Continuous position determination: concept and status of integration

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overview

- LHC: layout, measurement concept and experience
- HL-LHC: layout and continuous position determination
- Sensors and components: LHC vs HL-LHC
- Status of integration

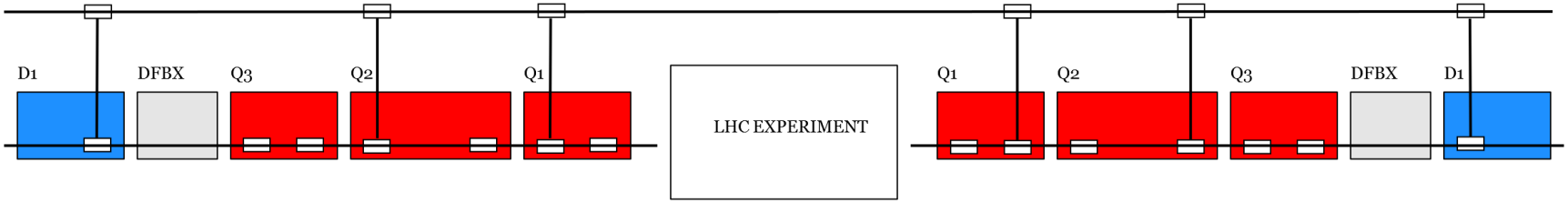
HL-LHC: continuing the LHC monitoring and alignment concept

- Continue monitoring concept based on
  - Hydrostatic levelling sensors (HLS) for vertical and roll measurements
  - Wire positioning sensors (WPS) for radial and vertical measurements
- Reuse existing infrastructure
  - Survey galleries (UPS14, UPS16, UPS54 and UPS56) providing link to experimental caverns of ATLAS and CMS + left to right side
- Experience gained from LHC
  - Operation of LHC system over 20 years
  - Consolidation of P2 and P8 during Long Shutdown 2
  - Remote validation concepts introduced in LHC
  - Calibration of sensors at CERN

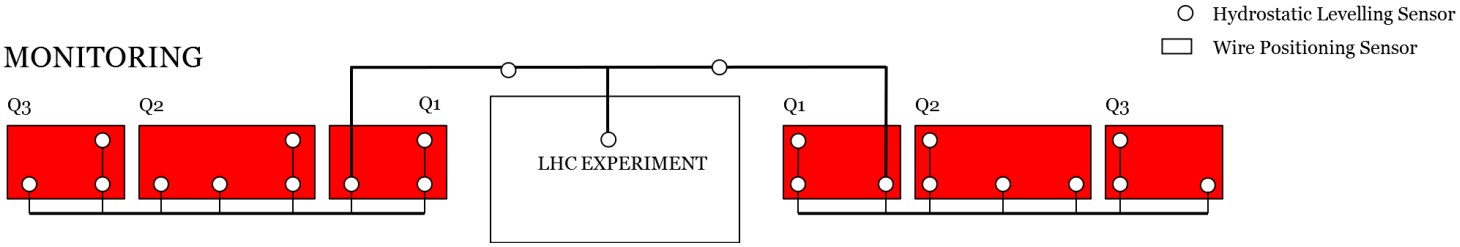

LHC - UJ14/C-02L1 Captured on 2018-02-21 by EN-ACE-CL
Please note that the situation may have changed since the picture was taken
hydrostatic levelling network
HLS sensor
WPS sensor
sensor support
HLS remote validation
HLS network pillars
stretched wire (protection)
motors
jacks
HCLQXC_001-F
Office of Science
RADIOPROTECTION
LAYOUT DB
GIS PORTAL

