Counting Photons with the DEAP experiment

Pierre Gorel for the DEAP Collaboration

CAP 2012 Congress – 14 June 2012

Outline

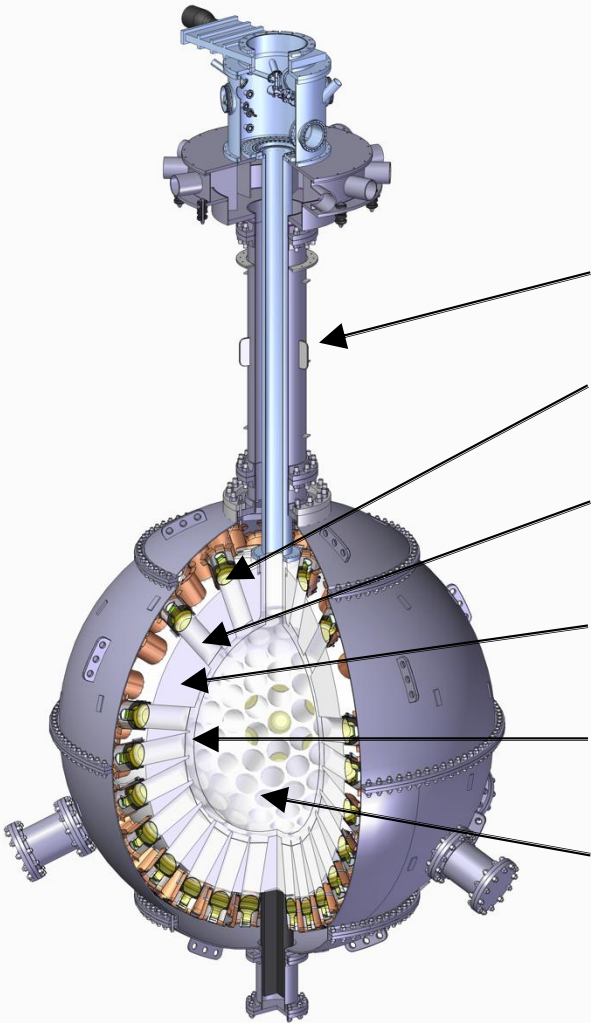
- DEAP 3600 overview
- Pulse Shape Discrimination
- Counting algorithms
- Comparison between methods

DEAP @ SNOLAB

- 2km underground
- 5000m² of clean space

DEAP3600 detector

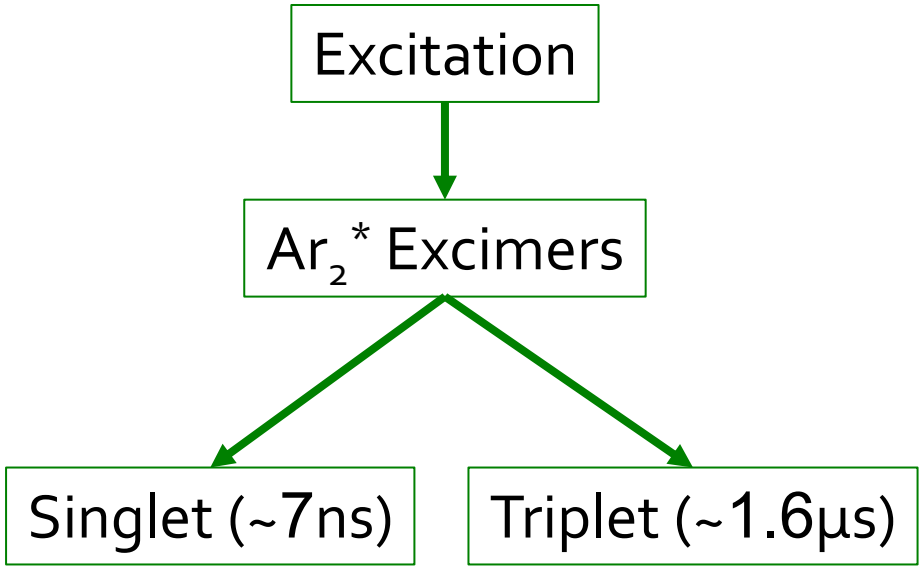
Courtesy: SNOLAB

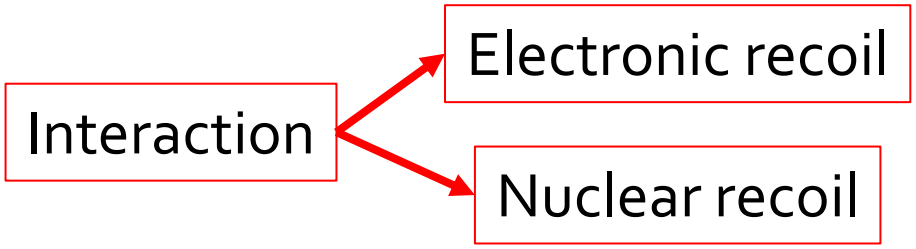


Courtesy: Koby Dering

Liquid Argon scintillation

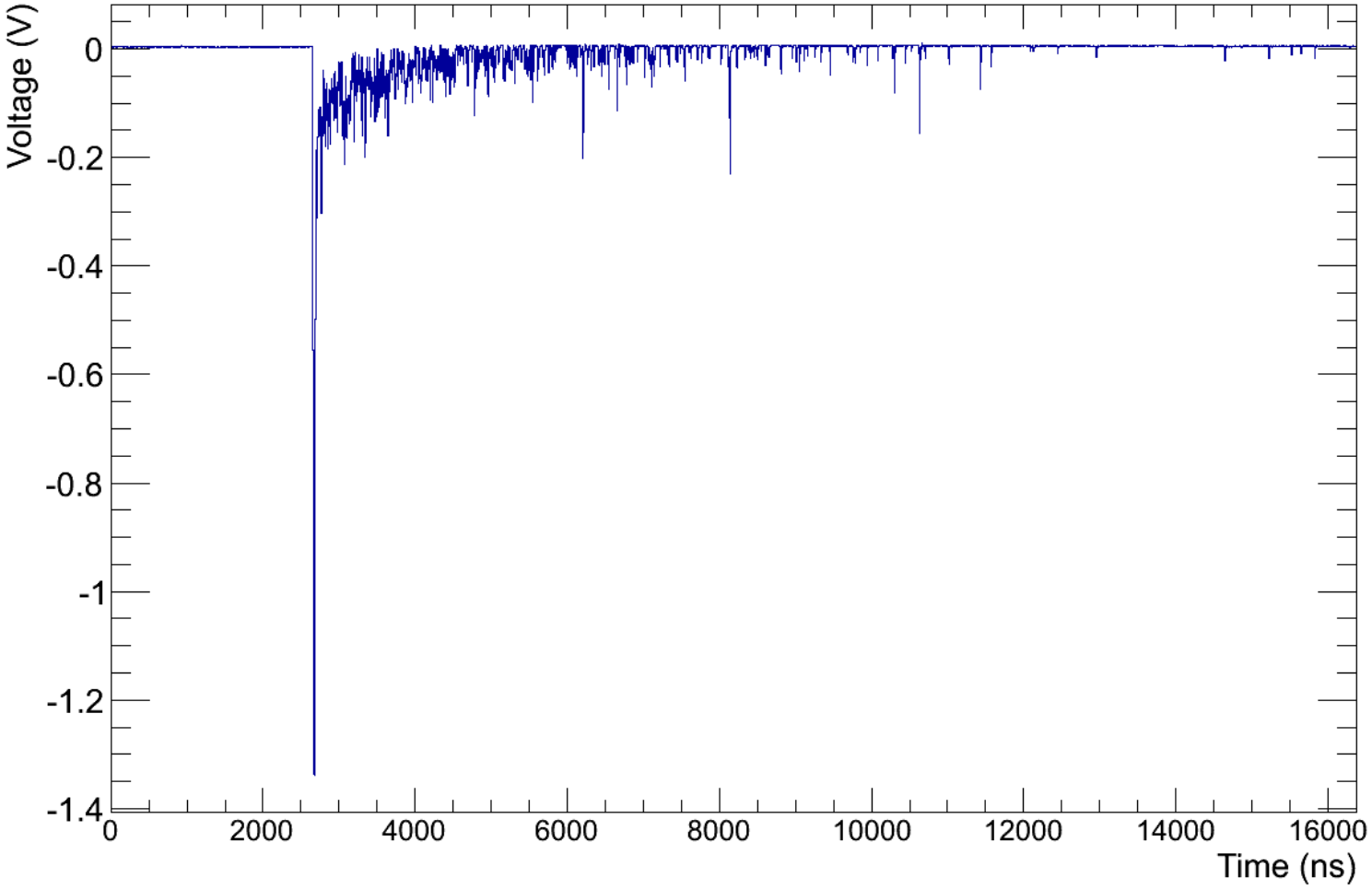
Two types of interaction
&
two types of excitation:



