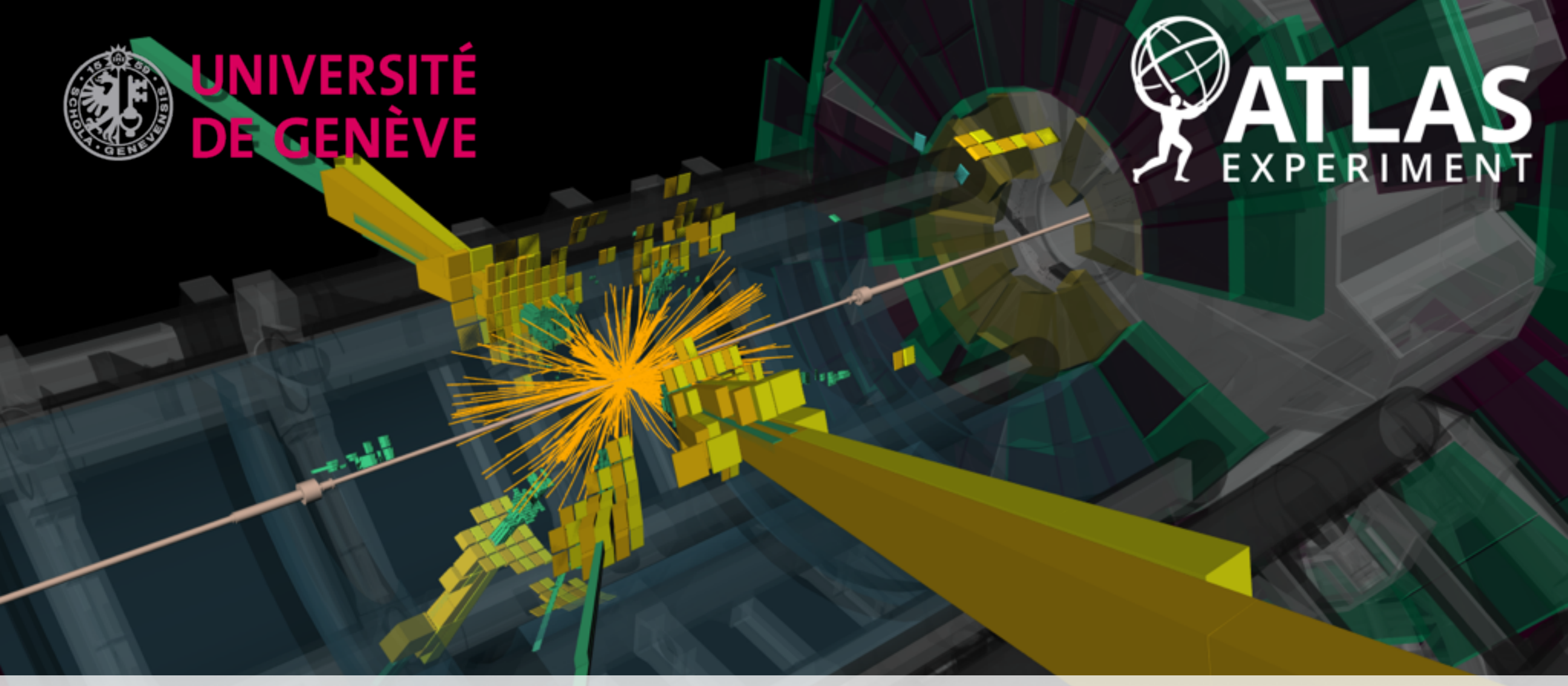


ONLINE TRACK-BASED PILEUP SUBTRACTION FOR THE ATLAS HL-LHC UPGRADE

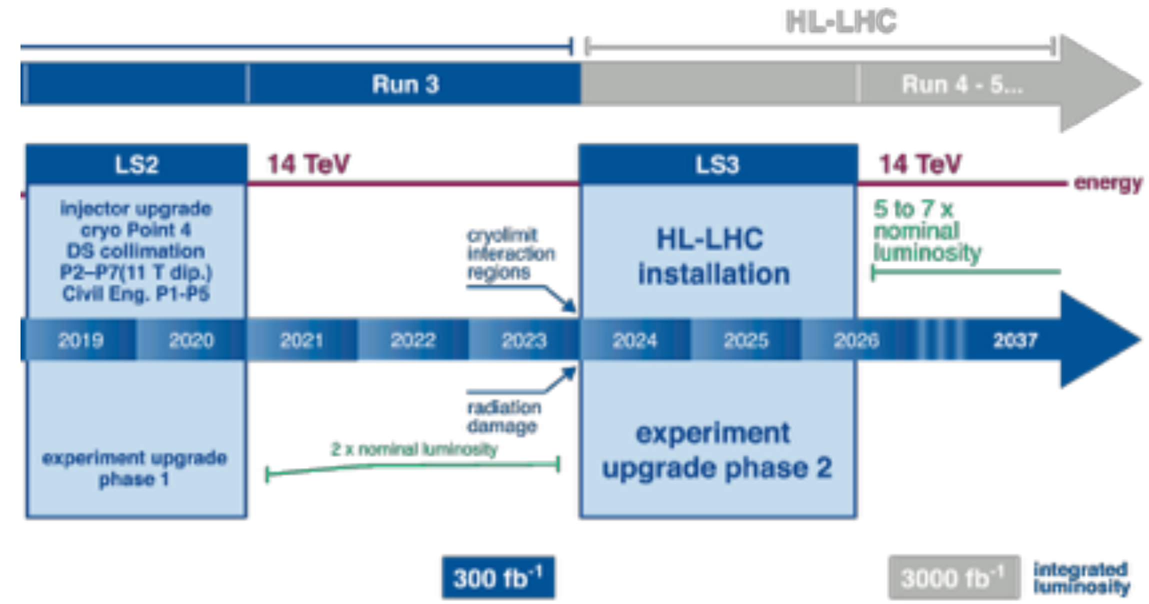
Join Annual Meeting of the Swiss and Austrian Physics Societies (SPS,ÖPG), August 23rd

