ATLAS Trigger Overview and Performance

Annika Vauth

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Topics

Trigger and DAQ

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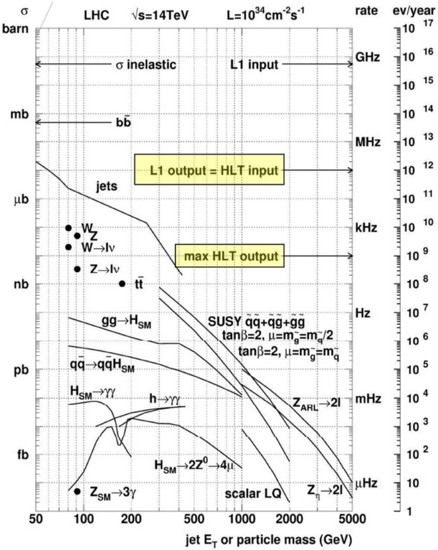
- Selecting interesting events,
- Rejecting high-rate background events,
- Moving the interesting data to permanent storage.



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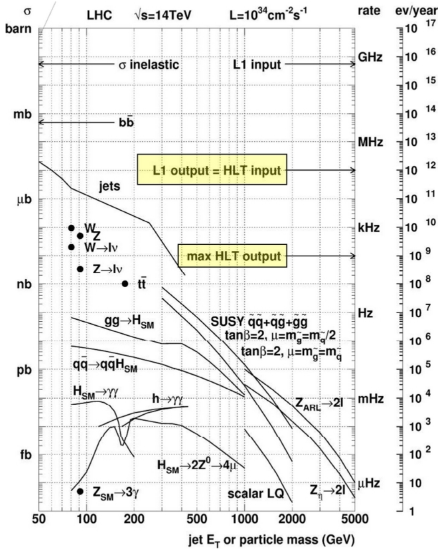

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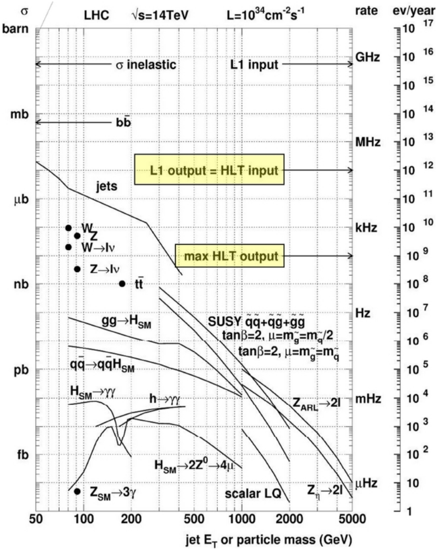

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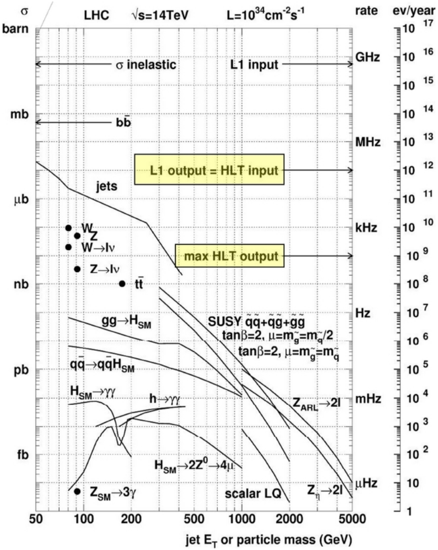

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Requirements

- At high Luminosity ($10^{-34}\ cm^{-2}\ s^{-1}$) :
  40 MHz bunch crossing Rate; approximately 25 collisions each, inelastic proton-proton-cross-section on the order of $10^9\ Hz$

- Must be reduced by a factor of 10^7 before writing to permanent storage ($\approx$ 100 events / 200-400 MB of data per second)

