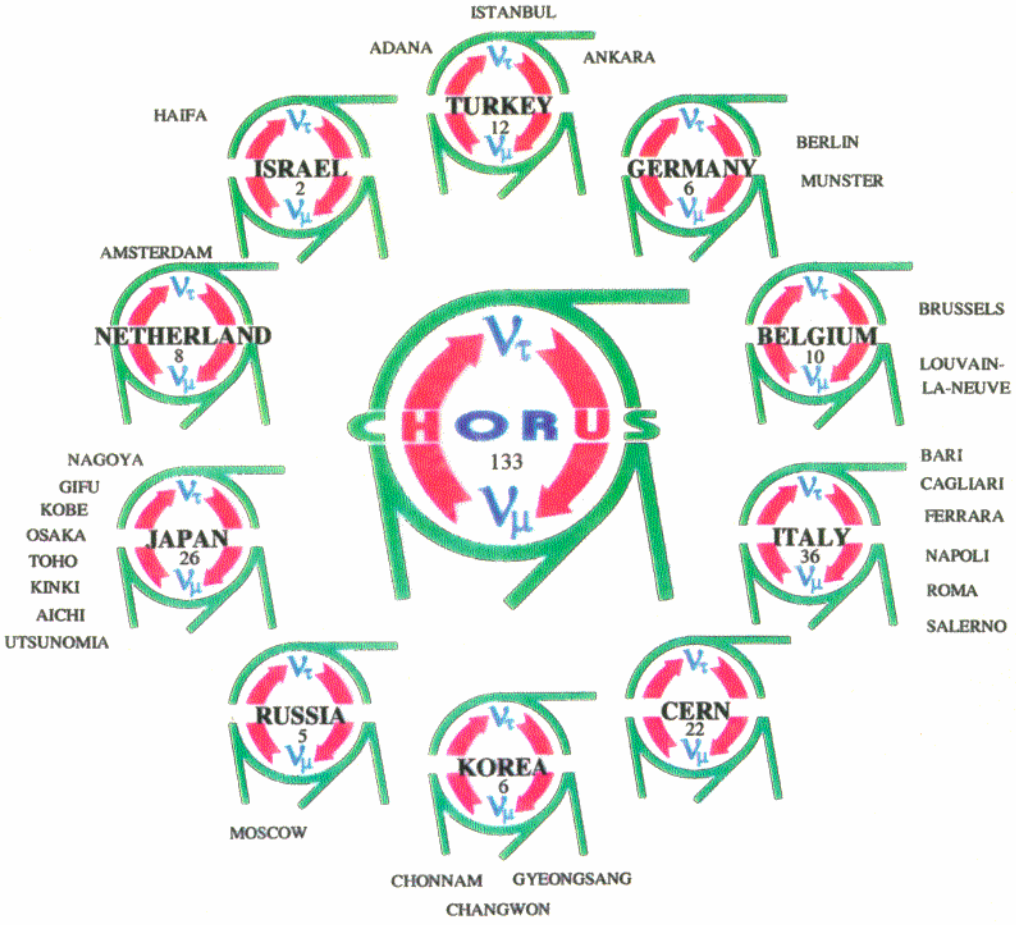
RESULTS from the CHORUS EXPERIMENT



Maria-Gabriella Catanesi
CERN - Geneva (Switzerland)

XXVI Slac Summer Institute
August 3-14 '98

OVERVIEW

- Physics Goals
- The Detector
- Data Selection
  and Analysis
- Results:
  Oscillation Limit
  Ds Observation
- OutLook and Conclusions

$\nu_\mu \rightarrow \nu_\tau$ Oscillations

- If $m_\nu > 0$ and mixing of family
- If $m\nu_\tau \sim$ 10eV (see-saw models)

ν_τ it's a good candidate as hot dark matter !

It's important study process involving ν_τ

- Prob($\nu_\mu \rightarrow \nu_\tau$) = $\sin^2(2\theta)\ \sin^2(\Delta m^2 \frac{L}{4E})$
- The previous limit for $\nu_\mu \rightarrow \nu_\tau$ oscillation (E531) was $sin^2(2\theta) < 5 * 10^{-3}$

Explore mixing angles down to $sin^2(2\theta) \sim 10^{-4}$

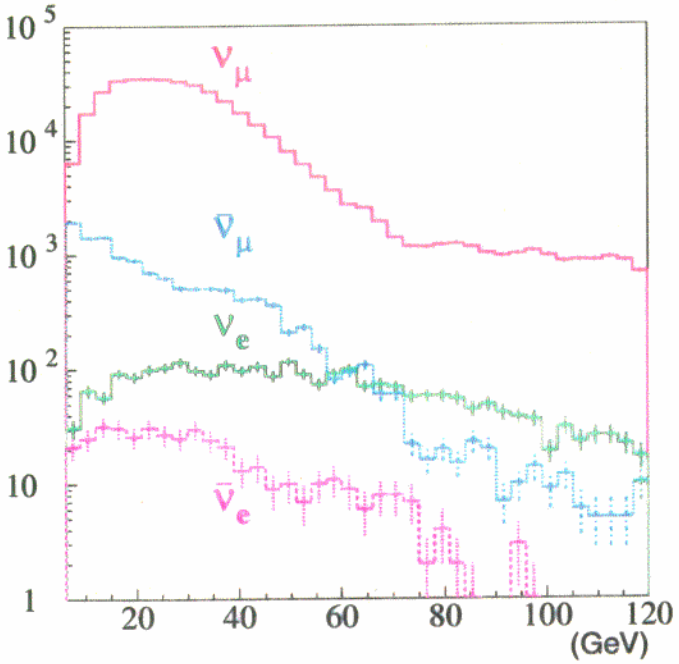
- Charm Physics

CERN Wide Band ν Beam

High Intensity: $> 2 \times 10^{13}$ protons/cycle

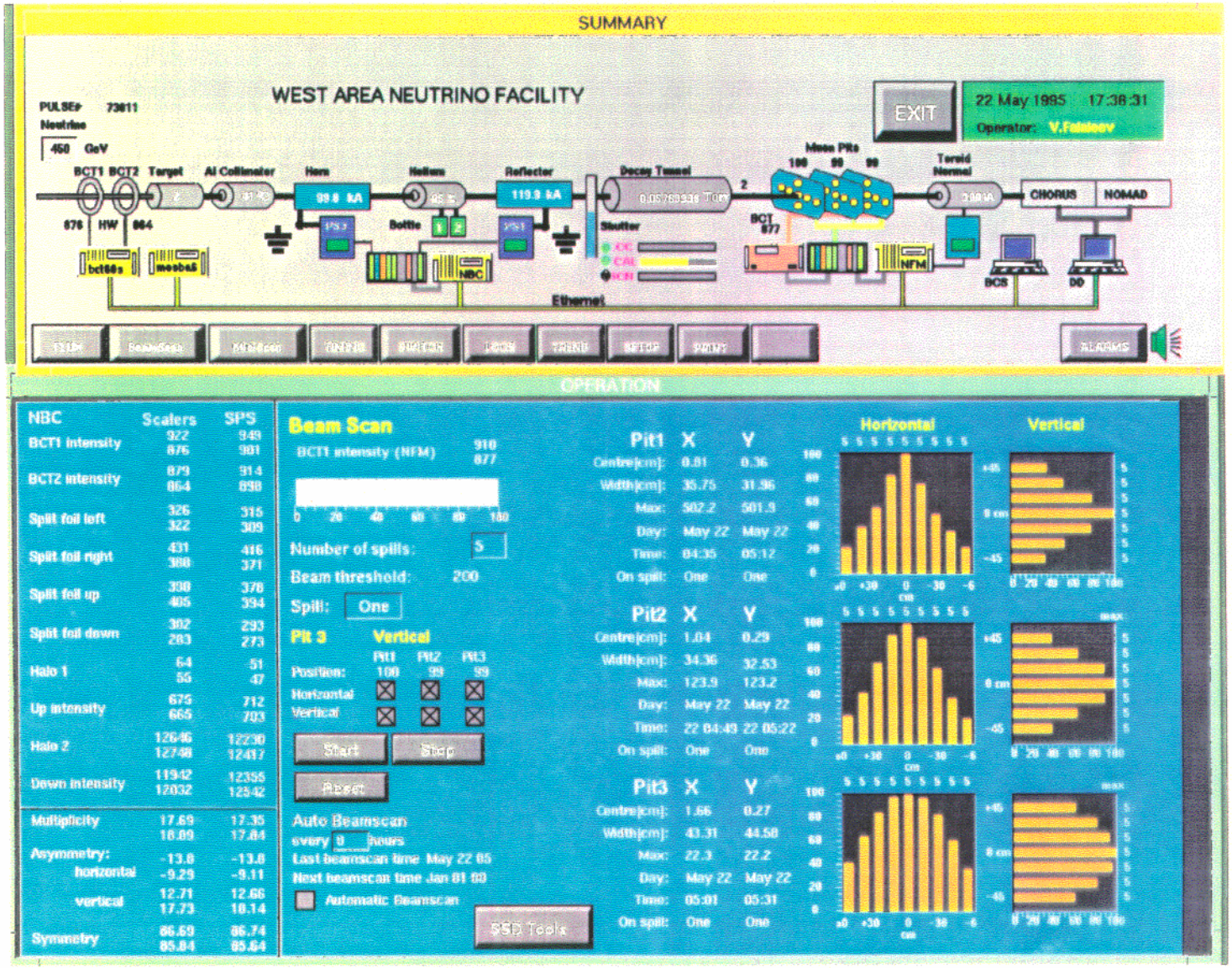
High Energy: $< E_{\nu_\mu} > \approx 27$ GeV

