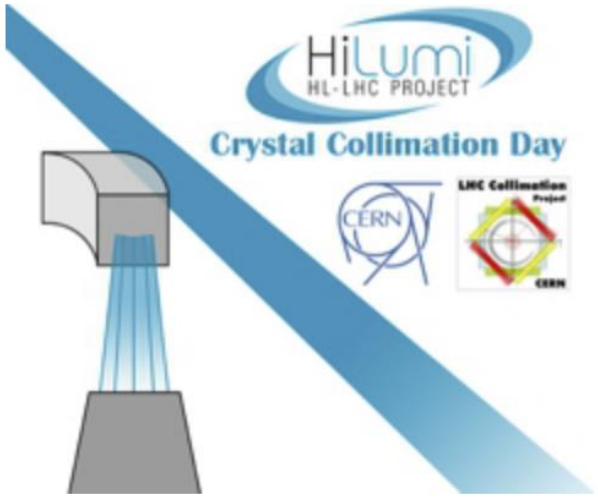


HL-LHC Crystal collimator day

Crystal HW LHC implementation

I. Lamas Garcia, R. Seidenbinder, C. Bahamonde, S. Gilardoni, M. Calviani (EN-STI)
in collaboration with EN-SMM

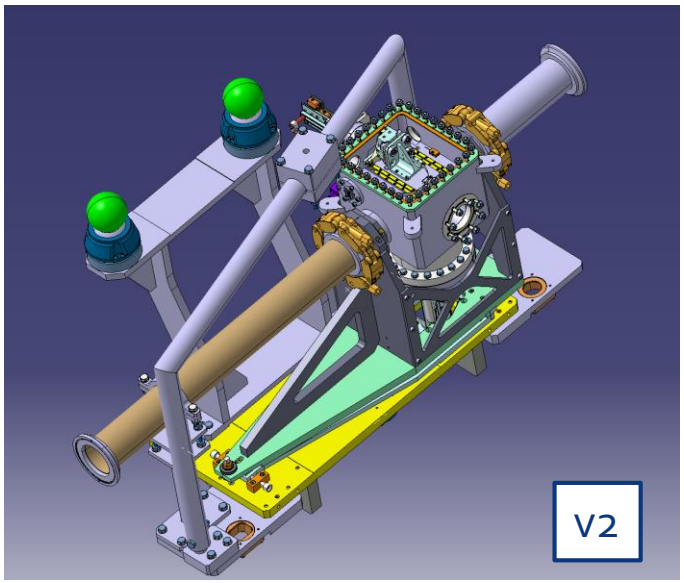
CERN | EN ENGINEERING DEPARTMENT

Outlook

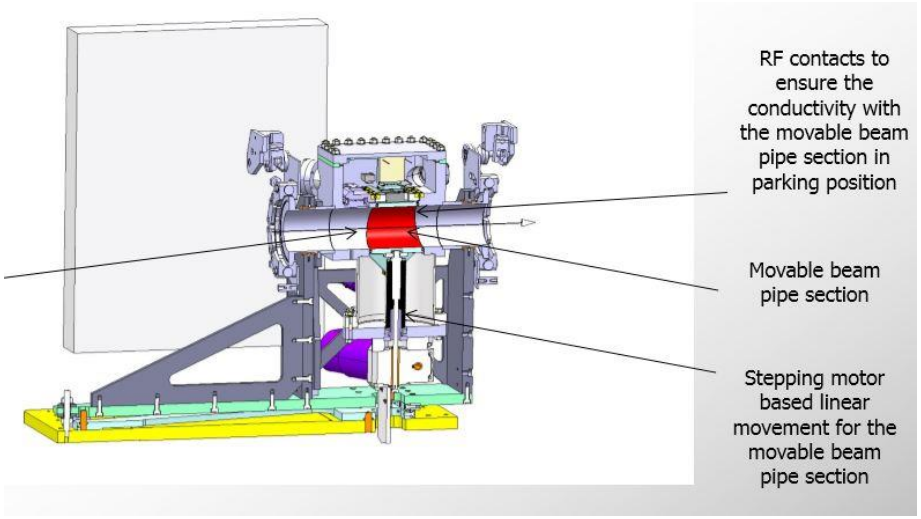
- Review of present system installed in the LHC machine
- Review of two version 1 installed goniometer, history and issues
- Review of two version 2 installed goniometer, history and issues
- Summary of new design (version 3) advantages plus possible new upgrades
- Radiation protection aspects and how much time it would take to change crystal and stage?
- Technical feasibility of the different proposed scenarios
- Conclusions

Review of present system installed in the LHC machine

Functional Type	Position	Crystal Type	Installation Year	Version
TCPCH	A4L7.B1	SD (INFN)	2013 (LS1)	1
TCPCV	A6L7.B1	QM (PINP)	2013 (LS1)	1
TCPCH	A5R7.B2	SD (PINP)	2018	2
TCPCV	A6R7.B2	QM (PINP)	2017	2

