FAST SIMULATION OF TIME-OF-FLIGHT DETECTORS AT THE LHC

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GOAL AND MOTIVATIONS

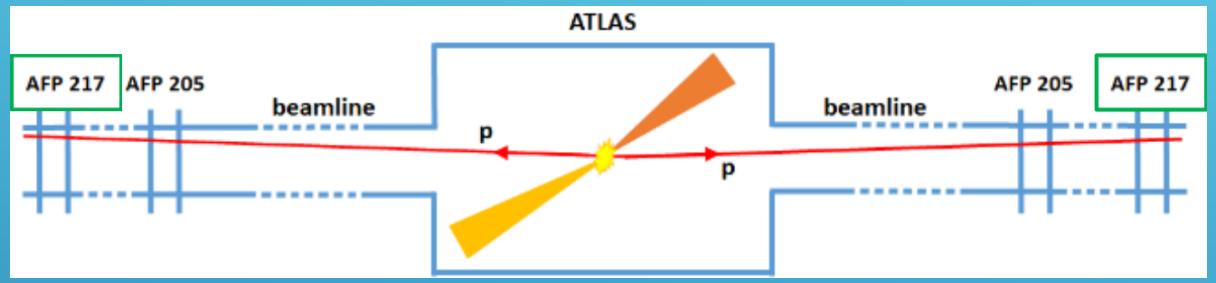
Geant4: Monte-Carlo toolkit to simulate the passage and interactions of elementary particles with matter. Disadvantages: complexity of code and very time-consuming.

Use of Python (programming language) and Numba (high performance compiler) with implementation of geometrical calculations to speed up the simulation of particle physics detectors.

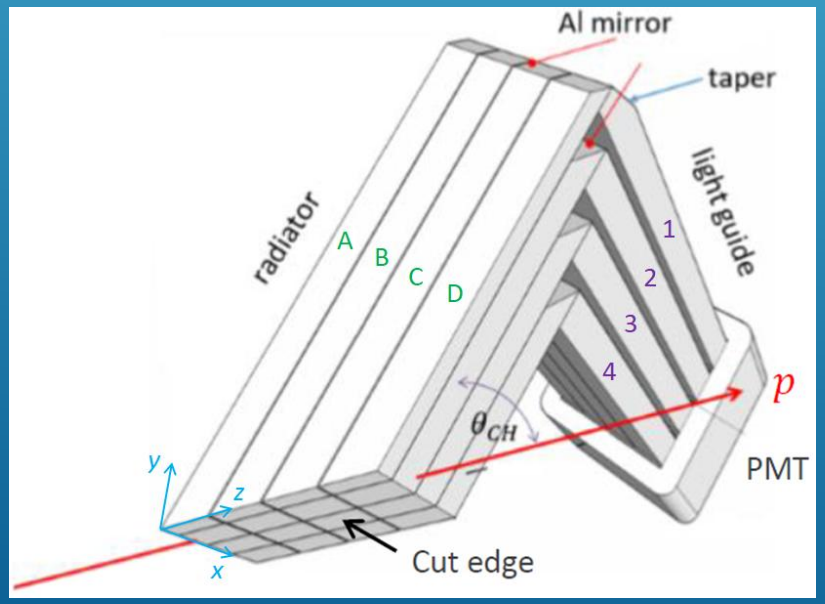
Example of study: ATLAS Forward Proton detector (AFP)

EXAMPLE: ATLAS FORWARD PROTON DETECTOR (AFP)

