Implementation of the Gluckstern parametrization in ParamSim CAF trees

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Nov 30, 2020

Checking Gluckstern implementation in code

- ParamSim uses Gluckstern approximation for long tracks to get an estimate of the reconstructed momentum
  - Input is anatree and output is caf tree
  - Code is here
- Check two things:
  - Usage of p vs p_T in formula
  - What value to use for pad pitch, when converting track length into number of hits

From the DUNE Near Detector Task Force Report, T. Alion et al. (undated)

$$\left(\frac{\sigma(p_{\mathrm{T}})}{p_{\mathrm{T}}}\right)^2 = \left(\frac{\sigma_x\, p_{\mathrm{T}}}{0.3\, B\, L^2}\sqrt{\frac{720}{N+4}}\right)^2 + \left(\frac{0.05}{B}\sqrt{\frac{1.43}{L\, X_0}}\right)^2$$

p_T is the momentum perpendicular to the B-field, i.e., $\sqrt{p_y^2 + p_z^2}$, and

L is the track length in the y-z plane. σ_x is the pad pitch, used to convert 3-D track length into N.

In the code, p_T has been replaced by ***p***. Check the validity of that approximation.

$$\sigma_\theta^2 = \left(\frac{\sigma_x}{L}\sqrt{\frac{12\,(N-1)}{N\,(N+1)}}\right)^2 + \left(\frac{0.015}{p}\sqrt{\frac{L}{3\,X_0}}\right)^2 .$$

As defined, θ is = (90 - λ), where the latter is the angle relative to the y-z plane

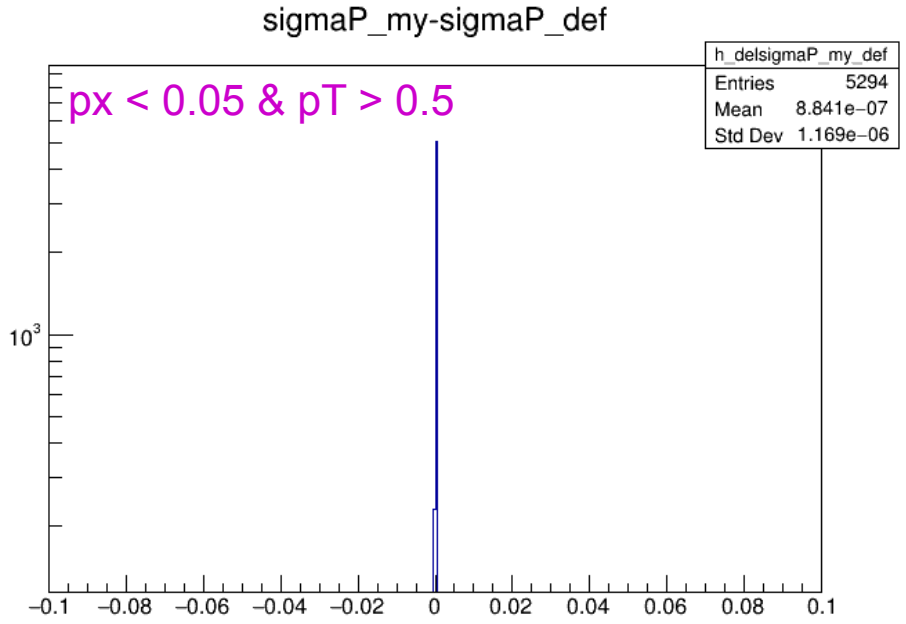
Two ways of calculating momentum uncertainty

