New Forward ToF For NA61: From construction to Simulation

- T2K experiment:
  - Overview of T2K physics
  - From T2K requirements to NA61 measurements
- NA61 ToF acceptance study
- Forward ToF construction
- First look at 2007 run data (S. Murphy)
- Overview of NA61 simulation chain

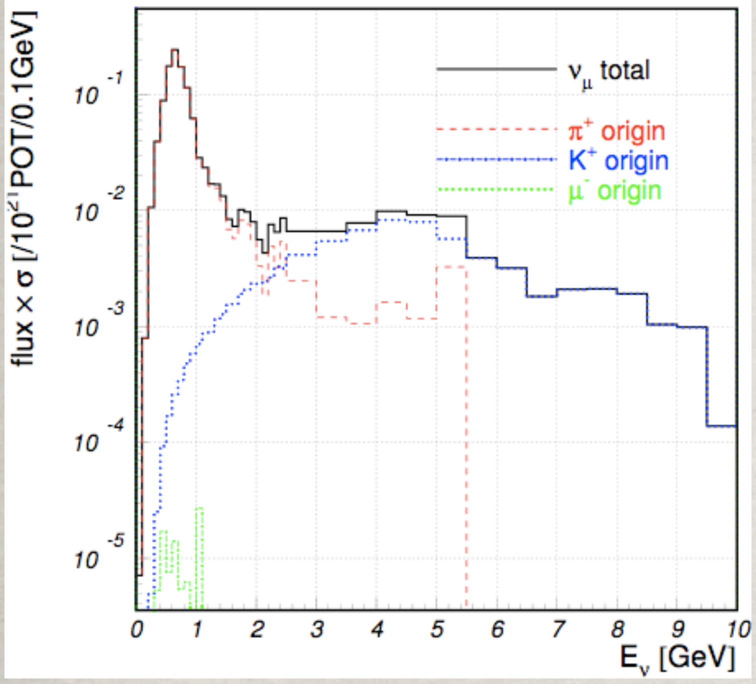
T2K Physics

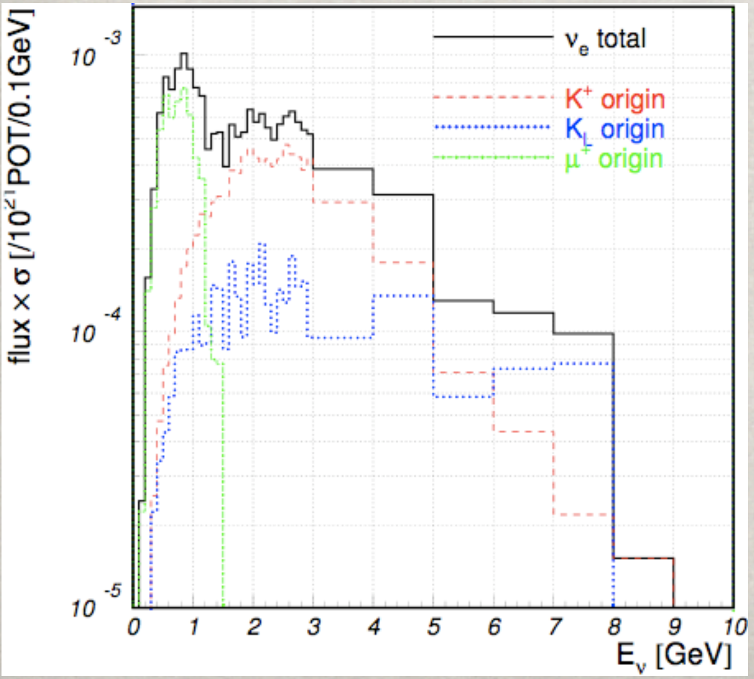
- Neutrino oscillations are probed by comparing observations at the far detector (SK) with predictions w/ or w/o oscillations
- Observables at SK depend on the neutrino fluxes at the near detector (ND, nd280).
- Fluxes at SK are predicted via the Far/Near Ratio (R) method:

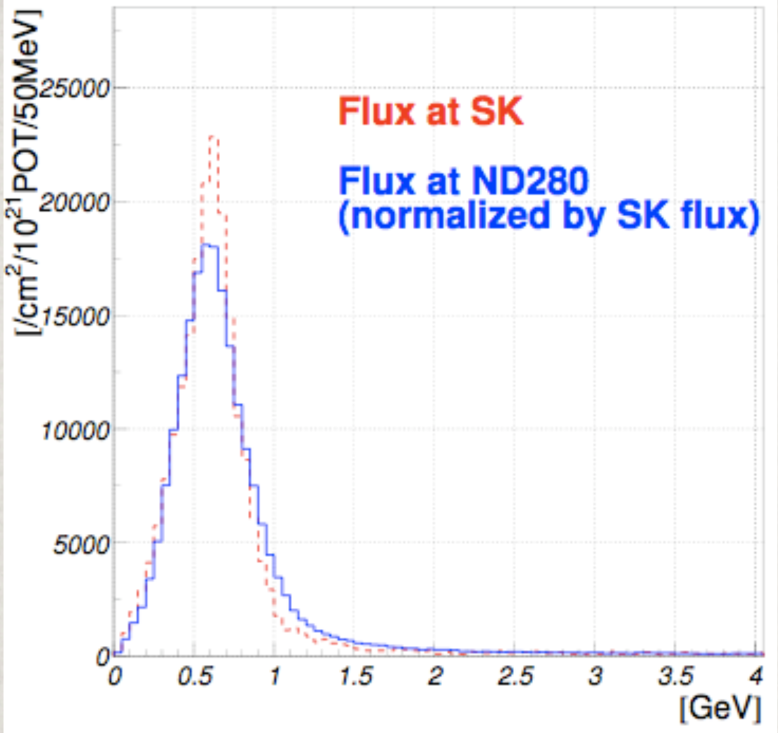
$$\Phi^{SK}_{\mu,e}(E_\nu) = R_{\mu,e}(E_\nu) \times \Phi^{ND}_{\mu,e}(E_\nu)$$

- For a point-like source, R is given by the solid angles ratio and is not energy dependent. In reality, due to the finite size of the source, R is strongly energy dependent and is determined by:
  - the relative rate(p) of pions, kaons and muons at production
  - the geometry of the source
- A detailed information on the hadroproduction off the T2K target is therefore highly needed.

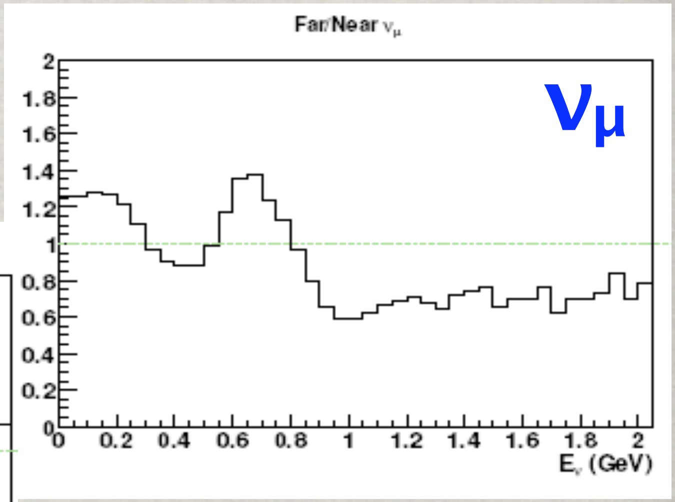
Parent contribution to neutrino fluxes

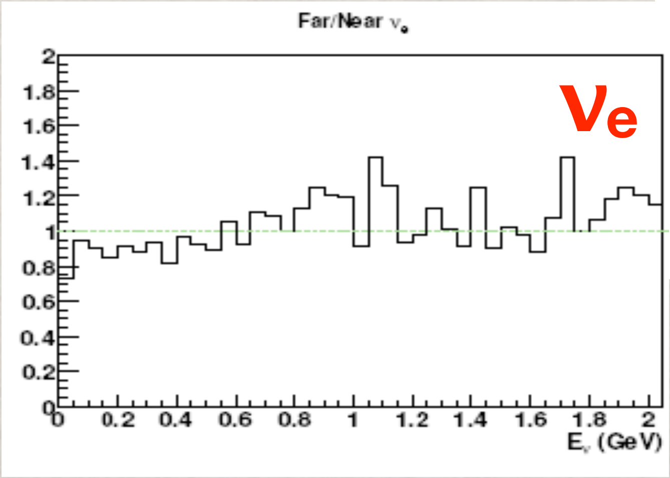






Different solid angles and finite size of the source lead to complicated far/near ratios.





T2K Physics

- Appearance channel: T2K phase I: $\nu_\mu \rightarrow \nu_e$ oscillations down to **$\sin^2 2\theta_{13} \sim 0.008$ (90%CL)** (current bound **$\sin^2 2\theta_{13} < 0.14$ (90%CL)** from global data).

- To achieve this goal the systematic error on the prediction of background events has to be less than 10%. But background for a given process is predicted as well via the F/N ratio:

  N_bkgd = R × ND meas. × cross-section × efficiency

- Thus, the error on the F/N ratio prediction contributes to the total syst. error on the background. The aim is to bring this contribution to a negligible level compared to the others.

- Disappearance channel: **$\delta(\sin^2 2\theta_{23}) \approx 0.01$ and $\delta(\Delta m^2_{23}) \approx 3 \times 10^{-5}$ eV^2** with T2K nominal stat. power (current bounds from global fit **$\delta(\sin^2 2\theta_{23}) \approx 0.04$ and $\delta(\Delta m^2_{23}) \approx 2 - 3 \times 10^{-4}$ eV^2**).

- MC studies converged to **$\delta(R) \approx 2 - 3\%$** for the precision of the F/N ratio prediction, for both electron neutrino appearance and muon neutrino disappearance channels.

NA61 Measurements

- W/o any measurements of hadroproduction, the F/N ratio error can roughly be taken as the difference between ratios obtained with different hadronization models at the peak energy, that is about 20%.

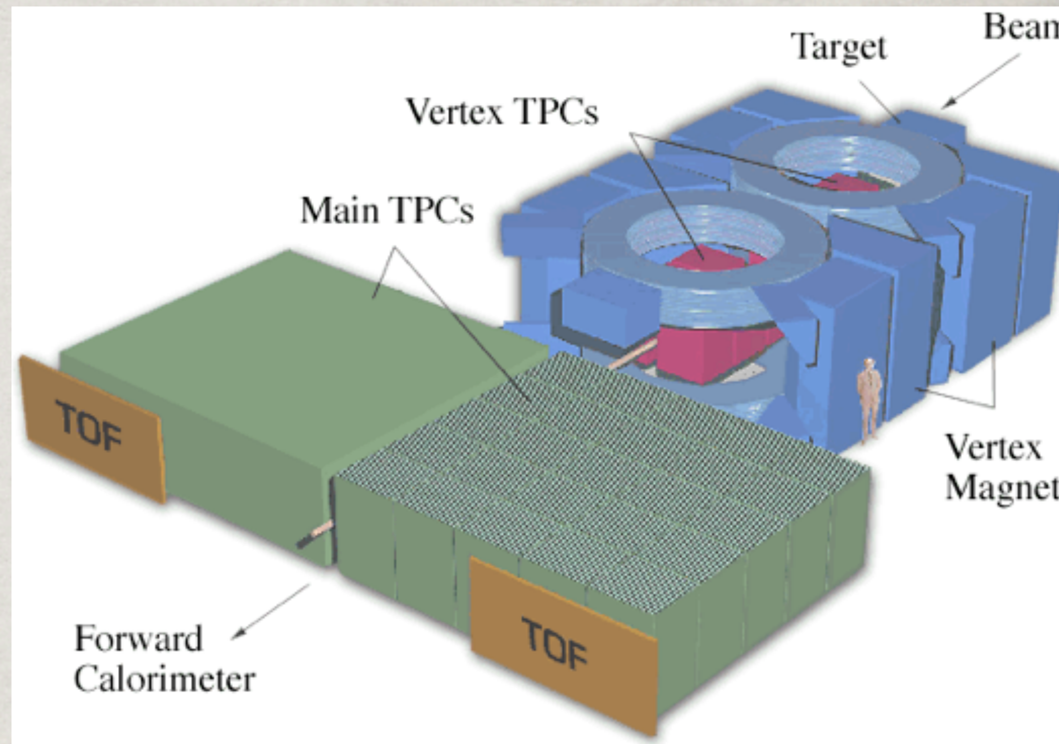
- This would lead to:
δ(bkgd) ≈ 10-20% (0-1 GeV), $\delta(\sin^2 2\theta_{23}) \approx \pm 0.03$, $\delta(\Delta m^2_{23}) \approx \pm 10 \times 10^{-5}$ eV^2
compared to the 2-3% case:
δ(bkgd) ≈ 2% (0-1 GeV), $\delta(\sin^2 2\theta_{23}) \approx \pm 0.005$, $\delta(\Delta m^2_{23}) \approx \pm 1.5 \times 10^{-5}$ eV^2

