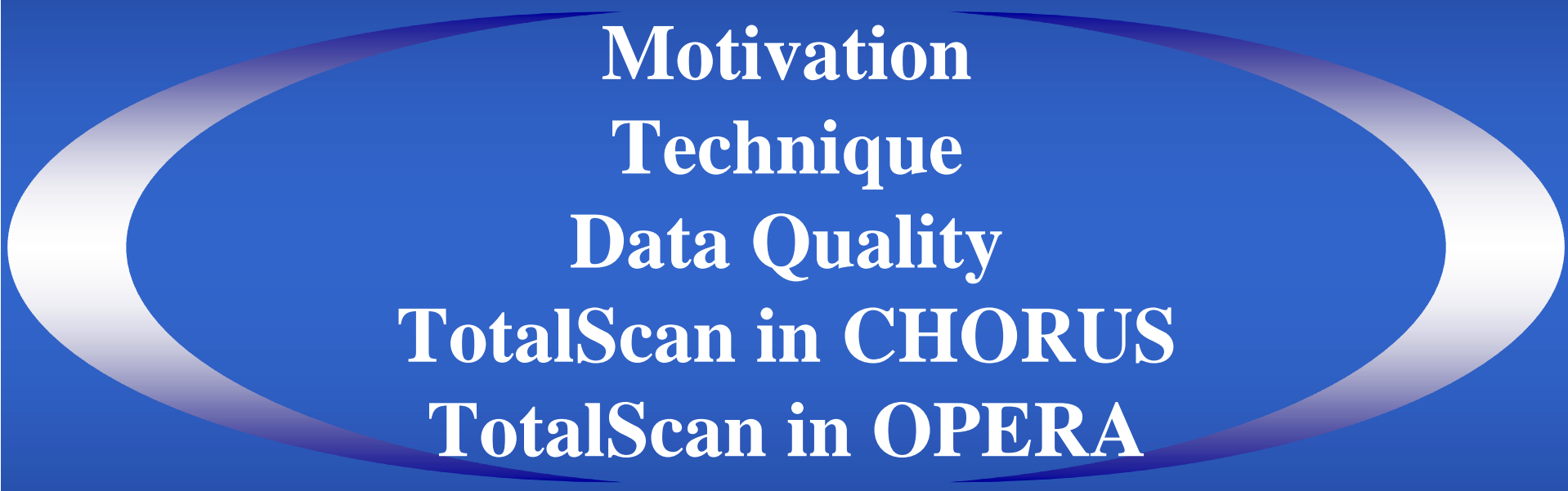


Cristiano Bozza  
Salerno Emulsion Group  
Nagoya, March 2002

# Total Scan



**Motivation**  
**Technique**  
**Data Quality**  
**TotalScan in CHORUS**  
**TotalScan in OPERA**

## Motivation

Automatic emulsion scanning has been usually performed by following a track (**scan-back** to arrive at the primary interaction vertex or **follow-down** to study the products of interaction / decays)

1 FOV centred around the expected position of the track being followed

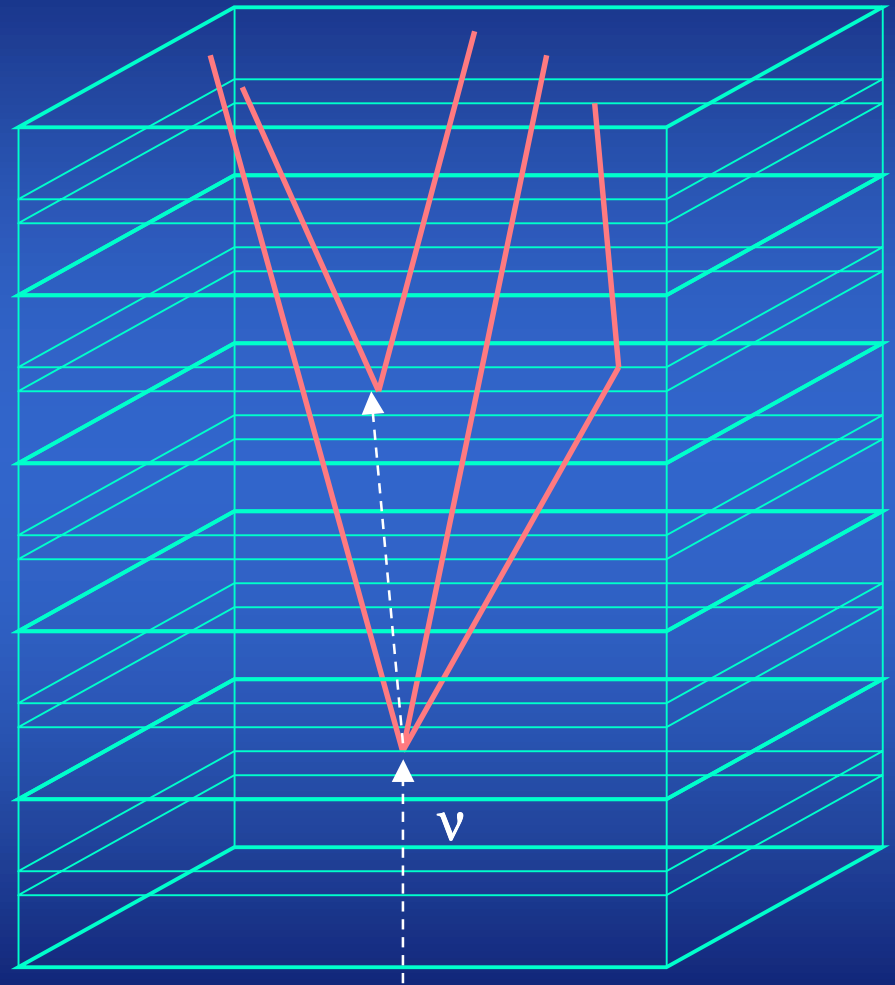
Only charged particles can be seen in emulsion, so processes involving a neutral primary particle were discarded *a priori*

Moreover, position and slope measurements have local systematic errors that are not estimated and thus are not accounted for

# Motivation

Total Scan: select a 3D box (or cylinder) around an interesting point in an emulsion stack and scan all views contained in that volume, reconstructing all tracks

In each emulsion sheet, volume scanning must be performed, in order to see even very small track segments that do not arrive at the emulsion surfaces



Sample event shape from CHORUS

## Improvements of Total Scan over traditional Scan-back

- Unbiased event reconstruction: external predictions are less critical (only need to know where to scan!)
- Secondary interactions and decays are detected
- Neutral particles ( $h^0$ ,  $\gamma$ ) can be detected in emulsion through charged daughters (from interactions, decays, pair creation)
- Local systematic measurement errors are estimated and corrected by using hundreds or thousands of reconstructed tracks  $\Rightarrow$  increased sensitivity!!!

