01

Recent Results from the CHORUS Search for $\nu_\mu \rightarrow \nu_\tau$ Oscillation

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Outline

- The CHORUS experiment
- Experimental layout and analysis
- Results from the "Phase I" full data analysis
- Prospects for the "Phase II" analysis

The CHORUS experiment

- Search for ν_τ appearance on a "pure" ν_μ beam

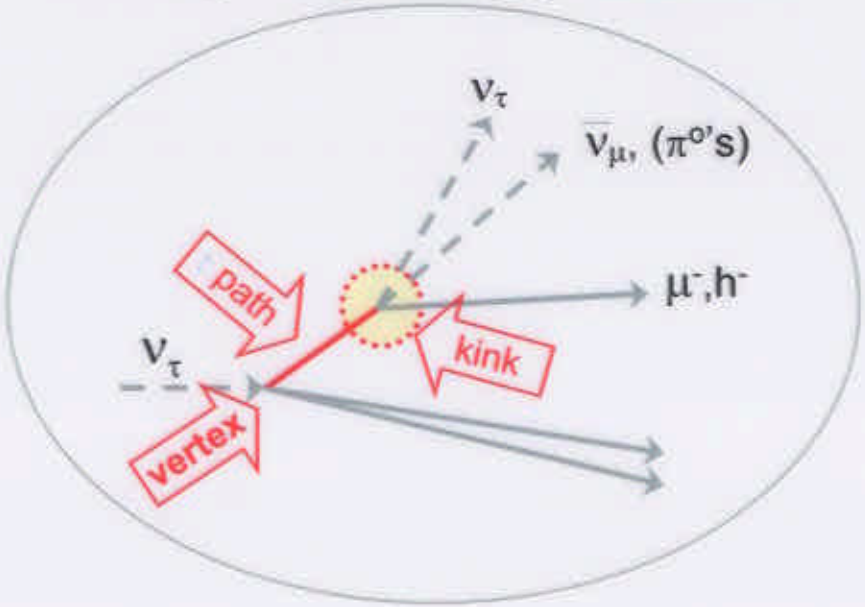
- High design sensitivity $P(\nu_\mu \rightarrow \nu_\tau)=10^{-4}$ for $\delta m^2 \approx 1\text{-}10 eV^2$ (relevant for cosmology & DM)

- A ν_τ is detected observing the τ^- production in a CC interaction and its subsequent decay vertex in an active nuclear emulsion target (DONUT ν_τ CC interaction)

The Chorus τ "signature"

- The τ lepton is identified by the three-fold simultaneous observation of:

1. the neutrino CC interaction vertex
2. the short τ^- path, $c\tau=87\mu m$, $\gamma\sim O(10)$
3. the τ^- decay topology: kink



Analysis Strategy

1 Electronic detector reconstruction

– pre-selection of events and tracks to reduce the scanning load

2 Event location in emulsion

– location of tracks in the interface emulsion sheets and follow-up to the interaction vertex (Scanback)

3 Kink finding

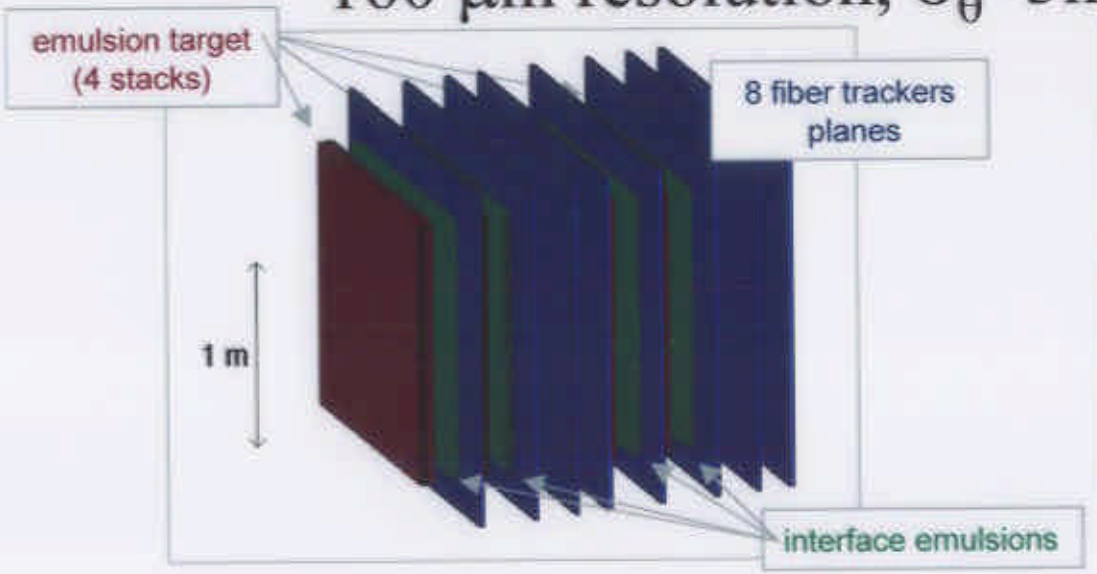
– Several "automatic" algorithms → confirmation by operator eye-scan

