Trigger and data acquisition at FCC-hh

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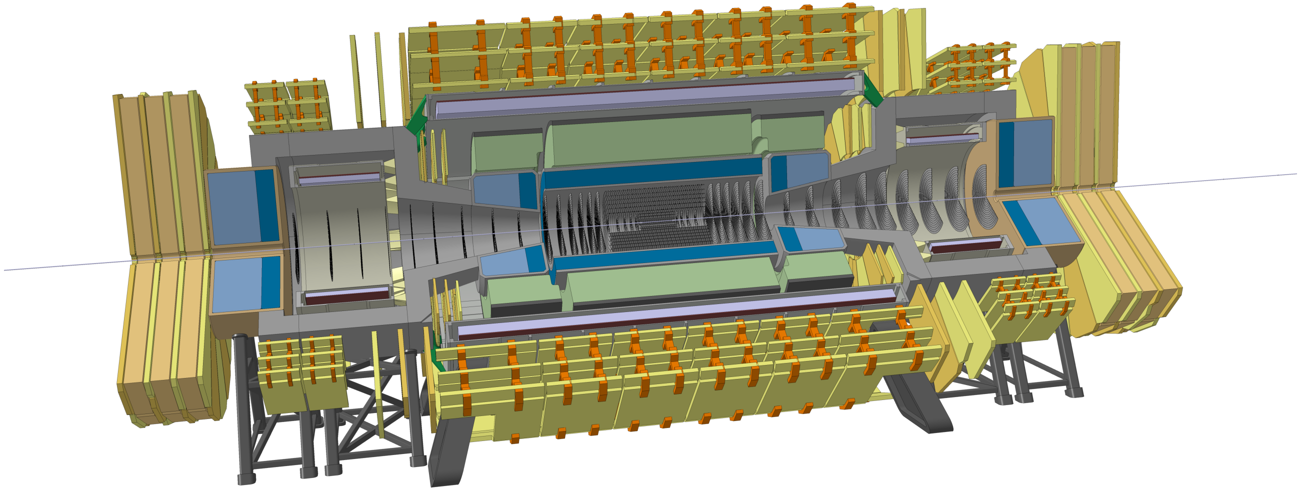
Data rates at FCC-hh



- Detector data rate ~ 1-2 PB/s
  - Tracker: ~800 TB/s [1]
  - LAr + Tile calo: ~200 TB/s [2]
  - Si/W calo: ~1000 TB/s[3] *(needs further studies)*

For more info:
1 – Zbynek Drasal & Estel Perez Codina
2 – Anna Zaborowska & Coralie Neubuser
3 – Tony Price

Readout options

- Continuous readout:
  - Full detector is read at the bunch crossing frequency
  - Full data set is used to select events
- Triggered readout:
  - A subset of detector data is transferred to a trigger system
  - First selection of the events performed with this data before proceeding to the full readout
- More complex system:
  - Multi-stage trigger, regional readout

Which option?

- There are many options we can choose:
  - We need studies to understand what is the most suited architecture
- Reading the full detector at full bunch crossing rate looks challenging even in 20 years time
  - Forwarding 1 PB/s data rate in a event builder network
  - Mainly driven by the innermost tracking layer
- We focussed on a triggered readout!
  - A la ATLAS & CMS
- Do we need to include a track trigger?
  - Drastically increases data rate, costs, and trigger complexity
  - Gives better resolution (especially in the muon sector), pile-up rejection and more powerful algorithms

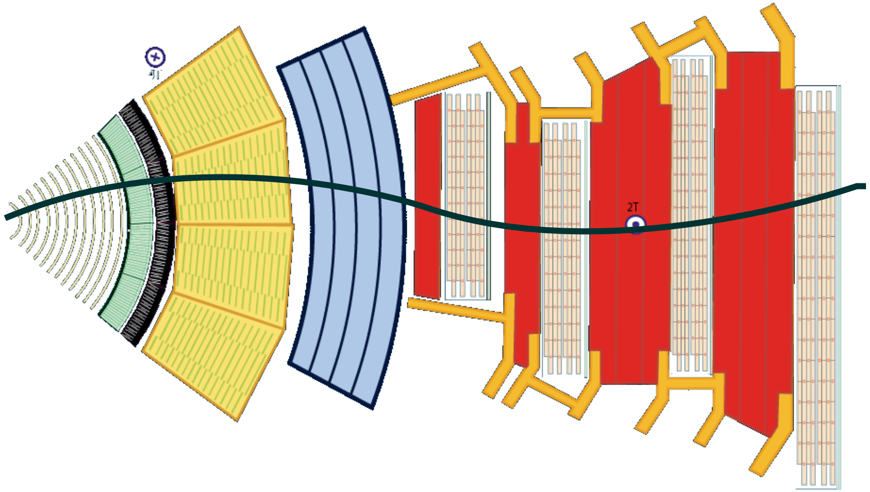
Simulating the current CMS L1T trigger

- We tried extrapolating the CMS Phase-1 L1T performance at FCC-hh
  - No tracker!
- Goal: obtain rates for jet, muon and egamma (electron+photon) triggers at FCC-hh based on the CMS trigger performance
- We developed a parametrised simulation of the CMS Phase-1 L1T
  - Parameters are taken from CMS full-simulations
- For each object type, we computed the rate from main contributions
- Results have been cross-checked with CMS full-simulations at 14 TeV and PU 140
- We run the simulation at 100 TeV, after updating the detector acceptance to the FCC-hh baseline detector

