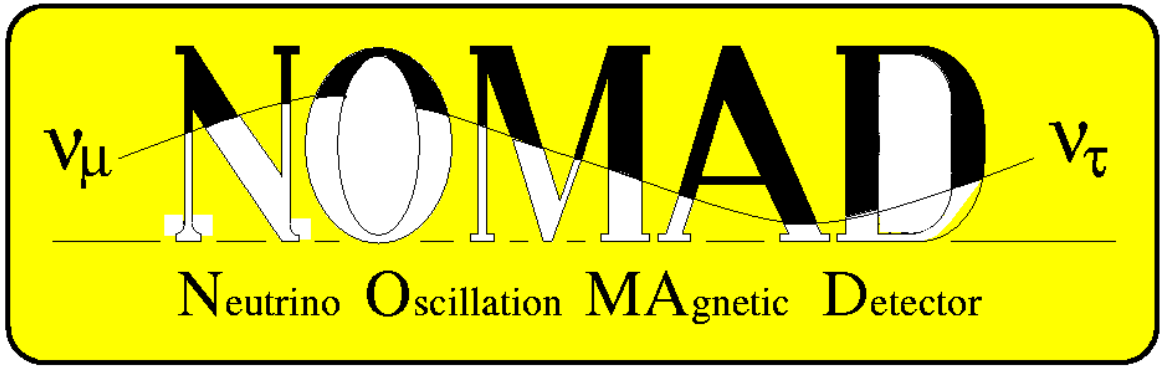
K. Zuber, University of Dortmund

Latest



Results

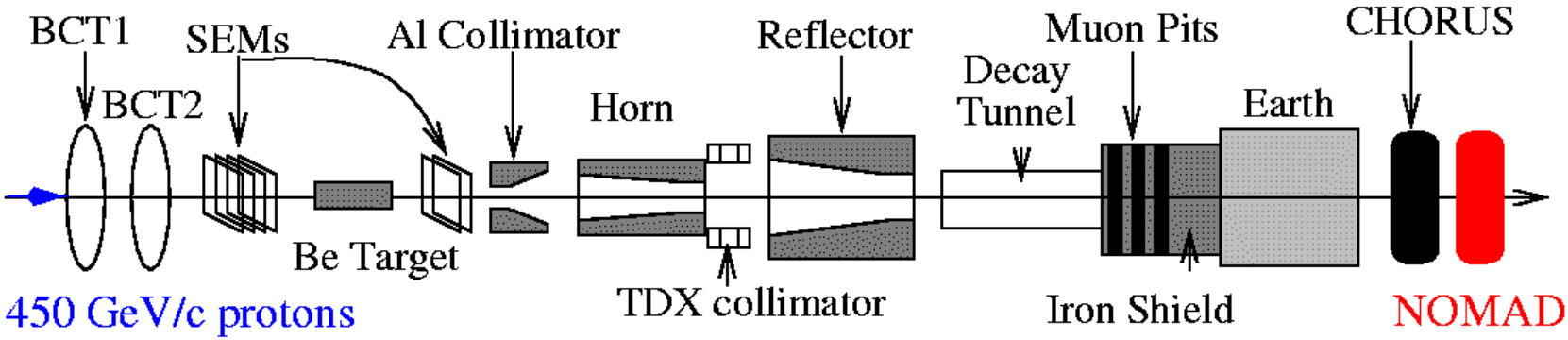
XXVII Rec. de Moriond, ElectroWeak Interactions and Unified Theories, Les Arcs, 9-16 Feb. 2002

Contents

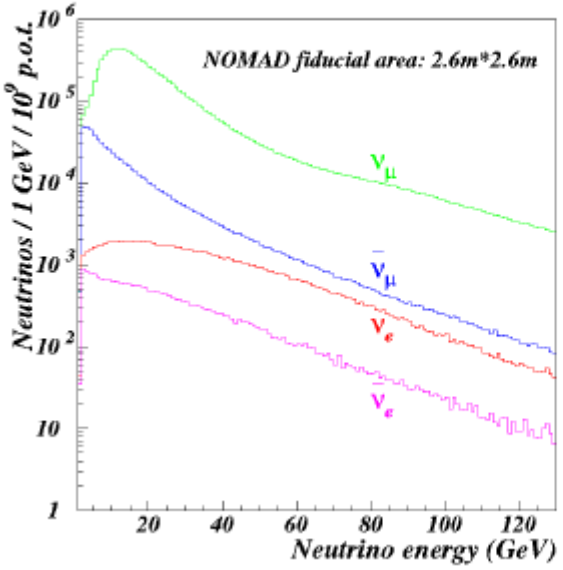
- ν_μ - ν_τ oscillations
- ν_μ - ν_e oscillations with NOMAD
- KARMEN anomaly search
- Charm production in νN-scattering

The CERN Neutrino Beam

(not in scale)



Neutrino fluxes at NOMAD:



	ν_x/ν_μ	$\langle E_\nu \rangle$, GeV
ν_μ	1.0	24.2
$\bar{\nu}_\mu$	0.064	18.5
ν_e	0.010	36.6
$\bar{\nu}_e$	0.003	28.7

Accurate knowledge of beam crucial

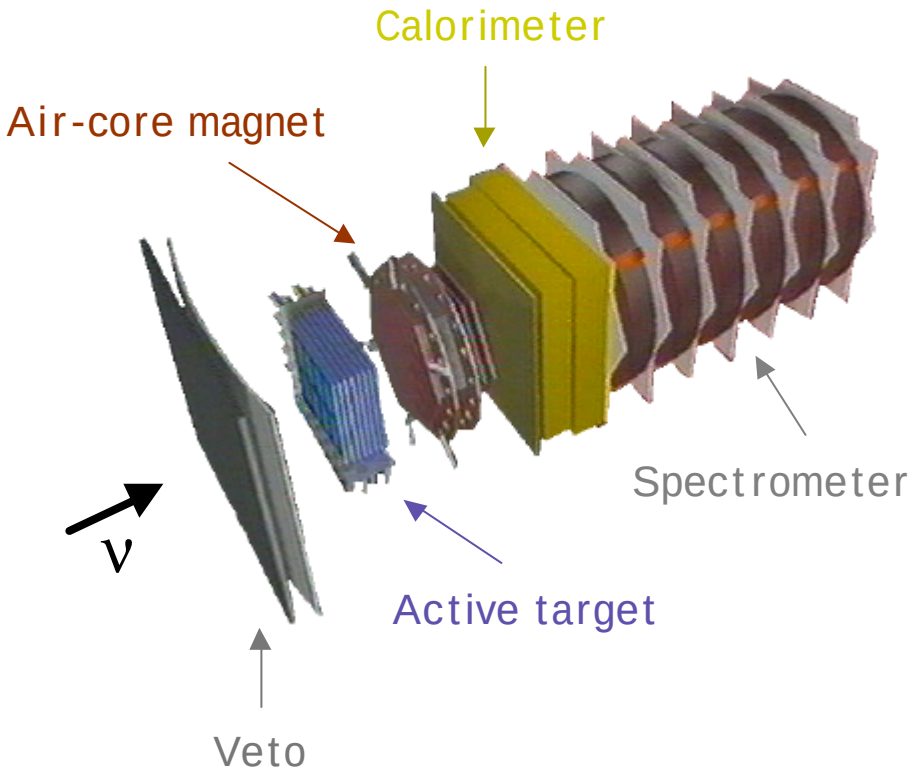
λ Beamline described by GEANT, secondary interactions simulated by latest FLUKA version

λ Cross sections and particle production in p Be simulated by latest FLUKA version modified with NA56-SPY and Atherton et al. data

