Field Off Scattering Studies

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What is a systematic error?

- Systematic errors are errors that are not determined by chance but are introduced by an inaccuracy inherent to the system

What are we measuring in this analysis?

- Multilple Coulomb scattering is being measured

$$\Theta = \frac{13.6\ \mathrm{MeV/c}}{p_\mu \beta} \sqrt{\frac{z}{X_0}} \left(1 + 0.038 \ln \frac{z}{X_0}\right). \tag{1}$$

- is dependant on p_μ
- Select monochromatic beam of $\mu \rightarrow$ narrow TOF window $\rightarrow$ narrow p_μ range
- Mean of p_μ for selected sample at a given value i.e. 200 MeV/c

Momentum Calculation

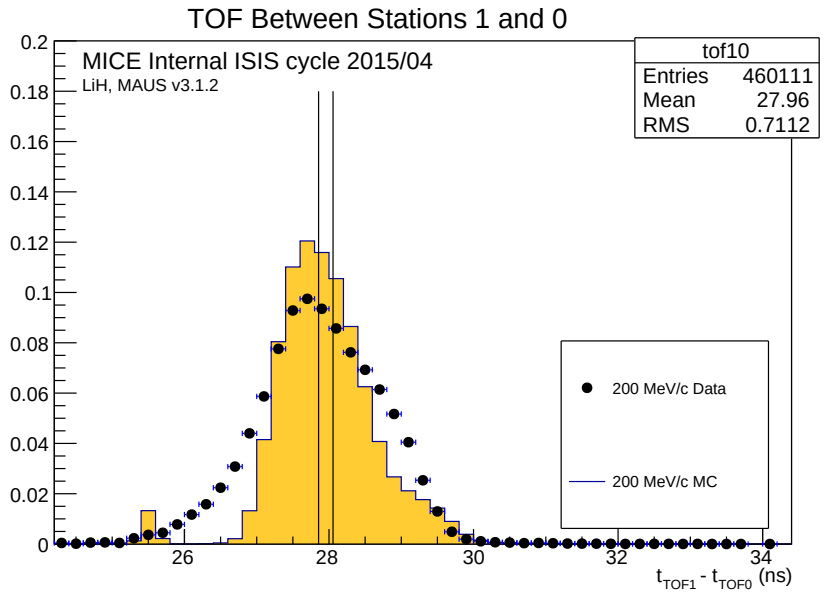
1. Momentum is measured with

$$p = \frac{m}{\sqrt{\frac{t_\mu^2}{t_e^2} - 1}} \tag{2}$$

2. If there is a hit in TOF2 this is done with TOF1+2 information
3. If there is no hit in TOF2 this is done with TOF0+1
4. Only in the case of TOF0+1 is a correction applied to account for the energy loss in the channel.