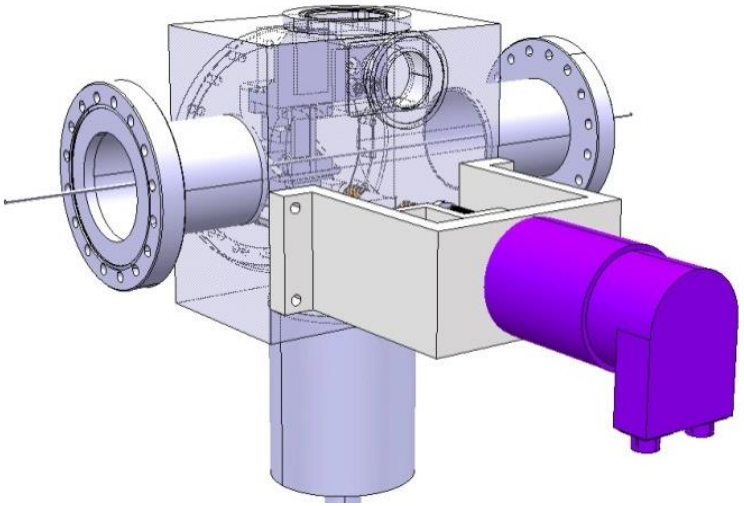


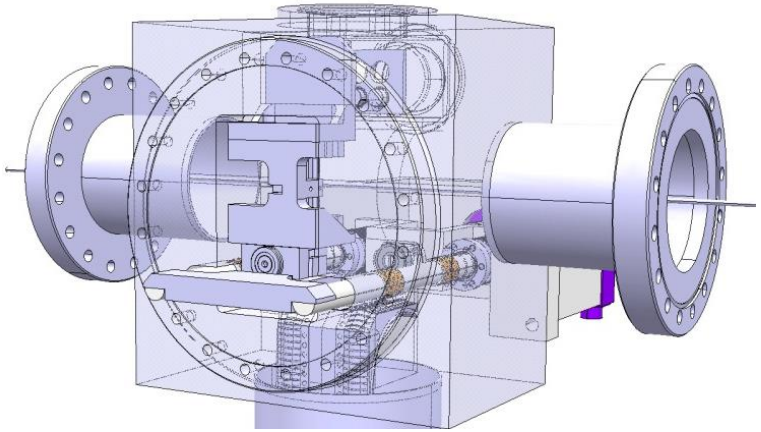
See M. Garattini's talk



Review of version 1 goniometer, history and issues

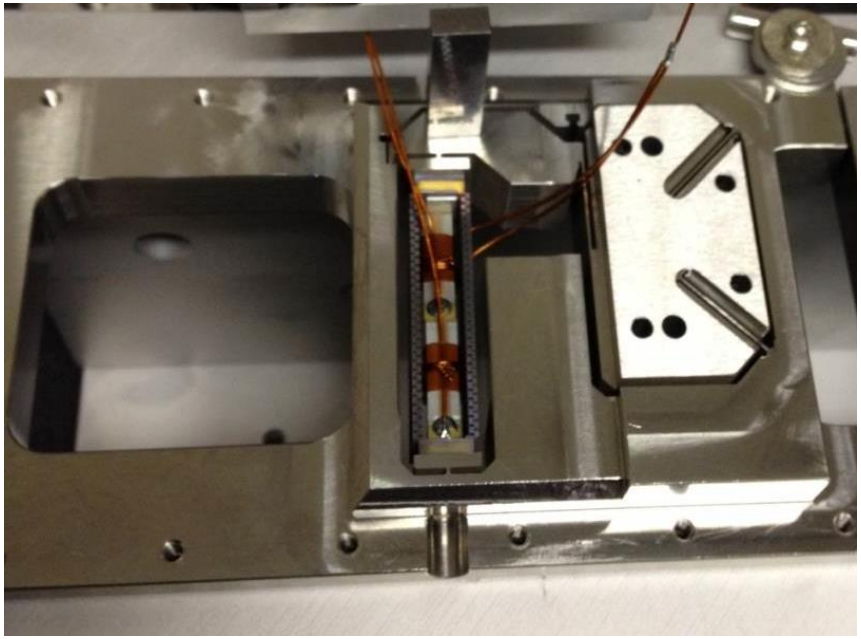
- 1st proposal version 1 included (prior to LS1):
  - The crystals parking position is located on the external side
  - Linear positioning/guiding system
  - View port in front of the crystal
  - Volume closed with a kind of portion of chamber just by closing the C-shape
  - **Electrical contact** between the tank and portion of the chamber

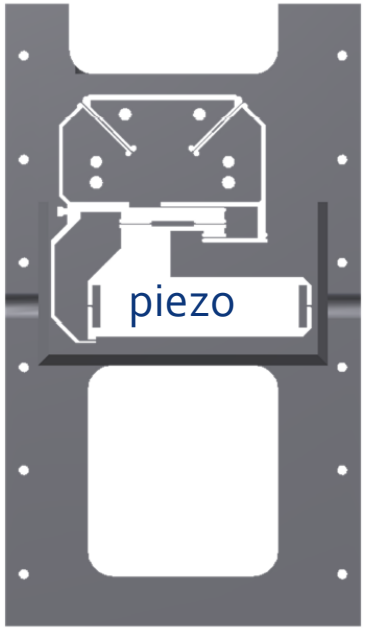




Review of version 1 goniometer, history and issues

- Final proposal version 1 included:
  - First generation of rotational stage, with piezo installed at 90 deg with respect to the piston/rotor
  - **Interferometric heads inside the vacuum**, i.e. impossible to modify after closure of the tank

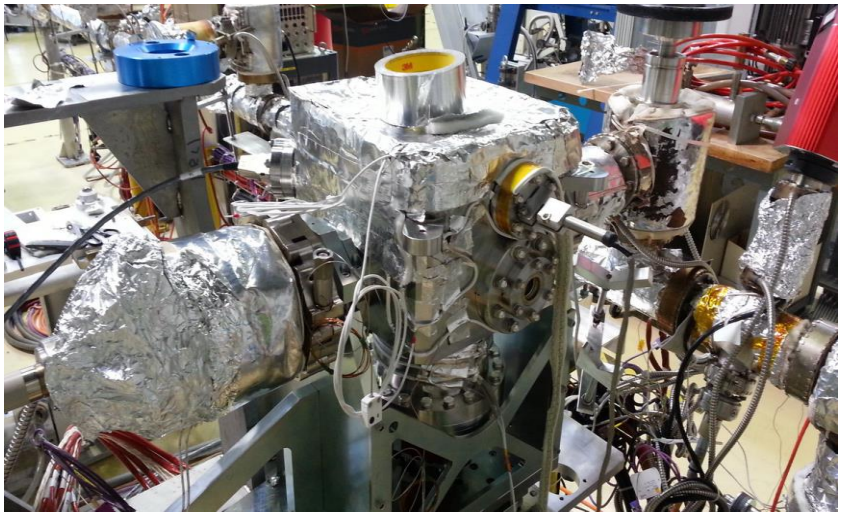


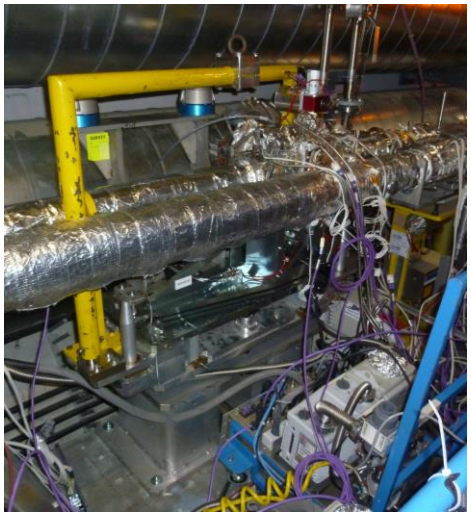


Review of version 1 goniometer, history and issues

- Final proposal version 1 included:
  - A lifting arm and supports for survey reference points
  - The center of gravity of the device was outside of the collimator stability plane – counterweight to move the center of gravity has been added
- Temperature limitations of optic fiber feedthrough for interferometric heads made device **unbakeable**

