EMITTANCE MEASUREMENT PAPER

V. Blackmore, C. Hunt
CM 50
2nd March 2018

CONTENTS

- Go through paper plots
  - A lot of these havn't changed, but some have
- Then hand over to C. Hunt to talk about systematic errors on magnetic field models

- What're we looking at:
  - Run 7469
  - ISIS @ 700 MeV
  - SSU ECE coils at 4T fields, M1, M2 off
  - SSD all off
  - **Muon-mode** beam (low π-contamination compared to other analyses)
- Improvements made since last CM:
  - Analysis loop is beginning to shrink
  - Better track reconstruction (minimise Pt hole)
  - Same reconstruction in MC and data
  - Global tracking

THE ANALYSIS LOOP

Someone proposes something interesting

... different cuts?
... better tracker reconstruction?
... better MC agreement?
... convenient global tracking?

Distribution/selection changes

Make new “final” plots

... go through processing loops
... remember all the steps
... do mystic rain dance
... new plots appear

Should it have changed?

... sometimes “yes”
... sometimes “no”

THE ANALYSIS LOOP

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Someone proposes something interesting

~~… different cuts?~~
~~… better tracker reconstruction?~~
… better MC agreement?
~~… convenient global tracking?~~

Distribution/selection changes

Should it have changed?

Yes, and it did
… and in one case: No, but it still did.

CUTS/BEAM SELECTION

CUTS

Table 1: The number of particles that pass each selection criteria. A total of 24 645 particles pass all of the described cuts.

Cut	No. surviving particles
None	53 276
One space-point in TOF0 and TOF1	37 619
Time of flight in range 27—32 ns	36 357
Single reconstructed track with $\frac{\chi^2}{N_{\mathrm{DOF}}} \leq 4$	40 110
Track within fiducial volume of tracker	52 039
Tracked radius at diffuser $\leq$ 90 mm	42 584
Muon hypothesis	34 121
All	24 645

A worry? →

CUTS

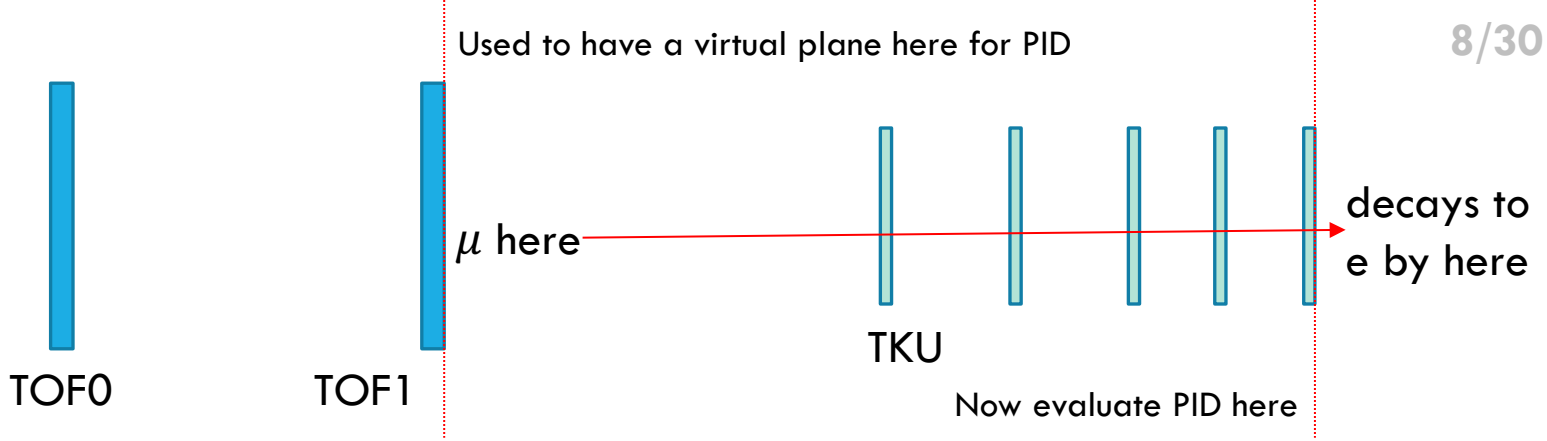
Table 2: The proportion of electrons, muons, and pions, at the upstream Tracker, that survive each cut in the Monte Carlo simulation. Application of all cuts removes all electrons and pions in the reconstructed Monte Carlo sample.

Cut	e	μ	π	Total
None	1 676	46 113	203	47 992
One space-point in TOF0 and TOF1	1275	37 574	151	40 015
Time of flight in range 27—32 ns	71	39 267	152	40 322
Single reconstructed track with $\frac{\chi^2}{N_{\mathrm{DOF}}} \leq 4$	1 205	43 824	163	45 194
Track within fiducial volume of tracker	1 641	43 903	175	45 719
Tracked radius at diffuser $\leq$ 90 mm	1 332	32 270	112	33 714
Muon hypothesis	298	38 285	40	38 630
All	0	26 414	0	26 414

← MC sample has 0.4% π

← Combination of cuts removes all MC contamination

CUTS



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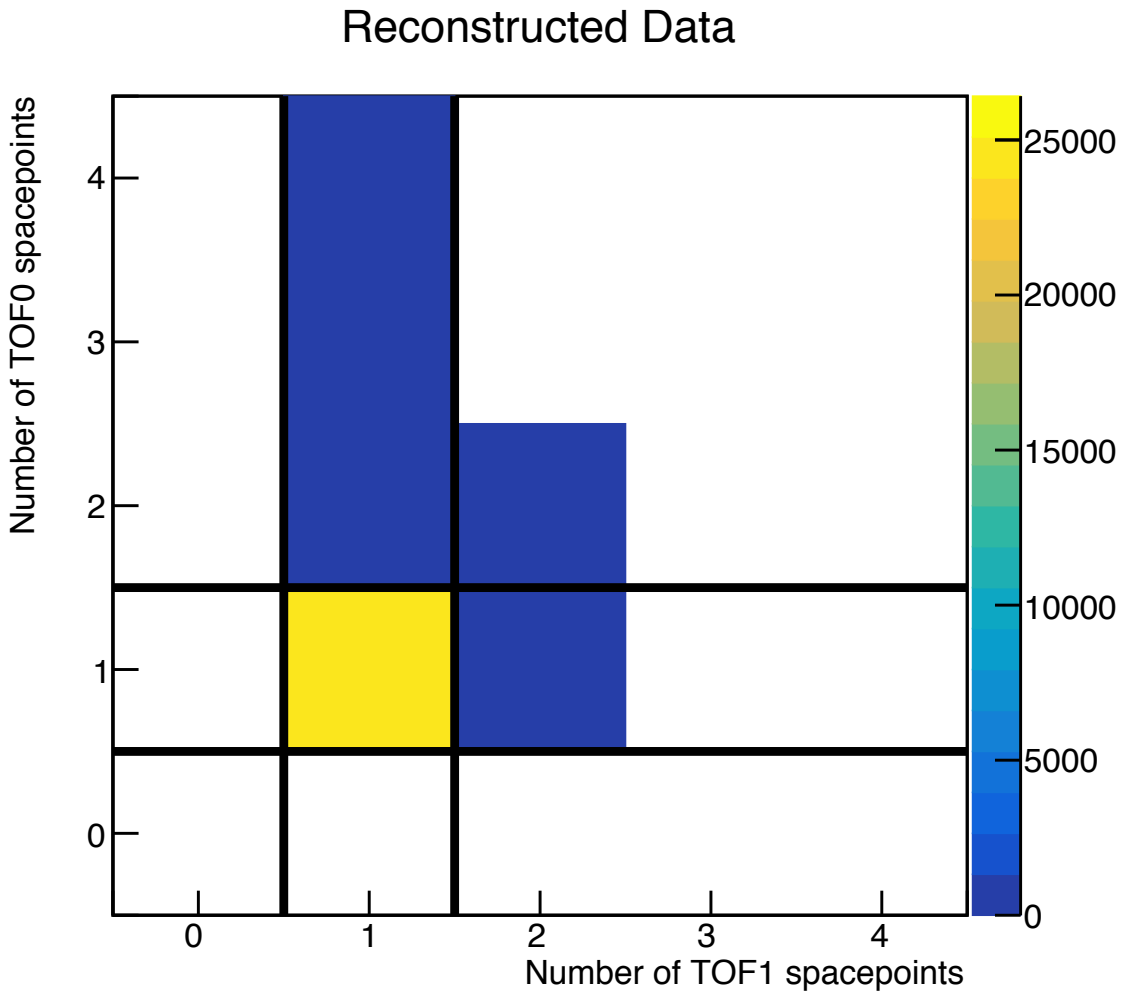
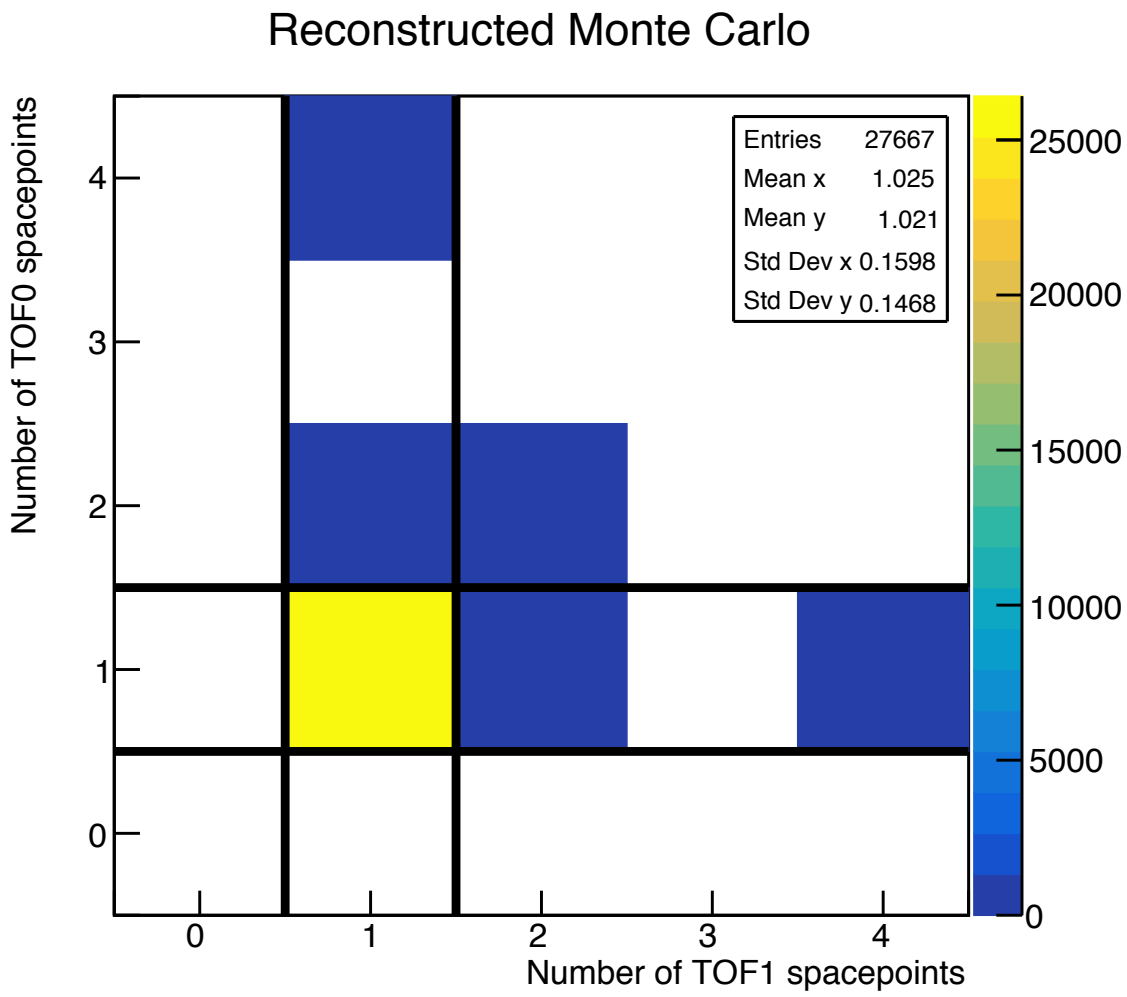
Plots are all cuts **except** the cut of interest

