Pion beam analysis

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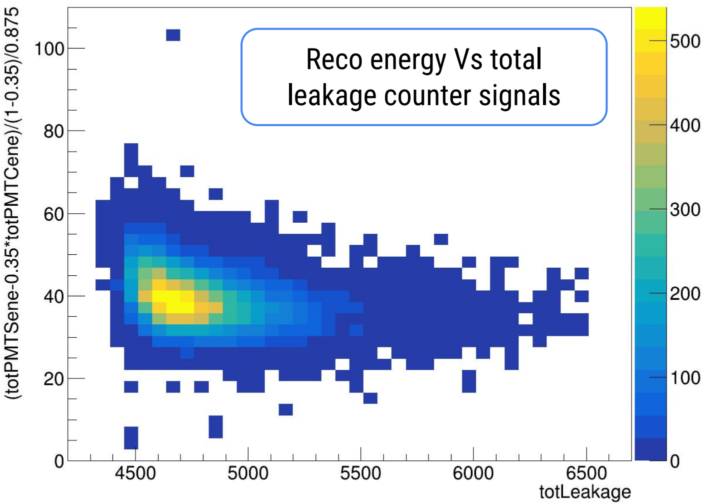
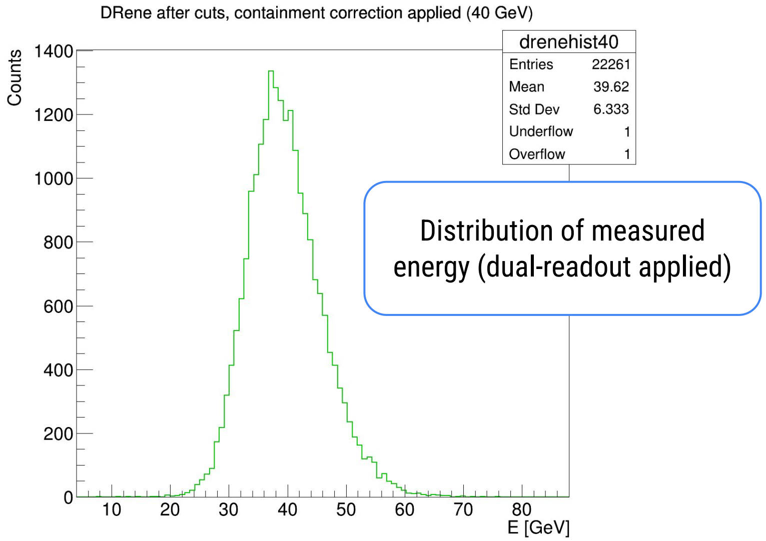
Previous results

Two main issues arising when looking at pion data:

- Energy leakage outside calorimeter -> low energy tail, corrected on average through simulation information, planning to also look at leakage counters
- Light attenuation in optical fibres -> high energy tail





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  - Asymmetry of signals due to tilted calorimeter
  - Time information in central towers

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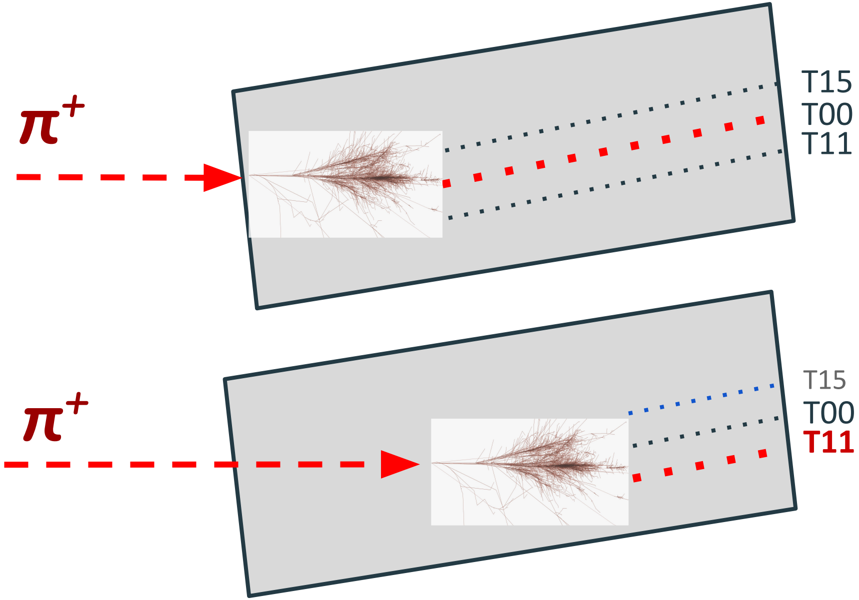
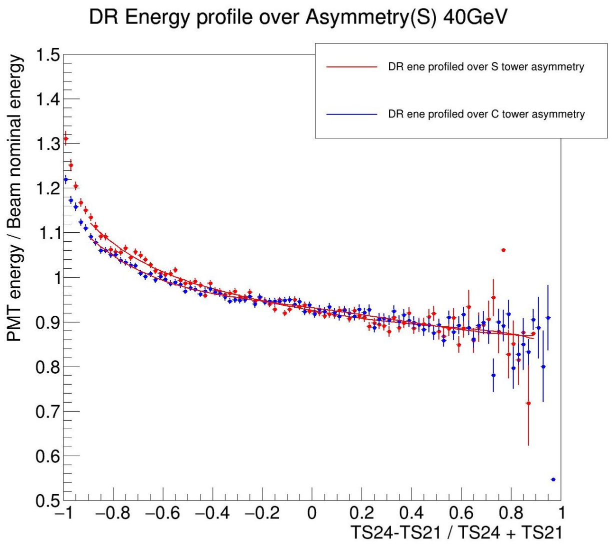
Asymmetry of signals due to tilted calorimeter





