Analysis of Neutron Background in the PandaX-II Experiment

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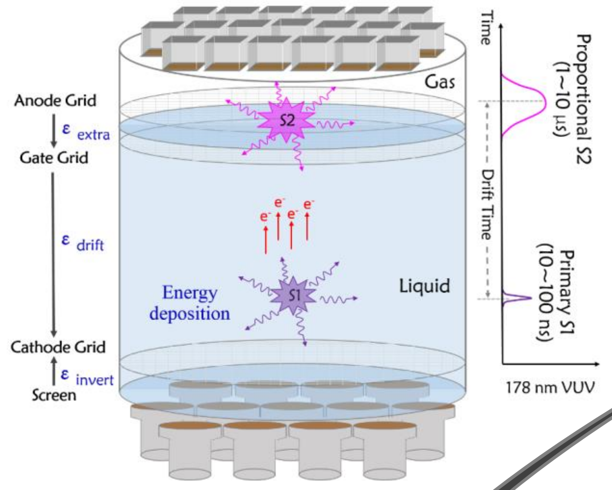
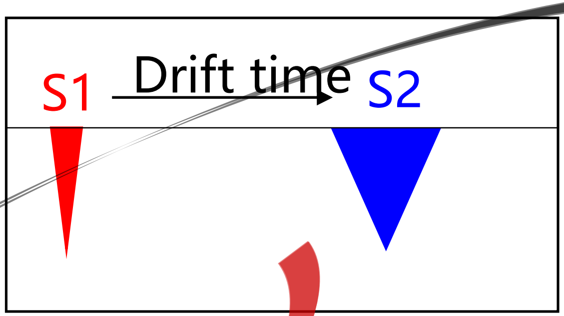
Motivation

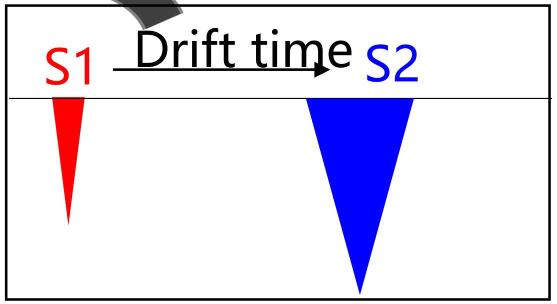
PandaX



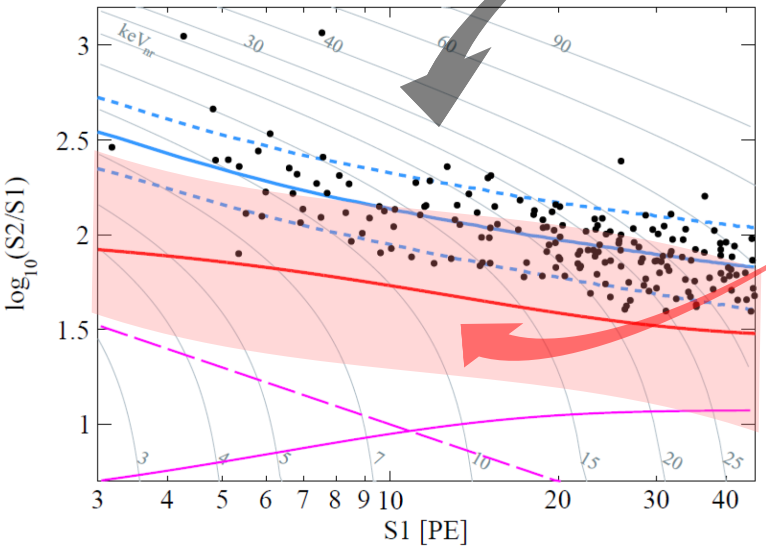
Dark matter & Neutron: nuclear recoil (NR)



γ & β: electron recoil (ER)



$(S2/S1)_{NR} << (S2/S1)_{ER}$



Three backgrounds

- Accidental
- ER: Kr, ^{127}Xe, others
- NR: radiogenic neutrons from detector material
  - (α,n)
  - Spontaneous Fission

resemble DM signals!