- Example: decay of SM-Higgs with mass of 120 MeV/c^2 into $\gamma\gamma$: occurs only at 10^{-13} of the interaction rate

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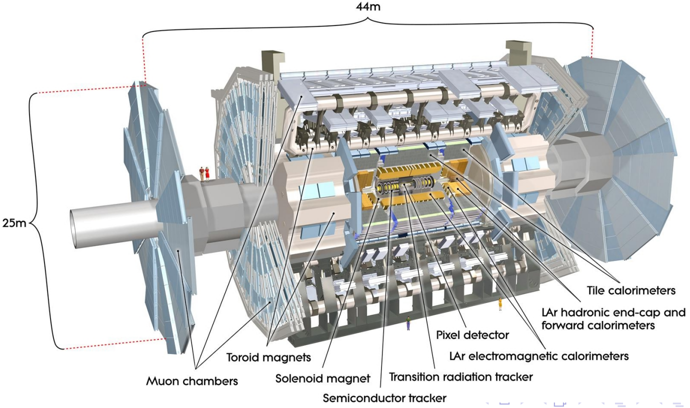
- *Level-2:* Full-granularity, analyse regions selected by Level 1.
- *Event Filter:* Decides which events from Level 2 will be recorded.



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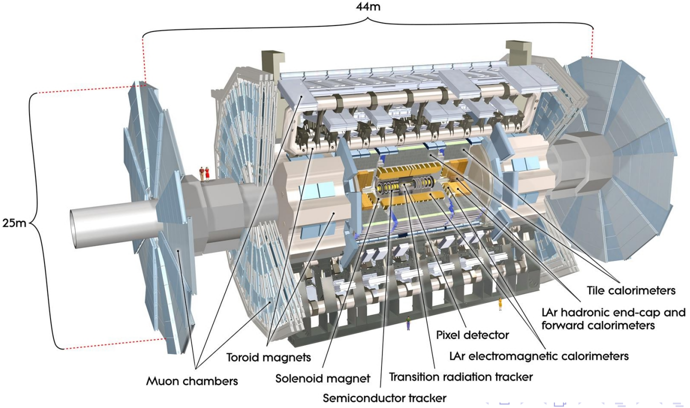

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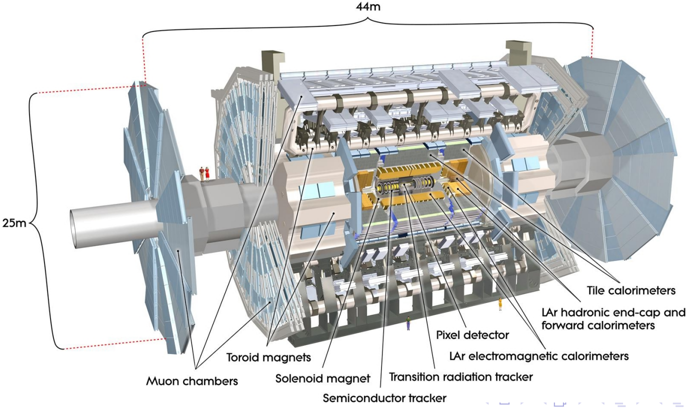

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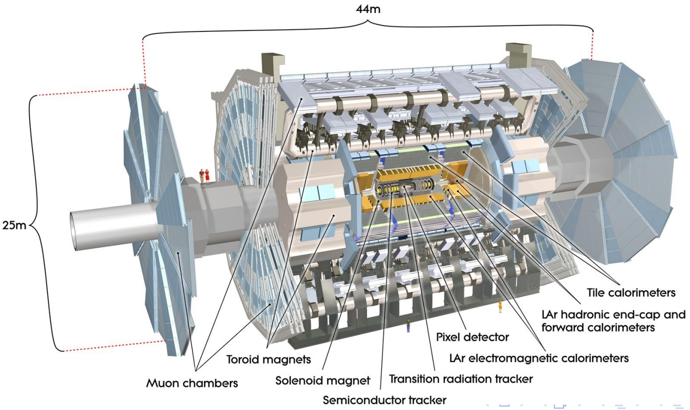

