



Alignment of TAXS and VAX

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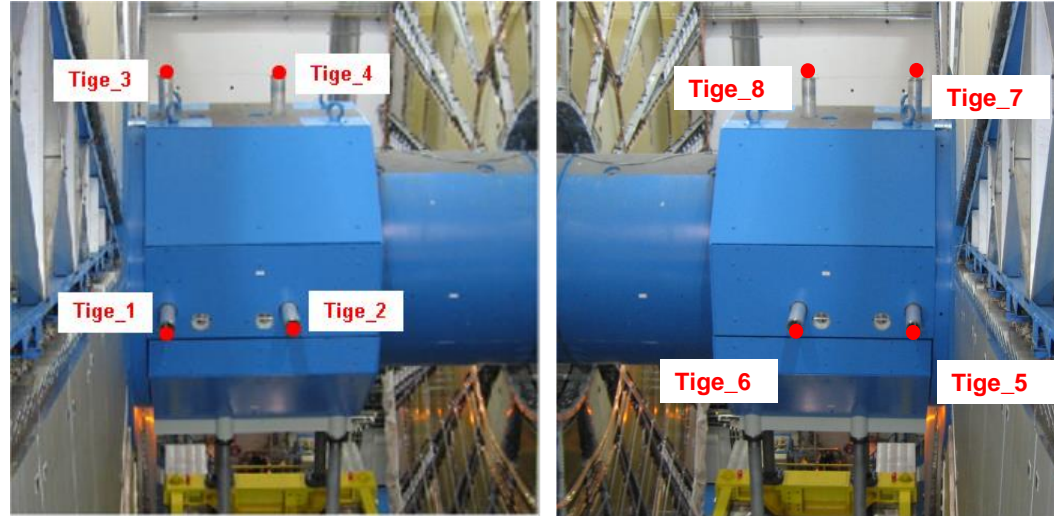
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TAS actual situation (ATLAS)

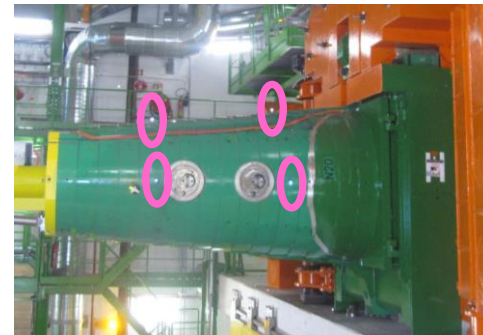
- The TAS has four reference points, no redundancy
- Measured using 2.5 m long and flexible rods
- The rods are of two pieces (ATLAS) passing through the shielding
- Only 4 out of the 6 DOF can be calculated
- The TAS has no roll interface
- The TAS has no longitudinal reference
- TAS is neighbouring element to Q1 but measured from the cavern side



- Movements of ATLAS TAS:
- Movement of TX1STM (and TAS) by 0.6-0.7 mm on IP-side due to removal of JFC1-3

TAS actual CMS situation (CMS)

- TAS alignment based on bars attached to TAS and traversing the FIN shielding (green)
- Single parts of bars stay permanently
- Only the 1st part is fix inside FIN
- Laser Tracker targets are used since LS2
- Non-contact measurement on permanent targets
- NFS shielding needs to be dismantled and rotating shielding open for measurement
- Z-coordinates of 2 top points determine vertical alignment
- X-coordinates of 2 side points determine radial alignment
- Manual intervention with constraints on configuration, planning

