Flip mode emittance analysis update

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Overview

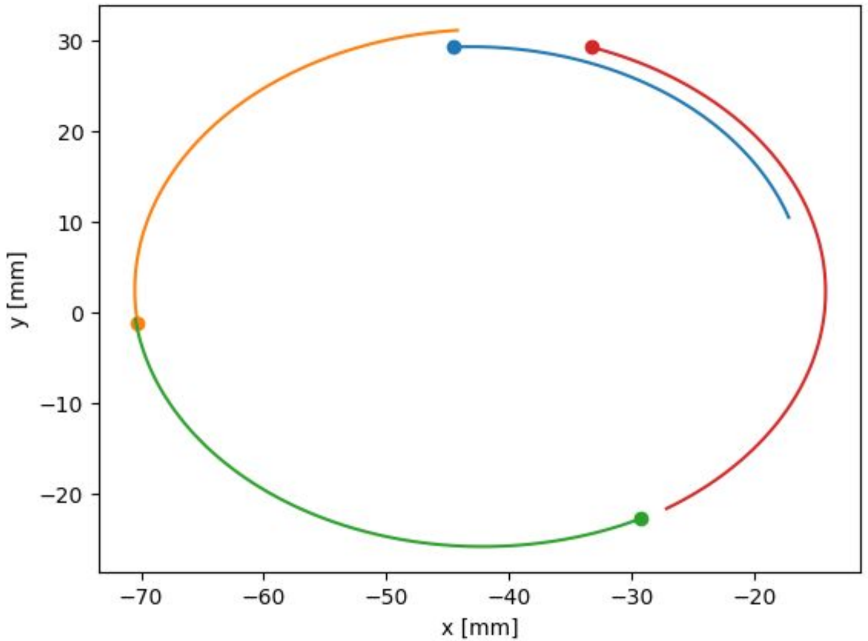
- Fiducial radius cut

- Update on the Empty vessel analysis (6 mm, 140 MeV/c)

- Update on Rejection Sampling - Normalisation

Tracker fiducial cut update

- Previously events were cut if the fiducial radius was exceeded at the tracker stations.
- However, particles can also exceed this radius in between the tracker stations.
- To account for this, particle trajectories are calculated in between the stations, assuming a constant B_z field.
- Cut tested and now incorporated in the analysis code.



Example of calculated particle trajectory between TKU stations. It starts in TKU5 (red) and ends at TKU1 (blue).

Empty vessel analysis (update with new radius cut)

- The new radius cut eliminates ~ 2k more particles from the parent ensamble.

- Mainly in the downstream tracker where the beam width oscillates with a relatively large amplitude.

- However, the issues seen before still persist - disagreement between Data and MC in the downstream tracker (see next slides).

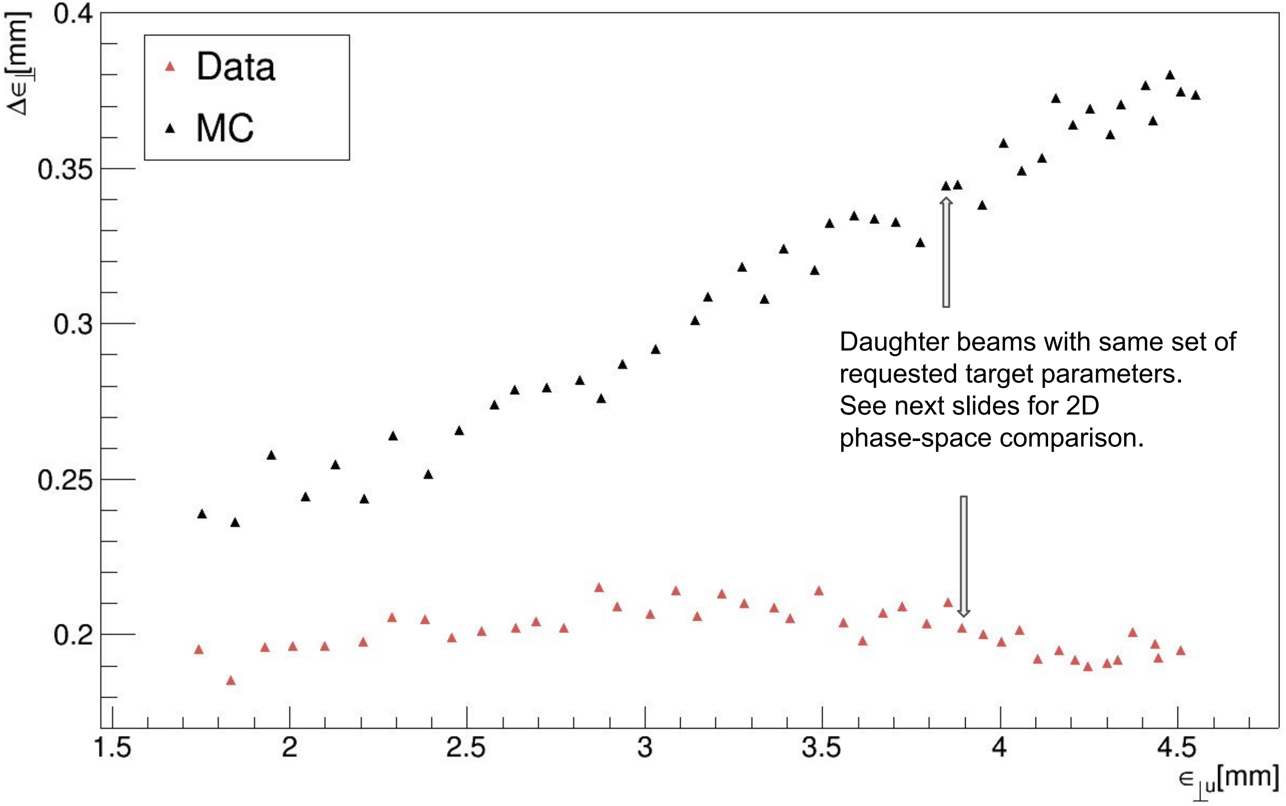
Empty vessel - Data vs MC

Similar discrepancy as in the *No Absorber* case: significantly more cooling in MC; cooling correlated with upstream emittance.

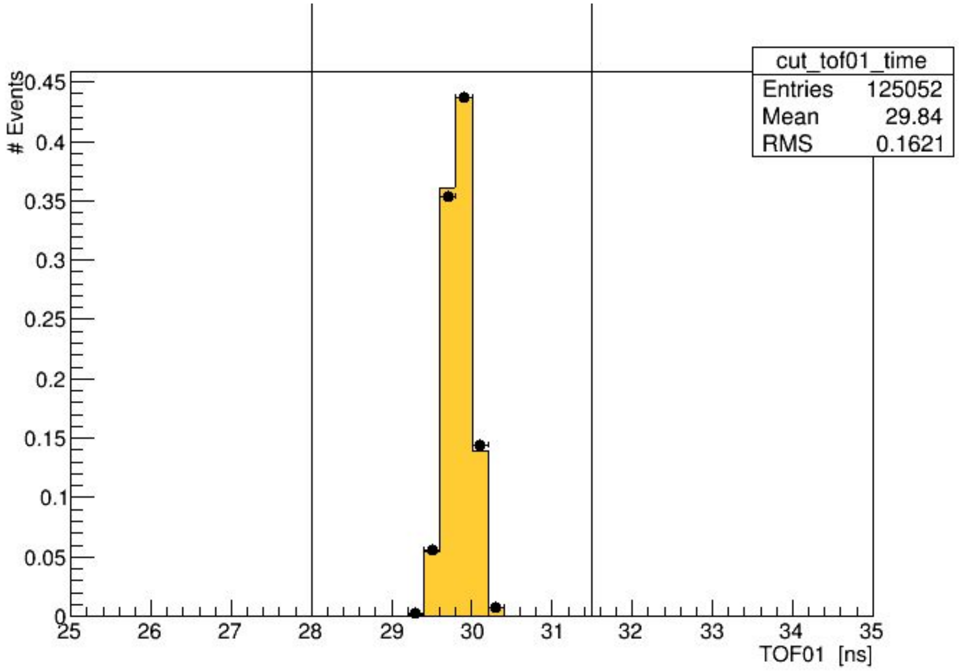
Could occur due to different optics.

Significant tails in (x,y) sub-space observed downstream.

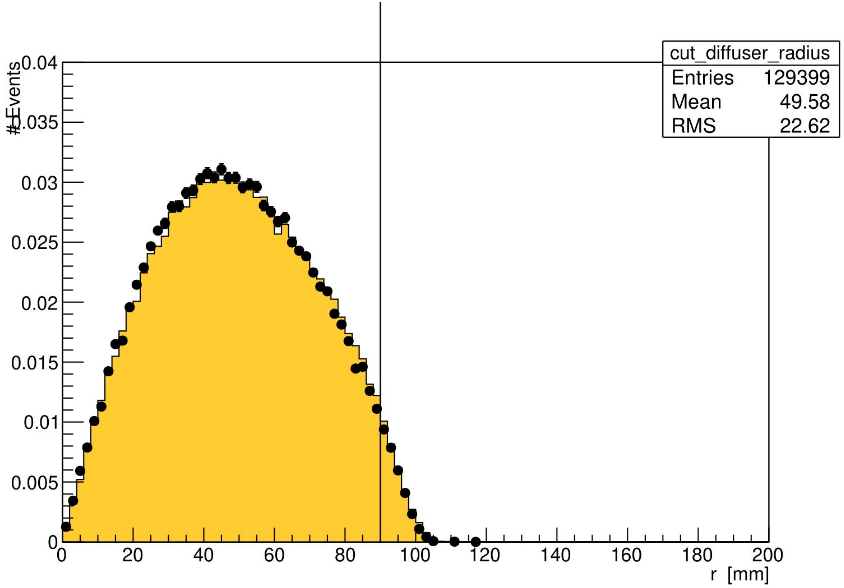
To be investigated



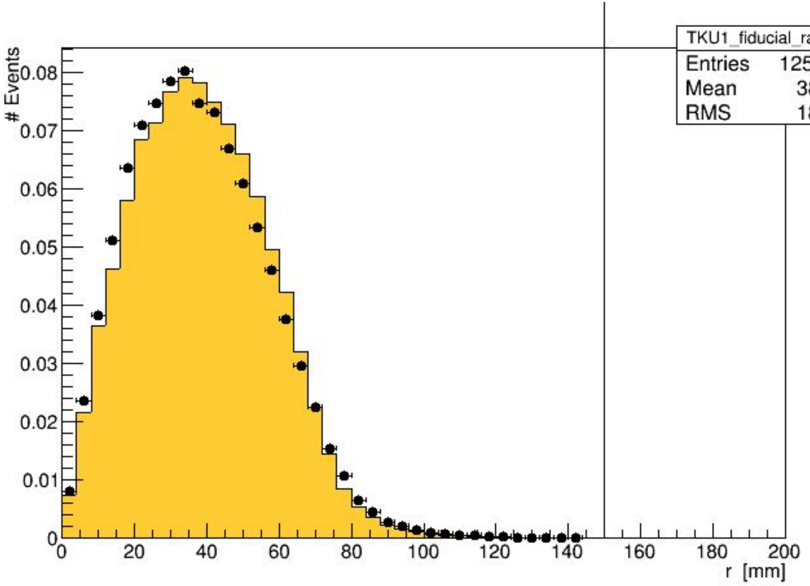
TOF01


cut_tof01_time
Entries 125052
Mean 29.84
RMS 0.1621
Events
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
25
26
27
28
29
30
31
32
33
34
35
TOF01 [ns]

