

Optical Measurements of the Radiator Shape

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PANDA/GSI

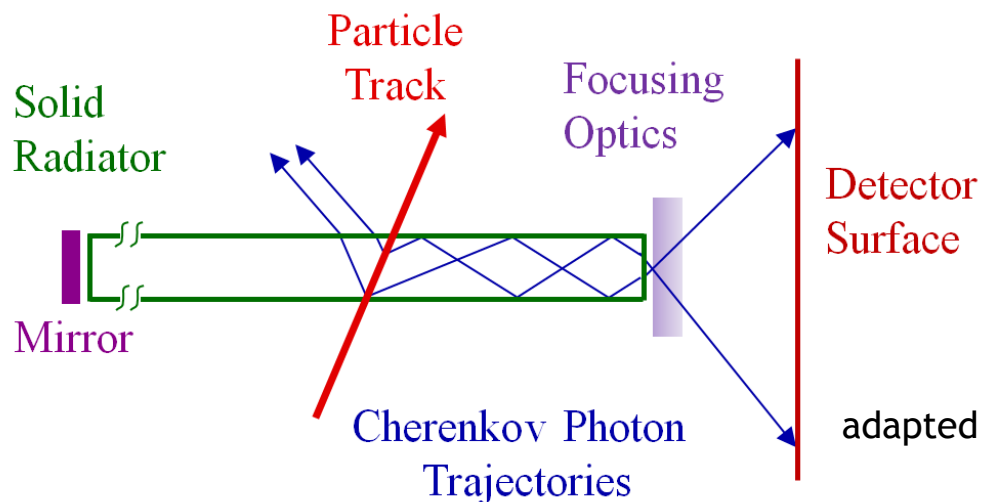
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Introduction

- ▶ Squareness and parallelism measurements of radiator bars
- ▶ Tight parallelism/squareness specifications:
 - ▶ **0.25mrad/0.5mrad** (sides/ends)
- ▶ Autocollimator setup
- ▶ Compare prototypes from different manufacturers



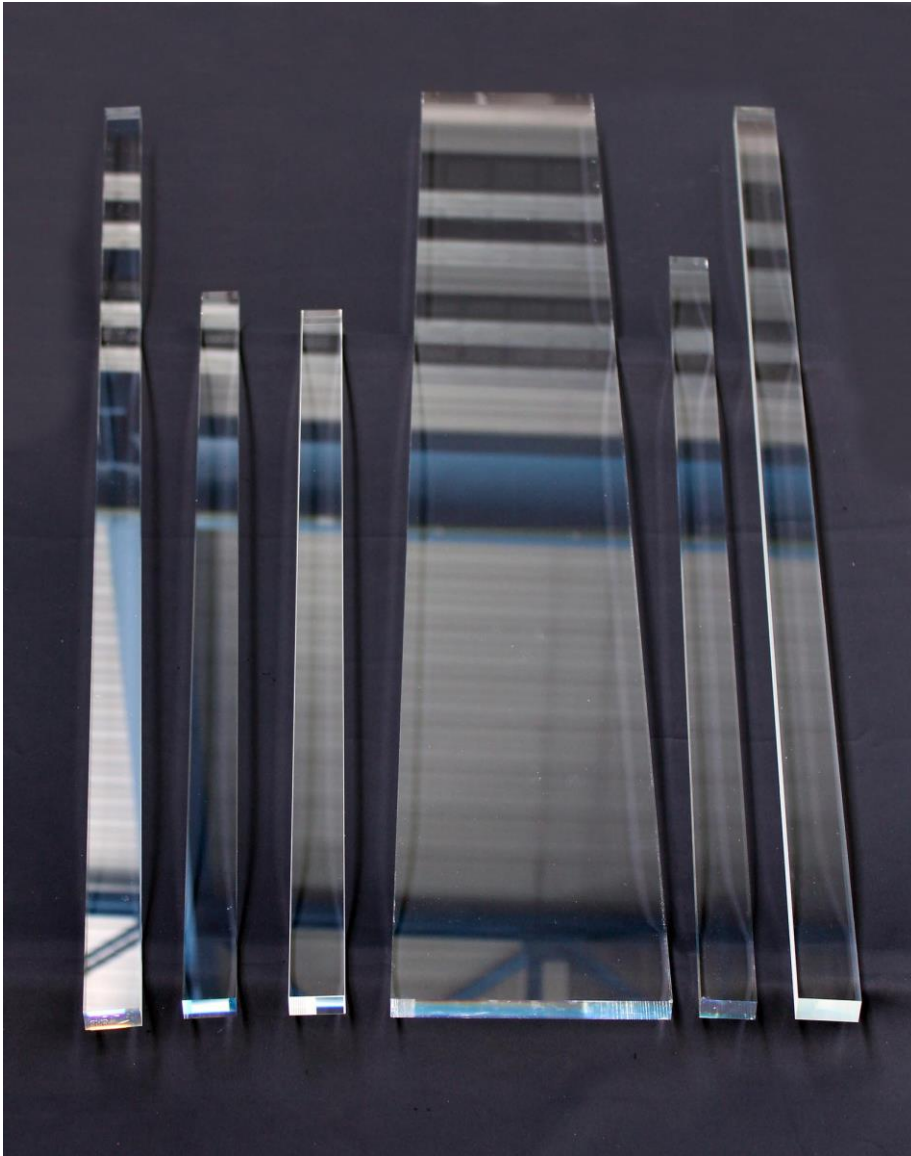
Components

Quartz Bars

- ▶ Material: Synthetic fused silica
 - ▶ Radiation hard, high transmittance, large refractive index, optical purity, very low birefringence
- ▶ Radiator dimensions: (17mm, 53mm, 1200mm)
- ▶ Prototype bars from different manufacturers

Manufacturer	Material	Production Method	Dimensions in mm
Lytkarino	Spectrosil 2000	abrasive polishing	(16.7, 34.8, 899.5)
Zeiss	Spectrosil 2000	pitch polishing	(17.1, 32.9, 833)
Heraeus	Suprasil 1	extruded, ground, glazed	(16, 34, 780)
Zygo	Corning 7980	pitch polishing	(17.9, 35.9, 1200.7)
InSync	Spectrosil 2000	pitch polishing	(17.12, 35.93, 1200.04)

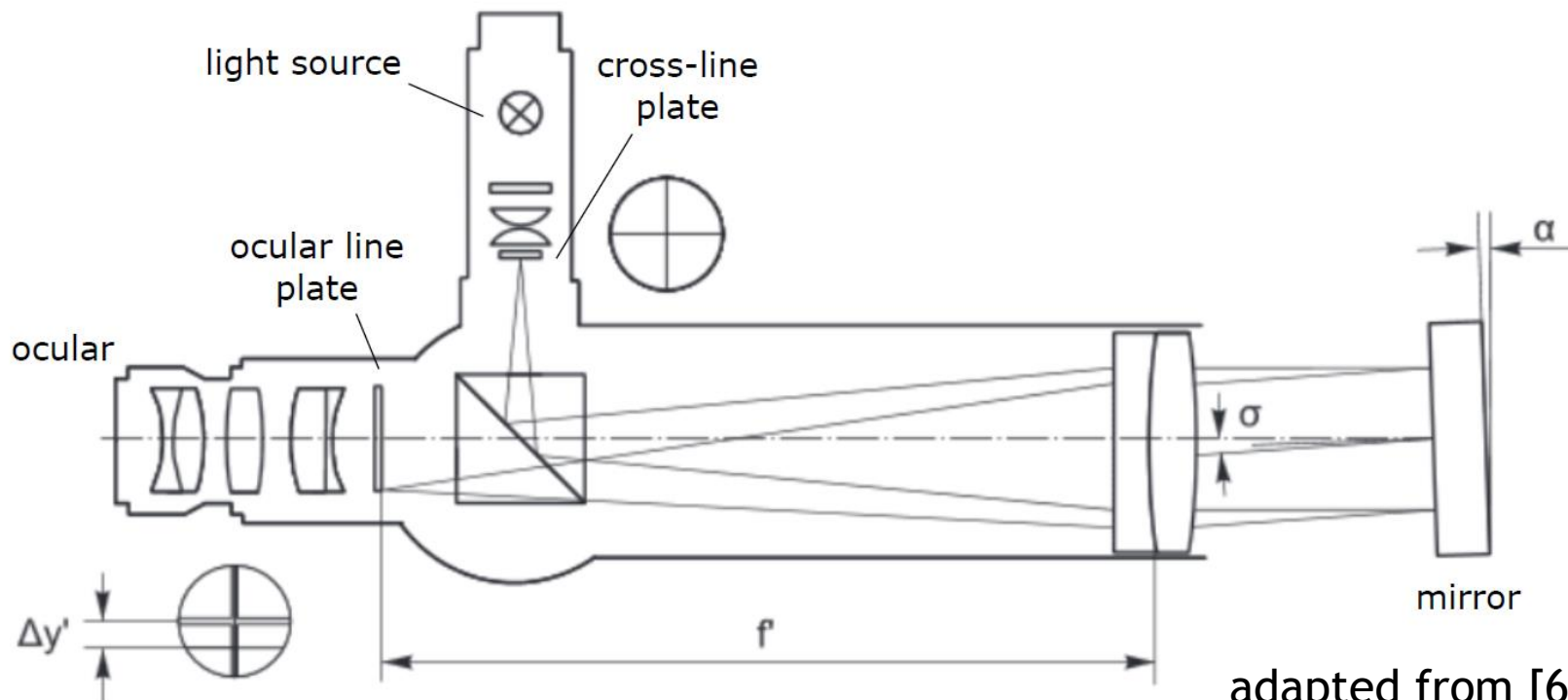
Quartz Bars



Autocollimator

- ▶ Telescope like measuring instrument to measure angular misalignment

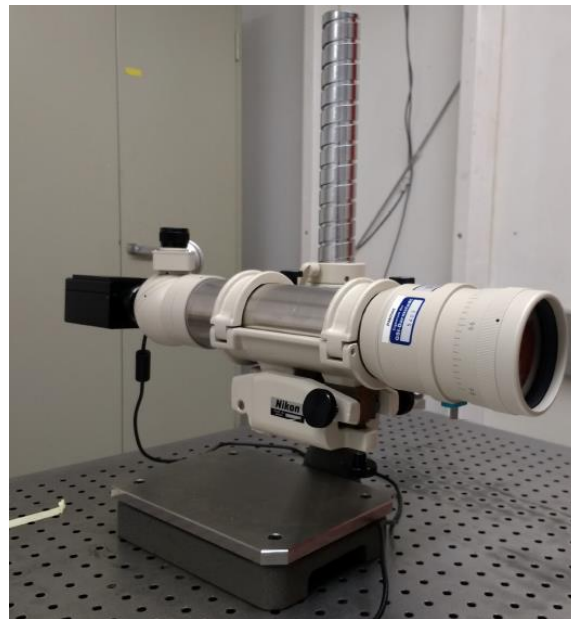
- ▶ Measuring tilt angle α :
$$\alpha = \frac{\sigma}{2} = \Delta\Theta_y = \frac{\Delta y'}{2f'}$$



adapted from [6]

