Top trigger strategies in ATLAS

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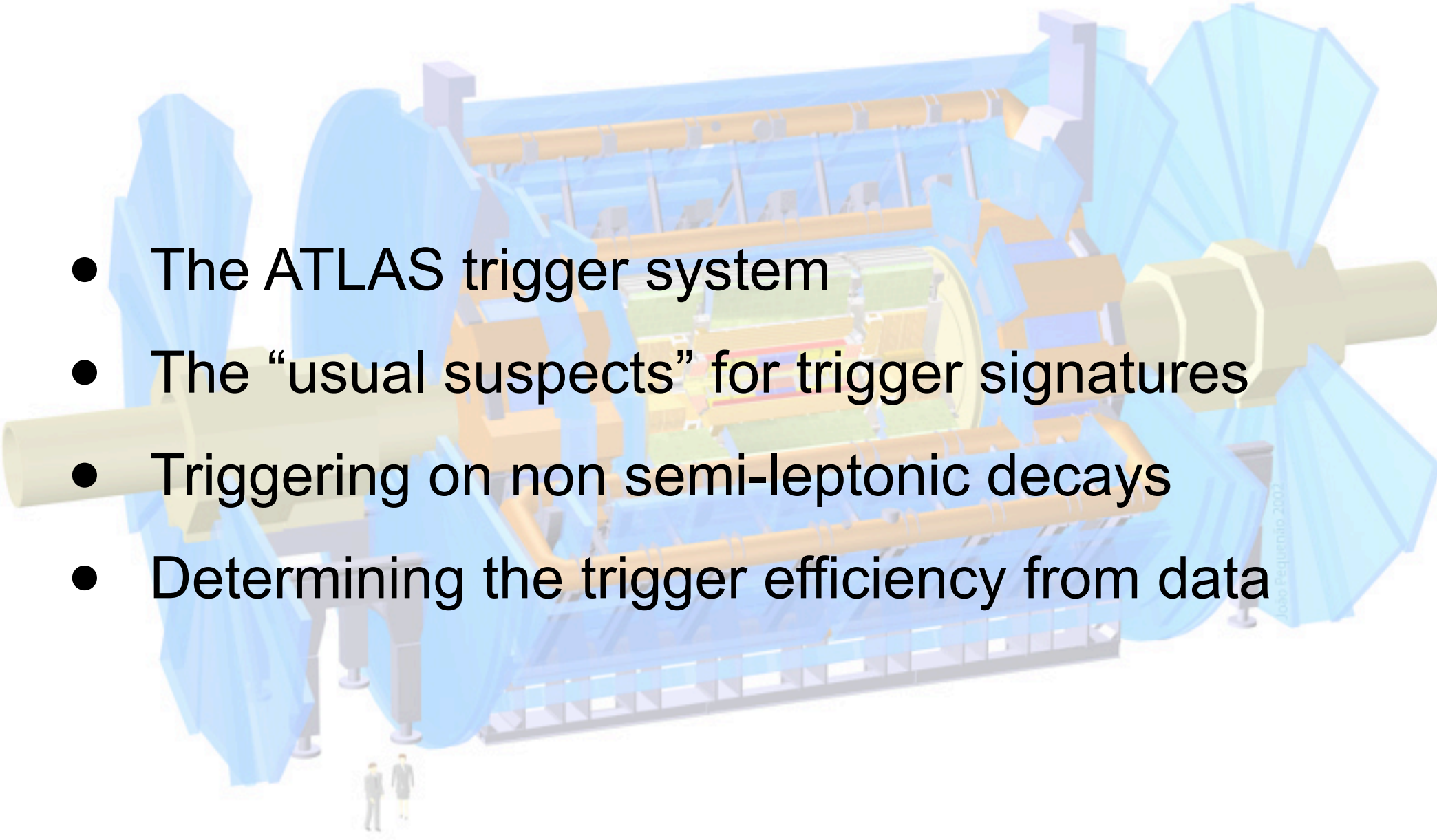
for the ATLAS top trigger WG

3rd Top Workshop @ Grenoble:
From the TeVatron to ATLAS

Overview

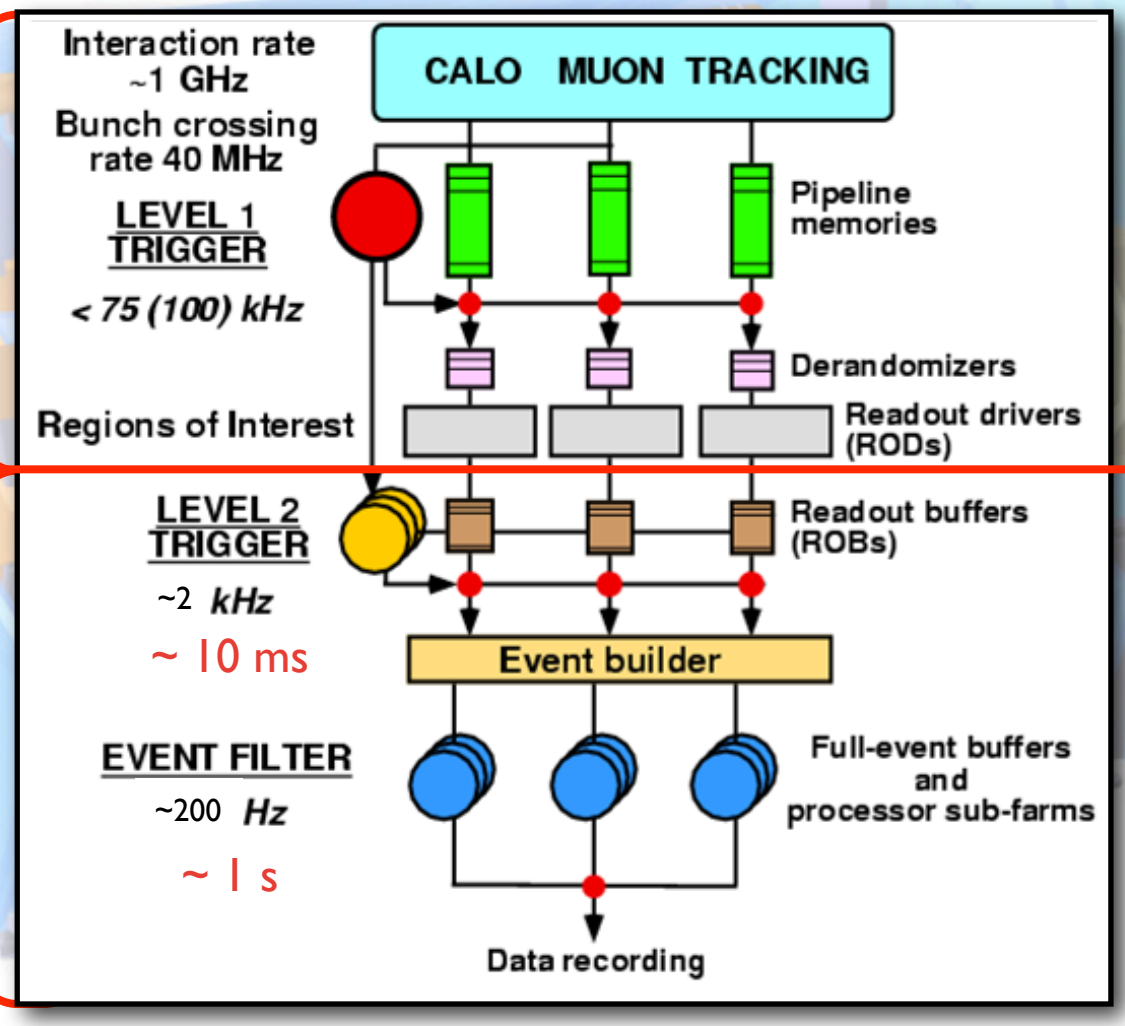


- The ATLAS trigger system
- The “usual suspects” for trigger signatures
- Triggering on non semi-leptonic decays
- Determining the trigger efficiency from data

