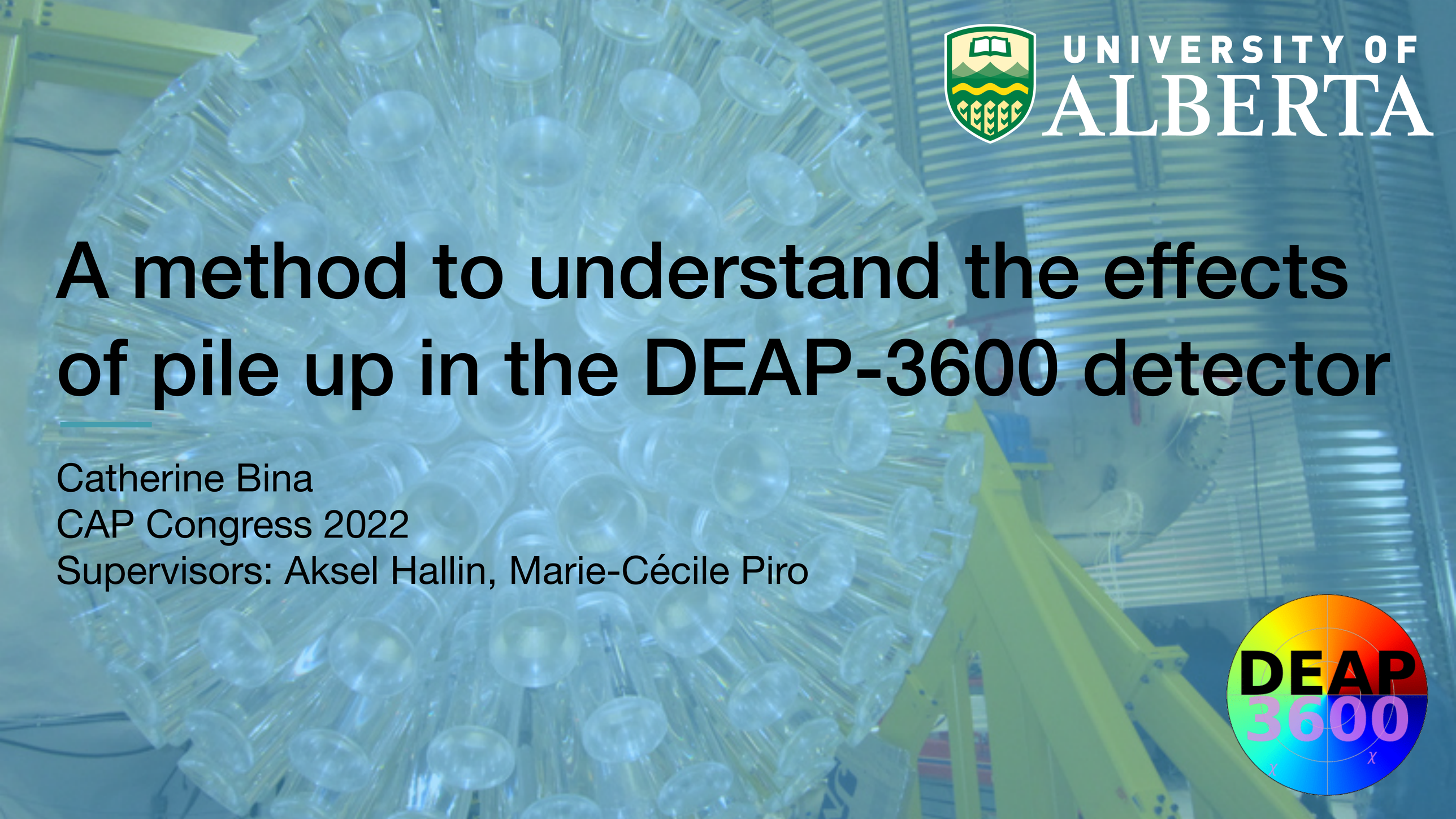
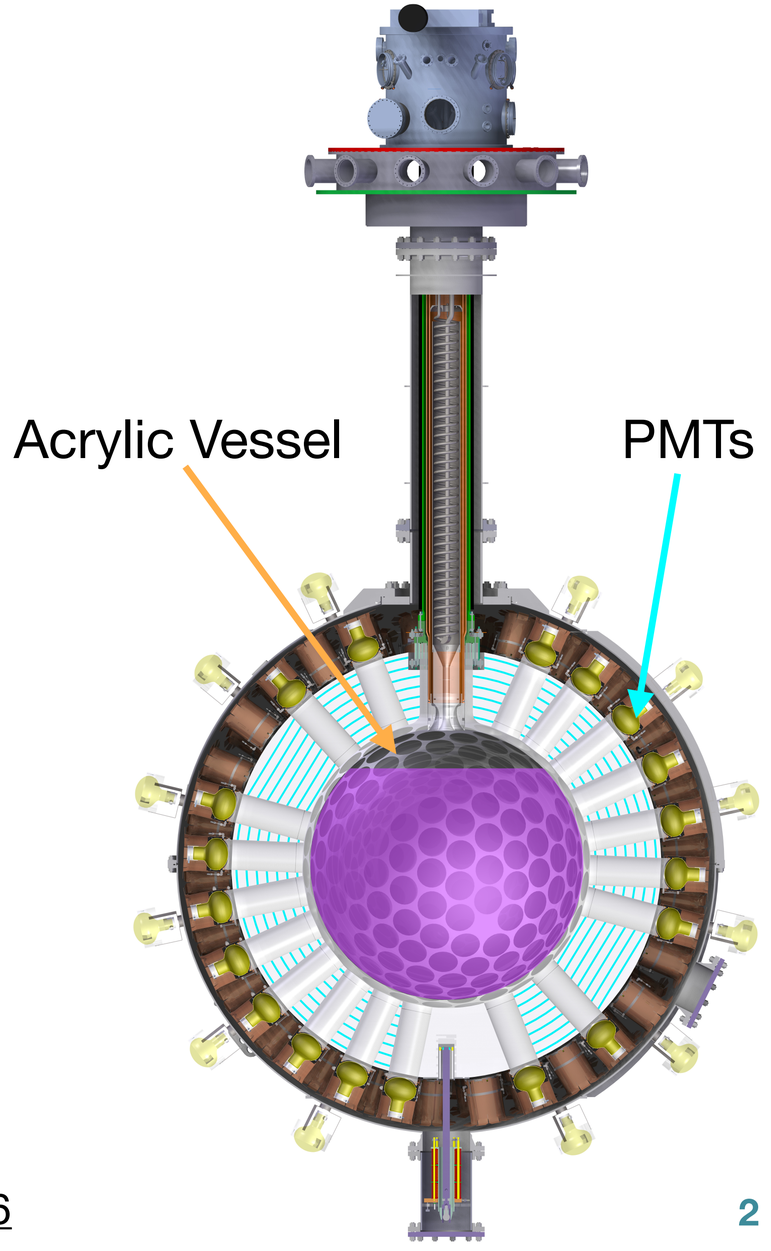


A method to understand the effects of pile up in the DEAP-3600 detector

Catherine Bina
CAP Congress 2022
Supervisors: Aksel Hallin, Marie-Cécile Piro

Dark matter Experiment using Argon Pulse shape discrimination (DEAP)

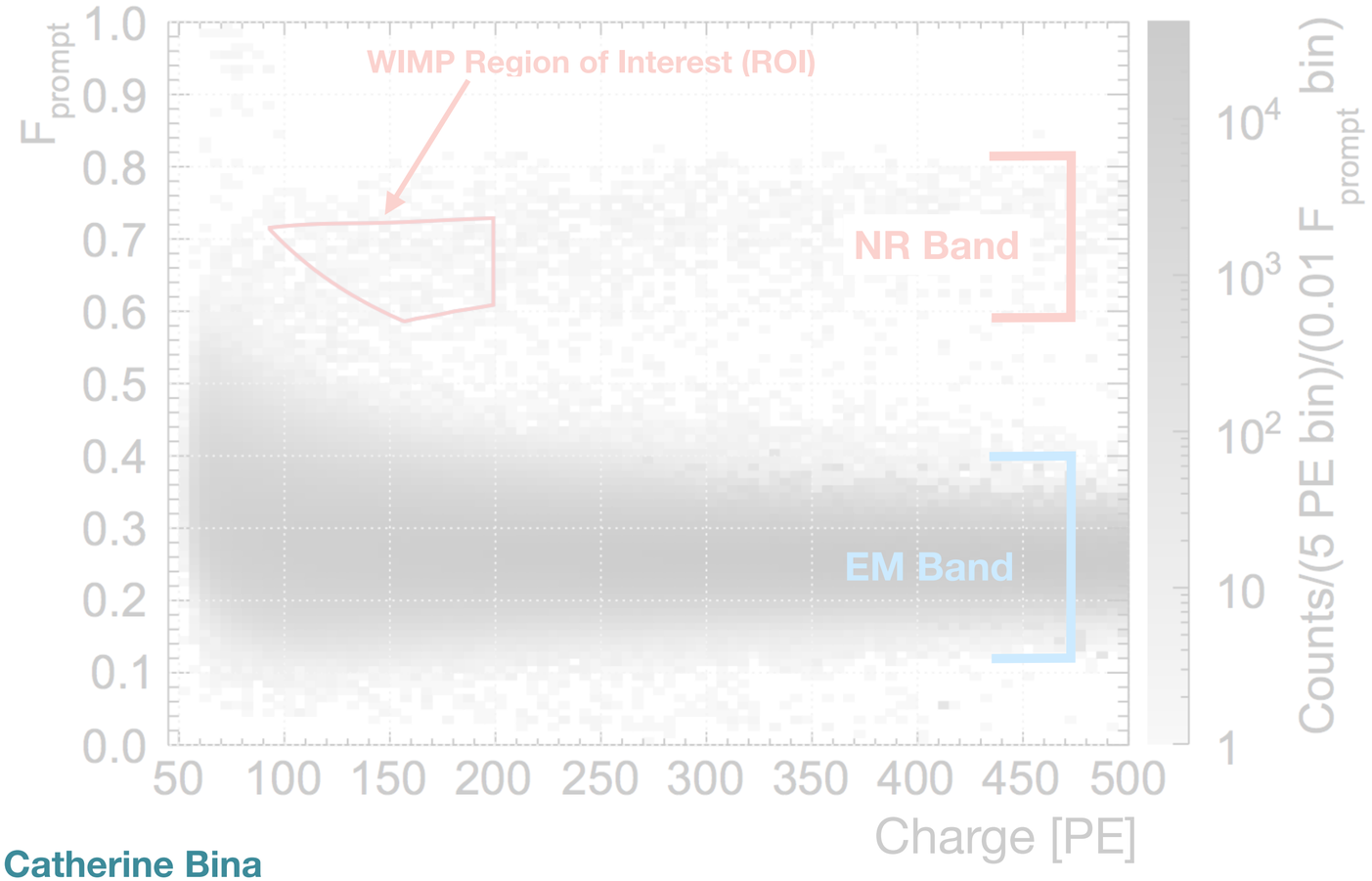
- Located 2 km underground at SNOLAB in the Cube Hall
- Searches for spin independent WIMP dark matter
- DEAP is a single phase scintillation detector => energy detected as light
- For this analysis, the acrylic vessel (AV) was filled with 3279 kg of liquid argon (LAr)
  - The top 30 cm of the AV contained gaseous Ar
- Signal is detected via 255 PMTs surrounding the AV

