Beam Optics in the Cooling Channel

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Overview

- Aim to evaluate the current understanding of the beam optics in the cooling channel
- Compare the beam optics (4D transverse emittance, beta function, alpha function) calculated from data and simulation (truth and reconstructed)
- Cuts update

Data

- Analysis H57a, Run 10448
- 2017-02-7 setting
- Flip mode, 3T in SSU (M1, M2 on), 2T in SSD (M1 off, **M2 on**)
- LiH Empty (None)
- 140 MeV/c, nominal emittance 3 mm, $\beta_{\perp} = 500$ mm

Analysis Procedure: Sample Selection

Reconstruct beam optics in the trackers from data, applying the following cuts:

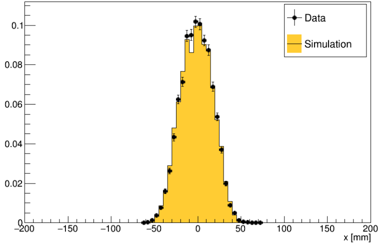
- 1 SP in both TOF0 and TOF1
- TOF01 consistent with muon peak : 29 - 31 ns
- Energy loss between TOF1 and TKD consistent with μ
- TKU: 135 MeV/c $<$ total momentum $<$ 145 MeV/c
- TKD: 110 MeV/c $<$ total momentum $<$ 170 MeV/c
- χ^2/ndf $<$ 4 (TKU & TKD)
- Transmission cut: analyse only events with 1 track in each tracker
- Fiducial radius cut: r $<$ 150 mm (TKU & TKD)
- Diffuser radius cut: r $<$ 90 mm

Analysis Procedure

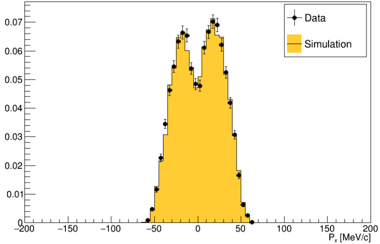
- All the particles that survive the cuts are extracted at the first SciFi plane in station 5 of TKU $\rightarrow$ fed it into the MC simulation

- Calculate beam optics of the MC simulated beam at a series of virtual planes along the cooling channel, between both stations 5 of TKU and TKD; also reconstruct the simulated data