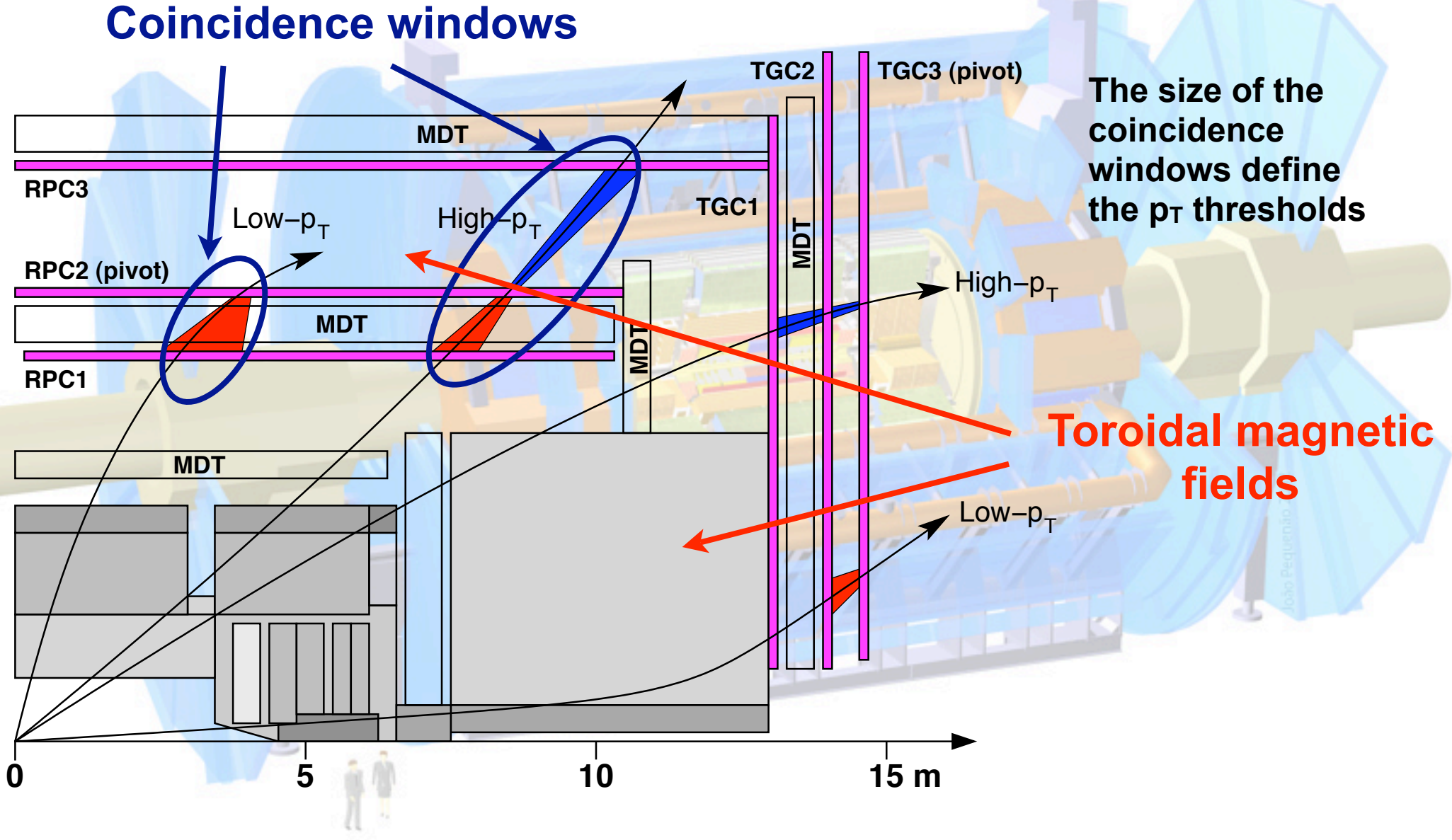
The ATLAS trigger

Hardware

Software

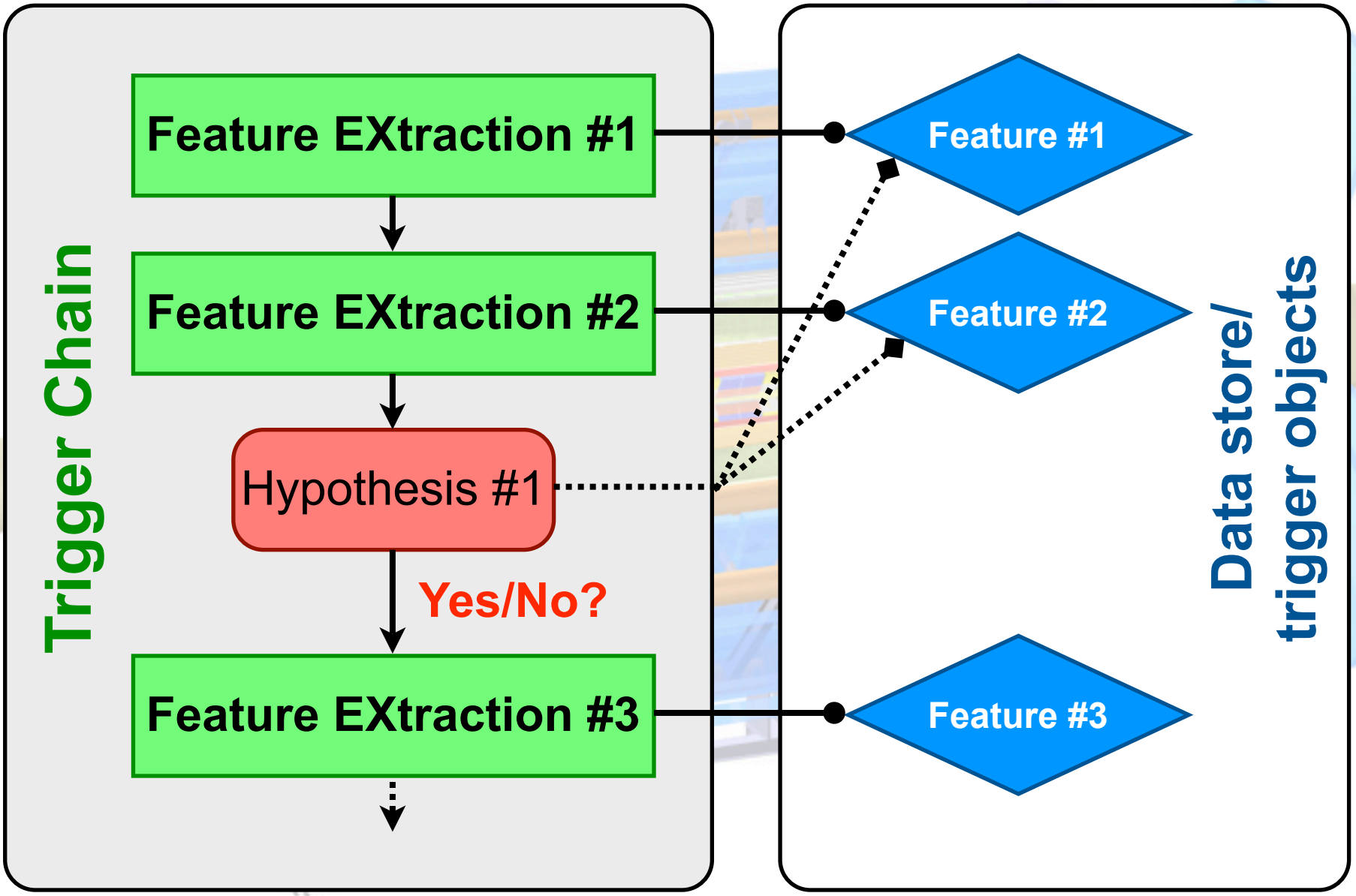


LVL1 muon trigger

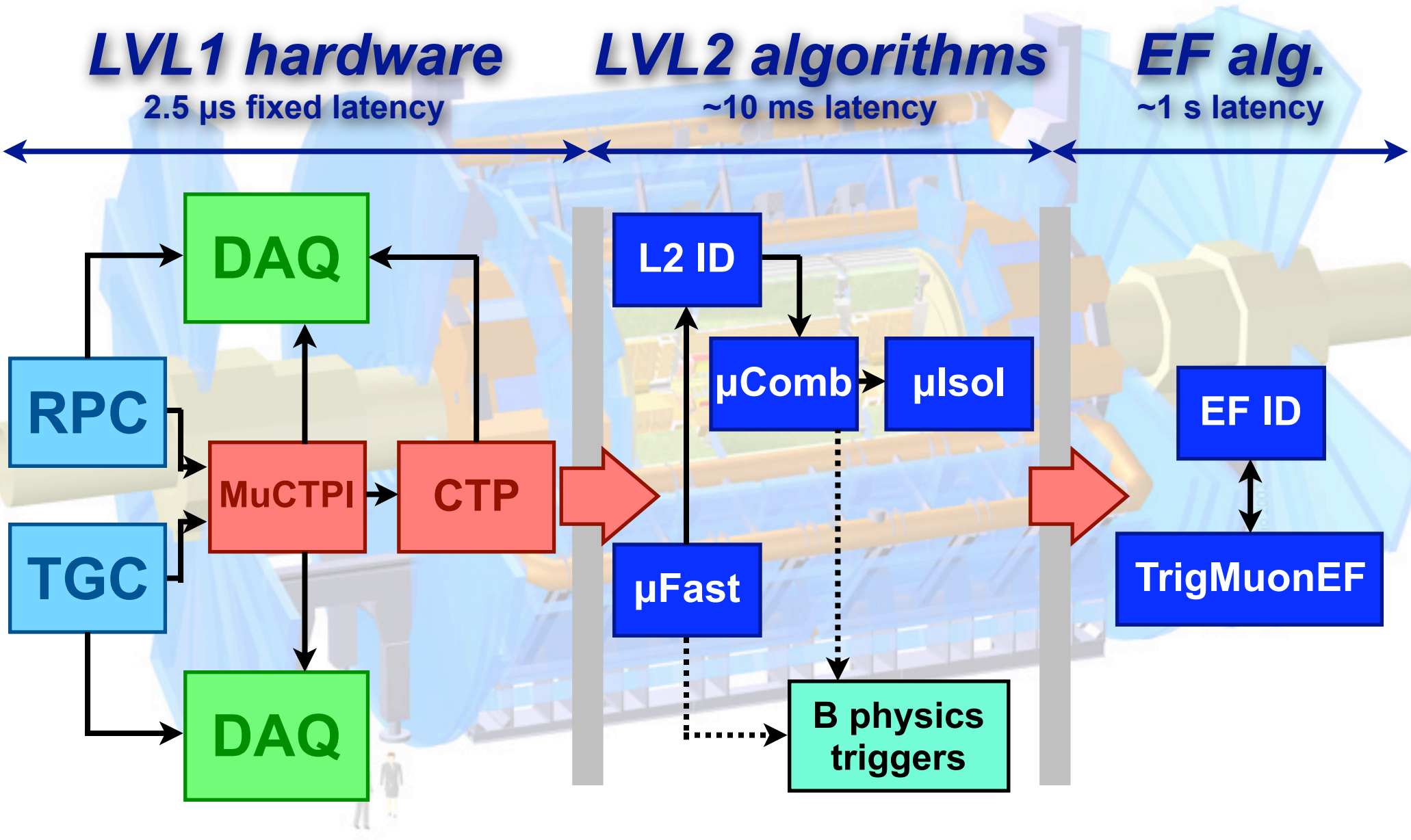


The size of the coincidence windows define the p_T thresholds

The High Level Trigger



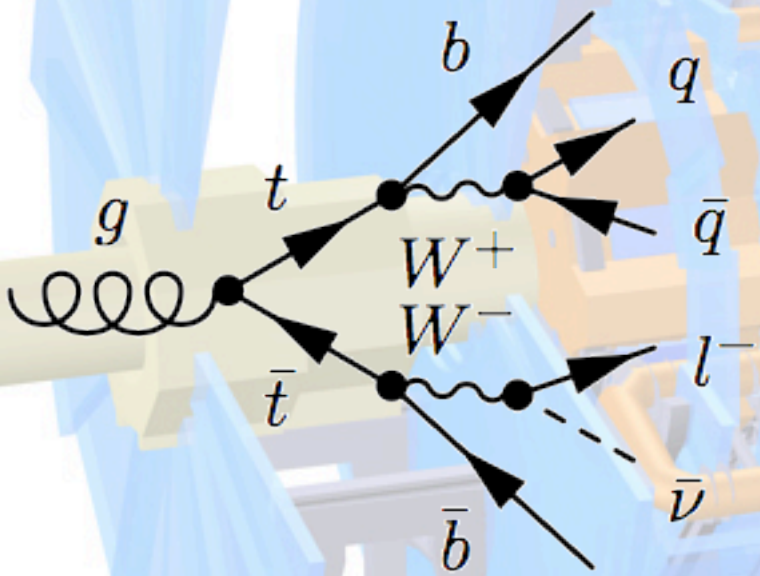
The ATLAS muon trigger



Trigger naming

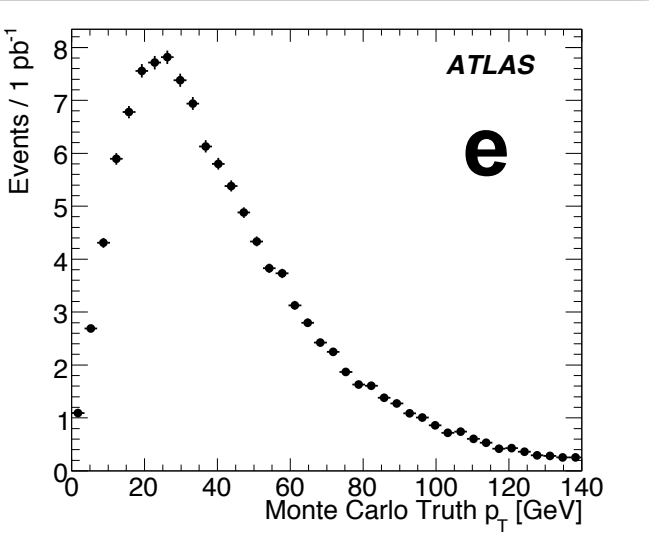
- **Trigger threshold:** Qualifies an RoI. Has a type, a p_T cut and in some cases special "extensions". For instance `EM18I` is an isolated e/m calorimeter cluster with $p_T > 18$ GeV.
- **Trigger item:** A requirement on the multiplicity of objects passing certain trigger thresholds. For instance `L1_2EM18I` is a LVL1 item requiring two objects passing `EM18I`. Complicated