Low Contamination : $\frac{N_{\nu_\tau}}{N_{\nu_\mu}} \sim 3 \times 10^{-6}$



Two 6 ms bursts/ 14.4 s

$L \approx 600$ m



CHORUS is...

- A classic "appearance experiment"....
- Aim:

CHORUS looks for:

identification of ν_τ EVENT by EVENT

detecting both ν_τ interaction and τ decay vertices

- In particular

  We should isolate "few" signal events

CC interaction: $\nu_\tau N \rightarrow \tau^- X$

$\hookrightarrow \mu^- \nu\nu$ 18%

$\hookrightarrow h^- \nu + n\pi^0$ 50%

$\hookrightarrow h^- h^- h^+ + n\pi^0$ 14%

- From the large background of
- $\nu_\mu N \rightarrow \mu^- X$ (CC)
- $\nu_\mu N \rightarrow \nu_\mu X$ (NC)

The Chorus Idea

- Use a "big" active target (800 kg) of Nuclear Emulsions

($\sim 1.\mu$m of resolution)

τ^- has lifetime $c\tau$=90 μm$\Rightarrow$ ~ 1.5 mm flight path

with:

- Automatic Scanning facilities
  (Reduce the Scanning Time)
- High resolution tracking devices
  (Reduce the Scanning Area)
- Electronic Detectors with good E,P,θ resolution
  (Scanning Sample Reduction and Kinematical Recostruction)