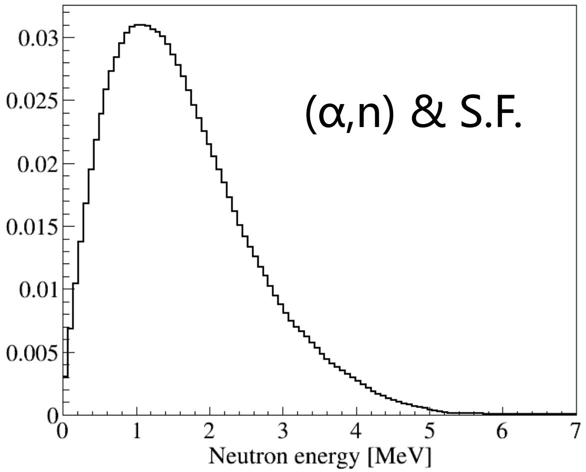
Traditional Calculation for Neutron Background

01 Material Radioactivity ($^{238}U/^{235}U/^{232}Th$)

precise knowledge of the radioactivities of detector materials

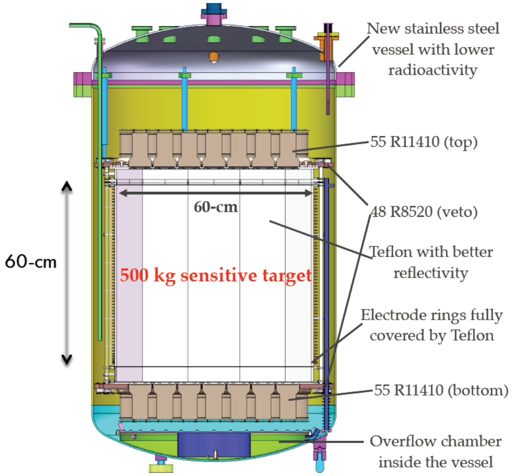
02 Neutron Generator (SOURCES4A)

a model convert material radioactivity to the number of neutrons and their energy spectrum



03 Detector Simulation (Geant4)

describe detailed neutron interactions in the xenon target and calculate the final DM-like background



Some Disadvantages

PandaX

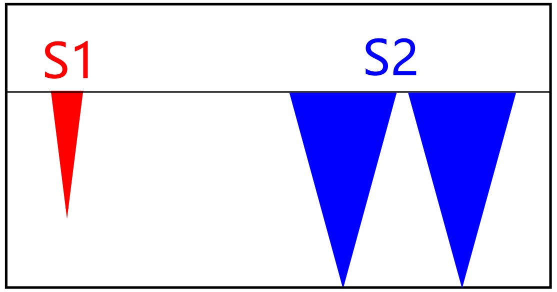
01 Material Radioactivity ($^{238}U/^{235}U/^{232}Th$)

- ❑ Excessive dependence on radioactivity
- ❑ Some samples with large uncertainties
- ❑ Uniformity assumption

02 Neutron Generator (SOURCES4A)

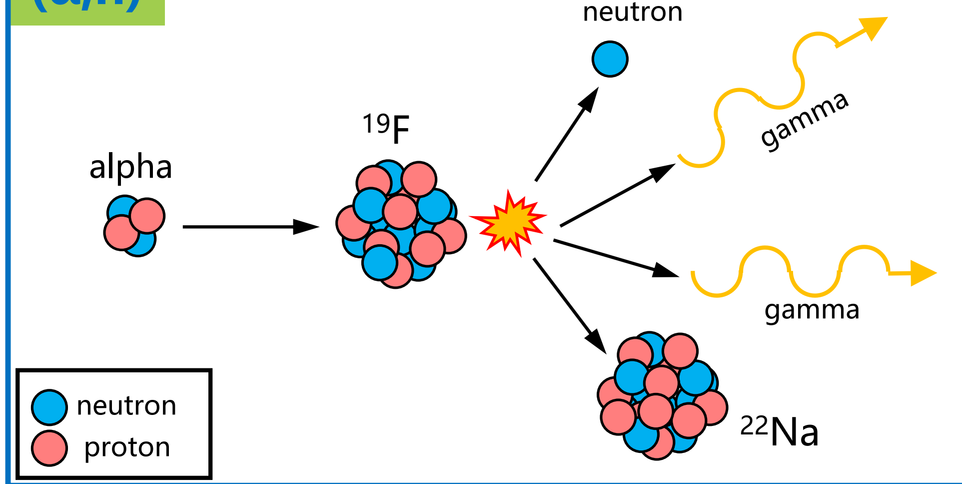
- ❑ Only produce SINGLE NEUTRON spectrum
- ❑ Ignore the correlated emission of neutron(s) and γ(s) in the process of (α,n) and spontaneous fission (SF)
- ❑ Would overestimate low energy background!