Using SySal, implementing Total Scan is very simple:

We just increase the number of views taken around a specified horizontal position in each plate

No special parameter setting is required

Scanning proceeds without even the need for any on-line feedback (just keep data quality under control)

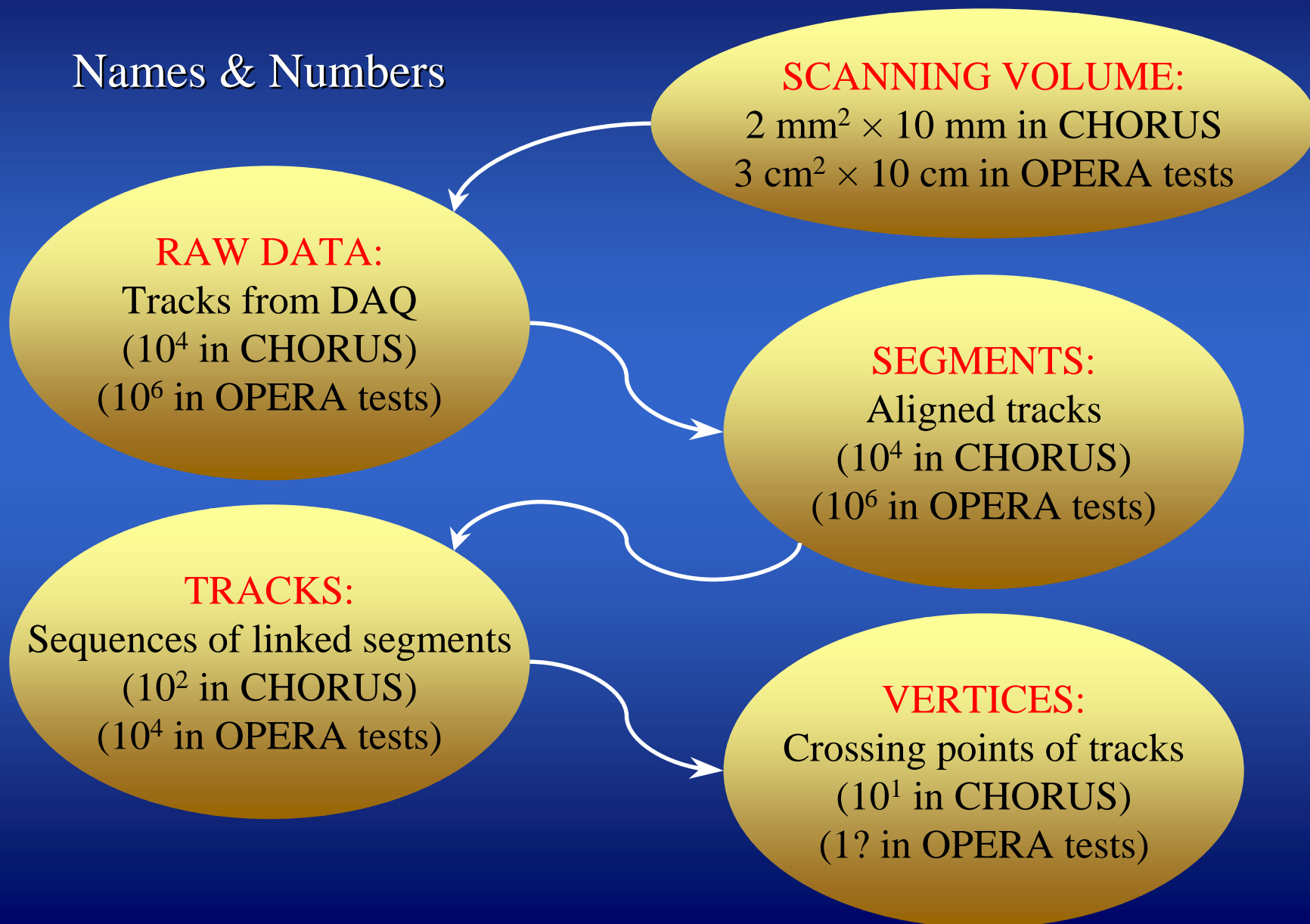
After data taking is complete, a single off-line program collects raw scanning data from several plates (10 or more) together and yields a full reconstruction that needs no further processing

## Total Scan Reconstruction steps:

1. Apply known corrections to track slopes in each sheet
2. Connect tracks from one plate to adjacent plates (pattern matching at the beginning, since there might be large shifts)
3. Optimize plate-to-plate alignment by applying affine transformations for positions and rotations / dilatation for slopes; iterate several times (usually 9) starting from step 2
4. Build sequences of connected segments (tracks) and require a minimum length (3 segments)
5. Recognize kinks / vertices and recover short tracks (2 segments) attached to kink / vertex points
6. Refine alignment using high momentum tracks

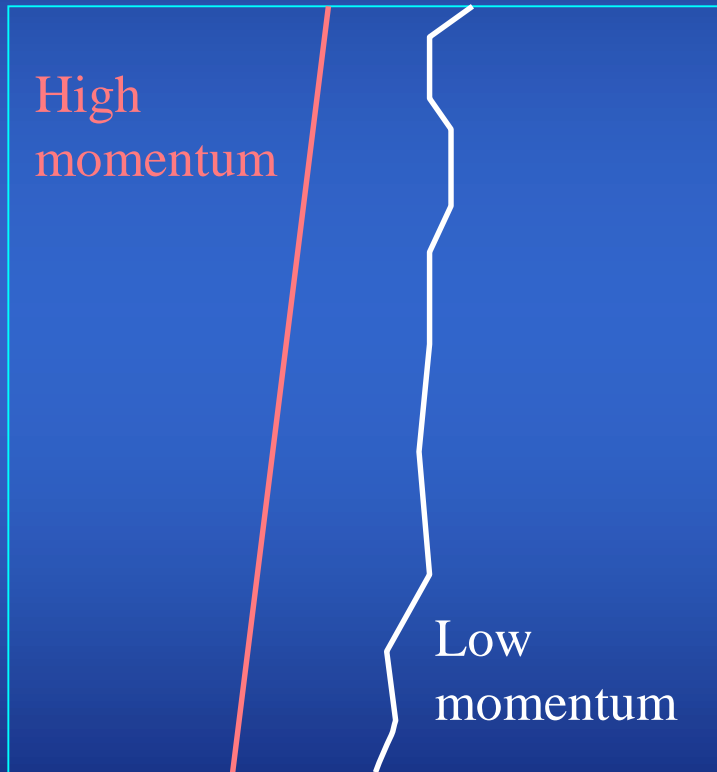
# Technique

## Names & Numbers





## Alignment refinement using high momentum tracks



A “high momentum track”: a track whose local slope is the same (within a proper tolerance) at the top and bottom of the volume

