The inclusive production of the meson resonances $\rho^0(770)$, $K^*(892)$, $f_0(980)$, $f_2(1270)$ in neutrino-nucleon interactions

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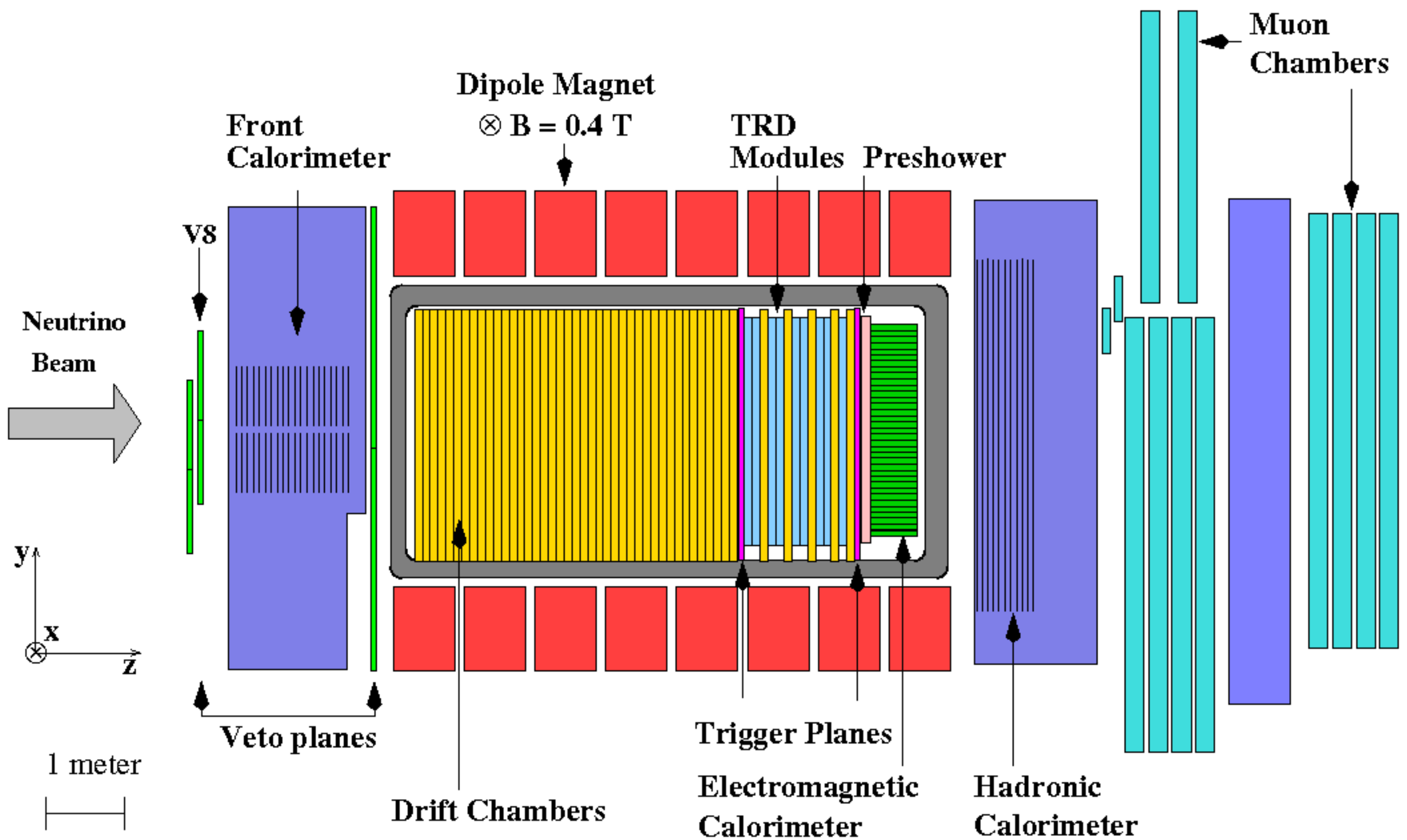
The inclusive production of the meson resonances $\rho^0(770)$, $K^*(892)^{\pm}$, $f_0(980)$, $f_2(1270)$ in neutrino-nucleon charged current (CC) interactions has been studied with the NOMAD detector exposed to the wide band neutrino beam generated by 450-GeV protons at CERN-SPS.

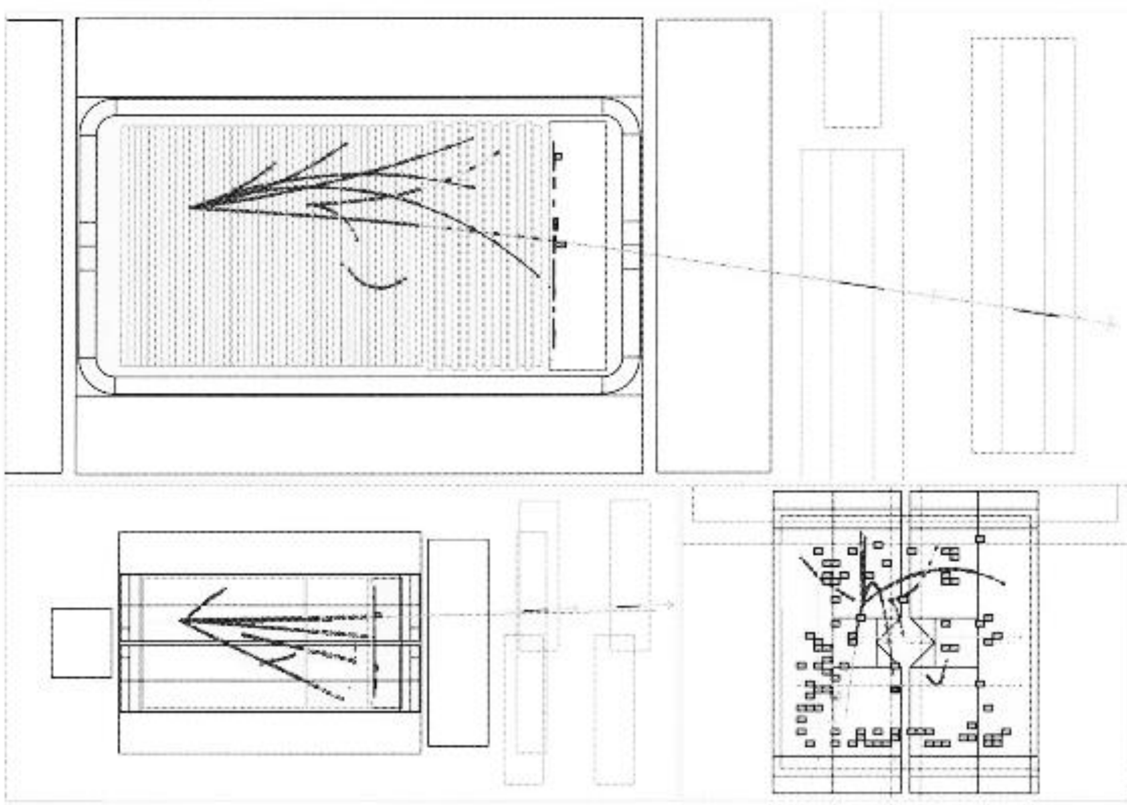
NOMAD detector



47 drift chambers, 2.7 tons

Typical νCC event

The main goal of the NOMAD experiment was the search $\nu_\mu \rightarrow \nu_\tau$ oscillation.
ν_τCC interactions identified by using kinematical criteria. This required a very good quality of event reconstruction.