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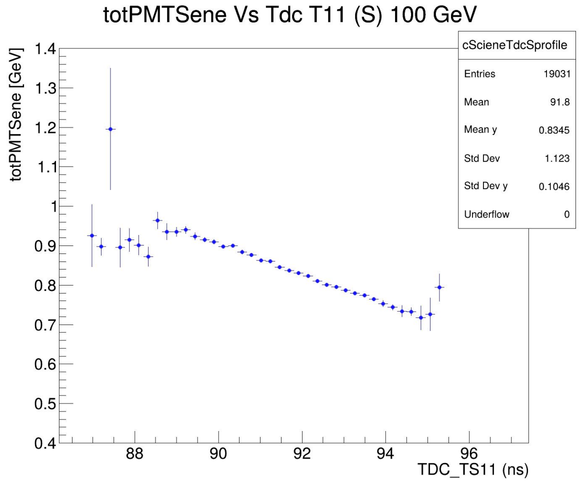
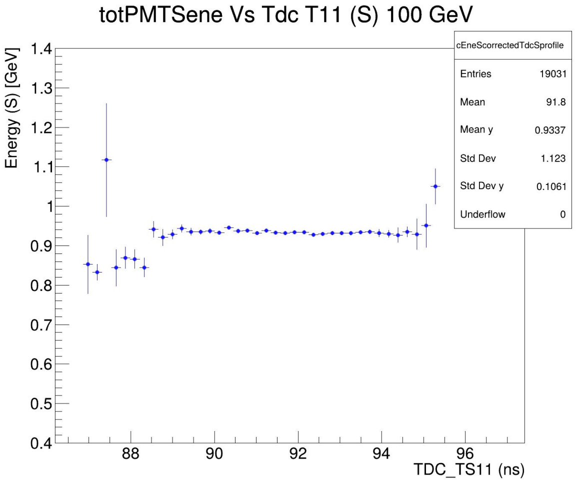
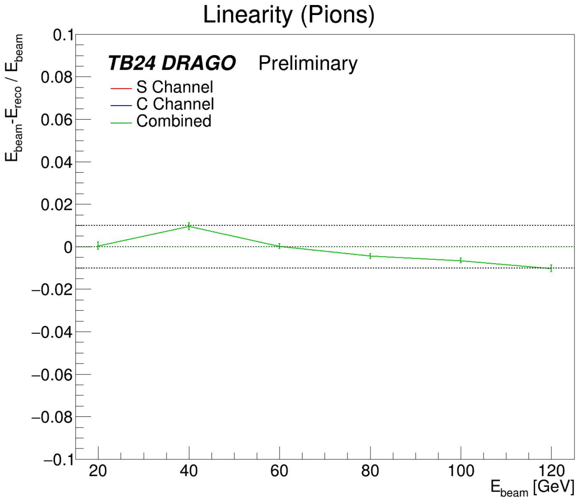
Asymmetry of signals due to tilted calorimeter

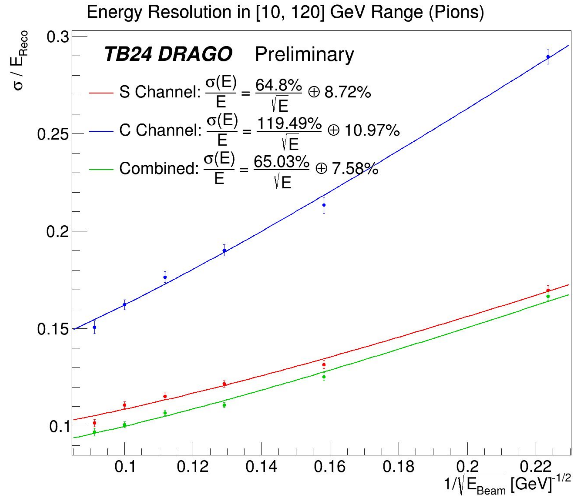
Time information in central towers





	Stochastic term (S)	Constant term (S)	Stochastic term (C)	Constant term (C)	Stochastic term (DR)	Constant term (DR)
Asymmetry correction	73.94%	7.2%	133.49%	8.24%	70.72%	6.51%
Timing correction (S, C and DR independently, parametrisation with truth E)	63.35%	8.86%	124.27%	10.48%	62.18%	7.93%
DR after timing-corrected S/C energy (chi = 0.35)	64.8%	8.72%	119.49%	10.97%	61.2%	8.01%
DR after timing-corrected S/C energy (chi = 0.44)	64.8%	8.72%	119.49%	10.97%	65.03%	7.58%