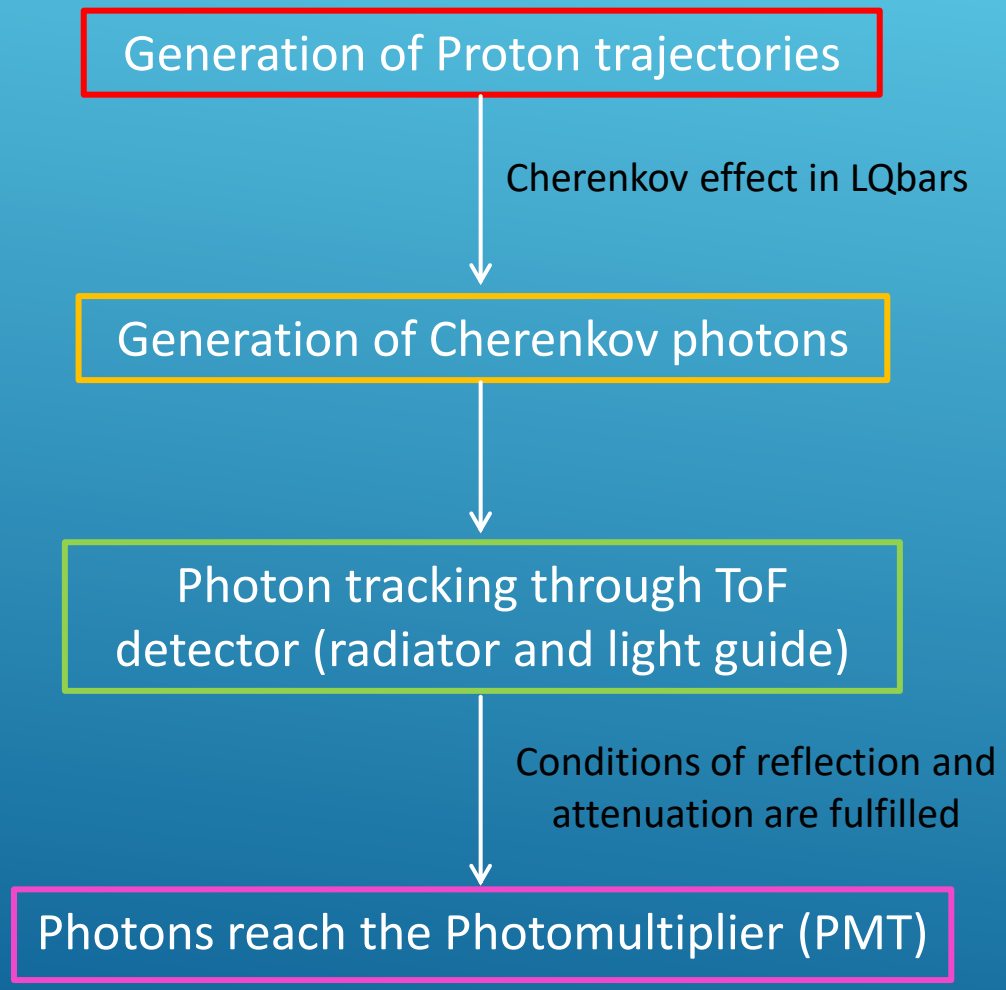
The AFP detector aims at measuring soft and hard diffractive protons leaving under very small angles the ATLAS interaction point (IP).



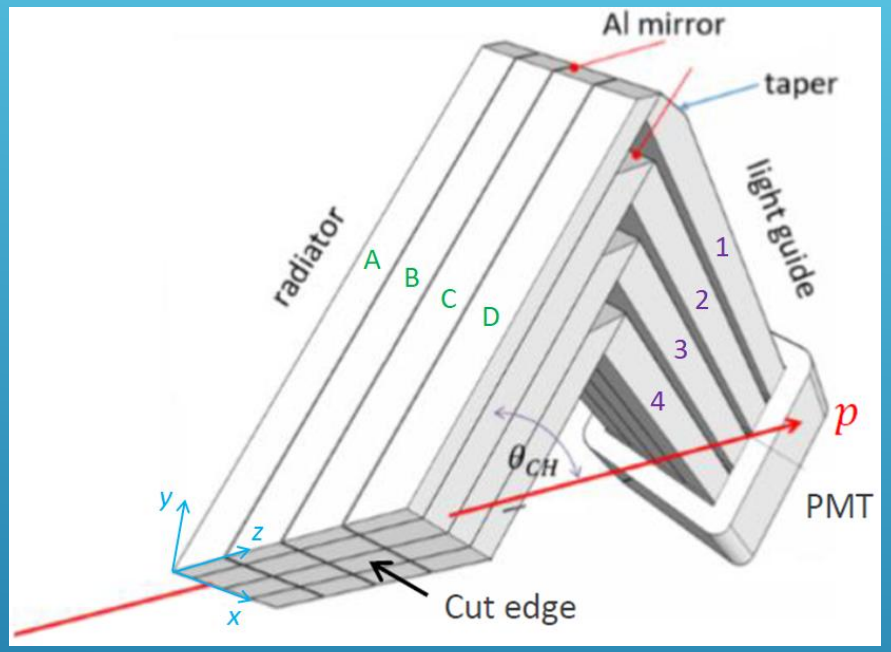
Far stations consist of two subdetectors: Silicon Tracker (SiT) and ToF detector. Time-of-Flight (ToF) system is used to reduce the background from multiple proton-proton collisions; it is composed of 16 "L-shaped" silica bars (4 × 4 LQbars).

