

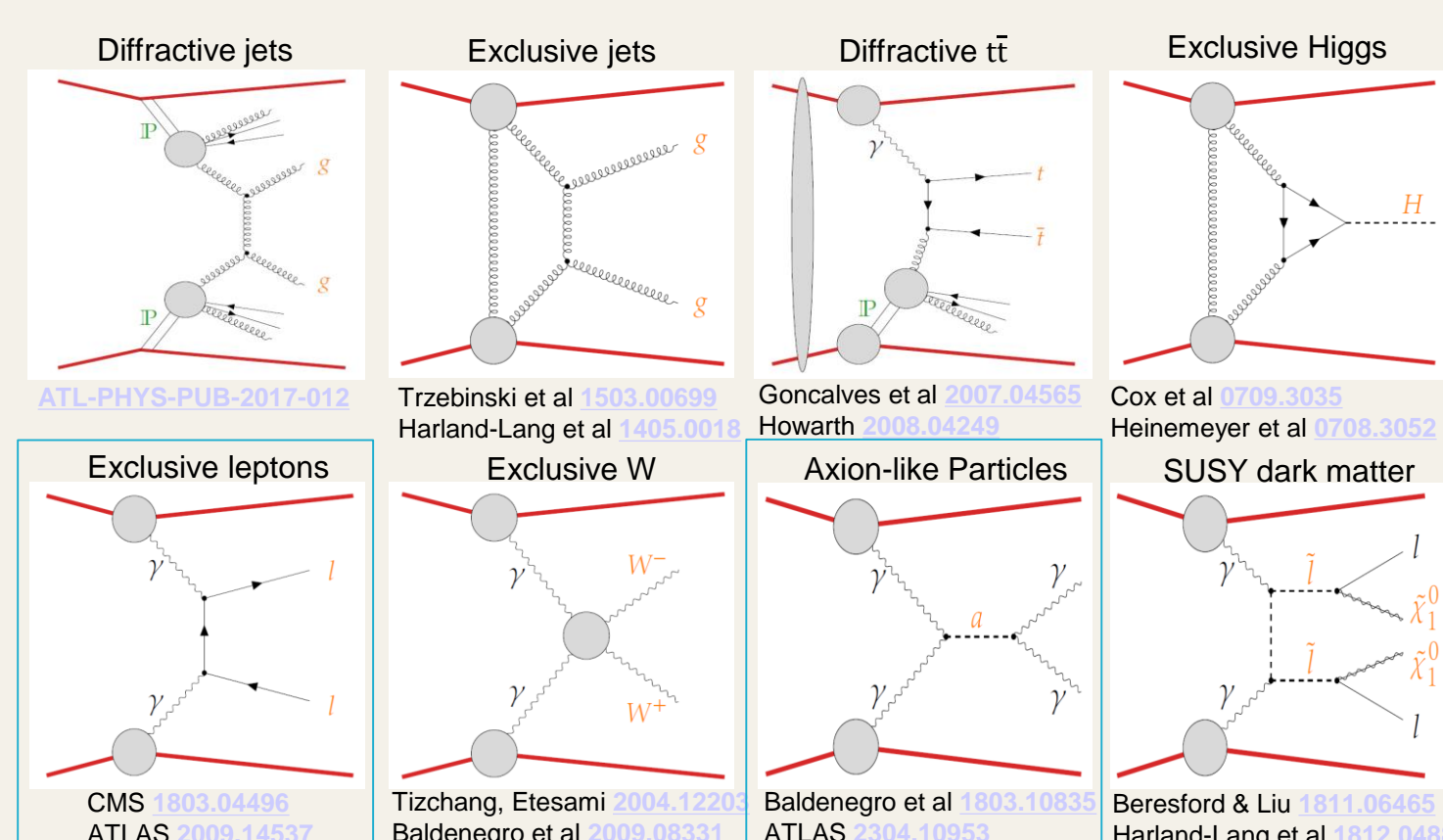
Overview of ATLAS forward proton detectors: status, performance and new physics results