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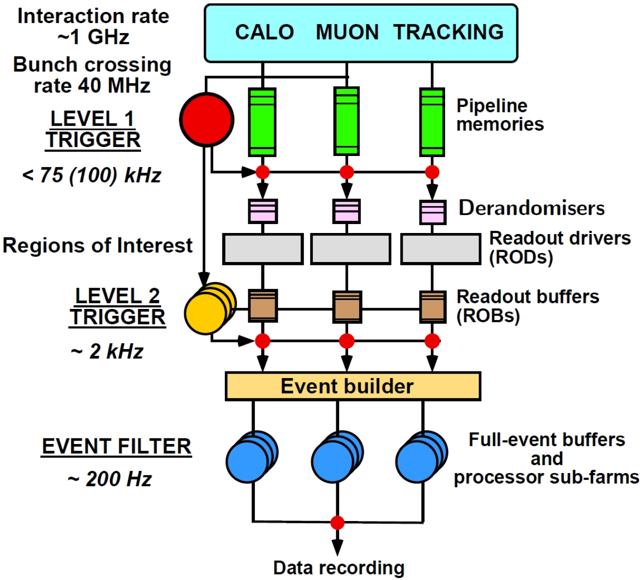

Level 1 Trigger

Hardware system

- based on dedicated electronics and pipelined memories,
- operates at the LHC bunch-crossing frequency of 40MHz,
- uses only coarse-granularity information:
  - from the calorimeters and
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Object	Number of thresholds	Isolation	$\lvert\eta\rvert$ range	description
MU	6	no	2.4	muon
EM	8	yes	2.5	e.m. cluster
T	8	yes	2.5	$\tau \rightarrow$ hadrons or single hadron
J	8	no	3.2	jet
XE	8	–	4.9	missing-E_T
SE	4	–	4.9	total scalar E_T

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Time Scale

- Latency is about 2 μs ,
- mainly due to cable propagation and trigger processing time.
- During processing, data from more than one bunch-crossing are held in pipeline memories
- Maximum accept rate is limited to 75 - 100 kHz.

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- Muon Trigger looks for coincidence of hits within different layers within a geometric road (width depends on p_T-treshold)
- Forwards information to the Central Trigger Processor (CTP)

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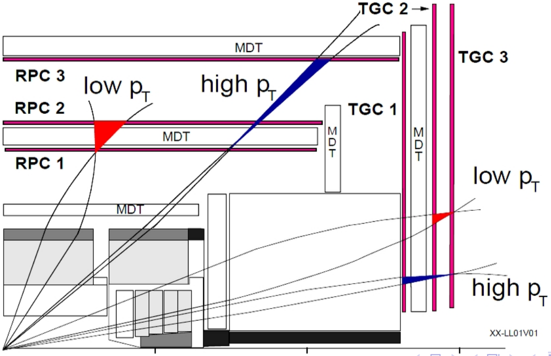

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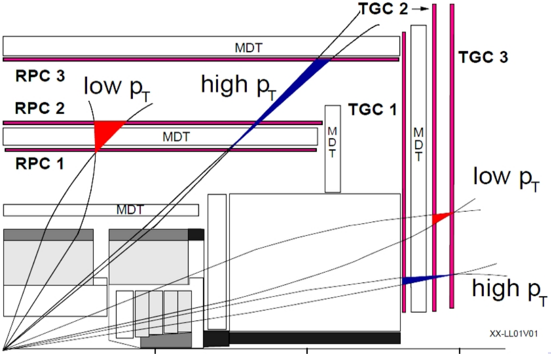

