Long target measurements for Future Neutrino experiments

Here mostly concentrates on T2K/T2K-II/HyperK beam

Believe most would apply for DUNE

-- longer target

-- higher energy particles so different PID probably needed (RICH?)

2009 **arXiv:1603.06774v2**

Measurements of $\pi^{\pm}$ differential yields from the surface of the T2K replica target for incoming 31 GeV/c protons with the NA61/SHINE spectrometer at the CERN SPS

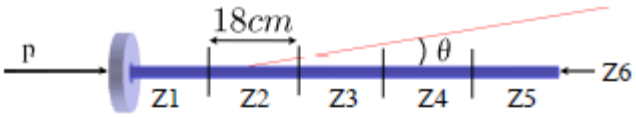


Fig. 2: A sketch of the longitudinal binning of the T2K replica target. The aluminum flange at the upstream edge is used in NA61/SHINE to hold and align the target.

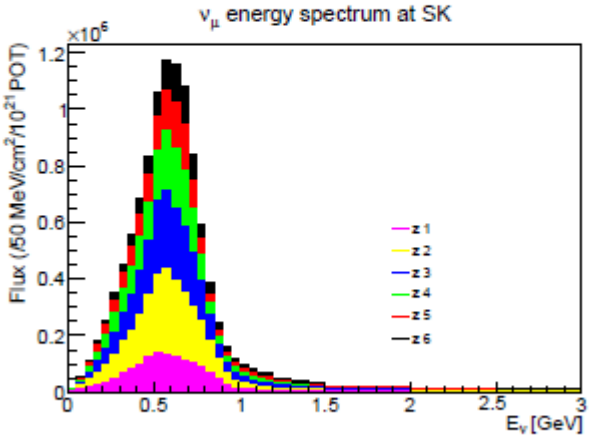


Fig. 3: Stacked histograms showing the contribution of each of the 6 longitudinal target bins (see Fig. 2) to the muon neutrino flux at SK.

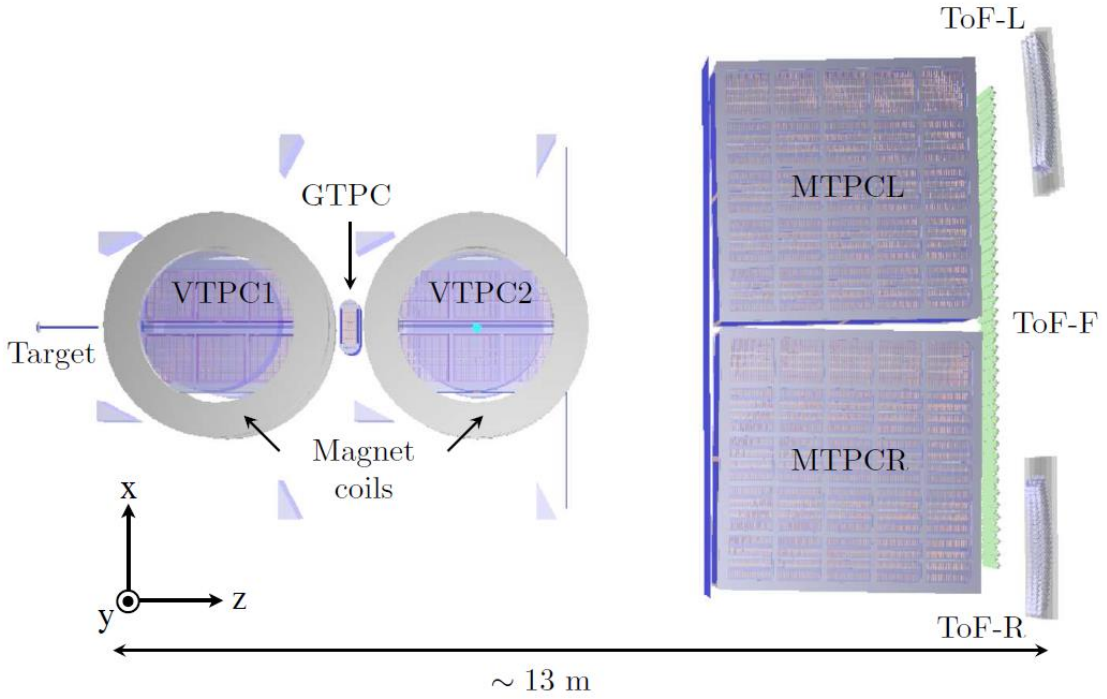


Fig. 6: The NA61/SHINE experimental setup (horizontal cut). The beam is coming from the left, impinging on the T2K replica target shown in this figure. The chosen coordinate system is as follows: its origin lies in the middle of the VTPC-2, on the beam axis. The nominal beam direction is along the z axis. The magnetic field bends charged particle trajectories in the x–z (horizontal) plane. Positively charged particles are bent towards the top of the plot. The drift direction in the TPCs is along the y (vertical) axis.