ONE SPACEPOINT AT TOF0 AND TOF1





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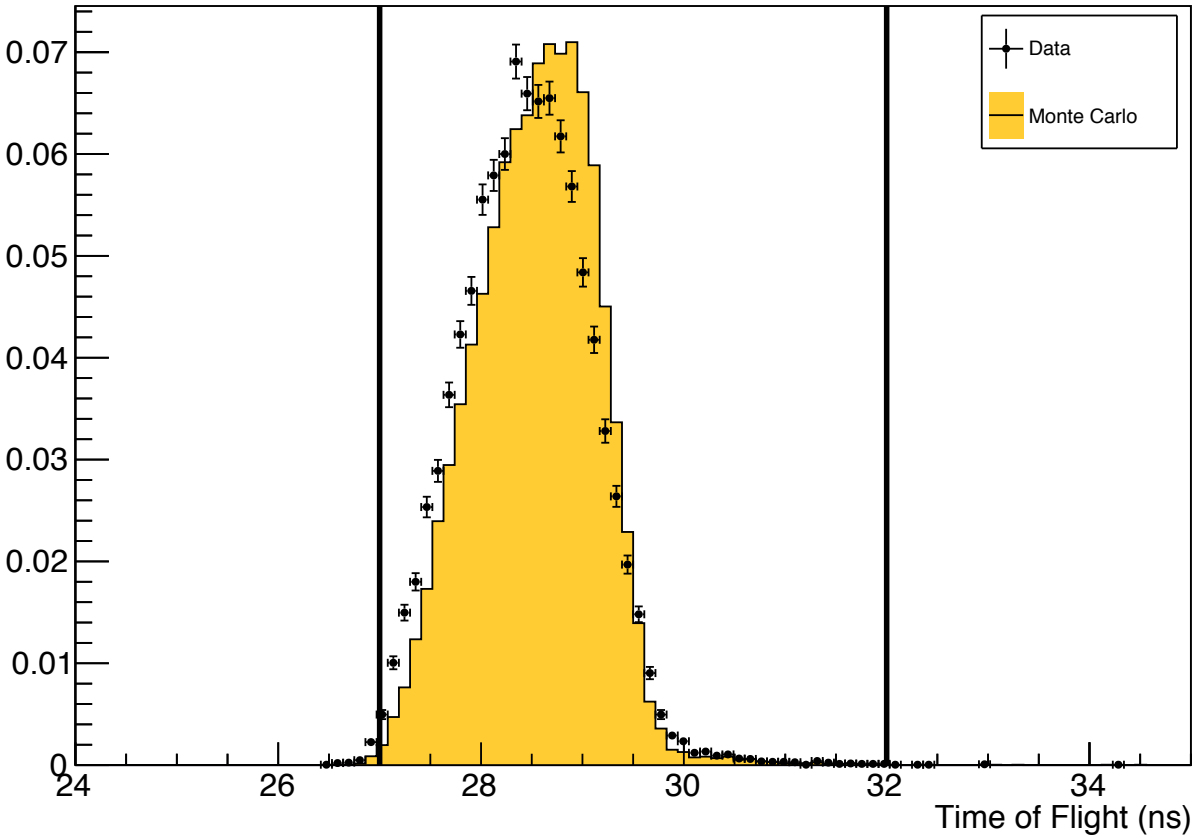
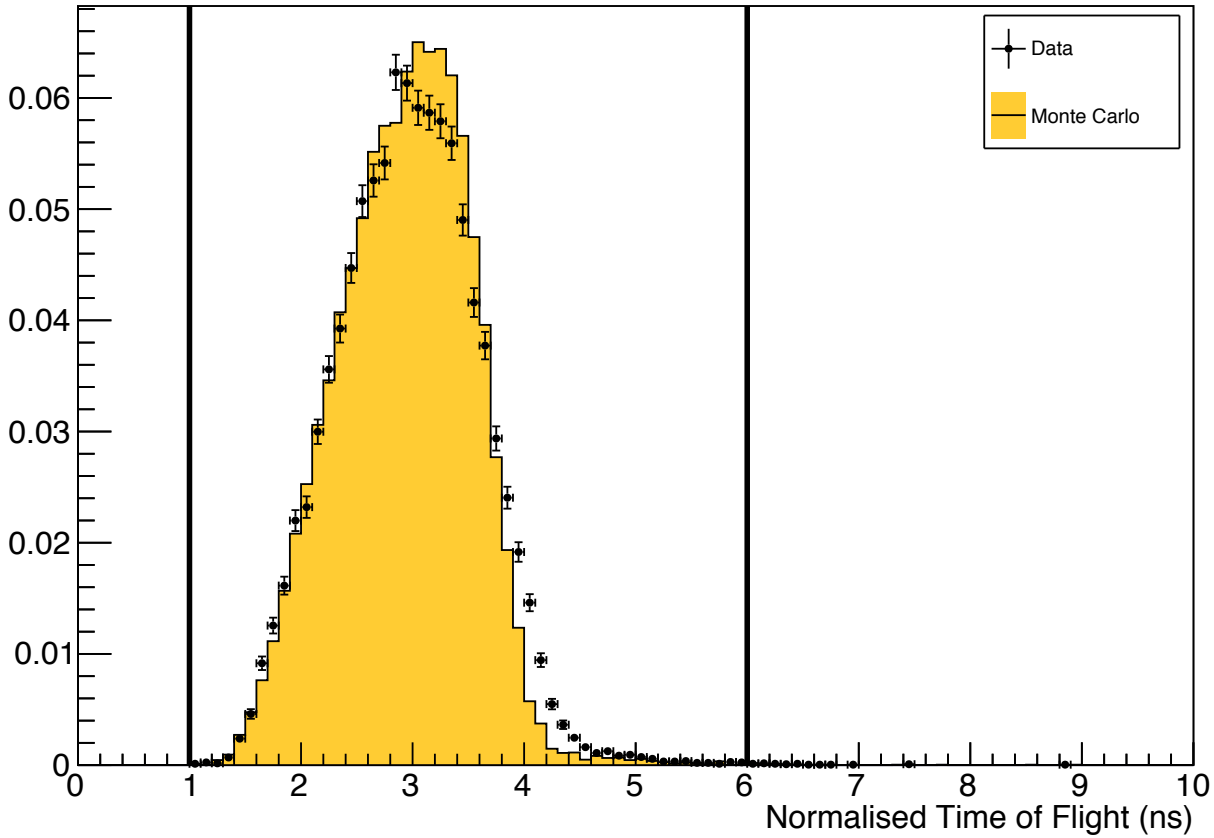
TIME OF FLIGHT ~ MUON

$$t_{\text{norm}} = t_{01} - t_e + \frac{(L+s)}{c}$$

electron tof from data

small path length correction: $L \sim 8\text{m}$, $s \sim 10\text{mm}$





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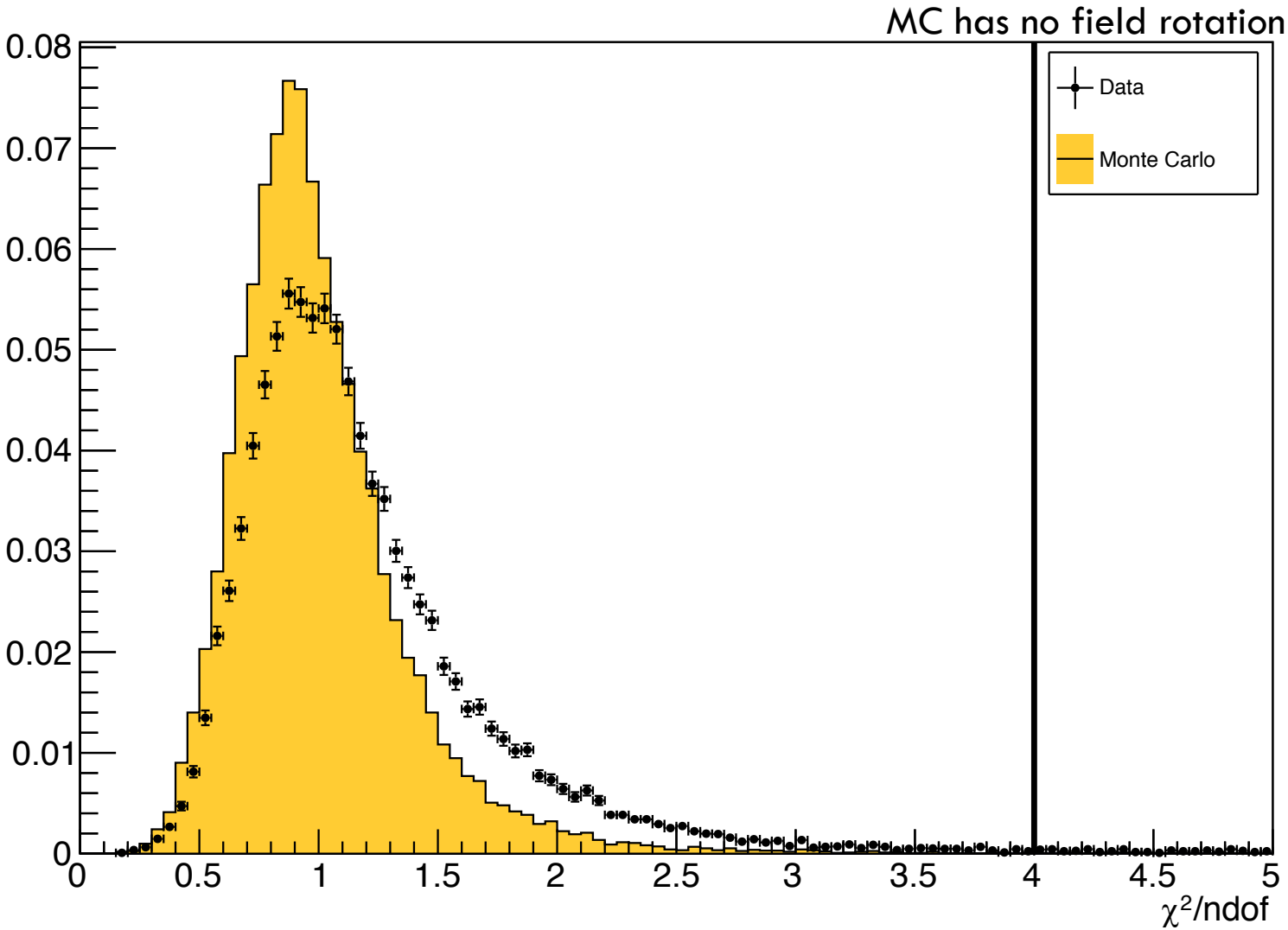
CHI-SQUARE

Agreement gets worse if field in MC is rotated

C. Rogers suggested could be insufficient noise in MC?



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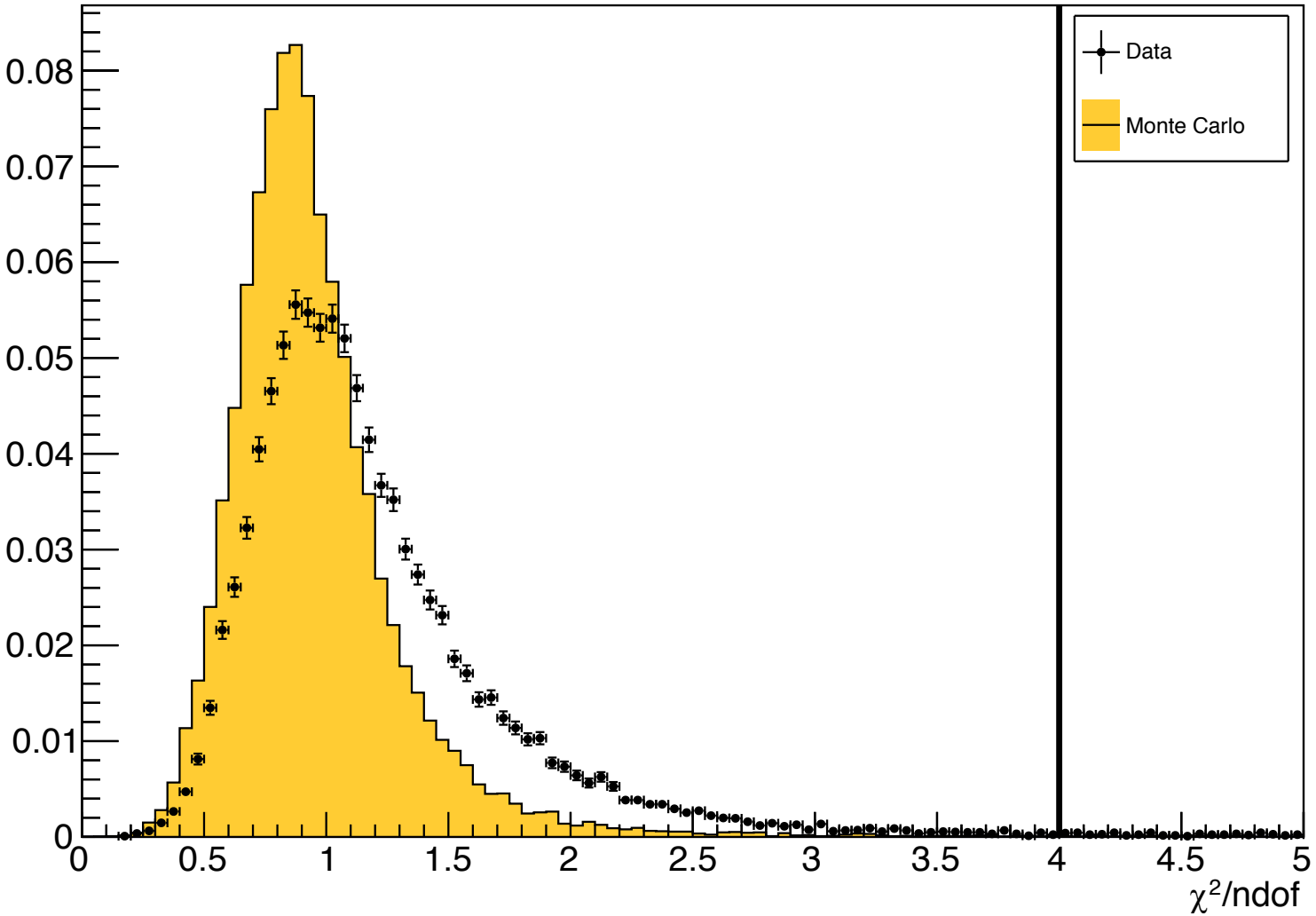
CHI-SQUARE

MC has 'aligned' field



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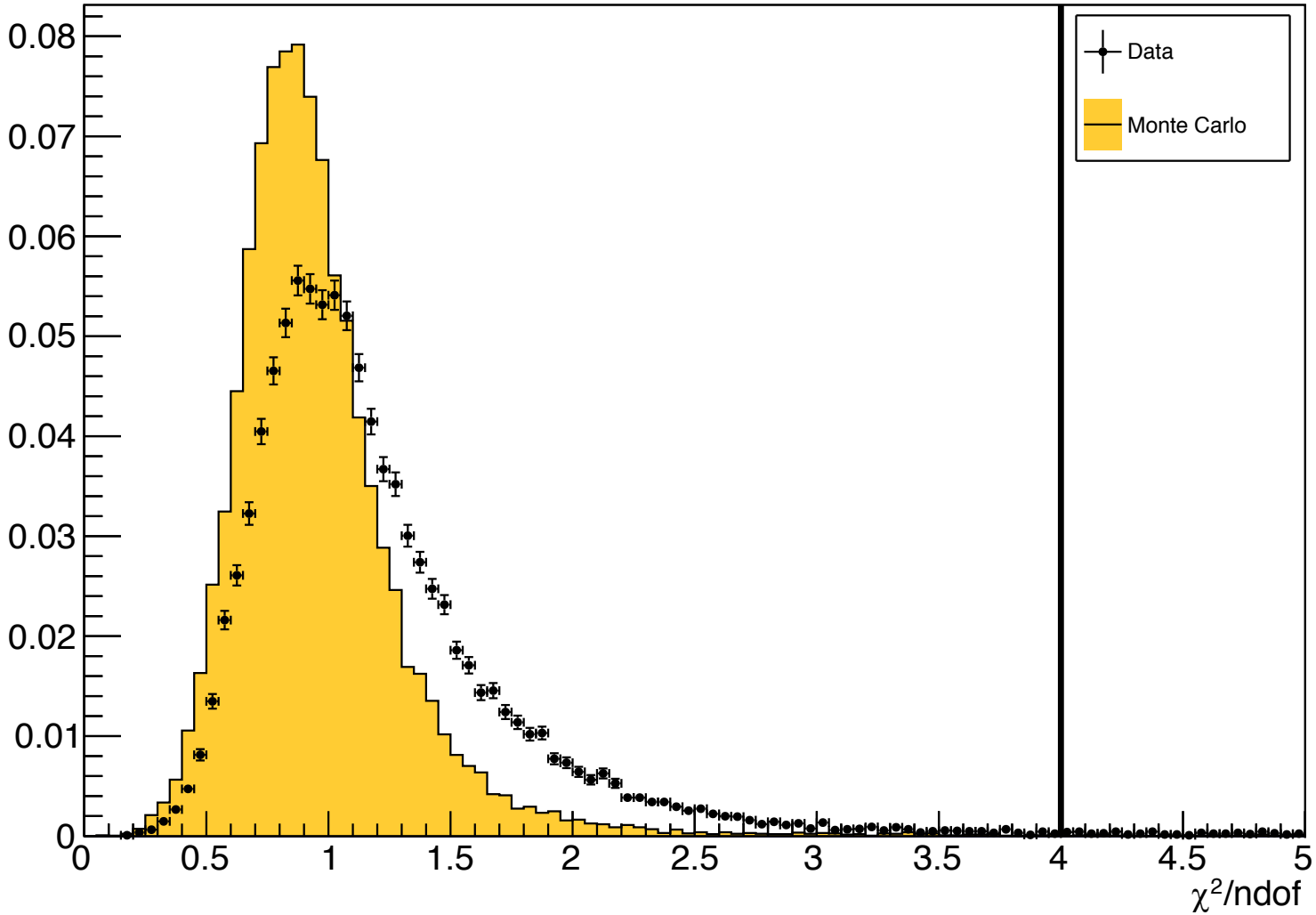
CHI-SQUARE

