

LHC crystal alignment

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HiLumi LHC - Crystal Collimation Day, 19 October 2018

Crystal Collimation Day (October 19, 2018)



CERN



PNPI



UA9 experiment

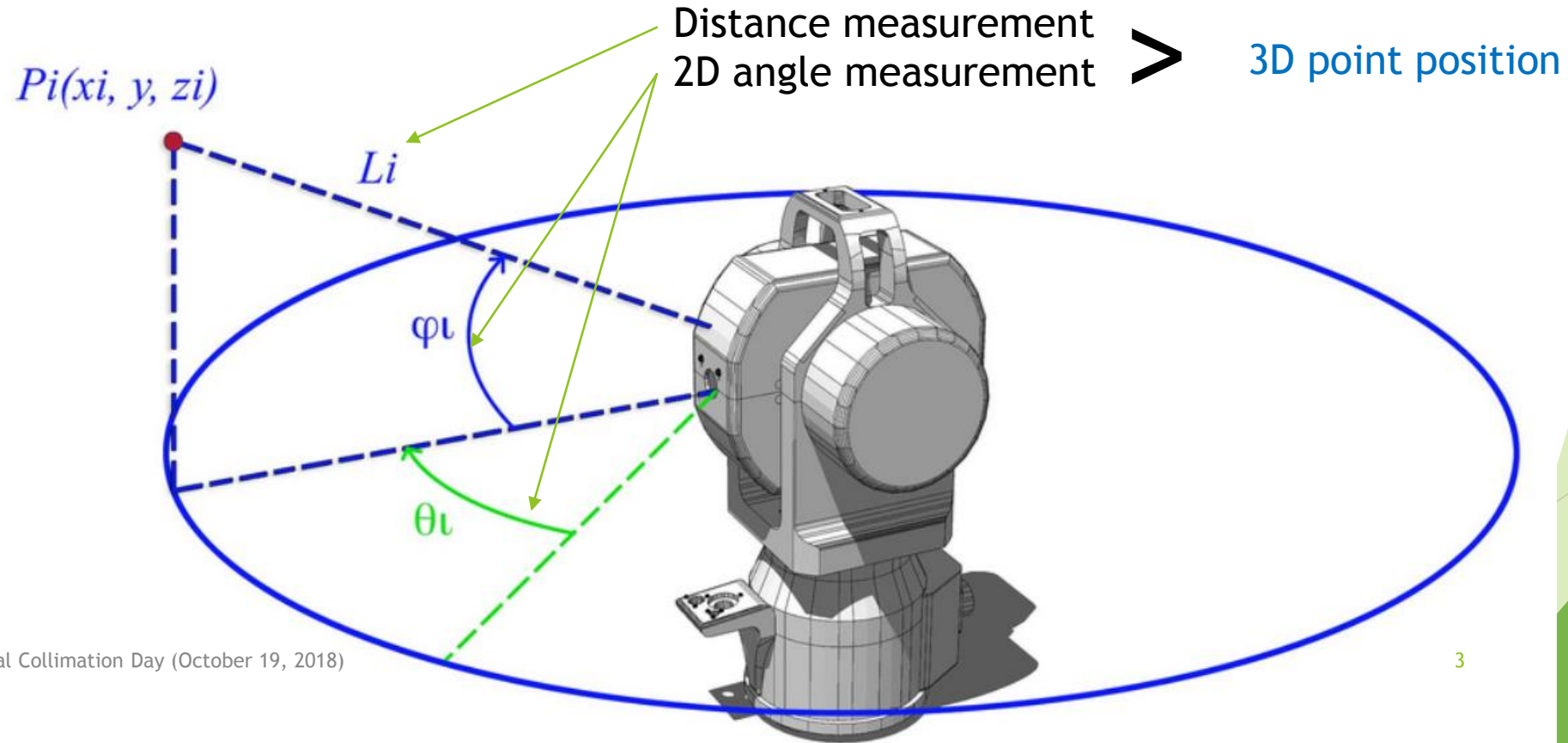
Content of presentation

- ▶ Alignment principle for position measurement
- ▶ Reference points for position measurement
- ▶ Alignment principle for angle measurement
- ▶ Reference for angular measurement
- ▶ Alignment of crystals in LHC
- ▶ Alignment uncertainty
- ▶ Conclusions

Alignment principle for position measurement

Laser tracker capabilities:

- For fiducialization of equipment (alignment and survey)
- Contact or contactless method
- Typical resolution is up to 1 μ m

