MICE Step IV Lattice and some target studies

Ao Liu
Fermilab

Outline

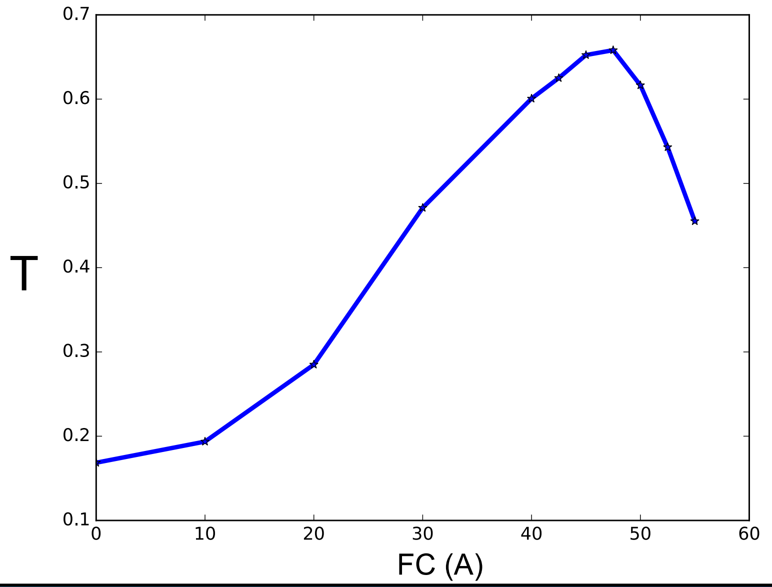
- Step IV lattice design with
  - No matching coils:
    - FC current scan and results;
    - Compare with recent data;
  - Matching coils upstream;
- Target simulation
  - Compare with the G4BL model in MAUS
- Discussion

Step IV with no matching coils

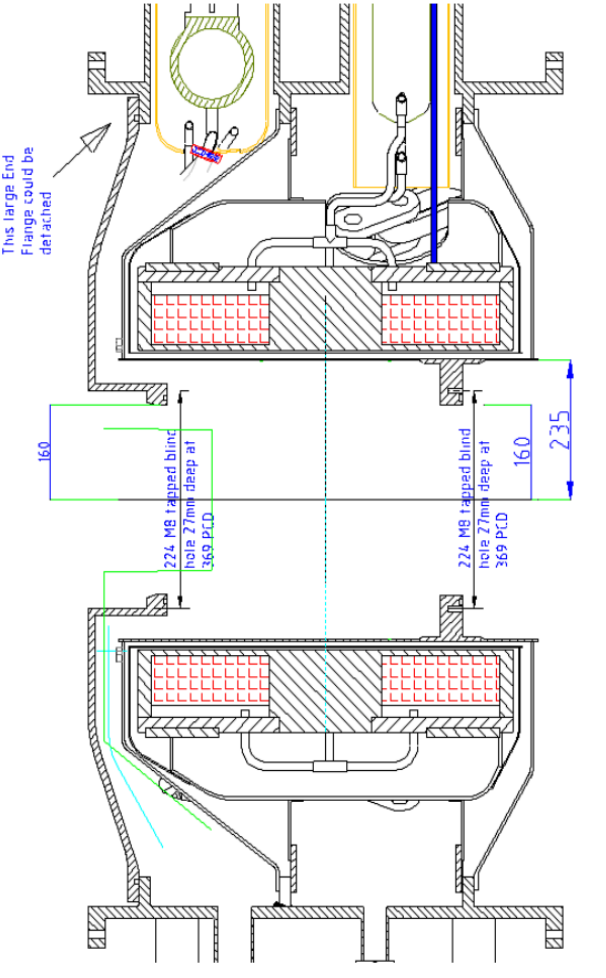
- Reason that I'm aware of: Avoid unexpected damage to the FC under differential force applied when full SSU is running but SSD quenched (sounds freshly familiar);
- Starts even more conservatively (i.e. with the realistic magnet work progress)
  - ECE @ 140 A, or 2 T;
  - FC @ max. 62 A (as indicated by John in an email but I guess not tested yet). Tested highest in the previous runs was 50 A.
- Started with 140 MeV/c, with FC @ 44.7 A
  - 44.7 A obtained from analytical calculation;
- Then scanned FC from 40 to 50 A
  - Data for 40, 42.5, 44.7, 47.5, 50 A FC current available.
- Aimed for 200 MeV/c also but then interrupted by magnet quench.