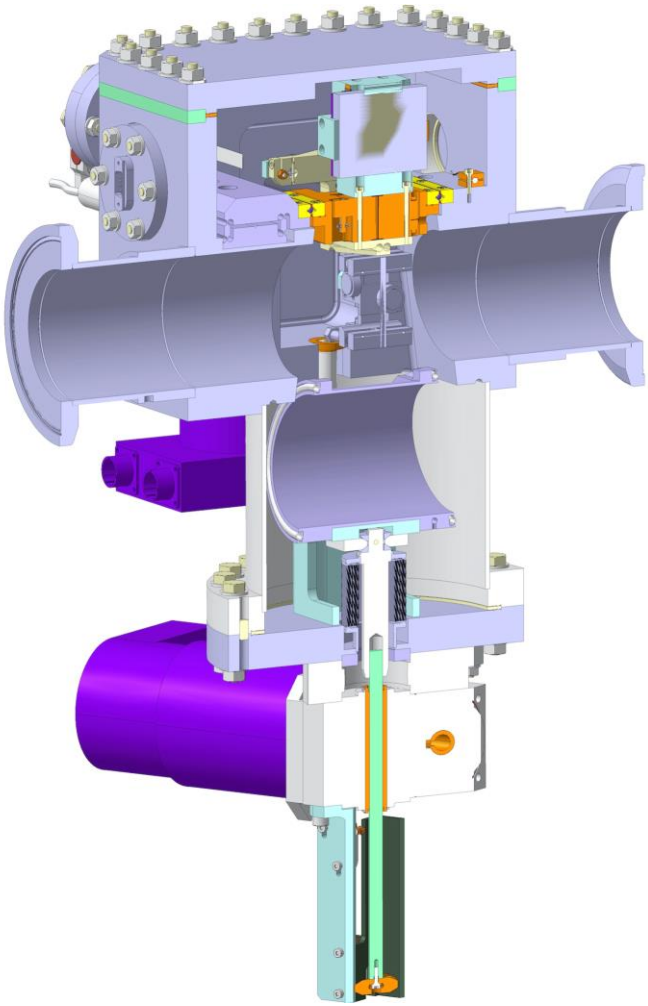
Two version 1 Crystal Collimators installed during LS1

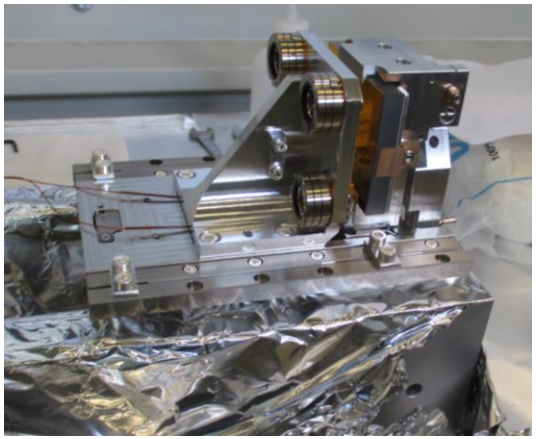


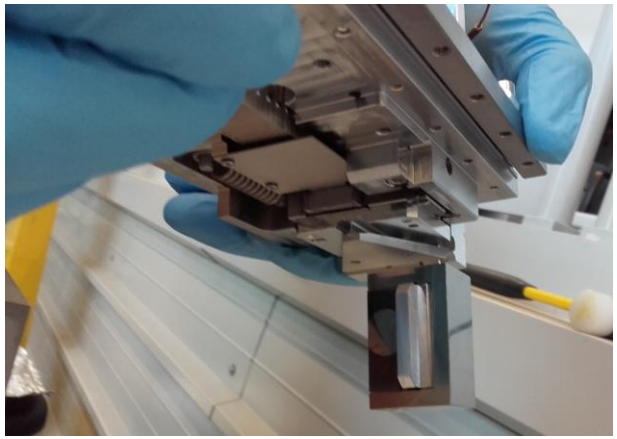


Review of version 2 goniometer, history and issues

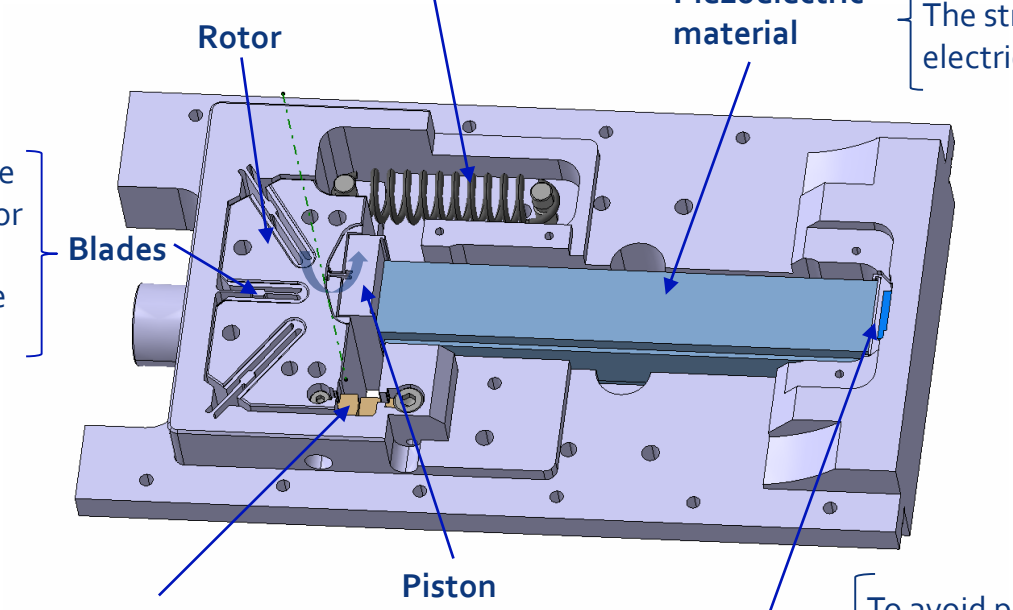
- Final proposal version 2 included:
  - A new design of the mechanical stage including a different kinematic chain
  - A new design of the mirror, optic heads support and the crystal holder, interferometer heads still **inside the vacuum tank**
  - Validated UHV optic fiber feedthroughs
    - → **Bake able device**