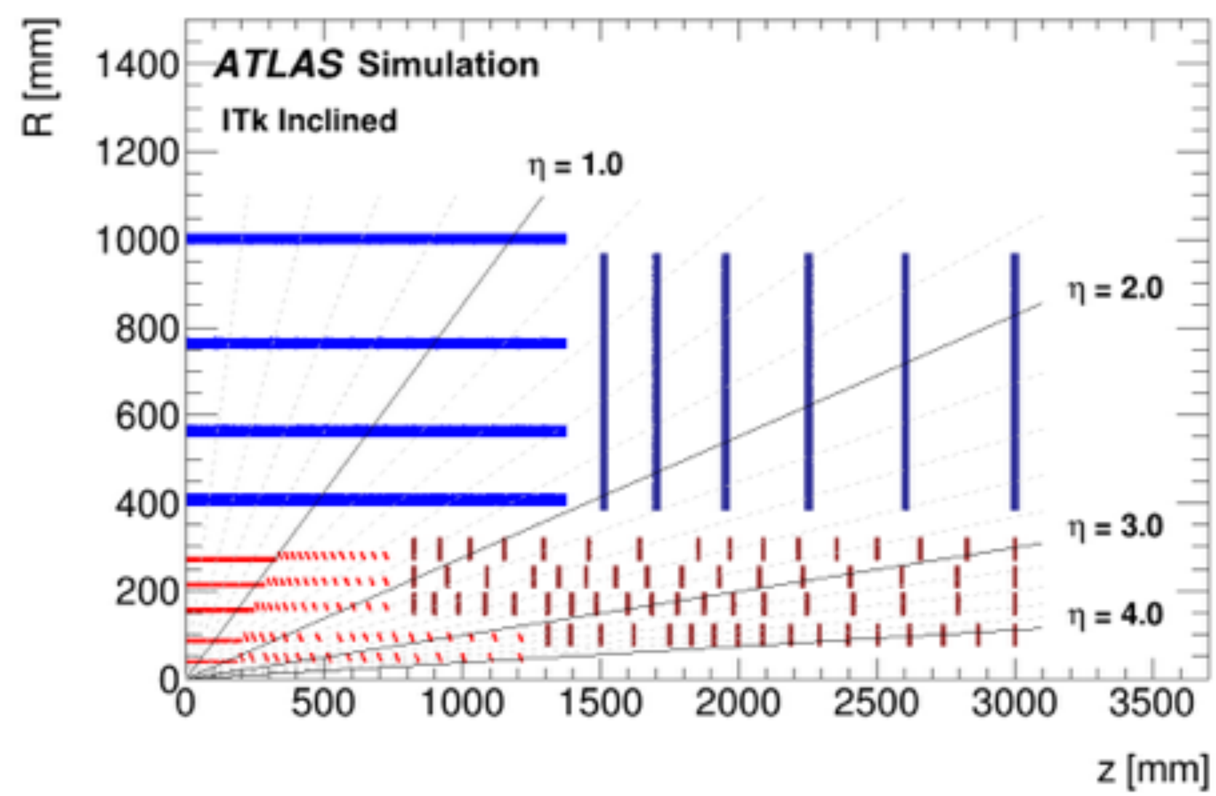
T.J. Khoo, A. Sfyrla, M. Valente

Département de Physique Nucléaire et Corpusculaire (DPNC)
Université de Genève

INTRODUCTION

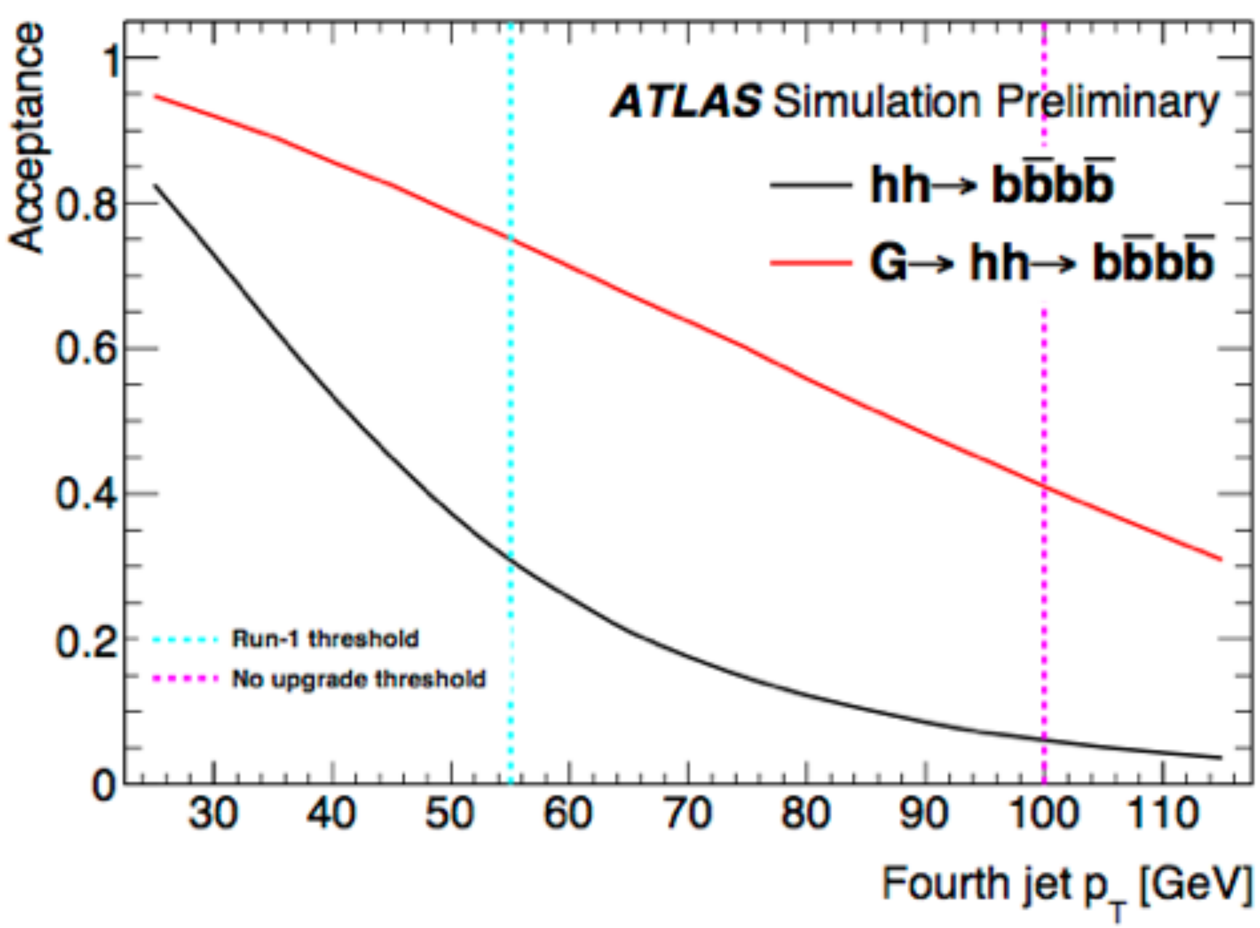
- 3000 fb-1 of data will be provided by the HL-LHC during Run 4.
- Increased signal rates and extreme contamination by multiple hadronic interactions (pileup).
- <u>Main detector upgrade:</u> new inner tracker (ITk) with extended η coverage (now |η| <2.4).
- Major TDAQ upgrade required to handle the enormous input rates. Current trigger system needs powerful pileup mitigation.
- <u>Presentation topics:</u>
    - Overview of the plans for the upgrade of the ATLAS TDAQ system.
    - Performance study about the utilisation of online tracking in the new DAQ system.

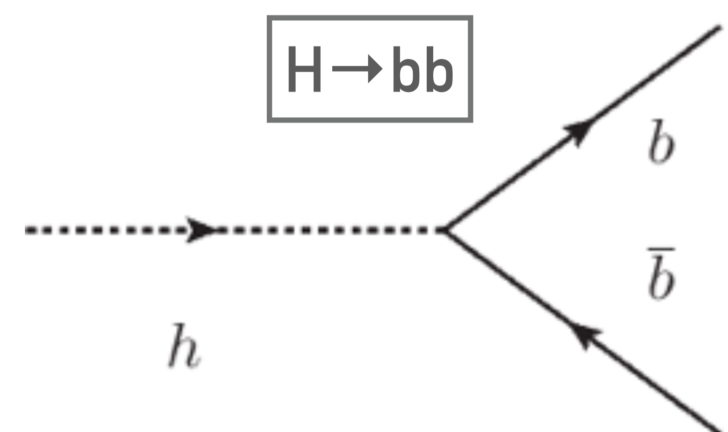


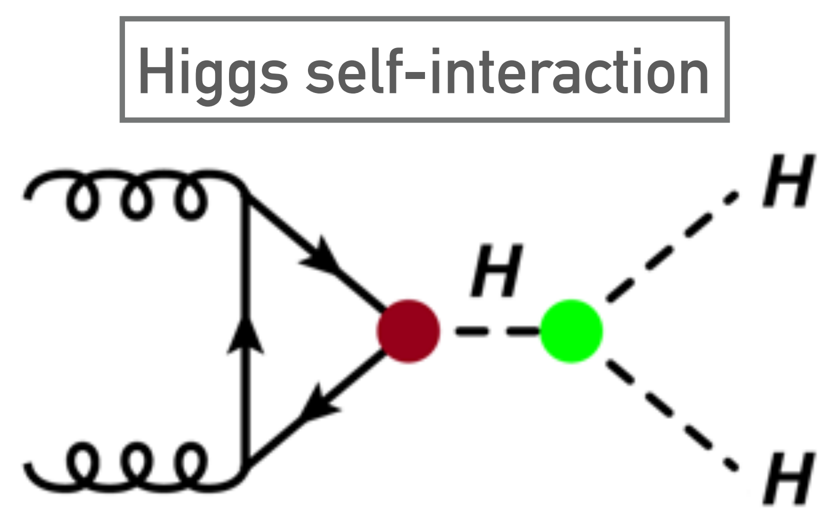


PHYSICS PLANS FOR THE HL-LHC

- So far no direct hints for SUSY, Exotics or new physics at the tera-scale. 😢
- New physics might be missing at this energy or produced with low cross-section → HL-LHC
- The new ATLAS trigger has to be optimised for:
  - **Challenging physics channels** uncovered by the current exclusion limits (EW SUSY, Higgsinos, etc.)
  - **Measurements of Higgs couplings**: H→bb/cc (fermions), HH→bbbb (self interaction), etc.

