Cristiano Bozza
Salerno Emulsion Group
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SySal

Motivation

Basic Ideas

Implementation

DAQ Clusters

SySal at Work

Motivation

SySal (System of Salerno) was born to:

- Reproduce the human way of scanning
- Recognize all tracks regardless of their slope
- Yield the maximum detail level of the information stored in the emulsion (i.e. track grains)
- Automate analysis to the maximum degree, leaving only Physics tasks to humans
- Software-based approach allows flexibility
- Scan fast and efficiently
- Use commercial, turn-key hardware whenever possible

Motivation

The original ideas of SySal date back to 1994

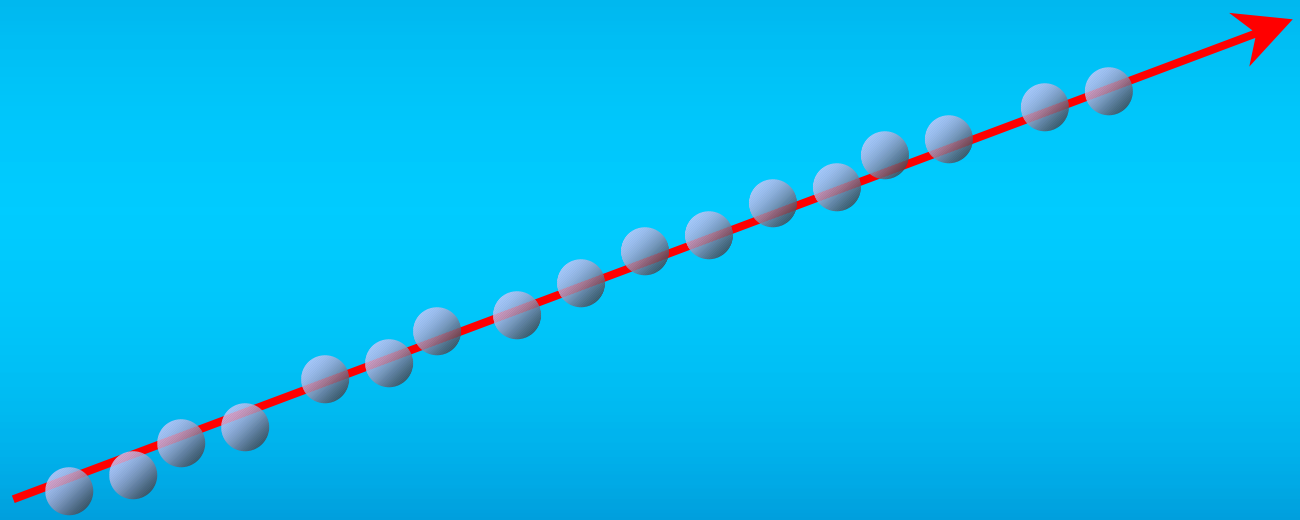
Working system started producing data in Dec. 1996

First multitracking system

Improvement and development continues...

Basic Ideas

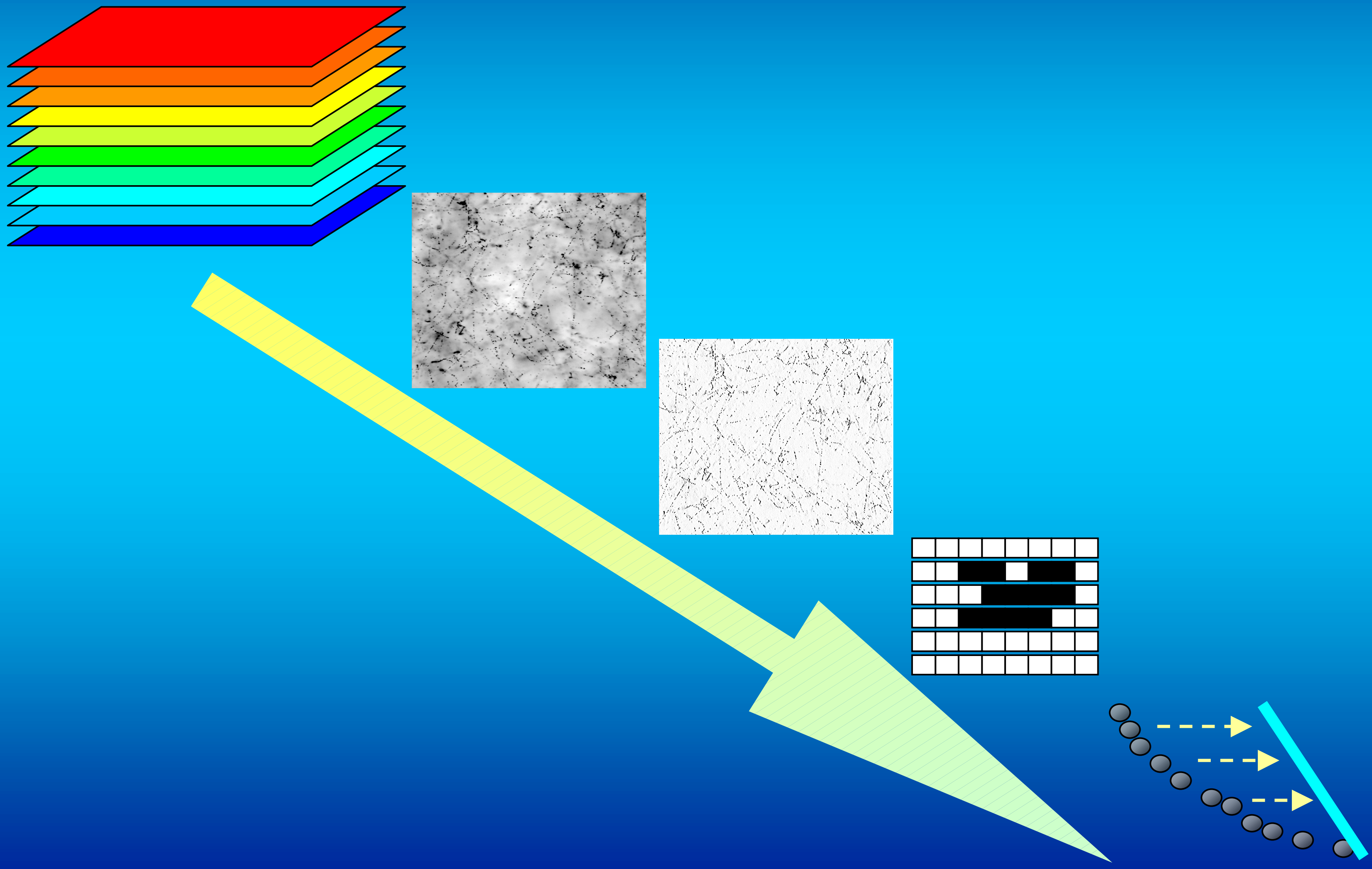
After the passage of an ionizing particle, the development process leaves a path metallic silver grains: the "track"



Knowing the exact position and shape of each grain gives the highest level of detail present in the emulsion

Basic Ideas

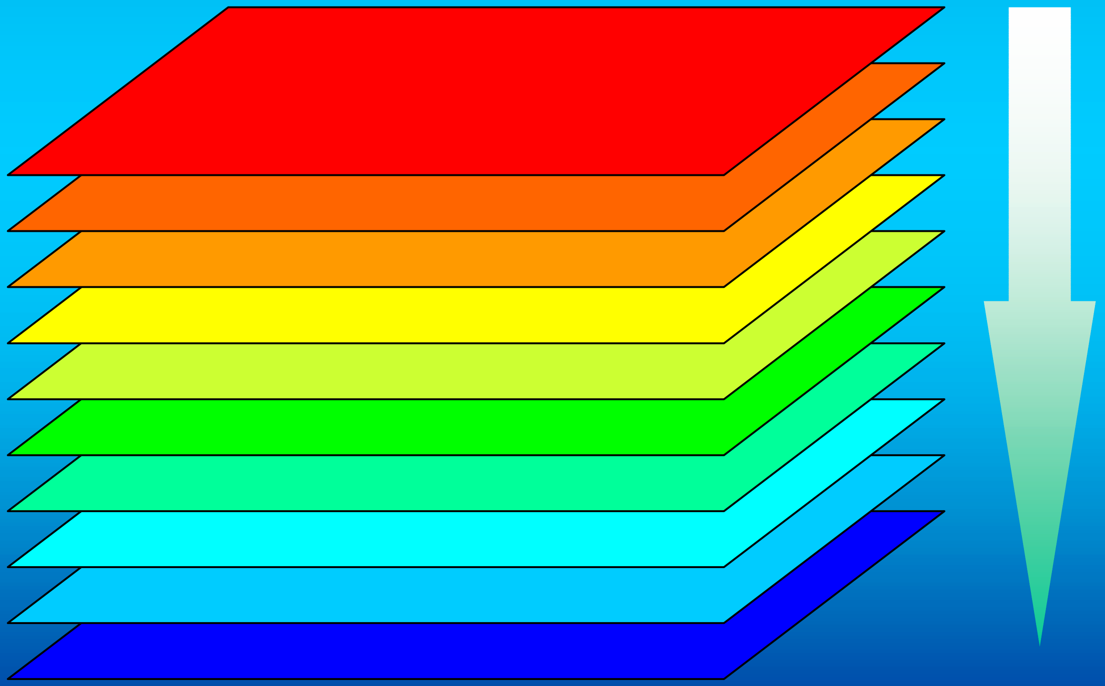
The data taking process involves several steps