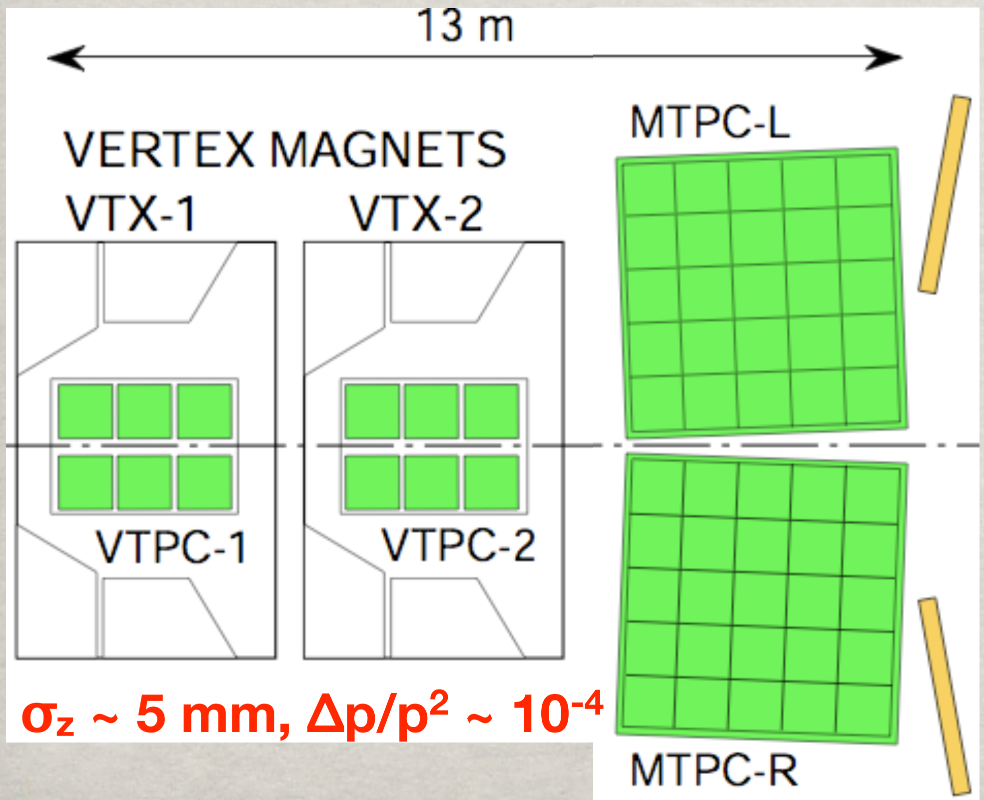
- To achieve a precision of 2-3% on R, MC studies showed that:
  - 10% accuracy on hadroprod. meas. in each p-θ bin is enough (that is about 200k tracks over T2K phase space)
  - same accuracy yields to errors <2% on the prediction of the neutrino energy spectrum at the near detector
  - 10% accuracy on the K/π ratio measurement is enough

NA61 Setup based on NA49 facilities

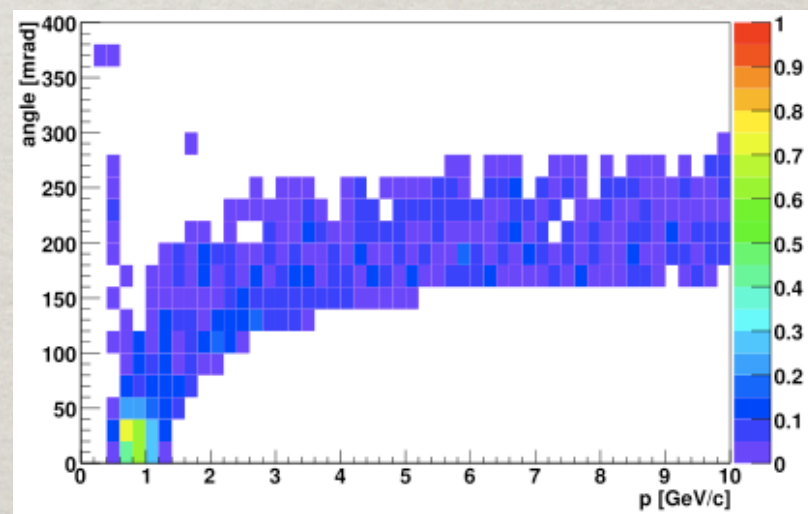
Particle identification:

- highly segmented TOF walls up to p < 4 GeV/c
- dEdx in TPCs + TOF above 4 GeV/c



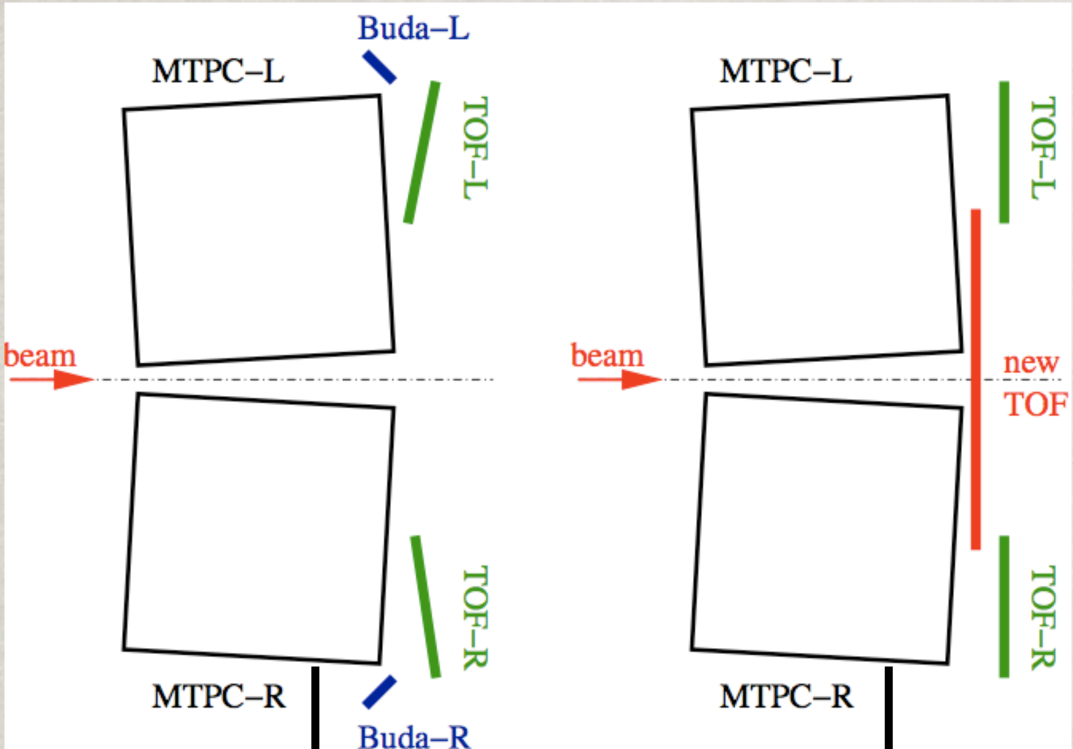


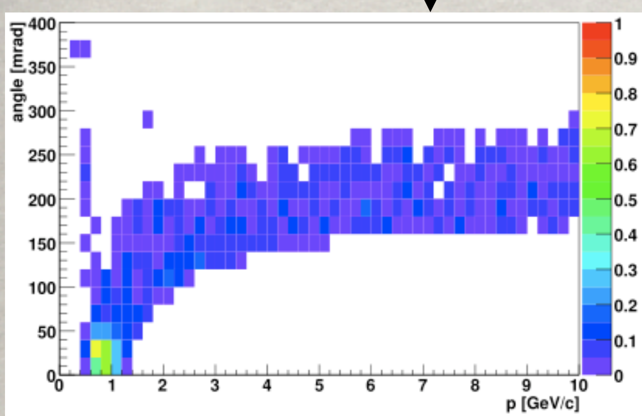
$\sigma_z \sim 5$ mm, $\Delta p/p^2 \sim 10^{-4}$



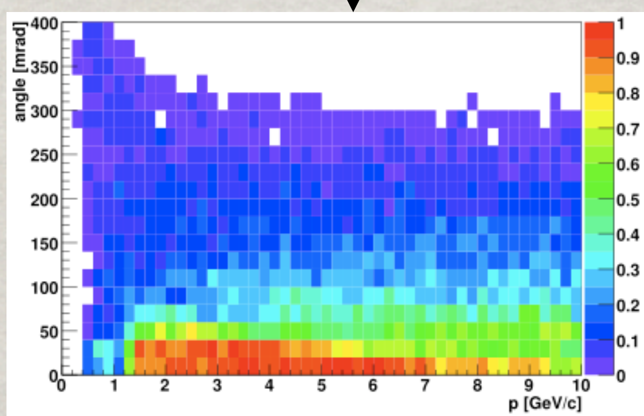
TOF acceptance w/ NA49 setup

NA61 Acceptance

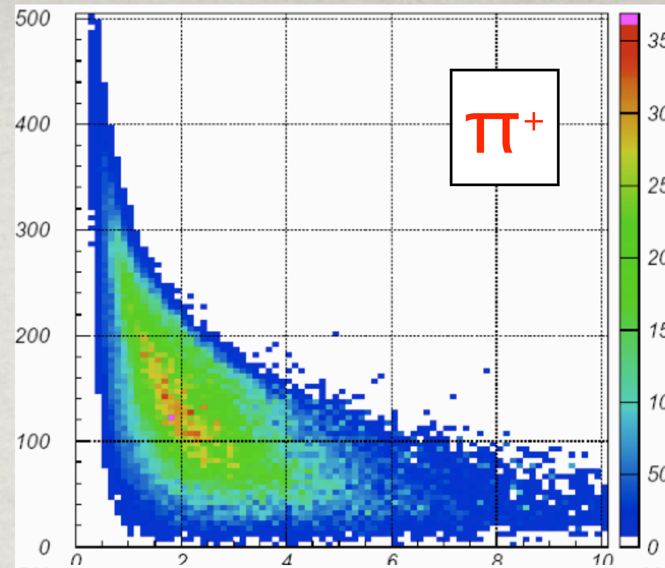


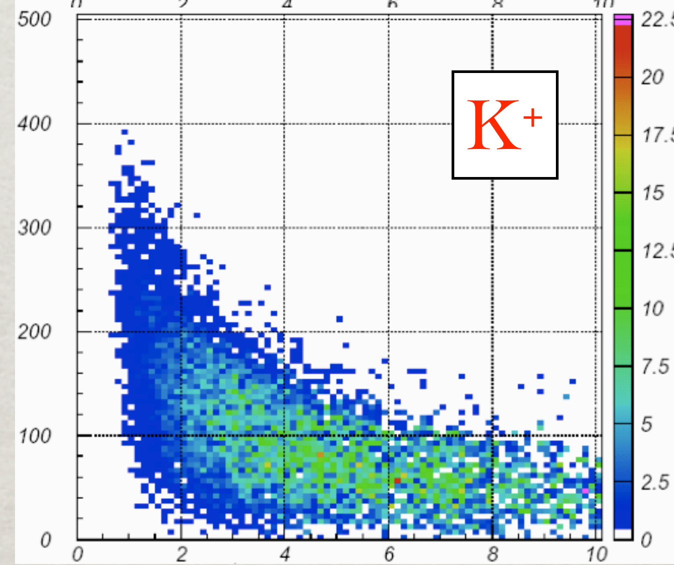


NA49



NA61





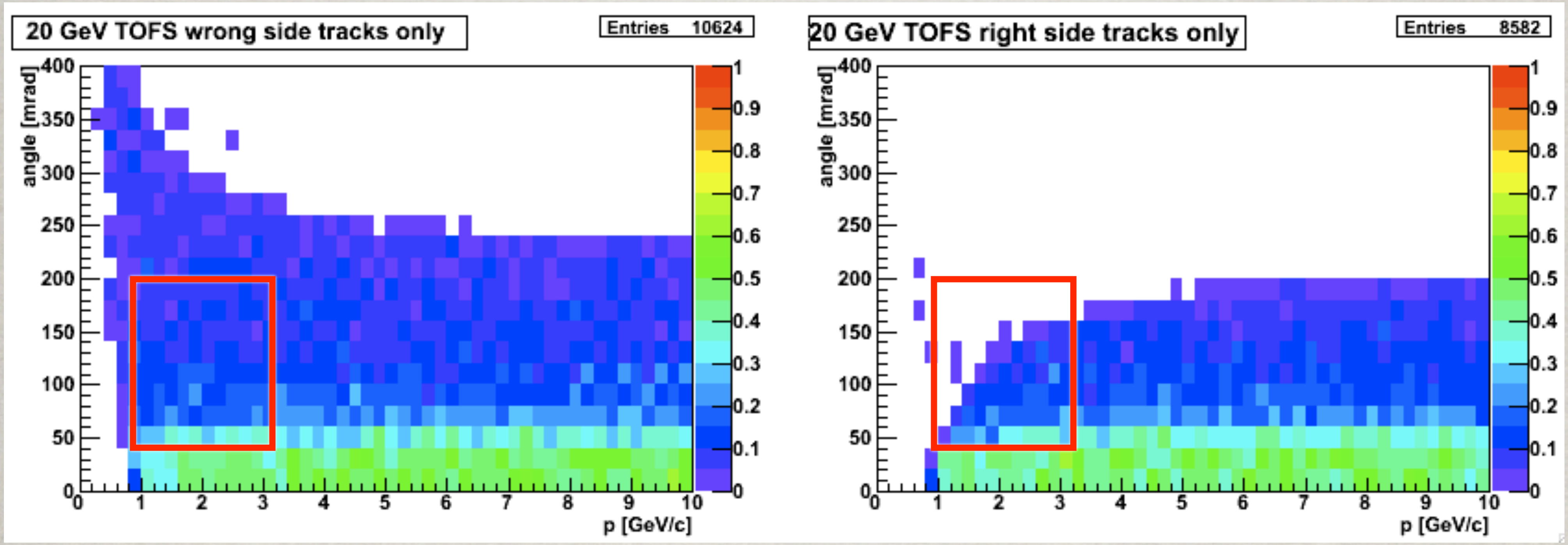
Pions mainly peaked in the low mom. low angle region:

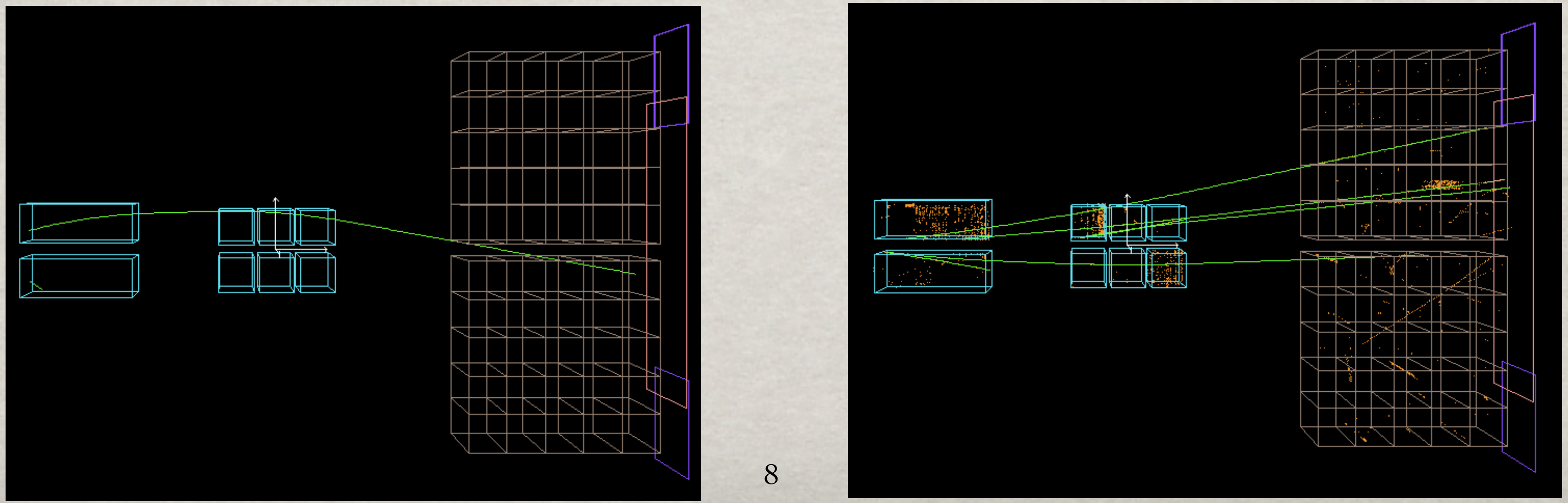
$1 < p < 3$ GeV/c

$50 < \theta < 200$ mrad

NA61 Acceptance

- Wrong side tracks refer to tracks with a product (P_x × charge) of negative sign. Those tracks are really important to cover plainly the relevant phase space for T2K physics:



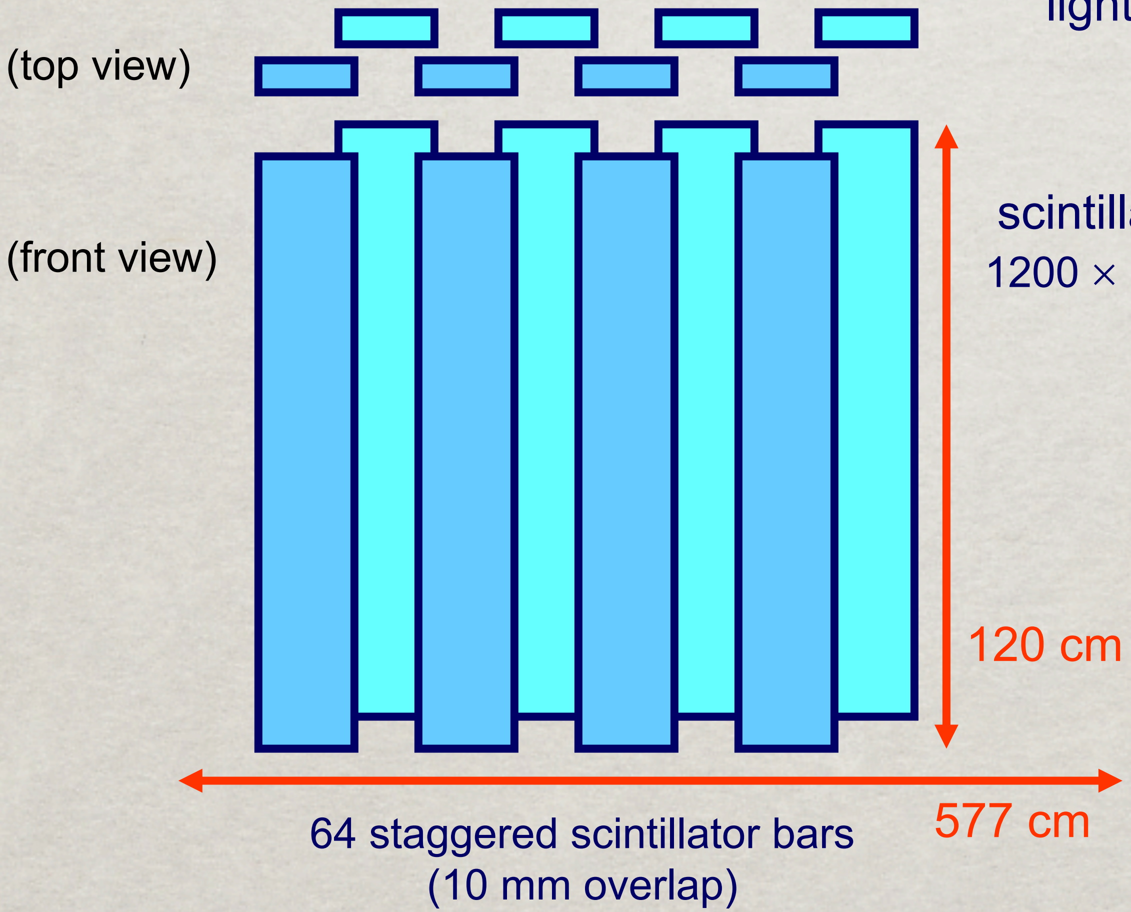


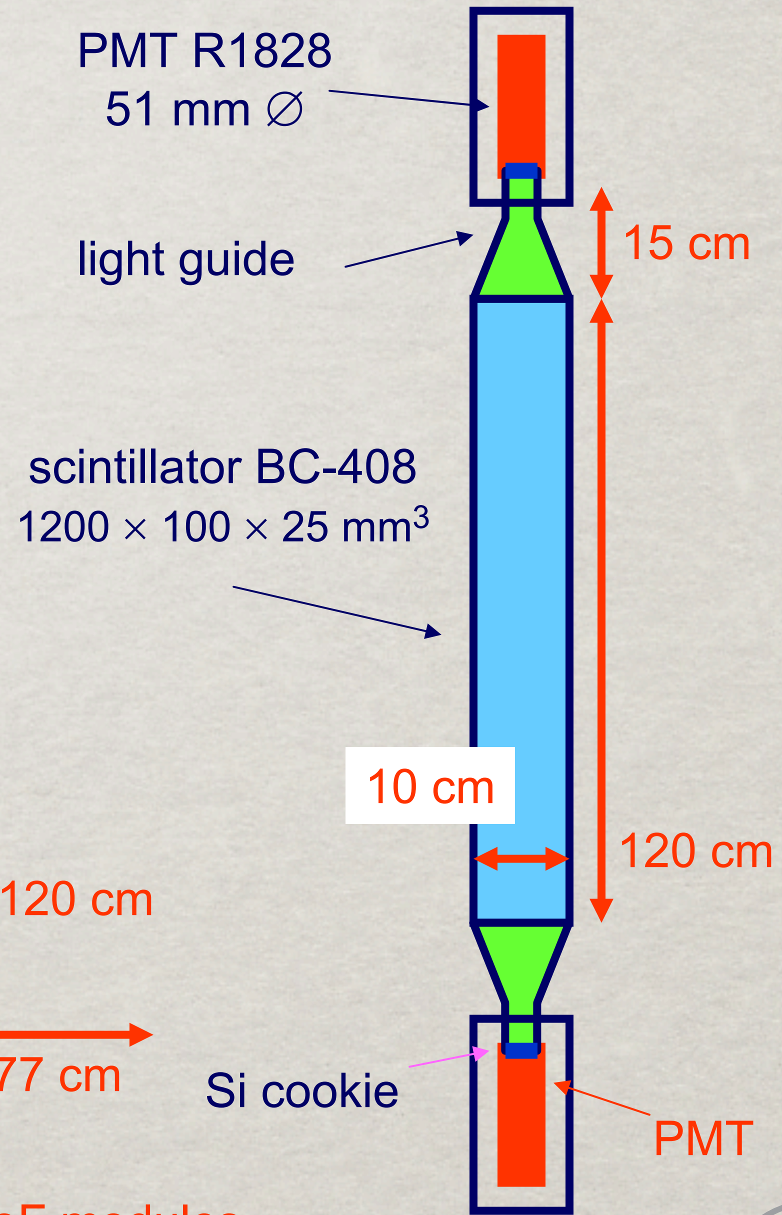
ToF-F Construction

Genava-Bern-Warsaw

total area 577 × 120 cm^2

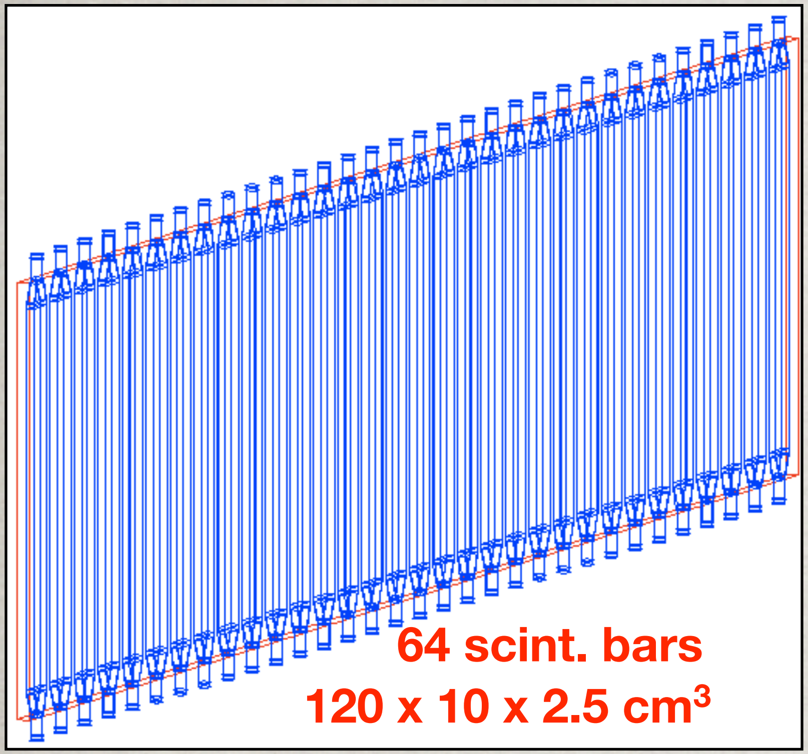
64 scintillator bars readout on both sides
128 readout channels