LHC measurement concept

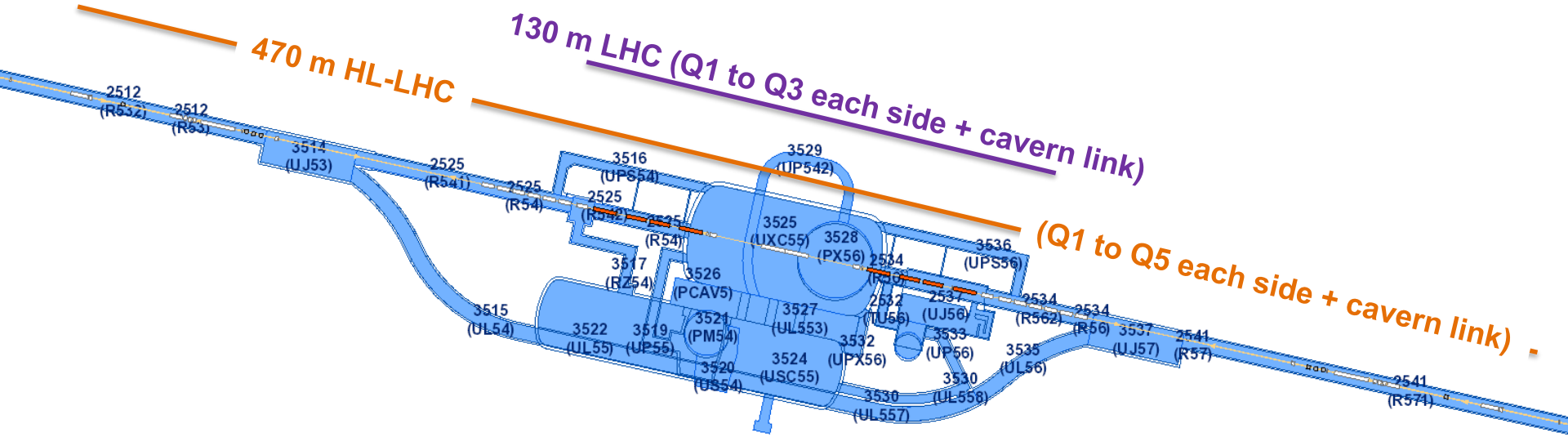
RADIAL MONITORING



VERTICAL/ROLL MONITORING



HL-LHC layout compared to LHC



	WPS	INC	HLS	LON	INT	W2W
PER IP	48	12	48	18	48	3
TOTAL	192	48	192	72	192	12

WPS	capacitive	Wire Positioning Sensor
INC	MT-FSI	Inclination Sensor
HLS	MT-FSI	Hydrostatic Levelling Sensor
LON	MT-FSI	Longitudinal measurements
INT	MT-FSI	Internal measurements
W2W	MT-FSI	wire to wire measurements

Not taking into account, environmental sensors and actuator equipment.

In addition to the sensors:

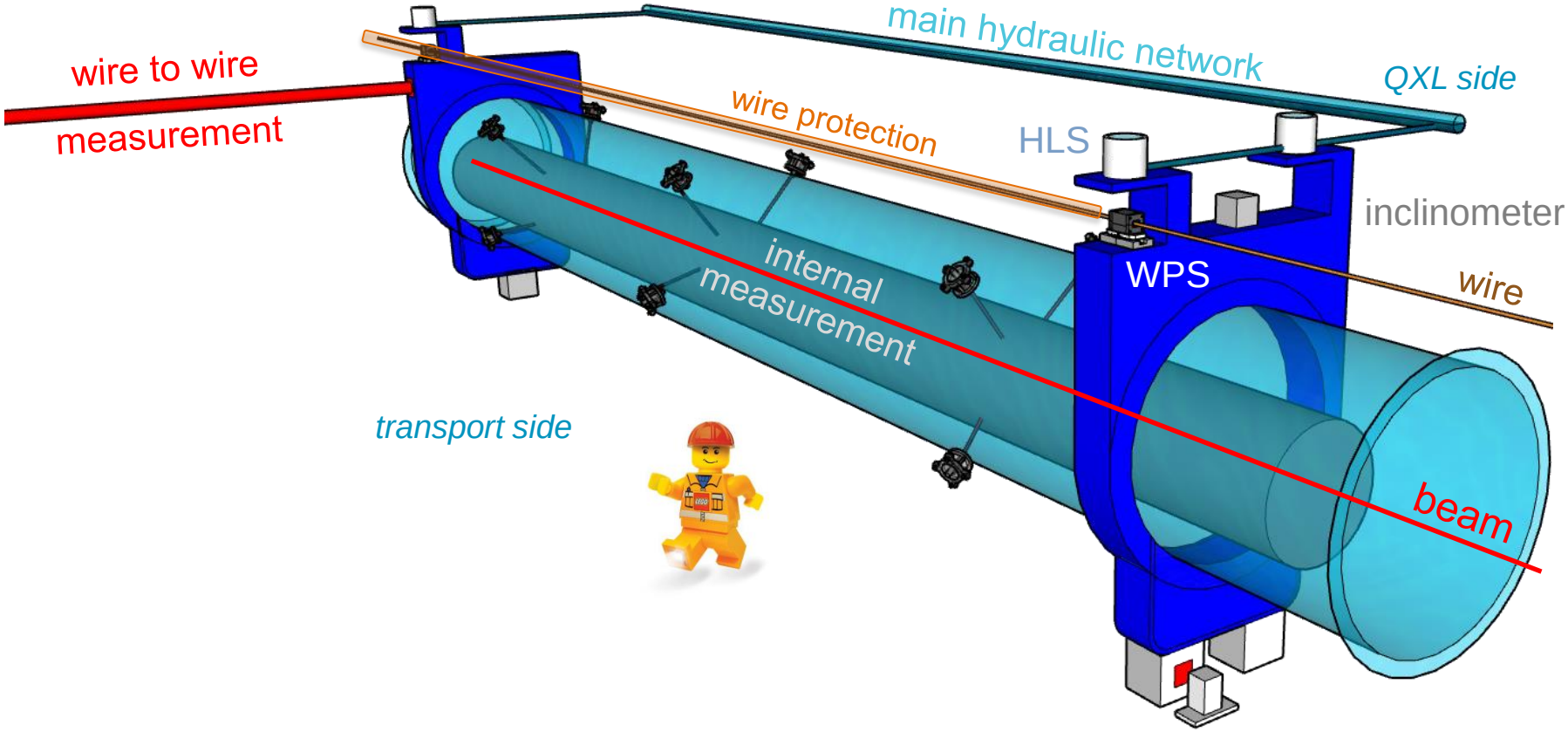
. 4 wire stretching devices

. approx. 1 km of wire and wire protection

. approx. 1 km of hydraulic network

. remote diagnostic tools for sensors and systems

continuous position determination systems



Radial and vertical measurement solutions

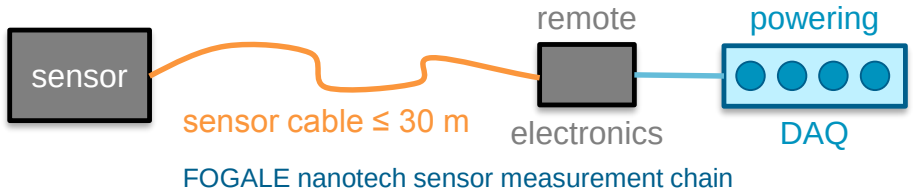
- Hydrostatic Levelling Sensors
  Manufacturer FOGALE nanotech
  with CERN added value: absolute determination within 10 µm
  . in-situ check methods

HLS sensor

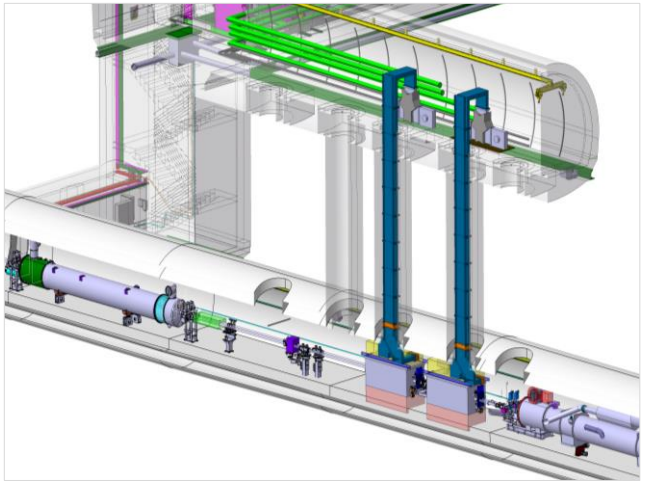
- Wire Positioning Sensors
  Manufacturer FOGALE nanotech
  with CERN added value: absolute determination within 5 µm
  . use of twisted pair cables
  . in-situ recalibration
  . application of methods of calibration developed in the CLIC project

