HL-LHC Remote Adjustment systems

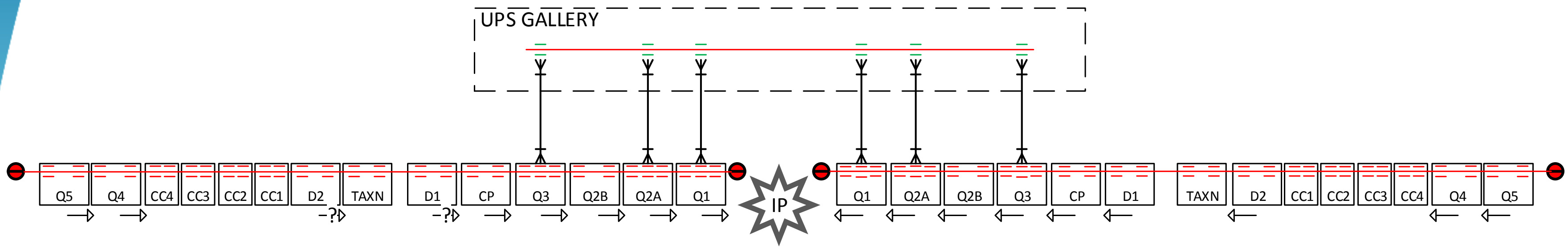
M. Sosin on behalf of MTI team

Projet HL-LHC: mini revue sur les activités SU CERN – 2017.06.29

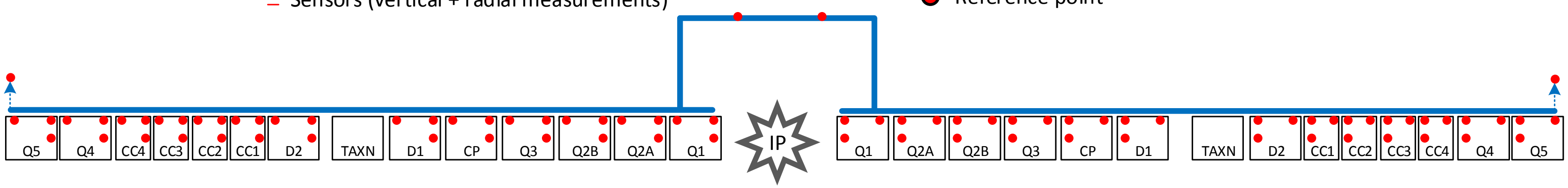
Outline

- HL-LHC remote adjustment - overview
- Scope of R&D linked with remote adjustment
- Motorized jacks and instrumentation
- Fast adjustment system
- New control electronics
- Multi-target FSI R&D

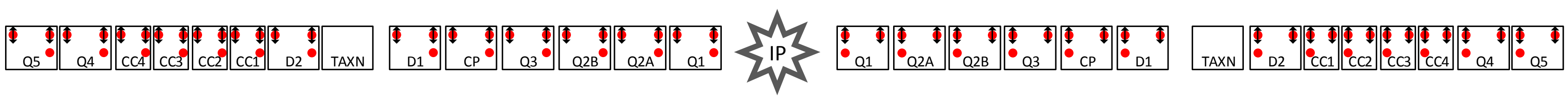
IP1/IP5 simplified layout



Stretched wire (or alternative)
Sensors (radial reference for the cavern)
Sensors (vertical + radial measurements)
Distance alignment system
Longitudinal monitoring system
Reference point



Hydraulic network (or alternative)
HLS sensors (or alternative)
Adjustable remote vertical reference