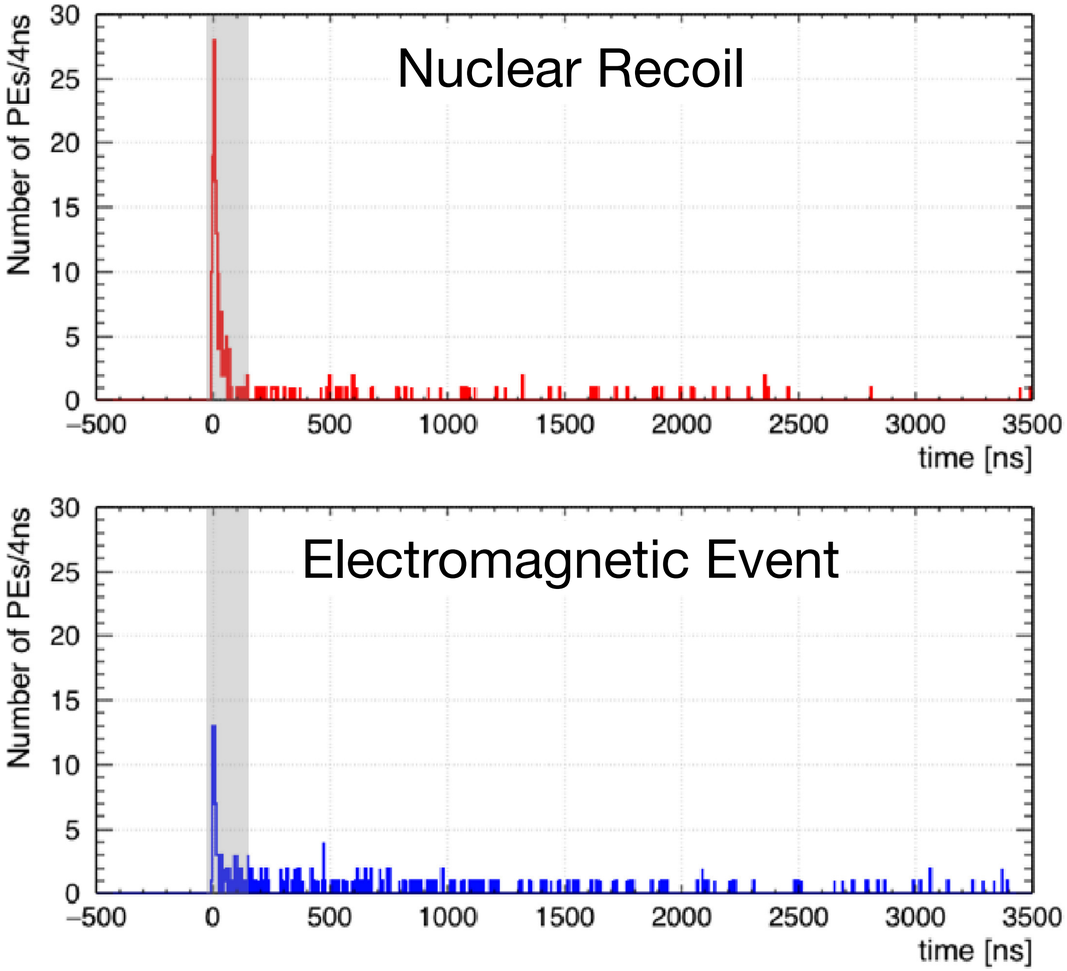


https://doi.org/10.1016/j.astropartphys.2018.09.006

PSD is the primary method of background discrimination for DEAP

$$\text{Fprompt} = \frac{\textit{Early Light}}{\textit{Total Light}}$$





Pulse shape: https://doi.org/10.1140/epjc/s10052-020-7789-x
PSD: https://doi.org/10.1140/epjc/s10052-020-7789-x

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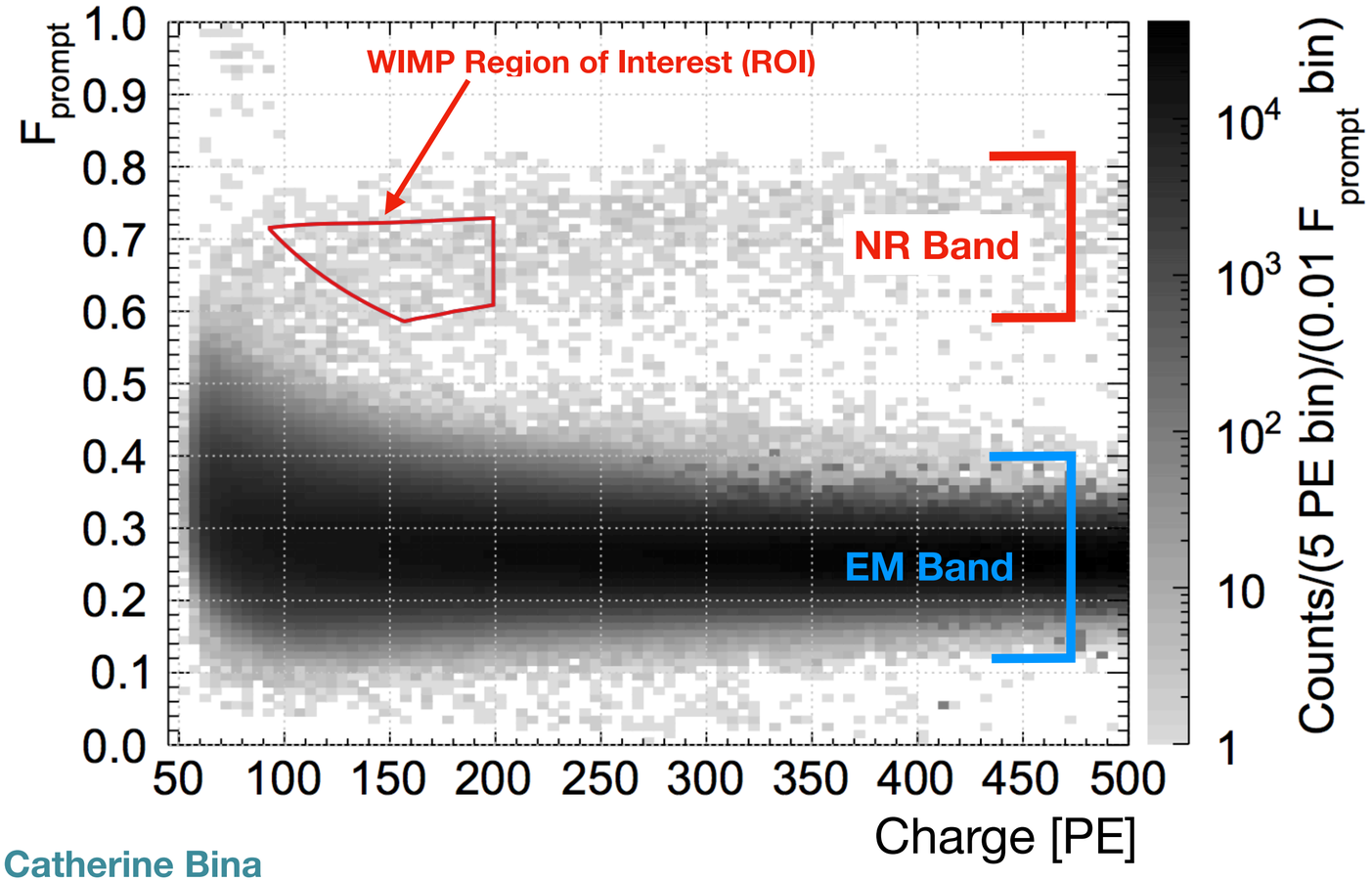
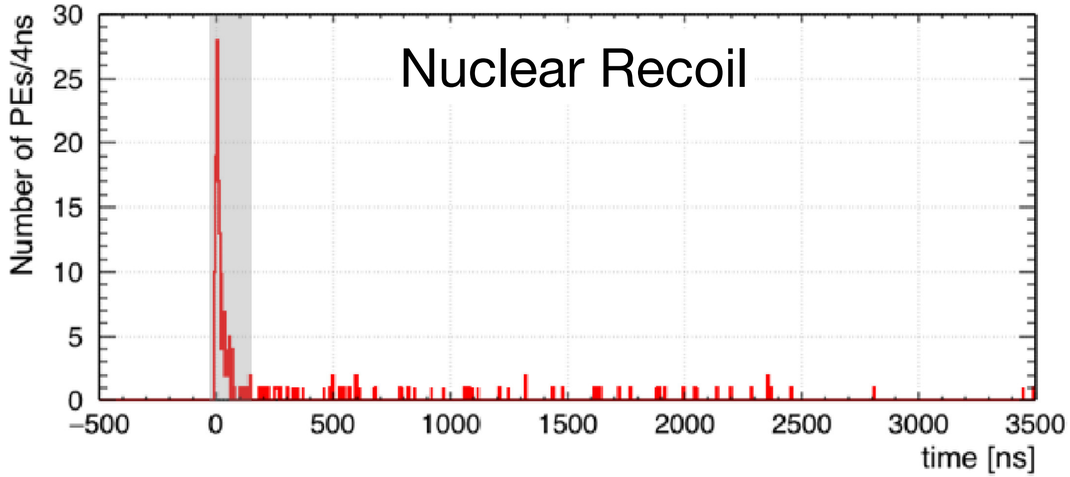
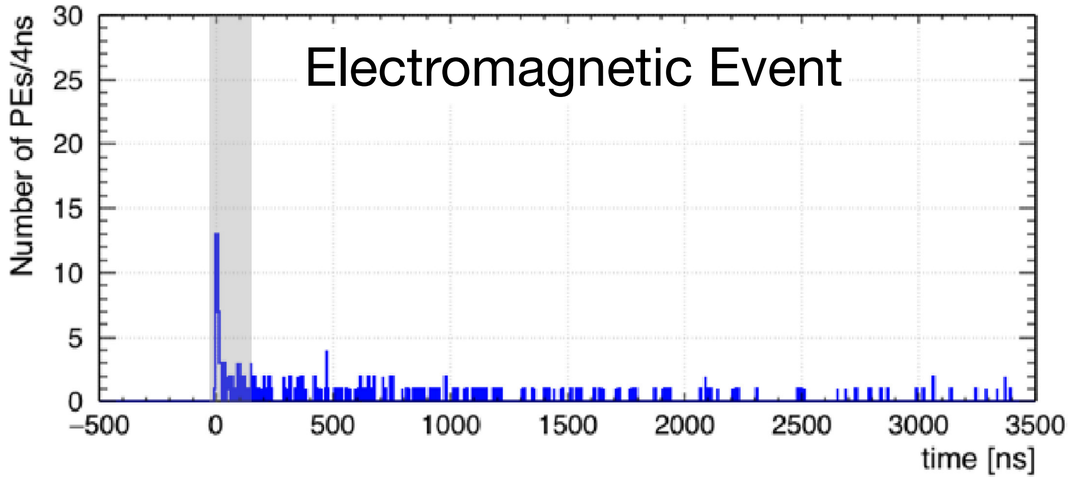