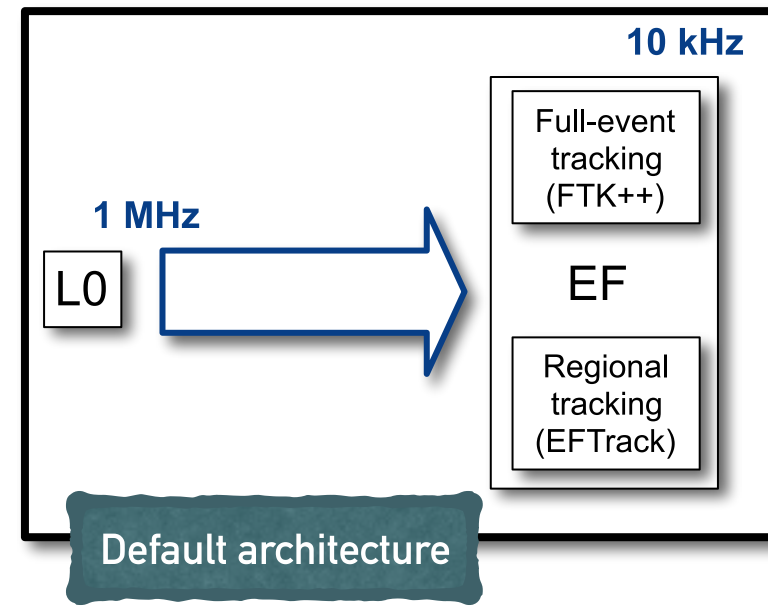


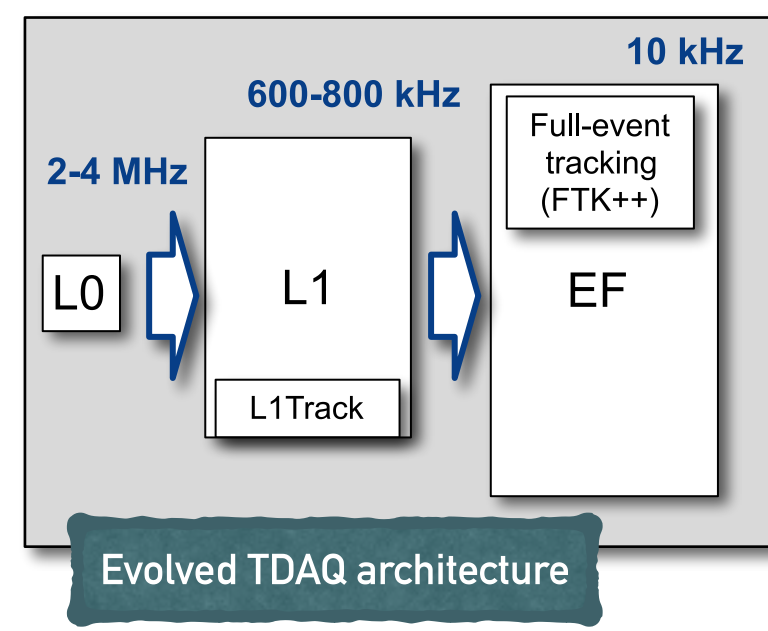




OVERVIEW OF TDAQ PLANS FOR THE ATLAS UPGRADE

- Two trigger layouts under discussion:
  1. L0-only hardware architecture:
     - **L0:** output rate 1MHz
     - **Event Filter:** output rate 10kHz
  2. L0/L1 hardware architecture:
     - **L0:** output rate 2-4MHz
     - **L1:** output rate 800-600kHz
     - **Event Filter:** output rate 10kHz
- Hardware tracking becomes an important component of the trigger upgrade:
  - Regional tracking, within "regions of interest" defined by calo & muons, provided by EFTrack.
  - Full-scan tracking, provided by FTK++.
  - Both based on the same hardware for flexibility and adaptability.
  - EFTrack moves to L1Track in the possible system evolution.





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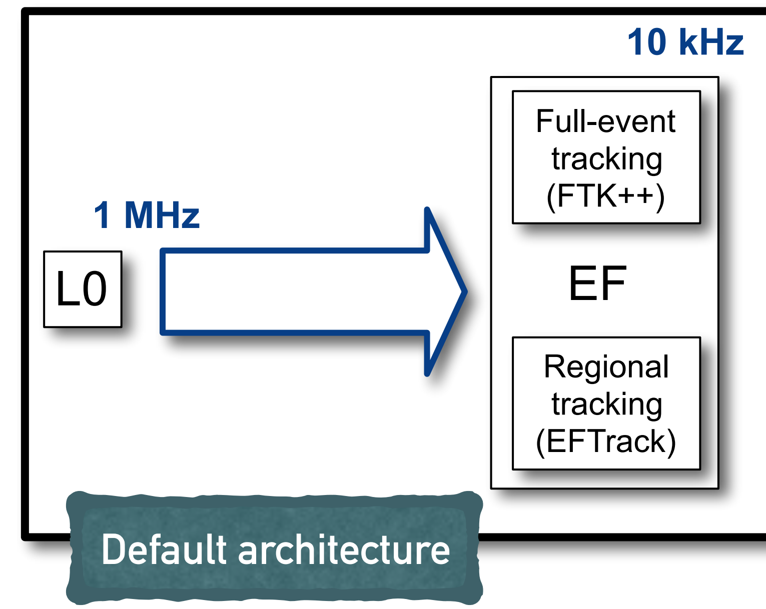

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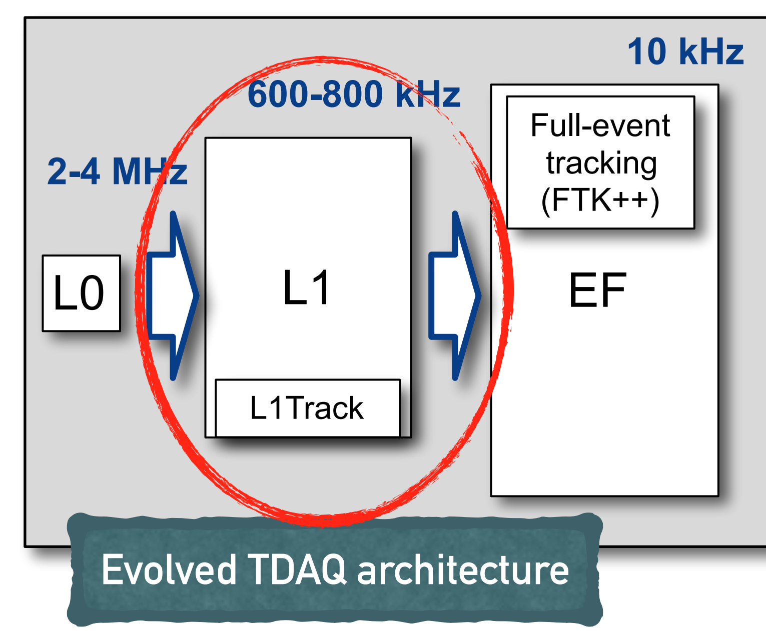