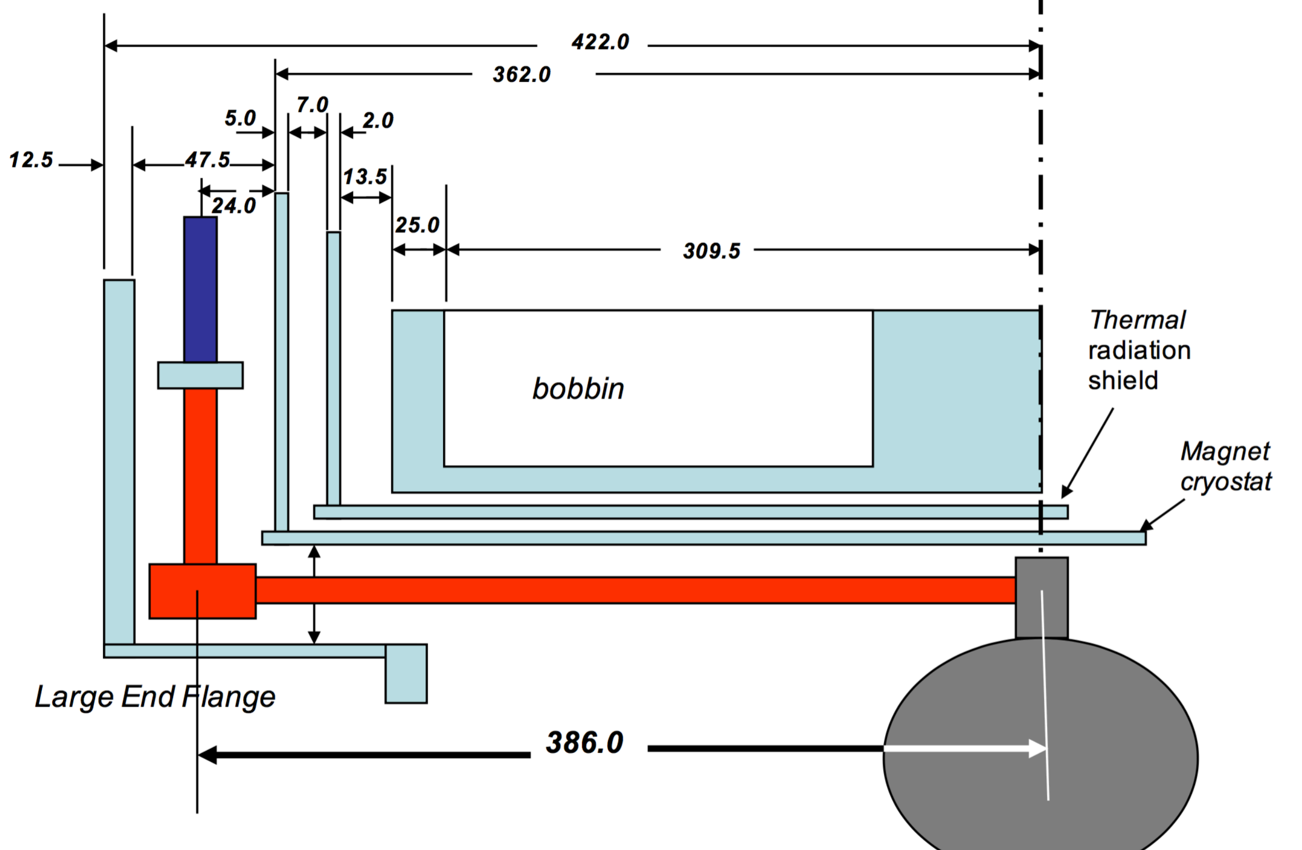
Step IV with no matching coils

- What does the FC scan in G4Beamline simulations look like?
  - Use 140 MeV/c beam and 4.2 mm norm. emit, matched solenoid beam, +-5% dp/p, starts at -3 m from the center of absorber;
  - Transmission = trans. from start to TOF2
  - Appears that transmission is highest @ 47.5 A
    - Although ~ flat from 45 to 48



Step IV with no matching coils





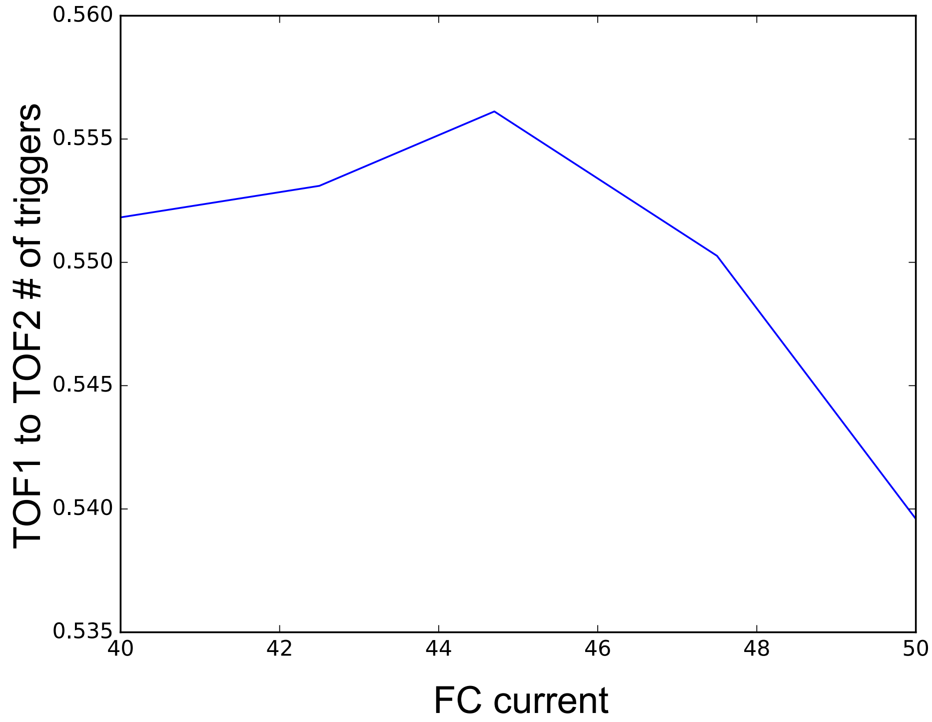
- I do have the flanges set up in these simulations, which turned out to have a big impact on the transmission, since beam is largest at the AFC in these cases.
- These drawings were obtained from a talk in 2009 – they are hard to find

Step IV with no matching coils

- What does the FC scan data look like?
  - See runs from 8157 to 8161
  - Plotted: trigger ratio from TOF1 to TOF2, directly obtained from CDB
  - Q: Shape similar, but why is 44.7 better than 47.5?