Multi-site scattering background (ER or NR)

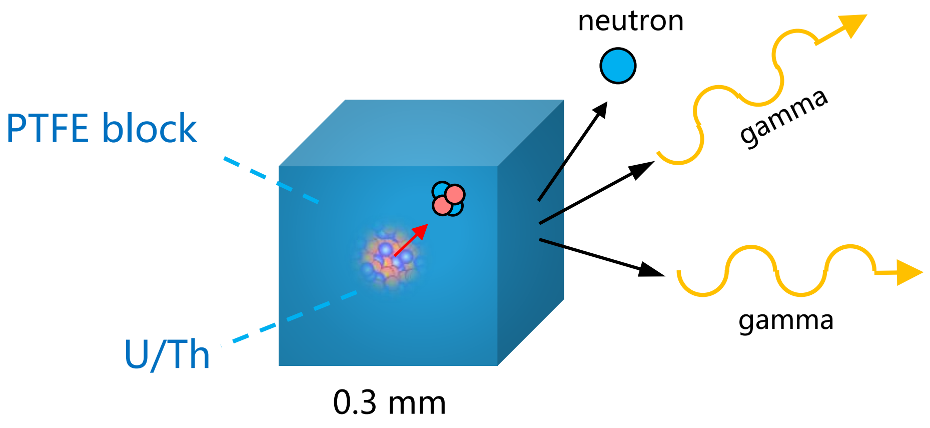


Improvement 1: Neutron-γ-Correlated Generator

(α,n)