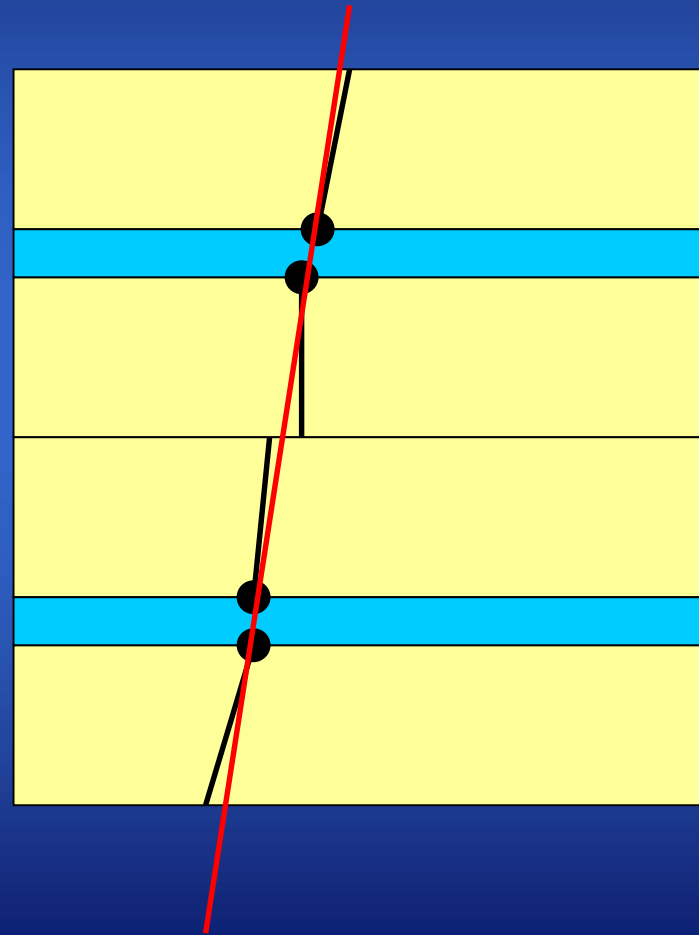
Alignment parameters are optimized for these tracks and then applied to all segments

## Alignment refinement using high momentum tracks

“Local slope”: a slope estimated by using position measurements of 4 segments at the plastic base

The tolerance to define high momentum tracks is “tailored” on the data quality: the RMS of the agreement between the “4 point local slope” and the single segment slope is used as a measure of data quality

The tolerance is set =  $(x \text{ RMS})$ ,  
with  $x = 0.5 \div 1.5$



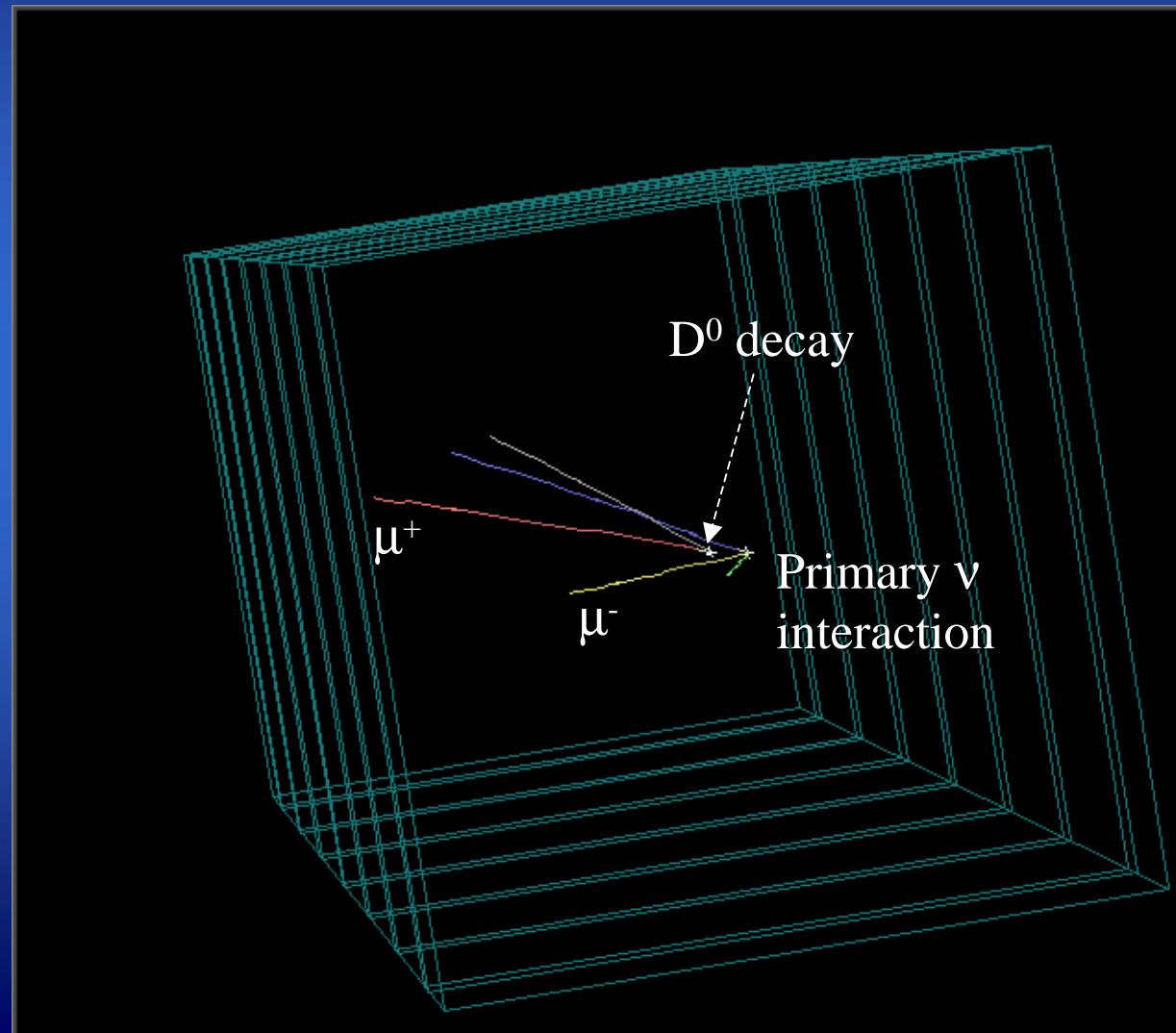
## A sample event from CHORUS

Color code:

Blue = near

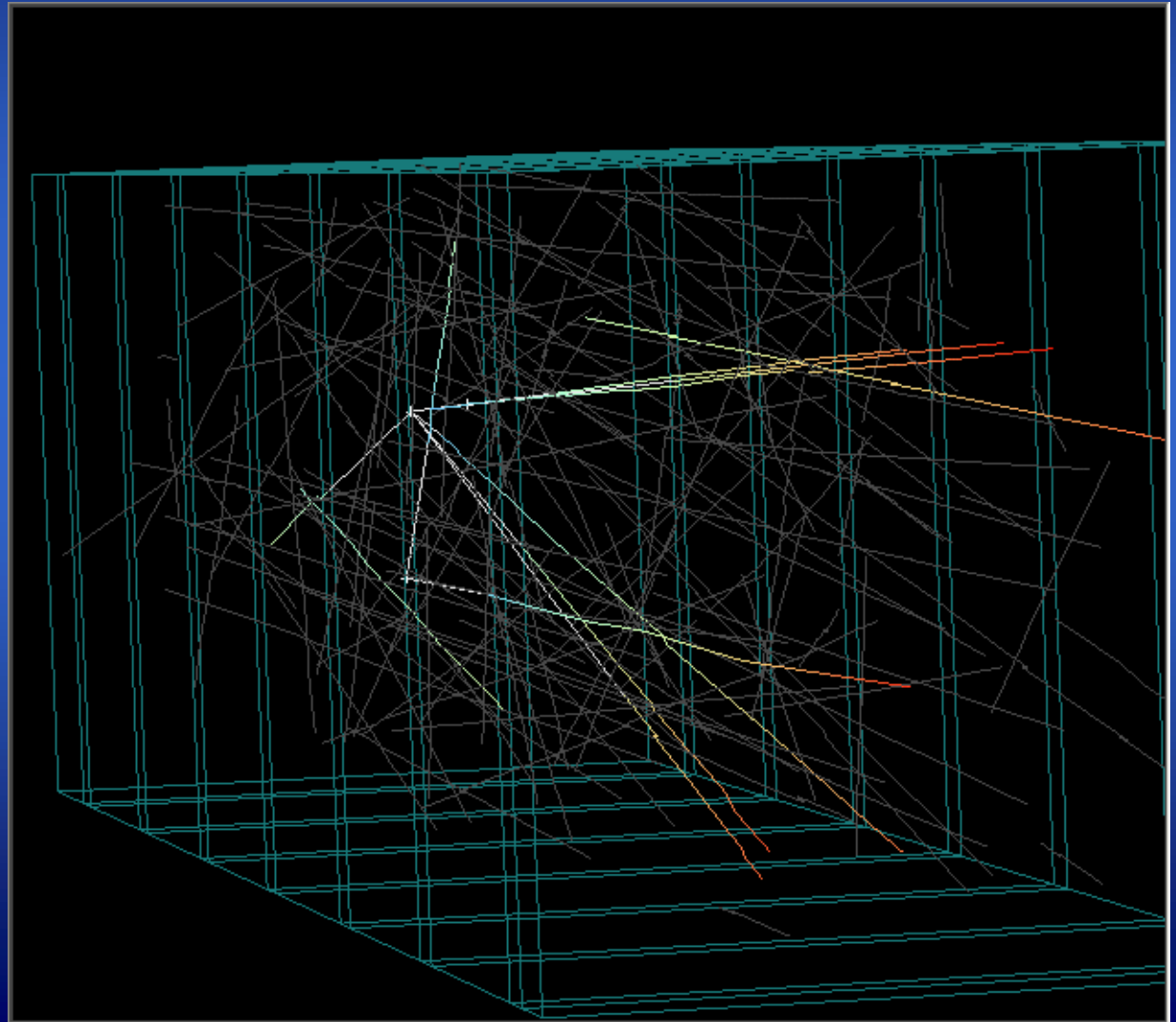
Red = far

Out of the Chaos:  
A  $D^0$  production  
and decay event  
in a  $\nu_\mu$  beam



