Pion yields in neutrino interactions measured in the NOMAD experiment

Dmitry Naumov, Oleg Samoylov

JINR, Dubna, Russia

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Outline

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1. Introduction
   - Fragmentation functions
   - Experimental view on fragmentation functions
   - The NOMAD experiment

2. Pion productions
   - Analysis scheme
   - Preliminary results of $\pi^{\pm}$ and π^{0} productions

3. Conclusions

WHAT ARE FRAGMENTATION FUNCTIONS?

1. They are dimensionless functions that discribed the final state single-particle energy distributions in hard scattering process

   $$F^h(x,s) = \frac{1}{\sigma_{tot}(\nu_\mu N \to \mu^- X)} \frac{d\sigma(\nu_\mu N \to \mu^- hX)}{dx},$$

   where $x = 2E_h/\sqrt{s}$, $\sqrt{s}$ is c.m. energy (standard definitions)
   We will use $E_\nu, Q^2, W, x_{B_j}, y$ and x_F, z, p_T, p
2. Multiplicity of those hadrons

   $$n_h(s) = \int dx\ F^h(x,s)$$

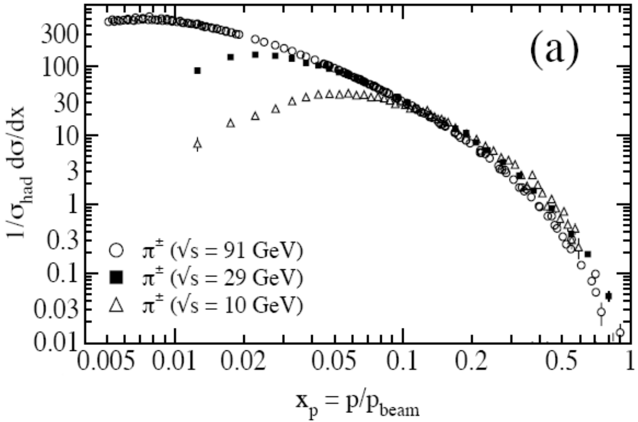
Why are fragmentation functions?

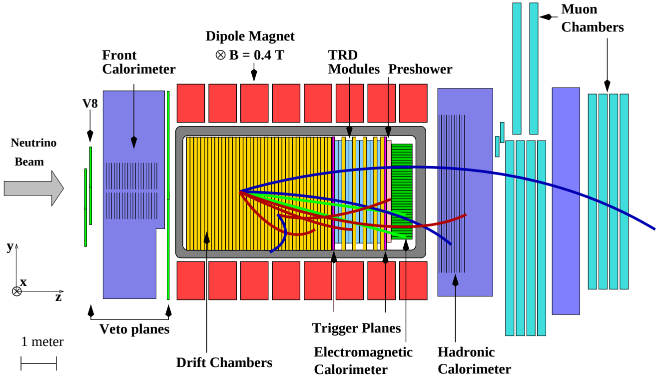
1. NOMAD potentials
   – wide energy spectrum
   provides us study different variables $E_\nu, Q^2, W, x_{B_j}, y$
   – excellent reconstruction and resolution of the individual tracks, good calorimetry
   let us taking good quality of the distributions
   – largest statistics of the neutrino interactions ($\sim$ 1.1M DIS)
   is good chance to get most accurate results
2. Important for theory
   Today exist THREE THEORIES: QEL, RES, DIS
   and no one for just νN (see talk by V.Naumov, O.Teryaev)
   Fundamental ingredients are prepared as model's cuts on Q^2, W

DATA RESULTS EXAMPLE

SLD, TPC, DELPHI, ALEPH, ARGUS, OPAL experiments

$$(e^+e^- \to \gamma/Z^0 \to hX)$$





GOOD QUALITY OF THE PARTICLE IDENTIFICATION

1. Current muon in Muon Chambers
2. Charged particles ($\pi^{\pm}$, p, ...) in Drift Chambers
3. Neutral particles (γ, n, ...) in Electromagnetic Calorimeter
4. Neutral strange particles (K_S^0, Λ, $\bar{\Lambda}$) and photons ($\gamma \rightarrow e^+e^-$) by V-like vertexes
5. Possibility to study $\pi^0 \rightarrow \gamma\gamma$ production

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ANALYSIS FLOW

1. Taking raw data

   is getting reconstructed informations (tracks, deposit energies, ...)

2. MC study

   is calculation of efficiency, smearing, ...
   $\varepsilon(x^{sim})$ - efficiency, $r(x^{rec}, x^{sim})$ - resolution matrix,
   $p(x^{rec})$ - purity