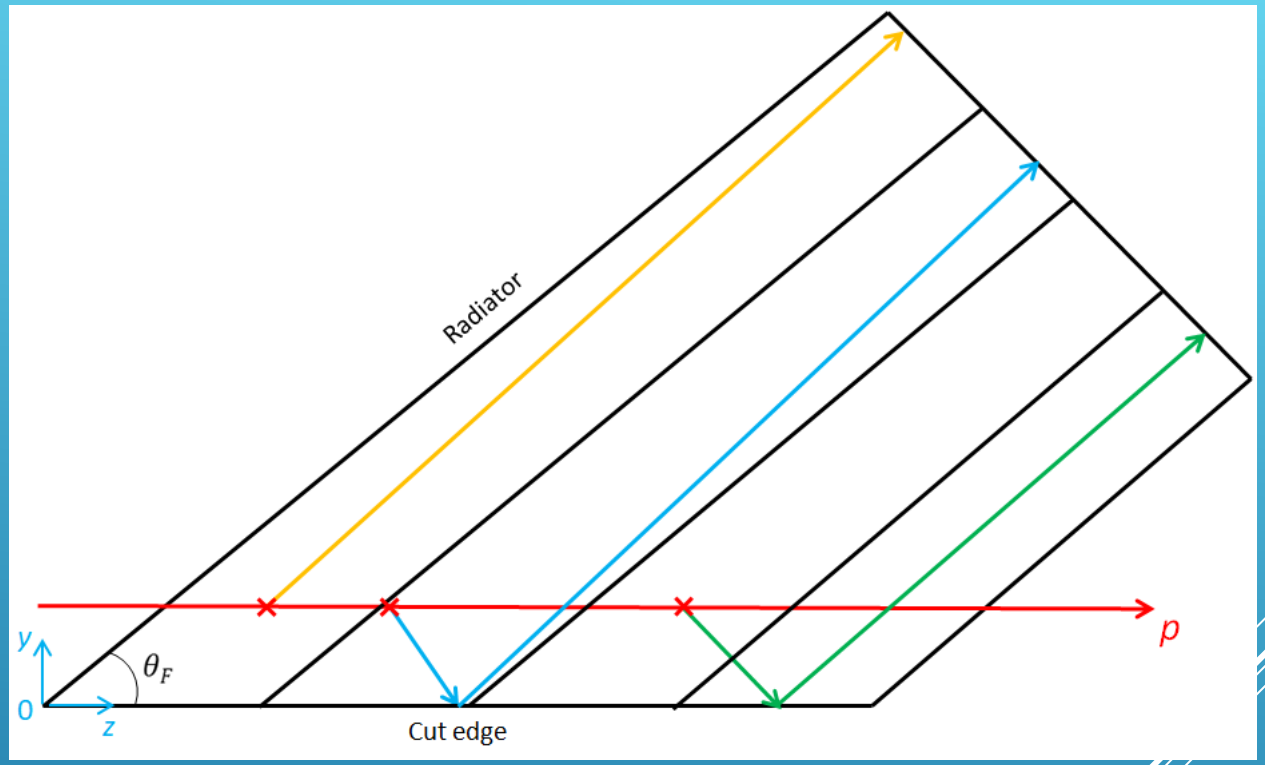


FAST SIMULATION FLOW



FAST SIMULATION : PHOTON TRAJECTORIES AND POSSIBLE CASES





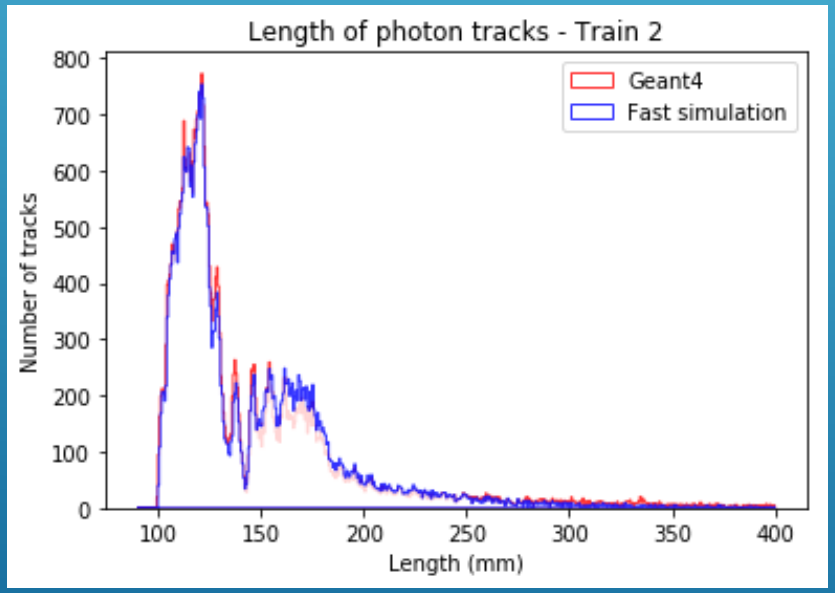
Case 1 : photon moves via the path A (vertex) → Aluminium (Al.) mirror → PMT;
Case 2 : photon moves via the path A → PMT (without touching Al. mirror);
Case 3 : photon moves via the path A → cut edge → PMT.

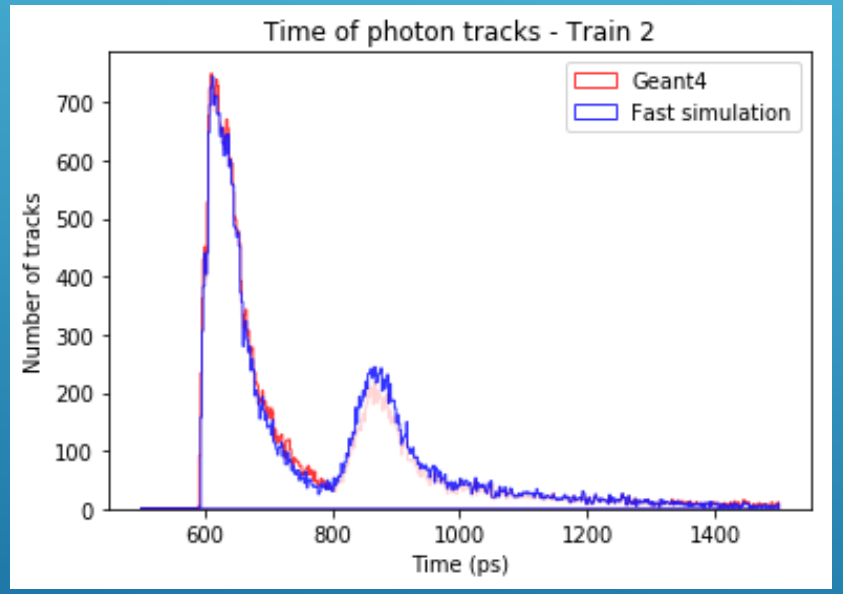
Track length for case 1 :

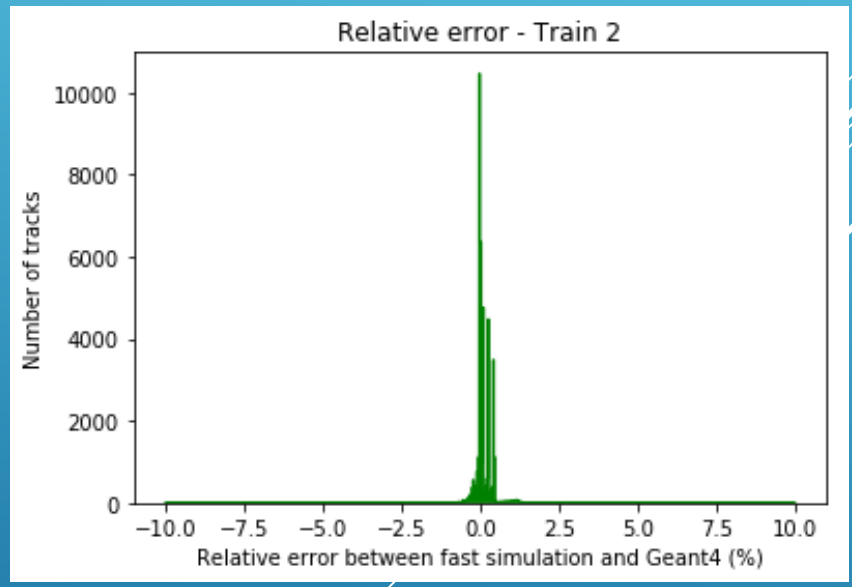
$$L = \frac{L_{rad} - y_A}{\cos(\alpha_1).\cos(\delta)} + \frac{L_{lg}}{\cos(\alpha_2).\cos(\delta_3)}$$

