A self-seeded track trigger for FCC-hh

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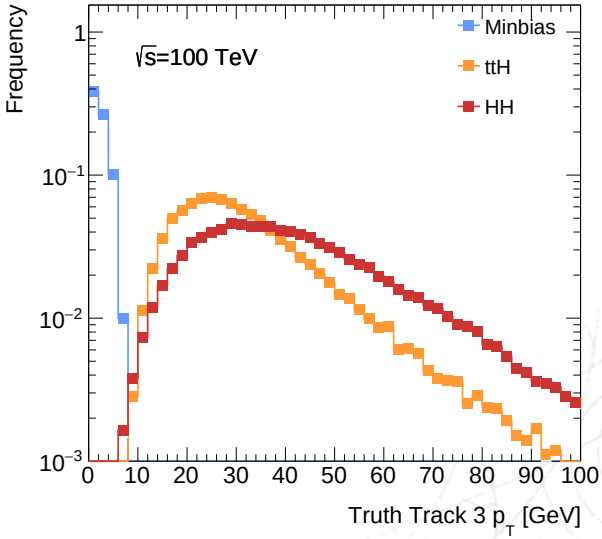
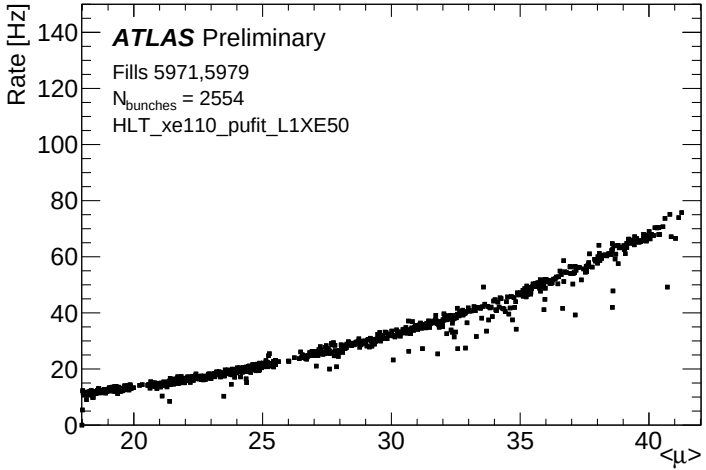
Thanks to: Zbynek Drasal, Valentin Volkl, Michele Selvaggi, Andre Schöening, Andreas Salzburger and many others!

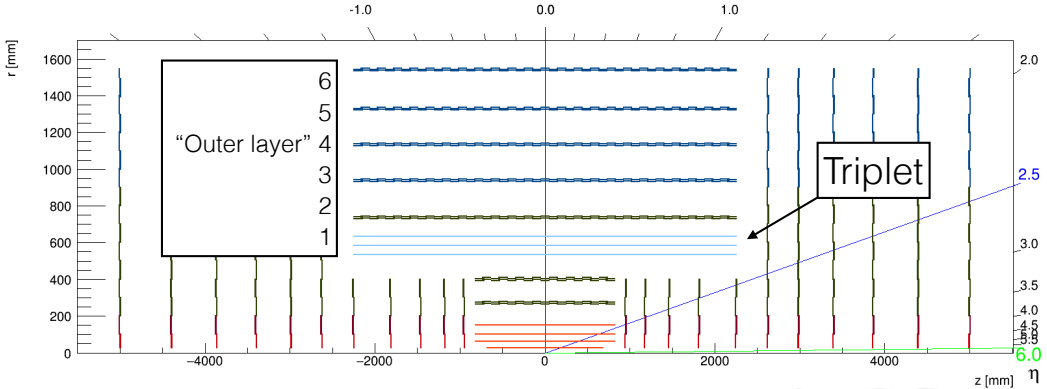
Motivation


Frequency
1
10^{-1}
10^{-2}
10^{-3}
√s=100 TeV
Minbias
ttH
HH
0
10
20
30
40
50
60
70
80
90
100
Truth Track 3 p_T [GeV]

