DO Run 2b Trigger Upgrades

- Run 2a Trigger System
- Trigger Strategies for Run 2b
- Upgrade Design
  - L1 track trigger
  - L1 calorimeter trigger
  - L1 cal-track matching
  - L2 upgrades
- Organization of Trigger Upgrades
- Schedule

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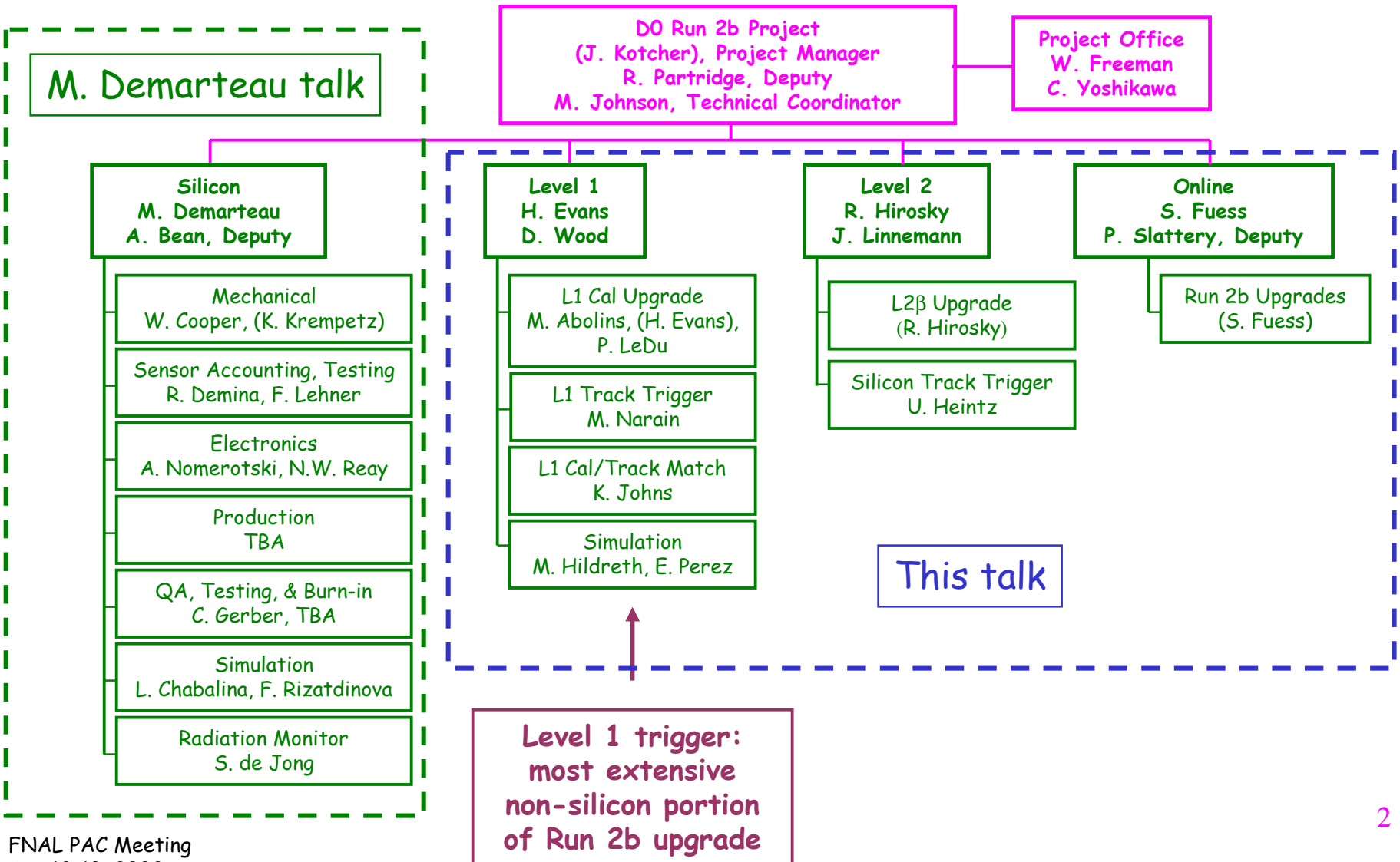
Run 2b Project Organization



