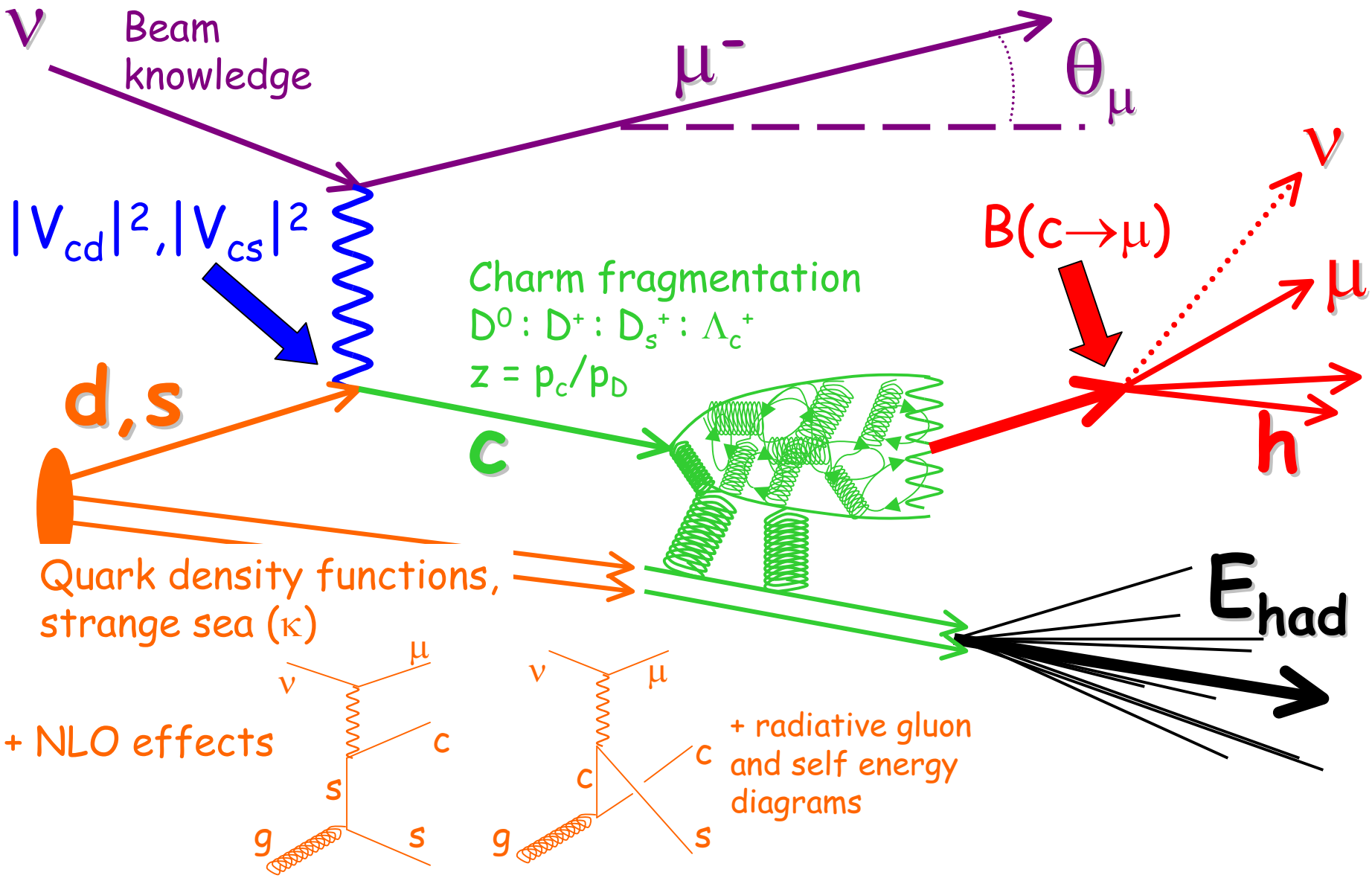
Charm in the CHORUS emulsion

Bart Van de Vyver (VUB,Brussels) IIHE (Brussels), 29 April 2002

- Charm in opposite-sign dimuons
- CHORUS detector & emulsion
- Automatic event location, 'analysis-driven' vertex analysis
- Net scan technique, 'general' vertex analysis
- Automatic reconstruction and charm selection
- Semi-leptonic branching fraction
- Outlook

Neutrino charm production



Previous experiments

CDHS (CERN WBB)	9922 $\mu^-\mu^+$, 2123 $\mu^+\mu^-$ events	*Zeitschr. Phys. C (1982) 19-31*
CCFR (NuTeV)	5044 $\mu^-\mu^+$, 1062 $\mu^+\mu^-$ events	*Zeitschr. Phys. C (1995) 189-198*
CHARMII (CERN WANF)	4111 $\mu^-\mu^+$, 871 $\mu^+\mu^-$ events	*Eur. Phys. J., C11 (1999) 19-34*
NOMAD (CERN WANF)	2714 $\mu^-\mu^+$, 115 $\mu^+\mu^-$ events	*CERN EP 2000-072, submitted to Phys.Lett.B*

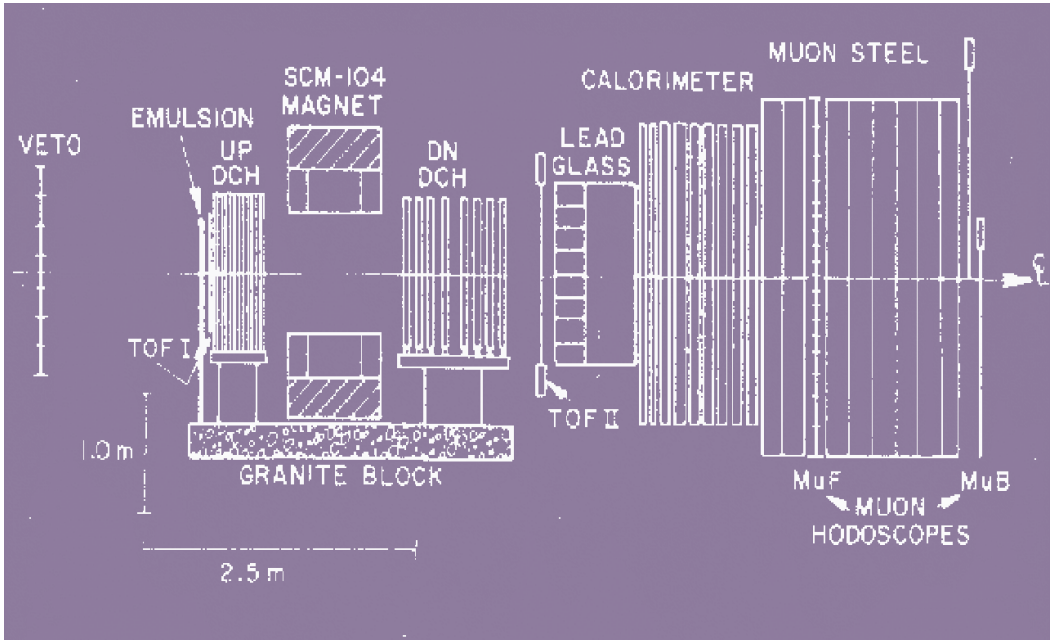
E531 (Fermilab, Nagoya)