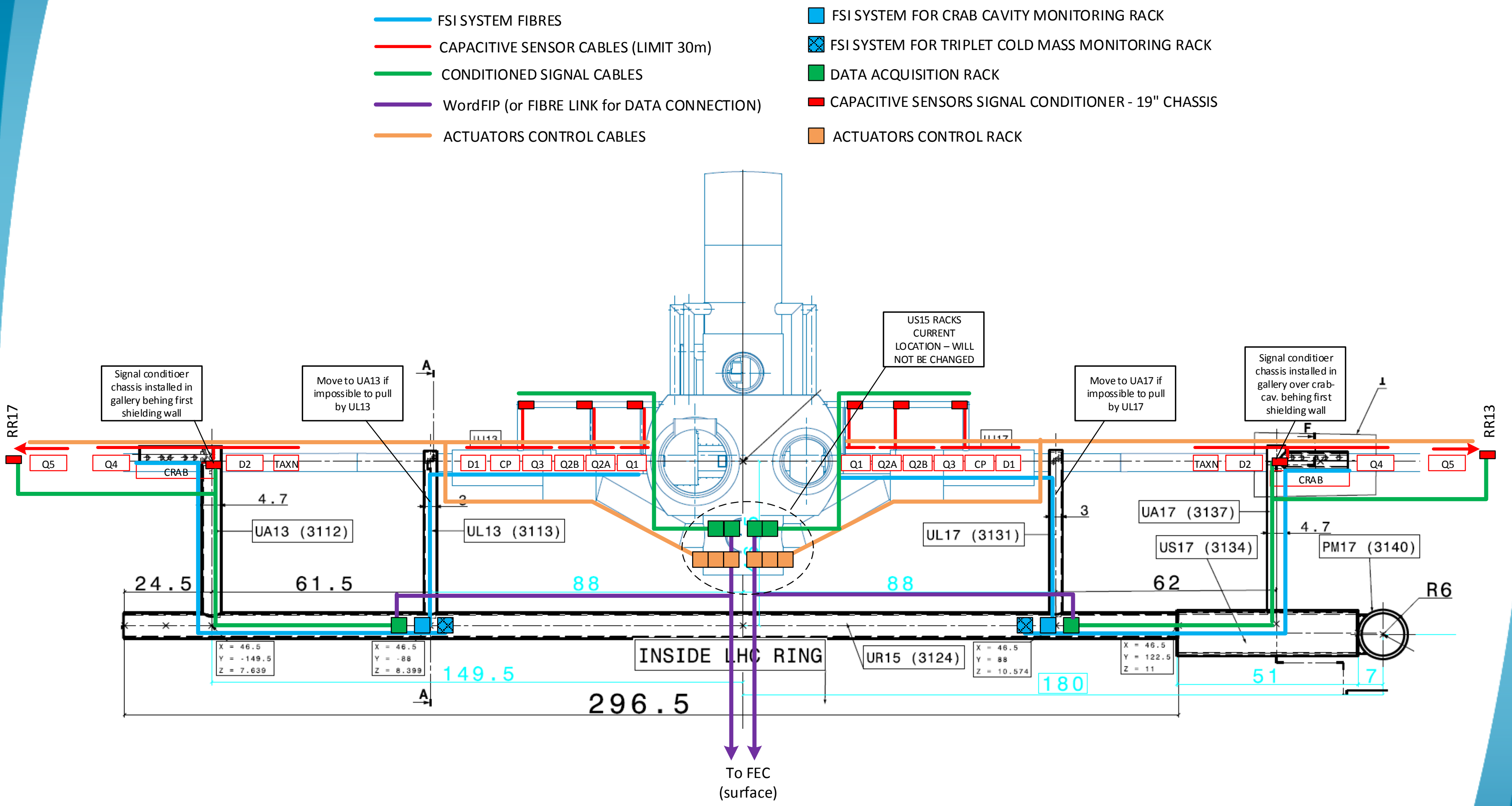


Combined Vertical/Radial actuator
Vertical actuator

But not only…

- Masks remote adjustment and monitoring (proposition of universal fast adjustment system)
- Collimators adjustment and monitoring
- BPMs monitoring
- Development of new RAD-HARD laser sensors (inclinometer, HLS, etc…)

Remote adjustment system control



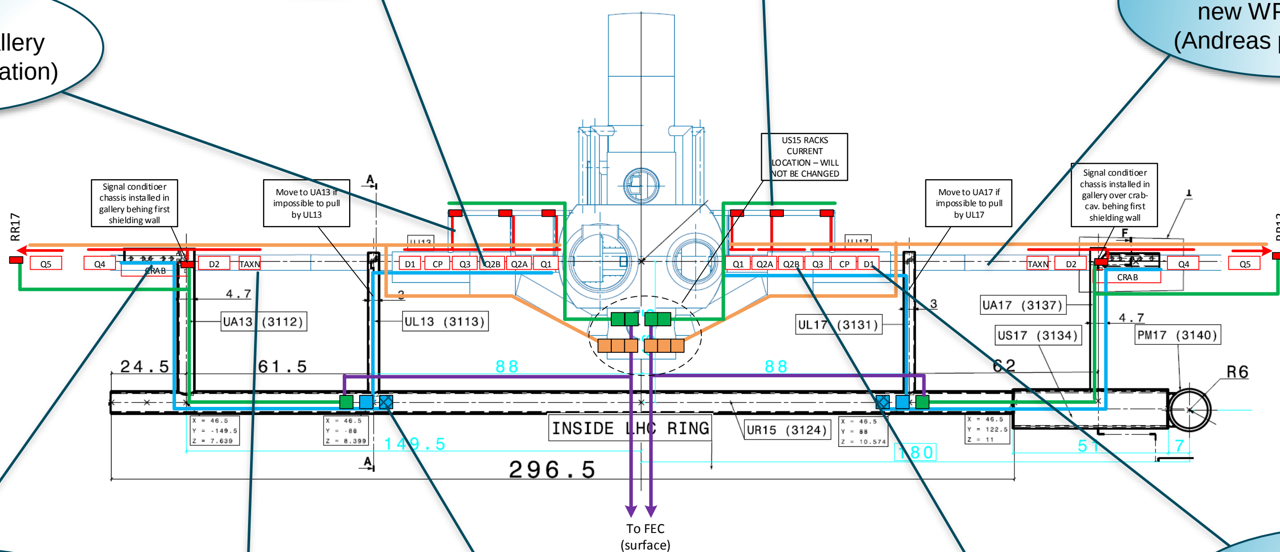
Scope of new R&D linked with remote adjustment

Inner triplet cold mass monitoring (later presentation)

New electronics for capacitive sensors and motors

WPS link
UPS – triplet gallery
(Mathieu presentation)

Automatic wire replacement system, new WPS sensors (Andreas presentation)



Crab cavity monitoring system (later presentation)

Fast adjustment system for radiation areas

Multi-target FSI Interferometer and sensors

Motorized jacks and jacks instrumentation

Interferometric HLS-lines (Andreas presentation)

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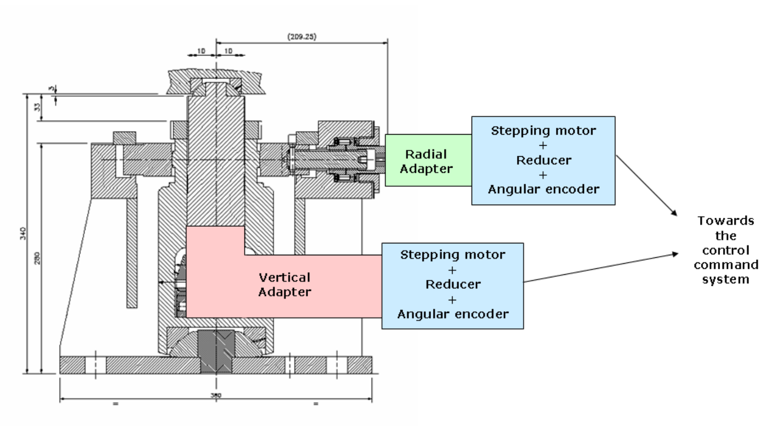
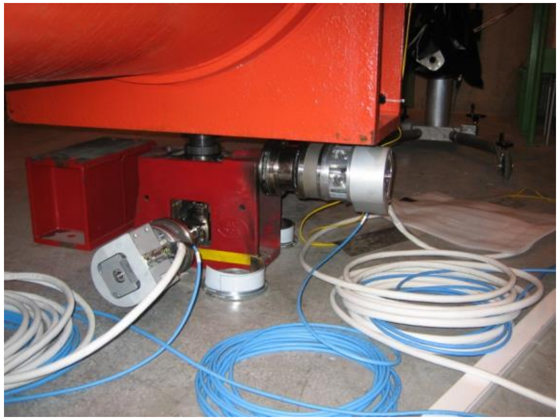
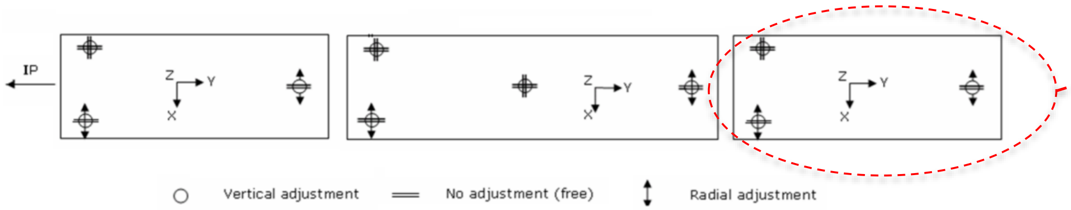
Motorized jacks and instrumentation