3. DATA unfolding

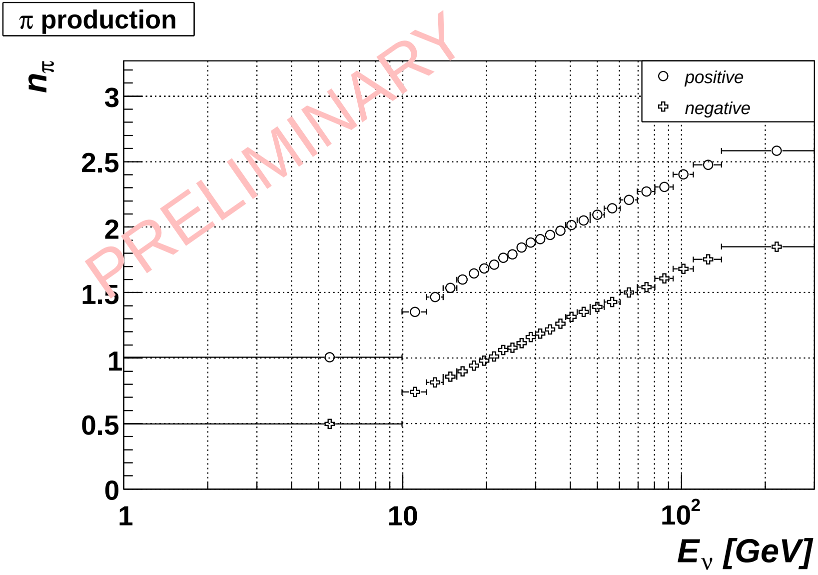
   is correction of raw data $\quad n_{\pi} = \frac{\varepsilon_{\pi}^{-1} r_{\pi}^{-1} p_{\pi}^{-1} N^{rec}(\nu_{\mu} N \rightarrow \mu^{-} \pi X)}{\varepsilon_{\nu cc}^{-1} r_{\nu cc}^{-1} p_{\nu cc}^{-1} N^{rec}(\nu_{\mu} N \rightarrow \mu^{-} X)}$

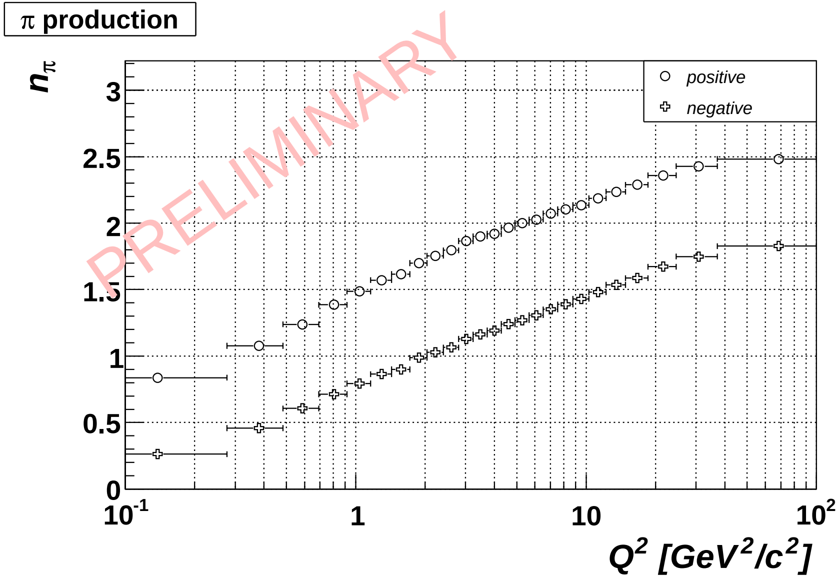
Data selection

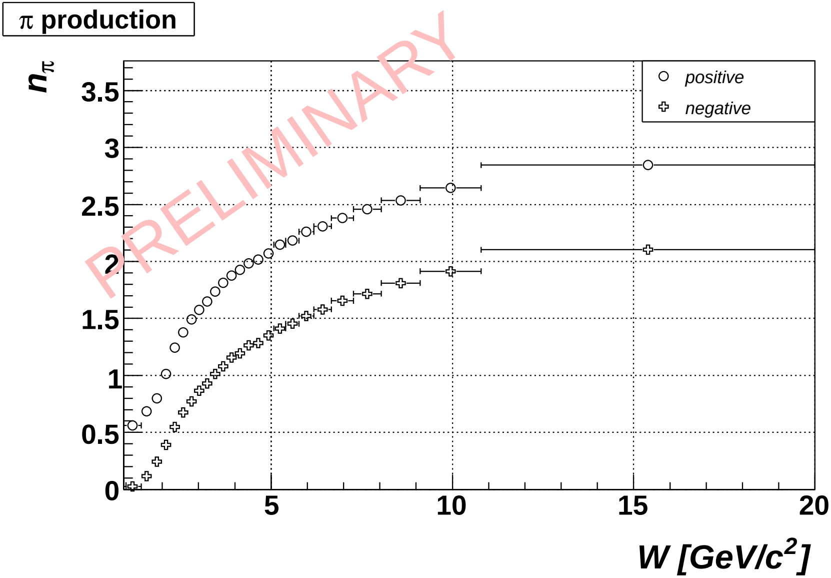
1. Fiducial volume of the Drift Chambers:
   $|x, y| < 120$ cm, $35 < z < 395$ cm
2. No kinematics cuts:
   $E_\nu, Q^2, W, x_{b_j}, y$
3. $\nu_\mu N$ total (QEL, RES, DIS) - DIS to be finished soon
4. Now just 96th years DATA subset ($\sim$ 320k events)

MC

1. NOMAD MC tuned to reproduce yields of π, ρ, K, f^0, ...-mesons, $\Lambda, \bar{\Lambda}, \Sigma$, ...-hiperons (many years of work) in DIS