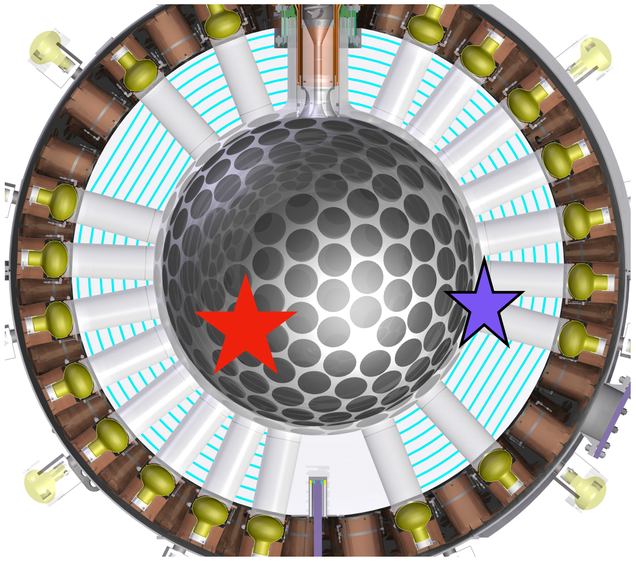




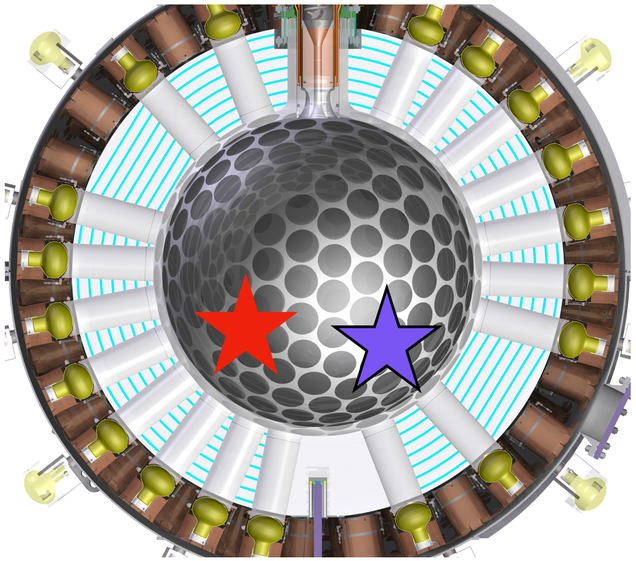
Pulse shape: https://doi.org/10.1140/epjc/s10052-020-7789-x
PSD: https://doi.org/10.1140/epjc/s10052-020-7789-x

What constitutes pile up?

- Pile up is any light added to a physics event
- Including, but not limited to:
  - Dark noise
  - Interactions with the detector materials
  - Other liquid argon scintillations
- I wanted a data driven method to study pile up and so turned to the data collected by our periodic trigger

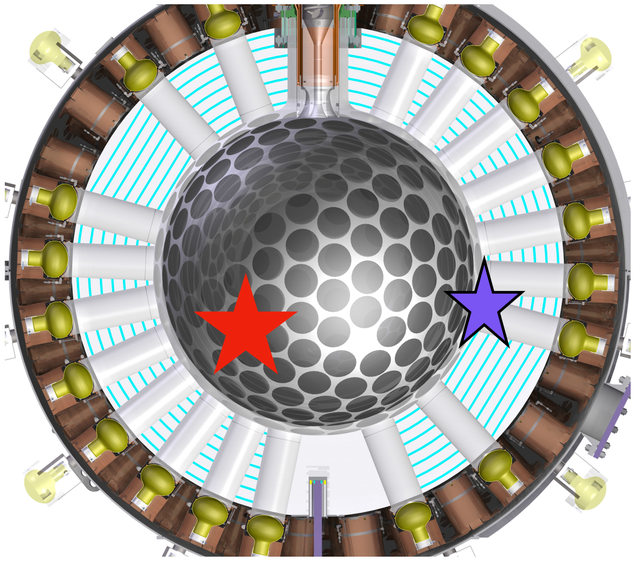


Physics event **Pile up**



Using periodic trigger events as pile up

- The periodic trigger is a threshold less trigger that reads out data 40 times a second
- This gives us snapshots of what is going on in the detector at any given moment, without any biases from trigger requirements
  - So it shows both interactions with the LAr as well as with the detector materials and noise
- This works to study pile up because it represents the part of an event that “piles up” with a physics event



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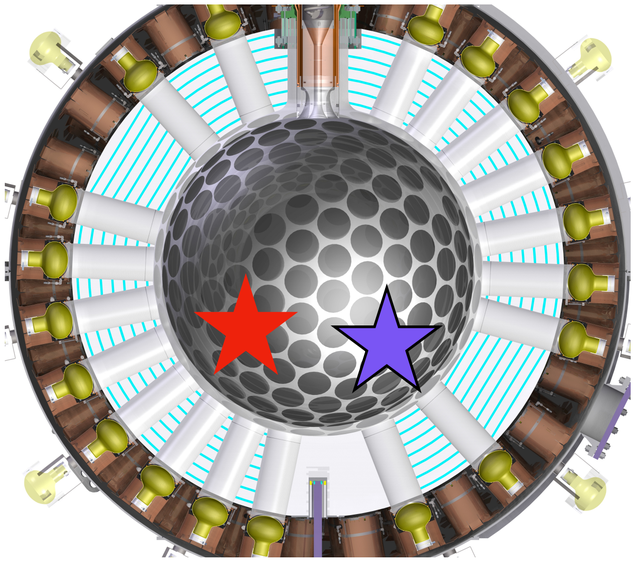
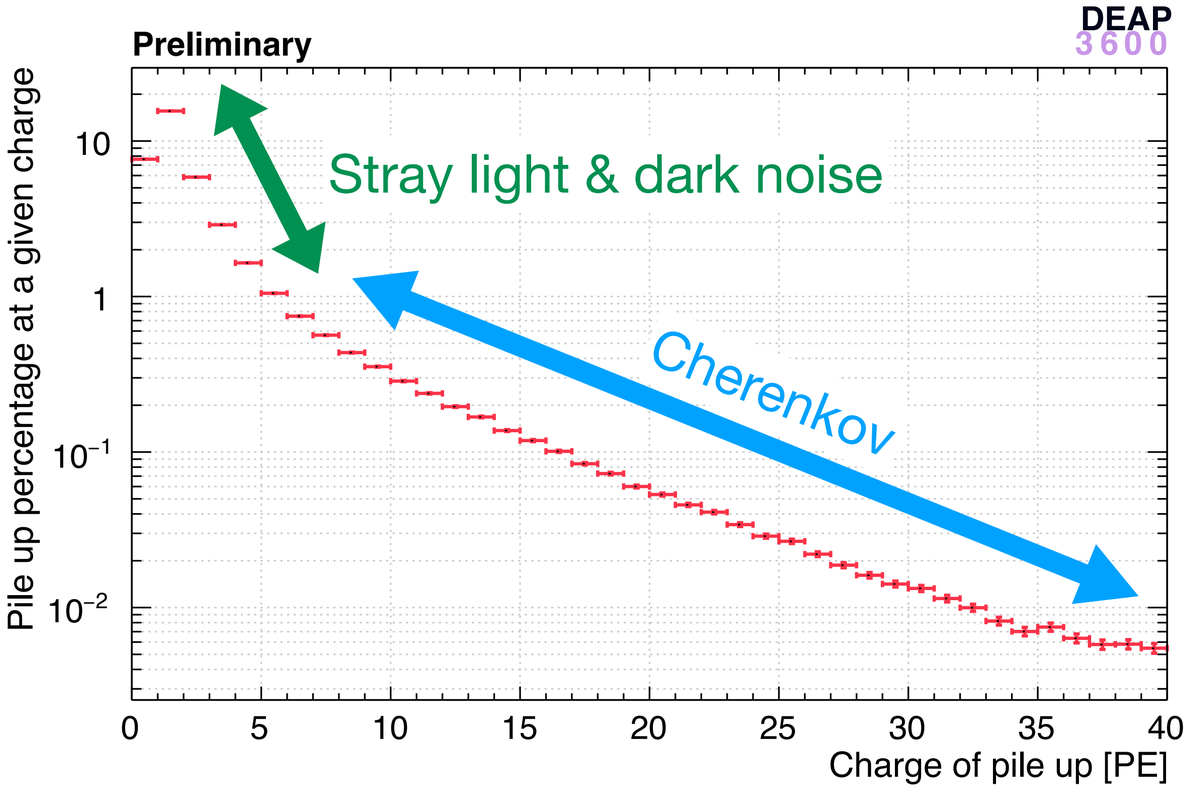
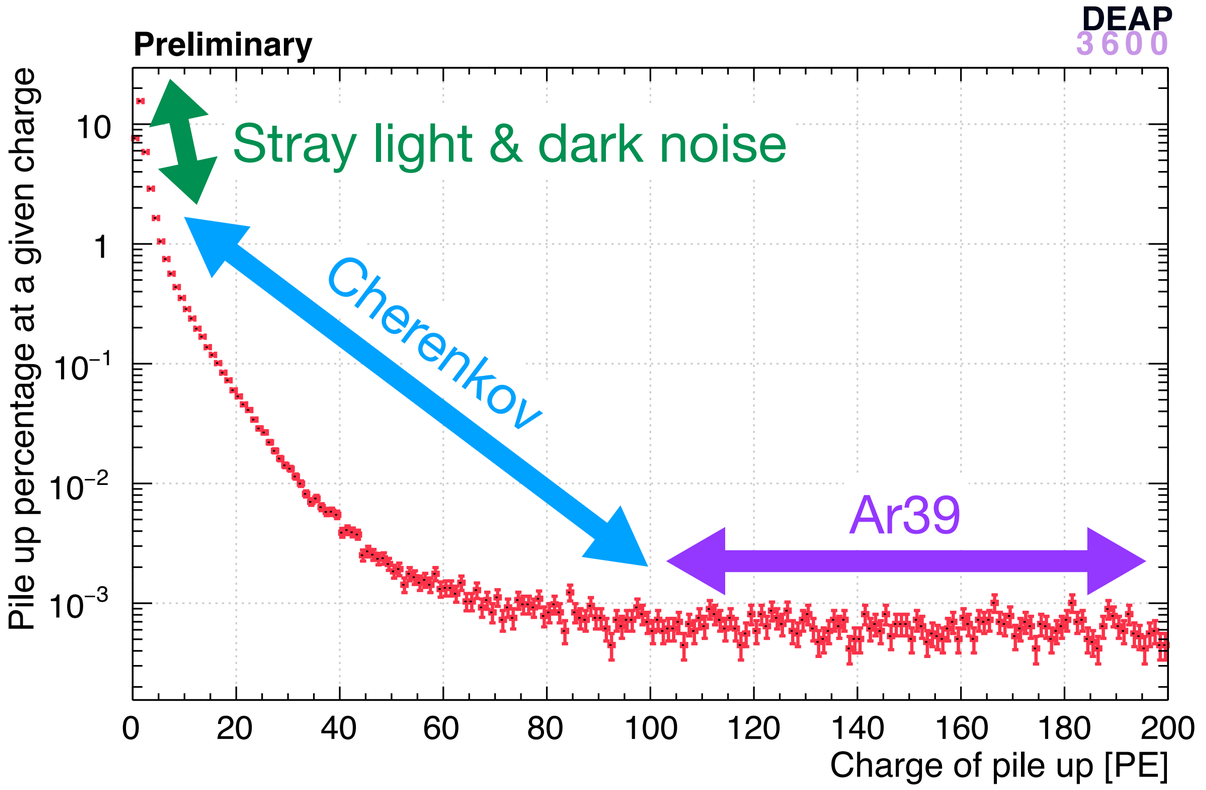


How likely is an event to have pile up?