Basic Ideas

For each FOV (field of view) we take several tomographic images of the emulsion

The camera axis (Z) moves during data taking, but an electronic shutter allows to obtain almost still images of each layer



Volume scanning: the number of layers varies in order to cover the full thickness (20÷60 layers)

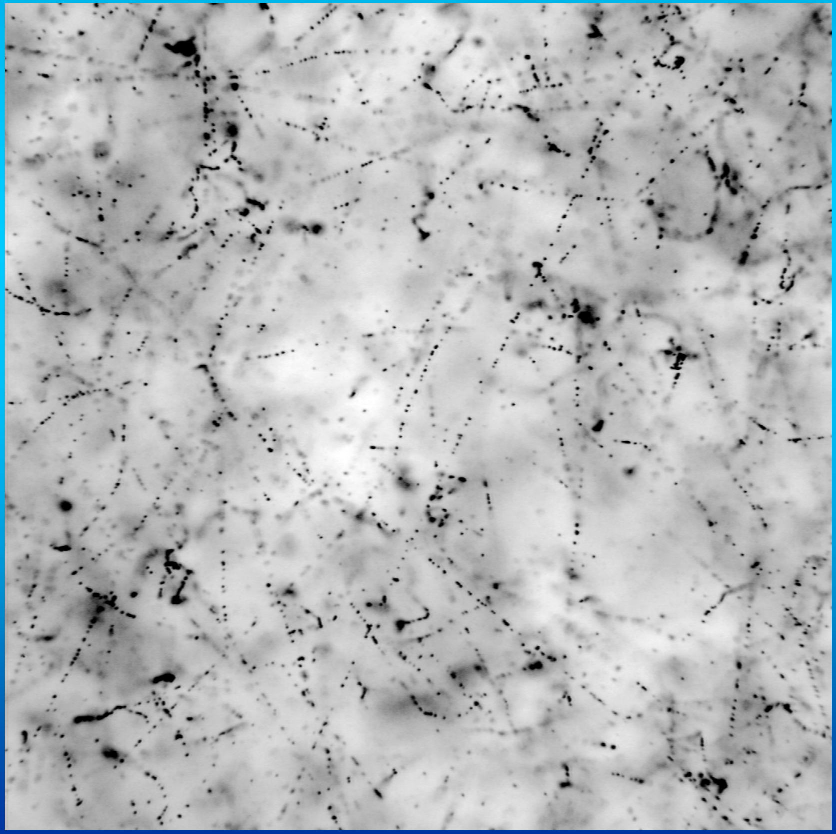
1 MPixel camera @ 30 fps

Wide FOV (200÷300 μm)

Basic Ideas

Images are grabbed by a commercial vision processor (currently we're using Matrox Genesis)

Clever image handling is crucial to obtain good results



~1000 background grains (fog + cosmics + Compton electrons) and ~10 track grains...

Completely indistinguishable in a 2D image!!!

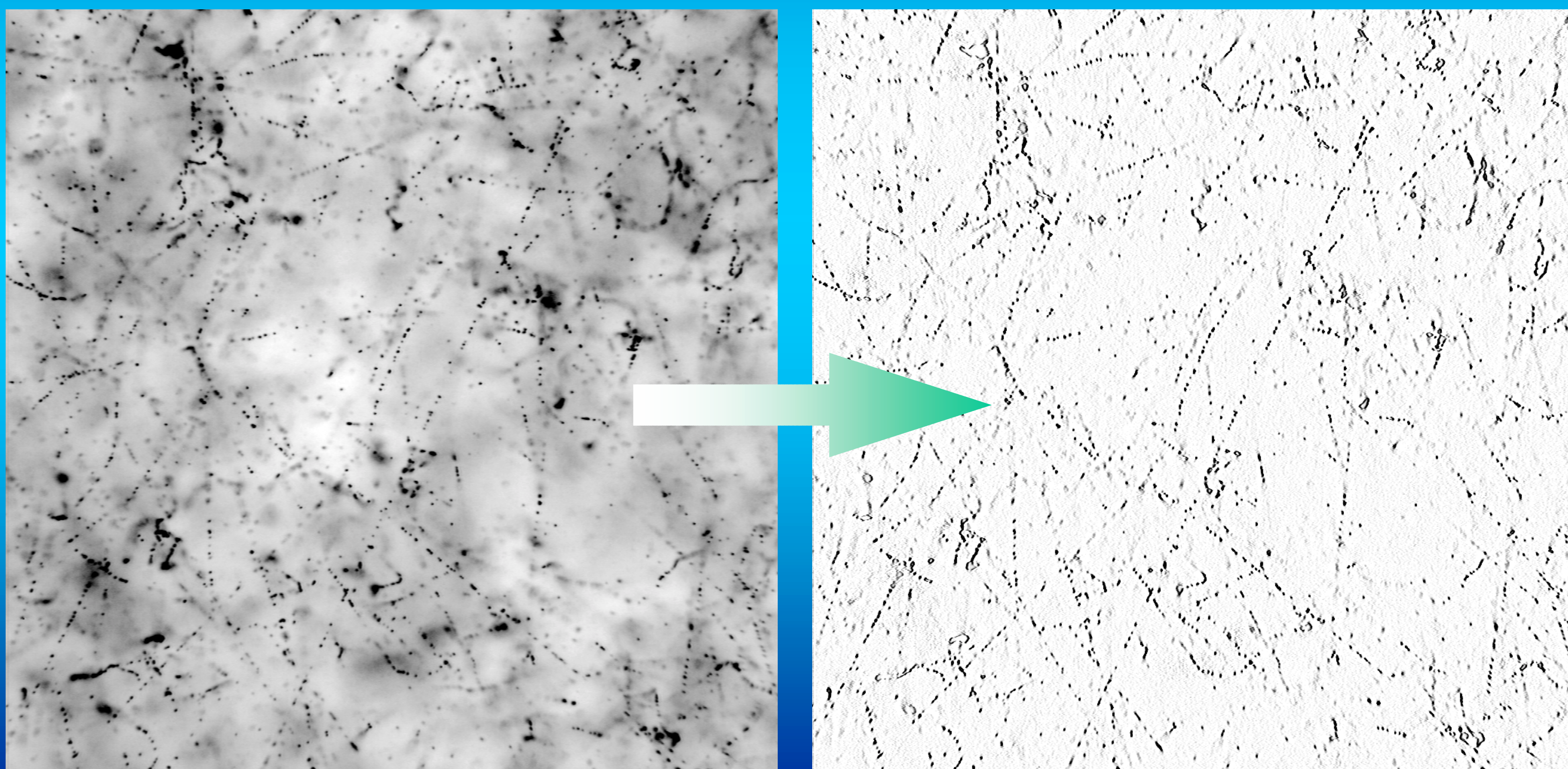
The image has lighter and darker zones because of shadows from neighboring layers

200×200 μm^2 in a CHORUS Target Sheet

Basic Ideas

Simple gray level threshold does not work...

