CNN for EM-like activity selection

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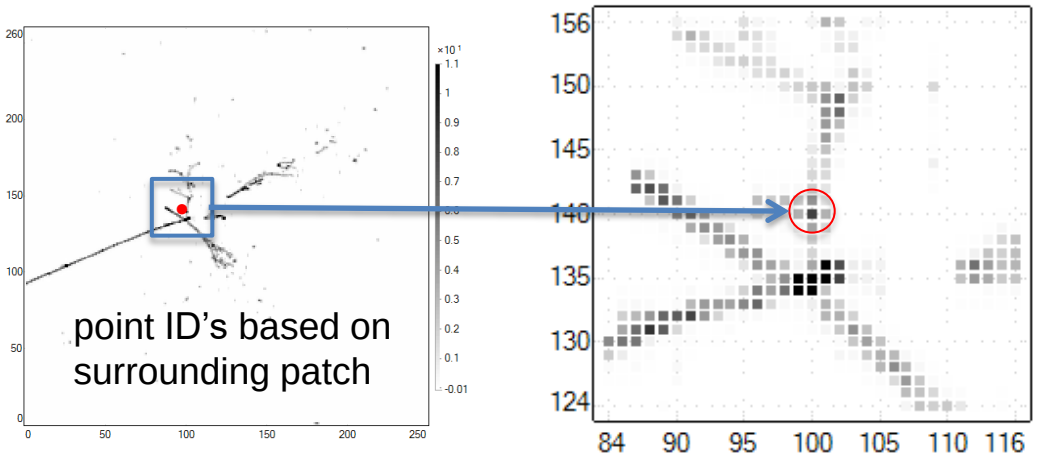
- brief update on the status
- details on the EM selection results

Network training

no changes in the concept, but was stucked due to lack of resources



- EM / track label: results today
- decay: in progress..
- vertex ID
- γ conversion

} next to do

Target:
single/few model for all labels

Most ProtoDUNE task can profit from such tool.

Several parameters of training data:

- downscale factor (in drift direction: x6, x10?)
- downscale method (mean, max pool, ..)
- patch sizes (~16 .. 32 cm^2)

and CNN model/training

- kernel size, number of kernels
- number of layers (conv, dense)
- … … …

➔ **full automatization of this search by Piotr**

➔ finally settled on TechLab computers at CERN!

Modules, input, output format

Input to CNN: deconvoluted ADC

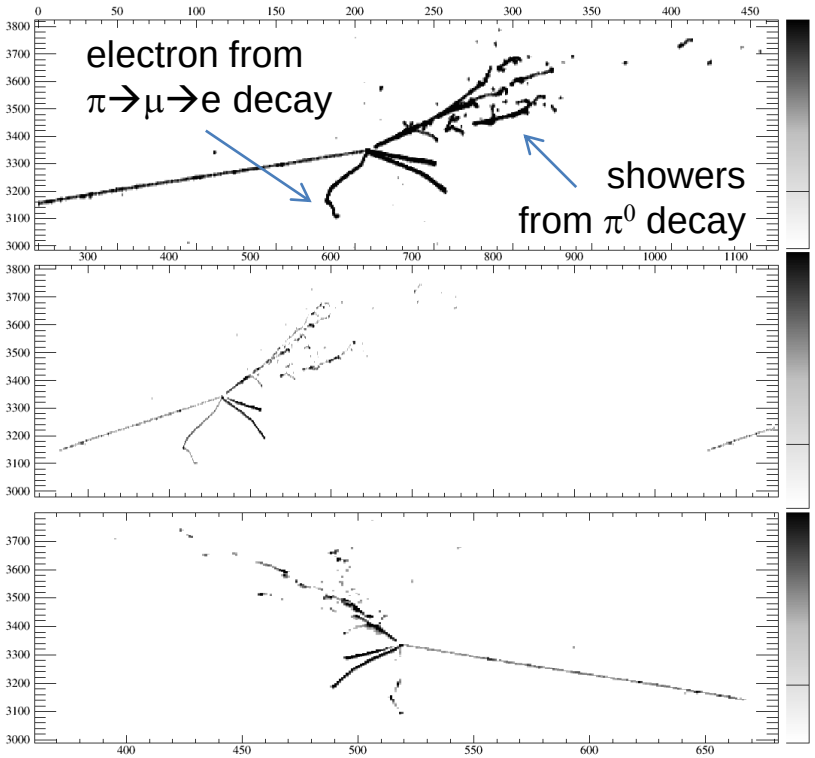
Output is calculated at each hit position.

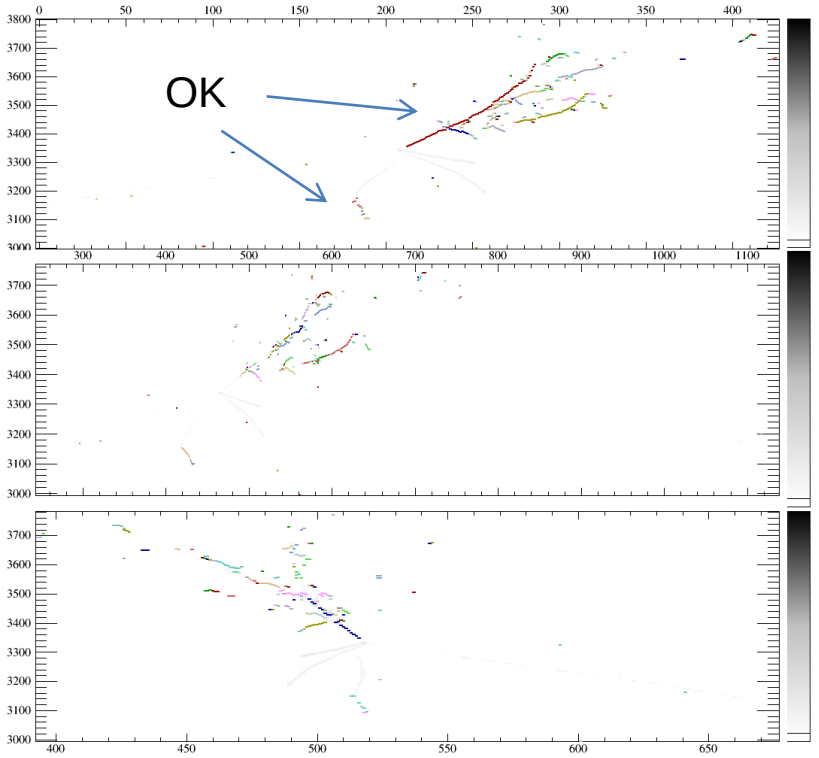
Accumulated output for:

- clusters (if availabe in the event)
- tracks (to be added to code)

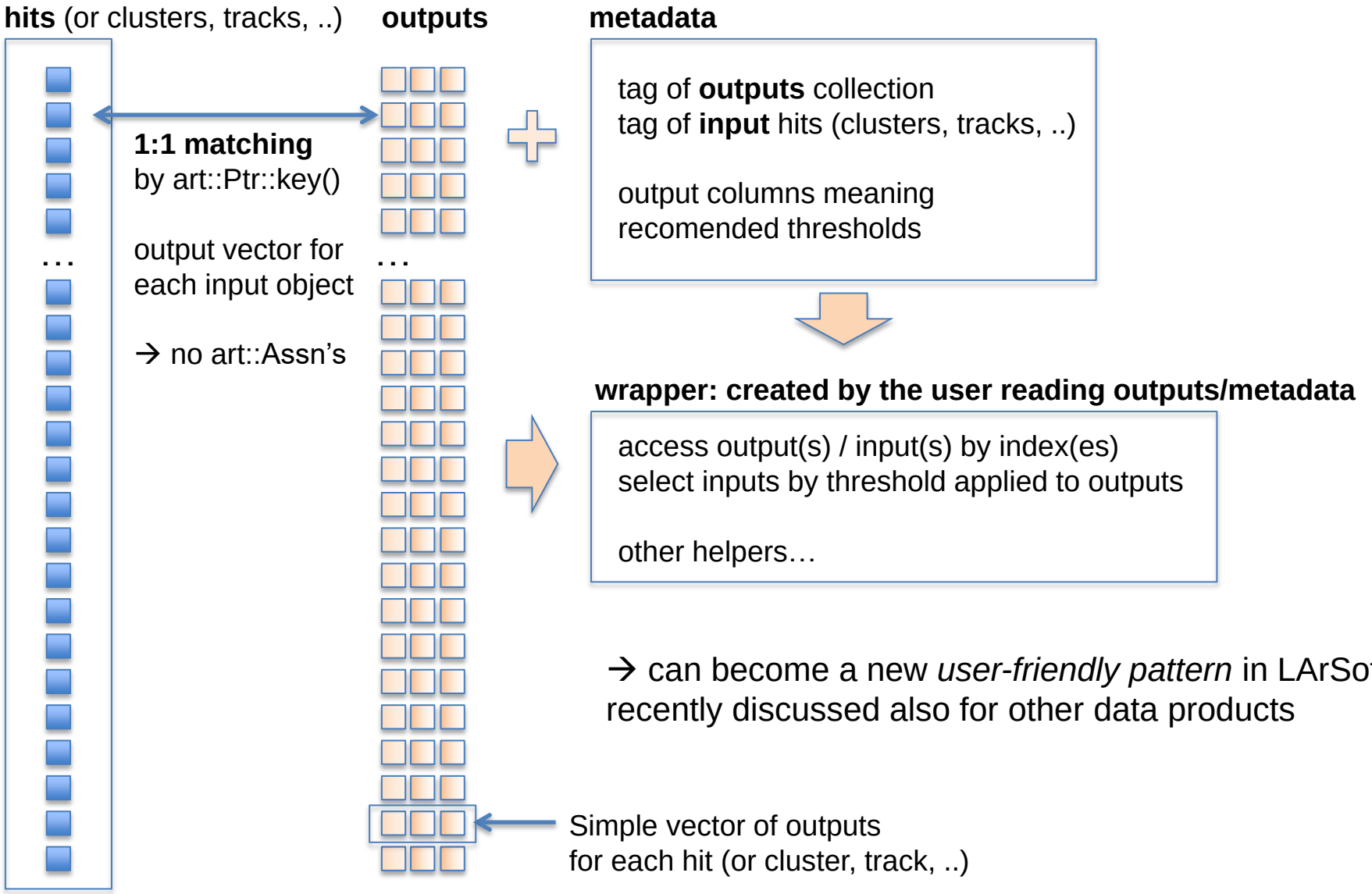
LArSoft module is now producing clusters for parts recognized as EM-like

- single hits are also labeled and outputed as clusters, nothing is missed
- **need more fexible way of saving result**



