L1CTT Physics Case and Simulations

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WBS 1.2.6.2

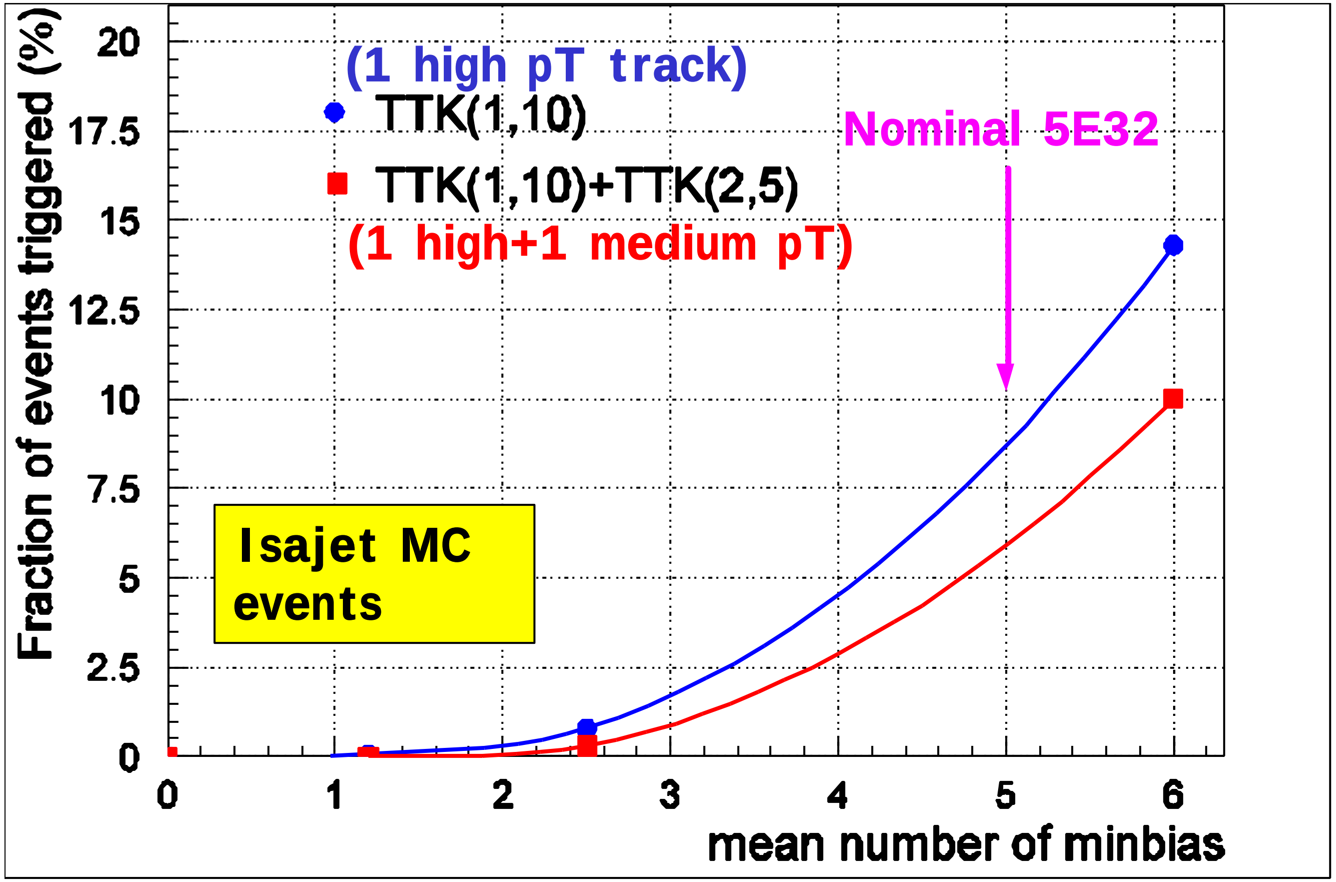
L1CTT Upgrade Motivation

- In Run IIa and RunIIb, the L1 Track Trigger Provides:
  - CFT tracks for L1Muon Seeds
  - CFT tracks +CPS clusters Þ embryonic electrons
  - High p_T isolated track trigger capability
  - Found tracks for STT Þ b-tagging
- We believe the Run IIa L1CTT will fail at the occupancies we expect in Run IIb, resulting in
  - Many more fake high-p_T tracks for all systems
  - The loss of rejection from combining subsystems

