Status of em shower reconstruction in DUNE-FD DP

Andrea Scarpelli
APC - Paris
Université Paris Diderot (VII)

Introduction

EM showers reconstruction is one of the main interests for DUNE

- **γ conversion induced cascaded** are a source of background for ν_e**CC event —> electron induced cascades**.

- **Photon conversion gap** between the ν interaction vertex and the shower starting vertex is a powerful discriminant, but **difficult to detect**

- **dE/dx at the beginning of the cascade is discriminating between signal and background events** (double m.i.p. from γ conversion)

- Single **electrons showers will be seen in the 6x6x6 prototype**

In this presentation

- **I tested "emshower" module in DP** with **single showers** events of **photons and electrons, isotropic** in direction and starting position (10k events)

- Observed the **Energy deposit** and the **dEdx**, as well as the **shower direction and reconstruction efficiency**

Status of showers reco in LArSoft

In LArSoft exist some modules for reconstructing showers in SP

- "**Emshower**" (Mike Wallberg): module **used in this presentation** and approved for MCC: http://docs.dunescience.org:8080/cgi-bin/RetrieveFile?docid=1369&filename=emShower.pdf&version=1

- "**Trajcluster**" (Bruce Baller): not yet tested for showers in DP: https://cdcvs.fnal.gov/redmine/documents/1026

- "**Pandora**": pattern recognition module. It seems not working very well on DUNE-FD: https://indico.fnal.gov/getFile.py/access?contribId=36&sessionId=16&resId=0&materialId=slides&confId=10641

Now the module "emshower" has been calibrated and tested and it can be used also for DP studies

DP Geo in LArSoft

- **DP geometry for DUNE 10kt DP is already present in LArSoft** (by Slavic Galymov): https://indico.fnal.gov/getFile.py/access?contribId=2&resId=0&materialId=slides&confId=11402

- **DP geometry for ProtoDUNE recently implemented** (see Christoph's talk), not used for this work)

- Known issues (See Christoph's talk):

    - **Gap** between the CRMs

    - **Drift direction** along x and not z

    - Plane implementation could be more realistic

A look into an event display

Electron 13 Shower 4.6 GeV
- Reco
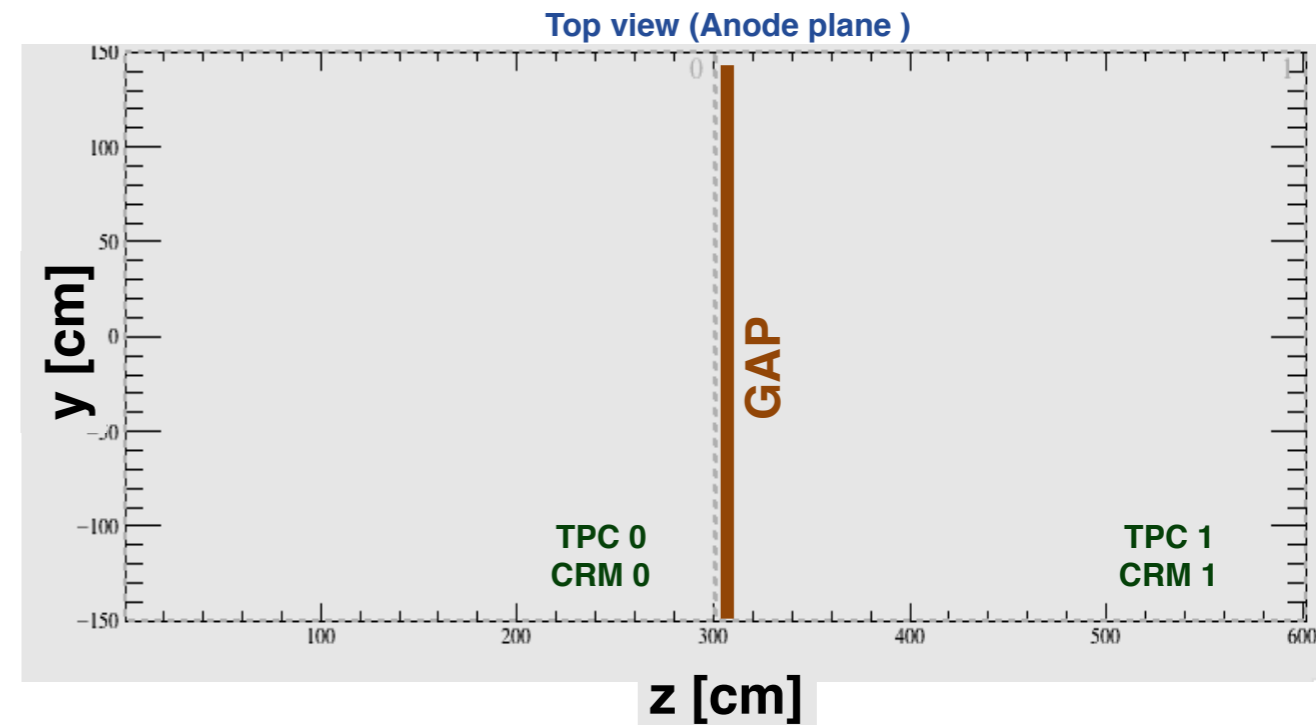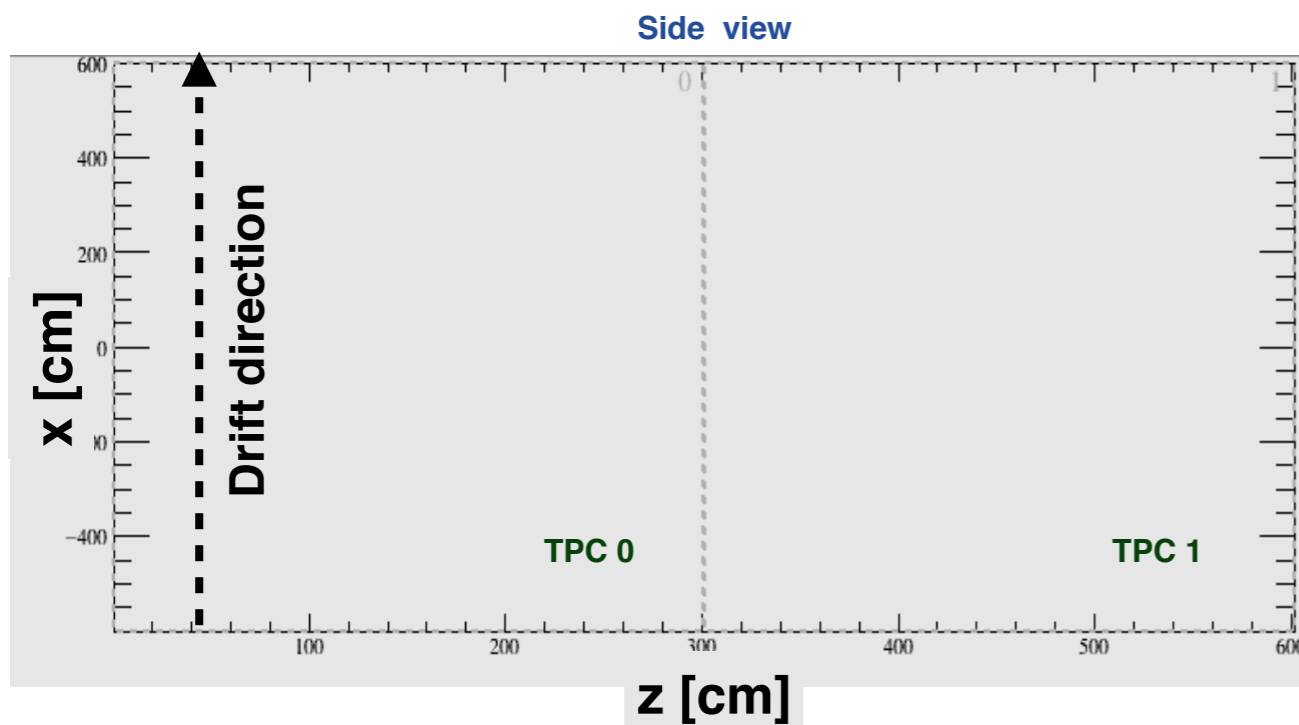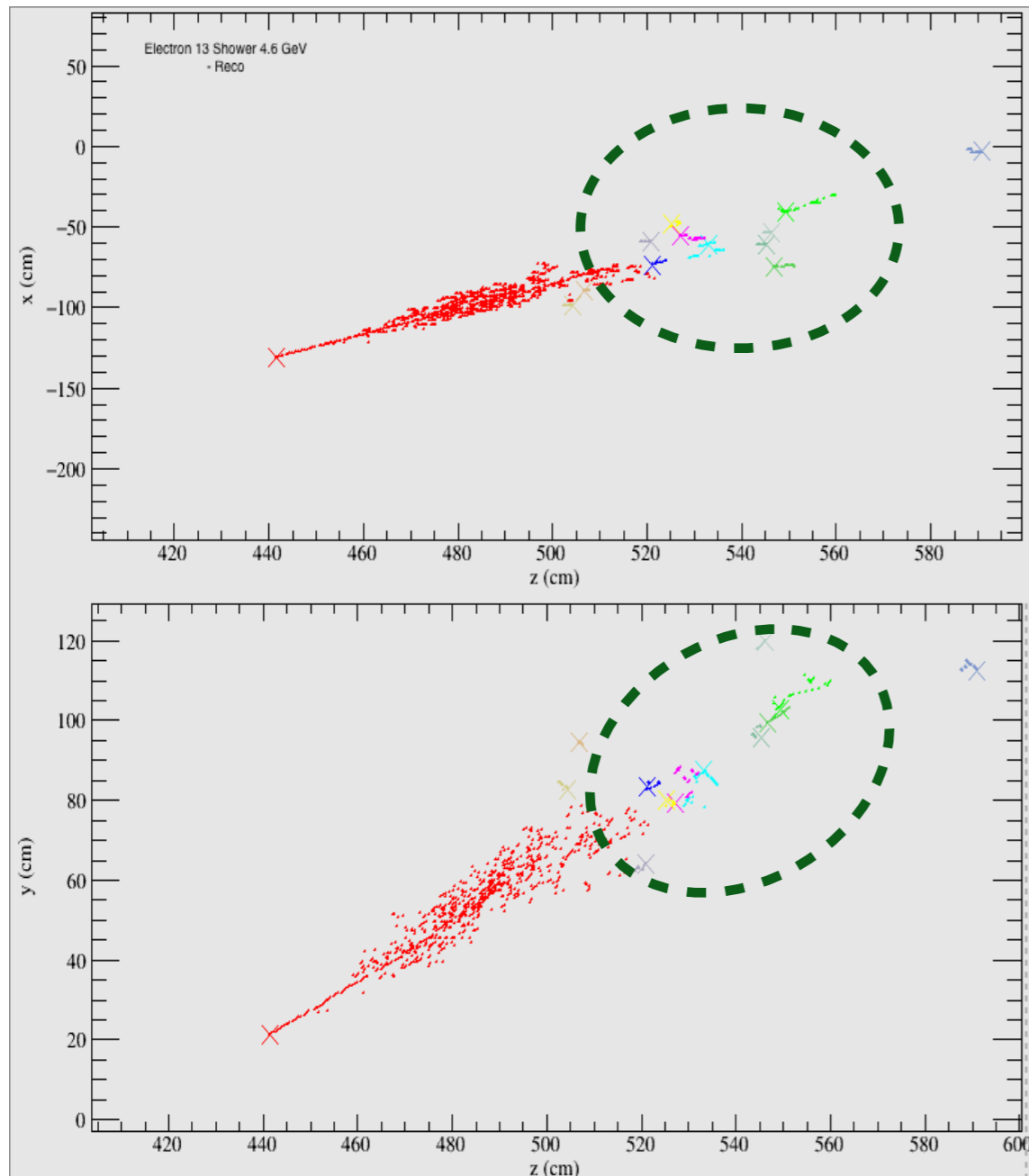
Most of the time a **best shower** is reconstructed, with **many secondaries**.