RESULTS – COMPARISON OF LENGTH AND TIME DISTRIBUTIONS

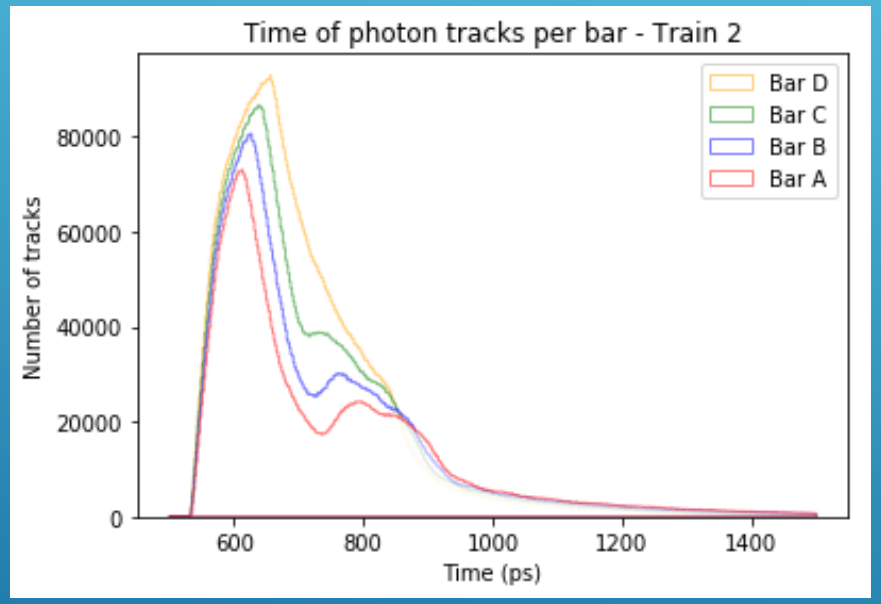
We perform the simulation by generating 10^5 Cherenkov photons with random positions of vertices, for a fixed trajectory of proton. About 43 % of initial photons reach the PMT.



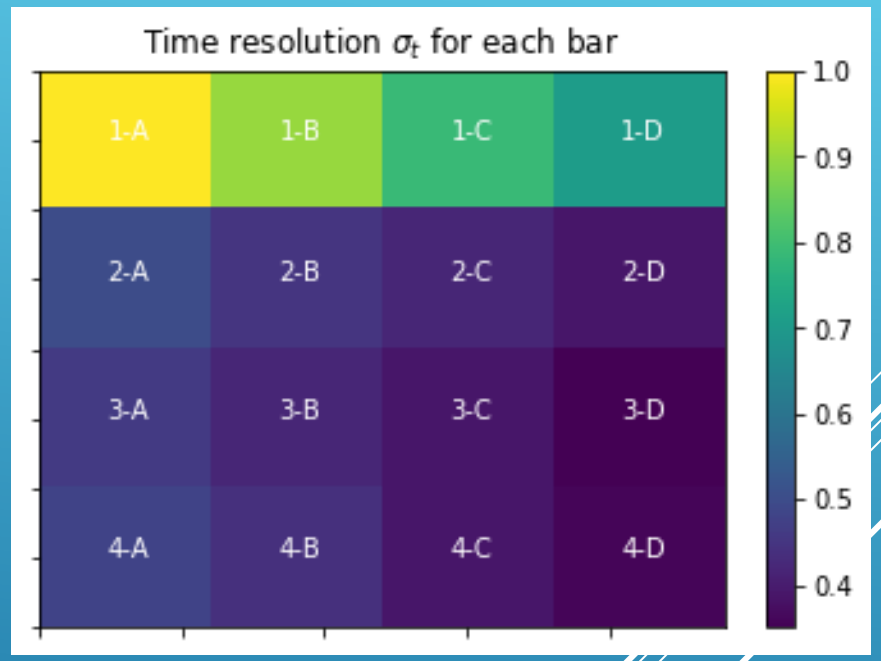




ANALYSIS OF TIME RESOLUTIONS



$\sigma_t \propto 1/\text{Amplitude}$



Due to edge effect (case 3), the amplitude of bar D is greater than the one of bar A: $A_A < A_B < A_C < A_D$.

Relative time resolutions of the different bars (with train 1 - bar A as reference)

CONCLUSION: FAST SIMULATION VS GEANT4

The distributions of lengths obtained by the Fast simulation and Geant4 have the same shape, with relative difference < 2%.

Duration of fast simulation: nearly 200 times faster than Geant4 !

Code of Fast simulation: *https://github.com/ olivierrousselle/Fast-simulation-AFP*

Opening: Such a Fast simulation with Python and Numba could be used to model other types of experiments.

Thank you for your attention !

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