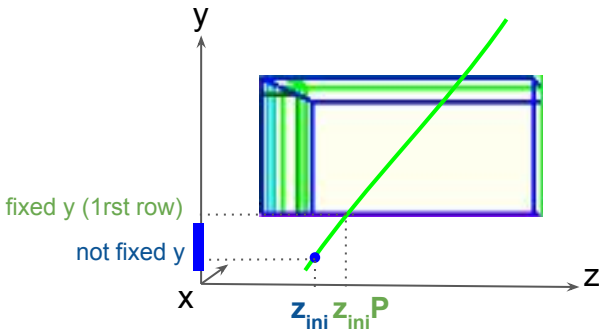
Neural Network for track reconstruction in the HA-TPC

Updates on the NN performances on momentum prediction and e+/mu+ PID

Anaëlle Chalumeau

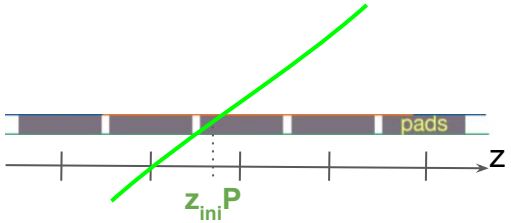
LPNHE T2K group meeting – 29/11/2023

Set-up



z_{ini} := z position of 1st energy deposit (at variable y) 'hat_start_pos[2]'

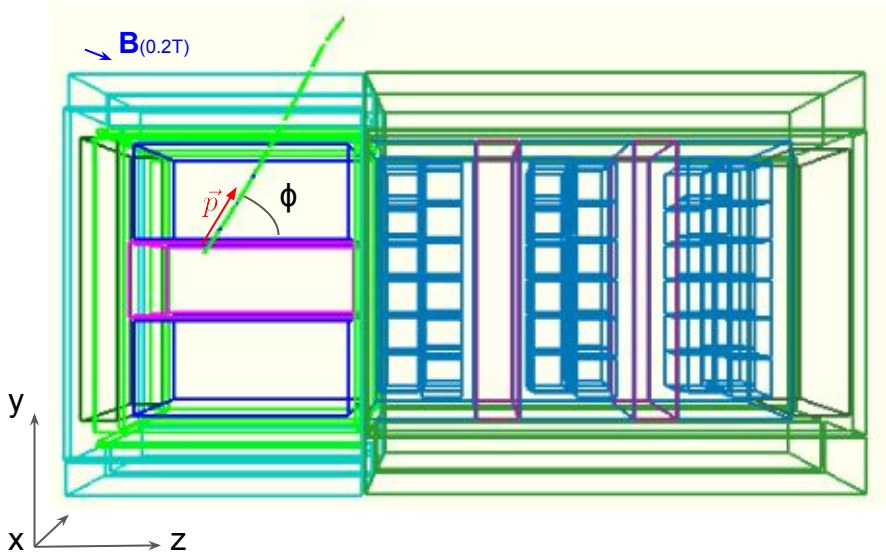
$z_{ini}P$:= projection of z_{ini} at y fixed (on first pad center)



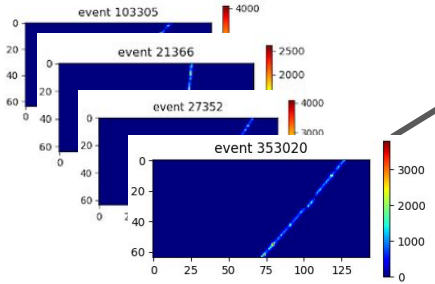
Simulated data with:
- $p_x = 0$
- x : fixed

↳ track in (y,z) plane

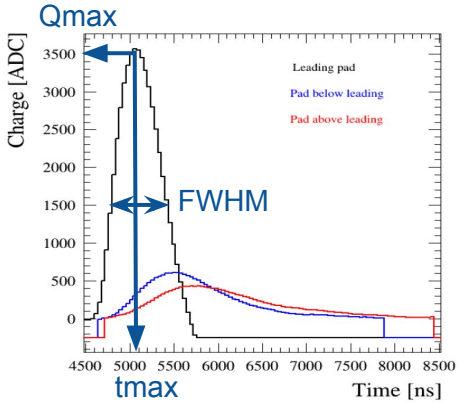
Particle gun

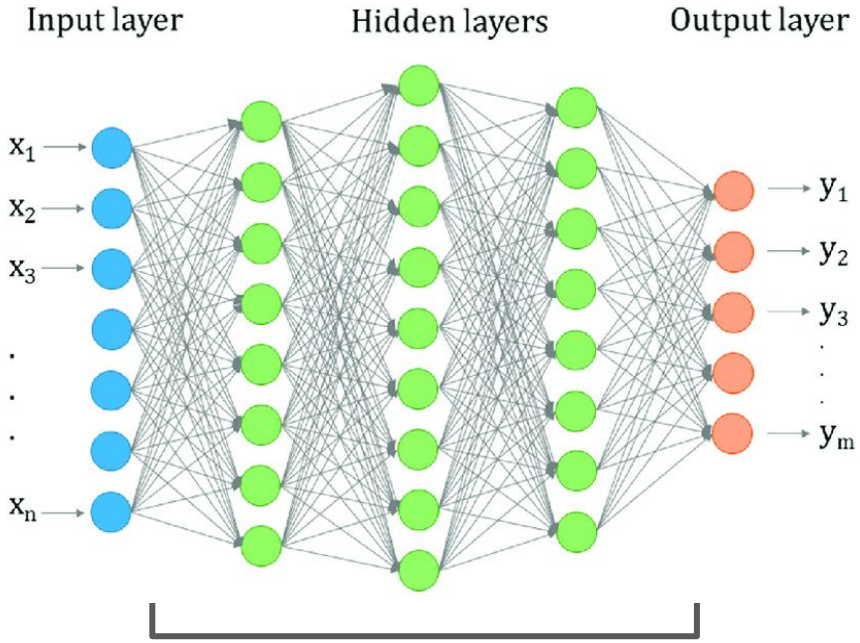


Set-up



only Qmax values now



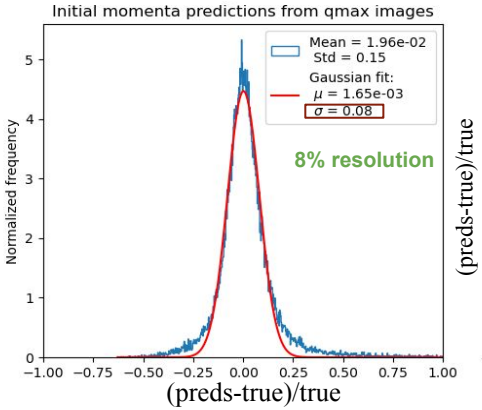


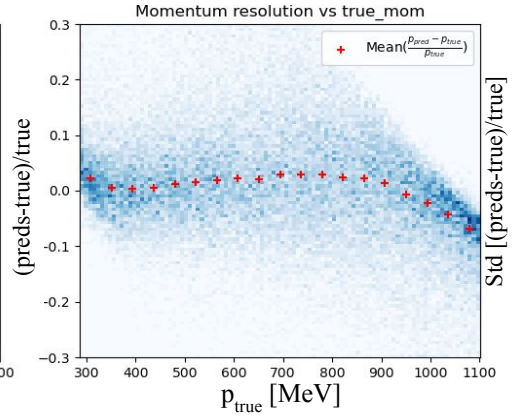
ResNet50 architecture
a convolutional NN

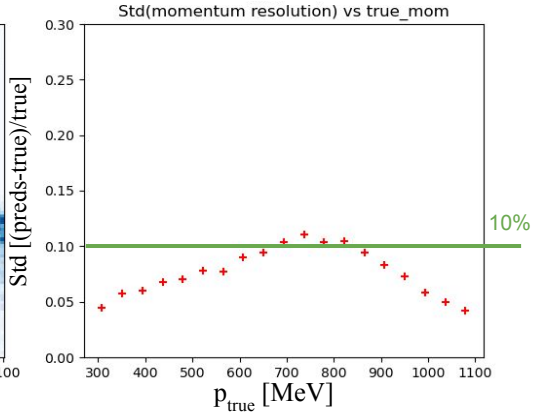
[initial positions z_{ini}]
[momenta p_z, p_y,]
[pdg code]
.
.
.
etc

Summary of previous results

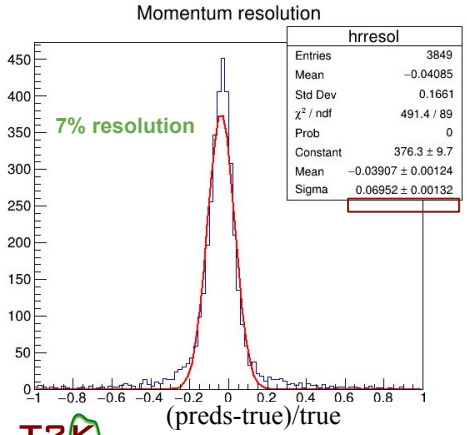
| Momentum resolution

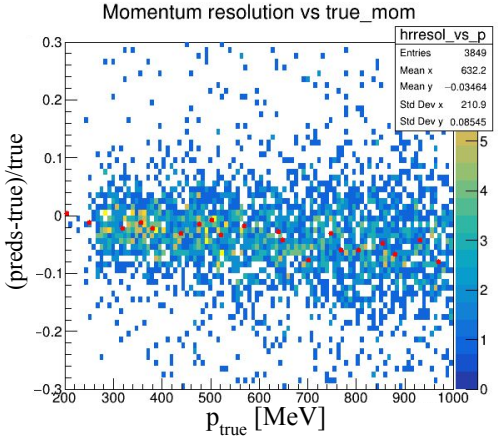


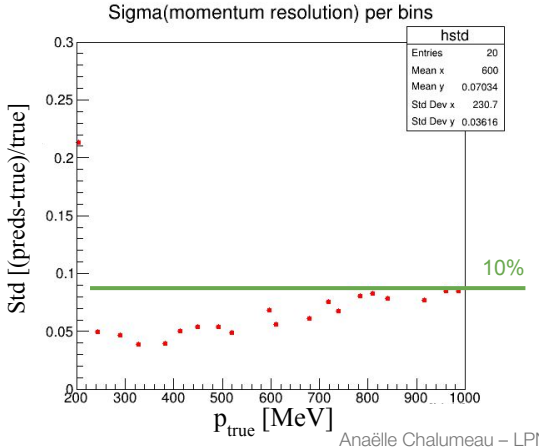




CNN
machine learning





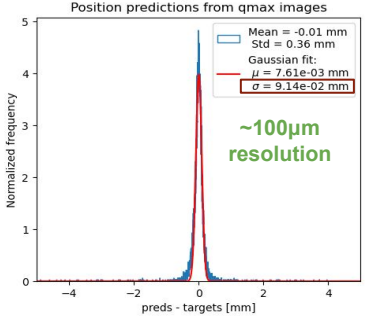


'hatRecon'
classical reconstruction

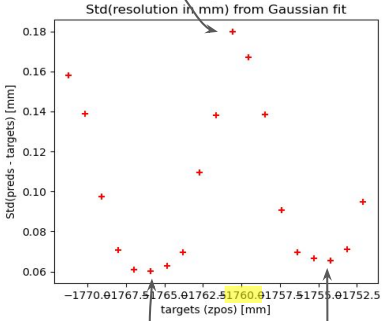
Summary of previous results

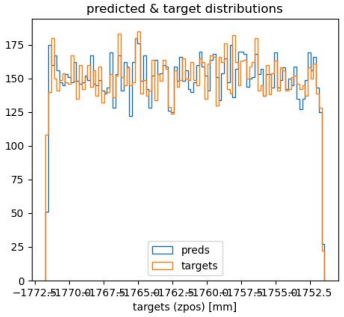
| Spatial resolution

(Δz := red area width = possible z start positions of the track)



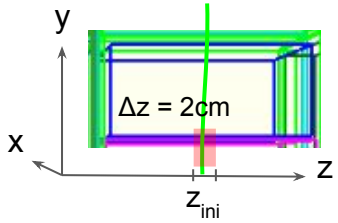
pad centers:
-1772.916
-1761.635
-1750.355





better resol between pads
(ok since 2 waveforms)

Simu: 100k events
vertical tracks
x = -900cm
p = 10GeV



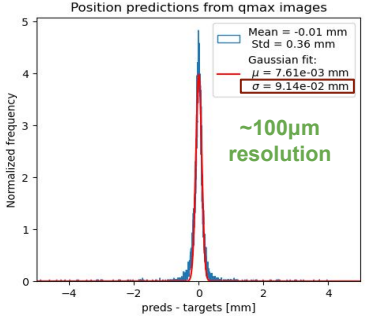
Summary of previous results

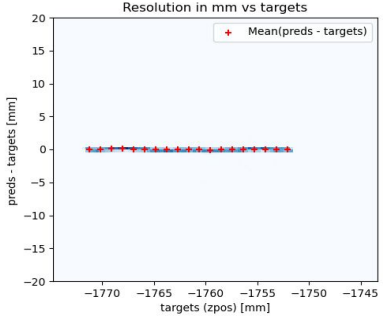
| Spatial resolution

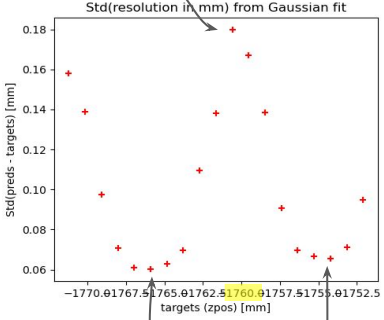
(Δz := red area width = possible z start positions of the track)

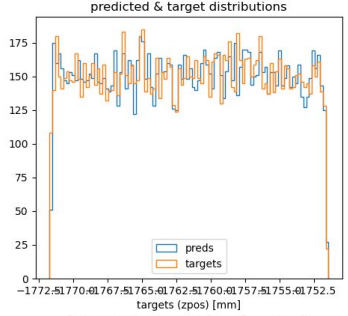
pad centers:
-1772.916
-1761.635
-1750.355