A 2D FIR filter yields much better results



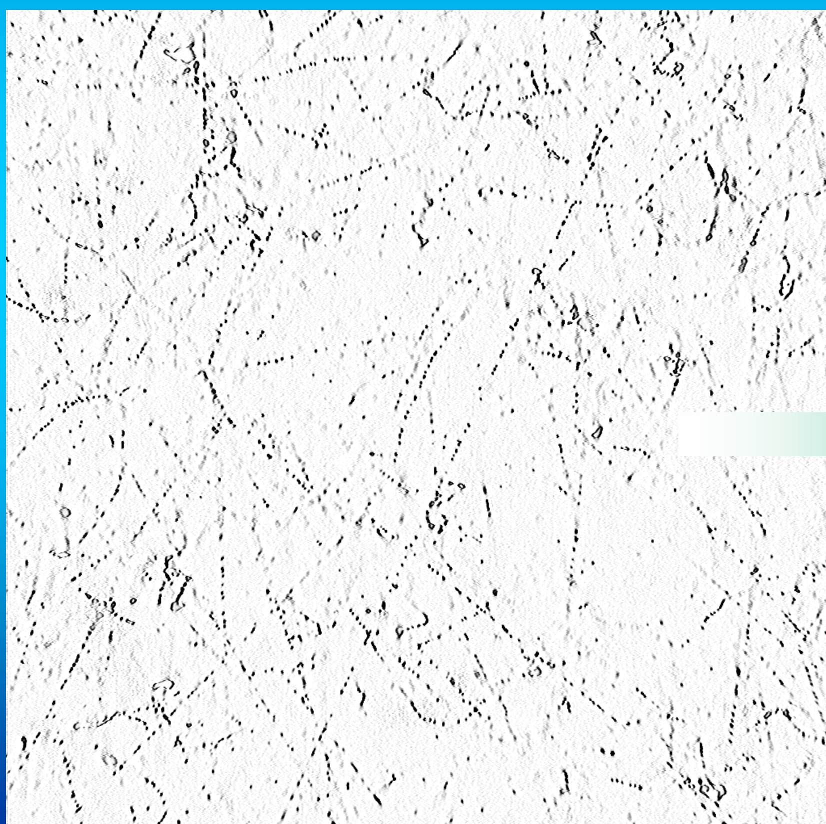
200×200 μm^2 in a CHORUS Target Sheet

Genesis filters on the fly

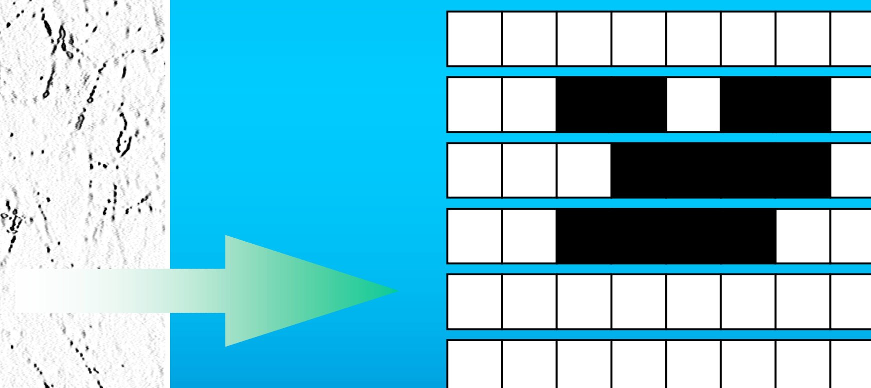
Basic Ideas

After filtering, a threshold is applied to the filter response, and pixels are marked as "black" or "white"

Cluster recognition proceeds on the host PC CPU



200×200 μm^2 in a CHORUS Target Sheet

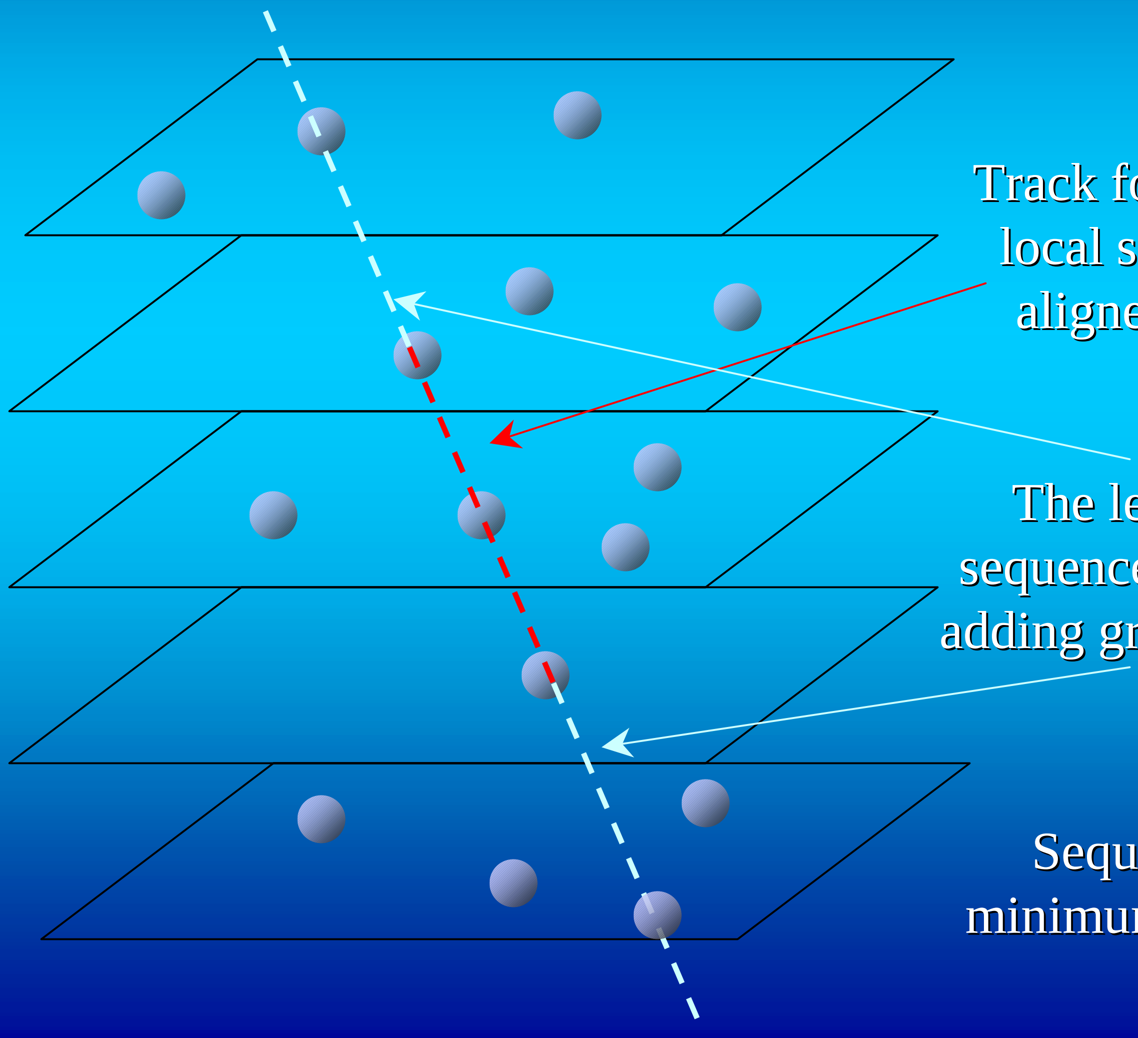


Horizontal black segments are assembled to form black clusters

Area and shape parameters are retained

Basic Ideas

Tracking selects grains with appropriate shape and size and searches for 3D sequences of aligned grains



Track formation starts when local sequences of 3 well aligned grains are found

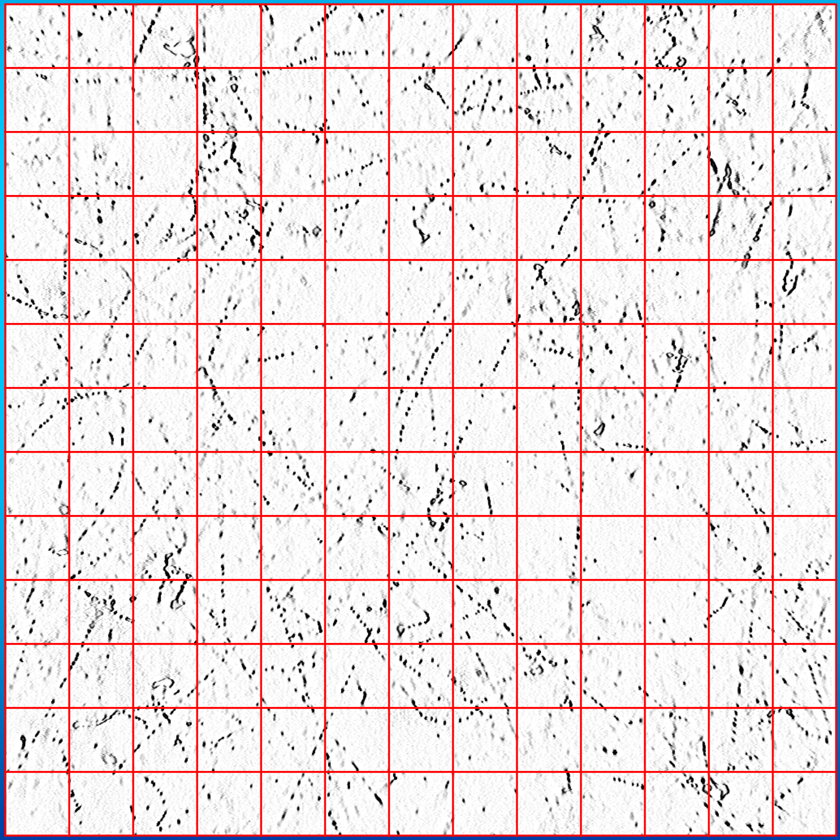
The length of the startup sequence is then increased by adding grains from other layers