NOMAD experiment

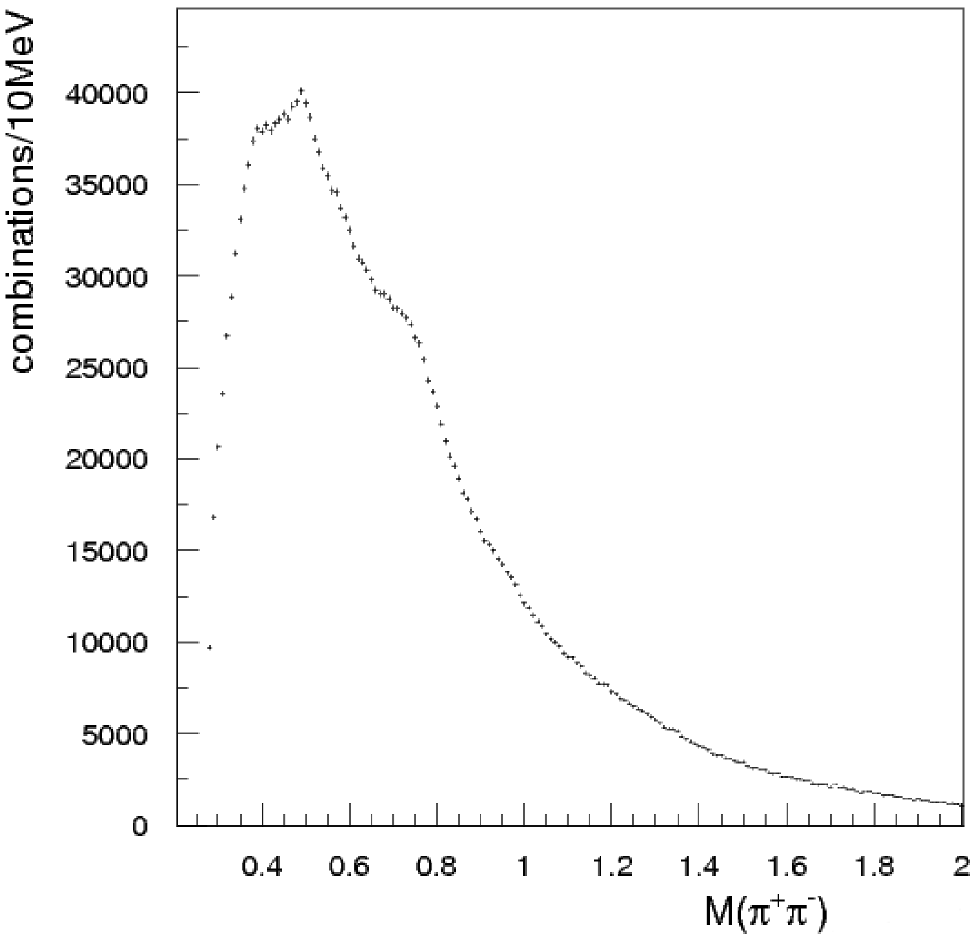
The present analysis is based on the full sample of data of NOMAD.

A neutrino event was selected for processing if

- the primary vertex is inside the following fiducial volume:
  $|X, Y| < 120$cm, 10cm $< Z < 390$cm;
- there was an identified muon at the primary vertex with momentum $p_\mu > 3$GeV/c
- the invariant mass of the hadronic system W was higher than 2 GeV;
- there were at least 3 tracks (including muon) at the primary vertex;
- the event should be measured with reasonable accuracy (ΔEvis/Evis < 30%);

After cuts we obtain 667252 ν_μCC 15927 $\bar{\nu}_\mu$ CC

In this analysis the Monte Carlo (MC) simulation software is based on the LEPTO6.1 - JETSET7.4 -Geant321.



Raw distribution of the invariant π+π- mass in ν_μCC sample.

Signal extractoin

$$\frac{dN}{dm} = [1 + a_1 BW_{\rho}(m) + a_2 BW_{f_0}(m) + a_3 BW_{f_2}(m)]BG(m).$$

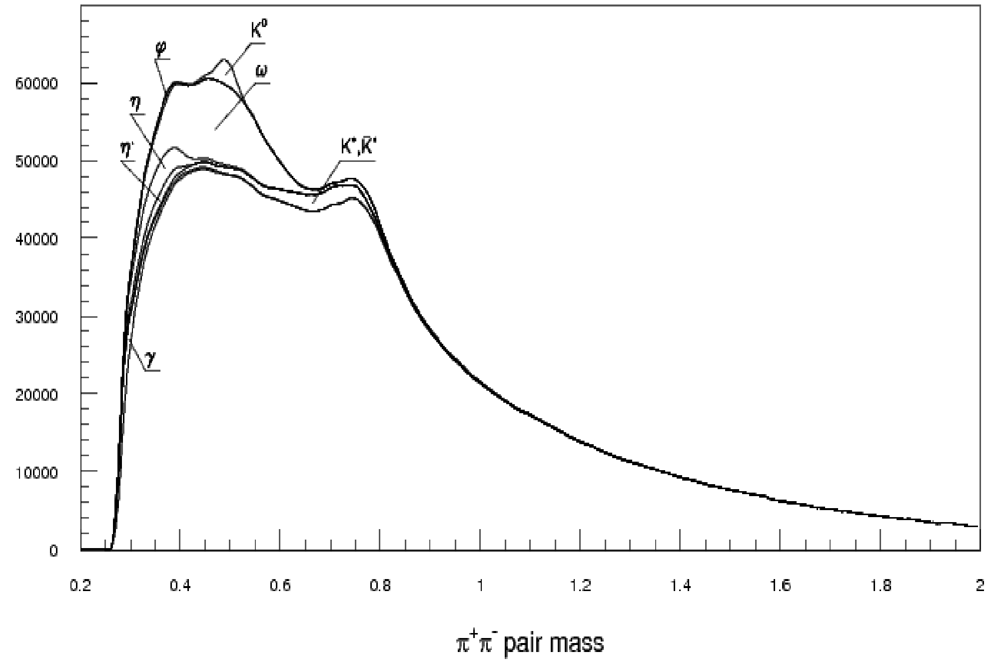
$$BW = \frac{m}{k}\frac{m_R \Gamma'_R}{(m^2 - m_R^2)^2 + m_R^2 \Gamma'^2_R}$$