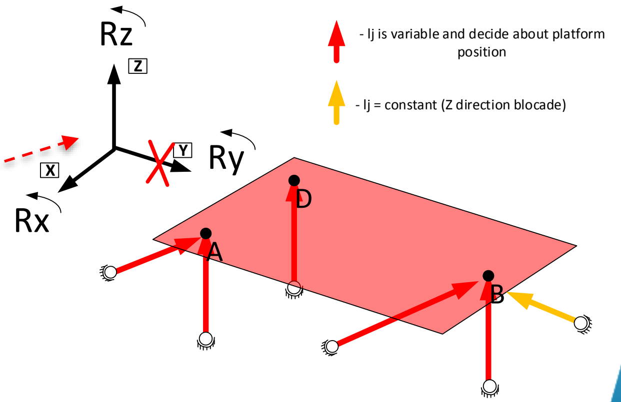
Supporting jack – current design vs. future needs

- All cryostats supported by modified Indian jacks, where actuators have been plugged to perform remote radial / vertical adjustments (a few µm resolution)
- To allow 5DOF adjustment 3 jacks and 5 actuators needed
  - Actuators - robust and rad-hard up to 0.5MGy
  - Big backlash – especially for radial actuator
  - Good design, but to be upgraded (rad-hard >1MGy, easily exchangeable, auto-diagnostic…)

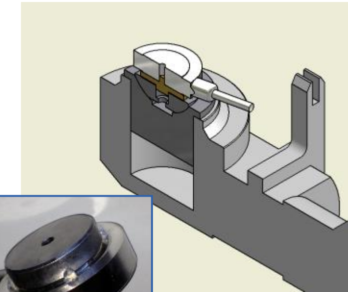


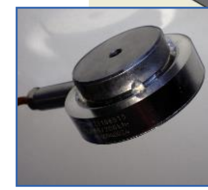




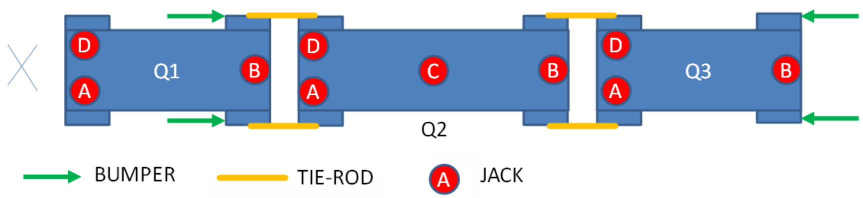


Supporting jack – current design vs. future needs





- Current triplet adjustment - over-constrained kinematics, hyper static
  - Interconnections, Tie-rods, Bumpers, Q2 central jack
- Future jacks have to be ready to detect problems during operation
- Additional jack instrumentation needed to provide safe adjustment:
  - load sensors
  - absolute piston position measurements
  - Transversal stress measurement in the jack pistons would be helpful



Summary

- No development works started yet (planned end of 2017)
- All constraints of adjustment discussed with TE-MSC to include proper solutions in cryostat design (contact with D. Ramos)
  - Current Indian jacks as a base for future LSS jacks
  - Jacks actuators and inserts to be developed and tested by EN-ACE-SU in cooperation with TE-MSC-CMI

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Standardized, universal fast and adjustment system

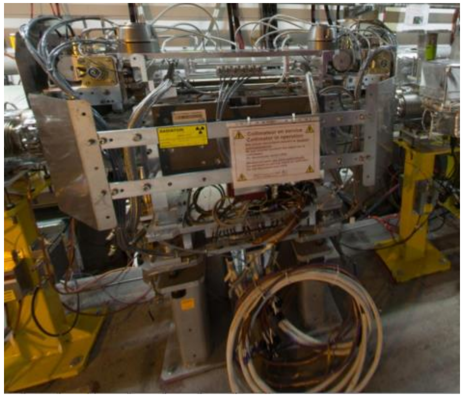
Tunell fast re-adjustment system

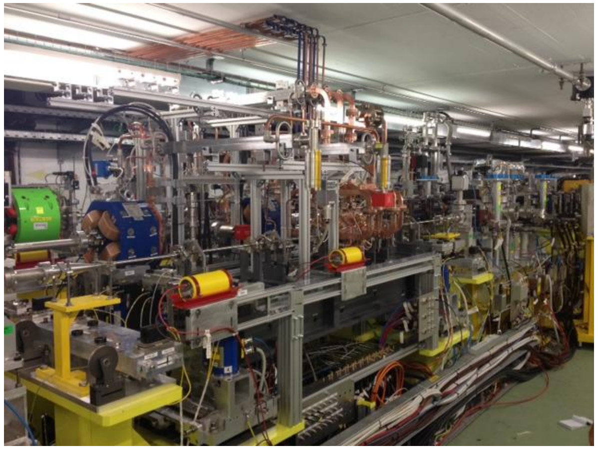
- High radiation levels in HL-LHC LSS areas
- Need to find the way how to decrease doses for personnel during components re-adjustment activities

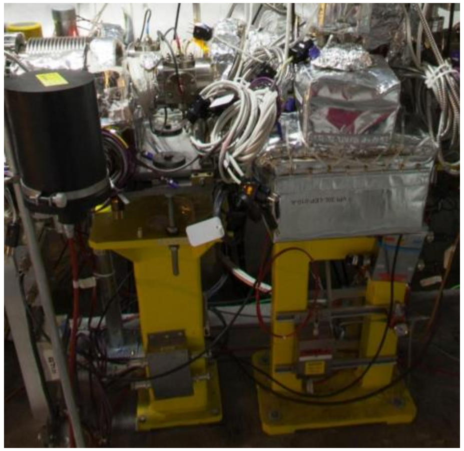
		LSS5 (one side only)							
		residual dose rate (uSv/h)				10 minutes dose (uSv)			
	distance from IP (cm)	1 week	1 month	4 month	1 year	1 week	1 month	4 month	1 year
D1	7442	800	410	140	55	133	68	23	9
	8450	350	150	50	20	58	25	8	3
TAXN	12626	900	450	150	55	150	75	25	9
	13047	400	220	90	30	67	37	15	5
D2	13779	650	350	130	65	108	58	22	11
	15224	15	10	5	5	3	2	1	1
Q4	17230	55	25	10	5	9	4	2	1
	18262	10	5	5	5	2	1	1	1
Q5	20115	125	65	25	10	21	11	4	2
	21027	20	10	5	5	3	2	1	1
Q6	22472	50	30	10	5	8	5	2	1
	23265	10	5	5	5	2	1	1	1
TCL4	13511	2500	1550	700	250	417	258	117	42
TCL5	19705	800	500	215	70	133	83	36	12
TCL6	22062	510	310	140	50	85	52	23	8
						1199	**682**	**280**	**106**
						2 hours (µSv)			
aisle	-	50	25	10	5	**100**	**50**	**20**	**10**
					Collective Dose (uSv)	**1299**	**732**	**300**	**116**

