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Results from the emulsion readout by the New Scanning System for OPERA

- Credits
- DAQ System Setup
- Emulsion Scanning
- Summary of Results
- Next Future

Credits

The hardware we are using is the product of the co-operation of several groups:

Bari, Bern, Bologna, Lyon, Münster, Napoli, Roma, Salerno

First system to break the 10 cm^2/h barrier!

DAQ System Setup

The prototype being used for the tests was “frozen” in the configuration it had in Dec. 2001

Only fine tuning of the optics to reach FOV width = 360 μm also with Nikon oil 50× objectives

Stage: MICOS

Optics: Nikon 50× oil + custom made optical tube

Motors: VEXTA RFK Nanostep

Motor controller: National Instruments FlexMotion

Camera: DALSA 1M60 Mpixel 60 fps

Vision Processor: Matrox Genesis +
G4 Double processing node

DAQ System Setup

Present version of the DAQ software is debugged and stable

A software microscope simulator has been developed to speed up development and debug

Remote control via TCP/IP

Tool for systematic manual checks

Some analysis tools now ready, more to come

- **Large track data sets handling (several $cm^2 \Rightarrow$ GB-size data sets are not easy to handle, and required us to develop specific analysis tools)**
- **Plate to plate alignment adapted from TotalScan Reconstruction software developed for CHORUS**
- **Data file-to-ROOT file converter ready**

Emulsion Scanning

Aim: to test speed and efficiency in routine duty

Scan large areas (realistic tests!) at 11 cm^2/h

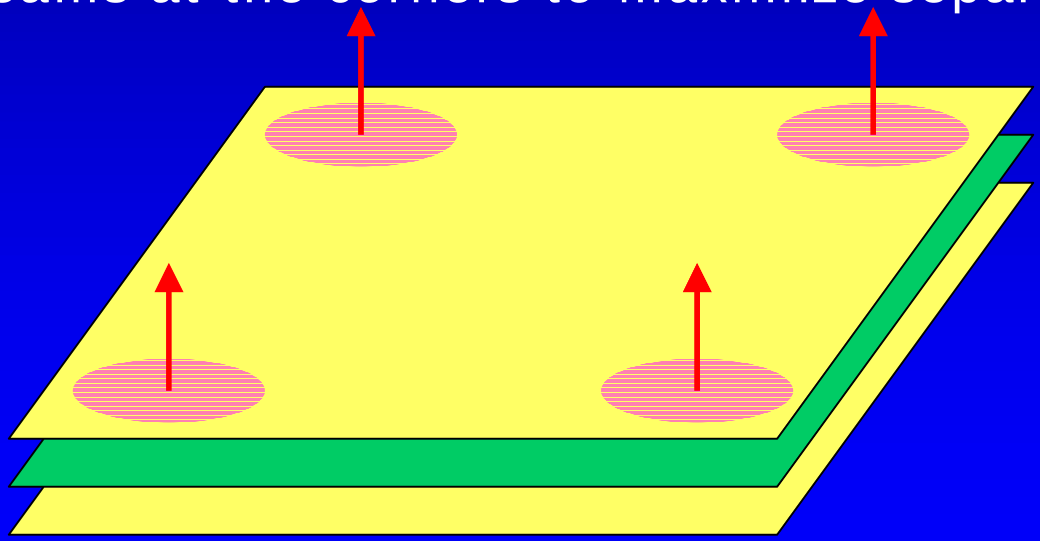
Let's test the efficiency and precisions at this speed

Emulsion Scanning

Emulsion: Fuji test batch with non-standard processing procedures, exposed in Oct. 2001

29 plates stacked in a brick with lead

4 beams at the corners to maximize separation



Emulsion Scanning

Emulsion at a glance:

Glycerine stains on the surfaces (due to non-standard processing) are present even after several trials to clean them out $\Rightarrow$ better cleaning at the centre than near the edges

The beam spot centres are near the edges but we didn't take data there

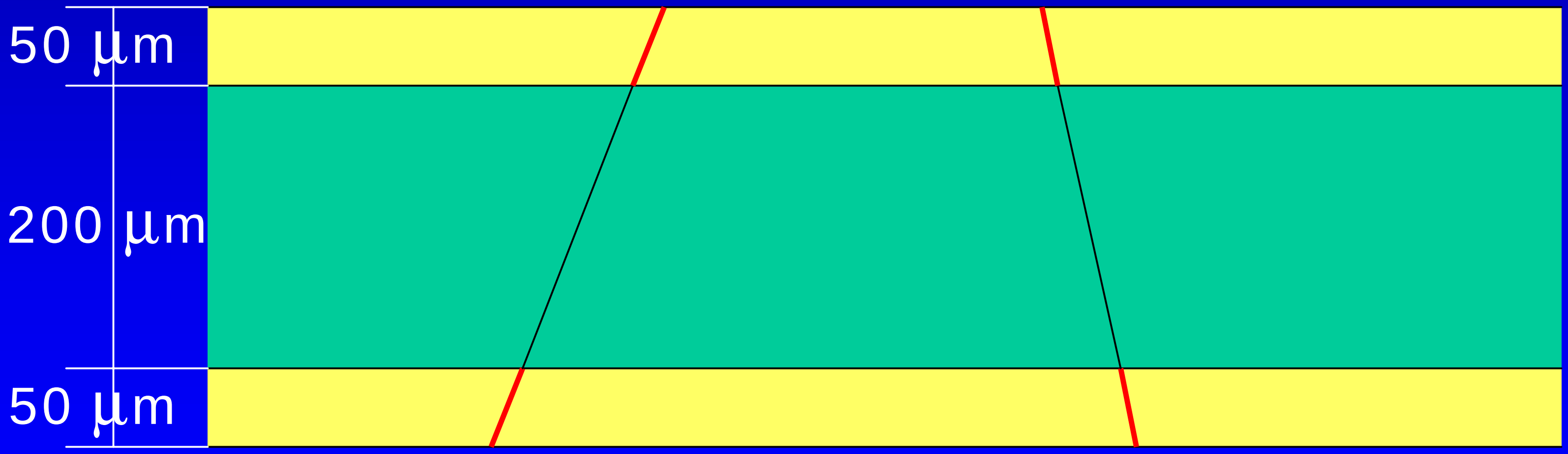
Only 12 layers / 30 μm to avoid surface

More feedback from scanning results...

Emulsion Scanning

Let’s recall how tracks are defined:

Each particle leaves grain paths in the two emulsion layers; the two segments must be linked across the plastic base to obtain the *base track*

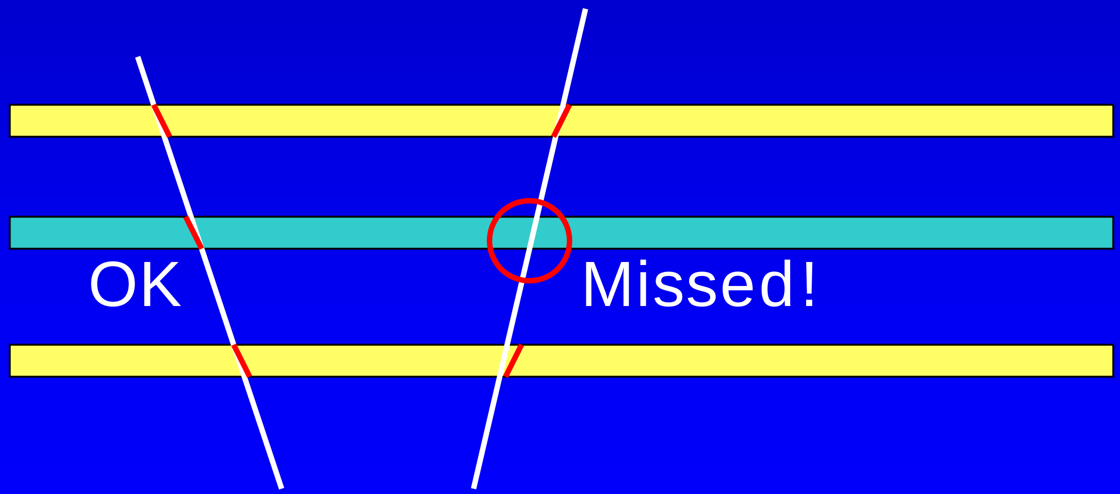


Emulsion Scanning

We chose a relatively clean area on sheet 26 for efficiency tests

Size = $1.81 \times 1.81\ cm^2 = 3.29\ cm^2$

The same zone was scanned on sheet 25 and 27 to select the tracks that were to be found on sheet 26



