Precision measurements by NOMAD

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(on behalf of NOMAD Collaboration)

JINR

LOMONOSOV CONFERENCE ON ELEMENTARY
PARTICLE PHYSICS.
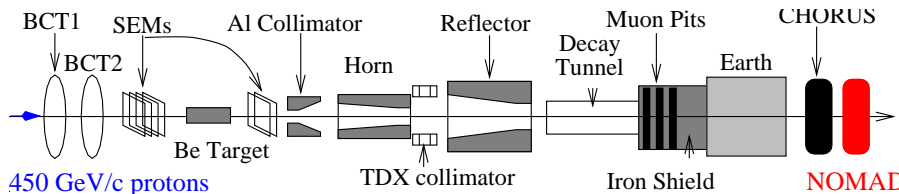21/08/2009

Outline

Neutrino Oscillation MAgnetic Detector
Neutrino beam

- Primary goal: $\nu_\mu \to \nu_\tau$ oscillations with $\Delta m^2 \geq 5eV^2$ (best cosmological guess at that time)
- Data taking 1994-1998
- Neutrino and Anti-Neutrino modes
- Two dedicated detectors: CHORUS and NOMAD
- NOMAD was 835 m from the Be target and 620 m from the decay region

Neutrino **O**scillation **MA**gnetic **D**etector
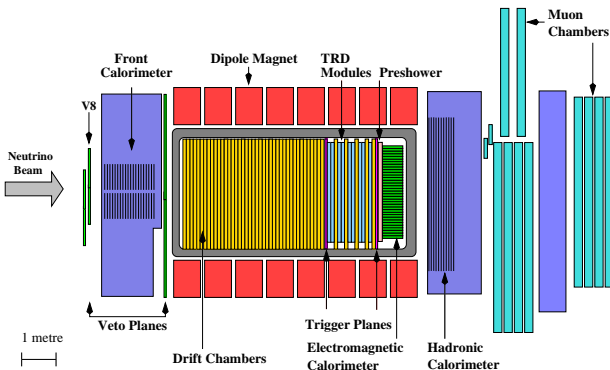**Neutrino beam**
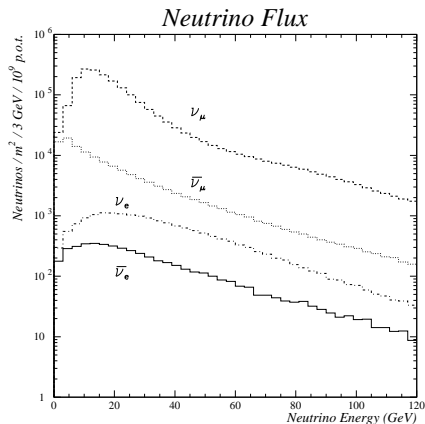
Neutrino Flux

- $\nu_\mu, \bar{\nu}_\mu, \nu_e, \bar{\nu}_e$
- $1 < E_\nu < 300$ GeV
- $\pi^\pm$ and $K^\pm$ by the SPY experiment constrained neutrino flux predictions

	$\langle E_\nu \rangle$	Rel.Abund.
ν_μ	23.6	1.000
$\bar{\nu}_\mu$	22.7	0.07
ν_e	37.0	0.01
$\bar{\nu}_e$	33.2	0.003

Neutrino **O**scillation **MA**gnetic **D**etector

The detector

- Drift Chamber Target - 2.7 tons, $\rho = 0.1 g/cm^3$
- Front Calorimeter Target - 17.7 tons
- Aluminium Coil
- $|\mathbf{B}| = \mathbf{0.4}$ Tesla

Neutrino **O**scillation **MA**gnetic **D**etector

The detector

- $\frac{\sigma_{\mathbf{p}}}{\mathbf{p}} \approx \frac{\mathbf{0.05}}{\sqrt{\mathbf{L}}} \oplus \frac{\mathbf{0.008 \times p}}{\sqrt{\mathbf{L^5}}}$
- Full event kinematics reconstruction
- Over 1.7 **millions** ν-interactions recorded in **Drift Chambers**
- Over 2 **millions** ν-interactions recorded in **Al-coil**
- Over 20 **millions** ν-interactions recorded in **Fe-scintillator** calorimeter