Sequences that reach a minimum length are retained

Basic Ideas

In order to reduce the combinatorial complexity, each 2D image is divided in a matrix of cells

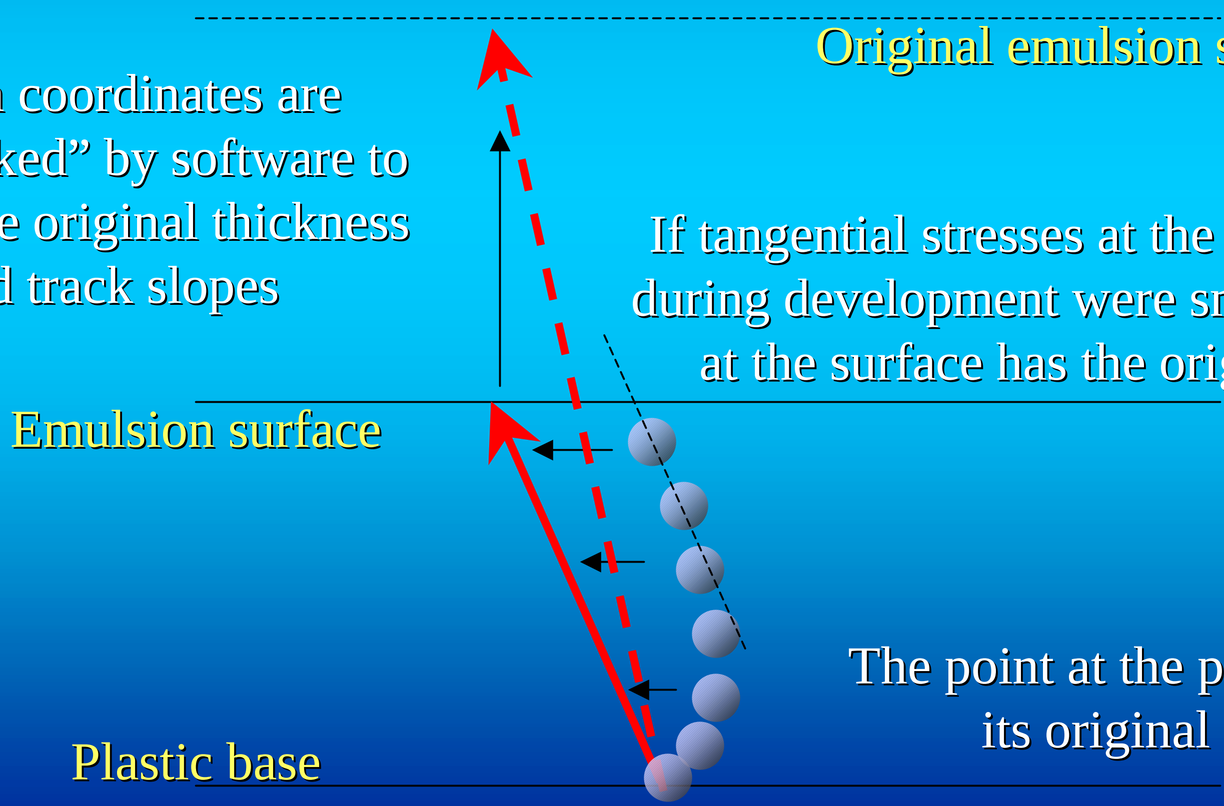
Tracking searches are performed using only a few cells at each iteration rather than the full image:
a search shortcut that causes no efficiency downgrading



Basic Ideas

Because of emulsion distortion during development, the tracks found by the tracking module are seldom straight

Moreover, the emulsion is usually shrinked w.r.t. its original thickness at exposure time



Depth coordinates are “unshrinked” by software to reproduce original thickness and track slopes

If tangential stresses at the outer surface during development were small, the slope at the surface has the original value

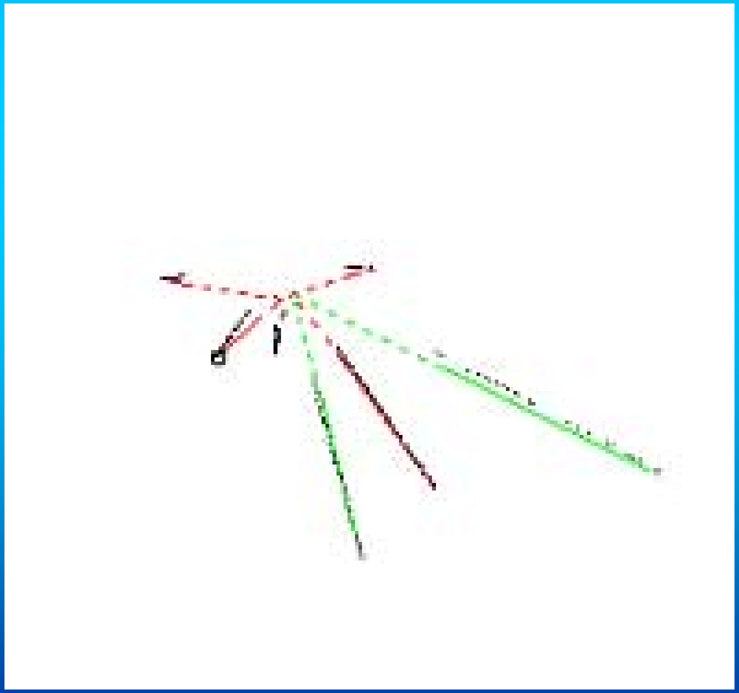
The point at the plastic base has its original position

Basic Ideas

Automatic decay/interaction vertex recognition

Since SySal reconstructs all tracks in a FOV, it is possible to check whether two or more trajectories cross at a common 3D point

