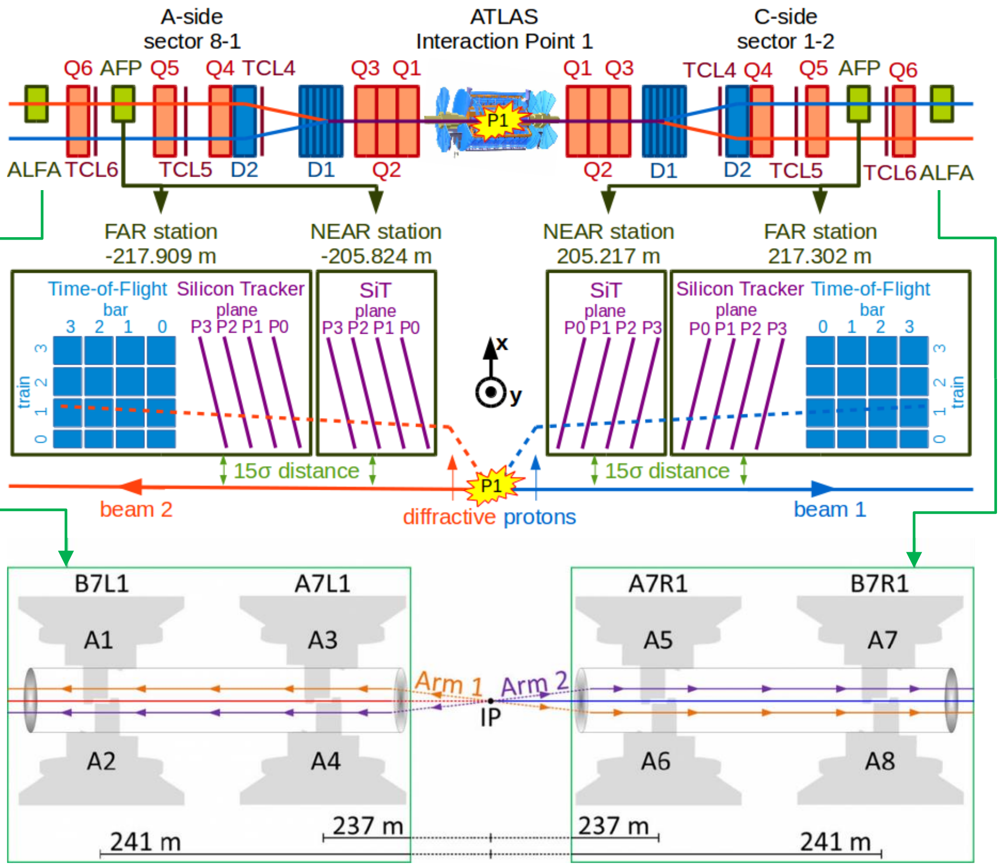
ECR/Plans for AFP shielding installation during YETS 24/25

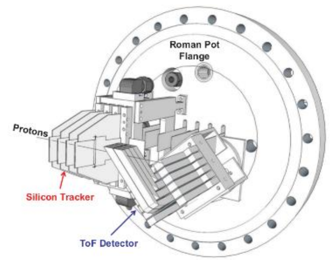
ATLAS EXPERIMENT

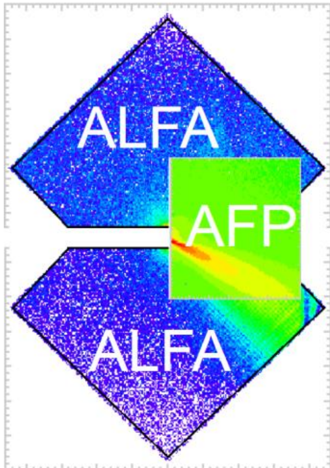
LHC Tunnel Region Experiments Working Group (TREX)

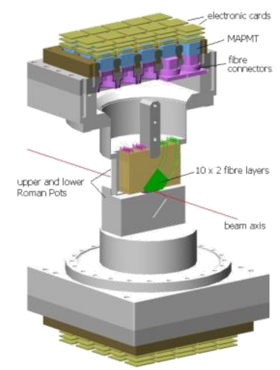


Marko Milovanovic

31.01.2025.





