Precision Measurement of the fibres of the ALFA-Detector

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Outline

1. Motivation
2. Precision Measurement
3. Measurement results
4. Automation
5. Summary

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ALFA Overview

What is ALFA?

- Absolute Luminosity For ATLAS
- Forward Detectors at ∼240m distance
- Measure elastic scattering at very small angles
  - ⇒ Absolute Luminosity at IP of ATLAS

Detector Layout

- ”Roman Pots” very close to the LHC Beam (mm-range)
- Scintillating fibres on 10 metal plates
  - 64 fibres on each side
  - 0.5 x 0.5 mm^2
  - glued to the plate

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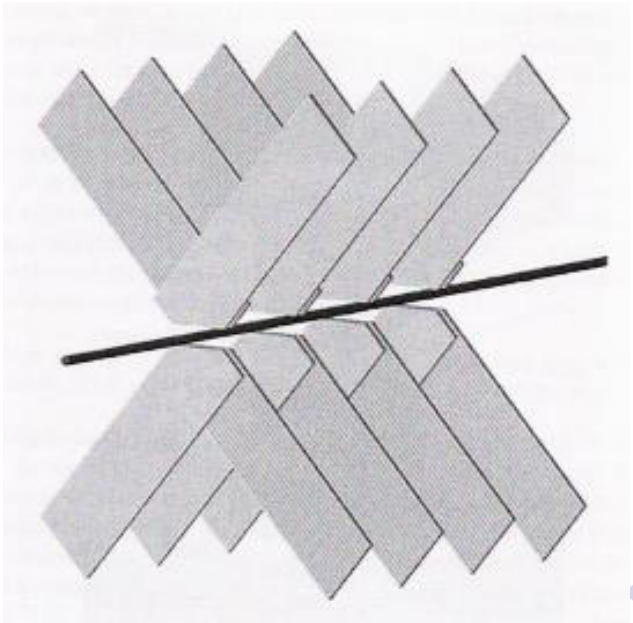
Requirements on ALFA

- Spatial Resolution much smaller than spot size of beam
  - $\Rightarrow$ a resolution of $30\mu m$ is adequate
  - But: precision of gluing $\simeq 100\mu m$!
- $\Rightarrow$ Measure the ”exact” position of the fibres to achieve a precision of $\leq 30\mu m$



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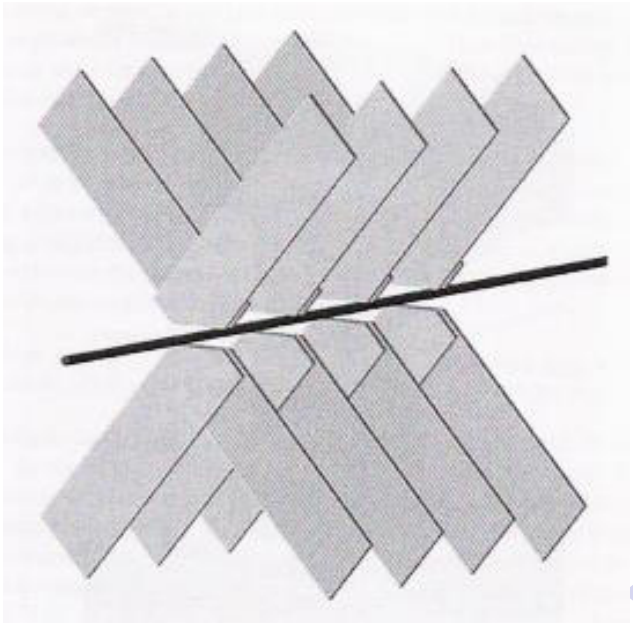

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- Spatial Resolution much smaller than spot size of beam
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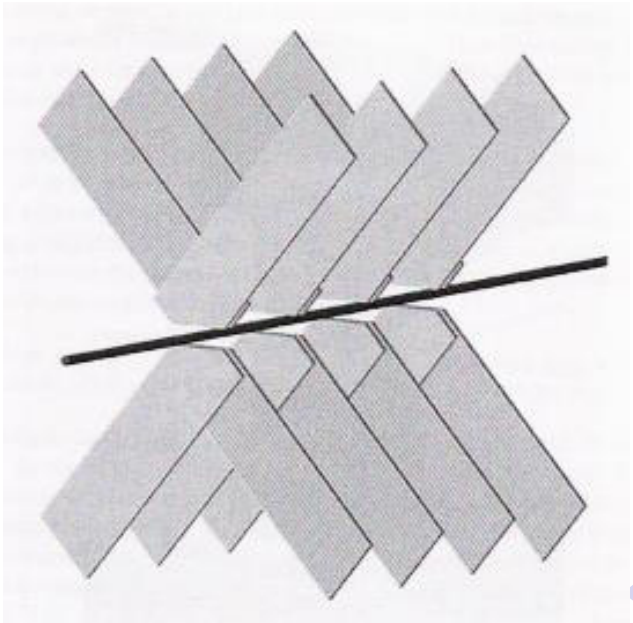

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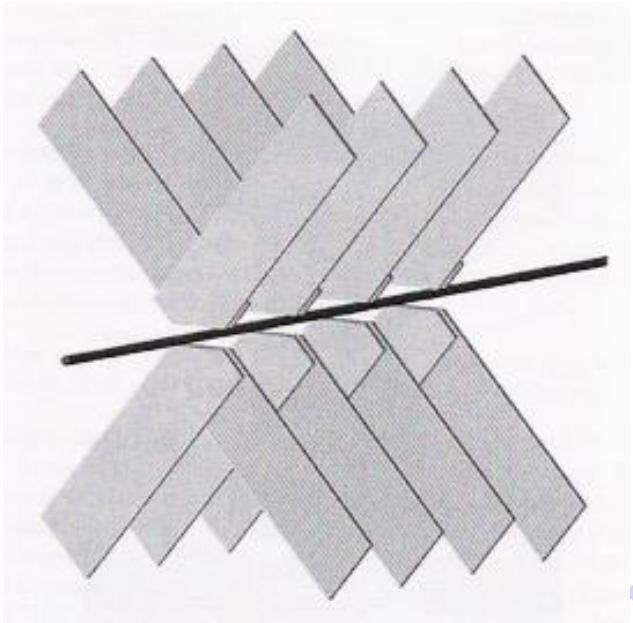

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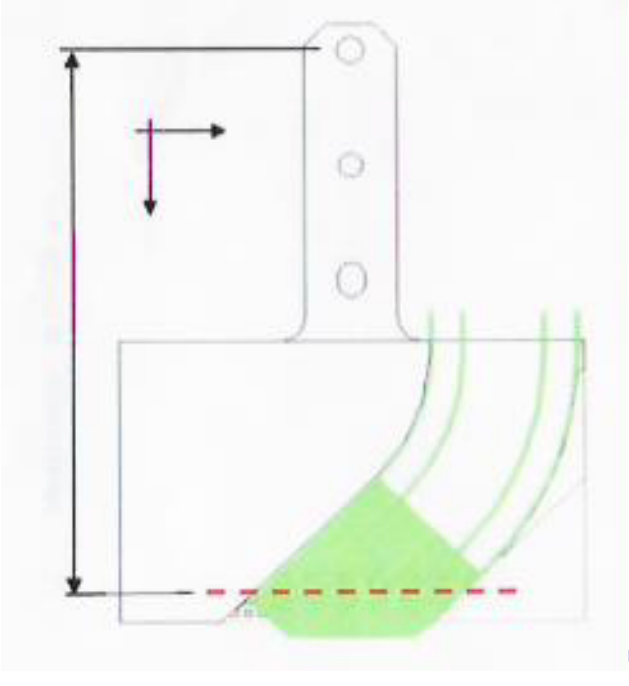
The measurement

Pre-considerations

- Get a linear equation for every fibre:
  - Measure the offset of the fibres in x-direction
- Assume constant width of the fibres:
  - Measure the middle of the gaps between the fibres



