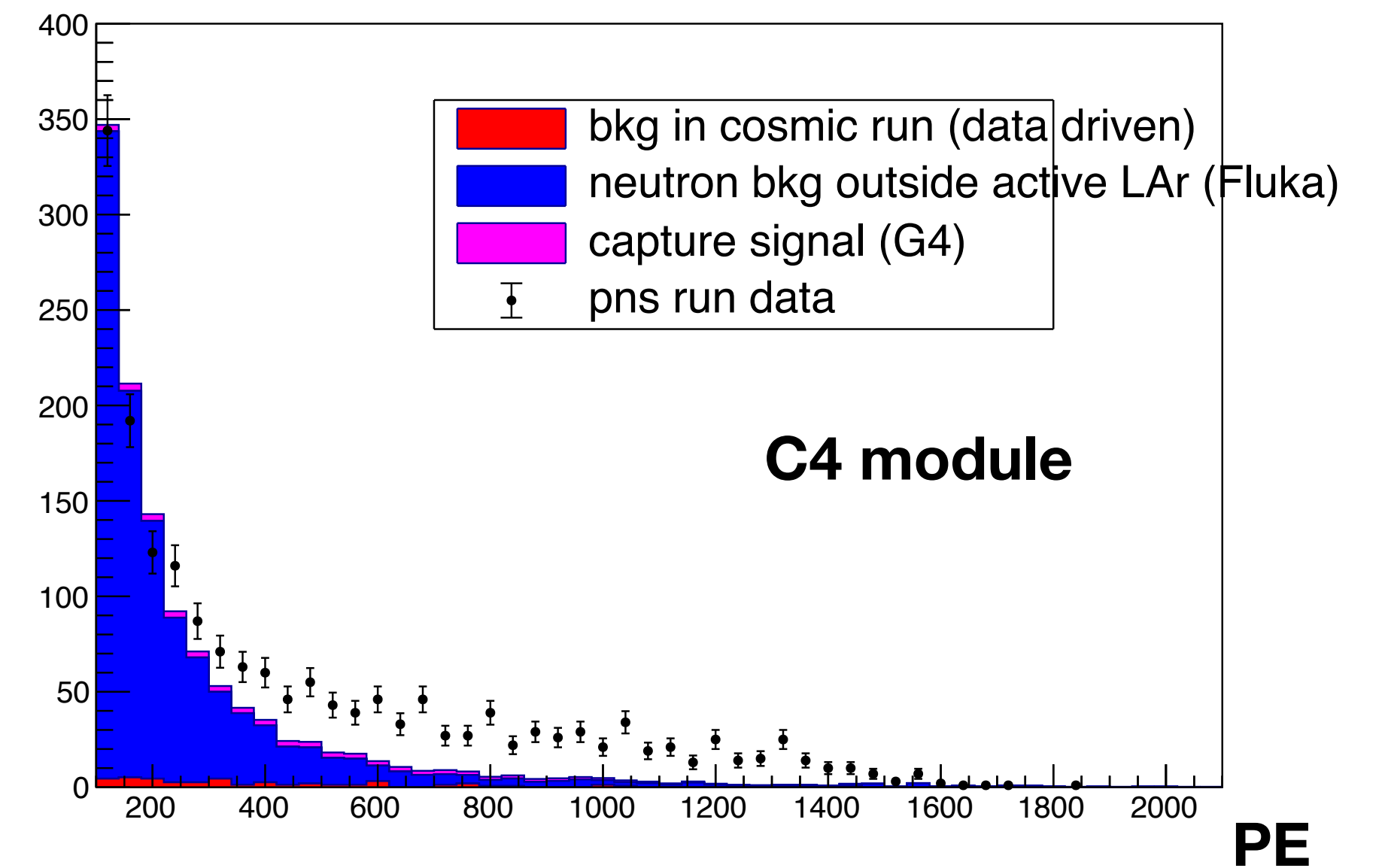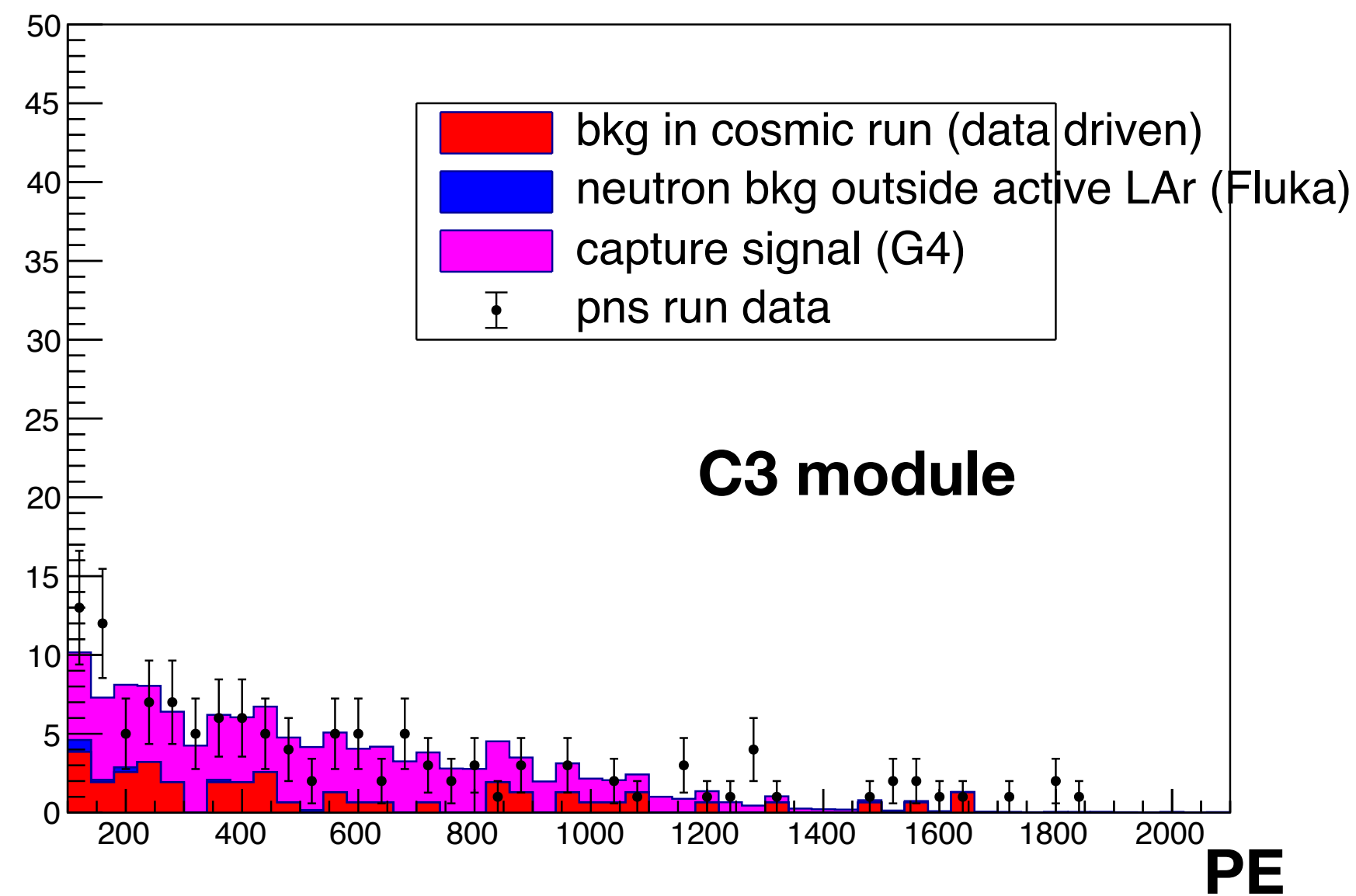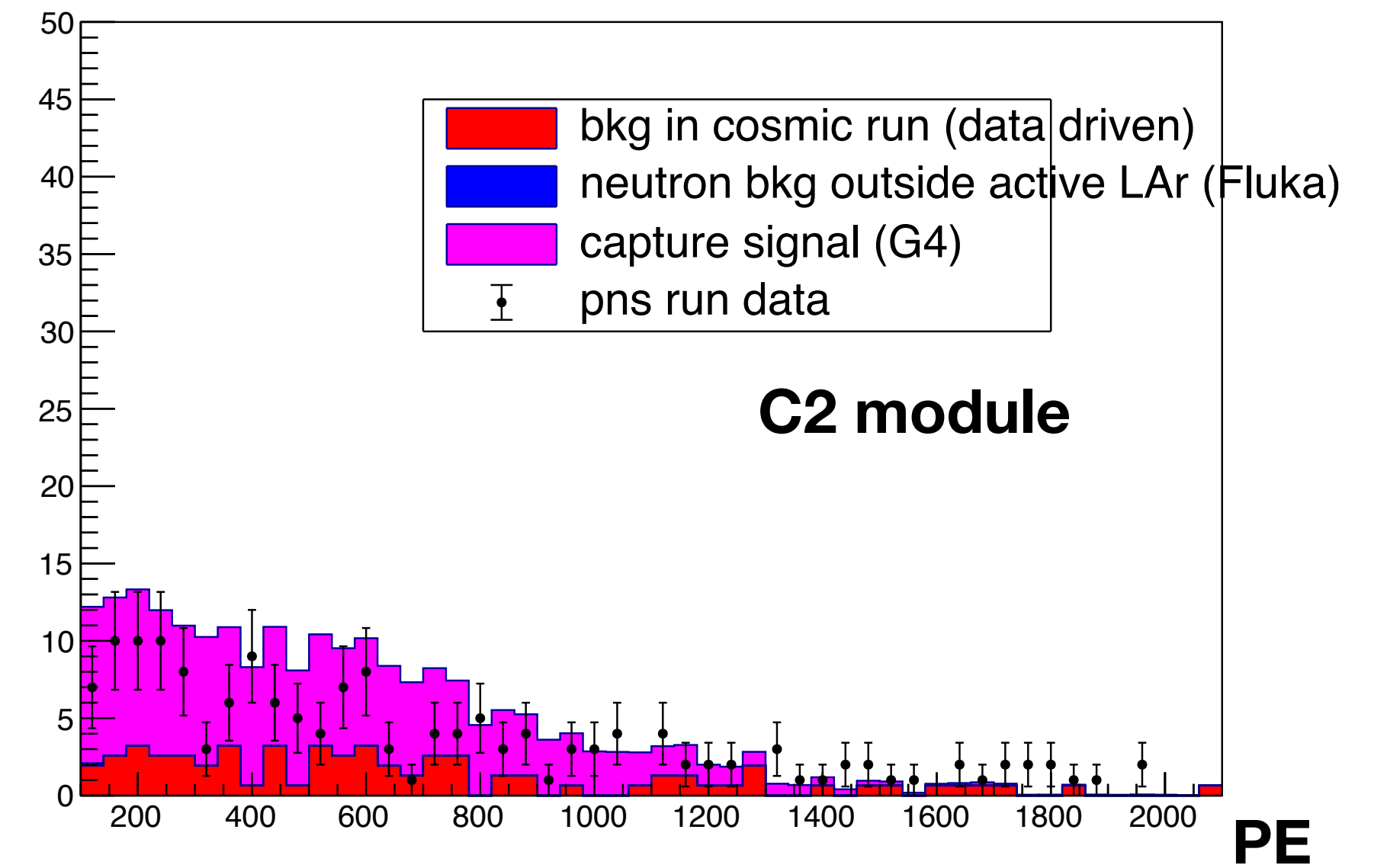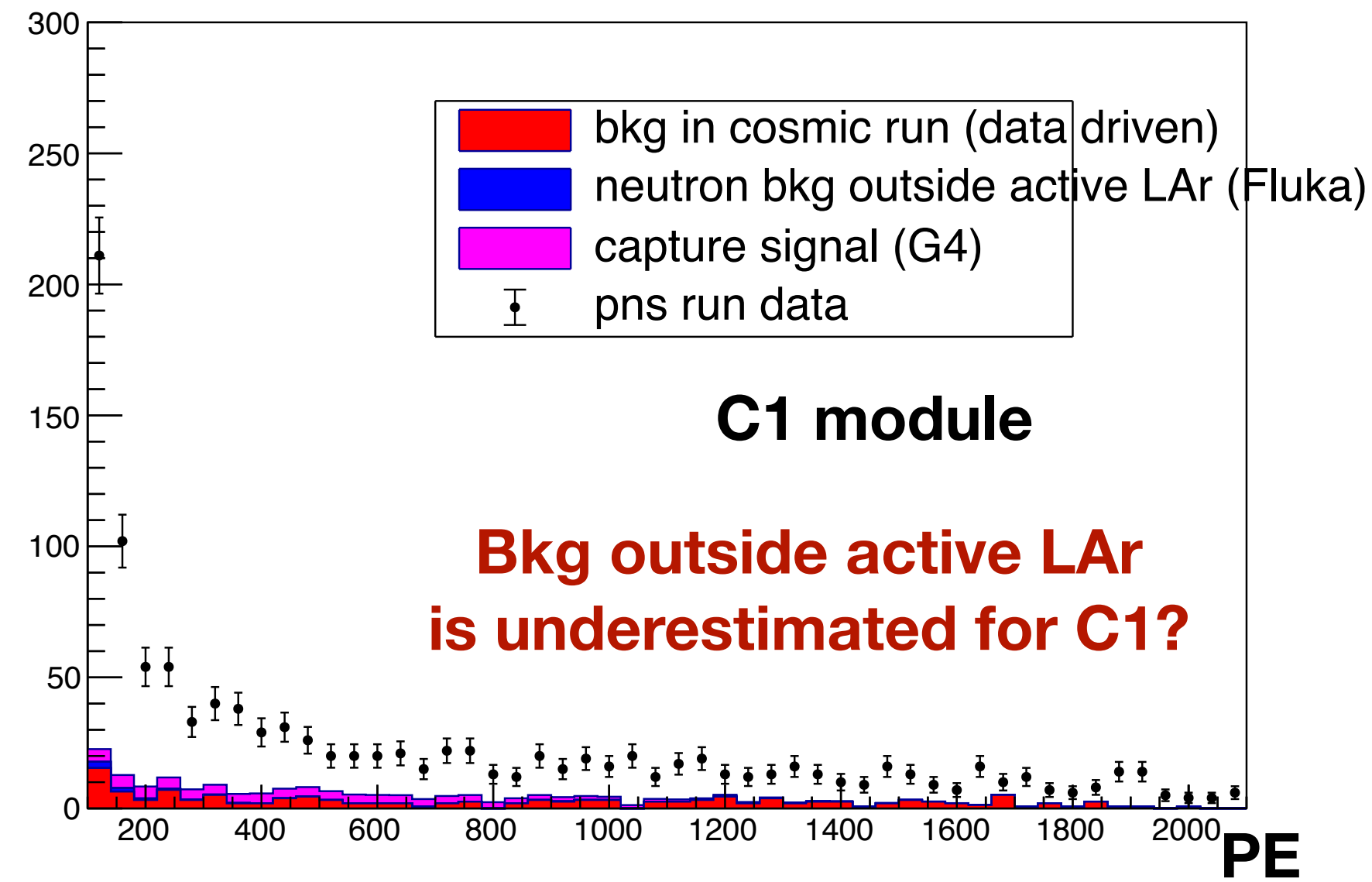# First attempt at data-MC comparison for ColdBox PNS runs in Apr-2024

