Single Photon Counting and PMT Characterization for DEAP-3600

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CAP Congress
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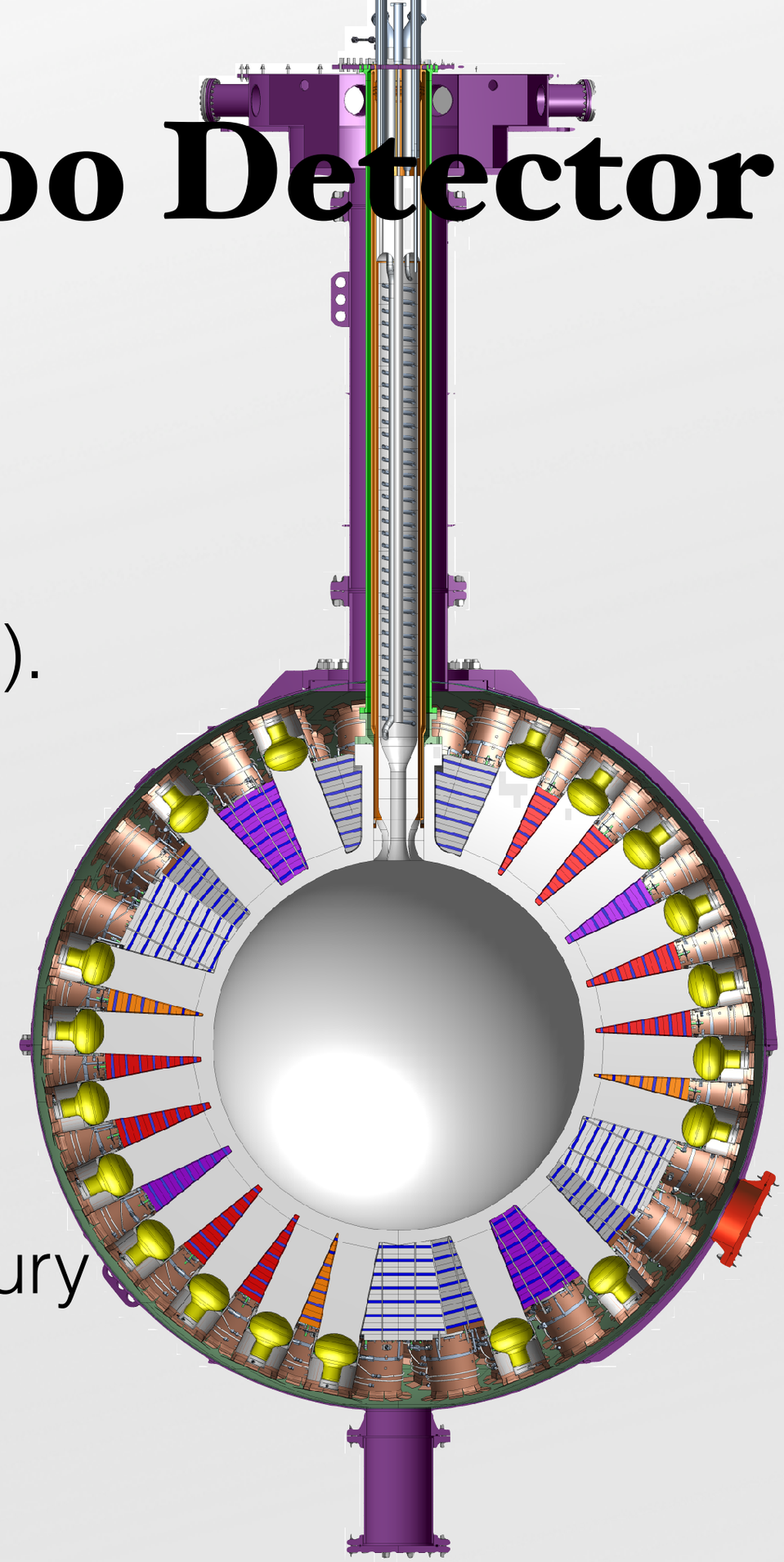
The DEAP-3600 Detector

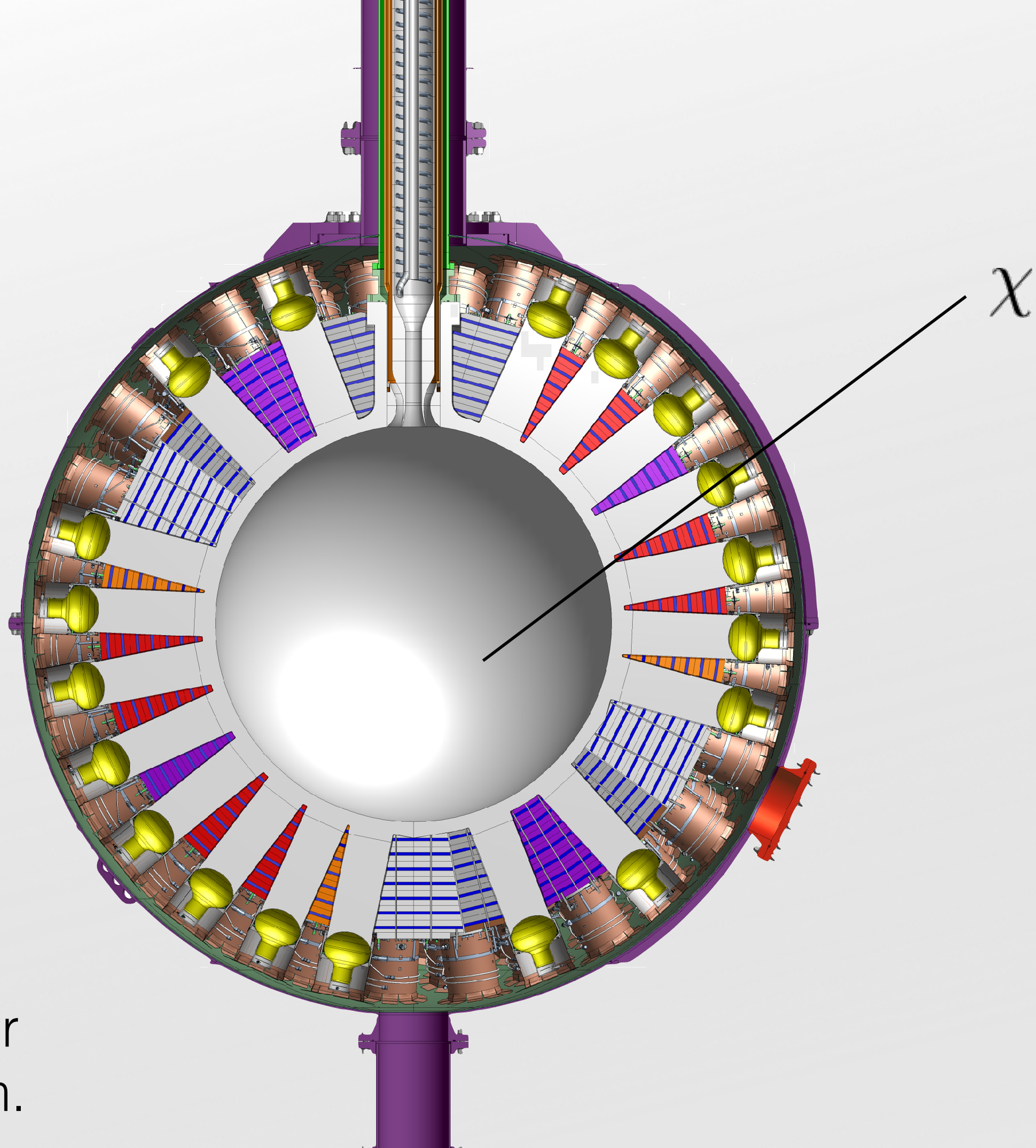
- **D**ark Matter **E**xperiment using **A**rgon and **P**ulse shape discrimination.

- **3600** kg of LAr (1000 kg fiducial).

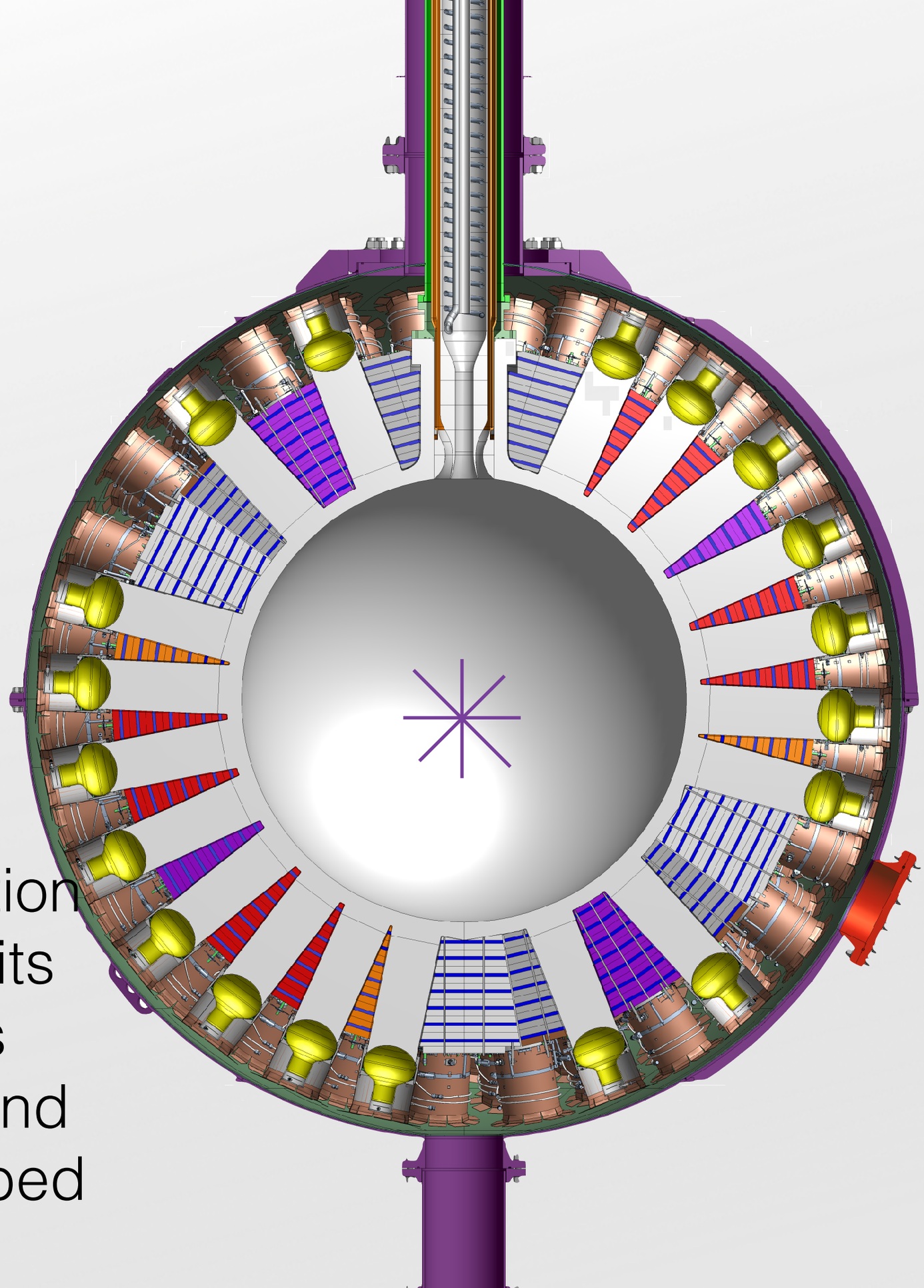
- Single phase detection with 255 PMTs giving ~70% cathode coverage.

- Located 2 km (6000 mwe) underground in SNOLAB, Sudbury ON.

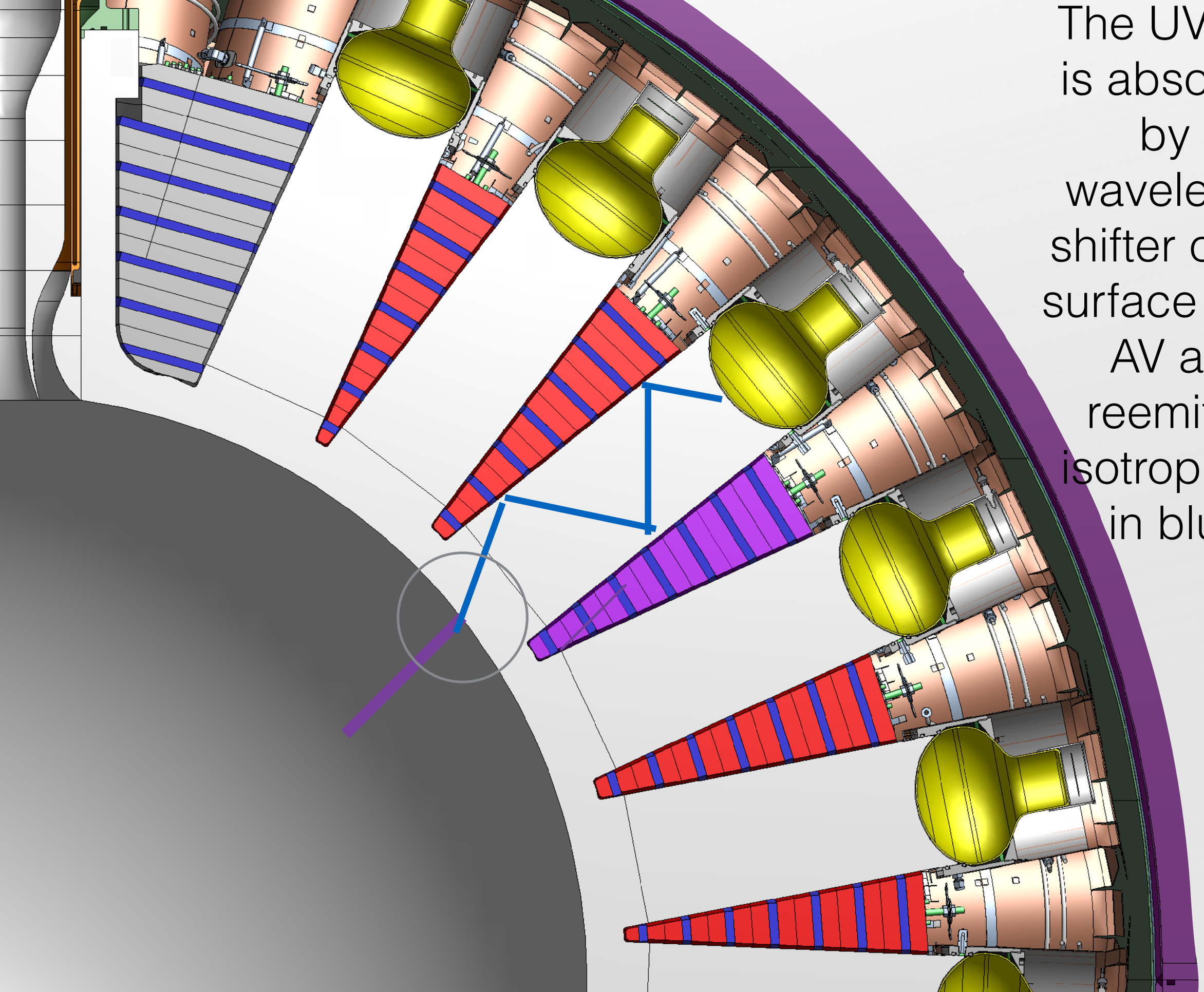




Particle collisions in LAr cause excited dimer states to form.

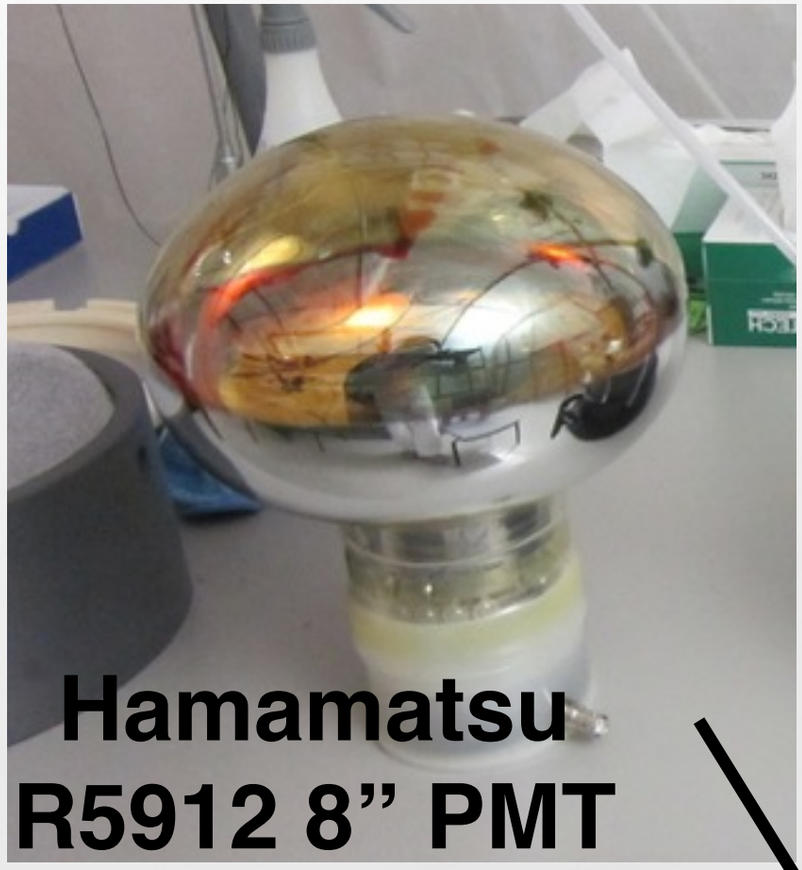


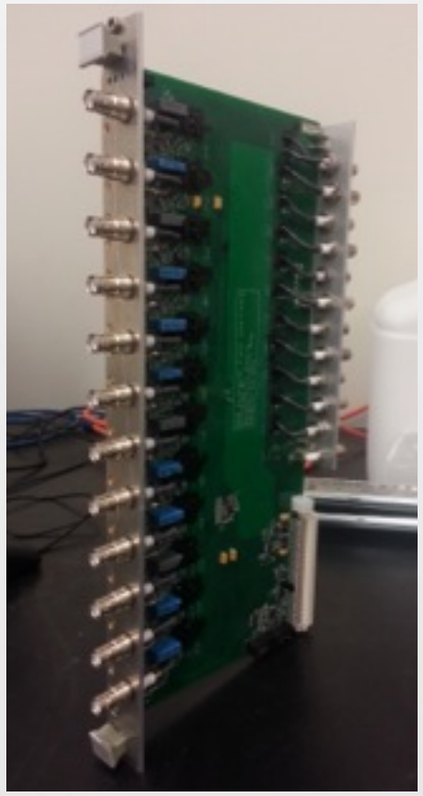
The de-excitation of dimers emits UV photons isotropically and is not reabsorbed by the LAr.