131 charm events in emulsion

only measurement of $D^0 : D^+ : D_s^+ : \Lambda_c^+$

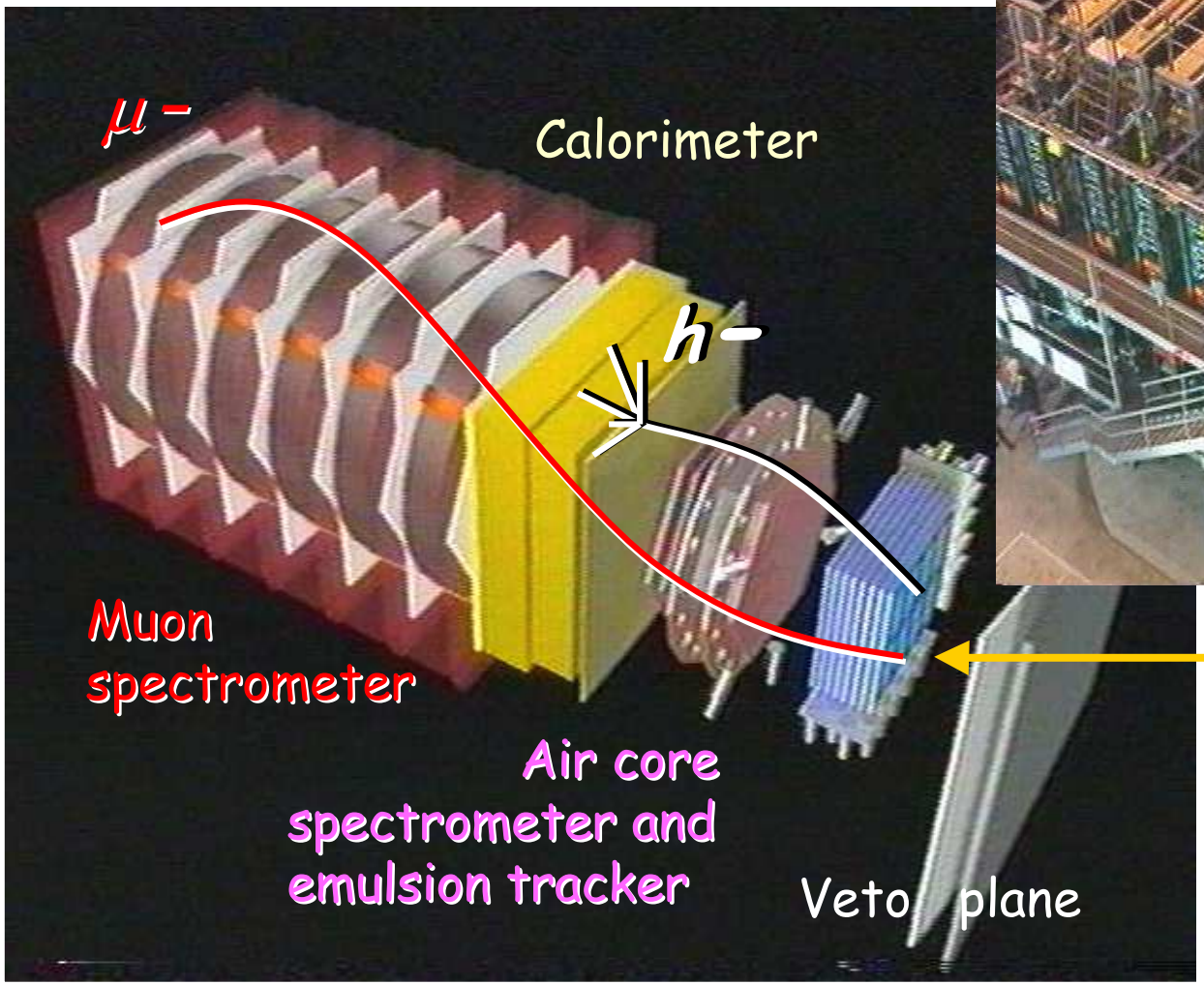
$B(c \rightarrow \mu)$ crucial for other experiments