Autocollimator

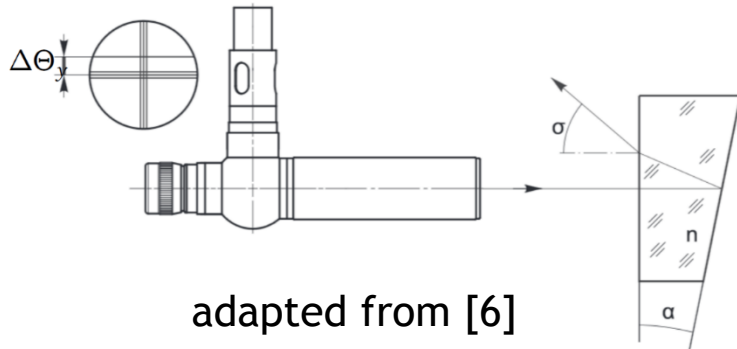
- ▶ Nikon 6D-LED autocollimator
- ▶ Accuracy: 0.5 arcsec



Autocollimator Measurements

- ▶ Wedge angle:

- ▶ Transparent wedge with refractive index n

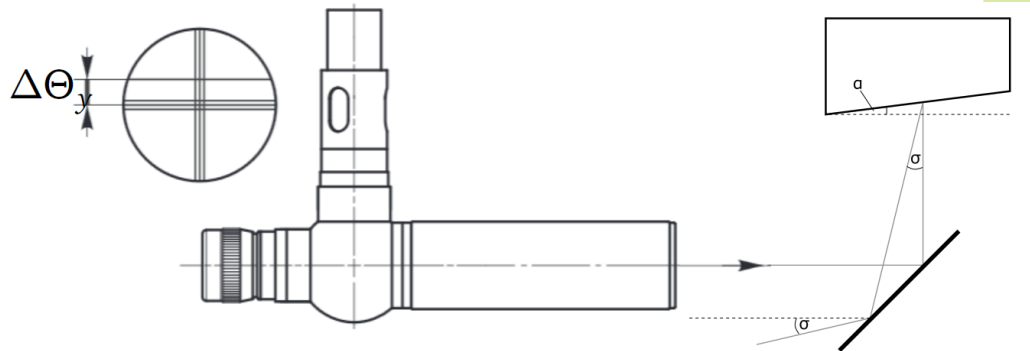


$$\alpha = \frac{\sigma}{2n} = \frac{\Delta\Theta_y}{n}$$

- ▶ Squareness measurements:

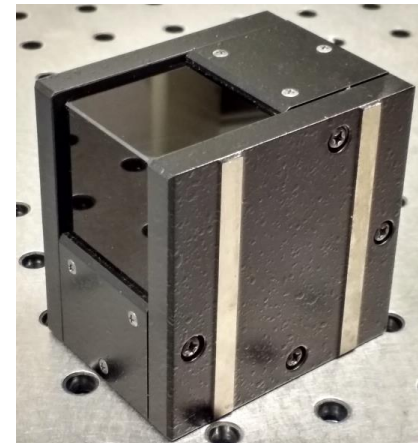
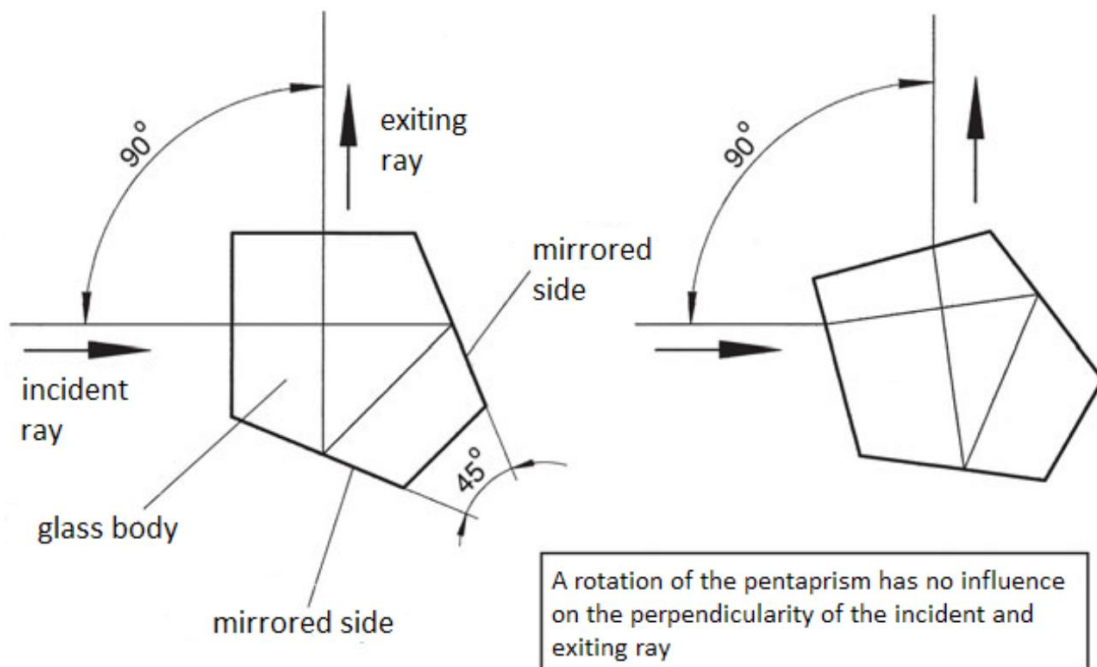
- ▶ Compare reflection from front and bottom side of a rectangular reflective body
- ▶ Use pentaprism

$$\alpha = \frac{\sigma}{2} = \Delta\Theta_y$$



Pentaprism

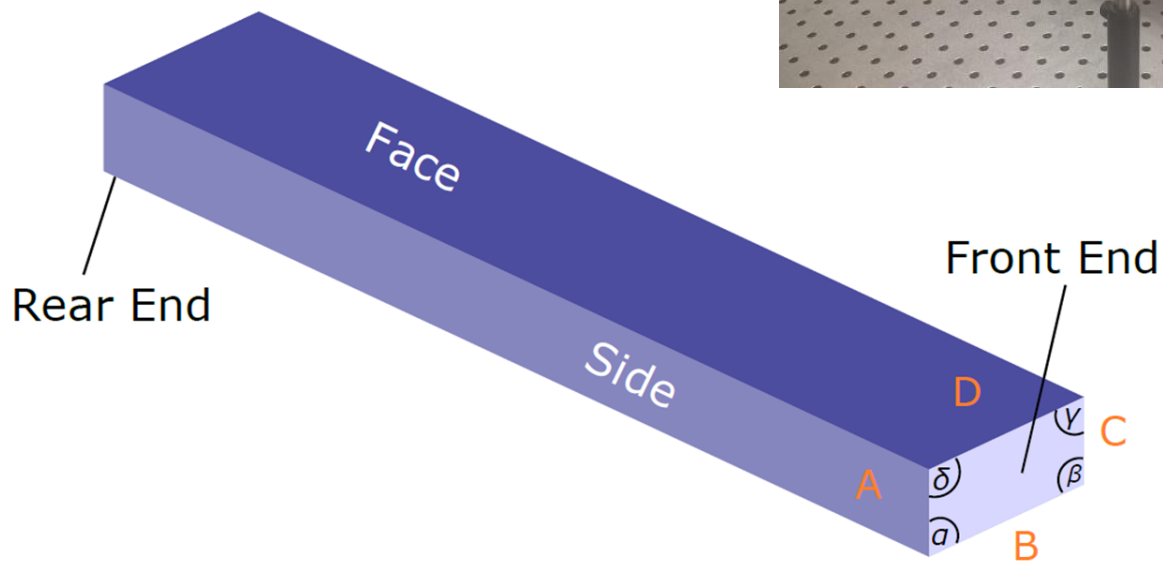
- ▶ Optical measurement standard for squareness
- ▶ Ray entering the prism is deflected by 90°
- ▶ Accuracy:
 - ▶ Vertical: $d_1 = -0.03\text{mrad}$
 - ▶ Horizontal: $d_2 = 0.013\text{mrad}$



