Event Selection and Reconstruction in PandaX

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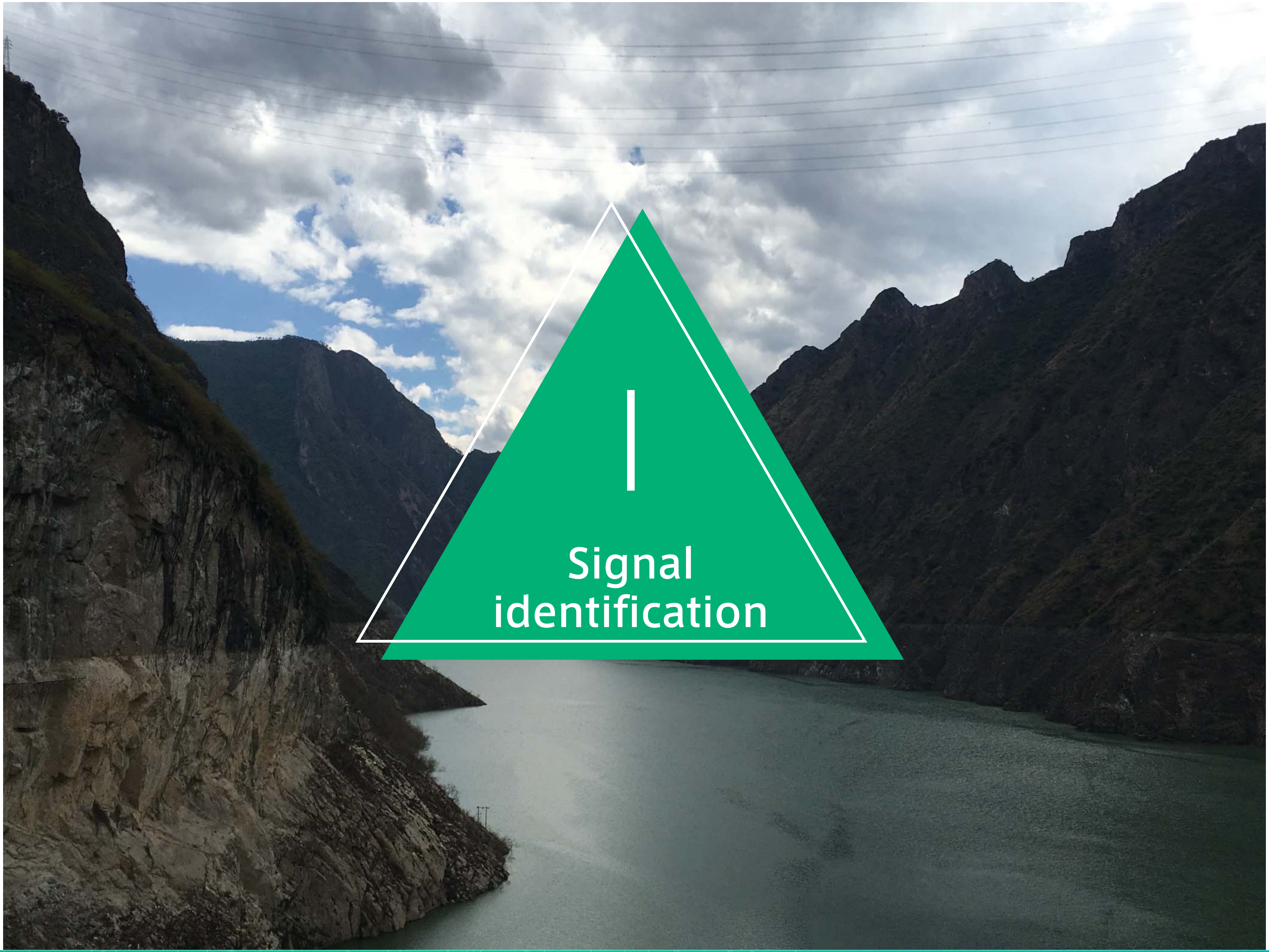
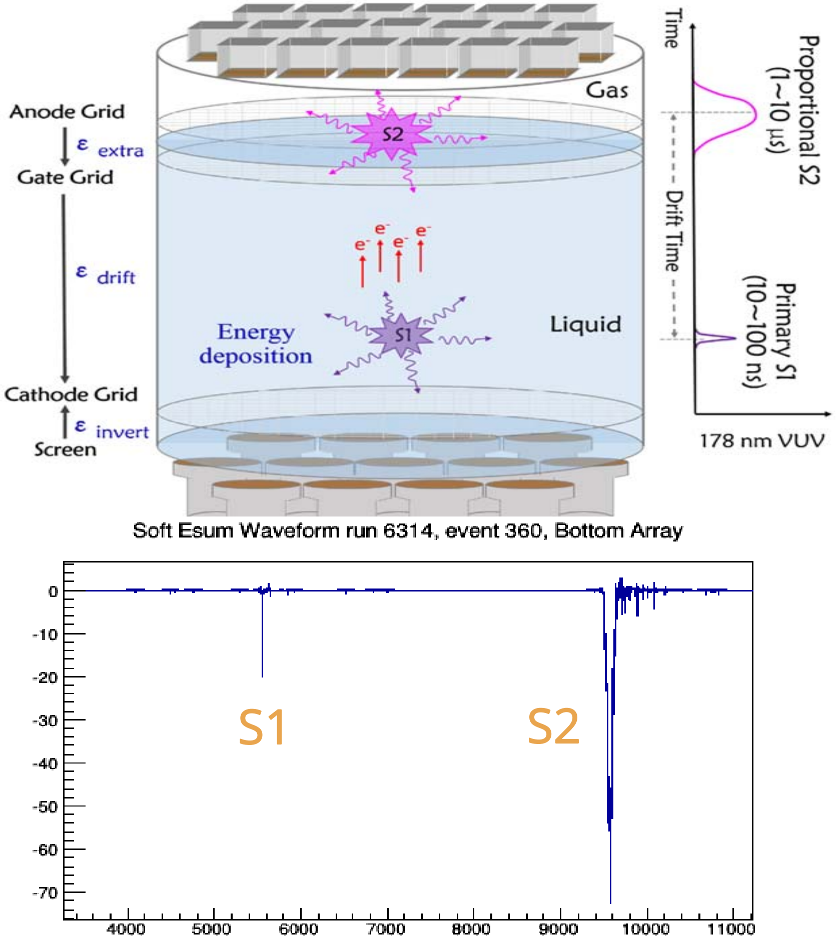
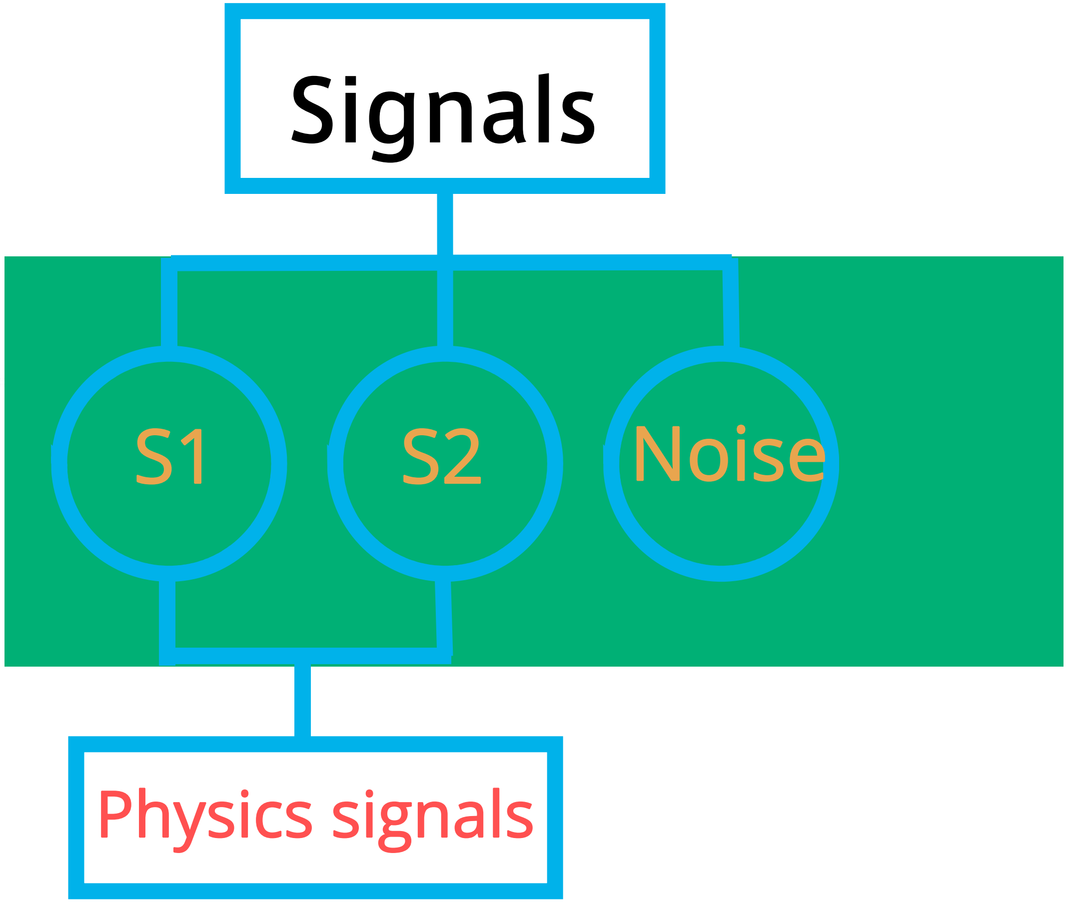