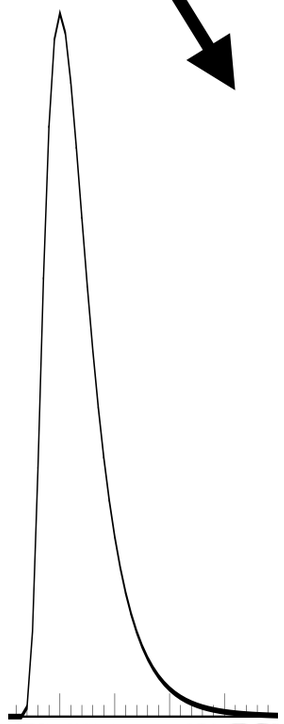


The UV light is absorbed by a wavelength shifter on the surface of the AV and reemitted isotropically in blue.

DEAP-3600 PMTs and DAQ



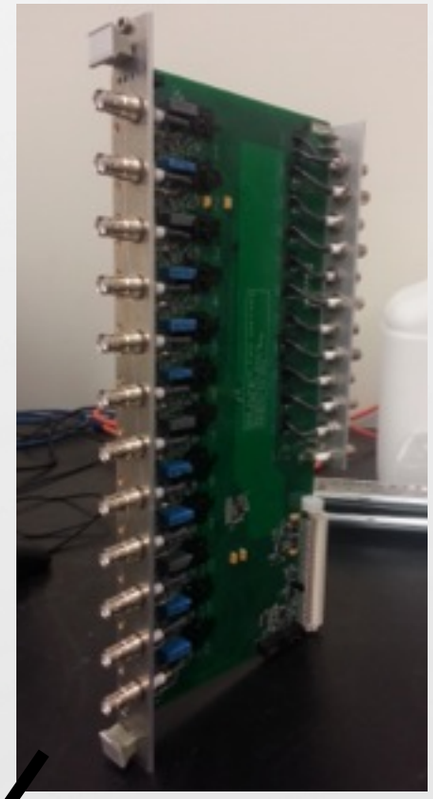


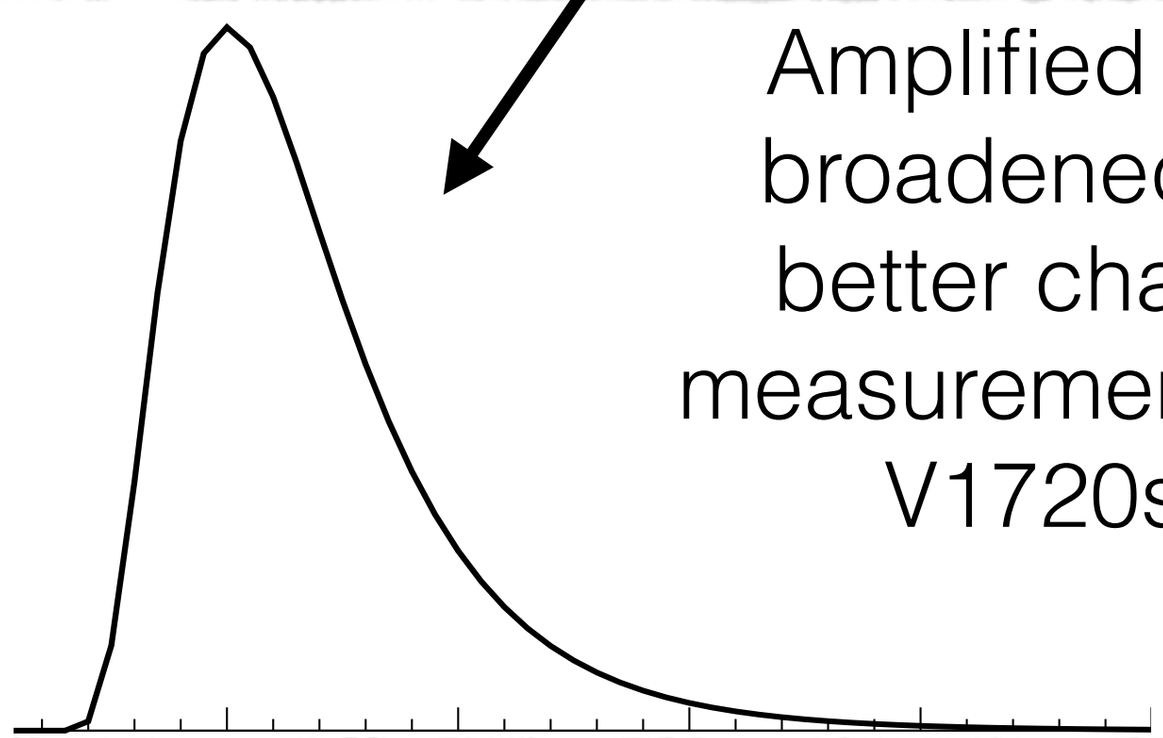


Fast rise time
pulse form PMT

DEAP-3600 PMTs and DAQ

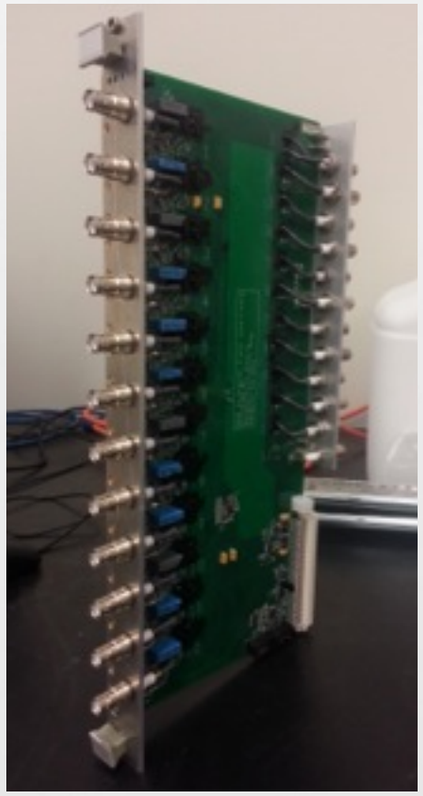
Custom signal conditioning board



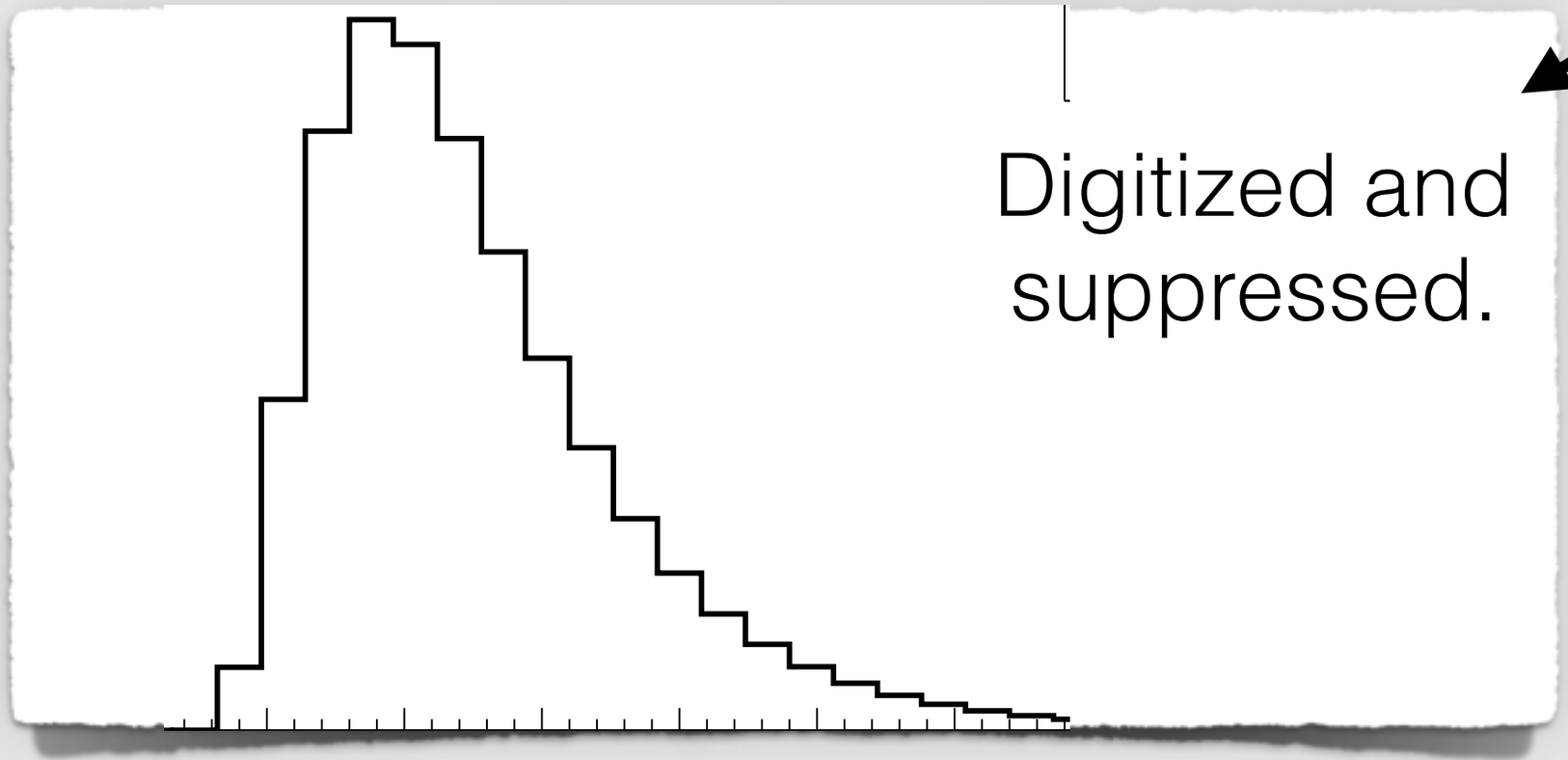


Amplified and broadened for better charge measurement with V1720s.