Setup

Setup

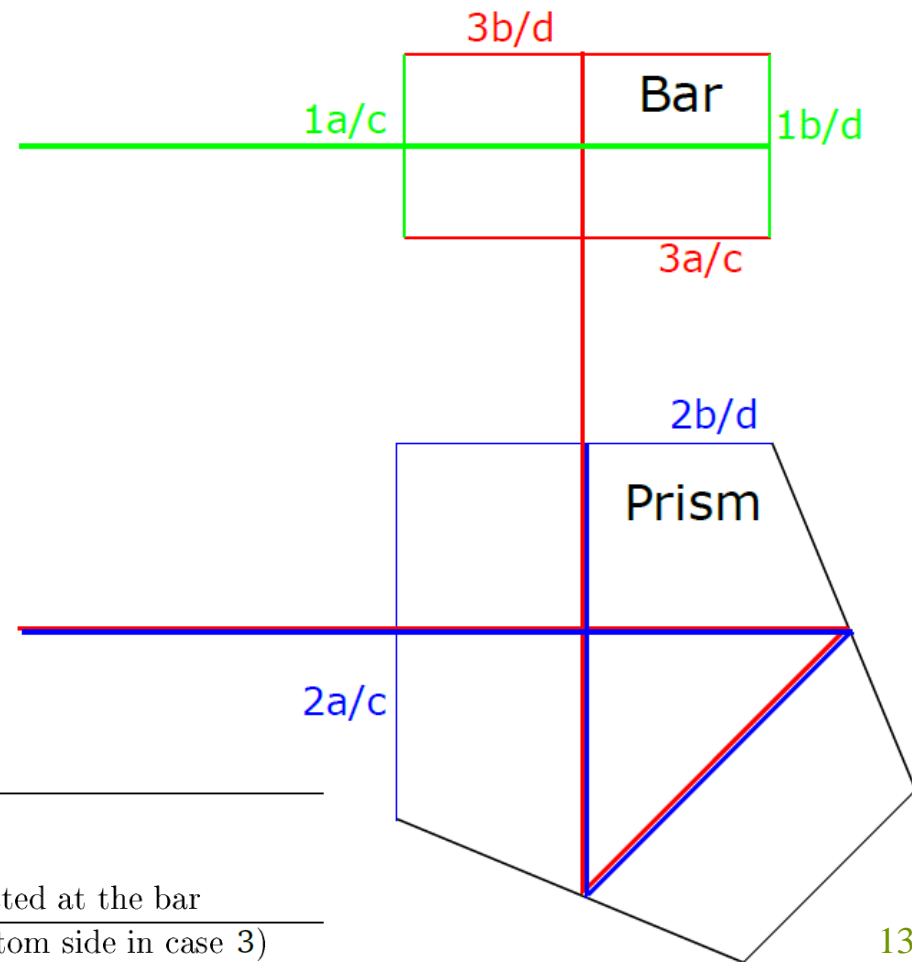
- ▶ Bars mounted on two supports, wrapped with cloth
- ▶ Autocollimator
- ▶ Pentaprism
- ▶ Optical table



Setup

- Ray path through bar and pentaprism

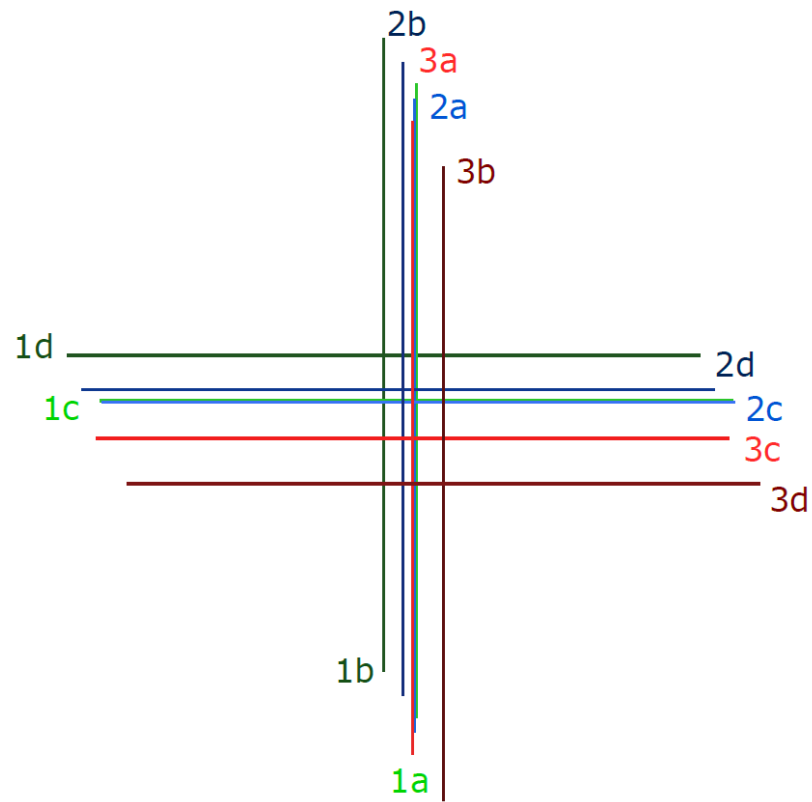
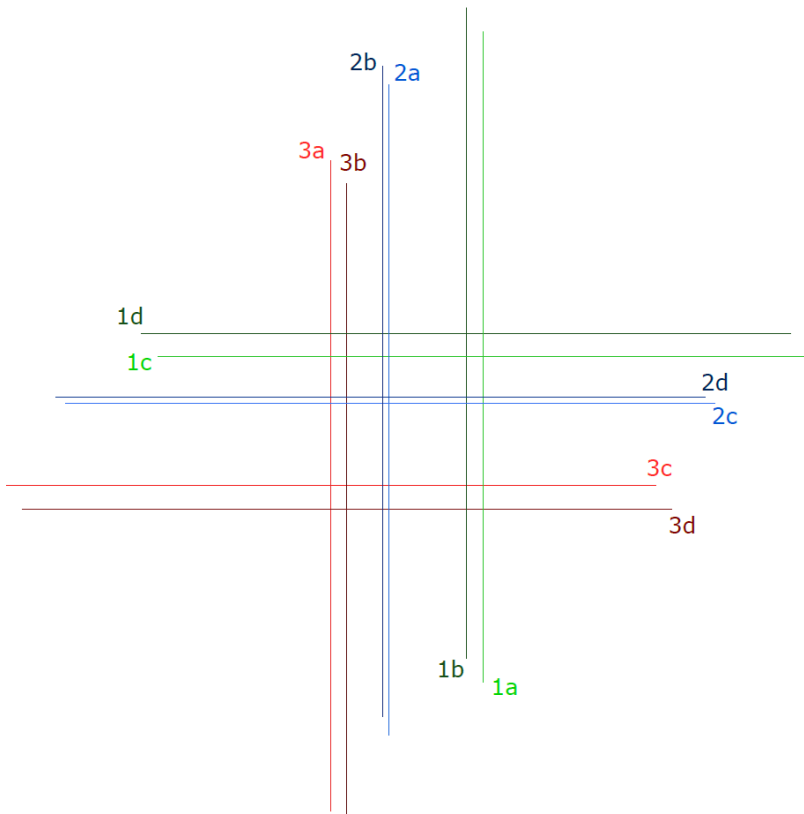
Autocollimator



Label	Origin
1	Directly from bar
2	Pentaprism
3	Deflected by the pentaprism and reflected at the bar
<i>a</i>	Vertical reflection from front side (bottom side in case 3)
<i>b</i>	Vertical reflection from top side (back side in case 1)
<i>c</i>	Horizontal reflection from front side (bottom side in case 3)
<i>d</i>	Horizontal reflection from top side (back side in case 1)