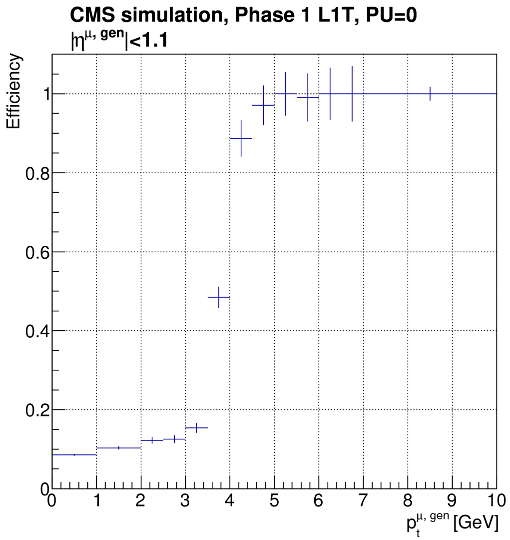
What are the main contributions to the muon trigger rate?

1. Muons from prompt quark decays (b and c)

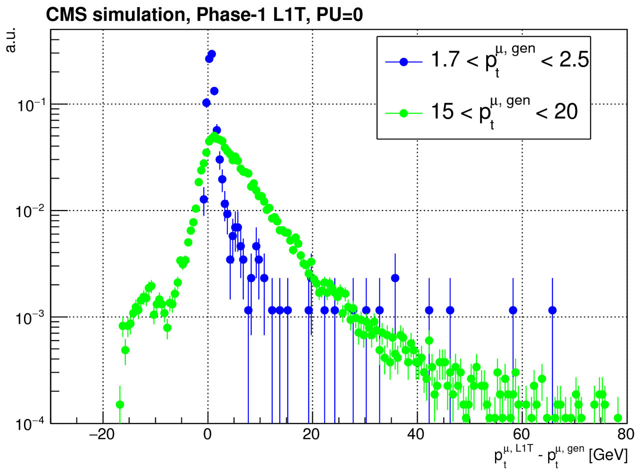
- We apply the CMS muon trigger efficiency and resolution to generator-level muons



Efficiency in barrel

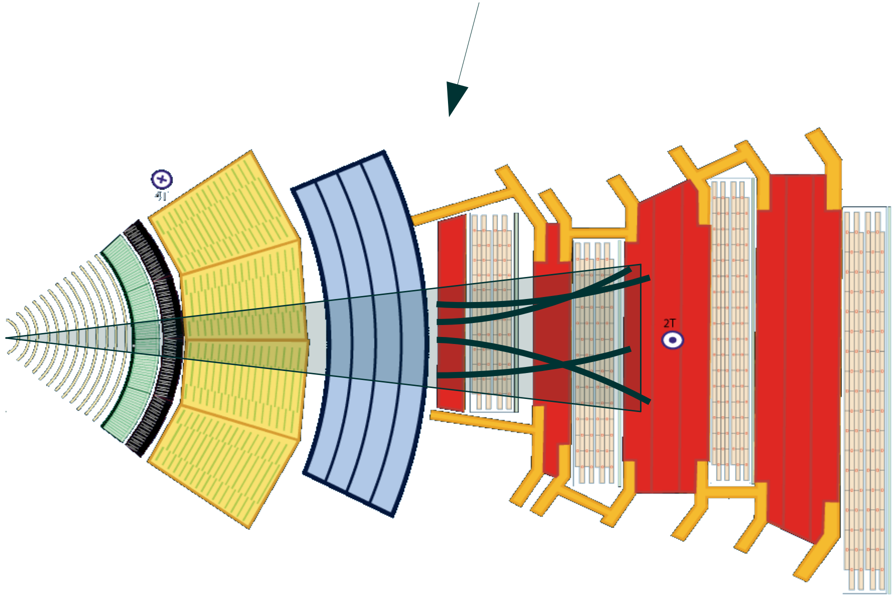


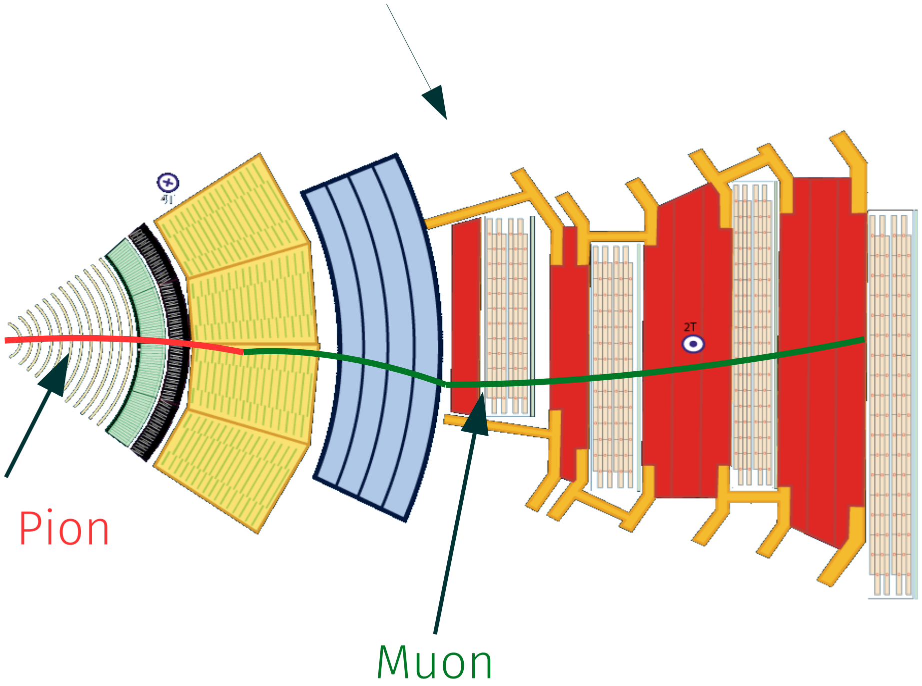
Resolution



What are the main contributions to the muon trigger rate?

