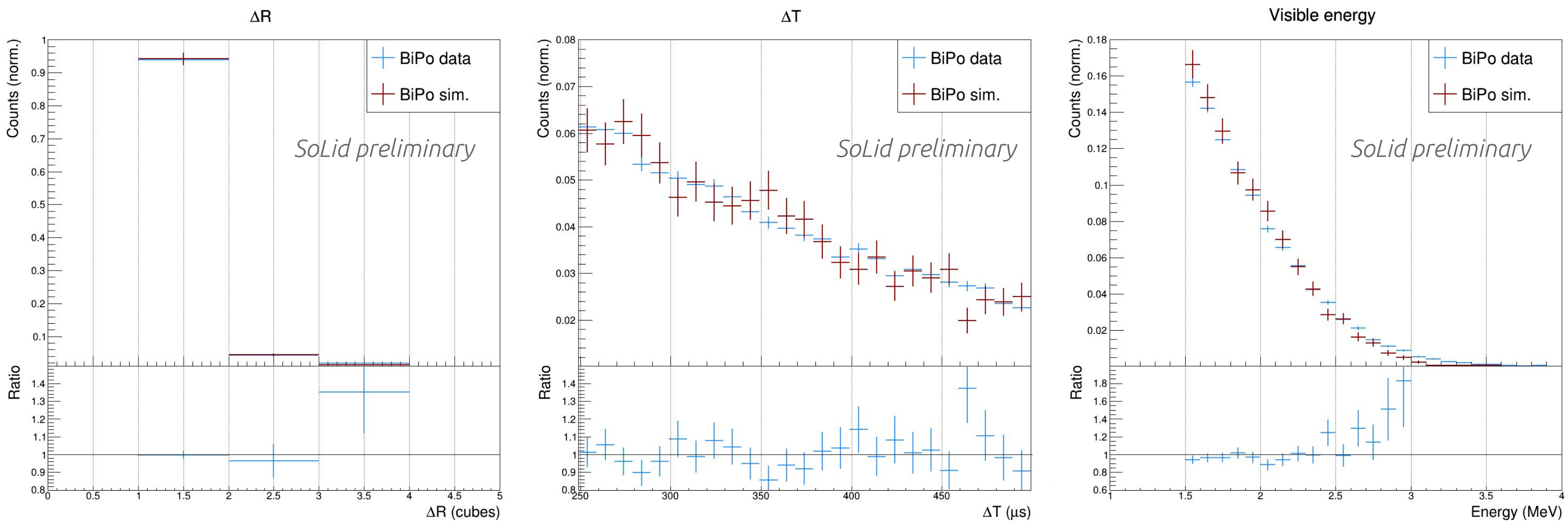
Background MC: Fast neutrons





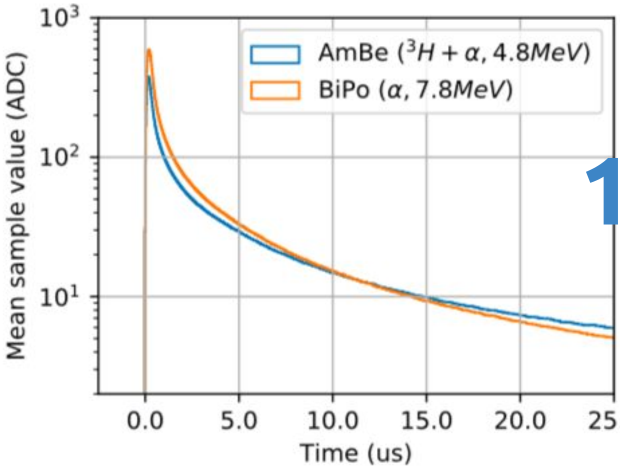
Combined model fit of spallation (42%) and atmospheric neutrons (58%), matches data very well in the ΔT and ΔR distributions.

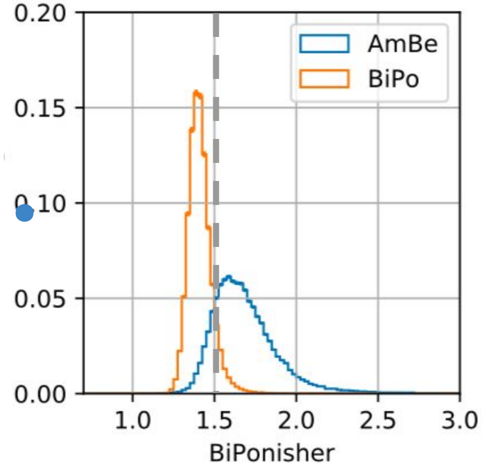
Background MC: BiPo

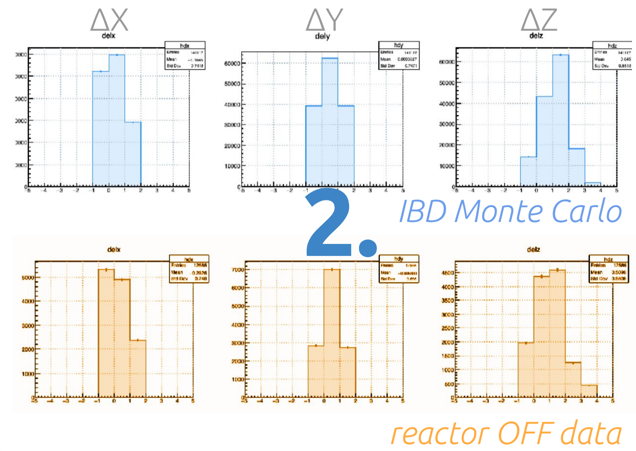


MC/Data comparisons of ΔT, ΔR and prompt E distributions show BiPo background is well understood.