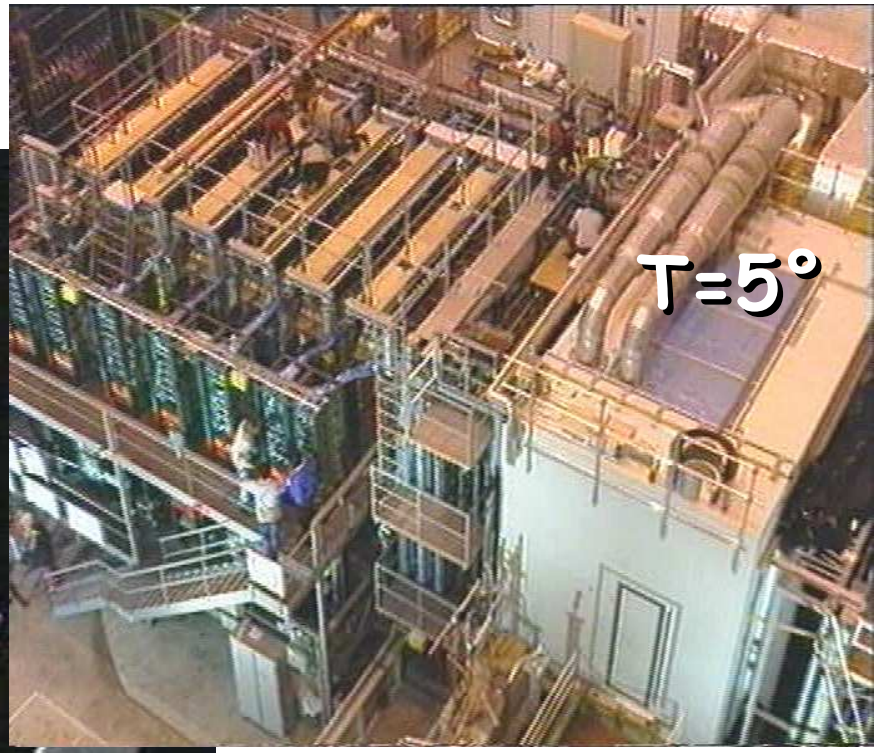
Phys. Lett. B 206 (1988) 375-379



CHORUS detector

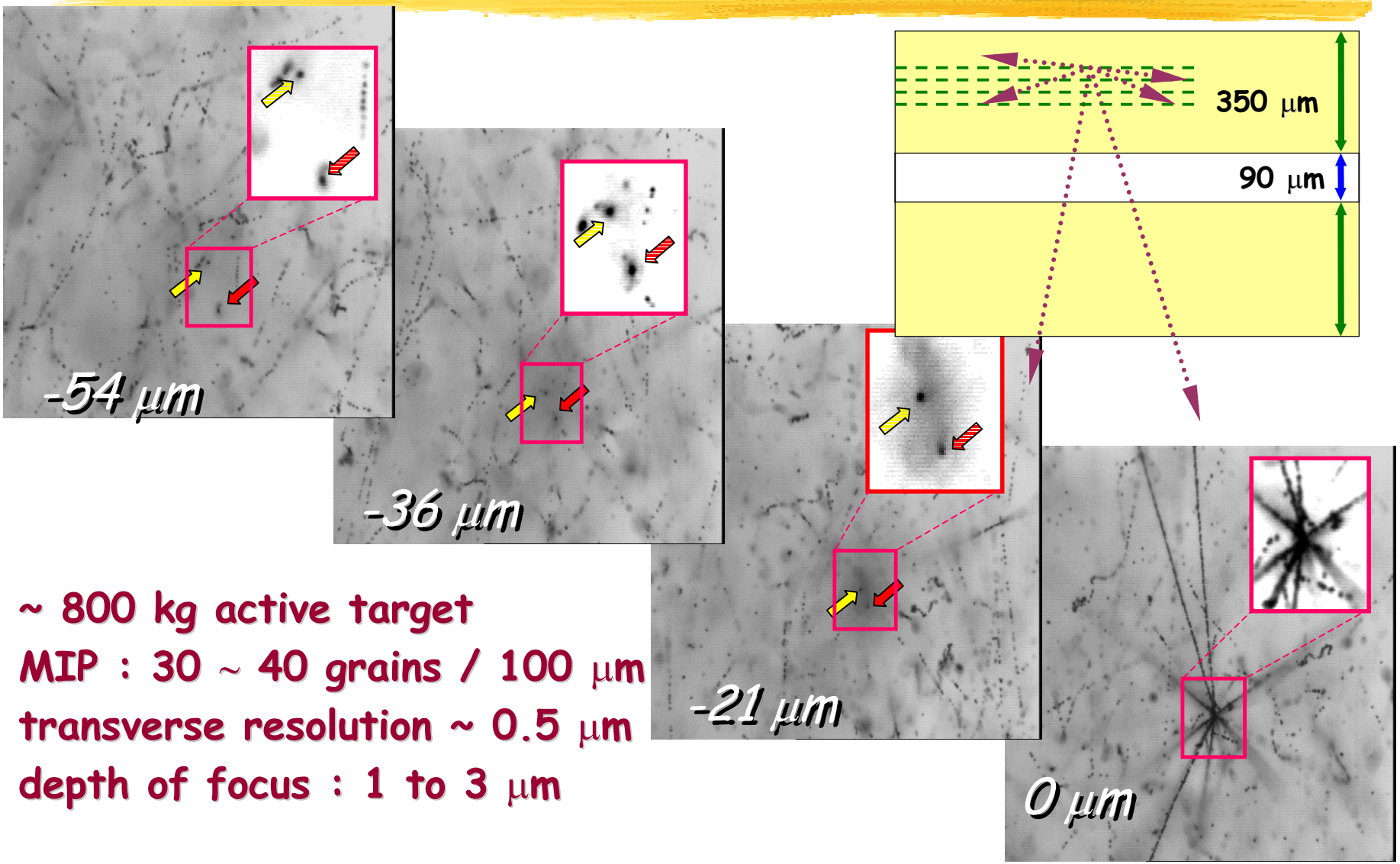
Nucl. Instr. Meth. A 401 (1997) 7-44





770 kg emulsion target and scintillating fibre tracker

CHORUS emulsion



~ 800 kg active target

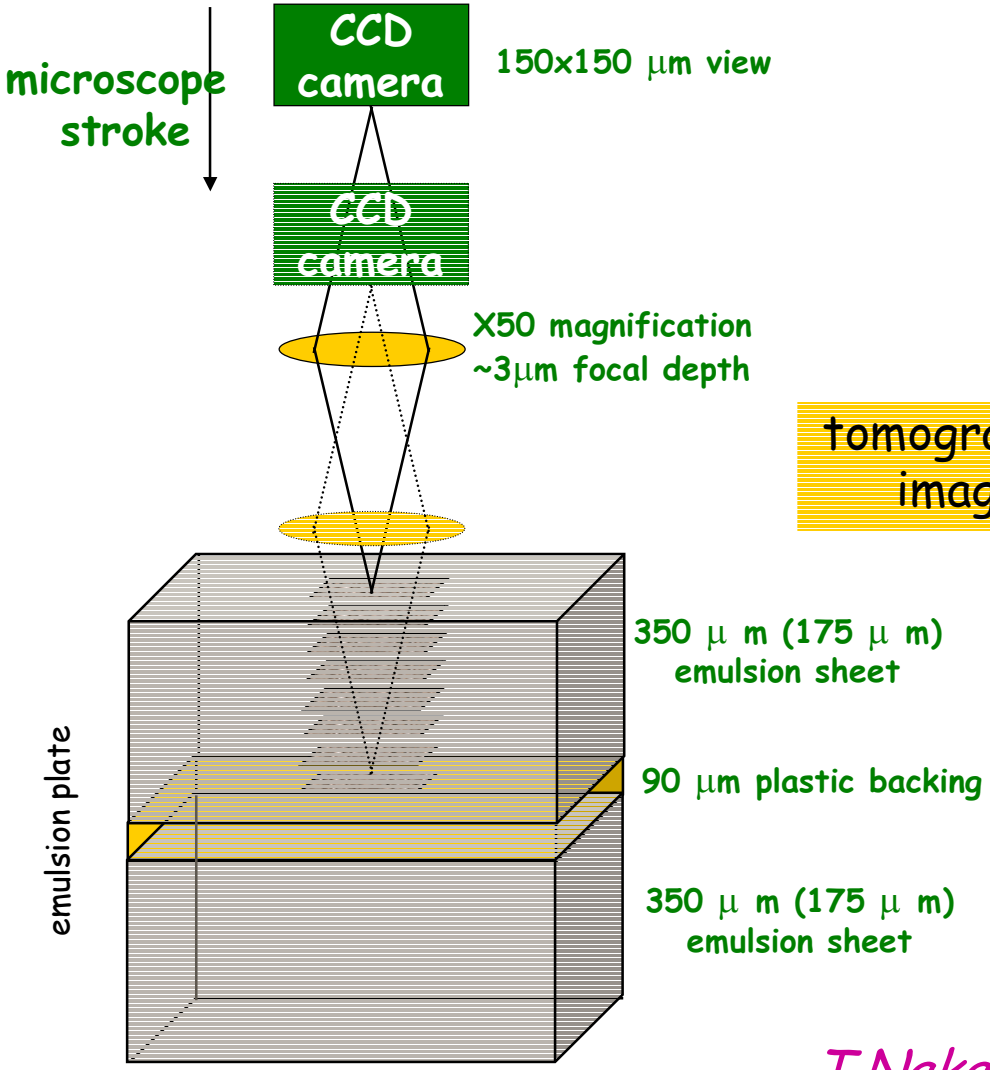
MIP : 30 ~ 40 grains / 100 μm

transverse resolution ~ 0.5 μm

depth of focus : 1 to 3 μm

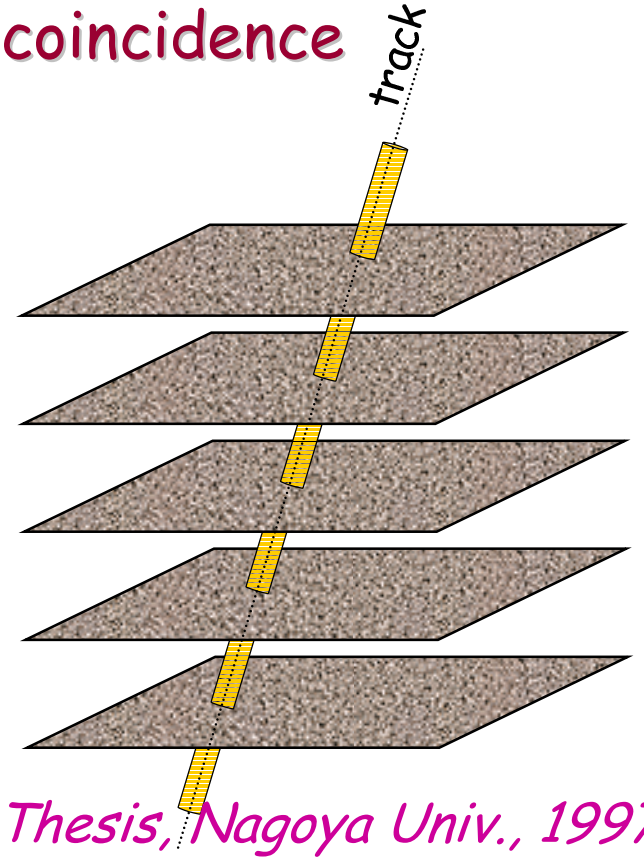