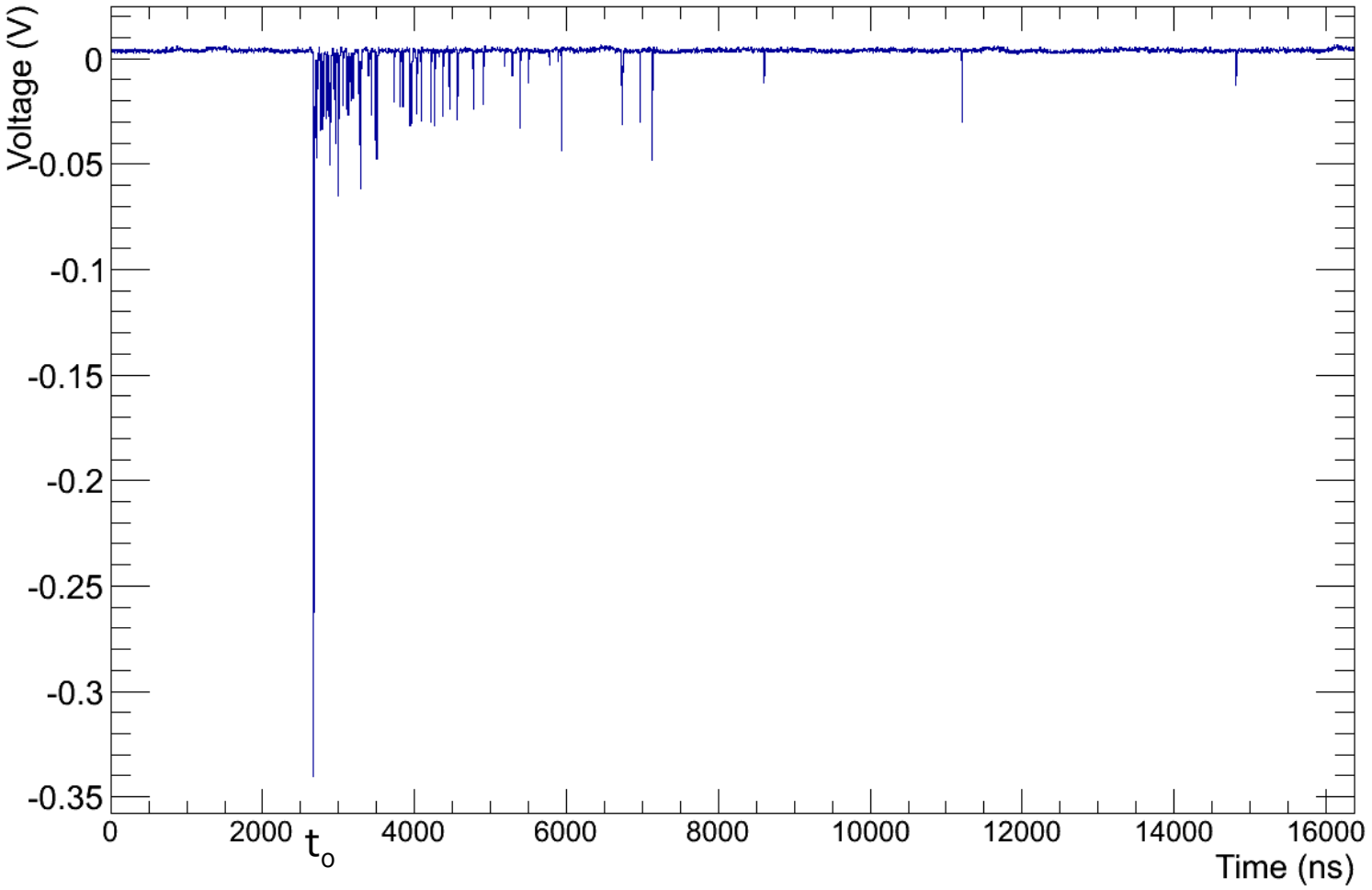


Electronic recoil	23%	77%
Nuclear recoil	75%	25%

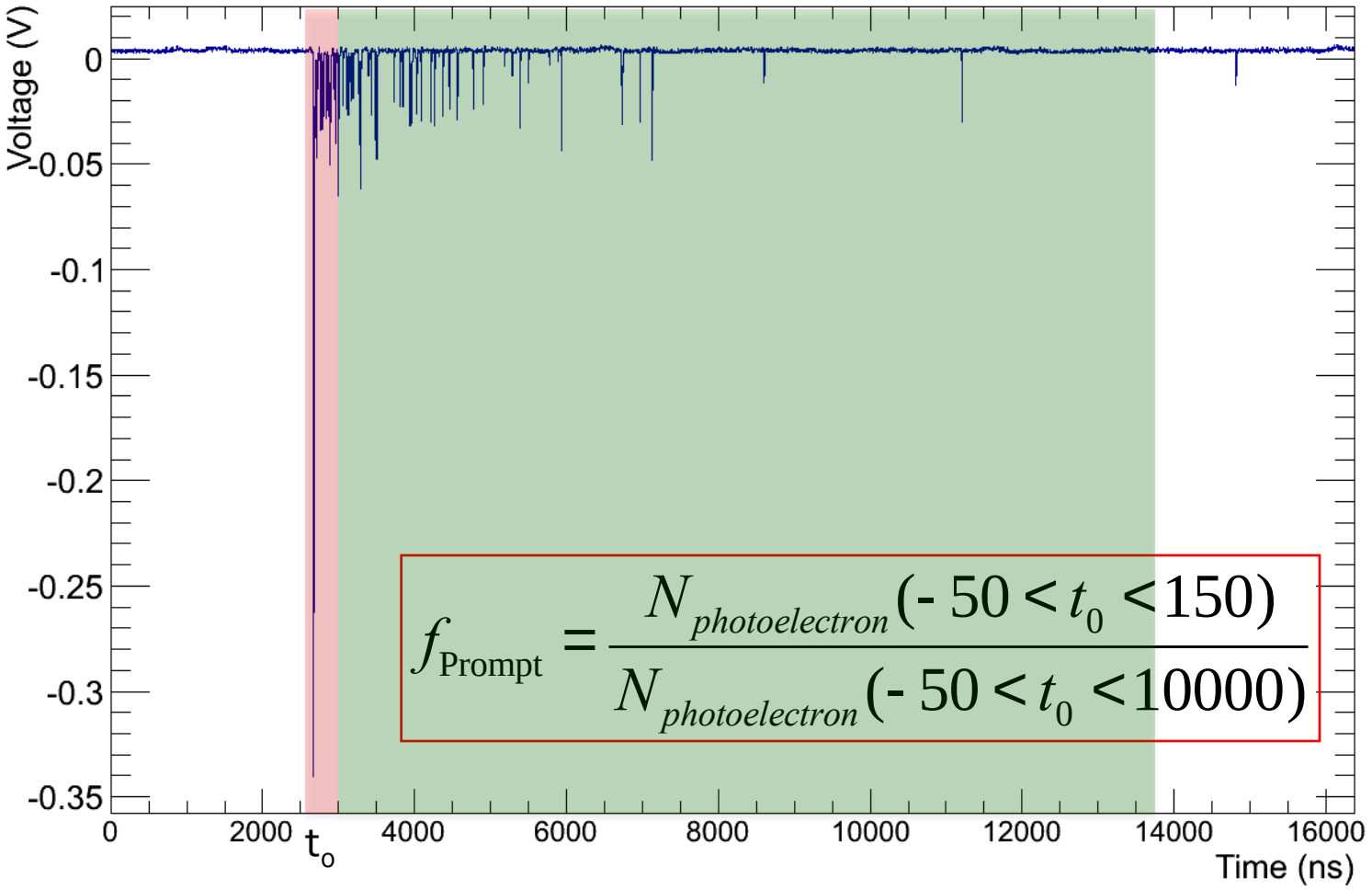
Two types of events : electronic…



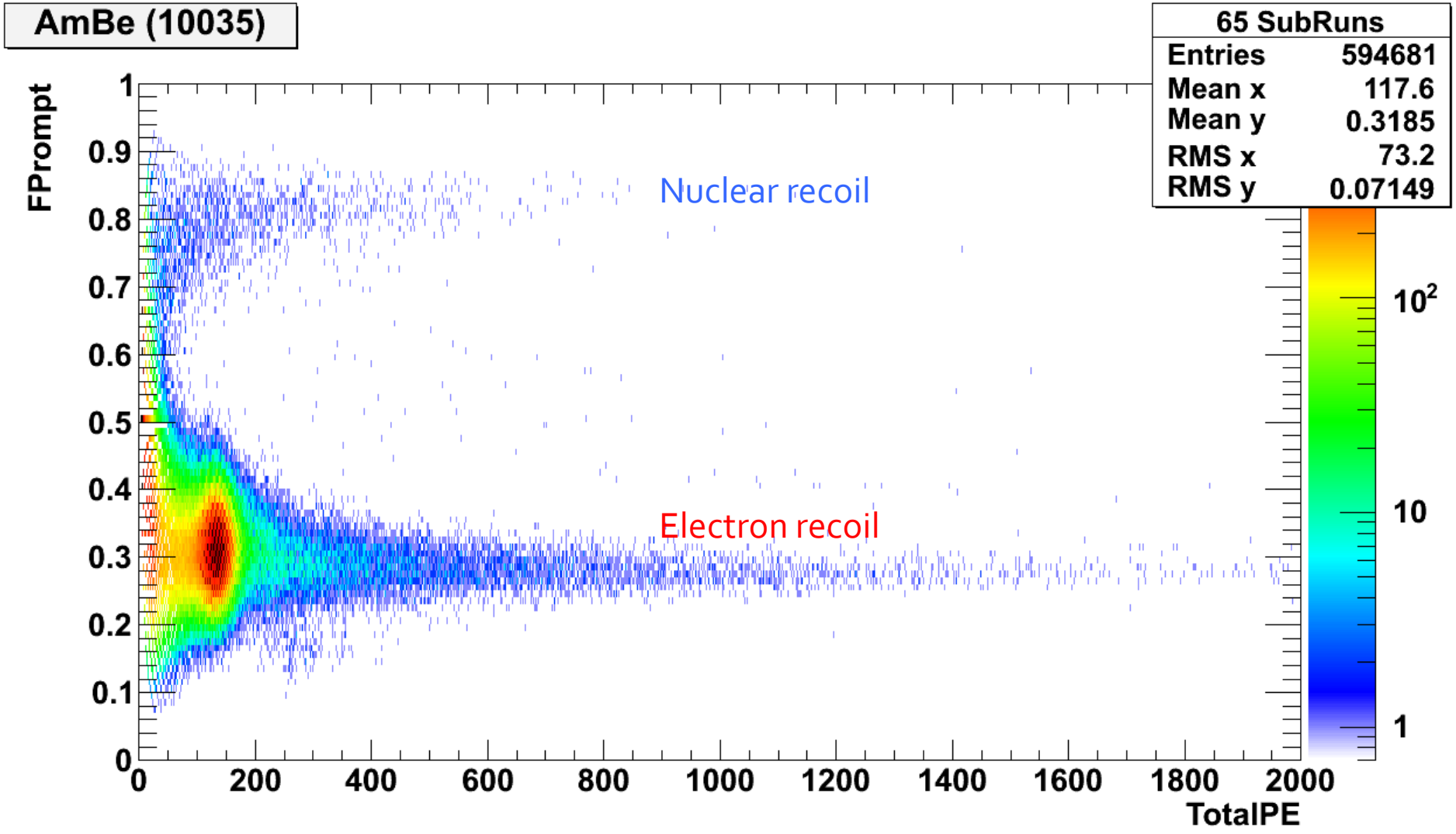
… and nuclear recoils



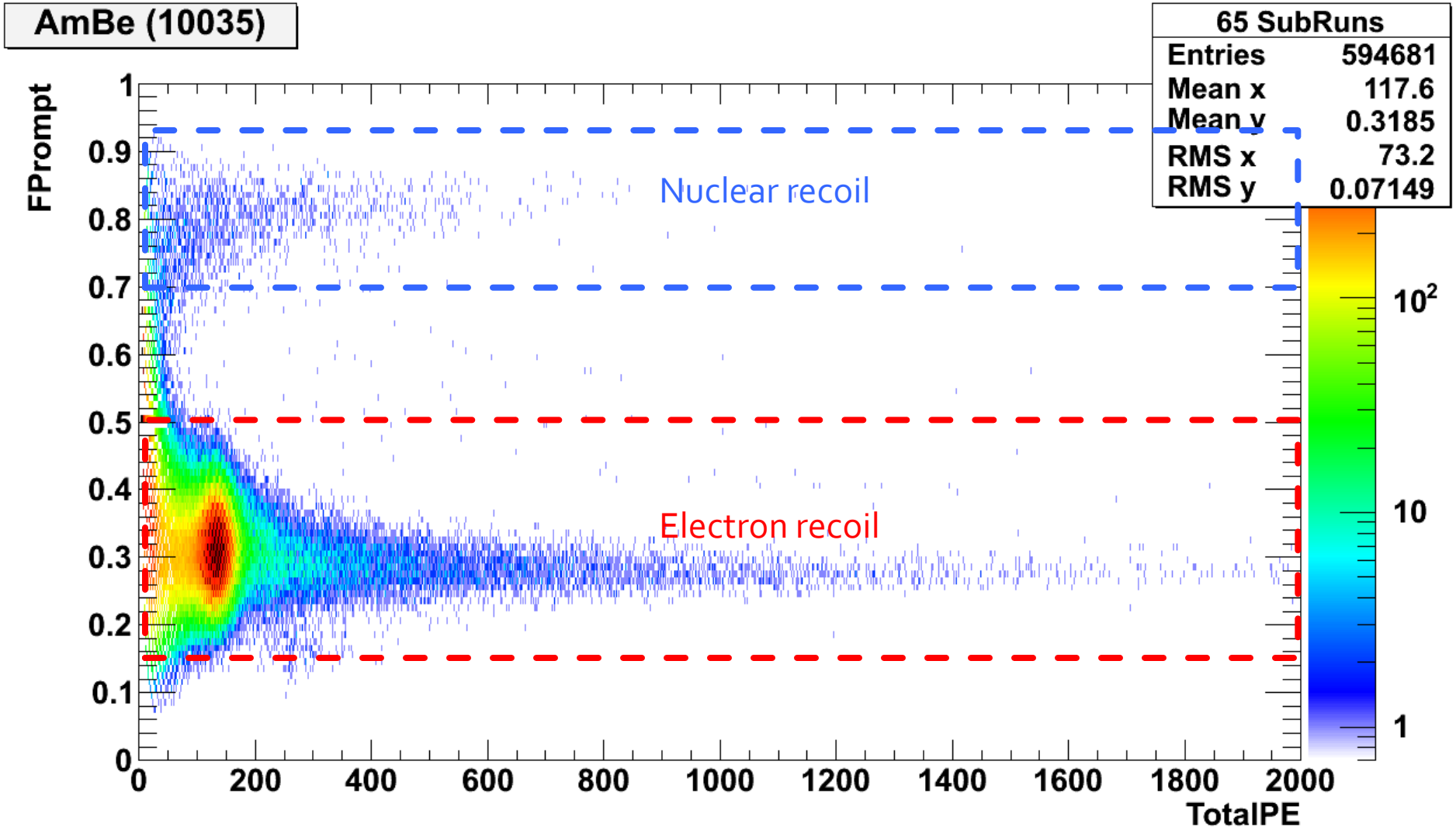
… and nuclear recoils



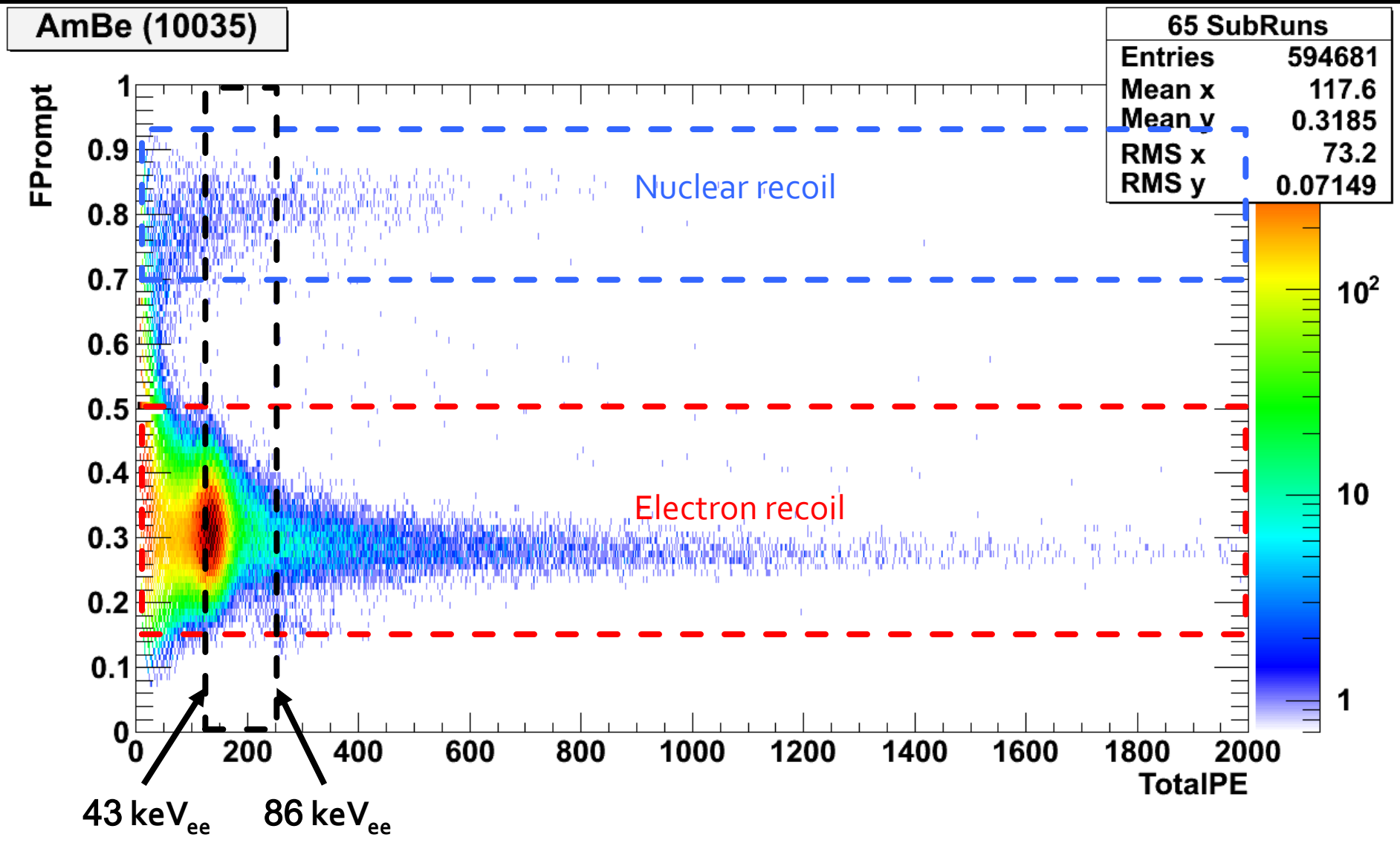