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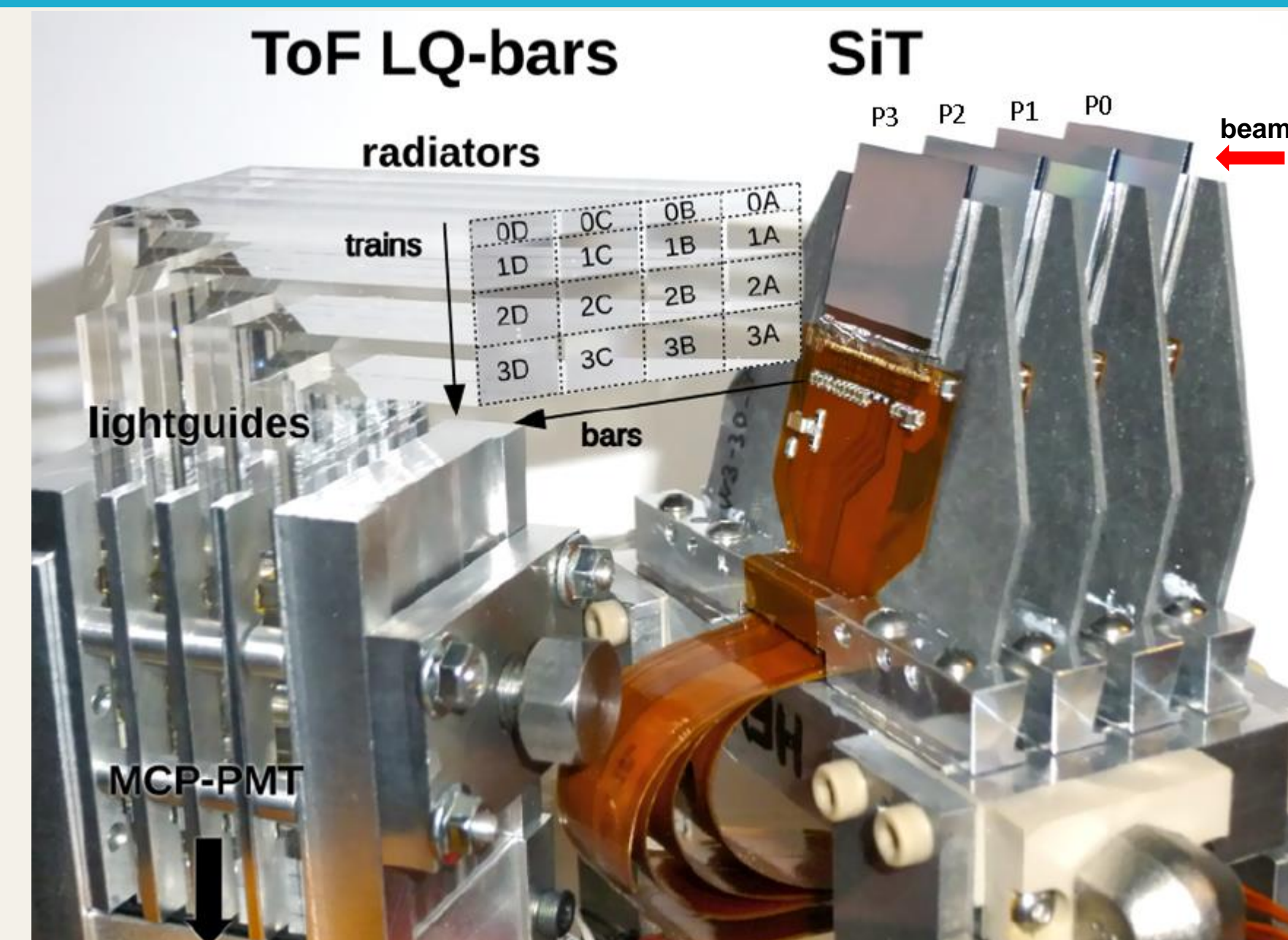
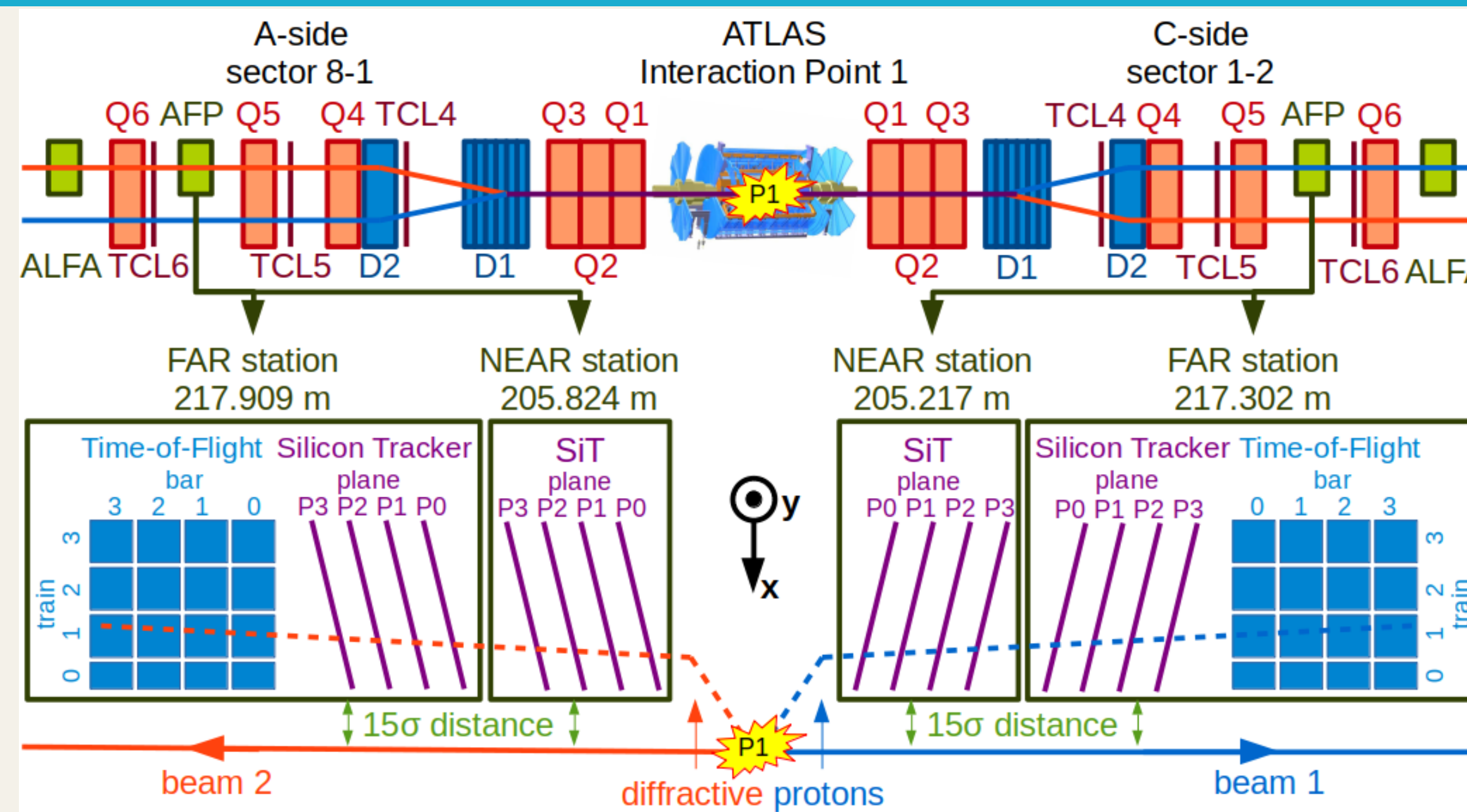
The AFP detector is a Roman Pot system - located in the LHC tunnel outside of the ATLAS cavern. Pots are moving close to the beam (1-3 mm) once Stable Beams are declared. AFP consists of four stations, which are located at approximately 205 m (NEAR) and 217 m (FAR) on both sides of the ATLAS interaction region (side A and C). For tracking the Silicon Tracker (SiT) is used, which consists of four layers of silicon pixel detectors. The FAR stations are, in addition, equipped with the Time-of-Flight (ToF) detectors. They collect Cherenkov photons created in L-shaped fused silica bars, which are placed behind the tracker plates.