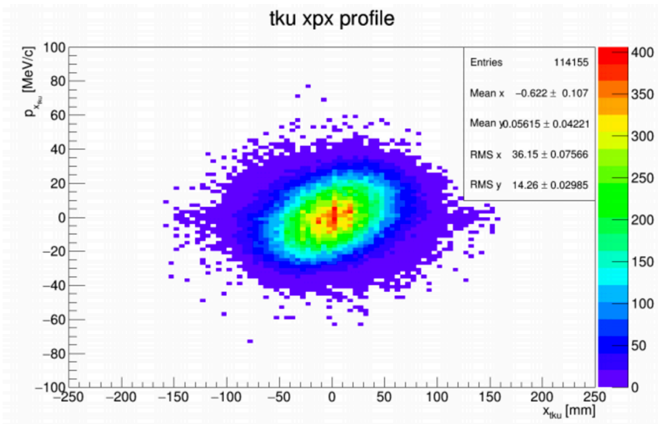
A1: Jaroslaw's intuition was better (acceptable Answer)

A2: The beam is mismatched, or magnet misaligned, etc.

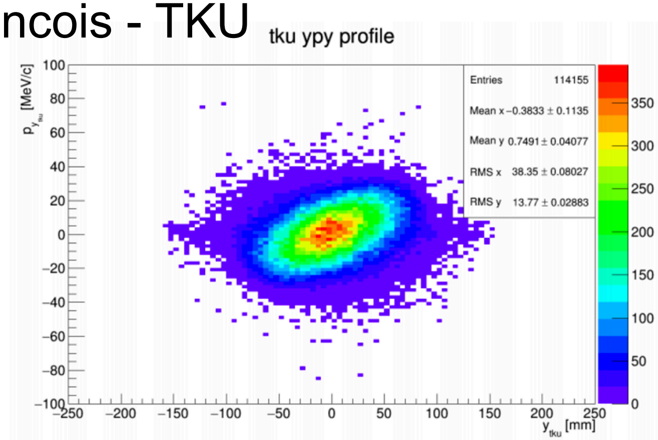


Step IV with no matching coils

- Look at Run 8155
  - Plot beam track at TKU station 1



Francois - TKU

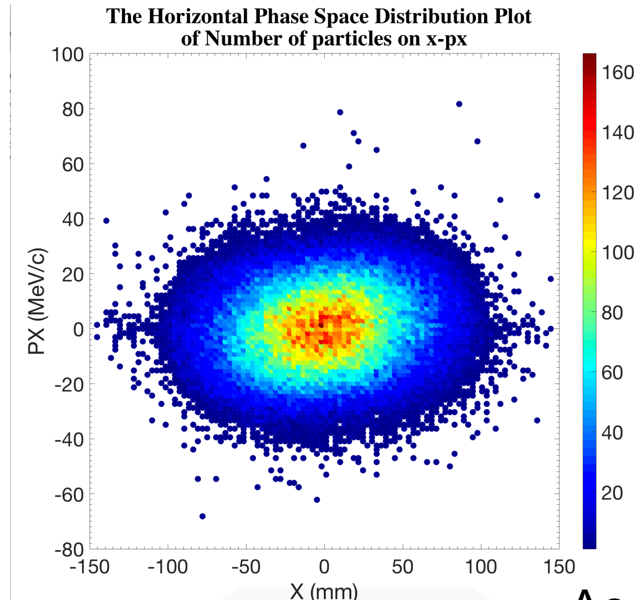


Cuts in my plots:
r<=150 mm;
P_x,y <= 100 MeV/c;
Z is physical

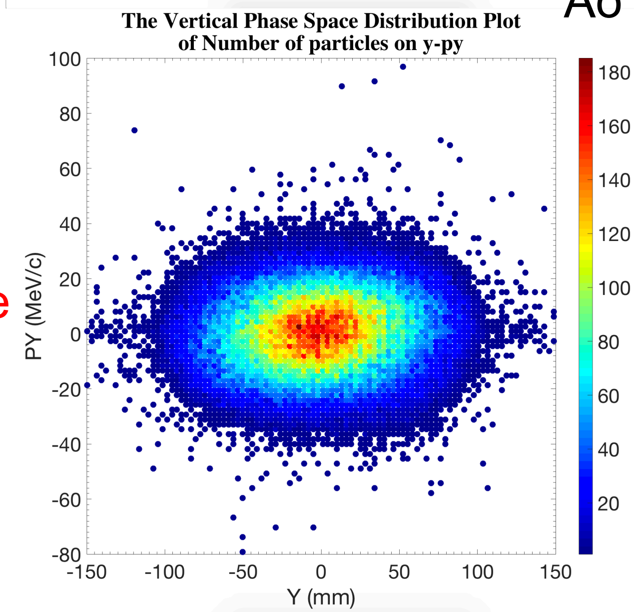
# of track points ~114000

Notice:
track points can return NAN;
tracks can have insane x,y,z,px,py,pz

OBVIOUS mismatch