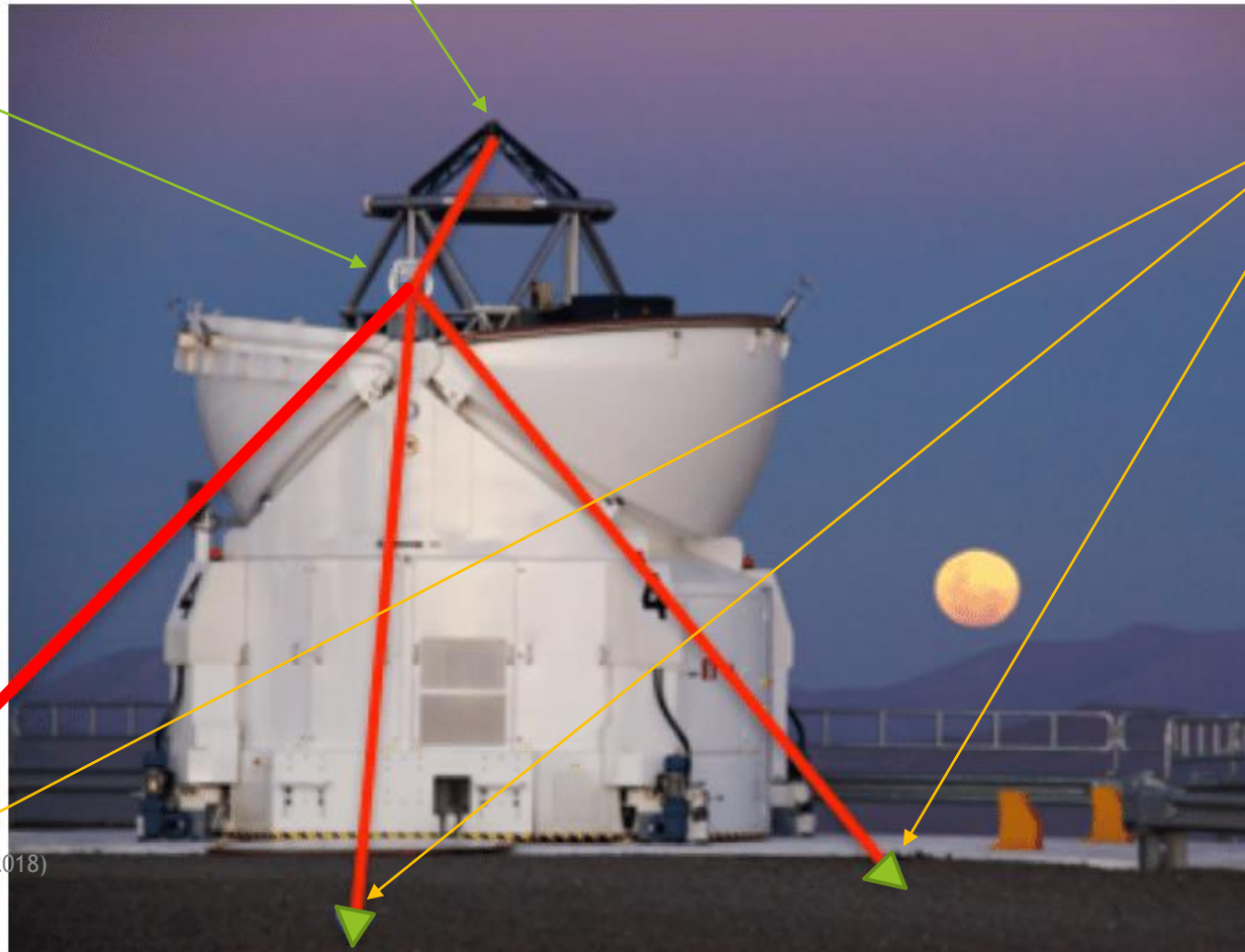


References for position measurement

3D point position measurement

Laser tracker

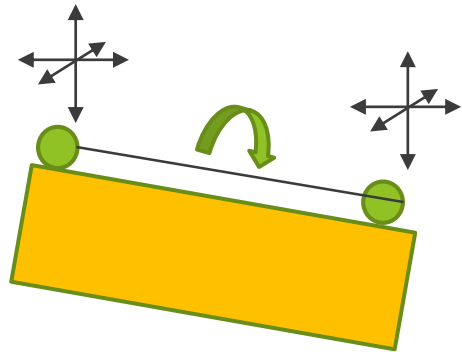
Fiducial point
(Reference)



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References for position measurement

- Big LHC magnet precisely oriented in 6 DoF along the LHC tunnel:
3D position + 3D angle
- 3D angle orientation achieved by positioning of 2 or more points



Reference points along tunnel

Fiducial points



Ancient alignment is still hi-end level !!!

How do edges of pyramids are aligned?



Nowadays it's still complicated task

How do edges of stones are aligned?



Almost impossible to repeat

BIG magnets - tiny crystals

What do work well for large objects like magnets
doesn't work for tiny crystals

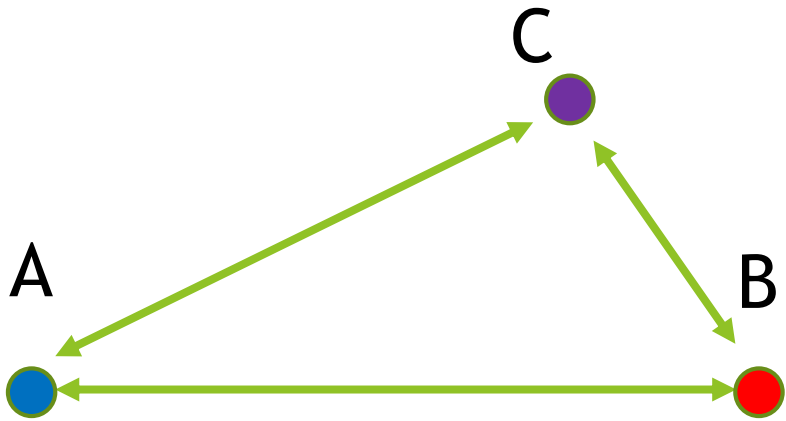
- Magnet dimension -> few meters
 V x1000 smaller
- Crystal dimensions -> few millimeters

Method of higher resolution by x1000 to be used

- Position of crystal is less critical -> easy to provide
- Angle of crystal is most critical -> tricky task