$$\Gamma'_R = \Gamma_R(\frac{k}{k_R})^{2L+1}\frac{m_R}{m}$$

$$BG = a_4(m - 2m_\pi)^{a_5} exp(a_6 m + a_7 m^2 + a_8 m^3),$$

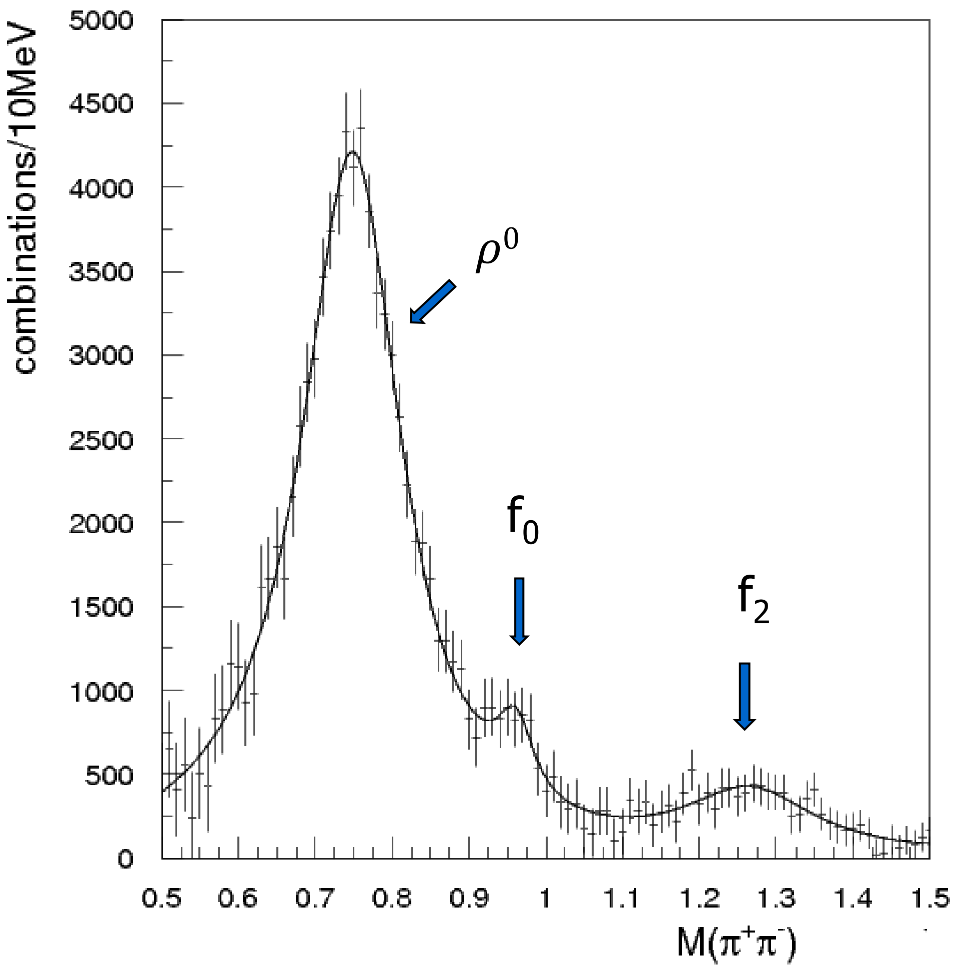
Reflectoins

Reflections are contributions to the $\pi^+ \pi^-$ – invariant mass distribution from resonances decaying to $\pi^+ \pi^-$ + some other particles or contributions from events where not all the particles of a resonance decay are correctly identified and thus a wrong mass is assigned to them.



$\omega \rightarrow \pi^+ \pi^- \pi^0$

After the combinatorial background subtraction



Masses and widths

NOMAD:

Resonance	Branching ratio π+π-	Number of resonances	Average multiplicity	Mass(MeV)	Γ (MeV)
$\rho^0(770)$	1.000	130368±4336	0.195±0.007	768±2	151±7
$f_0(980)$	0.666	11809±1965	0.018±0.003	963±5	35±10
$f_2(1270)$	0.564	25189±3958	0.038±0.006	1286±9	198±30

PDG:

$\rho^0(770)$	769.3±0.8	152±0.8
$f_0(980)$	980±10	40 to 100
$f_2(1270)$	1275±1.2	184.3±3.4