Typical issues with position adjustment

- Crowded neighbourhood of aligned components
  - Difficult access to regulation mechanisms/screws – (circus skills needed for some of components regulation)
  - Fragile equipment around workspace – slow an careful manipulation
- Ergonomics of adjustment
  - Mechanisms not always intuitive
  - **Long adjustment time**

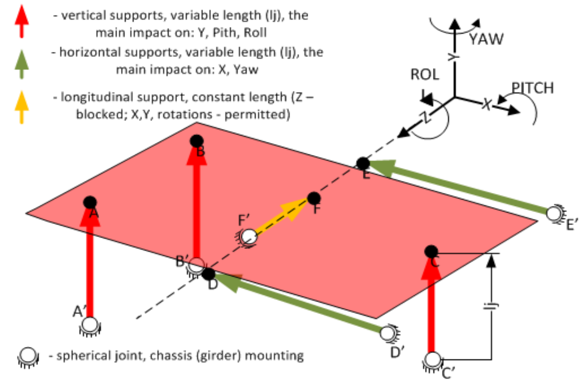


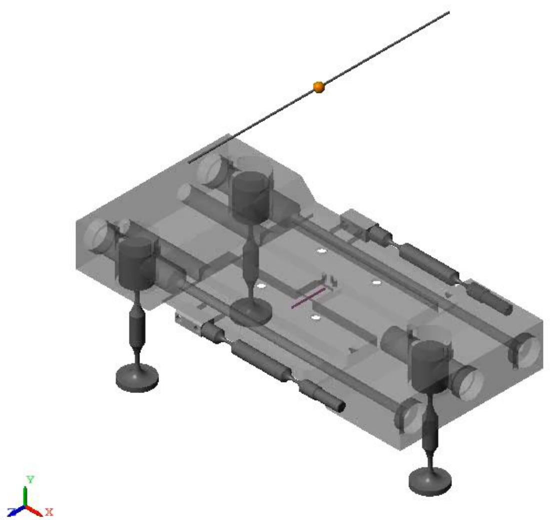


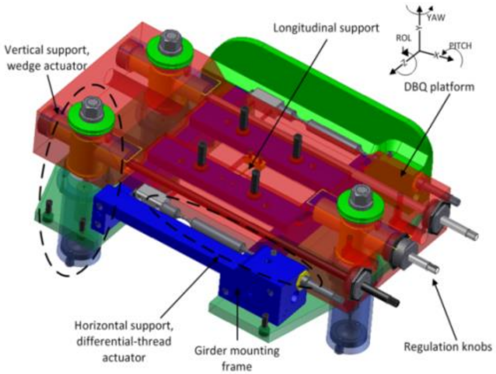


CLIC DBQ Support enabled to reduce pre-alignment time from one day to 20 minutes

- Standard adjustment solutions are not optimized to access time and components access space
- New solution design – adjustable platform concept
  - Stewart platform adaptation – 3 vertical and 2 horizontal supports
  - Simplified structure – reduced number of parts
  - Ergonomic – easy access
- With DBQ support, time was reduced to **20 minutes**

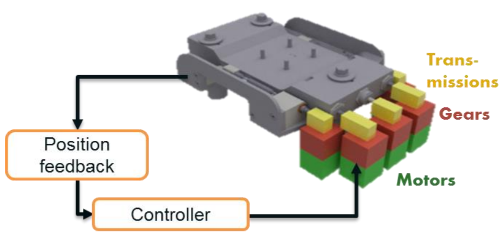


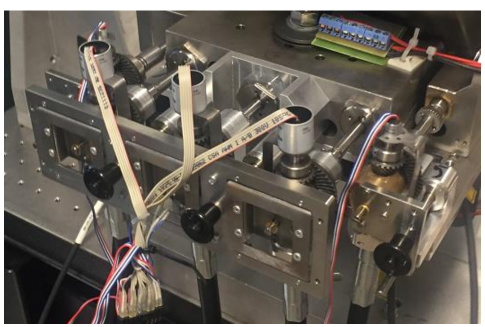


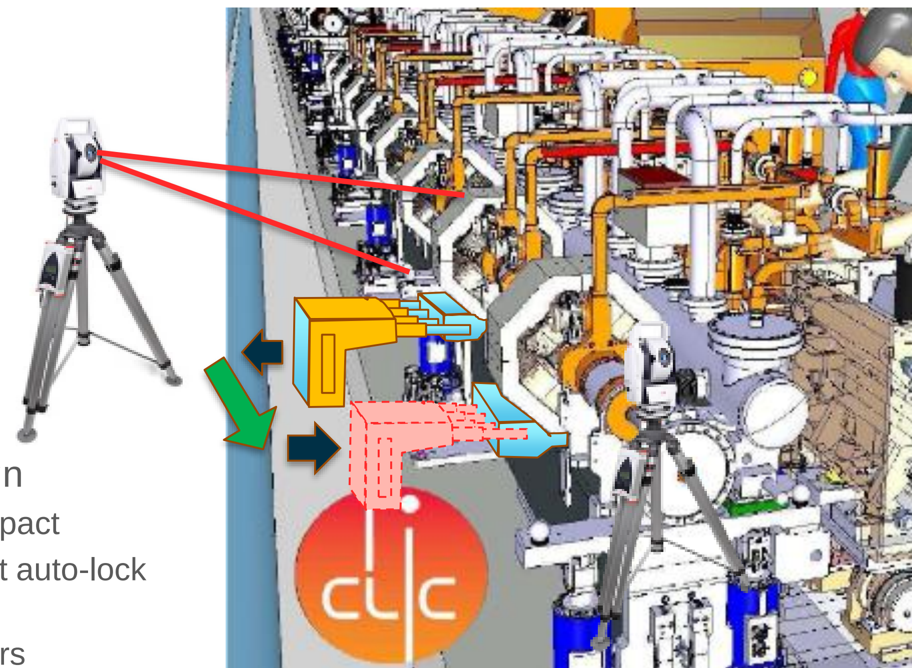


Tunnel fast re-adjustment

- **<u>Portable motorised adapter needed</u>**
  - Position and orientation feedback coming from tunnel survey (eg. the absolute tracker measurements)
- Option of permanent installation (remote adjustment)
  - Pos. feedback sensors as eg. WPS needed