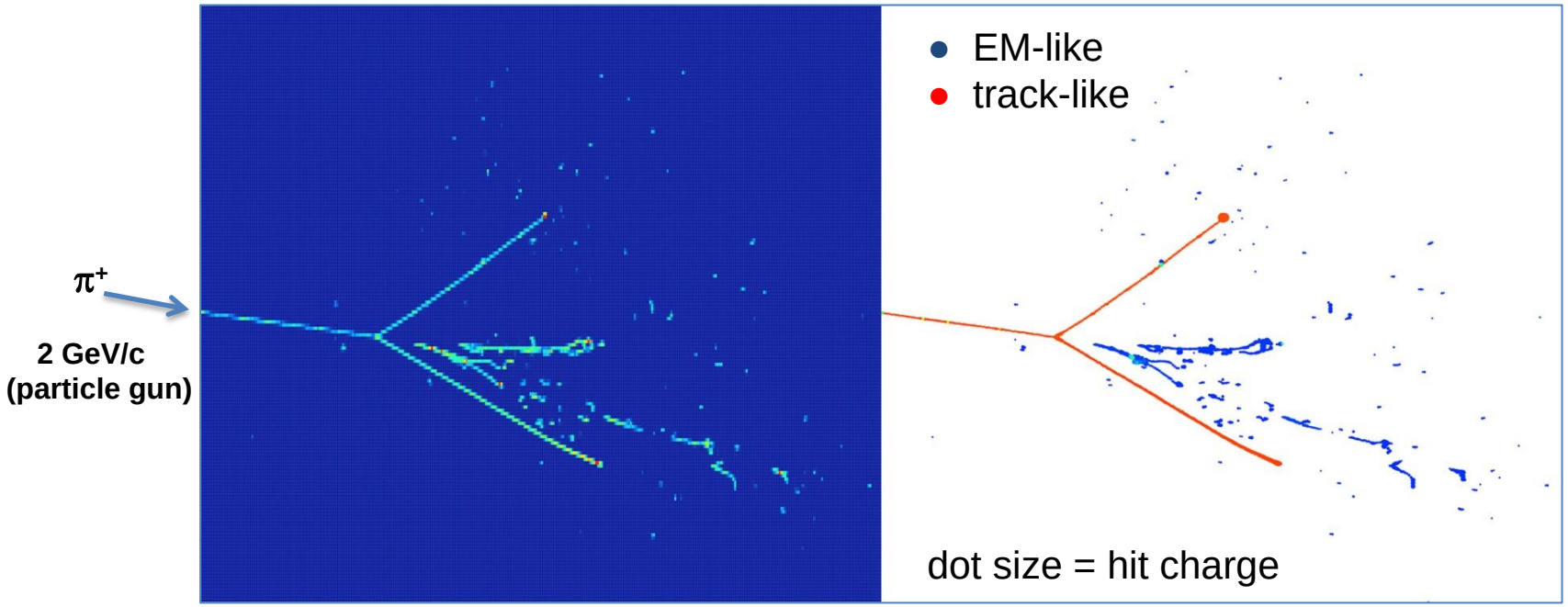


Output format: motivated by CNN work, but **generic for any MVA output**

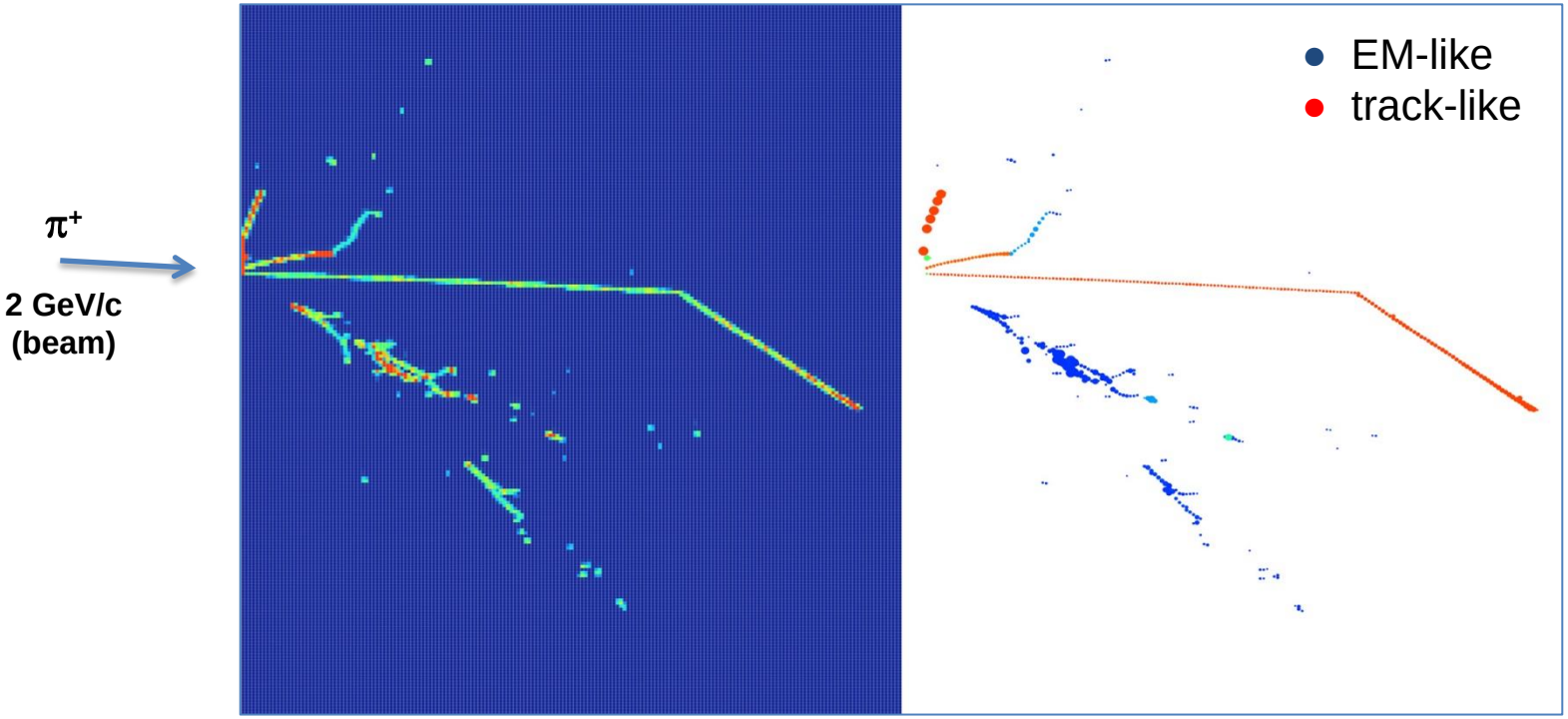


The original idea: separate EM-like from track-like parts

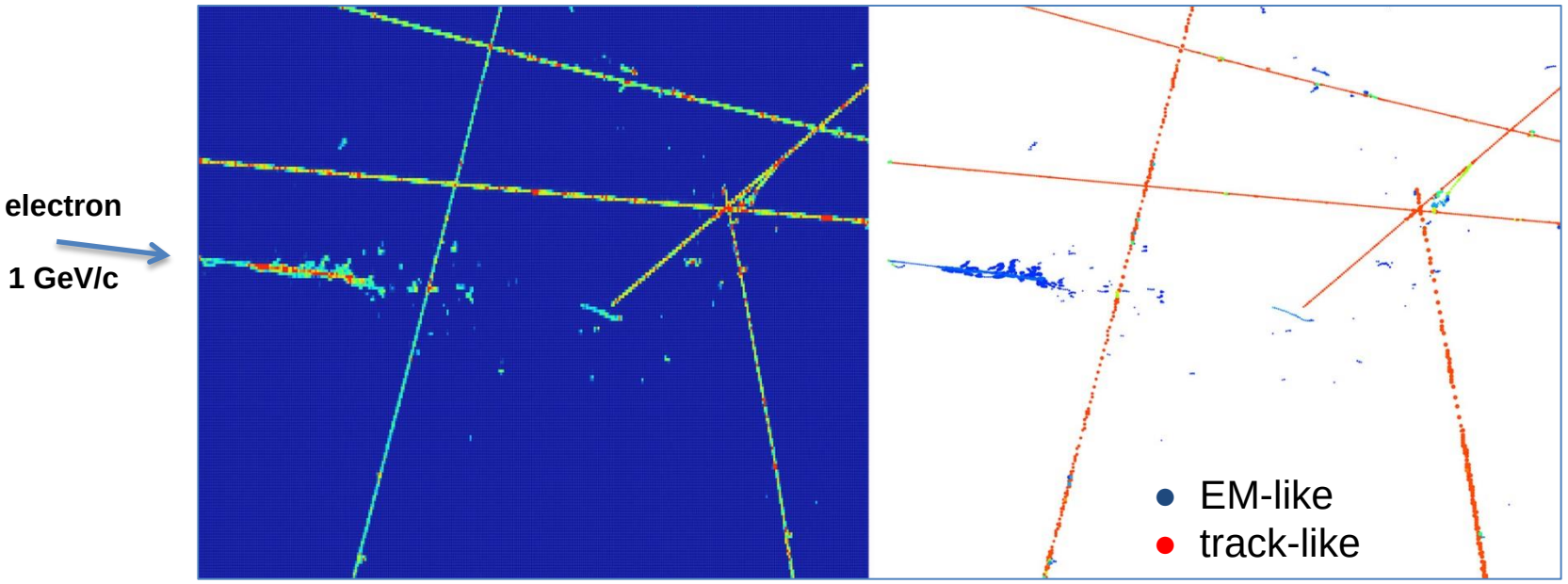
- needed for reconstruction
  - shower clustering is a completely different algorithm path from tracking
  - final goal are π^0 based measurements (γ conv. dist, dE/dx, π^0 mass)
- two ProtoDUNE measurements can use the discrimination directly:
  - EM fraction in hadronic showers → MC model testing, if model uncertain
    → more observations on this measurement on further slides
  - hadronic shower energy reconstruction (see Jiyeon slides today)



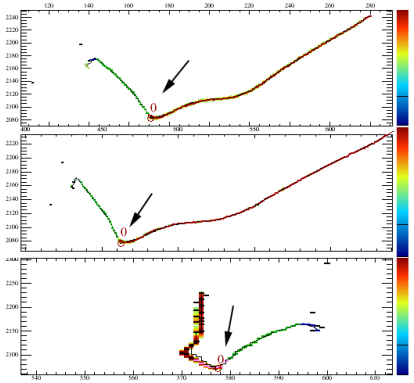
- **new sample:** beam simulation output in TPC simulation by Leigh
- here: interaction before active LAr volume
- likely enough to look at any activity close to beam-matched particle start to reject event, but if EM recognition useful – it works well
- **note the Michel electron** from $\pi \rightarrow \mu \rightarrow e$ decay, it may be useful to distinguish them in the training from other electrons and EM showers in the event (and maybe try the same for delta rays, however this is not that clear labeling)