- Best current limit on $\nu_\mu \rightarrow \nu_\tau$
- **Record statistics** and **excellent resolution** lead to a wide physics research program:
  - More than 20 papers
  - More than 700 citations
  - Several ongoing precision analyses

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Precision measurements

Completed precision measurements

- Total $\nu_\mu N$ charged current cross-section in $2.5 < E_\nu < 40$ GeV
- $\nu_\mu n \to \mu^- p$ QEL cross-section (talk by Jean-Michel)
- Coherent π^0 production in neutral current νN interactions

Ongoing precision measurements

- Measurement of strange sea and charm mass in $\mu^+ \mu^-$ production
- First Measurement of $\sigma(NC)/\sigma(CC)(E_{had})$ in $1 < E_{had} < 100$ GeV
- π^0 Production in ν-Interactions
- First Measurement of η Production in ν-Interactions
- $\pi^\pm$ production yields and measurement of fragmentation and fracture functions
- **Plus More**

Total ν_μ CC cross-section
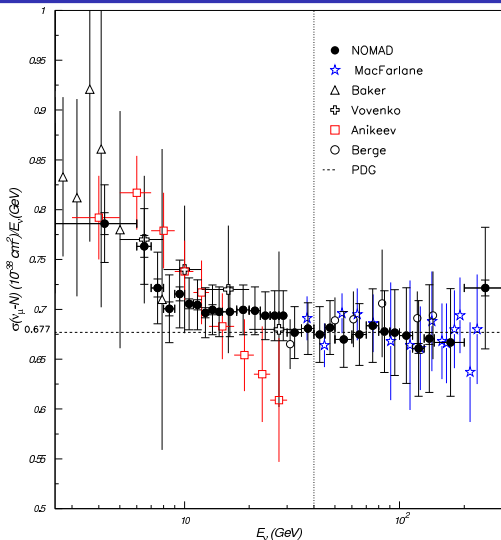
- E_μ-scale error constrained by K_S^0 mass $< 0.2\%$

- E_{had}-scale error $\sim 0.6\%$

- Cross-section error is dominated by rel.flux error

- 4% for $2.5 < E_\nu < 10$ GeV

- 2.6% for $10 < E_\nu < 40$ GeV

QEL $\nu_\mu n \to \mu^- p$ cross-section
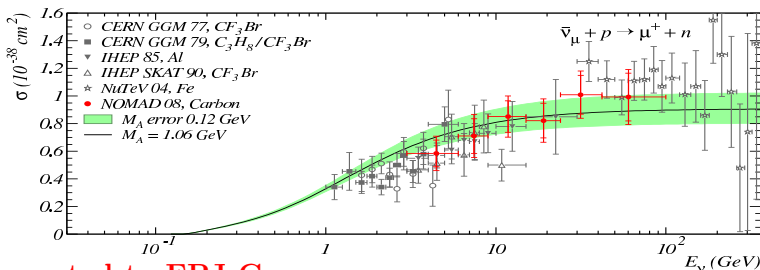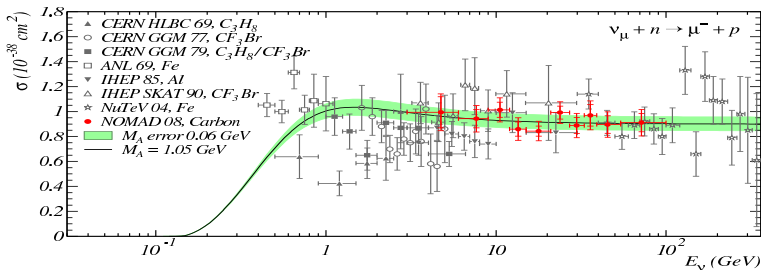
Accepted to EPJ C

Coherent π^0 production in νN NC interactions

π^0 (Coherent and not only) in νN NC - main background (up to 60%) for ν_e appearance in LBL experiments

- Select events with only two γs (no μ, no other tracks)
- Require γs to convert in DC $\gamma \to e^+ e^-$
- Use Data to predict the background
- Measure cross-secion