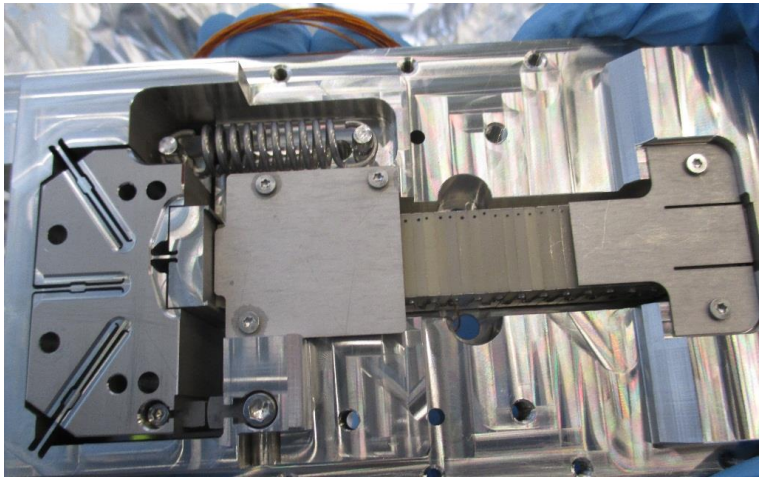


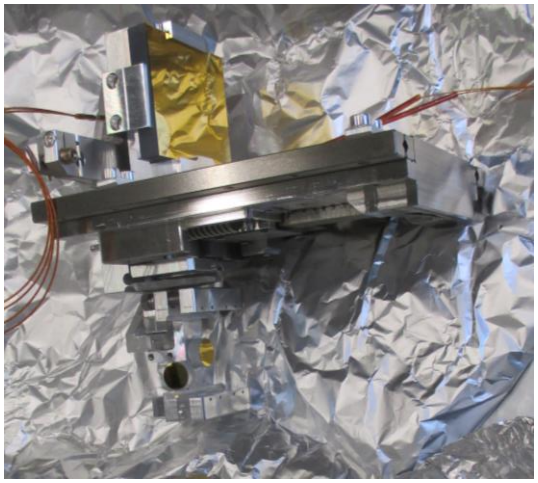


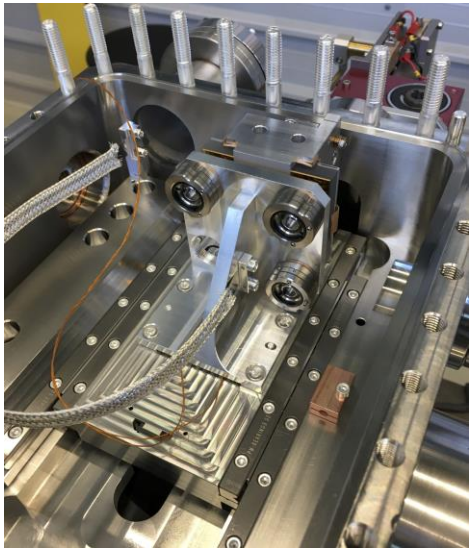
Rotational stage

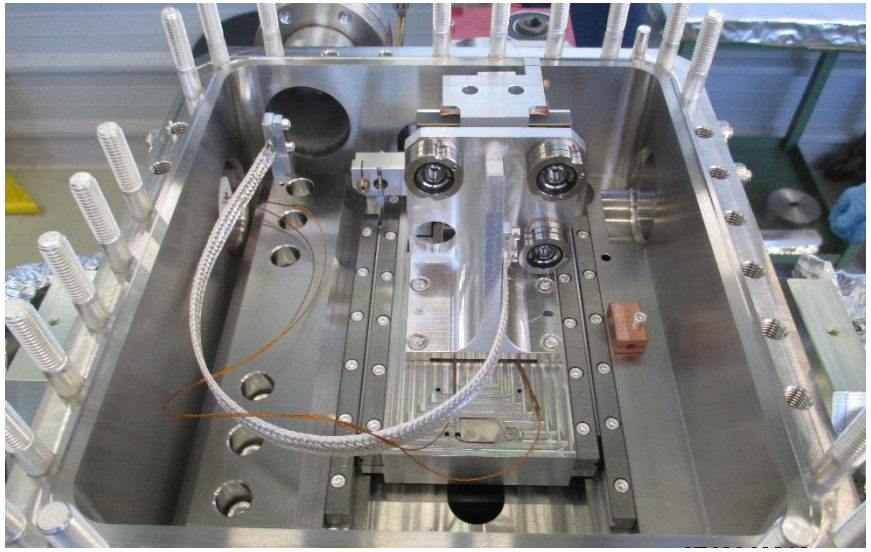


Review of version 2 goniometer, history and issues



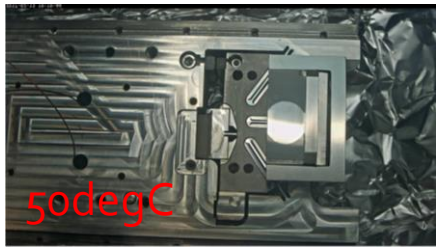


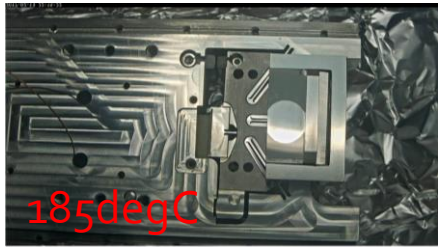


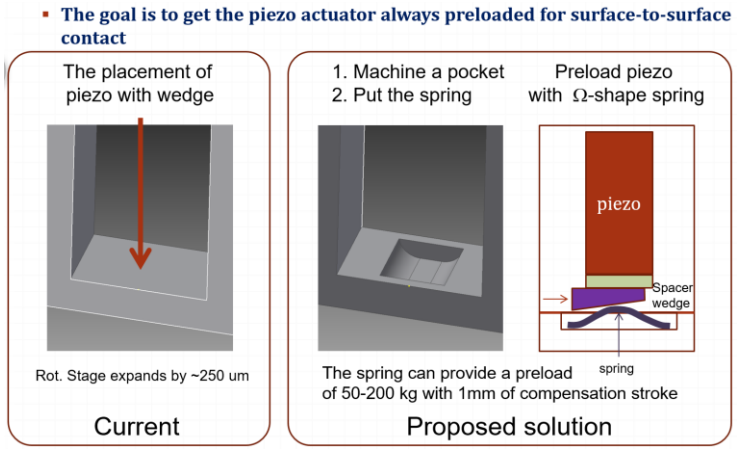


Review of version 2 goniometer, history and issues

- During the mechanical stage validation thermal cycle, a modification of the angular range was found
  - Due to different thermal expansion between the stainless steel frame and the stacked ceramic piezo
- **Preload of the piezo is a key parameters**
  → a compensated elastic contact was developed and put in operation