2009

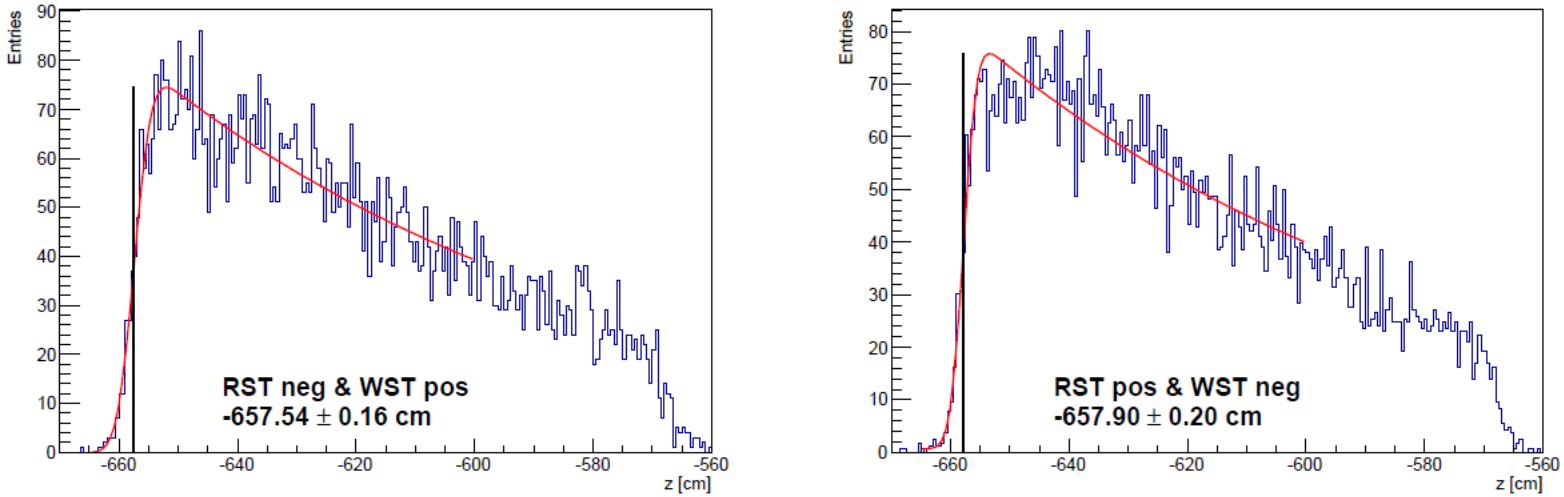


Fig. 10: The fitted z coordinate of primary interactions obtained using negatively charged RST and positively charged WST (*left*) and positively charged WST and negatively charged RST (*right*). The vertical line shows the position of the target upstream face obtained with the fit.

2009

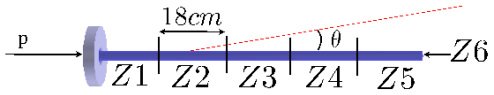


Figure 4.12: Sketch of the longitudinal binning of the target.

