Flip mode emittance analysis

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MICE CM57

Overview

- Updated MC (comparison with data)
- Detector resolution
- Analysis now contains 4-140, 6-140, 10-140 datasets
- Emittance change results : Data, MC, theory
- Next steps

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MC struggles & update

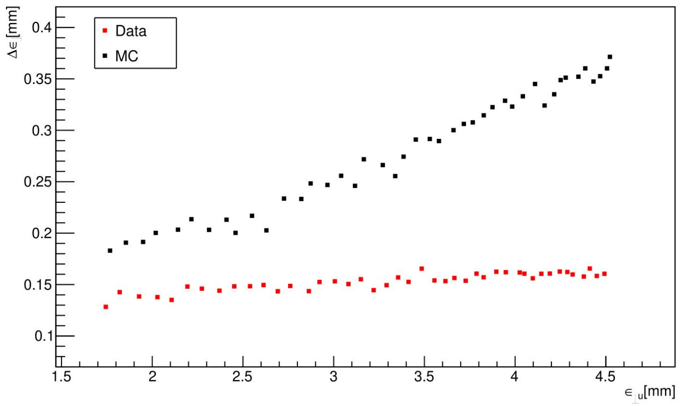
Around last CM - dealing with data / MC mismatch on emittance change

Problem: more heating observed in the empty cases in MC (No absorber case shown here)

Digging revealed disagreement on energy loss at tracker stations

Cause: mismatch in the density of the scintillating fibres used in the Kalman filter energy loss model (SciFiParams_Density parameter)

FIXED, next slide

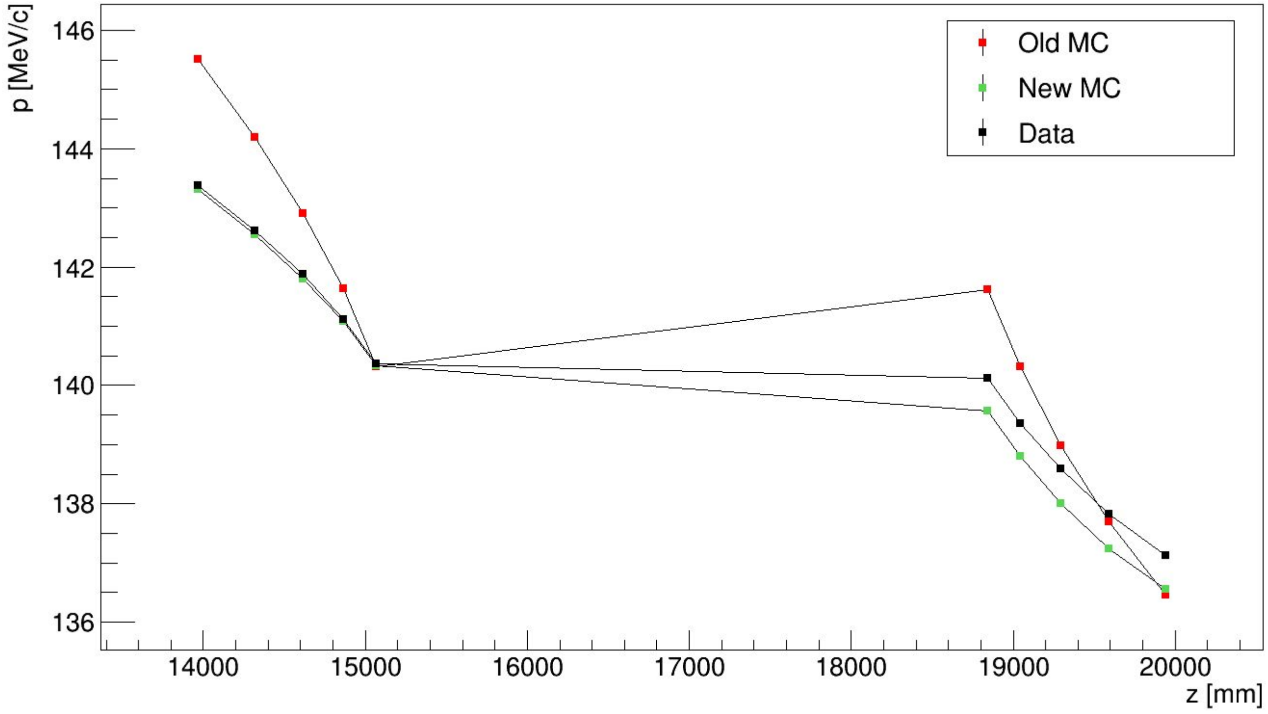


Momentum evolution in trackers (Old vs New MC)

NO ABSORBER (NA) case shown here

Good agreement on energy loss at stations between data and new MC

There is still a ~ 0.2 - 0.6 MeV/c offset in TKD, depending on the absorber setting

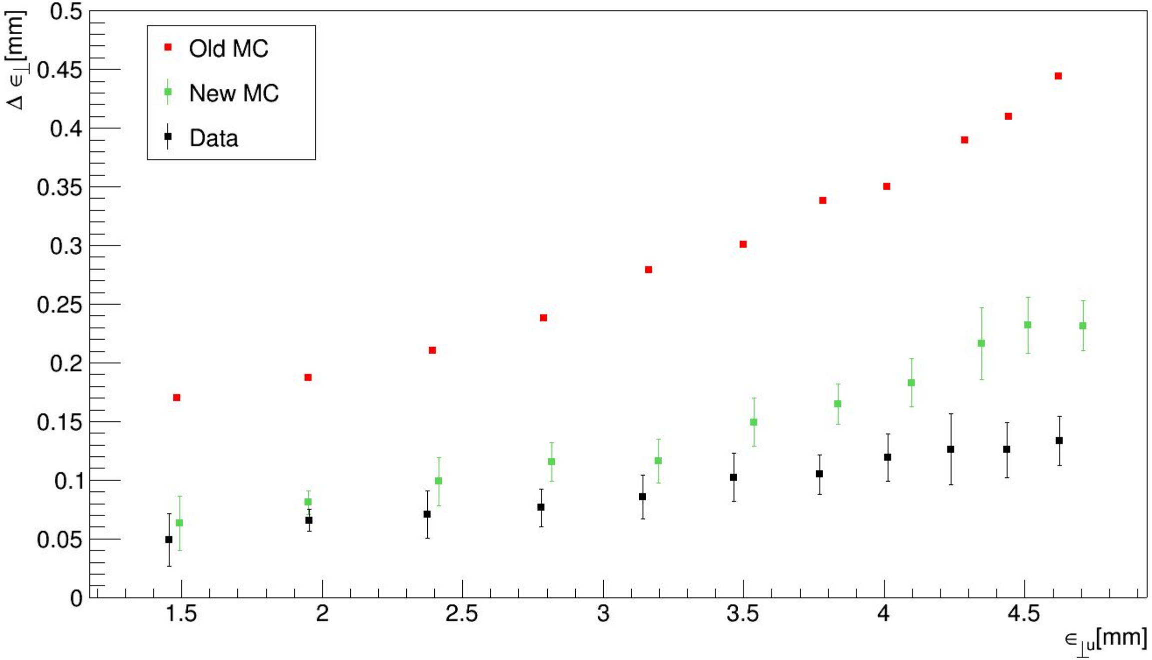


Emittance change: comparison with old MC

No absorber

Disagreement reduced

*corrections for reconstruction bias not applied here



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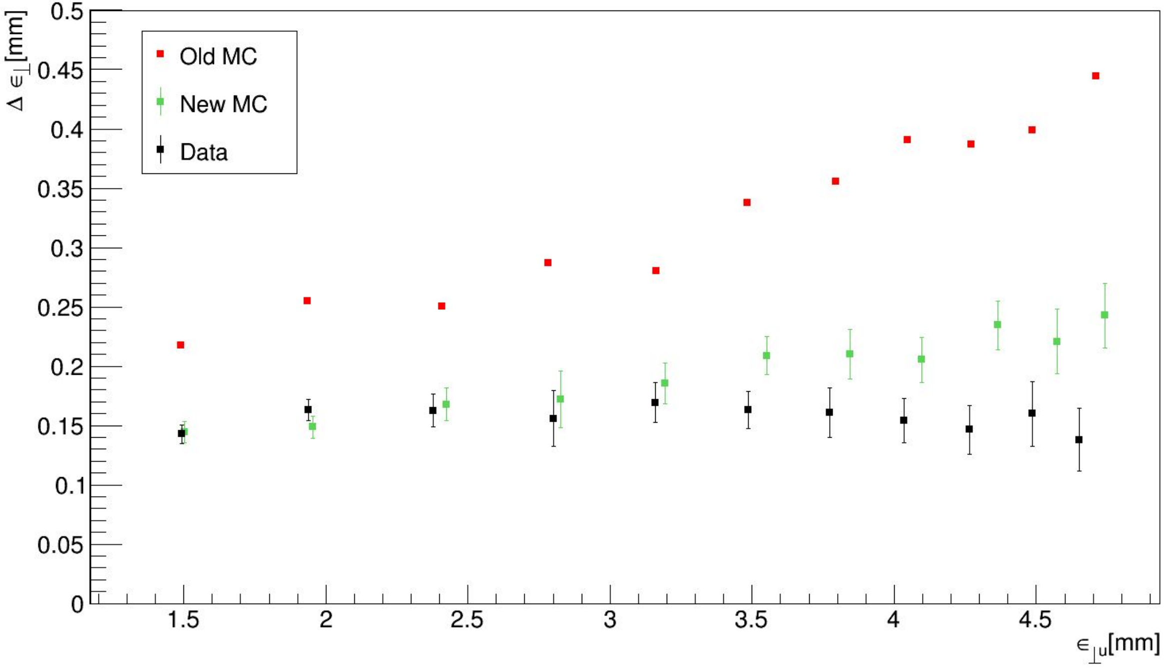
Emittance change: comparison with old MC

Empty LH2

Same as for the *No absorber* case, disagreement reduced

*corrections for reconstruction bias not applied here



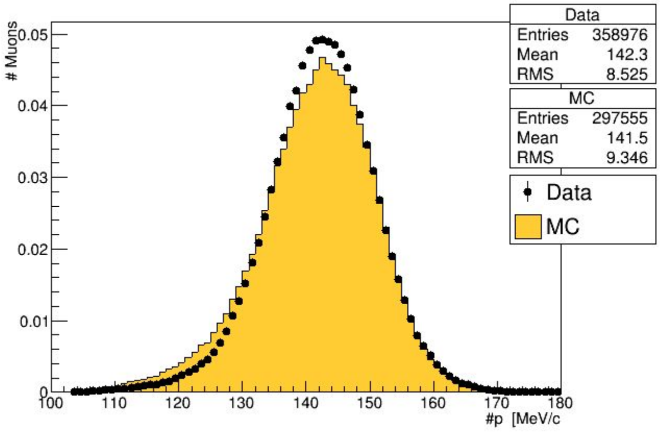
MC tuning & production

- setup a MC production routine on the IC HEP cluster
- D1, D2 dipole current tuning required to match momentum in TKU
- compromise between momentum distribution shape, momentum mean (after cuts) and x, p_x, y, p_y at TKU reference plane
- converged on the current values (further refining might be needed)
- produced samples for all 4-140, 6-140, 10-140 analyses (low stats for 4-140 LiH and full LH2 samples, currently under production)

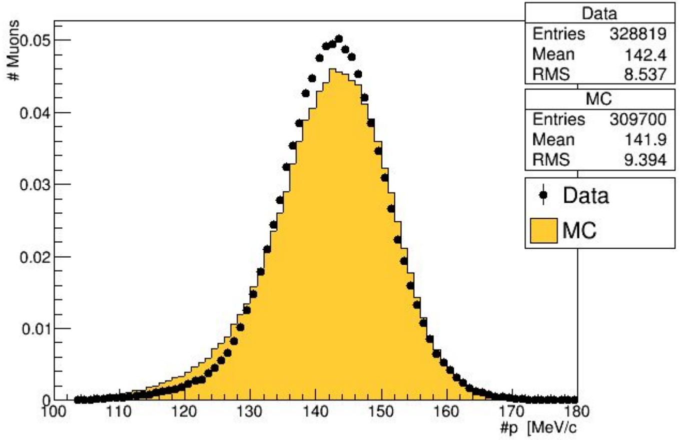
Updated MC vs Data: 6-140 Cuts

TKU momentum

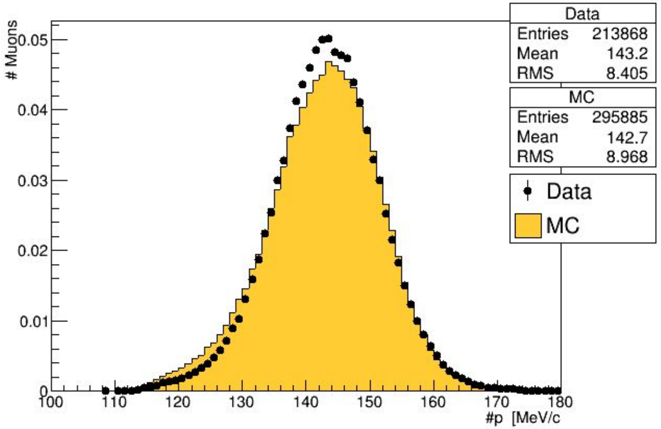
No abs



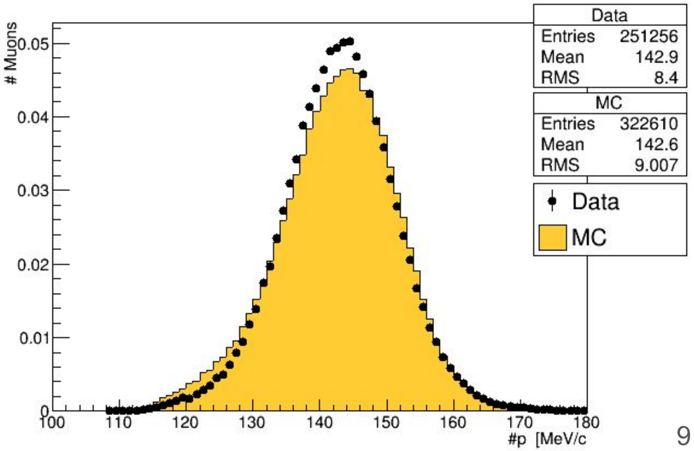
Empty LH2



LiH



LH2



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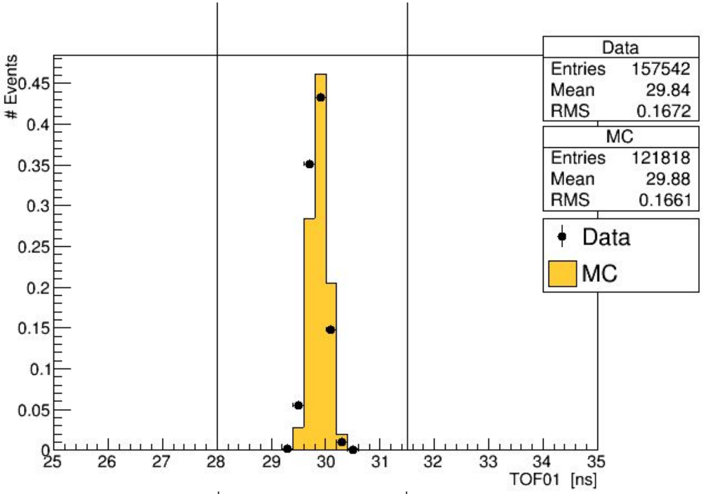
TOF01 time

No abs



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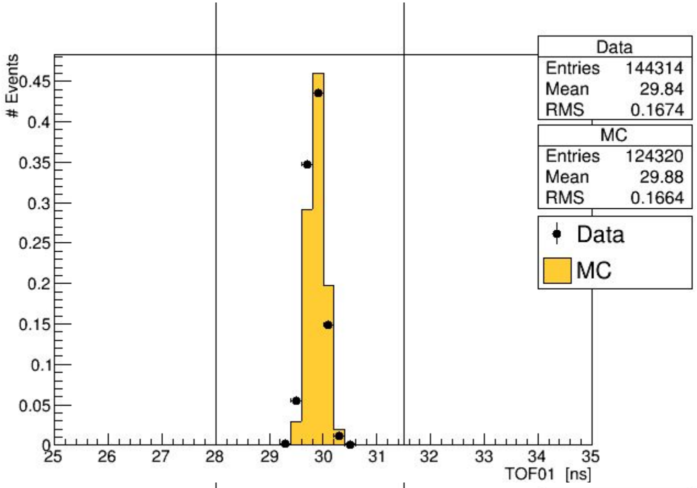

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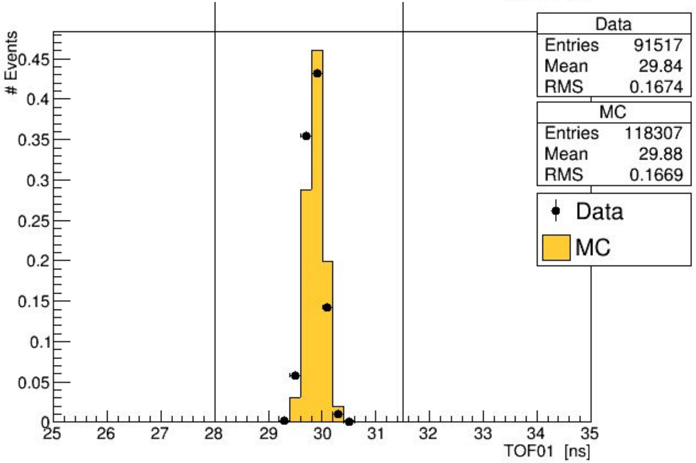

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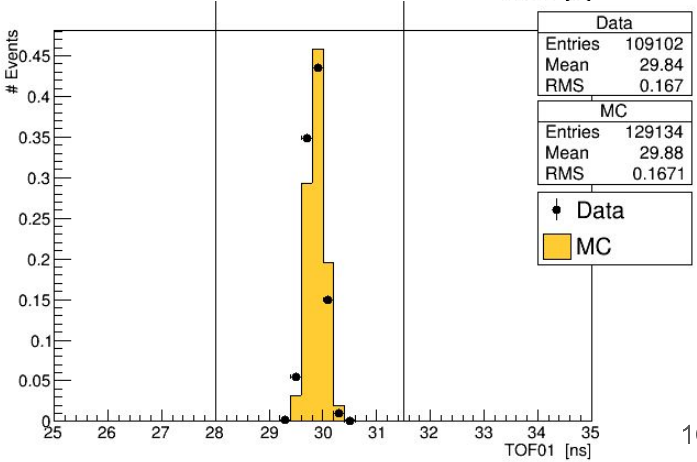


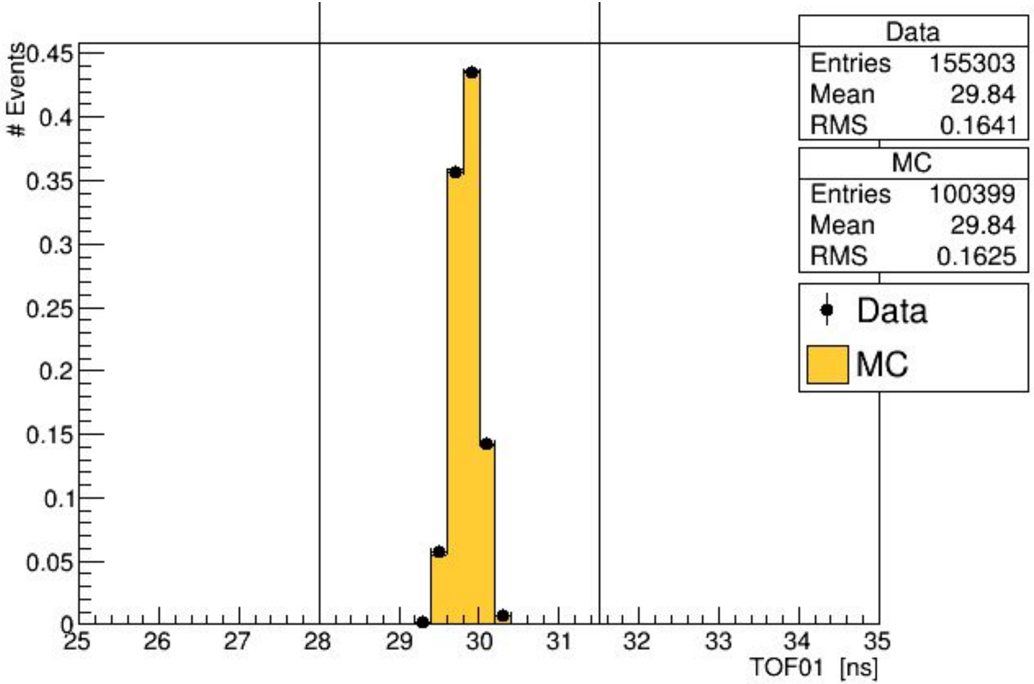
Old MC TOF01 example: No absorber

Better agreement observed with the old MC, shown here

~40 ps slower muons in new MC

(also in simulations that had identical dipole currents)

Did not spot any differences in the configuration files between the new and old MC yet



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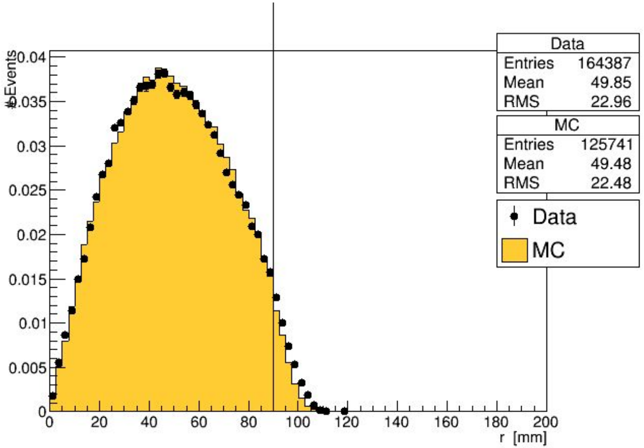
Radius at diffuser

No abs



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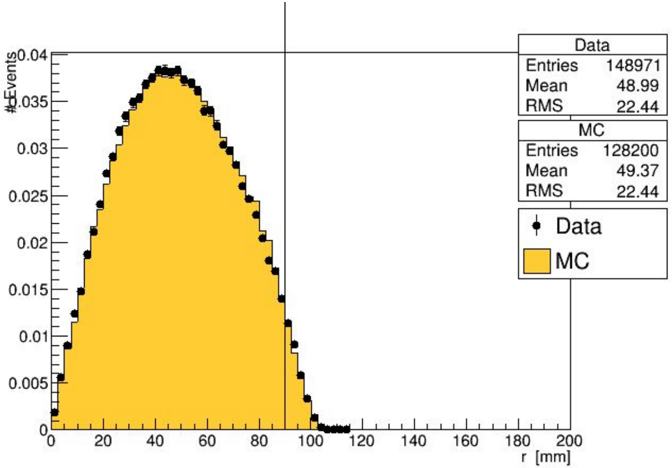

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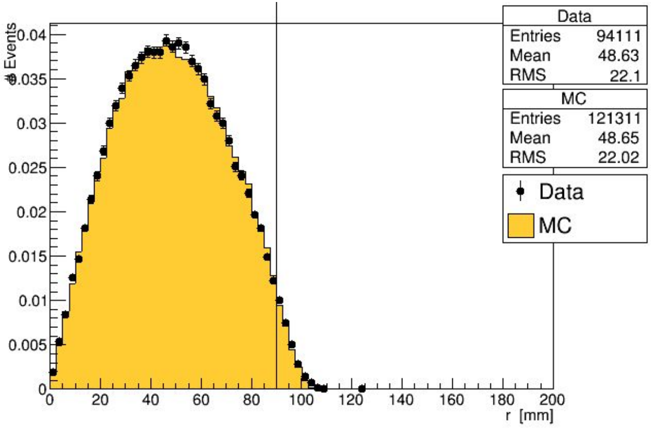

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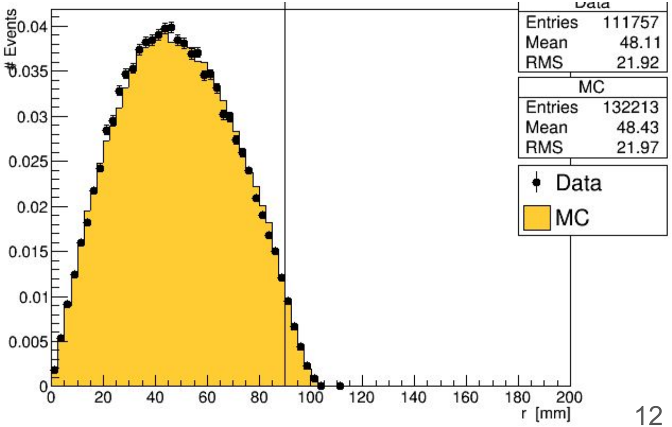
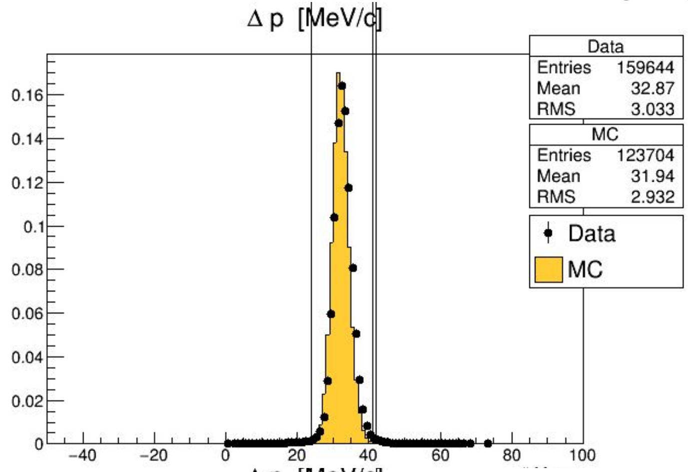
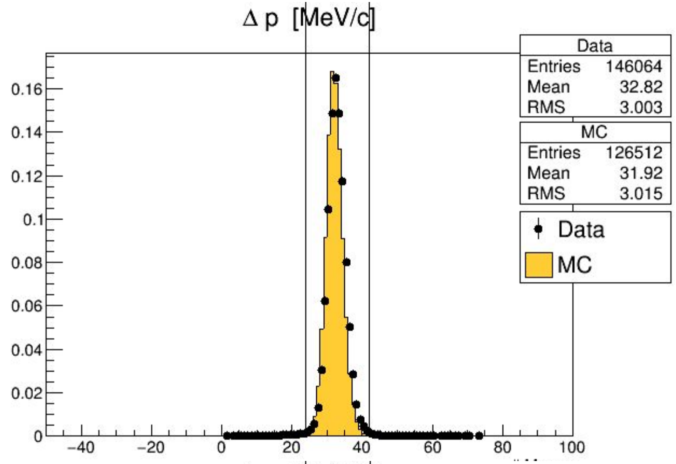


$p_{TOF01} - p_{TKU}$

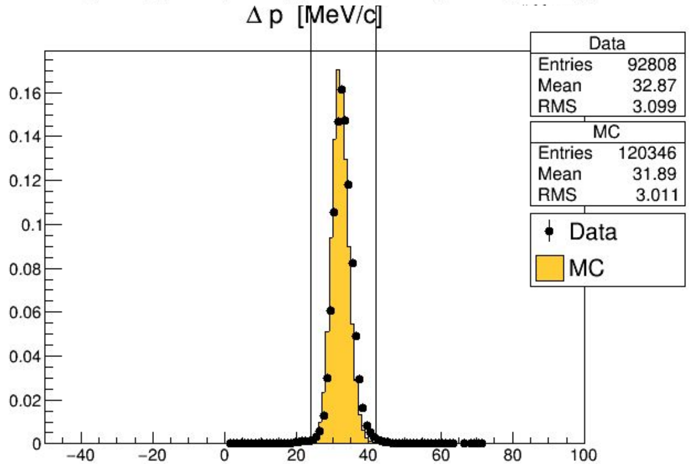
No abs



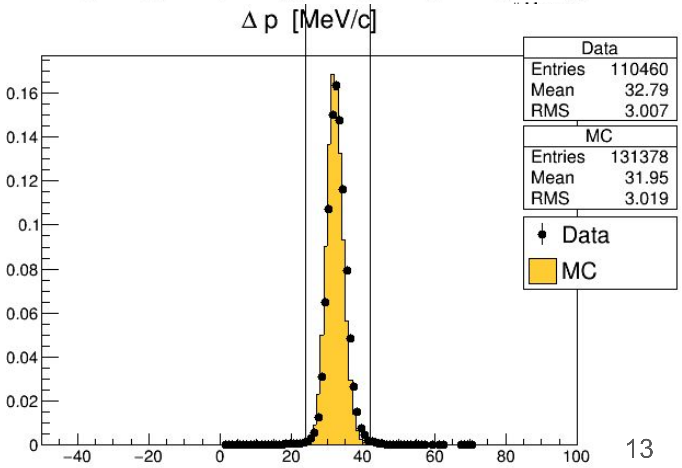
Empty LH2



LiH



LH2



p_{TOF01} - p_{TKU}

$$p_{TOF01} = \frac{m_\mu c}{\sqrt{\frac{t^2_{TOF01} c^2}{L^2_{TOF01}} - 1}}$$

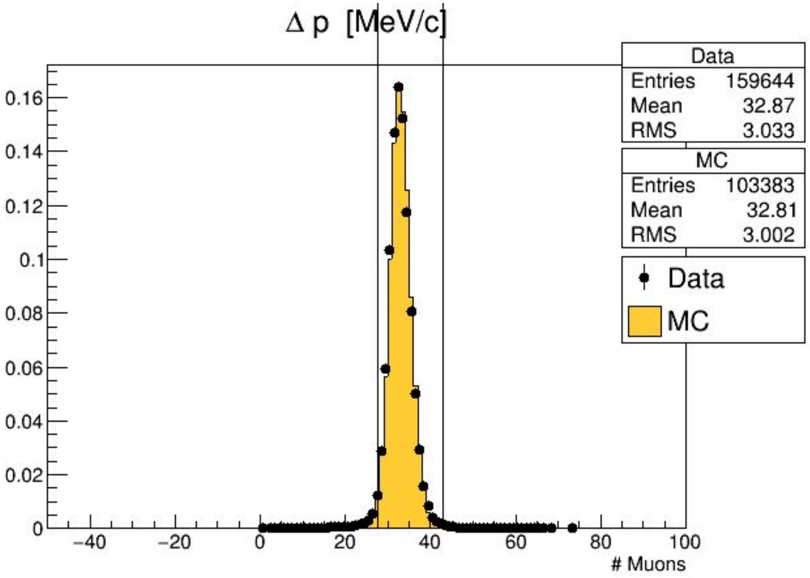
Better agreement with old MC, shown here

~ 1 MeV/c discrepancy in new MC corresponding to the 40ps discrepancy in the time of flight

Could be caused by mismatch in:

1. simulated energy loss at diffuser
2. simulated TOFs response?