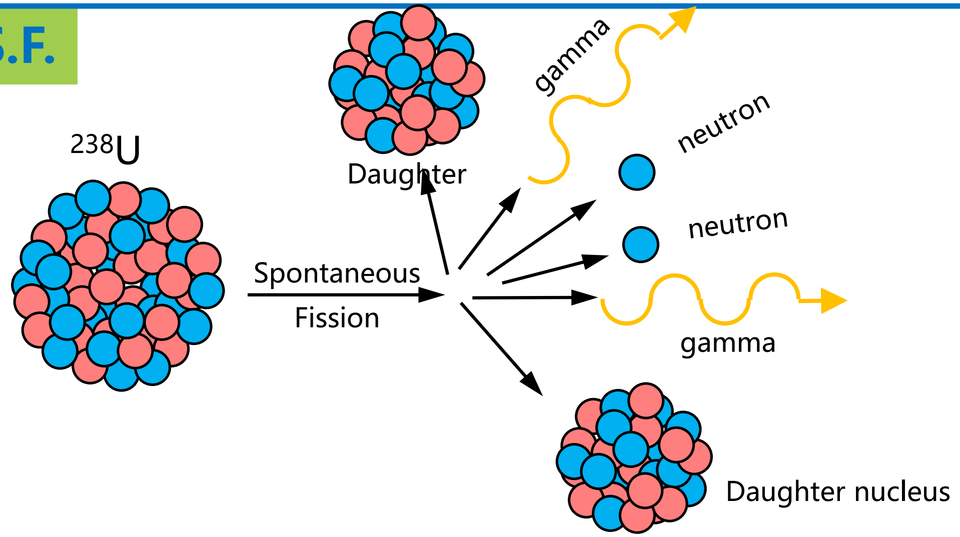


(α,n) Geant4-Based Simulation

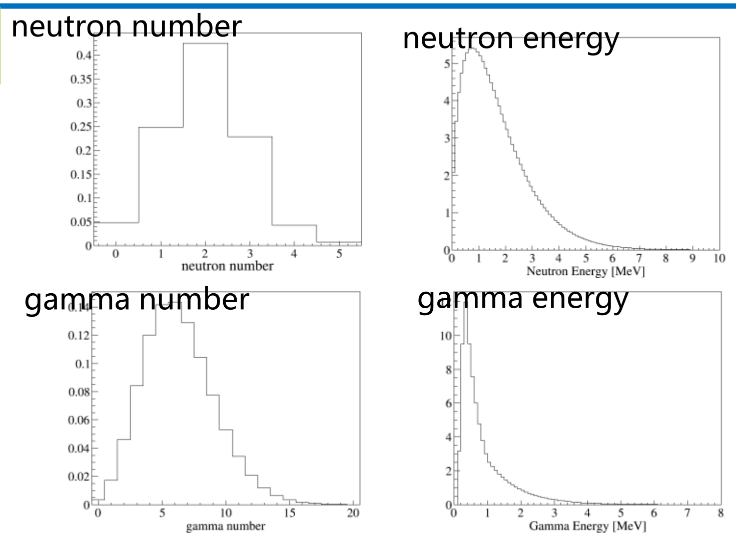


record the energy of single neutron and multiple γ's at the surface

S.F.

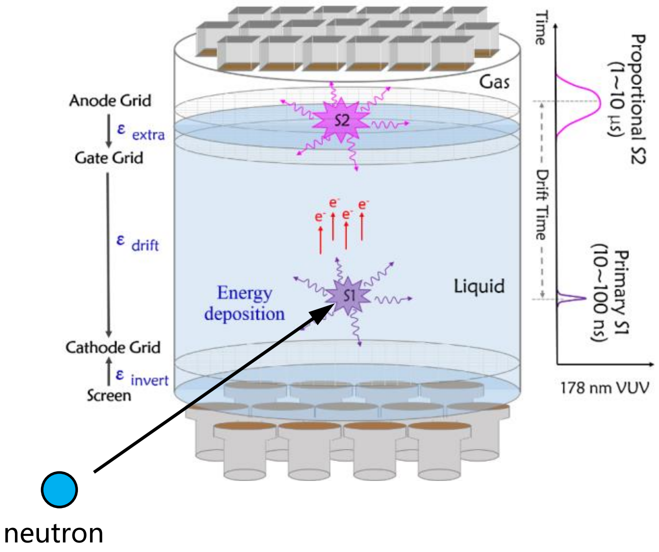


S.F.