Motivation

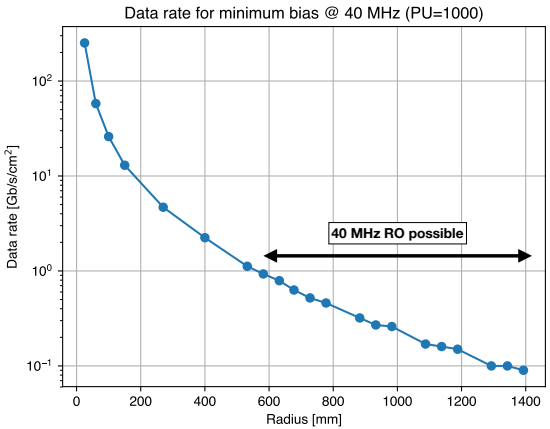

Rate [Hz]
140
120
100
80
60
40
20
0
ATLAS Preliminary
Fills 5971,5979
N_bunches = 2554
HLT_xe110_pufit_L1XE50
20
25
30
35
40
<μ>

Idea: a track trigger



- Simplest possibility: have a triplet of tracking layers
- Other ideas: quartet, pairs of doublets
- Advantage of triplet over doublet: possible to do displaced vertex tracking

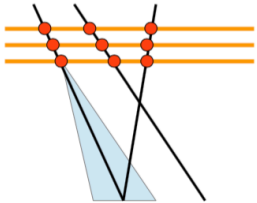
Data rate



- Rough estimate
- Readout of all hits for every bunch crossing only feasible at large radii
- Assumed rate at $\sim$600 mm from IP will be possible for the FCC
- Bonus: low p_{T} tracks won't reach the triplet $\rightarrow$ reducing combinatorics

Optimal distance between tracking layers?

- **Small gap** between layers:
  - increase in extrapolation uncertainties
  - reduction of ambiguities (fake tracks)
- **Large gap** between layers:
  - reduction of extrapolation uncertainties
  - increase in ambiguities (fake tracks)



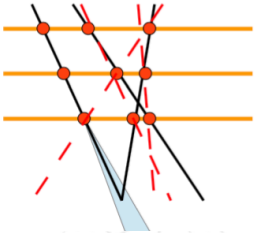
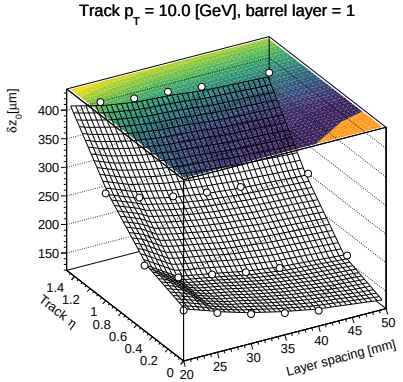
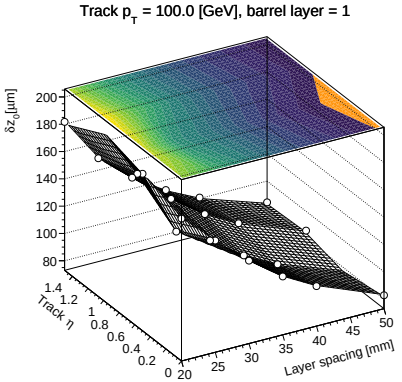


Image: A. Schöening

Triplet performance

- Analytic approach to extract track parameters: “Glukstern approximation”, calculated using tkLayout
- Multiple scattering taken into account
- Fake tracks not considered here