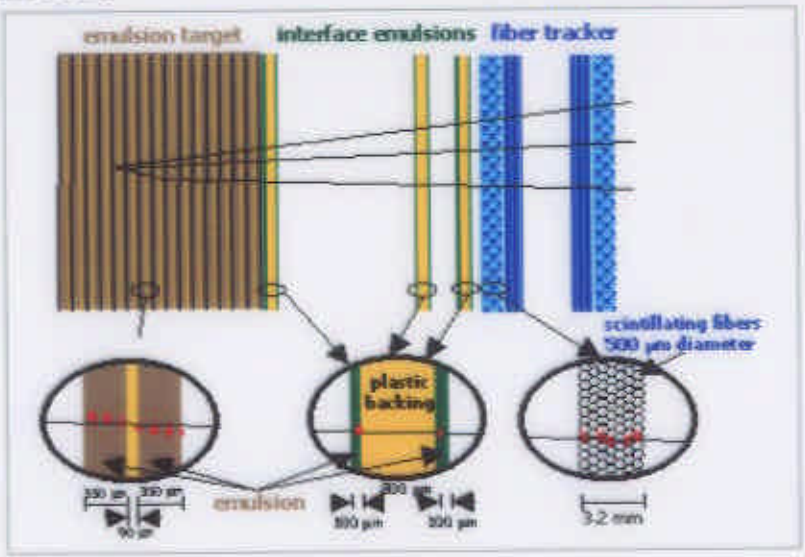
4 Post-scanning analysis

– Kinematic study, kink Pt cut, precise momentum measurement with ET

Detection Technique

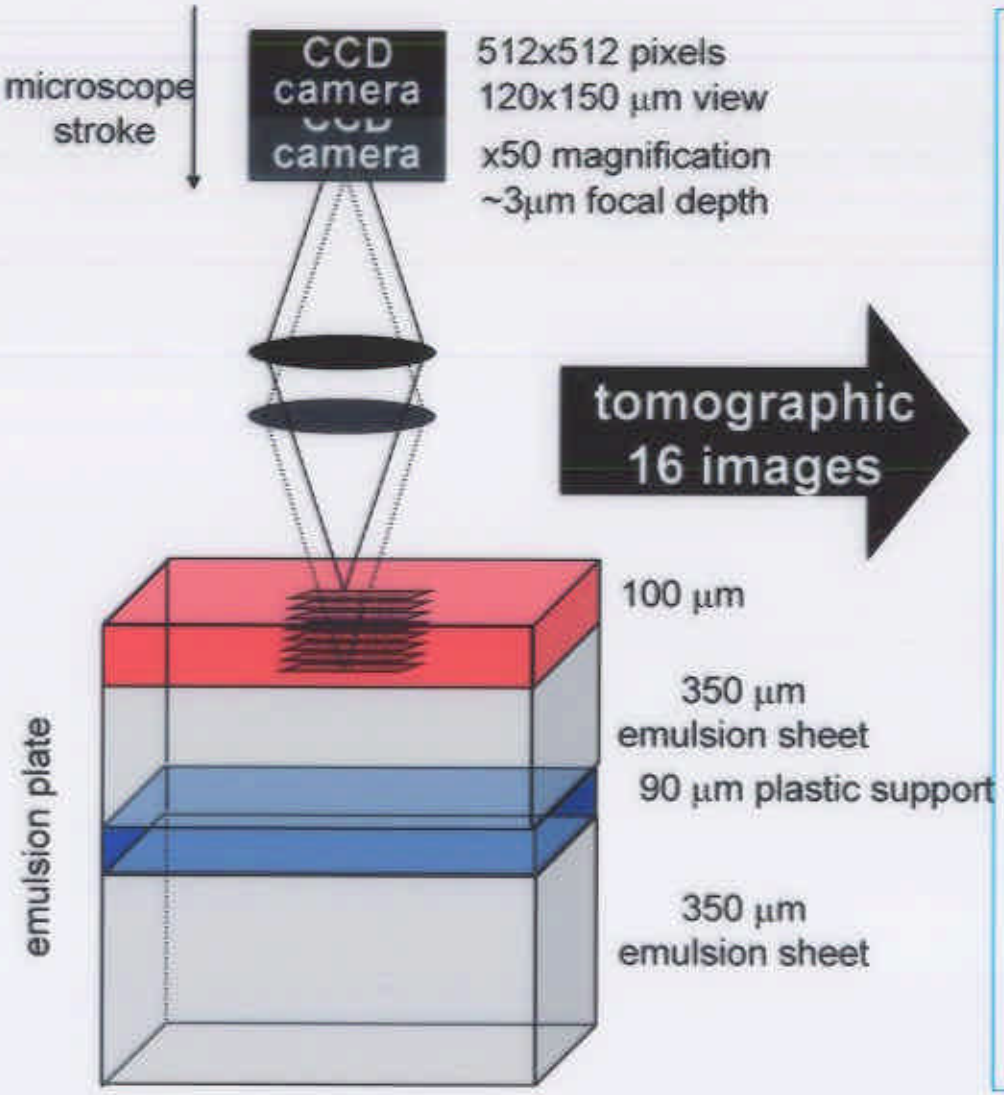
- 0.8 t emulsion as active neutrino target
  - 4 stacks of 36 plates perpendicular to the beam
  - A μvertex with ~μm resolution, 300 3D hits/mm
- The scintillating fiber tracker
  - reconstructs the primary vertex, tracks leaving the target and extrapolates back to emulsion: 160 μm resolution, σ_θ=3mrad