Nucl. Instr. Meth. A 447 (2000) 361-376

Automatic Scanning



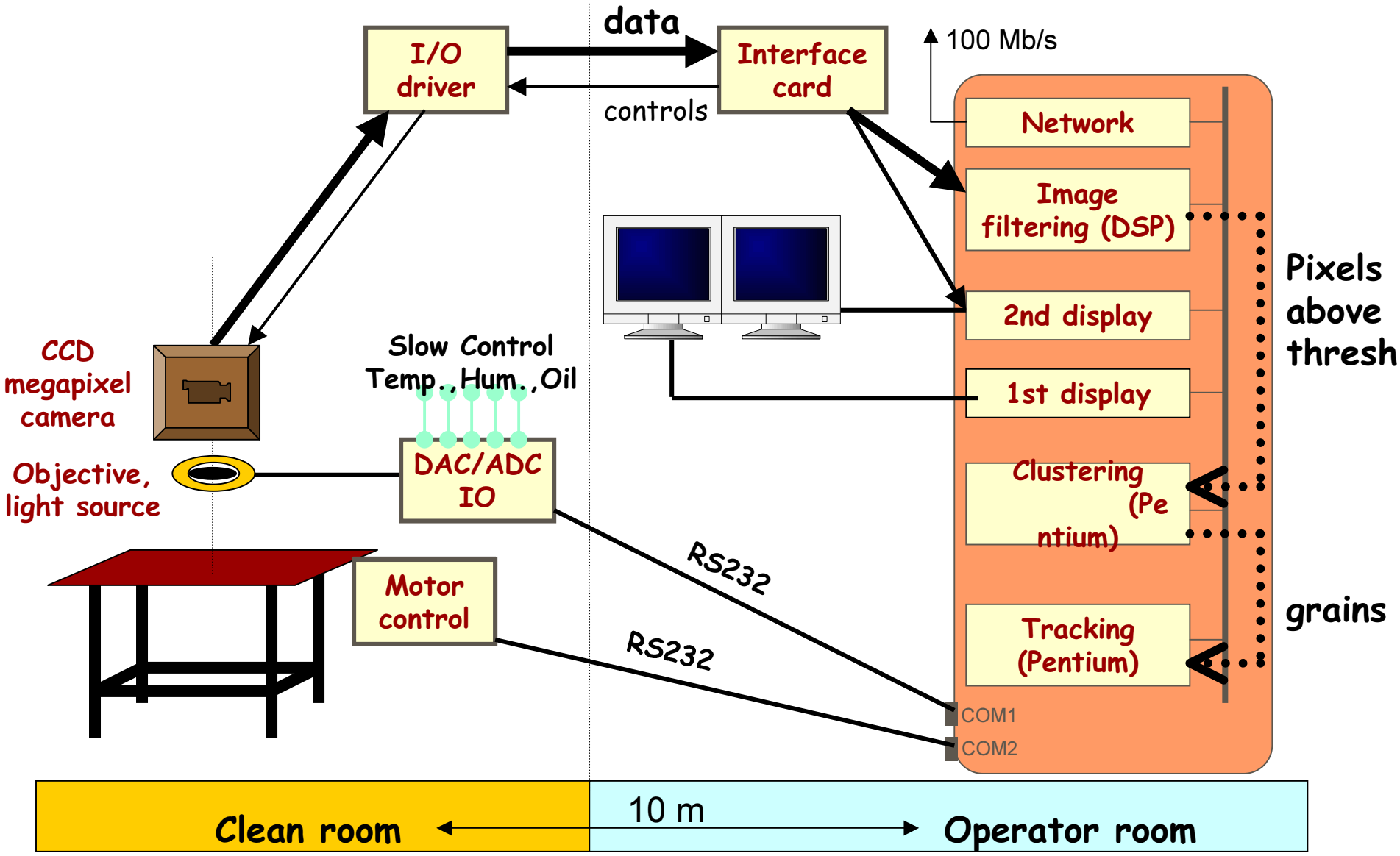
Tracks reconstructed by a hardware video processor
frame to frame emulsion grains coincidence

tomographic image



T.Nakano, Ph.D. Thesis, Nagoya Univ., 1997

Microscope layout



Microscope optics

Objective

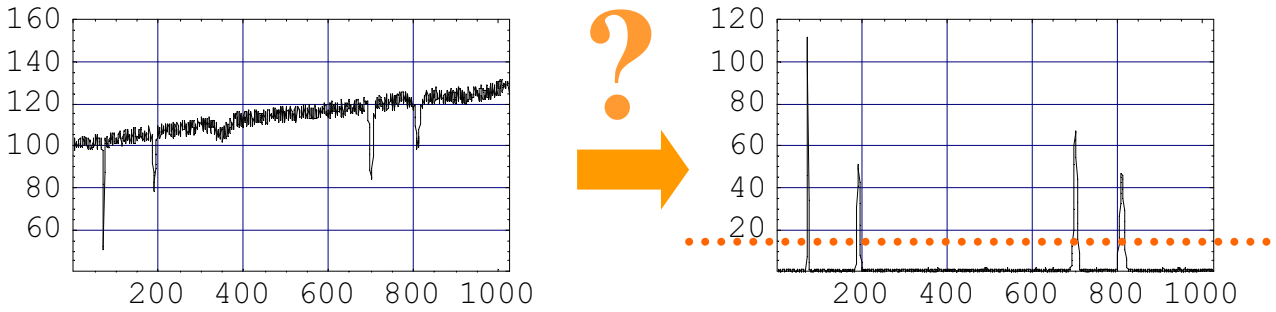
∅ FOV	0.5 mm
DOF	1.2 μm
FWD	1.2 mm
NA	1.05
M	40x (60x,80x)
λ	436 nm
n (emulsion)	1.48-1.54