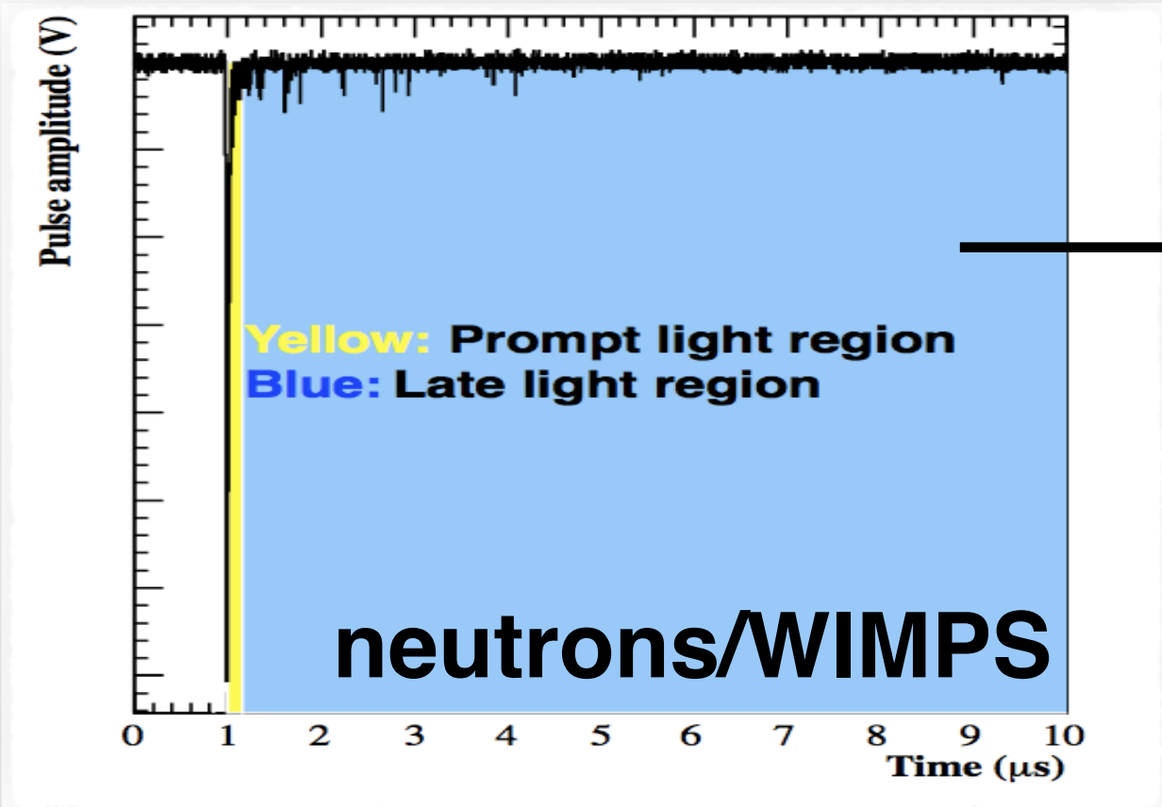
DEAP-3600 PMTs and DAQ

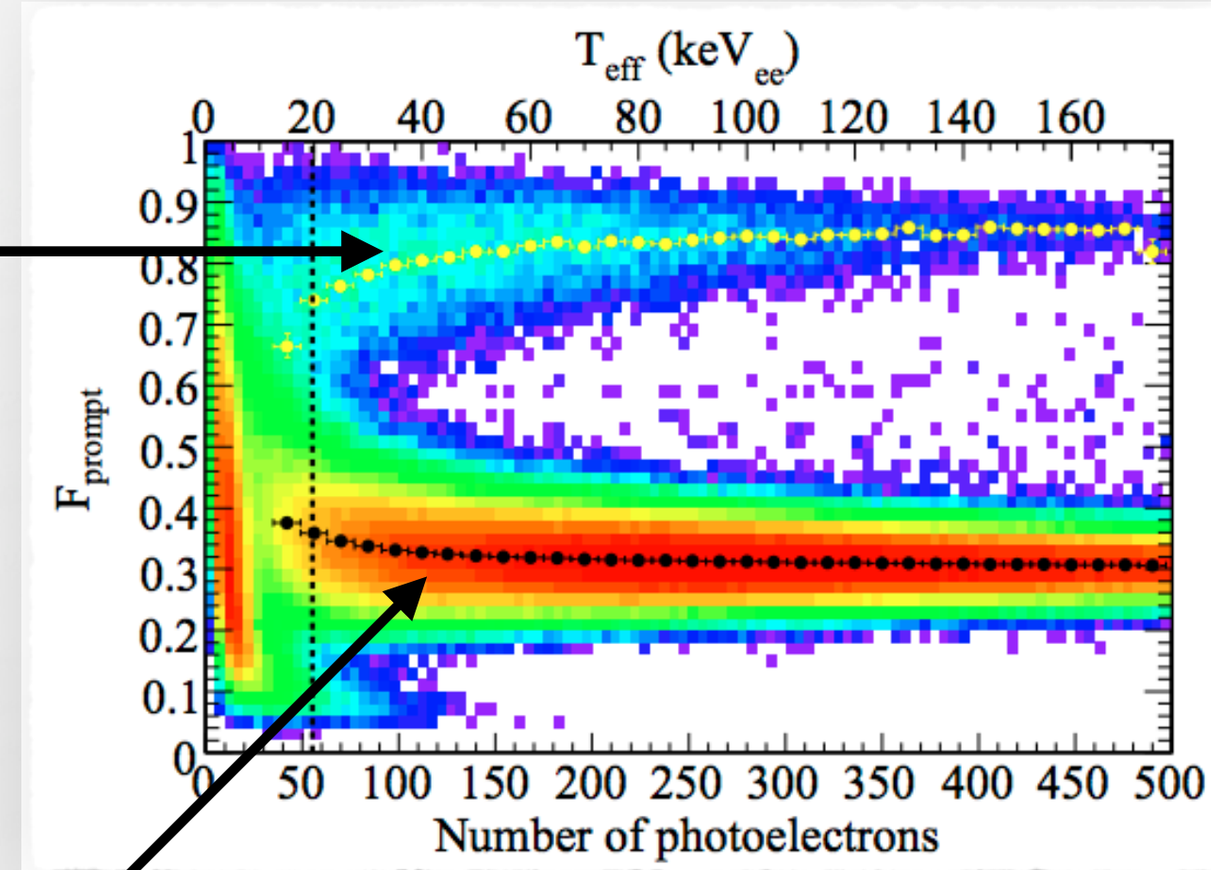


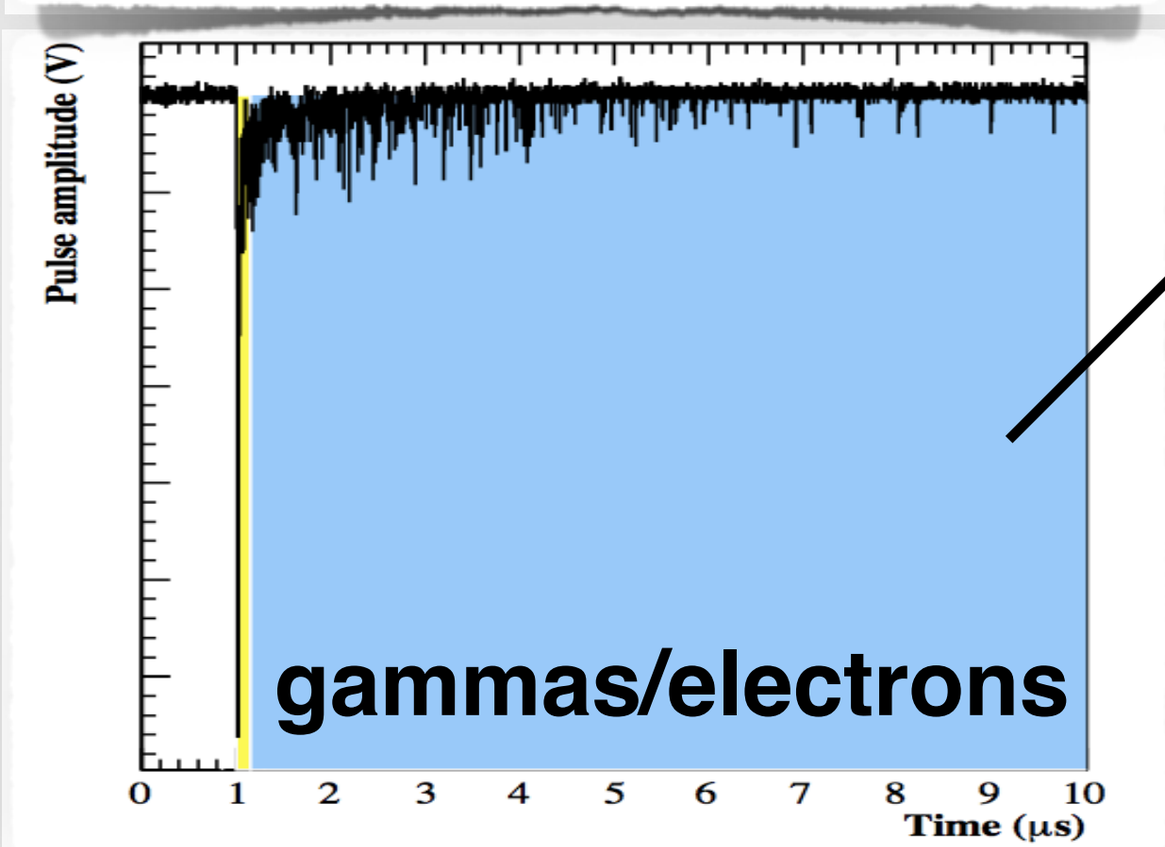
CAEN V1720 Digitizer



Pulse Shape Discrimination



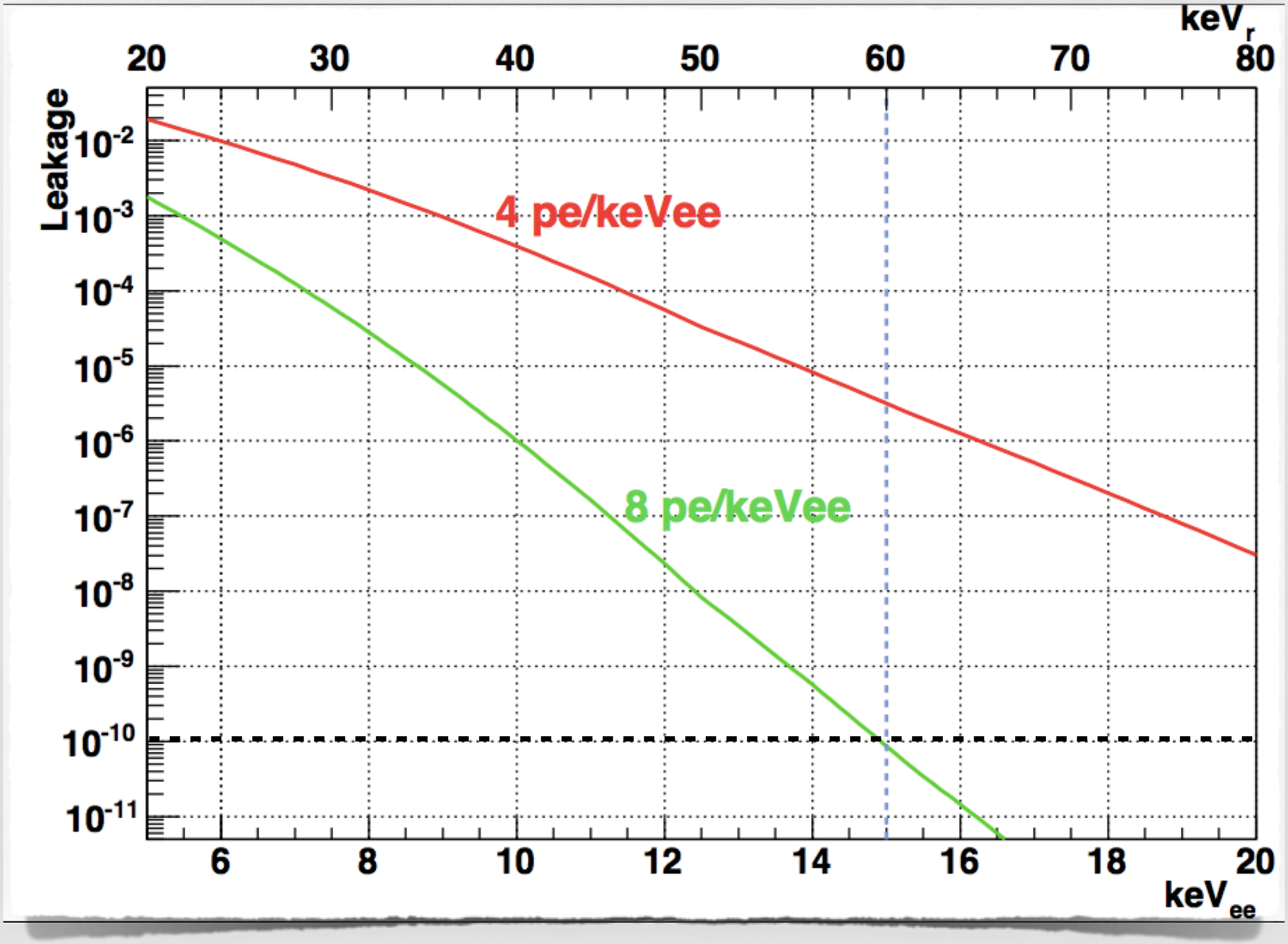




$$\text{fPrompt} = \frac{\text{prompt charge}}{\text{total charge}}$$

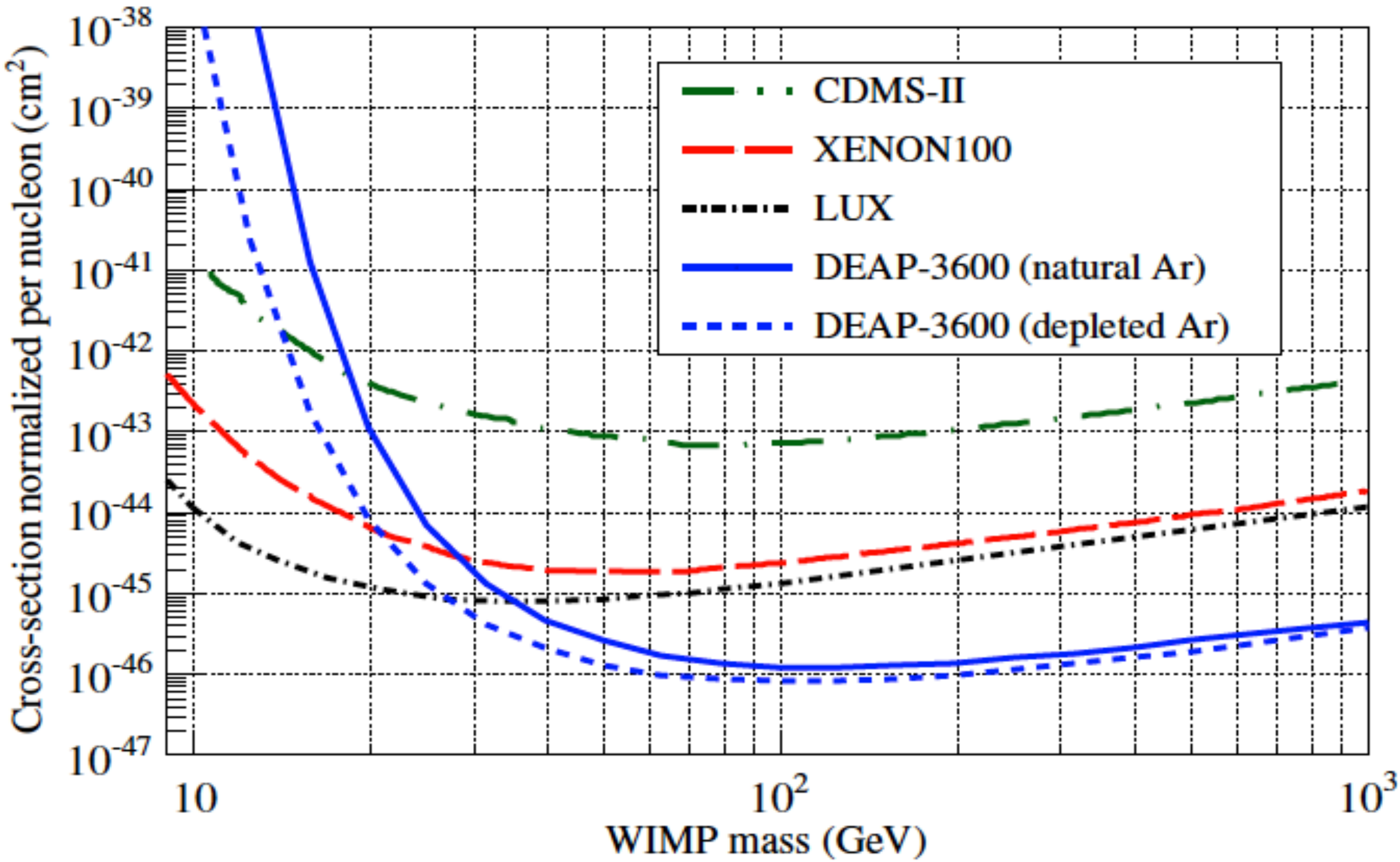
*From the DEAP-1 prototype

Pulse Shape Discrimination



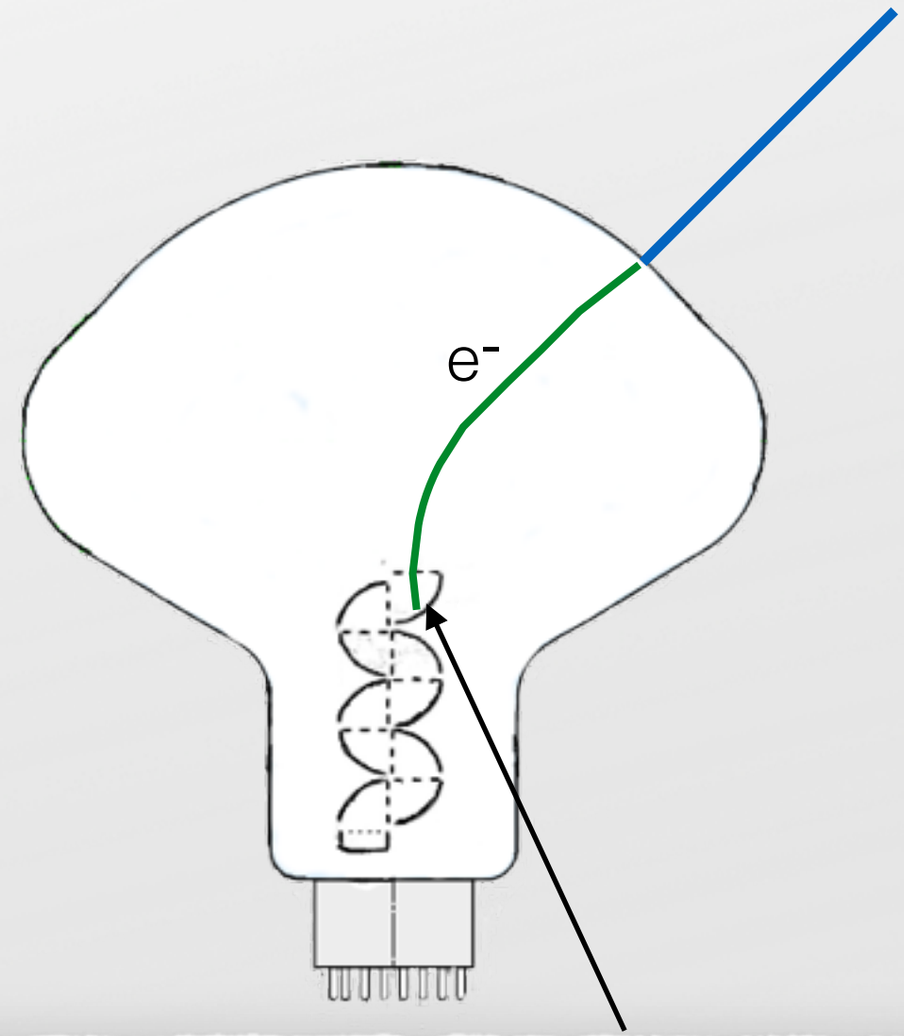
DEAP requires PSD to a level of 10^{-10}

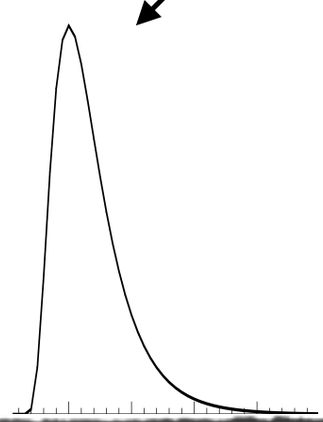
DEAP Physics Goal



PMT Characteristics

- Charge distribution for single photoelectron (SPE)



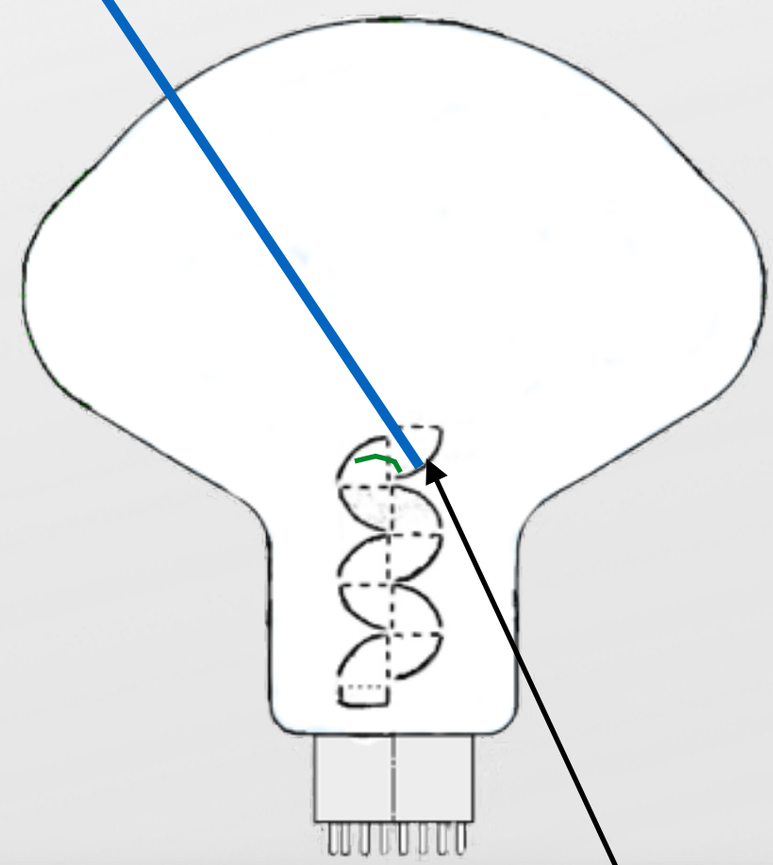


High variability in number of electrons released at first dynode causes wide SPE charge spread.