Discrimination γ-β/recoil



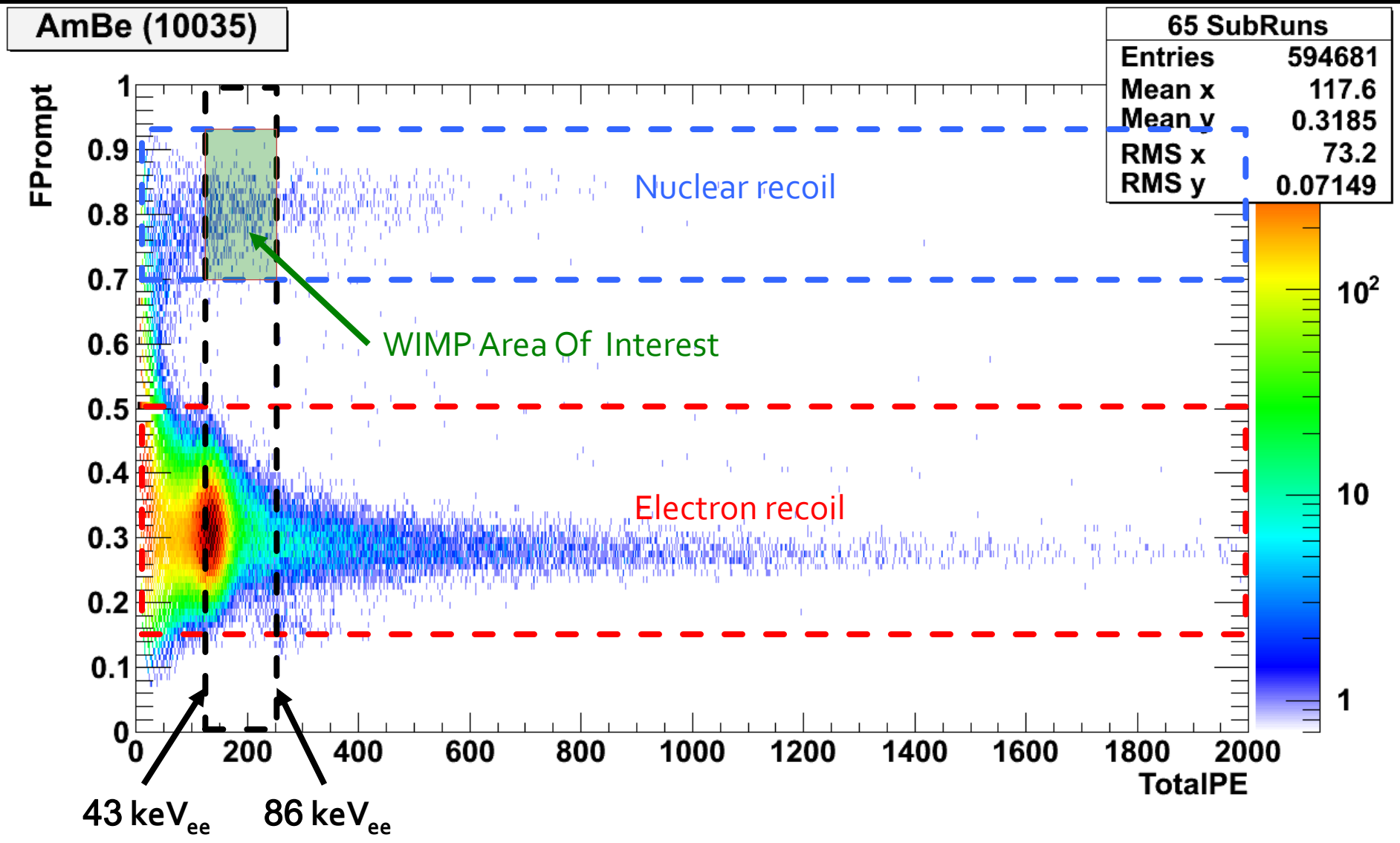
Discrimination γ-β/recoil



Discrimination γ-β/recoil

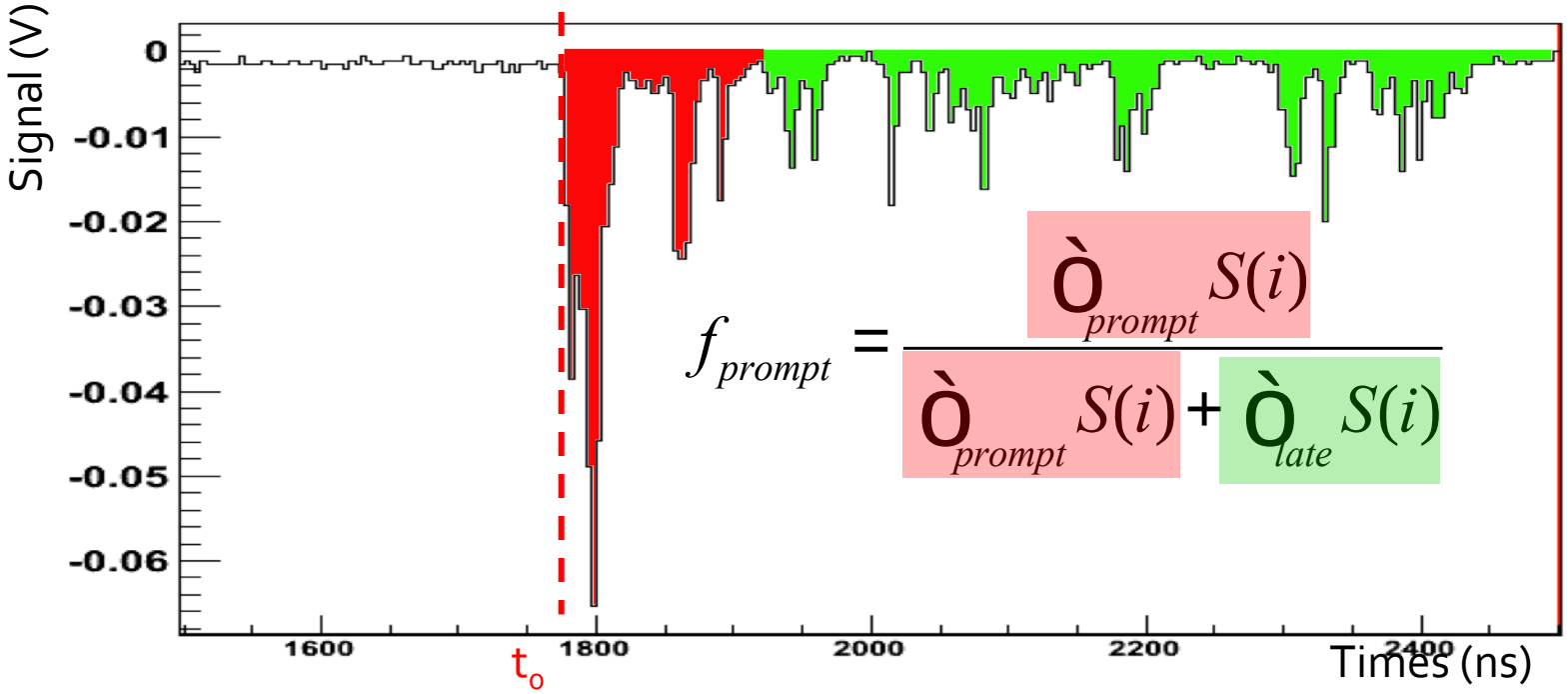


Discrimination γ-β/recoil

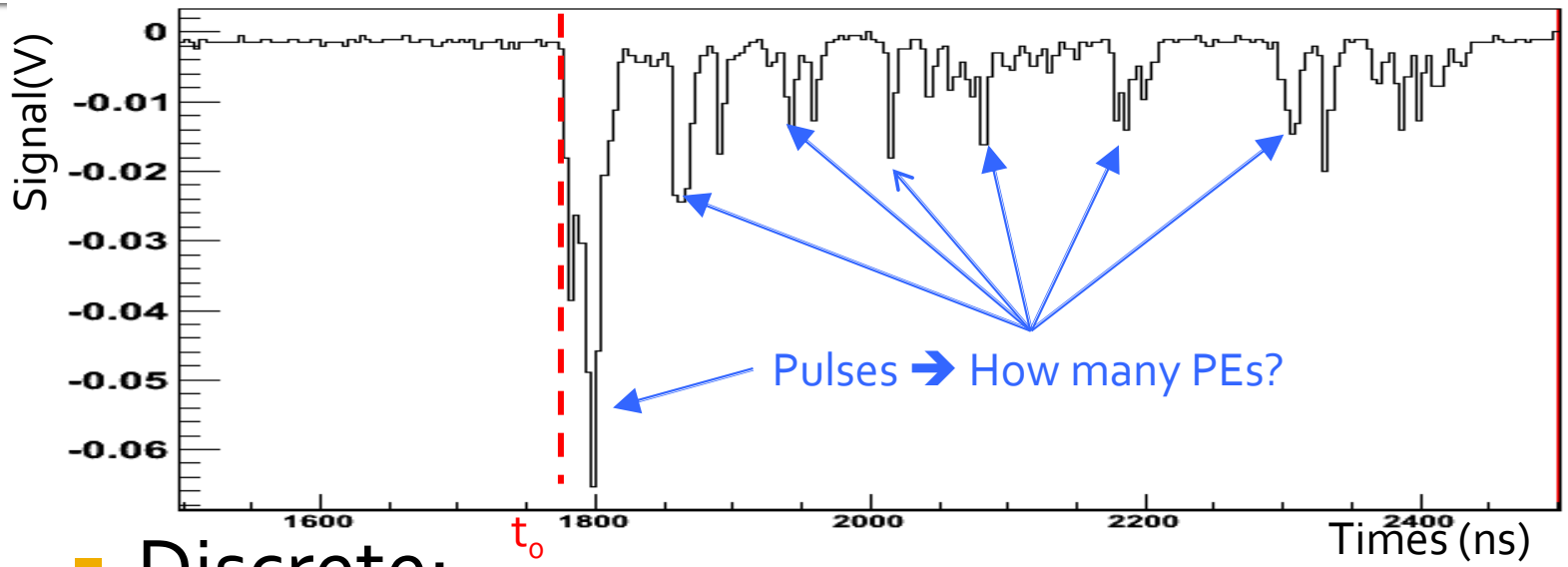


N_{PE} : Continuous/Discrete

- Continuous:
  - Integration over the all waveform