Wei
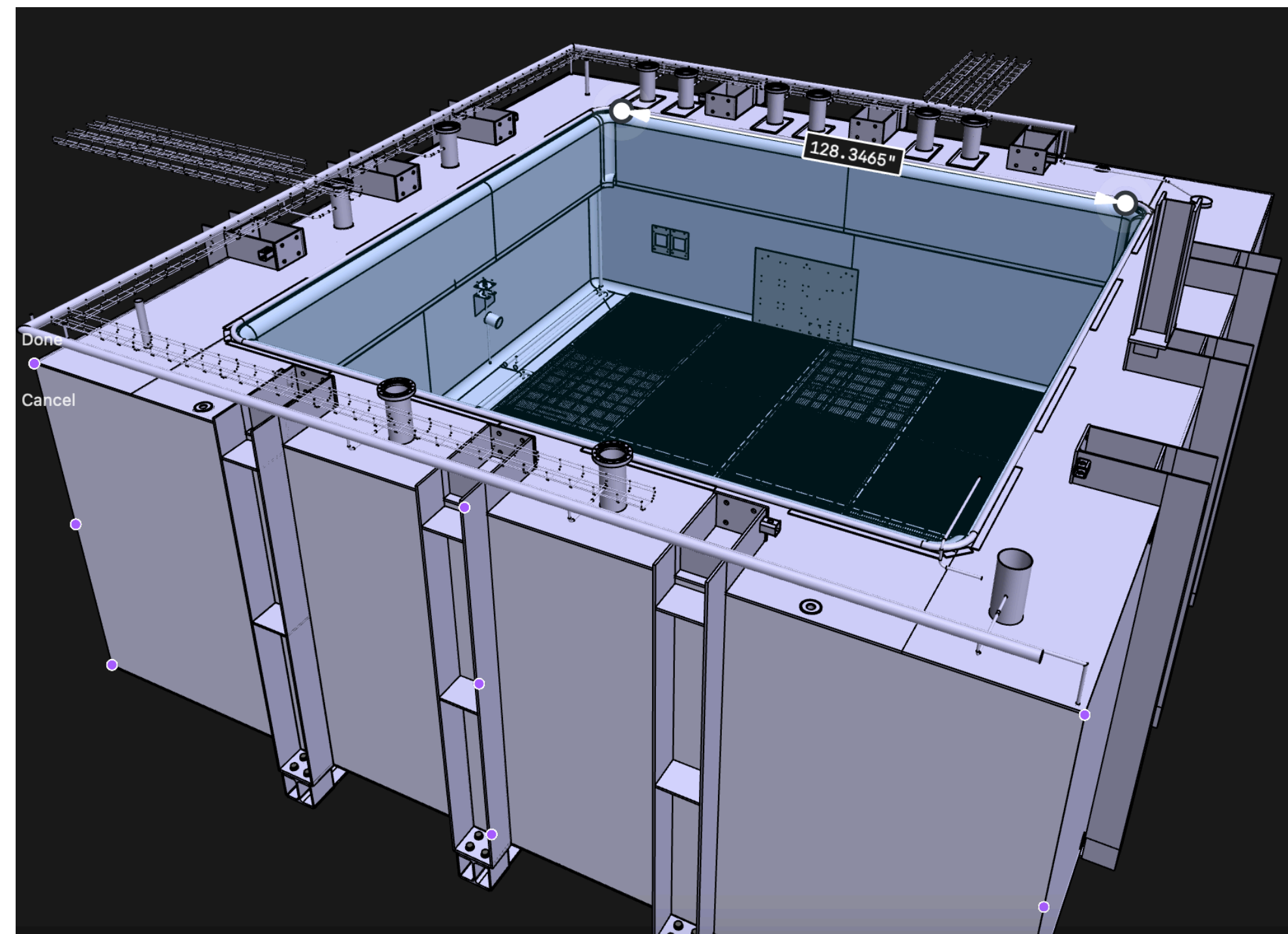
Preliminary PE comparison plots
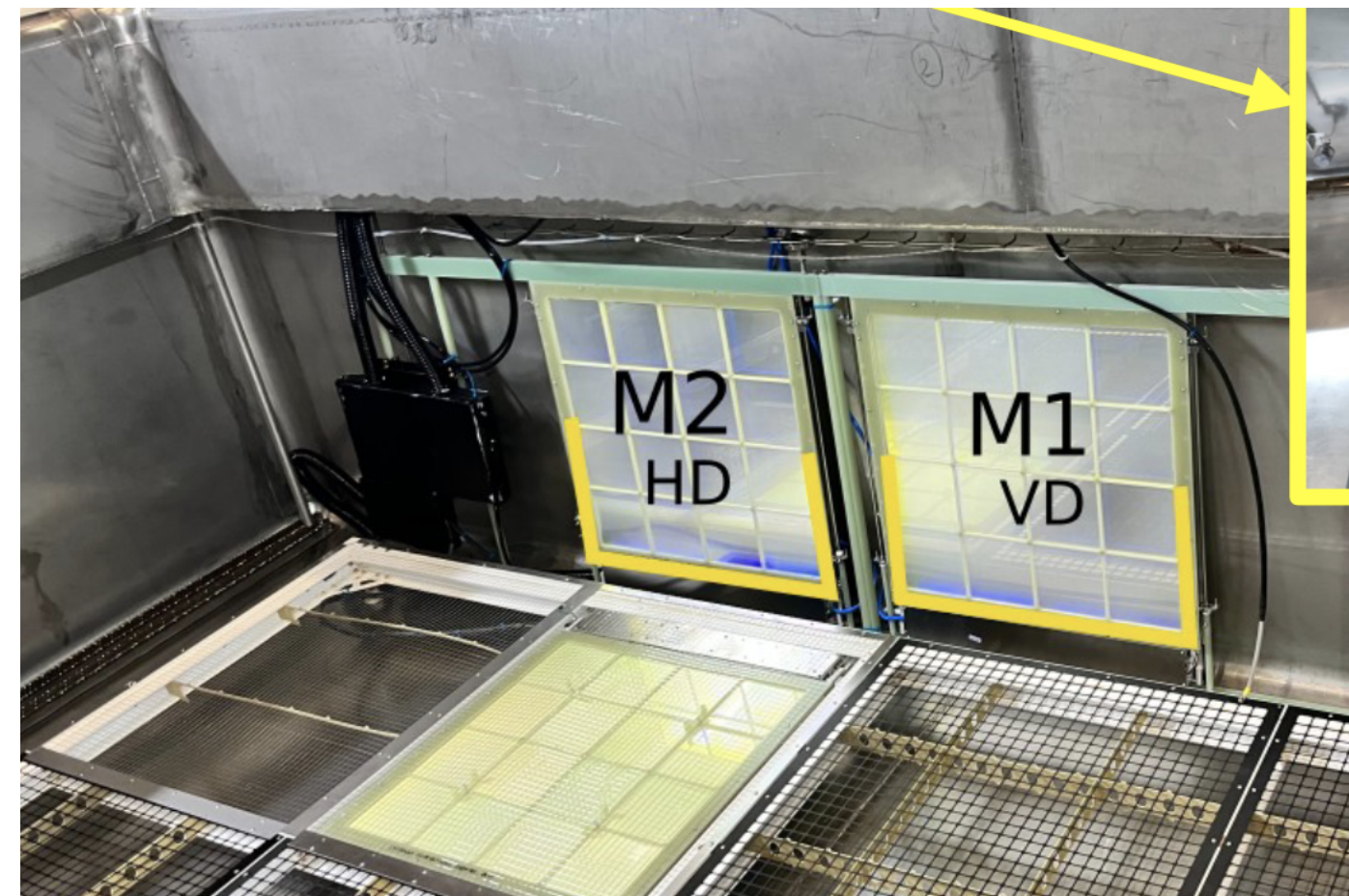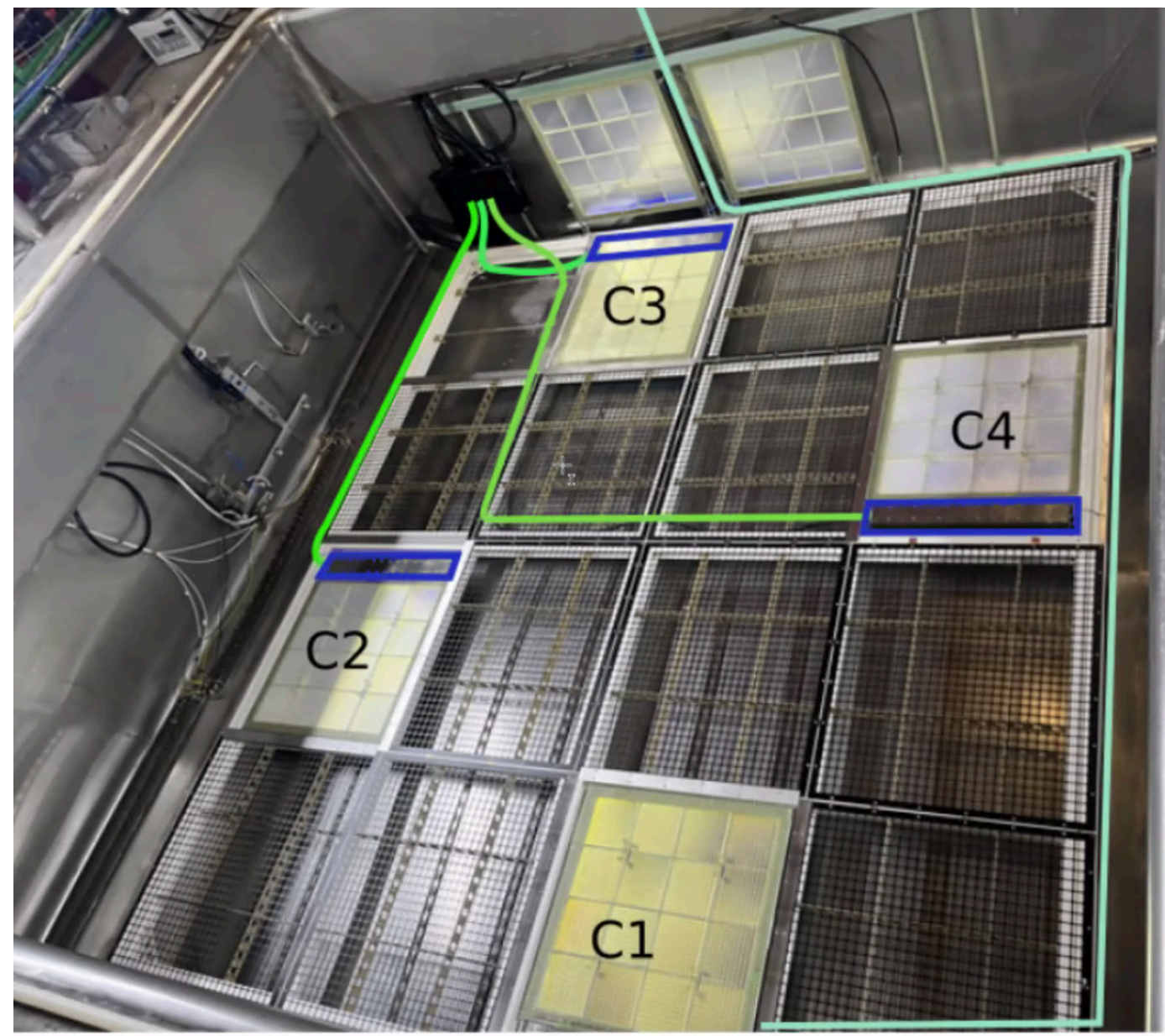## (Details