Pulseshape Discrimination using Silicon Photomultipliers with Argon-1

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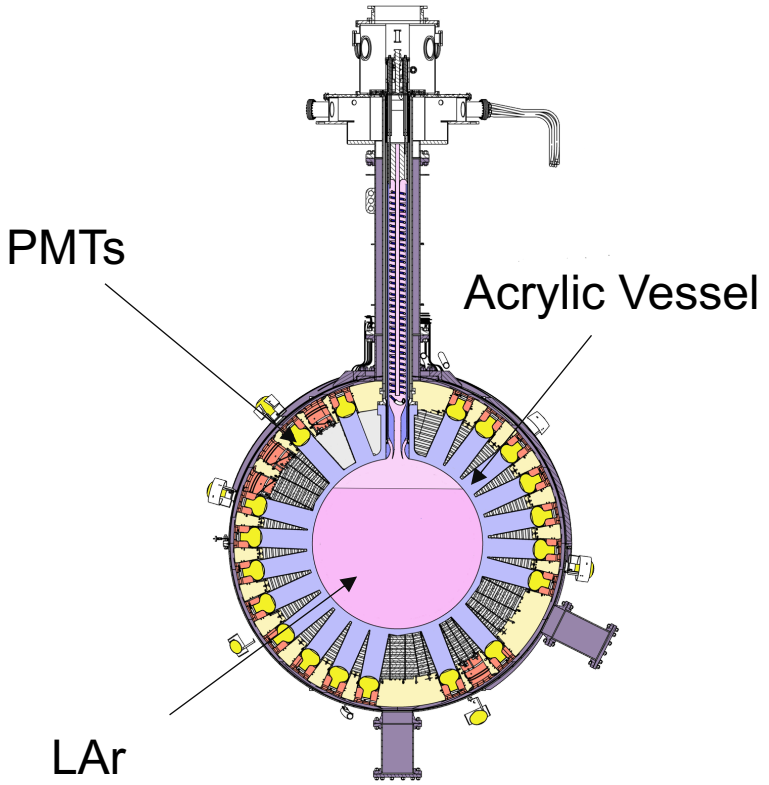
Overview

- DEAP-3600 Overview
- Pulseshape Discrimination (PSD)
- Argon-1 Prototype at Carleton
- PSD Differences between PMTs and SiPMs
- Results