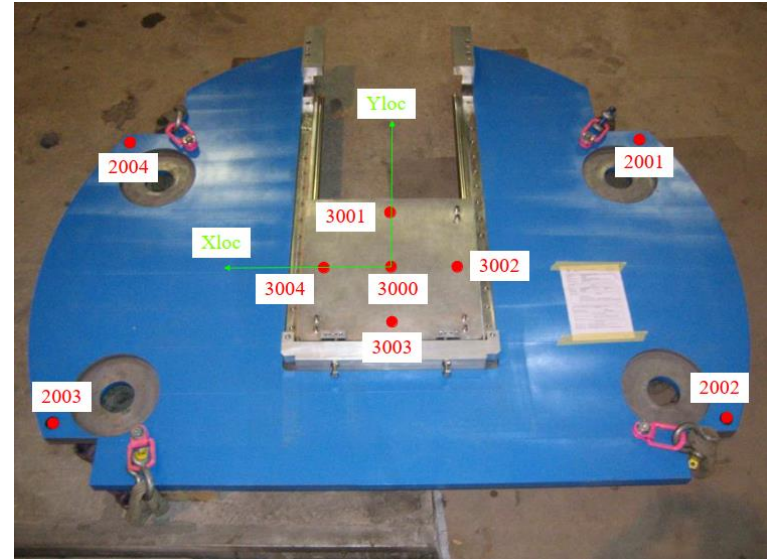


ATLAS TAXS Survey Procedure

- Same alignment procedure as since 2007 for TAS (no motorisation)
- Fiducials on 2 vertical and 2 horizontal bars, made of two parts
 - 1st part fixed and 2nd part needs to be (dis-)mounted manually for opening/closing
- Access with cherry picker for bar, target installation and adjustment
- Measurement frequency: twice every YETS/EYETS/LS
- Adjustment frequency to be defined, possible at each measurement
- ATLAS: YETS/EYETS/LS if difference to nominal > threshold
- Measurement with laser tracker (AT40x) and temporarily installed high precision 1.5-inch targets
- Radiation dose next to TAXS bars < 10uSv/h as outside JFS in LS6

Surface measurements TAXS (ATLAS) 1

- Fiducialisation measurement of the two new ATLAS VJ-plates (**0.05-0.10 mm at 1 sigma level**):
 - Definition of the survey reference holes on the new VJ-plate (4x close to adjustment system)
 - Fiducialisation in operational position (isostatic support)
 - Measurement of 4x survey reference holes, adapter plate sliding on the two rails with 5 reference points, direct measurement of guiding rails
 - Optional test measurement with the empty vaxbox

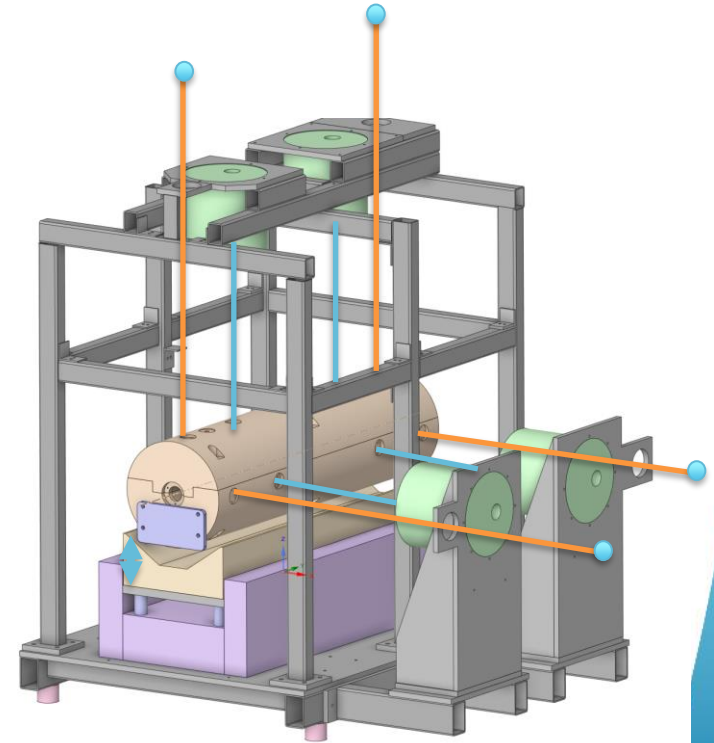


Original VJ-plate fiducialisation (2007)