of each component follow in next slides)
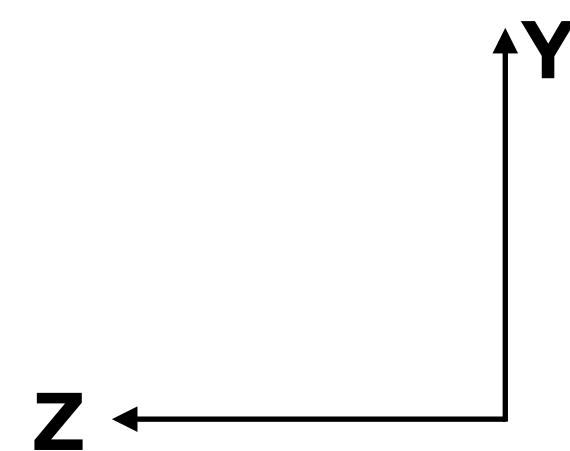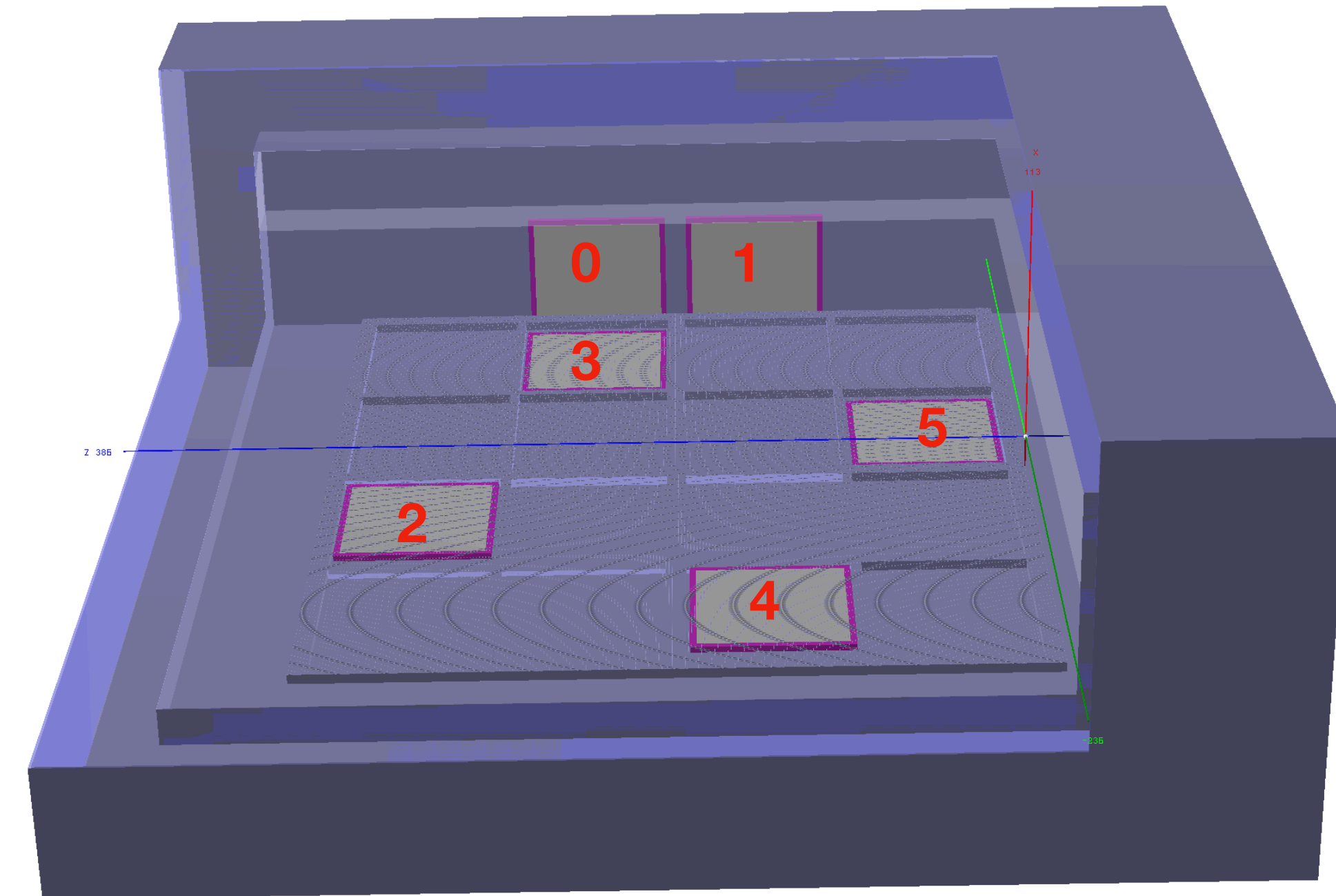
X-Arapucas in VD ColdBox PNS runs (Apr 2024)