Light source

∅ FOV	> 0.6 mm
NA	0.95
shutter/flash	up to 120 Hz
intensity range	1:30

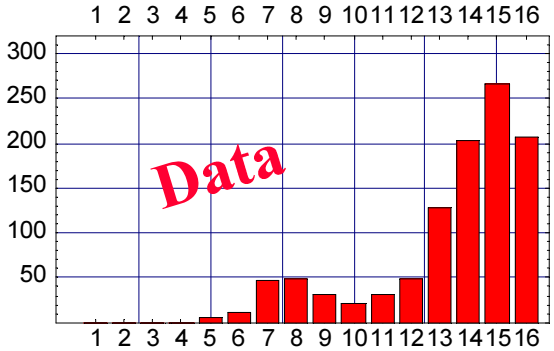
350 x 350 μm/view

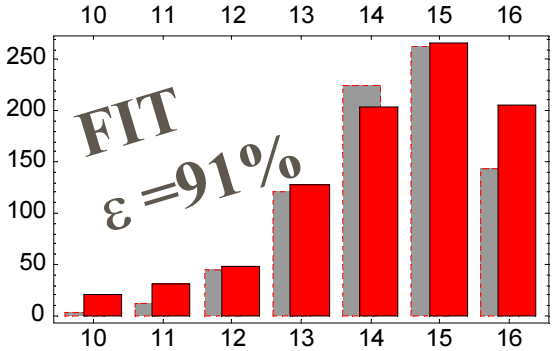
Digital filters



Concepts :
Chorus note 97/27

Number of layers hit out of 16 (tracks)





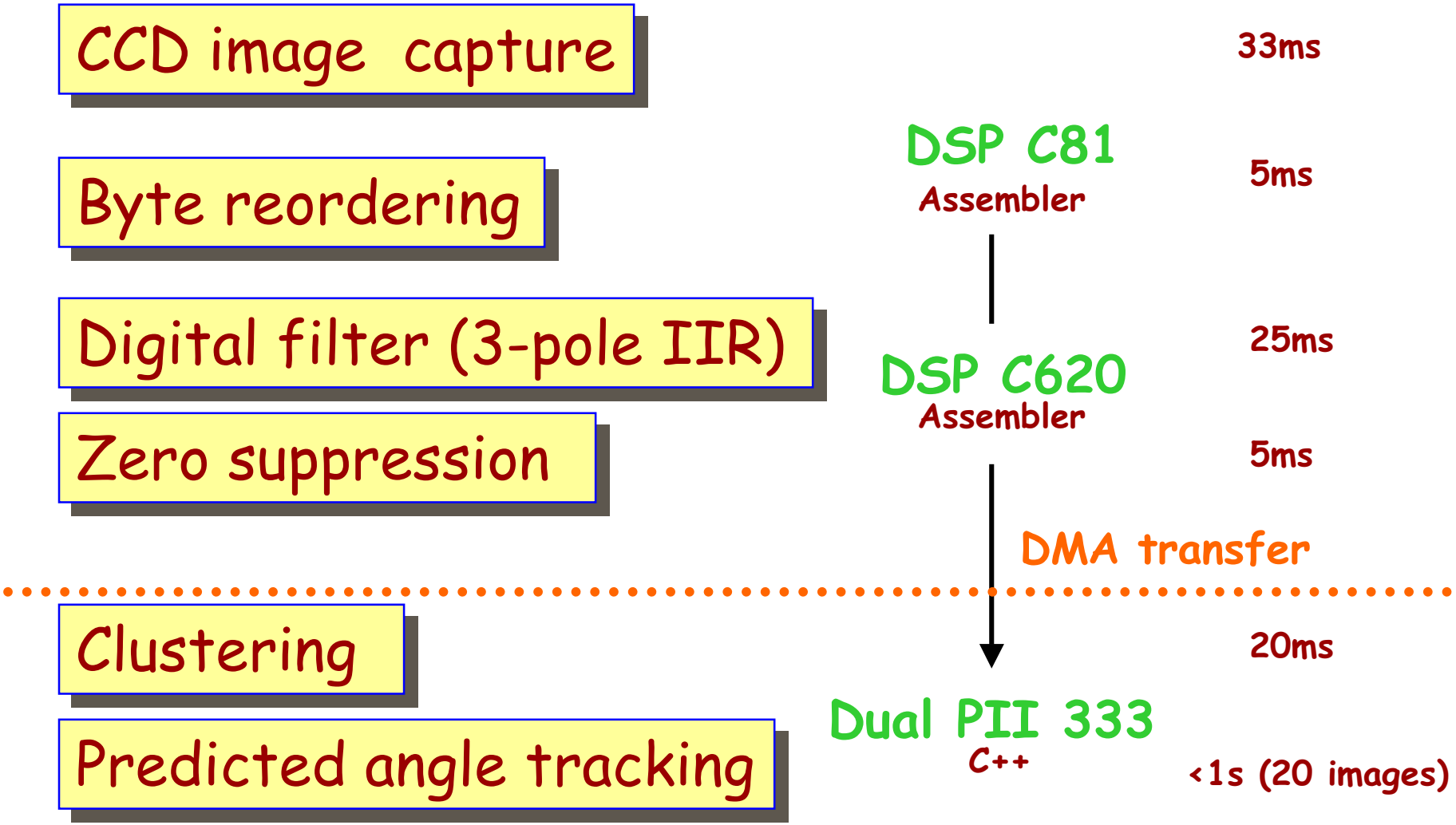
5 cycles/pixel

⇒ 2x40 Mpixel images/s

C620 implementation :
Chorus note 98/9

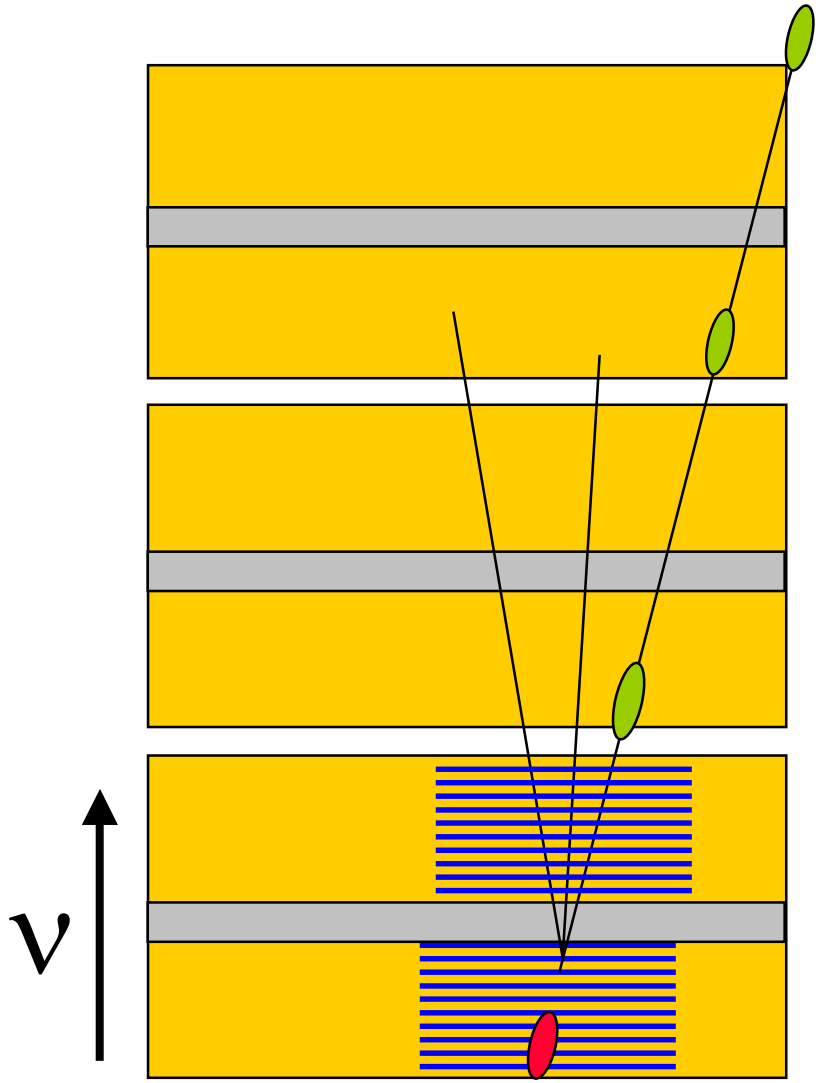
35 assembler instructions on C620 (VLIW)