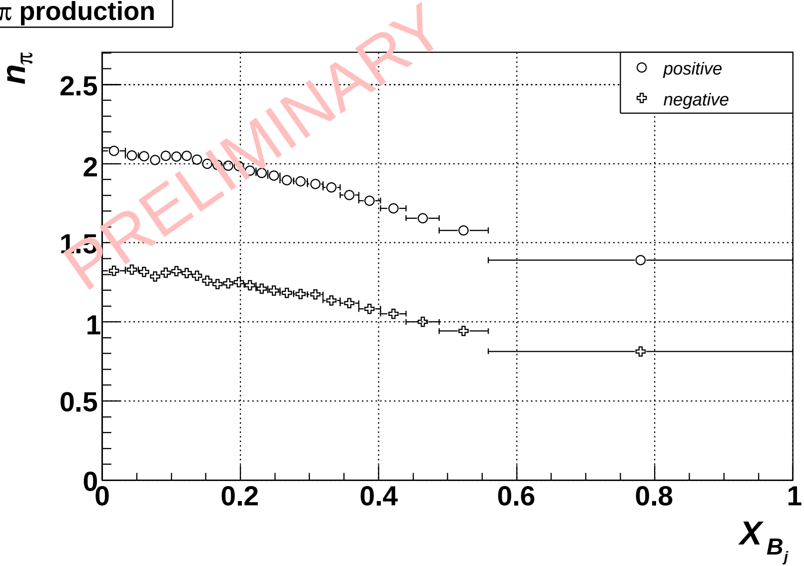

π production
PRELIMINARY
n_π
3
2.5
2
1.5
1
0.5
0
1
10
10^2
E_ν [GeV]
positive
negative

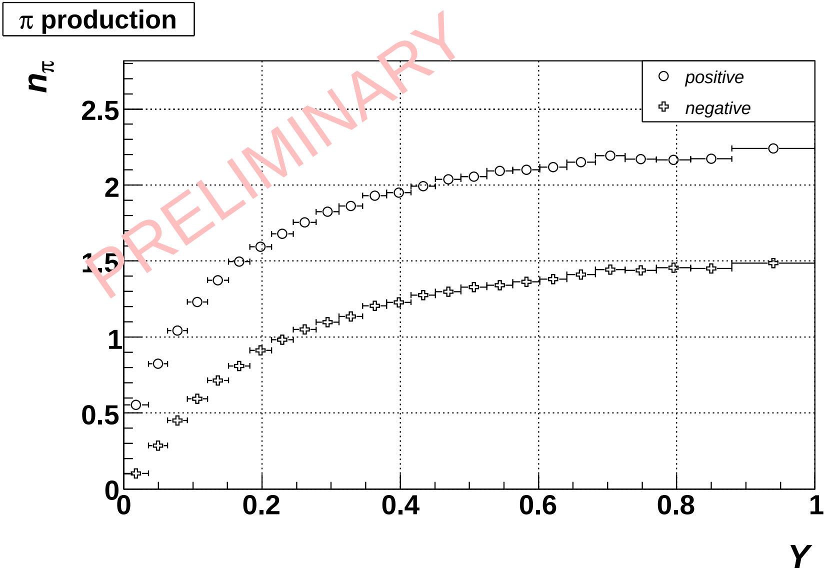

π production
PRELIMINARY
n_π
0
0.5
1
1.5
2
2.5
3
10^{-1}
1
10
10^{2}
Q^2 [GeV^2/c^2]
positive
negative

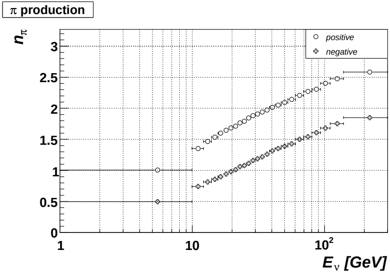


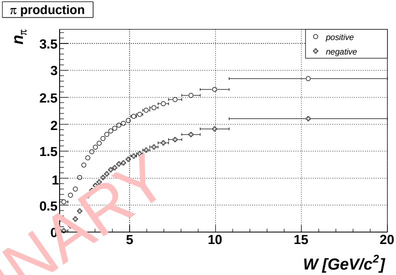
π production
PRELIMINARY
n_π
positive
negative
0
0.5
1
1.5
2
2.5
3
3.5
5
10
15
20
W [GeV/c²]