I

Signal identification

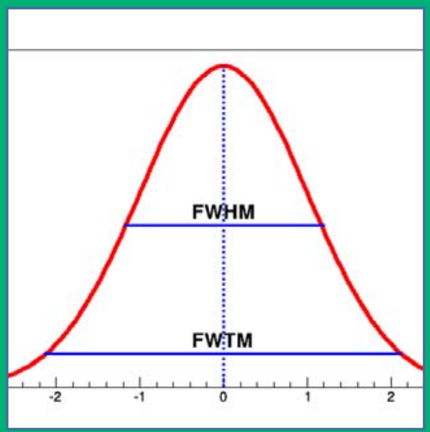
01 SIGNAL IDENTIFICATION



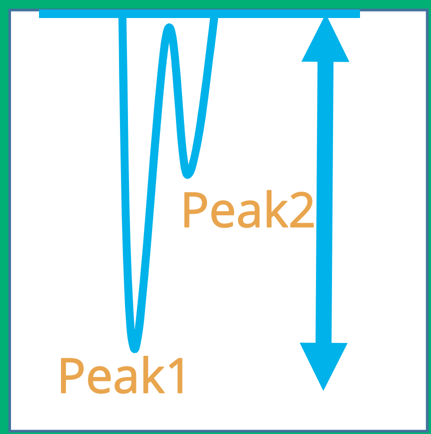


01 S1/S2 DIFFERENTIAL VARIABLES

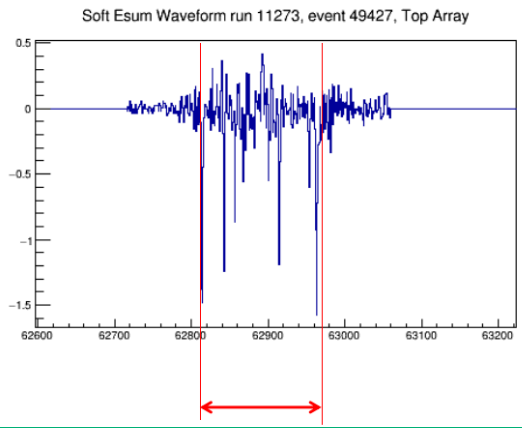
10% Width



Spikes

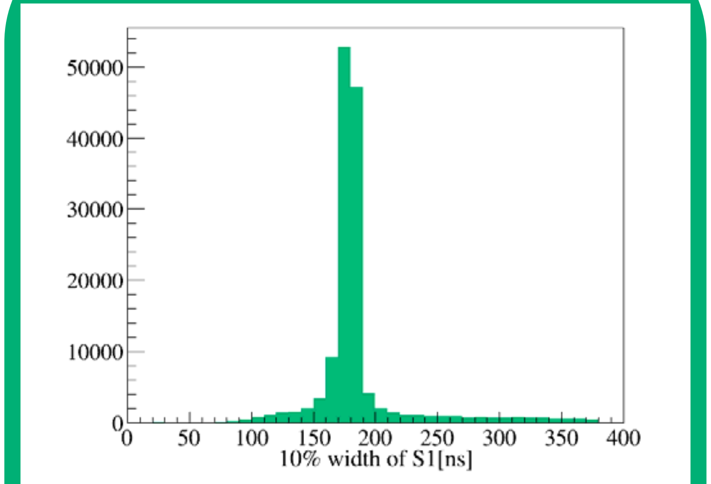


Single electron S2

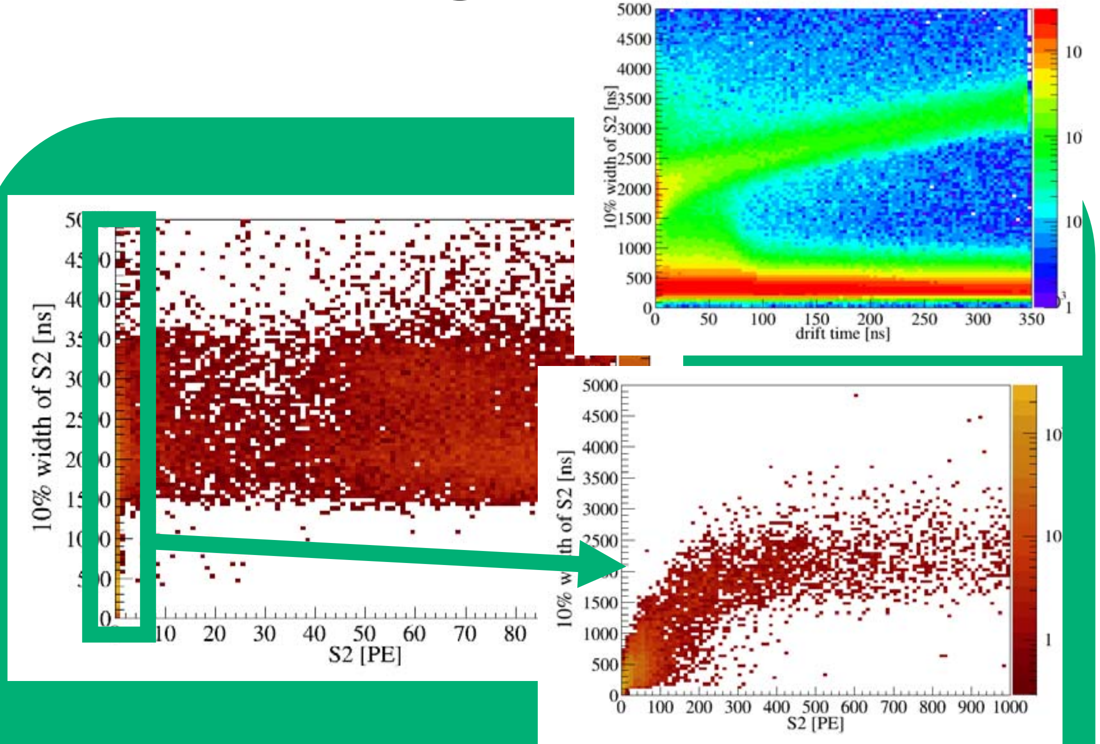


- Normally, S1 is narrow than S2.
- For small S2, use number of spikes to identify them.

01 S1/S2 DISCRIMINATION



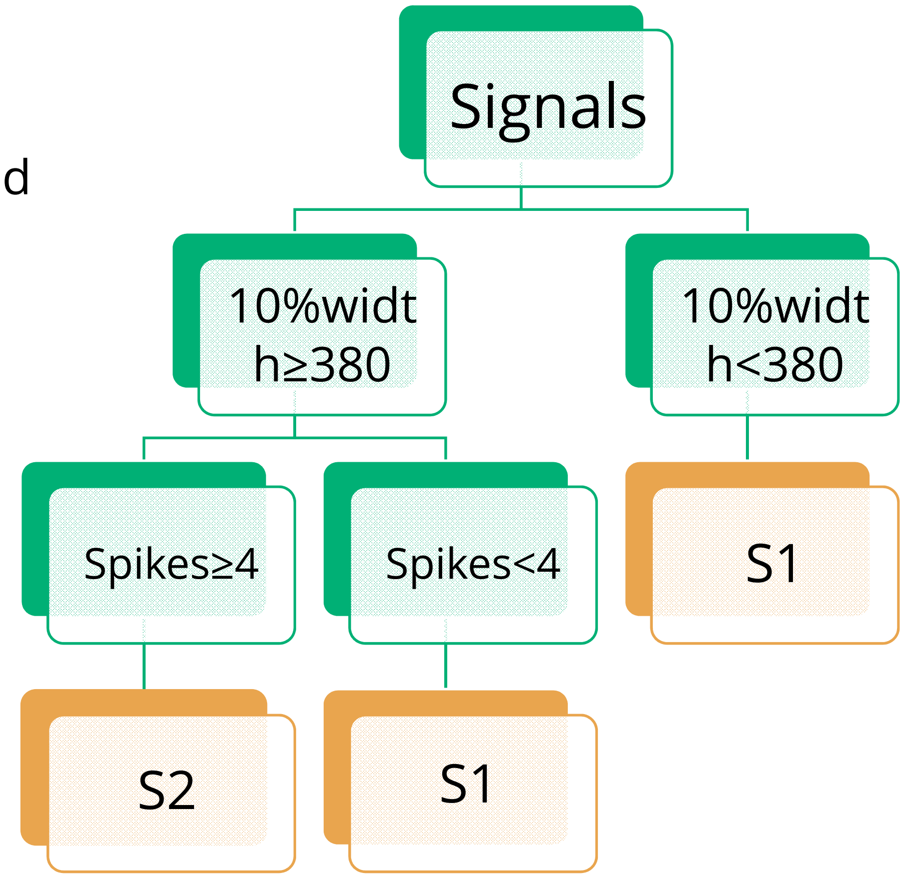
10% width of S1 centers at ~180ns



S2 width correlate with drift time and gas gap. For small s2, the 10% width do not work anymore.

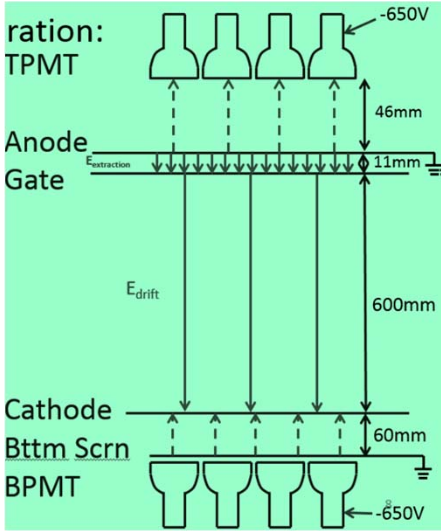
01 S1/S2 DISCRIMINATION

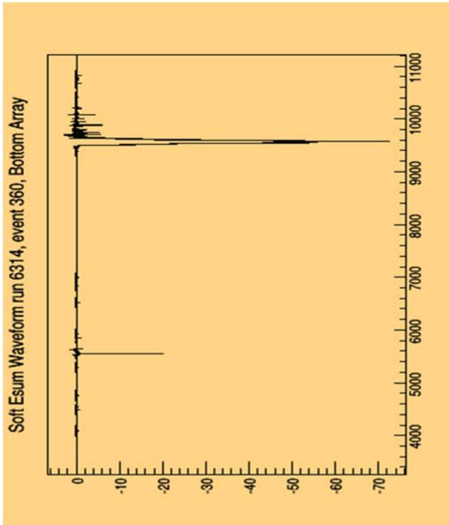
Using ~2000 manually tagged events.
Binary decision tree.
Discrimination power>99.9%