- Mechanical design
  - Light and compact
  - **Mobility** – fast auto-lock mechanism
  - Build-in sensors

- Control algorithms adopted to automated and semi-manual use
  - Feedback tunnel measurements (eg. Laser tracker or position sensors)

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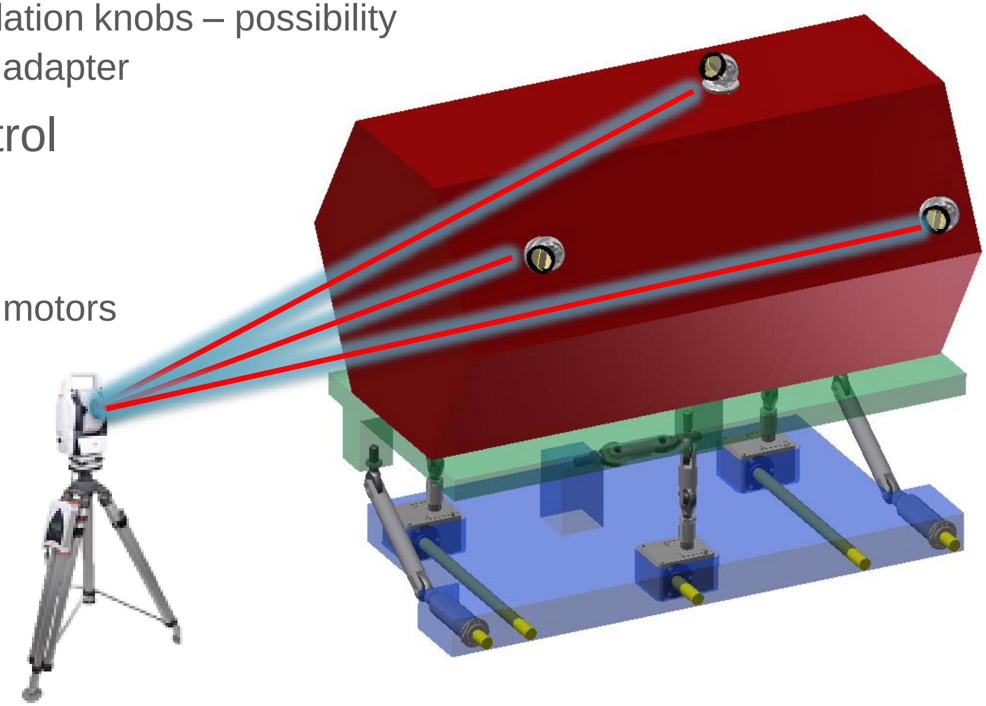
Motorized adapter functional prototype designed and preliminarily tested

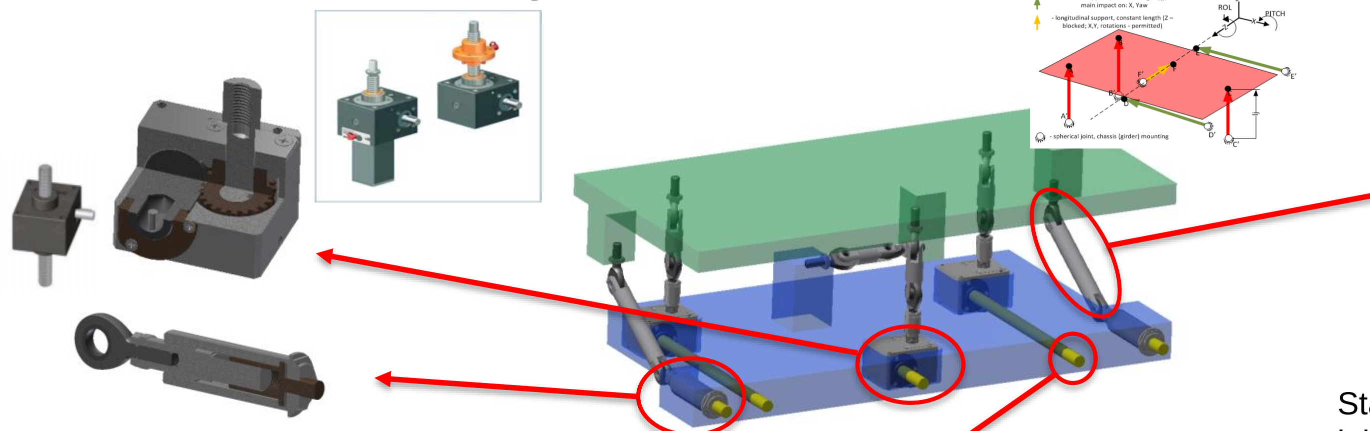
Standardized adjustment solution

- Universal adjustment platform based on vertical/horizontal Stewart platform configuration
  - Regulation knobs accessible on one side of platform
  - Easy and ergonomic manual operation, fast manual adjustment
  - Standardized interface to regulation knobs – possibility to easy connect the motorized adapter
- Full remote adjustment control
  - Upgrade in position sensors (eg. WPS, inclinometers, HLS)
  - Easy integration of permanent motors



Standardized adjustment solution

- Standardization of alignment mechanics



Standardized vertical/radial actuators mechanics

Standardized regulation and blocking interface

Standardized way of joints design

- Needed discussion with all interested users to recognize all requirements and future parameters:
  - Mechanisms accuracies, resolution, stiffness
  - Platform dimensions limitations, actuators dimensions
  - Maximal loads, external forces, etc.
- Validation of solutions chosen

Fast adjustment system - summary

- To increase safety of Survey personnel in radiation zones during components alignment - change of approach in design of adjustment supports is needed

- Standardized Stewart platform based 5DOF adjustment solution, allowing easy motorisation of components is proposed

- Final standardized platform design (for different objects size) to be defined (with collaboration with interested units) before end of 2018

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New control and DAQ electronics