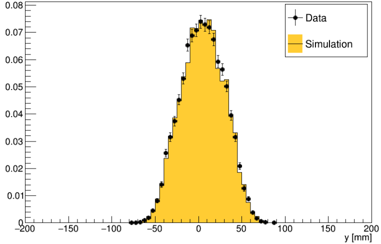
Phase Space: TKU Ref Plane



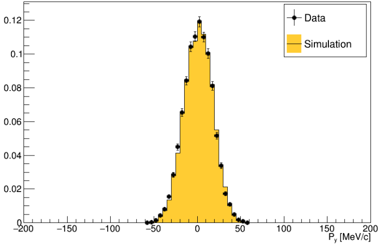
X



P_x

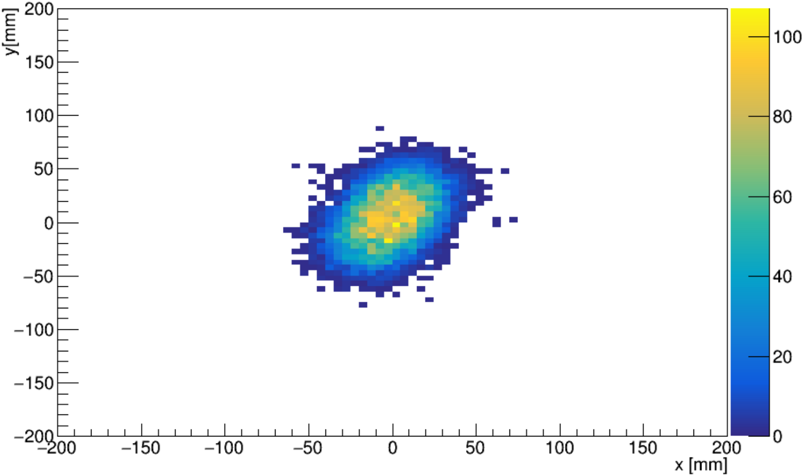


Y

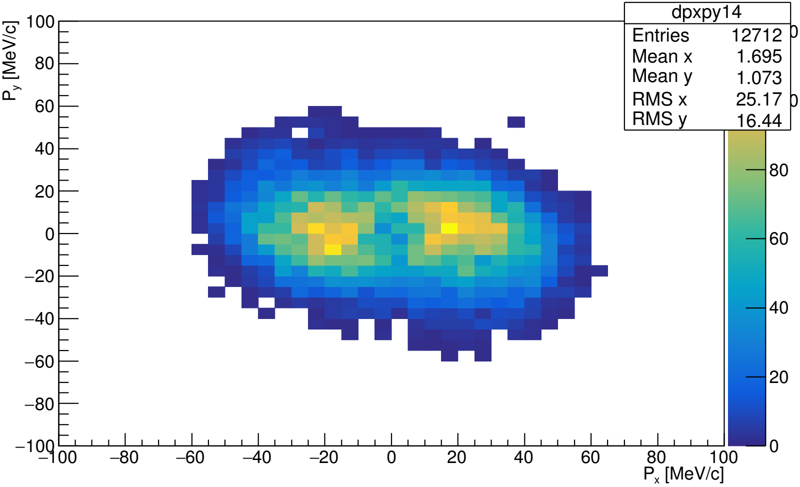


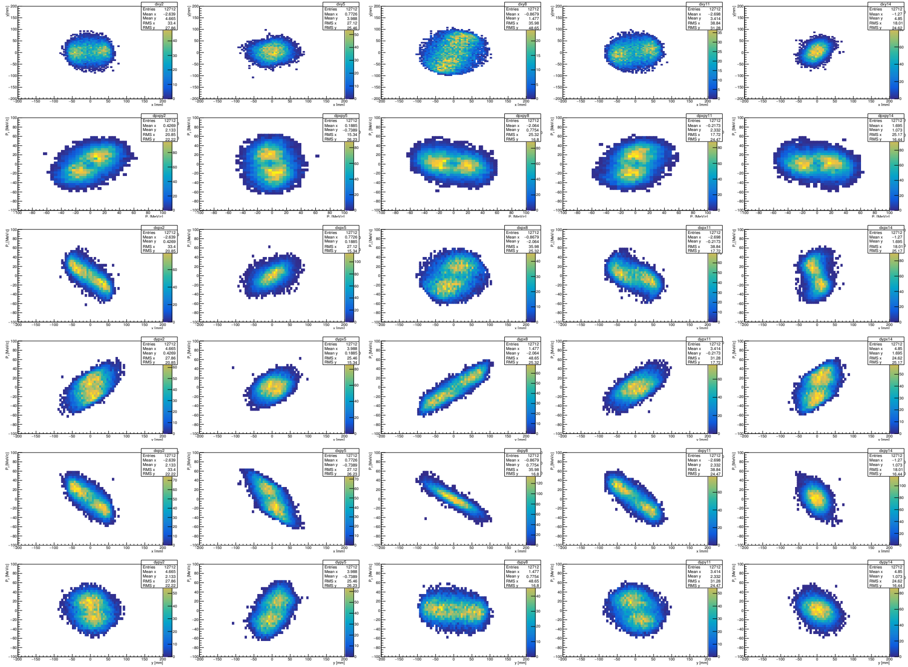
P_y

Beam Position at TKU Ref Plane

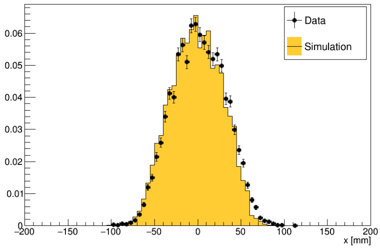


Beam Momentum at TKU Ref Plane

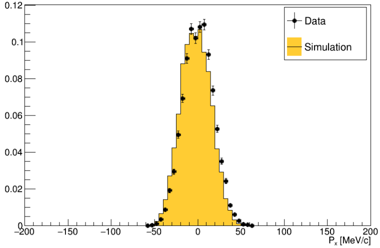



dxy2
dxy5
dxy8
dxy11
dxy14
dpxpy2
dpxpy5
dpxpy8
dpxpy11
dpxpy14
dxpx2
dxpx5
dxpx8
dxpx11
dxpx14
dypx2
dypx5
dypx8
dypx11
dypx14
dxpy2
dxpy5
dxpy8
dxpy11
dxpy14
dypy2
dypy5
dypy8
dypy11
dypy14