BIG magnets - tiny crystals

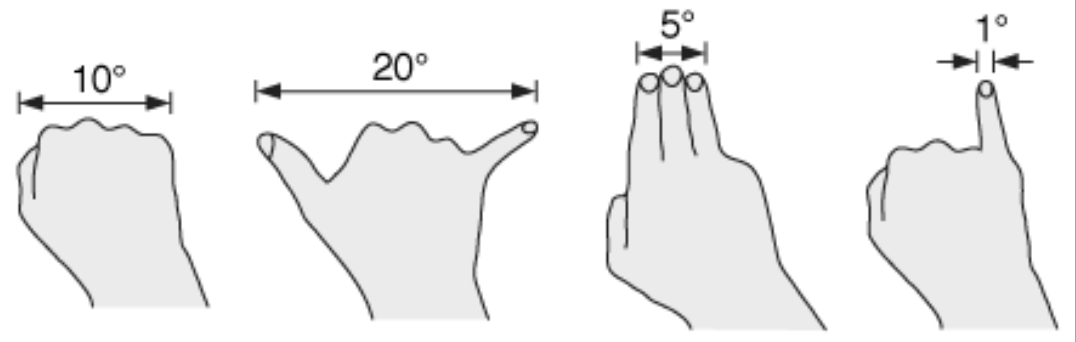
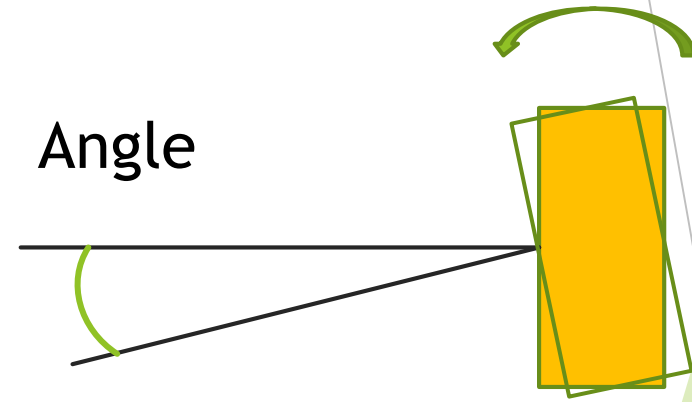
Large objects -> Position measurements



Triangulation allows 6DoF measurement

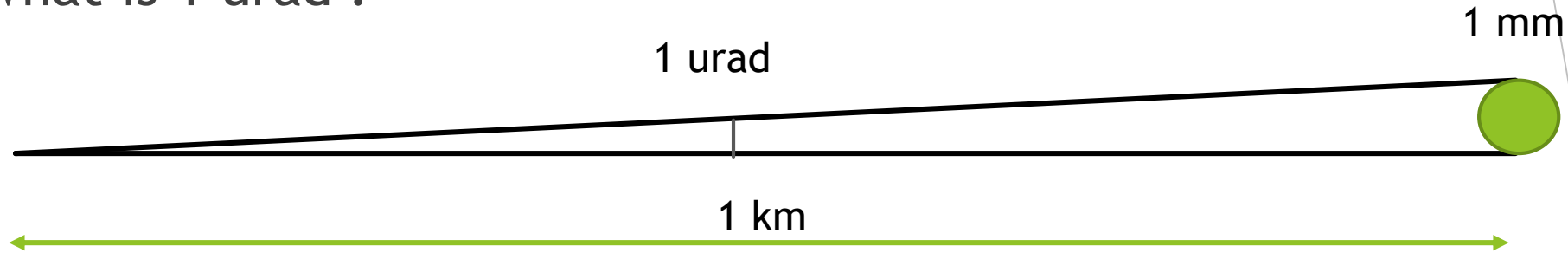


Small objects -> Angular measurement



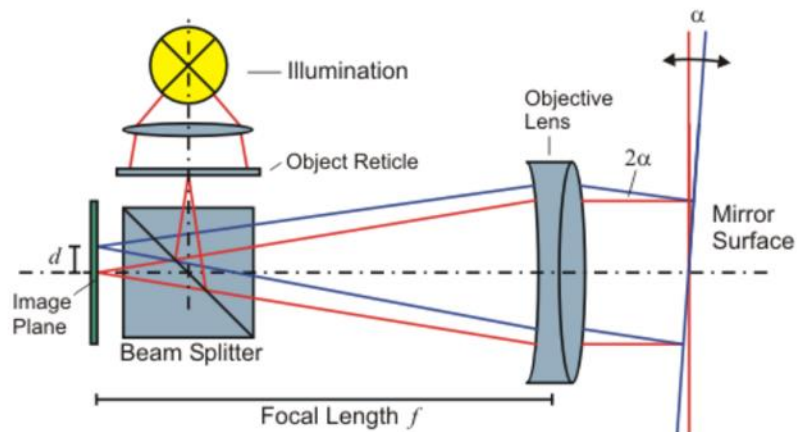
Level of magnitude in angle

What is 1 urad ?



How to measure?

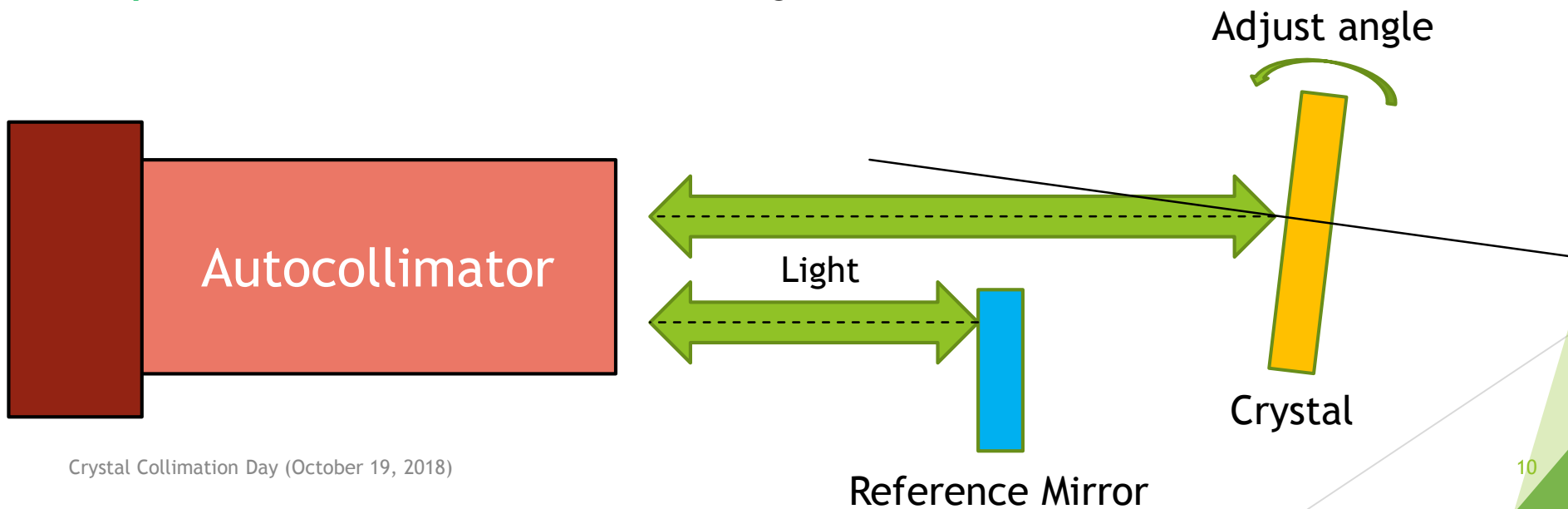
Autocollimator allows to measure angle in sub-urad level