Periodic trigger events show how often a given amount of charge is seen in the detector, which corresponds to the probability that a given amount of pile up occurs in a physics event

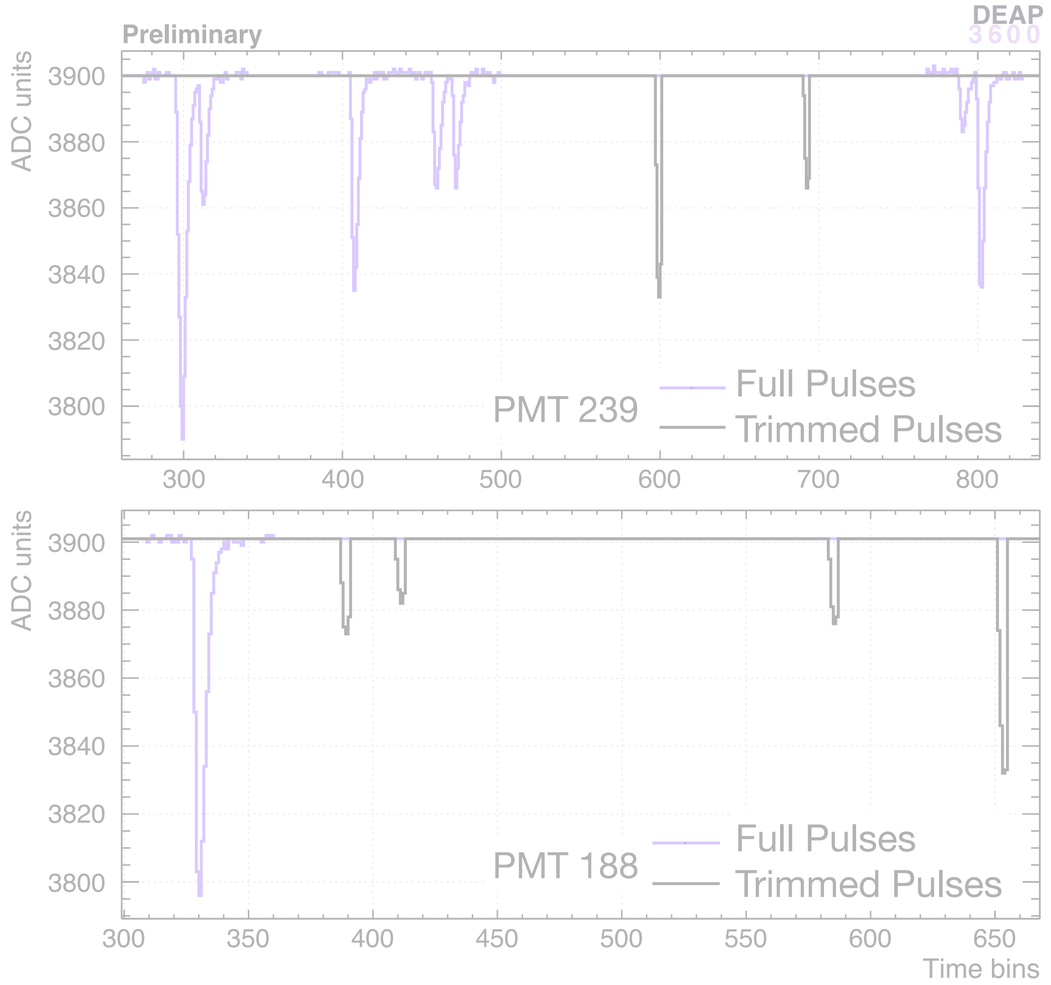
Low charge pile up is most likely and several features can be identified.





Reconstructing raw data

- The periodic trigger events are added to the physics events to create pile up events at the raw data level
  - This is done so that each pile up event will be processed as a single event by the software
- Raw data waveforms for individual PMTs consist of full pulses and pulses trimmed by the DAQ
- Adding a trimmed pulse to a full pulse would not correctly recreate the waveform of two pulses happening at the same time



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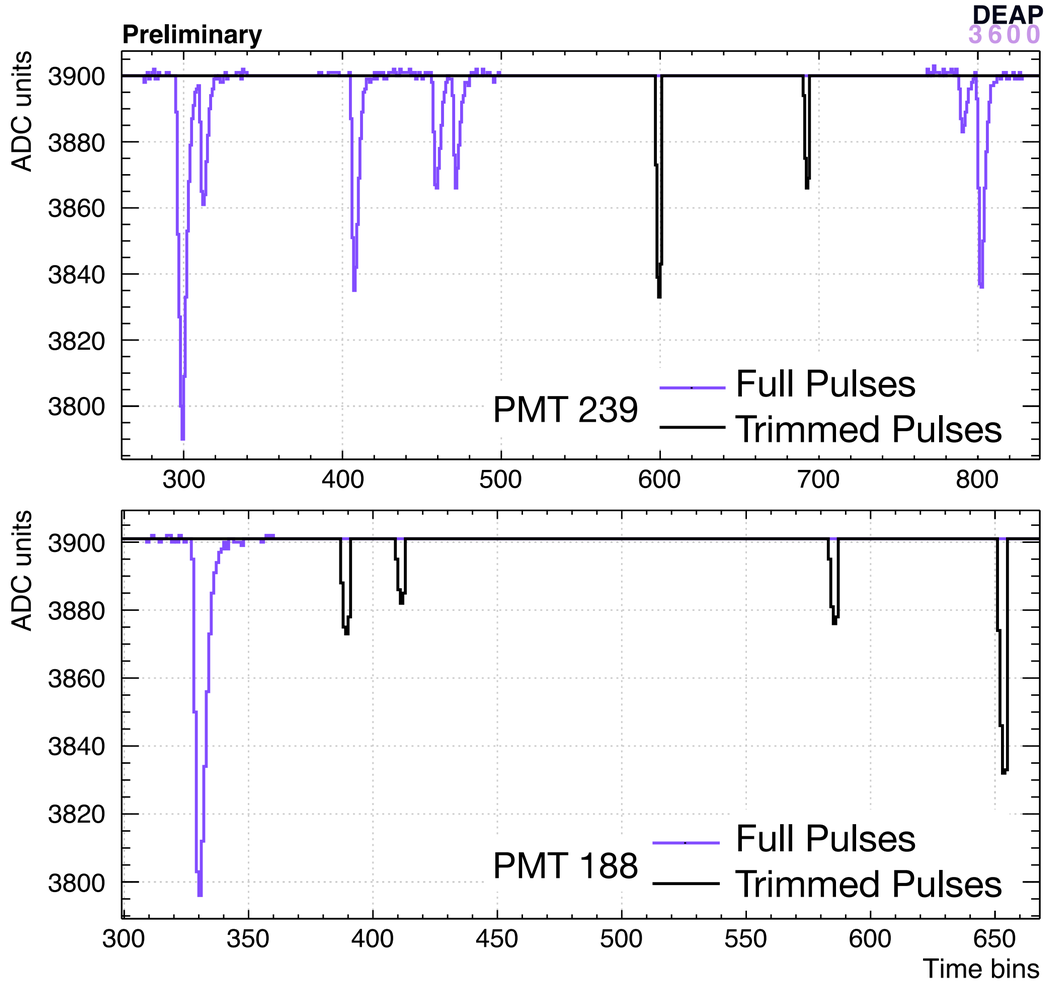

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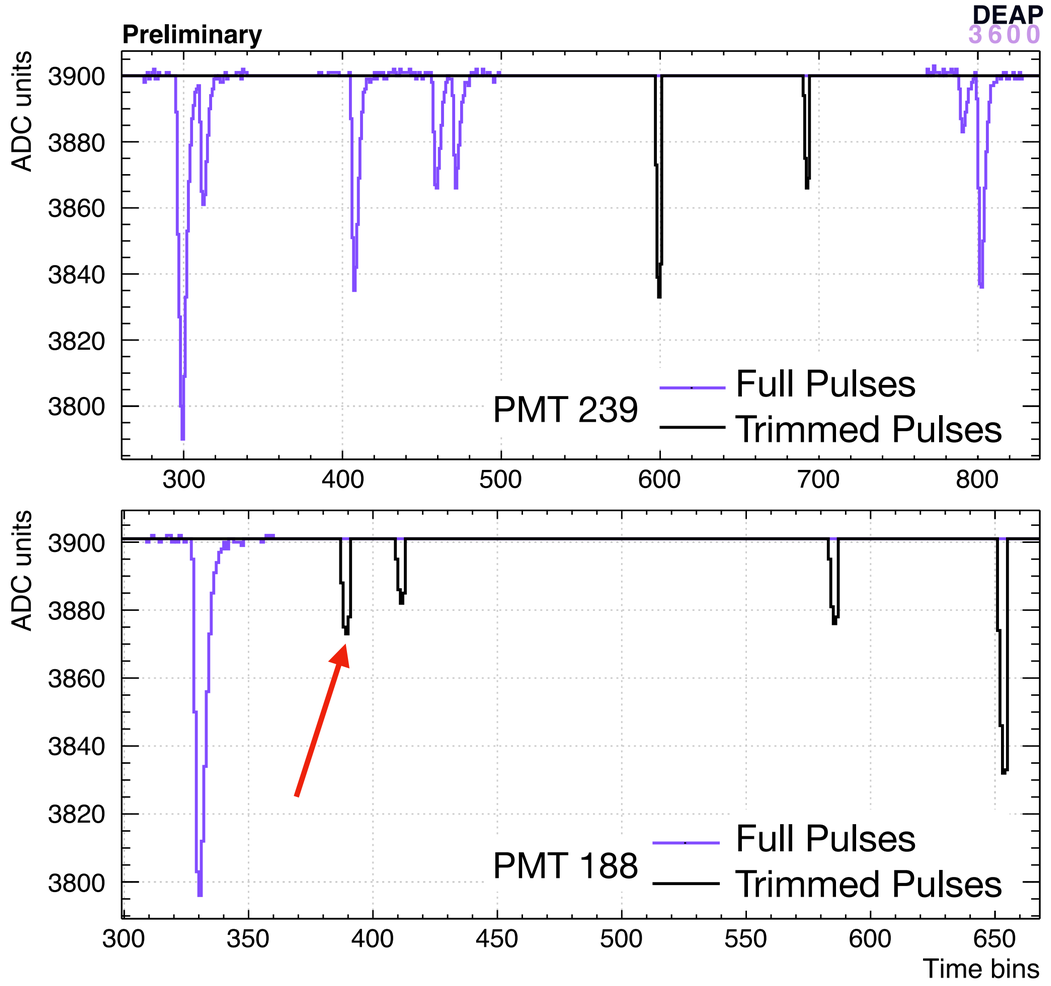