Previous neutrino experiments

BEBC WA21

15752 νp CC events

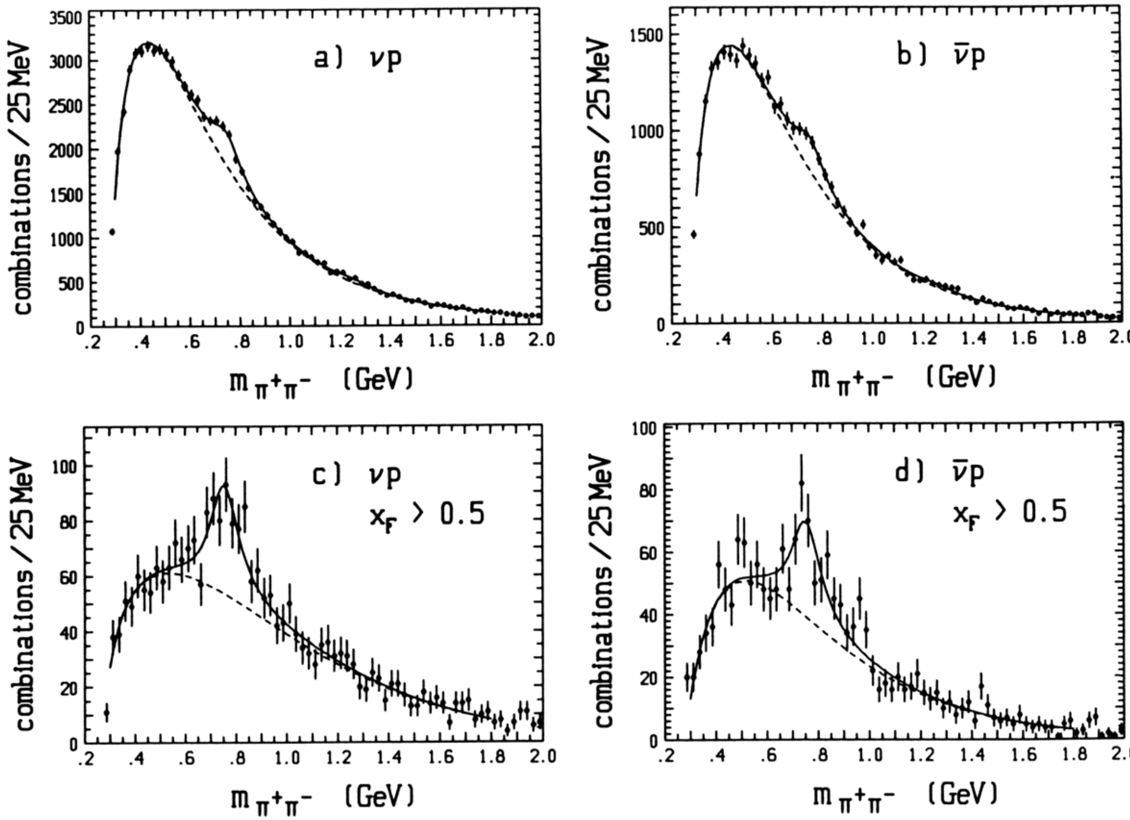
10452 $\bar{\nu}$p CC events

$N\rho_0 = 2838 \pm 245 \pm 340$

$< \rho_0 > = 0.180 \pm 0.016 \pm 0.022$

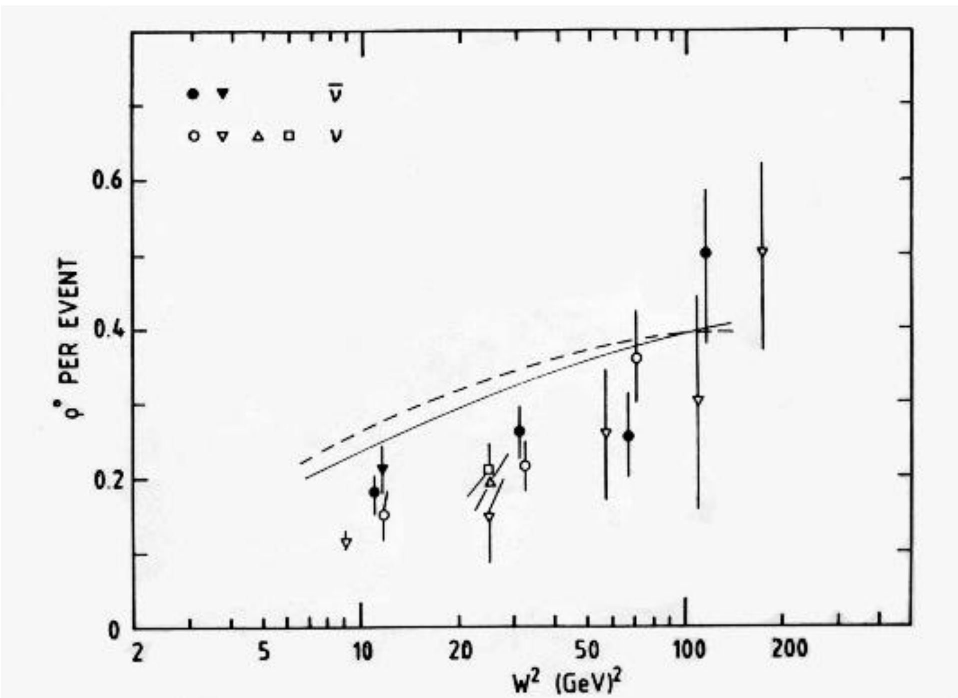
$N_{f_2} = 615 \pm 226$

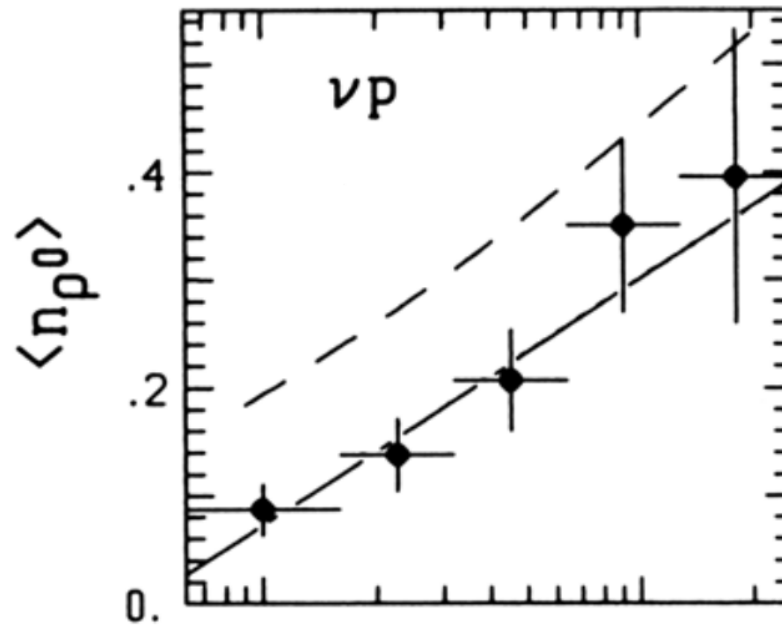
$<f_2> = 0.047 \pm 0.017$



Previous neutrino experiments

All the previous experiments observed an overestimation of the average multiplicities of $\rho^0(770)$ by the Lund model by 50-70%, while the shapes of the Lund distributions were in agreement with the experimental distributions.





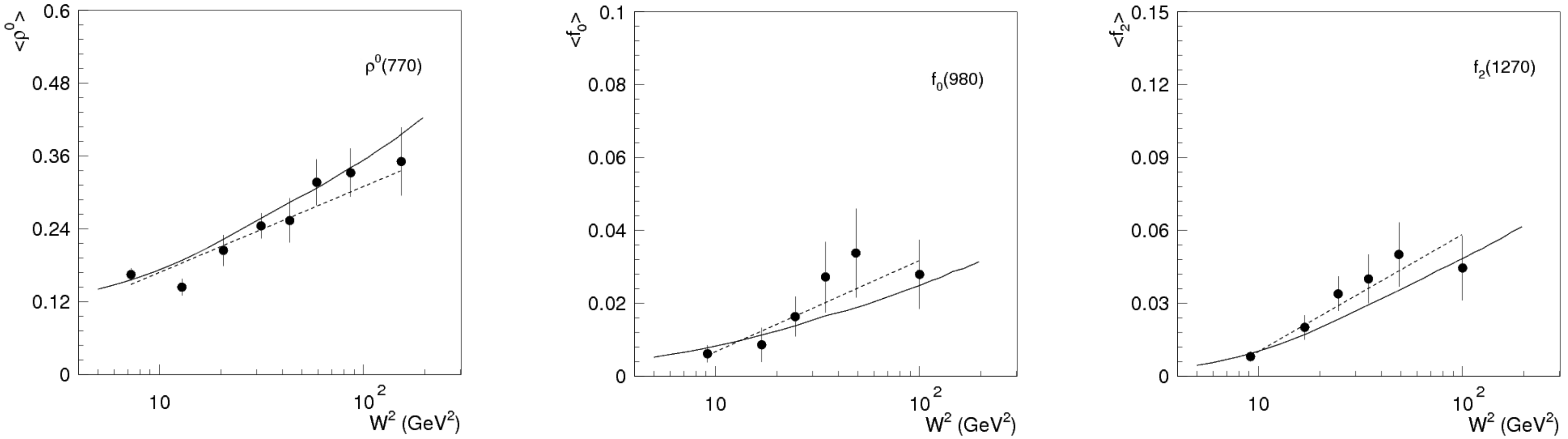
1986.

BEBC WA21 1991.

W^2 distribution

$W^2 = m^2 + 2m\nu - Q^2$ – the hadronic invariant mass squared.

$\nu = E_\nu - E_\mu$

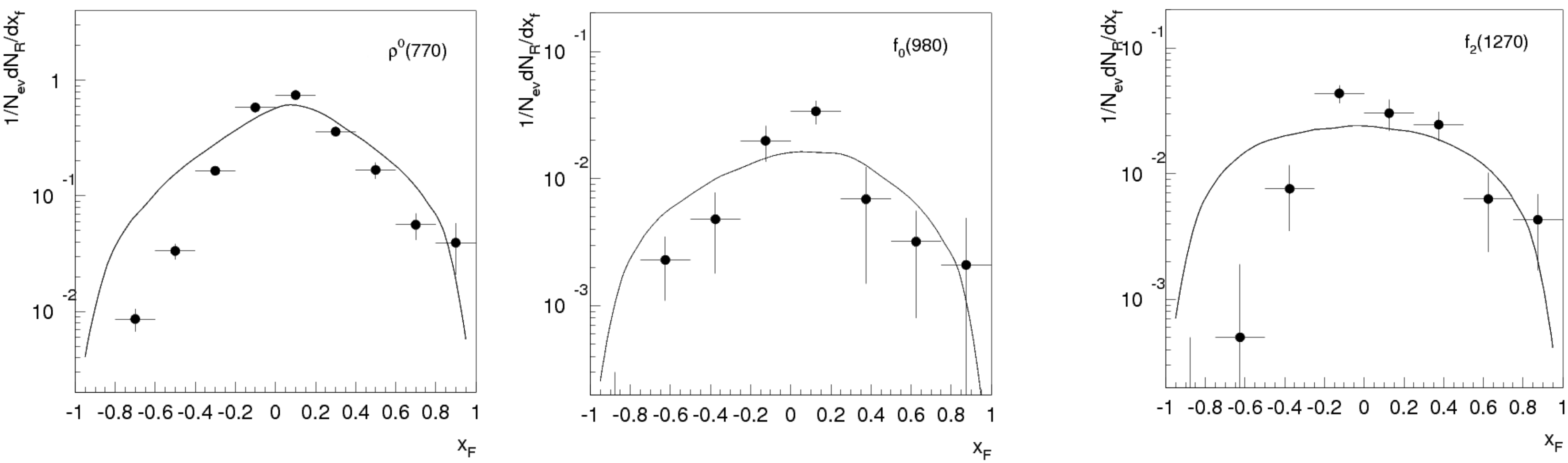


The solid line represents the result of the Lund simulation.