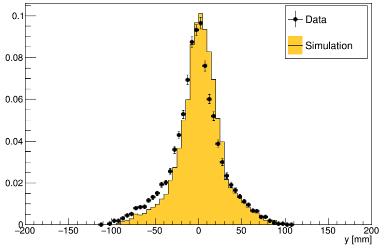
Phase Space: TKD Ref Plane



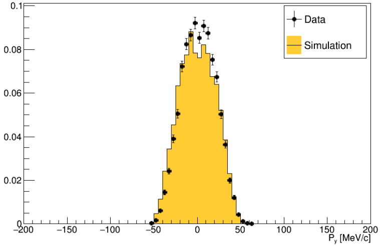
X



P_x

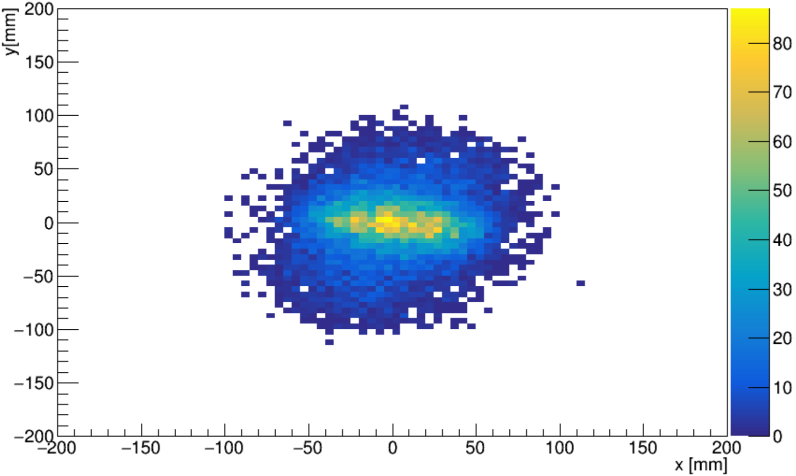


Y

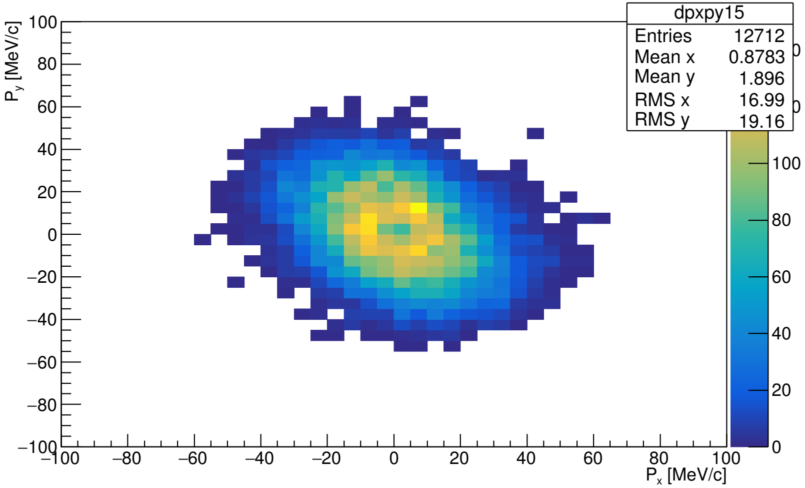


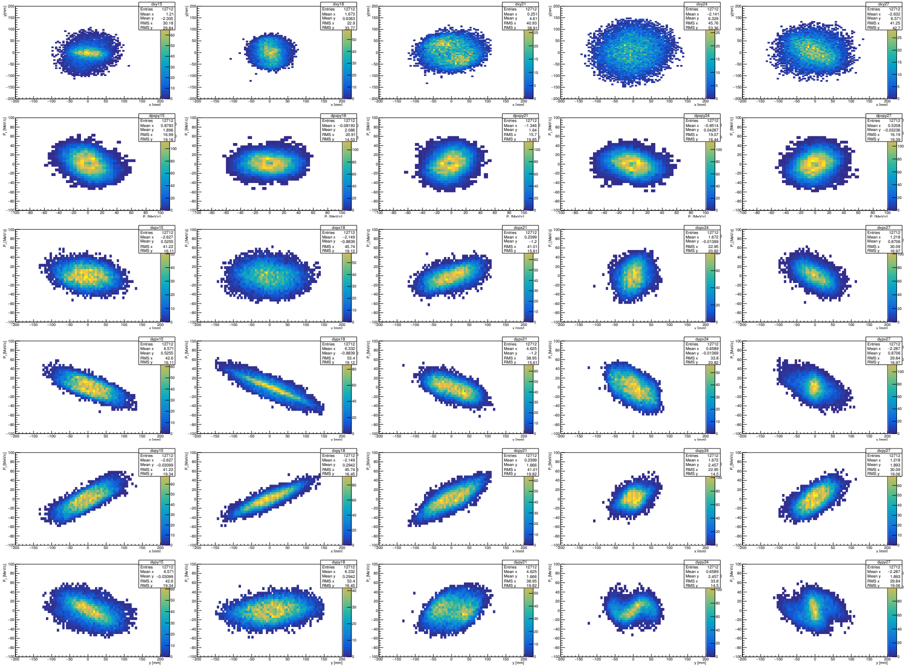
P_y

Beam Position at TKD Ref Plane

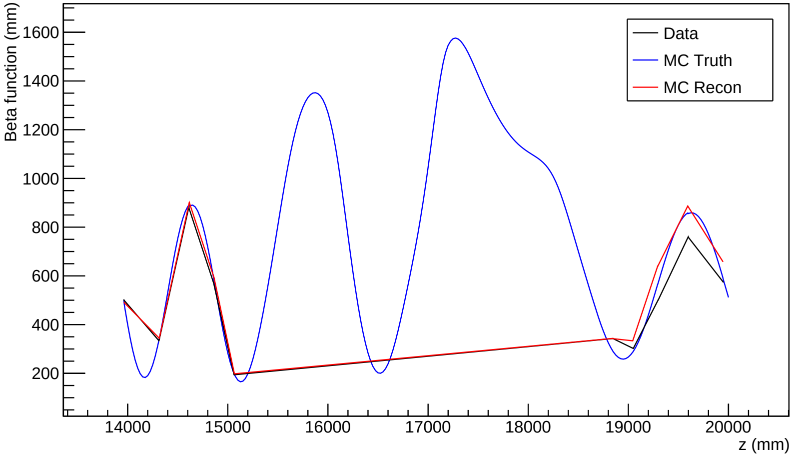


Beam Momentum at TKD Ref Plane

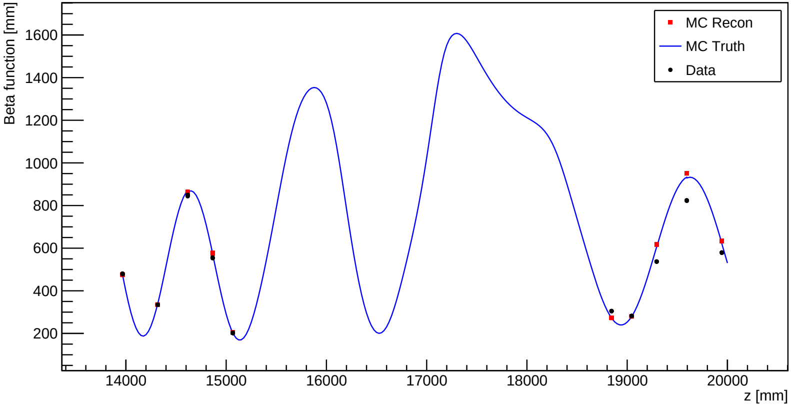



y [mm]
x [mm]
P_y [MeV/c]
P_x [MeV/c]
dxy15 Entries 12712 Mean x 1.21 Mean y −2.305 RMS x 30.18 RMS y 29.84
dxy18 Entries 12712 Mean x 1.673 Mean y 0.6363 RMS x 22.9 RMS y 33.77
dxy21 Entries 12712 Mean x 0.251 Mean y 4.61 RMS x 40.93 RMS y 38.91
dxy24 Entries 12712 Mean x −2.141 Mean y 6.329 RMS x 45.76 RMS y 53.36
dxy27 Entries 12712 Mean x −2.632 Mean y 6.571 RMS x 41.25 RMS y 42.7
dpxpy15 Entries 12712 Mean x 0.8783 Mean y 1.896 RMS x 16.99 RMS y 19.16