DEAP-3600 Overview

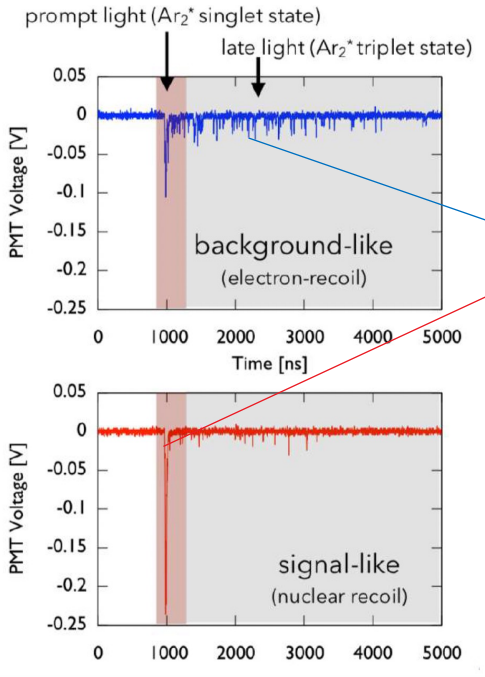
DEAP-3600

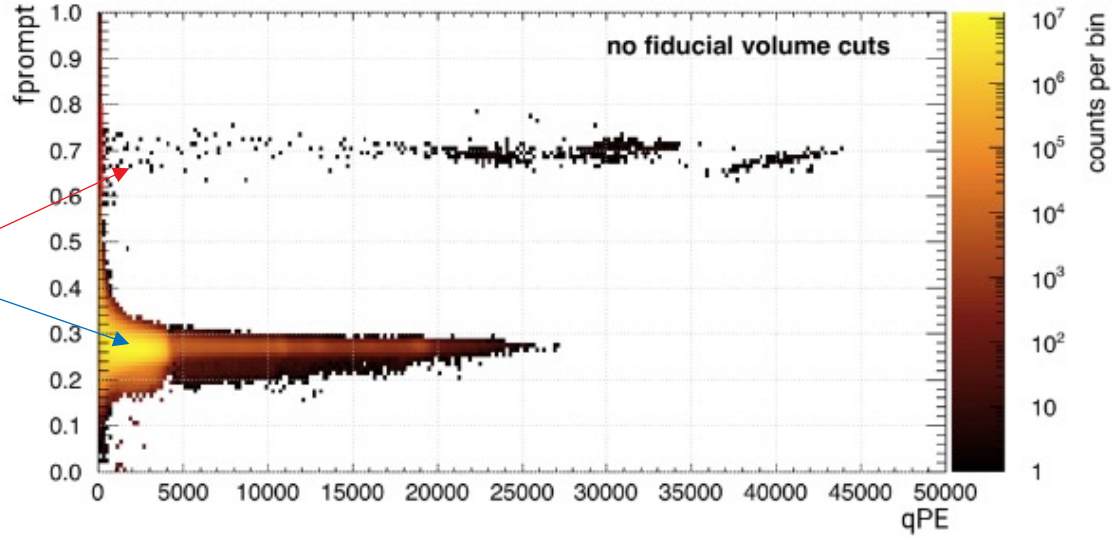
- **D**ark matter **E**xperiment using **A**rgon **P**ulseshape discrimination
- Single phase liquid argon (LAr) detector searching for WIMP dark matter
- 2km underground at SNOLAB in Sudbury, Ontario
- Scintillation light due to recoiling argon used to discern energy of incident particle
- Pulseshape discrimination is a powerful background rejection technique



Excimer Decay Times allow for PSD

- Argon will scintillate through **singlet state (NRs – alphas, neutrons, WIMPS)** or **triplet state (ER – electrons, gammas)**
- Define fPrompt = Prompt Light/ Total Event Light





Charge Integration in Prompt Window

$$F_{Prompt} = \frac{\Sigma_{t>t_{start}}^{t<t_{prompt}} PE(t)}{\Sigma_{t>t_{start}}^{t<t_{total}} PE(t)}$$

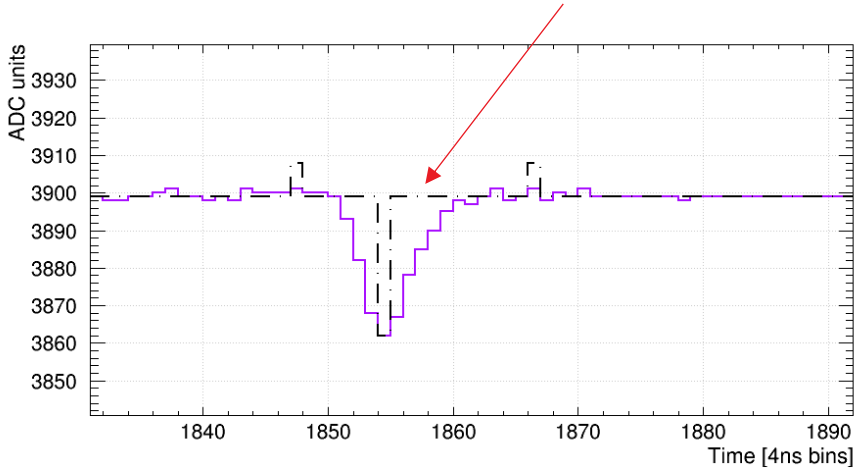
- Typical t_{prompt} = 60 ns, t_{start} = -28ns and t_{total} = 10000 ns
- Common estimator of PE is