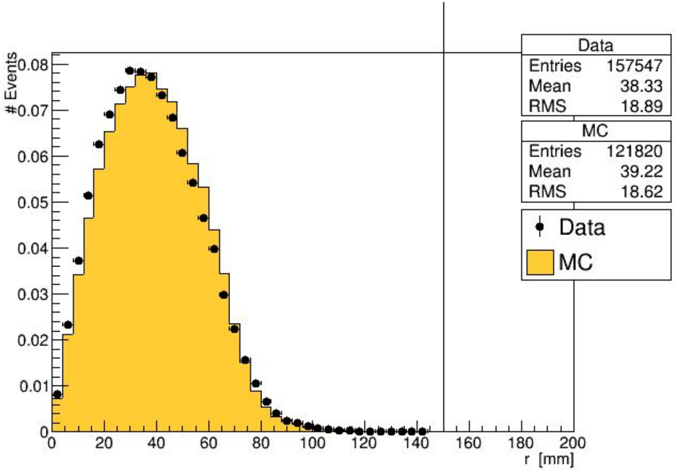
Cause not yet identified



Old MC (No absorber)

TKU fiducial cut

No abs



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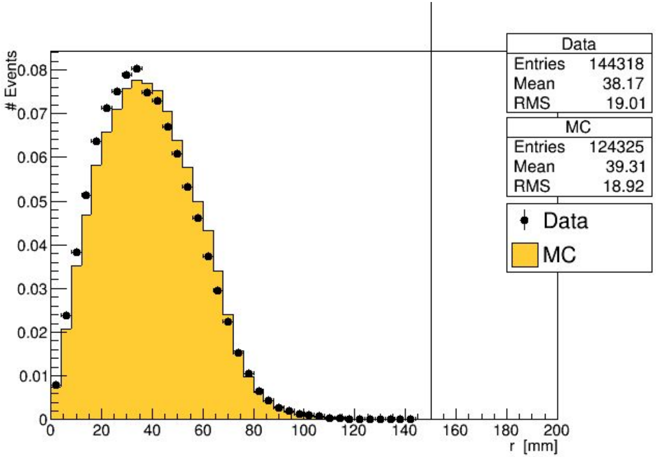

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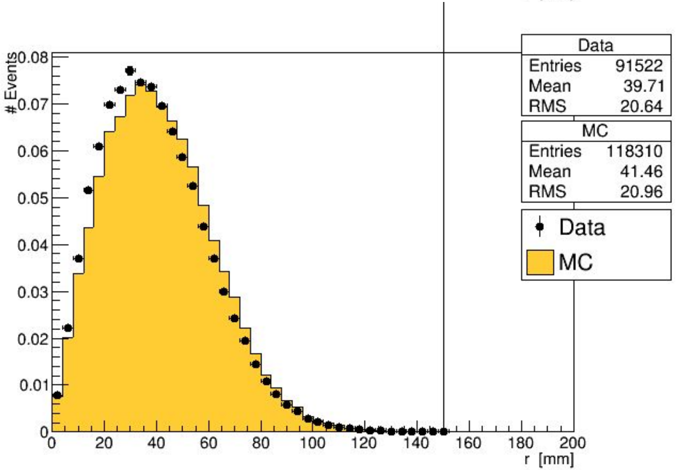

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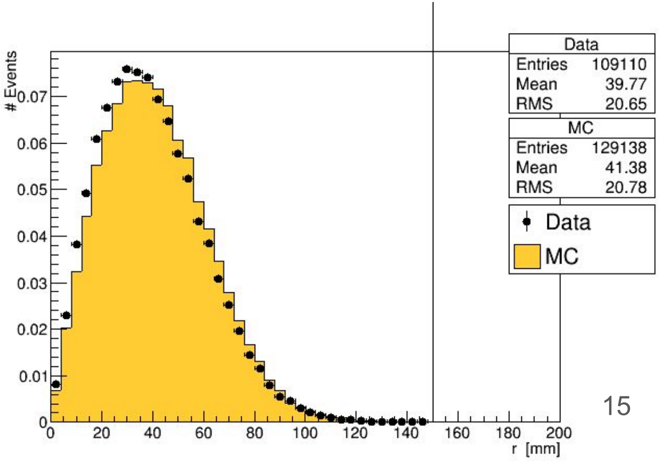
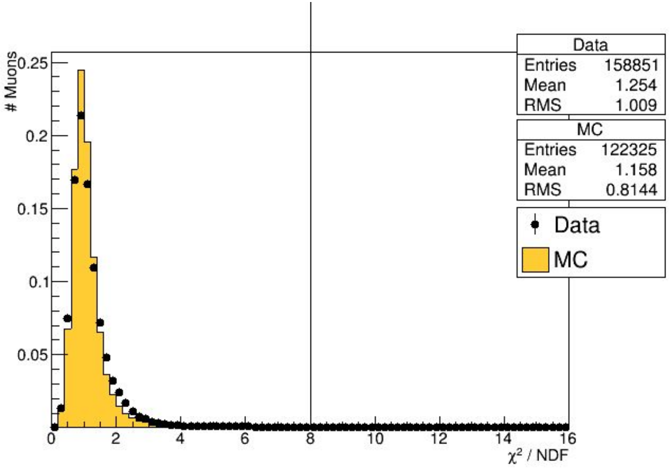


χ^2 / ndf TKU

No abs



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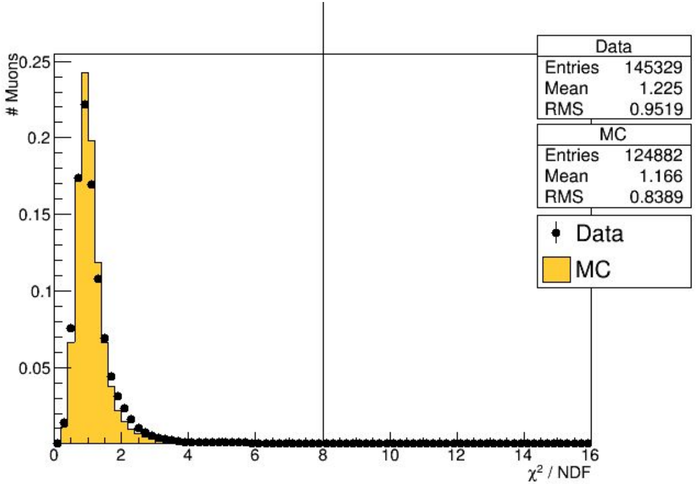

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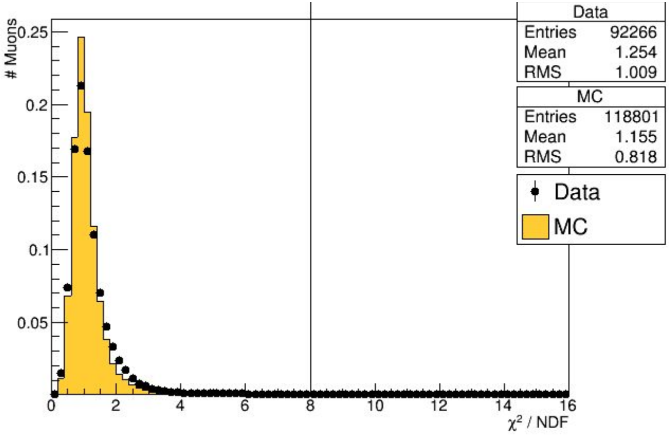
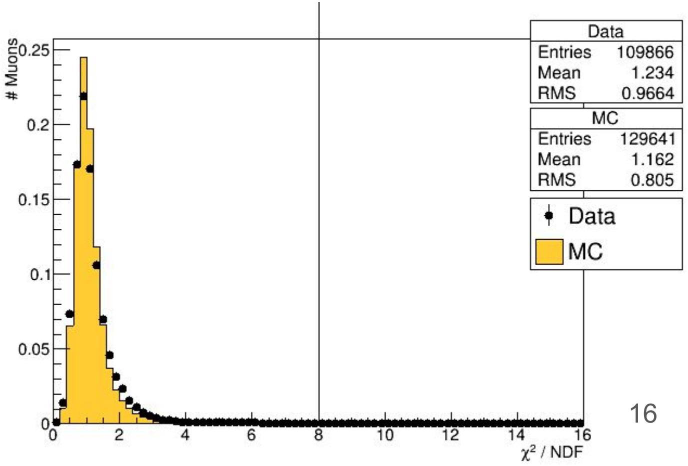
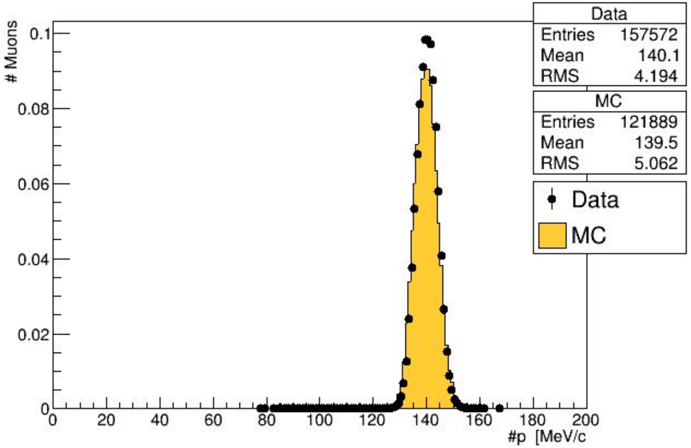


LH2



TKD momentum

No abs



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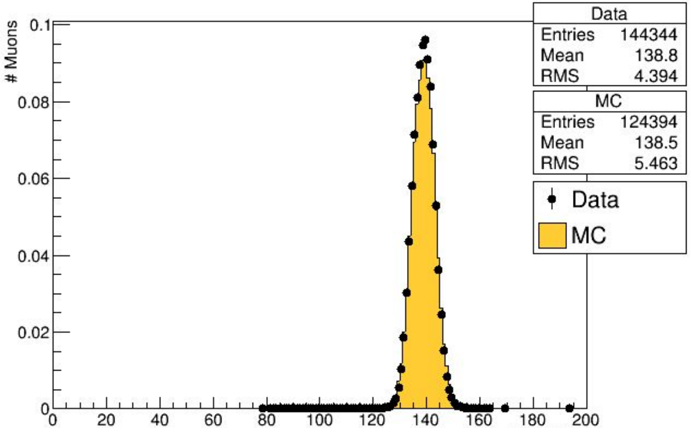

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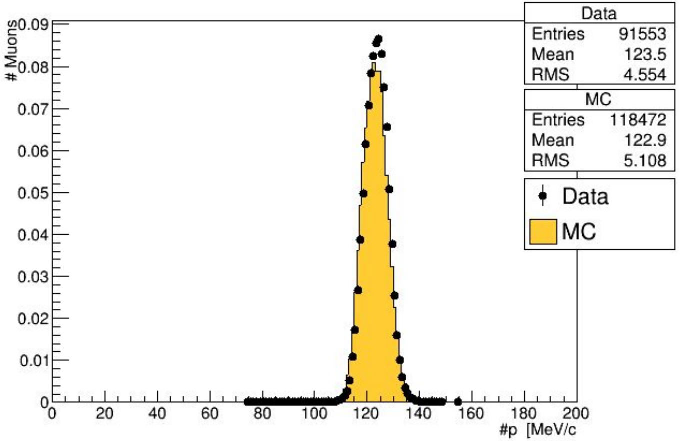

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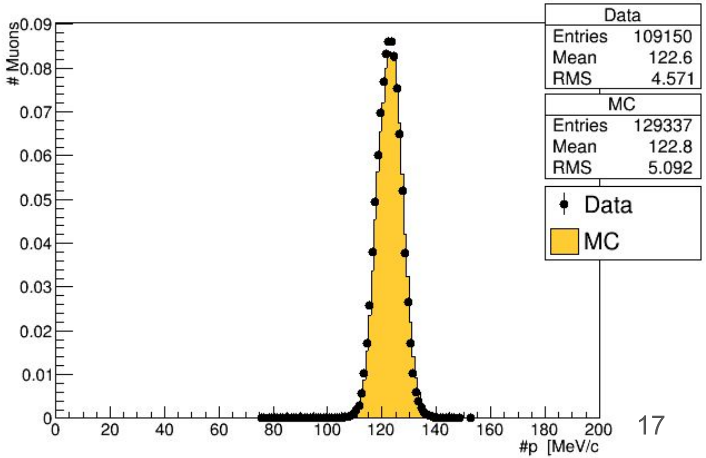
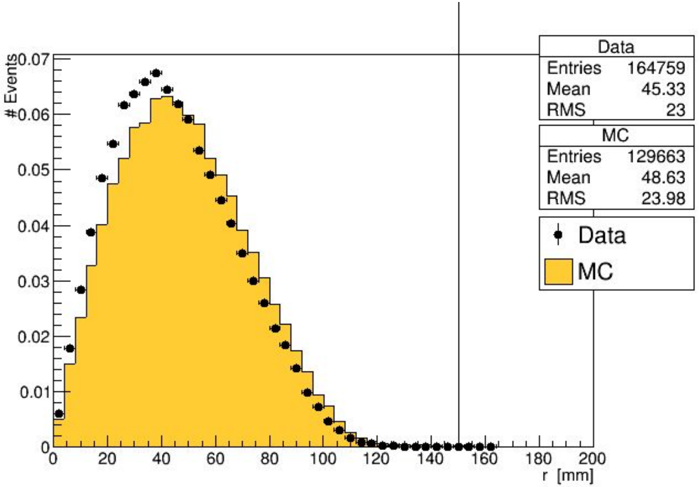


TKD fiducial cut

No abs



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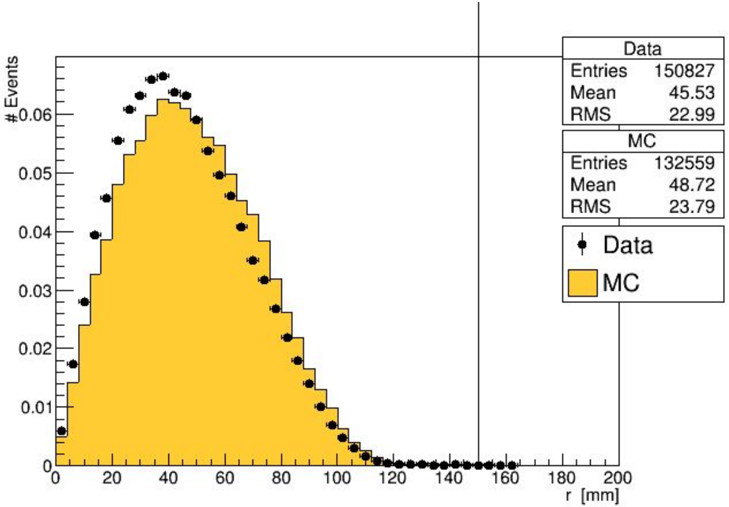

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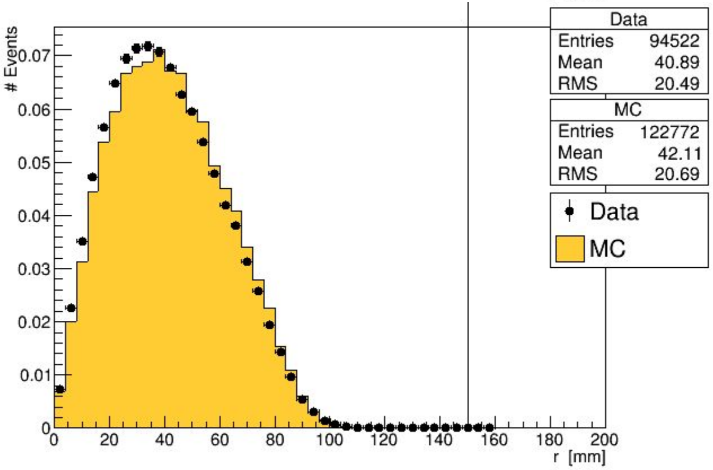
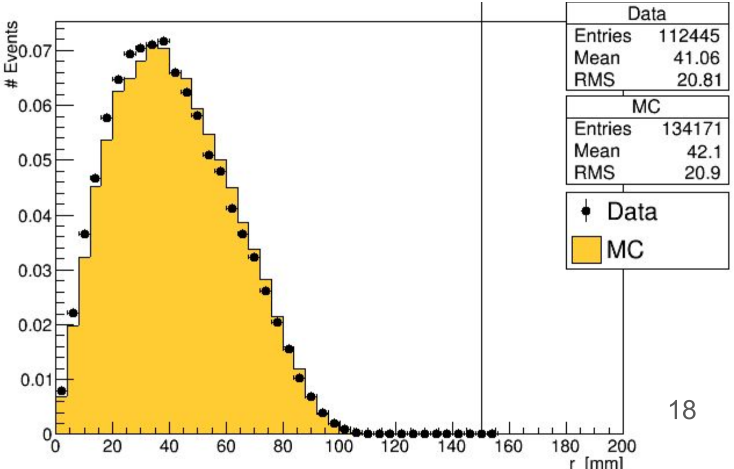
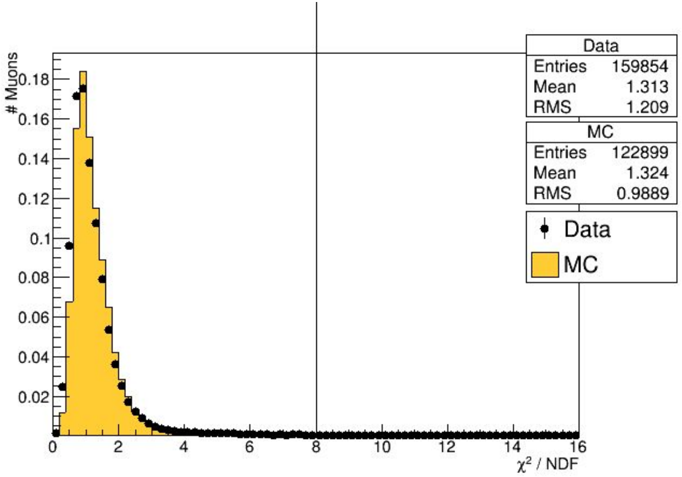


LH2



χ^2 / ndf TKD

No abs



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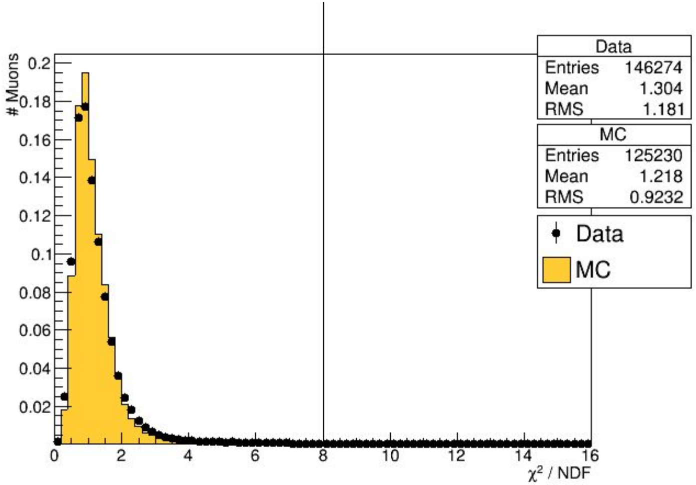

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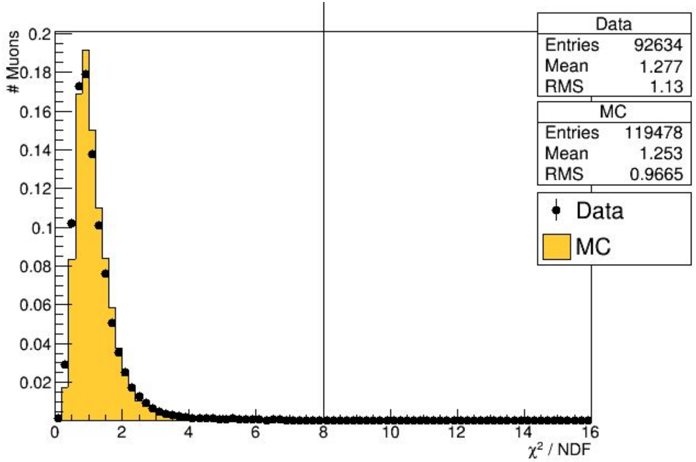
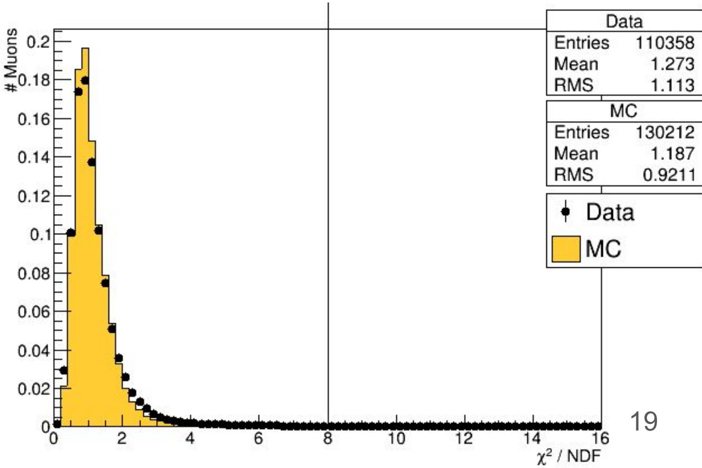


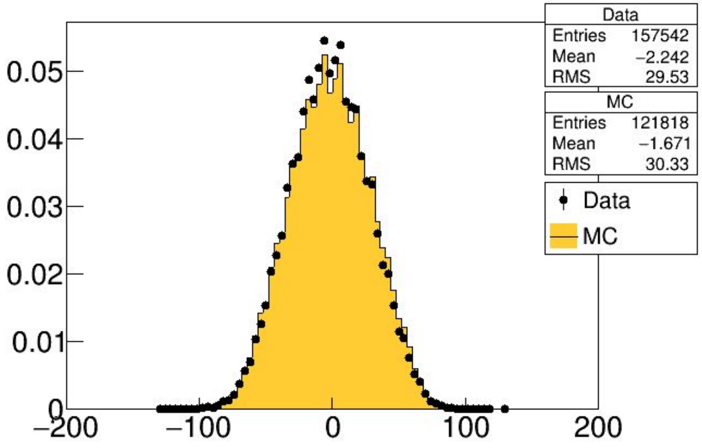
LH2



Parent distributions phase space

X TKU

No abs



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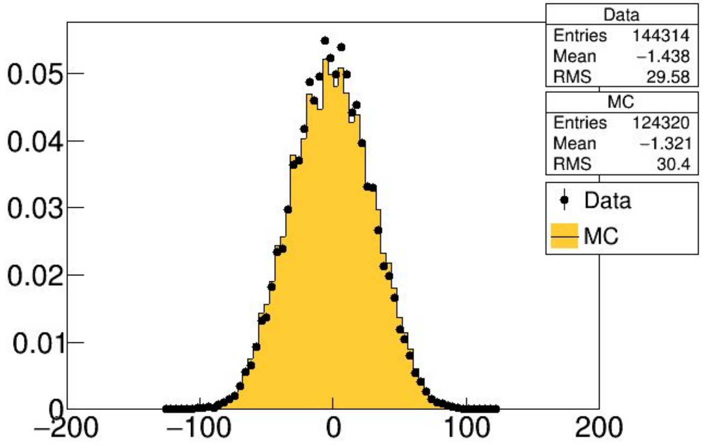

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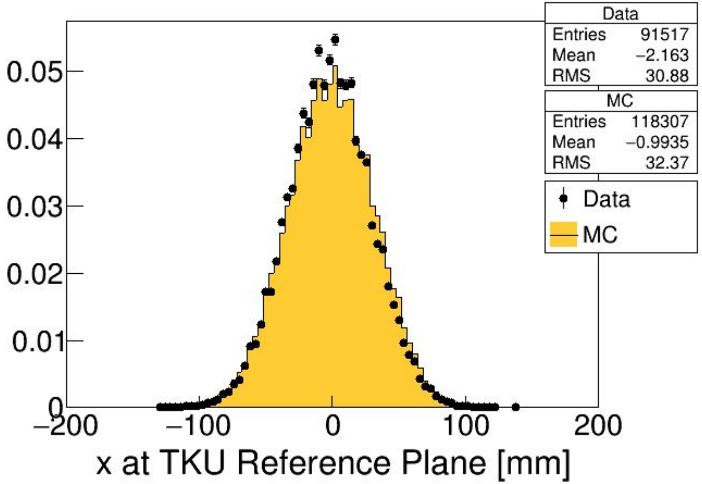

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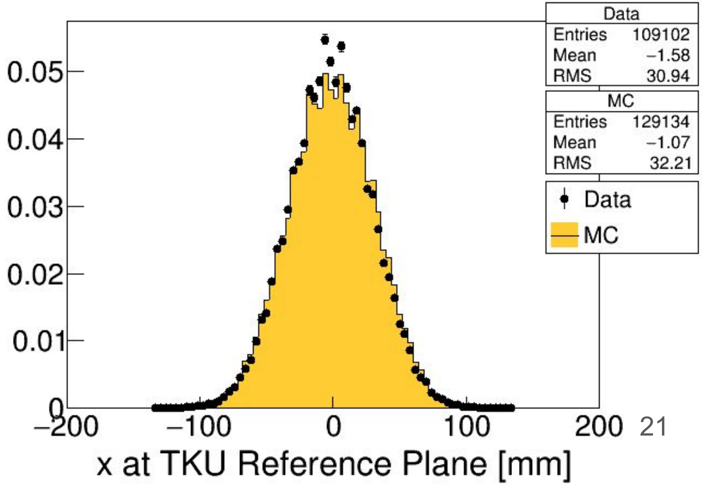
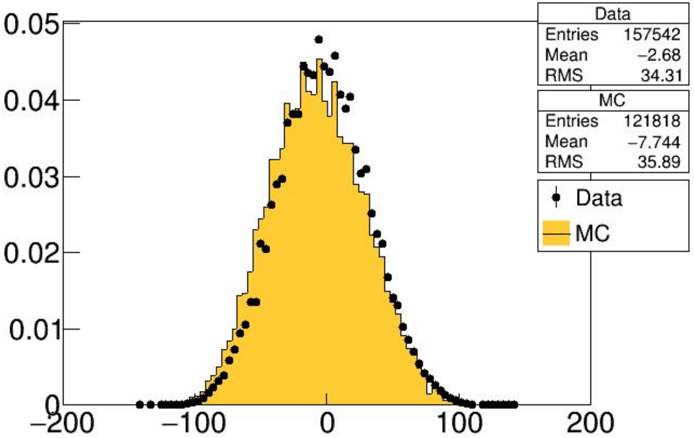


X TKD

No abs



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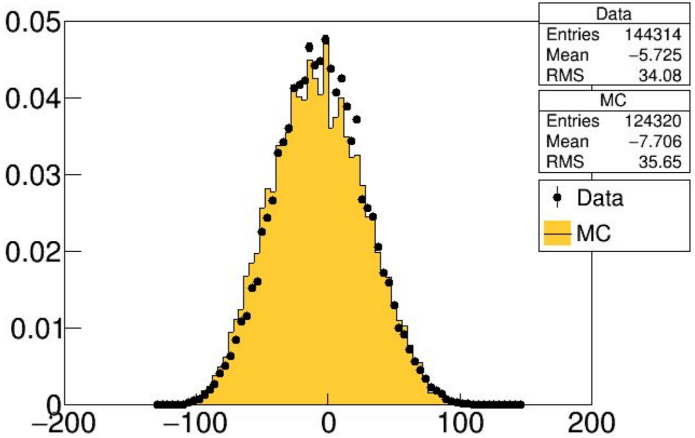

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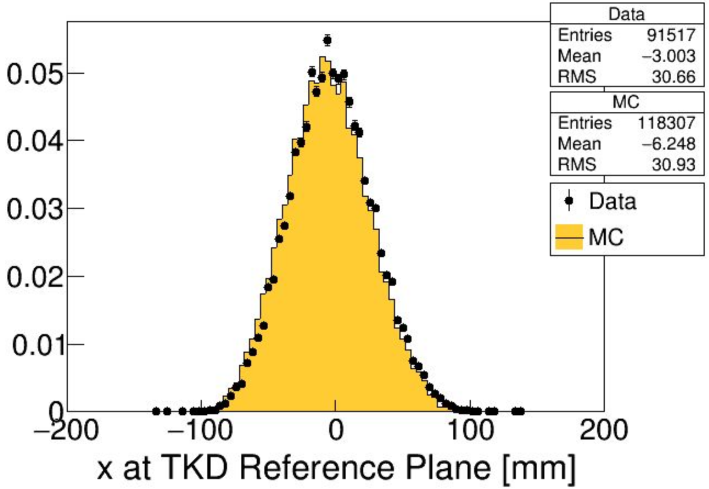

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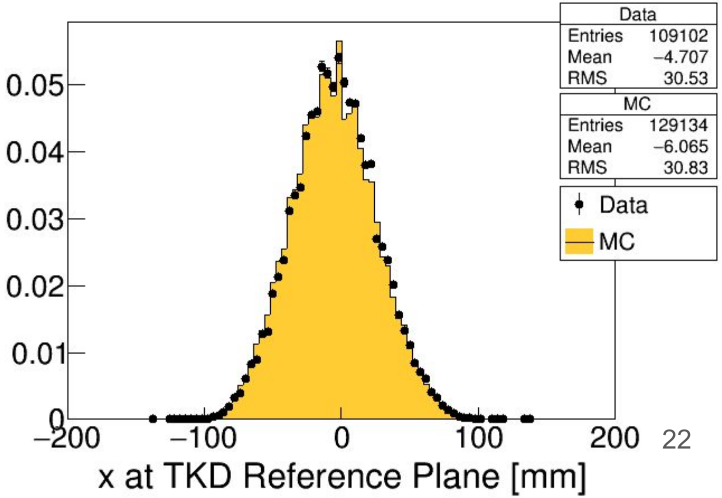
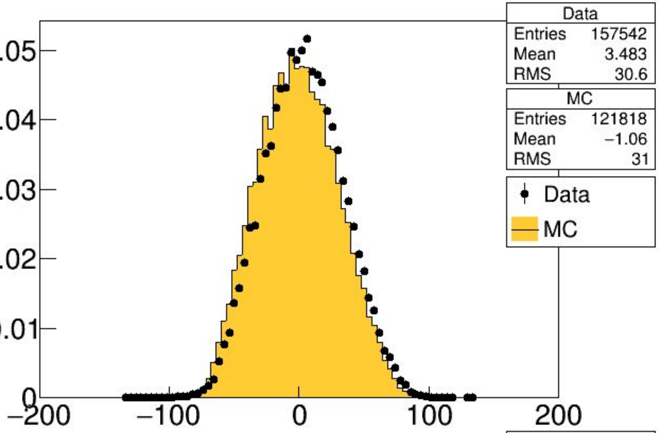
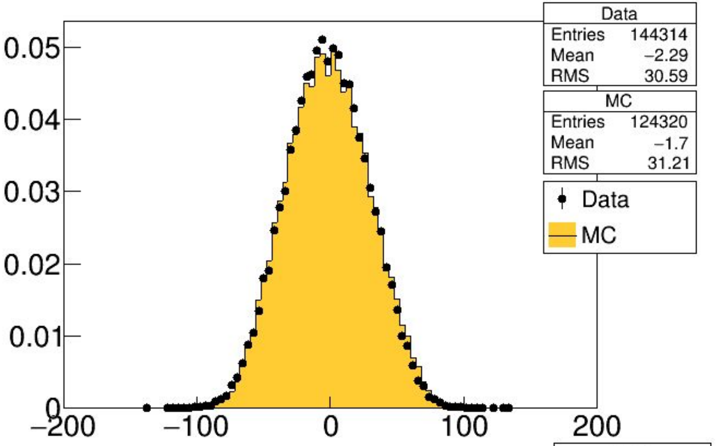


Y TKU

No abs



Empty LH2



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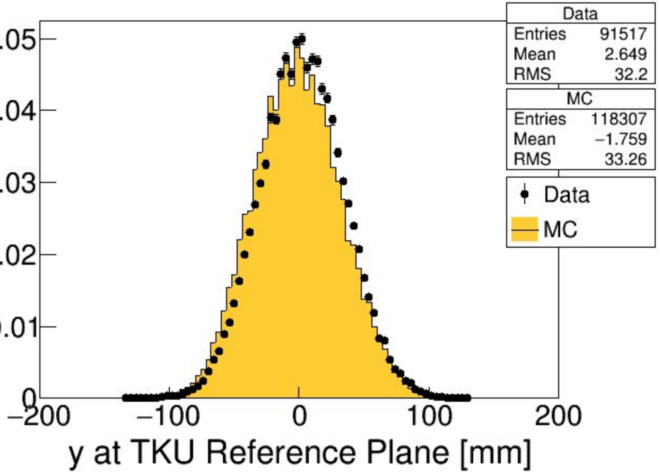

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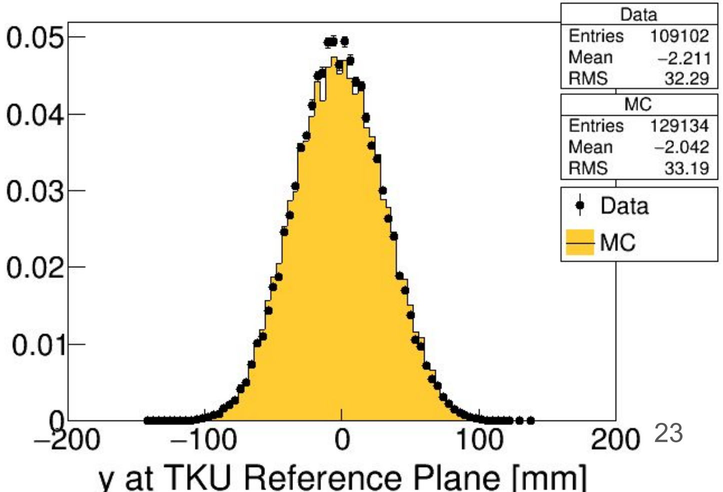
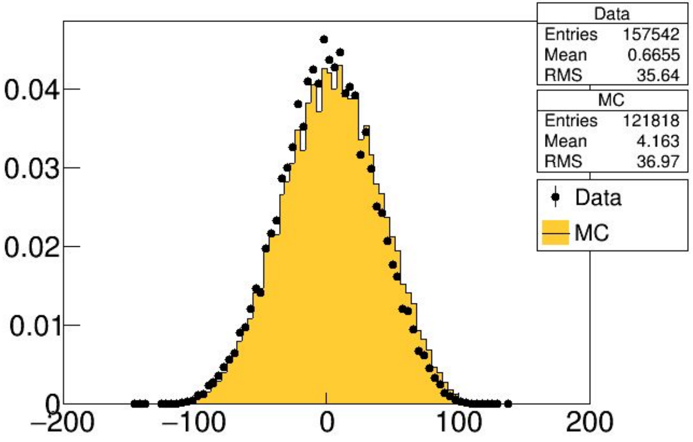


Y TKD

No abs



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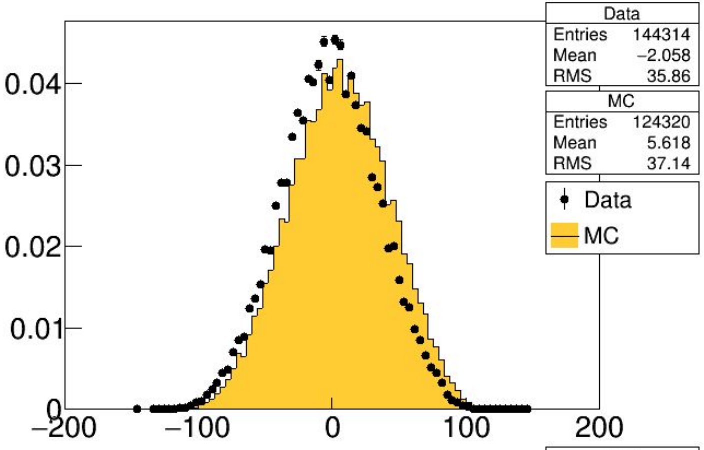

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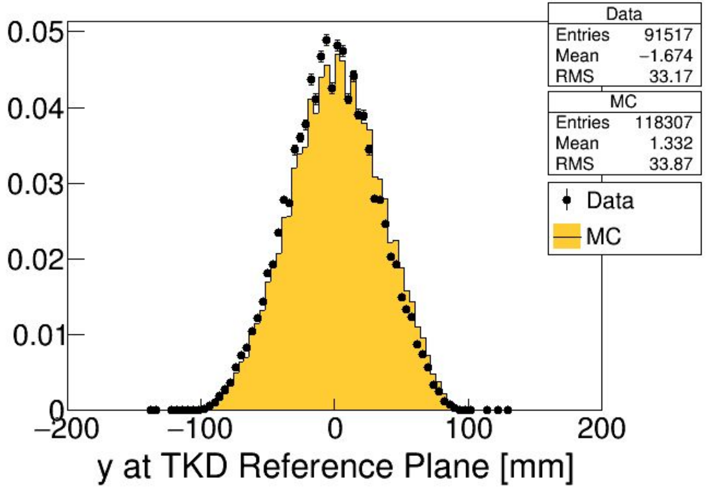

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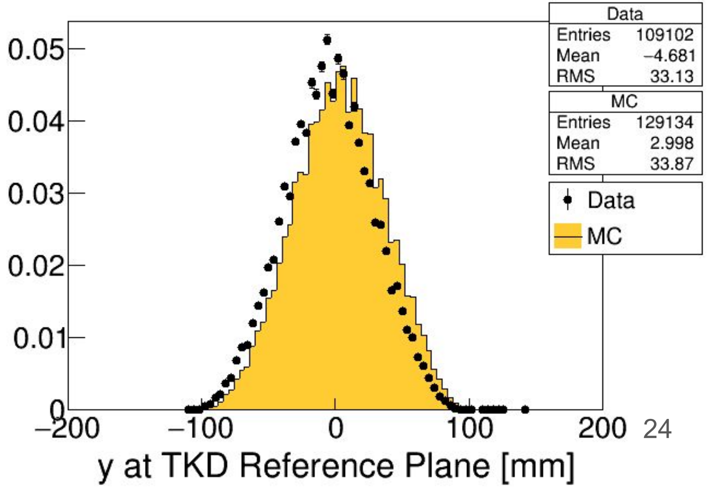