Physics Motivations

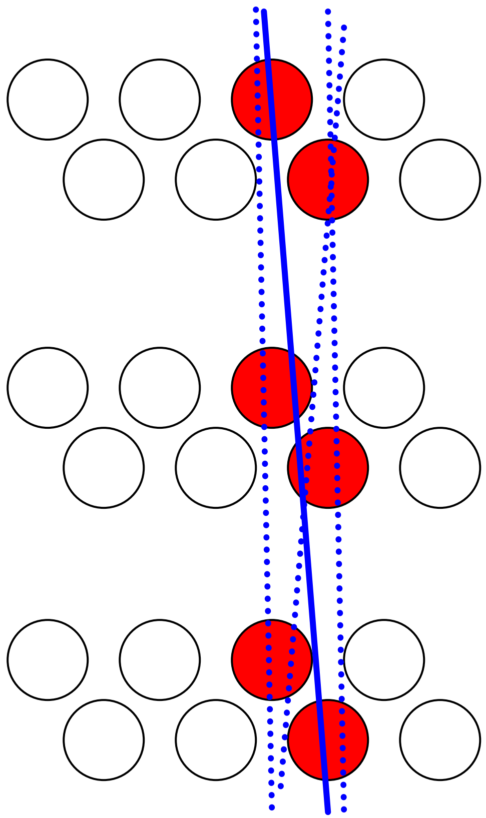
- Must trigger on high-p_T leptons with high efficiency, low fake rate:
  - HW®bbne or bbnm, HZ®bbll
  - Cal-Track match is important/necessary here
- Must provide clean track samples for b-tags with the STT
  - HZ®bbnn, Z®bb
- Could (Must?) provide high-p_T tracks for hadronic tau triggers
  - H®tt (gets you 35% equivalent lumi boost)
  - Cal-Track match is important/necessary here
- (Correlations between Systems is Necessary)

Run IIa at high luminosity

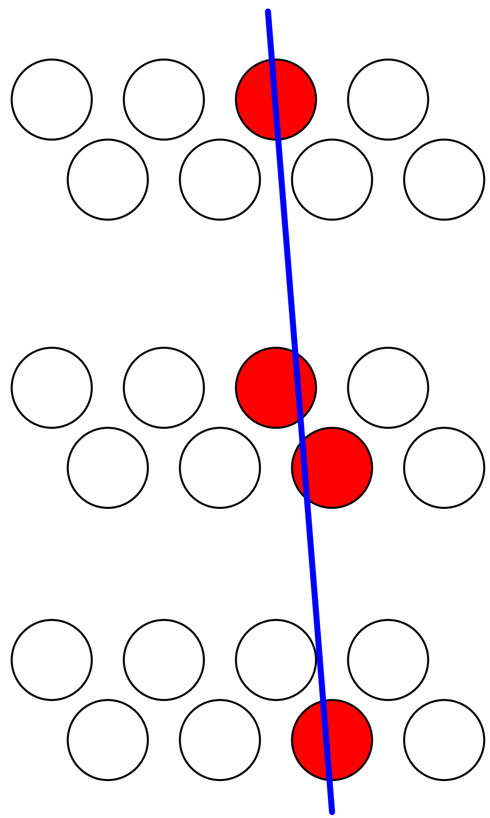


- Even at modest occupancies, the high-p_T single track trigger would fire on ~2% of events (>100kHZ)