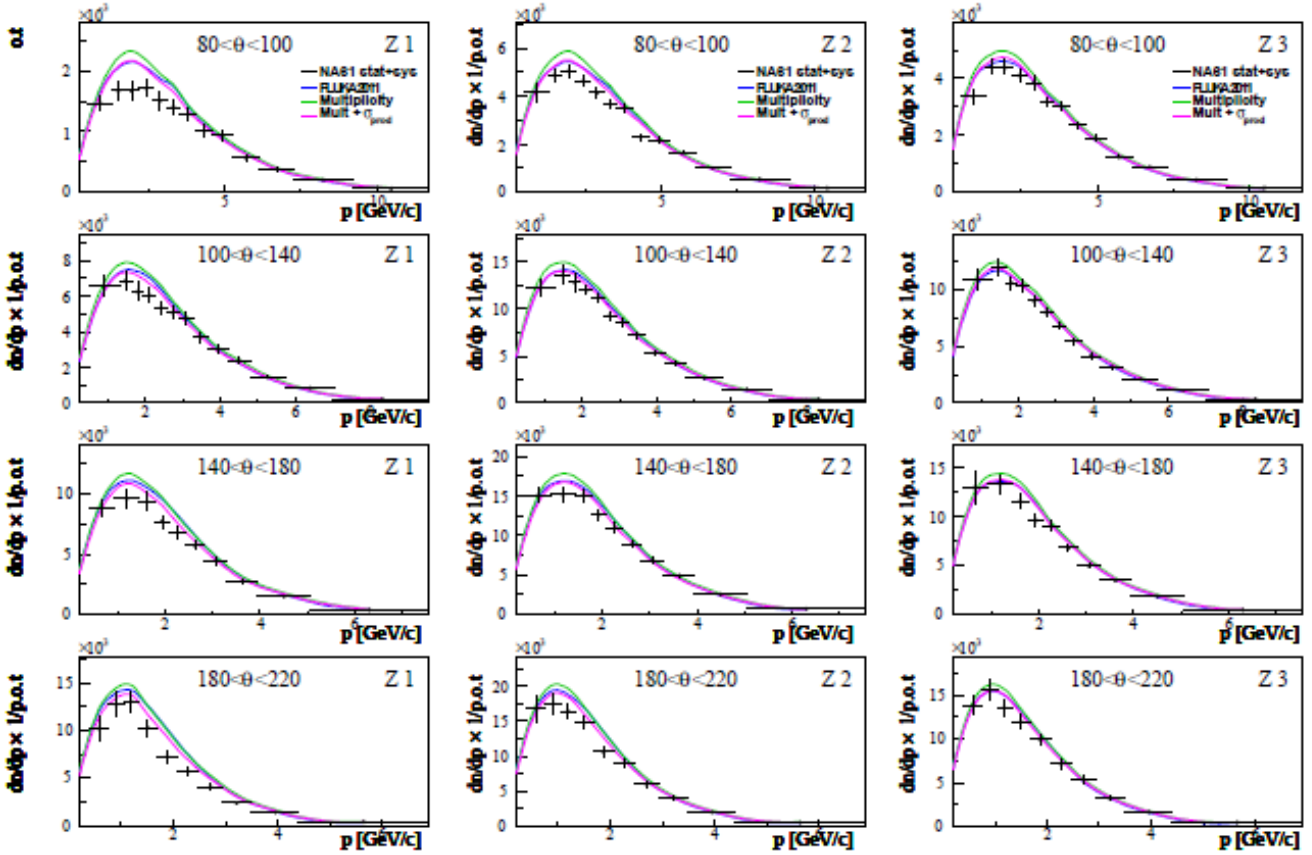
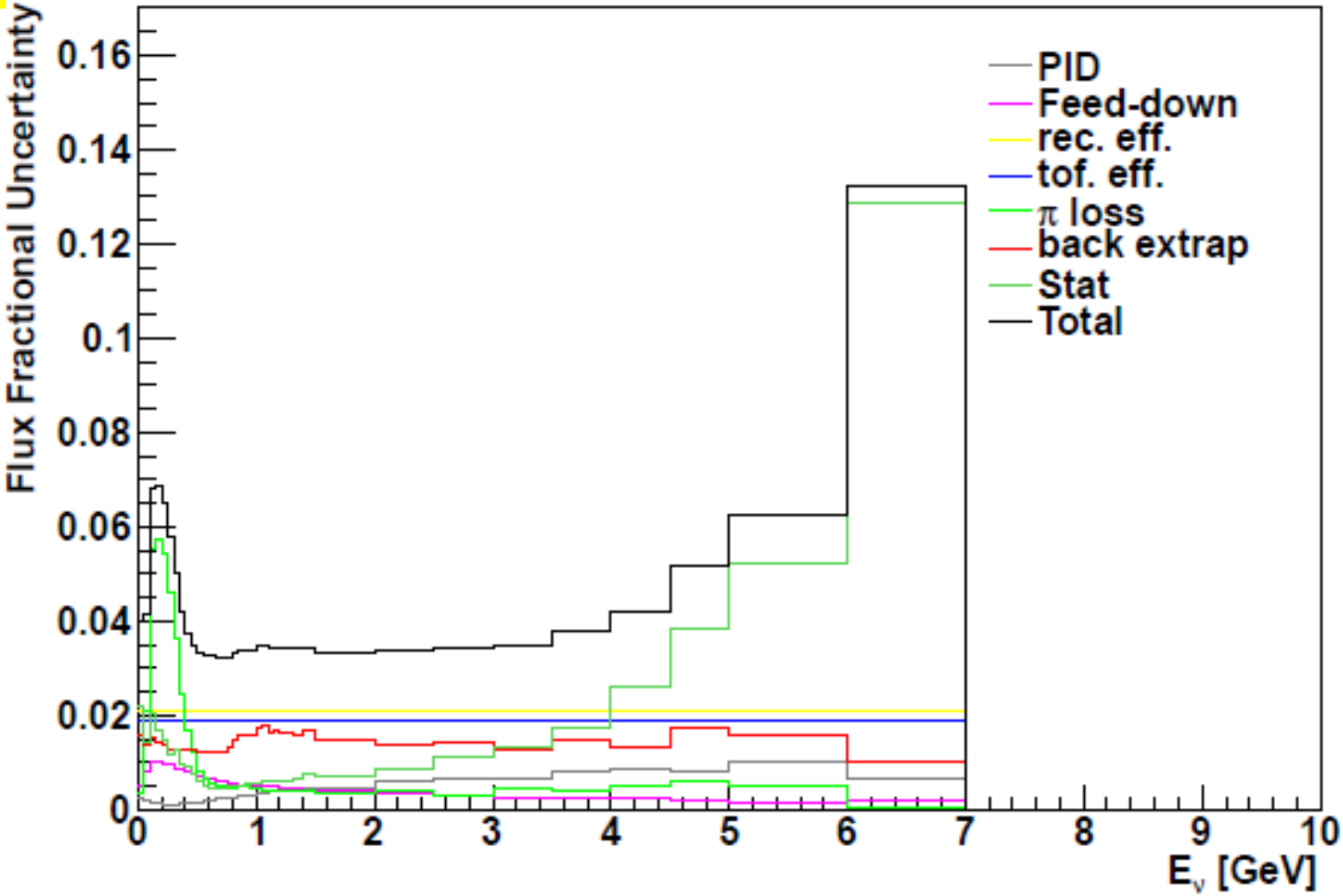


Figure 4.45: T2K replica target results for negatively charged pions with nominal FLUKA predictions (blue), FLUKA re-weighted for the multiplicities (green) and FLUKA re-weighted for multiplicities and production cross-section σ_{prod} for the three upstream longitudinal bins and in the polar angles between 80 and 220 mrad plotted as a function of momentum

Observe that even if FLUKA is reweighted to account for thin target measts a discrepancy is still observed in the early part of the target.