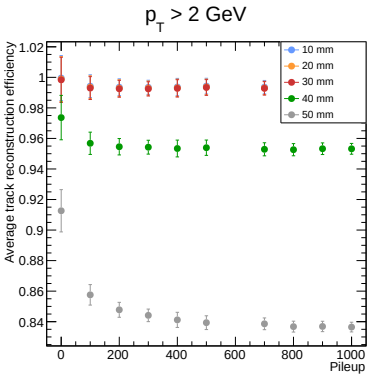


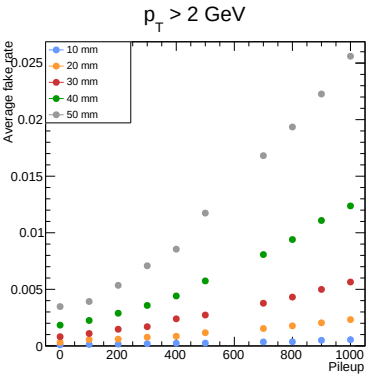


Fake track considerations

- **Hits**
  - Simulate pileup with pythia8, physics samples with madgraph+pythia8
  - Used Delphes framework to propagate particles in Helix
  - Hits are positions of tracks intersecting with barrel layers
- **Seeding**
  - Geometrical matching of triplet of hits
  - Easy since layers are close-by
  - Intentionally don't reconstruct tracks with $p_{\mathrm{T}} < 2$ GeV based on ϕ hit separation
  - Can also remove fakes with geometrical cuts
- **Track reconstruction**
  - Circle fit in r–ϕ plane
  - Straight line fit in r–z plane
  - Track parameters smeared with parameterisation from tkLayout to emulate effect of multiple scattering

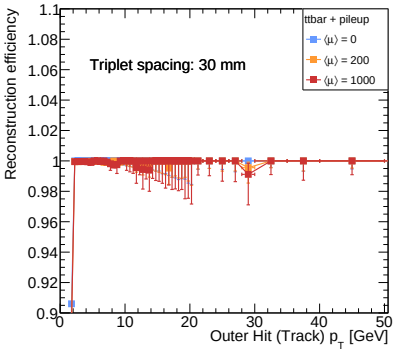
Average tracking performance

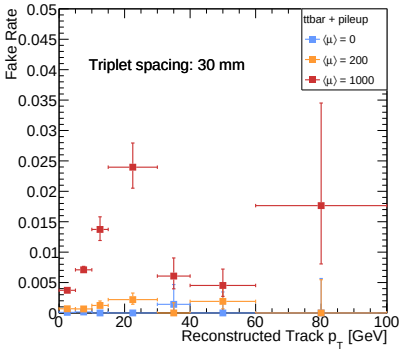




- 30 mm spacing optimal based on trade off between fake rate and track parameter resolution.
- All further results with 30mm geometry

Tracking Performance



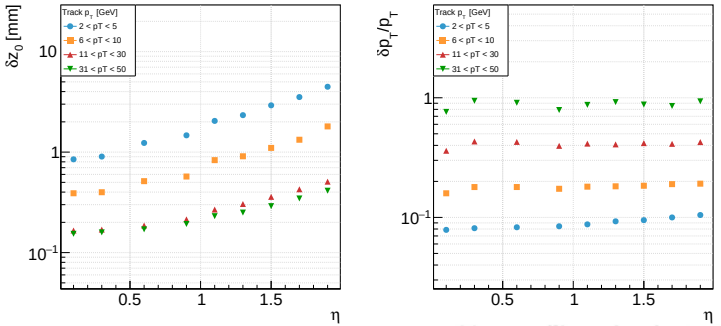


$$\epsilon = \frac{\text{Number of reconstructed tracks } [p_T]}{\text{Number of hits in outer layer} [p_T]}$$

$$\text{Fake rate} = \frac{\text{Number of fake tracks } [p_T]}{\text{Number of reconstructed tracks } [p_T]}$$