*Time Not To Scale

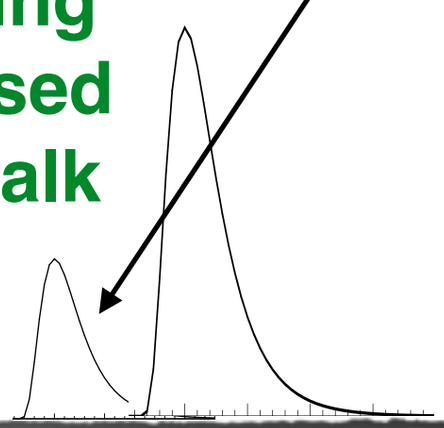
PMT Characteristics

- Early Pulsing



~25ns (PE transit time)

Early Pulse



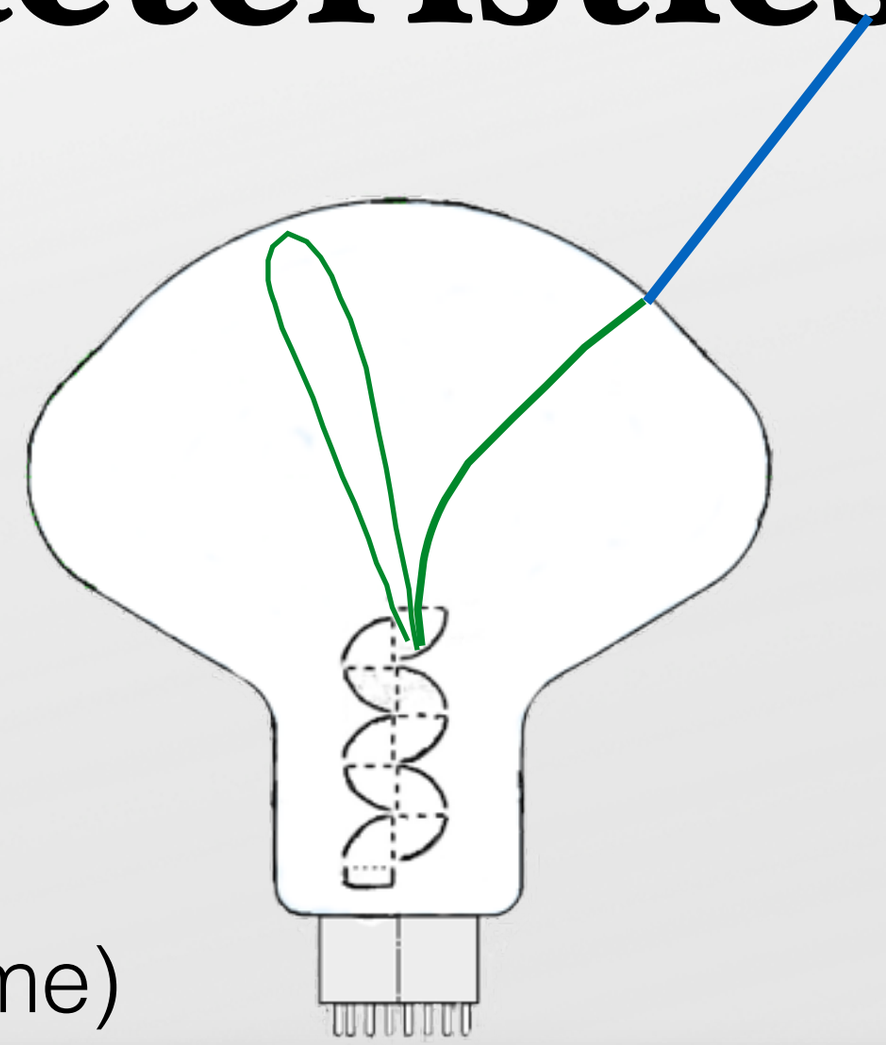
Early pulsing not discussed further in talk

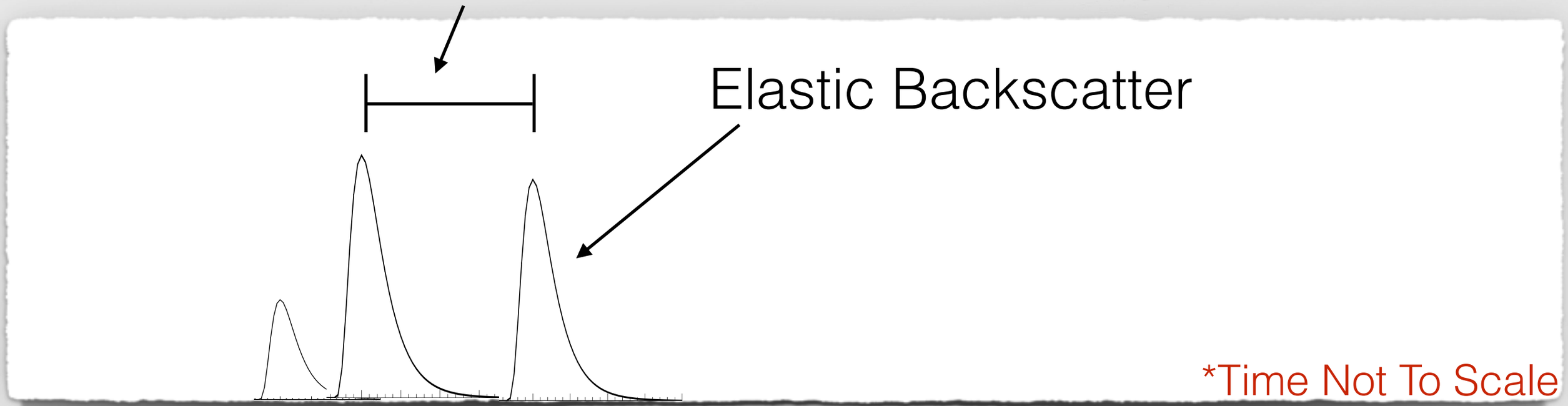
Photon only releases one electron at first dynode causing small pulse.