dpxpy18 Entries 12712 Mean x −0.08193 Mean y 2.086 RMS x 20.91 RMS y 14.53
dpxpy21 Entries 12712 Mean x −1.346 Mean y 1.64 RMS x 15.7 RMS y 19.85
dpxpy24 Entries 12712 Mean x −0.8514 Mean y 0.04287 RMS x 19.07 RMS y 16.44
dpxpy27 Entries 12712 Mean x 0.5208 Mean y −0.03236 RMS x 16.19 RMS y 19.39
dxpx15 Entries 12712 Mean x −2.627 Mean y 0.5255 RMS x 41.22 RMS y 16.11
dxpx18 Entries 12712 Mean x −2.149 Mean y −0.8839 RMS x 45.74 RMS y 19.12
dxpx21 Entries 12712 Mean x 0.2399 Mean y −1.2 RMS x 41.01 RMS y 15.61
dxpx24 Entries 12712 Mean x 1.672 Mean y −0.01369 RMS x 22.95 RMS y 20.82
dxpx27 Entries 12712 Mean x 1.218 Mean y 0.8706 RMS x 30.09 RMS y 16.97
dypx15 Entries 12712 Mean x 6.571 Mean y 0.5255 RMS x 42.6 RMS y 16.11
dypx18 Entries 12712 Mean x 6.332 Mean y −0.8839 RMS x 53.4 RMS y 19.12
dypx21 Entries 12712 Mean x 4.625 Mean y −1.2 RMS x 38.95 RMS y 15.61