The Run 2a Trigger System

Level-1

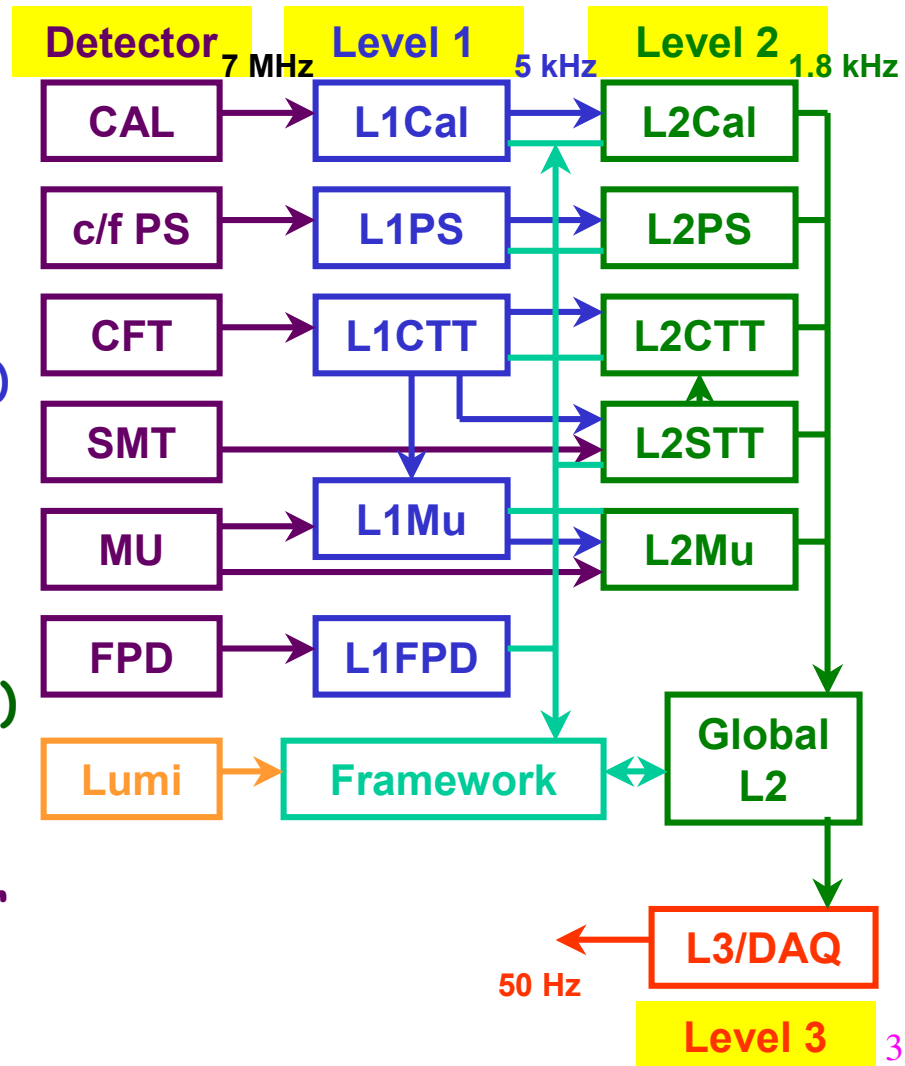
- Mainly detector-based
- Correlations
  - Cal-Trk: quadrant level
  - Mu-Trk: L1trk info → L1Mu
- Not deadtimeless
  - Out rate ~5 kHz (r'dout time)

Level-2

- Calibrated data
- Extensive correlations
- Physic objects out (e,μ,τ,j…)
- Out rate < 1.8kHz (cal r'dout)

Interdependence

- High level of connectivity
- All elements must function for system to work



Run 2b Trigger Priorities

- Main physics driver for Run 2b: Higgs search
  - Need efficient triggers for Higgs production/decay in all major modes
- Top, W, Z
  - Important for precision mass measurement to complement Higgs mass determination
  - Also important for background & calibration for higgs search
- Other background/calibration channels (e.g. $Z \rightarrow b\bar{b}$)
- Some trigger load can be relieved elimination of low-pt physics menu (lower energy QCD, b-physics, …), but this is not sufficient.