*Time Not To Scale

PMT Characteristics

- Backscatters



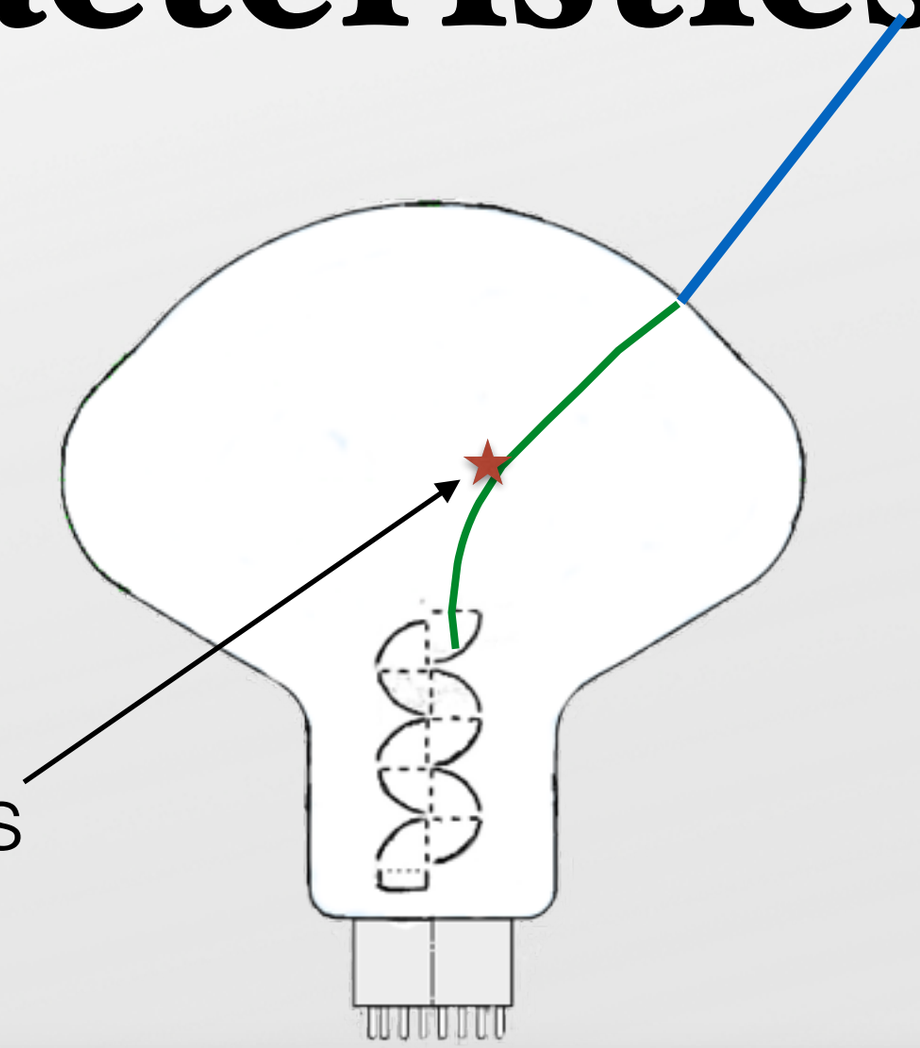


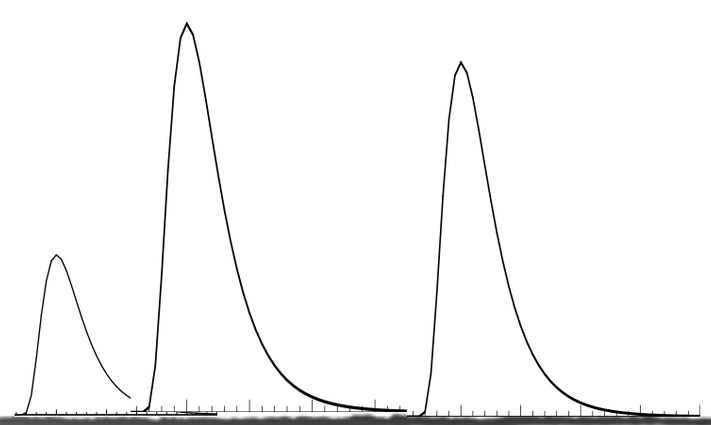
*Time Not To Scale

PMT Characteristics

- Afterpulsing

Ionization of residual gas

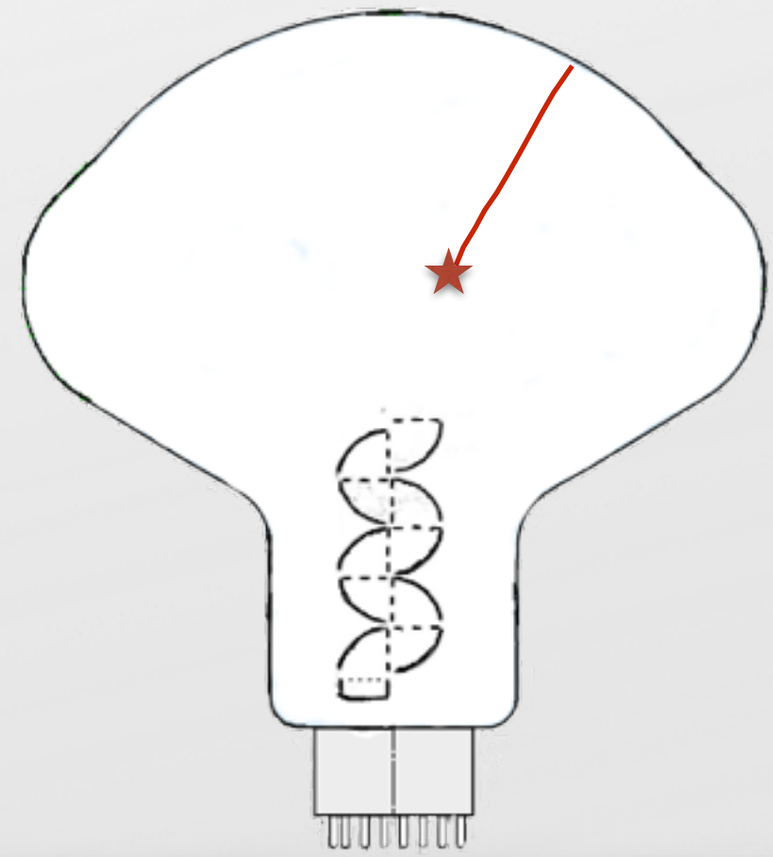


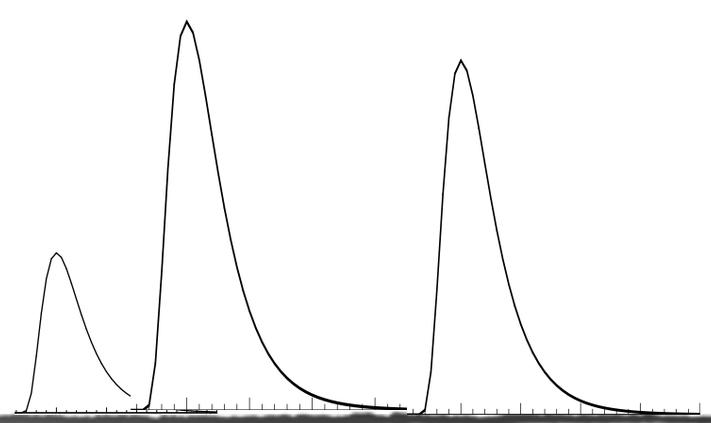


*Time Not To Scale

PMT Characteristics

- Afterpulsing

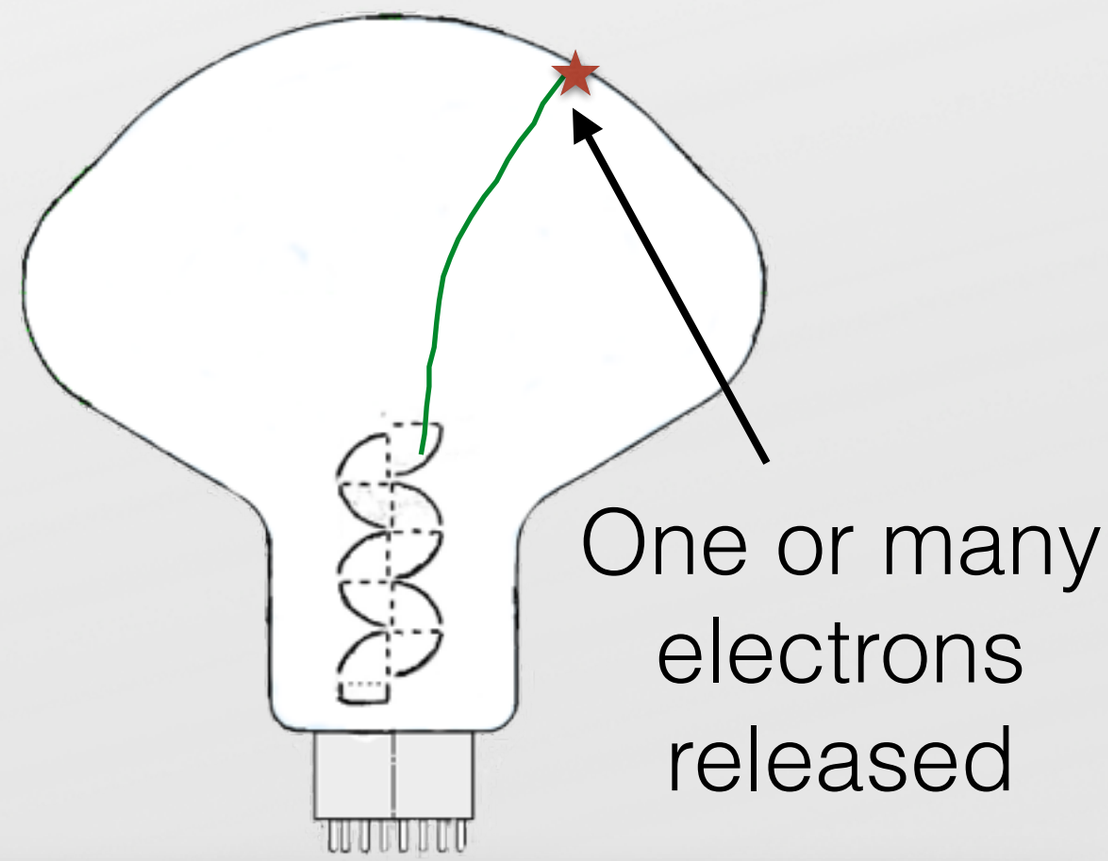


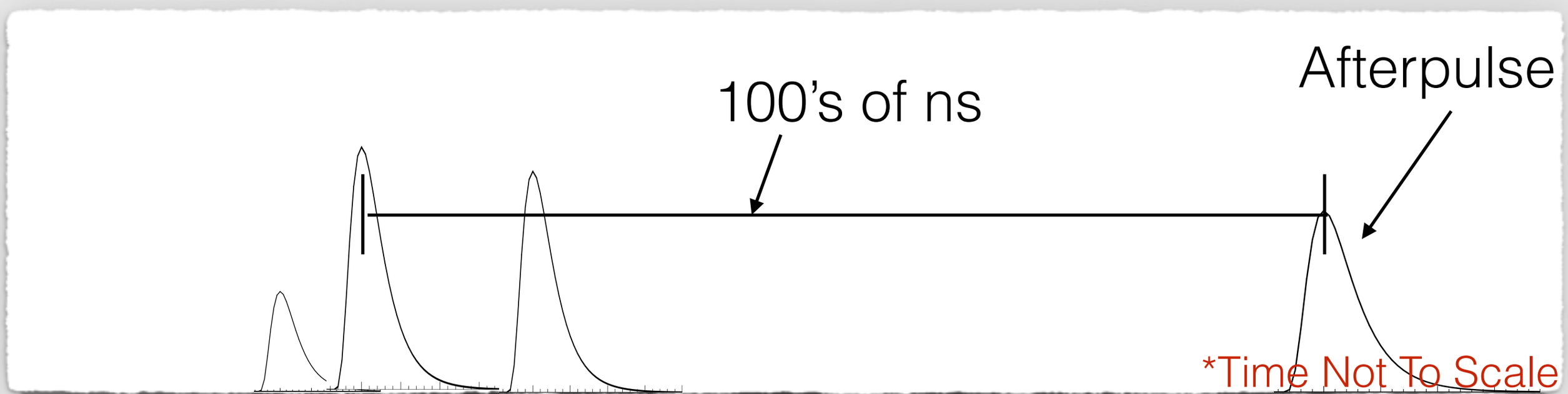


*Time Not To Scale

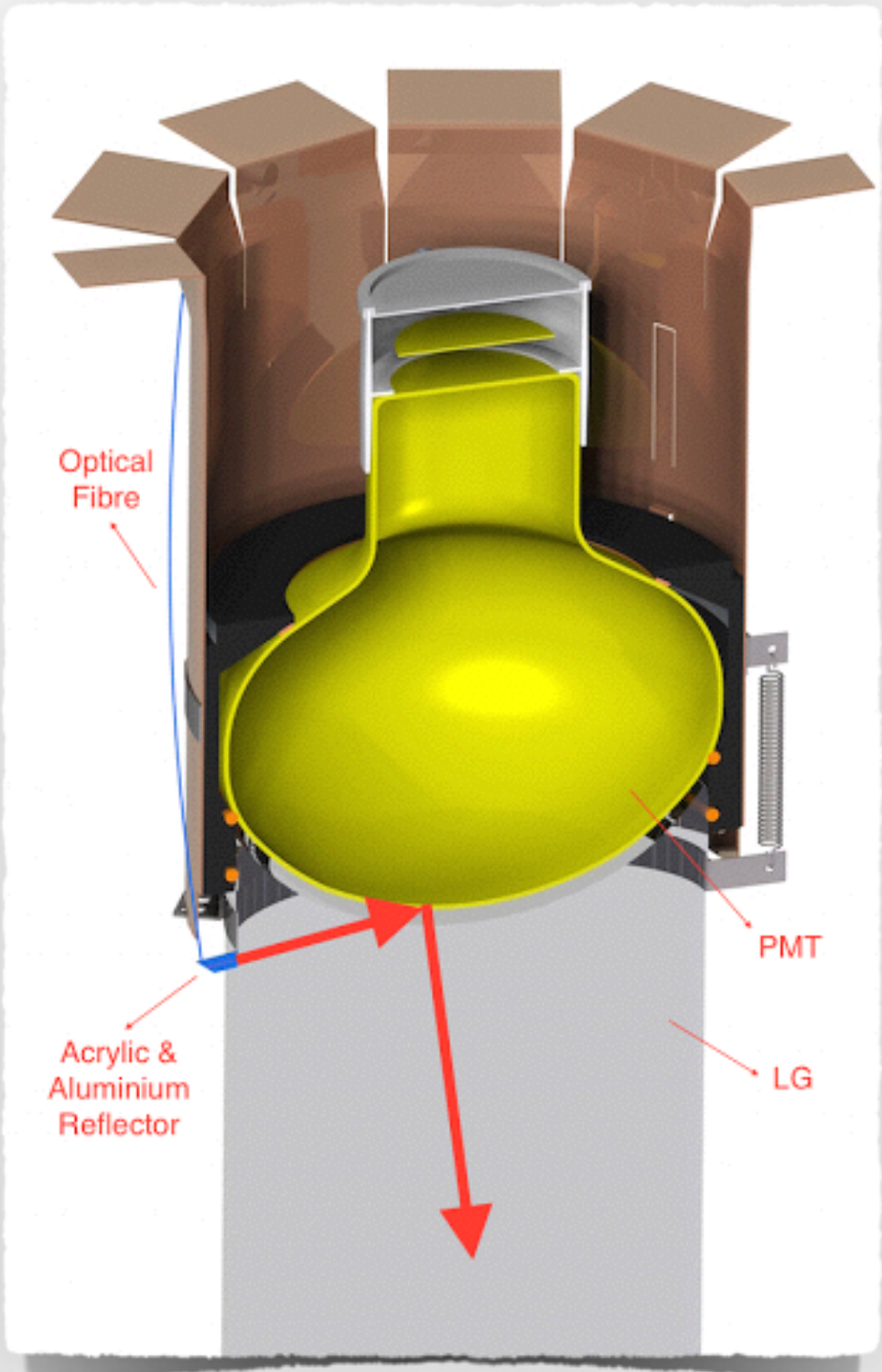
PMT Characteristics

- Afterpulsing



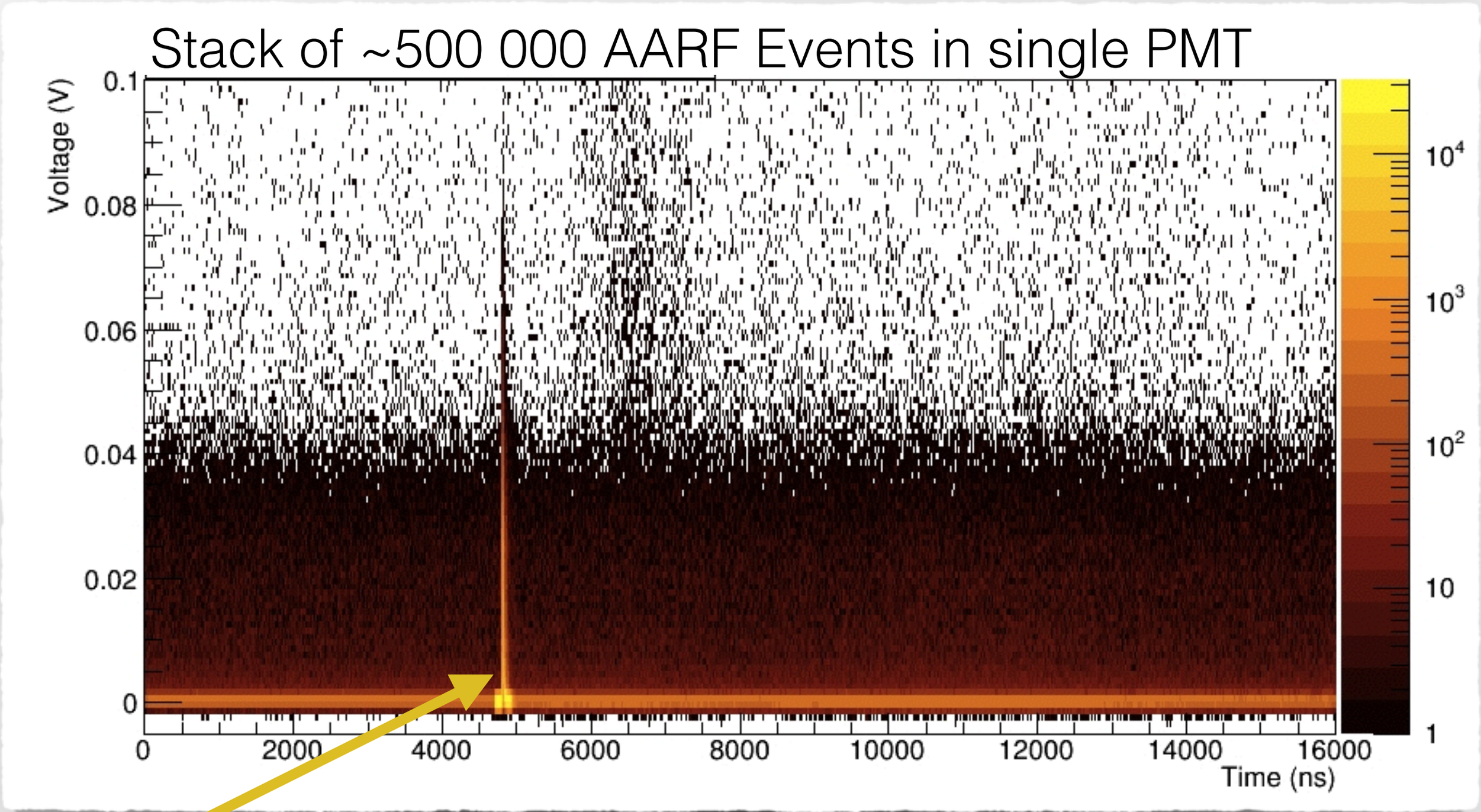


Acrylic and Aluminium Refletor and Fibre optic-System (AARF)



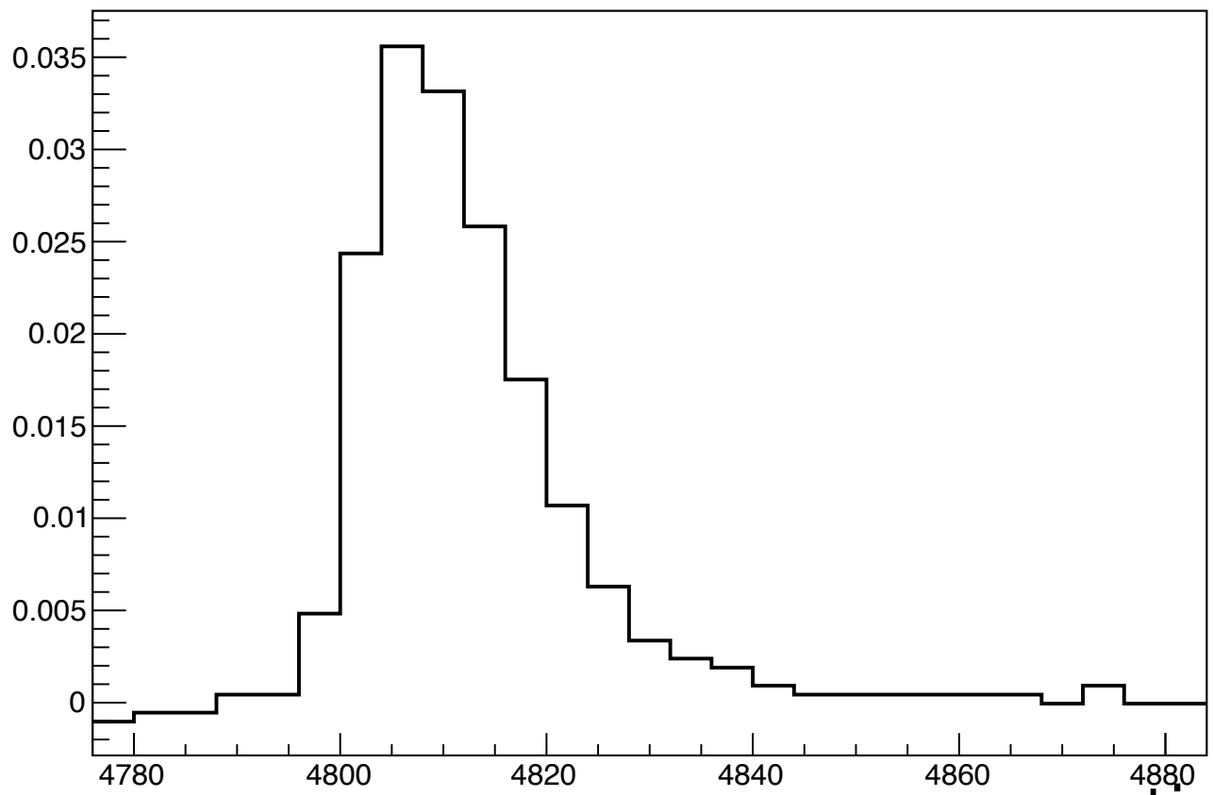
- Fibre optic lines are connected to 20 light guides throughout the detector.
- Each fibre is coupled to a LED at the opposite end.
- The LEDs can be flashed at different rates and intensities to help calibrate the detector.

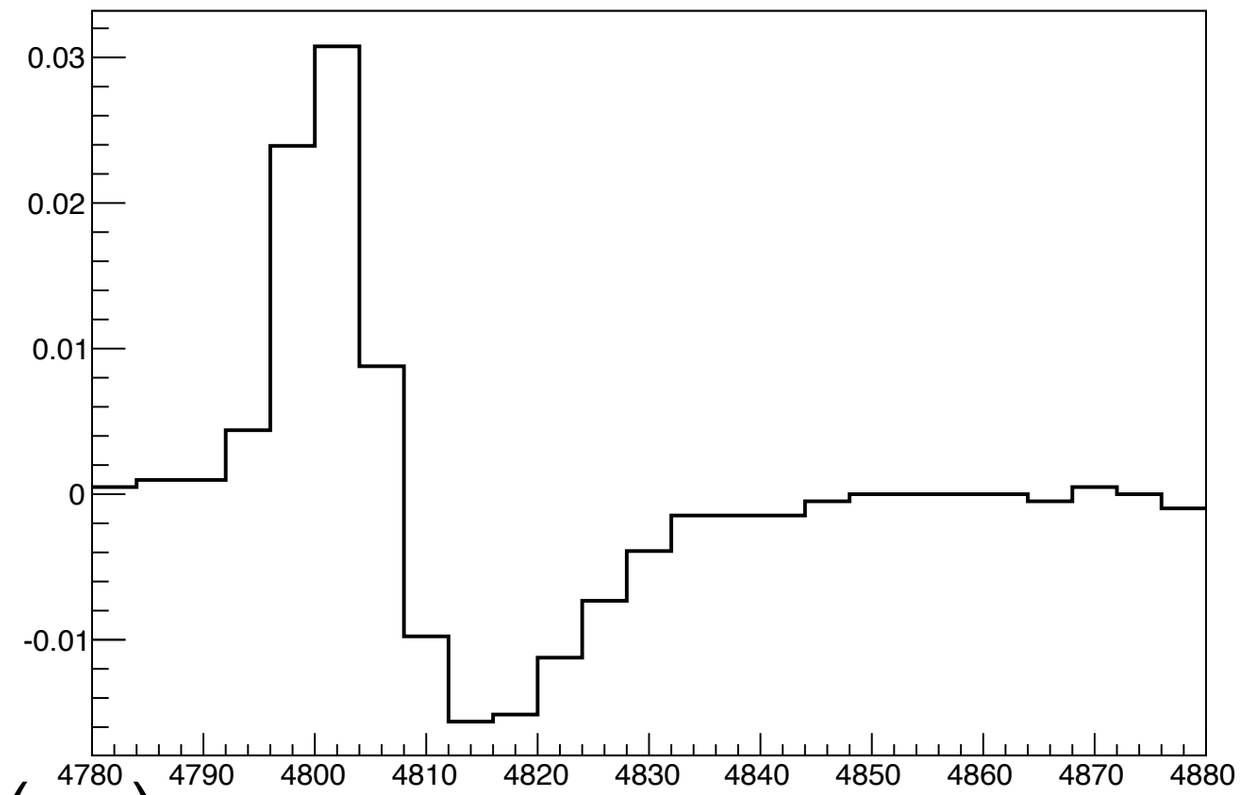
AARF Signal



- Sharp (~50 ns) prompt photon window

Pulse Finding



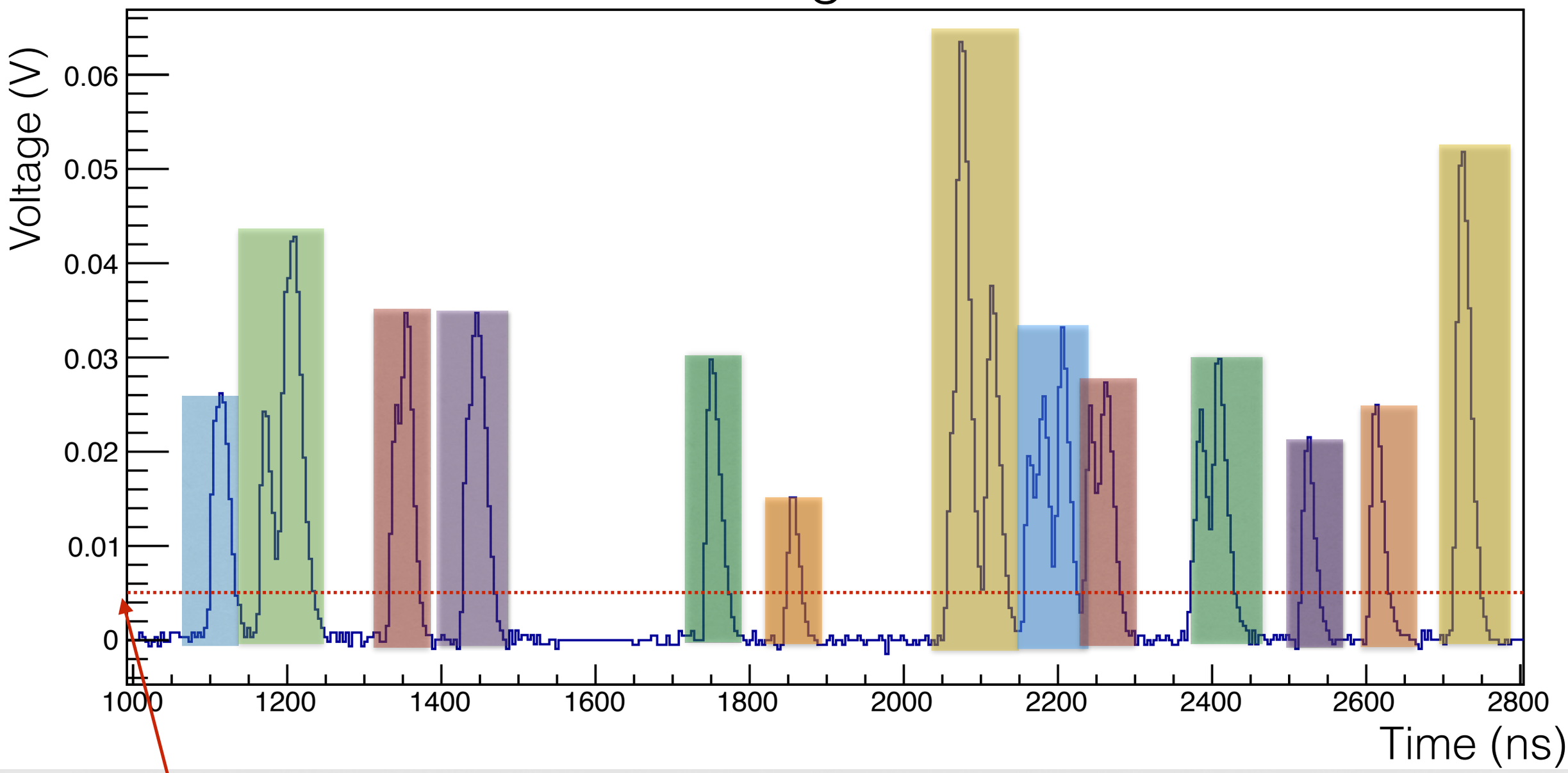


time (ns)

- The Standard pulse finder for DEAP looks at pulses in derivative space and looks for a derivative threshold crossing.
- Pulse finding in derivative space reduces error due to baseline shifts.