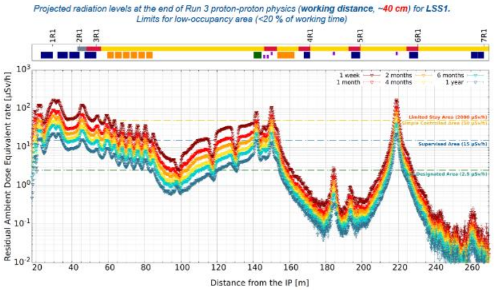


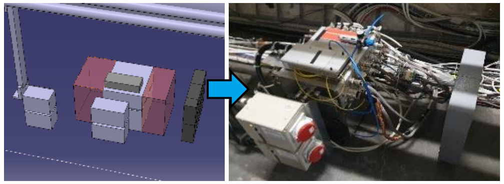
JUSTUS-LIEBIG-
UNIVERSITÄT
GIESSEN

CERN

Background

- Thanks to its location, i.e. close proximity to TCL6 (~1m) AFP keeps suffering from tremendous radiation damage throughout Run3, owing to increased luminosity, which particularly in 2024 produced a lot of very good data for physics.
  - This implies increased equipment activation, due to which even 2 months after LHC shutdown, 30uSv/h are measured at the location of FAR stations.
  - High loses in TCL6 were also identified during loss maps, which made it also the hottest spot in the LHC ring in terms of residual dose rate during YETS.
- These issues were first identified in 2022, when AFP was not able to calibrate equipment anymore during interfills, nor have enough time to repair/replace failing components in the tunnel. Two solutions:
  - Relax TCL6 settings to mimic favorable conditions in Run2 (~1.9mm).
  - Install possible shielding walls between AFP and TCL6 collimators.
- 2023 was a lot better year for AFP in terms of radiation damage.
- In 2024 however, with changed optics (TCL6 settings were again very tight, ~1.6mm) AFP started experiencing the same issues.
  - As relaxing TCL6 was no longer an option (due to negative radiation damage effects to other equipment in the tunnel), the only remaining choice was upgrading the shielding walls between AFP & TCL6 as much as possible.
  - ECR: https://edms.cern.ch/document/2914323/0.1 (approval accepted)
  - However, this did not improve situation much, and apart from weekly failures in FAR station electronics, the PP equipment (VREG CC & VB) also started dying at an alarming rate.





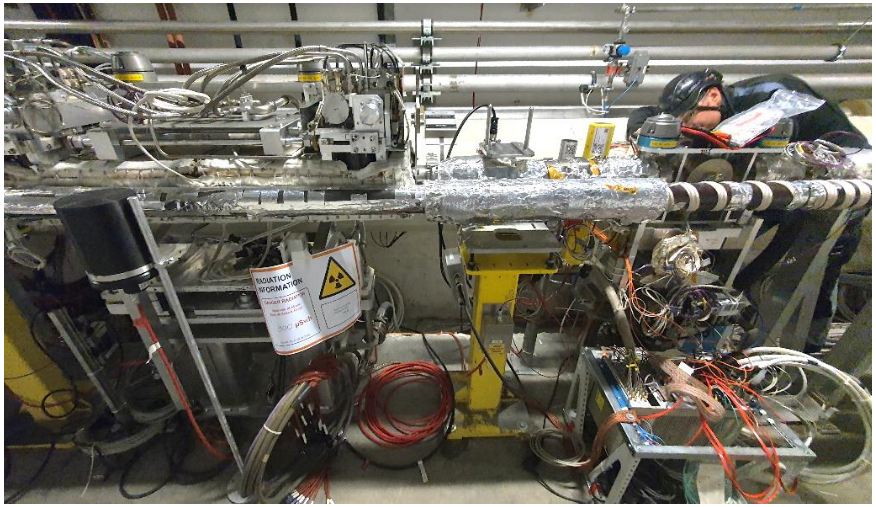
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

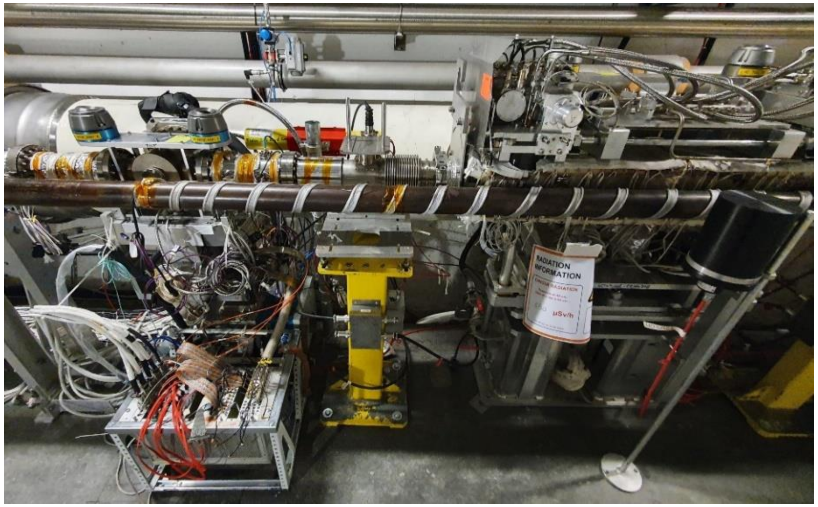
Background – BatMon deployment + shielding upgrade