OFFLINE JET/MET RECONSTRUCTION AND PILEUP SUPPRESSION

- Missing Transverse MomEntum ideally reconstructed as

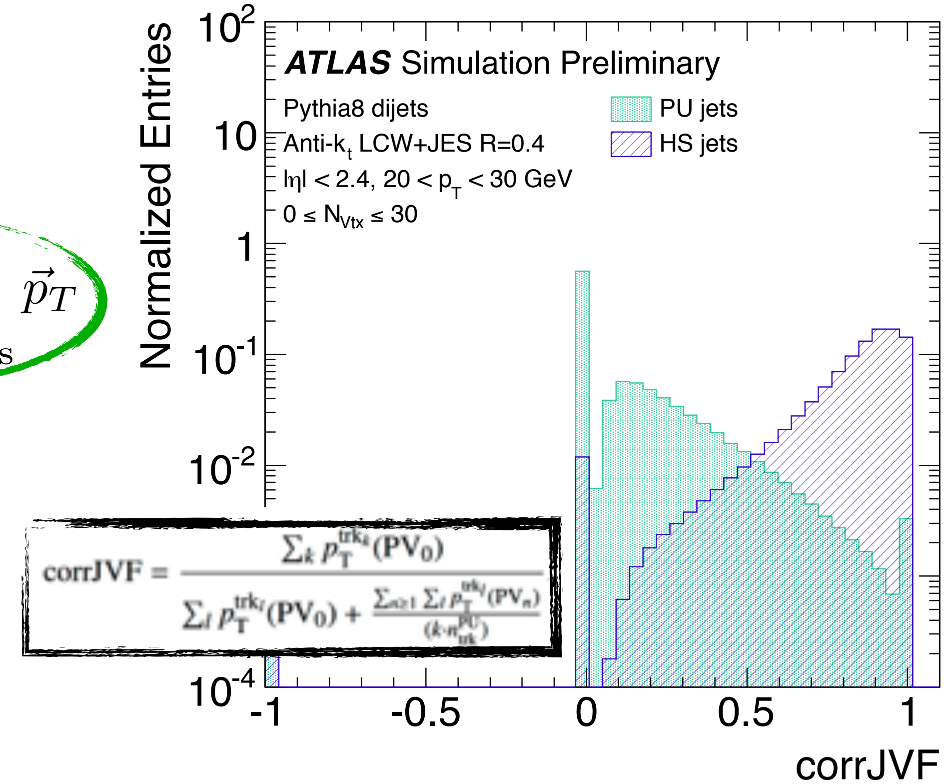
Hard Term

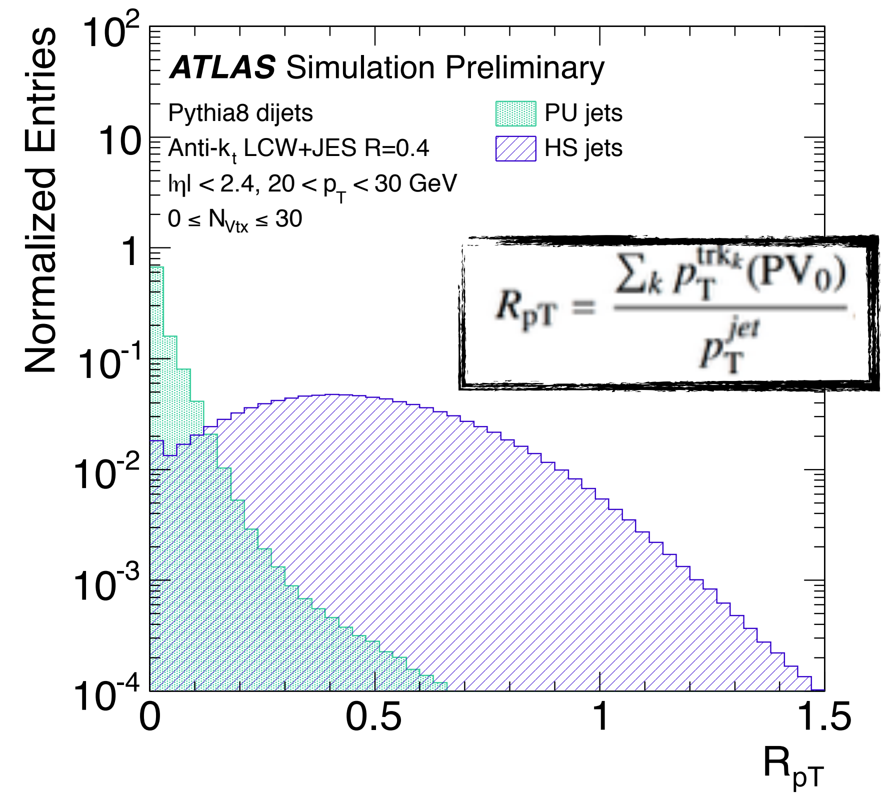
$$\text{MHT} = -\sum_{\text{HS jets}} \vec{p}_T$$

$$\vec{E}_T^{\text{miss}} = -\sum_{\text{electrons}} \vec{p}_T^{\,e} - \sum_{\text{photons}} \vec{p}_T^{\,\gamma} - \sum_{\tau-\text{leptons}} \vec{p}_T^{\,\tau} - \sum_{\text{muons}} \vec{p}_T^{\,\mu} - \sum_{\text{jets}} \vec{p}_T^{\,\text{jet}} - \sum_{\text{tracks}} \vec{p}_T^{\,\text{soft terms}}$$

(Track-based) Soft Term

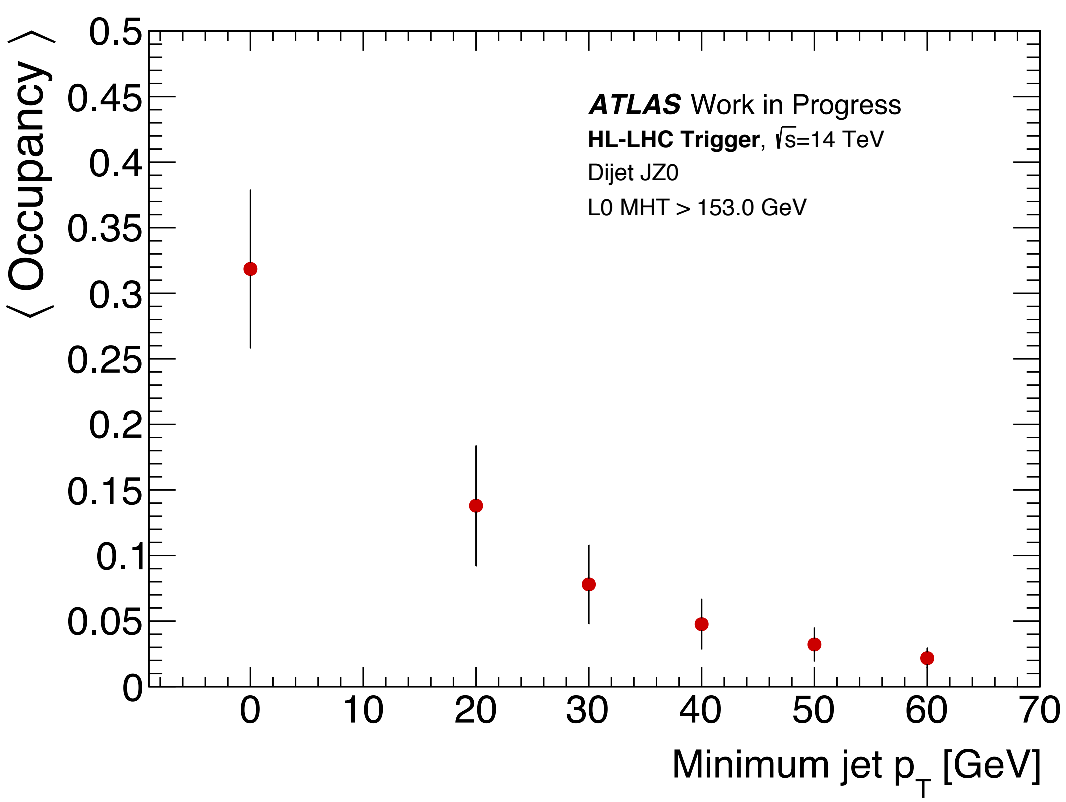
- Offline Jet pileup suppression mainly applied through:
  - Track activity in jets.
  - Primary vertex association.
- **Primary vertex reconstruction is a fundamental tasks for pileup jet suppression.**

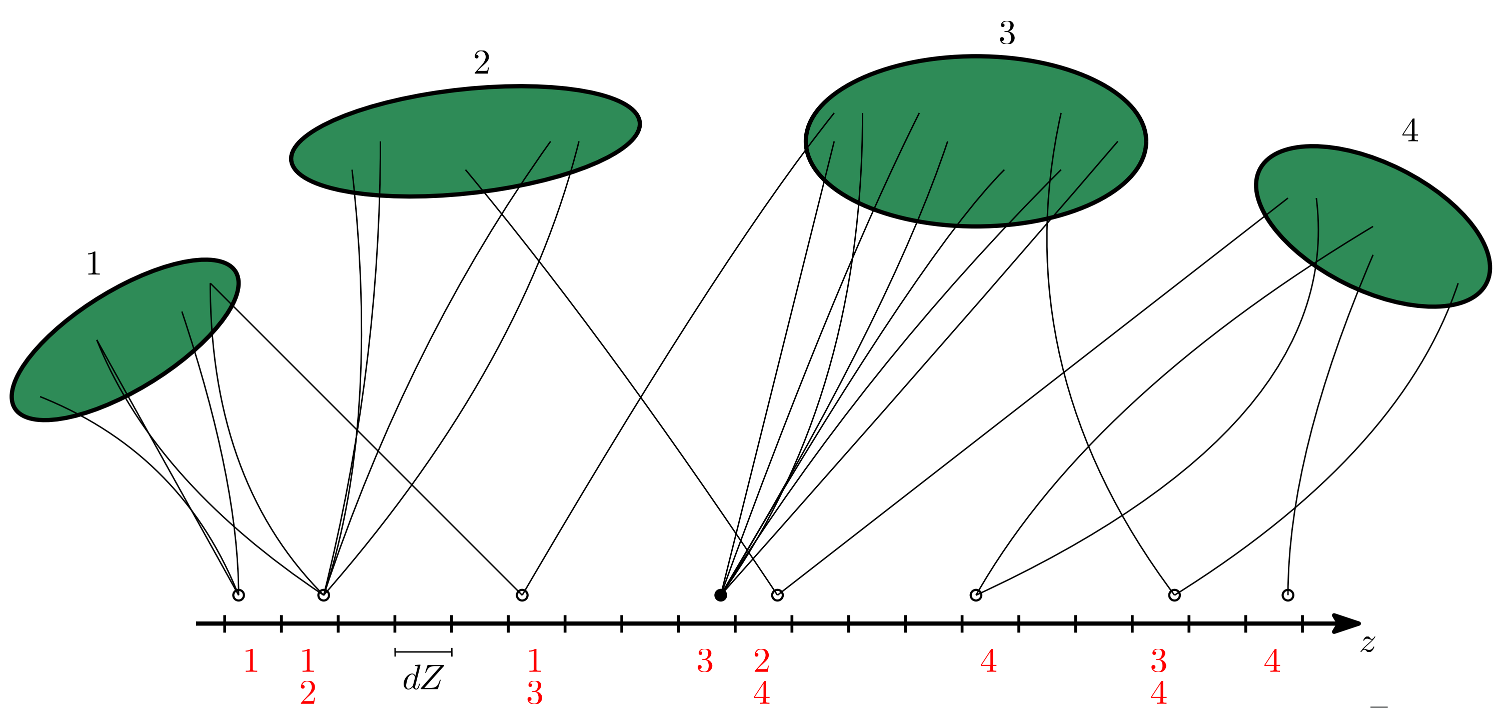




PILEUP SUPPRESSION WITH TRACKS AT L1

- L1-based pileup suppression:
  - Offline PV finding requires a long computational time.
  - A simplified PV finding has to be considered.
- On average, only 10% of the ITk volume can be read out at L0 output rate (⇒ regional tracking at L1). **This requirement is satisfied for the jet momentum regime relevant to triggering** (40-50 GeV).
- L1 PV finding idea:
  - Split the beam line into a set of segments with length dZ.
  - Identify the Hard Scatter segment (HS) and the Hard Scatter jets using RoI tracks.