Strategies for Trigger Upgrades

- Increase trigger rejection at Level 1
  - L1 Calorimeter trigger upgrade to sharpen thresholds
  - L1 Tracking trigger upgrade to maintain rejection
  - Additional rejection from cal-track matching
- Maintain rejection at Level 2
  - L2 Processor upgrades
  - Expand Silicon Track Trigger (STT) for new silicon detector geometry
- Upgrade/maintain DAQ/Online systems to support data collection through Run 2b (not discussed further in this talk)

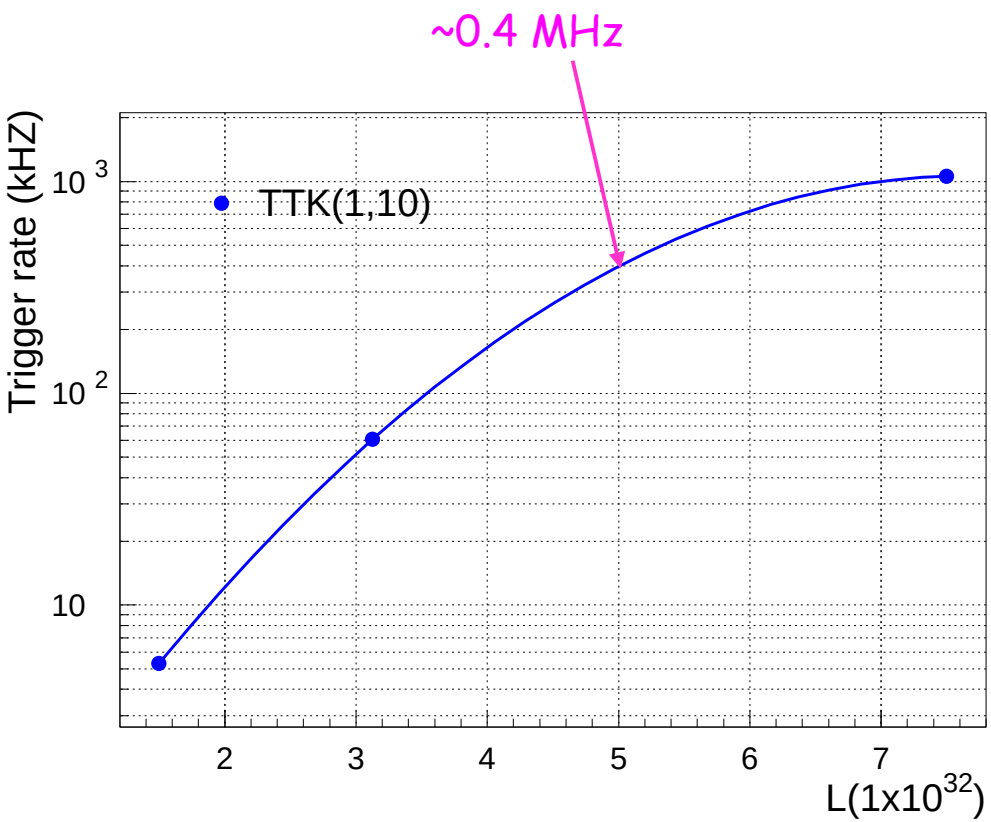
Sample Run 2b Level1 Trigger rates

- Run2b: Δt=132ns, L=5x10^{32} $cm^{-2}s^{-1}$
- High p_T trigger menu exceeds available bandwidth

Trigger	Example Physics Channel	Rate (no upg.)
EM Trigger (1 EM tower > 10 GeV)	$W \to e\nu$	9 kHz
Jet Trigger (2 trigger towers > 4 GeV)	$ZH \to \nu\bar{\nu}b\bar{b}$	2 kHz
Track Trigger (2 trk > 10, 5 GeV, iso, EM)	$H \to \tau\tau$	60 kHz
Muon Trigger (muon > 10 GeV)	$W \to \mu\nu$	6 kHz
TOTAL		77 hKz