Prediction tracking



I.M.Papadopoulos, Ph.D.thesis, in preparation

Flow diagram



Scanback

25 images
100 micron thickness
predicted angle

Vertex analysis

2 x 60 images
2 x 350 micron
all angles up to 400 mrad

General tracking

CCD image capture

Digital filter (3-pole IIR)

DSP C620 — Assembler — 25ms

Clustering

Dual PII 333 (WNT) — C++ — 20ms

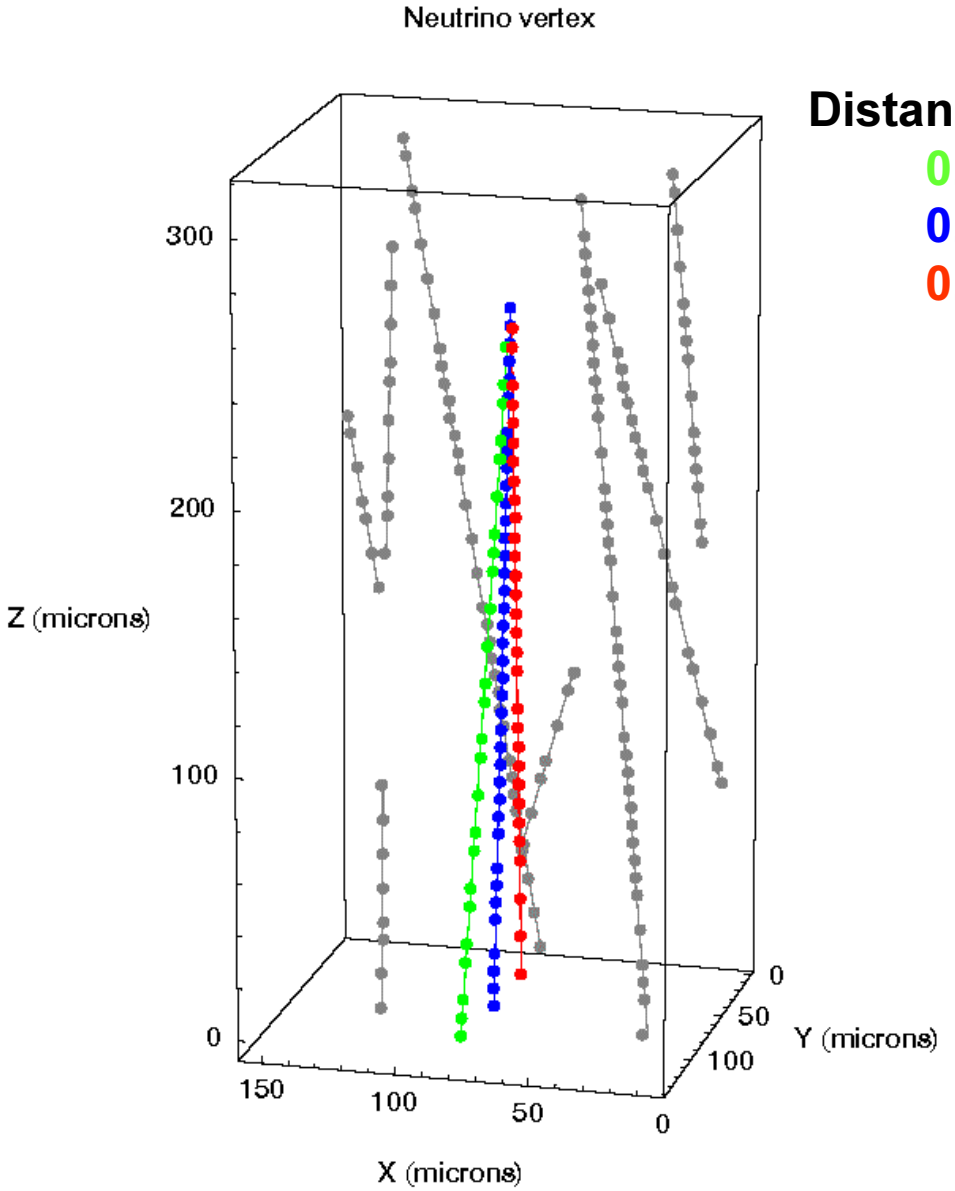
Dispatcher (100Mb Ethernet)

'Offline' Tracking

Dual PIII 450 (Linux) — C++ — 5-20s ~100 images

Scalable architecture !