  - Division by the average SPE charge

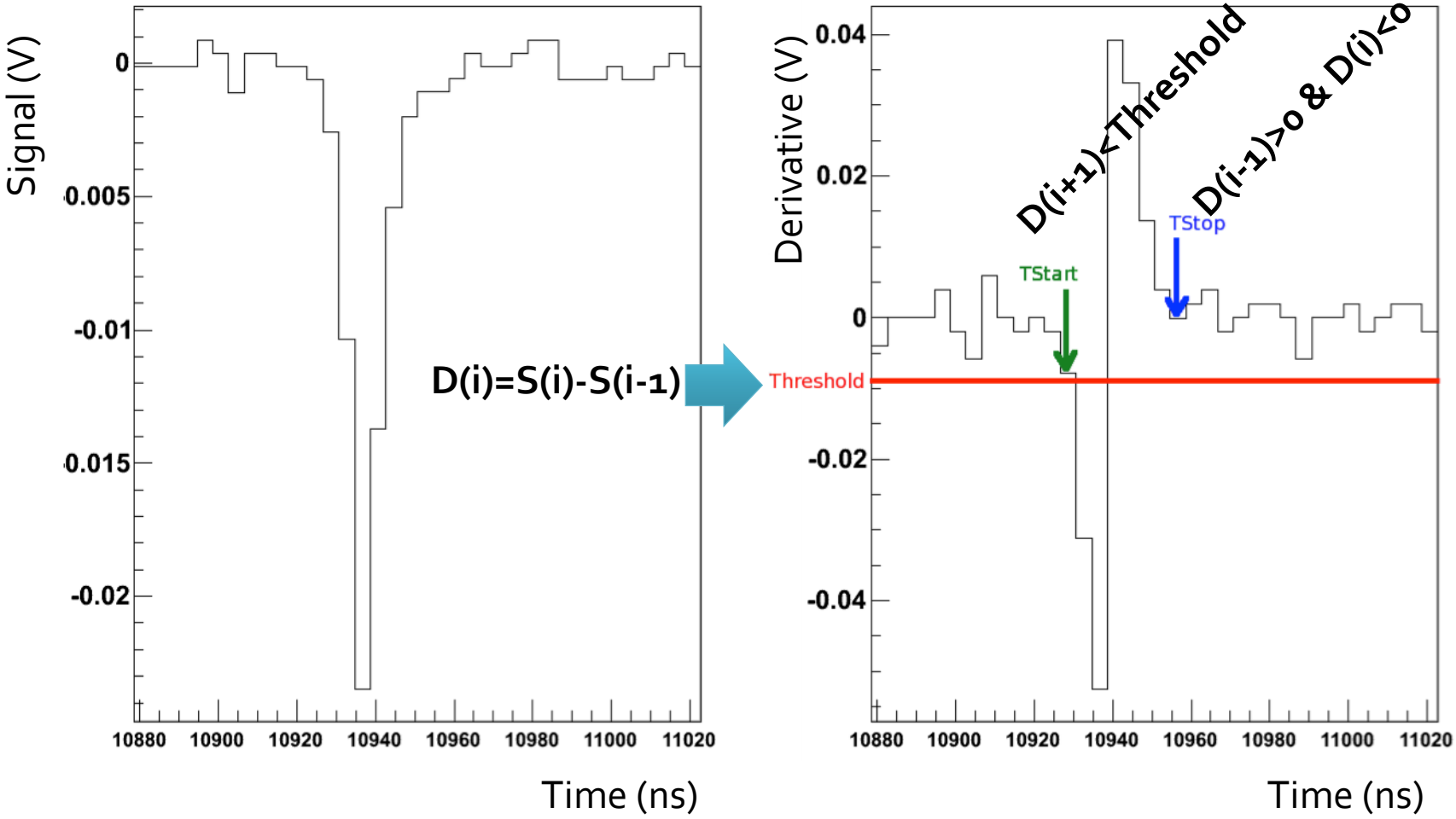


N_{PE} : Continuous/Discrete



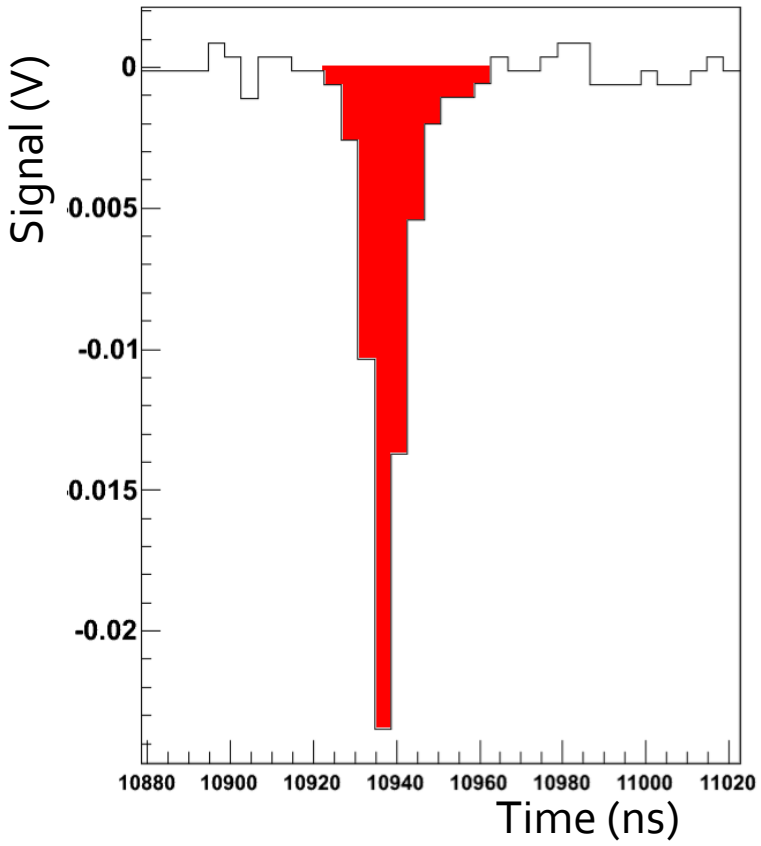
- Discrete:
  - Localization of every pulse
  - Determination of the number of PE in the pulse
    - With maximum likelihood (small pulses)
    - With integration and division by the charge (large pulses)