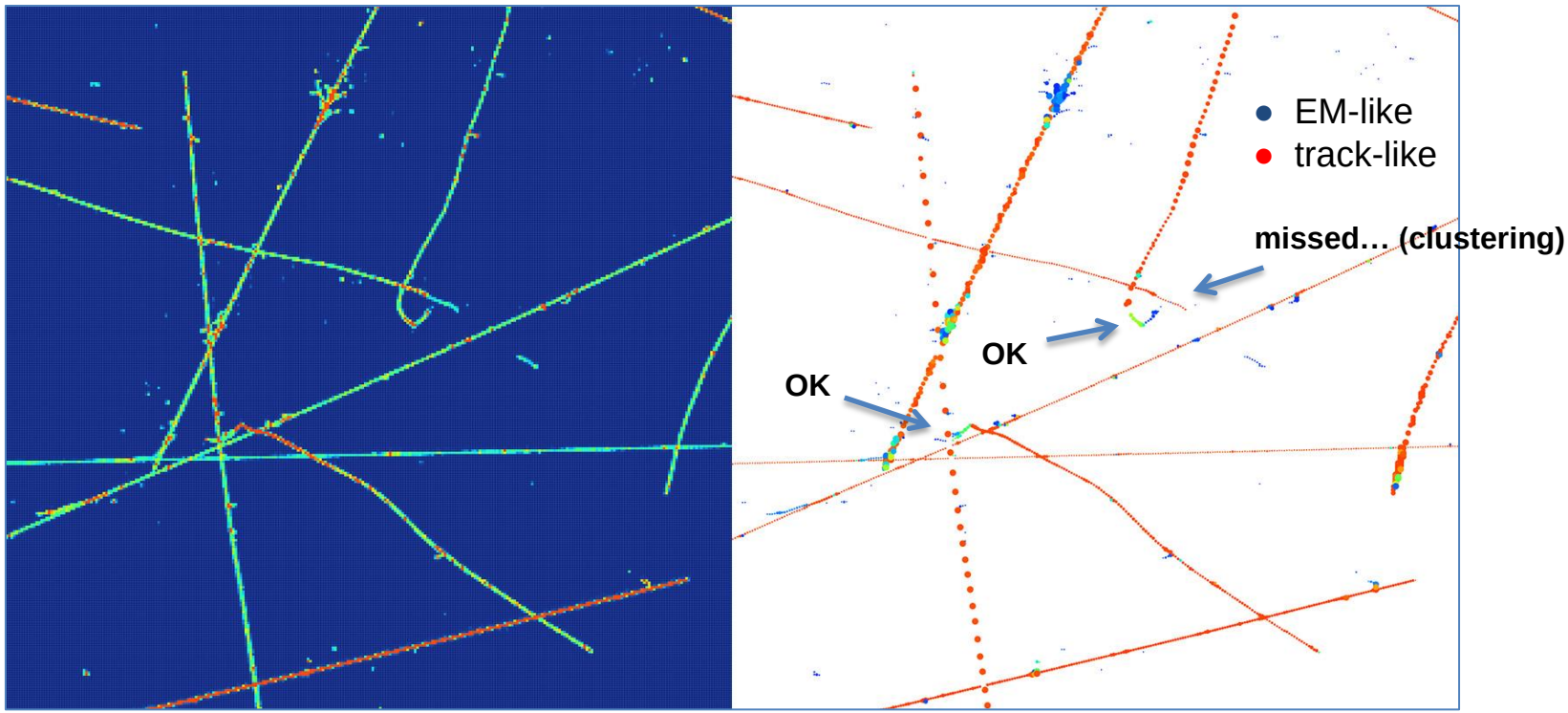


- beam in TPC + cosmics
  → CNN was not trained on cosmic μ's, nor beam electrons
- only a first look at result: reasonable at 1 GeV/c, but expect much more overlaps at higher momenta
- can be useful in finding which muon track section length (and resulting charge) should be subtracted from electron shower
- many eletrons in the beam → may need to tag / associate electron with cherenkov veto in case of electron entering in drift window together with the triggered particle



- next possible application: *selection of Michel electron hits*
- to be used in calibration together with decay tagging
- CNN not trained on cosmic μ's, but gives good outputs
  → cosmic μ available now, can be added to training data
- one may need the same CNN model, but different threshold value
  → recomended threshold values to be saved in data product





Aim :

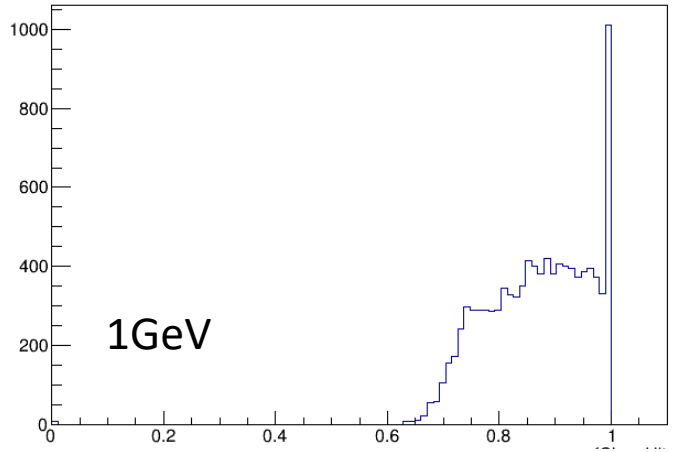
- use CNN-labeling as a generic tool (now EM/track, vertex labeling)
- build on it algotithms for dedicated analyses

Now some results…

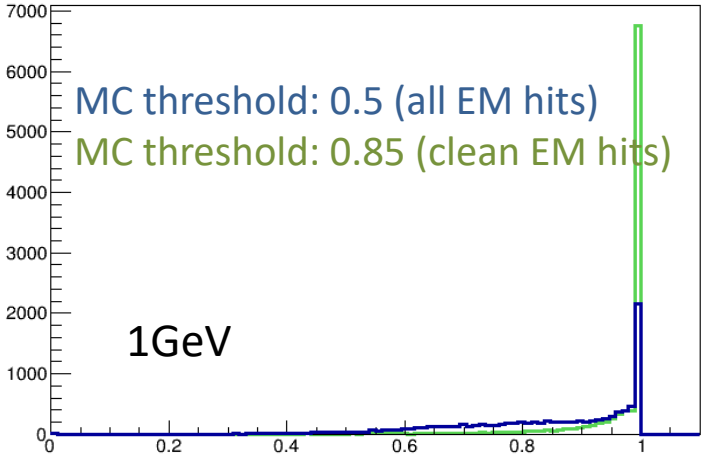
Tracks and showers/electrons overlap in 2D projection

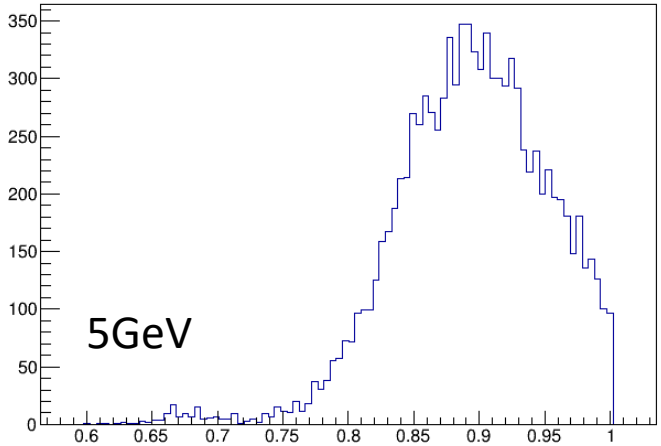
pions

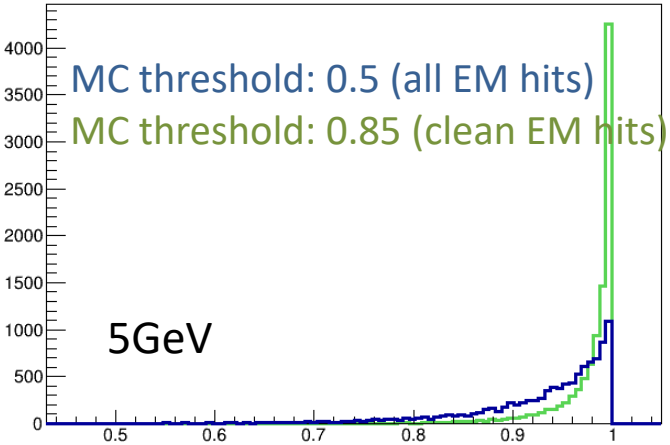
Percentage of clean hits in the event



Fraction of the EM hits correctly recognized per event







clean hit: >85% charge contribution from EM

Tracks and showers/electrons overlap in 2D projection

protons

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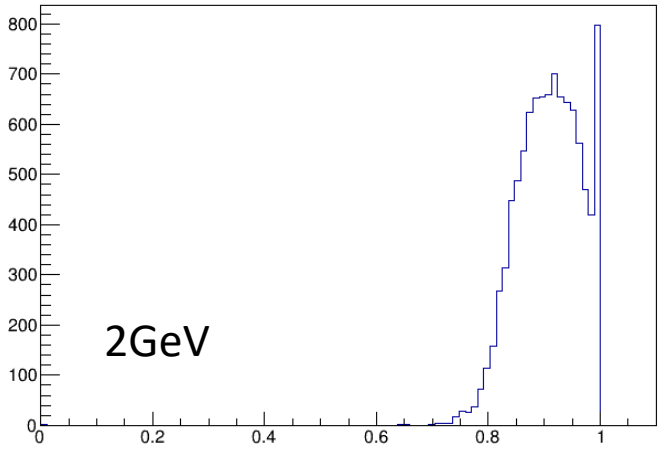

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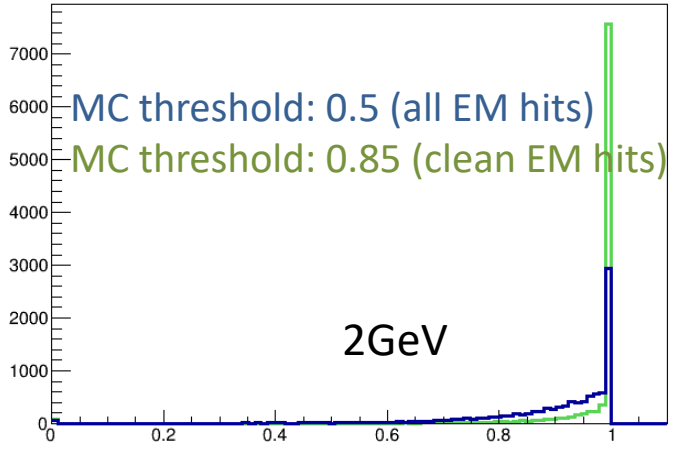

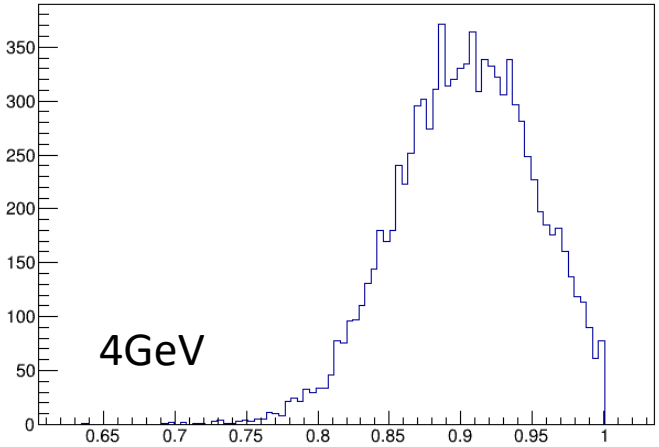

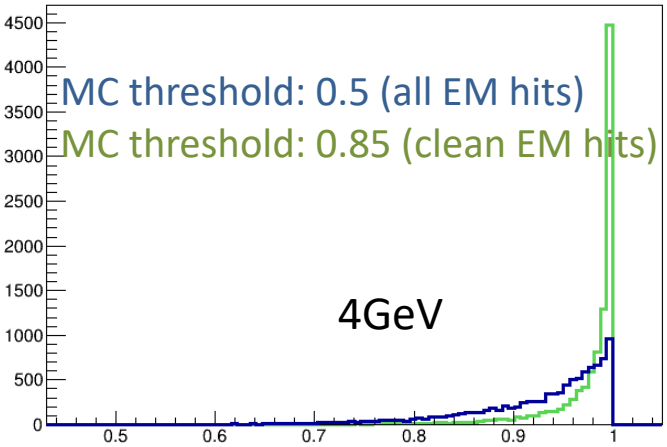

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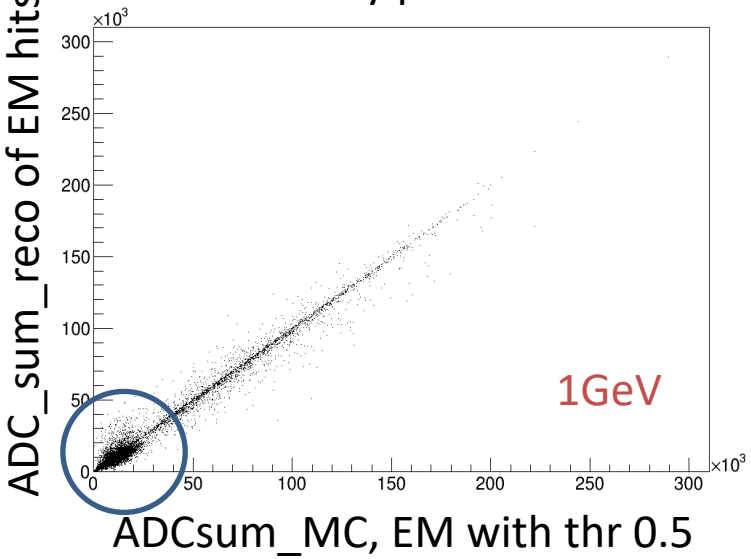
pions