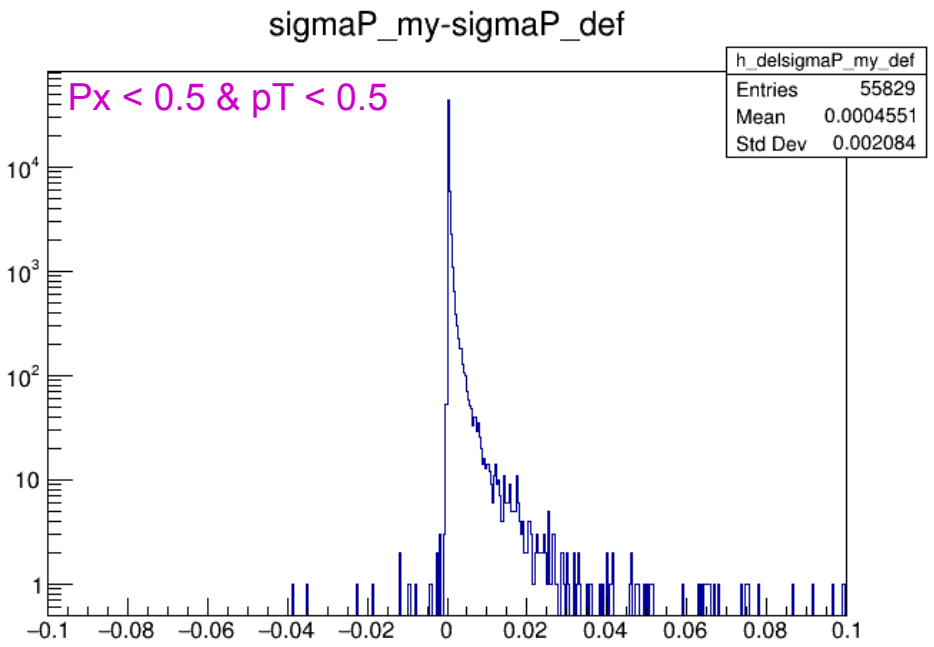
- By default, *p* is used, so we straight away get σ_p
- In my calculation, we first get σ_{pT} from use of Gluckstern formula, then use $p_T = p^* \cos(\lambda)$, and assume $\delta\lambda \sim 0.35^o$ to estimate σ_p
  - Tom said uncertainty on 3-D angle ~ 0.5^o
  - σ_p = [sum in quadrature of σ_{pT} and $p_T * \tan(\lambda)\ \delta\lambda$]/$\cos(\lambda)$
- Only use tracks with trackLength > 100 cm. – just to get long tracks

(a) Look at six regions of phase space

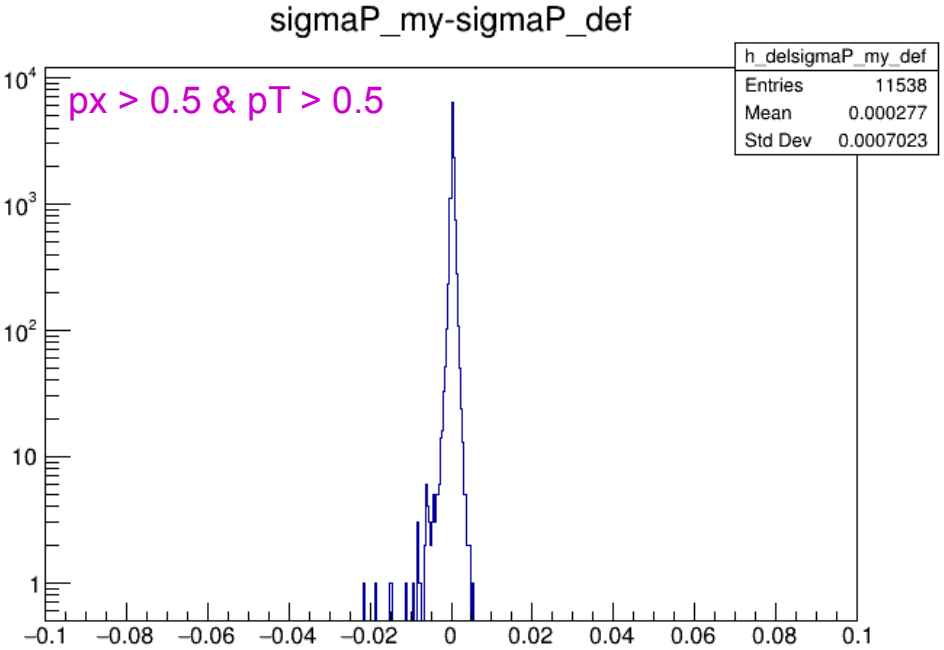
px, pT regions	# entries	Std. Dev. of (default preco – truep)	Std. deviation of (my preco – truep)
px < 0.05 & pT > 0.5	5294	0.0311	0.0313
px: 0.05-0.1 & pT > 0.5	5143	0.315	0.032
px: 0.1-0.5 & pT > 0.5	30462	0.0341	0.0342
px > 0.5 & pT > 0.5	11538	0.0425	0.044
px > 0.5 & pT < 0.5	2266	0.0179	0.0246
px < 0.5 & pT < 0.5	55829	0.008	0.009