Works **only** with reflective surface

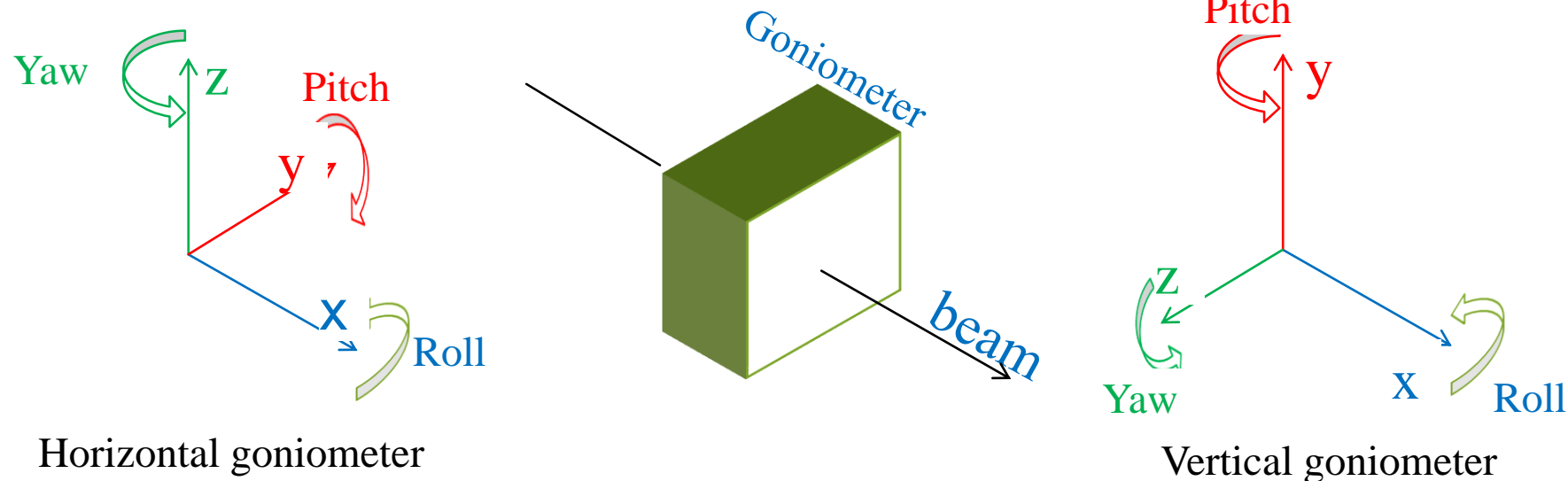
How to align crystal in angle?

- ▶ The good absolute reference is needed → “Large” **Mirror** as reference to be used
- ▶ Align **Reference Mirror** with traditional survey method by laser tracker
- ▶ Align **Autocollimator** with respect to **Reference Mirror**
- ▶ Align **Crystal** with respect to **Reference Mirror**
- ▶ **Repeat 3 times** for Yaw, Roll, Pitch alignment



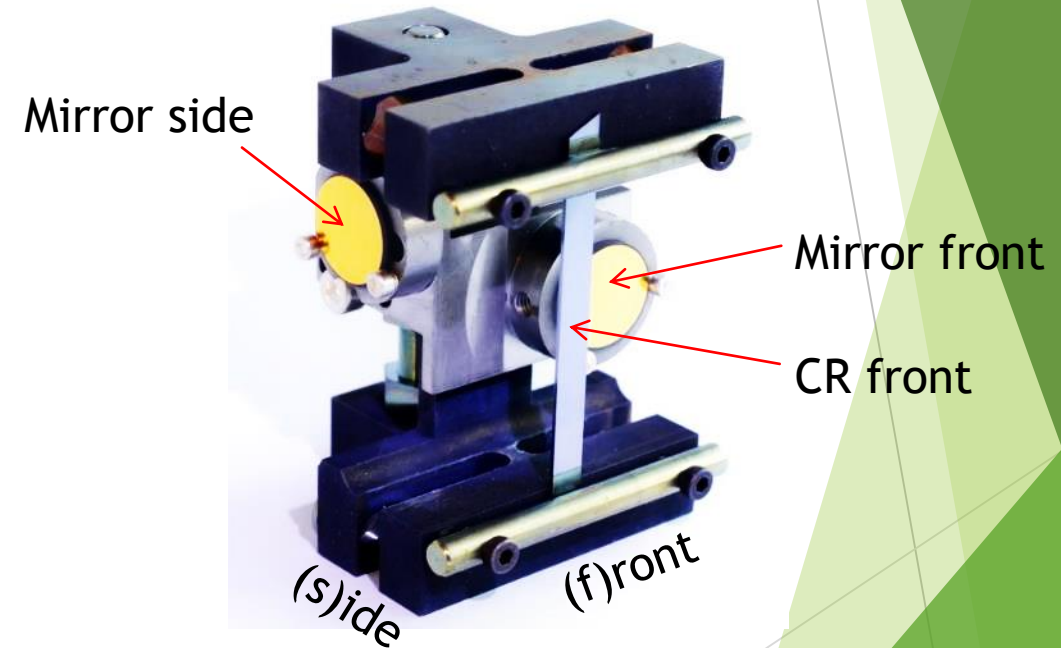
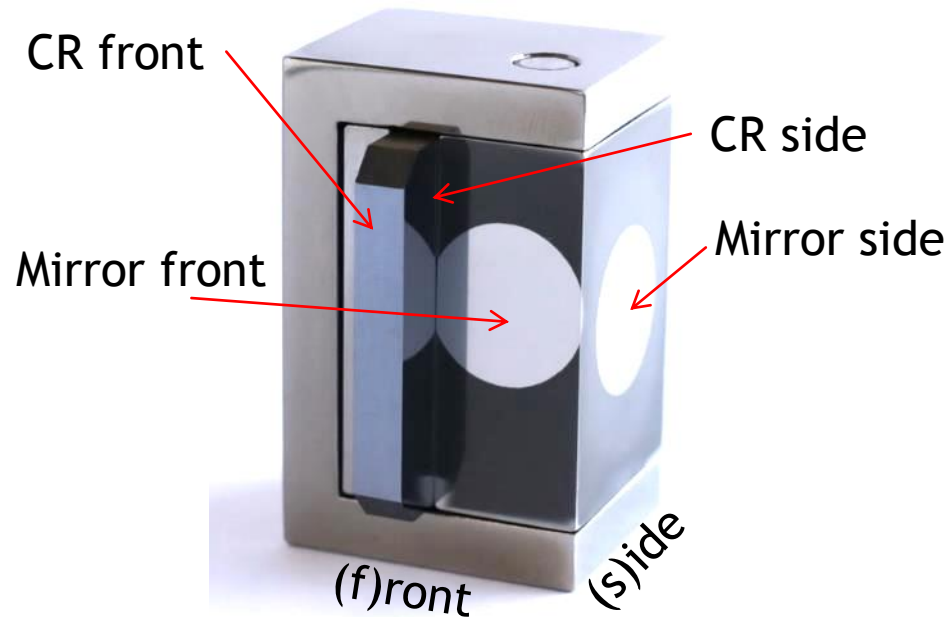
How to align crystal in angle?