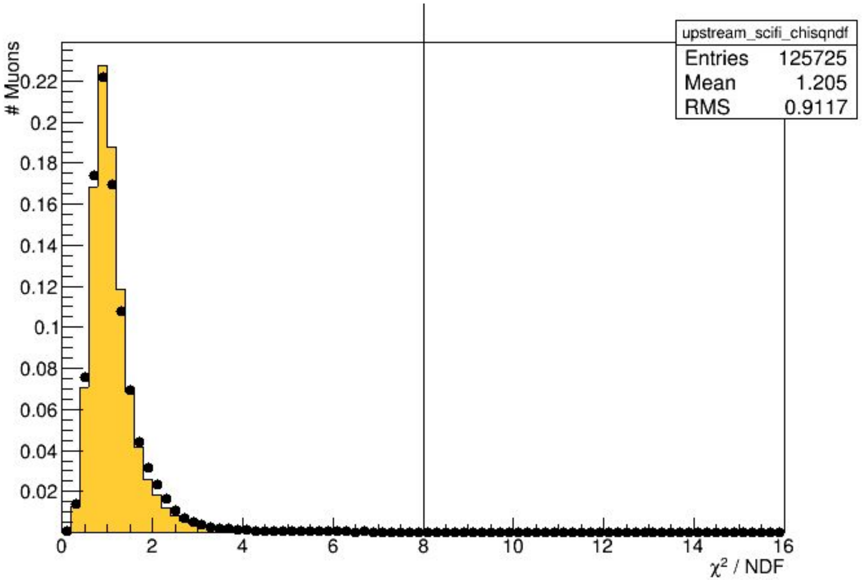
Radius at diffuser



Upstream tracker cuts

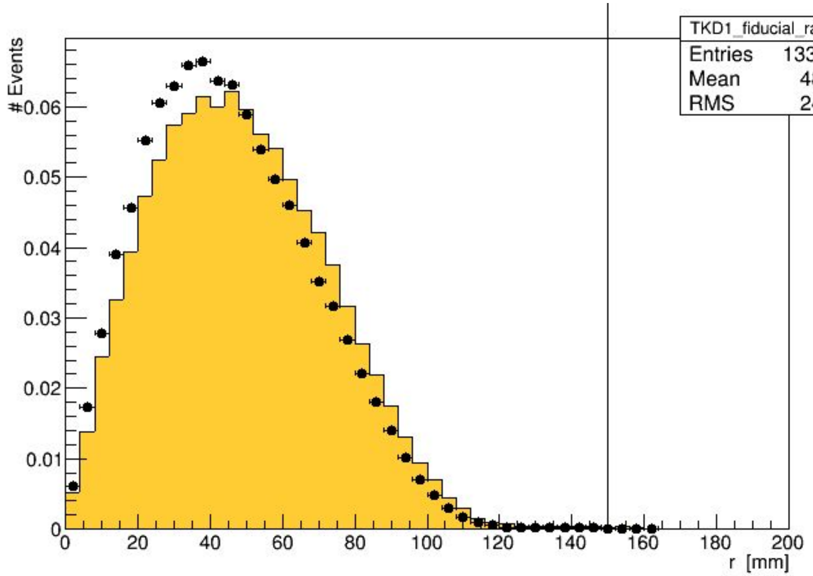


Fiducial radius cut

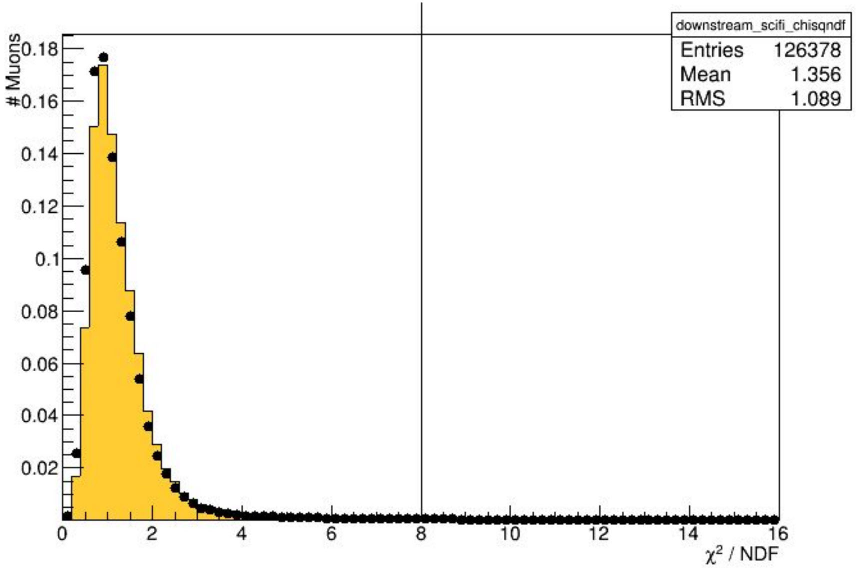


χ^2 / NDF

Downstream tracker cuts



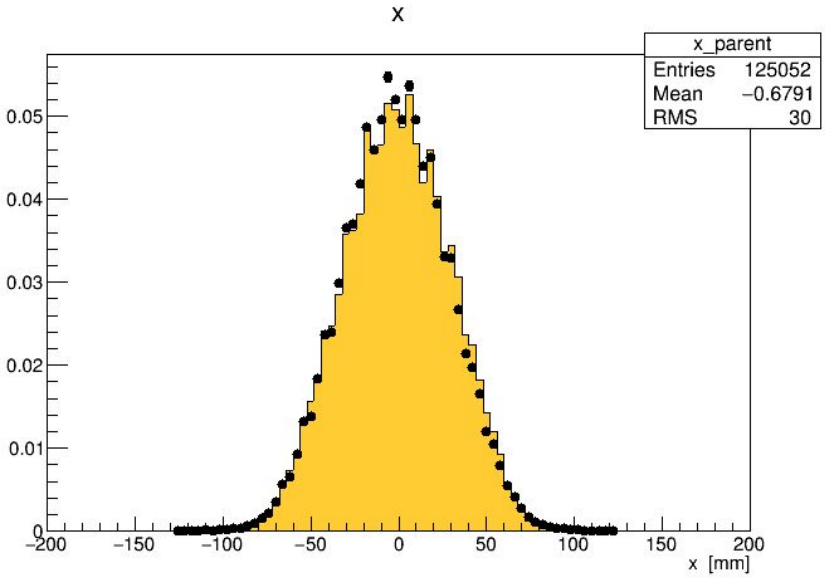
Fiducial radius cut



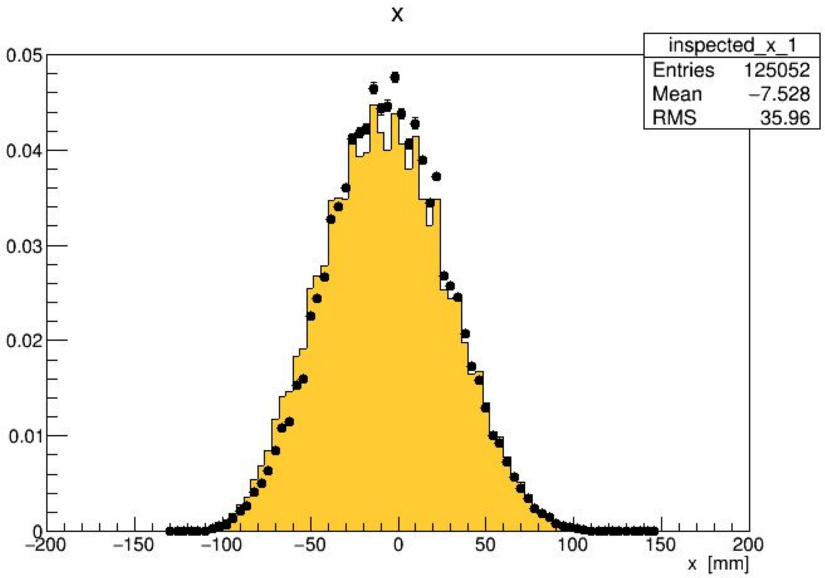
χ^2 / NDF

Beam Position: X

Upstream

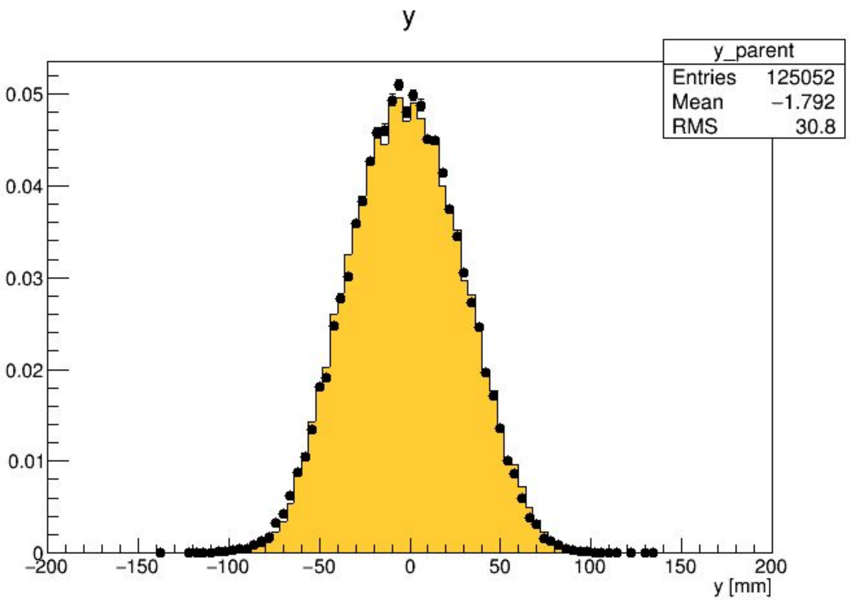


Downstream

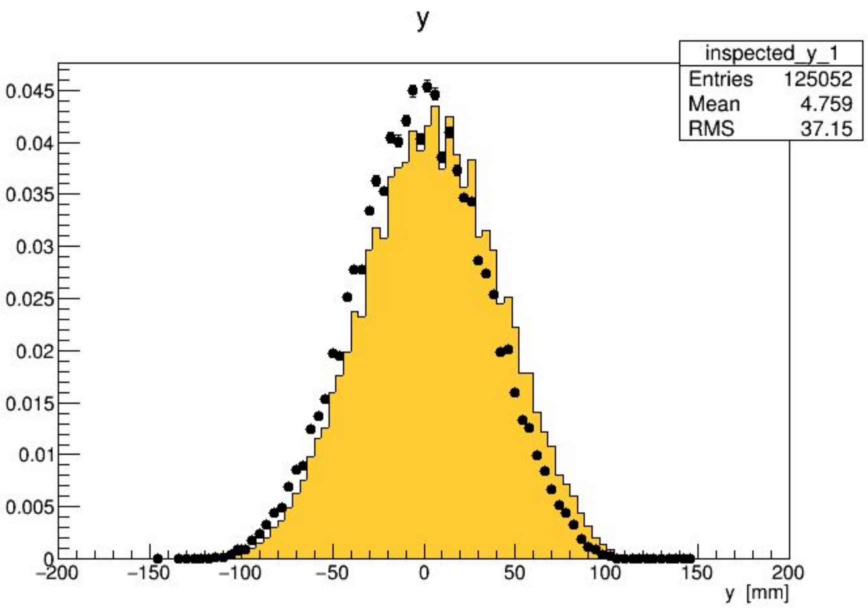


Beam Position: Y

Upstream

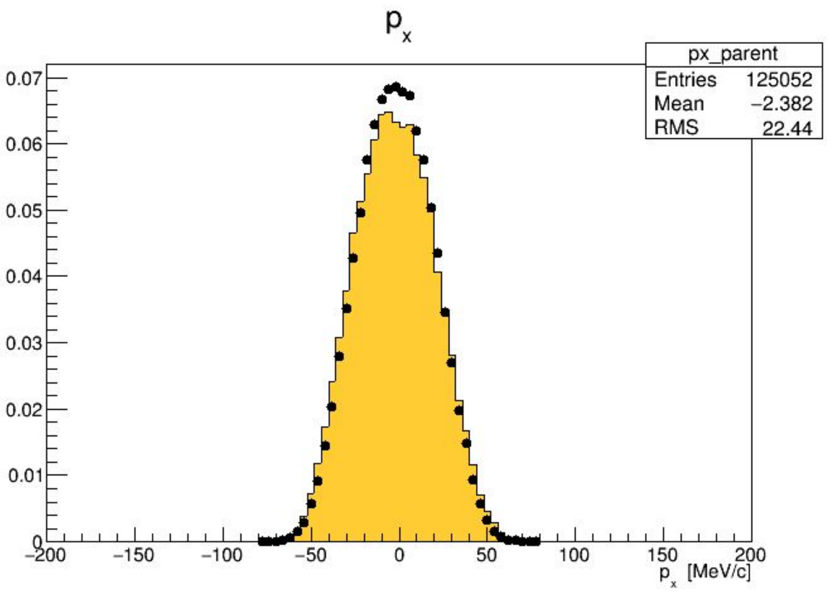


Downstream

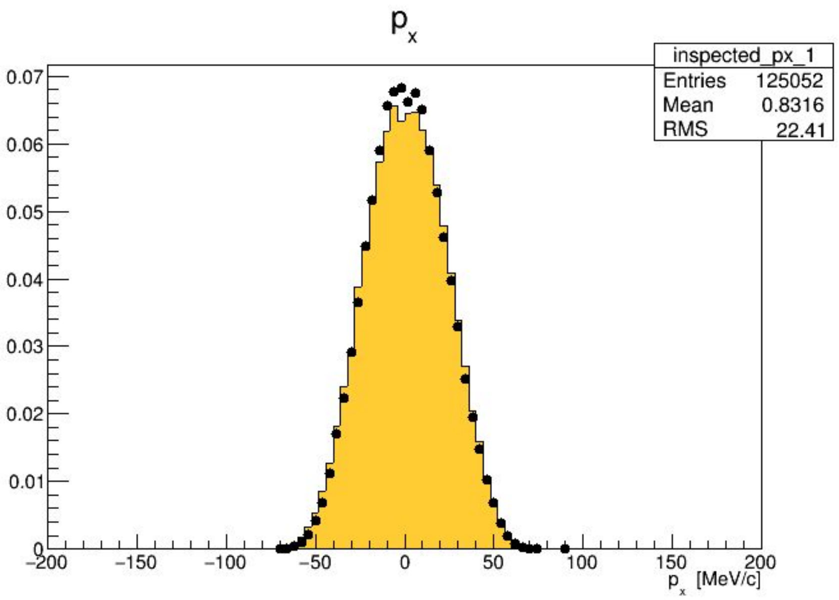


Beam Momentum: P_x

Upstream

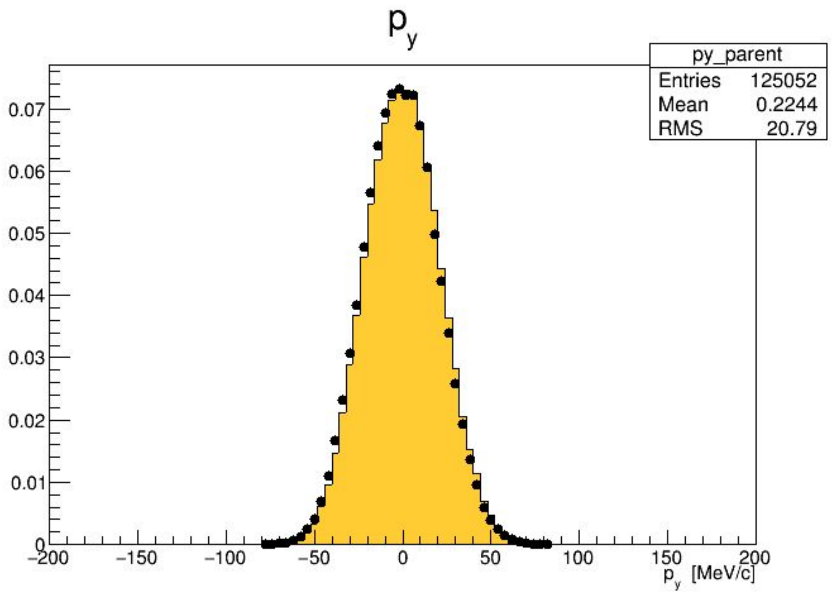


Downstream

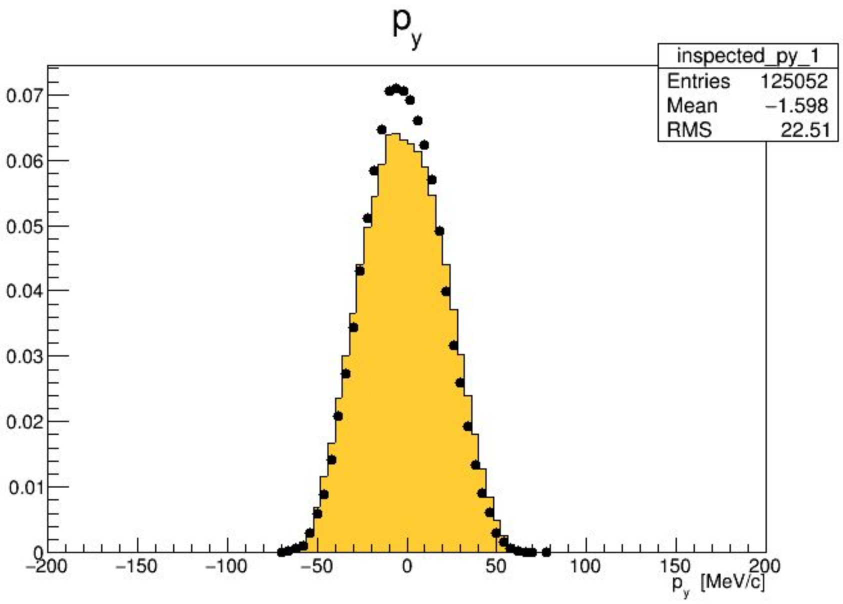