dypx24 Entries 12712 Mean x 0.6589 Mean y −0.01369 RMS x 33.8 RMS y 20.82
dypx27 Entries 12712 Mean x −2.287 Mean y 0.8706 RMS x 29.84 RMS y 16.97
dxpy15 Entries 12712 Mean x −2.627 Mean y −0.03099 RMS x 41.22 RMS y 19.34
dxpy18 Entries 12712 Mean x −2.149 Mean y 0.2942 RMS x 45.74 RMS y 16.45
dxpy21 Entries 12712 Mean x 0.2399 Mean y 1.666 RMS x 41.01 RMS y 19.82
dxpy24 Entries 12712 Mean x 1.672 Mean y 2.457 RMS x 22.95 RMS y 14.5
dxpy27 Entries 12712 Mean x 1.218 Mean y 1.893 RMS x 30.09 RMS y 19.06
dypy15 Entries 12712 Mean x 6.571 Mean y −0.03099 RMS x 42.6 RMS y 19.34
dypy18 Entries 12712 Mean x 6.332 Mean y 0.2942 RMS x 53.4 RMS y 16.45
dypy21 Entries 12712 Mean x 4.625 Mean y 1.666 RMS x 38.95 RMS y 19.82
dypy24 Entries 12712 Mean x 0.6589 Mean y 2.457 RMS x 33.8 RMS y 14.5
dypy27 Entries 12712 Mean x −2.287 Mean y 1.893 RMS x 29.84 RMS y 19.06