**Known problem also for SP, not yet addressed.**

Can define a **BestShower** as the shower with the largest number of hits

A look into an event display - 2

The best shower may be cut into **two pieces crossing the dead volume**

If the second part of the shower (right after the dead volume) is considered a shower and labelled as BestShower, direction and starting position are corrupted.

**Discard showers which are not fully included into a single TPC**
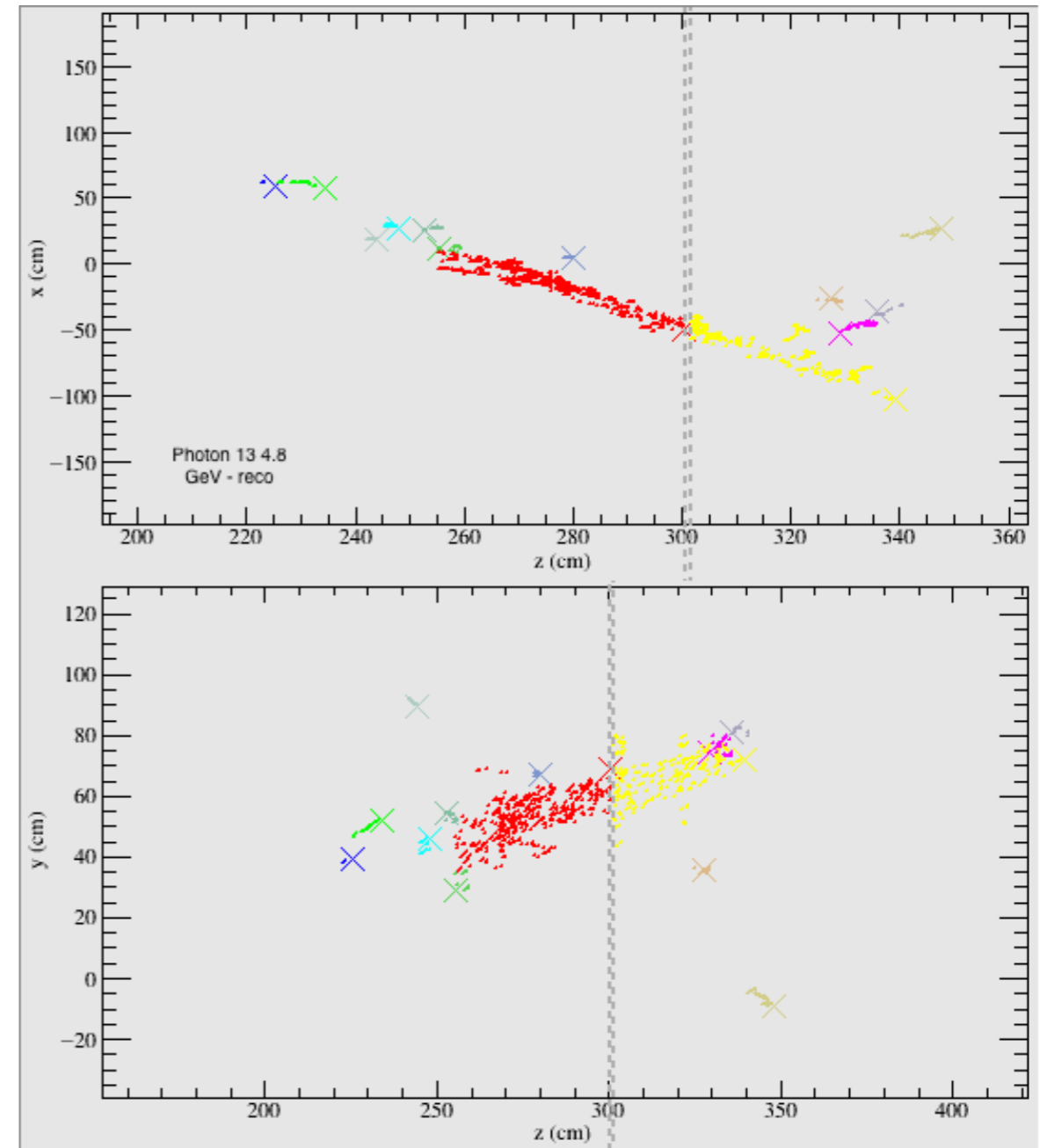
Energy deposit

- Crosscheck of the **linearity** between the truth Energy deposit (**EdepMC**) and the recon Energy deposit (**Edep**). **Ionization only**

- **Single hits** as benchmark, the **best-shower** and the **sum of all the showers**
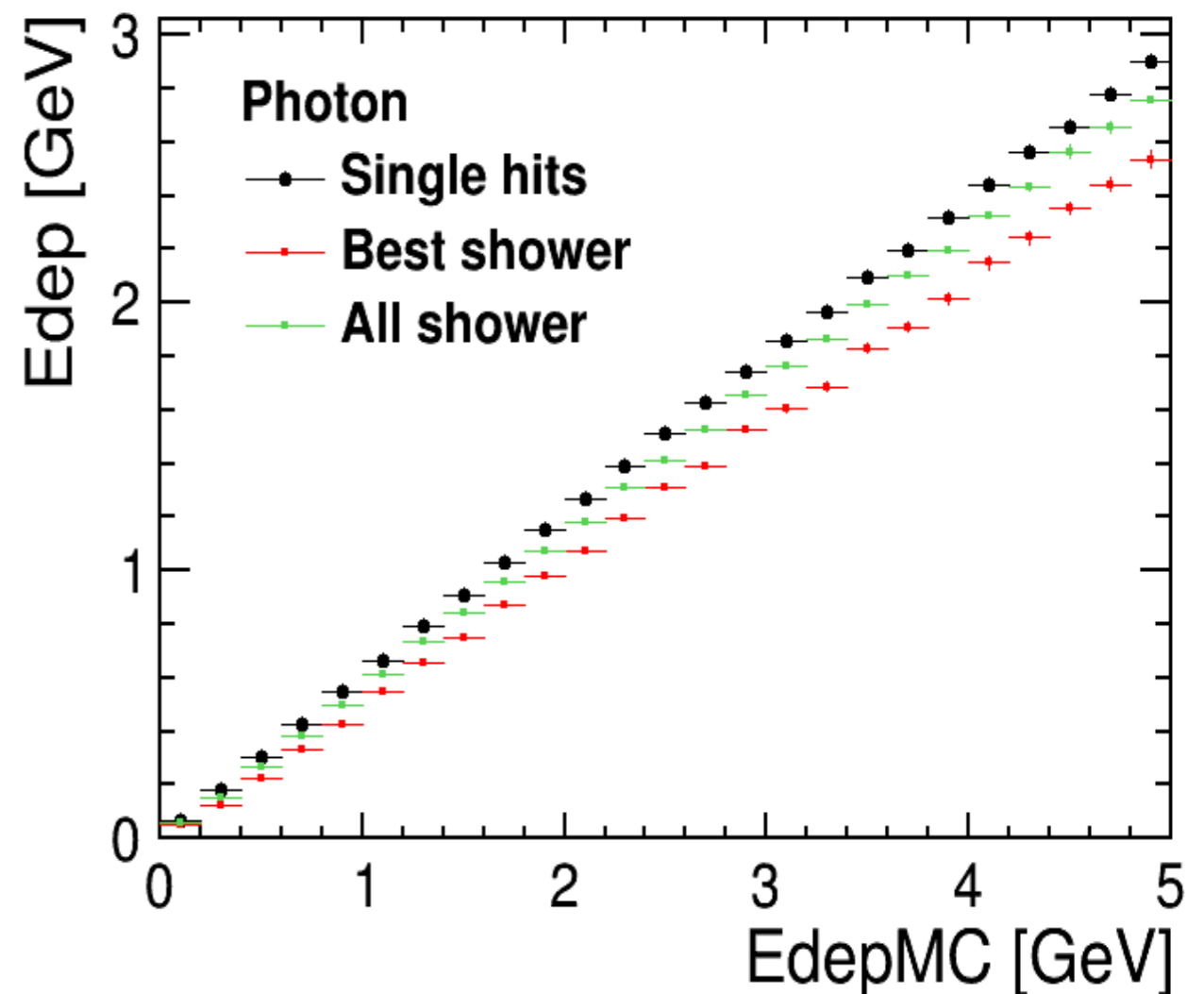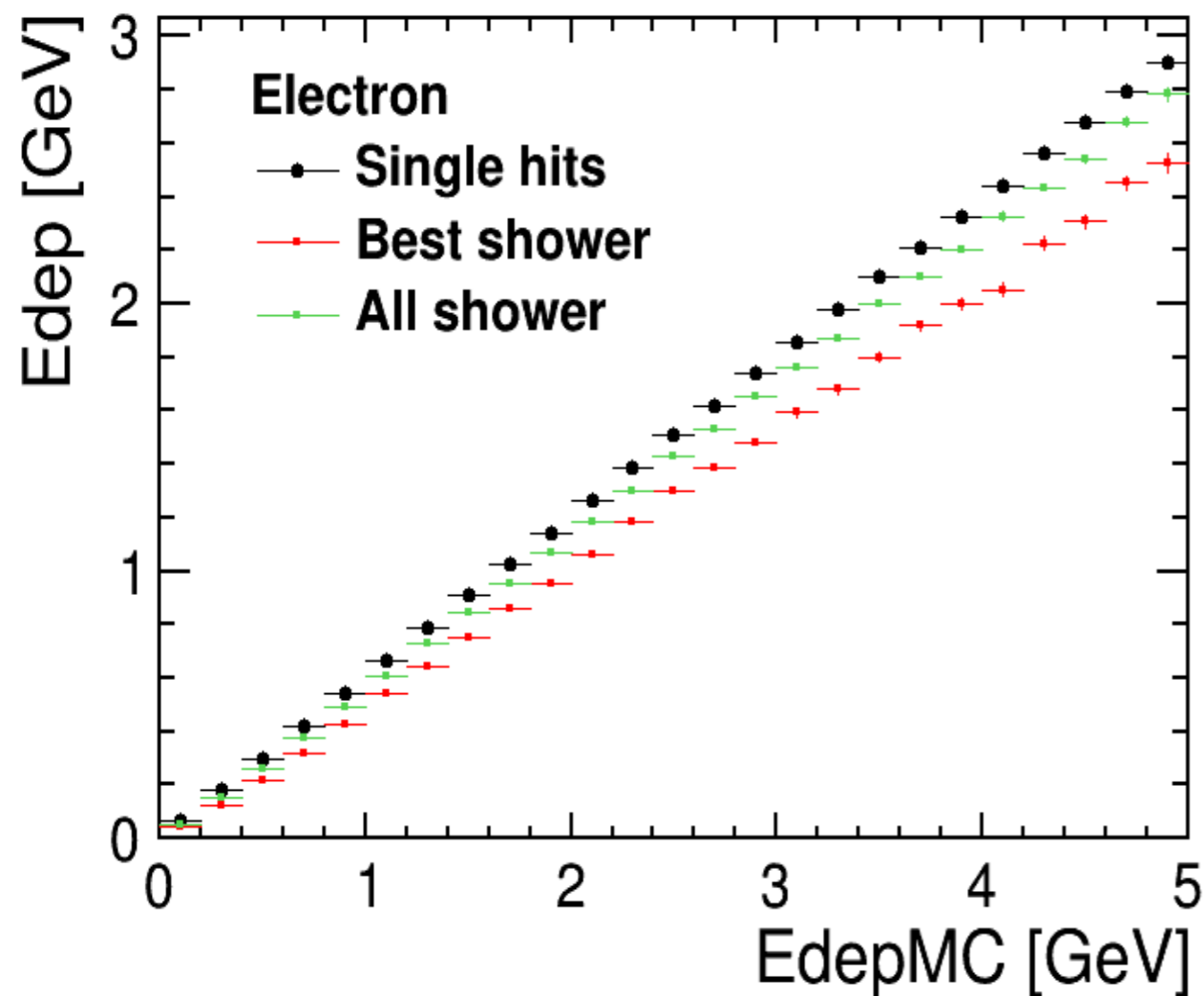
Energy deposit

- Plotting the ratio Edep/EdepMC: energy is no longer well reconstructed **below ~ 1GeV**