Tracking results

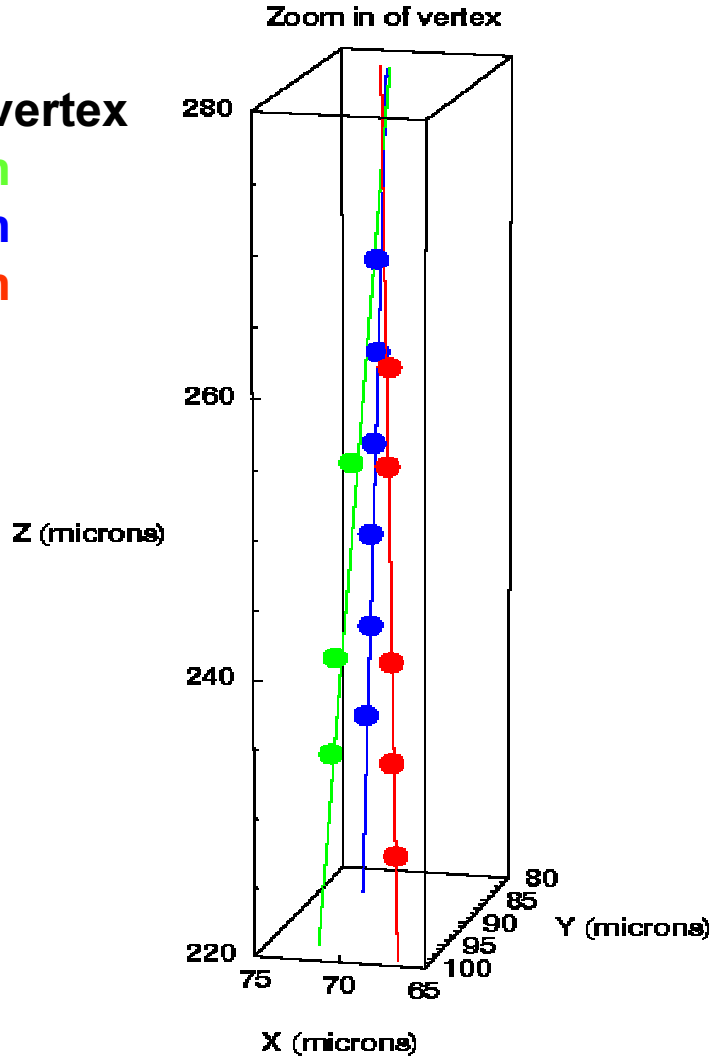


Distance to vertex

0.03 μm

0.05 μm

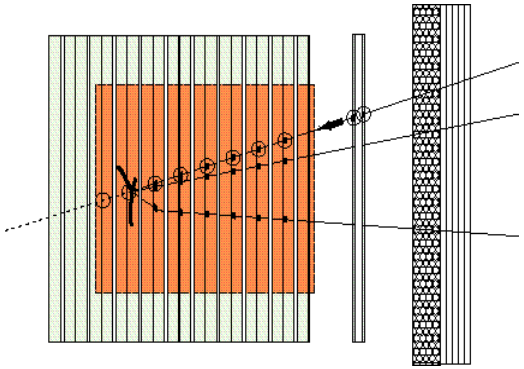
0.19 μm

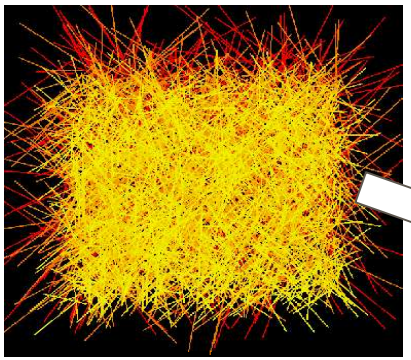


J.Uiterwijk et al., in preparation

CHORUS Phase II : net scan

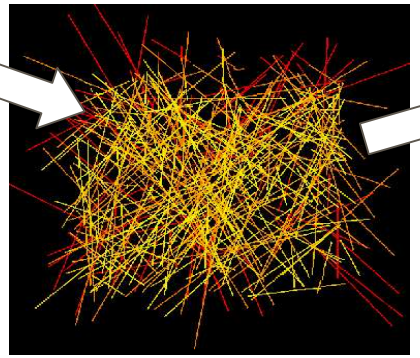
All track segments (θ < 0.4 rad) in
Fiducial volume: 1.5 x 1.5 mm^2 x 8 plates
Offline analysis of emulsion data

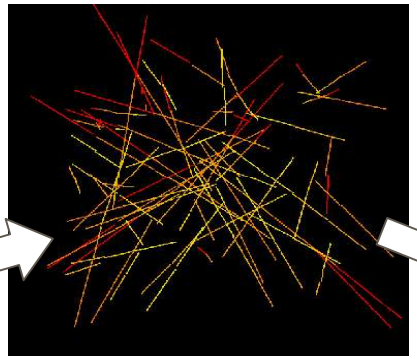




Track segments from 8 plates overlapped

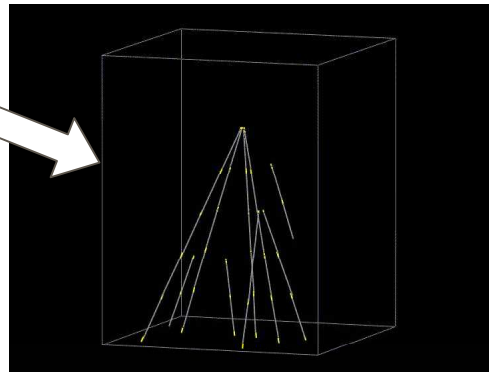
At least 2-segment connected tracks



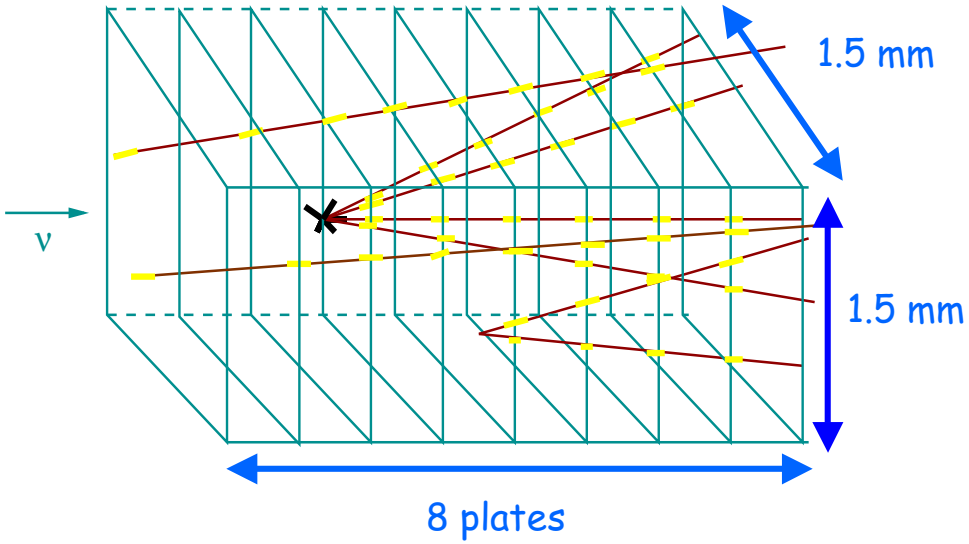


Eliminate passing-through tracks

Reconstruct full vertex topology



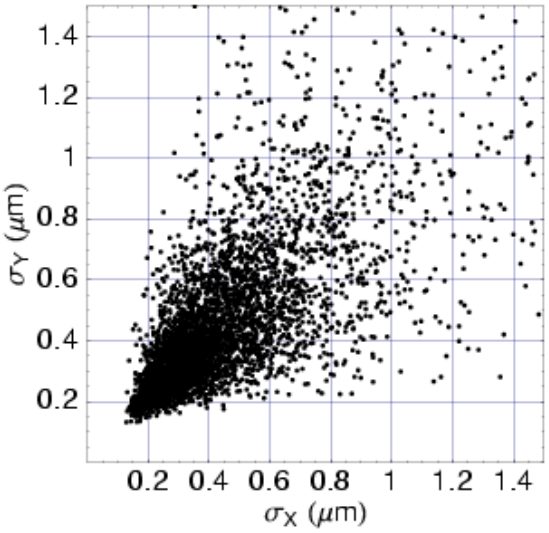
Charm selection

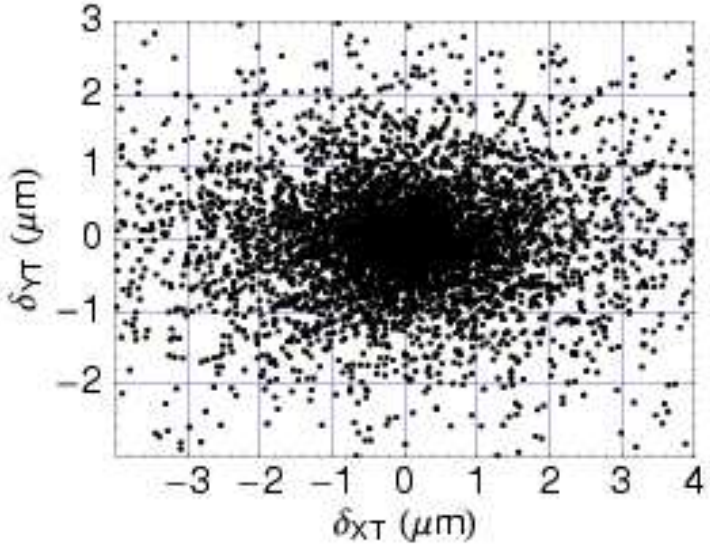


- matching to electronic detectors
- track and vertex fitting (MCS)
- displaced vertex with at least one or more matched tracks

OR

- isolated, matched track with large impact parameter





High purity selection

	original	*loose*	*tight*
selected	338	291	261
charm	261	242	236
secondary	29	28	13
background	48	21	12
not checked	14	0	0
primary	13	5	3
e+e-	6	5	3
passing	8	6	2
fake vee	3	1	1
unrelated 2ry	4	4	3

Outlook

- **D^0 production rate**

  Data taking ongoing : 25k CC → 200k CC

  Improved selection : purity 65% → 90%

  No need for manual?