WPS sensor

Radial and vertical measurement solutions



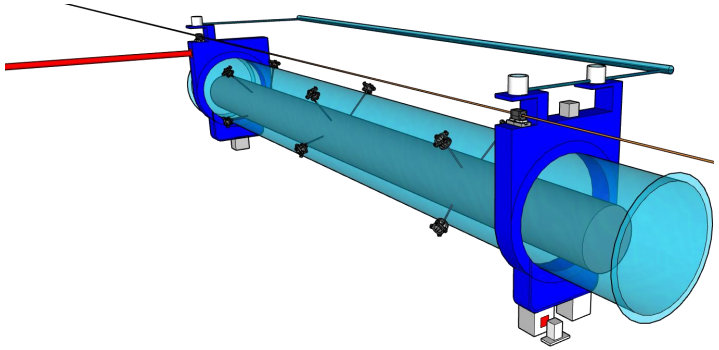
FOGALE nanotech sensor measurement chain



- Drawbacks
  - . Very expensive
  - . Dependent on one manufacturer
  - . Electronics is a «black box»
  - . Limited signal cable length
  - . Choice of components not guaranteed from one manufacturing batch to the other
  - . Same technologies are impacted by the same environmental factors
  - . HLS and the associated piping system is difficult to integrate on a platform system

- Developments
  - . interferometric HLS: iHLS and HLS-LINES
  - . in-house WPS
  - . in-house remote electronics: digital signal, components traceability, remote diagnostics
  - . inclinometer
  - . Acquisition systems compatible to CERN DAQ protocol

Longitudinal measurement solutions



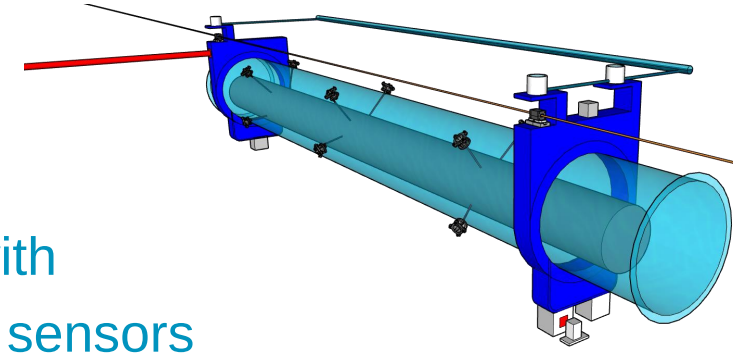
- Distance Offset Measurement Sensors
  - . Manufacturer FOGALE nanotech
  - . Limited range by manufacturer, range extension by CERN

DOMS sensor

- Drawbacks
  - . Very expensive
  - . Very sensitive to electrical ground

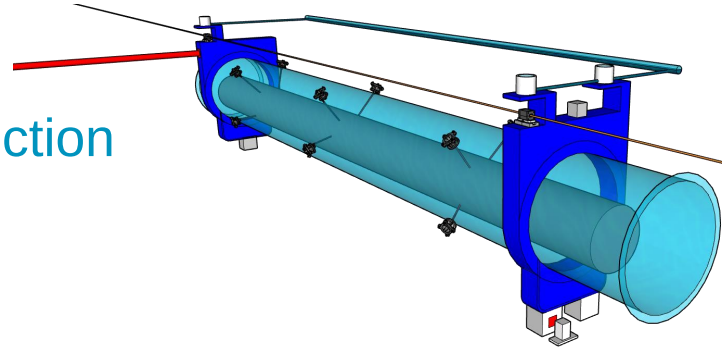
- Developments
  - . Alternative under study: short range MT-FSI (< 10 cm)

Wire to Wire (W2W) measurement solutions



- Combination of invar rods equipped with targets plus two DOMS and two WPS sensors
  - . Manufacturer of sensors FOGALE nanotech
  - . Invar rods are CERN development
- Drawbacks
  - . Four sensors to establish one measurement
  - . Complicated support of invar rods
  - . Calibration was very fastidious
  - . Invar is sensitive to magnetic field (of experiments)
  - . Invar bars were damaged several times due to very limited space available
  - . Air tightness between experimental cavern and tunnel difficult to establish
  - . costs
- Developments
  - . Alternative under study: long range MT-FSI (11 m to 15 m)