Surface measurements TAXS (ATLAS) 2

Fiducialisation measurement of TAXS on surface (0.05-0.10 mm at 1 sigma level):

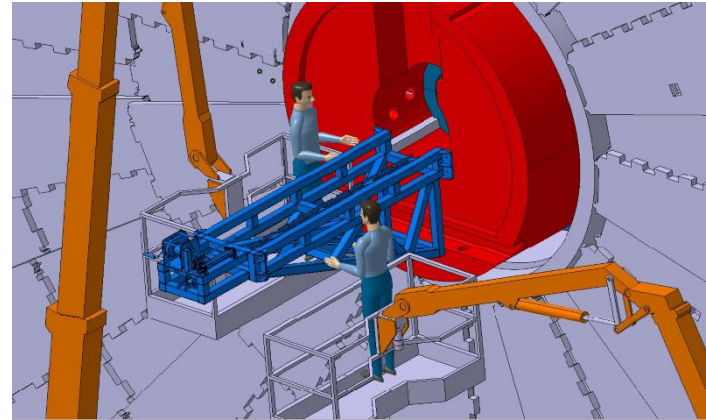
- In workshop B867 (stable floor, stable and stable bars installed perpendicular, which needs special tooling). The TAXS should be in inclined position ($\pm 0.708^\circ$).
- Check the perpendicularity of the bars to the beampipe. Measure M10 holes for bar fixation to TAXS.
- List of measured features:
 - 4 fiducials per half shell
 - 4 fiducials on bar ends
 - M10 holes for bar fixation
 - Points along the vacuum pipe steps using prism on bar or a mole
 - End flanges of the vacuum pipe
 - Measurement of the survey reference points and 3 balls of the M1 support plate
 - Measurement of the M1 references as beam pipe flanges (no bellows) to validate the alignment wrt TAXS beam pipe



Cavern measurements TAXS (ATLAS)

Initial placement in the cavern at installation of TAXS before connection to beampipes (**0.75 mm at 1 sigma level**)

- Access via cherry-picker and special configuration with JFS and JFC1,2,3 dismantled and Big Wheel open
- Laser tracker on the extraction/insertion tool of the TAXS (visibility)
- Considering the ATLAS floor movements (~ 0.2 mm/year in cavern centre).
- Measurement of longitudinal position and initial roll of the TAXS at installation.



Cavern measurements TAXS (ATLAS)

Final alignment at end of LS3 (**0.75 mm at 1 sigma level**):

- Configuration and access for measurement (BW in run position, JFS, TAXS bars installed and accessible with Palazzani)
- Measurement of 2 x 2 TAXS reference points and access outside JFS shielding
- Precise alignment using alignment pods and fiducialisation data
 - Nominal position to be provided by equipment owner
 - Eventually considering the ATLAS ITK position after installation and its movement up to end of LS3.
 - No measurement of longitudinal position
 - No measurement of roll of TAXS

Cavern measurements TAXS (ATLAS)