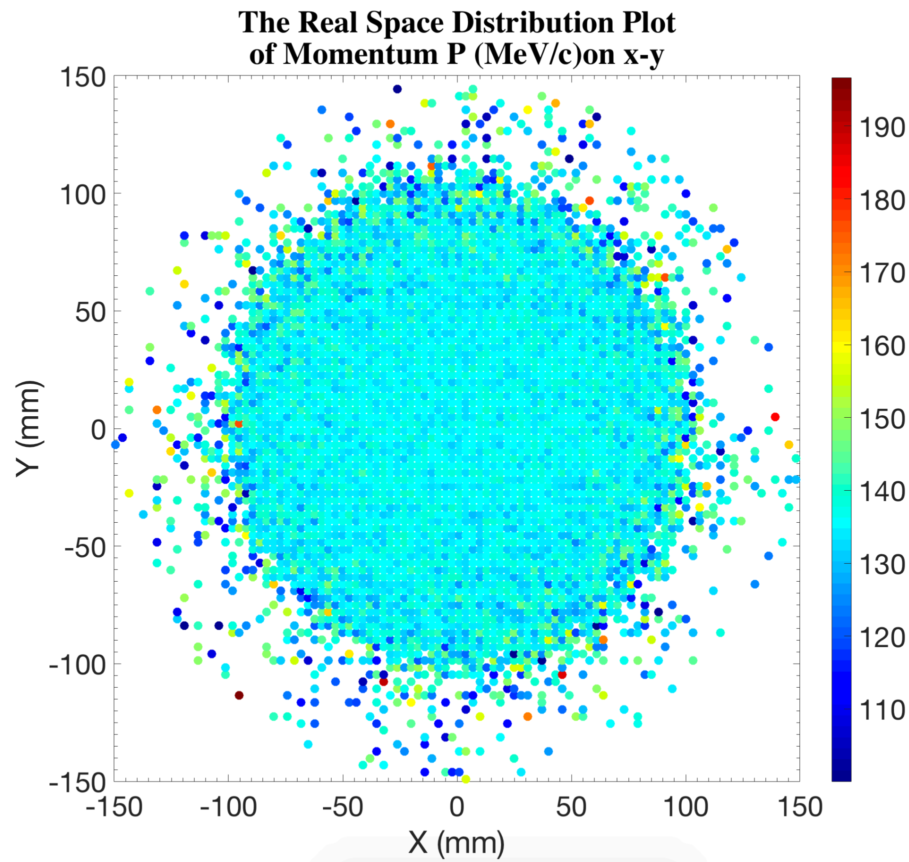


Ao



Step IV with no matching coils

- Look at Run 8155
  - Plot beam momentum at TKU station 5 on X-Y coordinates:
  - No obvious dispersion seen in the bending plane, nor non-bending plane at least by eye.



Liked it.  * many

Step IV with no matching coils

- Use data from 8155
  - Try to recover dependence of transmission on FC – back to the previous topic!
  - Use real data in G4BL

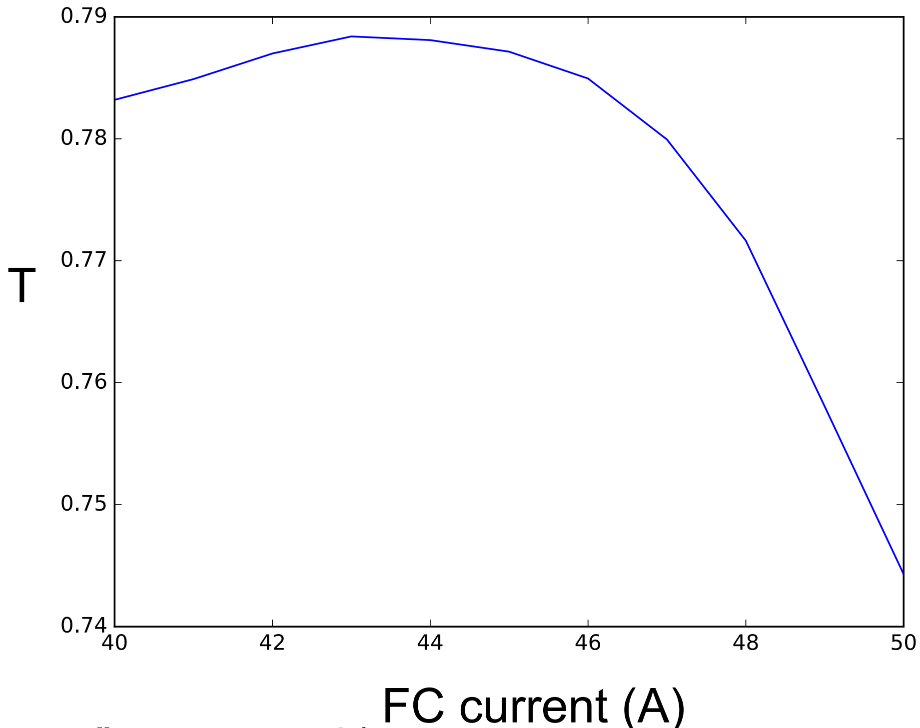
tracking and obtained this->

T still means to TOF2;

Shape agrees with data

Will compare apple to apple

later (e.g. TKU to TKD)