Run IIb L1CTT: Granularity



Run IIa

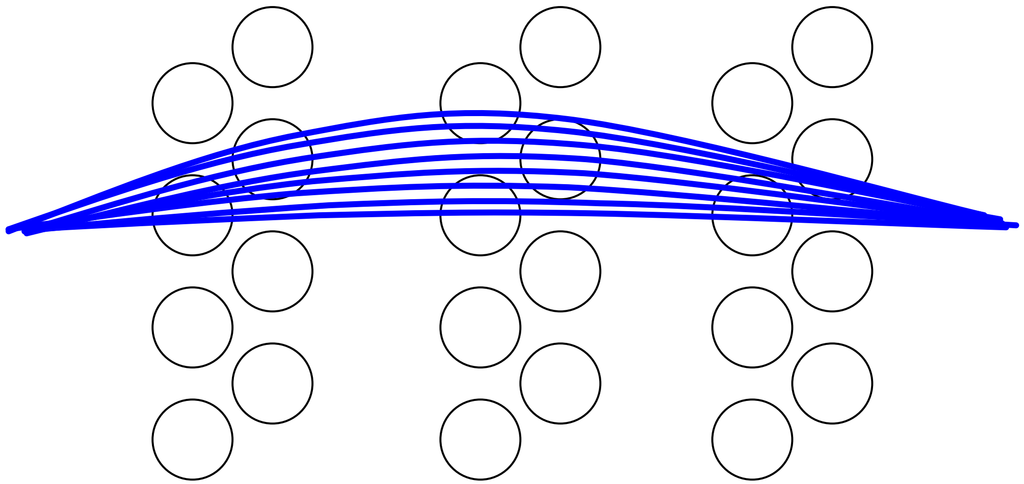


Run IIb

- Use full fiber resolution to restrict roads

Equation Generation

- An "equation" is a list of up to 16 fibers specifying a possible track trajectory:
  - e.g.: 20 0 24 0 28 0 32 32 35 36 0 39 0 42 45
- These are derived using MC trajectories and the CFT geometry, with a uniform sampling in $1/p_T$ for each momentum bin



Fraction of trajectories accepted by each equation is recorded

Equation Generation, cont.

- **Hardware Threshold Simulated:**
  - For each hit fiber, a Poisson distribution of the number of photoelectrons is generated based on the ionization path length. A cut of 1.5 p.e. is applied
- **Missing hits are allowed Þ retain efficiency**
  - Will allow to compensate for fiber ageing, too

Equation "Pruning"

- The previous procedure generates 697k 16-term equations for tracks with p_T>10 GeV in a single trigger sector(!)
- Pruning is necessary to fit in an FPGA:
  - ~~All equations missing an entire CFT layer~~
  - ~~All equations with an acceptance $< 3\times10^{-5}$ (high p_T) or 1.5×10^{-6} (low p_T)~~
  - ~~Long equations with redundant subset~~
- Reduces 697k to 9.4k, with better fake rate!
  - Equations with low acceptance are more likely to fire on random noise than real tracks

Minimum bias Simulation

- Pythia MC tuned to match CDF Run I data
  - Includes Diffractive events
  - Cross-sections:

Pythia QCD processes:

11	f+f' -> f+f'	1.28 mb
12	f+$\bar{f}$ -> f'+$\bar{f}$'	0.03 mb
13	f+$\bar{f}$-> g g	0.004 mb
28	f+g -> f+g	12.5 mb
53	g+g -> f+$\bar{f}$	0.55 mb
68	g+g -> g+g	23.96 mb
95	low pT scatter	1.21 mb

Total cross section: 39.53 mb

Pythia CDF Tune:

Pythia QCD + New processes:

Single diffr. (AX)	6.24 mb
Single diffr. (XB)	6.24 mb
Double diffr. (XX)	6.95 mb

Total cross section: 58.96 mb

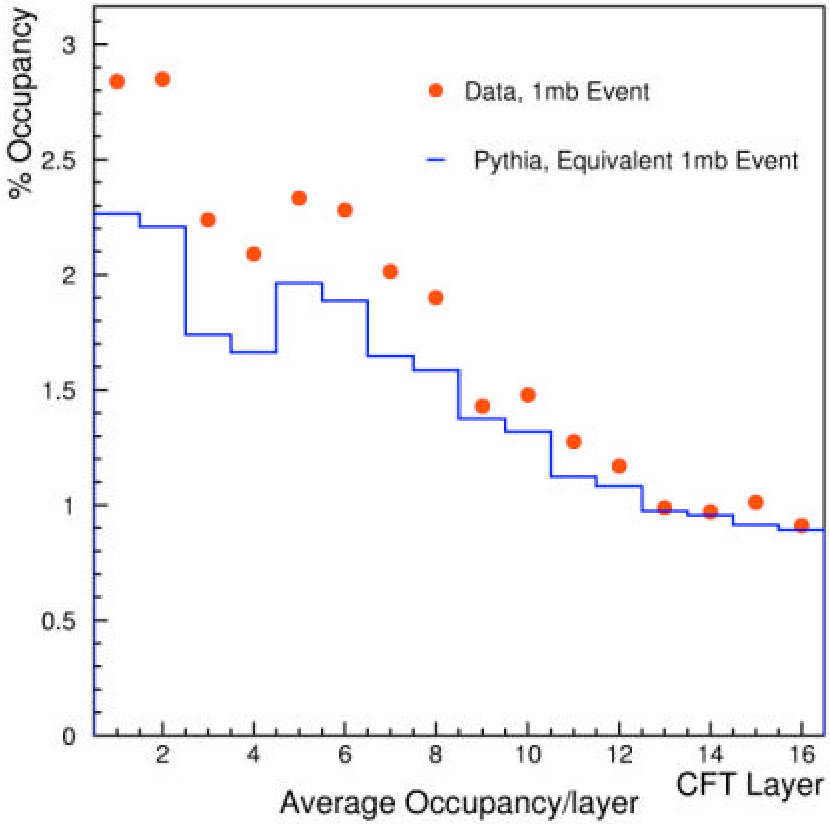
Total "non-Diffr." Xsec = 46.48 mb

5E32@132ns Simulation

- **Minbias cross section of 47mb implies poisson average of 5 “non-diffractive” events/crossing.**
  - **comparison of very early data (prototype CFT electronics) and MC suggested MC occupancy was too low**
  - **We generated <n>=7.5 Pythia Minbias/crossing to get better agreement with MC.**
    - **occupancy discrepancy from GEANT material treatment**
  - **no detector noise included**
    - **Pedestal shifts in production electronics “understood” only in mid-July 2002**
    - **Physics occupancy dominates detector noise at L=5E32**

Data/MC Minbias Comparison

- **With new CFT data, can compare minbias occupancy to that from MC:**



Data: Minbias = lumi correction X (minbias triggers-zerobias triggers)

Þ Gives measured occupancy in one minbias event

MC: Minbias =xsec correction X (events passing minbias trigger)