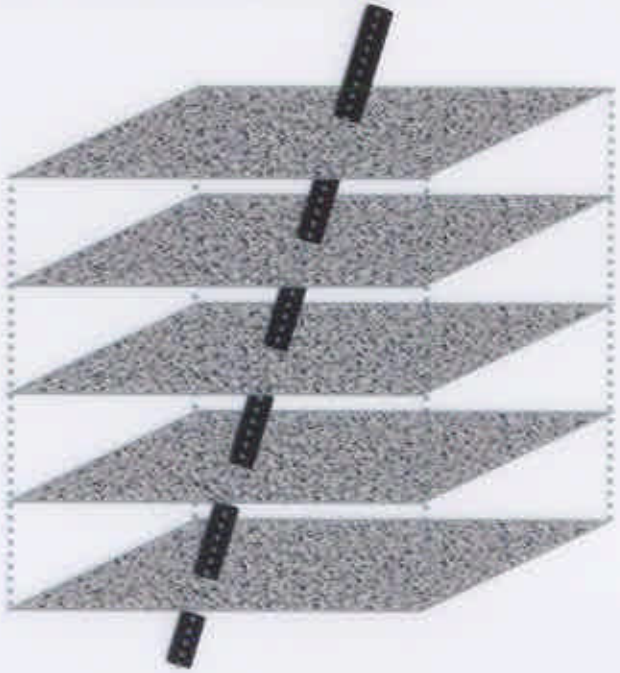


Automatic Emulsion Data Taking

(pioneered by the Nagoya Chorus group)

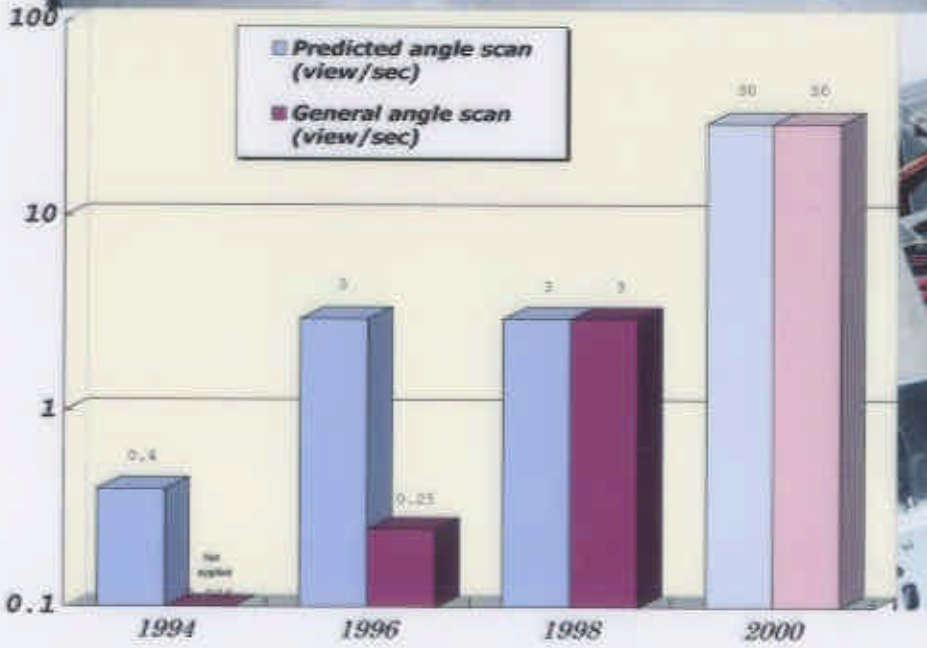


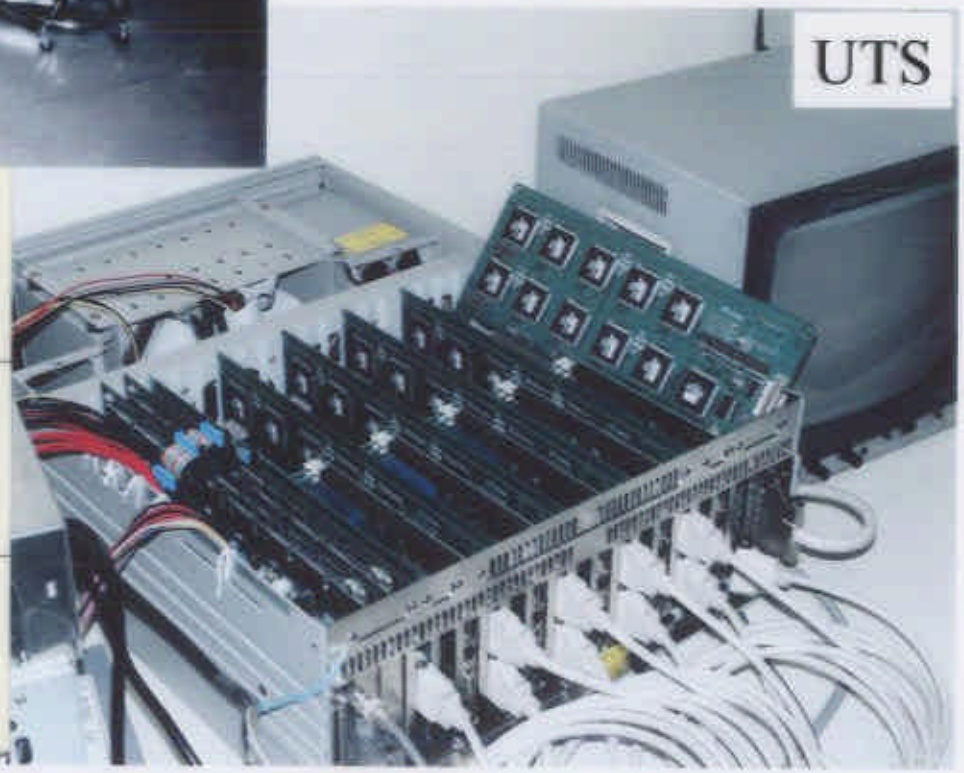
Hardware video processors reconstruct tracks as frame-to-frame emulsion grain coincidence.