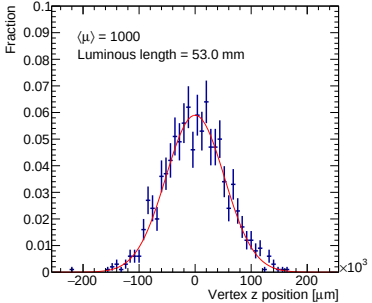
Tracking Performance

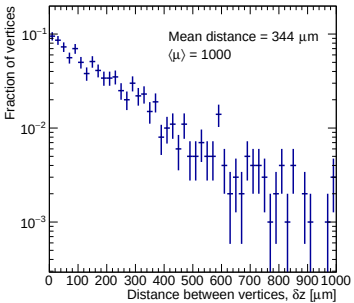
- z_0 resolution important for identification of the PV
  - 1–5 mm for low p_{T} tracks (2–5 GeV)
  - 0.1–1 mm for high p_{T} tracks (> 10 GeV)
- p_{T} resolution degrades as track p_{T} increases
  - ~ 8% for 2 GeV tracks, ~ 80% for 50 GeV tracks

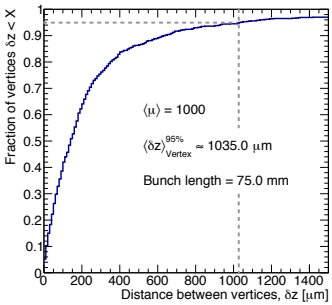


Pileup considerations

- For luminous region of $\sigma_z = 53$ mm (beam length $\sigma_{z,beam} = 75$ mm)
  - pileup 1000: 95% of vertices are separated by $\lesssim 1$ mm
  - average separation between vertices $\sim$0.3 mm
- Won't be able to unambiguously identify the vertex of each track with z_0 resolution of $> 100\ \mu$m



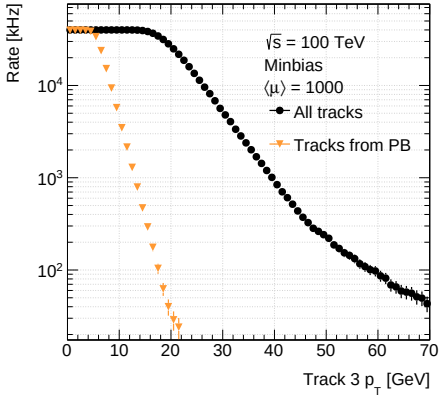


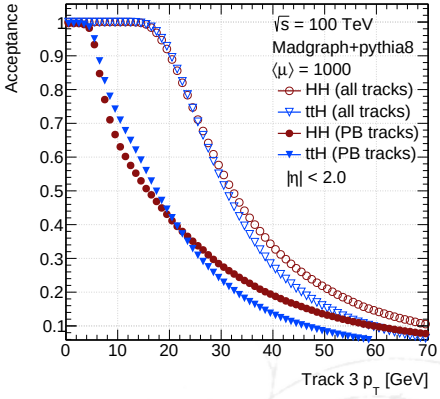


Identifying the Primary Vertex (PV)

- The PV cannot be unambiguously distinguished from other vertices
- Use a sliding window algorithm to identify the 'primary bin' (PB)
  - Find region of length 1mm that has the largest sum(p_{T}) of tracks
- For ttbar events, the true PV is inside the PB:
  - 83% for pileup 1000
  - 93% for pileup 200