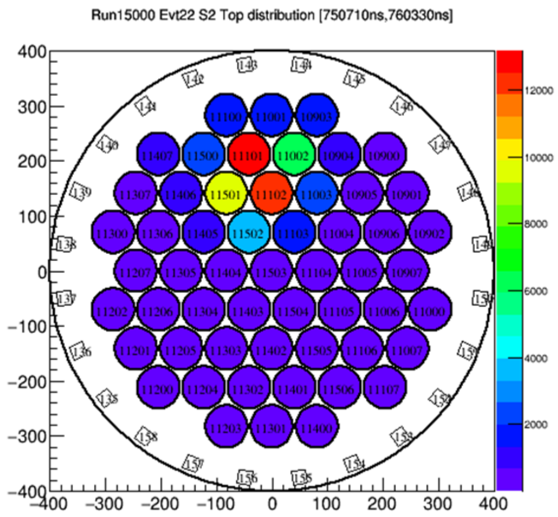


2 Position reconstruction

02 Position Reconstruction







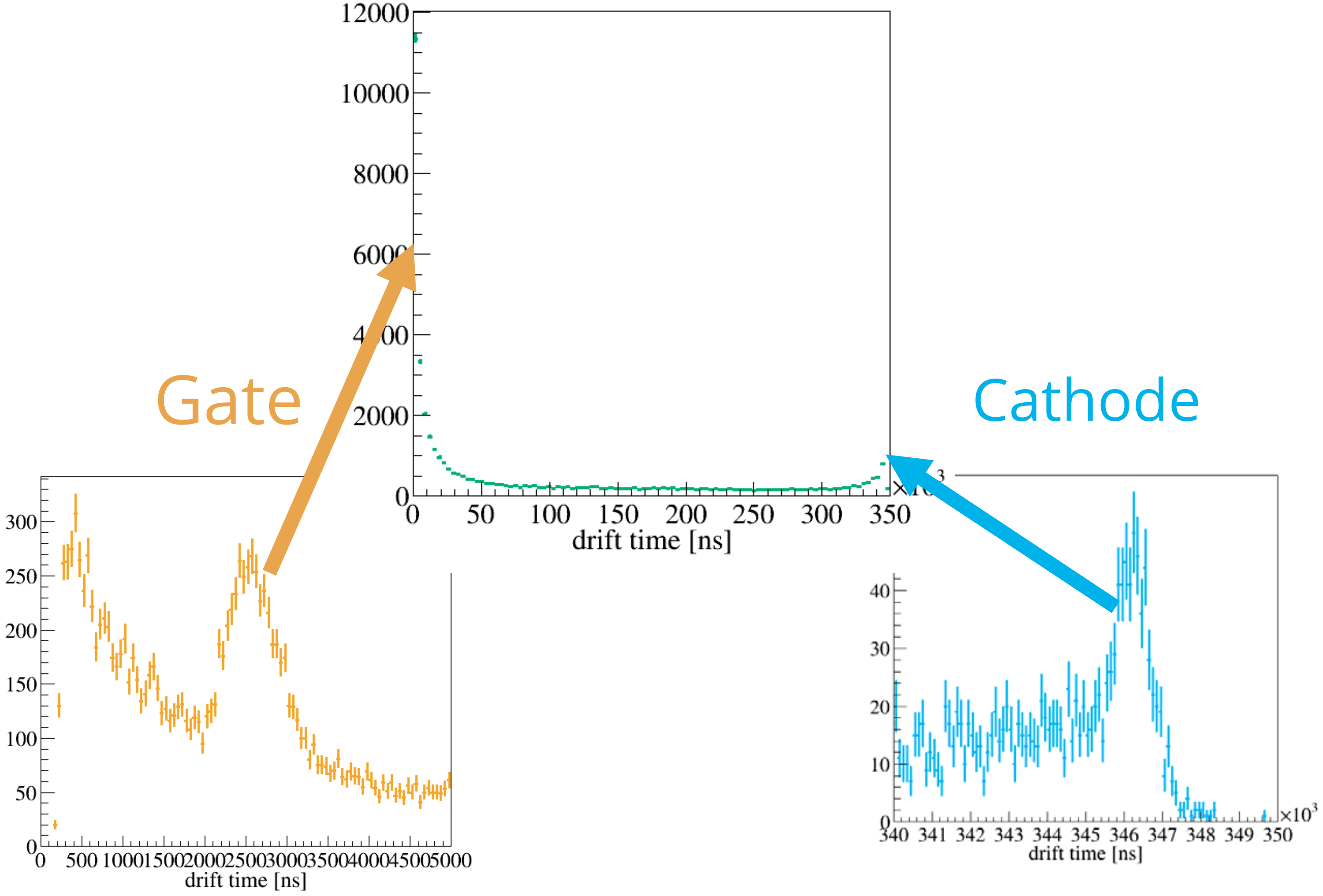
Z: Separation between S2 and S1

X,Y: Center of Gravity

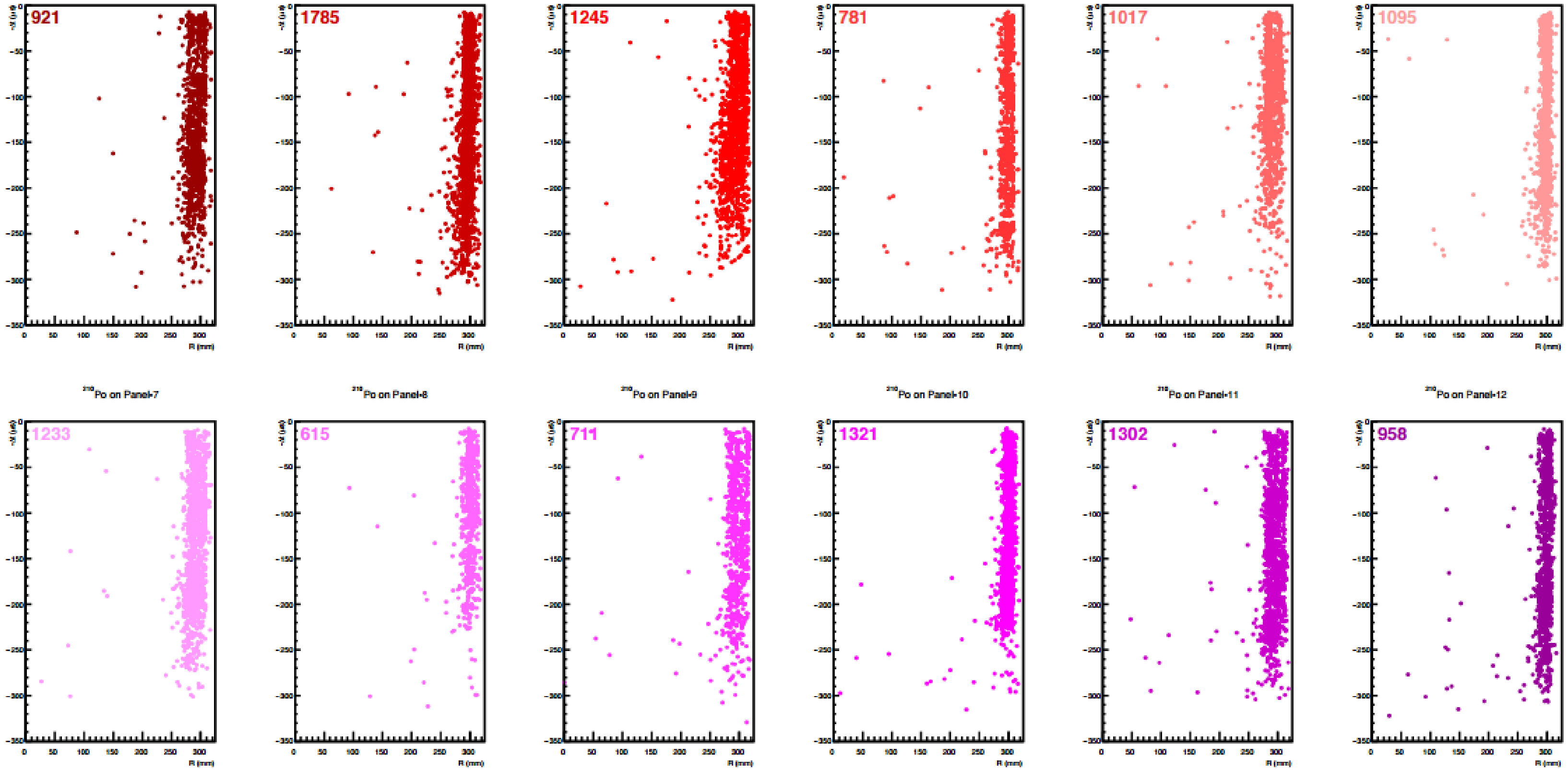
X,Y: Template Matching

X,Y: Photon acceptance function

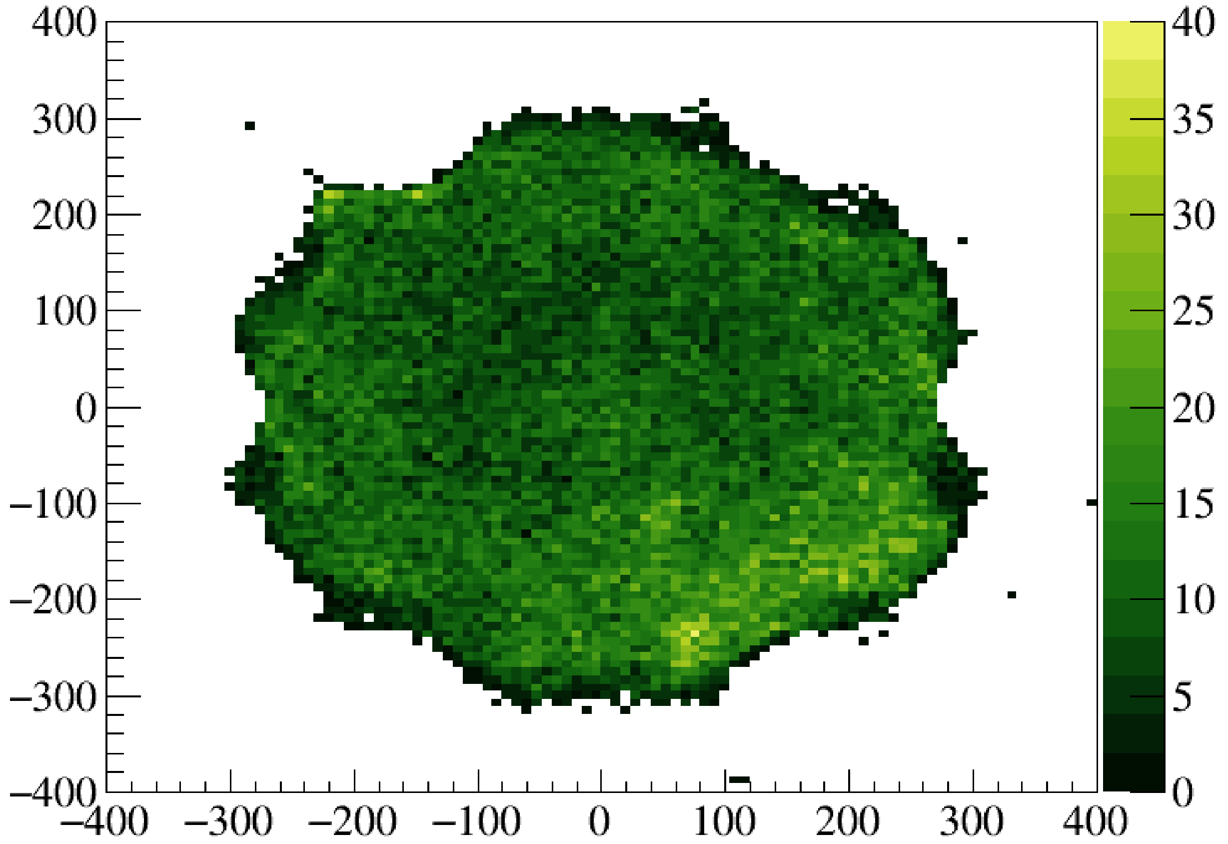
02 DRIFTTIME



^{210}Po ON TEFLON WALL



02 CENTER OF GRAVITY

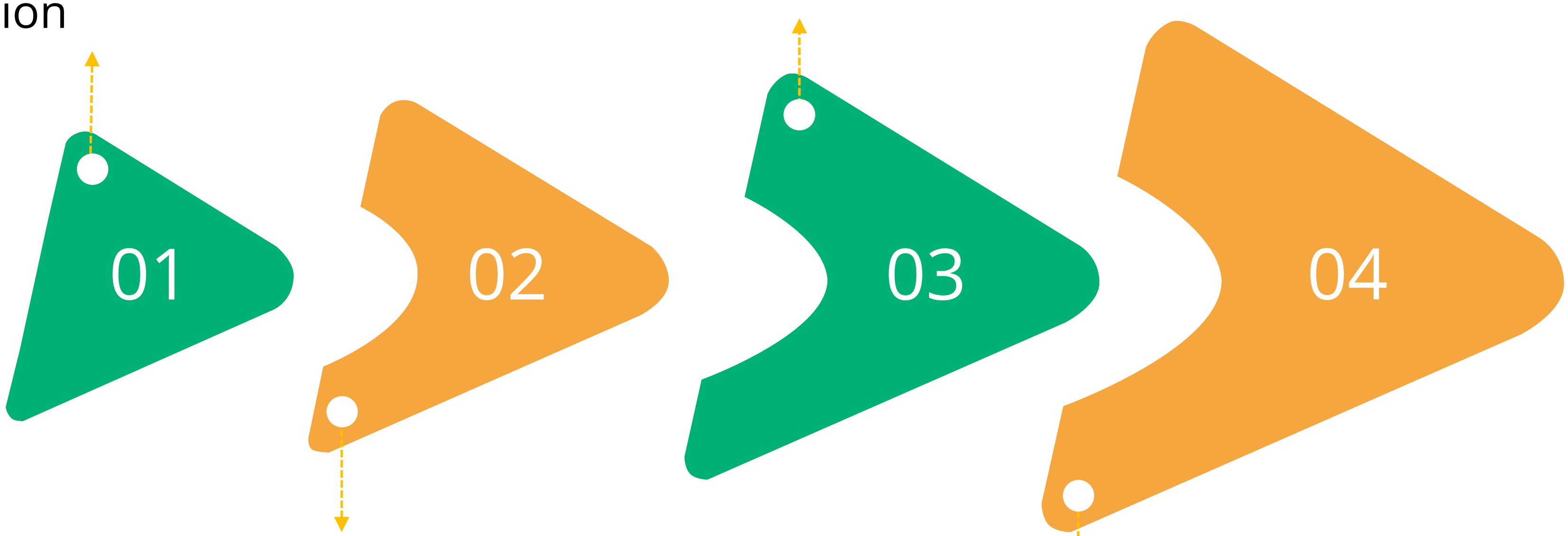


Poor resolution！

02 TEMPLATE MATCHING

Generate massive templates from light simulation

Find the maximum likelihood number

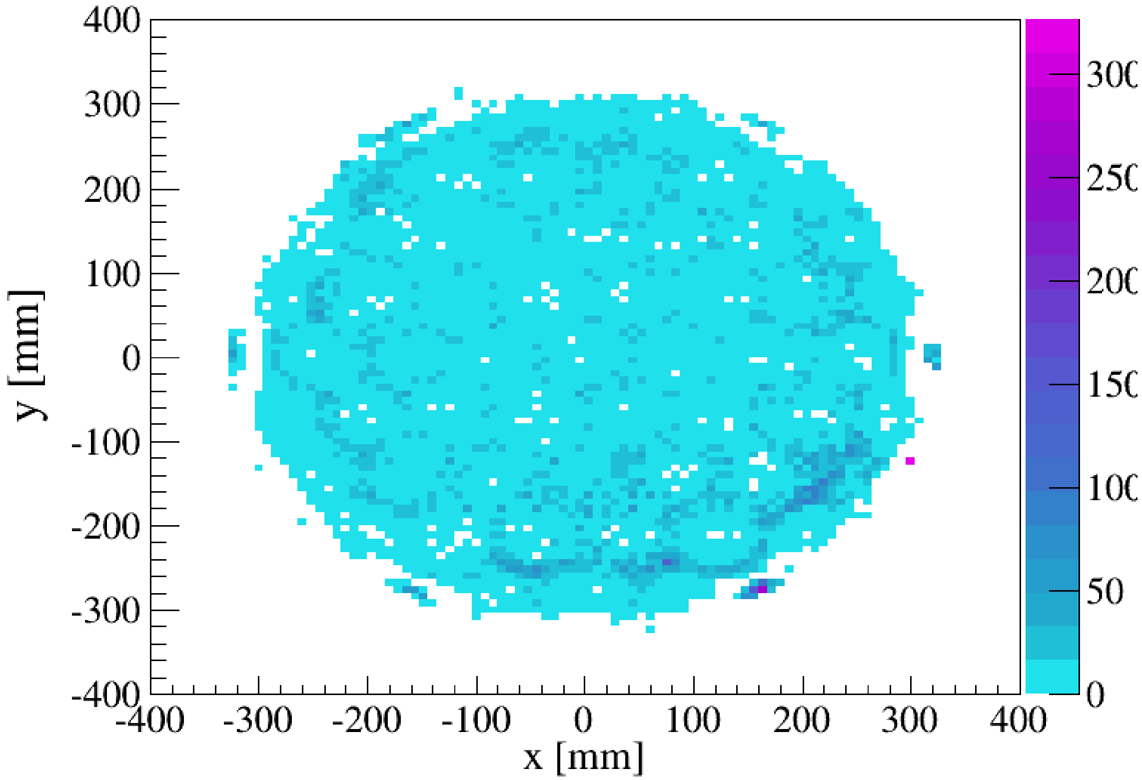


Construct likelihood function

$$L(p_i; n_i) = \prod_{i=1}^{r} p(n_i) = \prod_{i}^{r} \frac{e^{-Np_i}(Np_i)^{n_i}}{n_i!}$$

Interpolation

02 TEMPLATE MATCHING



Poor construction for fringe events.