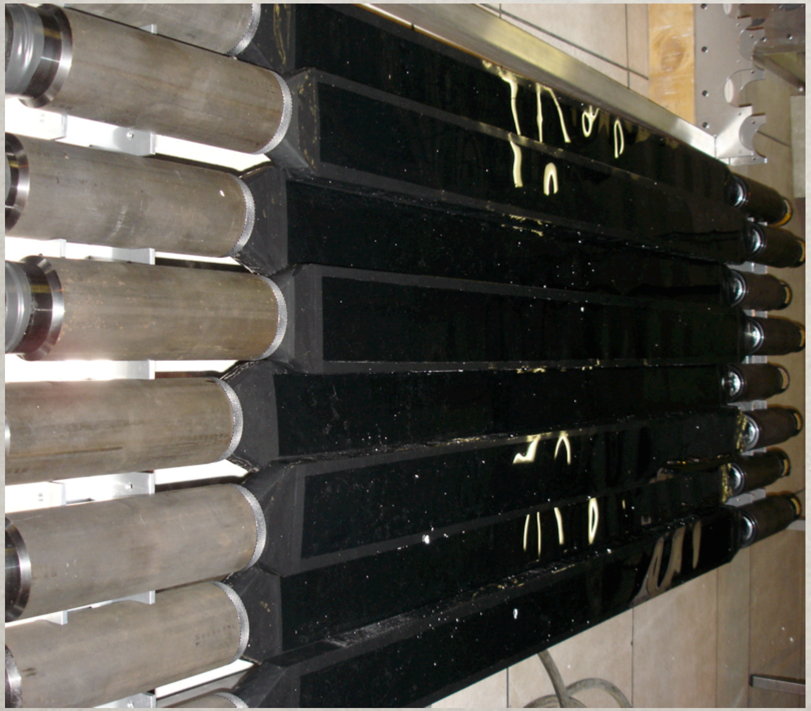




8 scintillators mounted on a single frame → 8 ToF modules

ToF-F Construction

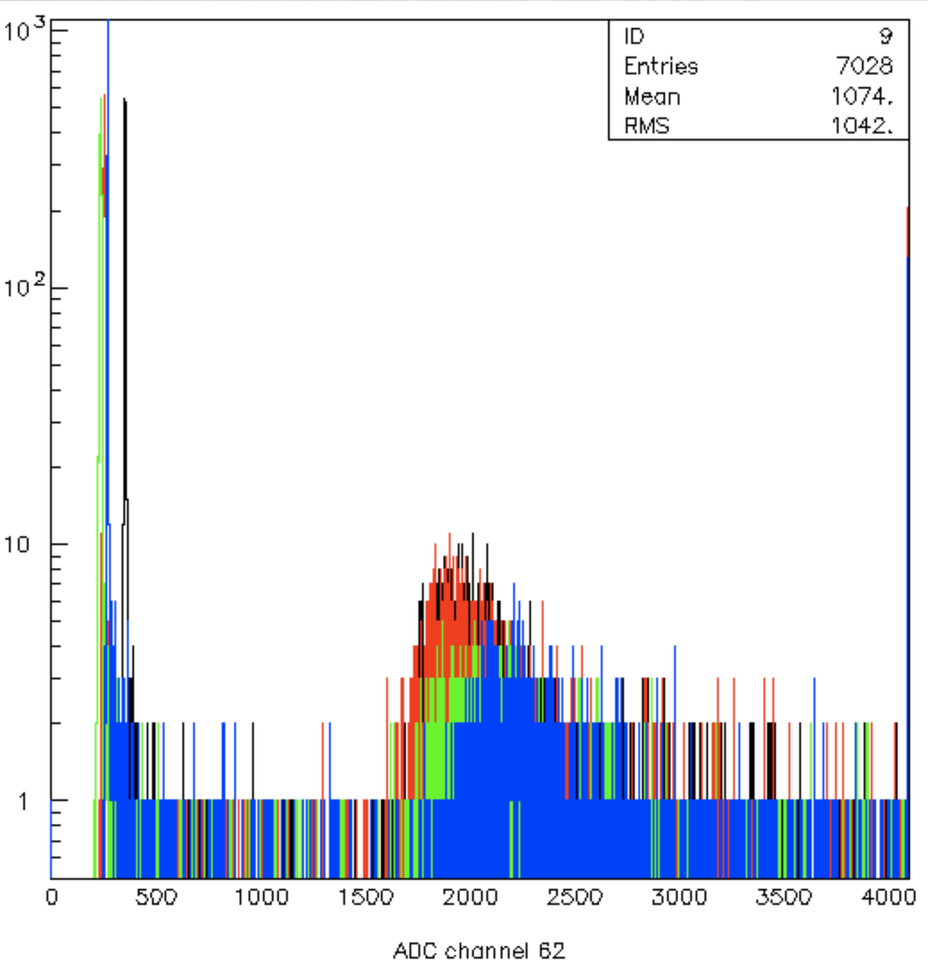


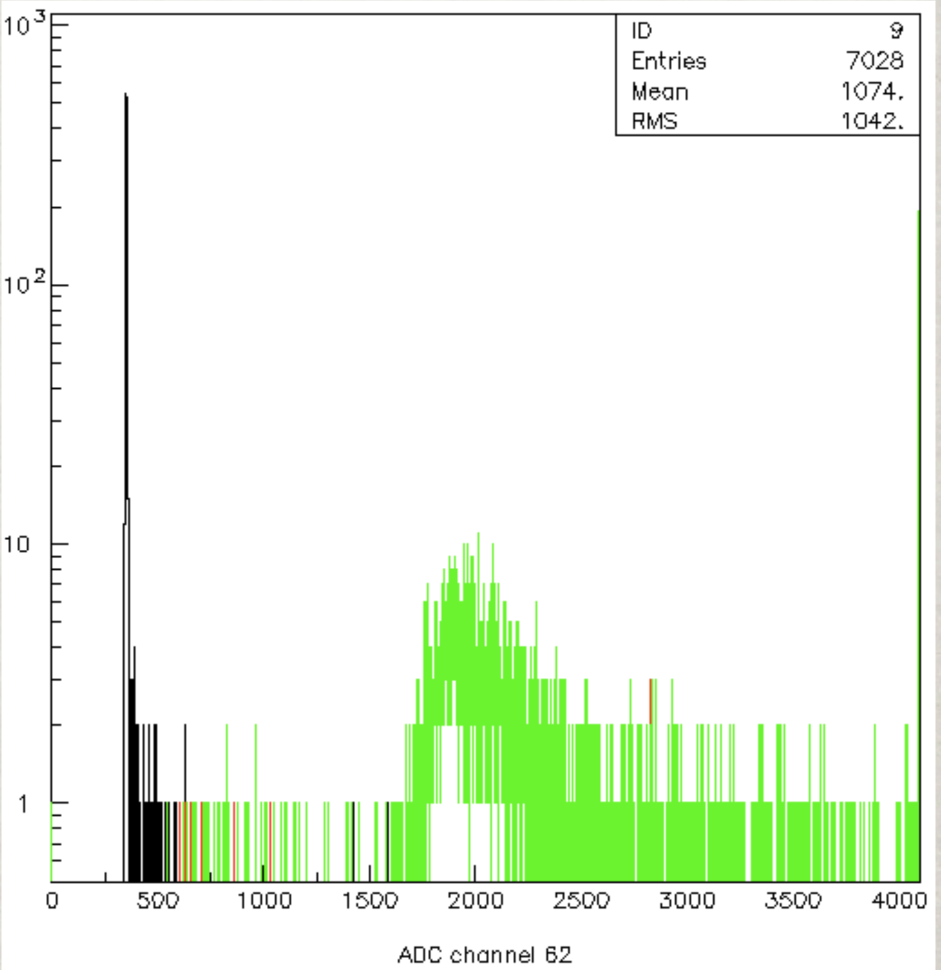


Many thanks to our russian colleagues !

2007 RUN DATA

- Raw data



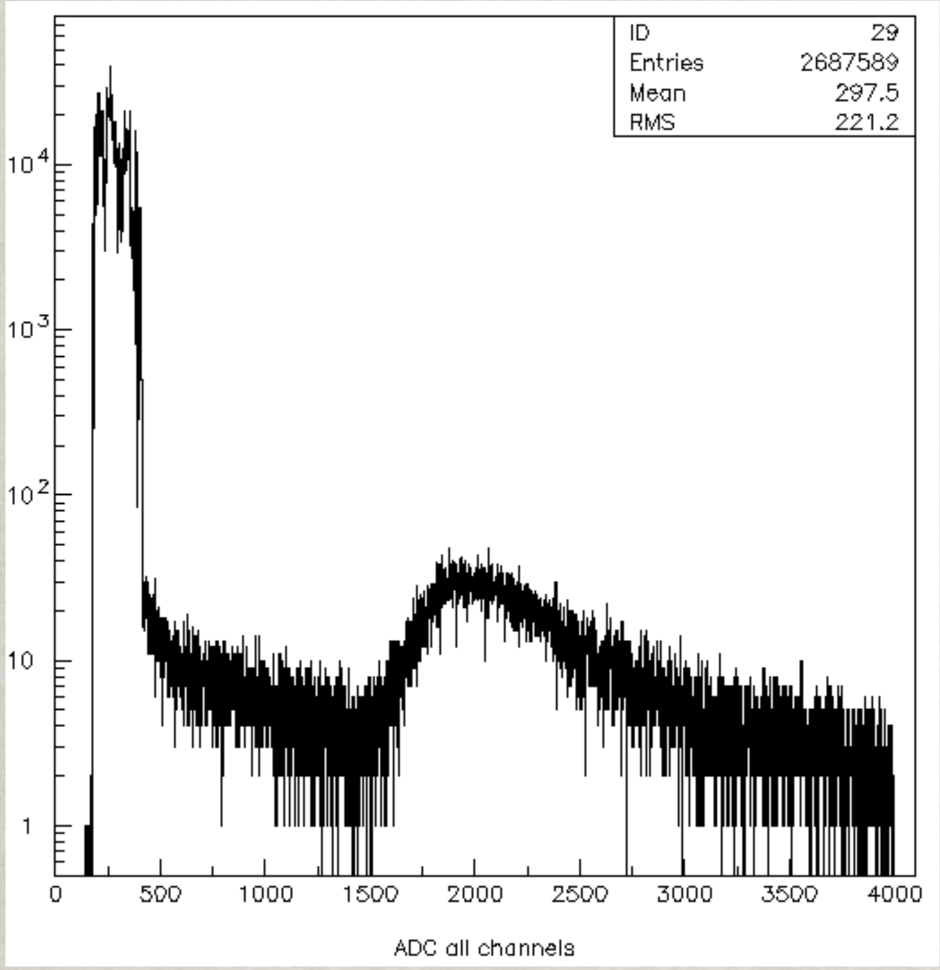


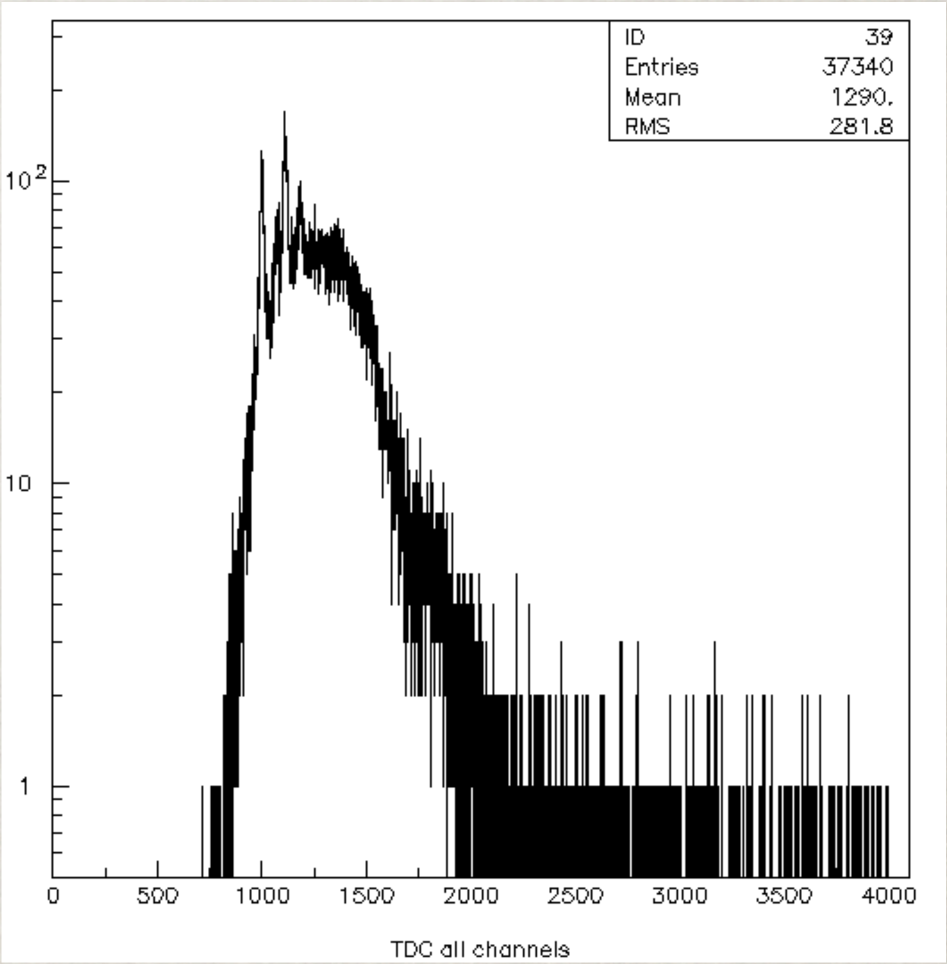
channel 61
channel 62
channel 63
channel 64

