DNN-ROI Finding for ICARUS

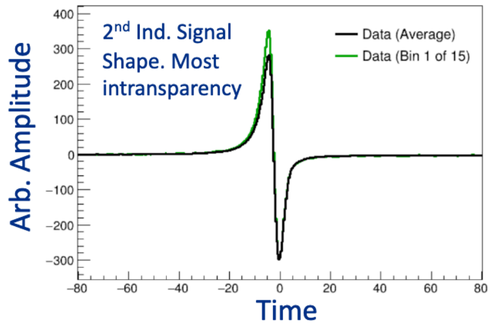
WireCell Meeting (09/19/2024)

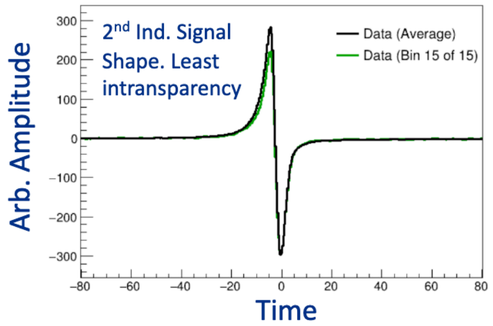
Avinay Bhat, Gray Putnam

ICARUS Challenges

Signal Processing in ICARUS

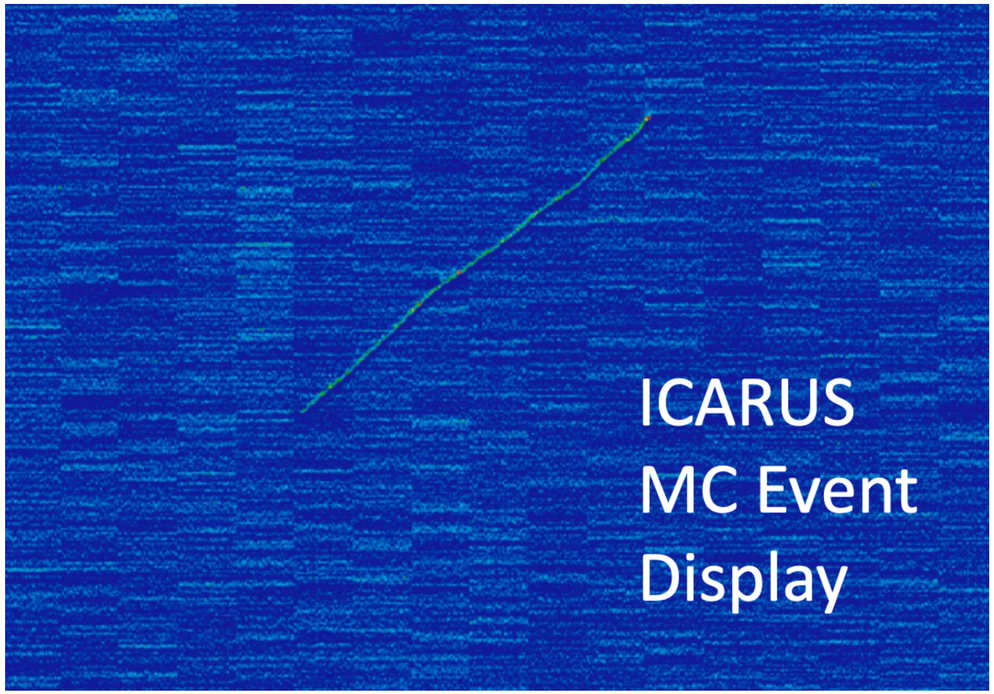
- The ICARUS TPC is a challenging environment for precise charge extraction
- Challenges:
  - Warm readout electronics, long wires
  - Significant coherent noise on each readout board (64 channels)
  - Smoothly varying signal shapes across detector (middle induction intransparency)





SBN DocDB 32136

Fermilab

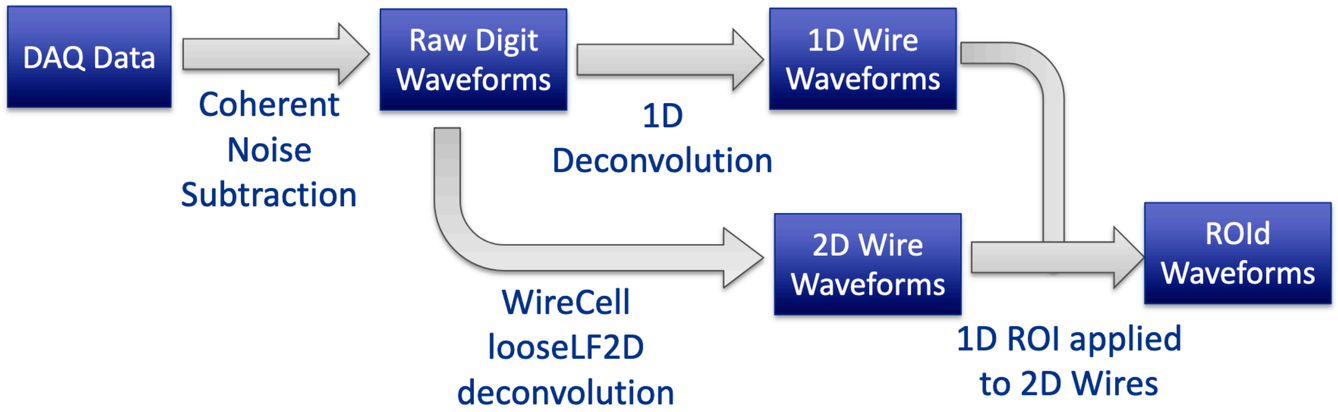


Presentation by Gray Putnam on 7/25/24

ICARUS Challenges

Alternative WireCell Implementation in ICARUS

- Sergey and Tracy also put together a partial integration of WireCell into ICARUS simulation (1D ROI + 2D charge extraction)



- Drawbacks: no 2D deconvolution for ROI finding, looseLF filter (Wiener-style filter w/ low-frequency cutoff) is not suitable for charge extraction

What I want to do

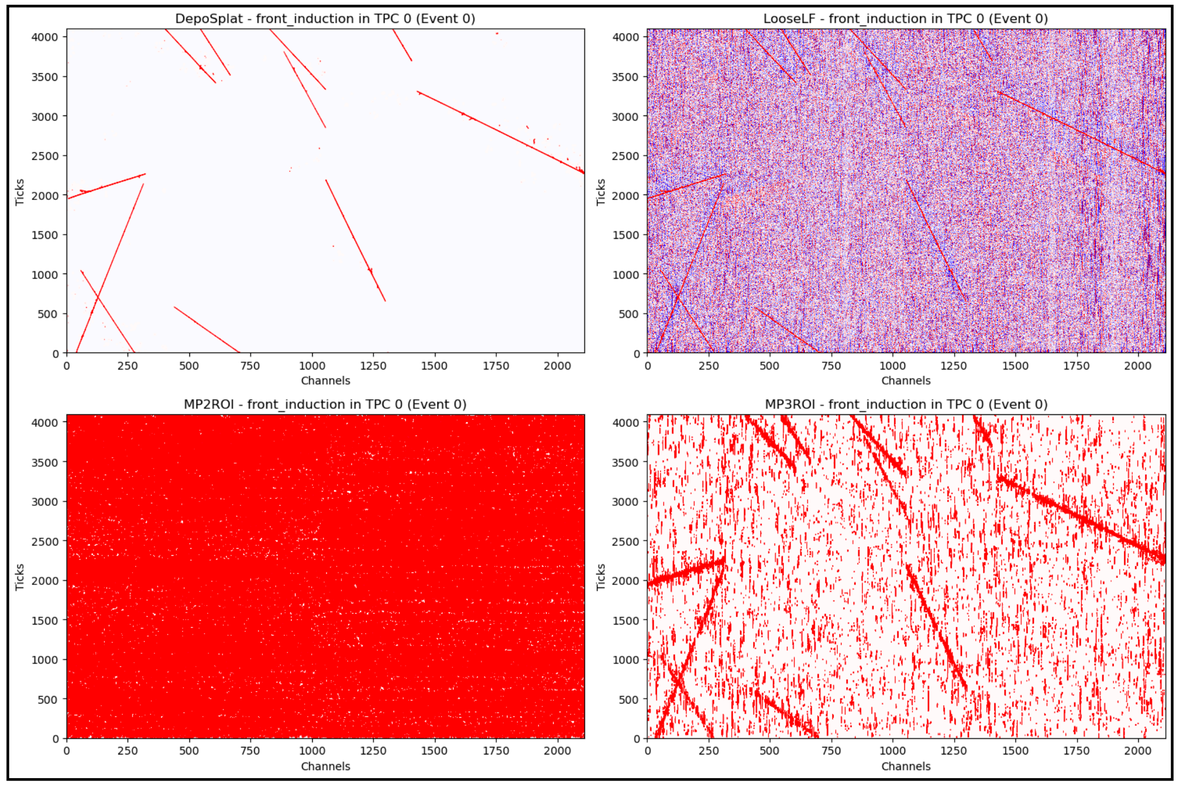
- I want to get 2D deconvolution working in ICARUS to improve charge extraction performance
- To do this, I plan to:
  1. Optimize the filters in the standard 2D deconvolution ICARUS
  2. Implement DNN-ROIs for ICARUS (with Avinay+Moon) ✅

Presentation by Gray Putnam on 7/25/24

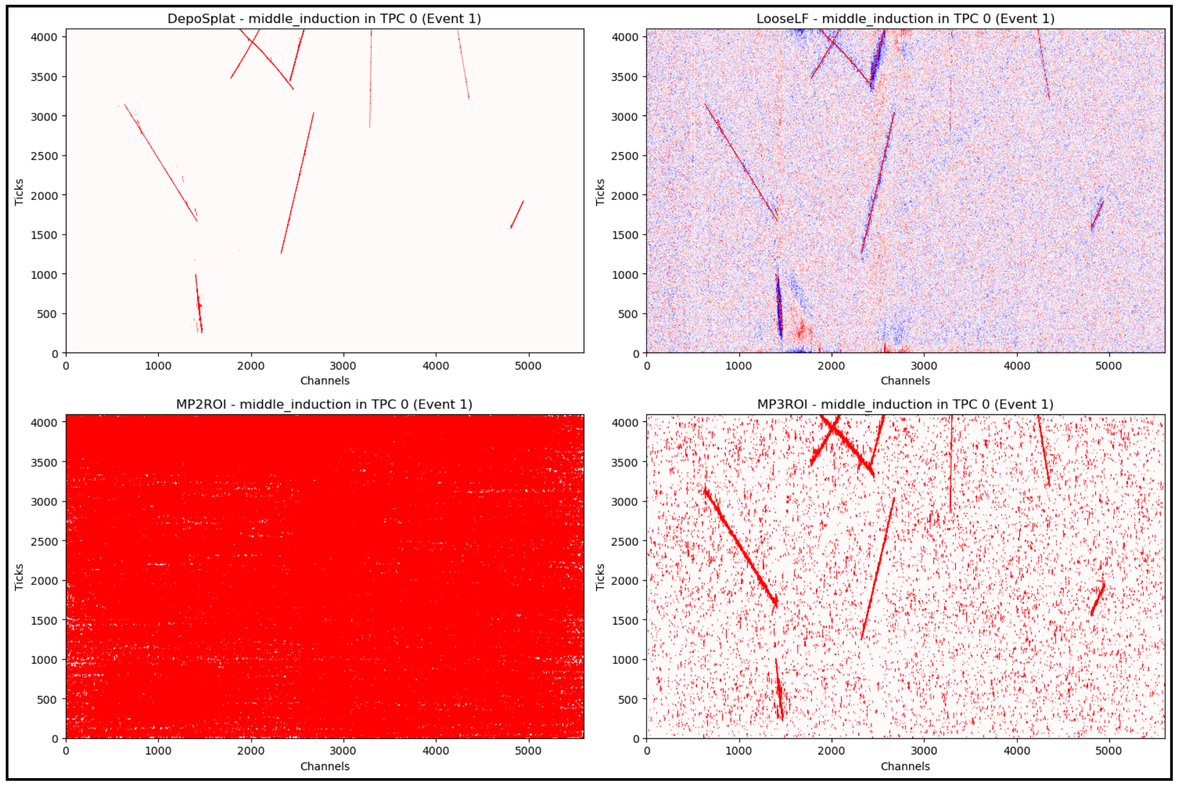
DNN ROI Training Samples

- Gray produced a sample of ~1000 BNB + Cosmics Events for ICARUS.
- ICARUS has 4 TPC readouts with 2 induction planes each.
- The induction planes themselves have different number of channels
  - 2112 for Front Induction Plane (say U Plane)
  - 5600 for Middle Induction Plane (say V Plane)
- Started with a strategy of trying to train different models, one for each induction plane.
- Used a rebin factor of 8. (Can increase them number in later iterations)

DNN ROI Training Samples

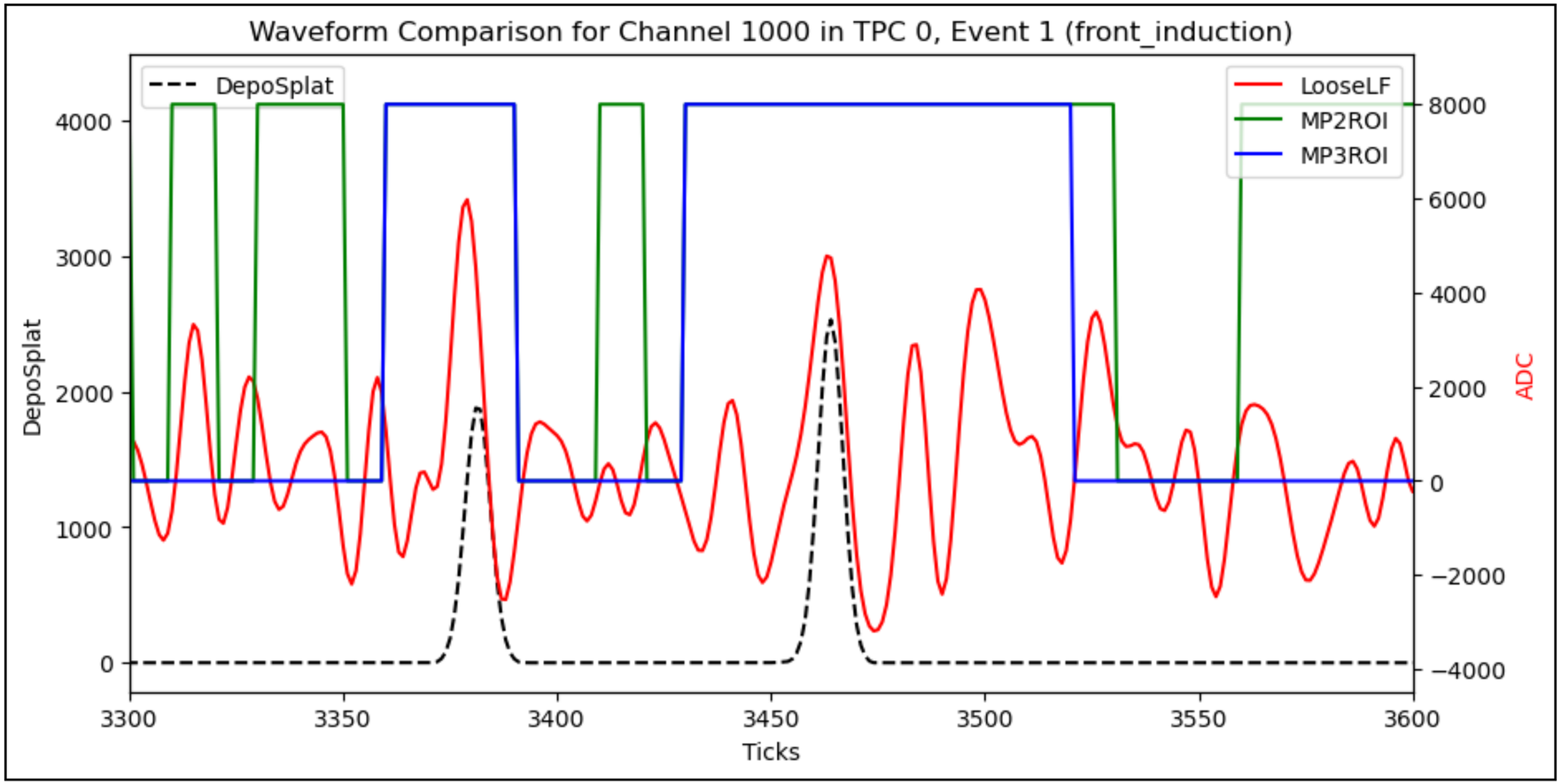


U Plane

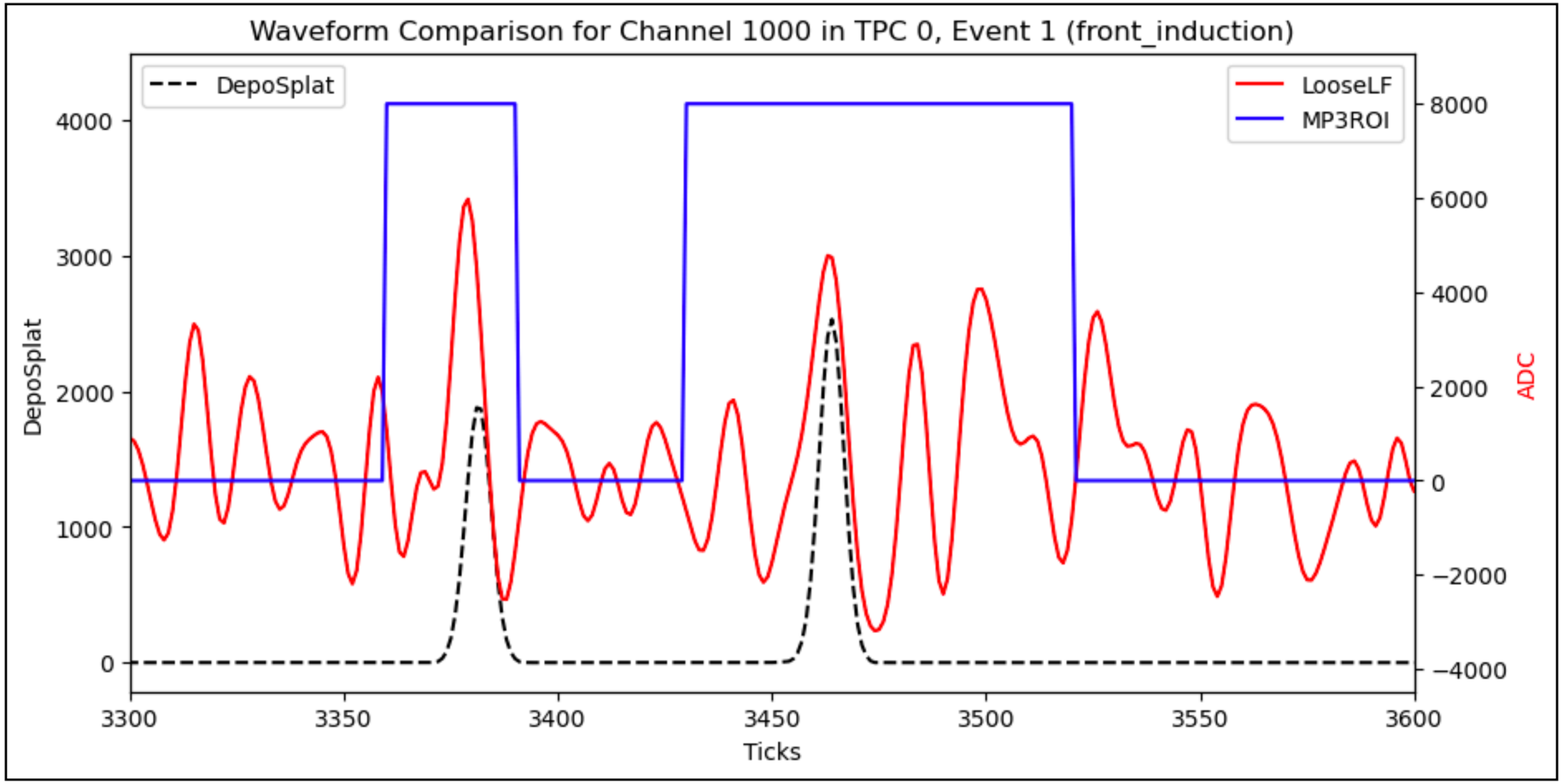


V Plane

DNN ROI Training Samples

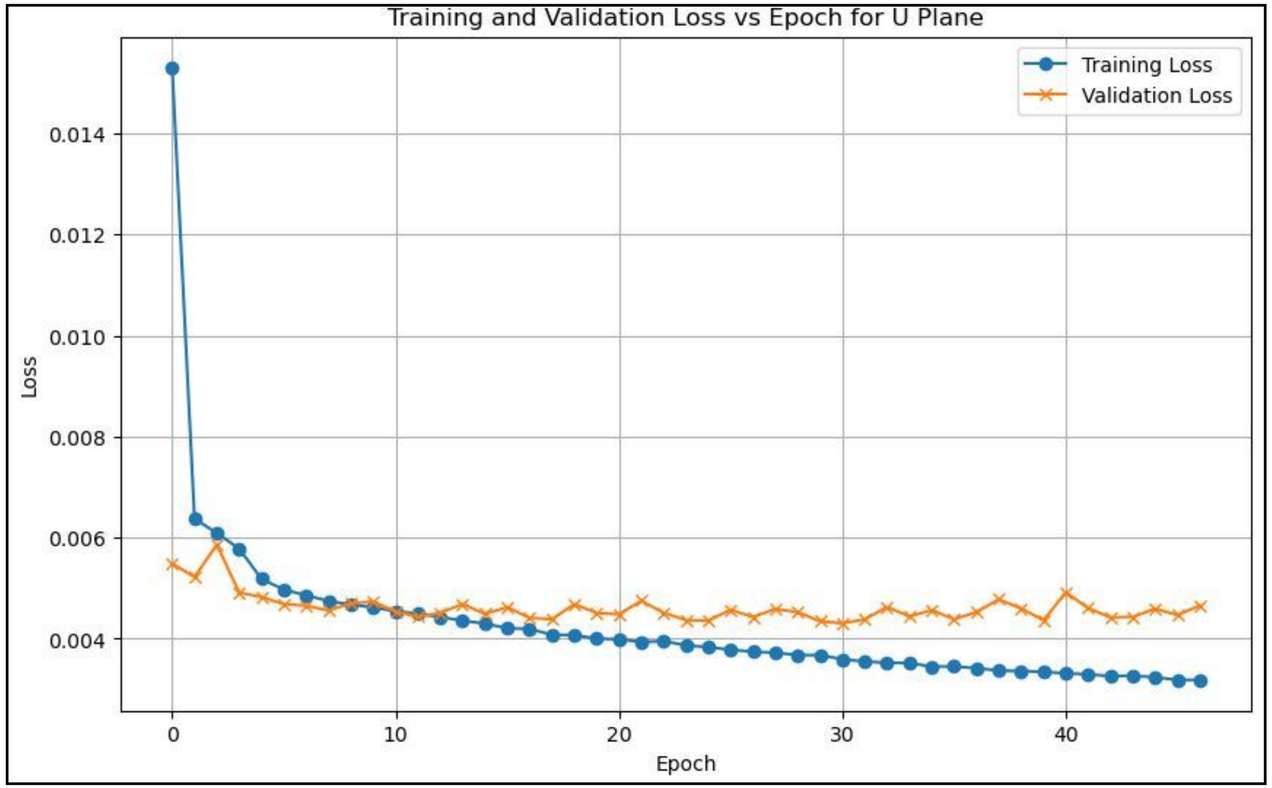


DNN ROI Training Samples



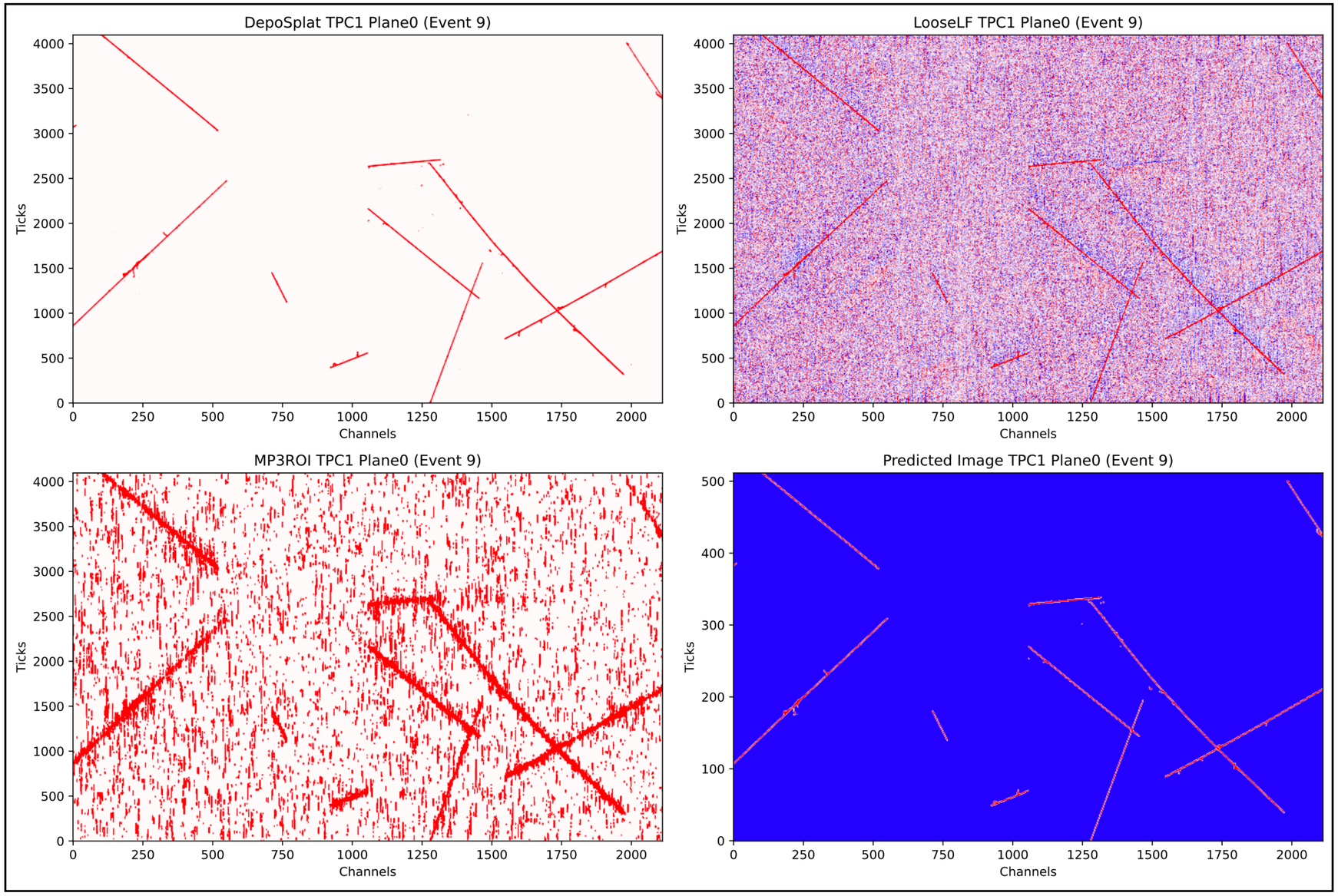
Decided to drop MP2
and only use Loose LF and MP3

DNN Training

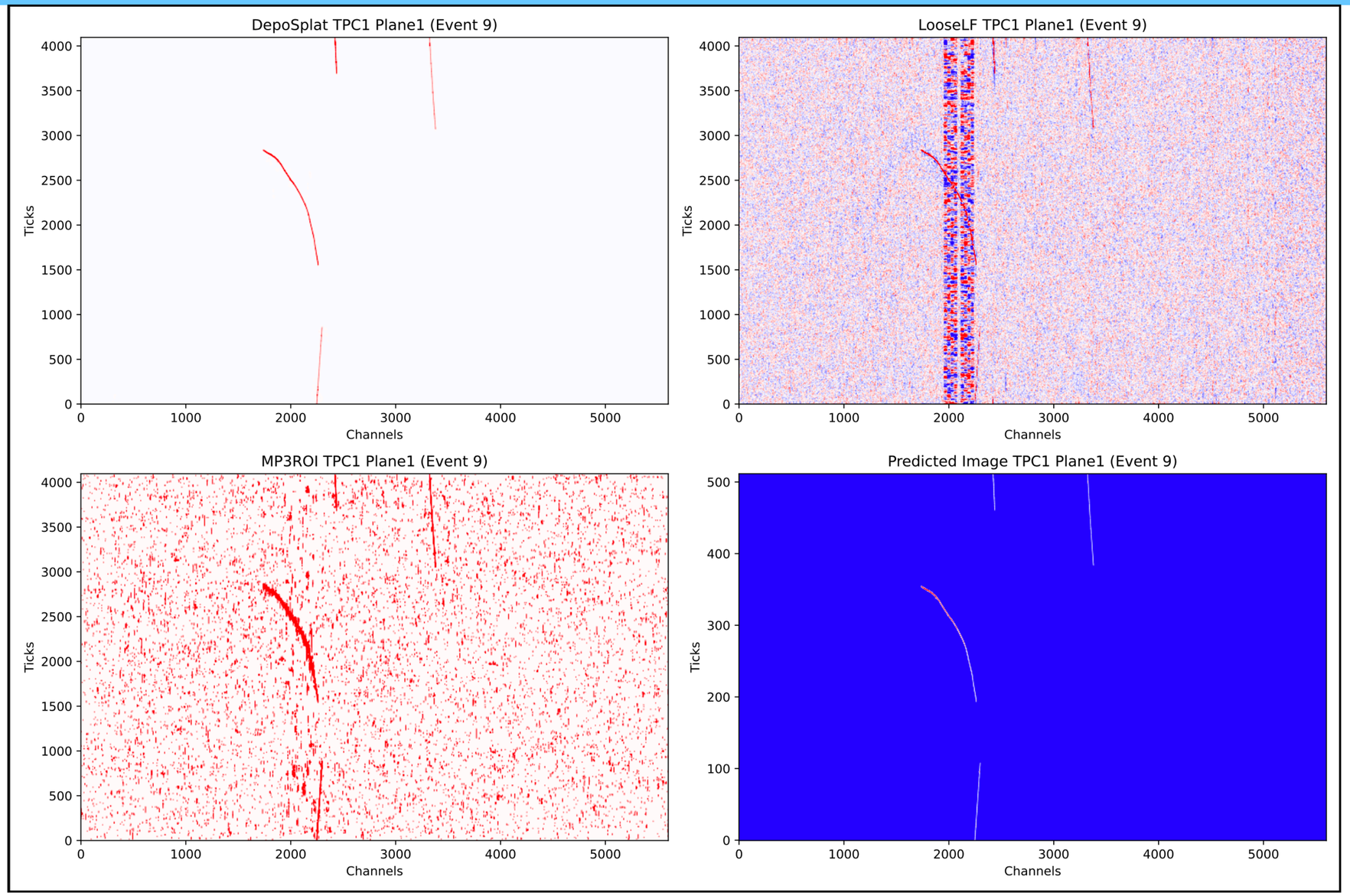


- Trained two different models using UNet architecture, Adam Optimizer with learning rate of 0.001
- Dataset consists of ~1000 BNB + Cosmic events
- Validation loss curve drops for the first 10 epochs and then saturates.
- Saved the least loss and highest dice score models for prediction for both planes.
- Took about 50 minutes per epoch for U Plane and about 2 hours for V Plane