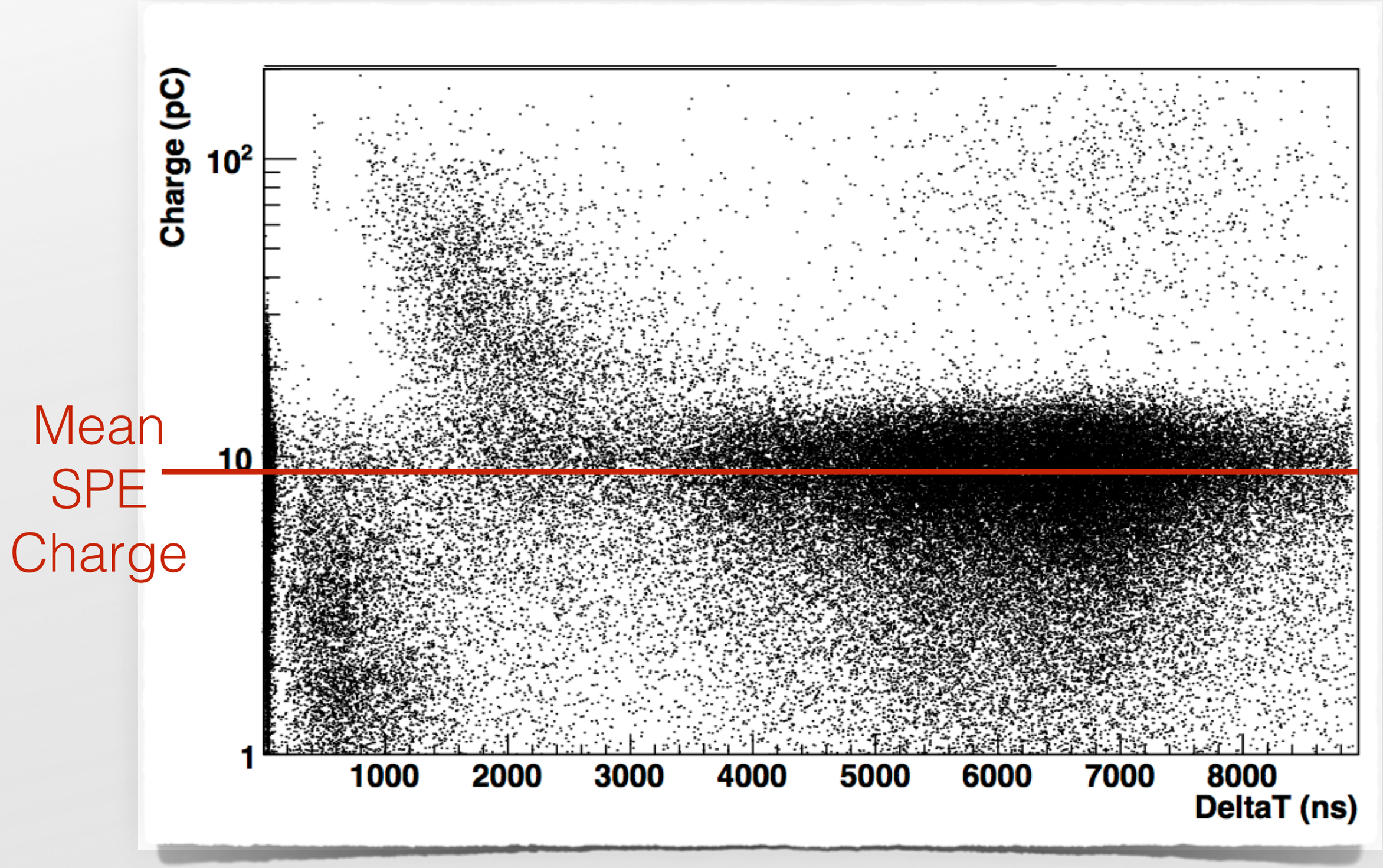
Pulse Finding

Pulses found in MC generated waveform.