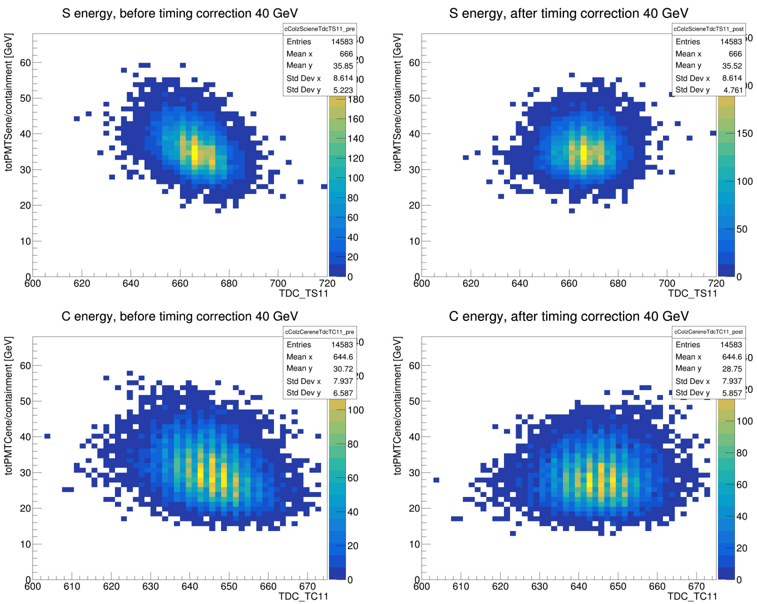


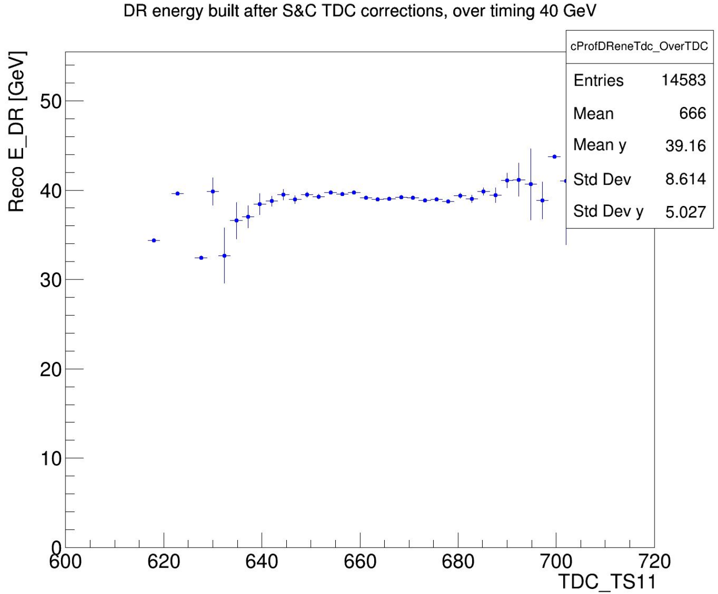


Correction procedure

At first, tried to correct DR energy alone through parametrization at a fixed point (e.g. 40 GeV run), and later repeat procedure for S/C channels. However, this was brute-forcing the three distributions to have the same energy

Then, tried to use the Most Probable Value of the Cerenkov/Scintillation distributions at 40 GeV as the point at which the timing parametrization should be centred, and later apply the DR formula to the corrected distributions



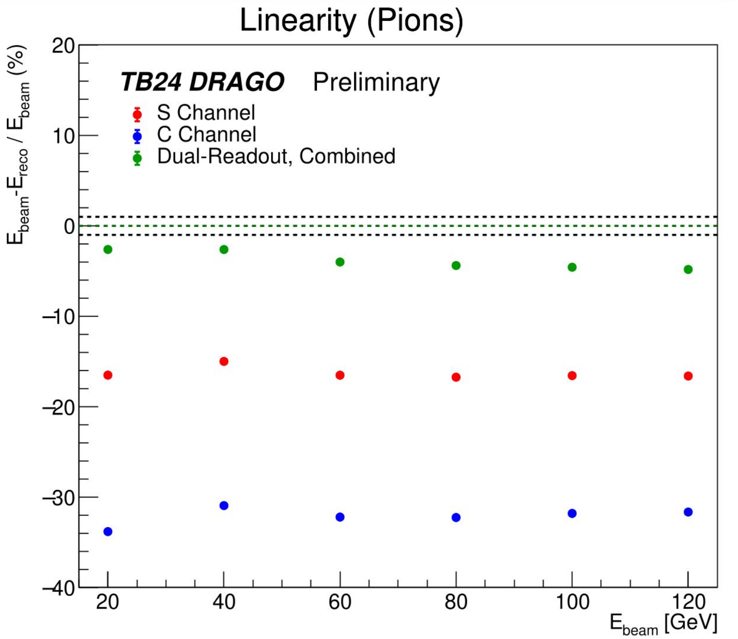


Correction procedure

Almost linear response for dual-readout channel, scintillating and Cerenkov keep their original value.
But, we expect the S(C) measured signal to increase with increasing energy due to larger electromagnetic fraction