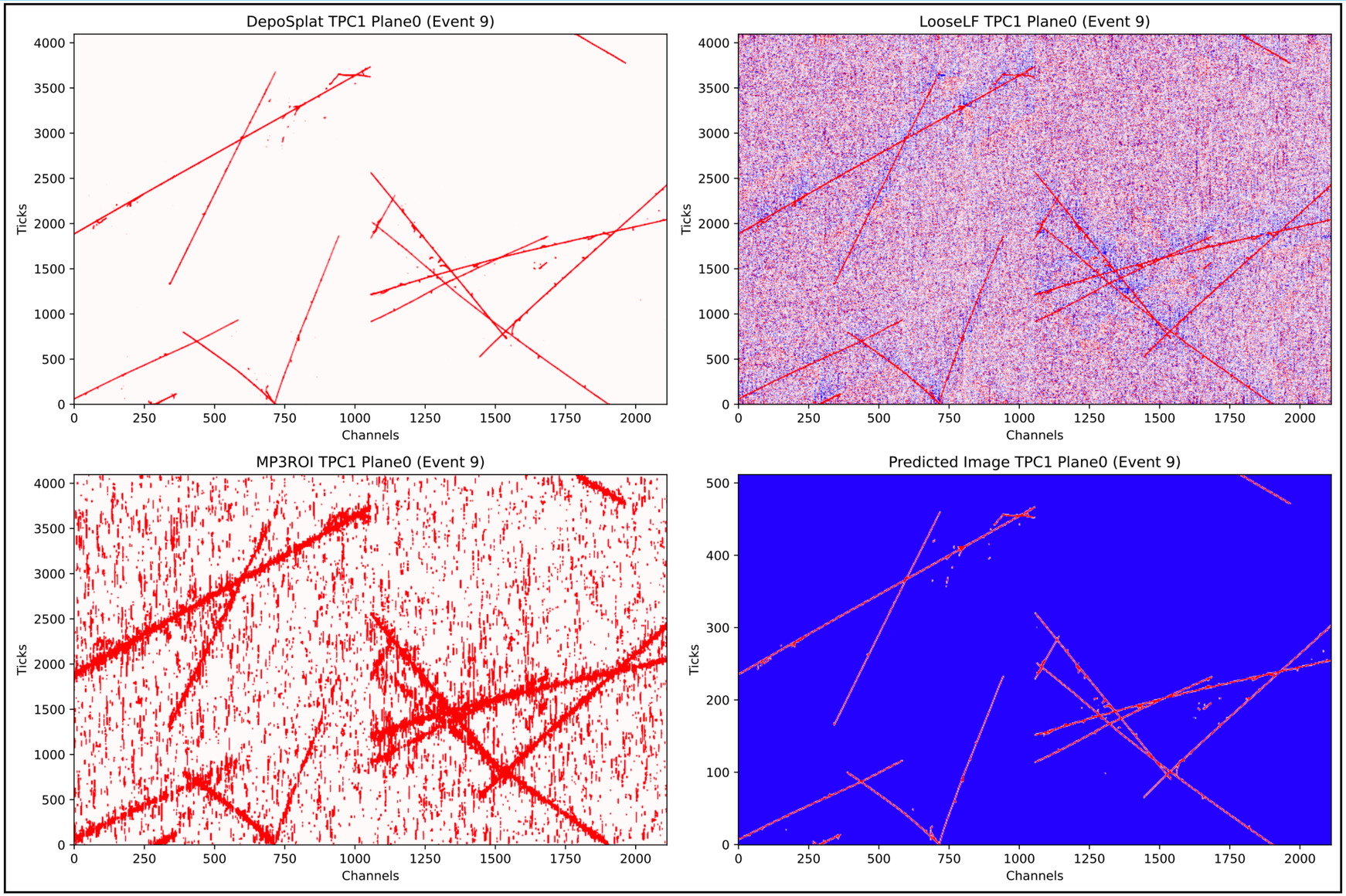
DNN ROI Prediction



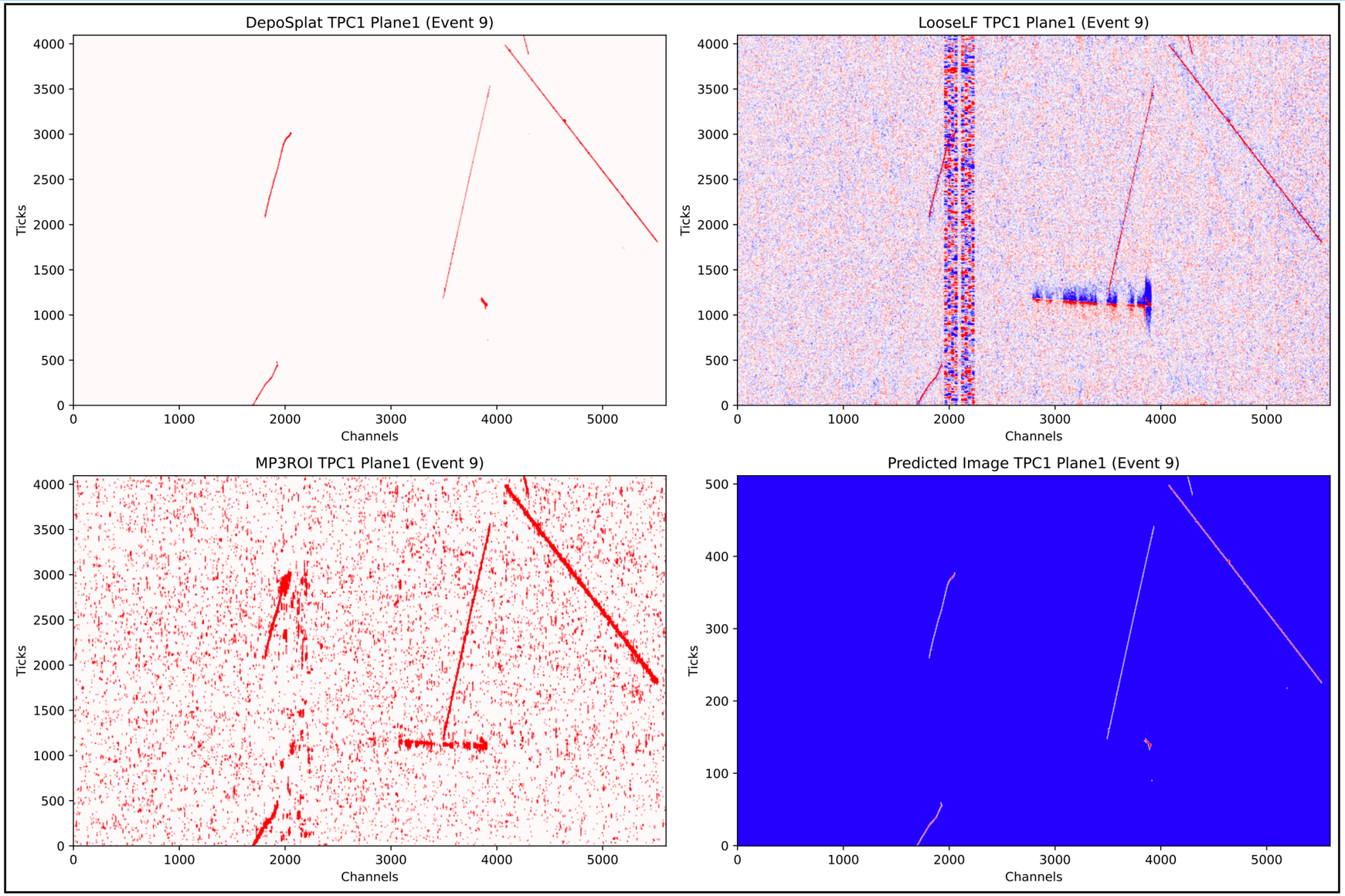
DNN ROI Prediction



DNN ROI Prediction



DNN ROI Prediction



Summary and Future Plans

- First pass at DNN ROI Prediction on ICARUS looks very promising.
- Need to further optimize the training process and pre-processing of samples for training.
- Gray has been working on producing new samples with optimized filter parameters as well as smear values for filters.
- Would like to train the model with samples containing varying noise conditions within ICARUS.
- Want to estimate the ROI pixel efficiency and purity.
- Would like to start working on inference to get a sense of how charge extraction looks like

DNN-ROI Finding for SBND

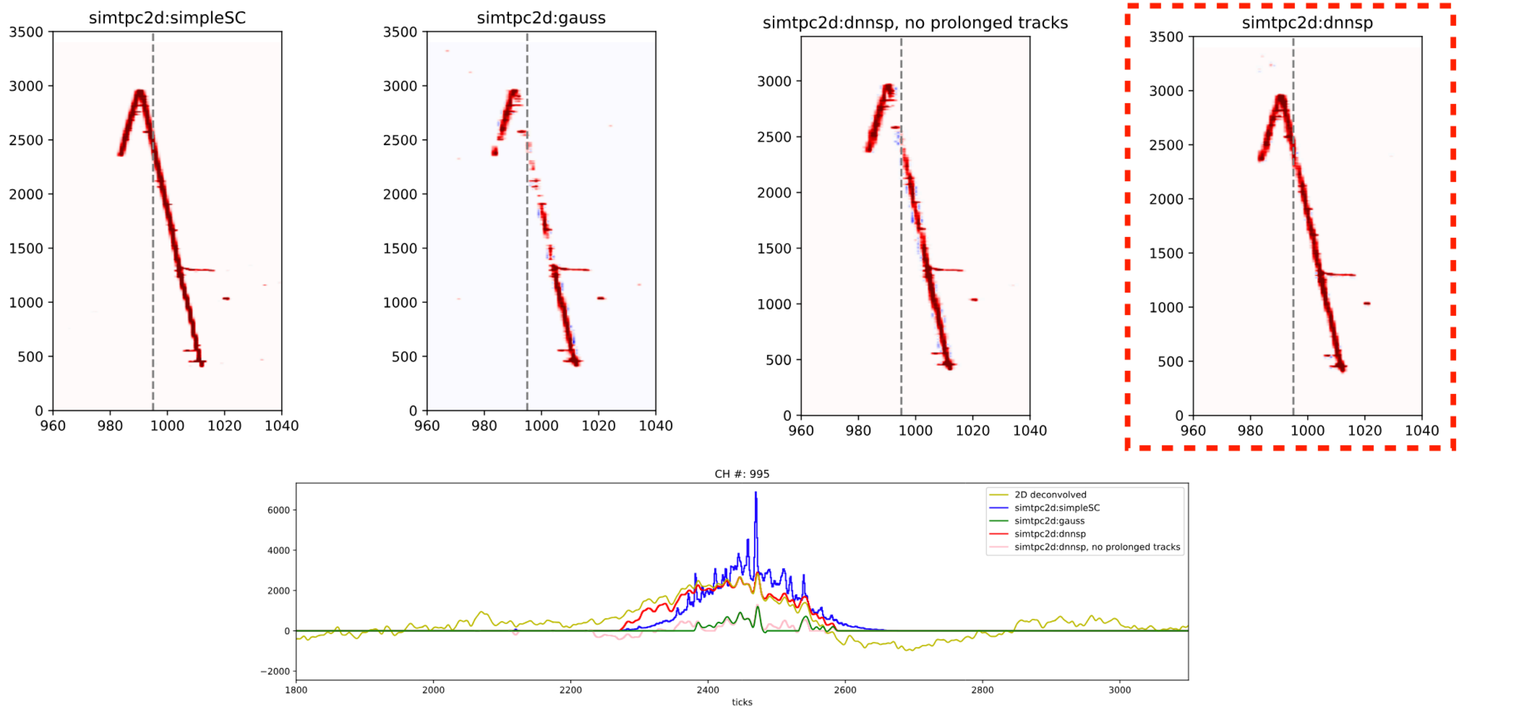
WireCell Meeting (09/19/2024)

Avinay Bhat

SBND DNN ROI Performance on PTs

DNN ROI @ SBND SP - MC

- UResNet trained for SBND

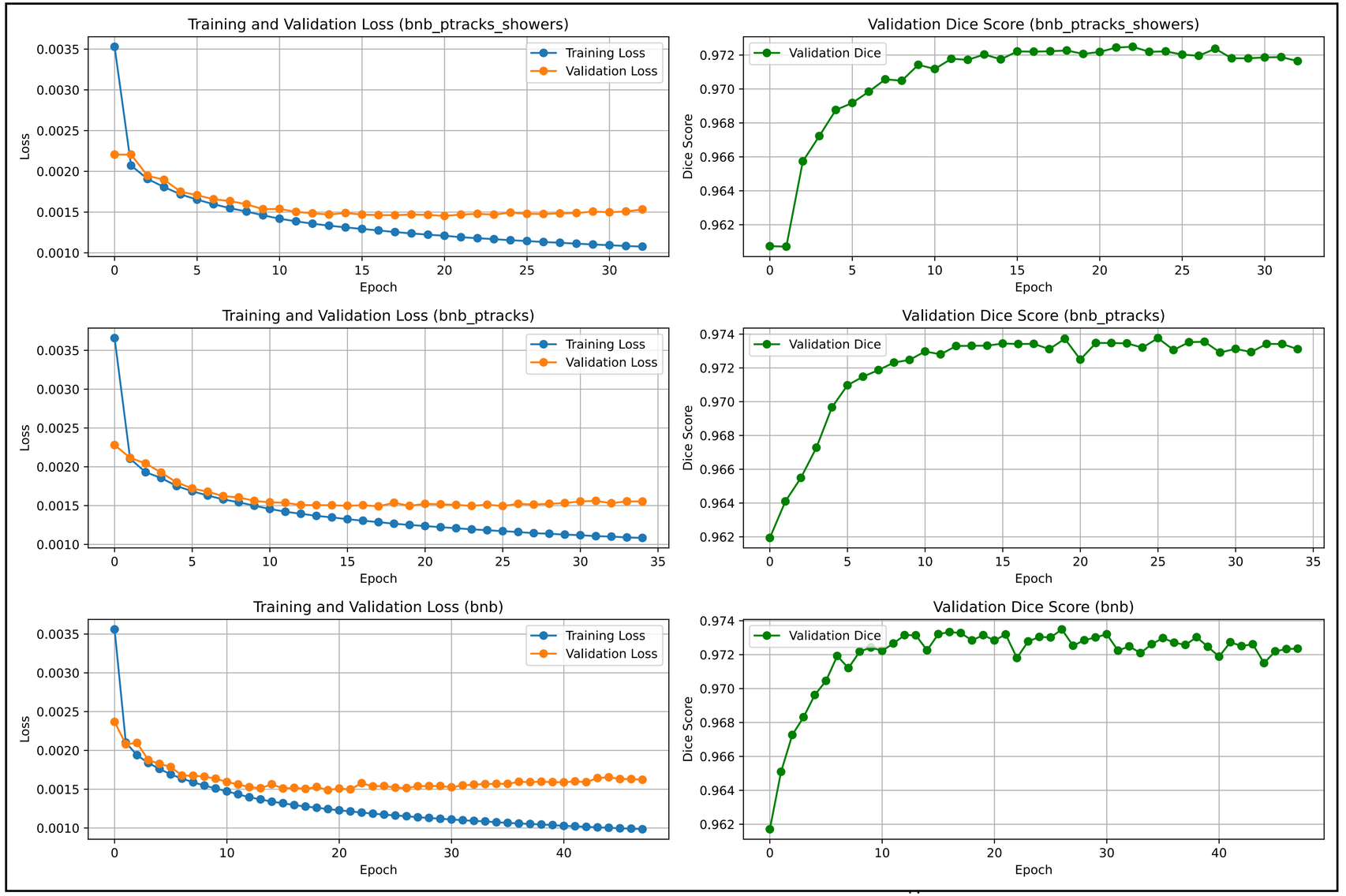


Presentation by Moon Jung on 7/25/24

Performance on Showers

- Trained three different models using UResNet architecture
- Used Adam optimizer to optimized the learning rate (started with lr=0.001)
- Used BCE to calculate the loss
- Trained and evaluated on Augmented sample set of:
    - BNB Cosmics (5000 events)
    - Prolonged Tracks (θ_{xz} [75-87]) (800 events)
    - BNB Electron Showers (400 events)
- Showers were generated with binned energies between [0.15-1.5 GeV] with bin size of 0.3 GeV
- Tested on a test sample of showers

Performance on Showers



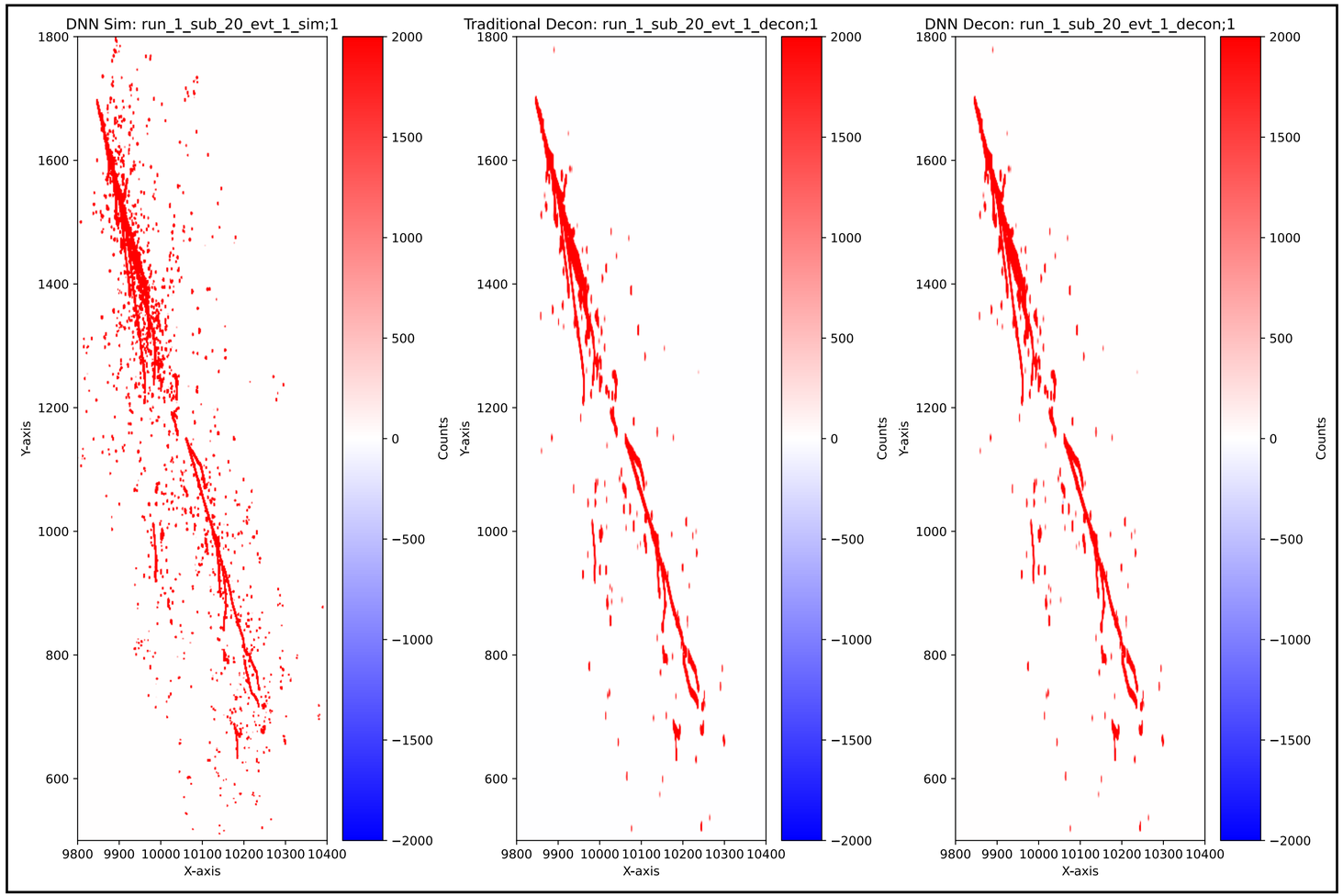
BNB + Cosmics + PT+ Showers

BNB + Cosmics + PT

Only BNB + Cosmics

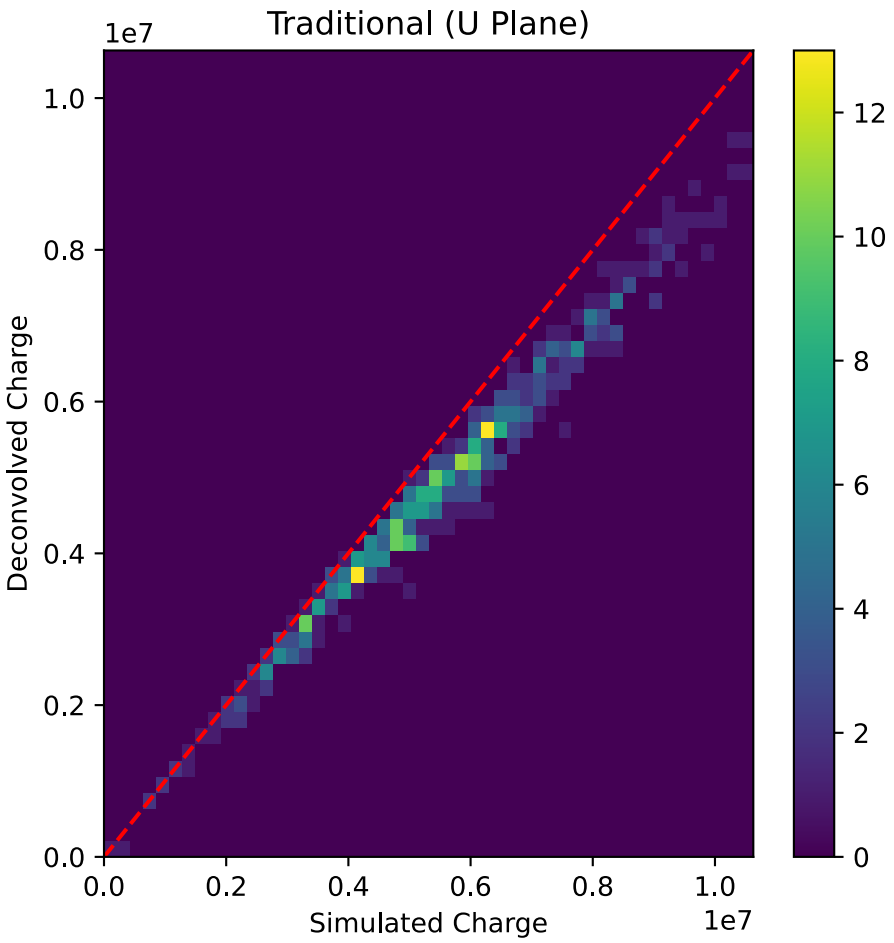
Performance on Showers

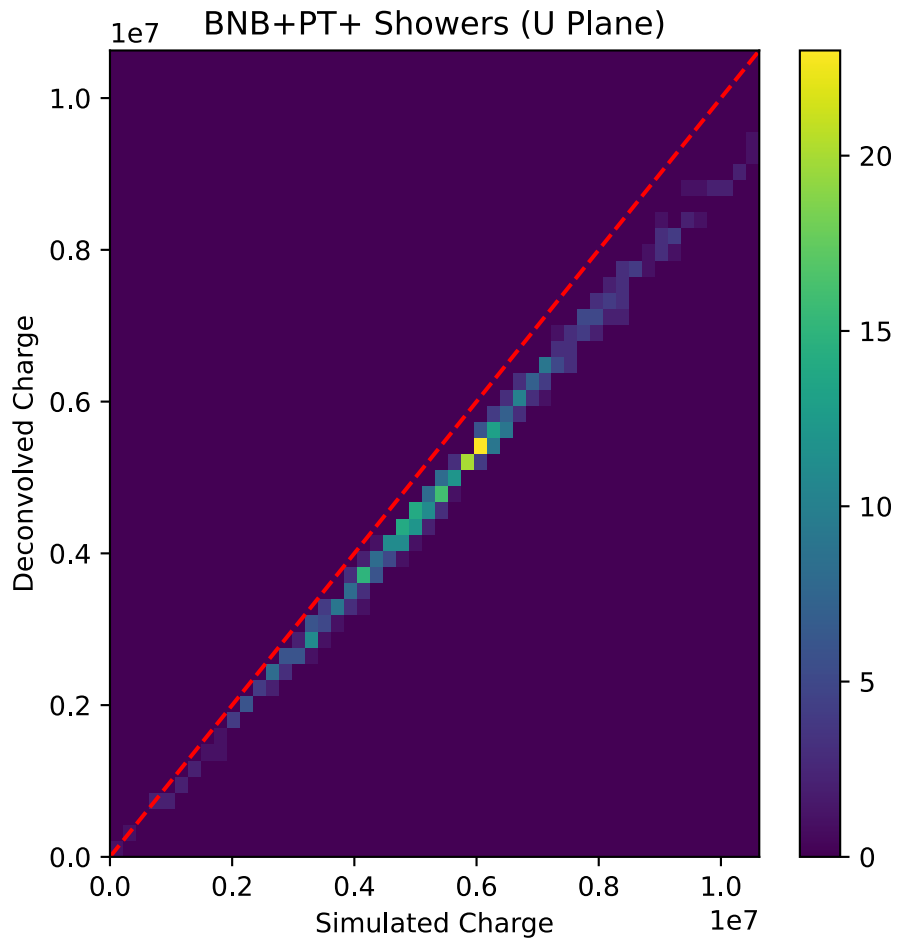
Example for E [1.4 GeV-1.5 Gev]

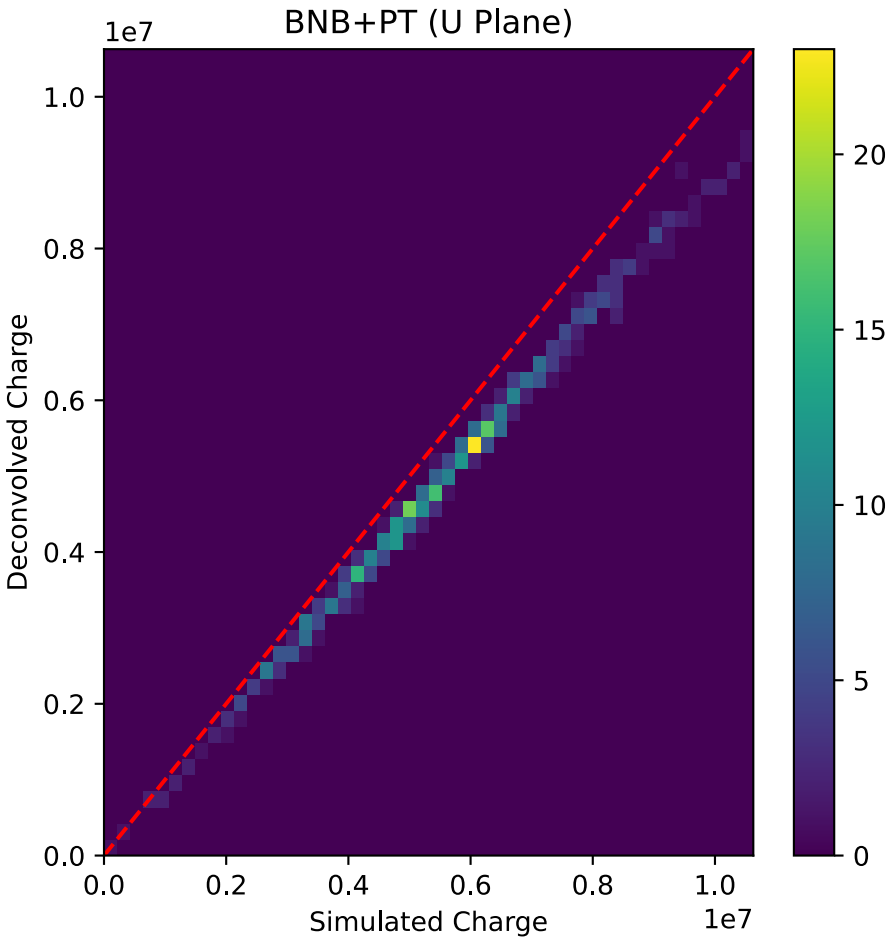


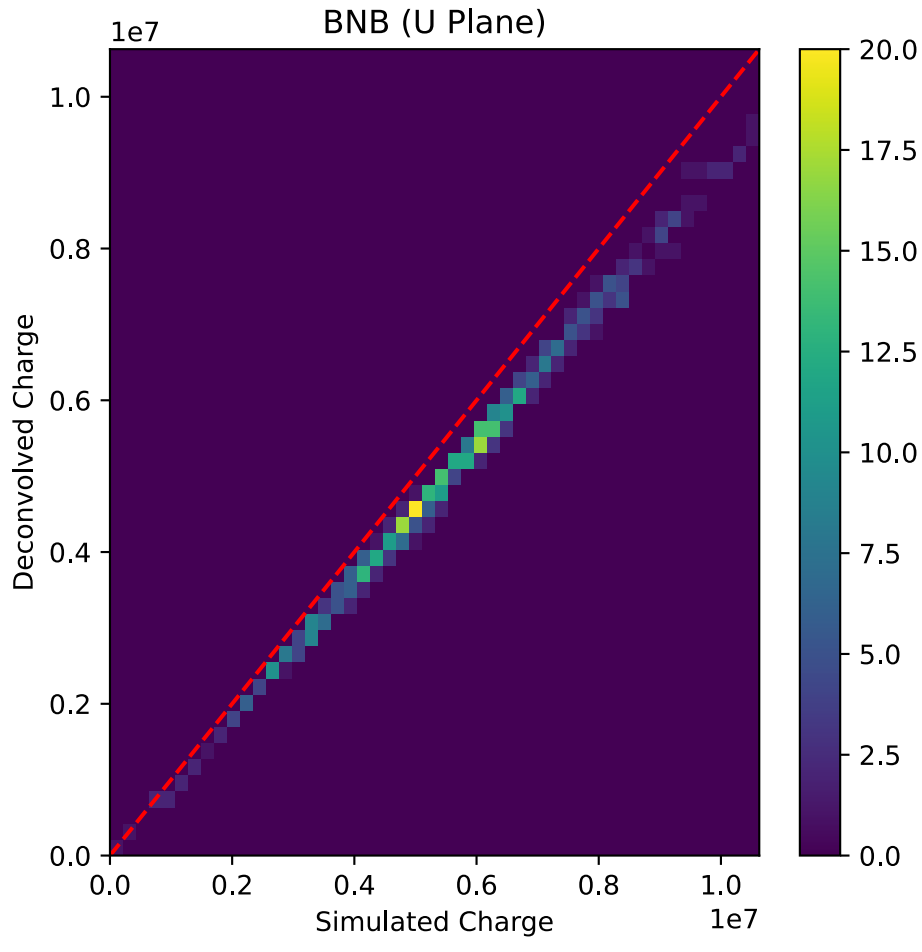
Charge Extraction on Showers

$E_{\text{shower}} \in$ [0.15 GeV, 0.30 GeV]