C1-C4 numbering by detector installation team

Channel numbering scheme in LArSoft sim


```
Optical Channels positions: 6
0  -5.42   187.2  186.701
1  -5.42   187.2  111.701
2  -15.387  -38   257.901
3  -15.387  118   186.701
4  -15.387 -118   111.701
5  -15.387  37.2   40.9009
```

Main Differences to Ajib's LArSoft Analysis

- Analysis mainly done using **Lardon** (independent framework to LArSoft)
  - A framework primarily used by CRP group for quick ColdBox data analyses in the past years (developed primarily by L. Zembelli)
  - Reco objects include pds peaks, blips and tracks in TPC), somewhat different to LArSoft language (Spacepoint based), especially when doing event selection
  - For PD: no waveform deconvolution (not sure LArSoft?)
    - For my PNS analysis: PE is derived using channel ADC / ADC-per-SPE conversion factors (from Henrique)

- Focus on captures happening on top of each **single** cathode XA
  - Ajib looks at all captures inside ColdBox by reconstructing positions from PD flashes based on 4 cathode XAs

Run Statistics

- Run 25036: PNS, PDS + TPC, 70945 triggers (1ms window)
- Run 25068: PNS, PDS + TPC, 53817 triggers (1ms window)
- Run 25071: PNS, PDS + TPC, 38146 triggers (1ms window)
  —> PNS run (PDS + TPC) total: 162908 triggers

- Run 25004: cosmic run (no PNS), 22327 triggers (4ms window)
- Run 25066: cosmic run (no PNS), 56221 triggers (4ms window)
- Run 25078: cosmic run (no PNS), 51234 triggers (4ms window)
- Run 25084: cosmic run (no PNS), 33204 triggers (4ms window) - no membrane pd
- Run 25086: cosmic run (no PNS), 90748 triggers (4ms window) - no membrane pd
 **—> Cosmic run (PDS + TPC) total: 253734 triggers**

60+20us

Period

1 2 3 4 5

$400 \ \mu s \ (80 \ \mu s \times 5 = 400 \mu s)$

Burst Period

V. Popov

5
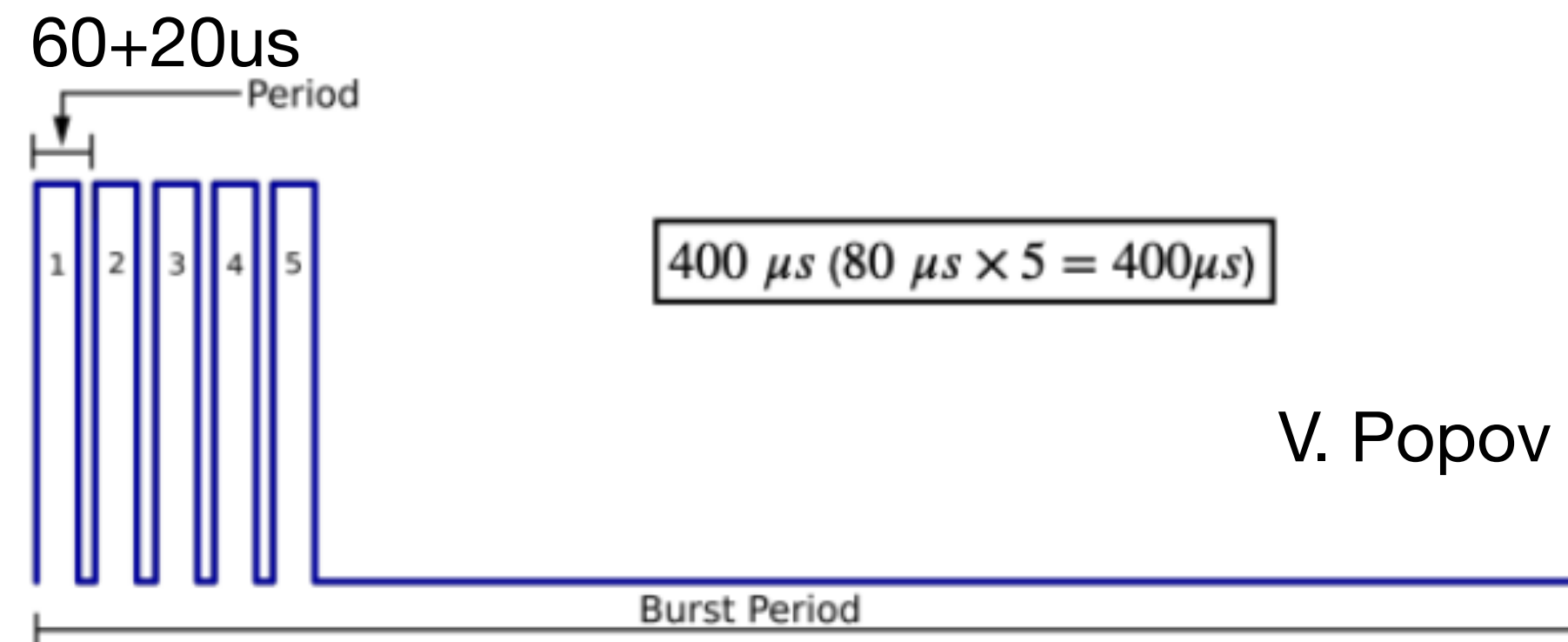
Background Processes

- Expect following 4 bkgs in a typical PNS run (and —> estimation methods):
  - **Cosmics**: ~ 50% anode-cathode crossing cosmics, the rest are cosmics entering from the side —> present in cosmic run —> **Data driven estimation using cosmic runs data**
  - **Bkg outside active LAr:** include captures @ buffer LAr (no instrument CRP/cathode), cryostat structure, etc —> Unique to PNS run —> **Estimated from Paola's Fluka simulation**
  - **Gammas from beam neutron inelastic scattering** —> **Only look at both TPC + PD triggers after neutron beam stops**
  - **Ar39** radiological beta decay background (0.565 MeV) → irreducible bkg —> present in cosmic run —> **Data driven estimation using cosmic runs data**

PNS run 25036

Cosmic run 25004

trk2d dz [cm]

Crossing cosmics have full 20cm drift
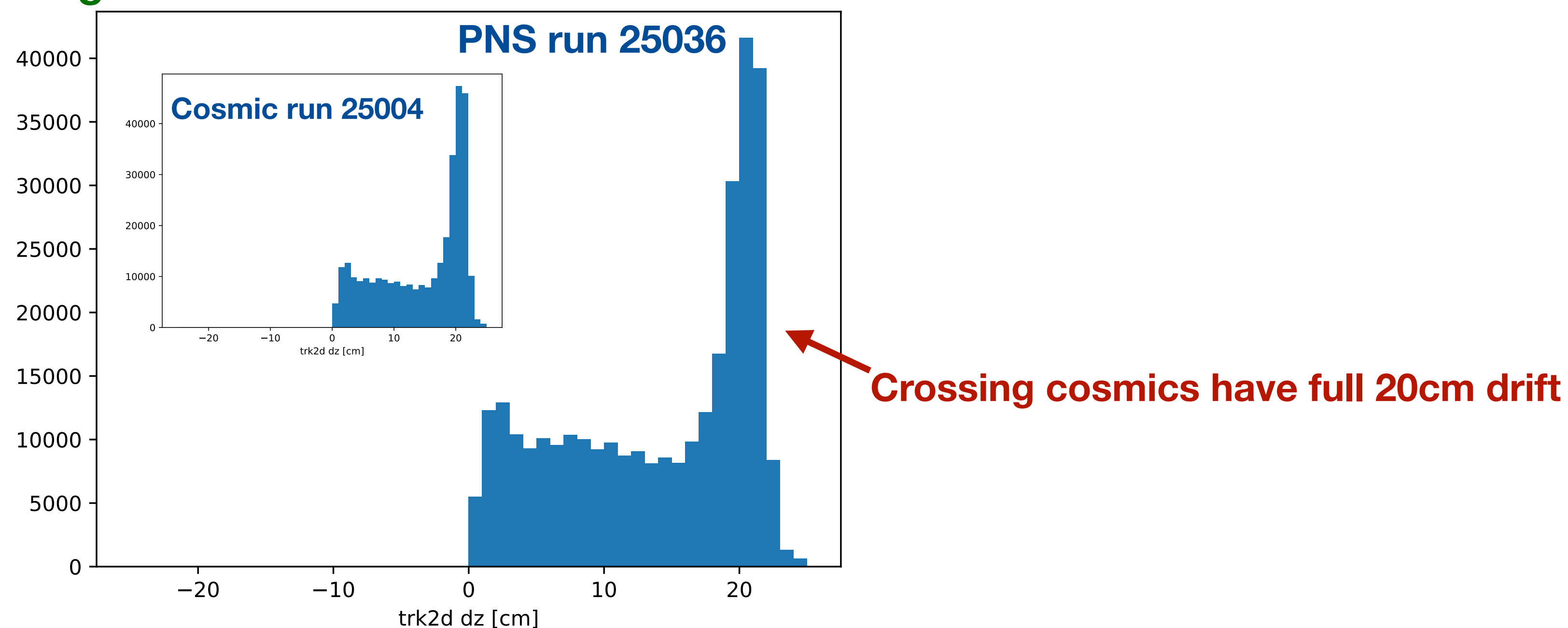
Neutron Capture Simulated Signal

- Simulated 1 million neutron captures (1capture/event) using **Walker's G4 PNS simulation**
  - PNS placed on the side of ColdBox, captures only inside active LAr