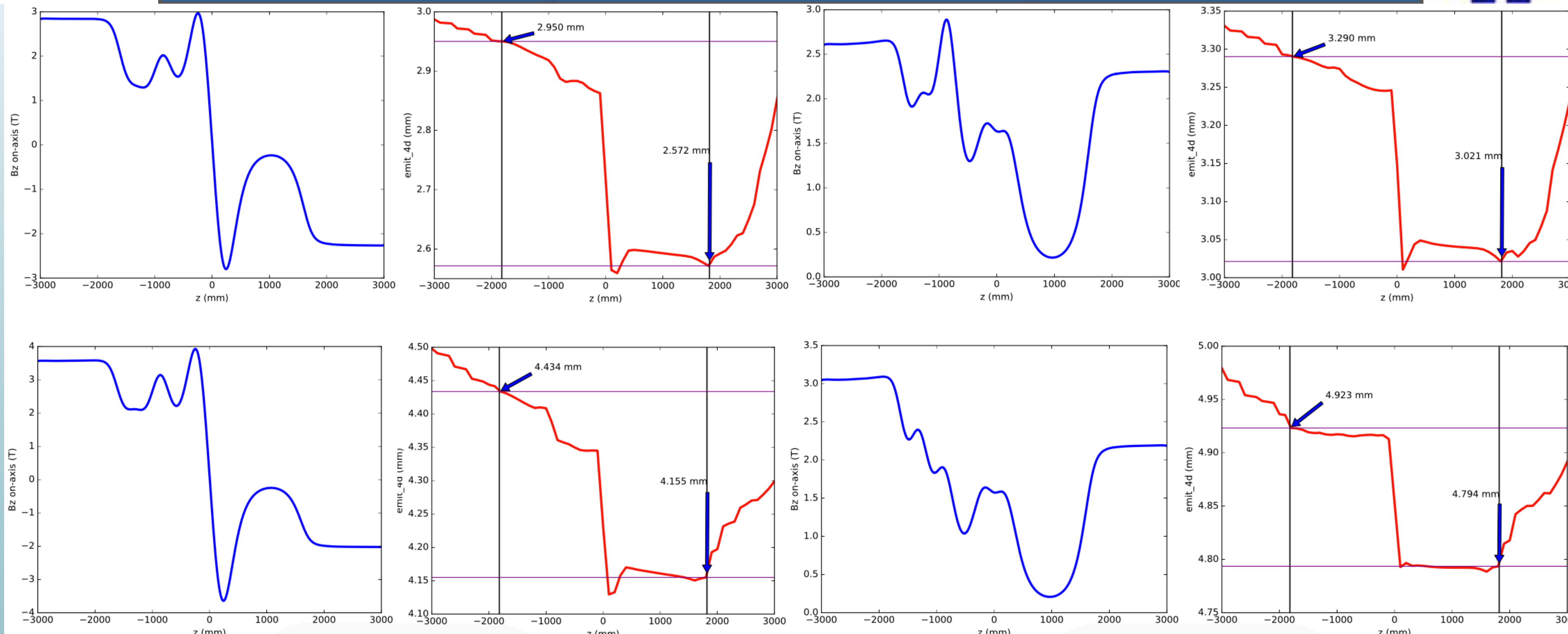


Note: TKU station 1 to TKD station 1 transmission = 76.3% from data and 79.5% from G4BL. (note G4BL “recon” every track)

To do for no M settings

- MC in MAUS;
- Compare apple to apple, or to Linux, or to Android;
- How to correct mismatch
  - How mismatch affects the performance
- Popping up ideas.

Optimization result – B_z and emit. evolution (no M1D nor M2D)