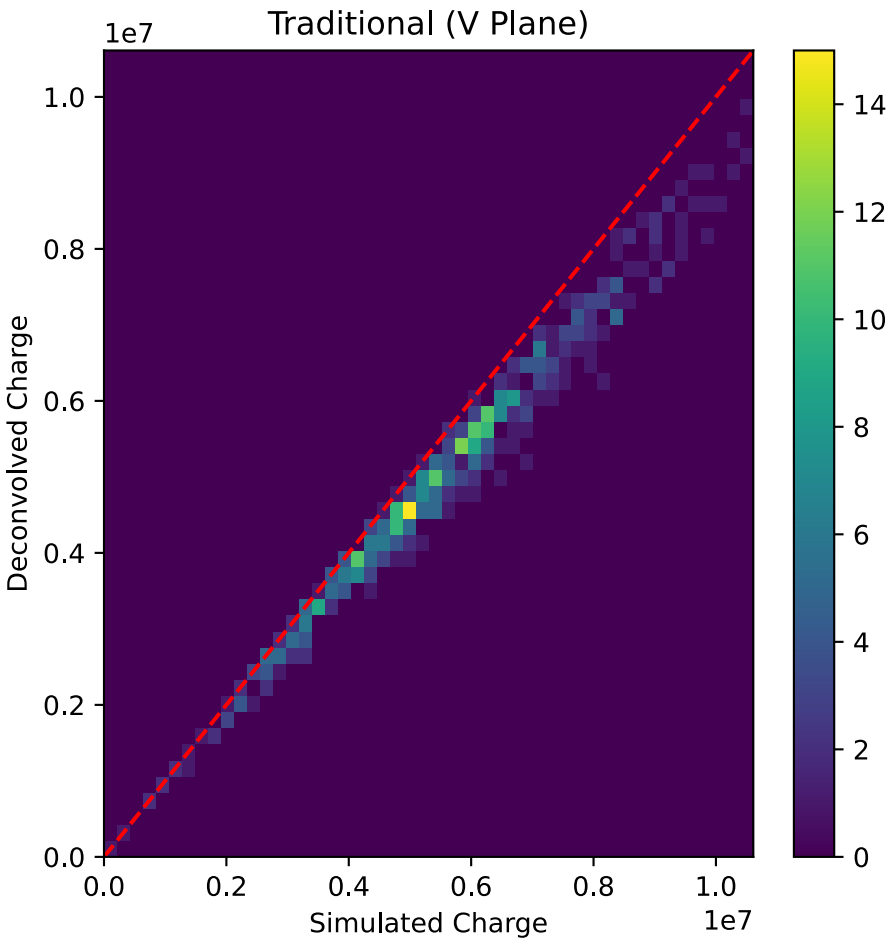


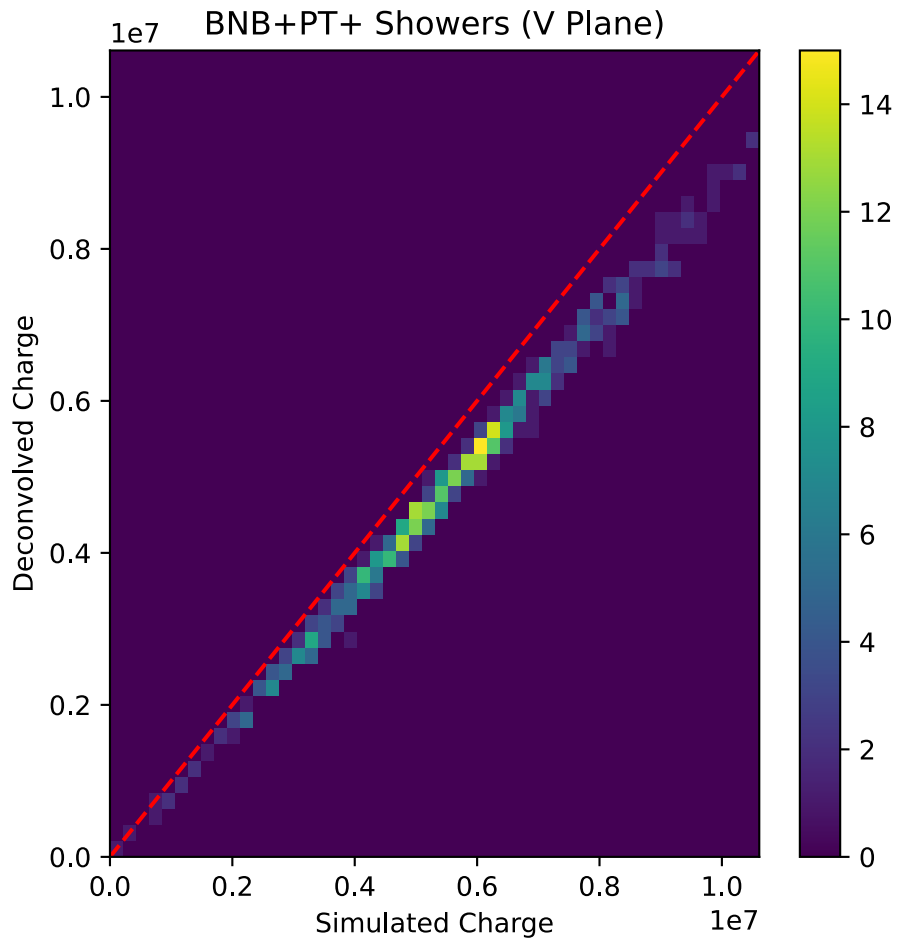


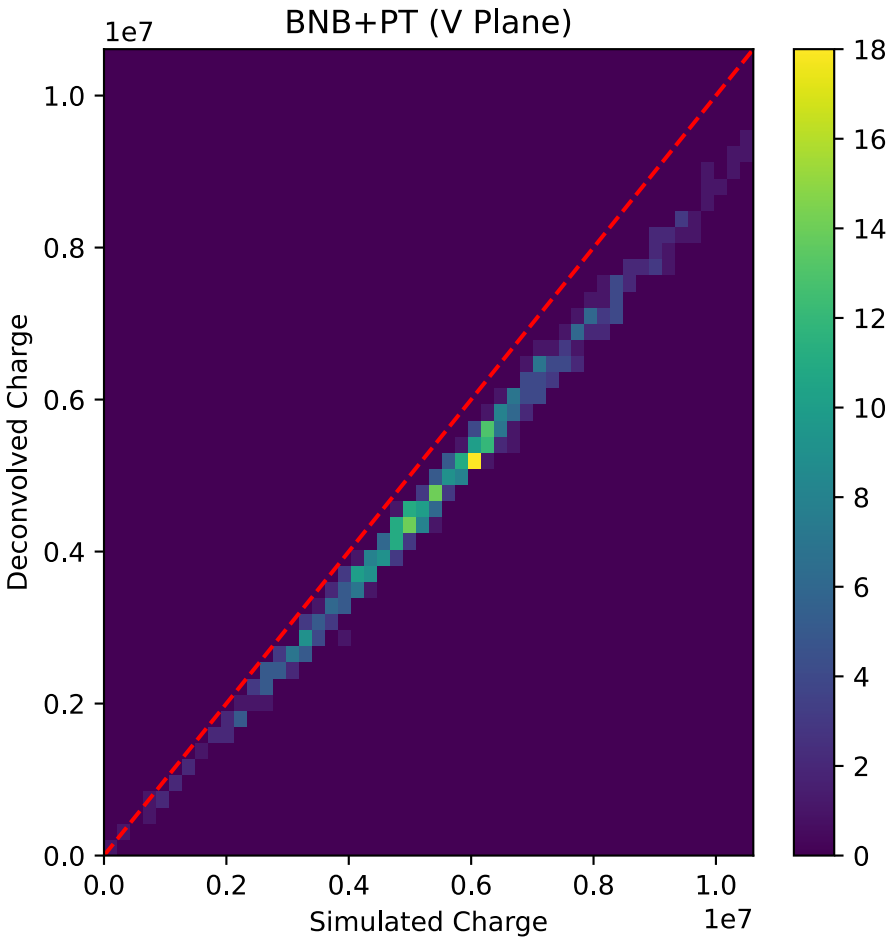


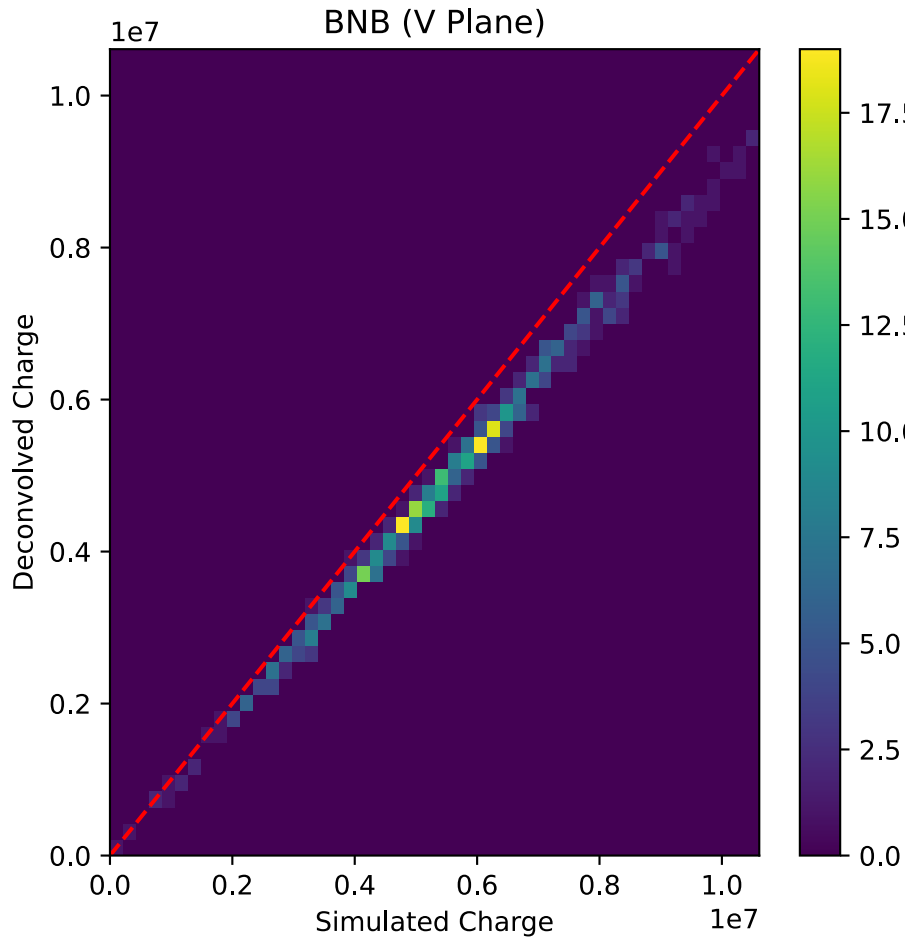


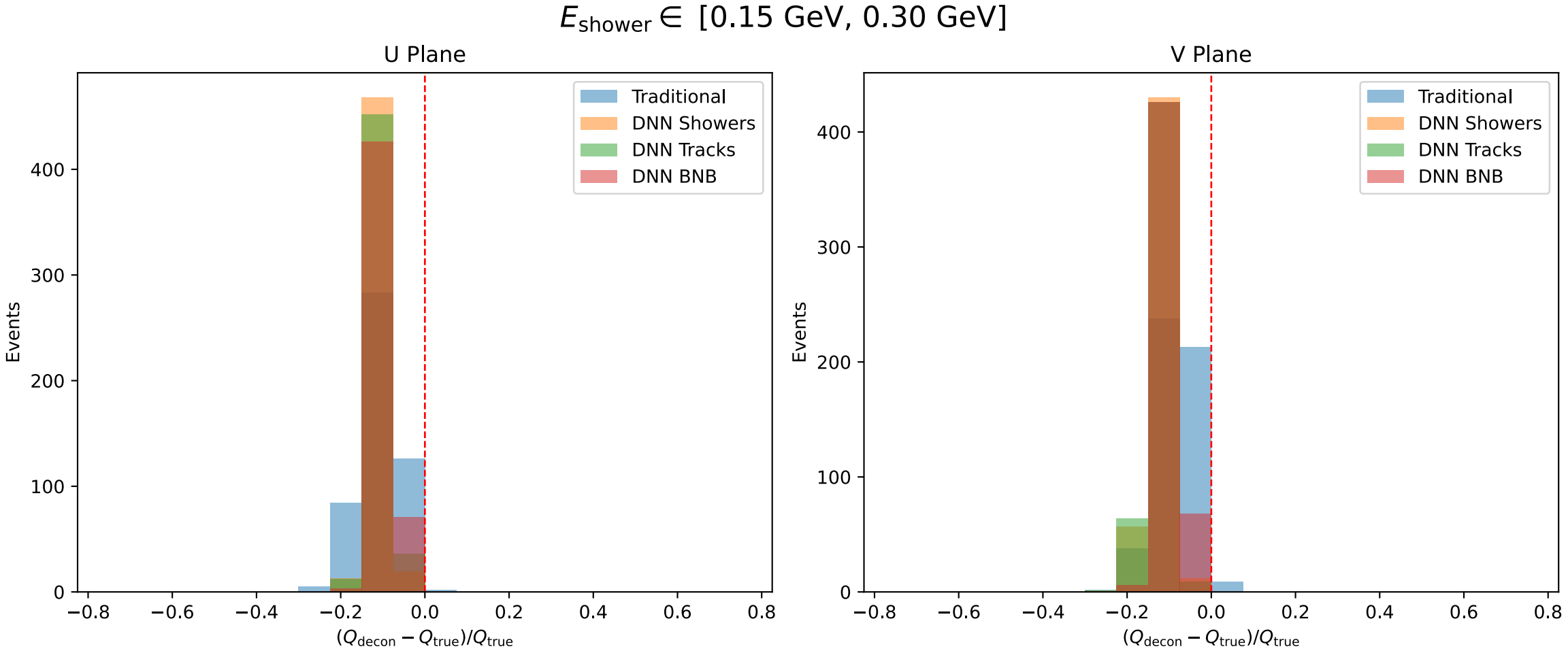
$E_{\text{shower}} \in$ [0.15 GeV, 0.30 GeV]



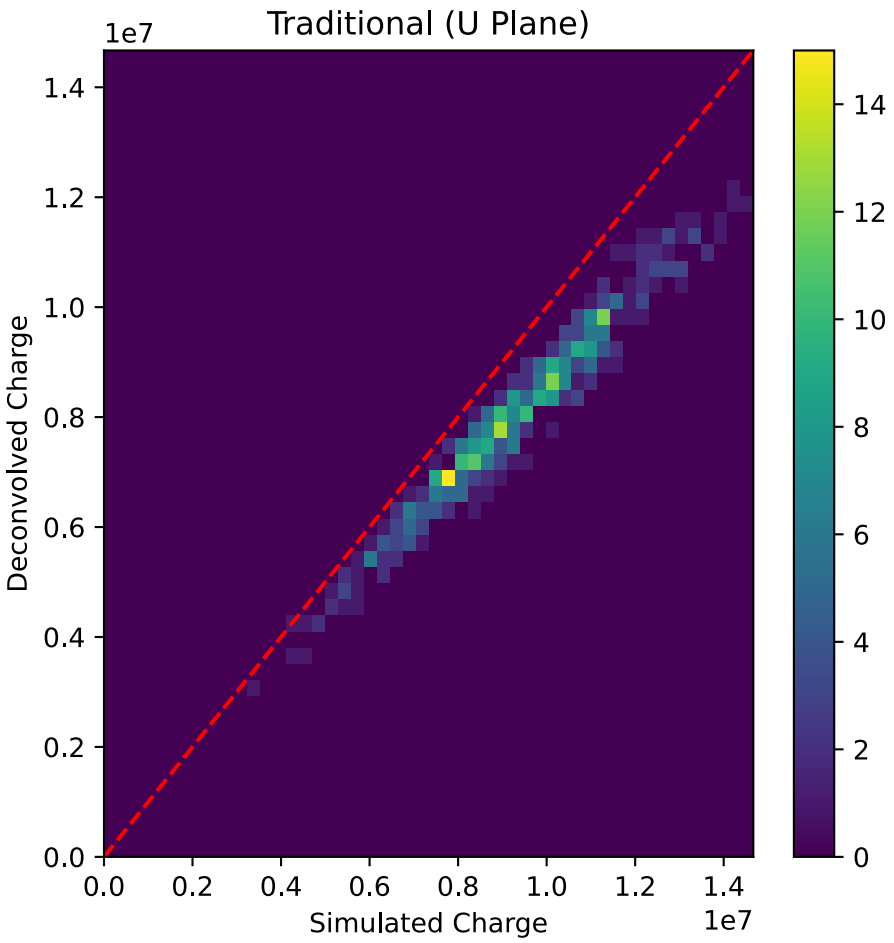


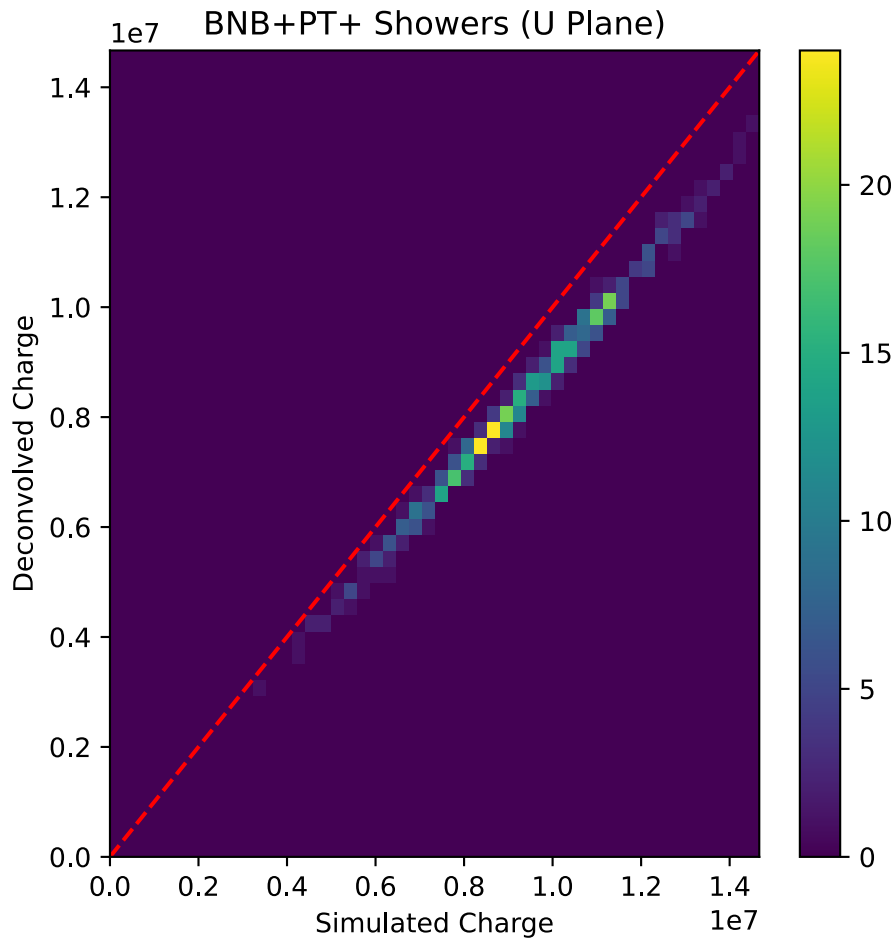


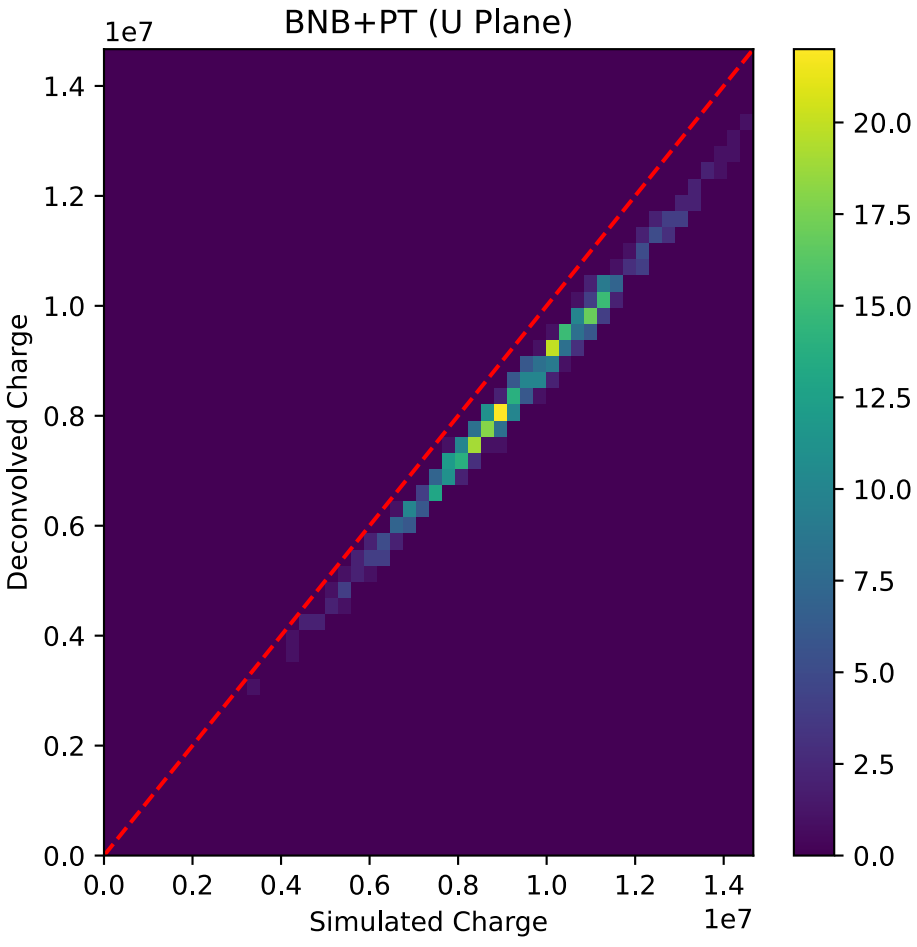


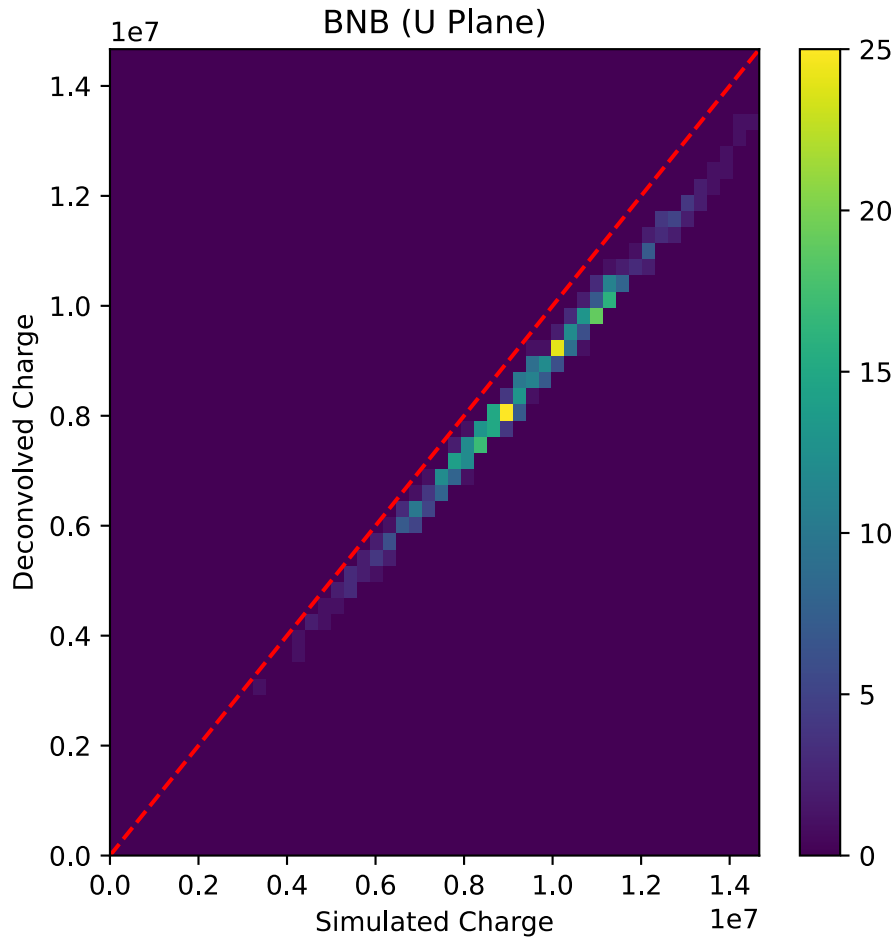

$E_{\text{shower}} \in$ [0.15 GeV, 0.30 GeV]
U Plane
V Plane
Traditional
DNN Showers
DNN Tracks
DNN BNB
Events
$(Q_{\text{decon}} - Q_{\text{true}})/Q_{\text{true}}$
0
100
200
300
400
−0.8
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8

$E_{\text{shower}} \in$ [0.30 GeV, 0.45 GeV]

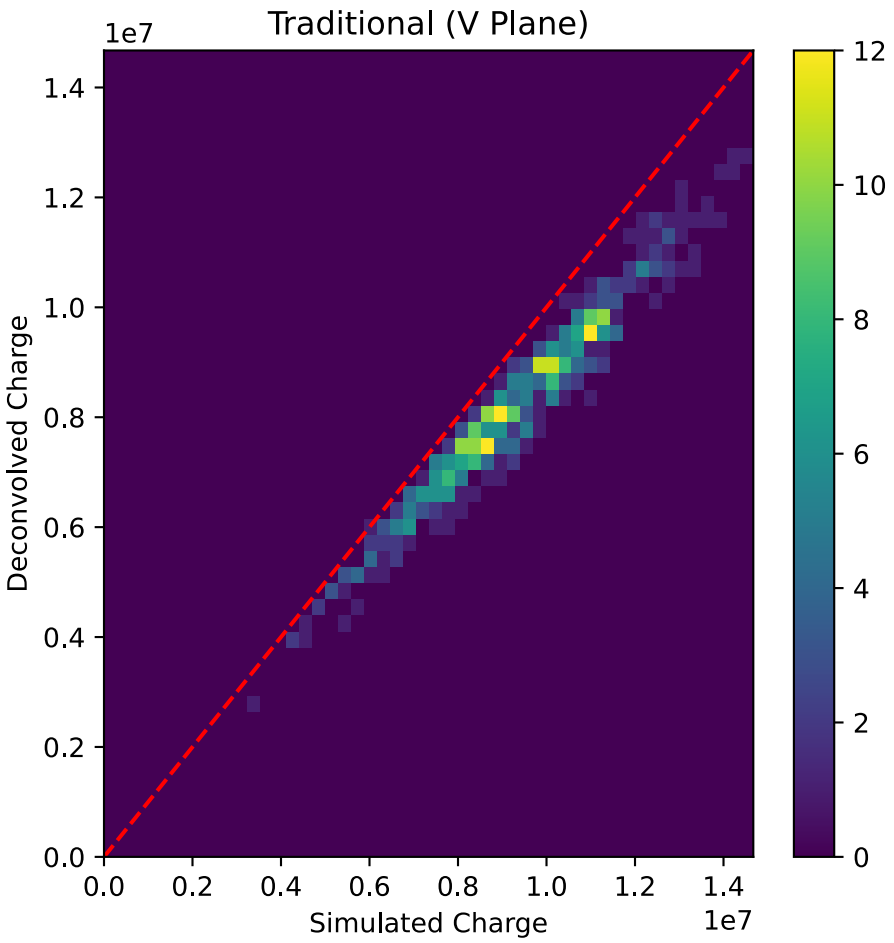


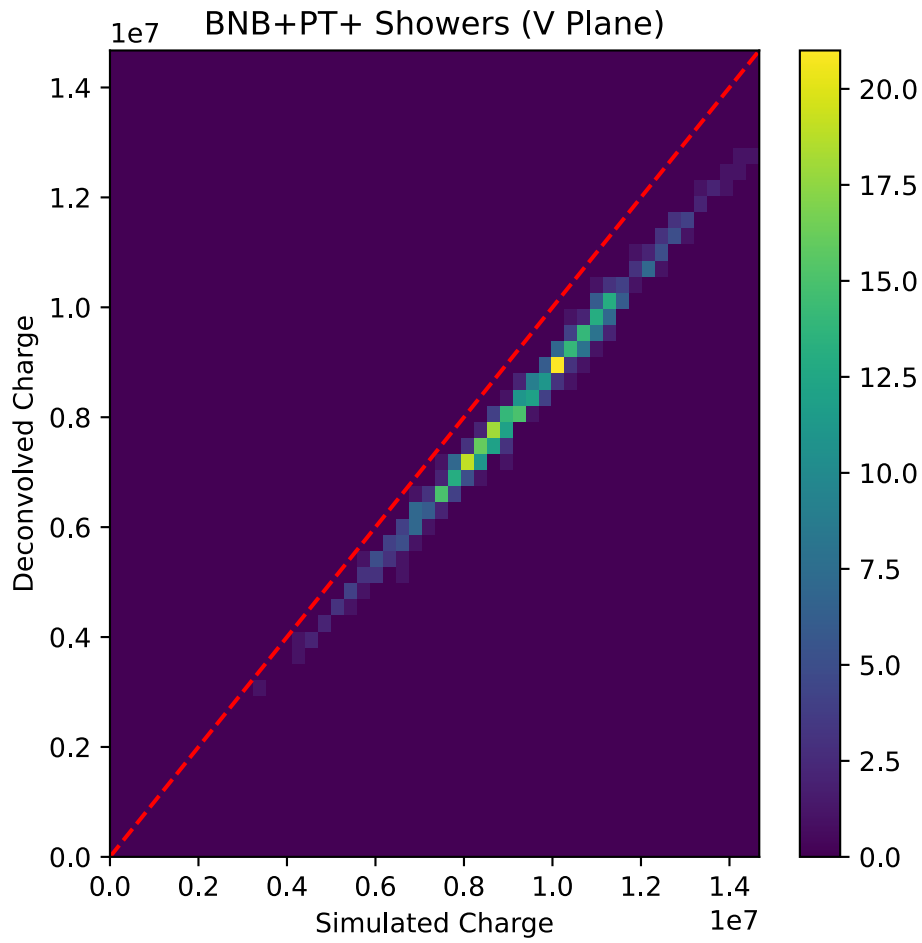


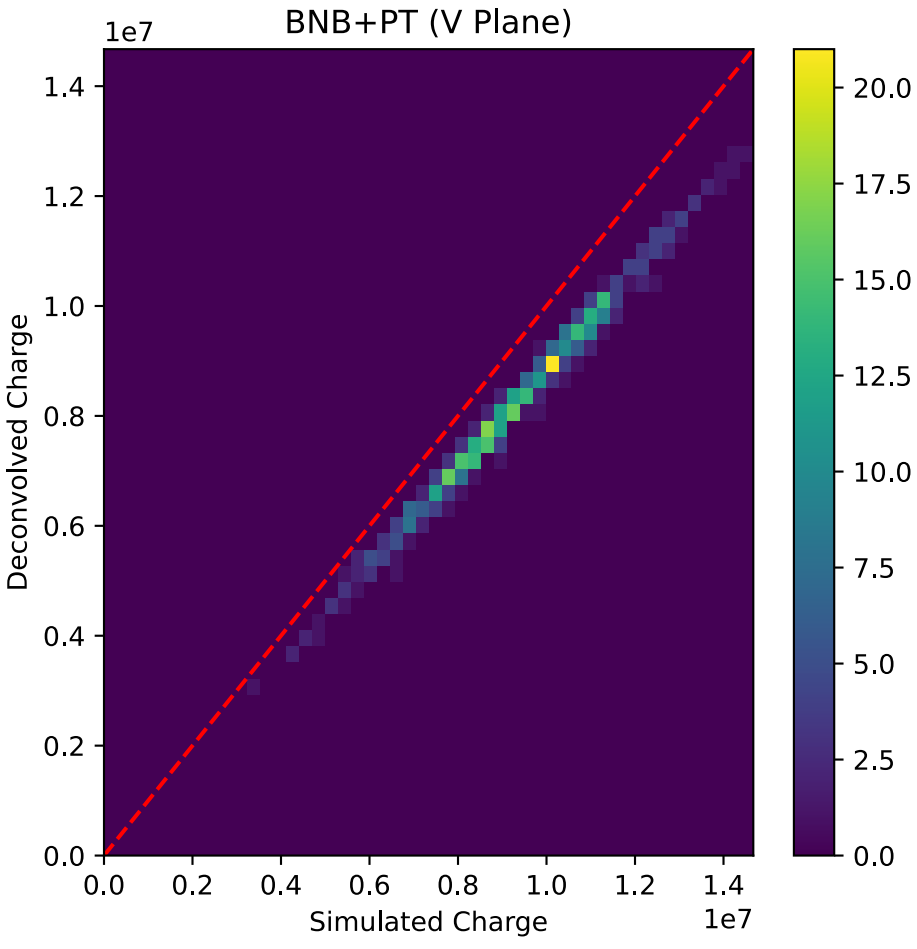


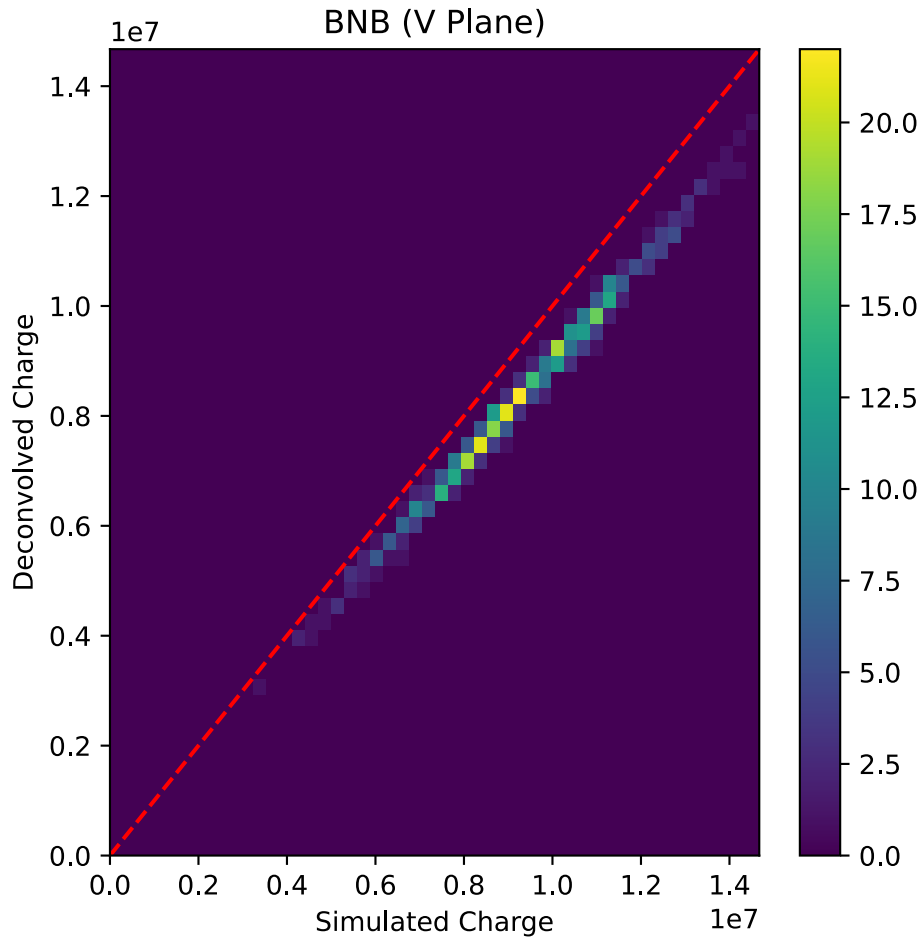


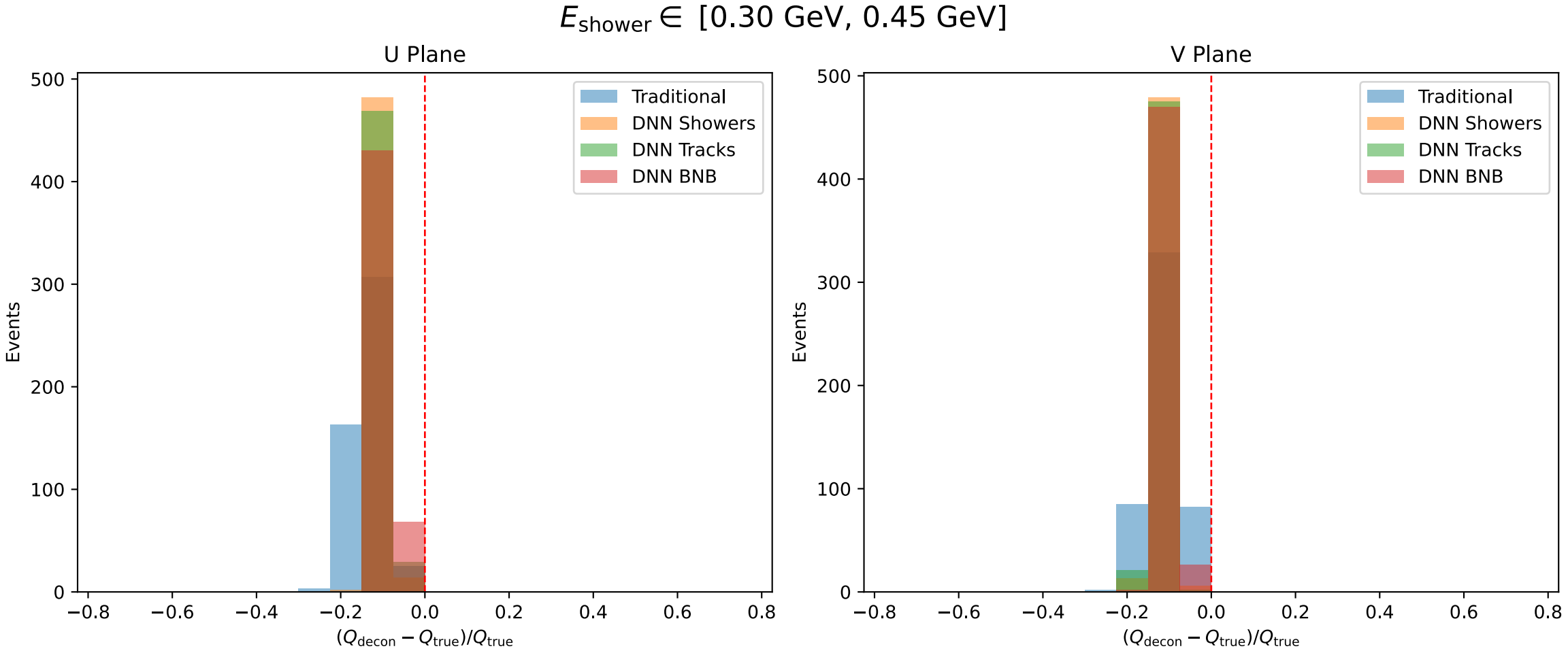
$E_{\text{shower}} \in$ [0.30 GeV, 0.45 GeV]