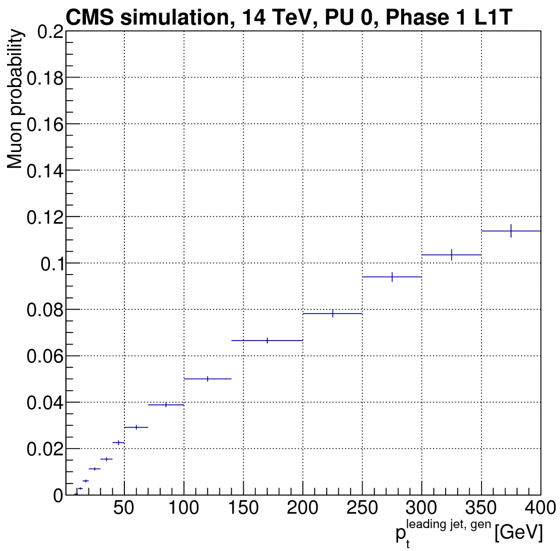
2. & 3. Jet punch-through and non prompt in-flight decay of particles



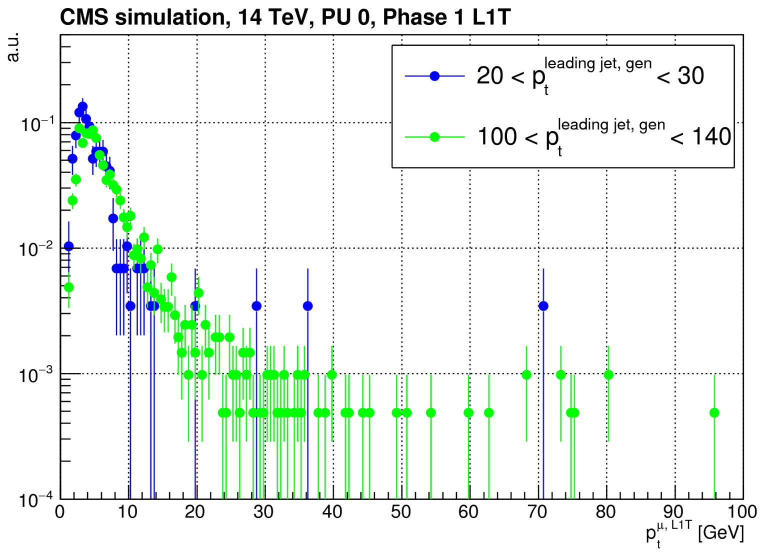


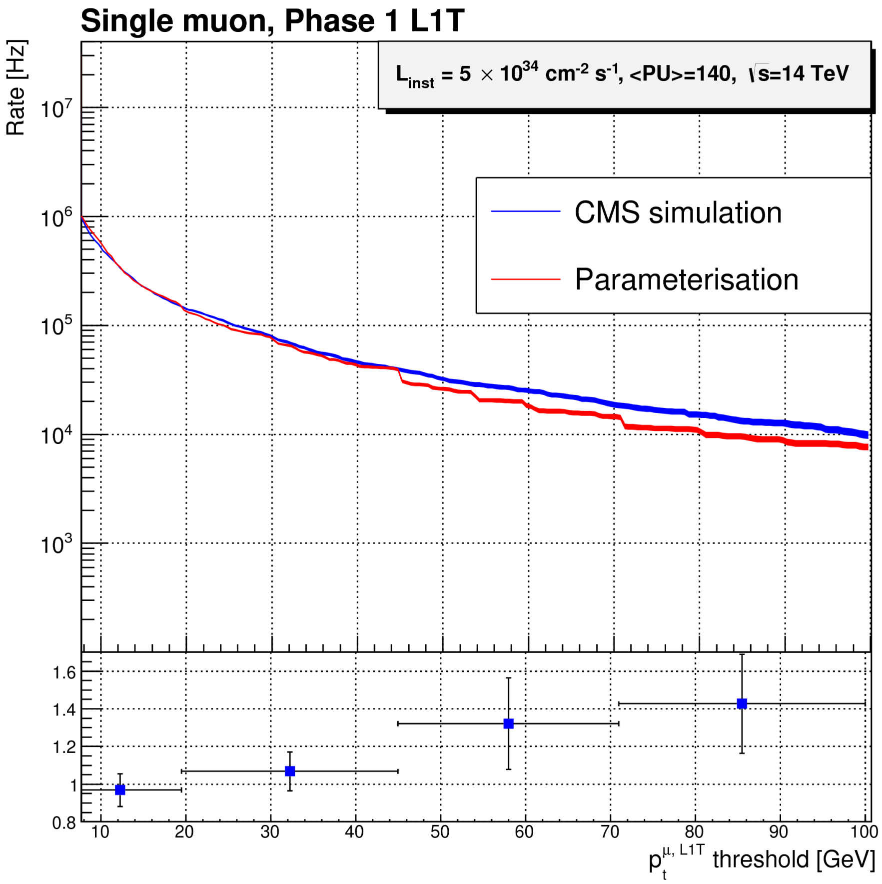
- We model the two processes together
- We compute the l1t-muon probability and pt p.d.f. for pp interactions with no generator-level muon
  - If there is no generator-level muon, the trigger muon has to come from one of these two processes
- We reapply these two parameters in our simulation

Muon probability



Muon pt p.d.f.