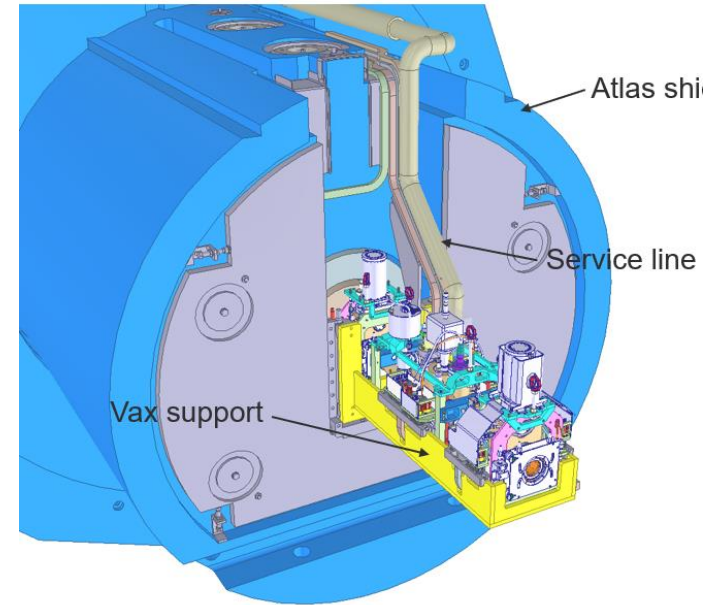
- Maintenance measurement at start and end of each YETS, EYETS and LS (**0.75 mm at 1 sigma level**)
 - Measurement of position at opening
 - Measurement and adjustment at closure based on physics data of ITK and inner triplet position
 - No measurement of longitudinal position
 - No measurement of roll of TAXS
 - Access to survey targets outside the JFS possible up to LS6 confirmed by RP simulations

Measurements for ATLAS Vaxbox (surface)

- Preparation:
 - Integration of 4-8 permanent CERN survey references holes 8H7 that can be equipped with permanent targets
 - Mainly facing USA-side, distributed close to the vaxbox corners
 - Validation of the reference targets and the vaxbox envelope and visibility of references in cavern
 - Deformation test of the vaxbox based on the weight of modules 2 and 3 and attached VJ beam pipe mechanics
- Fiducialisation measurement of the vaxboxes (**0.05-0.10 mm at 1 sigma level**):
 - Measurement of the spherical contact surfaces for the modules 2 and 3 (directly and using the alignment plates)
 - Measurement of all available CERN survey reference holes on each vaxbox
 - Measurement of the reference surfaces for the installation and local coordinate system
 - Measurement of the cylindrical pins at different diameters (**0.3 mm at 1 sigma level**)
 - Measurement of the key features for envelope as defined by equipment owner (**1-2 mm at 1 sigma level**)

Measurements for ATLAS Vaxboxes (cavern)

- Initial placement and adjustment in the cavern at end of LS3 (**0.75 mm at 1 sigma level**)
 - Configuration and access using cherry picker for point installation and mechanical adjustment
 - Precise alignment as for final adjustment using VJ-plates and bottom pushing screws
 - Nominal position to be provided by equipment owner
 - Eventually considering the ATLAS floor movements for the positioning.
- Maintenance measurements of vaxbox (**0.75 mm at 1 sigma level**):
 - Regular measurement of the permanent CERN survey reference points (every YETS, EYETS and 2x in LS approximately 1x per year)
 - No further adjustment of the vaxbox is expected



Maintenance of ATLAS vaxbox

- Preparation for the extraction of the vaxbox from ATLAS
 - Measurement of TAXS position and vaxbox position (**0.75 mm at 1 sigma level**):
 - Analysis of the TAXS and vaxbox measurement data to evaluate the relative alignment
 - If better than 1 mm – no further action
 - If worse than 2 mm
 - Definition of displacement values for TAXS by WP8 and vacuum
 - Voluntary displacement of TAXS to reduce the offset for disconnection of modules 1/2 (**0.75 mm at 1 sigma level**):
 - If between 1 mm and 2 mm, discussion with vacuum and WP8 to take decision
- Preparation for the re-installation of the vaxbox and connection of modules 1 and 2
 - Optional re-measurement of TAXS position (**0.75 mm at 1 sigma level**):
 - Analysis of the TAXS and earlier vaxbox measurement data to evaluate the relative alignment and action if needed
- Re-installation of the vaxbox from ATLAS (**0.75 mm at 1 sigma level**):
 - Measurement of vaxbox position
 - Measurement and adjustment of TAXS position based on ATLAS ITK data
 - Attention: vaxbox installation and TAXS measurement need different configuration!