Beam Momentum: P_y

Upstream

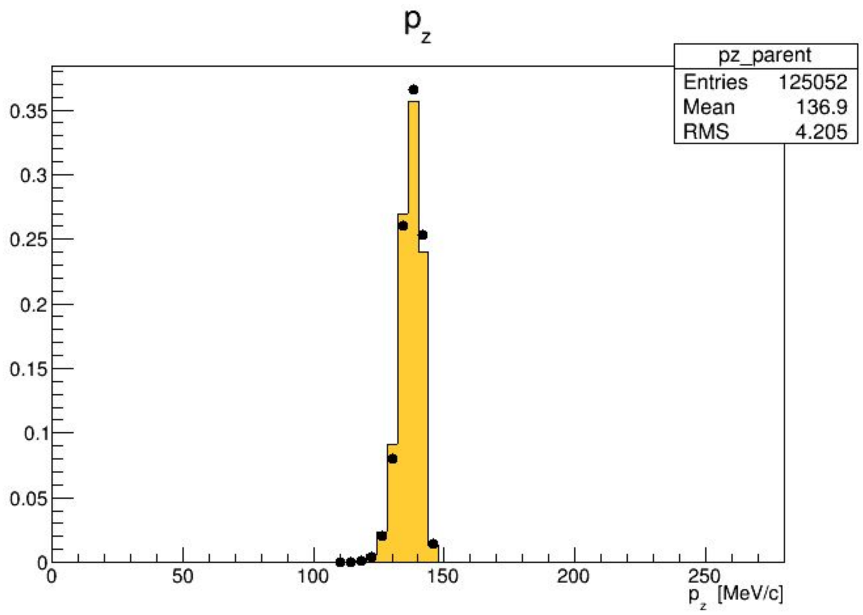


Downstream

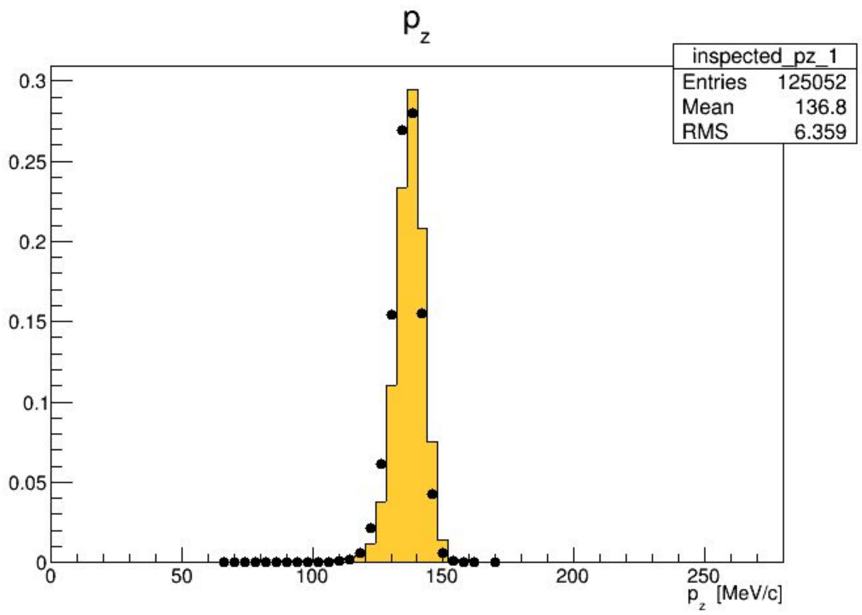


Beam Momentum: P_z

Upstream

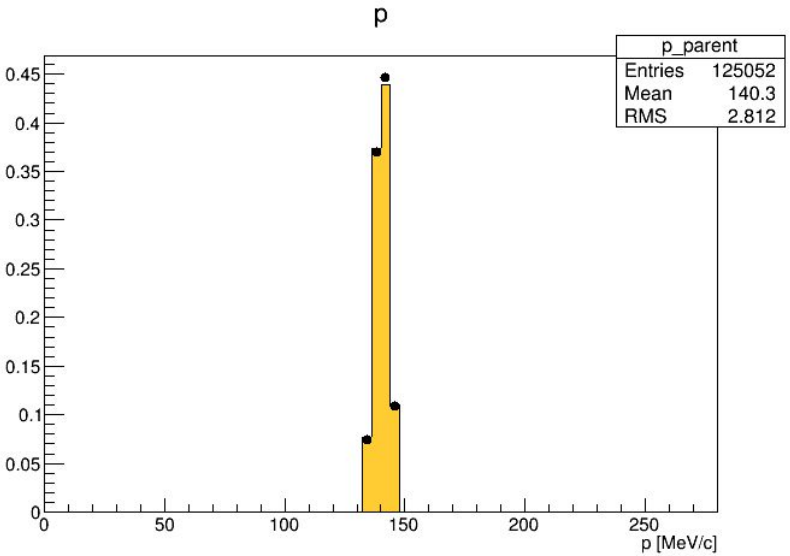


Downstream

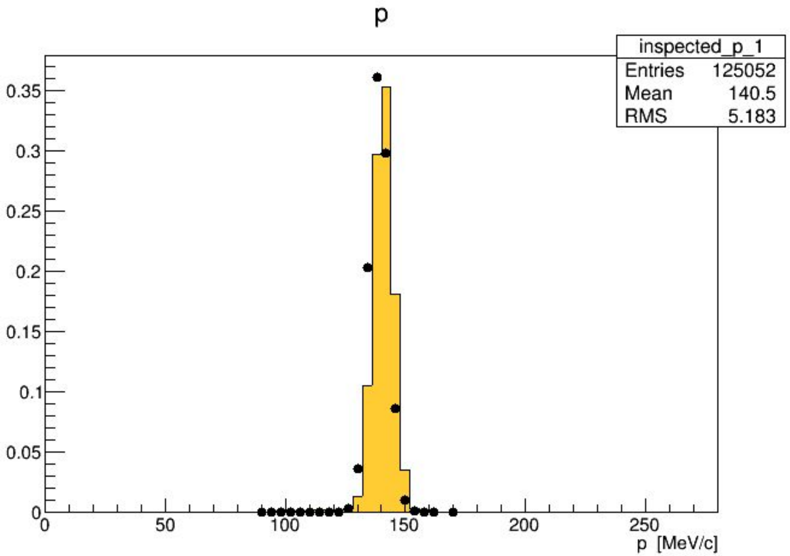


Beam Momentum: P

Upstream



Downstream

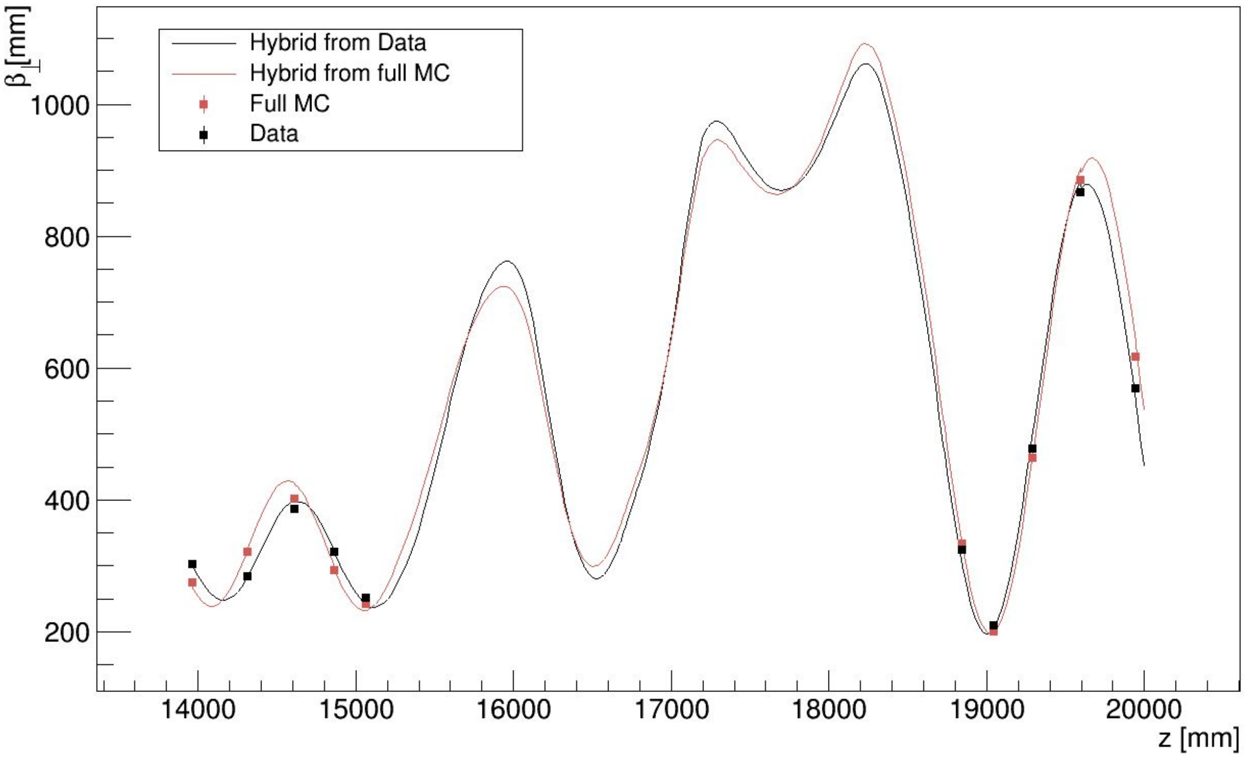


In Data, the beam losses ~ 1.6 MeV/c between trackers, while in MC it gains ~0.2 MeV/c

Hybrid MC (Truth)

- Extracted Data and full MC parent beams at TKU5 and produced hybrid MC simulations
- Simulated 15k particles
- Events in the simulated beams only required to pass through all the virtual planes in the cooling channel (from TKU5 to TKD5)

Beta



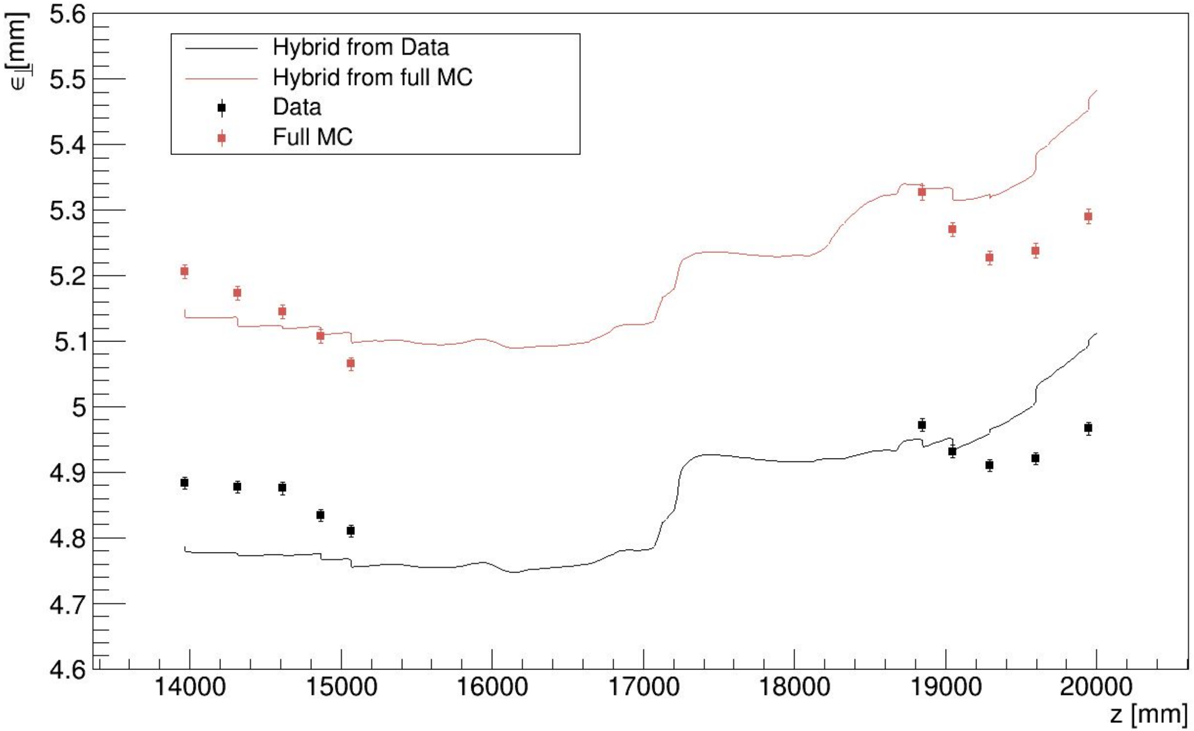