$$qPE = \frac{Q}{Q_{SPE}}$$

- Integrate charge in prompt window, divide by total charge

Ref: Eur. Phys. J. C (2021) 81:823

Integrate waveforms to get Q, divide by Q for a 1 PE (SPE) pulse



Generic PMT Pulse from DEAP Data

Argon-1

Detector and Deployment System

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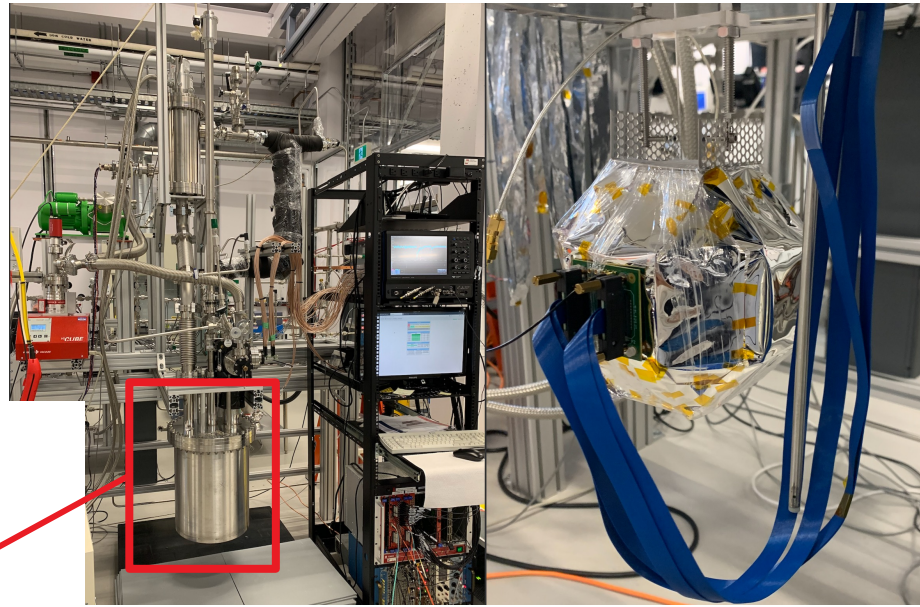
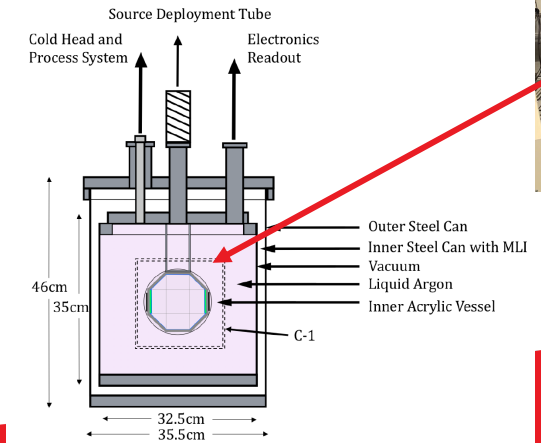
Argon-1

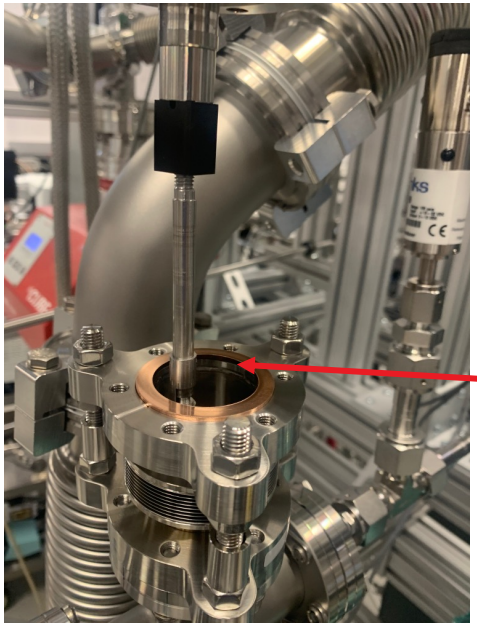
- Liquid argon cryostat containing ~35kg LAr (~10% within AV)
- Signal detection facilitated by Hammatsu MPPC Silicon Photomultipliers (SiPMs)
- Fully instrumented DAQ and purification system
- Useful for ex-situ measurements for DM experiments