My interpretation:
parametrising the energy dependence at 40 GeV and using the curve for all points is wrong, as the average hadron shower position changes with time

-> at higher energy the hadron shower develops deeper, but I'm treating it as a 40 GeV shower that develops later



Correction procedure

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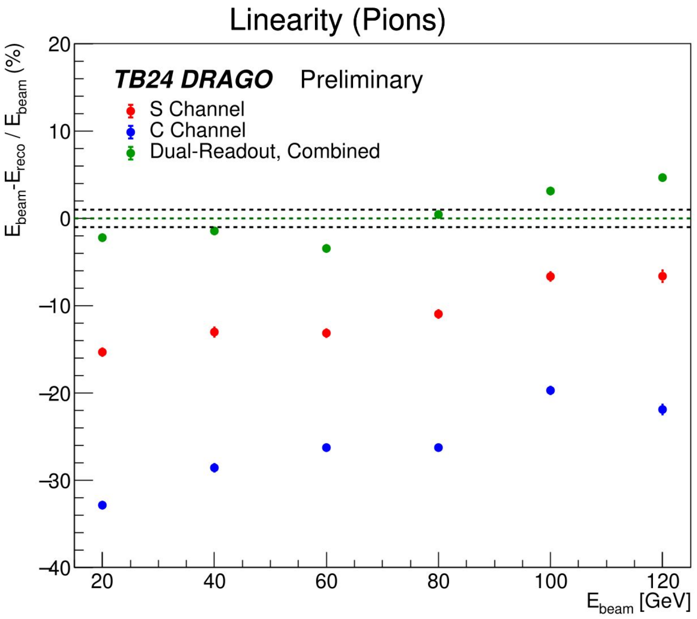
Using a different time dependence for S, C signals for each run
-> Not that good, most probable value seems to not be stable for flattening the two distributions at the correct value for dual-readout to be linear

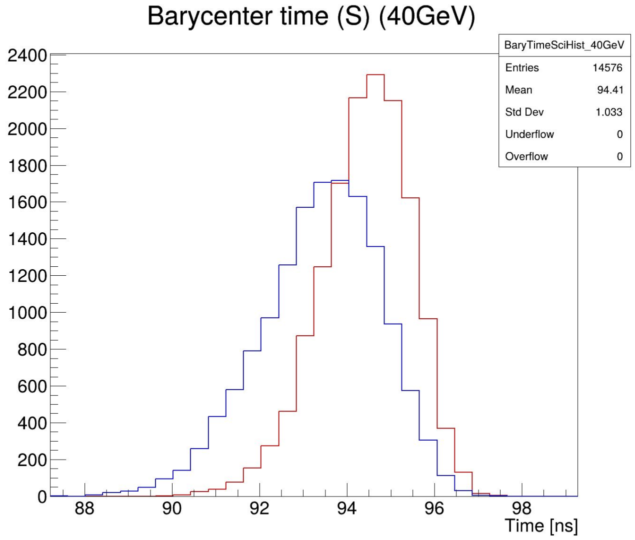


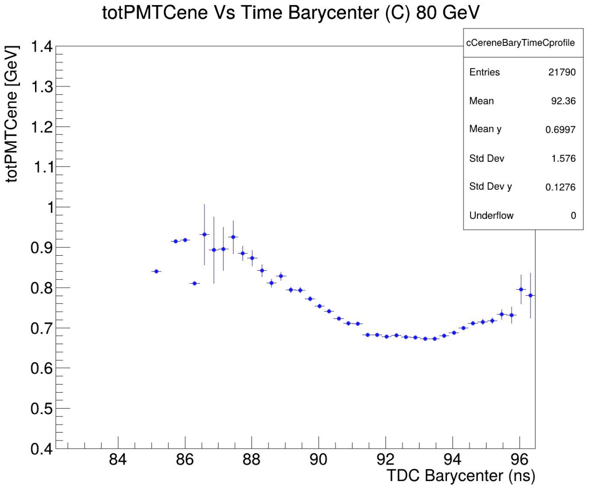
Other tests

Build time barycenter distributions from the three towers T11, T00 and T15 (where we have time information)