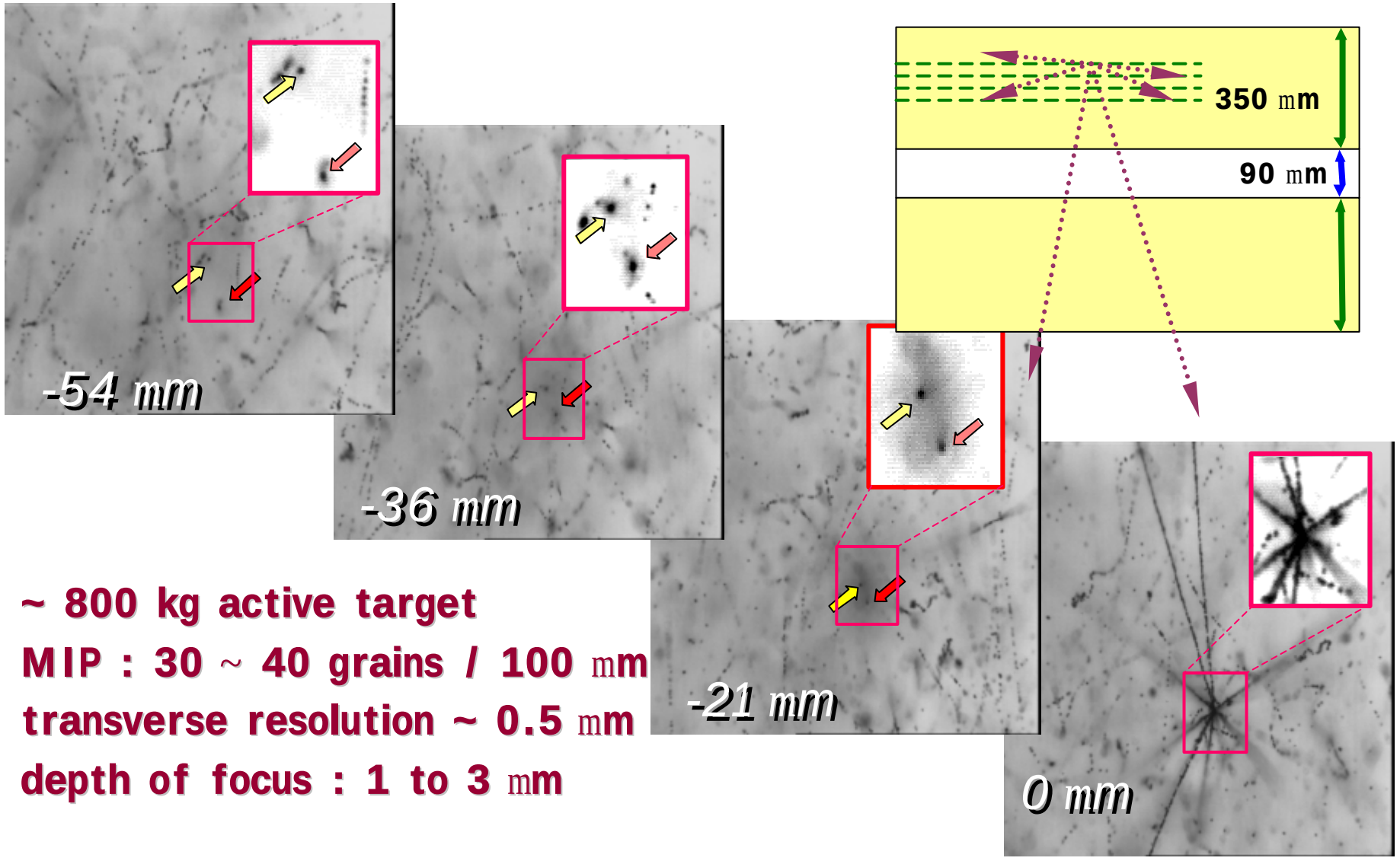
CHORUS detector

(Data taking 1994 - 1997)

- Active target
  - nuclear emulsion target
  - scintillating fiber tracker
- Air-core magnet
  - $\Delta p/p = 0.035\ p\ (\mathrm{GeV}/c) \oplus 0.22$
  - 1996-97 upgrade : ET, HC
- Calorimeter
  - $\Delta E/E = 32\ \%/\sqrt{E}$ (hadrons)
    $= 14\ \%/\sqrt{E}$ (electrons)
  - $\Delta\theta_{hadrons} = 60$ mrad @ 10 GeV
- Muon spectrometer
  - $\Delta p/p = 10 - 15\%$ $(p < 70\ \mathrm{GeV}/c)$



CHORUS emulsion



~ 800 kg active target

MIP : 30 ~ 40 grains / 100 mm

transverse resolution ~ 0.5 mm

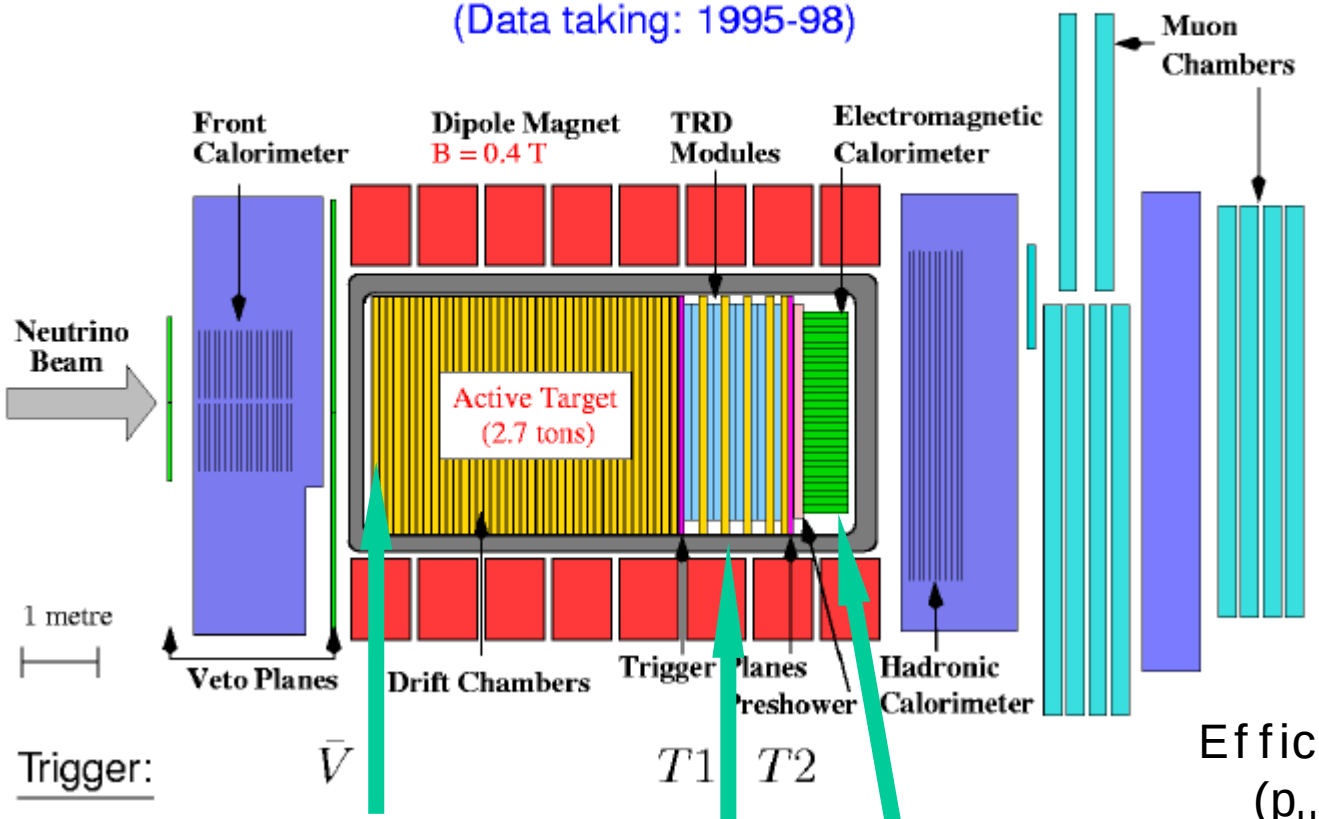
depth of focus : 1 to 3 mm

Nucl. Instr. Meth. A 447 (2000) 361-376

Nucl. Instr. Meth. A 404 (1998) 96

NOMAD Detector

(Data taking: 1995-98)



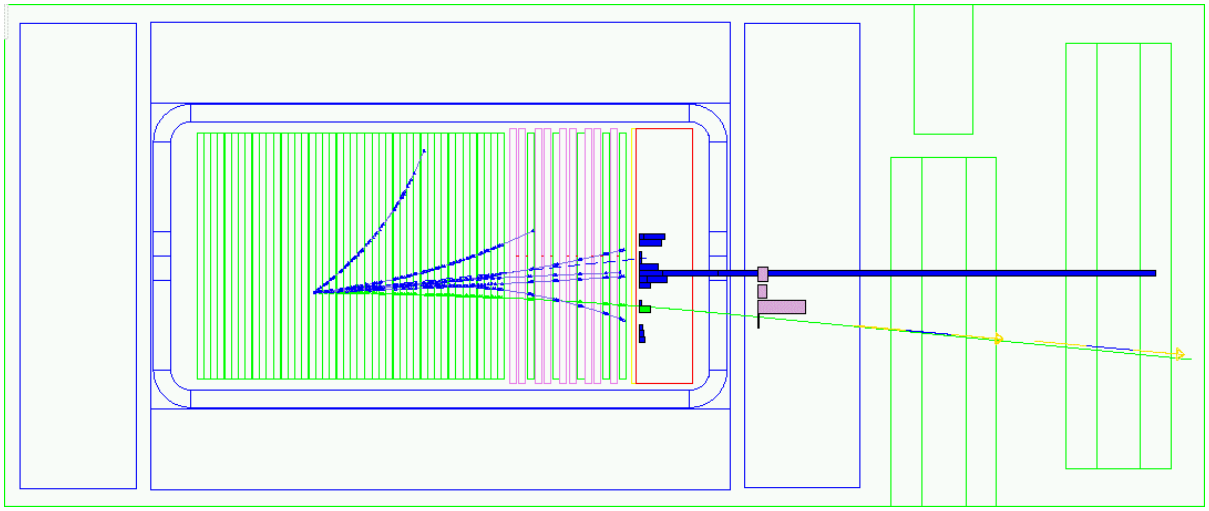
Momentum resolution ~3.5 %
(p<10 GeV)
Position resolution < 200 μm
(small angle tracks)