Wire protection

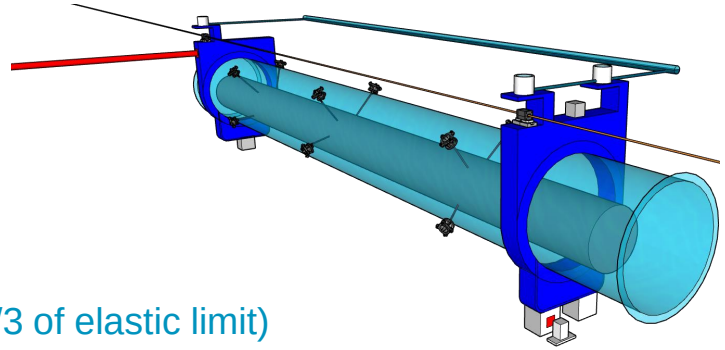


- CERN designed solution for wire protection

- Drawbacks
  . Current solution too fragile
  . LS2 consolidation solution good stability, but too expensive
  . Both cases: based on manual installation and replacement of wire

- HL-LHC requirements
  . Due to radiation levels, necessity to develop a **semi-automatic solution**
    . Install wire from area with little radiation (typically beyond Q5)
    . Wire is pulled from Q5 to Q1 in an automated way,
      with no intervention from personnel
    . Old wire is cleared during the same operation by the system
  . The wire protection system has to be **modular** in order to be only
    partially dismounted in case of replacement of a component

Measurement wire



- Carbon-PEEK wire
  - . Manufacturer FOGALE nanotech
  - . Conductive
  - . High tension over linear mass, stretched at 15 kg (2/3 of elastic limit)

- Drawbacks
  - . Manufacturing issues to have an homogenous wire; scale factors between reels

- Solutions
  - . Short term: carbon-Kevlar wire, stretched at 20 kg
    - . Wire sag is more important
    - . Huge influence of humidity over 200 m
  - . HL-LHC: new wire under development with EMPA*