single TDC cut
double TDC cut

2007 RUN DATA

- Raw data



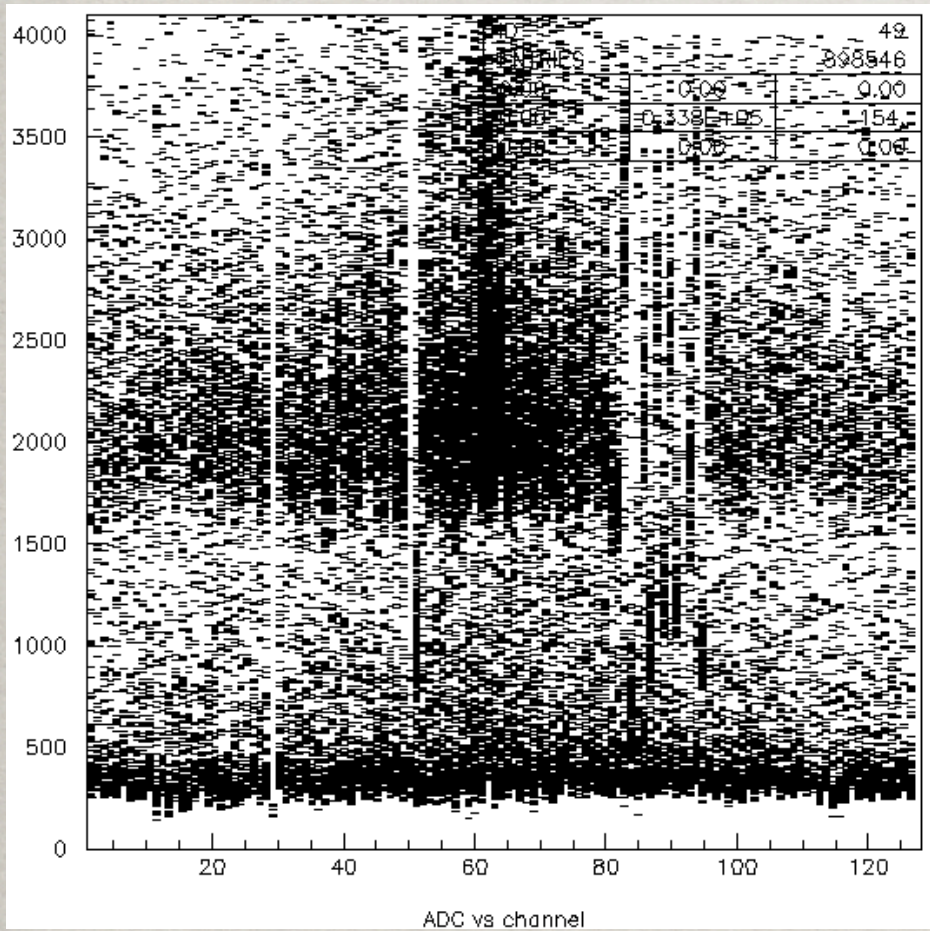


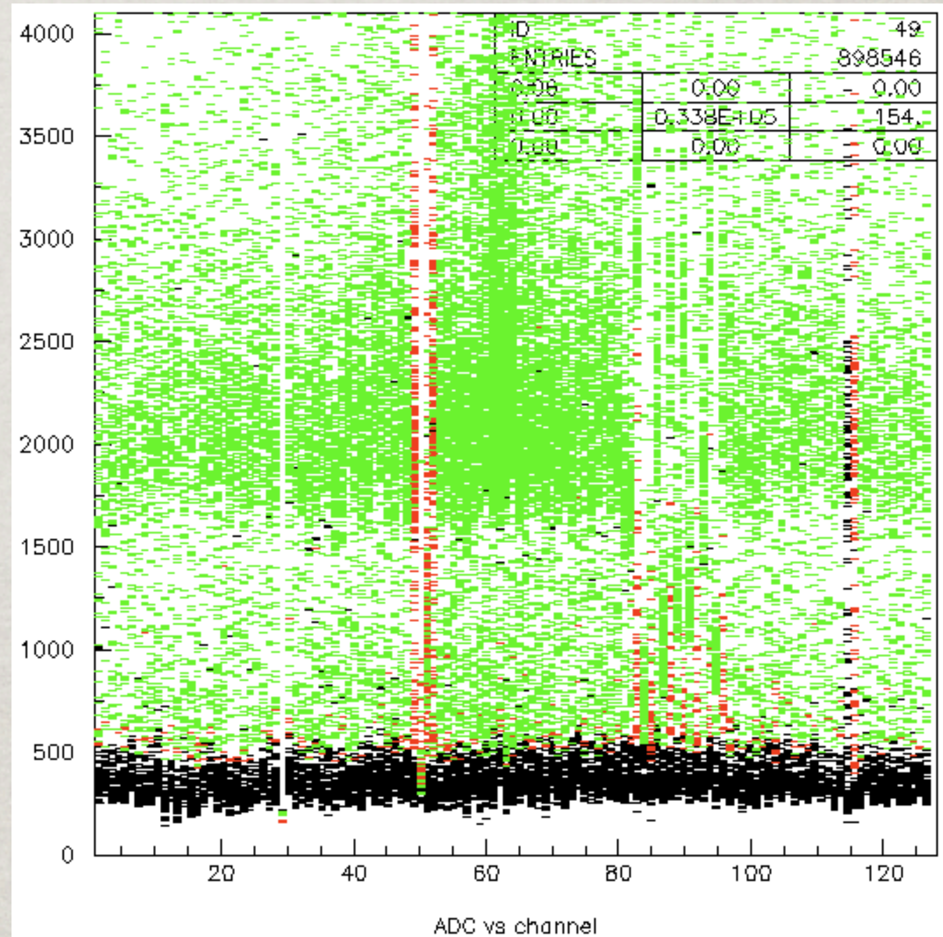
ADC distribution all channels

TDC distribution all channels

2007 RUN DATA

- Raw data

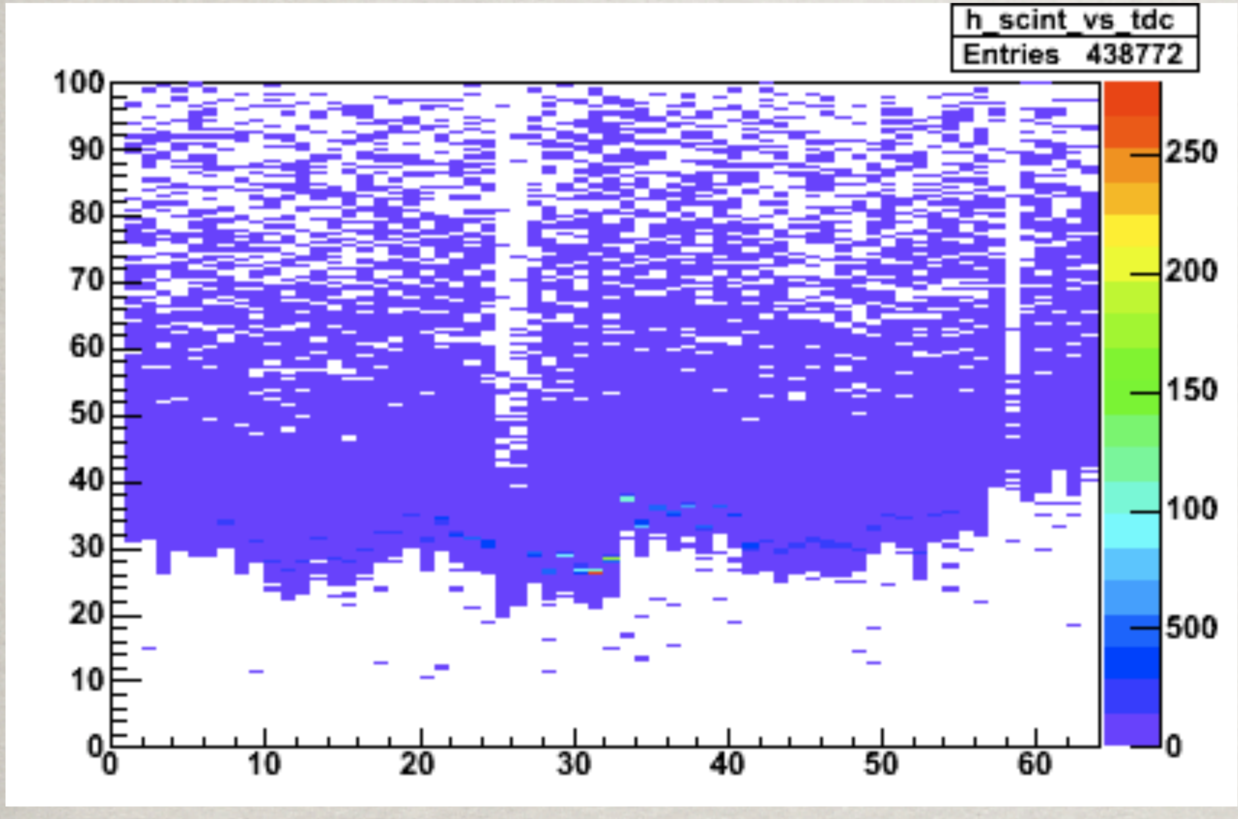




ADC distribution vs channel

2007 RUN DATA

- Raw data

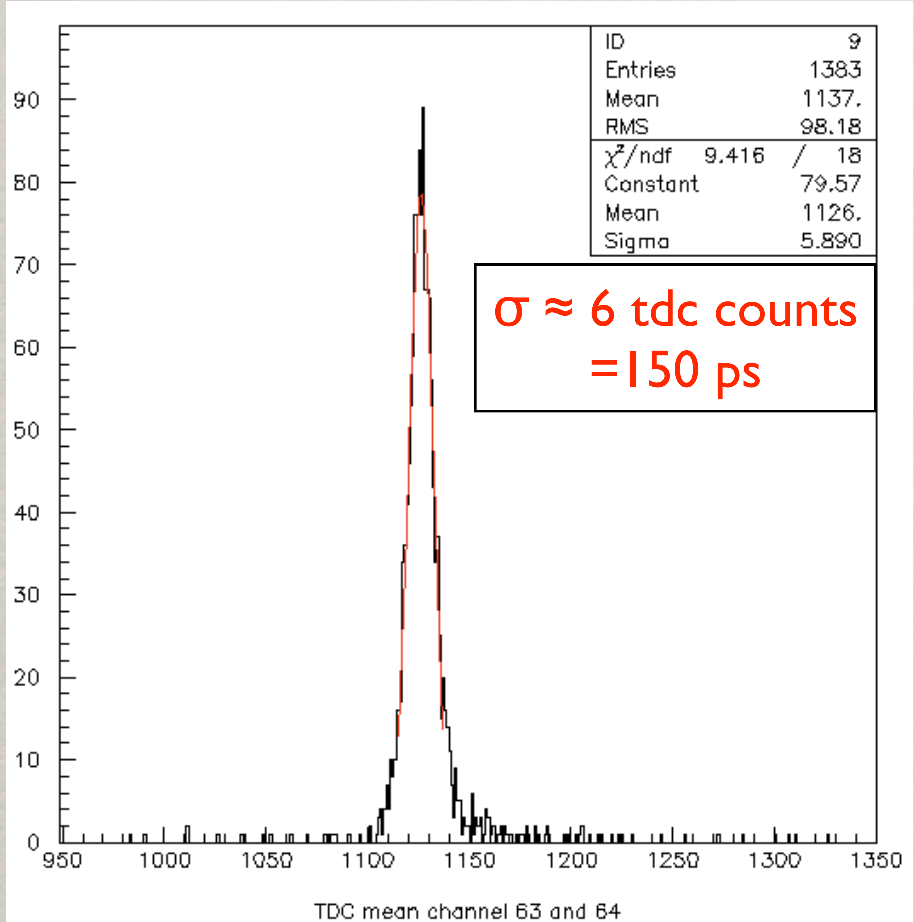


TDC distribution
vs channel

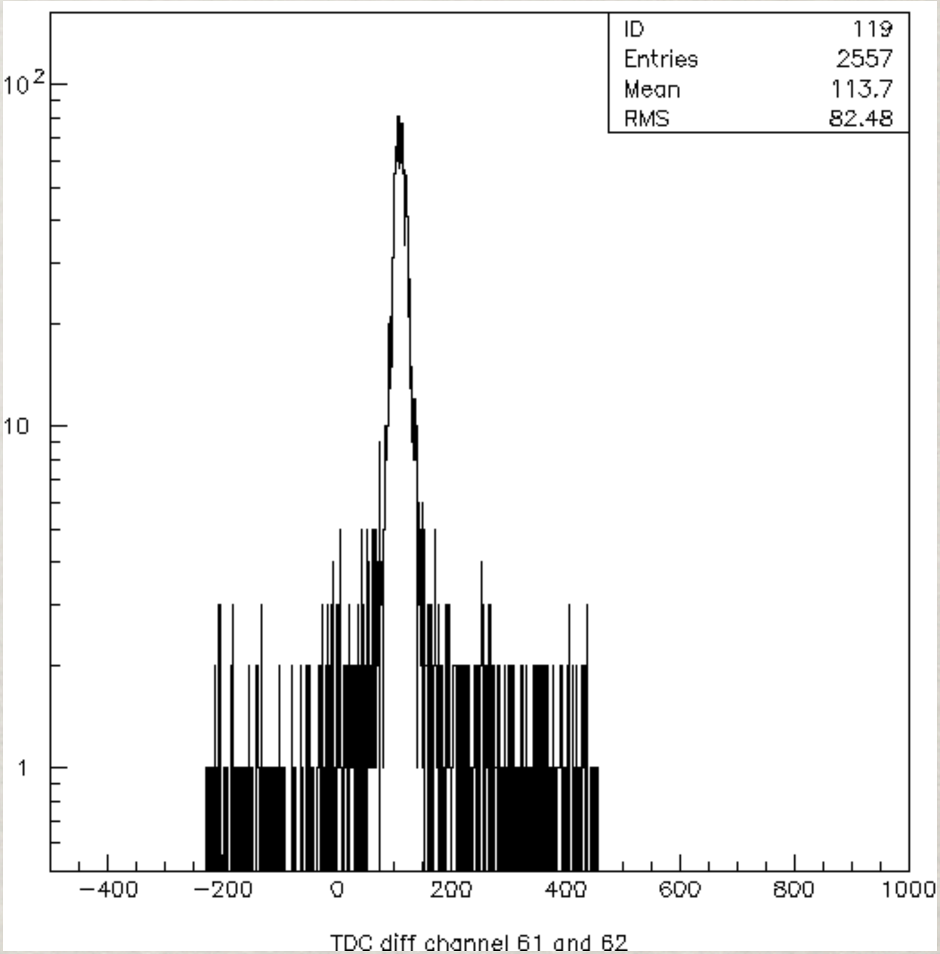
Time shift spreading is quite large even inside a single module.
Need for channel by channel corrections.