IBD selection cuts

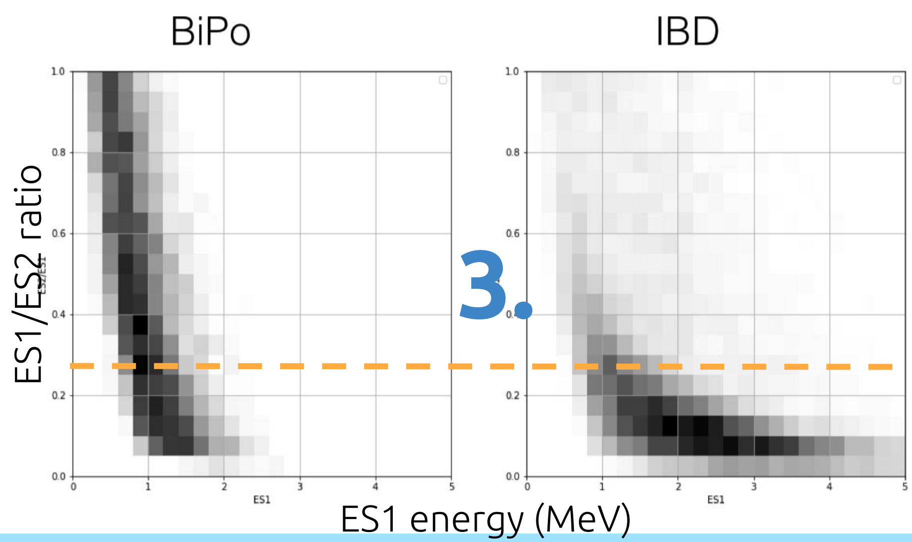






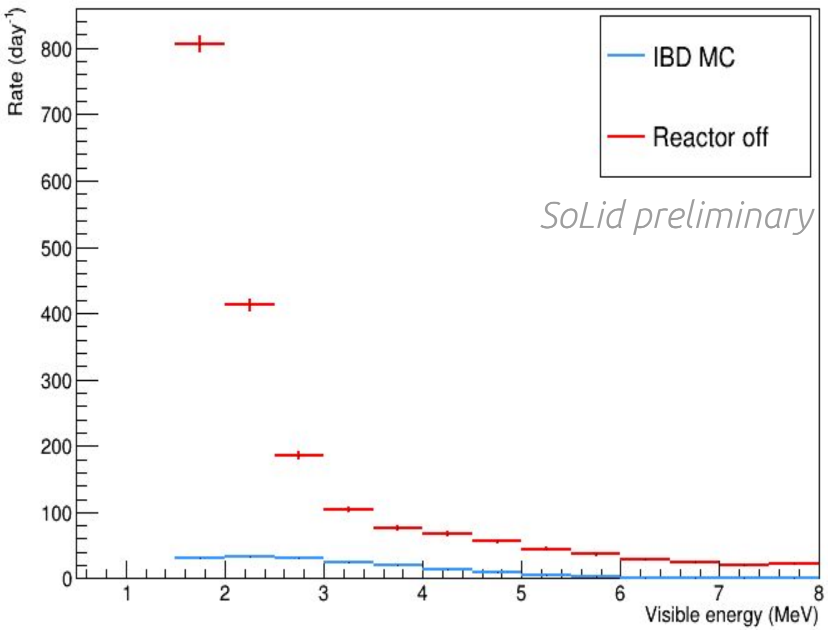
MOST EFFECTIVE:

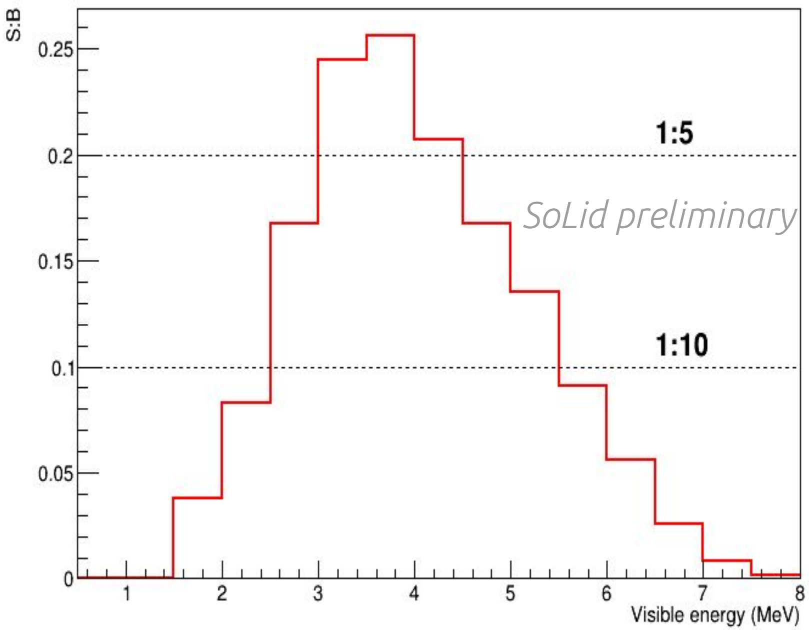
1. PSD for **neutron** & **α** in ZnS
2. Spatial distance between ES and NS (**ΔX, ΔY, ΔZ**)
3. Difference in energy balance between "max E" (ES1) cubes

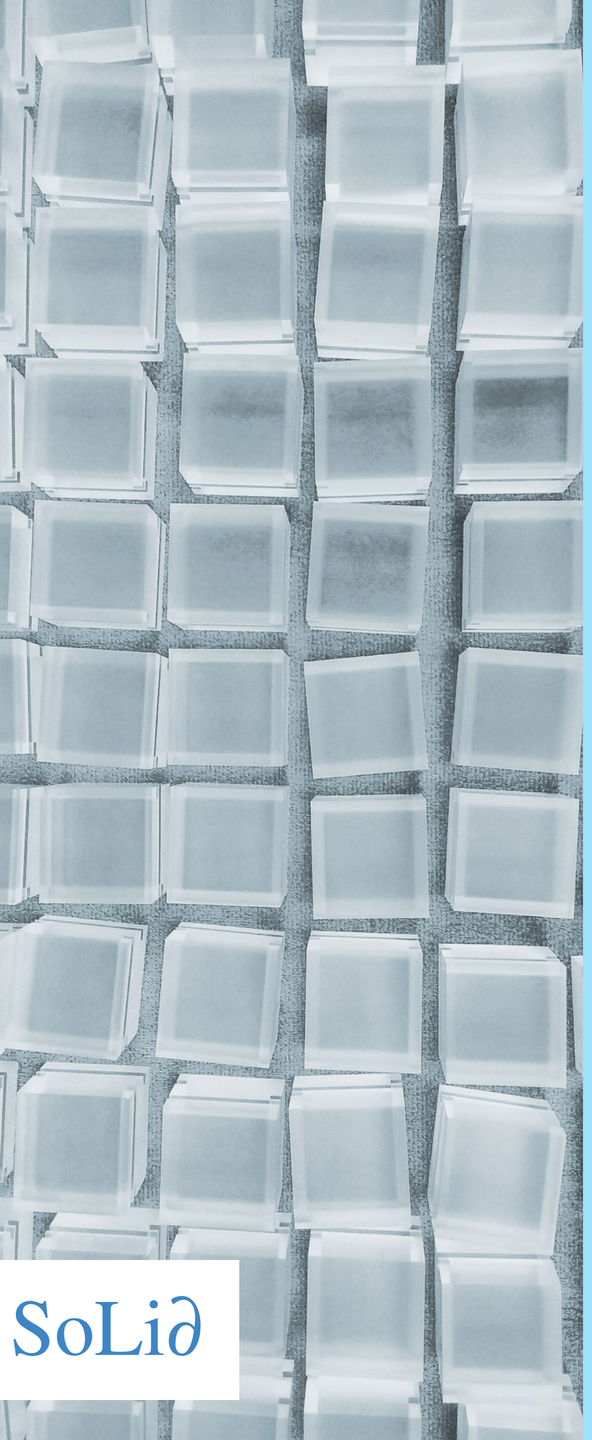


Predicted S:B

- Current cut menu results in IBD efficiency of ~15% ***(WIP!)***
- Signal based on MC calculated number of 1087 IBD interactions/day
- Bg based on 7.28 days of reactor off data







Analysis status

1. Good progress in developing a precise reconstruction and first IBD selection.

2. The data analysis is ongoing and focusses on topological information for background reduction.

3. Expect further improvement on S:B figure with lower energy threshold.

4. Further developing the oscillation and ‘5 MeV bump` analysis.

Thank you for your attention.

Does anyone have any questions?

simon.vercaemer@uantwerpen.be

Credits

The members of the SoLid Collaboration and their institutes.