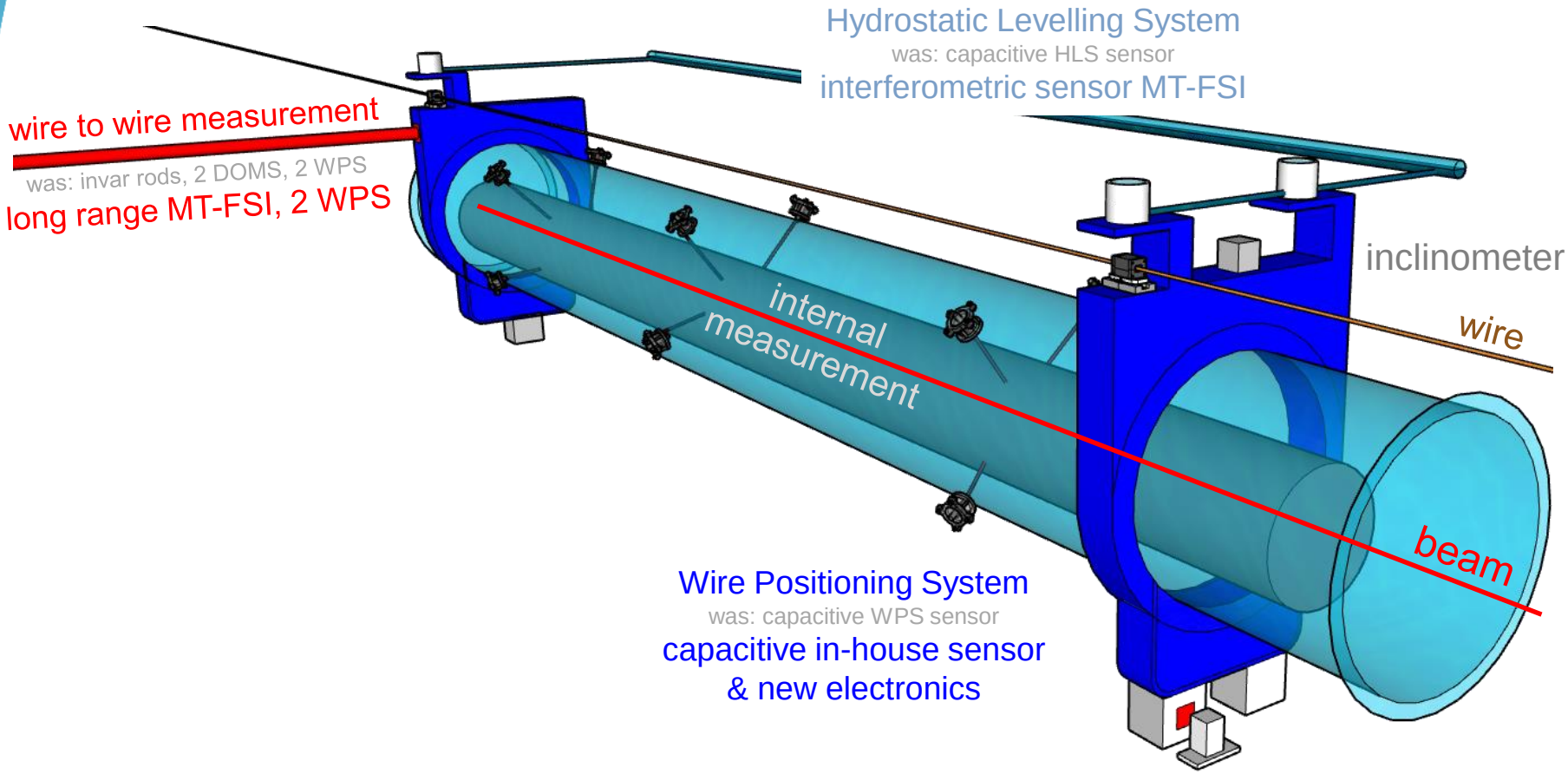
examples Carbon-PEEK wire

*EMPA: Swiss Federal Laboratories for Materials Science and Technology

HL-LHC: introducing additional features

- Longitudinal monitoring
  - concept as already installed for cryostats in LHC since YETS 2017/18 and LS2
- Internal cold mass monitoring
  - request to determine the cold mass position and not only cryostat position
  - testing and validation of concept for crab cavities and dipole measurements
- Permanently monitored reference points
  - deep references (GITL) for vertical network to be installed
- Inclination sensors
  - additional concept either for HLS redundancy or where no HLS can be diploid
- Different measurement technologies
  - capacitive sensors and Multi Target Frequency Scanning Interferometry

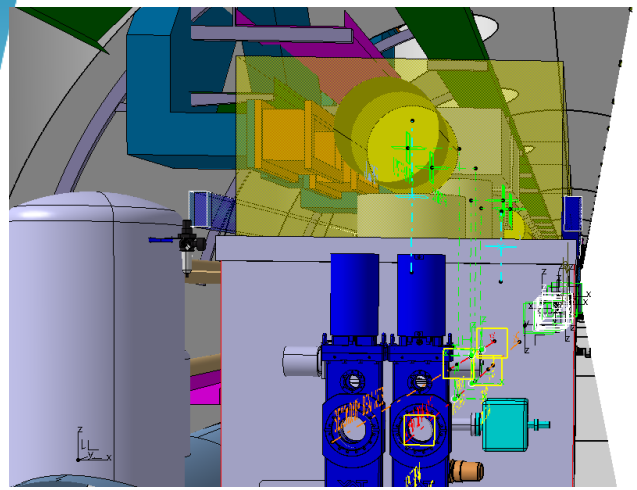
continuous position determination systems