P_x TKU

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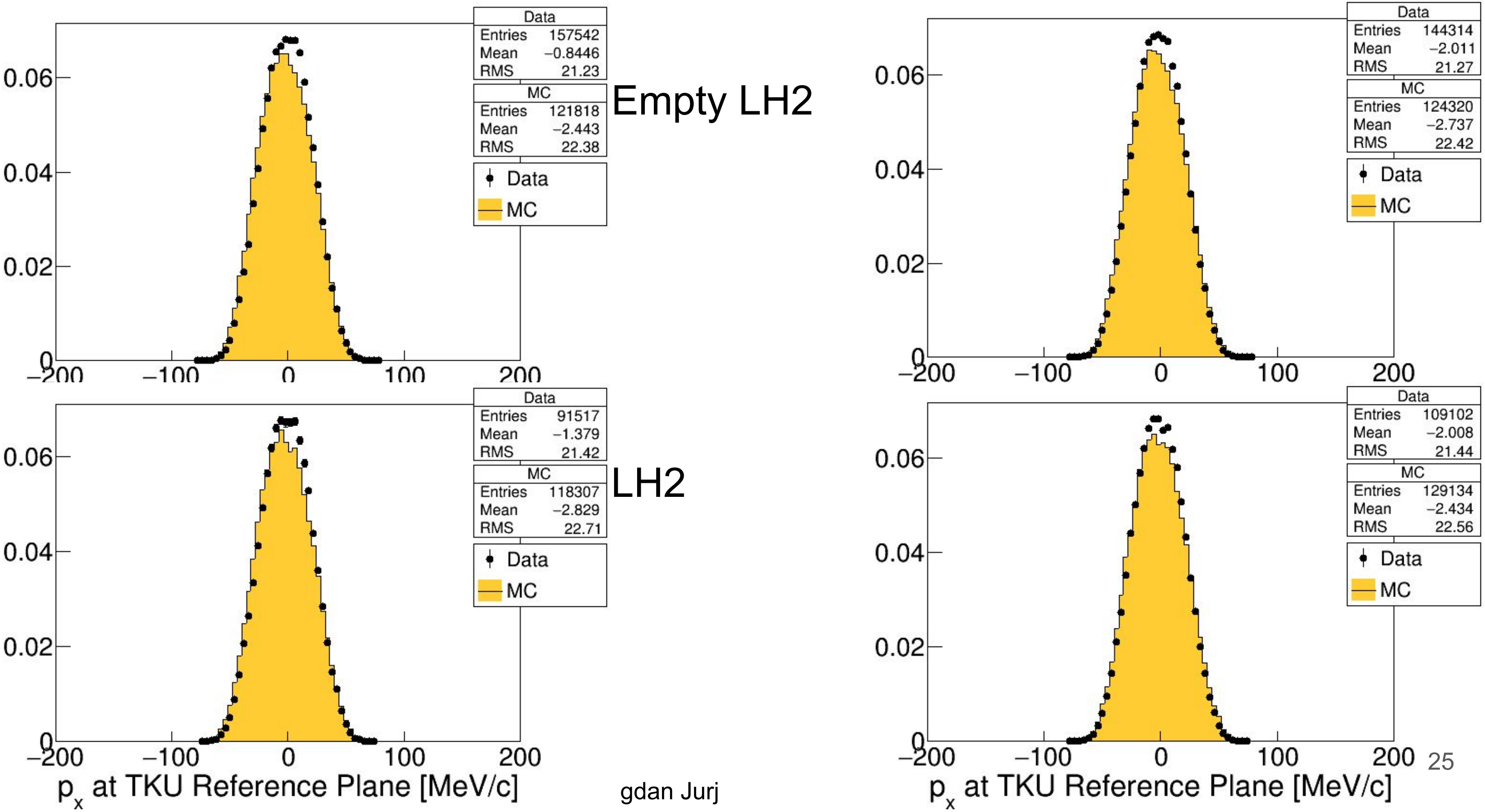
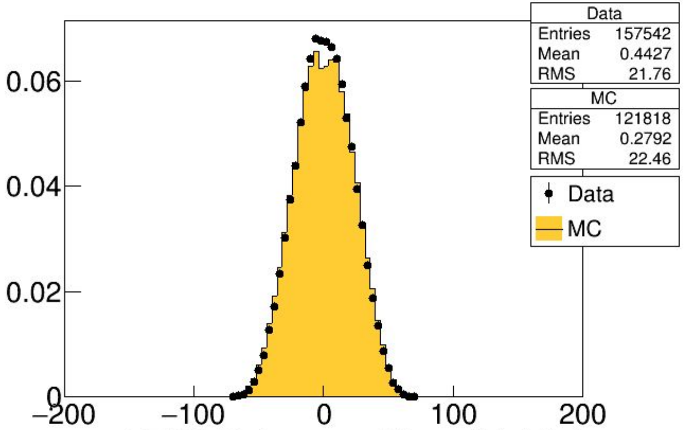
No abs

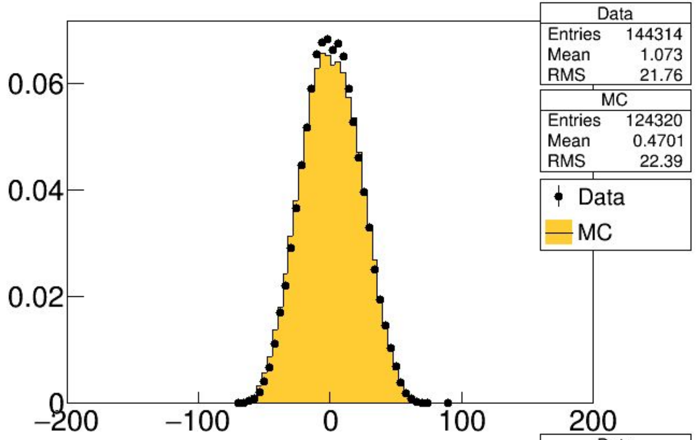


P_x TKD

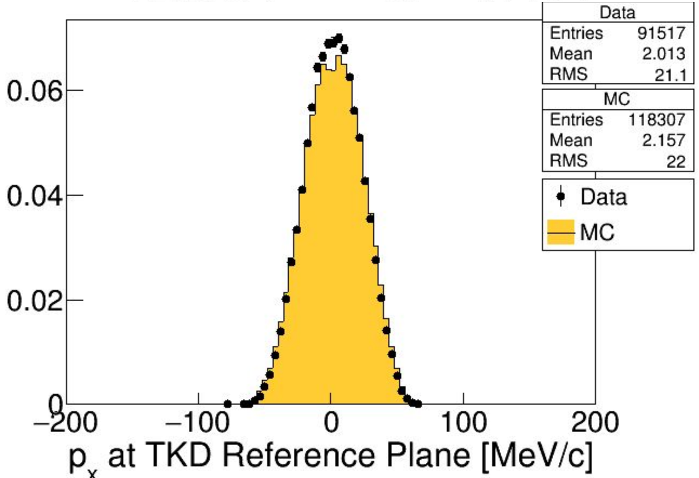
No abs



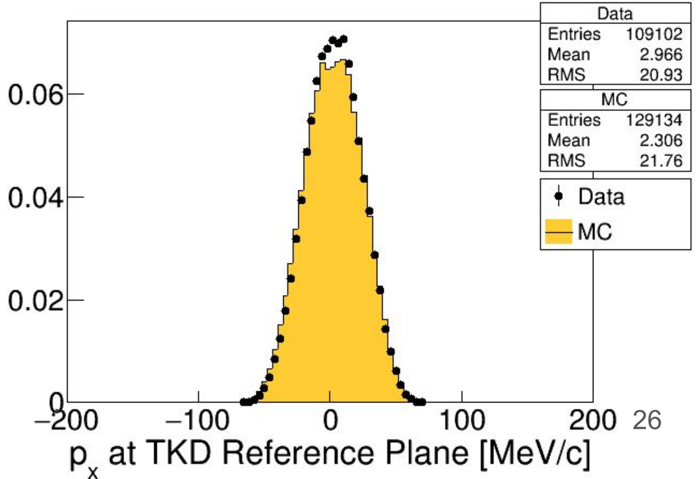
Empty LH2



LiH

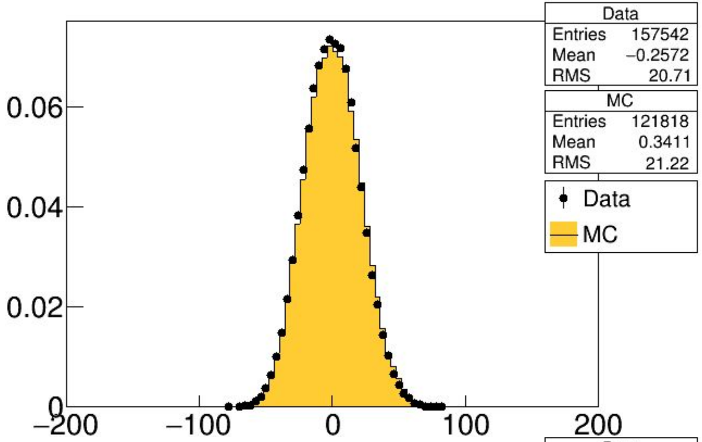


LH2



P_y TKU

No abs



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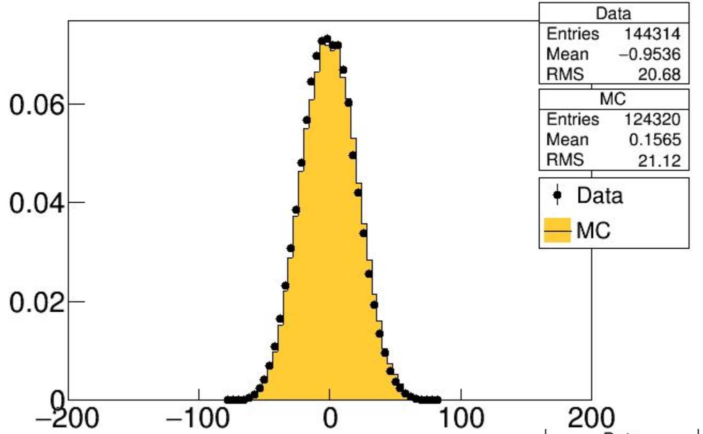

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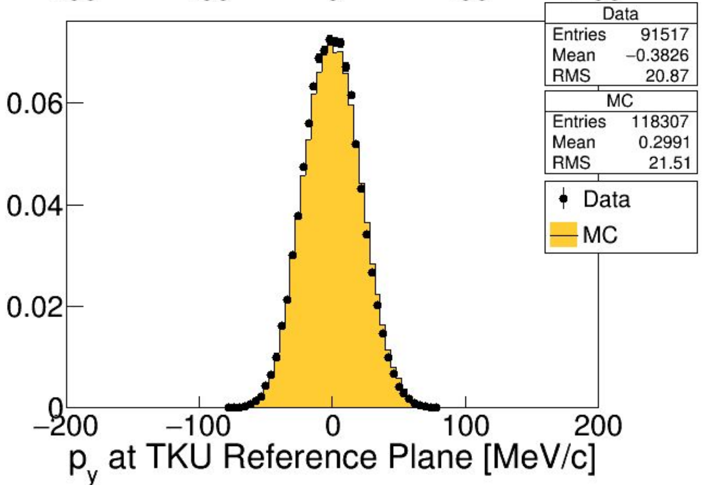
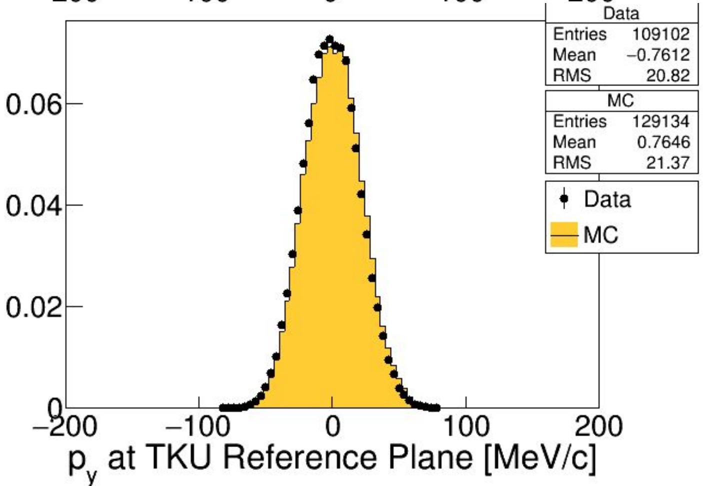


LH2



P_y TKD

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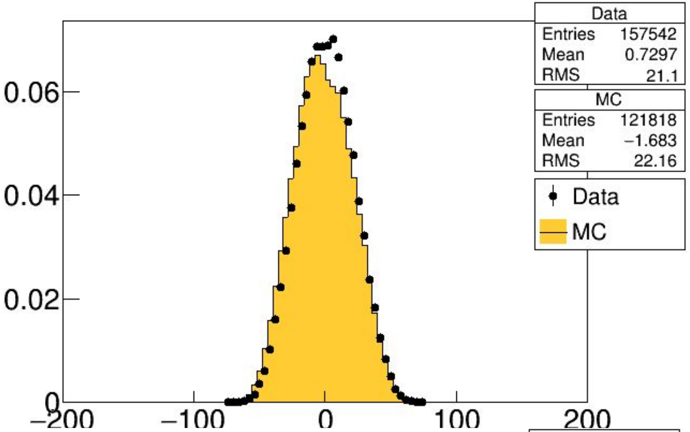
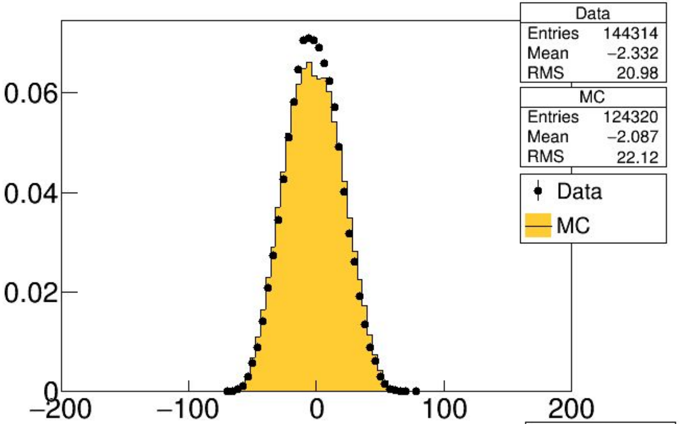
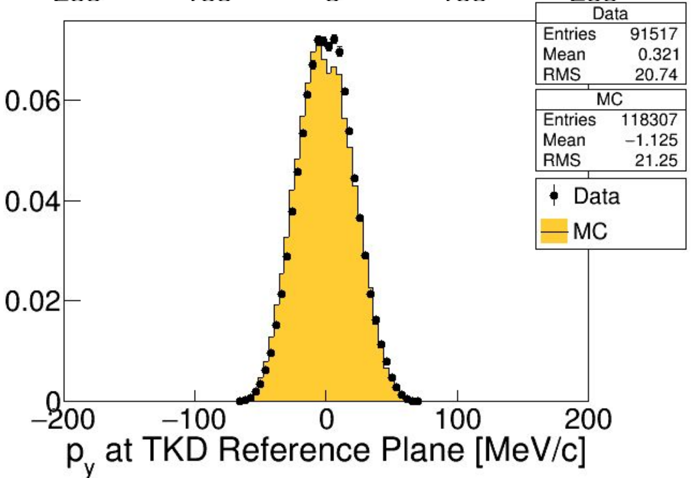
No abs



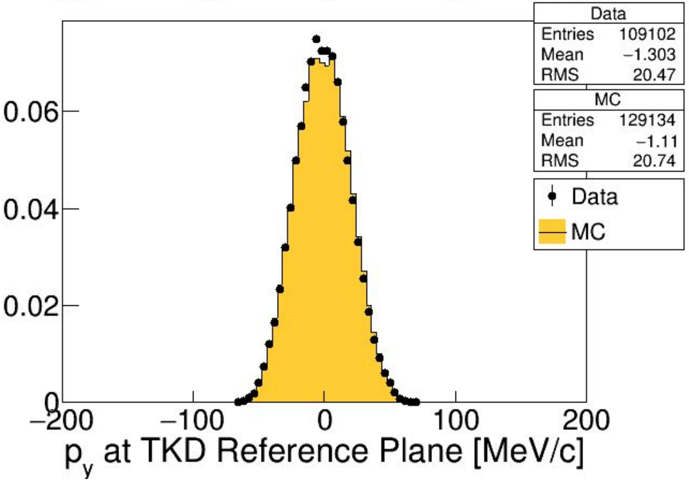
Empty LH2



LiH

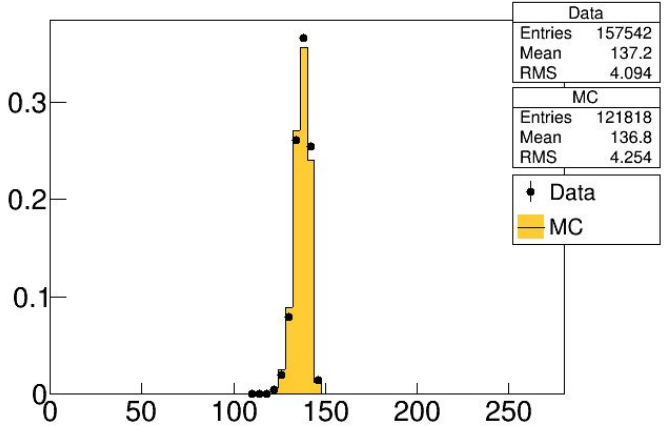


LH2

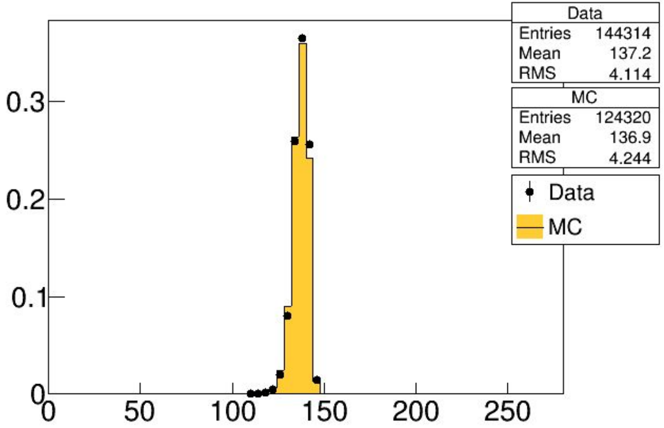


P_z TKU

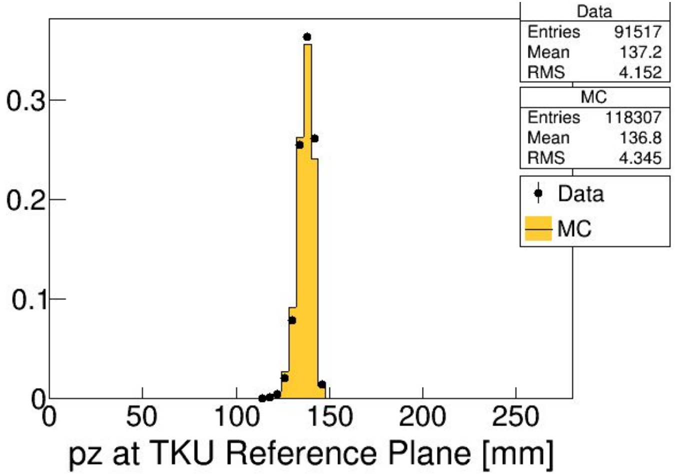
No abs



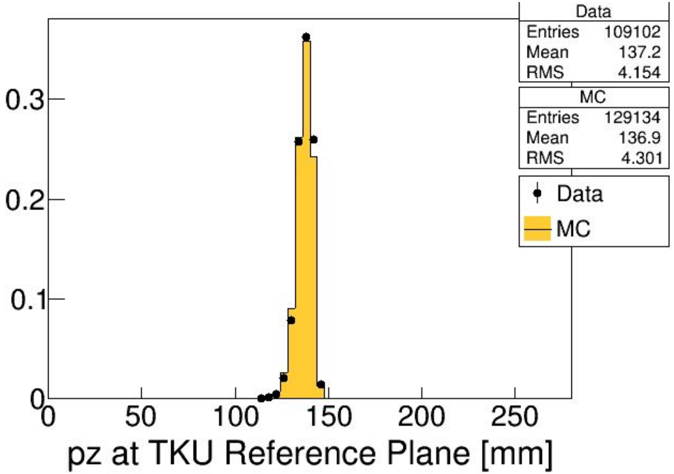
Empty LH2



LiH

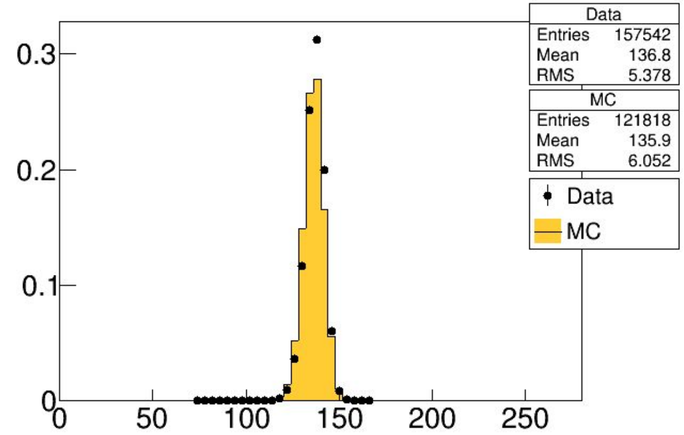


LH2

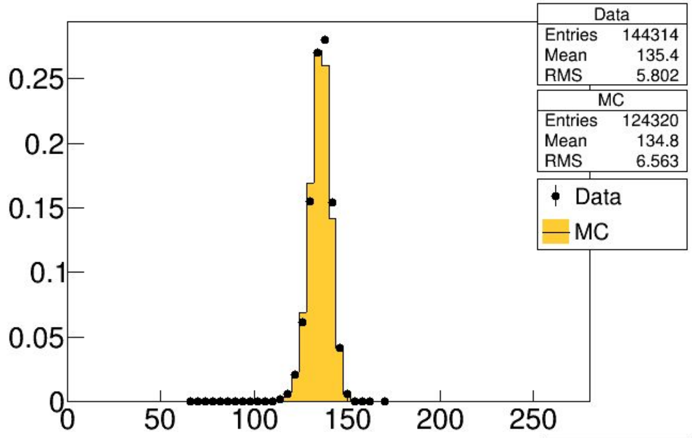


P_z TKD

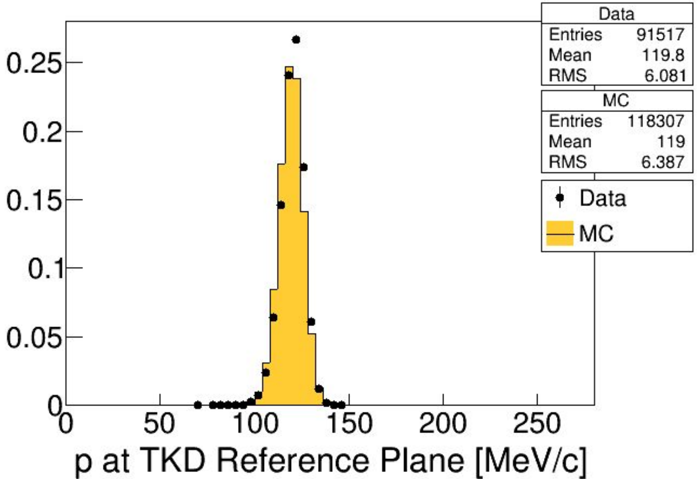
No abs



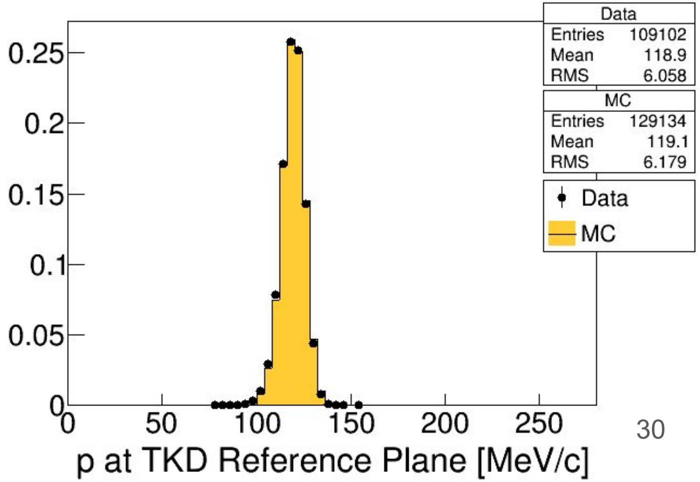
Empty LH2



LiH

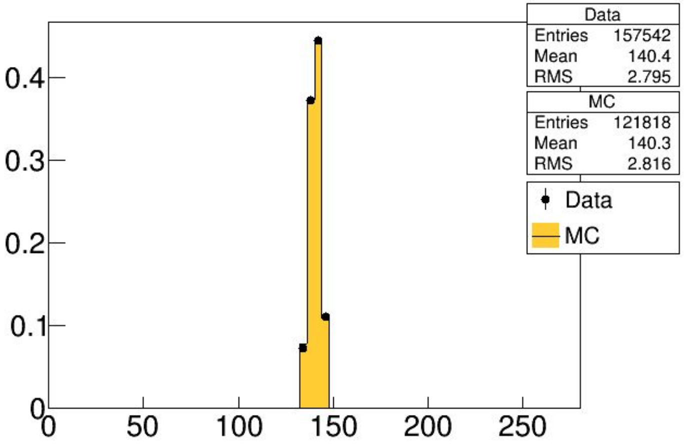


LH2

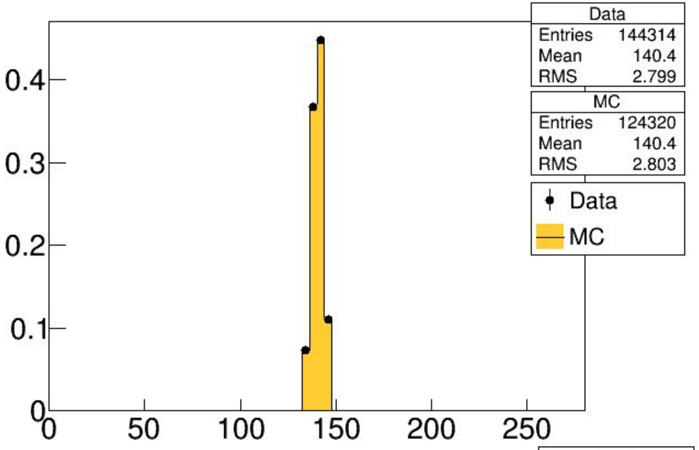


P TKU

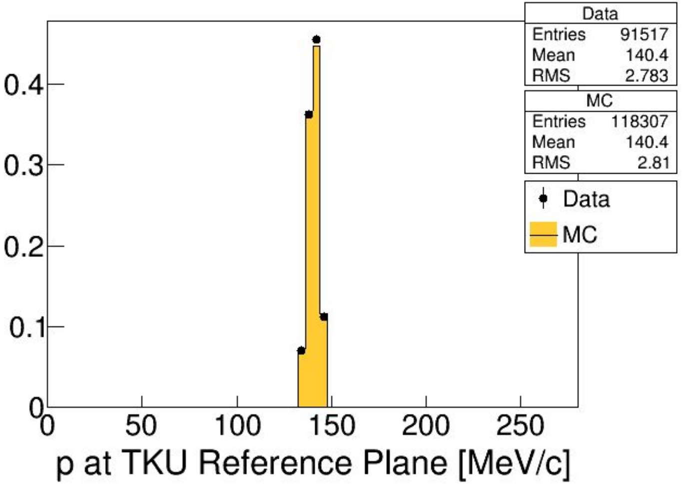
No abs



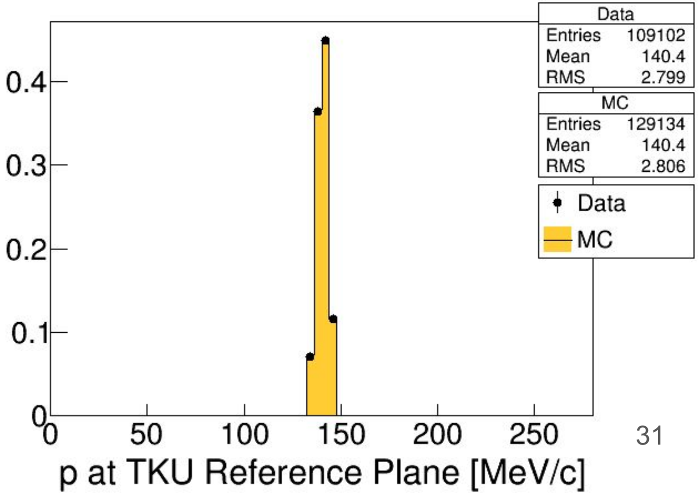
Empty LH2



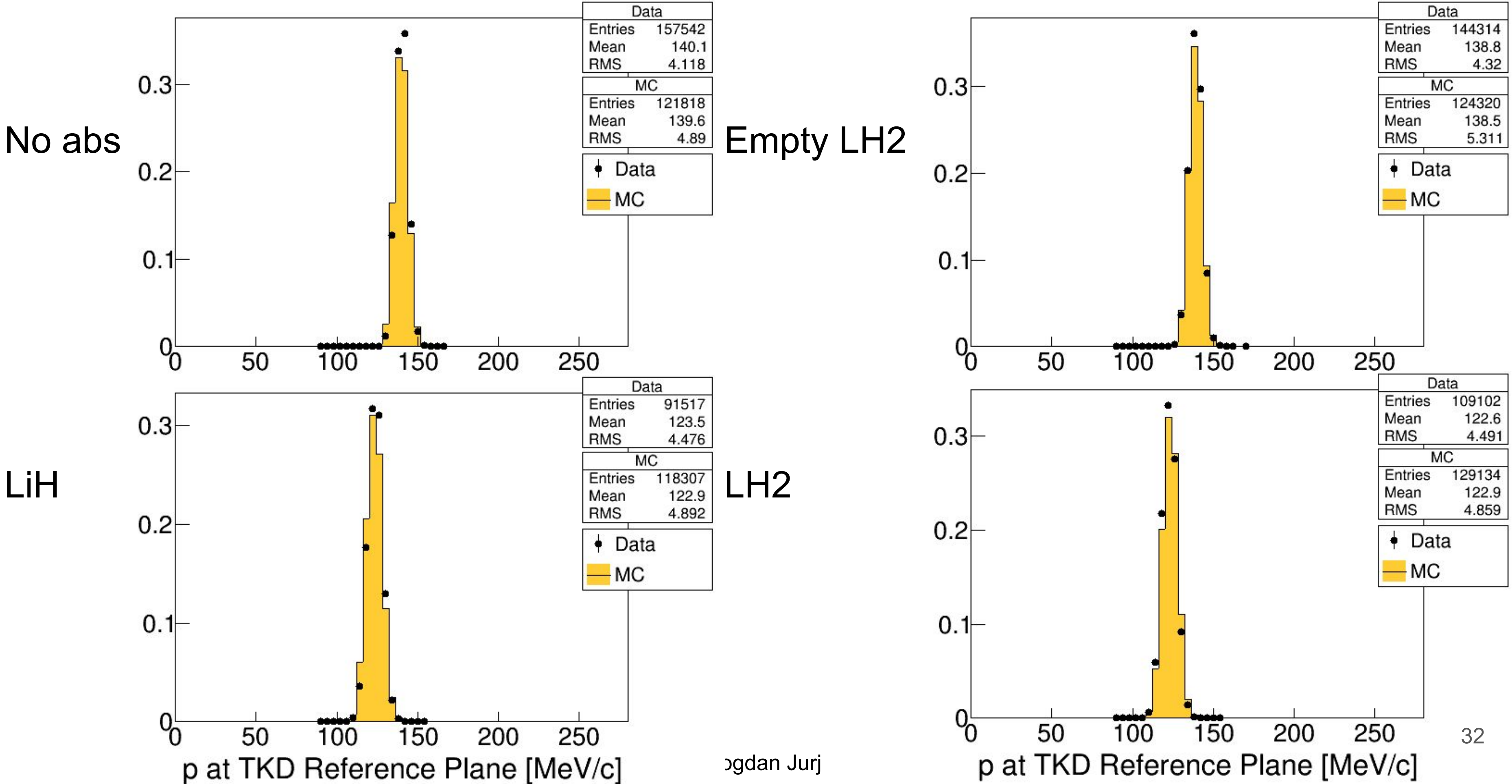
LiH



LH2



P TKD


No abs
Data
Entries 157542
Mean 140.1
RMS 4.118
MC
Entries 121818
Mean 139.6
RMS 4.89
Data
MC
Empty LH2
Data
Entries 144314
Mean 138.8
RMS 4.32
MC
Entries 124320
Mean 138.5
RMS 5.311
Data
MC
LiH
Data
Entries 91517
Mean 123.5
RMS 4.476
MC
Entries 118307
Mean 122.9
RMS 4.892
Data
MC
LH2
Data
Entries 109102
Mean 122.6
RMS 4.491
MC
Entries 129134
Mean 122.9
RMS 4.859
Data
MC
0.3
0.2
0.1
0
0
50
100
150
200
250
p at TKD Reference Plane [MeV/c]