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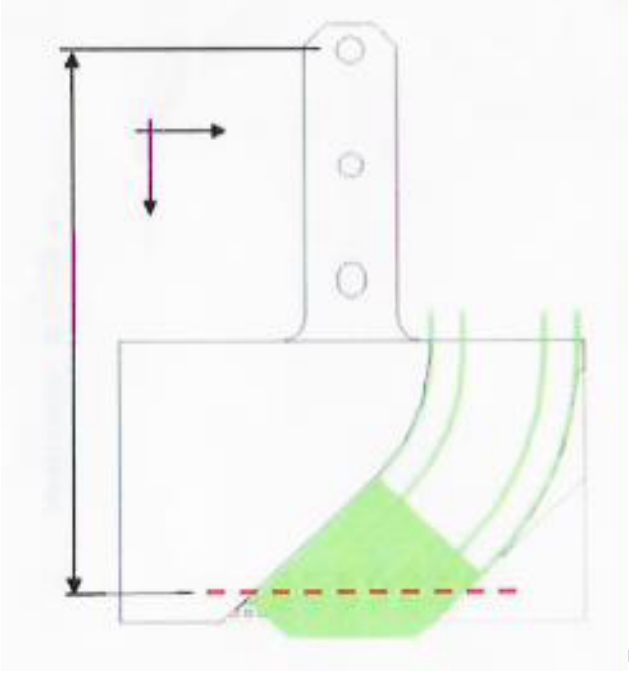

Equipment

The measuring equipment

- Air damped table to compensate vibration
- Monocular microscope, movable in x-, y- and z-direction (precision $\simeq 2\mu m$)
- CCD-Camera on microscope (5 megapixels)
- Both connected to the PC

The microscope . . .

- . . . has 12x zoom (upper side), a 10x zoom (lower side) and a variable zoom (0.58x-7x) in the middle
- . . . can be driven by Hand (Joystick) or by the PC

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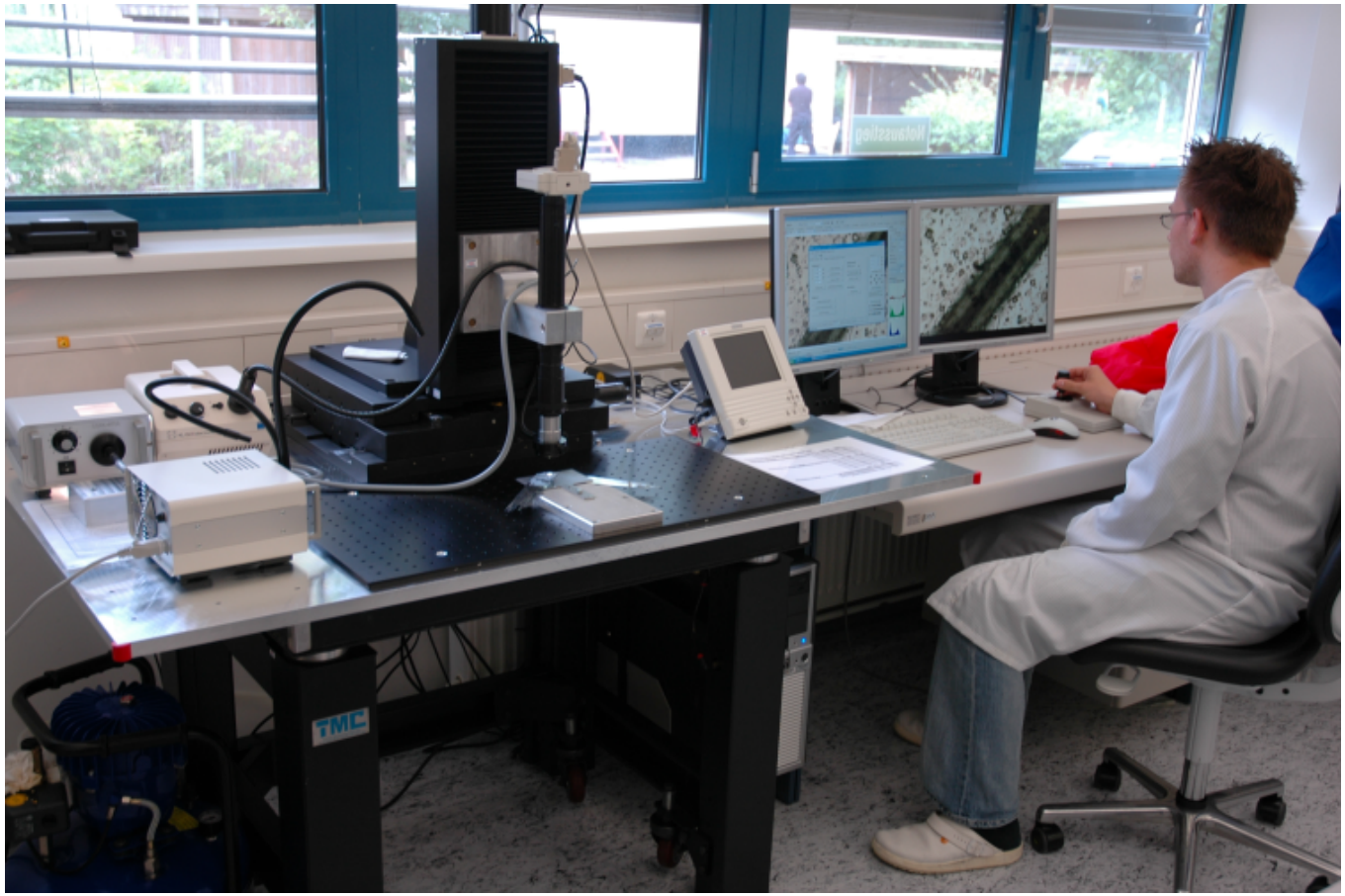

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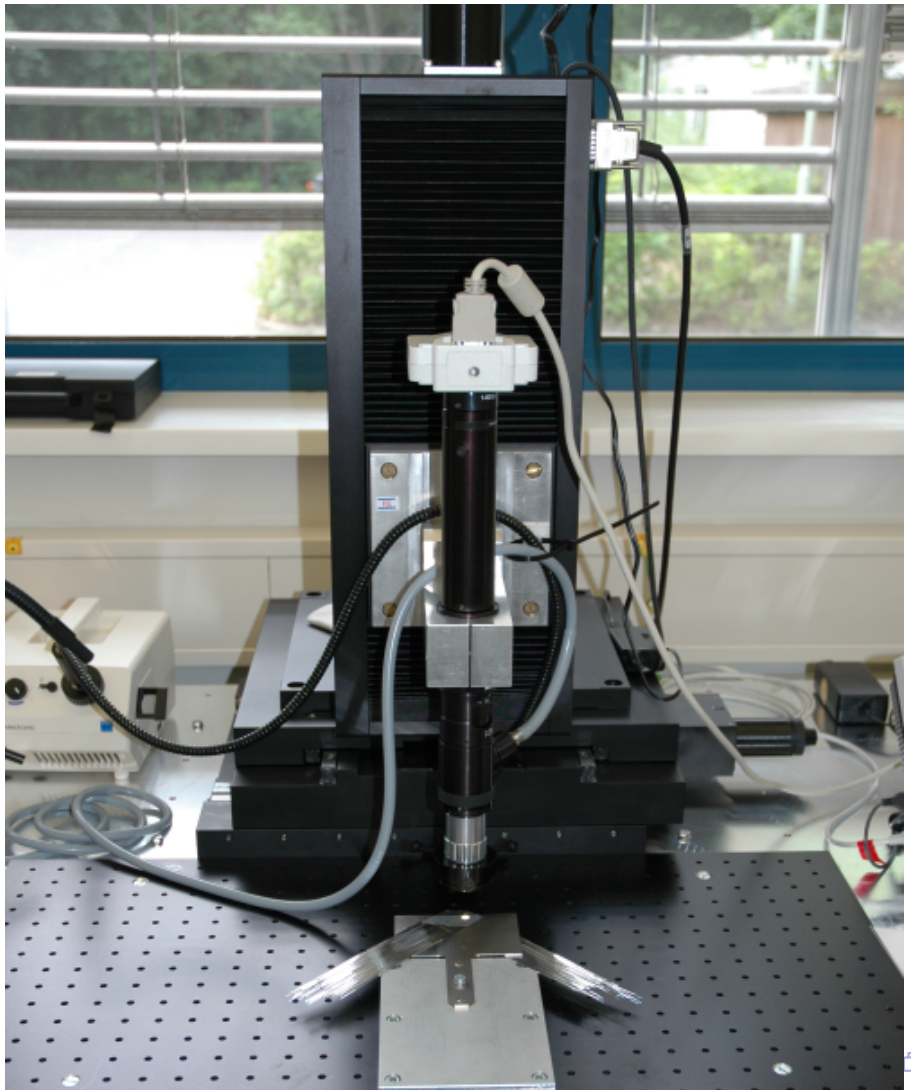

