Trigger Studies in the semileptonic $t\bar{t}H$ ($H \rightarrow b\bar{b}$) channel with the ATLAS detector

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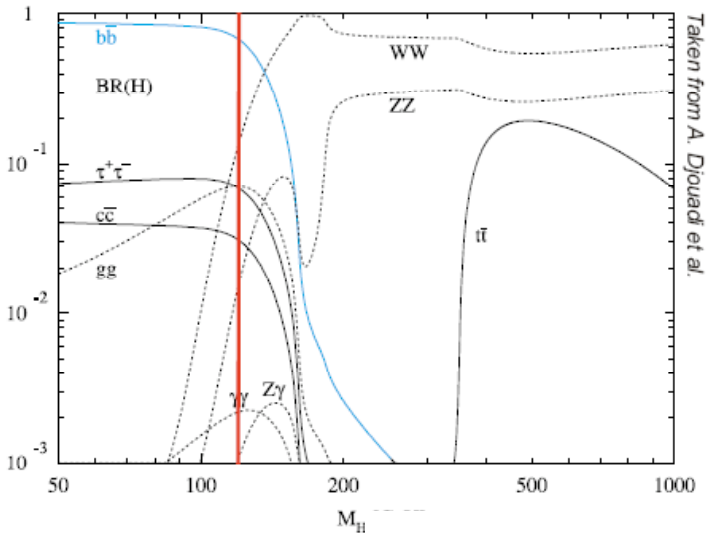
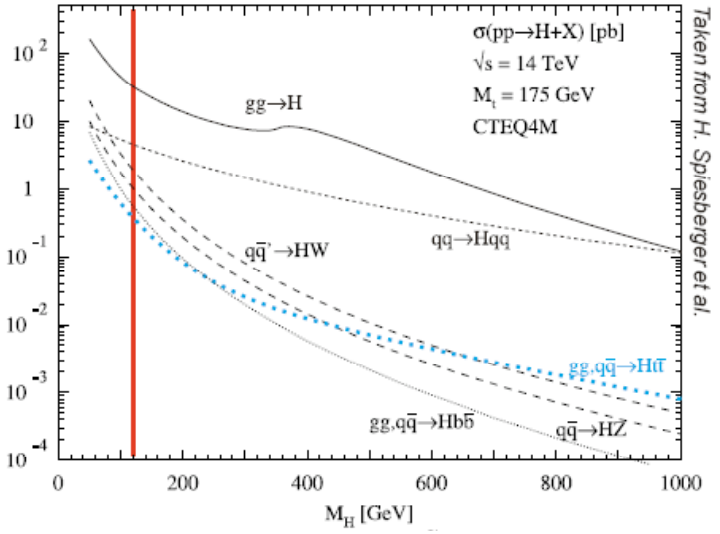
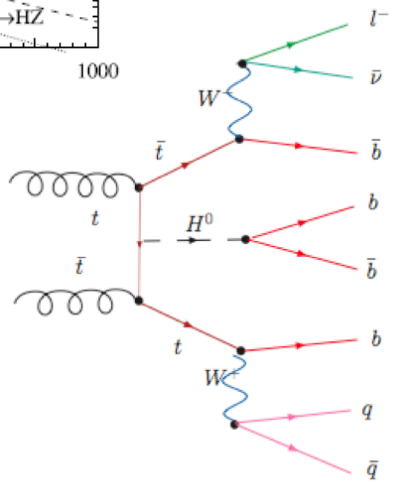
$t\bar{t}H^0$ ($H^0 \rightarrow b\bar{b}$)

- To devise search strategies for a low mass Higgs (120 - 140 GeV), it is important to know the dominant production and decay channels as a function of the different possible Higgs masses:
  - below WW threshold $H \rightarrow b\bar{b}$ decay dominant
  - direct production $gg \rightarrow H$ highest production cross section
    - but (with $H \rightarrow b\bar{b}$) suffers from large QCD dijet backgrounds and cannot be efficiently triggered