2007 RUN DATA

- Raw data



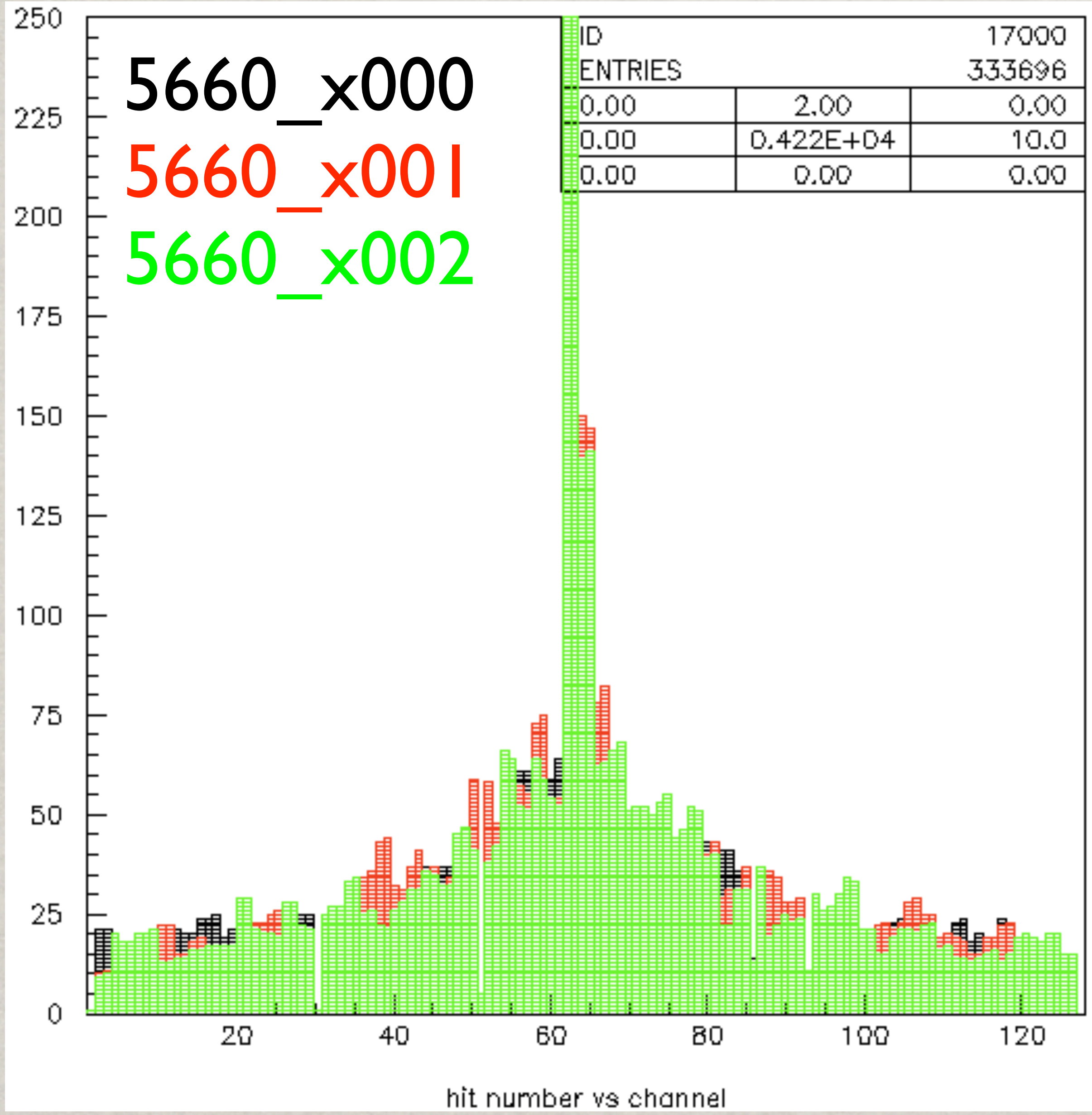
TDC mean
for a single scintillator



TDC difference
for a single scintillator

2007 RUN DATA

- Raw data

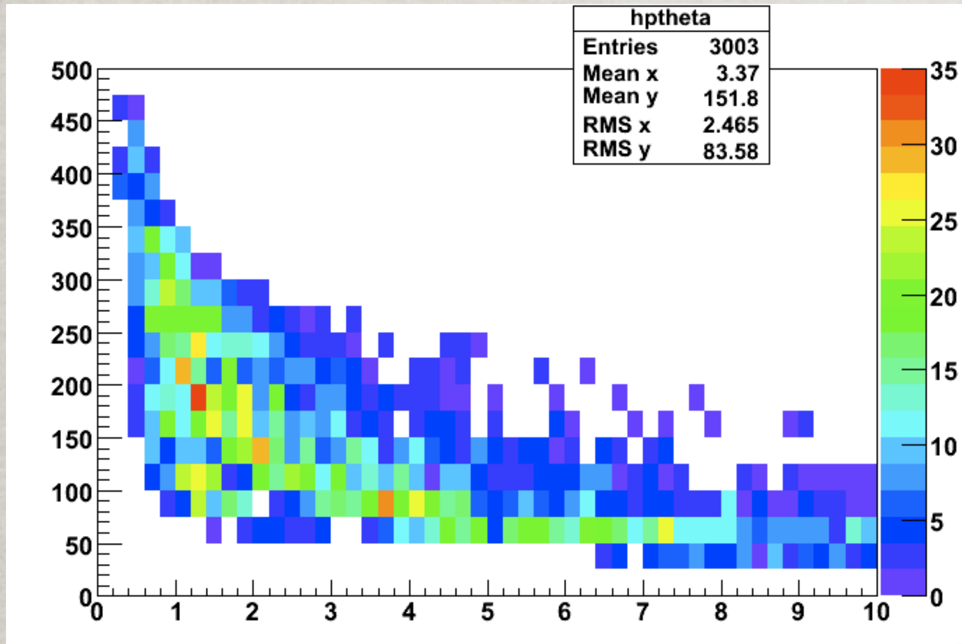


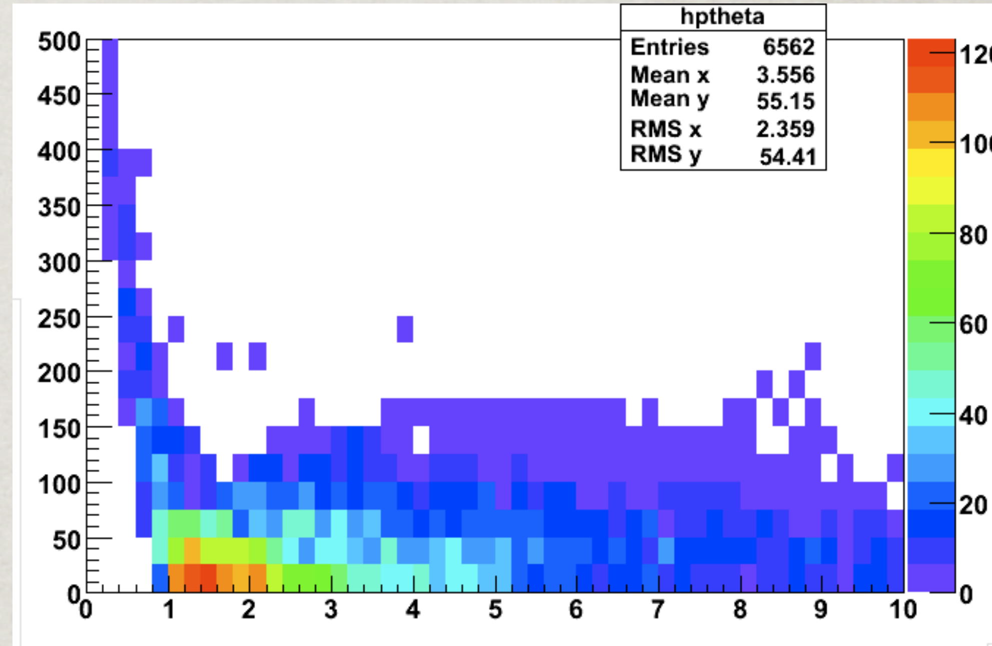
Number of hits per channel

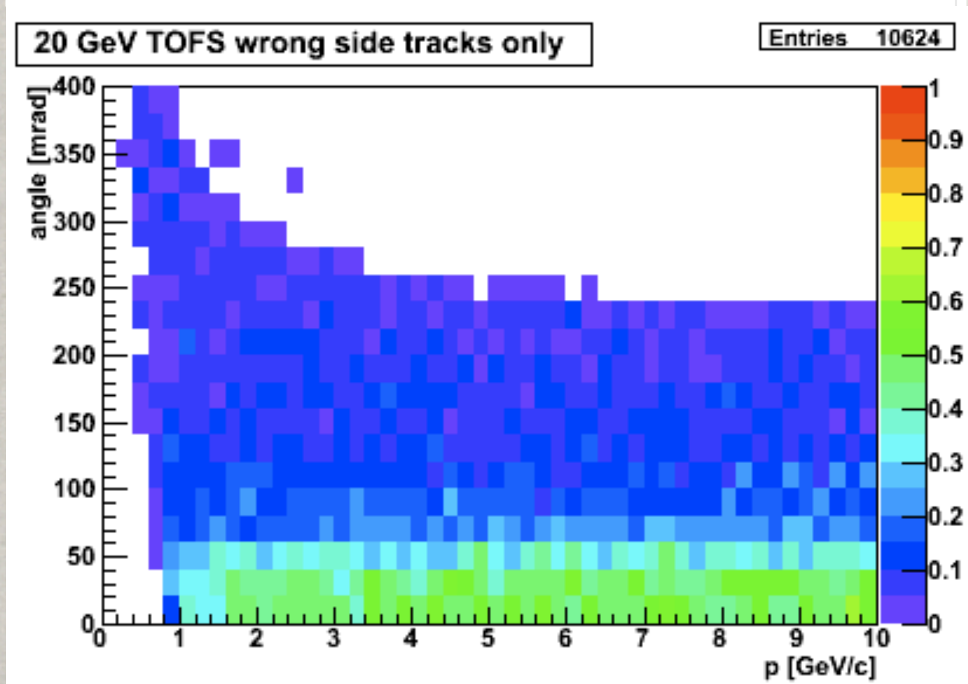
~2.5% hit/sc = 1.6 hit/event

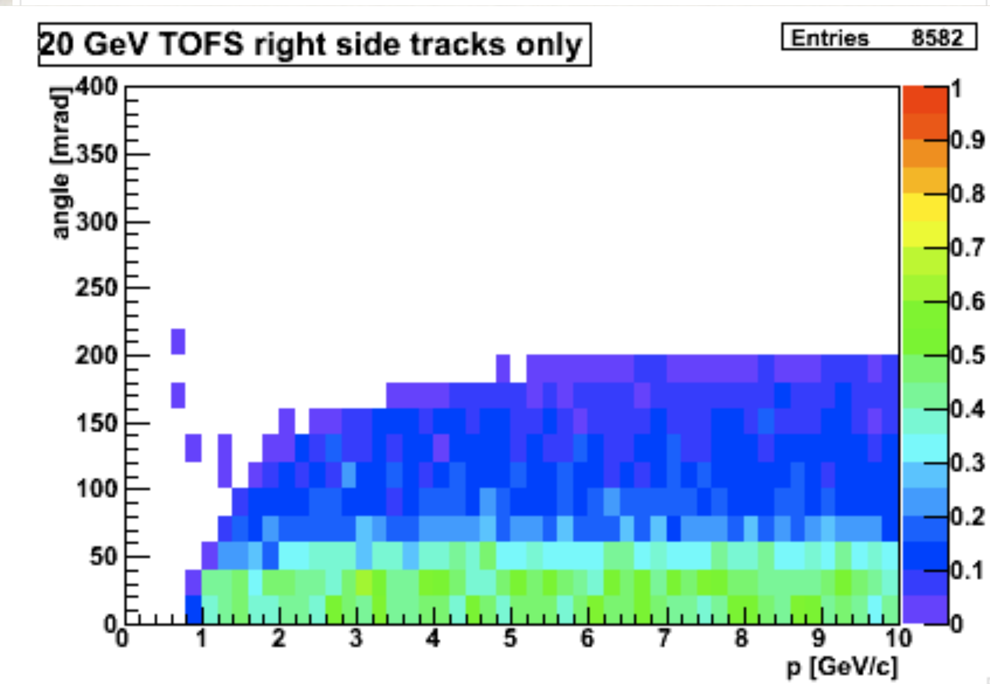
2007 RUN DATA (S.MURPHY)