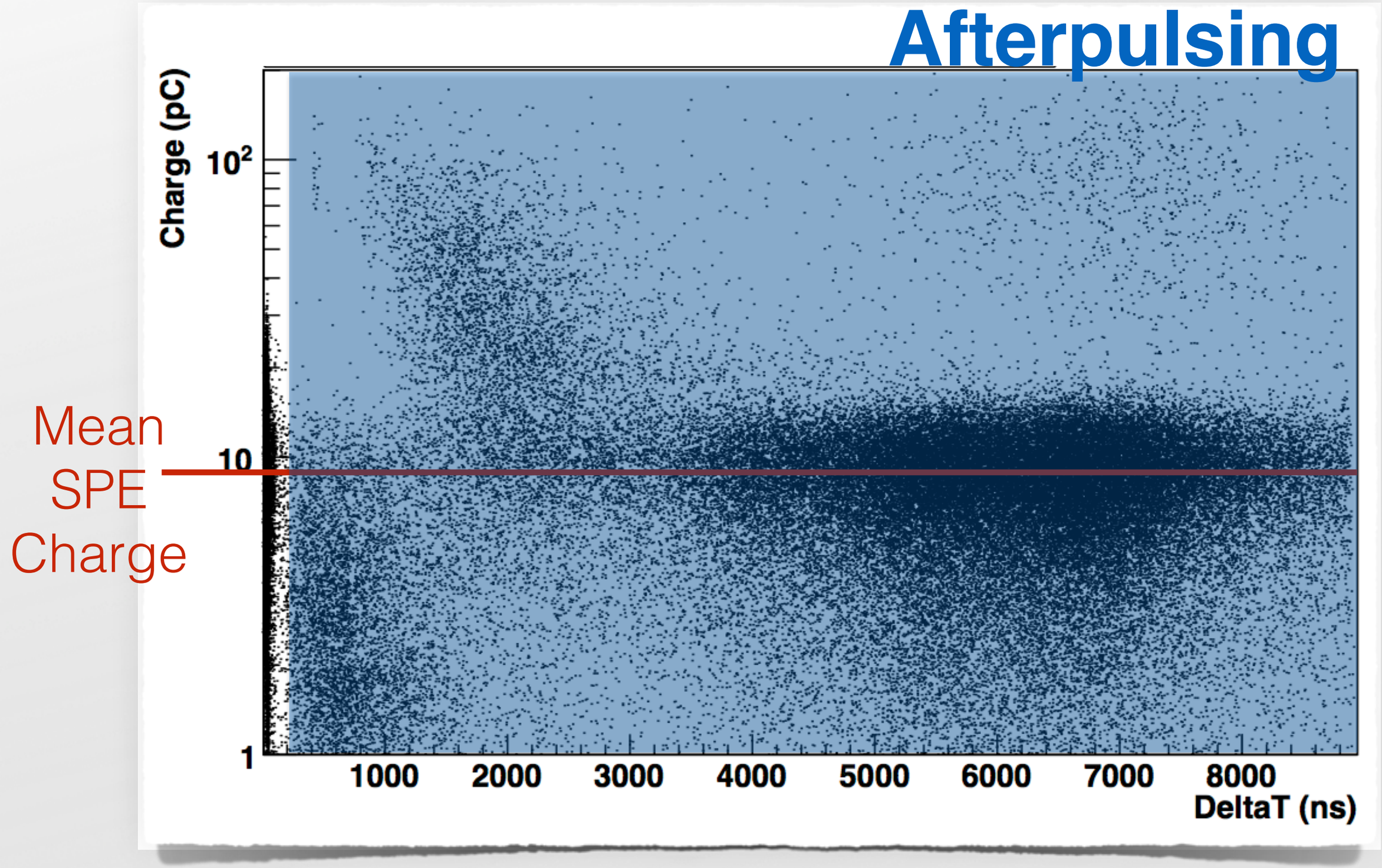


Pulse splitting voltage threshold at 0.005 V

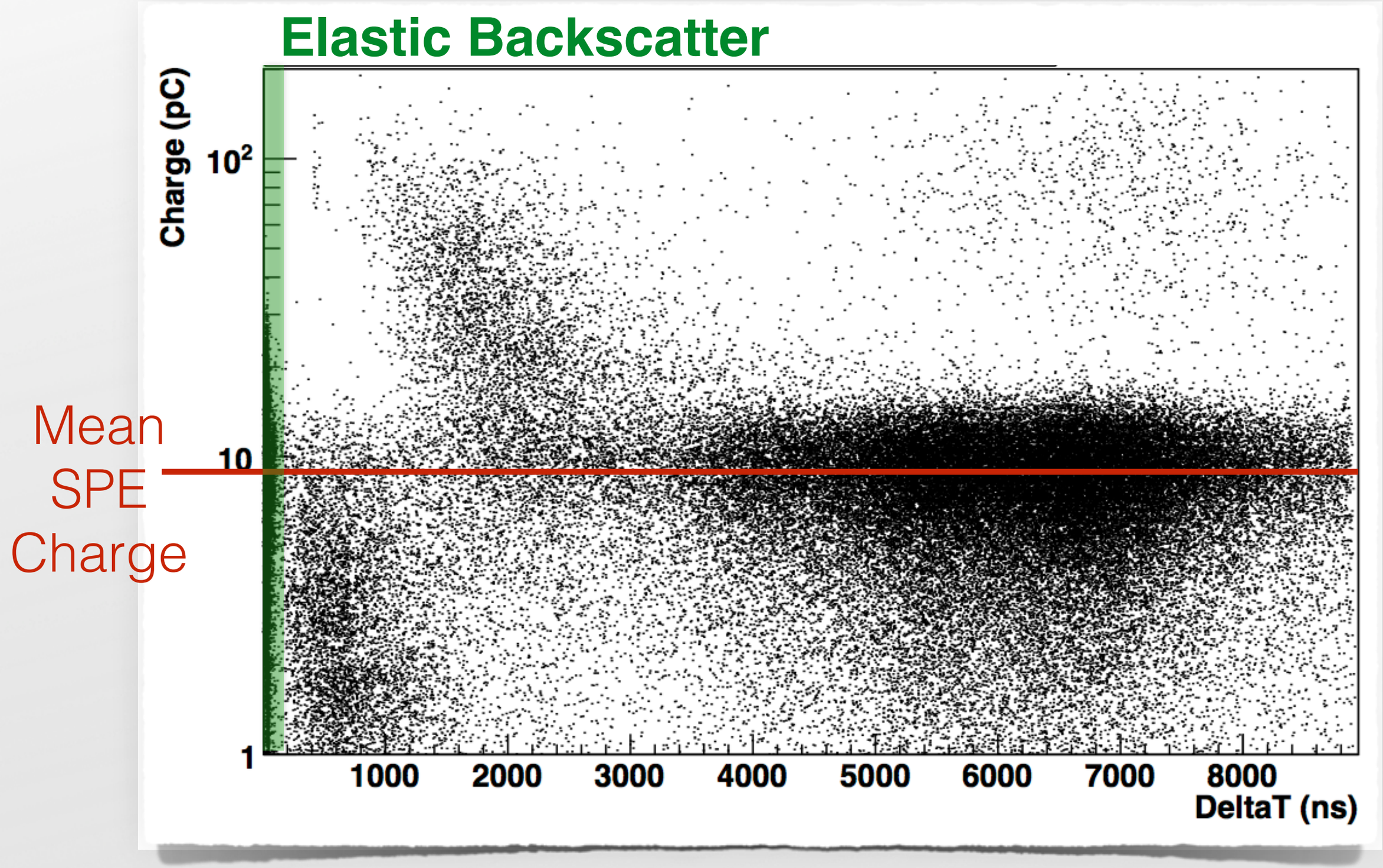
Secondary Pulses



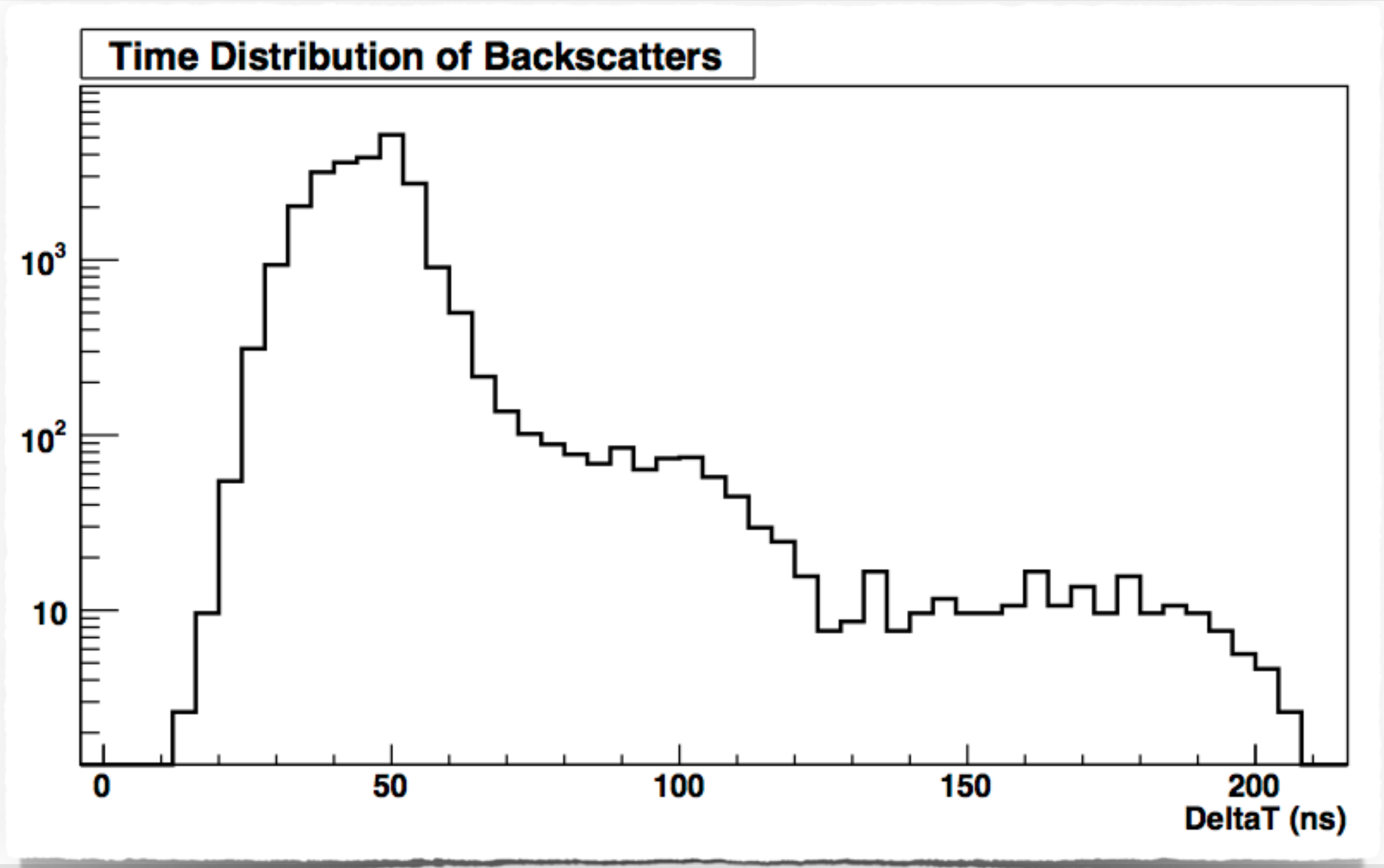
Secondary Pulses



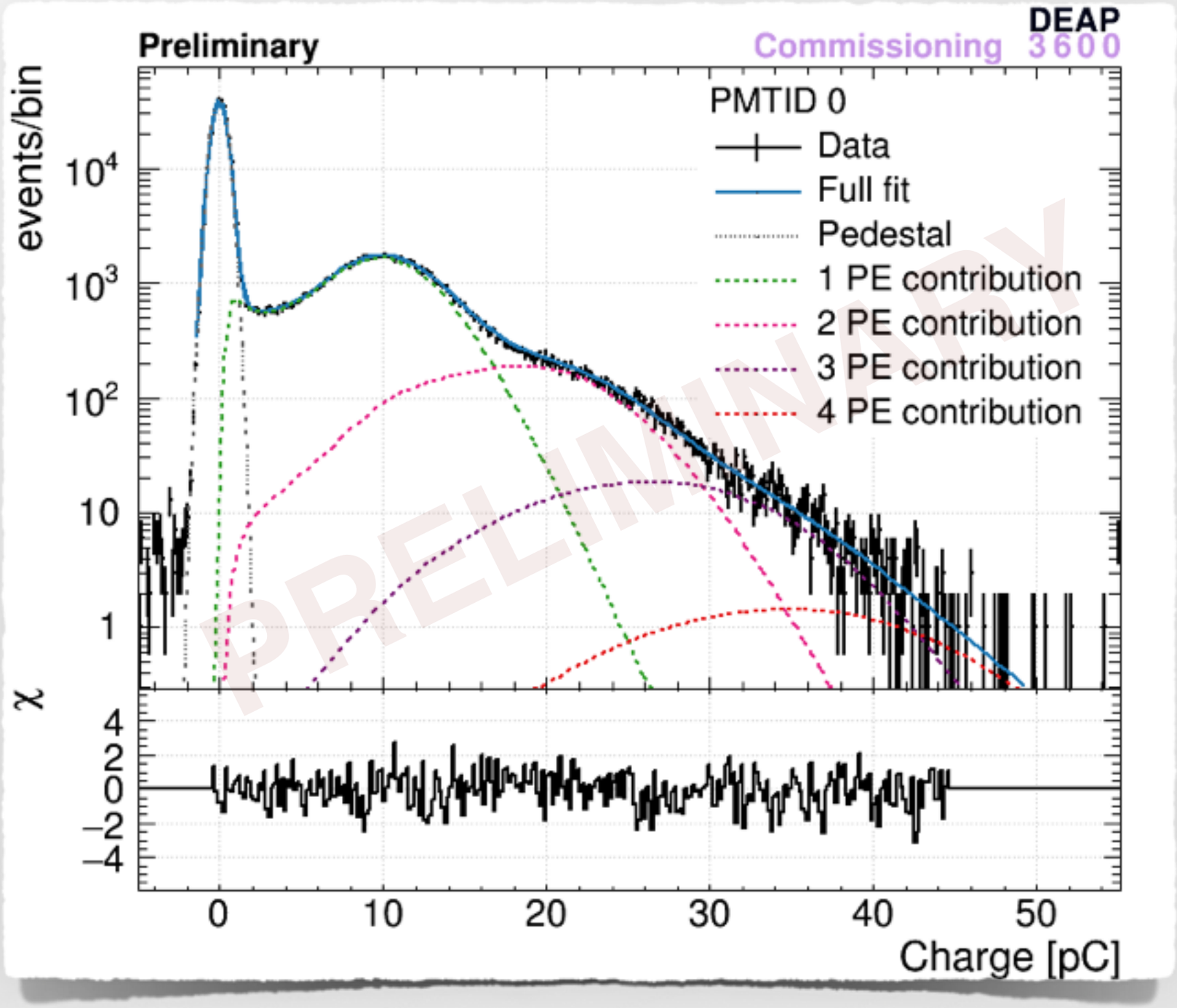
Secondary Pulses



Elastic Backscatter

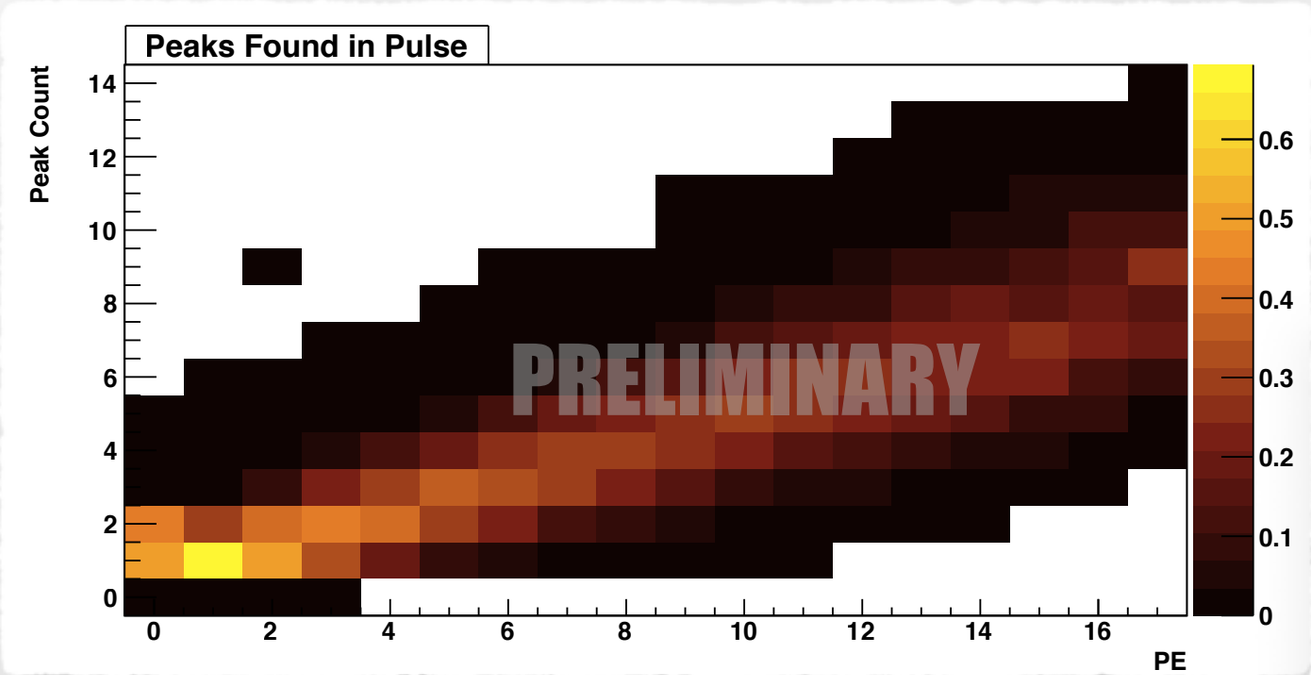


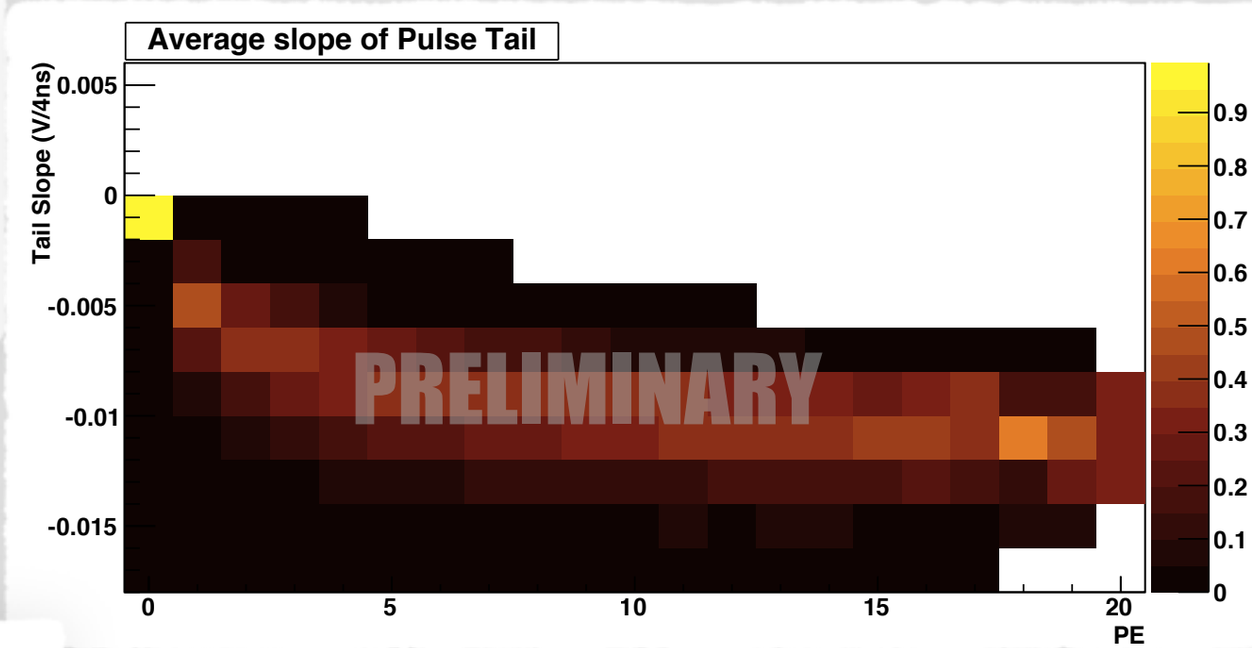
Pulse Charge

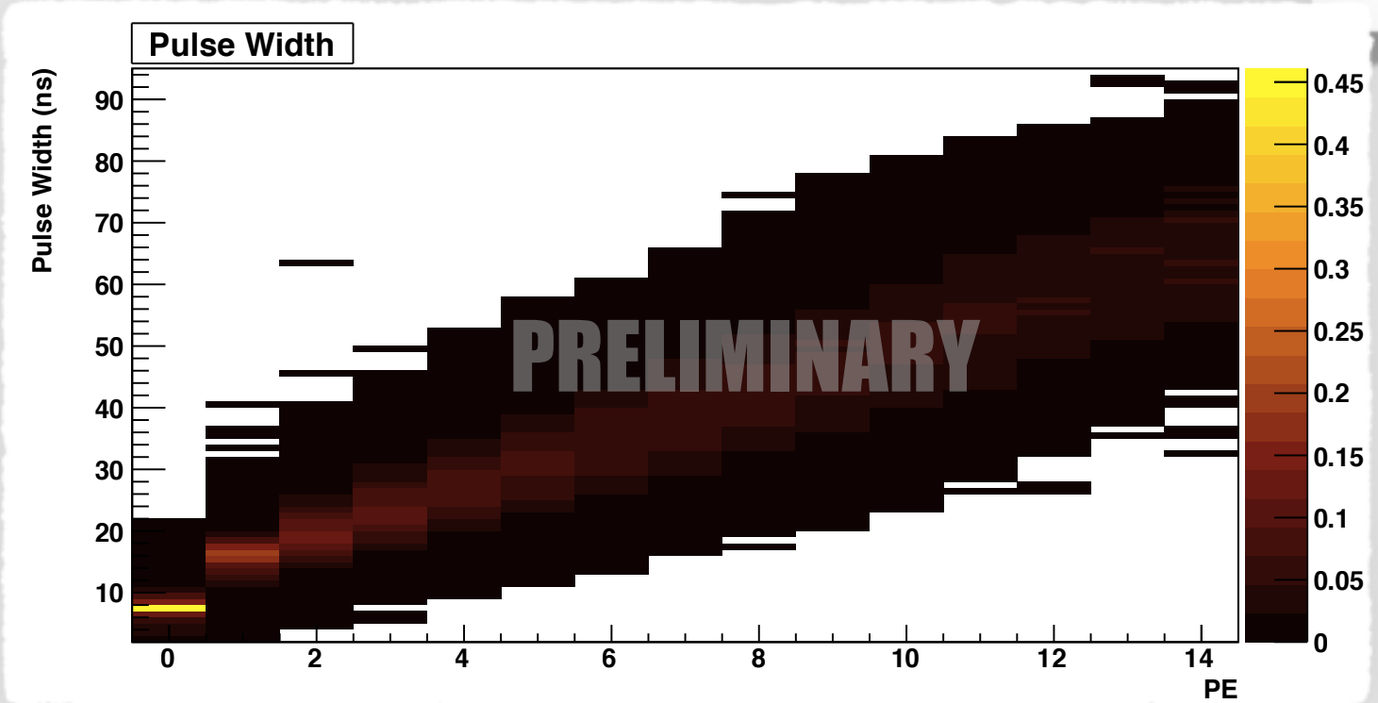


Measured from prompt window in AARF data.

Sample of Other Pulse Variables



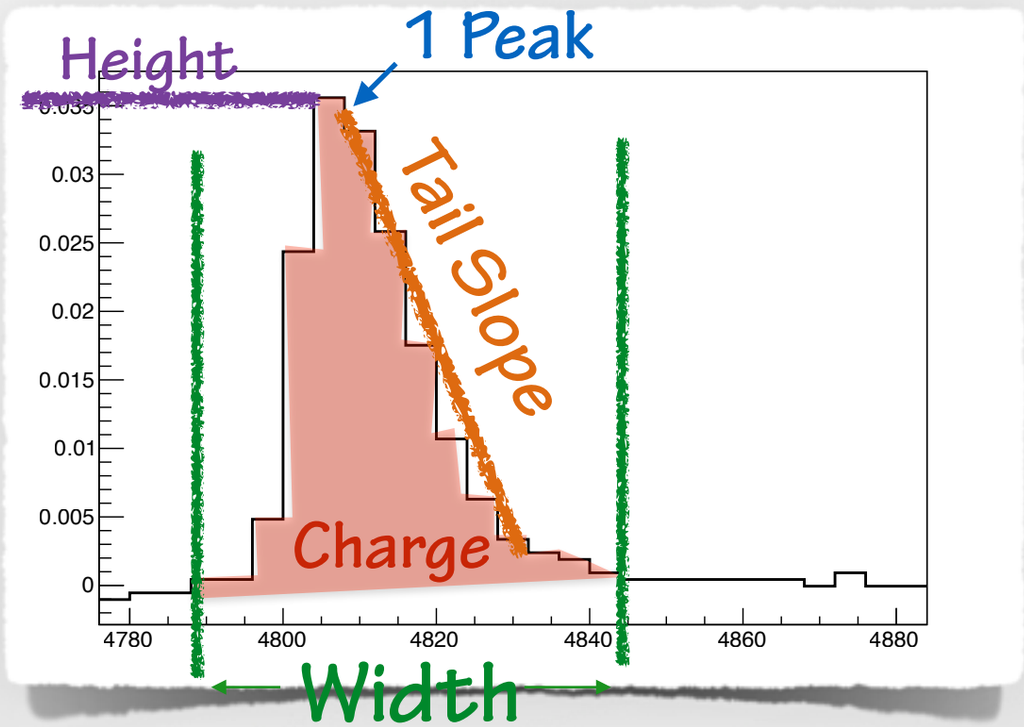




*Preliminary MC Data

DEAP Single PE

DSPE measures the pulse observables and does a maximum likelihood fit for the number of PE that contribute to the pulse.