MC has 'aligned + 1sigma' field



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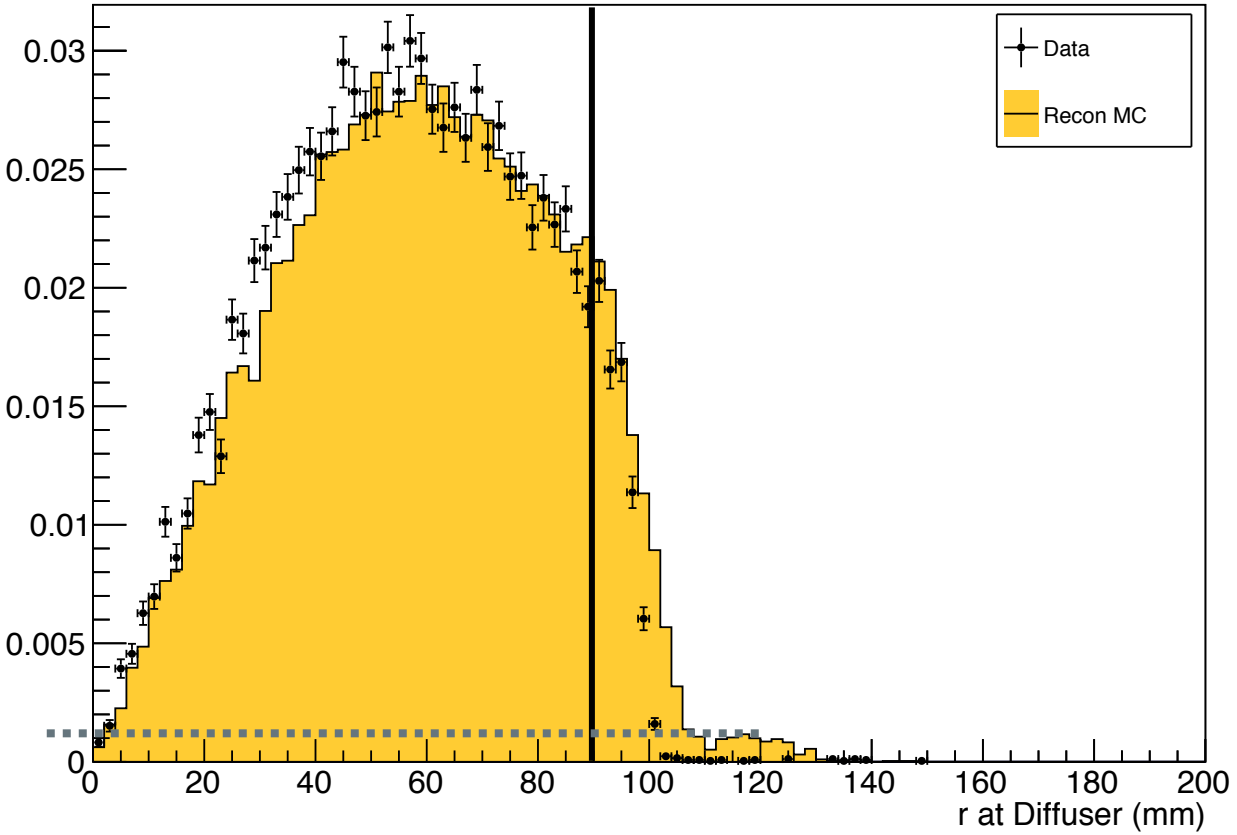
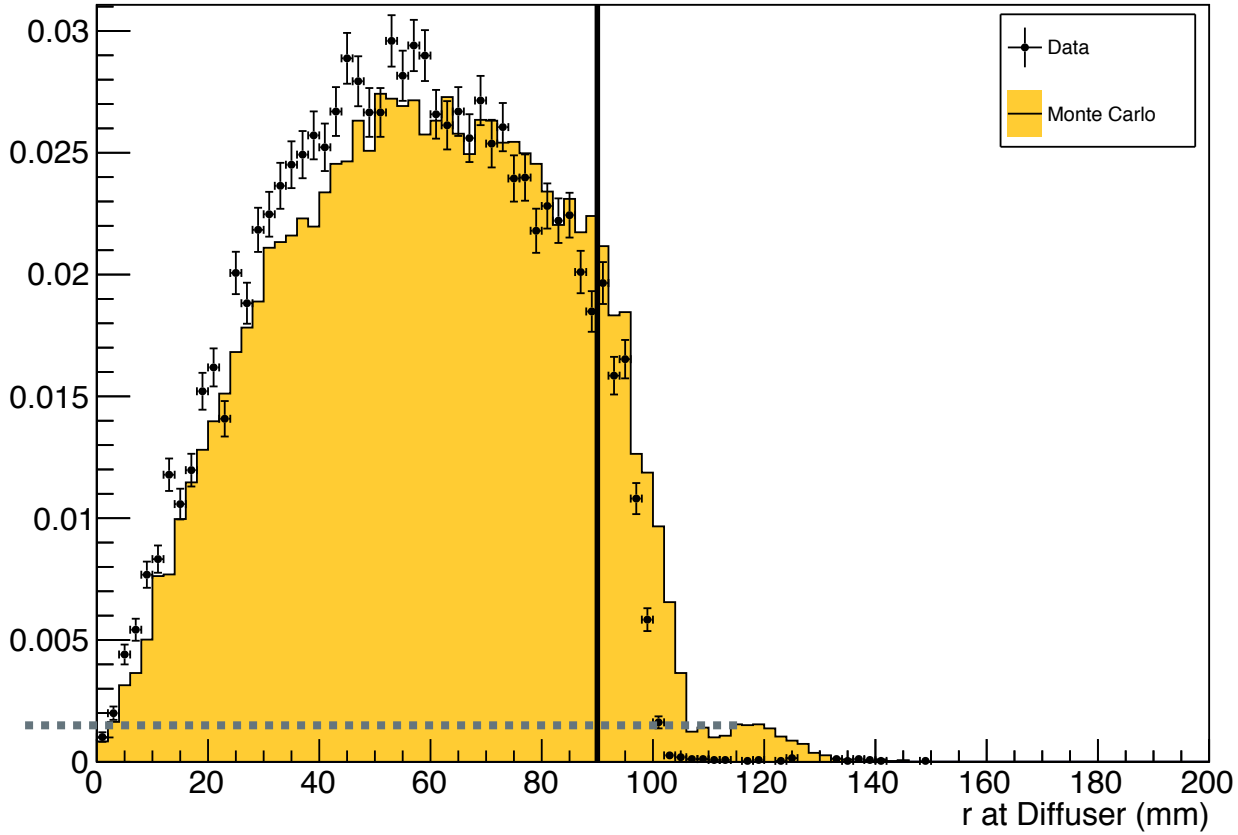
DIFFUSER CUT

MAUS 3.0



MAUS 3.1

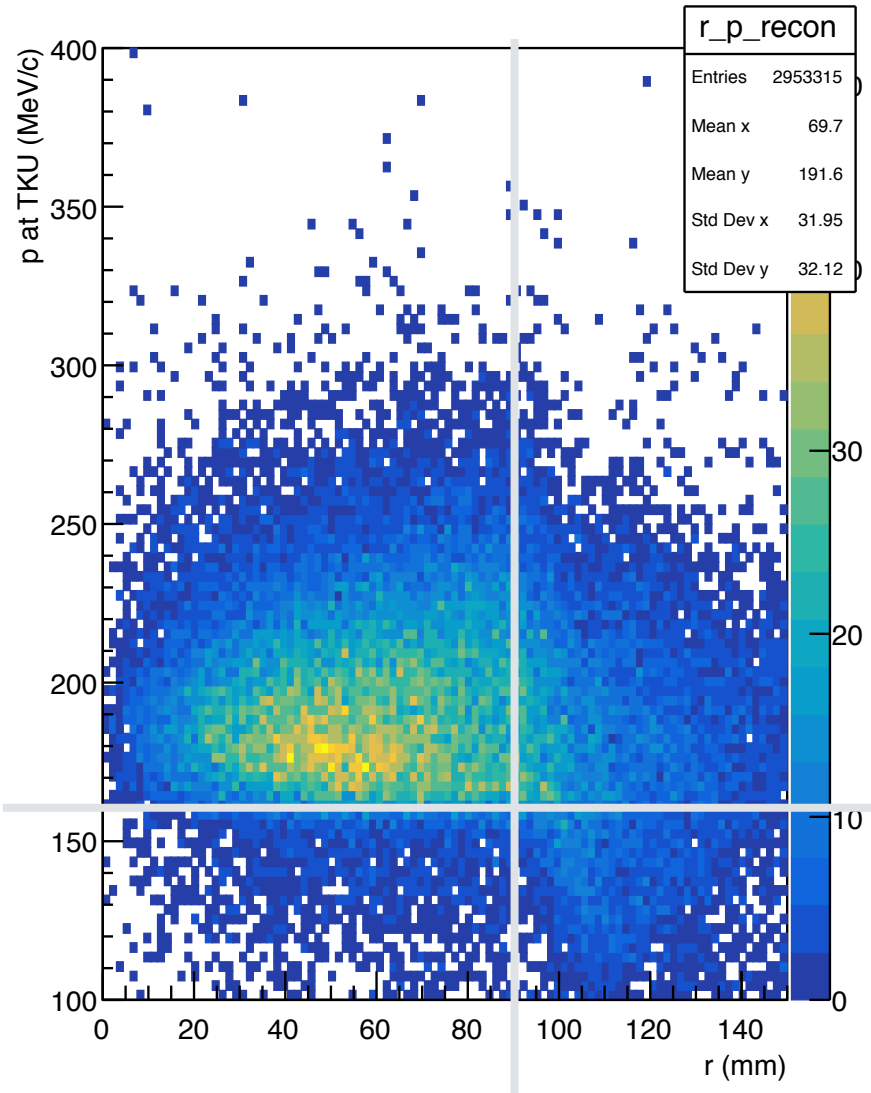


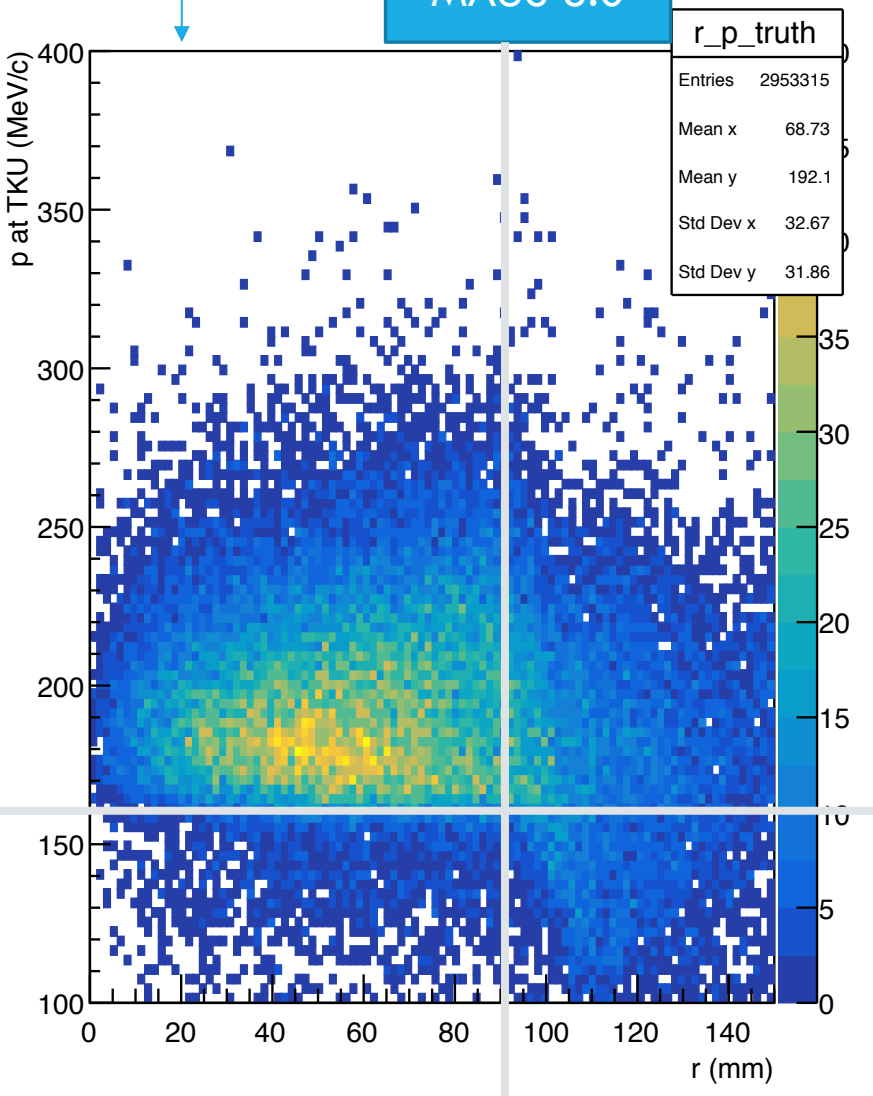
DIFFUSER CUT

- Explanations?
  - Diffuser geometry hasn't changed...?
  - Input distribution hasn't changed
  - Track fitting routine **has** changed
    - But shouldn't change the **truth.**
  - Plots are **without cuts**
  - MAUS 3.1and 3.0 MC's
  - P at TKU ref plane
  - r at d/s side of diffuser
    - Tracked w/ globals
    - Truth at virtual plane

Why does MC truth change?