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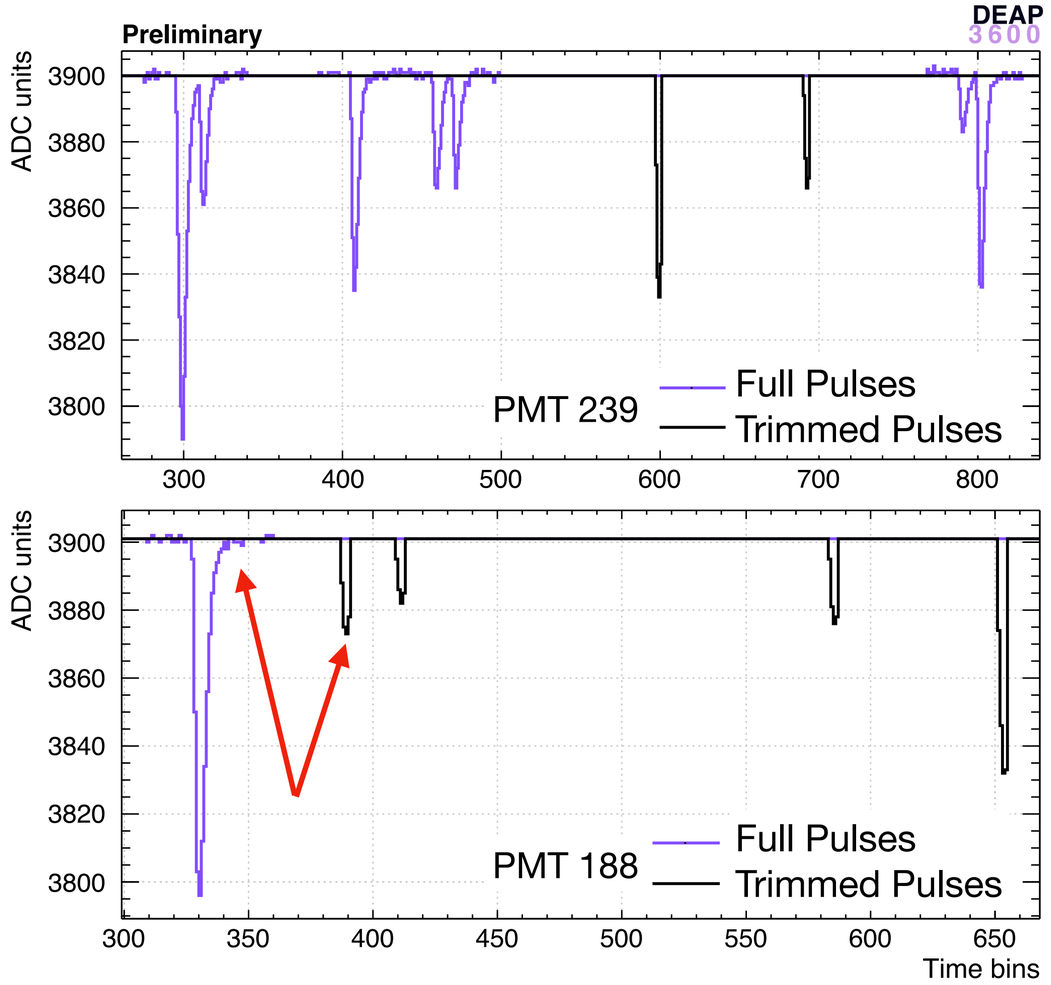

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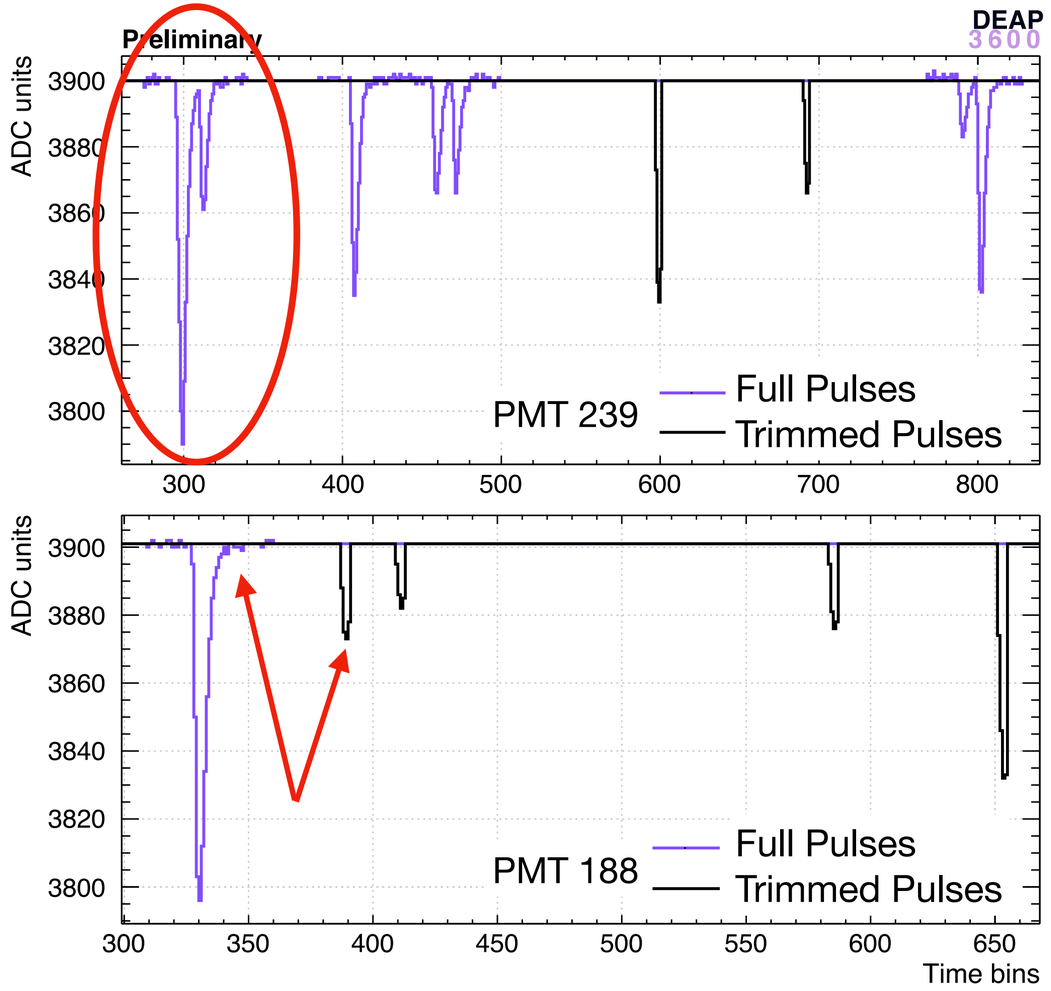
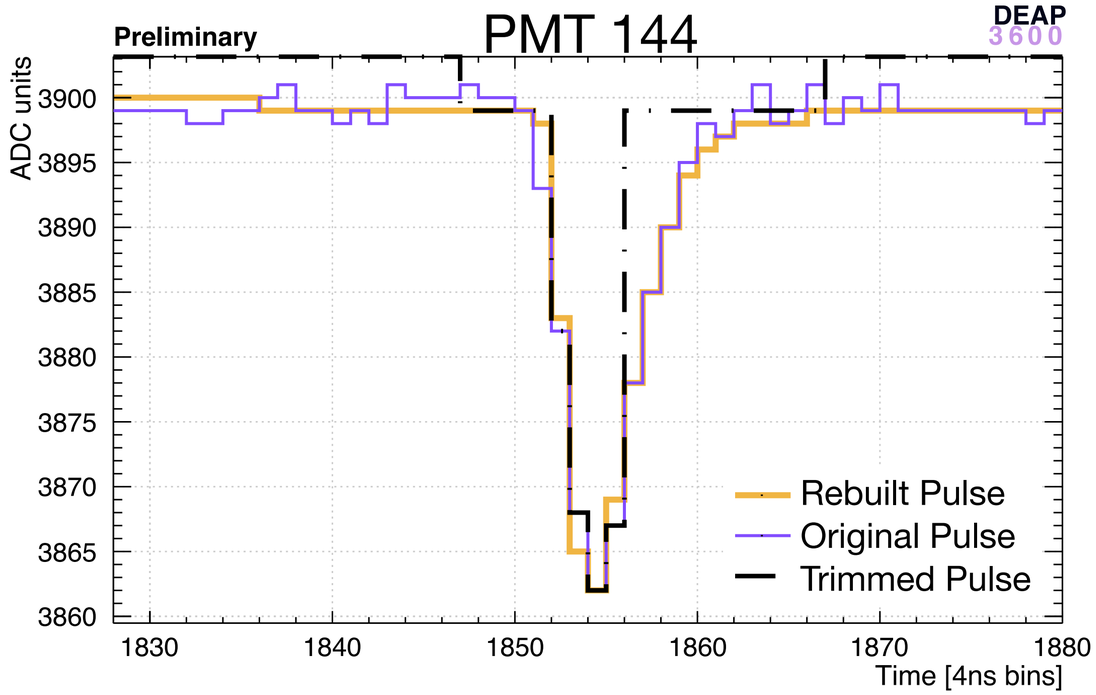