Physics Motivation

- Detection of events containing scattered intact protons
- Focused on low-cross section processes with high p_T objects in the final state
- Diverse physics program (ATL-PHYS-SLIDE-2023-104)



ATLAS Forward Proton Detector



SiT and ToF: Readout and Trigger chains

Silicon Tracker (SiT)

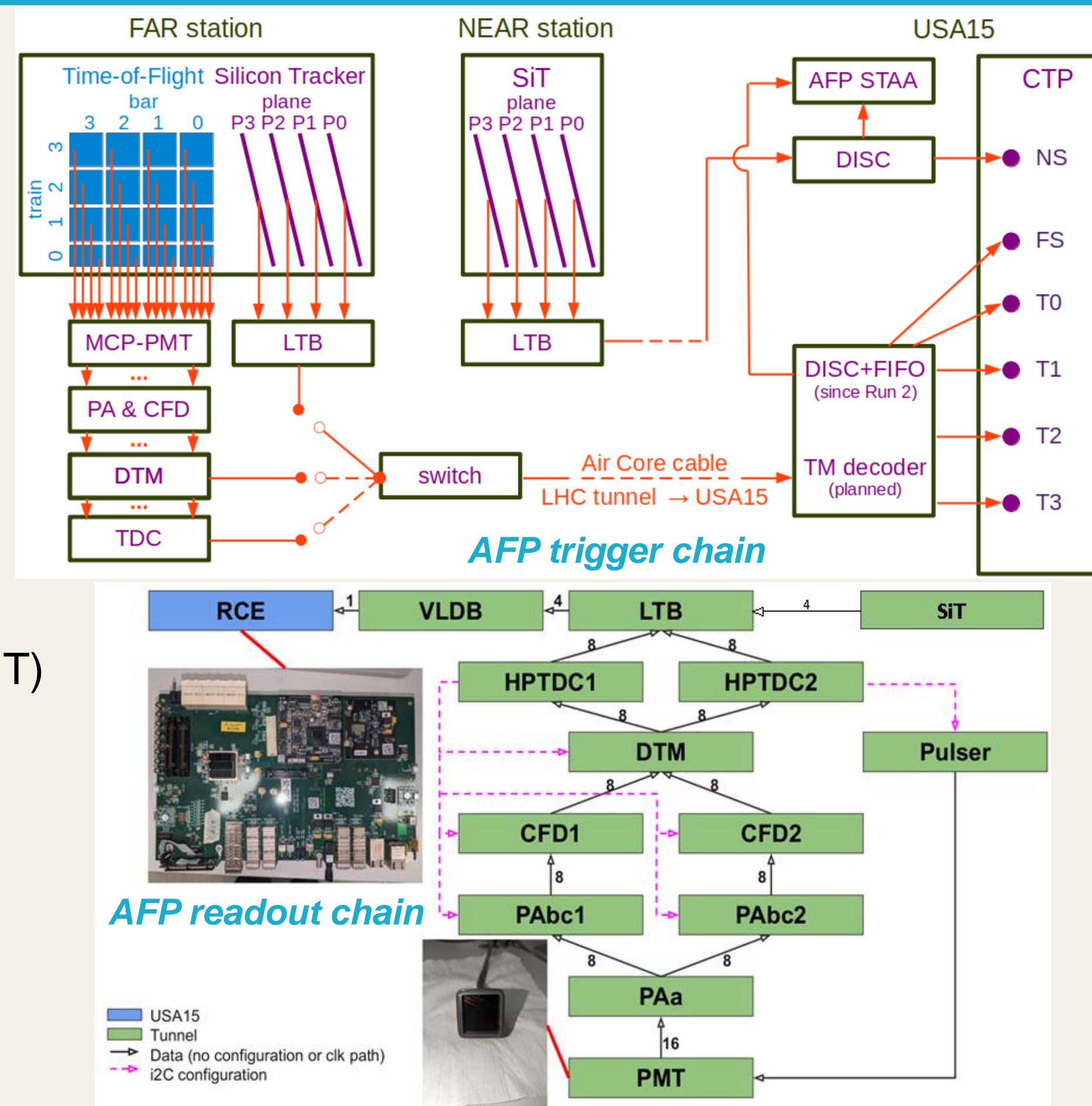
- Position measurement of scattered protons
 - Reconstruction of its kinematics
- 4 silicon pixel sensors, spaced 9 mm apart
 - Sensor size: 16.8x20 mm² (336x80 pixels, 50x250 μm^2 each)
- Read out by FE-I4B chips (same as ATLAS Pixel IBL)
- 14° angle wrt. beam axis
 - To improve reconstruction resolution

Time-of-Flight (ToF)

- Suppression of combinatorial background
- 16 quartz bars grouped in 4 trains
- Train/bar widths: 3 mm, 3 mm, 5 mm, 5.5 mm
- Directing light to Micro-Channel Plate Photo-Multiplier Tube (MCP-PMT)
- Amplified by 3-stages of Pulse Amplifiers (PAa and PAbc)
- Processed by Constant Fraction Discriminator (CFD)
- Passed through Digital Trigger Module (DTM)
- Processed by High-Performance Time-to-Digital Converter (HPTDC)*
- Double PAbc, CFD, and HPTDC; each for 2 trains

Common DAQ chain: Local Trigger Board (LTB), Versatile Link Board (VLDB) and Reconfigurable Control Element (RCE)