Beta: Before

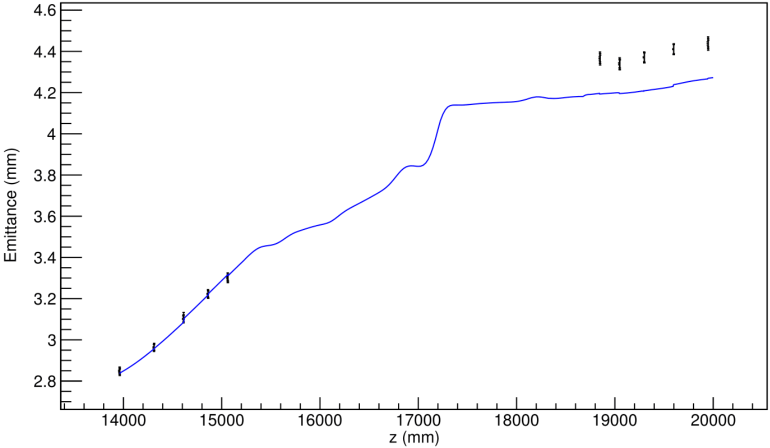

Data
MC Truth
MC Recon
Beta function (mm)
1600
1400
1200
1000
800
600
400
200
14000
15000
16000
17000
18000
19000
20000
z (mm)

Beta: Update

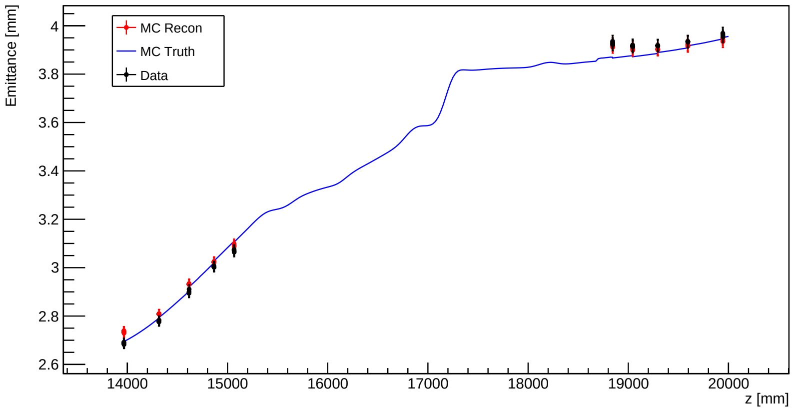


Beta function [mm]
1600
1400
1200
1000
800
600
400
200
14000
15000
16000
17000
18000
19000
20000
z [mm]
MC Recon
MC Truth
Data