π rejection ~ 10^3
for electron efficiency >90%

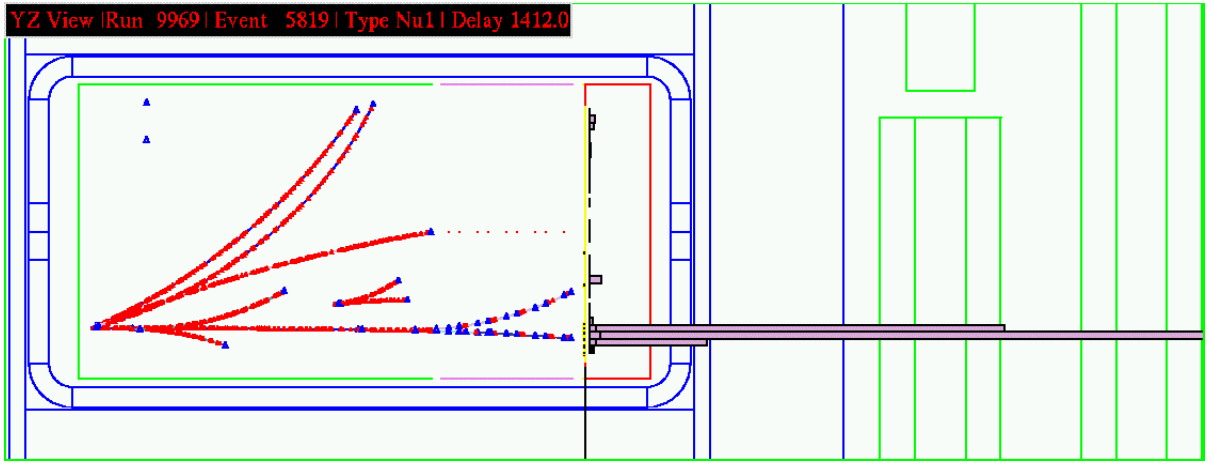
σ(E)/E = (1.04 ±0.01)% +
(3.22±0.07)%/√E(GeV)

Efficiency ≈97%
(p_μ > 5 GeV)