- More promising is associated production with $t\bar{t}$ pair:
  - require semileptonic decay of one of the tops to have a handle for triggering
  - complex final state: 1 lepton (muon, electron), 1 neutrino, 4 b jets, 2 jets



ATLAS Trigger

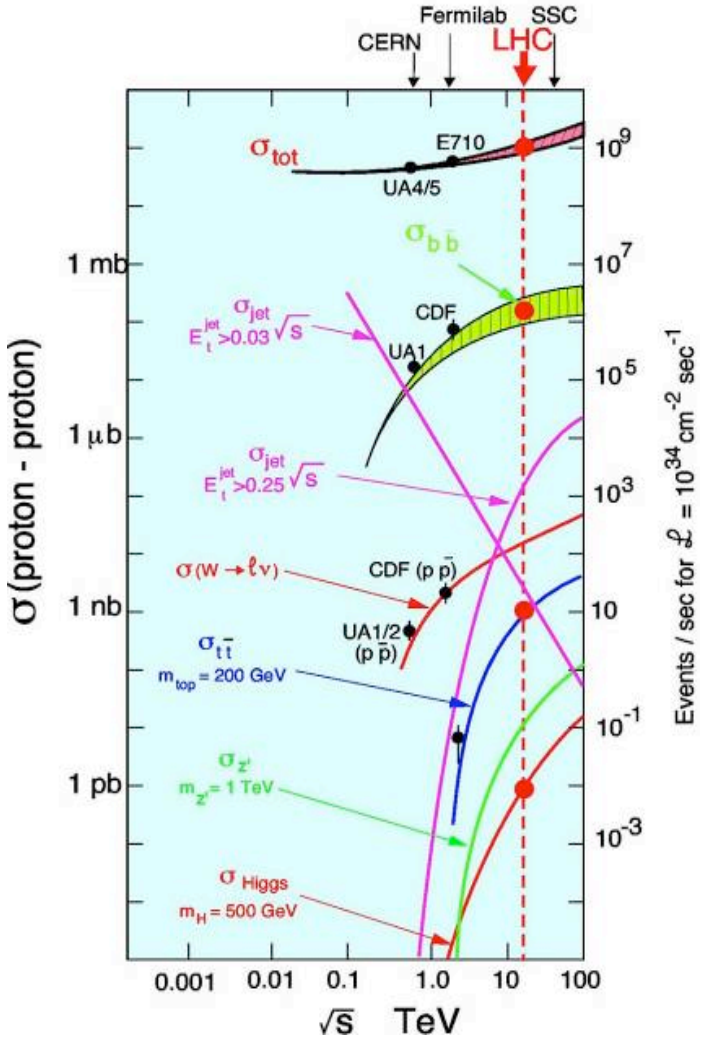
Three level trigger system:

- Level 1 (L1):
  - hardware based
  - only coarse data from Calorimeter and Muon detectors
  - seeds "Regions of Interest" (RoI)
  - makes decision in < 2.5 μs
- High Level Trigger : software based
  - Level 2 (L2):
    - algorithms are restricted to RoIs
    - 40 ms to process RoIs
  - Eventfilter (EF):
    - can access the entire event
    - about 4 s for decision

In one second at design luminosity (10^{34} $cm^{-2}s^{-1}$) at center of mass energy of 14 TeV:

- 40 M bunch crossings
- ~ 2000 W, ~ 10 top, ~ 0.1 Higgs events

BUT: only 200 events can be written out



Study of trigger signatures important for selecting events of interest with the highest possible efficiency!

