Simulation of the ATLAS Forward Proton detector

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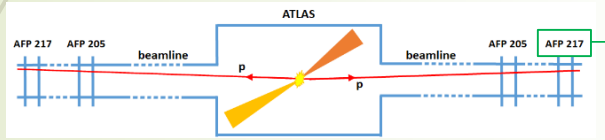
1. Summer student project – motivation

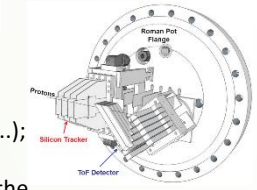
The main objective of the proposed project is a comparison of data with the AFP detector simulation, using multiplicity distributions, background estimates and eventually leading to improvements of detector modeling.

2. What is the ATLAS Forward Proton detector (AFP)? [1]

- The AFP detects events in which photons emerge from ATLAS collisions in very forward directions (emitted under very small angles ~10-100 µrad).
  Detectors are placed in both LHC beams at ~210 m from the ATLAS Interaction Point (IP).
  The magnets between the IP and the AFP induce the deflection of proton, which depends on energy loss ξ and emission angles (θ, φ) at the IP.

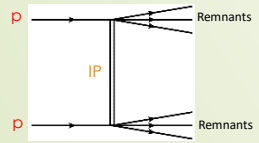


- The AFP detector is embedded in: - Roman Pot;
  - Silicon Tracker SiT (4 layers of 3D pixel sensors with resolution < 10µm)
    → digitization of detections (with information of hit position, energy,...);
  - Time-of-Flight Detector ToF (with resolution < 30ps)
    → at high luminosity, reduction of background (particles detected in the AFP that don't originate in the IP).



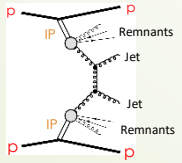
The AFP detector

- Observation and measurement of a range of processes:
  At low / medium luminosity (optimal µ~1): diffractive processes, with exchange of pomeron.



Soft diffraction process

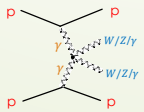
Feynman diagrams



Hard diffraction process

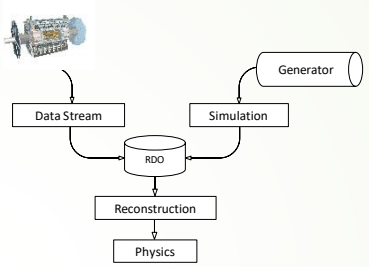
IP (Pomeron) :
colorless object with quantum numbers of the vacuum.

At high luminosity (µ>50): possibility of new studies of exclusive diffractive processes beyond standard model (double-photon/double-gluon processes such as anomalous quartic gauge boson couplings).



3. Aims and Methods

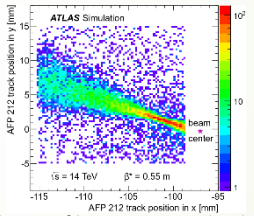
Toolkit for the simulation: Athena (ATLAS Framework including GeoModel for the description of detector geometries and Geant4 for the simulation of the passages of particles) [2]; Pythia8 (HEP Monte Carlo Generator); ROOT (data analysis); and Virtual Point 1- VP1 (3D event display) [3].



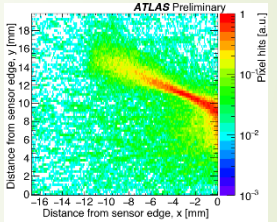
Different steps of our work :

- Event generation using Pythia8 within the Athena framework. Physics events are visualized using diagrams with a graph structure, where the nodes correspond to the vertices and the edges correspond to the particles [4];
- Reconstruction: derivation of the properties of the particles (transverse momentum distribution of diffractive protons, energy flow, emission angle,...) from the information recorded by the detectors;
- Comparison of the results between the simulation and real data (from Run 2 of the LHC);
- Visualization of detector geometries and tracks of particles by using Geomodel and VP1.

4. Results



Simulation of hit pattern on the detector



Hit pattern from data taking - May 2016 [5]

Observations :
The simulated hit pattern (left) and the real one (right) have similar shape, where the diagonal line corresponds to the detected diffractive protons.

5. Status

The AFP provides an extension to the physics reach of ATLAS by tagging and measuring the momentum and emission angle of very forward protons.
We observe differences in simulation of the AFP detector on the C-side of the ATLAS IP. After solving this issue, we plan to make a comparison with data and then, if time allows, we will implement fast Cherenkov algorithm for the AFP ToF detector into Athena.

References

[1] ATLAS Collaboration, *ATLAS Forward Proton – Technical Design Report*, CERN-LHCC-2015-009; ATLAS-TDR-024
[2] Athena Framework, https://twiki.cern.ch/twiki/bin/viewauth/AtlasComputing/AthenaFramework
[3] N. Tsutskiridze, *Simulation Loop between CAD systems, Geant4 and GeoModel: Implementation and Results*, ATL-SOFT-SLIDE-2015-750
[4] M. Dobbs et al., *HepMC 2 - a C++ Event Record for Monte Carlo Generators*, Comput.Phys.Commun. 134 (2001) 41-46
[5] ATLAS Experiment – *Public Forward Detector Plot for Collision Data,* https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ForwardDetPublicResults