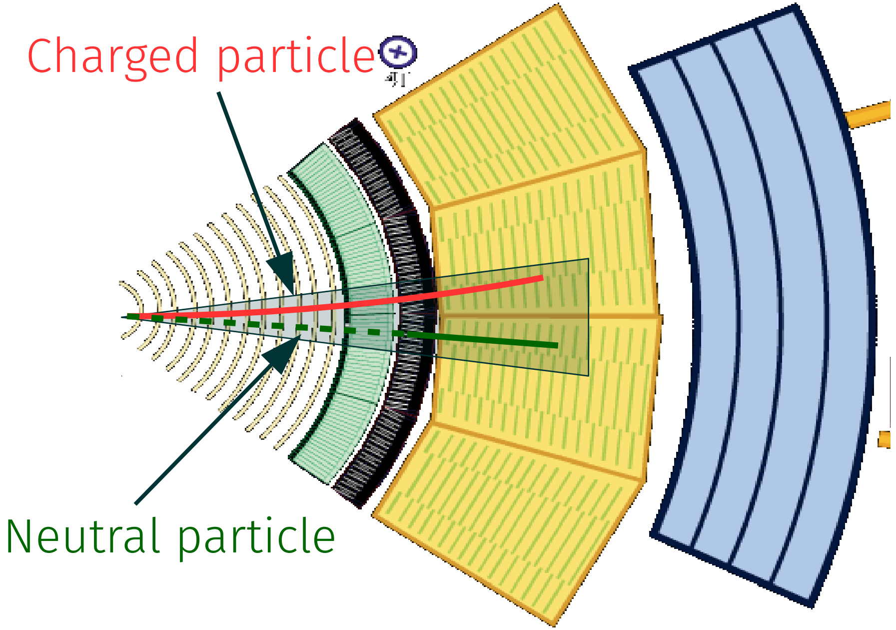




- Inst. luminosity = 5 × 10^{34} cm^{-2} s^{-1} (PU ~ 140)
- 50% of the rate comes from prompt muons, 50% from PT and DIF
- Rate flattening due to pt resolution
  - Standalone muon chamber
- Drops in rate under investigation
- Ratio plot is used to derive scale factors and systematics for the 100 TeV extrapolation

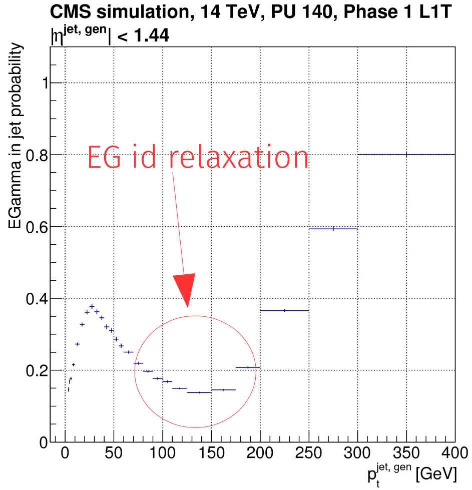
What are the main contributions to the electron and photon trigger rate?