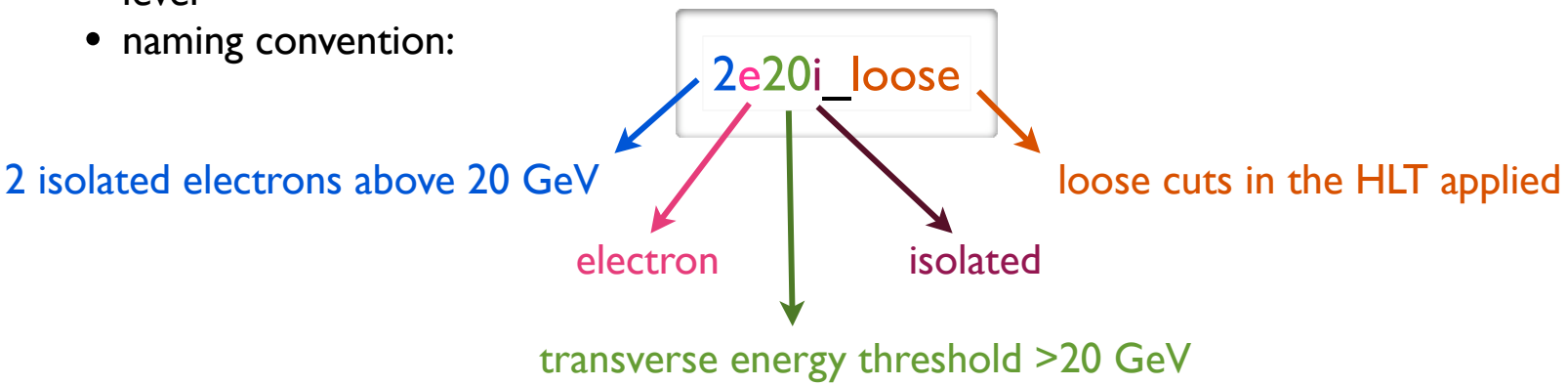
Trigger menus and signatures

Trigger menus:

- list of all possible signatures which are implemented
- based on identification of potential candidates for interesting objects such as electrons, muons, jets, b-tagged jets, missing energy, taus, etc.
- Included in the menu are:
  - inclusive triggers for each of the objects
  - more sophisticated signatures in which two or more of the objects are combined
- For this study, a trigger menu for the start-up luminosity of $\mathbf{10^{31}cm^{-2}s^{-1}}$ is used

Trigger signatures:

- names given describe the whole chain and don't specify the requirements for passing the trigger level
- naming convention:



- Signatures chosen wrt final state particles and wrt to no/very low prescale (keep only a fraction of events that satisfy the threshold)

Efficiency and simulated data

- $t\bar{t}H^0$ ($H^0 \rightarrow b\bar{b}$) is a complex channel, therefore basic selection applied before the actual reconstruction
  - 1 isolated lepton (electron or muon) in central detector region with $p_T(e) > 25$ GeV, $p_T(\mu) > 20$ GeV,
  - at least 6 jets with $p_T > 20$ GeV, at least 4 of these jets must be tagged as b jets

- Efficiency calculation is applied after this basic selection
  - no significant interference/correlation between reconstruction cuts with the trigger efficiency
  - higher statistics compared to after the final selection

$$\text{Efficiency} = \frac{\text{number of events passing preselection \& trigger level}}{\text{number of events passing preselection}}$$

In the following slides, the efficiencies are calculated from 50 000 simulated Higgs events, simulated for a Higgs mass of m_H=120 GeV, a centre of mass energy of **10 TeV**, and without pileup.
The **trigger menu** used if for a luminosity of $\mathbf{10^{31} cm^{-2} s^{-1}}$.

Trigger menu: $10^{31}cm^{-2}s^{-1}$
simulated data: 10TeV

Single lepton triggers

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	e15_medium	e20_loose	e20i_loose	e25i_loose	mu15	mu20	mu20i_loose
L1	100%	99.9%	89.4%	88.3%	88.3%	87.0%	87.0%
L2	96.3%	95.1%	86.8%	85.4%	84.4%	81.7%	62.3%
EF	84.2%	92.9%	85.6%	84.2%	83.0%	80.6%	61.5%

errors ~ 0.1-0.3%

- Electron trigger: ~ 85%
- Muon trigger:
  - Without isolation criteria: ~ 81%
  - With isolation: ~ 62 %
    - mu20i_loose chain is tuned to have 95% efficiency (wrt L2_mu20) on isolated muons from W and Z decays.
    - On not fully isolated muons like in $t\bar{t}$ events the efficiency is much smaller.
    - Decrease in efficiency of about 15-20% has been observed in $t\bar{t}$ validation samples.