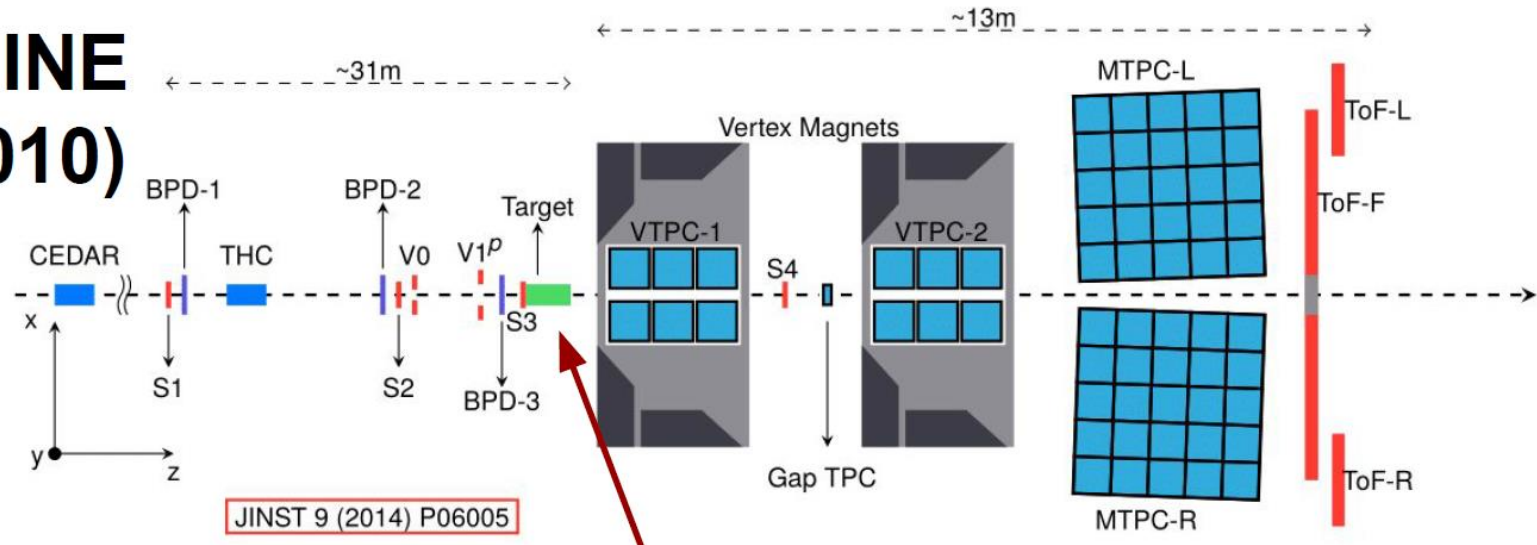
absorption length error? experimental error in early part of target?

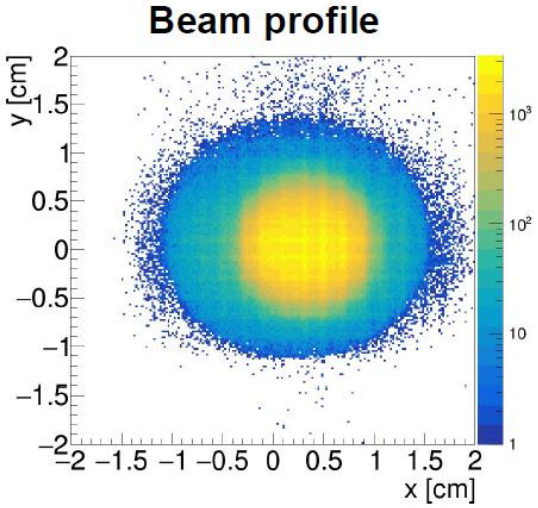
2009

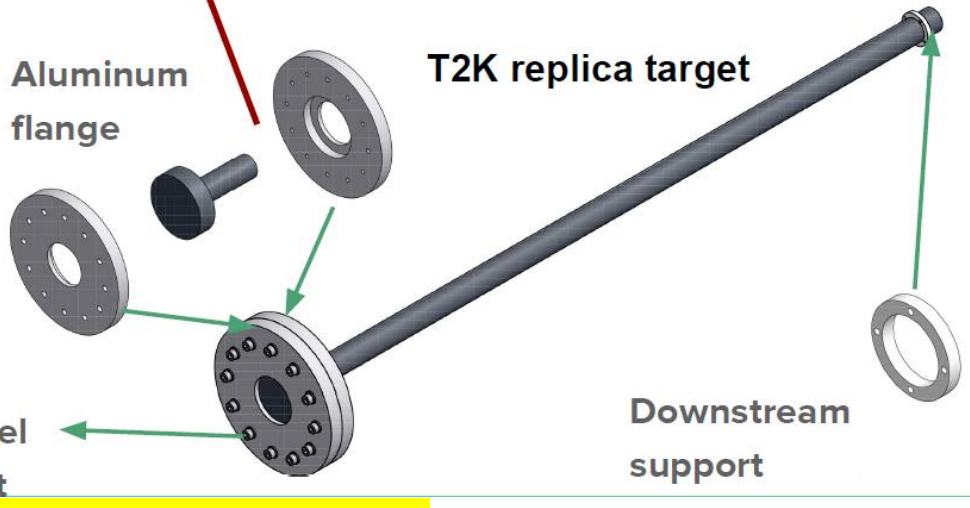


estimated errors from pion production (not the complete set of errors.

NA61/SHINE setup (2010)