Charged and neutral particles from hadronic jets

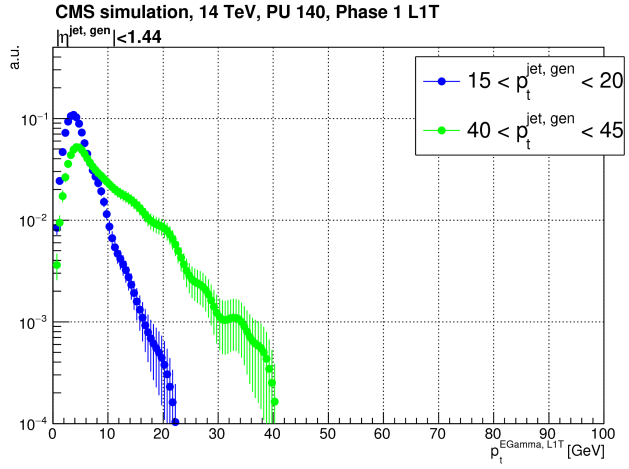


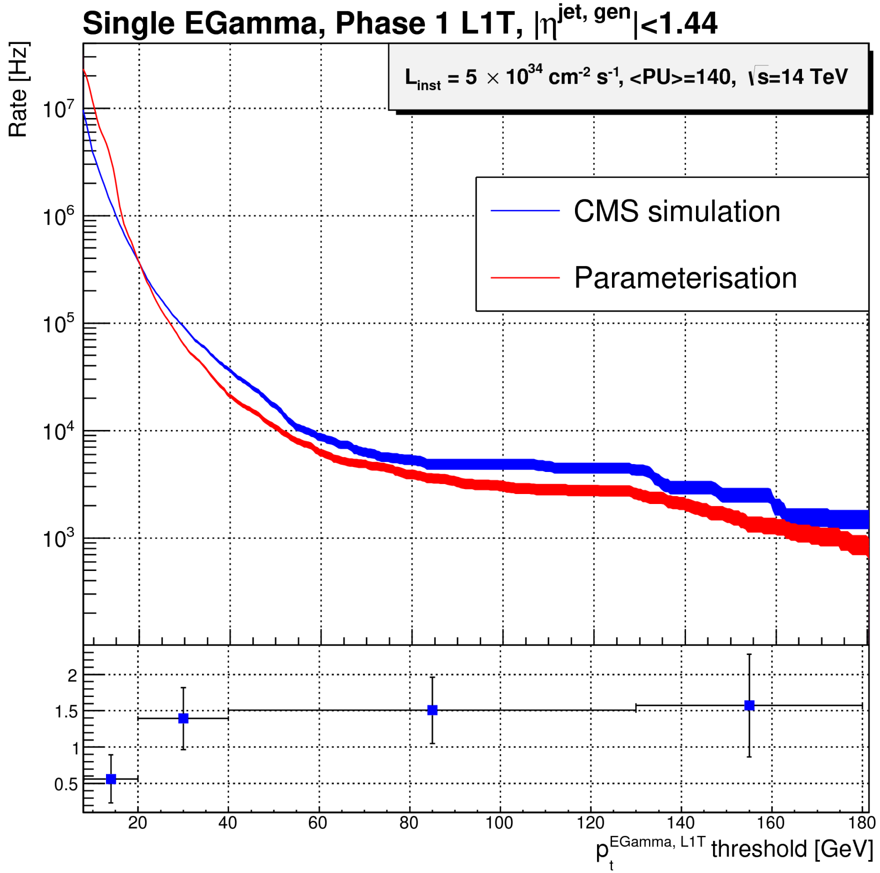
- We apply the CMS egamma trigger probability and pt p.d.f. to generator-level jets
  - Barrel performance only

EGamma in jet probability



EGamma pt p.d.f.



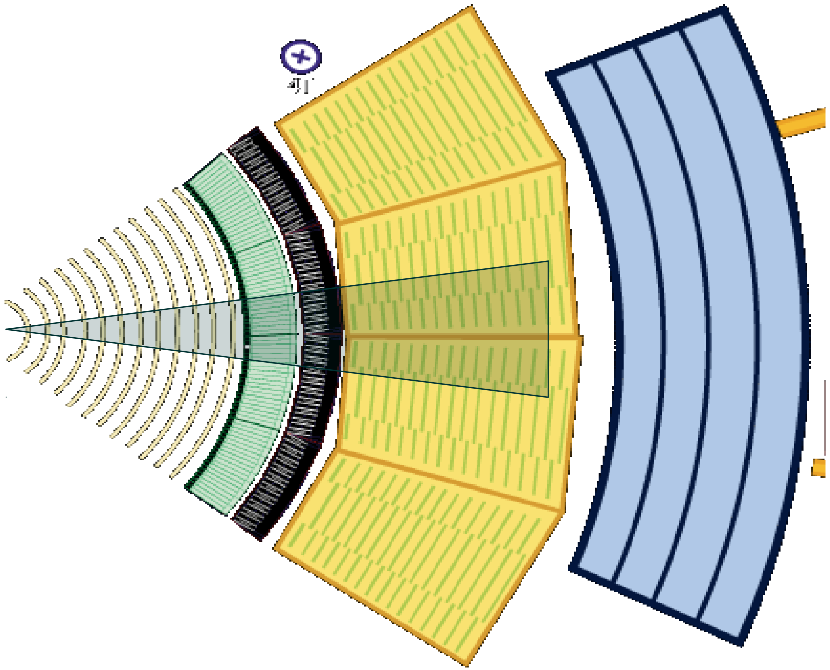


- Inst. luminosity = 5 × 10^{34} cm^{-2} s^{-1} (PU ~ 140)
- Rate flattening is due to relaxation of EGamma identification criteria at 128 GeV
  - Algorithm-dependent feature
- Ratio plot is used to derive scale factors and systematics for the 100 TeV extrapolation

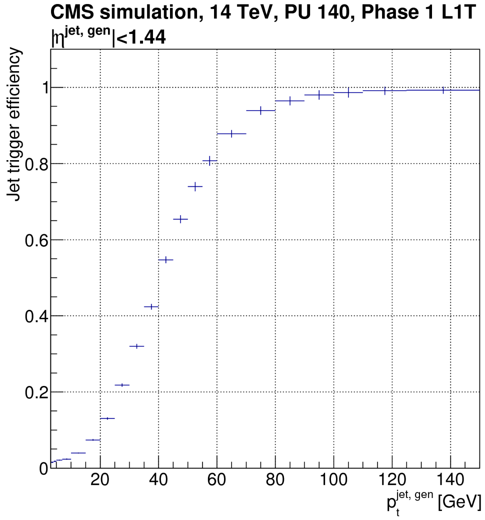
What are the main contributions to the jet trigger rate?

Hadronic jets

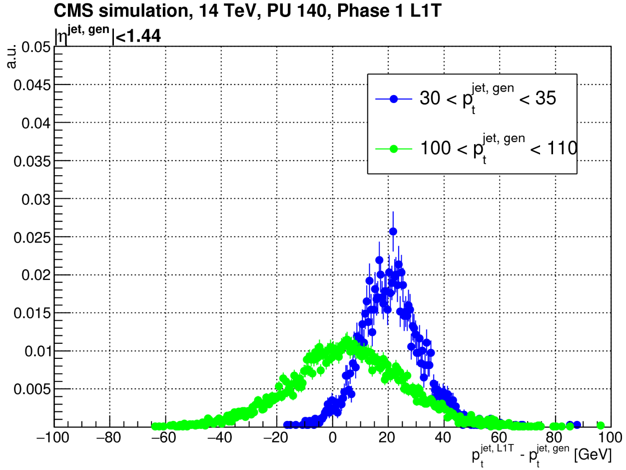
- We apply the CMS jet trigger efficiency and resolution to generator-level jets
  - Barrel performance only

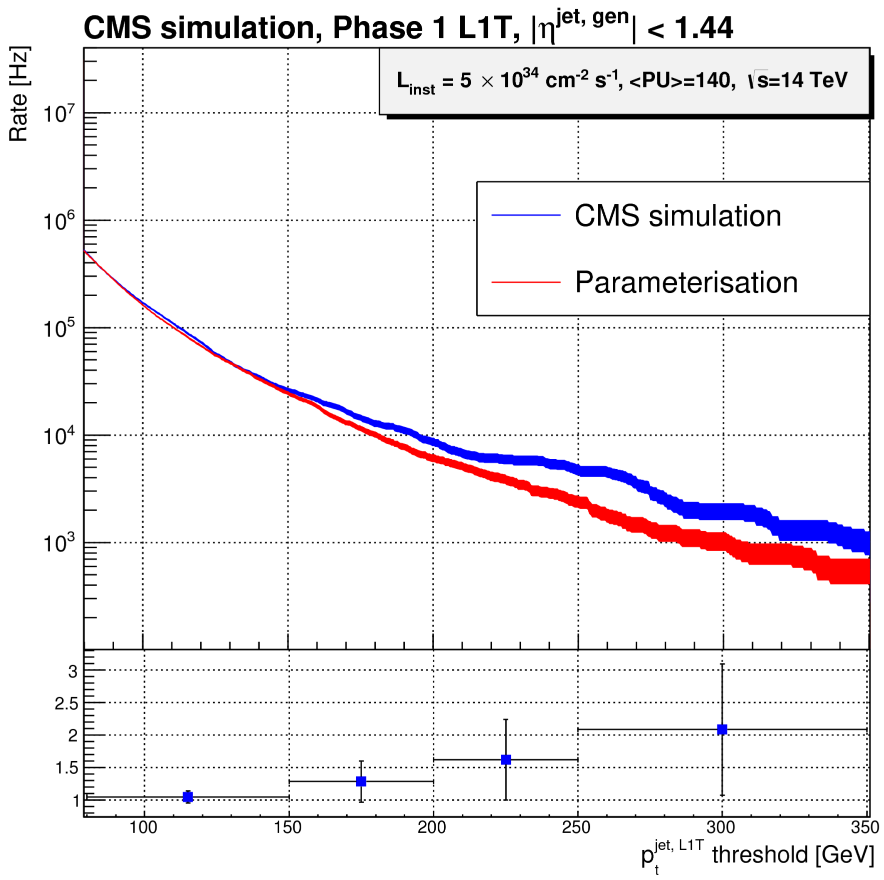


Efficiency



Resolution





- Inst. luminosity = 5 × 10^{34} cm^{-2} s^{-1} (PU ~ 140)
- Rate is dominated by true hadron jets coming the hard interaction
- Ratio plot is used to derive scale factors and systematics for the 100 TeV extrapolation

Extrapolating to 100 TeV

- To switch to FCC-hh base conditions:
  - Increase the centre-of-mass energy to 100 TeV
  - Maintain same luminosity level, 5×10^{34} cm^{-2} s^{-1} (PU ~ 140)
  - Extend the detector eta to cover up to |eta| < 6 for the three object types
- Closure test ratio plots are used as a base for systematic errors
  - Rate at 100 TeV is scaled by the ratio to compensate for systematic divergences in the rates
  - Ratio plot uncertainties are used to compute the systematic uncertainty

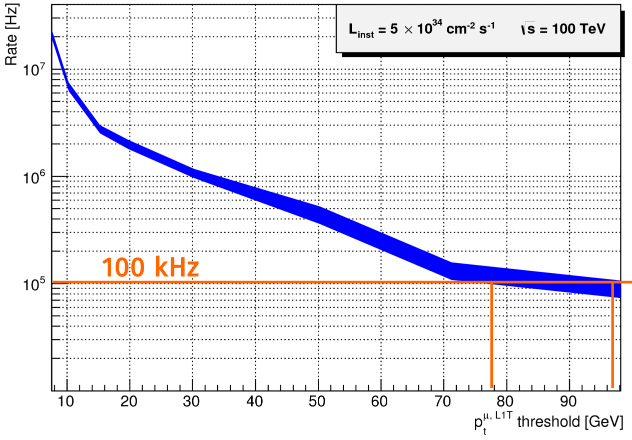
Rates at 100 TeV

100 kHz threshold @ CMS 14 TeV:

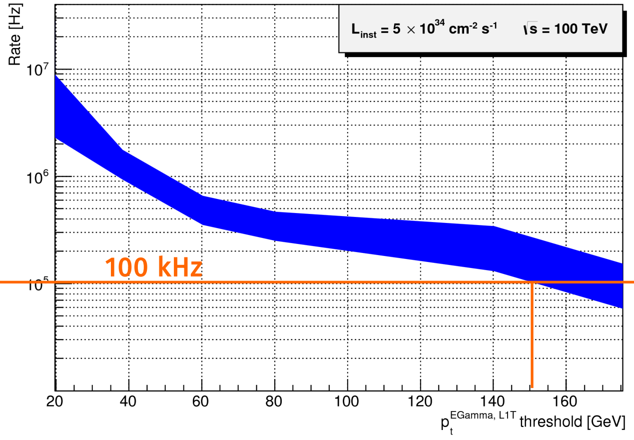
- Muon: 25 GeV
- EGamma: 30 GeV
- Jet: 120 GeV

