ATLAS Forward Proton (AFP) view on a long low-mu run

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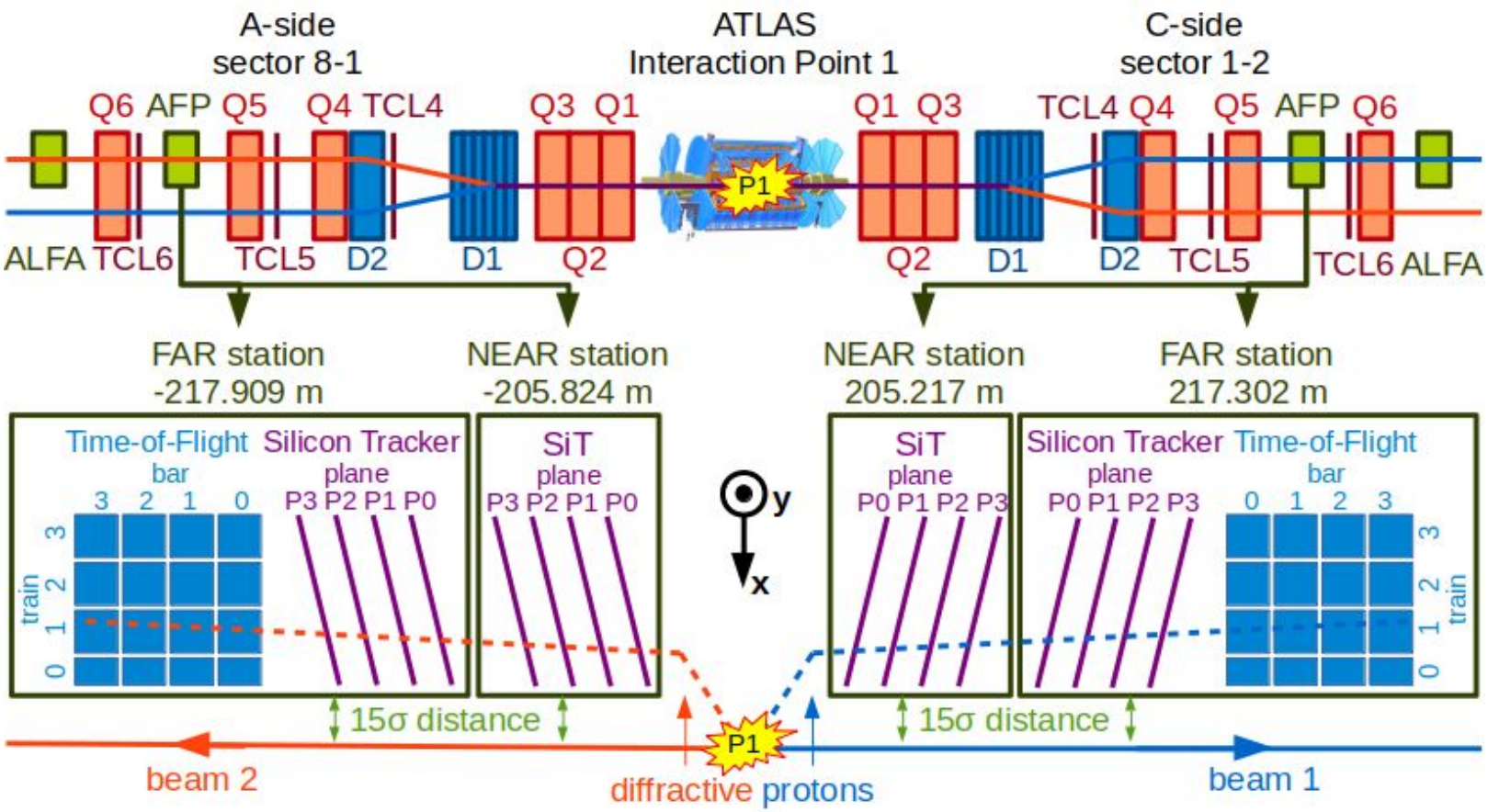
HELMHOLTZ

DESY.

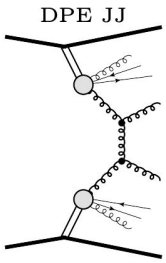
ATLAS EXPERIMENT

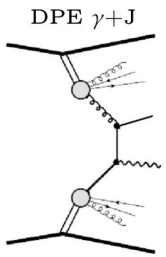
What is AFP?

