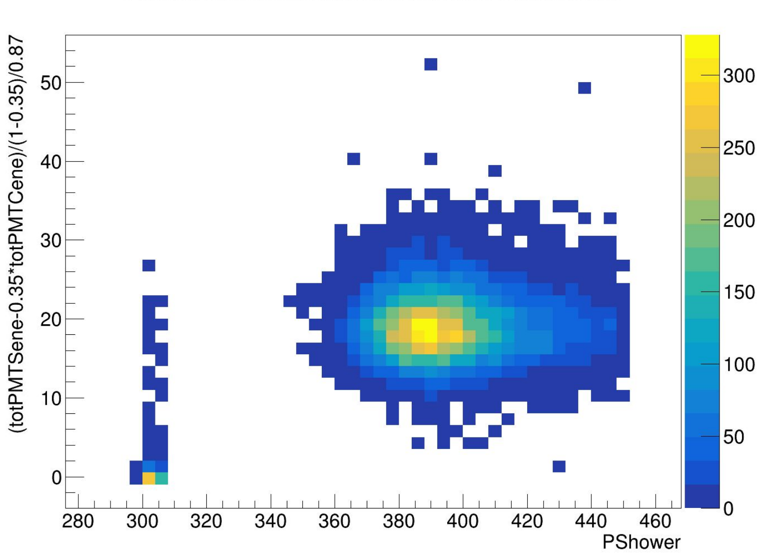
# Test Beam 2024
# Pion beam analysis

Andrea Pareti - 04/03/2025

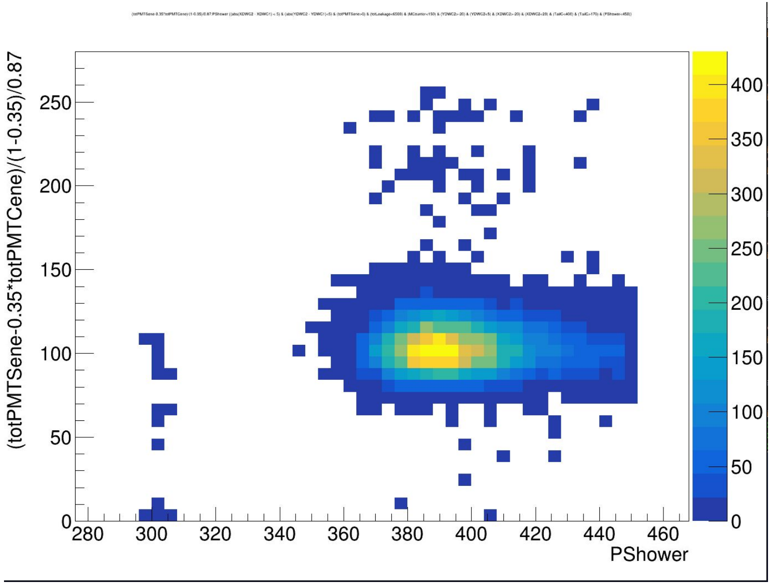
# Pion selection

```
myCut = "(abs(XDWC2 - XDWC1) < 5) & (abs(YDWC2 - YDWC1)<5) & (totPMTSene>0) & (PShower<450) &
(TailC<400) & (TailC>170) & (totLeakage<6500) & (MCounter<160) & (PShower>350) & (YDWC2>-20) &
(YDWC2<5) & (XDWC2>-20) & (XDWC2<20)"
```

Reco E Vs PreShower, 20 GeV pions




Reco E Vs PreShower, 100 GeV pions



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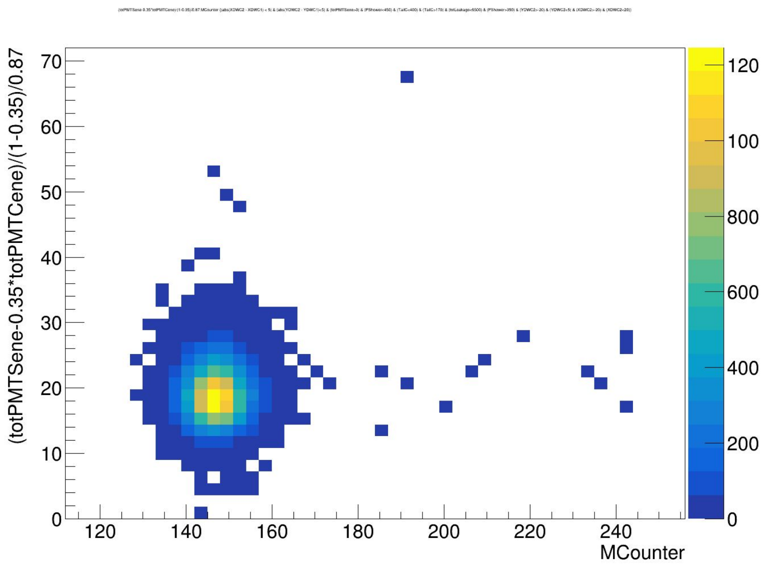
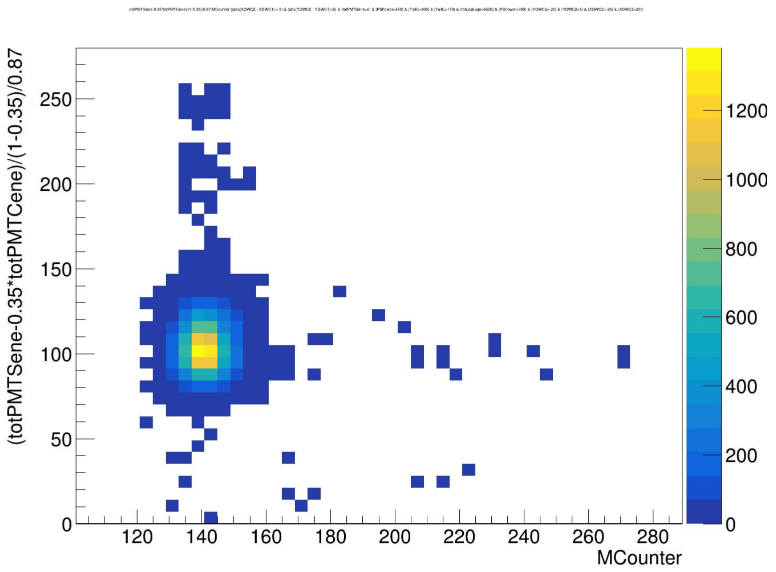
(YDWC2<5) & (XDWC2>-20) & (XDWC2<20)"
```

Reco E Vs MCounter, 20 GeV pions




Reco E Vs MCounter, 100 GeV pions



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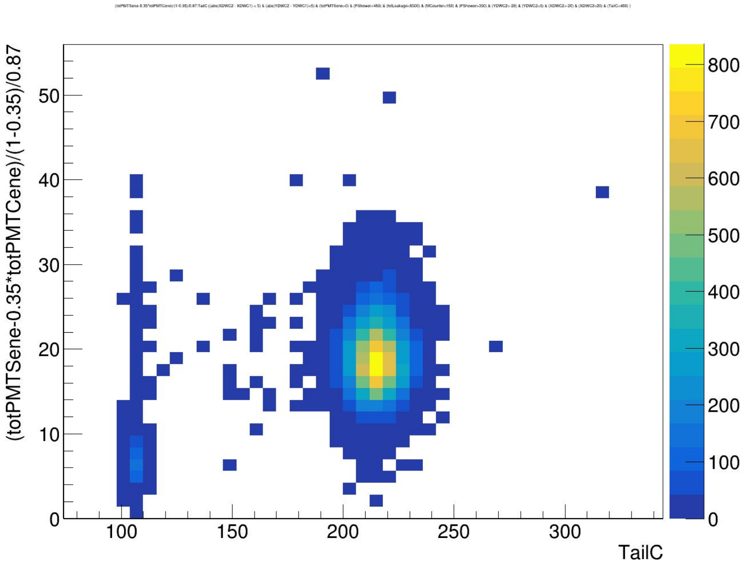
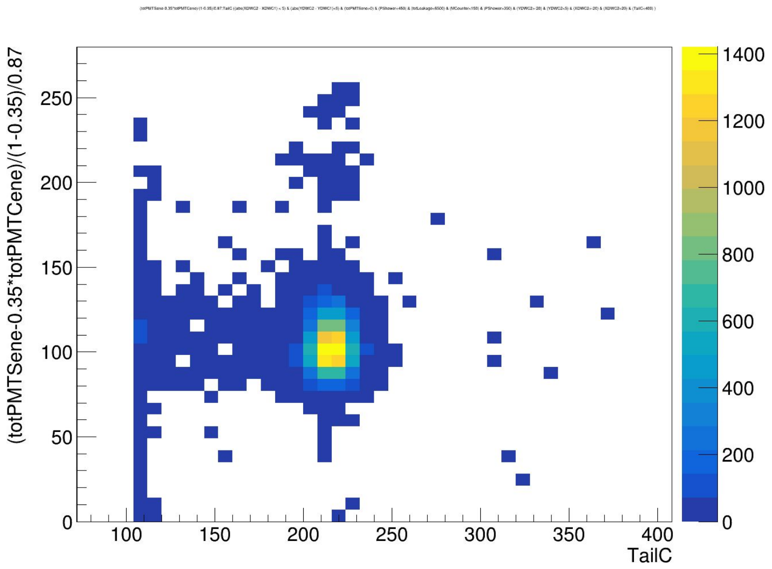
(YDWC2<5) & (XDWC2>-20) & (XDWC2<20)"
```

Reco E Vs TailC, 20 GeV pions




Reco E Vs TailC, 100 GeV pions



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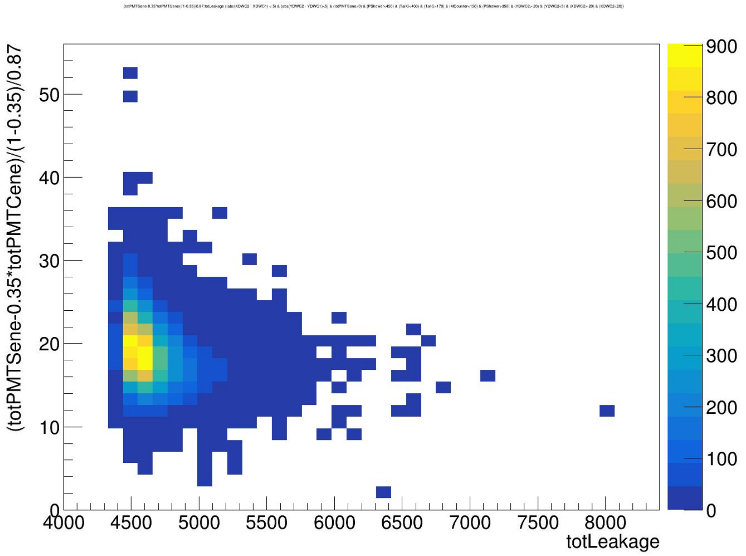
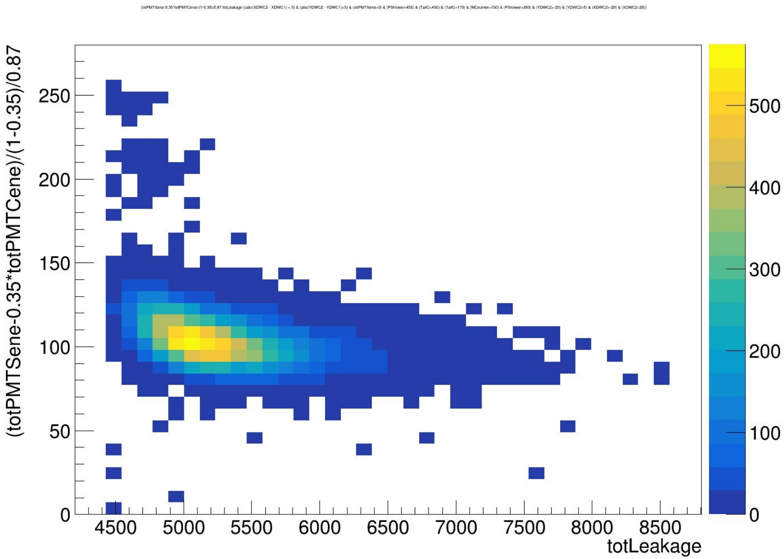
(YDWC2<5) & (XDWC2>-20) & (XDWC2<20)"
```

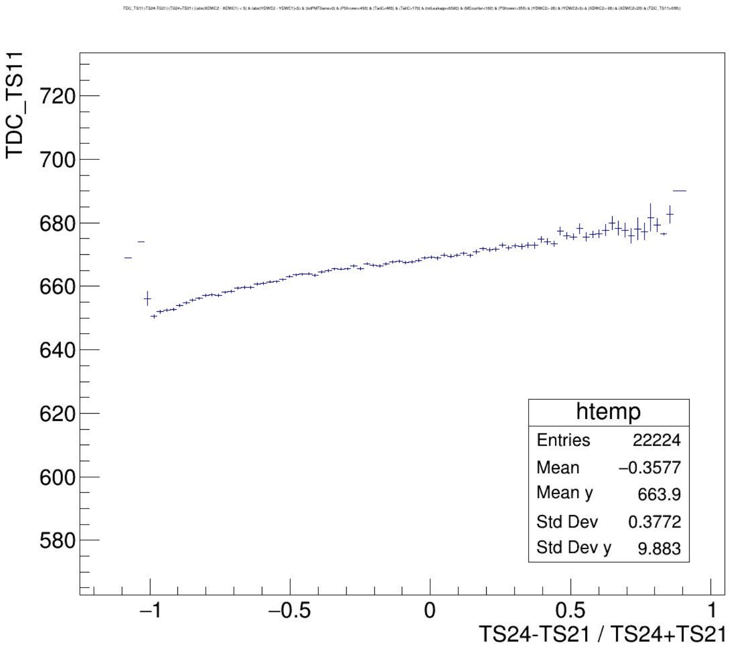
Reco E Vs totLeakage, 20 GeV pions




Reco E Vs totLeakage, 100 GeV pions