The CHORUS Detector

Calorimeter

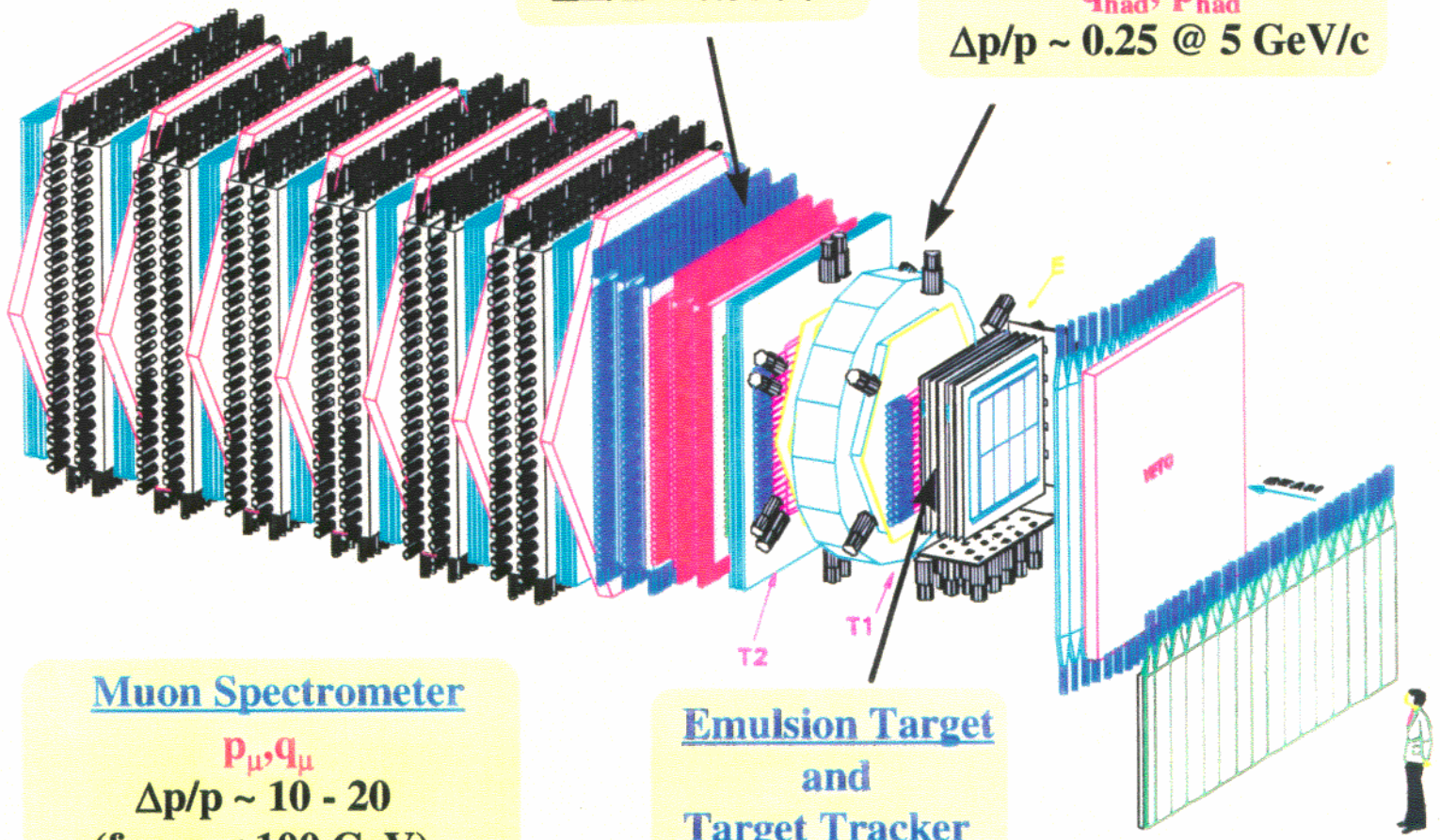
E_{had}, Θ_{had}

$\Delta E/E \sim 0.35/\sqrt{E}$

Magnet Spectrometer

q_{had}, p_{had}

$\Delta p/p \sim 0.25$ @ 5 GeV/c



Muon Spectrometer

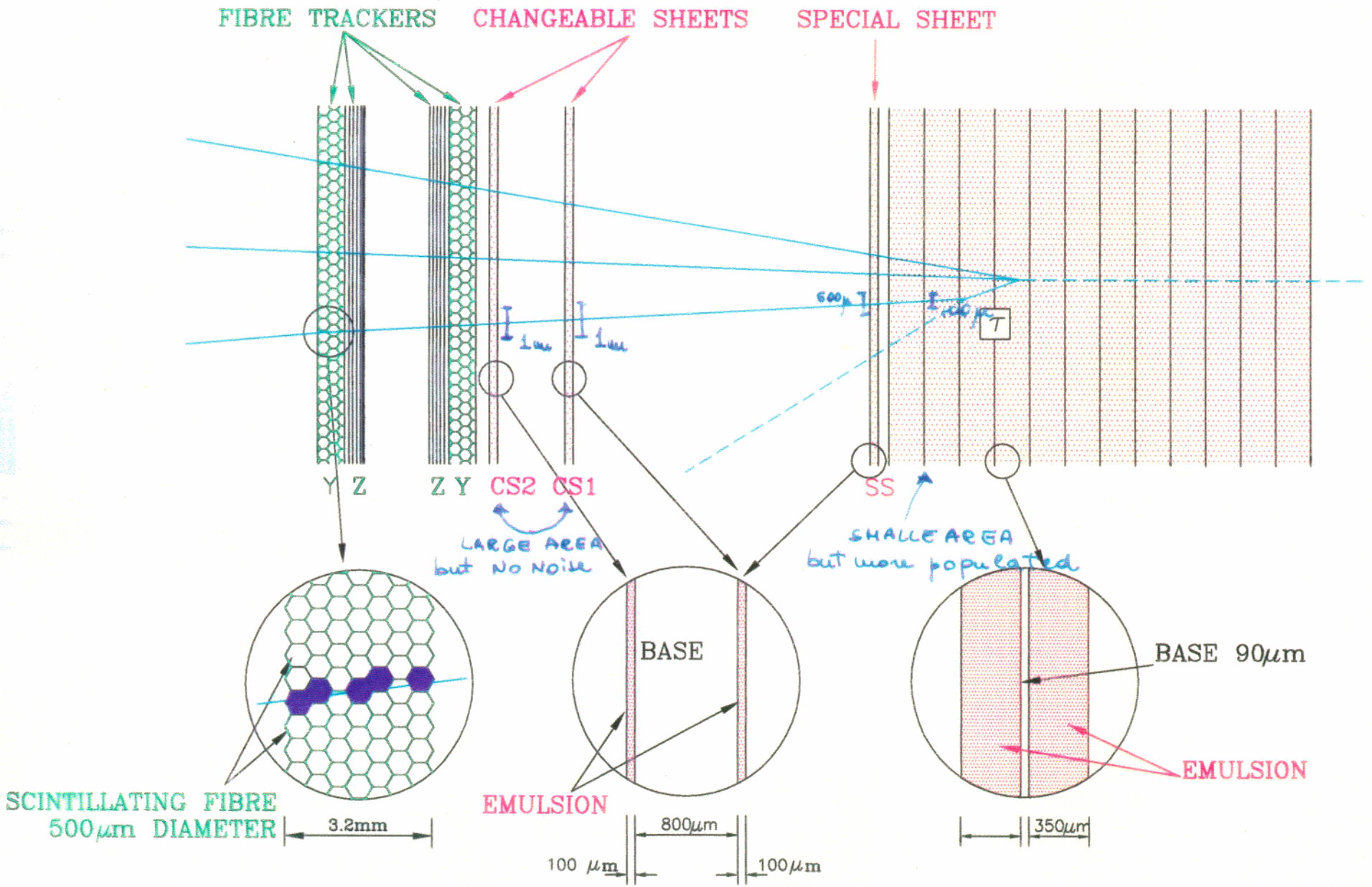
p_μ,q_μ

$\Delta p/p \sim 10 - 20$

(for $p < 100$ GeV)

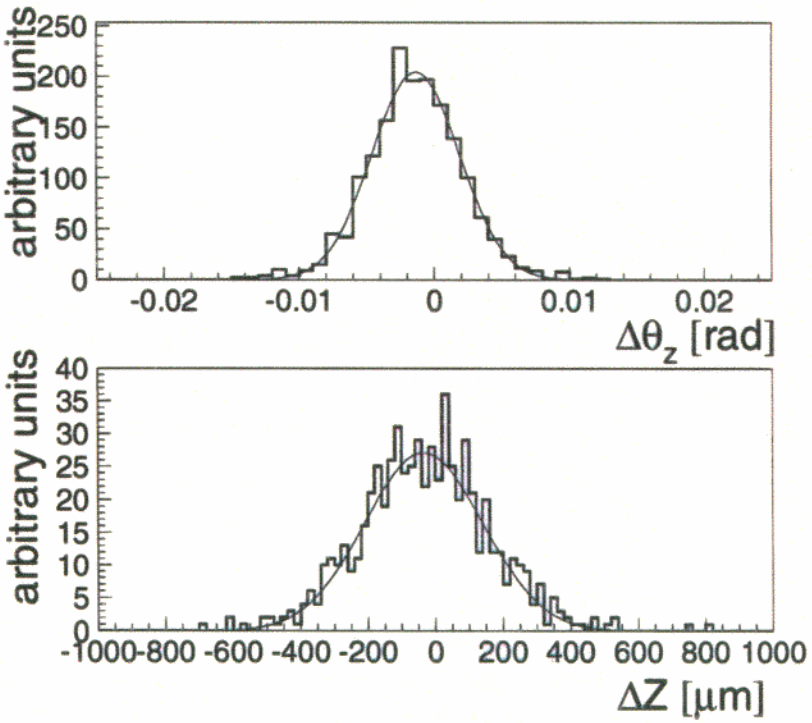
Emulsion Target and Target Tracker

CHORUS TARGET

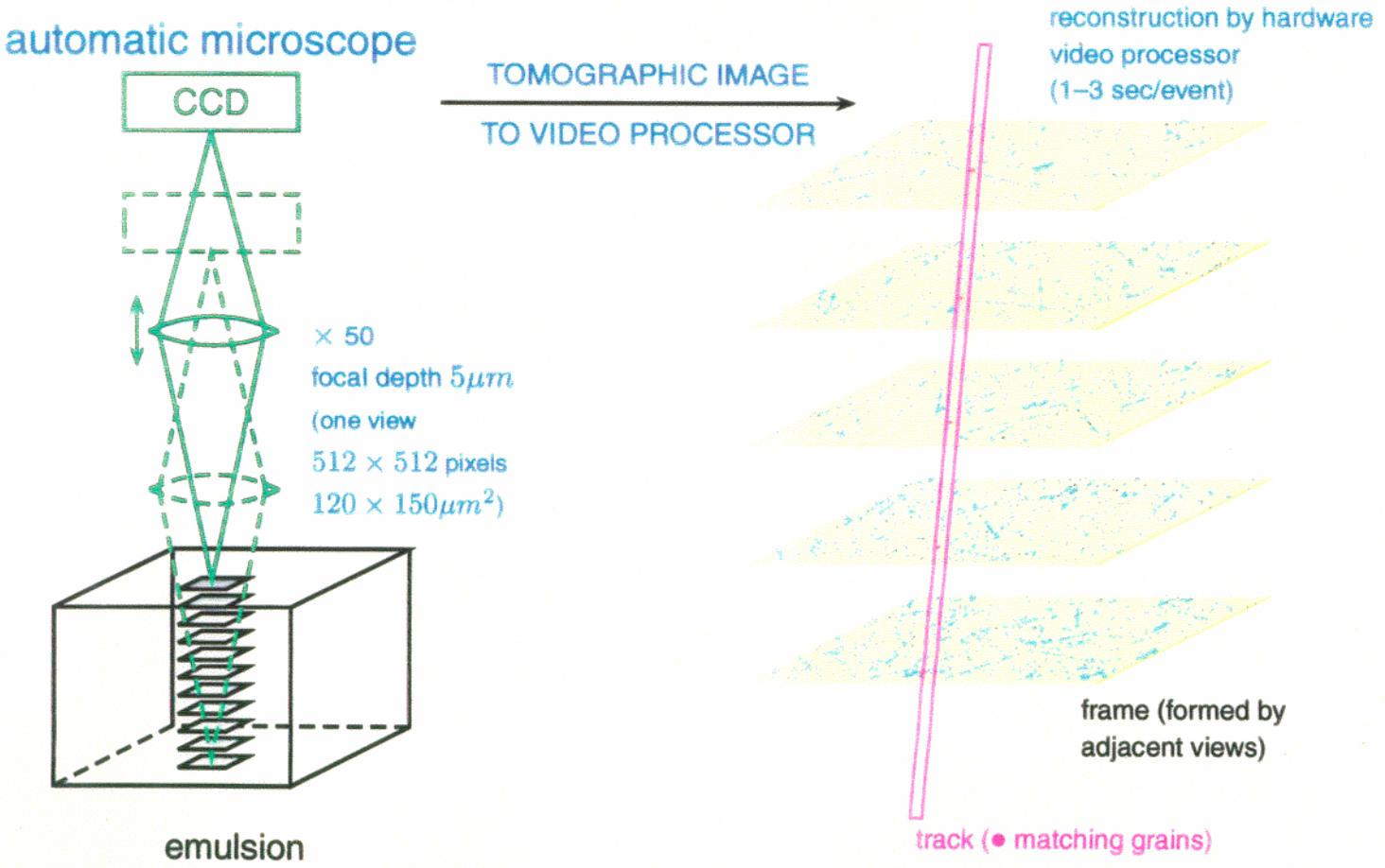


Target Tracker resolution

- Obtained by comparing reconstructed tracks with tracks scanned in emulsion
- Resolution: 200 μm, 3mrad