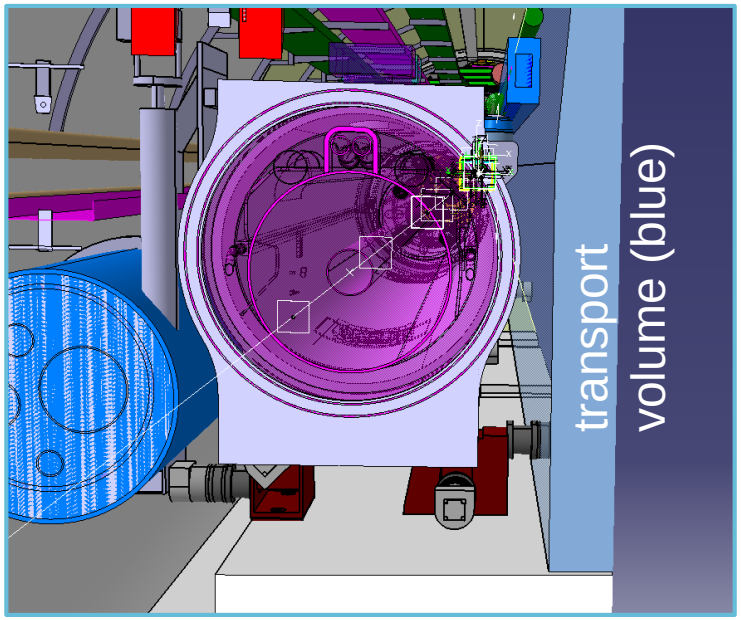


Integration: key points WP15.4

- Accessibility of the reference points during complete lifecycle of components (installation, operation, dismounting)
  - Compatibility with standard geodetic measurements
  - Provide interfaces for linking LSS to the arc sections of LHC
- Little as possible «interruption» of measurements in case of component exchange
  - Main hydraulic network behind the components
  - Wire protection system to be modular per component
- Installation and operation environment
  - Influence of adjacent equipment or infrastructure
  - Bake-out of beamline / gas line components
  - Temperature and humidity in the tunnel
  - Dust protection of the measurement systems
  - Different air pressure systems: tunnel vs. cavern

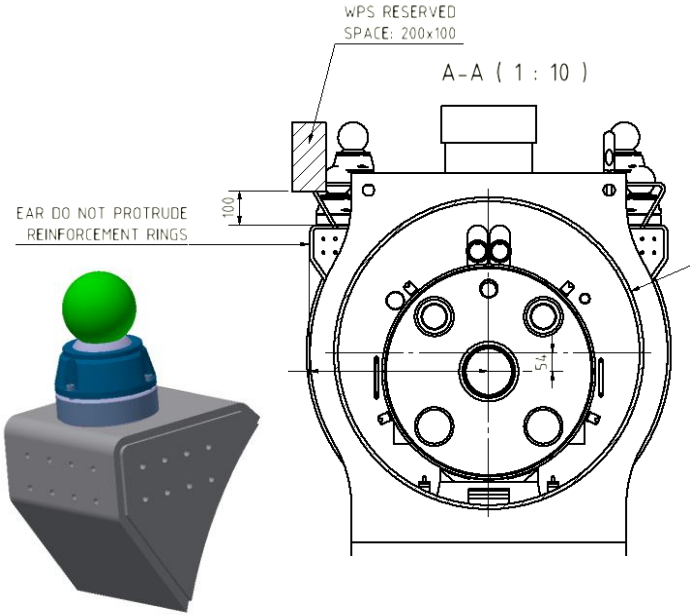
Integration: transport volume





Wire protection

- is a single, straight volume
- Crab cavities define position



sensor supports

- some cannot be installed an thus not fiducialised before transport
- fiducialisation measurements on site

Integration: WP15.4 systems

The HL-LHC is a very crowded machine in a lot of places!

- completed
  . space reservation for systems and infrastructure (thank you Marian!)

- next steps
  . design of supports and detailed layout of sensor support
  . design will be related to system consolidation during LS2 (copy and improve)
  . all «additional» equipment, such as supporting structures
    - Wire stretching devices
    - Borehole covers
    - Routing of hydraulic network
    - Remote validation systems

Summary

Measurements

- 3 axis measurement system
- from pseudo absolute to true absolute measurement system
- Q1-Q3 & CC: from cryosat monitoring to cold mass measurements

Sensors and Systems

- Individual sensors and components are tested as prototypes
- Volumes compatible with «currently used sensors»
- Concepts for measurements during installation to be refined

Integration

- next: from space reservation to design
- Full Remote Alignment approved – integration and design
- Define interfaces on components, e.g. inclinometer, supports for W2W system, supports for wire protection