Trigger menu: $10^{31}cm^{-2}s^{-1}$
simulated data: 10TeV

Combined lepton trigger

	e20_loose || mu15	e20i_loose || mu15	e20i_loose || mu20
L1	99.8%	92.2%	91.5%
L2	91.8%	87.8%	86.3%
EF	90.0%	86.7%	85.2%

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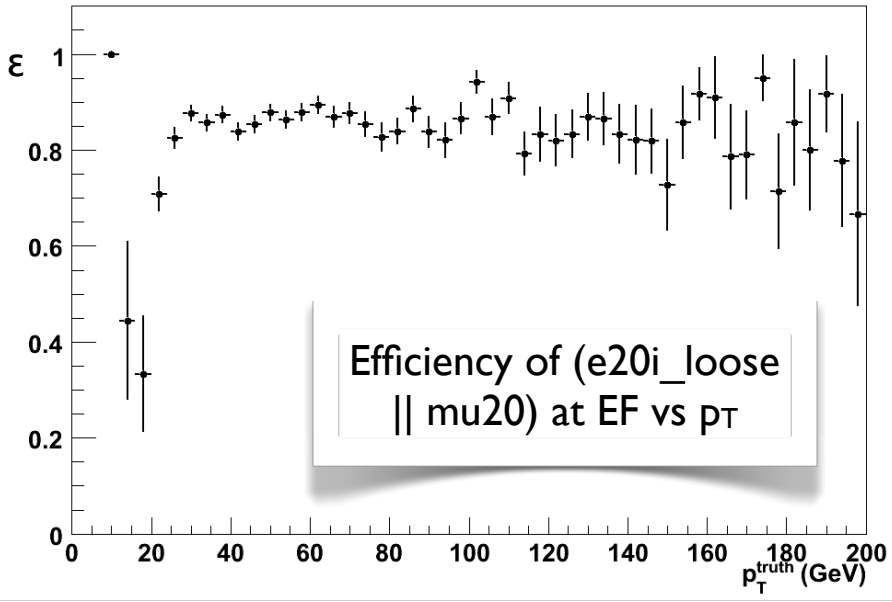
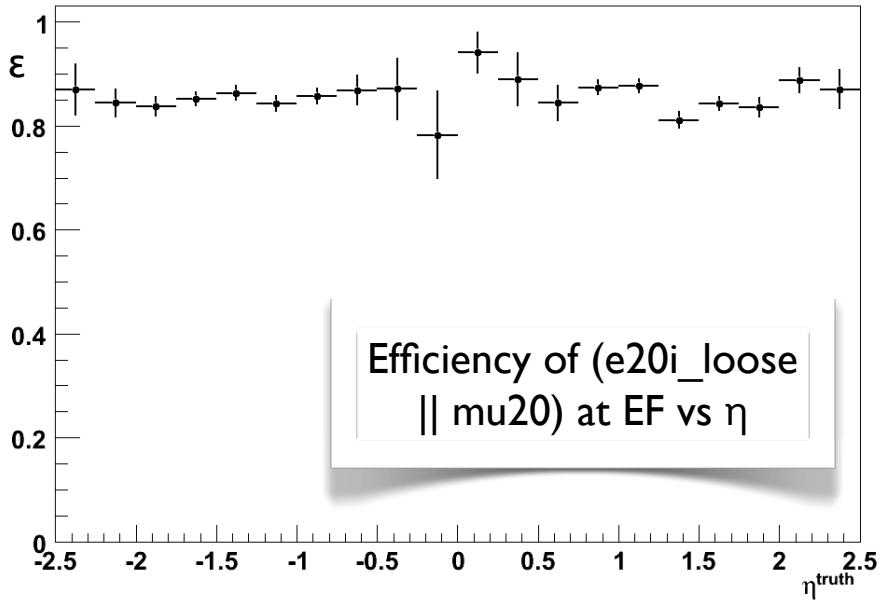
errors ~ 0.1-0.3%