The dashed line represent a fitted function $a+b\times\ln W^2$

x_F distribution

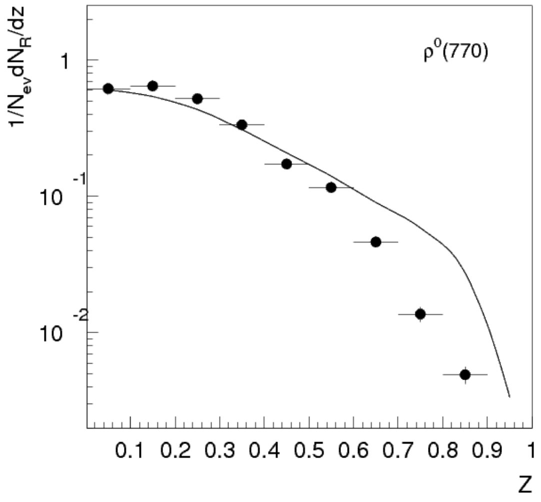
$x_F = 2p_L^*/W$

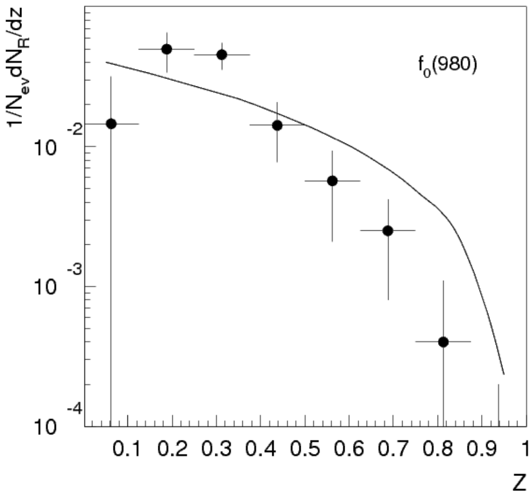


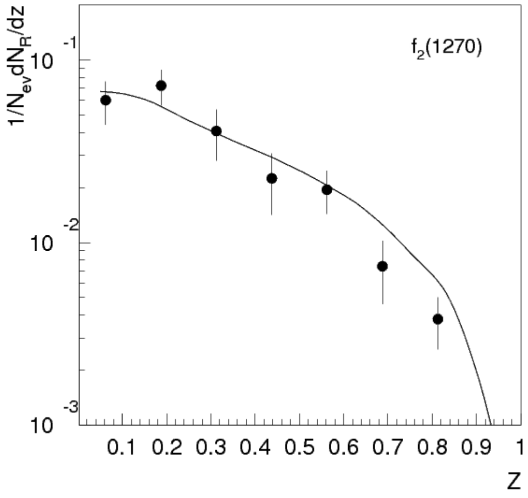
Forward production of ρ^0 (770) and $f_2(1270)$ is stronger than the backward production.

Z distribution

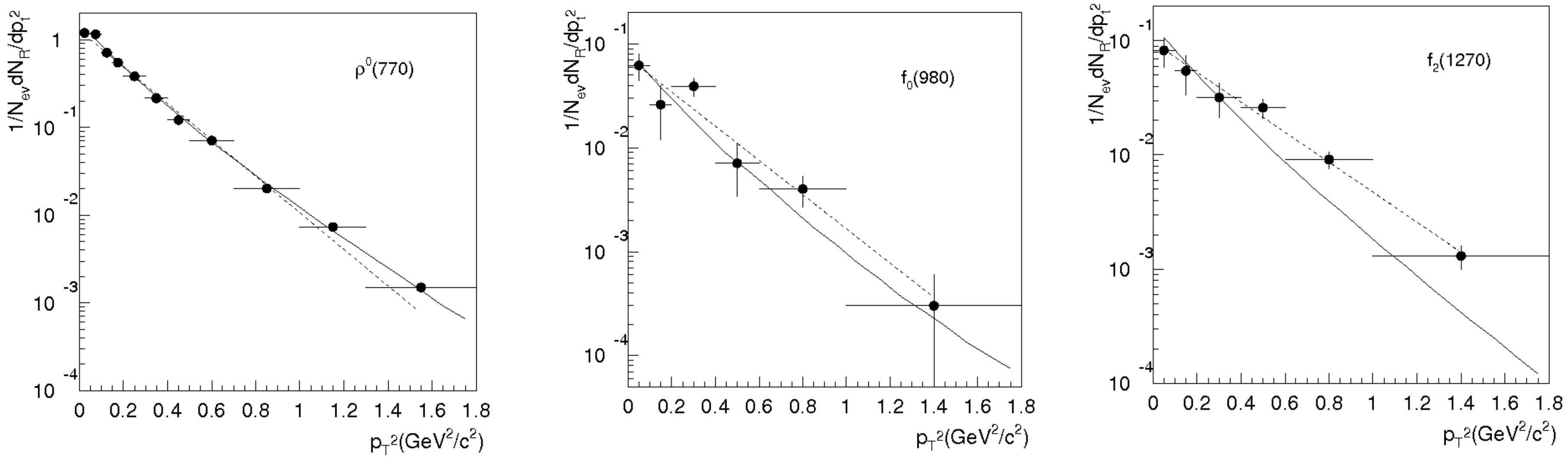
$Z = E_\rho / E_{hadr}$







P_T^2 distribution



The solid line represents the result of the Lund simulation.

The dashed straight line represents the result of the fit by the exponent function.

A fit performed in the range

$p^2_T < 0.5(GeV/c)2$gives the following result:

$b = (5.33 \pm 0.19)(GeV/c)^{-2}$.

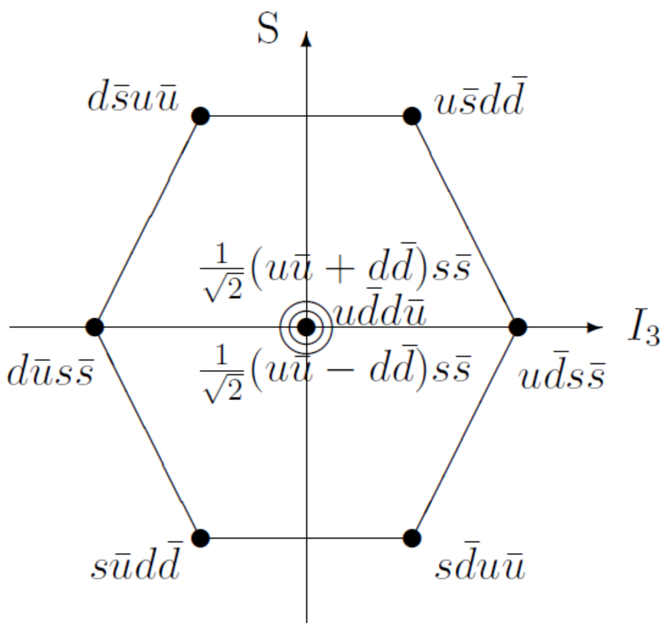
$p^2{}_T > 0.5(GeV/c)2$ we obtain values:

$b = (4.12 \pm 0.12)(GeV/c)^{-2}$.