$\beta_\perp$[mm]
1000
800
600
400
200
14000
15000
16000
17000
18000
19000
20000
z [mm]
Hybrid from Data
Hybrid from full MC
Full MC
Data

Emittance

Offset between the starting points due to cutting extra particles from the hybrid beams.

Emittance growth at z ~ 17200 mm larger in Data, corresponding to a slightly larger beta in that region.

Extra emittance growth observed in MC between ~[18200, 18600] mm. Slightly higher beta observed in MC in the same region.

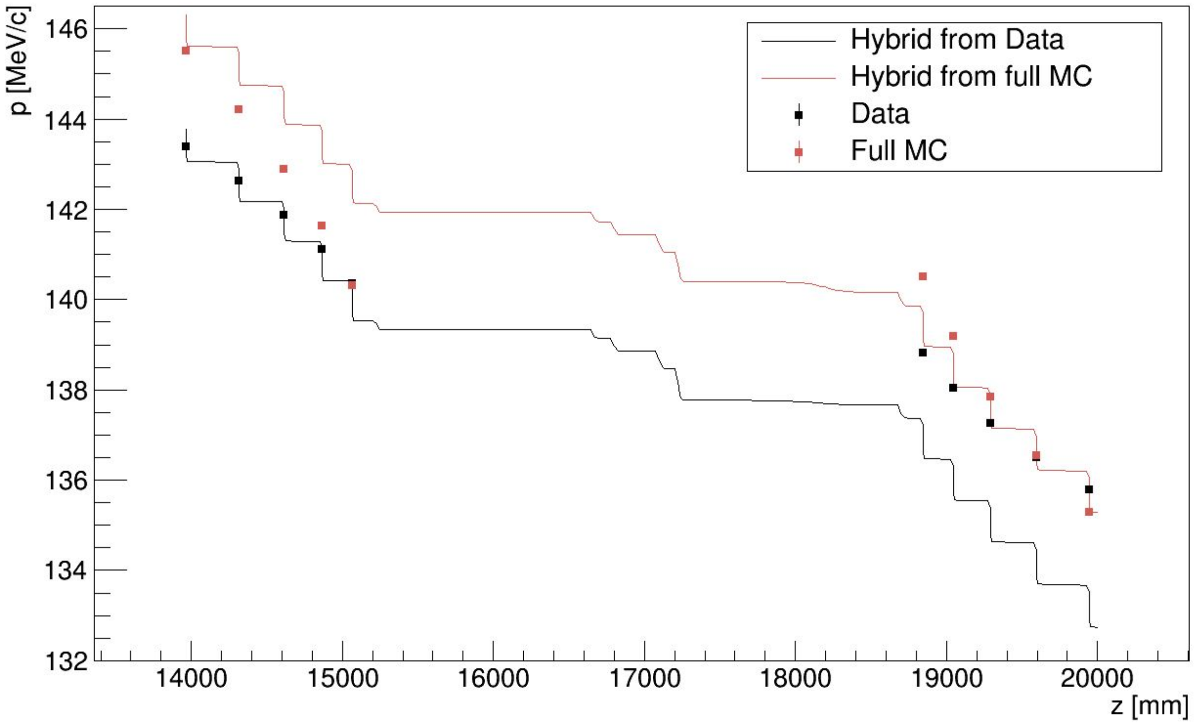


Momentum

More energy/momentum loss at tracker stations observed in the full MC than in Data. However, while in Data the beam losses 1.6 MeV/c by passing through the vessel windows, there is a 0.2 MeV/c gain in the full MC.