- ▶ Align goniometer
- ▶ The good absolute reference is needed → “Large” **Mirror** as reference to be used
- ▶ Align **Reference Mirror** with traditional survey method by laser tracker
- ▶ Align **Autocollimator** with respect to **Reference Mirror**
- ▶ Align **Crystal** with respect to **Reference Mirror**
- ▶ **Repeat 3 times** for Yaw, Roll, Pitch alignment respectively



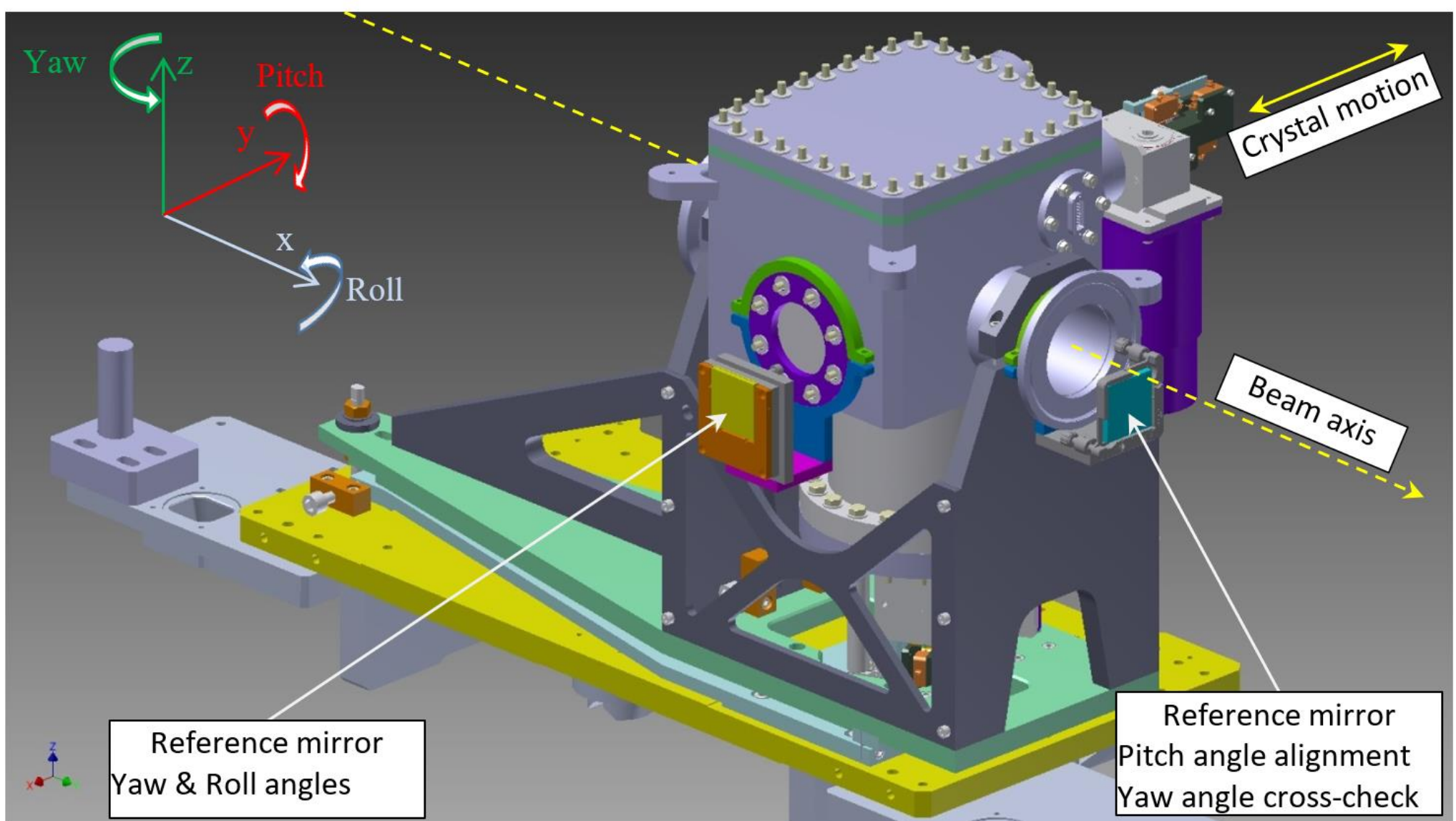
Crystal vs. Mirrors alignment

- ▶ Crystal surface is visible by autocollimator
- ▶ In some cases additional mirror to be embedded in crystal assembly