- At low energy the number of spare hits increases, since the condition for shower development are lost after few radiation lengths
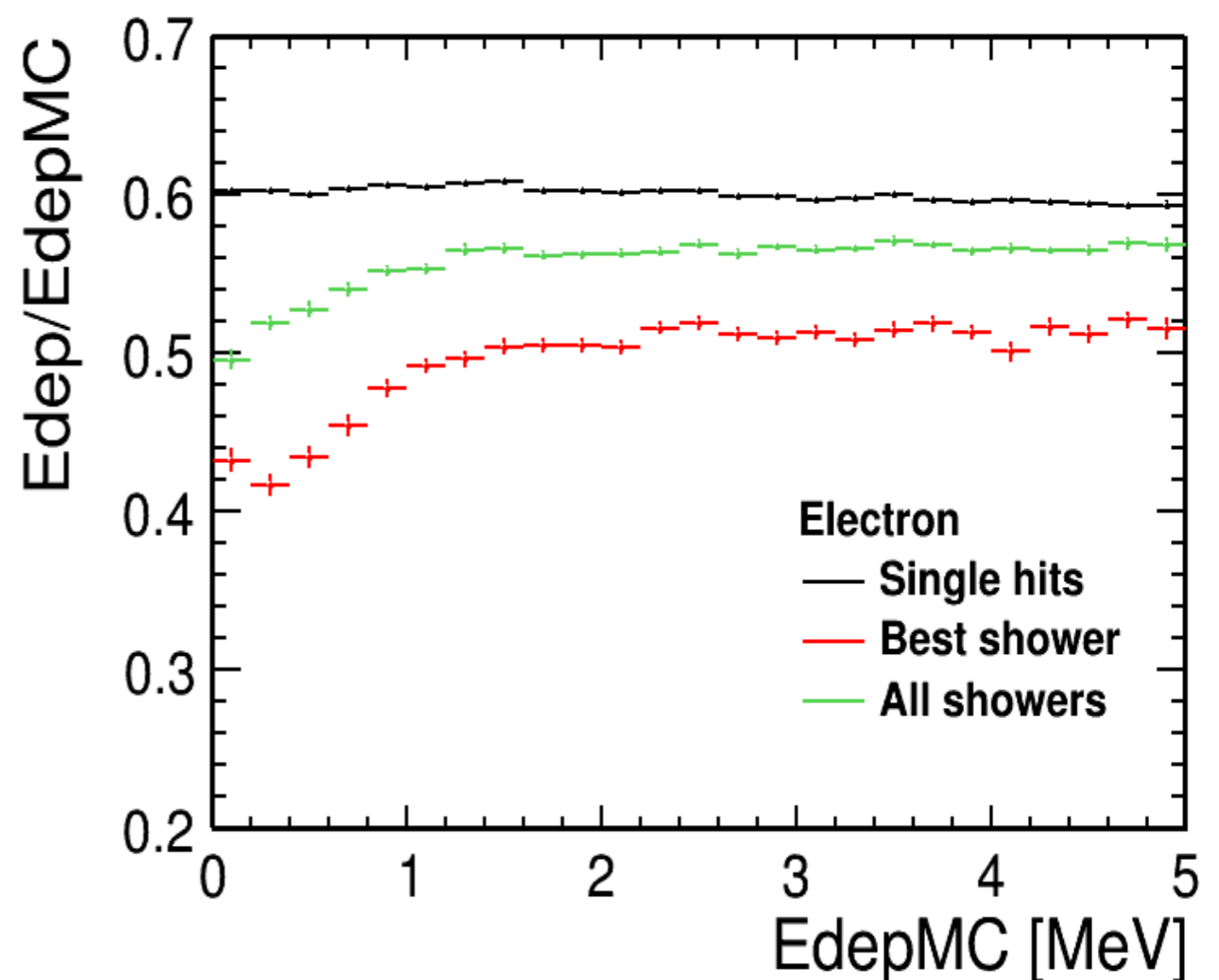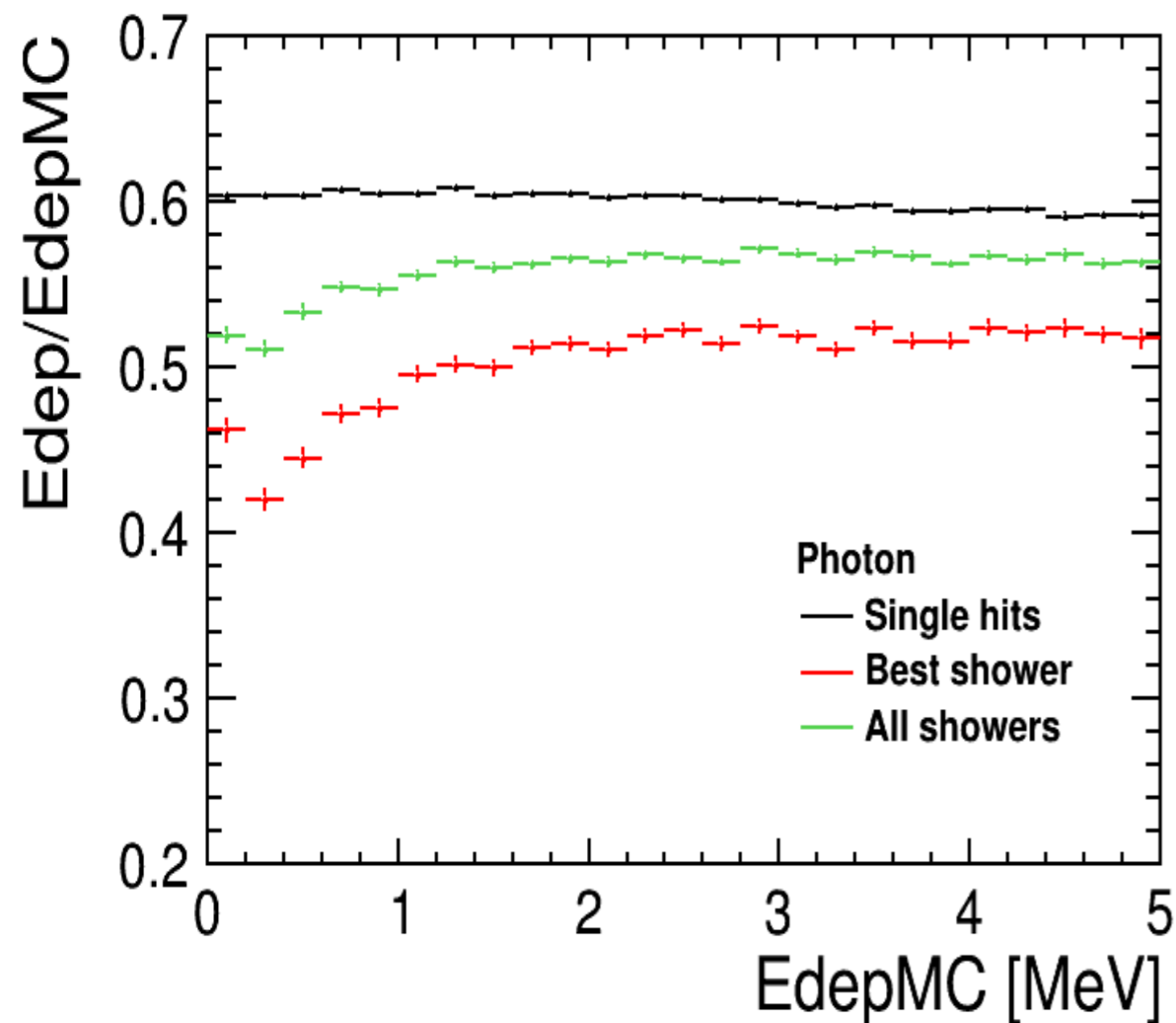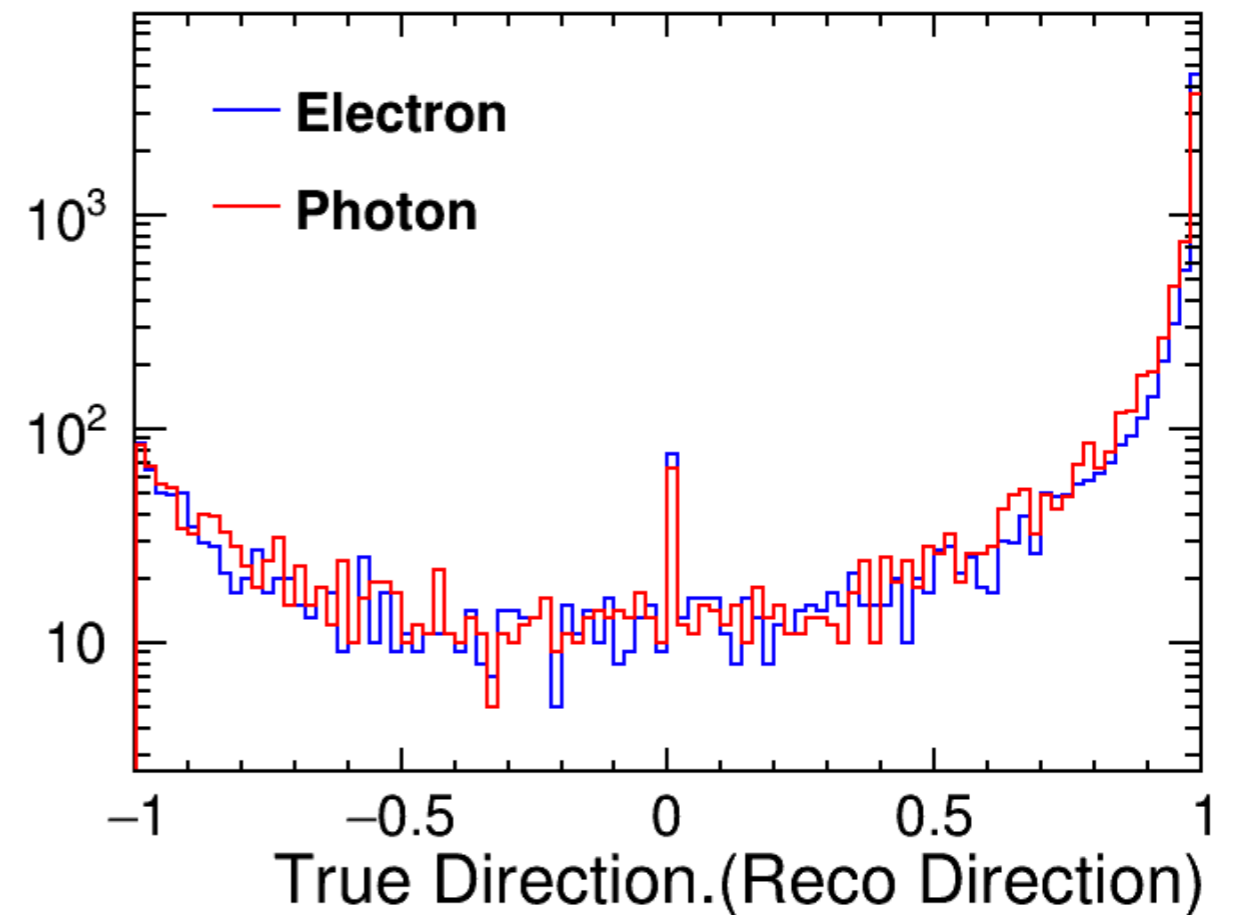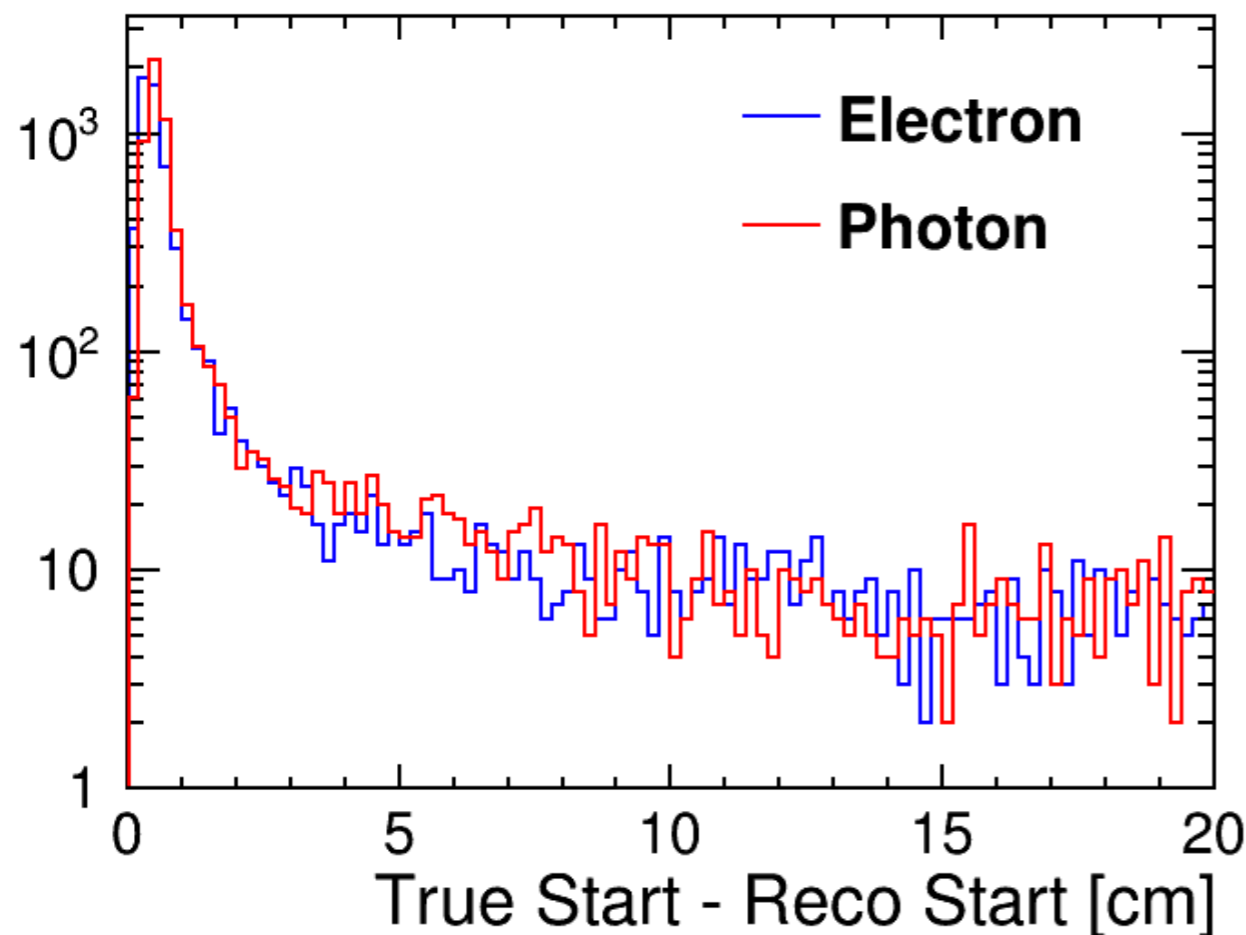
Shower start and direction reco