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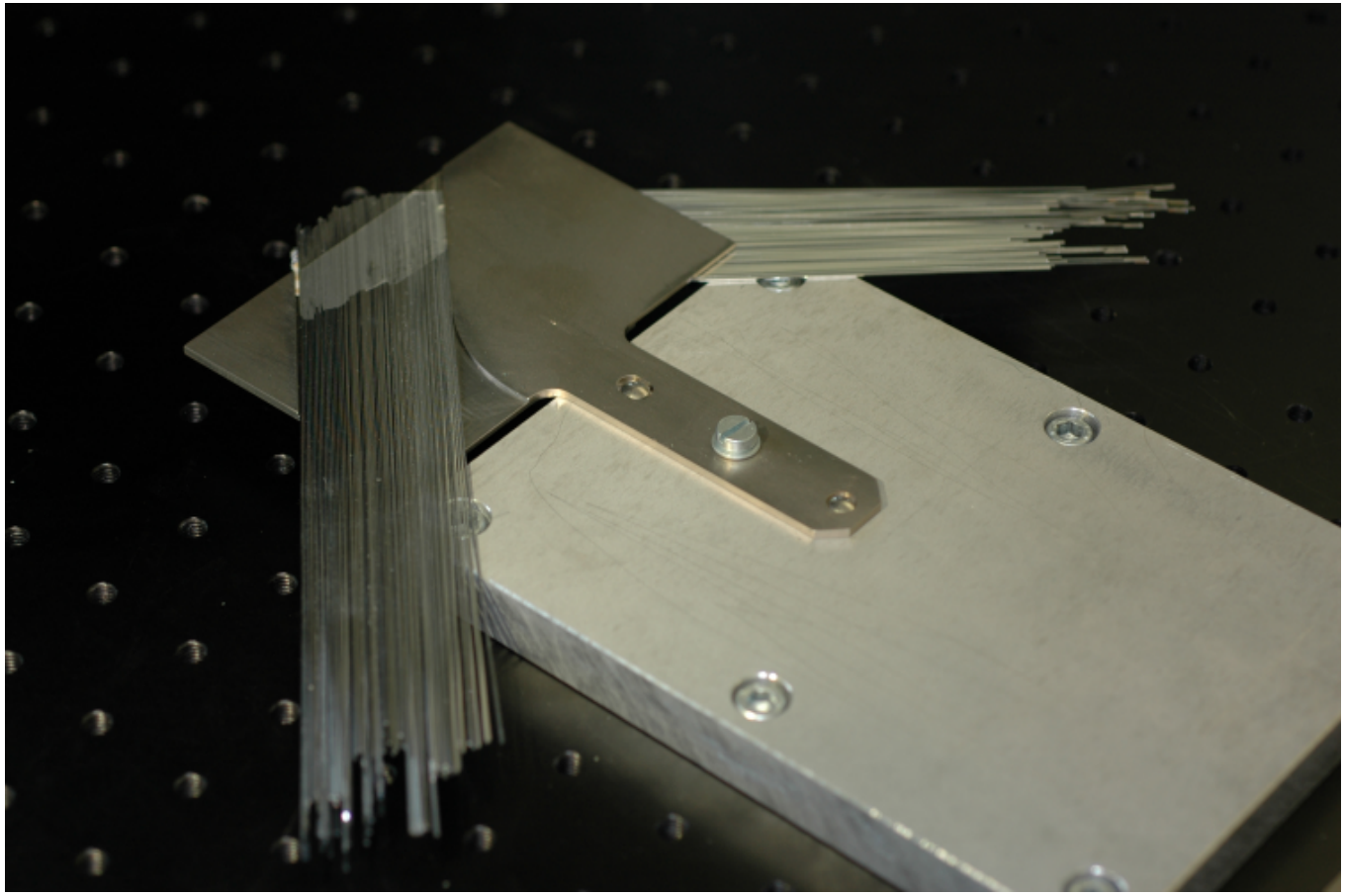

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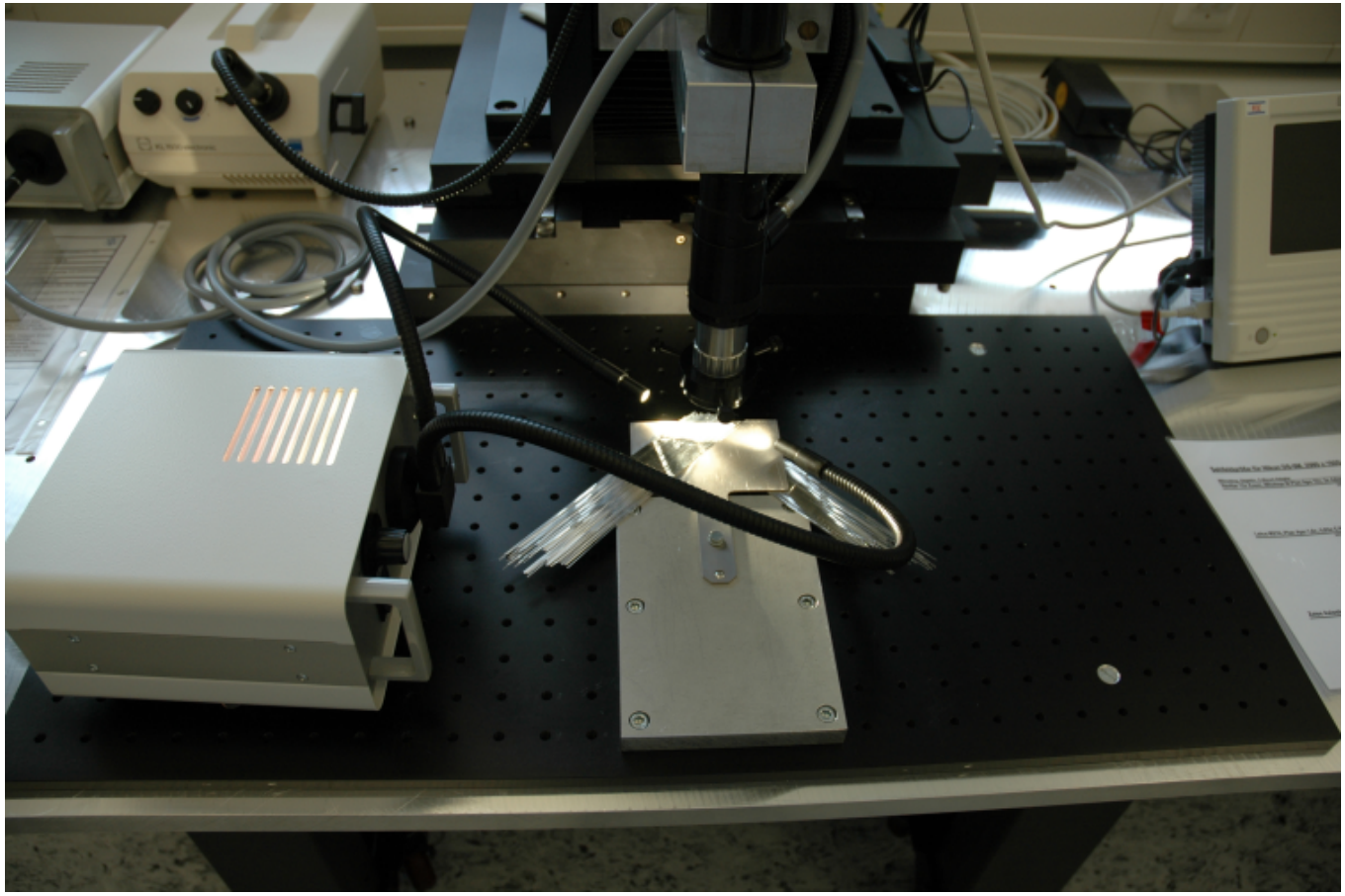