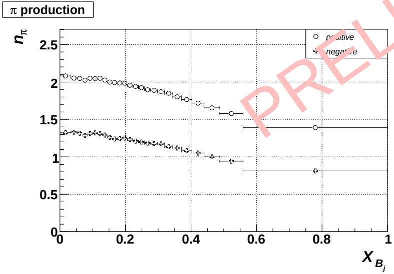
π production

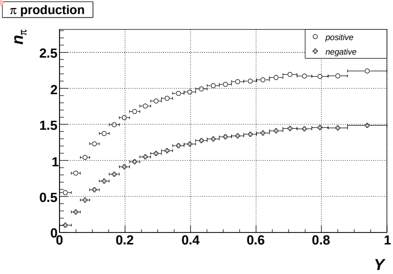


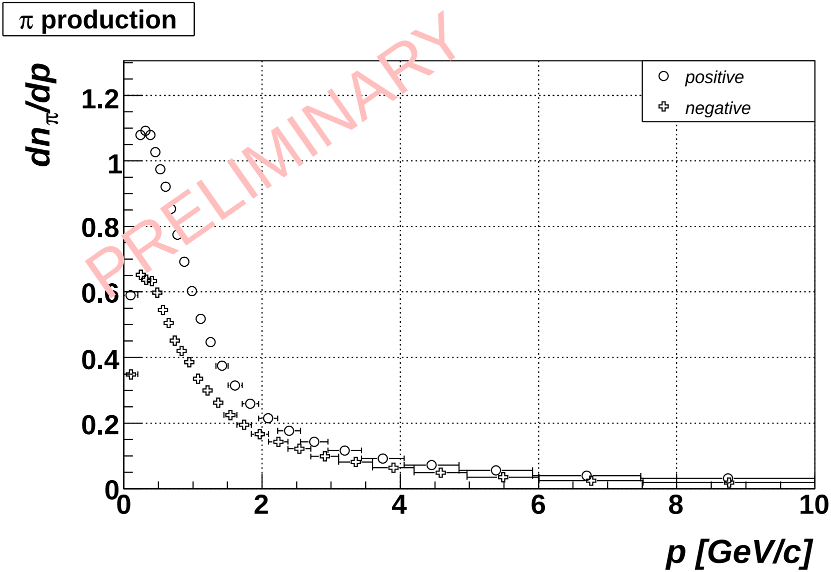

π production
n_π
2.5
2
1.5
1
0.5
0
0.2
0.4
0.6
0.8
1
Y
positive
negative
PRELIMINARY

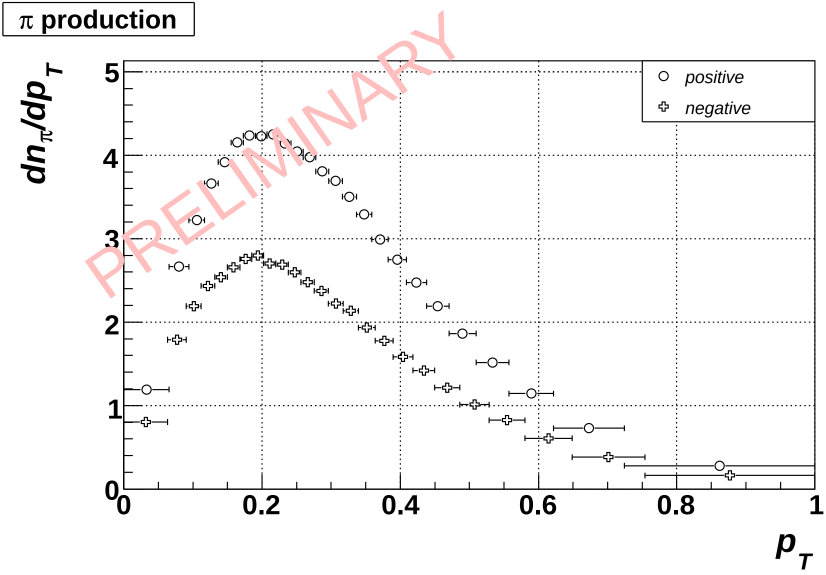

π production
n_π
positive
negative
E_ν [GeV]

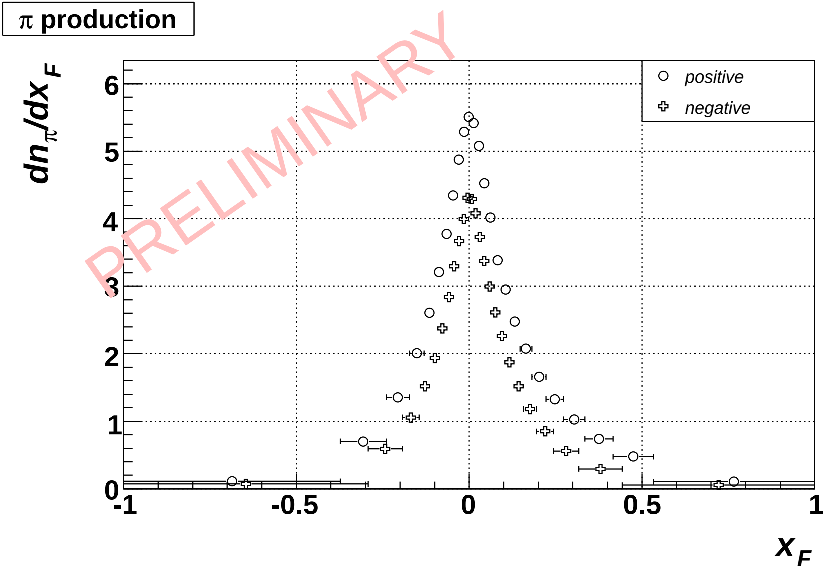

π production
n_π
positive
negative
W [GeV/c^2]