NOMAD events

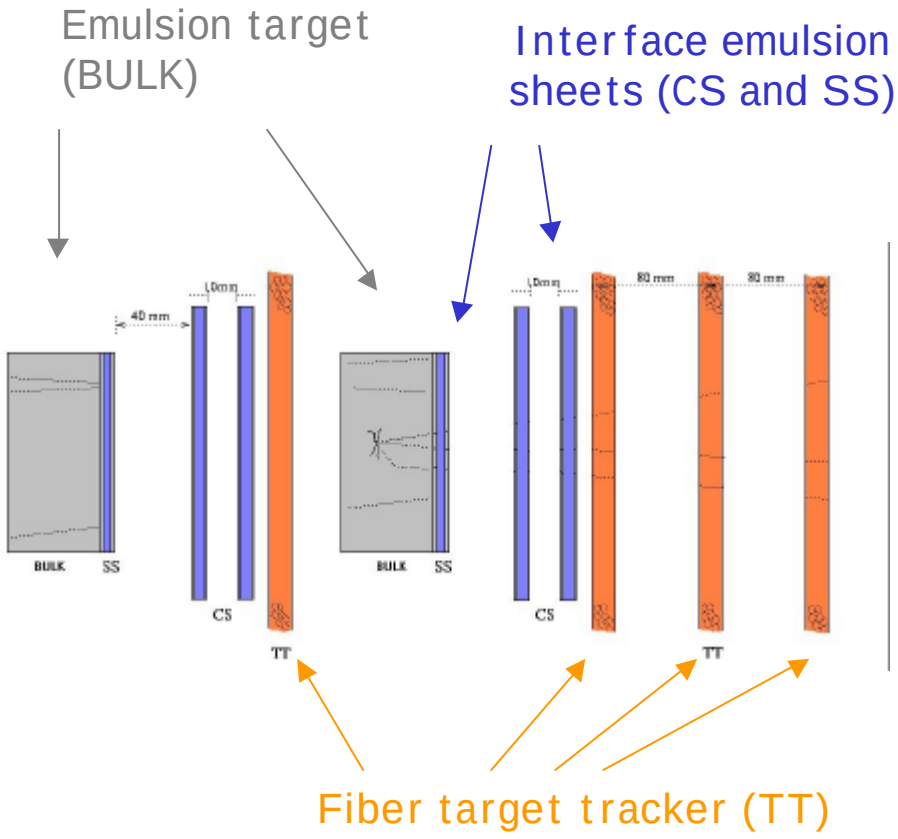


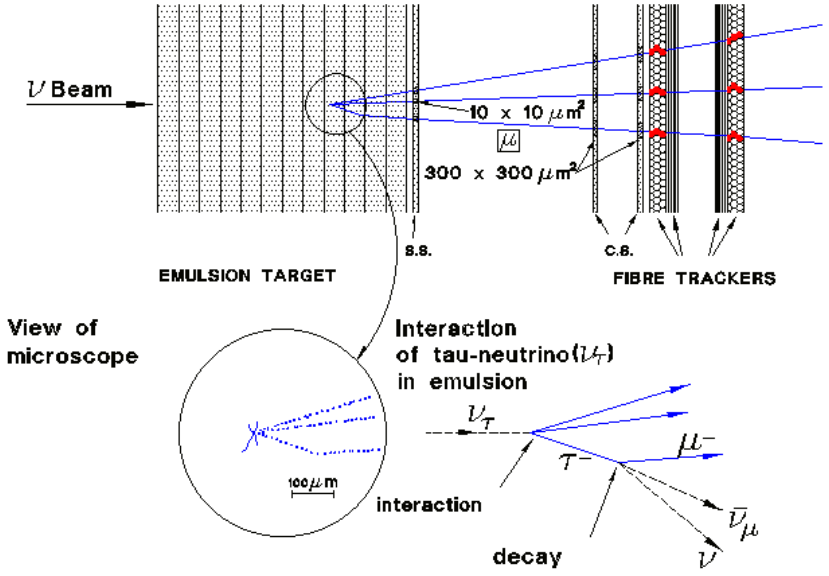
ν_μCC



ν_eCC

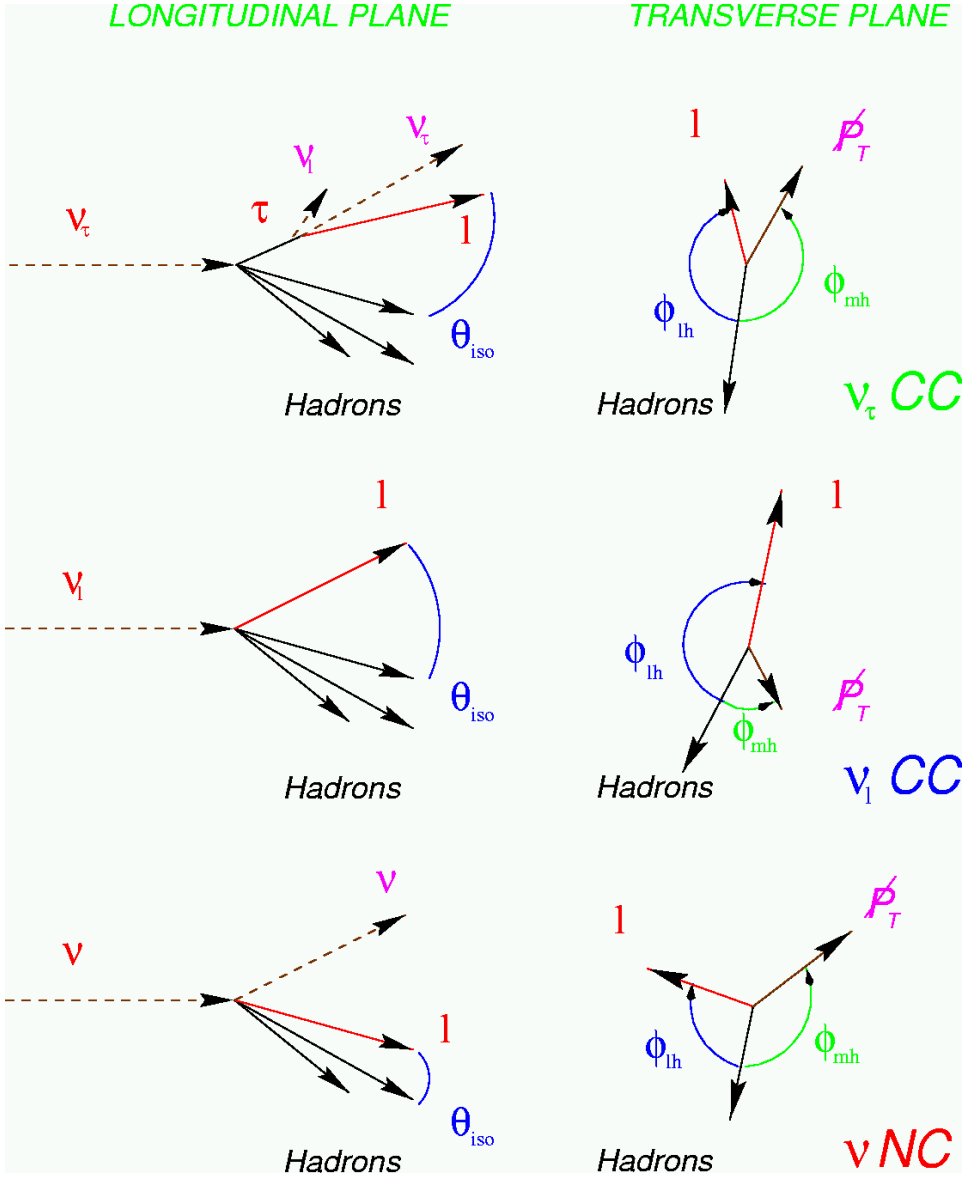
CHORUS - ν_τ Detection principle





Kink search in emulsion target

NOMAD - ν_τ Detection principle



Search by kinematical criteria

Basically isolation and imbalance

Likelihood Analysis

"Blind Analysis"

Procedure of analysis

1) Event reconstruction by electronic detectors

Pre-selection of events

Momentum cuts $P_{\mu^-} < 30$ GeV/c, $1 < P_{h^-} < 20$ GeV/c (Only for τ search)

Angle cut $\theta < 0.4$ rad

→ reduce scanning load

2) Vertex location

Automatic emulsion scanning : follow-up the selected tracks until interaction vertex

3) Decay search

Automatic scanning and offline selection for decay topology search

4) Post-scanning analysis

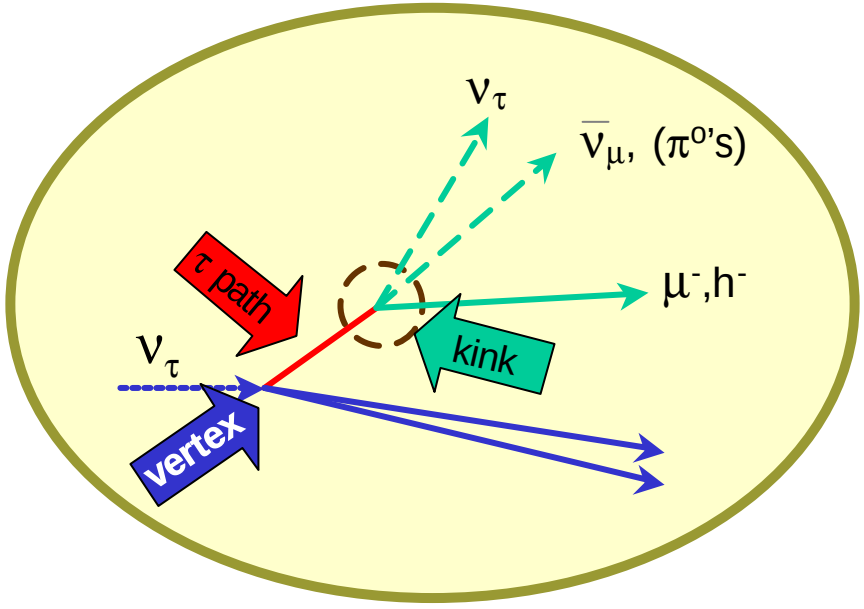
Computer assisted eye-check

→ confirm presence of decay

Kinematic study

→ Important to measure momenta

to identify the sign of charge (for τ candidate)



CHORUS (Phase I)

Emulsion triggers : 2,305K

channels: $\tau \rightarrow \mu^- \nu_\tau \bar{\nu}_\mu$, $\tau \rightarrow h^- (n\pi^0) \nu_\tau$

1μ sample		0μ sample	
Initial sample	713,000	Initial sample	335,000
Momentum and angle selection	477,600	Momentum and angle selection	122,400
Events scanned	355,395	Events scanned	85,211
Vertex located	143,742	Vertex located	20,081
Selected for eye-scan	11,398	Selected for eye-scan	2,282
τ candidates	0	τ candidates	0

1μ sample : events with one negative charged muon

0μ sample : events without muon

Osc. Prob.: $P_{\mu\tau} \leq 3.4 \times 10^{-4}$

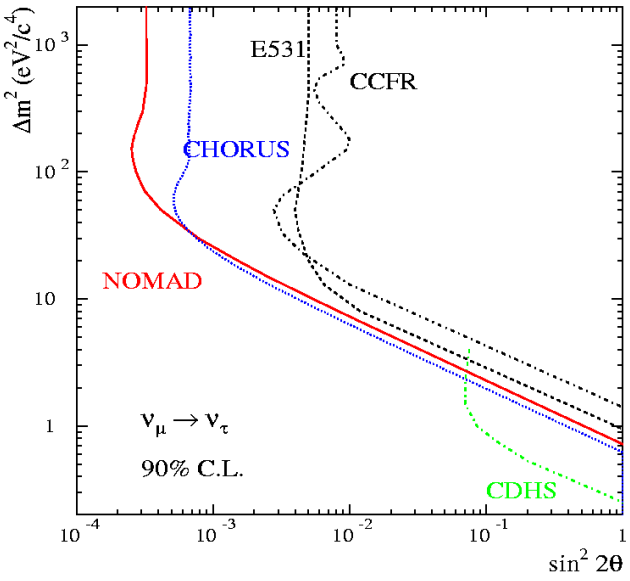
NOMAD (Final)

channel		Obs.	Tot. Backgnd
$e\nu_e\nu_\tau$	DIS	5	$5.3\ ^{+0.7}_{-0.5}$
$h^-(n\pi^0)\nu_\tau$	DIS	21	19.5 ± 3.5
$3h^-(n\pi^0)\nu_\tau$	DIS	3	4.9 ± 1.5
$e\nu_e\ \nu_\tau$	LM	6	5.4 ± 0.9
$h^-(n\pi^0)\nu_\tau$	LM	12	11.9 ± 2.9
$3h^-(n\pi^0)\nu_\tau$	LM	5	3.5 ± 1.2
total		52	50.5 ± 10.6

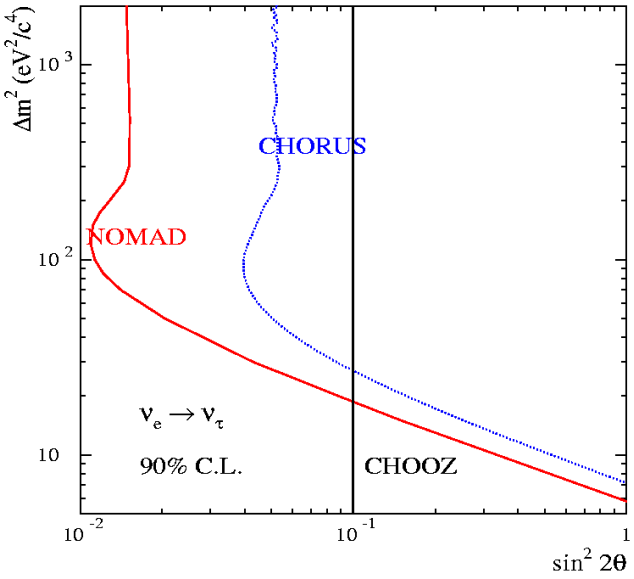
Osc. Prob.: $P_{\mu\tau} \leq 1.63 \times 10^{-4}$

Results of ν_τ search

- $\nu_\mu \rightarrow \nu_\tau$



- $\nu_e \rightarrow \nu_\tau$



NOMAD
$$\begin{cases} S_{\nu_\mu \to \nu_\tau} = 2.50 \times 10^{-4} \\ L_{\nu_\mu \to \nu_\tau} = 1.63 \times 10^{-4} \\ P(\leq L) = 37\% \end{cases} \quad (90\%\ \text{C.L.}) \quad \begin{cases} S_{\nu_e \to \nu_\tau} = 1.10 \times 10^{-2} \\ L_{\nu_e \to \nu_\tau} = 0.74 \times 10^{-2} \\ P(\leq L) = 39\% \end{cases}$$

CHORUS $sin^2\ 2\theta < 6.8 \times 10^{-4}$ large Δm^2

NOMAD (final): Nucl. Phys. B 611,3 (2001)