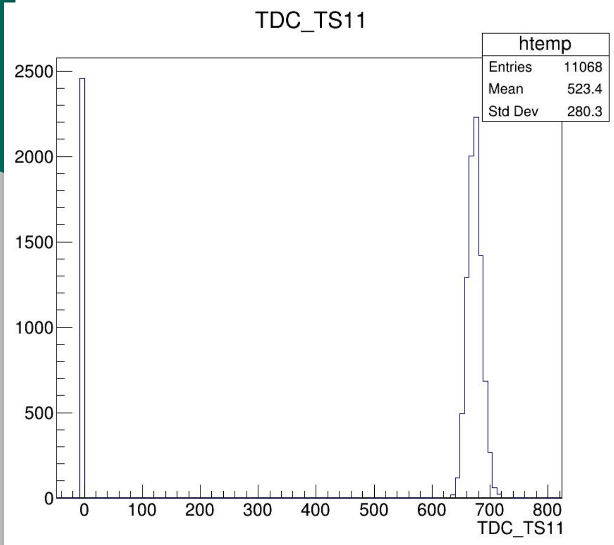
# TDC correlation with asymmetry variable



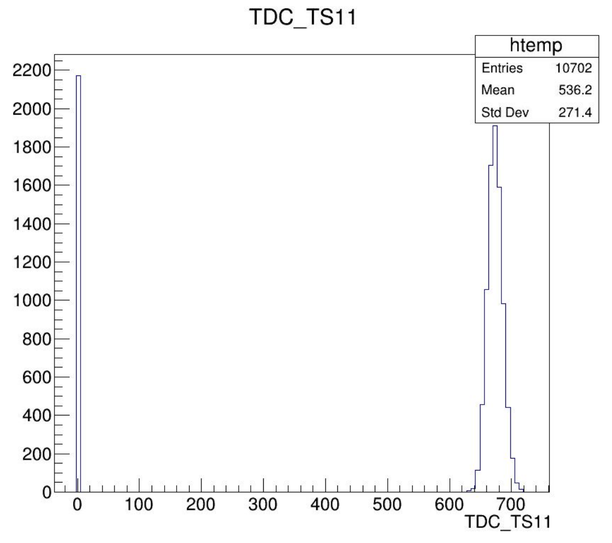
# TDCs

Runs 0968-0972 (pion energy scan) have  large “pedestal” -> not sure what’s wrong
After cuts, quite low statistics
Run 1000 is good, but taken after time info was amplified -> offset for this energy sample on all TDCs

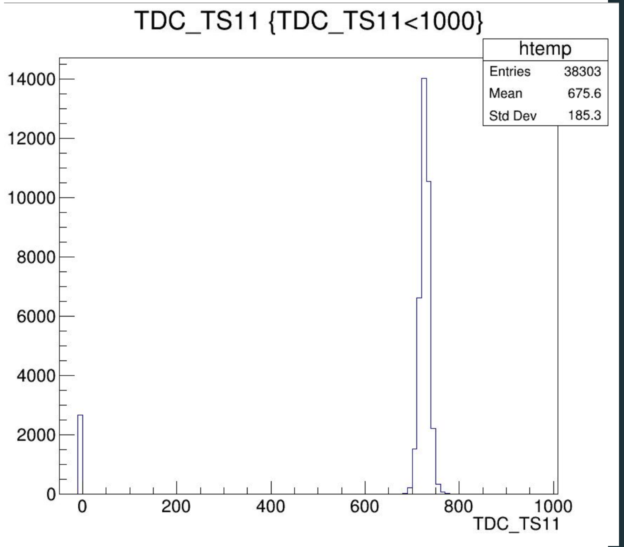
Run 0968, 20 GeV pions




Run 0972, 20 GeV pions

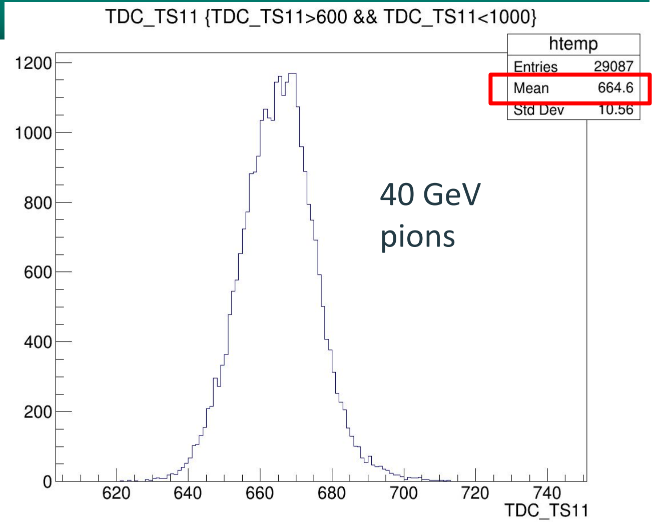


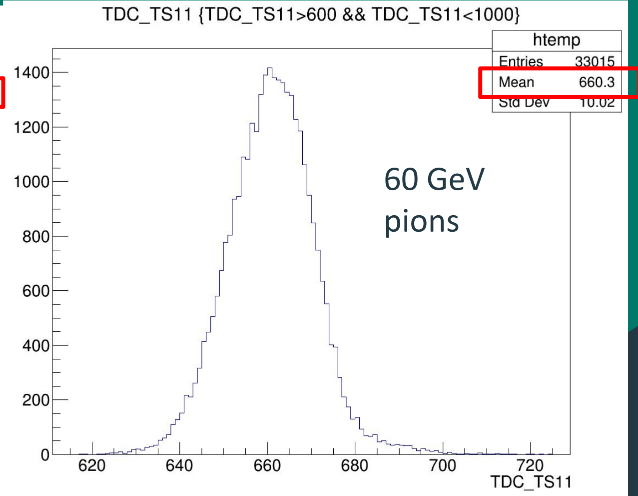

Run 1000, 20 GeV pions

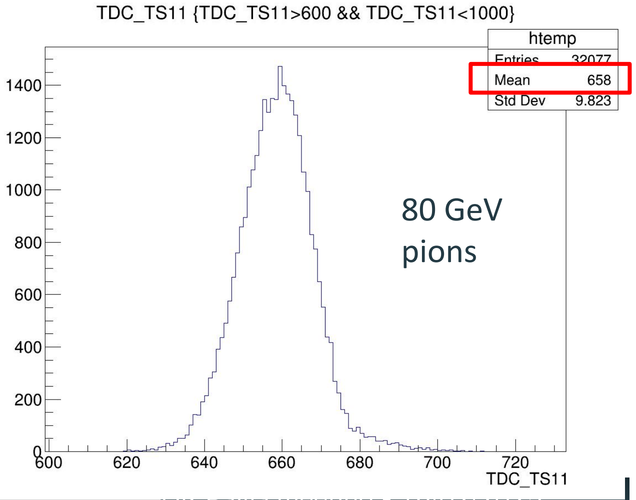


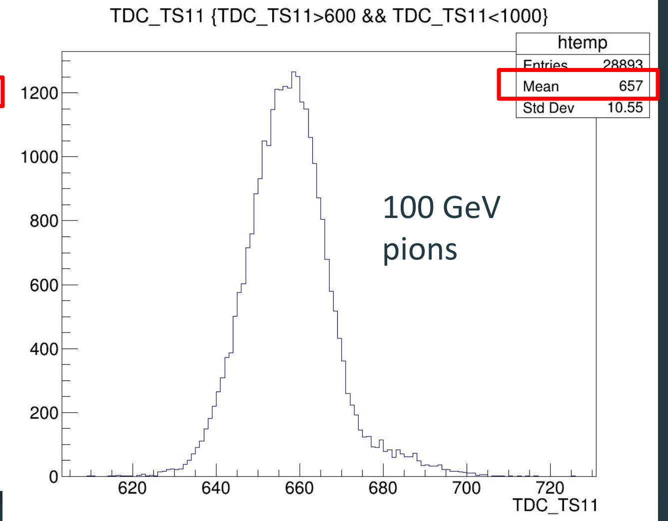
# TDCs

Not clear how to shift TDC distribution with energy



# TDCs

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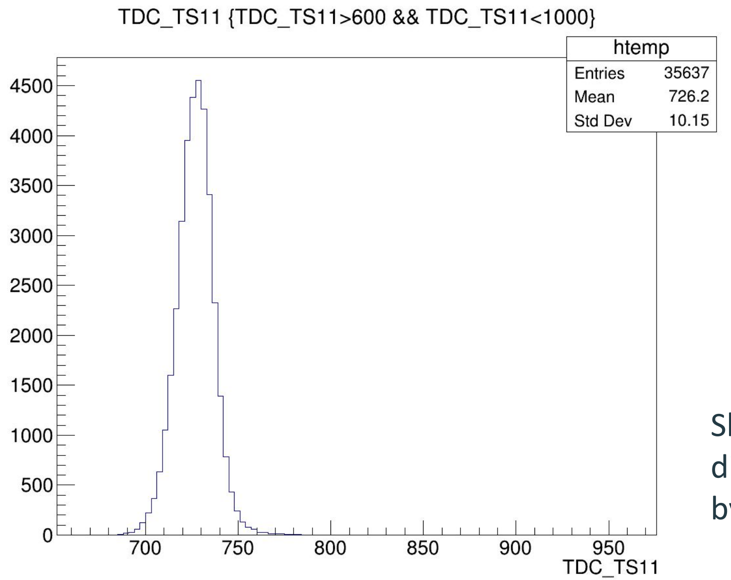
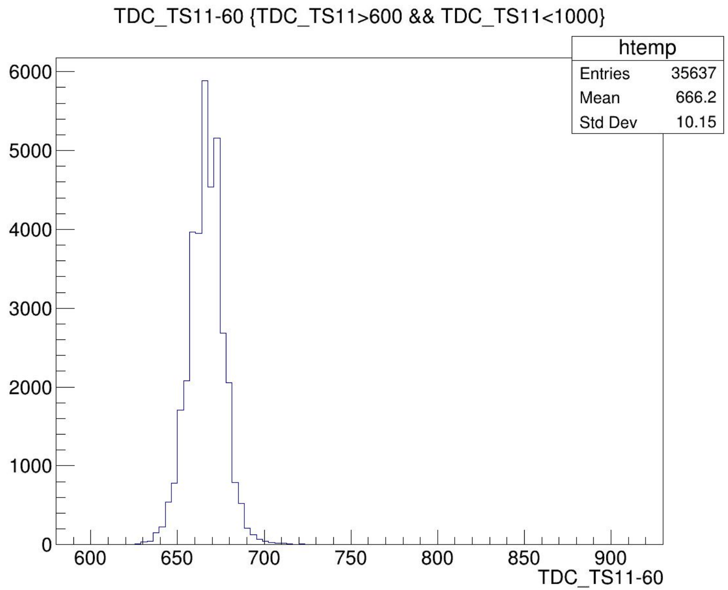


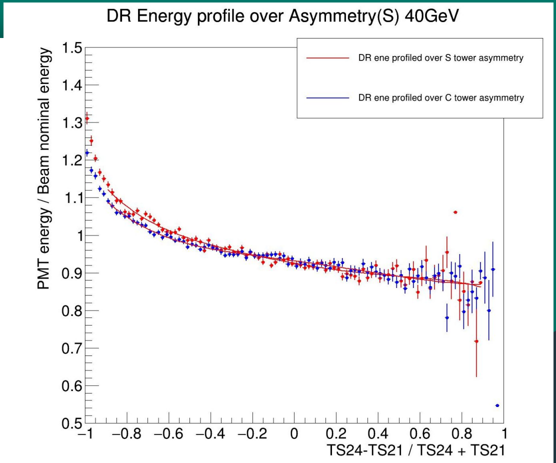

Shifting distribution by 60 tdcs

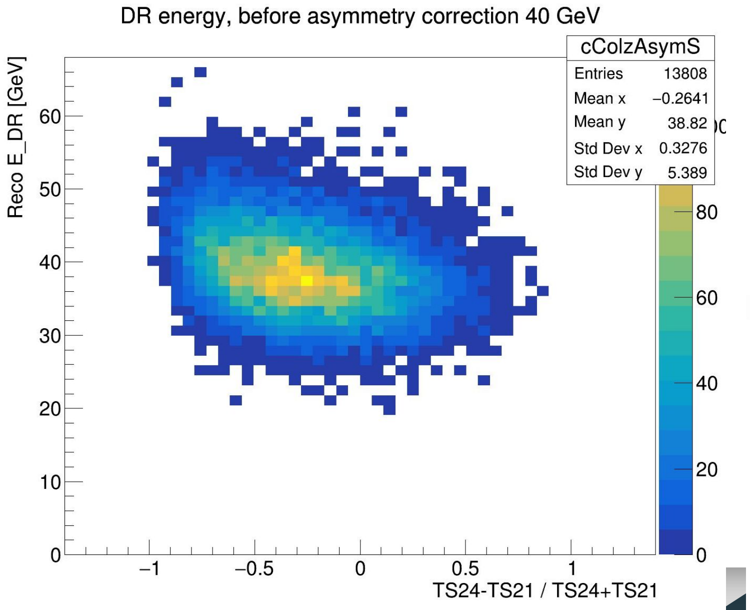


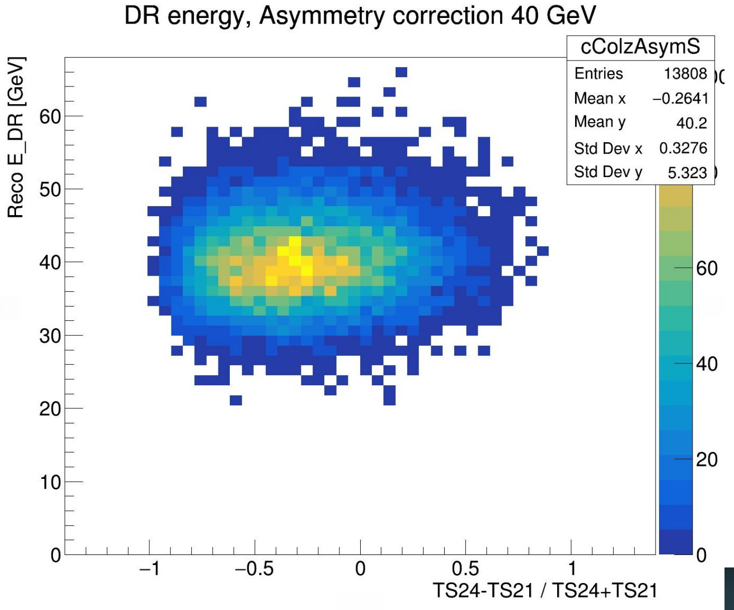
# On pion energy corrections

Fit asym = (TS24-TS21)/(TS24+TS21) with 5deg polynomial

For any point, $E_{DR} = E_{DR}/fS_{40GeV}(asym)$



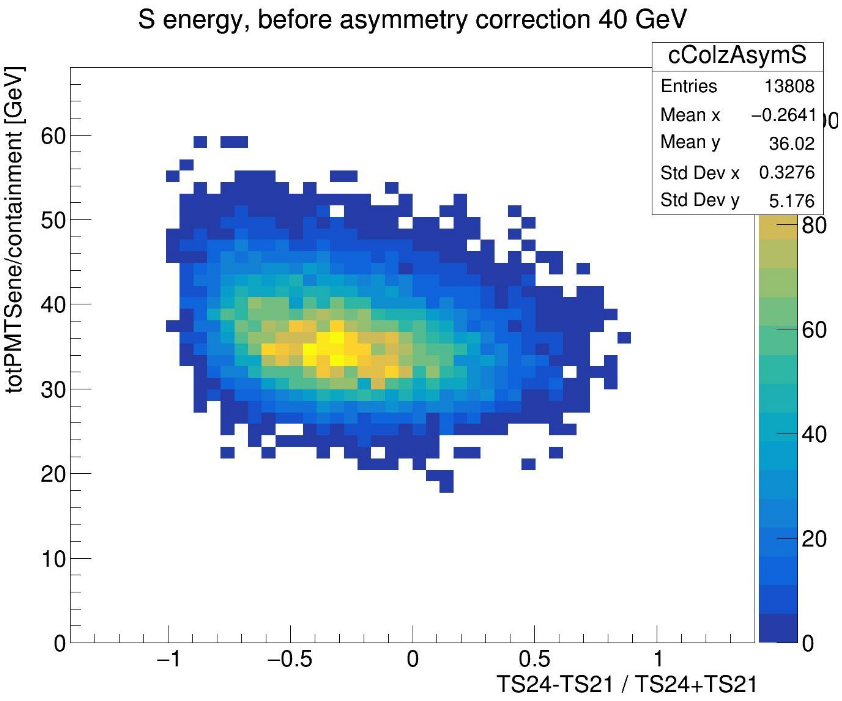



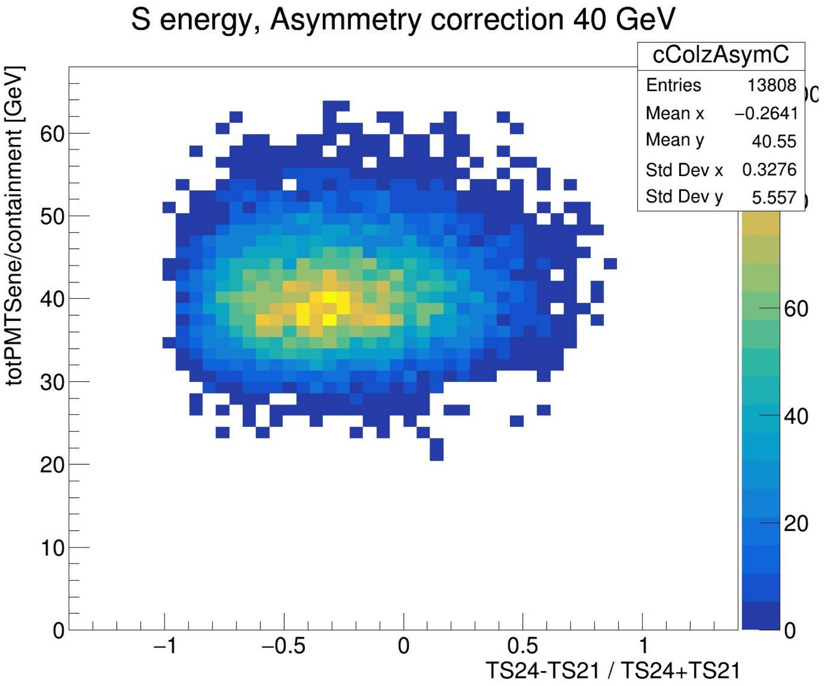