Parent distributions optics

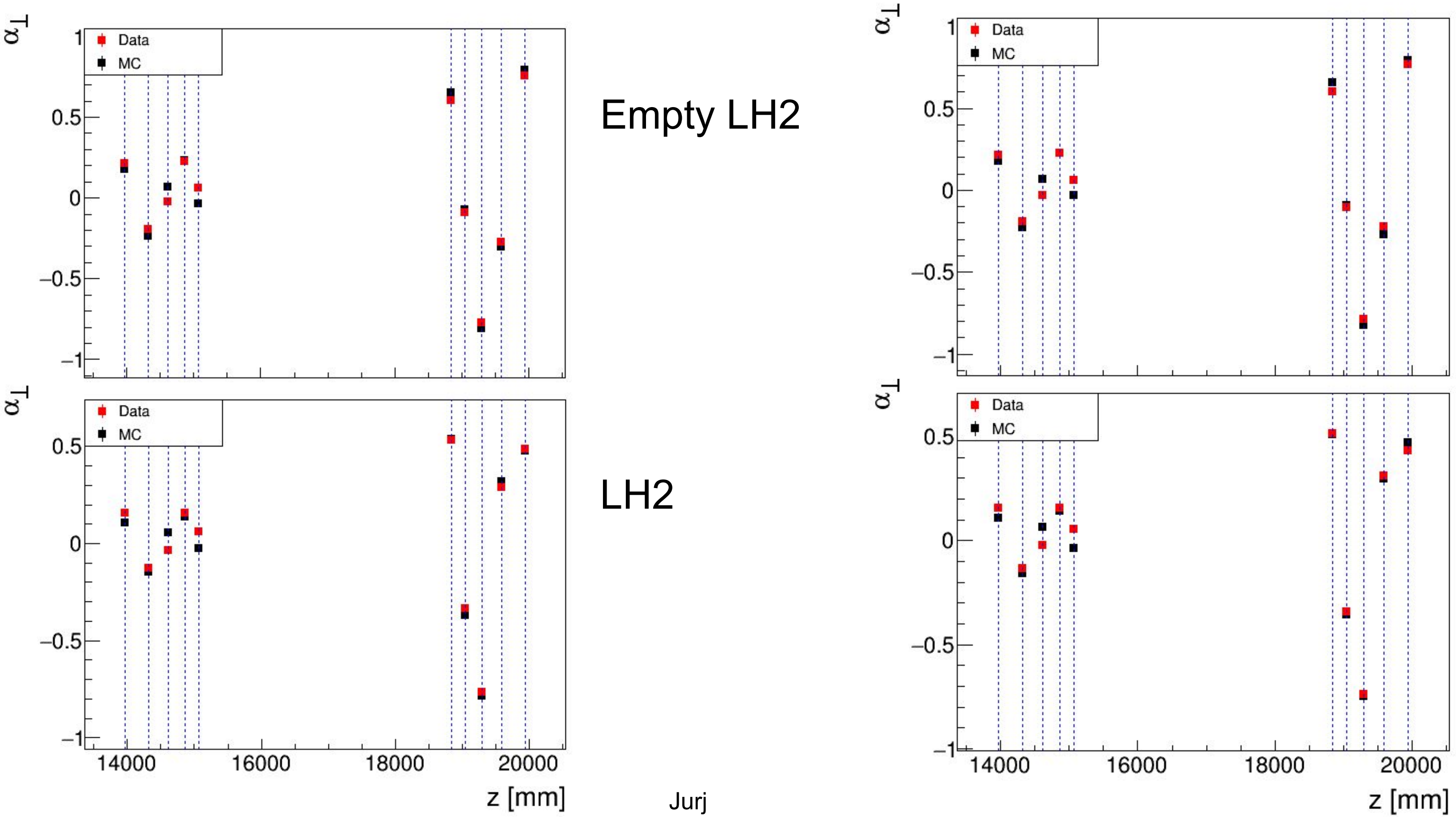
Alpha

No abs

Empty LH2

LiH

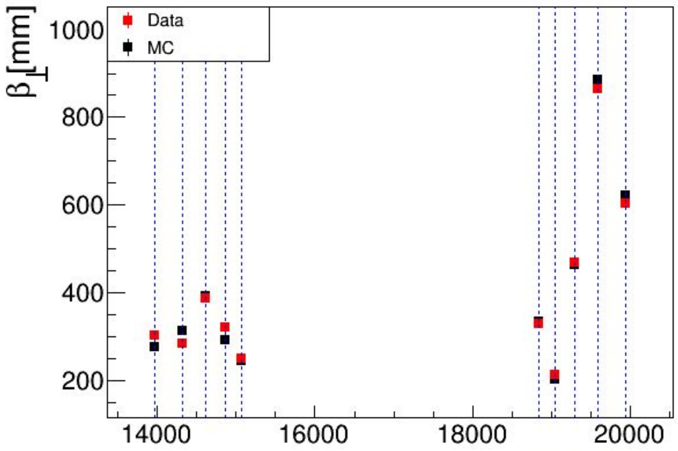
LH2



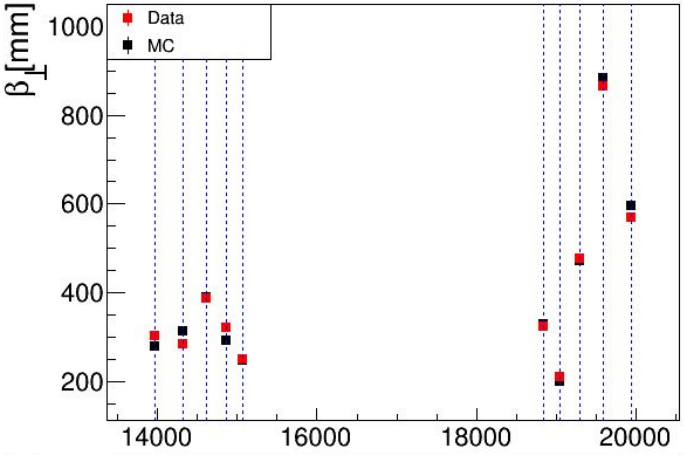
Jurj

Beta

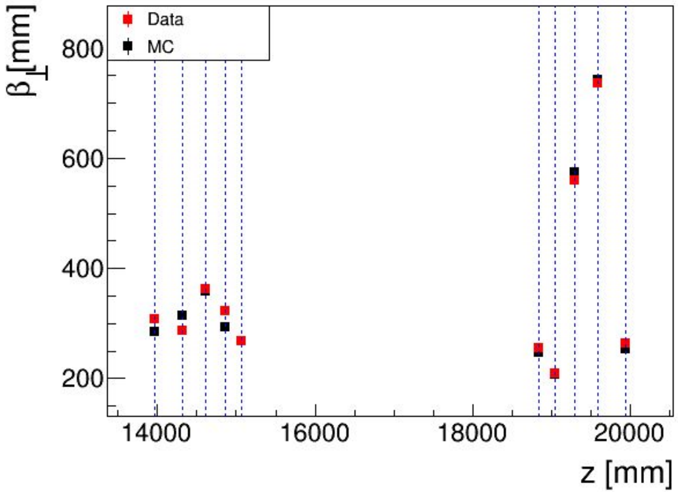
No abs



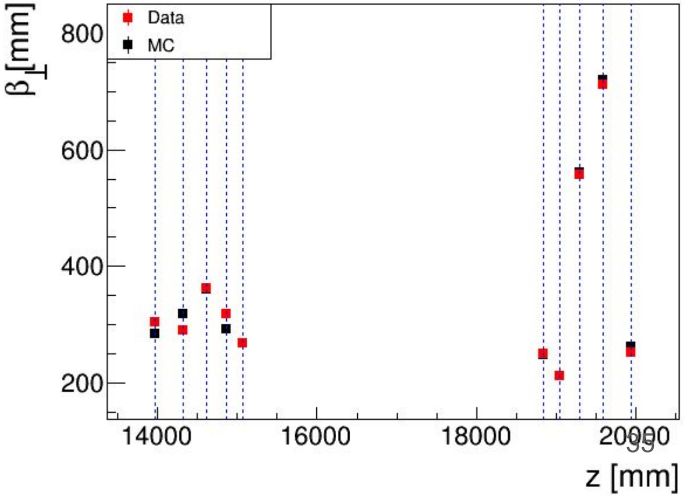
Empty LH2



LiH

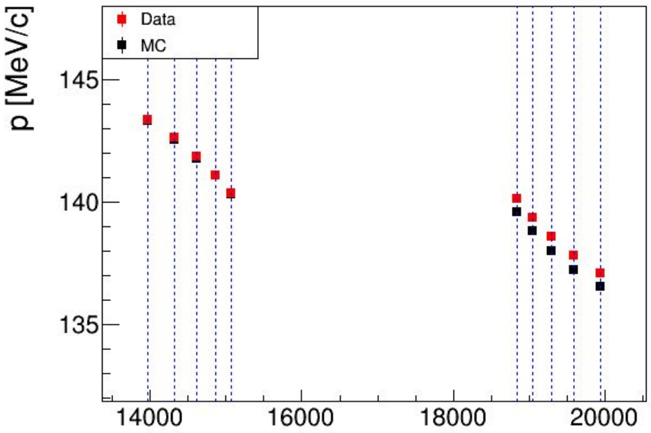


LH2

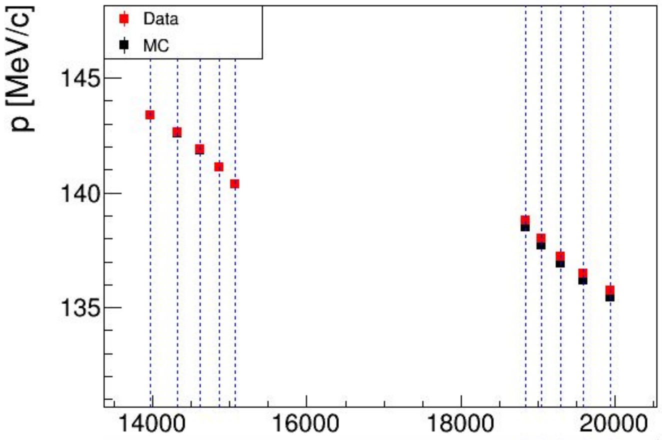


Momentum

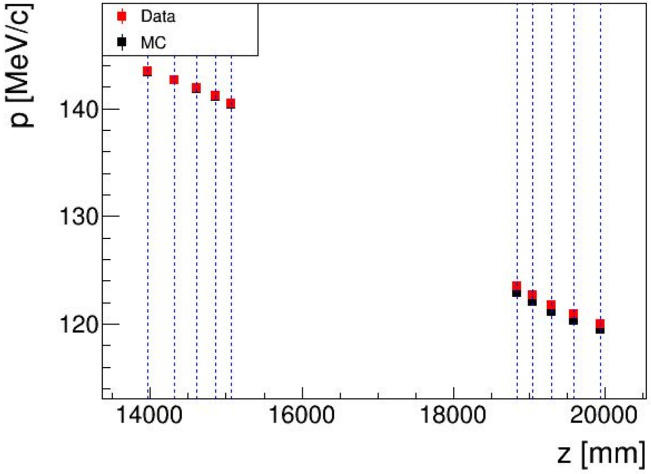
No abs



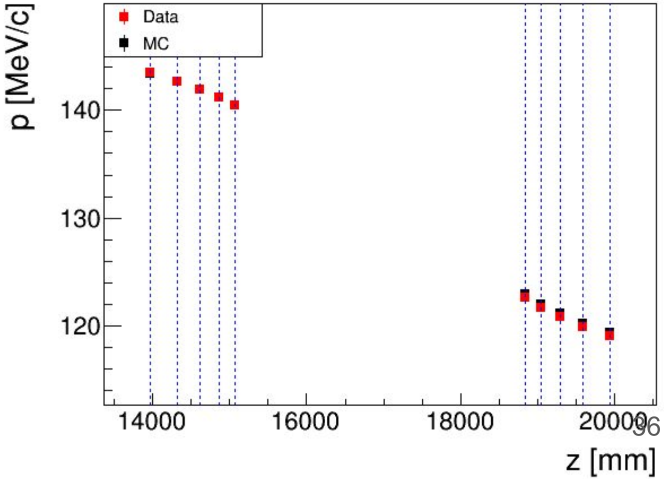
Empty LH2



LiH

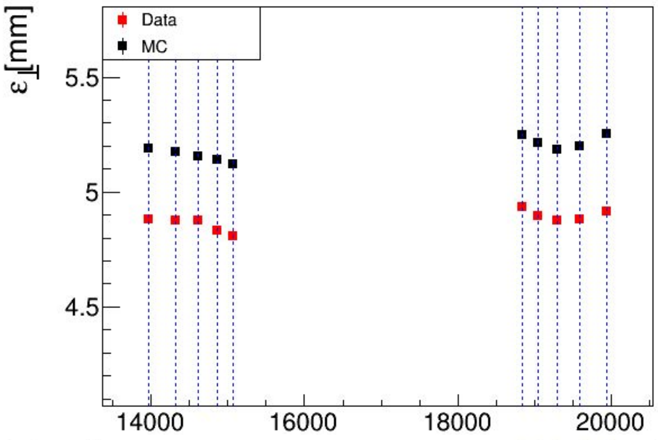


LH2

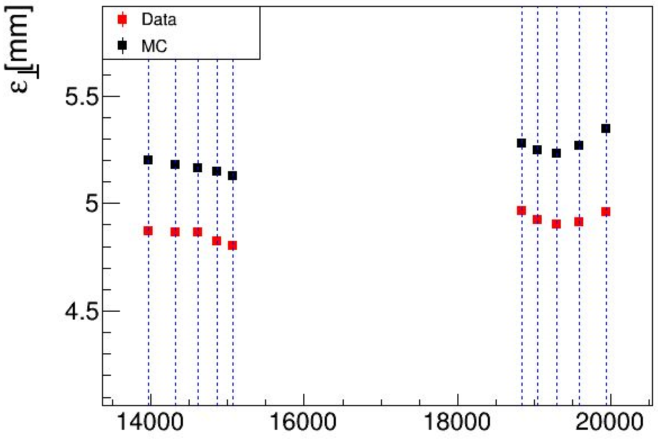


Emittance

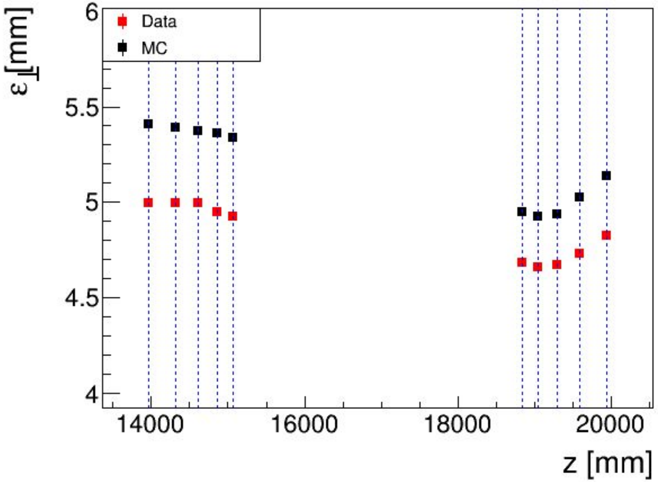
No abs



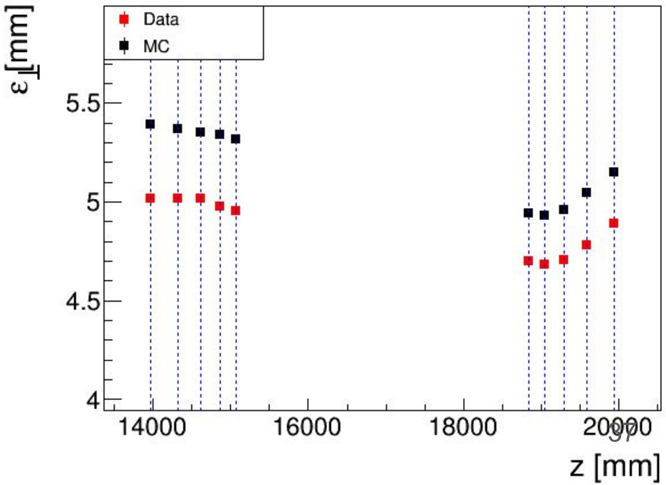
Empty LH2



LiH

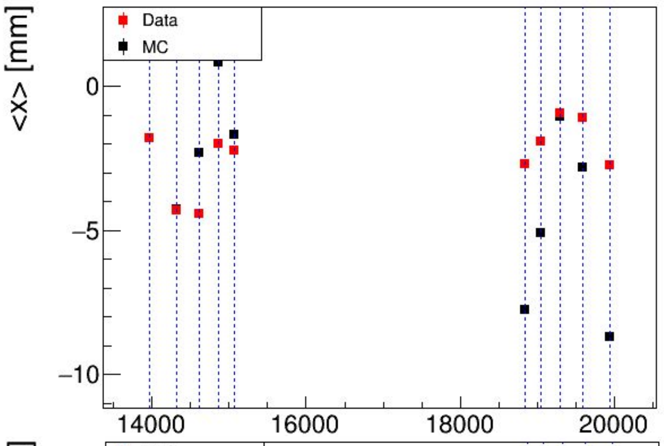


LH2

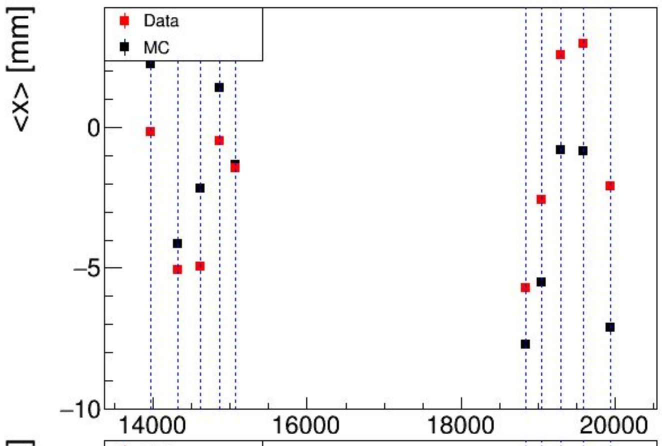


Mean X

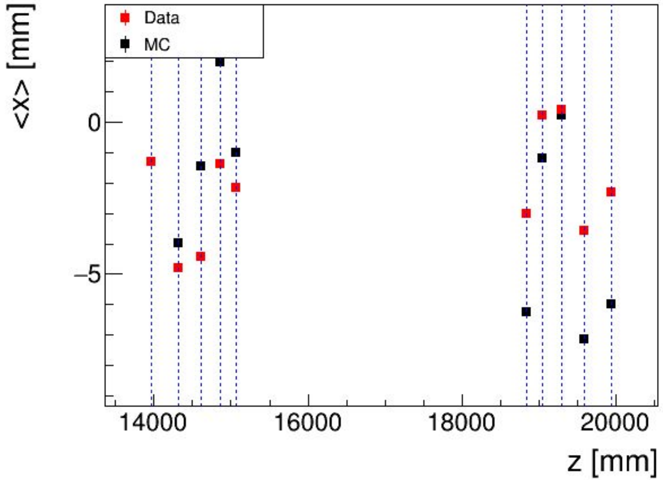
No abs



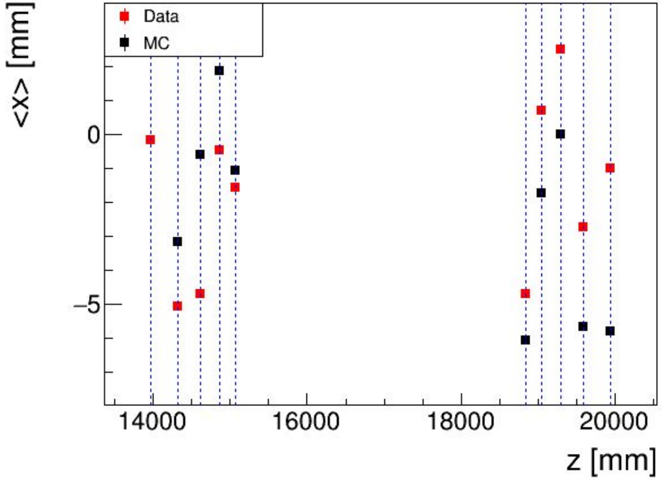
Empty LH2



LiH

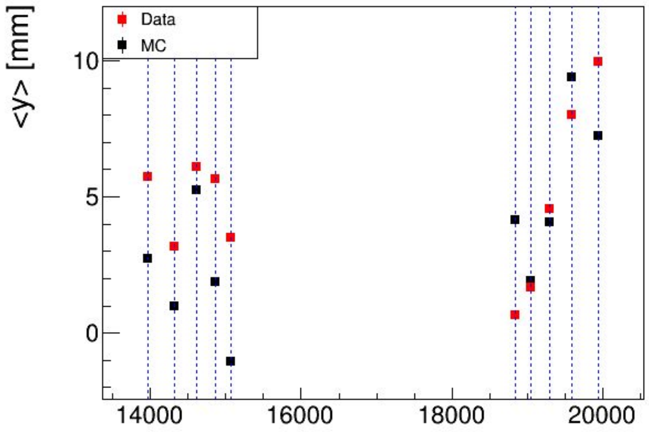


LH2

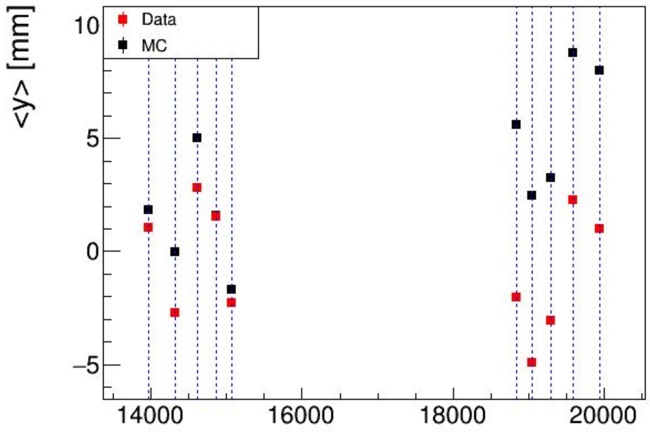


Mean Y

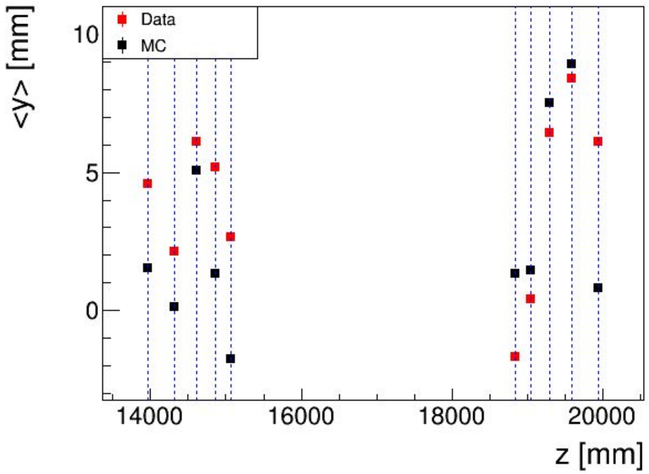
No abs



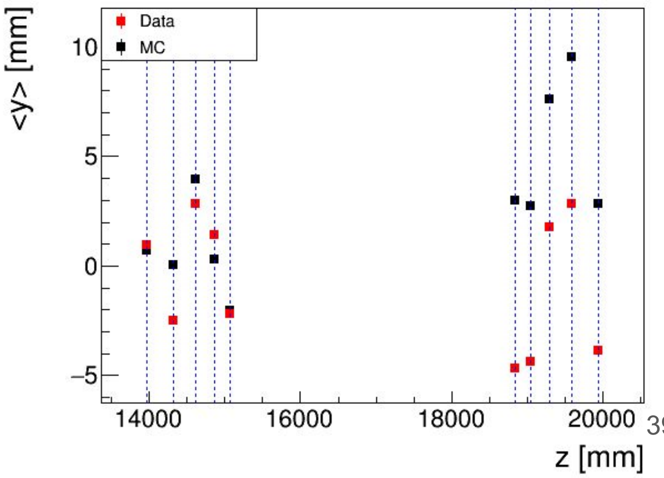
Empty LH2



LiH

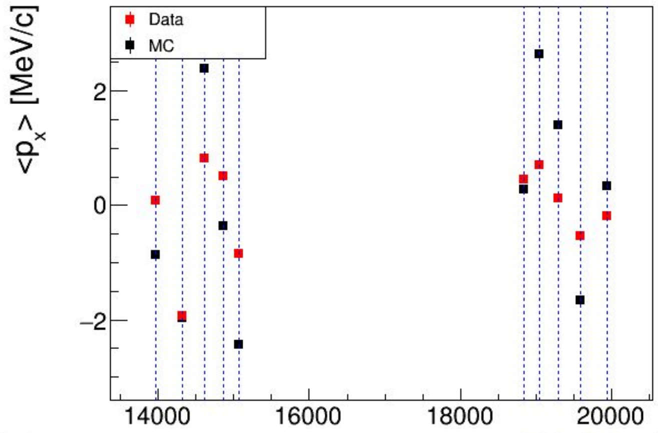


LH2

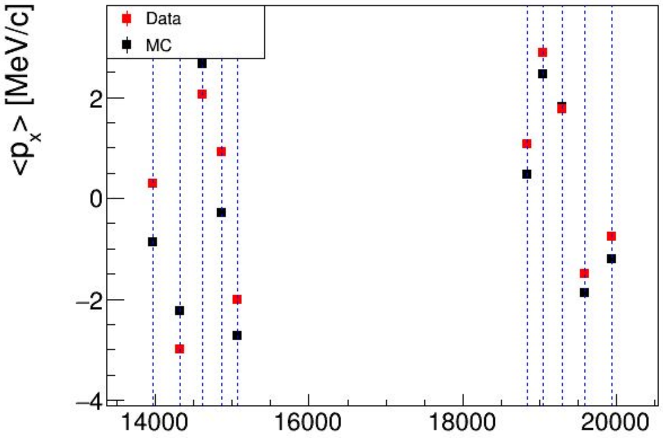


Mean P_x

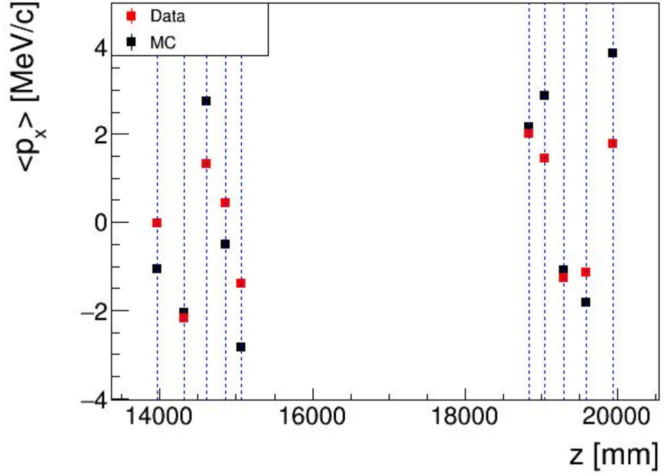
No abs



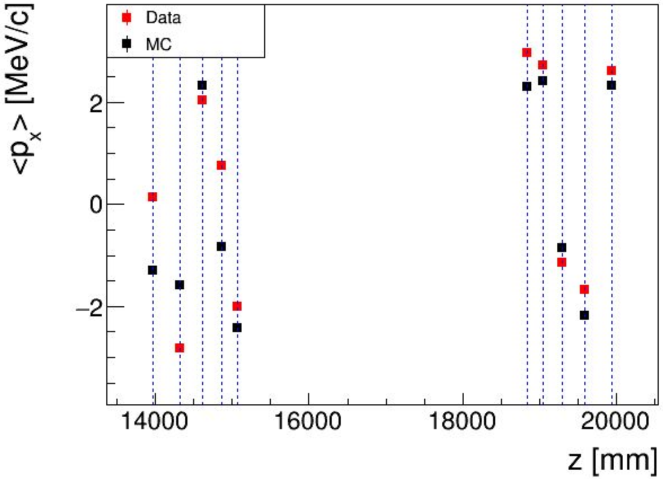
Empty LH2



LiH

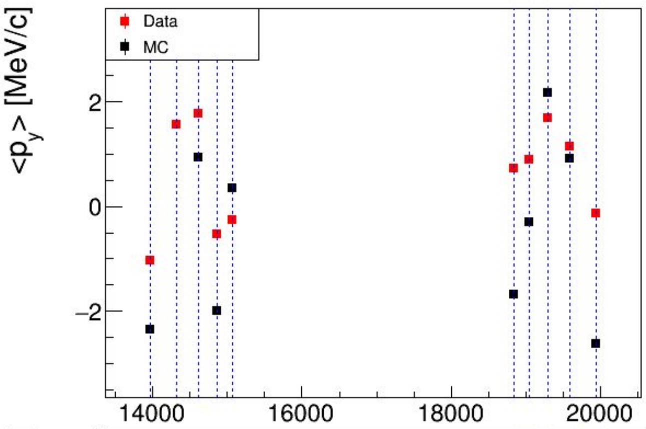


LH2

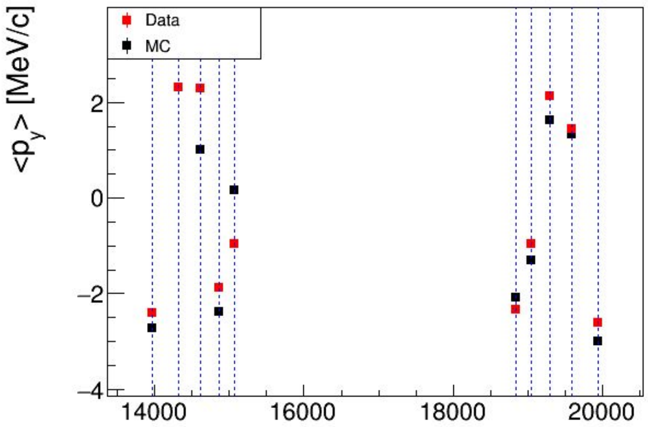


Mean P_y

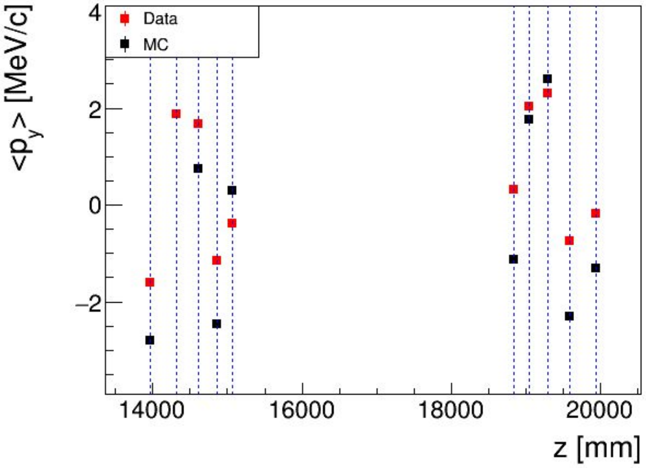
No abs



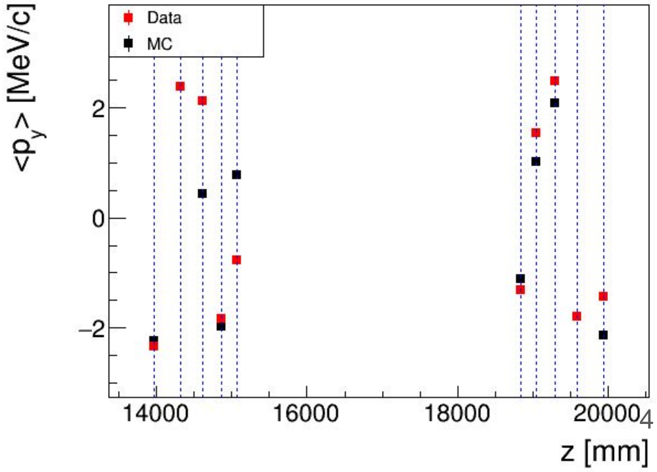
Empty LH2



LiH



LH2



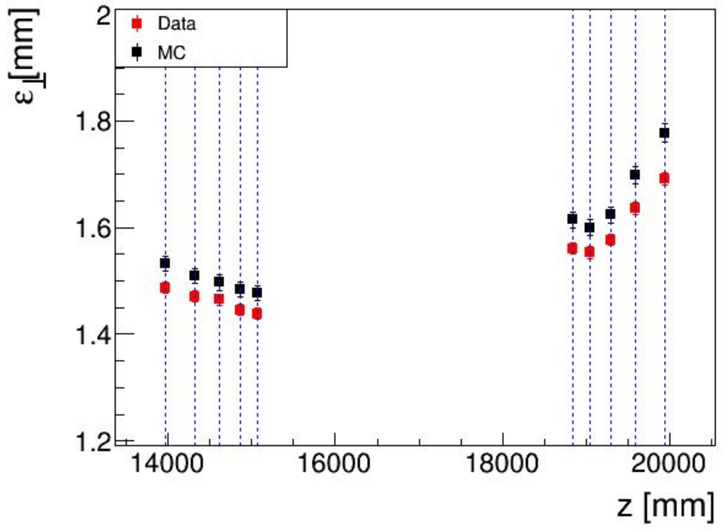
Sampled beams optics

Parent beams have optics discrepancies both in TKU and TKD

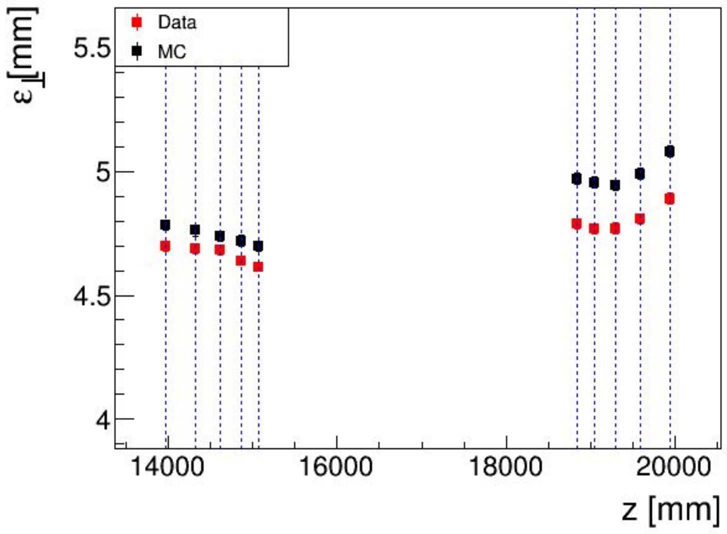
Beam sampling is supposed to largely iron out discrepancies in TKU