5.5mm for S2~1000PE

Was selected in phase-i(1-inch PMTs in top array)

02 PHOTON ACCEPTANCE FUNCTION

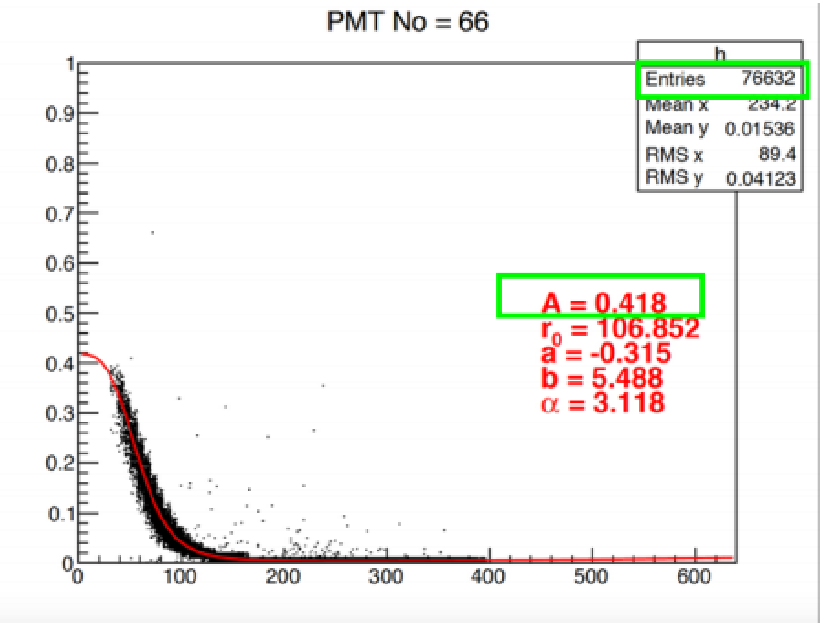
Difficulties for position construction

1 **3" PMT**

optimizing photon collection, but naively causing coarse quantization

2 **Complicated optics**

particularly due to the photon reflections on the PTFE reflector



Procedures for PAF

1) Fit function for PAF, the input position is from COG

$$\eta(r) = A \cdot \exp\left(-\frac{a \cdot \rho}{1+\rho^{1-\alpha}} - \frac{b}{1+\rho^{-\alpha}}\right), \quad \rho = \frac{r}{r_0}$$

02 PHOTON ACCEPTANCE FUNCTION

2) Maximum likelihood to determine a new position

3) Iterations

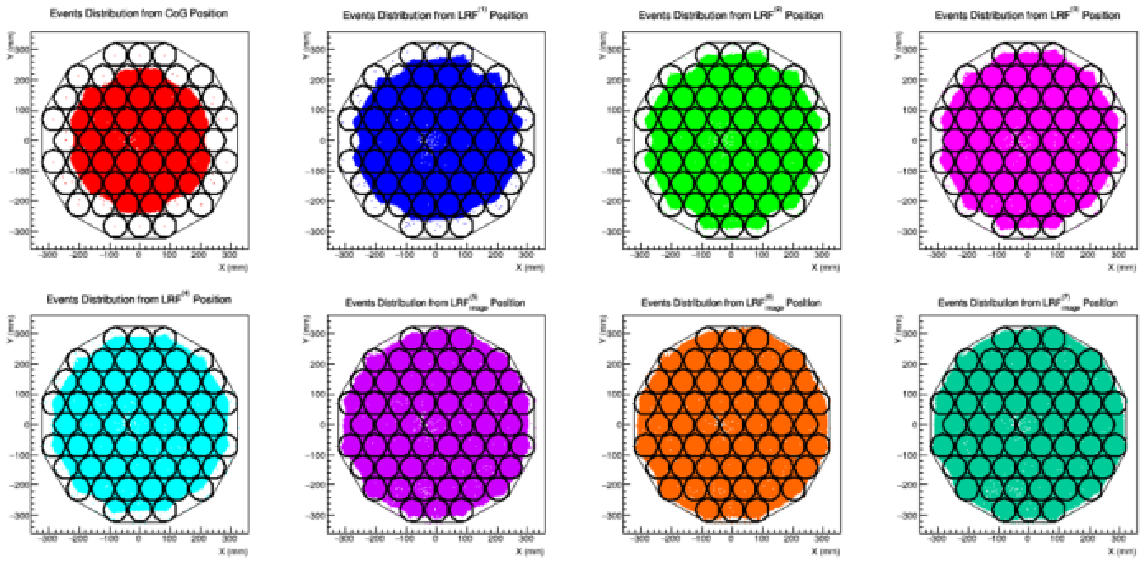
$$\vec{r}^{(0)} = \vec{r}_{\mathrm{CoG}}$$

$$\eta_i^{(1)} \rightarrow \vec{r}^{(1)}$$

$$\eta_i^{(2)} \rightarrow \vec{r}^{(2)}$$

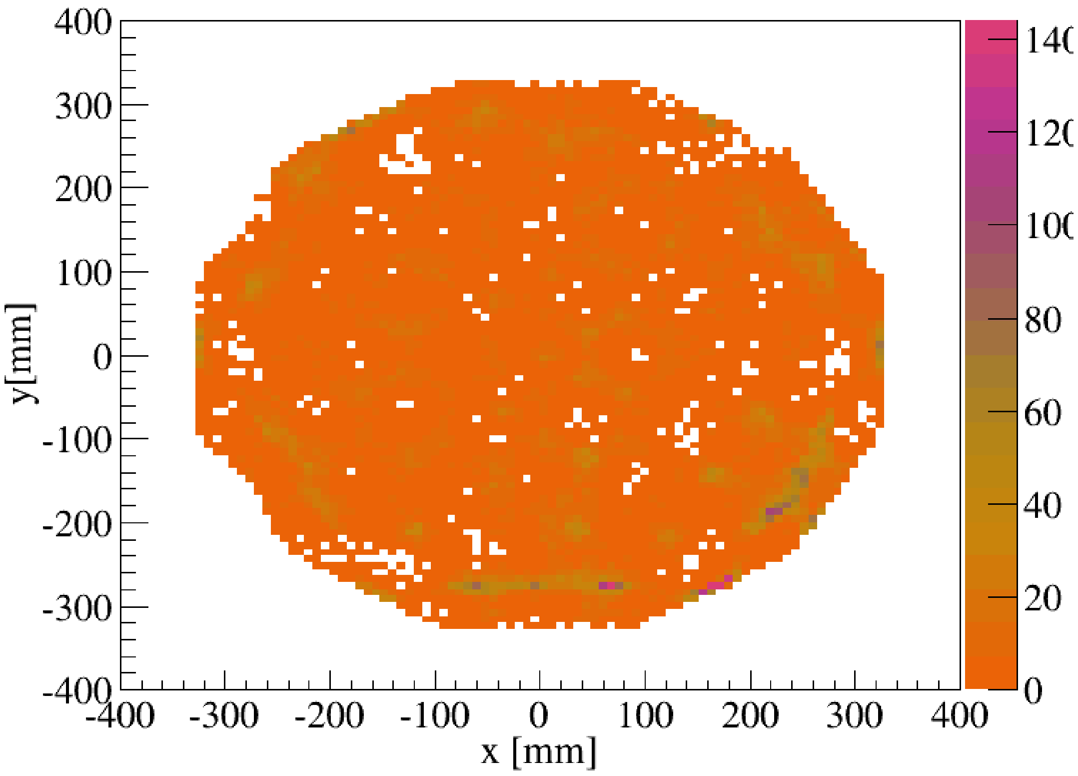
$$\vdots$$

Converge



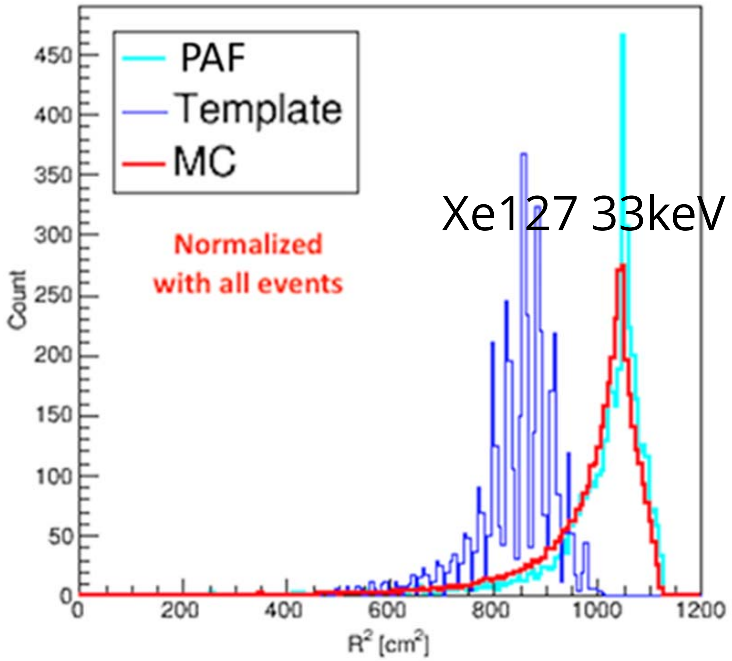
V. N. Solovov *et al*, *IEEE* doi: 10.1109/TNS.2012.2221742

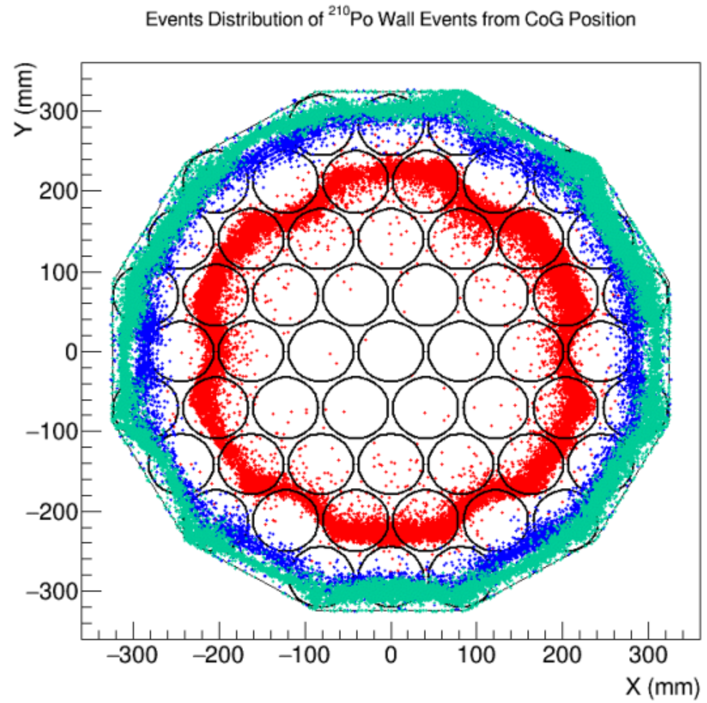
02 PHOTON ACCEPTANCE FUNCTION



With consideration of reflection.