One entry per event



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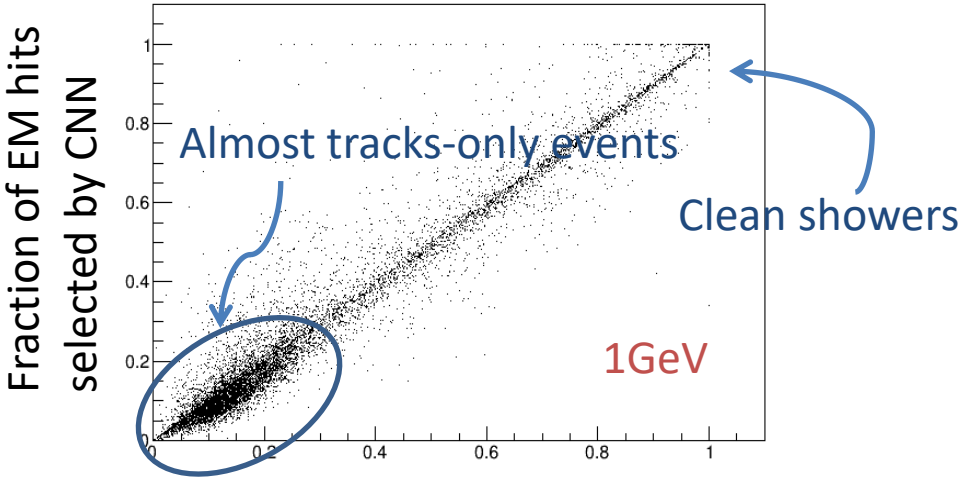
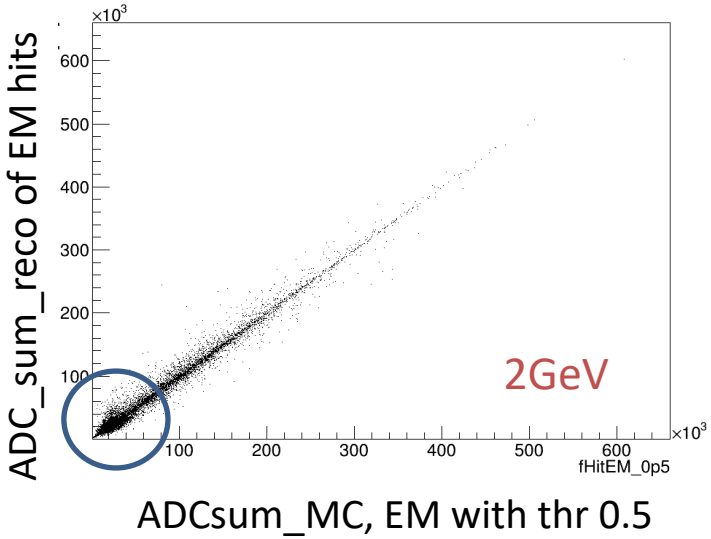
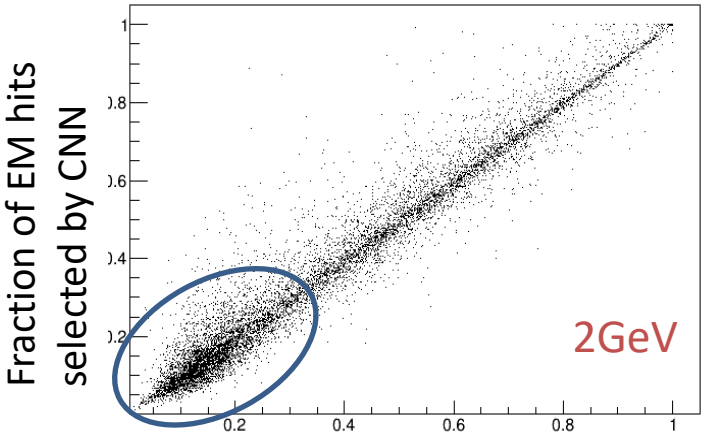
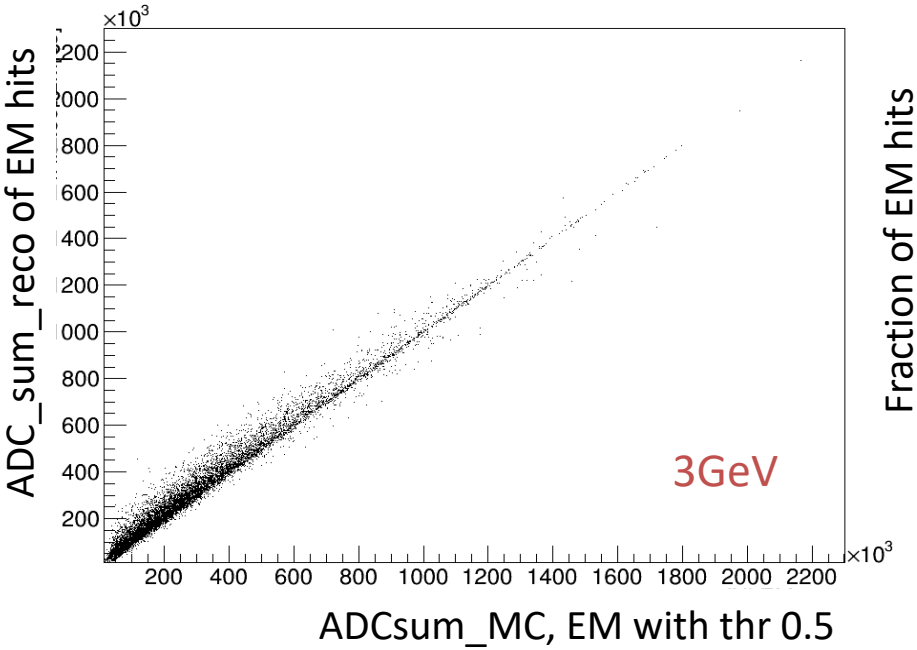


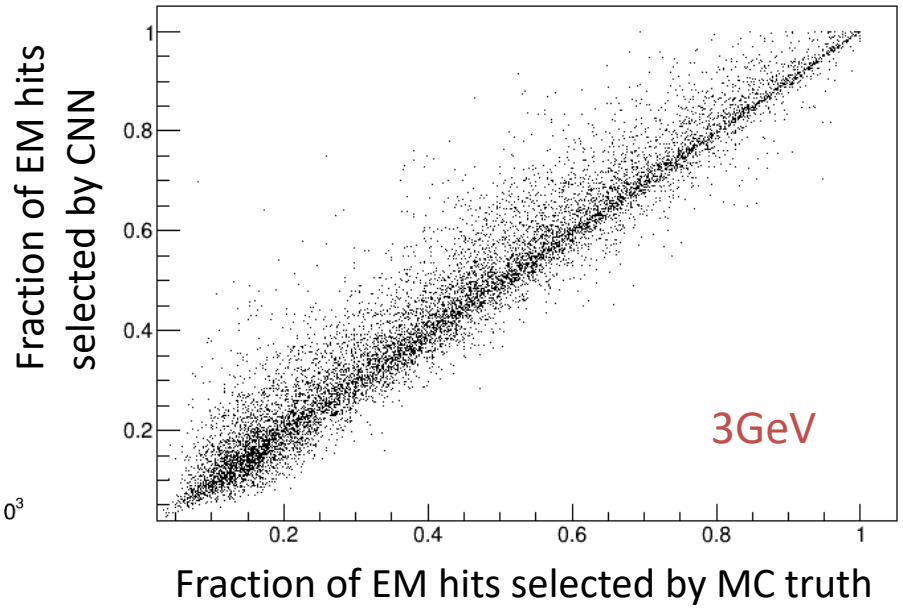


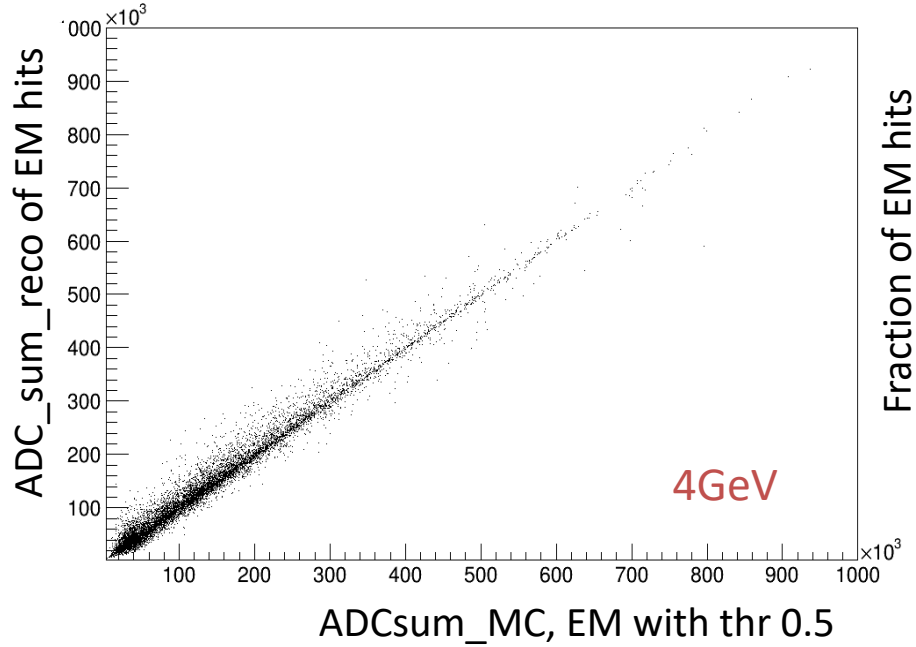


In the circle: tracks with delta rays → small EM fraction which overlap a lot with tracks

pions


ADC_sum_reco of EM hits
ADCsum_MC, EM with thr 0.5
3GeV


Fraction of EM hits selected by CNN
Fraction of EM hits selected by MC truth
3GeV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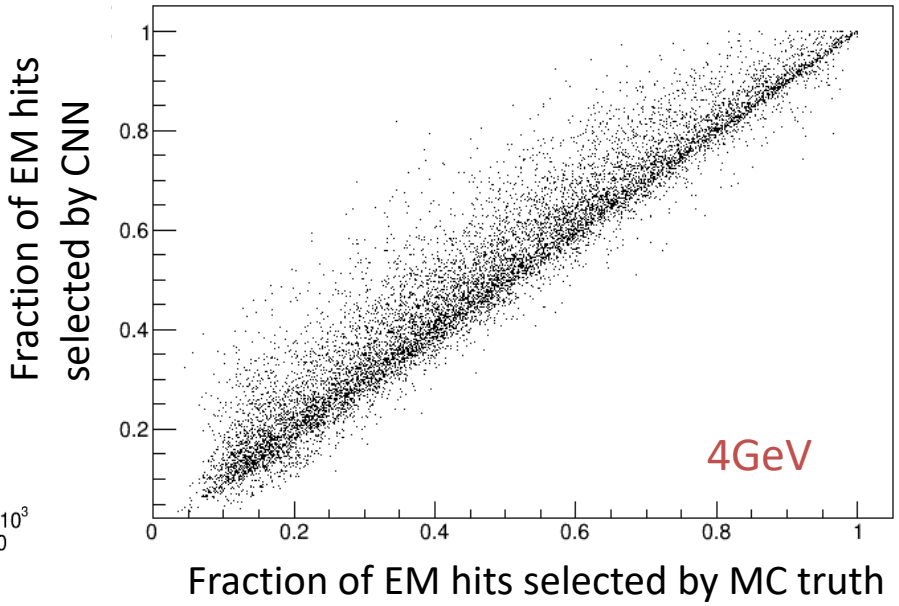
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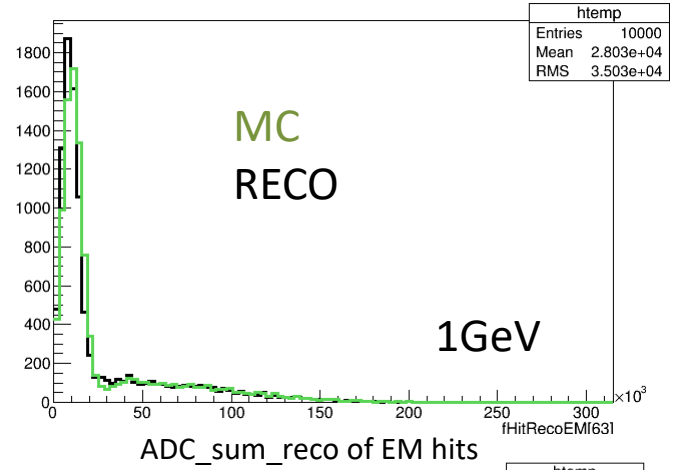
pions