Next: optics of two sampled beams from 6-140 No absorber analysis

Emittance

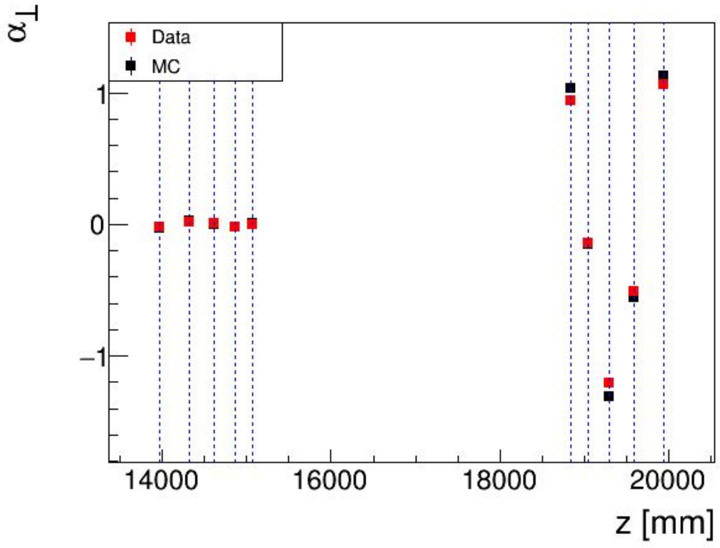


~ 1.5 mm beam

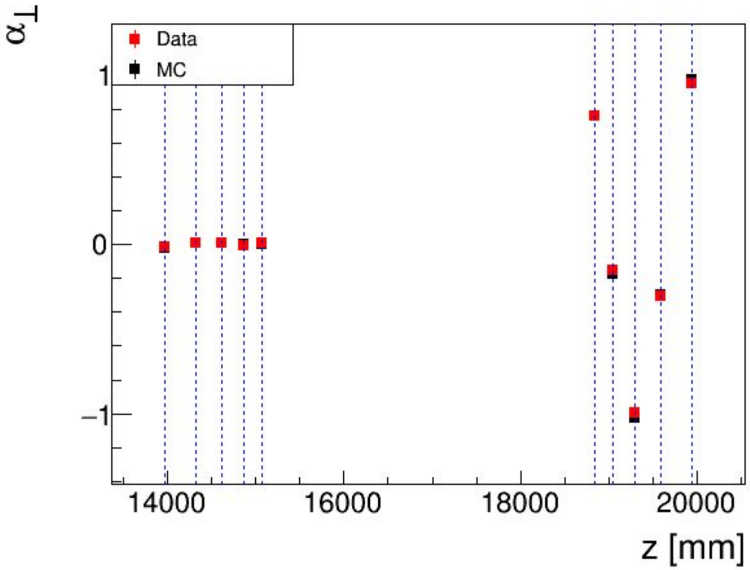


~ 4.7 mm beam

Alpha

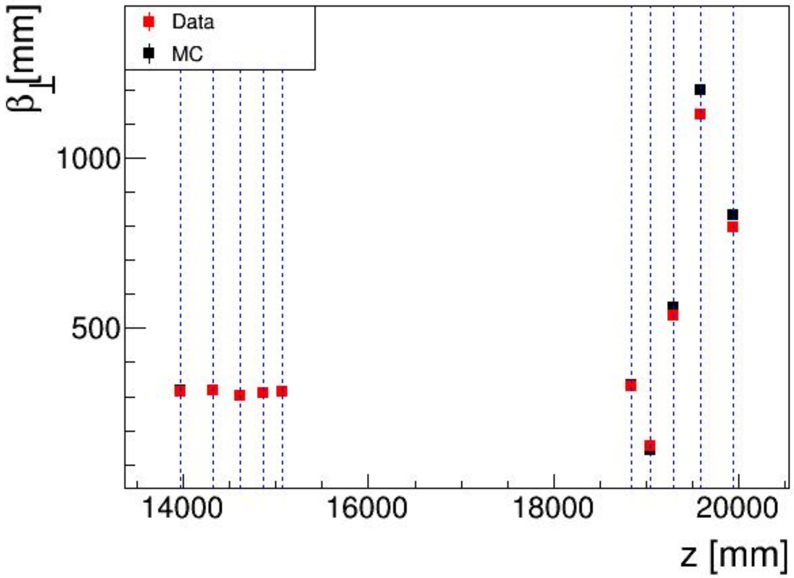


~ 1.5 mm beam

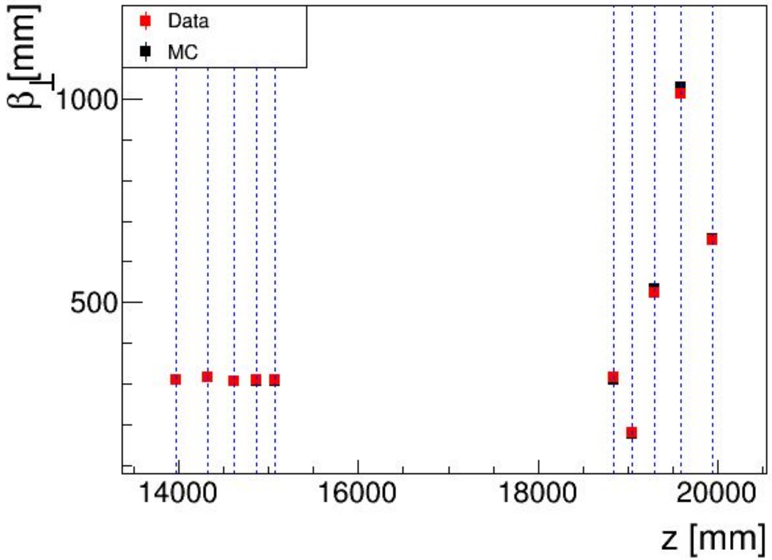


~ 4.7 mm beam

Beta

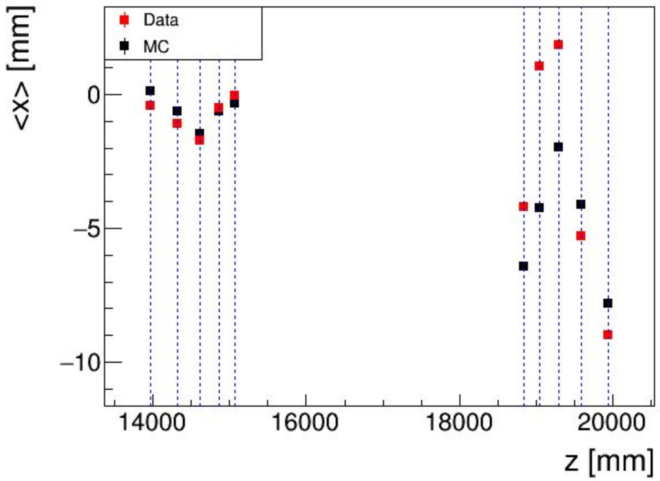


~ 1.5 mm beam

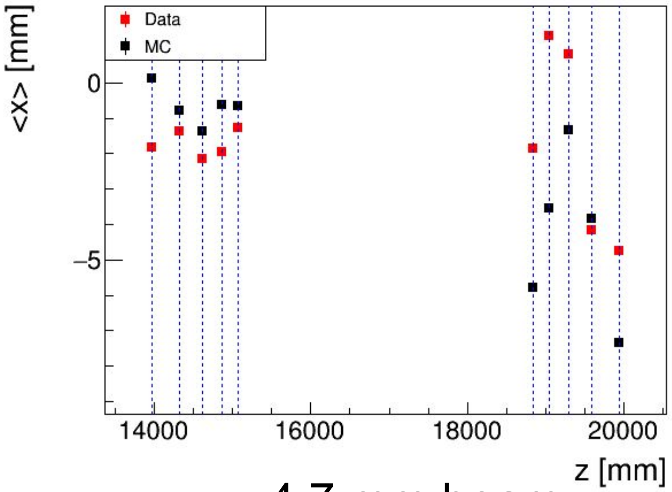


~ 4.7 mm beam

Mean X



~ 1.5 mm beam

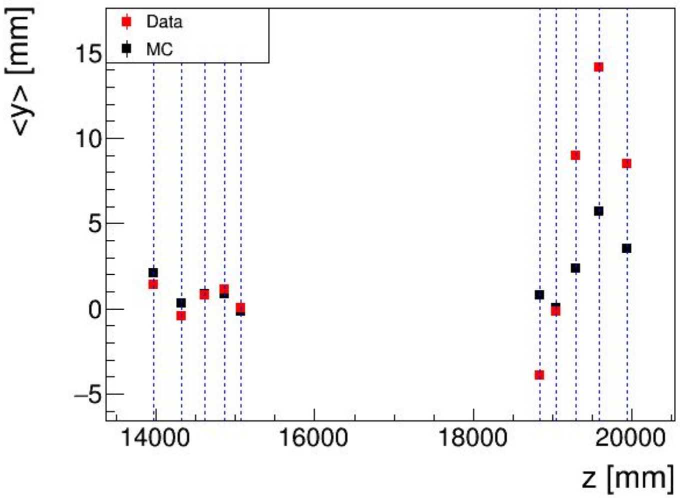


~ 4.7 mm beam

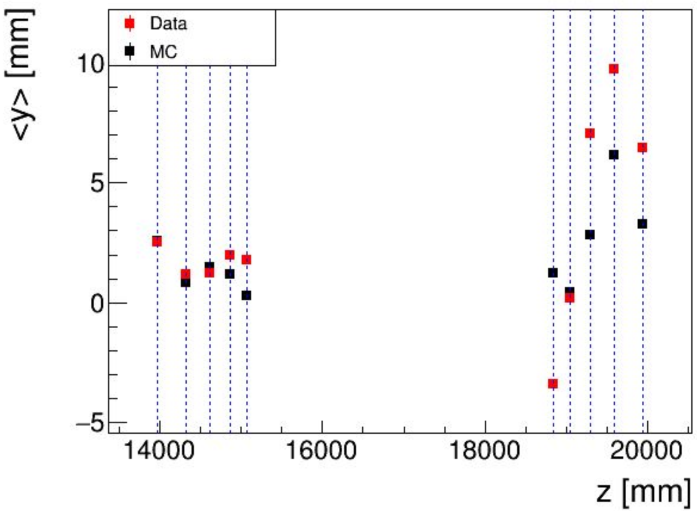
TKU agreement better for lower emittance beams

TKD discrepancies indicators of misalignment

Mean Y



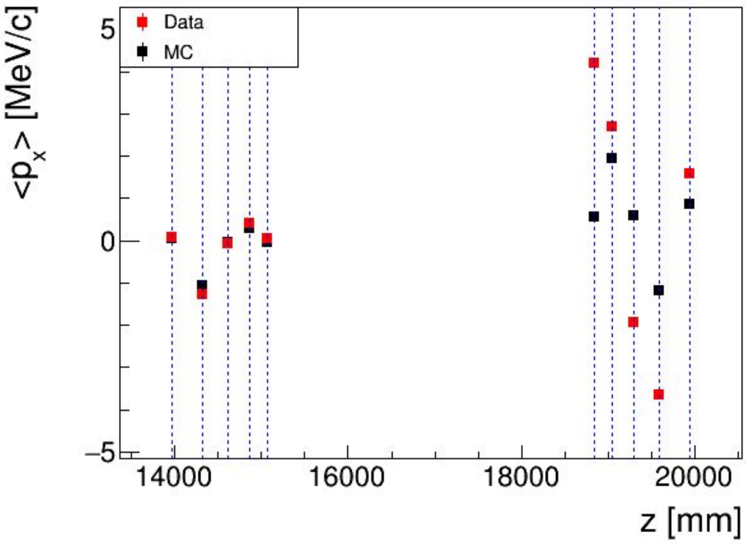
~ 1.5 mm beam



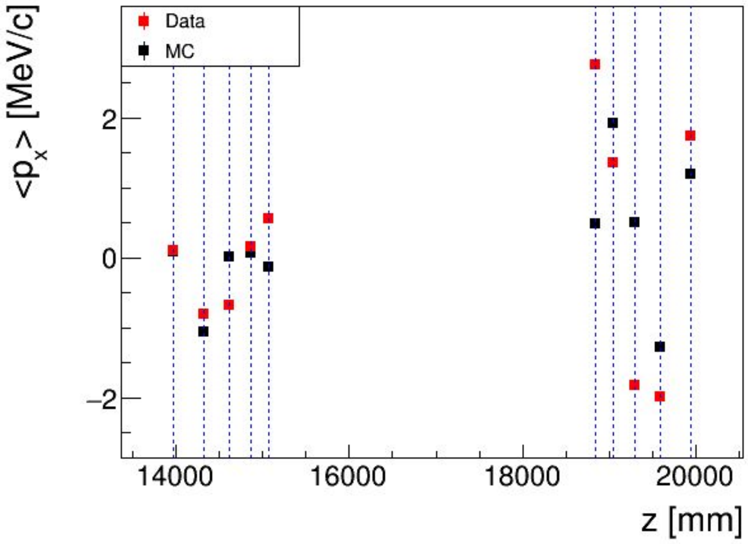
~ 4.7 mm beam

Misalignment generates differences in the amplitude and frequency of TKD oscillations

Mean P_x

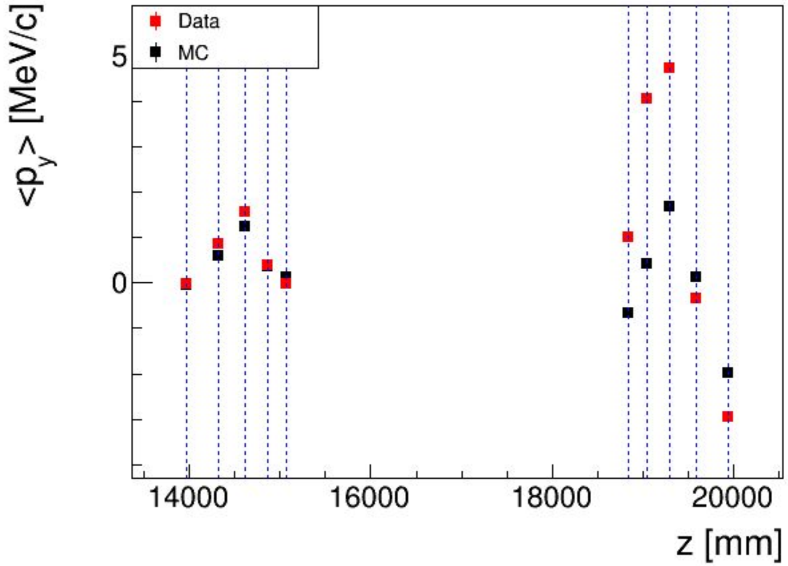


~ 1.5 mm beam

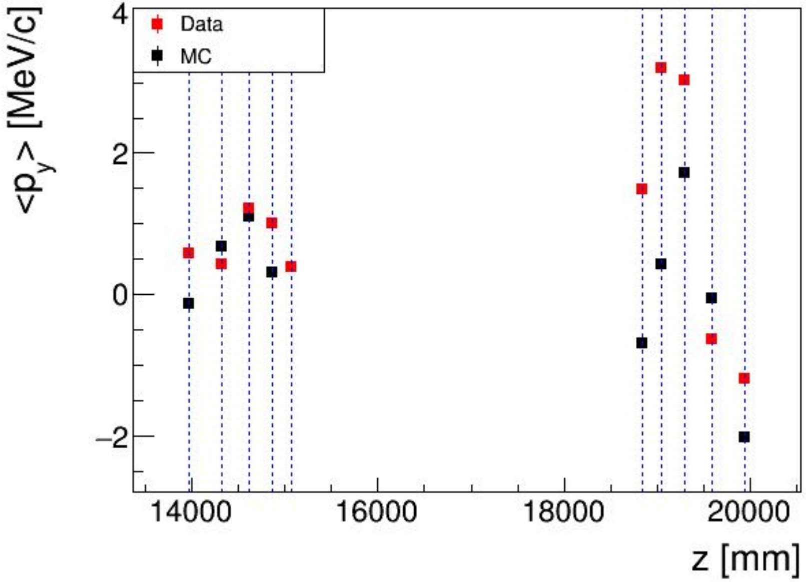


~ 4.7 mm beam

Mean P_y



~ 1.5 mm beam



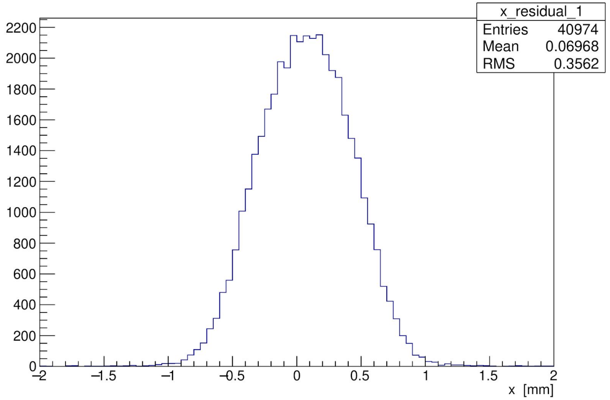
~ 4.7 mm beam

Detector resolution

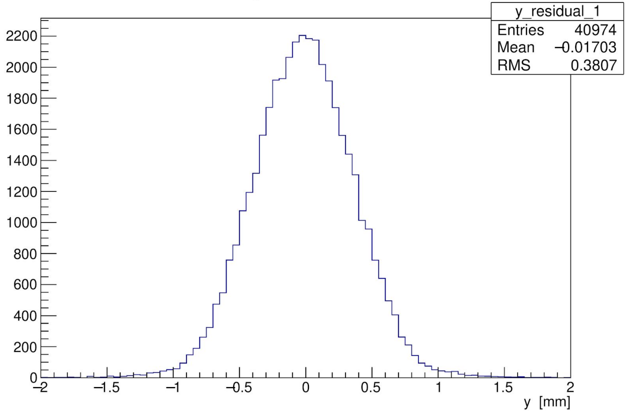
- Simulated resolutions for both TKU and TKD
- Resolutions based on *No absorber* 6-140 MC are presented next

TKU res

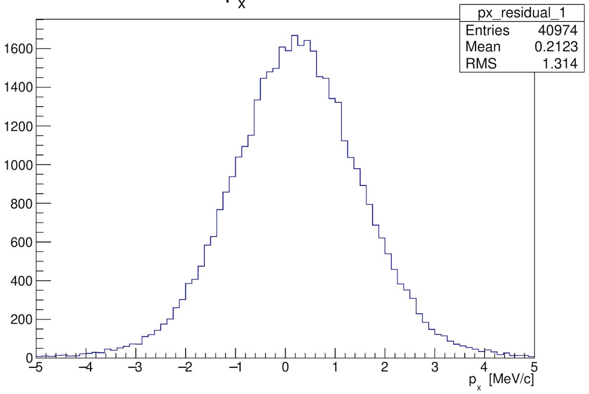
x residuals



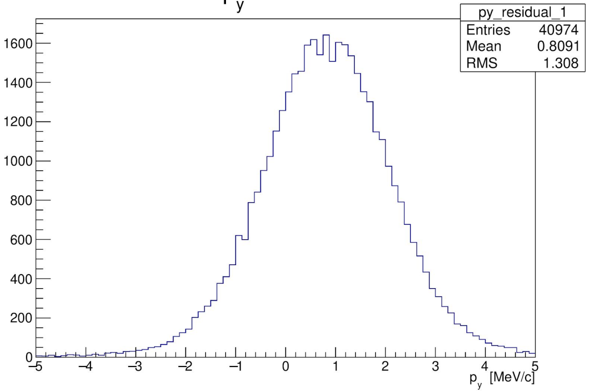
y residuals



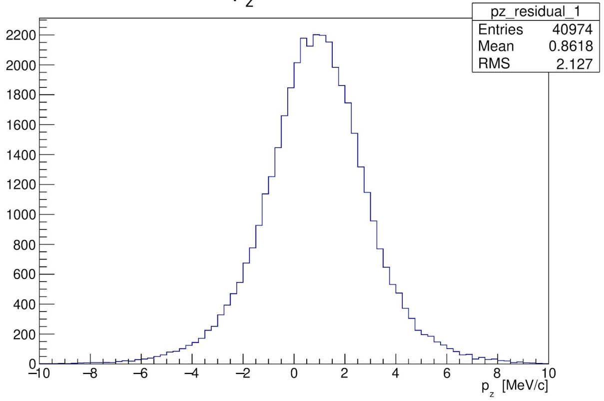
p_x residuals



p_y residuals

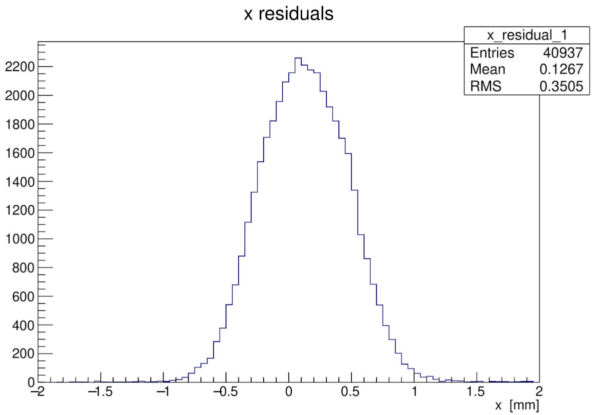


p_z residuals

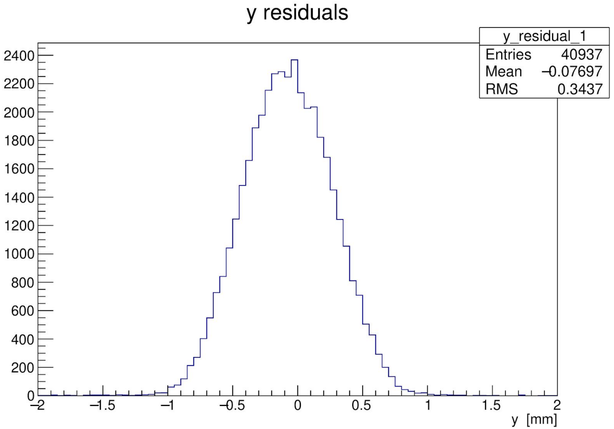


Paul Bogdan Jurj

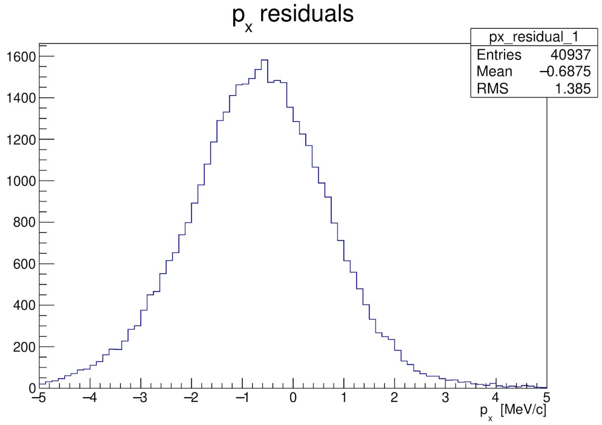
TKD res



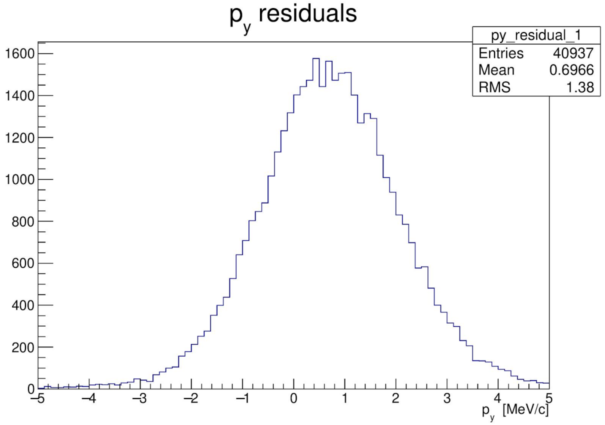
x residuals
x_residual_1
Entries 40937
Mean 0.1267
RMS 0.3505
x [mm]



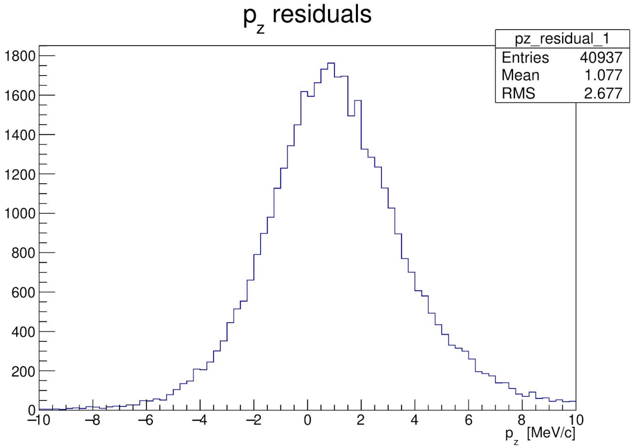
y residuals
y_residual_1
Entries 40937
Mean −0.07697
RMS 0.3437
y [mm]



p_x residuals
px_residual_1
Entries 40937
Mean −0.6875
RMS 1.385
p_x [MeV/c]



p_y residuals
py_residual_1
Entries 40937
Mean 0.6966
RMS 1.38
p_y [MeV/c]

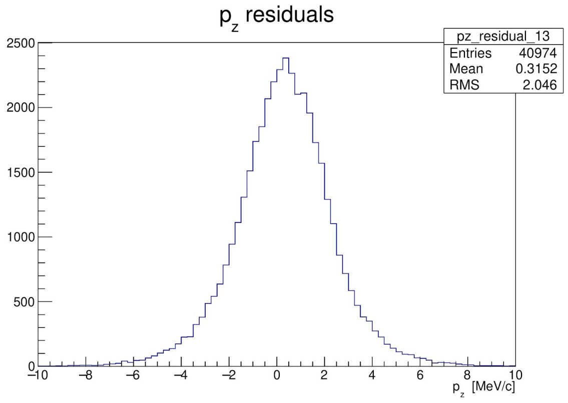


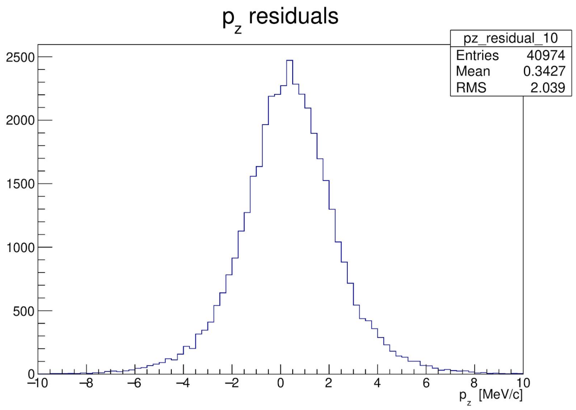
p_z residuals
pz_residual_1
Entries 40937
Mean 1.077
RMS 2.677
p_z [MeV/c]

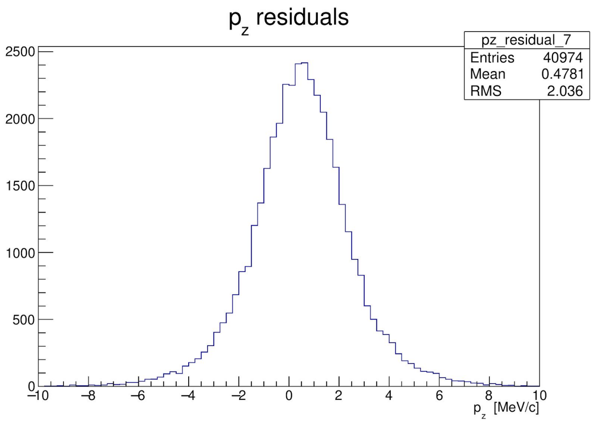
Detector resolution

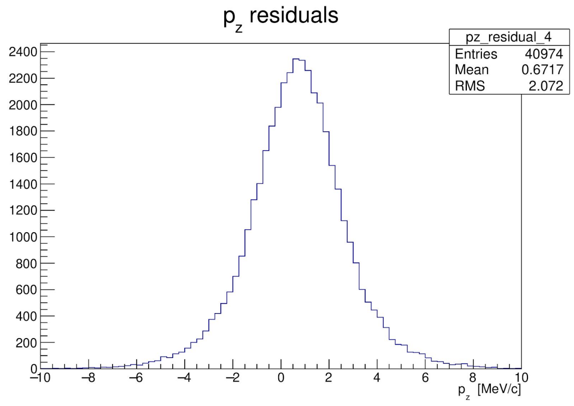
- Small systematic bias observed in momentum reconstruction
- Longer tails in p_z residual

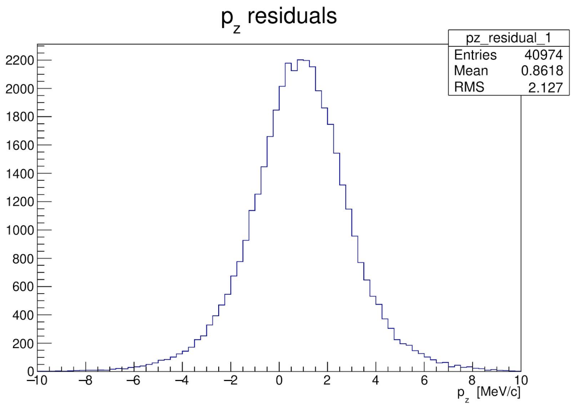
TKU P_z res











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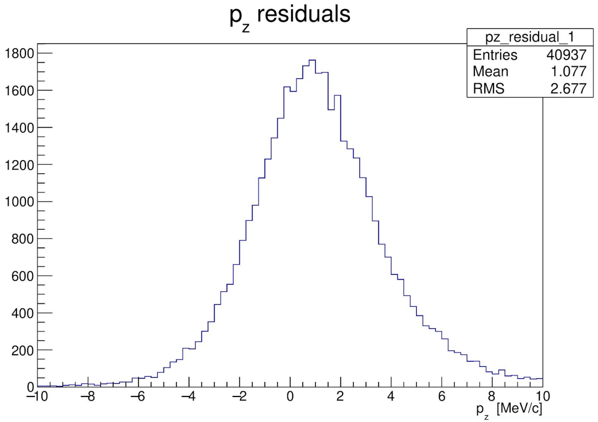
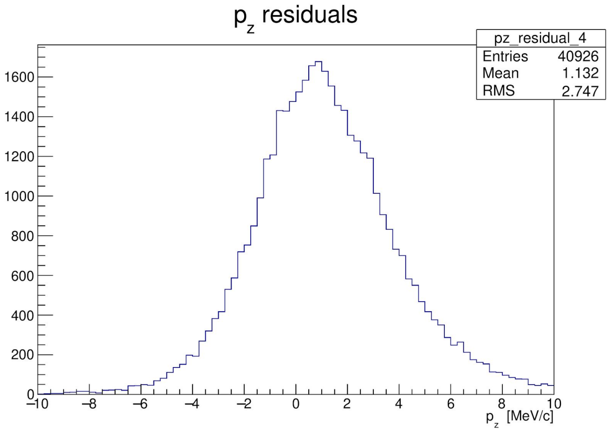
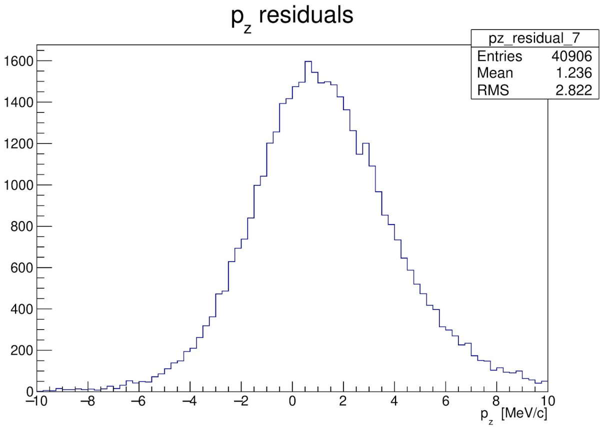
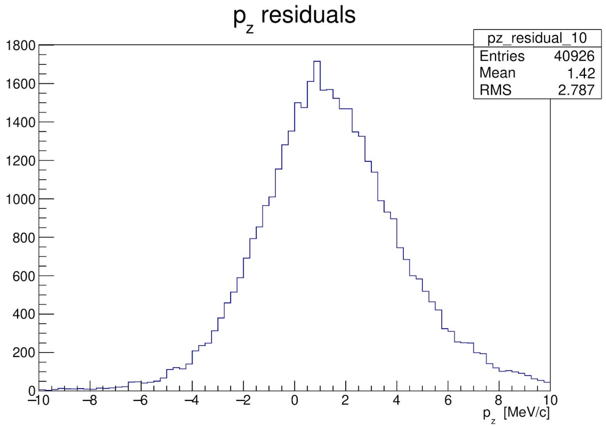
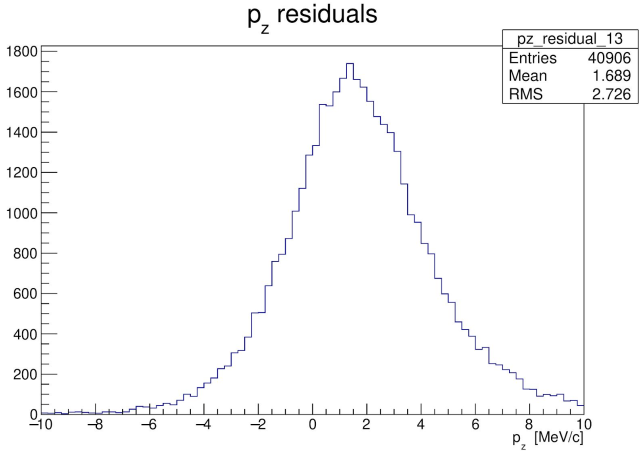
TKD P_z res


p_z residuals
pz_residual_1
Entries 40937
Mean 1.077
RMS 2.677
p_z [MeV/c]

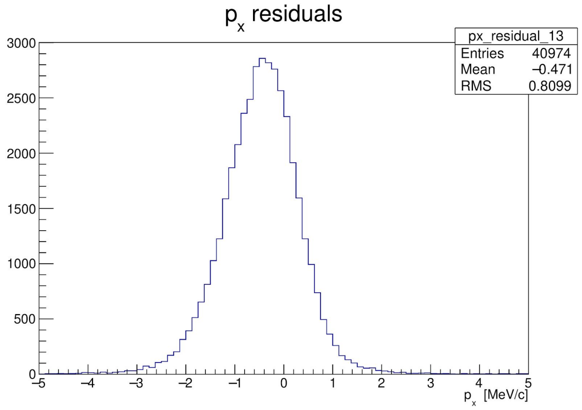

p_z residuals
pz_residual_4
Entries 40926
Mean 1.132
RMS 2.747
p_z [MeV/c]


p_z residuals
pz_residual_7
Entries 40906
Mean 1.236
RMS 2.822
p_z [MeV/c]

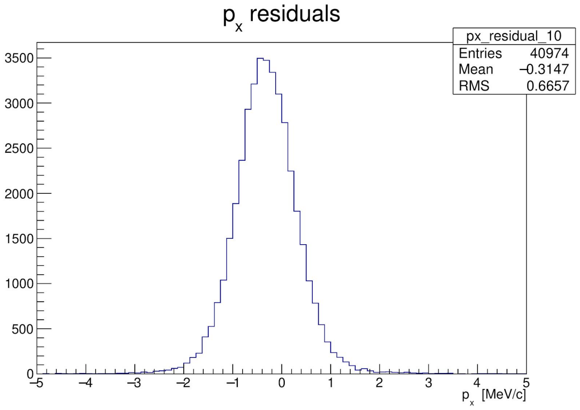

p_z residuals
pz_residual_10
Entries 40926
Mean 1.42
RMS 2.787
p_z [MeV/c]


p_z residuals
pz_residual_13
Entries 40906
Mean 1.689
RMS 2.726
p_z [MeV/c]

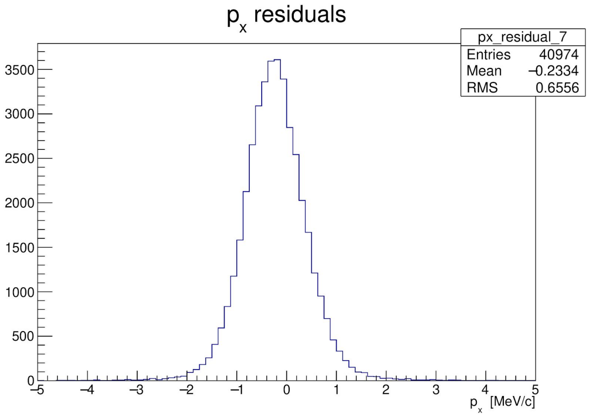
TKU P_x res



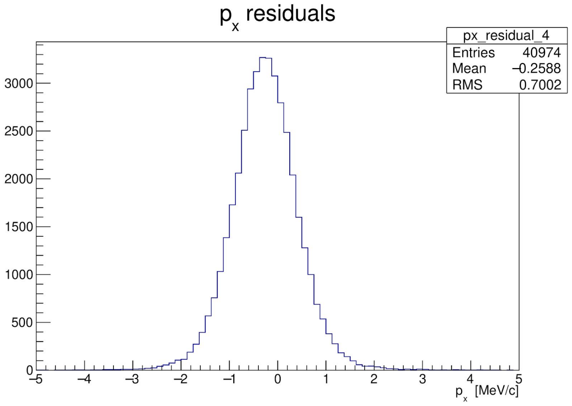
p_x residuals
px_residual_13
Entries 40974
Mean −0.471
RMS 0.8099
p_x [MeV/c]



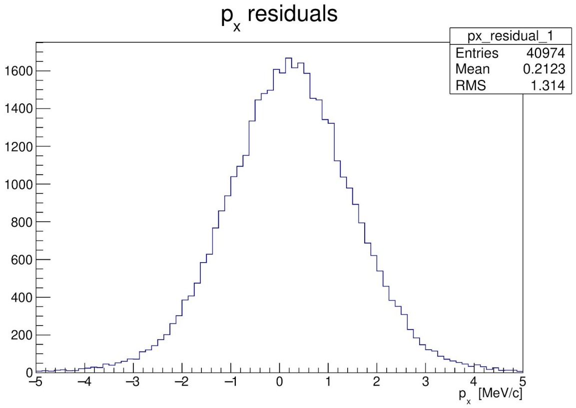
p_x residuals
px_residual_10
Entries 40974
Mean −0.3147
RMS 0.6657
p_x [MeV/c]



p_x residuals
px_residual_7
Entries 40974
Mean −0.2334
RMS 0.6556
p_x [MeV/c]

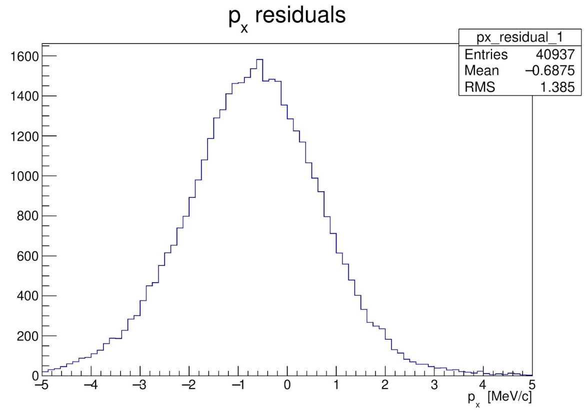


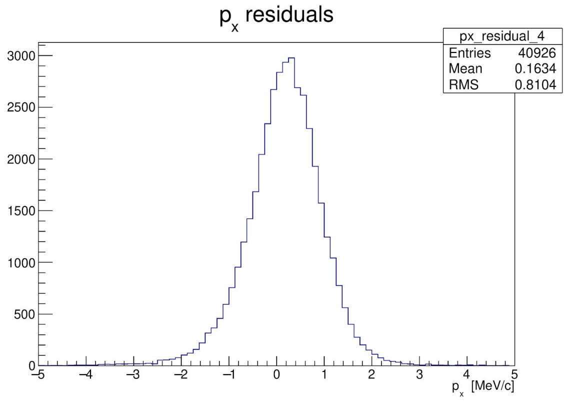
p_x residuals
px_residual_4
Entries 40974
Mean −0.2588
RMS 0.7002
p_x [MeV/c]