Also, the energy loss in the full MC is greater than the loss observed in the Hybrid MC. I know CR tweaked the glue density in the tracker stations -> are the trackers descriptions the same in CR’s full MC and my Hybrid MC?

Also, the Hybrid MC observed the presence of the vessel.

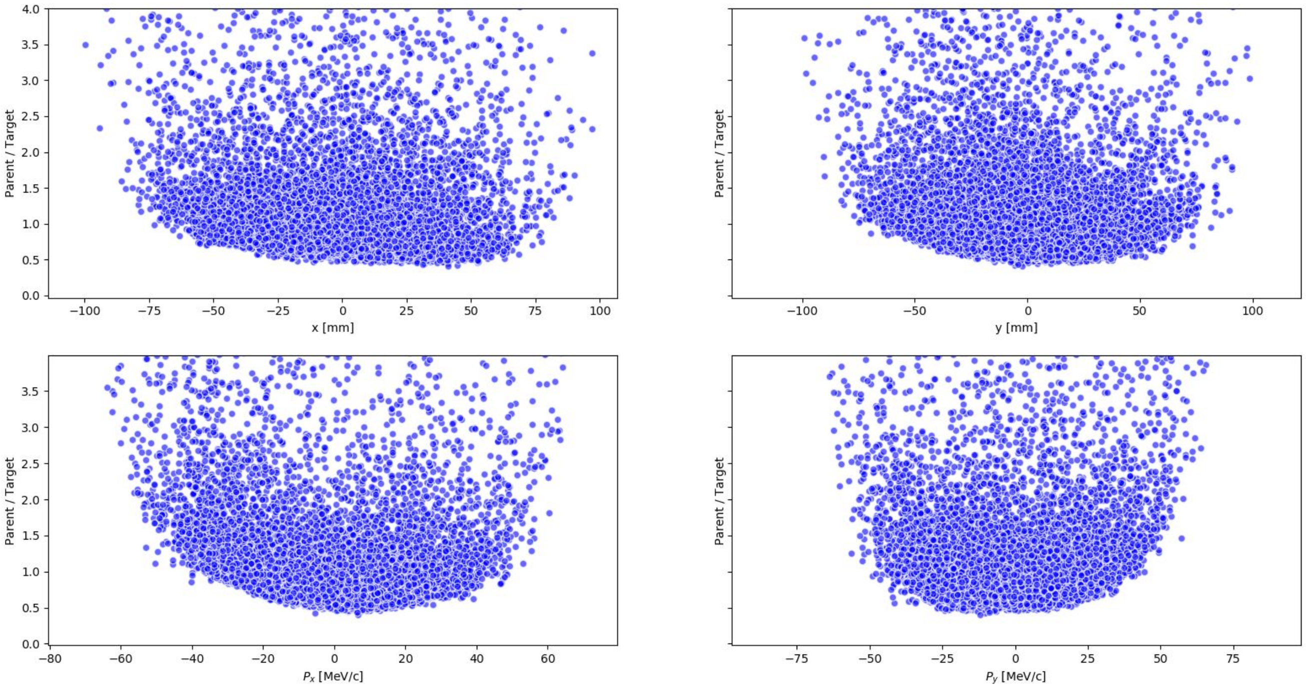


Rejection Sampling Normalisation - Parent (x) / Target (x)

The higher likelihood of particles coming from the target distribution leads to N < 1. In this case N ~ 0.5.

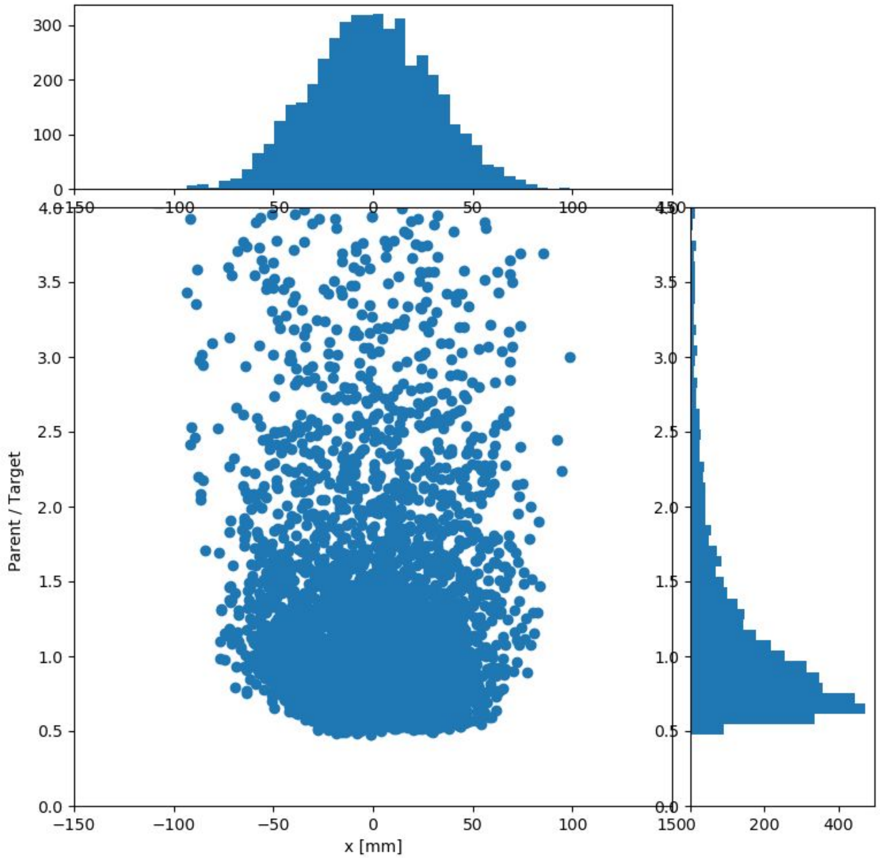
Tails seem not to impact the N estimation.

Seek to change the N estimation method such that more particles are accepted into the daughter beam, without impacting the selection performance.



Choose N as the most probable value of Parent(x) / Target(x), rather than the minimum.

Study the improvement in the number of particles accepted in the daughter beams and the impact on the daughter beam parameters.



BACKUP

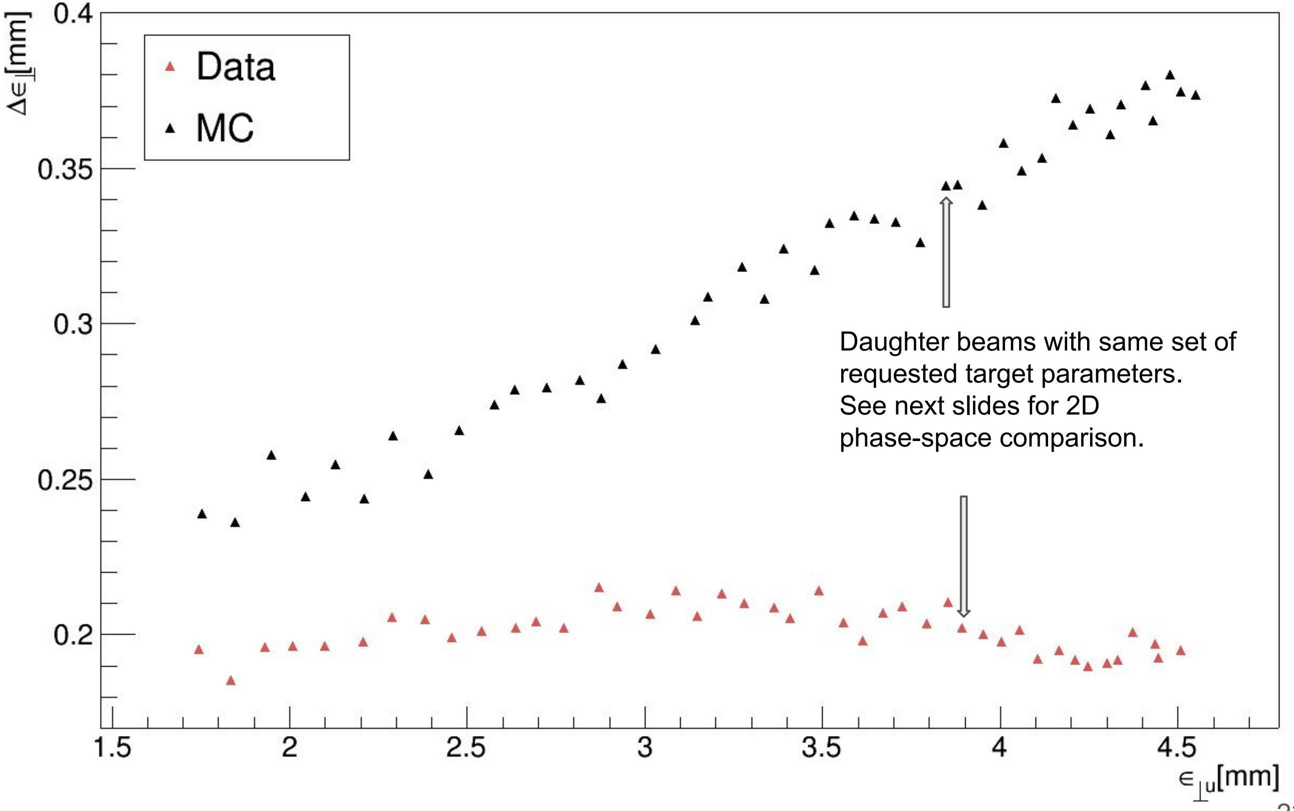
Empty vessel - Data vs MC

Similar discrepancy as in the *No Absorber* case: significantly more cooling in MC; cooling correlated with upstream emittance.

Could occur due to different optics.

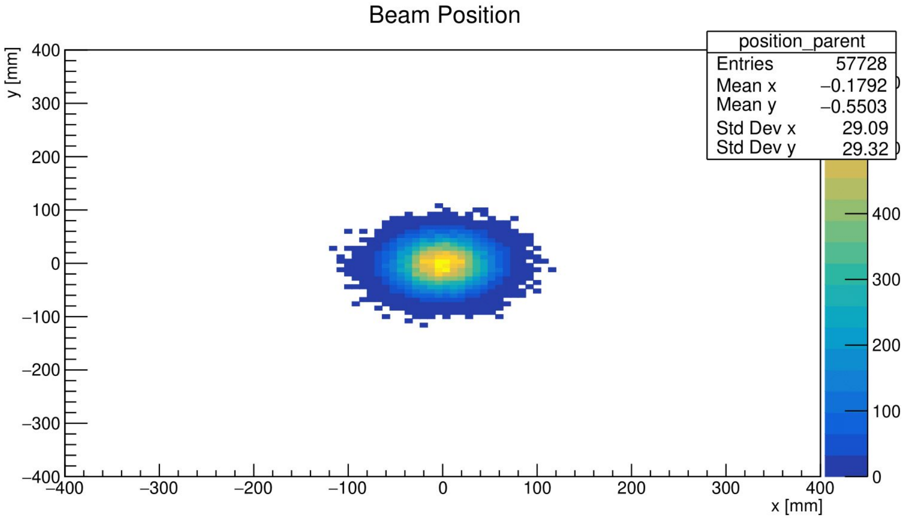
Significant tails in (x,y) sub-space observed downstream.

