Nu_01_2 : R/D of neutrino beam production for future (Multi-) MW proton facility

Measurement of hadron production for T2K at CERN: the NA61 experiment

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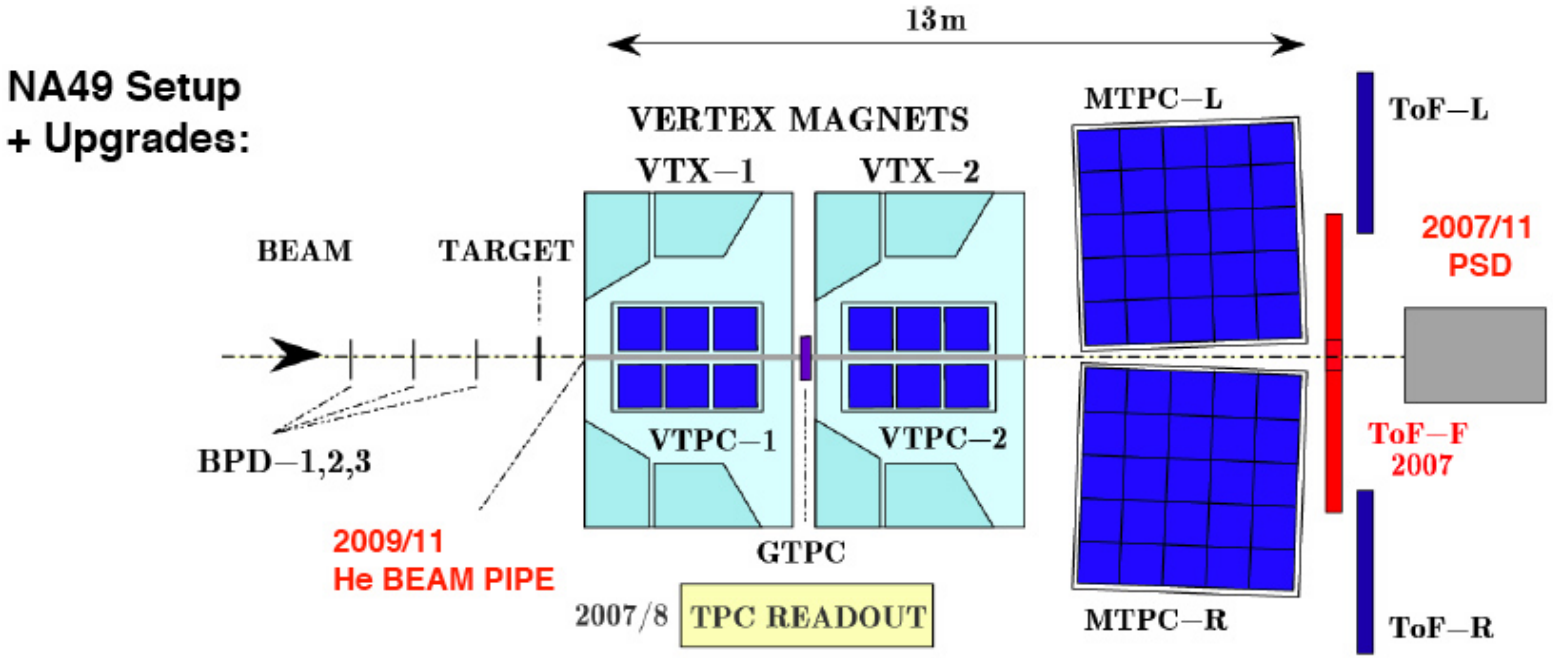
TYL'10: FJPPL annual workshop Annecy, June 15, 2010

NA61 (SHINE) experiment: status and plans for the T2K physics program

- **Available data**
  2007 thin target charged pion measurements
- **Work in progress**
  - paper in preparation
  - 2007 long target analysis
  - calibration of 2009 data
- **Goals for Summer 2010**

NA61/SHINE - Fixed Target Experiment at CERN SPS

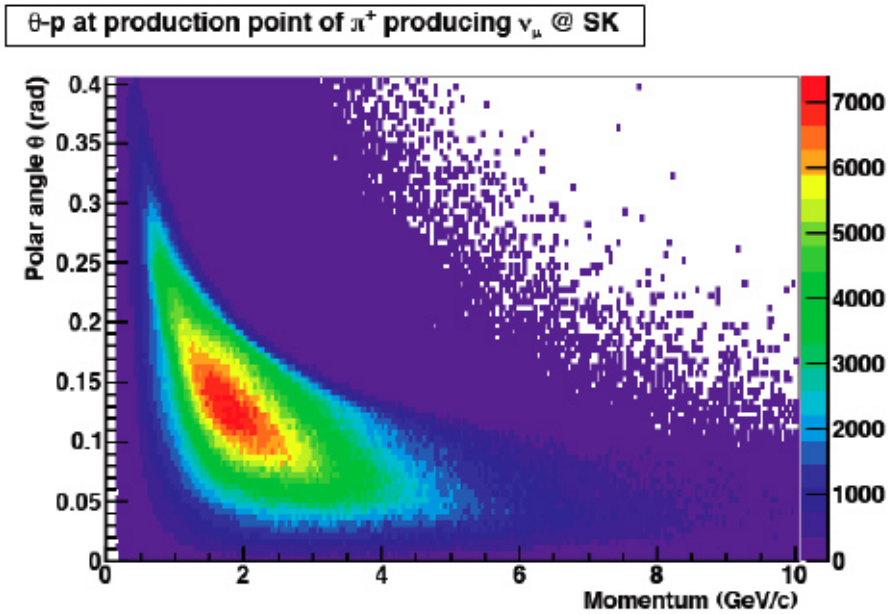


- **Large Acceptance Spectrometer for charged particles: (TPCs as main tracking devices; 2 dipole magnets with bending power of max 9 Tm over 7 m length** (2007-Run: 1.14 Tm); **new ToF-F to entirely cover T2K acceptance; high momentum resolution; good particle identification)**

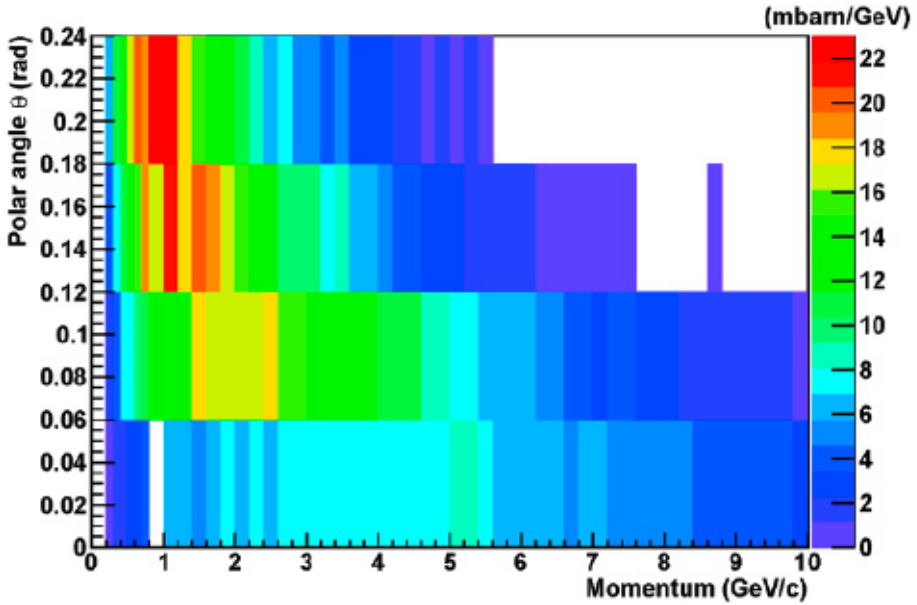
▪ Data taking for T2K:	Year	Target	Statistics	Status
▪	2007	thin C	670k triggers	*Preliminary pion spectra*
▪	2007	replica	230k triggers	*First analysis loop*
▪	2009			*Under calibration*

NA61 data available

from Jnubeam MC



π+ 2007 thin target data



Data released in December 2009
~10% error on inelastic cross section
20% error on pion multiplicity

NA61 data already available

Analyzed p-Carbon [thin target (4% λ_I)] data at 31 GeV/c from 2007

- determination of absolute inelastic cross section
- π^- up to 15 GeV/c in angular bins of 60 mrad
- π^+ up to 10 GeV/c in angular bins of 60 mrad

20% systematic errors!

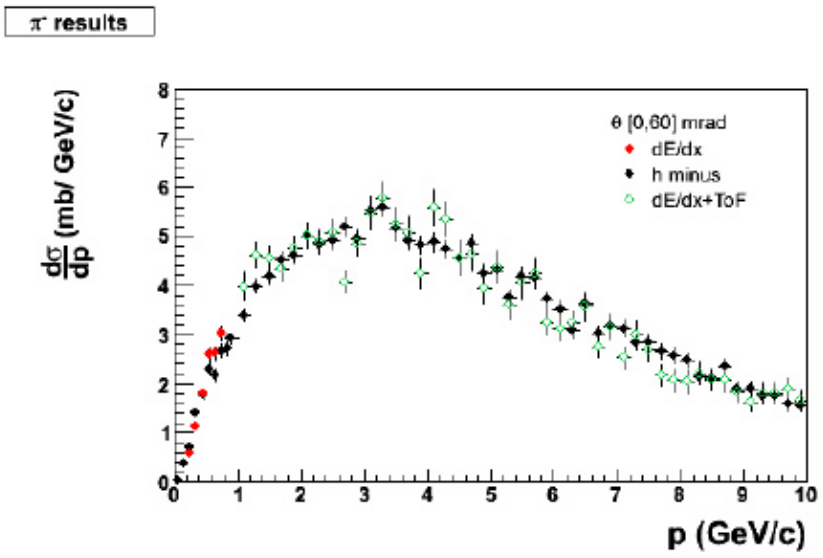
(current binning as suggested by T2K: 200 MeV/c x 50 bins; coarser binning could be needed for the publication of 2007 data)

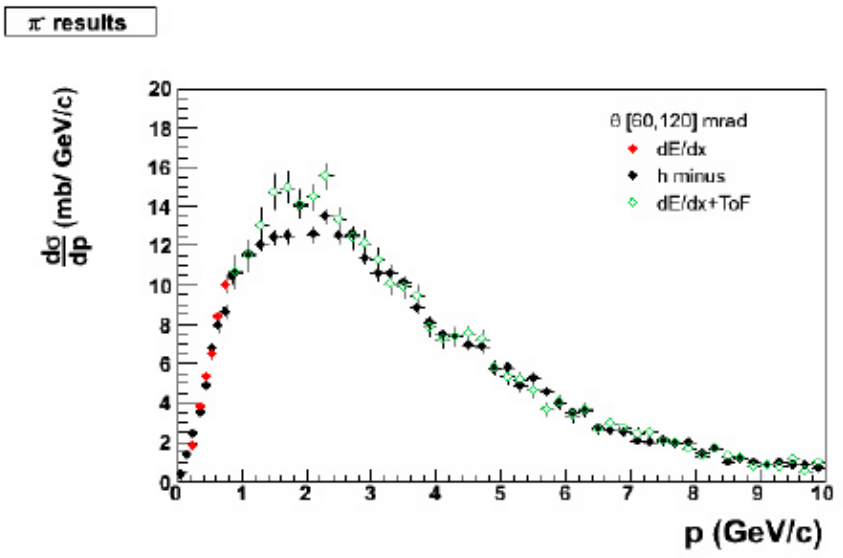
- preliminary comparison with GFLUKA, GEANT4, VENUS, FLUKA-standalone, GiBUU (Sakashita-san, Claudia, Volodya, Tomek, Boris)
- no measurements of reinteractions yet ⇒ need to analyze long target data

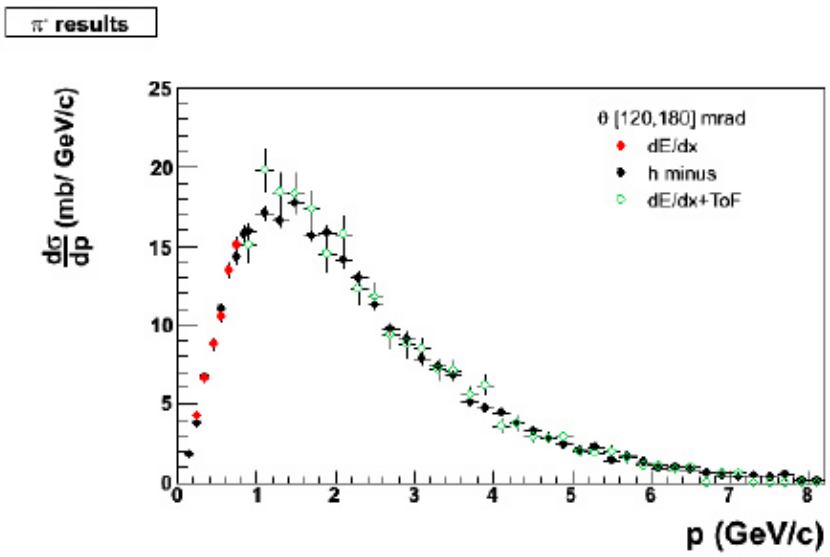
Preliminary NA61 data have been reported at international conferences and are currently being used by the T2K beam MC group

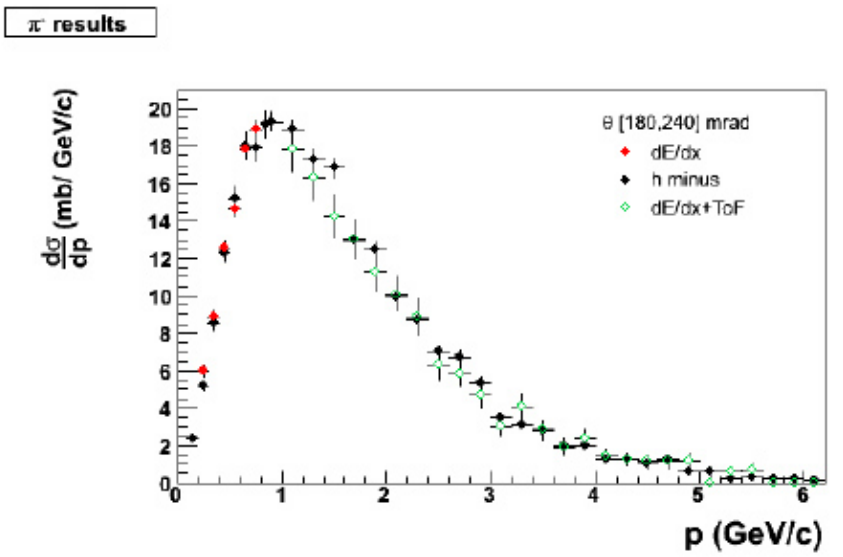
Work on paper preparation started

NA61 data already available: π^-



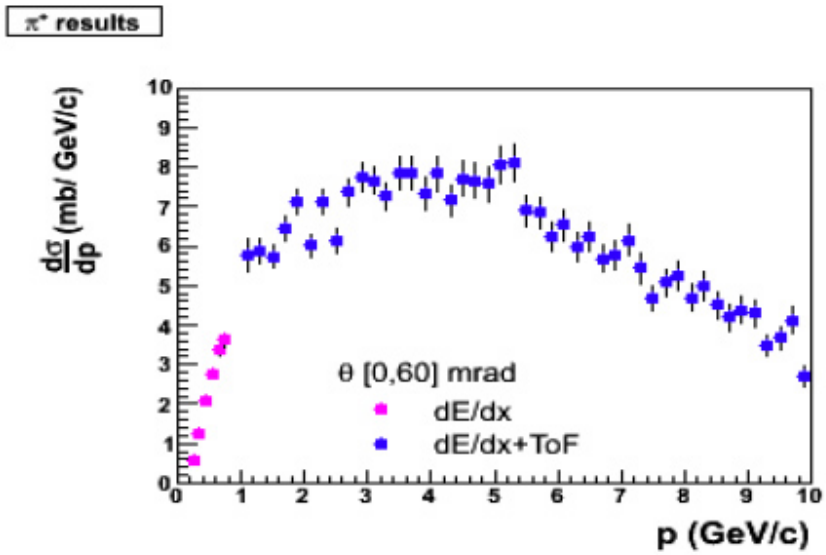


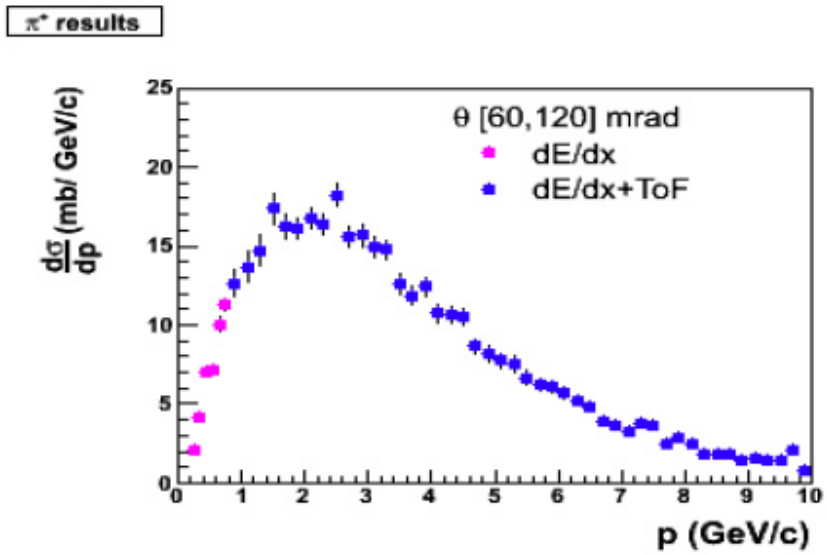


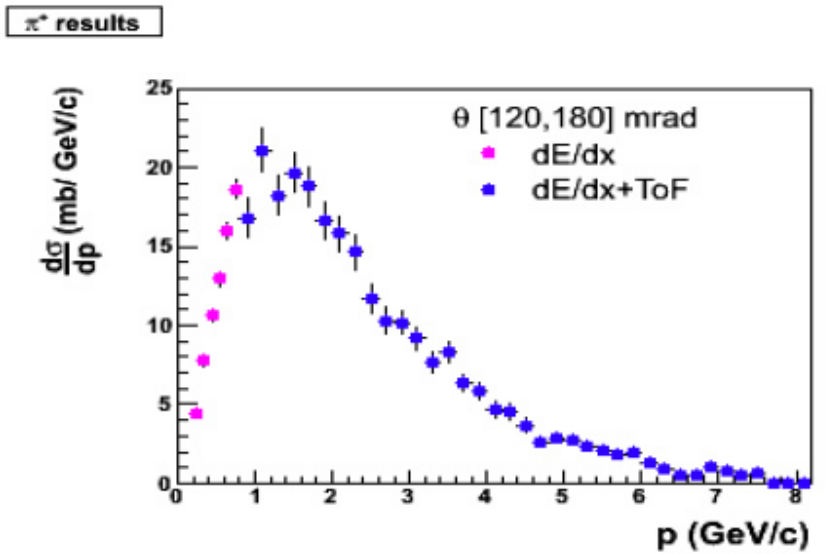


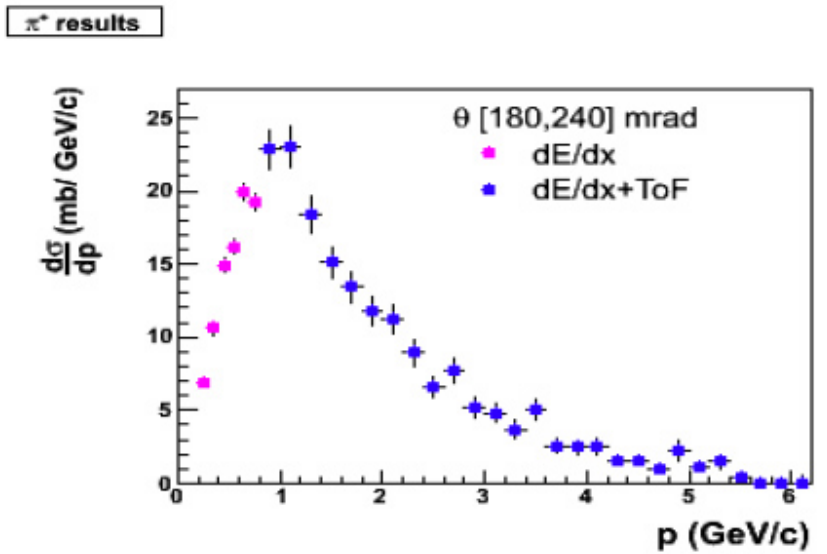
Three different analysis methods: currently estimated systematic errors ~20%

NA61 data already available: π^+





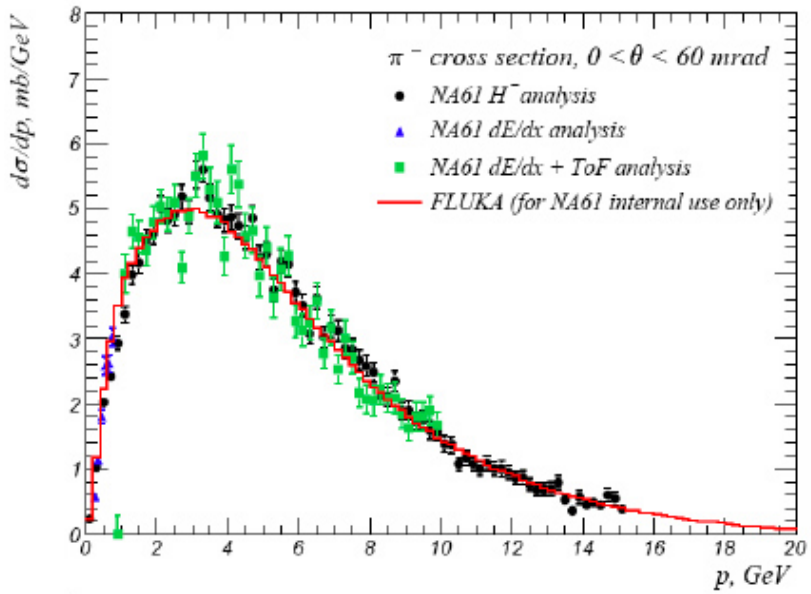


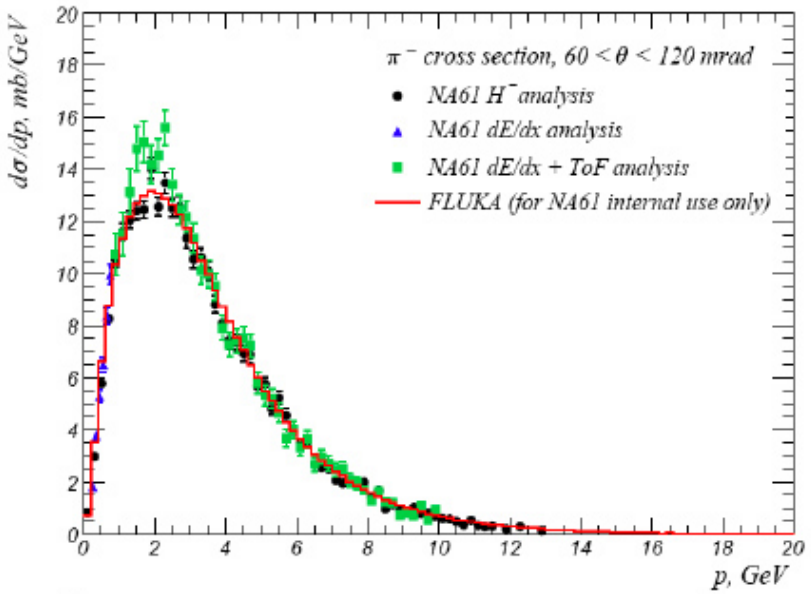


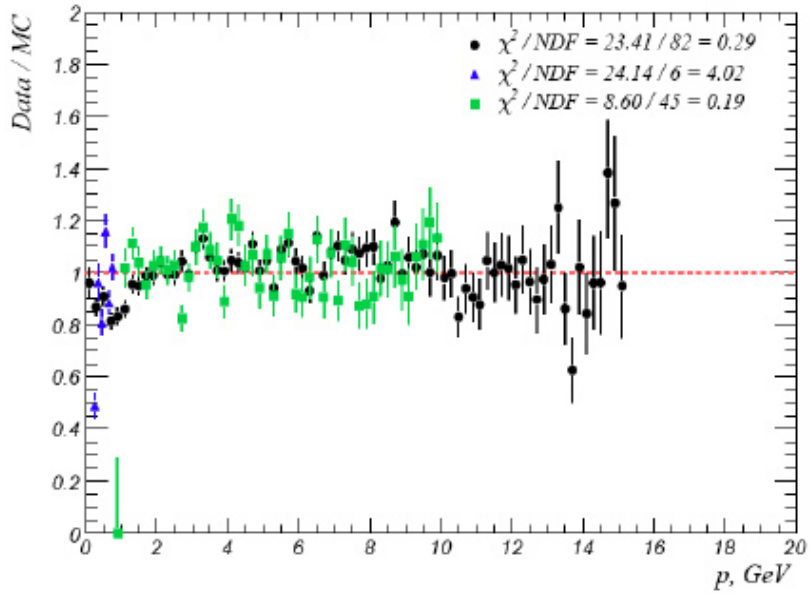
Two different analysis methods: currently estimated systematic errors ~ 20%

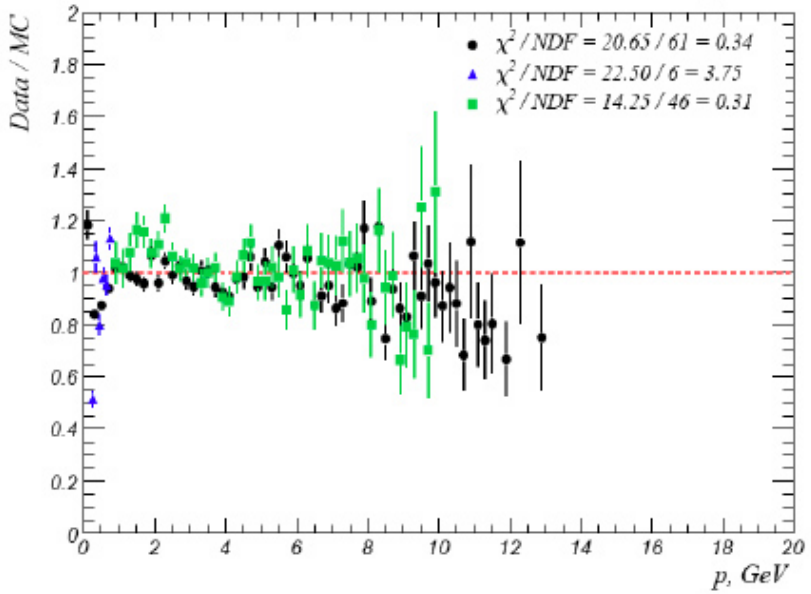
π^- cross section & FLUKA predictions

For internal use only



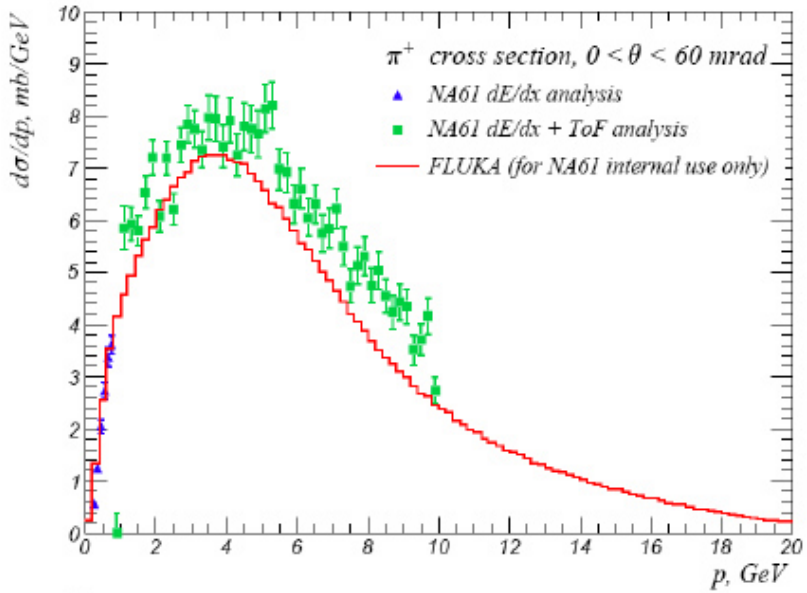


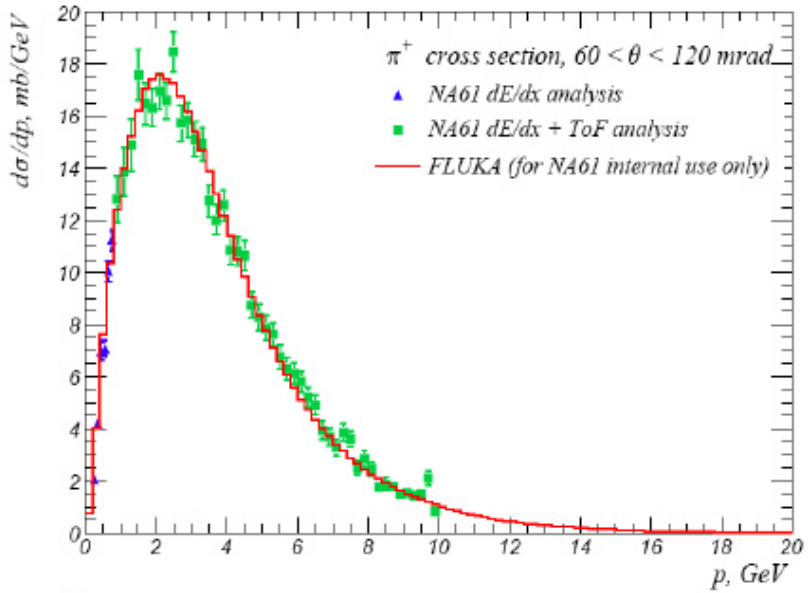


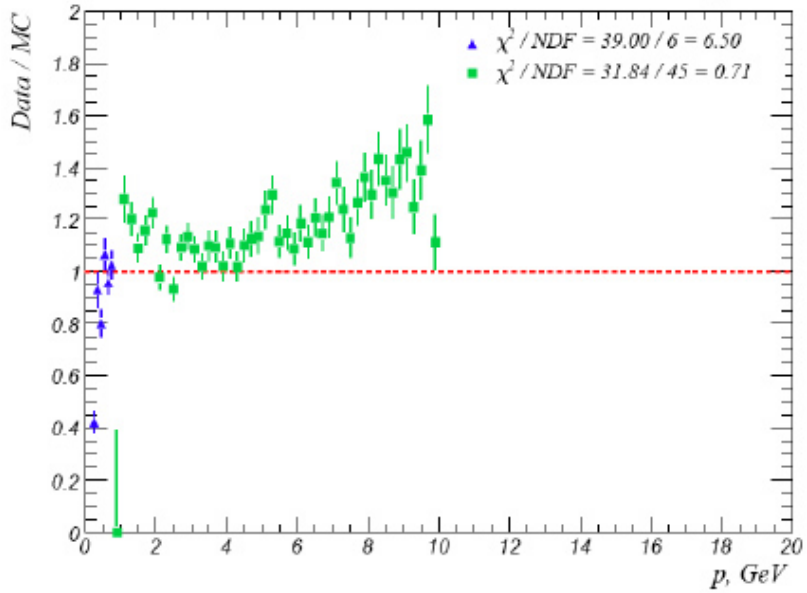


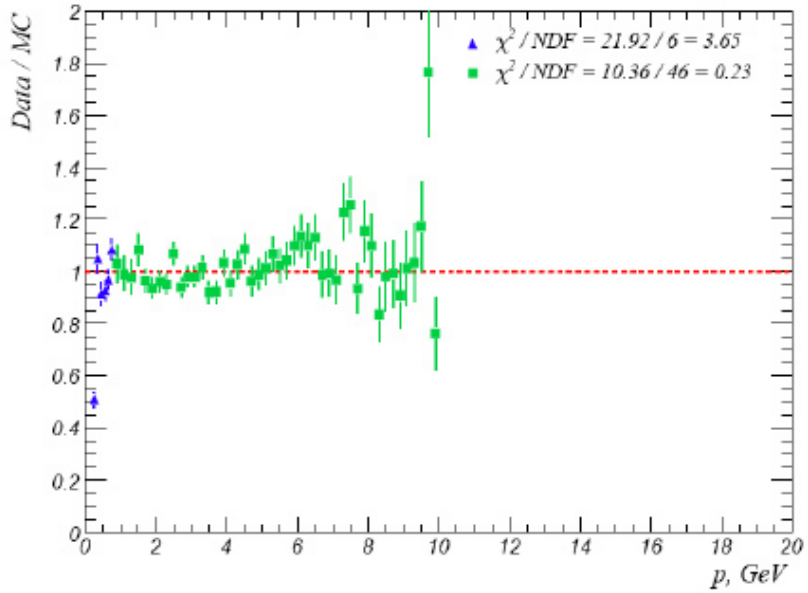
π^+ cross section & FLUKA predictions

For internal use only





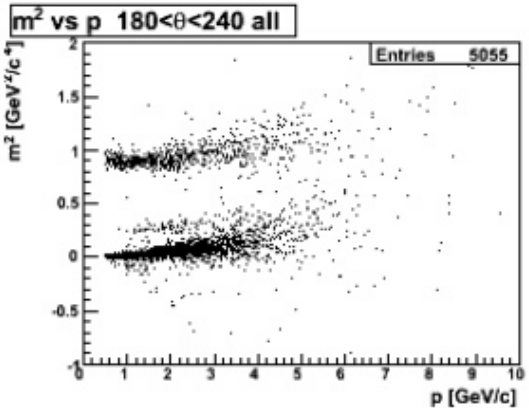




Work in progress (1)

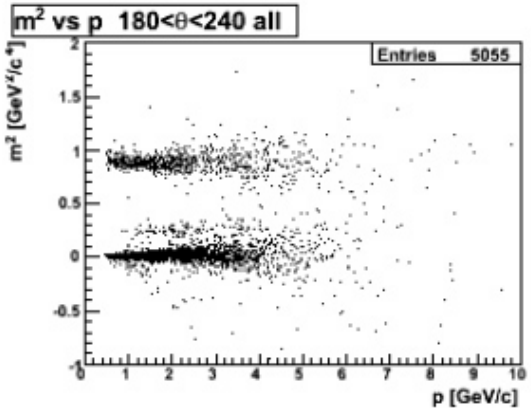
- **2007 thin target data**
  - improve systematic errors on pion measurements
    - refine analysis procedures
    - perform additional cross-checks
  - comparison of results with different data productions (with and w/o Gap TPC)
  - important progress in the error propagation and track fit
  - good progress on improving resolution on TOF PID
  - dE/dx analysis in the relativistic rise region
  - more careful look into the 0-20 mrad region
  - extend pion analysis to high momenta (up to 20 GeV/c)
  - start looking at kaons (not enough statistics for 200 MeV/c bin in momentum)

old



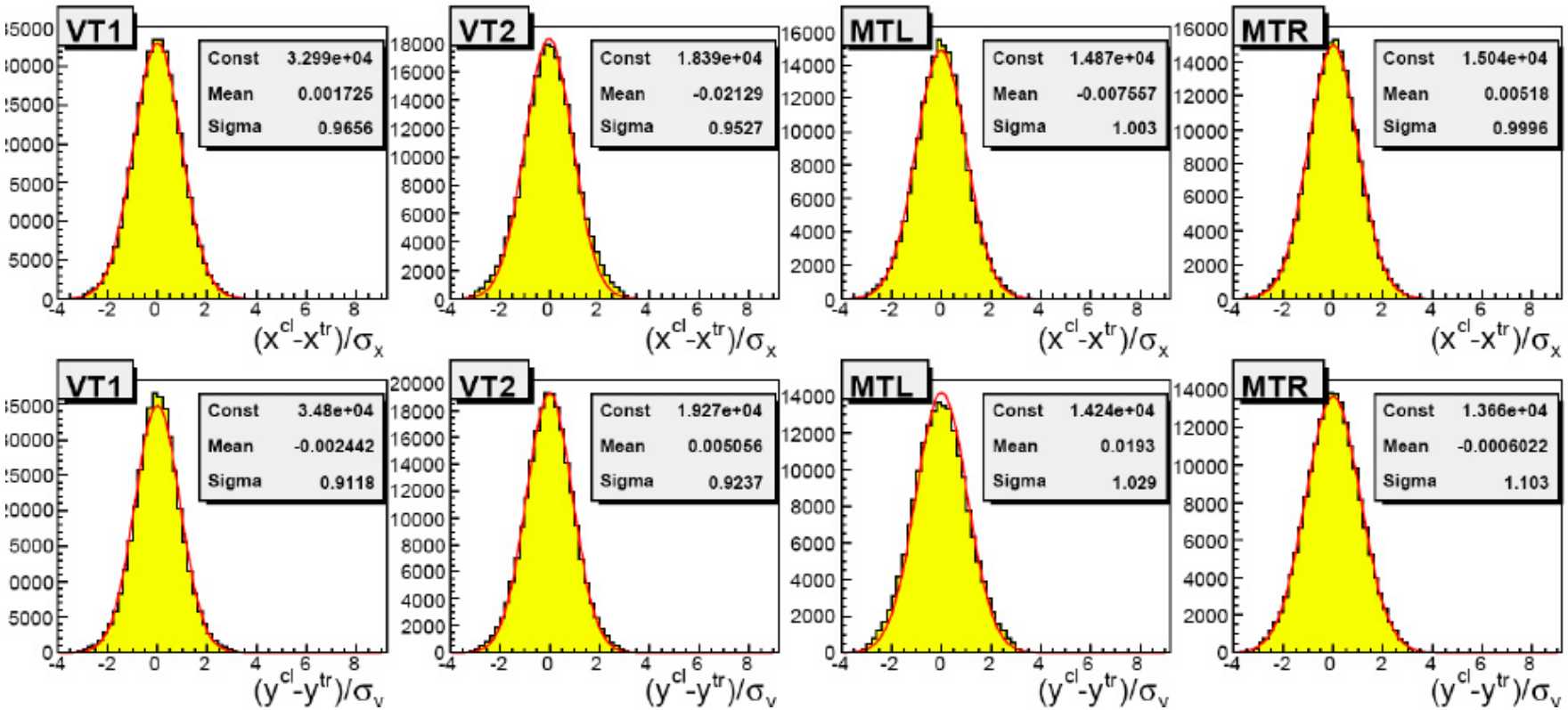
after correcting for proper track length

new



S.Murphy, A.Korzenev

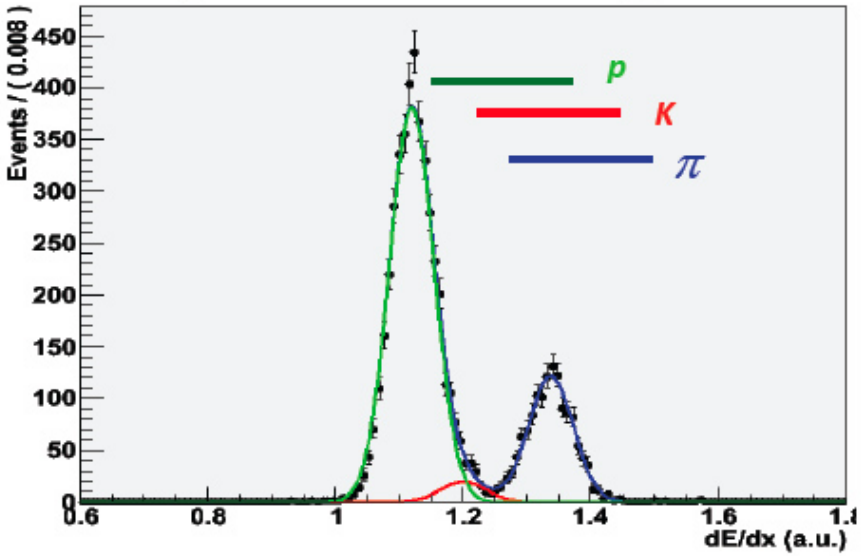
Track fit pulls (in different TPCs) after calibration



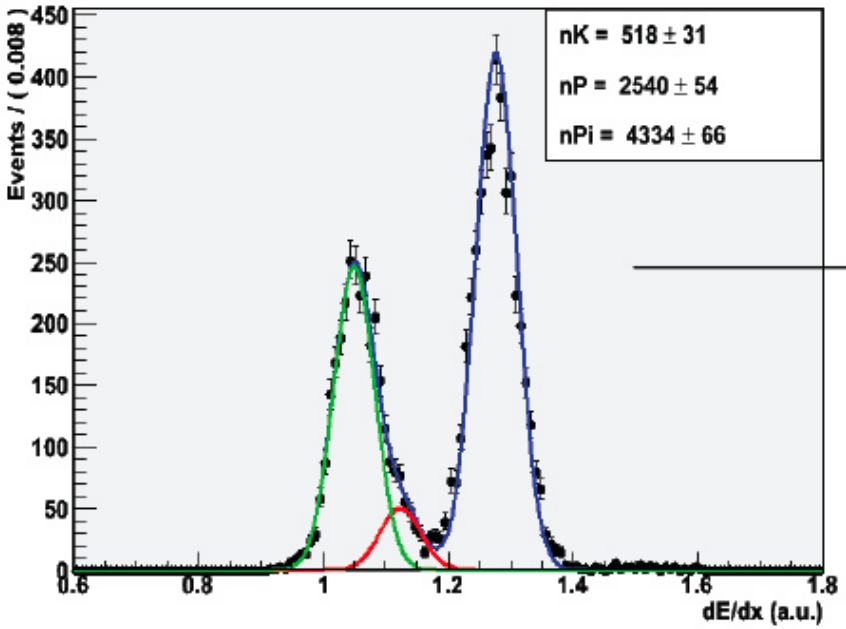
A.Korzenev

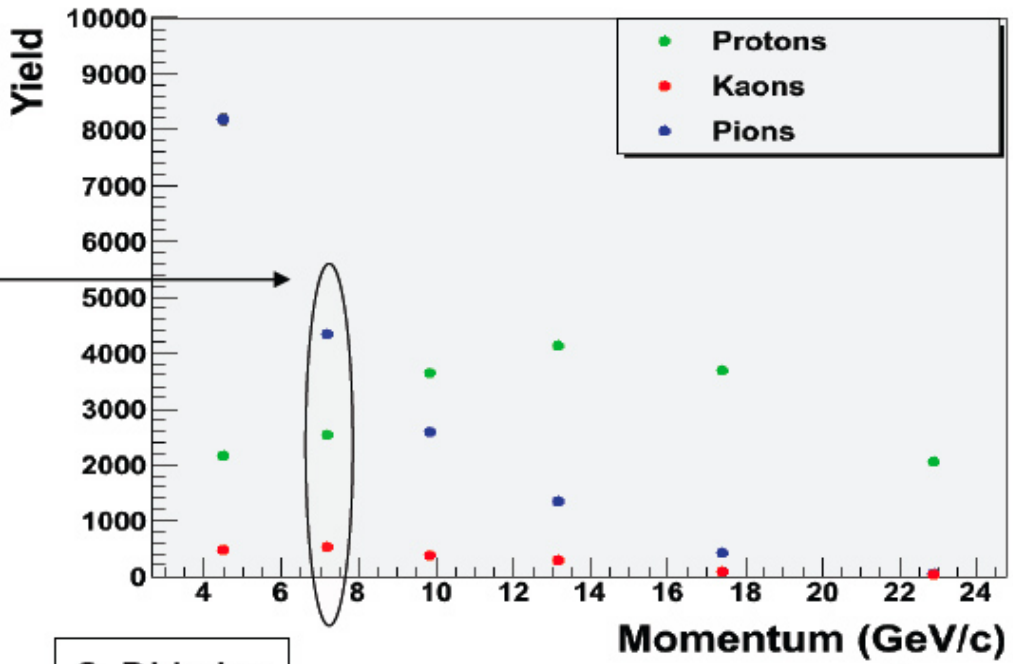
Preliminary Results form the dE/dx analysis in the RR region

- Dataset: 2007 p+C (Thin Target).
- Track Momentum > 3 GeV/c



- Example for the 20-120 mrad angular range
- Relative Yields (Not Corrected for Acceptance, Efficiency and Decay-in-Flight)
- Errors: ~6-20% for Kaons
  ~1-5% for protons, pions





S. Di Luise

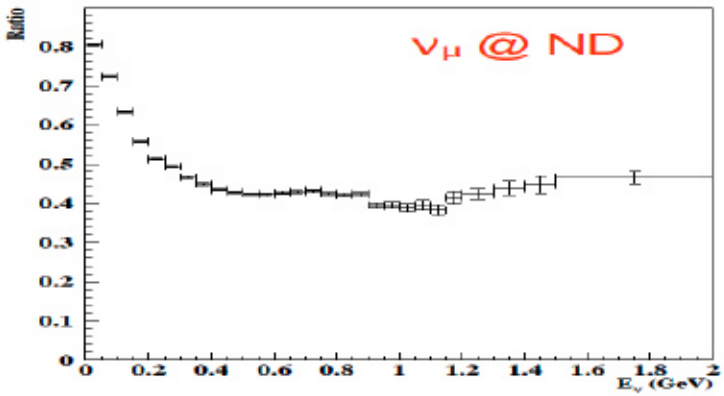
Work in progress (2)

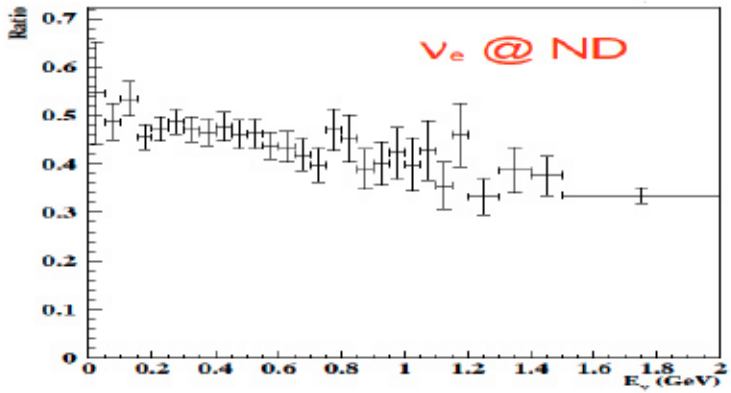
- **2007 long (T2K replica, 90 cm) target data**
  - current analysis strategy is to provide momentum and angle of all tracks at target surface, no attempt to reconstruct primary/secondary vertices
  - back-tracking of particles to target skin already implemented, taking into account error propagation (Luigi, Alexander)
  - first results on TOF PID for long target (Sebastien, Sandro)
  - analysis chain for h^- analysis ready, first distributions with low statistics (Tomek)
  - can be used to tune re-interactions
  - currently consider 5 longitudinal bins along the target + the target downstream face
  - need to understand the effect of different densities between the NA61 "T2K replica" target (ρ = 1.84 g/cm^3) and the currently installed T2K target (ρ = 1.804 g/cm^3)

Motivations for T2K replica target data

N.Abgrall, B.Popov, internal NA61-T2K note 2009-01, updated version 2.0 April 2010

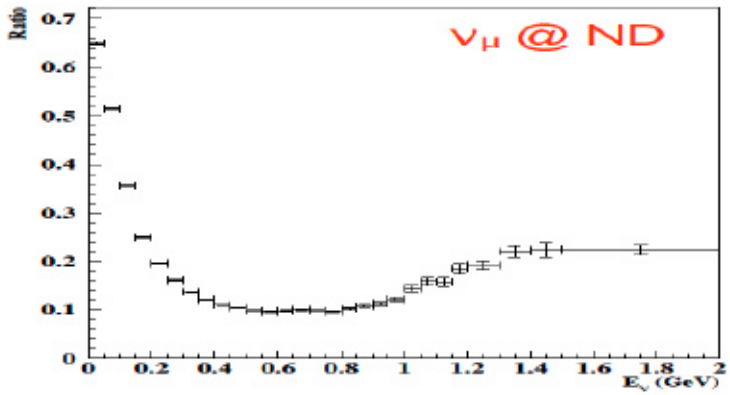
Ratio of indirect / total contribution for ν_μ and ν_e ~ 40% at peak energy

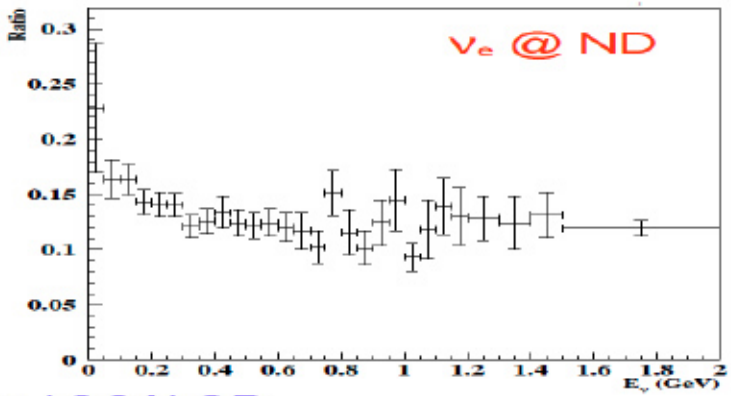




indirect contribution: neutrinos from particles coming from re-interactions

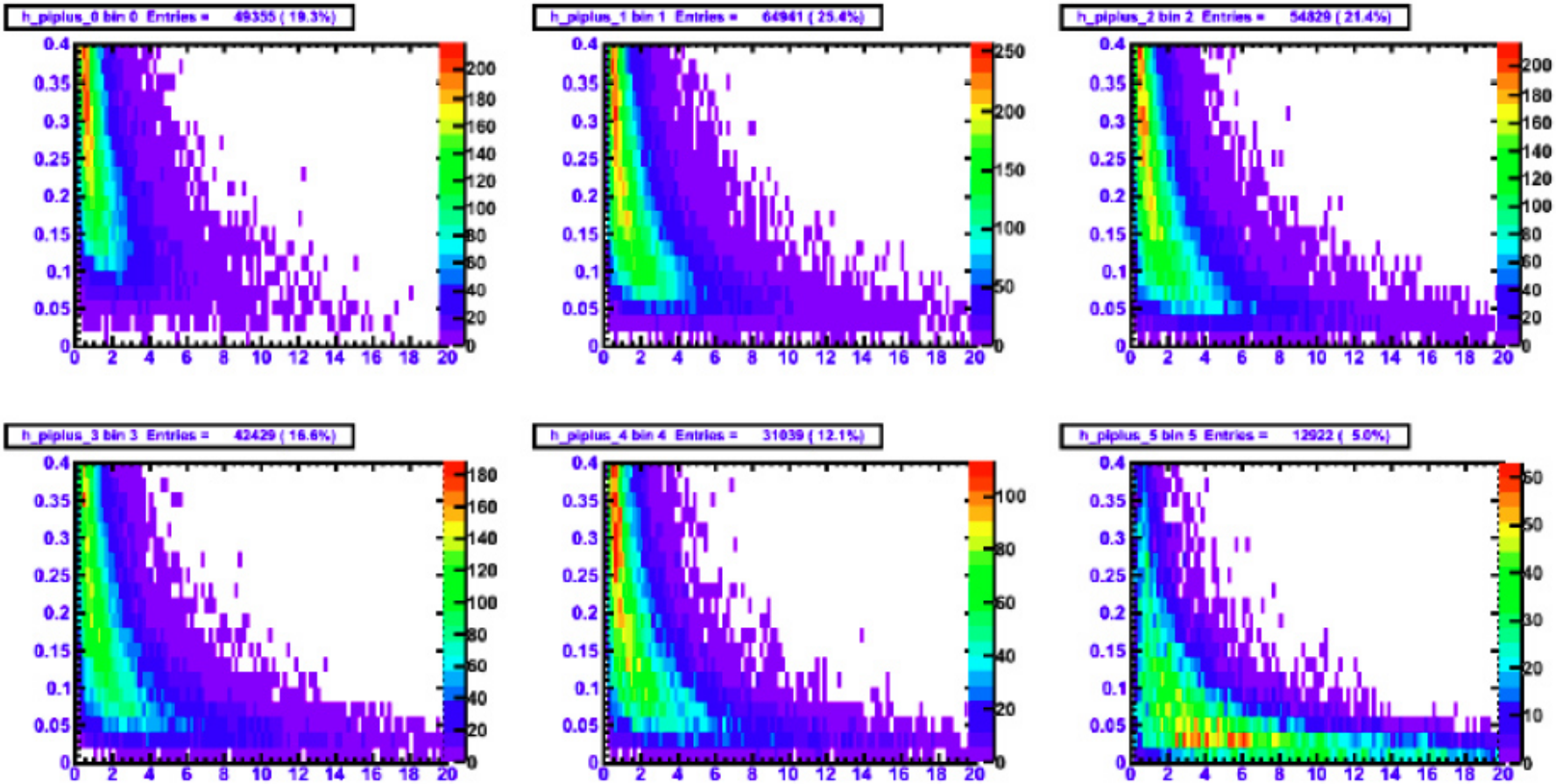
Ratio of out-of-target / total contribution for ν_μ and ν_e ~ 10% at peak energy





Long target longitudinal distributions in MC

π^+ {p, θ} distributions for 5 longitudinal bins of 18 cm + target downstream face



Longitudinal distributions sensitive to reinteractions, beam shape on target, interaction length

L. Esposito

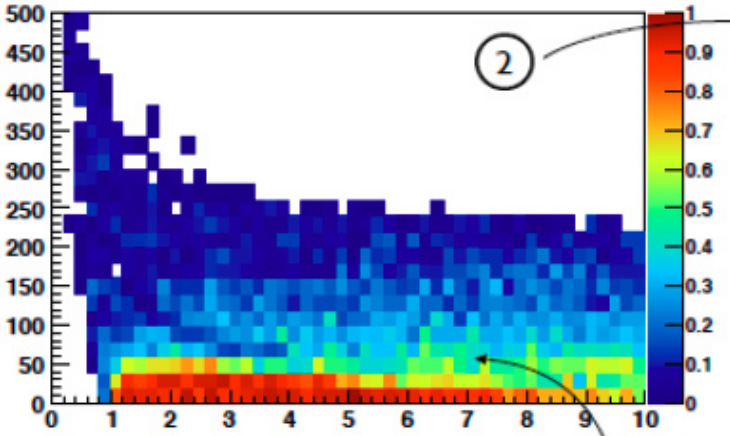
Work in progress (3)