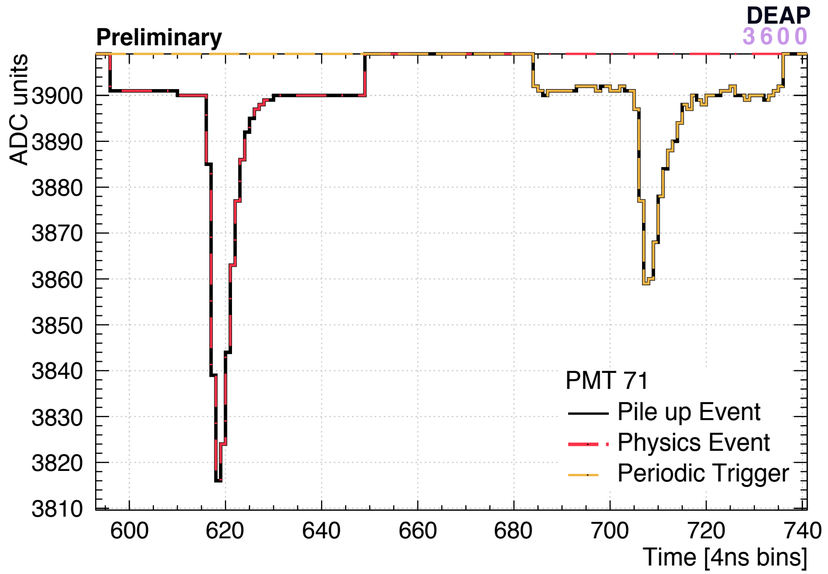
Rebuilding the Trimmed pulses

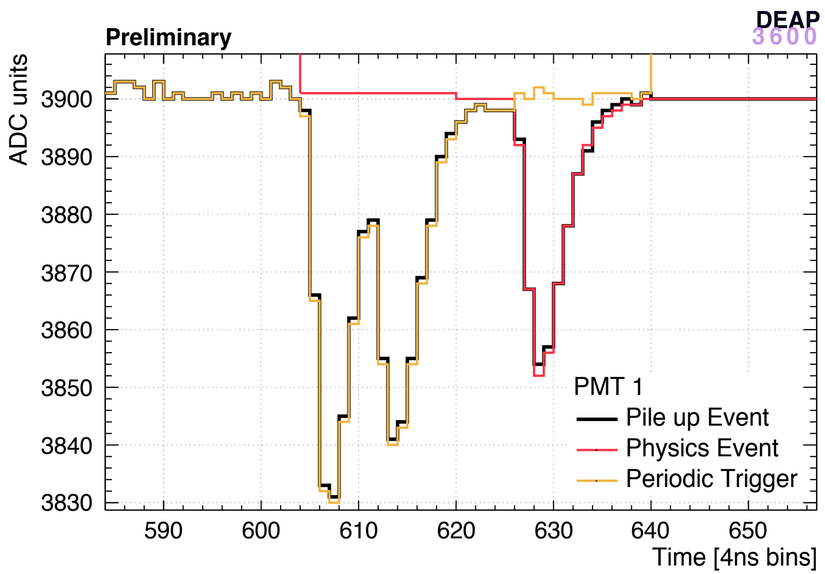
- I fit a generalized pulse shape to the trimmed pulse to rebuild the full pulse
  - Generalized pulse is derived from detailed electronics study
  - It is also fit to the pulses to help determine the calibrated charge and time. I reversed this process
- I confirmed that events processed with the rebuilt pulses reasonably matched those processed with the trimmed pulses

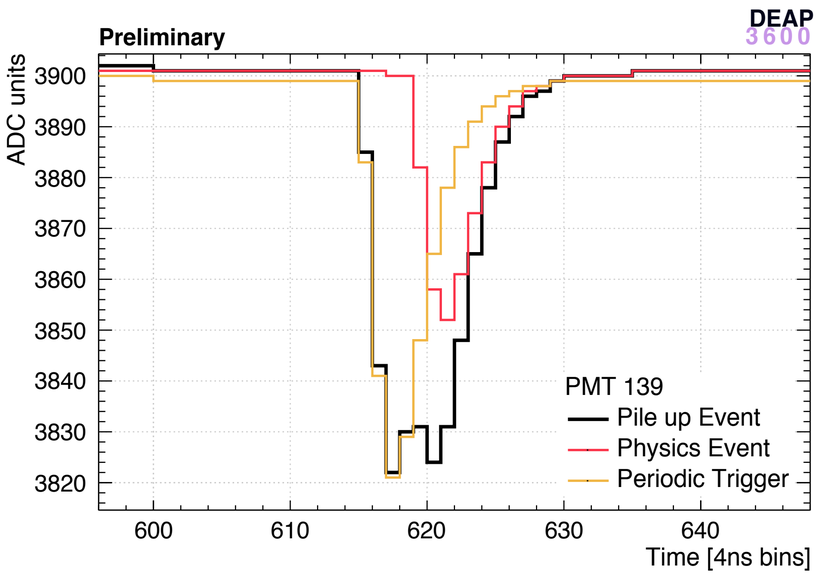


Algorithm for creating artificial pile up events

- The raw waveforms for the periodic trigger event and the physics event are combined for each PMT
- The plots show different scenarios of periodic triggers piled up on a physics event and that the algorithm works on all of them