2024 BatMon deployment in AFP: context

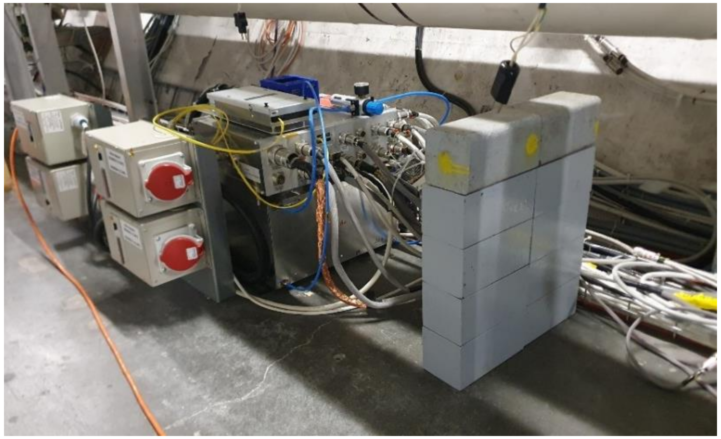
- The closed **TCL6** settings in IR1, as well as the large amount of **integrated luminosity** being delivered to ATLAS, is causing **issues** to AFP equipment, including (among others):
  - Electronics crate (roughly 1m upstream of the TCL6, at floor level)
  - Patch panel (roughly 7m upstream of the rack)
- The option of relaxing the TCL6 setting has been considered, upon request by AFP, to reduce the radiation levels on the equipment and the local activation (see ColWG#281).
- However, **TCL6 could not be relaxed** due to conflicting constraints (R2E in the DS, FASER/SND backgrounds). Moreover, RP measurements after a dedicated test run have shown that small changes in the half-gap don't yield significant improvements on the activation (EDMS 3096203).
- The following actions were undertaken during TS1 (see next slides for details and layout):
  - **Implementation** of **shielding** using iron bricks
  - **Deployment** of **BatMons** to measure the radiation levels on the racks and patch panels, on the left and right side of P1

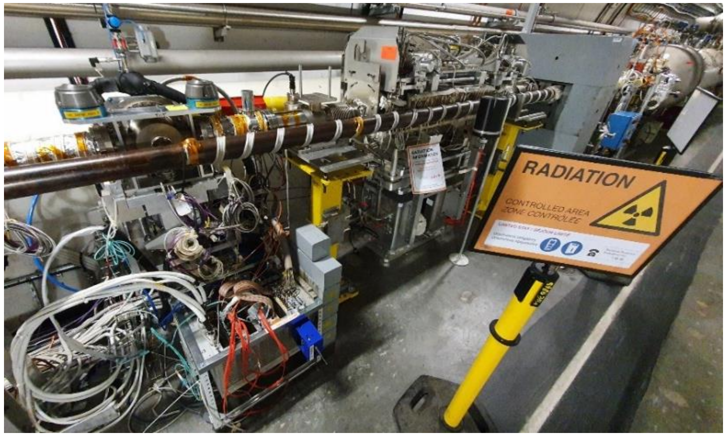
Background – BatMon deployment + shielding upgrade

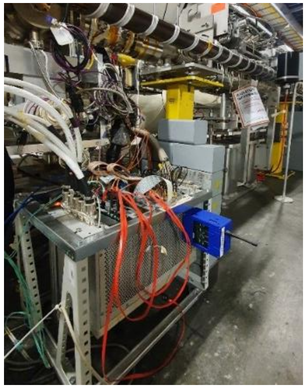




- LSS1L: 900 µSv/h (dose rate at 40cm)   LSS1R: 650 µSv/h (dose rate at 40cm)
- Average dose at AFP location during short access: 400 µSv/h (max. allowed dose per day/person: 50/100 µSv according to ALARA lvl.1 – now increased to ALARA lvl.2)







Thanks to prompt reaction by JPC & M.Lazzaroni!

Conclusions from R2E-MCWG on BatMon measurements

Conclusions/2

- The measurements (summarized on slide 19) indicate that neither the AFP crate **nor** the patch panel are **safe for electronics** (as known for the IR1-IR5 tunnel areas)
- In particular, considering the target luminosity of 120 fb^{-1} for the 2024 run, the crate and patch panel are **expected to receive TID levels between ~100 Gy and ~200 Gy, and HEH fluences varying between around 10^{11} and 10^{12} HEH/cm²** (see the table on slide 20 for the full numbers, including the thermal neutron fluences)
- For the above values, the occurrence of radiation-induced failures may be **critical**, both in terms of lifetime degradation and (very high) probability of Single Event Effects (SEEs)
- The BatMons could not test the efficiency of the shielding deployed in TS1 **with the current deployment**. However, the installed bricks are not large enough (and hermetic enough) to make a substantial impact.
- The above radiation levels can serve as a starting point to determine an appropriate mitigation strategy in view of 2025, which also needs to take into account:
  - The **level of criticality of the electronics,** and any information about their lifetime and/or SEE sensitivity
  - **Practical constraints** for the possible installation of **larger** local shielding (ideally, an iron bunker)

Controls Electronics & Mechatronics 07/16/2024 2024 BatMon measurements at IR1 AFP racks and patch panels 20

> The small shielding walls were to remain until end of AFP program (at the time seemed most likely until end of 2024) and it was just struggling to survive until this point.

Background – decision that keeps AFP until end of Run3!