Crystal alignment in LHC

Horizontal goniometer requires 2 reference mirrors



Crystal

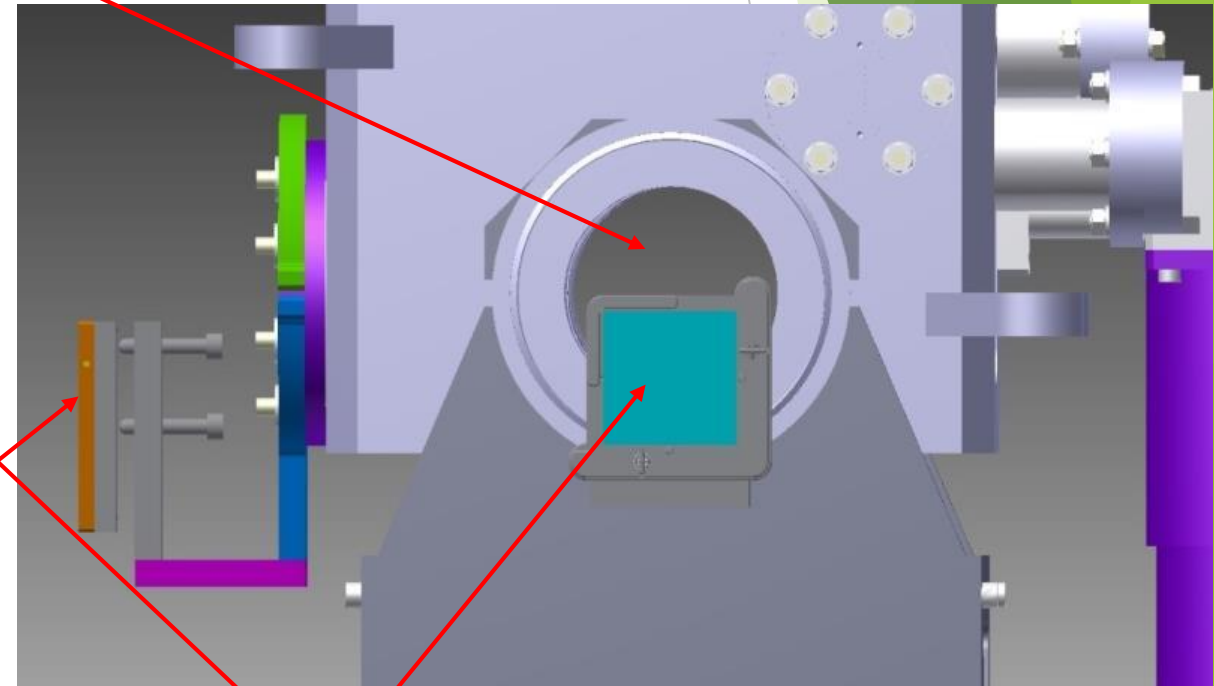
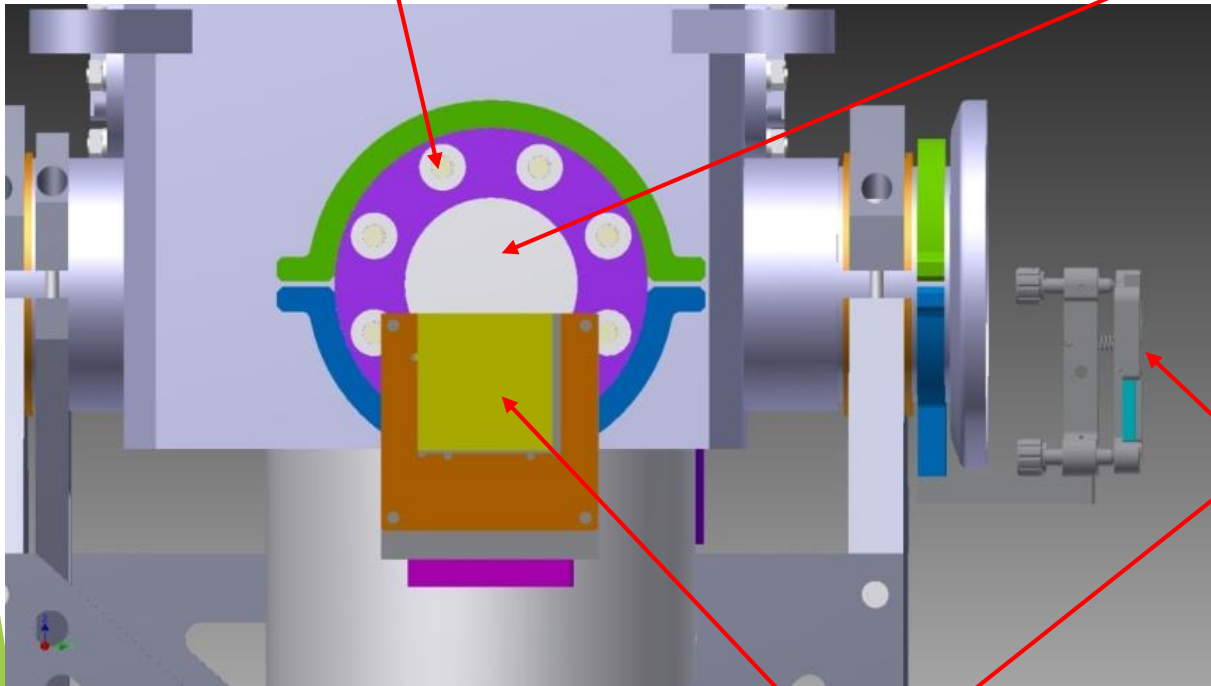