# On pion energy corrections

Same process also for S and C channels

For any point, $E_S = E_S/fS_{40GeV}(asym)$, $E_C = E_C/fS_{40GeV}(asym)$



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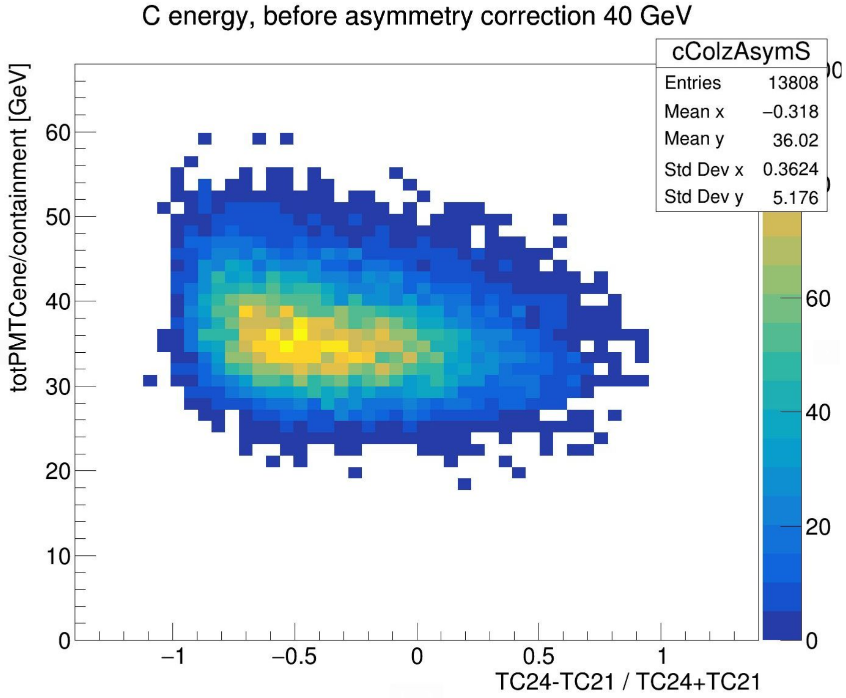
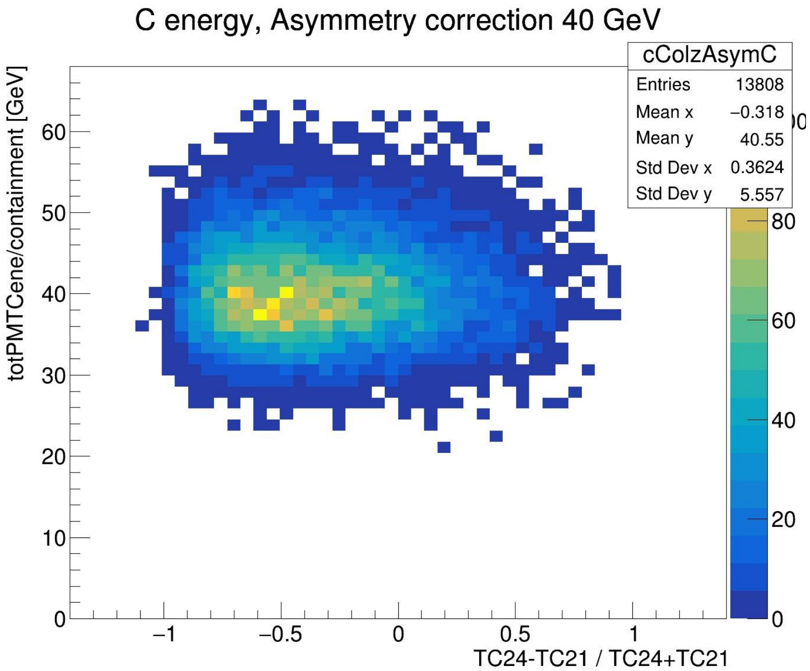
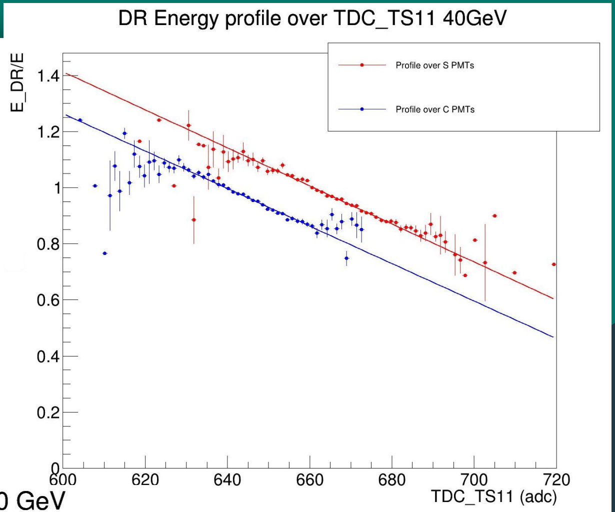


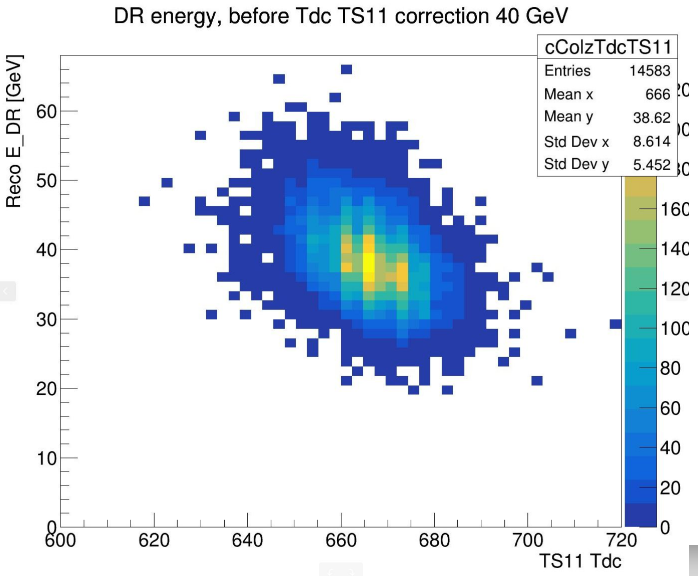



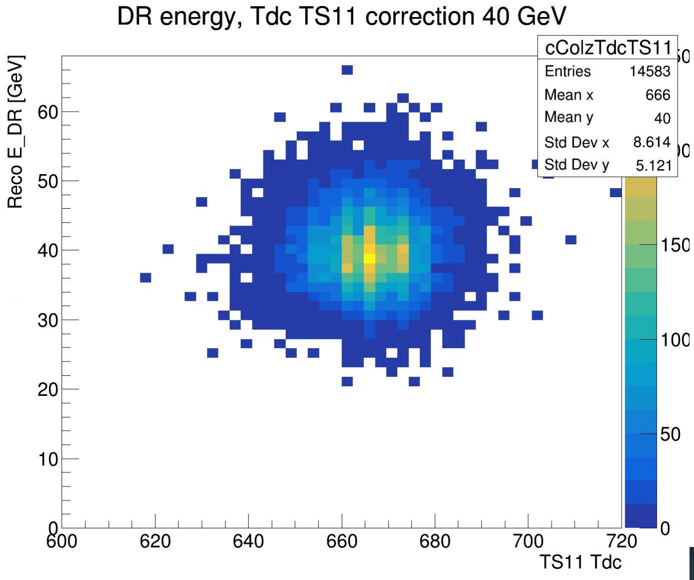
# On pion energy corrections

Fit TDC_TS11 with 1deg polynomial

For any point, $E_{DR} = E_{DR}/fS_{40GeV}$(asym)



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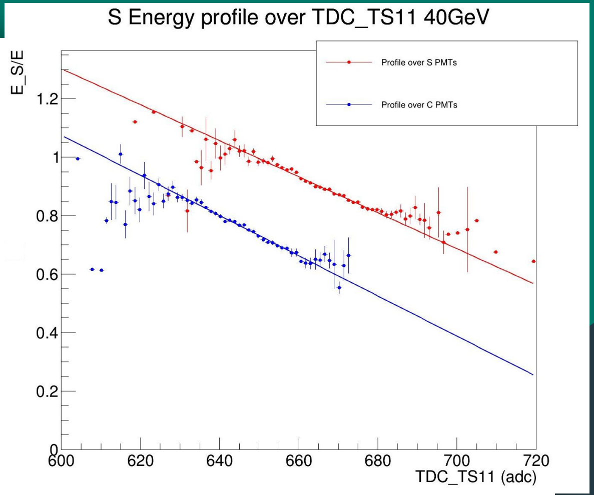



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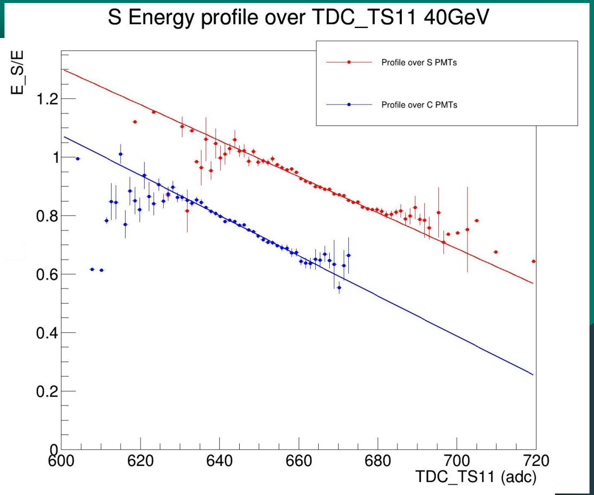
Fit TDC_TS11 with 1deg polynomial

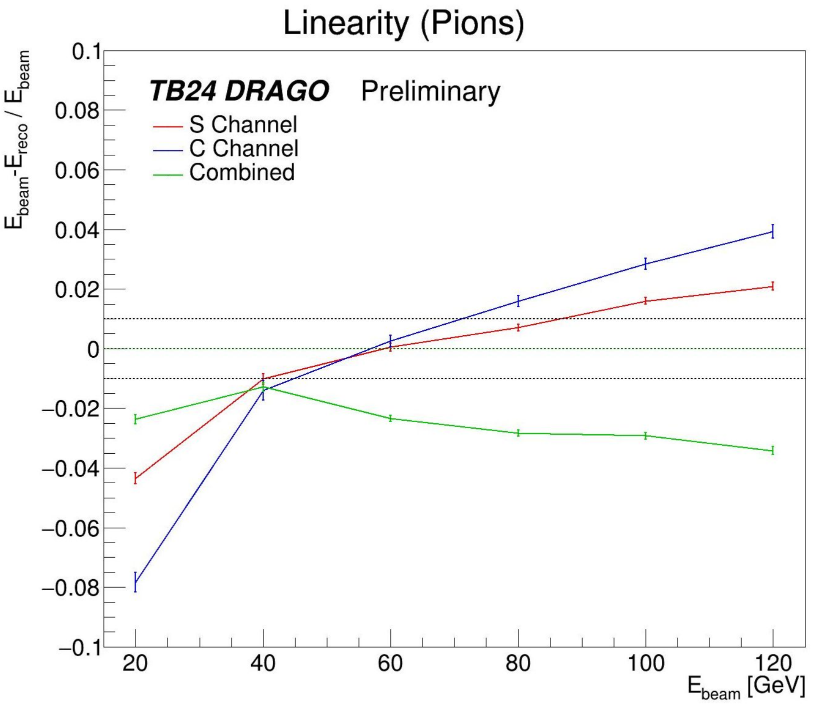
For any point, $E_{DR} = E_{DR}/fS_{40GeV}(asym)$

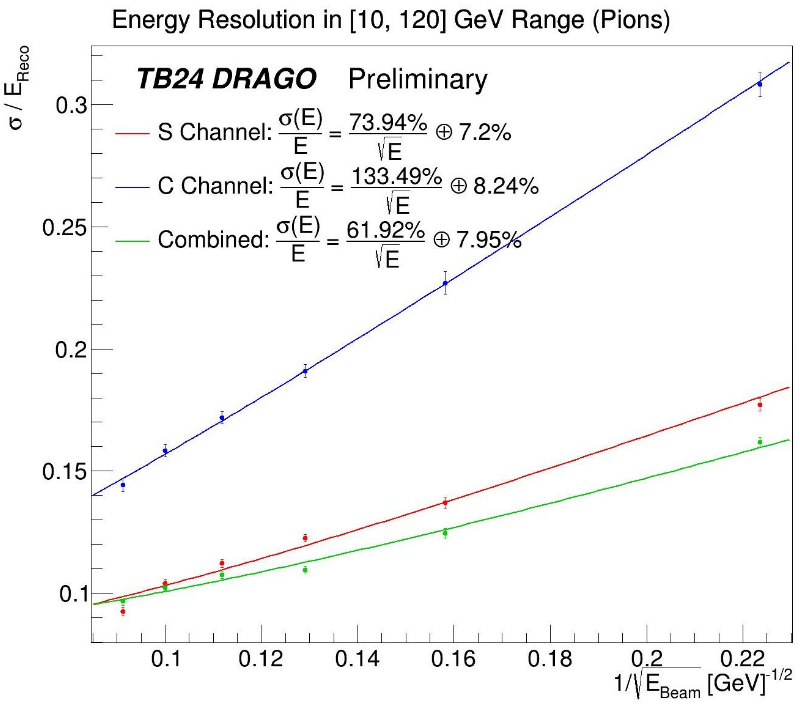




# On pion energy corrections

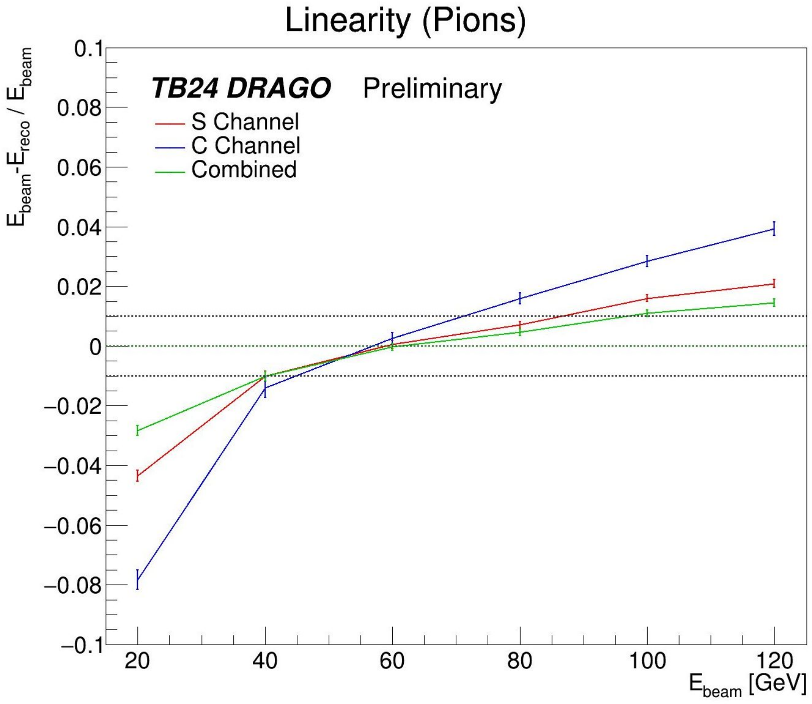
Using correction with timing only information

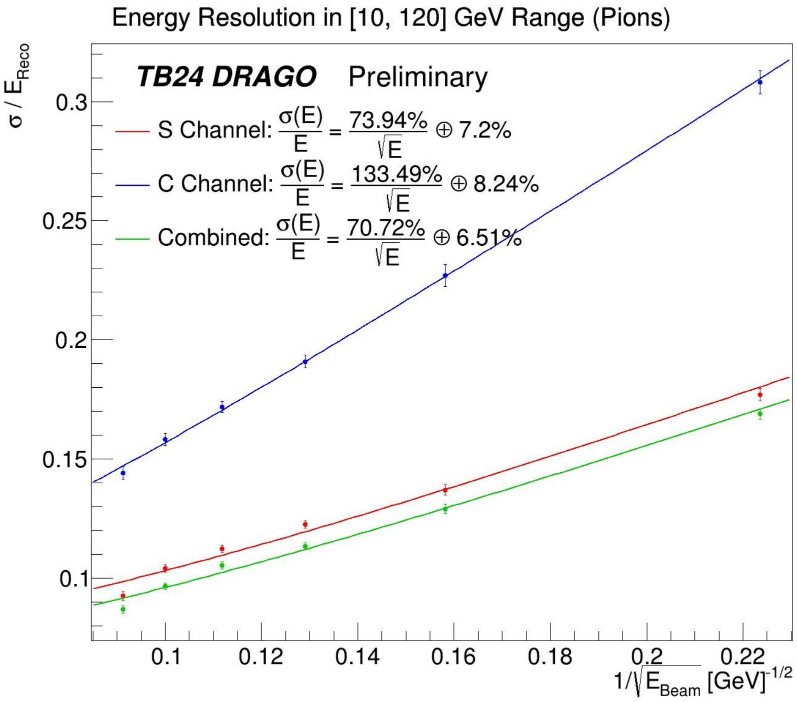


# On pion energy corrections

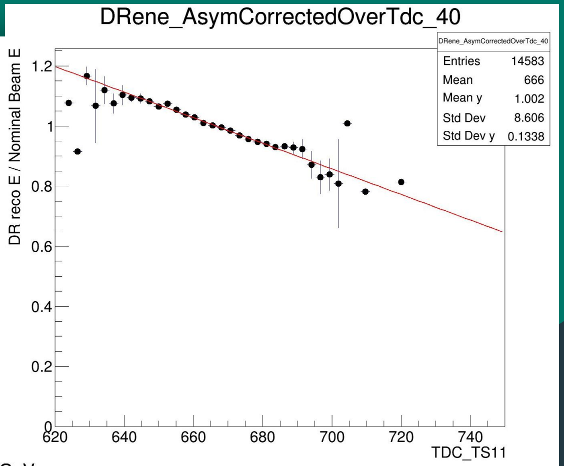
Using correction with asymmetry only

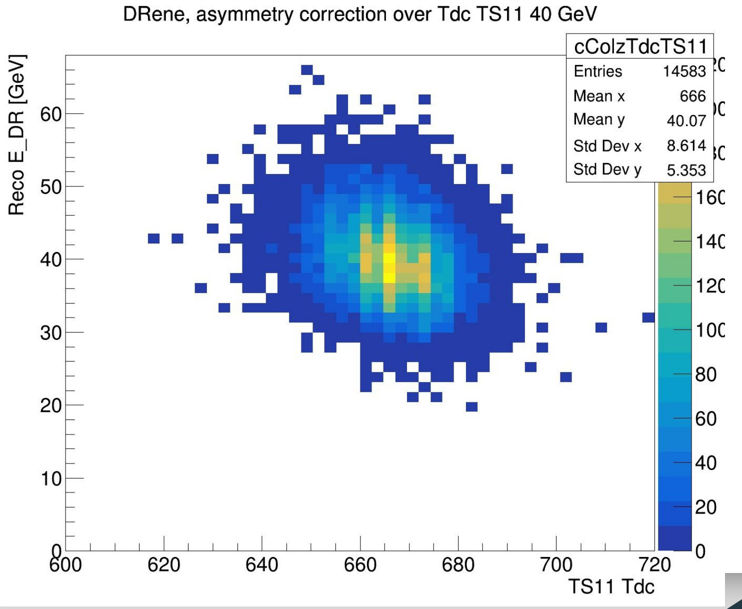


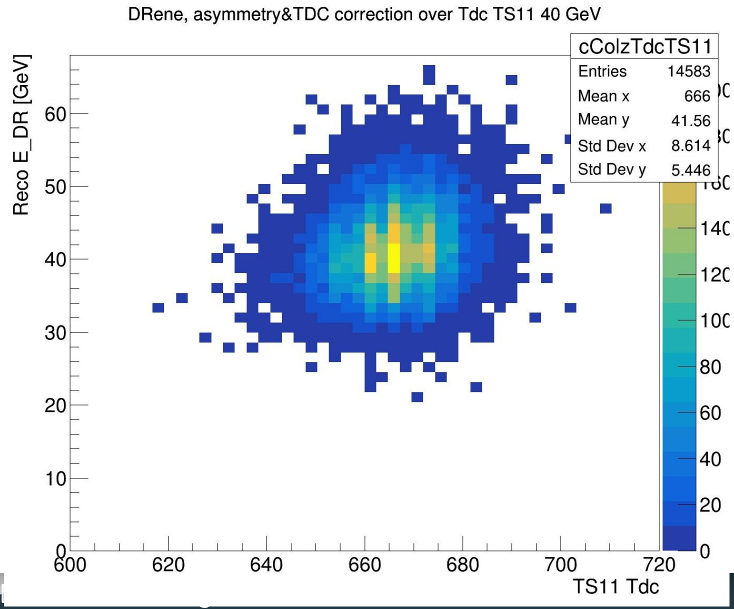