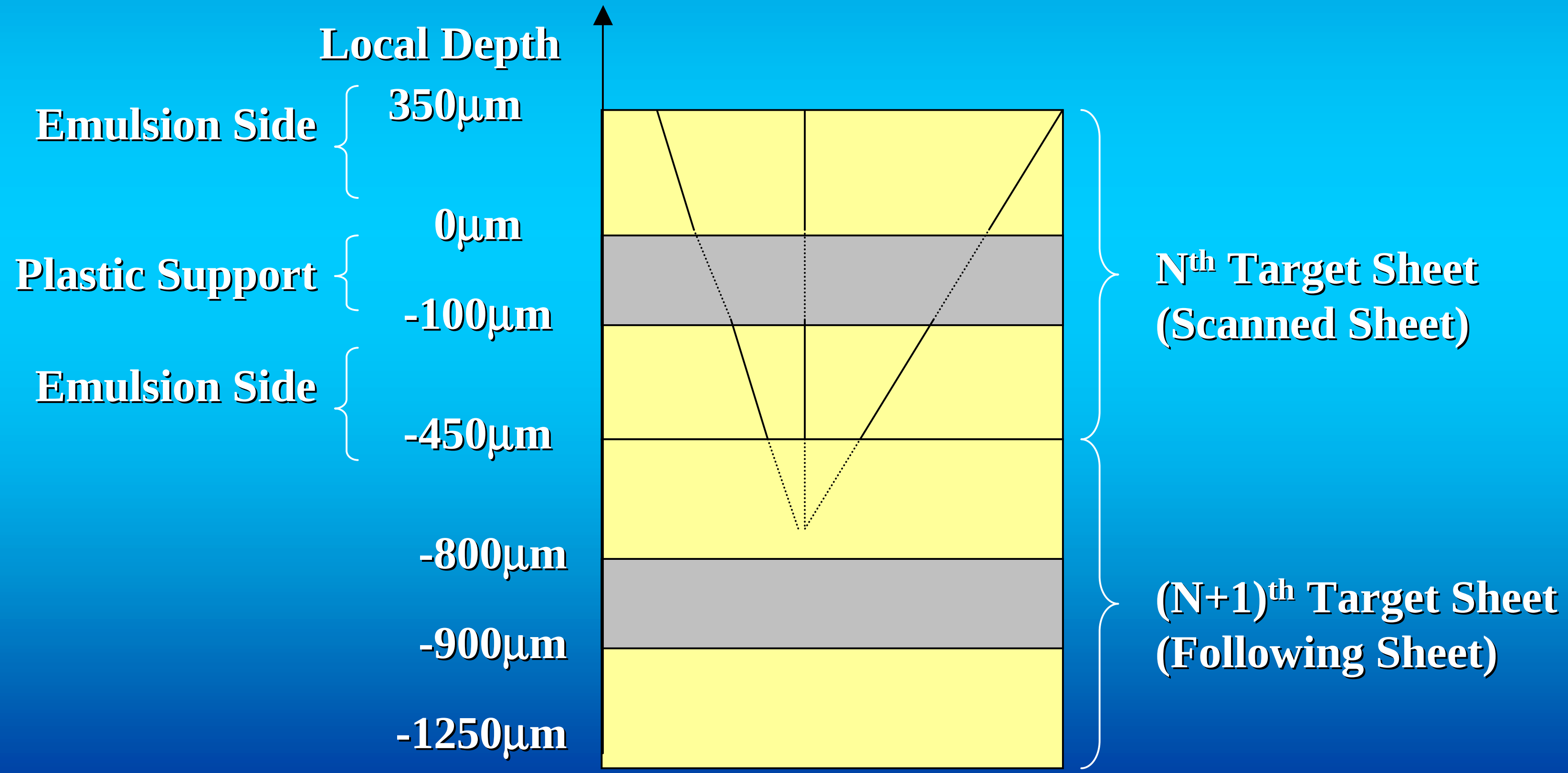
Track crossing measurement is very precise because 3D grain positions are known