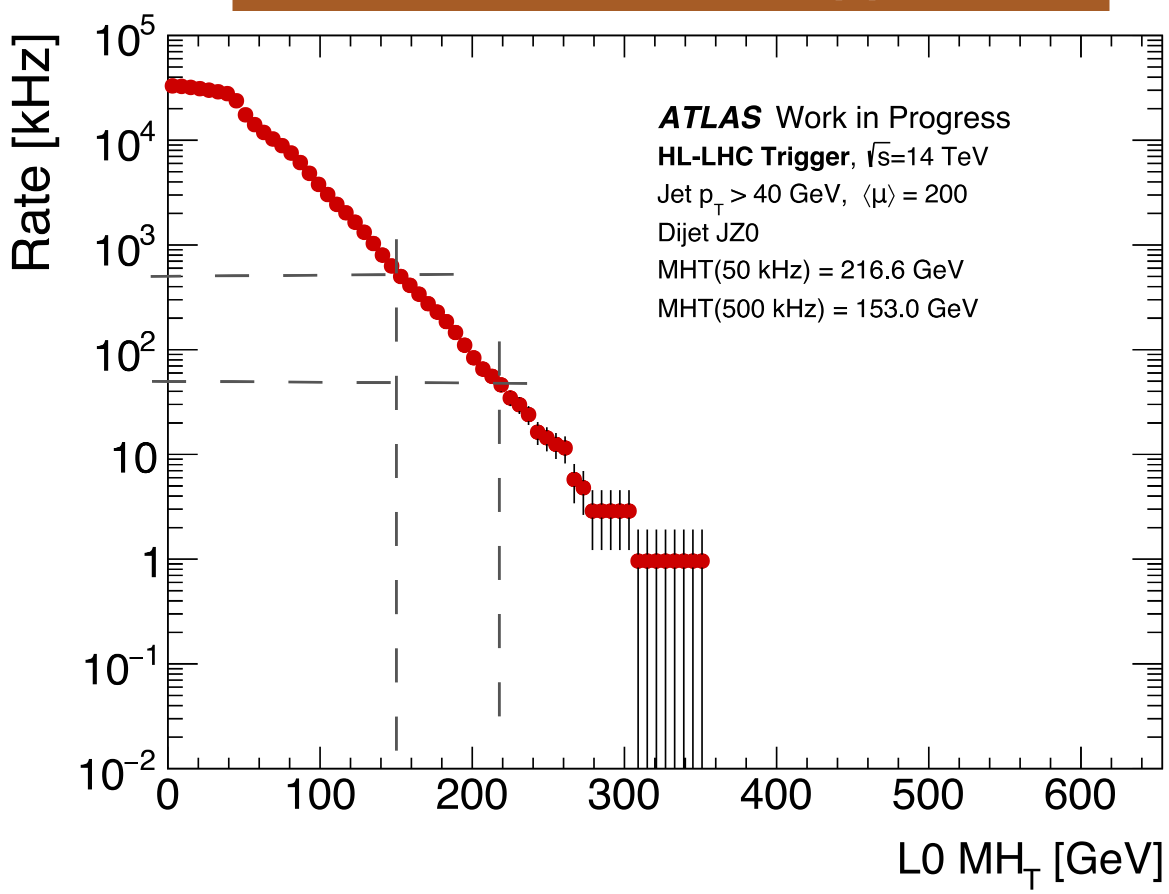


MET TRIGGERS AND BACKGROUND RATES (1)

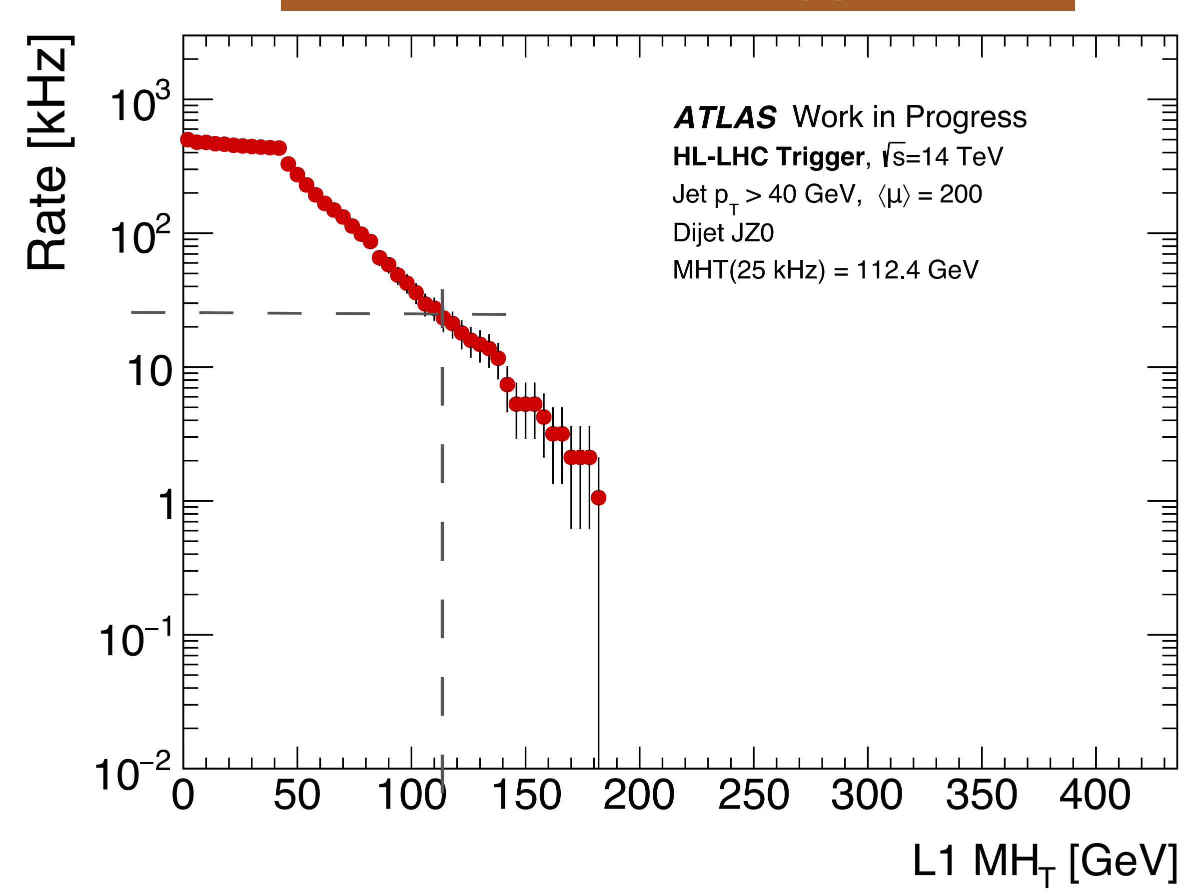
- MET trigger rates and performance are very sensitive to pileup.
  $\Rightarrow$ **Important improvements expected with use of tracking** based on observations in offline MET reconstruction.
- MET triggering is based on MHT.
- Without tracking available, a trigger decision is made by using all the jets in the event.