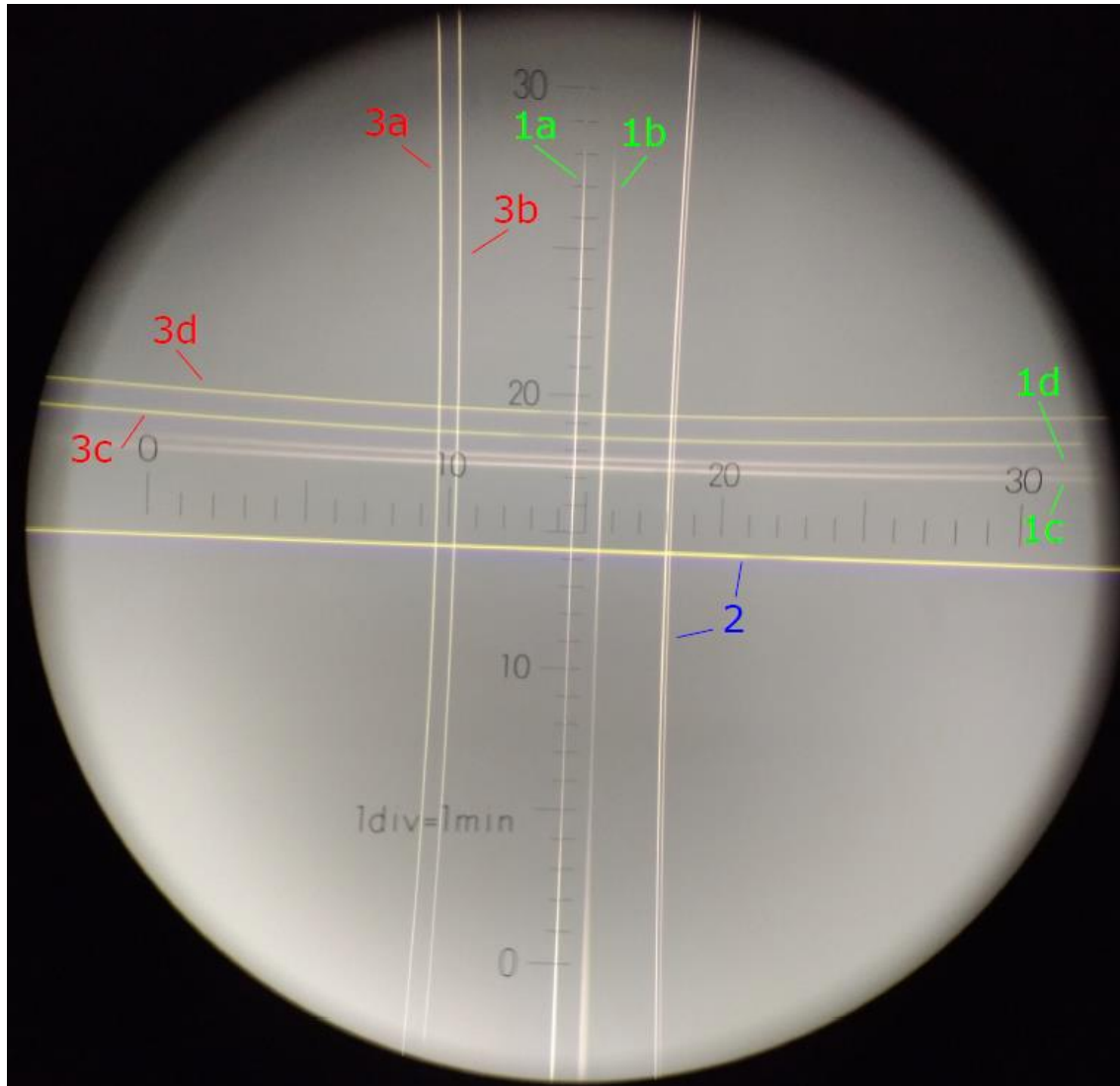
Setup

Alignment of Prism and Bar



Setup

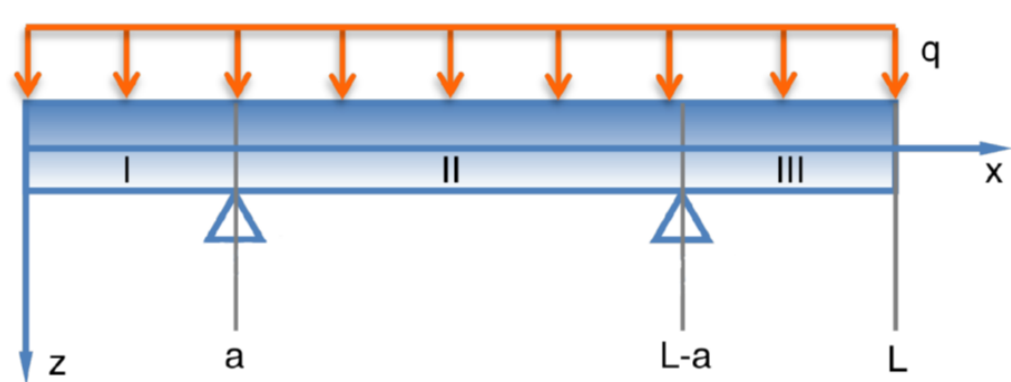
Alignment of Prism and Bar



Error Determination

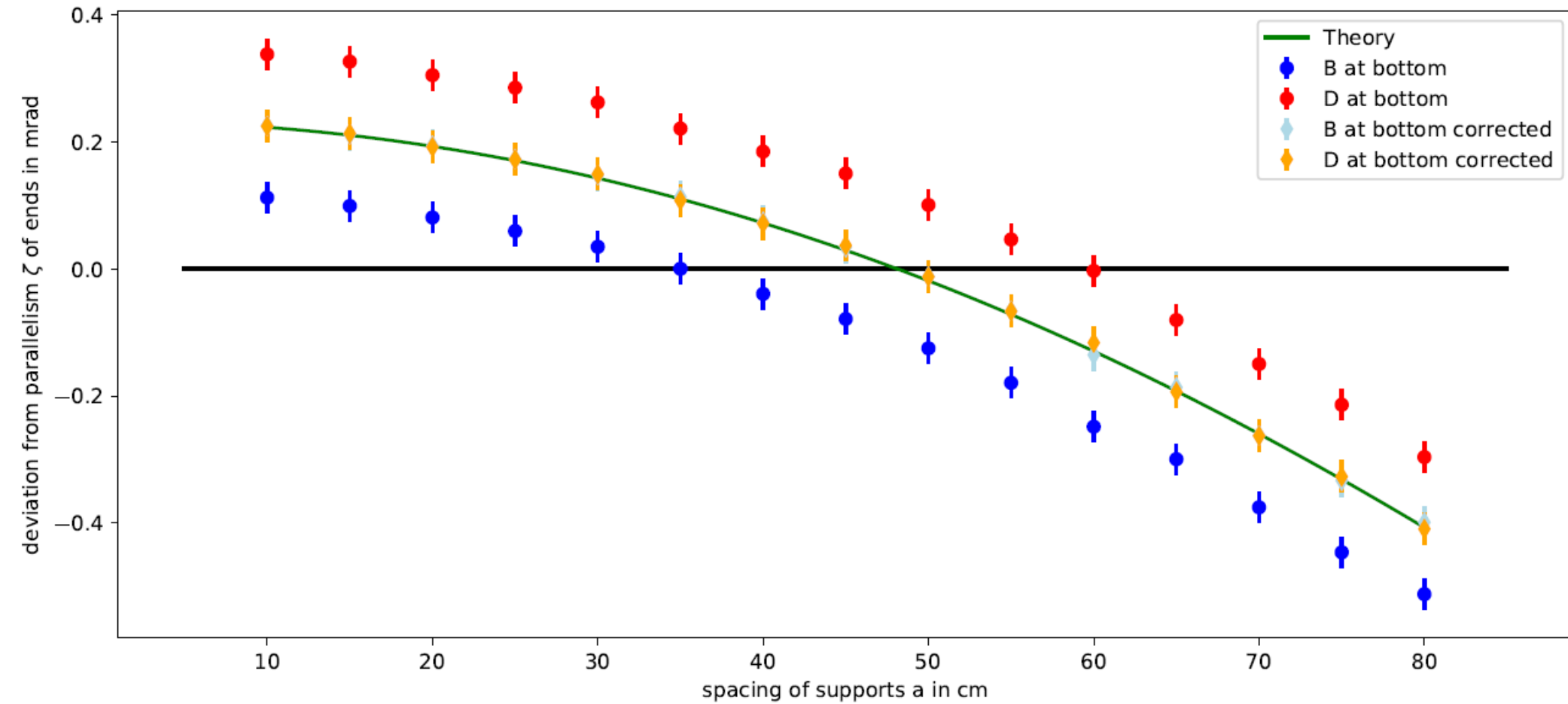
Mounting

- ▶ Bars are mounted on two supports
- ▶ Bending of bar due to its own weight
- ▶ Calculation of the elastic line
- ▶ Minimum bending: $a = 0.22 L$
- ▶ „AIRY“-Mounting: $a = 0.19 L$
- ▶ Bending is related to parallelism of the bar's ends



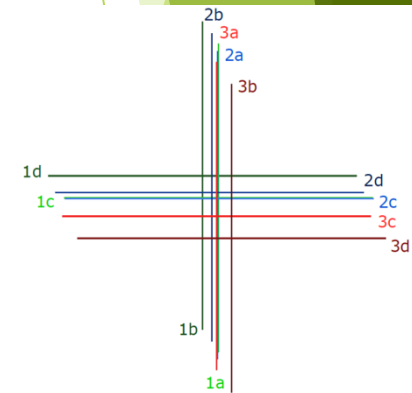
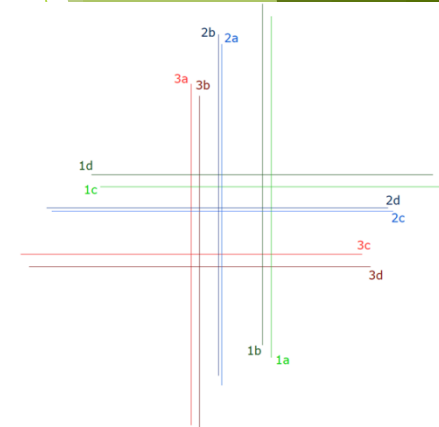
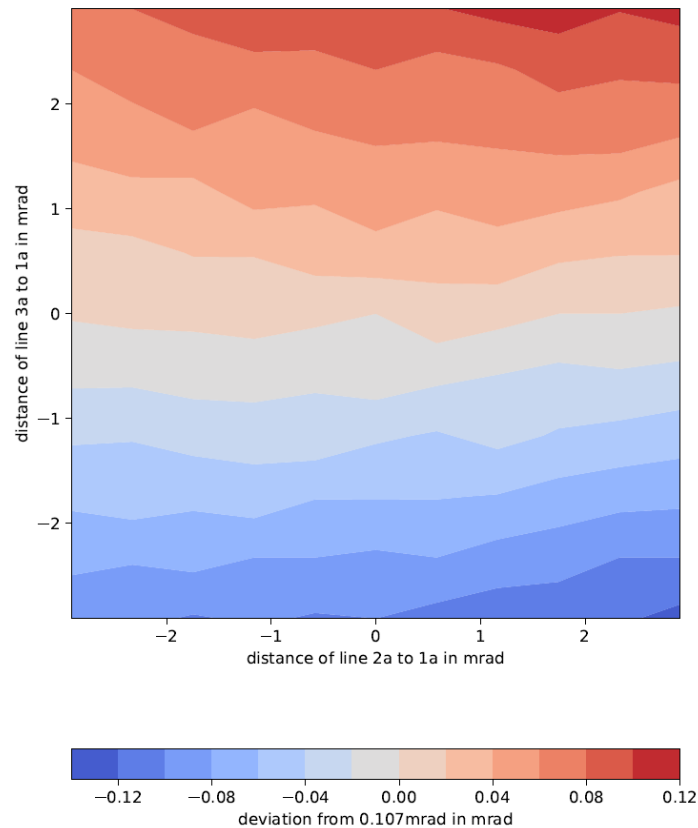
adapted from [10]

Positioning of Bar Supports



Alignment of Prism and Bar

- ▶ Dependency of measurements on alignment
- ▶ No dependency for parallelism measurements
- ▶ No dependency on alignment of horizontal lines
- ▶ Dependency on alignment of vertical lines



Reproducibility

- ▶ One position at one bar is measured nine times
- ▶ Reproducibility is very good: $\sigma \cong 0.01\text{mrad}$
- ▶ Possibility of bar identification
- ▶ All squareness measurements have an offset of -0.03mrad
- ▶ Error of clear line: 0.01mrad

Total Error

- ▶ Parallelism measurement without pentaprism:

$$\Delta\zeta = \sqrt{h_1^2 + h_2^2} = 0.014\text{mrad}$$

- ▶ Parallelism measurement with pentaprism:

$$\Delta\zeta = \sqrt{h_1^2 + d_i^2 + h_2^2 + d_i^2} = \sqrt{h_1^2 + h_2^2 + 2d_i^2}$$

- ▶ Squareness measurement:

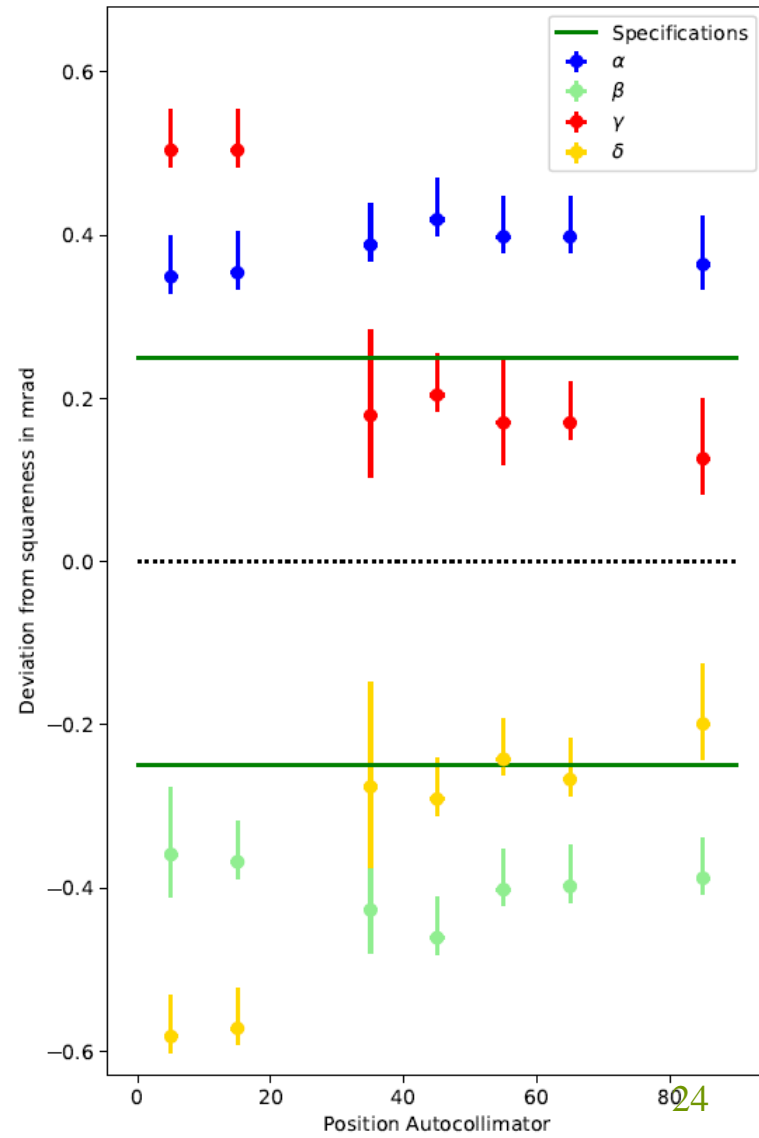
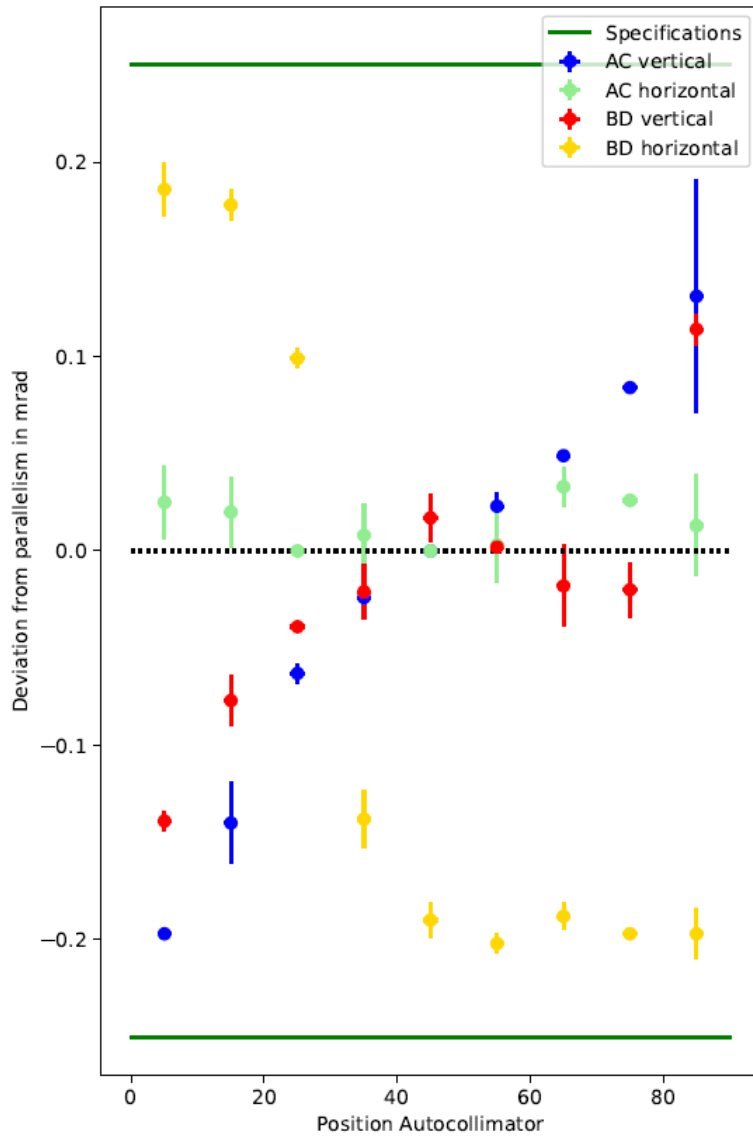
$$\Delta_{-}\xi = \sqrt{h_1^2 + h_2^2 + d_2^2} = 0.020\text{mrad}$$

$$\Delta_{+}\xi = \sqrt{h_1^2 + h_2^2 + d_2^2} + s = 0.050\text{mrad}$$

Survey of the Prototype Bars

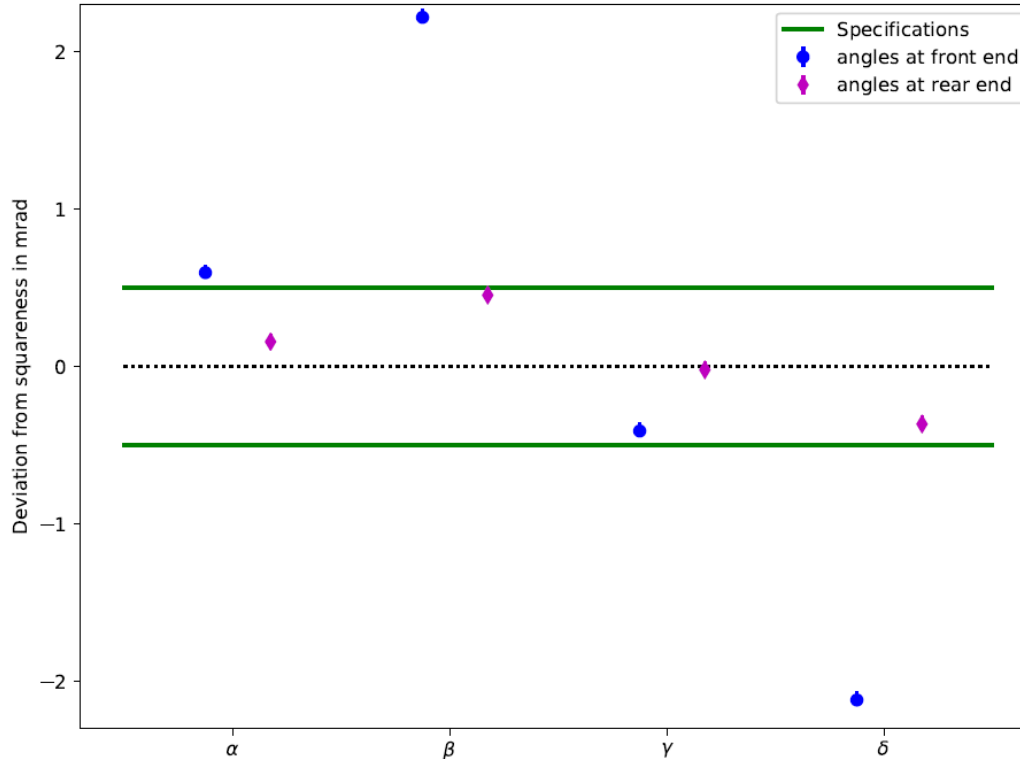
- ▶ Parallelism and squareness of the faces and sides of each bar are measured in steps of 10cm
- ▶ One bar of each manufacturer is measured in detail
- ▶ Parallelism and squareness measurements of the bars' ends
- ▶ Compare with previous/manufacturer measurements