# On pion energy corrections

Profile energy, already corrected with the asymmetry variable, over timing fit with 1deg polynomial, and use fitted function

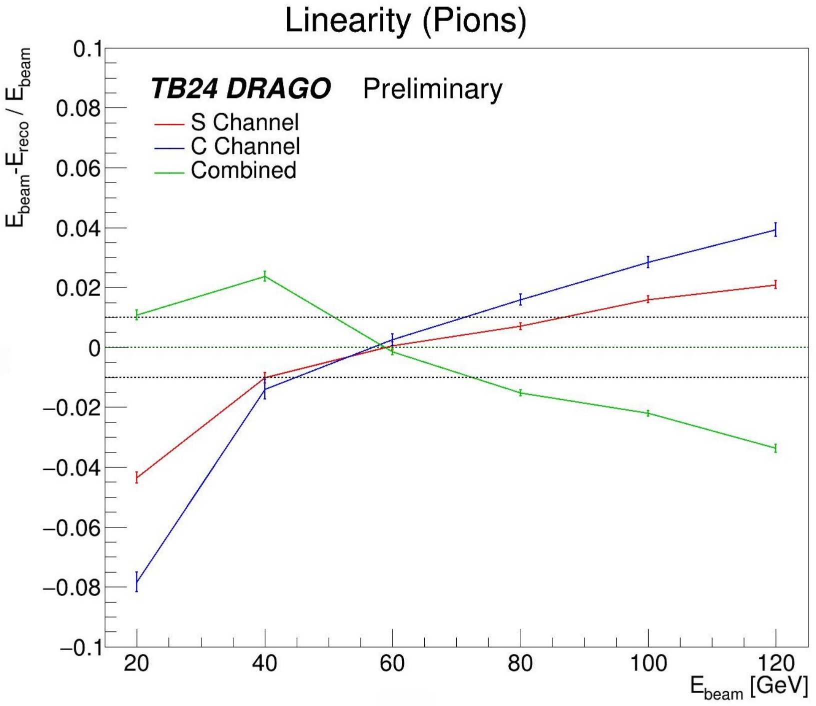


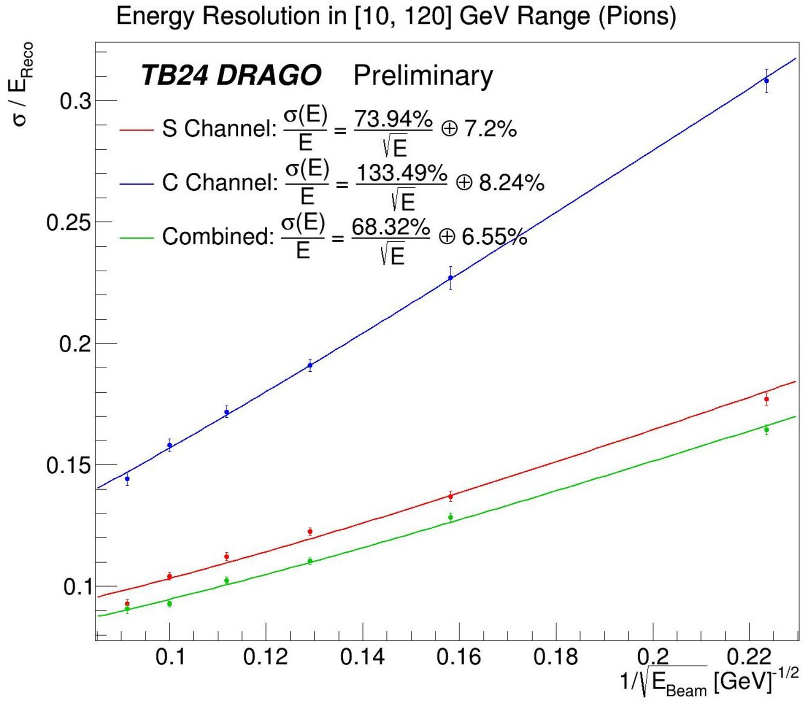



# On pion energy corrections

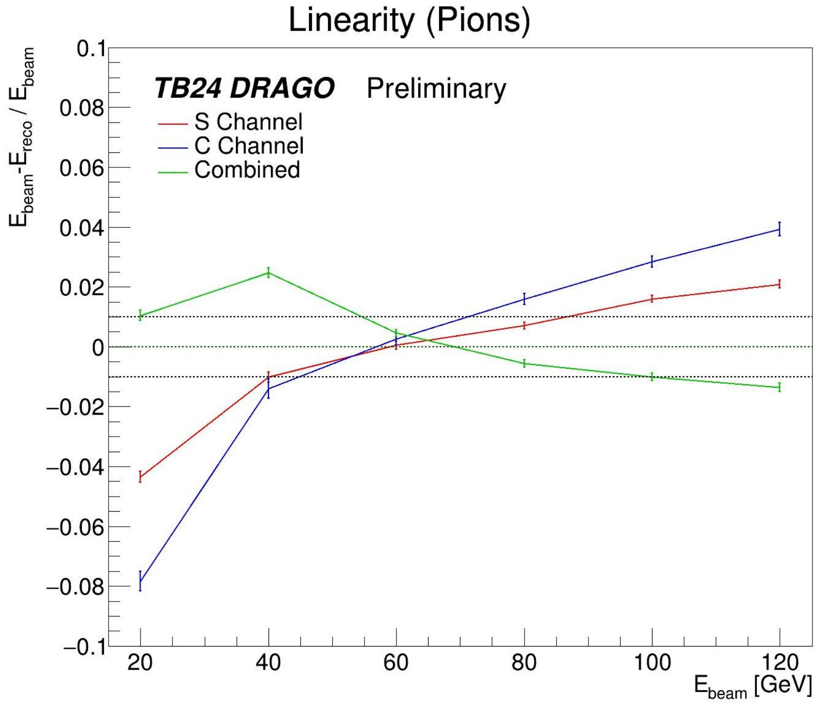
Profile energy, already corrected with the asymmetry variable, over timing fit with 1deg polynomial, and use fitted function

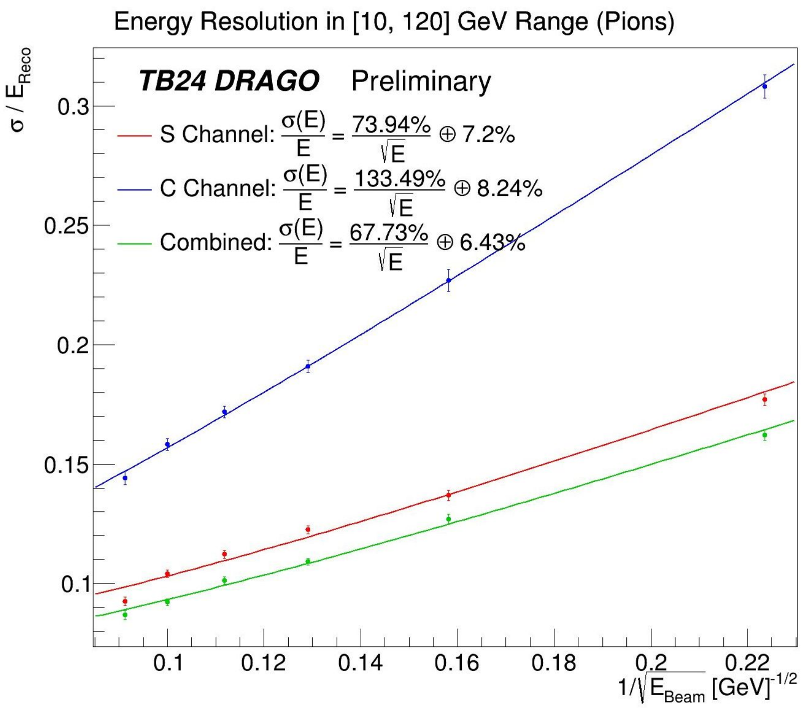


# On pion energy corrections

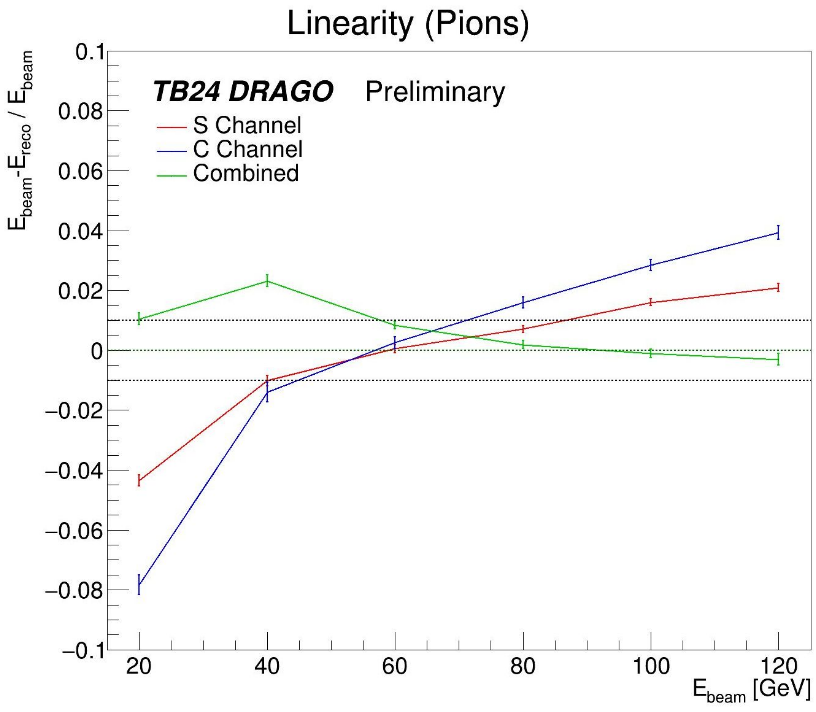
Selecting `data = data[ (np.abs(data["TDC_TS11"]-666)<15 )]`

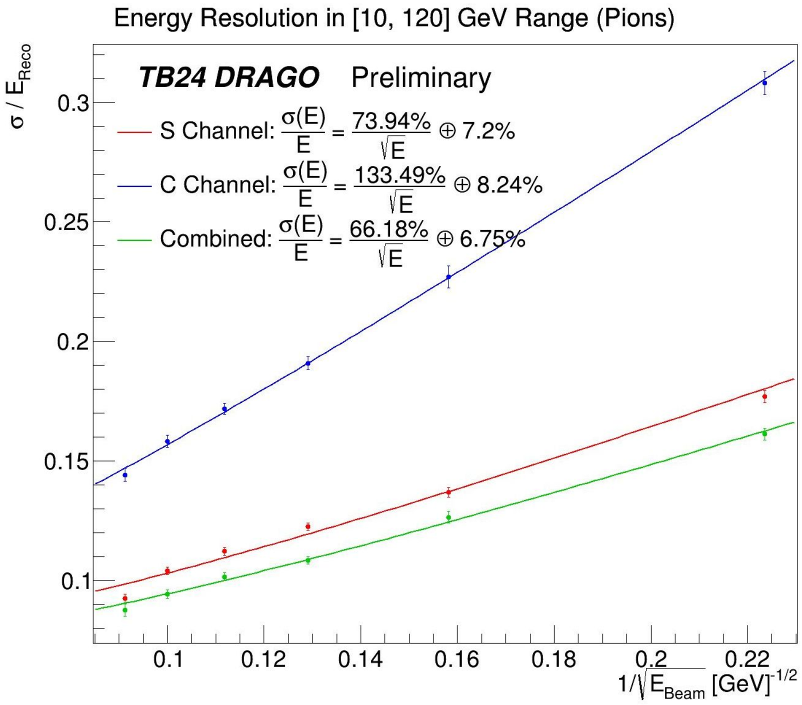


# On pion energy corrections

Selecting `data = data[ (np.abs(data["TDC_TS11"]-666)<10 )]`

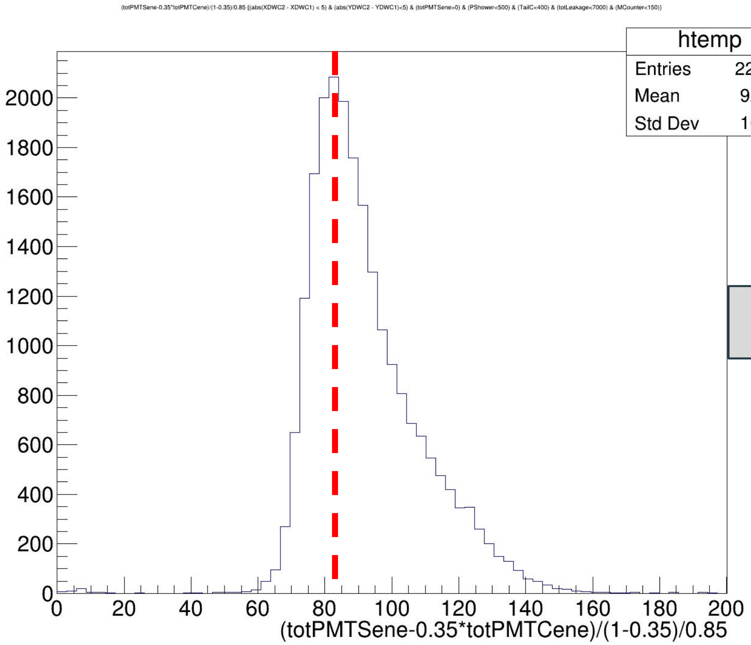


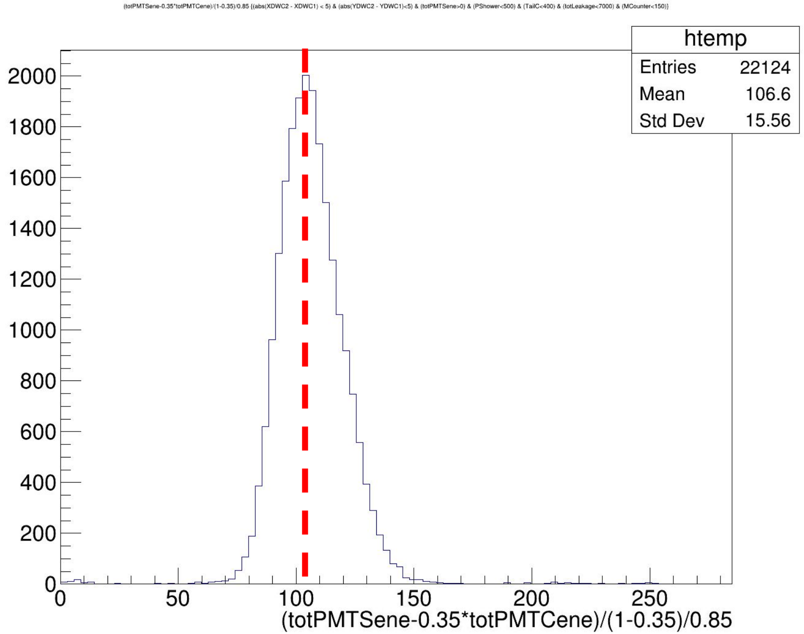
# Backup

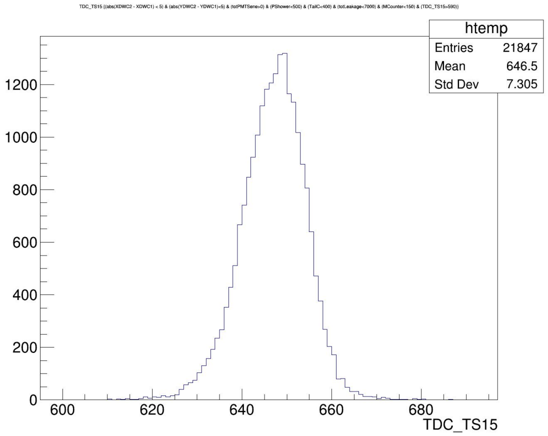
- Been working with Iacopo to produce the final ntuples from TB24, with old/new HVs on all samples
- TDC information from T00, T11 and T15 included, both S and C

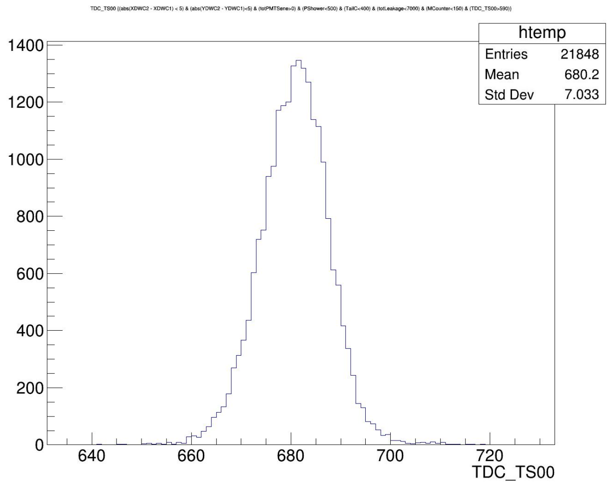
From last presentation, 100 GeV pions, run 0963

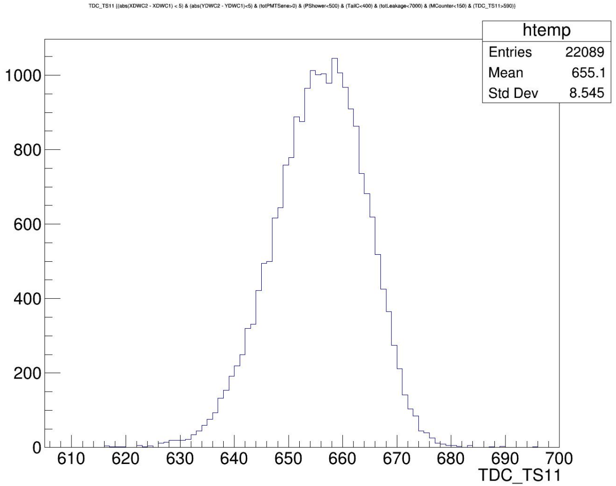



New calibration, 100 GeV pions, run 0963

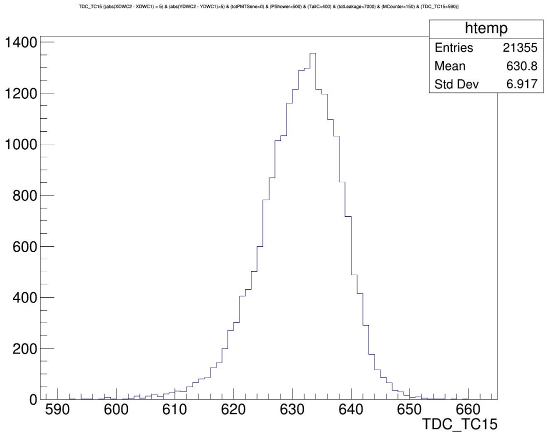


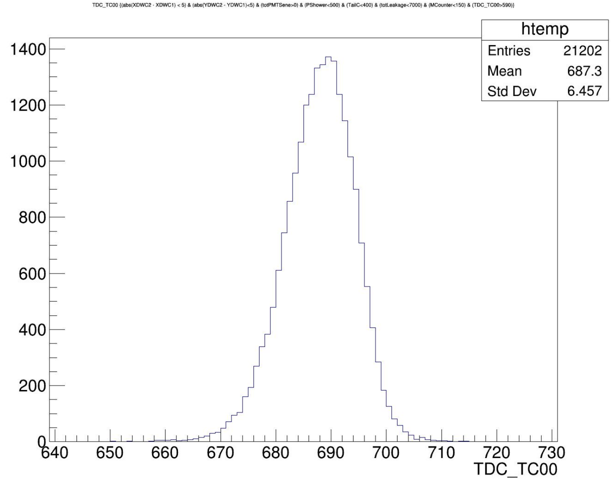