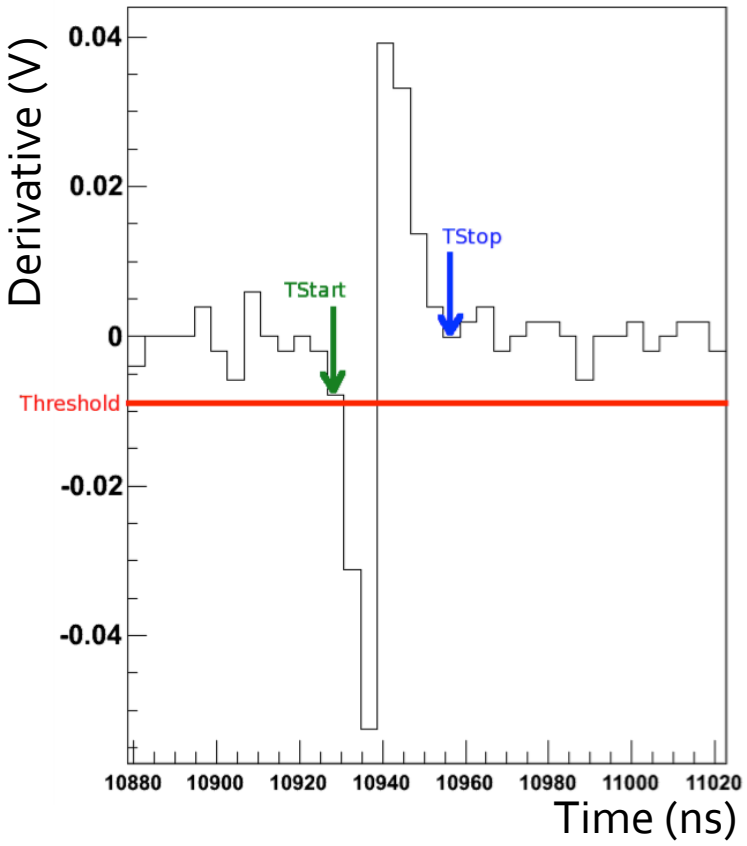
Derivative and pulse finder



Each pulse ➔ 6 observables:

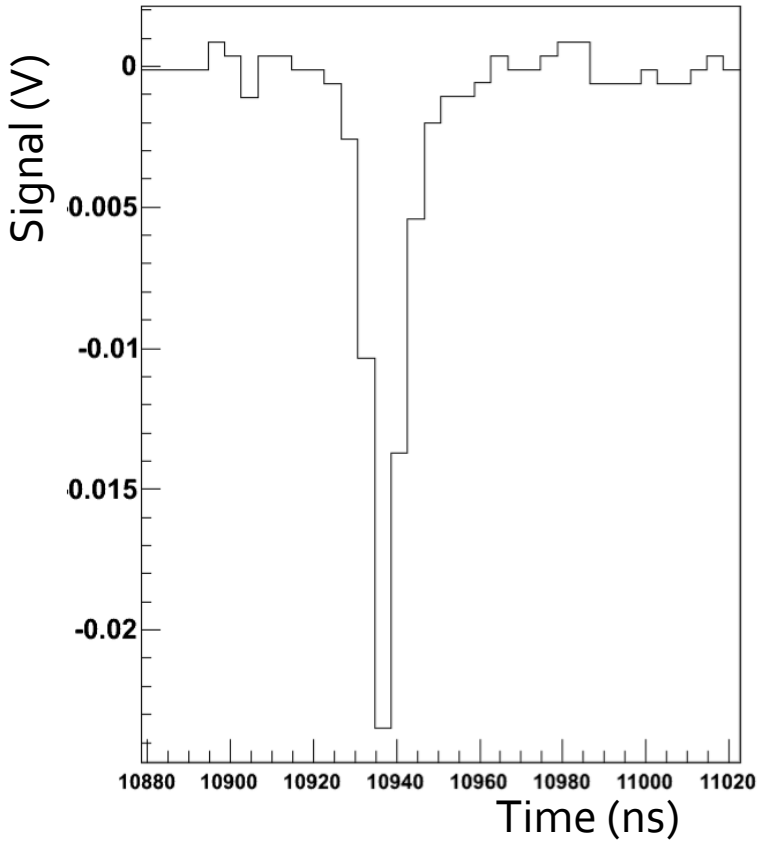
- Pulse integration

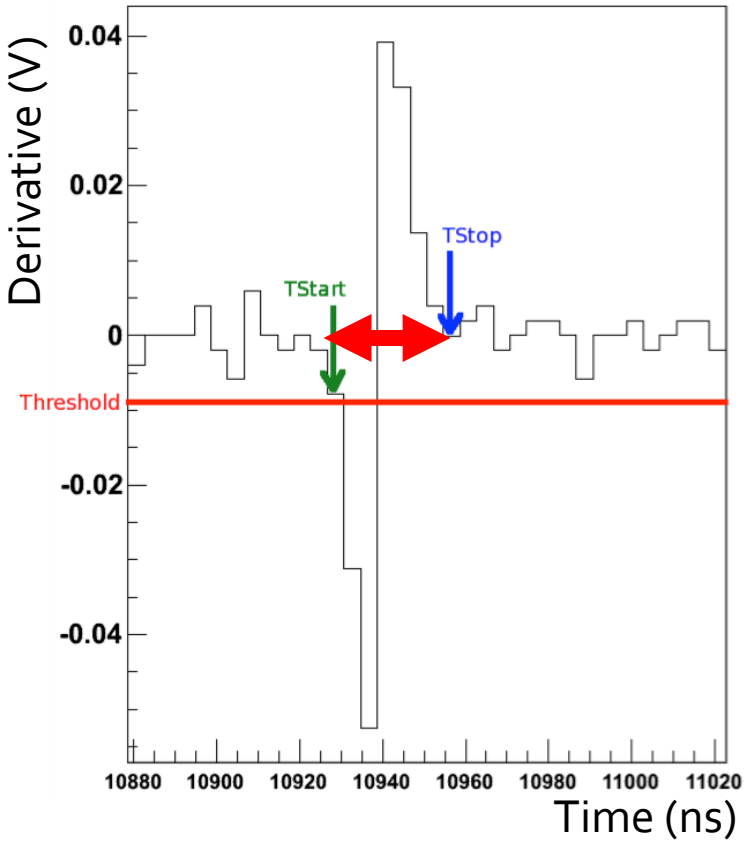




Each pulse ➔ 6 observables:

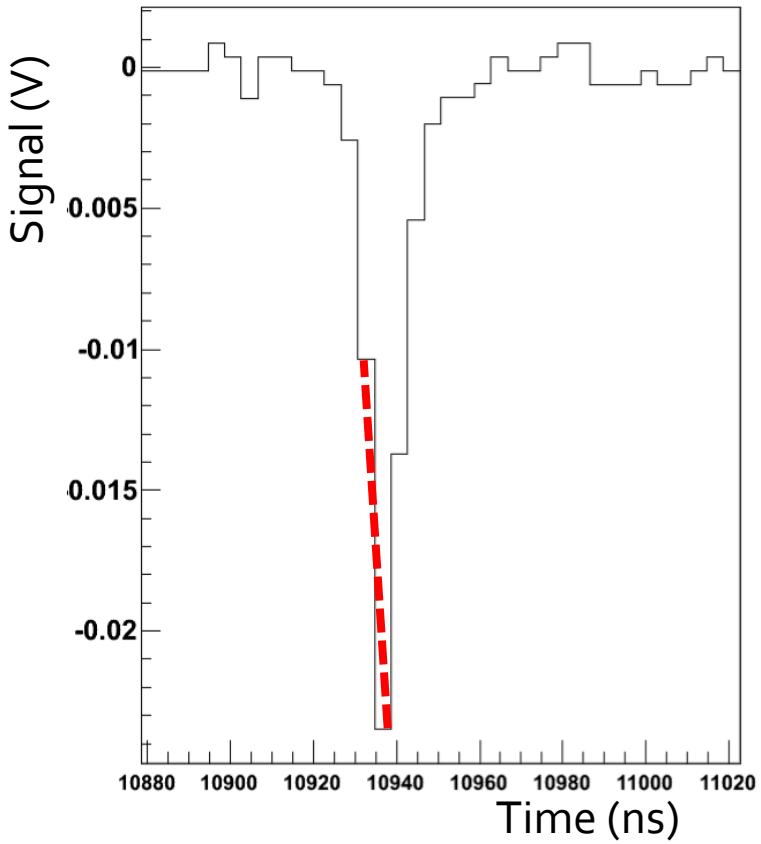
- Pulse integration
- Pulse length

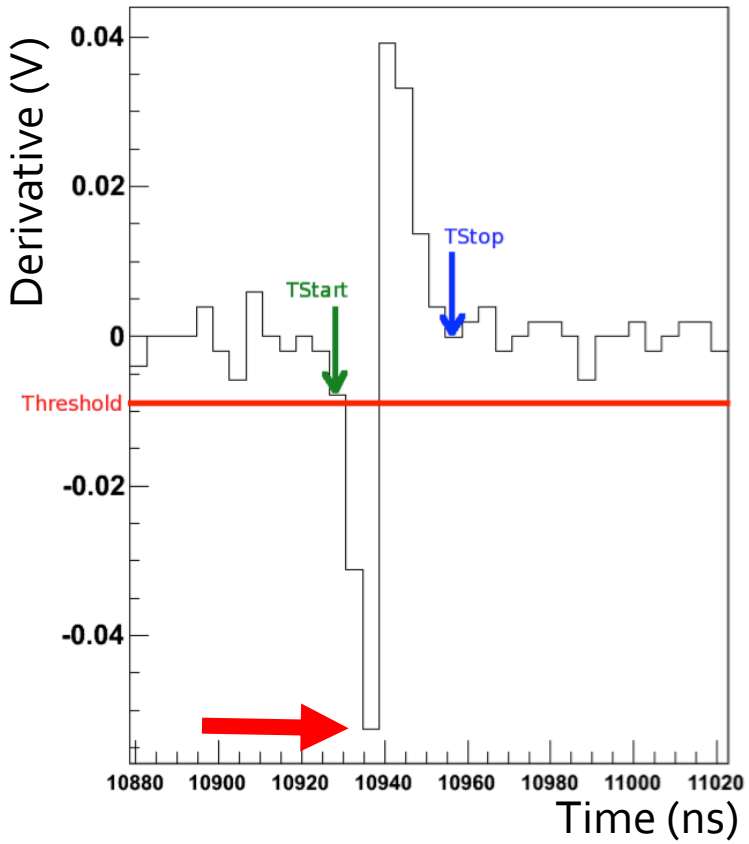




Each pulse ➔ 6 observables:

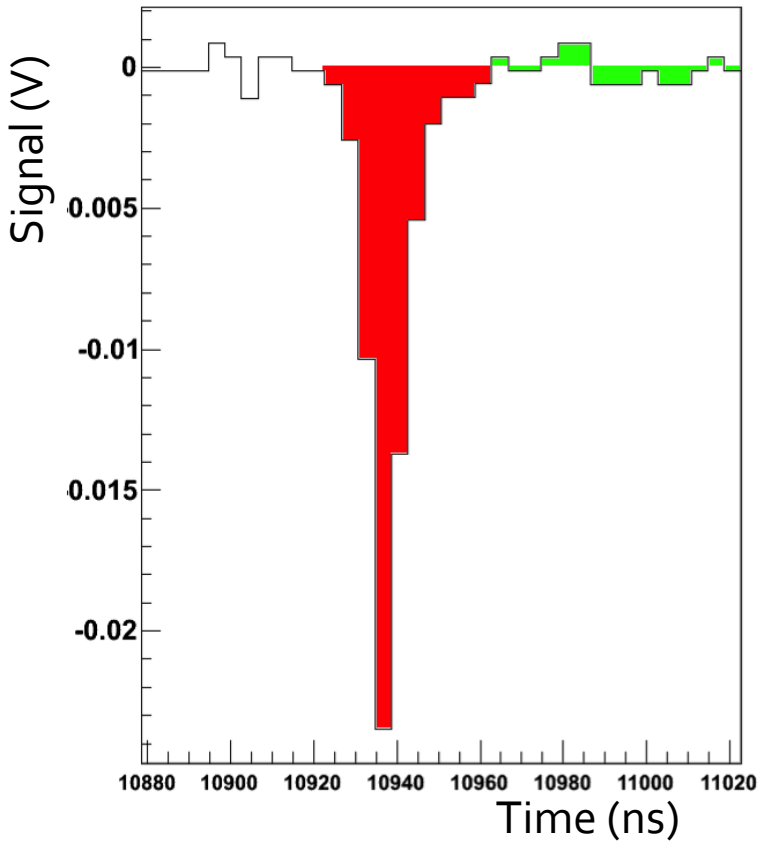
- Pulse integration
- Pulse length
- Minimum derivative