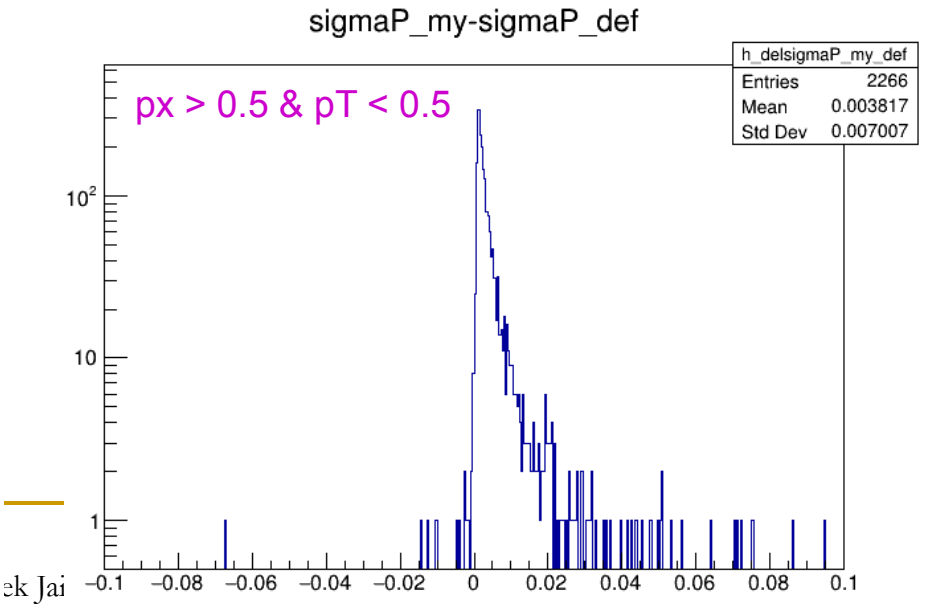
As px increases relative to pT, effect gets bigger – no surprise