Automatic Scanning



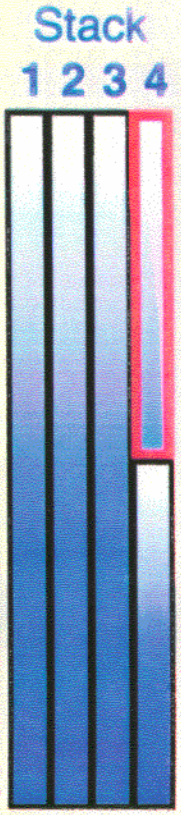
CHORUS Runs

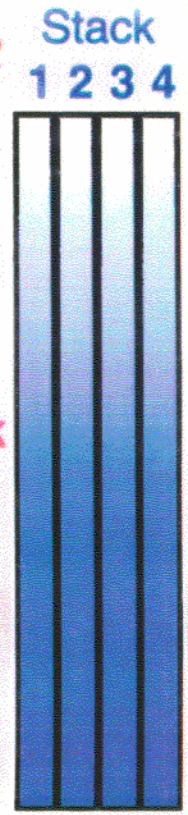
Run I

		Σ CC
May 94	Start of data taking *(Proposal 1991)*	
Oct 94	Stack 4 developed and replaced ➔1st pilot analysis	117 k
Oct 95	All emulsion developed	317 k

Run II

		Σ CC
Apr 96	New emulsion	
Sep 96	3.4 x 10^{19} pot	554 k
Nov 97	End of data taking	842 k





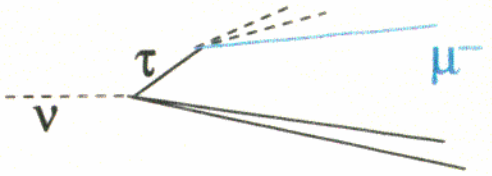
μ^- Channel

Flightlength: $20\,\mu m \leq \gamma c\tau \leq 5\,mm$

...to reject K decays

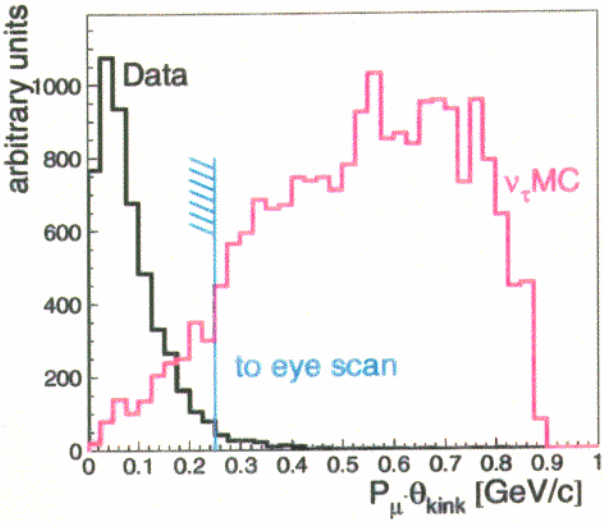
Conditions for Daughter-Track :

$$\tau \xrightarrow{17\%} \mu\,\bar{\nu}_\mu\,\nu_\tau$$

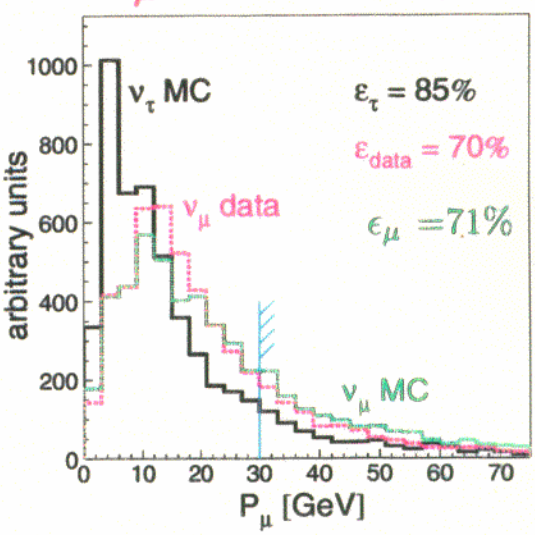


- **Track to follow :** negatively charged muon

$P_T \geq 250\,MeV/c$



$P_{\mu^-} \leq 30\,GeV/c$

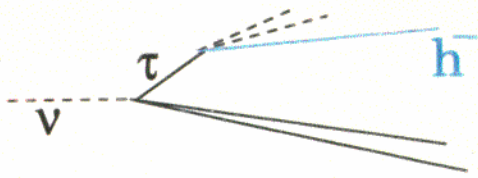


- **Main BG Source :**

$$\bar{\nu}_\mu N \rightarrow \mu^+ X D^-$$

escapes identification ... $\hookrightarrow \mu^- \bar{\nu}_\mu K^o$ $\approx \frac{10^{-7}}{N^{obs}_{\nu_\mu}}$

$\tau \xrightarrow{50\%} \nu_\tau\, h^-\, (n\pi^o)$



- **Track to follow :** negatively charged hadron

- **Kinematical Cut :**

$$1\,GeV/c \leq P_{h^-} \leq 20\,GeV/c$$

$$+ \qquad P_T \geq 250\,MeV/c$$

- **Main BG Source :**

$\bar{\nu}_\mu N \rightarrow \mu^+ X D^-$; $D^- \rightarrow h^- + neutr.$ $\approx 10^{-7}/N^{obs}_{\nu_\mu}$

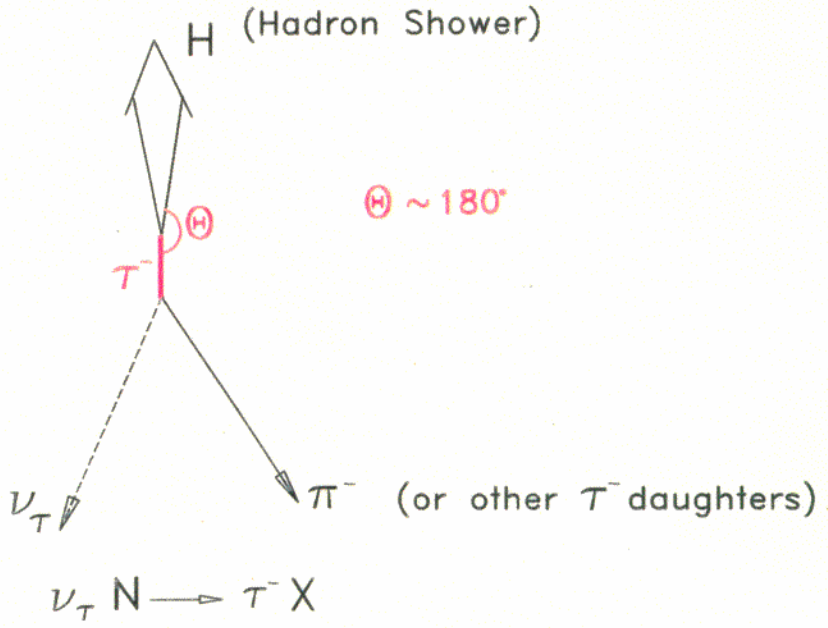
escapes identification ...

$h^- N \rightarrow h^- N$ (WK) $\approx 10^{-6}/N^{obs}_{\nu_\mu}$

without visible recoil ...