Emulsion Scanning

First step: reproducibility measurements @ 11 cm^2/h

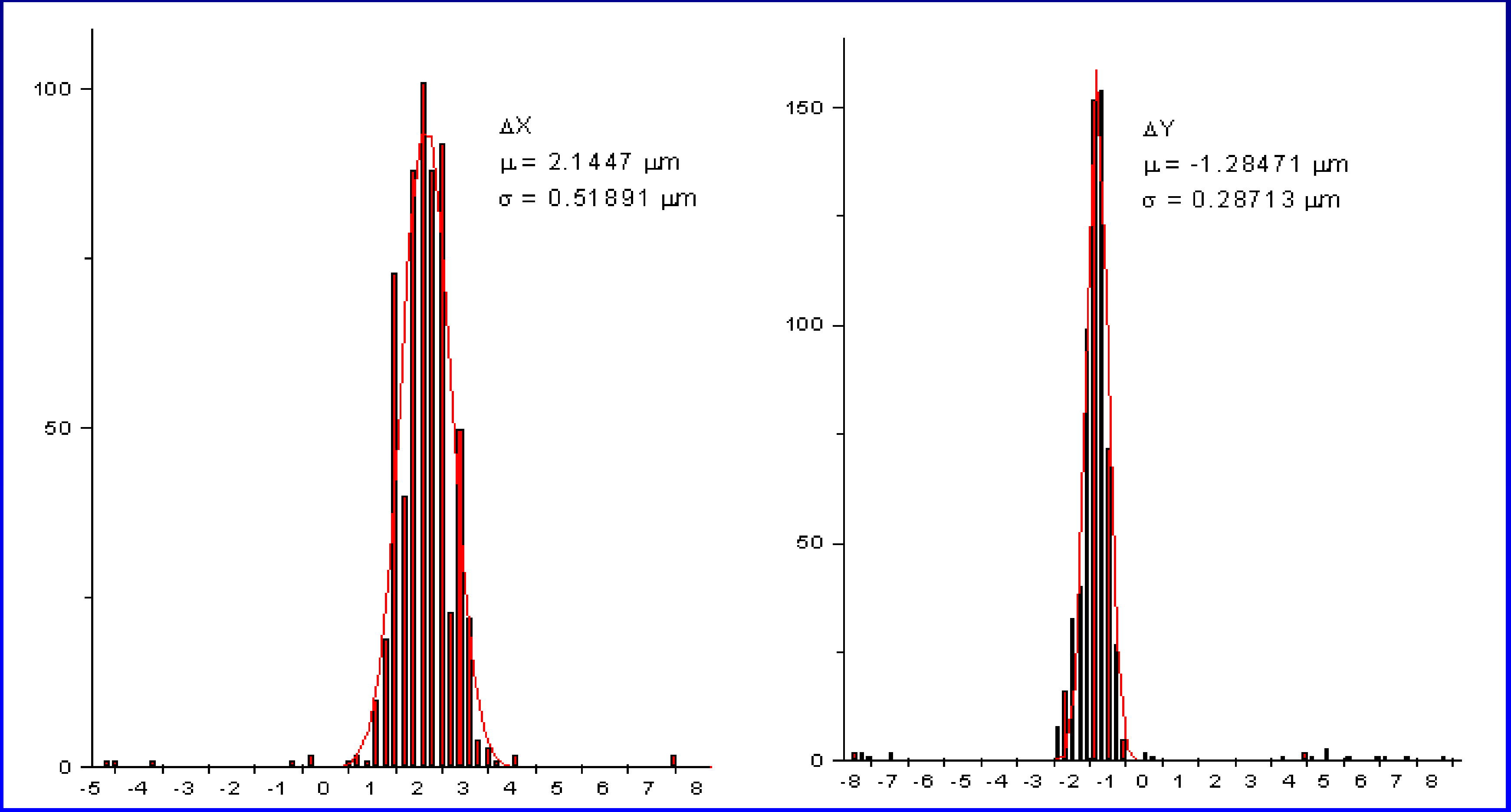
Scan the same zone more than once and then compare the position and angles of the tracks

~1500 tracks in 3.29 cm^2 $\Rightarrow$ ~700 are found twice, so 50% are fakes (due to combinatorics... wide tolerances for linking were used: 50 mrad, 50 μm)

Emulsion Scanning

First step: reproducibility measurements @ 11 cm^2/h

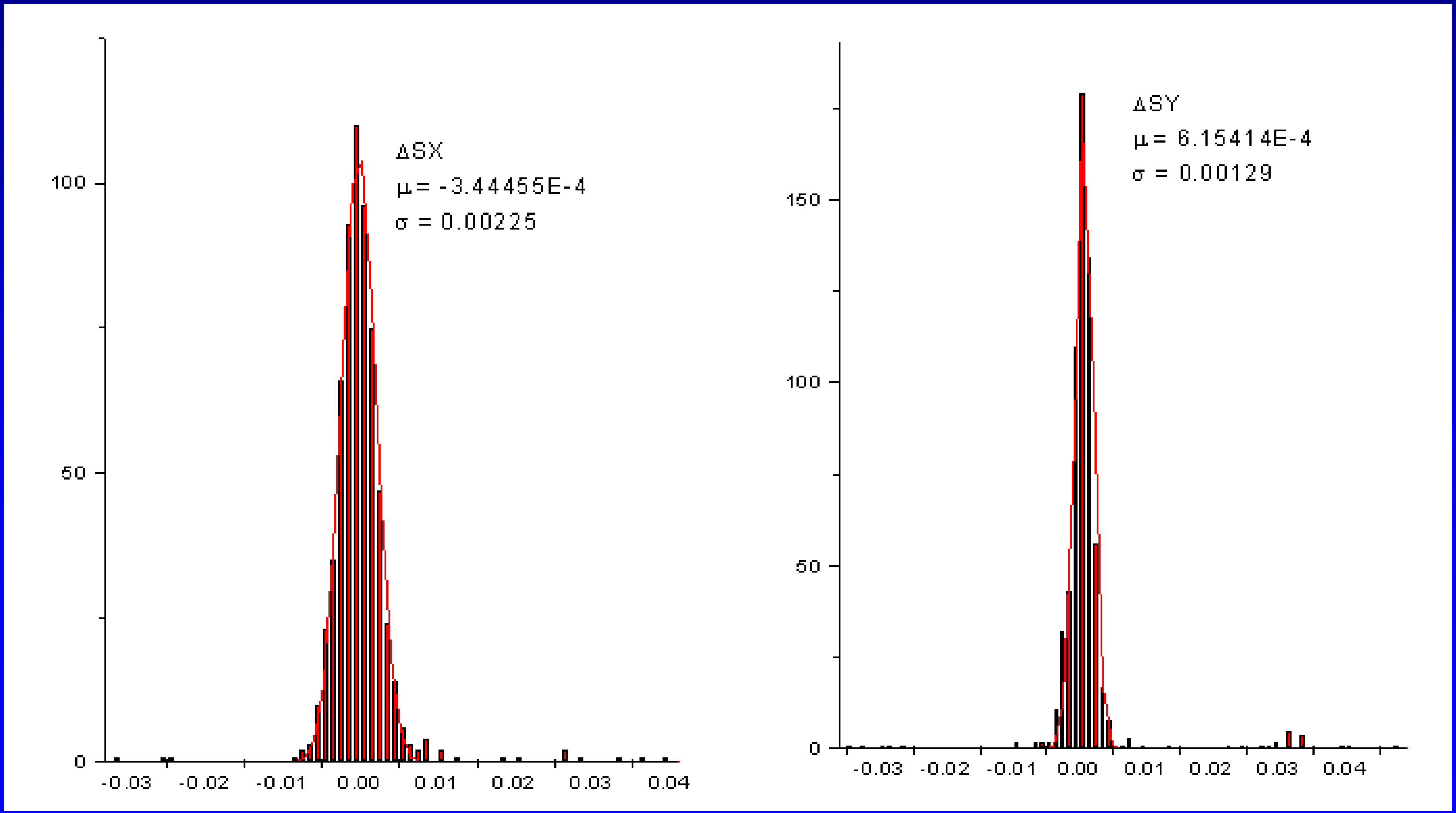
Scan the same zone more than once and then compare the position and angles of the tracks