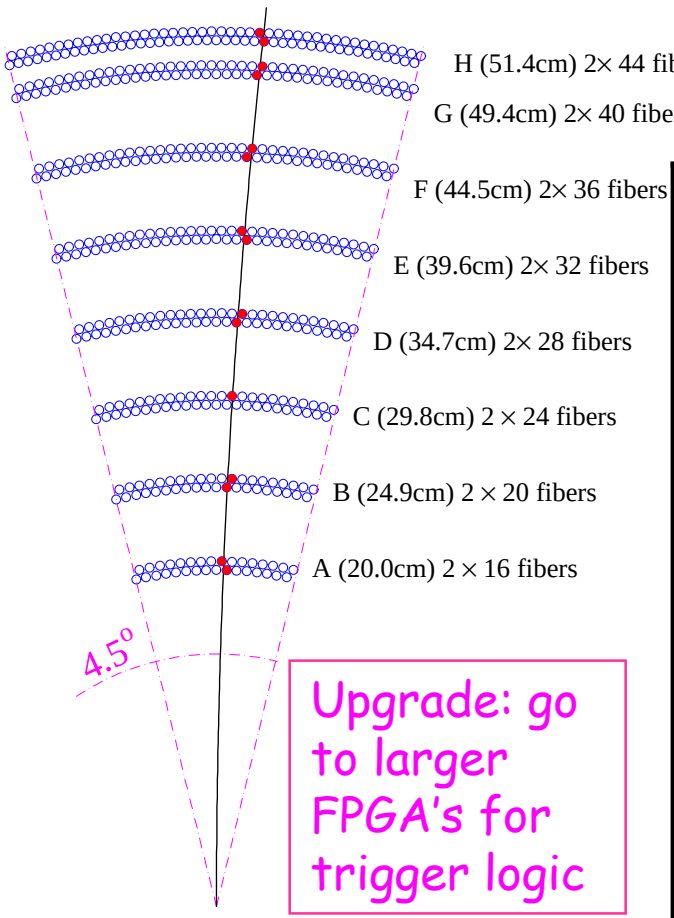
Total rate into Level 2 limited to 5 kHz

L1 Tracking Trigger Upgrades



- Level 1 Central Track Trigger (CTT) essential for electrons, muons, taus ($WH \rightarrow l\nu jj$)
- Tracking trigger rates sensitive to occupancy
- Upgrade stategy:
  - Narrow tracker roads by using individual fiber hits (singlets) rather than pairing adjacent fibers (doublets)
  - Cal-track matching