Basic Ideas

Automatic decay/interaction vertex recognition

It is often possible to detect a vertex located in another plate



Implementation

Stage: Nikon, MICOS

Motors: VEXTAStep RFK

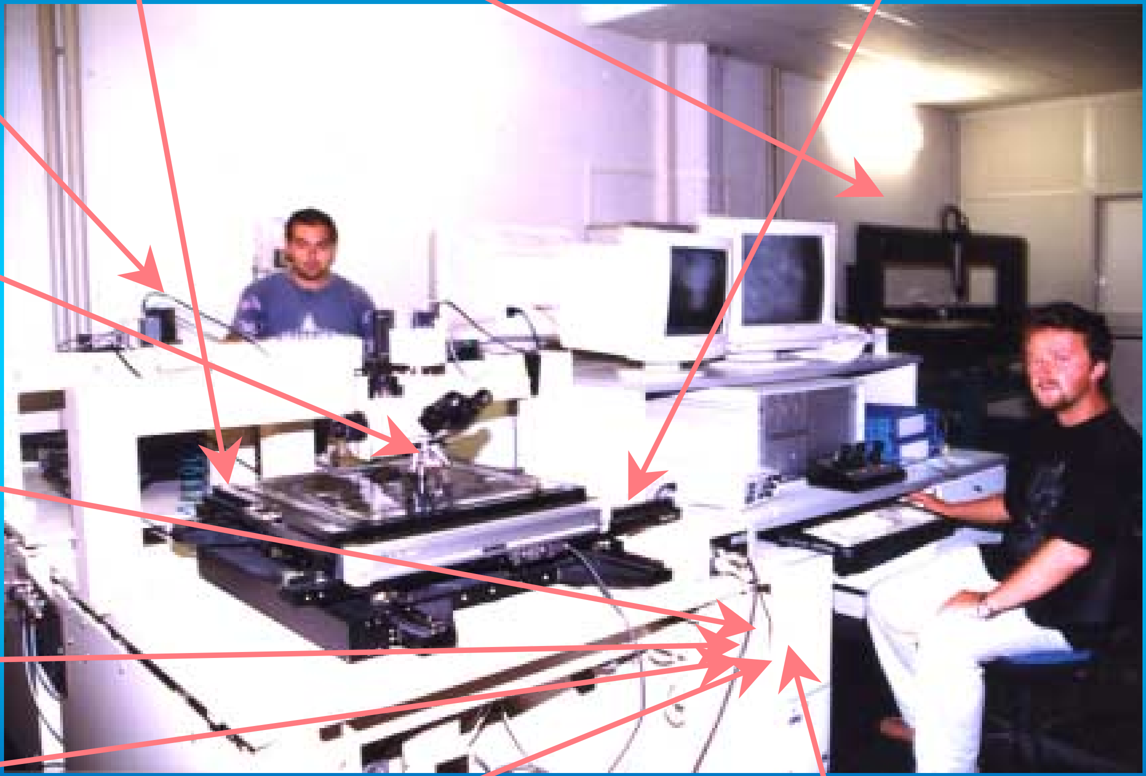
Camera: Hitachi KP-F110

Objective:
Tiyoda 50×, Leitz 22×

Host PC:
Pentium I – II – III – IV

Operating System:
Windows NT – 2000 – XP

DAQ Software: SySal 1.0

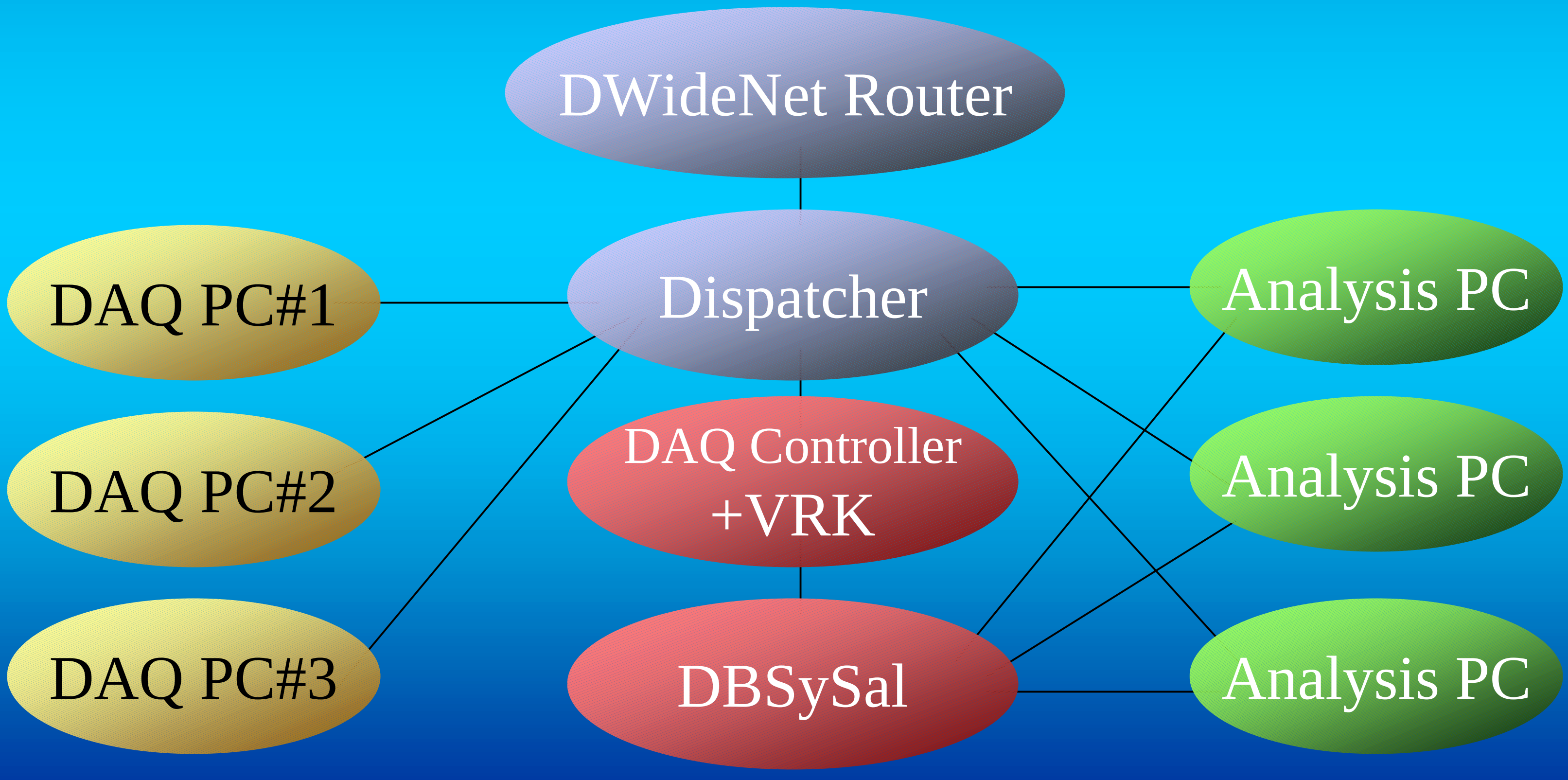


Vision Processor: Matrox Genesis

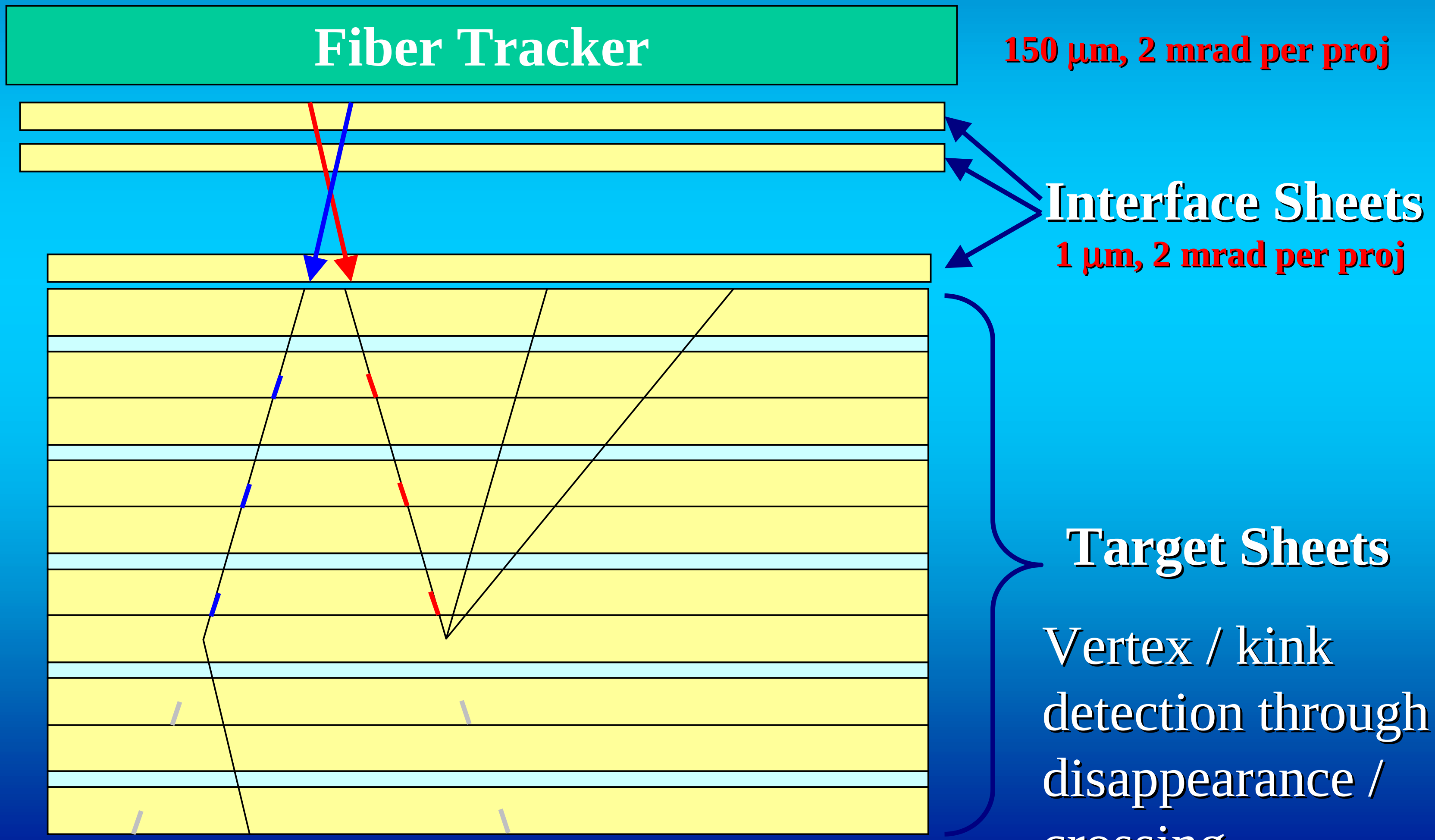
Motor Controller: National Instruments FlexMotion

SySal DAQ Clusters

SySal is seldom implemented as a single stand-alone DAQ machine, because of course this would limit the number of tasks one could perform with a certain data set



SySal in CHORUS: Scan-back + Total Scan (next talk)



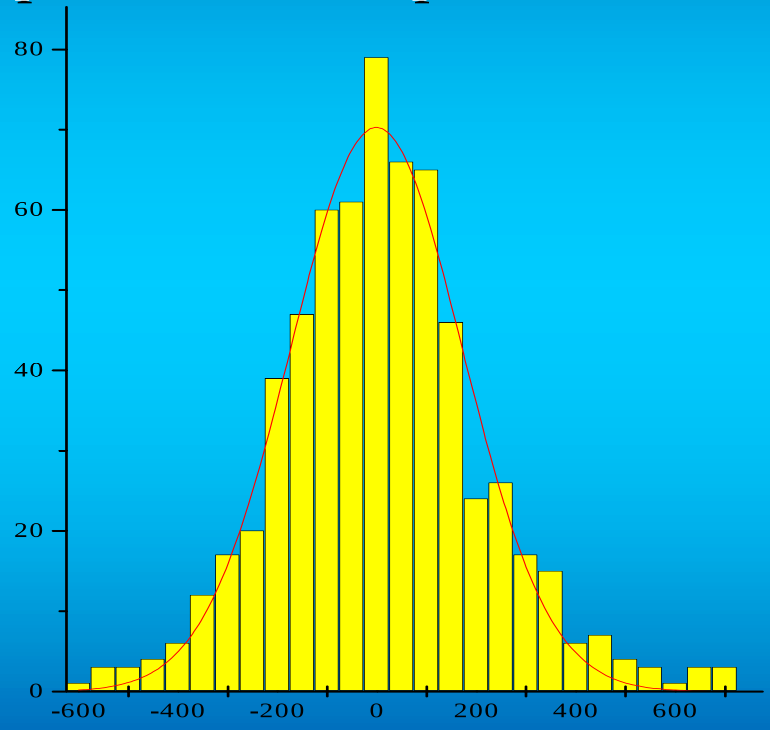
Vertex / kink detection through disappearance / crossing

SySal at Work

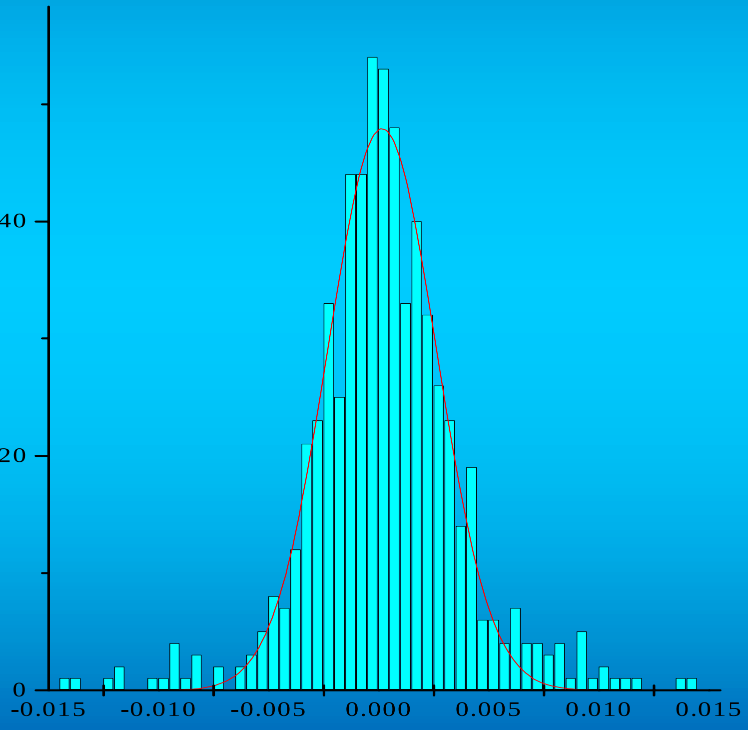
SySal in CHORUS: Scan-back on interface sheets (CS233T)