Configuration proposal

RP-V in IP5

seems to be mandatory to avoid major risks on the inner triplet region magnets

CONSEQUENCES:

- TOTEM pots rotation
- Modification of powering scheme (IT+Q4)

~~**RP-H in IP1**~~

~~best configuration for magnet protection~~

~~**CONSEQUENCES:**~~

- ~~Increased background for FASER & SND~~
- ~~AFP is lost~~

LHC-BOC final decision:

NOM-H in IP1

increased risk for D1 & IT toward the limit at the end of Run3

CONSEQUENCES:

- Reduced background for FASER&SND
- Preserve AFP experiment

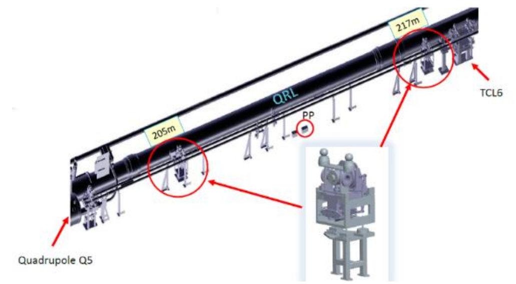
CERN 2025(6) configuration 14

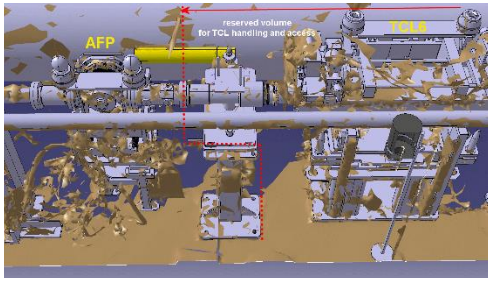
Swap magnet with spare possible:

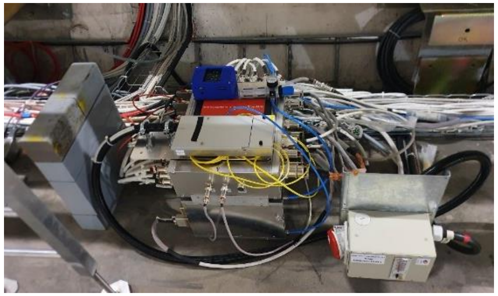
- Operation estimated to last 6-7 weeks – not optimized!
- Partial reconditioning to be done

Current situation

- During 2024, AFP had to borrow the last (two) remaining spare(s) of VREG Controller Cards from Pixels, in order to complete the final/p-p reference run program.
  - In total, AFP needs 1 functioning VREG Controller Card (located in PP) per arm. In total, we had 5 broken cards just before p-p reference run.
  - An enormous effort was invested to find a way to repair these cards finally during YETS, as new production was not possible.
  - Still struggling to repair all the VREG Voltage Boards (located in PP) to be able to operate this year.
- Since it is NOT possible to make any proper shielding near TCL6 (without modifying the vacuum layout), an IB decision was taken NOT to run w/ToF detector during nominal LHC operation until end of Run3.
  - ToF crates would be installed only during ramp-up or special runs in order to avoid so many issues/equipment failures experienced during 2024 and reduce costs
  - In 2024 AFP overspent the foreseen budget in order to produce enough spares to be able to operate until end of the year.
- While it is possible to operate without ToF, it is not possible to do so without the PP electronics (VLDBs, VREG Controller Cards and Voltage Boards.
- This is why we are in desperate need of a better shielding wall for our Patch Panel at least in order to reduce the unsustainable equipment failure and operation downtime in 2025/26.



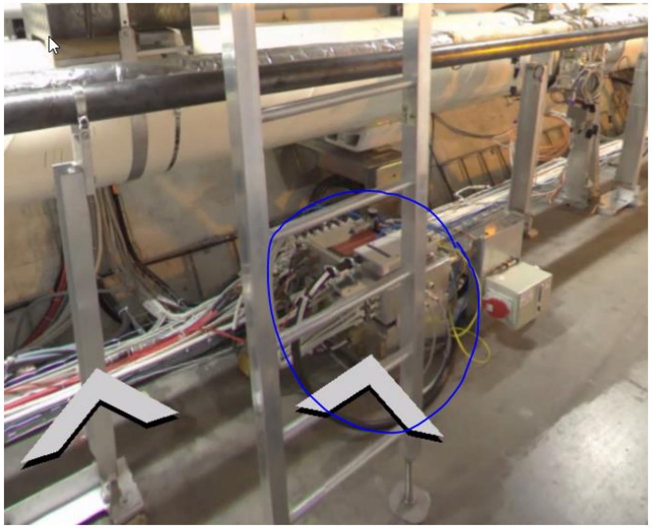




JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Proposal by R2E (PP upgraded shielding wall) – *GL, JPC & ML*

- For FLUKA/R2E, in an ideal world, the patch panel should be in a bunker-like shielding, covered both on the sides and on the top
  - The BSRT in P4 is a good example, or similarly, the bunkers in the TD62/68 tunnels upstream of the beam dumps.
  - From R2E experience with similar bunker studies (both with FLUKA + measurements) one would need at least 10cm of iron shielding on all sides; but the more, the better.
- The main constraints in P1 are related to integration:
  - A full bunker like the one of P4 or TD62/68 is impossible to implement, but in order to achieve a non-negligible reduction of the dose, one would need to implement at least something that "encapsulates" the full racks (i.e., with walls on the two sides, and a "ceiling" made of iron bars).
- Before running FLUKA studies, integration study needs to be done to determine the max. amount of shielding to be realistically added in YETS
  - Once a realistic shielding layout is available, we could then launch a quick FLUKA study to compute the expected reduction of the dose and include it in an ECR to justify the intervention.
  - 1st step: understand if a shielding of this sort can be put in place during this YETS.
- Integration team might need some assistance to do it in time, which AFP is more than willing to provide.