CMS TAXS Survey Procedure

- Similar alignment procedure as for TAS (no motorisation)
- NFS dismounted and open position of the rotating shielding
- Fiducials on 2 vertical and 2 horizontal bars
 - Single part fixed on TAXS and with permanent laser tracker target
 - Short and rigid bars provide 3D coordinates. In best case scenario redundancy, roll value and longitudinal position.
- Measurement frequency: 1-2x every YETS/EYETS/LS
- Adjustment frequency to be defined, possible at each measurement
- Measurement with laser tracker and permanent installed 0.5-inch RFI targets

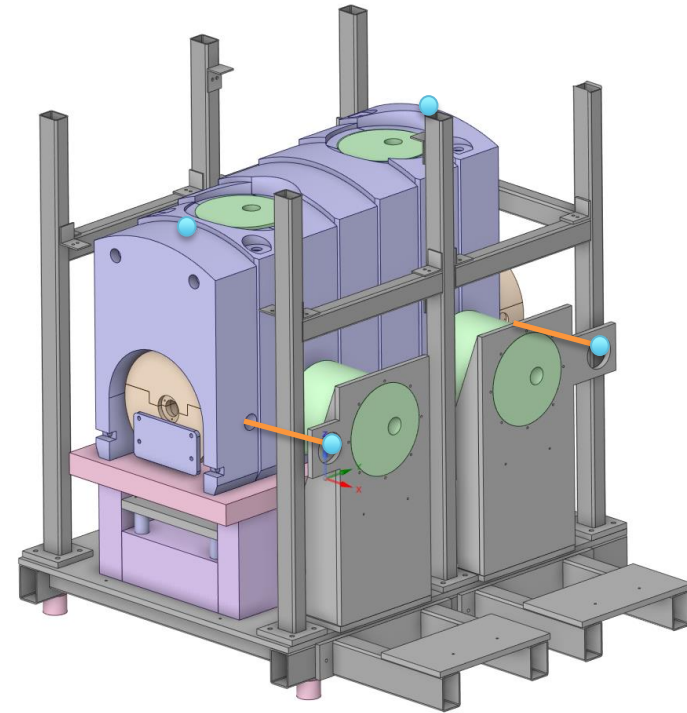
List of necessary measurements (CMS)

- Test of adjustment system on surface mock-up (similar to ATLAS)
- Fiducialisation of the two TAXS (similar to ATLAS)
 - Installation of bars without support (single, shorter piece) to get them stable and straight during the measurement.
- Fiducialisation of CMS vaxbox with ball interfaces and guiding pins
- Adjustment of the new TAXS to final position soon after installation (pre-alignment, longitudinal)
- Final adjustment of the TAXS at the moment of CMS closure following the usual procedure. A small adjustment of the TAXS has to be expected and authorized by vacuum team

CMS preparation sequence (surface)

Fiducialisation measurement of TAXS on surface (0.05-0.10 mm at 1 sigma level):

- In workshop B867 (stable floor, stable bars). The TAXS should be in inclined position ($\pm 0.708^\circ$).
- Check the perpendicularity of the bars to the beampipe. Measure M10 holes for bar fixation to TAXS.
- List of measured features:
 - 4 fiducials per half shell
 - 4 fiducials on short bar ends
 - M10 holes for bar fixation
 - Points along the vacuum pipe step xxx mm using prism on bar or a mole
 - End flanges of the vacuum pipe
 - Measurement of the survey reference points and 3 balls of the M1 support plate
 - Measurement of the M1 survey references and beam pipe flanges (no bellows) to validate the alignment to TAXS beam pipe