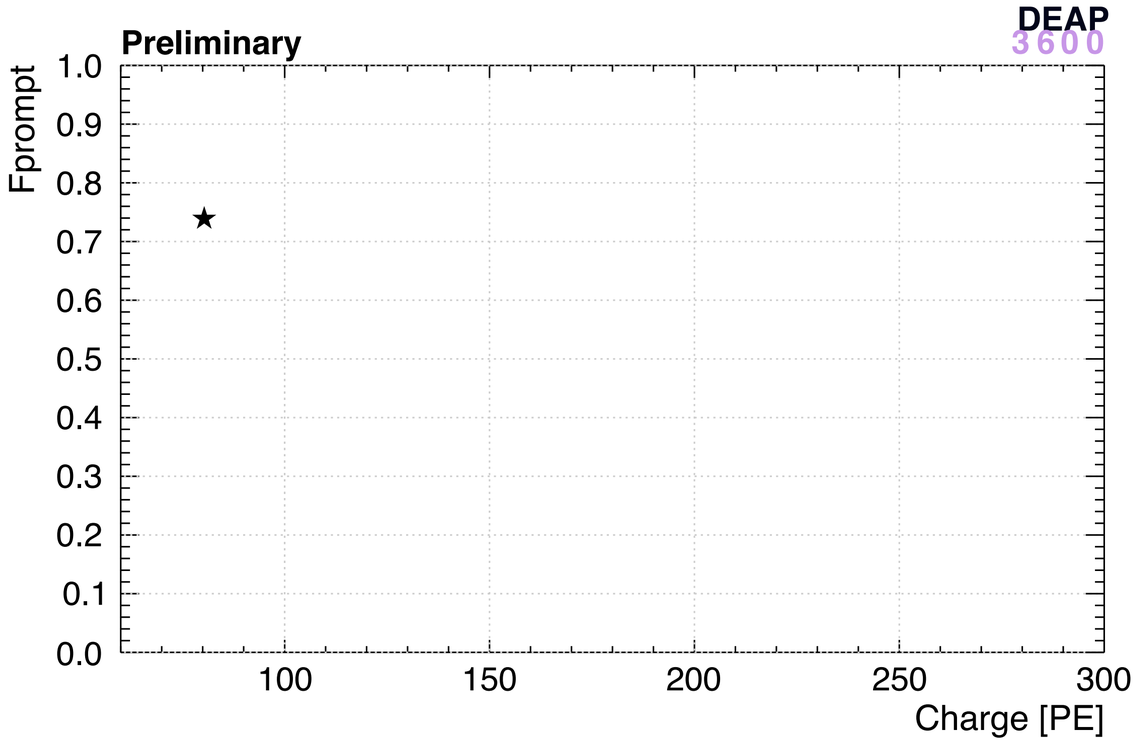


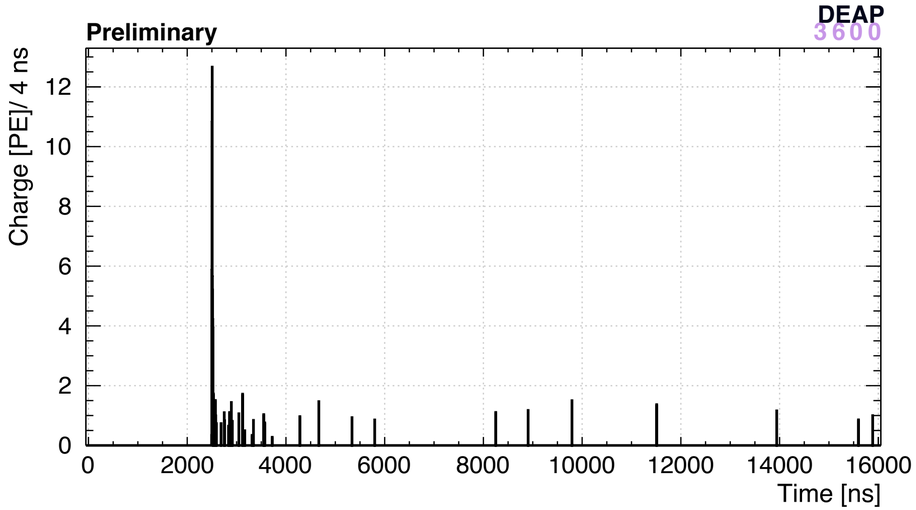




Analyzing artificial pile up events

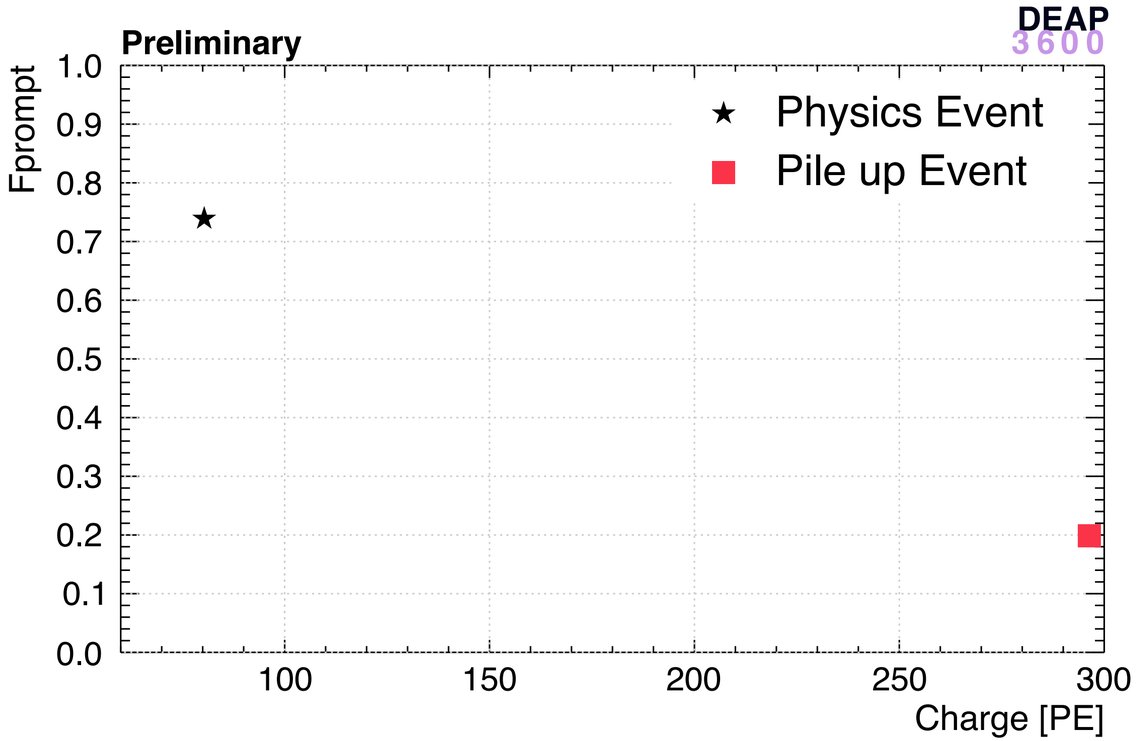
1. Take an original physics event

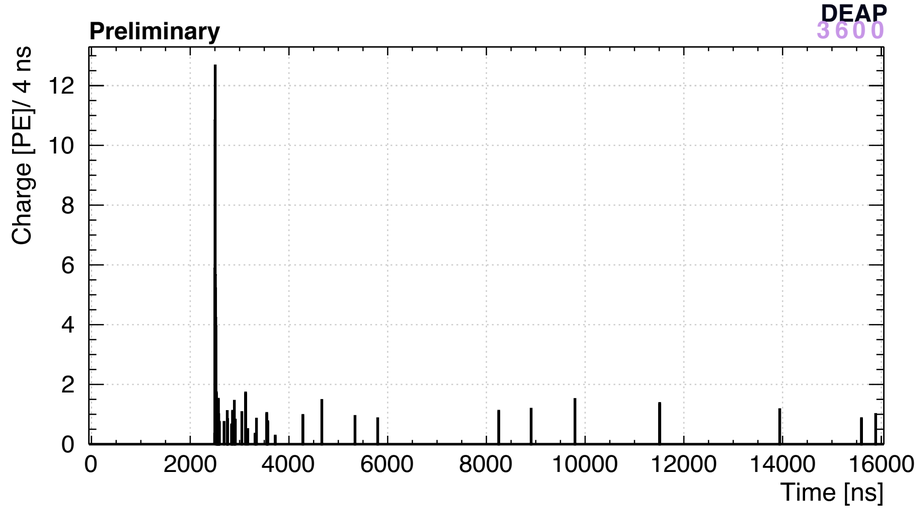


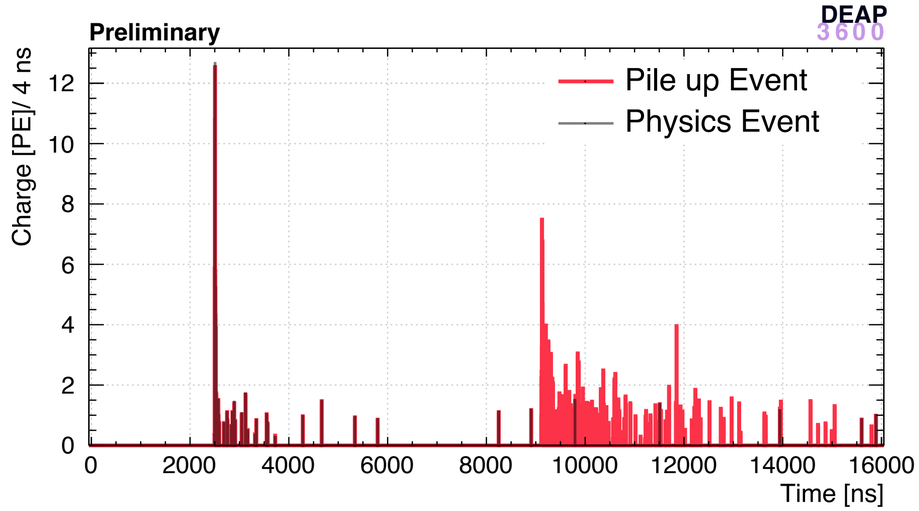


Analyzing artificial pile up events

1. Take an original physics event
2. Pile up a periodic trigger event on the physics event to create a pile up event

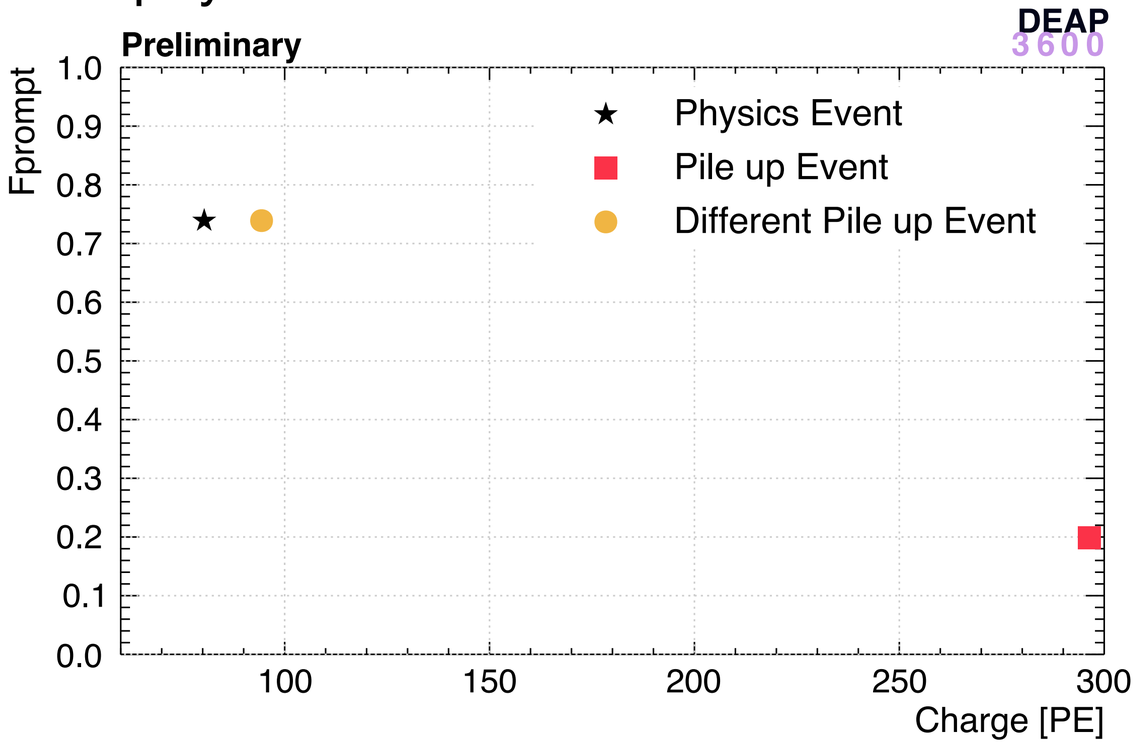


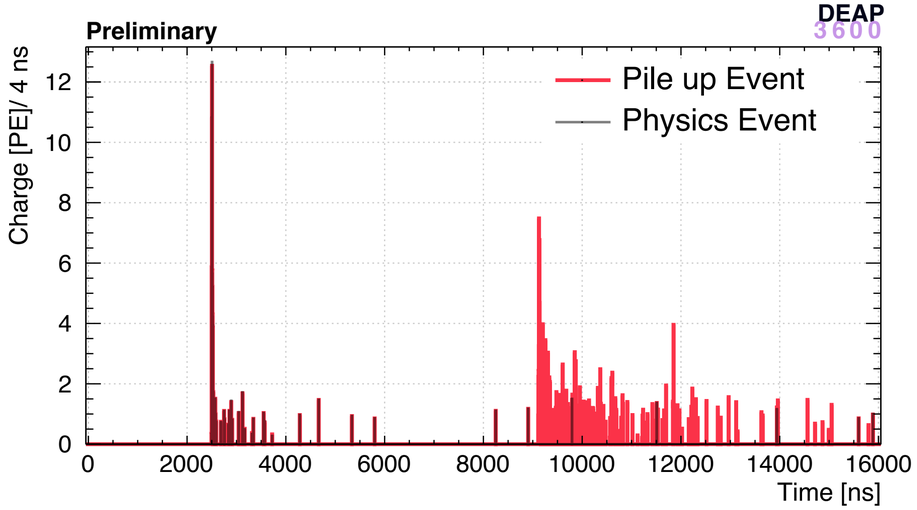


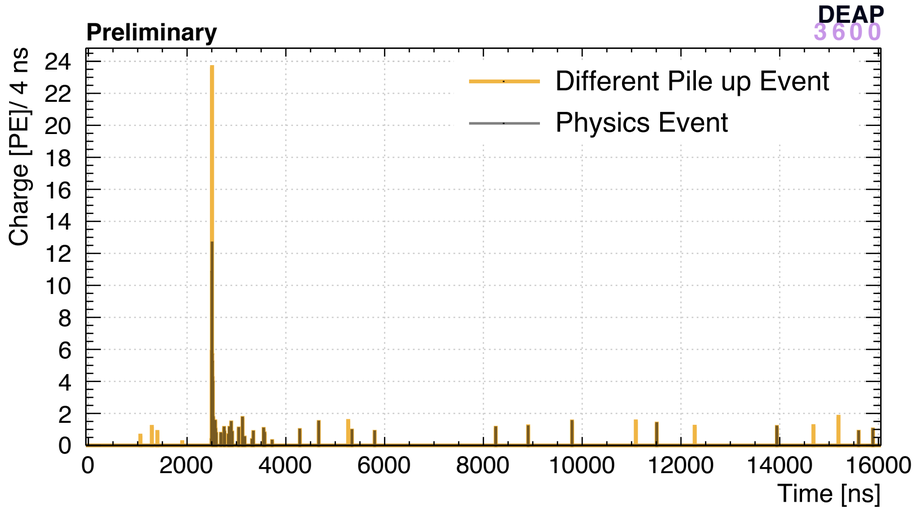


Analyzing artificial pile up events

1. Take an original physics event
2. Pile up a periodic trigger event on the physics event
3. Pile up a different periodic trigger event on the same physics event