- Inst. Lumi = $5 \times 10^{34}\ cm^{-2}\ s^{-1}$ (PU ~ 140)
- Muon rate is driven by resolution
- EGamma rate is strongly dependant on algo
- Jet rate is led by physics and resolution

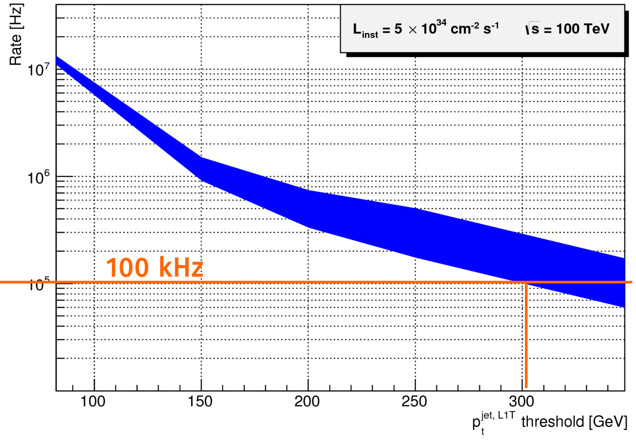
Muon trigger



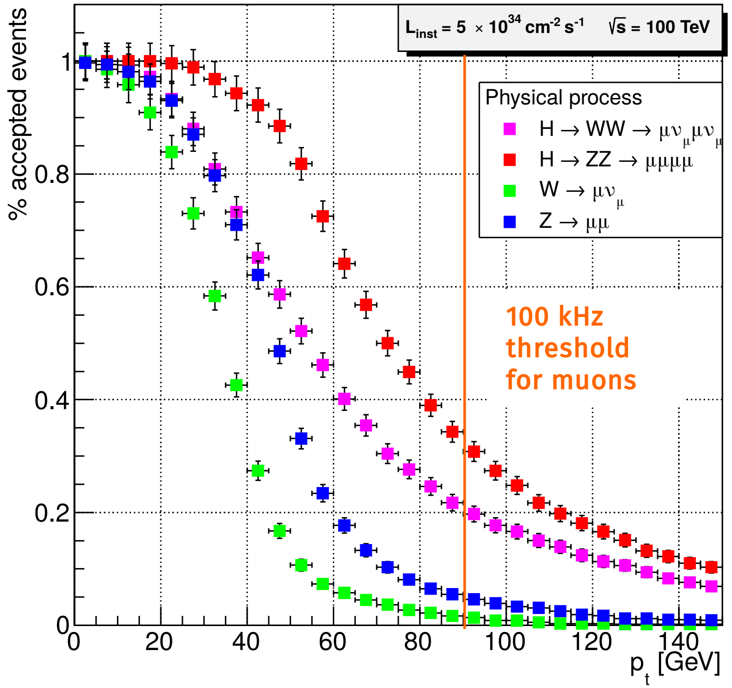
EGamma trigger



Jet trigger



- Collecting EWK & Higgs physics via single-object triggers is going to be challenging
  - Improvements to E/G algorithms and muon resolution will be needed



Track trigger

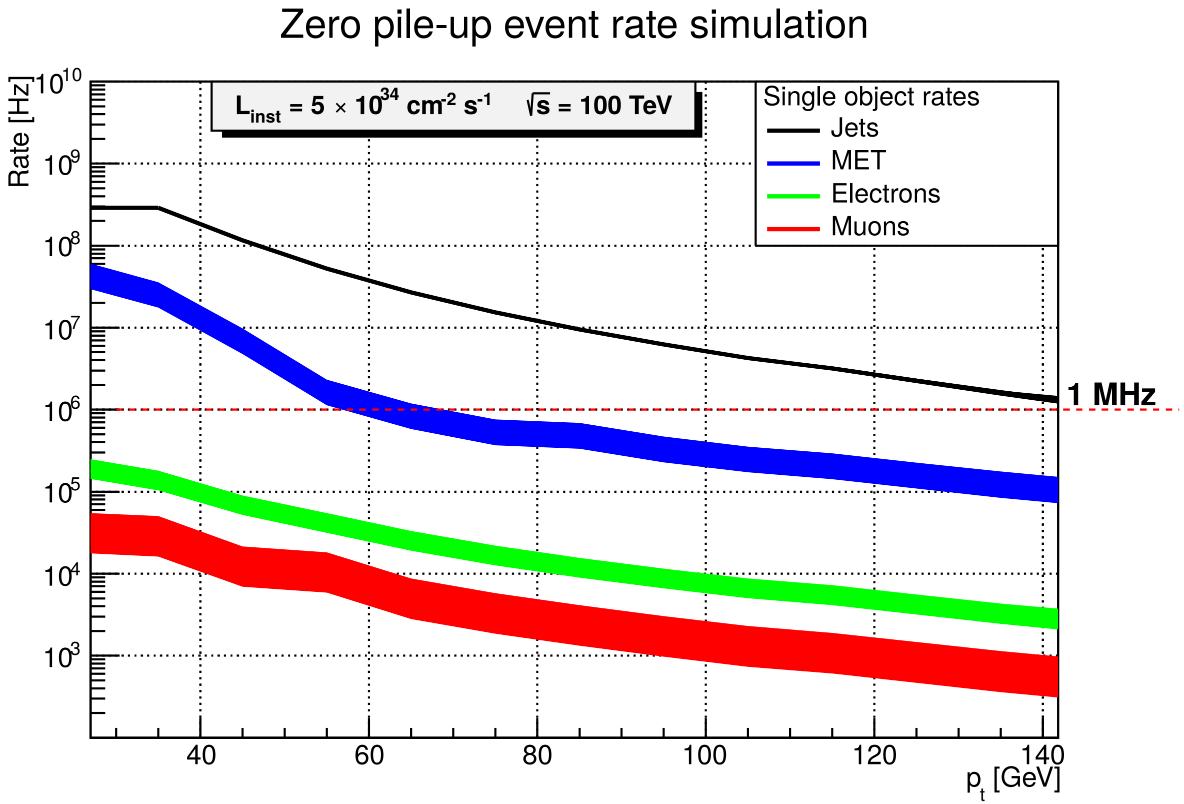
- Including the tracker would greatly improve the trigger performance
  - Improved muon performance
  - Electron/photon discrimination
  - Pile-up suppression
  - Improved multi-object trigger performance
- See Will Fawcett's talk for further studies on including tracking at trigger-level
  - This morning, 9.45 AM, link to contribution
- Further studies are required to understand if a better standalone calo/muon performance can be achieved or if including tracking is the best option for this scenario