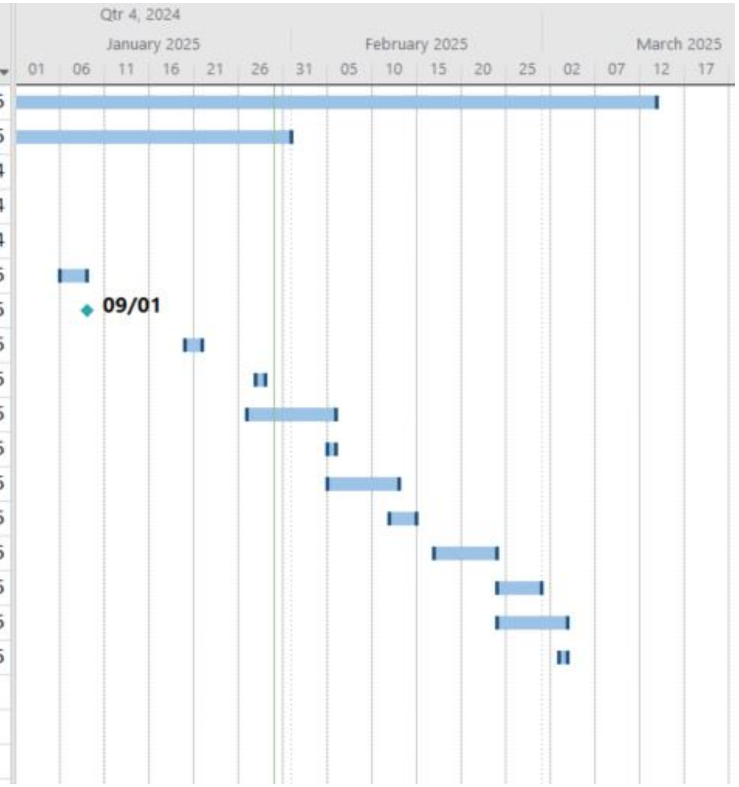


JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

YETS 2024/25 plan

GANTT CHART

	Task Name	Duration	Start	Finish
1	YETS 24/25 - constraints in LSS1; work until 28/02.	79 days	25/11/2024	13/03/2025
2	Refurbishment + test of the whole readout chain	50 days	25/11/2024	31/01/2025
3	AFP laser survey	5 days	09/12/2024	13/12/2024
4	AFP cable survey	1 day	10/12/2024	11/12/2024
5	Switch off all equipment in USA15 before AC	0 days	19/12/2024	19/12/2024
6	AUG et. Al. tests P1	3 days	06/01/2025	08/01/2025
7	Switch back on all equipment	0 days	09/01/2025	09/01/2025
8	Movement system maintenance - FAR flanges extraction	2 days	20/01/2025	21/01/2025
9	Removing both ToF crates for refurbishment	1 day	28/01/2025	29/01/2025
10	New SiT module building and testing in 180	8 days	27/01/2025	05/02/2025
11	Replacing a failing ALFA turbine with spare	1 day	05/02/2025	06/02/2025
12	New detector package assembly and metrology	6 days	05/02/2025	12/02/2025
13	Installation of new detector packages in LSS1	3 days	12/02/2025	14/02/2025
14	Recommissioning of the whole TDAQ chain	6 days	17/02/2025	23/02/2025
15	Contingency/spare	5 days	24/02/2025	28/02/2025
16	Re-measurement & re-alignment of AFP stations	6 days	24/02/2025	04/03/2025
17	Installation of a new PP shielding wall (?)	1 day	03/03/2025	04/03/2025
18				
19	Sector 1-2; access posible until 13/03			
20	Sector 8-1; access possible until 04/03			



- Still on track with the YETS schedule. Hopefully the shielding wall will be approved before end of YETS.
- ECR is kept up-to-date with the progress with the help of M.Majstorovic (BE-EA-EC) in order to circulate it in time (2 weeks before the LMC approval).

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Backup

Backup slides.