- **Calibration and quality checks of 2009 data**
  - calibration of 2009 data is on-going for drift velocity in TPCs, then need calibration of ToF and dE/dx. This is a very lengthy process!
  - raw data statistics for 2009 data is about 4.4 M interactions
  - determination of interaction rates from 2009 thin target data (Claudia)
  - careful assessment of long target data statistics collected in 2009: about 2 M interactions after preliminary quality cuts (Jeremy)
- **Preparation of a document for long target data taking: with estimates on how much NA61 data we need to collect** (inputs from the beam MC group + Nicolas/Boris, Luigi)
  - internal NA61-T2K note 2010-03 (Nicolas, Boris)
  - NA61 needs to understand if data taking with p at 10 GeV/c is possible in 2010
  - some preliminary distributions on long target data submitted to SPSC referees on April,9 2010
  - 3 weeks of data taking with the T2K replica target have been included into the preliminary NA61 2010 beam request

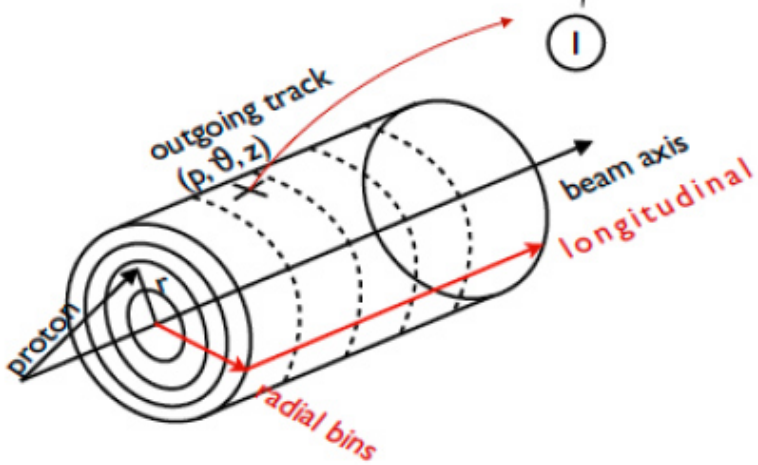
T2K neutrino flux uncertainty from NA61 replica target measurements

N. Abgrall

- Developed method to implement the NA61 acceptance in the T2K beam Monte-Carlo to account for hadron cross-section measurements uncertainty consistently over the T2K phase space



e.g. Acceptance at target downstream face for track hitting the ToF-F

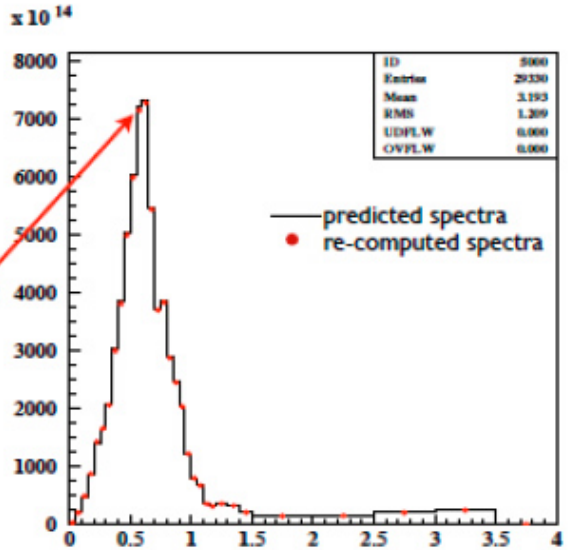


Compute contribution of each bin (p,θ,z,r) to different bins of neutrino energy. This contribution is factorized in fraction and normalization weights

4

Re-compute spectra @ far and near detectors propagating hadron cross-section uncertainties:

$$W = \sum_{i=1}^{N_i} \frac{w_i}{N_i} = \sum_{j=1}^{n} w_{ij}^{f} \sum_{k=1}^{N_j} \frac{w_k}{N_j} = \sum_{j=1}^{n} w_{ij}^{f} w_{ij}^{n} \longrightarrow N(E_\nu)_j = N_i \times w_{ij}^{f} \times w_{ij}^{n}$$



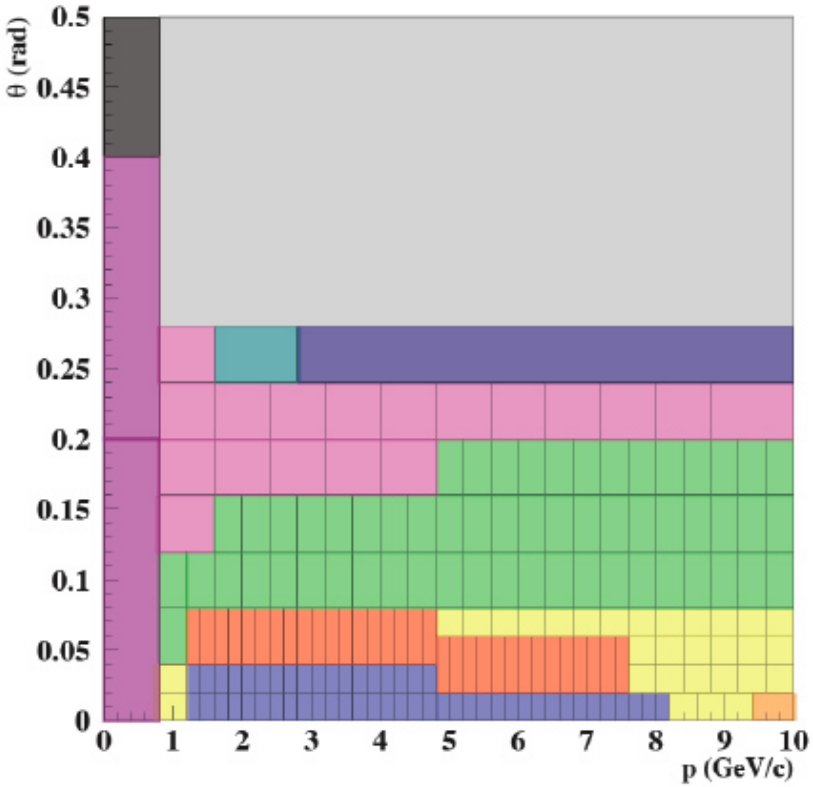
This method can be used to estimate required statistics of NA61 measurements with respect to the T2K physics goals
e.g. maximal uncertainty on hadron cross-section measurements to get an error less than 2-3% on the far-to-near ratio prediction

N.Abgrall, B.Popov, internal NA61-T2K note 2010-03

Towards statistics estimates for T2K replica target measurements

N. Abgrall

- Binning template in (p, ϑ) defined over the relevant T2K phase space:
  - regions of maximal acceptance define a default binning of 200 MeV/c bins in momentum and 20 mrad bins in polar angle (e.g. Sakashita-san)
  - for regions of lower acceptance an appropriate bin size is found to account for the same statistical power



Binning based on NA61 acceptance

Bin sizes range from:
- 200 to 1200 MeV/c in momentum
- 20 to 200 mrad in polar angle

Bins at the edges of the considered phase space have opened bounderies to account for overflows that contribute to the energy spectra

- This template allows to vary each (p, ϑ) bin content over the T2K phase space by the same amount to account for uncertainties of hadron production cross-section measurements in NA61

Conclusion: Goals for summer 2010

- **publish pion distributions from 2007 thin target data**
- **preliminary results on pions in the very forward region (0-20 mrad) for MUMON muon flux measurements**
- **preliminary results on protons and kaons from 2007 thin target data**
- **preliminary results on pions and protons from 2007 replica target data**
- **finalize the calibration of 2009 data and start analyses**
- **take 15 more days of data (mostly replica target) this summer**