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The Calorimeter Trigger

- Uses info from EM and hadronic calorimeters with reduced granularity.
- data trigger towers (in which all samplings are summed) in each of the EM and hadronic calorimeter.
- Subsequent processing is divided into three sub-triggers, which process information independently and in parallel on: high-p_T EM clusters, hadron $/\tau$ clusters, and high E_T jets.
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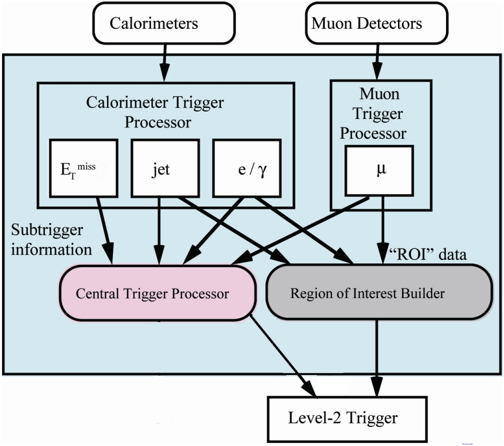

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Overview

- Software, runs on large processor farms
- uses full-precision information from the inner detector and full-granularity data from calorimeters and muon detectors:
- only inspects the geometrical regions of the detector that the LVL1 trigger has identifed as interesting ("Regions of Interest")
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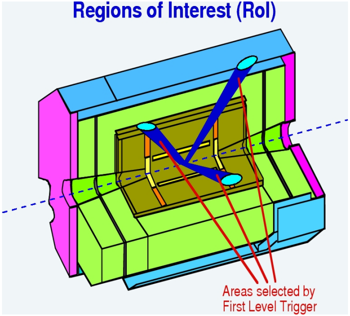

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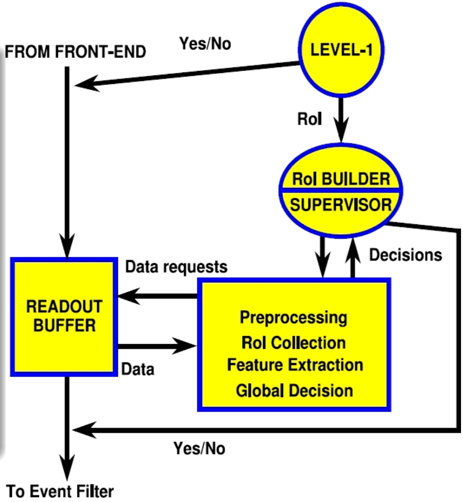
Supervisor / RoI Builder

- The RoI builder receives data from LVL1, builds a record containing list of RoIs, their type and position
- The Supervisor assigns LVL2 processors and forwards the RoI reports, also transmitts LVL2 decisions to the Readout Buffer so that data of rejected events is cleared.



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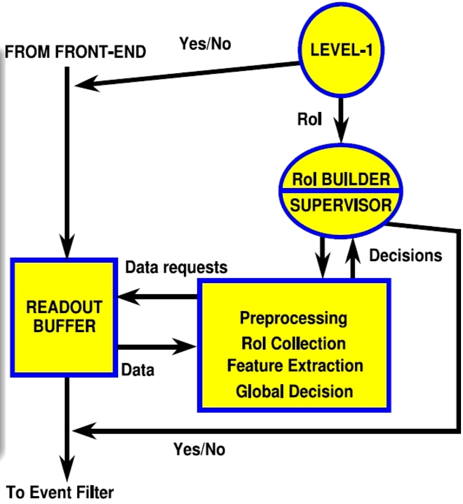