Reminders, updates & constraints

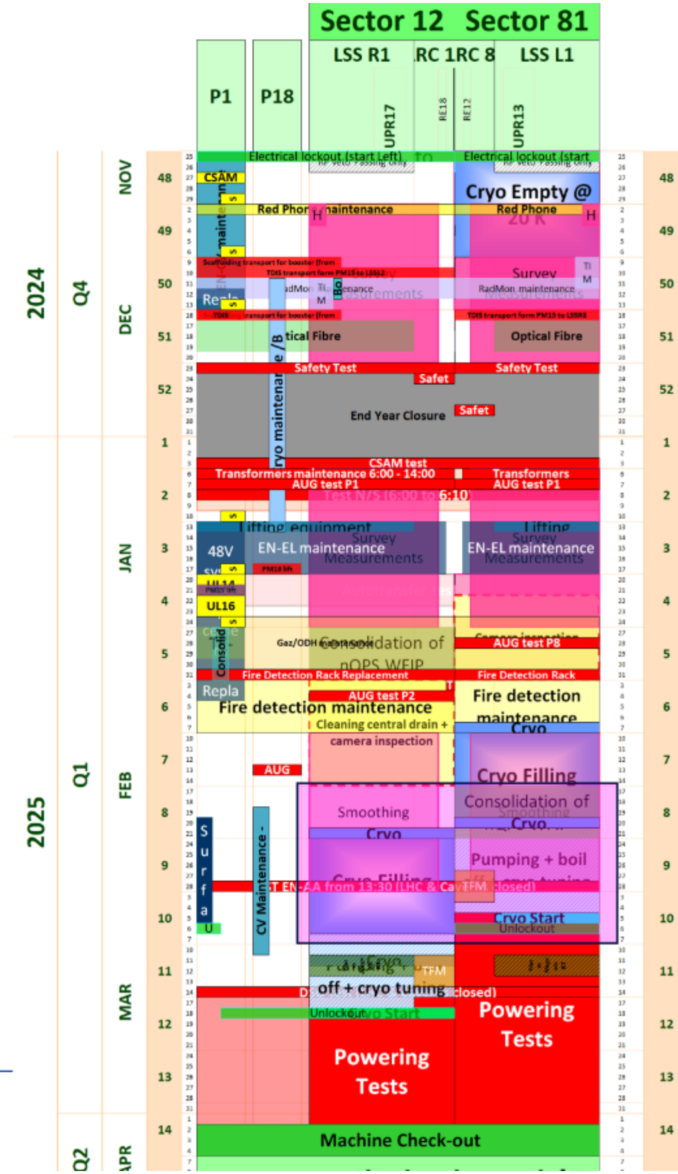
- Replacing Stainless Steel ALFA blind flanges in S81 with Al ones:
  - Scheduled for 28-29/11. Sune will use his own impact.
- ARP cable survey
  - Scheduled for 10/12 – Giulio, Elzbieta, Luis, Maciej, Marko.
- 1st AFP laser survey
  - Scheduled for W50 (ca.12-13/12).
- 2nd AFP laser survey
  - New fiducialisation (if necessary) and new LVDT calibration (~2 days): for these. Precise slot tbd; aiming for W9. A short slot can be locked in order to optimize our presence
  - Smoothing alignment: the regular LSS1 smoothing will be done between 2025-02-10 and 2025-02-21 (no help required).
- New SiT modules production at IFAE:
  - Bump-bonding machine broken at IFAE & wire-bonding technician over-committed. Might send the modules to CERN for wire-bonding.
  - Ideally to be ready for pick up by 12/01 (W2) or deliver by 27/01 (W5) to CERN for wire-bonding and testing.
- Extraction and re-insertion of flanges w/refurbished detector packages:
  - Aiming for removal of flanges in W4 (+-1 week)
  - Assembly and metrology of detector packages in W6-7
  - Re-installation of flanges w/refurbished packages: W7-8.
  - Recommissioning, 2nd survey & smoothing alignment: W9
- Sector 8-1 access possible only until 04/03!
  - Sector 1-2: access possible until 13/03.

Survey requests

To optimize the availability of BE-GM:

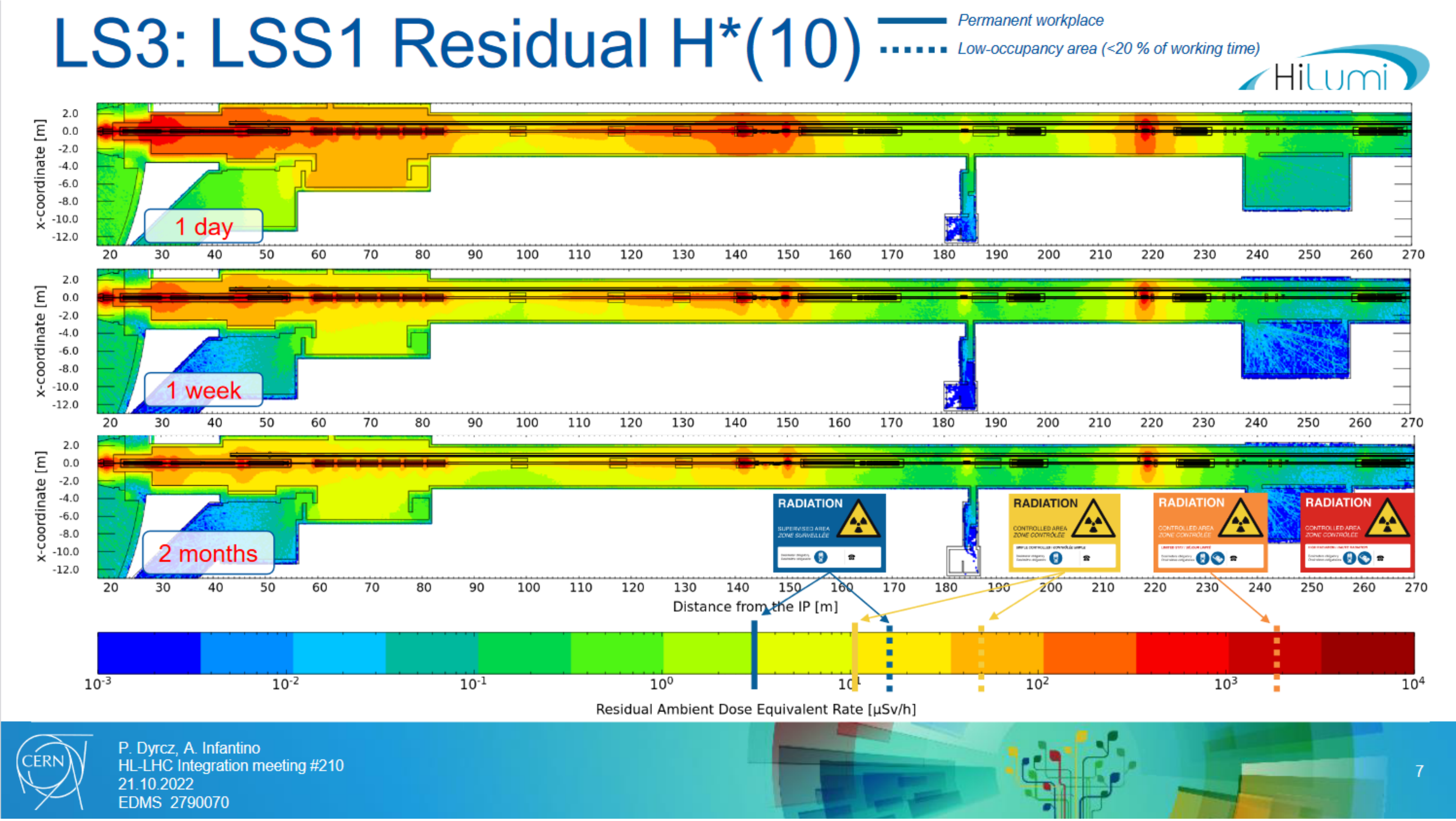
- LSS1 Smoothing shift from W7-8-9 to W8-9-10?
    - LSSL1 it means only 3 days of work in W10, but LSSR1 seems free at that time.

- S78 – BE-GM would like to add one more activity in W8-9-10. It would be a 3D measurement.
    - in this case could they merge it to a single block W6-W10 and micromanage it Fortunately, physically it should not block completely anybody with those activities.