- Reconstructed data



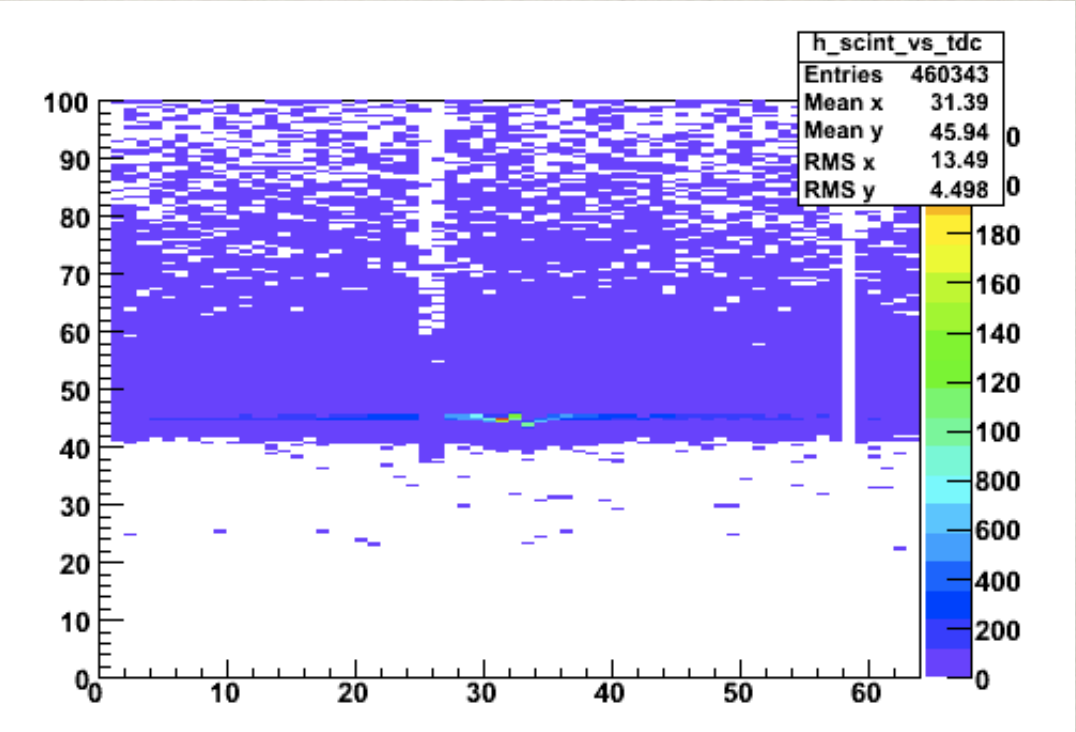




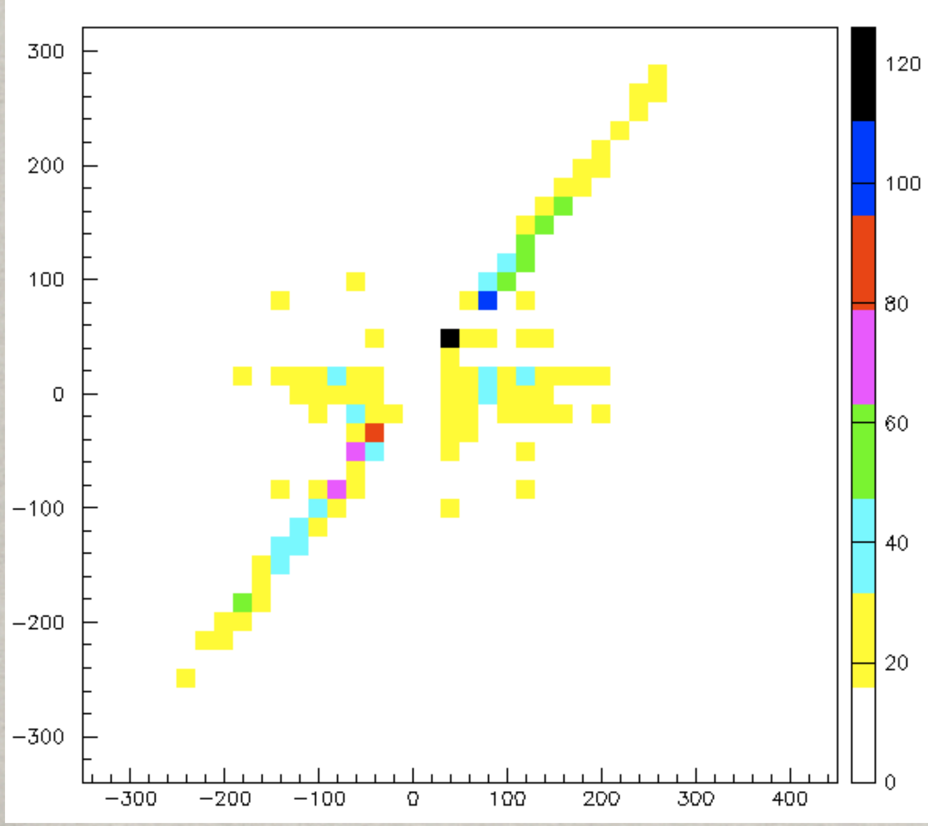


2007 RUN DATA

- Reconstructed data



First rough correction of TDC shifts / channel



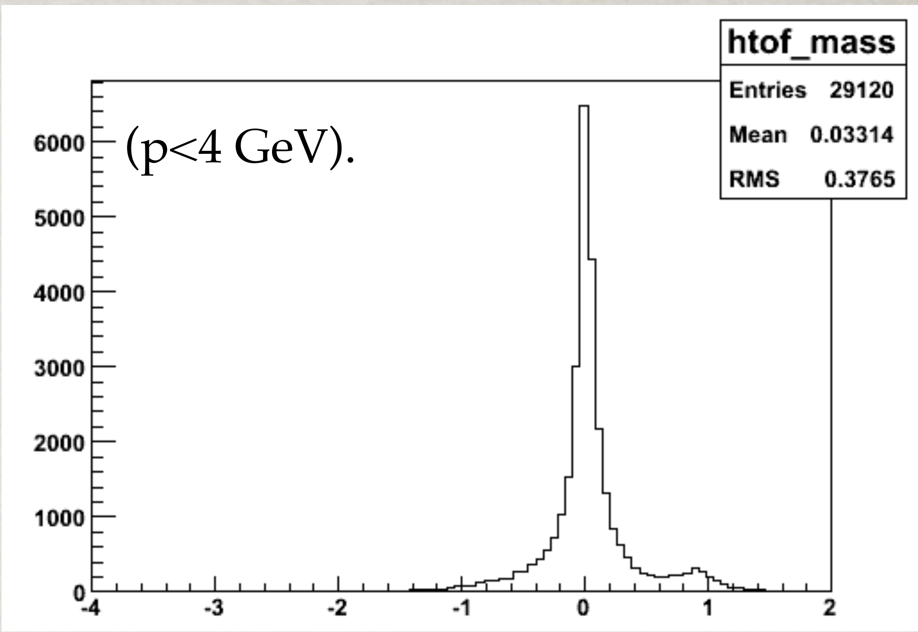
Correlation between x position extrapolated from end point in MTPCs and x position of hits in the ToF

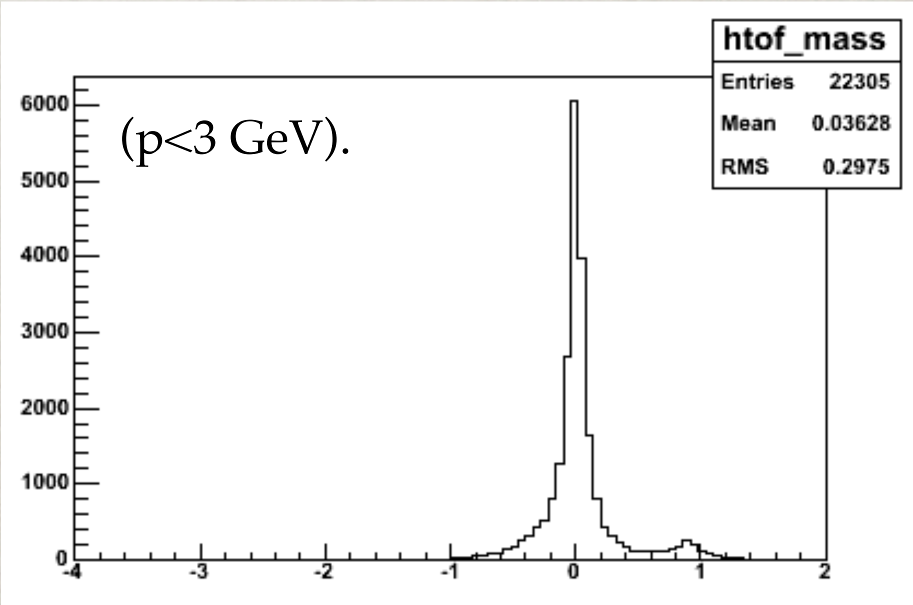
2007 RUN DATA

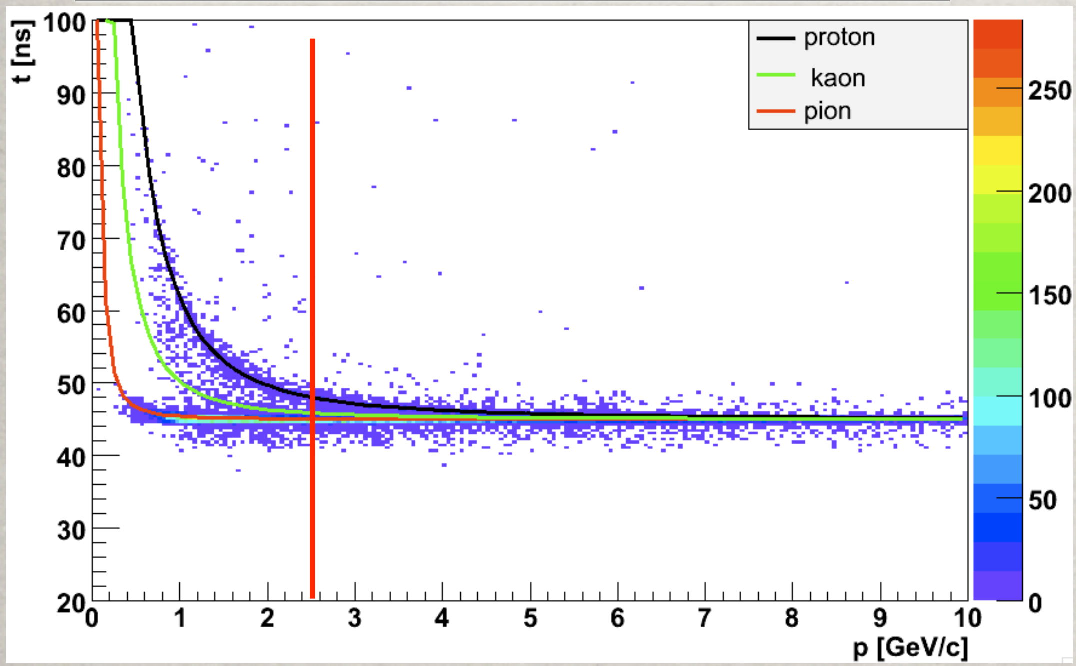
-> First rough corrections

-> Quality cuts on the global tracks:

- n_fit_points>50
- id_det>6 (tracks in MTPcs) and z_last>500 cm (middle of mtpc)
- i_flag==0







Overview of NA61 Simulation Chain

- Global structure inherited from NA49. Based on Geant3.
- The whole chain is contained in the following directories of NA61 CVS repository on afs:
  - pro/GEANT/GEO -> source + name list files (/V07A)

    Basic geometry (volumes, rotations, etc.), detector sets and hits definitions
  - pro/GEANT/GNA61 -> modified version of GNA49

    Geant initialization and main user routines
  - pro/G2DS_NA61 -> modified version of G2DS

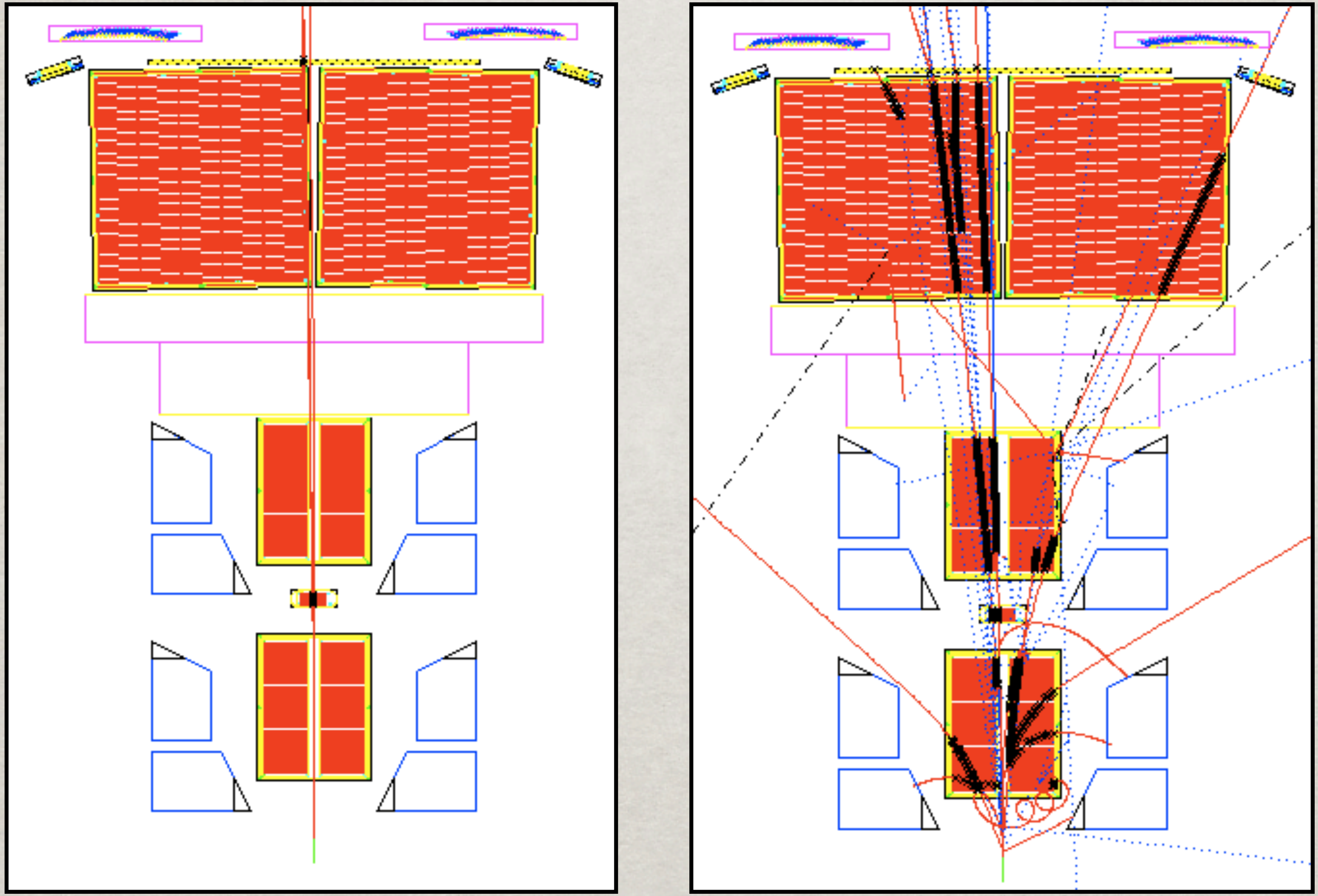
    Package for zebra to dspack format conversion
  - pro/ODF -> modified version

    Includes the na49_run_mc and na49_event_mc structure declarations

NA61 Simulation Chain

- New/modified subsystems compared to NA49 are included in those files (/pro/GEANT/GEO/src):
  - CAVE: nml_create_**cave**_**V07A**.F -> T2K target, 2cm target
  - TOFR/L: nml_create_**tofr/l**_**V07A**.F -> rotated ToF walls
  - TOFS: nml_create_**tofs**_**V07A**.F -> new forward ToF
  - GTPC: nml_create_**gpc**_**V07A**.F -> GAP TPC
  - BPDs: nml_create_**bpds**_**V07A**.F -> beam position detectors
- Different kinematics input can be given to Geant, either a model generated input (using Venus as primary hadronization model) or whatever input written in ascii file. Geant is simply used to transport the particles through the detectors geometry. There is no digitization inside Geant; an external client (MTSIM) is used to simulate the TPCs response.