Difference in the two uncertainties





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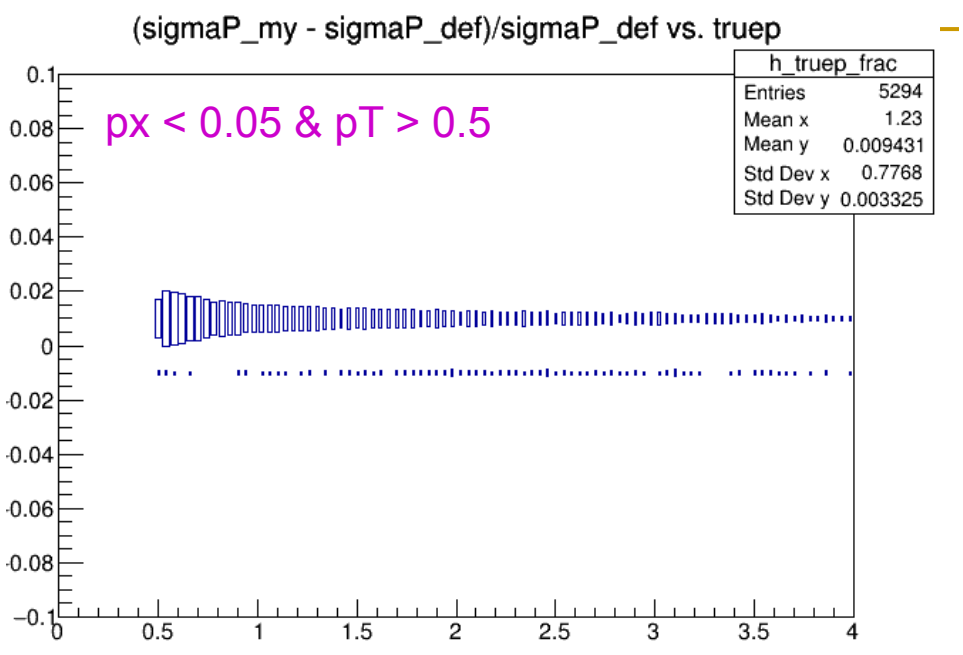
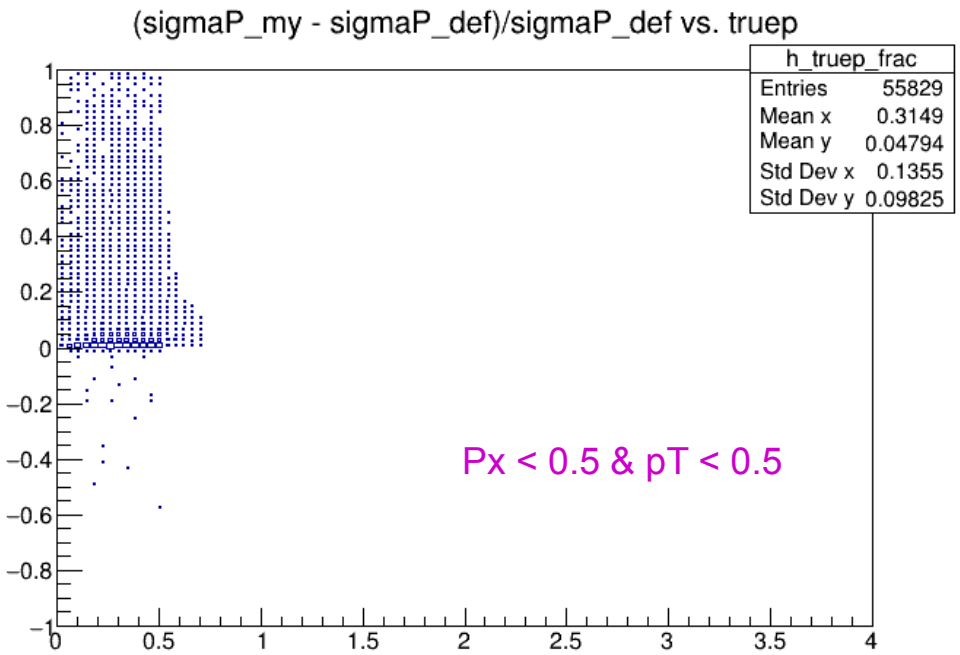
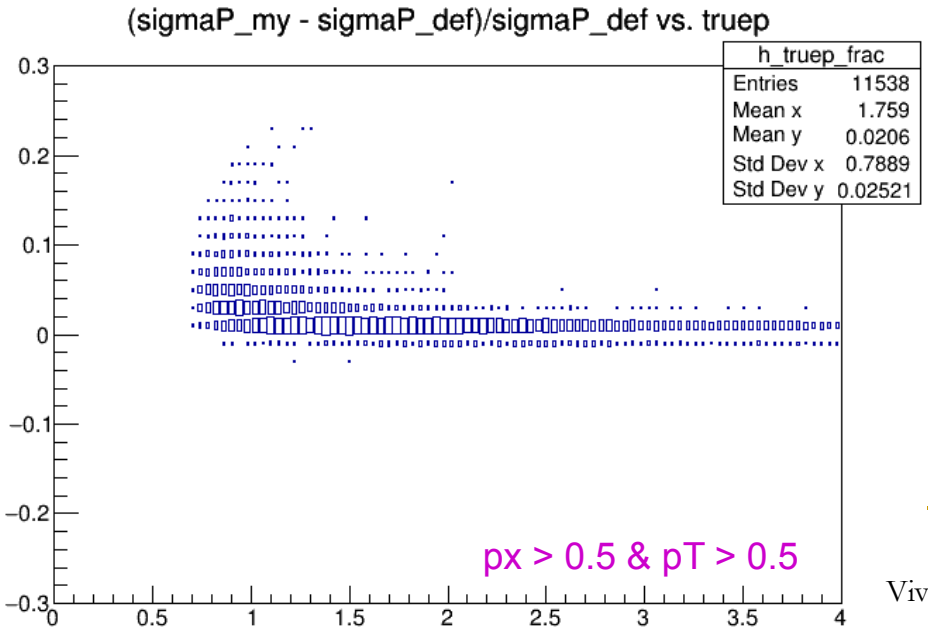
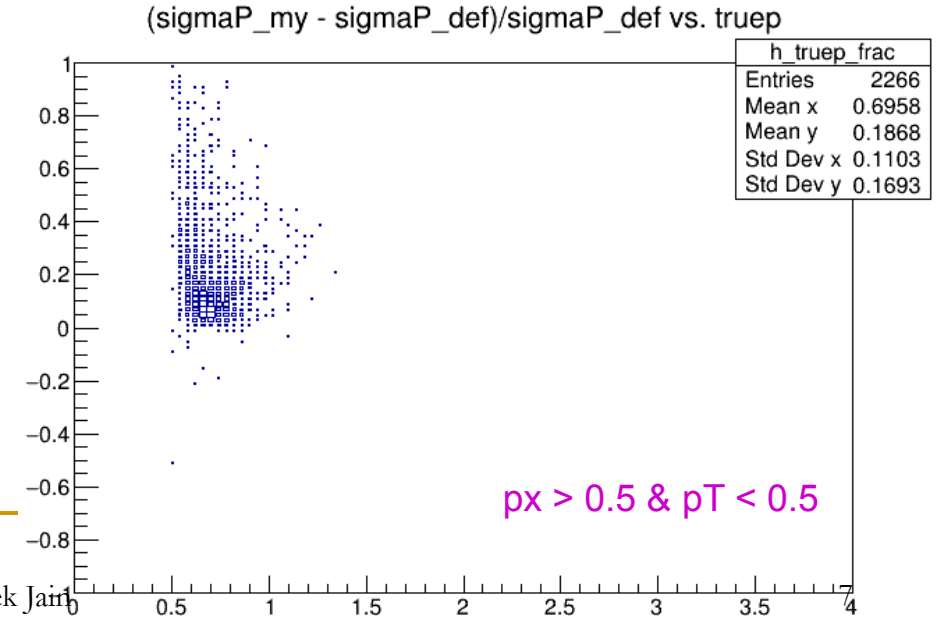