- Plot below is PE distribution from all captures in a voxel on the top of any of the 4 cathode XAs
  - Voxel spans from 5cm-20cm above the center of a XA (in drift direction x)
    - Blue curve: +/- 30cm in y-z plane
    - Red curve: +/- 10cm in y-z plane
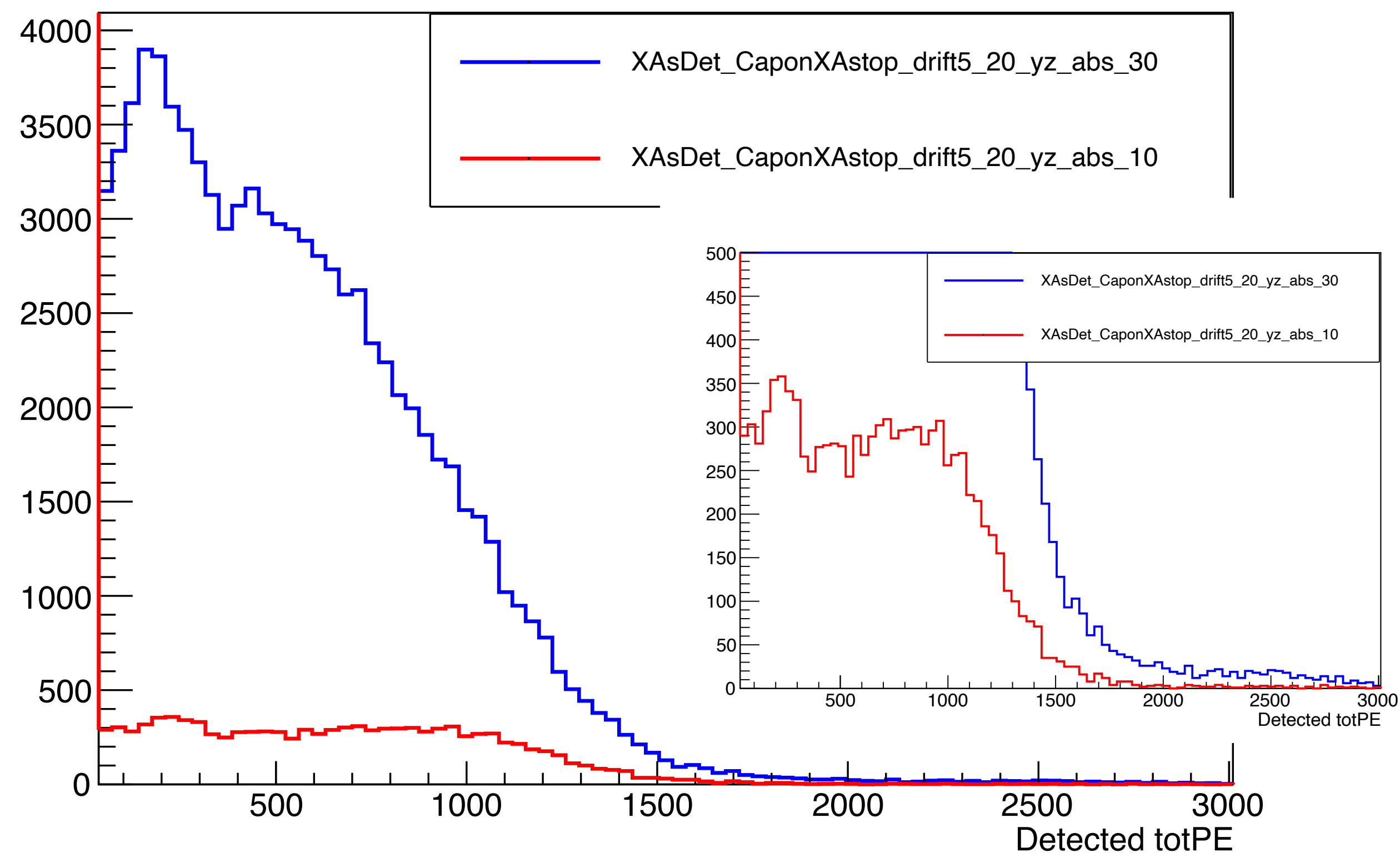
PD Data Selection

- **Calculate total PE per PD peak on each XA module**
  - PD signal peaks on each XA 2 channels closest in time (*min_dt*):
    min_dt < **80ns (5 PD ticks)**
  - Add total PE from each of the 2 channel (apply ADC/PE conversion factor)

- **PD peaks selection**
  - **PE signals from capture are relatively large**
    - Total PE > 100 PE per XA module
    - Remove saturated signals - per channel ADC <14000
  - **Neutron beam bkg rejection**
    - Only look at **PD peaks** after last neutron pulse (run dependent)
  - **Cosmic bkg rejection**
    - Remove PD peaks that has **3d tracks** within **dt:** dt < 70 tpc ticks (See backup: anode-cathode crossing cosmics delays up to 70 tpc ticks)
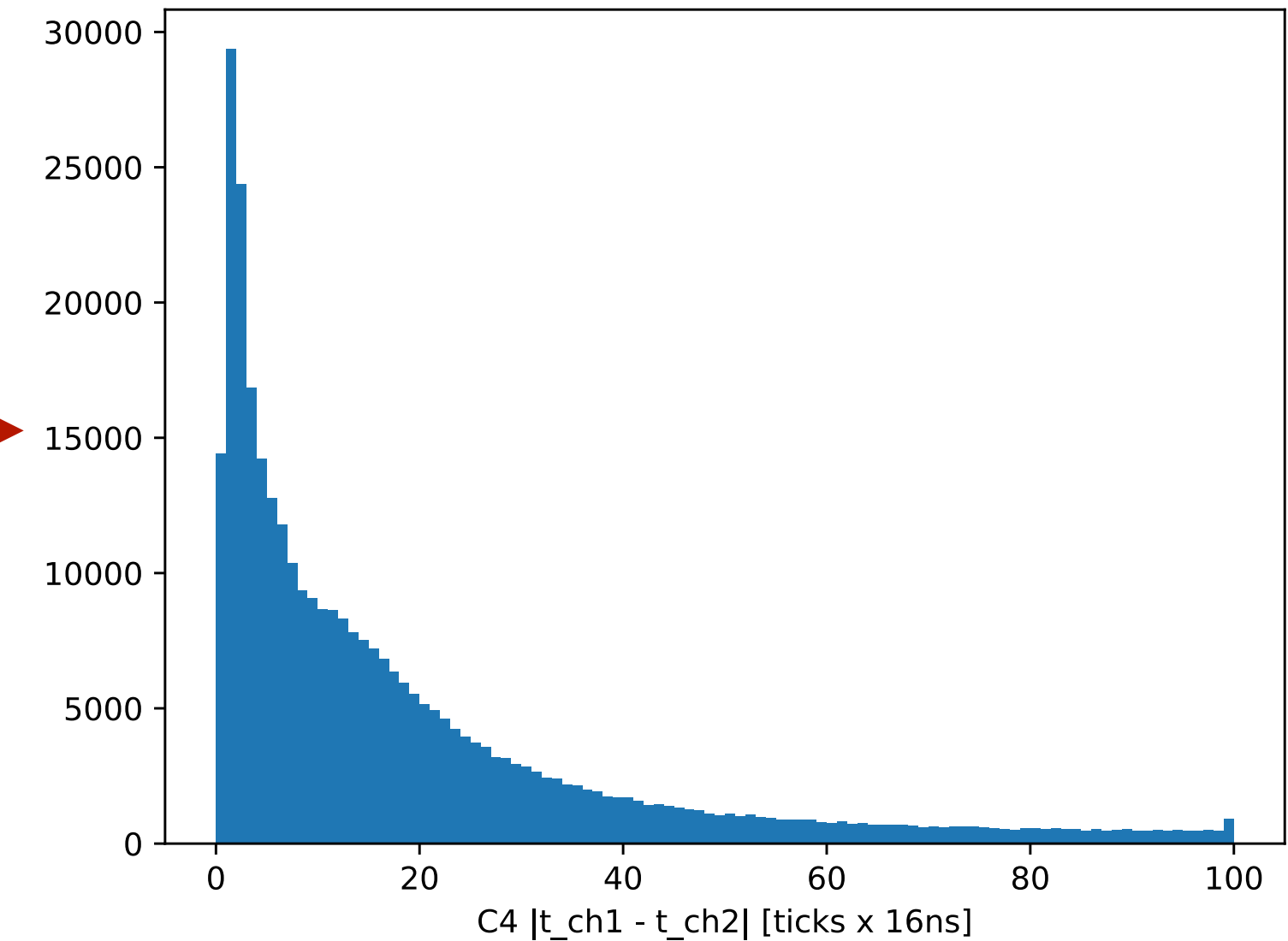
TPC Data Selection and Matching

- **Capture related charge signals** - Use single hits (blips) collection
  - **Single hits are those that are not used in tracks (>=2.5cm) reconstruction**
    - **Transverse 2D** distance (d_track_2D > 30cm, CRP default) between single hit and closest 2D track
      - Make sure blips are well isolated (not from a certain track)
    - Single hit **barycenter-coordinate** (d_bary_max < 3cm, CRP default), this removes bad association among three views
    - **tdc_max**: Require collection Z plane time >= V induction plane time >= U induction plane time
    - Identify all single hits on each XA and within **5cm-20cm drift**
      - Single hit time within 105us of the PD peak: U induction plane hit time >= 0, collection Z plane < 105 us
      - Single hit located +/- 30cm of XA center