02 COMPARISION OF THREE WAYS





Choose PAF!

To be improve: fix saturation.

3

Noise filters

03

QUALITY CUTS

Reject runs with shot runtime, hot spot etc.

Manually remove files with abnormal trigger rate, dark rate and efficiency

Remove triggers within 10 ms to previous triggers

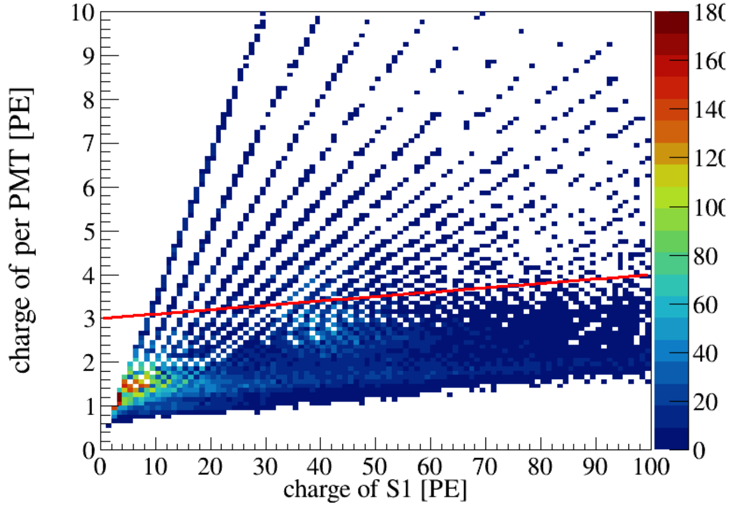
03

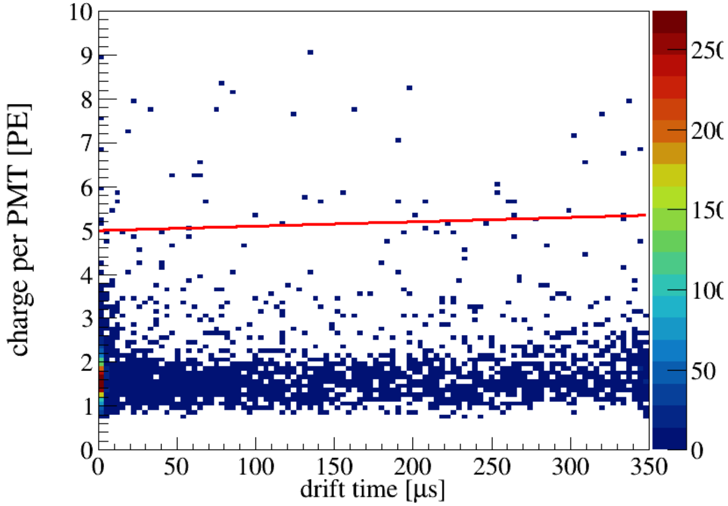
NOISE REMOVAL

S1 CONCIDENCE	S1 PATTERN	S1NOISEFILTERS
s1 charge vs. fired pmts	Charge from largest bottom channel vs total charge	Remove ripple-like electronic noise
S2T/BRATIO	**SELECTION WINDOW**	**OTHER**
Remove abnormal S2	Random coincident S1 and single electron S2	“S1” number<3 etc

03

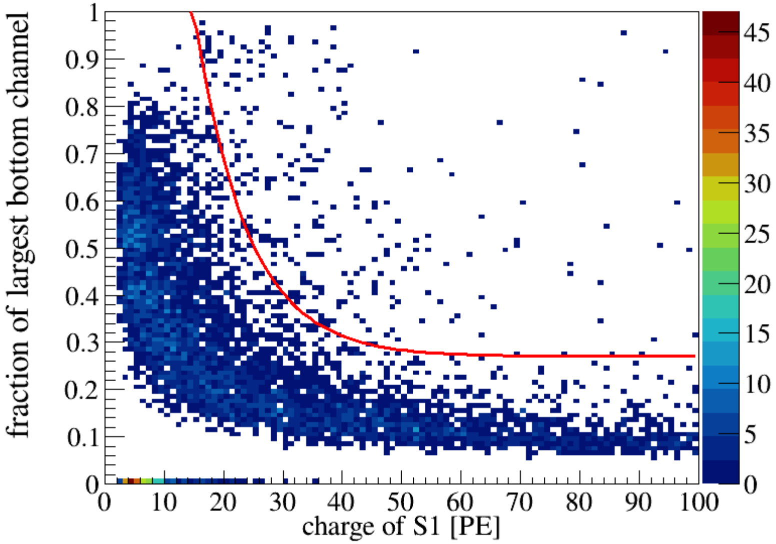
S1 COINCIDENCE CUT

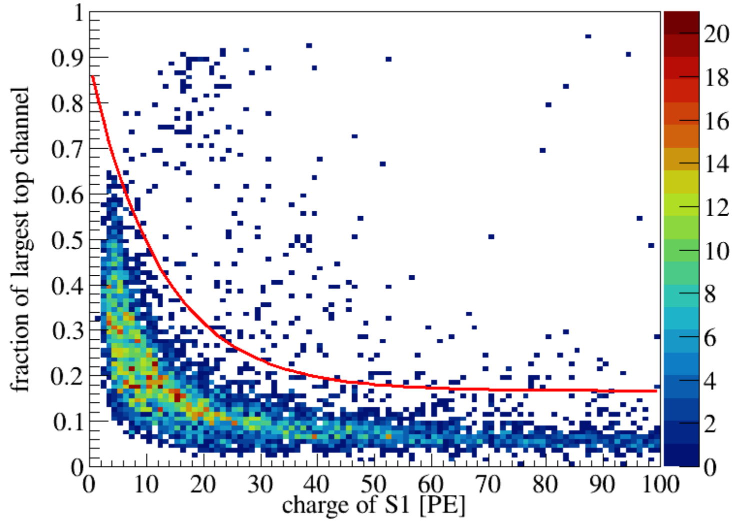




S1 charge per PMT vs S1 charge(left) and drift time(right).

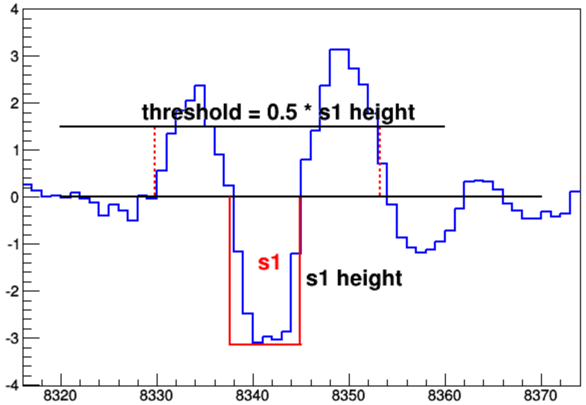
03 S1 PATTERN CUT





Applied in phase-I to remove X-events.

03 WAVY S1 FILTERS



Used to be the most serious noise

Two cuts are applied to remove those wavy noise.

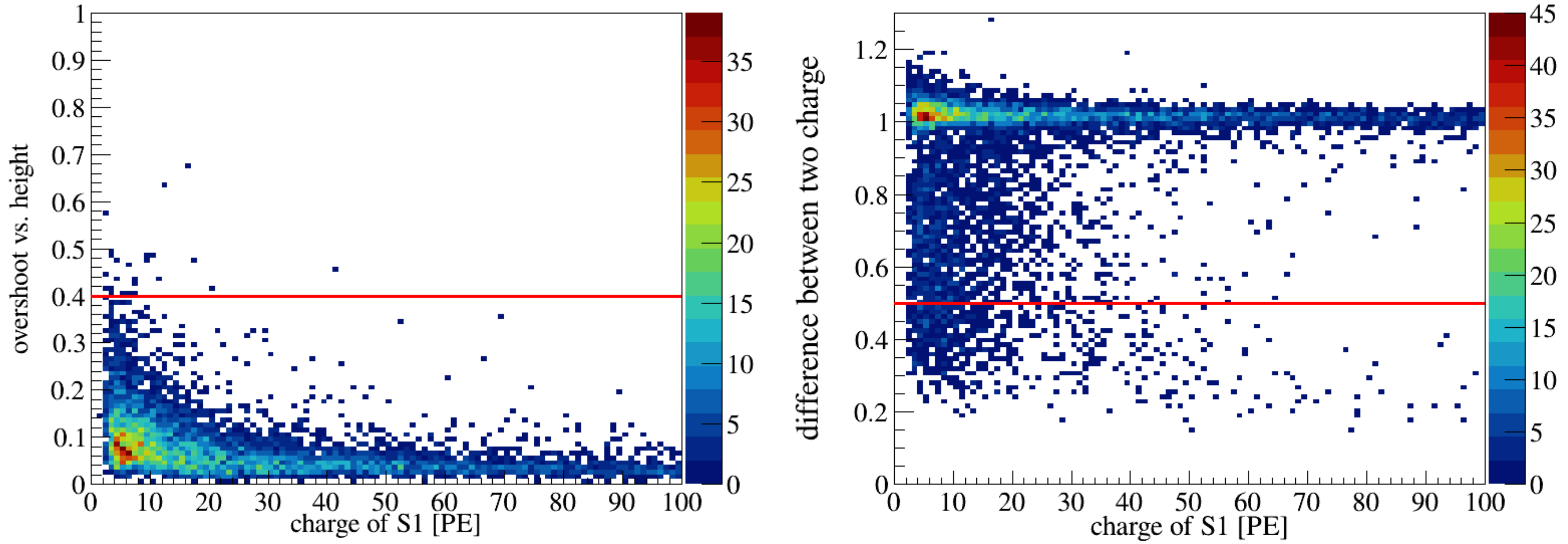
1) Based on overshoot

   Less than 0.4 of the height of S1

2) Based on difference of charge calculation from two methods

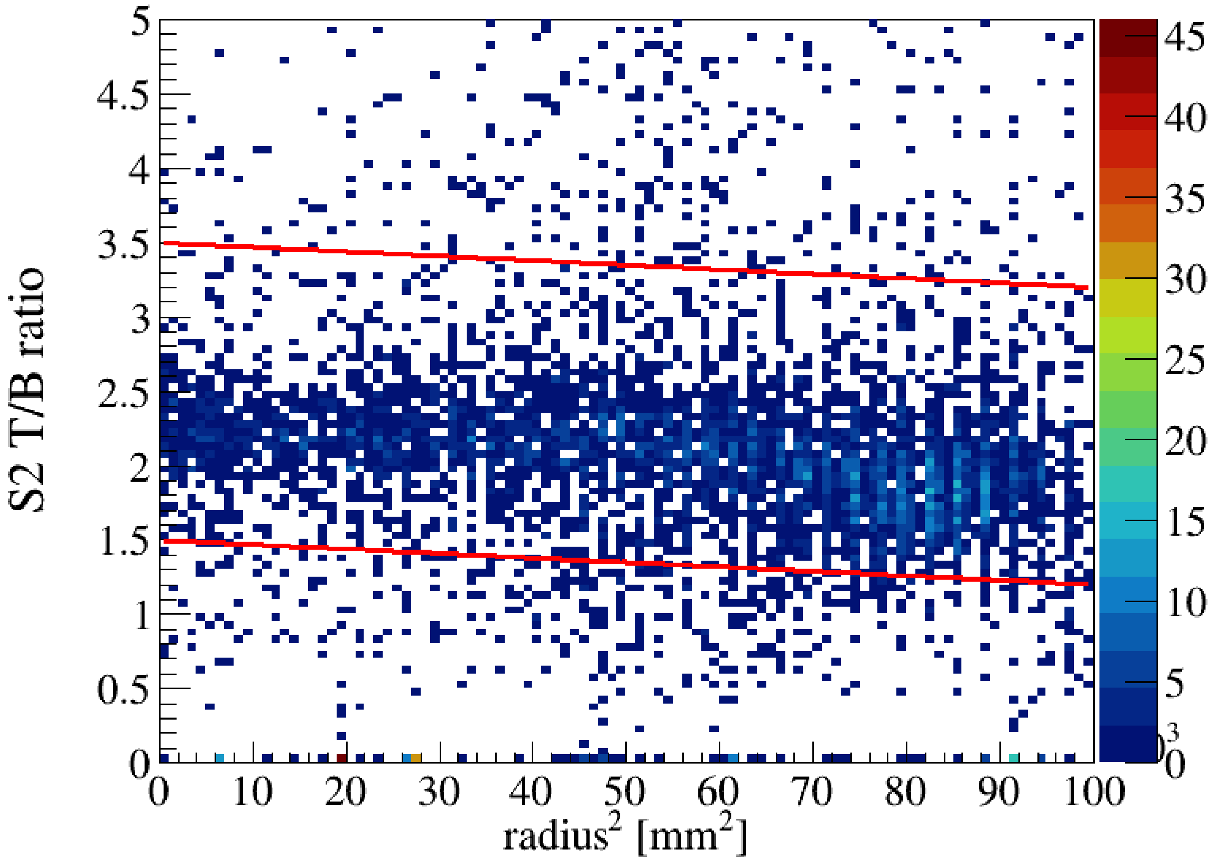
   - Charge calculated by integrating PMT hits.
   - Charge calculated by integrating summed waveform.