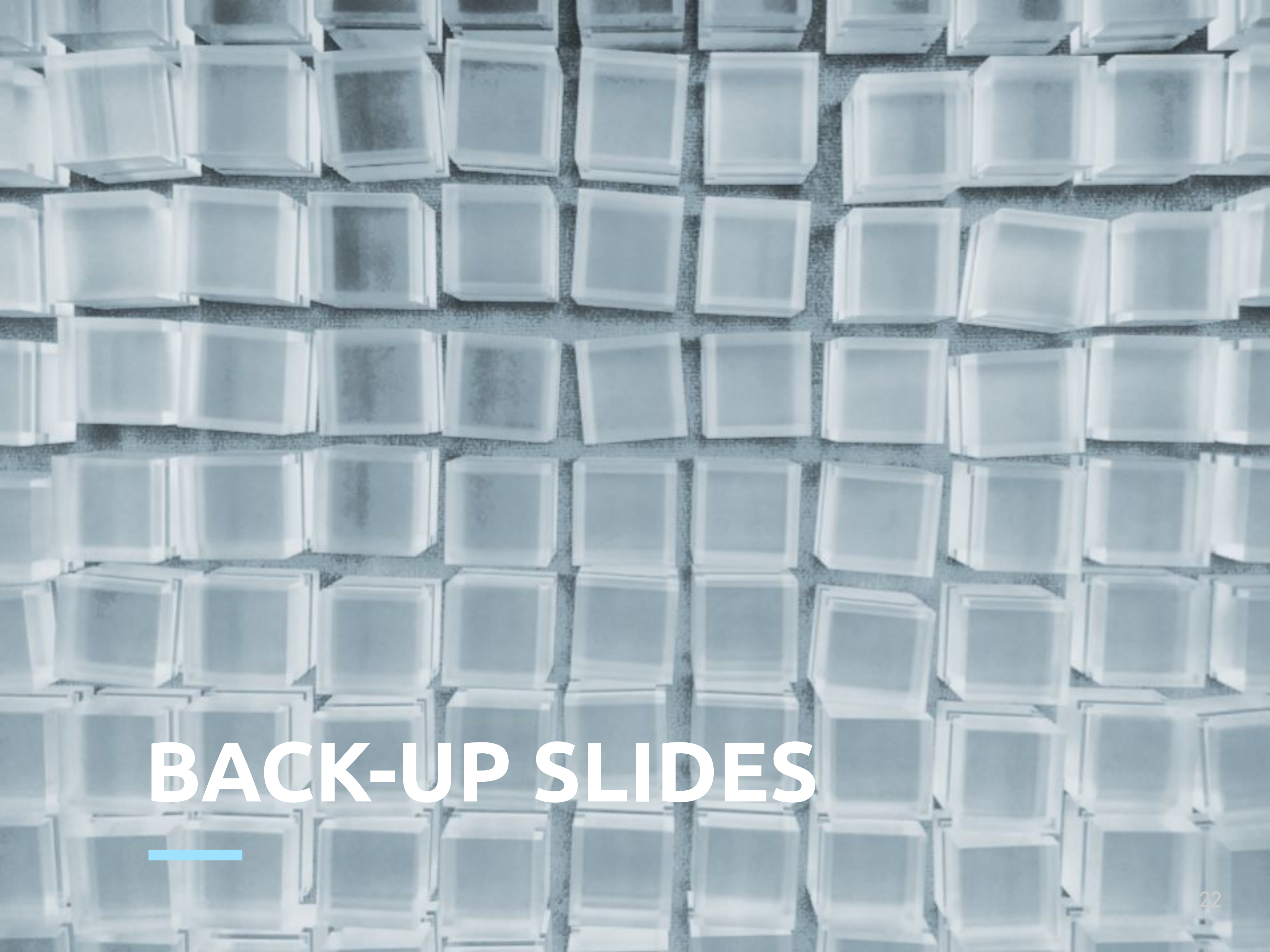
Funded by:

Presentation template by SlidesGo

Icons by Flaticon

Images & infographics by Freepik

First version by Ianthe Michiels



BACK-UP SLIDES

SoLid Phase I Timeline

December 2016

STARTED CONSTRUCTION

JINST 12 P04024

November 2017

DETECTOR SHIPMENT & INSTALLATION AT BR2

December 2017

DETECTOR COMMISSIONING AT BR2 WITH 4 MODULES

JINST 13 P05005

April 2018

START DATA TAKING WITH FULL PHASE I DETECTOR

JINST 13 P09005

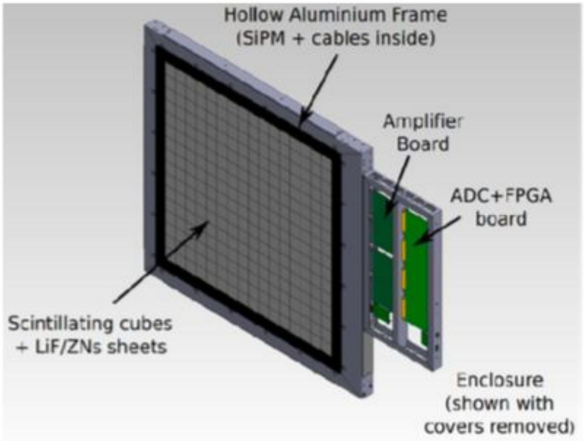
JINST 14 P02014

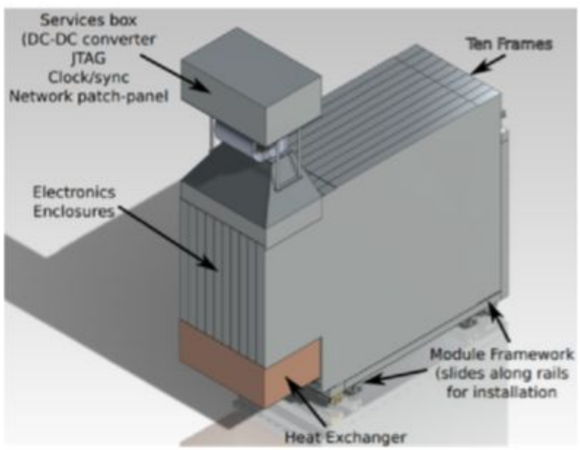
Today

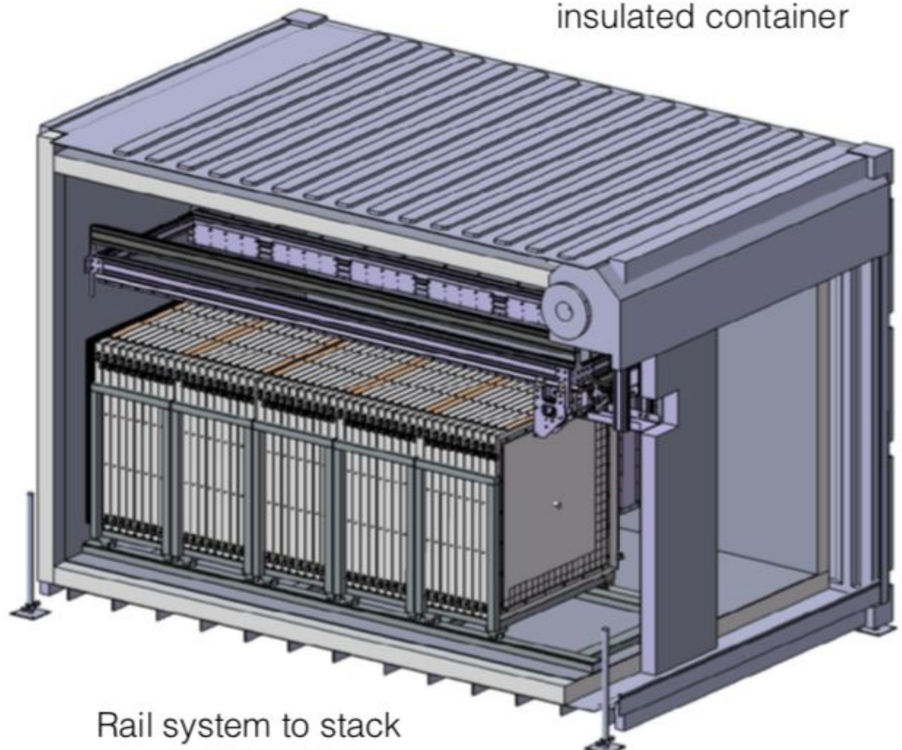
ANALYSIS OF 6 REACTOR CYCLES

Subject	arXiv	Journal
SoLid detector technology	1703.01683	2017 JINST 12 P04024
SM1 prototype performance	1802.02884	2018 JINST 13 P05005
Light-yield optimisation	1806.02461	2018 JINST 13 P09005
SoLid quality assurance	1811.05244	2019 JINST 14 P02014
SoLid readout system	1812.05425	Submitted to JINST