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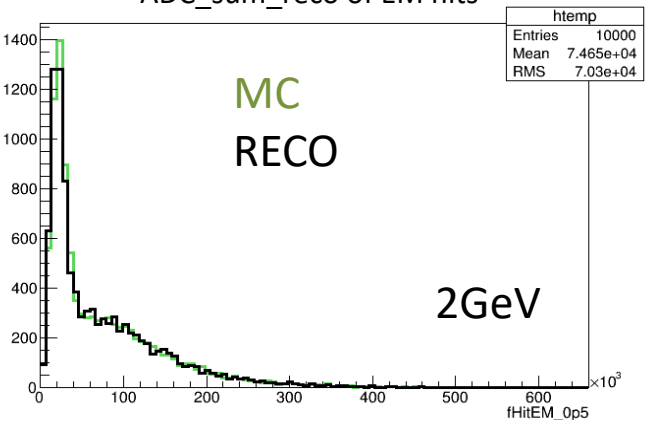

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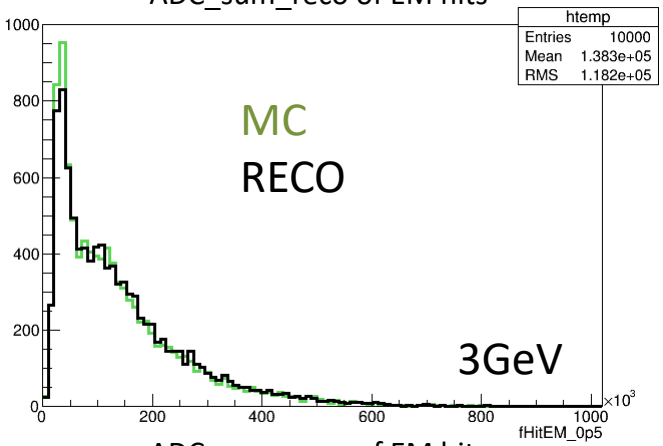

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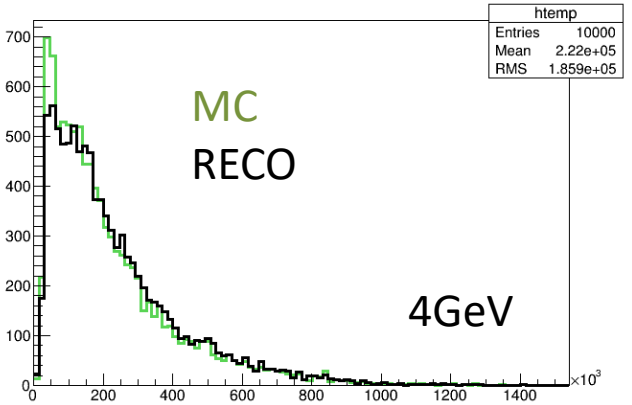
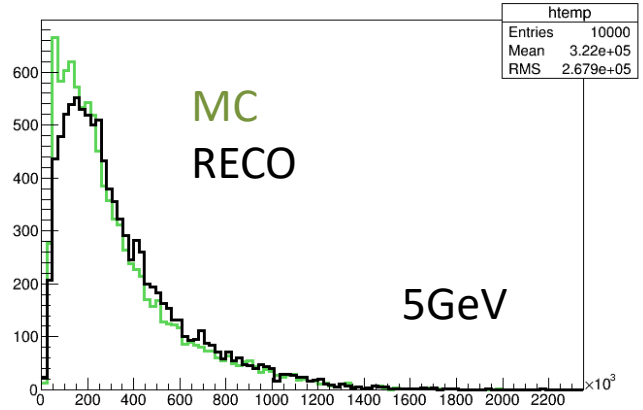
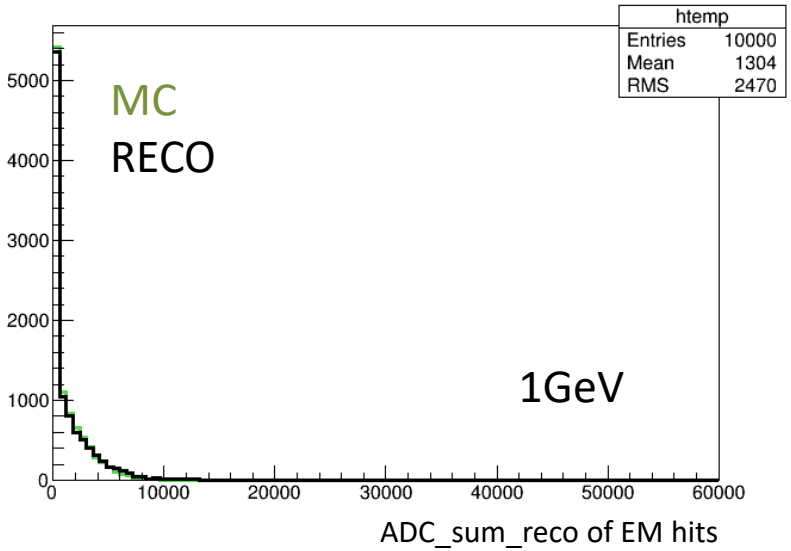


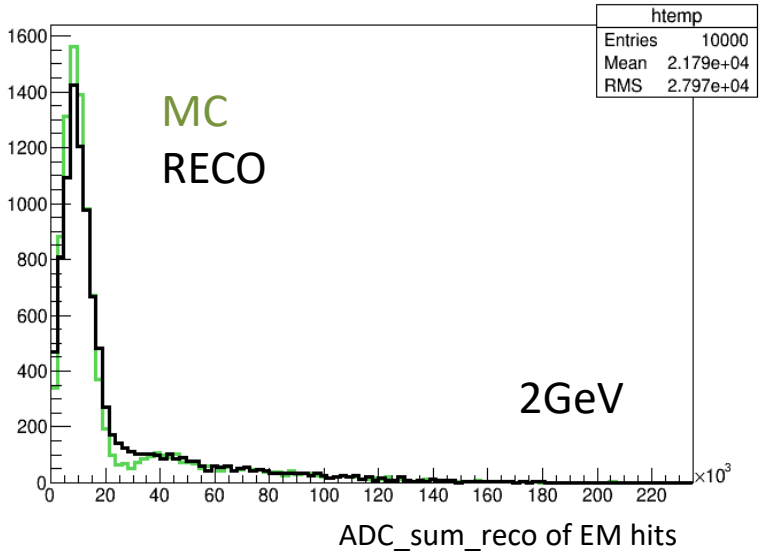
ADC_sum_reco of EM hits

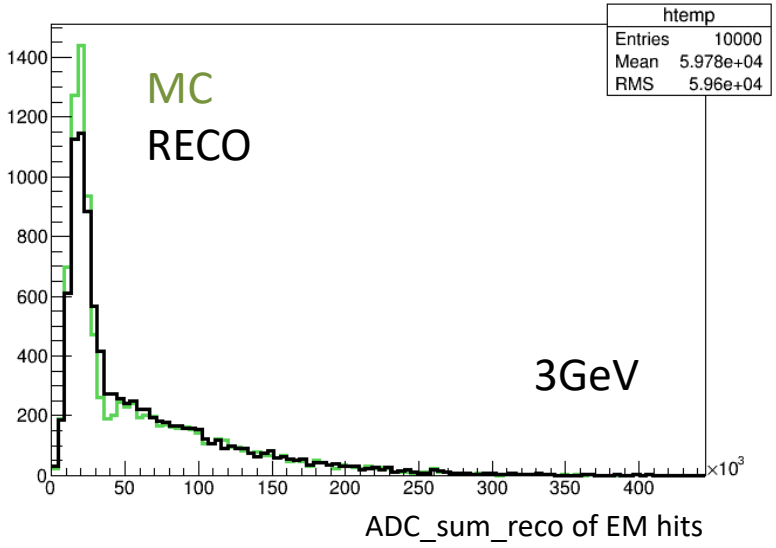


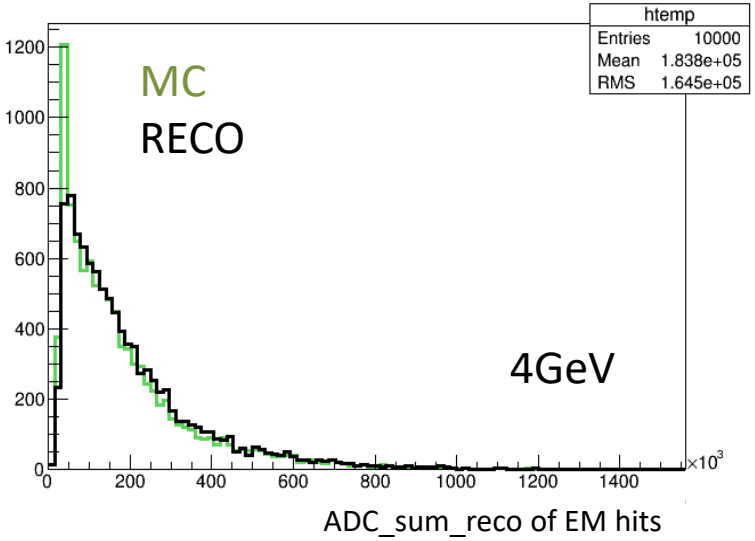
ADC_sum_reco of EM hits

protons







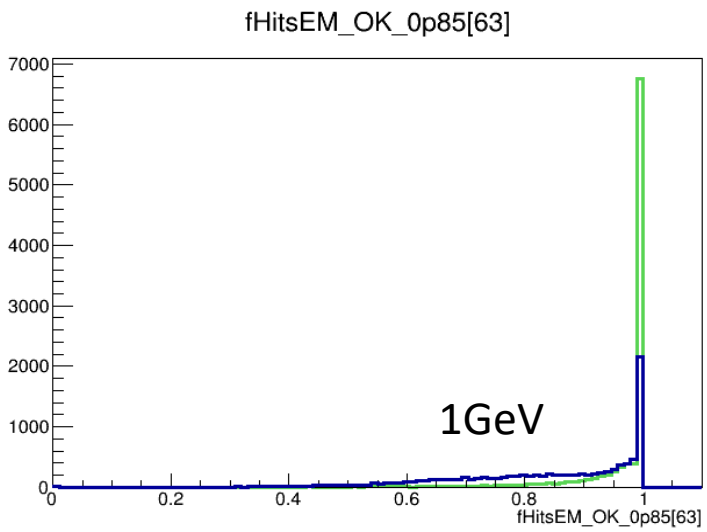


In the low-end peak: tracks with delta rays → small EM fraction which overlap a lot with tracks