$$\mathrm{MHT} = -\sum_{\mathrm{HS\ jets}} \vec{p}_T$$

No track-based PU suppression



Track-based PU suppression

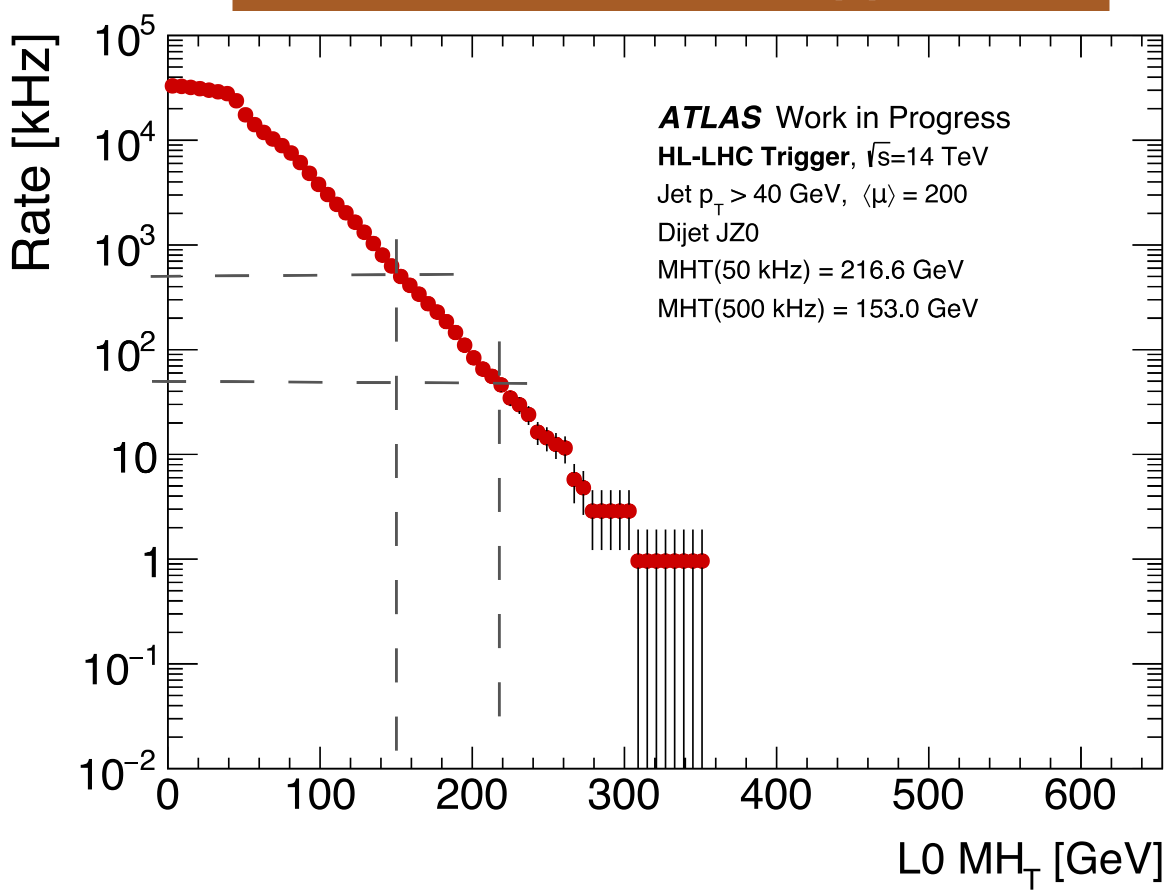


MET TRIGGERS AND BACKGROUND RATES (2)

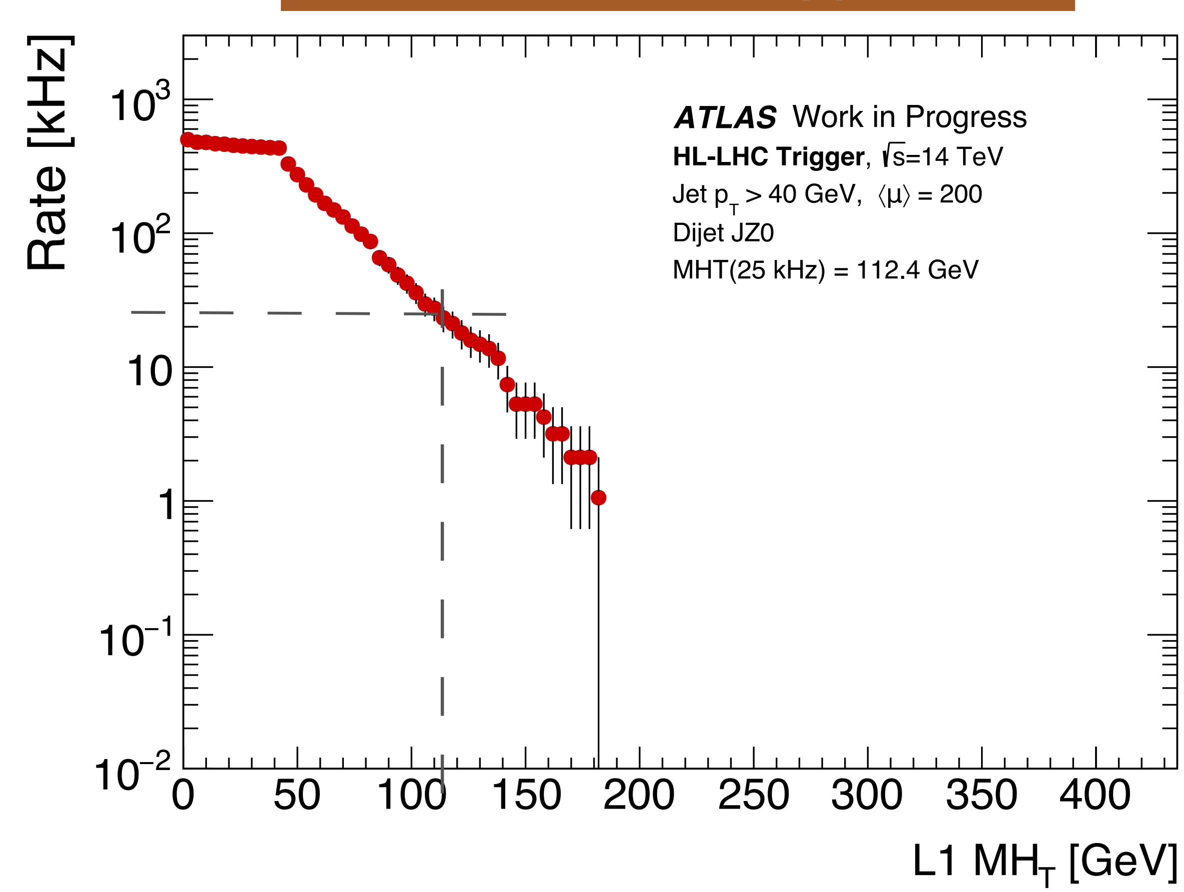
Quantity	L0-only scenario	L0+L1Track scenario
L0 total output rate	1 MHz	2-4 MHz
L0 MET rate	~50 kHz **(216.6 GeV)**	~500 kHz **(153 GeV)**
L1 MET rate		~25 kHz (112 GeV)

Threshold reduced by 50 GeV.