Simu: 100k events
vertical tracks
x = -900cm
p = 10GeV

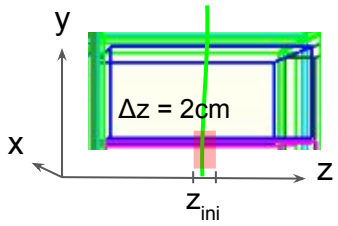


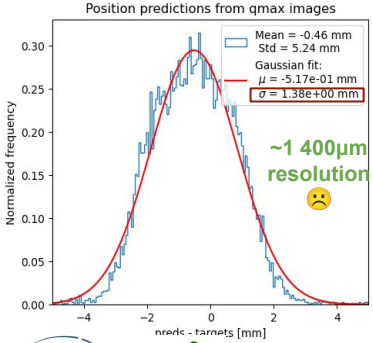


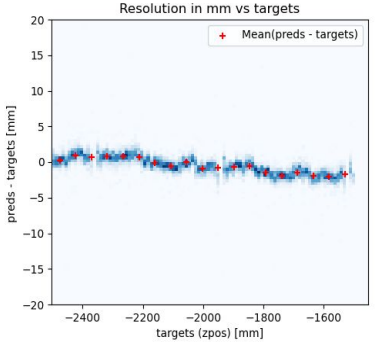


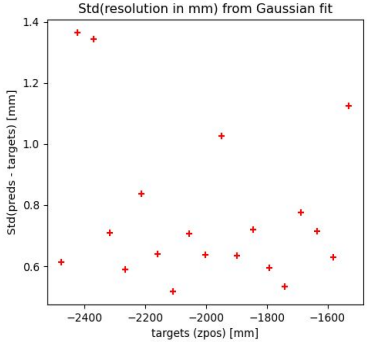


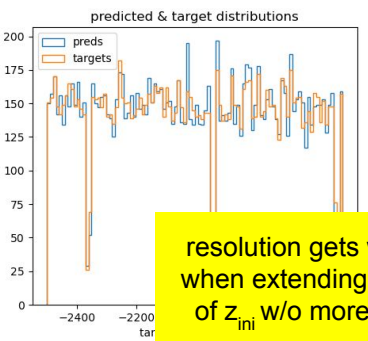
better resol between pads
(ok since 2 waveforms)



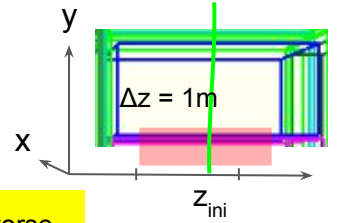








resolution gets worse when extending range of z_{ini} w/o more data

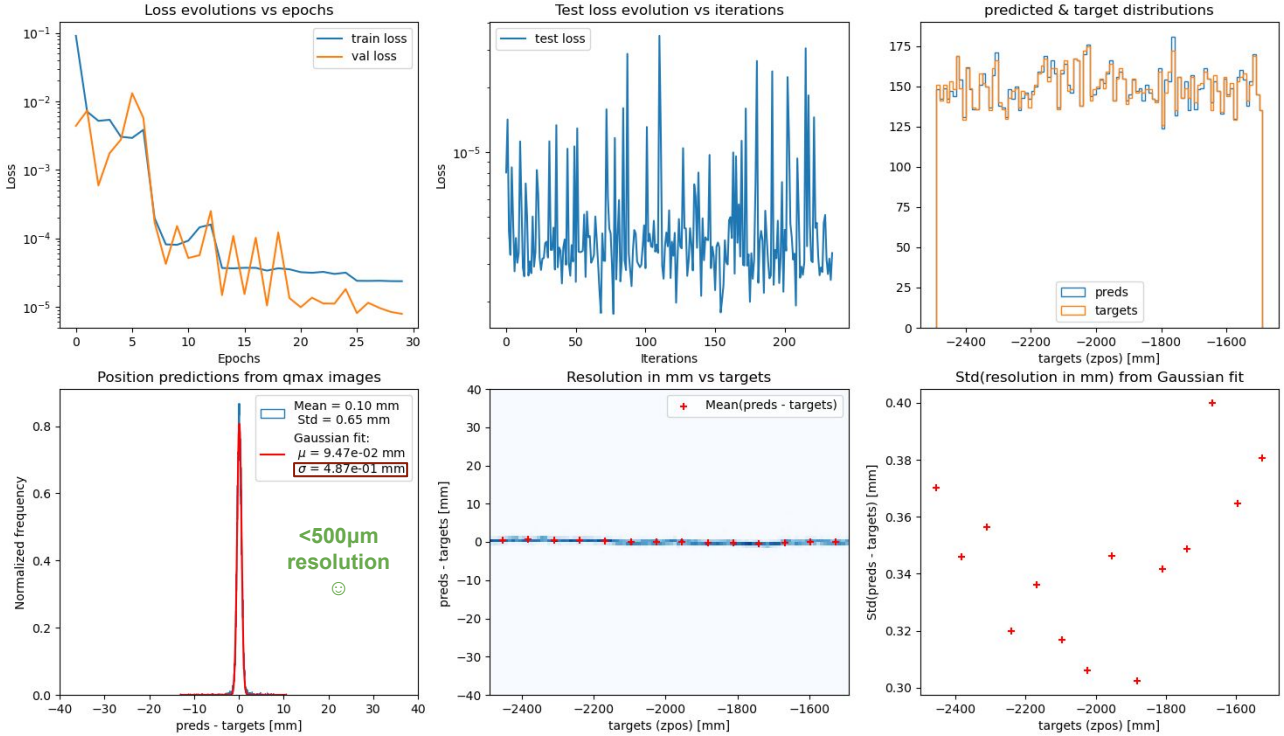


Summary of previous results

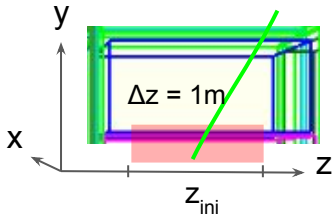
| Spatial resolution

prediction: $z_{ini}P$

M-ResNet50_b64l001p3e30h10stdz_45deg-50cmz_ziniN: Tepoch=1.1min, Ttrain=31.5min, Ttest=4.3s



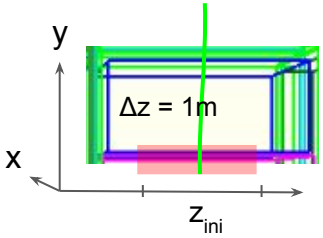
Simu: 100k events
45° tracks
x = -900cm
p = 10GeV



Issues with initial position predictions

| NN random fluctuations

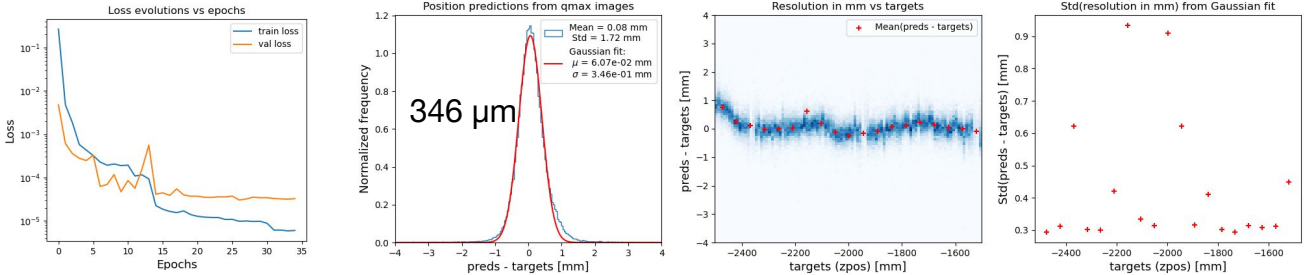
Simu:
Bmap
vertical tracks
10GeV
x = -90cm



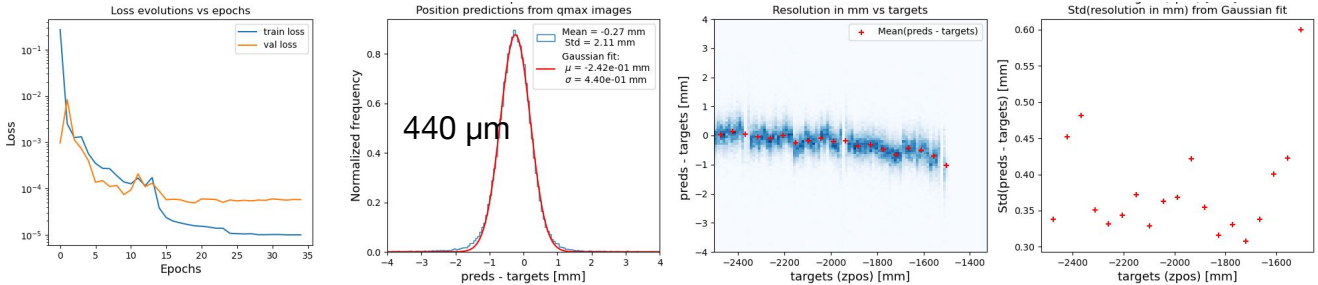
Issues with initial position predictions

| NN random fluctuations

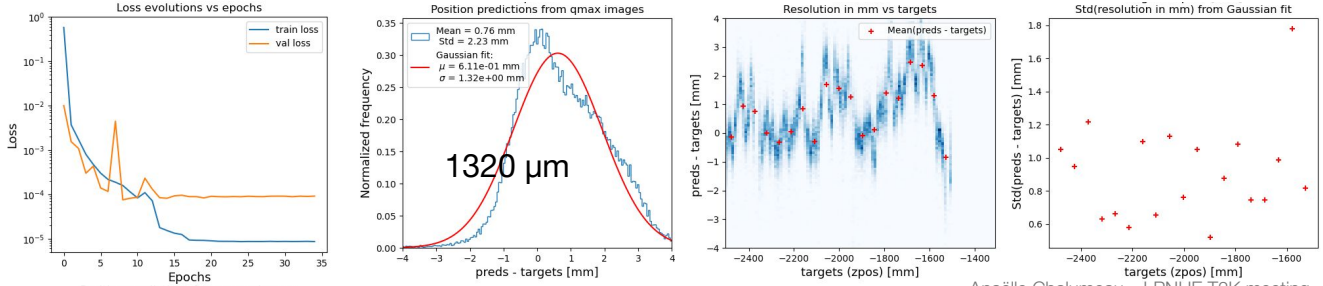
random_seed = 23



random_seed = 51



random_seed = 799



Issues with initial position predictions

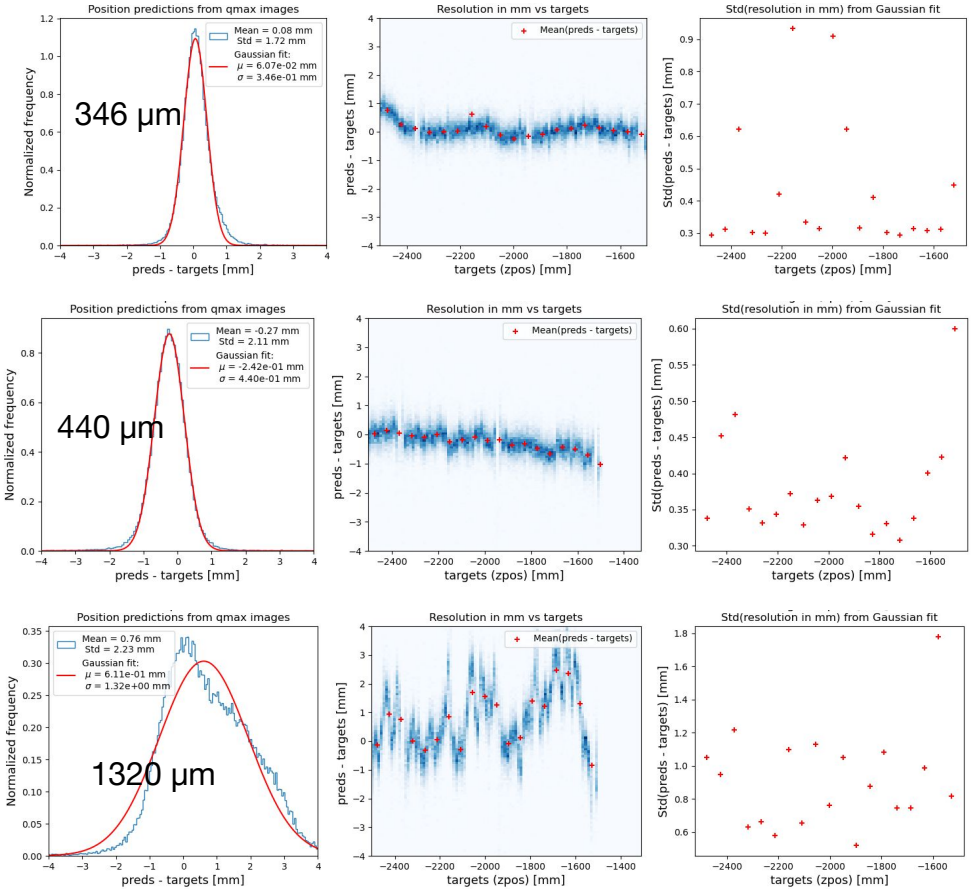
| NN random fluctuations

NN do not provide intrinsic uncertainties related to their own predictions

Some solutions/ideas:

↳ average over several training on exactly same model and data but with ≠ random_seed values

↳ use bayesian neural networks (but takes a lot of computational ressources)