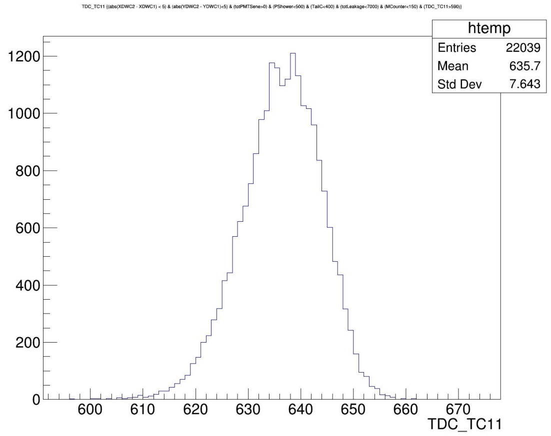



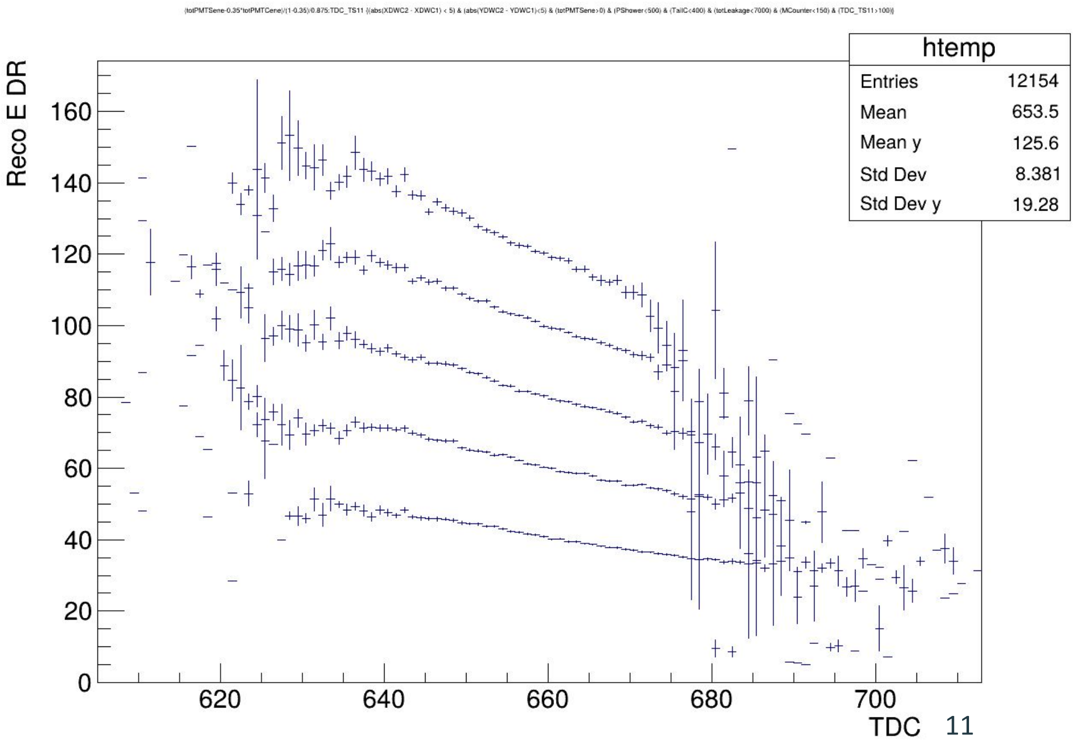

## Timing information are not calibrated



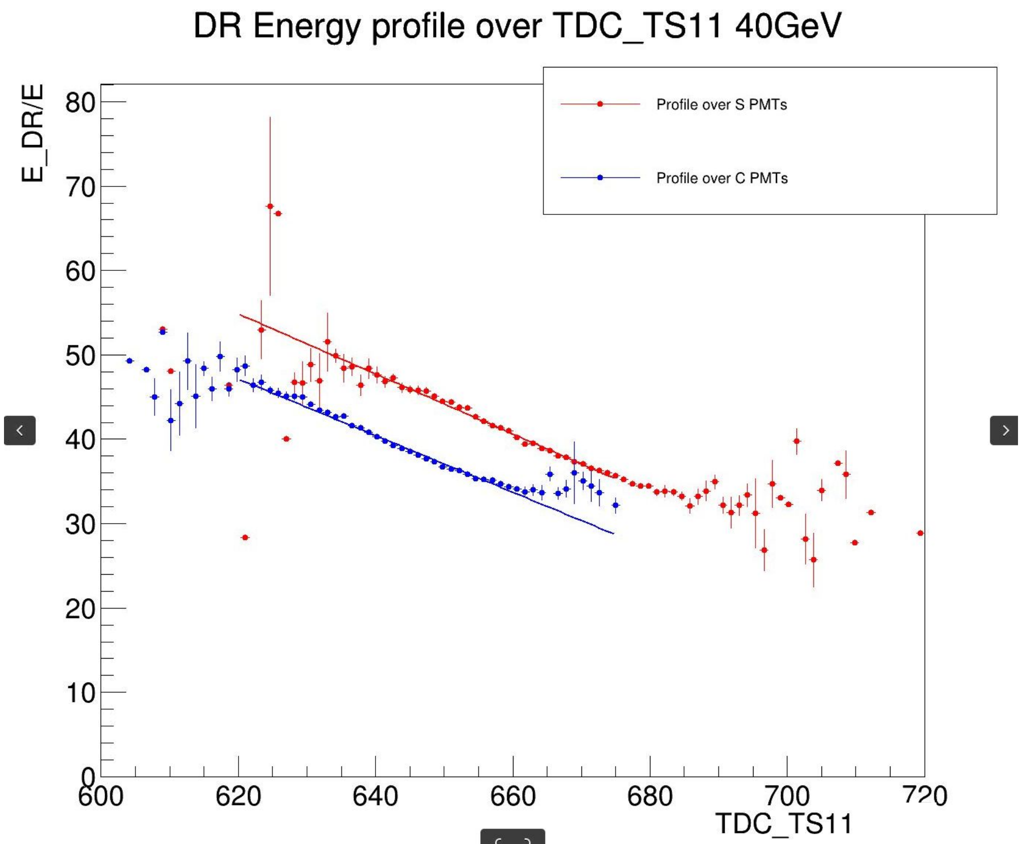



Studying dependency of reco energy with respect to TDC (TS11 in the plot)



Similar dependence of $E_{DR}$ when profiled over S or C T11 tdc

Parametrise with a straight line to reduce tail effect

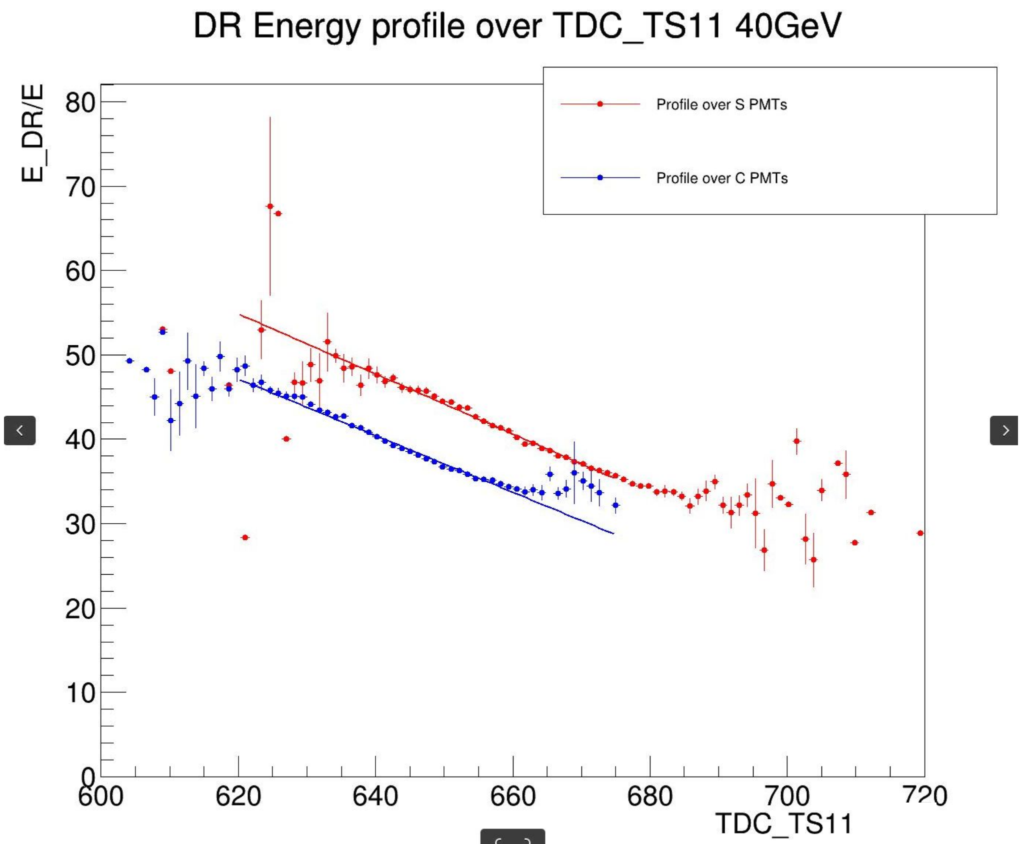


Similar dependence of $E_{DR}$ when profiled over S or C T11 tdc

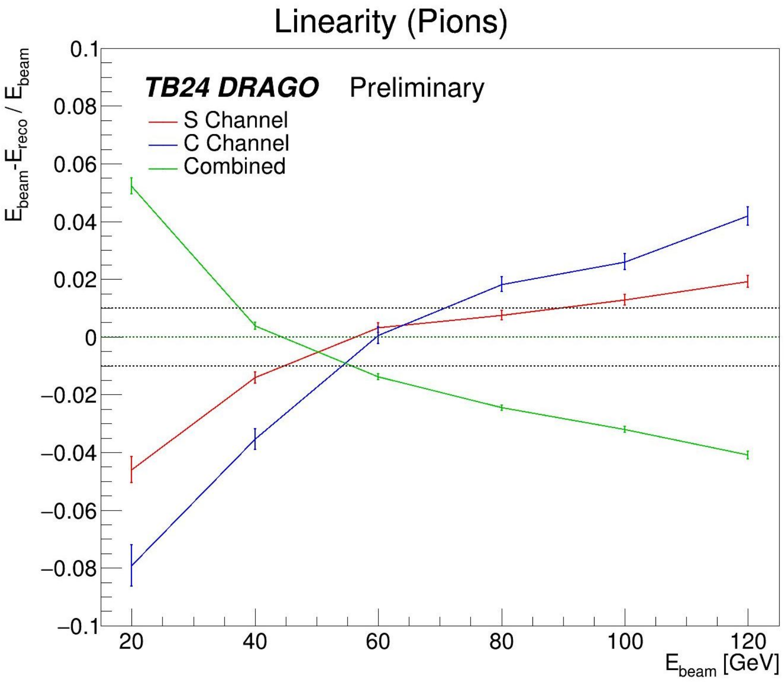
Parametrise with a straight line to reduce tail effect

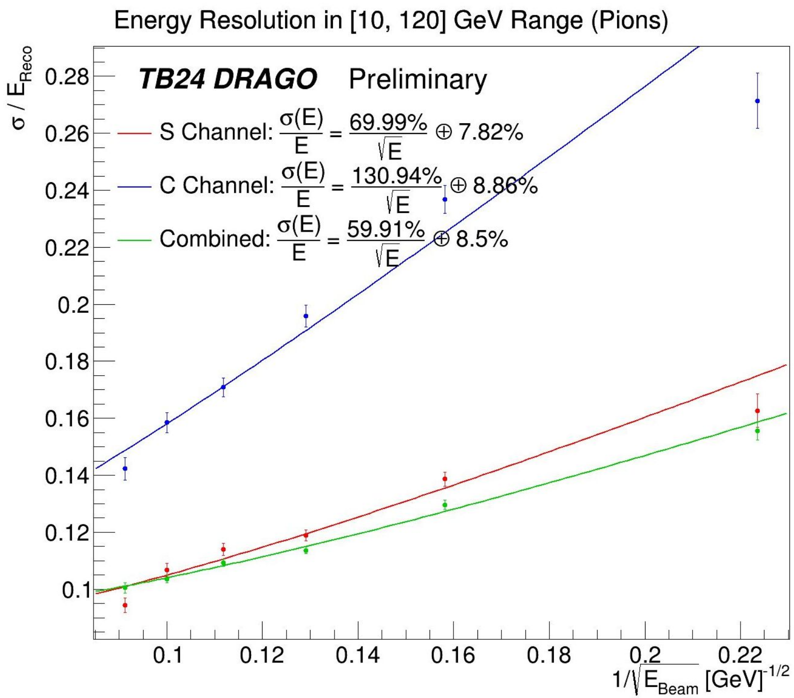
Same exercise done with asymmetry variable:

fit at 40 GeV and take reconstructed energy as $E_{reco} = E(raw) / f_{40}(tdc)$

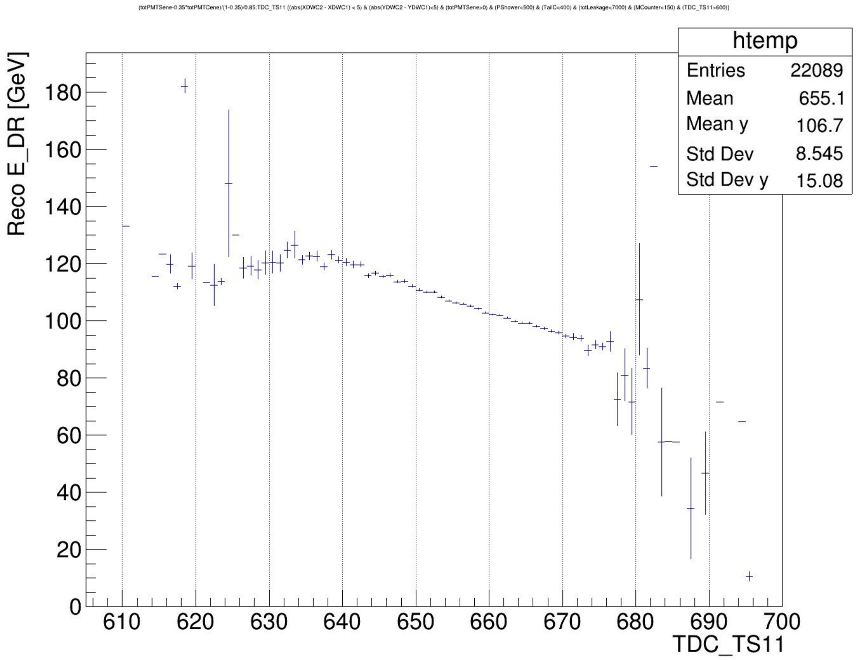


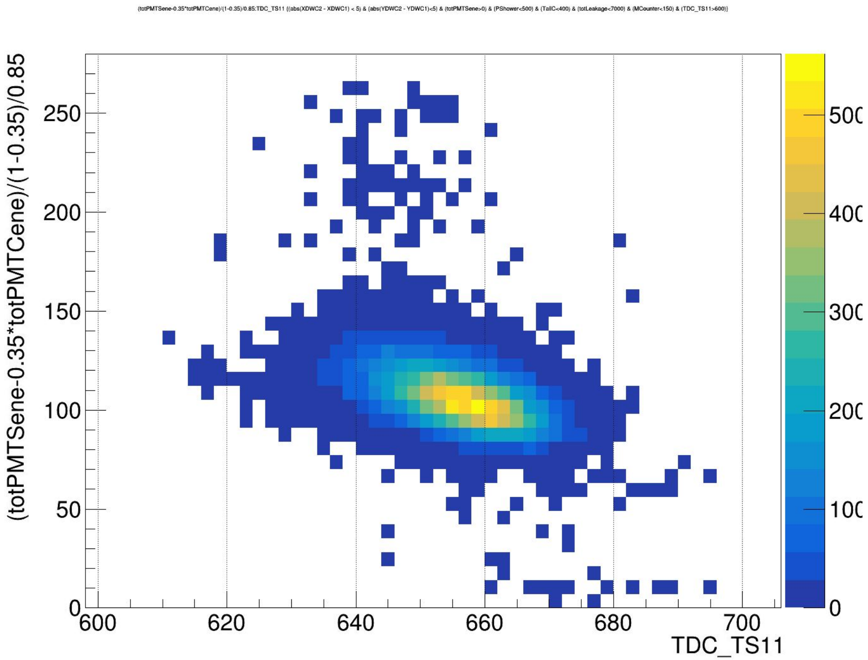
Fitted line slope changes a little with energy -> quite different behaviour of DR energy once corrected
Not exciting results, but this is only extremely preliminary result (yesterday afternoon)



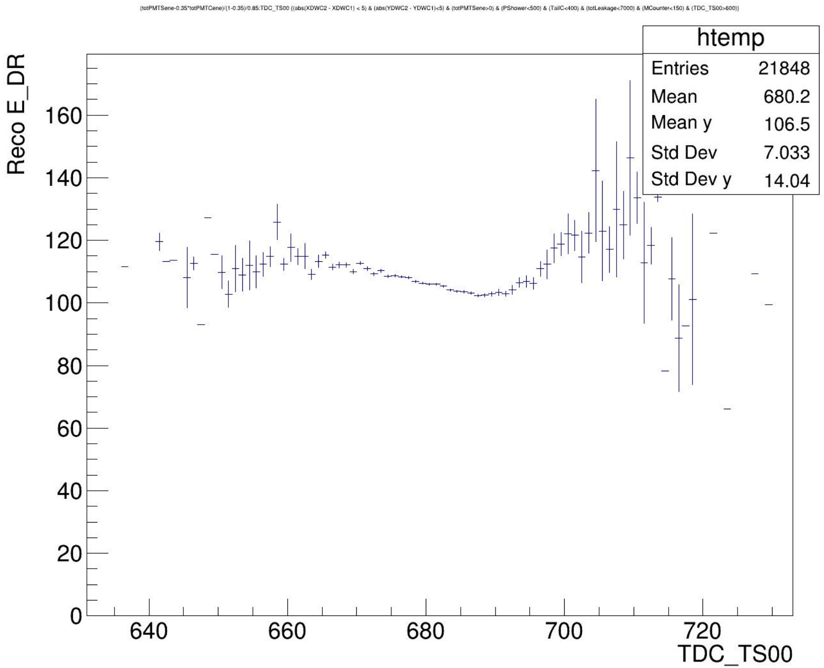



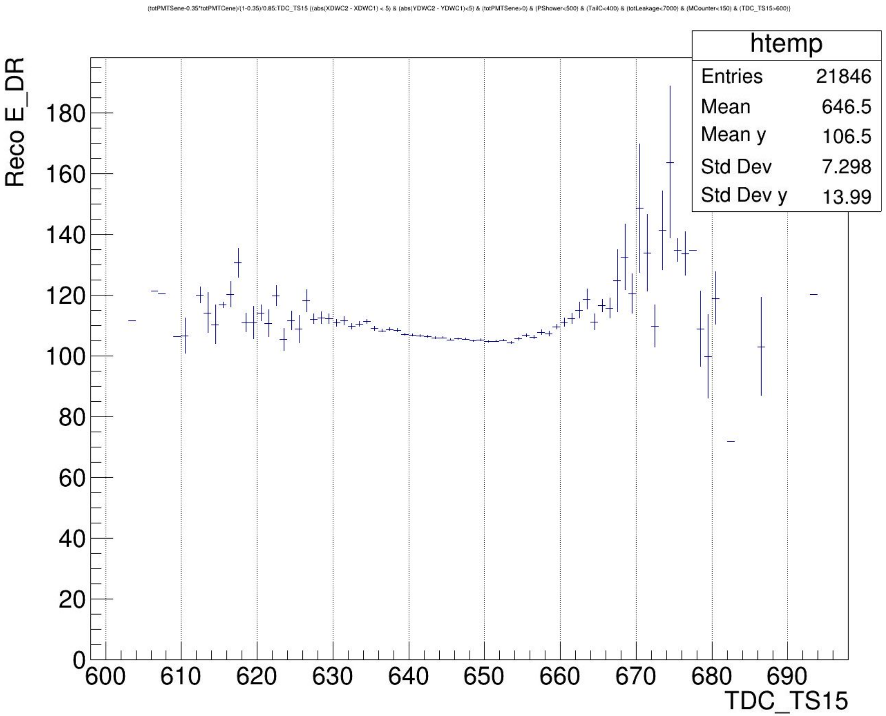
Large distribution of reconstructed energy, would not expect miracles even after rotating the profile until its horizontal (thus, reducing the tail effect)