MAUS 3.0





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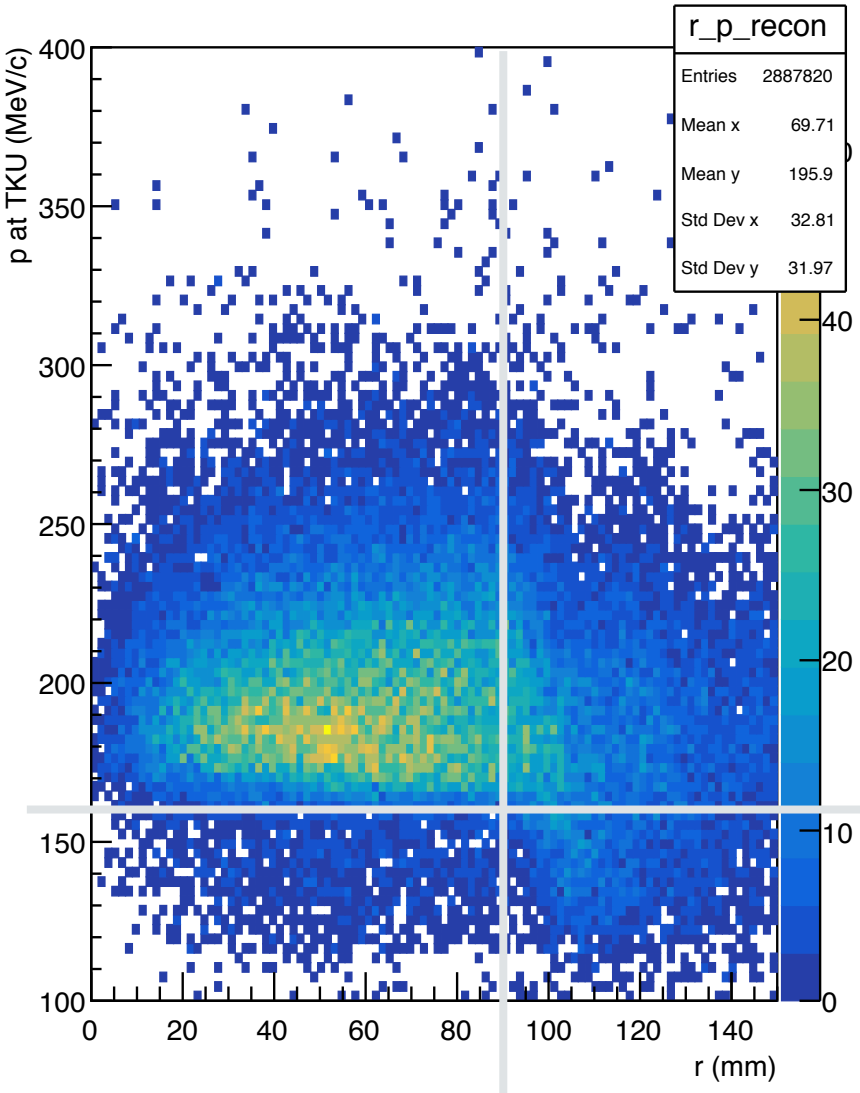
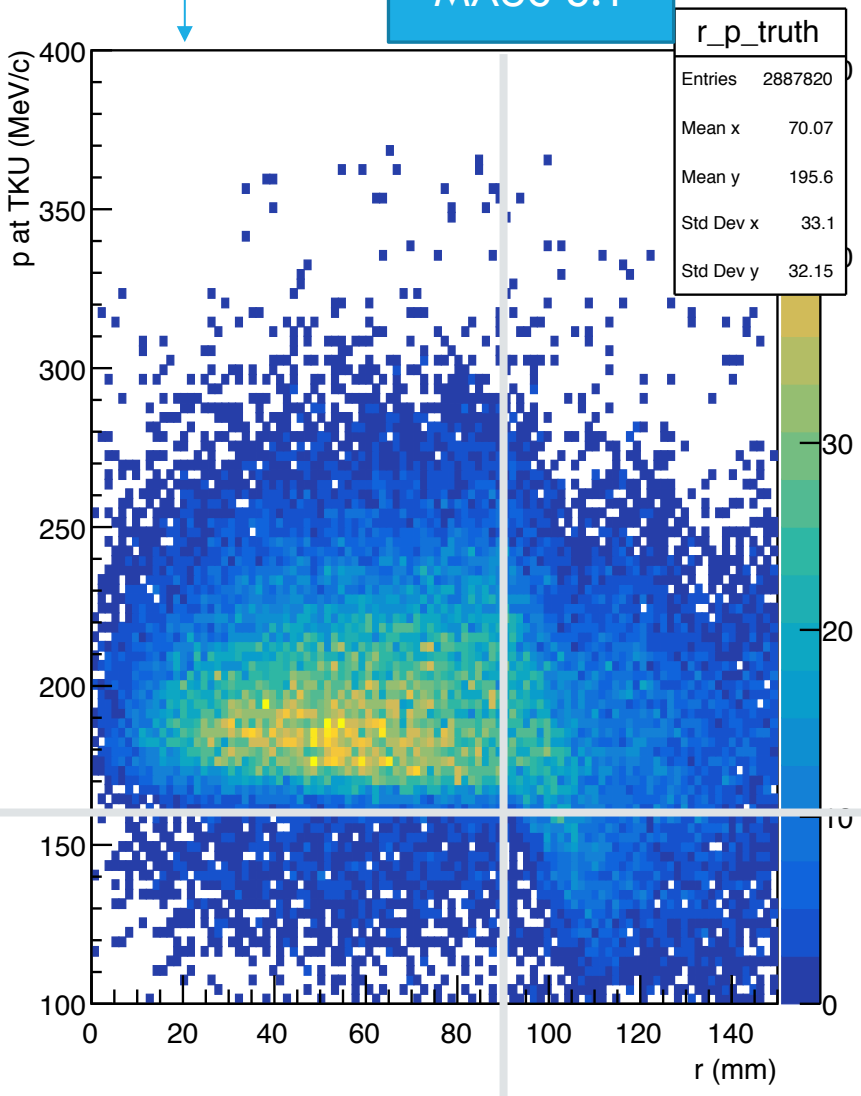
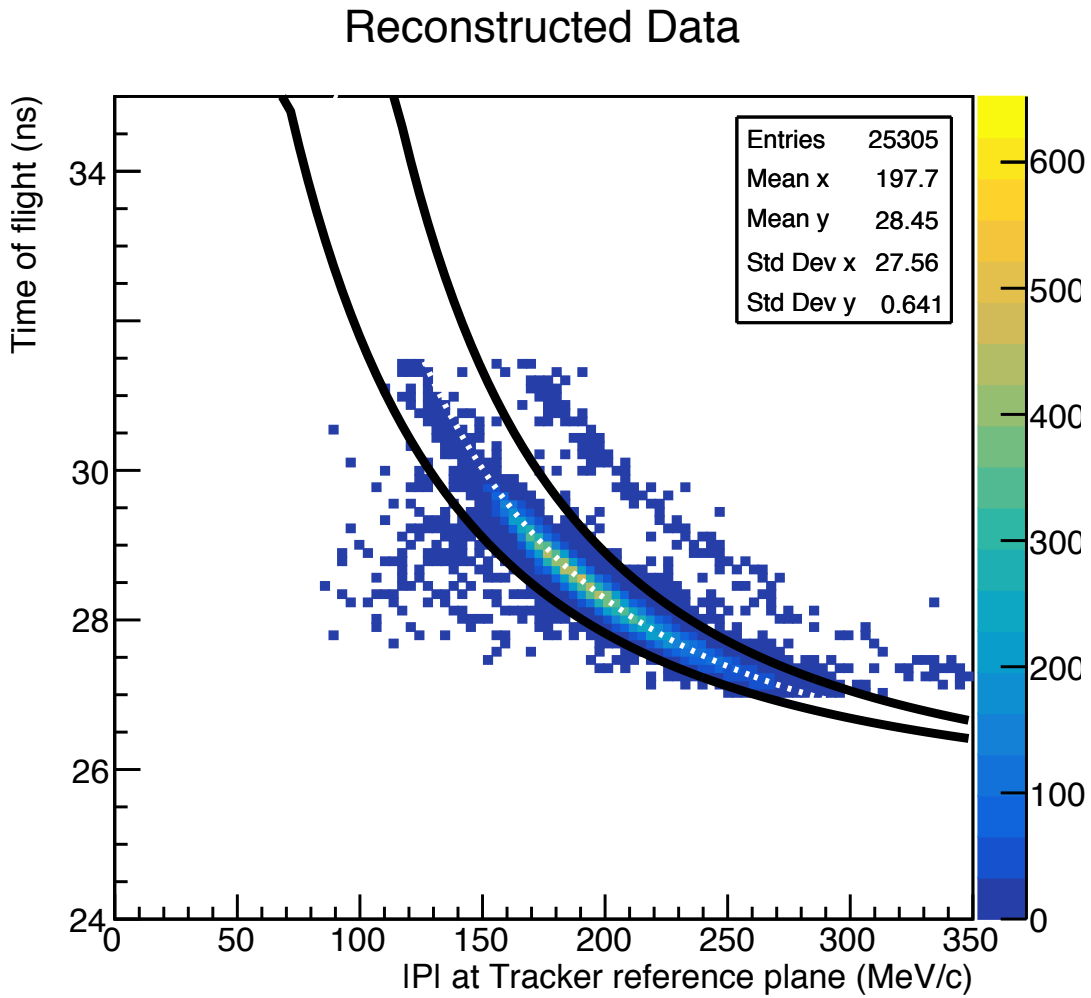
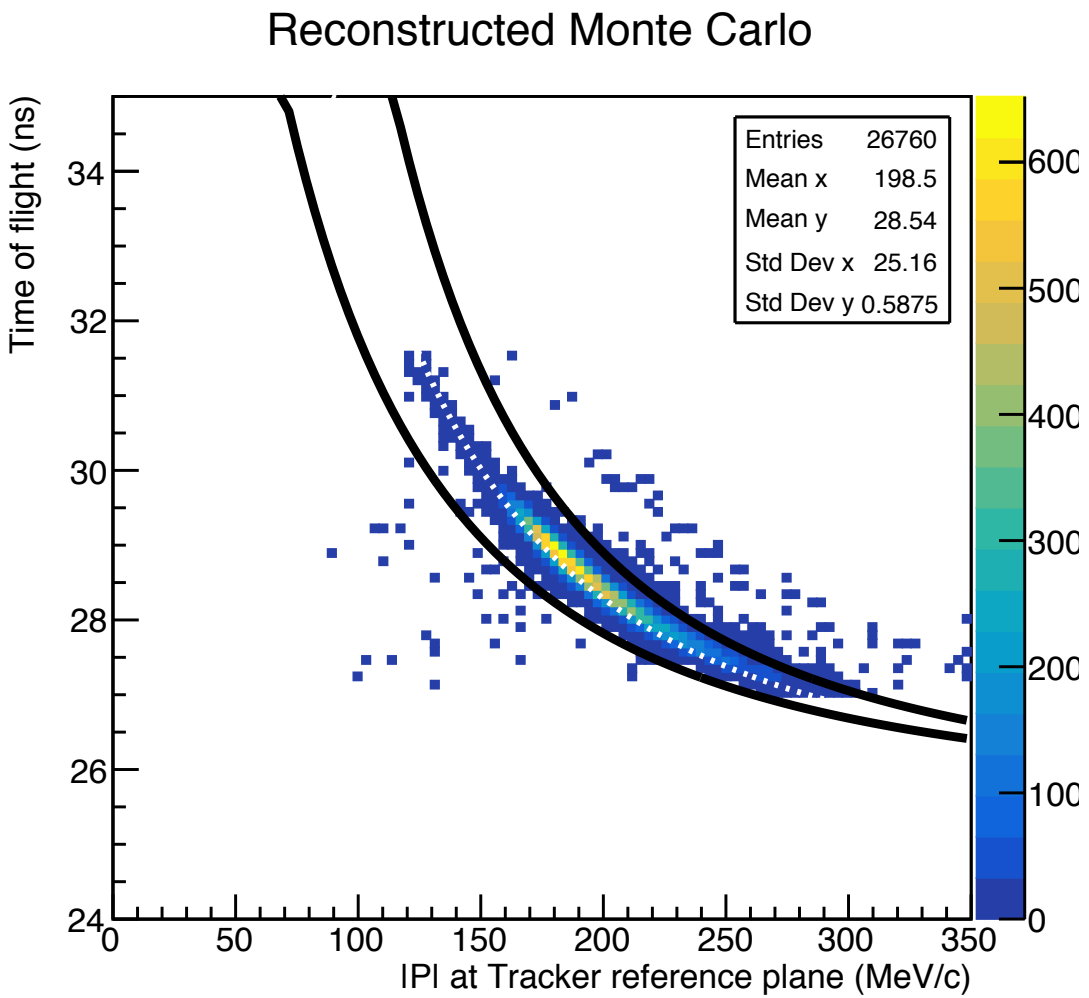
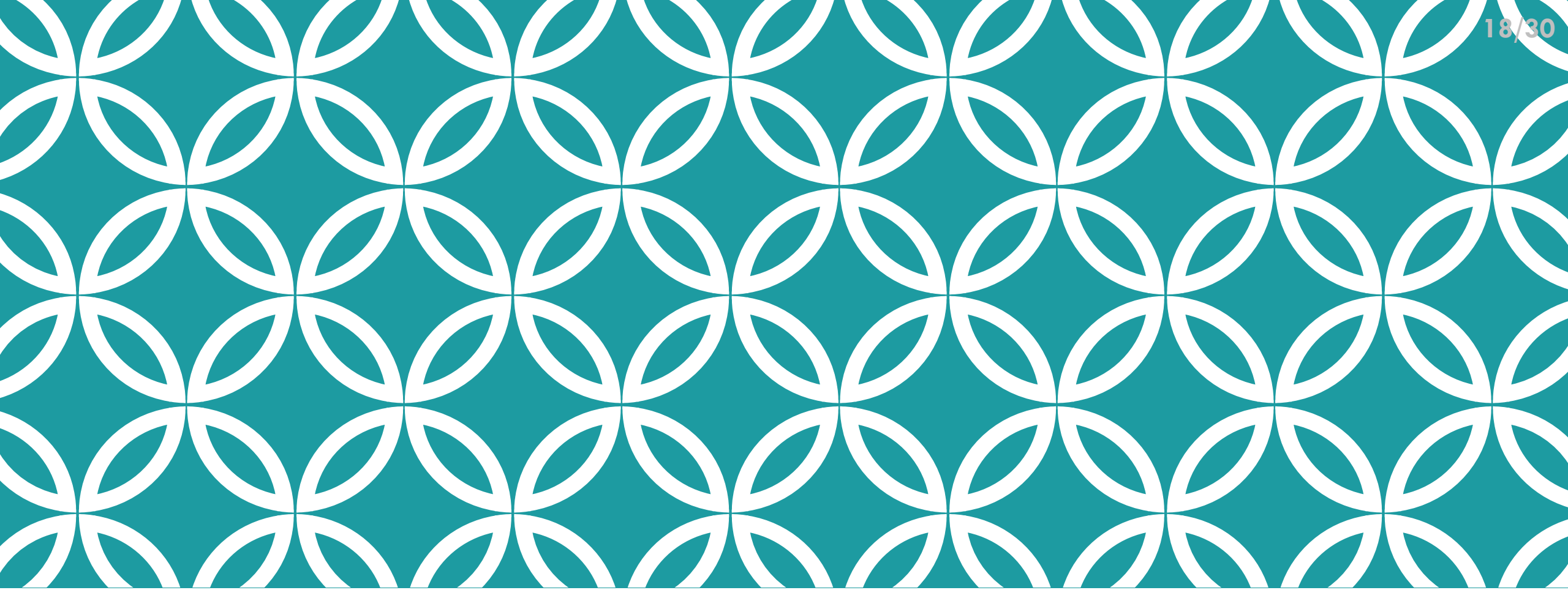