No track-based PU suppression

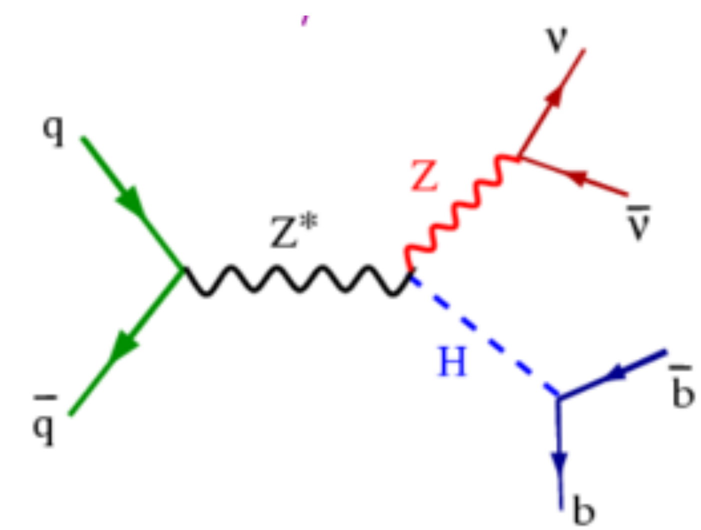


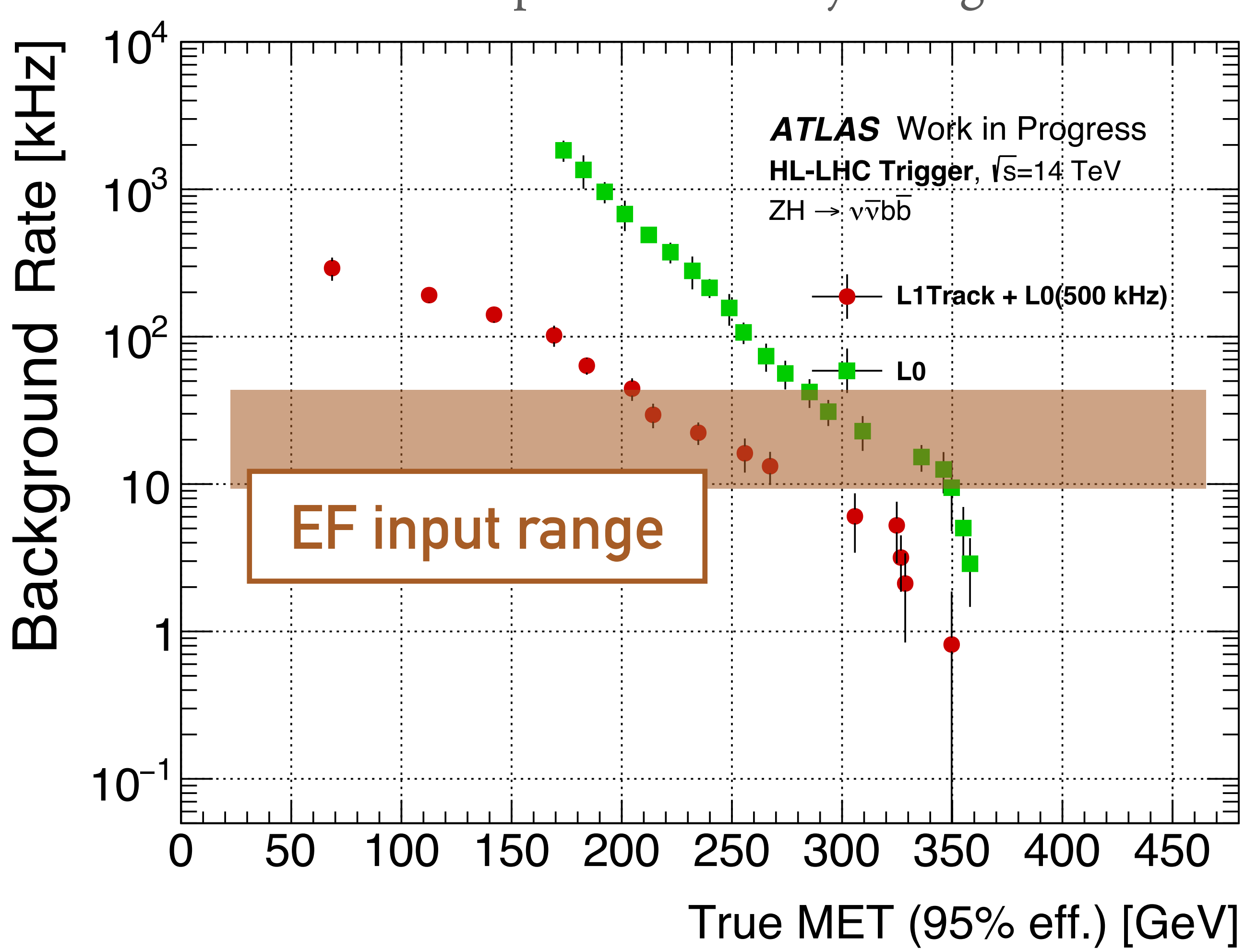
Track-based PU suppression

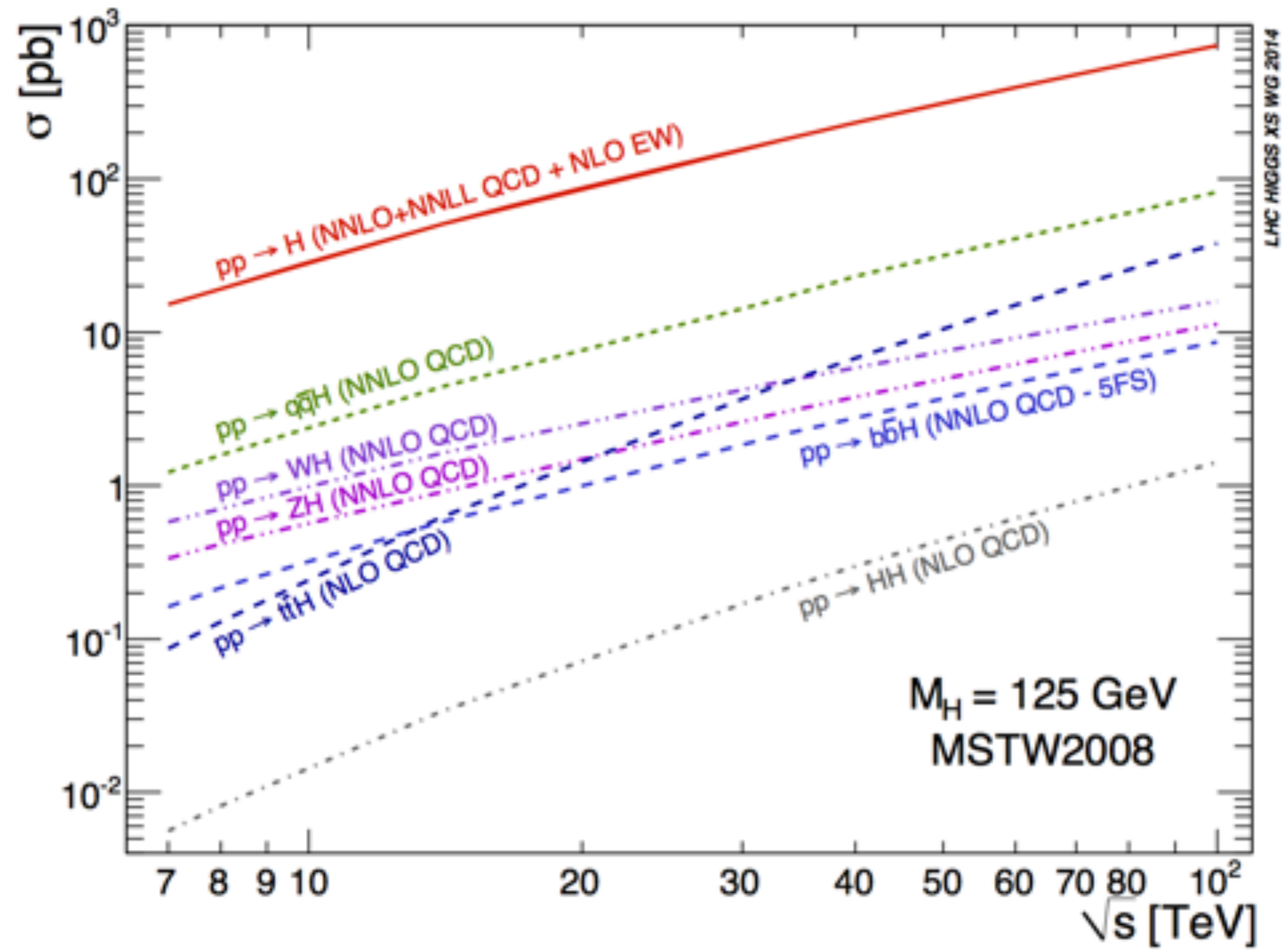


EFFICIENCIES ON SIGNAL

- Lower background rates result in an increased signal acceptance.
- MET triggers play a fundamental role in SUSY and other Exotics searches, as well as measurements of challenging Higgs channels, e.g. ZH → νvbb.
- ZH production has a very low cross section.
- Improvements to the true MET 95% efficiency have been observed for L1Track with respect to L0-only using ZH → νvbb samples.







SUMMARY AND OUTLOOK

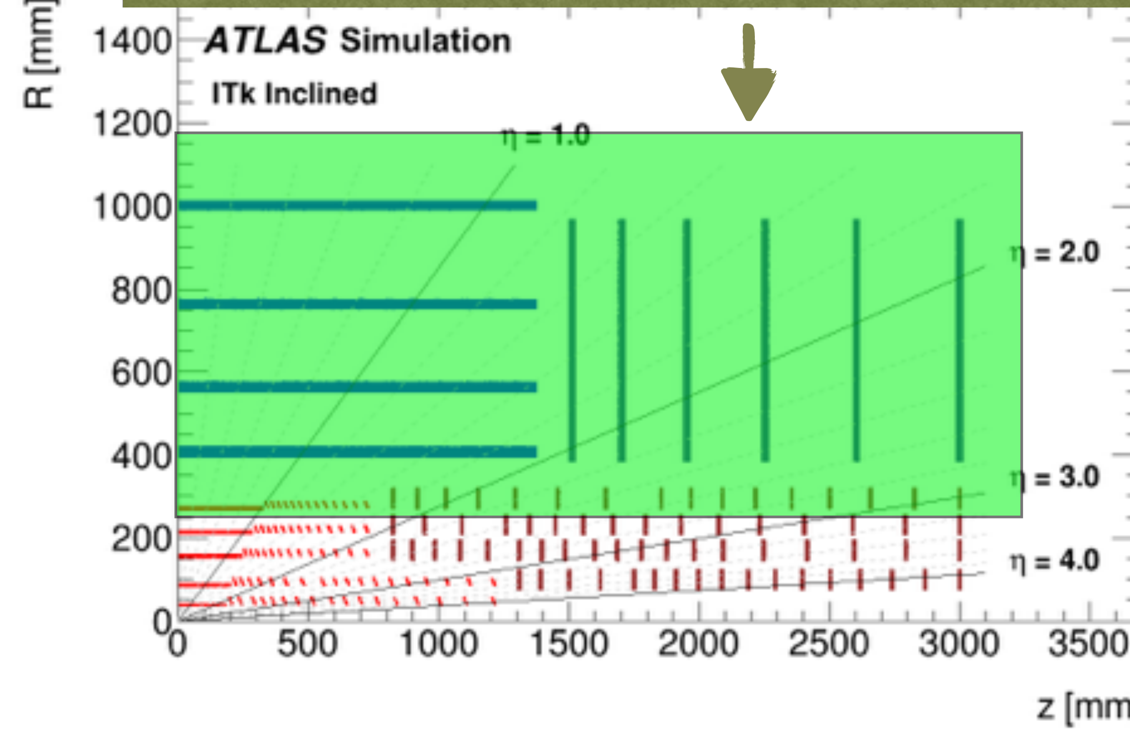
- Many activities to be ready for the ATLAS HL-LHC upgrade.
- Due to the high luminosity peak, very efficient pileup suppression at trigger level will play a fundamental role for a successful ATLAS physics program.
- Promising results (all work in progress) have been observed for MET based signatures.
- Right now, signal acceptance of **ZH → vvbb can be improved by a factor of 2-4** using tracks in an evolved ATLAS TDAQ architecture.
- On-going studies:
  - Check impact of L1Track on Multijet signatures ⇒ key trigger selection for HH→4b.
  - Include Event Filter studies using a Track-based Soft Term analogous to the offline MET definition.
  - Targeting ATLAS TDAQ TDR scheduled for the end of 2017.