Amount of components to be installed

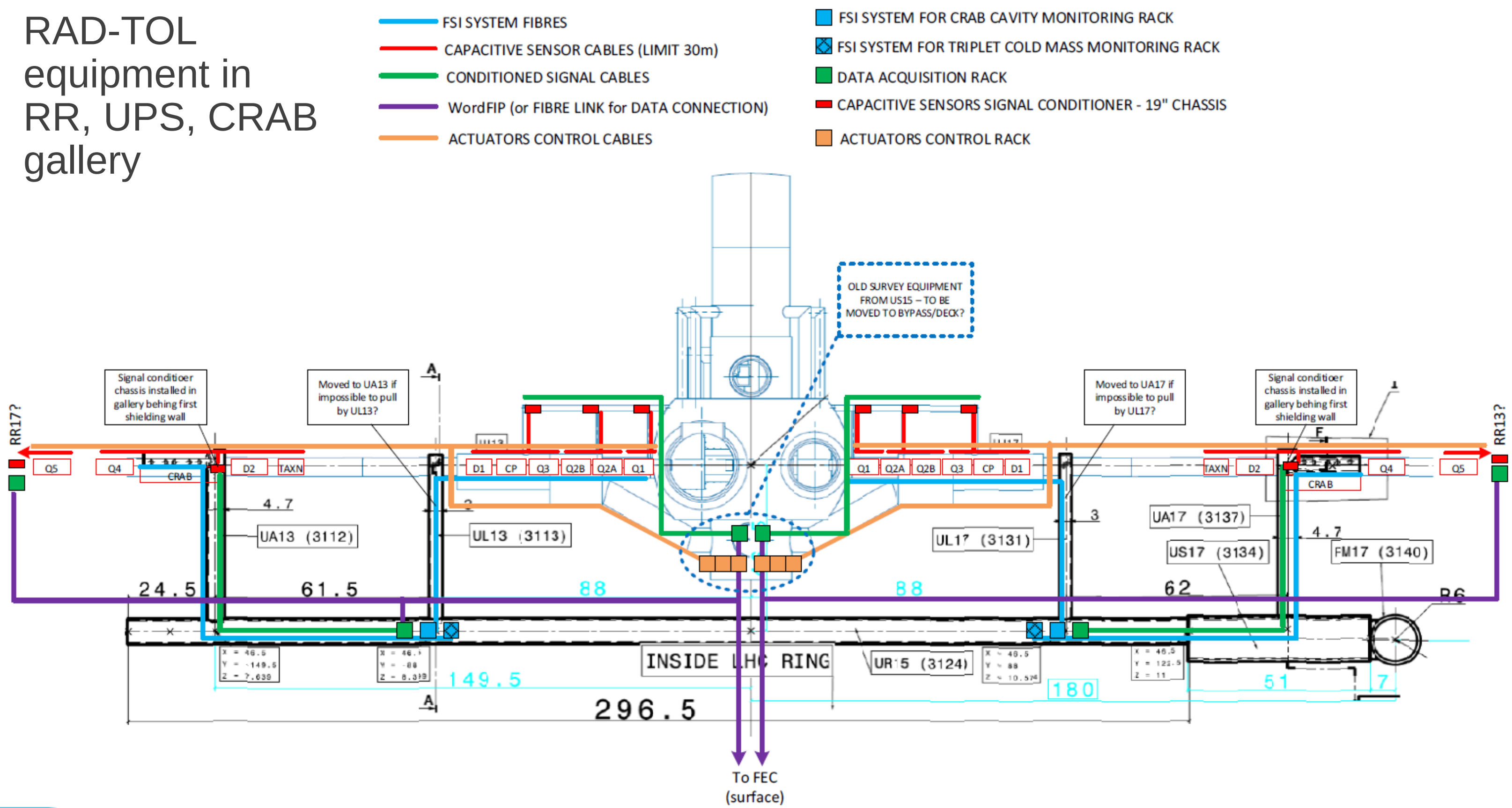
Not includes:

- PT100
- HLS network transition sensors (due to tilt of the tunnel)
- Load sensors in the motorized jacks
- Unknown for now instrumentation due to integration works pending (eg. possible motorization/monitoring of other components)

Equipment type / Component	WPS Sensor	HLS Sensor	DOMS Sensor	FSI channel (Frequency Scanning Intrferometer)	Vertical actuator	Radial actuator
Q1	2	3	1	9	3	2
Q2a	2	3	1	9	3	2
Q2b	2	3	1	9	3	2
Q3	2	3	1	9	3	2
CP	2	3	1		3	2
D1	2	3	1		3	2
D2	2	3	1		3	2
4x Crab-Cavity cryostat	8	12		72	12	8
Q4	2	3	1		3	2
Q5	2	3	1		3	2
L-R UPS connection	6		6			
Other sensors needed	2	4				
TOTAL:	34	43	15	108	30	20
ALL EQUIPMENT (P1/5)	**136**	**172**	**60**	**432**	**120**	**80**

Layout of HL-LHC control/monitoring system connections

- Most of control equipment (motors, FSI) in RAD safe locations
- Big number of motor cables, FSI fibre issue not a big problem
- Capacitive conditioners electronics in radiation zones due to cable length limitation
- RAD-TOL equipment in RR, UPS, CRAB gallery



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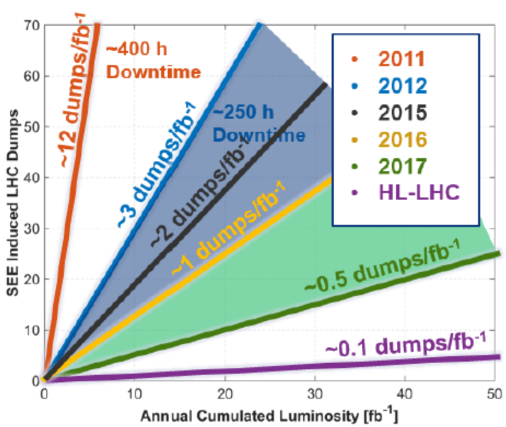
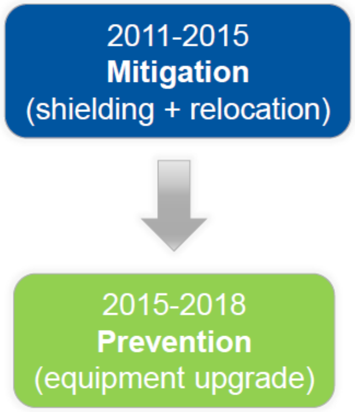
Survey installations reliability

Up to now – triplets installations not treated as critical for the LHC operation (however maintenance of equipment still consumes big amount of time)

For HL-LHC – situation may change – position monitoring especially of the triplets and crab cavities might be critical (waiting for dipole tests, SPS crab cavity test)

HL-LHC R2E – Availability Workshop outcome:
"Common efforts on developing highly available systems suggested"