MUON HYPOTHESIS



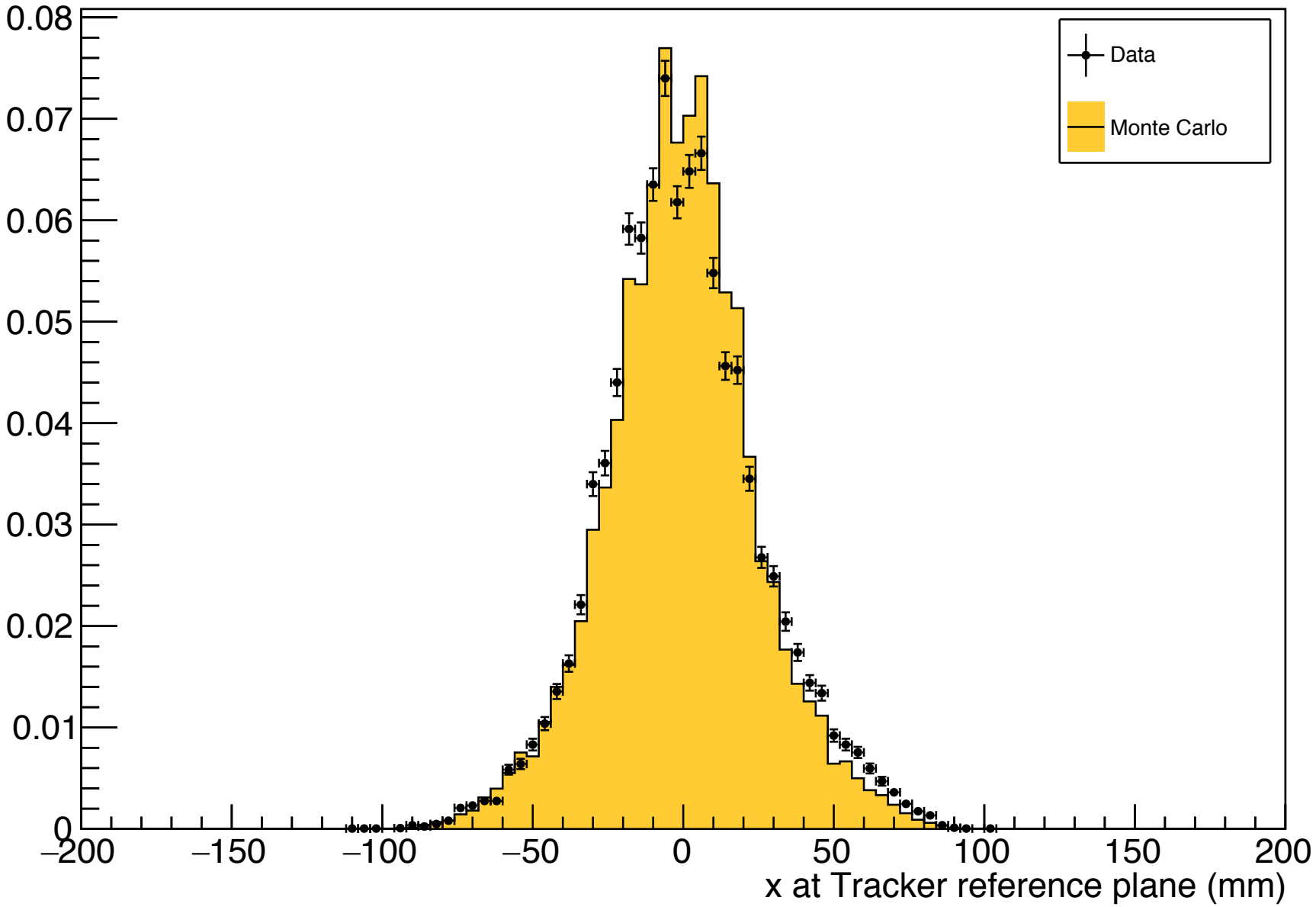




1D SELECTED DISTRIBUTIONS

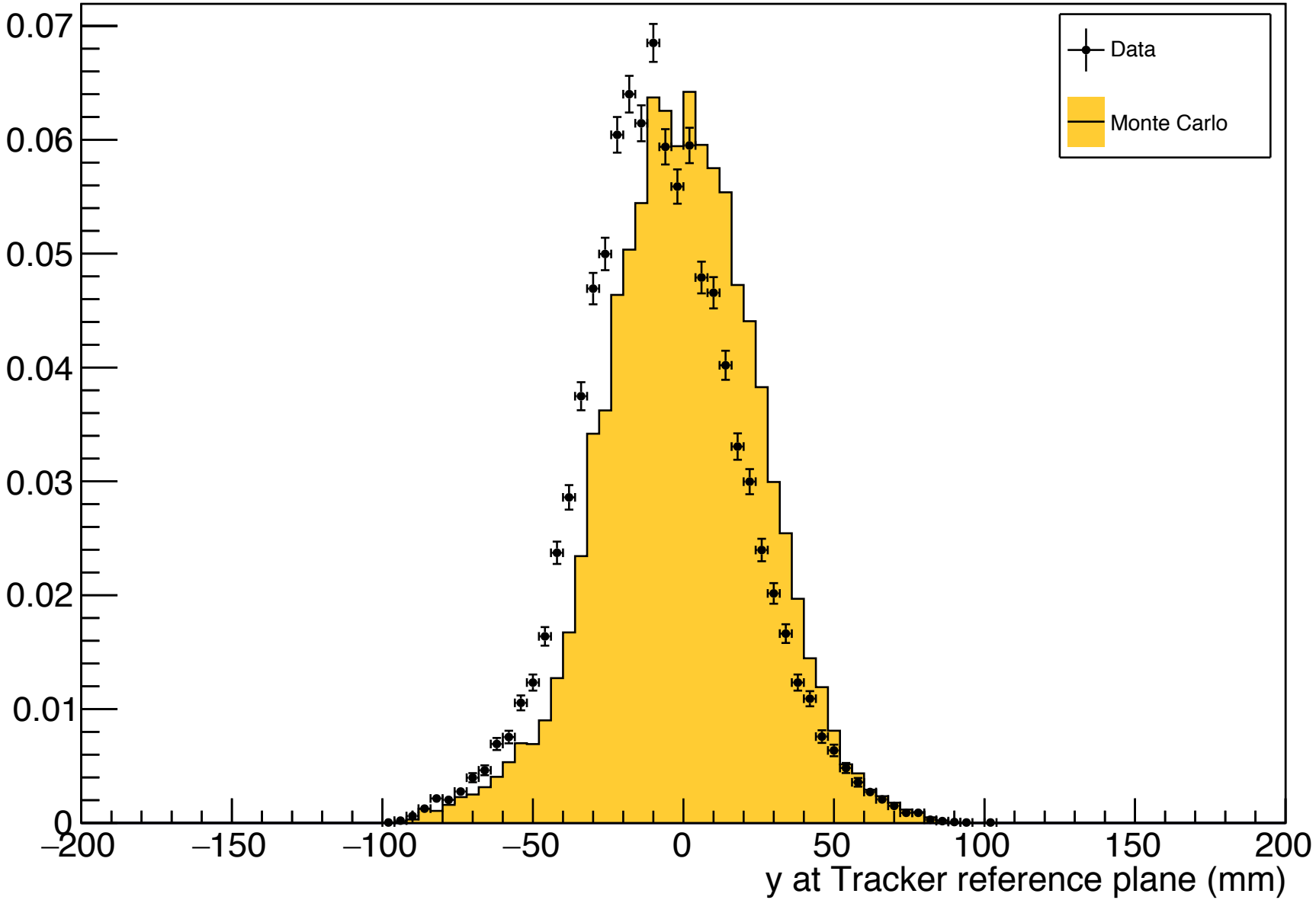
All cuts have been applied to these plots

X



All cuts have been applied to these plots

Y



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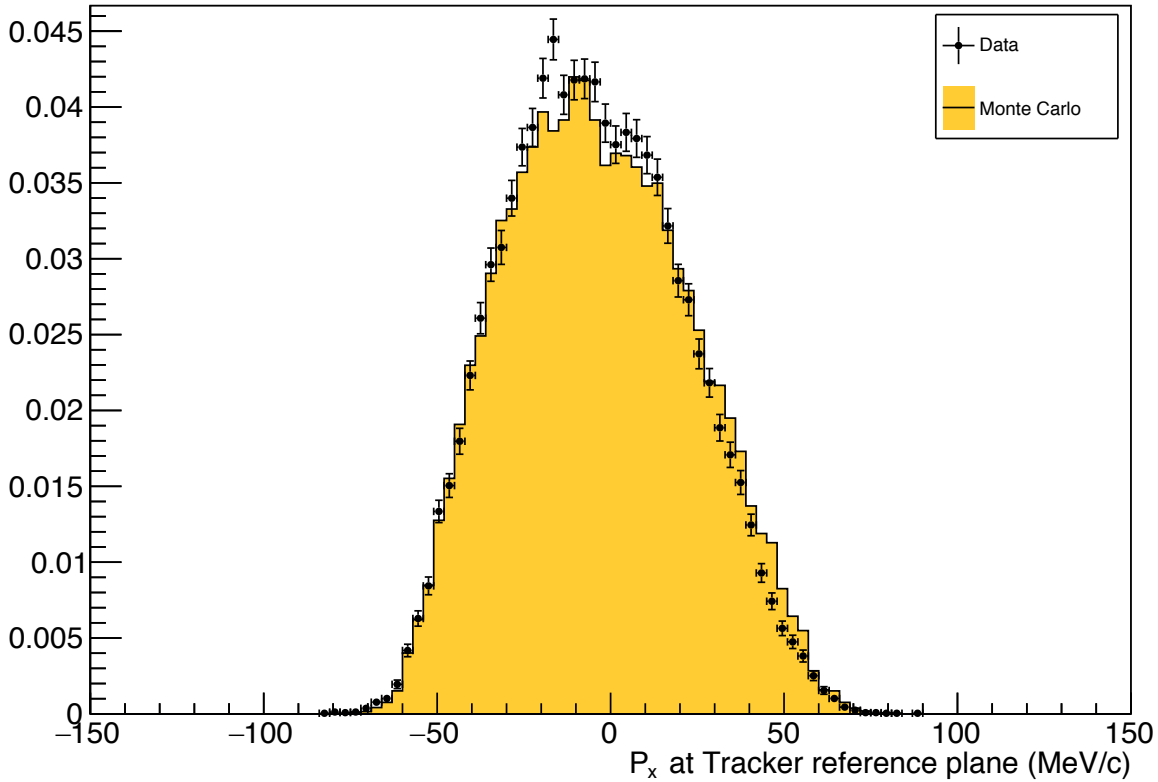
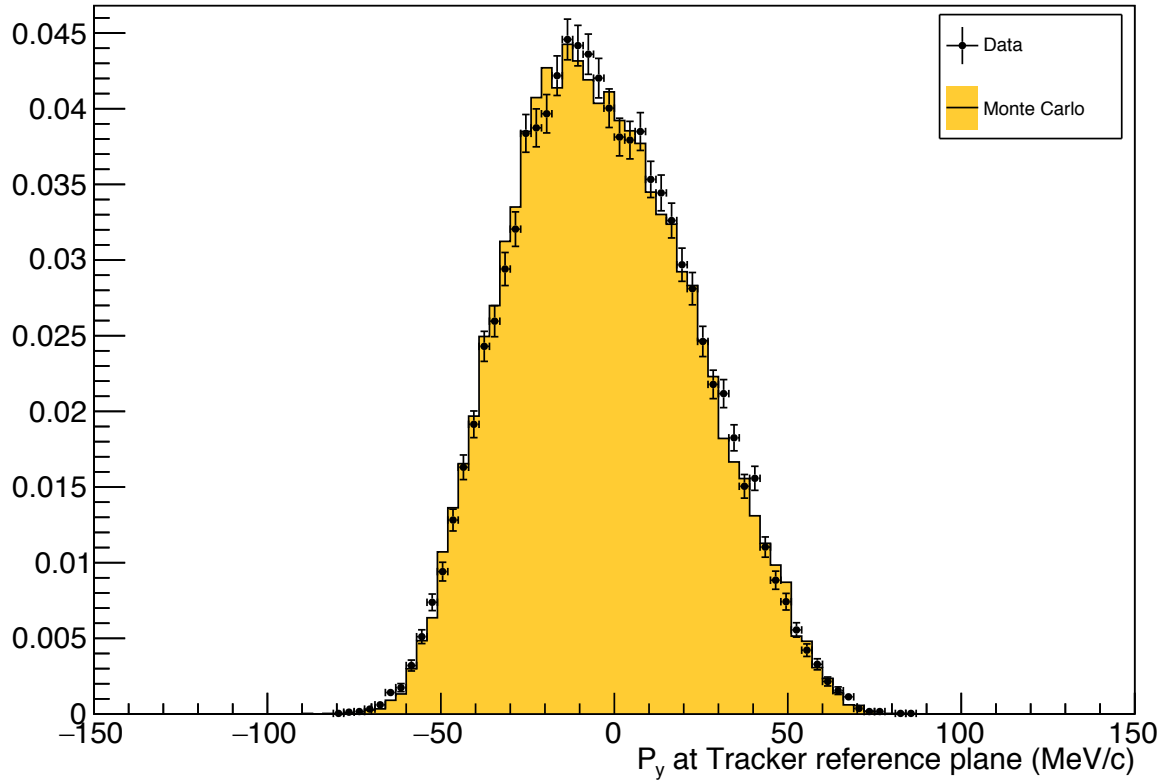
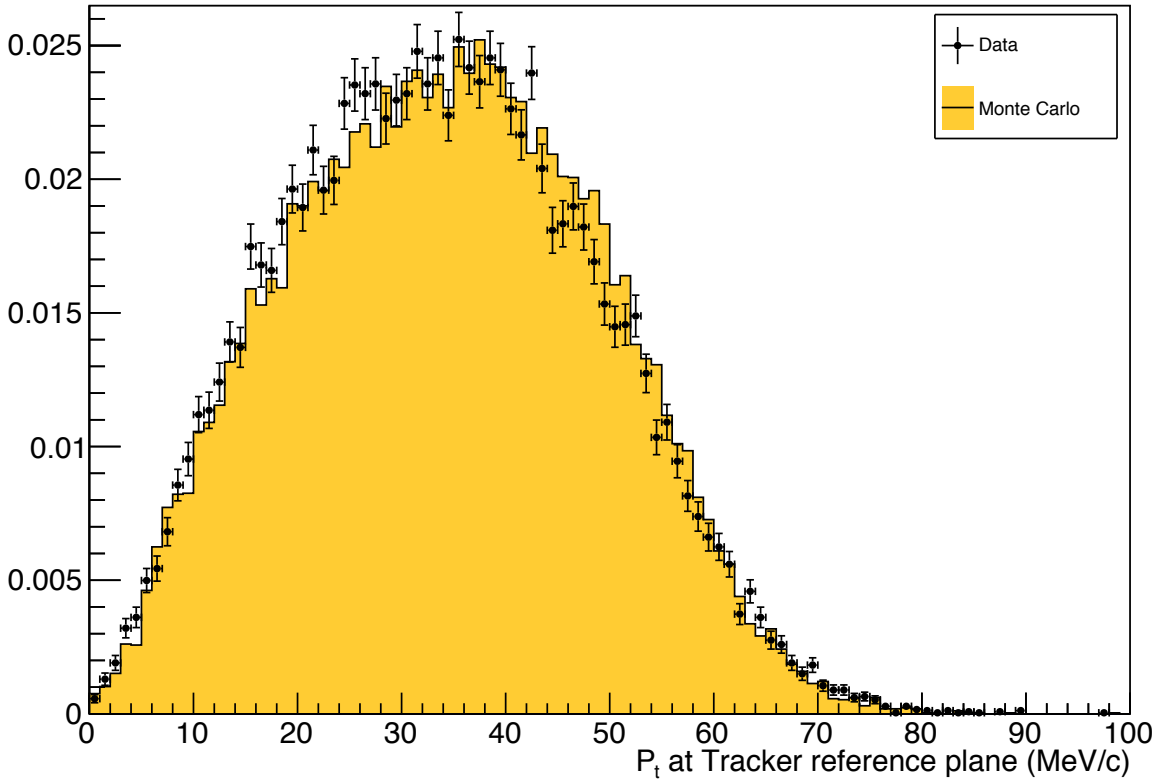
PX, PY