Emulsion Scanning

First step: reproducibility measurements @ 11 cm^2/h

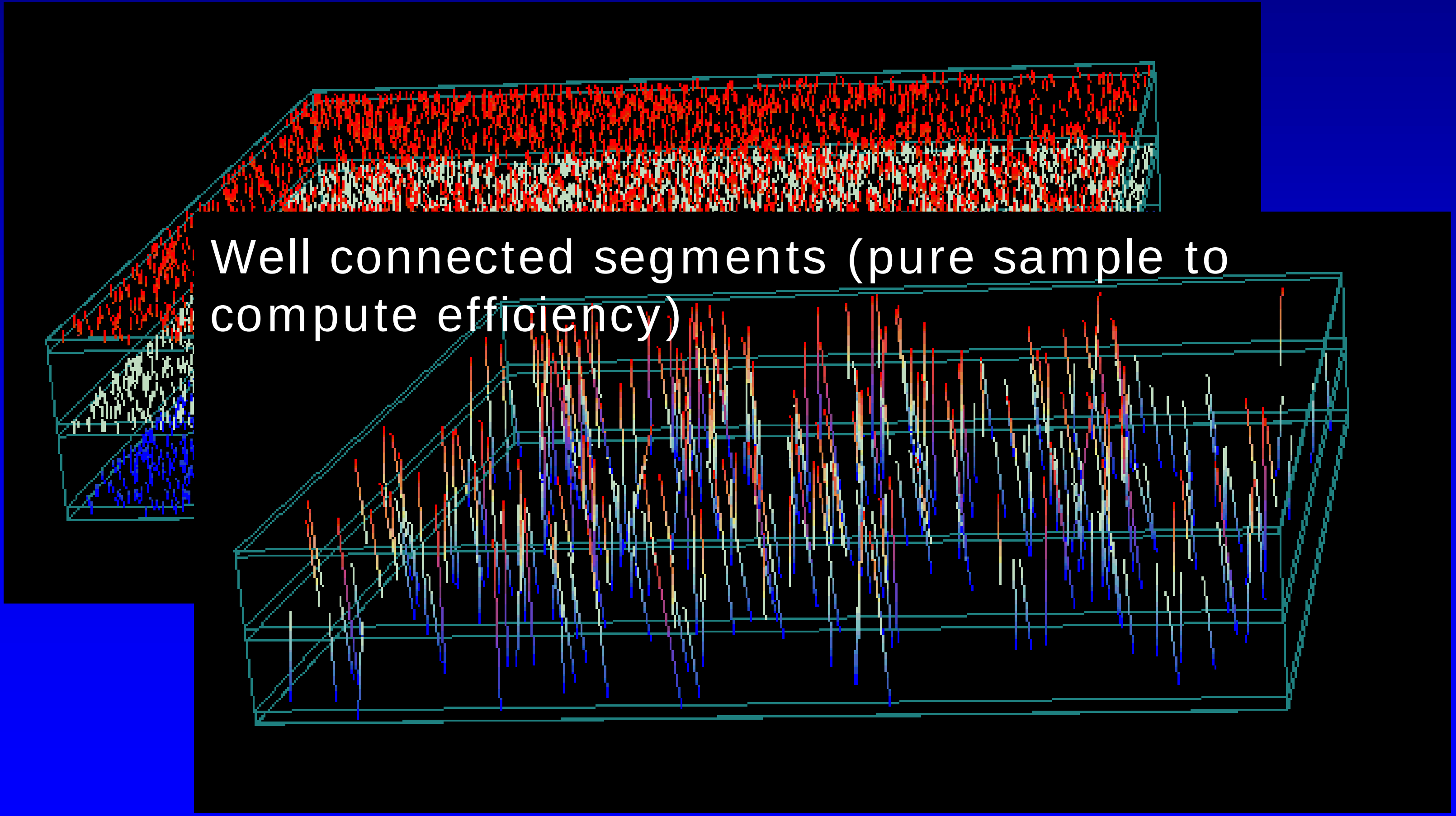
Scan the same zone more than once and then compare the position and angles of the tracks



Emulsion Scanning

Second step: plate to plate alignment

Scan the same zone on three consecutive plates
and obtain information about the efficiency



Emulsion Scanning

Second step: plate to plate alignment

Scan the same zone on three consecutive plates and obtain information about the efficiency

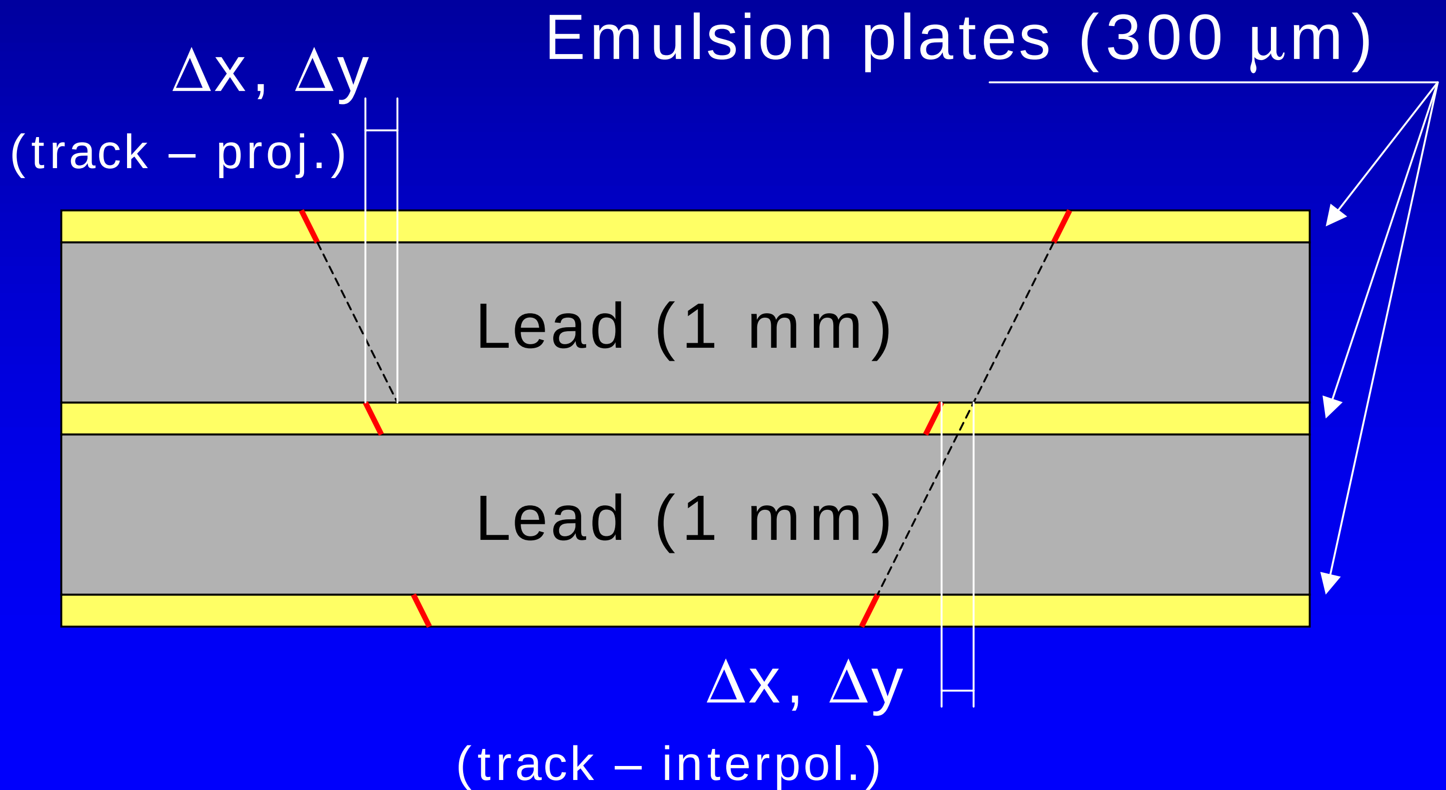
Purity of the sample of tracks to be found must be 100% to avoid bias (20 μm @ 2600 μm distance, 20 mrad)
We choose very well connected track pairs on sheets 25 and 27 and then go to sheet 26 to search for them (Total Scan mode)

Sample of 120 connected tracks (we are outside of beam spots: base tracks contain electrons, low energy particles...)