Scanning systems @ Nagoya

Scanning power almost one order of magnitude every two year

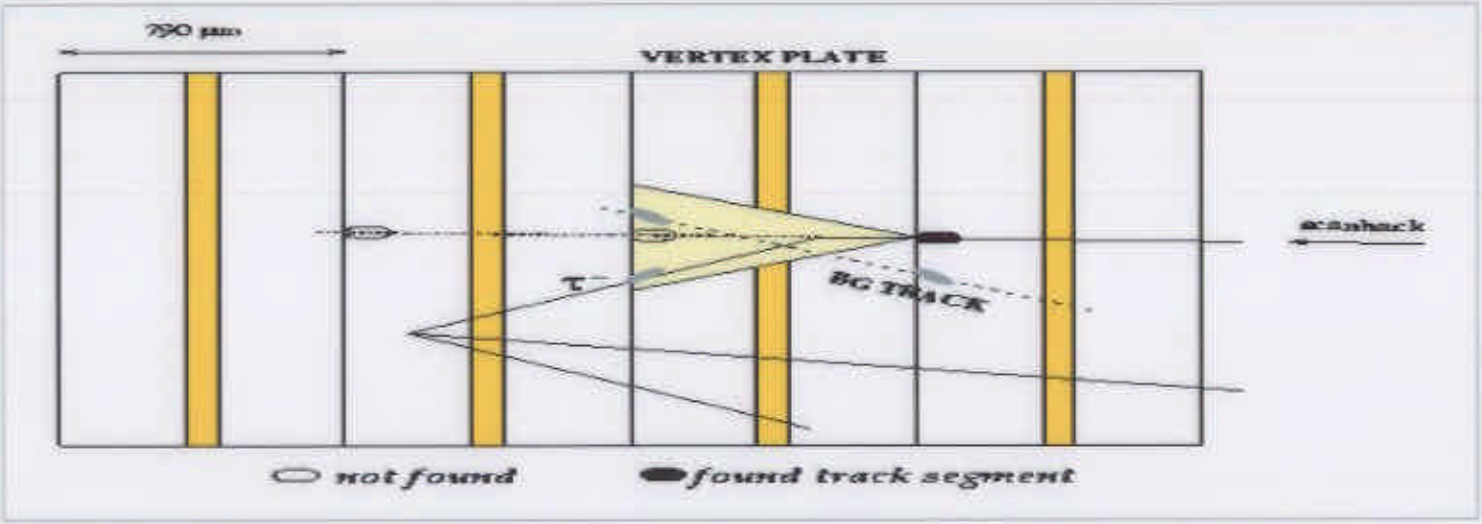




Kink Finding (Parent Search)

(Large Angle-Long Path kinks)

- 100 μm most upstream of the vertex plate are searched for all track segments in a cone of width = 1/P(GeV/c)



- Segments with small impact parameters with the follow-up track are candidates track parent

→ Kink signature

→ Manual scanning measurements

Data flow

Protons on target		$5.06 \cdot 10^{19}$
Good emulsion		~93%
Emulsion triggers		2,305 K
1μ	Events with 1 negative muon and vertex predicted in emulsion	713,000
	P_{muon} < 30 GeV/c and angular cuts	477,600
	Events scanned	355,395
	Vertices located and kink search	143,742
	Events selected for eye-scan	11,398
	Kink candidates after eye-scan	0
0μ	Event with vertex predicted in emulsion	335,000
	1 negative track with P[-20,-1] GeV/c and angular cuts	122,400
	Events scanned	85,211
	Vertices located and kink search	20,081
	Events selected for eye-scan	2,282
	Kink candidates after eye-scan	0

Expected Background Events

P_t>250MeV/c, L_{decay}<5plates(1μ), 80%(0μ) and Φ<π/2(0μ)

	1μ	0μ
Charm from ν CC with missed primary lepton $\nu_{\mu/e} N \rightarrow D^- X \mu^+/e^+$ $\hookrightarrow \mu^-/h^- +$ neutrals	0.11	0.02
Charm from ν CC with μ^+/h^+ wrong charge	< 0.03	0.3
Associated charm production in NC D^+/D^o missed, associated to $D^- \rightarrow \mu^-/h^- +$ neutrals	< 0.05	
Hadronic "White kinks elastic scattering with no recoil or nuclear breakup	---	0.8
Prompt beam ν_τ	< 0.1	
Total background	0.11	1.1