triggers such as `EF_4j60_2j100_j170` require 4 jets passing `j60`, 2 jets passing `j100` and one jet passing `j170`. (It can be fulfilled by a total of 4 jets!)
- **Trigger chain:** A combination of trigger items from all levels. For instance *2e18i* would be a combination of `L1_2EM18I`, `L2_2e18i` and `EF_2e18i`.
- **Trigger menu:** A list of trigger chains.

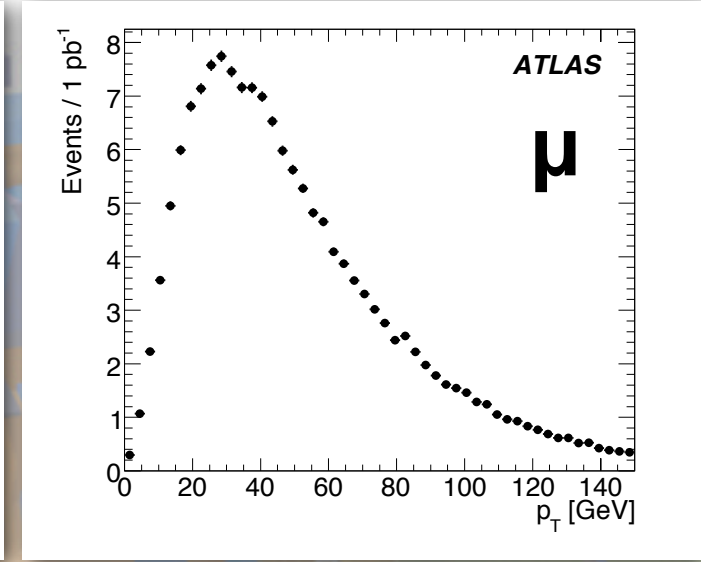
Things to trigger on

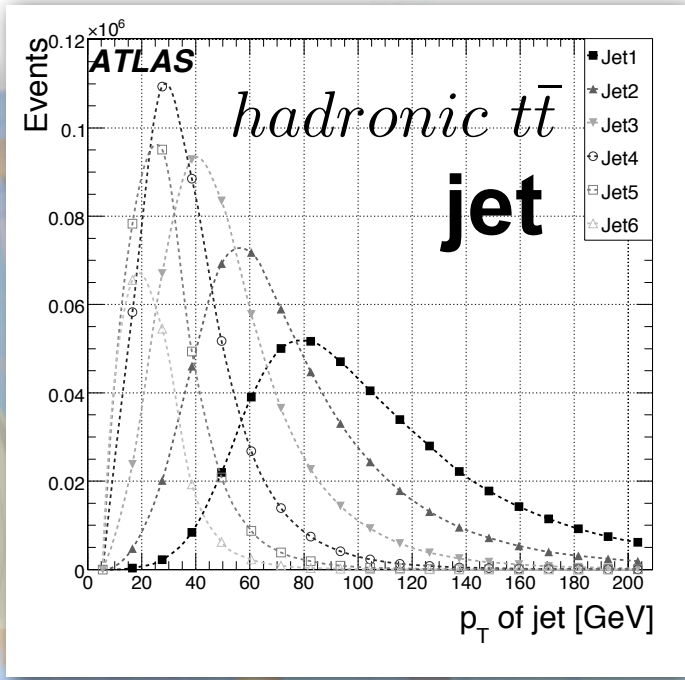


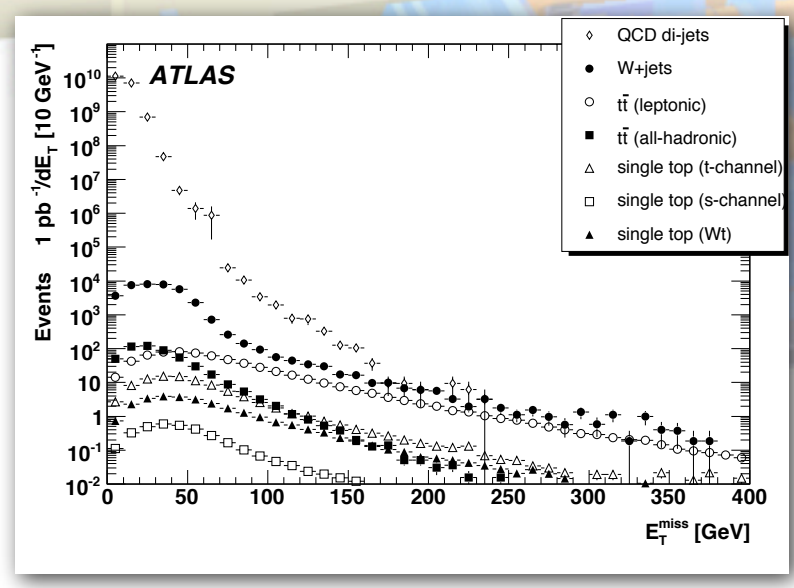
- The ttbar decay has a very “rich” final state
- Easiest to select decays with leptons
- In the semi-leptonic decay:
  - 2 light jets
  - 2 b jets
  - high-p_T lepton
  - missing-E_T
- Other channels are a bit harder to select, but still feasible