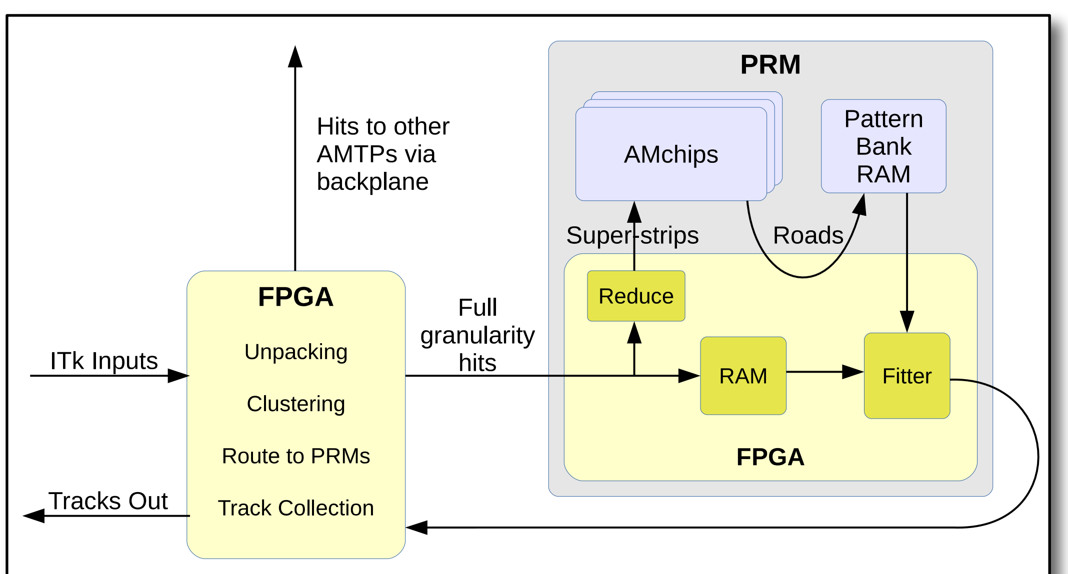
BACKUP

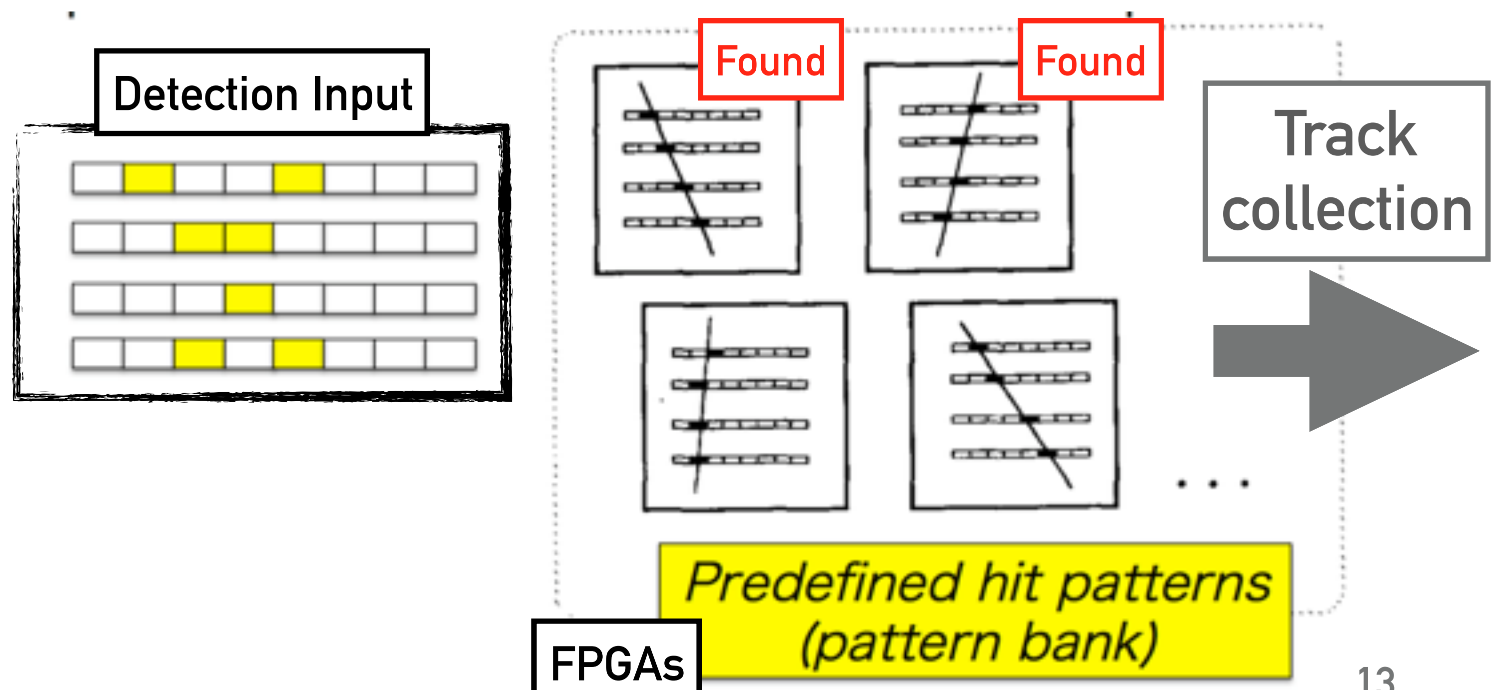
TRIGGERS AND HARDWARE TRACKING

- The Fast Tracker (FTK) is already providing online tracks to the current ATLAS High Level Trigger (HLT).
- Hardware tracking:
  - Micro-second scale track reconstruction.
  - Massive parallelisation through FPGAs.
  - Based on predefined patterns loaded in FPGAs memory (associative memory).
- For L1Track, only the ITk modules which are readable at the L1 rate can be used (strips + outermost pixel layer).

All strips detectors + outermost pixel layer available for online tracking







L0-ONLY RATES

Trigger selection	2016 offline threshold (GeV)	Phase II offline threshold (GeV)	L0 (kHZ)	Output EF (kHZ)	Physics case
isolated single e	27	22	200	1.8	WH, ZH, ttbar, EWK SUSY
single μ	27	20	40	2.0	
single γ	145	120	66	0.3	GMSB SUSY, QCD
forward e		35	40	0.2	
di-γ	40,30	25	8	0.2	H→γγ, HH→bbγγ
di-e	18	15	90	0.1	H→ττ, compressed EWK SUSY
di-μ	15	11	20	0.3	
e-μ	8,25 / 18,15	15	65	0.1	
single τ	160	150	20	0.3	W'→τν, Z', heavy Higgs
di-τ	40,30	40,30	200	0.3	H→ττ, HH→bbττ, SUSY di-τ
single jet w/ a tight b-jet	235	180	60	0.6	Exotics, QCD.
single jet	420	375		0.3	
large-R jet	460	375	35	0.4	G→HH, ttbar resonance
four-jet w/ two tight b-jets	45	75	50	0.6	(G→)HH→4b, RPV SUSY, VBF Higgs
four-jet	110	100		0.2	
HT w/ a tight b-jet	300	500	60	0.2	
MET	200	200	50	0.5	Compressed SUSY, ZH→ννhh, exotics, LLPs
jet & MET w/ a tight b-jet		140, 125	60	0.5	
forward jet	280	180	30	0.3	QCD, VBF

Final Totals: 1MHz 10kHz

Final totals:

- properly account for overlaps;
- include backup and supporting as well as other primary triggers.