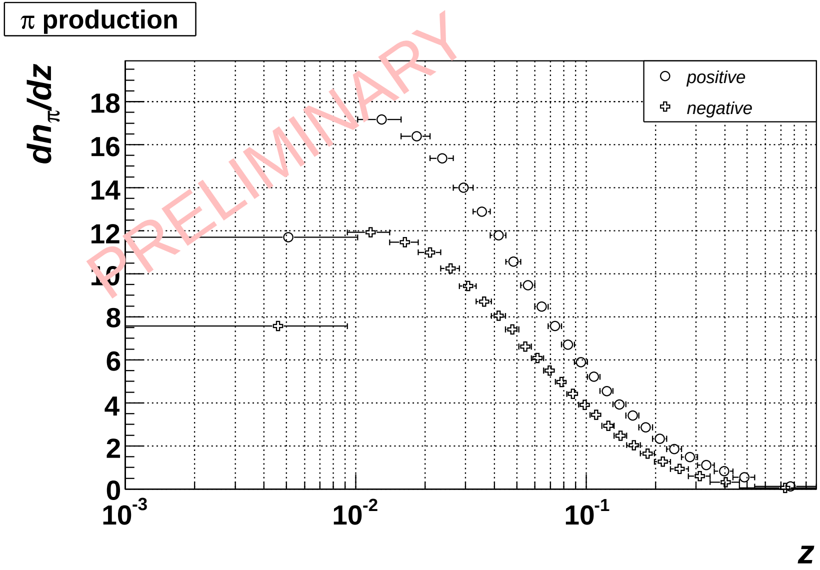

π production
n_π
positive
negative
X_{B_j}

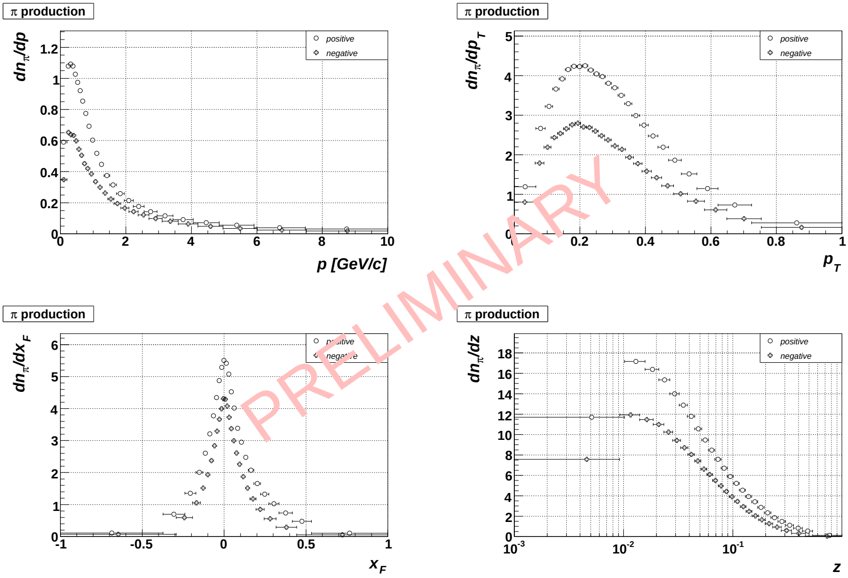

π production
n_π
positive
negative
Y


π production
dn_π/dp
1.2
1
0.8
0.6
0.4
0.2
0
2
4
6
8
10
p [GeV/c]
positive
negative
PRELIMINARY


π production
PRELIMINARY
positive
negative
dn_π/dp_T
p_T
0
1
2
3
4
5
0.2
0.4
0.6
0.8


π production
PRELIMINARY
dn_{π}/dx_F
6
5
4
3
2
1
0
-1
-0.5
0
0.5
1
x_F
positive
negative

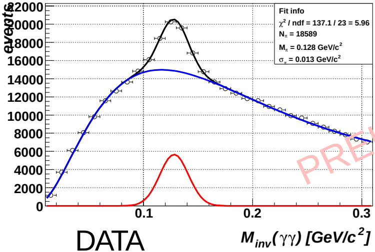

π production
PRELIMINARY
dn_{π}/dz
0
2
4
6
8
10
12
14
16
18
10^{-3}
10^{-2}
10^{-1}
z
positive
negative


π production
dn_{π}/dp
positive
negative
p [GeV/c]
π production
dn_{π}/dp_{T}
positive
negative
p_{T}
π production
dn_{π}/dx_{F}
positive
negative
x_{F}
π production
dn_{π}/dz
positive
negative
z
PRELIMINARY

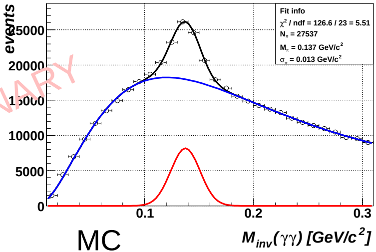
π^0 production

π^0 productions (just integral)

$$n_\pi = \frac{\varepsilon_\pi^{-1} N^{rec}(\nu_\mu N \to \mu^- \pi X)}{\varepsilon_{\nu cc}^{-1} N^{rec}(\nu_\mu N \to \mu^- X)}$$