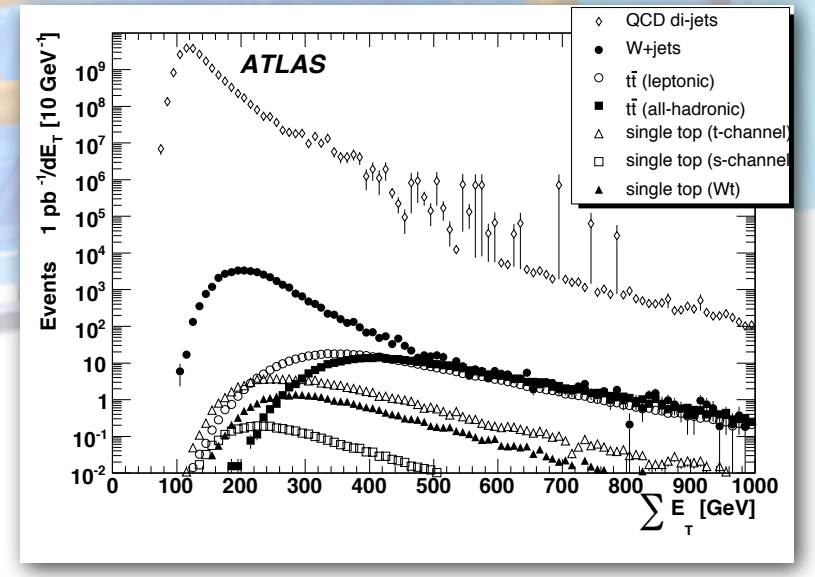
Things to trigger on





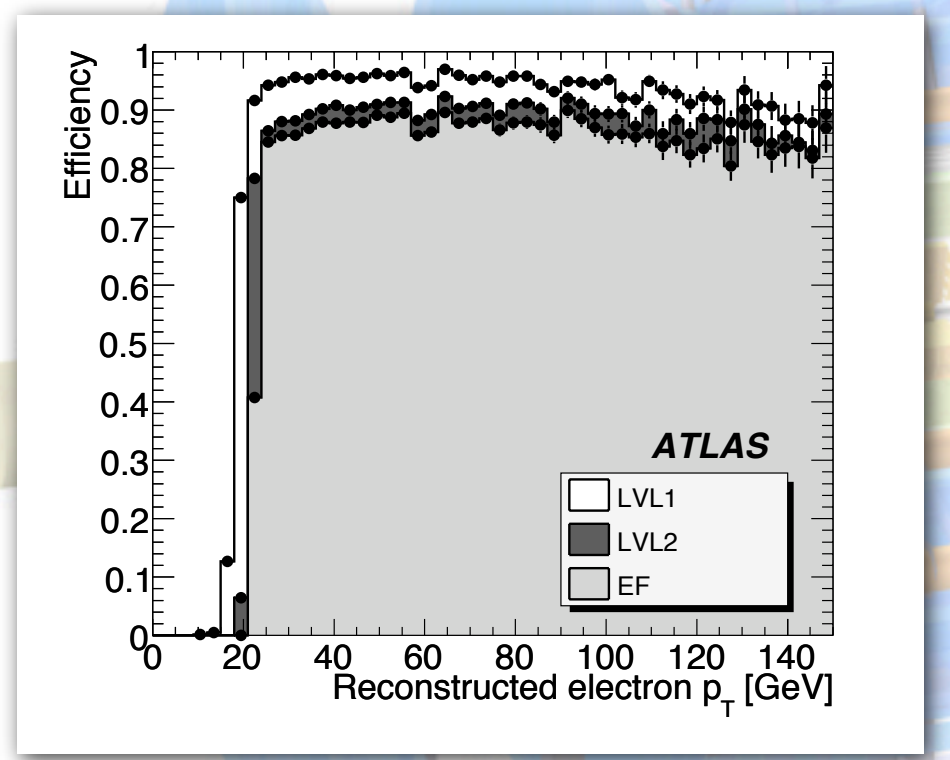






Electron triggers

Turn-on curve shown for matched reco. lepton

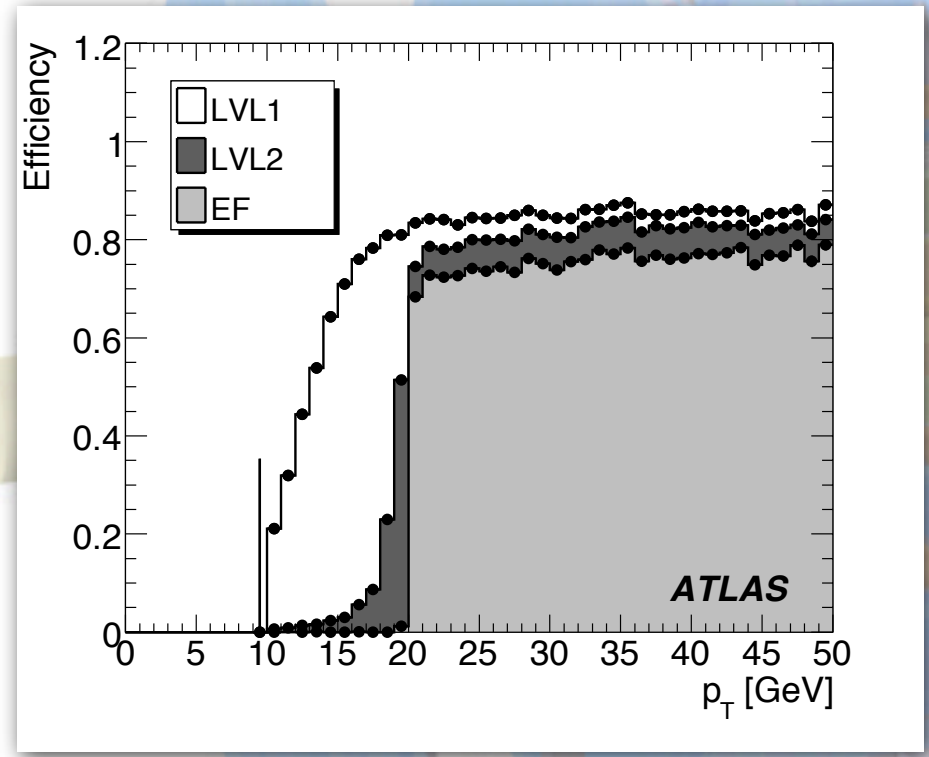


Trig. item	wrt. MC	wrt. offline*
L1_EM18I	74.7	96.0
L2_e22i	59.6	92.7
EF_e22i	52.9	89.8
L1_EM7I	83.6	98.6
L2_e12i	66.7	92.6
EF_e12i	63.5	91.8

***Offline requirements:** reconstructed isolated electron with p_T > 20 GeV, miss-E_T > 20 GeV, 3 reco. jets with p_T > 40 GeV, 4 reco. jets with p_T > 20 GeV