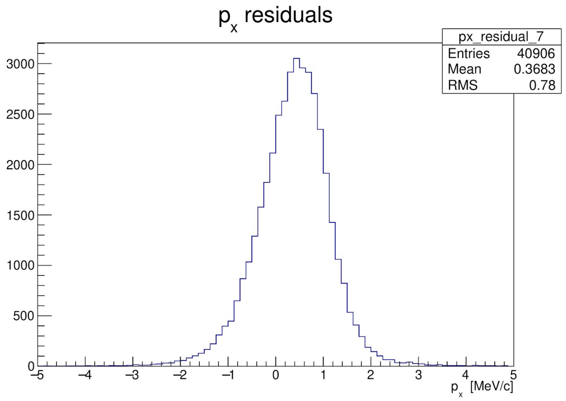


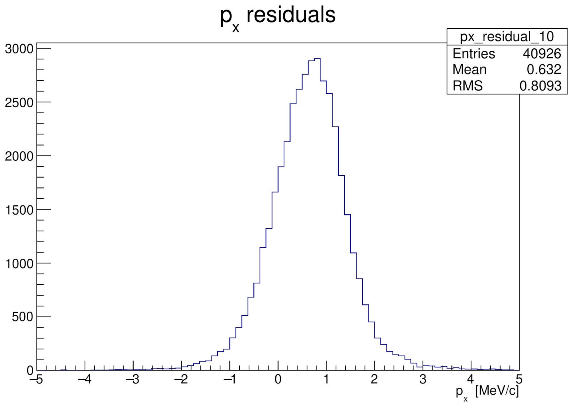
p_x residuals
px_residual_1
Entries 40974
Mean 0.2123
RMS 1.314
p_x [MeV/c]

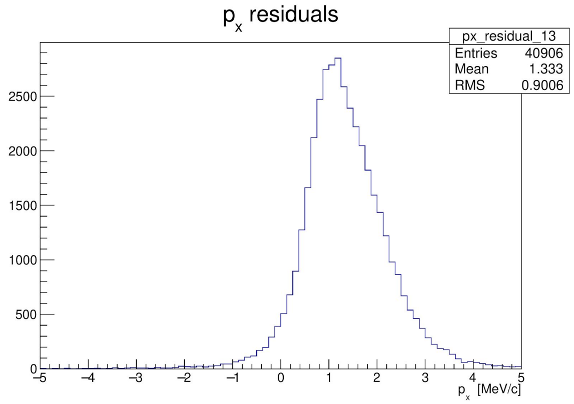
TKD P_x res


p_x residuals
px_residual_1
Entries 40937
Mean −0.6875
RMS 1.385
p_x [MeV/c]

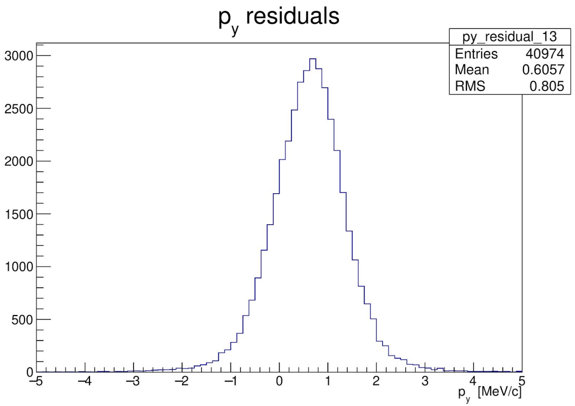

p_x residuals
px_residual_4
Entries 40926
Mean 0.1634
RMS 0.8104
p_x [MeV/c]


p_x residuals
px_residual_7
Entries 40906
Mean 0.3683
RMS 0.78
p_x [MeV/c]

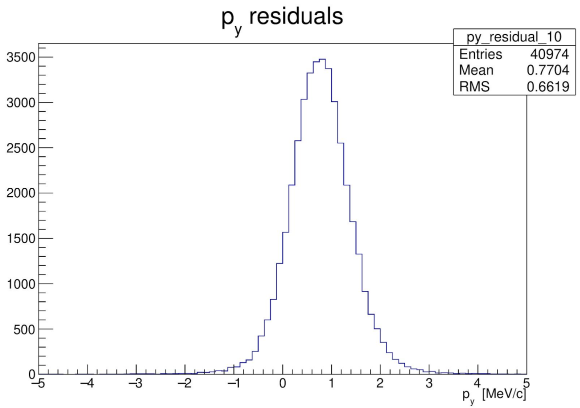

p_x residuals
px_residual_10
Entries 40926
Mean 0.632
RMS 0.8093
p_x [MeV/c]


p_x residuals
px_residual_13
Entries 40906
Mean 1.333
RMS 0.9006
p_x [MeV/c]

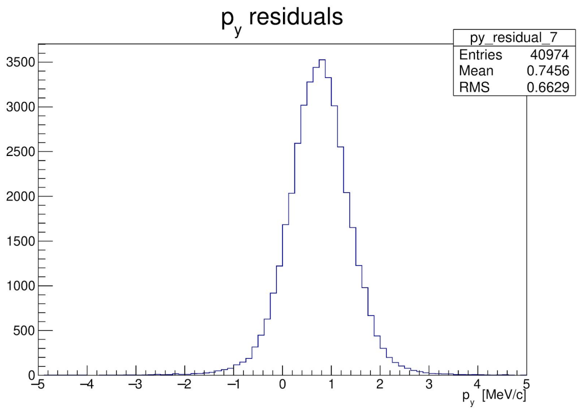
TKU P_y res



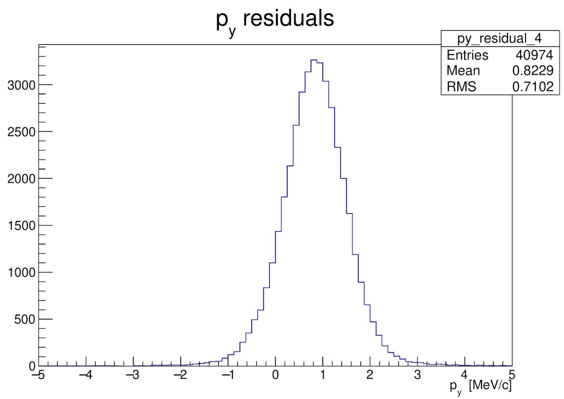
p_y residuals
py_residual_13
Entries 40974
Mean 0.6057
RMS 0.805
p_y [MeV/c]



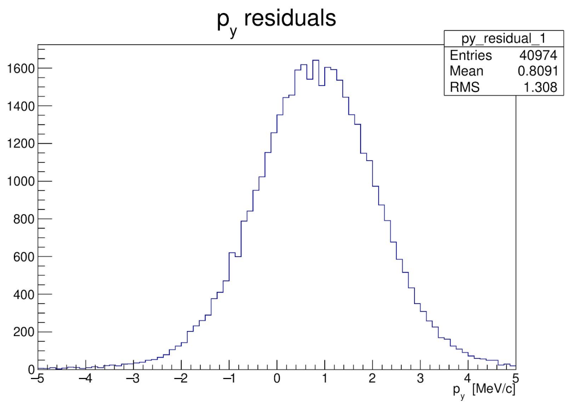
p_y residuals
py_residual_10
Entries 40974
Mean 0.7704
RMS 0.6619
p_y [MeV/c]



p_y residuals
py_residual_7
Entries 40974
Mean 0.7456
RMS 0.6629
p_y [MeV/c]

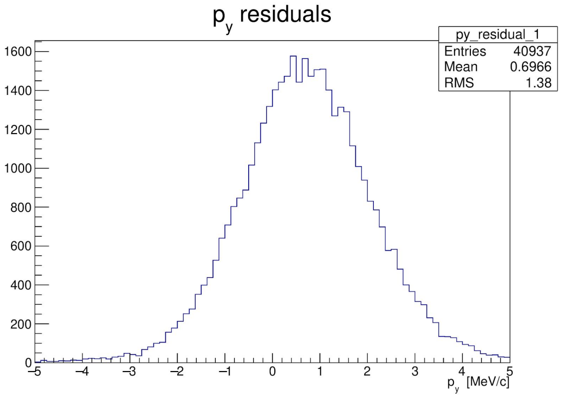


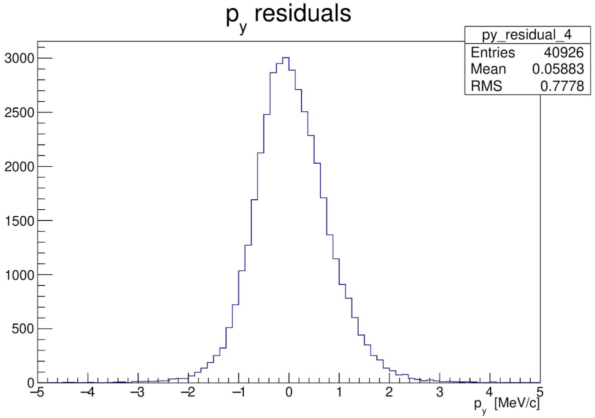
p_y residuals
py_residual_4
Entries 40974
Mean 0.8229
RMS 0.7102
p_y [MeV/c]

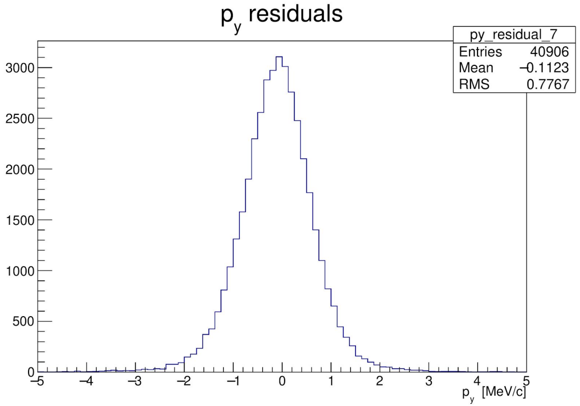


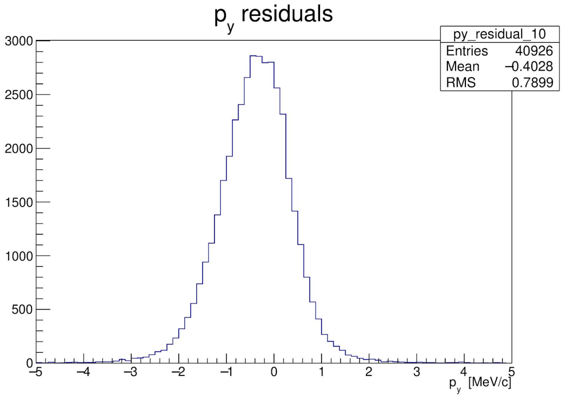
p_y residuals
py_residual_1
Entries 40974
Mean 0.8091
RMS 1.308
p_y [MeV/c]

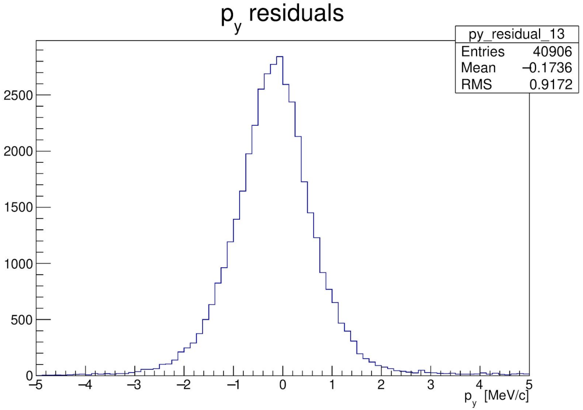
TKD P_y res


p_y residuals
py_residual_1
Entries 40937
Mean 0.6966
RMS 1.38
p_y [MeV/c]


p_y residuals
py_residual_4
Entries 40926
Mean 0.05883
RMS 0.7778
p_y [MeV/c]


p_y residuals
py_residual_7
Entries 40906
Mean −0.1123
RMS 0.7767
p_y [MeV/c]


p_y residuals
py_residual_10
Entries 40926
Mean −0.4028
RMS 0.7899
p_y [MeV/c]


p_y residuals
py_residual_13
Entries 40906
Mean −0.1736
RMS 0.9172
p_y [MeV/c]

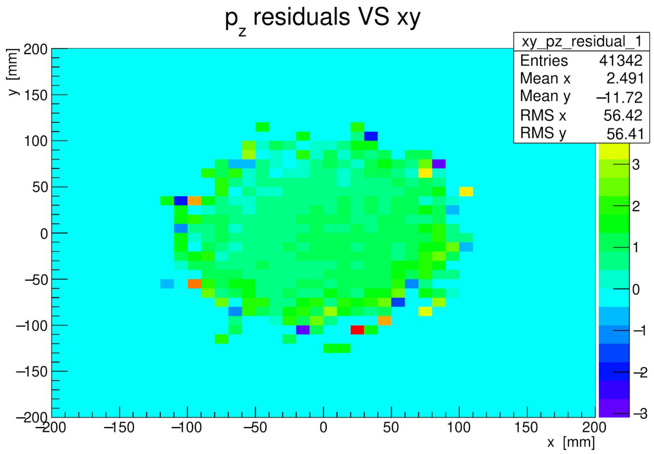
Detector resolution

- p_z stable resolution across all TKU and TKD stations; bias shows some variation
- p_x, p_y show *lower* resolution at reference plane

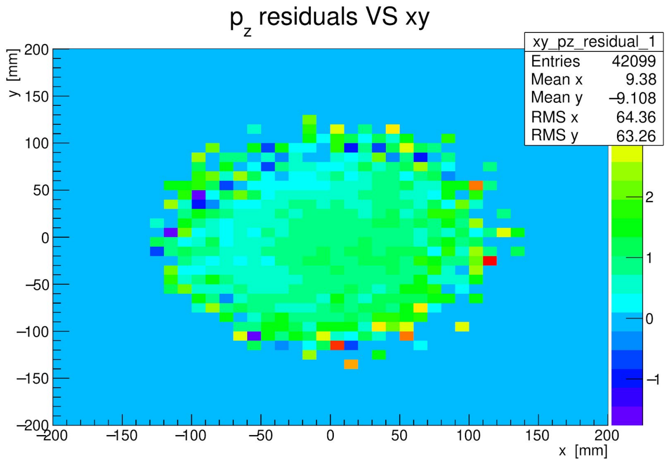
Next: looked at p_z residual as a function of x-y and p_x-p_y

P_z res vs xy MC truth at TKU

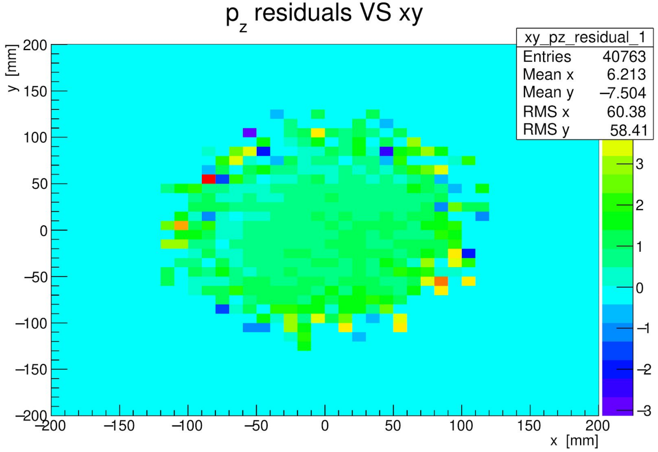
No abs



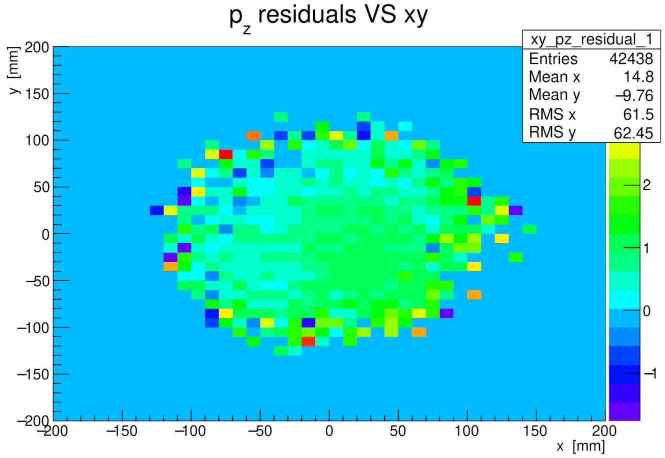
LiH



Empty LH2

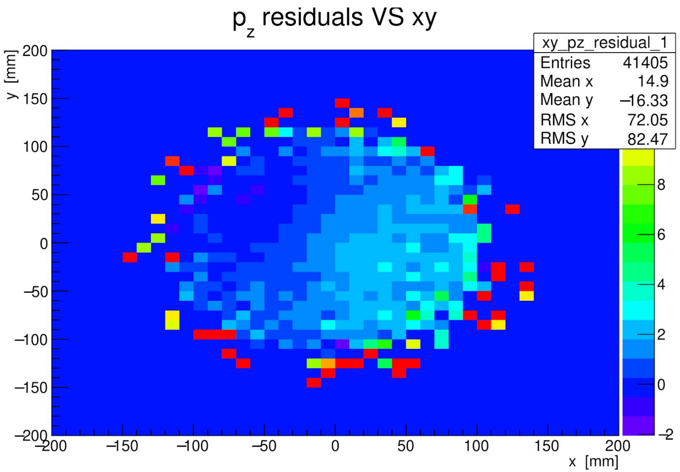


LH2

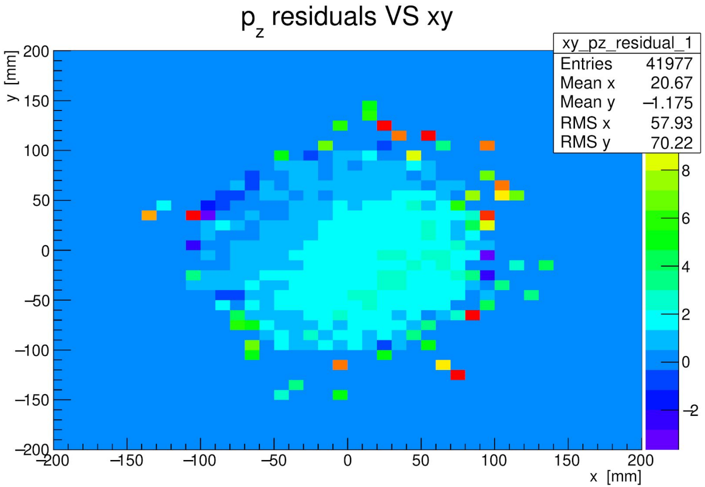


P_z res vs xy MC truth at TKD

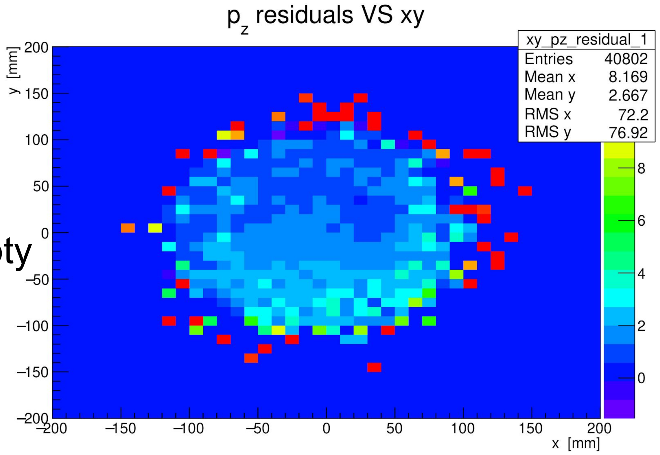
No abs



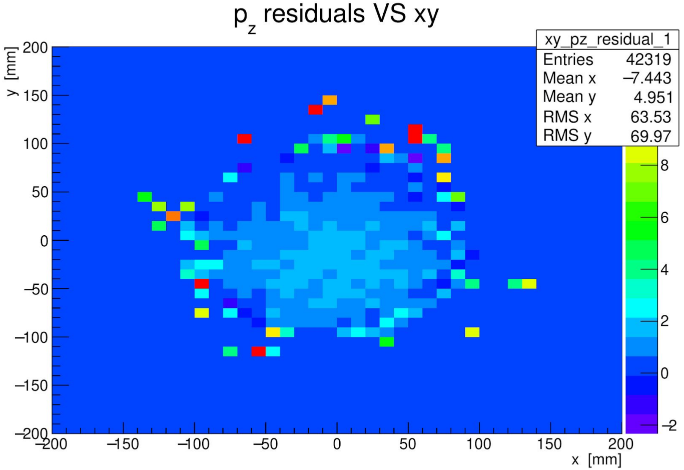
LiH



Empty LH2

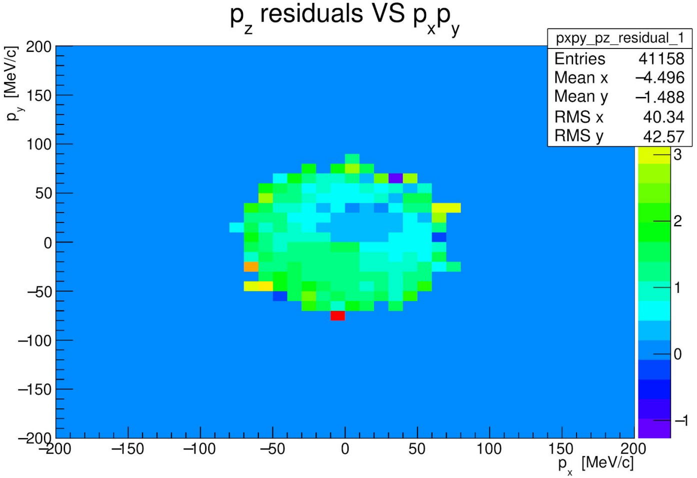


LH2

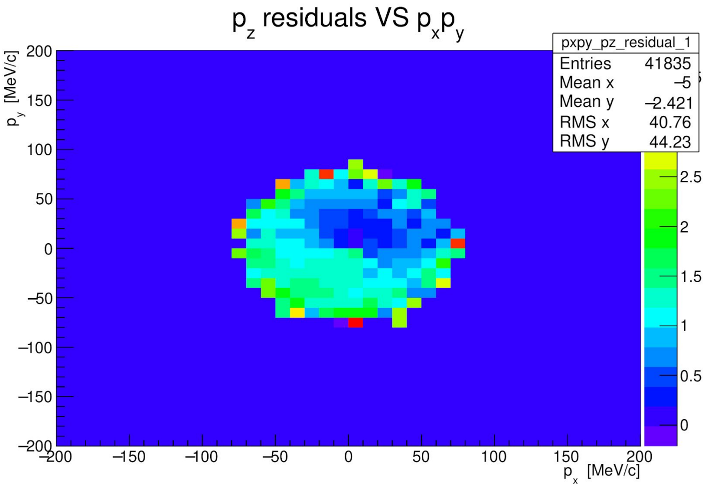


P_z res vs P_xP_y MC truth at TKU

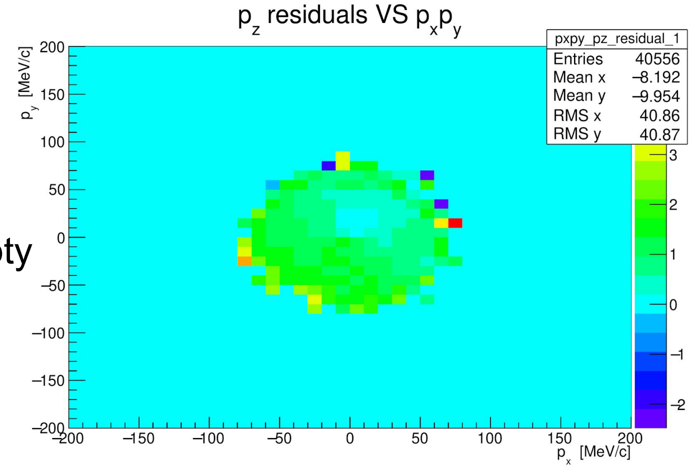
No abs



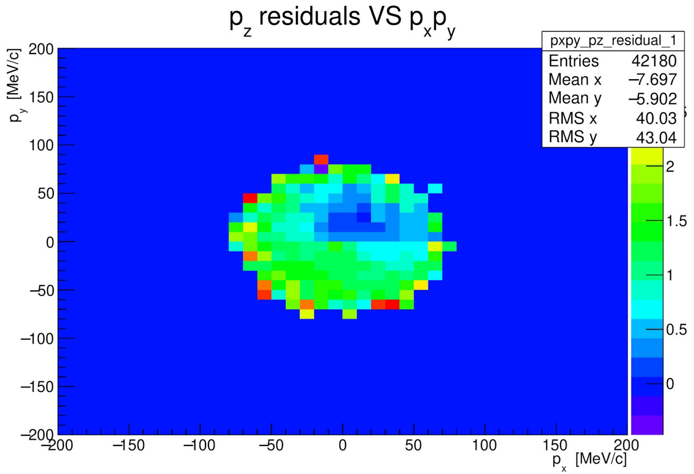
LiH



Empty LH2

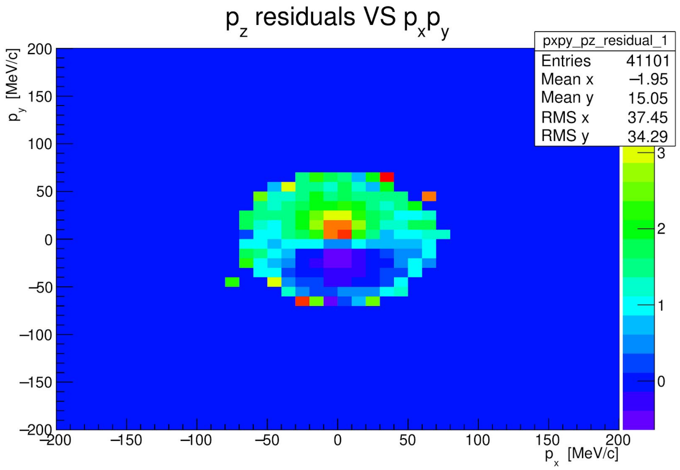


LH2

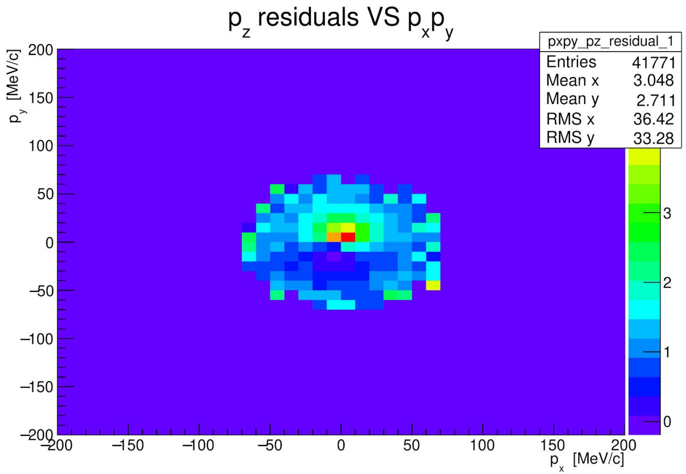


P_z res vs P_xP_y MC truth at TKU

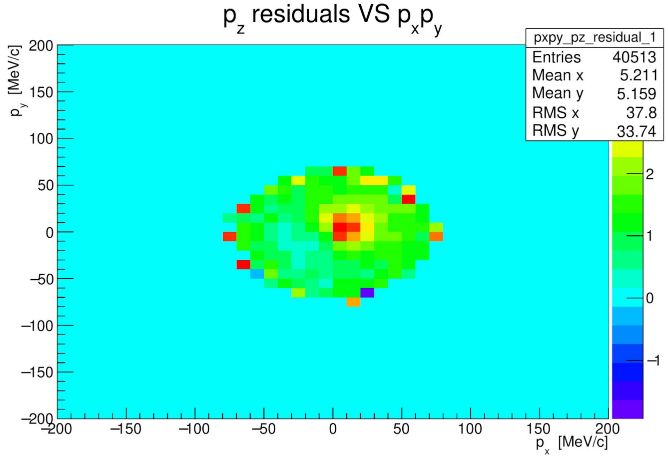
No abs



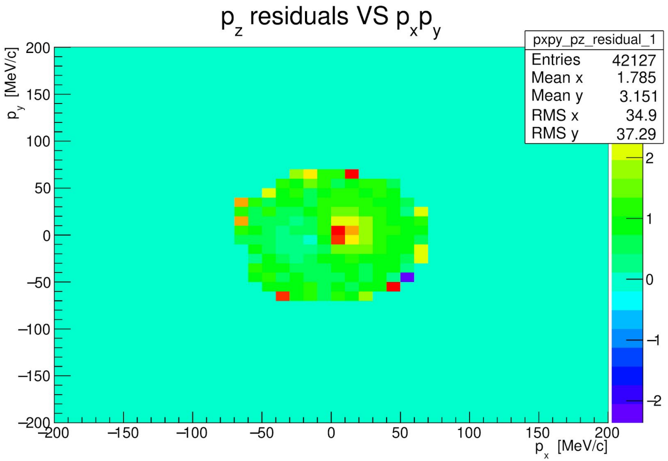
LiH



Empty LH2



LH2



Detector resolution

- Bias pattern relatively constant upstream across all 4 absorber settings
- Downstream bias pattern similar within same *empty - full* absorber setting pair, but slightly different between the two *No abs - LiH* and *Empty - Full LH2*, indicating a change in the simulated misalignment of the detector and field
- Higher p_z bias at low transverse momentum downstream; challenging to reconstruct such tracks
- Could explain difference in mean reconstructed momentum at TKD between data and MC

Reconstruction bias correction

Procedure account for systematic bias in emittance reconstruction

- Calculate bias at the TKU and TKD reference planes (using multiple independent samples) as:

$$bias = \epsilon_{RECO} - \epsilon_{TRUE}$$

- Individually, for all sampled beams
- Apply correction to both Data and MC

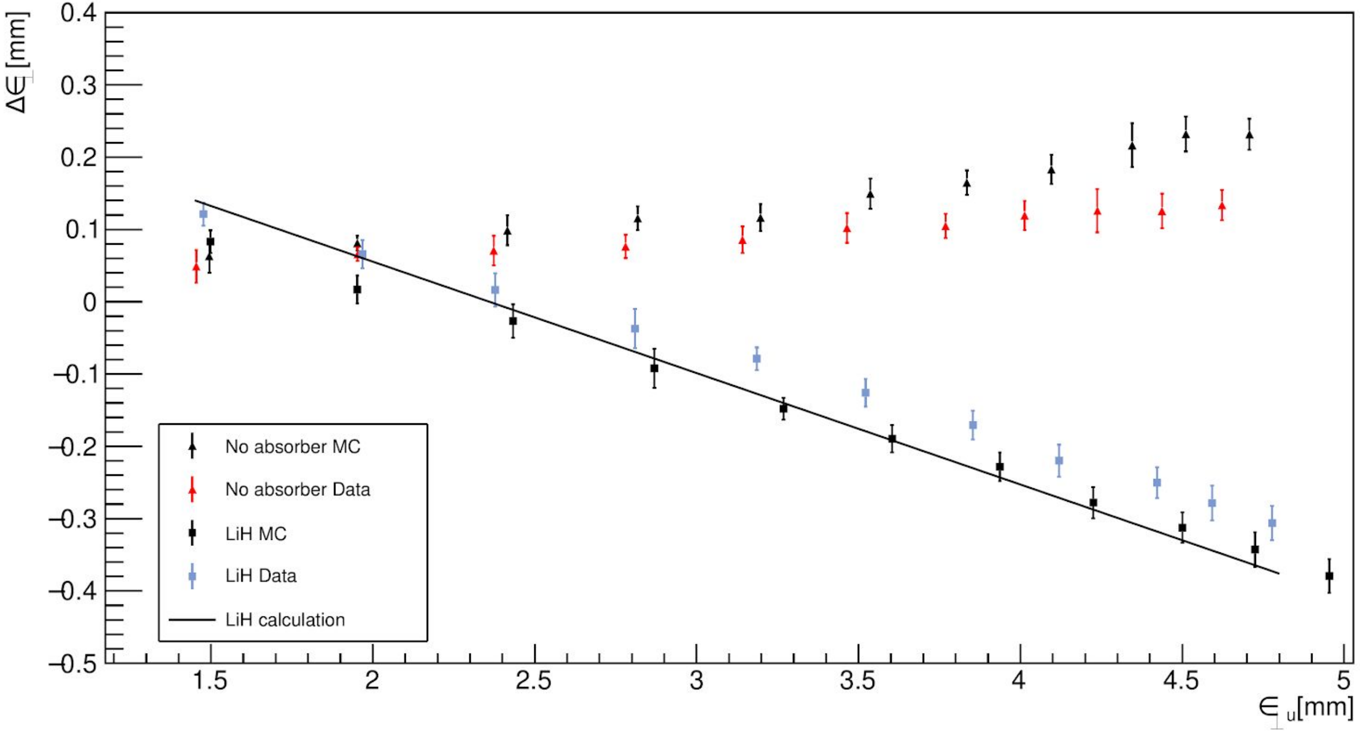
Emittance change

All beams sampled from 6-140 datasets, not statistically independent

Slight overall offset in LiH: more cooling in MC

No absorber: more heating in MC as emittance increases

Statistical errors only



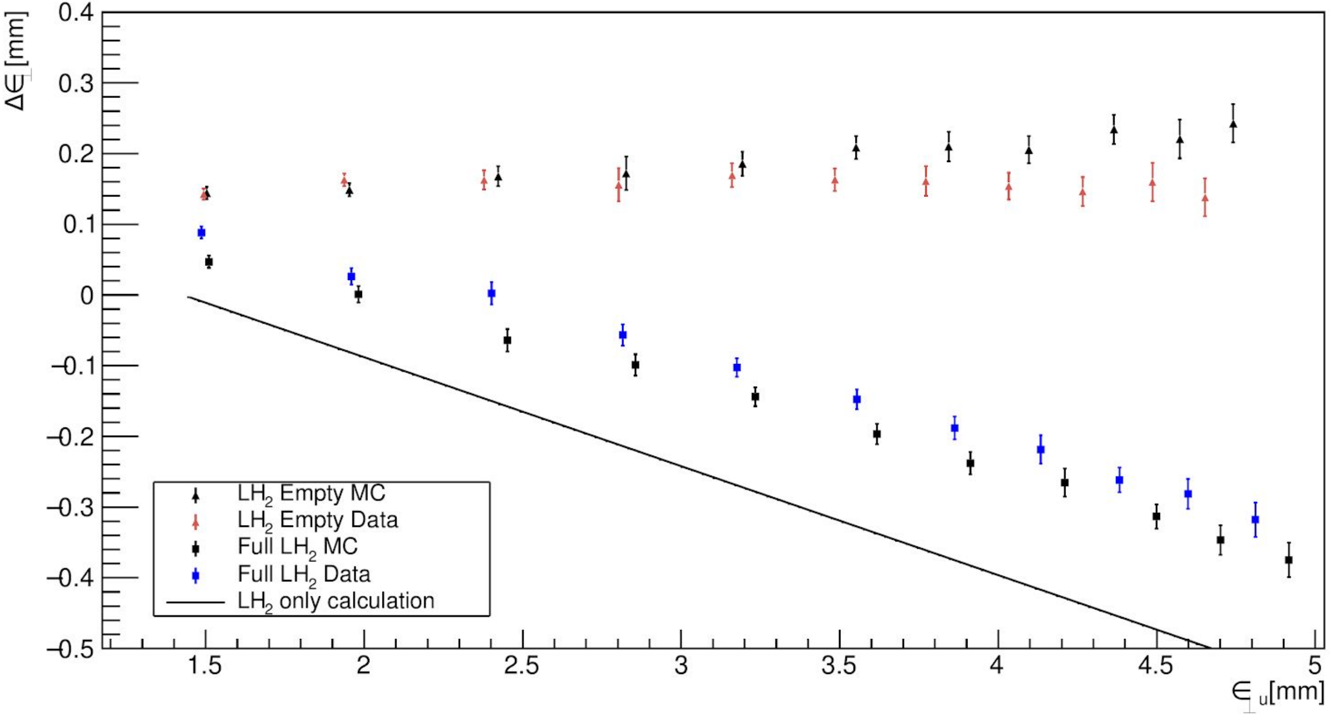
Emittance change

All beams sampled from 6-140 datasets, not statistically independent

Slight overall offset in LH2: more cooling in MC, same as seen in LiH

Empty LH2: more heating in MC as emittance increases

Statistical errors only



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Emittance change: update

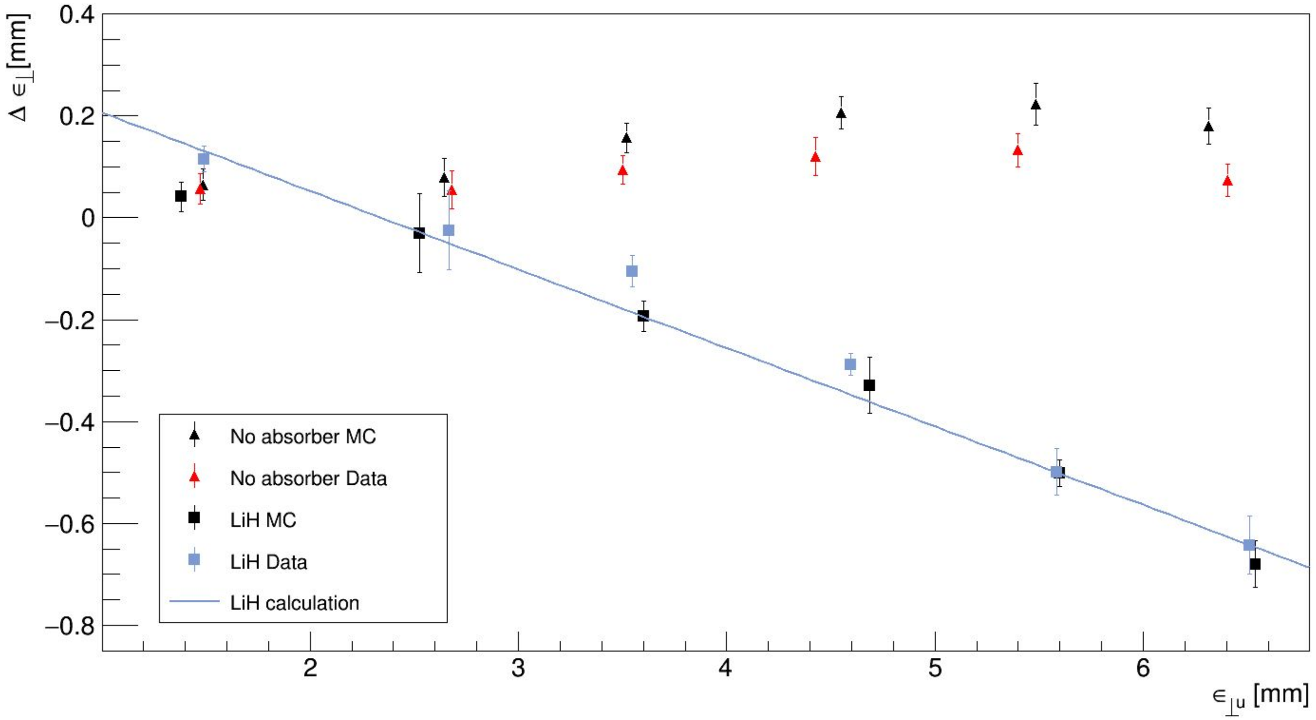
- Added 4-140 and 10-140 datasets
- Tuned and produced corresponding MC (10-140 data/MC comparison in backup slides)
- Update: sampled beams *statistically independent*
- Two from each dataset, 6 in total