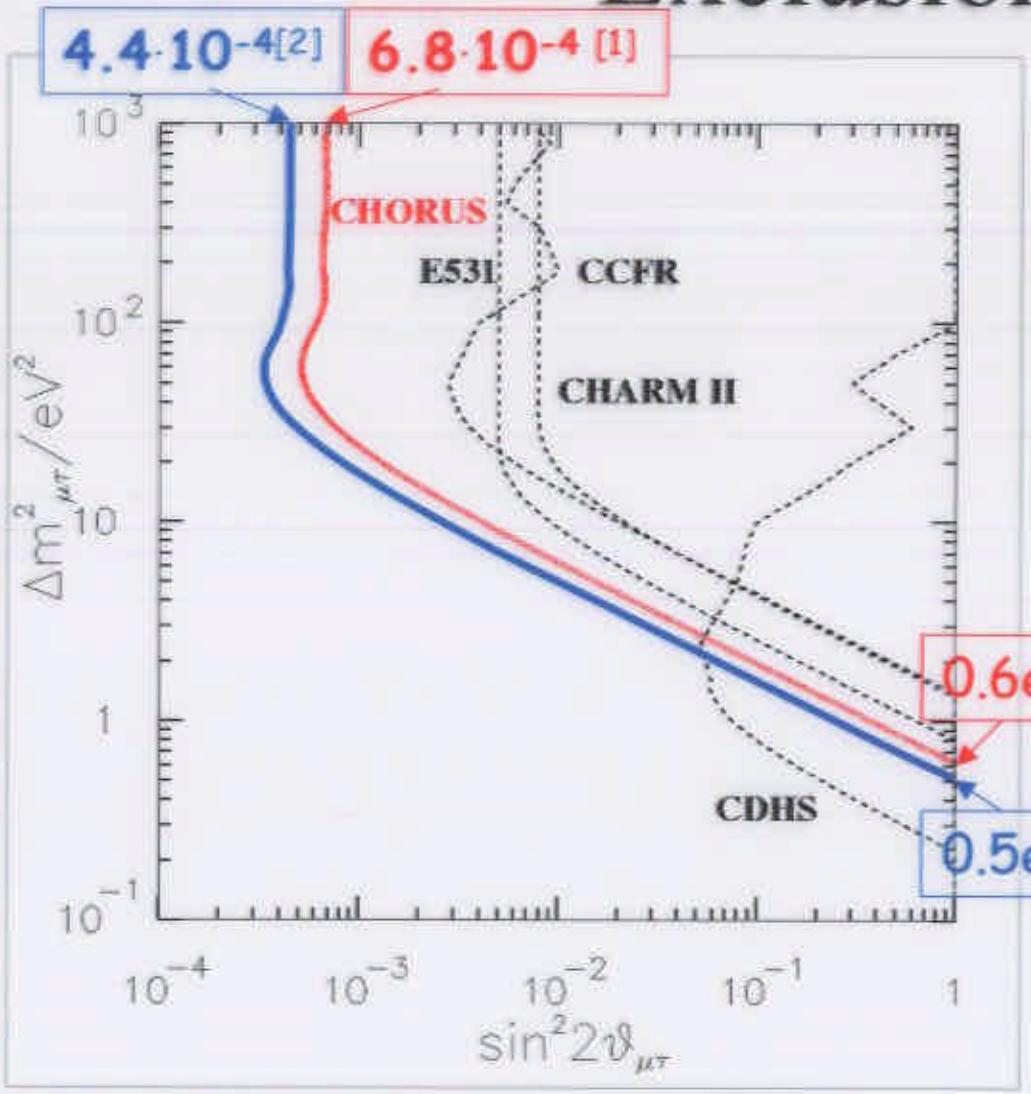
Limit Evaluation

$$P_{\mu\tau} = \sin^2 2\theta_{\mu\tau} \cdot \sin^2\left(\frac{1.27 \cdot \Delta m^2_{\mu\tau} \cdot L}{E}\right)$$

$$P_{\mu\tau} = \frac{N_\tau}{\sum_{i=\{1\mu,0\mu\}} BR_i \cdot N_i \left\langle \frac{\sigma_\tau^{CC}}{\sigma_\mu^{CC}} \cdot \frac{A_i^\tau}{A_i^\mu} \cdot \varepsilon_i^{\text{kink}} \right\rangle}$$

$\sigma_\tau^{CC}/\sigma_\mu^{CC}$	$N_{1\mu}$	$\langle A_{1\mu}^\tau / A_{1\mu}^\mu \rangle$	$\varepsilon_{1\mu}^{\text{kink}}$	$N_{0\mu}$	$\langle A_{0\mu}^\tau / A_{0\mu}^\mu \rangle$	$\varepsilon_{0\mu}^{\text{kink}}$
0.53	143,742	0.97	0.39	20,081	2.3	0.13

Exclusion Plot



$P_{\mu\tau} < 3.4 \cdot 10^{-4}$
Or, for large Δm^2
$\sin^2 2\theta_{\mu\tau} < 6.8 \cdot 10^{-4}$

at 90% CL [1]

Our exclusion power (sensitivity) is:
$P_{\mu\tau} = 3.7 \cdot 10^{-4}$

$P_{\mu\tau} = 2.2 \cdot 10^{-4}$
Or, for large Δm^2
$\sin^2 2\theta_{\mu\tau} < 4.4 \cdot 10^{-4}$