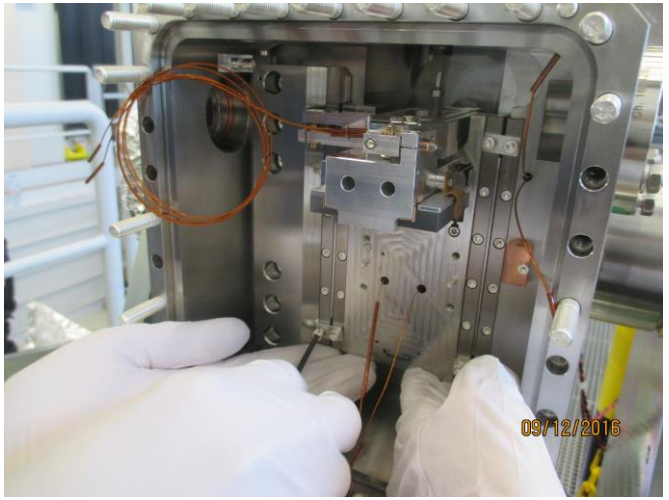




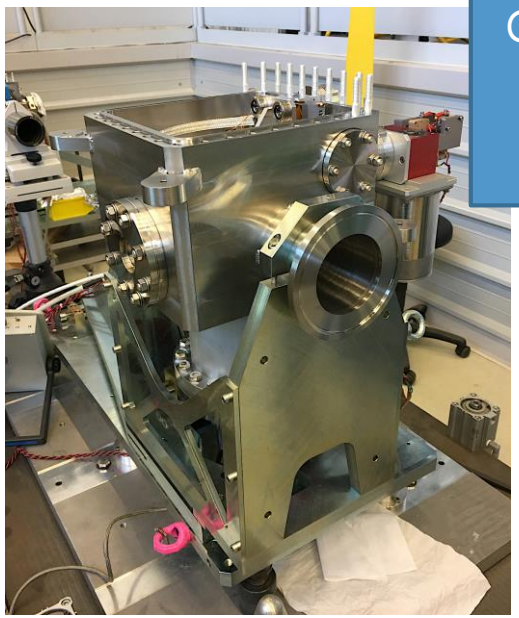


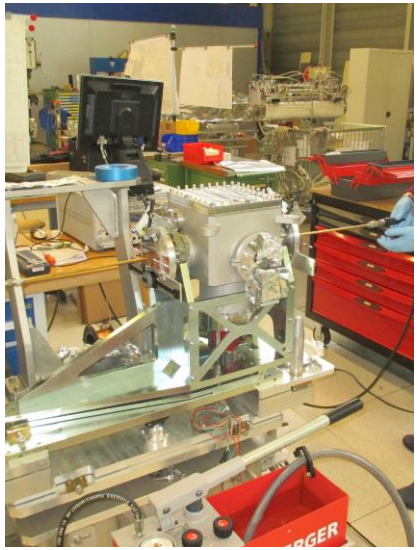
Review of version 2 goniometer, history and issues

- Two version 2 (V & H) crystal collimators were assembled, aligned, adjusted, tested (mechanical, electrical, impedance), validated and baked



Two version 2 Crystal Collimators installed during YETS2016/2017



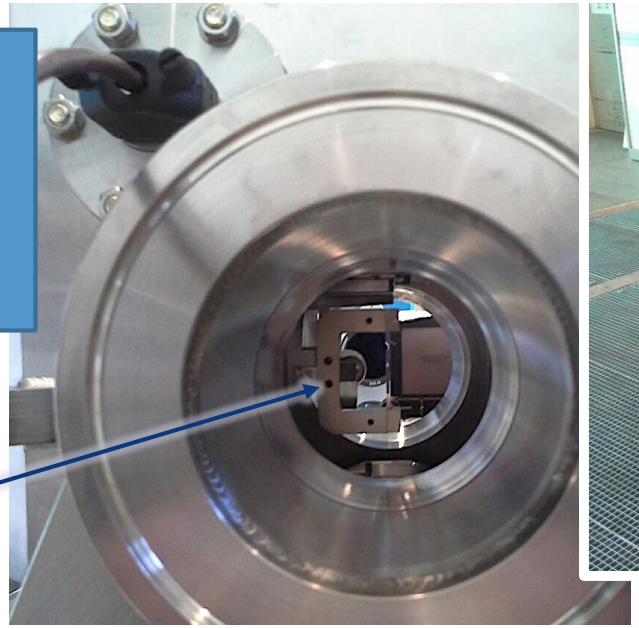


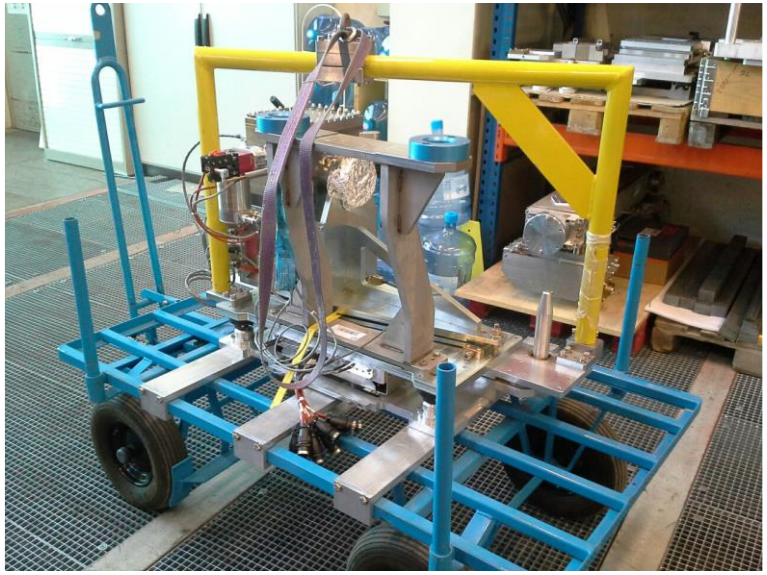
Review of version 2 goniometer, history and issues

- After an MD, data showed TCPCH.A5R7.B2 not correct crystal roll angle → reflection of skew planes
- Required an exchange of the complete hardware
  - **Installation of the only remaining available unit, used also for testing → no more available for further studies/development/SPARE**