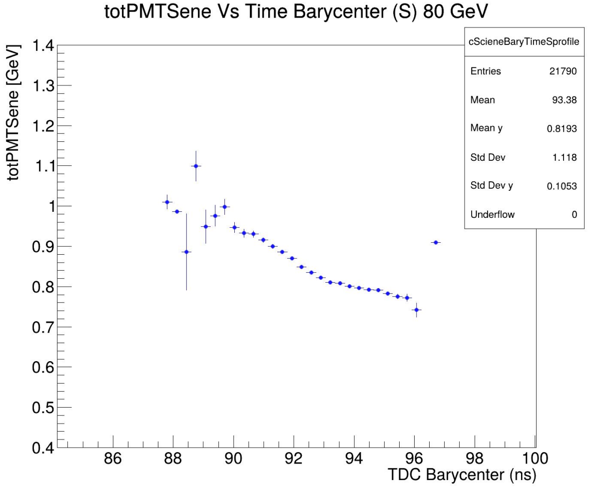
df["BaryTimeS"] = (df["TS00"]*df["TDC_TS00"] + df["TS11"]*df["TDC_TS11"] + df["TS15"]*df["TDC_TS15"]) / (df["TS00"]+df["TS11"]+df["TS15"])

df["BaryTimeC"] = (df["TC00"]*df["TDC_TC00"] + df["TC11"]*df["TDC_TC11"] + df["TC15"]*df["TDC_TC15"]) / (df["TC00"]+df["TC11"]+df["TC15"])





Energy profiles over time barycenter position of the three towers



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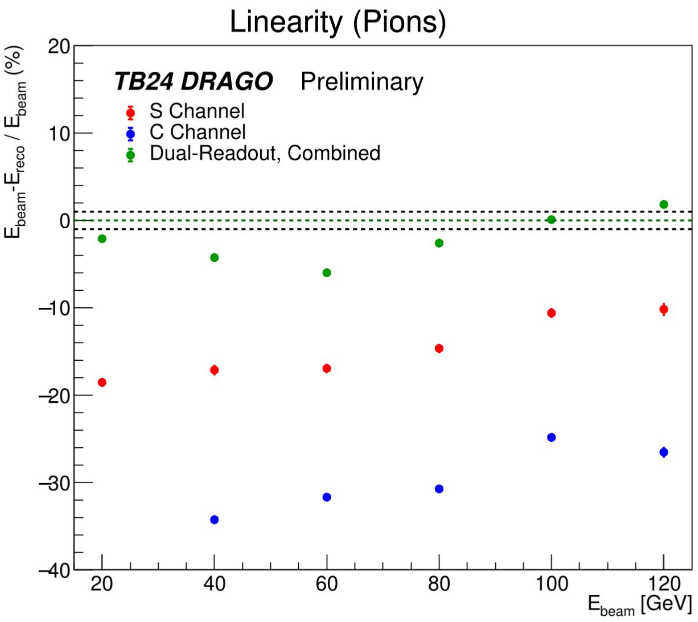

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```

One single variable may not be enough to recover linearity.

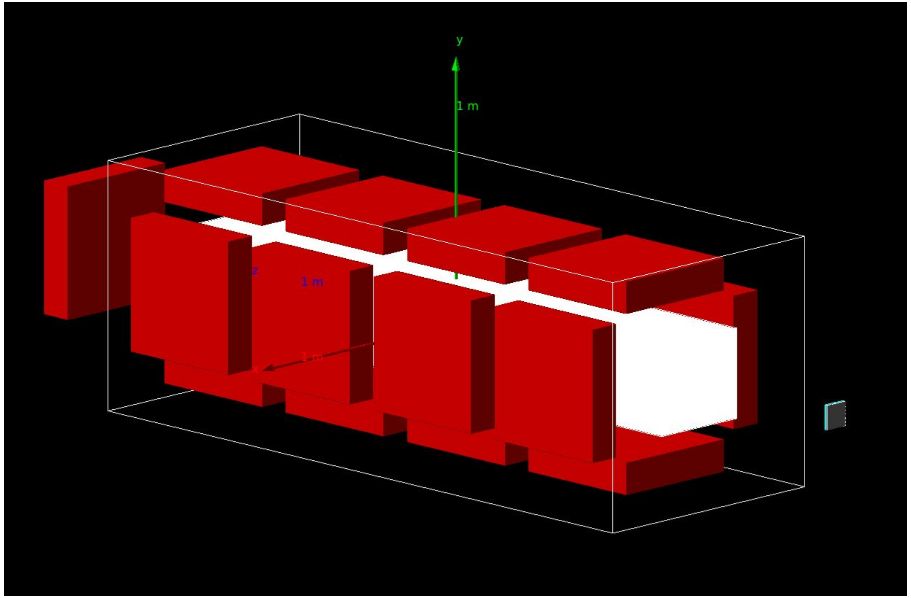
Ideas:

1) launch everything into a neural network (tried quick test with boosted decision tree, but could not generalize at different energies from the training set ones)
2) Analytical way to estimate signal emission position along fiber through timing, and calculate what the signal would be if it was emitted at a ~electromagnetic shower depth

   -> Would require knowing time for all towers, not just three (and SiPMs) ?