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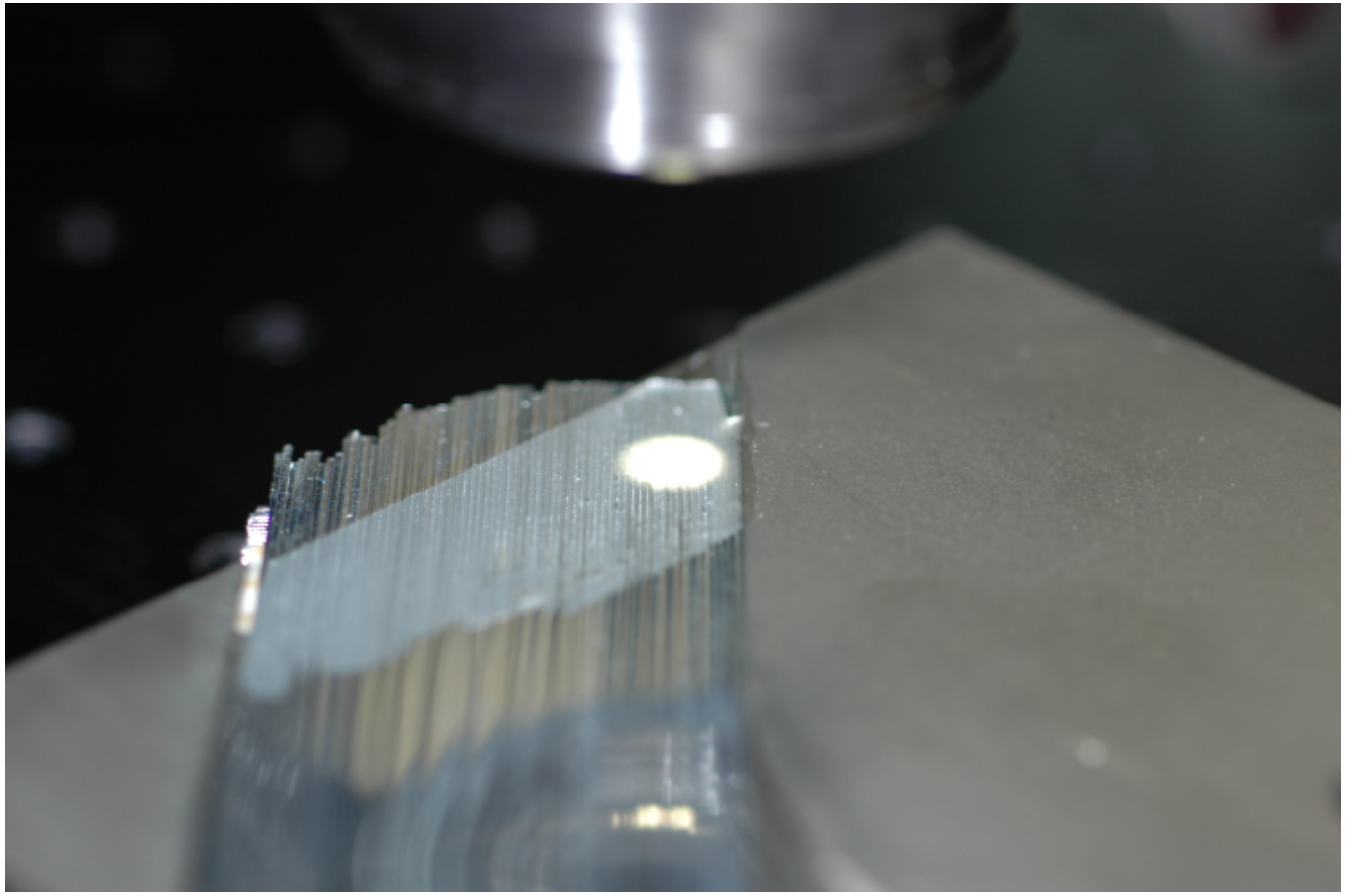

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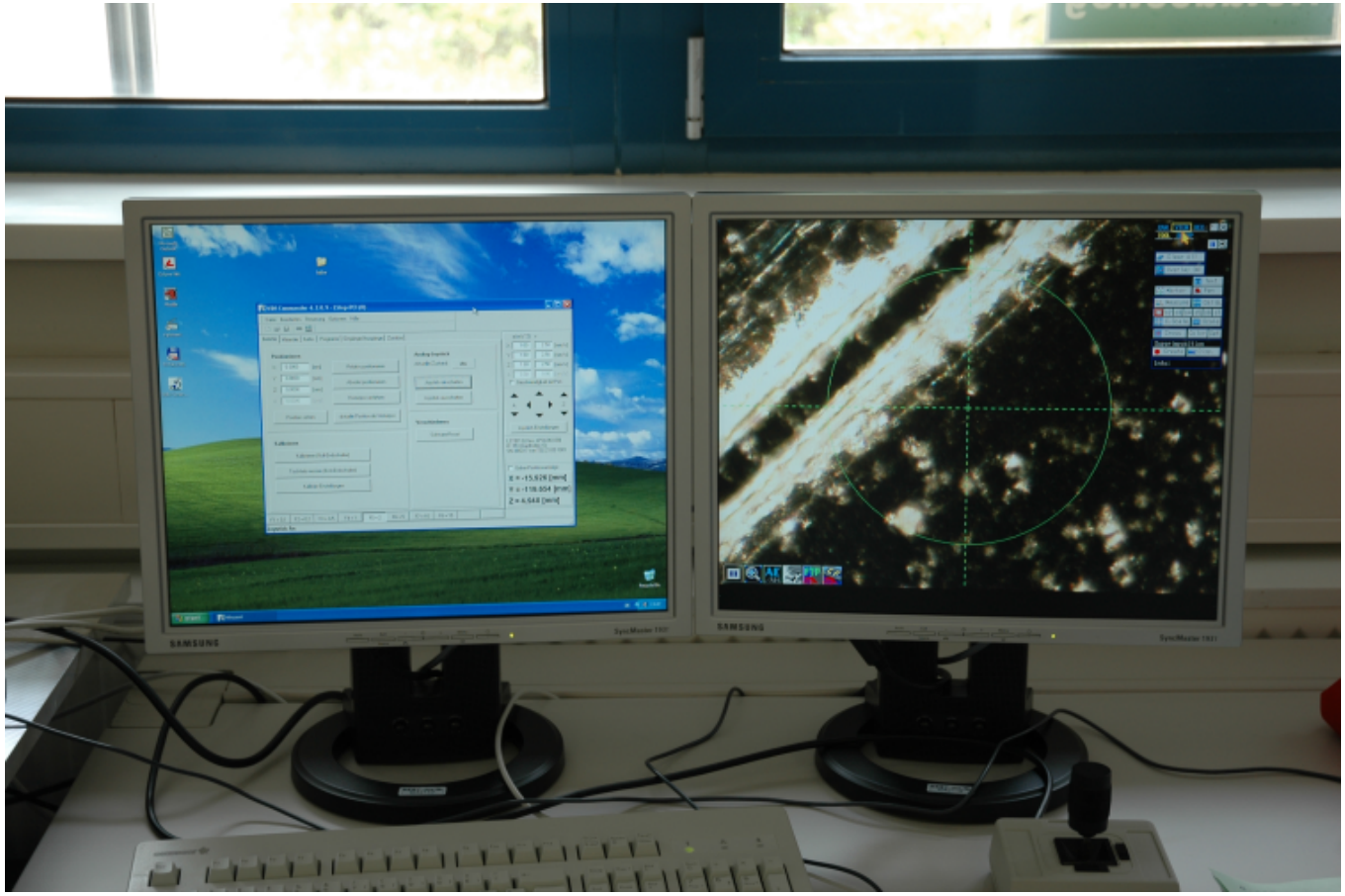
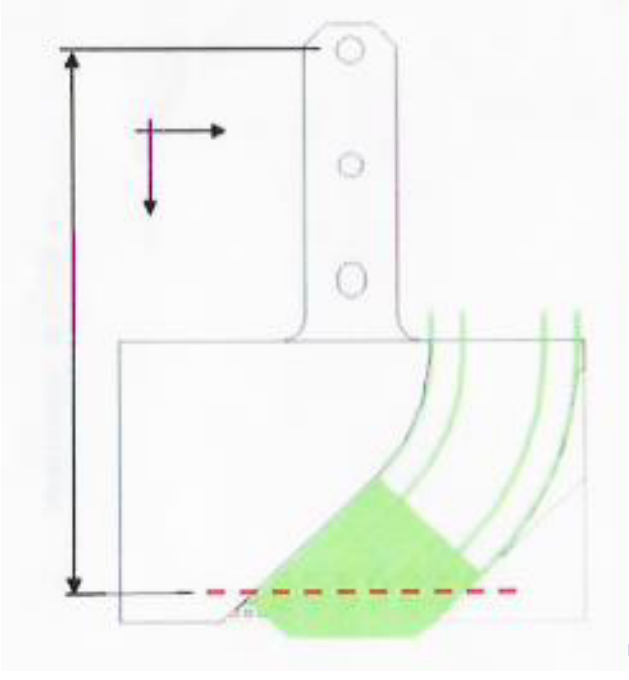