TCPCH version 2 Crystal Collimator replace by same type during YETS2017/2018

Holder w/ crystal



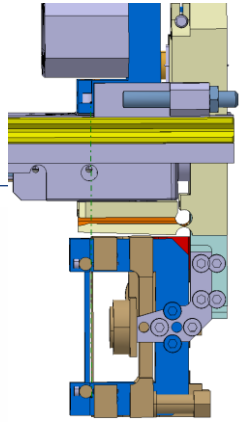


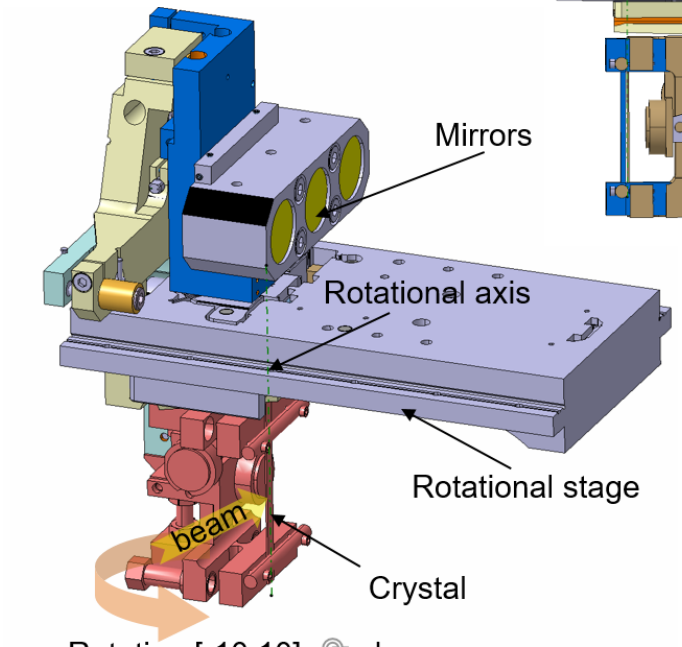
Goniometer assembly version 3

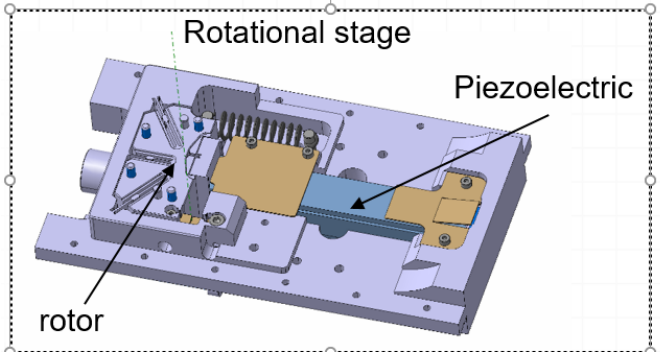
- Due to several technical issues encountered during the operation of version 2 and version 1, it was decided to **proceed towards the design of a version 3 during 2017-2018**, in order to have a "well thought" design within CERN
- In addition, version 1 and version 2 were basically manufactured outside, with **no control of the mechanical design and drawings (no CATIA model available)**
- **This version will be the reference for new potential production**
- **NB: no prototype was financed – the mechanical & control parts have to be validated for final construction**
- **NB2: still no possibility for realignment from outside of the tank**

Summary of new design (version 3)

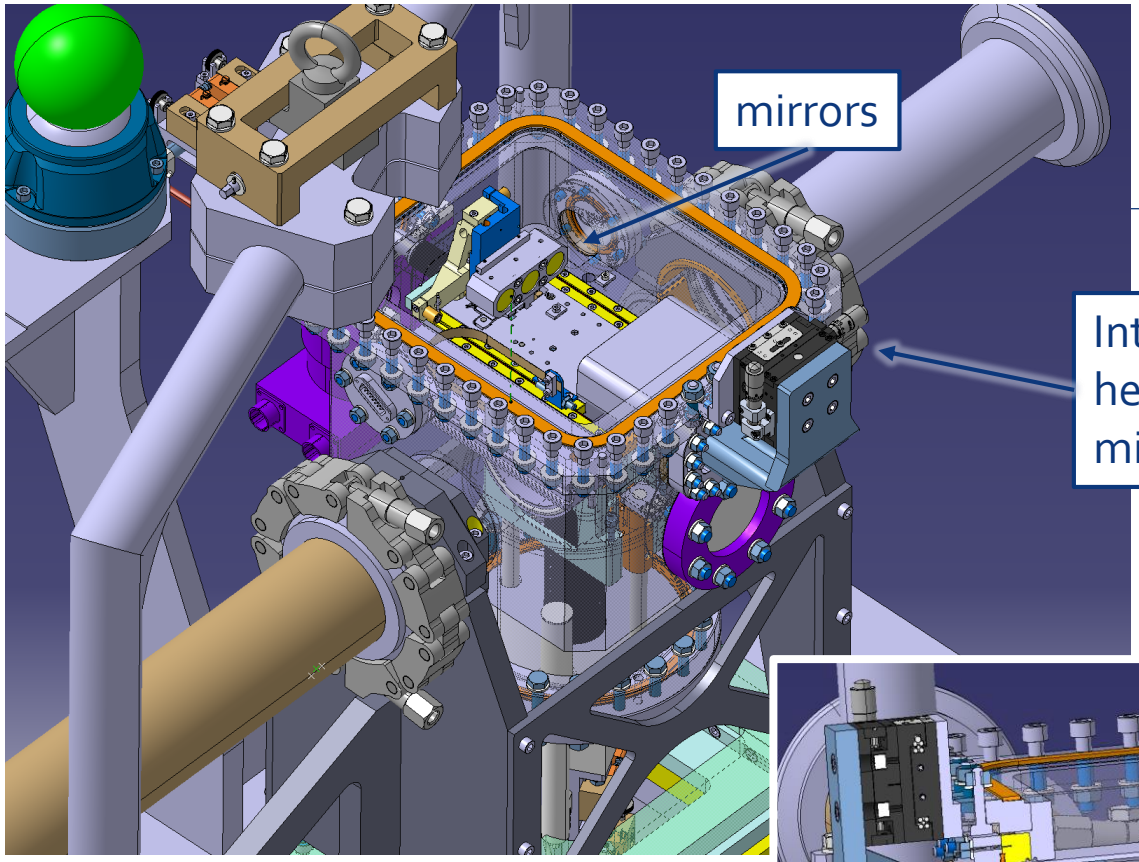
- **Increase of clearance** between crystal and beam pipe
- Additional viewport to anticipate possible interference
- Movement of the **interferometric heads outside of the vacuum tank**, plus possibility to **independently align each mirror**
- Increased stroke for stage and beam pipe
- Addition of m**echanical positioning references**
- Improved hoisting point to be balanced with respect to center of gravity