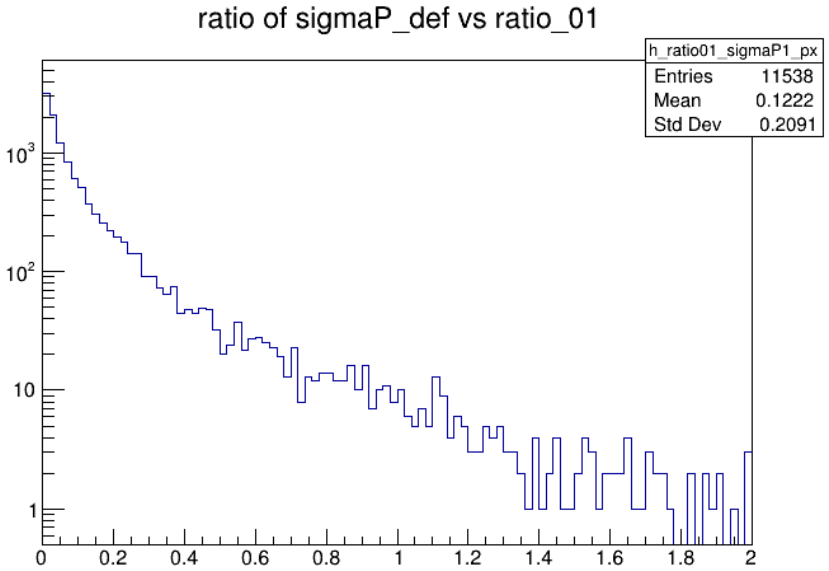
Fractional change in uncertainty vs. true p (Y-scales are different)