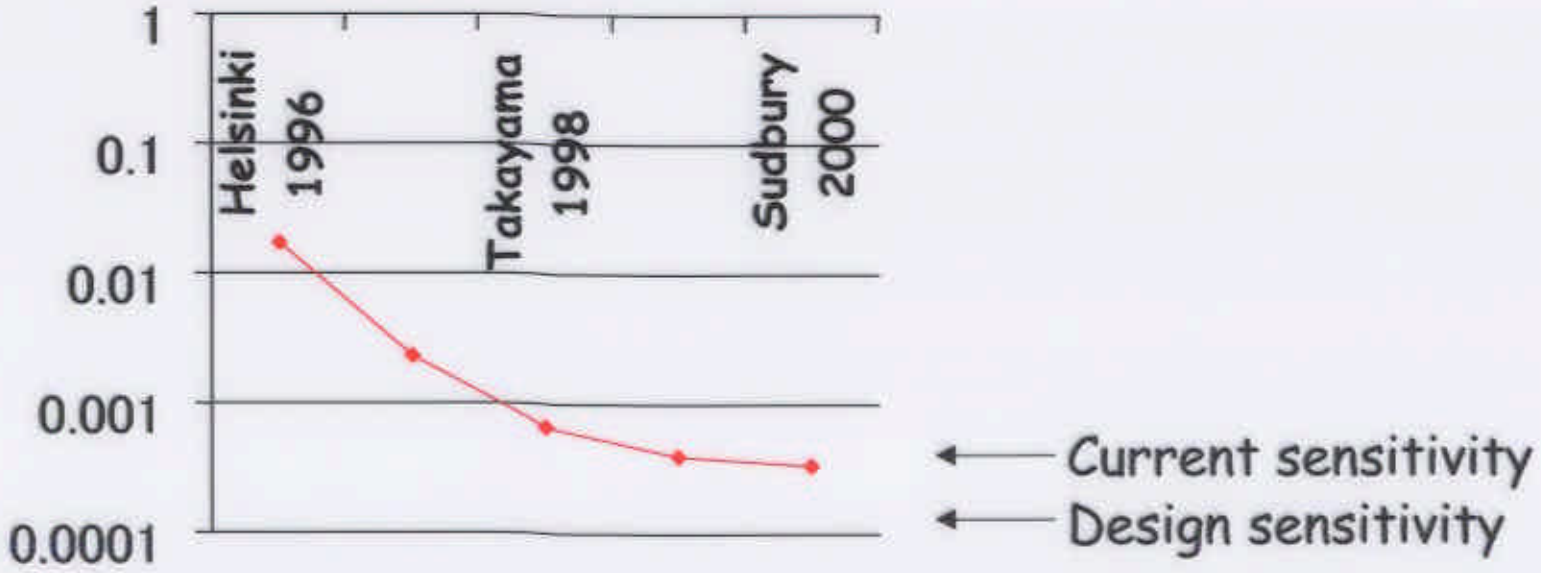
at 90% CL [2]

Comparable with NOMAD
$\sin^2 2\theta_{\mu\tau} < 4.1 \cdot 10^{-4}$@ν2000

[1] T.Junk, NIM A434 (1999) 435
[2] G.J.Feldman and R.D. Cousins, Phys.Rev. D57 (1998) 3873

Chorus Phase II Analyis

- New scanning methods (Netscan,...)
  - higher kink finding efficiency (also charm physics)
  - electron channel
- Improved reconstruction (tracking, vertex finding, muon ID,momentum)
- Additional vertices located