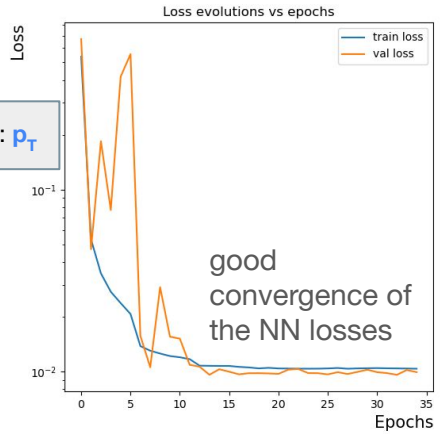


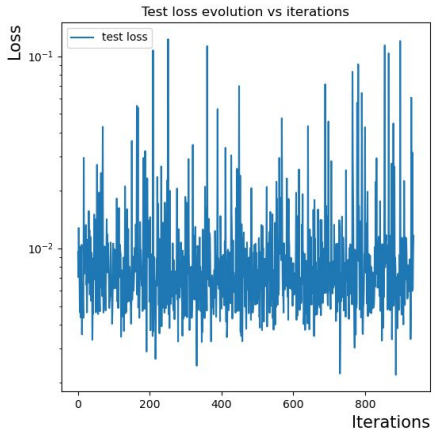
Momentum predictions

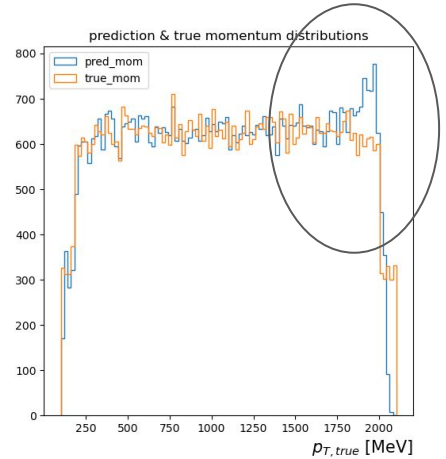
45° tracks

M-ResNet50_b64l01p3e35h40stdzOdrop_unifB-45deg-50cmz-60cmx-rangeP+_momT: Ttrain=4.9min, Tepoch=173.0min, Ttest=19.4s

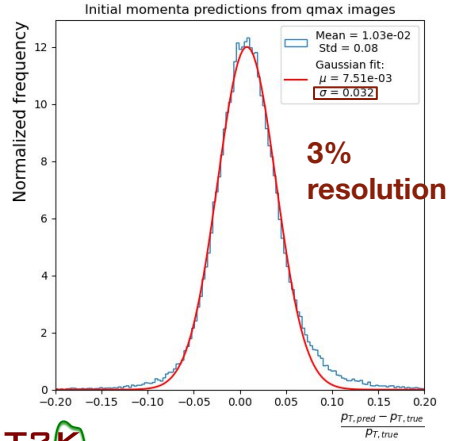
prediction: p_T

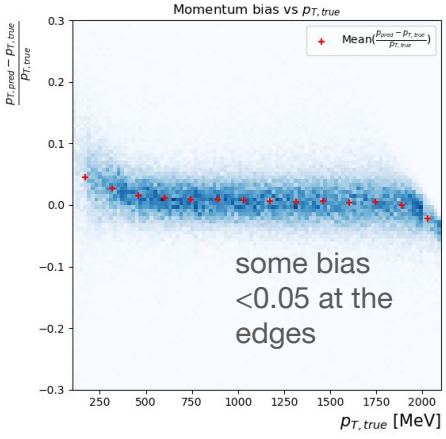


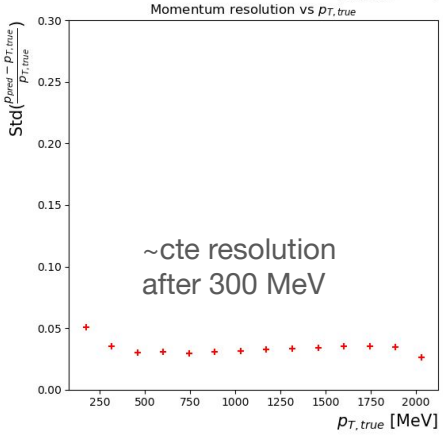




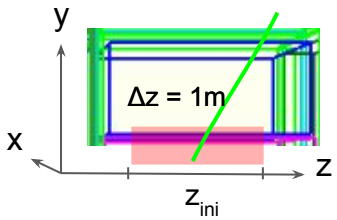
still some troubles at this edge







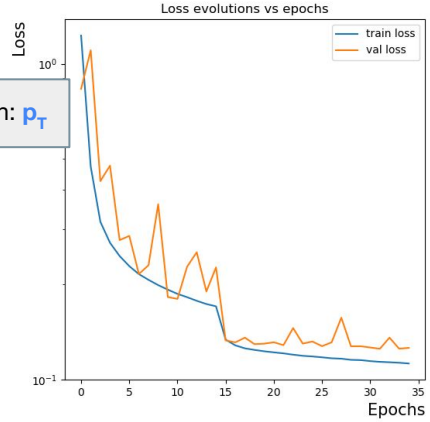
Simu: 400k events
45° tracks
e+/mu+
x = -600cm
p = 200-**2000** MeV

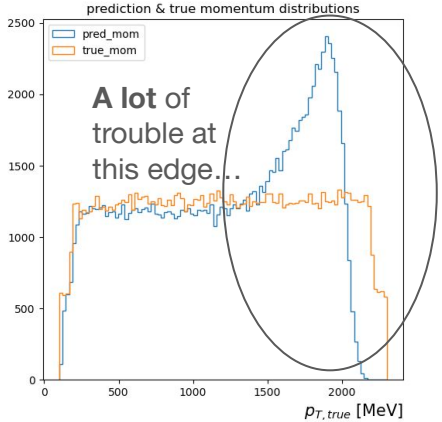


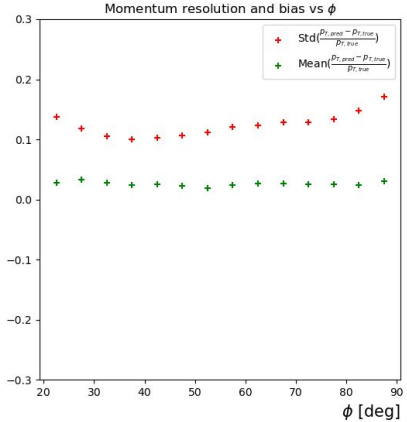
Momentum predictions
20-160° tracks

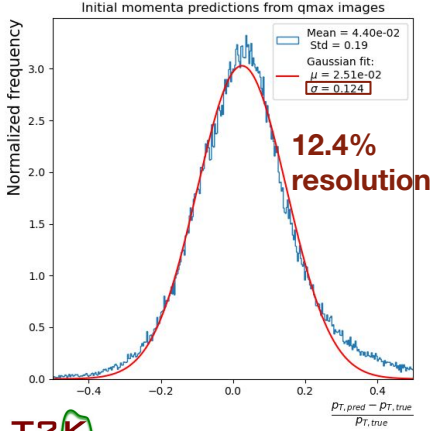
M-ResNet50_b64l01p3e35h80stdzOdrop_unifB-rangeA-50cmz-60cmx-rangeP+_momT: Ttrain=340.4min, Tepoch=9.7min, Ttest=37.0s

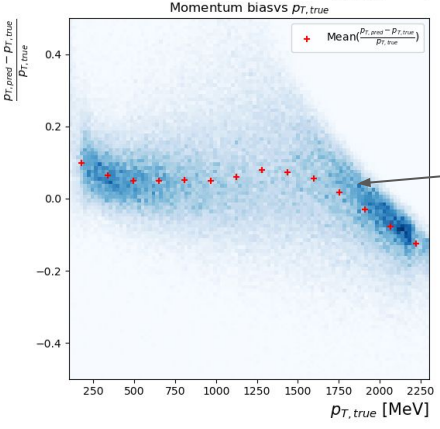
prediction: p_T

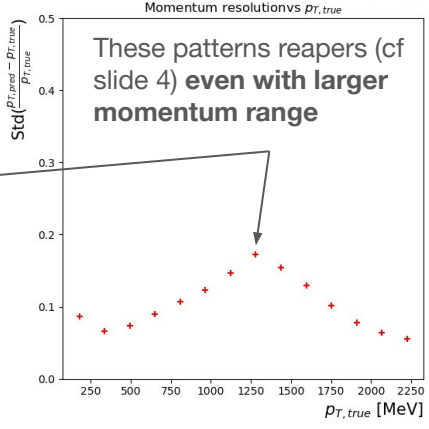




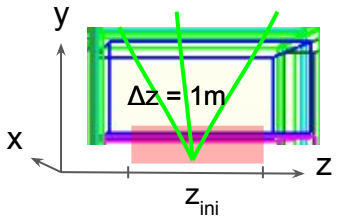








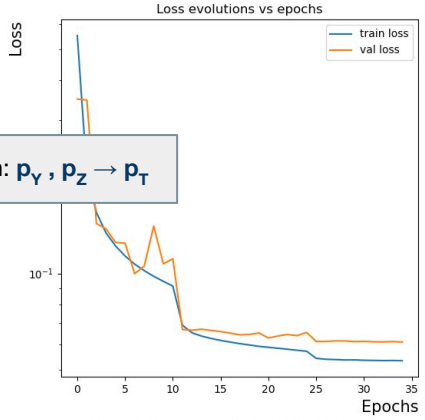
Simu: 800k events
20-160° tracks
e+/mu+
x = -600cm
p = 100-2200 MeV

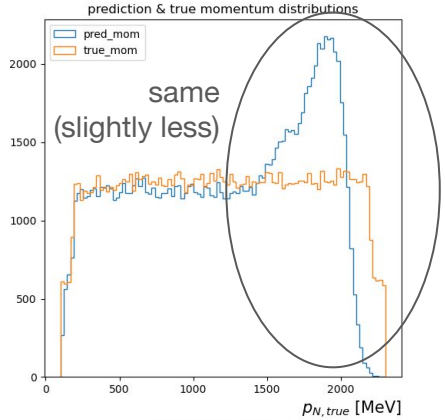


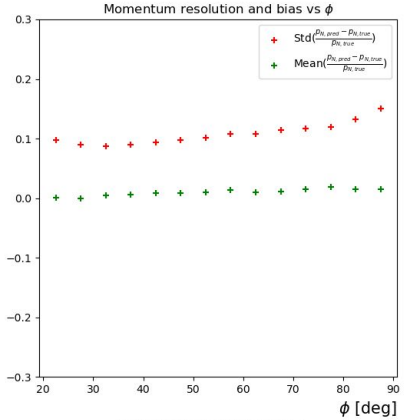
Momentum predictions
20-160° tracks

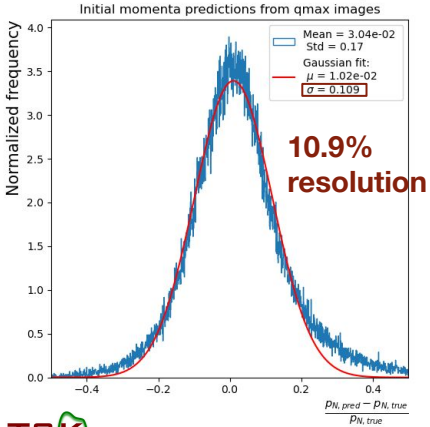
M-ResNet50_b64l01p3e35h80stdzOdrop_unifB-rangeA-50cmz-60cmx-rangeP+_momy-momzN: Ttrain=336.3min, Tepoch=9.6min, Ttest=36.5s

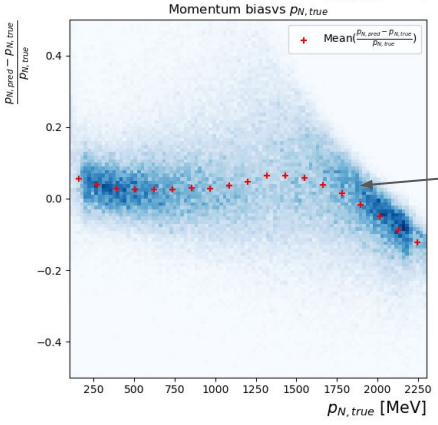
prediction: p_Y , $p_Z \rightarrow p_T$

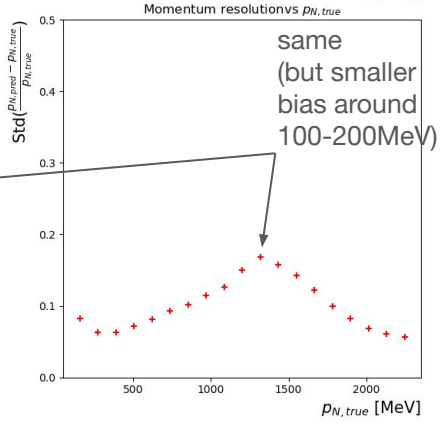




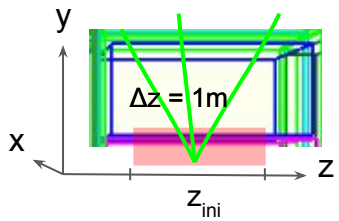








Simu: 800k events
20-160° tracks
e+/mu+
x = -600cm
p = 100-2200 MeV

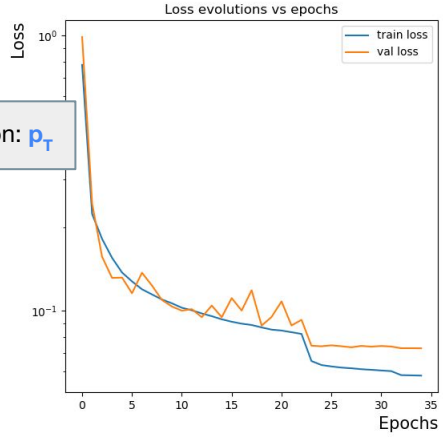


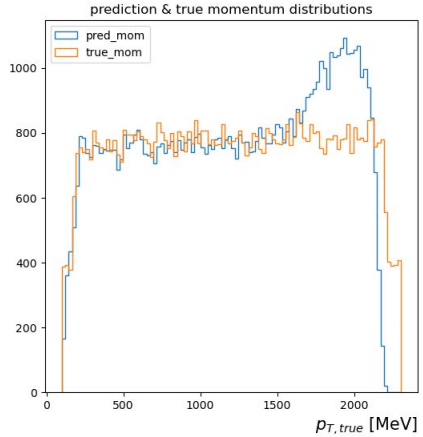
Momentum predictions

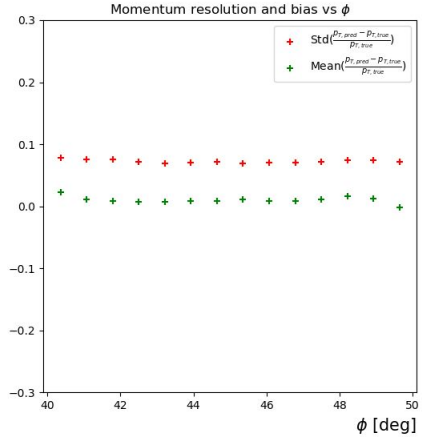
40-50° tracks

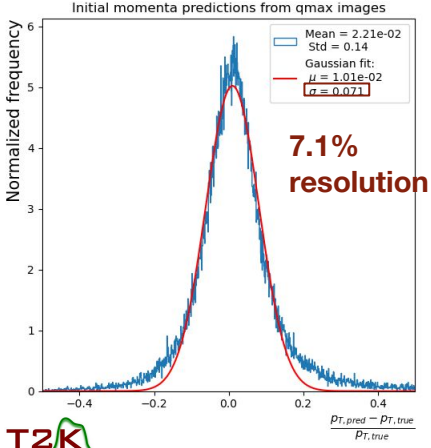
M-ResNet50_b64l01p3e35h50stdzOdrop_unifB-4050deg-50cmz-60cmx-rangeP+_momT: Ttrain=194.6min, Tepoch=5.6min, Ttest=21.1s