→ EM part related to π^0's is the high values tail – here we could test the MC model

backup

pions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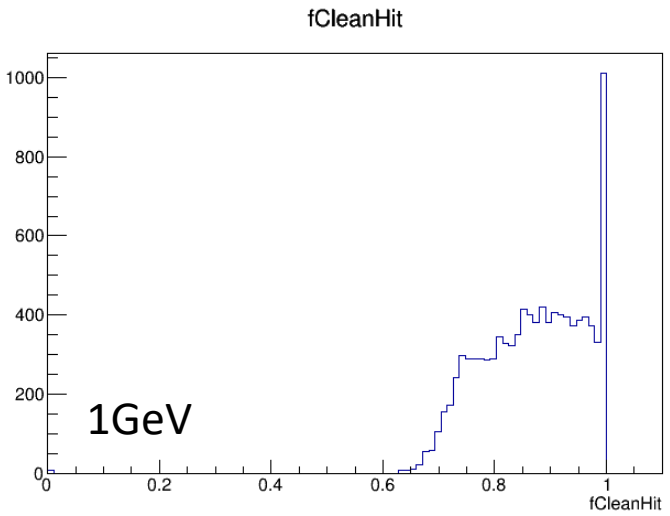
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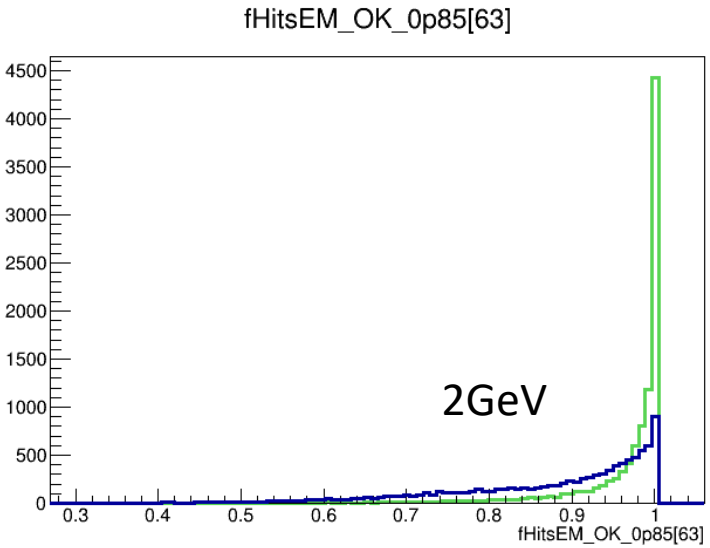
fCleanHit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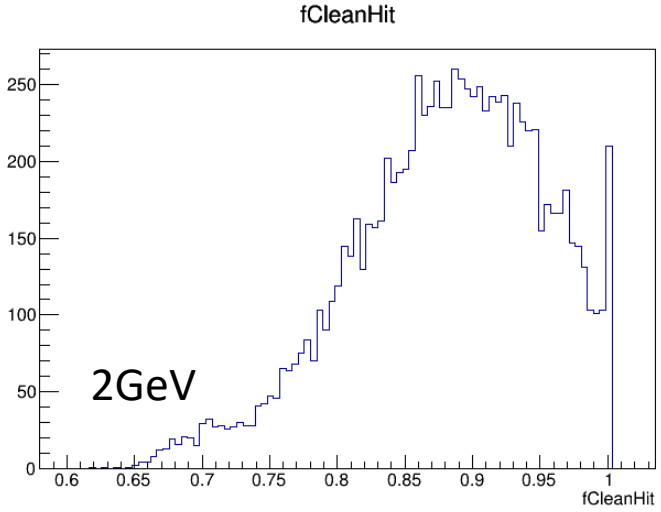
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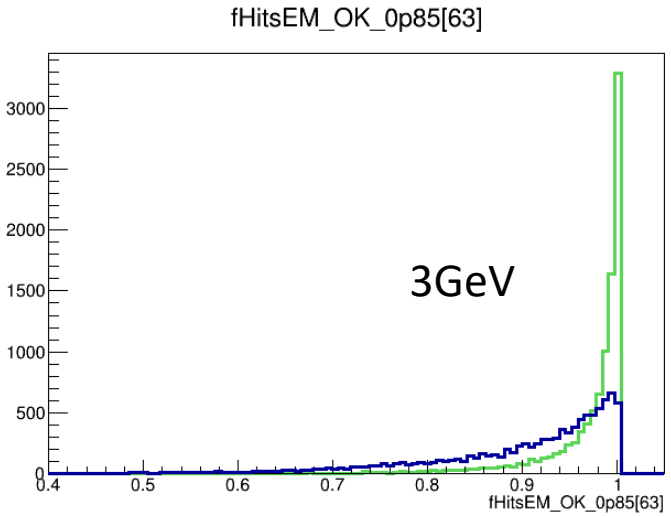
2GeV
fCleanHit

pions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3GeV
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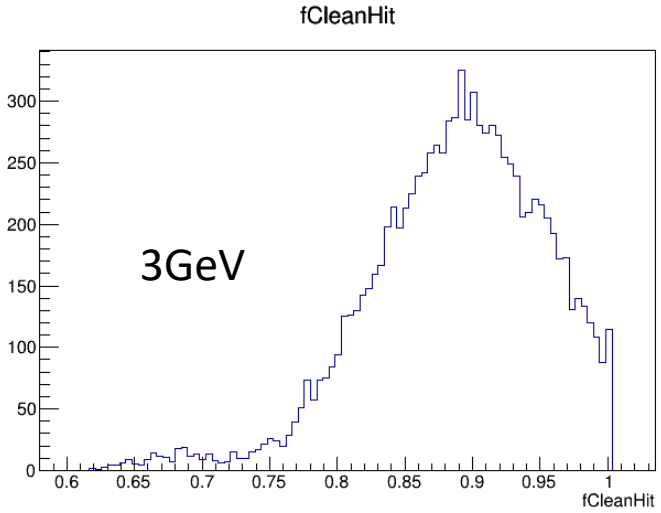
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3GeV
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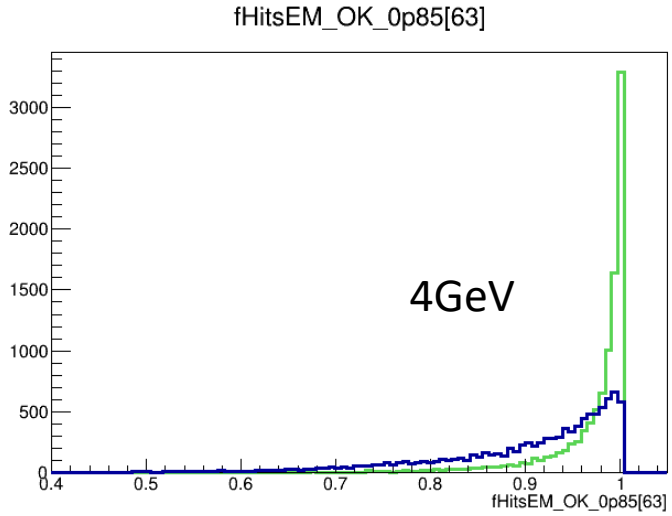
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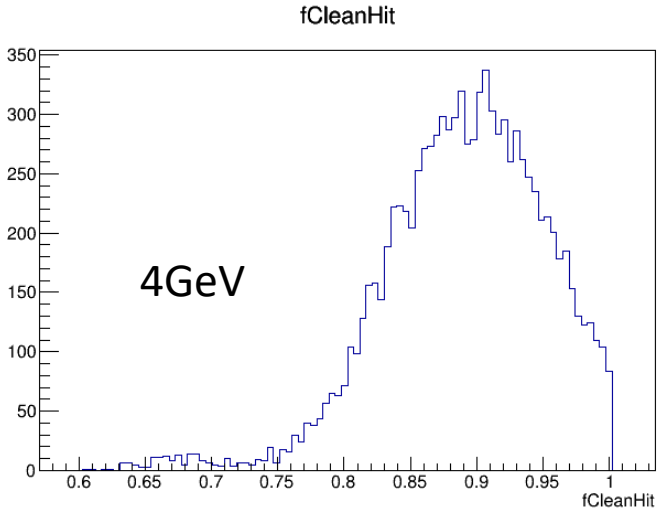
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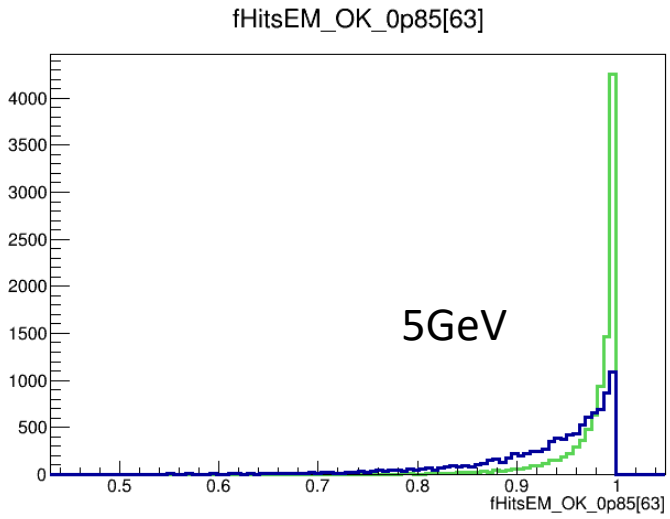
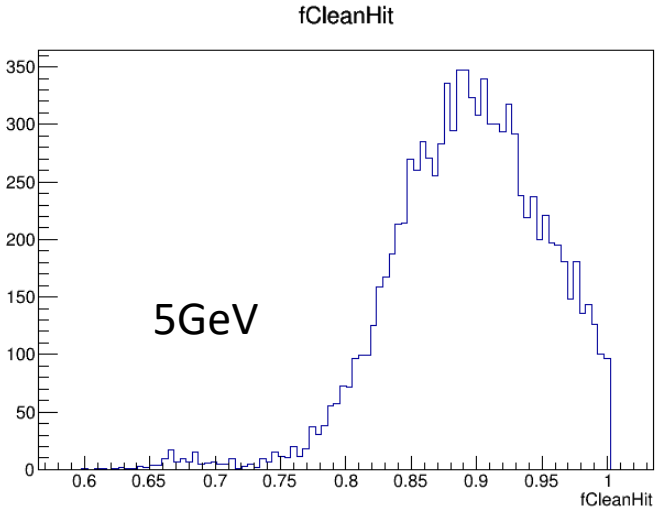
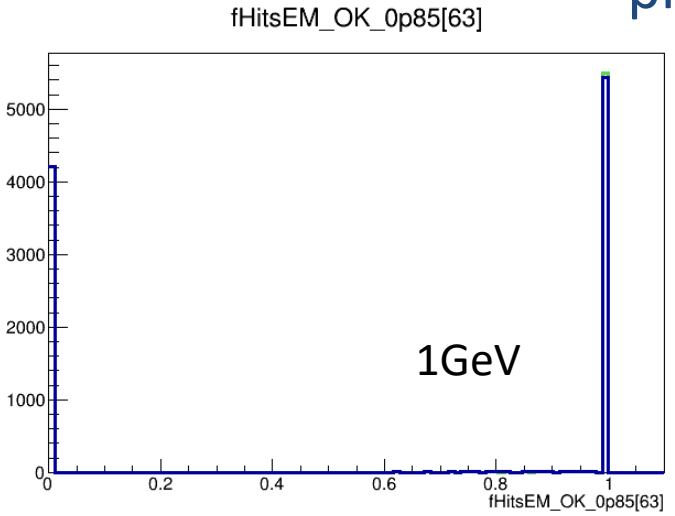
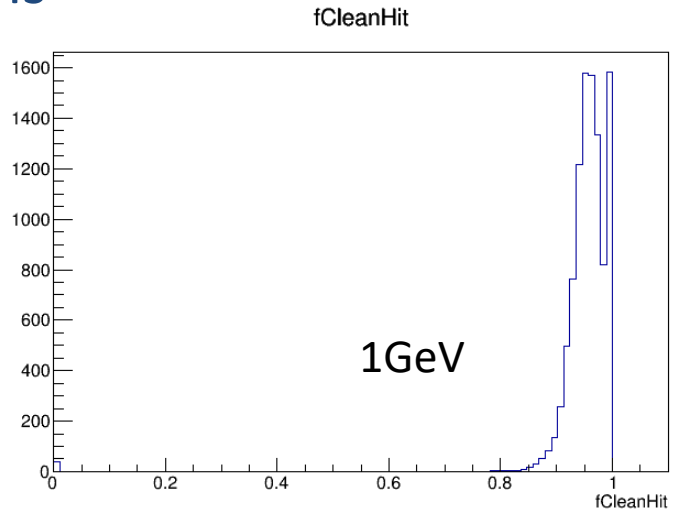
pions