Muon triggers

Turn-on curve shown for matched reco. lepton

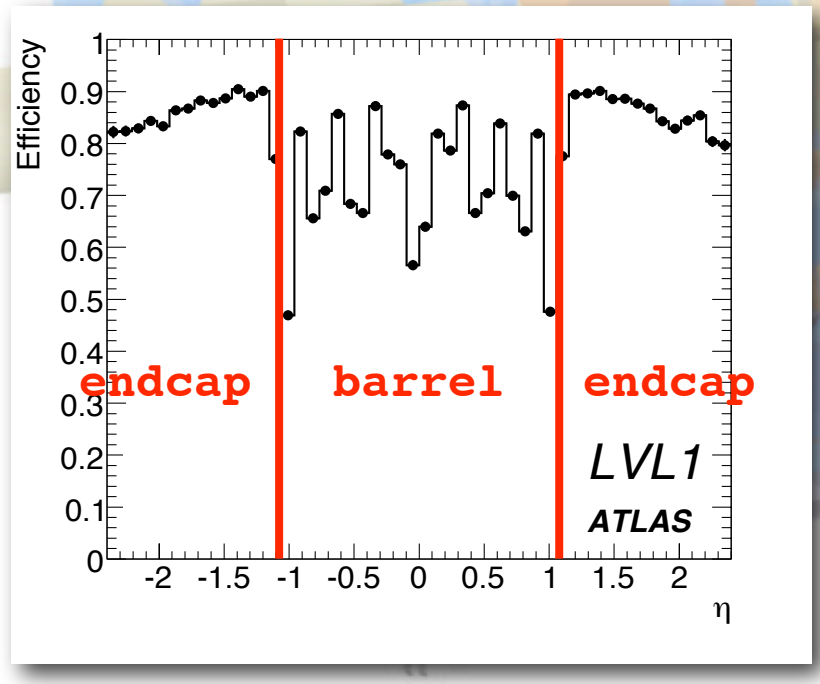


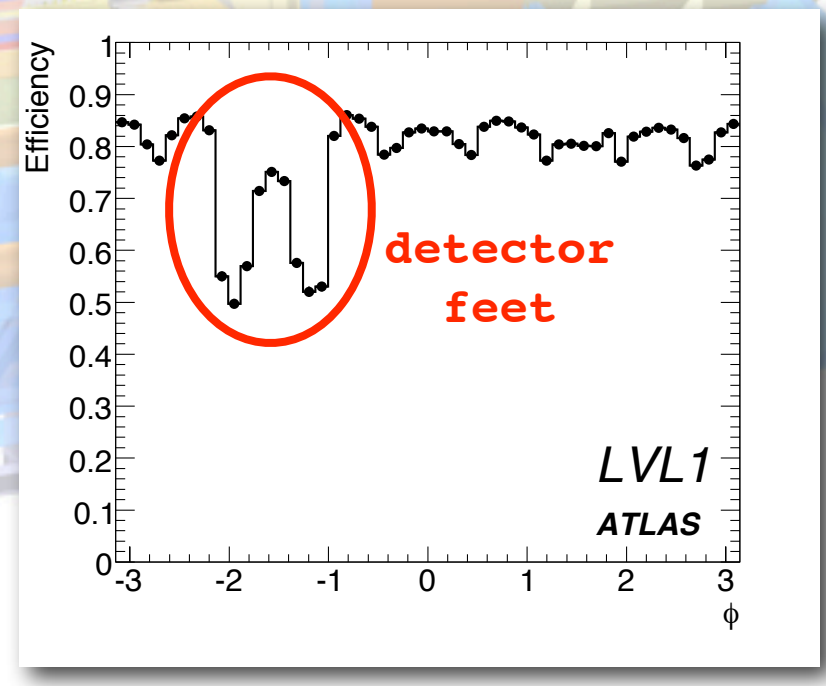
Trig. item	wrt. MC	wrt. offline*
L1_MU06	83.8	91.9
L2_mu6	80.2	88.7
EF_mu6	73.1	83.1
L1_MU20	74.6	86.4
L2_mu20	66.3	82.3
EF_mu20	58.8	76.6

***Offline requirements:** reconstructed isolated muon with p_T > 20 GeV, miss-E_T > 20 GeV, 3 reco. jets with p_T > 40 GeV, 4 reco. jets with p_T > 20 GeV

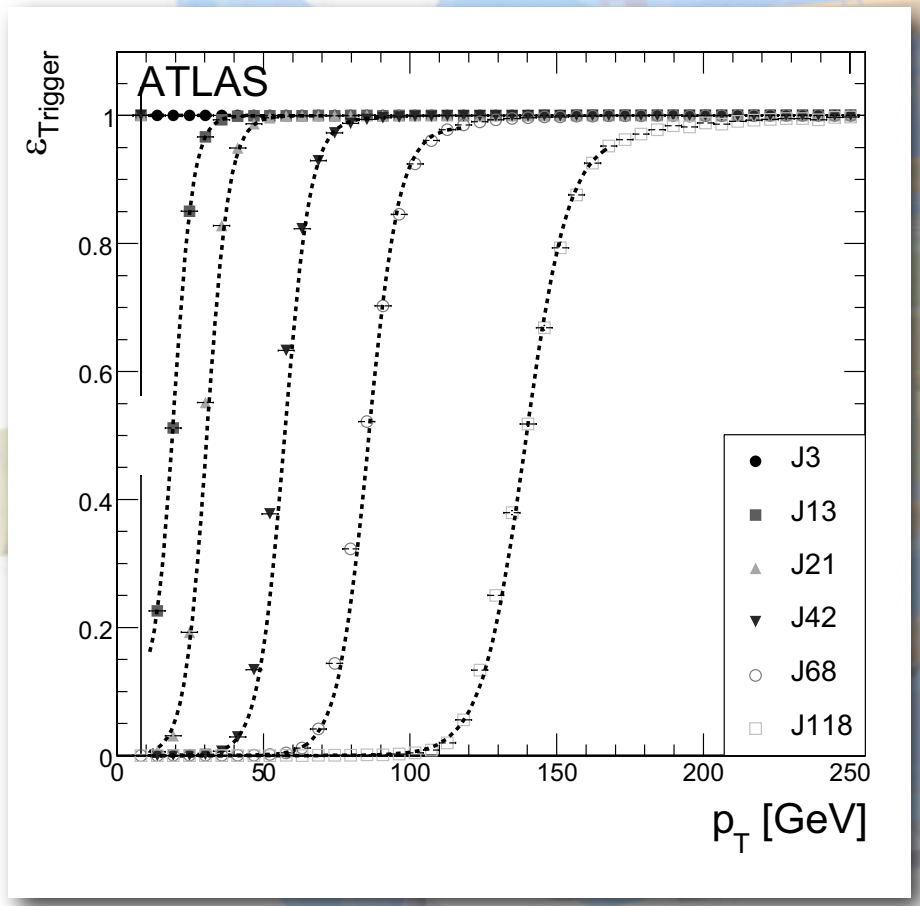
Muon triggers

- The trigger efficiency (especially for muons) is usually direction dependent
- Analyses using angular distributions have to correct for this!





Jet triggers



Proc.	EF_j160		EF_4j50	
	Eff. [%]	Rate [Hz]	Eff. [%]	Rate [Hz]
$t\bar{t}_{lep}$	11.2	$5.1*10^{-4}$	9.9	$4.5*10^{-4}$
$t\bar{t}_{had}$	12.9	$4.8*10^{-4}$	21.0	$7.7*10^{-4}$
QCD	-	1.3	-	$5.5*10^{-1}$
W+jet	-	$4.9*10^{-4}$	-	$1.0*10^{-4}$

Efficiencies are total MC event selection efficiencies

Fully hadronic top triggers

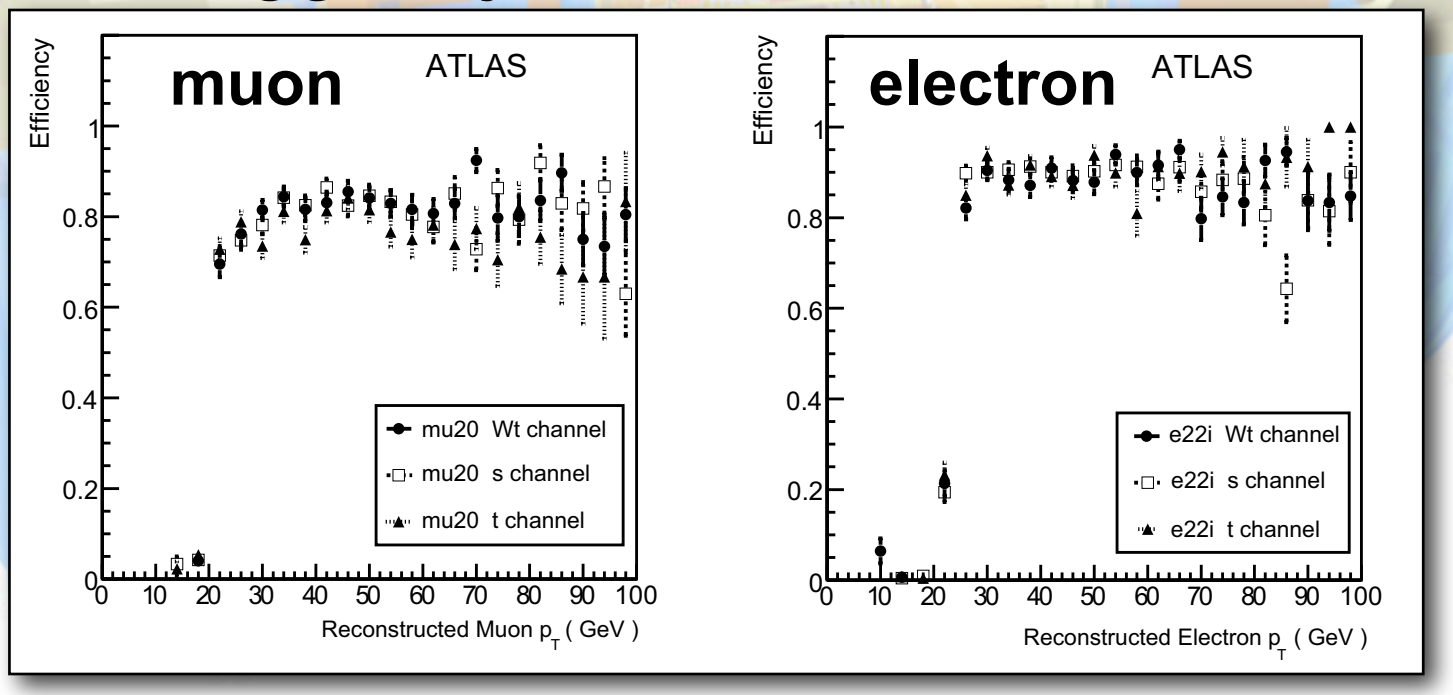
- Many problems with selecting these events:
  - No high energy lepton, no missing energy
  - Very similar to QCD background
- First studies for selecting them suggest (at $L = 10^{31}\ cm^{-2}s^{-1}$):