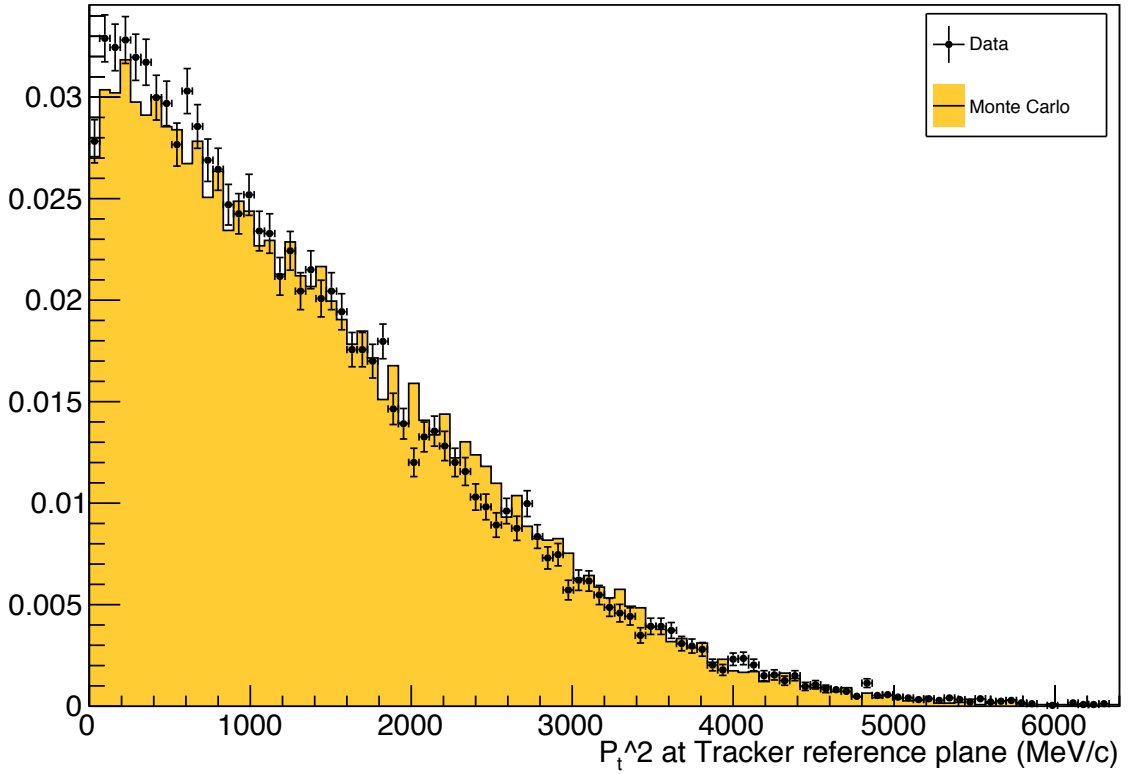




All cuts have been applied to these plots

PT, PT^2





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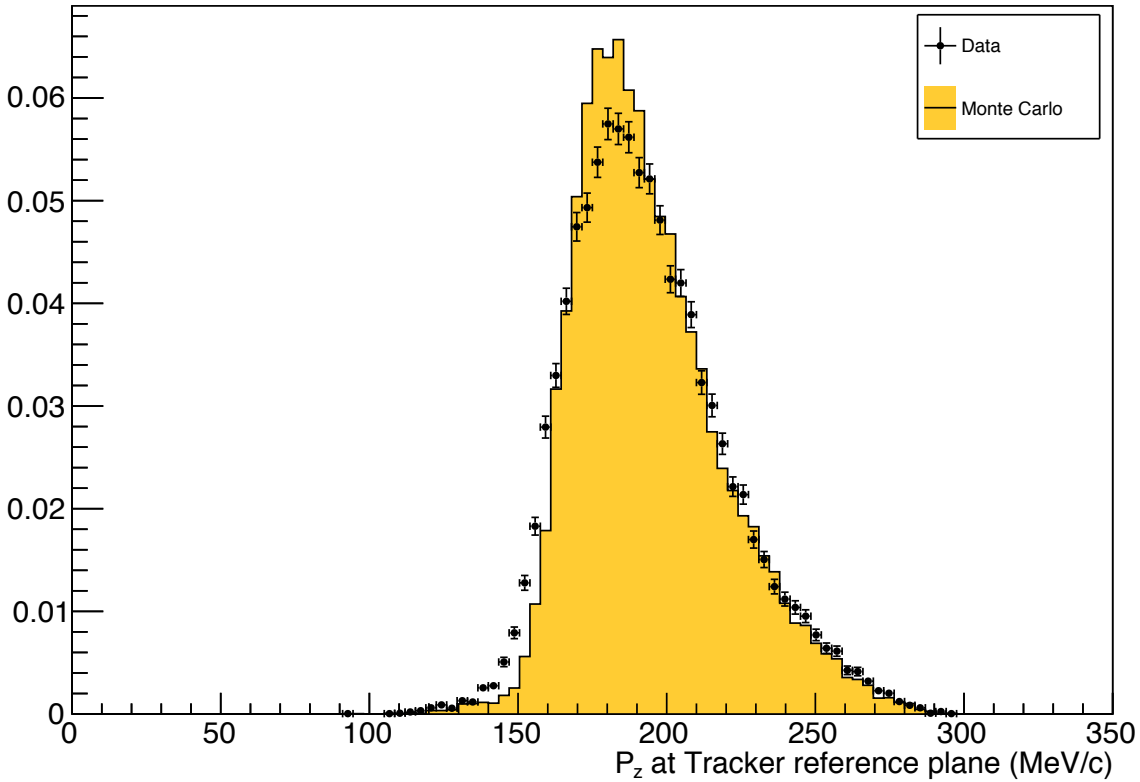
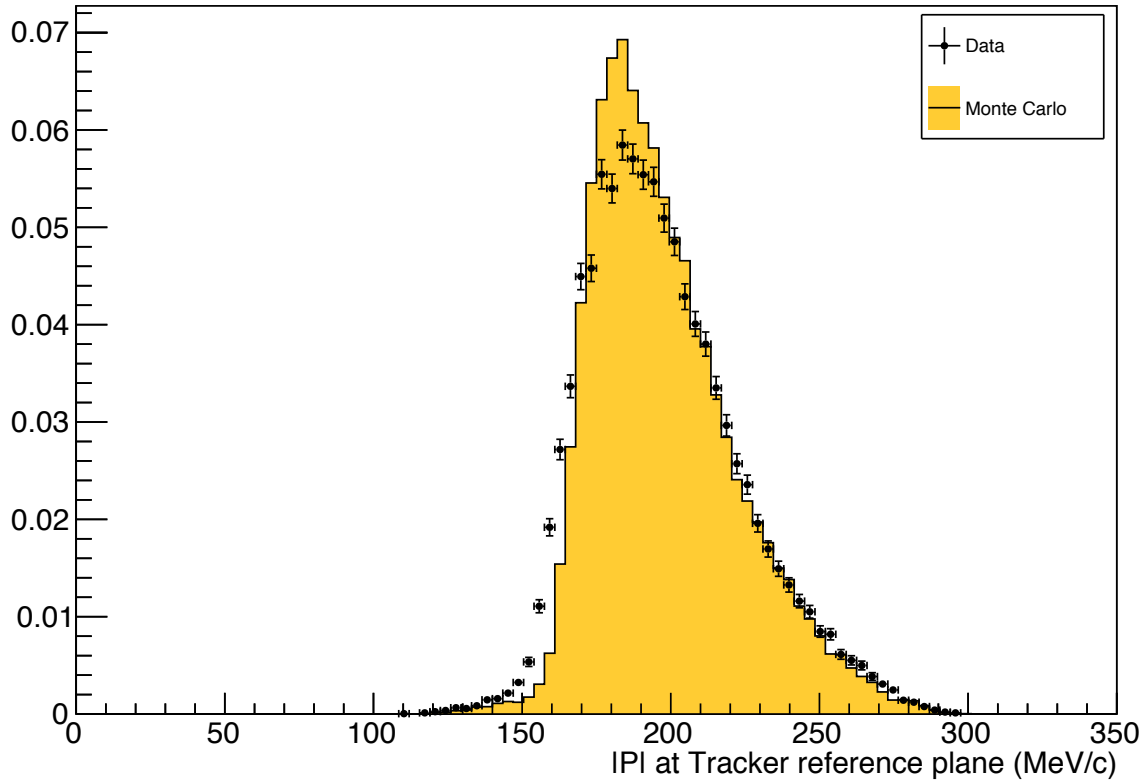
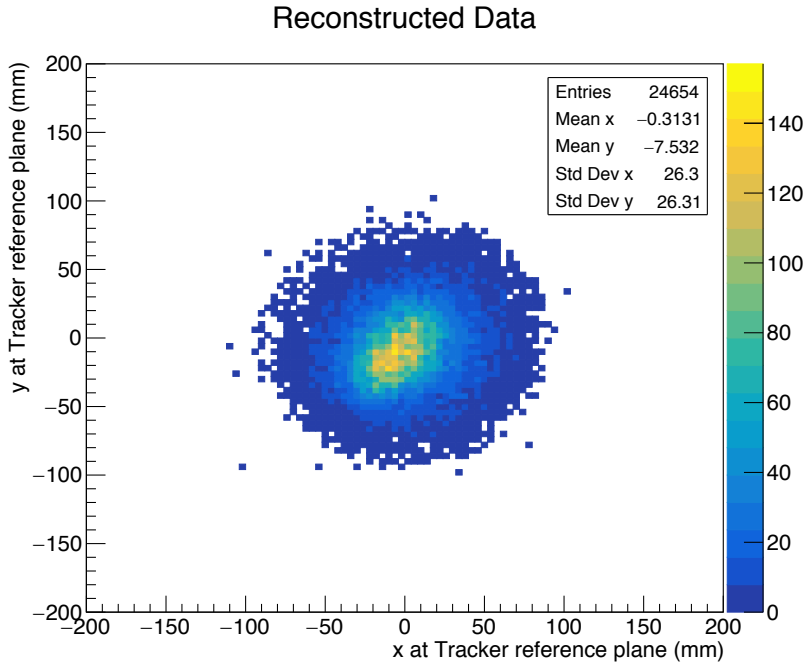
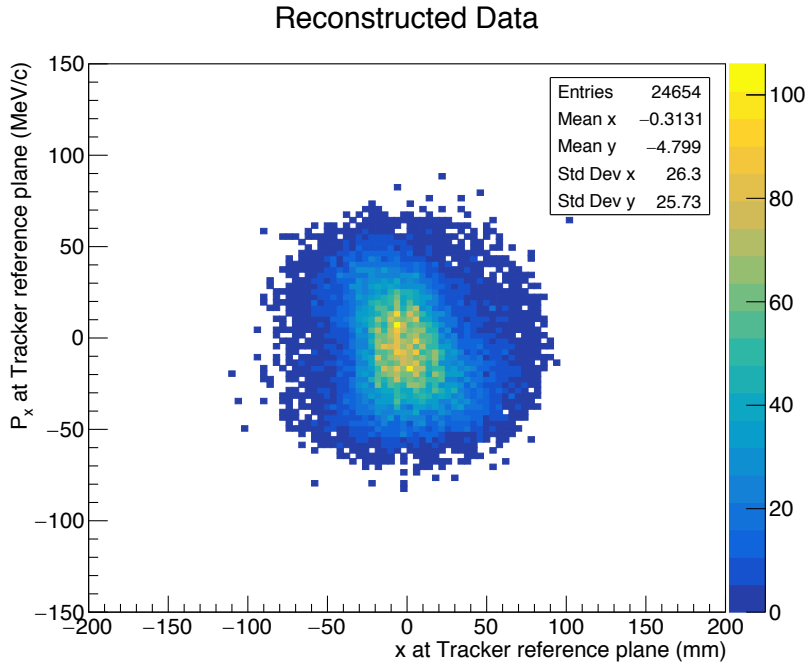
PZ, |P|





PHASE SPACE PROJECTIONS


Reconstructed Data
Entries 24654
Mean x −0.3131
Mean y −7.532
Std Dev x 26.3
Std Dev y 26.31
y at Tracker reference plane (mm)
x at Tracker reference plane (mm)