Lytkarino Bar

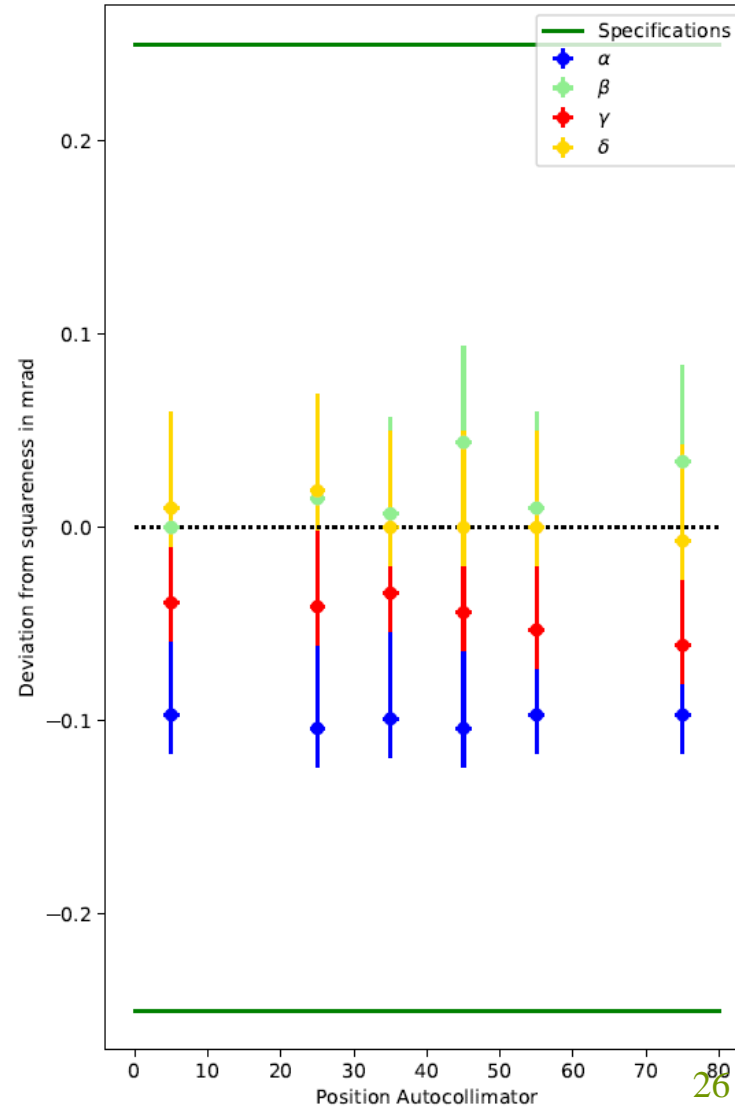
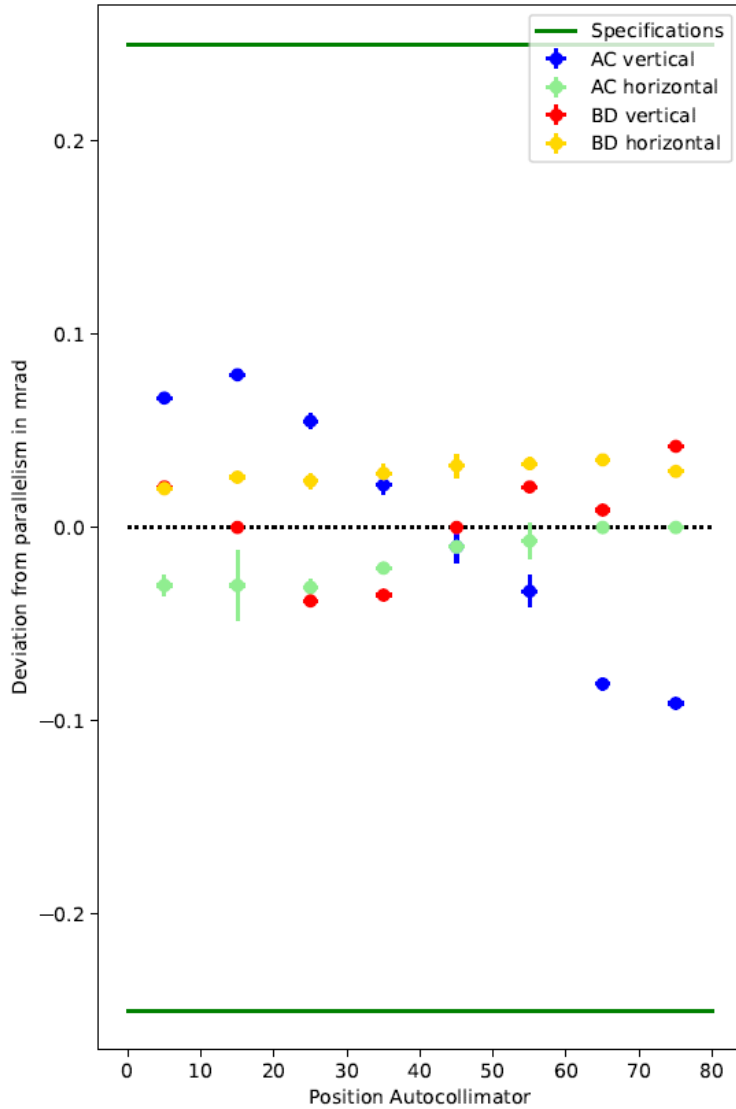


Lytkarino Bar - Ends

- ▶ Deviation from parallelism: $\zeta_{\text{end}_{\text{horiz}}} = 0.42 \pm 0.13 \text{ mrad}$
 $\zeta_{\text{end}_{\text{vert}}} = -2.166 \pm 0.021 \text{ mrad}$
- ▶ Deviation from squareness:

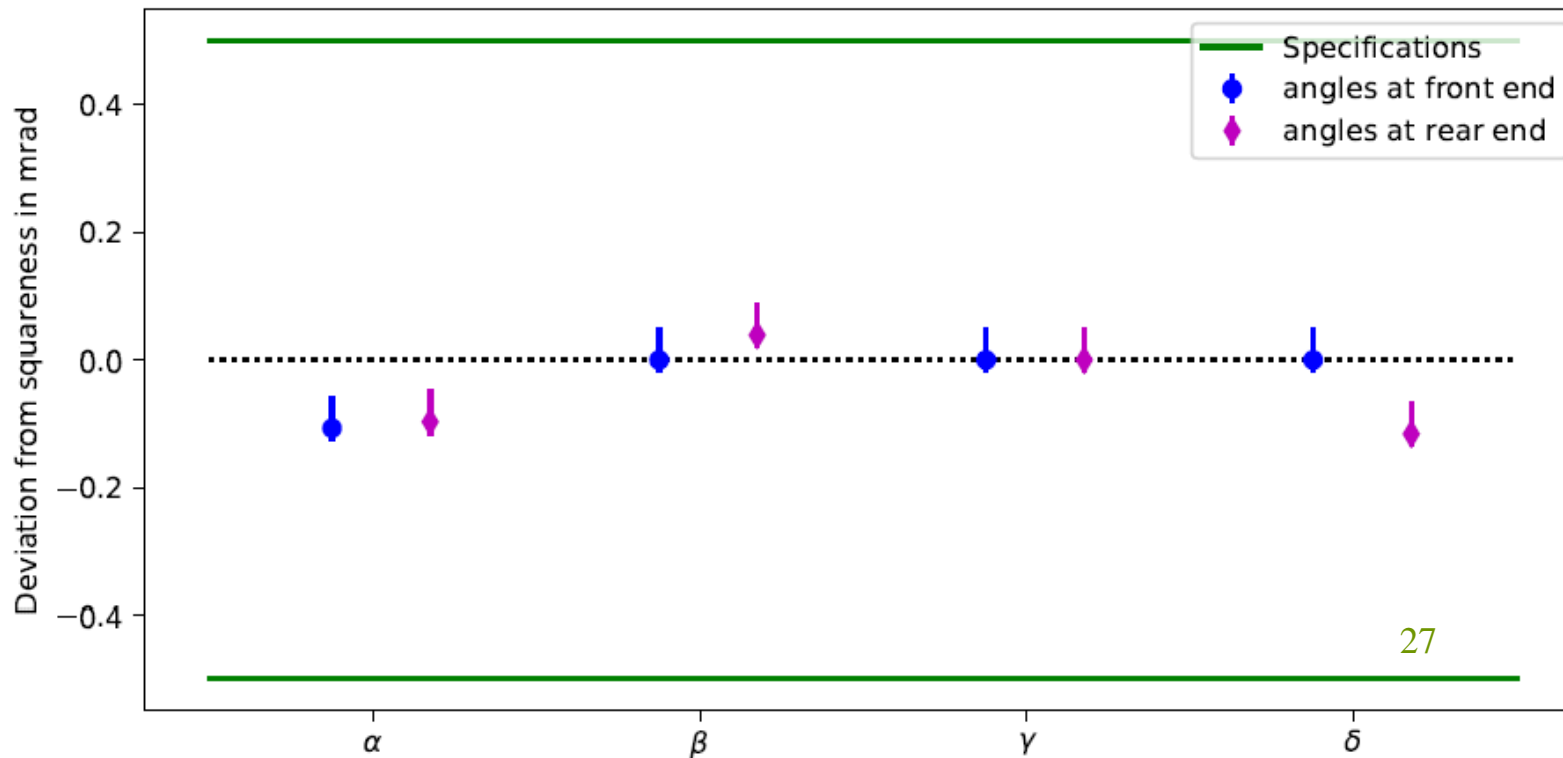


Zeiss Bar



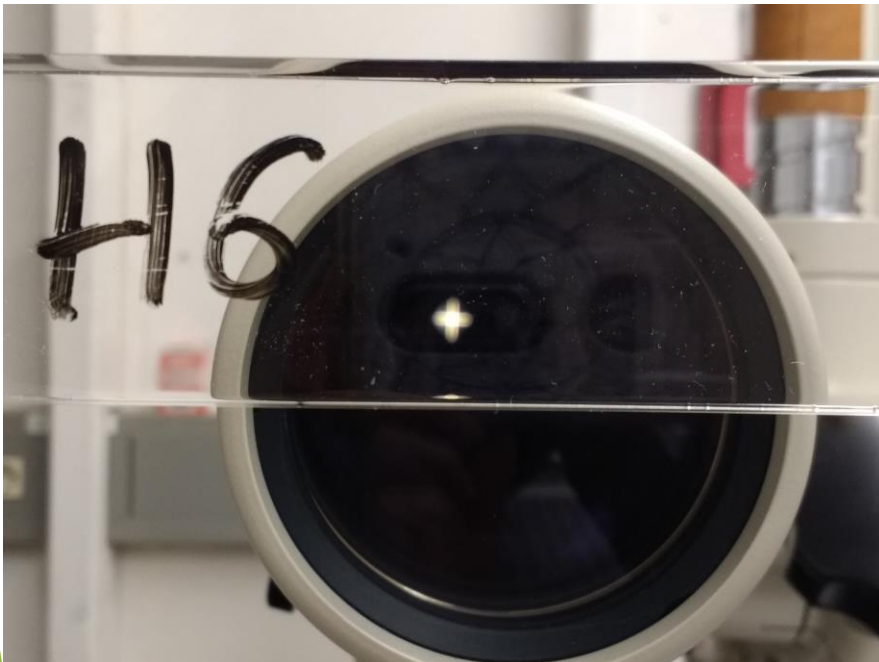
Zeiss Bar - Ends

- ▶ Deviation from parallelism: $\zeta_{\text{end}_{\text{horiz}}} = 0.117 \pm 0.006 \text{ mrad}$
 $\zeta_{\text{end}_{\text{vert}}} = -0.129 \pm 0.007 \text{ mrad}$
- ▶ Deviation from squareness:

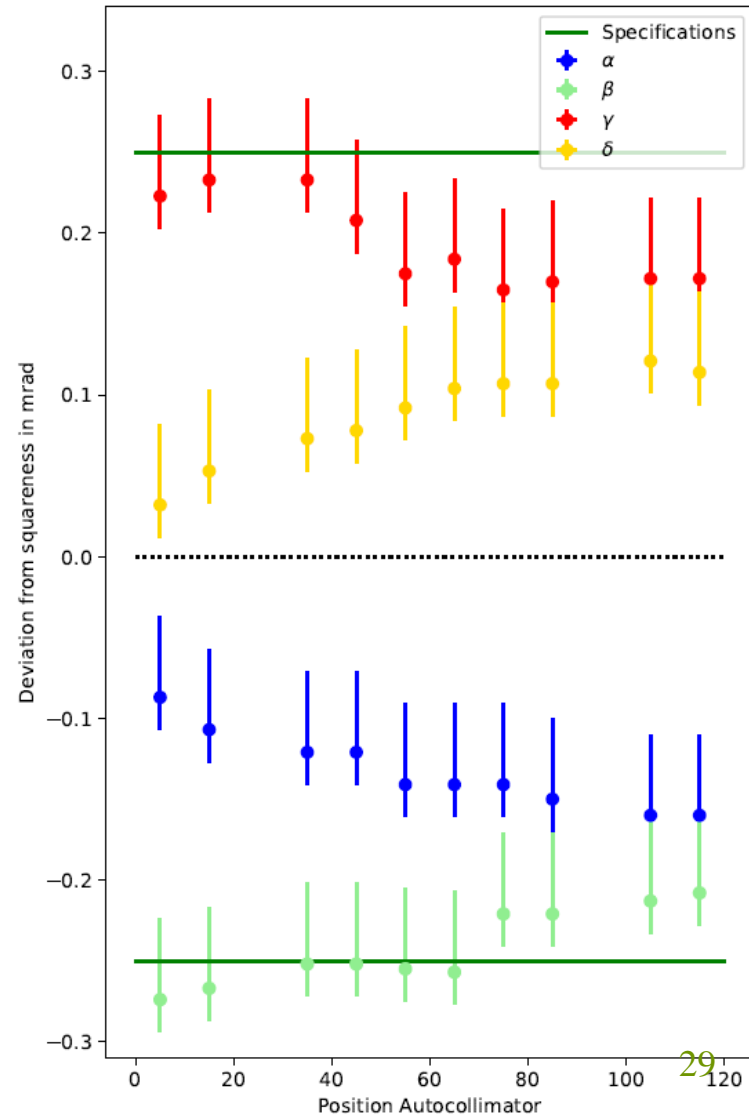
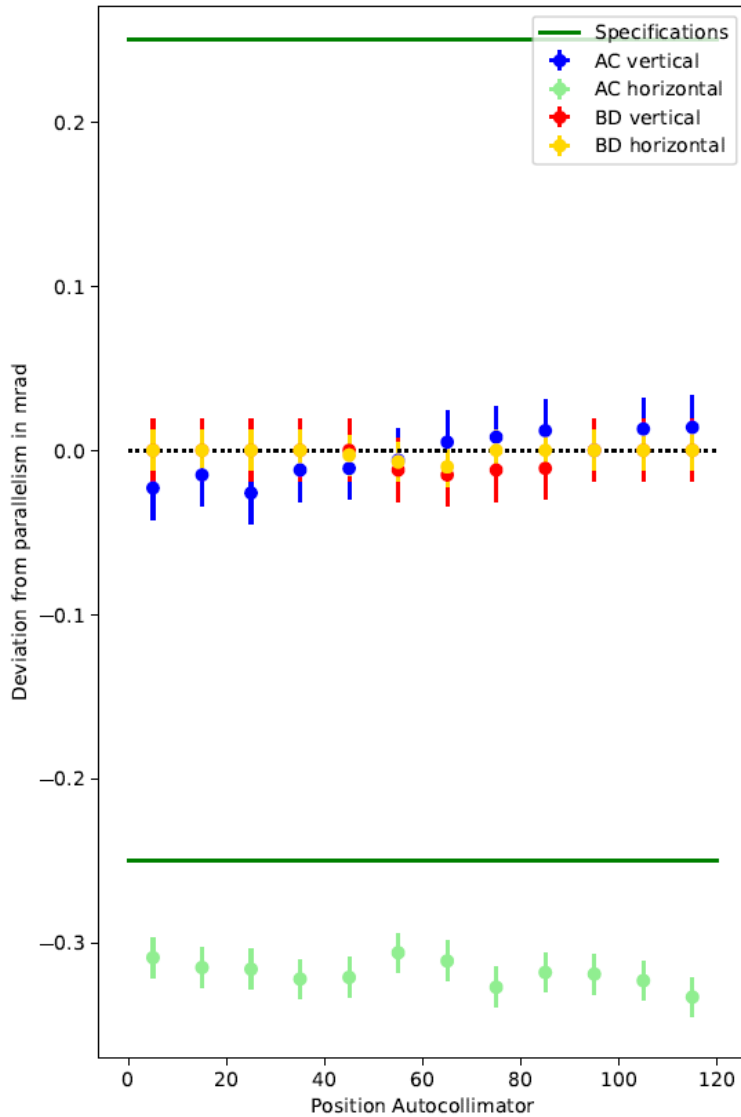


Heraeus Bar

- ▶ No autorcollimator measurements possible
- ▶ Production method “extruding” not applicable for detector bars

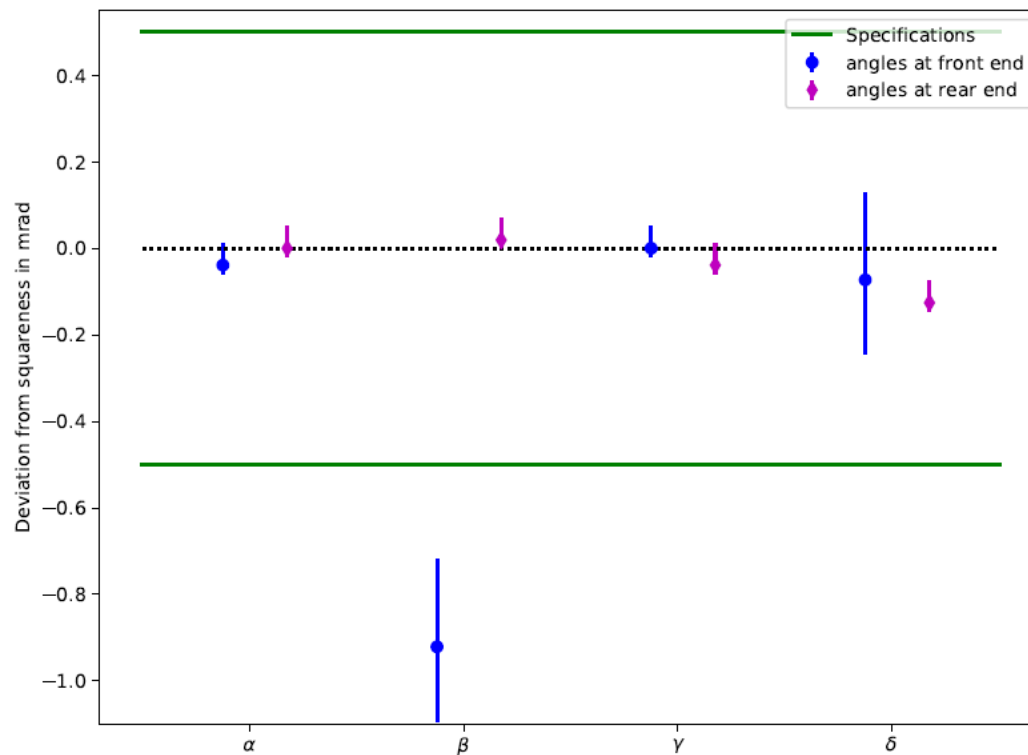


Zygo Bar

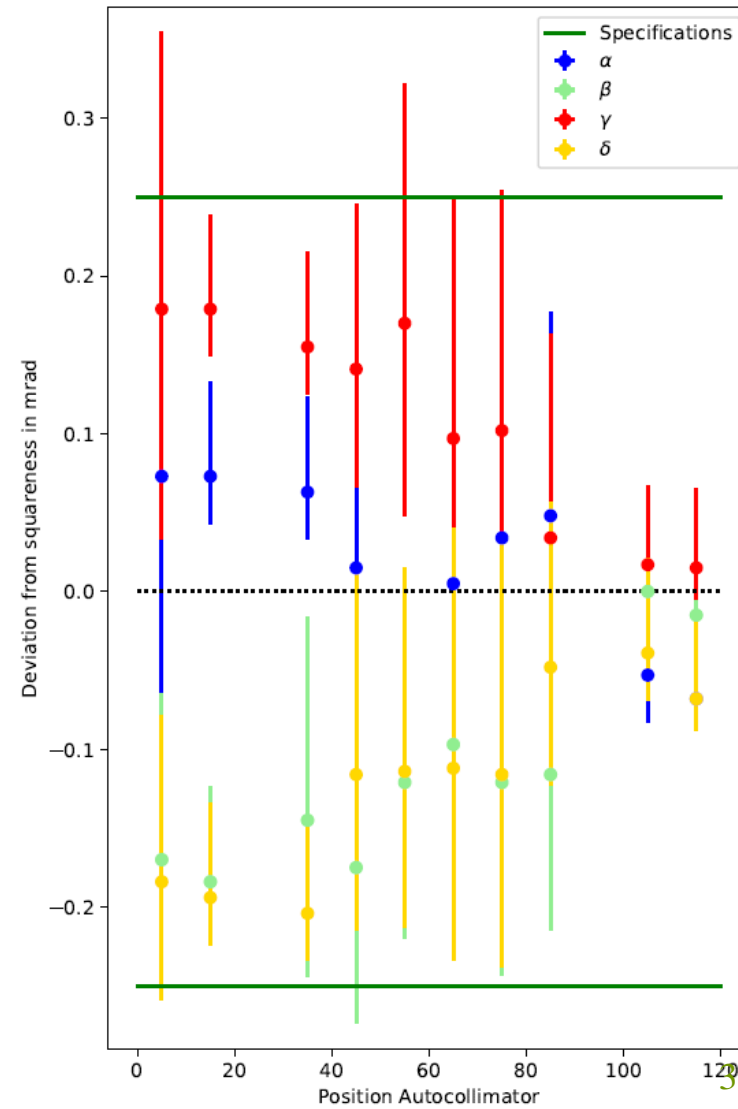
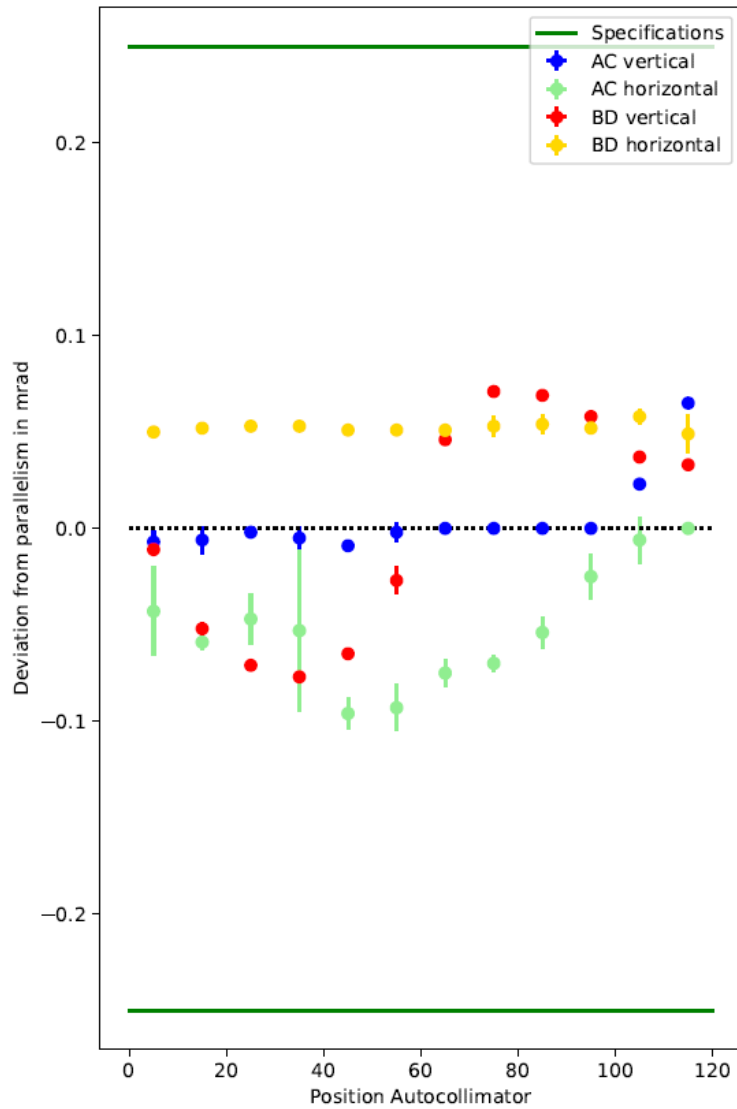