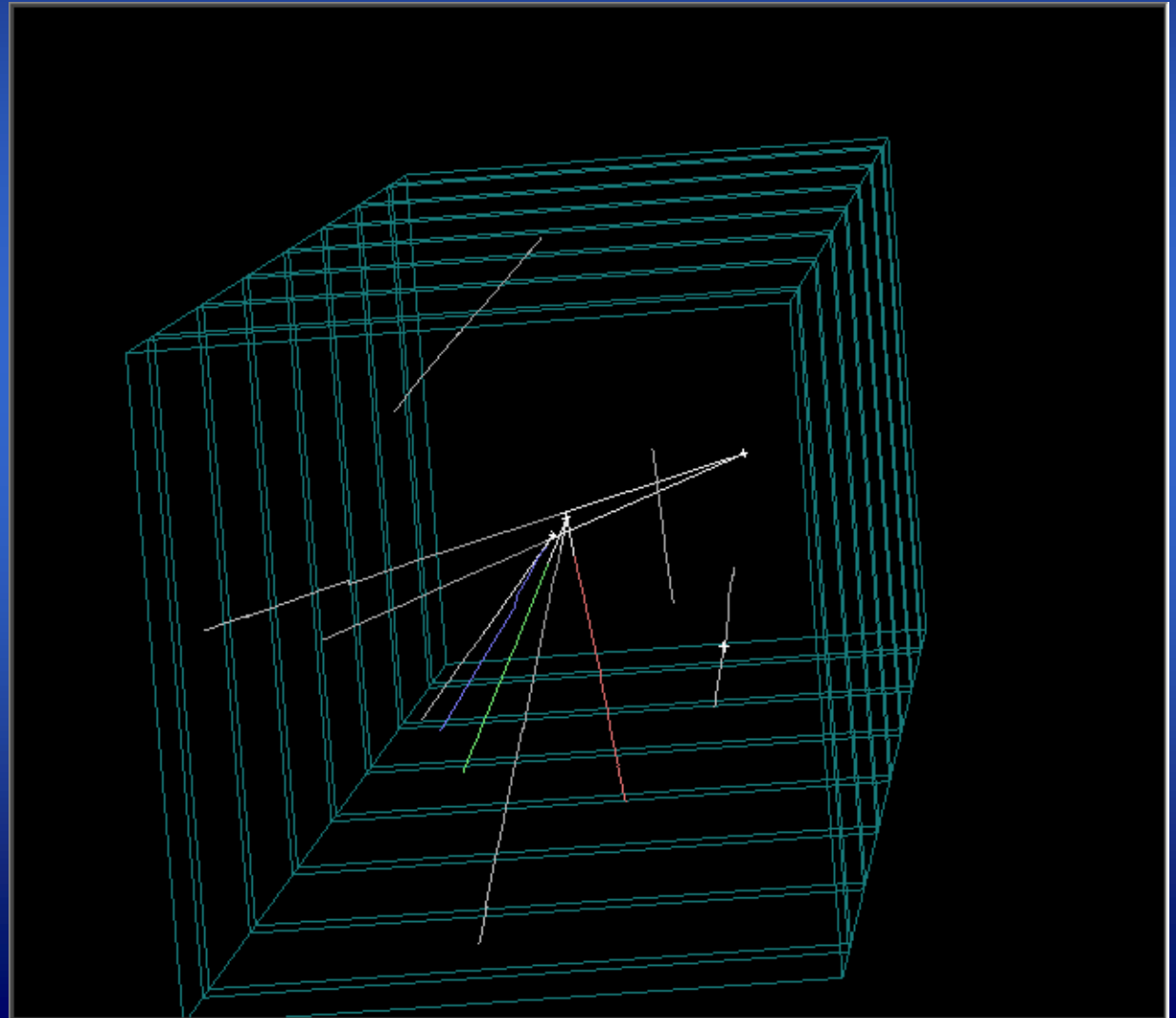
## More nice events from CHORUS

A hadron jet



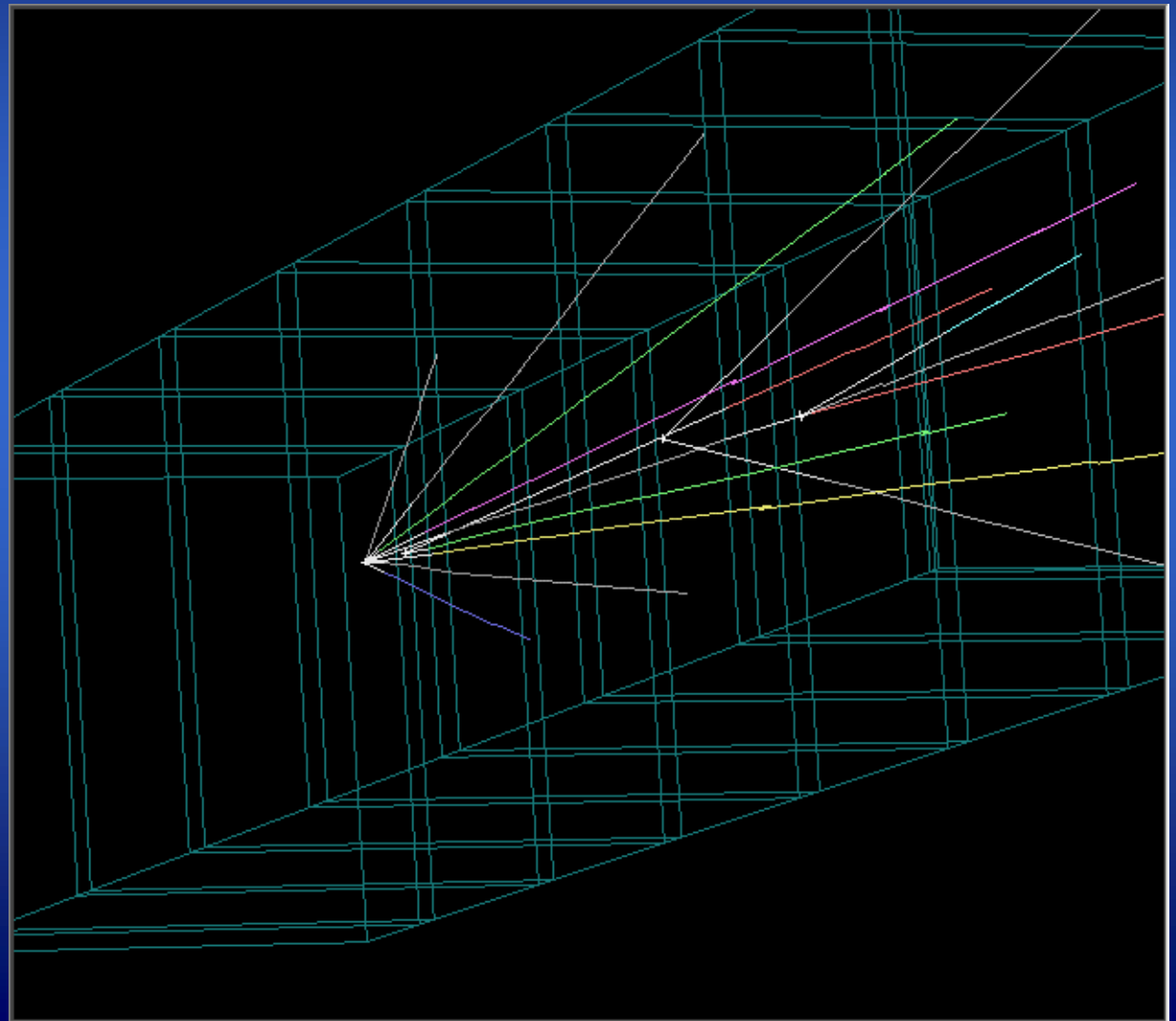
## More nice events from CHORUS

Decay: a  $V$



## More nice events from CHORUS

Secondary interactions:  
Trident  
(+ a  $V$  from decay)



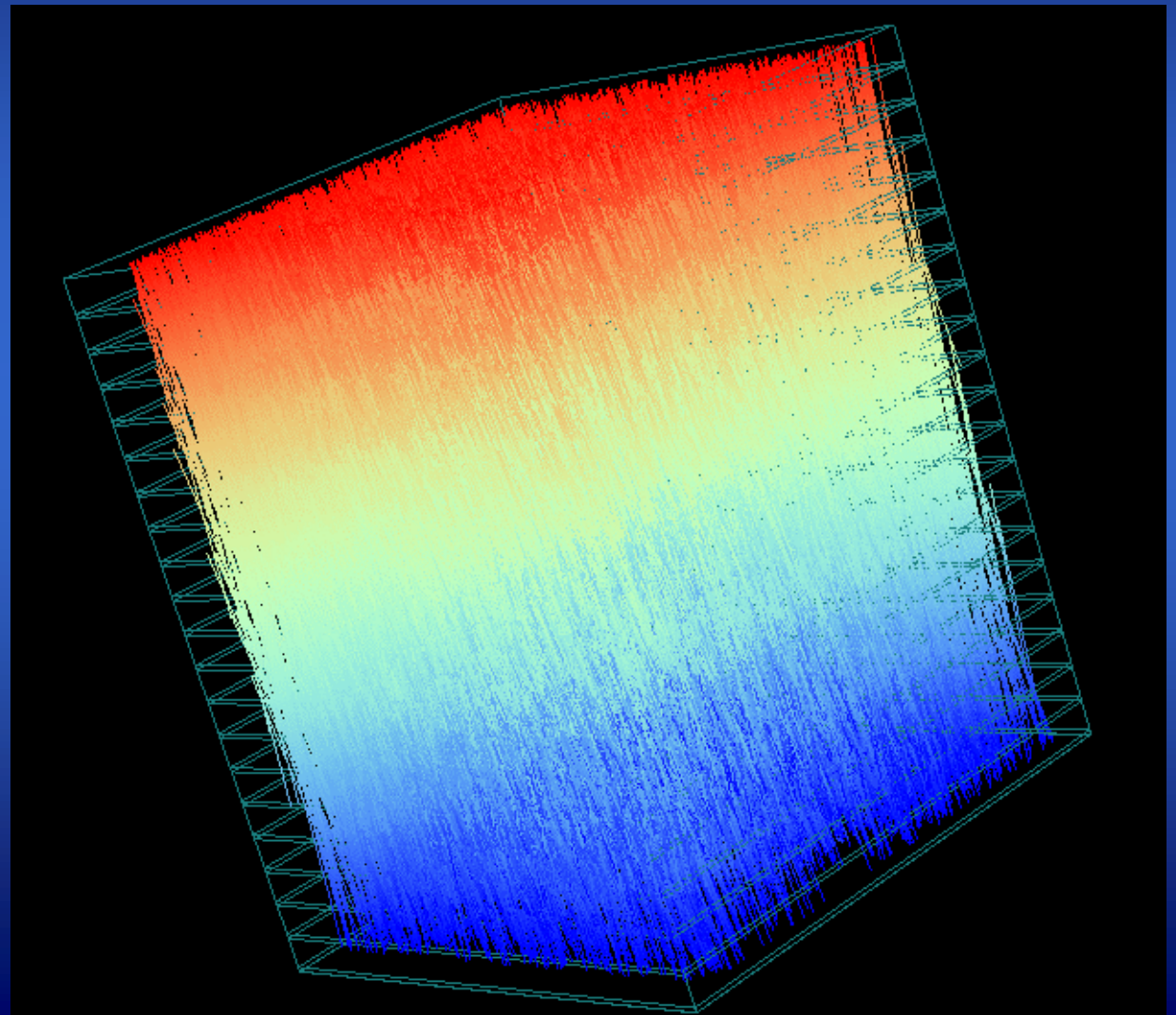
# Technique

## Sample from OPERA test exposure (May 2000)

4.2 cm<sup>2</sup>, 20 plates

337,577 segments  
(37 MB)