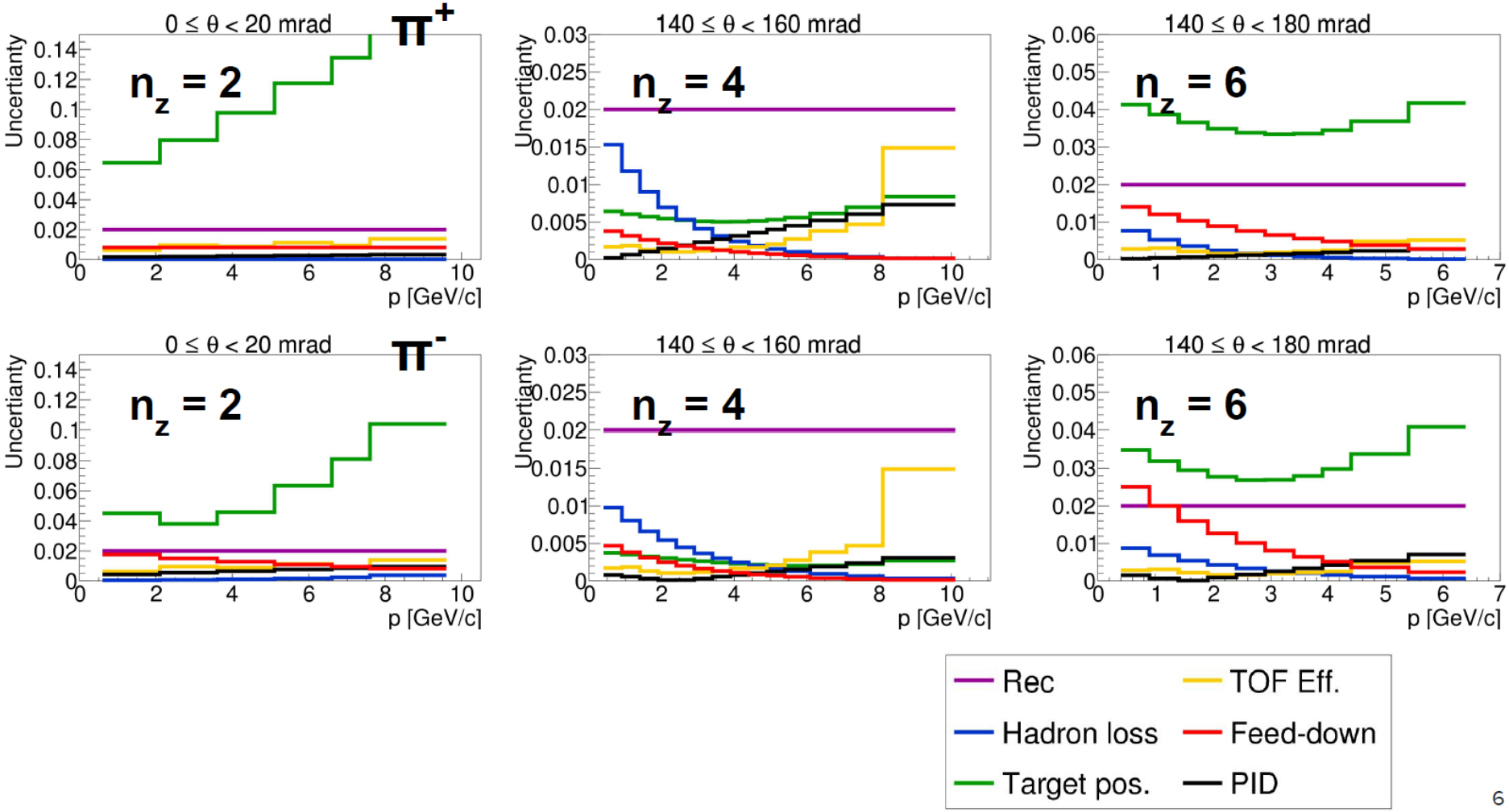


5 times more data in 2010
- four different simultaneous triggers
-- high field data
-- doing the kaons too.

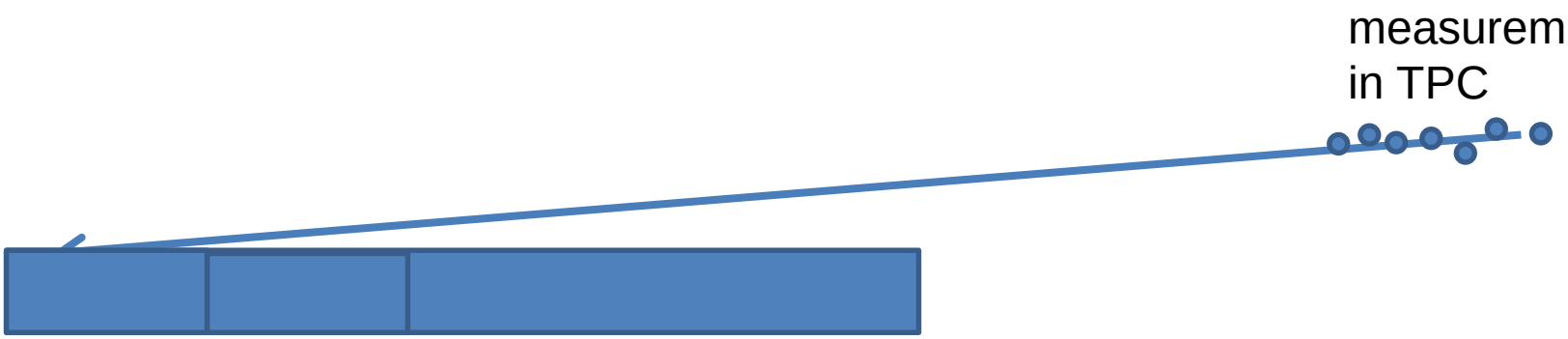
Systematic uncertainties

1. TOF efficiency
2. Hadron loss
   - Hadron loss should be only due to decays or re-interactions before FTOF
   - By selecting tracks with longer(shorter) segments in MTPC yields are expected to stay the same
   - Change in the cuts: no cut on points in MTPC or 50 points
3. Target position (extrapolation efficiency and bin migration)
   - How change of the target position changes the spectra
4. Feed-down
   - Contribution to the pions coming from the V0 decays and re-interactions in the detector (strongly model dependent) ➔taken as 30% of the correction
5. Reconstruction (assigned **2%**)
   - Track merging and fitting algorithms
6. PID
   - 1 Gaussian ➔ 2 Gaussians

Dominant (and curable)
-- backward extrapolation
-- reconstruction efficiency
-- PID, TOF efficiency etc…