Flip mode (left), 140 and 200 MeV/c (upper and lower), *T=72% and 74%*

Solenoid mode (right), 140 and 200 MeV/c (upper and lower), *T=73% and 82%*

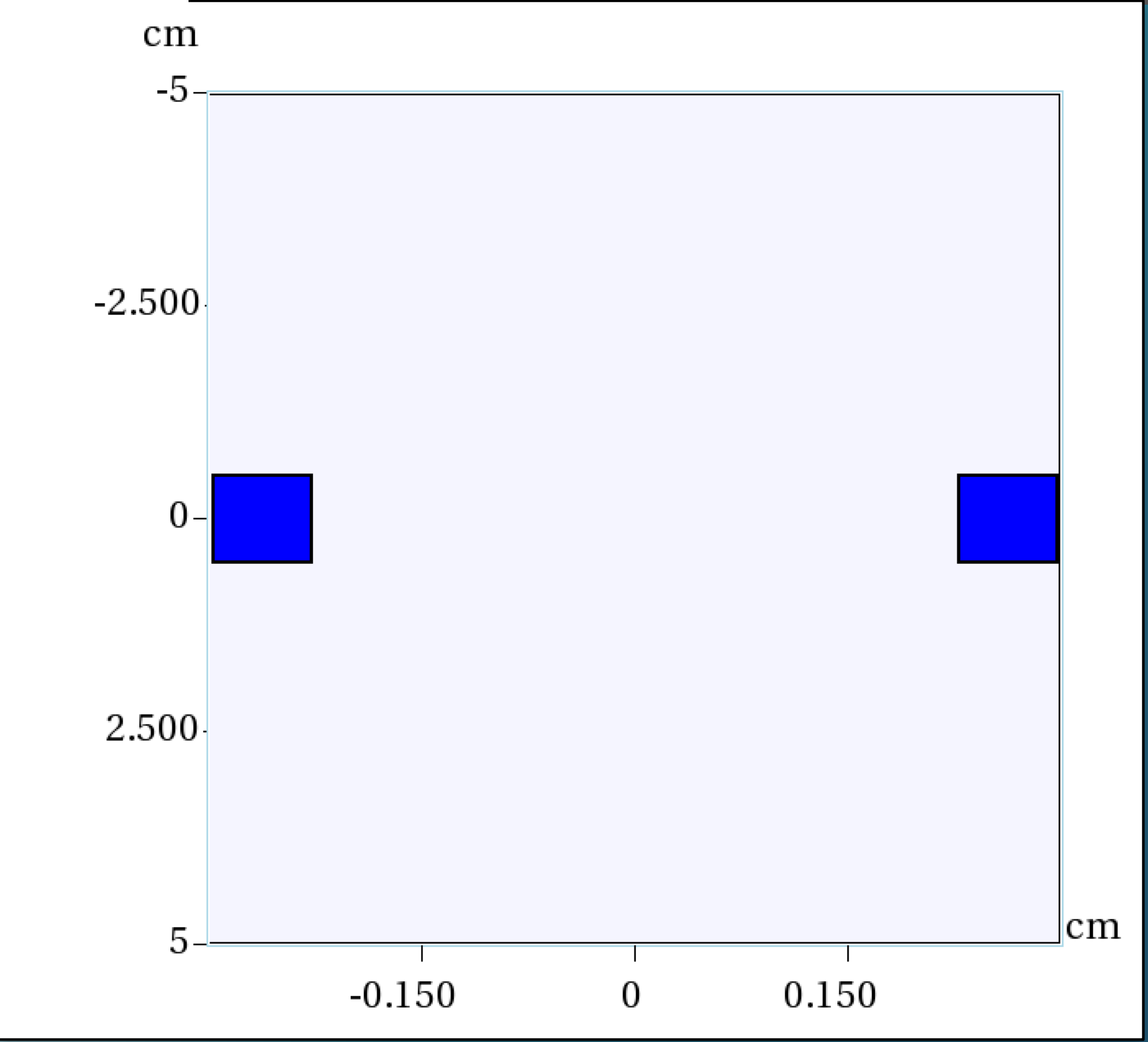
How likely are these currents possible at all?
Will see.
For configurations without M1D only, refer to MICE note

variable	flip, 140	flip, 200	sole, 140	sole, 200
x_1	0.71	0.89	0.65	0.76
x_2	80.00	153.19	172.39	236.83
x_3	158.14	251.15	242.20	135.21
x_4	172.05	224.99	56.15	55.98
x_5	0	0	0	0
x_6	-0.56	-0.5	0.57	0.5412
$\Delta\epsilon/\epsilon_i$	12.8%	6.3%	8.2%	2.6%
T	72%	74%	73%	82%

Simulation of the target

- What can be done
  - Models a cylindrical tubular Titanium target;
    - From MICE-PUB-BEAM-392: The tip of the shaft has a cylindrical cross section of ~11.5 mm2 (5.95 mm outside diameter and 4.55 mm inside diameter);
    - Max. length into the halo not found from above – assuming (from MICE-NOTE-BEAM-170) 10 mm
  - Use an real-space-wise (x-y) uniform proton beam and no divergence;
  - Bombard the target from the side;
  - Investigate all the secondary particles (pions, kaons, muons, and protons), at the extraction angle (20 degrees, rotated w.r.t. y axis);
  - Compare with the current G4BL beam library

Simulation of the target



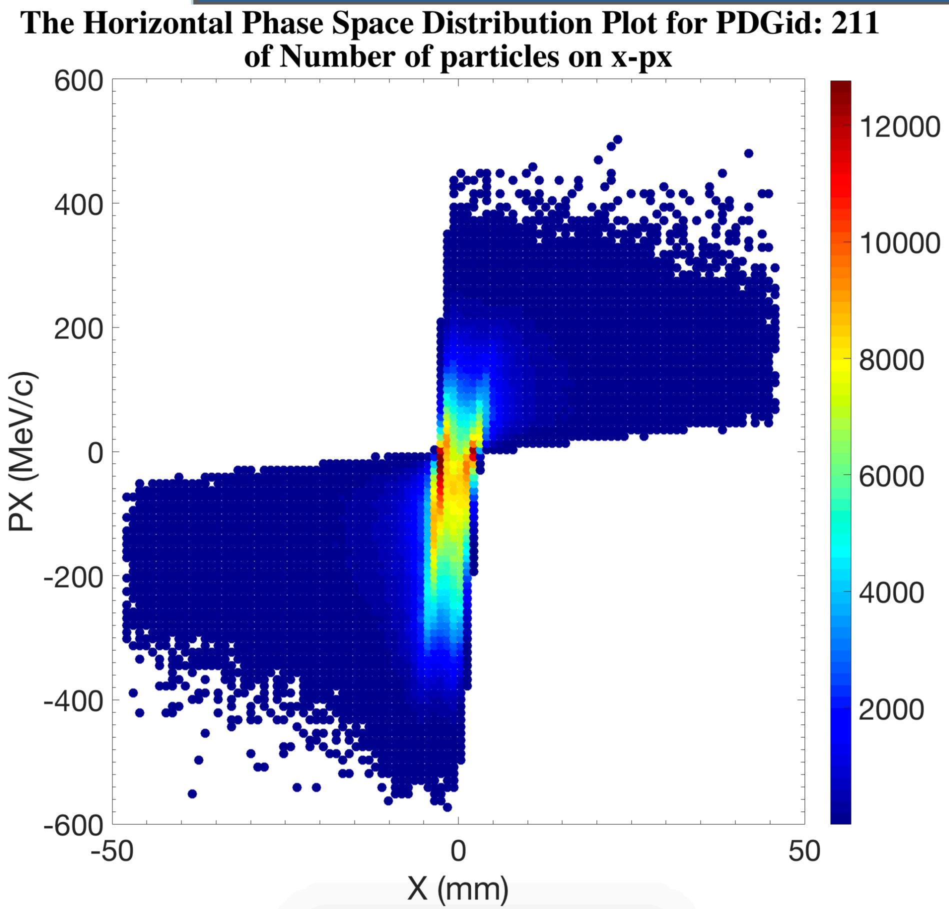
Simplest model ever (cut view, this is a tubular target!):
proton direction: z to the right;