Emulsion Scanning

Second step: plate to plate alignment

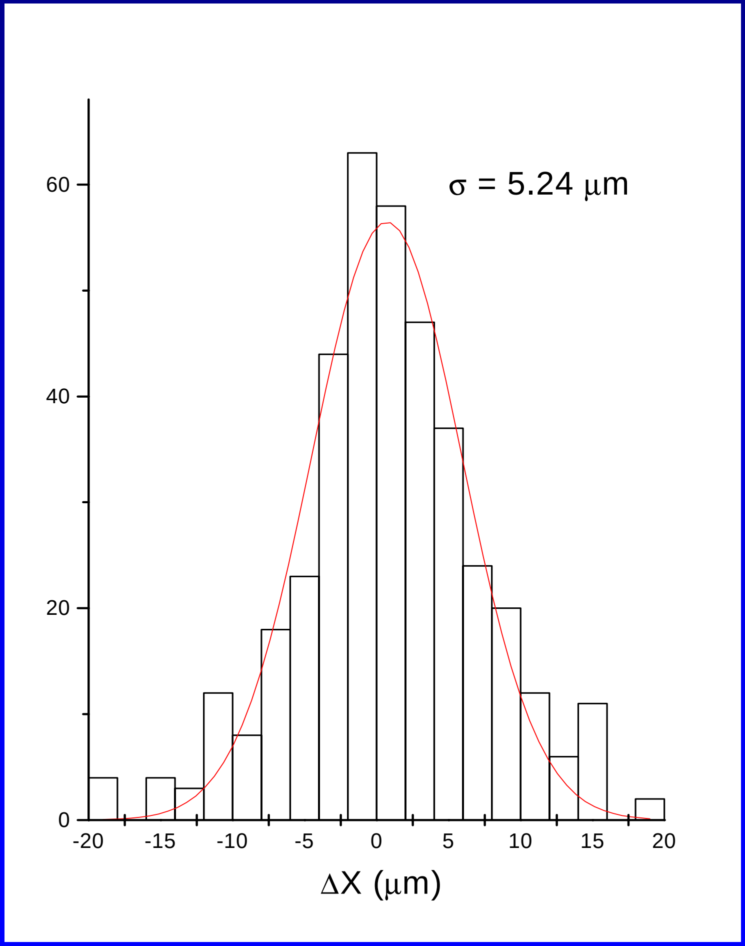
Scan the same zone on three consecutive plates and obtain information about the efficiency

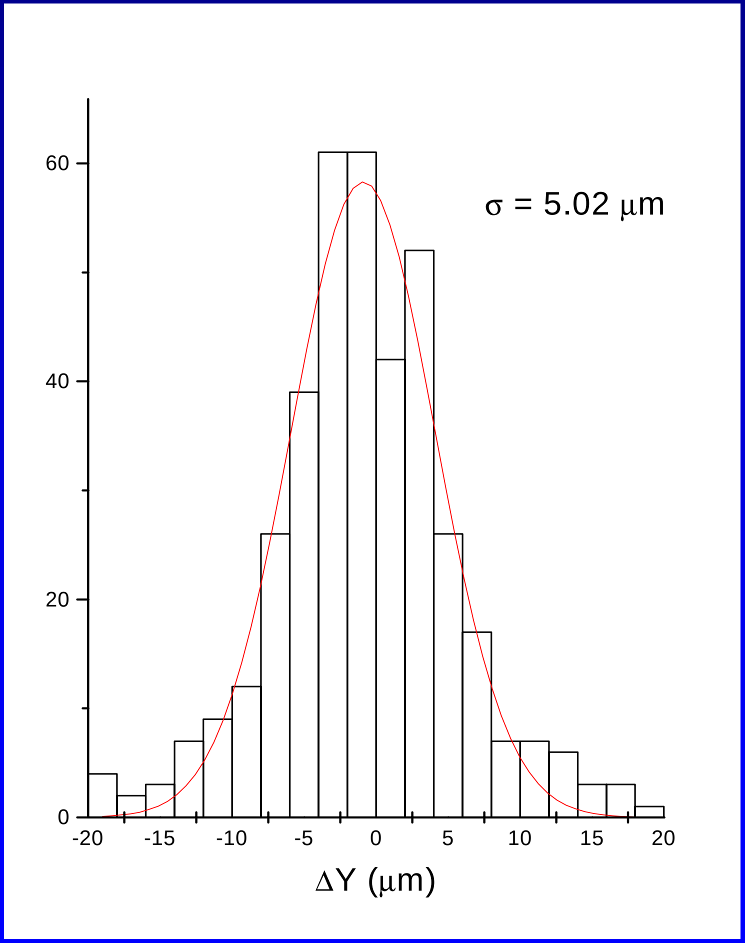


Emulsion Scanning

Second step: plate to plate alignment @ 11 cm²/h

Position agreement (track – proj. (1300 μm))

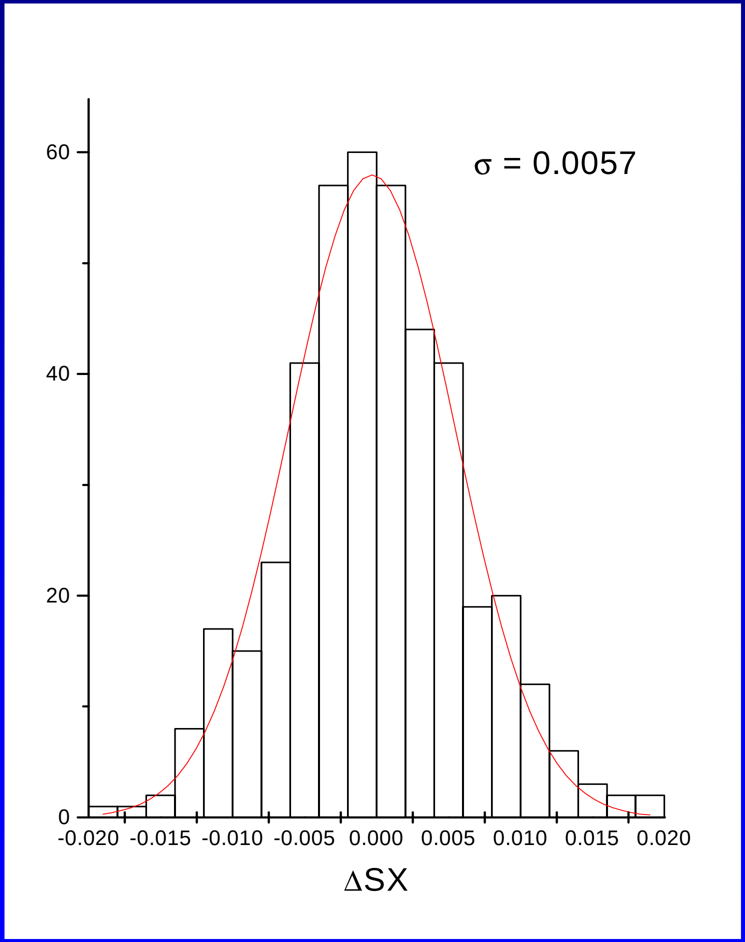


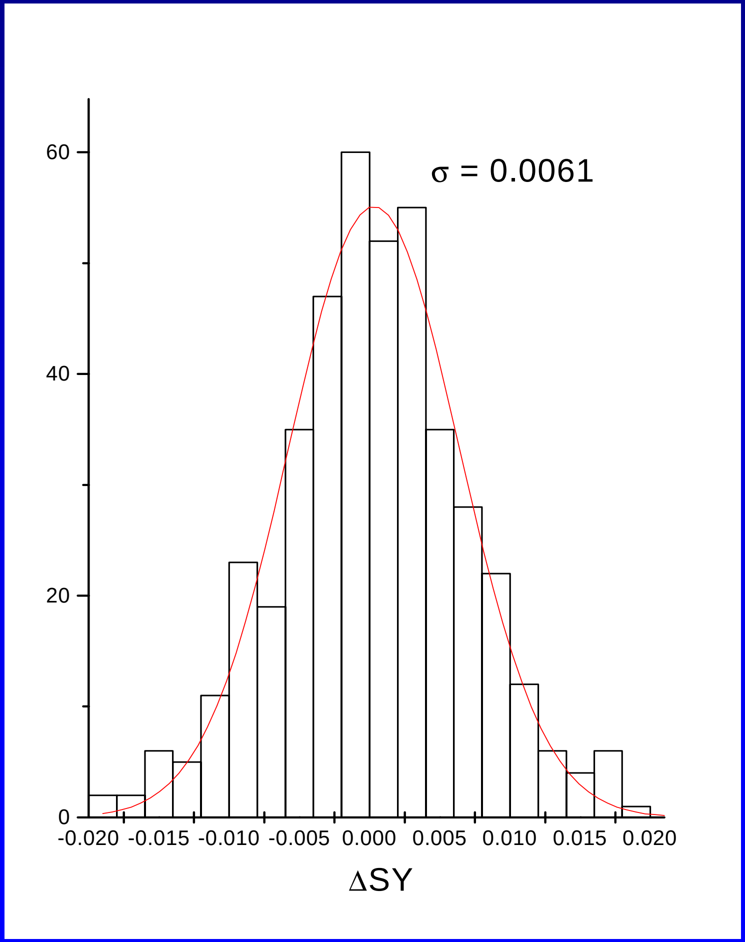


Emulsion Scanning

Second step: plate to plate alignment @ 11 cm^2/h

Slope agreement (track – proj.)