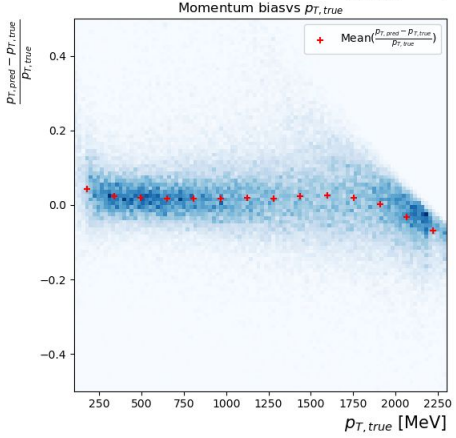
prediction: p_T

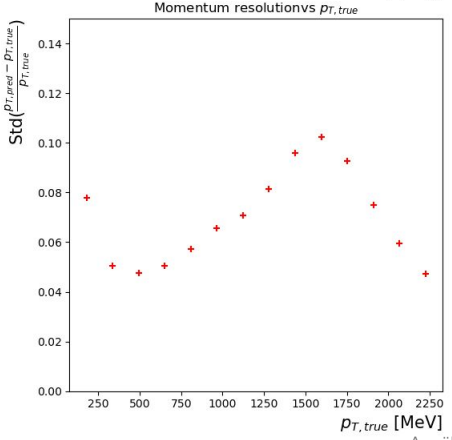




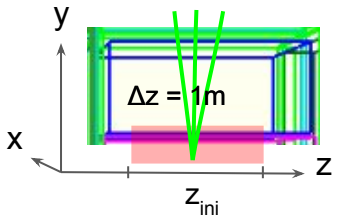








Simu: 500k events
40-50° tracks
e+/mu+
x = -600cm
p = 100-2200 MeV

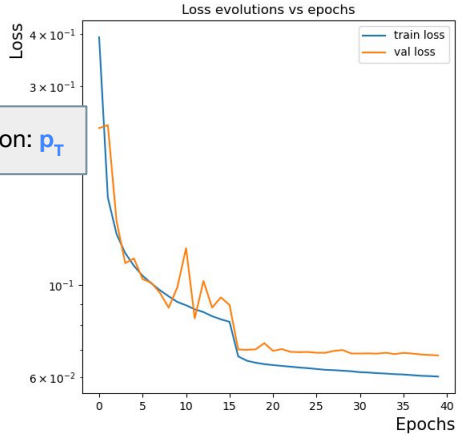


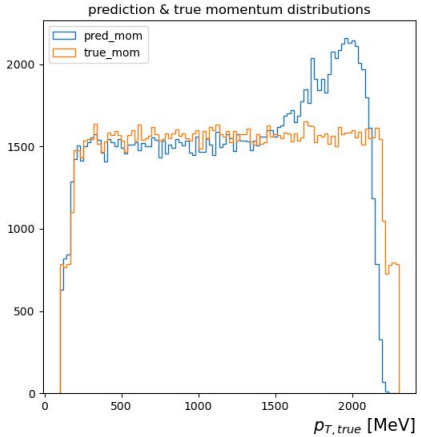
Momentum predictions

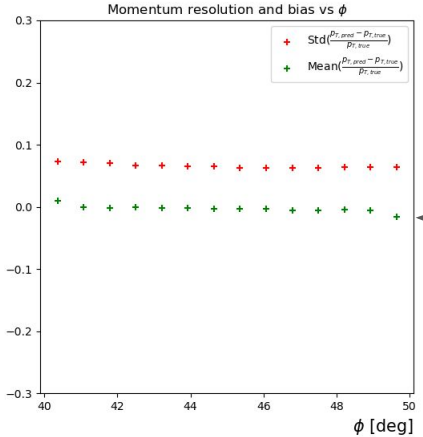
40-50° tracks

M-ResNet50_b64l01p3e40h100stdzOdrop_unifB-4050deg-50cmz-60cmx-rangeP+_momT: Ttrain=514.0min, Tepoch=12.8min, Ttest=48.9s

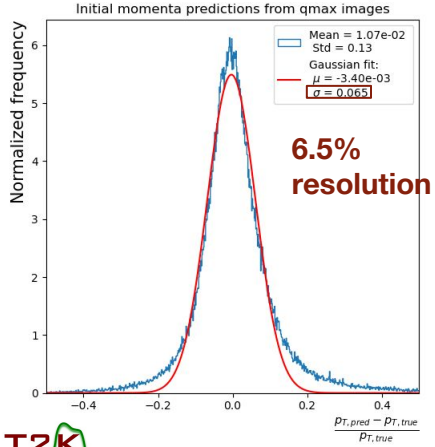
prediction: p_T



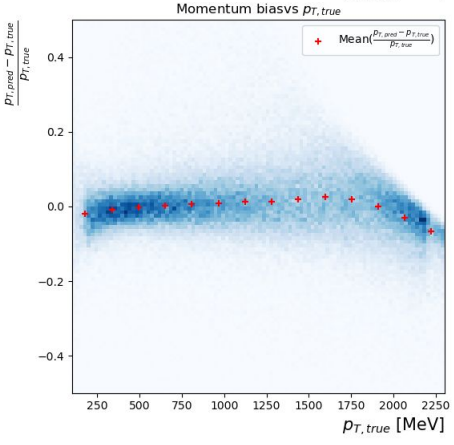


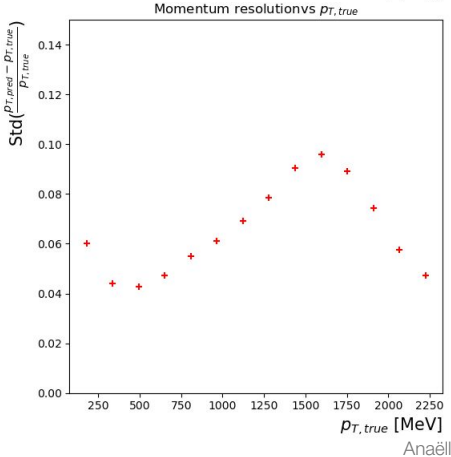


slightly less bias here

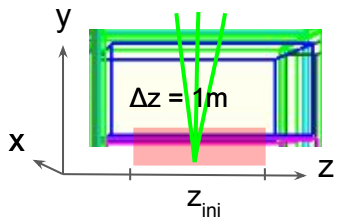


6.5% resolution





Simu: 1m events
40-50° tracks
e+/mu+
x = -600cm
p = 100-2200 MeV



Momentum predictions

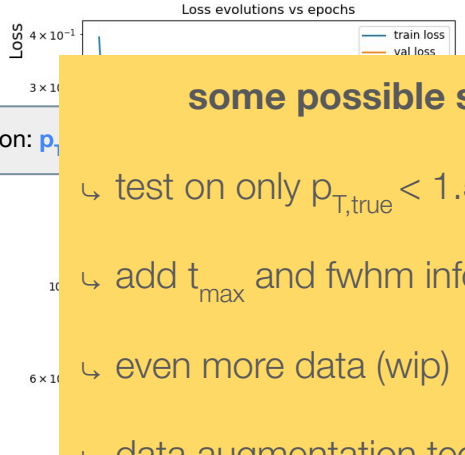
40-50° tracks

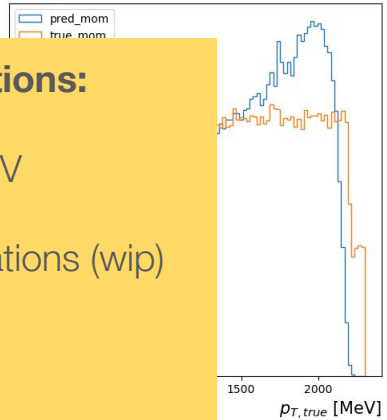
M-ResNet50_b64l01p3e40h100stdzOdrop_unifB-4050deg-50cmz-60cmx-rangeP+_momT: Ttrain=514.0min, Tepoch=12.8min, Ttest=48.9s

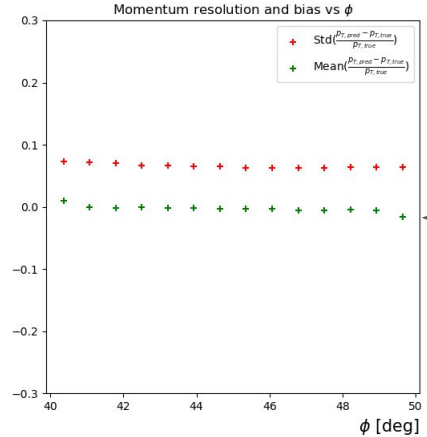
prediction: p_T

some possible solutions:

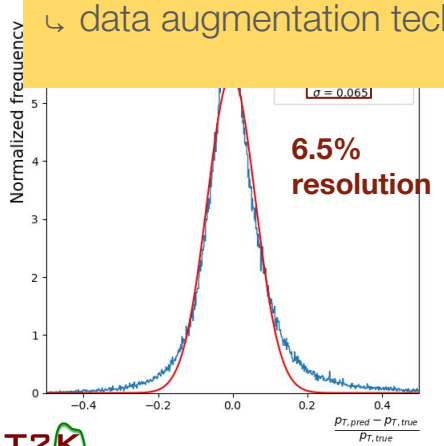
- ↳ test on only $p_{T,true} < 1.5$ GeV
- ↳ add t_{max} and fwhm informations (wip)
- ↳ even more data (wip)
- ↳ data augmentation techniques?



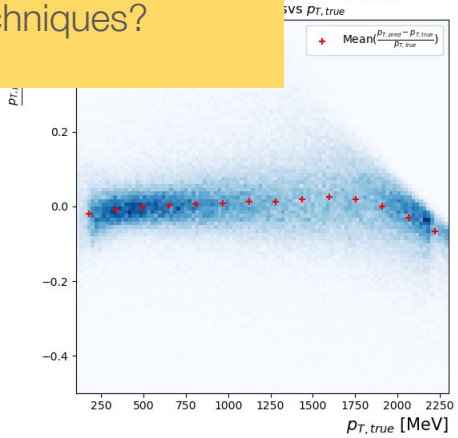


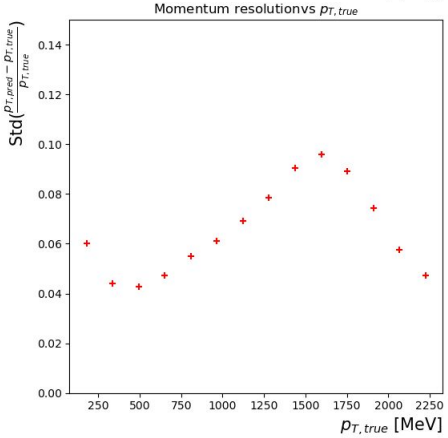


slightly less bias here

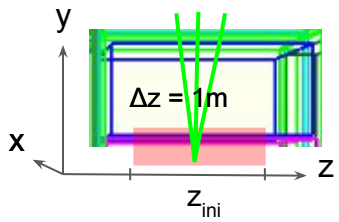


6.5% resolution

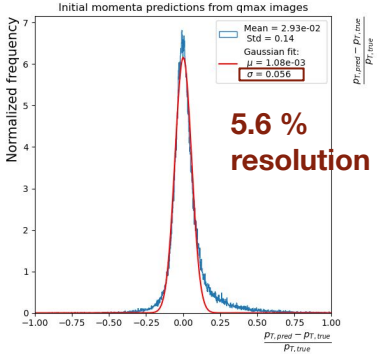




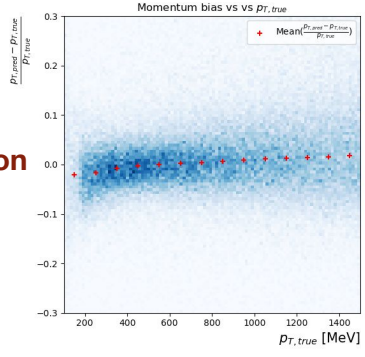
Simu: 1m events
40-50° tracks
e+/mu+
x = -600cm
p = 100-2200 MeV