Simulation

Comparisons between TB24 data and Monte Carlo simulations



Comparing time information

In order to access time information, the optical photon time-of-arrival given by the SiPM simulation package is stored (one number per fiber).
However, during the TB we had one value for the whole tower

Tested two approaches:

1) Take ToA of first optical photon in each tower

2) Mean of optical photons belonging to the same tower

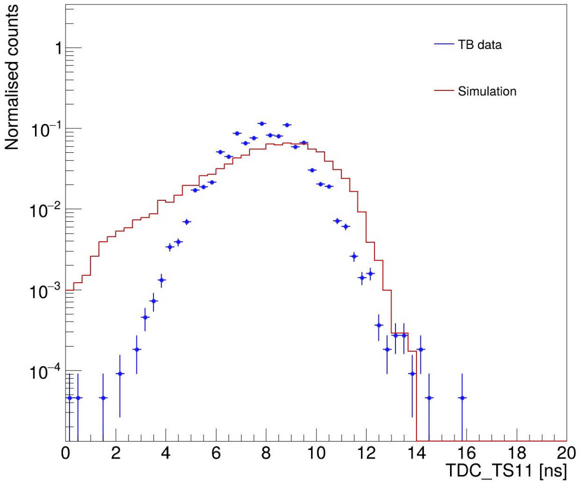
Comparing time information

1) Take ToA of first optical photon in each tower

Data: time in [ns] is given by TDC*140/1000 (time resolution in [ps]). An offset of ~90ns is found with respect to the simulation, so the data distribution is shifted until the two have the same peak position

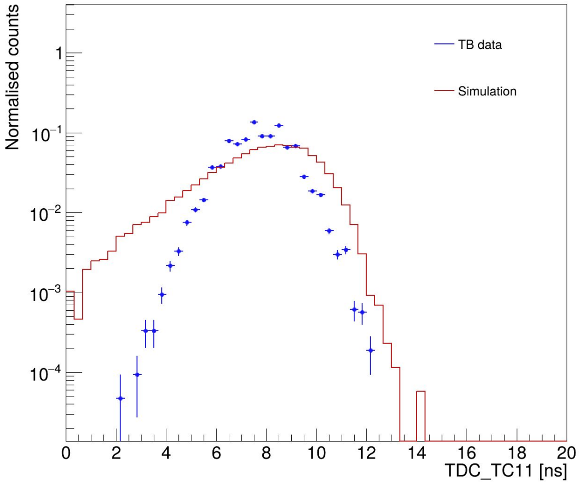
S channel, Tower 11

TDC_TS11 40 GeV



C channel, Tower 11

TDC_TC11 40 GeV

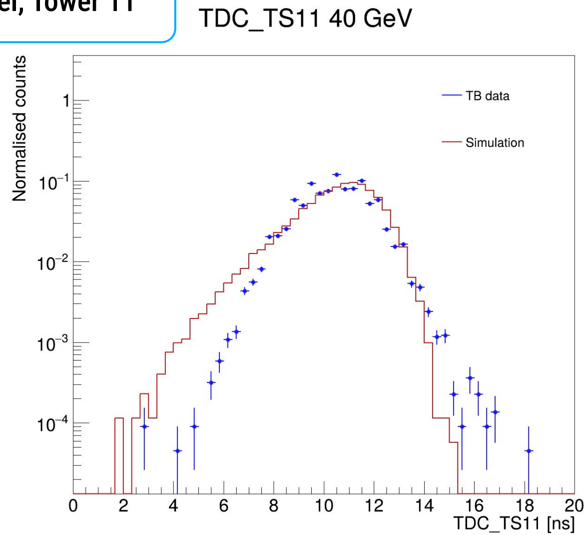


Comparing time information

2) Mean of optical photons belonging to the same tower

Somewhat better agreement, probably a threshold on the number of optical photons required to pass a threshold should be required -> maybe take the mean of the first n photons

S channel, Tower 11



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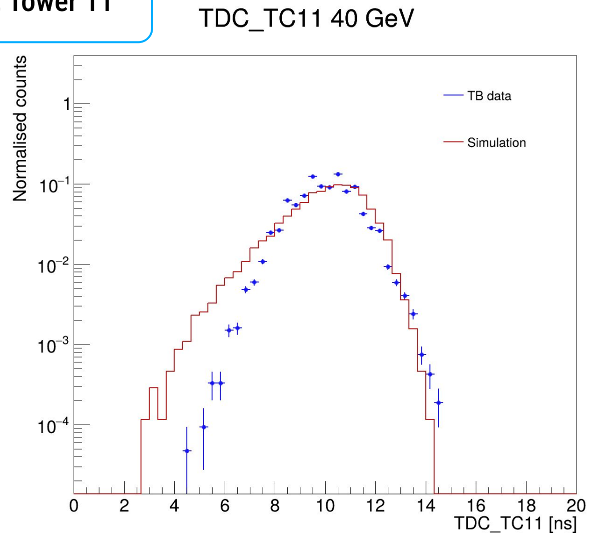
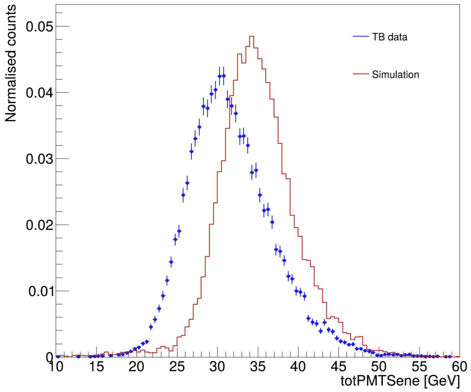