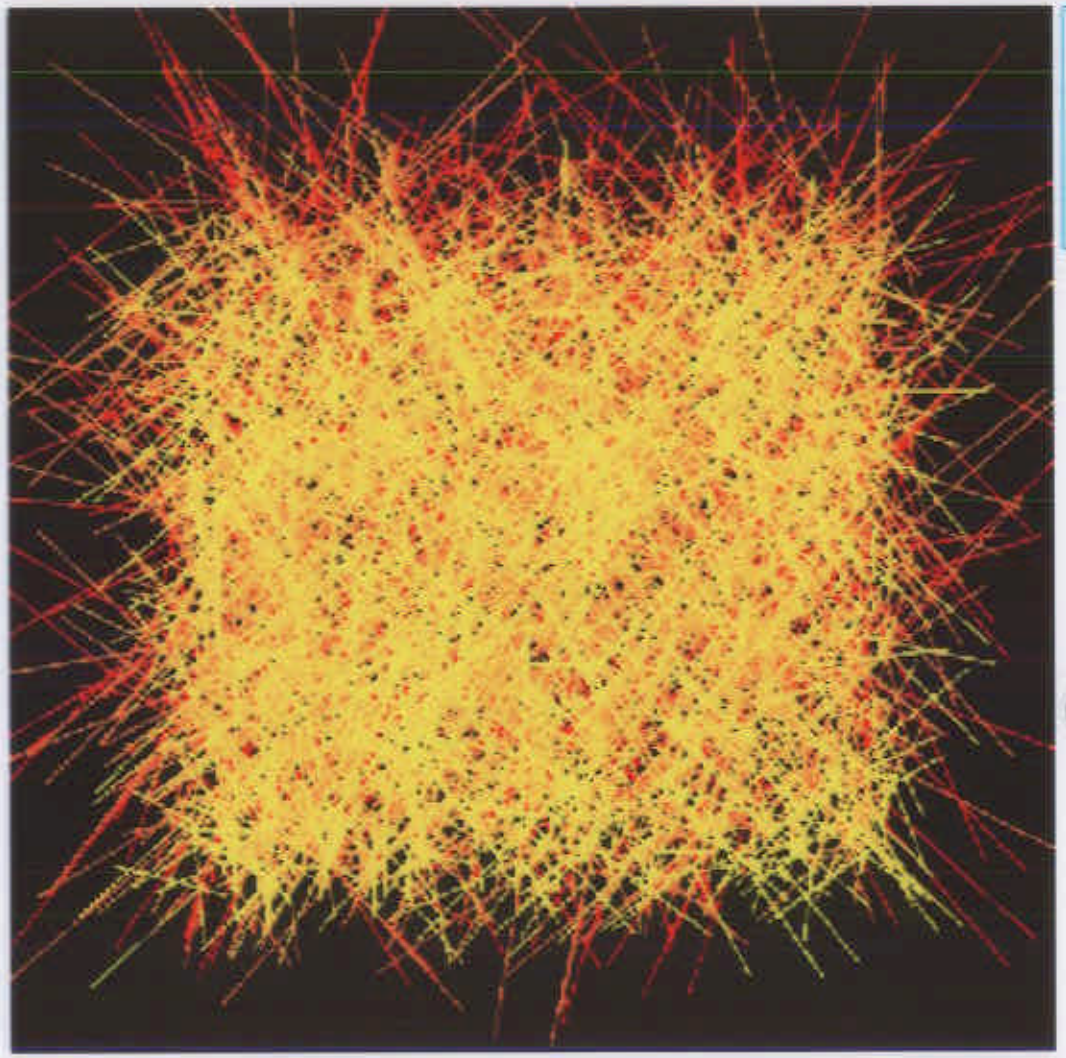
Netscan in CHORUS

- Developed in DONUT analysis
  - 3D tracking in emulsion using fast automatic scanning system(UTS)
  - Reconstruct all tracks recorded in emulsion
- Application in CHORUS "Phase II"
  - 1.5mm x 1.5mm x 6.3mm(8 plates)
  - Efficiency study in progress using charm
  - Backward TT reconstruction
    - Check hits for tracks reconstructed in Netscan
- Data taking
  - 6,000 events/month (200 events/day)
  - Pilot analysis using 8,974 events for charm detection

Netscan

(in progress for Chorus phase II)

Yellow : Upstream
Red : Downstream



All track segments (6k hits)