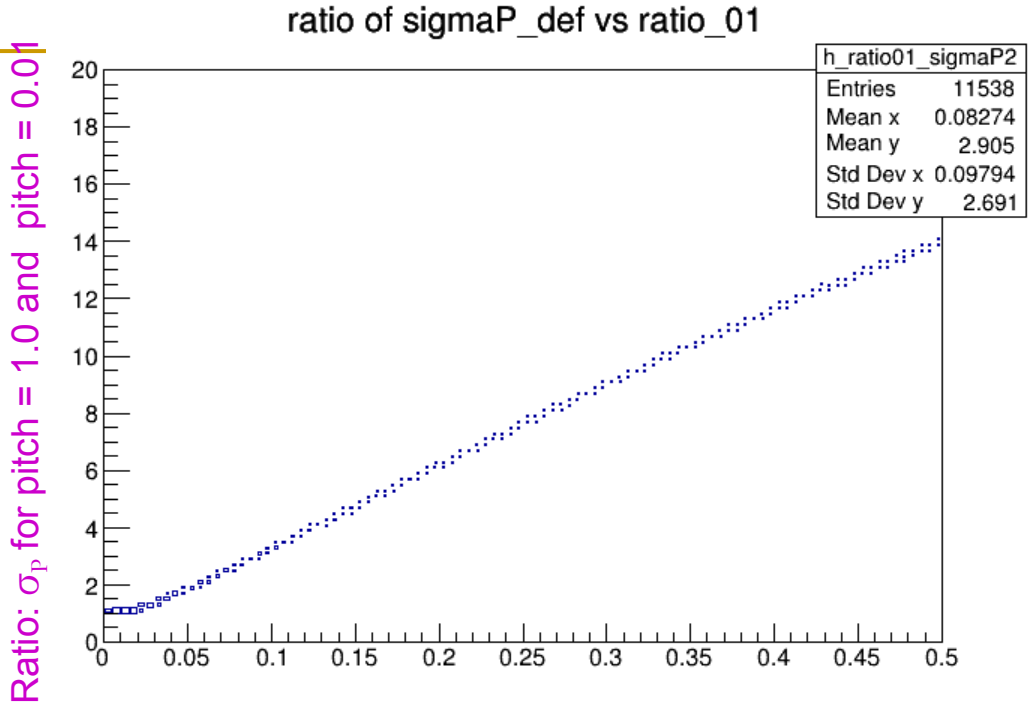


What value of pad pitch to use, i.e., what to assume for σ_x

- This makes a difference, since N_{hits}=3-D trkLength/pad pitch, and the pitch itself appears in the Gluckstern formula
  - However, momentum uncertainty has two terms – the pad pitch only affects the measurement term (α (pitch)$^{3/2}$), while the MCS term is unaffected
- In the code, it is set to 0.1 cm
- From Tom: "The TPC Cluster search window is an adjustable fcl parameter. I believe by default it is set to 2 cm."
  - For now, I set it to 1 cm, just to get an estimate
- In my test, the measurement term increases by ~ 31, but most of the time MCS term is much larger, so the overall uncertainty changes by a smaller amount



Ratio of Meas/MCS terms
for pitch = 0.1 cm
(~95% have ratio < 0.5)



Ratio of Meas/MCS terms, pitch = 0.1 cm

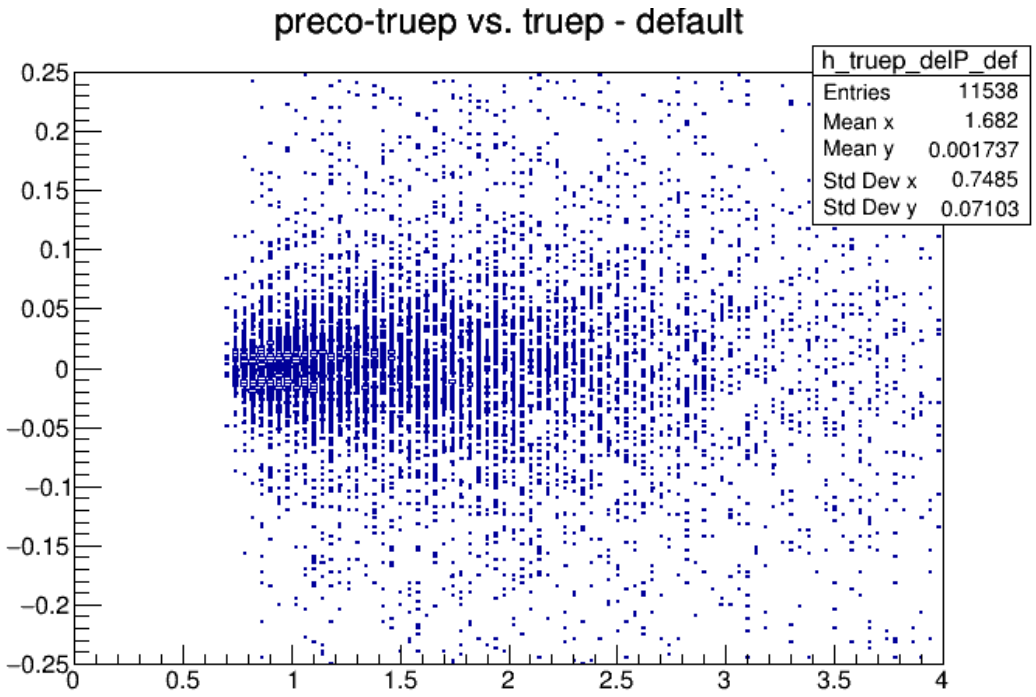
These two plots used the default calculation for the momentum uncertainty