To be investigated

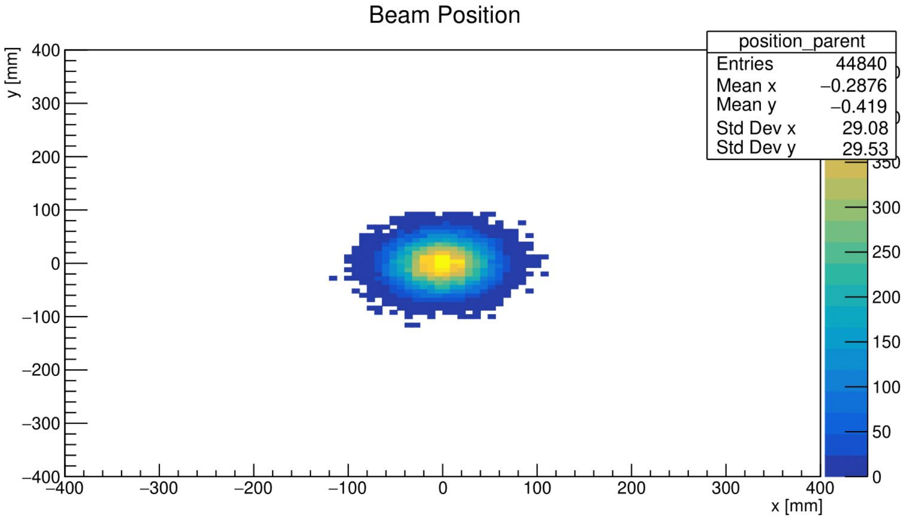


Beam Position Upstream

Data

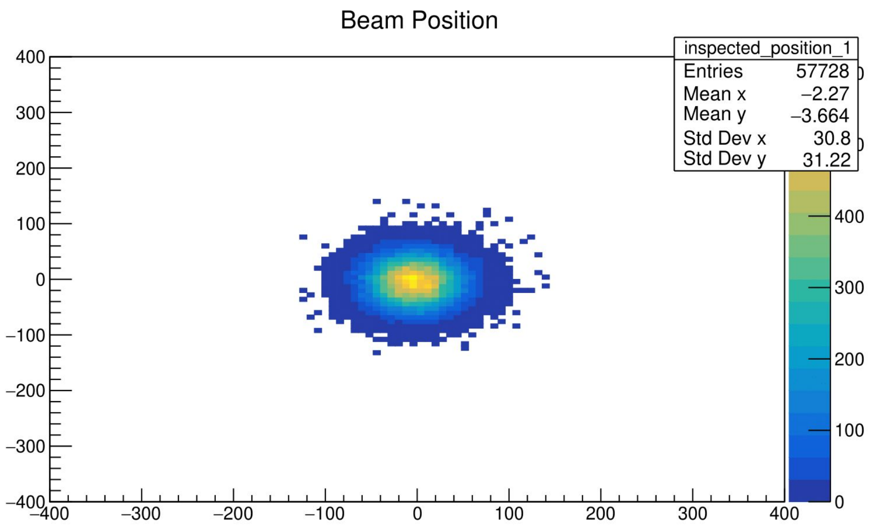


MC

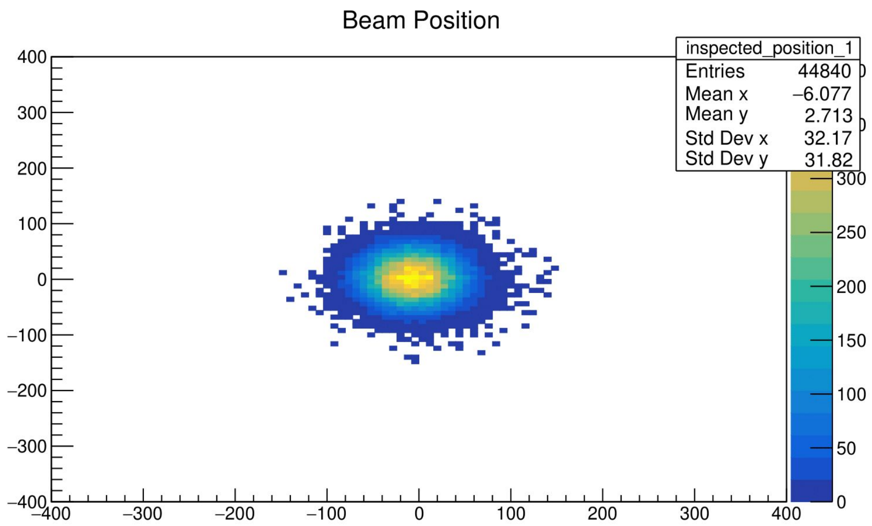


Beam Position Downstream

Data

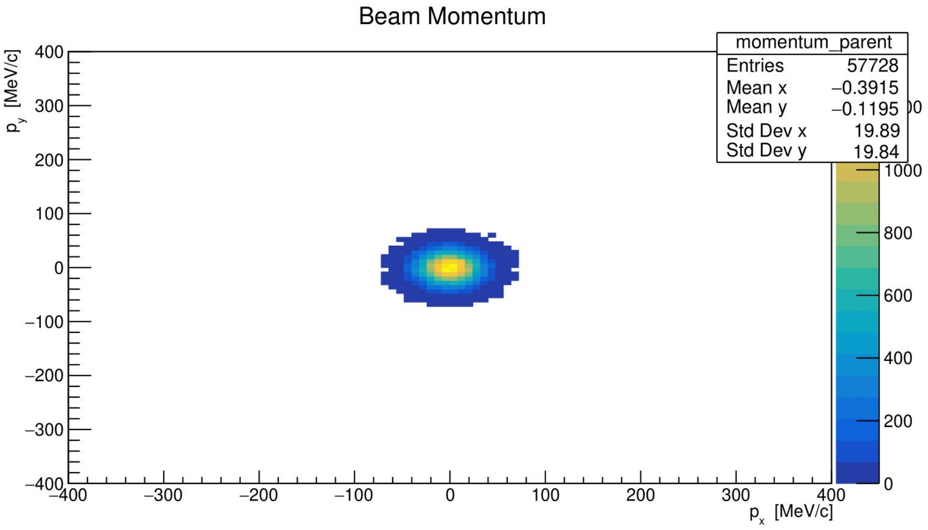


MC

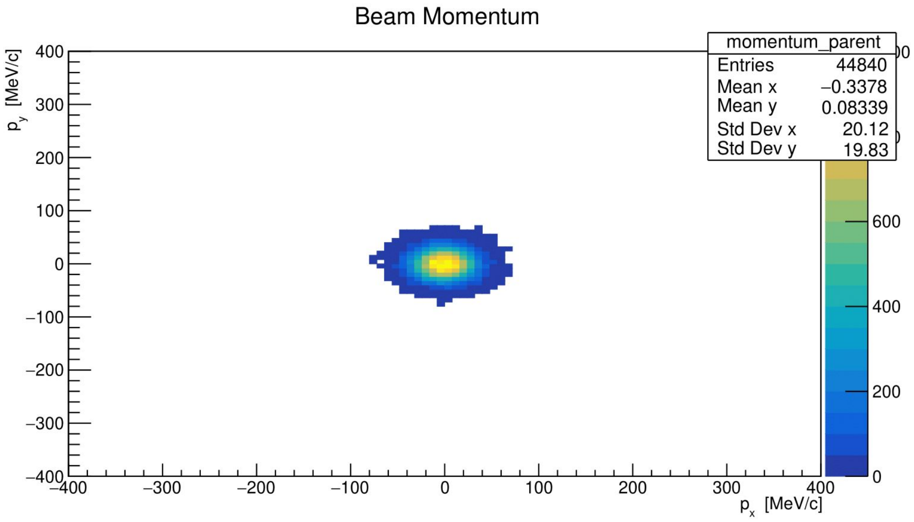


Beam Momentum Upstream

Data

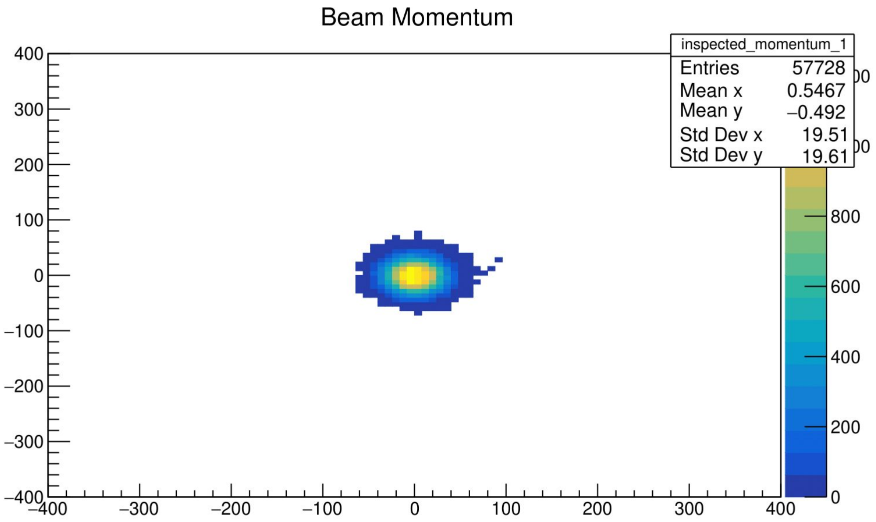


MC

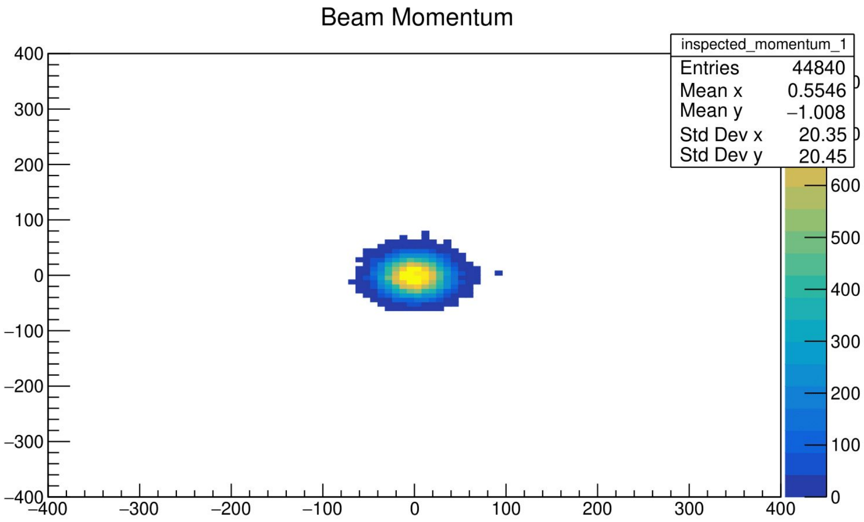


Beam Momentum Downstream

Data

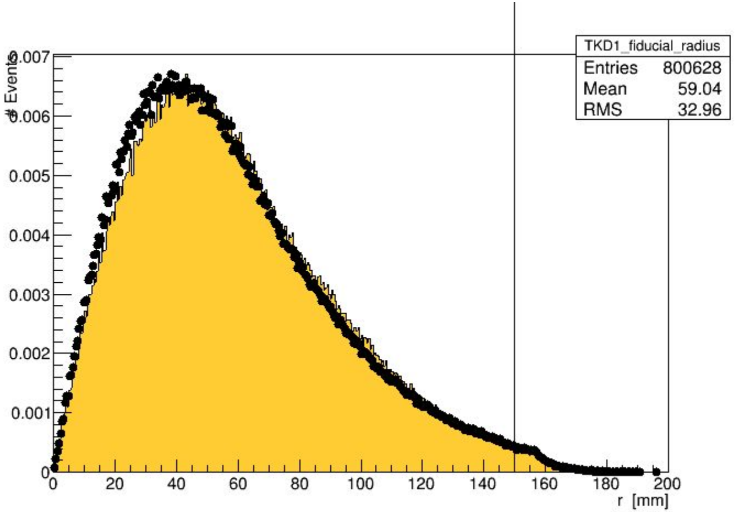


MC

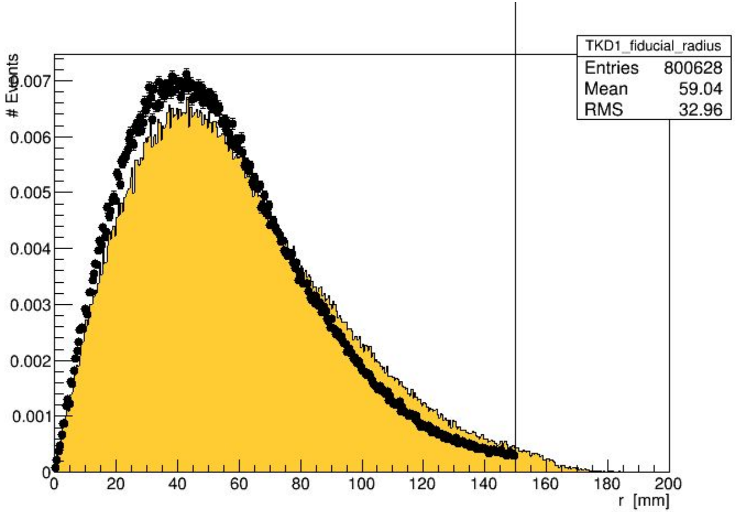


TKD fiducial cut (parent beam selection)

No momentum cut applied on data



With momentum cut applied



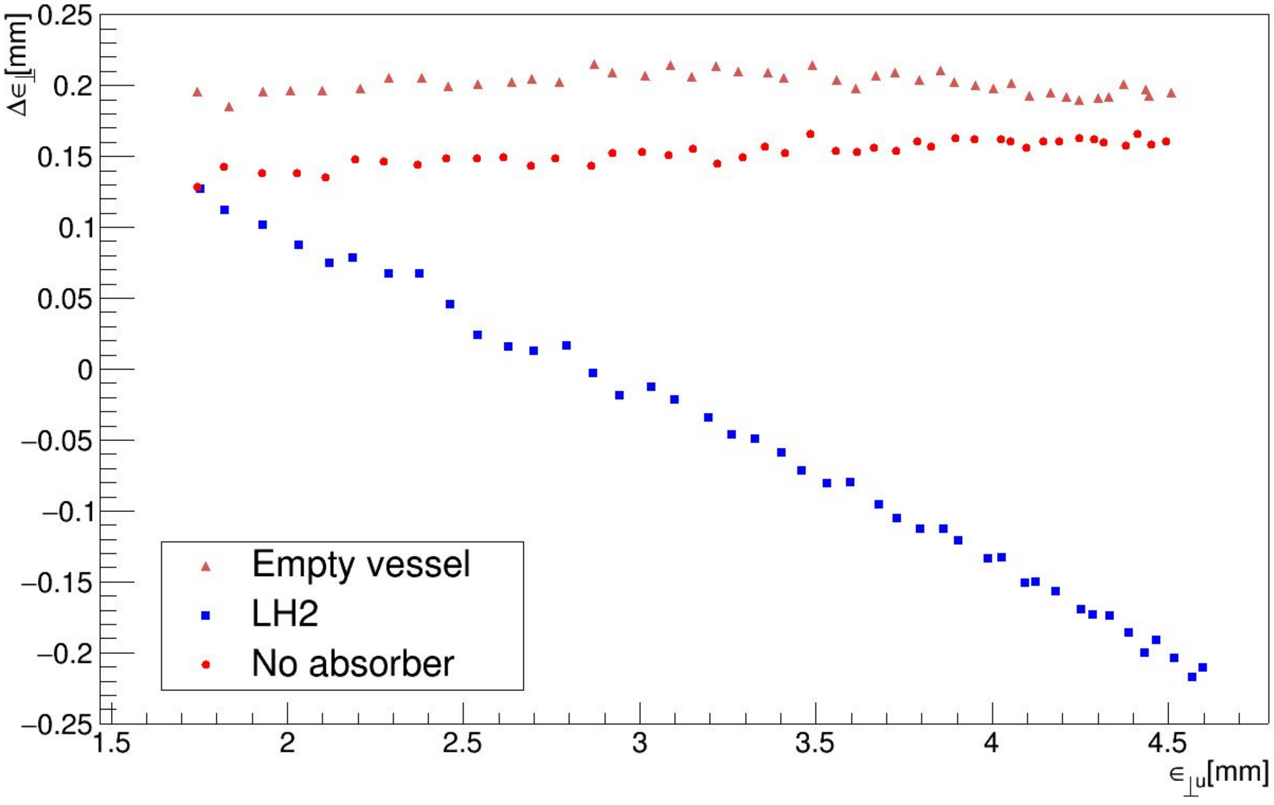
LHS: Bug in data cut (no 135 -145 MeV momentum cut applied). Cut applied on MC.

RHS: Bug fixed. Momentum cut applied to both data and MC. However, worse agreement. More particles at larger radius seen in MC.

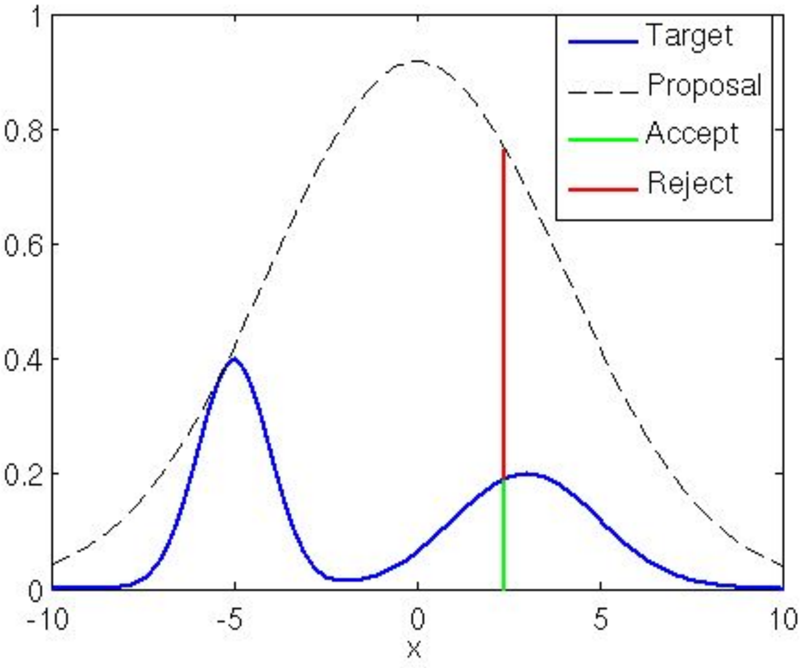
Emittance change (Data)

More heating observed than in the *No absorber* case due to scattering from the vessel windows.