Compared to other mesons within its mass region the $f_0(980)$ has a small total width and a low partial width to γγ.

A number of nonstandard interpretations of the $f_0(980)$ state were suggested:

- one approach regards the $f_0(980)$ as four quark bound state [1].
- Jaffe had combined $f_0(980)$, $a_0(980)$, $f_0(470)$, $K^*(700)$ to form a nonet tetraquark states.



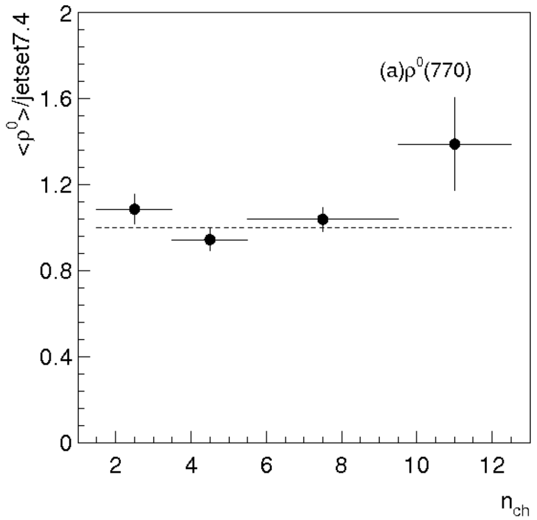
$f_0, a_0 = n\bar{n}s\bar{s}, \quad 980$ MeV

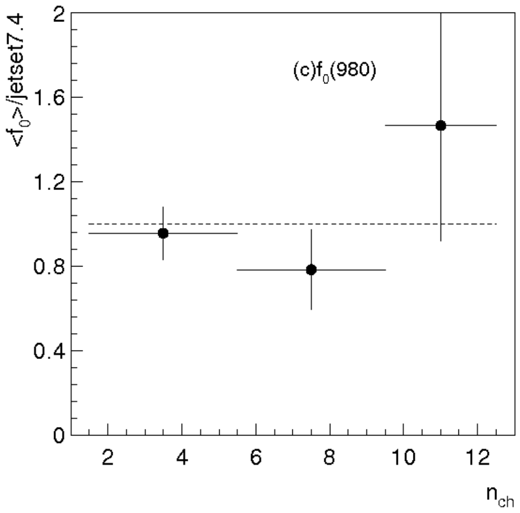
$\kappa = n\bar{s}n\bar{n}, \quad \sim 810$ MeV

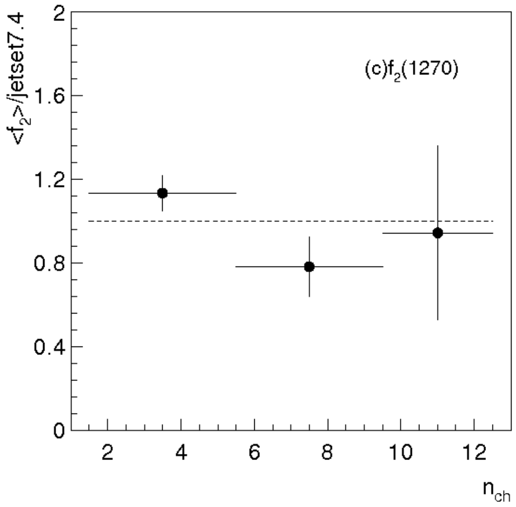
$\sigma = n\bar{n}n\bar{n}, \quad 650$ MeV

- K^+K^- molecule states.
- D. Robson proposed an interpretation of the $f_0(980)$ as scalar glueball.
- V.N.Gribov has proposed a theory of confinement in QCD, in which the $f_0(980)$ plays a special role of a novel vacuum scalar state.
  F.E. Close et al. noticed that signature of Gribov's vacuum scalar states would be a large yield in low multiplicity events.