- **Matching**: Each large PD peak has **>=1 single hits** in TPC matched
  - **Matched TPC single hits are excluded** in subsequent matching
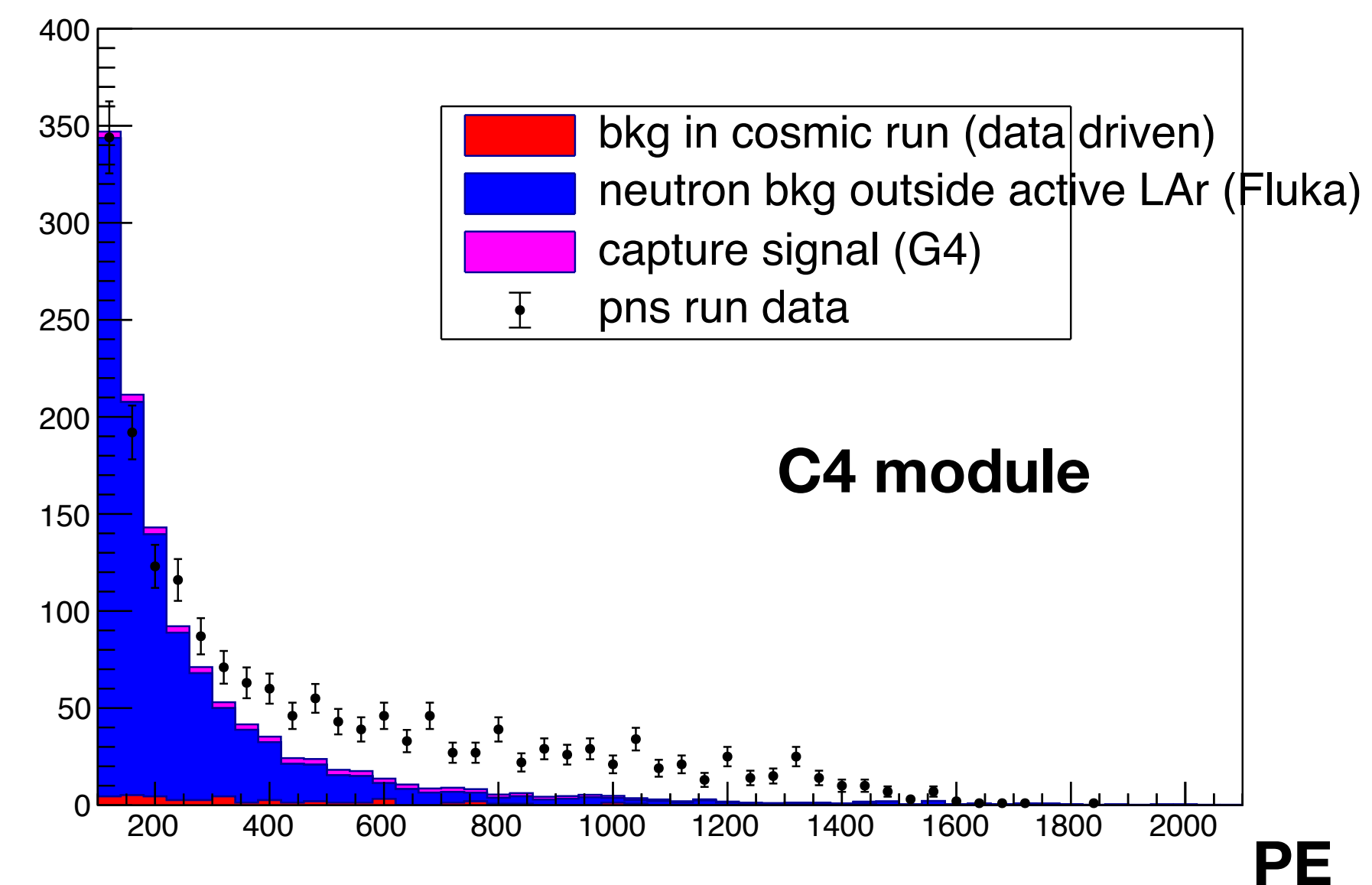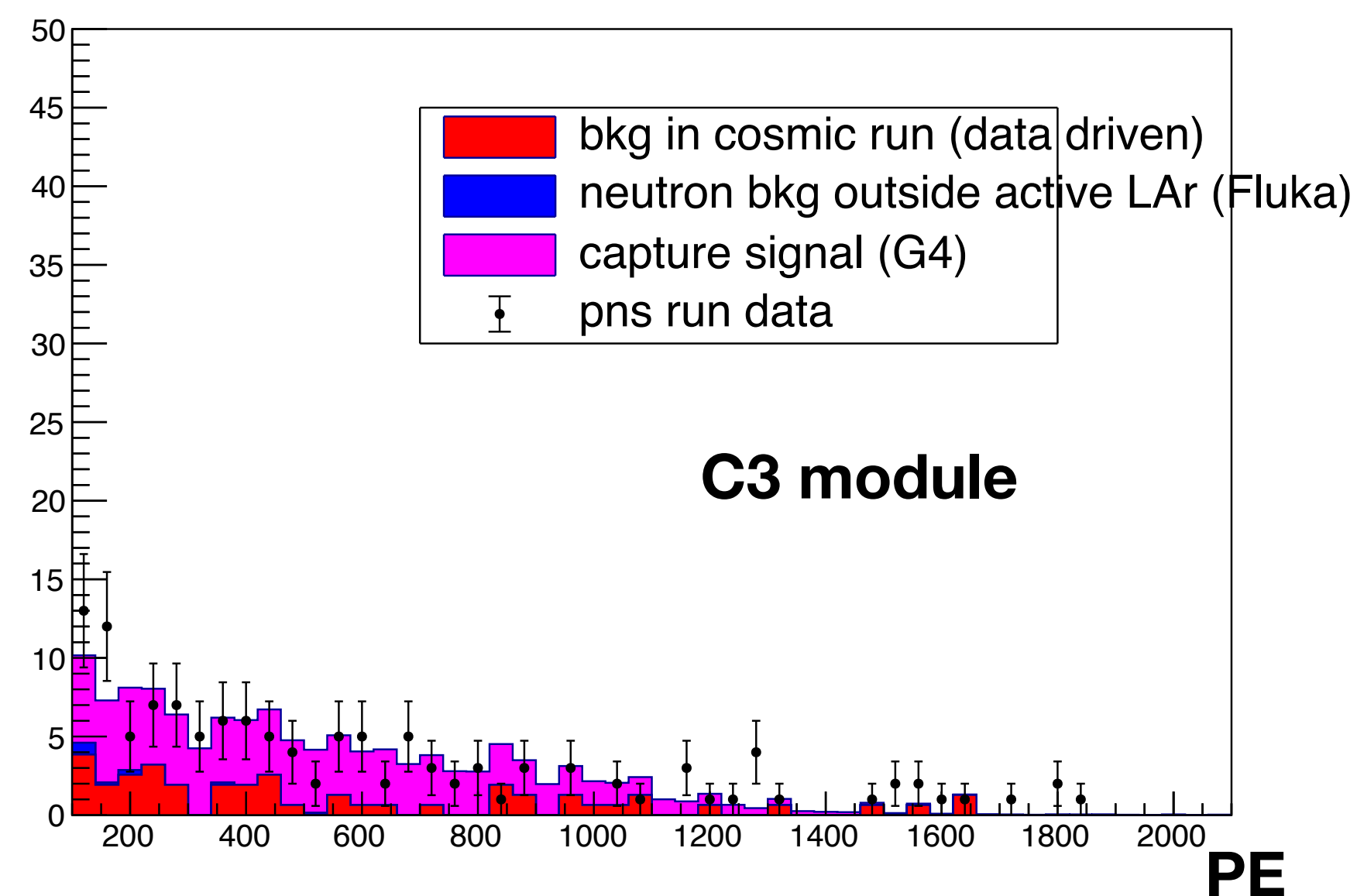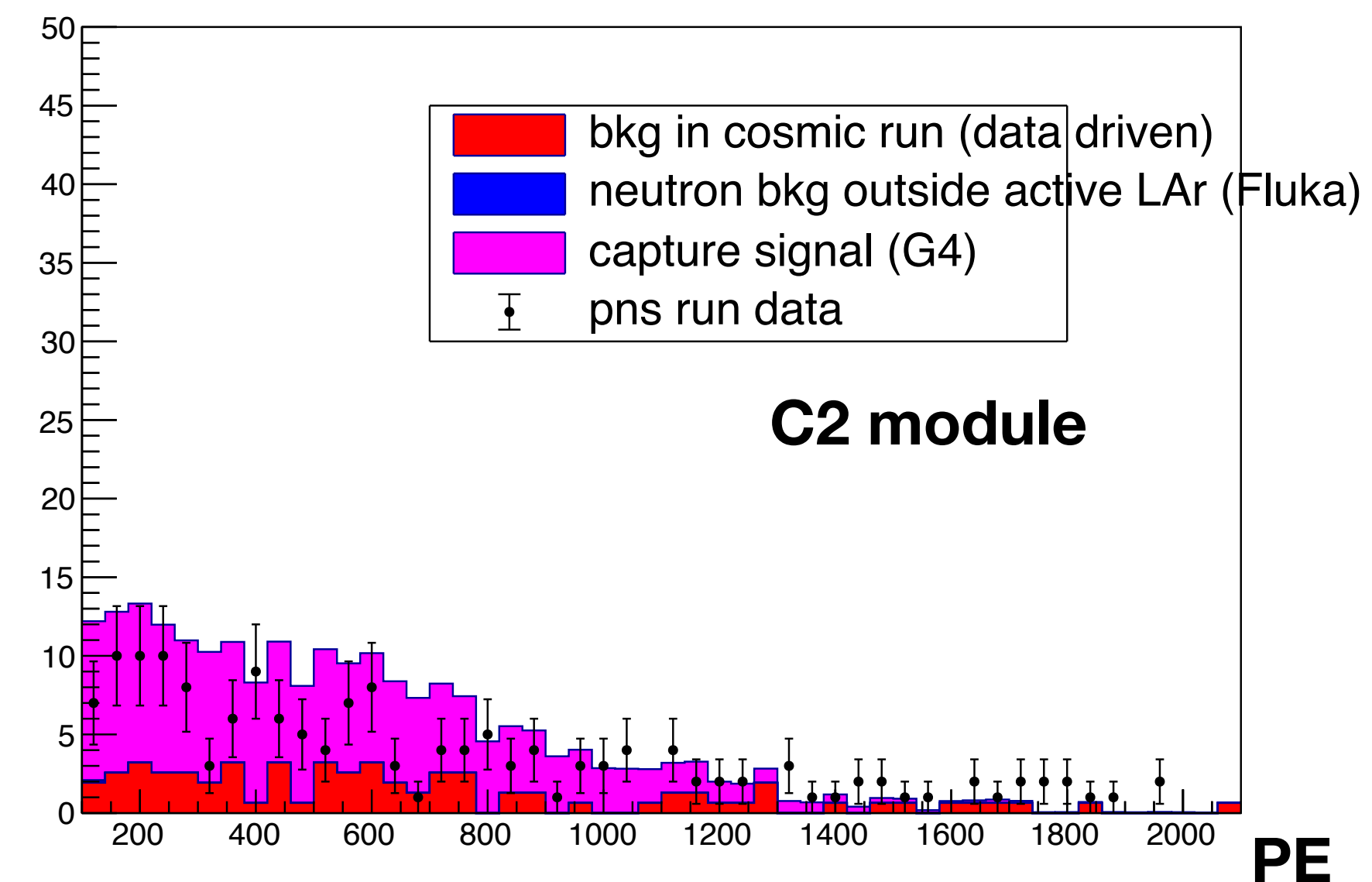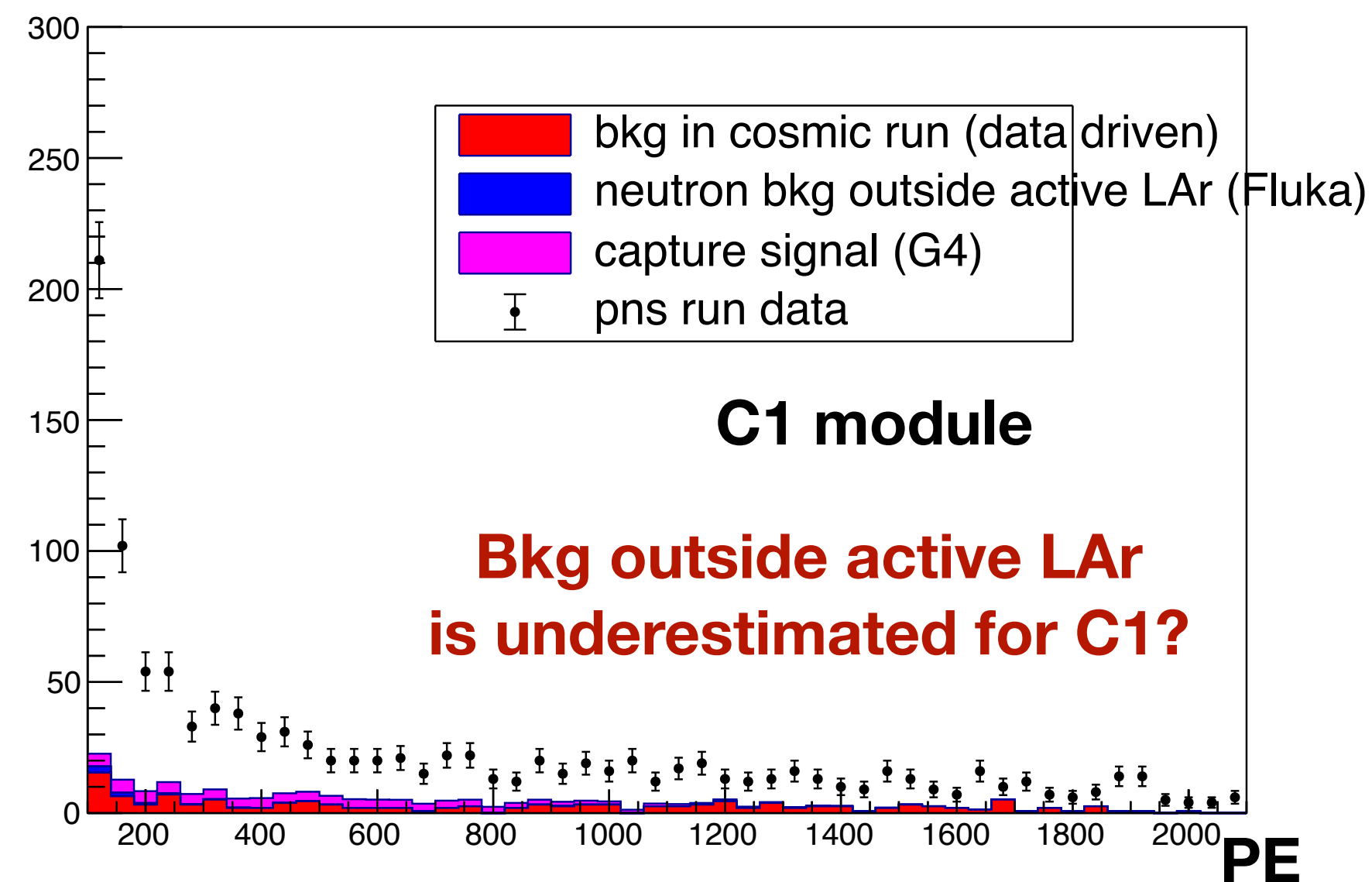
Data-MC Comparison Caveats