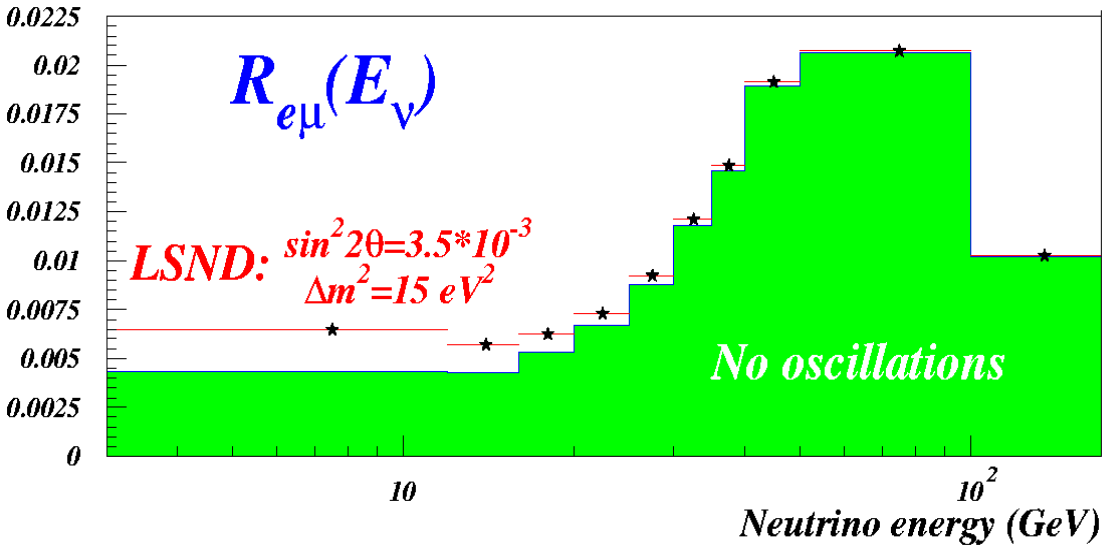
CHORUS: Phys. Lett. B 497, 8 (2001)

Search for $\nu_\mu \rightarrow \nu_e$ Oscillations in NOMAD

Blind analysis in $R_{e\mu}$ and ν_e CC

$$R_{e\mu} = \frac{\text{“}\nu_e \text{ CC”}}{\text{“}\nu_\mu \text{ CC”}}(E_\nu, r)$$

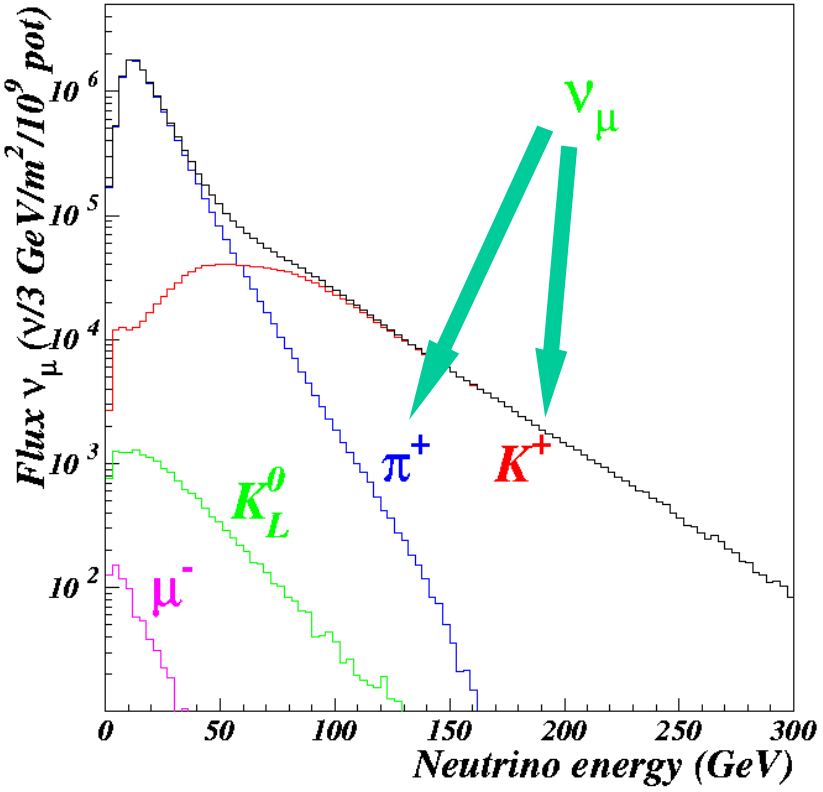
$$= \frac{e^-(\nu_e \text{ CC}) + e^-(bkg) + e^-(\nu_e^{osc} \text{ CC})}{\mu^-(\nu_\mu \text{ CC}) + \mu^-(bkg)}$$



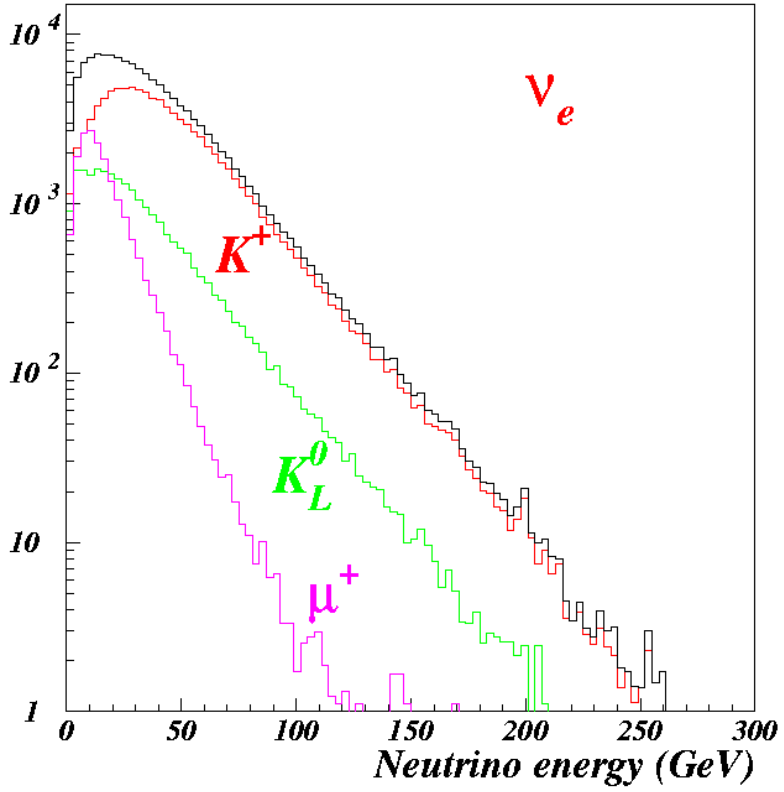
- Detailed estimation of systematic errors and background
- Robust flux prediction

Neutrino flux

analysed



predicted



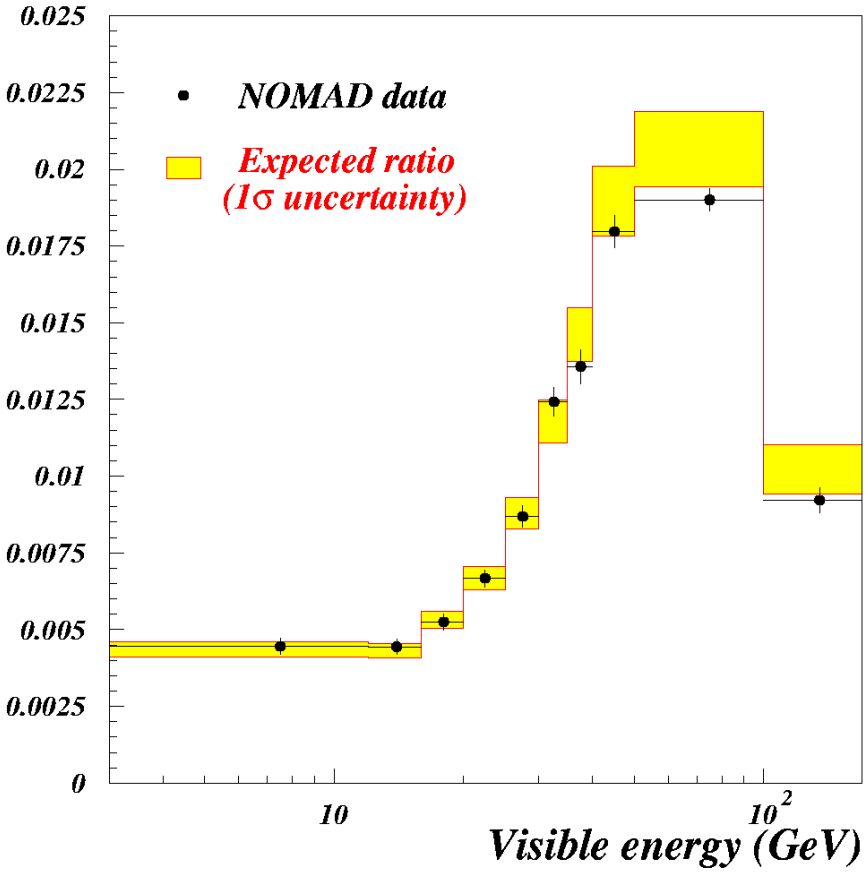
also analysed: $\bar{\nu}_\mu \rightarrow K^-$ $\bar{\nu}_e \rightarrow K_L, K^-$