$E_{\text{shower}} \in$ [0.30 GeV, 0.45 GeV]
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100
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0.0
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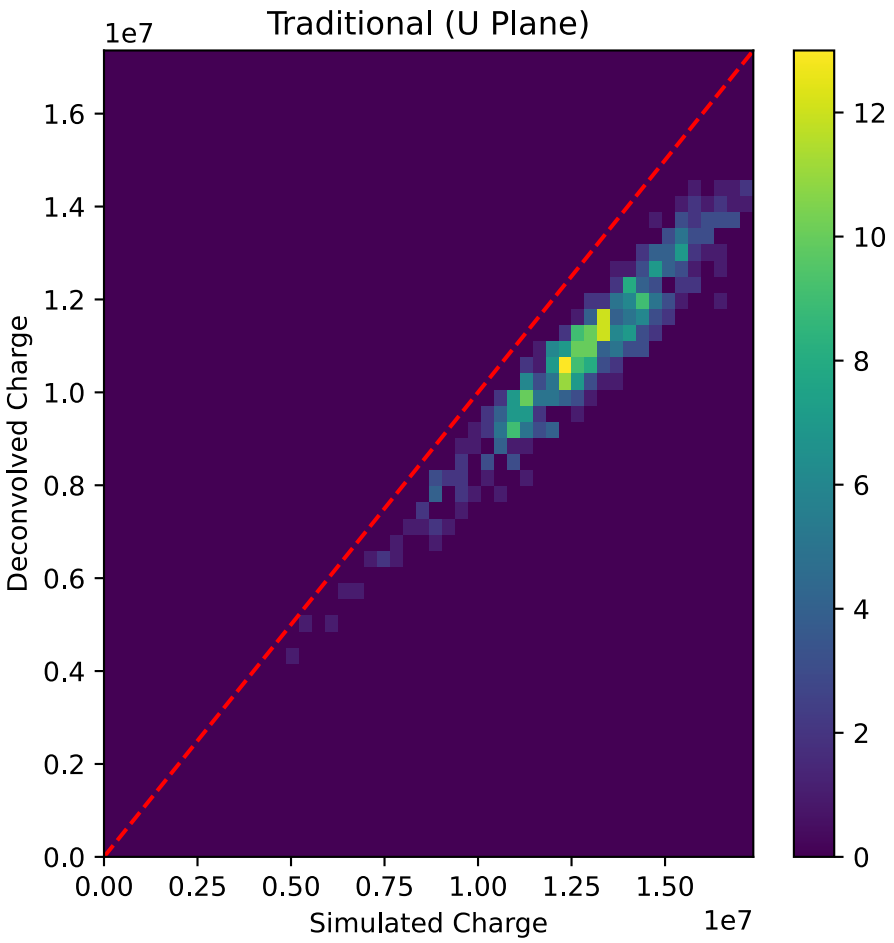
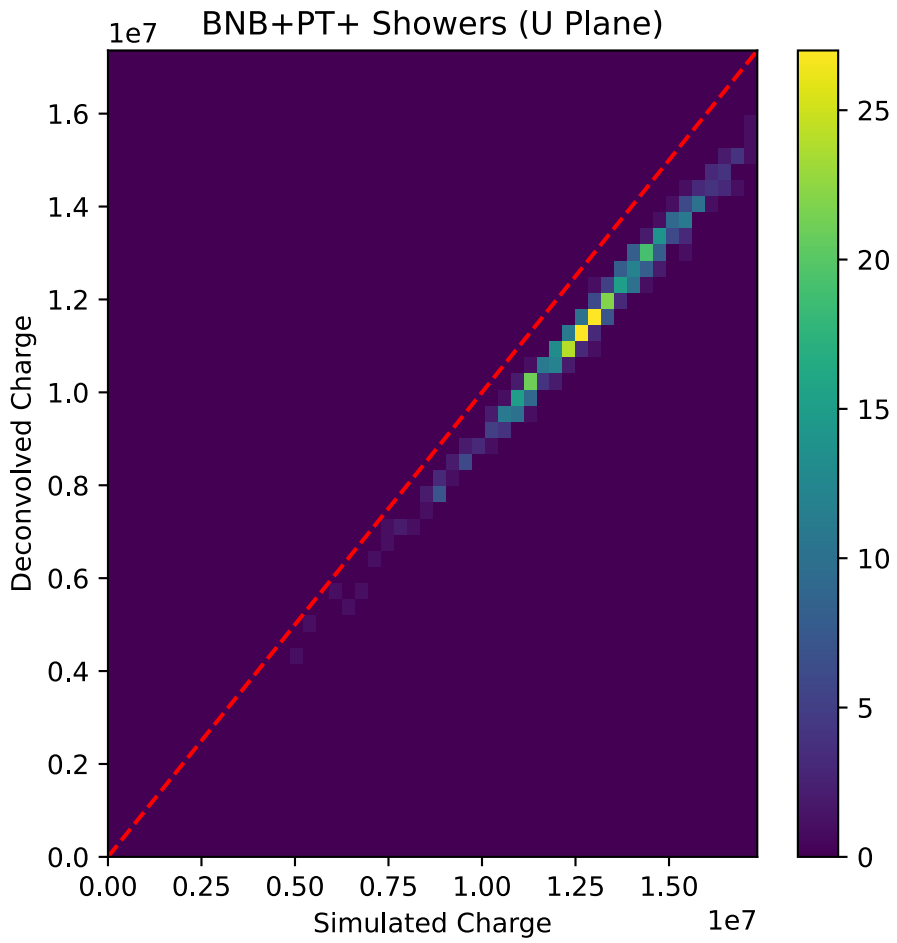
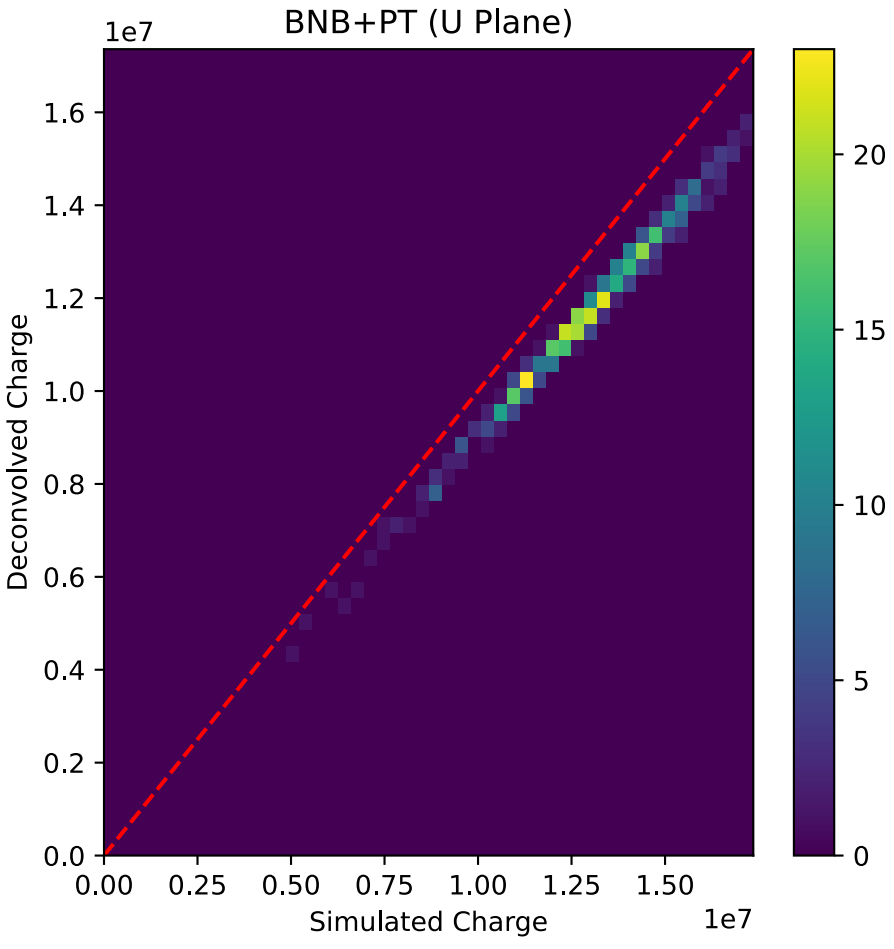
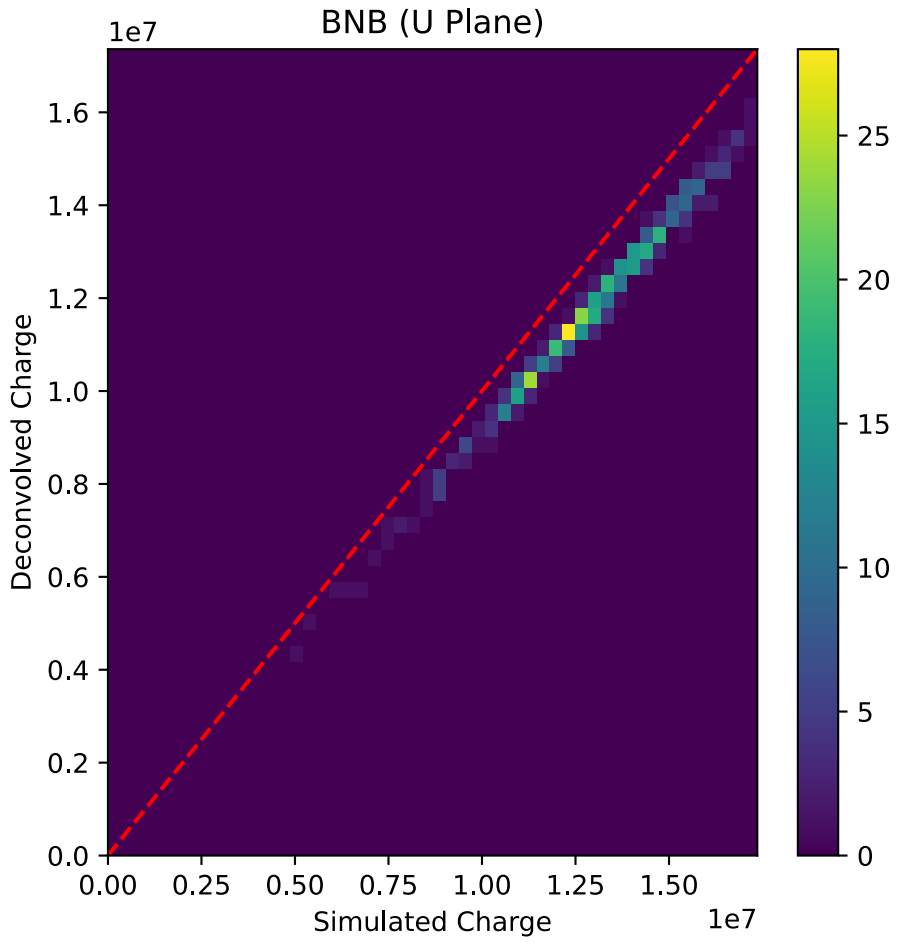
$E_{\text{shower}} \in$ [0.45 GeV, 0.60 GeV]

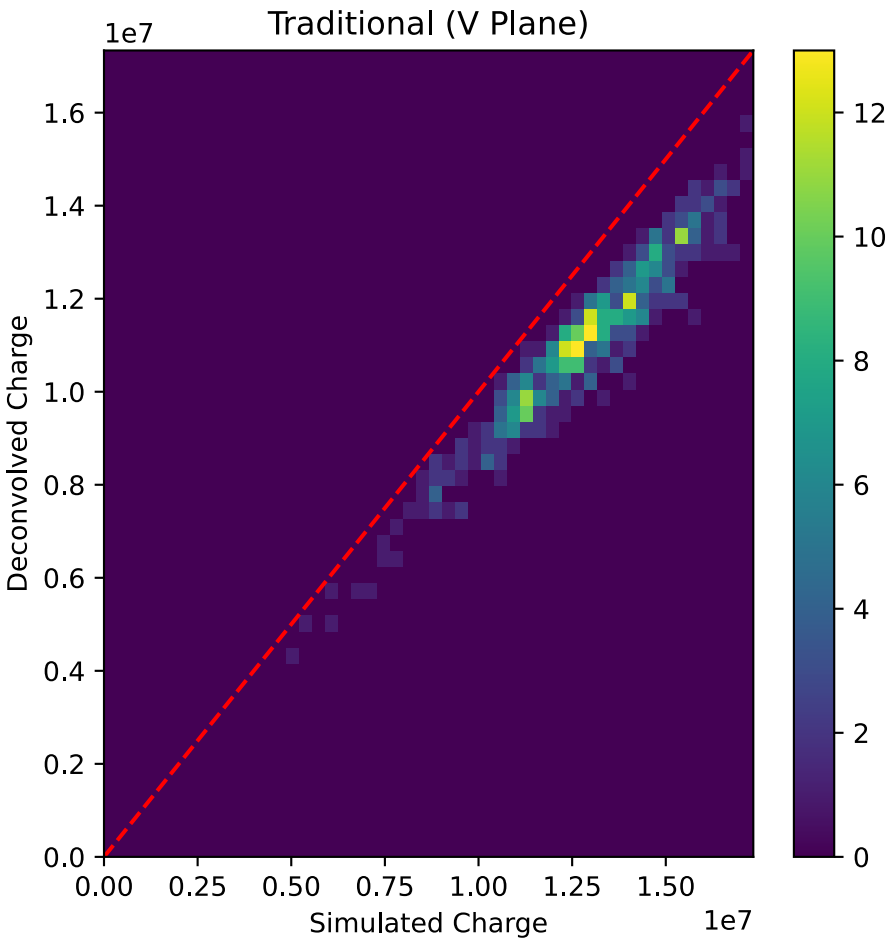


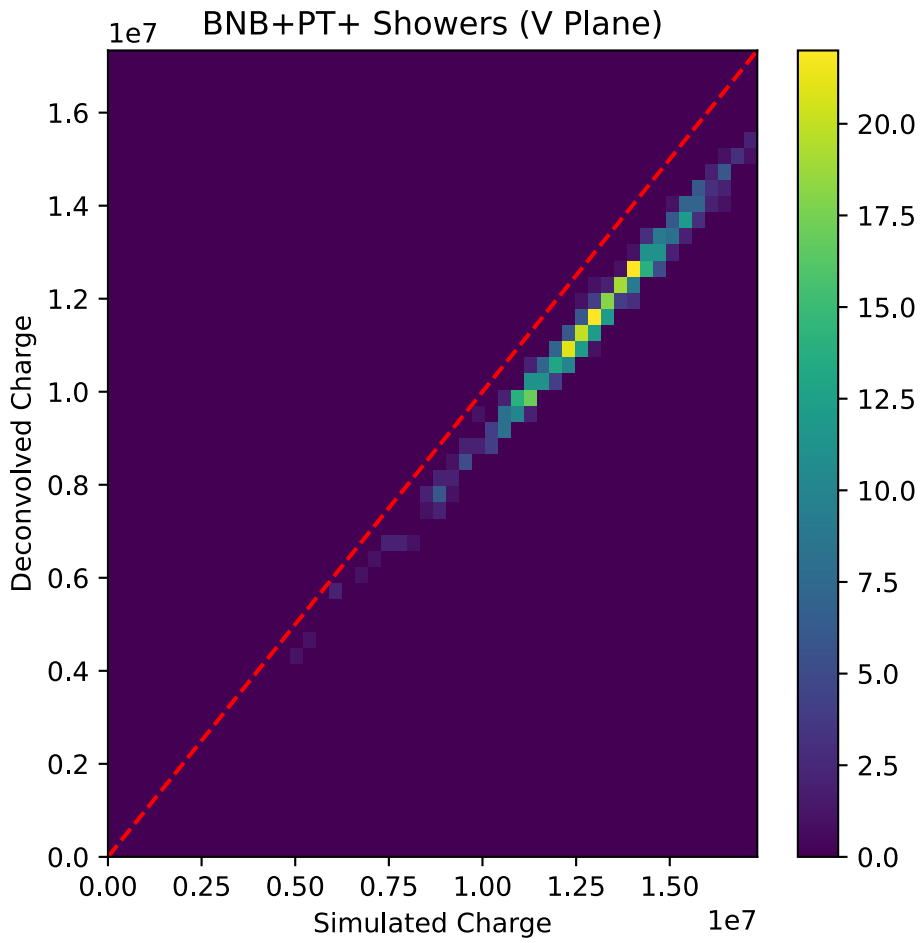


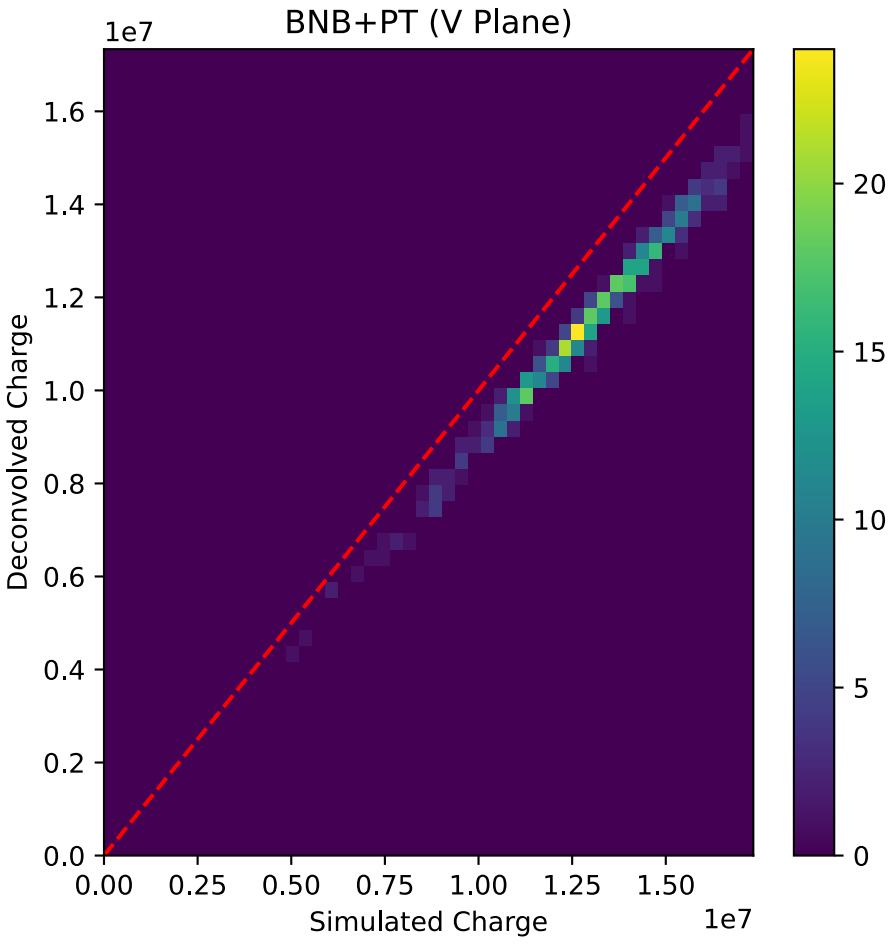


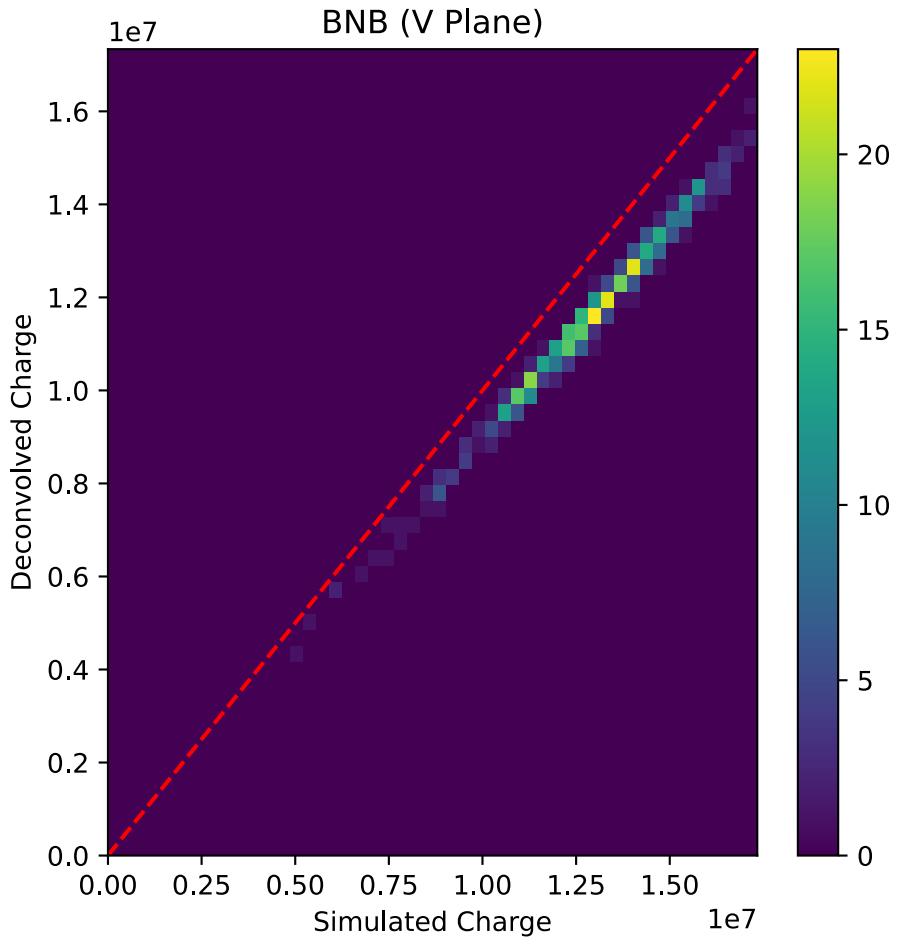


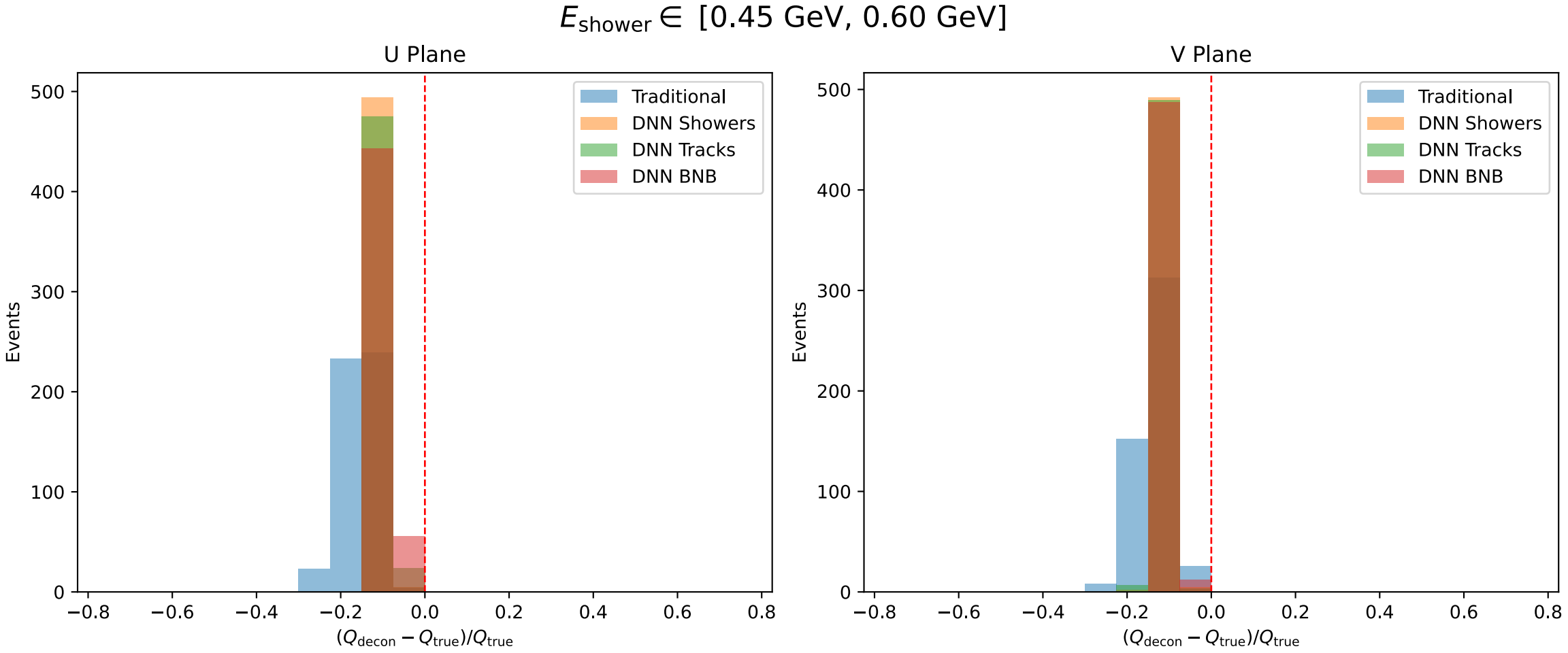
$E_{\text{shower}} \in$ [0.45 GeV, 0.60 GeV]







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−0.6
−0.4
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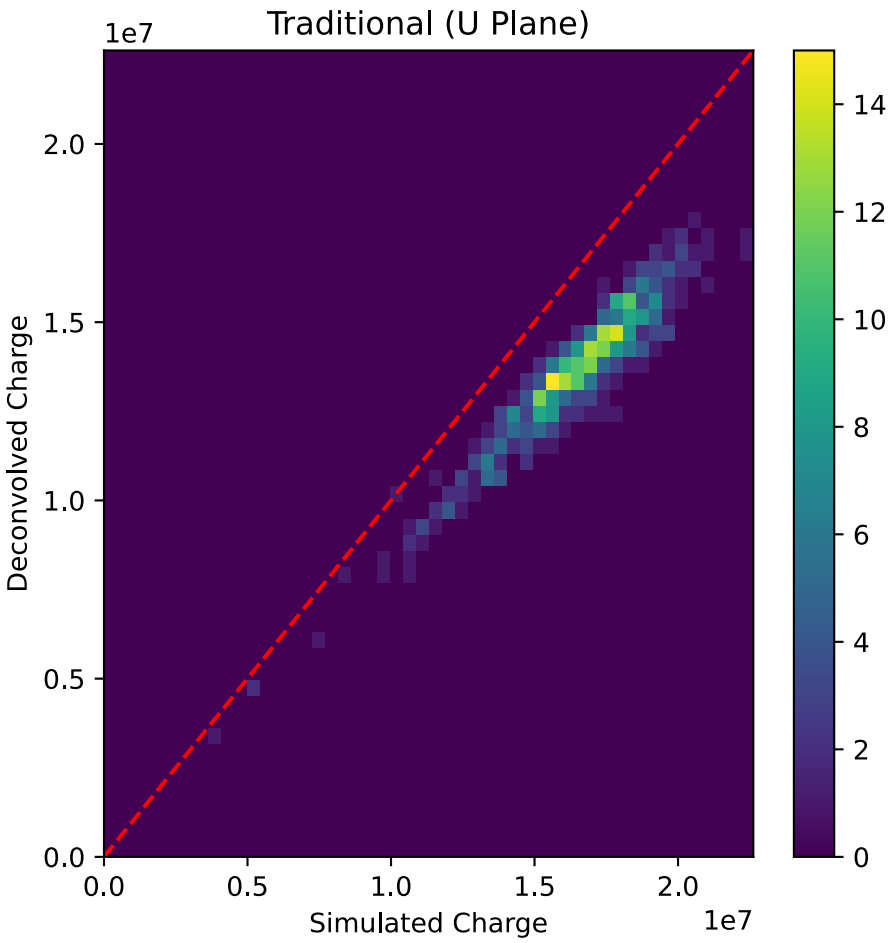
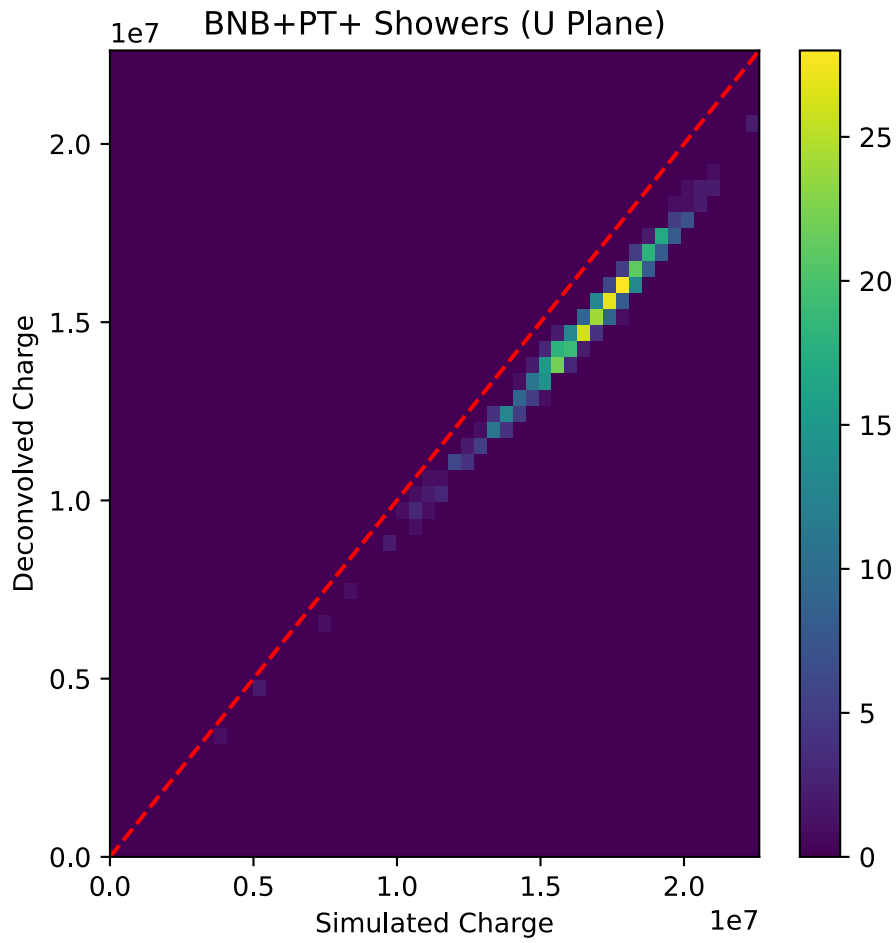
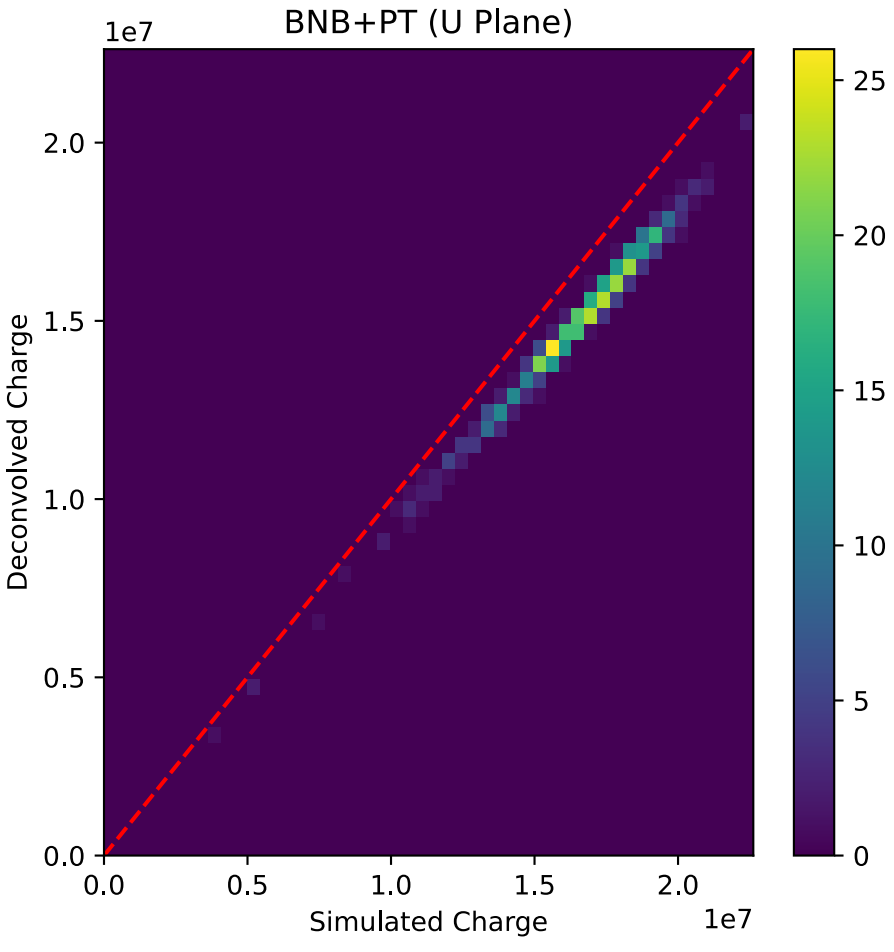
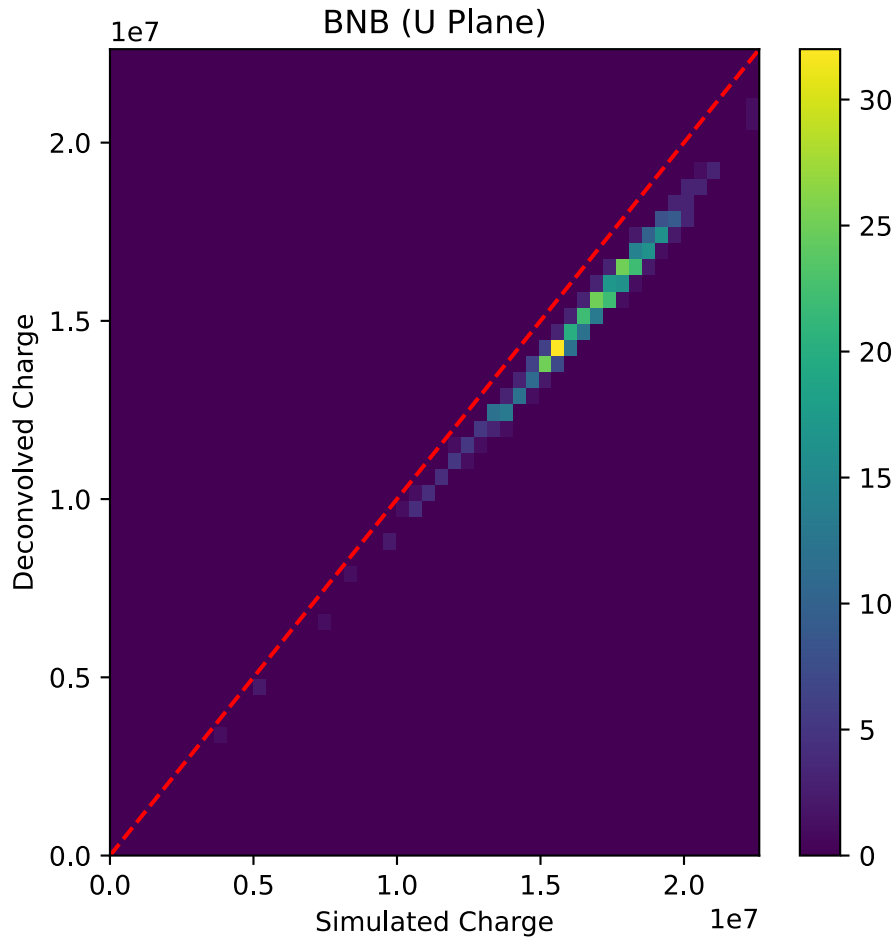
$E_{\text{shower}} \in$ [0.60 GeV, 0.75 GeV]