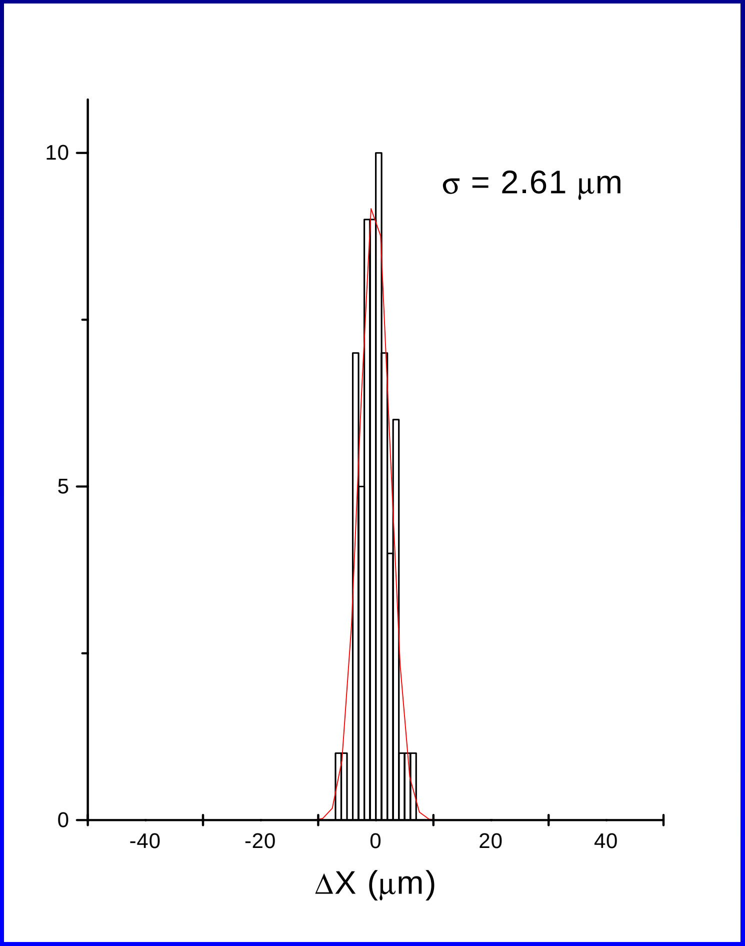


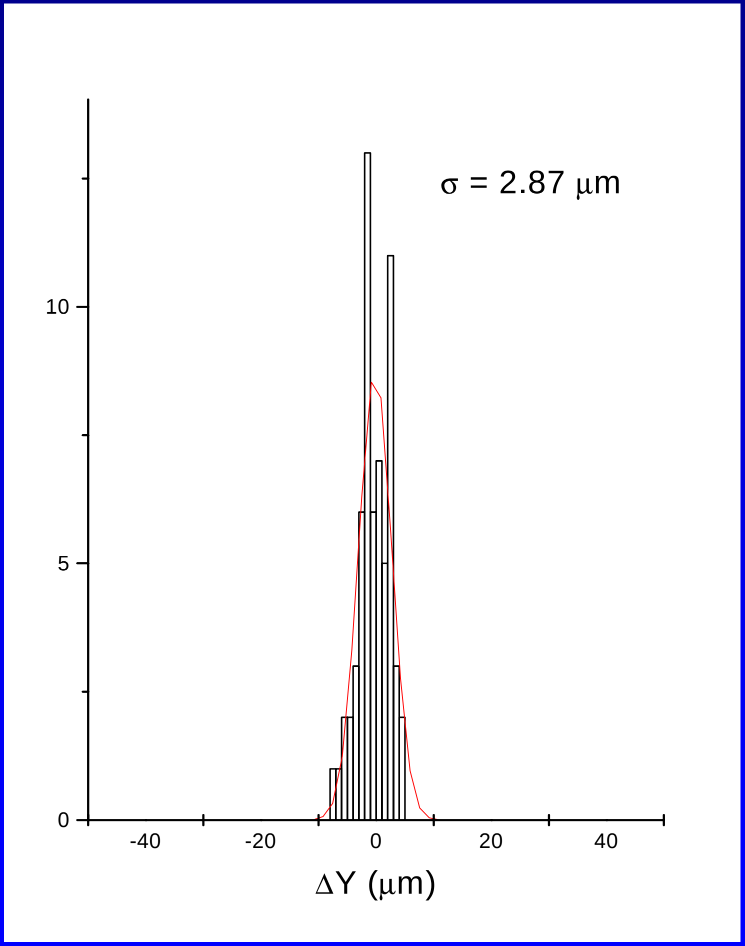


Emulsion Scanning

Second step: plate to plate alignment @ 11 cm^2/h

Position agreement (track – interpol.)