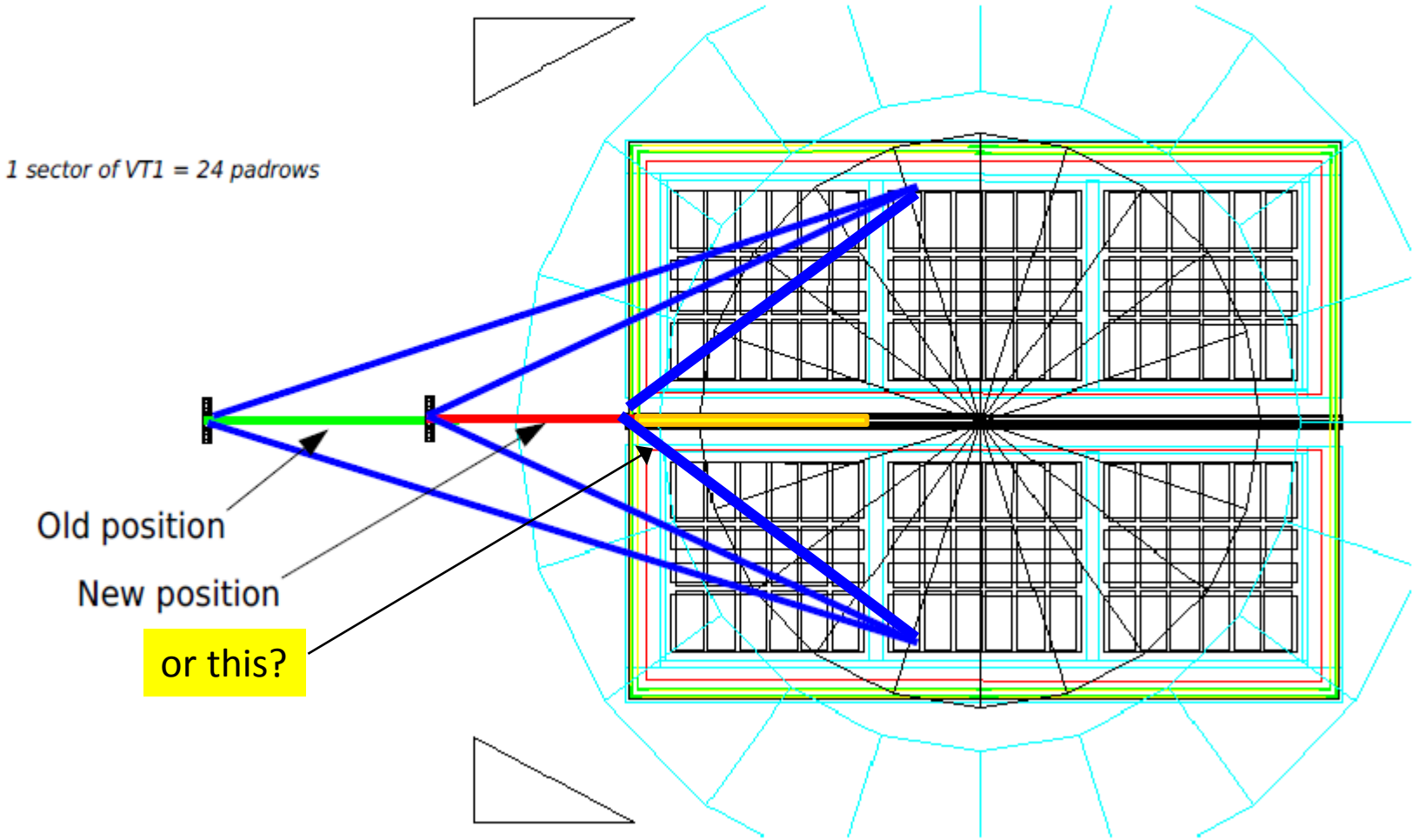

0 ≤ θ < 20 mrad
π+
n_z = 2
140 ≤ θ < 160 mrad
n_z = 4
140 ≤ θ < 180 mrad
n_z = 6
0 ≤ θ < 20 mrad
π-
n_z = 2
140 ≤ θ < 160 mrad
n_z = 4
140 ≤ θ < 180 mrad
n_z = 6
Uncertianty
p [GeV/c]
Rec
TOF Eff.
Hadron loss
Feed-down
Target pos.
PID

6



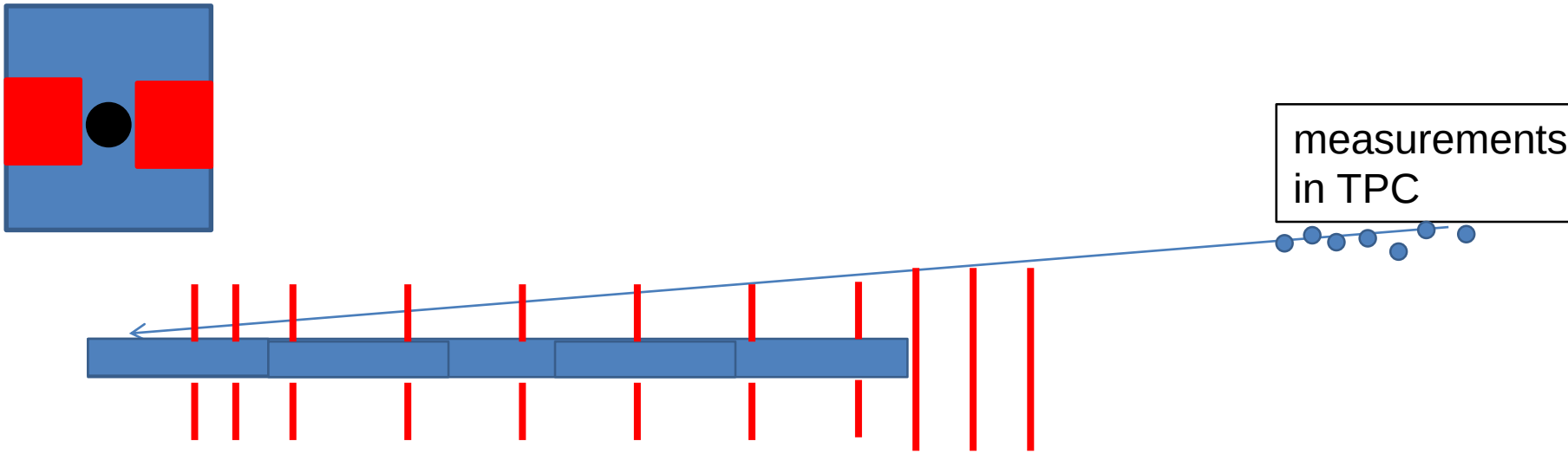
Uncertainty of backward extrapolated track on longitudinal intercept is amplified by $1/\theta$!
On first and last bin there is only migration from one neighbour→ asymmetric.
→ need measurement point closer to target