03 WAVY S1 FILTERS



03

S2 T/B RATIO



The average number is 2 which conforms with MC.

03 SELECTION WINDOW

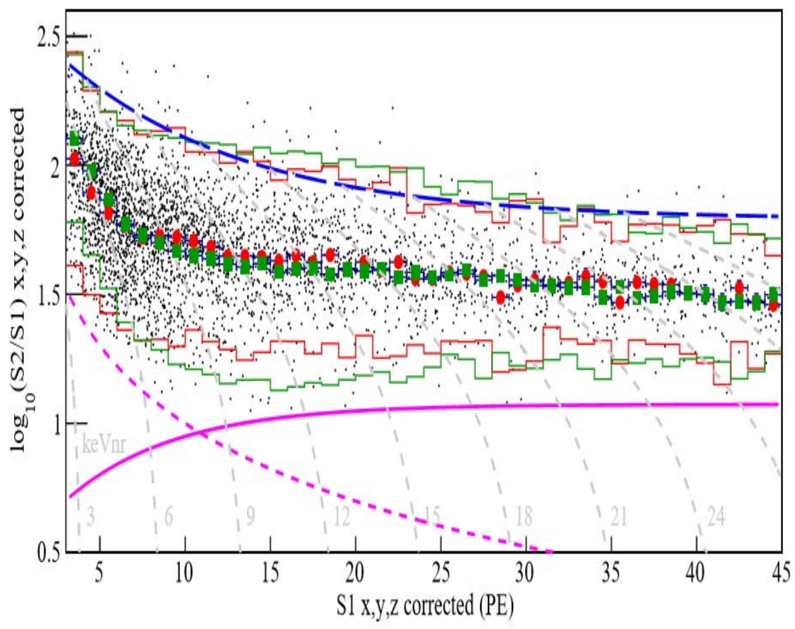
S1: 3 fired PMTs, [3,45] PE

Limited by dark rates

S2: [100,10000] PE

Limited by floating small S2.

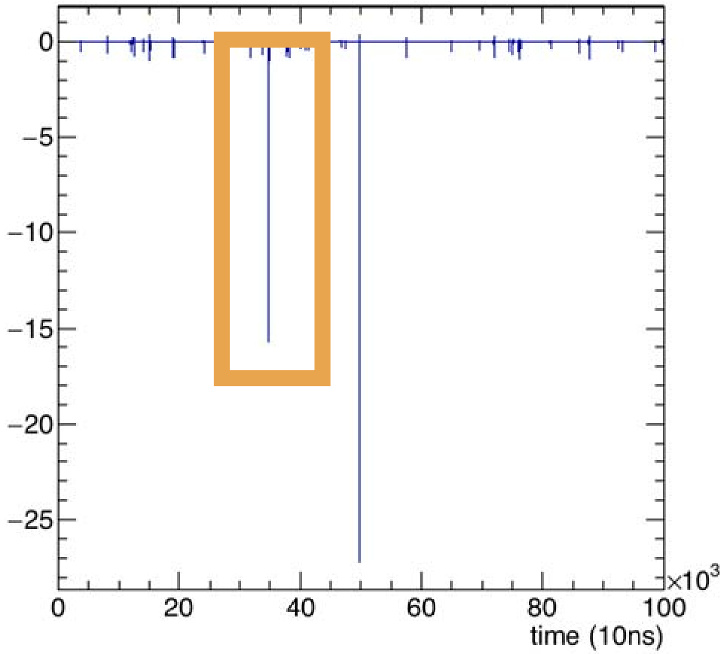
NR 99.99% Acceptance line



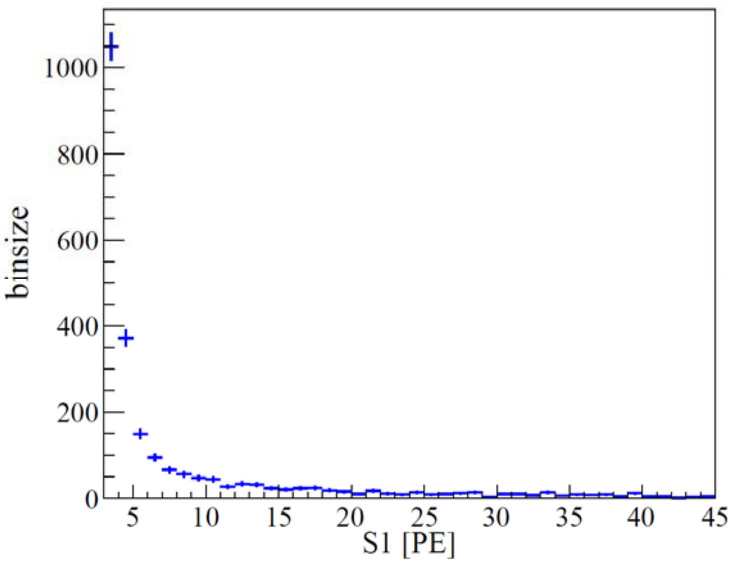

4
Boosted decision tree for accidental background

04 ACCIDENTAL S1

Isolated S1



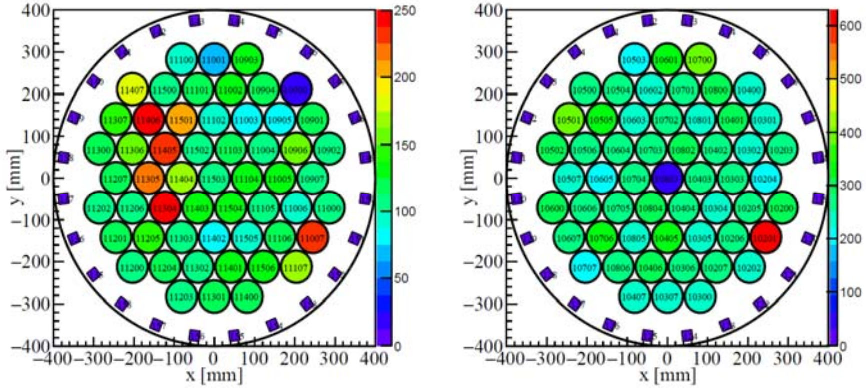
Spectrum



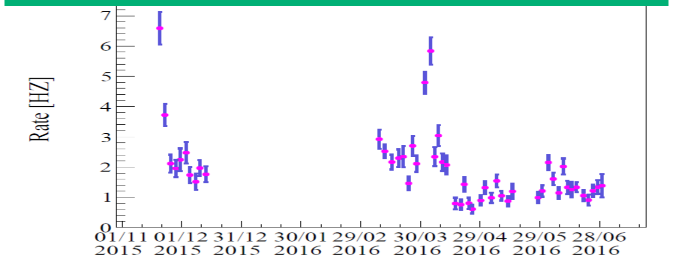
Search “s1” before s1-only events

04 ACCIDENTAL S1

Collective pattern



Evolution



Cause

PMT Sparking

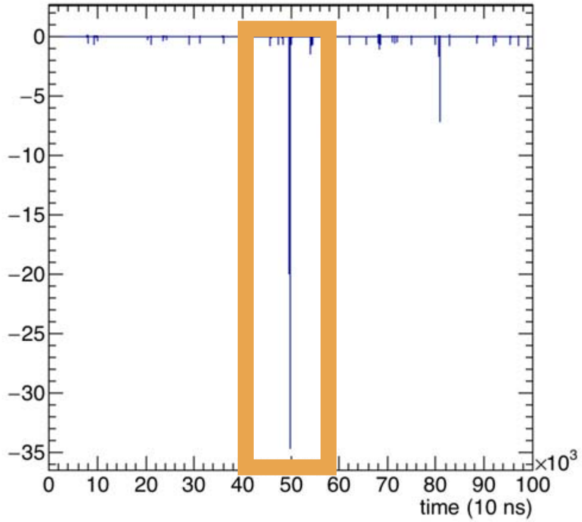
Electrodes Sparking

S1 from "dead" region

etc.