Heating ~ constant with respect to the emittance of the incoming beam. Possible reduction in heating at higher emittances, as the cooling effect due to the windows increases.



Rejection Sampling



- $P_{selection}(x)$ = *Norm * Target(x) / Parent (x)*
- Draw *u* from *U[0,1]*. If *u* < $P_{selection}(x)$ then accept event. Otherwise reject it.
- Normalisation calculation:
  - for a large number of times randomly draw a sample *x* from the target distribution and take the minimum of *Parent (x) / Target (x)*
  - **OR** draw samples from the parent beam and take the minimum of *Parent (x) / Target (x)*
  - Normalisation ensures that $P_{selection}(x) <= 1$
  - **# of particles in the daugher beam ~ Norm** (currently rejection rate relatively high - can we improve?)

Event likelihood

Draw an particle from the parent distribution.

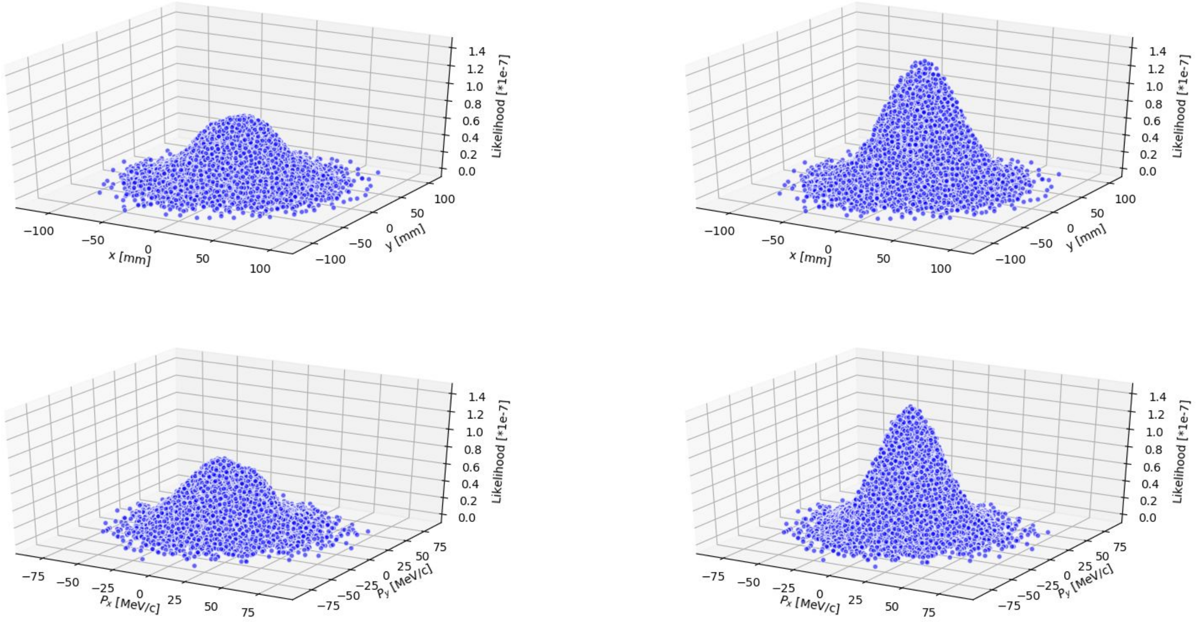
Calculate its likelihood of being sampled from the parent (KDE) and target (analytical 4D Gaussian) PDFs.

Here, likelihoods projected on the (x,y) and (p_x, p_y) subspaces.