Scalar product between true and reco direction: reconstruction seems nice
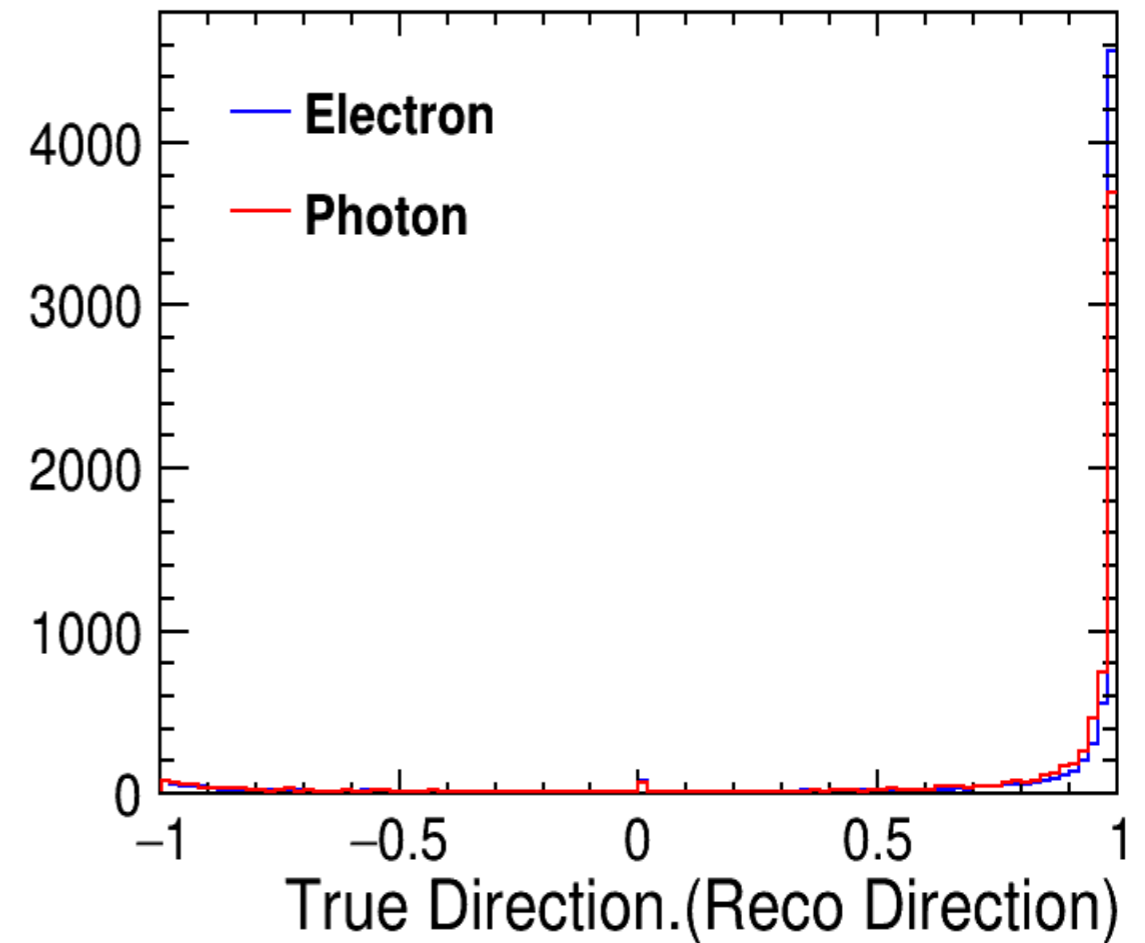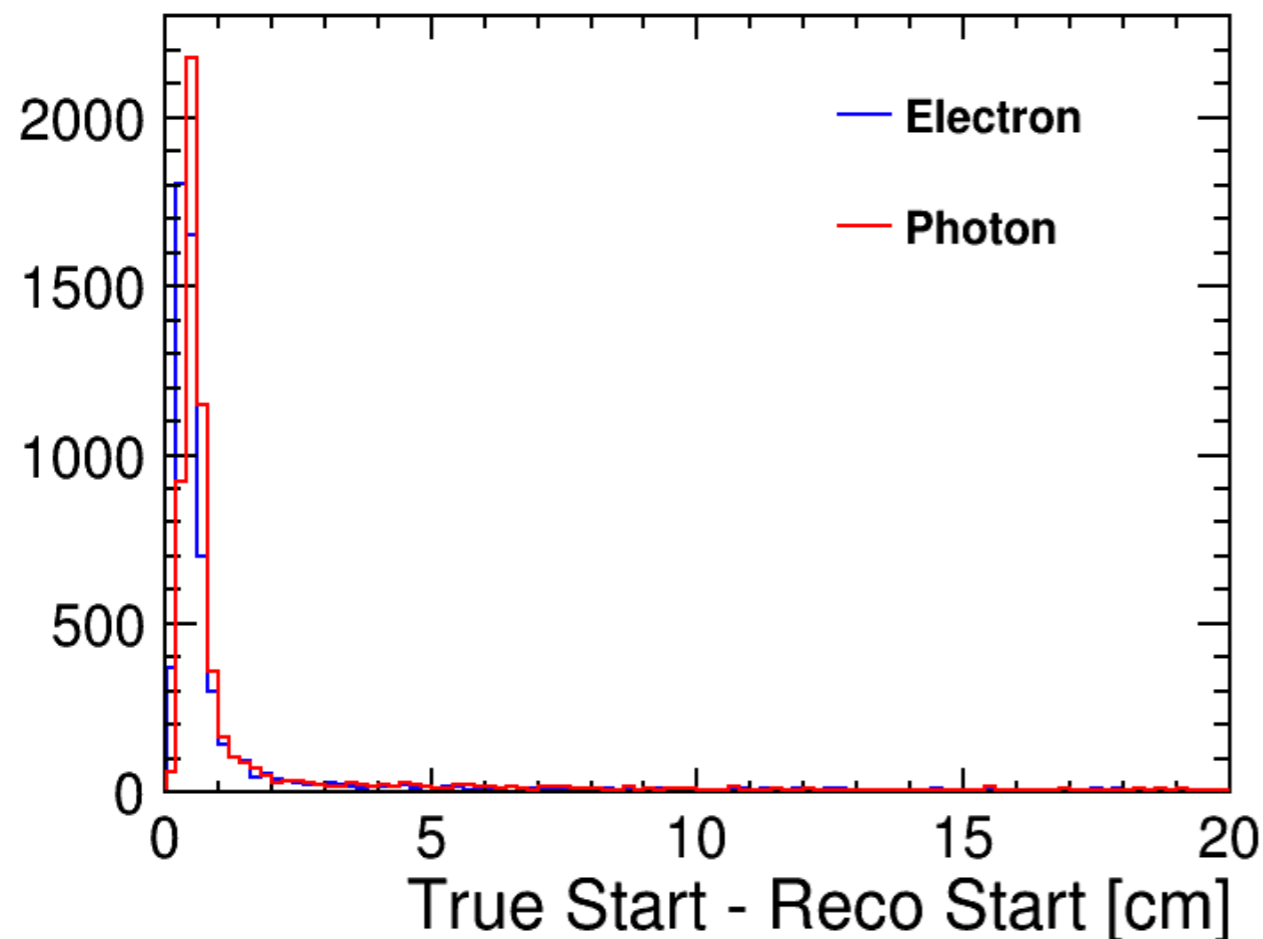
True Start Vector - Reco Start Vector: Good reconstruction: within 2cm

...In Log Scale

Scalar product between true and reco direction: reconstruction seems nice

True Start Vector - Reco Start Vector: Good reconstruction: within 2cm

Stopping Power

- **dE/dx at the beginning of the cascade is discriminating between signal and background events** (double m.i.p. from γ conversion)

- Study of the **average dE/dx** in the first part of the shower using **ShSeg_module** (by Dorota):
  - ‣ **Truth or Reco** information on shower direction: **initial true track**
  - ‣ **Reconstructed hits** (projected on the initial track)
  - ‣ **Smearing** on initial position to simulate difficult **vertex region**

~1-2.5 cm
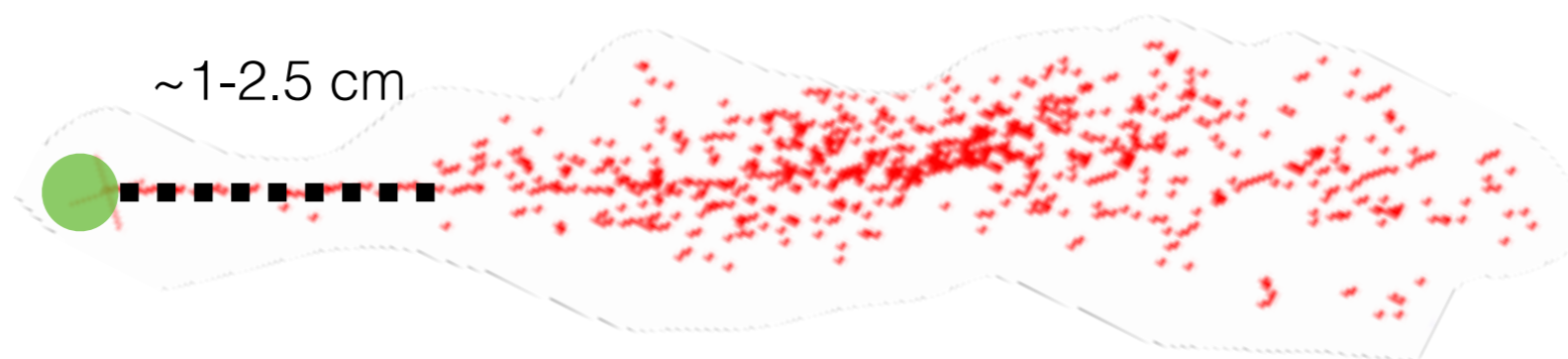
- dE/dx on the initial track-like part of the shower: **compare truth start and direction with reco.**

- I am still looking into **single showers events**

- **dE/dx only from the best shower and on the best plane**

Stopping Power

Very nice separation between electrons and photons , but…..