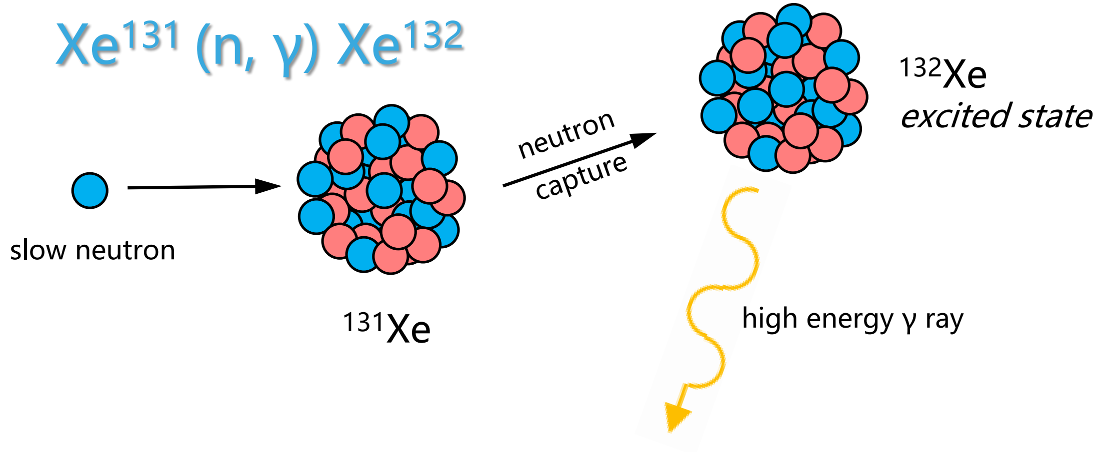


randomly sample neutrons and γ's from the distributions

Improvement 2: Neutron Capture as Data-Driven Method

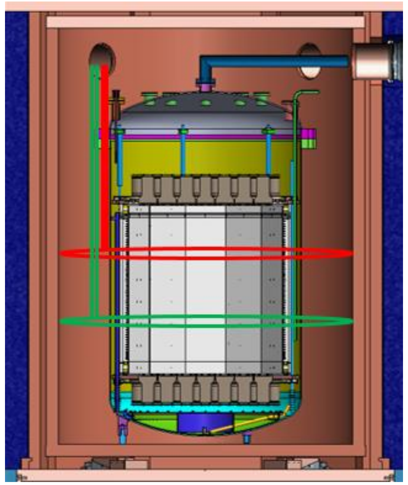


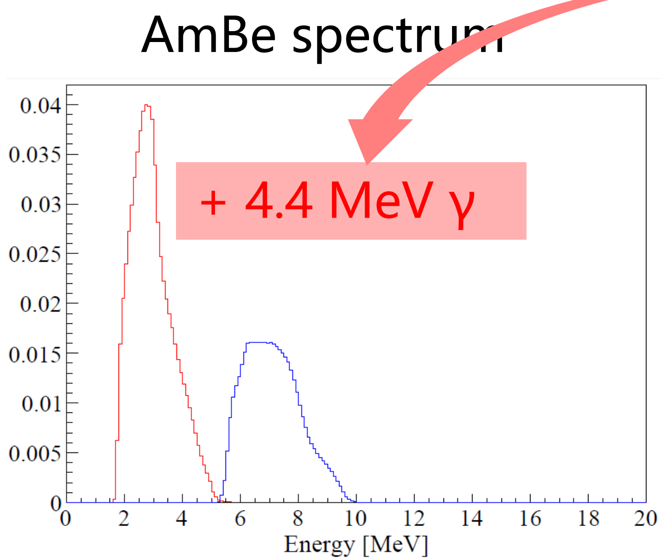
Xe^{131} (n, γ) Xe^{132}

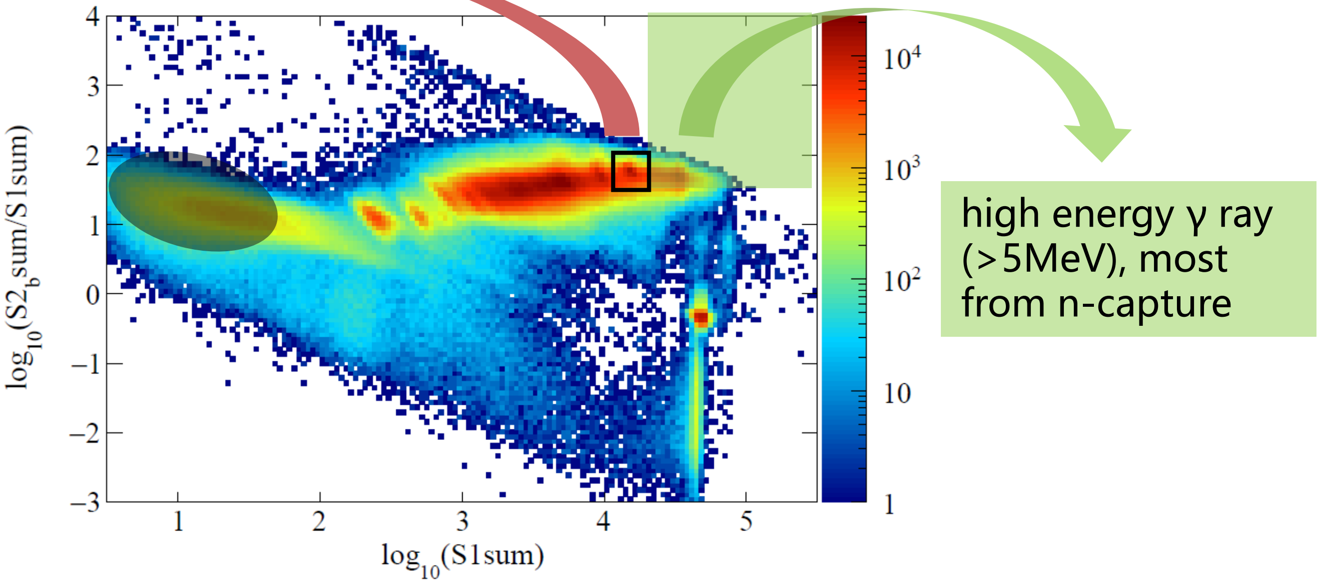


- Use the high energy neutron capture signals in the target xenon as the in situ normalization
- Data-driven method: neutron capture signal → low energy signal
- First use AmBe data to study the features of neutron capture signals