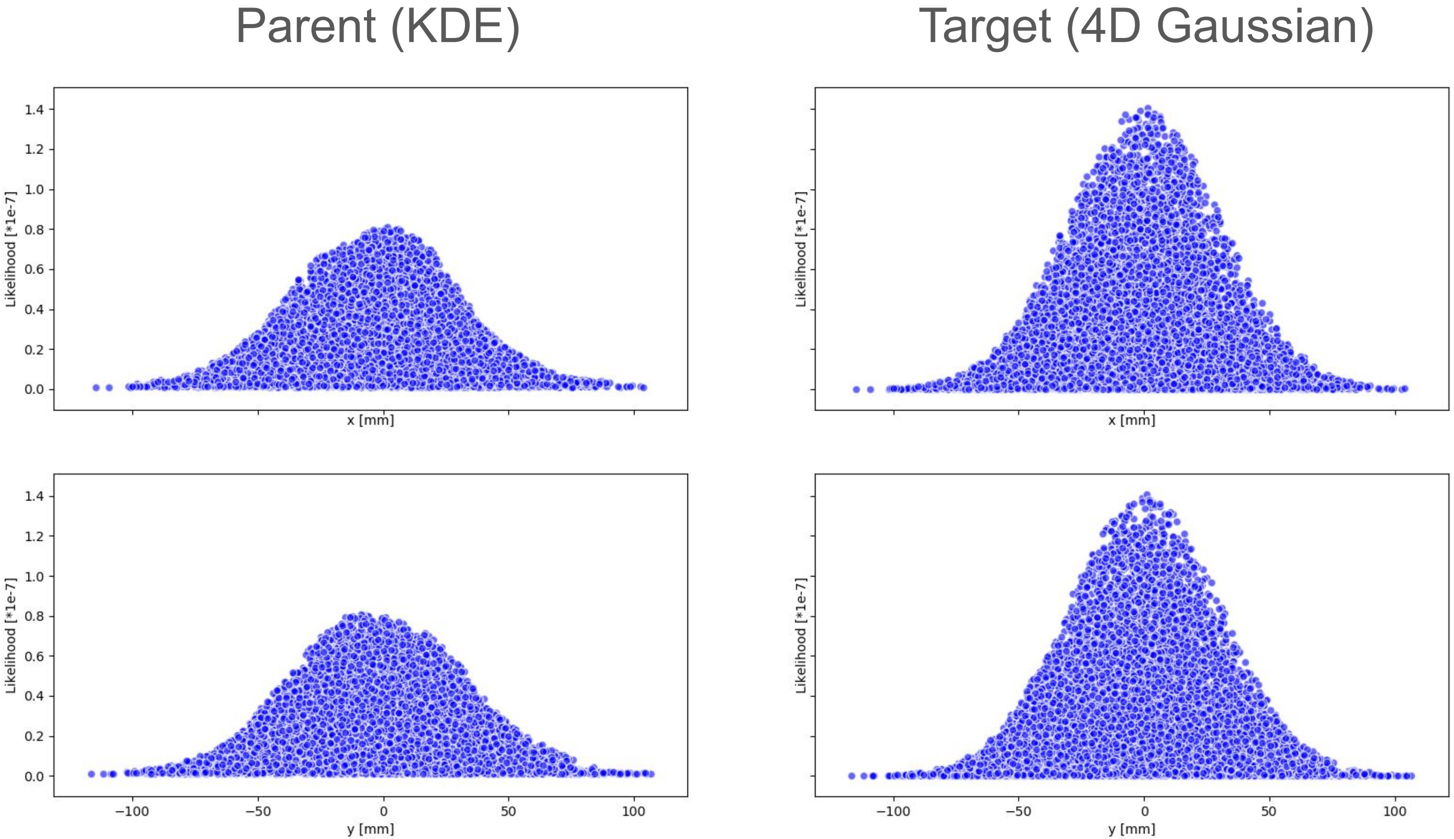
Beam parameters:

- Parent: [ϵ=4.85 mm, β = 282 mm, α = 0.36, L = 1.1]
- Target: [ϵ=4 mm, β = 310 mm, α = 0, L = 1.1]

Parent (KDE) | Target (4D Gaussian)



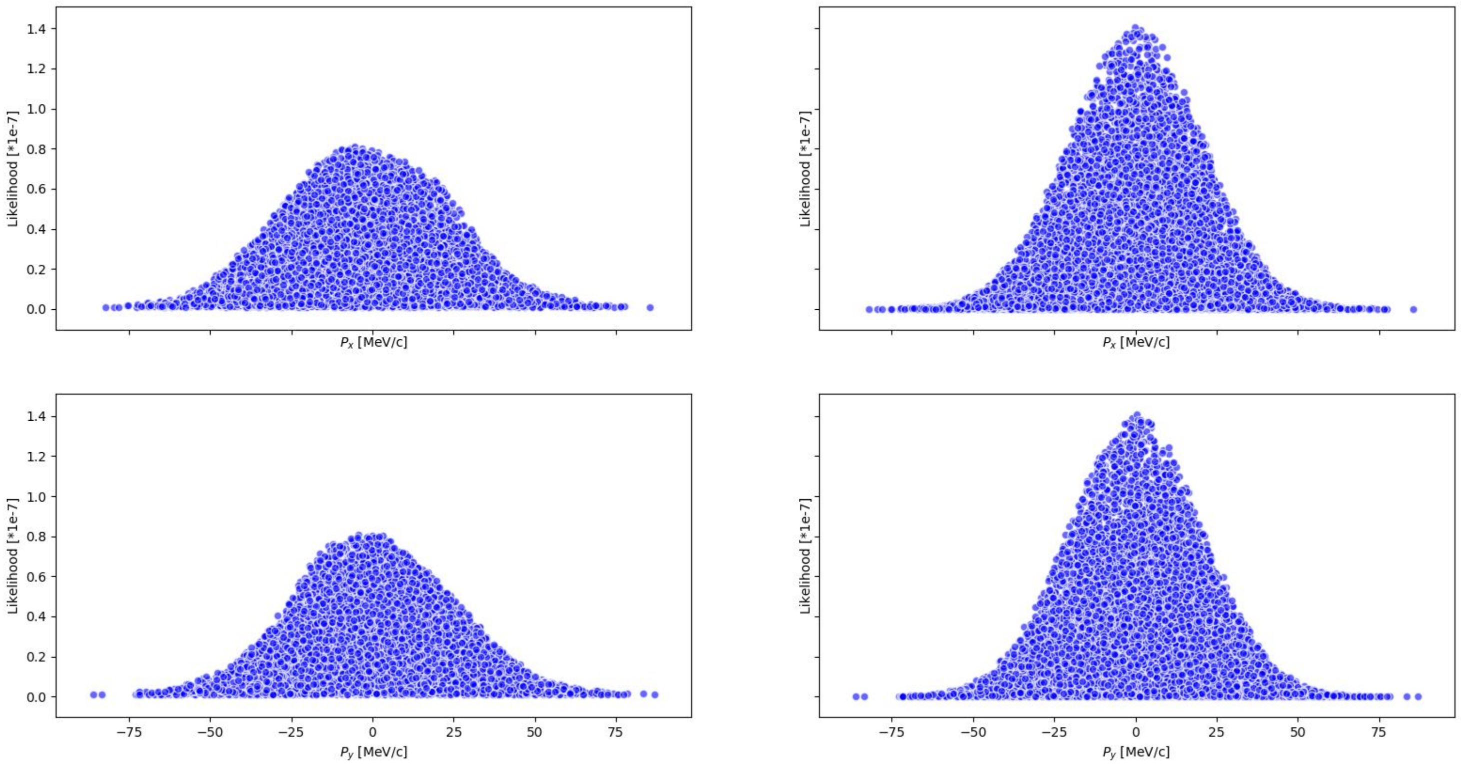
Event likelihood: 1D projections (position space)



Event likelihood: 1D projections (momentum space)

Parent (KDE)

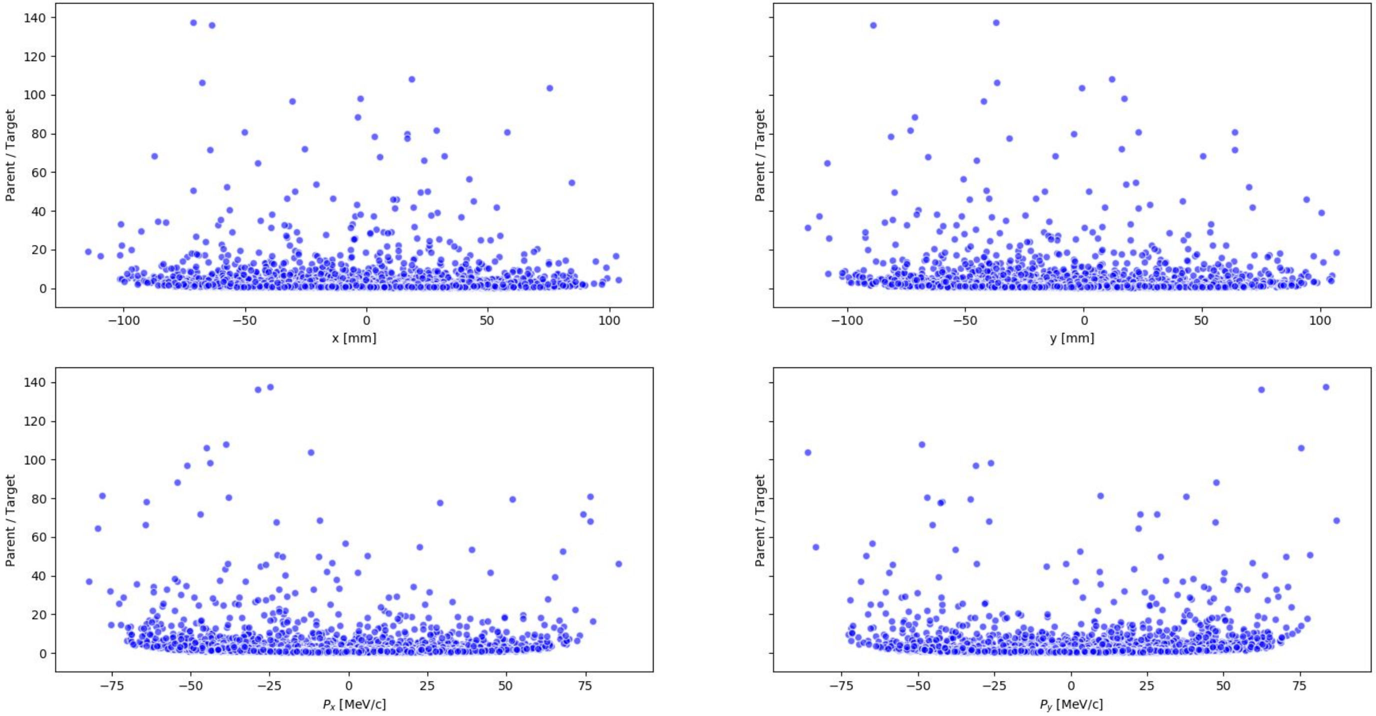
Target (4D Gaussian)



Parent (x) / Target (x)

Ratio of likelihoods projected on the 4D phase-space components.

Current procedure takes the normalisation as the minimum of these points.



Parent (x) / Target (x) (zoomed in)

The higher likelihood of particles coming from the target distribution leads to N < 1. In this case N ~ 0.5.

Tails seem not to impact the N estimation.

Seek to change the N estimation method such that more particles are accepted into the daughter beam, without impacting the selection performance.