… **many dE/dx = 0 and dE/dx > 10**
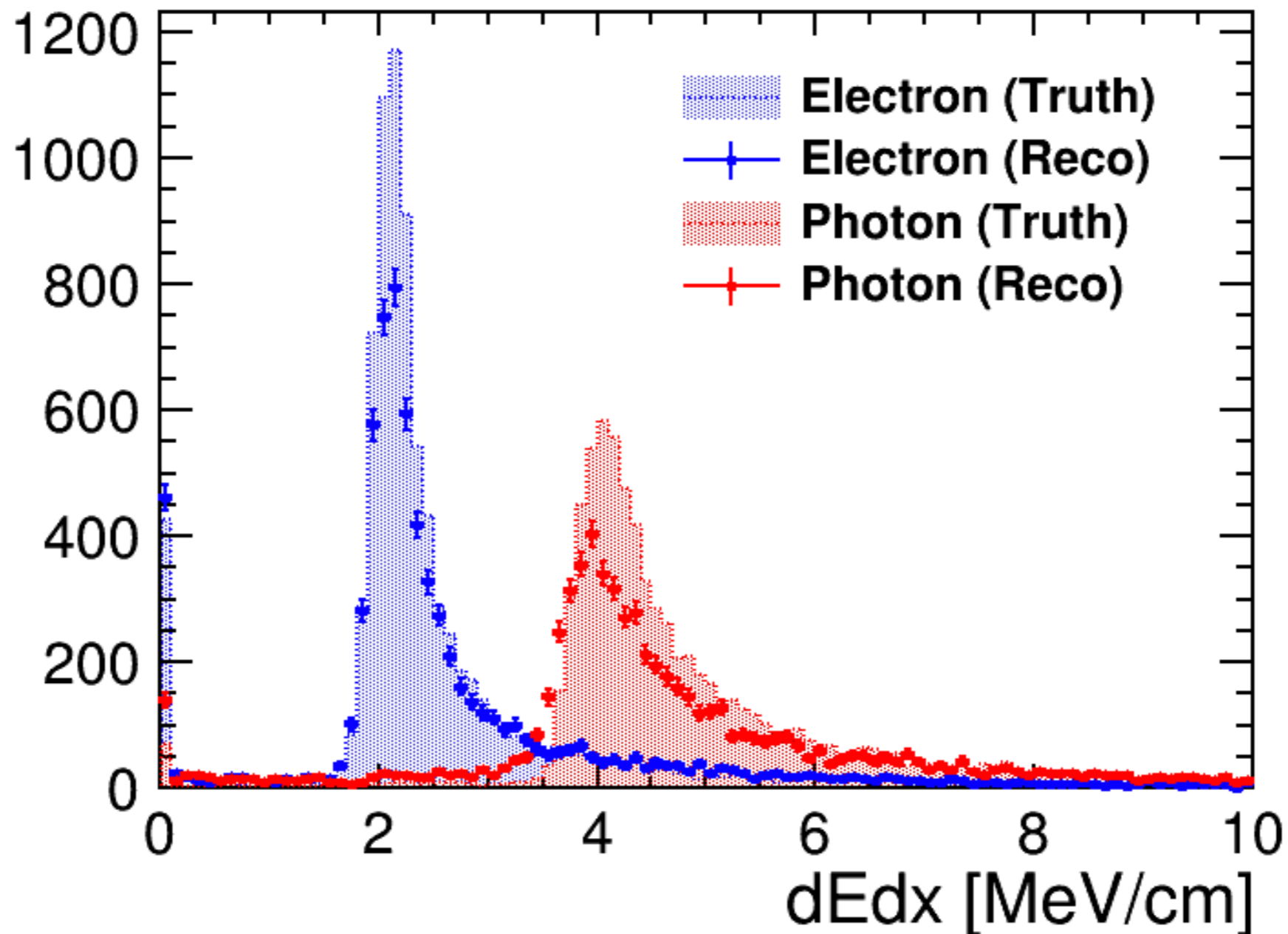
Angular distribution

Direction cosine along **x (drift direction)** and along **y (parallel to one of the wire planes).**

For all the events: dir. cosines distributed on a sphere. **More entries along the drift direction and the wire planes**
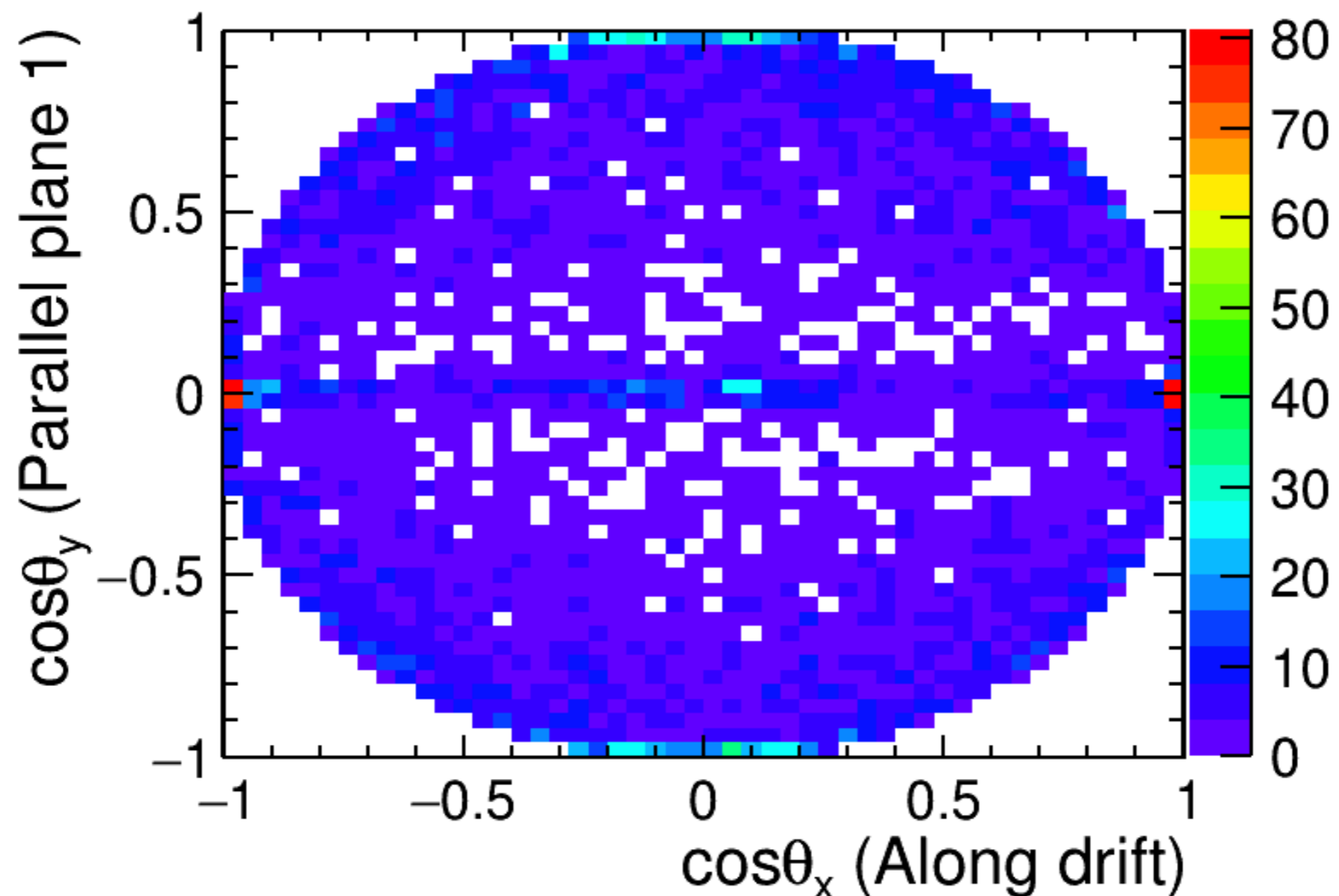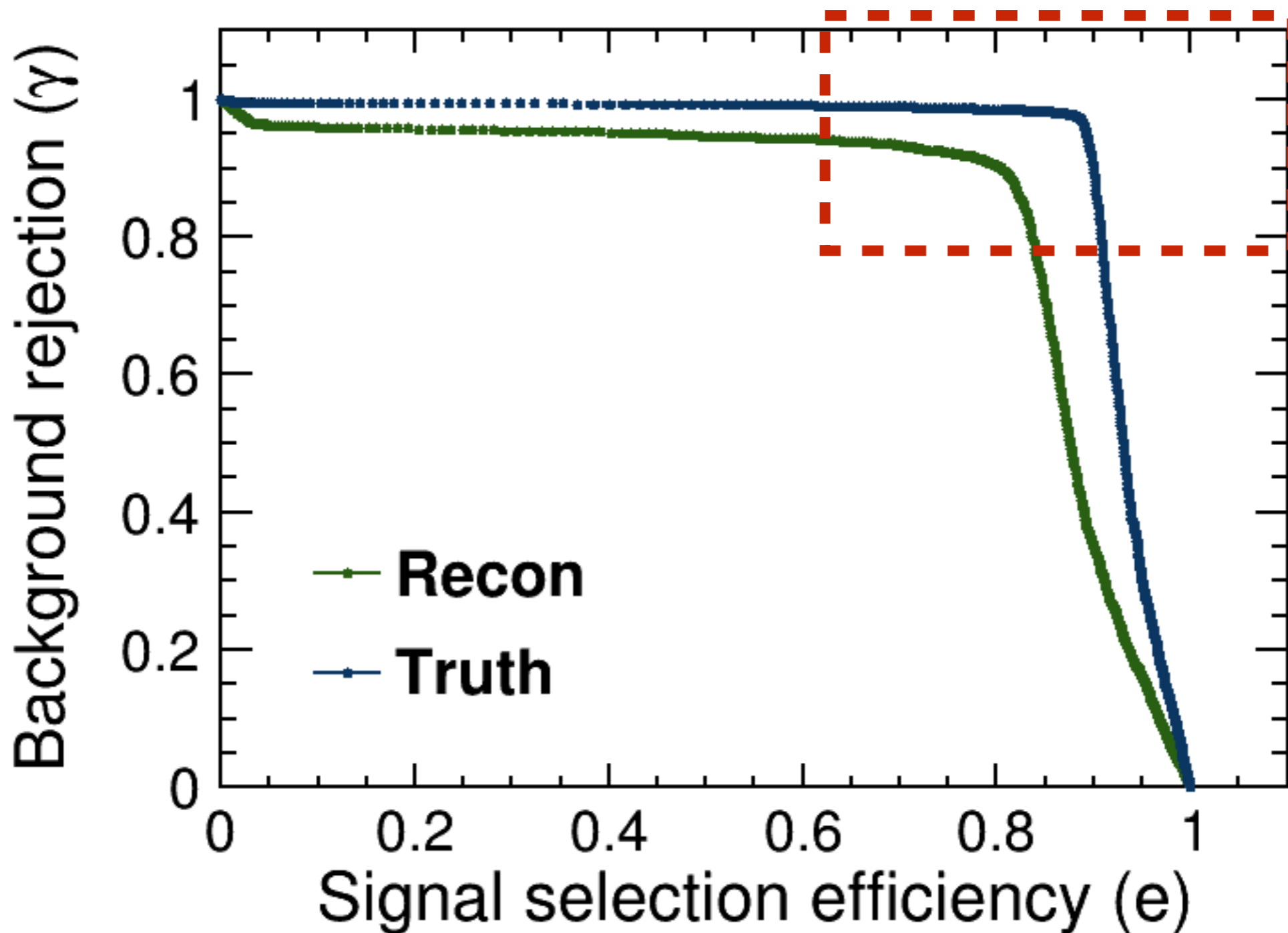
Angular distribution