The measurement

So far: manually

- Define a coordinate system:
  - Choose upper precision hole as origin
- Manually measure fibre offsets:
  - Use joystick to move to next gap and write down position



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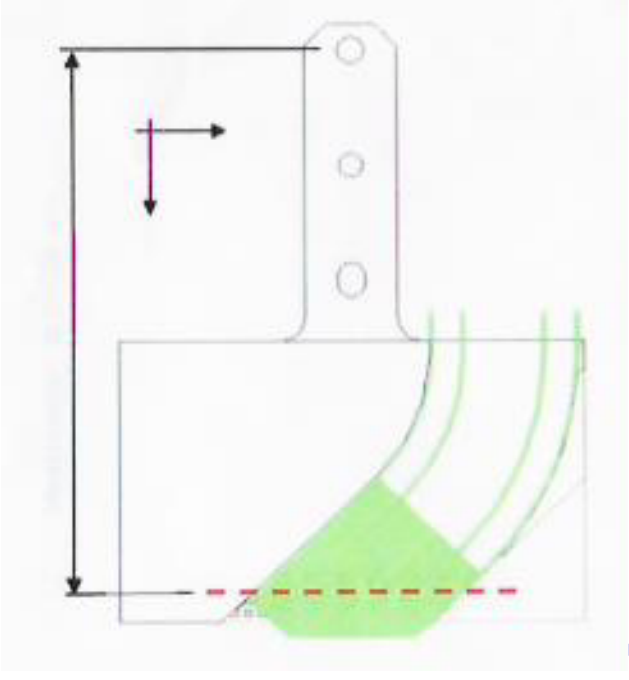

Manual measurement

Disadvantages

- It takes ∼2 hours for one row on each side of one plate
  - ⇒ ∼12 hours for each plate ⇒ ∼120 hours for one detector (10 plates)
- Looking at same position, human eye gets tired after a while → source of error

Advantages

- Human eye itself is ”perfect” measuring machine

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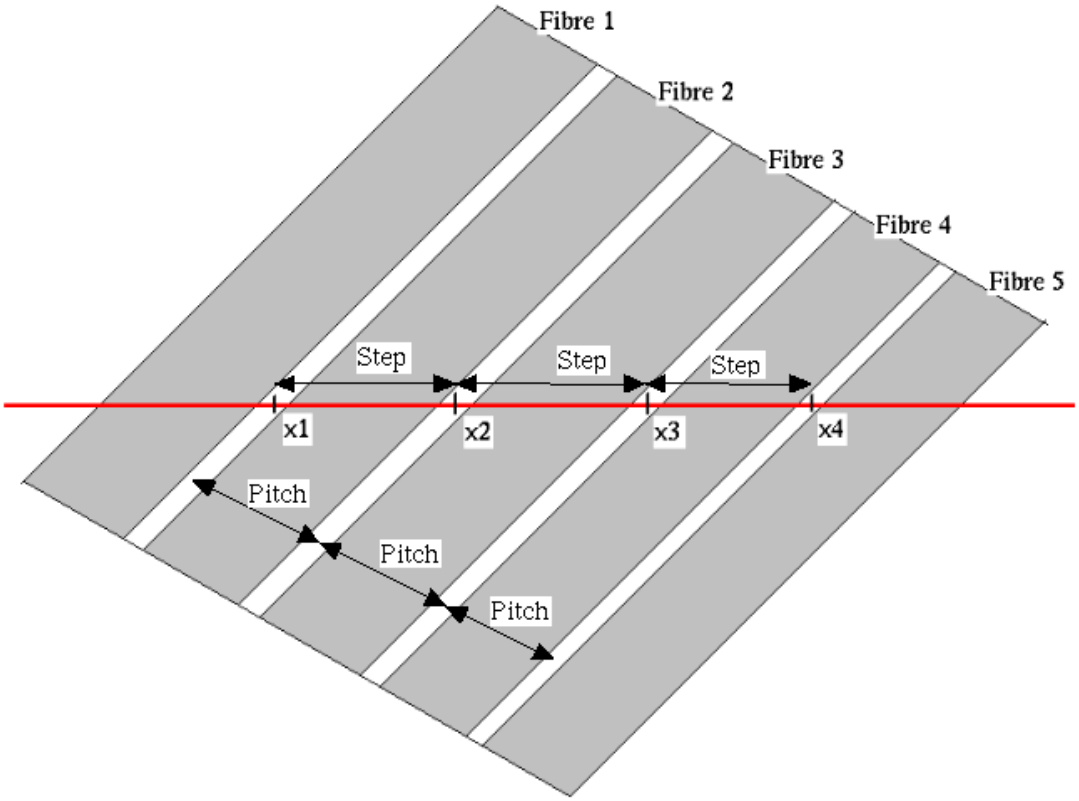
Explanatory sketch