Maximum Likelihood Fit

Pulse Observables
+
Observable PDFs

most probable
# of PE in Pulse

Further processing:

Energy, fPrompt,Position…

Current/Future Work

- Characterizing and understanding inelastic backscatters
- Update and verify MC pulse characteristics
- Optimize pulse finding and DSPE parameters
- Calculate efficiency and systematics for pulse finding / SPE counting

DEAP Collaboration

Special Thanks to:

CFI, NSERC, Province of Alberta, Province of Ontario and SNOLAB

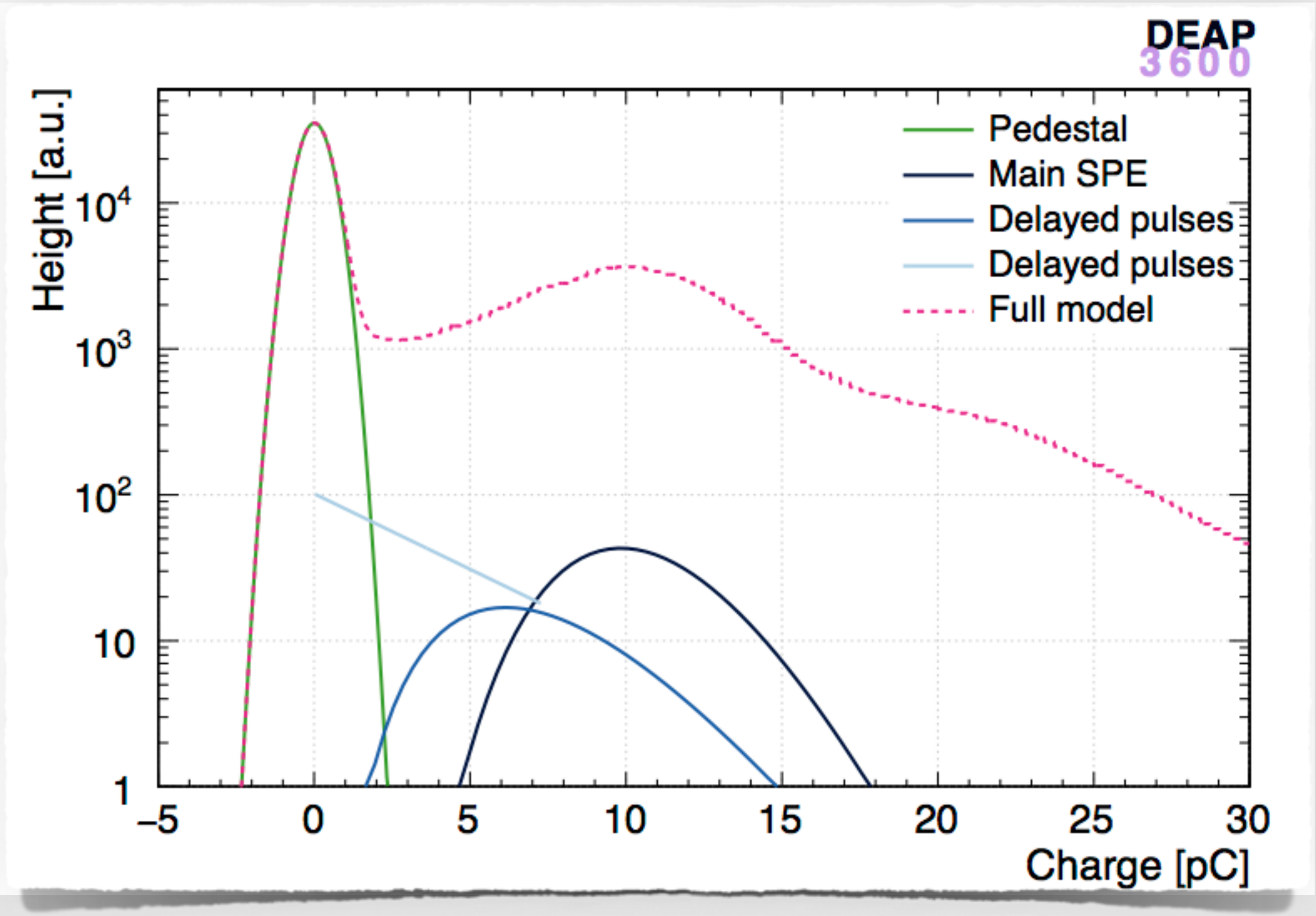
Upcoming CAP DEAP Talks:

Session T3-4: James Bueno - Alpha Backgrounds
Derek Cranshaw - Wavelength-shifter

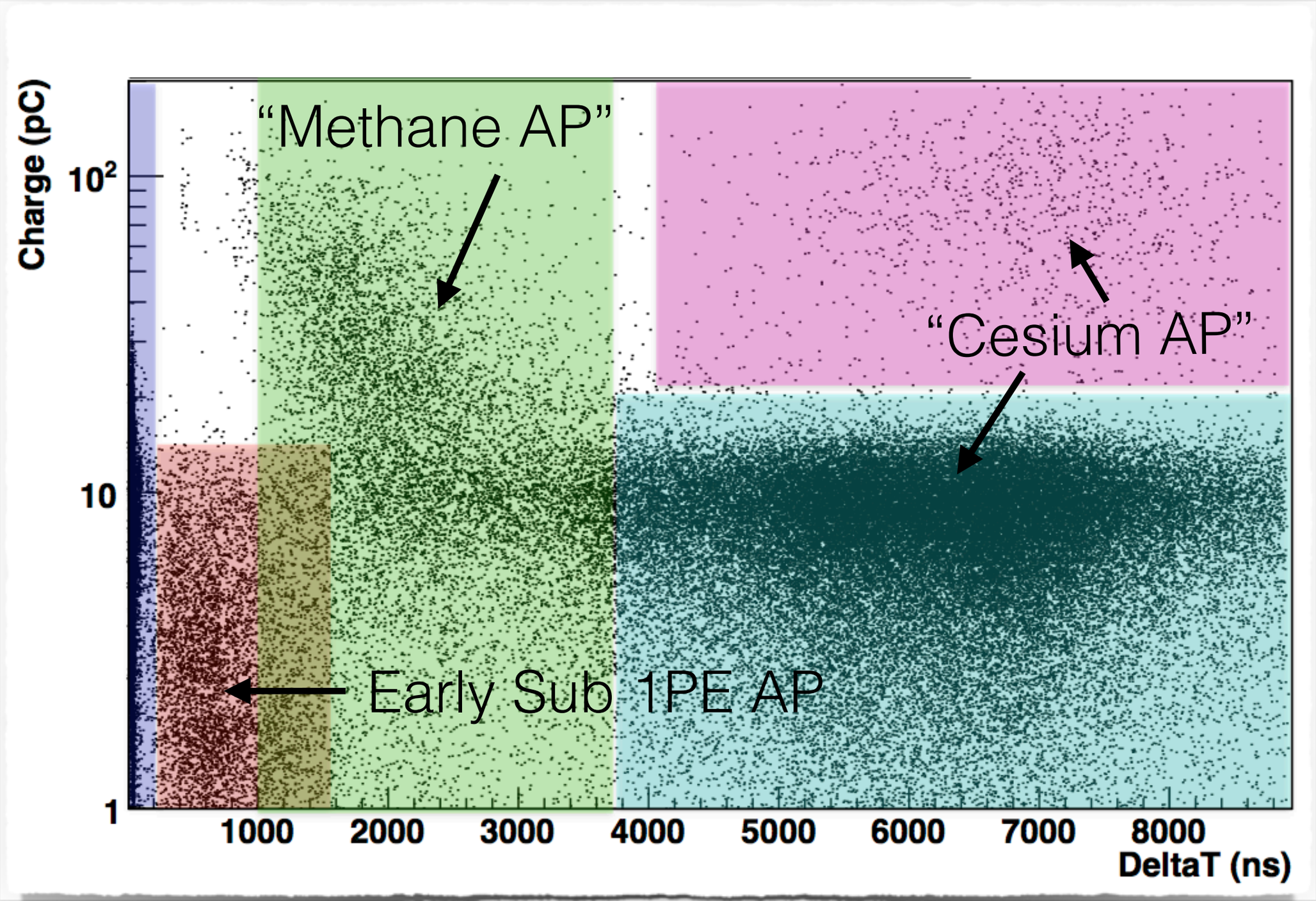
Also, checkout DEAP Posters at the poster session.

Backup Slides

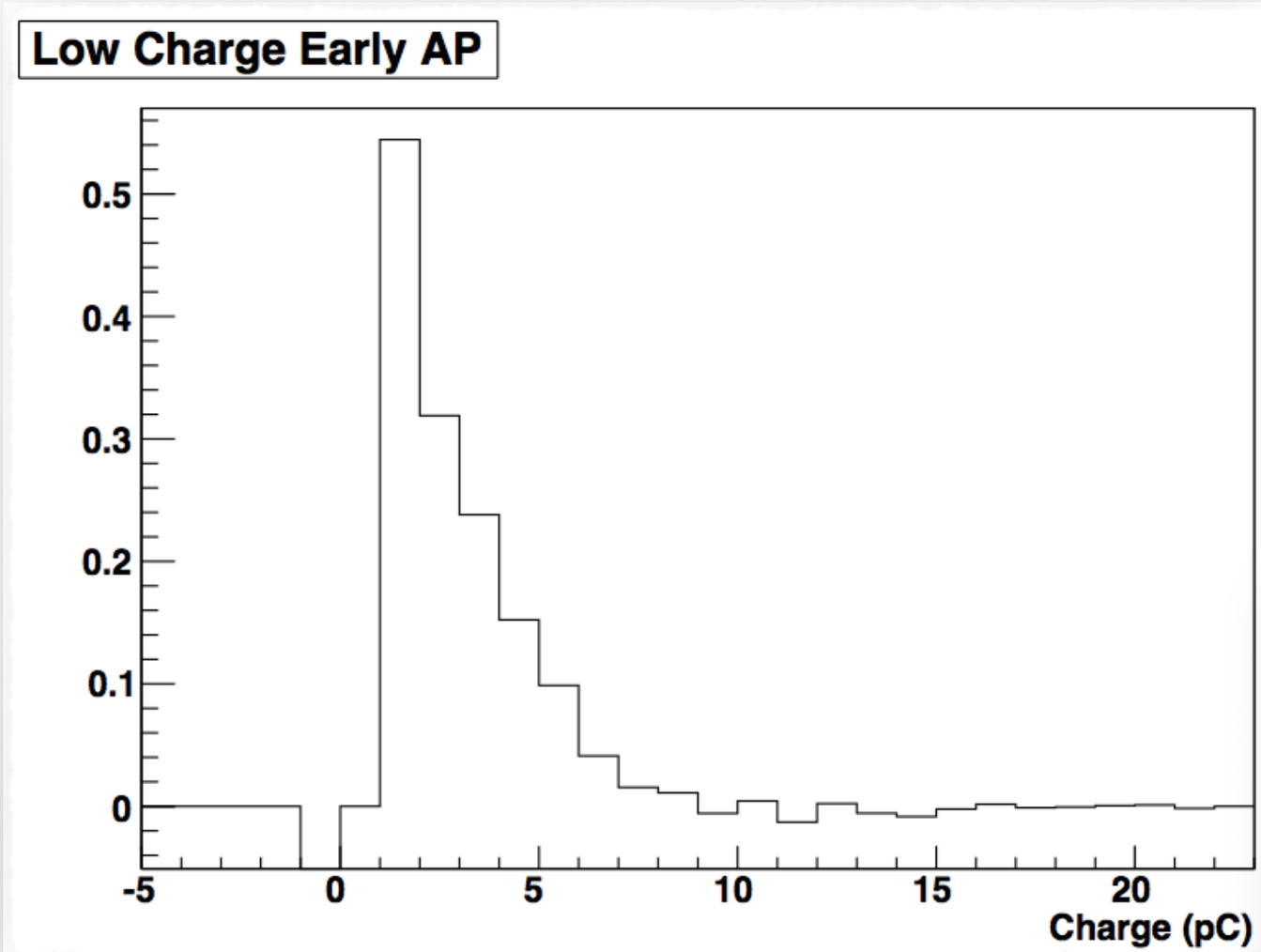
SPE Spectrum Model

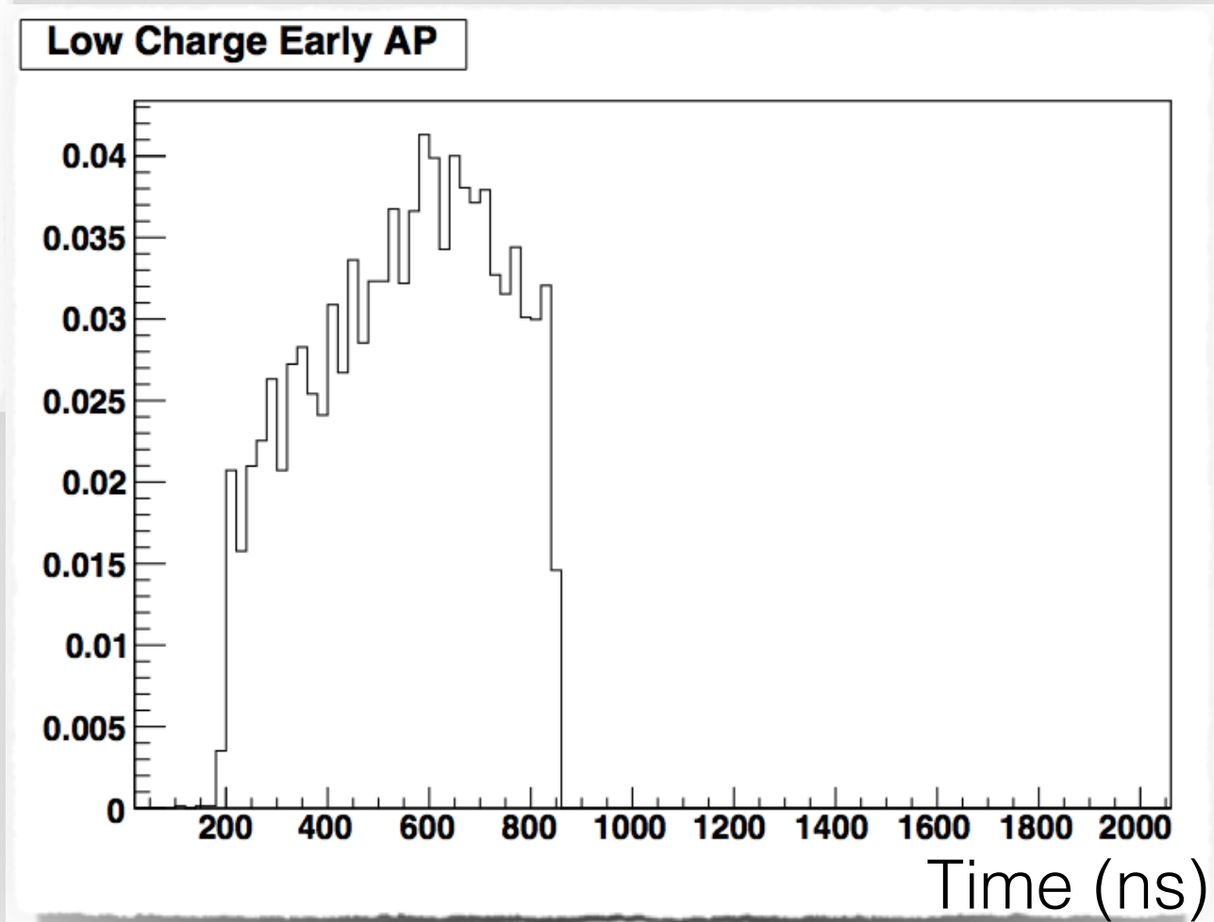


Secondary Pulses

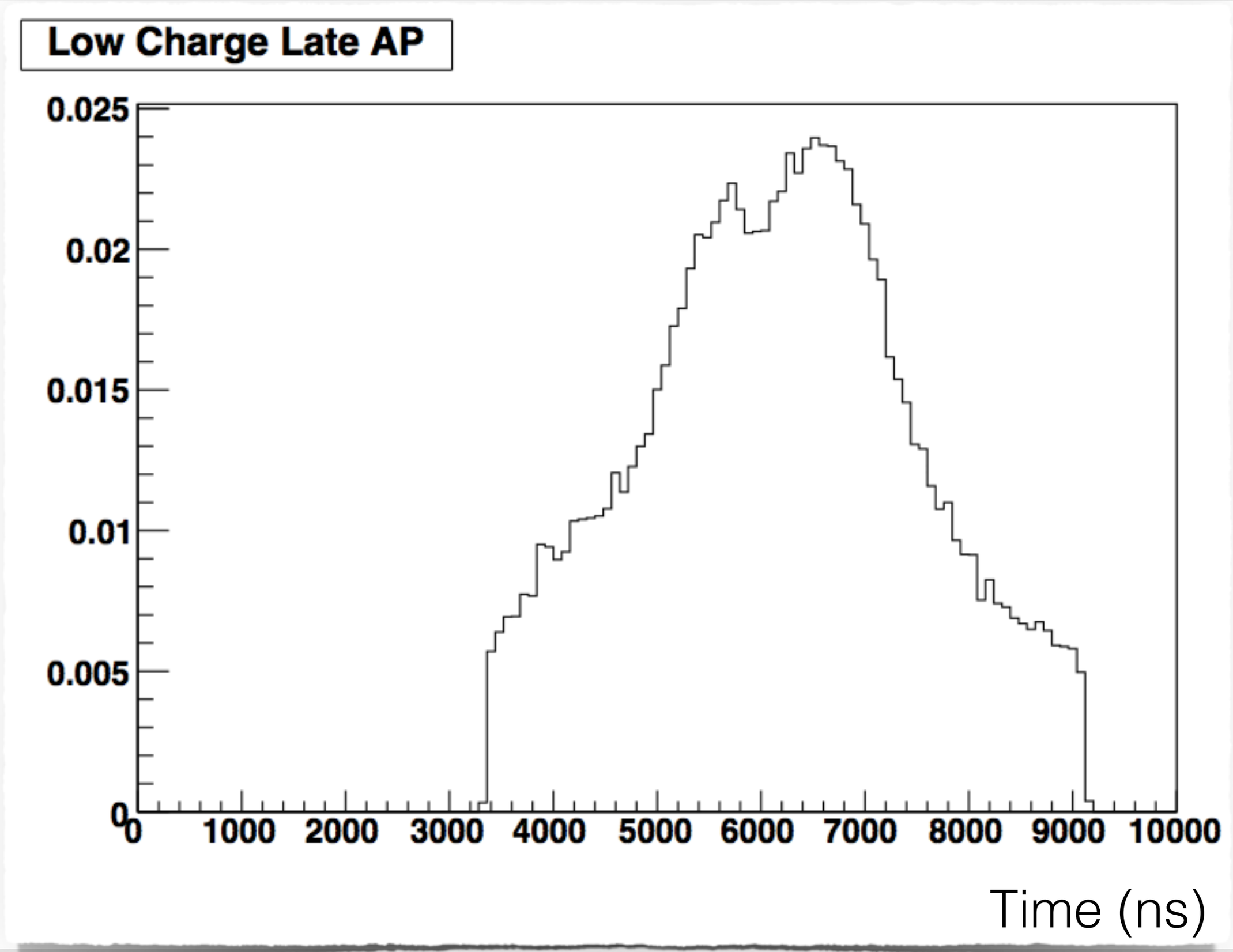


Early Sub-1PE AP





“Cesium” AP


Low Charge Late AP
0.025
0.02
0.015
0.01
0.005
0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Time (ns)