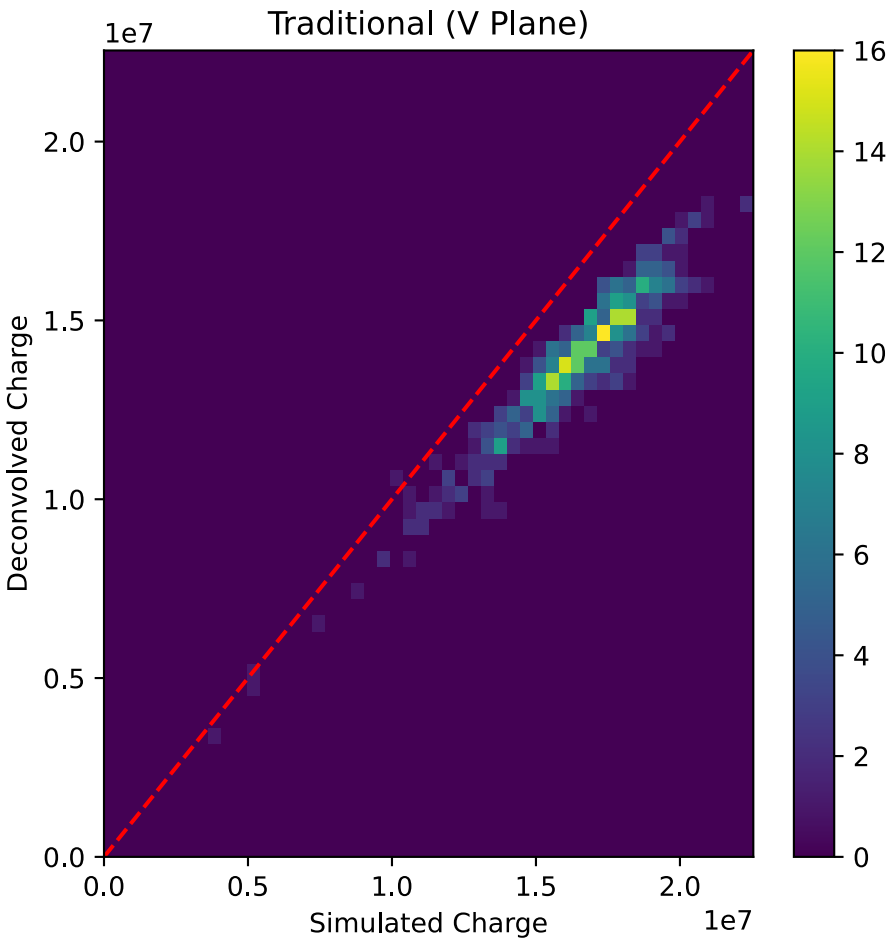


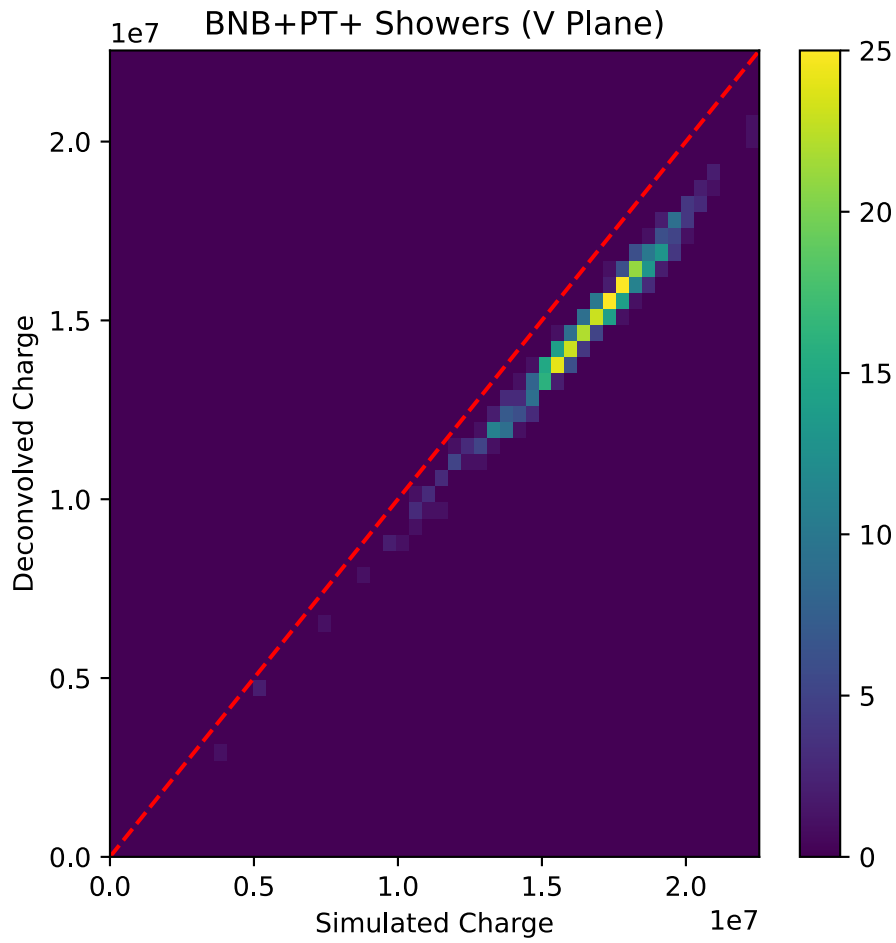


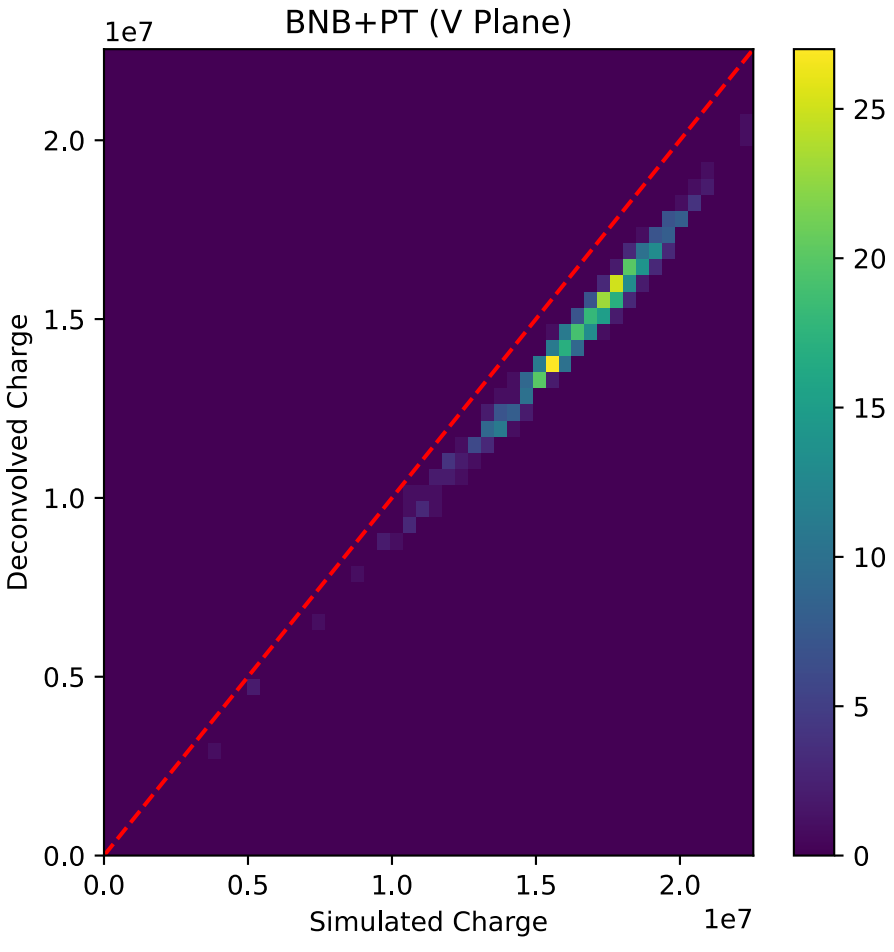


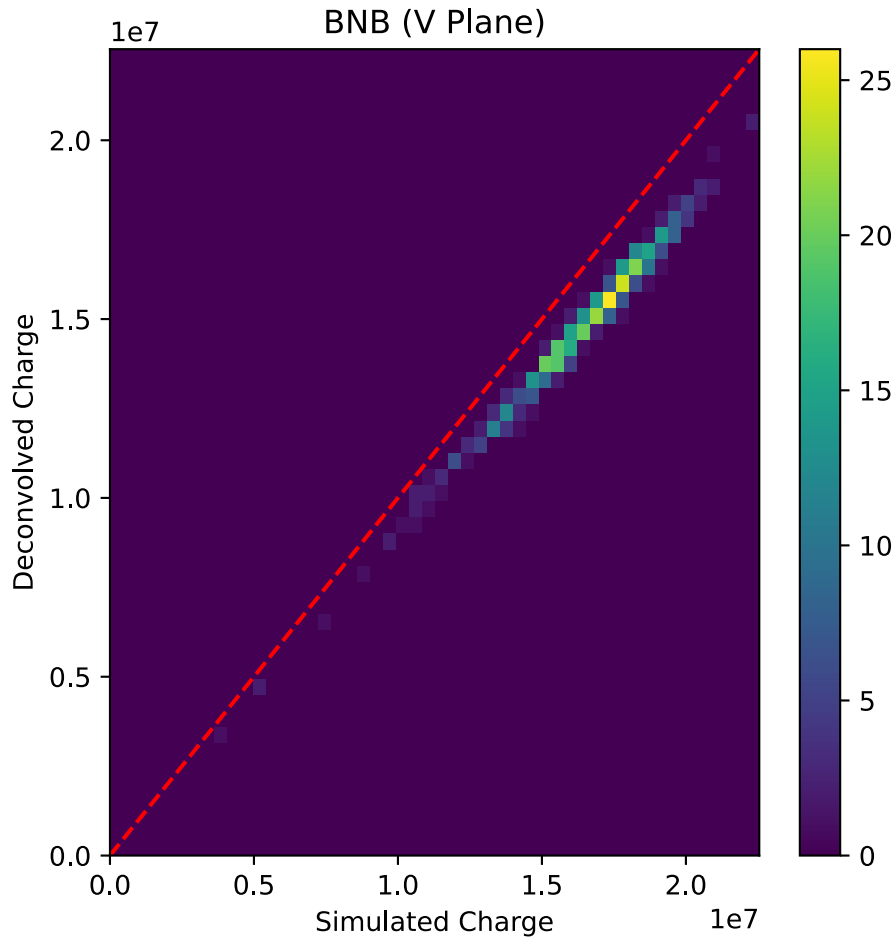


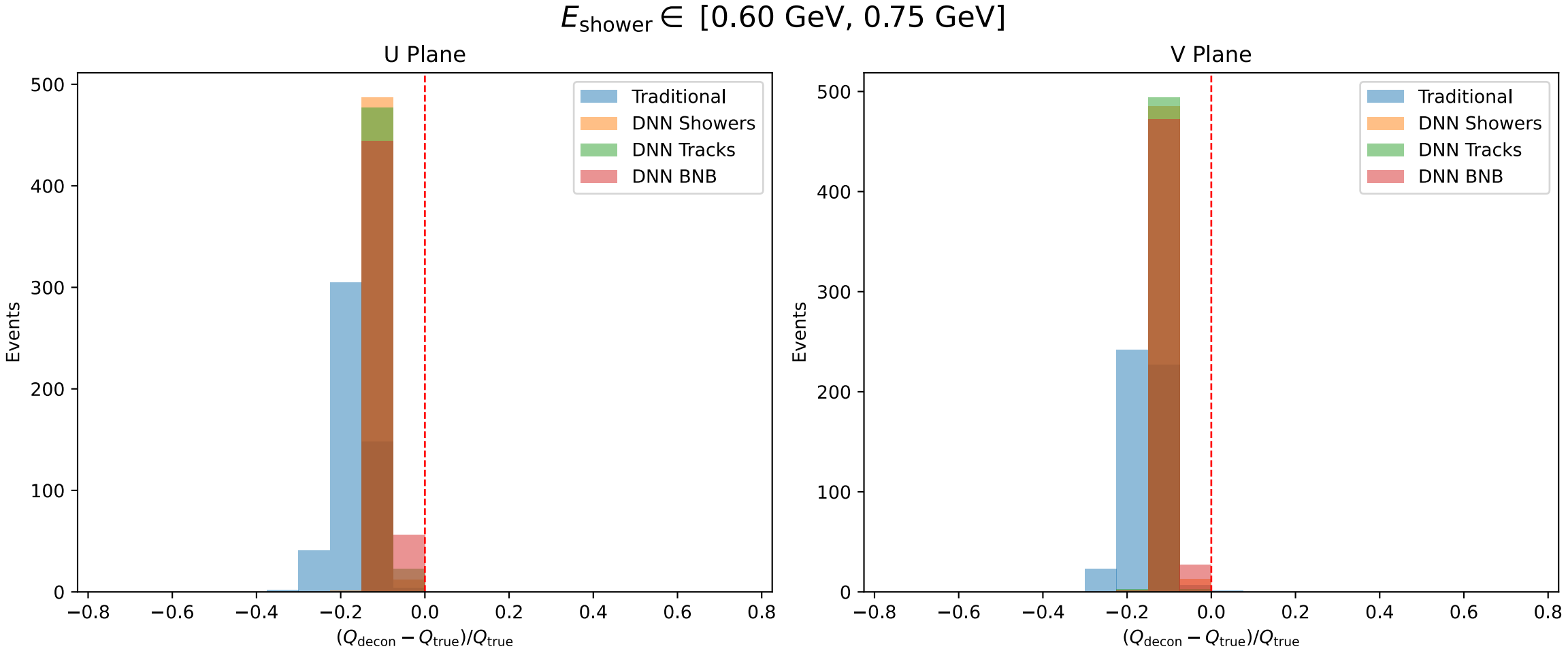
$E_{\text{shower}} \in$ [0.60 GeV, 0.75 GeV]



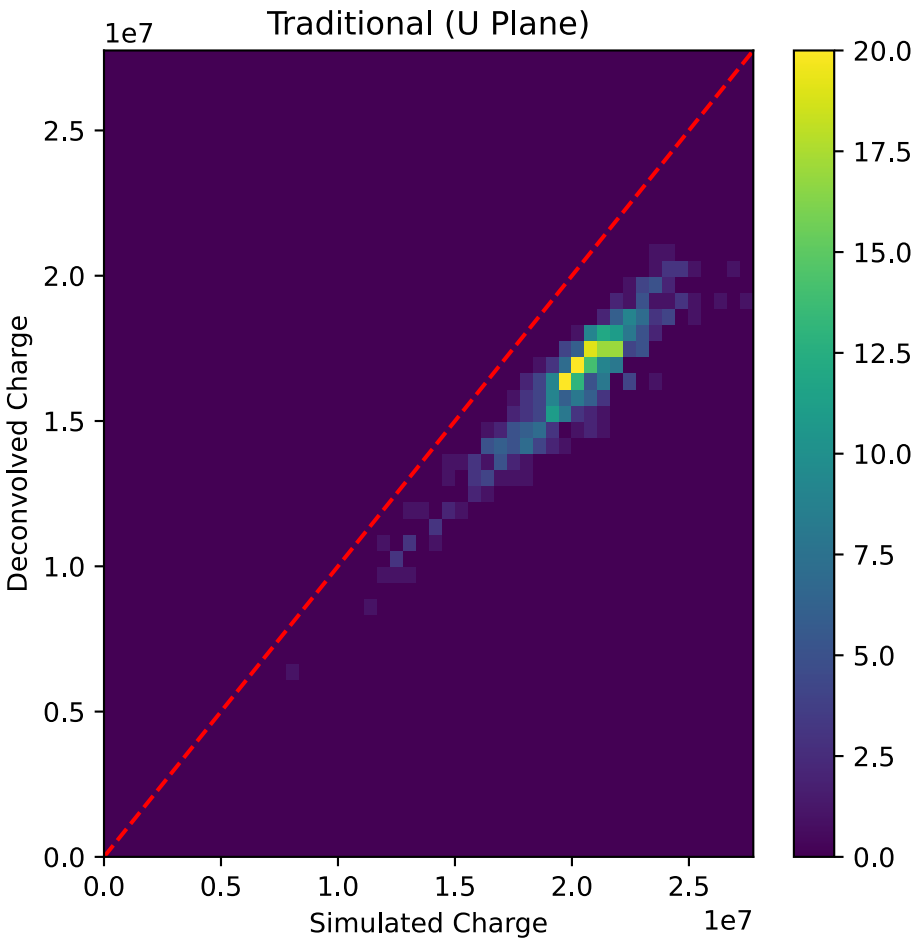


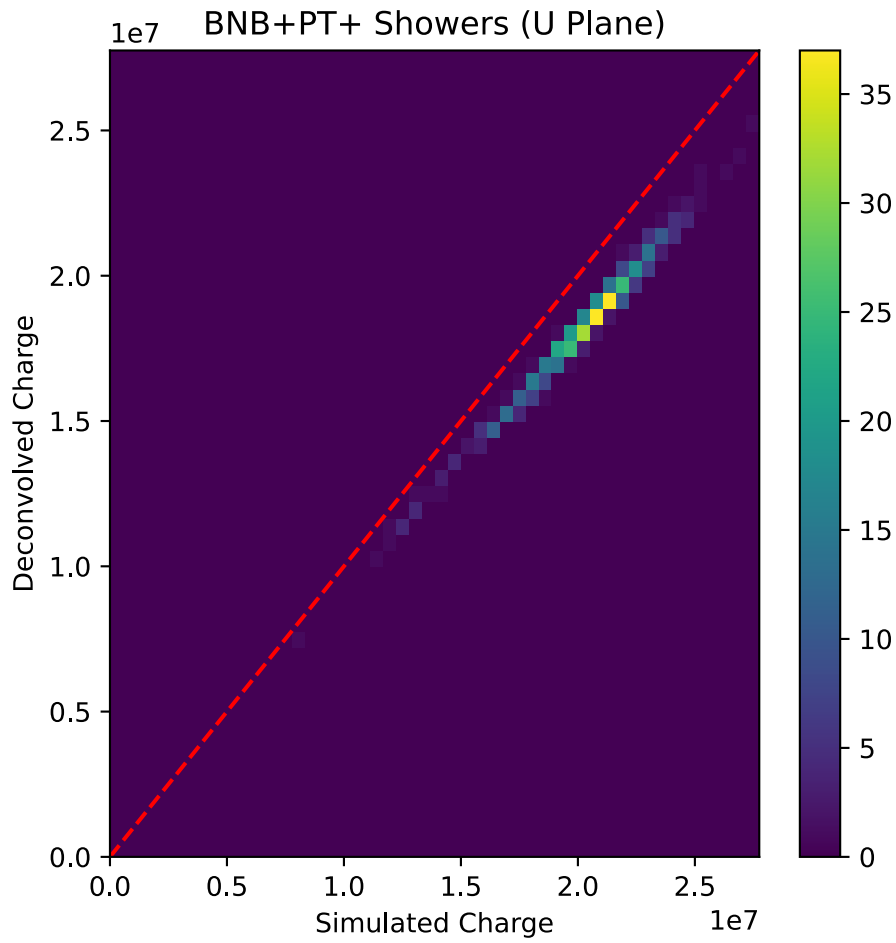


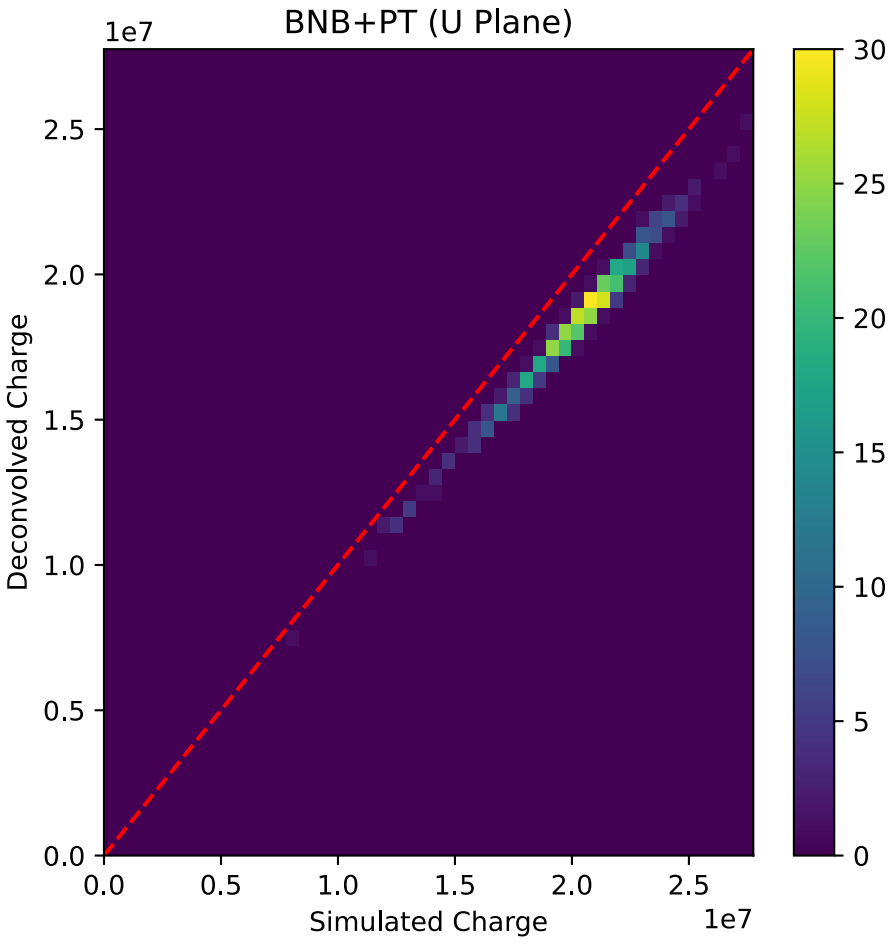


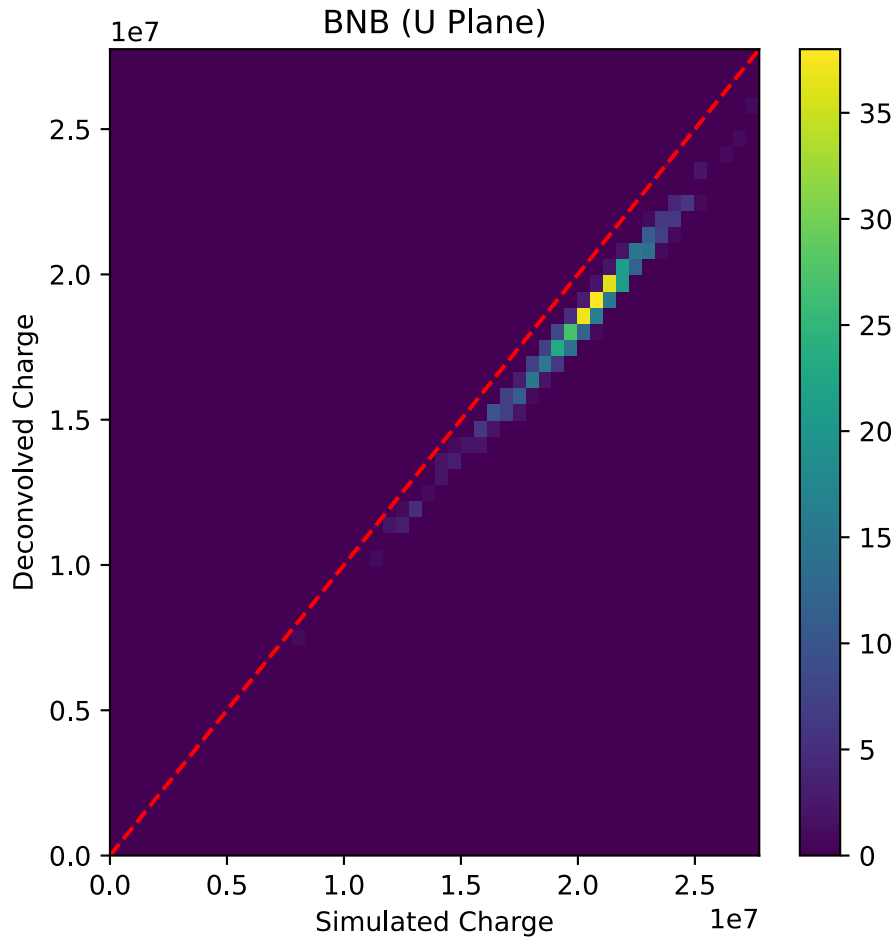

$E_{\text{shower}} \in$ [0.60 GeV, 0.75 GeV]
U Plane
V Plane
Traditional
DNN Showers
DNN Tracks
DNN BNB
Events
$(Q_{\text{decon}} - Q_{\text{true}})/Q_{\text{true}}$
0
100
200
300
400
500
−0.8
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8

$E_{\text{shower}} \in$ [0.75 GeV, 0.90 GeV]

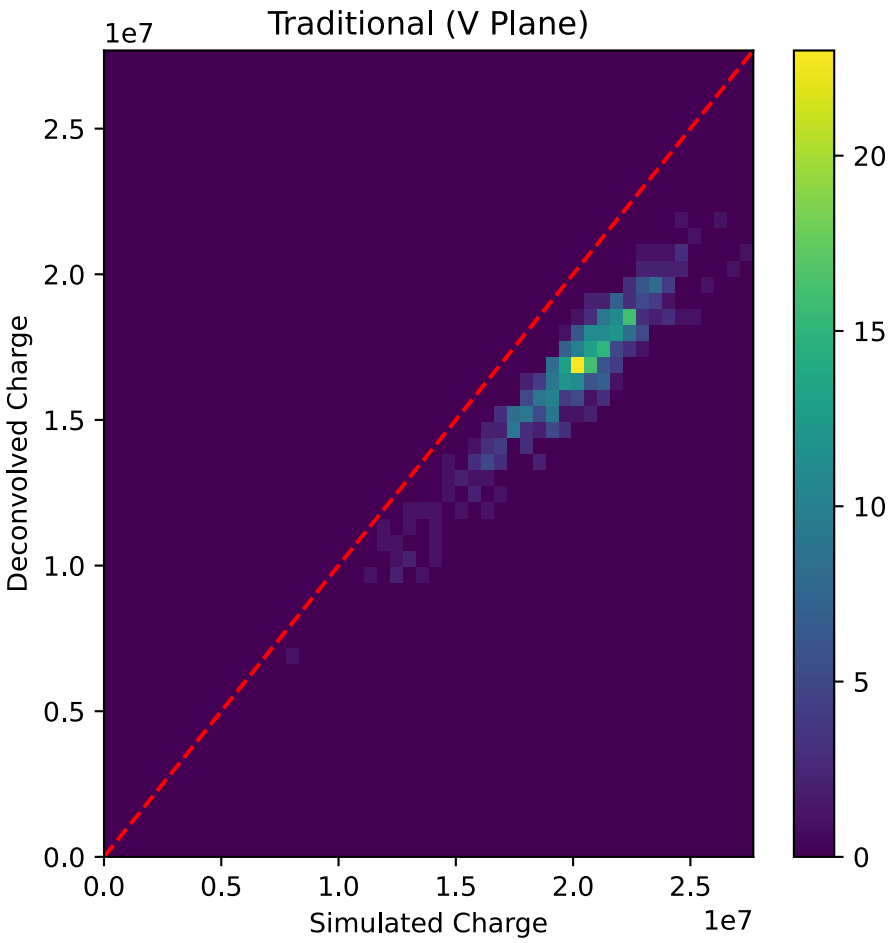


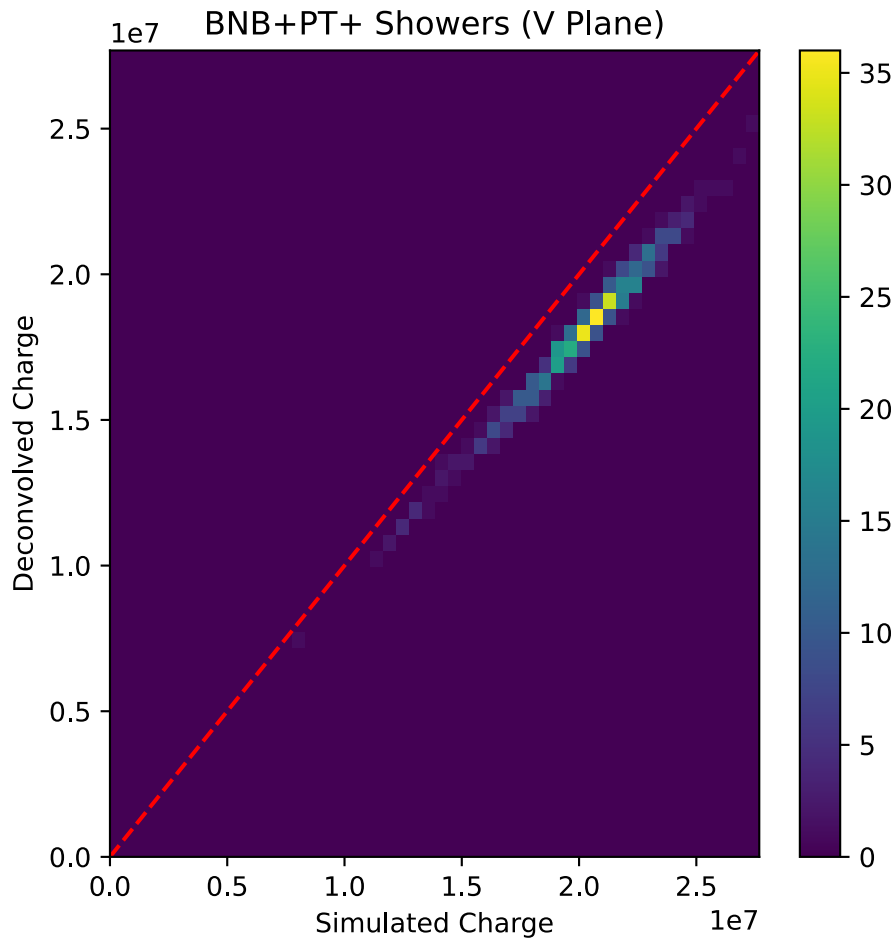


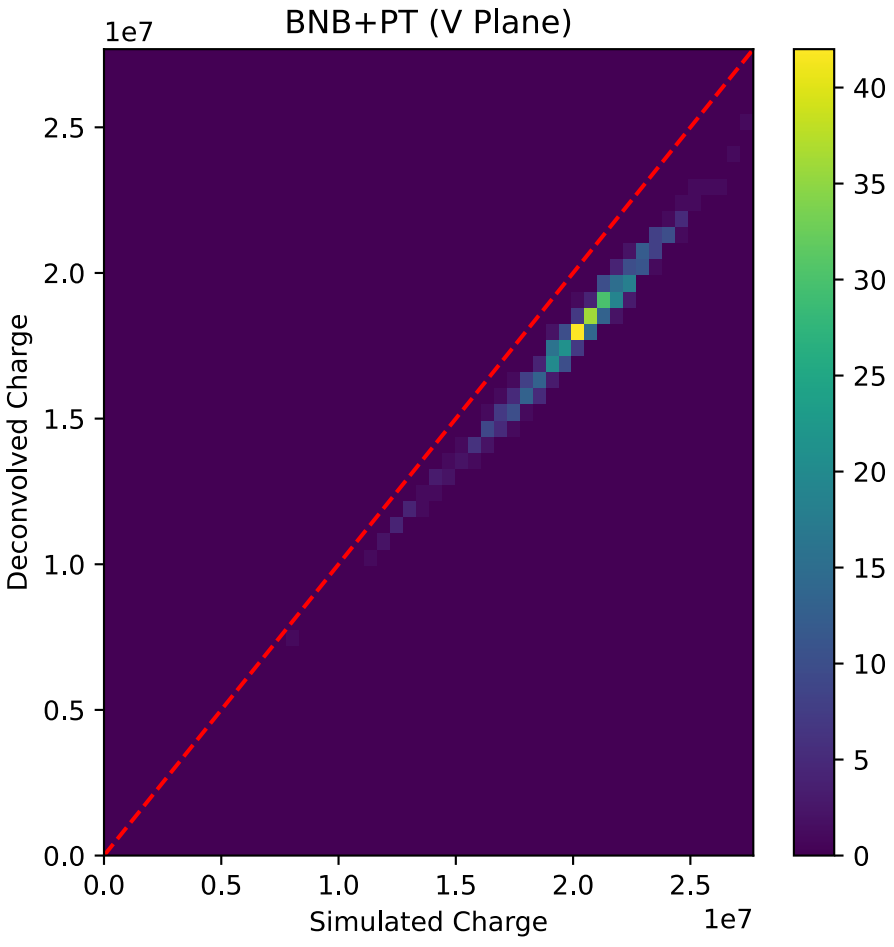


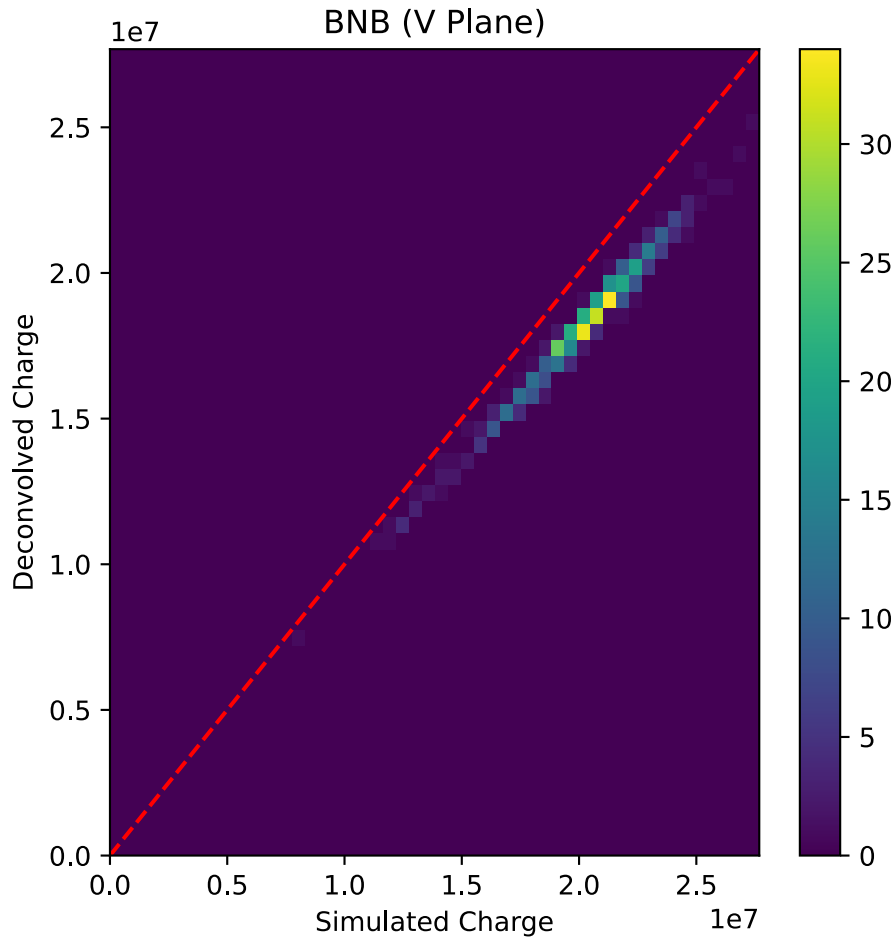


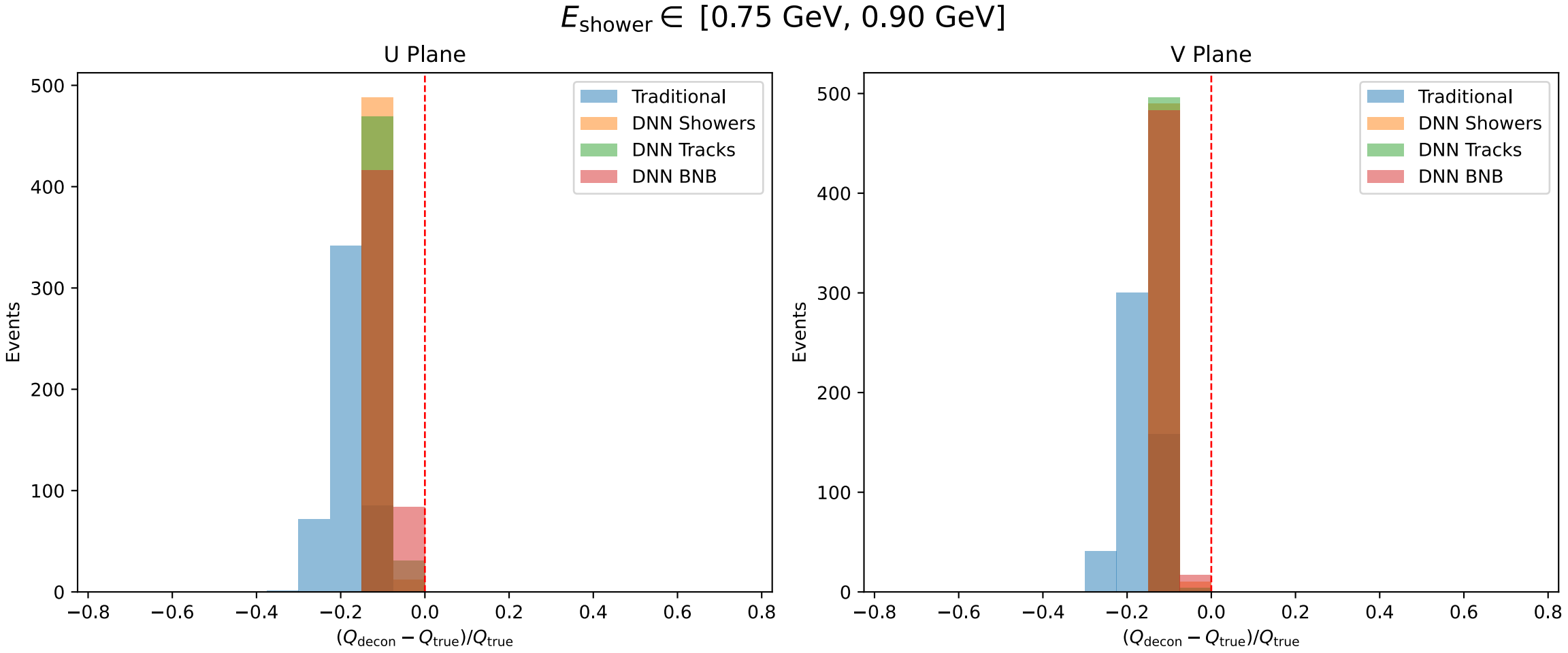
$E_{\text{shower}} \in$ [0.75 GeV, 0.90 GeV]