15,505 tracks

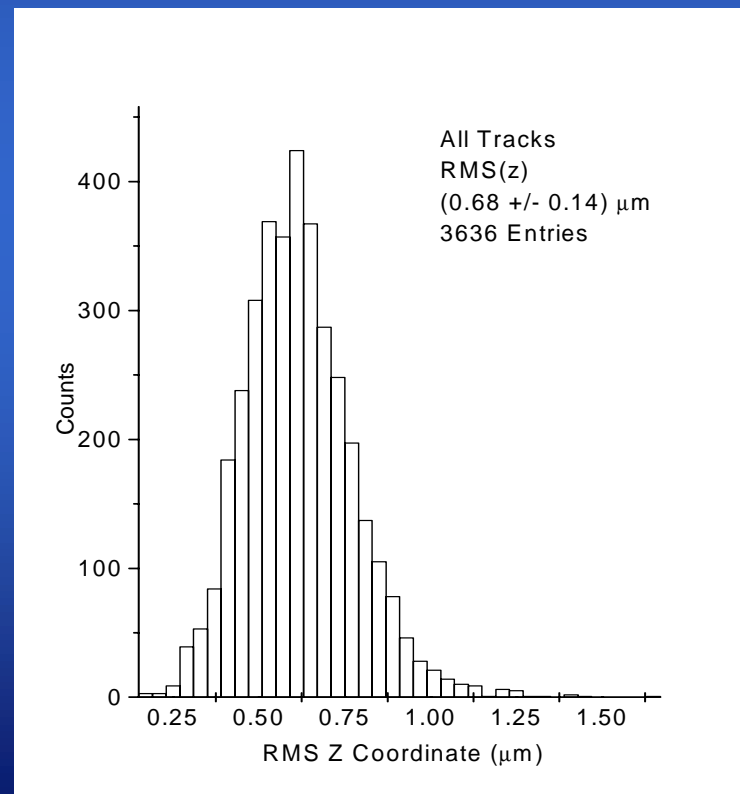
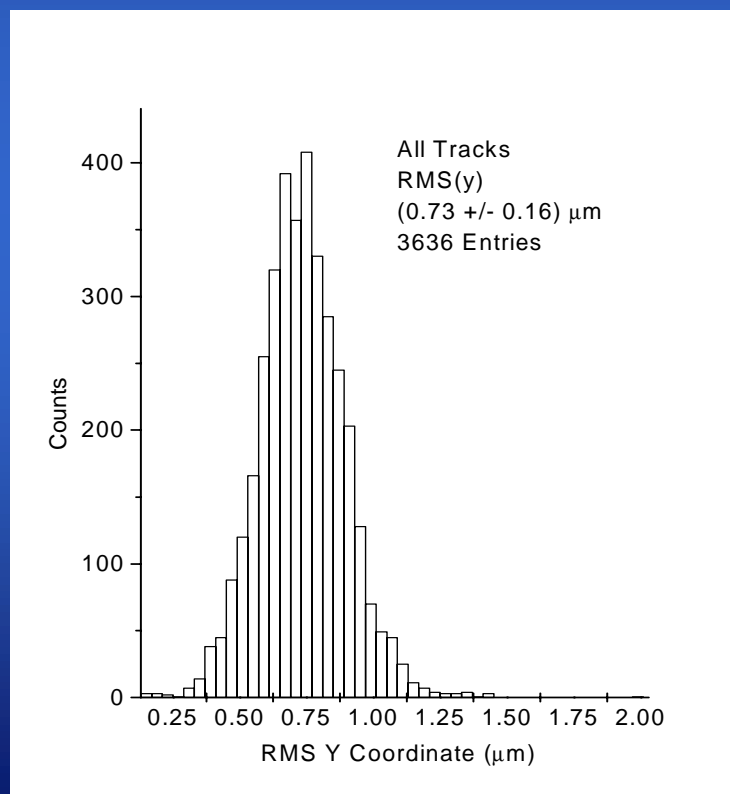


## Position residuals (CHORUS)

Position residual:  $X_{\text{meas}} - X_{\text{fit}}$

$X_{\text{meas}}$  = segment position measured at the plastic base

$X_{\text{fit}}$  = position expected from track fit



RMS  $\approx 0.7 \mu\text{m}$

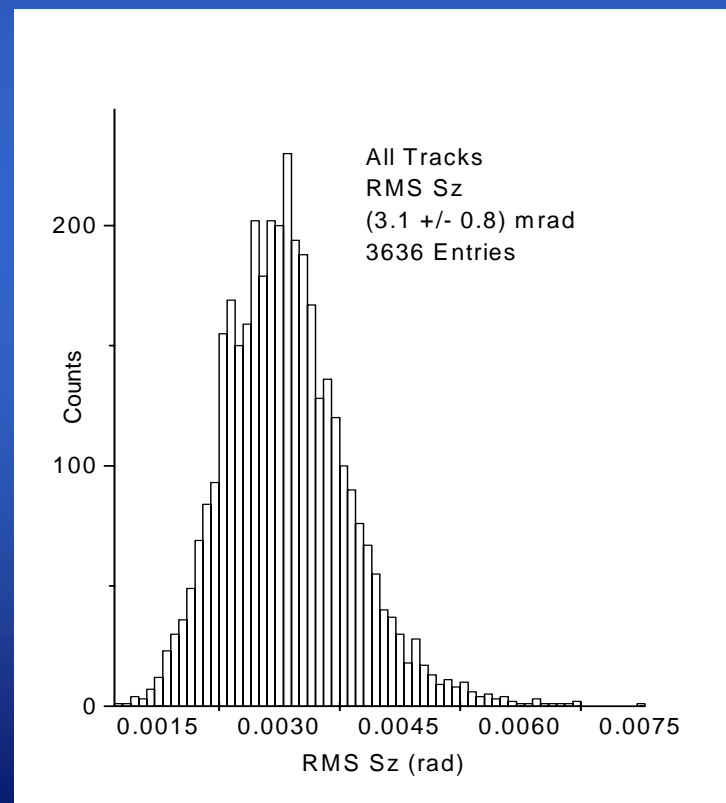
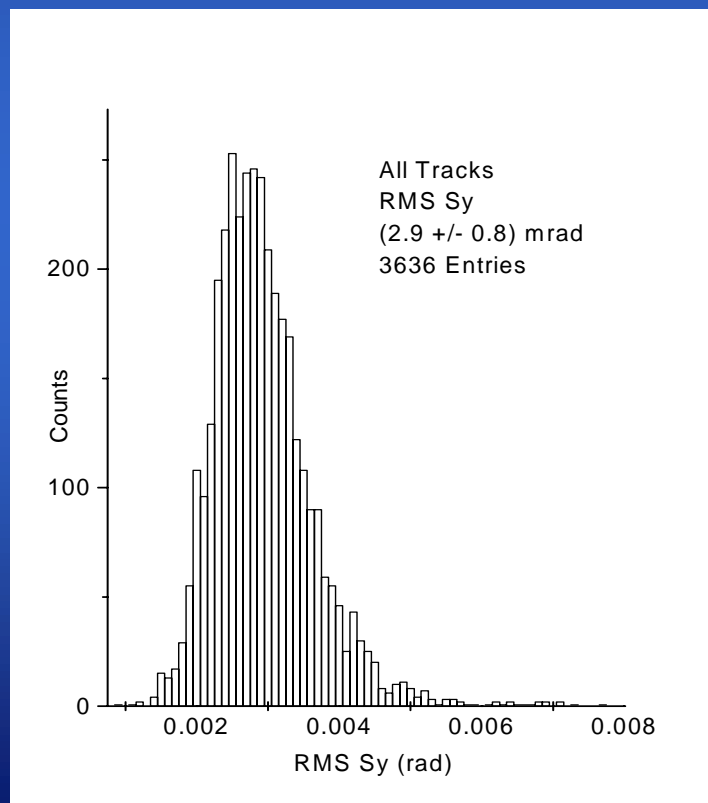