Coherent π^0 production in νN NC interactions
Coherent π^0 candidate
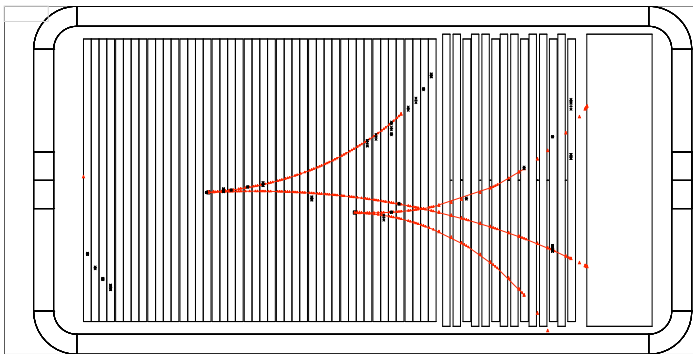
Red crosses $\times$ used in the reconstructed tracks, **black** $\times$ are not used.

Coherent π^0 production in νN NC interactions

Experiment	Nucleus	$\langle E \rangle$ GeV	$\sigma(Coh\pi^0)$ $10^{-40}cm^2/\mathcal{A}$	$Coh\pi^0/\nu_\mu CC$ 10^{-3}
Aachen-Padova	27	2	(29 ± 10)	
Gargamelle	30	2	(31 ± 20)	
CHARM	20	30	(96 ± 42)	
SKAT	30	7	(79 ± 28)	(4.3 ± 1.5)
15 BC	20	20	(0.20 ± 0.04)	
MiniBooNE	CH2	1.2	N/A	N/A
NOMAD	**12.8**	**24.3**	$(\mathbf{72.6 \pm 10.6})$	$(\mathbf{3.21 \pm 0.46})$

All the dimuon data

		Exp.	Publ.	Stat. ($N_{\mu\mu}$)	E_ν (GeV)
νN					
		CDHS	Jun 1982	660	$30 - 250 \ (> 100)$
		NuTeV	Feb 2001	5102	$20 - 400 \ (157.8)$
		CCFR	Feb 2001	5030	$30 - 600 \ (> 100)$
		CHORUS	Apr 2008	8910	$10 - 240 \ (27)$
		NOMAD		$\sim 17\text{k}$ exp.	$6 - 300 \ (24.3)$
$\bar{\nu} N$					
		CDHS	Jun 1982	171	$30 - 250 \ (> 100)$
		NuTeV	Feb 2001	1458	$20 - 400 \ (157.8)$
		CHORUS	Feb 2001	1060	$30 - 600 \ (> 100)$
		CHORUS	Apr 2008	430	$10 - 240 \ (27)$

The NOMAD experiment has the highest statistics and is closer
to the charm production threshold
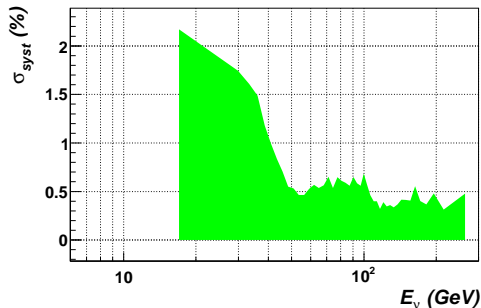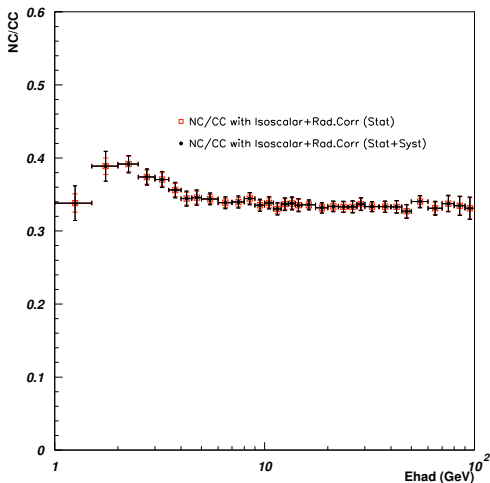
Charm dimuon distributions
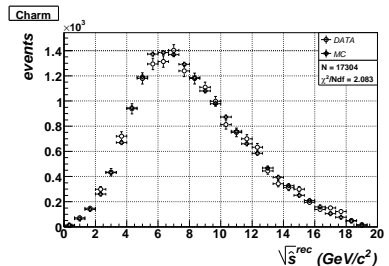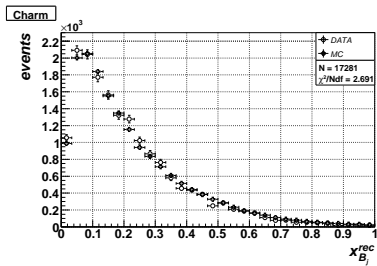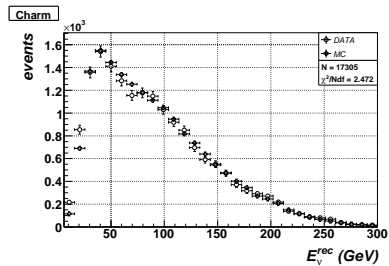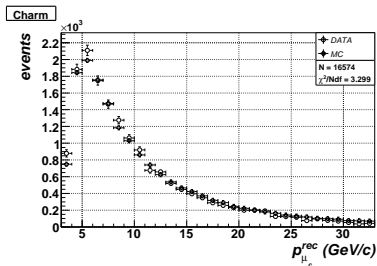
Expected NOMAD uncertainties