Efficiency on μ's: ~90% (also includes TT fakes)

Speed: 500÷700 predictions / day



Z Found – Z Pred.
μ=-1.2 μm σ=173. 2 μm

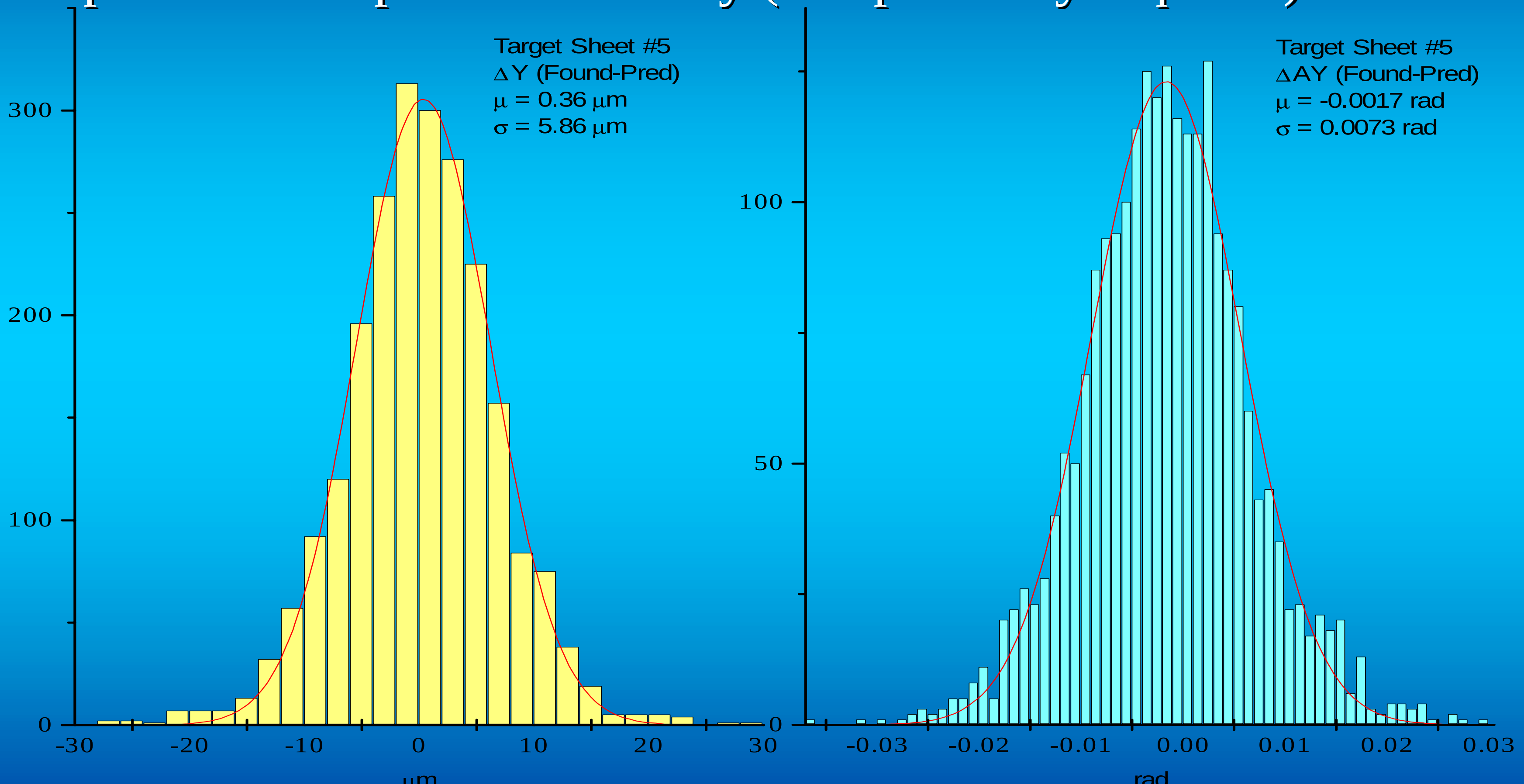


AZ Found – AZ Pred.
μ=0.0002 rad σ=0.0025 rad

SySal at Work

SySal in CHORUS: Scan-back on target sheets

Speed: ~4000 predictions / day (one pass only required)