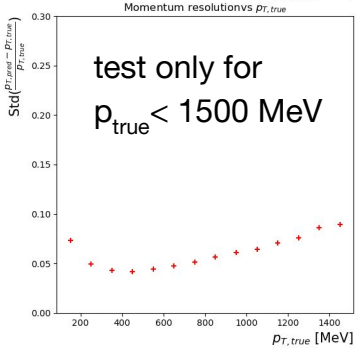


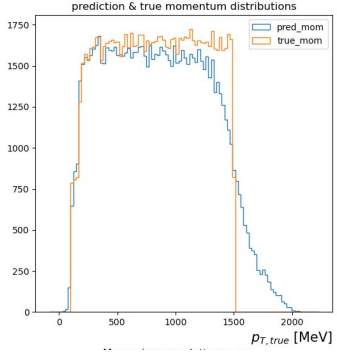
Momentum predictions
40-50° tracks



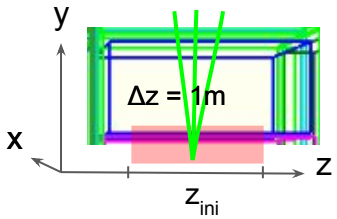
5.6 % resolution



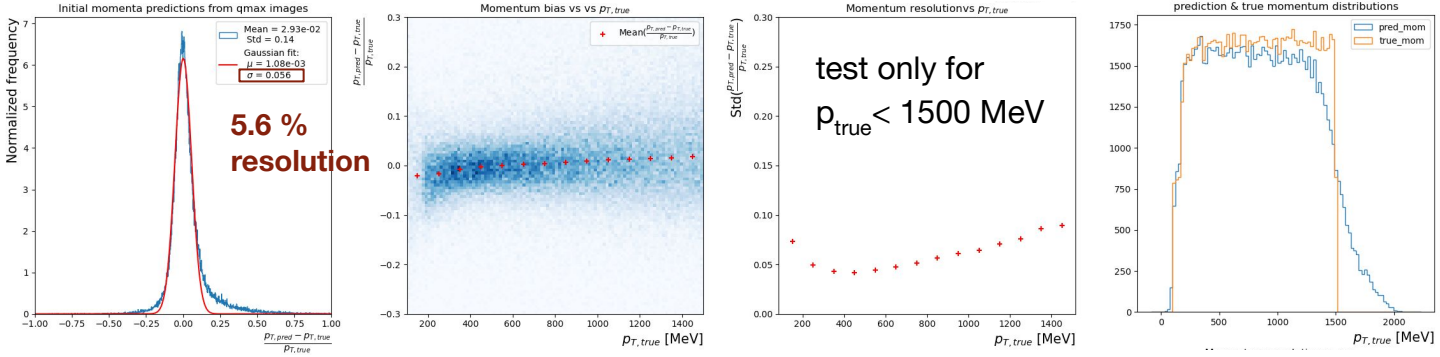


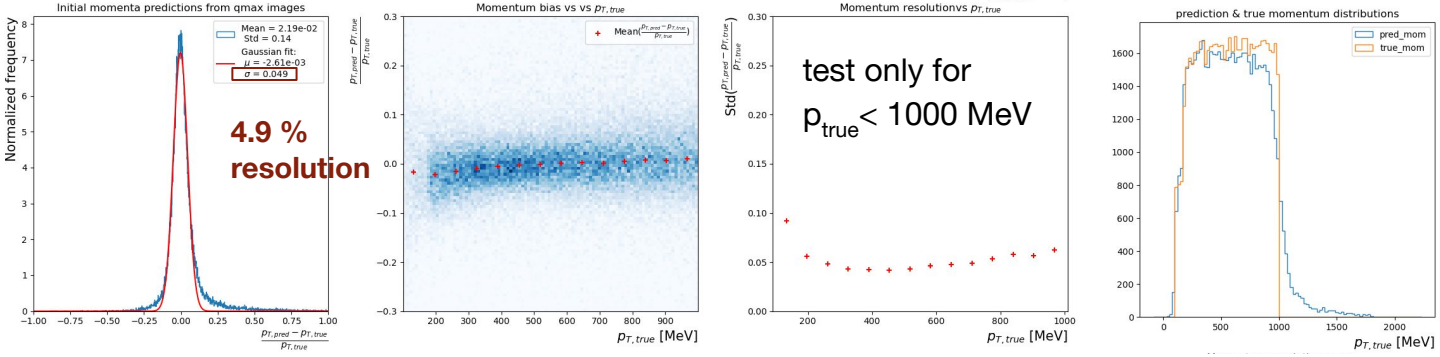


Simu: 1m events
40-50° tracks
e+/mu+
x = -600cm
p = 100-2200 MeV

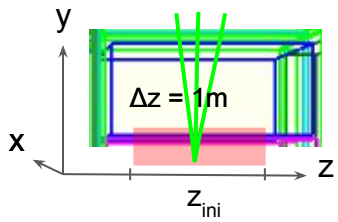


Momentum predictions
40-50° tracks





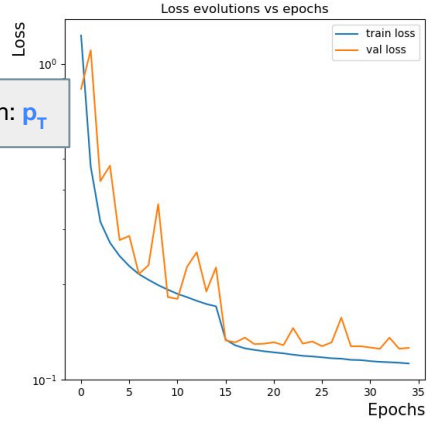
Simu: 1m events
40-50° tracks
e+/mu+
x = -600cm
p = 100-2200 MeV

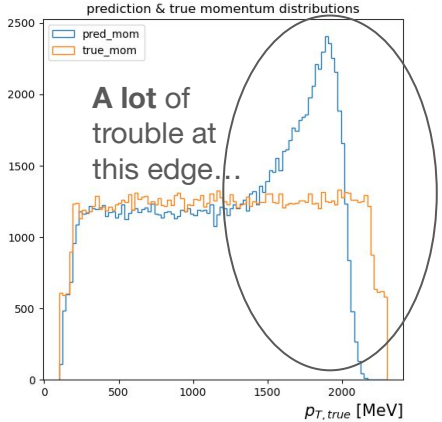


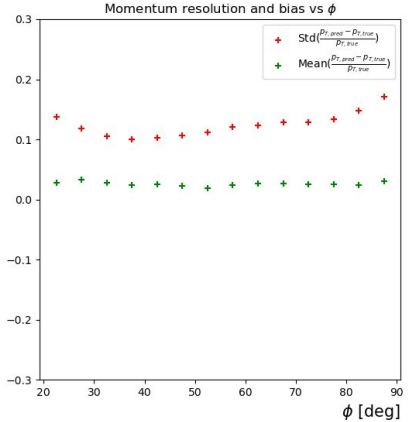
Momentum predictions
20-160° tracks

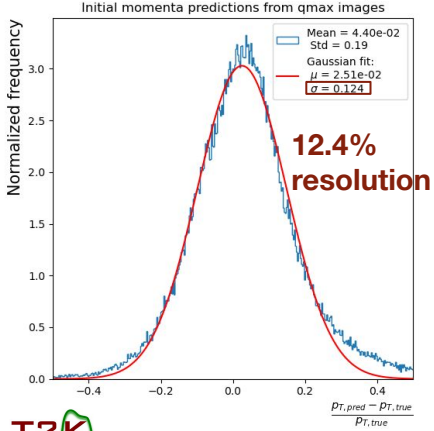
M-ResNet50_b64l01p3e35h80stdzOdrop_unifB-rangeA-50cmz-60cmx-rangeP+_momT: Ttrain=340.4min, Tepoch=9.7min, Ttest=37.0s

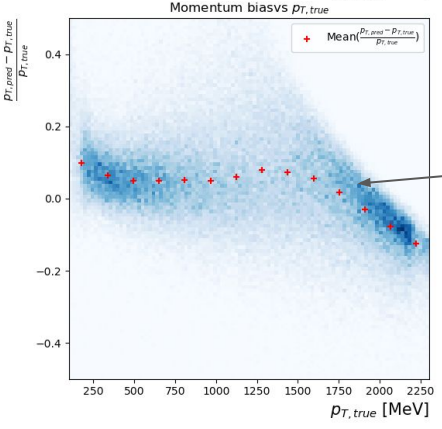
prediction: p_T

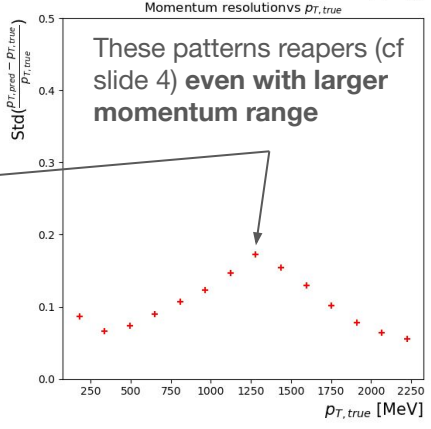




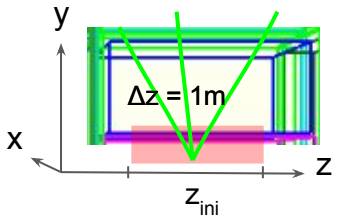








Simu: 800k events
20-160° tracks
e+/mu+
x = -600cm
p = 100-2200 MeV

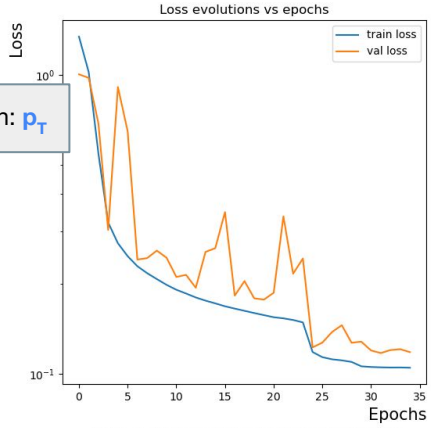


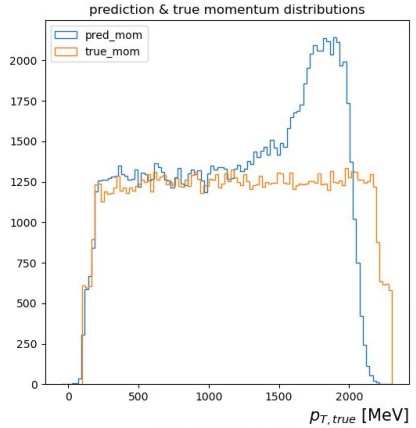
Momentum predictions
20-160° tracks

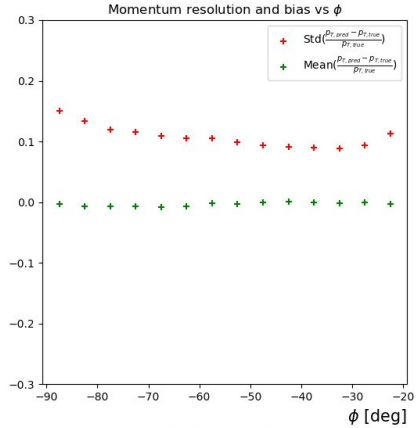
change to ResNet101

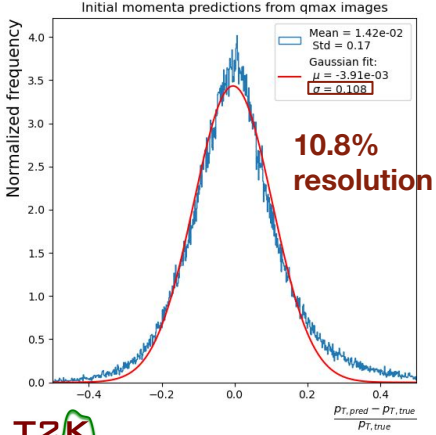
M-ResNet101_b64l01p3e35h80stdzOdrop_unifB-rangeA-50cmz-60cmx-rangeP+_momT: Ttrain=552.7min, Tepoch=15.8min, Ttest=58.9s