I can not show you the results yet...

NOMAD uncertainties

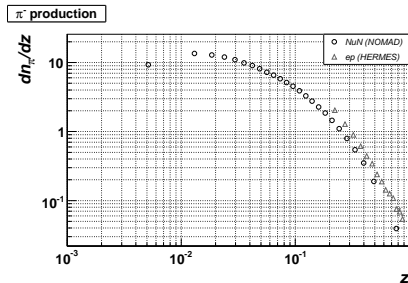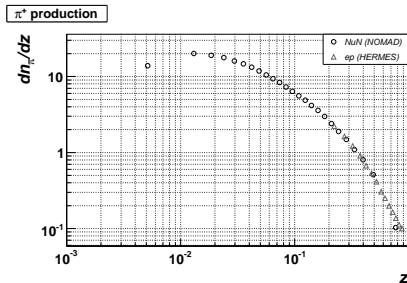|	Value (%)
Stat.	$\simeq 5.0 - 6.0$
Syst.	$\lesssim 2.5$

$\sigma(NC)/\sigma(CC)$ as a function of E_{had}

- 2.5% for $E_{had} > 5$ GeV
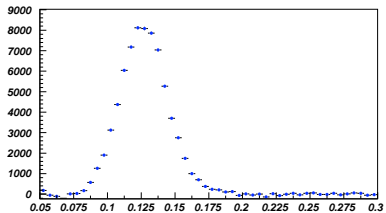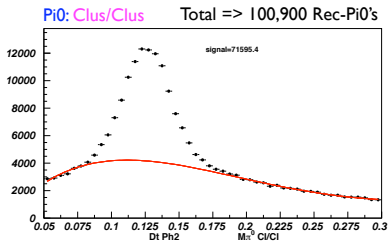- 5% for $E_{had} \sim 2$ GeV
- Corresponds to $Y_{Bj} > 0.04$
- Will improve background predictions for LBL

Charged Pions
π **production. Fragmentation and fracture functions**

- The lowest z is 30 times smaller than that of HERMES
- The plots include only 1/4 of the total NOMAD statistics.
- We will measure $D_q^\pi(z)$ and fracture functions with best accuracy.

Inclusive π^0

Precision measurements by NOMAD
└─Recent and Ongoing Analyses
  └─Other ongoing analyses

Other ongoing analyses

- Differential $\nu_\mu N$ charged current DIS cross-section
- Checking the NuTeV Dimuon Anomaly
- Measurement of nuclear effects from $\sigma(\nu_\mu Fe)/\sigma(\nu_\mu C)$ in the same experiment
- Checking ν_μ/ν_e universality
- Inclusive η^0 production

Outline

1 NOMAD Experiment

2 Recent and Ongoing Analyses

3 Summary

Summary

- The NOMAD experiment accumulated the highest resolution $\nu_\mu/\bar{\nu}_\mu/\nu_e/\bar{\nu}_e$ data in $2.5 < E_\nu < 300$ GeV. The analyses are still ongoing

- A number of precision measurements performed

- A list of ongoing analyses

- A rich physics can be extracted from:

- Over 1.7 **millions** ν-interactions recorded in **Drift Chambers**

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