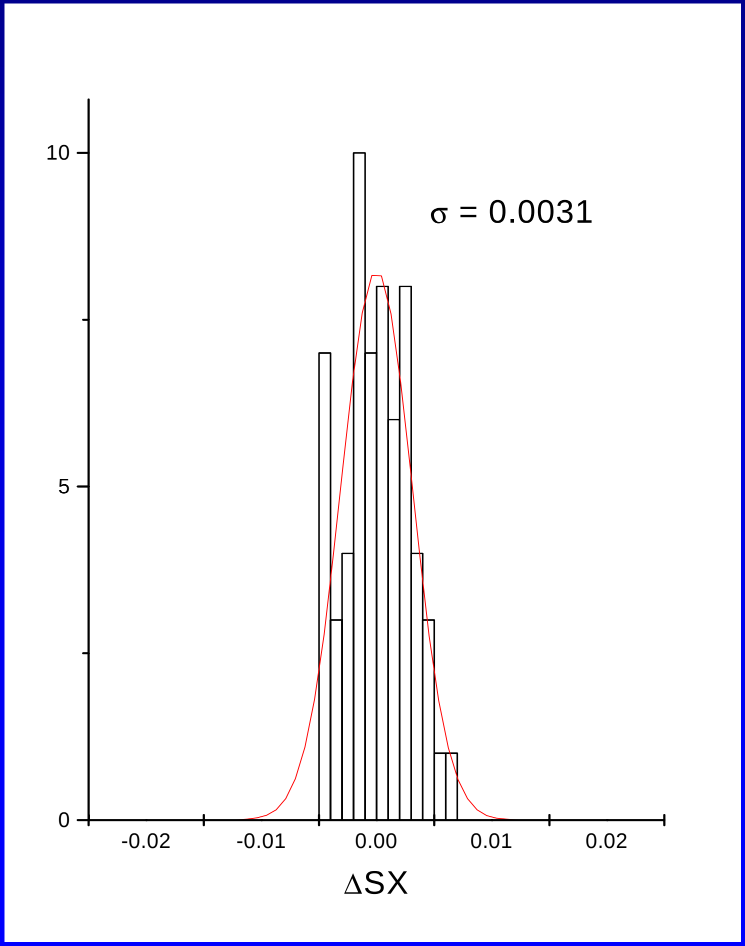


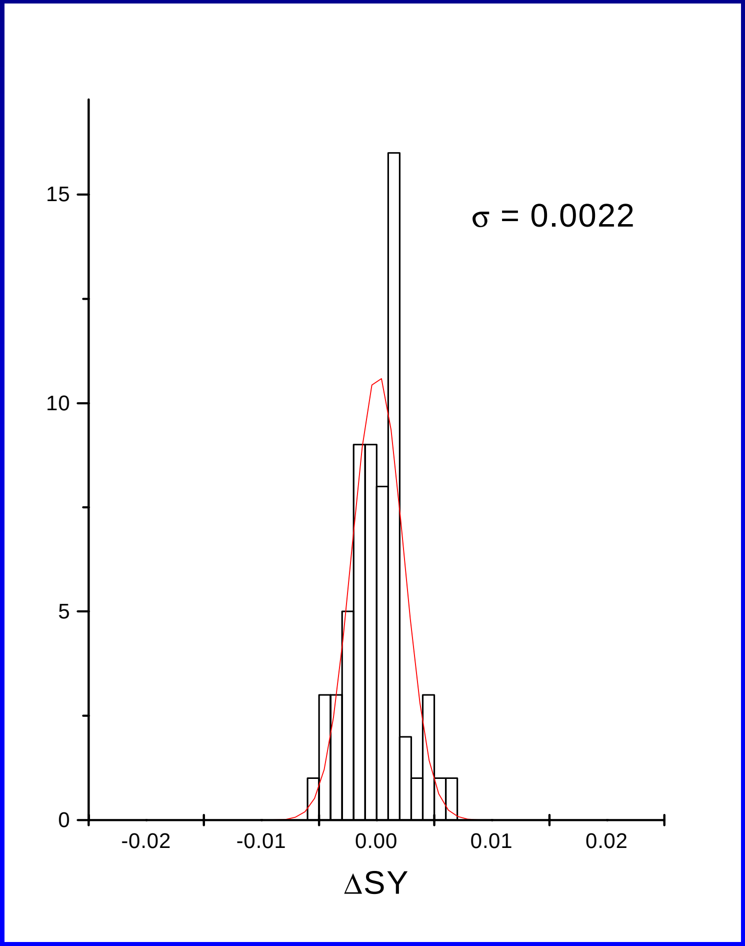


Emulsion Scanning

Second step: plate to plate alignment @ 11 cm^2/h

Slope agreement (track – interpol.)





Emulsion Scanning

The precision confirms Dec. 2001 preliminary data

However, the efficiency is not so good...
Only 59% of the tracks are found

These data were obtained by sampling 12 layers
(30 μm thickness, 11 cm^2/h) per side

So we tried sampling 24 layers (60 μm thickness, partly out of emulsion, 6 cm^2/h) per side to check whether the efficiency increased
Also, we changed the magnification

Surprisingly, the efficiency did not increase at all!

We checked manually some of the lost tracks

Emulsion Scanning

Results of the manual checks on Fuji emulsion

Track category	Fraction
Good	48%
Fake	5%
Distorted on top side	20%
Distorted on bottom side	14%
Damaged on top side	4%
Damaged on bottom side	9%

Thus, there were some non instrumental reasons to miss these tracks... emulsion inefficiency!

Taking these effects into account, our estimate of the present efficiency is 75% ($\Rightarrow$87% per side)

Emulsion Scanning

Results of the manual checks on Fuji emulsion

Distorted tracks: we see very local distortions of more that 50 mrad, whereas the base points of the track are in the expected positions!!!
The distortion seems linear rather than parabolic

Damaged tracks: tracks that fall into a dark stain of glycerine, or tracks that have very few grains (4÷6 grains at most)

Emulsion Scanning

To confirm this result, we scanned the same plate by the old DAQ software running a traditional Nikon microscope

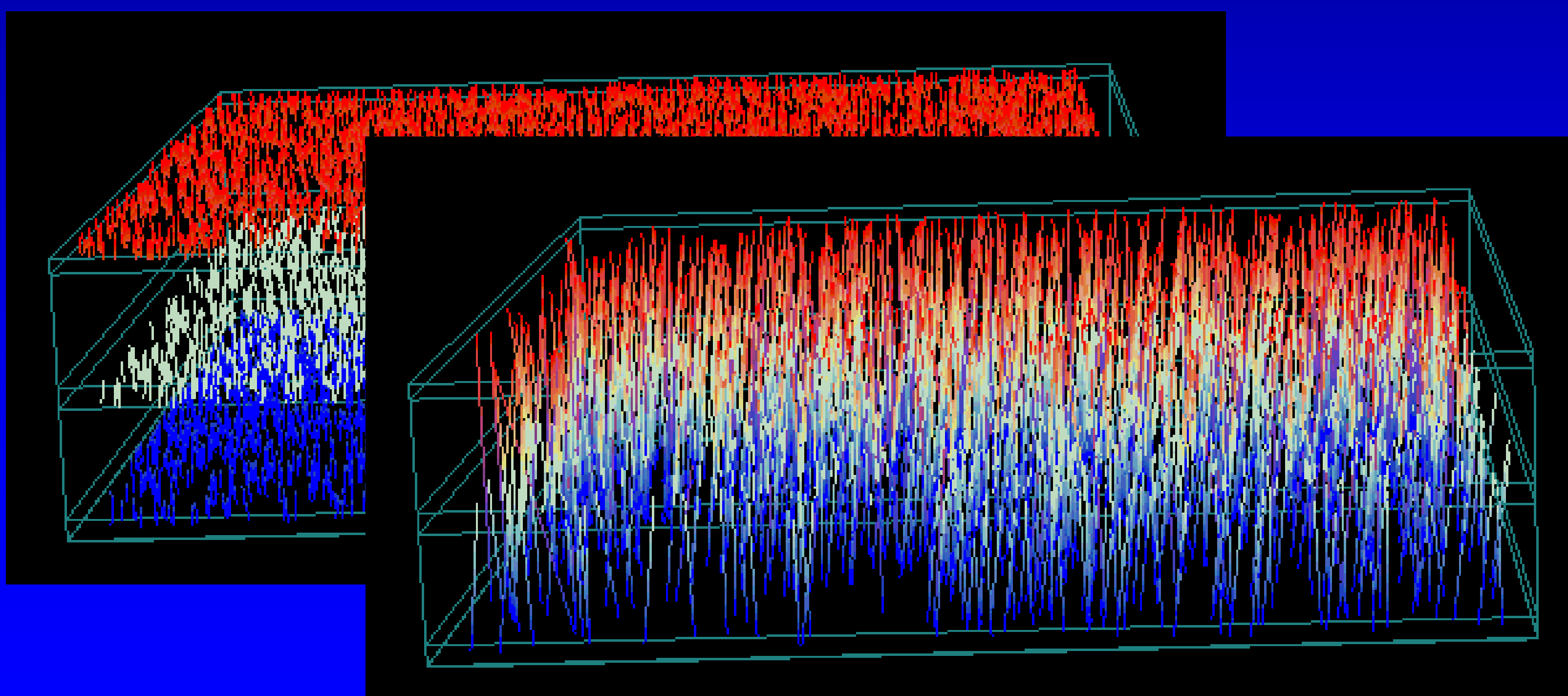
Indeed, even the slow DAQ (2 cm^2/h) was not able to go beyond 65% (at least 24 layers on 40 μm fiducial thickness, refocusing at each field)

Then we tried to scan old FOMOS emulsion (May 2000 test beam - distorted and full of fog, but surface very clean and regular) to decouple emulsion effects from instrumental effects

Emulsion Scanning

Scanning results from FOMOS emulsion

Similar test: search on plate 23 for tracks reconstructed by connecting plate 22 and 24



Emulsion Scanning

Scanning results from FOMOS emulsion

Similar test: search on plate 23 for tracks reconstructed by connecting plate 22 and 24

Higher track density – 3 beams within acceptance

Efficiency estimate:
463 found / 535 within area = 87% (93% per side)

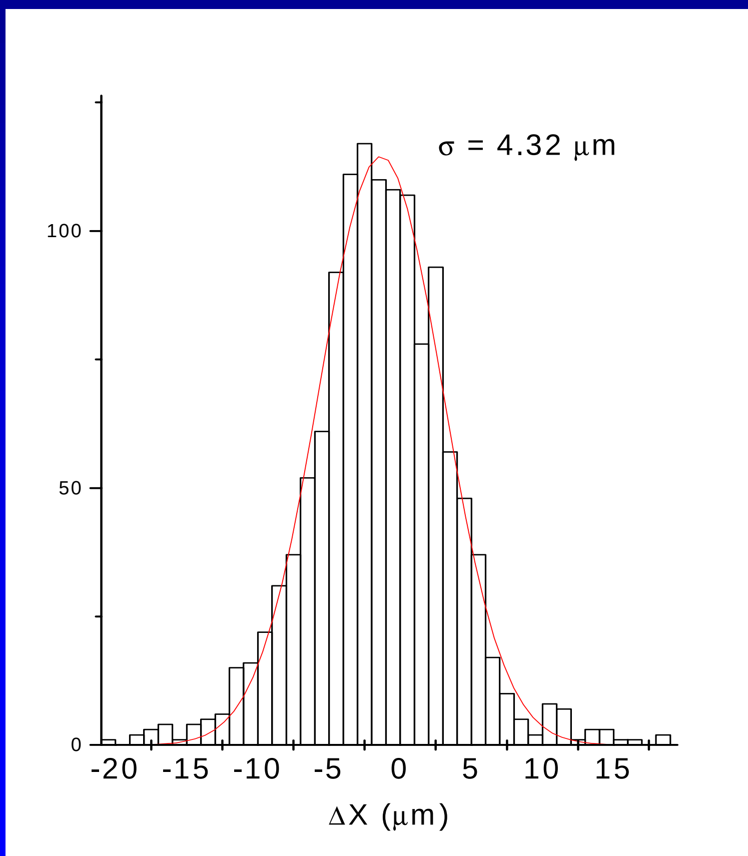
Very dense fog slows down tracking
DAQ parameters are tuned for 11 cm^2/h
However, at each field the system waits for completion of tracking procedure
Resulting speed is 5 cm^2/h