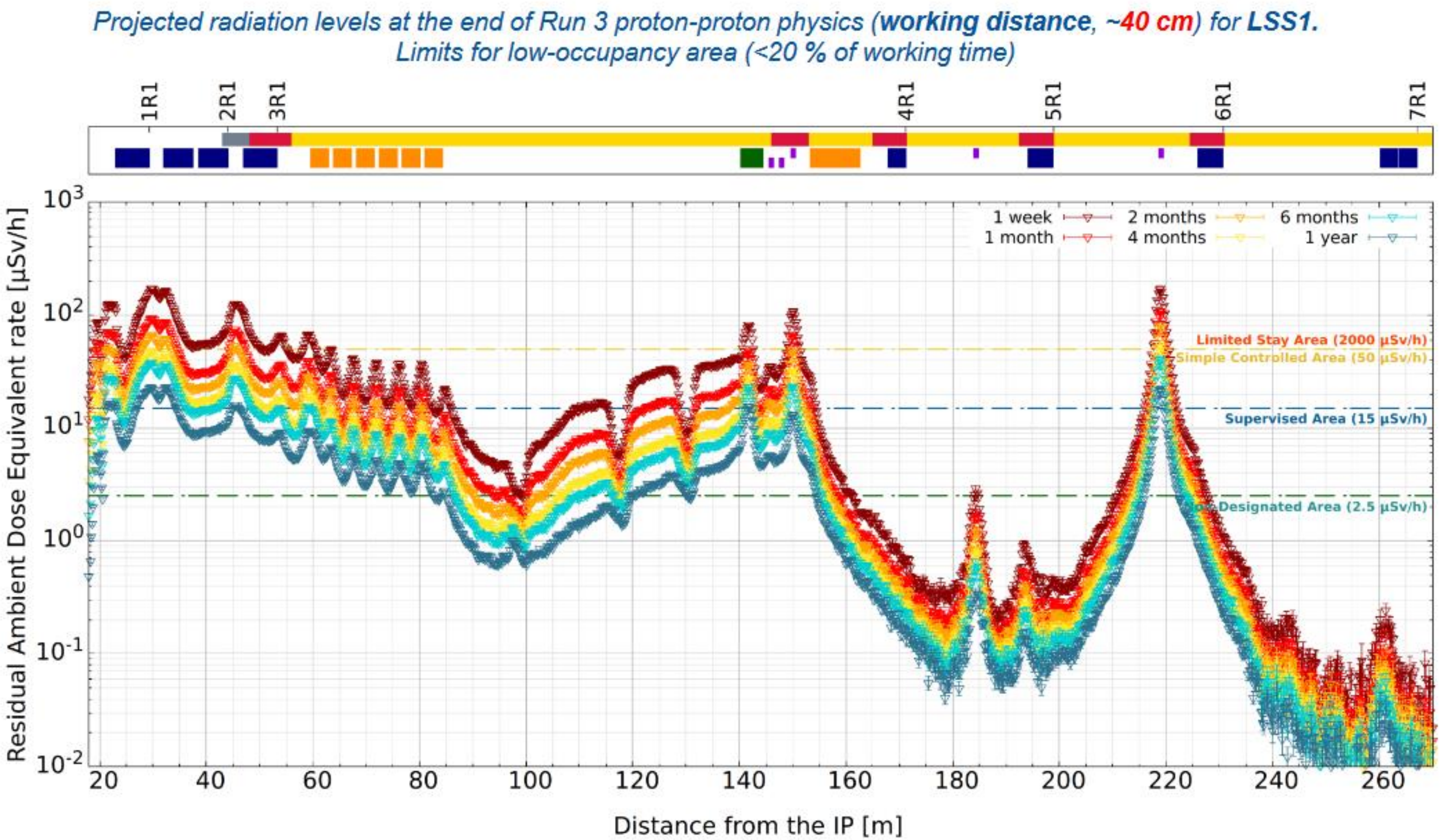


ENGINEERING DEPARTMENT
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Projected radiation levels in LSS1



Projected radiation levels in LSS1



Update from R2E-MCWG on BatMon measurements

Summary and Normalized Measurements for IR1-AFP racks

		P1 Left Side			P1 Right Side		
Position	**Magnitude**	****5.7 fb-1**	**1 fb-1**	**120 fb-1**	****5.7 fb-1**	**1 fb-1**	**120 fb-1**
CRATE	TID	8.27	1.45	174	5.6*	0.98*	117.6*
	ϕ_{HEH} [pp/cm²]	3.99×10^{10}	7×10^{9}	8.4×10^{11}	3.12×10^{10}*	5.4×10^{9}*	6.5×10^{11}*
	ϕ_{ThN} [pp/cm²]	1.96×10^{11}	3.44×10^{10}	4.13×10^{12}	1.80×10^{11}*	3.16×10^{10}*	3.8×10^{12}*
PATCH PANEL	TID	9.03	1.58	190	6.12	1.07	128.4
	ϕ_{HEH} [pp/cm²]	5.91×10^{9}	1.03×10^{9}	1.24×10^{11}	4.62×10^{9}	8.11×10^{8}	9.73×10^{10}
	ϕ_{ThN} [pp/cm²]	3.30×10^{10}	5.79×10^{9}	6.95×10^{11}	3.05×10^{10}	5.35×10^{9}	6.42×10^{11}

**Atlas Luminosity from 2024-06-14 to 2024-07-01

**Expected values considering the measurements of the three devices and a similar geometry for the two areas*

Conclusions, (still) open questions and ECR status

- Suffering from enormous amounts of radiation damage, **AFP ‘upgraded’ its small shielding wall(s)** to try to compensate as much as possible for the increased radiation doses coming (mostly) from its vicinity to TCL6 collimators (since larger opening is no longer an option as last year).
- BatMons (online radiation monitoring) installed in 2 crucial locations per side to determine precise radiation doses which, after the 1st measurements, are **confirmed not safe for the electronics** in that area.
- These values will serve as a starting point to determine appropriate mitigation strategy:
  - Radiation testing of modules to get a better estimate at which doses our equipment fails and determine the exact cause (TID, SEE, DD)
  - Re-investigate practical/layout constraints for possible installation of larger local shielding (ideally, an iron bunker).
- AFP still does not know if it will be able to run next year due to triplet polarity inversion/change of crossing angle (from vertical to horizontal) in P1.
- ECRs still pending in anticipation of more information.

6. High Precision Time Digitizer

The High Precision Time Digitizer board, HPTDC, was developed by the University of Alberta. The 12-channel board uses 4 HPTDC ASICs developed and produced by CERN in 0.25 μm CMOS technology (HPTDC, J. Christiansen *et al.*, http://tdc.web.cern.ch/tdc/hptdc/hptdc.htm). The four ASICs are controlled by an on-board FPGA which also handles the flow of data and controls. This and previous versions of the HPTDC board have been used successfully at various beam tests. The HPTDC, and new developments were presented by Pinfold at this workshop [6].

The intrinsic resolution of the current HPTDC is 16 ps, which is a significant contributor to the per-channel resolution. However, new HPTDC ASIC development with smaller feature size are ongoing at CERN and may lead to significant improvements in the near future. Note that the 16 ps resolution of the HPTDC is per channel and that the contribution for a system of four quartz bars in sequence would only be 8 ps.

The radiation tolerance of the HPTDC is not guaranteed. The HPTDC ASIC is expected to be radiation tolerant to a degree sufficient for it to be located on the tunnel floor, near the detectors. The FPGA firmware must be re-designed to provide the appropriate checking of HPTDC registers for

ATLAS Forward Proton Detectors: Time-of-Flight Electronics 757

upsets. Moreover, the FPGA itself has to be radiation tolerant, which can be done by choosing a radiation-hard part (expensive!) or going to a fuse-programmable part. Alternatively, the FPGA can be programmed to do self-checking and organized with majority decisions in critical paths. It is the latter choice that will be pursued.

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN