The Hardware Track Trigger for the ATLAS upgrade

Physics performance studies and fast simulation design

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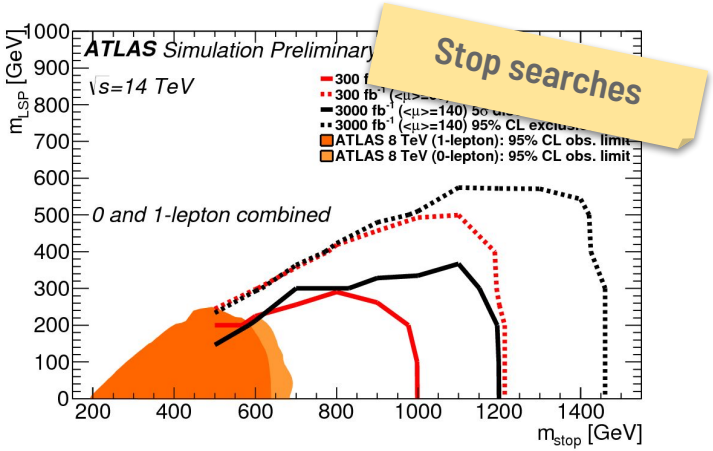
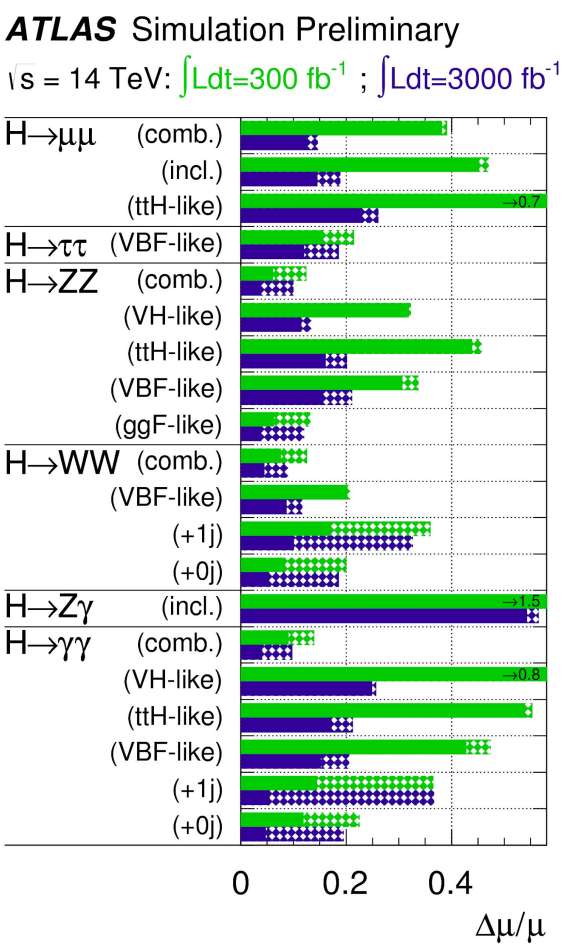
LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS

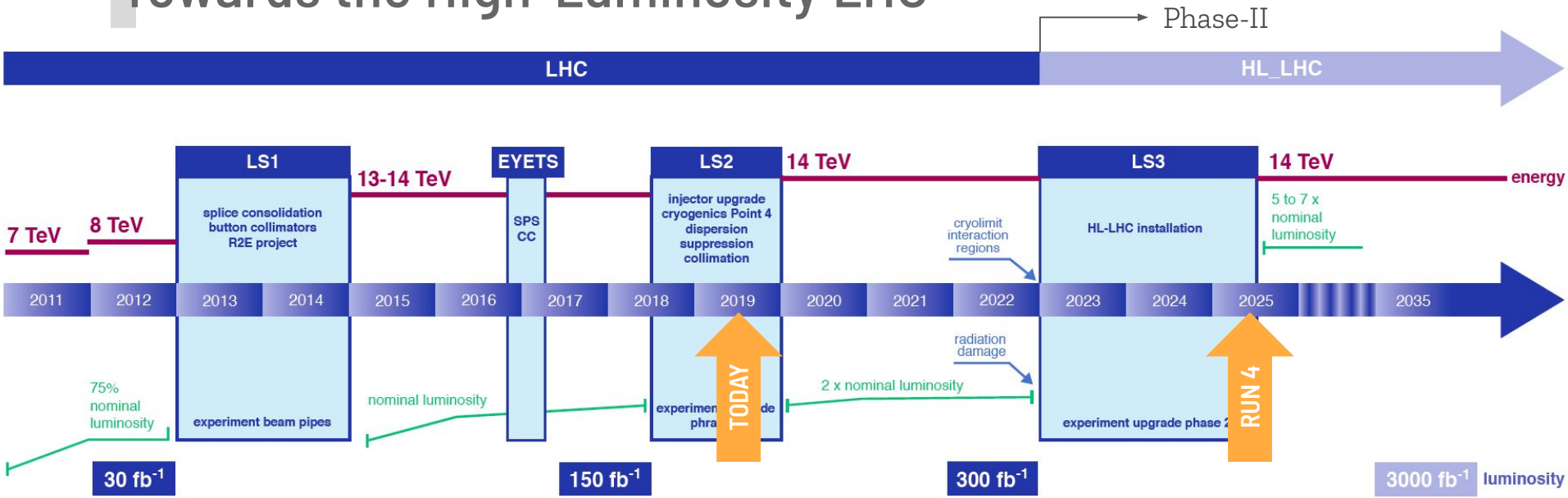
Why going to high luminosity ?

- ➔ Higgs couplings precision measurements
- ➔ Might be only way to get clues about new physics if no discoveries happen
- ➔ Direct searches need a lot of stats





Towards the High-Luminosity LHC



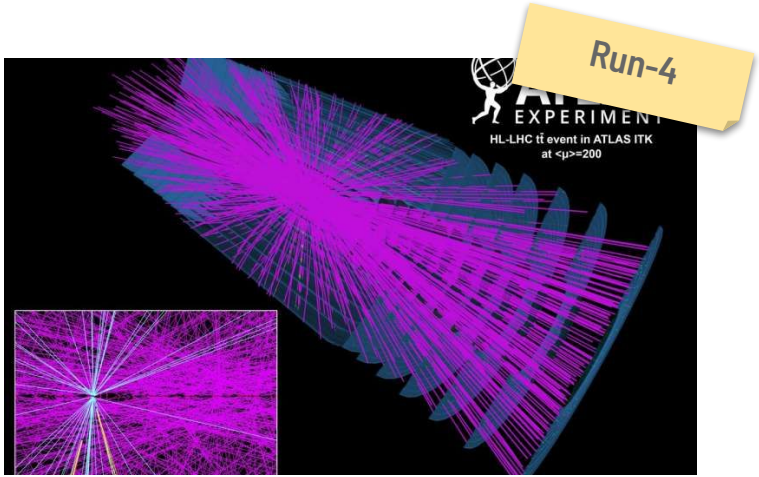
- ➔ Increase nominal luminosity by ~ x10
- ➔ Collect 3000 /fb at a center of mass energy of 14 TeV

Why do we need a better detector ?

ATLAS will be upgraded to handle harsher pileup → **Improve trigger system**

- ➔ 200 collisions per bunch crossing
- ➔ ~ 10 000 particles per event
- ➔ Mostly low p_T particles

In a few µs the trigger selects events to be further processed



The Hardware Track Trigger - HTT

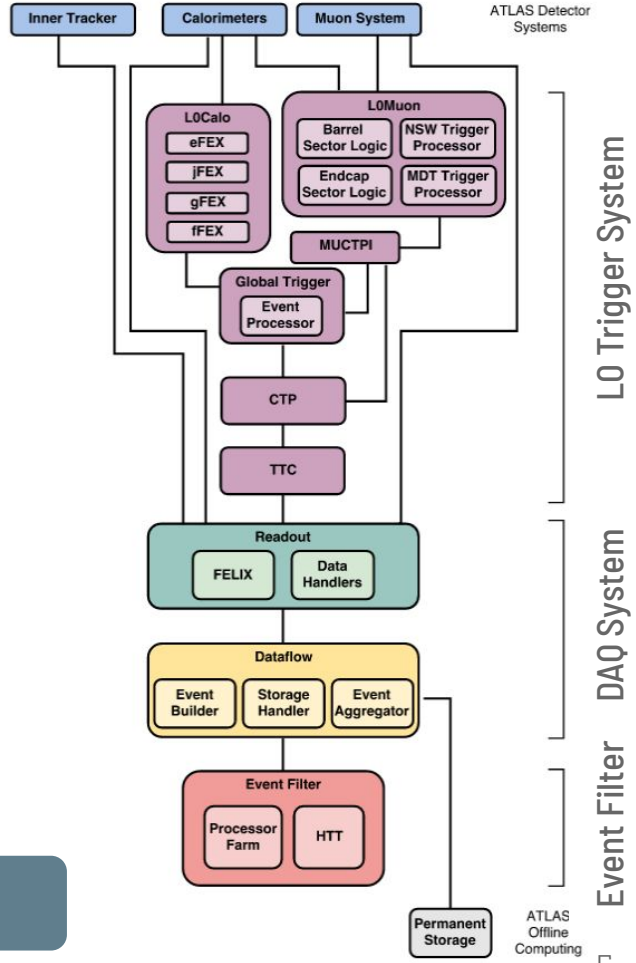
What is it ?

- ➔ Highly parallel hardware-based tracking co-processor for the ATLAS upgrade
- ➔ Capable of doing global / regional tracking at 100 kHz / 1 MHz

How does it work ?

- ➔ Pattern bank with track templates to fit to inner detector hits

Reduce Event Filter farm by factor 10



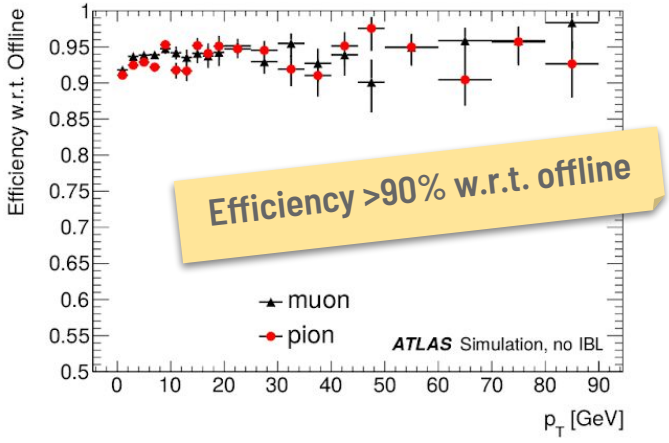
The FastTracKer legacy - FTK

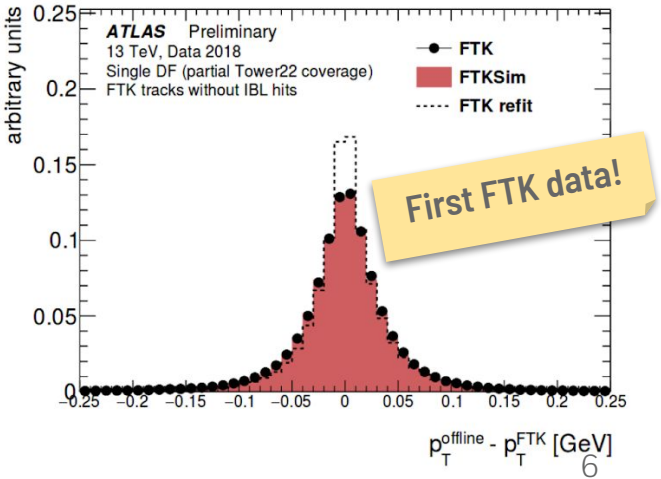
How does it work ?

- ➔ Global tracking only
- ➔ Provides full tracking for every event passing the Level-1 trigger at 100 kHz
- ➔ ~½ the number of FPGAs

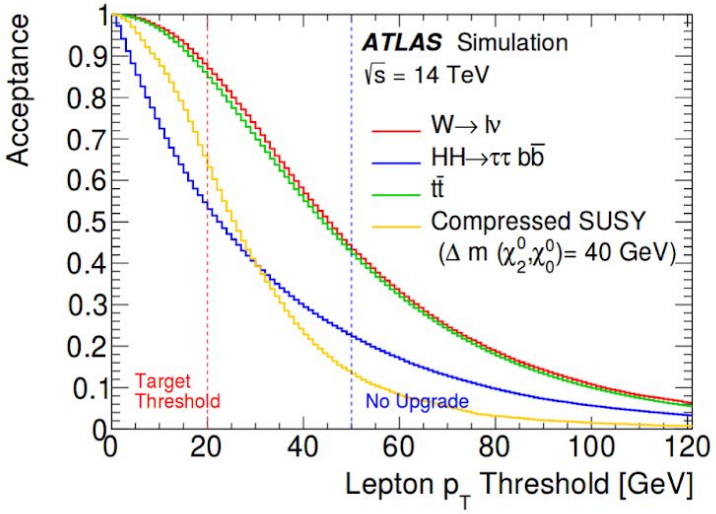
FTK status

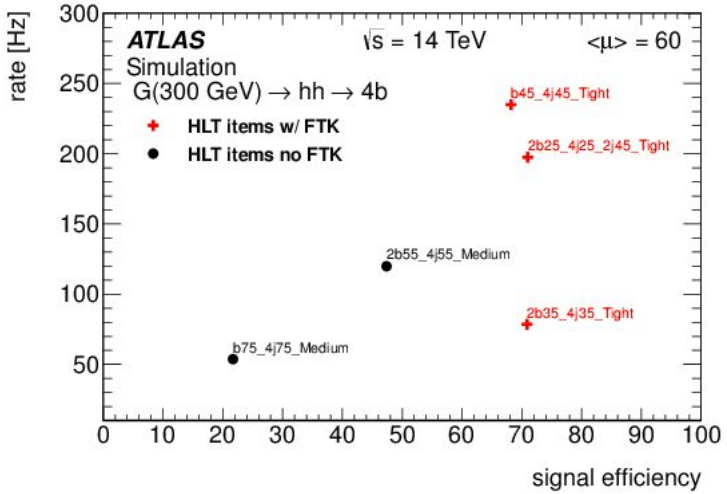
- ➔ Precedes HTT already in Run-3
- ➔ Production is underway
- ➔ First data with FTK already collected





Upgrade and FTK / HTT physics case





➔ **The Phase-II TDAQ upgrade |** Lower single lepton threshold to 20 GeV from 50 GeV

➔ **B-jet triggers for hh⟶4b |** FTK helps reduce the rates at HLT

Our contribution to HTT

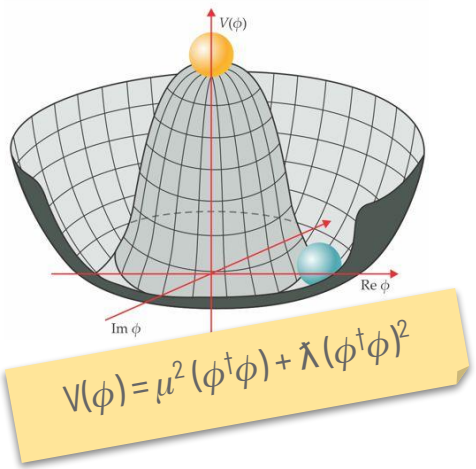
Physics performance studies : hh→4b

- ➔ Understand how the HTT performance will influence the analyses

Development of fast simulation

- ➔ Full simulation is extremely time and CPU consuming
- ➔ Tracking is one of the most expensive steps of the simulation
- ➔ Performance studies require a lot of statistics

Physics performance : hh→4b→ jets



Why hh→4b ?

- ➔ Sensitivity to shape of Higgs potential
- ➔ Key benchmark channel for the HL-LHC

Analysis strategy

- ➔ Apply b-tagging parameterization based on jet's truth flavor to offline jets
- ➔ Evaluate how b-tagging affects triggers used in hh→4b searches

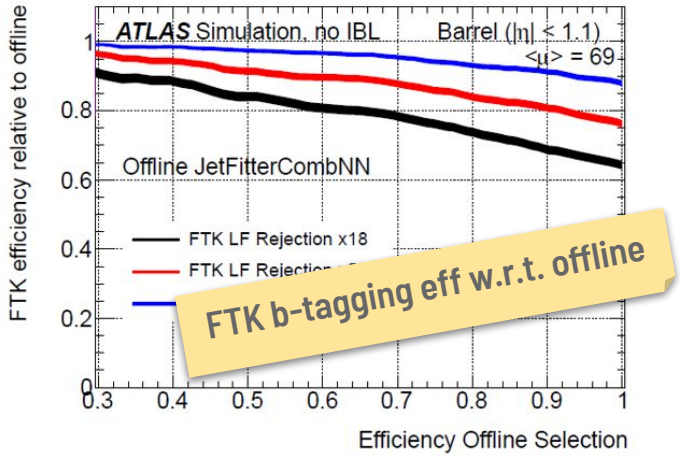
TRIGGER	Level 1 (L1)	High Level Trigger (HLT)
HLT_2b35_2j35_L1_4j15	⩾ 4j15	⩾ 2j35, ⩾ 2b35
HLT_b225_L1_j100	⩾ j100	⩾ b225
HLT_2b55_j100_L1_3j20_j75	⩾ j75, ⩾ 3j20	⩾ j100, ⩾ 2b55

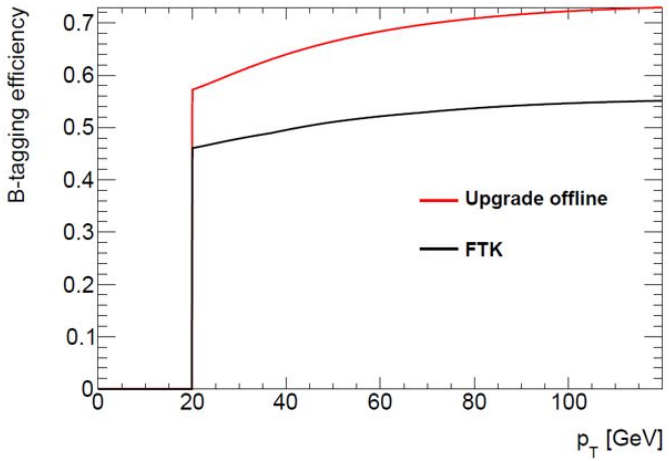
B-Tagging Parameterization

- ➔ Start with offline b-tagging efficiencies
- ➔ Worsen efficiency to emulate trigger b-tagging performance

Understand how bad can the b-tagging performance at the trigger be such that the physics analysis does not suffer

	B-TAGGING EFFICIENCY	C-MISTAG	L-MISTAG
OFFLINE	0.72	0.05	0.001
FTK LIKE	0.56	0.1	0.002





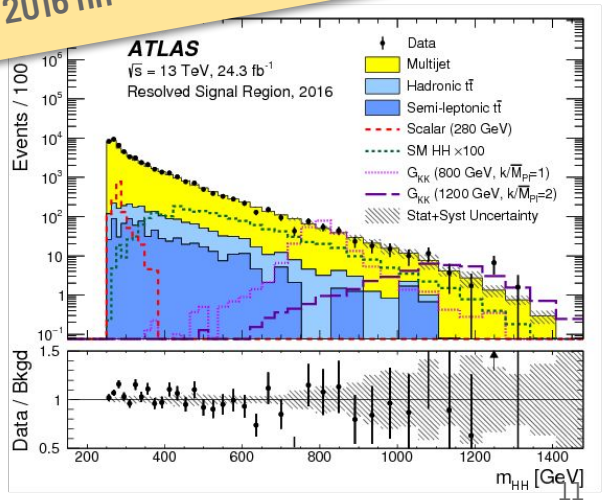
Monte Carlo samples

Signal and dominant background samples

- ➔ Full simulation (detailed detector simulation) samples at 14 TeV
- ➔ Average pileup of 200

PROCESS	NO. EVENTS	CROSS SECTION [fb]
Signal | hh→G(800 GeV)→4b	100 000	130
Dijet w/ 0<pT<20 GeV (JZ0)	1 000 000	8×10^{13}
Dijet w/ 20<pT<80 GeV (JZ1)	999 800	2×10^{10}
Dijet w/ 80<pT<200 GeV (JZ2)	997 800	3×10^{8}
Dijet w/ 200<pT<500 GeV (JZ3)	999 300	3×10^{6}
ttbar	995 900	4×10^{5}

2016 hh→4b resolved search



Preliminary results - trigger

HLT rates
Dijet JZ0 sample

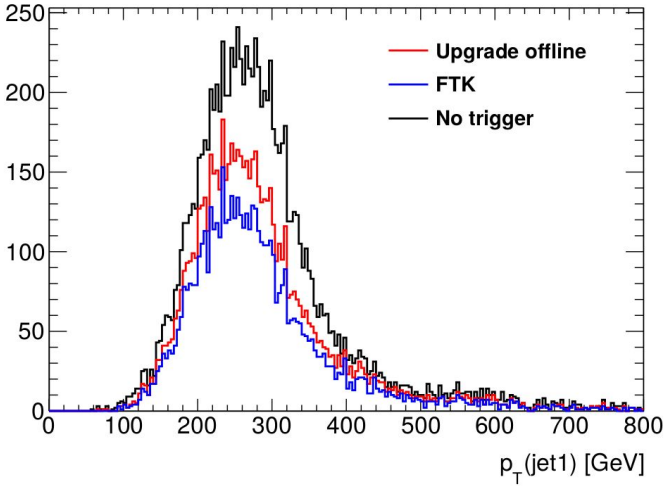
Rate = $\mathcal{L}$ x ε x σ

TRIGGER	OFFLINE RATE [Hz]	FTK RATE [HZ]
HLT_2b35_2j35_L1_4j15	3.0±0.5	1.0±0.3

B-tagging purity

#true b-jets / #b-tagged jets

PARAMETER	OFFLINE	FTK-LIKE
TOTAL NO. B-TAGS	27±6	24±5
NO. TRUE B-JETS	17±5	11±3
PURITY (%)	63±5	46±2



➔ **Slightly smaller rate for FTK |**
Most events passing the trigger have true b-jets

➔ **Lower b-tagging purity for FTK |**
As expected from lower track resolution

Physics performance studies

Next steps

Include other b-tagging parameterization points

➔ Possibly Summer student project

Estimate impact on physics analysis

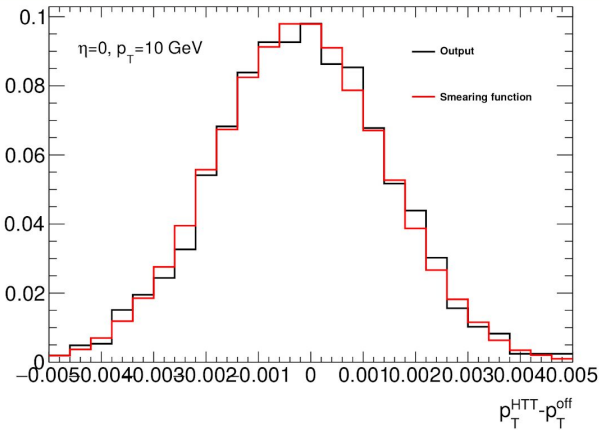
➔ Kinematic distributions
➔ Signal acceptance
➔ Background rejection
➔ Sensitivity

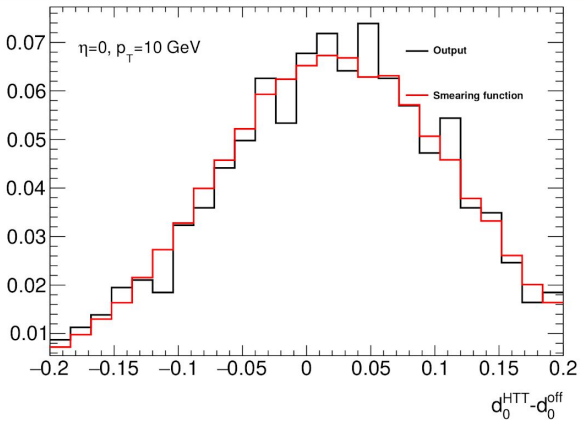
HTT Fast Simulation

Derived for ATLAS TDAQ Phase-II TDR

Offline tracks → **Gaussian smearing** → **HTT tracks**

➔ Compare smearing functions for given η and p_T with track resolution for tracks in same η and p_T





Fast Simulation

Next steps

Implement Athena tool to do the smearing

Increase complexity/precision of simulation

- ➔ Include fake tracks estimation
- ➔ Keep drawing inspiration from FTK

Summary

- ➔ Presented work being done towards the development of the Hardware Track Trigger for the ATLAS upgrade
- ➔ This is part of my qualification task that started in January
- ➔ Good HTT performance fundamental to guarantee efficient data selection during Phase-II
- ➔ In addition, collaborating in ttH(H→bb) analysis (see Emanuel's talk)

- ➔ **Physics performance |** Results seem promising but there is still very large uncertainties regarding the b-tagging parameterization
- ➔ **FastSim |** Very simple approach is implemented, keep adding features in order to increase precision

Thank you !