Crystal alignment in horizontal LHC

Horizontal goniometer requires 2 reference mirrors

Viewport

Yaw - Roll
Reference mirror

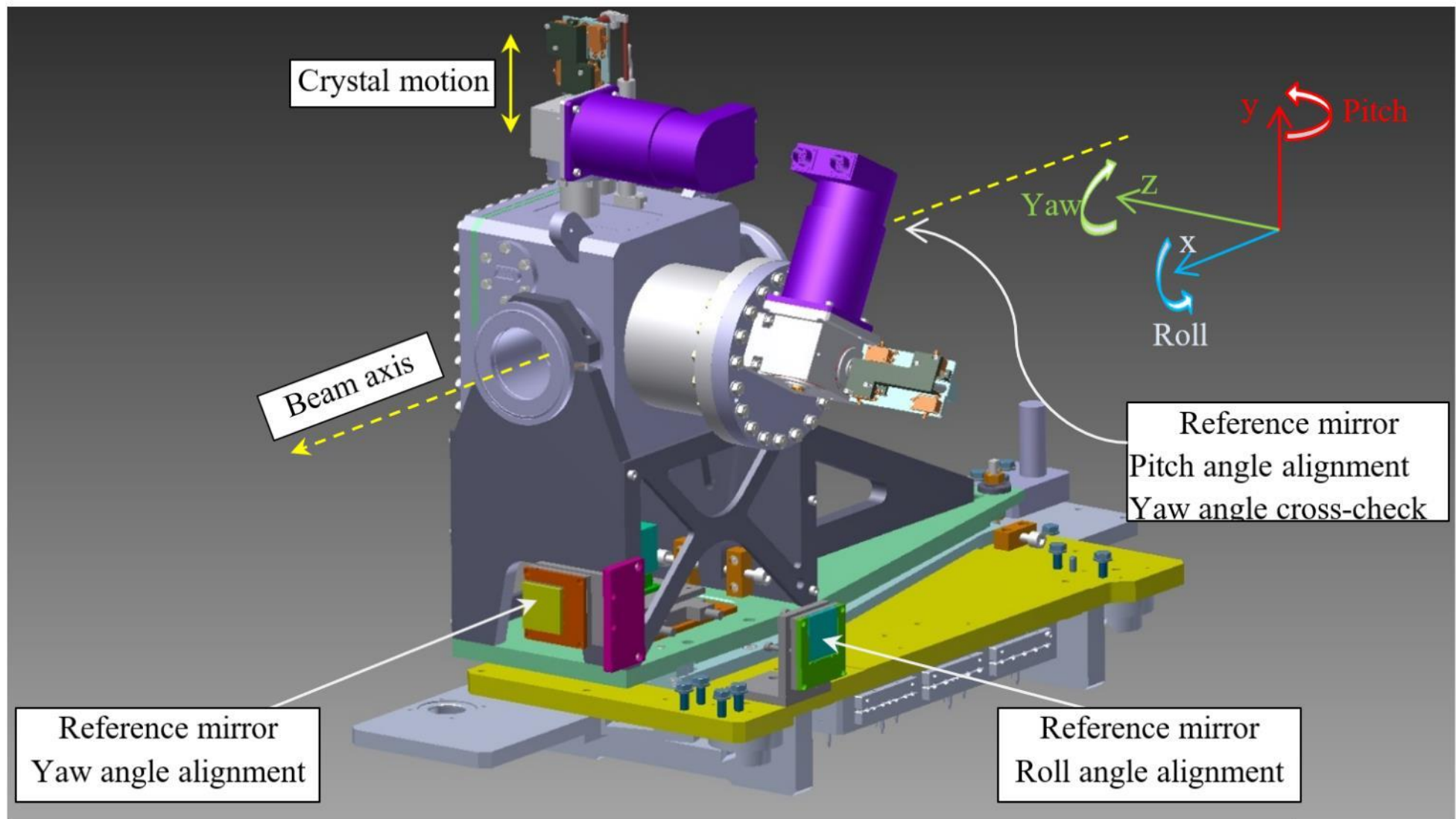


Yaw - Roll
Reference mirror

Pitch (Yaw cross-check)
Reference mirror

Crystal alignment in LHC

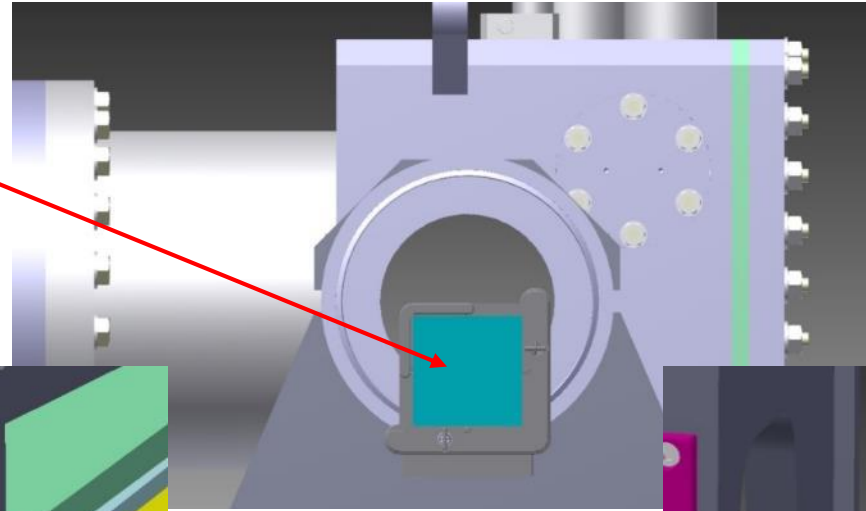
Vertical goniometer requires 3 reference mirrors for Yaw, Roll, Pitch respectively