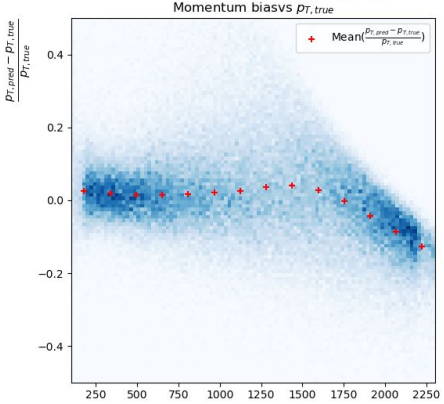
prediction: p_T

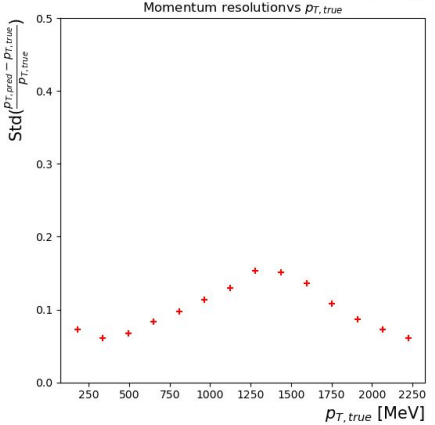




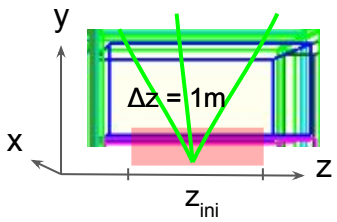








Simu: 800k events
20-160° tracks
e+/mu+
x = -600cm
p = 100-2200 MeV

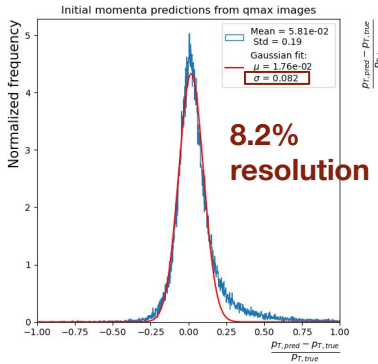


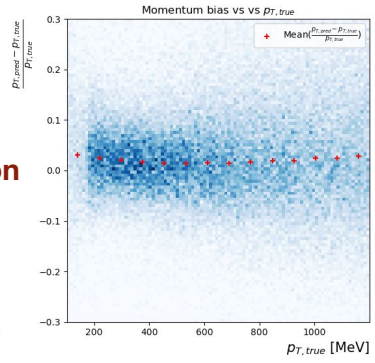
Momentum predictions
20-160° tracks

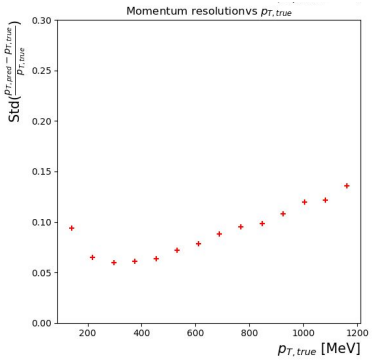
change to ResNet101

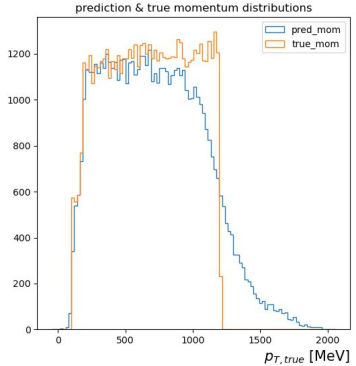
test only on p_{true} < 1200 MeV

prediction: p_T

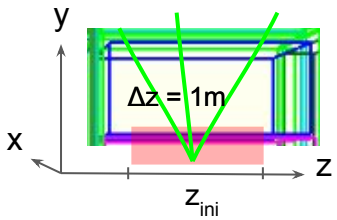








Simu: 800k events
20-160° tracks
e+/mu+
x = -600cm
p = 100-2200 MeV



Momentum predictions

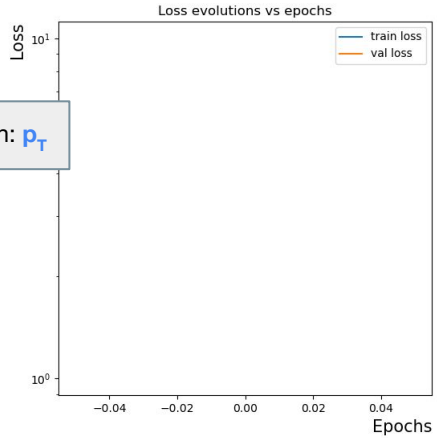
20-160° tracks

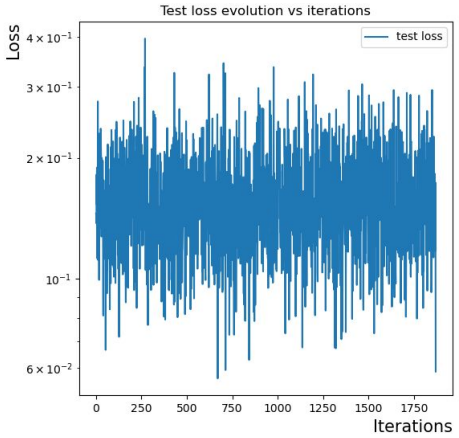
M-ResNet101_b64l01p3e35h80s31stdzOdrop_unifB-rangeA-50cmz-60cmx-rangeP+_momT: Ttrain=0.0min, Tepoch=0.0min, Ttest=67.6s

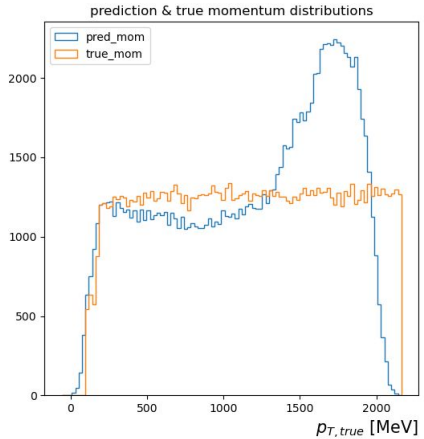
change to ResNet101

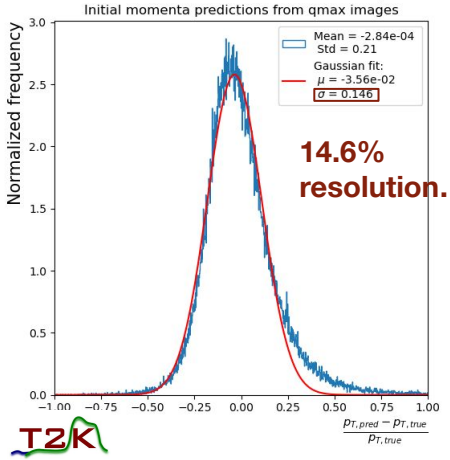
(with another random_seed)

prediction: p_T

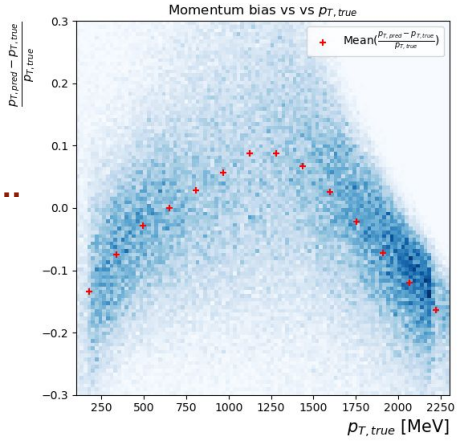


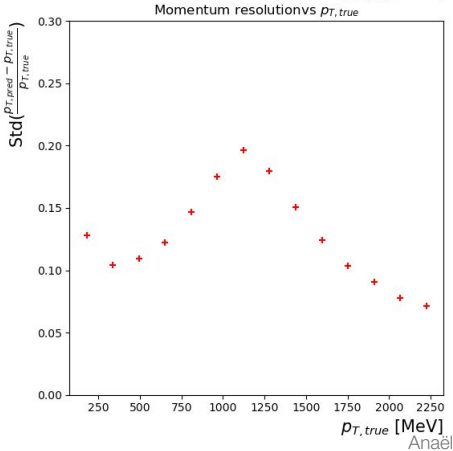




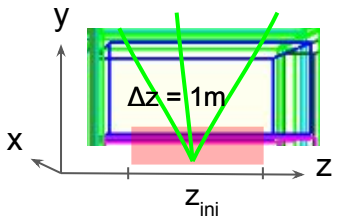


14.6% resolution…





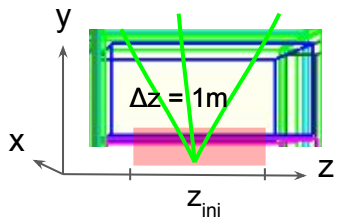
Simu: 800k events
20-160° tracks
e+/mu+
x = -600cm
p = 100-2200 MeV



e+/mu+ particle identification

prediction: **pdg_code**

Simu: 800k events
20-160° tracks
e+/mu+
x = -600cm
p = 100-2200 MeV



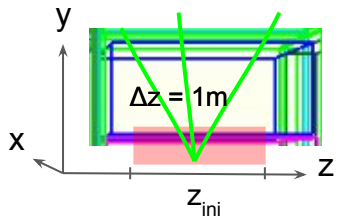
e+/mu+ particle identification

prediction: **pdg_code**

$$\text{eff} = N_i^{\text{selected}} / N_i^{\text{generated}}$$
$$\text{pur} = N_i^{\text{selected}} / (N_i^{\text{selected}} + N_j^{\text{selected}})$$

$$e^+\text{selection: } -11.5 < \texttt{pdg\_code} < -10.5$$
$$\mu^+\text{selection: } -13.5 < \texttt{pdg\_code} < -11.5$$

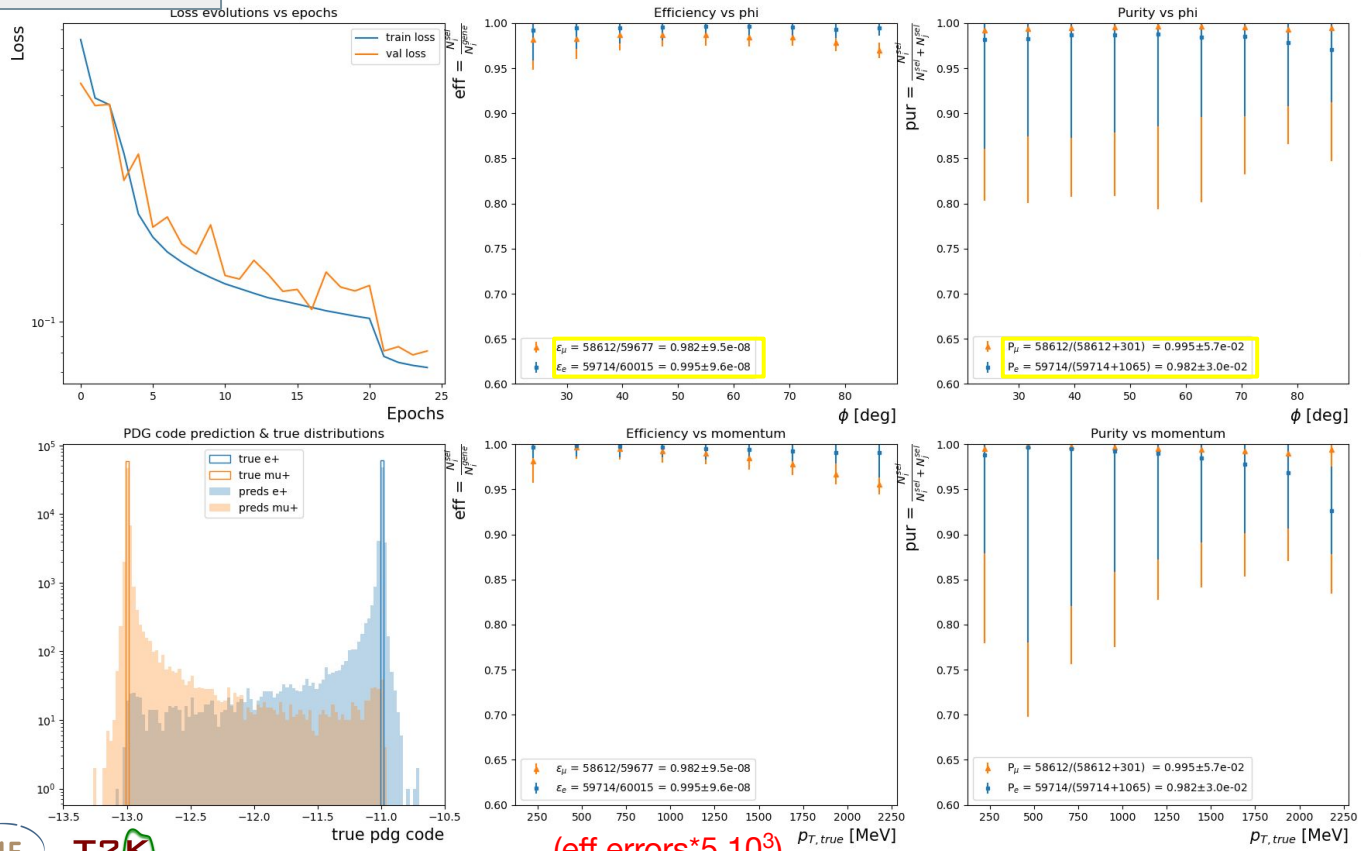
Simu: 800k events
20-160° tracks
e+/mu+
x = -600cm
p = 100-2200 MeV



e+/mu+ particle identification

prediction: **pdg_code**

e+: (eff, pur) = (0.995,0.982)
mu+: (eff, pur) = (0.982,0.995)

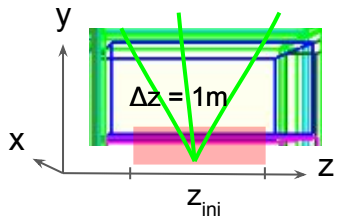


(eff errors*5.10^3)

$$\text{eff} = N_i^{\text{selected}} / N_i^{\text{generated}}$$
$$\text{pur} = N_i^{\text{selected}} / (N_i^{\text{selected}} + N_j^{\text{selected}})$$

e^+selection: $-11.5 < \texttt{pdg\_code} < -10.5$
μ^+selection: $-13.5 < \texttt{pdg\_code} < -11.5$

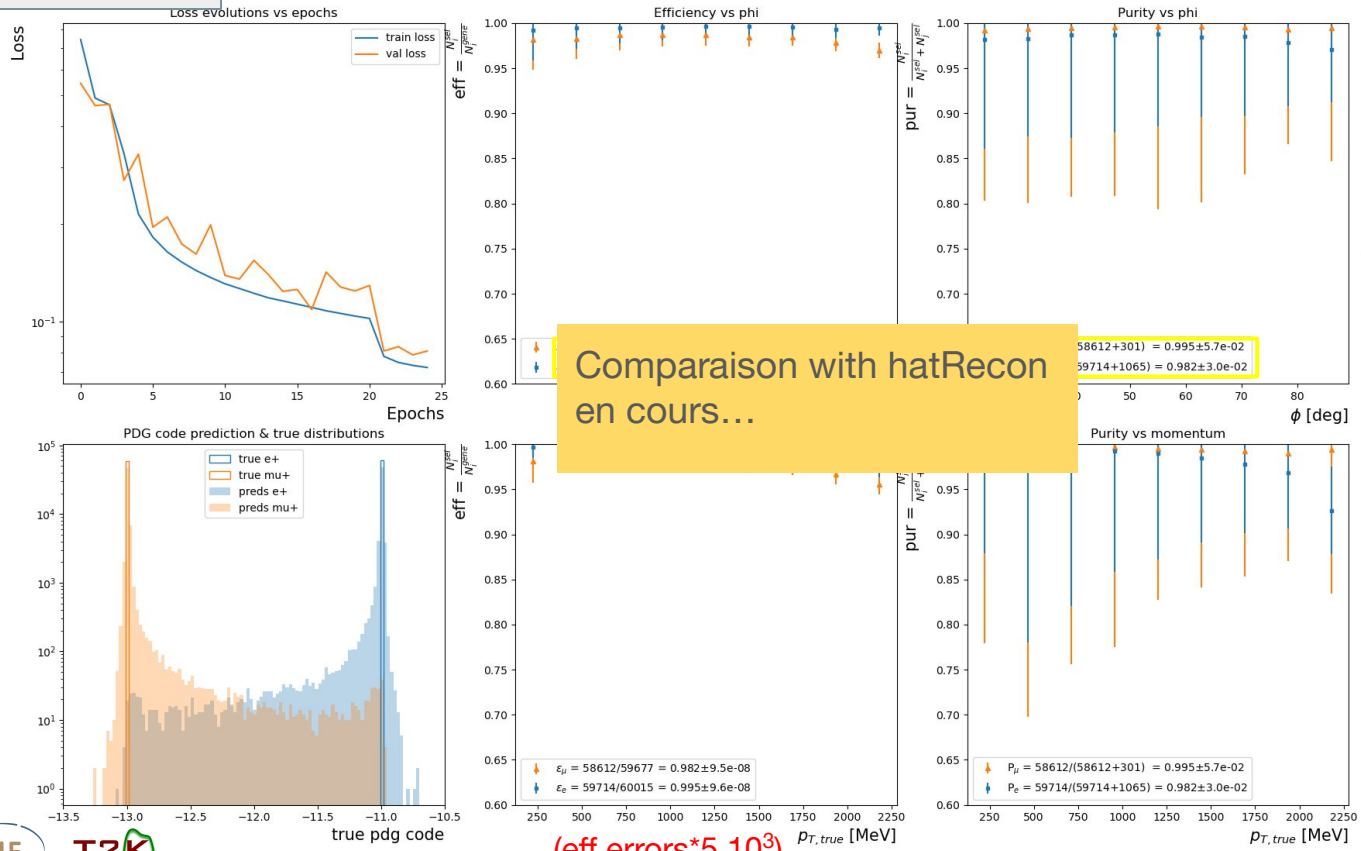
Simu: 800k events
20-160° tracks
e+/mu+
x = -600cm
p = 100-2200 MeV



e+/mu+ particle identification

prediction: **pdg_code**

e+: (eff, pur) = (0.995,0.982)
mu+: (eff, pur) = (0.982,0.995)