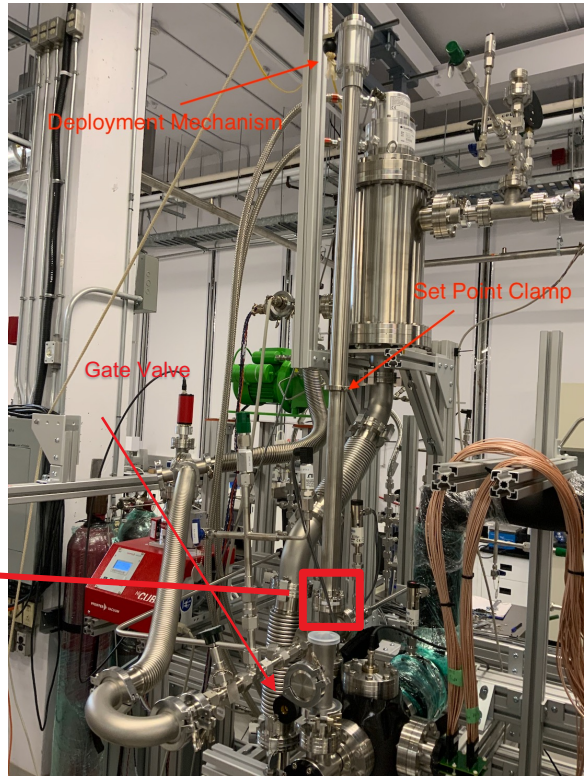




Source Deployment System

- Ability to deploy alpha sources directly into LAr volume
- Allows for PSD studies for ER and NR events with external gamma sources (Cs-137, Co-60) and internal alpha sources (Am-241, Rn-222 decay chain)