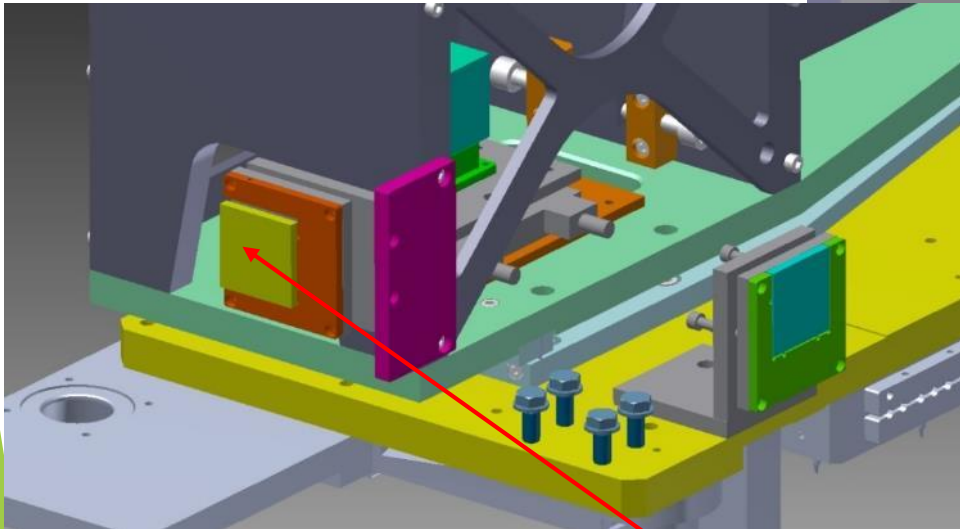
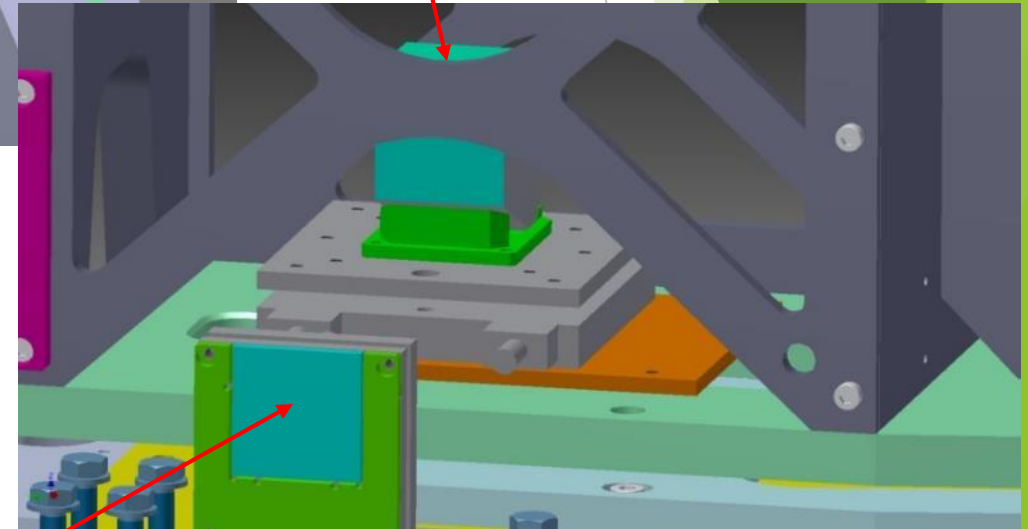
Crystal alignment in vertical LHC

Vertical goniometer requires 3 independent reference mirrors for Yaw, Roll, Pitch axis

Pitch
Reference mirror
(Yaw cross-check)



Pentaprism

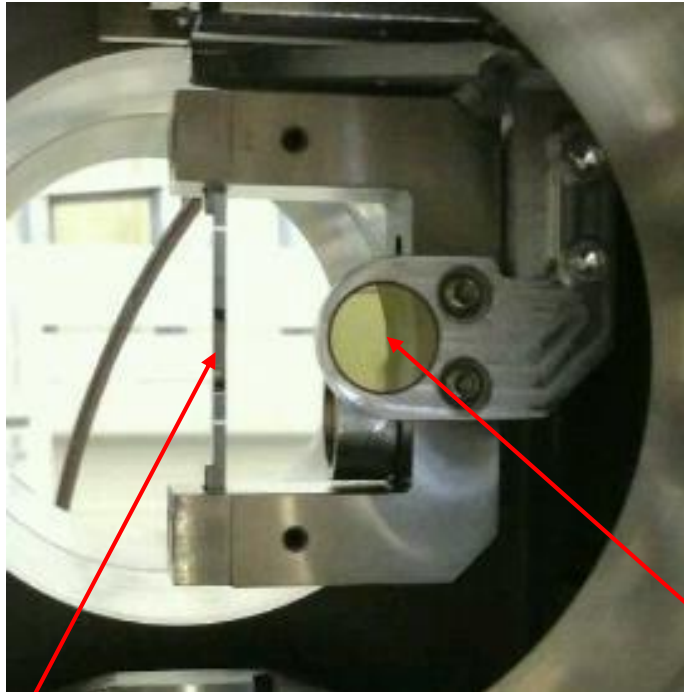


Yaw
Reference mirror

Roll
Reference mirror

Crystal Installation into LHC goniometer

Alignment of horizontal piezoLHCgonioH for B2 with TCP76 in January - February 2018



Crystal

Additional reference mirror

Conclusions

- ▶ Installation and Alignment of crystal is still delicate task
- ▶ Methods of crystal alignment were developed within UA9 experiment
- ▶ Alignment of crystals was performed few times:
 - In SPS since 2010
 - For LHC since 2015
- ▶ The total uncertainty of alignment can reach up to ± 1000 urad due to:
 - Reference mirror alignment uncertainty \rightarrow typically ± 100 urad
 - Viewport non-flatness getting angular offset due to refraction \rightarrow Some viewport gets ± 300 urad
 - Back-out up to 250 degC deforms goniometer mechanisms
- ▶ The design of goniometer to be compatible with crystal alignment procedure

Backup

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