# Different dependency of $E_{DR}$ when profiled over S or C T00 or T15 tdcs (?)



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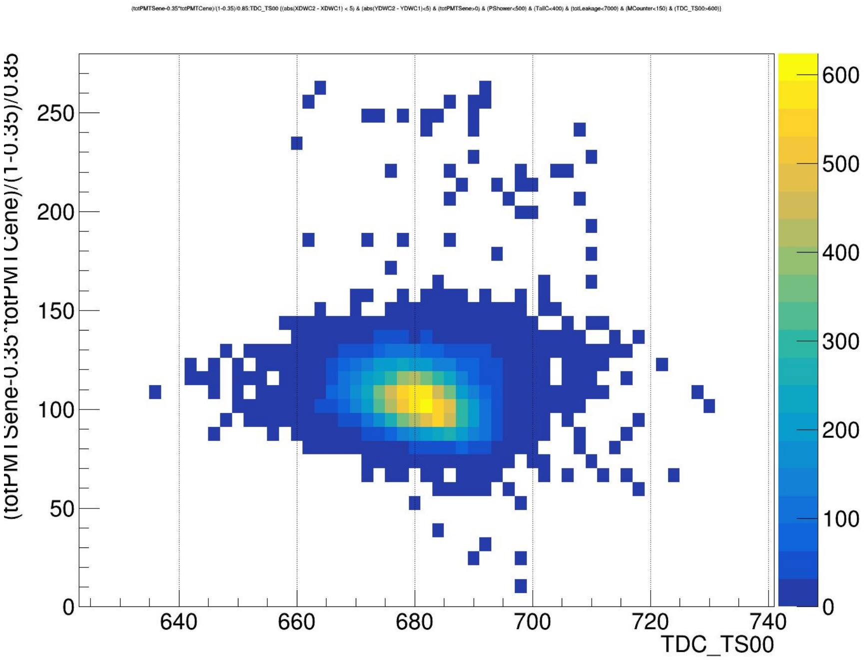
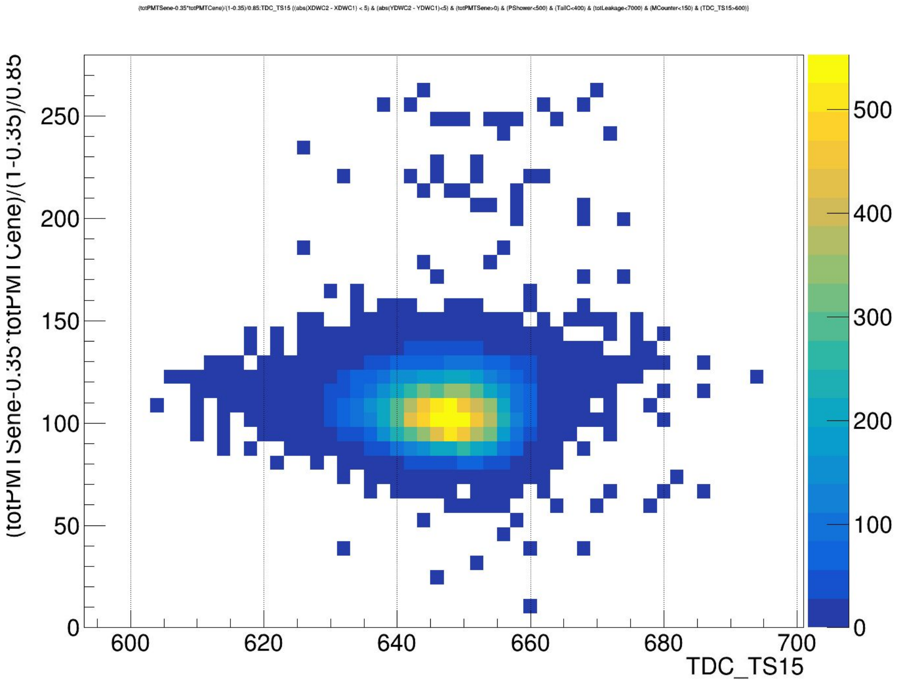


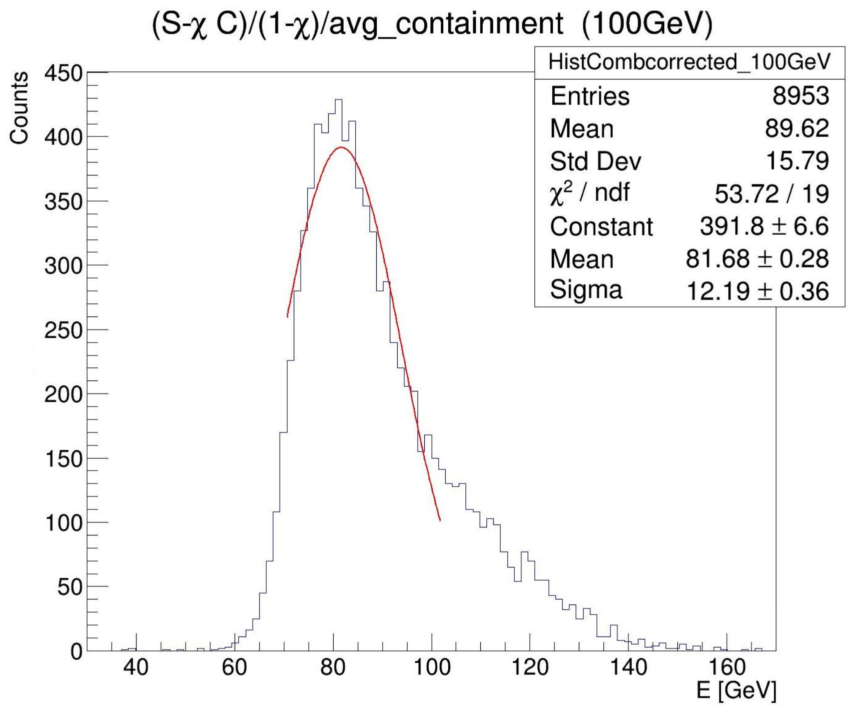
# Backup

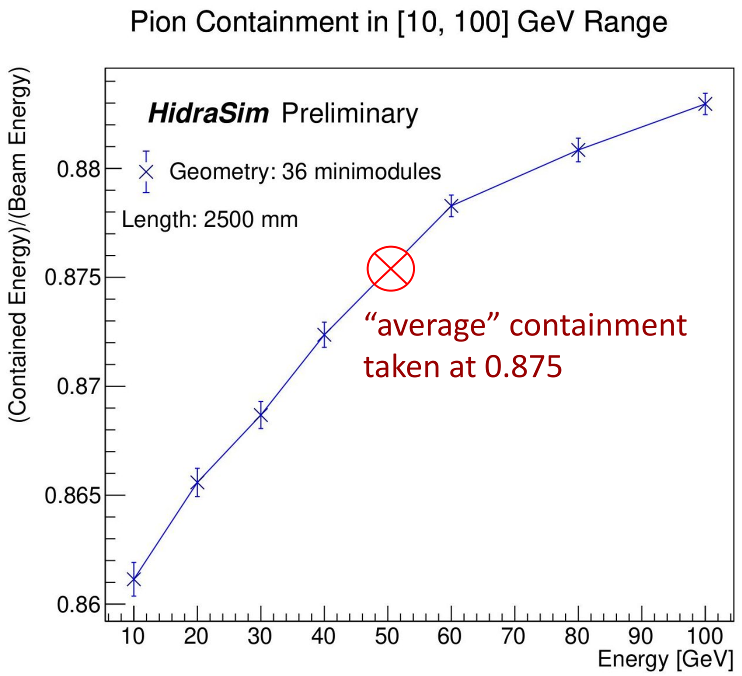
## On correct energy reconstruction

Using “newHV” runs = ["0968", "0967", "0966", "0965", "0963", "0962"] -> not correct calibration, hence peak of DR reco energy at incorrect value. Used value Chi = 0.35

Nevertheless, important high energy tail contribution arising from short attenuation length

-> Showers developing deeper inside calorimeter are less attenuated than early showering ones (in agreement with simulation)



## On correct energy reconstruction

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Nevertheless, important high energy tail contribution arising from short attenuation length

-> Showers developing deeper inside calorimeter are less attenuated than early showering ones (in agreement with simulation)

- Timing information from TDCs currently not part of produced test beam ntuples. Would be useful for cuts or some parametrisation
- Tried to weight differently signals from electromagnetic and hadronic showers, depending on average shower max position given by simulation:

  meanZbarS_ele = 227.718 # in mm

  meanZbarS_had = 590.164 # in mm

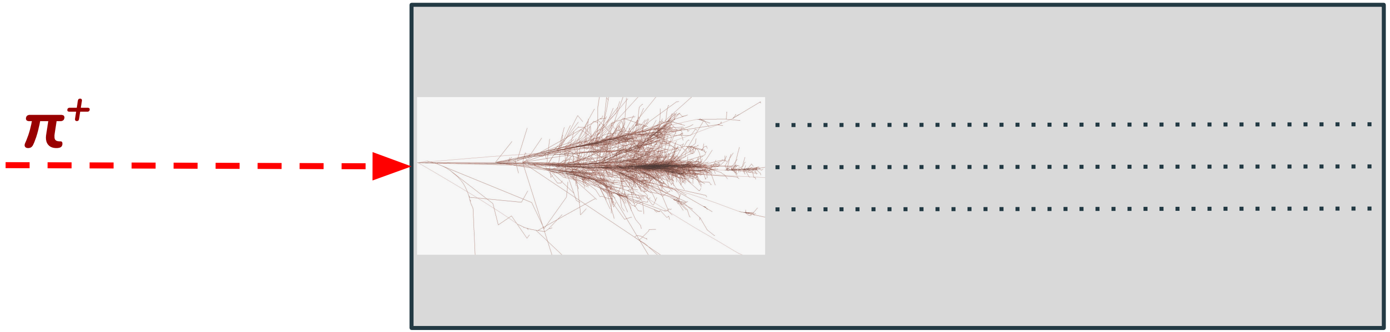
  att_length_S = 3500 # in mm

  S_attenuation_correction = (ROOT.TMath.Exp(-(2500-meanZbarS_had)/att_length_S) ) / (ROOT.TMath.Exp(-(2500-meanZbarS_ele)/att_length_S) )

  -> Currently not very significant results with this method, but trying again in the next days
- Since “asymmetry” variable was already defined for electron beam analysis, tried to use it also for pions. Reasoning in following slides

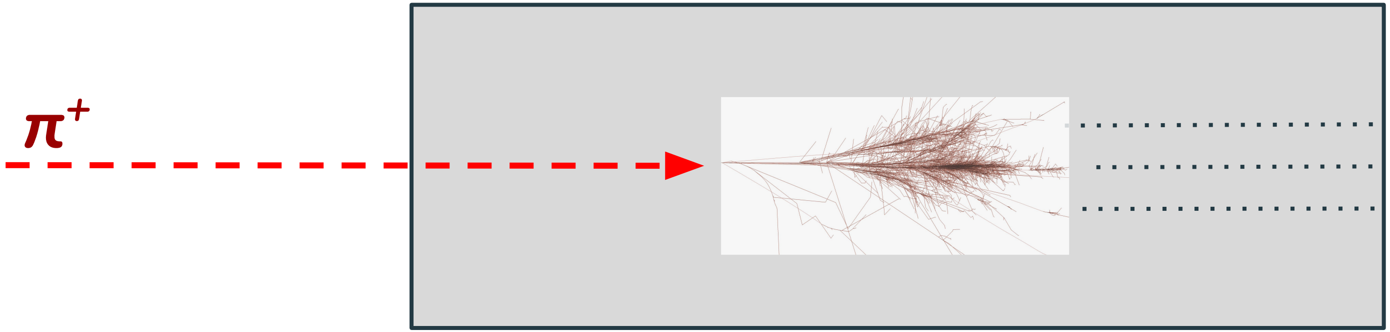
**Calorimeter not tilted**

On average, same amount of energy deposited in rows above and below the central one
(independent on longitudinal position of shower development starting point )



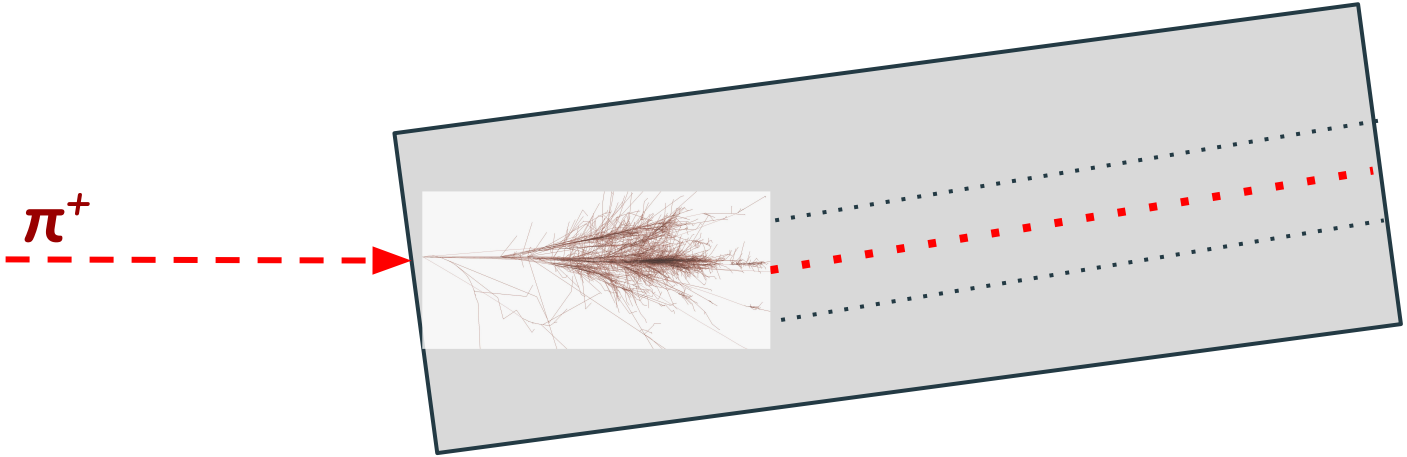
**Calorimeter not tilted**

On average, same amount of energy deposited in rows above and below the central one (independent on longitudinal position of shower development starting point )