- **Inclusive charm, including charged**

  ~ 4,000 neutrino-induced charm events

  Fragmentation fractions D^0 : D^+ : D_s^+ : Λ_c^+

  $B(c\rightarrow\mu)$, V_{cd}, s(x), ...

- **Associated charm production**

  Background evaluation based on CHORUS data and FLUKA

  Improved selection : efficiency 1% → 25%

- **Exclusive channels**

  Proton identification

  MCS momentum measurement

  $\Sigma^{\pm}$ detection

  Λ_c absolute BR, QE Λ_c production, $D^{*+}\rightarrow D^0\pi^+$

The CKM matrix

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

V_{ud}: **0.1 %** nuclear beta decay

V_{us}: **1 %** K_{e3} decay

V_{ub}: **25 %** $b \rightarrow u\ l\ \nu$

V_{cd}: **7 %** ν charm production

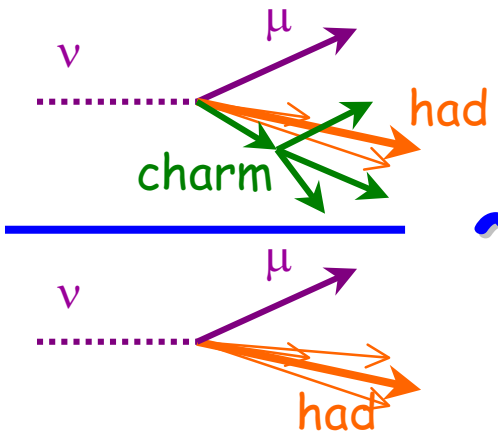
V_{cs}: **15 %** D_{e3} decay

V_{cb}: **5 %** B_{e3} decay

V_{tb}: **30 %** $t \rightarrow b\ l\ \nu$

Review of particle physics, 98 edition

Measuring V_{cd}



$$\frac{\sigma^{charm}_{\nu_\mu CC}}{\sigma^{all}_{\nu_\mu CC}} \sim \propto \frac{d(x)\,|V_{cd}|^2 + s(x)\,|V_{cs}|^2}{d(x) + s(x)}$$

$$\propto \frac{|V_{cd}|^2}{1 + s/d} + \frac{s|V_{cs}|^2}{d + s}$$

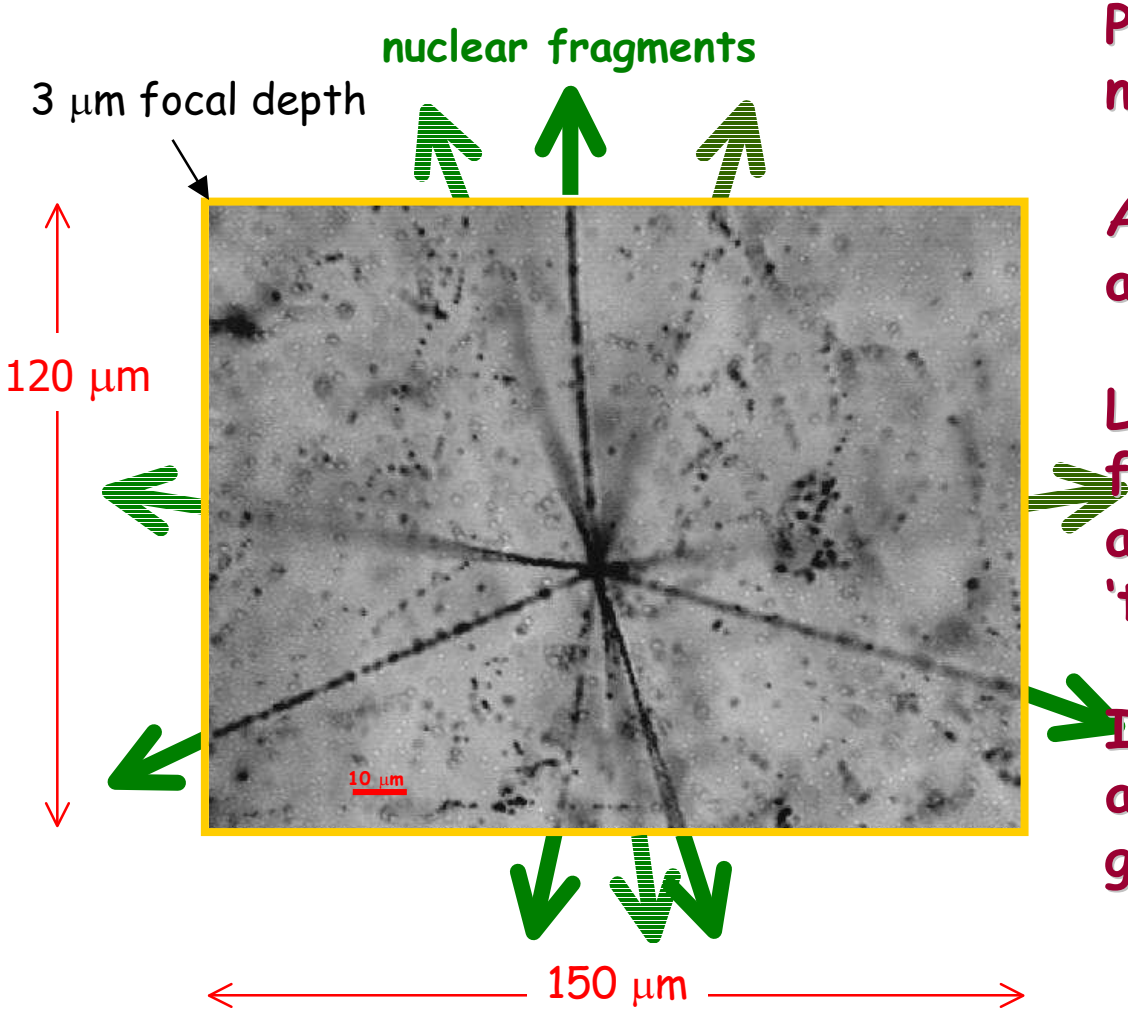
$$\propto |V_{cd}|^2$$

$s \to 0$ for large $x_{Bjorken}$

Difficulties

No antineutrino data in emulsion
(5 % contamination in neutrino mode)
No invariant mass reconstruction or particle ID
(inclusive analysis)
Biases in the sample of vertices located in Nagoya
(CERN microscopes)
Too low statistics for the time being
(Phase II rescan of all events)
Hadronic decays more interesting than muonic ones, but harder
(Net scan both in Nagoya and at CERN)

A microscope view



Plates are orthogonal to the neutrino beam

An AgBr emulsion grain has about 0.5 mm diameter

Large angle nuclear fragments (if any) are seen as a 'star' of heavy ionizing 'tracks' in the vertex view

Interaction tracks are seen as the coincidence of a single grain from each view