Neutron Capture in AmBe Calibration





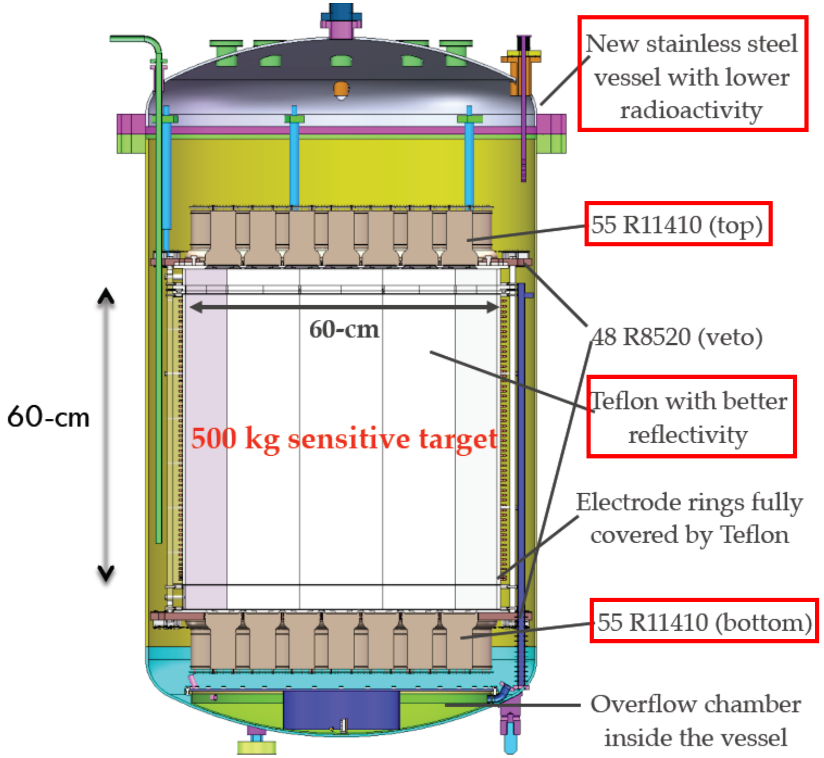


AmBe Run	Data			MC		
	low energy	high energy	Ratio	low energy	high energy	Ratio
Run 9 @P2-Up	3415	48402	1 : 14.2	$13732/10^7$	$259111/10^7$	1 : 18.9
Run 10 @P2-Up	6888	122573	1 : 17.8	$13711/10^7$	$259111/10^7$	1 : 18.9
Run 10 @P2-Down	3502	57578	1 : 16.4	$13852/10^7$	$270572/10^7$	1 : 19.5

- Consistent in the order of magnitude
- Take the difference as the uncertainty for high energy signal selection