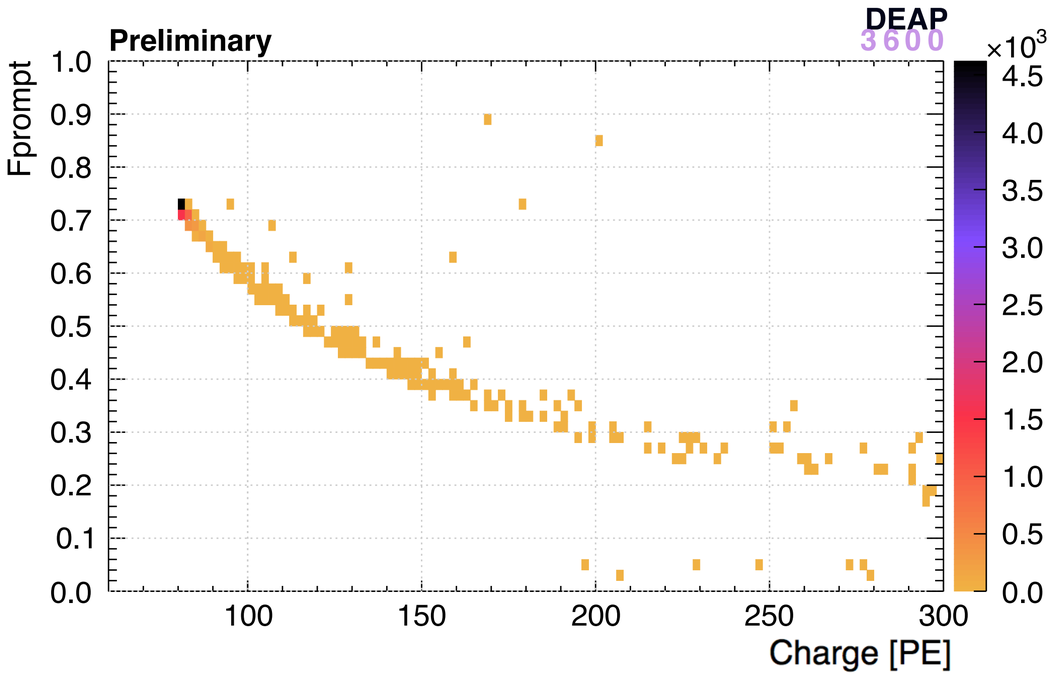




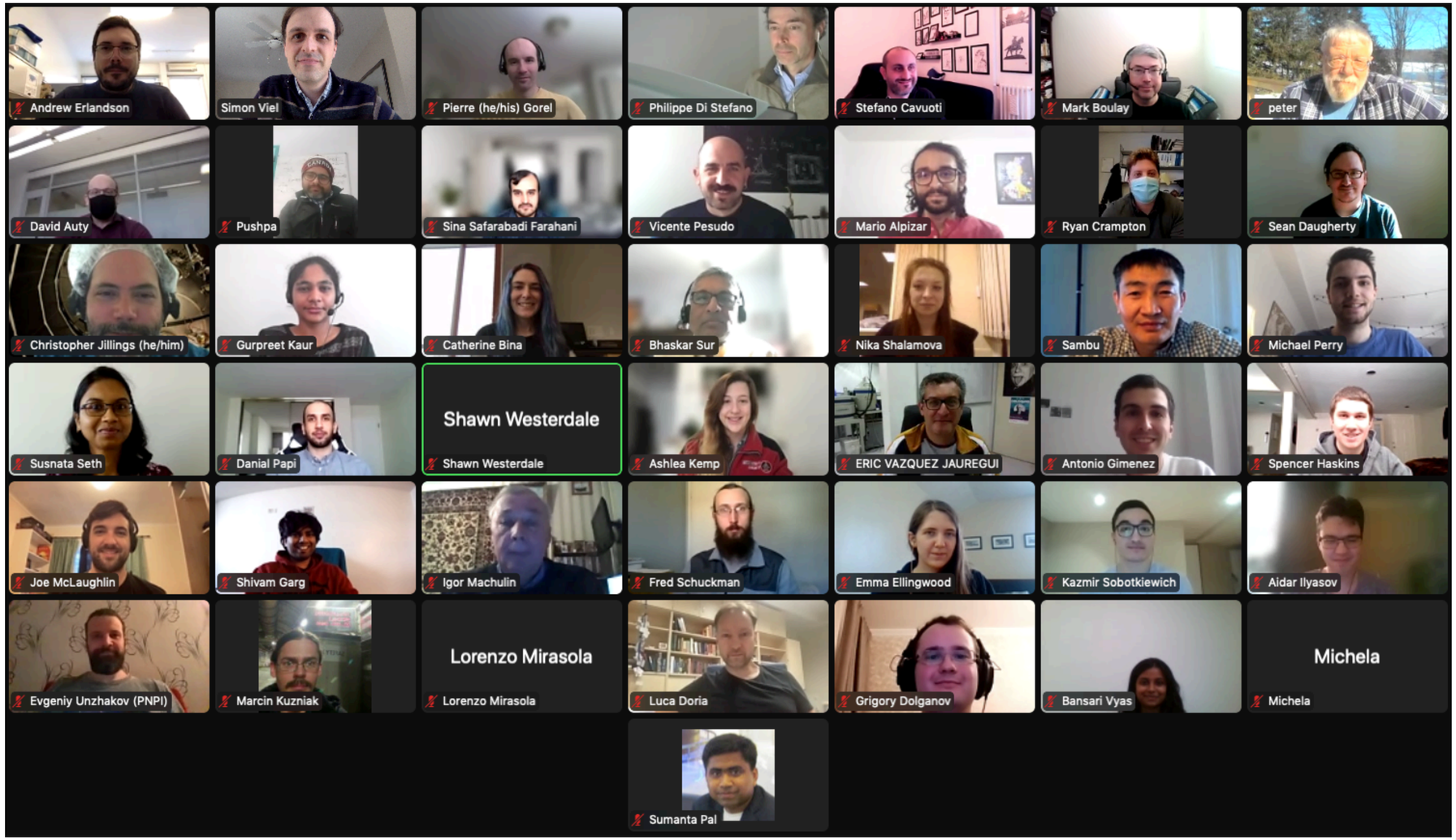


Physics event with 9,000 different periodic trigger events piled up on it

- Most pile up is so low charge as to have no significant effect on the event
- Most pile up adds late light, lowering Fprompt while increasing the charge. Much rarer to have prompt light added to the event.
- Pile up is more complicated than just adding up the charge from two events and how it affects events in detail is important
- The ultimate goal for this project is to determine if our ability to reject pile up is limiting our dark matter search



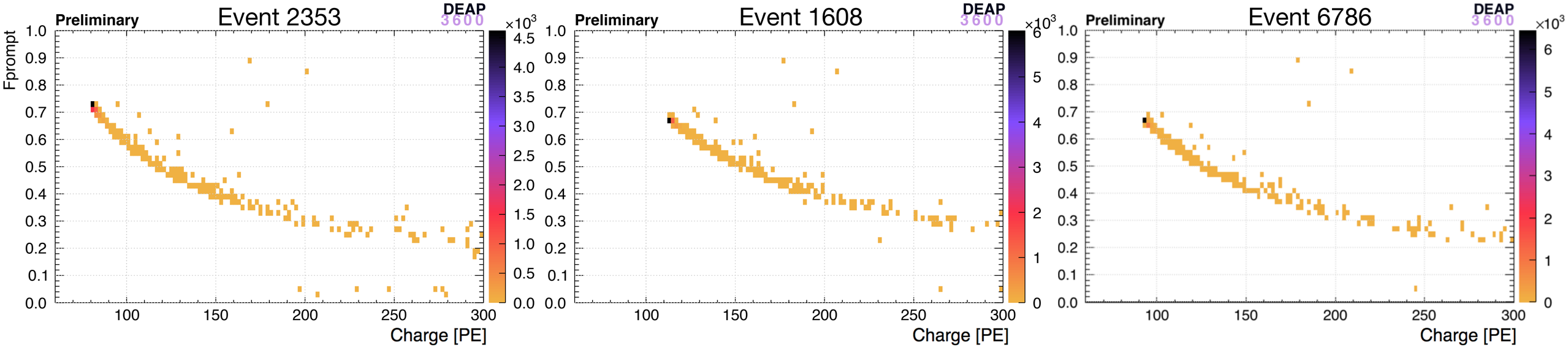
NO CUTS APPLIED


Andrew Erlandson
Simon Viel
Pierre (he/his) Gorel
Philippe Di Stefano
Stefano Cavuoti
Mark Boulay
peter
David Auty
Pushpa
Sina Safarabadi Farahani
Vicente Pesudo
Mario Alpizar
Ryan Crampton
Sean Daugherty
Christopher Jillings (he/him)
Gurpreet Kaur
Catherine Bina
Bhaskar Sur
Nika Shalamova
Sambu
Michael Perry
Susnata Seth
Danial Papi
Shawn Westerdale
Shawn Westerdale
Ashlea Kemp
ERIC VAZQUEZ JAUREGUI
Antonio Gimenez
Spencer Haskins
Joe McLaughlin
Shivam Garg
Igor Machulin
Fred Schuckman
Emma Ellingwood
Kazmir Sobotkiewich
Aidar Ilyasov
Evgeniy Unzhakov (PNPI)
Marcin Kuzniak
Lorenzo Mirasola
Lorenzo Mirasola
Luca Doria
Grigory Dolganov
Bansari Vyas
Michela
Michela
Sumanta Pal

Back up slides

Effects of pile up on different events

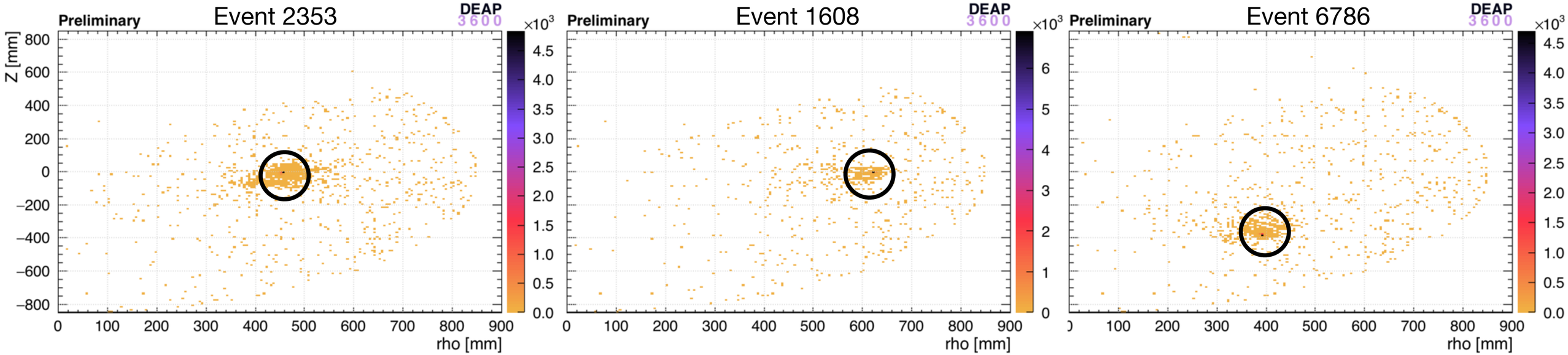
- Most pile up is so low charge as to have no significant effect on the event
- Most pile up adds late light, lowering the fraction of prompt light while increasing the charge



NO CUTS APPLIED

Effect of pile up on position reconstruction

- Most pile up events stay within 5-10 cm of where the original event was reconstructed
- Shows that pile up may sometimes have an effect on event reconstruction, but need to apply cuts to know more



NO CUTS APPLIED