Processing Farms

- *Feature Extraction:* data from one RoI in a single subdetector is processed to give compact description of it.
- *Object building:* combines RoI features from all relevant subdetectors.
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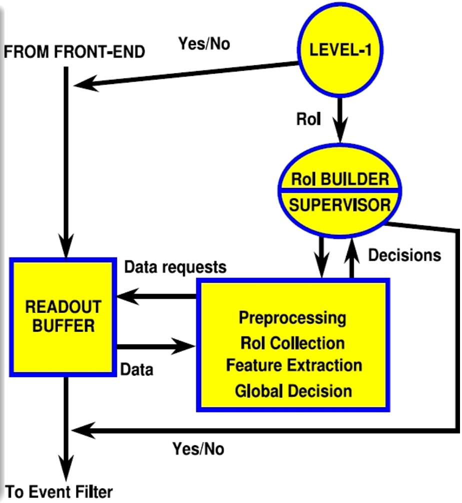

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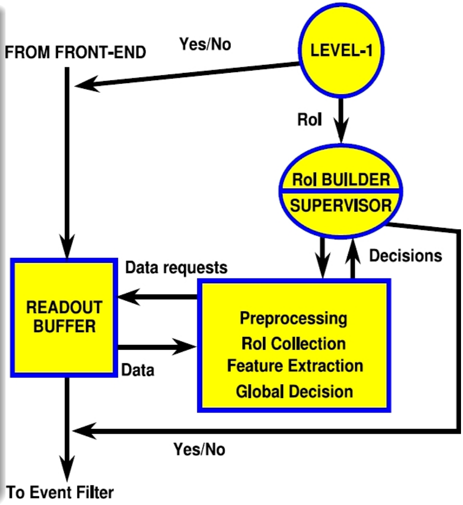

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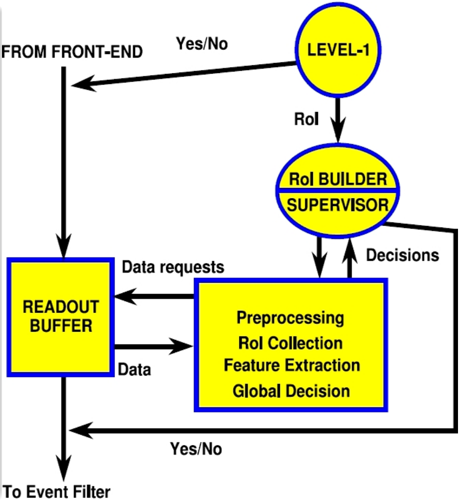

Event Filter

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- Software, runs on large processor farms
- After an event is accepted by the LVL2, the data for the event is moved from the Readout Buffers to the EF processors
- latency is on the order of 1 s $\Rightarrow$ run more sophisticated algorithms
- Vertex reconstruction and track fitting are performed at this level
- may also perform some data preparation steps before storage, e. g. zero suppression
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Requirements

- *Bunch Crossing Identification*:
  LVL1 trigger must identify bunch crossing that gave rise to the trigger.
- *Transverse momentum range:*
  for example B-physics studies require the ability to trigger on low-p_T muons with thresholds down to $p_T \approx 6 GeV$
- *Efficiency*:
  Ratio of the number of triggered muons to the number generated should be high.
- *Rates*:
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Performance: Trigger Menus

Trigger Menus

Tables of signatures adressing specific physic goals (tresholds and selection criteria at each level).

Notation

- e (electron), g (photon), MU (muons), tau (tau leptons), EM (electromagnetic), J (jets), FJ (forward jets), XE (missing E_T), TE (total scalar sum E_T)
- an "'i"' stands for isolation,
- multiple required objects are connected by an underscore.

Example: *2e15* requires two electrons with E_T over 15 GeV; *tau25i_XE30* requires an isolated tau lepton with E_T over 25 GeV AND a missing E_T above 30 GeV.

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Tables of signatures adressing specific physic goals (tresholds and selection criteria at each level).