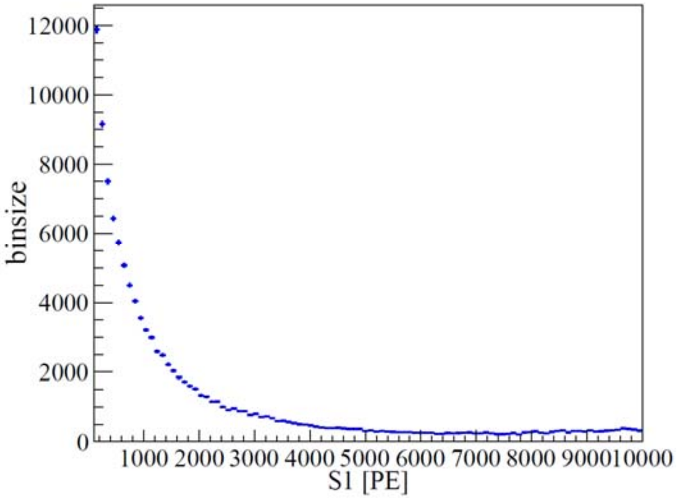
04 ACCIDENTAL S2

Isolated S2



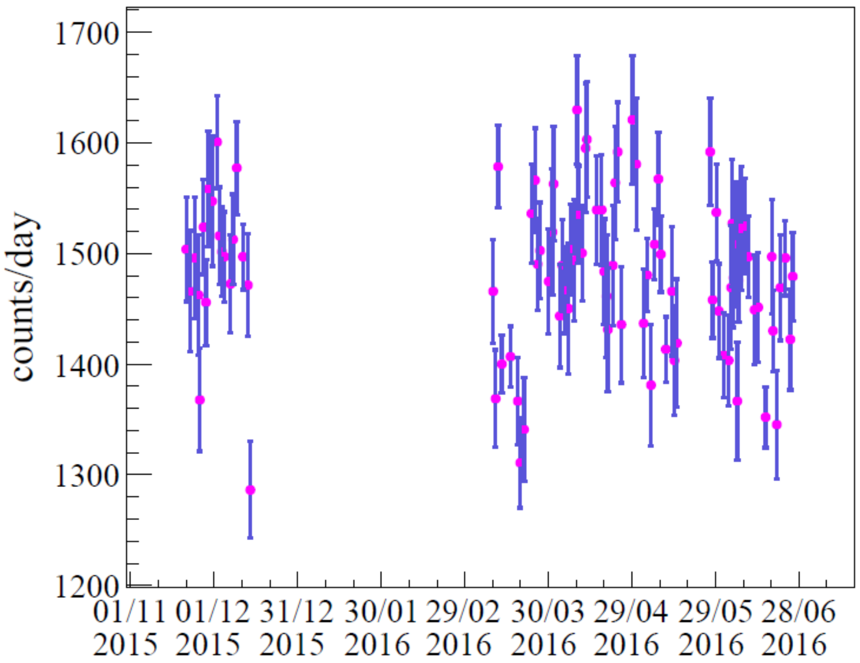
No s1 before s2

Spectrum



04 ACCIDENTAL S2

Evolution

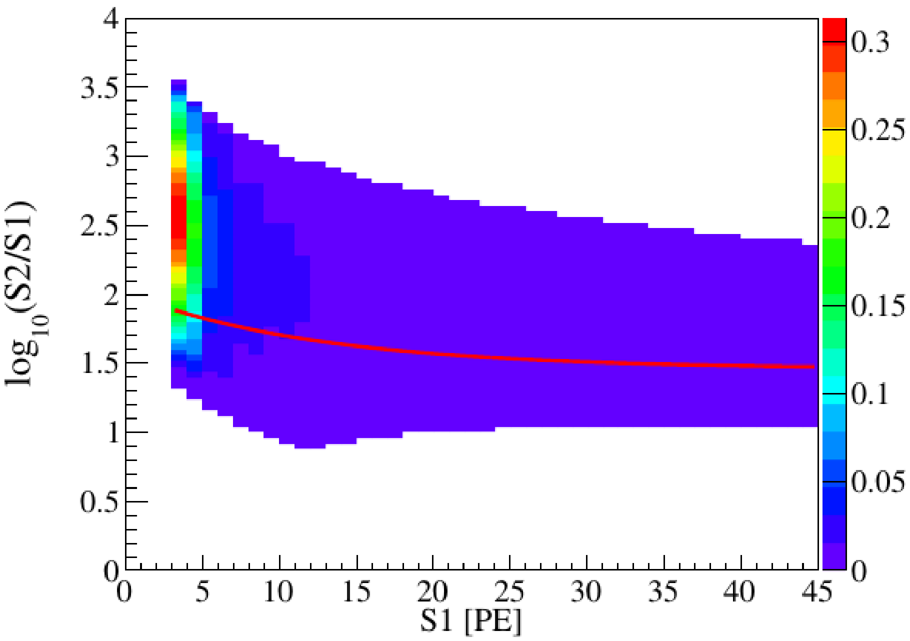


Cause

Real S1 quenched. Lots of events generated from gate

04 RANDOM COINCIDENT EVENTS

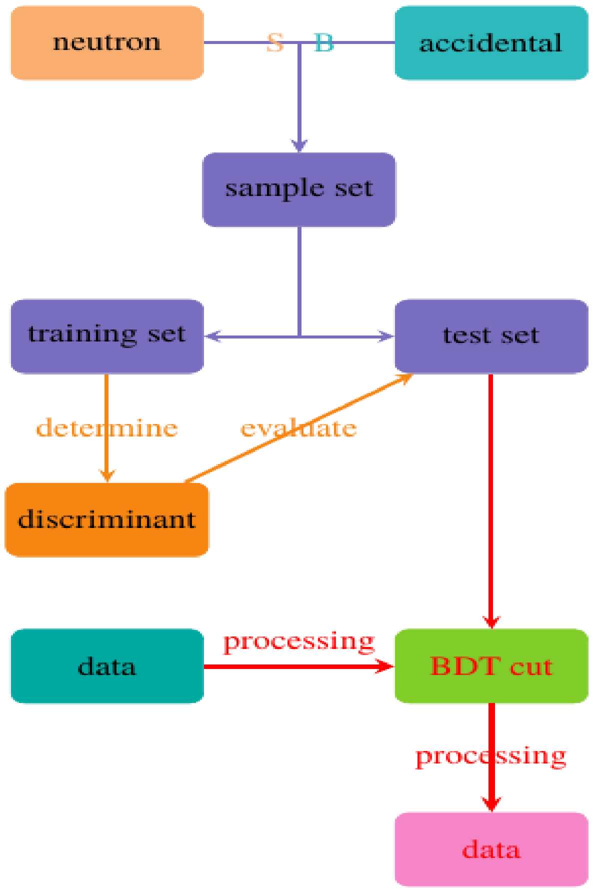
Randomly pairing



Isolated S1:1.8HZ
Isolated S2:1500/day
Accidental events: 4.3 in 98.7 days

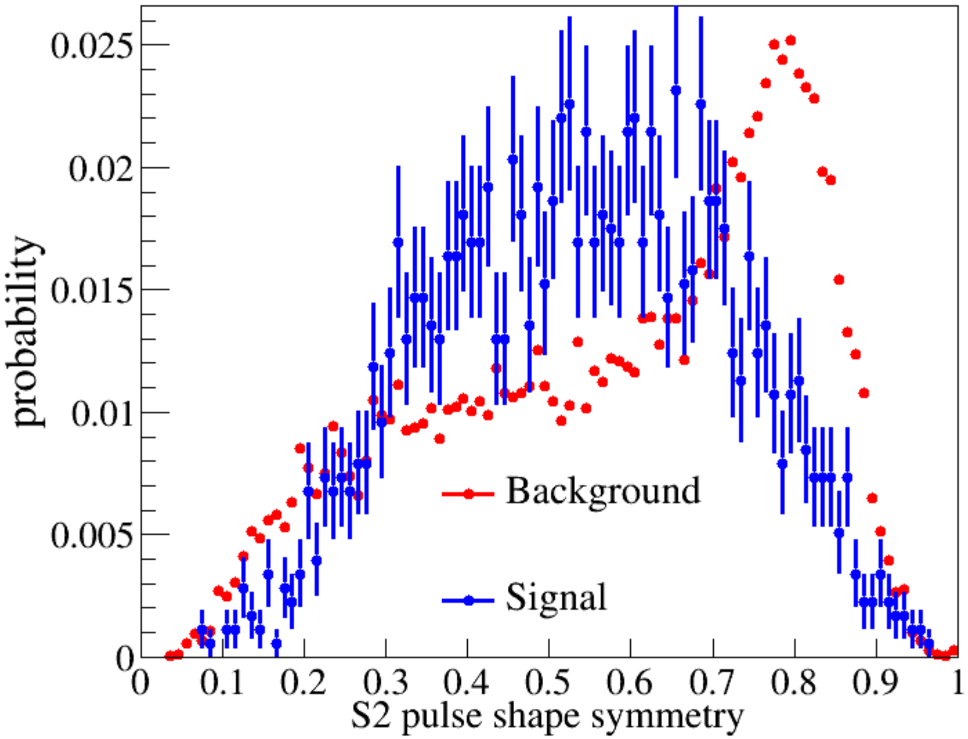
04 BOOSTED DECISION TREE

- Seek additional suppression of accidental background using a multivariate approach (BDT)
- Training and test samples: randomly paired coincident events (background) and AmBe low energy events (signal)
- Variables:
  - S1 charge, S2 charge, drift time
  - S2 pulse shape symmetry, S2 Top/Bottom ratio
  - S2 width, S2 10% width, S2 rising edge
  - S2 charge pattern
  - S1 charge pattern
  - “gate charge”



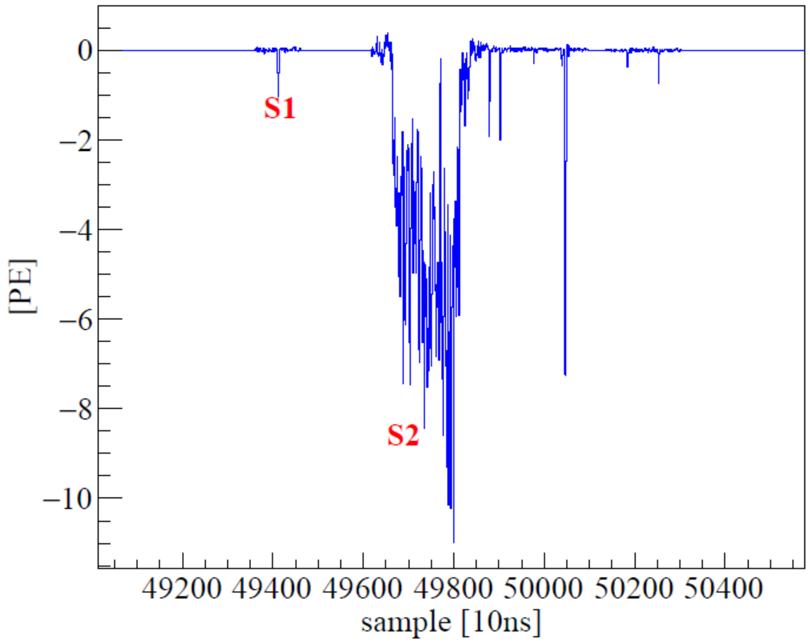
04 BOOSTED DECISION TREE

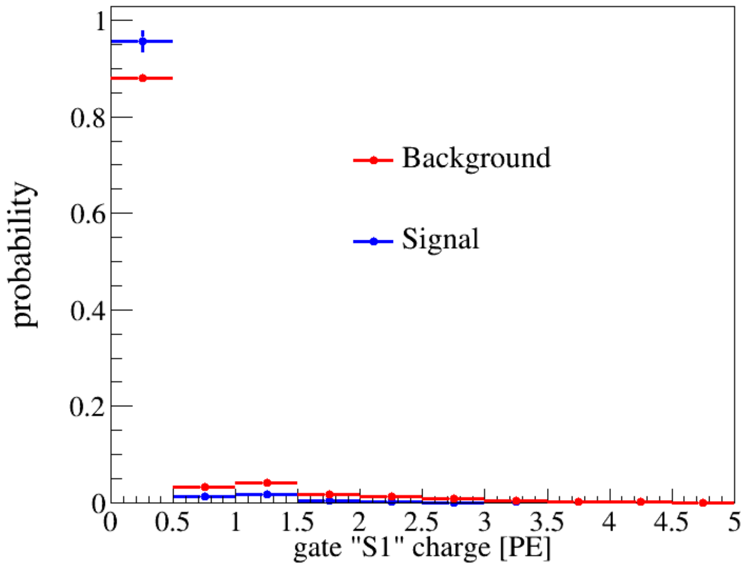
S2 pulse shape symmetry



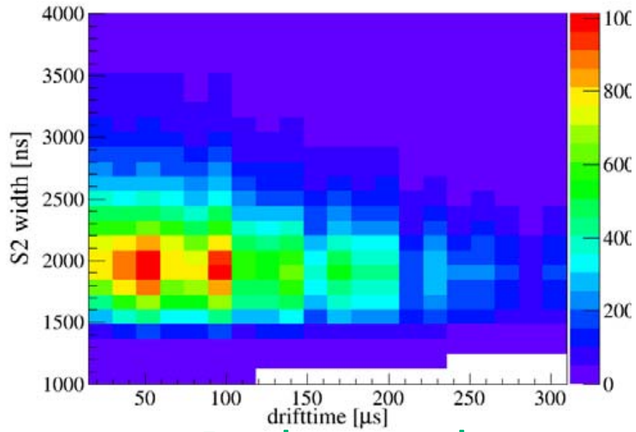
04 BOOSTED DECISION TREE

"Gate charge"