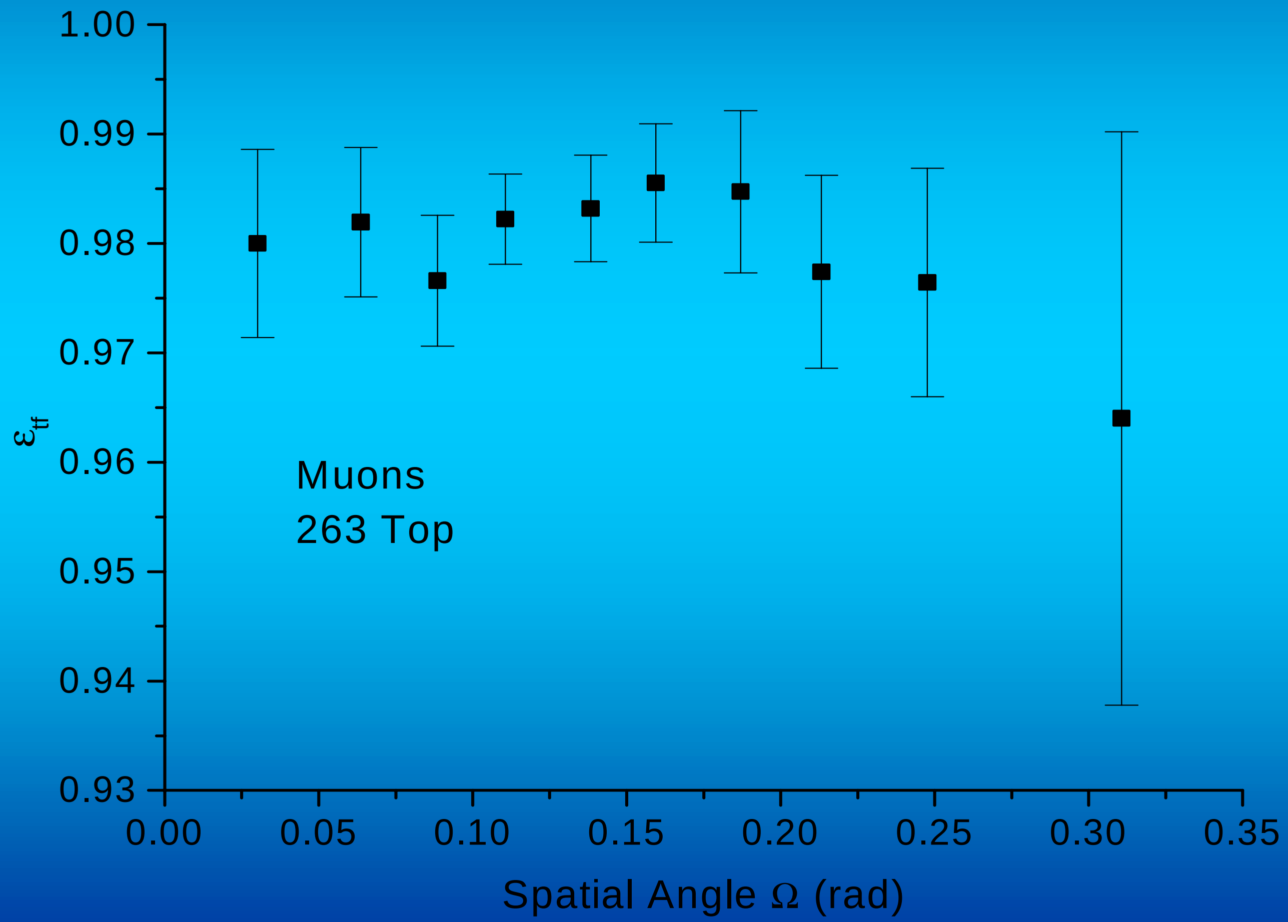
Y Found – Y Pred.
μ=0.36 μm σ=5.86 μm

AY Found – AY Pred.
μ=-0.0017 rad σ=0.0073 rad

SySal at Work

SySal in CHORUS: Scan-back on target sheets

Finding efficiency on Target Sheets



SySal at Work

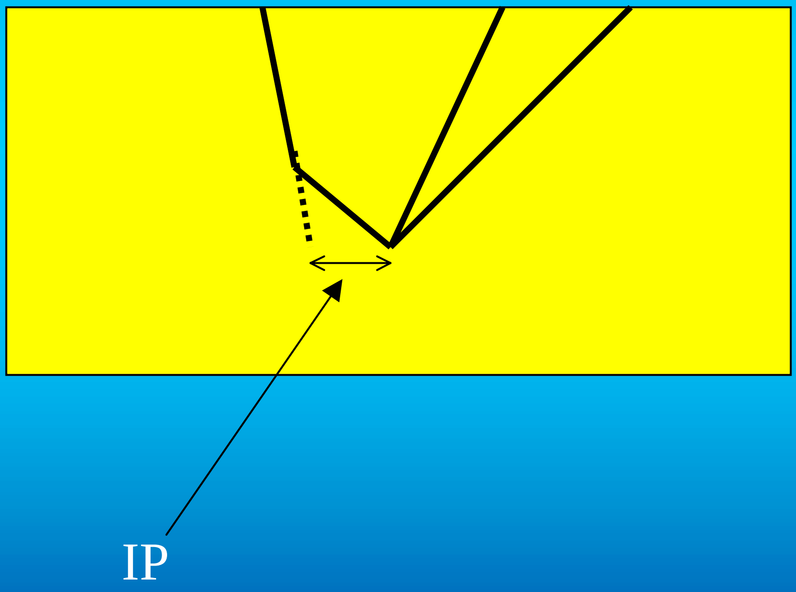
The DAQ Controller runs VRK on data files to obtain automatic analysis before putting them into the scanning DB (DBSySal)

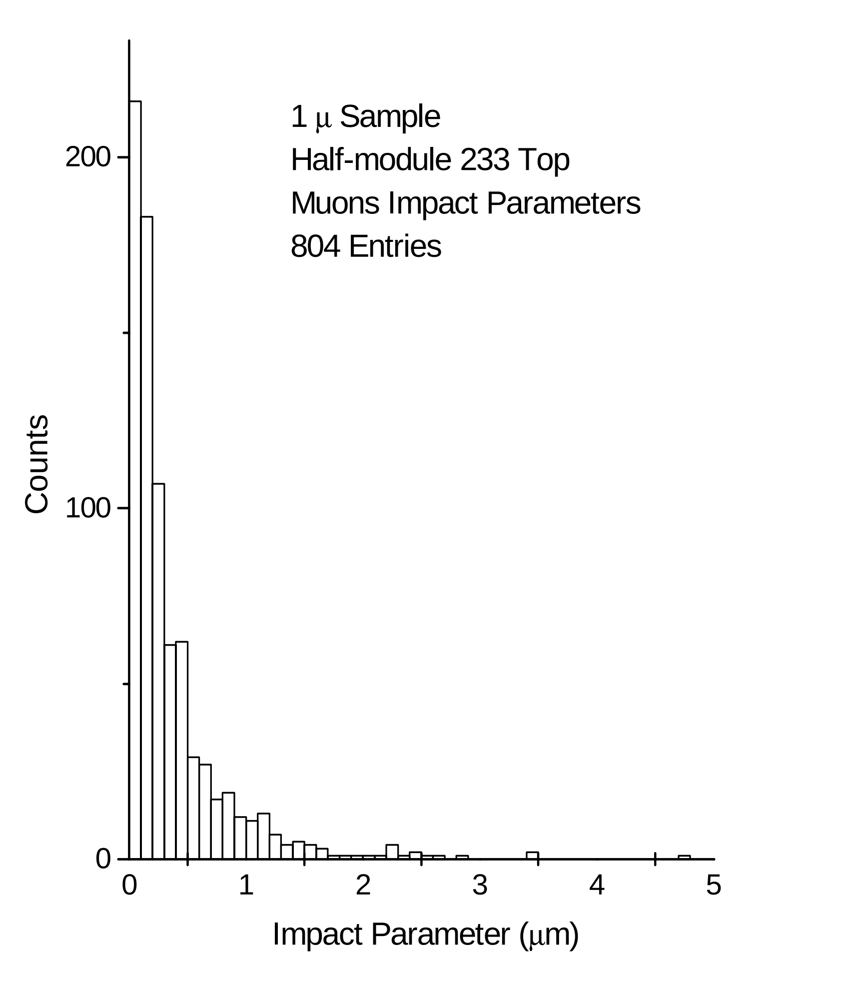
The VRK (Vertex Reconstruction Kit) plug-in is able to reconstruct and measure interaction vertices while the scanning batch is in progress

When a vertex / kink alarm is issued, a request to take a tomographic sequence of photos of the vertex zone is scheduled into the scanning batch

Output: ≈ 5 k Events (up to now) + a neutrino interaction image library

Precision of vertex reconstruction: the Impact Parameter method

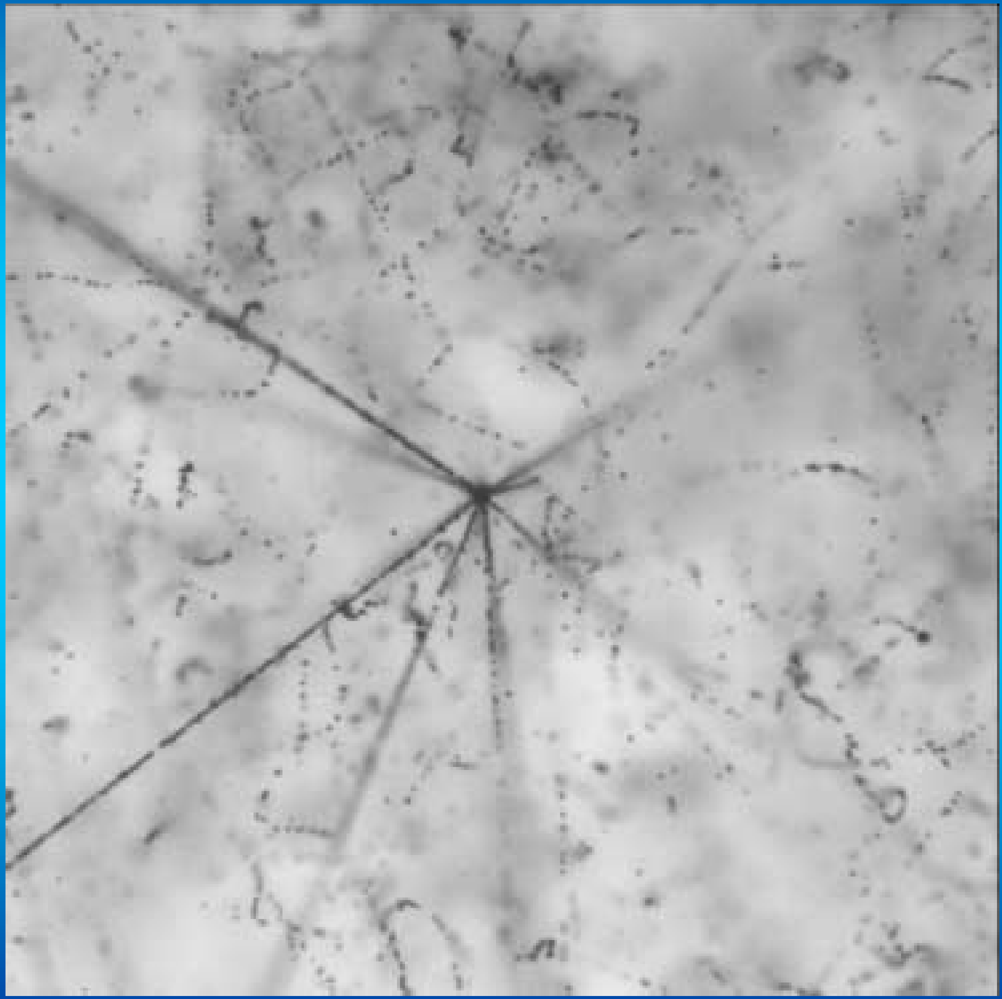




SySal at Work

We have ≈ 2 k 3D Images of neutrino interactions

Manual checks are possible without physically being at the microscope



SySal at Work

SySal in CHORUS: also non-oscillation physics

Charm hunting

Special events (e.g. Charm production by anti-ν)

Search for hyperfragments / superfragments (new – listen to talk on black tracks!)

Momentum measurement through multiple scattering (dedicated talk)

SySal at Work

SySal in OPERA: Total Scan (next talk) for test exposures

Main result up to now:
Momentum measurement through multiple scattering
(dedicated talk)