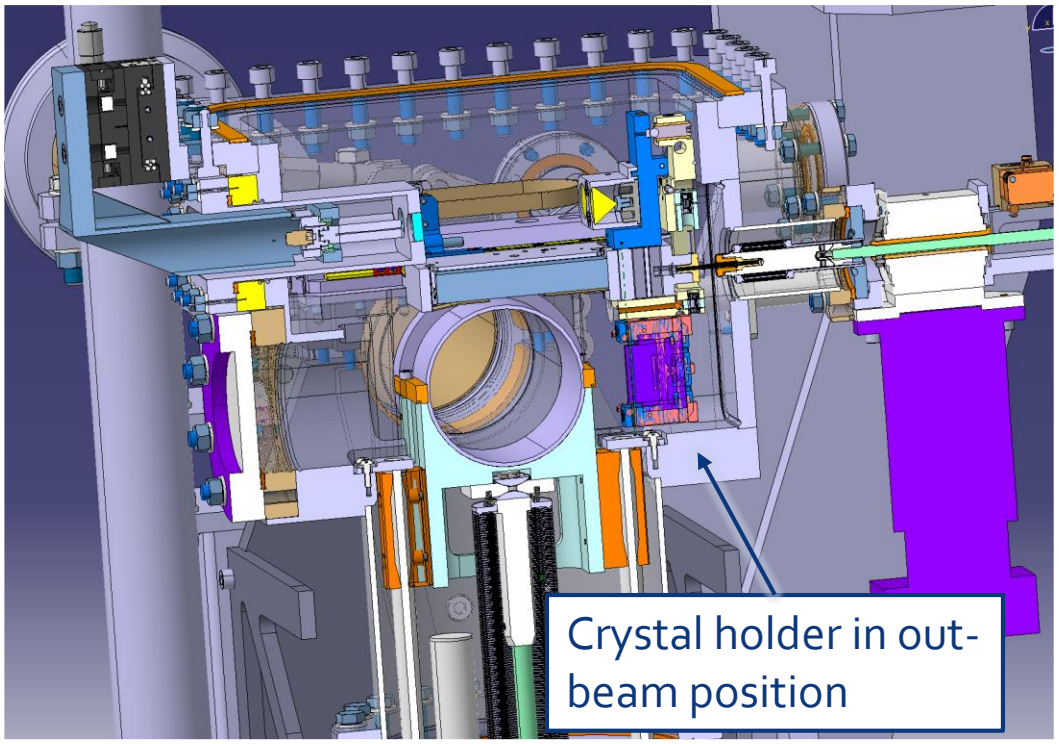






V3 design


mirrors
Interferometric heads on micrometric plate


Crystal holder in out-beam position

Mechanical modelling of version 3

- In order to better understand the behavior of the system & anticipate potential issue, a suite of FEM analysis have been performed
  - Elastic behavior of the piezo + mechanical stage subassembly
  - Definition of the initial pre-load necessary to reach the require angular range
  - Mechanical analysis (stressed, deformation, buckling) of the piezo-mechanical stage subassembly
  - Modal analysis of the piezo-mechanical stage subassembly
  - Mechanical analysis of crystal collimator during bake-out
  - Mechanical analysis of crystal collimator and lifting tool during transport
- Will be documented in a dedicated EDMS document

Radiation protection aspects related to crystals

- Current values measured on the TCPC installed in the LHC – clearly dependent on the use of the device → difficult to make projections towards LS2

		2017 TS#2	2018 TS#1	2018 TS#2
		~1 week ct	~1week ct	~1 week ct
		19/09/2017	20/06/2018	17/09/2018
19843	TCPCV.A6L7.B1	80	139	225
19919	TCPCH.4L7.B1	23	40	70
20090	TCPCH.A5R7.B2	62	98	208
20144	TCPCV.A6R7.B2	55	98	242

µSv/h @ 40 cm

- Radioactive crystal collimator in storage (HCTCPC_001-CZ000001) is at around ~300 uSv/h at contact with the tank

How much time would it take to change the crystal and stage?

- In order to prepare it for installation, the activities that require working at close distance are (**based on real work**):
  - Set up crystal collimator in 272 survey pit and removal of heating straps ➔ 2h
  - Opening of the tank and removal of the mechanical stage subassembly ➔ 4h
  - Mechanical stage thermal cycle including crystal and crystal holder ➔ 2h (effective)
  - Installation of mechanical stage subassembly and shim to avoid parasitic angles in linear stroke ➔ 8h
  - Adjustment of LVDTs and switches ➔ 2h
  - Alignment/adjustment of tank and crystal ➔ 8h
  - Closing up tank and installation of heating straps ➔ 4h
  - Bake-out ➔ 4h (effective)
- TOTAL time at <40 cm from the tank **O(30 hours)**

Comment on technical feasibility of different scenarios

- **Scenario 1** = basic interventions outside the tank, in the tunnel
  - Potentially possible, but it would depend on the dose rate in P7 close to the TCPCs and the foreseen duration of work (30 minutes / 1 hours estimated)
  - Pending detailed analysis by RP and validation of WDP
- **Scenario 2** = required opening of tank to exchange crystal (and stage)
  - Would require transport of the gonio tank on the surface (b 272) and opening of the assembly, including realignment, etc.
  - Given the time required (O(30 hours)) and the equipment dose rate, assuming 100 µSv/h at 40 cm → **estimated collective dose would be too high (O(several mSv))**
  - **Option very unlikely, pending final survey from RP at the end of the year and projections during LS2**

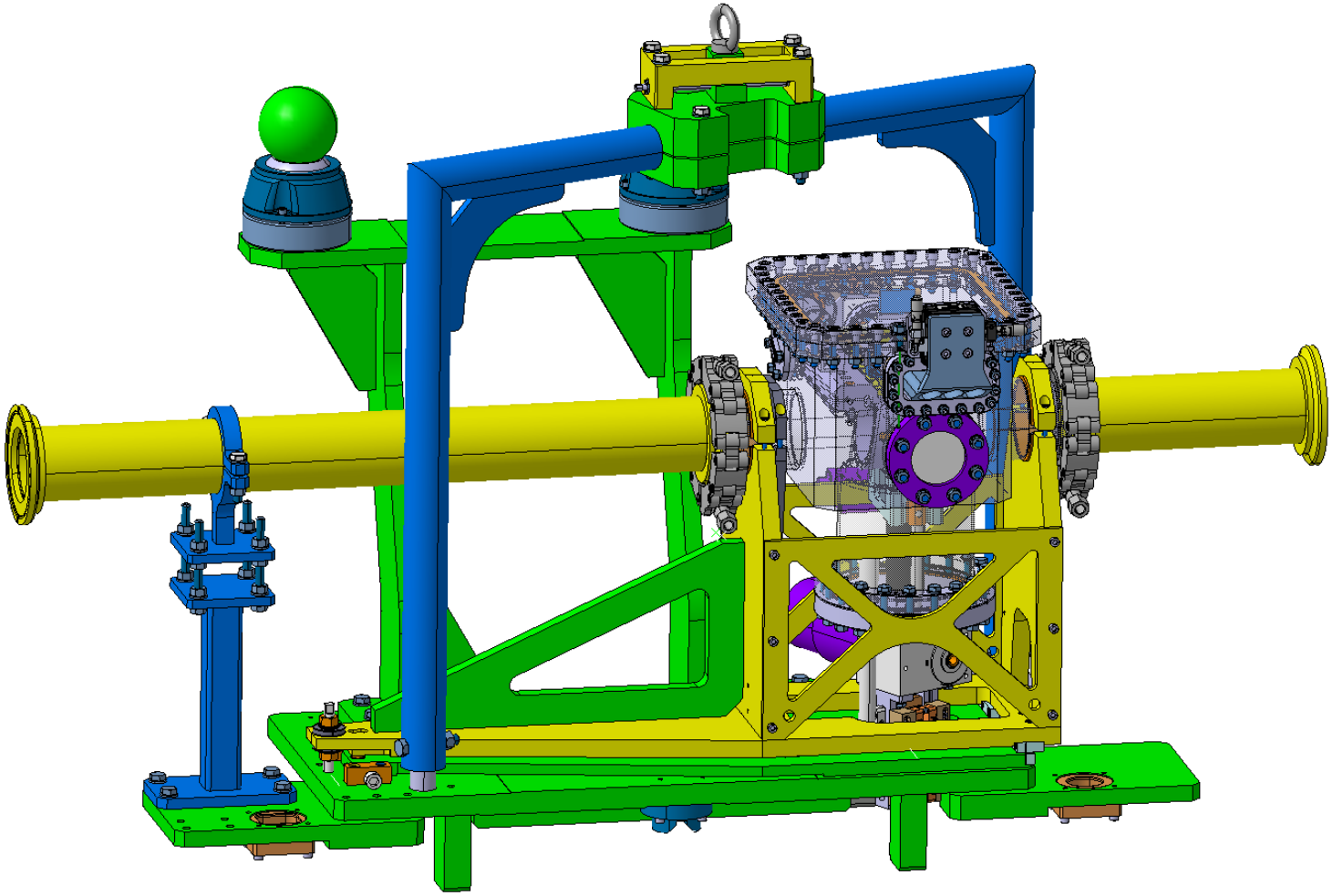
Comment on technical feasibility of different scenarios