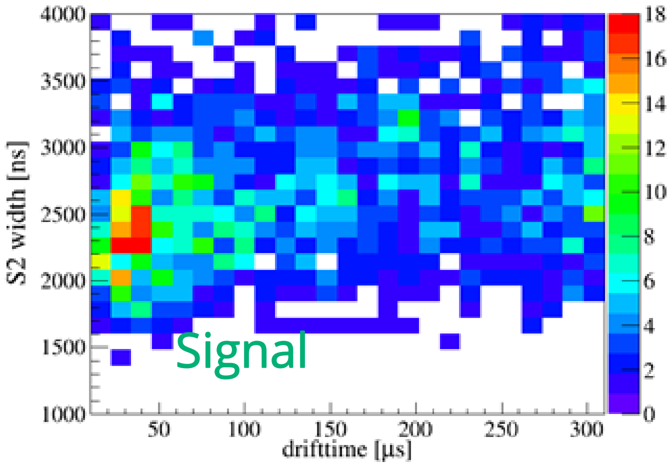




04 BOOSTED DECISION TREE

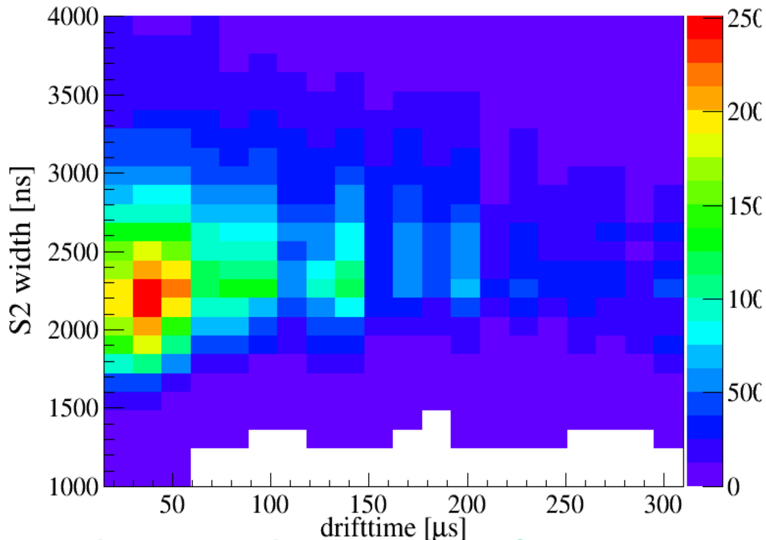


Background



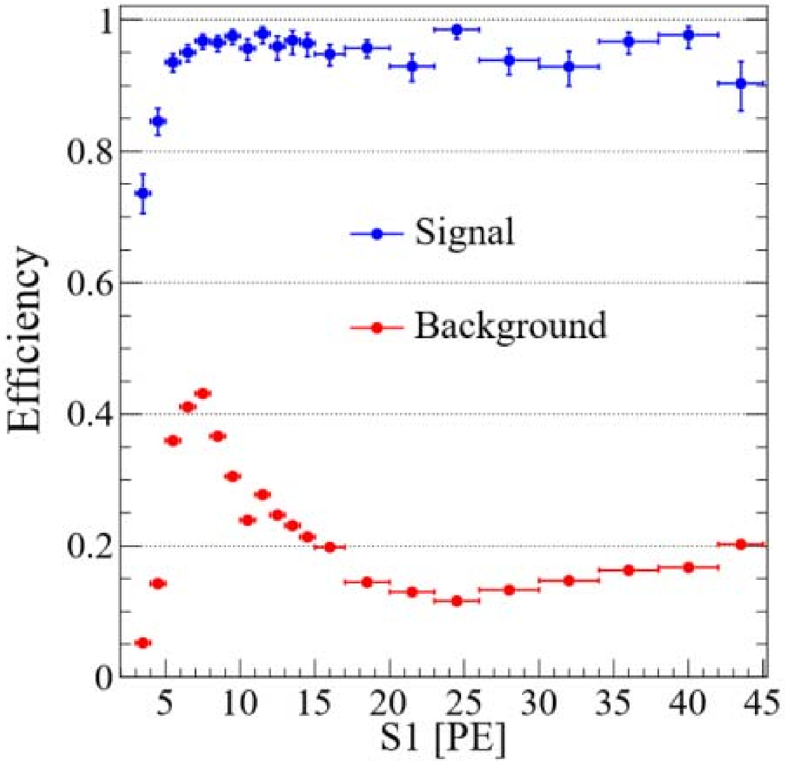
Signal

- Accidental S1 and S2 lack intrinsic correlations
- Single S2 likely originated from the gate grid (small width)



Background surviving from BDT cuts

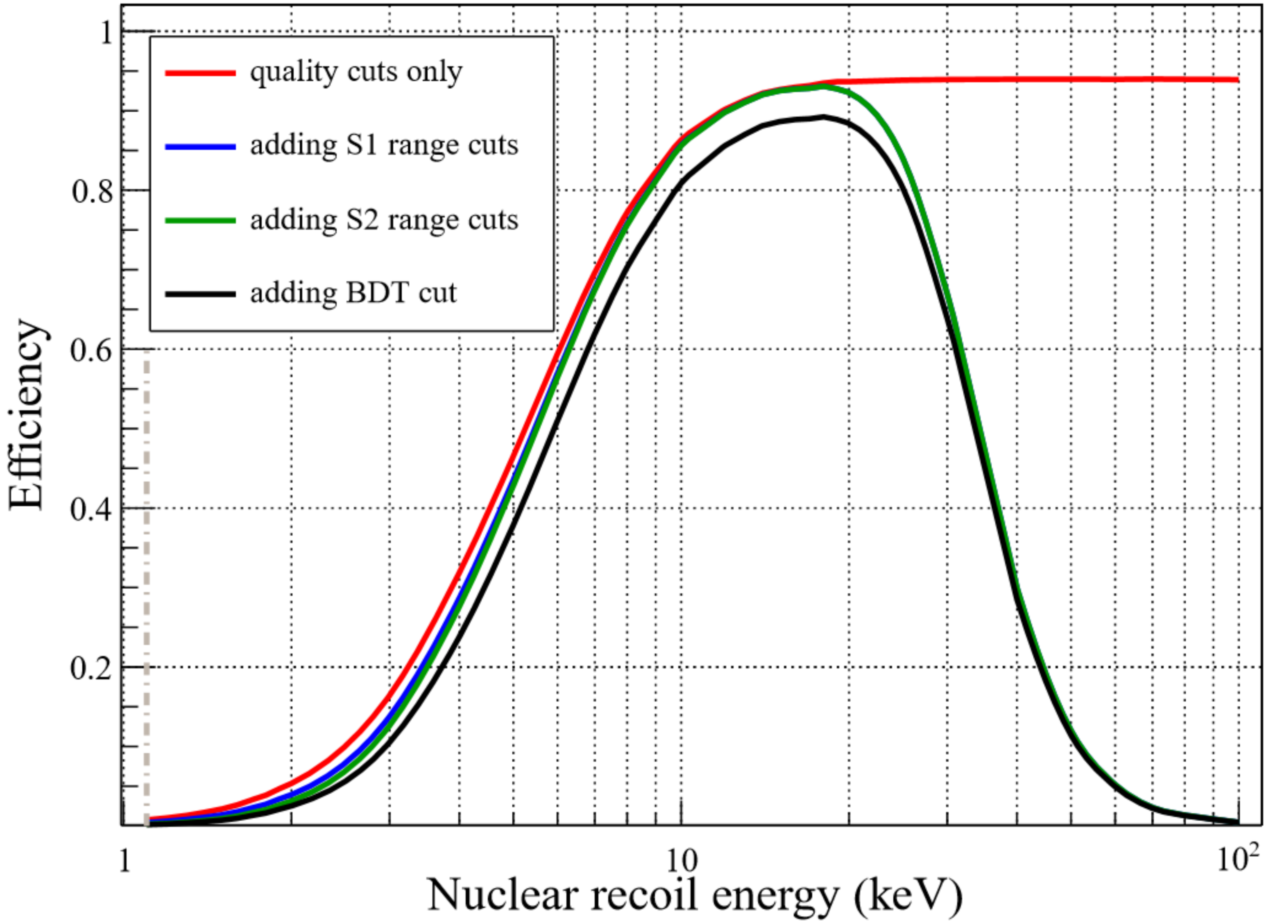
04 BDT EFFICIENCY

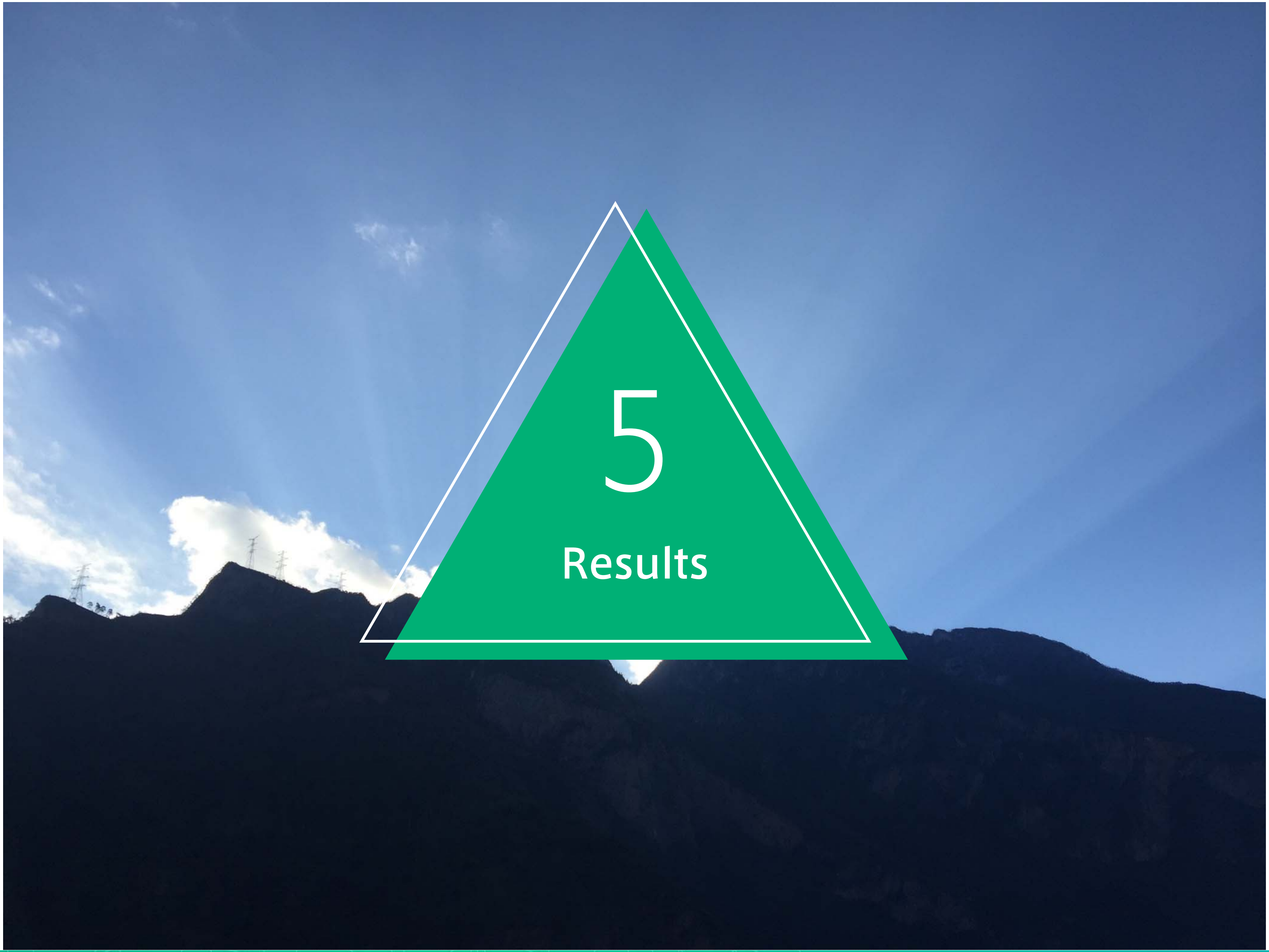


BDT removes the accidental events by more than a factor of 3, while maintaining an average 90% efficiency

04

NR EFFICIENCY

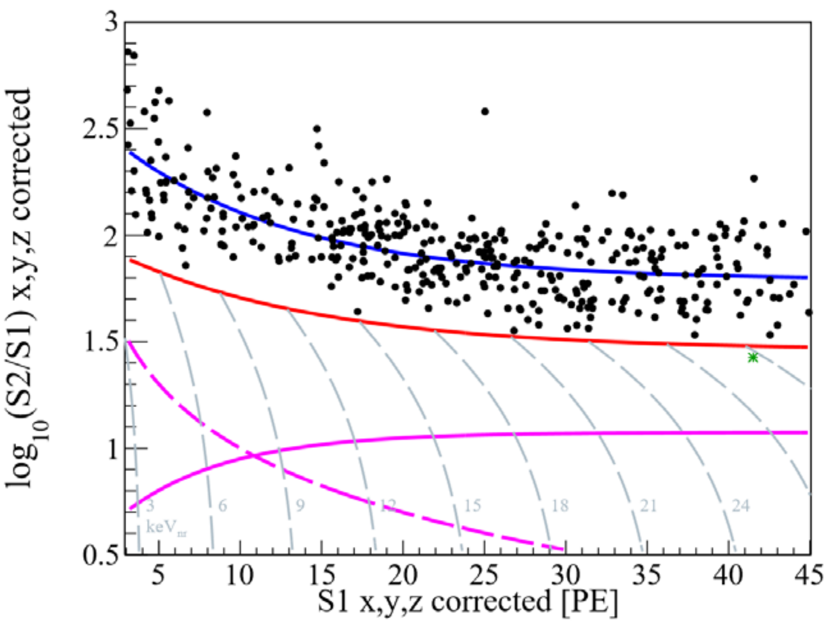




5 Results

05 FINAL CANDIDATES

Cut	#Events	Rate[HZ]
All	24502402	3.56
Single site	9783090	1.42
Quality cuts	5160513	0.75
Low energy window	131097	$1.91*10^{-2}$
Fiducial Volume	398	$5.79*10^{-5}$
BDT cut	389	$5.66*10^{-5}$



THANKS!