Neutron Capture in Material-Neutron-MC

set neutron-γ-correlated generator as sources

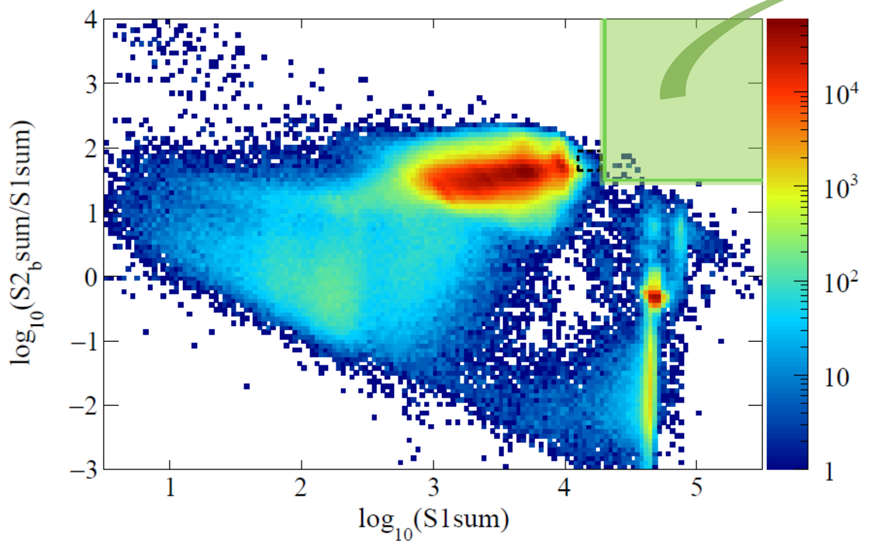


Components	LowE Run 9	LowE Run 10	HighE	Ratio in Run 9	Ratio in Run10
Total PTFE	$1.88 \cdot 10^{-3}$	$2.03 \cdot 10^{-3}$	$6.91 \cdot 10^{-2}$	1 : 36.8	1 : 34.1
Inner Vessel	$3.34 \cdot 10^{-4}$	$3.50 \cdot 10^{-4}$	$3.31 \cdot 10^{-3}$	1 : 9.9	1 : 9.5
PMT Stem	$1.21 \cdot 10^{-4}$	$1.63 \cdot 10^{-4}$	$1.51 \cdot 10^{-3}$	1 : 12.5	1 : 9.3
PMT Window	$5.44 \cdot 10^{-6}$	$6.88 \cdot 10^{-6}$	$4.78 \cdot 10^{-4}$	1 : 88.0	1 : 69.5
Total	$2.34 \cdot 10^{-3}$	$2.55 \cdot 10^{-3}$	$7.44 \cdot 10^{-2}$	1 : 31.8	1 : 29.2

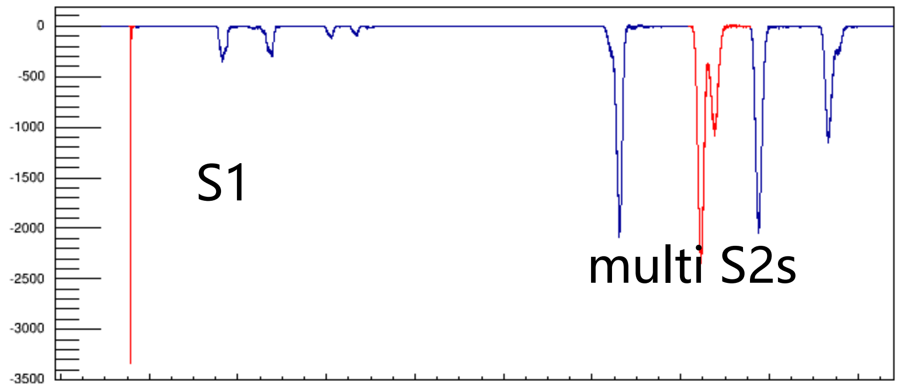
- The ratio between low energy background and high energy neutron capture signals is ~ 1:30
- The uncertainties are taken from AmBe calibration, 25% in Run 9 and 16% in Run 10.

Neutron Capture Signals & Background in DM Runs

Run 10 DM band



waveform



- 17 n-capture signals in Run 9 and Run 10 respectively
- Neutron background in Run 9 = $^{17}/_{31.8}$ = 0.53 count
- Neutron background in Run 10 = $^{17}/_{29.2}$ = 0.58 count
- Statistical uncertainty = $^{1}/_{\sqrt{17}}$ = 24%

Summary

- Updated neutron generator: neutron(s)-γ(s) correlation
- Use high energy neutron capture signals as the normalization for neutron background
- More accurate evaluation:

EVALUATION METHOD	Run 9 DM (stat+sys)	Run 10 DM (stat+sys)
Traditional Method	0.85 (50%)	0.83 (50%)
Improved Method Here	0.53 (35%)	0.58 (29%)

Thank you for your attention!