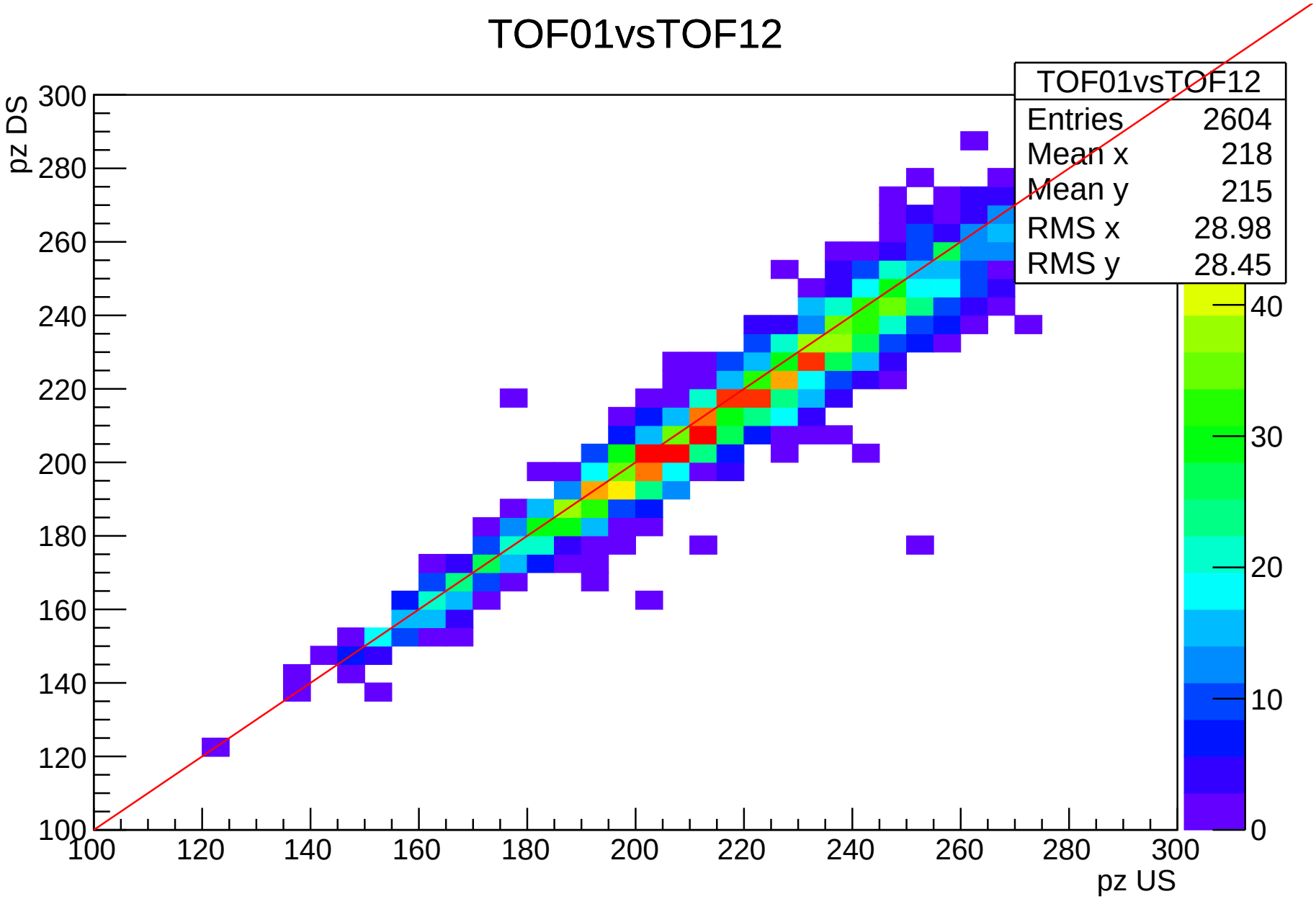
Where does primary error come from?

- All error in p_μ comes from TOF measurement
- Largest source of error in analysis
- Resolution of TOFs ~ 70 ps $\rightarrow 3$ MeV/c
- Analysis done in 200 ps bins
- μ can either be in selected bin or TOF bin above or below