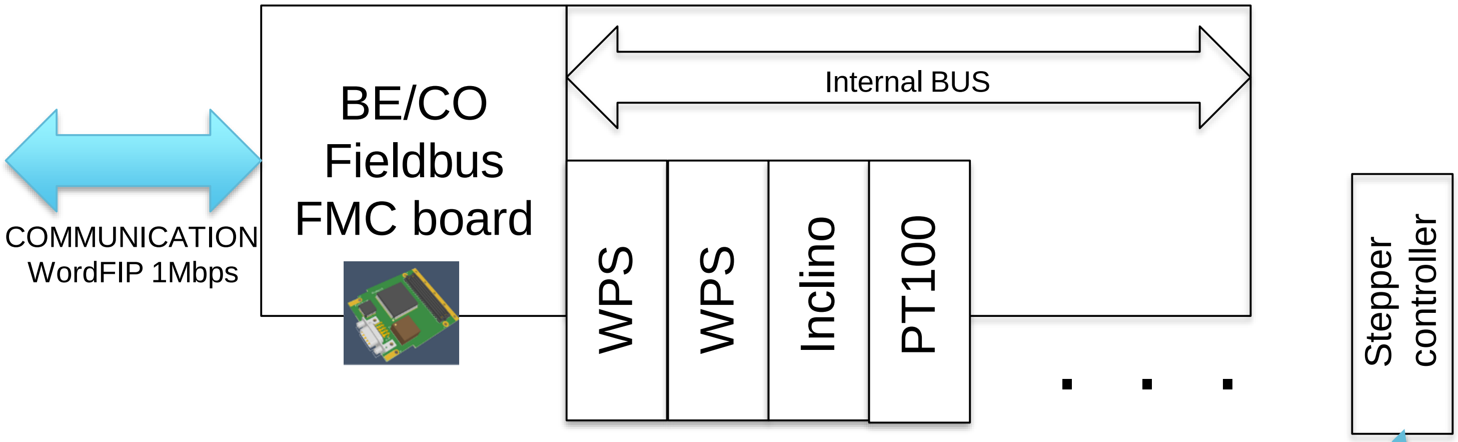




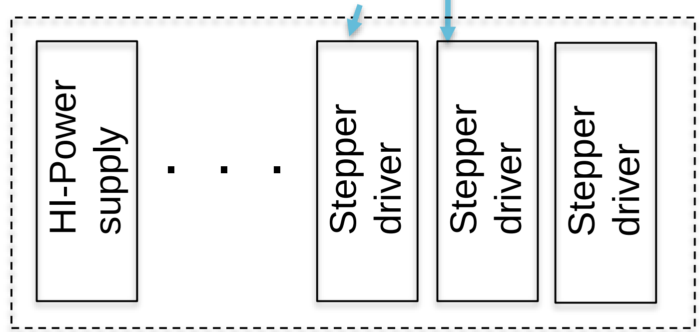
5th August 2016, Rubén García Alía et.al., HL-LHC integration meeting n51

„R2E strategy:from mitigation to prevention"

HL-SAS chassis

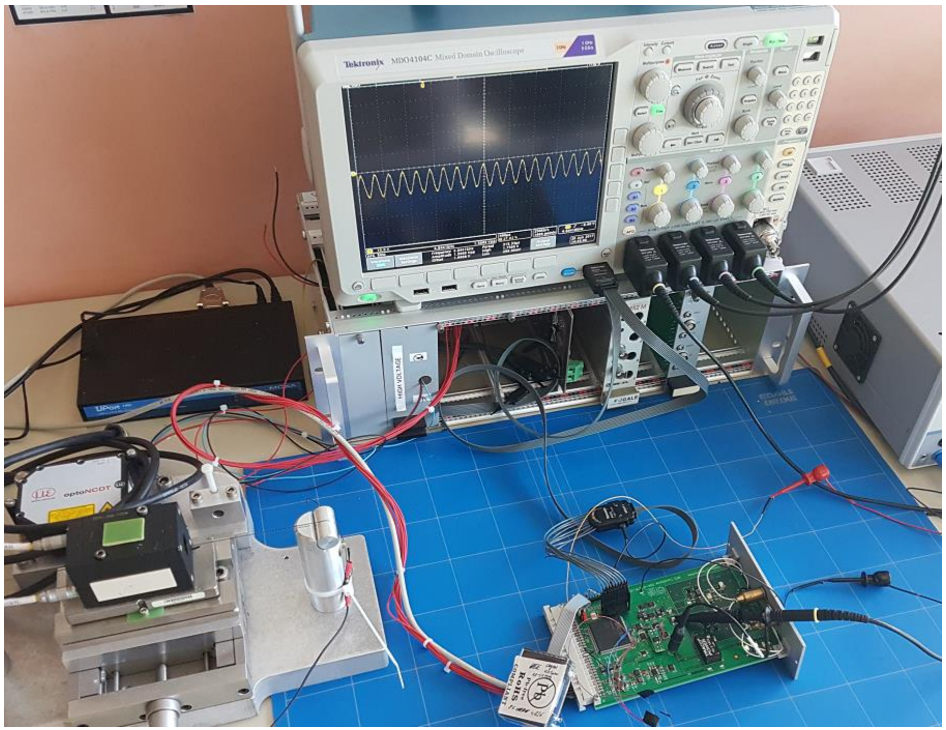


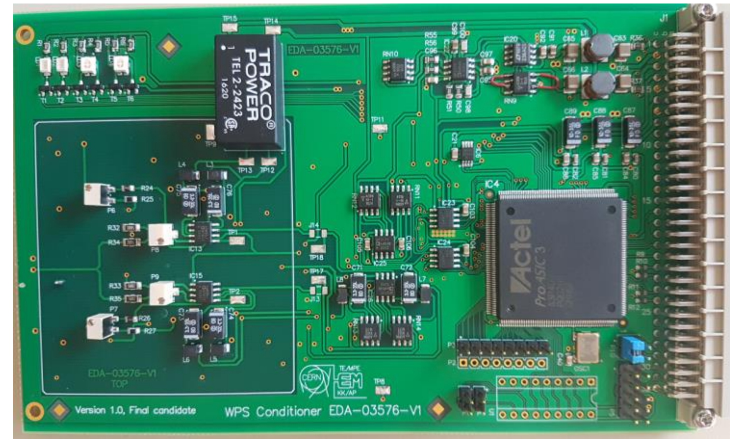
- Unified main-board for all kind of used modules
- Single hardware and software development
- HL-SAS chassis for RAD-TOL and safe locations
- Motor drivers powered from external supply or in separated chassis due to higher power consumption and noise isolation need
- Chassis electronics using BE/CO fileldbus module
- Standardized and custom made signal conditioners
  - In safe locations NI-CRIO cards might be used
  - In radiation locations custom made conditioners (eg. capacitive conditioner but other not excluded)