*To be replaced by Pico-TDC with higher saturation limits

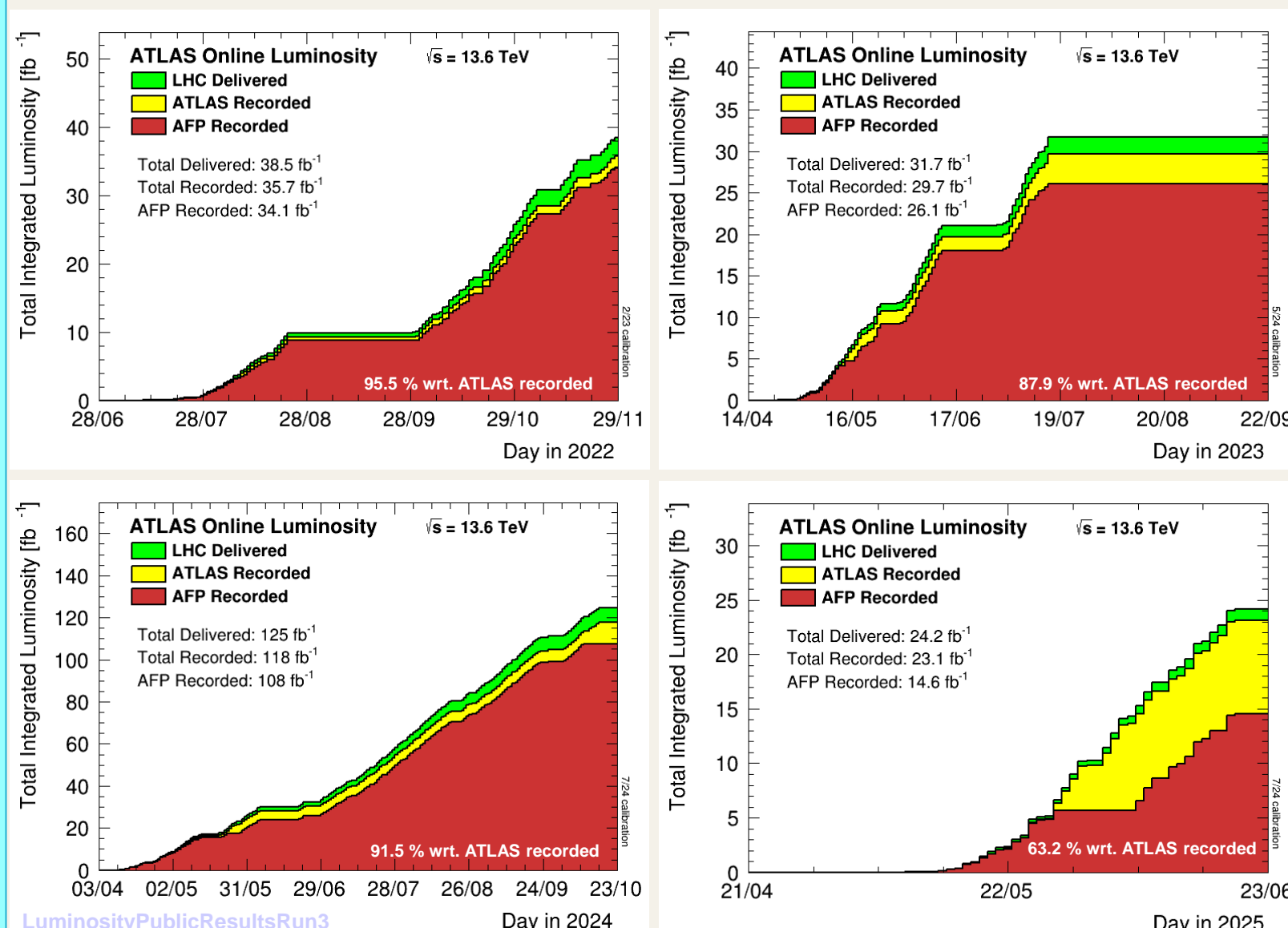


Trigger

- SiT trigger signal sent by Local Trigger Board (LTB)
 - Standardly, requires signal from at least 3 planes
 - Can be reprogrammed to different logic
 - 400 ns deadtime
- ToF trigger signal sent by Digital Trigger Module (DTM)
 - Requires signal from at least N bars in a train
- Far stations can trigger either on SiT or ToF
- Passed to ATLAS cavern (USA15) by ultra-fast Air Core cables
 - To arrive in time to trigger the "central" detector
- Far station signal connected to 5 Central Trigger Processor (CTP) inputs
 - 1 SiT and 1 for each ToF train
- Different latency for SiT and ToF triggers
 - Dedicated timing-in campaigns

Run-3 data-taking and Data Quality

- AFP recorded luminosity, calculated for both sides of AFP taking data simultaneously
- Total in LHC Run-3 so far:
 - Total AFP recorded: 182.8 fb⁻¹
 - 88.5 % wrt. ATLAS