DATA



MC

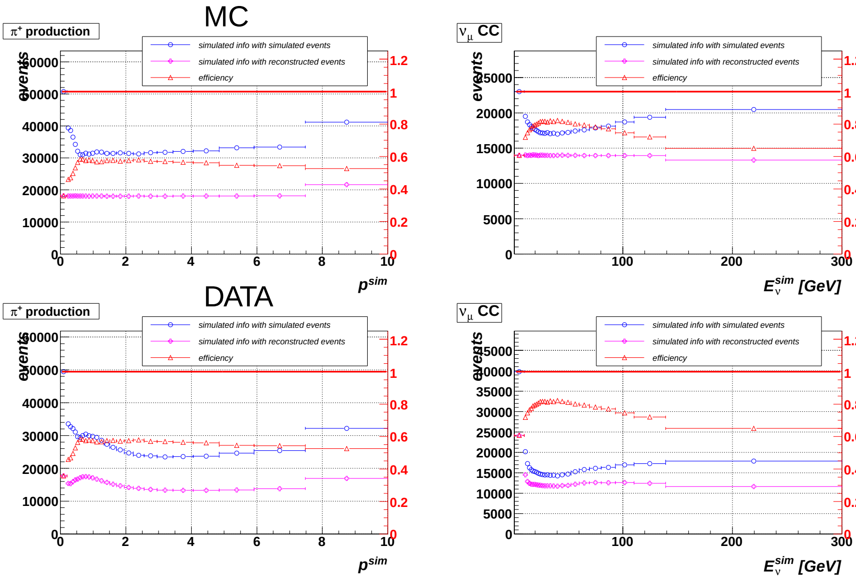
DATA (MC)	π^+	π^-	π^0
n_π	1.86(1.99)	1.17(1.22)	1.32(1.78)

Outline

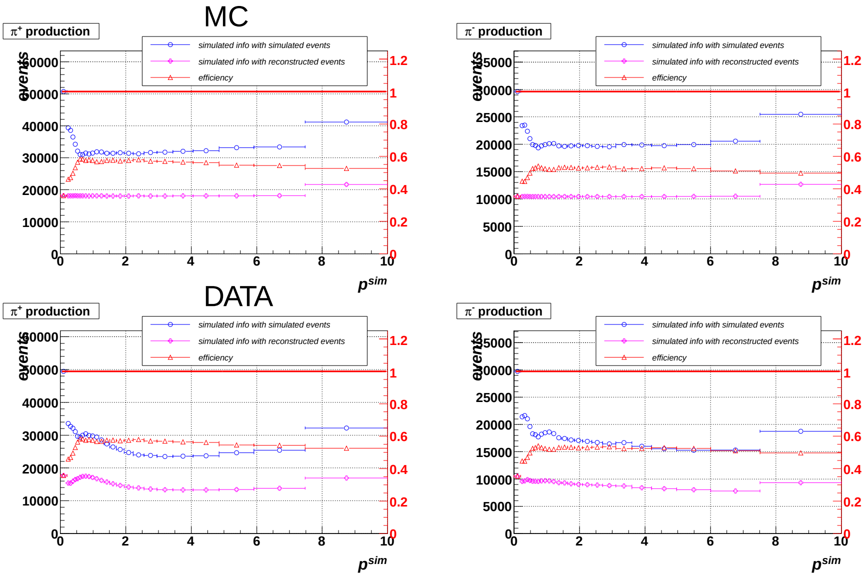
SUMMARY

1. We started to study pion production properties in $\nu_\mu N$ interactions in the NOMAD experiment
2. Based on fragmentation function conception and using 96th year data subset we got preliminary $\pi^\pm$-mesons yields as functions of kinematics variables $E_\nu, Q^2, W, x_{B_j}, y$ and fragmentation variables x_F, z, p_T, p in $\nu_\mu N$ total
3. We got integral production of π^0-meson and compared it with the same of $\pi^\pm$-mesons
4. We plan to get π^0-meson yields, study DIS and select RES from total $\nu_\mu N$ interactions

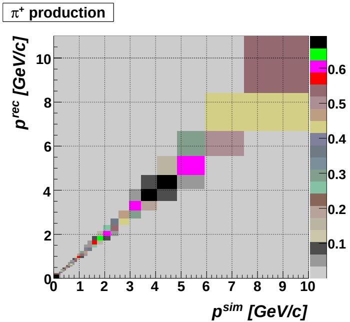
EFFICIENCY

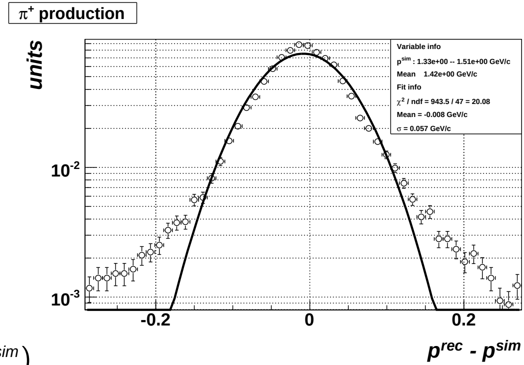

MC
π^+ production
events
simulated info with simulated events
simulated info with reconstructed events
efficiency
p^{sim}
ν_μ CC
E_ν^{sim} [GeV]
DATA
π^+ production
ν_μ CC

EFFICIENCY


MC
DATA
π+ production
π- production
simulated info with simulated events
simulated info with reconstructed events
efficiency
events
p^sim