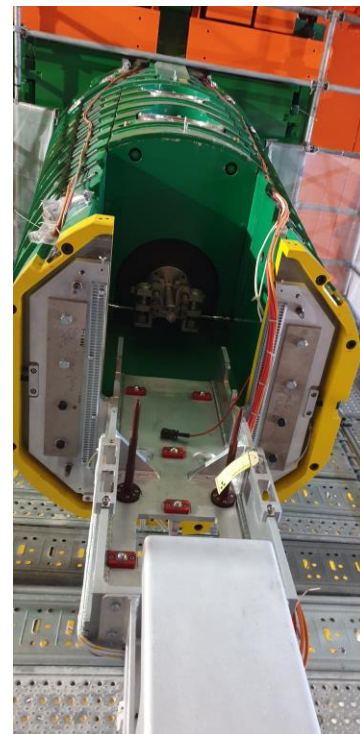


CMS TAXS alignment in cavern

- Initial placement in the cavern at installation of TAXS before connection to beampipes (**0.75 mm at 1 sigma level**)
 - Configuration like final measurement
 - Measurement of 2 x 2 TAXS reference points
 - Alignment precisely as for final adjustment using alignment pods using fiducialisation data
 - Nominal position to be provided by equipment owner
 - Using Fiducialisation results to define longitudinal position and initial roll of the TAXS at installation and fixation using the z-stopper.
- Final measurement (alignment) at end of LS3 (**0.75 mm at 1 sigma level**):
 - Alignment precisely for final adjustment using alignment pods using fiducialisation data
 - Nominal position to be provided by equipment owner
 - Eventually considering the CMS Inner Tracker position after installation and its movement up to end of LS3.
 - measurement of longitudinal position based on fiducialisation
 - measurement of roll of TAXS based on fiducialisation

CMS VAX Box - Prototype

- Integration of survey reference holes
- Fiducialisation and installation of prototype done
- Laser Tracker measurements of fiducials, VAX equipment guiding balls and rods
- Re-design of vaxbox following feedback from LS2 installation
- Detailed procedure to be defined once the new design is available



Main differences of CMS to ATLAS

- Single, stiff bars with permanent targets for TAXS
- Measurement in different shielding configuration
 - Run configuration for ATLAS
 - Open rotating shielding for CMS
 - No Shielding plugs in FIN
- Non-contact measurements (no physical access needed after installation)
- Mounting and adjustment procedure of the vaxbox
- Different support of CMS vaxbox
- Control of measurement in 3D due to stiff bars with longitudinal and roll information

Measurement needs for vacuum modules

ATLAS and CMS Vacuum modules 1, 2 and 3

- Needs to be discussed in detail with equipment owner and could be:
- Measurement of the beam pipe axis of module 1, 2 and 3 with respect to the contact surfaces (V1, V2, V3) as preparation for future replacement (**0.05-0.10 mm at 1 sigma level**):
 - Measurement of beam pipe axis of installed modules with respect to TAXS or vaxbox fiducials in B867 mock-up
 - Access and visibility to beam pipe flanges is mandatory (no bellows)
 - Maintenance measurements for replacement module 1, 2 and 3 on surface (**0.05-0.10 mm at 1 sigma level**)
 - Measurement of the beam pipe axis of module 1, 2 and 3 with respect to the contact surfaces (V1, V2, V3) as preparation for future replacement
 - Envelope measurement of the module extremities as the valve top (**1-2 mm at 1 sigma level**)
 - Maintenance measurements for modules in cavern – NONE!

Error budget for TAXS measurements

- A) Target precision with support
 - B) Fiducialisation using mole or bar (to be produced)
 - C) Cavern network and link to UPS gallery
 - D) FRAS system (UPS gallery to Q1, Q2, Q3)
 - E) Fiducialisation of low-beta magnets
-
- Worst case (linear add 1 sigma):
 - A) 0.03 mm, B) 0.25 mm, C) 0.30 mm
 - D) 0.10 mm, E) 0.08 mm => **Total = 0.76 mm**