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Prescale	60	1	1	1	1	1	1	1
Rate (Hz)	674	4900	950	480	369	143	53	1.5
Trigger Item	2EM3	2EM7	2EM13	2EM13I	2EM18	2EM18I	2EM23I	3EM7
Prescale	1	1	1	1	1	1	1	1
Rate (Hz)	6500	534	108	8	47	2	0.6	53

Signature	tau6	tau9I	tau11I	tau16I	tau25	tau25I	tau40
Prescale	750	300	1500	10000	20	10	1
Rate (Hz)	19	16	2	< 0.1	16.1	25	83
Signature	2tau6	2tau9I	2tau16I	tau6_tau16I	tau9I_EM13I	tau9I_MU6	tau9I_XE30
Prescale	100	1	1	10	1	1	1
Rate (Hz)	19	413	65	46	100	25	160

Trigger Item	XE15	XE20	XE25	XE30	XE40	XE50	XE70	XE80
Prescale	30000	7000	1500	200	20	2	1	1
Rate (Hz)	2.5	3	4	7.5	7.5	14	2	1

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Reminder: the two different approaches

- *Track-based:* tracks as initial reconstruction seed
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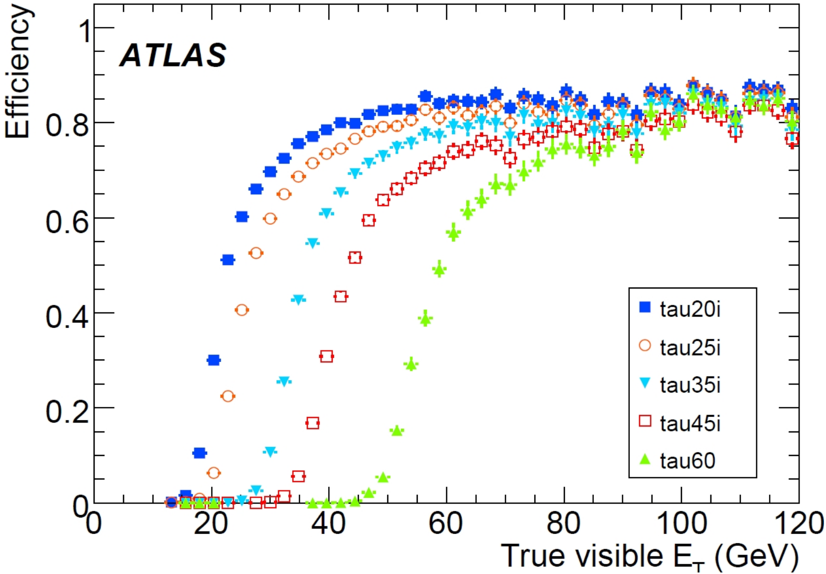
	Threshold Signature				
Algorithm	tau10i	tau15i	tau20i	tau25i	tau35i
L2 Calo	8.1	8.0	8.0	8.1	8.1
L2 Tracking	15.4	15.5	15.0	14.9	14.7
L2 Combined	1.9	1.9	2.0	2.0	2.2
L2 TotalTime	41.6	35.9	19.7	14.1	7.9
EF Calo	12.3	12.5	13.4	13.0	14.0
EF Tracking	289.7	297.7	269.5	268.4	247.8
EF Combined	77.0	76.9	80.7	77.8	78.9
EF TotalTime	149.1	133.6	67.5	51.2	24.6