Emittance change: LiH vs No abs

No absorber: more heating in MC as emittance increases. Similar behaviour observed in the Nature analysis results

Cooling: decent agreement with MC and theoretical calculation

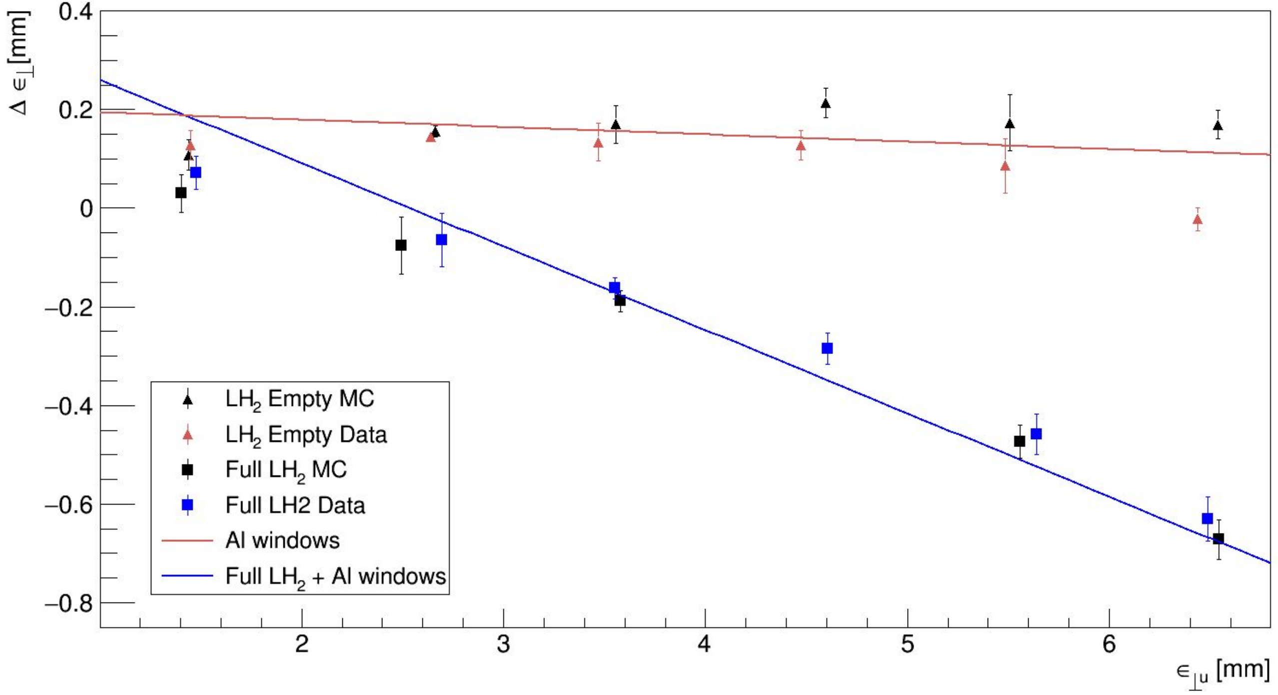
Full systematics analysis not included yet



Emittance change: Full LH_2 vs Empty LH_2

Included effects of Al windows in the theoretical calculation

No absorber: more heating in MC as emittance increases. Similar behaviour observed in the Nature analysis results



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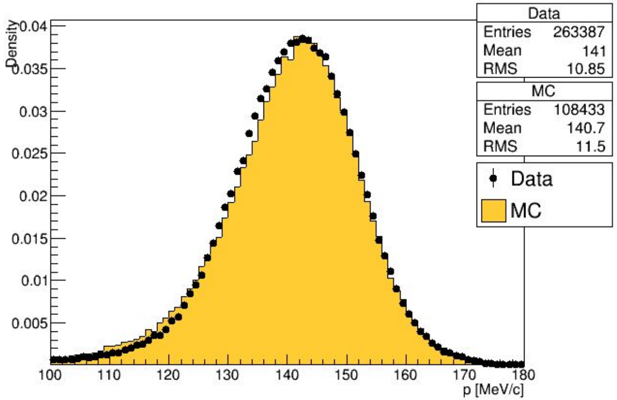
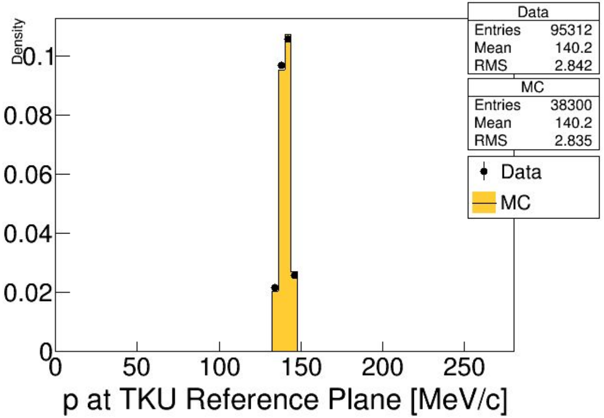
Summary

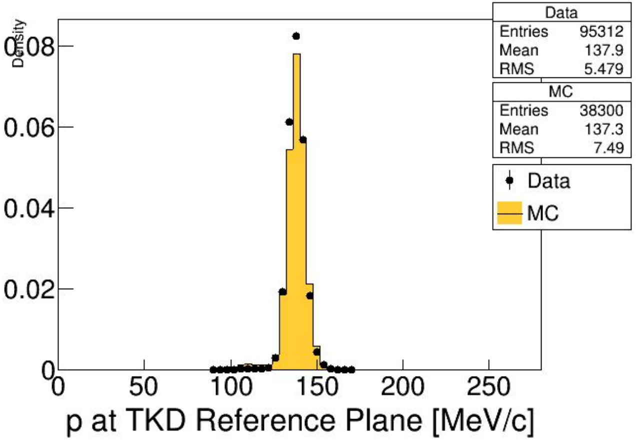
- Updated MC, better agreement with Data
- Room for improvement..
  - on the agreement of beams entering the cooling channel
  - misalignment in AFC, M2D, TKD
  - TOF01
- Added 4-140, 10-140 datasets and produced MC
- Job list
  - Systematics
    - bias due to full transmission requirement
  - TOF01 / Diffuser
  - Misalignment?
  - Angular momentum

Back up

10-140 Empty LH_2: Data / MC comparison
Momentum



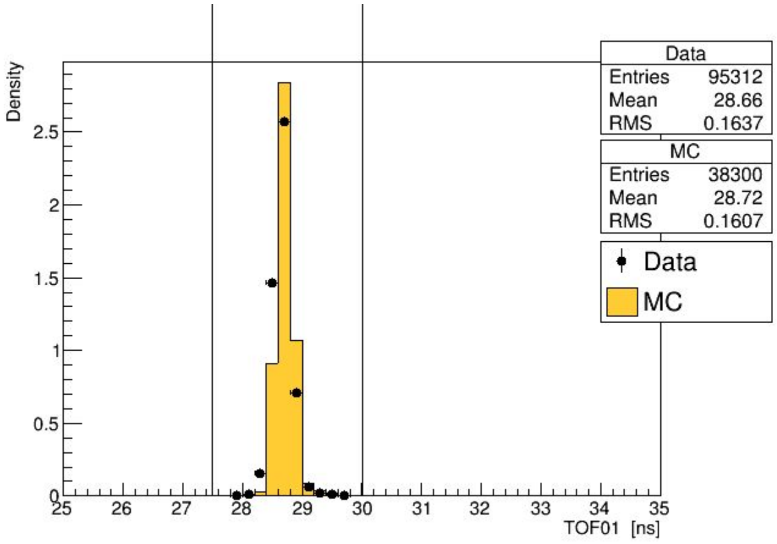




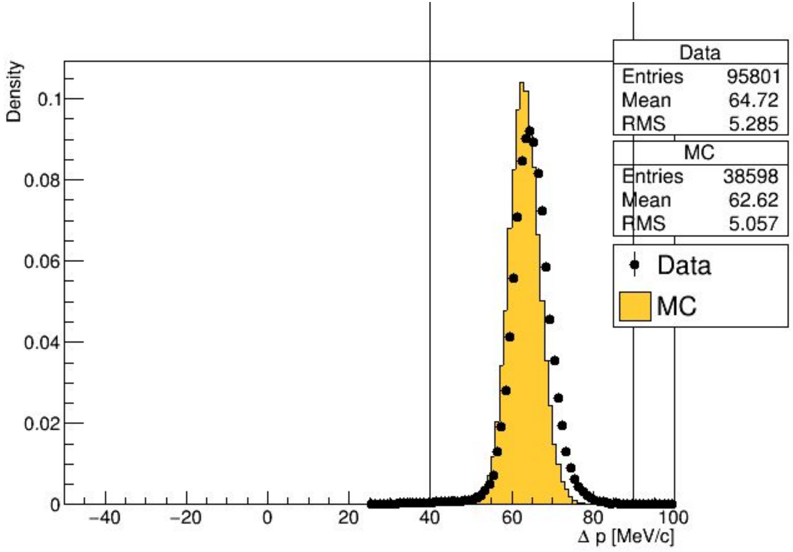
10-140 Empty LH_2: Data / MC comparison

Imperial College London

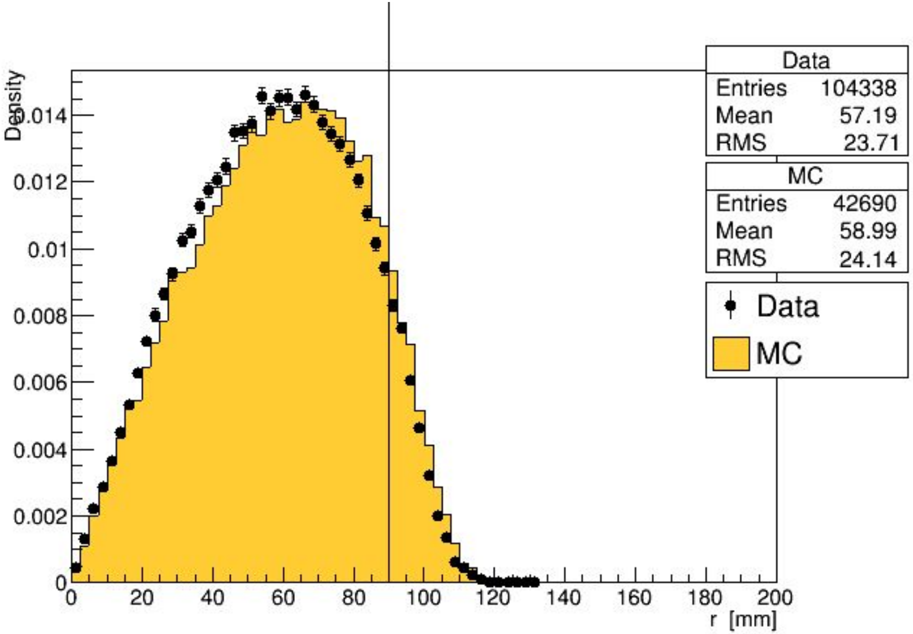
TOF01



$p_{TOF01} - p_{TKU}$



10-140 Empty LH_2: Data / MC comparison
Radius at diffuser



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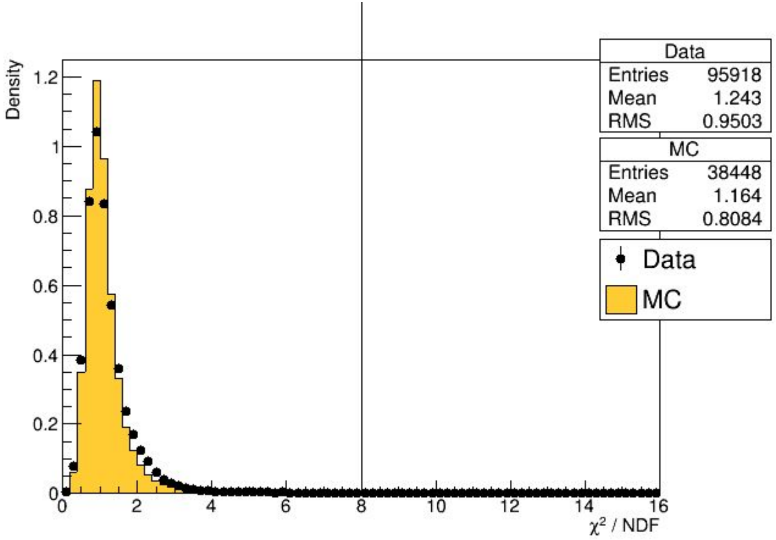
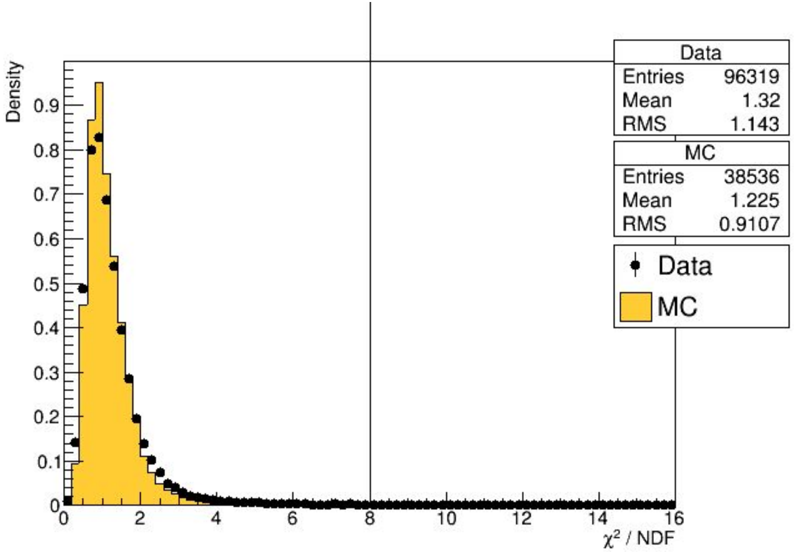
10-140 Empty LH_2: Data / MC comparison
χ^2 / ndf

TKU



TKD



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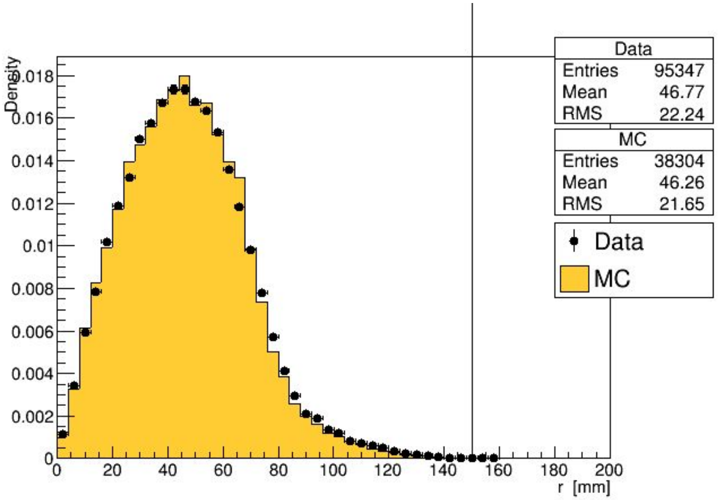
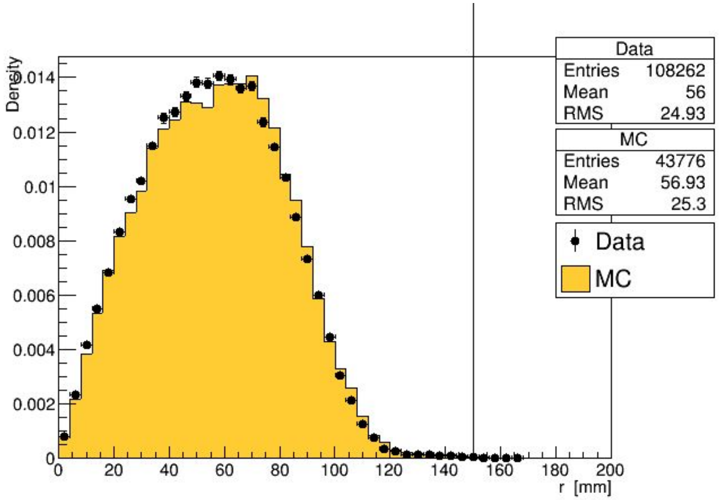
10-140 Empty LH_2: Data / MC comparison
Fiducial cut at ref planes

TKU

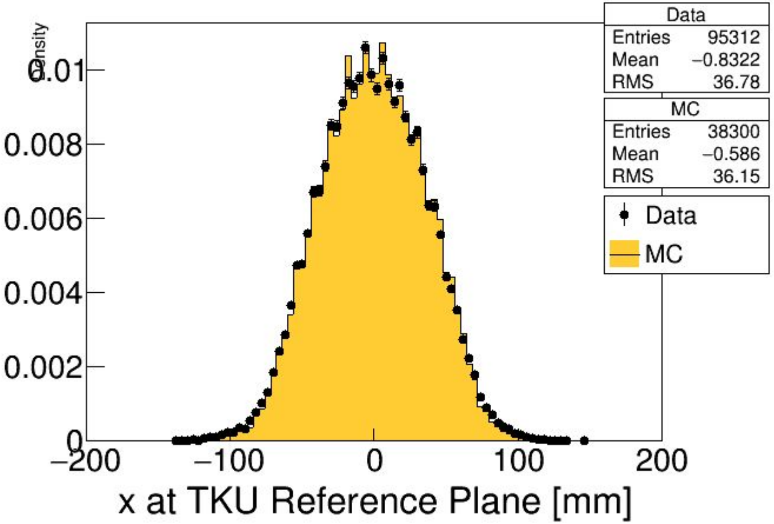


TKD

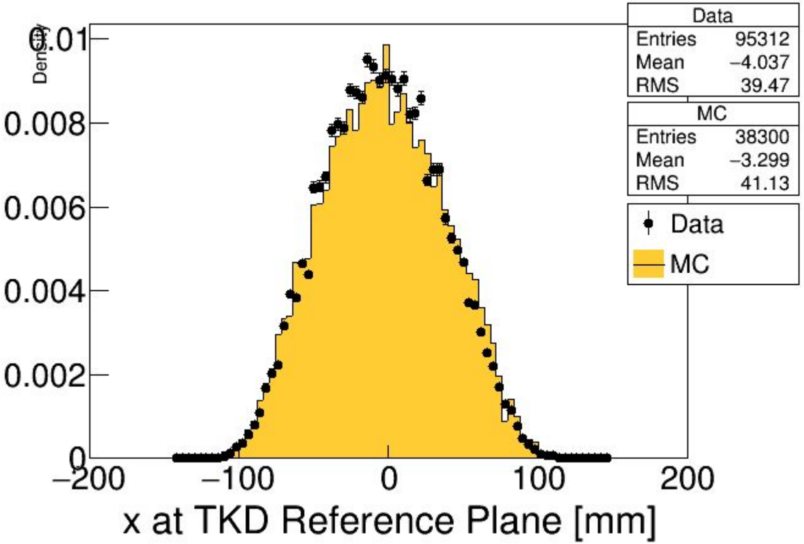


10-140 Empty LH_2: Data / MC comparison
X

TKU

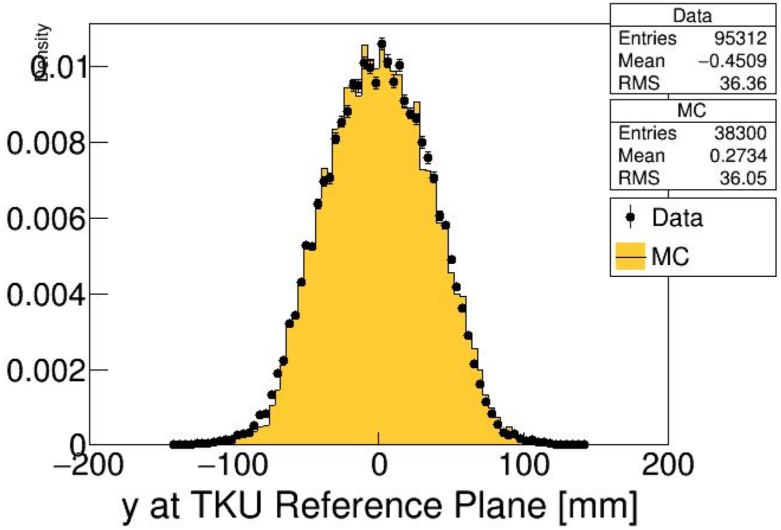


TKD

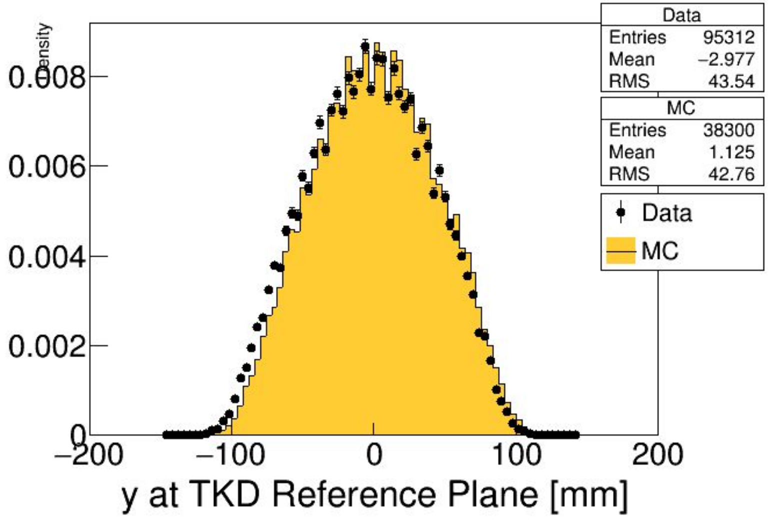


10-140 Empty LH_2: Data / MC comparison Y

TKU

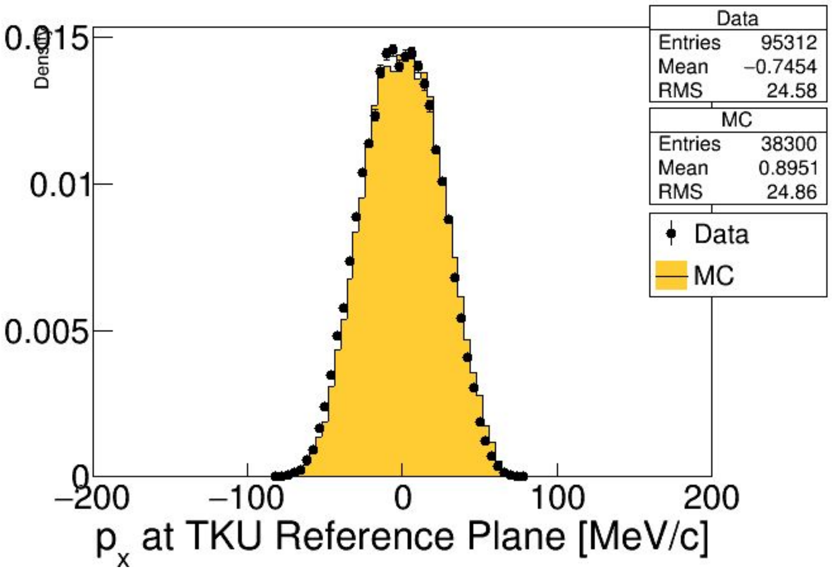


TKD

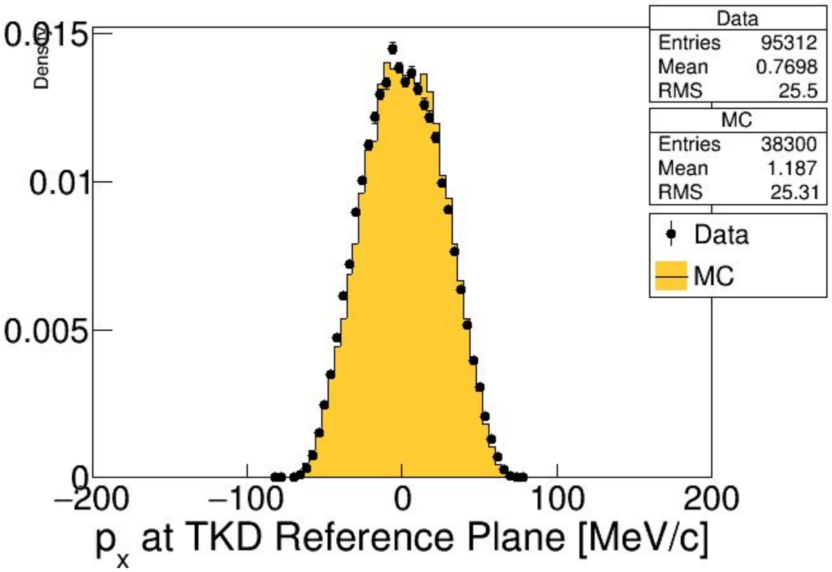


10-140 Empty LH_2: Data / MC comparison P_X

TKU



TKD



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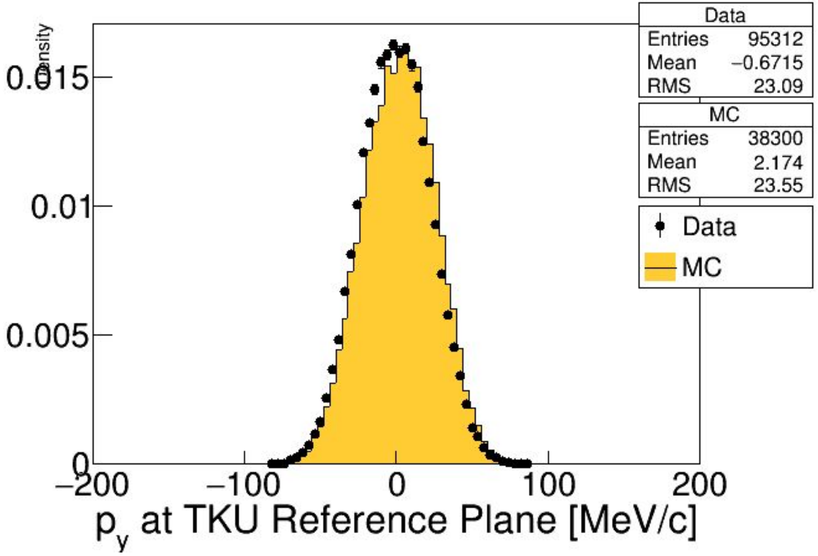
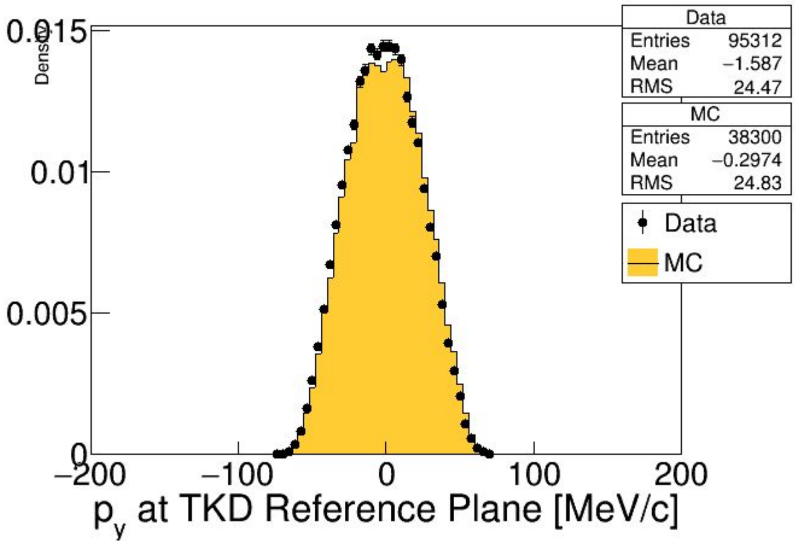
10-140 Empty LH_2: Data / MC comparison P_Y