Above plots are for one corner of phase space:
trackLength>100 cm, and p_x & p_T>0.5

Look at other regions of phase space for pad pitch 1 cm (numbers in black are for pad pitch = 0.1 cm)

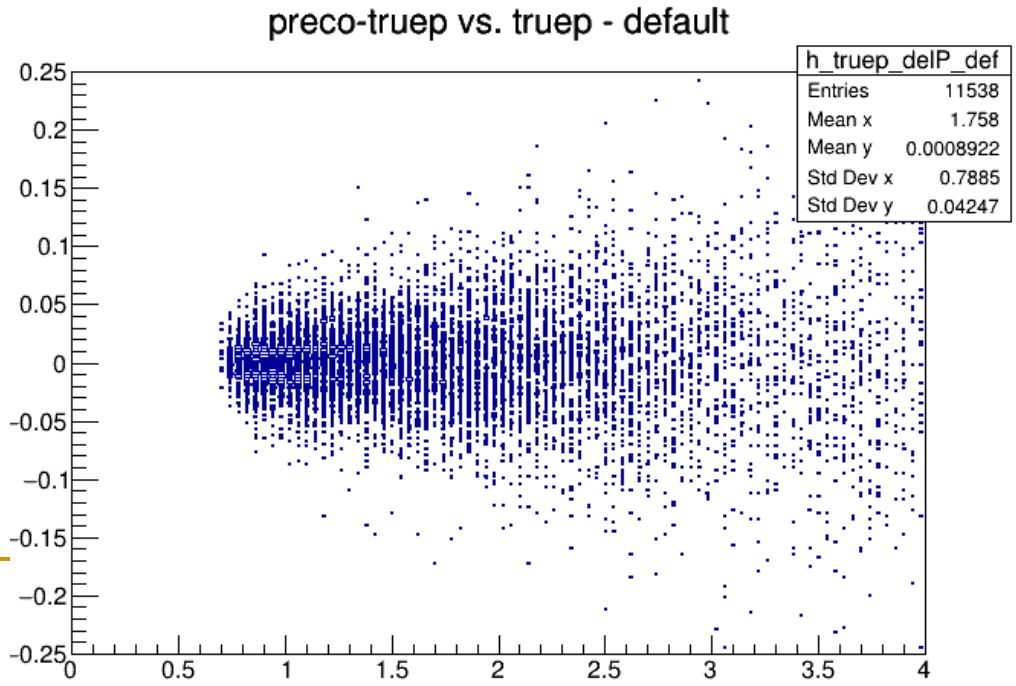
px, pT regions	# entries	Std. Dev. of (default preco – truep)	Std. deviation of (my preco – truep)
px < 0.05 & pT > 0.5	5294	0.0494 (0.0311)	0.0492 (0.0313)
px: 0.05-0.1 & pT > 0.5			
px: 0.1-0.5 & pT > 0.5			
px > 0.5 & pT > 0.5	11538	0.071 (0.0425)	0.0705 (0.044)
px > 0.5 & pT < 0.5	2266	0.0375 (0.0179)	0.033 (0.0246)

Interestingly enough, for the larger pad pitch size, the behavior of the two sigmas flips in the last case – not sure if that means something, or just turns out like that



px > 0.5 & pT > 0.5
Use default calculation

Pad pitch = 1 cm



Pad pitch = 0.1 cm

Summary

- Gluckstern formulation for momentum uncertainty is affected more by the pad pitch size than by using pT

- The calculation of the uncertainty of the angle depends on pad pitch – but I didn't check this.
  - It depends on total momentum, so the pT issue does not apply

- Also, I didn't check the case when we use the range, i.e., for tracks ending within the TPC
  - I noticed that σ_p is set to 0.1 GeV for all tracks, and only the uncertainty on the angle is calculated (same formula as for tracks leaving the TPC)