Vertex Kinematics : Transverse Plane

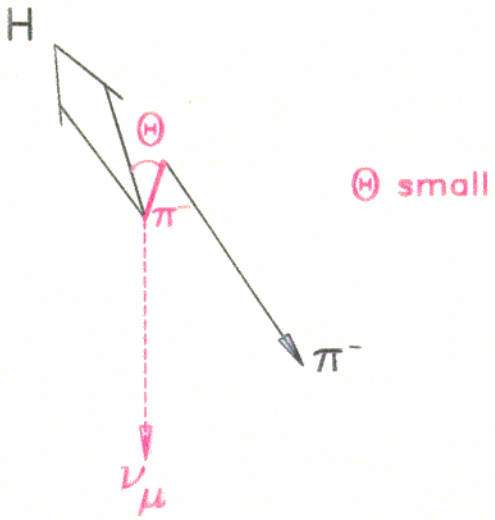
Signal : τ^-



$\nu_\tau N \longrightarrow \tau^- X$

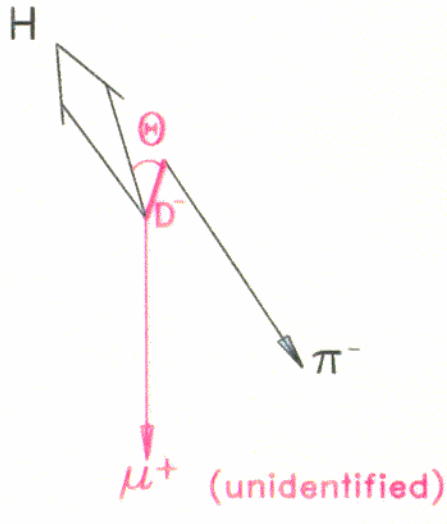
Background:

"White Kink"



$\nu_\mu N \longrightarrow \nu_\mu \pi X$

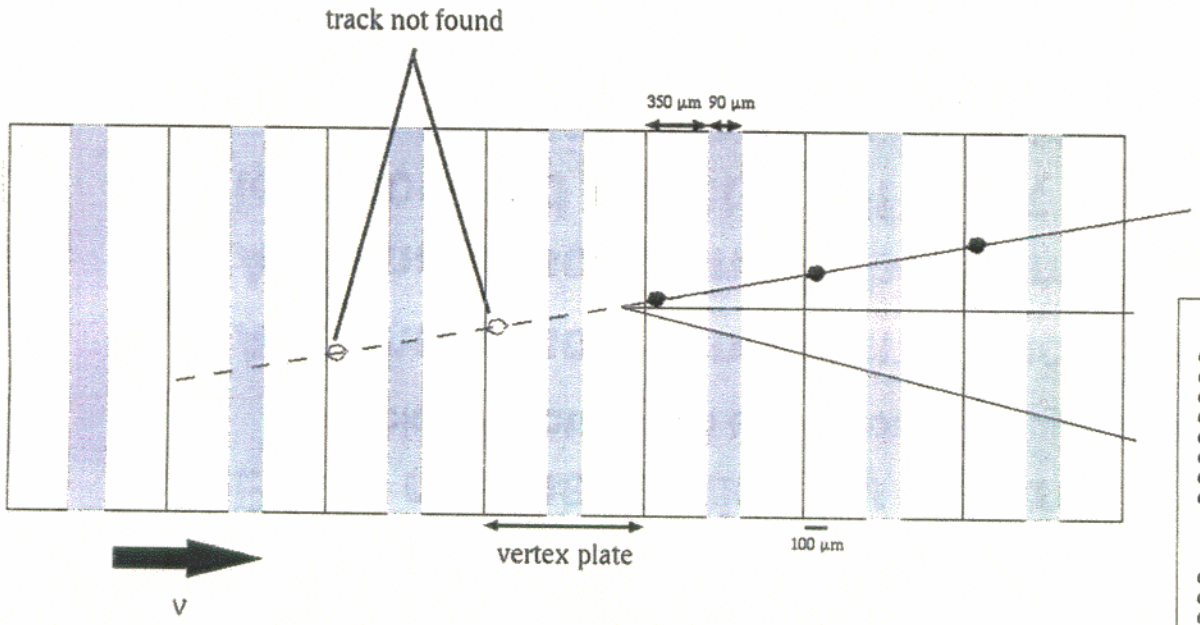
Charm (D^-) Decays



$\bar{\nu}_\mu N \longrightarrow \mu^+ D^- X$

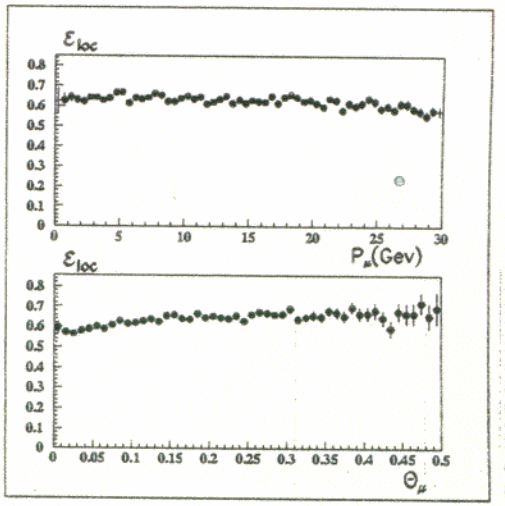
Θ ≡ Transverse Angle between Kink Parent and Hadron Shower

Vertex location



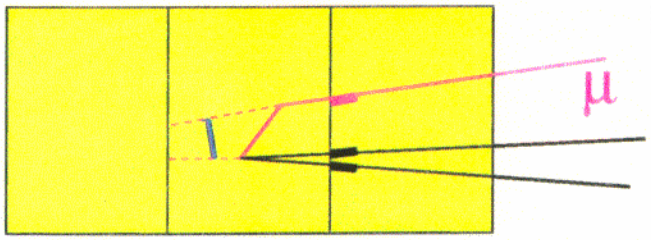
Vertex location procedure

Location efficiency



Detection Strategy

SHORT DECAY (1 plate) [30%]

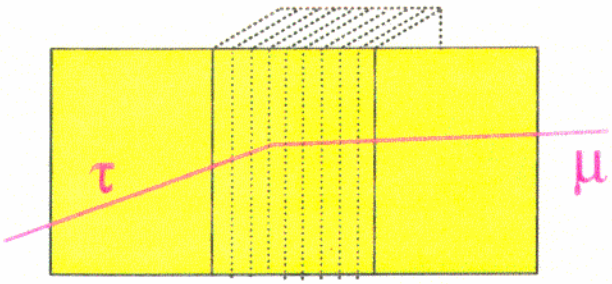


Impact Parameter Methode

$\nu_\mu \rightarrow IP \sim 0$

$\nu_\tau \rightarrow IP > 0$

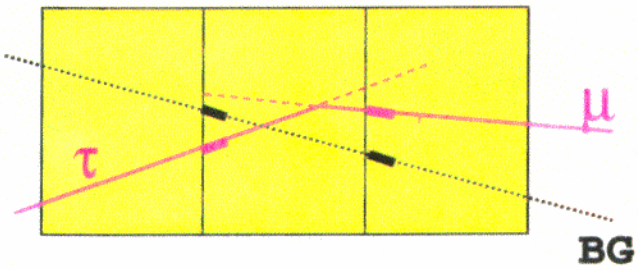
LONG DECAY, LARGE ANGLE [60%]



Video Image Analysis

Tracking through CCD pixel clusters from 96 emulsion slices

+ 1995 :

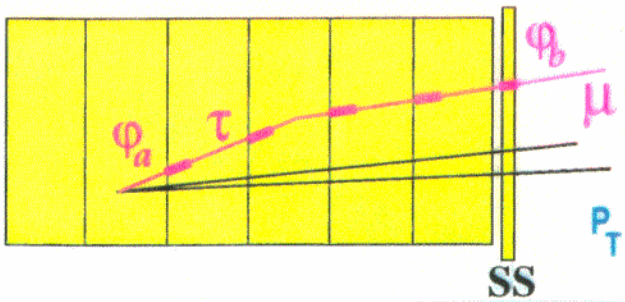


Parent Track Search

Connection of parent with muon by IP

BG track suppression

LONG DECAY, SMALL ANGLE [10%]