Alternative: Empirical parametrisation - more accurate flux

Preliminary results

10 energy bins and 3 radial bins

$R_{e\mu}$ ratio as a function of neutrino energy:



Bin-to-bin systematic errors: 5-8 %

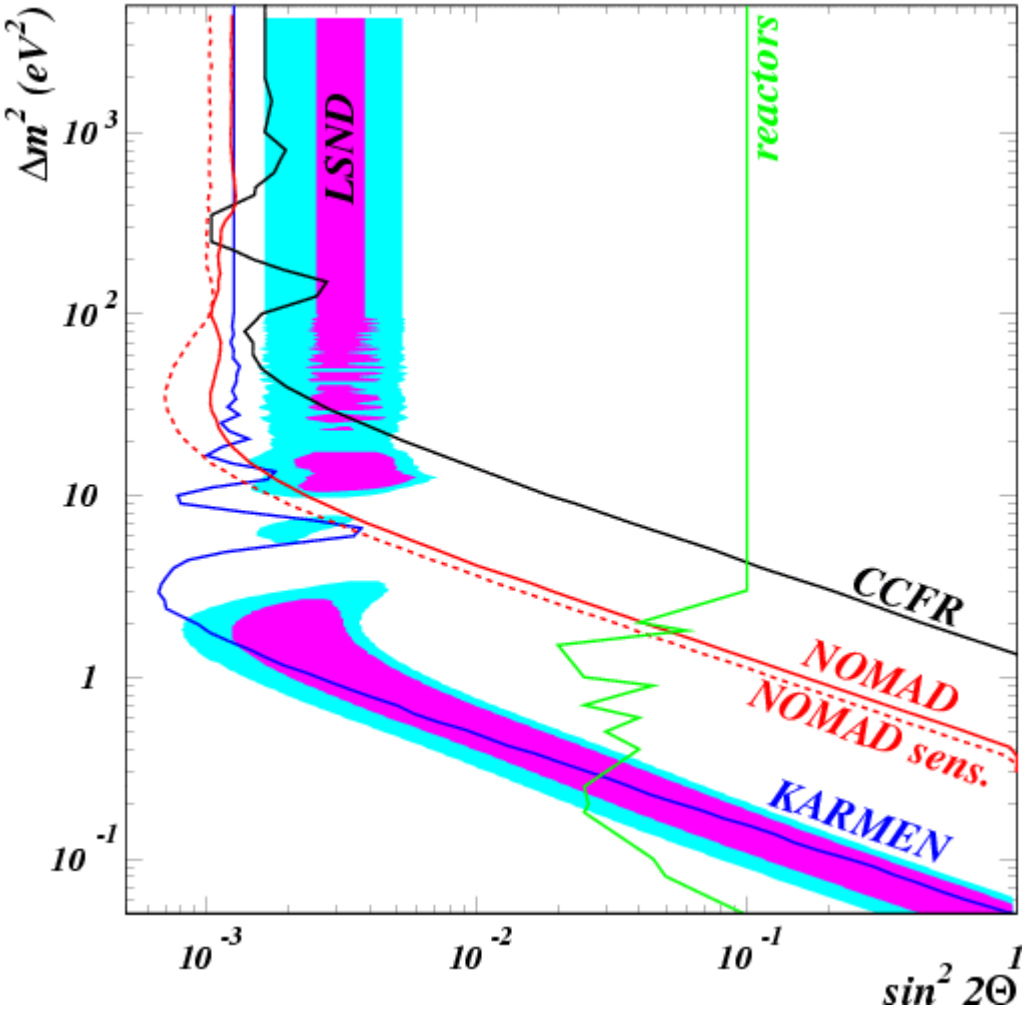
Overall (normalization) uncertainty: 2%

χ^2: 19.7/29 d.o.f. (no osc.)

χ^2_{min}: 18.6/27 d.o.f. (with osc.)

No evidence for oscillations

Exclusion Plot (Preliminary)



Large Δm^2:

$\sin^2 2\theta < 1.2 \times 10^{-3}$

(90 % CL)

(Feldman-Cousins method)

NOMAD excludes high Δm^2 ($\Delta m^2 > 10\ eV^2$) region of allowed LSND parameters

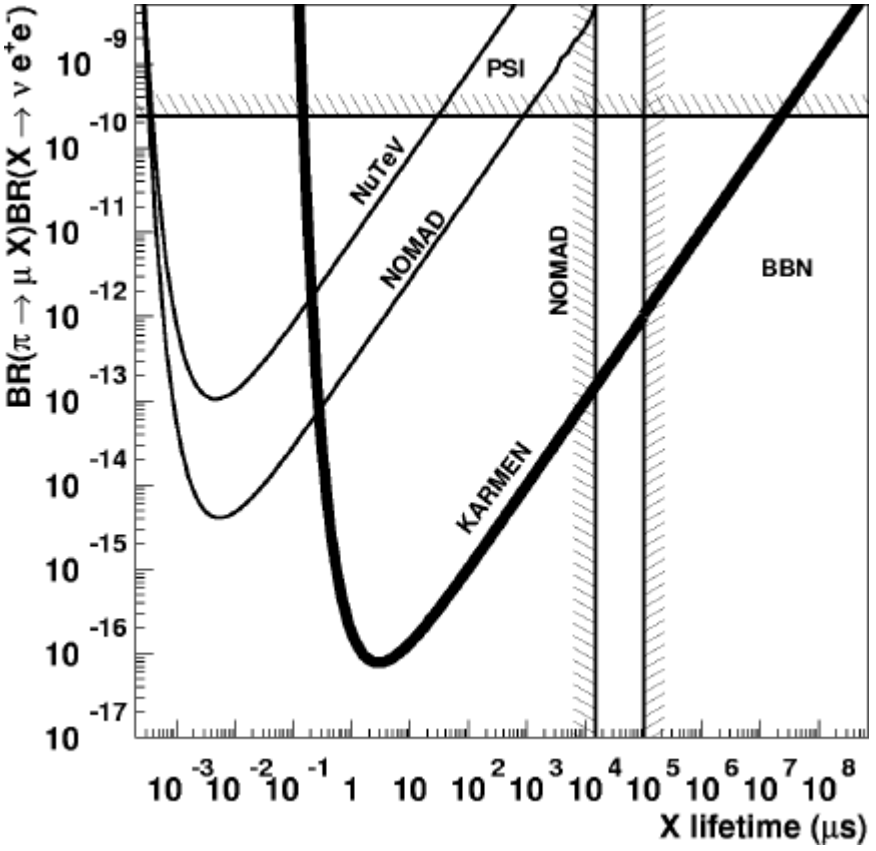
Neutral 33.9 MeV particles in π^+-decay?

Motivated by KARMEN Anomaly

$BR(\pi^+ \rightarrow \mu^+ + X)\ BR(X \rightarrow \text{visible})$
$X \rightarrow \nu e^+ e^-$ favoured

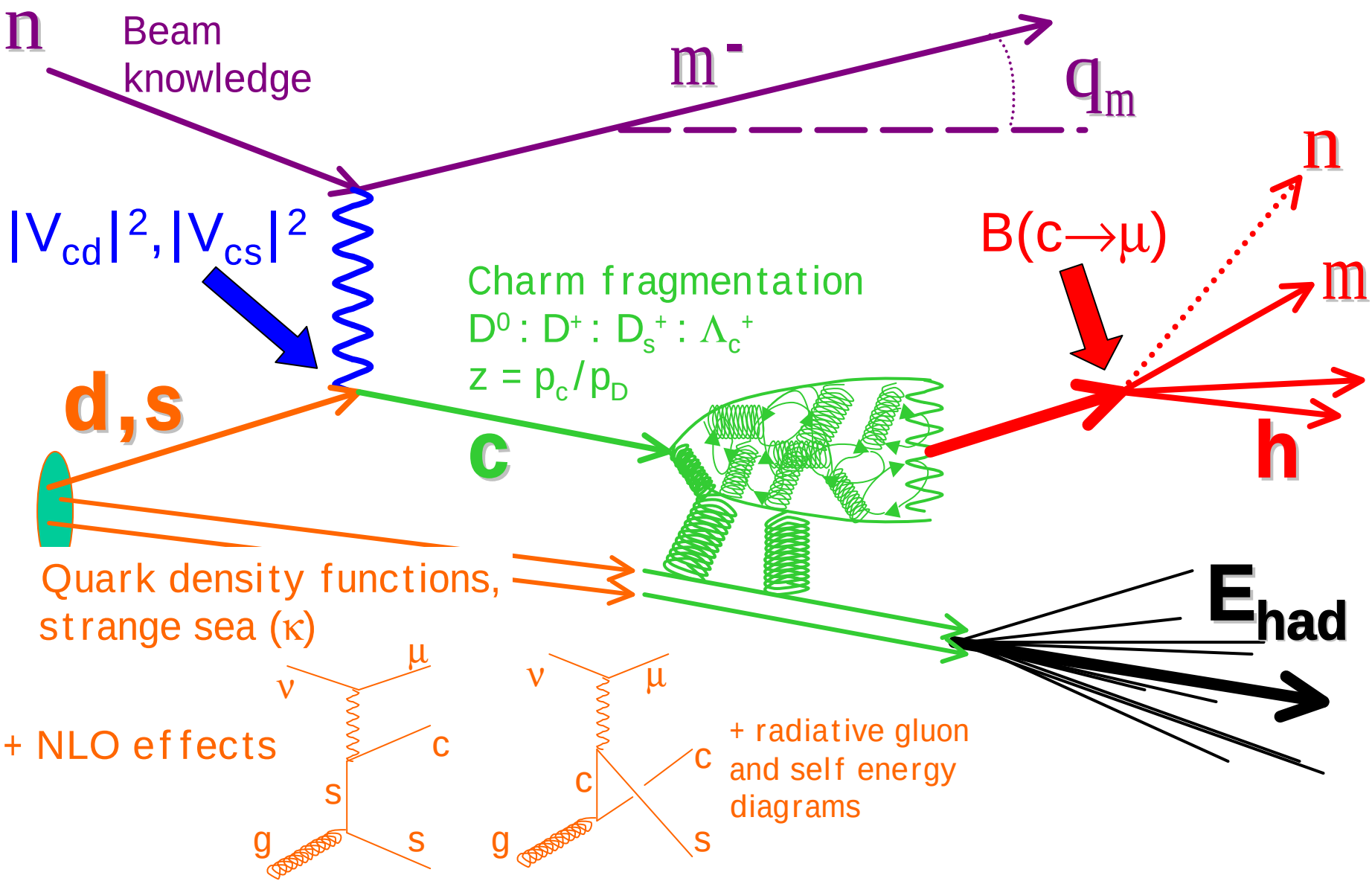
NOMAD search for excess in isolated e^+e^- -pairs