SoLid Publications

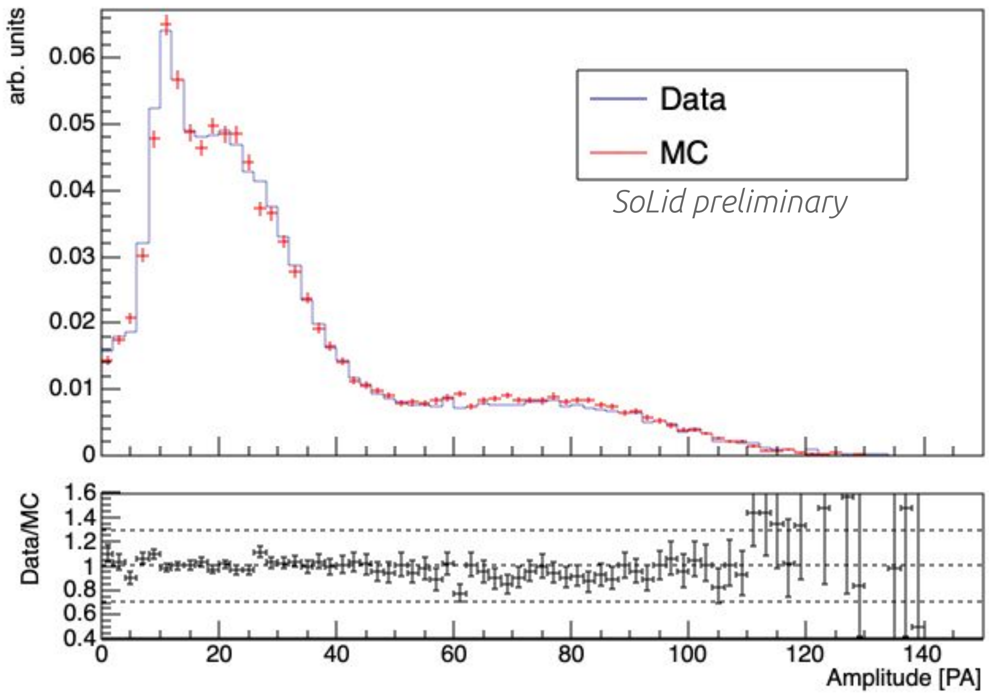






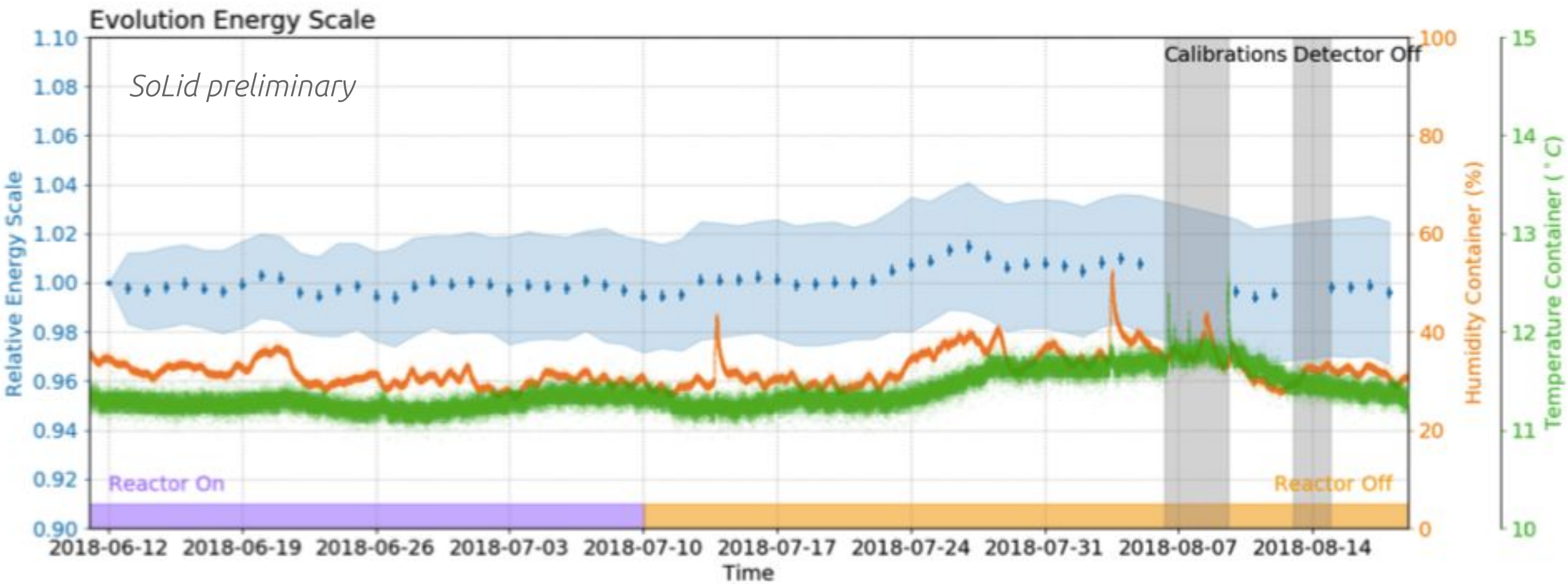
Detector design

Detector energy response



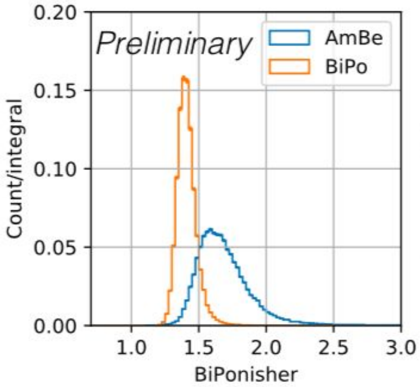
Energy reconstruction and MC simulation validated against calibration runs with ^{22}Na (work in progress).