Data/MC comparison - Pions

3.5 m attenuation length in simulation, for both scintillating and Cerenkov fibers

totPMTSene 40 GeV



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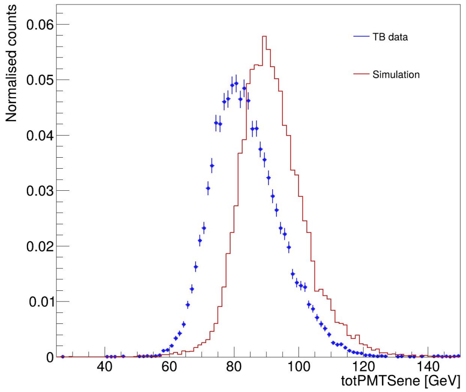
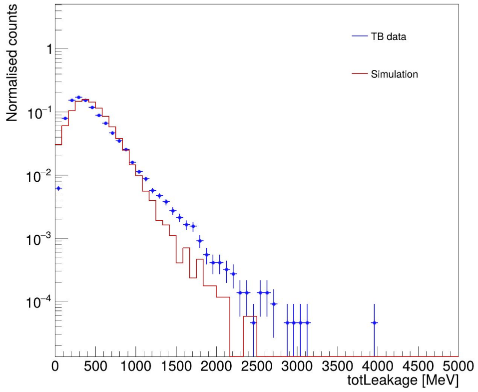


totLeakage 40 GeV



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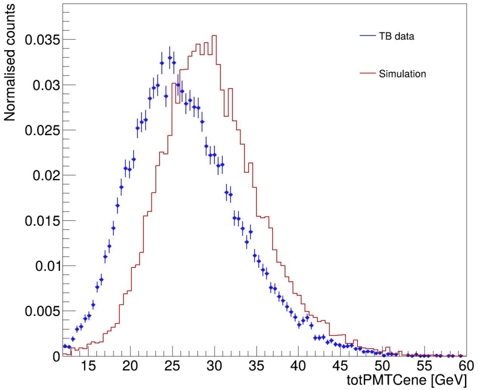

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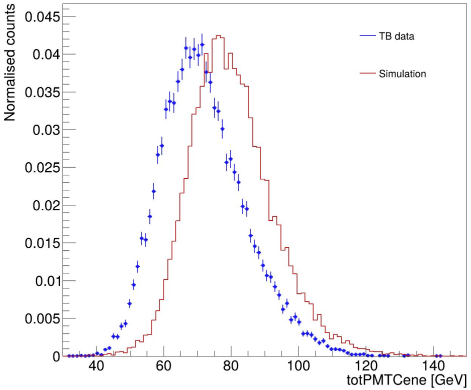

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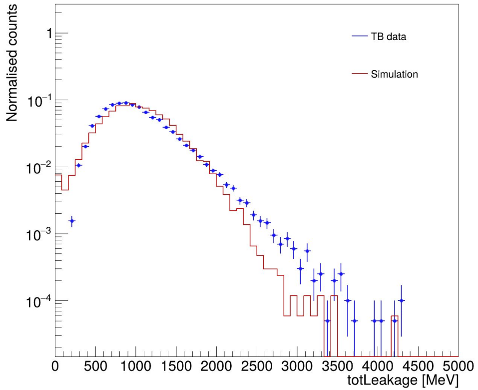