Each pulse ➔ 6 observables:

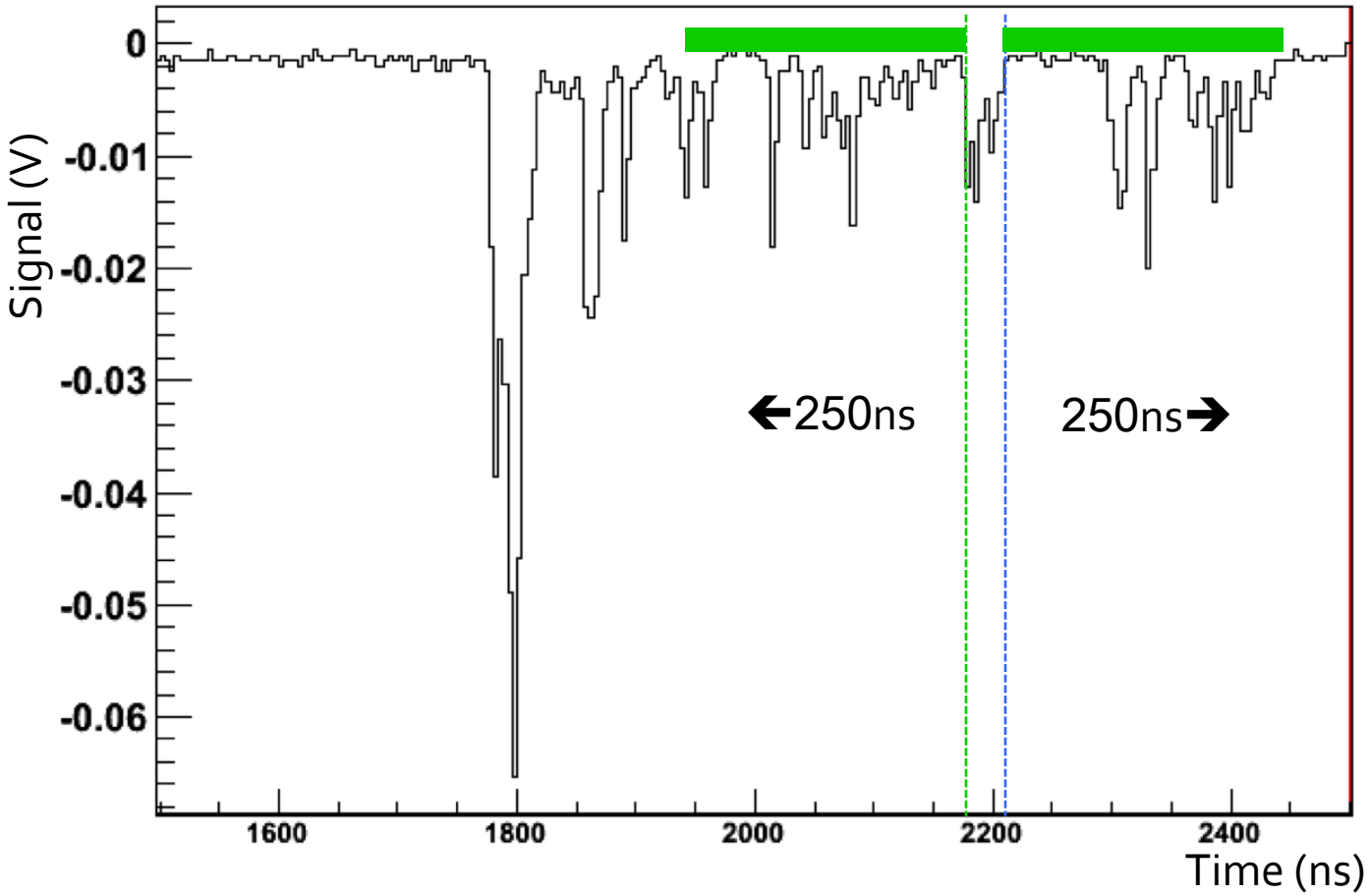
- Pulse integration
- Pulse length
- Minimum derivative
- Q1525



$$Q1525 = \frac{\int_{Start}^{Stop} S(i)}{\int_{Start}^{Stop} S(i) + \int_{Stop}^{Stop+60\,ns} S(i)}$$

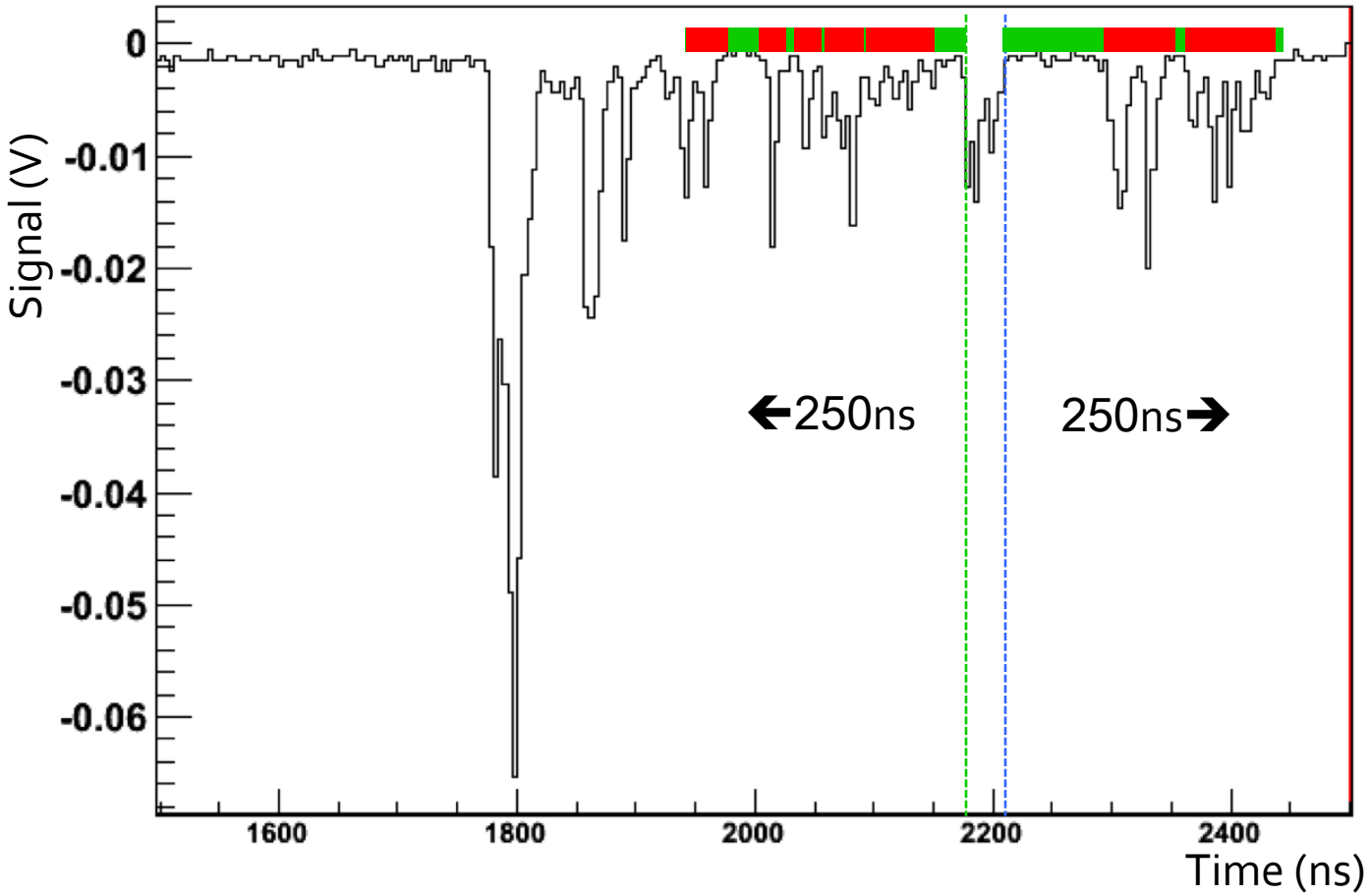
Each pulse ➔ 6 observables:

- Pulse integration
- Pulse length
- Minimum derivative
- Q1525
- Occupancy



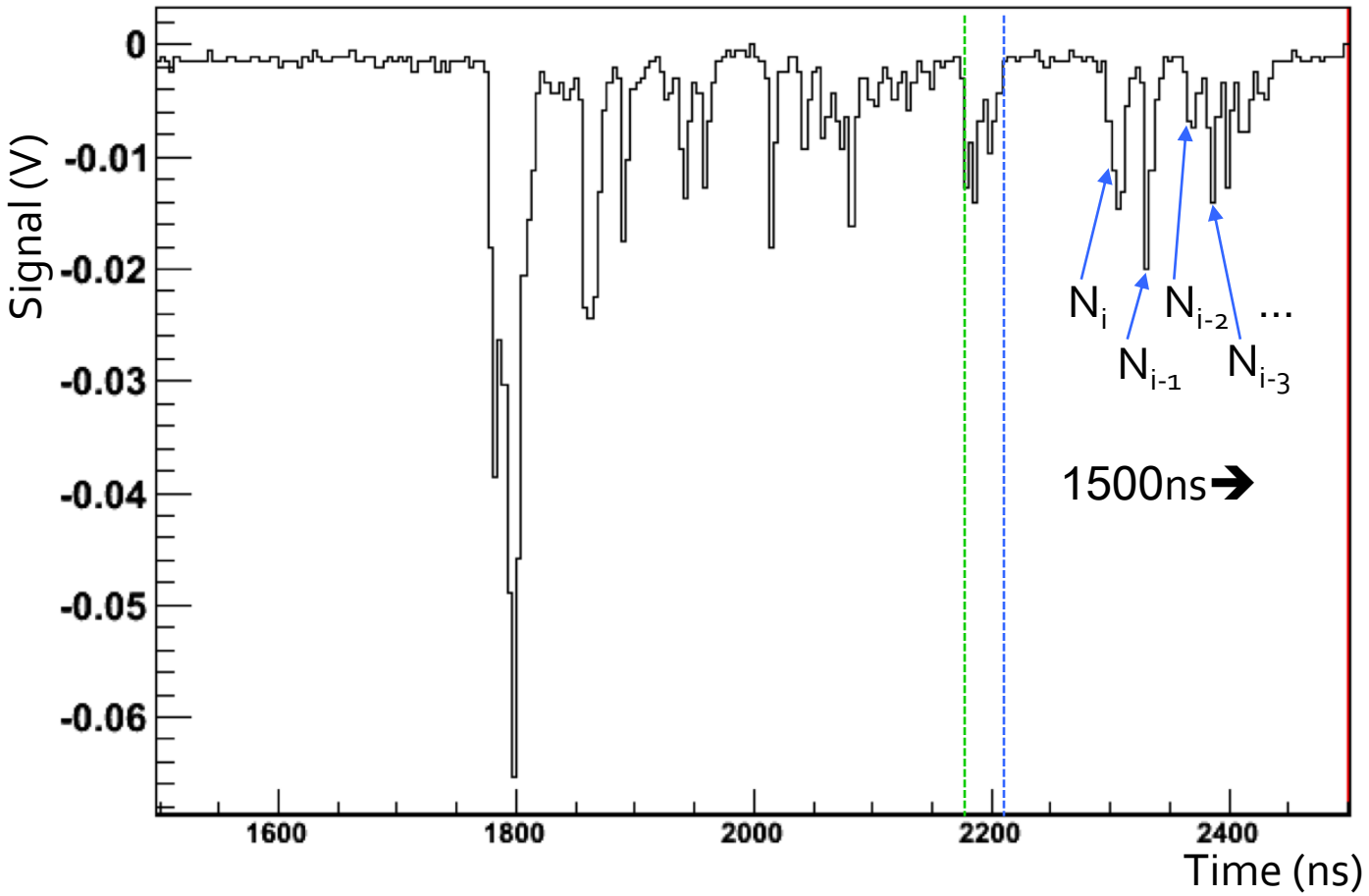
Each pulse ➔ 6 observables:

- Pulse integration
- Pulse length
- Minimum derivative
- Q1525
- Occupancy



Each pulse ➔ 6 observables:

- Pulse integration
- Pulse length
- Minimum derivative
- Q1525
- Occupancy
- Rate



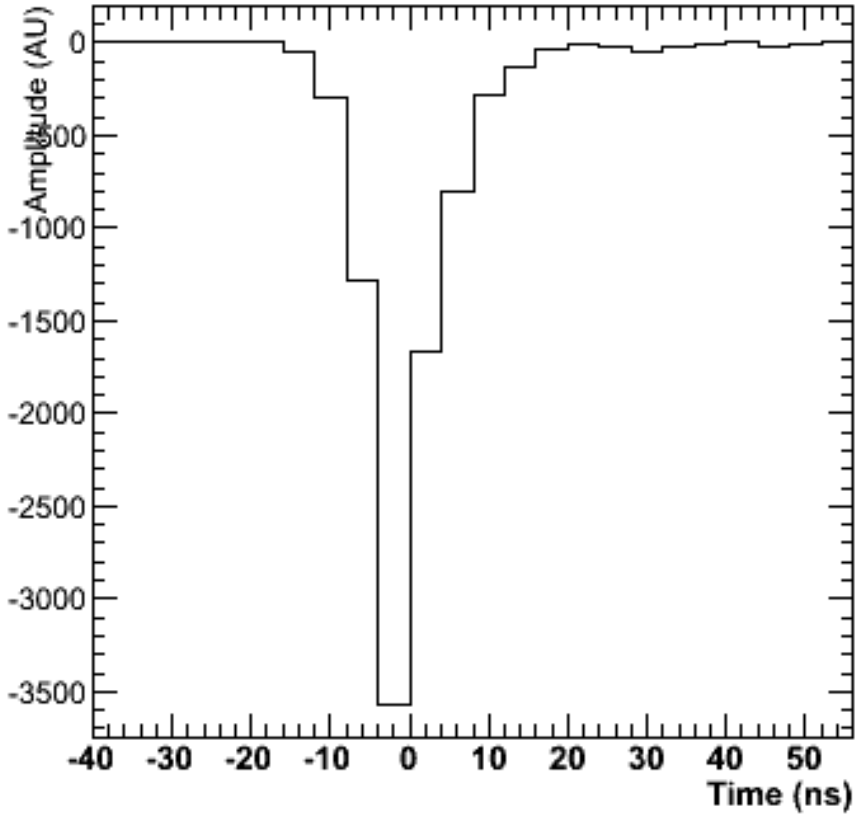
PDF for each observables

- Maximum likelihood over the full waveform
  - Weight of each number of PE
- Maximum likelihood over each pulse
  - Most probable number of PE