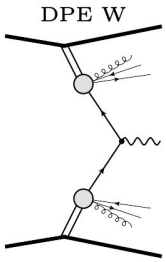


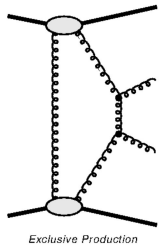
- Four detector stations housed in **Roman Pots (RP)** inside the LHC vacuum chamber
- All stations have a **Silicon Tracker (SiT)** to reconstruct proton kinematics
- FAR stations have additional **Time-of-Flight (ToF)** detectors to reconstruct proton interaction vertex
  - Additional background suppression when mu $\gtrsim$ 1

AFP physics interest and needs at low-mu









- AFP takes data in both standard high-mu and special low-mu runs
- Lots of interesting physics potential with forward proton tagging in low-mu
- Group focus is mainly on jet physics:

Single diffractive dijets

Double pomeron exchange dijets

Photon+jet

DPE jet-gap-get

Single diffractive Z/W

Central exclusive dijets

Diffractive top physics

Analysis	$\mathcal{L}$ [pb^{-}1]	Rough idea of Optimal μ
SD jj	10-100	0.01–1.0
DPE jj	10-100	0.5–5.0
DPE γ+j/jj	> 200	1.0–2.0
DPE j-g-j	> 100	0.1–2.0
SD Z/W	10-100	0.1–1.0
QCD CEP jj	$\sim 10^3$	10–20
$\gamma\mathbb{P}$ / $\mathbb{P}\mathbb{P}$ $\rightarrow t\bar{t}$	$\sim 10^4$	5

Upper range of optimal mu for processes with two intact protons assumes working ToF detector with timing resolution between 10 – 20 ps

Table by Maciej Lewicki and Marek Tasevsky

How much data is already available?

- AFP has always been a customer of low-mu runs
- Dedicated special runs already in Run 3, with $0.005 \leq \mu \leq 1$
  - → Total integrated luminosity of ~ 1 pb^{-1} (dominated by $\mu = 1$)

- **Unforeseen $\mu \sim 1$ run recently with ATLAS magnets down**
  - → Collected 18 pb^{-1} of data = ~18x increase in integrated luminosity of all previous Run 3 low-mu runs combined!!
  - → A quick look at data quality suggests that at least 80% of this will be usable in analysis
  - → **Challenge:** requires development of new jet calibrations
  - → **Caveat:** No working time-of-flight system

- AFP also plans to take data during pp reference run this year
  - → Foreseen to have $\mu = 4$
  - → Plan is to demonstrate working ToF system
  - → Probe different $\sqrt{s} = 5.36$ TeV

Need for more low-mu data?

The short answer is:

From the physics point of view

AFP would like to participate in a long low-mu run

**to enhance dataset for double-tagged semi-exclusive analyses,
e.g. ttbar, searches for New Physics or dijets**

We believe such a run will be especially interesting for us if we can demonstrate a working time-of-flight system (but does not depend on this)

The longer story: LHC optics

- AFP acceptance depends heavily on the LHC beam optics
- Concerns from LHC about total radiation dose to inner triplet magnets

We foresee two possible scenarios in 2025 (and 2026):

1. Current 2024 optics (inner triplet polarity inverted w.r.t. 2022 and 2023)
2. Current 2024 optics + switch to horizontal crossing angle at ATLAS IP1

- **Scenario 1** is easy in terms of this low-mu run as we will operate as normal
  - → The only question would be to keep the detector fully operational until the point at which such a run would happen

The longer story: LHC optics

- In the case of **Scenario 2**, AFP has ~zero acceptance with nominal optics setup

- CT-PPS will set their pots to run with vertical crossing angle
  - ➞ Changing back to horizontal (current setup) is not an option for them since this is mechanical movement of stations

- For AFP to participate in a special low-mu run, we will have to request for this run to be taken with vertical crossing angle at IP1
  - ➞ Probably feasible, but LHC will need dedicated time to qualify the machine
  - ➞ Extra AFP alignment would then be needed which will add additional time

- To participate in this scenario, the AFP community will have to either:
  - **A.** Ask the LHC if they can operate with vertical crossing angles in both ATLAS and CMS during this run
  - **B.** Ask CT-PPS to take data with non-optimal conditions (horizontal crossing angle)

Summary

- AFP would like to take part in a long low-mu run
- Main physics interest is diffractive (semi)-exclusive processes
- However there are several unknowns and challenges
  - → LHC optics determines our acceptance
  - → Ageing detector with high radiation damage
  - → Many analyses would benefit from working ToF system

For more details and feasibility studies, see:
Comprehensive overview of forward physics at the LHC [arXiv:1611.05079]
Single-tagged Exclusive Jets at the LHC [arXiv:1503.00699]
Exclusive top quark pair production at the LHC [arXiv:2202.01257]

Backup