Reconstructed Data
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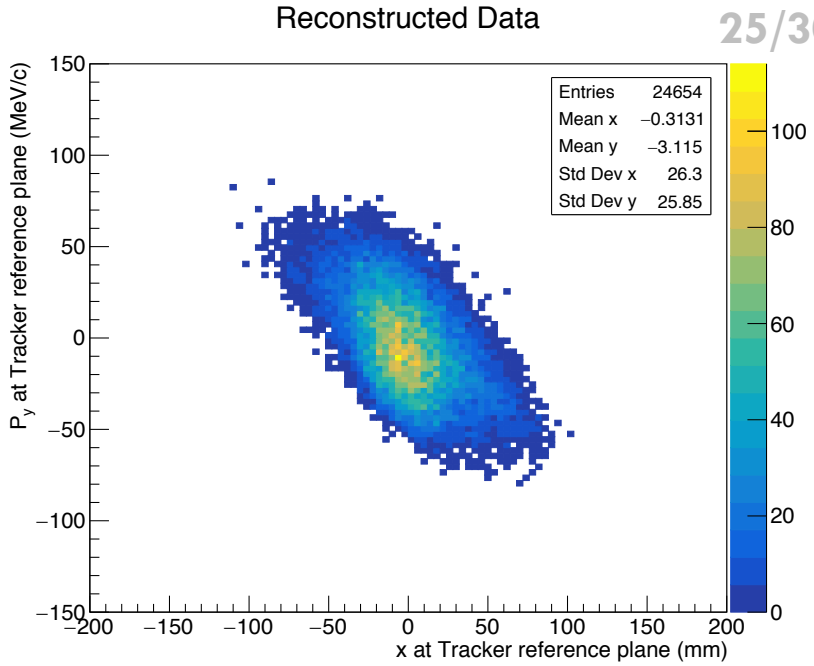
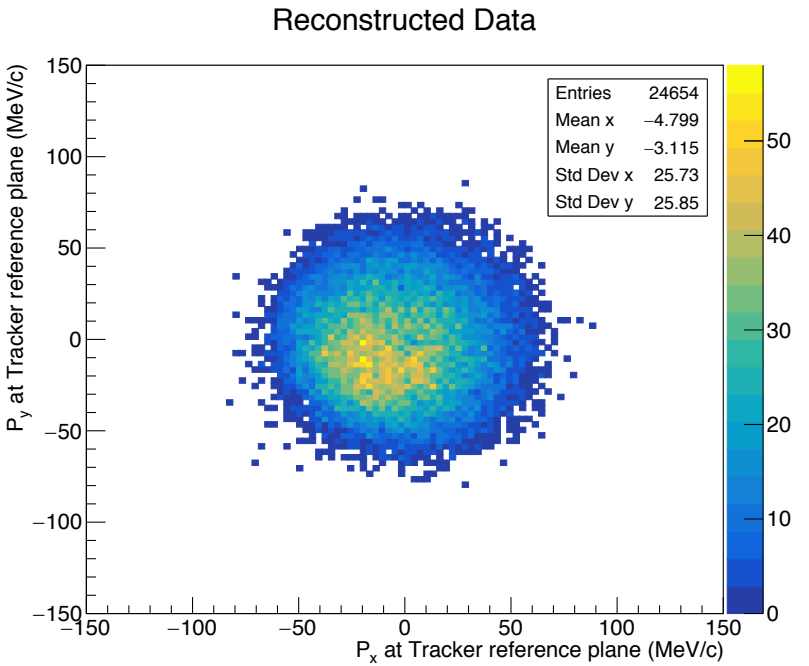
Mean x −0.3131
Mean y −4.799
Std Dev x 26.3
Std Dev y 25.73
P_x at Tracker reference plane (MeV/c)
x at Tracker reference plane (mm)


Reconstructed Data
Entries 24654
Mean x −0.3131
Mean y −3.115
Std Dev x 26.3
Std Dev y 25.85
P_y at Tracker reference plane (MeV/c)
x at Tracker reference plane (mm)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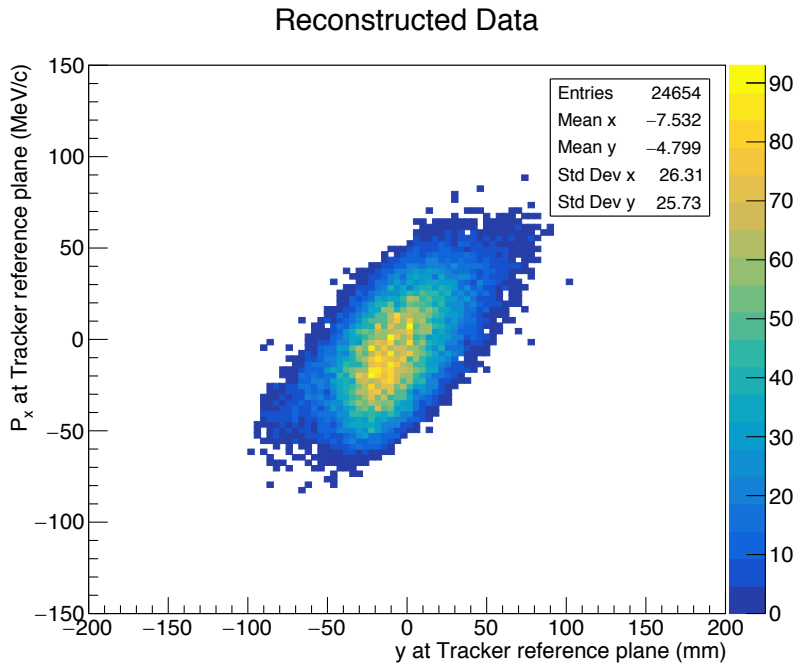
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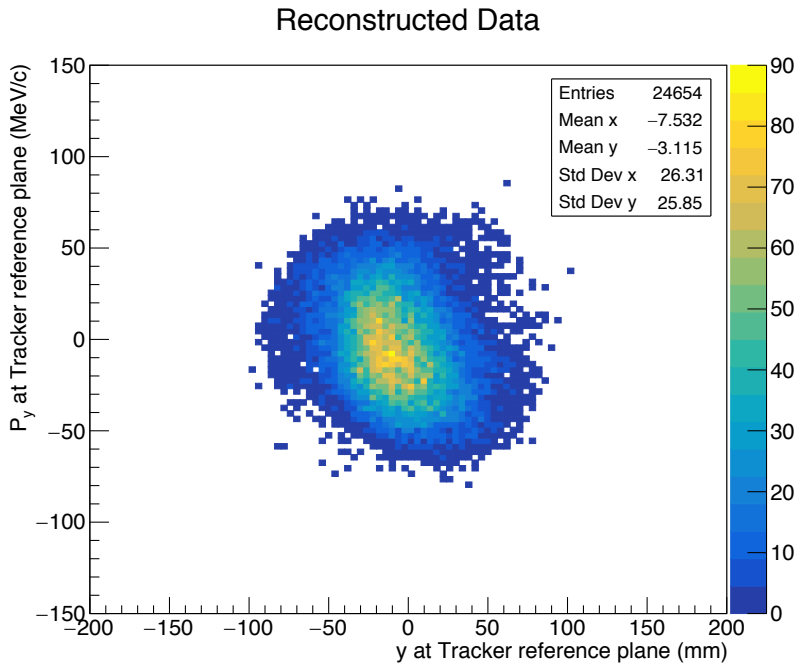
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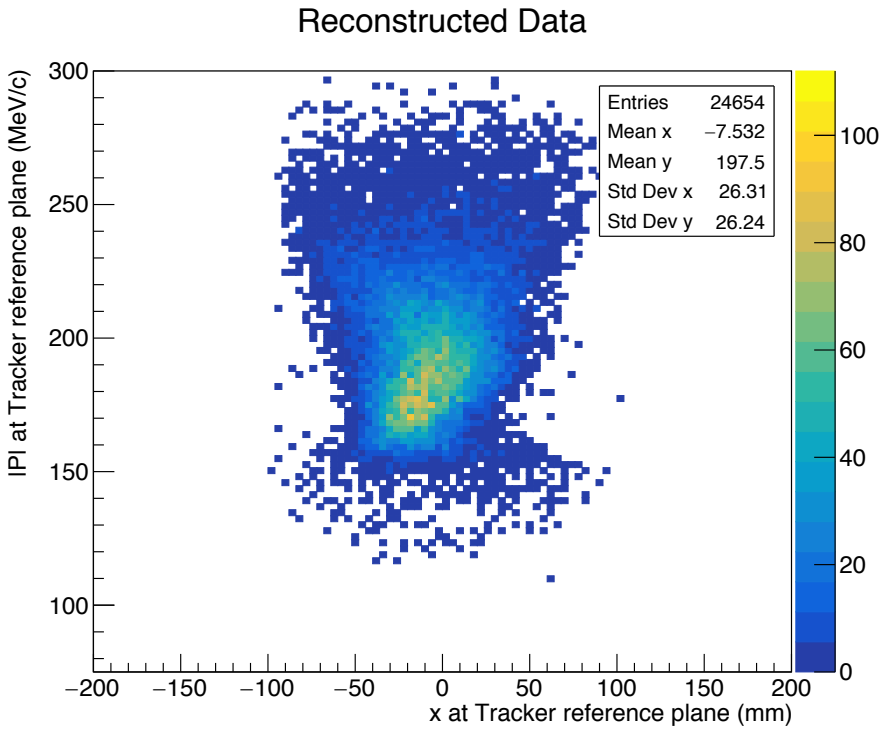
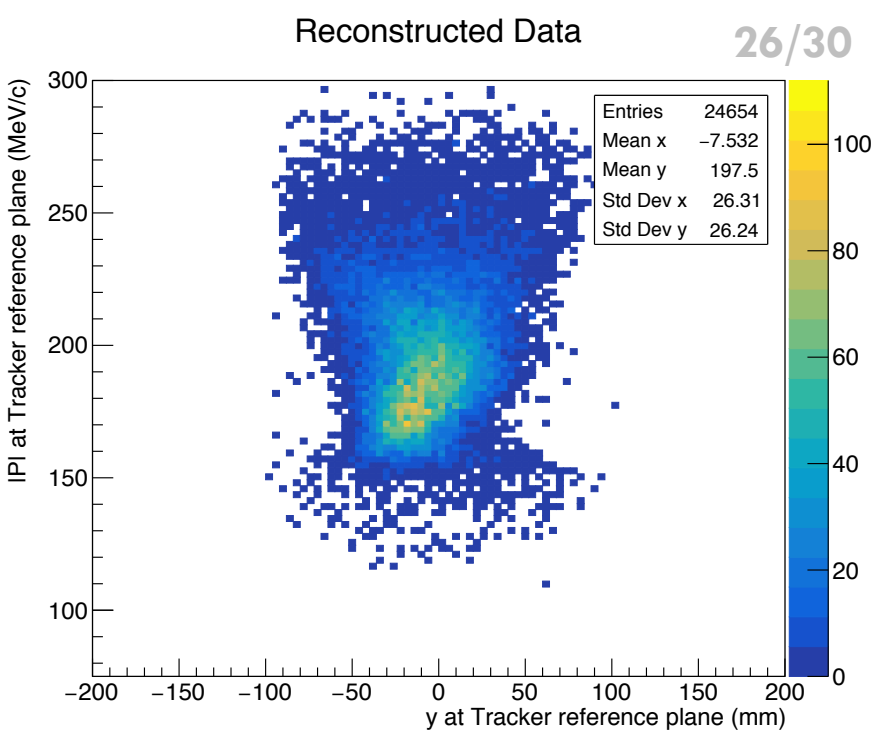
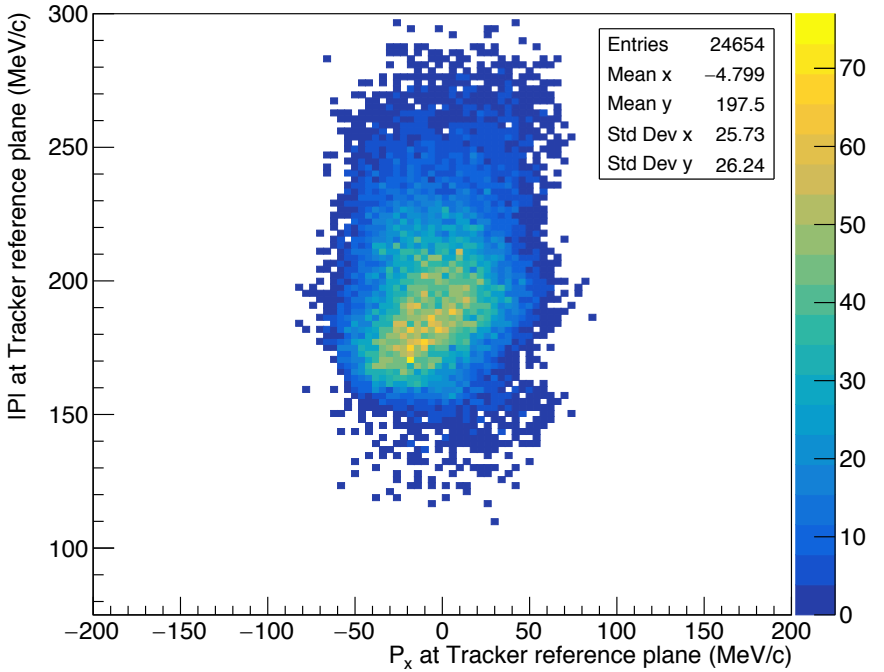
DISPERSION

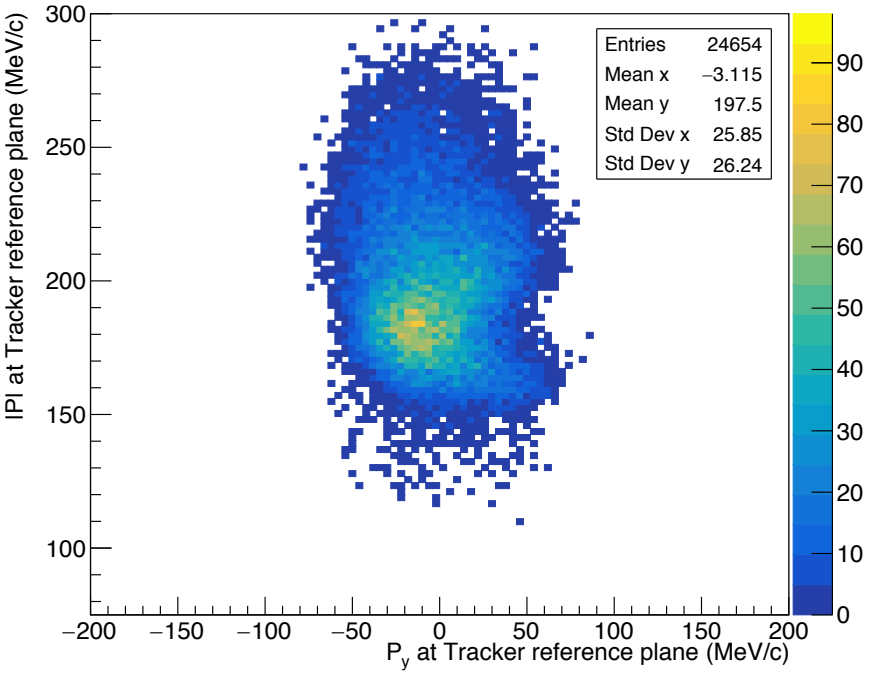
- Will look at emittance in 10 MeV slices of |P|
- Can make phase-space plots for each of these slices
- Can see that each slice is approx. ellipse
- Can see rotations!

- [Difficult-to-see plot coming – sorry!]