Conclusions

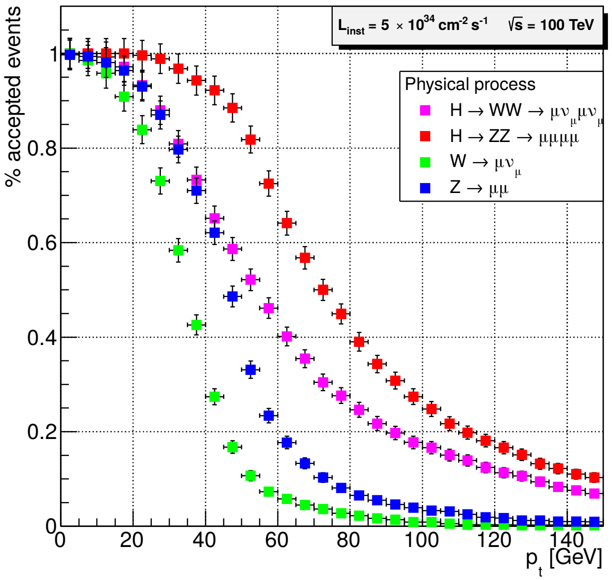
- Built a parametrised simulation of the CMS Phase-1 L1T to replicate rates at LHC
- Simulation has been used to estimate the performance and trigger rates at FCC-hh at inst. lumi=$5 \times 10^{34}\,cm^{-2}\,s^{-1}$ (PU ~ 140)
  - Single muon: 100 kHz @ 85 GeV
  - Single egamma: 100 kHz @ 170 GeV
  - Single jet: 100 kHz @ 350 GeV
  - No MET estimate yet; work in progress
- Single lepton trigger rates are too high to collect EWK physics
  - Performance improvements are required:
    - Better muon resolution
    - Improved and optimised egamma identification algorithms
- A track trigger can give a substantial improvement
- Is single-object triggering really suited for FCC-hh physics?

Backup

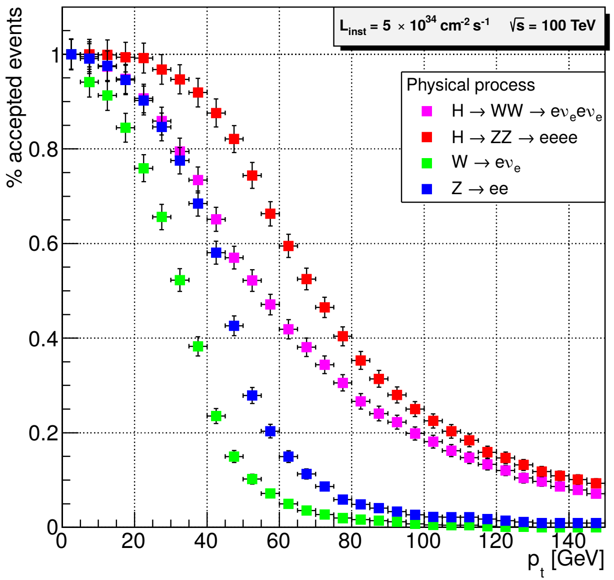
Object rate estimation from last year



Muons

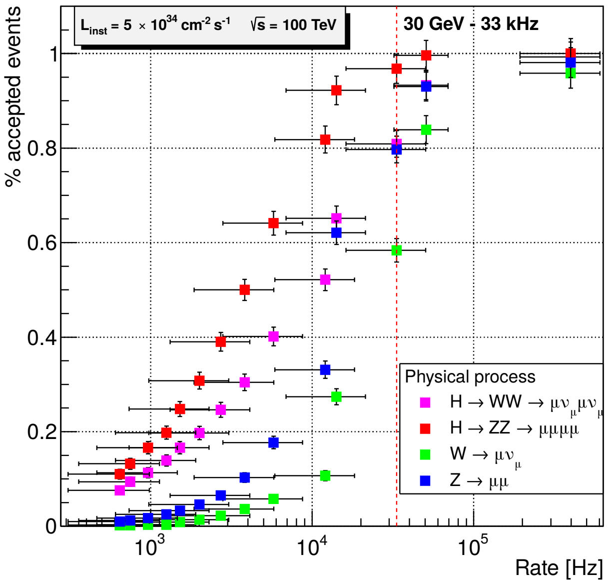


Electrons



Rate vs EWK acceptance from last year

Muons



Electrons