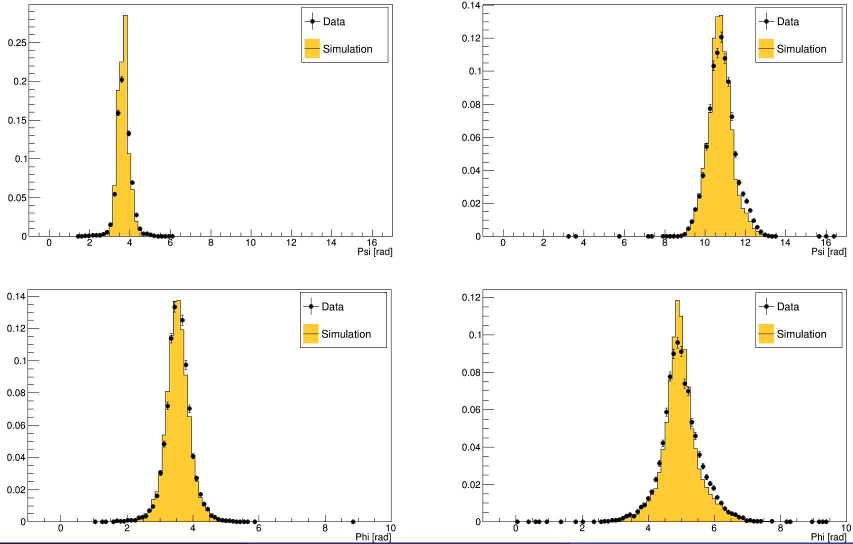
Emittance: Before



Emittance: Update



Linear optics model: ψ and ϕ - Data vs MC Recon



ψ

ϕ

Next: Non-linear emittance growth study

- Expand the Hamiltonian around the reference orbit:

$$H = H_0 + H_1 + H_2 + H_3 + H_4 + ...$$

where the indices represent the order in the deviation variables.

- First non-linear term (H_3) is purely chromatic; H_4 contains terms that are independent of B_z, proportional to B_z and proportional $\partial^2 B_z / \partial z^2$.

- Lie algebra used to compute the transfer map (MaryLie code).

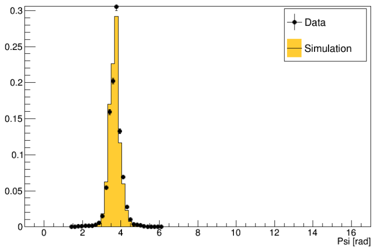
Conlcusions

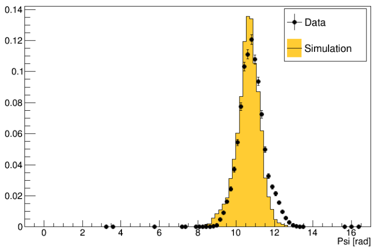
- Good optics agreement in TKU, agreement in TKD significantly improved
- Low $p_\perp$ hole at TKD, 2-lobe feature in TKU
- Next steps
  - Look into the 2-lobe feature
  - Update analysis on the linear transport map
  - Perform a study to disentangle the various contributions to the emittance growth

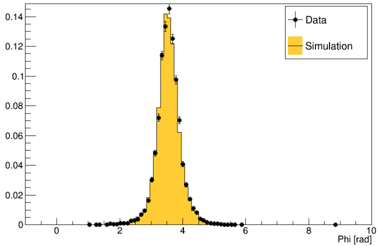
Thank you!