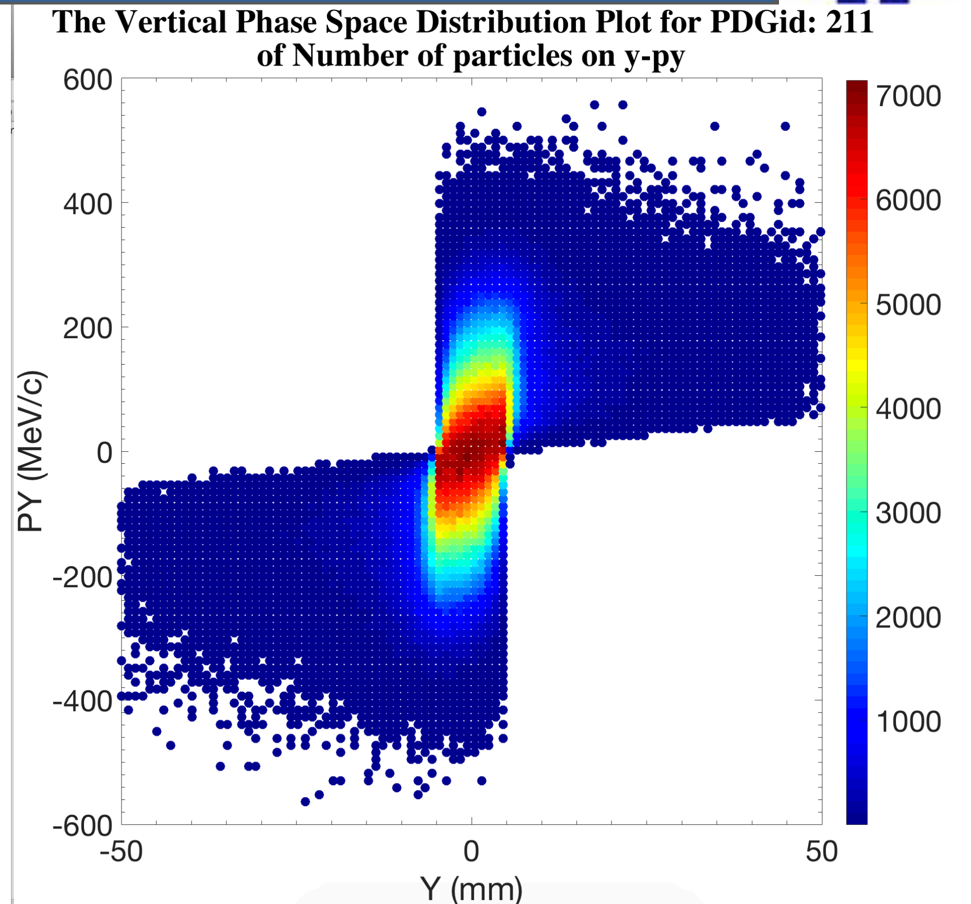
y direction pointing down;

proton beam covers the whole target

records pi+ @ z=0.3 cm

Simulation of the target





Rotated the view angle w.r.t. y axis by 20 degrees already;
Basically, the above correlation is expected.

From G4BL library in MAUS

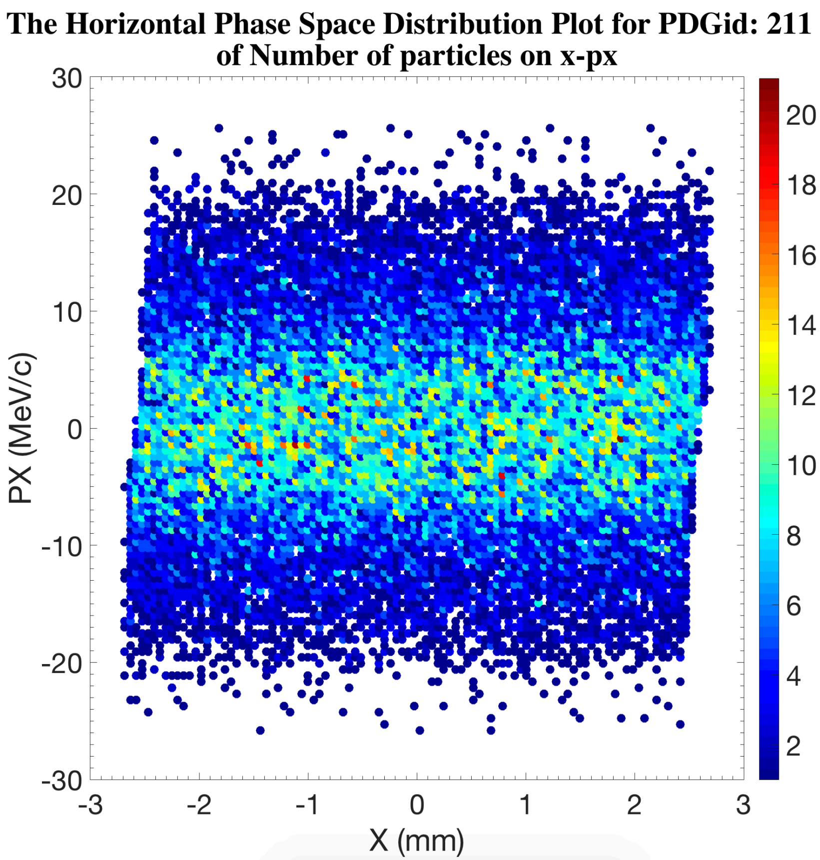
- In src/map/MapPyBeamlineSimulation/G4bl;
- Initial beam is defined in the TargetModel/beam_secondaries.in
  - In which the pi plus are defined in the way below