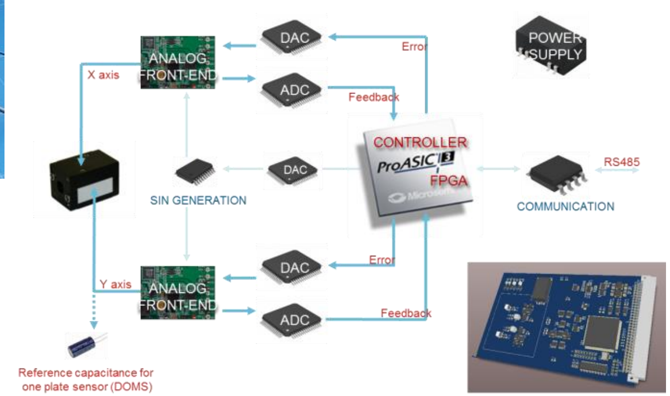


New electronics – standardized modules

- Standardized capacitive sensors signal conditioner
- Same hardware for WPS, HLS, DOMS
- ‚Deep' diagnostics of signals and sensing chain
- RAD-TOL (200Gy)







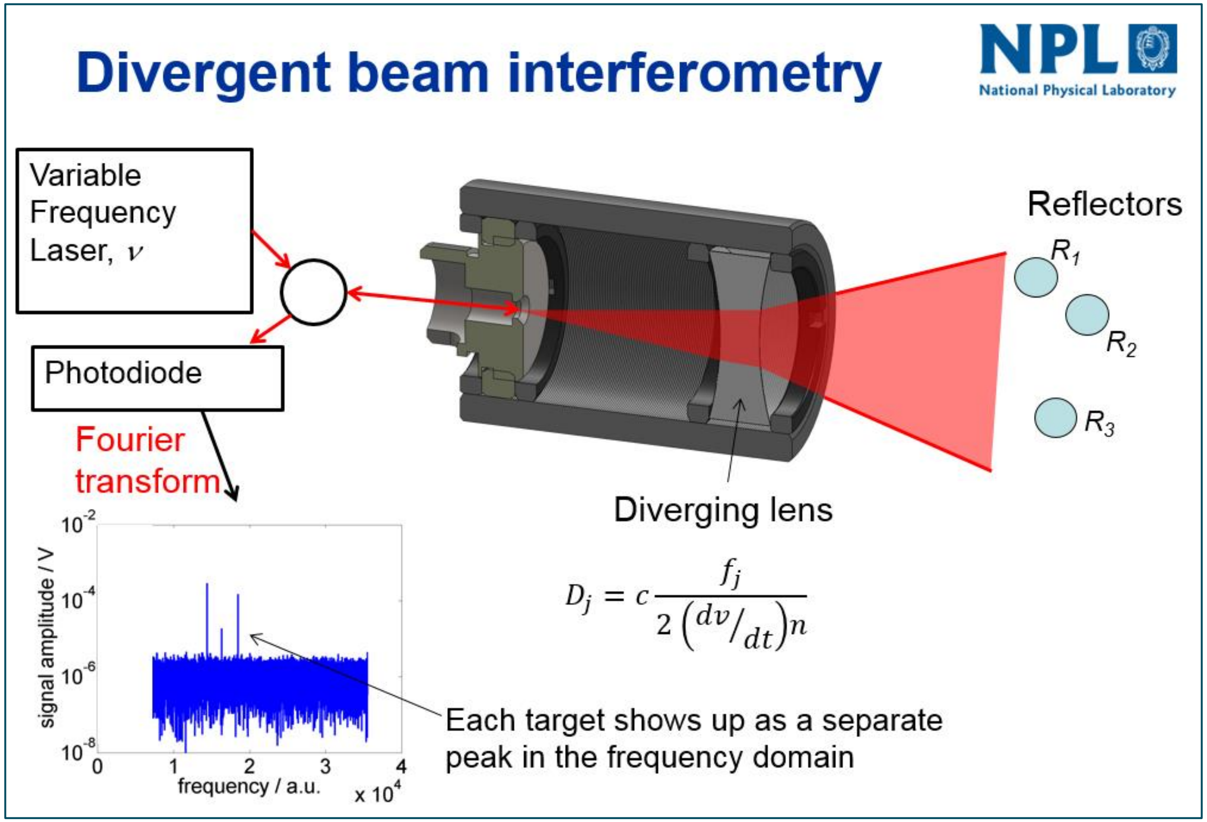
New electronics – summary

- New capacitive signal conditioner under development (initial tests Autumn 2017
- DAQ acquisition chassis prototype (HL-SAS) to be developed September-November 2017, with use of BE/CO nanoFIP rad-hard modules
- DAQ chassis + capacitive conditioner prototype field test in UPS gallery corner will start YETS 2017-2018
- RAD-TOL electronics tests in CHARM planned for 2018

Multi-target Frequency Scanning Interferometry

Multi-target FSI R&D

- New approach to FSI signal analysis
- Distance to multiple targets measured simultanously in single laser sweep, calculations based on interference beat-frequencies in sweep frequency response
- Measurements traceability thanks to gas cells absorption frequencies
- Very robust measurement method – almost insensitive to the light intensity



B. Hughes et.al. 1st PACMAN Workshop 2016

Multi-target FSI R&D

Summary

- Parallel R&D not included in the HL-LHC instrumentation baseline
- Allows for accurate distance measurement to low-cost S-LAH79 targets and other surfaces (detectable reflections from variety of materials, water, etc…)
- Easy to adapt in radiation – pure optics without any active components in dangerous zones
- Allows for construction of simple and cheap sensors for future precise accelerator metrology

- Prototype interferometer rack ready
- Software under preparation
- Initial tests planned in Autumn 2017

Thank you for your attention

Radiation levels vs. installation constriants

Protected areas (considered as safe)

Equipment in safe zones

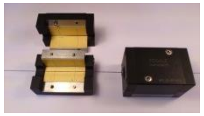
(US15, UL55, double deck)

Electronics radiation zones (RR, UPS, galleries over CRABs)

- TID <$100Gy_{HL\text{-}LHC}$
- ~$1\cdot10^7$ (10^{10} RR ultimate) HEH/cm^2/100 fb^{-1}
- Limited access (only technical stops)

Low radiation zones – RAD-TOL components

High radiation zones – only passive components



Equipment in the tunnel

- 10x bigger TID (up to $1MGy_{HL\text{-}LHC}$)
- 4x more of equipment
- Difficult to access and repair components in high radiation zones (LSS – long cooling time)