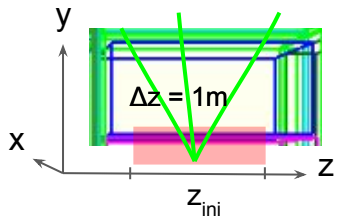
Comparaison with hatRecon en cours…

(eff errors*5.10^3)

$$\text{eff} = N_i^{\text{selected}} / N_i^{\text{generated}}$$
$$\text{pur} = N_i^{\text{selected}} / (N_i^{\text{selected}} + N_j^{\text{selected}})$$

e^+selection: $-11.5 < \texttt{pdg\_code} < -10.5$
μ^+selection: $-13.5 < \texttt{pdg\_code} < -11.5$

Simu: 800k events
20-160° tracks
e+/mu+
x = -600cm
p = 100-2200 MeV

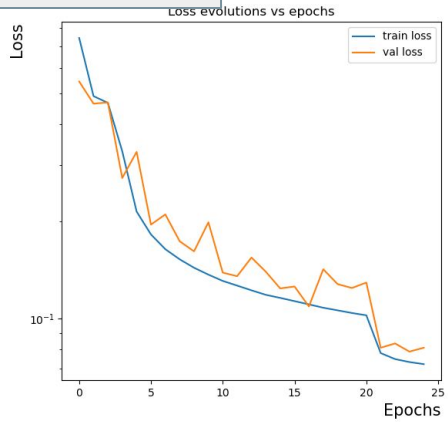


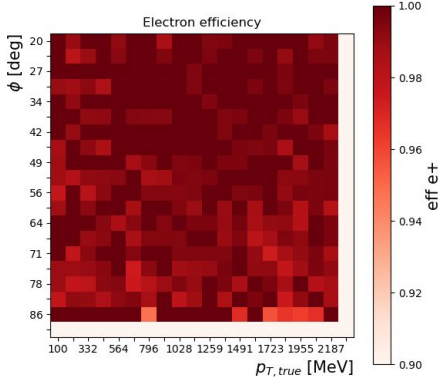
e+/mu+ particle identification

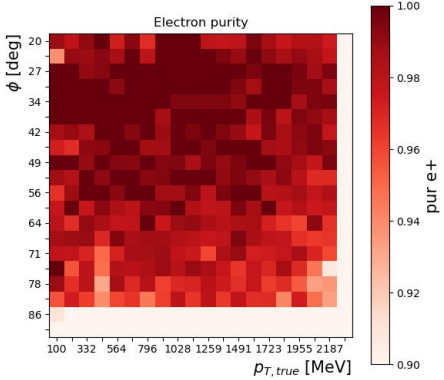
e+: (eff, pur) = (0.995,0.982)
mu+: (eff, pur) = (0.982,0.995)

prediction: **pdg_code**

M-ResNet50_b64l01p3e25h80stdzOdrop_unifB-rangeA-50cmz-60cmx-rangeP+_momT-pdgPDG: Ttrain=225.2min, Tepoch=9.0min, Ttest=34.4s

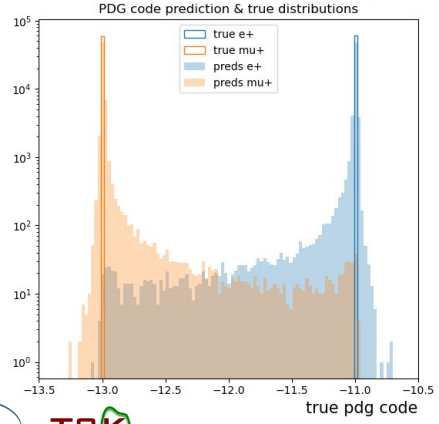


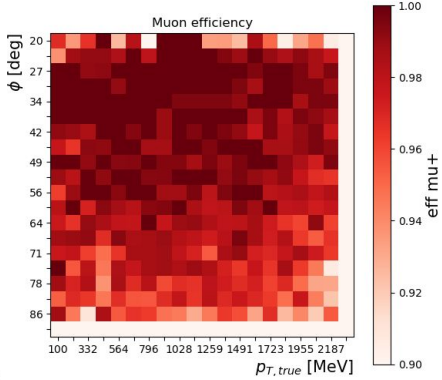


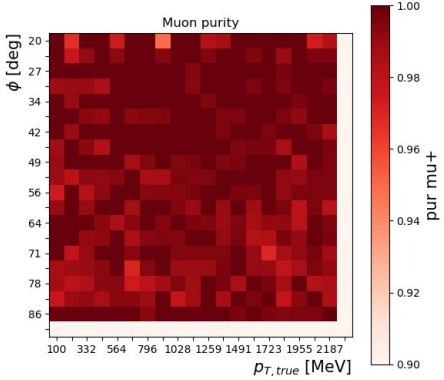


$$\text{eff} = N_i^{\text{selected}} / N_i^{\text{generated}}$$
$$\text{pur} = N_i^{\text{selected}} / (N_i^{\text{selected}} + N_j^{\text{selected}})$$

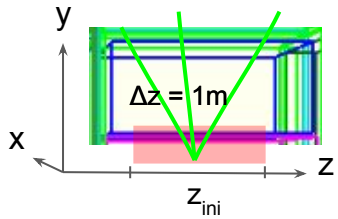
e^+selection: $-11.5 < \texttt{pdg\_code} < -10.5$
μ^+selection: $-13.5 < \texttt{pdg\_code} < -11.5$







Simu: 800k events
20-160° tracks
e+/mu+
x = -600cm
p = 100-2200 MeV



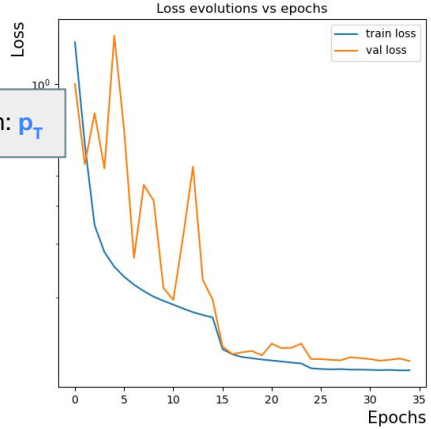
Back-up

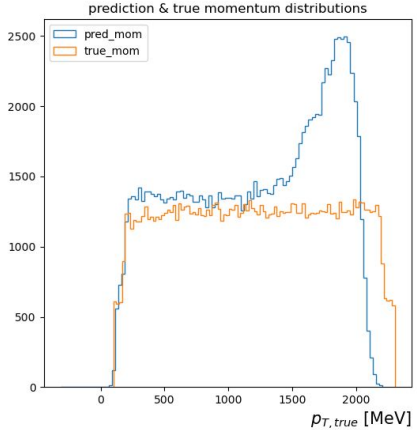
Momentum predictions
20-160° tracks

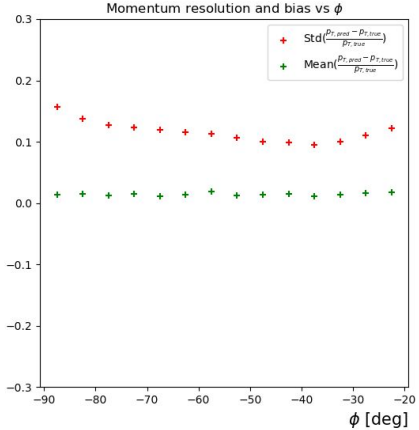
ResNet152

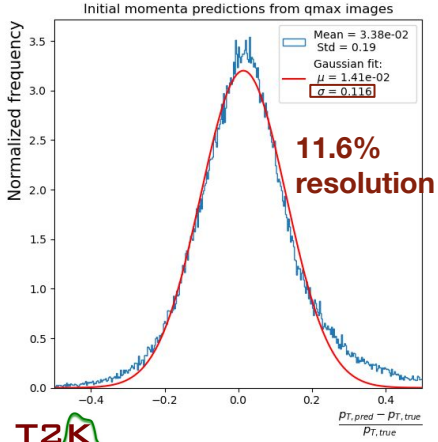
M-ResNet152_b64l01p3e35h80stdzOdrop_unifB-rangeA-50cmz-60cmx-rangeP+_momT: Ttrain=894.9min, Tepoch=25.6min, Ttest=91.4s