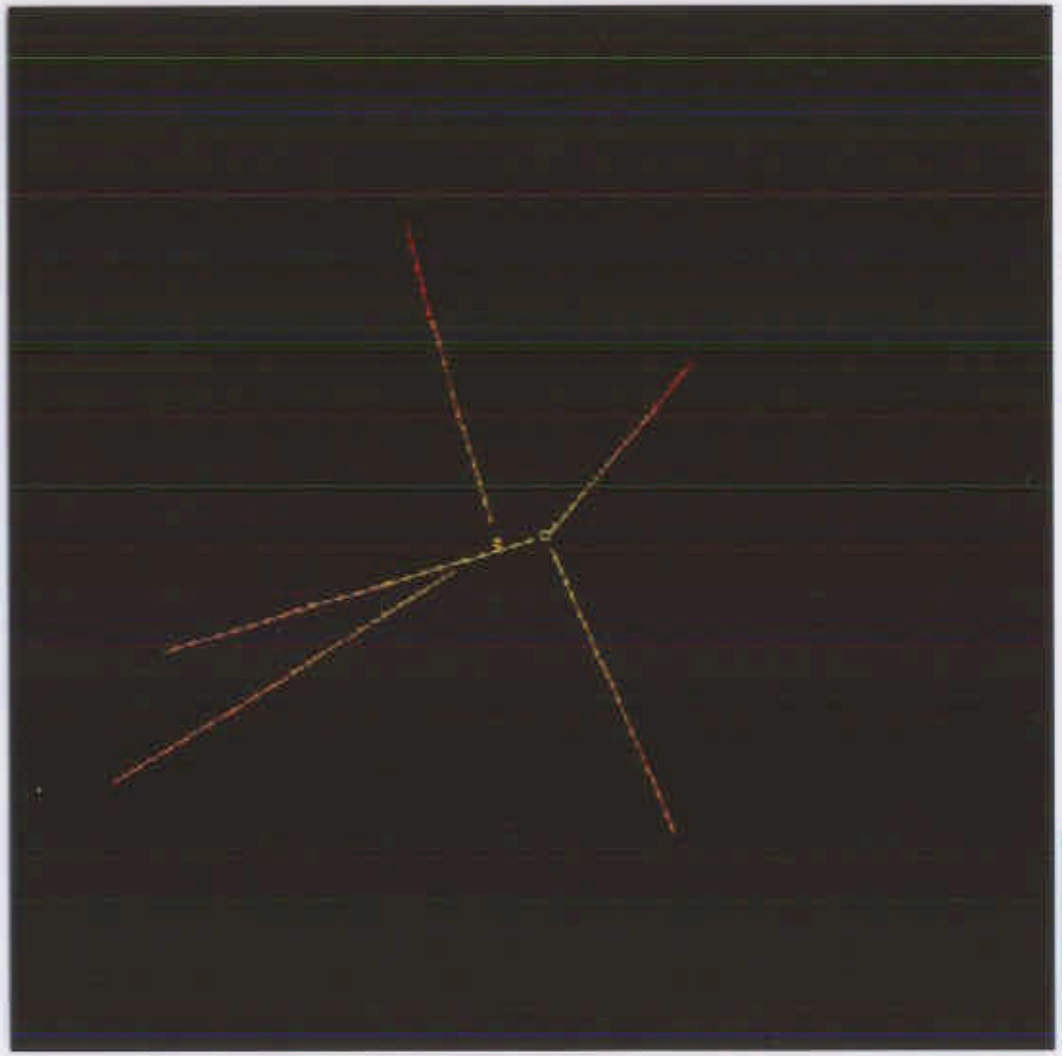
1.5 mm

1.5 mm

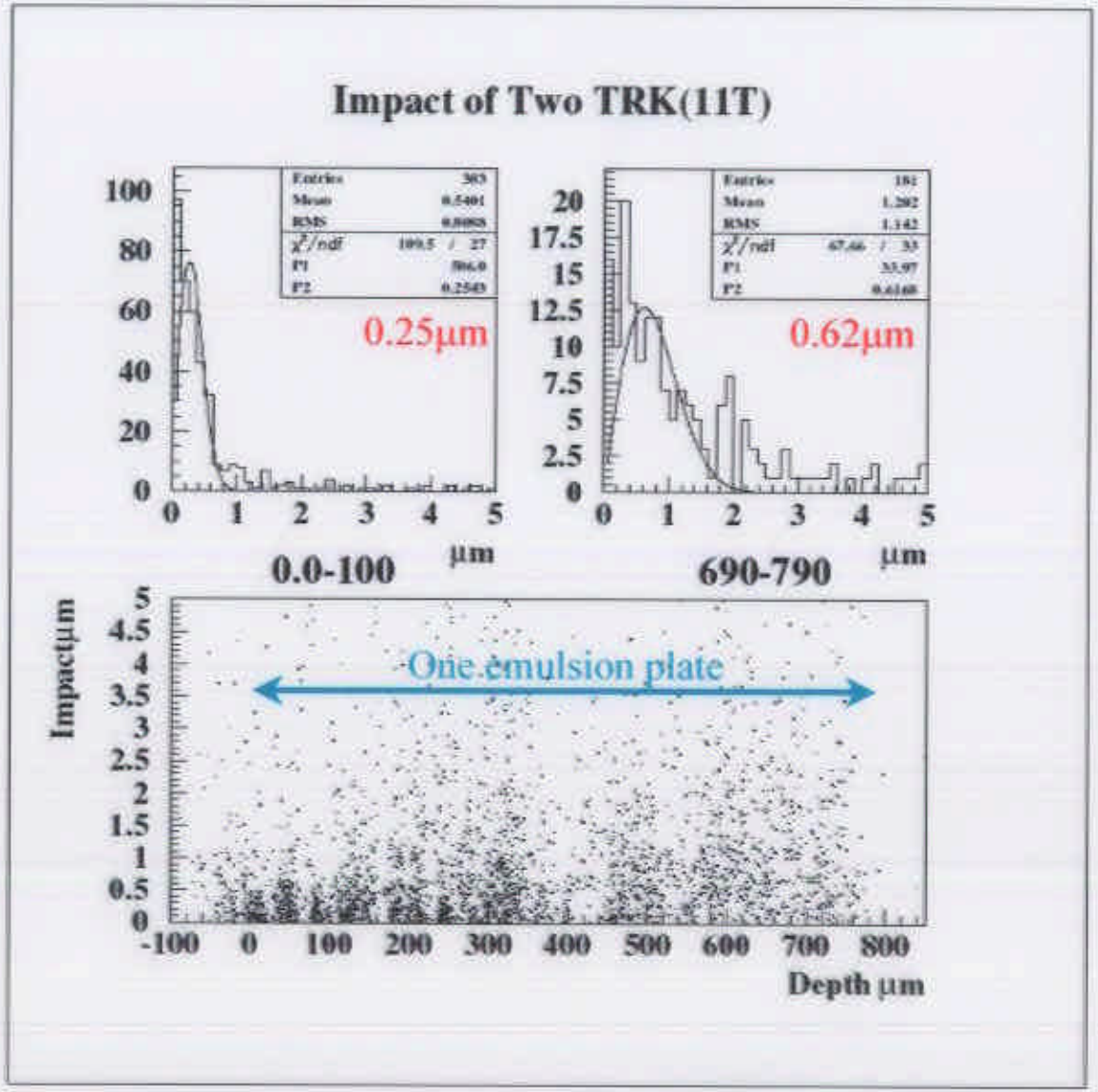
6.3 mm

Netscan

(in progress for Chorus phase II)



Small impact parameter


Impact of Two TRK(11T)
0.25μm
0.62μm
0.0-100
690-790
μm
One emulsion plate
Impactμm
Depth μm

Global Quality

- Impact parameter of two track
  - 0.25 to 0.62 μm (depth 0-100 to 690-790)
- Transverse and longitudinal resolution of reconstructed vertex.
  - 0.33 to 0.74 μm and 3.6 to 9.7 μm
- Impact parameter from Vertex
  - 0.36 to 0.76 μm
- Angular resolution
  - 0.4 μm / 690 μm = 0.58 mrad

Pilot charm detection

- 8,974(4147+4827) CC interaction
  - Decay daughters are required to be reconstructed in Target Tracker(TT)
  - 196 charm candidates (about 120 in E531)
- Efficiency study in progress

DATA

	Kink	Vee	Trident	4Vee	5-pr	Total
Stack1(4147 CC)	14	38	19	9	2	82
Stack8(4827 CC)	33	48	21	11	1	114
Total(8974 CC)	47	86	40	20	3	196

196/(8974*0.05) =0.44

Conclusions

- We have completed our first run of data analysis (phase I)
- We observed no candidates with expected backgrounds 0.11 in the 1μ and 1.1 in the 0μ channel with an exclusion power (sensitivity) of $P_{\mu\tau}=3.7\cdot10^{-4}$ (including systematic) [Junk]
- 90%CL for $\nu_\mu \rightarrow \nu_\tau$ oscillation
  - $P_{\mu\tau} < 3.4\cdot10^{-4}$,$\sin^2 2\theta_{\mu\tau} < \mathbf{6.8\cdot10^{-4}}$,$\delta m^2 < 0.6 eV^2$ [Junk]
  - $P_{\mu\tau} < 2.2\cdot10^{-4}$,$\sin^2 2\theta_{\mu\tau} < \mathbf{4.4\cdot10^{-4}}$,$\delta m^2 < 0.5 eV^2$ [FC](NOMAD)
- We have started our phase II analysis with the aim of reaching our design sensitivity of $P_{\mu\tau} = 10^{-4}$
  - 6k events/month (Using four scanning systems)
  - Pilot study