NA61 Simulation Chain



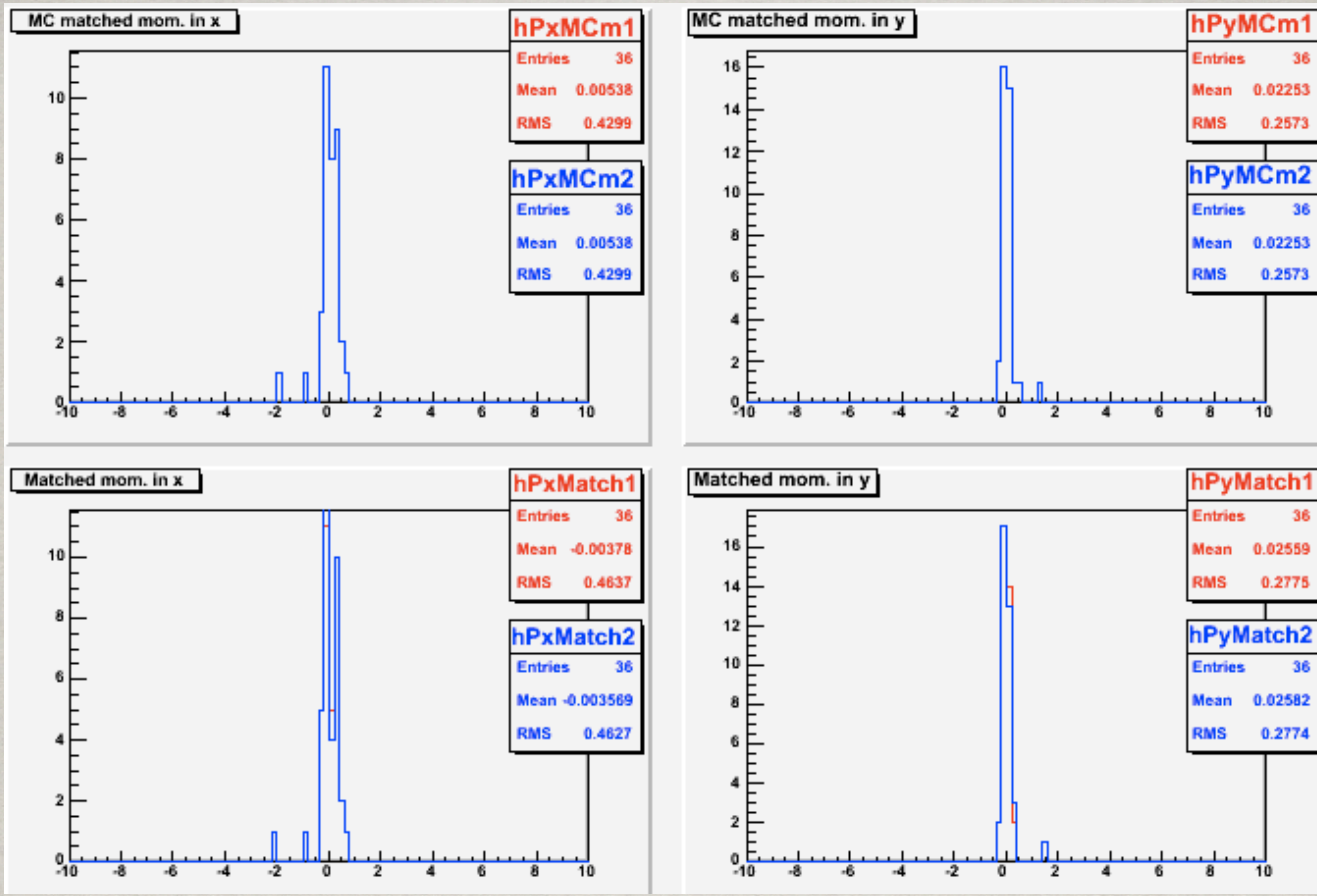
p + C, 30GeV/c, B = 1 Tm

NA61 Simulation Chain

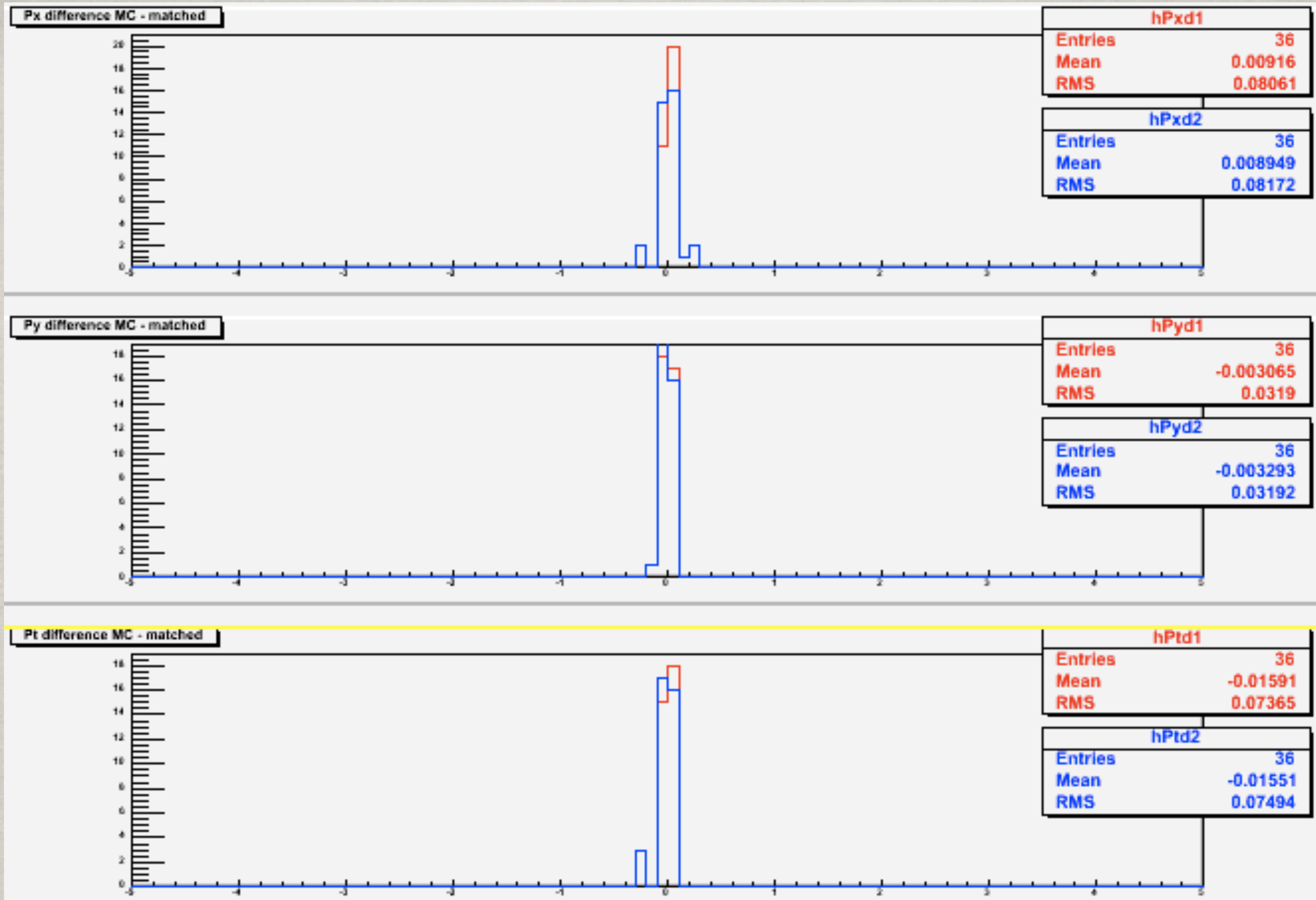
- At the Geant level, the new NA61 geometry is now almost entirely implemented. Still need to work on BPDs and PSD and adjust some positions. Another effort has to be made to allow the control of the main and secondaries random sequences by the user.

- At the Dspack conversion level, should try to make things more uniformly but in principle the current version is consistent enough to run the conversion properly.

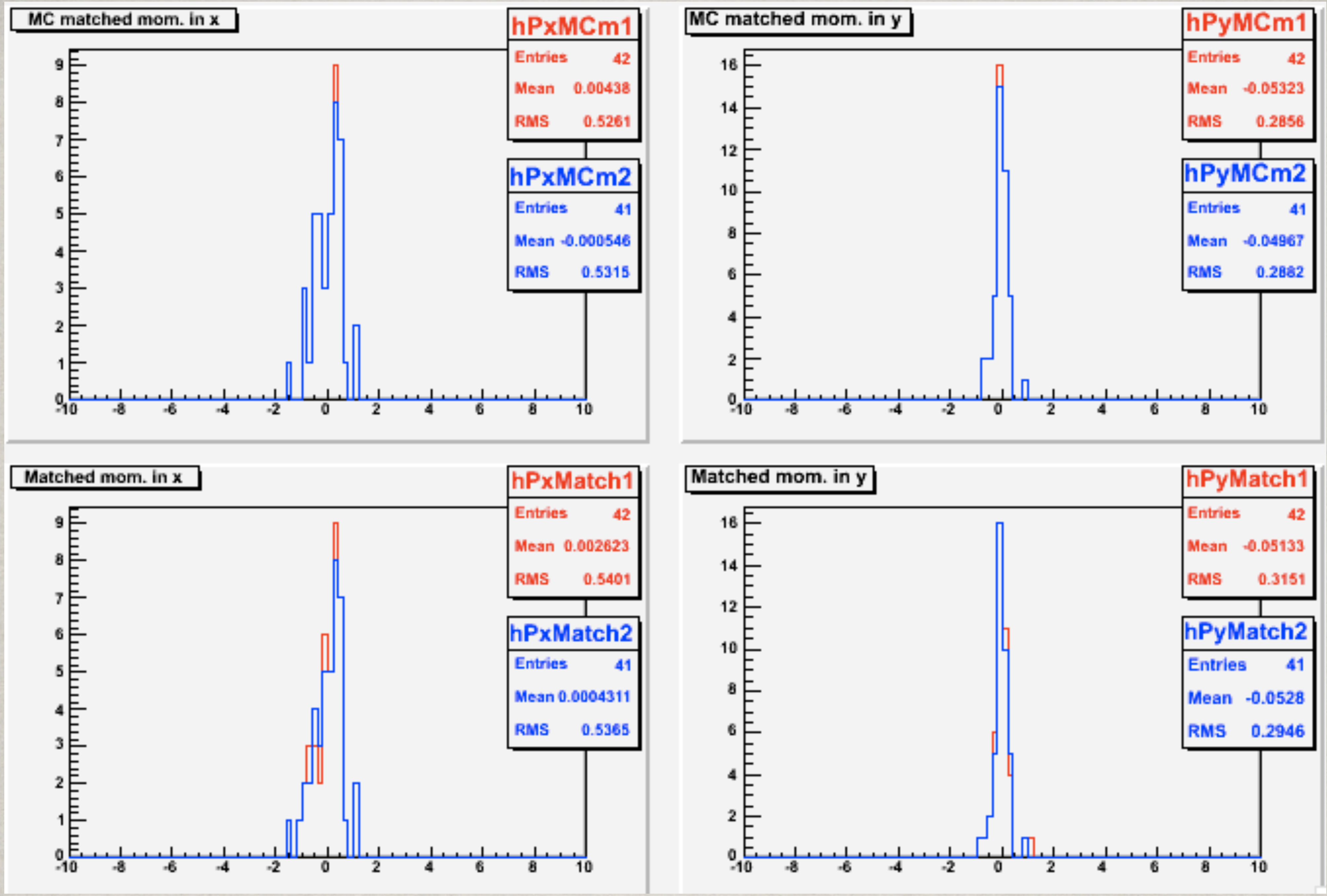
- At the reconstruction level, before any detailed studies of the NA61 rec. chain, a direct comparison with NA49 rec. is needed to assure that we are starting on a good basis. There might be some small differences between the two reconstructions but results have to be equivalent.



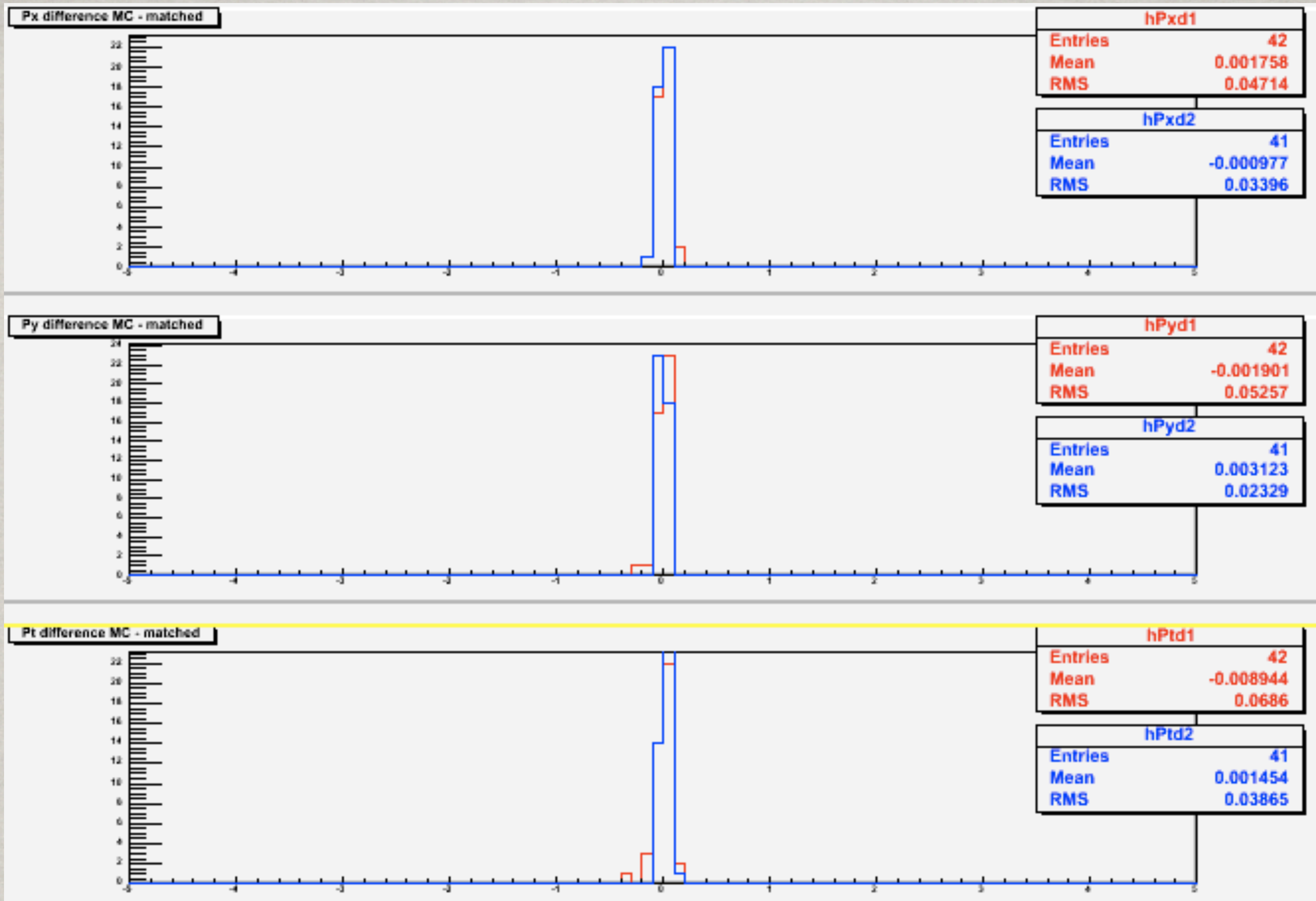
na49 dev / na61 pro
512tb mode



na49 dev / na61 pro
512tb mode



na49 dev / na61 pro
256tb mode



na49 dev / na61 pro
256tb mode

NA61 Simulation Chain

- NA61 sim. chain runs properly and reconstructed MC event do not differ significantly from NA49 reconstruction.
- It is now time to start studying the rec. in detail and agree asap on the global and client options to be used both for MC and real data.
- Concerning a first MC production: it is of course highly needed and we seem to be now in position to provide it quite soon.