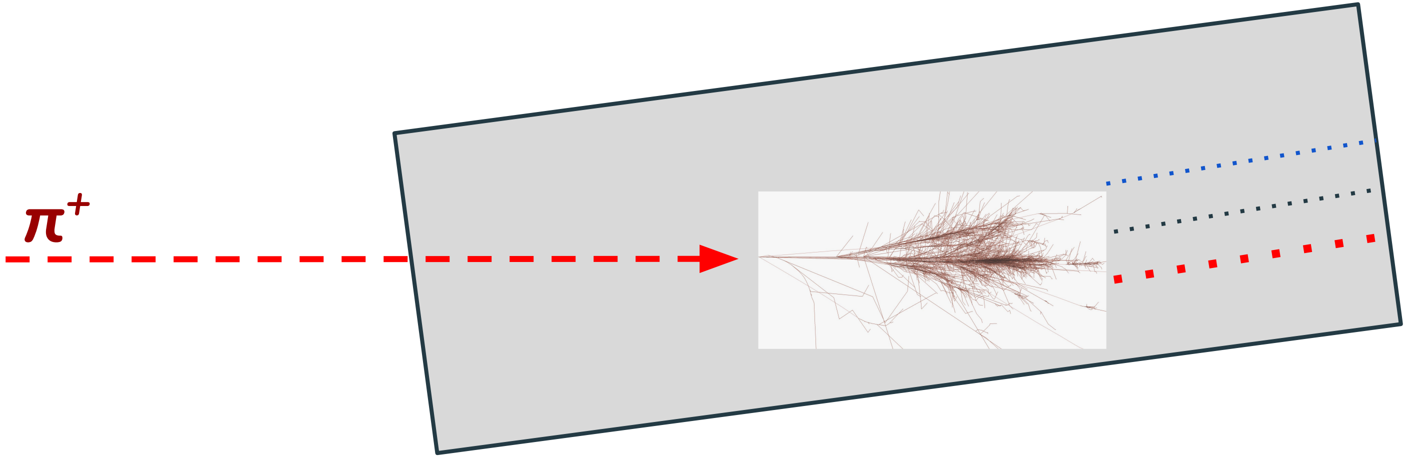
**Calorimeter tilted**

For early-initiating showers (hence, similar attenuation with respect to electromagnetic ones) still similar energy deposit in rows above and below central one

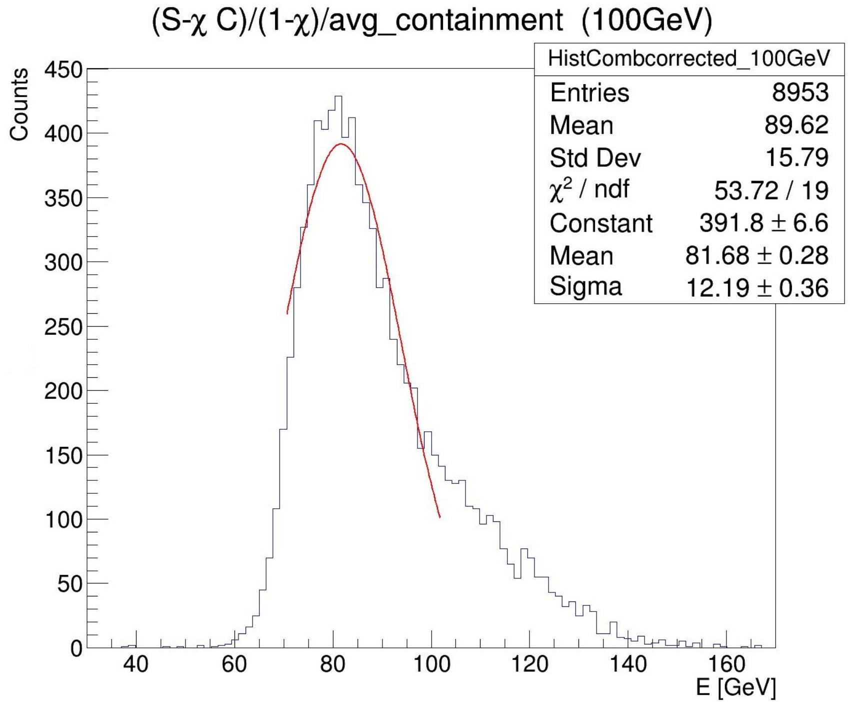


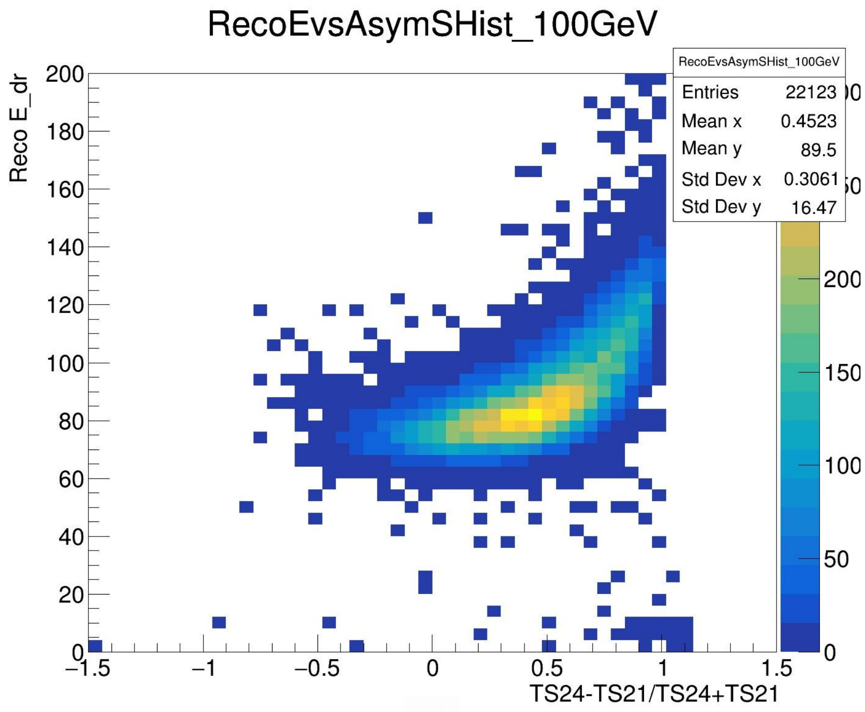
**Calorimeter tilted**

For late-initiating showers (less attenuated signal) lower towers read higher energy with respect to higher ones (on average) -> more asymmetrical



Plotting energy given by DR formula over asymmetry (using ring2 towers to allow for larger displacement)



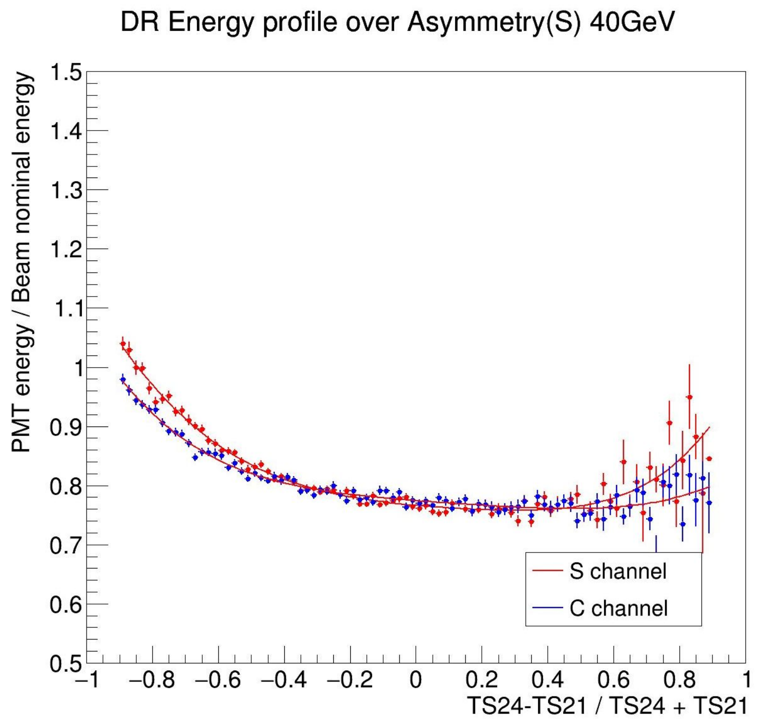



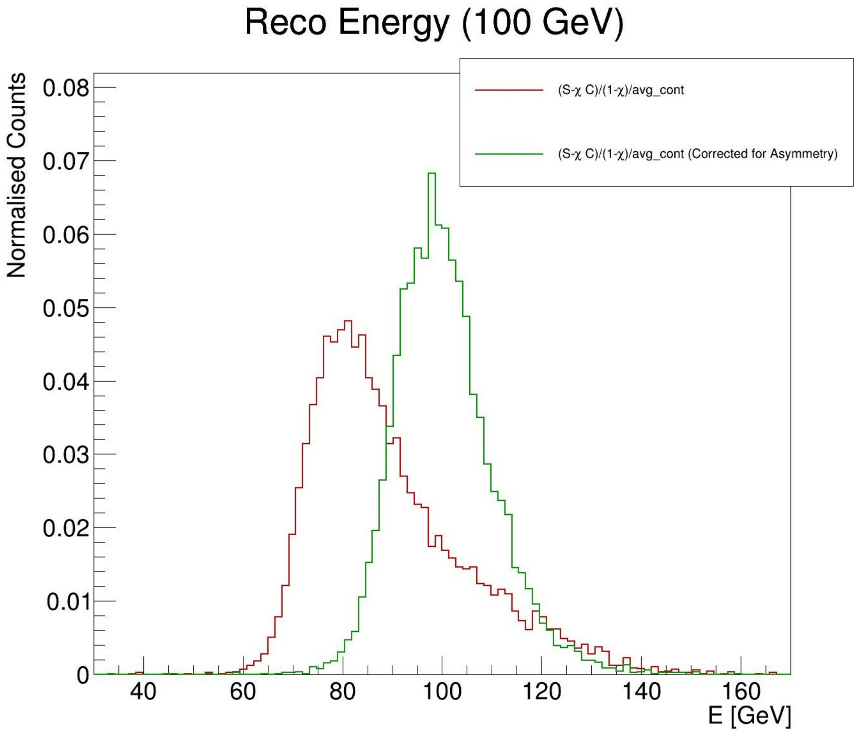
Just like electron beam analysis, parametrise energy with respect to asymmetry with a 5 degree polynomial

Use fitted function at 40 GeV to correct for all points

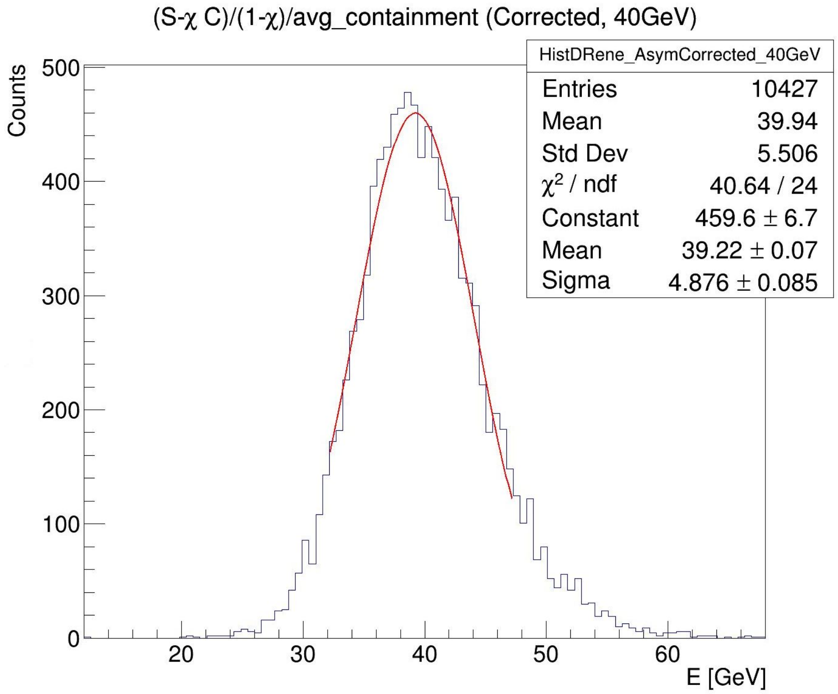
E(corrected) = $E_{DR}/fS_{40GeV}$(asymmetry)

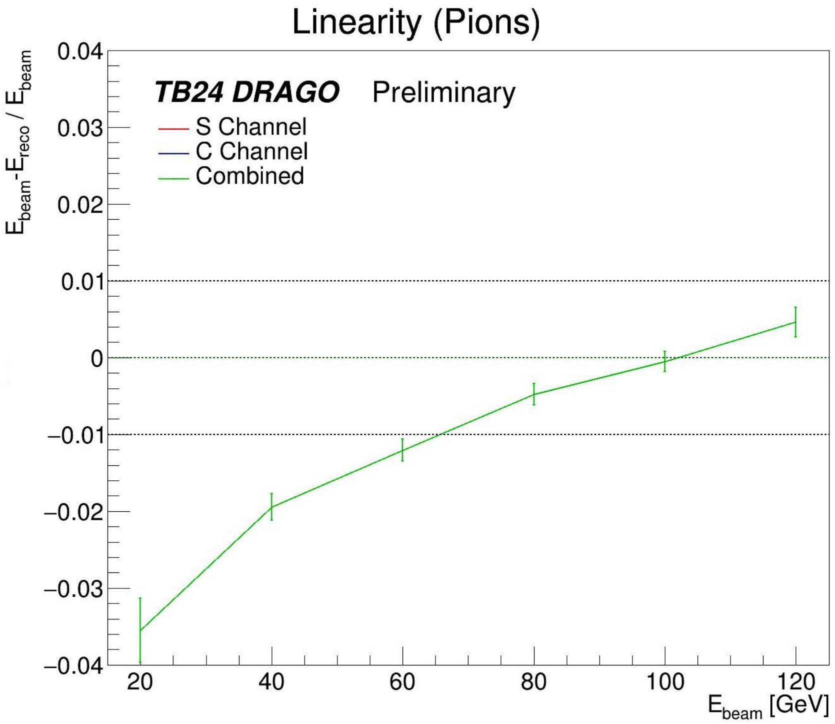
Since i'm using nominal beam energy for parametrisation, this will push non-calibrated energies closer to correct value



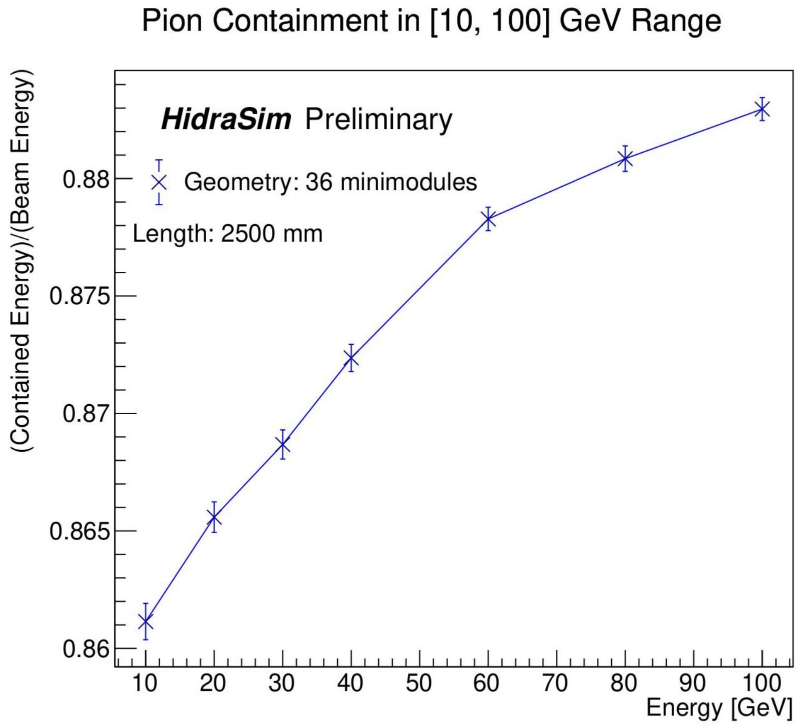



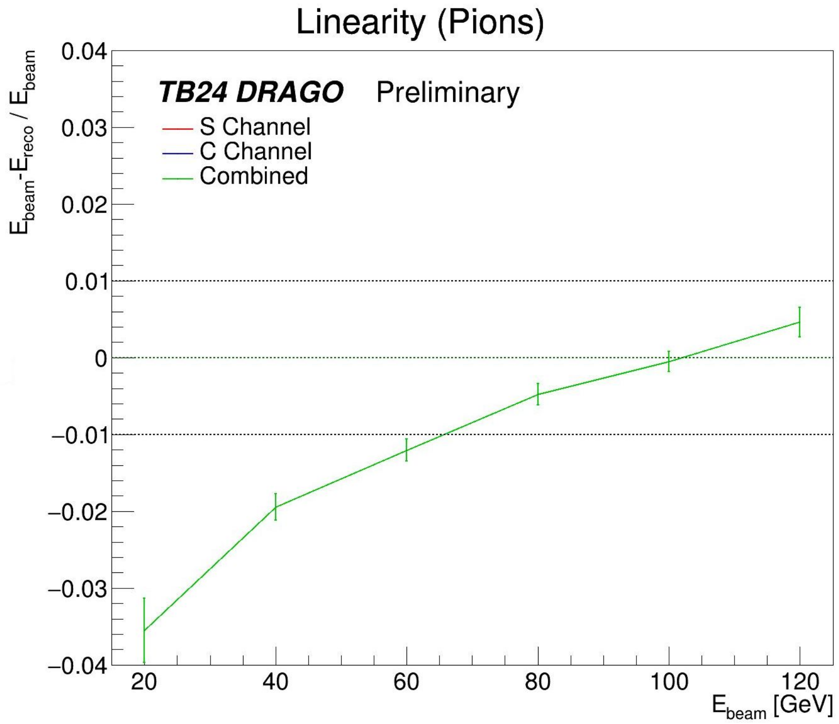
Fitting corrected distributions between +-1.5 sigma (don’t judge me)
Containment fixed at 0.875 for all energy points



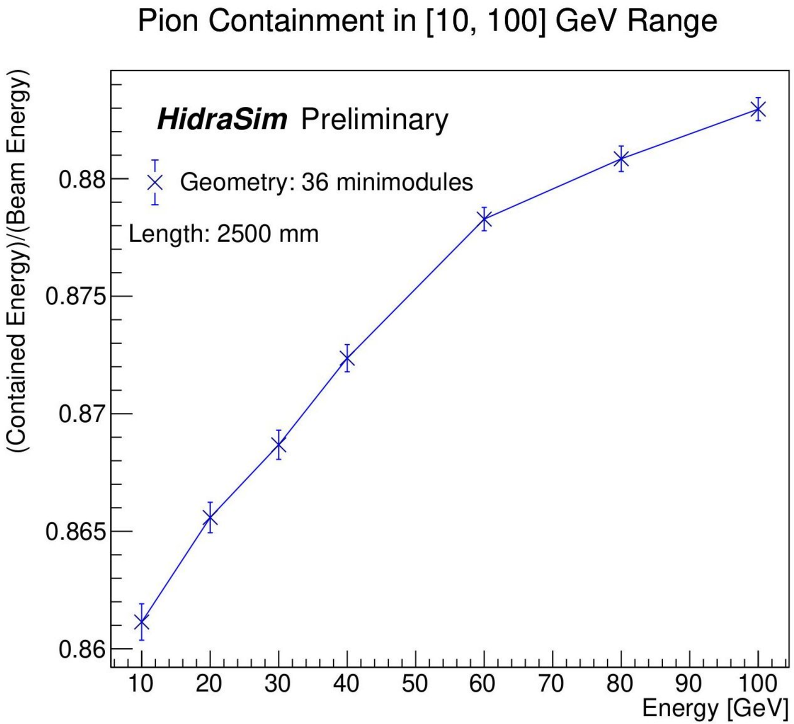



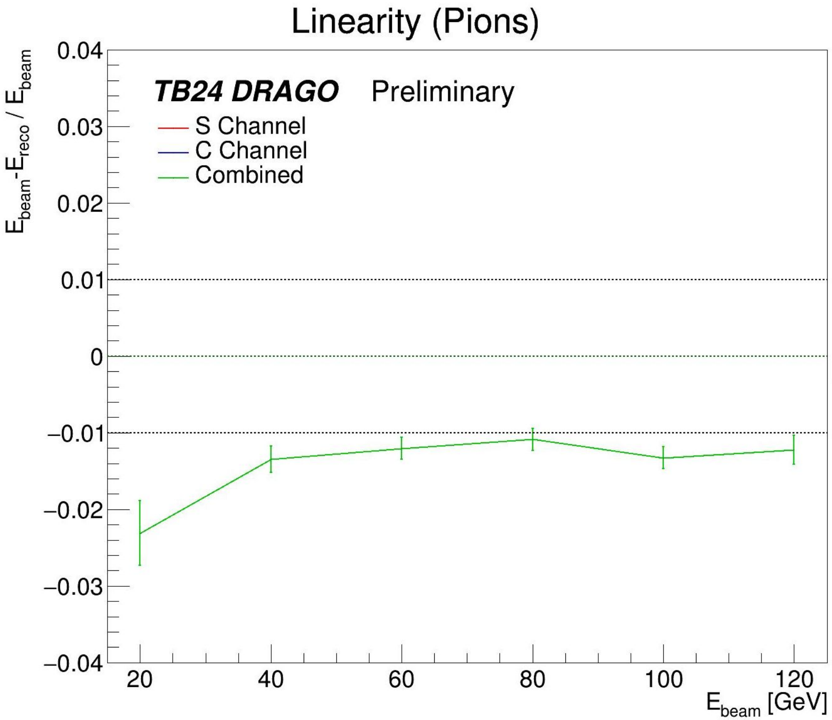
Fitting corrected distributions between +-1.5 sigma (don’t judge me)
Containment fixed at 0.875 for all energy points
Containment is increasing with energy



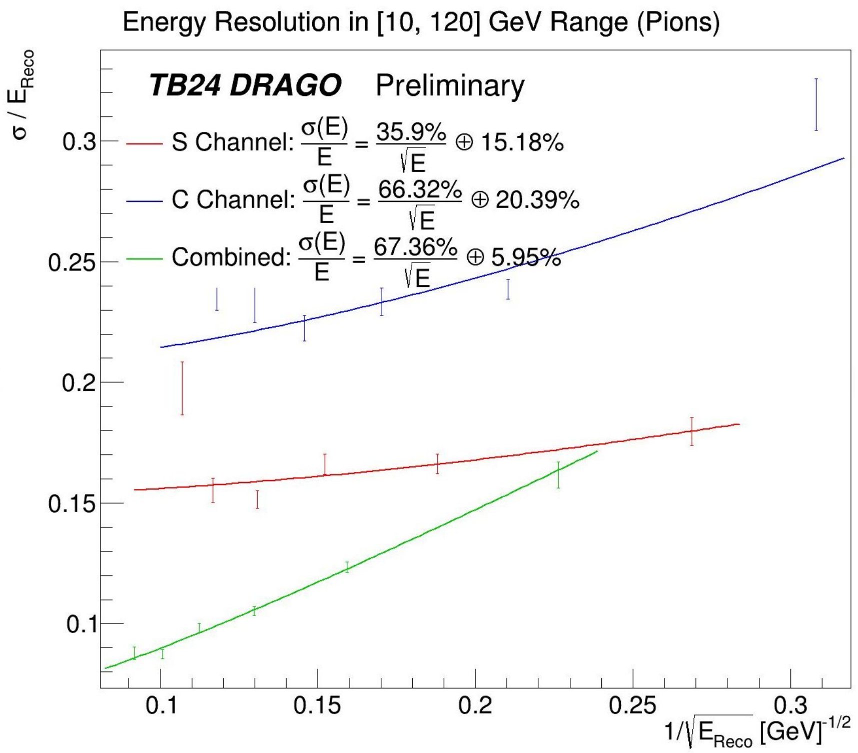



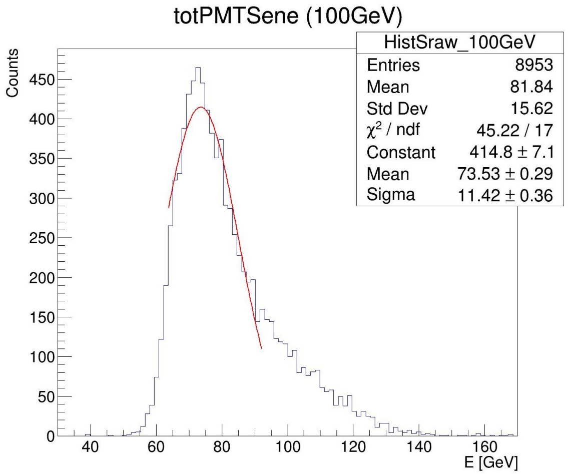
Fitting corrected distributions between +-1.5 sigma (don't judge me)
Containment fixed at 0.875 for all energy points
Containment is increasing with energy
Using exp_containment = [0.865, 0.87, 0.875, 0.88, 0.885, 0.89]

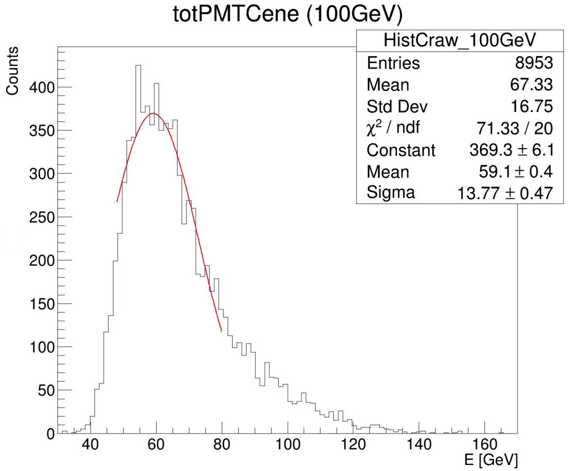


Independent scintillating and Cerenkov energies not treated, please ignore them
Comparison with simulation ongoing



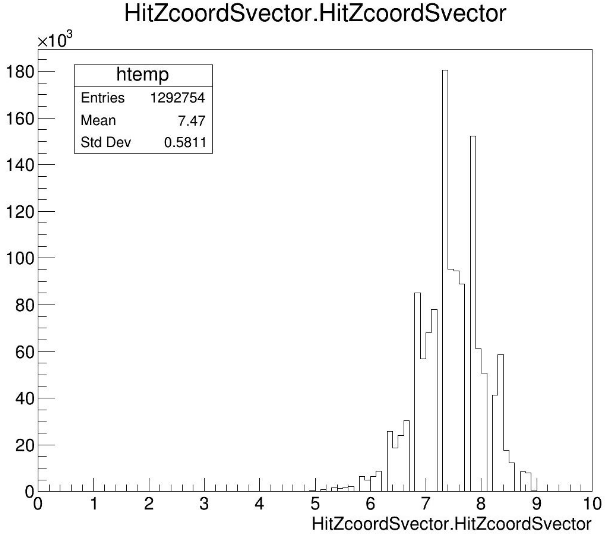
## In the meanwhile, simulation side

Inserted SimSiPM simulation inside HidraSim, under testing.