Events for dE/dx =0 and dE/dx > 10 are mostly distributed along drift direction and parallel to the wire planes. Those are both difficult directions for the recon algorithms
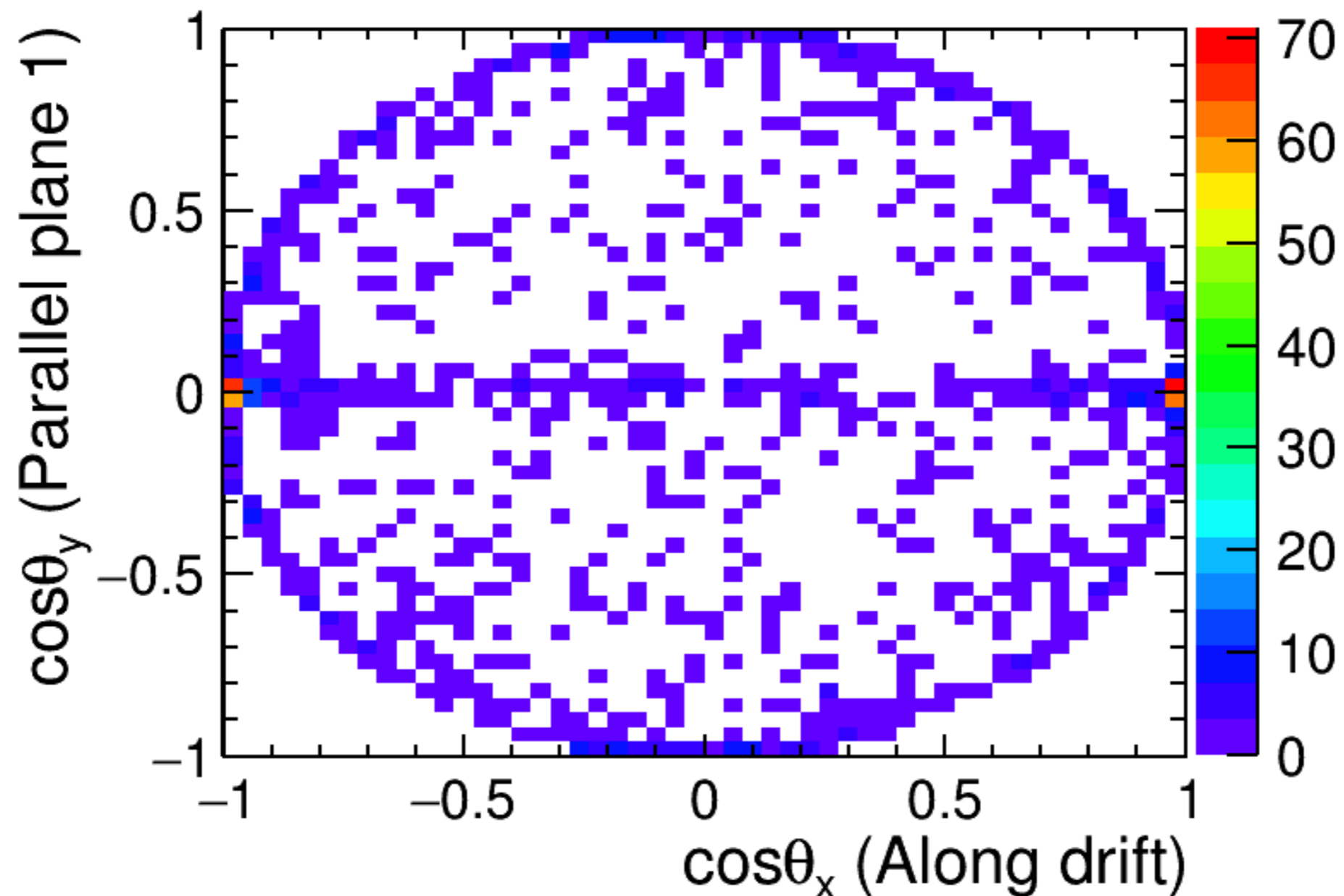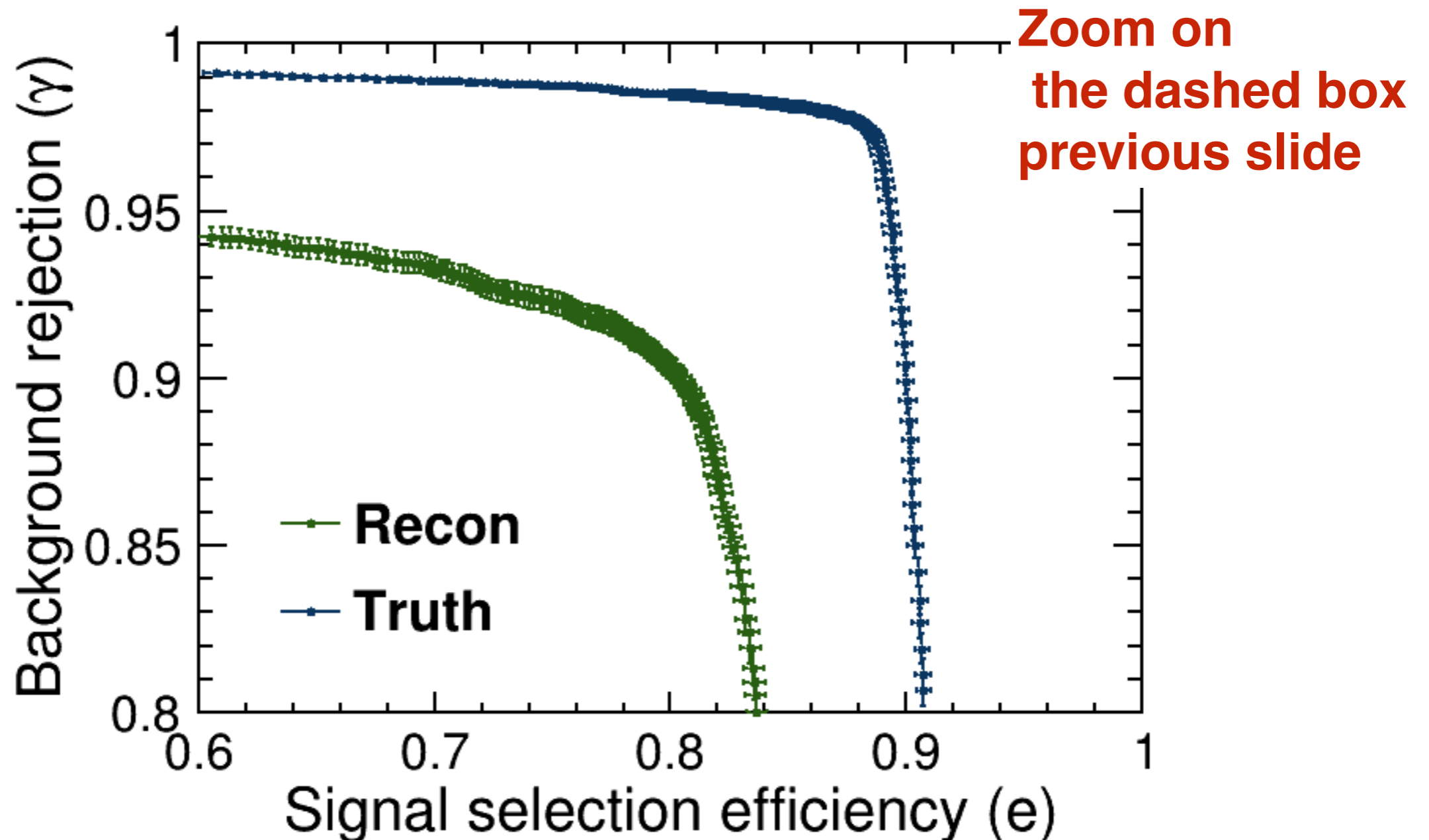
Efficiency Curve

Curve for the signal efficiency vs background rejections are built.

Efficiency Curve

For truth not remarkable difference w.r.t. SP configuration

Recon curve lose a bit of efficiency. This might be due to the absence of the third plane.

Zoom on the dashed box previous slide

Conclusions

Showers reco works in DP:

- Several algorithms exists, I tested only one of them

- Calibration of the module for DP has been done, but not yet committed

- Nice performances, comparable with SP

DP geo in LArSoft needs more improvements

- Drift direction along z (in progress)

- More realistic implementation of the readout planes

Outlooks:

- Protodune LArSoft geometry implementation is currently underway

- Continue working on e/γ separation, in particular I am going to focus more on the photon conversion gap

Thanks for your attention

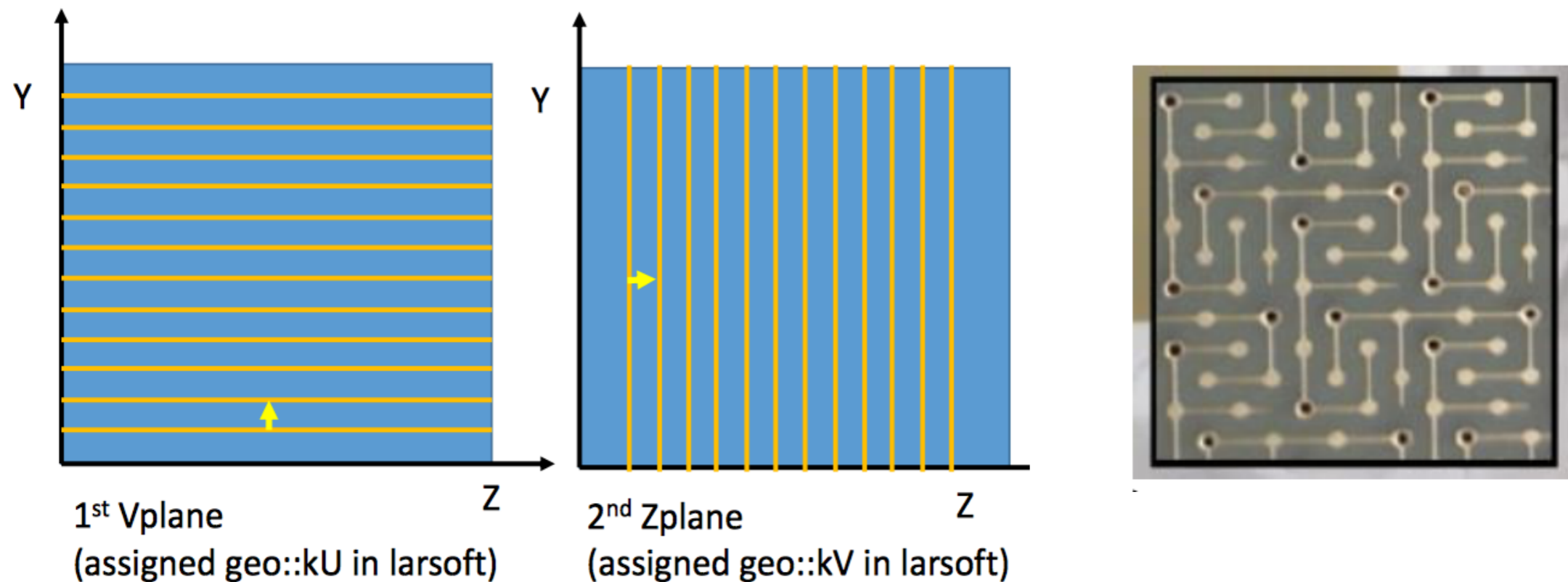# Backup slides

DP Geo in LArSoft

- DP geometry for DUNE 10kt DP is already present in LArSoft (by **Slavic Galymov**)

- DP geometry for ProtoDUNE recently implemented (by **Christoph Alt**, not used for this talk)