## Slope residuals (CHORUS)

Slope residual:  $SX_{\text{meas}} - SX_{\text{fit}}$

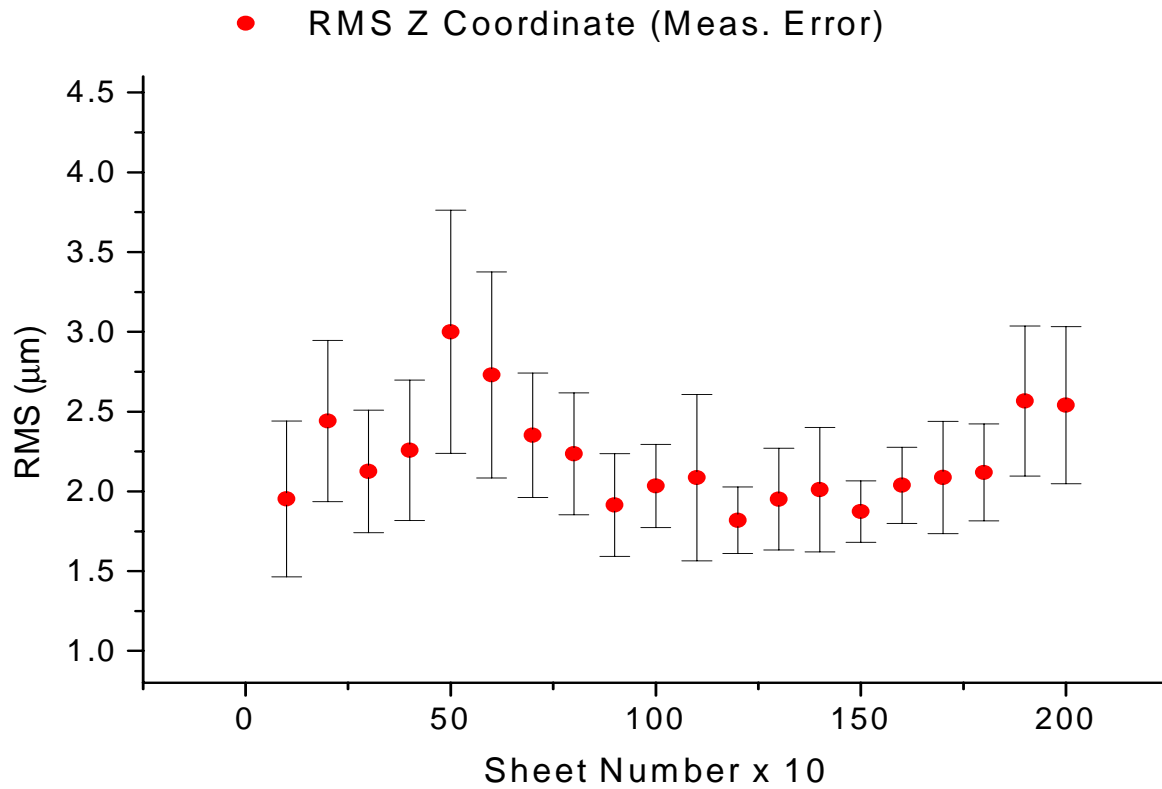
$SX_{\text{meas}}$  = segment slope

$SX_{\text{fit}}$  = slope expected from local track fit



RMS  $\approx$  3 mrad

## Position residuals (OPERA test May 2000)



# TotalScan in CHORUS

Sorry... no  $\nu_{\mu} \rightarrow \nu_{\tau}$  oscillation detected!

Charm hunting

14 Vees

1 4-Vee

8 Kinks

7 Tridents

1 5-prong decay

Special events

# TotalScan in OPERA

Always used in all technical tests up to now:

- Alignment
- Efficiency
- Emulsion quality

Multiple Coulomb Scattering measurements

(listen to dedicated talk!)

C. Bozza - M. De Serio  
European Emulsion Group  
Nagoya, March 2002  
Presented by C. Bozza

## A joint scanning test by SySal

- DAQ System Setup
- Emulsion Scanning
- Remarks

## ■ DAQ System Setup

The systems used for the scanning are similar (not identical) and they use the same software