What if we move RT partially into VT1?



Cheap, but delicate. No need to build new detector,
→ but does not address very well the issue for low angle tracks.

Better: surround the target with a precise tacking device (assume pixel)



-- number of sensors should be optimized by simulation
-- transverse size do not need to exceed 5cm
-- Typical track should have 3-4 points.

-- Essential to have tracker downstream of target **with no hole !**
to ensure good extrapolation of low angle tracks.

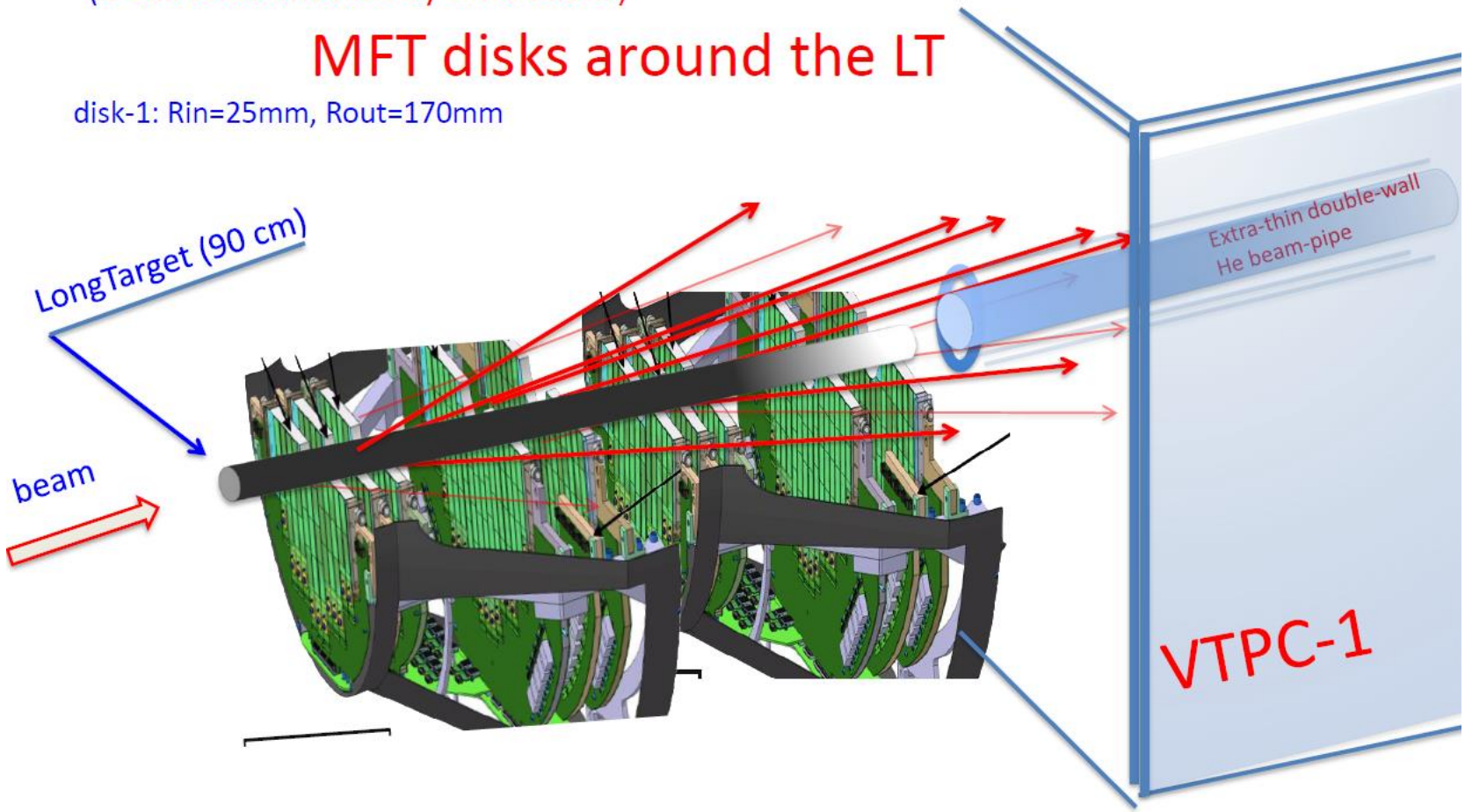
Vertexing for T2K LongTarget (LT) replica ?

Conceptual Option-1

(is still to be checked by simulations)

MFT disks around the LT

disk-1: Rin=25mm, Rout=170mm



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yes, but need detectors on x-z plane + downstream of target.

We know that replica target are essential but we have seen limitations in the long target measurement of 2009 and 2010

-- backward extrapolation delicate

-- some ***lack of confidence*** on observation of the particle production on early part of target. ***Cross-section issue or extrapolation issue?***

-- best is to surround the long target with appropriate pixel devices

-- knowledge of material around beginning of target → **need to do empty target data**.