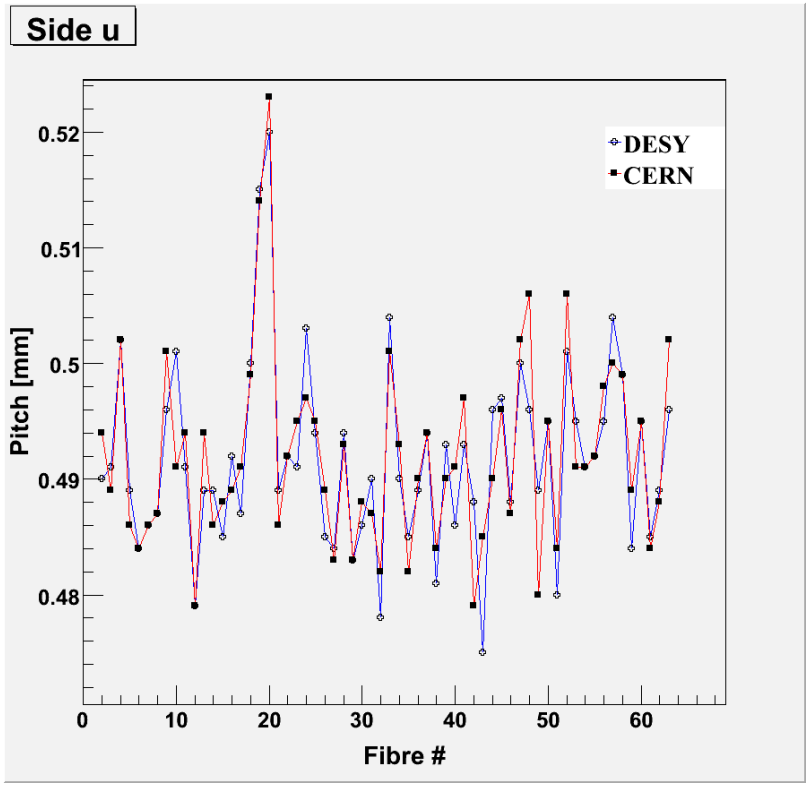
Pitch:

$$\Delta x^{(i)} = \frac{x_{i+1} - x_i}{\sqrt{2}}$$

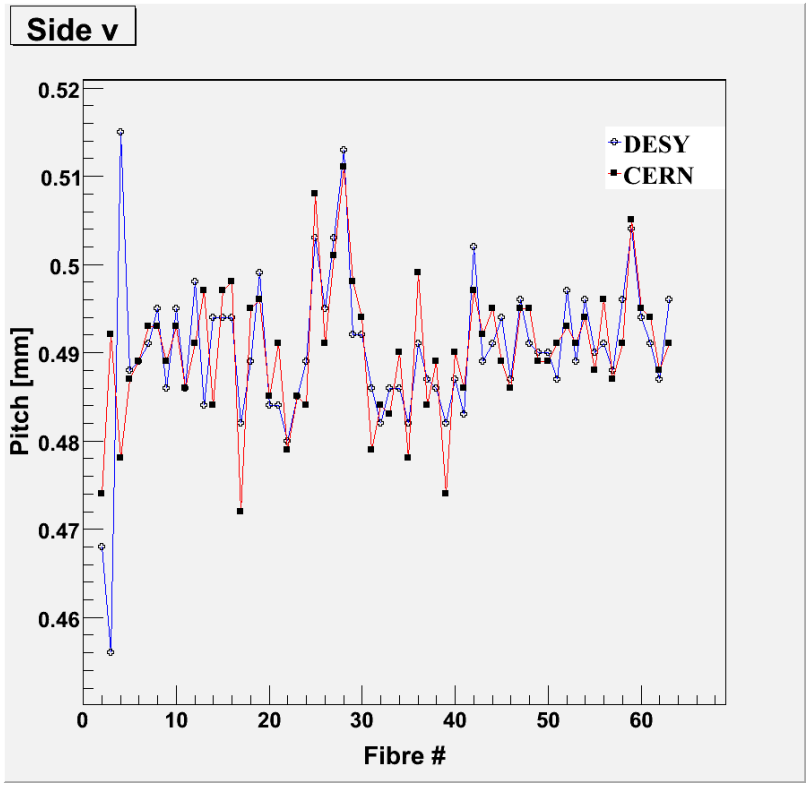
Offset from average:

$$\Delta x^{(i)} = x_i - [x_1 + (Gap\#_i - 1) \cdot step_{avg}]$$

Comparison of pitch measurement

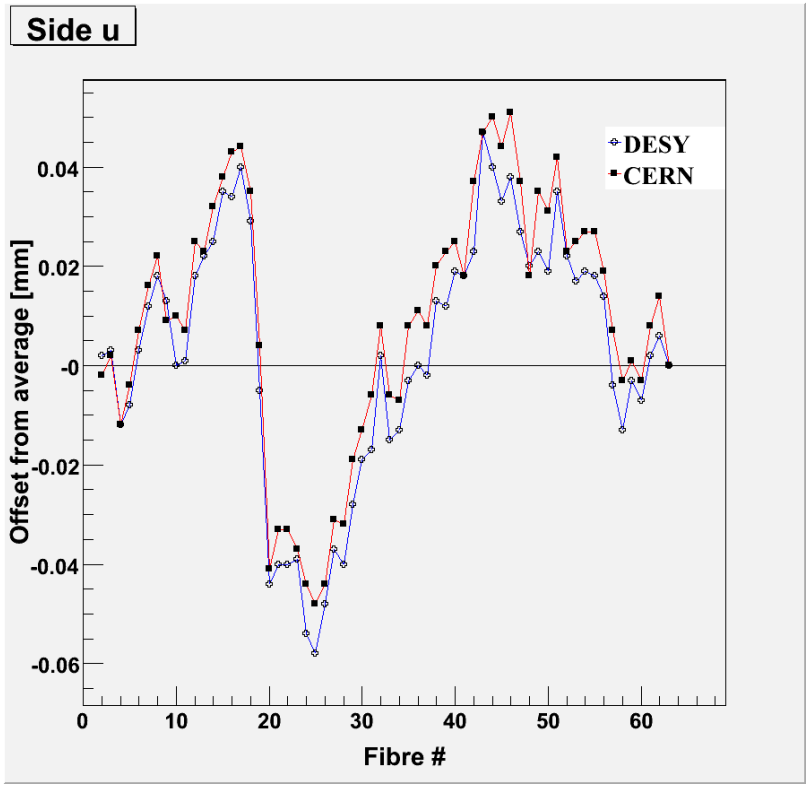


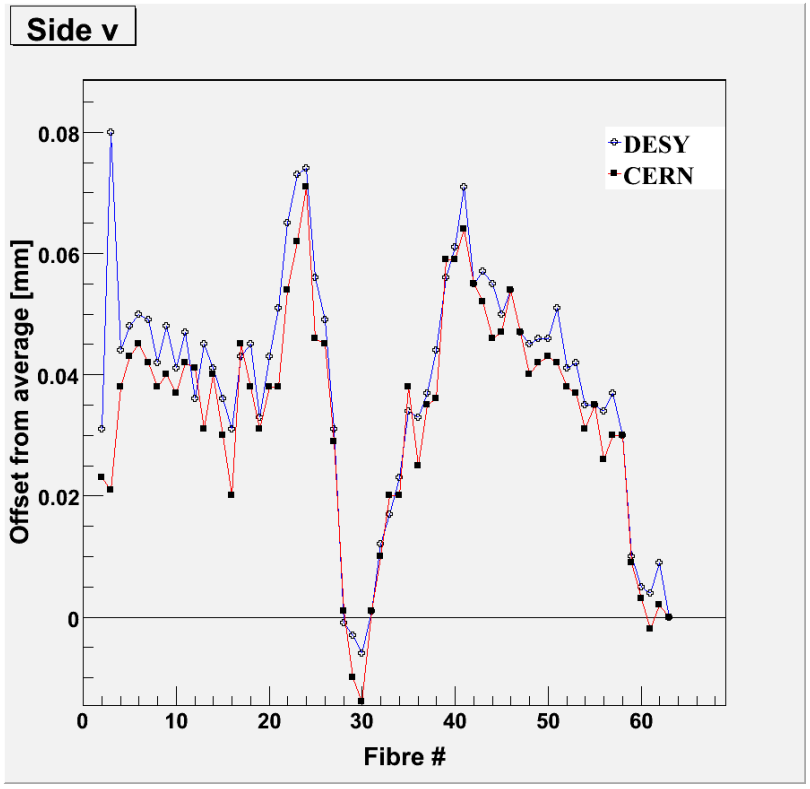
Average pitch: 0.492 mm

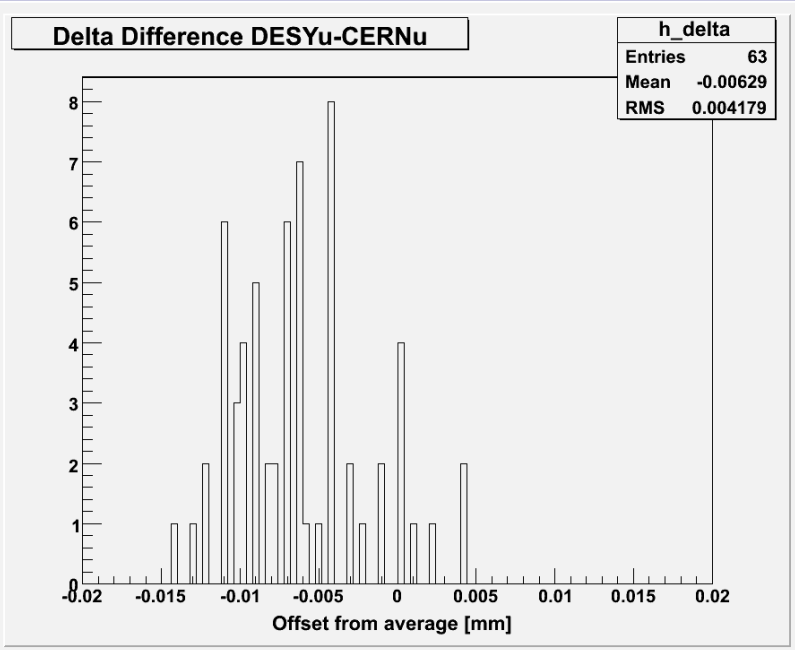


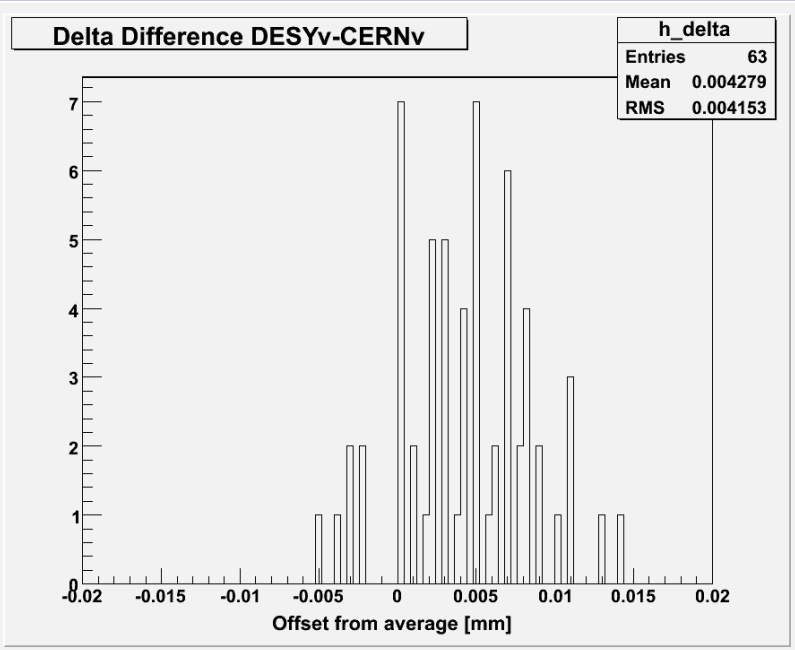
Average pitch: 0.490 mm

Comparison of offset from average






Delta Difference DESYu-CERNu
h_delta
Entries 63
Mean -0.00629
RMS 0.004179
Offset from average [mm]


Delta Difference DESYv-CERNv
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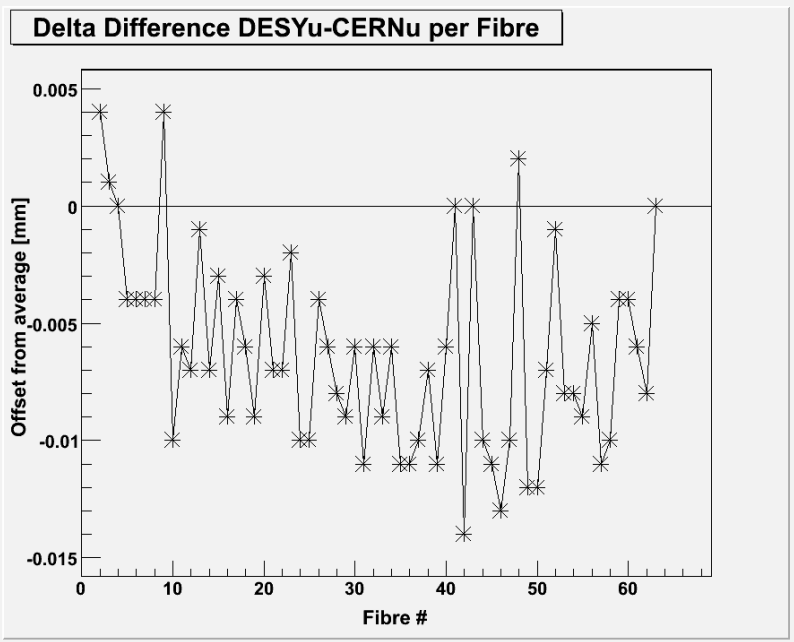
Delta Difference DESYu-CERNu per Fibre
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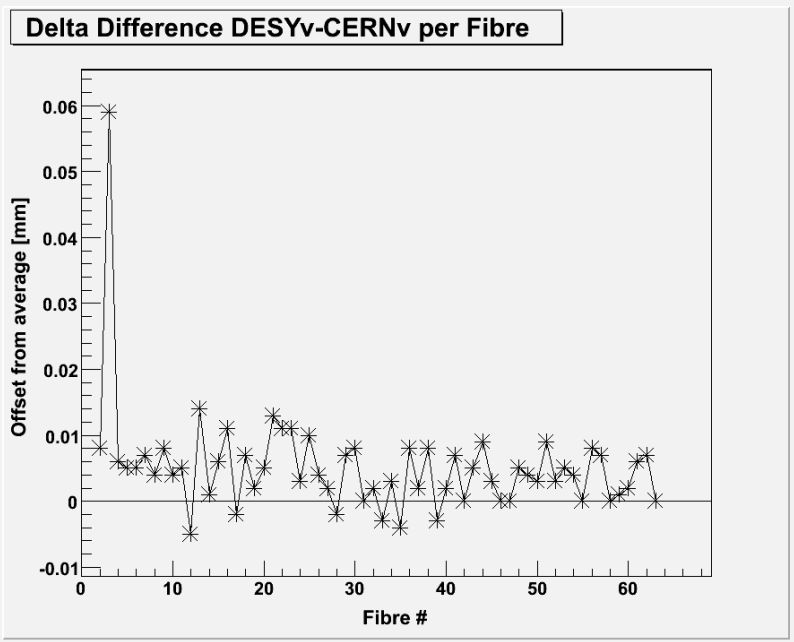
Fibre #


Delta Difference DESYv-CERNv per Fibre
Offset from average [mm]
Fibre #

Results

The DESY measurements . . .