Trigger	Sig. Eff. [%]	Bkg. Rate [Hz]	S/B
`EF_4j60_2j100_j170*`	6	0.07	$2.8*10^{-3}$
`EF_5j45_2j60_j100*`	16	0.19	$3.0*10^{-3}$
`EF_6j35_5j45_4j50_3j60*`	10	0.10	$3.7*10^{-3}$

***Reminder:** These items require a total of 4, 5 and 6 jets respectively.

Single-top triggers

- Final state:
  - high-p_T lepton (W decay)
  - missing-E_T
  - 1-3 jets
- Lepton triggers just as suitable as for ttbar



Single top efficiencies

Total MC trigger efficiencies for the W->μν and W->eν decay channels separately

Sample	Muon channel		Electron channel	
	Trigger	Efficiency [%]	Trigger	Efficiency [%]
Wt	mu06	88.4	e22i	87.1
	mu20	82.5	e22i or e55	90.6
s	mu06	88.0	e22i	89.2
	mu20	82.6	e22i or e55	90.7
t	mu06	86.0	e22i	89.5
	mu20	79.6	e22i or e55	90.6

Redundant triggering

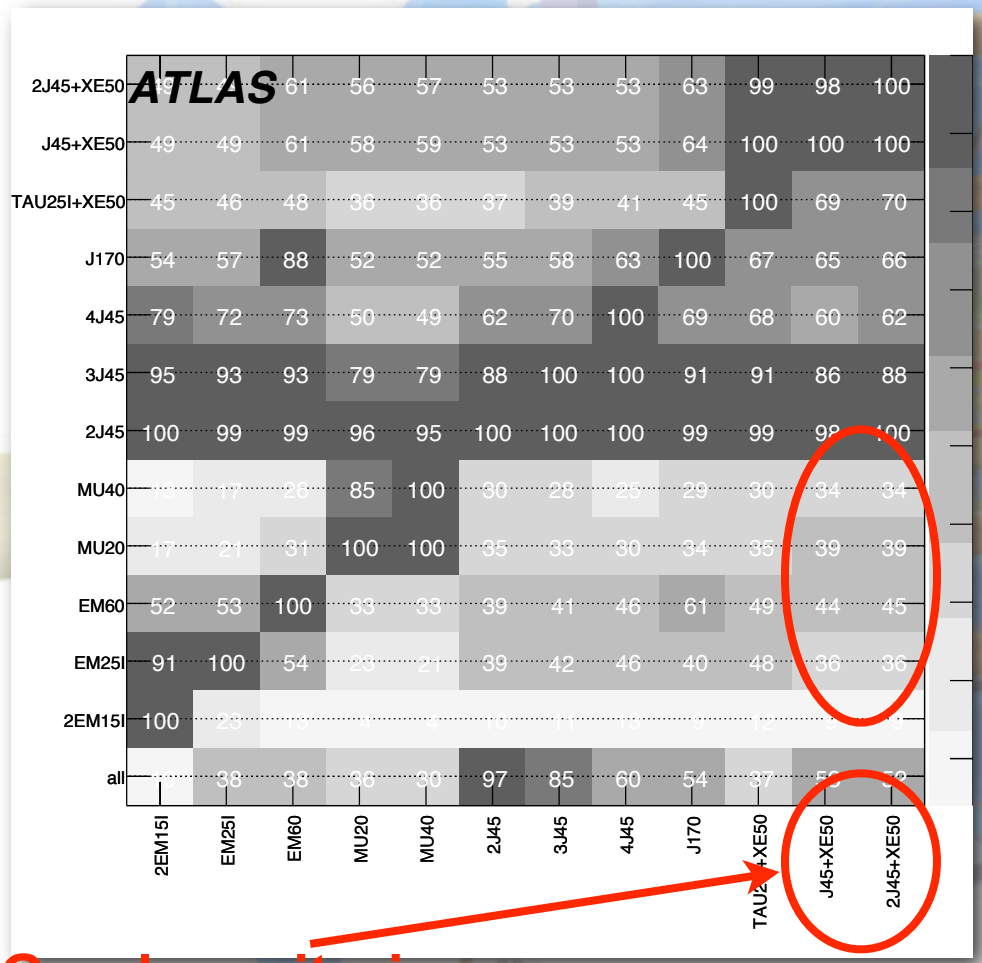
- Requirements for a top trigger:
  - High efficiency
  - Low total (i.e. background) trigger rate
  - ***Efficiency can be calculated from data***
- How to calculate efficiency from data?
  - Select top signal using trigger “A” and calculate the efficiency of (orthogonal) trigger “B” using the sample (biases?)
  - Single-jet efficiencies from minimum-bias sample
  - High threshold efficiencies wrt. lower threshold
  - ***Use multi-object final states (“tag and probe”)***