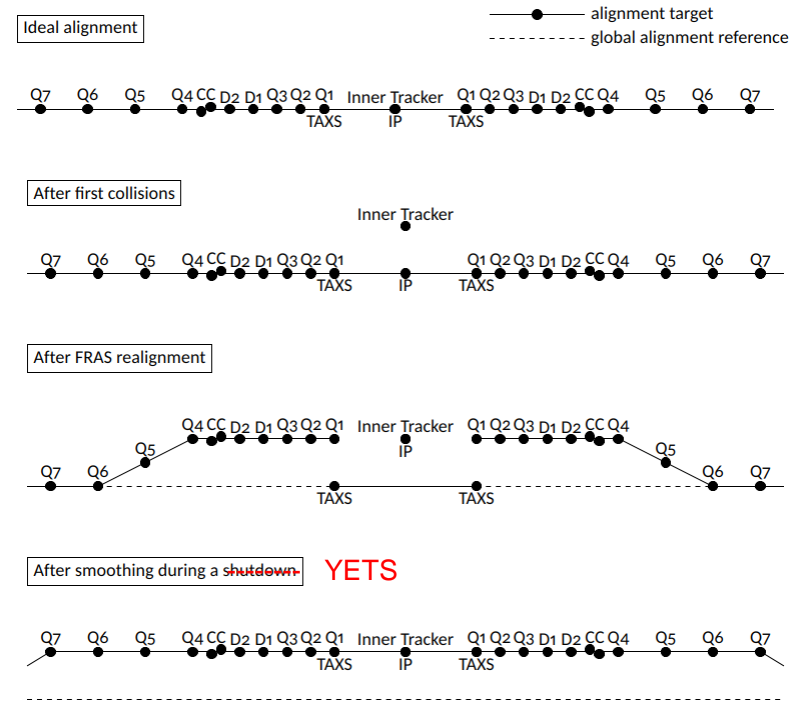
TAXS alignment sequence (ATLAS and CMS)

- The TAXS is NOT part of the FRAS system and needs manual alignment
- Major constraints for TAXS alignment due to inaccessibility of targets in RUN configuration
 - NFS and rotating shielding in CMS, missing cherry picker in ATLAS
- Critical case after first collisions and before first YETS to adjust the TAXS.

Table 13: Measurement uncertainty ($\xi_{\text{alignment}}$ at 3σ values) of the position of equipment external fiducials to requested position w.r.t. the global alignment reference for different equipment. TAXS longitudinal position is not measurable, mechanical tolerance would need to be used. For TAXS and beam pipes, the roll uncertainty is not relevant because the aperture is round.

Zone	Monitoring	H [mm]	V [mm]	S [mm]	Roll [mrad]
TAXS	No	2.25	2.25	not measurable	n.a
Q1 - D1	Yes	0.45	0.45	0.6	0.15
TAXN - CC	Yes	0.45	0.45	0.6	0.3
Q4-Q5	Yes	0.45	0.45	0.6	0.15
Q6-Q7	No	3.00	1.00	1.0	0.3
Beam pipes	No	1.00	1.00	5.0	n.a.

REFERENCE : LHC-G-ES-0023



General conclusion

- Measurement equipment and general procedure ready
- Detailed testing procedure for mock-up needs to be developed
- More details are needed for the measurements of vacuum modules 1, 2 and 3.
 - Survey procedure for the exchange of modules
- ATLAS and CMS procedure are similar but with significant differences in details
- Deformation can be critical (vabox, shielding weight)
- Alignment setups will be improved with respect to TAS
- Link to FRAS is manual but considered in procedures



Thanks for your attention!
Any questions?