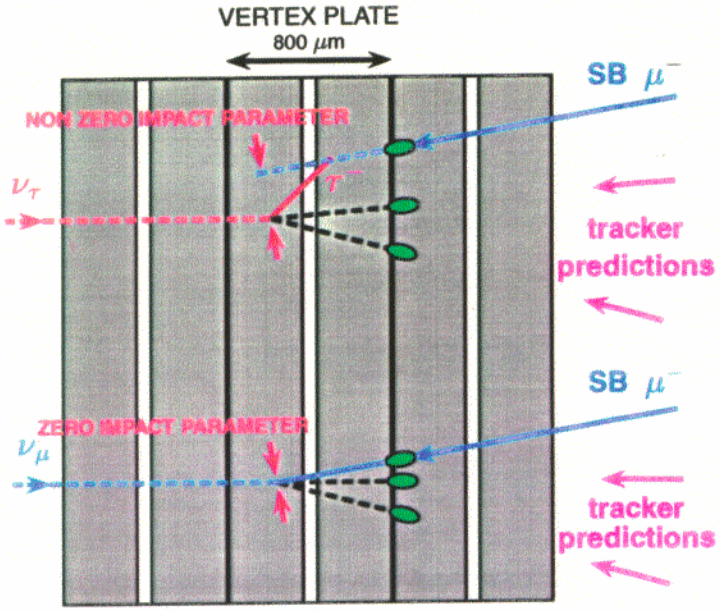
P_T Analysis

Cut on :

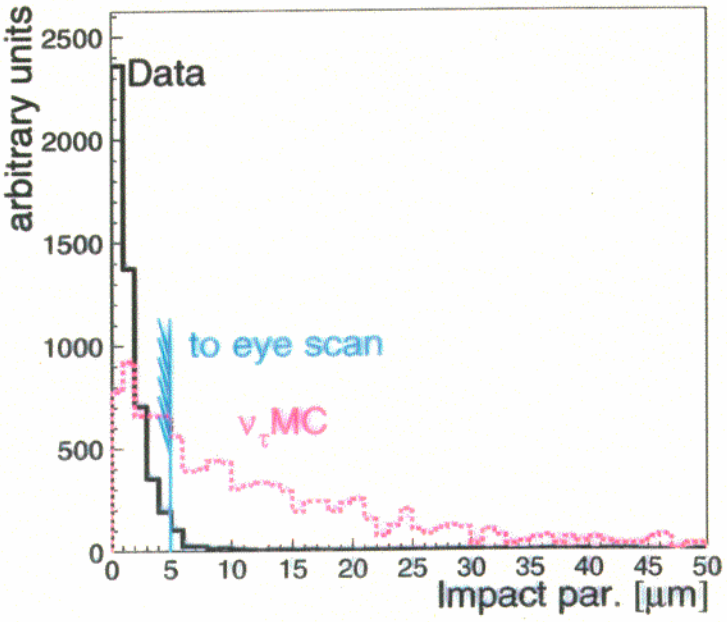
$P_T = P_\mu \cdot |\varphi_a - \varphi_b| \geq 250$ MeV/c

"Short" Decay (27 %)

vertex and decay in same plate



impact parameter cut



Vertex Properties

Nuclear Fragments:

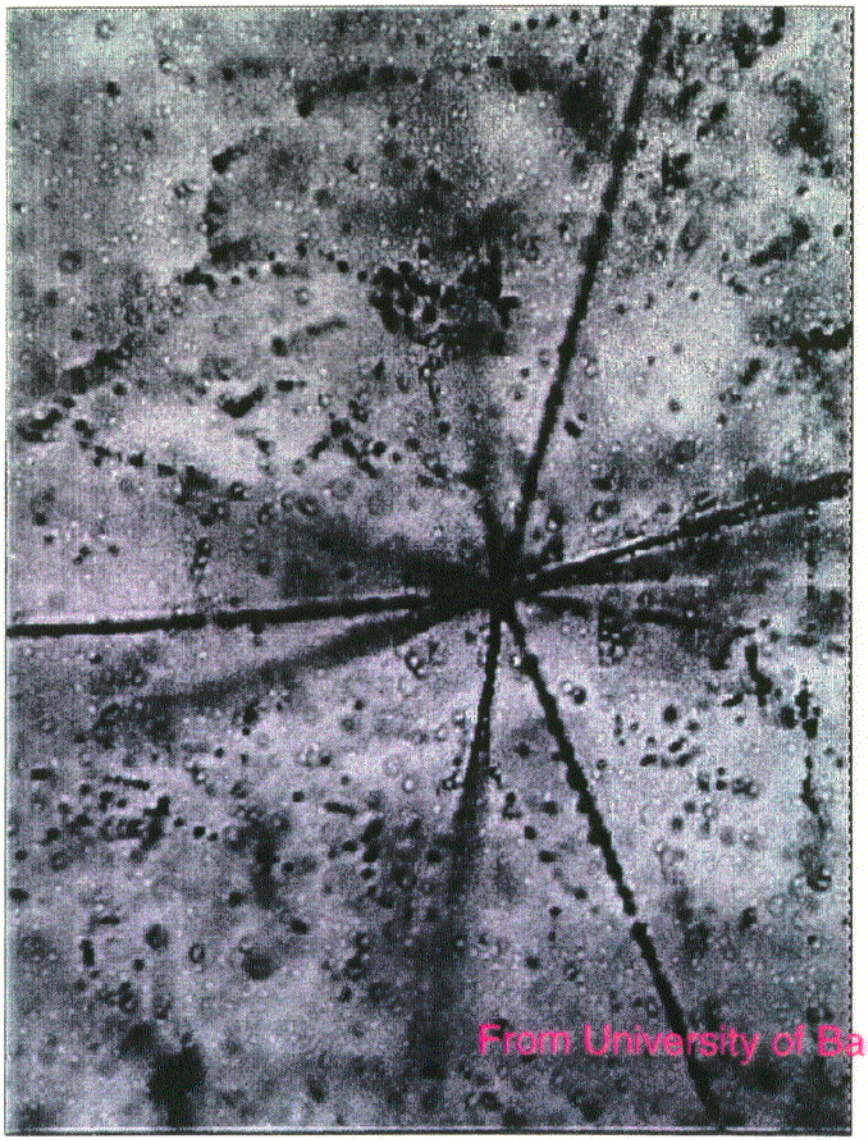
> 200 grains/ 100 μm

$\sim$ 5.3 tracks/ event

Shower particles

$30-40$ grains/100 μm

$\sim$ 3.6 tracks/event

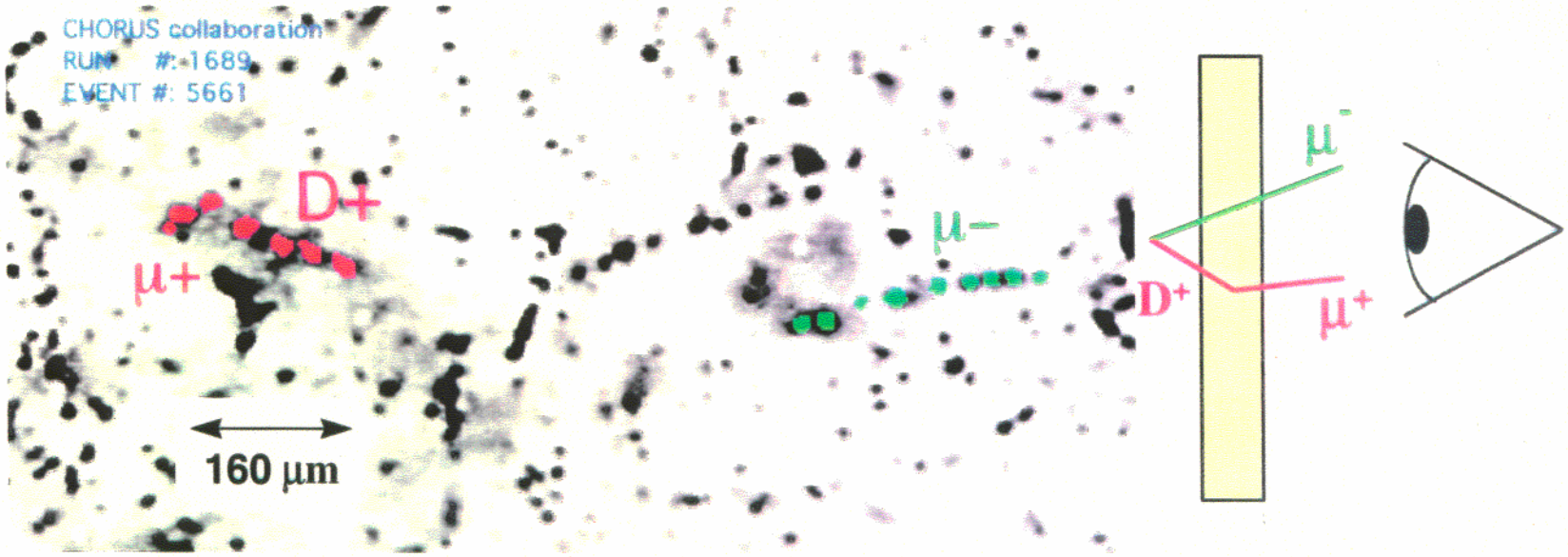


From University of Bari

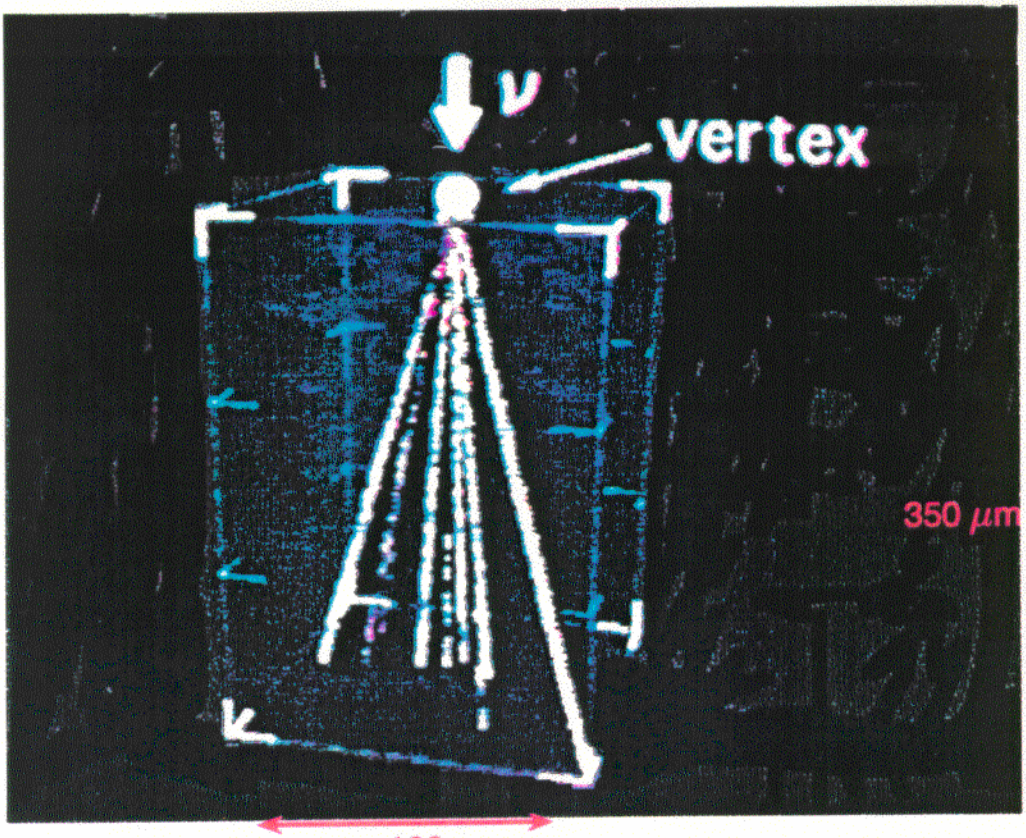
Dimuon Event in the Emulsion

$\nu N \rightarrow D^+ \mu^- X$

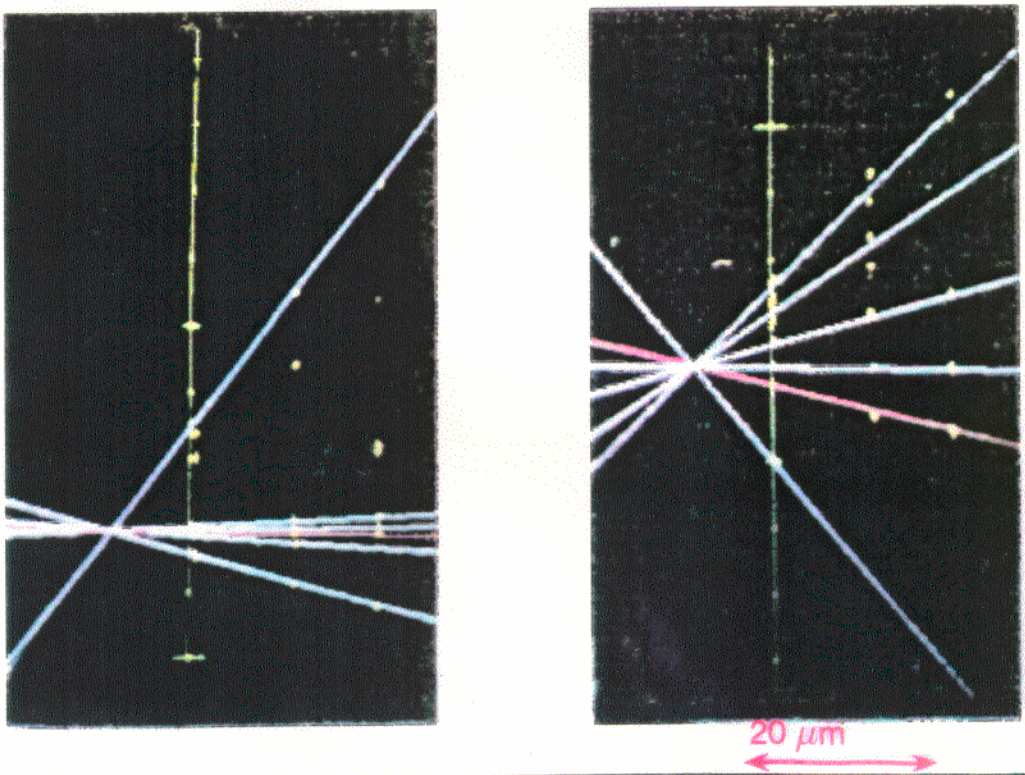
$\hookrightarrow \mu^+ +$ neutrals



Video image of vertex reconstruction in Emulsion at Nagoya



Video image of tracks reconstruction at the vertex in two projections



Data

(data taking finished in 1997)

	1994	1995	1996	1997	All
Pot/10^{19}	0.81	1.20	1.38	1.67	5.06
Chorus efficiency	0.77	0.88	0.94	0.94	0.90
Potato/10^{19} *)	0.62	1.06	1.30	1.76	4.74
Deadtime	0.10	0.10	0.13	0.12	
Main triggers	388 k	547 k	617 k	719 k	2271K
CC per main trigger	0.30	0.37	0.38	0.40	0.37
1μ events	66911	110916	129669	151105	360K
0μ events	17731	27841	32548	37929	120K .
1μ scanned so far	63%	45%	56%	0%	36%
0μ scanned so far	50%	30%	0%	0%	15%
1μ located so far	18286	20642	30128	0	68156
0μ located so far	3401	3805	0	0	7206

*) Protons On Target And Tape On

Results

$36182 N_{1\mu} + 6844 N_{0\mu} \Rightarrow$ Accepted for publication on Phys. Lett. B (CERN-EP/98-73)