No excess found



P.Astier et al., Phys. Lett. B 527, 23 (2002)

Neutrino charm production



Opposite sign dimuons in ν N scattering

$\nu_\mu N \rightarrow \mu^- + c + X$

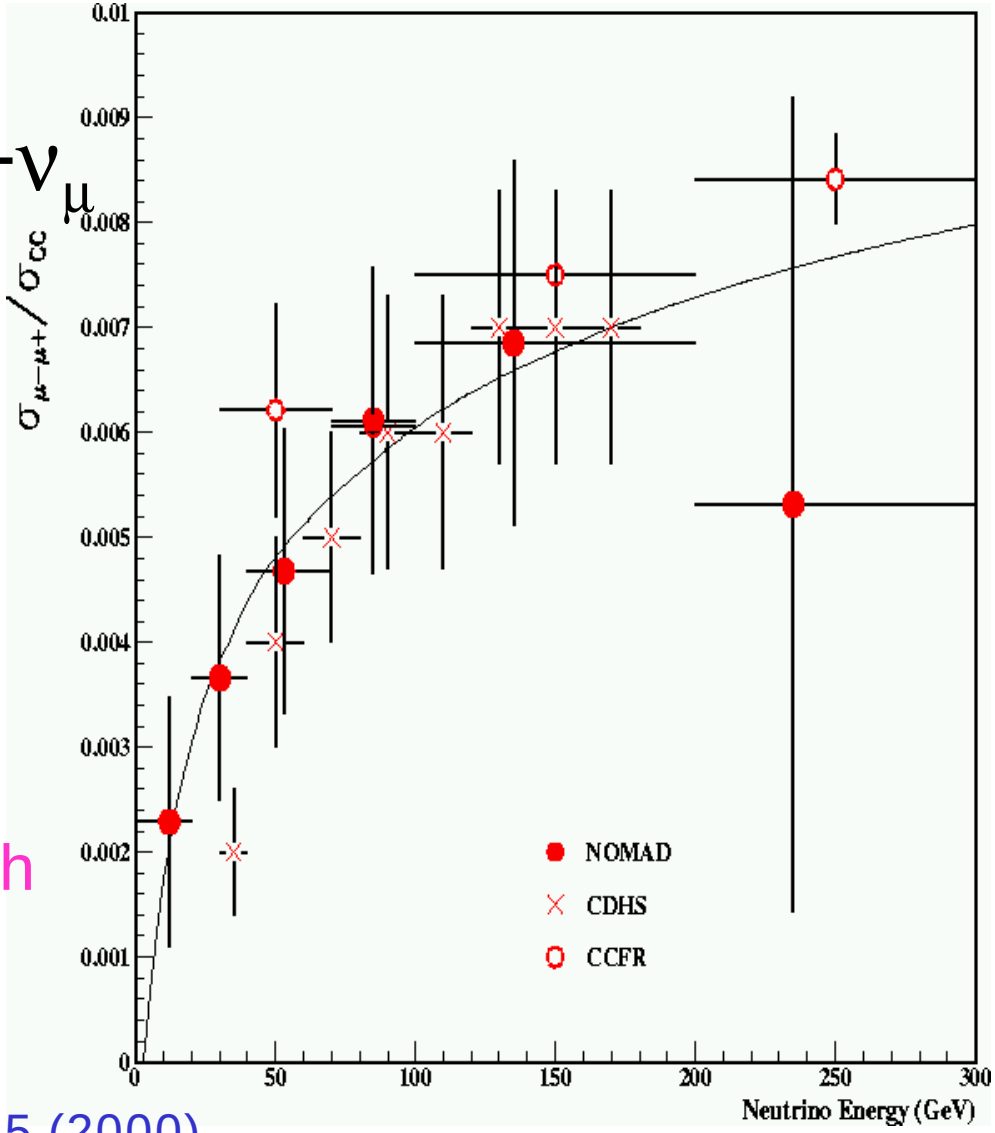
$\hookrightarrow s + \mu^+ + \nu_\mu$

Using FCAL data of NOMAD (~15 % of total FCAL data)

2714 $\mu^- \mu^+$ events (ν_μ)

115 $\mu^- \mu^+$ events ($\bar{\nu}_\mu$)

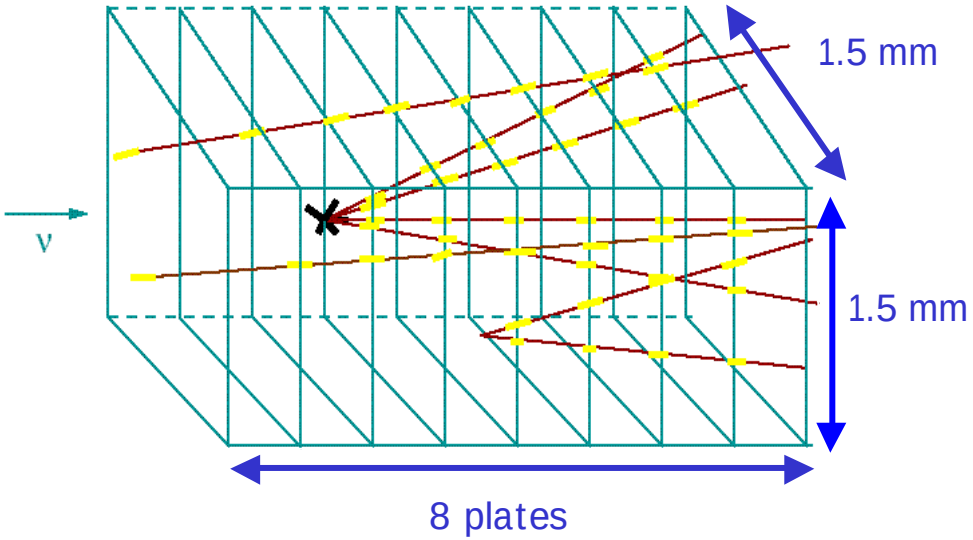
m_c, κ and B_c consistent with other experiments



P.Astier et al., Phys. Lett. B 486, 35 (2000)

D^0 production

CHORUS net scan



V2 226 V4 57

Neutral ~ 33 %

- **Sample of 25,693 ν_μ CC interactions, ~15% of final statistics**
- **selection efficiency : V2 ® 58.6±0.7% , V4 ® 70.1±1.7%**
- **851 (3.3%) selected events**