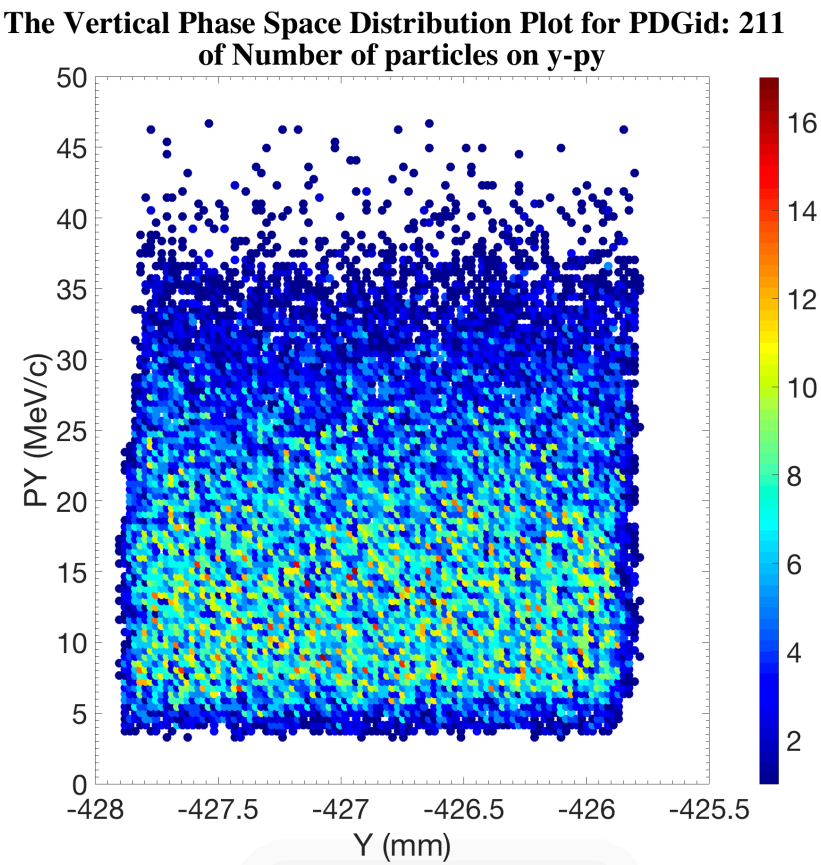
```
if $piplus
  beam gaussian sigmaX=-2.57 sigmaY=-1.0 sigmaXp=-0.040 sigmaYp=-0.020 \
    particle=pi+ meanMomentum=320 sigmaP=-220 nEvents=$n4 \
    firstEvent=$first beamY=-427 rotation=X-2.98
  param first=$first+$n4
  beam gaussian sigmaX=-2.57 sigmaY=-1.0 sigmaXp=-0.040 sigmaYp=-0.020 \
    particle=pi+ meanMomentum=190 sigmaP=30 nEvents=$n5 \
    firstEvent=$first beamY=-427 rotation=X-2.98
  param first=$first+$n5
  beam gaussian sigmaX=-2.57 sigmaY=-1.0 sigmaXp=-0.040 sigmaYp=-0.020 \
    particle=pi+ meanMomentum=440 sigmaP=50 nEvents=$n6 \
    firstEvent=$first beamY=-427 rotation=X-2.98
  param first=$first+$n6
  beam gaussian sigmaX=-2.57 sigmaY=-1.0 sigmaXp=-0.040 sigmaYp=-0.020 \
    particle=pi+ meanMomentum=600 sigmaP=-60 nEvents=$n6a \
    firstEvent=$first beamY=-427 rotation=X-2.98
  param first=$first+$n6a
endif
```

  - It's approximated by combo of Gaussians at each center P with uniform x' and y' distributions, and uniform x, y distributions

From G4BL library in MAUS

- Or, this (@ 3 mm after target. Y offset because of elevation change):





Questions

- They look a bit different to me.
- G4BL beam does not look rotated w.r.t. y axis;
- Figuring out why the target is approximated this way is beneficial.
- Does that affect our beamline setting at all?
  - I guess very likely.
  - How much?
- More investigation needed.

Conclusions

- Expect valid optimization results from G4BL + Genetic algorithm. More detailed geometry can be added when we compare data with model;
- FC scan consistent with expectation, considering the real initial beam in the channel;
- Mismatched initial beam – understanding the pion beamline and target simulation might be helpful to resolve the issue.
- Suggestions and comments?