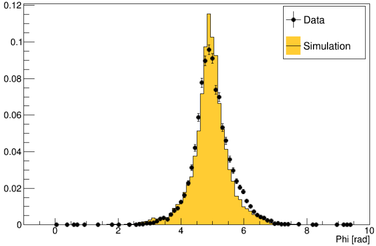
Backup

ψ and ϕ: Data vs MC Truth

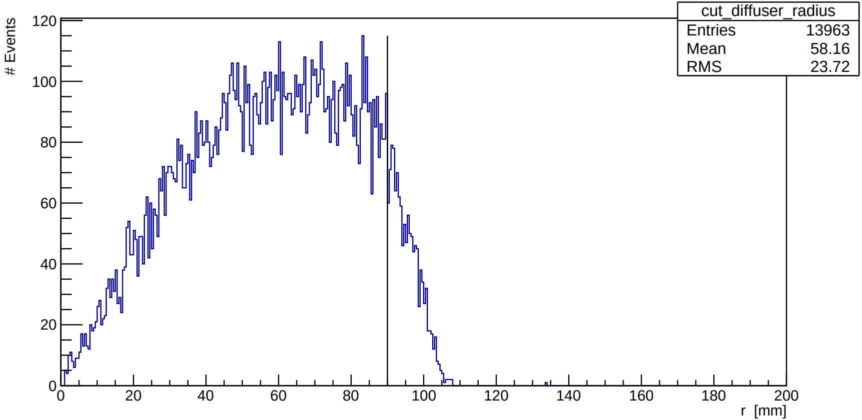




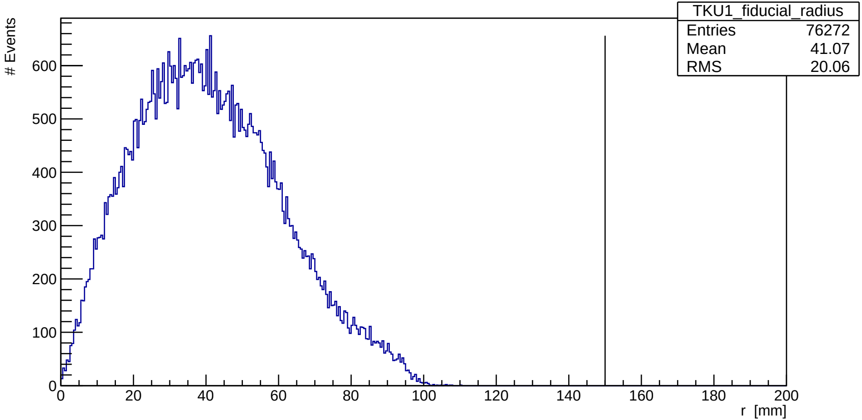




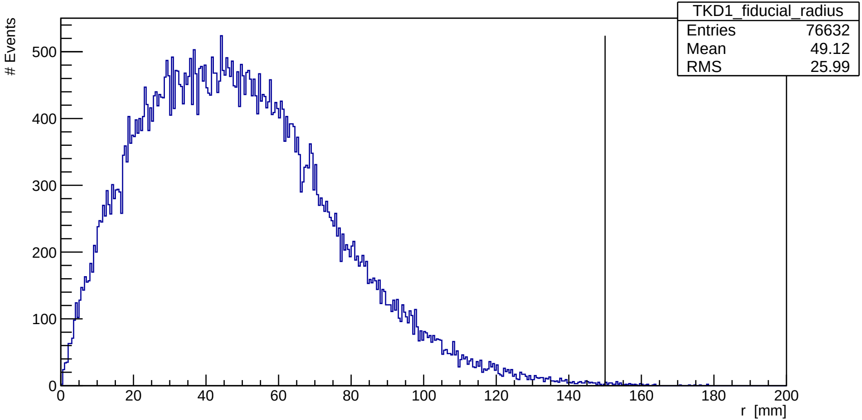
Diffuser Cut



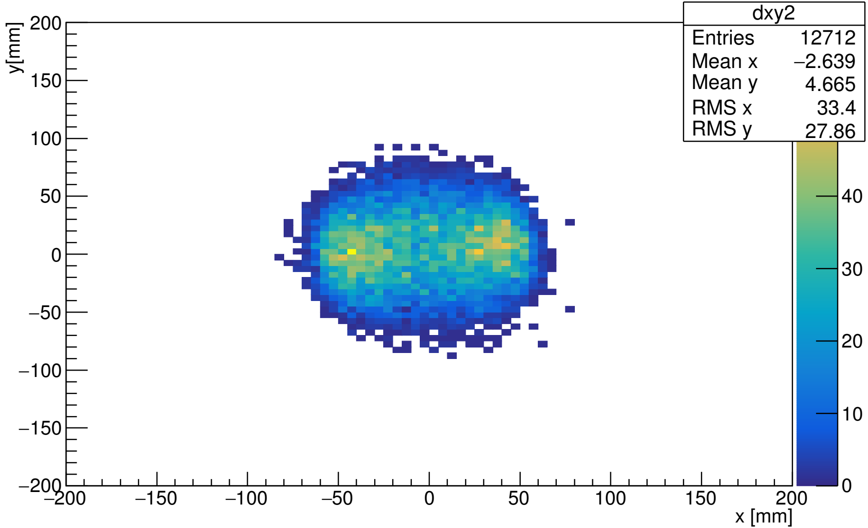
TKU Fiducial Radius Cut



TKD Fiducial Radius Cut



TKU5 Beam Position



TKU5 Beam Position