- Use of a "**Working space**" geometry to reduce computational time

  ‣ **Two CRMs** 3x3 m^2 each

  ‣ **Drift length** along **X** :12 m

  ‣ 1 cm thick **dead volume** between the CRMs

Side view

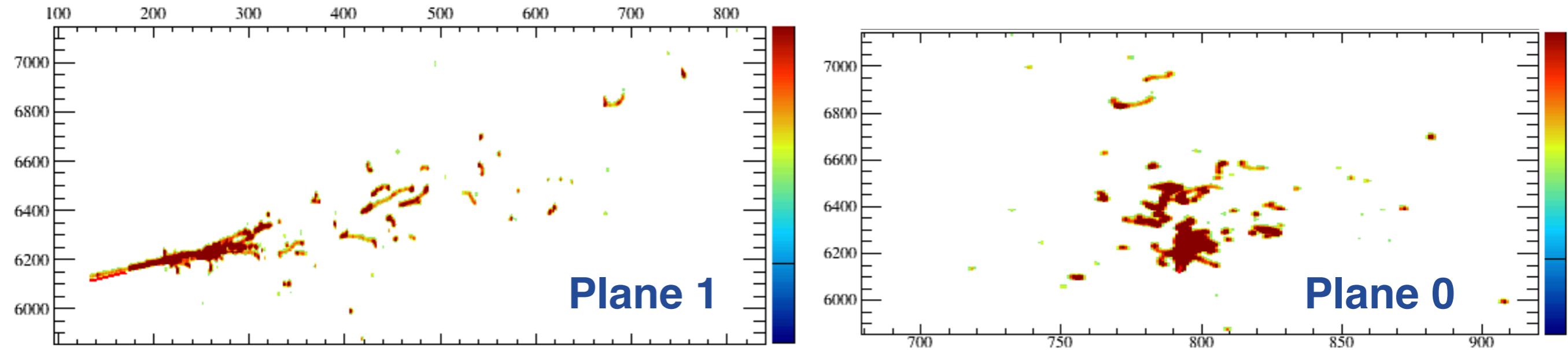

Top view (Anode plane)
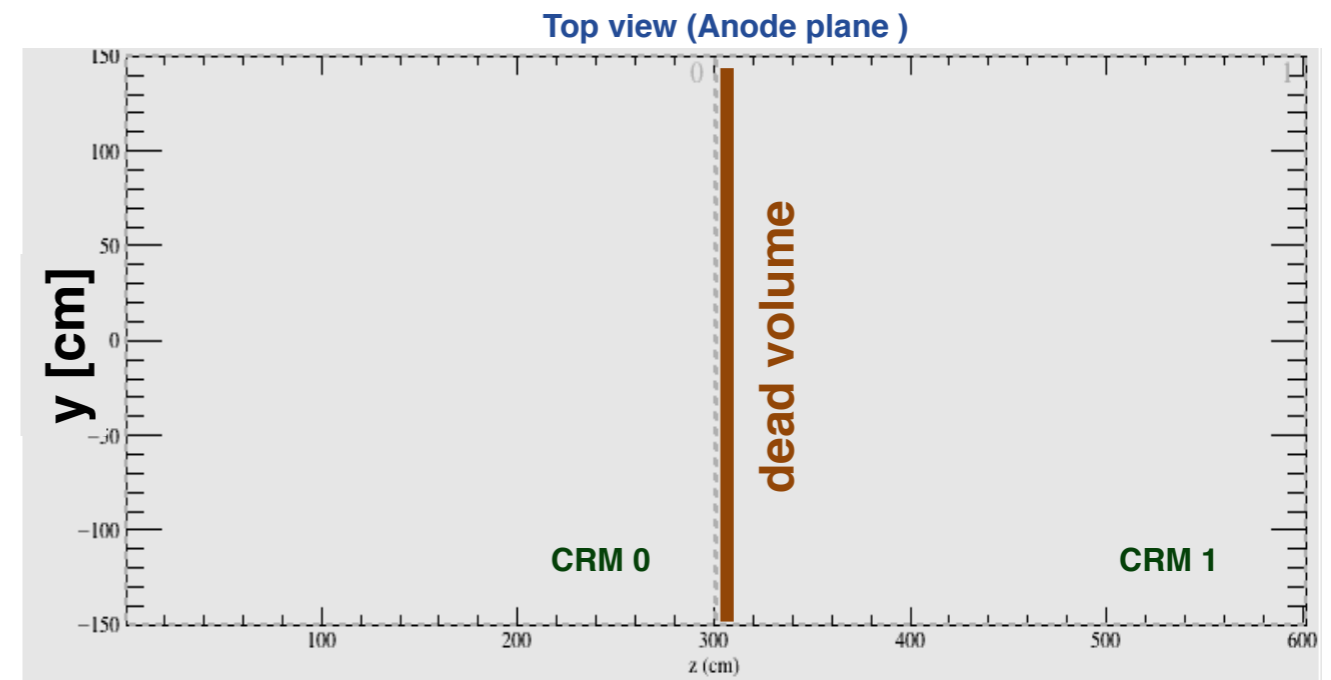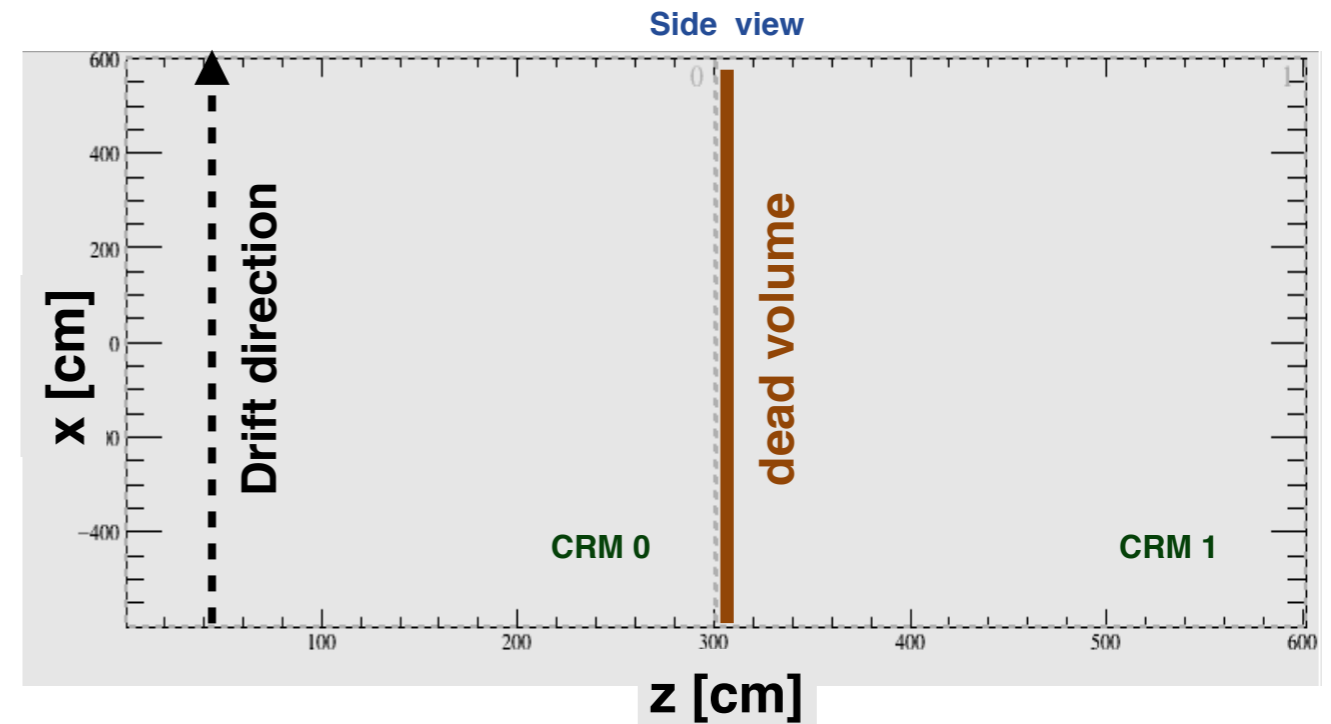
Plane implementation

- Collection planes: implemented in LArSoft as "wire"-planes in analogy with the SP geometry

- The actual readout is done with multilayered PCB with 2D pattern of strips

1st Vplane
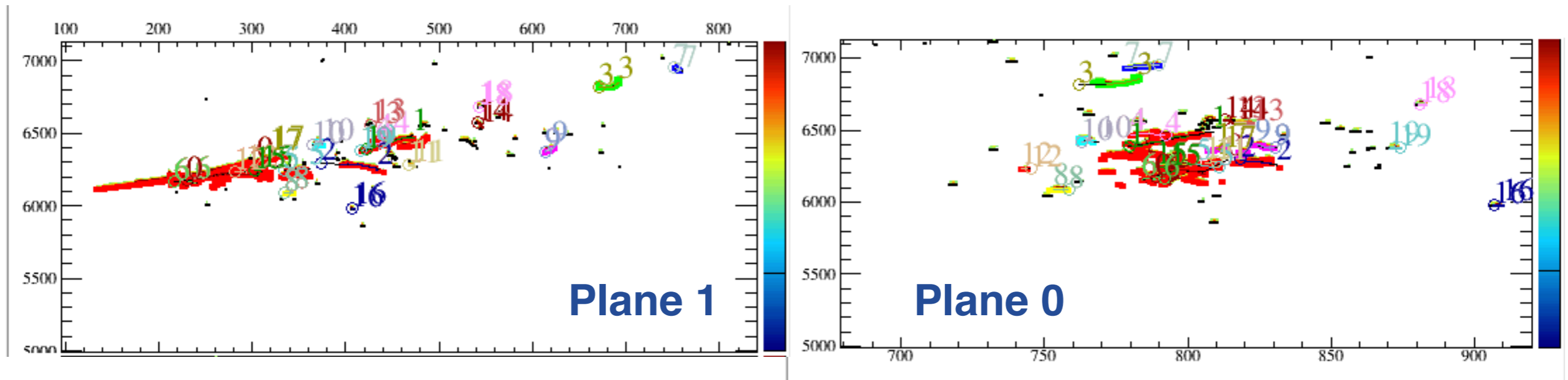(assigned geo::kU in larsoft)

2nd Zplane
(assigned geo::kV in larsoft)