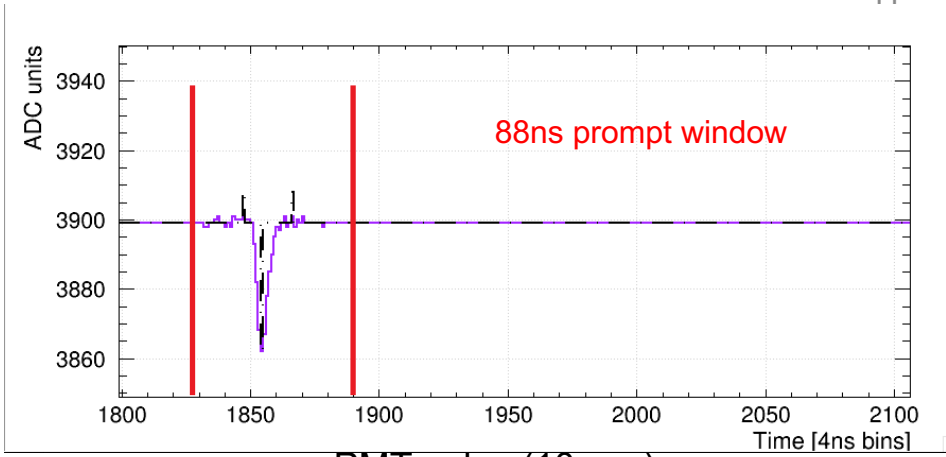




Results of PSD with SiPMs

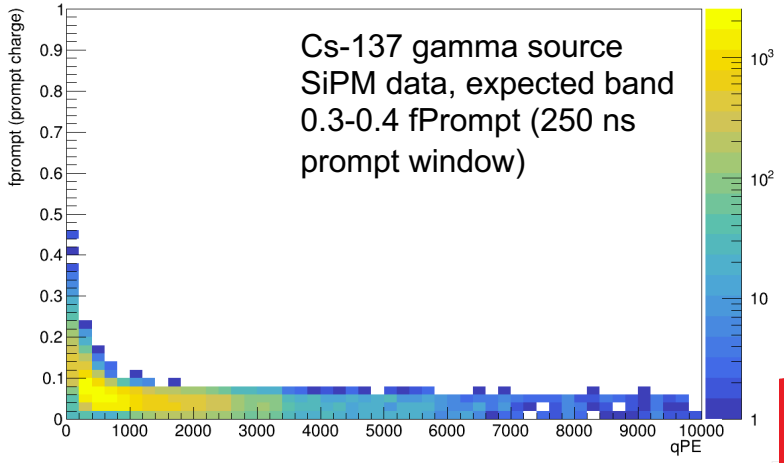
PSD with SiPMs

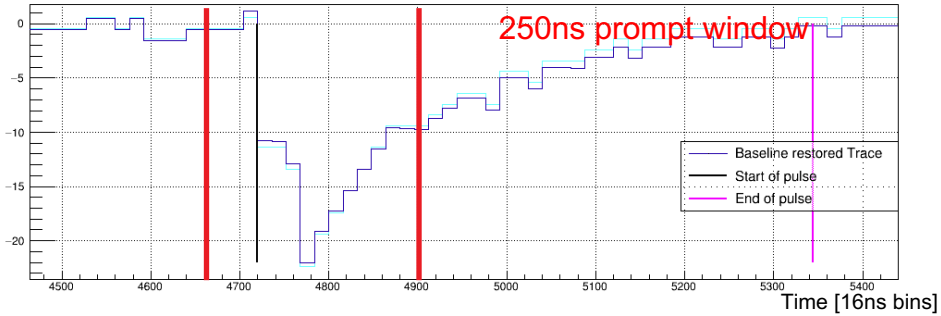
- Slight issue doing charge based PSD…**charge response of SiPMs is slow (compared to PMTs)**
- **Cannot lengthen prompt window**
- **A SiPM pulse is longer than a typical prompt window, low prompt charge!**



PMT pulse (10s ns)

Charge Model





SiPM Pulse (100s ns)

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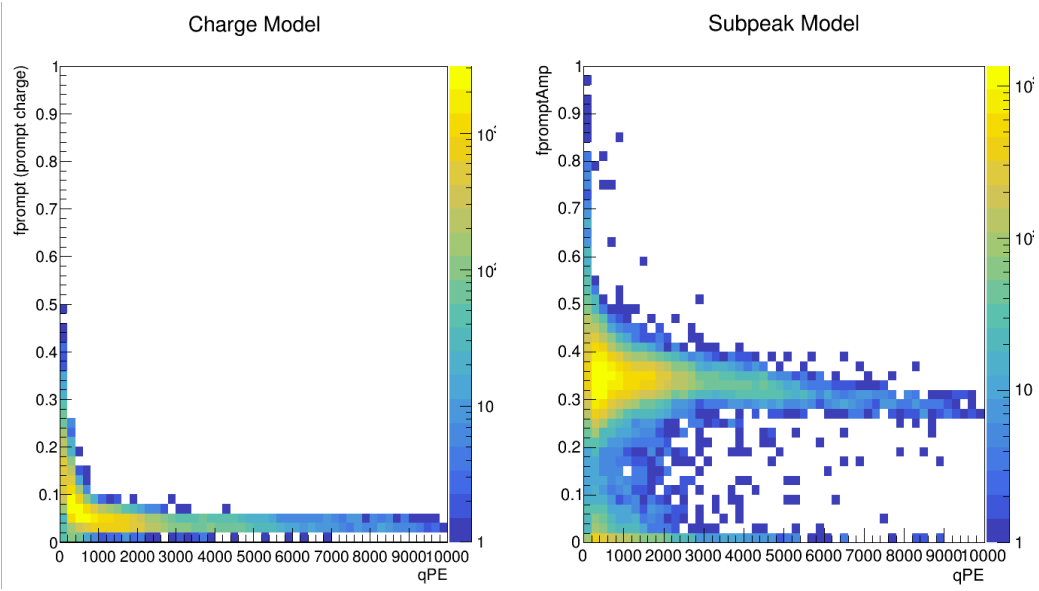
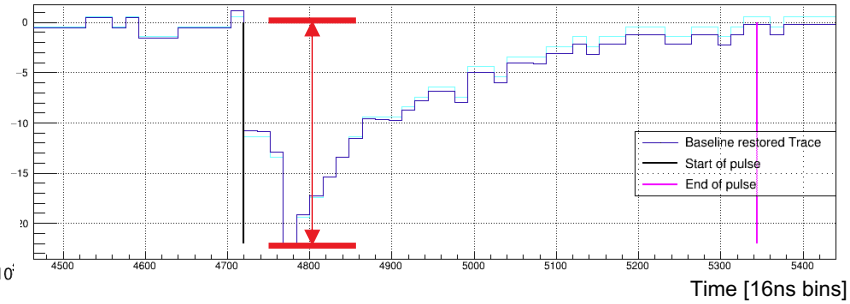
Subpeak Heights