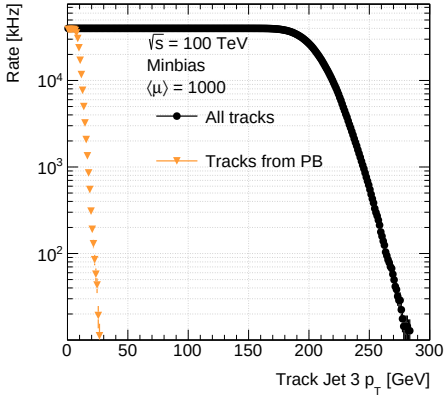
Trigger rate & acceptance

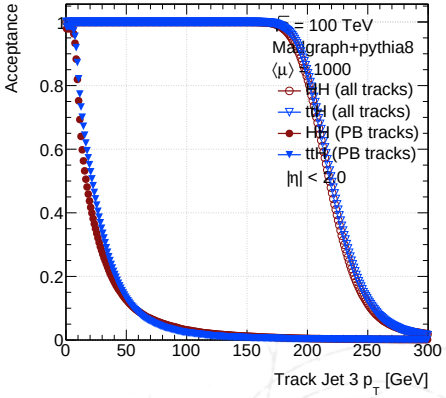




- 3rd track would require $p_{\mathrm{T}} > 60$ GeV w/o pileup suppression, acceptance $\sim$ 15% (100 kHz)
- 3rd track with pileup suppression (identification of PB), $p_{\mathrm{T}} > 17$ GeV gives acceptance $\sim$ 50% (100 kHz)

Multijet triggers





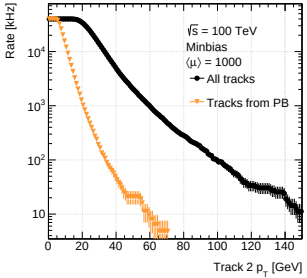
- Can cluster tracks into jets (note these plots show anti-kt 4.0 “track jets”)
- Jets are much more sensitive to pileup, identifying the PB more powerful
- For 100 kHz and with pileup suppression can have 50% acceptance
- See Simone’s talk for more on calorimeter based triggers (11:30 today!)

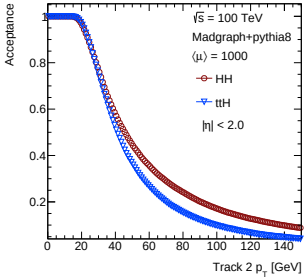
Summary

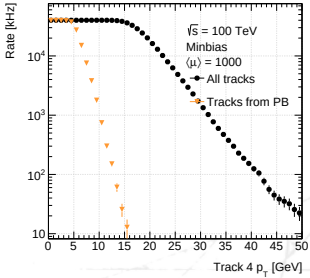
- Triplet of tracking layers sufficient to reconstruct tracks with high efficiency and relatively low fake rate, even with $\langle \mu \rangle = 1000$
- If the "primary bin" can be identified:
  - Can trigger on interesting signals, 50% acceptance of HH or ttH for 100 kHz rate
- Real power of tracking at trigger level would be to match with calorimeter or muon triggers
- Other possibilities for a track trigger:
  - Impact on MET triggers potentially enormous if PV can be identified
  - Could also be used as a displaced track trigger

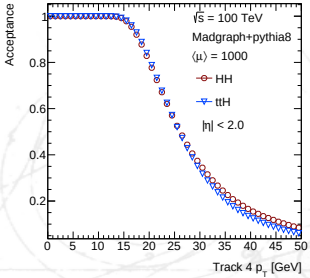
Backup

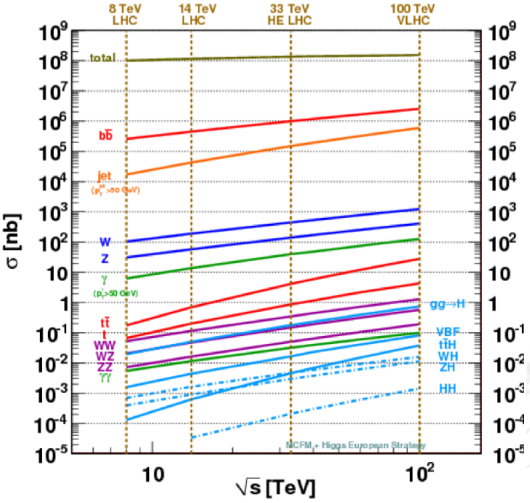
Trigger rate & acceptance










8 TeV LHC
14 TeV LHC
33 TeV HE LHC
100 TeV VLHC
total
bb̄
jet
(p_T^jet >50 GeV)
W
Z
γ
(p_T>50 GeV)
tt̄
t
WW
WZ
ZZ
γγ
gg→H
VBF
tt̄H
WH
ZH
HH
σ [nb]
√s [TeV]
10
10^2
MCFM+ Higgs European Strategy