- **Due to technical difficulties, some data selection isn't applied to some simualted components**
  - neutron bkg outside active LAr (Fluka)
    - No cosmic bkg rejection (no cosmic simulation)
    - No tpc and matching (no detailed tpc sim)
  - Capture signal (G4)
    - No neutron beam bkg rejection (no beam sim)
    - No cosmic bkg rejection (no cosmic simulation)
    - No tpc and tpc-pds matching (no detailed tpc sim)
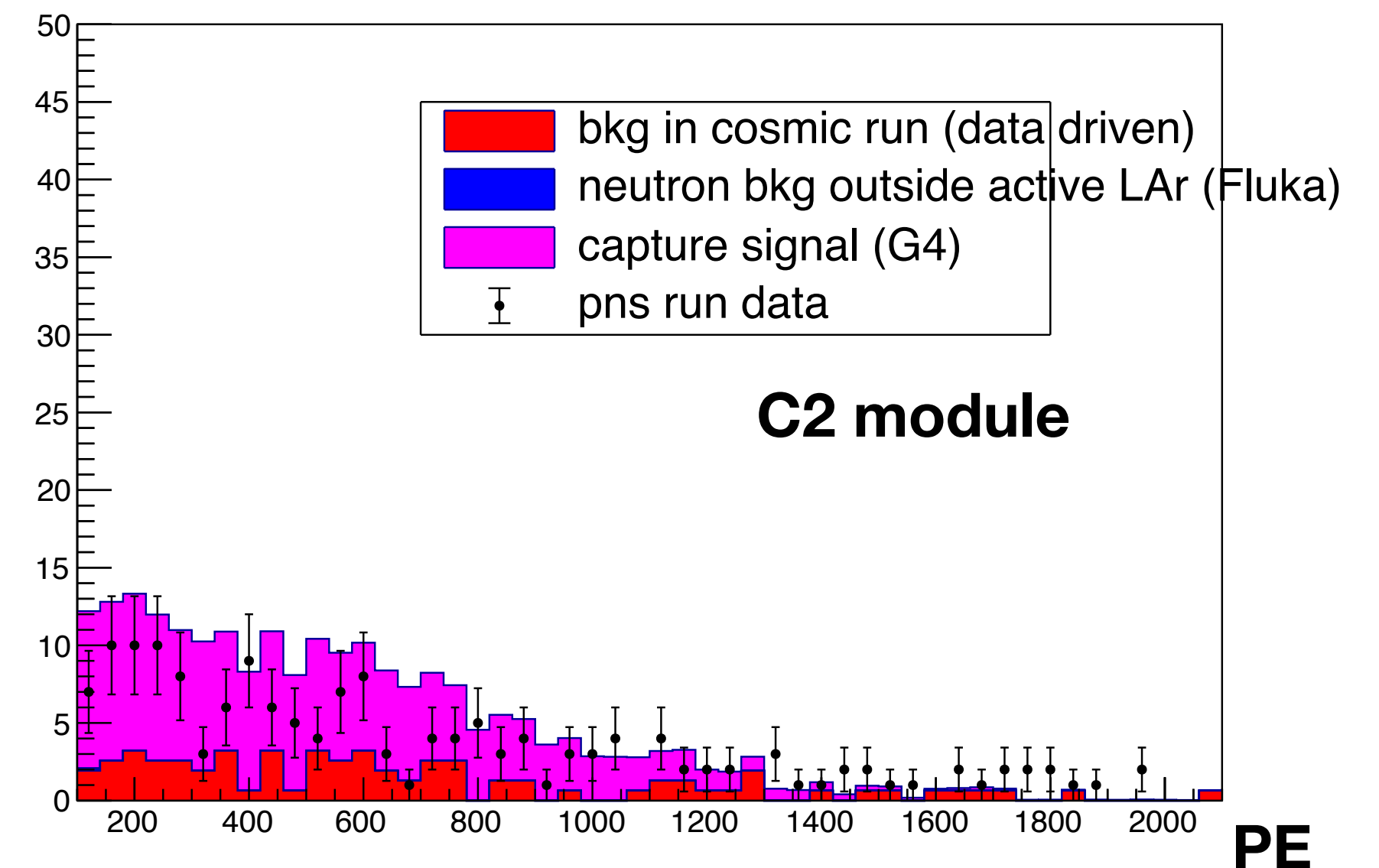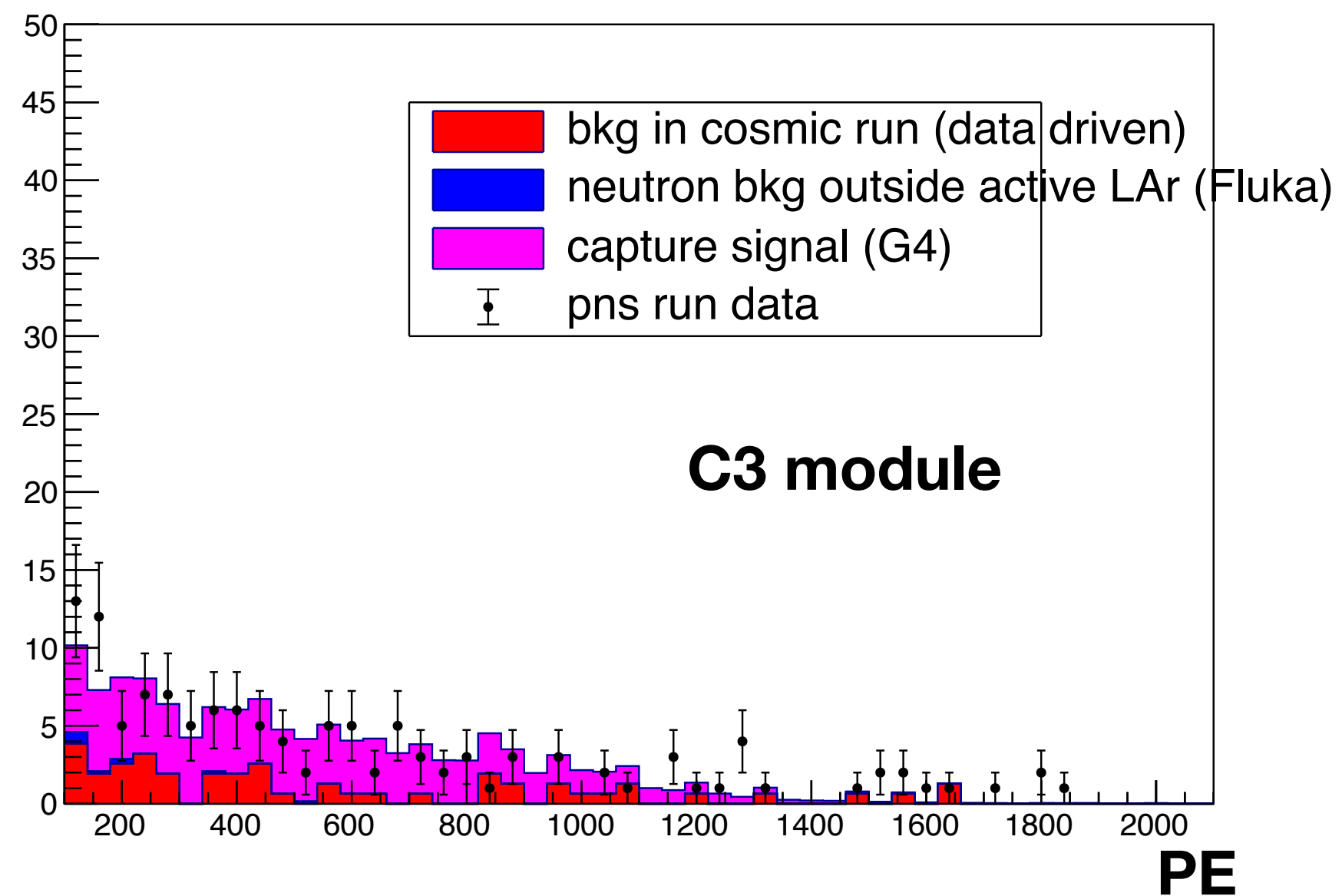
PE comparison plots