- Instead, take **sub-peak time, use sub peak heights!**



Cs-137 run with integrated charge model (left) and sub peak height model (right)



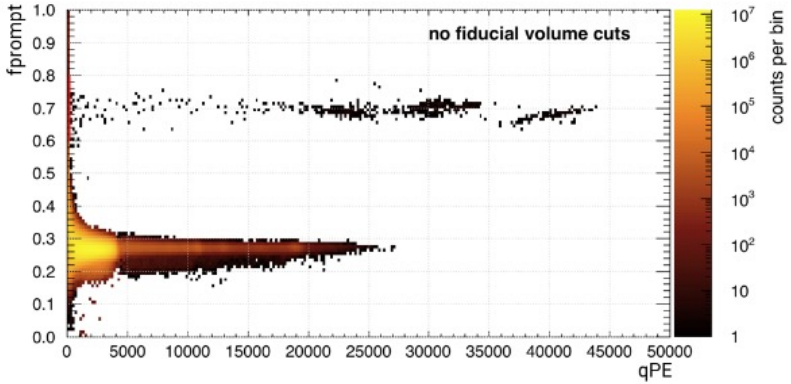
Amplitude base PE $aPE = \frac{h}{h_{SPE}}$

Where h is the subpeak height in ADC units

Model relies on if the sub-peak time is in prompt window now

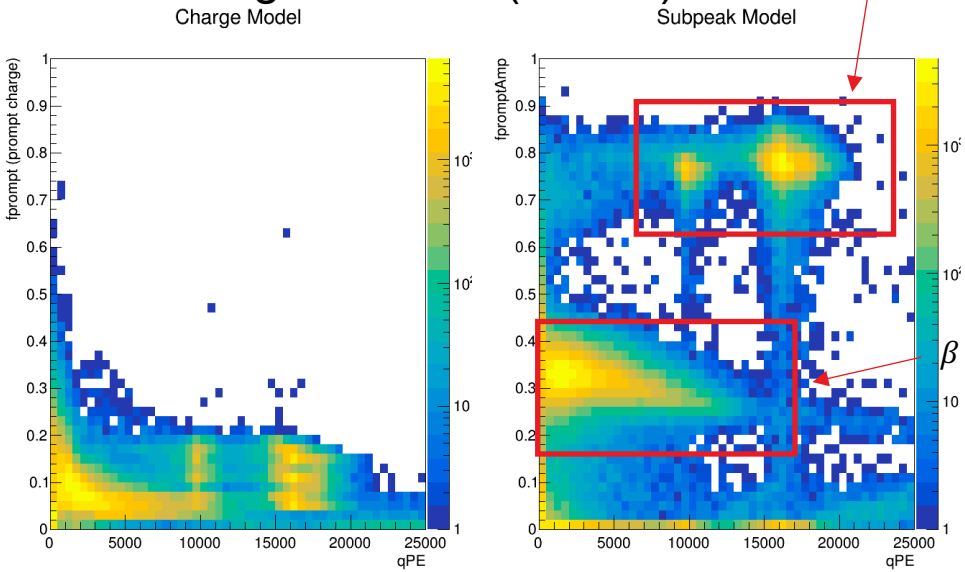
Preliminary Results

DEAP-3600 Data (PMTs)