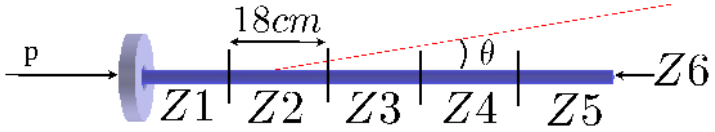
-- the error due to reconstruction efficiency should be fixed

-- not clear what the angular or momentum or particle type dependencies are

-- too large for a TPC based detector with > 70 points per track

-- need a campaign of dedicated data with empty target and various momenta to measure reconstruction efficiency

-- may also think of replacing GAP TPC with a more stable and fast device. (drift chambers, MWPC's?)



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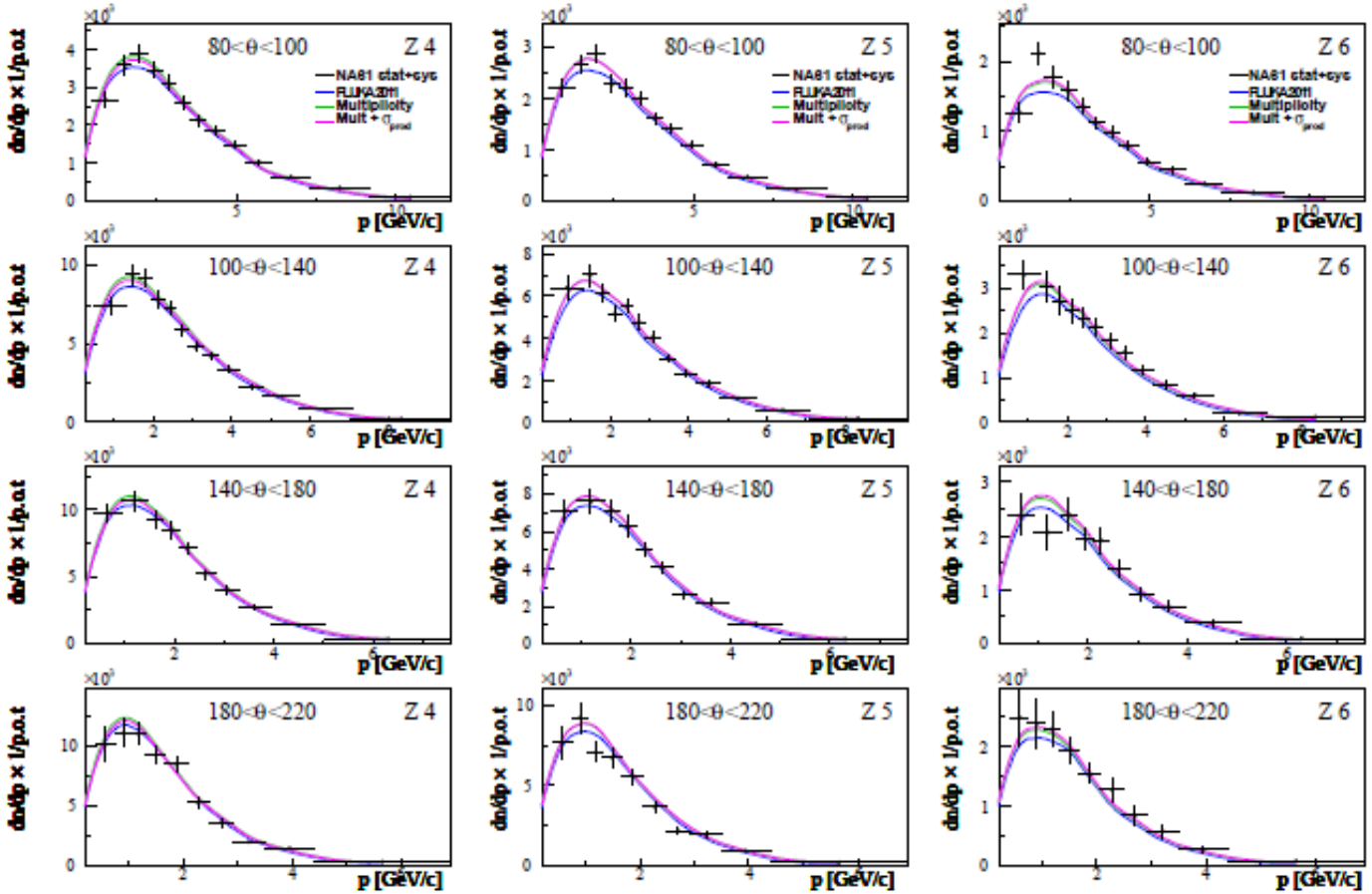

Figure 4.48: T2K replica target results for negatively charged pions with nominal FLUKA predictions (blue), FLUKA re-weighted for the multiplicities (green) and FLUKA re-weighted for multiplicities and production cross-section σ_{prod} for the three downstream longitudinal bins and in the polar angles between 80 and 220 mrad plotted as a function of momentum

Conclusions

With the advent of the giant neutrino experiments DUNE and HYPERK, NA61 data will become more and more important.

We must be even more confident in the quality of our data and of the systematics. For this, design the data taking and analysis even more carefully.

Simulation but also careful and critical thinking is needed.

For the long target several sources of uncertainties have been identified that can be improved

-- additional tracking to improve extrapolation from spectrometer to target
sci-fi and or sci-pix

-- empty target data with various momenta and mag field to establish reconstruction efficiency.

-- increase statistics (e.g. target position can be refined from data themselves).

we should now design the next generation data taking for neutrinos in NA61,
so that they are available for T2K flux before 2020.