- cosmic run bkg: 0.642
- neutron bkg outside active LAr: 0.15
- capture signal: 0.005

C1 module

Bkg outside active LAr is underestimated for C1?

Legend:
- bkg in cosmic run (data driven)
- neutron bkg outside active LAr (Fluka)
- capture signal (G4)
- pns run data

C2 module

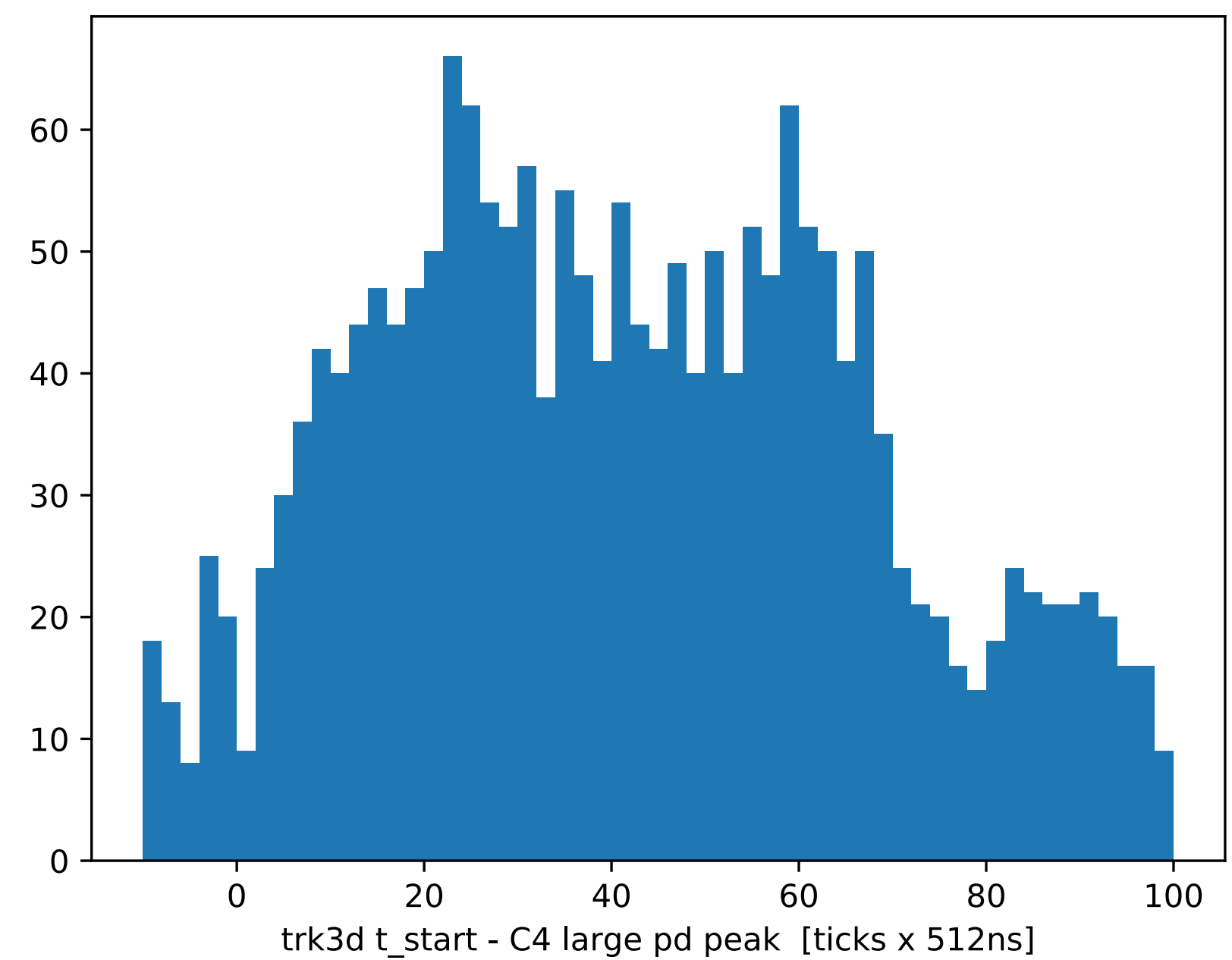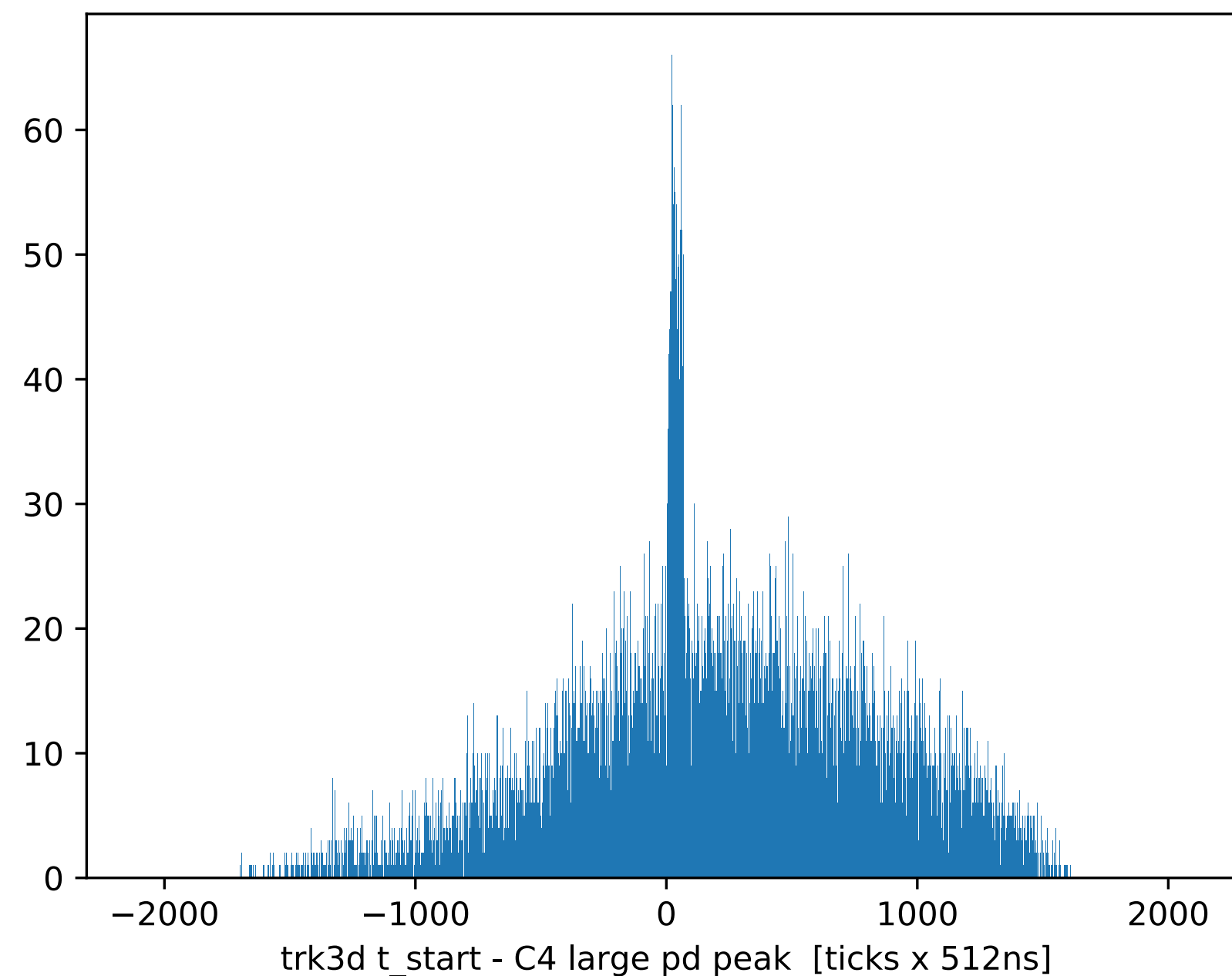**C3 module**

C4 module

Back up

3d-track anode-cathode crossing: PNS run 25036

100 PE threshold, trk length in drift direction >= 19 cm

3dtrk start t - C4 pd peak time

Zoom in plot of left plot
Crossing tracks has up to 70 TPC ticks delay in time

Example PDS-TPC matched TPC blips: Neutron capture candidates on C2, C3