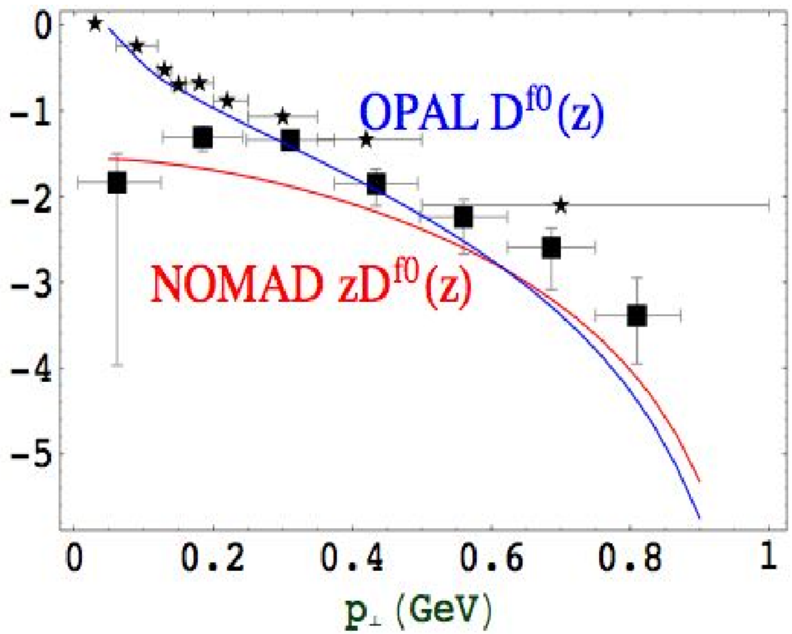
Gribov theory verification

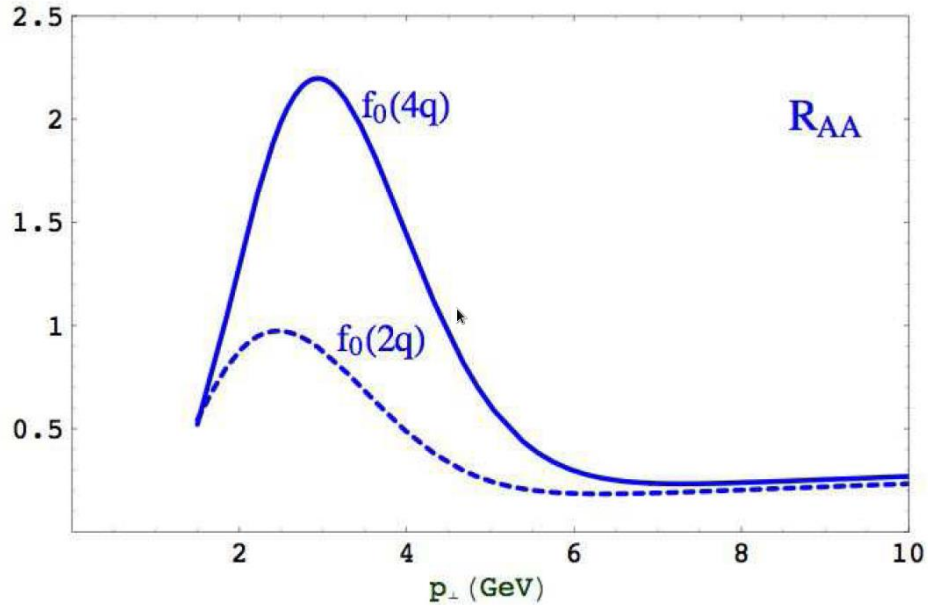






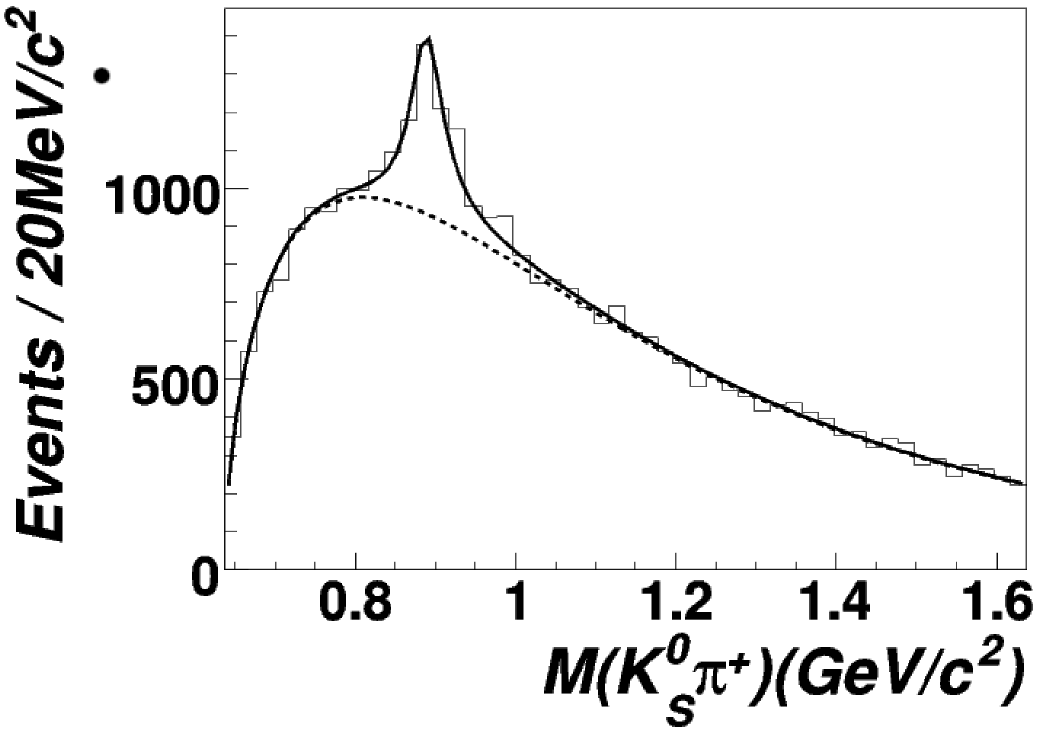
L. Maiania, et al.   arXiv:hep-ph/0606217