Tau Trigger: Efficiency



Tau Trigger: for various physics signals

Trigger Item	$W_{\tau\to hX}$	$Z_{\tau\tau}$	$t\bar{t}$	$A_{\tau\tau}(800)$	SU3	$H_{\tau\tau\to\ell hX}$	$H_{\tau\tau\to hhX}$
tau10	82.6±0.3	91.9±0.2	93.6±0.4	97.1±0.1	94.3±0.3	93.8±0.2	96.9±0.1
tau10i	78.7±0.4	89.8±0.2	91.1±0.4	96.4±0.2	92.0±0.4	92.1±0.3	95.8±0.1
tau15	78.2±0.4	88.7±0.3	91.9±0.4	96.5±0.1	92.4±0.4	91.6±0.3	95.4±0.1
tau15i	74.1±0.4	86.0±0.3	89.1±0.5	96.1±0.2	90.4±0.4	90.0±0.3	94.1±0.1
tau20i	68.5±0.5	79.9±0.3	83.2±0.6	89.8±0.2	82.5±0.5	85.0±0.4	89.8±0.2
tau25i	66.5±0.6	76.0±0.4	80.1±0.7	89.0±0.3	79.7±0.6	82.0±0.4	87.1±0.2
tau35i	65.8±0.9	70.0±0.6	77.4±0.9	87.5±0.3	76.9±0.7	78.2±0.5	82.0±0.2
tau45	82.7±1.3	78.7±0.8	88.0±0.9	94.9±0.2	89.6±0.6	86.2±0.5	88.5±0.2
tau45i	72.1±1.5	68.5±0.9	76.0±1.2	86.1±0.3	75.1±0.9	75.8±0.7	78.5±0.3
tau60	77.5±2.6	74.4±1.5	74.7±1.7	91.4±0.2	78.2±1.1	76.1±0.9	77.5±0.4
tau100	83.9±6.6	78.2±4.1	80.2±3.5	90.0±0.3	81.7±1.9	79.1±1.6	80.7±0.7
2tau25i	0.0±0.0	47.2±1.5	60.0±11.0	62.6±1.2	62.6±2.7	61.5±6.7	59.3±0.6
2tau35i	0.0±0.0	43.1±3.1	57.1±18.7	60.6±1.3	62.0±3.8	50.0±9.1	55.6±0.9
tau15i_xe20	56.3±0.6	48.4±0.8	80.1±0.7	92.7±0.2	89.5±0.4	80.8±0.5	80.2±0.3
tau20i_xe30	45.4±0.9	38.6±1.2	70.1±0.9	84.5±0.3	81.4±0.6	73.9±0.6	73.2±0.4
tau25i_xe30	44.2±1.0	38.0±1.3	67.5±1.0	83.8±0.3	78.7±0.6	71.4±0.7	71.1±0.4
tau35i_xe20	55.1±1.2	42.0±1.2	68.7±1.1	84.5±0.3	76.3±0.7	70.8±0.7	69.5±0.4
tau35i_xe30	47.7±1.5	38.5±1.7	63.3±1.2	82.3±0.3	76.2±0.7	69.2±0.8	66.9±0.4
tau35i_xe40	42.1±2.5	39.2±2.4	58.0±1.4	80.8±0.4	75.6±0.8	68.3±1.0	65.3±0.5
tau45_xe40	54.7±3.6	48.3±3.0	67.4±1.6	87.6±0.3	88.2±0.7	76.5±1.0	71.0±0.6
tau45i_xe20	60.1±2.1	43.8±1.7	67.3±1.4	83.2±0.3	74.7±0.9	69.0±0.9	66.7±0.4
tau20i_e10	0.0±0.0	68.1±1.2	73.7±2.9	79.6±0.8	77.1±1.7	73.2±0.8	0.0±0.0
tau20i_mu6	0.0±0.0	72.0±0.9	81.4±2.4	80.3±0.7	83.3±1.3	79.4±0.7	0.0±0.0
tau20i_j70	70.8±1.4	78.8±0.7	81.6±0.7	89.4±0.2	82.7±0.6	65.6±0.7	72.6±0.3
tau20i_3j23	61.1±2.1	80.2±0.8	82.0±0.7	89.9±0.2	83.2±0.6	83.7±0.7	80.7±0.3
tau20i_4j23	58.2±4.1	82.7±1.6	80.5±0.9	90.3±0.3	84.5±0.6	86.9±1.7	83.9±0.7

Summary

- Event rate must be reduced by a factor of 10^7 before writing to permanent storage.
  $\Rightarrow$ Triggering is important!

- Trigger structured into three levels
  (Level 1, Level 2, Event filter)

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