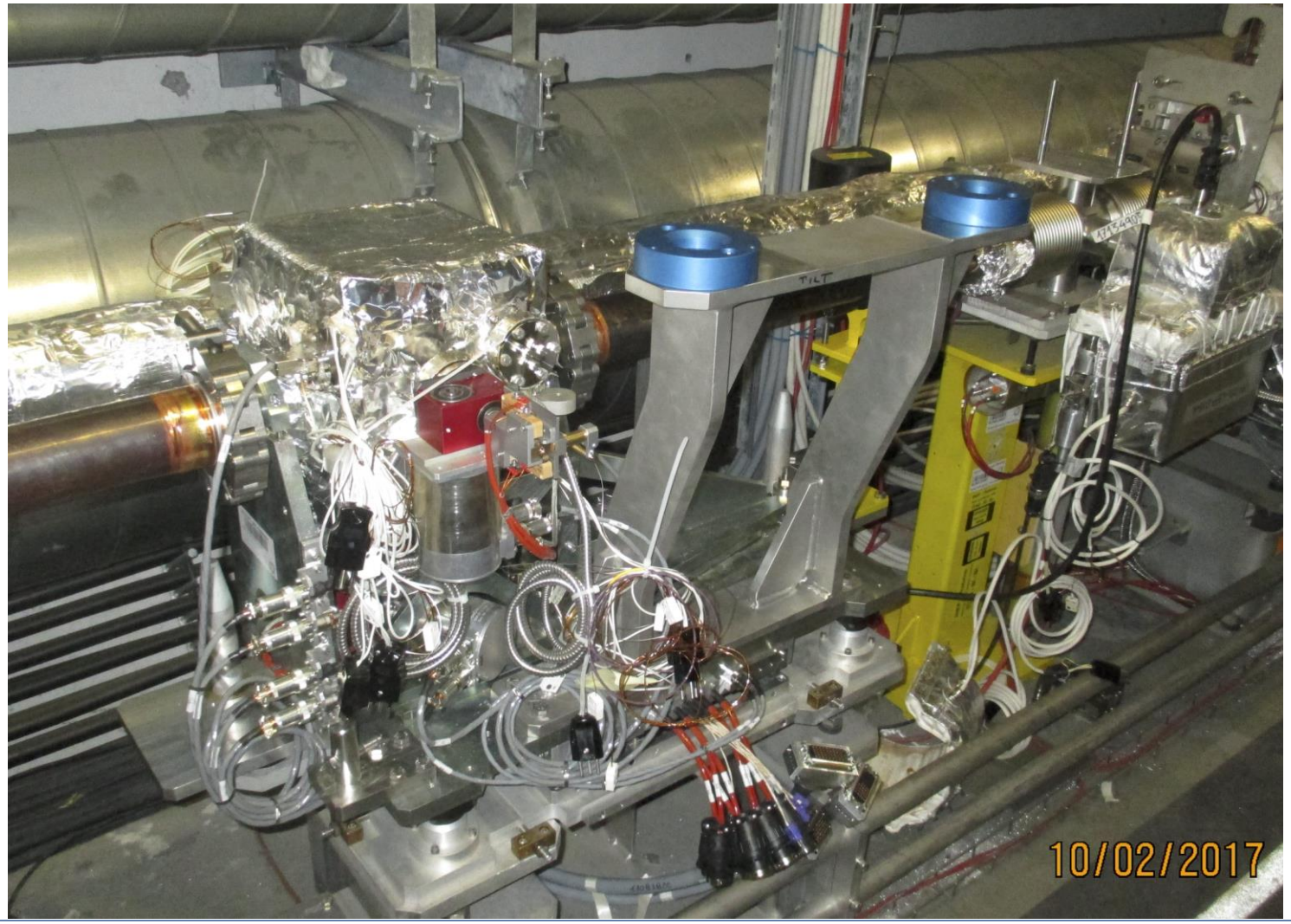
- **Scenario 3** = new generation of goniometers
  - **Replacement of full 4 crystal systems not compatible with LS2 (counting only on CERN resources) due to:**
    - Purchasing procedures
    - Available man-power
    - Time available between now and end of LS2
  - Potential to start procuring **1 unit towards the end of LS2** should serve as a **prototype unit to validate mechanics and controls and spare of existing system**
- **Procurement of 4+ units would be possible only after the end of LS2 (clear functional specification required) with installation at first YETS after LS2**
- All of these pending the results of last MD – crash program needed in case MD reveals that 1 or 2 crystals have to be changed for beam dynamic reasons or operational scenarios to be re-discussed

Conclusion

- Reviewed the different generations of crystal goniometers installed in the LHC machine
- Difference scenarios for installation and re-work briefly discussed
- It will be difficult – if not impossible - to rework a radioactive v2 coming from the LHC tunnel
- Procurement of a new v3 goniometer only possible towards the end of LS2 at the level of a prototype if counting only on CERN resources
  - To be revised if beam dynamics shows that it is not possible to use the existing system

Thanks a lot




TILT
10/02/2017