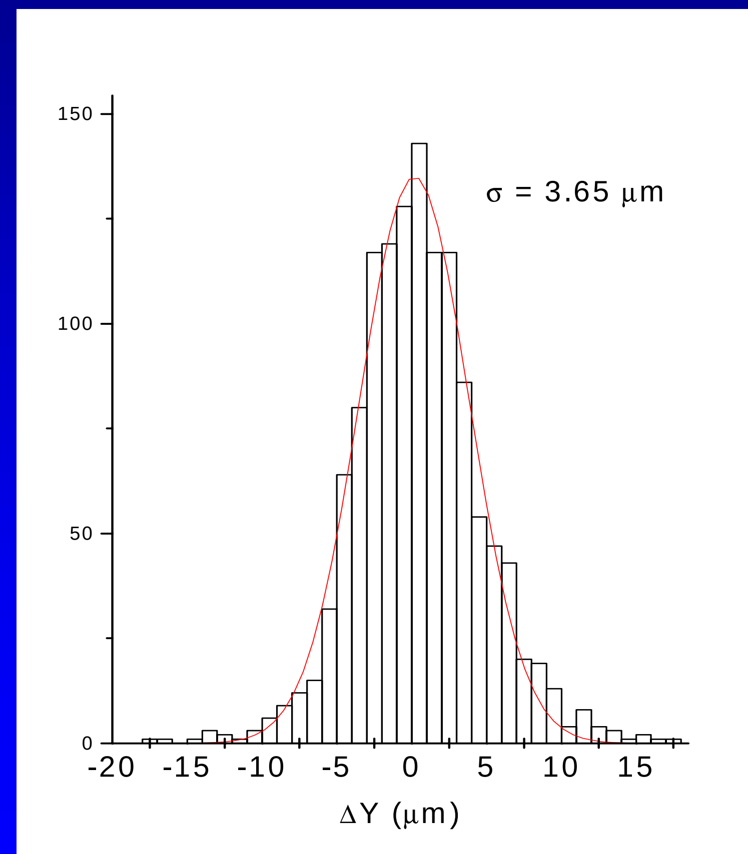
A look at data quality…

Emulsion Scanning

Scanning results from FOMOS emulsion @ 5 (11) cm^2/h

Position agreement (track – proj. (1300 μm))

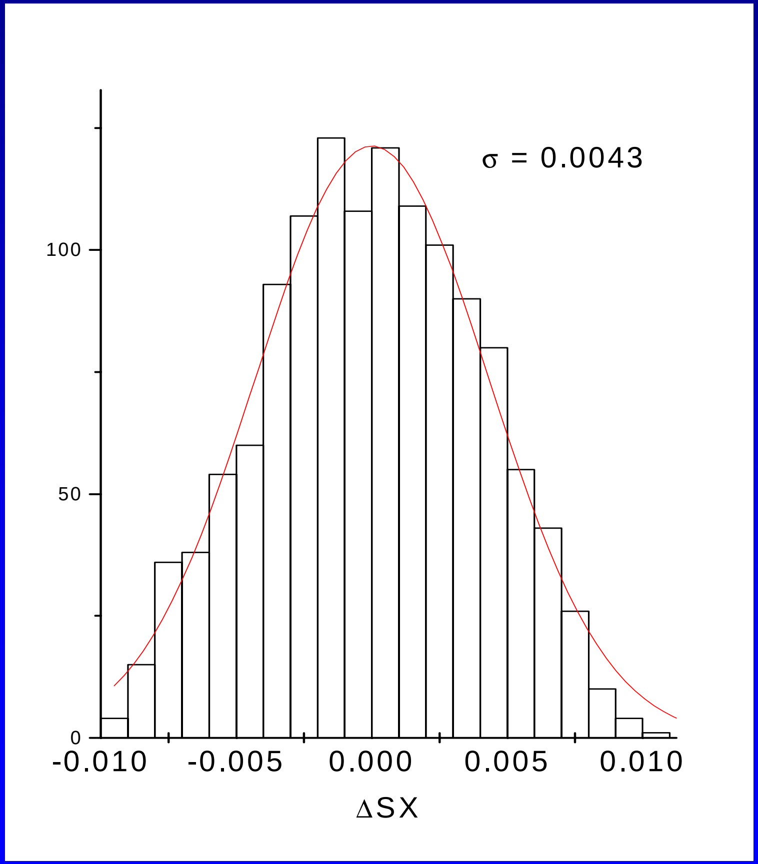


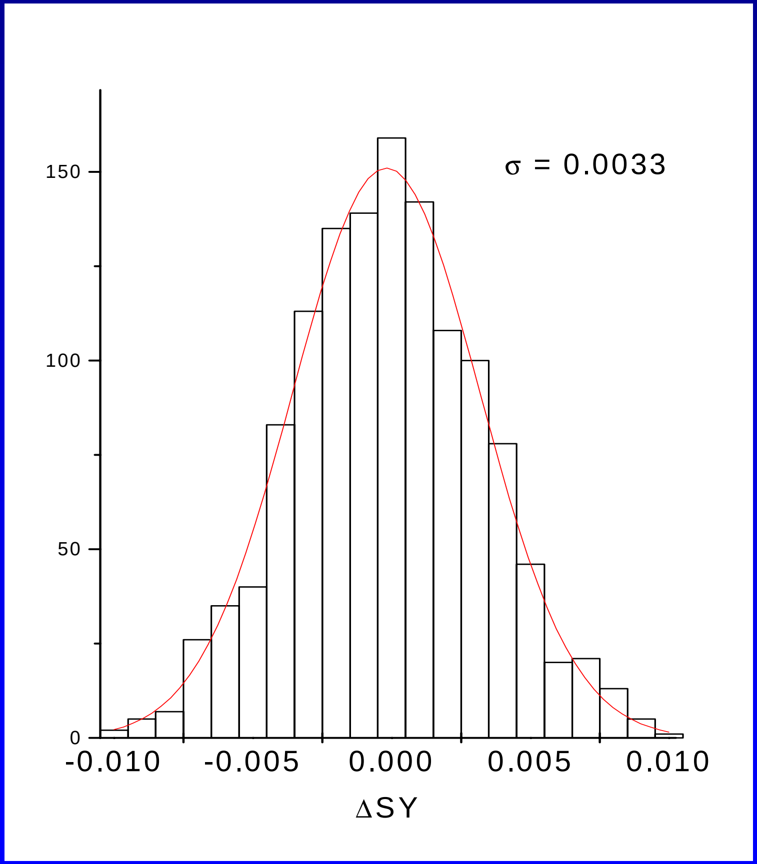


Emulsion Scanning

Scanning results from FOMOS emulsion @ 5 (11) cm^2/h

Slope agreement (track – proj.)