RESOLUTION

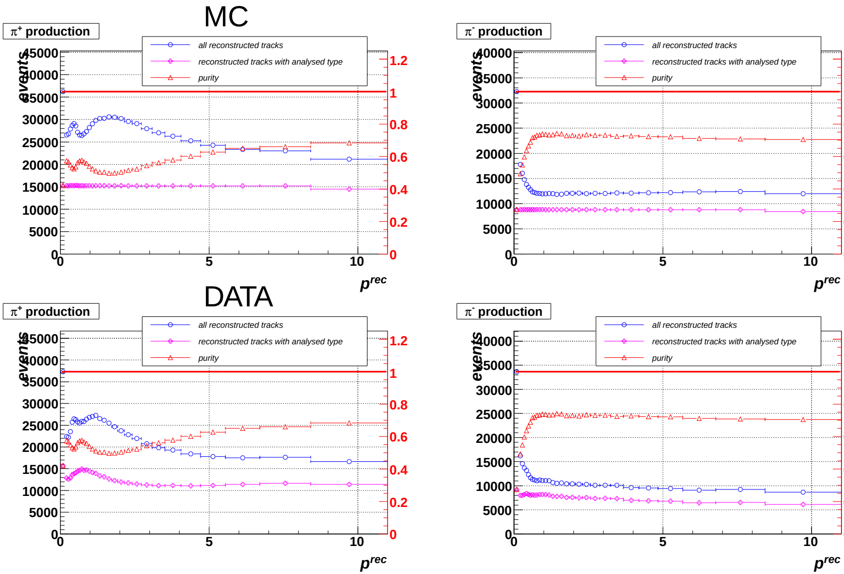




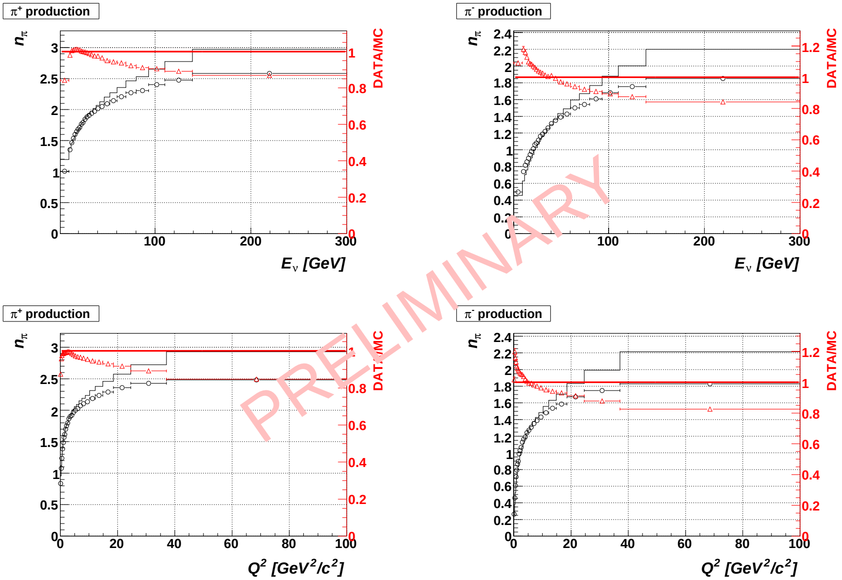
$$f^{rec}(p^{rec}) = r(p^{rec}, p^{sim}) \cdot f_{\varepsilon}^{sim}(p^{sim})$$

An example of one slice

PURITY

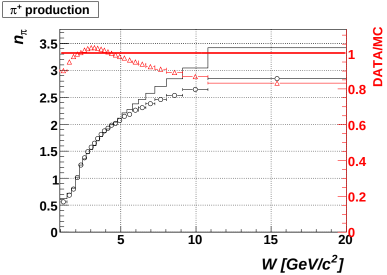

MC
DATA
π^+ production
π^- production
all reconstructed tracks
reconstructed tracks with analysed type
purity
events
p^{rec}
0
5
10
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
0.2
0.4
0.6
0.8
1
1.2