R_{AA} - nuclear modification factor

$K^*(892)^+$

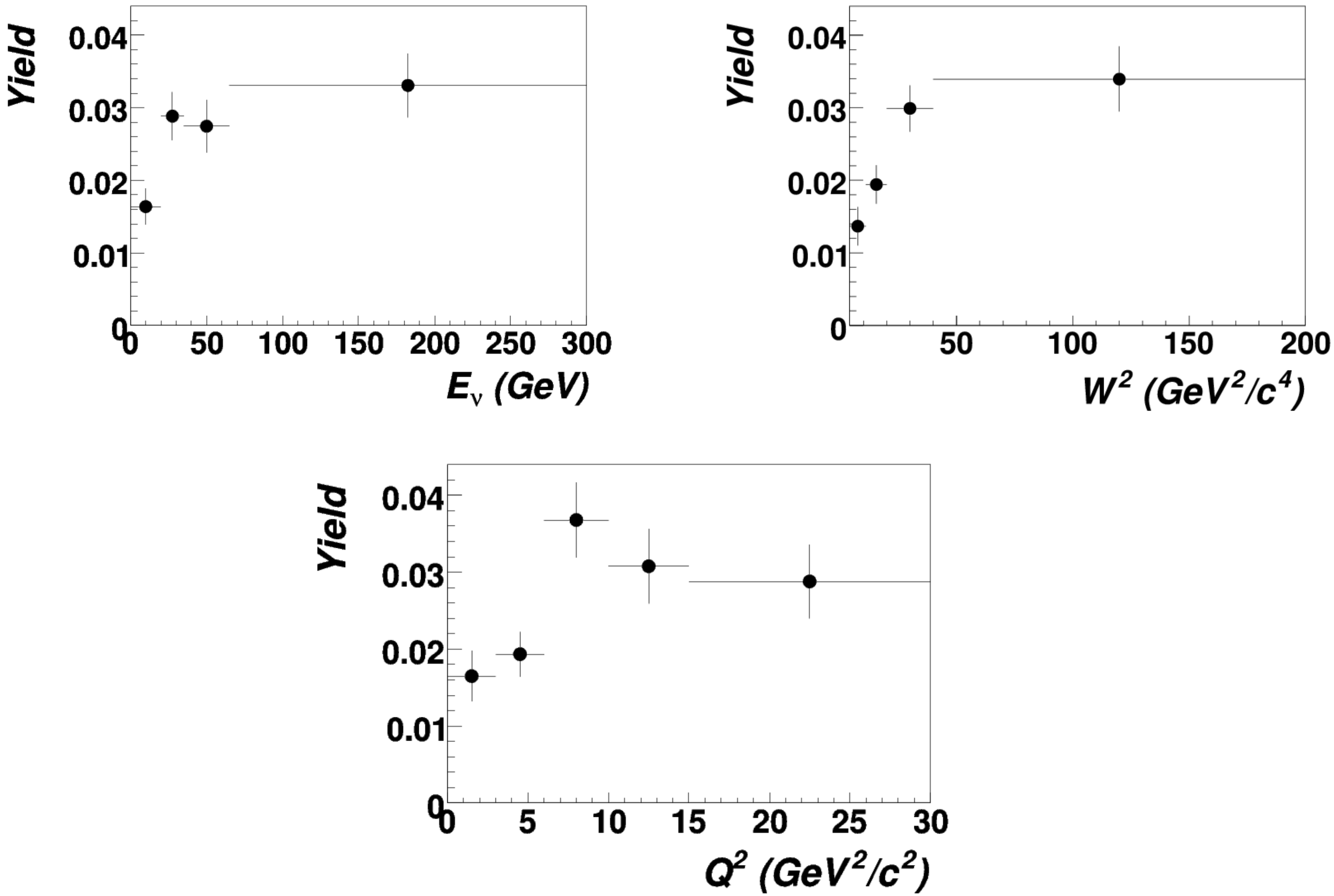


$N_{K^{*+}} = 26676 \pm 1784 \pm 1863$

$K^*(892)^+ \rightarrow K^0 + \pi^+$

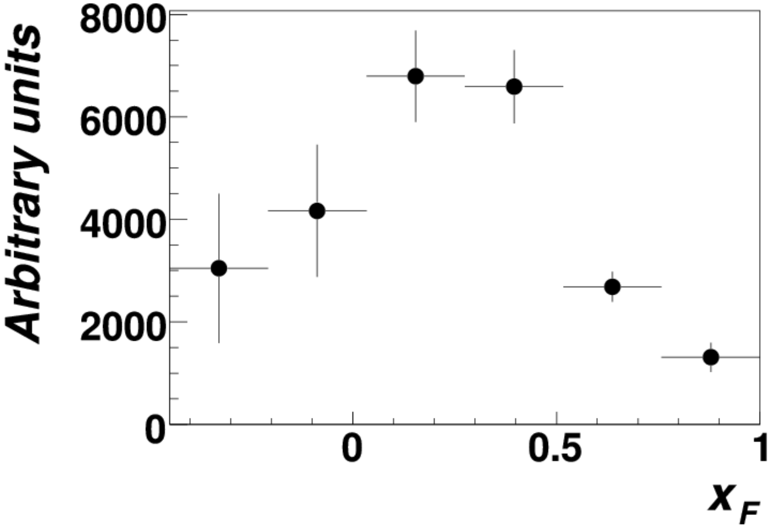
$\langle K^{*+} \rangle = 0.026 \pm 0.002 \pm 0.002$

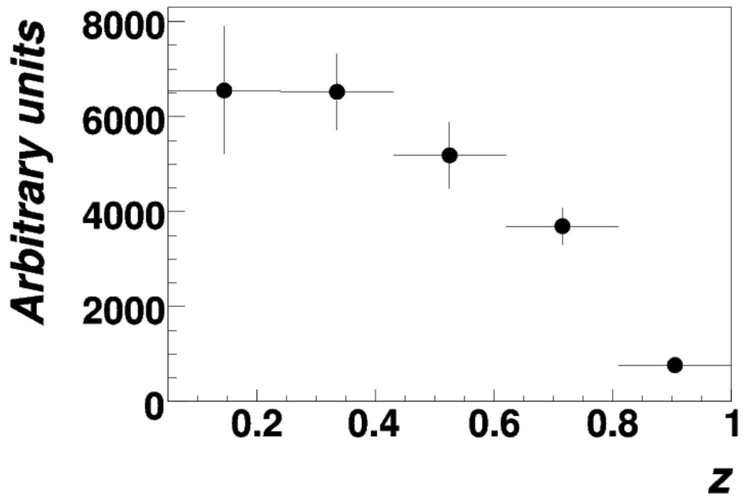
K*(892)+

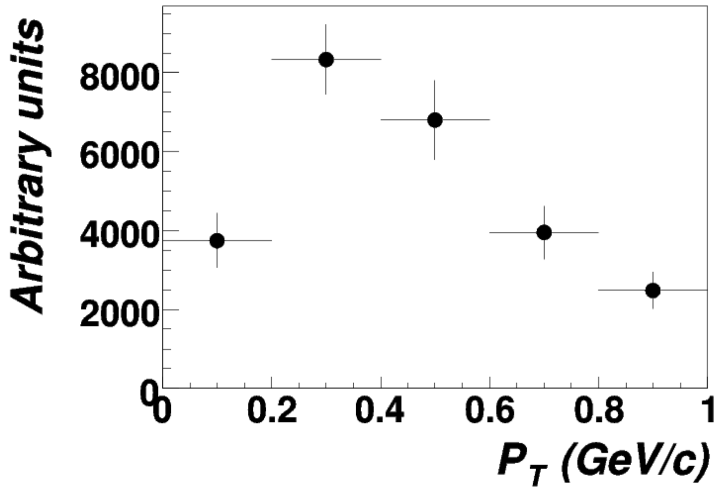


For K*+ (892) we present the dependencies of production yields for the same kinematic variables.

$K^*(892)^+$


Arbitrary units
8000
6000
4000
2000
0
0
0.5
1
x_F


Arbitrary units
8000
6000
4000
2000
0
0.2
0.4
0.6
0.8
1
z

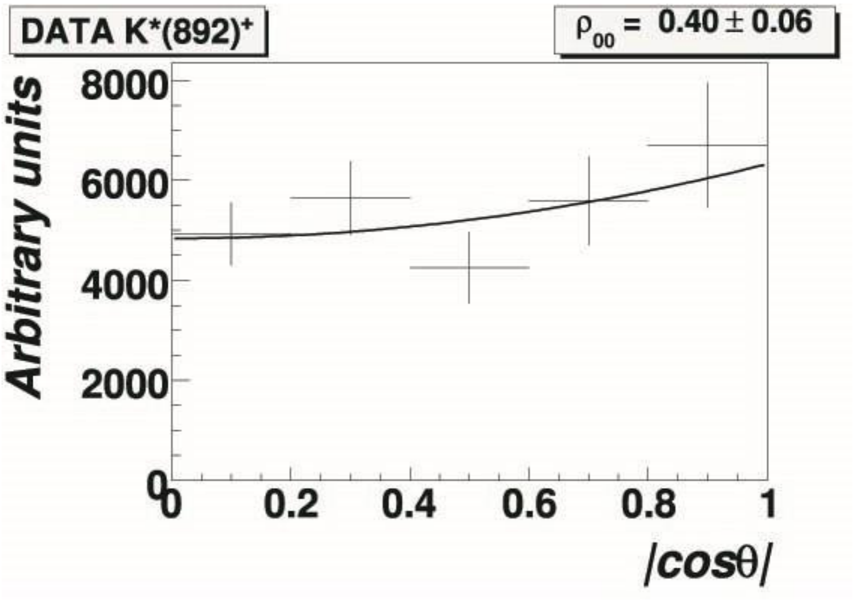

Arbitrary units
8000
6000
4000
2000
0
0
0.2
0.4
0.6
0.8
1
P_T (GeV/c)

$K^*(892)^+$

Matrix element of spin density matrix for K^{*+} (892) meson have been measured

$$\rho_{00} = 0.40 \pm 0.06(\text{stat}) \pm 0.03(\text{syst.})$$

Result are in agreement within errors with the $\rho_{00} = 1/3$, which corresponds to no spin alignment for this meson.



Conclusion

- The inclusive production of the meson resonances $\rho^0(770)$, $K^*(892)^\pm$, $f_0(980)$, $f_2(1270)$ in neutrino-nucleon charged current (CC) interactions has been studied with the NOMAD detector exposed to the wide band neutrino beam generated by 450-GeV protons at CERN-SPS.
- For the first time the $f_0(980)$, K^* (892) mesons are observed in neutrino interactions. The significance of its observation is more than 5 standard deviations.
- The presence of $f_2(1270)$ in the neutrino interactions is reliably established.
- The average multiplicity of all these resonances is measured as a function of several kinematic variables. The experimental results are compared to the multiplicities obtained from a simulation based on the Lund model.
- Matrix element of spin density matrix for K^* (892) meson have been measured.

- We checked the dependence on the hadron jet multiplicity in our W range for $f_0(980)$ against the predictions of the model of Gribov. We see no evidence of the enhanced $f_0(980)$ production in low multiplicity events.
- For $K^*(892)$ we present the dependencies of production yields for the same kinematic variables.
- Matrix element of spin density matrix for $K^{*+}(892)$ meson have been measured

$$\rho_{00} = 0.40 \pm 0.06(\text{stat}) \pm 0.03(\text{syst.})$$

Result are in agreement within errors with the $\rho_{00} = 1/3$, which corresponds to no spin alignment for this meson.