Recall from DEAP data, expect
NR events to be 0.6-0.8 fPrompt
(no source deployed)

Argon-1 Data (SiPMs)



Expected fPrompt behaviour
can be reproduced with sub-peak height model! (Rn-222 source)

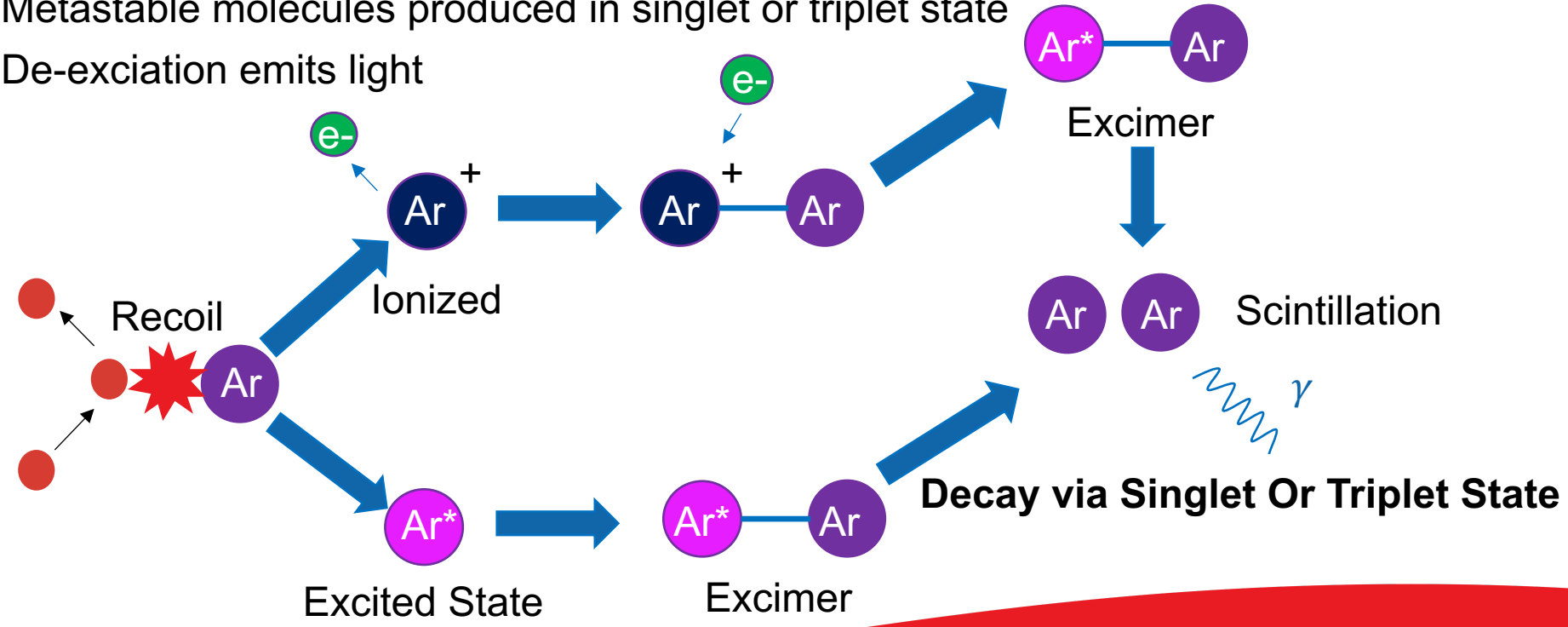
Conclusions

- Pulseshape discrimination is a powerful tool for rejecting background in rare event searches in liquid argon
- Future experiments will rely on SiPM technology for signal detection
- Even with a slow charge response, SiPMs still demonstrate powerful PSD capabilities
- Thank you!

Backup

Scintillation Physics of Argon

- Incident radiation excites or ionizes argon
- Metastable molecules produced in singlet or triplet state
- De-exciation emits light



PE Estimator Comparison