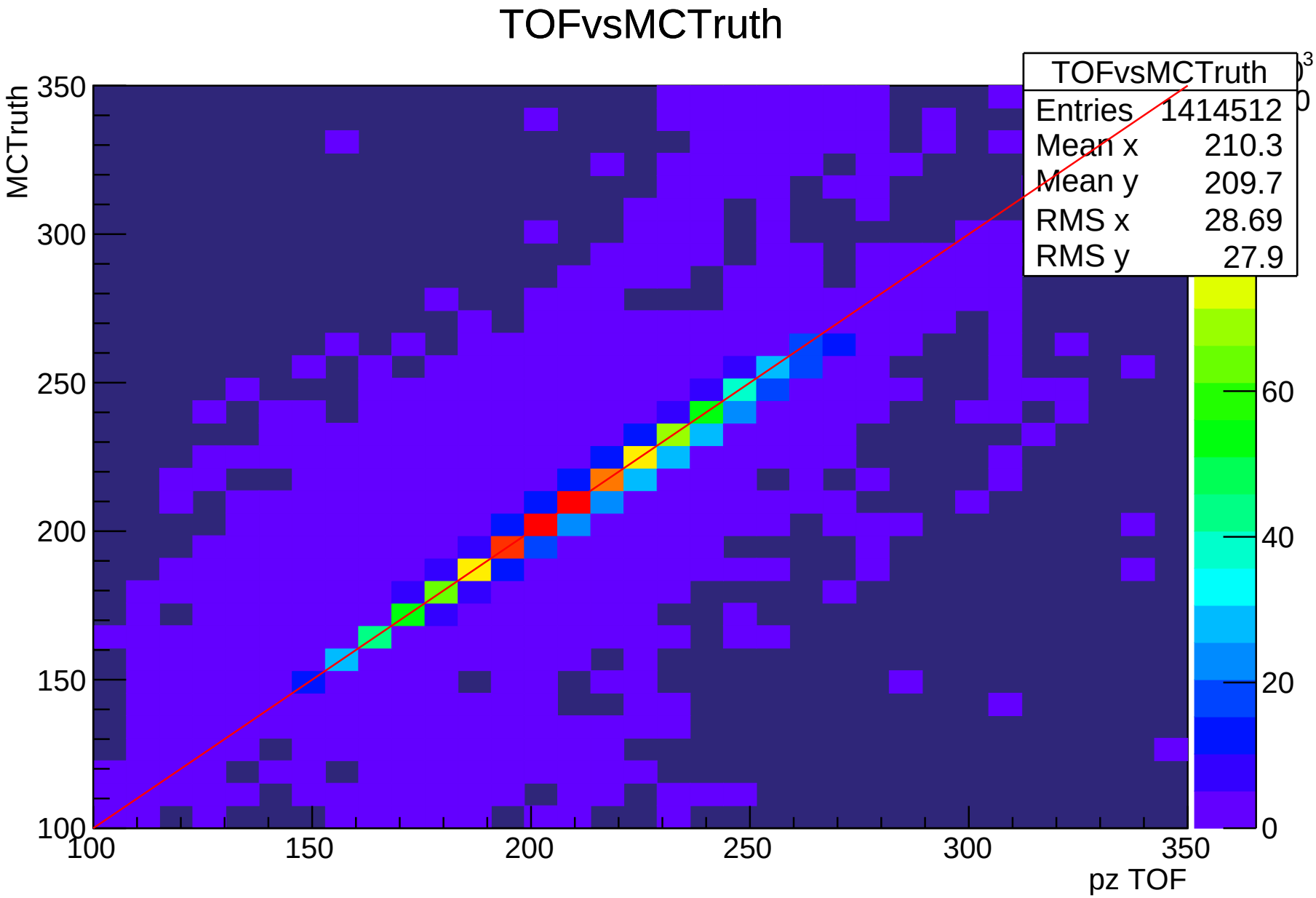


- Why 200 ps bins?
  - Need statistics in each bin
  - Larger than resolution of TOFs

TOF01 vs. TOF12



Truth P vs. recon



Comparing to a model simulated at a given p_μ

- Sometimes μ in sample selected will systematically have a p_μ higher than that quoted
- (numbers for illustration only)
- bin from 26.8-27.0 ns
- i.e. measured TOF 27.0 ns actually $\rightarrow$ 27.07 ns
- i.e. measured p_μ 200 MeV/c actually $\rightarrow$ 197 MeV/c
- We don't know this and we will never know this - it is due to the intrinsic resolution of the TOFs
- Cutting in p_μ does nothing to change this

Comparing to a model simulated at a given p_μ

- Sometime μ which are in the next TOF bin will be selected by analysis
- The σ_P of this sample is 200 MeV/c
  - actually mean is 201 MeV/c, within resolution of TOFs
- We crosscheck our methodology in MC, σ_P is consistent Truth/Recon but it can always vary

Comparing to a model simulated at a given p_μ

- μ at different P will contribute to scattering distribution differently
- Change the width of distribution and measured probabily of scattering at each angle
- These are the values that we report at the end of the analysis
- $\therefore$ comparison is only valid when quoting the result including an error on how each paramter varies as a function of the momentum of the selected sample
- How can this error be quantified?
- Vary the TOF window selected by the resolution of the TOFs and repeat measurement $\rightarrow \Theta\pm$ (some error)

Deconvolution

- Final result is after deconvolution
- Two samples are selected
  - LiH
  - Empty
- Two different P measurements
- Use one sample to deconvolve the other
- Truth 20 mrad (decon with) 14 mrad $\rightarrow$ 15 mrad
- Recon 21 mrad (decon with) 13 mrad $\rightarrow$ 16 mrad
- NOT due to deconvoluation - see my talk 22/2/19
- Due to the momentum of the selected samples
- Not determined by chance but introduced by an inaccuracy inherent to the system $\rightarrow$ systematic error

Momentum Correction

- Bethe-Bloch most probable energy loss for known material budget in channel

$$\Delta_p = \xi \left[\ln \frac{2mc^2\beta^2\gamma^2}{I} + \ln \frac{\xi}{I} + j - \beta^2 - \delta(\beta\gamma) \right] \tag{3}$$

where

$$\begin{aligned} \xi &= (K/2)\langle Z/A \rangle z^2 (x/B^2) \\ I &= \text{mean excitation energy} \\ j &= 0.2 \end{aligned} \tag{4}$$

- Tracks crossing the diffuser ring are cut