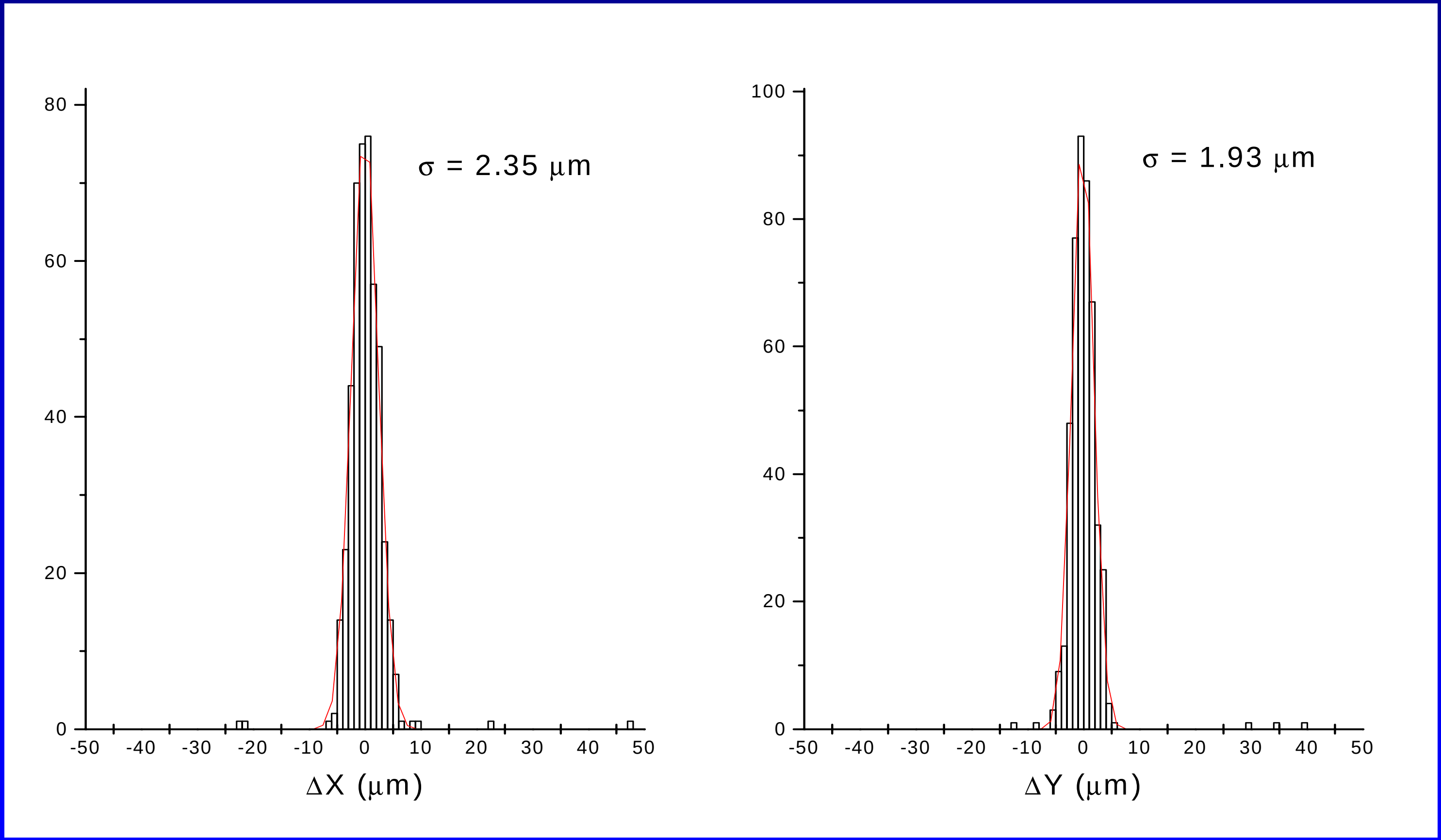




Emulsion Scanning

Scanning results from FOMOS emulsion @ 5 (11) cm^2/h

Position agreement (track – interpol.)

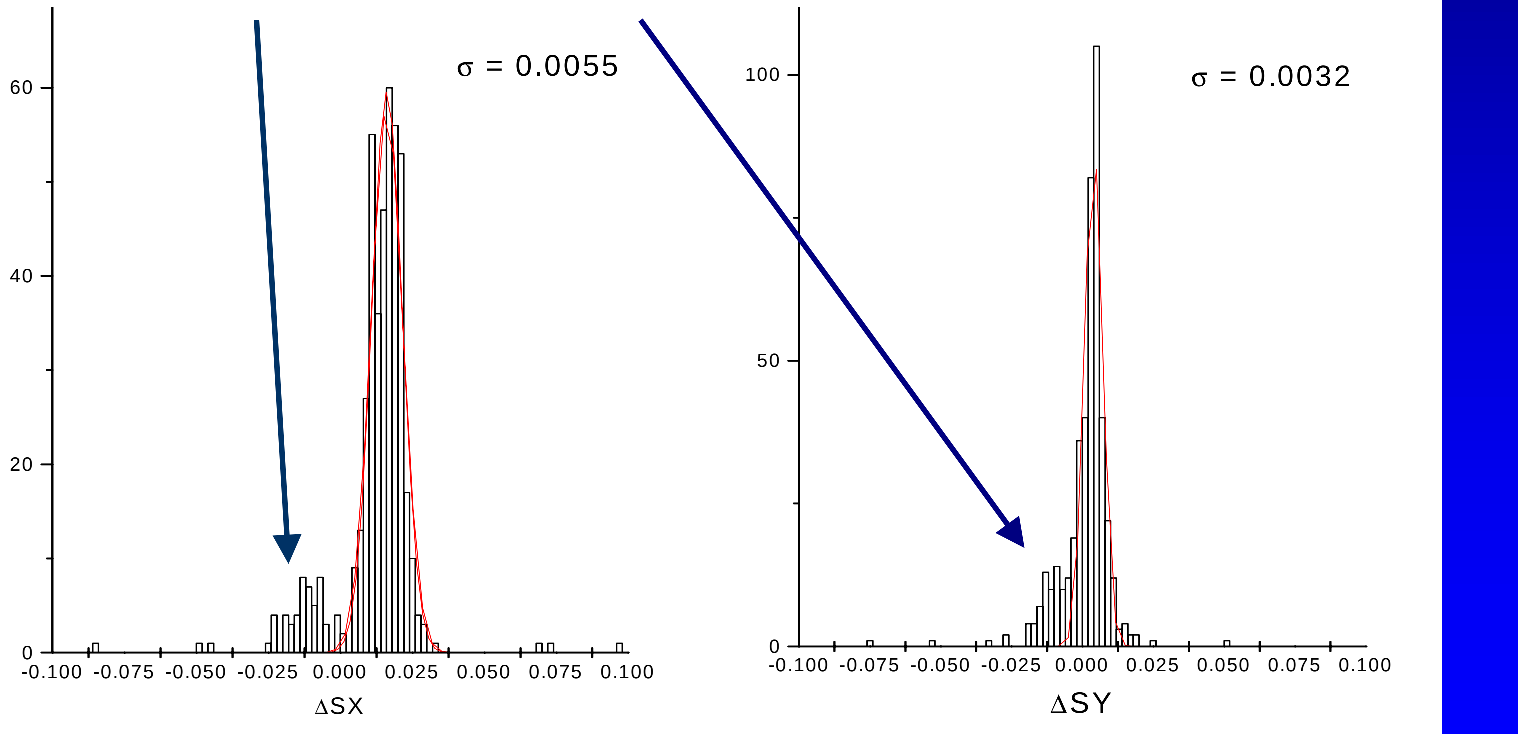


Emulsion Scanning

Scanning results from FOMOS emulsion @ 5 (11) cm^2/h

Slope agreement (track – interpol.)

Systematic effects due to misalignments of the camera... Fine “tuning” of the hardware!!!



Summary of Results

Scanning on Fuji emulsion:

- Good precision confirmed
- Speed does not affect efficiency and precision
- Low efficiency mostly due to (partly) unknown reasons that downgraded emulsion performance

Scanning on FOMOS emulsion:

- Precision similar to Fuji
- Instrumental efficiency estimate: 93% single side, 87% both sides
- Parabolic distortion is very strong and evident
- Particle tracks are bent and may be discarded or missed by the tracking module
- Dense fog decreases speed (5 cm^2/h) because of high combinatorial complexity during tracking
- Possible instrumental inefficiency can be studied with this emulsion while we wait for latest Fuji

Summary of Results

Possible reasons for inefficiency:

- Tracks with slope < 0.010 are discarded to avoid fakes due to dirt on the CCD sensor
- The image has darker zones
  We must check whether this depends on the sensor or on the optics
- More unknown causes to be studied...

Next Future

Now that the speed result is consolidated we can work hard on turning this prototype into a routine duty machine

We hope we will be able to take part in the scanning activity for the next test exposures by this system rather than the old DAQ

A large effort will be devoted to improve efficiency as soon as possibile, but we are now aware that

latest emulsion is needed

(Good set of ***handling*** specs also needed!)

Speed is expected to increase considerably in the next months since new CMOS-based cameras are coming