protons





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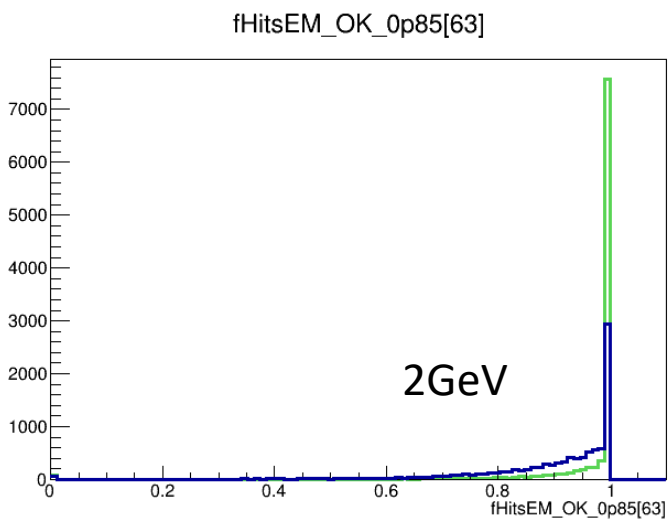
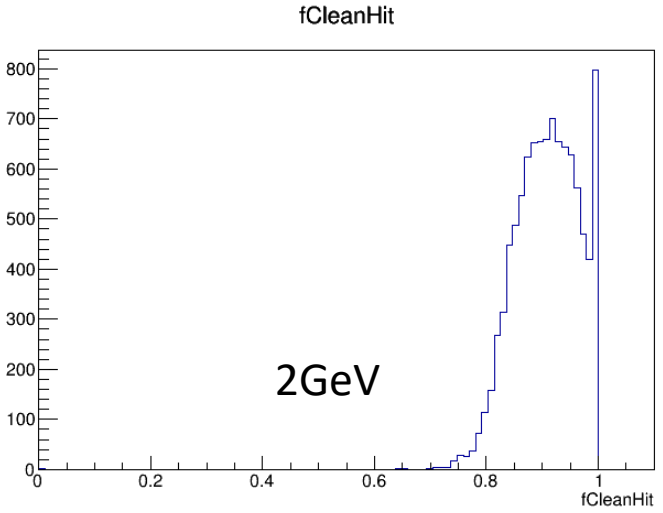
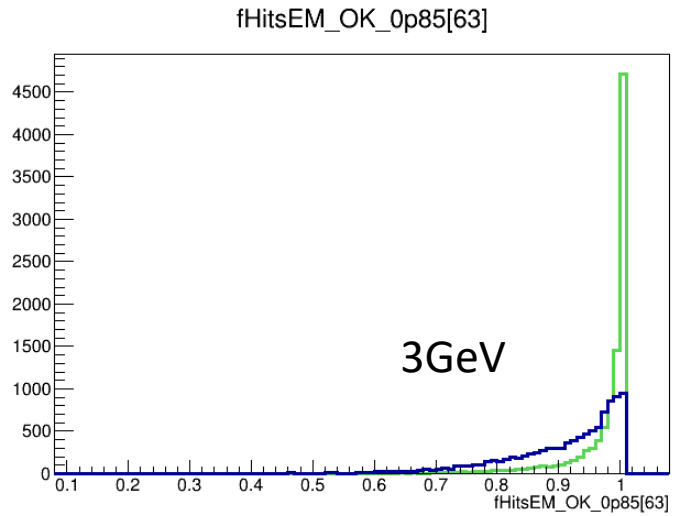
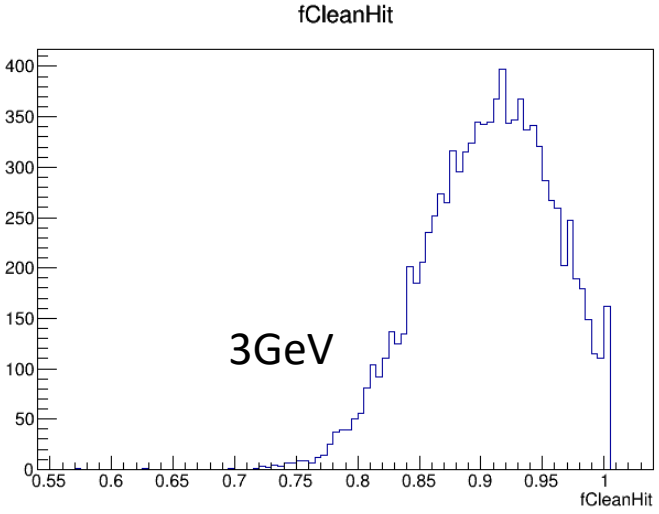


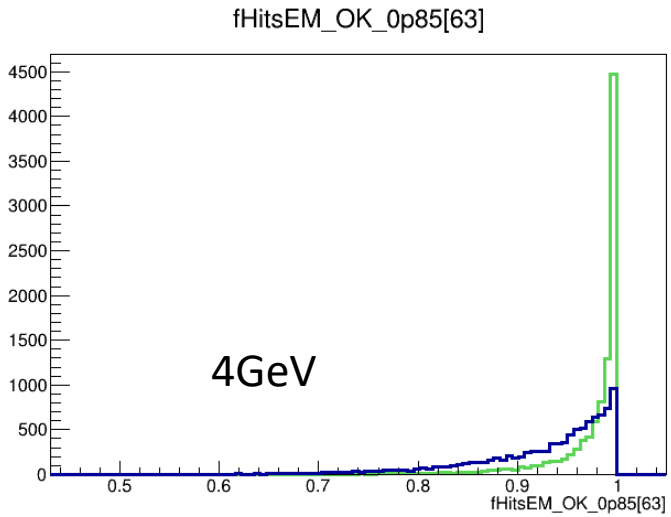






Nakladaja się coraz bardziej z energia

protons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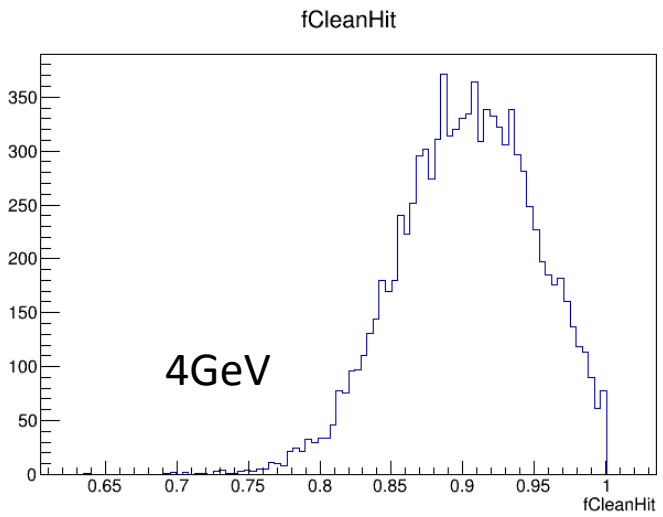
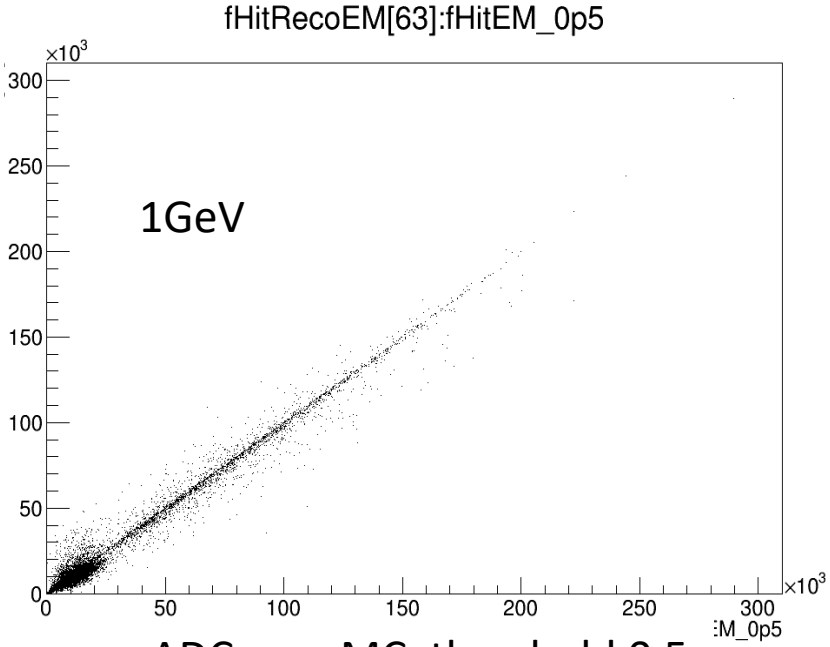
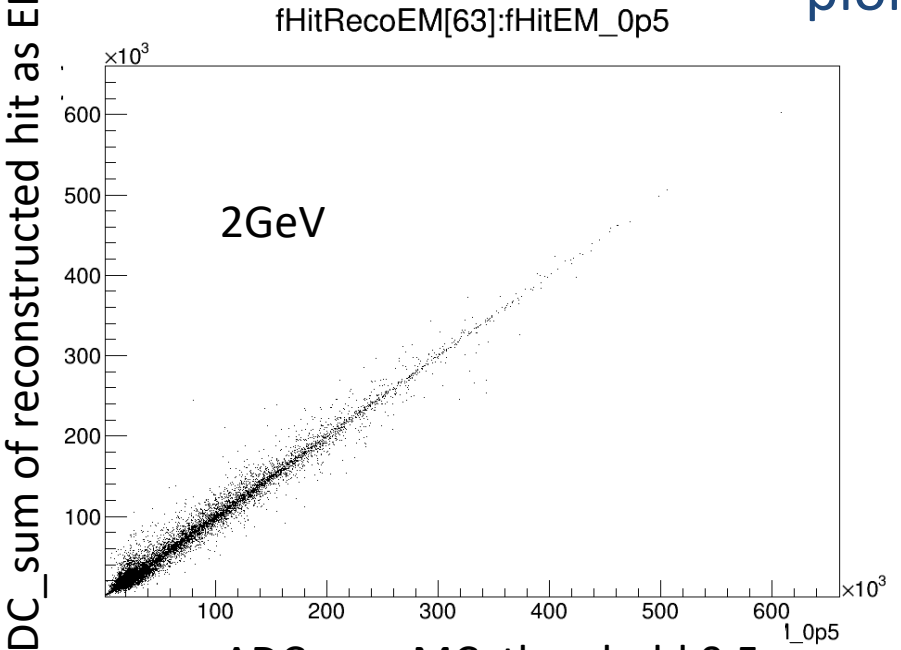
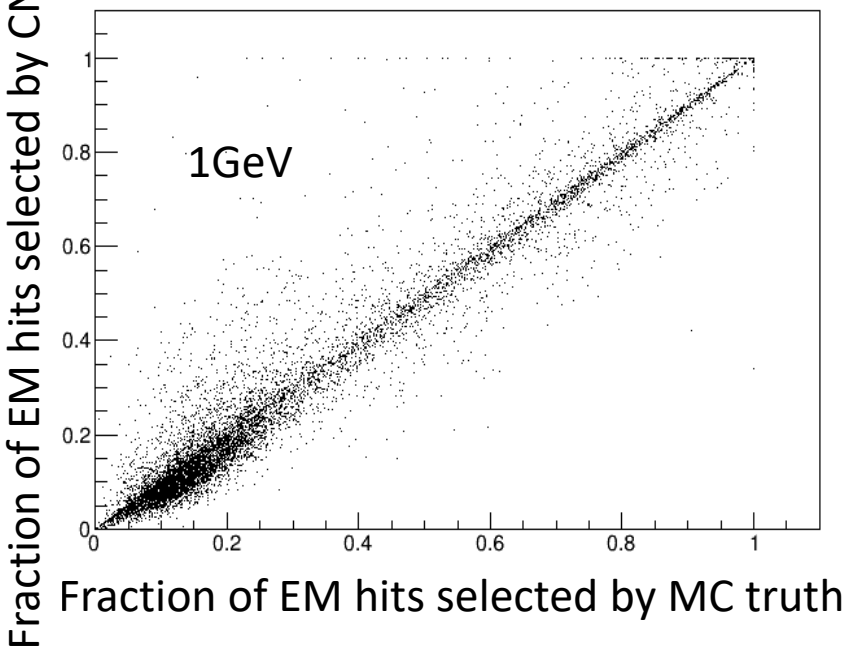
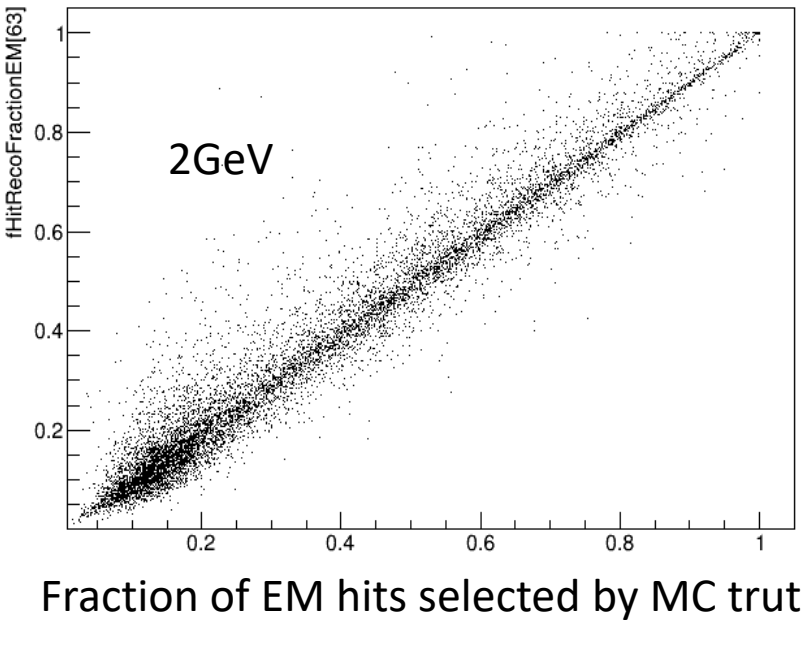