Trigger menu: $10^{31}cm^{-2}s^{-1}$
simulated data: 10TeV

Jet and Missing Energy trigger

- In final state of ttH events missing energy and 6 jets in total: 4 b-tagged jets and 2 jets
  - b jet trigger: 3b23_3L1J23
    - b jet trigger requires 3 b-tagged jets for the event to pass it
  - jet trigger: 3j180, 4j95, 4j125
    - requiring 3/4 jets above p_T threshold
    - 4j95 presecaled at L1, prescale NOT included in calculation
  - missing Energy trigger: xe40, xe50
    - both prescaled at L1, prescale NOT included in calculation
- jet, b jet and missing energy trigger low efficiency, but possibly helpful to reduce background events when using to lepton trigger in addition
- to test: use of lower threshold trigger with higher prescale in combination with lepton trigger

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	b jet trigger (3b23_3L1J23)	3j180	4j95	4j125	xe40	xe50
L1	90.0%	35.6%	86.8% (PS: 20)	68.4%	65.9% (PS: 20)	55.6% (PS:2)
L2	15.2%	22.0%	71.1%	27.1%	56.8%	44.7%
EF	13.5%	9.9%	37.7%	13.7%	49.1%	37.9%

errors ~ 0.1-0.3%

Trigger menu: $10^{31}cm^{-2}s^{-1}$
simulated data: 10TeV

Combined signatures

- Combining trigger objects (errors ~ 0.5%)

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e20i_loose || mu20 || bjet	79.3%
e20i_loose || mu20 || bjet || xe40	86.4%
e20i_loose || mu20 || 3j180 || xe40	86.1%
e20i_loose || mu20 || 4j95 || xe40	86.4%

- Combinations from the trigger menu (errors ~ 0.5%)
  - Letpon and jet:

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4j23_e15 || 4j23_mu15	72.2%
EF_4j23_e15i	35.4%
EF_4j23_mu15	41.1%

Lepton trigger efficiency comparison

Comparison between:

- trigger menu for luminosity of $10^{31}cm^{-2}s^{-1}$ and simulated data for 10 TeV (no pileup)
- trigger menu for luminosity of $10^{34}cm^{-2}s^{-1}$ and simulated data for 14 TeV (no pileup)

Slightly different signatures because of different menus:

- electron trigger:
  - for $10^{31}cm^{-2}s^{-1}$: e20i_loose
  - for $10^{34}cm^{-2}s^{-1}$: e22i || e55 (e55 improves the efficiency for high-p_T electrons where the e22i trigger efficiency was reduced due to the isolation criteria)
- muon trigger:
  - for $10^{31}cm^{-2}s^{-1}$: mu20
  - for $10^{34}cm^{-2}s^{-1}$: mu20

	$10^{31}cm^{-2}s^{-1}$	$10^{34}cm^{-2}s^{-1}$
electron trigger	85.6%	84%
muon trigger	80.6%	79%
combined lepton trigger	83.0%	82%

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Expected Performance of the ATLAS Experiment - Detector, Trigger and Physics. ATLAS Collaboration (G.Aad et al.) Jan 2009. 1852pp. **arXiv:0901.0512**

Conclusion & Outlook

- Lepton trigger efficiencies vary between 85% and 90% depending on choice of electron and muon trigger
  - Exception: isolated muon trigger with efficiency loss at L2 of ~20% due to isolation criteria

- Jet, b jet and missing energy signatures have low efficiencies but looking promising in combination with lepton trigger

- Efficiencies obtained from simulated data with 10TeV ($10^{31}cm^{-2}s^{-1}$ trigger menu) and 14TeV ($10^{34}cm^{-2}s^{-1}$ trigger menu) maintain similar efficiencies

Outlook:

- Run analysis on background samples to study the effect of combined trigger signatures (reduction of background events?)