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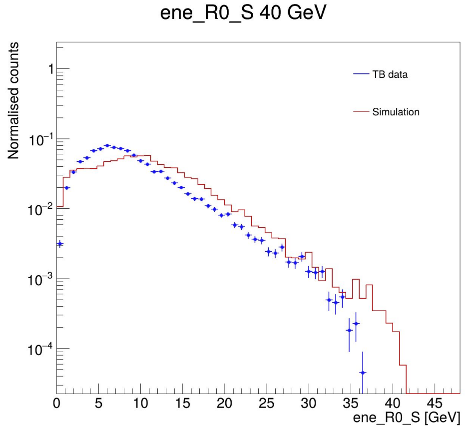
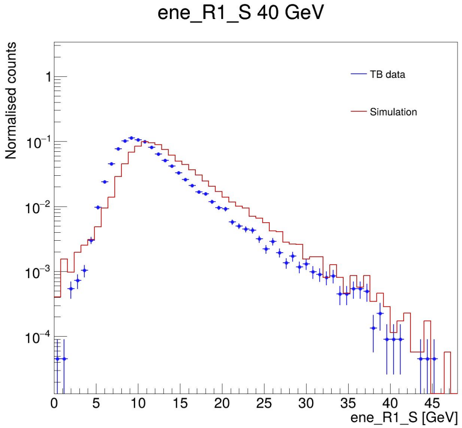
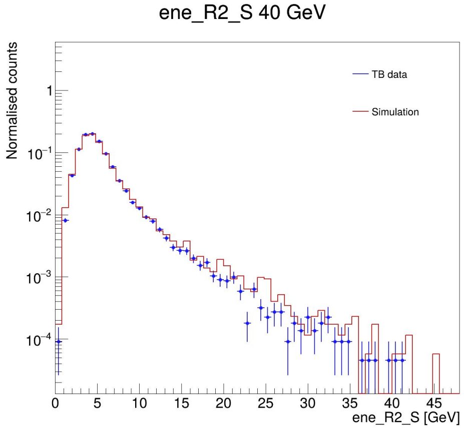
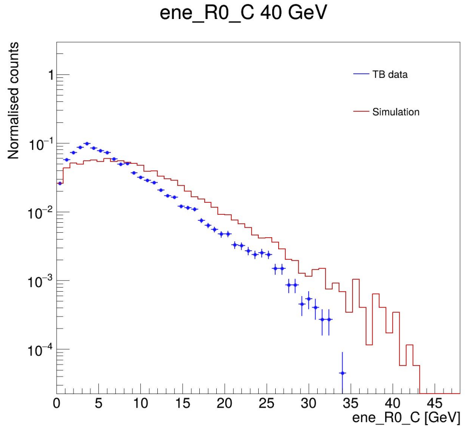
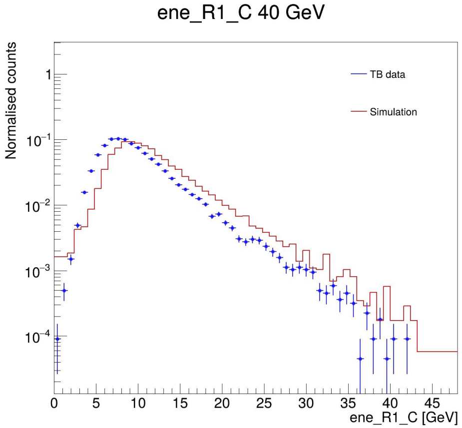
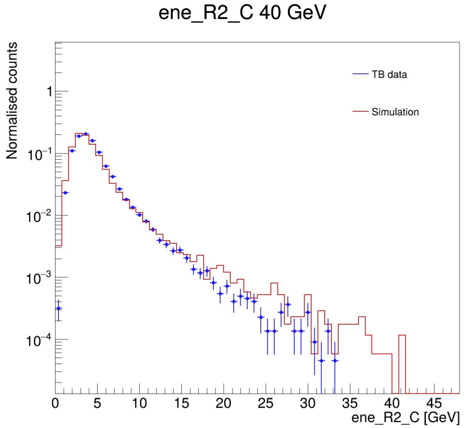






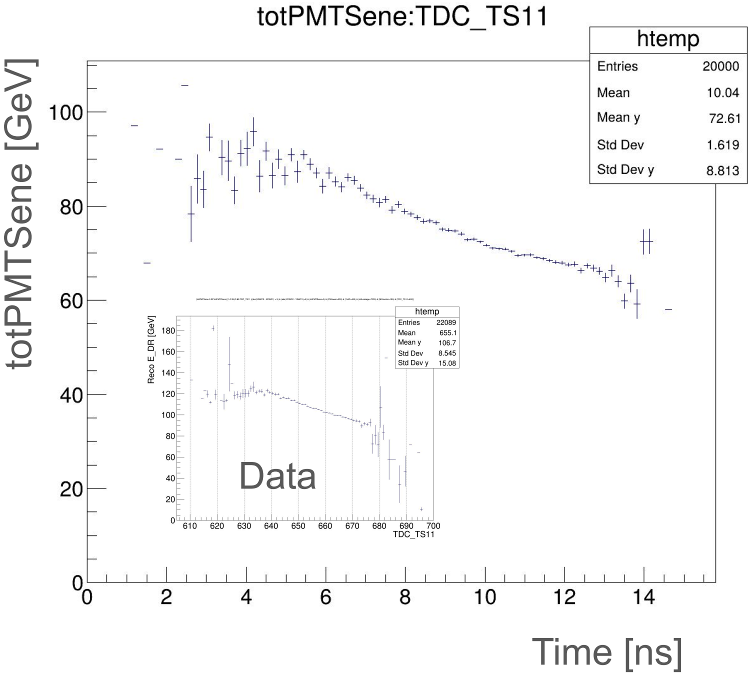






Data/MC comparison - Pions

80 GeV pions



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