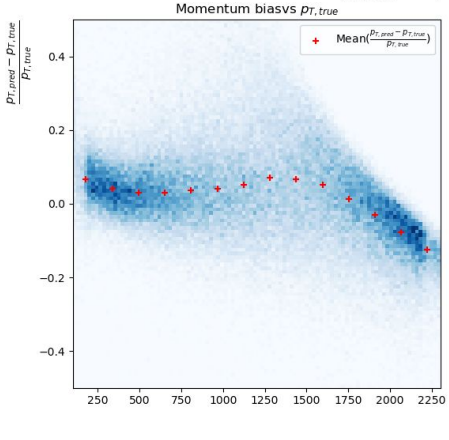
prediction: p_T

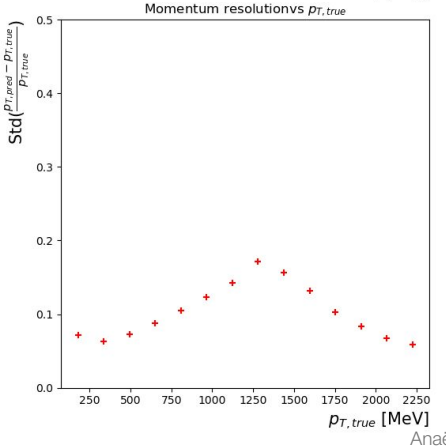




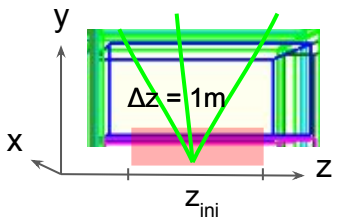






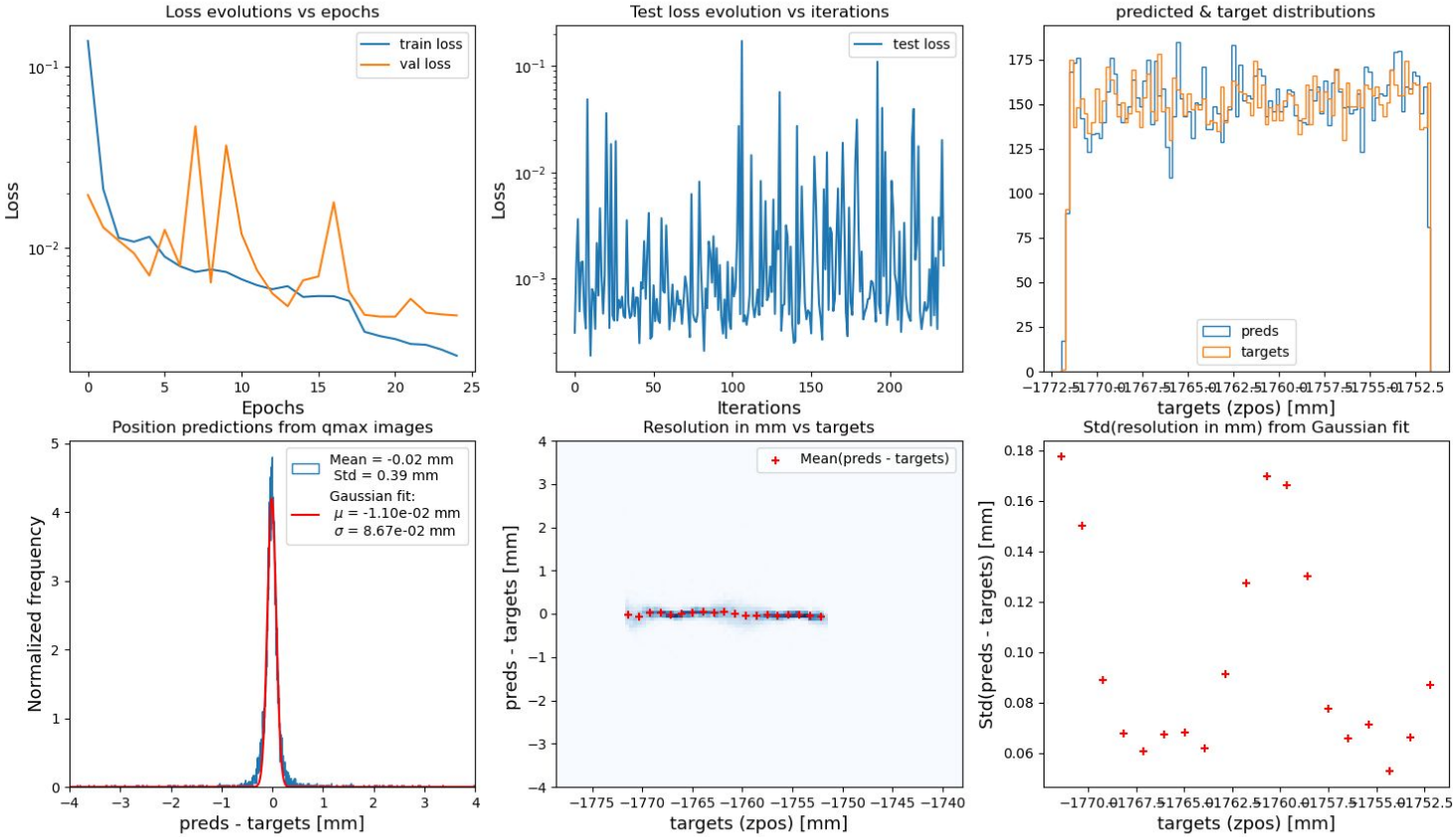


Simu: 800k events
20-160° tracks
e+/mu+
x = -600cm
p = 100-2200 MeV

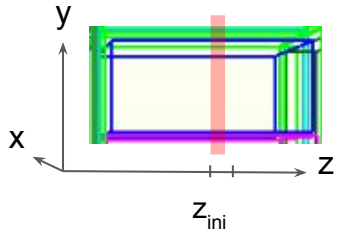


Increasing Δz

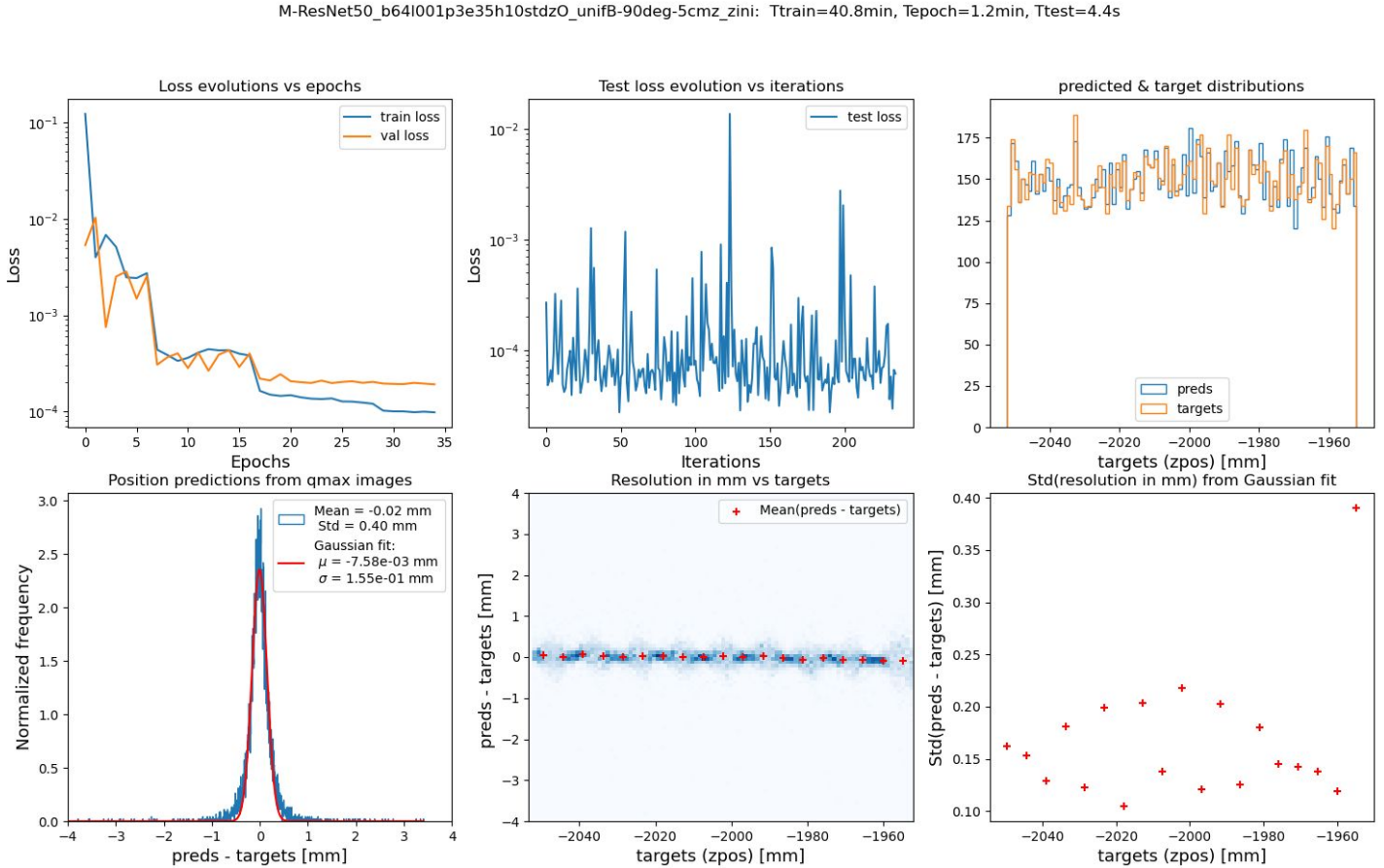
M-ResNet50_b64l001p3e25h10stdzOdrop_90deg-1cmz_zini: Ttrain=28.0min, Tepoch=1.1min, Ttest=4.2s



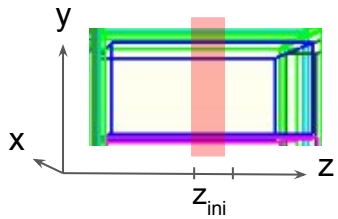
simu:
unifB
vertical tracks
Δz = 2cm
10GeV
x = -90cm



Increasing Δz

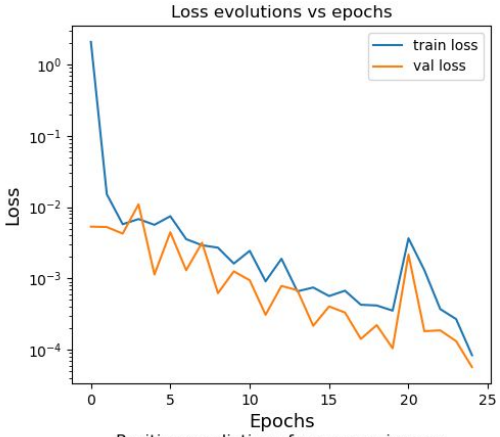


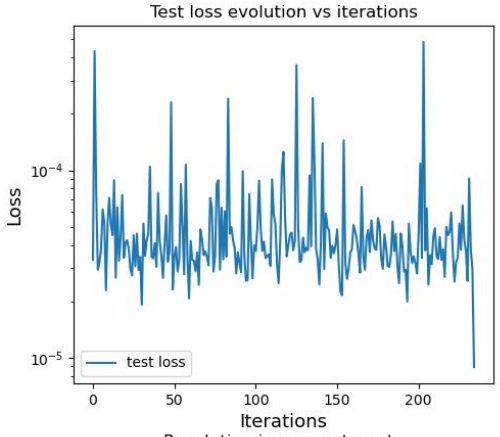
simu:
unifB
vertical tracks
Δz = 5cm
10GeV
x = -90cm

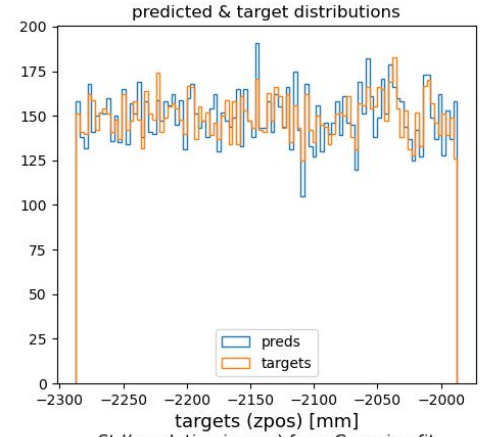


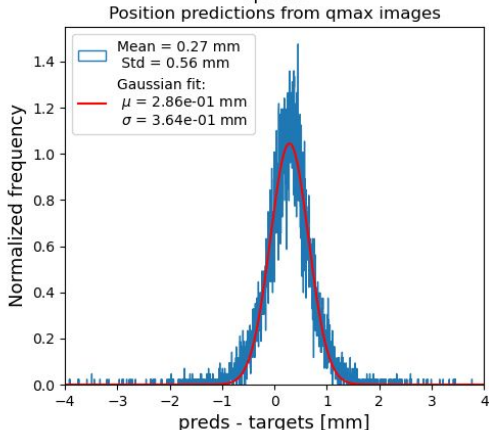
Increasing Δz

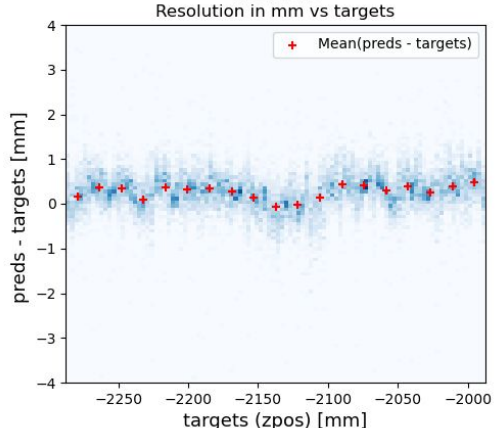
M-ResNet50_b64l01p3e25h10stdzOdrop_unifB-90deg-15cmz_zini: Ttrain=30.5min, Tepoch=1.2min, Ttest=4.6s

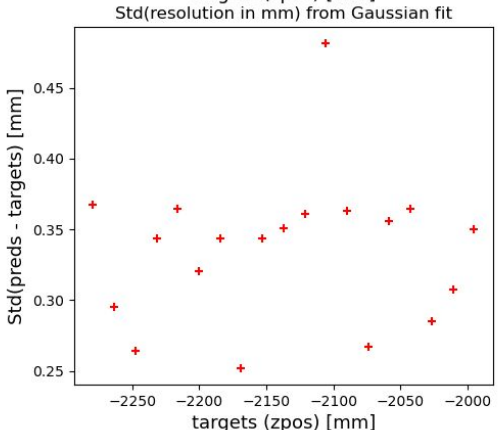




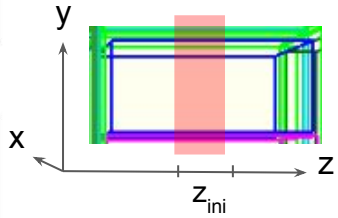






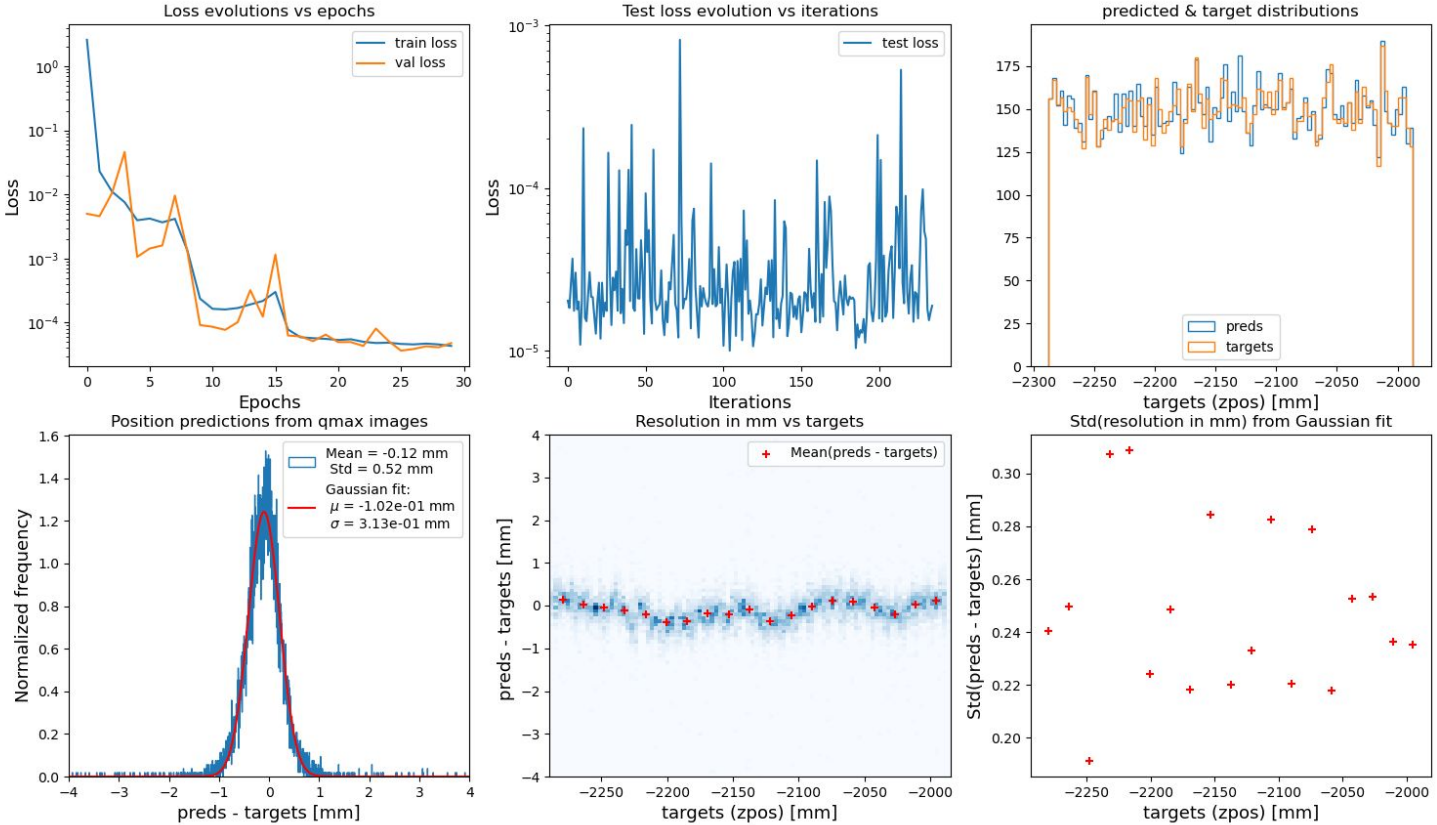


simu:
unifB
vertical tracks
Δz = 15cm
10GeV
x = -90cm



Increasing Δz

M-ResNet50_b64l01p3e30h10stdzOdrop_90deg-15cmz_zini: Ttrain=39.3min, Tepoch=1.3min, Ttest=4.8s



simu:
Bmap
vertical tracks
Δz = 15cm
10GeV
x = -90cm