New data: 31974$N_{1\mu}$ + 362$N_{0\mu}$ events have been analysed

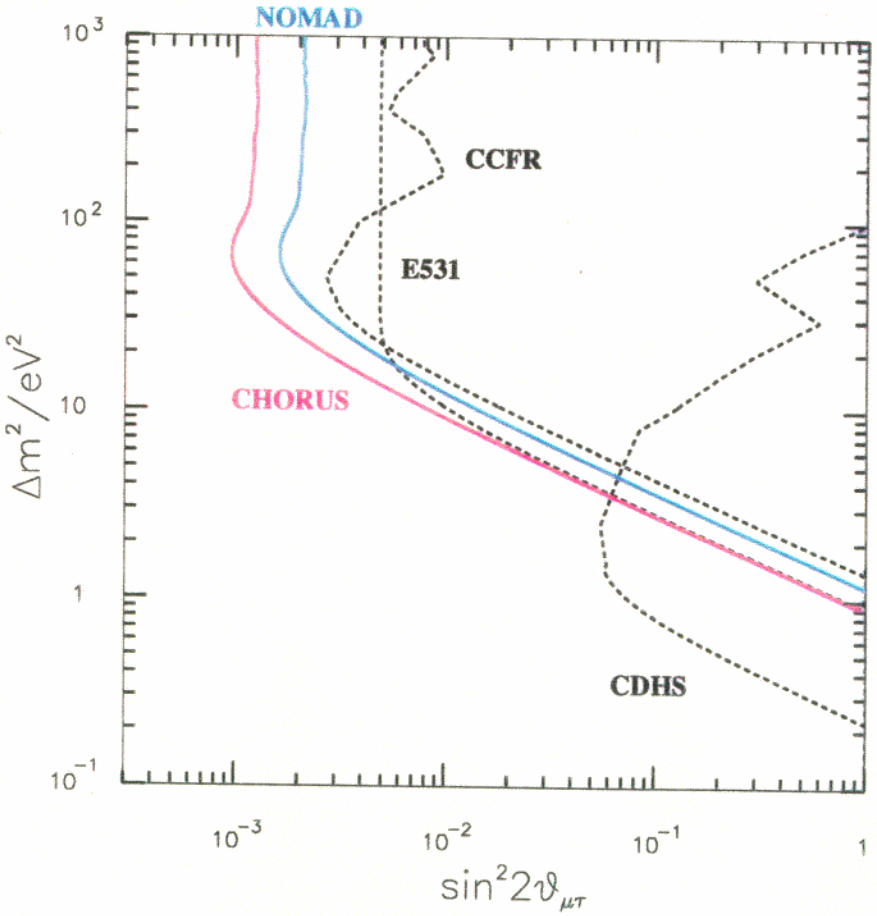
No ν_τ candidate has been found!

@ 90% C.L. $$P_{\mu\tau} \leq \frac{2.38 \cdot r_\sigma \cdot r_A}{BR_\mu \cdot <\varepsilon_{\tau\mu}> \cdot [N_\mu + N_\mu^{eq}]} = 6.0 \cdot 10^{-4}$$

where $$N_\mu^{eq} = (N_\mu)_{0-\mu} \cdot \sum_{i=2}^{4} \frac{\langle A_{\tau i} \rangle}{\langle A_{\tau\mu} \rangle} \cdot \frac{\langle \varepsilon_{\tau i} \rangle}{\langle \varepsilon_{\tau\mu} \rangle} \cdot \frac{BR_i}{BR_\mu}$$

if i=4 the μ is not identified

The exclusion plot (@ 90% C.L.)



A special event

$\nu_\mu N \to \mu^-$

$D_s^{*+} N$

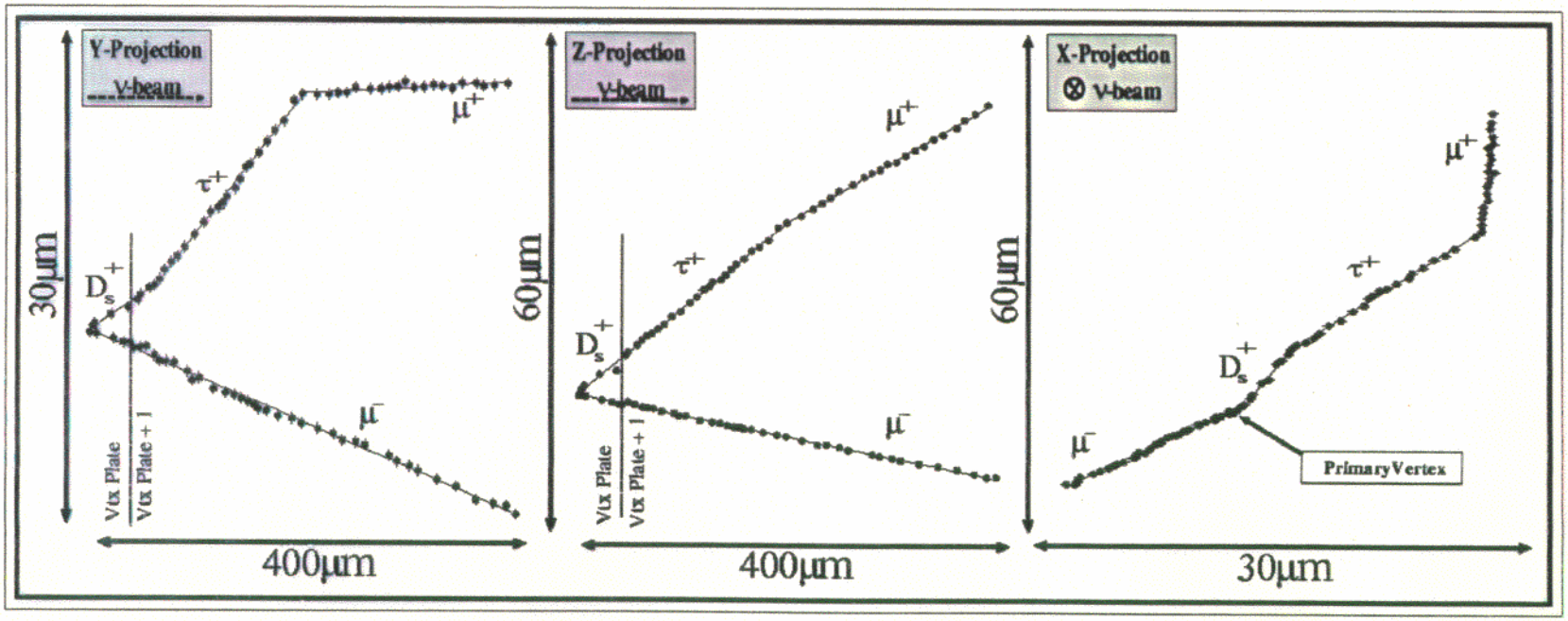
$\to D_s^+ \gamma$

$\to \tau^+ \nu_\tau$

$\to \mu^+ \nu_\mu \bar{\nu}_\tau$

CERN-EP/98-87

Parallel session 5 July 25th
talk given by O. Meizer



INTERPRETATION

- Two Decays within 215 μm

$\Rightarrow$ CHARM Decay

- Double KinK:

$D^+ \to K^+ \to \mu^+$ Prob: 9x10$^-$4

$D_s^+ \to K^+ \to \mu^+$ Prob: 2x10$^-$4

$D_s^+ \to wk \to \mu^+$ Prob: 3x10$^-$3

$D_s^+ \to K^+ \to \mu^+$ Prob: 0.96

$$D_s^+ \to K^+ \to \mu^+$$

- γ Conversion

$$D_s^* \to D_s \gamma$$

- neutral particle interaction in calorimeter

$\to$ Signal of a neutron

INTERPRETATION-2

- ...Small Q^2 ... Small t

$$Q^2 = (0.8 +\pm 0.1)\ GeV^2/c^2$$

$$t = (1.1 +\pm 0.4)\ GeV/c^2/c^2$$

- ...no nuclear break-up at the primary vertex

DIFFRATTIVE PRODUCTION of D_s^*

OUTLOOK and CONCLUSIONS

- The Electronic Detector Data Taking finished succesfully in 1997 and the Emulsion Scanning is goin on
- The Automatic Vertex location is realible and fast
- The Automatic Kink finding procedure works and is improving in speed and efficency
- When we will complete the scanning of the whole statistic we will gain:

$\rightarrow$ a factor 3.0 for the 1 μ sample

$\rightarrow$ a factor 6.7 for the 0 μ sample

If no τ candidate will be found :

$$sin^2(2\theta) \sim 2 \times 10^{-4}$$