fCleanHit
4GeV
fCleanHit

pions

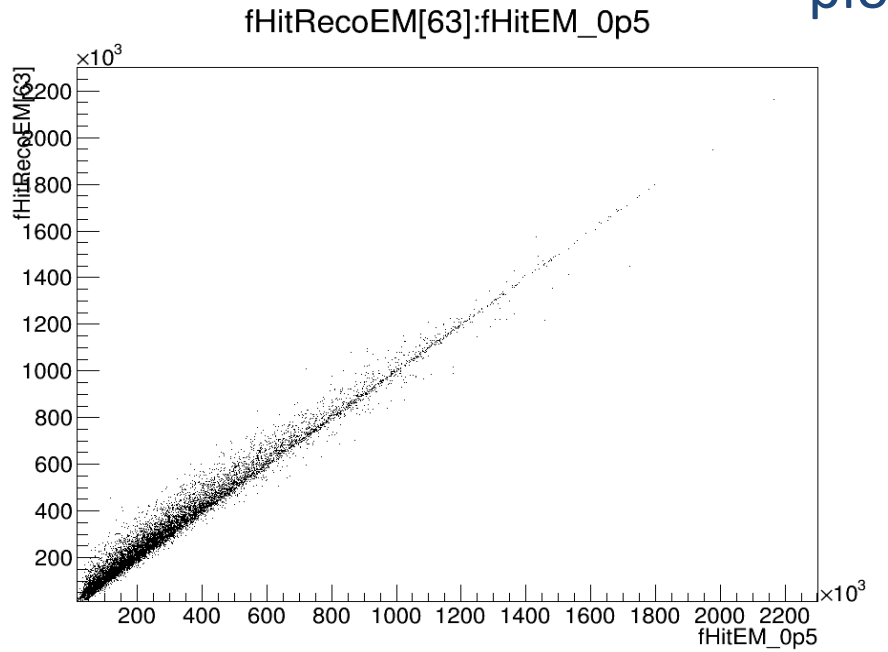

fHitRecoEM[63]:fHitEM_0p5
1GeV
ADCsum_MC, threshold 0.5

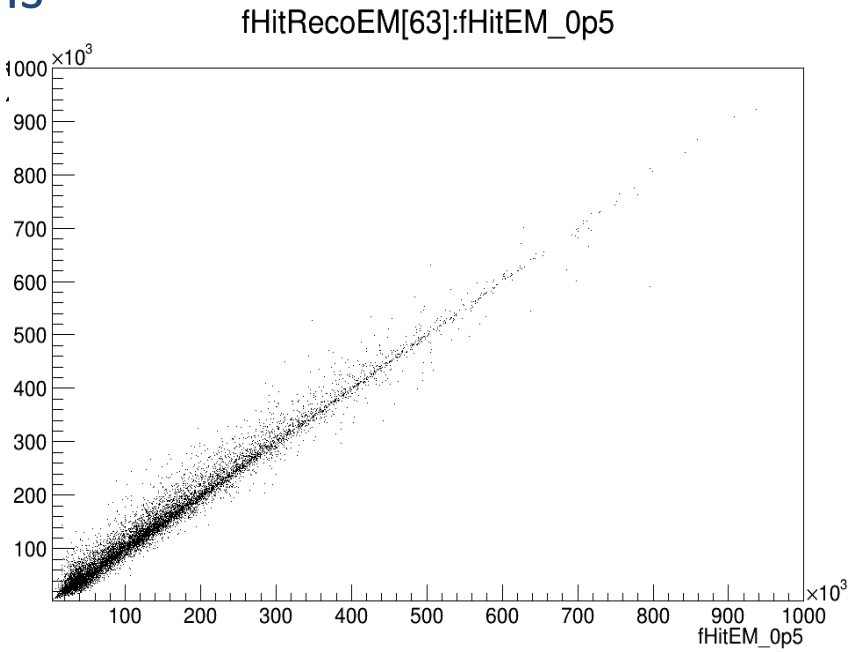

fHitRecoEM[63]:fHitEM_0p5
2GeV
ADCsum_MC, threshold 0.5

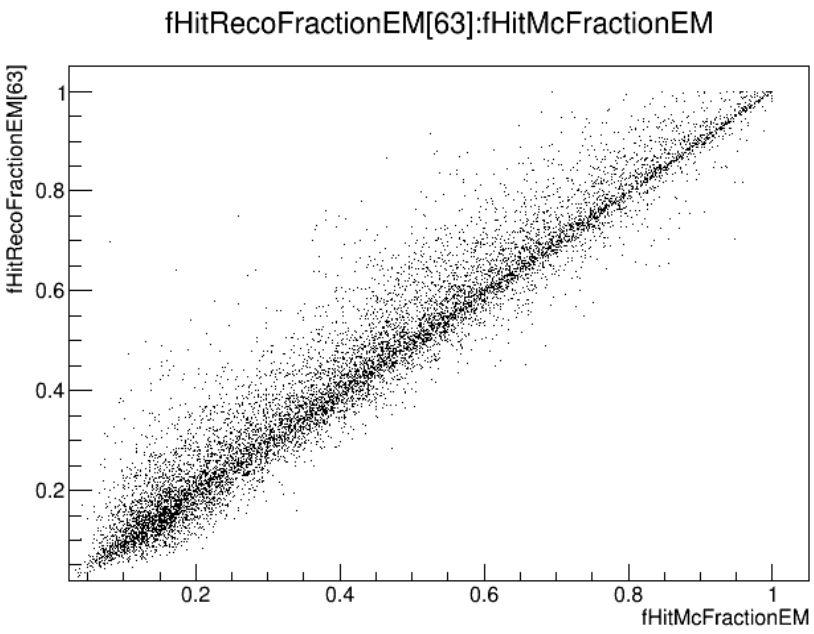

1GeV
Fraction of EM hits selected by MC truth

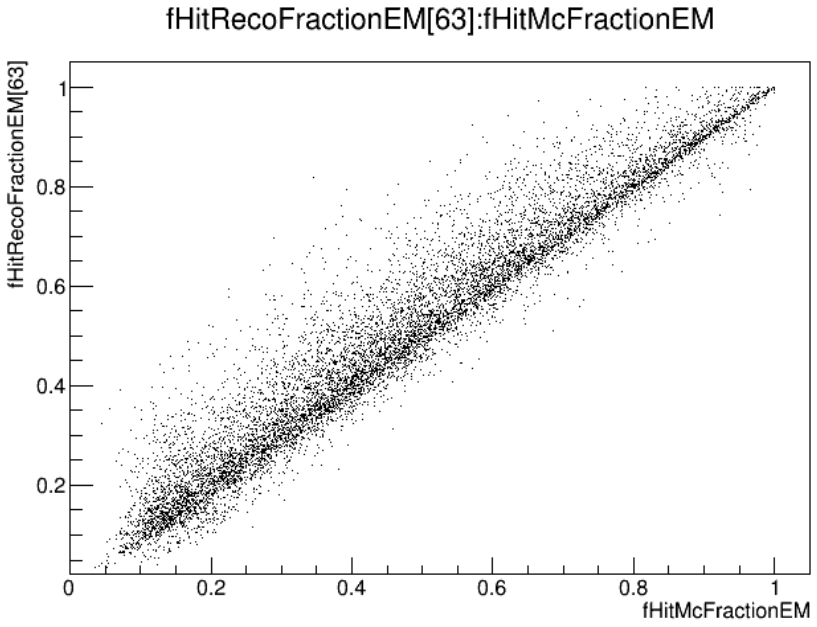

fHitRecoFractionEM[63]
2GeV
Fraction of EM hits selected by MC truth

pions


fHitRecoEM[63]:fHitEM_0p5
×10^3
fHitRecoEM[63]
fHitEM_0p5
×10^3


fHitRecoEM[63]:fHitEM_0p5
×10^3
fHitEM_0p5
×10^3


fHitRecoFractionEM[63]:fHitMcFractionEM
fHitRecoFractionEM[63]
fHitMcFractionEM


fHitRecoFractionEM[63]:fHitMcFractionEM
fHitRecoFractionEM[63]
fHitMcFractionEM