Þ Gives effective occupancy in one minbias event for 7.5 minbias MC sample

L1CTT Algorithm Results

- **With baseline version of new L1CTT:**

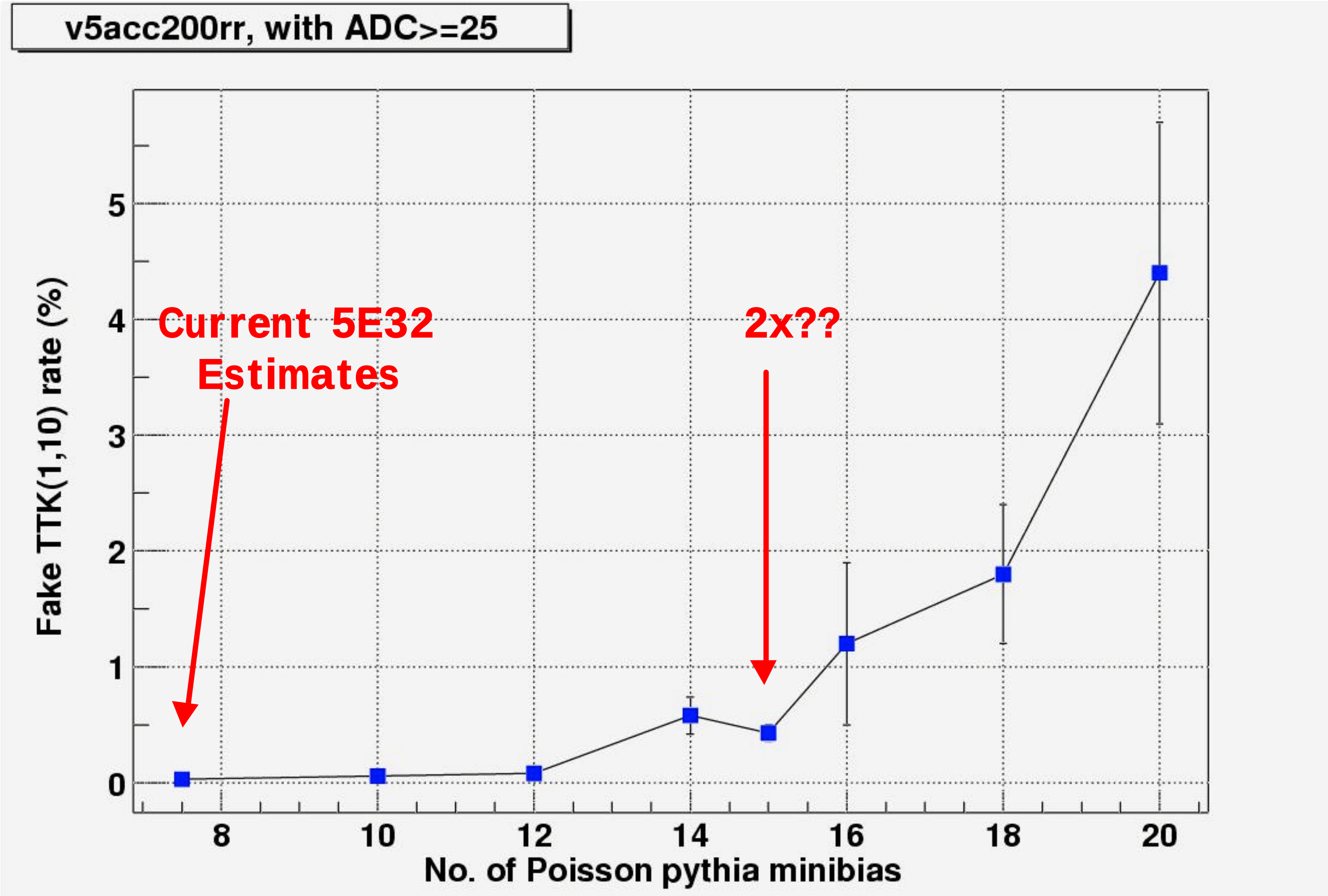
Scheme/ p_T range	Tracking Efficiency (%)	Rate of Fake Tracks (% events)	Resources
ABCDEFGH (RunIIa) (p_T>10 GeV)	96.9	1.02 ± 0.10	11k X 8
abcdefgh (p_T>10 GeV)	98.03 ± 0.22	0.056 ± 0.009	9.4k X 16
abcdEFGH (5 GeV<p_T<10 GeV)	99.20 ± 0.14	0.89 ± 0.11	8.9k X 12
abcdEFGH (3 GeV<p_T<5 GeV)	98.40 ± 0.20	4.5 ± 0.2	11.3k X 12
abcdEFGH (1.5 GeV<p_T<3 GeV)	95.15 ± 0.32	25.4 ± 0.2	15.5k X 12

Comments on Results

- New equations yield better efficiency, factor of 20 less fakes at high p_T
  - lack of explicit fiber vetoes renders efficiency luminosity-independent
- x2-x3 Run IIa L1CTT resources required
- Use of doublets at lower p_T reflects balance between resources and physics:
  - number of equations increase with $1/p_T$
  - multiple scattering makes singlets inefficient
  - fine granularity in inner layers with more occup.

Performance vs. Luminosity

- Rate of fake high-p_T tracks vs. Luminosity:



Software Infrastructure

- Equation generation code
  - stand-alone code capable of using any CFT geometry
  - can generate VHDL code for Run IIa Hardware
  - 40k lines of code+scripts
- 1 new DØ software package (l1ft2b)
  - applies equations to CFT data
  - 3000 lines of code + documentation
- VHDL code
  - implementation of algorithms
  - infrastructure (data handling, packing outputs)

Conclusions

- Significant advances in understanding strengths/weaknesses of equation algorithms over Run IIa work.
- Solid software infrastructure developed
- Comparisons with data look sensible
- Baseline design has ***HUGE*** performance gain over Run IIa L1CTT
  - Correlations with other L1 Triggers will allow us to do the physics even at the highest Luminosities