Types of AFP GRLs

- Based on subdetectors: SiT per side and combined, ToF
- Based on strictness level: each SiT detector has at least 3/4 (or 2/4) planes operational

Fraction of good luminosity after AFP loose Data Quality wrt. ATLAS:

Type	2022	2023	2024
SiT A-side only	96%	82%	83%
SiT C-side only	93%	79%	82%
SiT A and C sides	92%	78%	70%
ToF only	83%	36%	5%**

**All fractions are preliminary

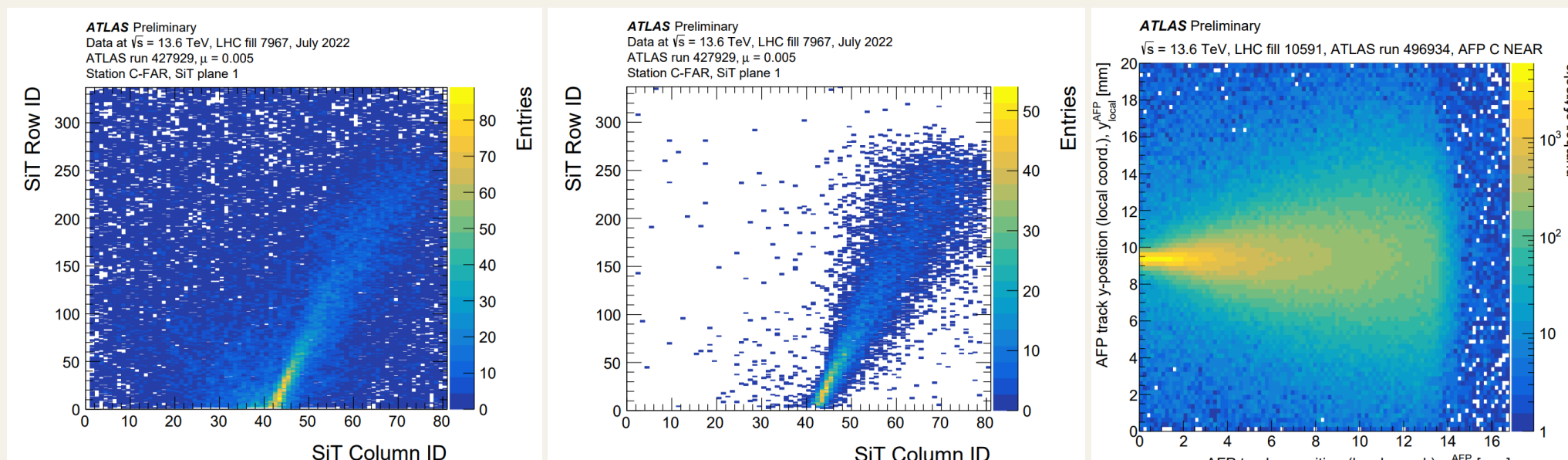
**ToF electronics was taken out from the tunnel after ramp-up

New AFP control systems in LHC Run-3

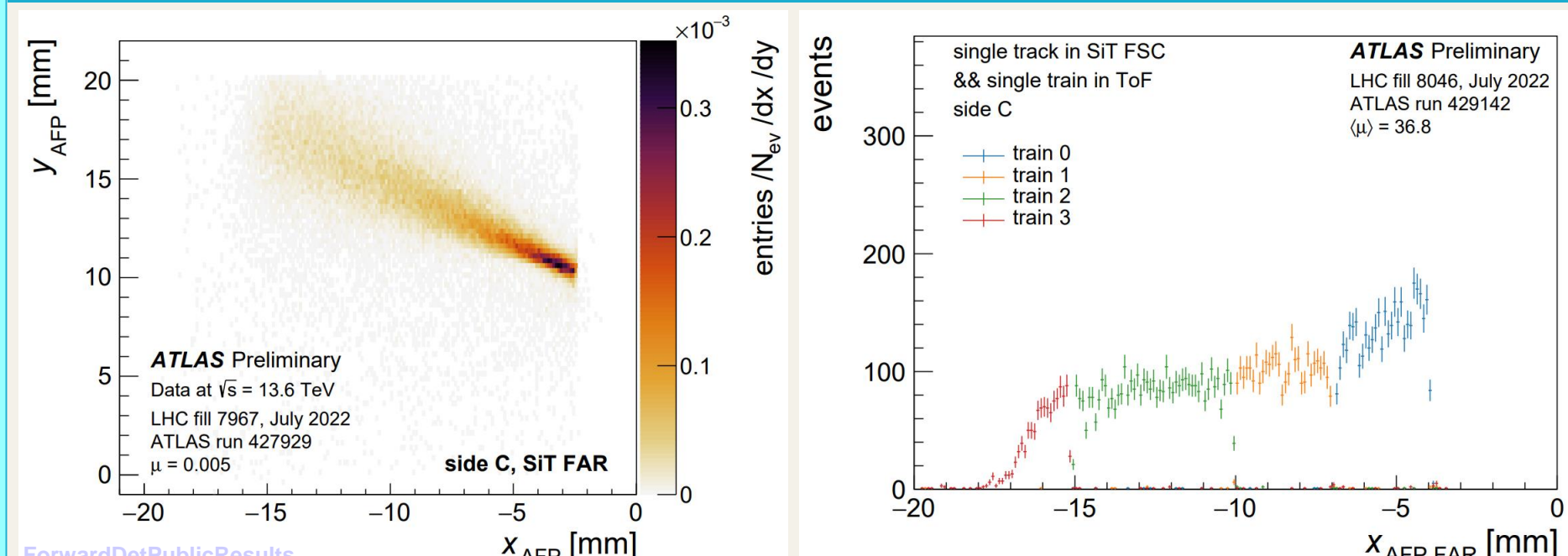
- Automatized system of defects covers hardware and TDAQ malfunctions of each module for both sub-detectors (SiT and ToF)
- Automatic recovery: reconfiguration of individual modules on a fly
- Mattermost bot: sending warnings and AFP state and issues