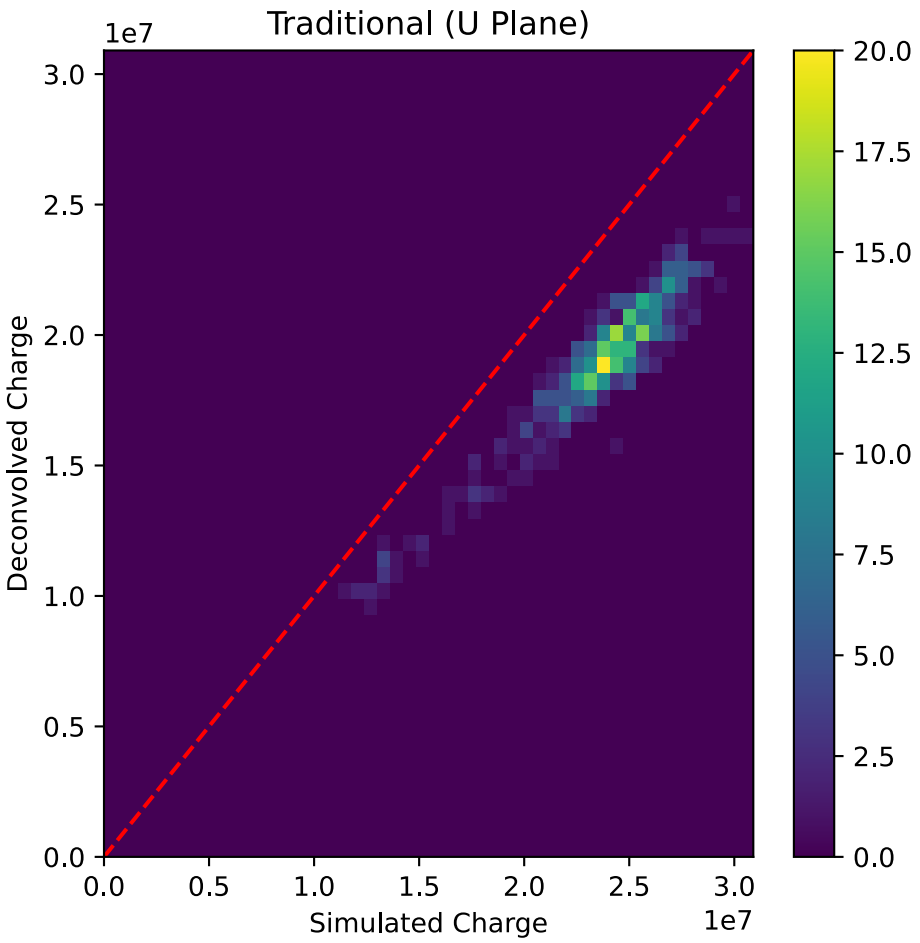


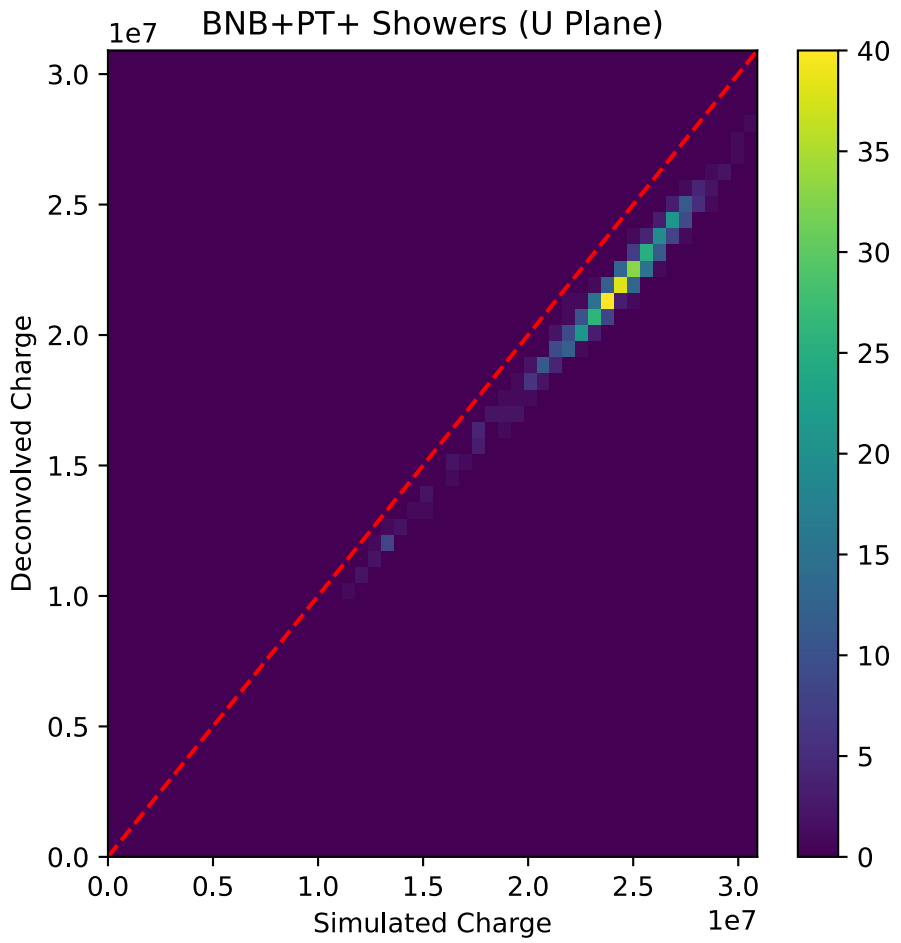


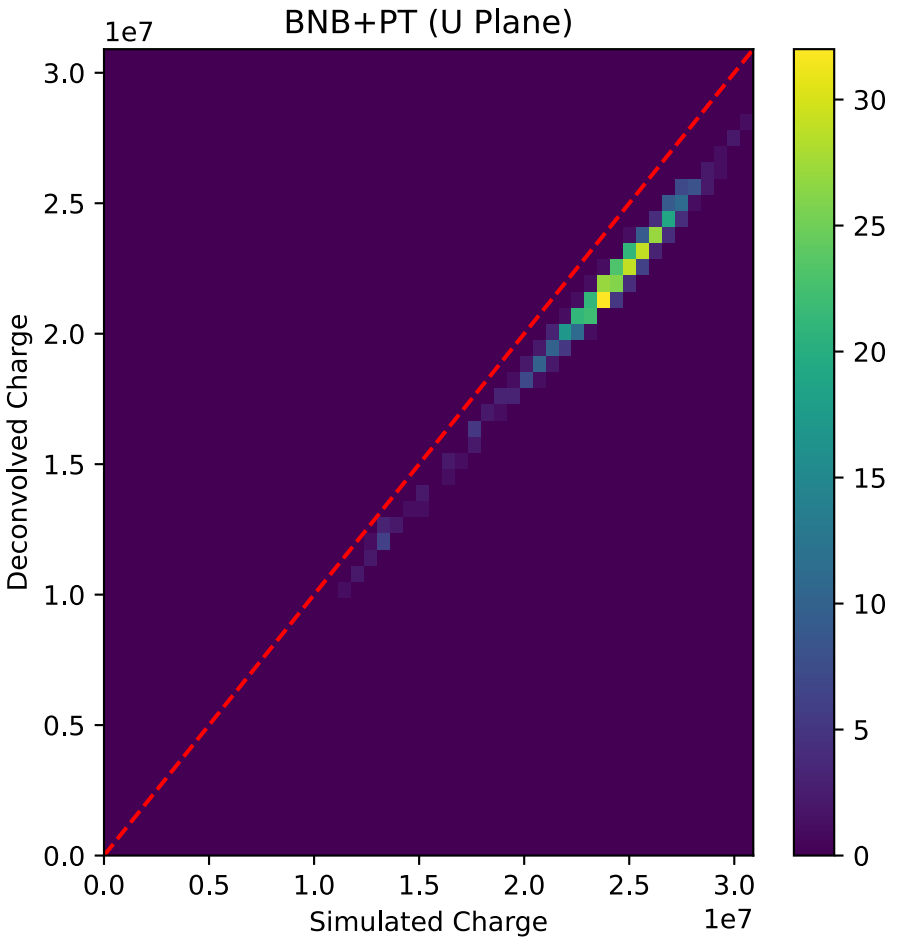


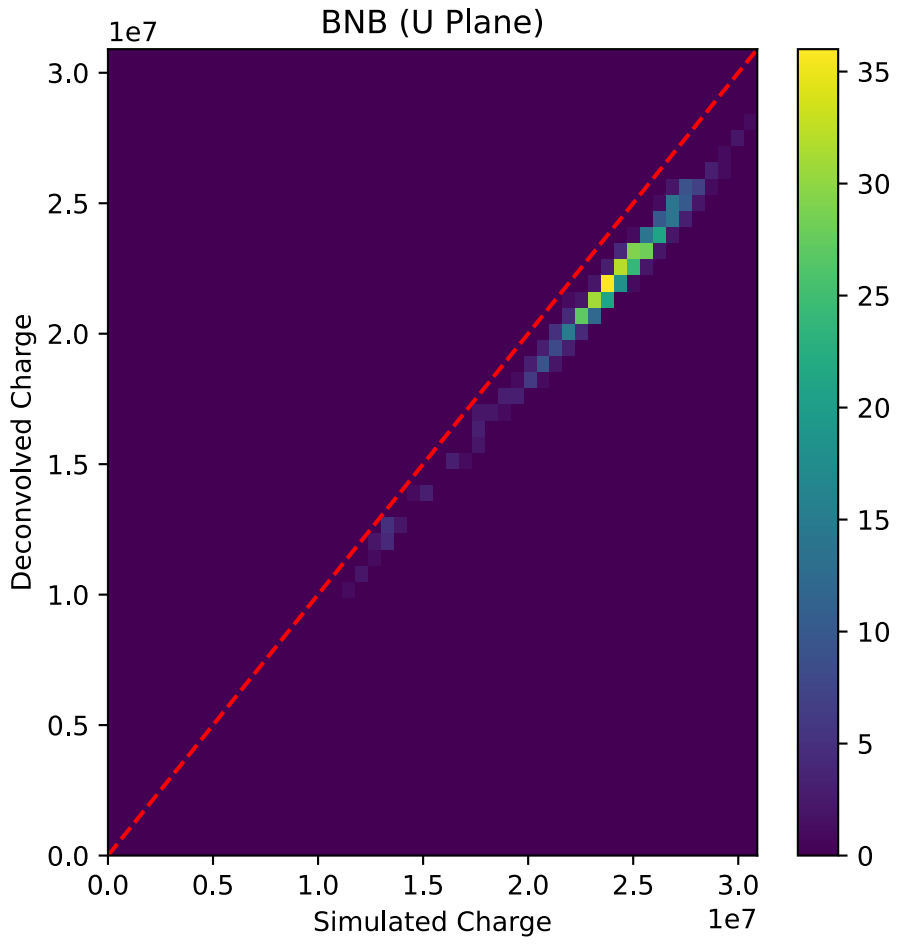

$E_{\text{shower}} \in$ [0.75 GeV, 0.90 GeV]
U Plane
V Plane
Traditional
DNN Showers
DNN Tracks
DNN BNB
Events
$(Q_{\text{decon}} - Q_{\text{true}})/Q_{\text{true}}$
0
100
200
300
400
500
−0.8
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8

$E_{\text{shower}} \in$ [0.90 GeV, 1.05 GeV]

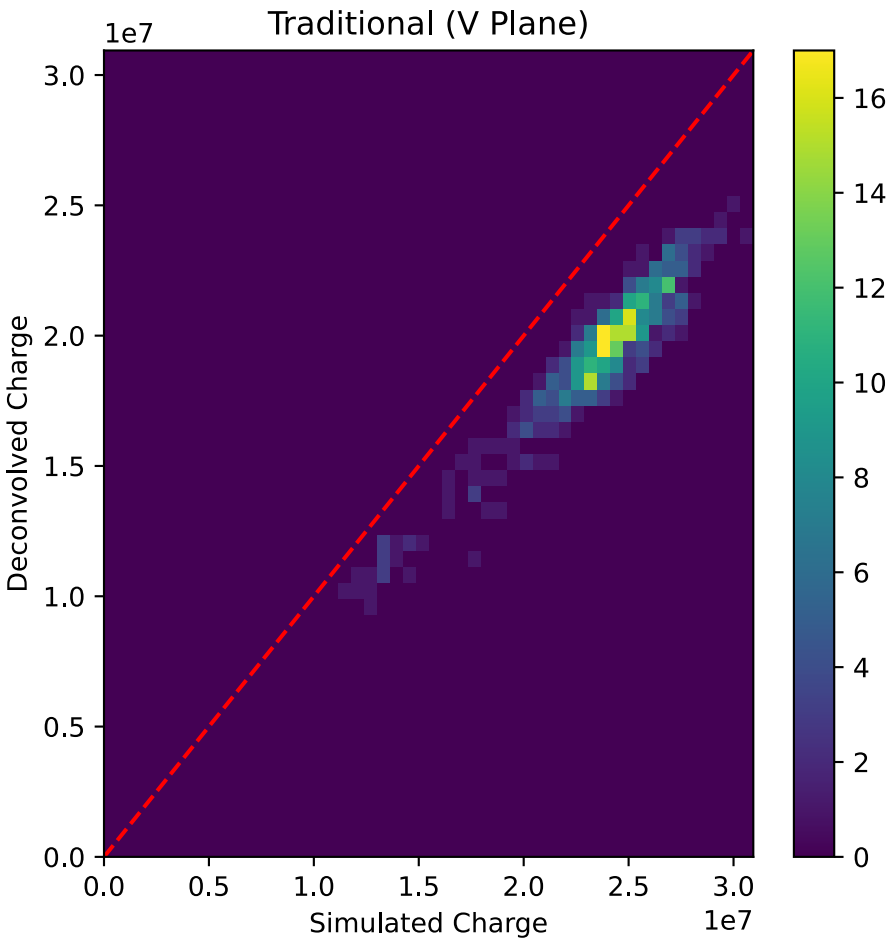


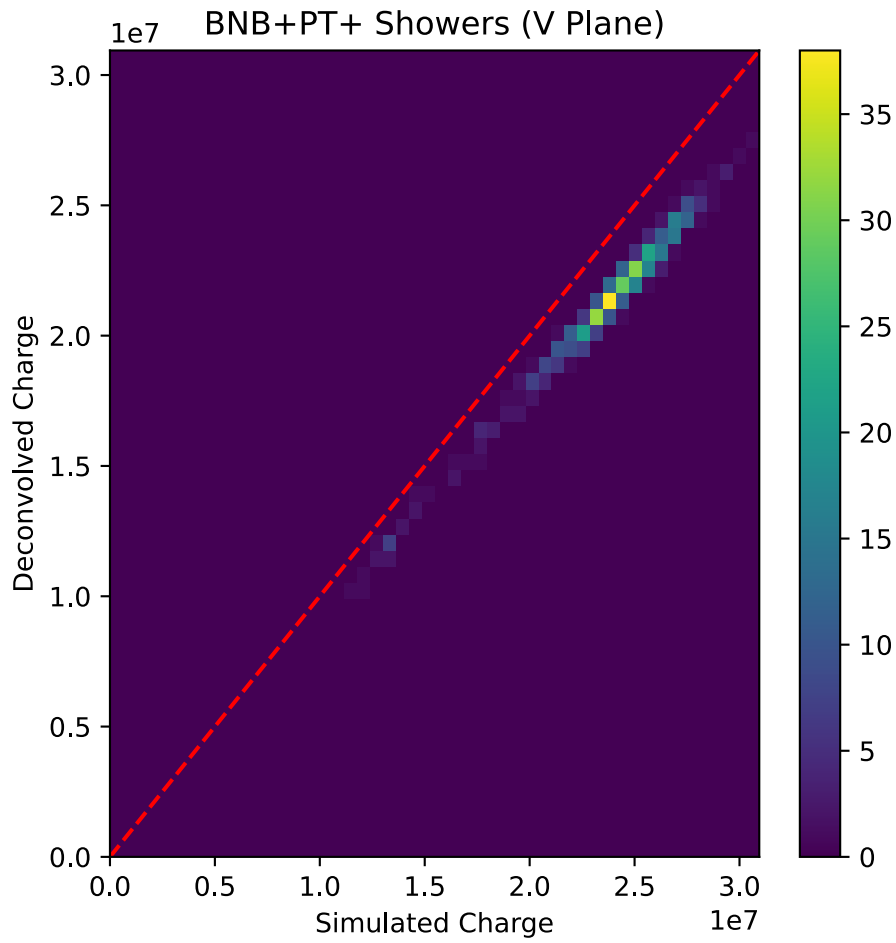


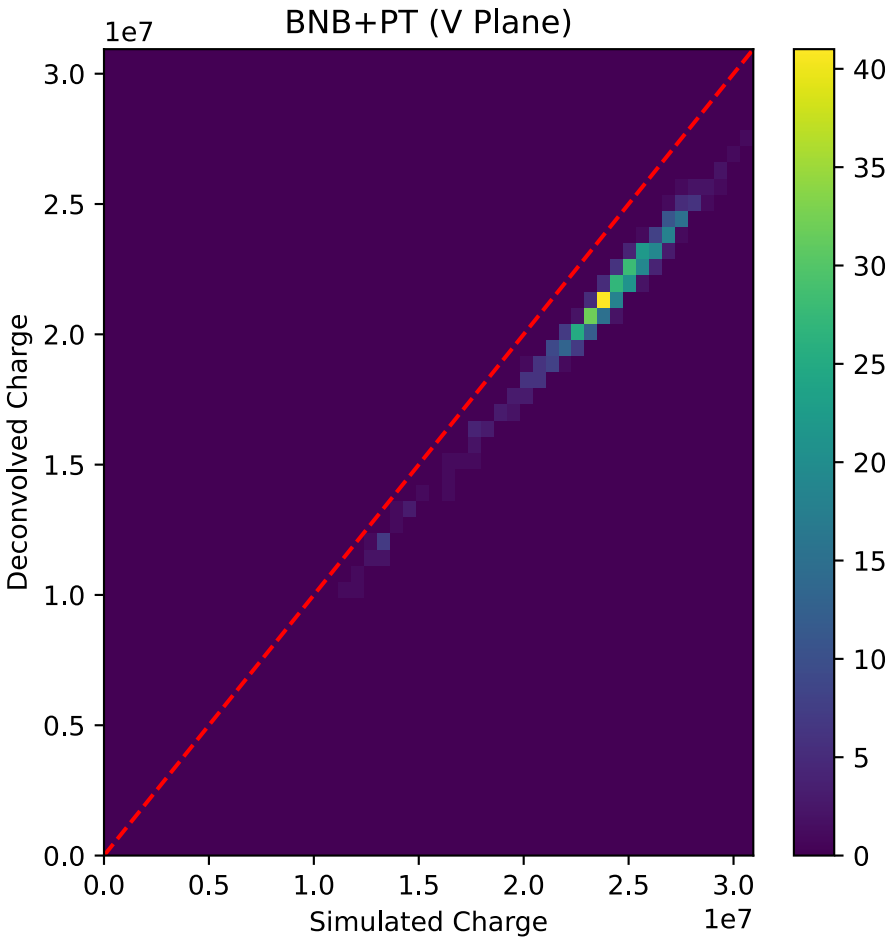


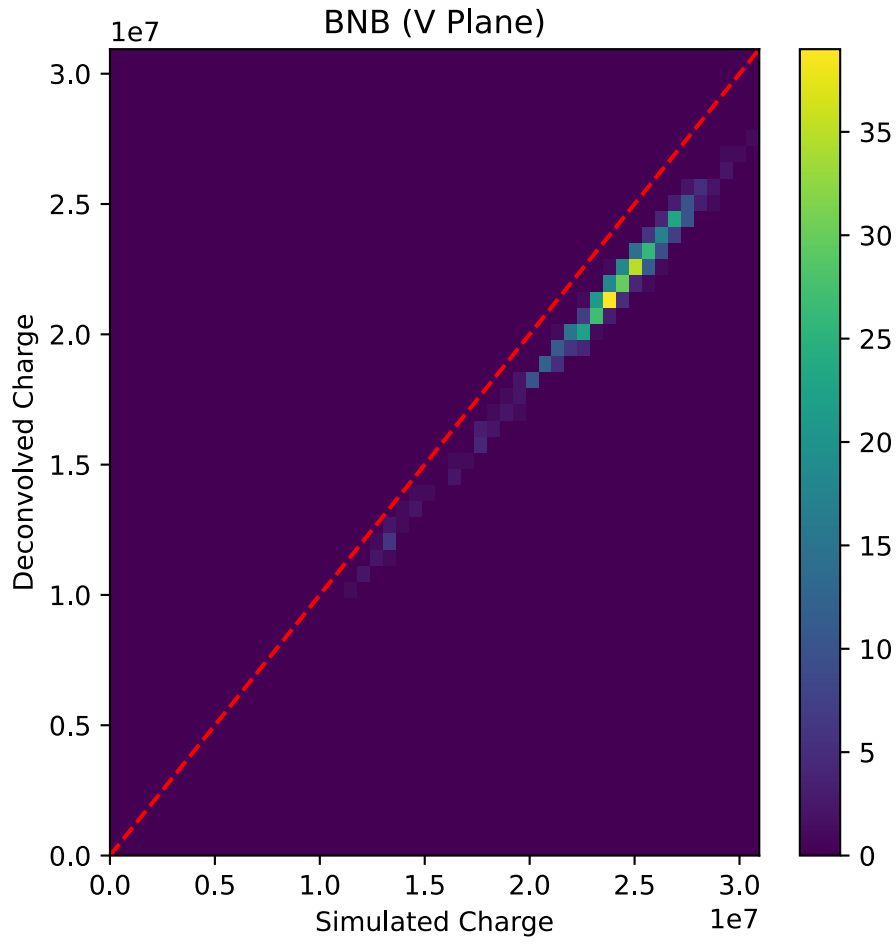


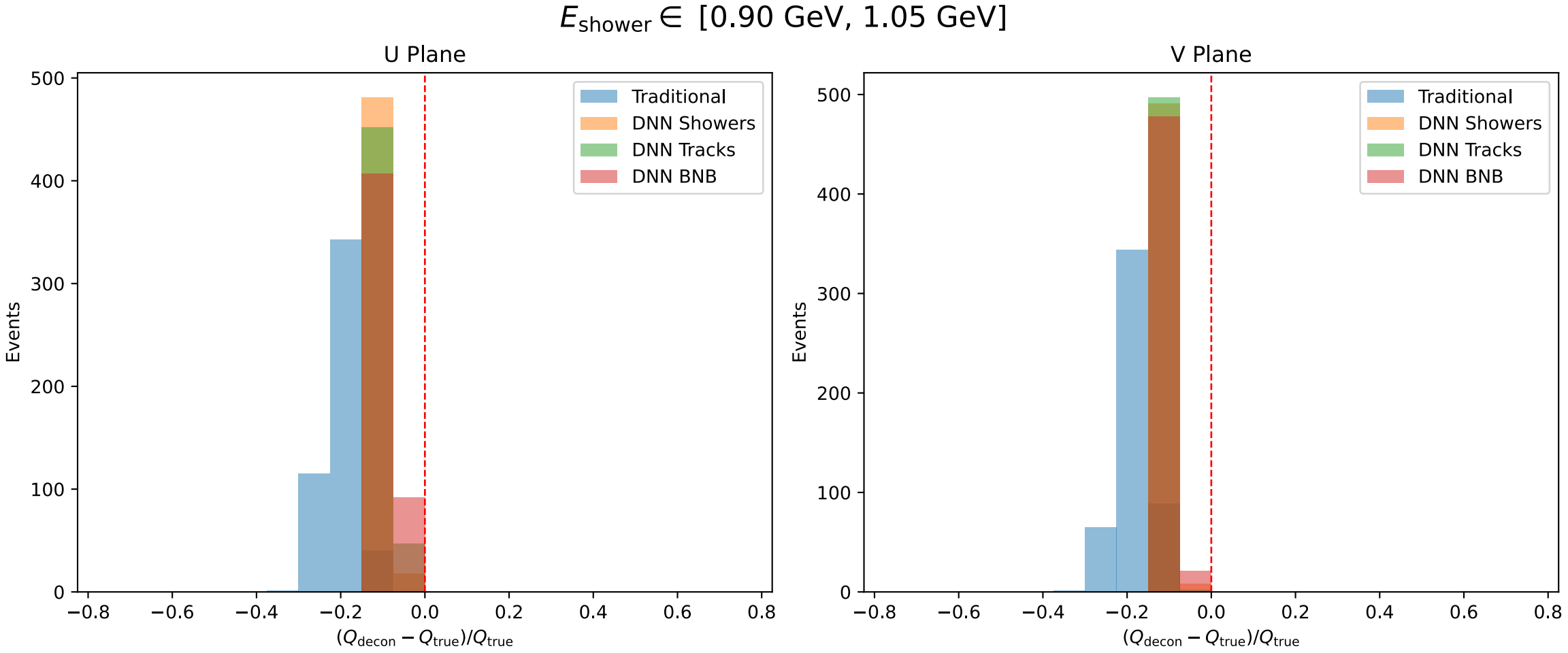
$E_{\text{shower}} \in$ [0.90 GeV, 1.05 GeV]



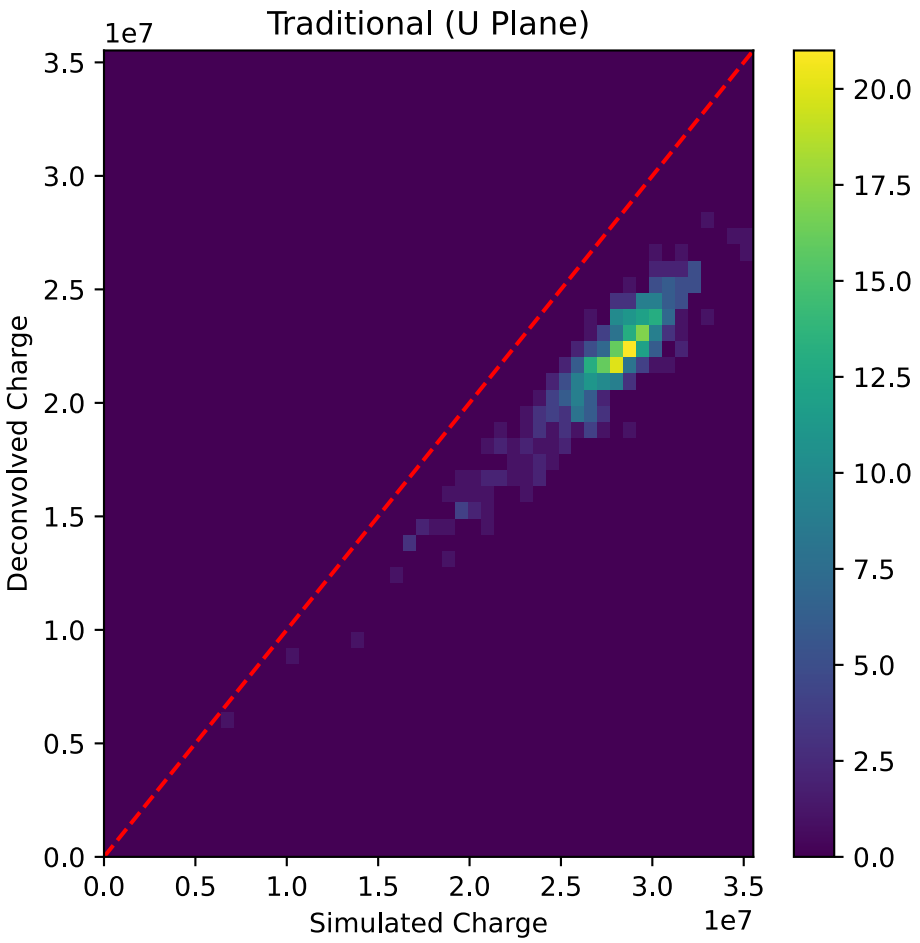


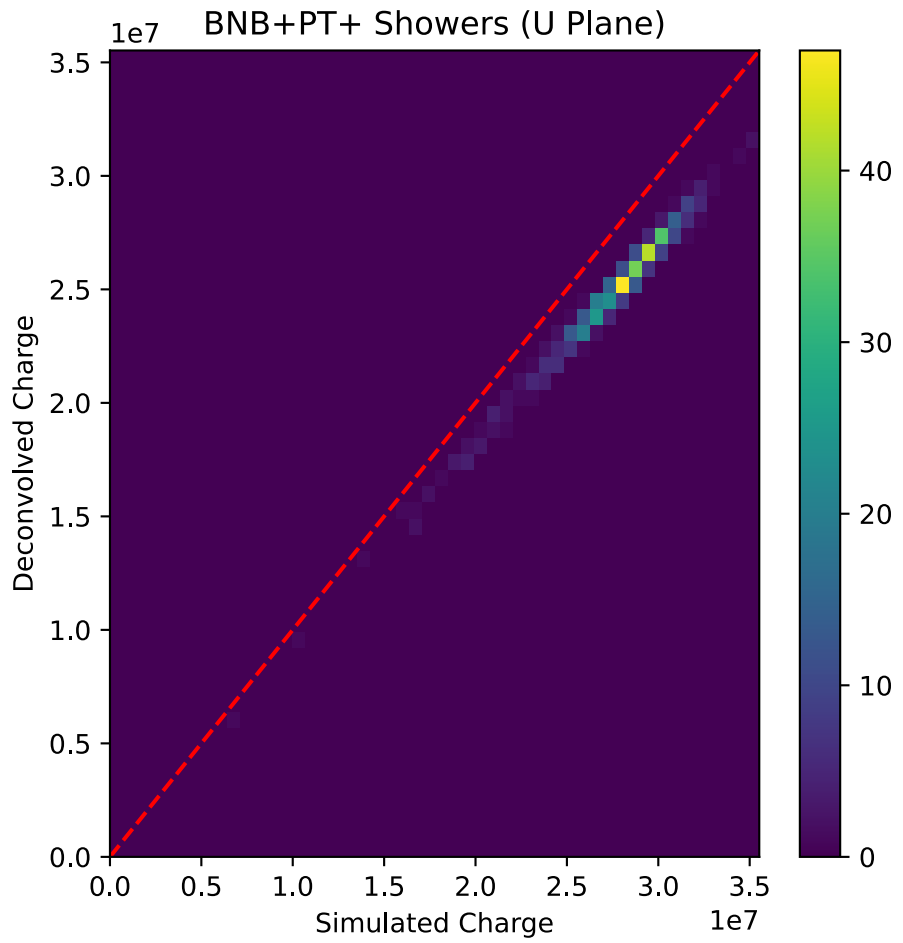


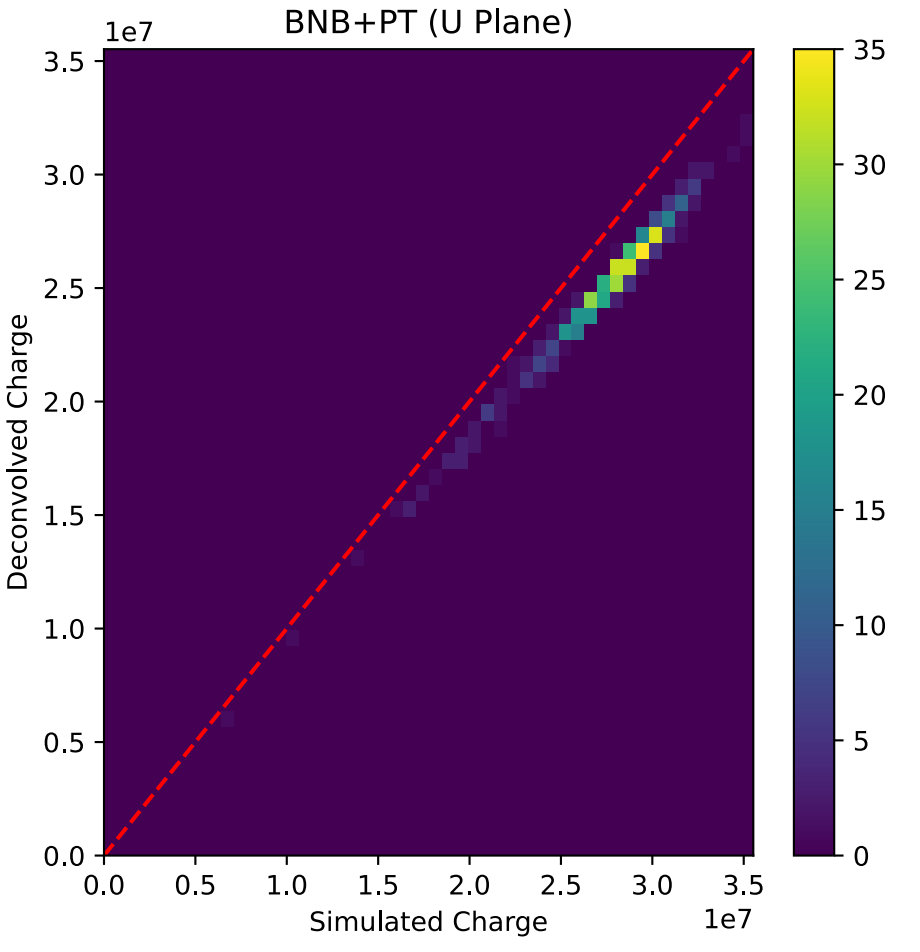


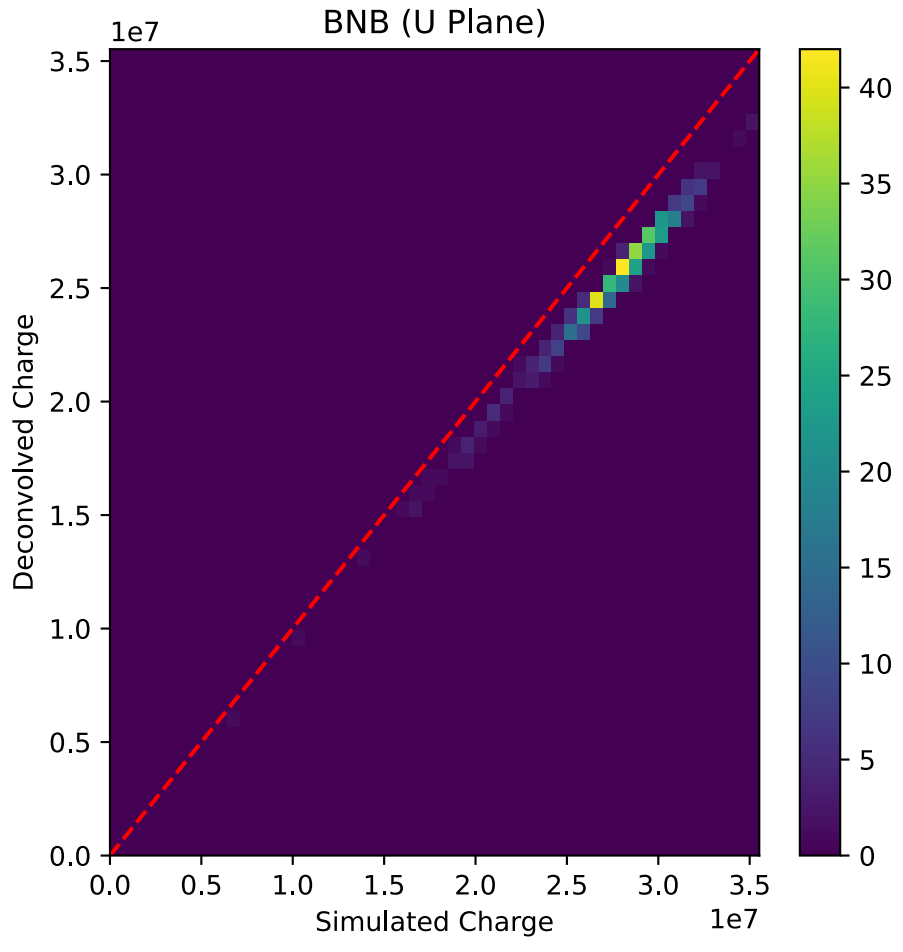

$E_{\text{shower}} \in$ [0.90 GeV, 1.05 GeV]
U Plane
V Plane
Traditional
DNN Showers
DNN Tracks
DNN BNB
Events
$(Q_{\text{decon}} - Q_{\text{true}})/Q_{\text{true}}$
0
100
200
300
400
500
−0.8
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8

$E_{\text{shower}} \in$ [1.05 GeV, 1.20 GeV]

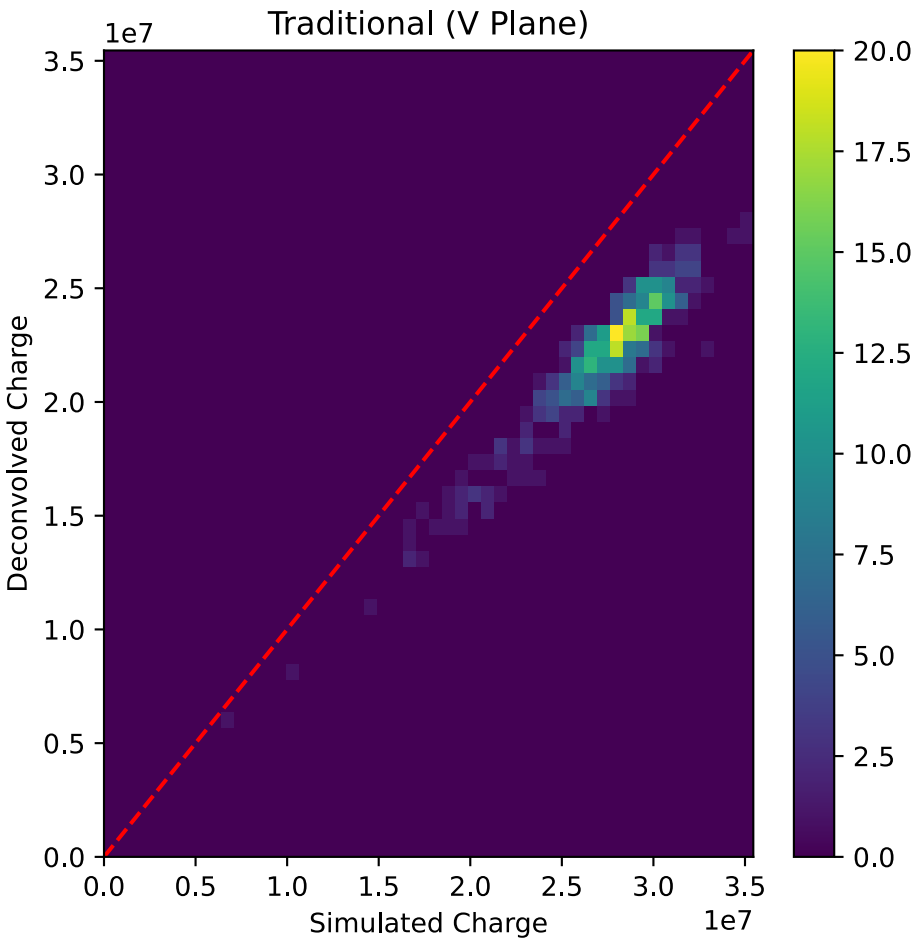


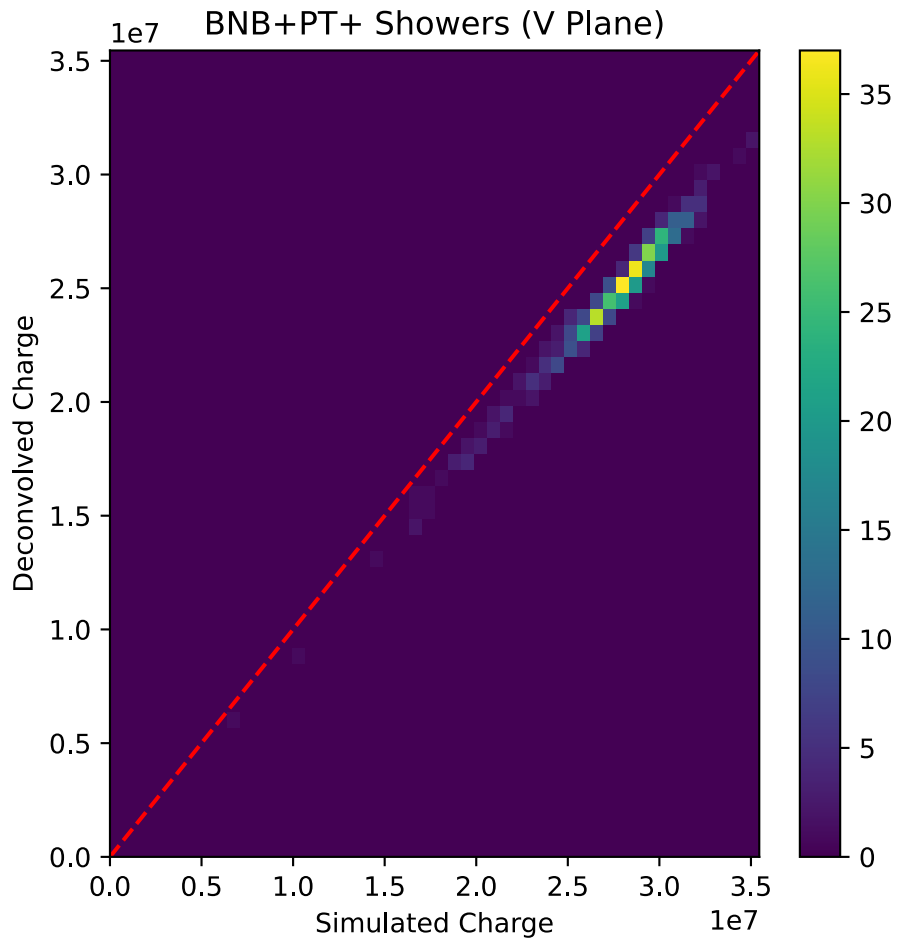


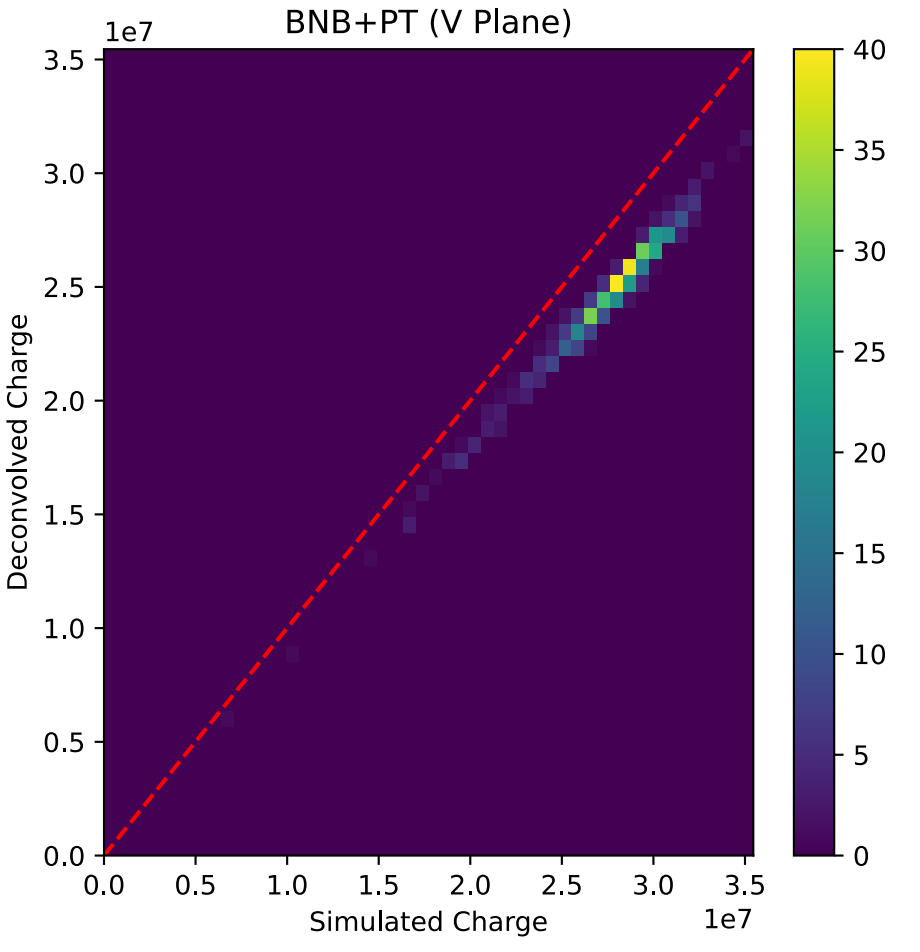


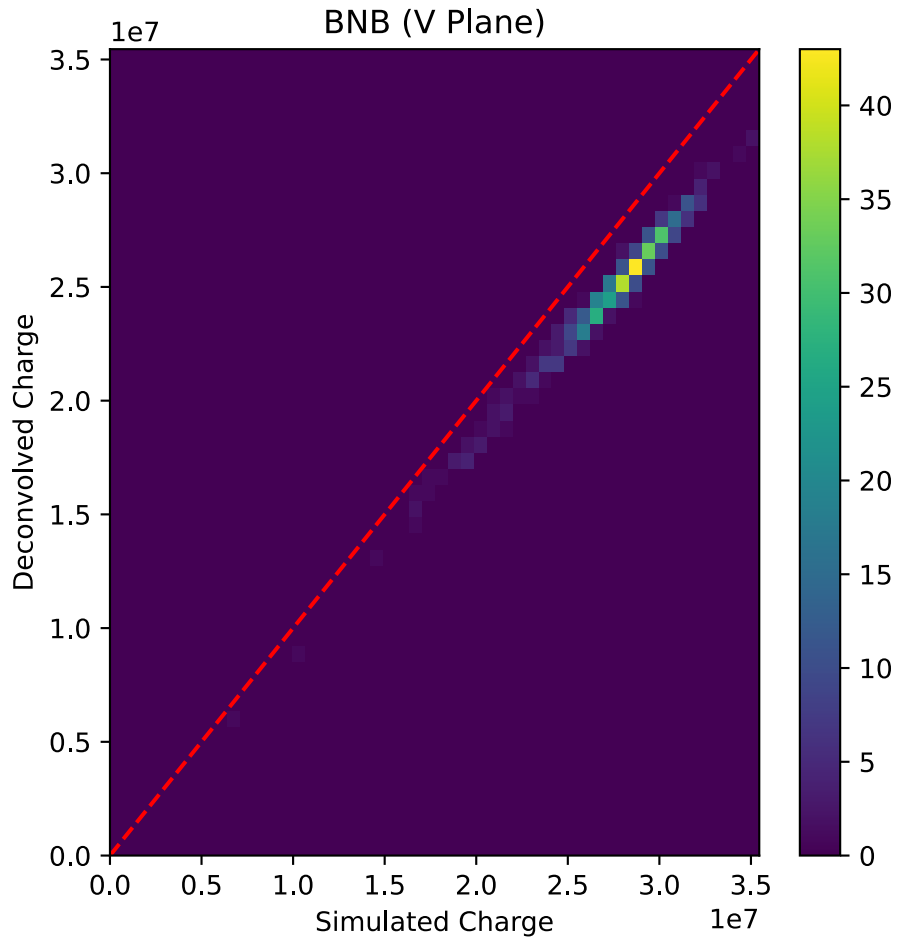


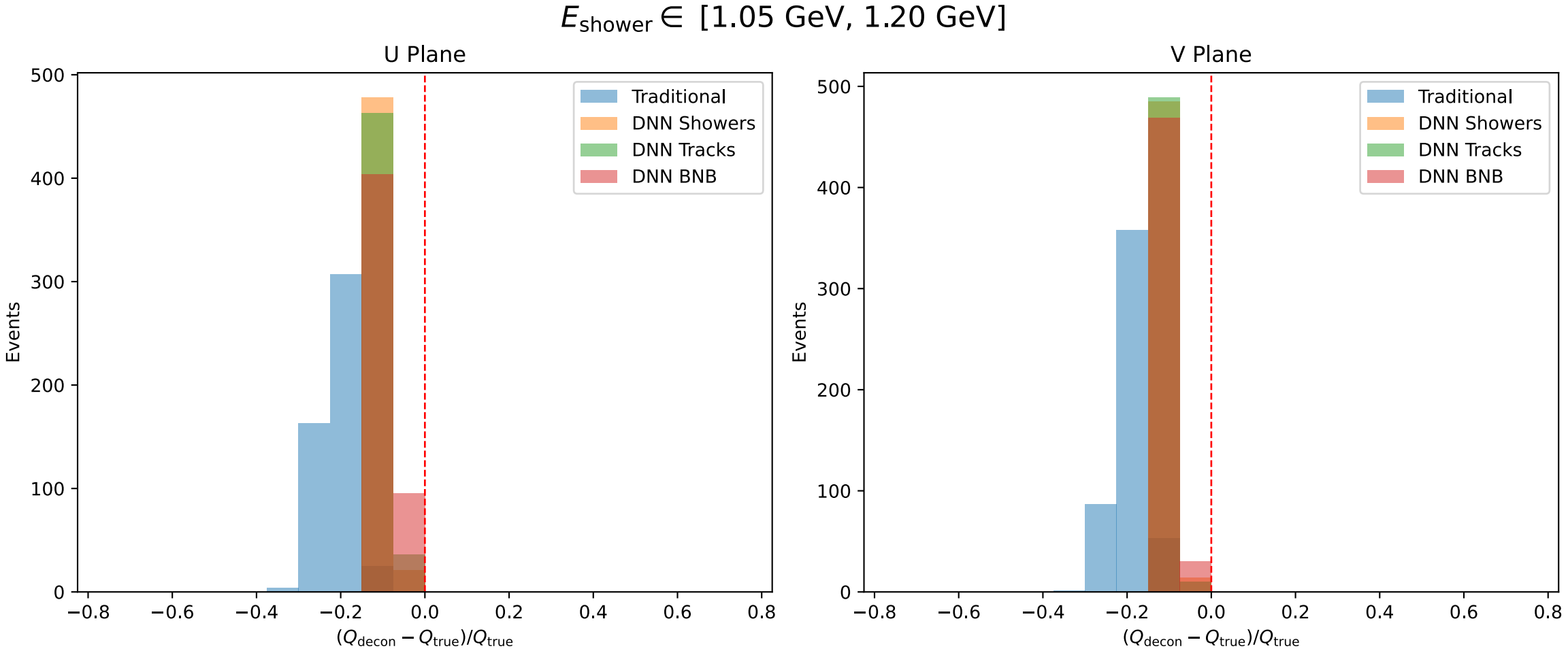
$E_{\text{shower}} \in$ [1.05 GeV, 1.20 GeV]



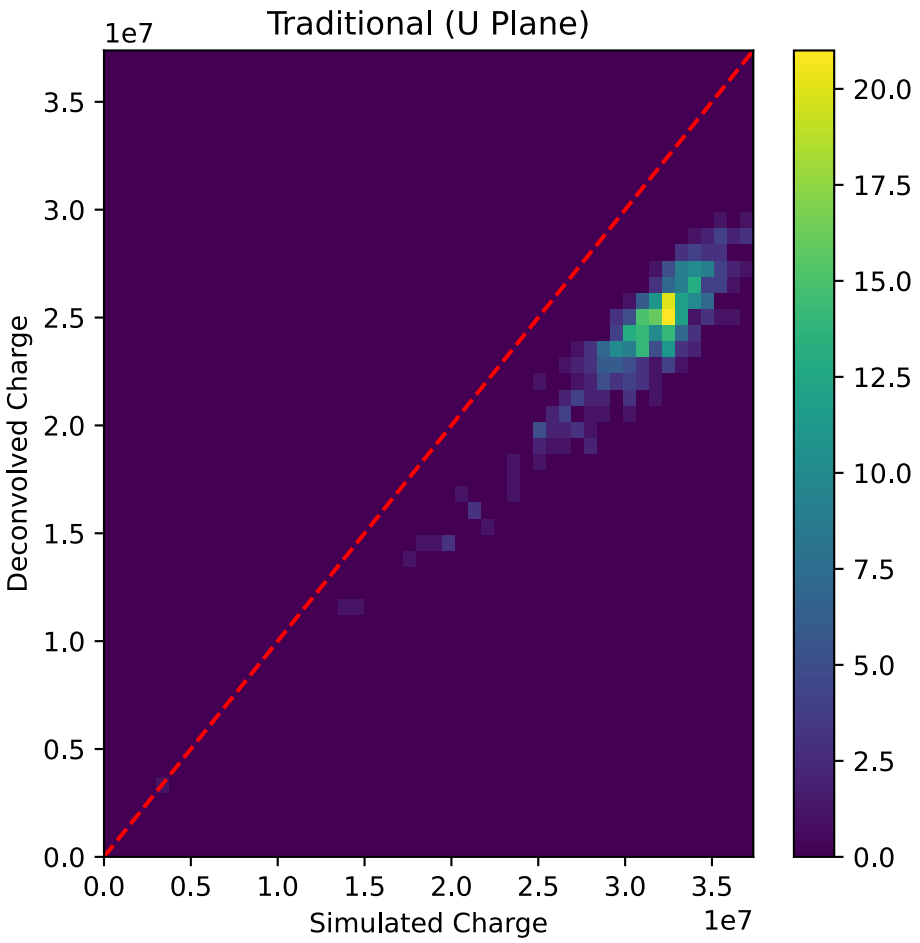


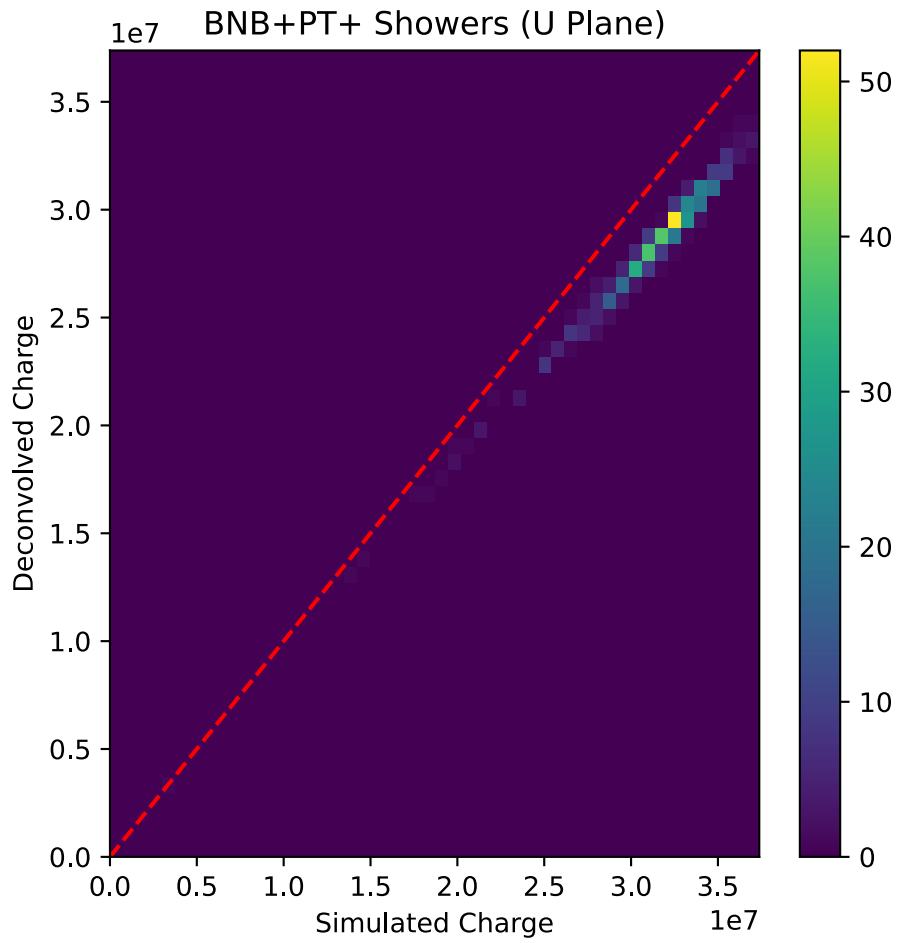


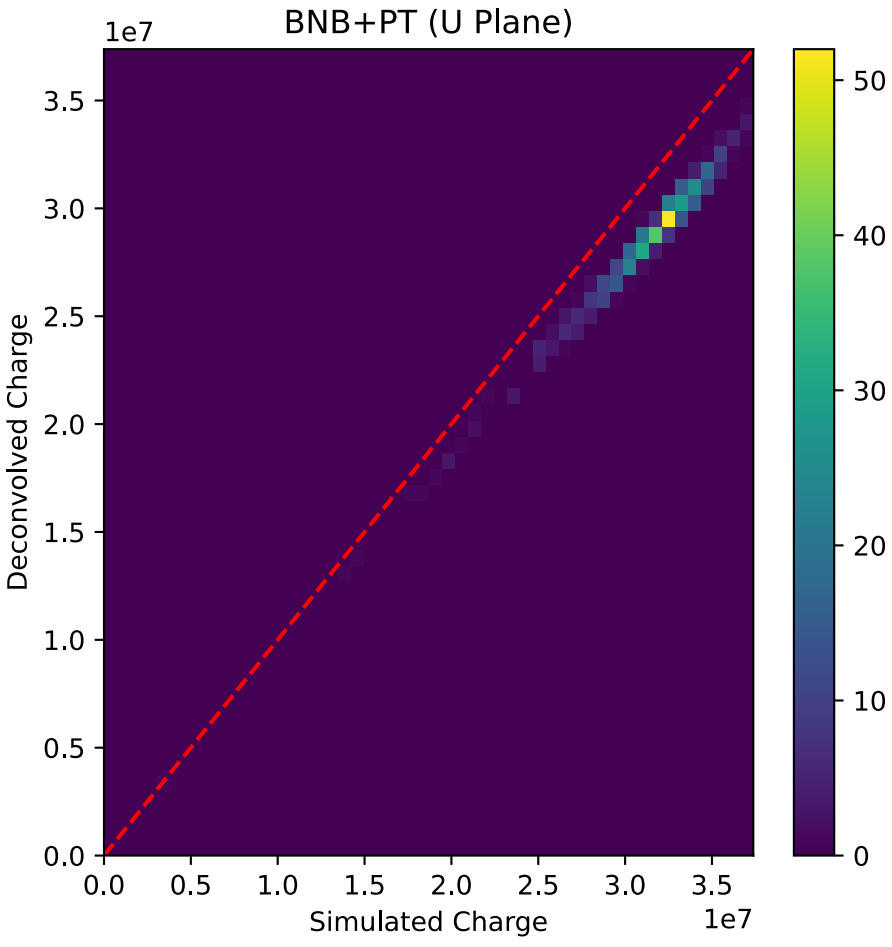


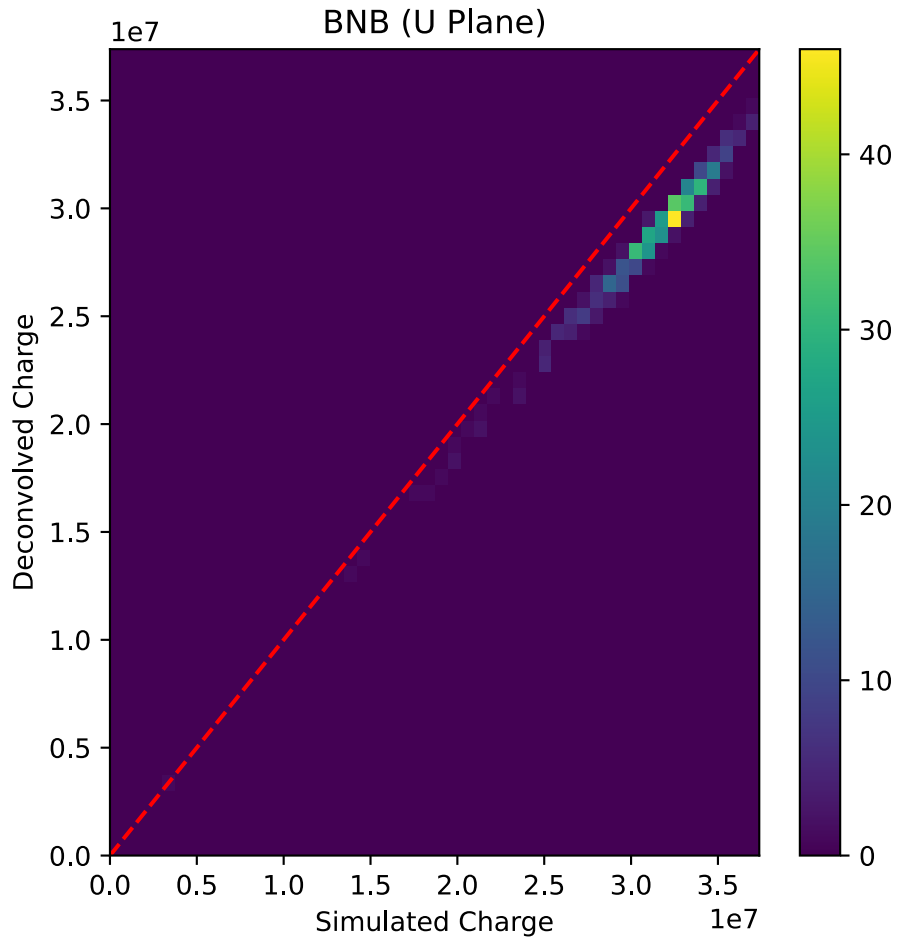

$E_{\text{shower}} \in$ [1.05 GeV, 1.20 GeV]
U Plane
V Plane
Traditional
DNN Showers
DNN Tracks
DNN BNB
Events
$(Q_{\text{decon}} - Q_{\text{true}})/Q_{\text{true}}$
0
100
200
300
400
500
−0.8
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8

$E_{\text{shower}} \in$ [1.20 GeV, 1.35 GeV]

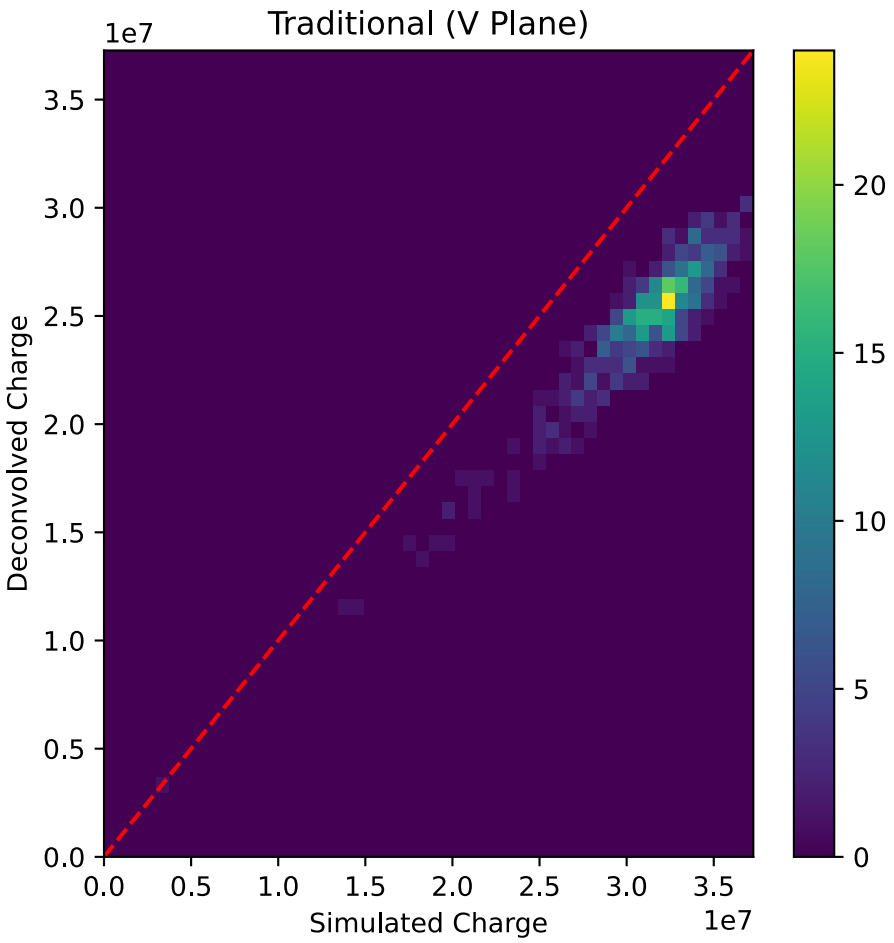


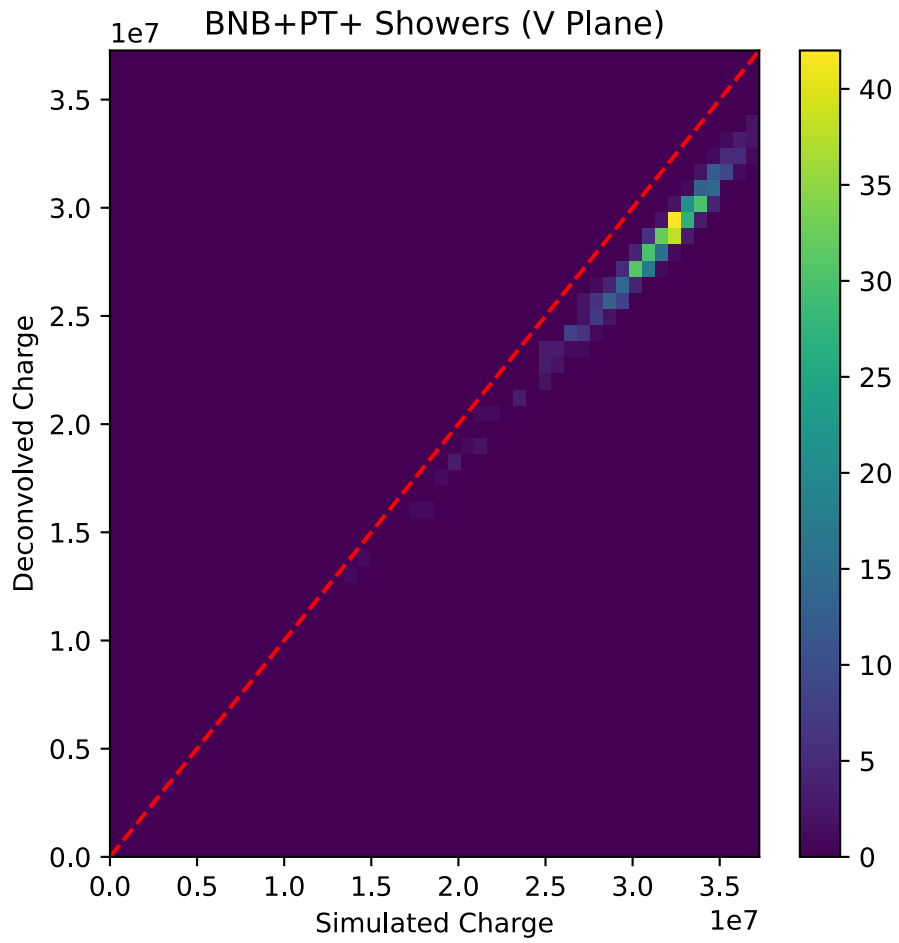


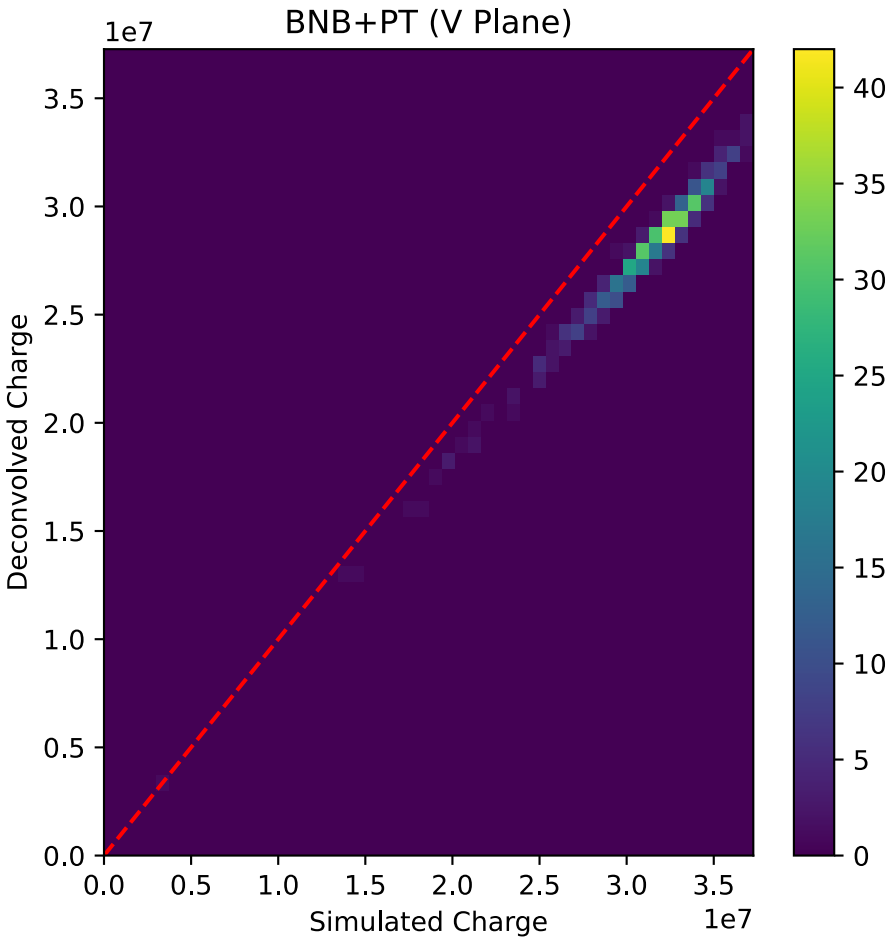


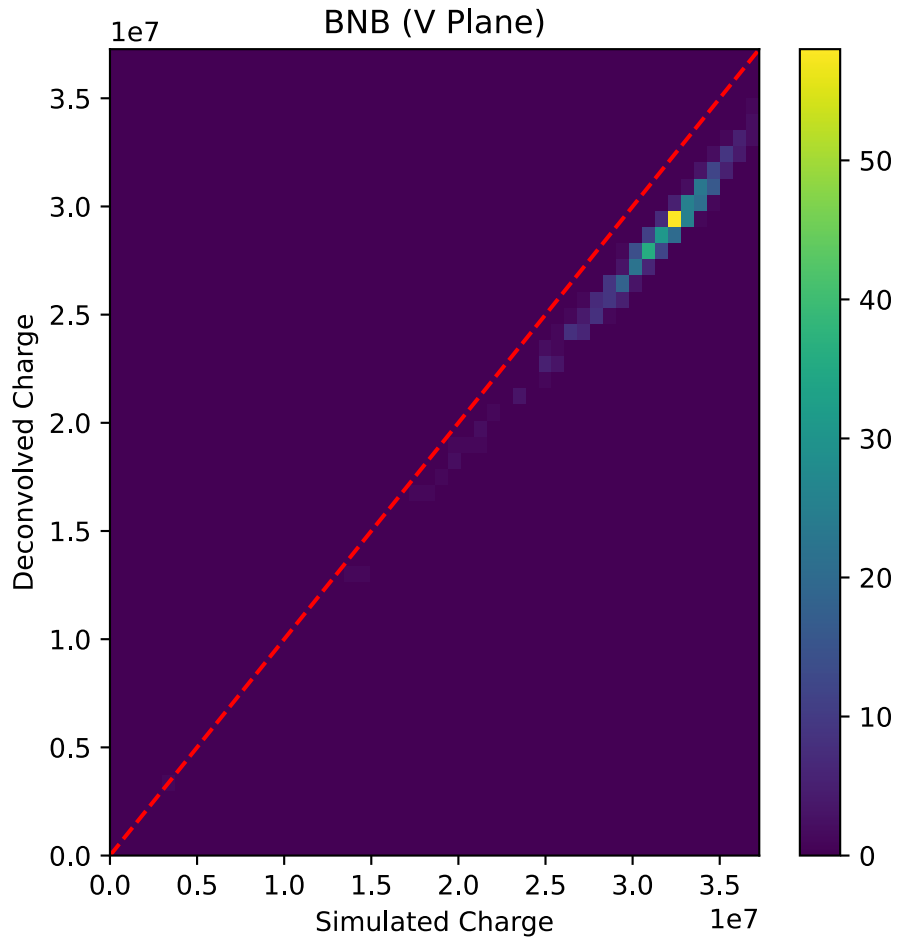


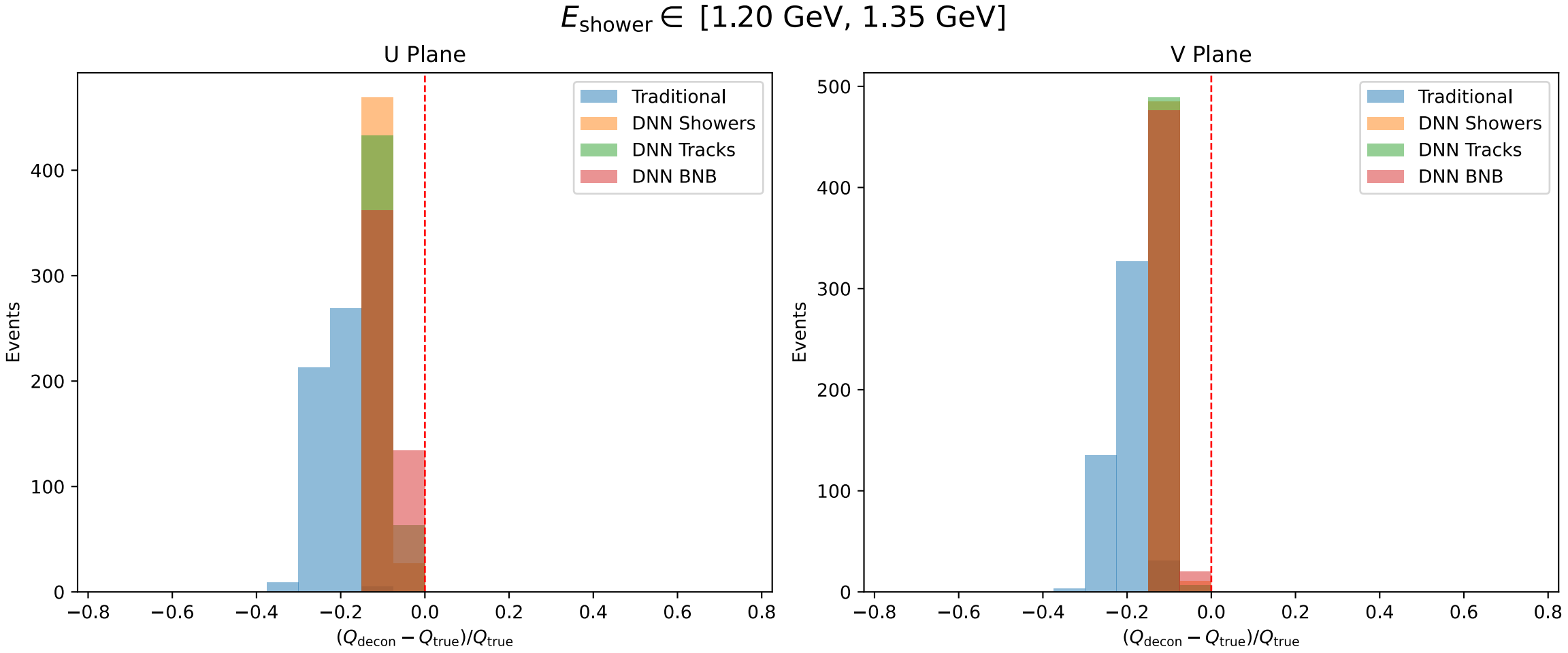
$E_{\text{shower}} \in$ [1.20 GeV, 1.35 GeV]



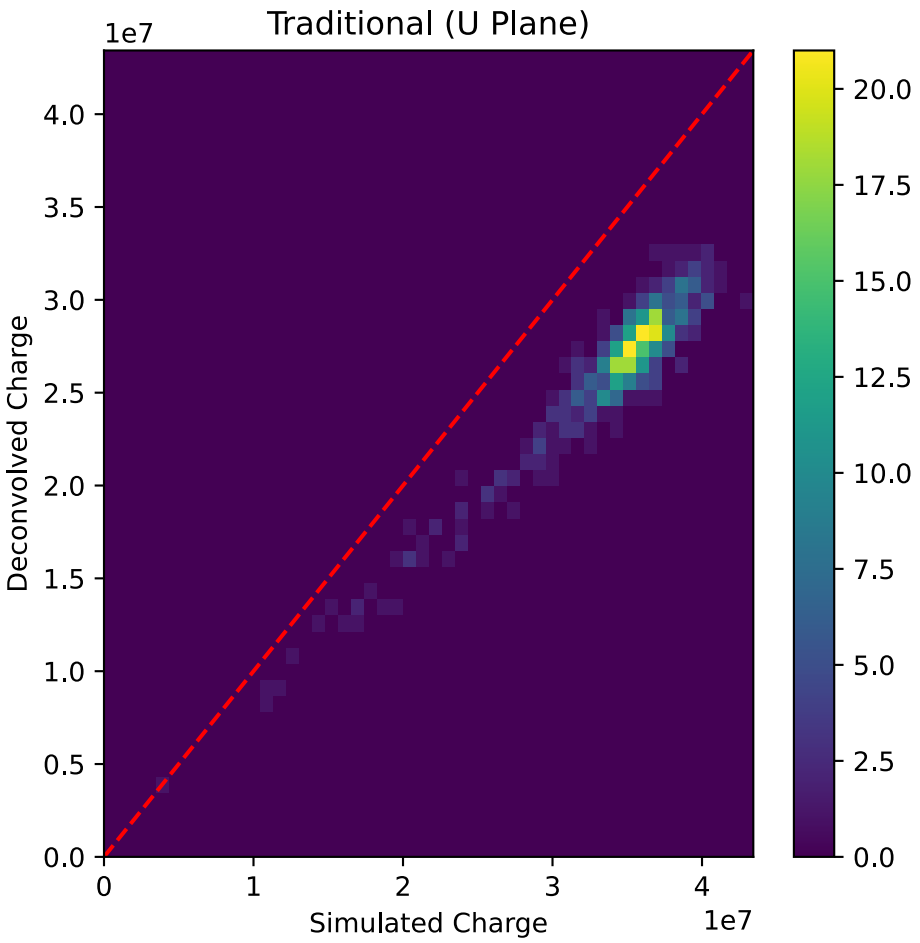


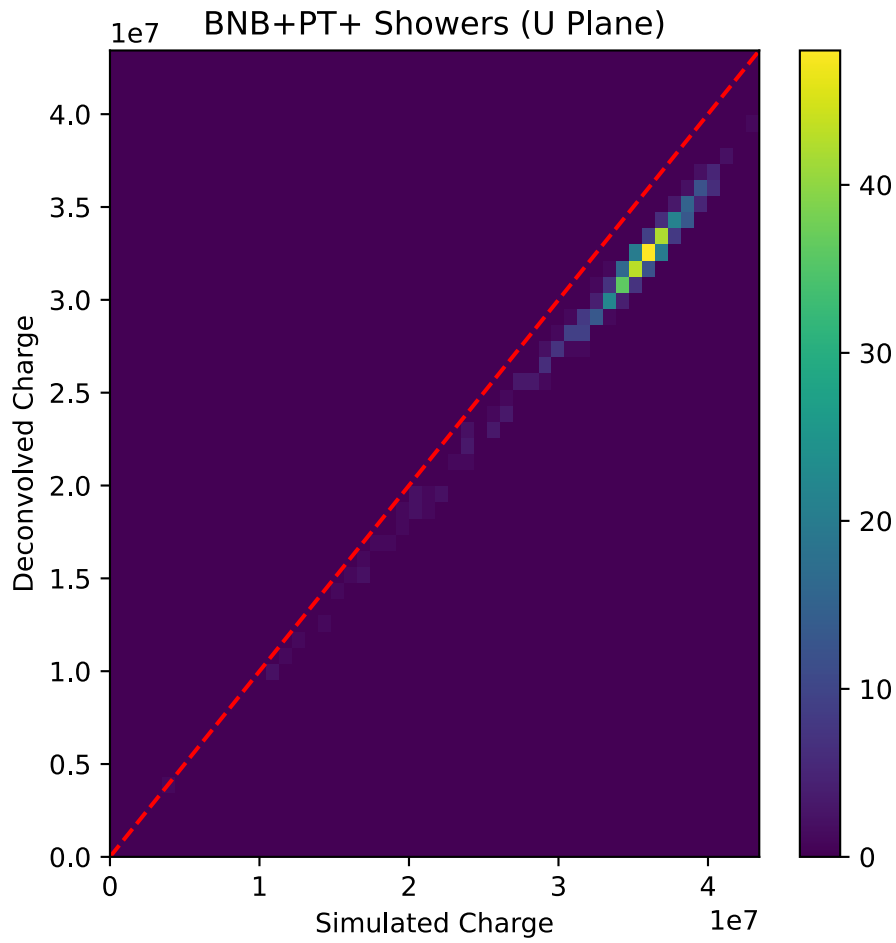


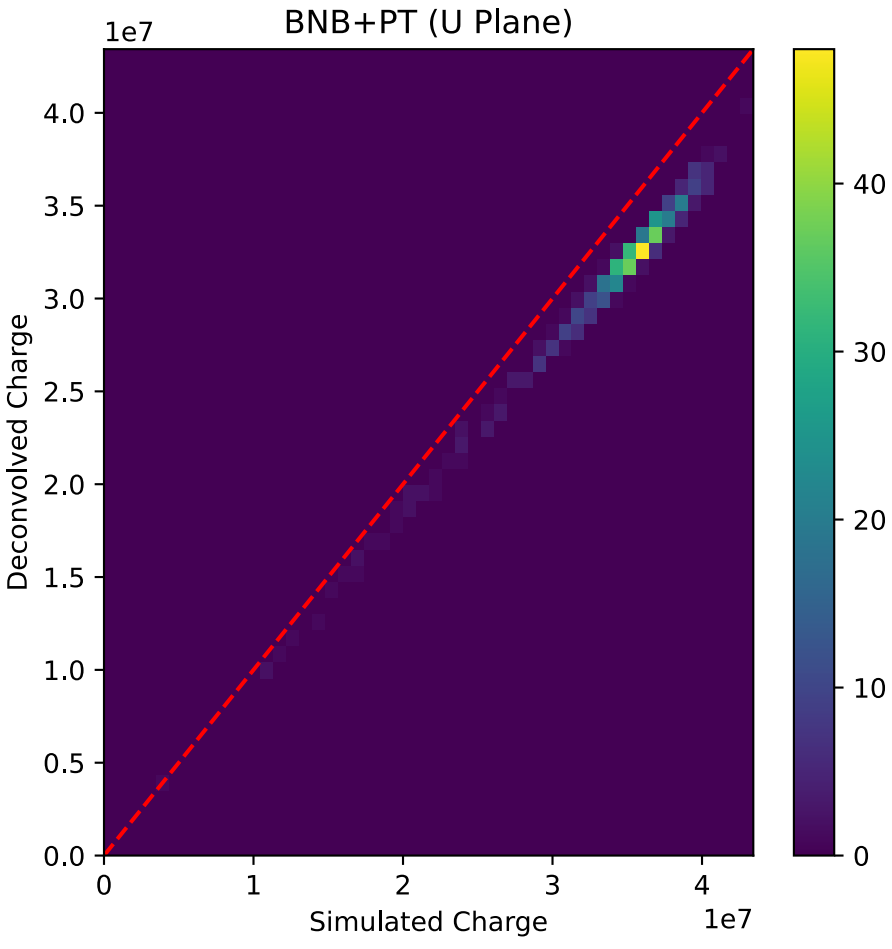


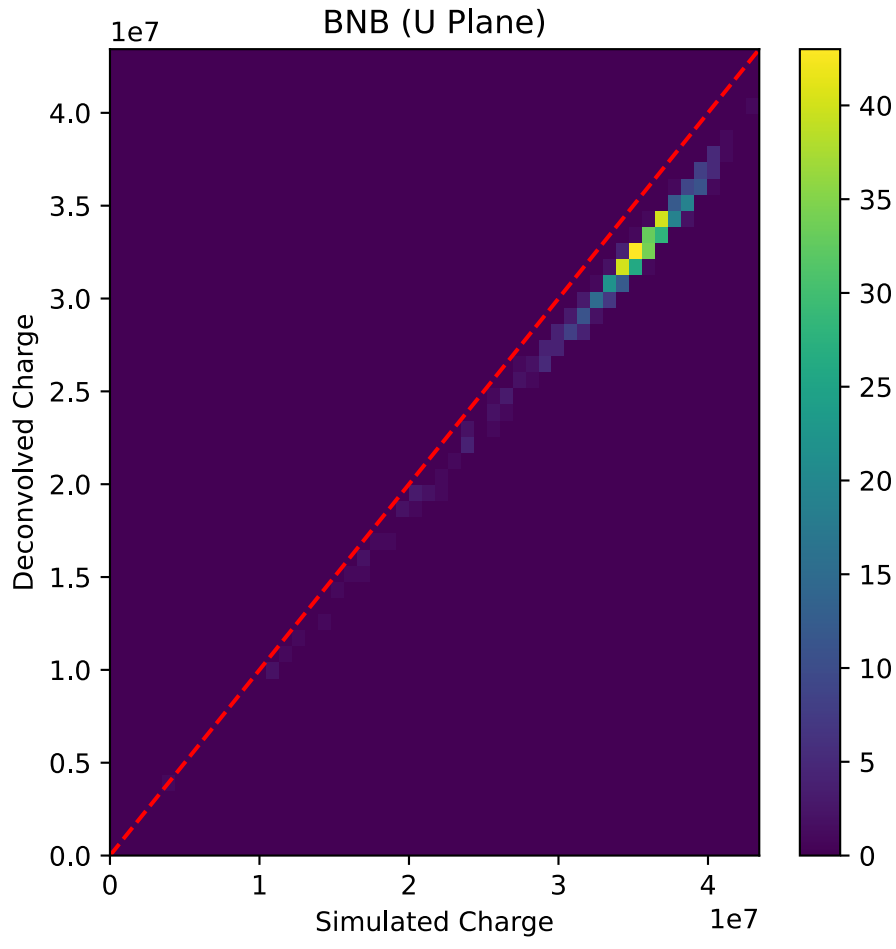

$E_{\text{shower}} \in$ [1.20 GeV, 1.35 GeV]
U Plane
V Plane
Traditional
DNN Showers
DNN Tracks
DNN BNB
Events
$(Q_{\text{decon}} - Q_{\text{true}})/Q_{\text{true}}$

$E_{\text{shower}} \in$ [1.35 GeV, 1.50 GeV]

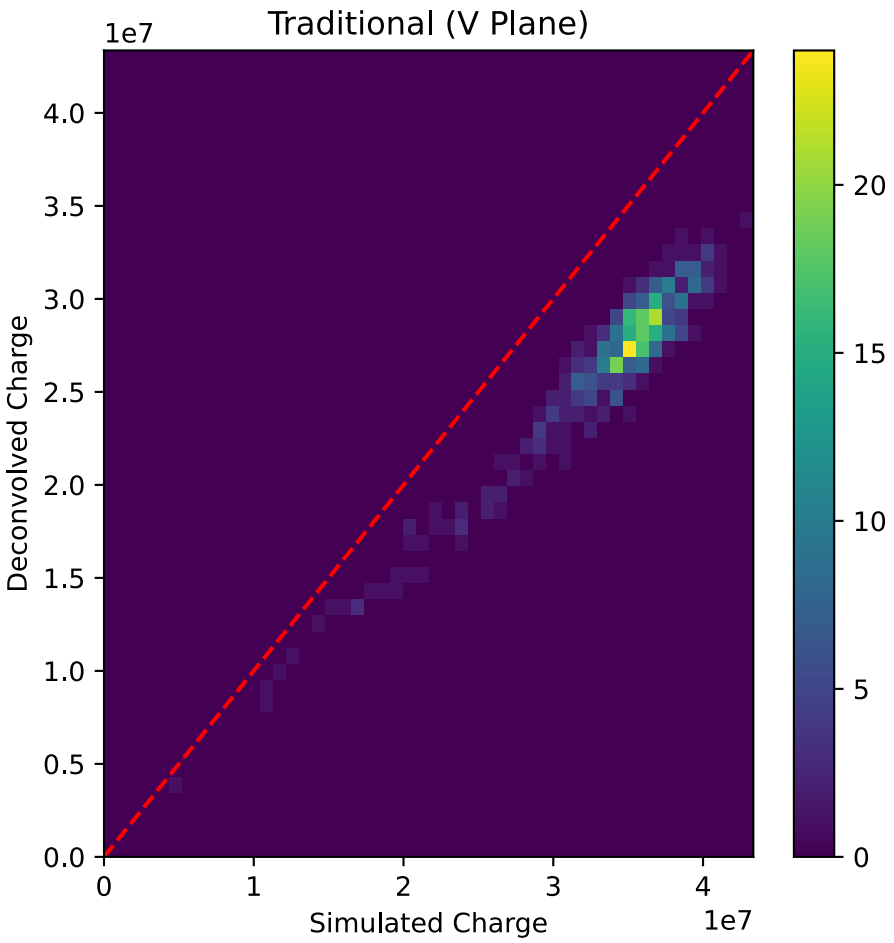


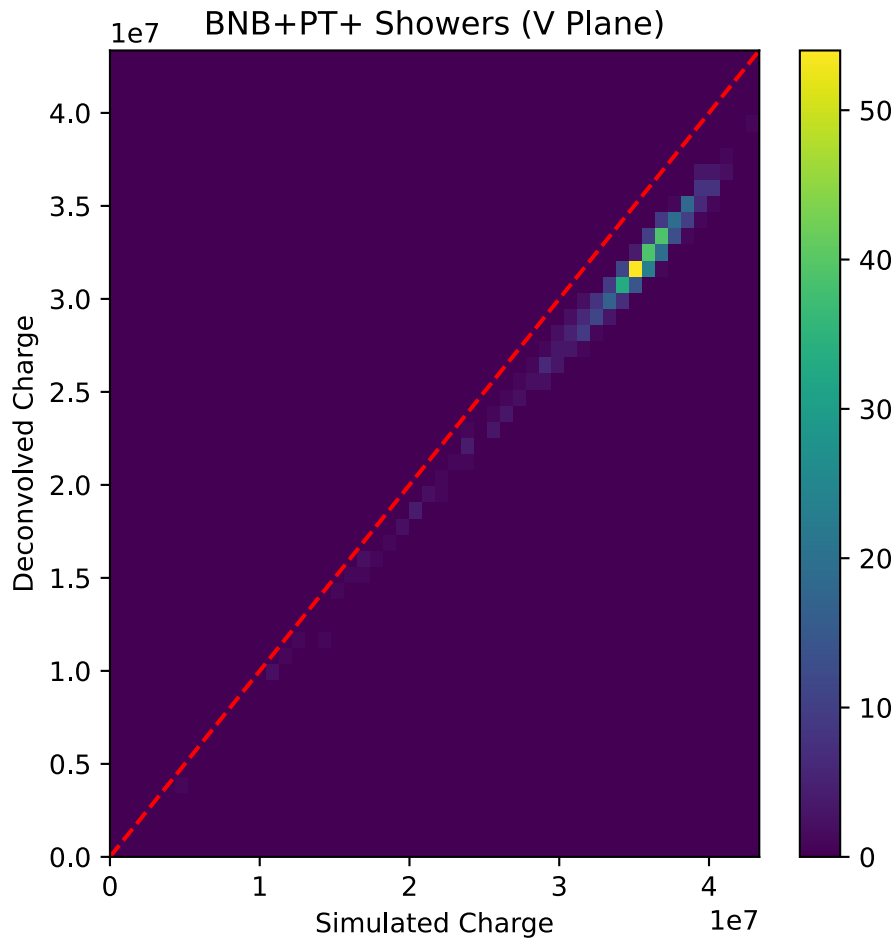


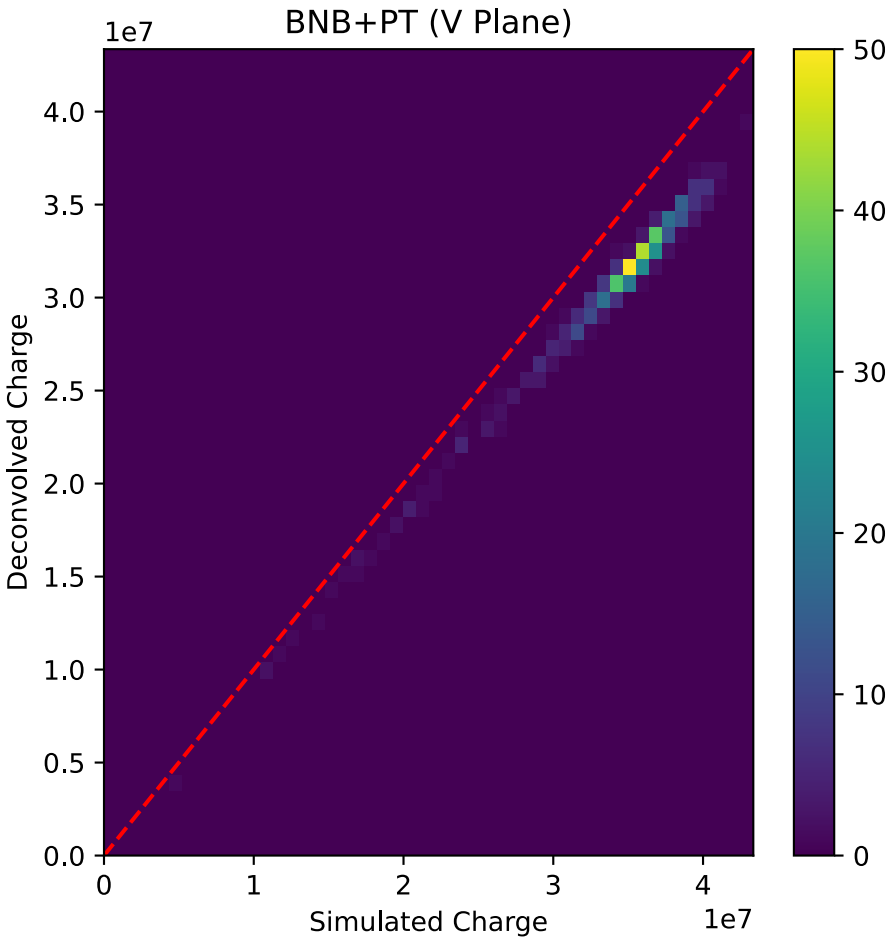


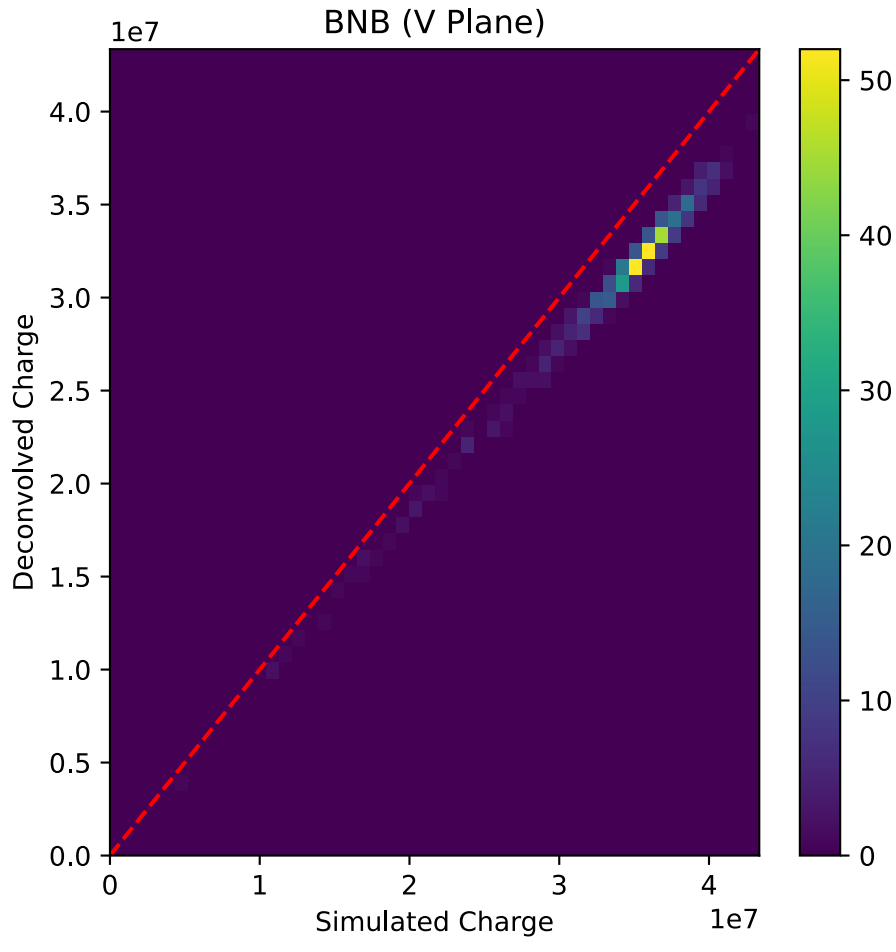


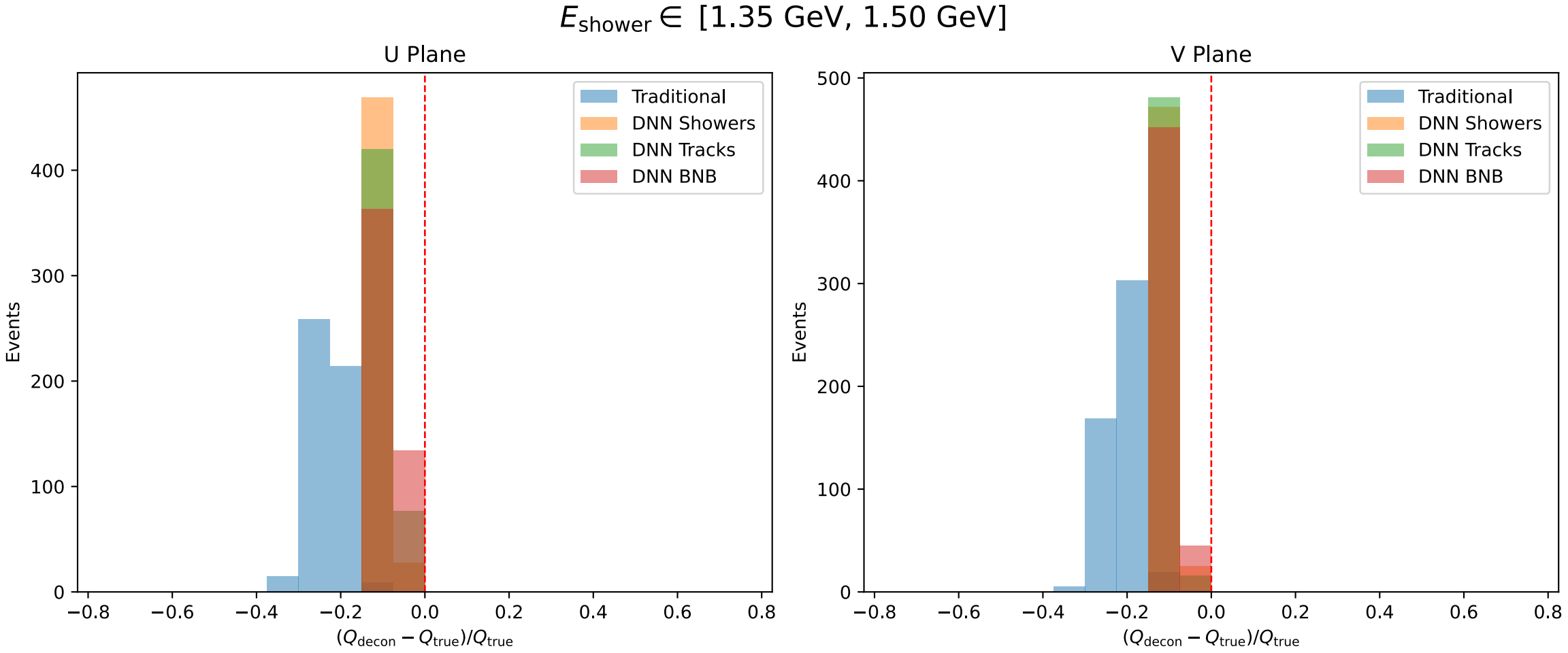
$E_{\text{shower}} \in$ [1.35 GeV, 1.50 GeV]










$E_{\text{shower}} \in$ [1.35 GeV, 1.50 GeV]
U Plane
V Plane
Traditional
DNN Showers
DNN Tracks
DNN BNB
Events
$(Q_{\text{decon}} - Q_{\text{true}})/Q_{\text{true}}$

Future Plans

- Evaluate the issues with traditional signal processing output that is jointly produced in the output files with the dnn row output.

```
WCLSre..... | simtpc2d..... | dnnsp..................................... | std::vector<recob::Wire>.................................... | 11264
WCLSre..... | simtpc2d..... | simpleSC.................................. | std::vector<sim::SimChannel>................................ | 11264
WCLSre..... | simtpc2d..... | wiener.................................... | std::vector<recob::Wire>.................................... | 11264
WCLSre..... | TriggerResults | ......................................... | art::TriggerResults......................................... | ....1
WCLSre..... | simtpc2d..... | gauss..................................... | std::vector<recob::Wire>.................................... | 11264
```

- Generate showers with BNB energy distribution and expected BNB angle distribution.

- Perform charge extraction again.