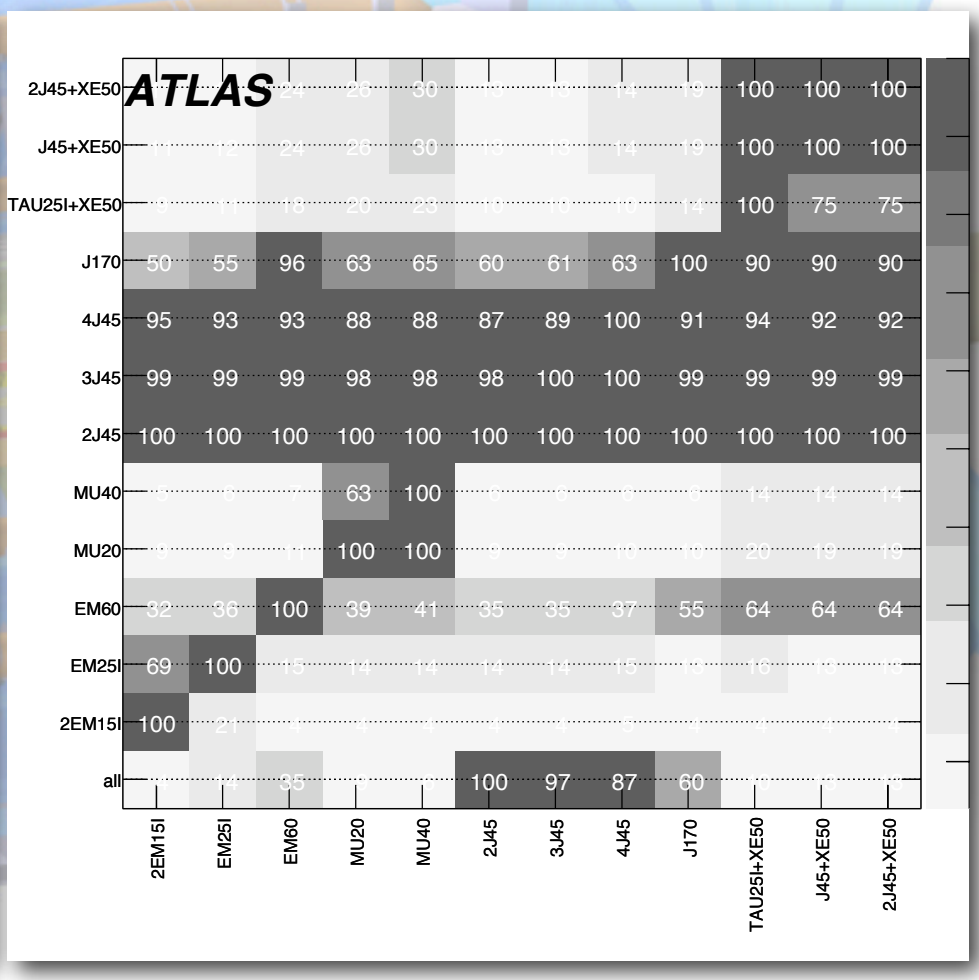
Trigger overlaps

Semi-leptonic decay

Fully hadronic decay

"Secondary" trigger

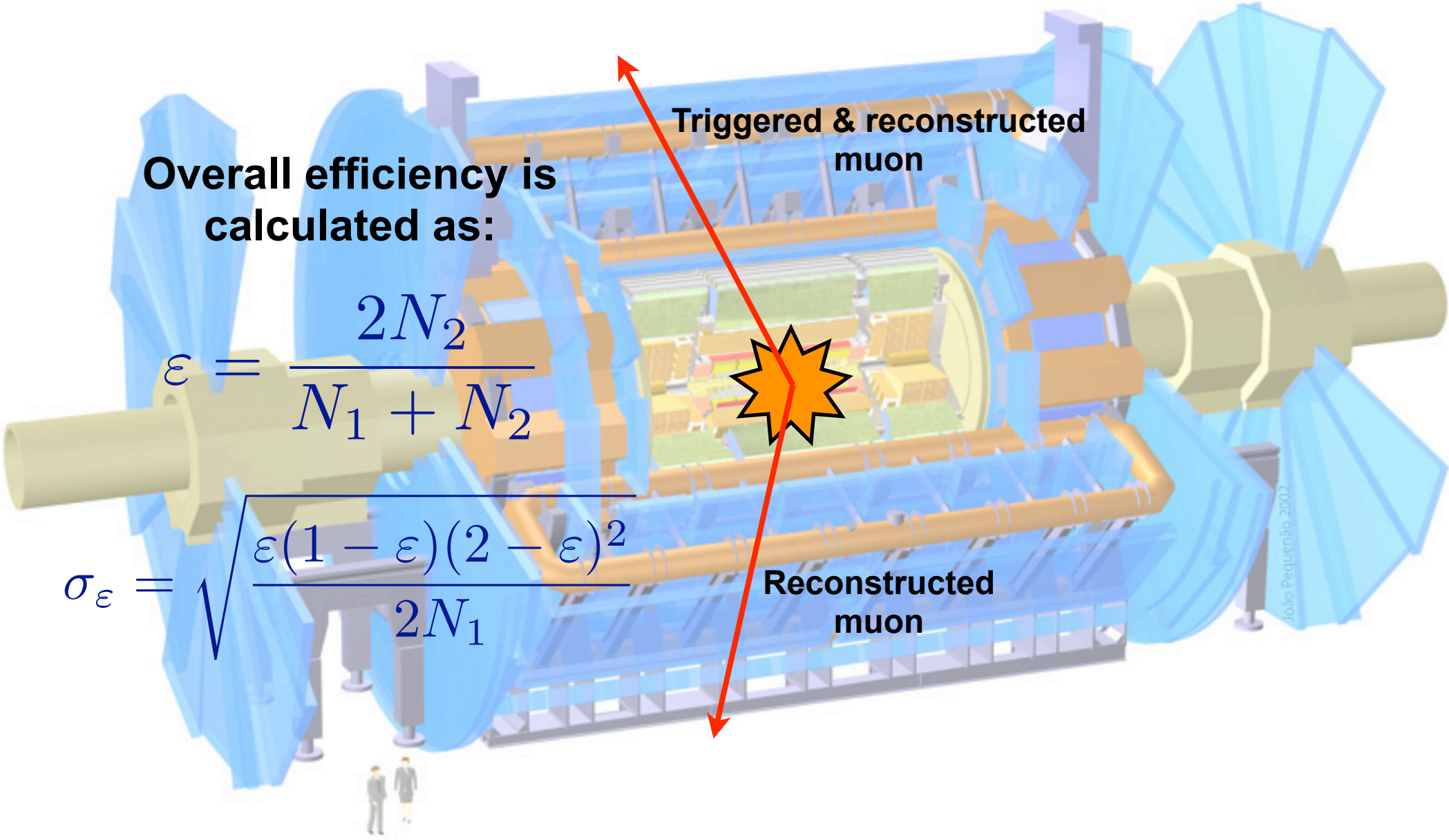




Good monitoring trigger candidates

"Primary" trigger

“Tag and probe” method



Overall efficiency is calculated as:

$$\varepsilon = \frac{2N_2}{N_1 + N_2}$$

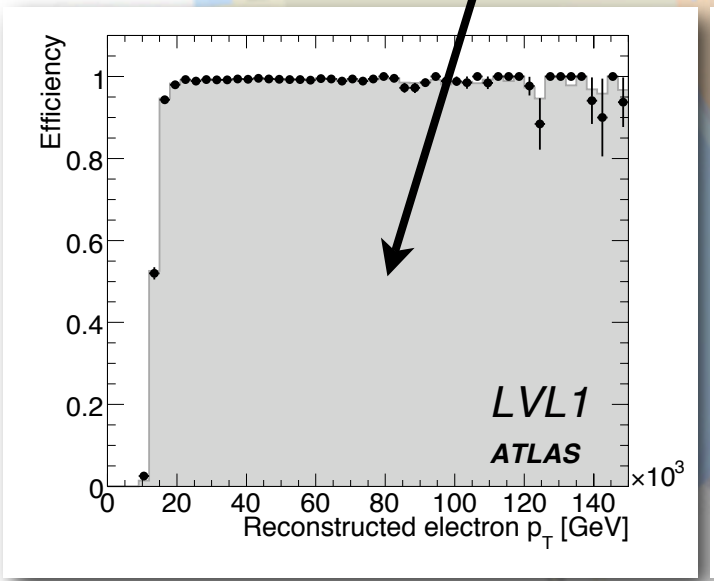
$$\sigma_\varepsilon = \sqrt{\frac{\varepsilon(1-\varepsilon)(2-\varepsilon)^2}{2N_1}}$$

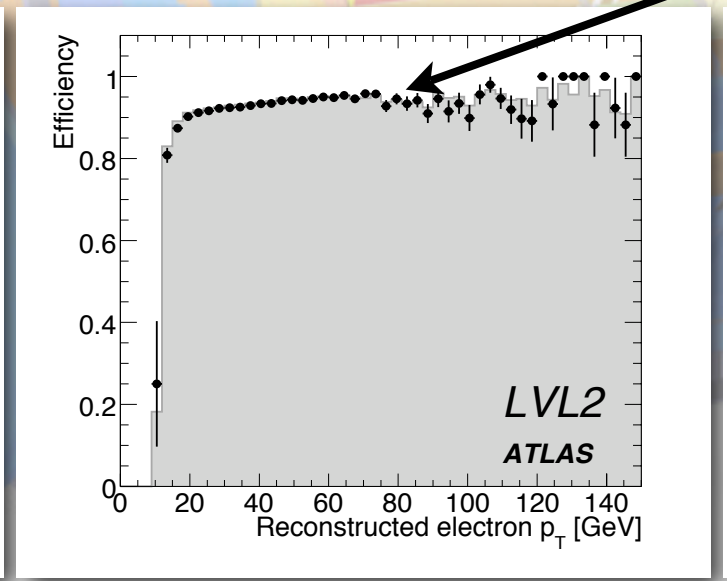
Efficiency from Z->ee

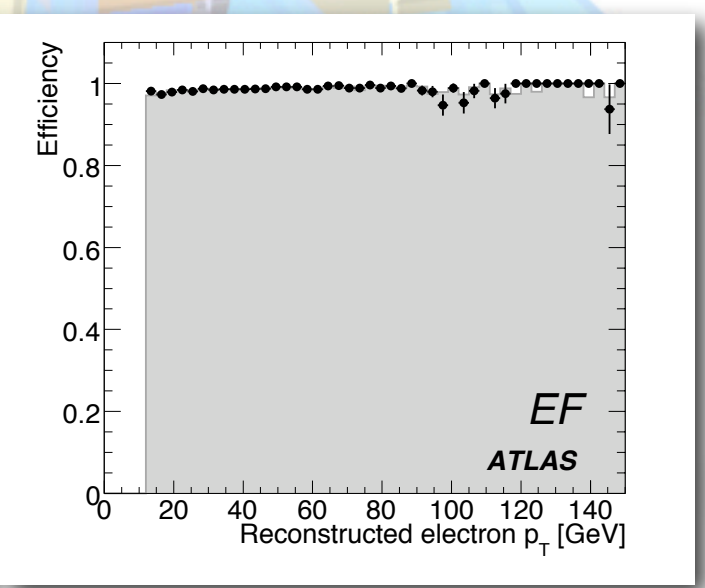
- Select clean Z->ee sample using a single-electron trigger
- Tag the triggered electron, probe the other one.