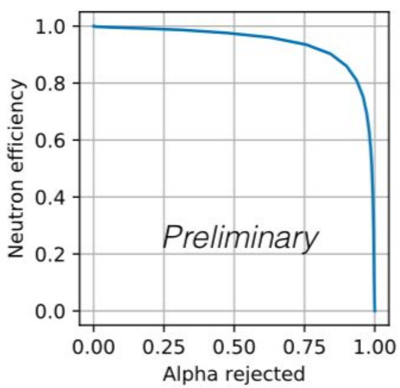
Energy scale stability

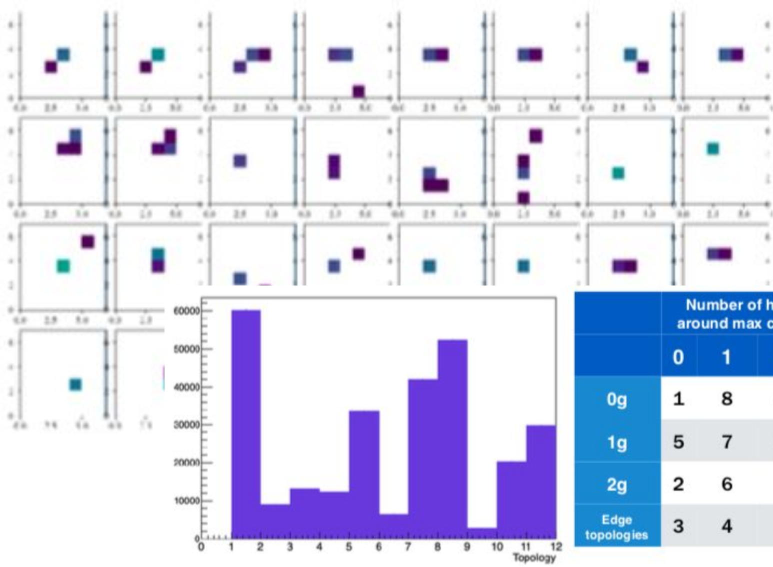


- Based on muon dE/dx distribution (average over full detector)
- Shows good stability of energy scale over data taking period

Main backgrounds







	Number of hits around max cube		
	0	1	2
0g	1	8	11
1g	5	7	10
2g	2	6	9
Edge topologies	3	4	-

BiPo

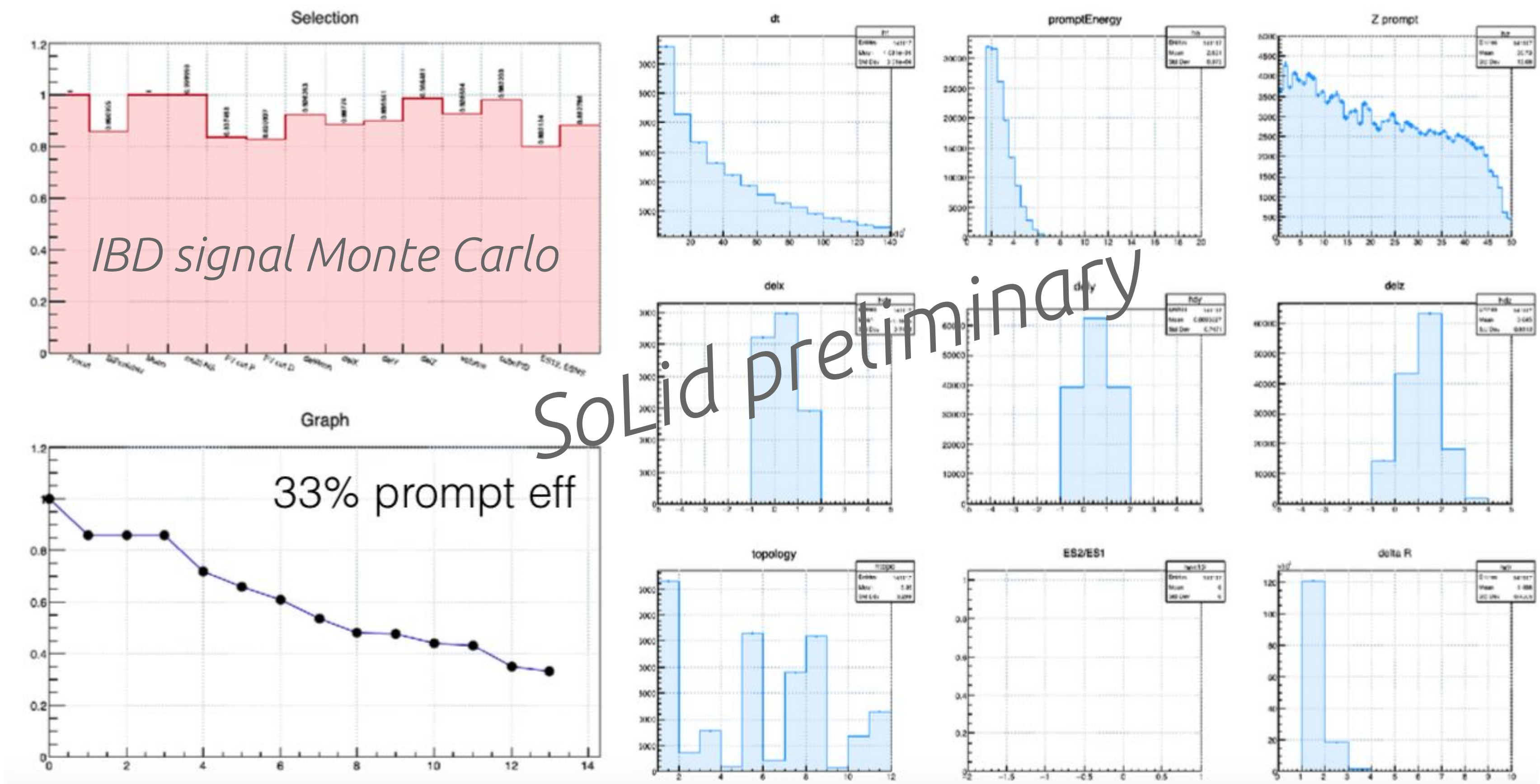
- Contamination from $^{238}U/^{232}Th$ series in LiF:ZnS(Ag) screens:

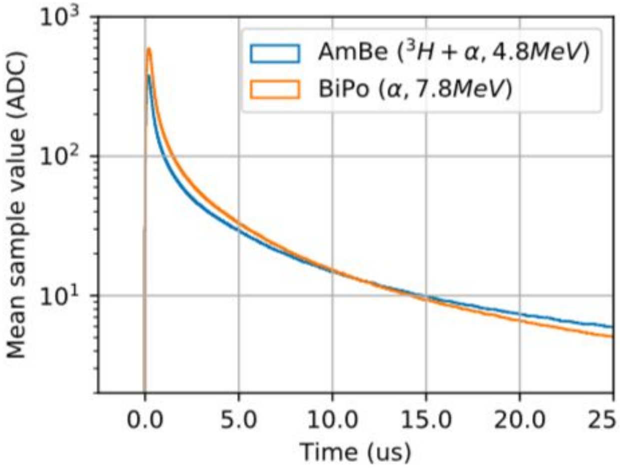
$^{214}Bi \rightarrow {}^{214}Po \rightarrow {}^{210}Pb$
gives β and α with $T_{1/2}(Po)$ = 164 μs

- **Use PSD capabilities of ZnS scintillator for neutron/alpha discrimination**
- **Use difference in signal topologies (i.e. distribution over neighbouring cubes) between IBD and BG events**

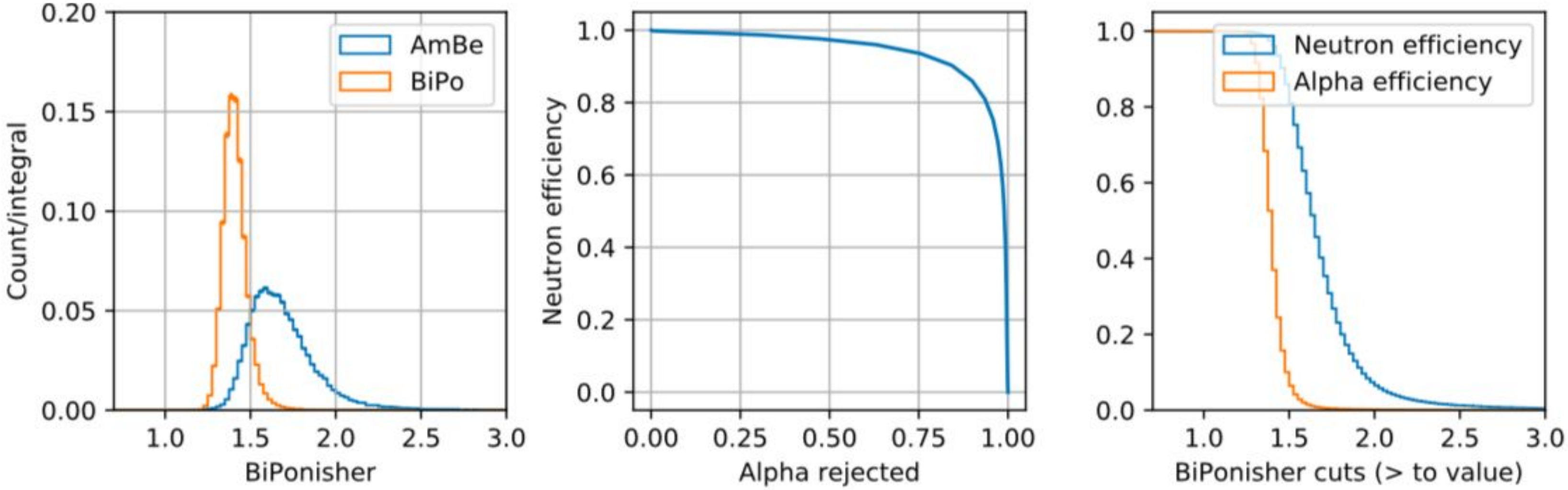
IBD selection cuts

- Muon and NS multiplicity veto
- Δx, Δy, Δz, Δr topological cuts
- 1.5 MeV < prompt E < 20 MeV
- Energy balance + BiPonisher cut
- Fiducial cut on outer layer
- 0 < Δt < 150 μs





- Discrimination between neutron and alpha, based on integral shape from ZnS.
- AmBe data set is taken in a very close volume around the source to increase purity
- BiPo is selected using delta t (side band) and topological cuts.



BiPonisher