TKU

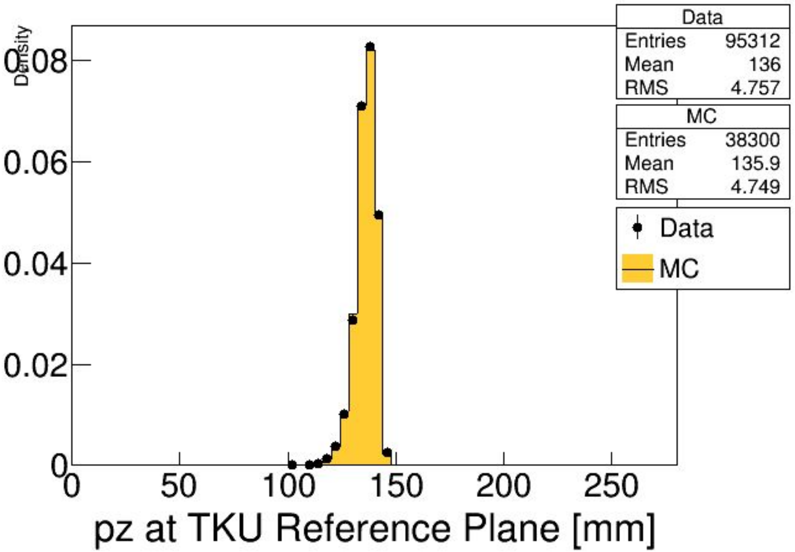


TKD

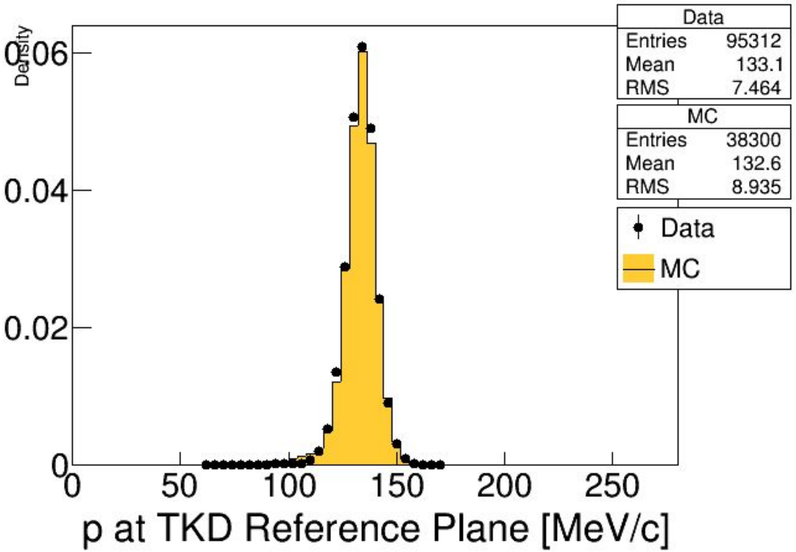


10-140 Empty LH_2: Data / MC comparison P_Z

TKU



TKD



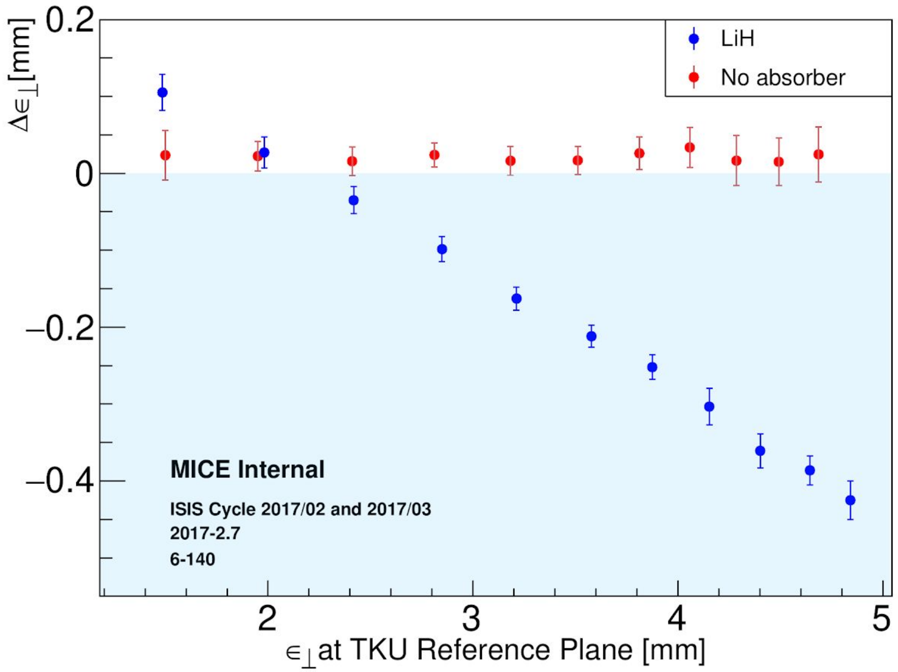
Equilibrium emittance calculation

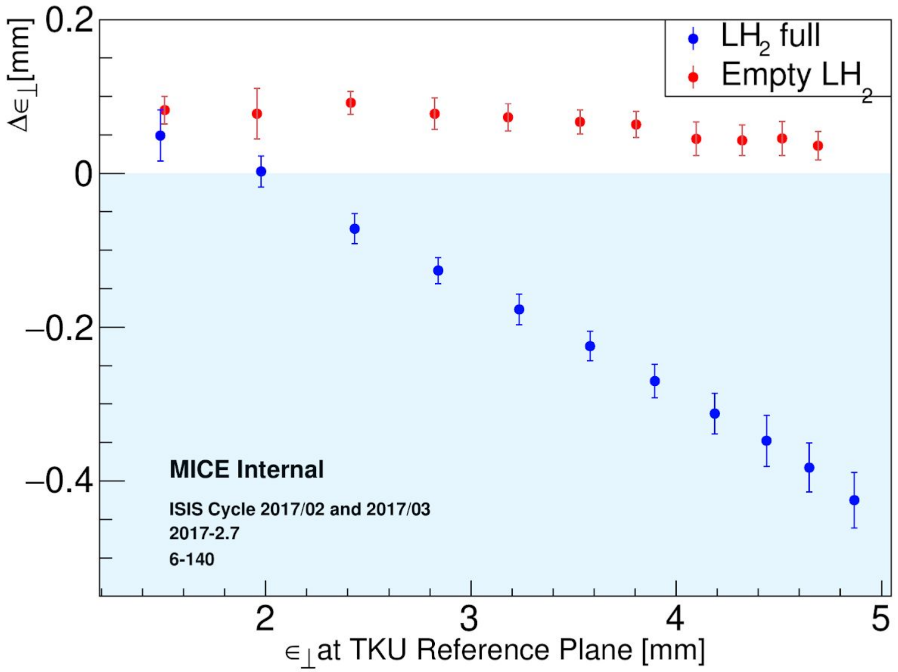
- used Bethe's mean stopping power formula to calculate dE/dz at 140 MeV/c
- parameters used for eqm. emittance:

$$
\begin{aligned}
&LiH\\
&p = 140\,MeV/c\\
&dE/dz = 1.925\,MeV/cm\\
&X_0 = 102.04\,cm\\
&\beta_\perp = 420\,mm
\end{aligned}
$$

$$
\begin{aligned}
&LH_2\\
&p = 140\,MeV/c\\
&dE/dz = 0.361\,MeV/cm\\
&X_0 = 890.4\,cm\\
&\beta_\perp = 420\,mm
\end{aligned}
$$

Previous iteration





Emittance change

- The main focus of the analysis is to measure the transverse emittance change of beams passing through the LH2 and LiH absorbers for a range of input emittances, momenta and optics configurations ($\beta_\perp$ at the absorber)
- Used the 6mm - 140 MeV dataset while refining the analysis chain
- Study of all dataset available due soon
- Analysis chain:

Data / MC -> Cuts -> Parent sample -> Beam selection -> Emittance change calculation (applied to the improved optics sampled beams)

Statistical errors on absolute emittance change

- Starting from John Cobb's derivation of statistical errors on relative emittance change in Note 268
- John has also worked on this derivation and came up with a result
- Currently our results are not identical, will take some time to revise

$$\sigma^2_{\Delta\epsilon} = \frac{1}{2n}\left[(\epsilon_d - \epsilon_u)^2 + \epsilon_u\epsilon_d - \alpha^2\frac{\epsilon_u^3}{\epsilon_d}\right]$$

Optics matching

Imperial College London

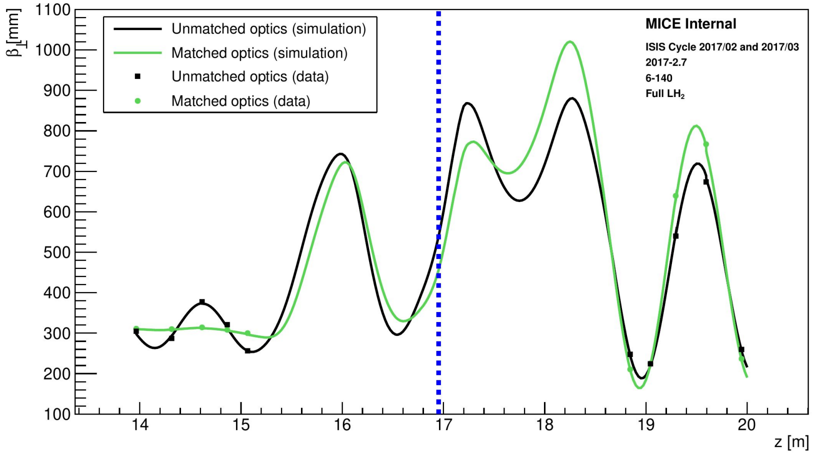
Black - parent beam optics (4.8 mm)

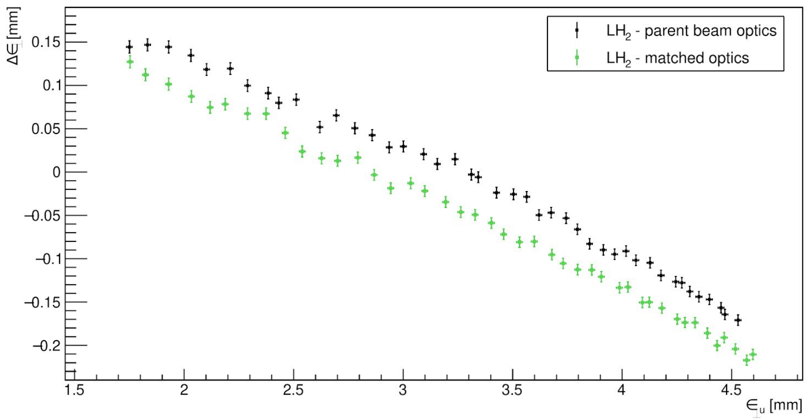
Green - sampled beam optics (4 mm)

Beta at absorber reduced from ~540 mm to ~ 450 mm (~17% reduction)

Results in an enhanced cooling effect, seen in the bottom plot

Bottom plot - absolute emittance change across the absorber for beams sampled from 6-140 LH2 data . More cooling observed in beams that have matched optics than for beams that keep the optics of the parent sample





Emittance change calculation

1) $\Delta\epsilon_{\perp} = \epsilon_d - \epsilon_u$ or $\Delta\epsilon_{\perp rel} = (\epsilon_d - \epsilon_u)/\epsilon_u$

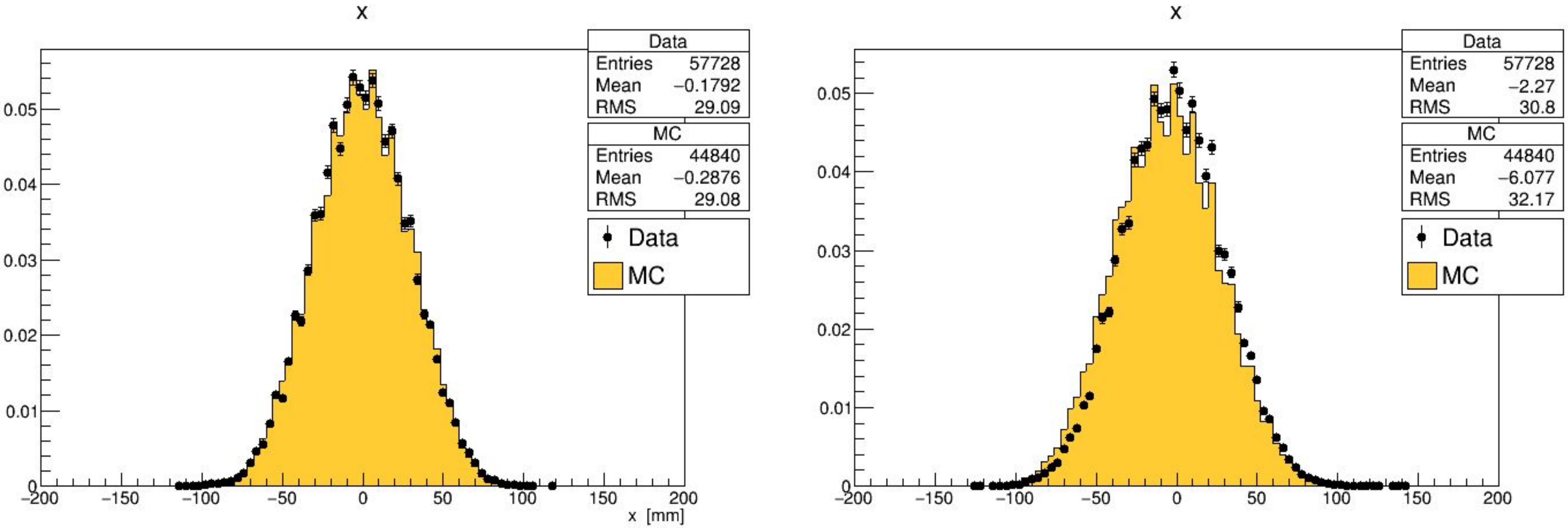
2) Amplitude migration at the core of the beam can also be used to estimate the emittance change. The ratio of the upstream and downstream emittances can be calculated from the ratio of upstream and downstream numbers of particles in the smallest amplitude bin (core), as shown below. (low statistics and efficiency in the core bin)

$$\lim_{A_{\perp}\to 0} \frac{f^d(A_{\perp})}{f^u(A_{\perp})} = \left(\frac{\varepsilon_{\perp}^u}{\varepsilon_{\perp}^d}\right)^2$$

Results shown here using the **first** method.

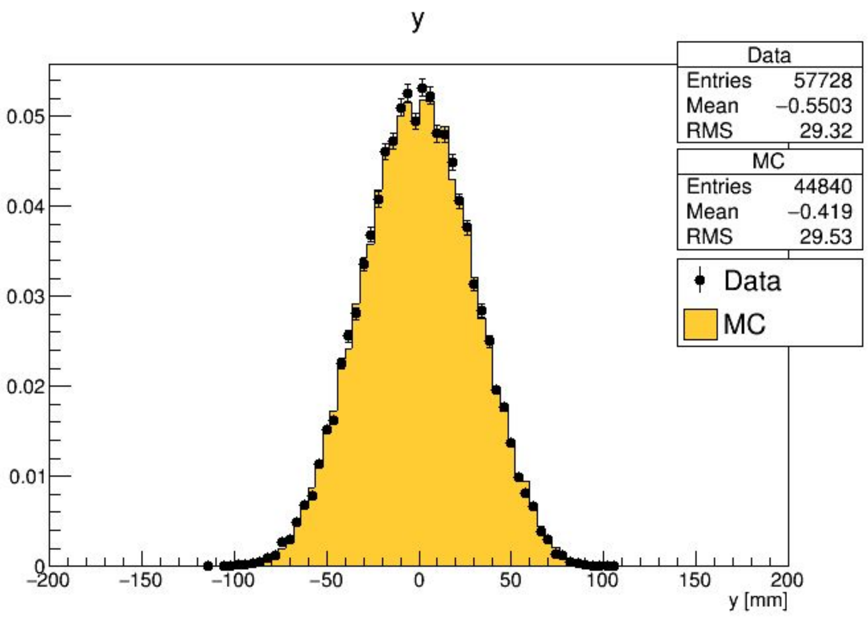
Beam Position: X

Upstream | Downstream

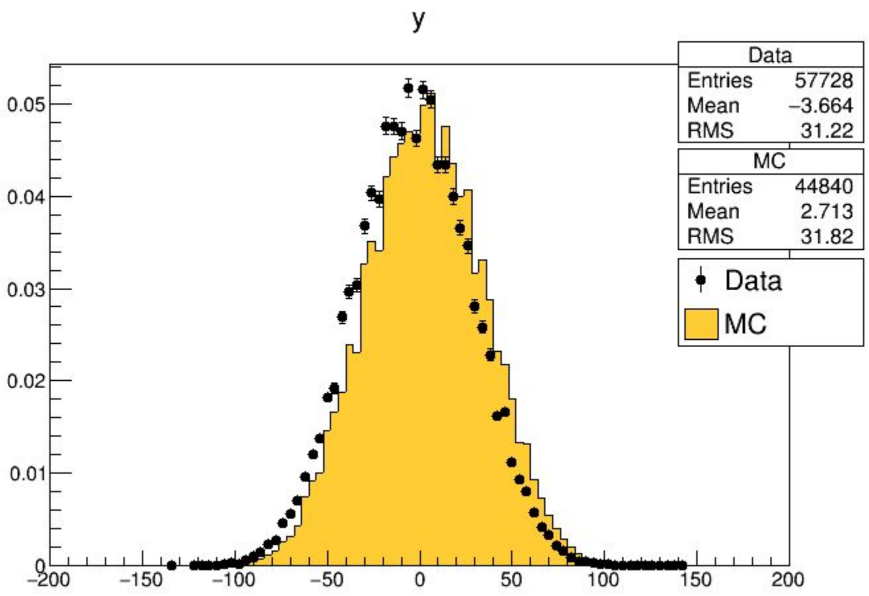


Beam Position: Y

Upstream



Downstream



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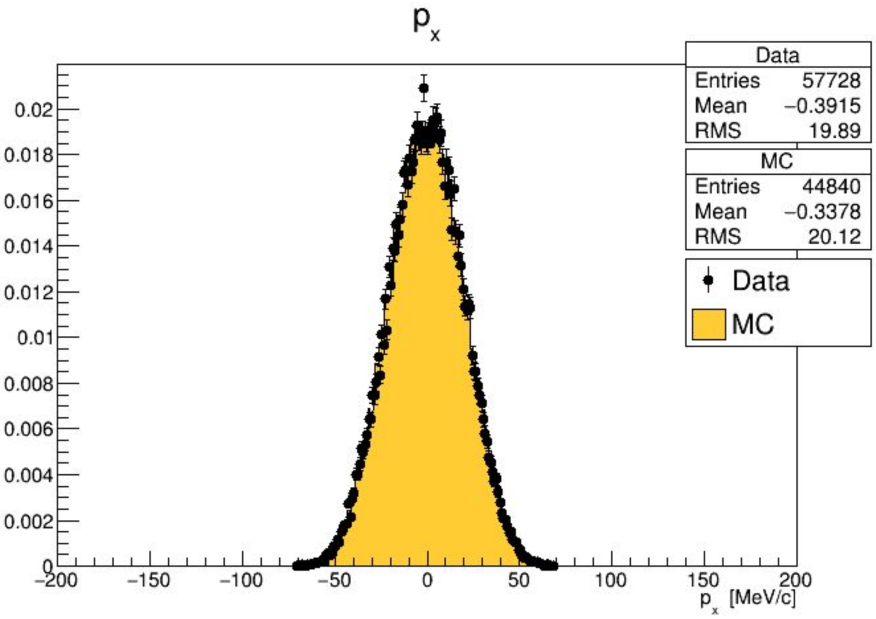
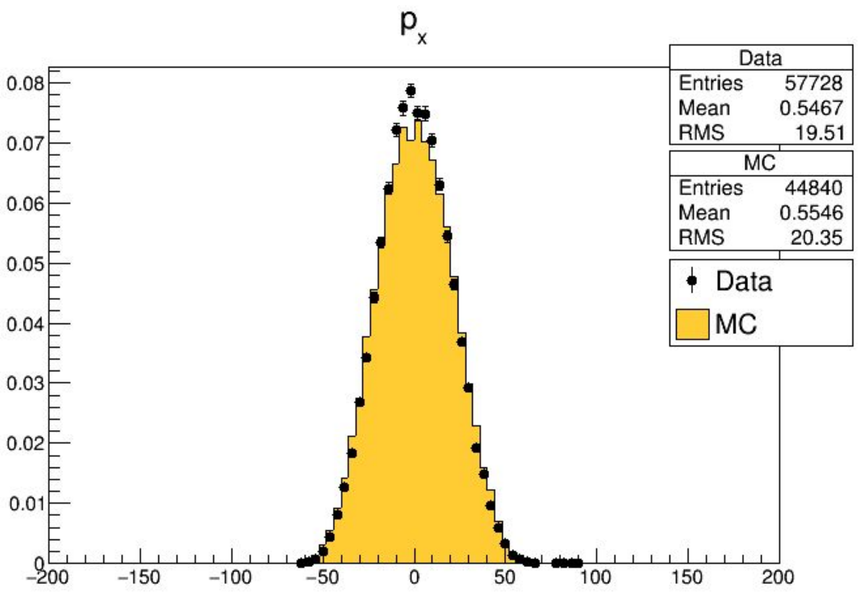
Beam Momentum: P_x

Upstream

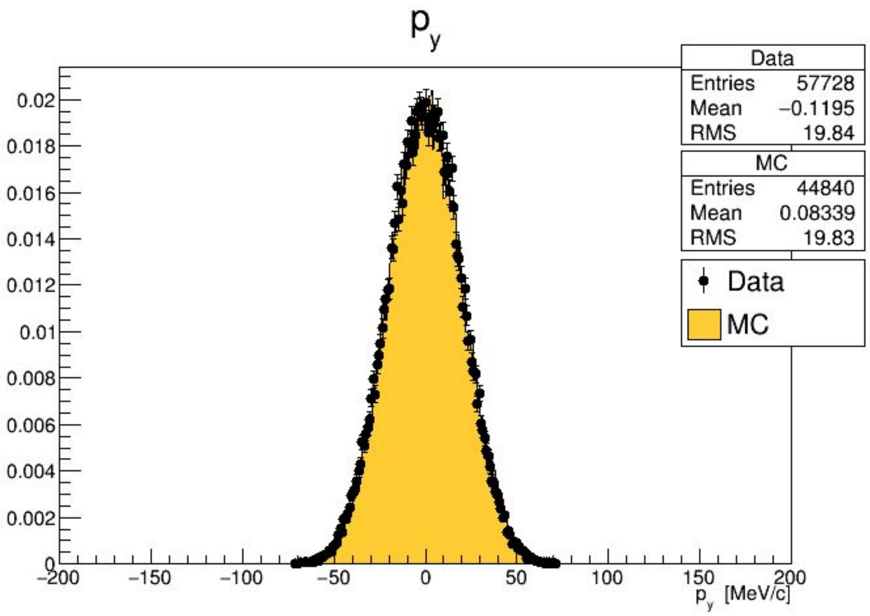


Downstream

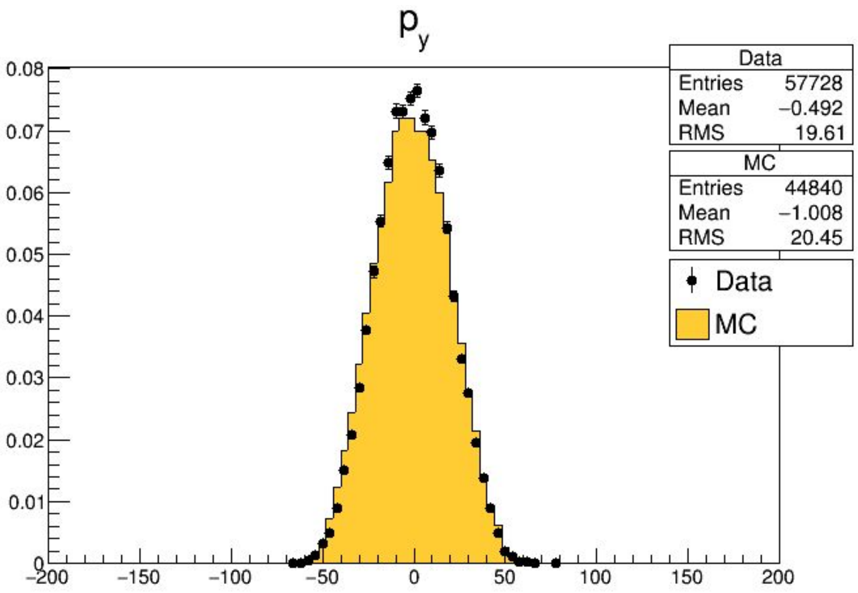


Beam Momentum: P_y

Upstream



Downstream



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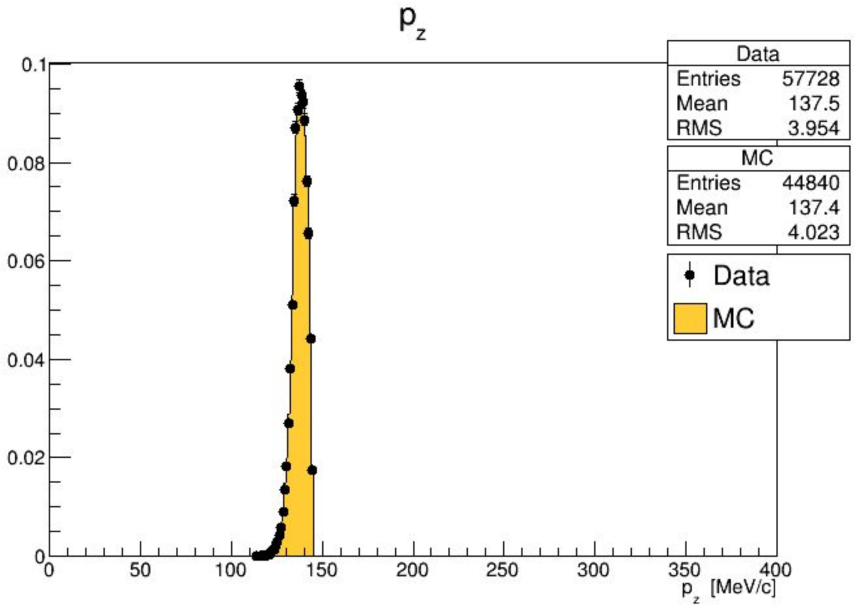
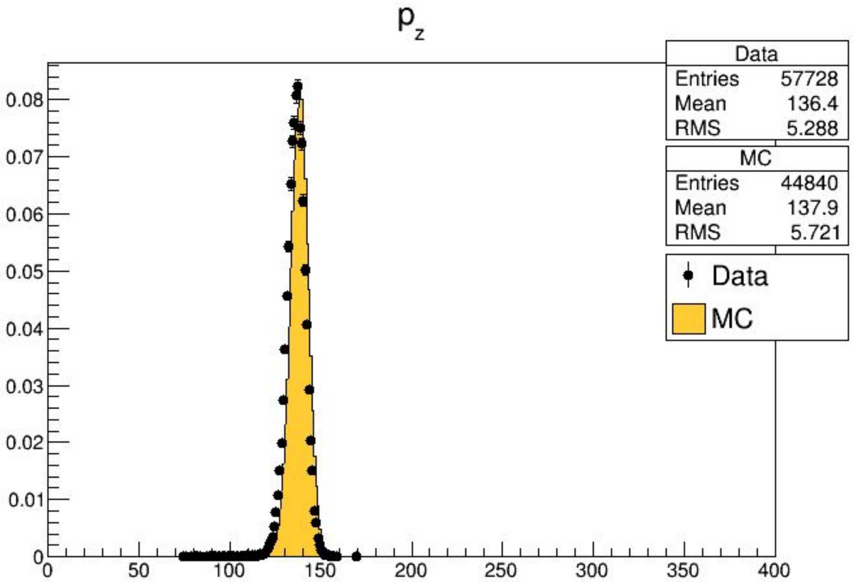
Beam Momentum: P_z

Upstream

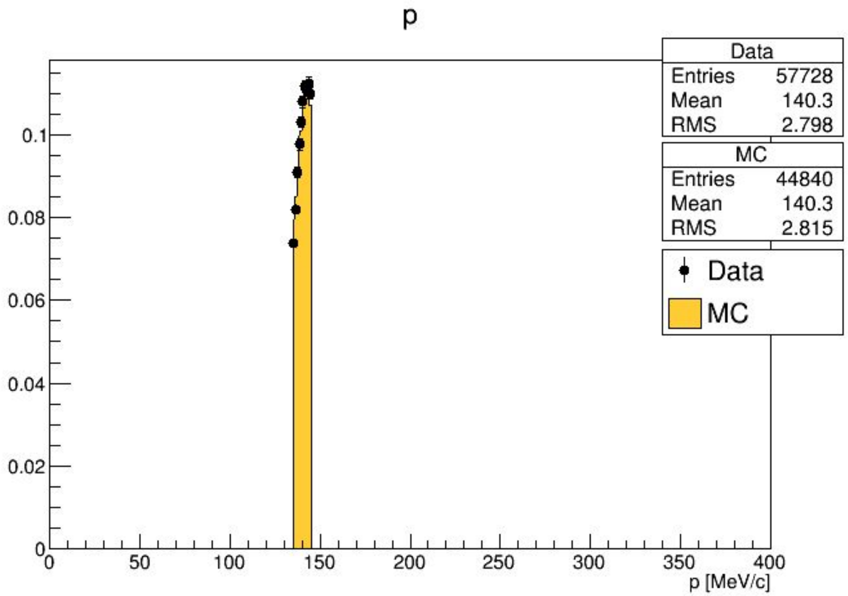


Downstream

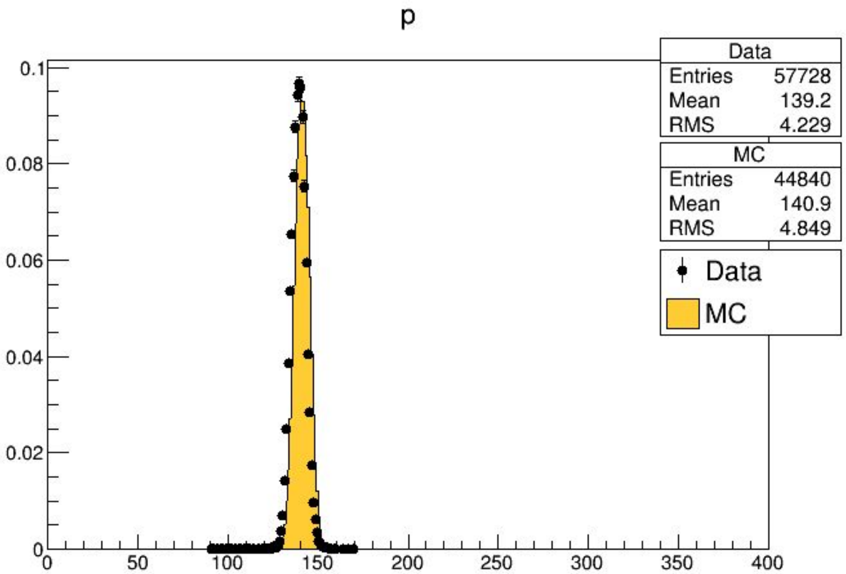


Beam Momentum: P

Upstream



Downstream



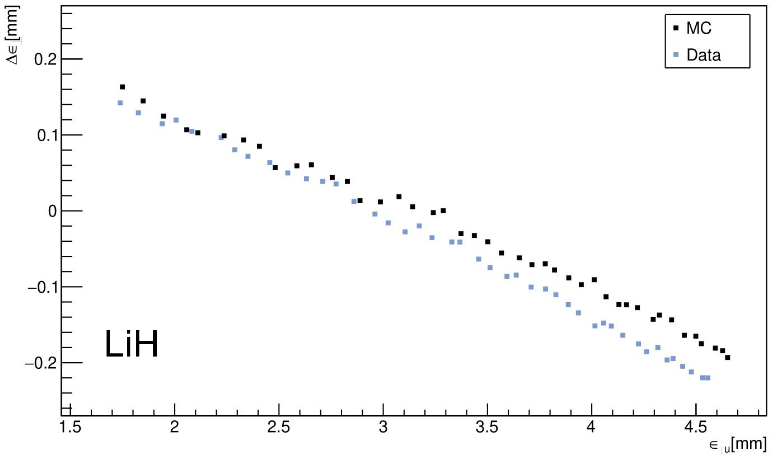
Data / MC disagreement

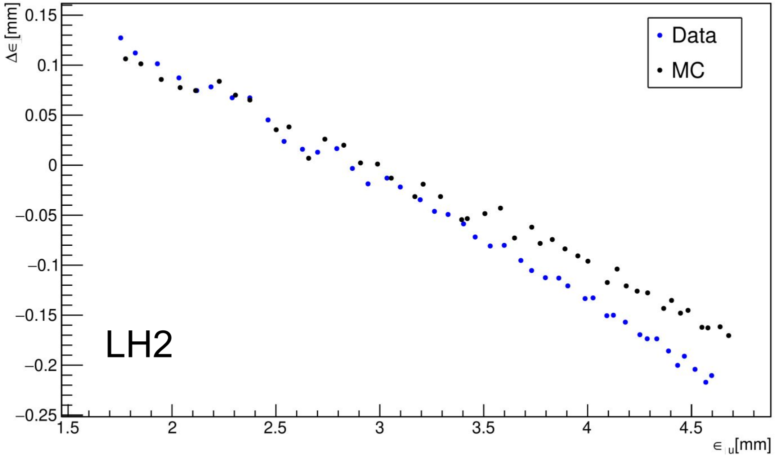
Good agreement upstream given by the sampling routines!

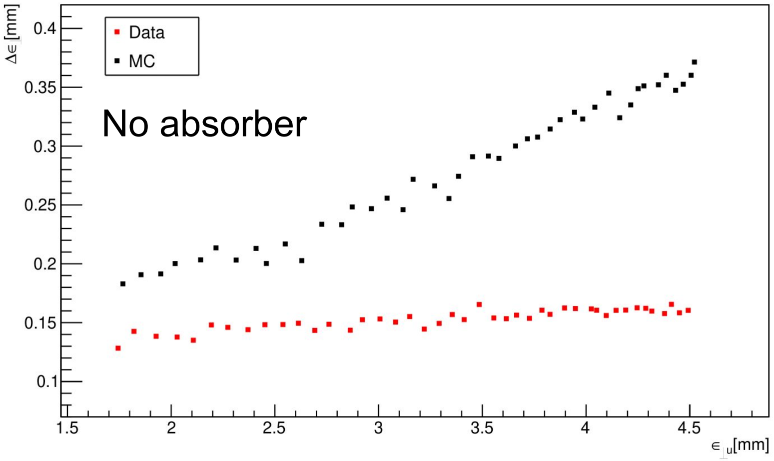
However, downstream:

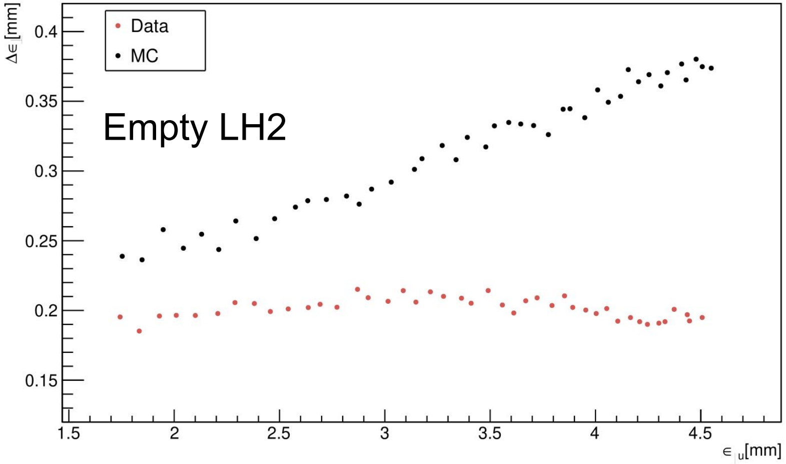
1) Wider distributions seen in MC
2) x,y centroid discrepancies -> misalignment (AFC, TKD)
3) Higher momentum in reco MC than in reco data

Data vs MC: Emittance change (old)



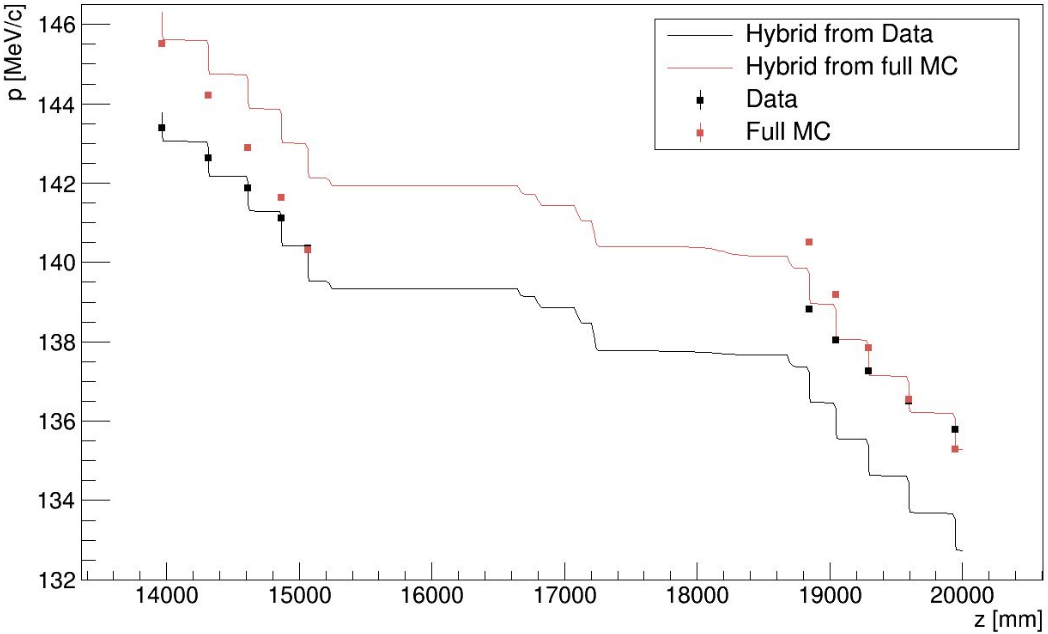






Data / MC disagreement

- large disagreements seen in *No absorber* and *Empty LH2* in the absolute emittance change
- search for potential causes revealed issues with the mean total momentum evolution in the channel: potential energy loss model discrepancy at tracker stations



MC digging

- SciFiParams_Density was the root of the problem
- it sets the density of the scintillating fibres used in the Kalman filter energy loss model
- default value in MAUS is 1.06 g/cm^3 (used for data reconstruction in this analysis)
- in the old MC version, SciFiParams_Density = 2.0 g/cm^3