Calculated with MC info

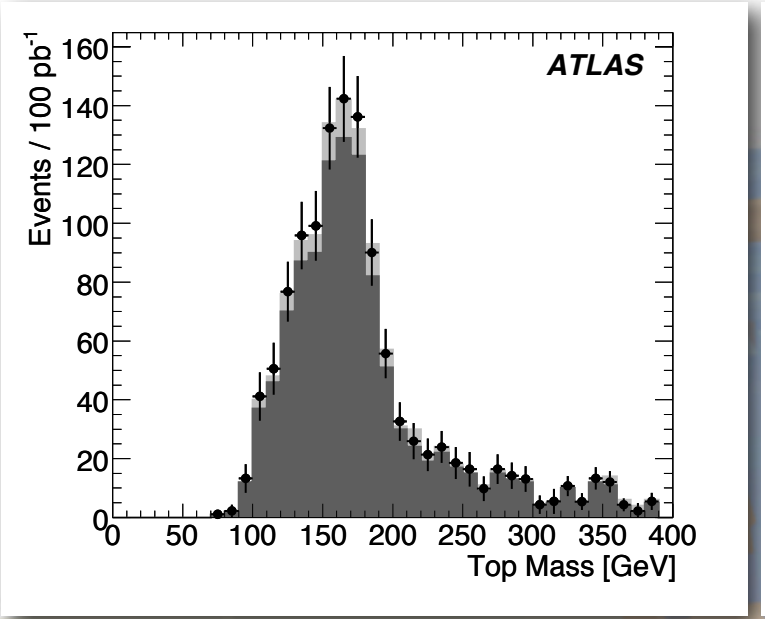
Calculated with tag & probe

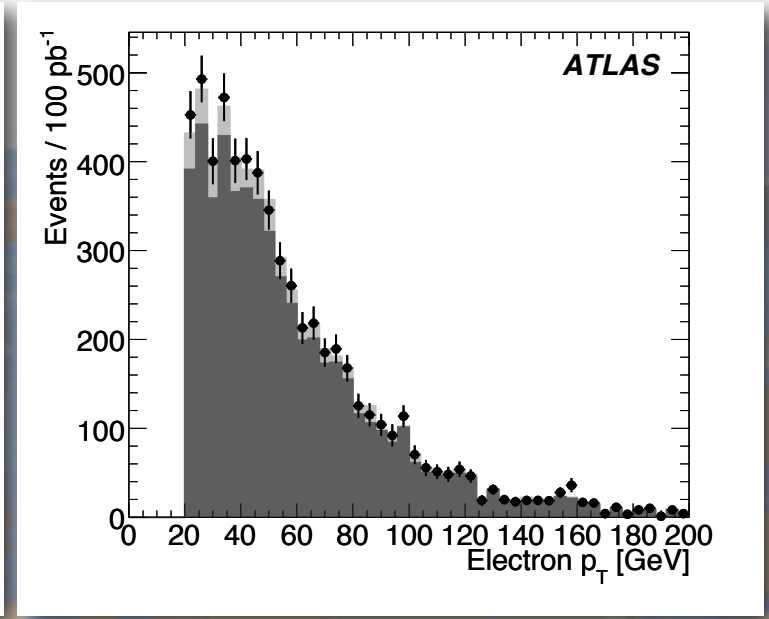


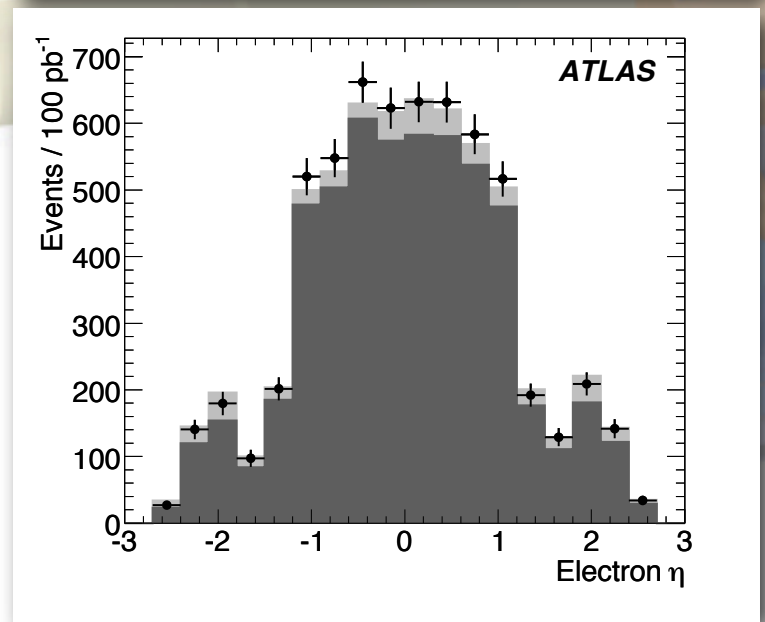


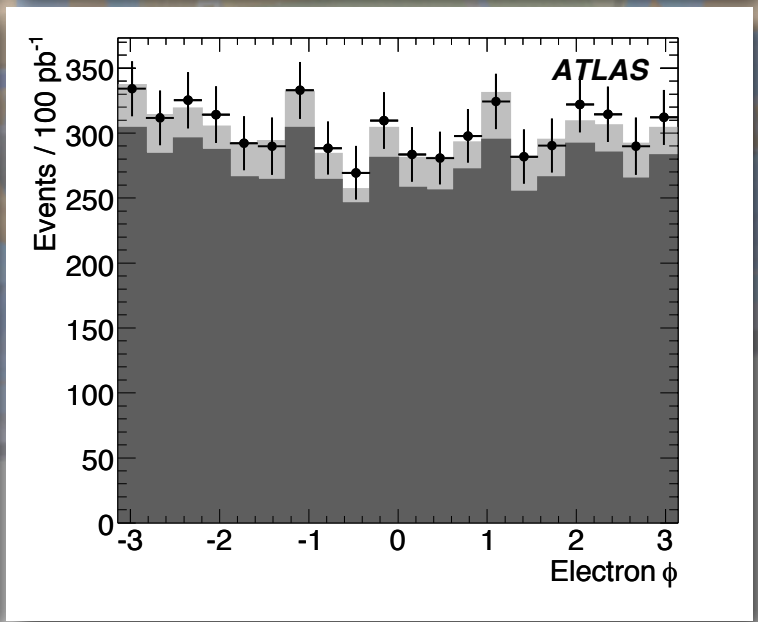


Using the efficiencies





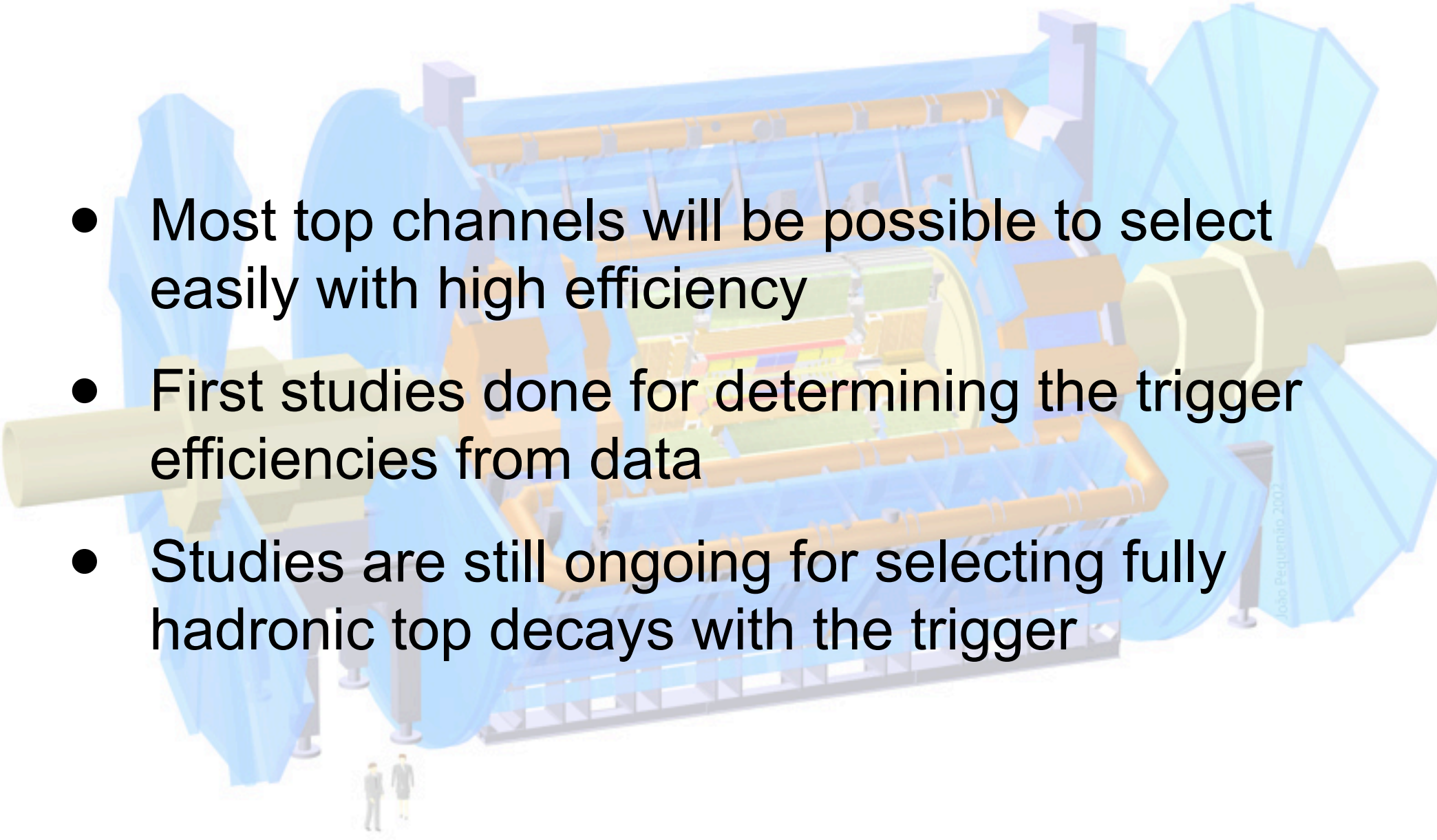




- **points:** trig. corr. reco.
- **dark hist.:** reco. w/o trig. corr
- **light hist.:** reco. w/o trig. selection

Effects of backgrounds not studied here.

Summary



- Most top channels will be possible to select easily with high efficiency
- First studies done for determining the trigger efficiencies from data
- Studies are still ongoing for selecting fully hadronic top decays with the trigger