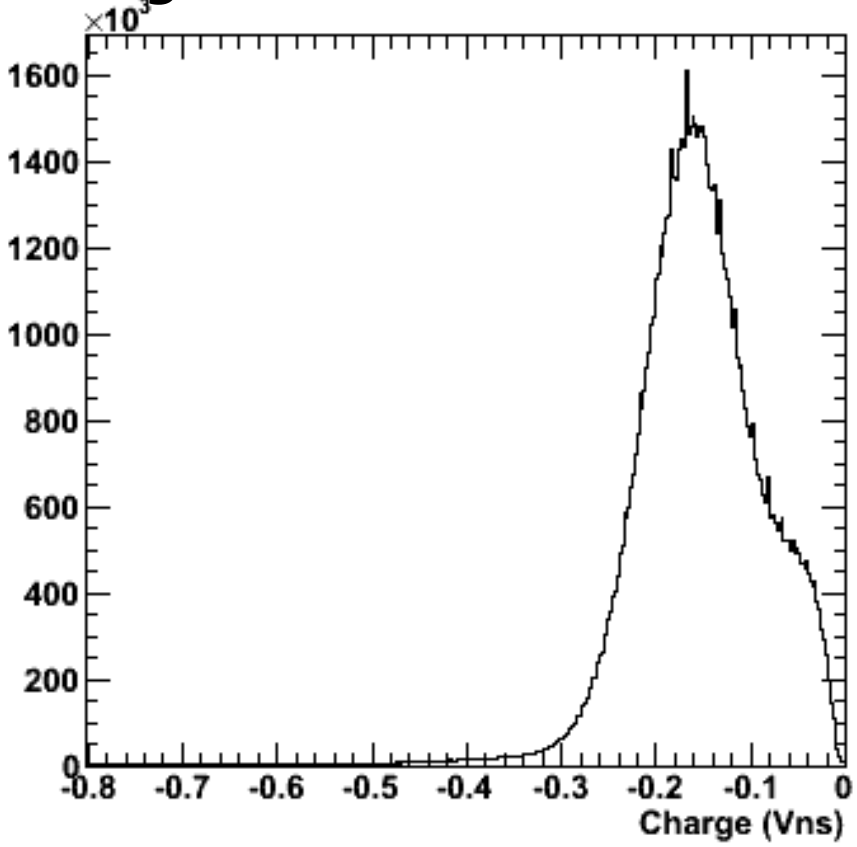
Single PE pulse shape & Spectrum

Best candidate for SPE: Isolated PE

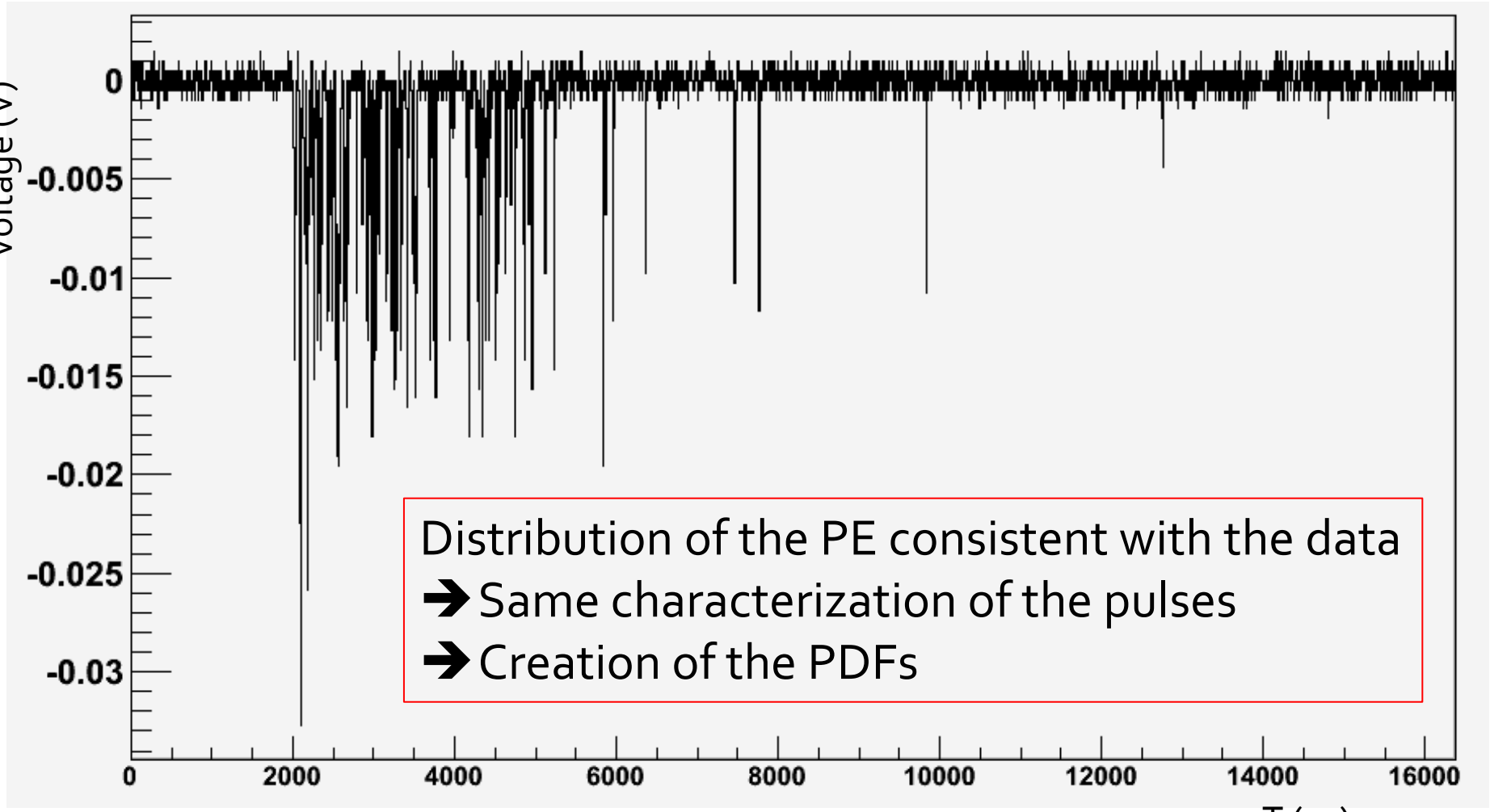
Average pulse shape



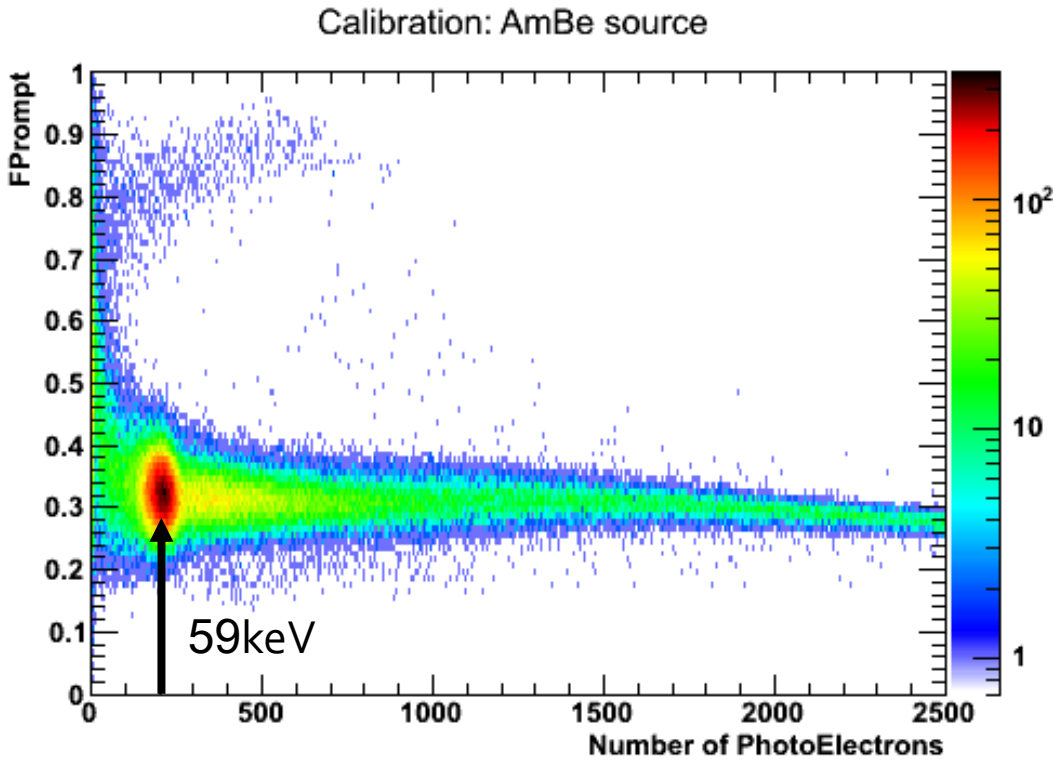
Charge distribution



Creation of an artificial waveform

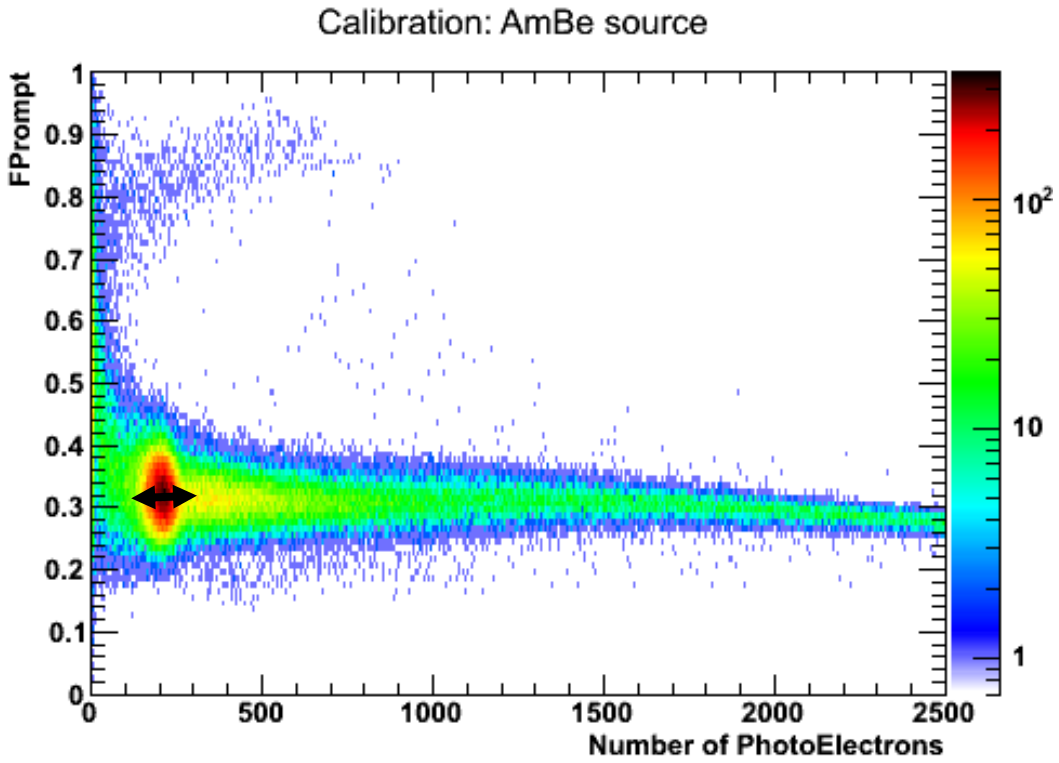


Algorithm efficacy (DEAP-1 data)



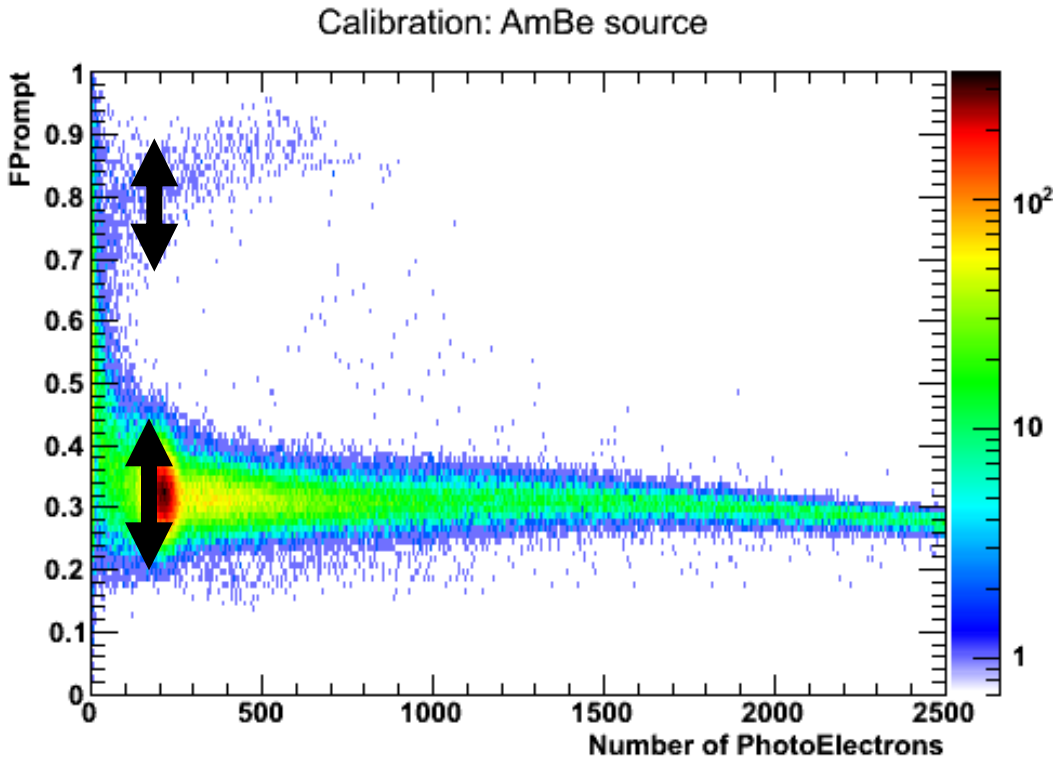
- Light yield

Algorithm efficacy (DEAP-1 data)



- Light yield
- Energy resolution

Algorithm efficacy (DEAP-1 data)



- Light yield
- Energy resolution
- Pulse shape discrimination efficiency

Comparison Continuous/Discrete

Preliminary !!!

	Continuous	Discrete
Light Yield (59keV): PE/keV	3.6	4.0
Energy resolution σ/E	0.128	0.127
PSD efficiency (50%)	$< 10^{-8}$	$< 10^{-7}$
PSD efficiency (90%)	$< 10^{-7}$	$<10^{-6}$

Analysis (Continuous): H. Mulcahy

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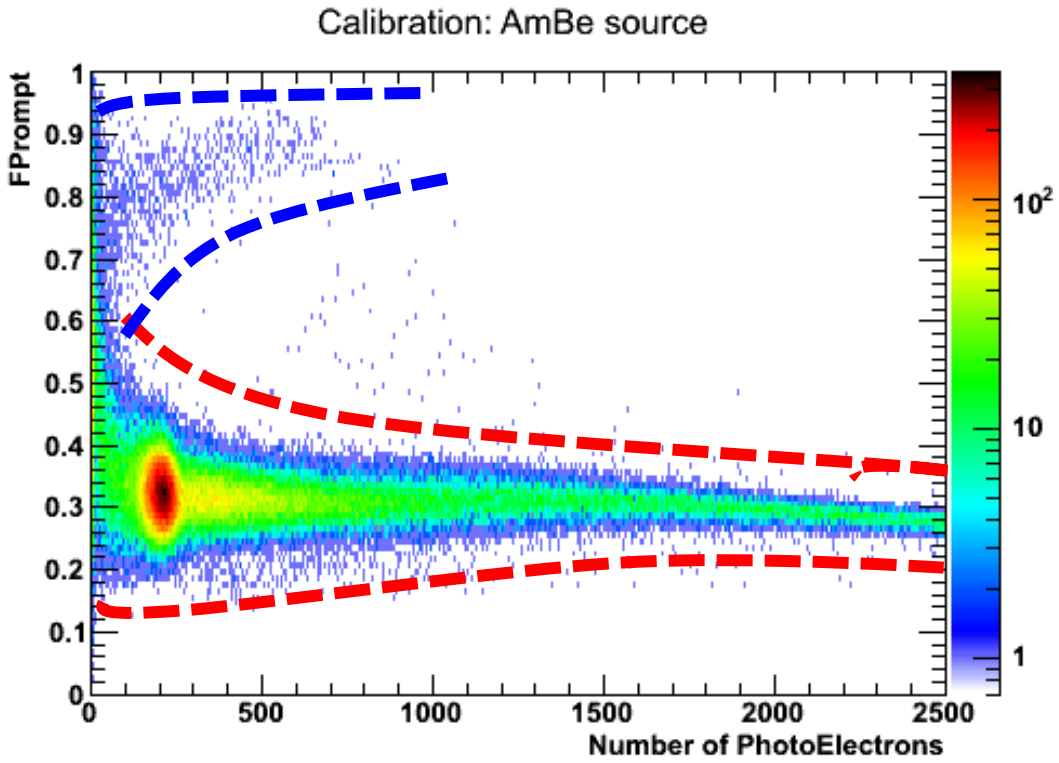
Room for optimization

Analysis (Continuous): H. Mulcahy

What about DEAP-3600 ?



- 255 PMTs => more electronic noise
  - The bands will get wider except if we can recognize it
  - Full scale simulation work in progress

Current development of Discrete

- Main drawback: likelihood algorithm slow
  - DEAP-1: 2channels/ DEAP-3600: 255 channels
  - Rates higher in DEAP-3600
- Real time analysis for ^{39}Ar background rejection

➢ Parallelization of the process
➢ GPU computing / CUDA framework

Conclusion

- Discrete counting looks promising, with still some room for optimization
- Expected electronic noise makes the discrete counting a good contender for DEAP-3600
- Simulation work in progress to characterize the algorithm efficiencies with DEAP-3600