Zygo Bar - Ends

- ▶ Deviation from parallelism: $\zeta_{\text{end}_{\text{horiz}}} = -0.061 \pm 0.010 \text{ mrad}$
 $\zeta_{\text{end}_{\text{vert}}} = 0.670 \pm 0.037 \text{ mrad}$
- ▶ Deviation from squareness:



InSync Bar



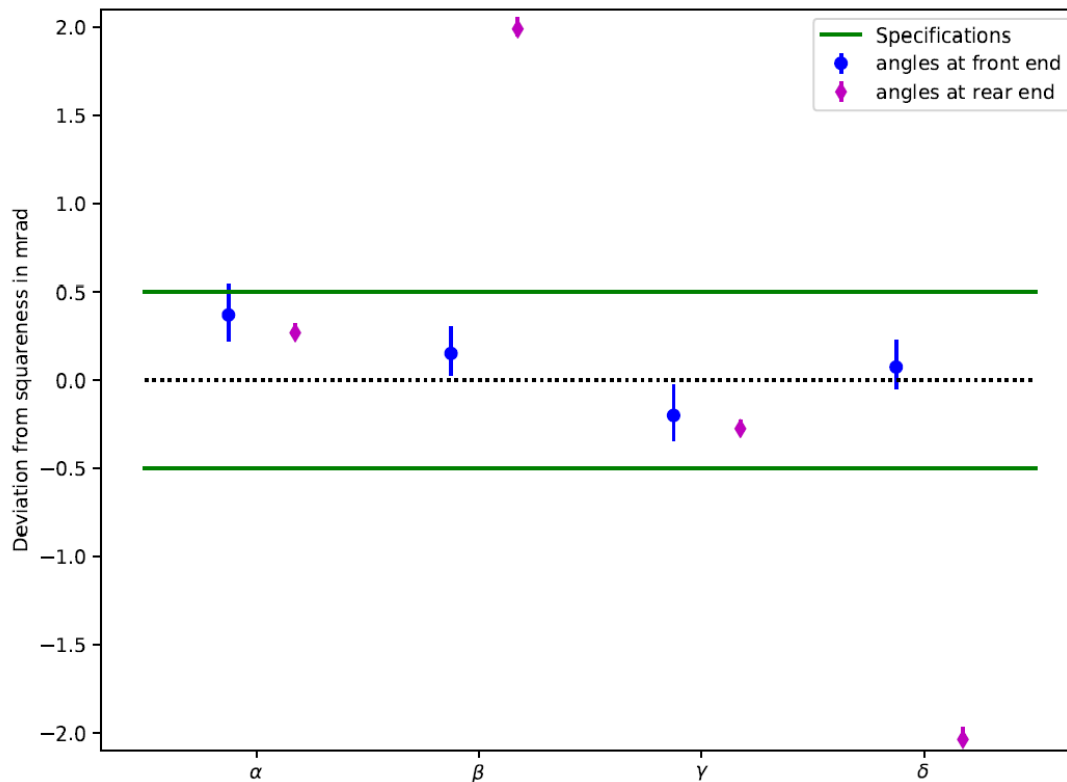
InSync Bar - Ends

- Deviation from parallelism:

$$\zeta_{\text{end}_{\text{horiz}}} = 0.57 \pm 0.17 \text{ mrad}$$

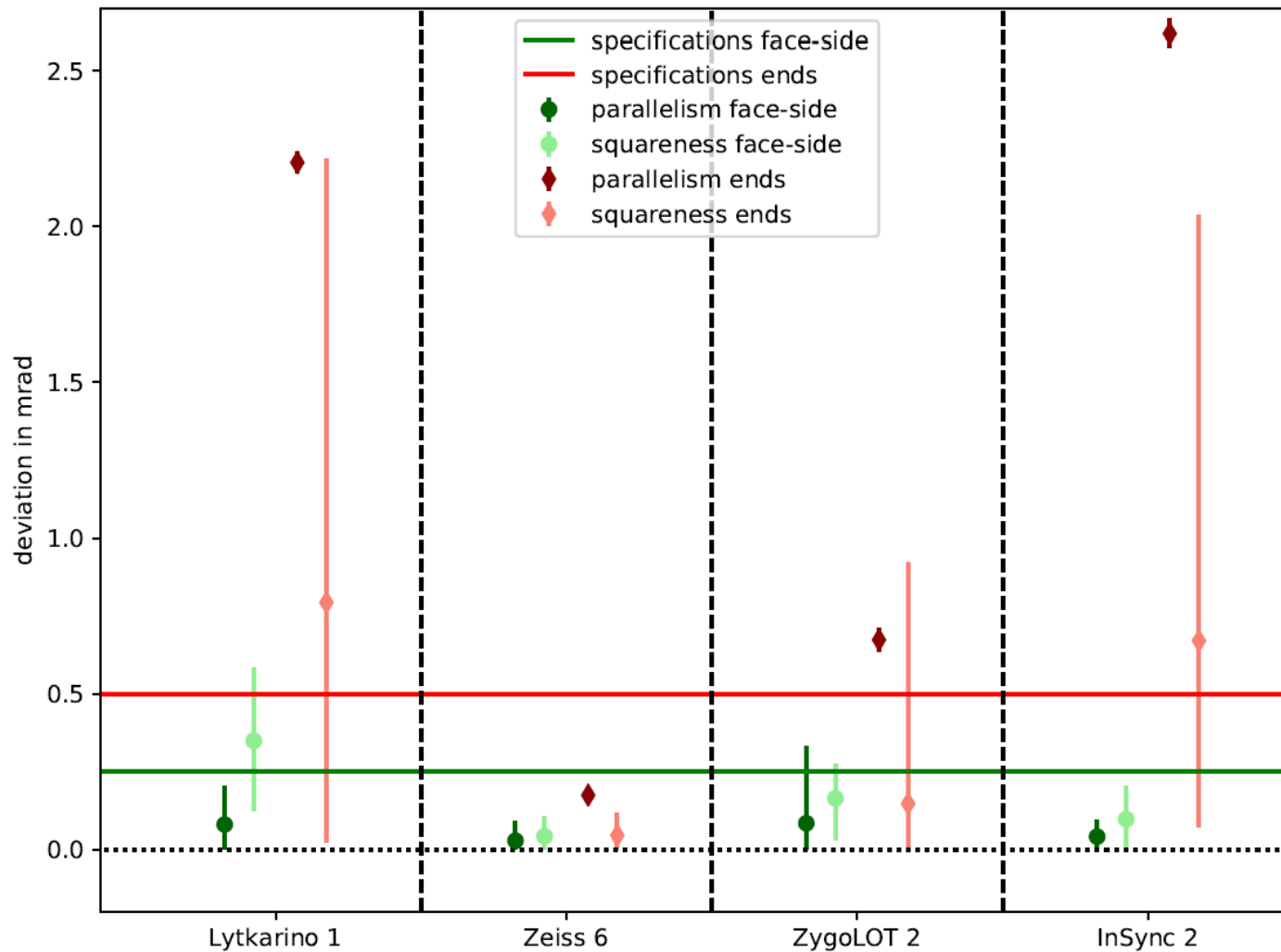
$$\zeta_{\text{end}_{\text{vert}}} = -2.56 \pm 0.03 \text{ mrad}$$

- Deviation from squareness:



Qualification

- ▶ Mean of all measured values
- ▶ Errorbars represent maximum and minimum measured value



Conclusion

- ▶ Prototype bars have been measured and qualified
- ▶ Zeiss and Insync bars fulfill detector specifications
- ▶ Zygo is close to specifications
- ▶ Heraeus and Lytkarino bars do not fulfill the specifications
- ▶ Measurement setup can be used for quality assurance of mass production detector bars

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