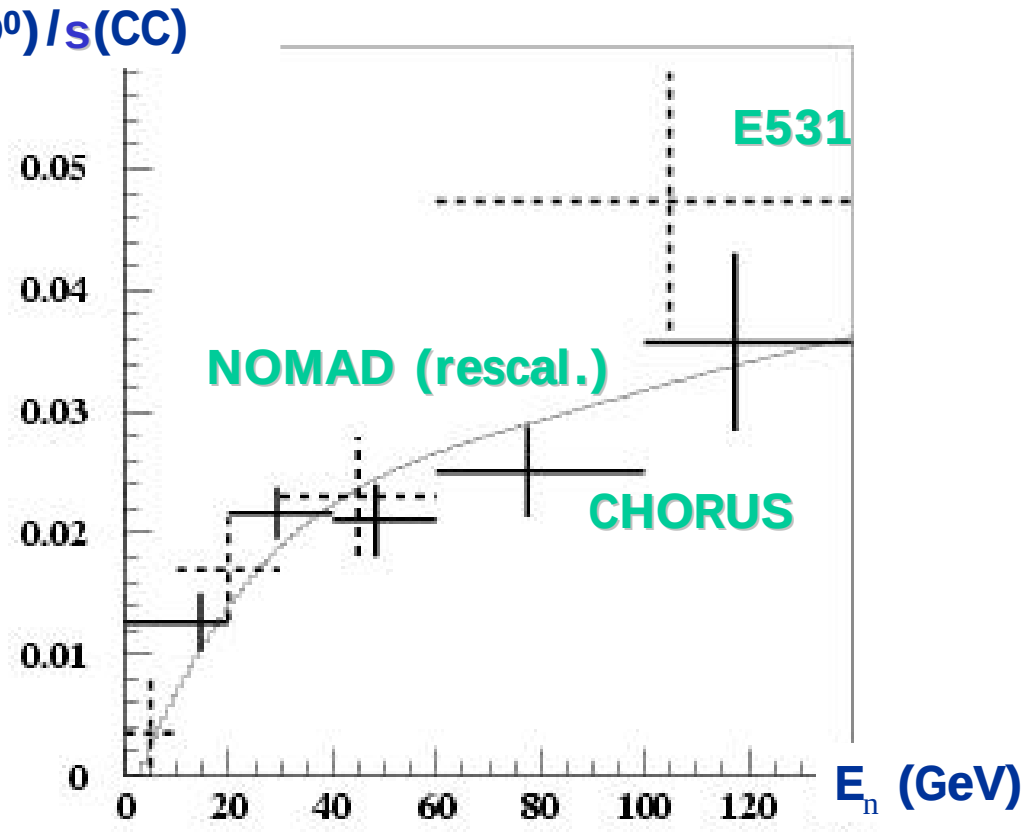
D^0 Production rate

- $\sigma(D^0) / \sigma(CC) = 1.99 \pm 0.13$ (stat.) $\pm$ 0.17 (syst.) %
- $\langle E_n \rangle = 27$GeV, $P_m < 30$GeV/c

$D^0 \to V4 / D^0 \to V2$
$= 23.1 \pm 4.0$ %

$\sigma(D^0) / \sigma$(charm)
$= 53 \pm 11$ %

Slow rescaling model
$m_c = 1.3$ GeV/c^2



To appear in Phys.Lett.B (Measurement of D^0 production in …, A.Kayis-Topaksu et al.)

Study of D^{*+} - production

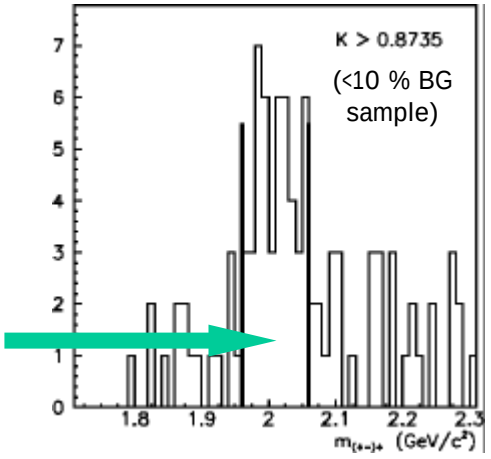
NOMAD search

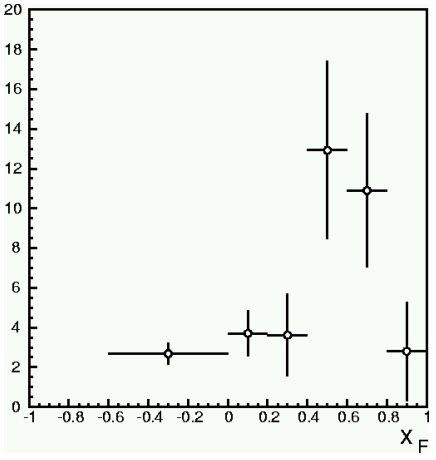
$D^{*+} \rightarrow D^0 + \pi^+$

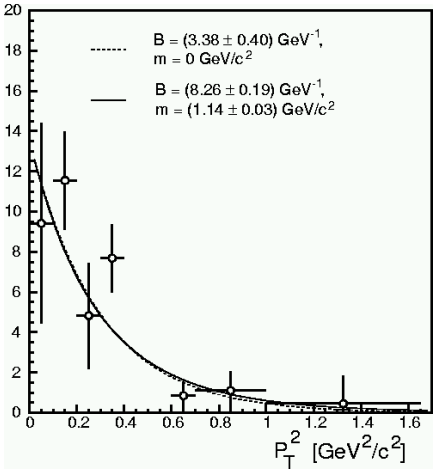
$\hookrightarrow K^- + \pi^+$

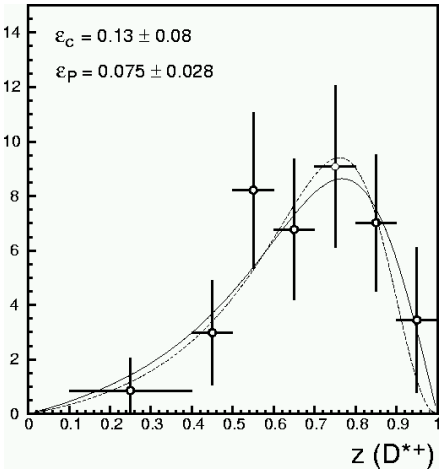
Analysis is using neutral net

35 ± 7.2 events









D^{*+} yield in ν_μCC: T = 0.79 ± 0.17 (stat.) ± 0.10 (syst.) %

P.Astier et al., Phys. Lett. B 526, 278 (2002)

Summary

No oscillations in ν_μ - ν_τ channel observed

Improved limits in ν_e - ν_τ channel

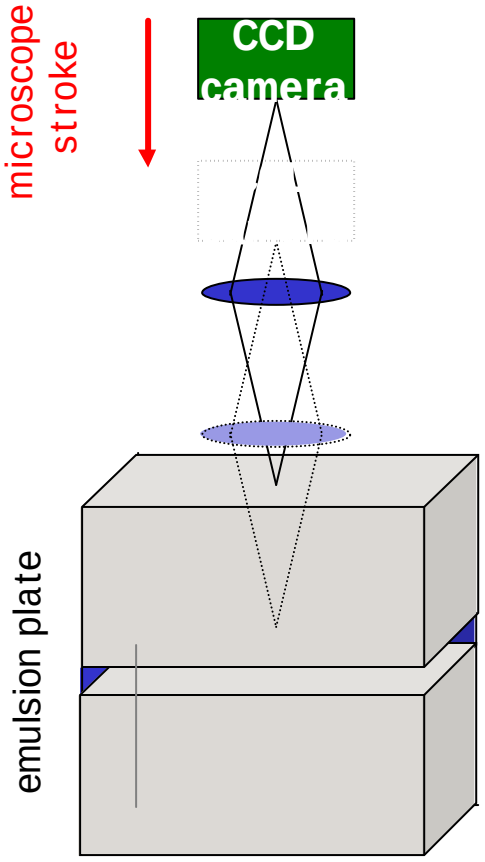
NOMAD excludes large Δm^2 region of LSND

No hint for a 33.9 MeV neutral found in NOMAD

First new results on Charm physics
(OSDM, D^0, D^{*+})

A lot of interesting results from
CHORUS and NOMAD still to come

Automatic emulsion scanning



tomographic image

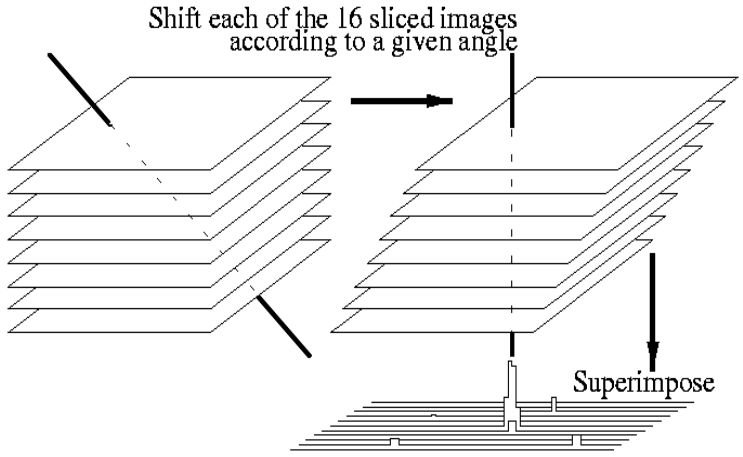
350 μ m (175 μ m) emulsion sheet

90 μm plastic base

350 μ m (175 μ m) emulsion sheet

Hardware tracking

developed by Nagoya group



Software tracking CERN group

- Flexible and adaptable
- Profit from Moore's law