Aim of the test: share software – know how – experience – data formats

Stage: MICOS, Nikon

Optics: Leitz 22× oil

Motors: VEXTA RFK Nanostep

Motor controller: National Instruments FlexMotion

Camera: Hitachi KP-F110 1 Mpixel 30 fps

Vision Processor: Matrox Genesis

DAQ Software: SySal 1.0

## ■ Emulsion Scanning

Emulsion: Fuji from Oct. 2001 test exposure

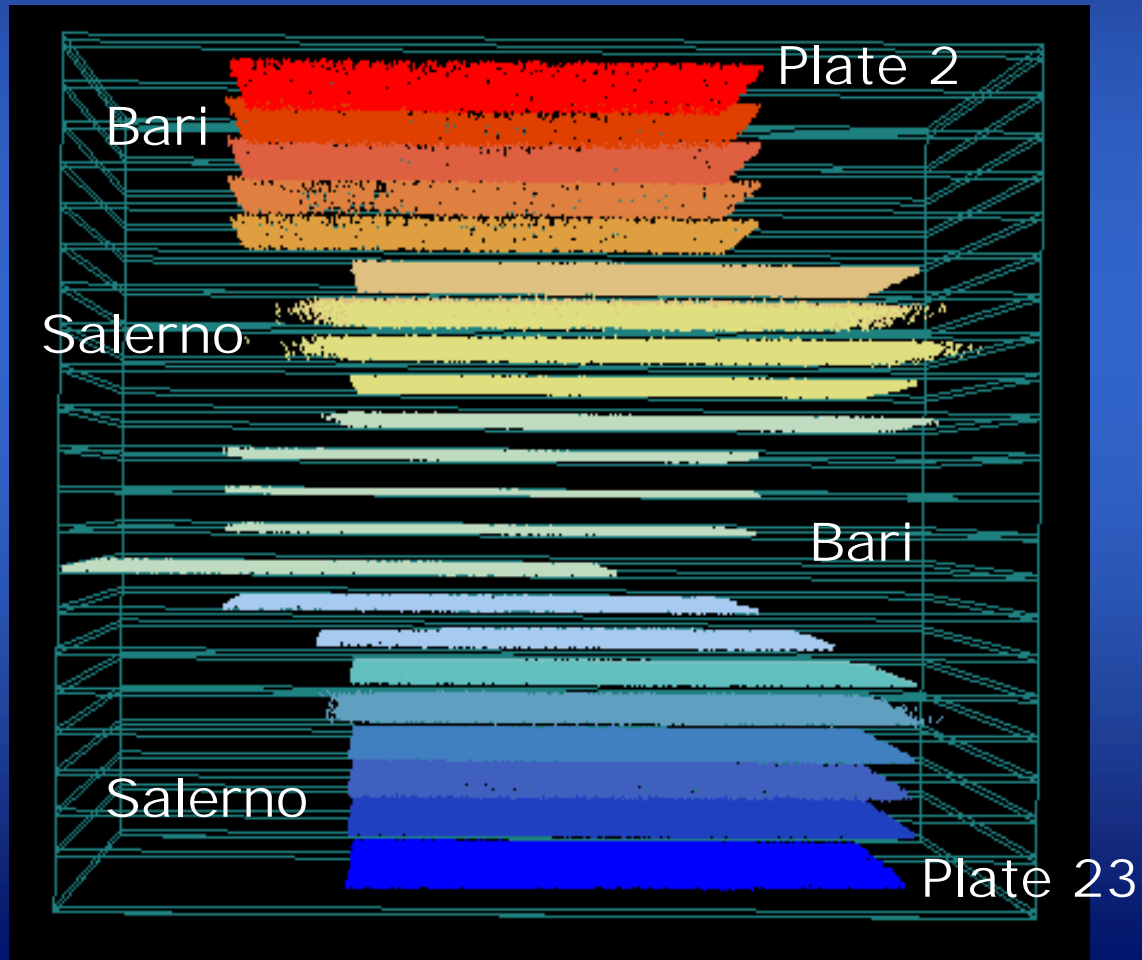
Emulsion sharing:

- plates 2÷6 Bari
- plates 7÷11 Salerno
- plates 12÷17 Bari
- plates 18÷23 Salerno

2.6 cm<sup>2</sup> were scanned (Total Scan technique) on each plate, but because of emulsion conditions it was not possible to choose exactly the same zone on all plates

## Emulsion Scanning

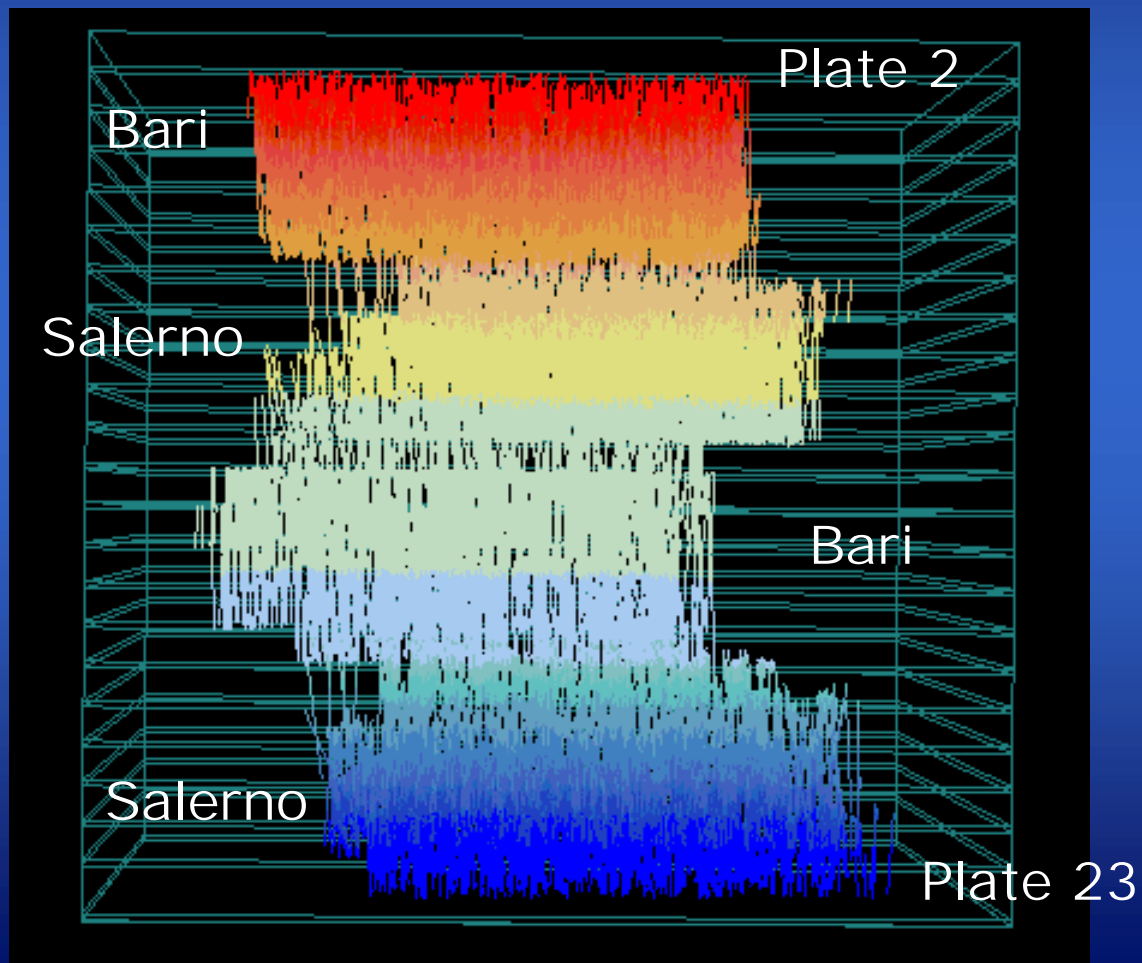
22 plates stacked - 389,618 segments - 89 MB raw data  
44 MB Total Scan Reconstruction file





## Emulsion Scanning

22 plates stacked – 5932 tracks ( $\geq 2$  plates connected)



## Remarks

This result is the product of the co-operation of two groups, but also other Italian and European groups are involved in important activities

Not only emulsion plates are being shared, but knowledge and tasks too

A tight interplay among groups is helping all of us to get ready for OPERA