- . . . could reproduce the CERN measurements within a precision of 5 μm
- . . . had a positive offset of $\sim 5\mu m$ on the v-side
- . . . had a negative offset of $\sim 5\mu m$ on the u-side

Possible error sources

- Systematic error
  - would accumulate from fibre to fibre
- ”Wrong” center of coordinate system
  - would lead to constant offset for each fibre

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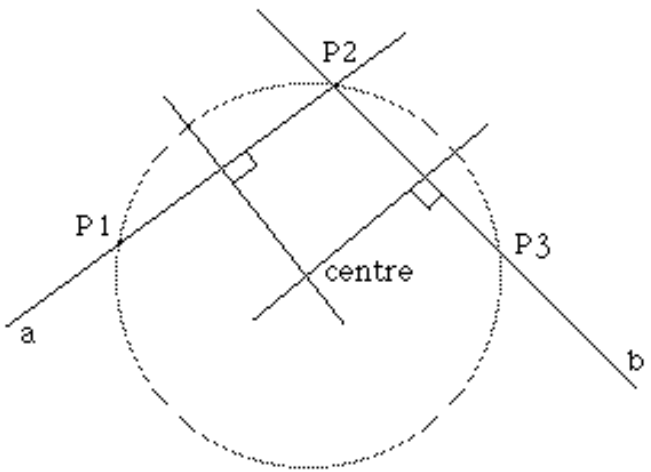
Find center of circle from points on circumference

Two methods

1. 3 points on circumference $\rightarrow$ 2 secants
   - middle-perpendicular of the 2 secants intersect in center of circle
2. $\geq$ 10 points on circumference $\rightarrow$ fit circle
   - center of circle



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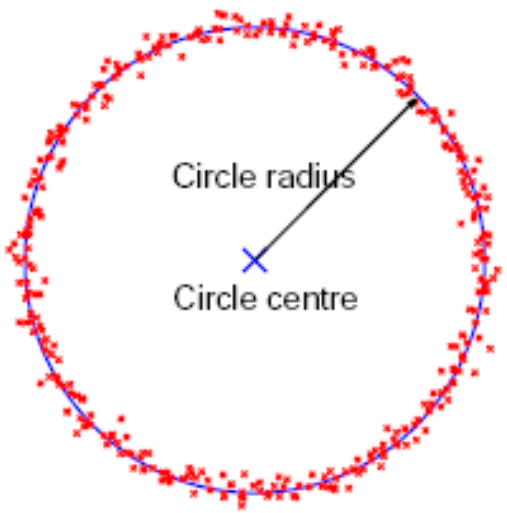

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Implementation of above methods

- Method 1 (self-written C++ program)
  - Pro: less then 10 points is enough
  - Con: not reliable enough, slow for $\geq$ 10 points
- Method 2 (RFit program used in RICH-detectors)
  - Pro: fast, reliable, well tested
  - Con: more then 10 points needed

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Up next: Automatic measurement

Pre-considerations

- Microscope has API for VisualC++, Delphi and LabView
- Camera has FTP-Server/Client and Telnet-Server built-in
- LabView has a wide range of image processing capabilities

$\Rightarrow$ use LabView + camera's FTP-Server

1. get the image from the camera's FTP-Server
2. process the image to find the gap
3. move the microscope into the region of the next gap
4. $\Rightarrow 1$

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3. move the microscope into the region of the next gap
4. $\Rightarrow 1$

Up next: Automatic measurement

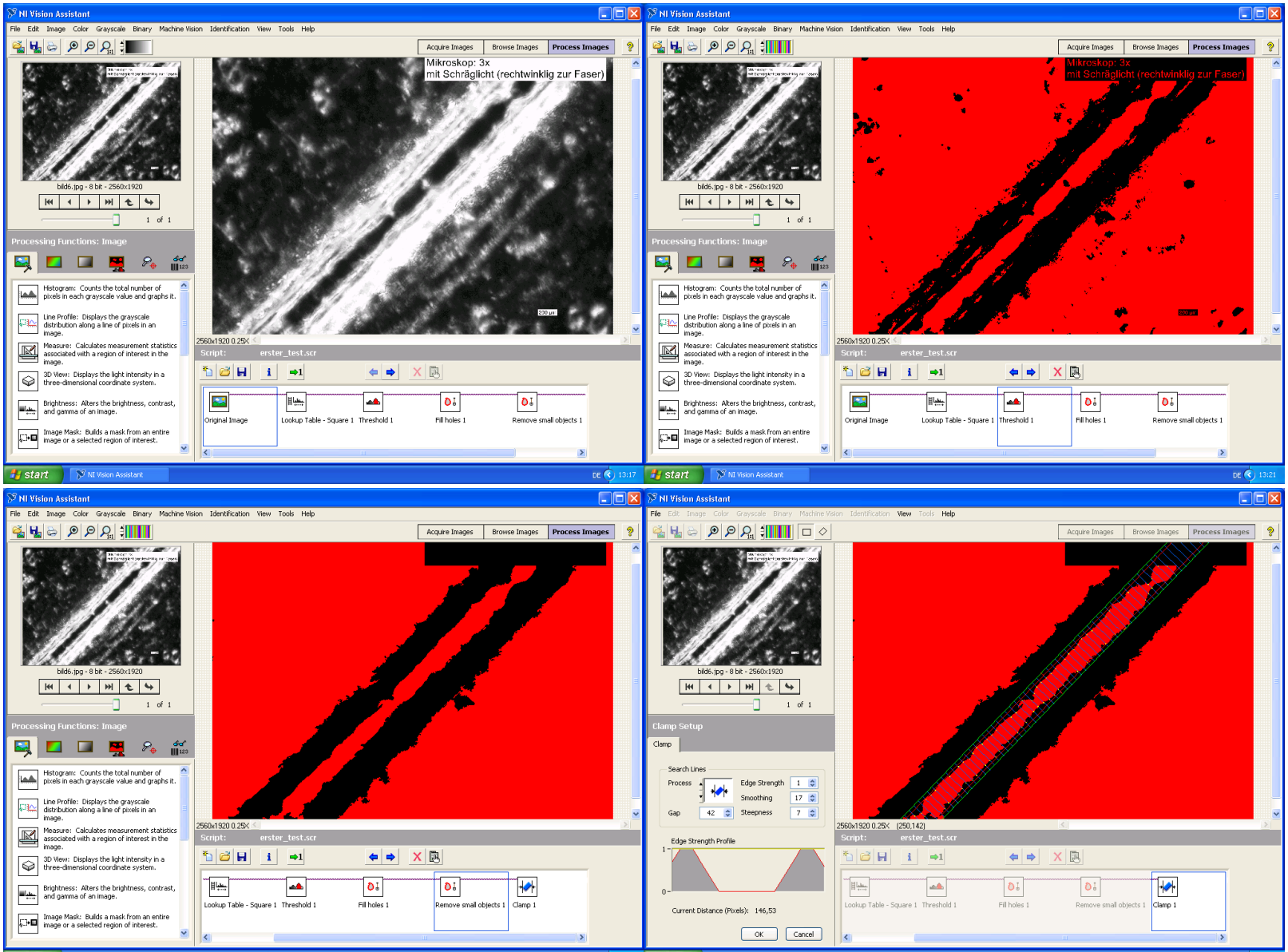
Pre-considerations

- Microscope has API for VisualC++, Delphi and LabView
- Camera has FTP-Server/Client and Telnet-Server built-in
- LabView has a wide range of image processing capabilities

$\Rightarrow$ use LabView + camera's FTP-Server

1. get the image from the camera's FTP-Server
2. process the image to find the gap
3. move the microscope into the region of the next gap
4. $\Rightarrow 1$

First impressions from LabView's image processing



Outline

1 Motivation

2 Precision Measurement

3 Measurement results

4 Automation

5 Summary

Summary

Q: Why ALFA?

A: Measure absolute Luminosity for ATLAS.

Q: What kind of detector?

A: Scintillating Fiber Detector.

Q: What needs to be done?

A: Measure the ”exact” fibre position.

Q: Whats the outcome of the manual measurements?

A: The CERN measurements could be reproduced.

Q: Whats up next?

A: Program LabView to automate the process.