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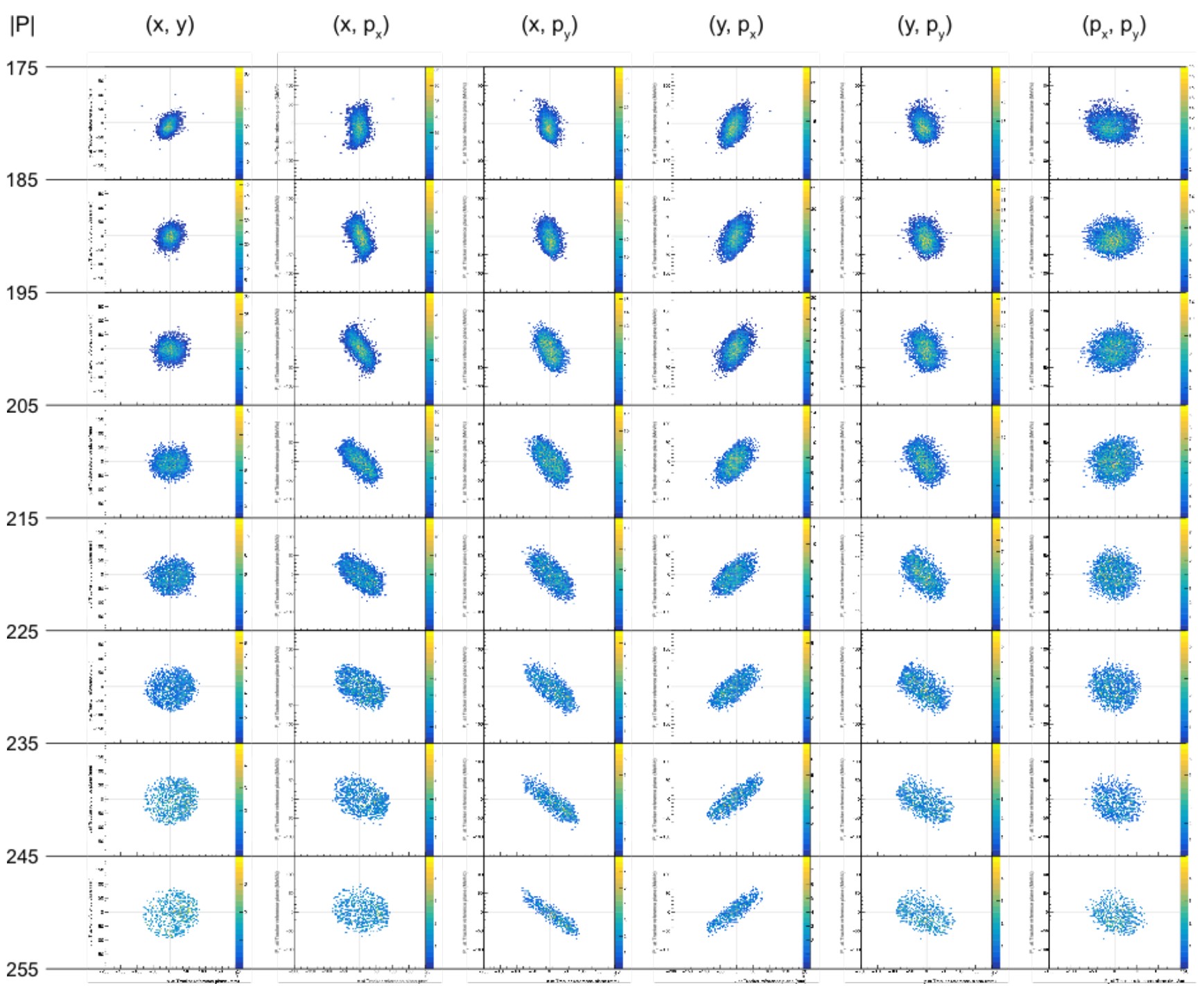
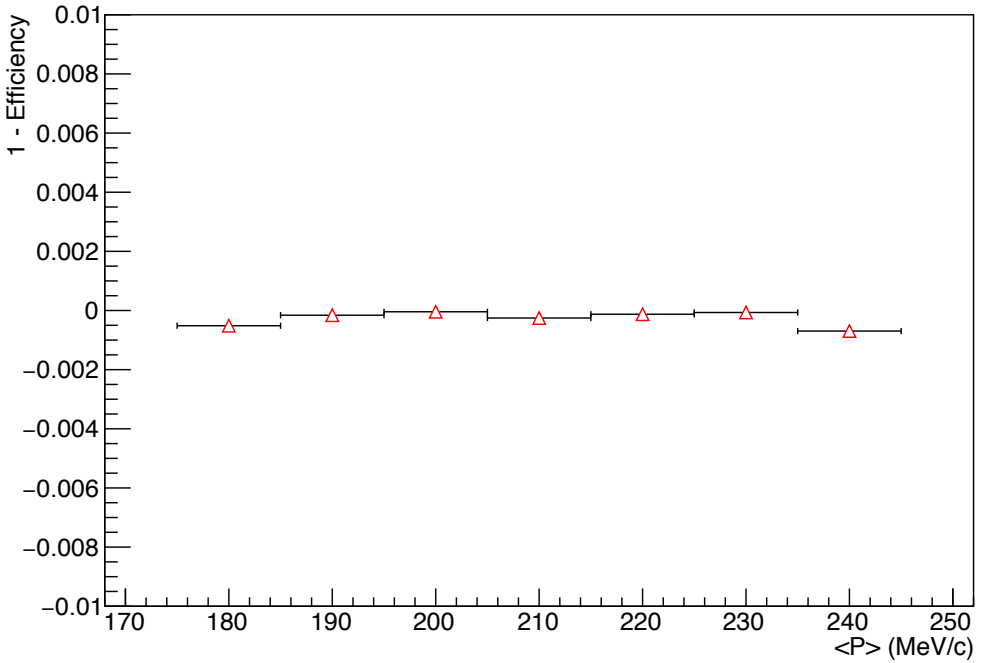
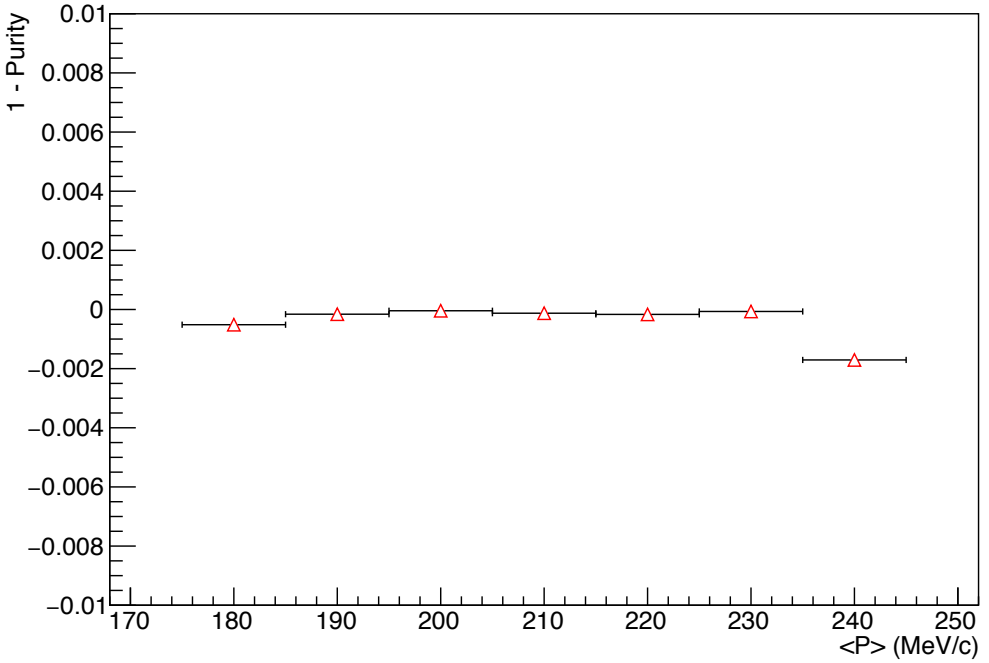


EFFICIENCY, PURITY

- For each momentum bin:
  - N_G = number particles in MC truth in this bin
  - N_R = number particles in MC recon in this bin
  - N_C = number particles that were generated, reconstructed **and** passed all cuts
- Efficiency $= \frac{N_C}{N_G}$
- Purity$= \frac{N_C}{N_R}$
- *Plotting 1 – quantity*





UNCERTAINTY CALCULATIONS

Beam selection: Dominant contribution from diffuser aperture cut

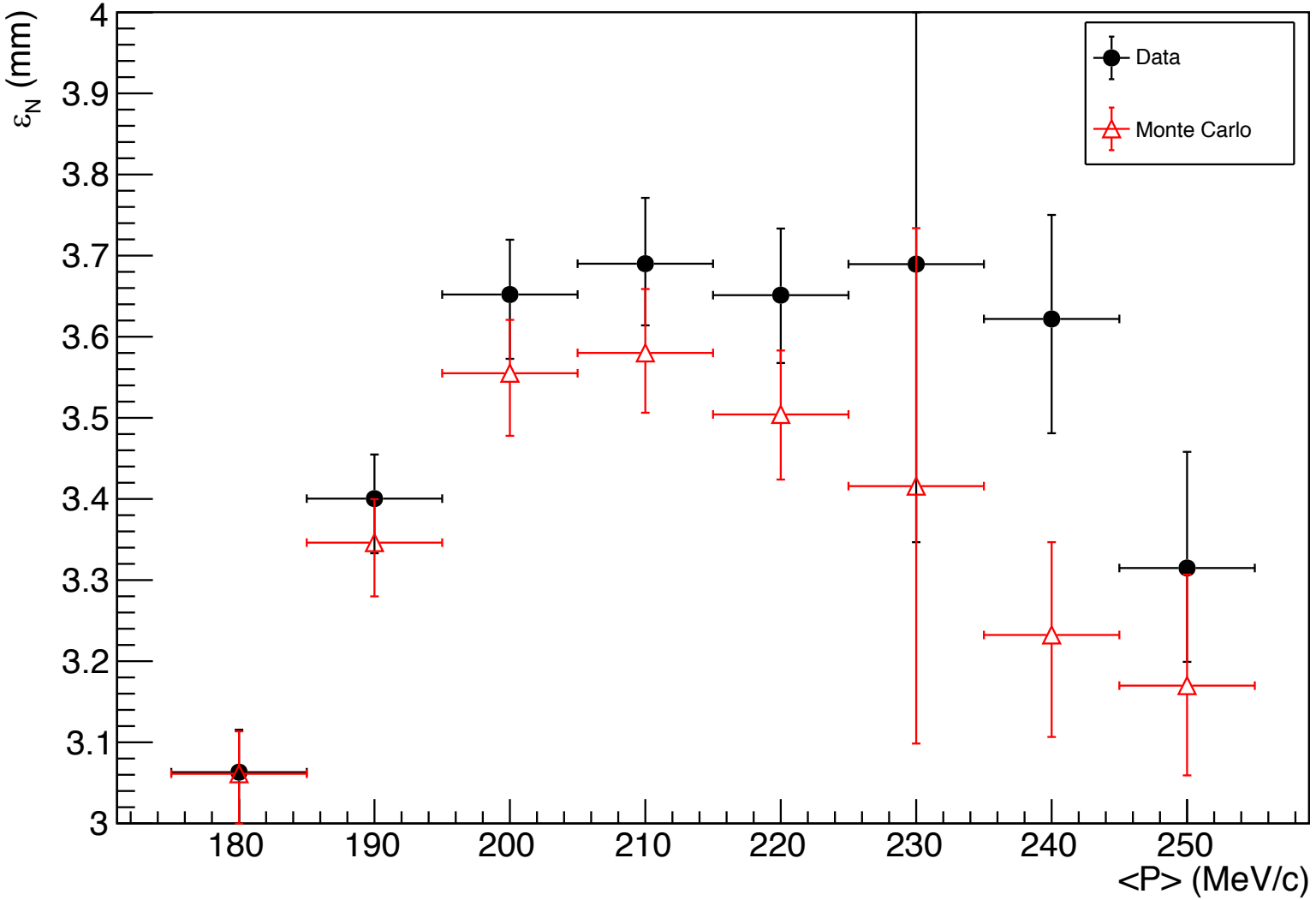
Table 3: Statistical and systematic uncertainties on the measured emittance as a function of p.

Source	$\langle p \rangle$ (MeV/c)							
	180	190	200	210	220	230	240	250
Measured emittance (mm rad)	3.06	3.40	3.65	3.69	3.65	3.69	3.62	3.31
Statistical uncertainty	± 0.03	± 0.04	± 0.04	± 0.05	± 0.05	± 0.07	± 0.08	± 0.09
Beam selection	$^{+0.05}_{-0.04}$	$^{+0.05}_{-0.04}$	$^{+0.06}_{-0.05}$	$^{+0.05}_{-0.06}$	± 0.05	$^{+0.04}_{-0.05}$	± 0.1	$^{+0.05}_{-0.1}$
Binning in p	± 0.02	± 0.02	± 0.02	± 0.02	± 0.03	± 0.33	± 0.04	± 0.05
Non-uniform magnetic field	$\pm$???	$\pm$???	$\pm$???	$\pm$???	$\pm$???	$\pm$???	$\pm$???	$\pm$???
Low $p_\perp$ tracks	$\pm$???	$\pm$???	$\pm$???	$\pm$???	$\pm$???	$\pm$???	$\pm$???	$\pm$???
Tracker-field misalignment	$\pm$???	$\pm$???	$\pm$???	$\pm$???	$\pm$???	$\pm$???	$\pm$???	$\pm$???
Magnetic field scale	$\pm$???	$\pm$???	$\pm$???	$\pm$???	$\pm$???	$\pm$???	$\pm$???	$\pm$???
Tracker resolution	± 0.00	± 0.00	± 0.00	± 0.00	± 0.00	± 0.01	± 0.01	± 0.01
Total systematic uncertainty	$^{+0.06}_{-0.04}$	$^{+0.06}_{-0.04}$	$^{+0.07}_{-0.05}$	± 0.06	± 0.06	± 0.34	$^{+0.11}_{-0.10}$	$^{+0.07}_{-0.11}$
Total uncertainty	$^{+0.07}_{-0.05}$	$^{+0.06}_{-0.05}$	$^{+0.08}_{-0.07}$	± 0.08	± 0.08	± 0.34	$^{+0.14}_{-0.13}$	$^{+0.12}_{-0.14}$
Total uncertainty (%)	$^{+2.14}_{-1.71}$	$^{+1.98}_{-1.60}$	$^{+2.17}_{-1.85}$	$^{+2.06}_{-2.20}$	$^{+2.29}_{-2.25}$	$^{+9.29}_{-9.31}$	$^{+3.89}_{-3.54}$	$^{+3.49}_{-4.32}$

Suspicious bin – big track error outliers?

EMITTANCE COMPARISON

- Statistical uncertainty from data or MC
- Systematic uncertainty from data
- Summed in quadrature
- 230 MeV bin is suspicious

- For field systematic uncertainty → C. Hunt

- Just a few things left...
  - Field systematics
  - Diffuser problem?
  - Suspect bin?