In SiPM mounted towers, for each fiber an array of optical photons arrival times is passed to SiPM simulation library directly within the Geant4 calorimeter sim.

Arrival time in ns is calculated as truth Z position of optical photon emission (distance from the end of the fiber) over photon velocity in each tipe of fibers:
For S fibers, velocity $v_S = c/rindex_S$

SiPM simulation generates waveform and outputs some parameters:
for now I'm using integral, time-over-threshold, time-of-arrival.
Integral and time of arrival of activated SiPMs are saved to output ntuples (together with SiPM ID number) to reduce storage requirement.

Using two different SiPMs for S and C fibers, with 10 and 15 micron pitch.
Sampling time = 100 ps.
Will discuss details with Romualdo asap.




Time of arrival in ns
for em showers

# Backup

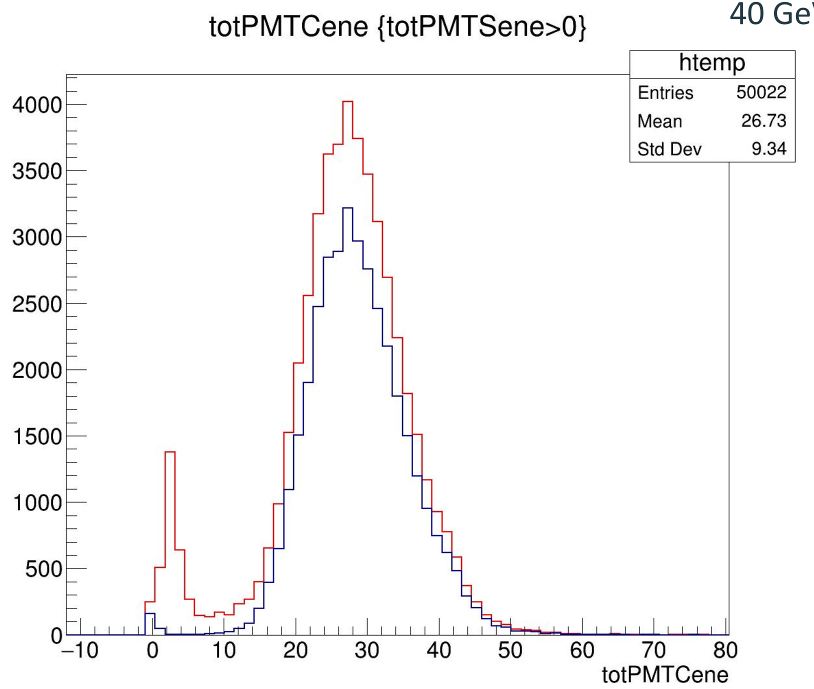
## A first look into pions

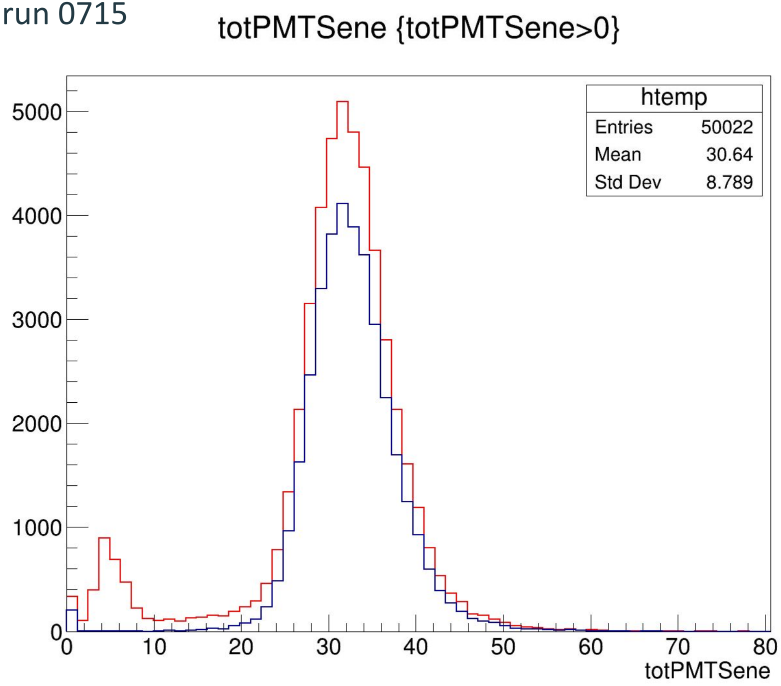
Starting from first pion runs (old HV), runs = ["0714", "0715", "0716", "0717", "0718", "0721"]

Using cuts: "(abs(XDWC2 - XDWC1) < 5) & (abs(YDWC2 - YDWC1)<5) & (totPMTSene>0) & (PShower<500) & (TailC<400) & (totLeakage<7000)"

Red histogram without cuts (only S signal >0); Cerenkov counters cut tested but mostly reduce signal under peak (work ongoing)

40 GeV pions, run 0715



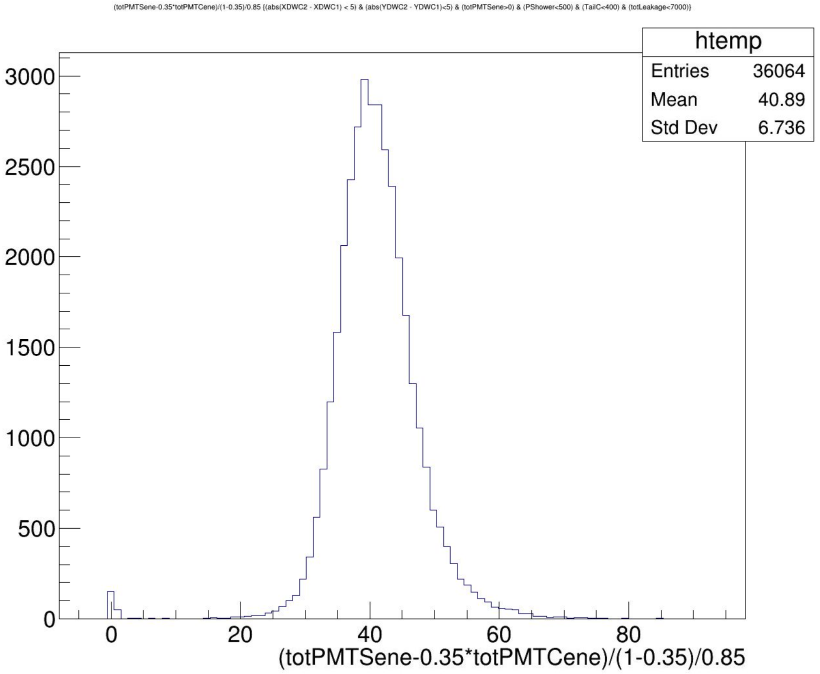



## A first look into pions

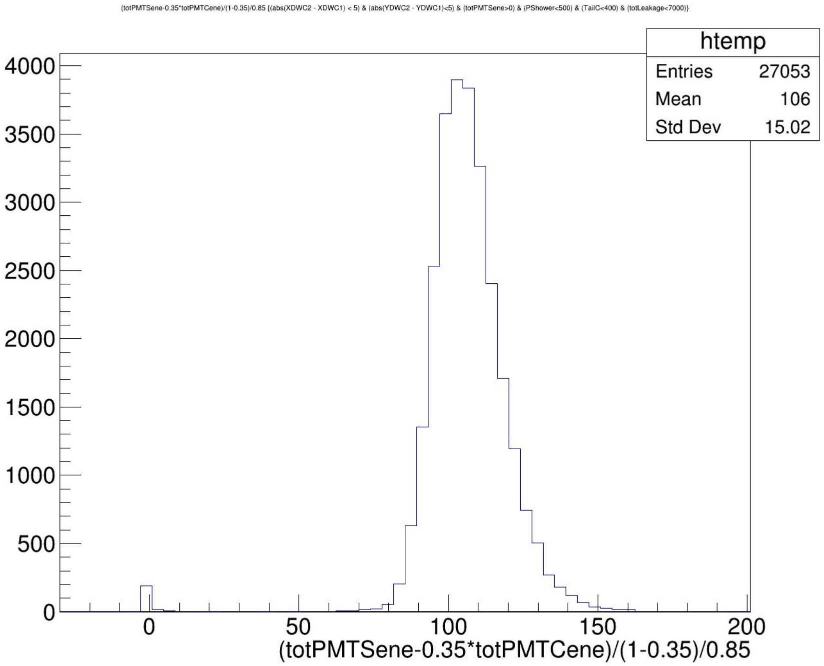
From DRAGO simulation studies: chi = 0.35, containment = 0.85

**Reco E = (totPMTSene-0.35*totPMTCene)/(1-0.35)/0.85**

40 GeV pions, run 0715



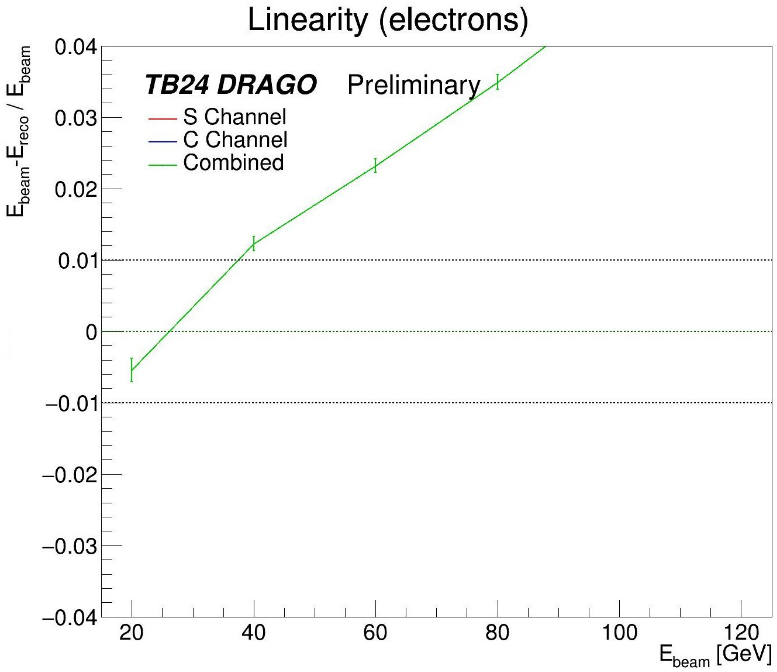

100 GeV pions, run 0718

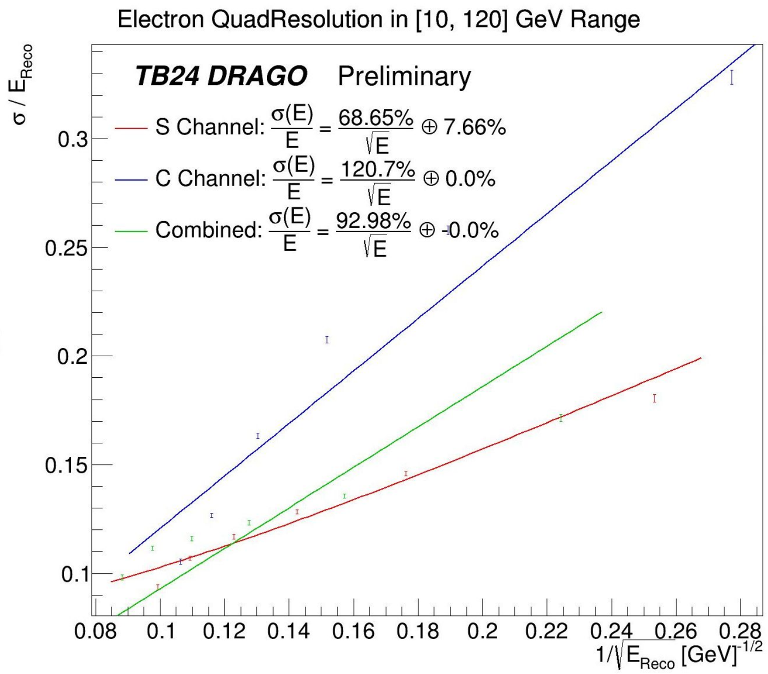


**A first look into pions**

From DRAGO simulation studies: chi = 0.35, containment = 0.85

Work in progress :)



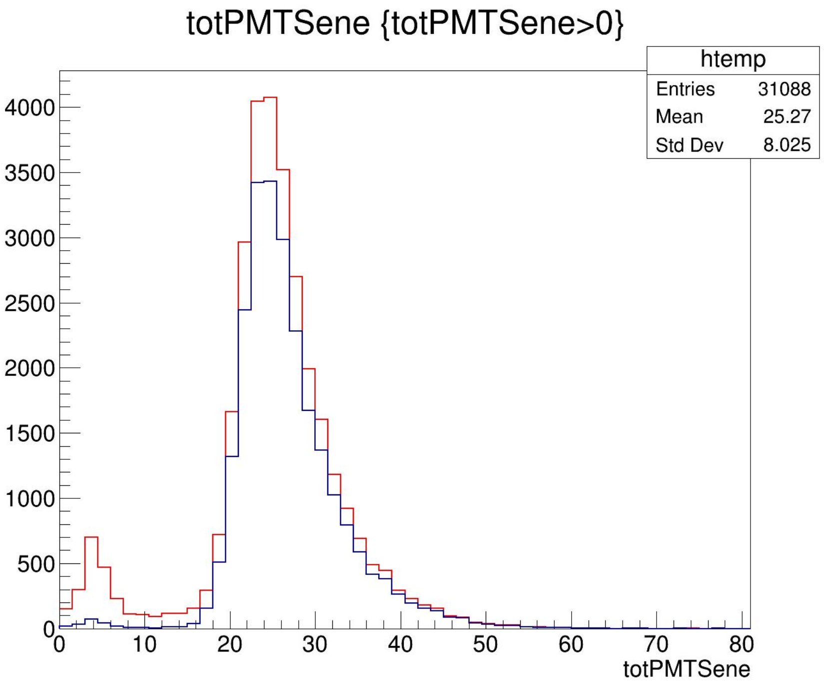



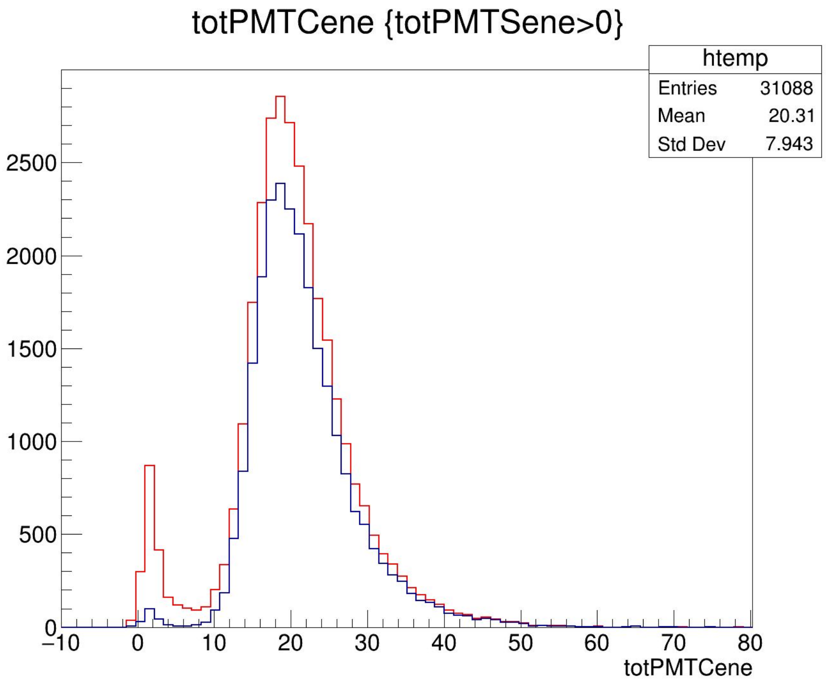
## A first look into pions

From DRAGO simulation studies: chi = 0.35, containment = 0.85

Using “newHV” runs = ["0968", "0967", "0966", "0965", "0963", "0962"]

Using cuts: "(abs(XDWC2 - XDWC1) < 5) & (abs(YDWC2 - YDWC1)<5) & (totPMTSene>0) & (PShower<500) & (TailC<400) & (totLeakage<7000) & (MCounter<150)”



## A first look into pions

From DRAGO simulation studies: chi = 0.35, containment = 0.85

Using “newHV”

**(totPMTSene-0.35*totPMTCene)/(1-0.35)/0.85**

Always lower than nominal E -> is calibration correct for these runs?

Important high-energy tail contribution, probably due to short (3.5 m) attenuation length