Details about the Dune 10kt Dual-Phase geometry can be found here:
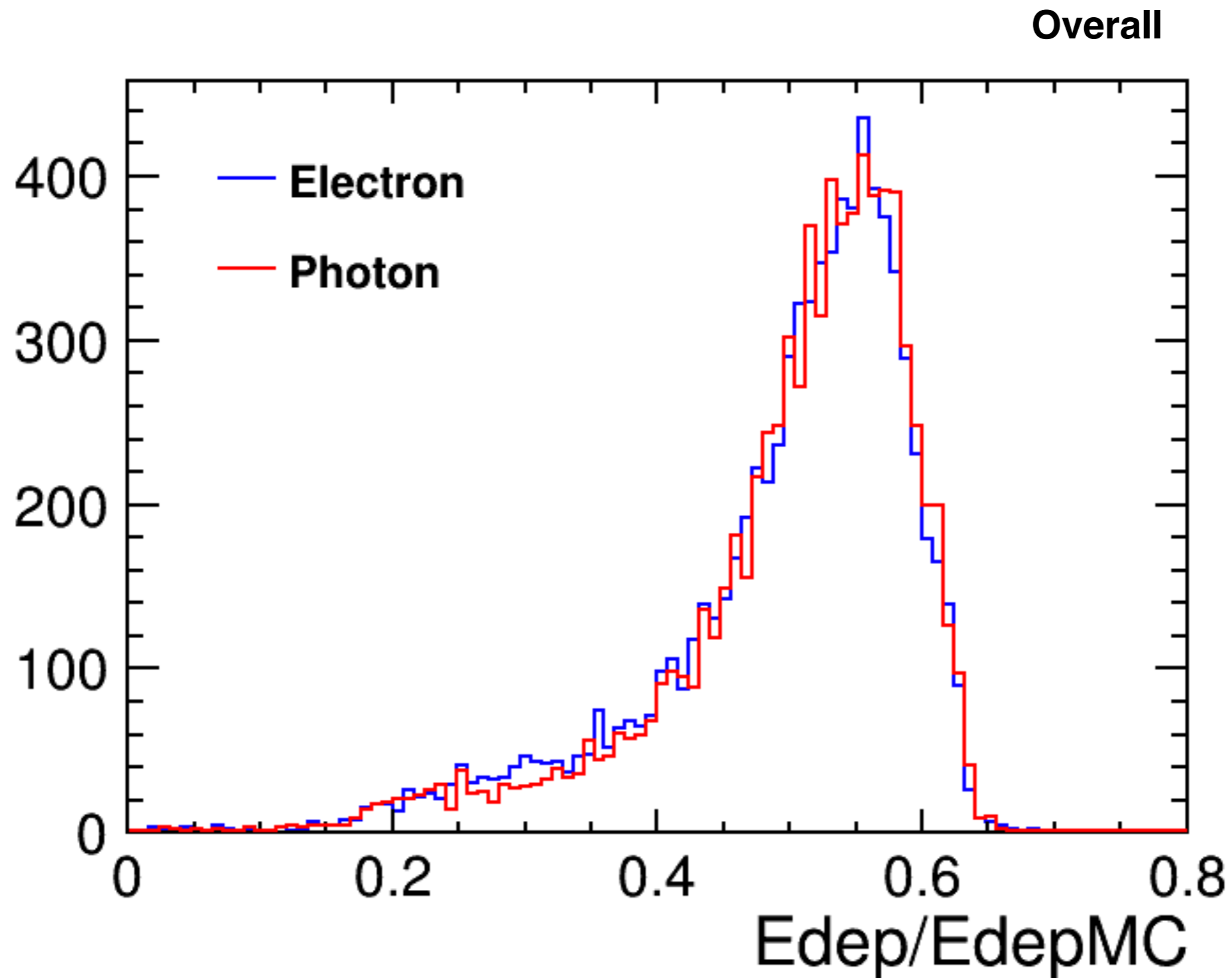https://indico.fnal.gov/getFile.py/access?contribId=2&resId=0&materialId=slides&confId=11402
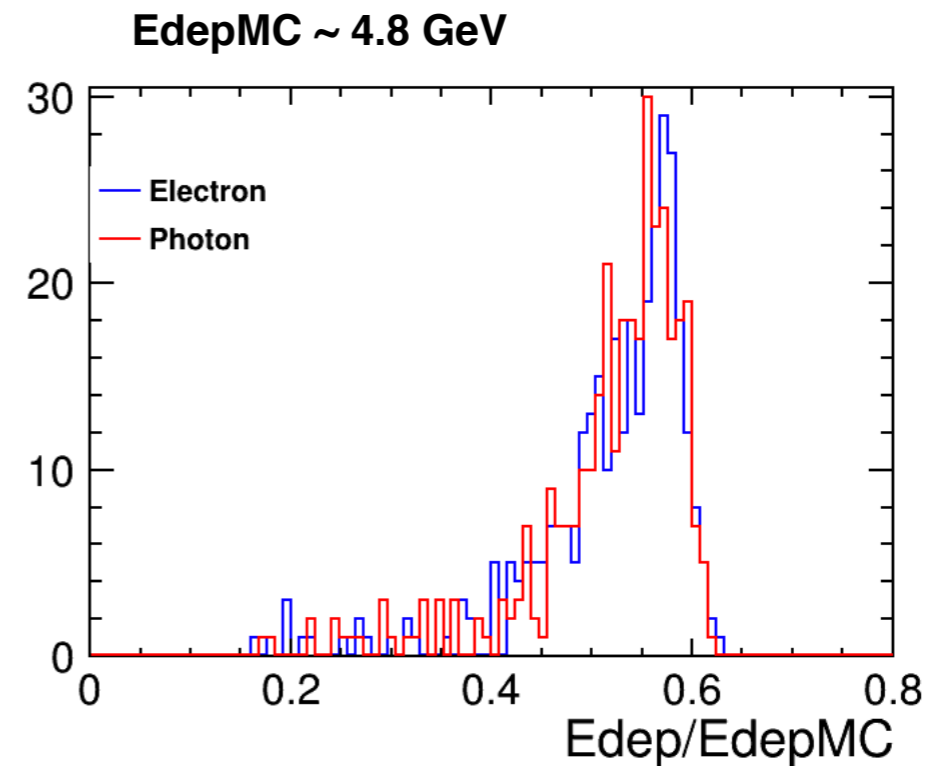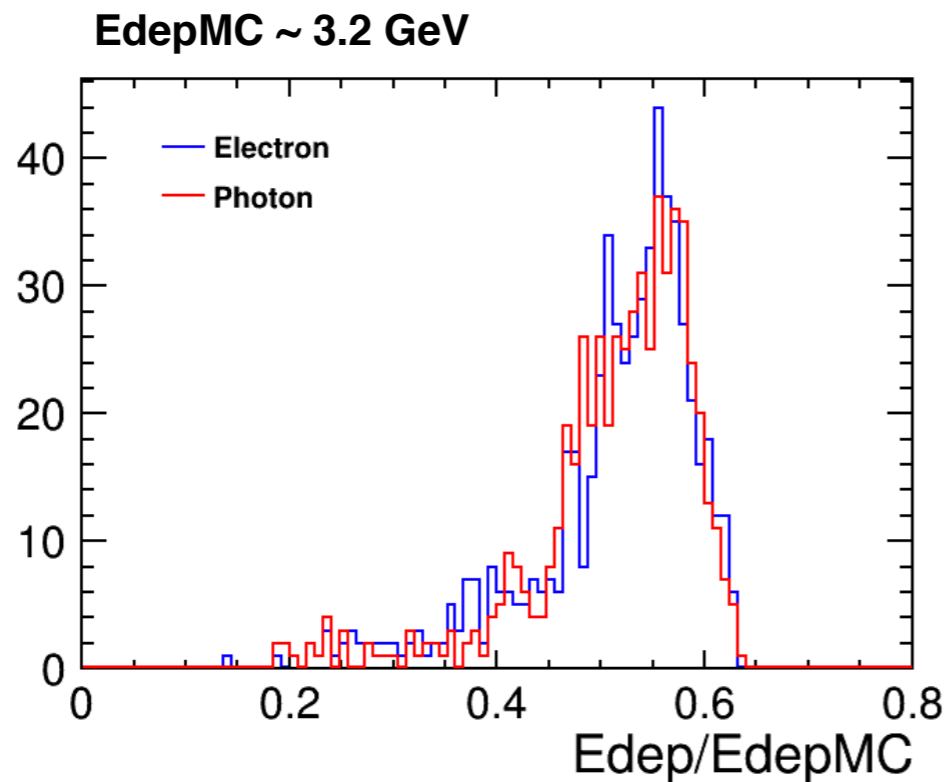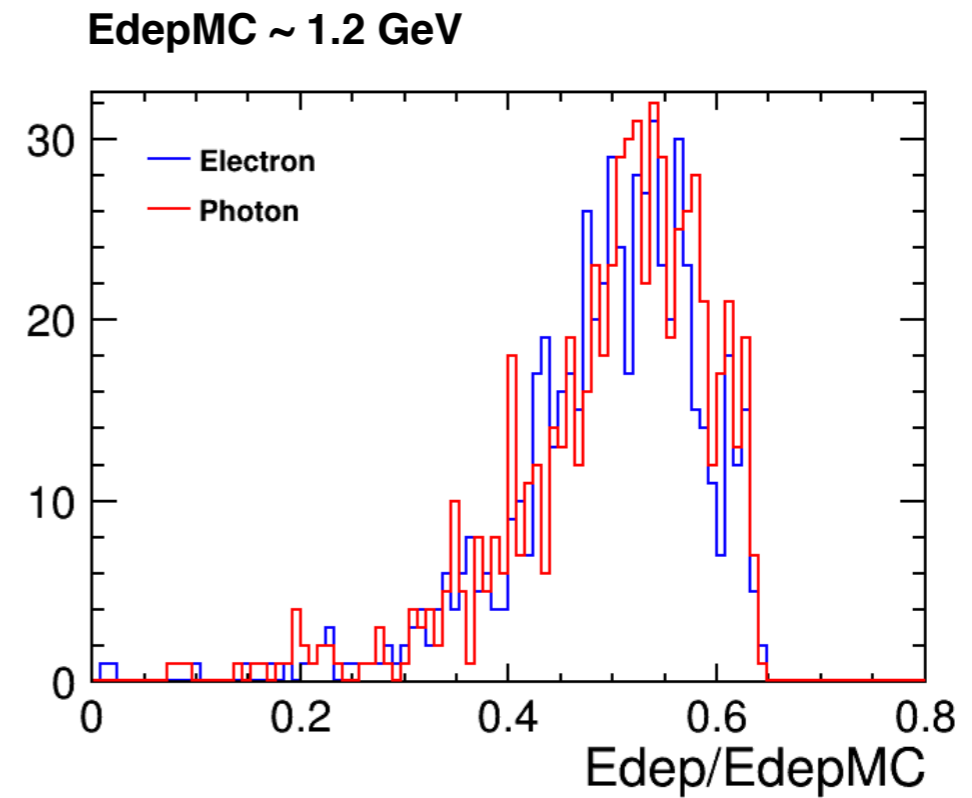
Event display - a closer look

Raw data

Reconstructed

Energy resolution

Energy resolution

EdepMC ~ 0.4 GeV

EdepMC ~ 1.2 GeV

EdepMC ~ 3.2 GeV

EdepMC ~ 4.8 GeV
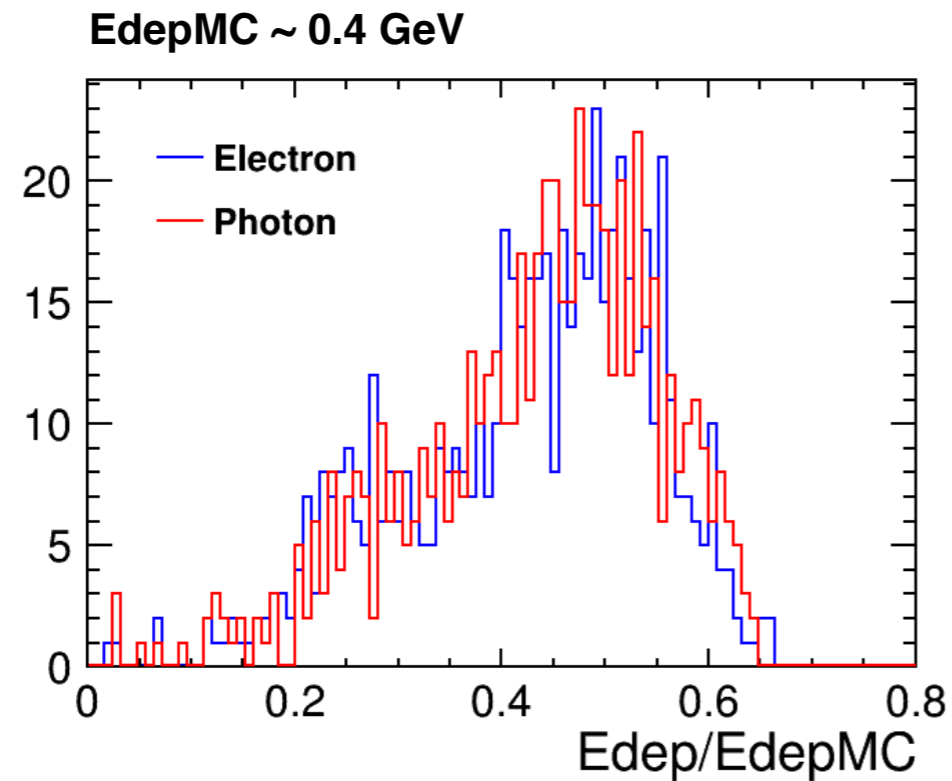
Selecting the good showers

- 10k electrons and 10k photon generated

- Discard all the showers non fully contained in the same TPC

- **Selecting on the dE/dx drops ~20% of the fully contained showers for reco**

dEdx	Events processed	dE/dx > 10, dE/dx = 0
Electron (Truth)	8289	516
Electron (Reco)	8301	1578
Photon (Truth)	8070	615
Photon (Reco)	8201	1819