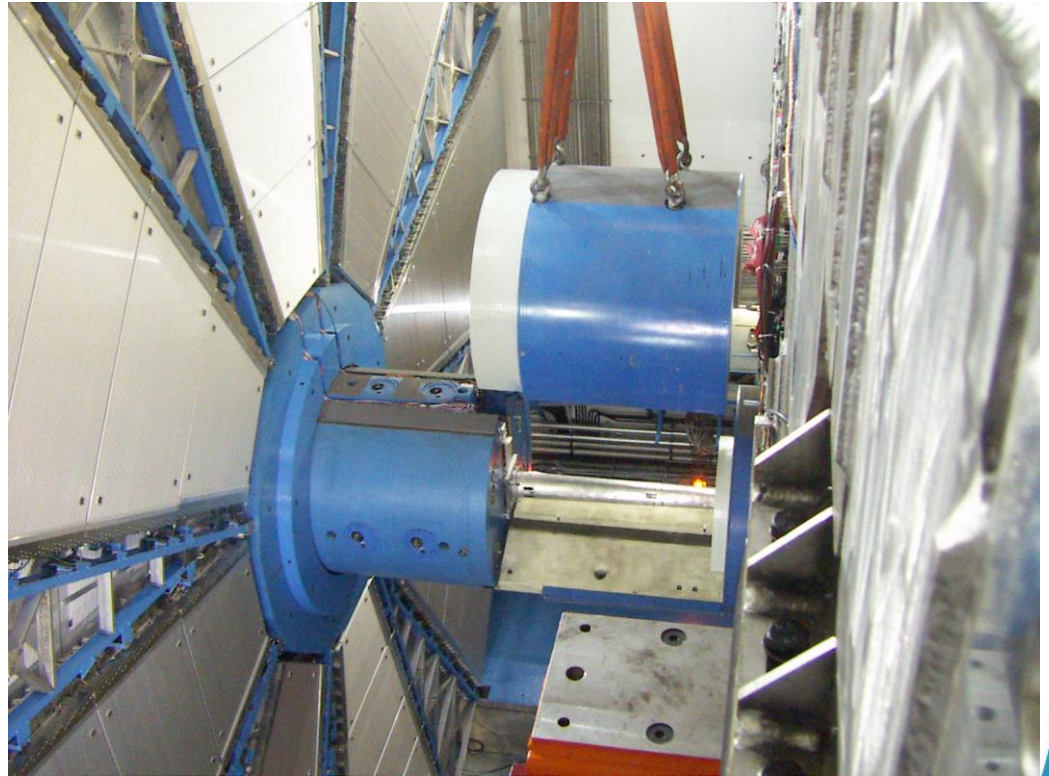


Special thanks to all WP 8 members

- **BACK-UP SLIDES**

ATLAS TAXS movements due to JFC1-3

- Weight of JFC1,2,3 changes position of TAXS and vaxbox
- Vaxbox aligned without JFC2,3
- TAXS aligned with JFC1,2,3 installed

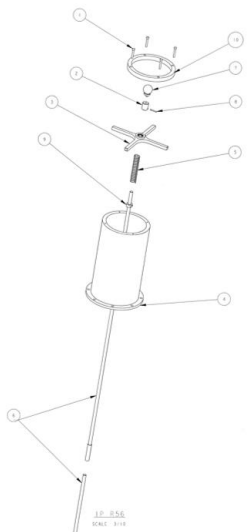


Disadvantages in ATLAS

- The survey system in ATLAS, consists of four bars from the TAS to the outside of the shielding where each target is placed.
- ATLAS: Removable targets on a removable bar connected to a permanent bar which connects with the TAS.
- The connection of these two bars is complicated: deep distance, no vision and no feedback.
- As there is no feedback, an endoscope is used to verify the connection is well done.
- The aim is to simplify this operation and therefore to reduce the time of radiation exposure.
- New system for bar connection to provide direct feedback at bar installation



Details of ATLAS installation



- ATLAS two bar system with fixation and survey target head
- ATLAS shielding plugs in JFS and TX1STM shielding parts
 - Reduction of background noise for the ATLAS experiment
 - Diameters of holes 25 mm – 40 mm
- Movement of TX1STM (and TAS) by 0.6-0.7 mm on IP-side due to removal of JFC1-3 shielding