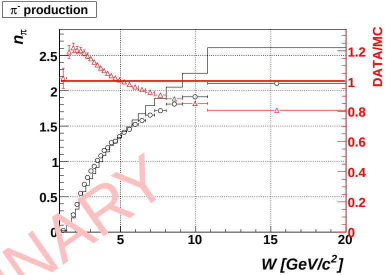
DATA vs MC



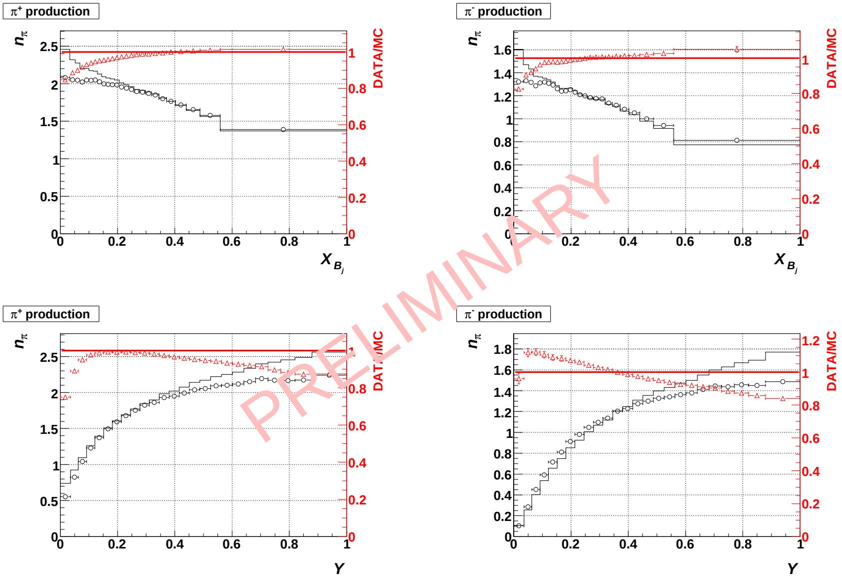
π^+ production
π^- production
n_π
DATA/MC
E_ν [GeV]
π^+ production
π^- production
Q^2 [GeV^2/c^2]
PRELIMINARY

DATA vs MC

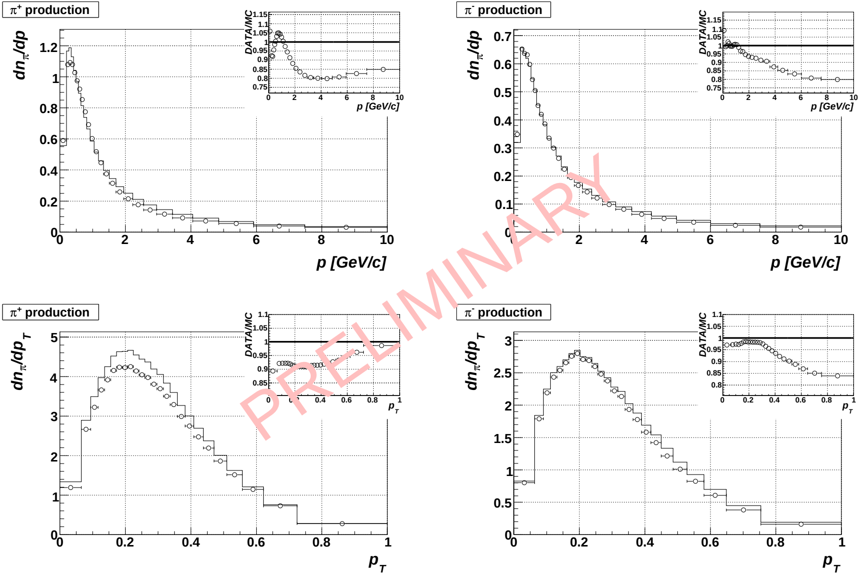

π^+ production
n_π
DATA/MC
W [GeV/c^2]


π^- production
n_π
DATA/MC
W [GeV/c^2]

DATA vs MC

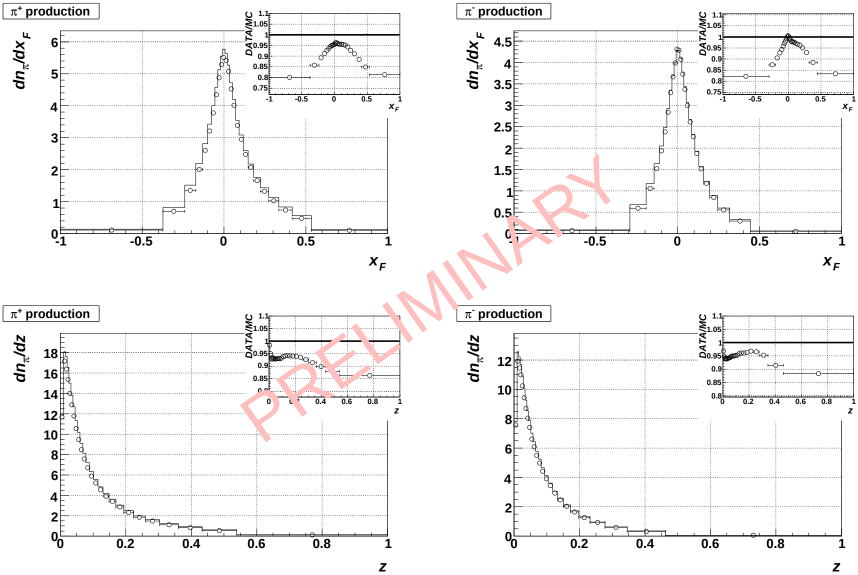

π^+ production
n_π
DATA/MC
X_{B_j}
π^- production
n_π
DATA/MC
X_{B_j}
π^+ production
n_π
DATA/MC
Y
π^- production
n_π
DATA/MC
Y
PRELIMINARY

DATA vs MC



π^+ production
dn_π/dp
DATA/MC
p [GeV/c]
π^- production
dn_π/dp
DATA/MC
p [GeV/c]
π^+ production
dn_π/dp_T
DATA/MC
p_T
π^- production
dn_π/dp_T
DATA/MC
p_T
PRELIMINARY

DATA vs MC



π+ production
π- production
dn_π/dx_F
x_F
DATA/MC
dn_π/dz
z
PRELIMINARY