SiT Hit Map

- Effect of signal cleaning on hit distribution in a single SiT plane
 - Single track reconstructed per station
 - Single cluster reconstructed per plane
 - Only 1 or 2 hits recorded per plane
- "Diffraction pattern"
 - Caused by settings of LHC magnet between ATLAS interaction point and AFP detectors
 - In 2025 horizontal crossing angle was changed from vertical to horizontal



ToF-SiT alignment



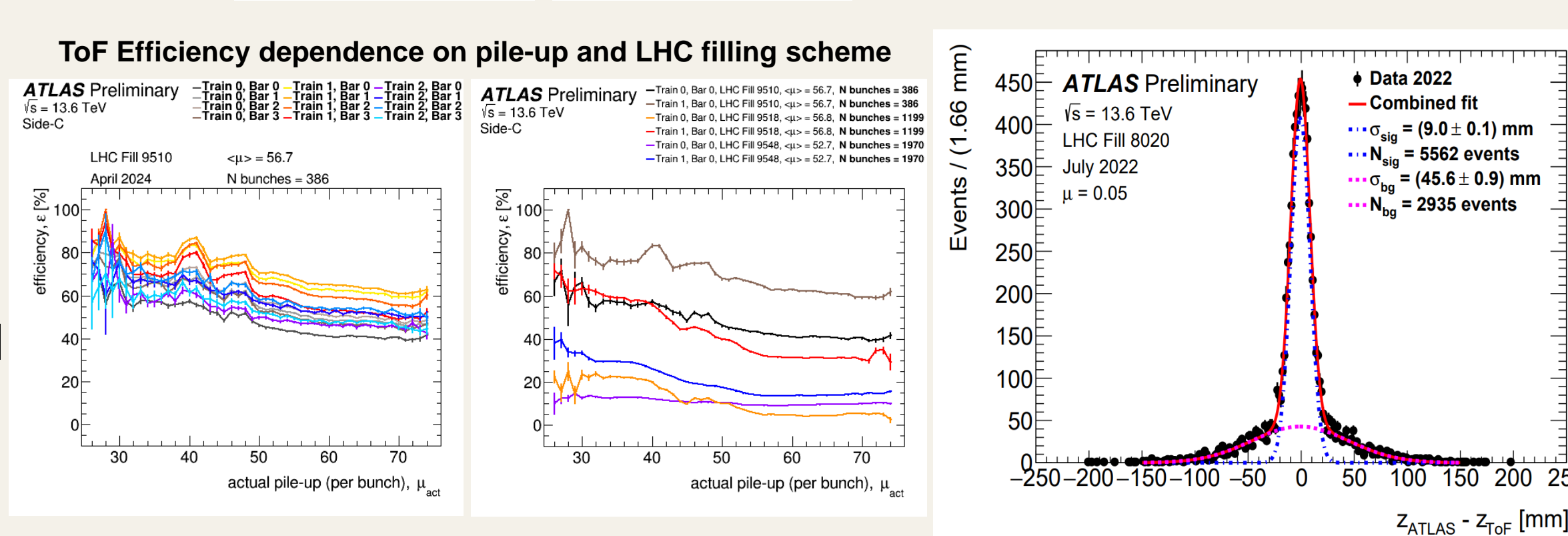
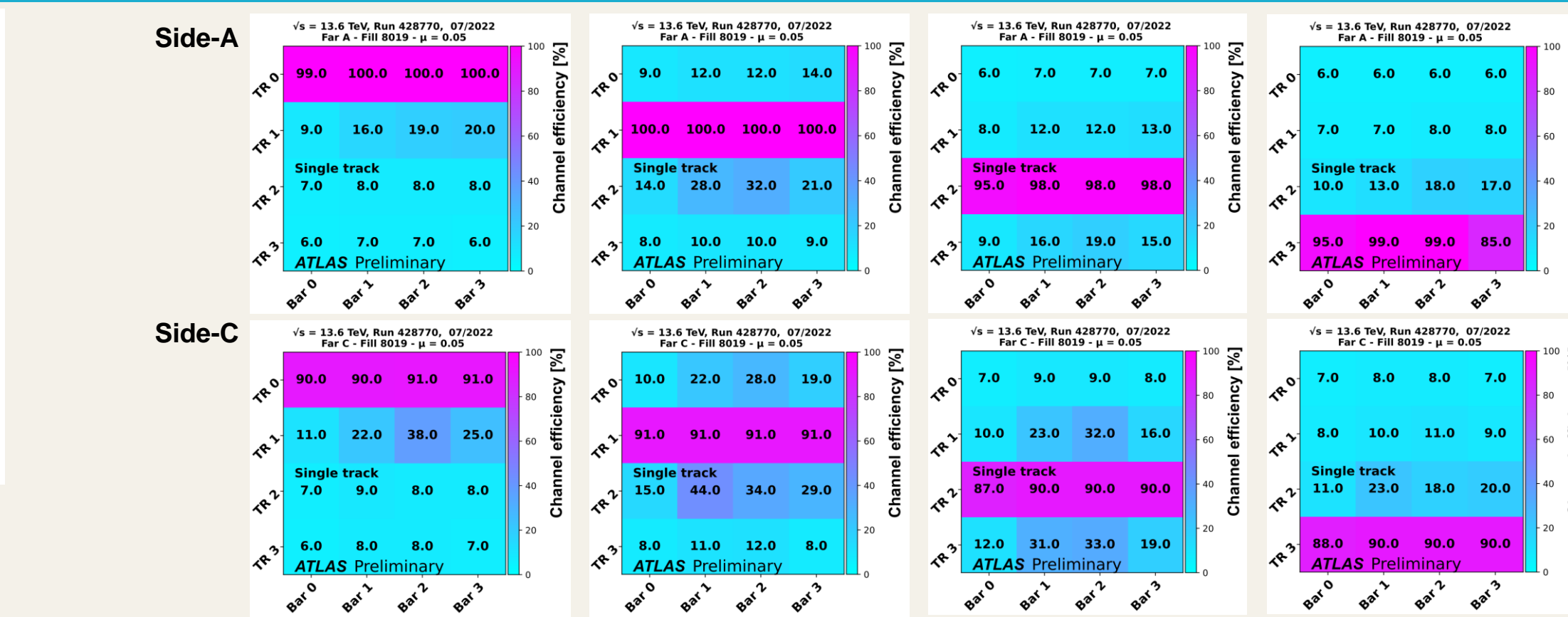
Distribution of reconstructed tracks (center of beam pipe at [0, 10 mm])

- Selection:
 - Events triggered by Minimum-Bias Trigger Scintillators (MBTS)
 - Exactly one reconstructed vertex
 - Single track in each station on a given side

Correlation of SiT track x-position to ToF train signal

- Selection:
 - Single SiT track in the station
 - Single ToF train signal in the station

ToF efficiency and vertex matching



Efficiency: Probability of getting hit in the ToF detector during the low- μ run in July 2022

- Tag and Probe method, tagged by SiT
- Selection: Single SiT track in the Far station
- Dependence on μ and bunch structure
- Vertex matching:** Difference between longitudinal vertex position measured with AFP ToF and ATLAS Inner Detector
- Small initial background contribution wrt. expected signal: low pile-up data-taking conditions
- Evident possibility of background rejection
- Selection:
 - Primary vertex in ATLAS Inner Detector
 - Single track in AFP SiT in each Far station
 - Single AFP ToF train signal in each Far station
 - SiT track position matching the ToF train position
 - Maximum of one hit in each ToF channel
- Resolution:** $9.0 \pm 0.1 \text{ mm} \approx 40 \text{ ps}$