Tracking Trigger Upgrades

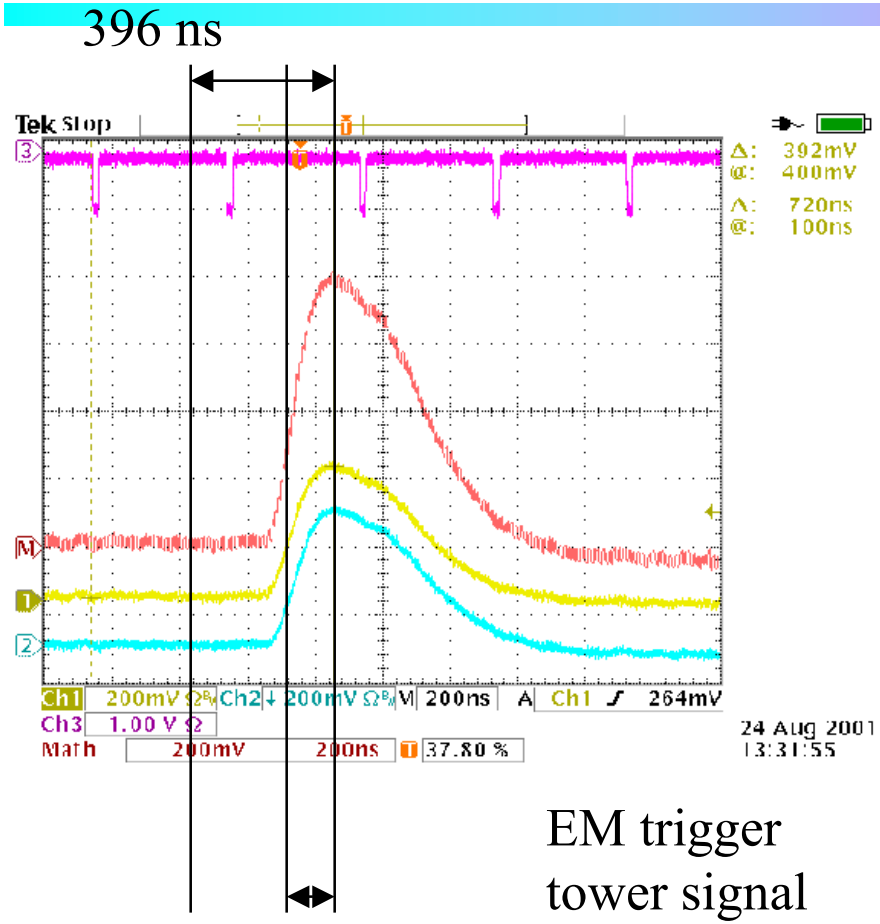


Upgrade: go to larger FPGA's for trigger logic

Simulation results (prelimiary): 5 min. bias events

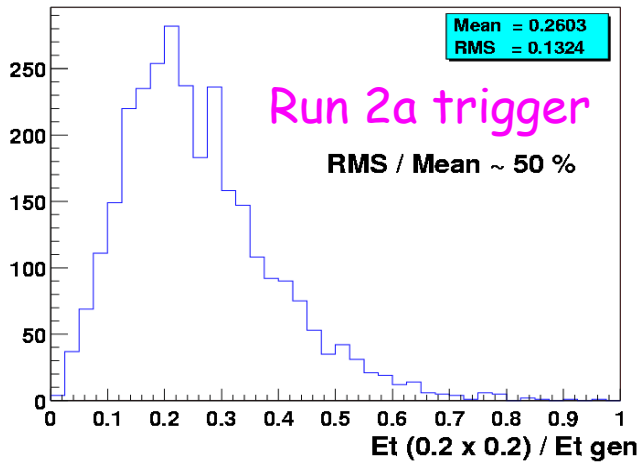
	Default eq'ns	16-layer singlet	12-layer eq'ns	14-layer eq'ns
Eff. For pt>10 Gev	96.9	99.3	98.6	99.2
Fake % (1 trk >10)	5.8	0.4	1.6	0.7
Fake % (2 trk > 10 Gev)	0.7	0	0.13	0.03

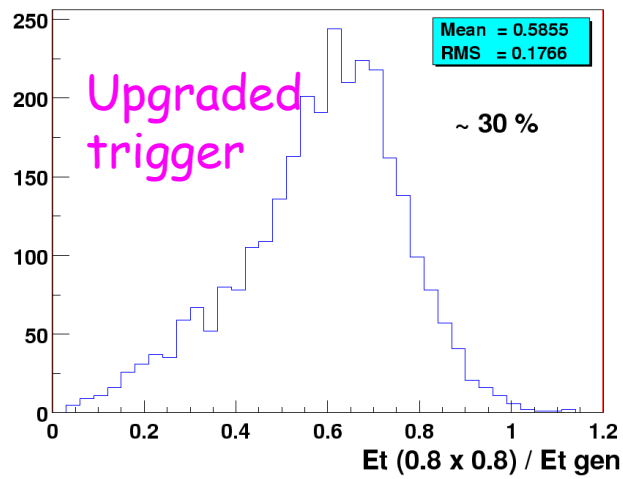
Calorimeter Trigger Upgrade



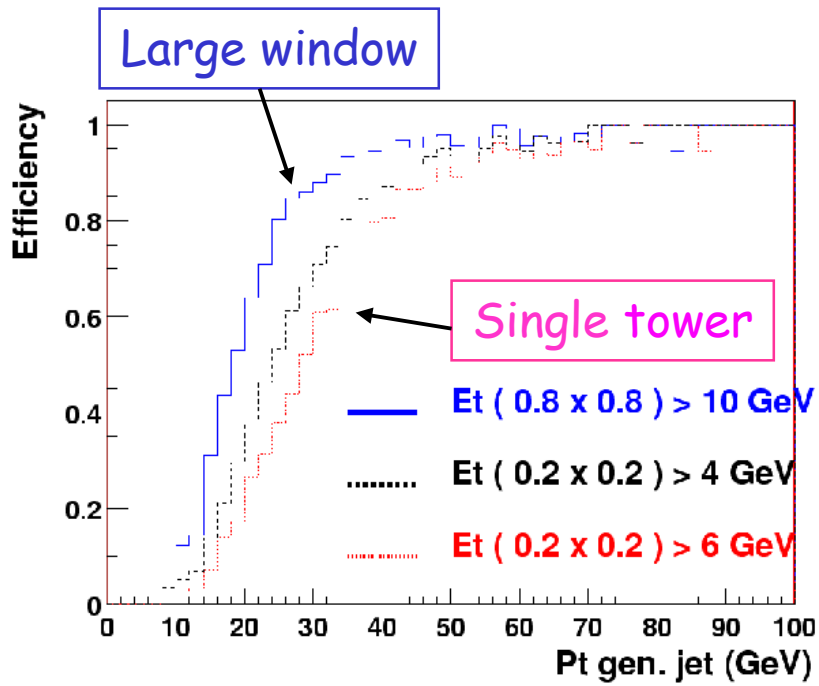
- Introduce digital filter on trigger tower signals
- Suppress pile-up effects
- Improve energy resolution
- Avoid triggering on wrong crossing (signal rise time > 132 ns)
  - Sample at peak to avoid timing variations
  - Previous crossing will often be above threshold
  - It would be the highest energy events (most interesting) which are mis-assigned

Calorimeter Trigger Upgrade



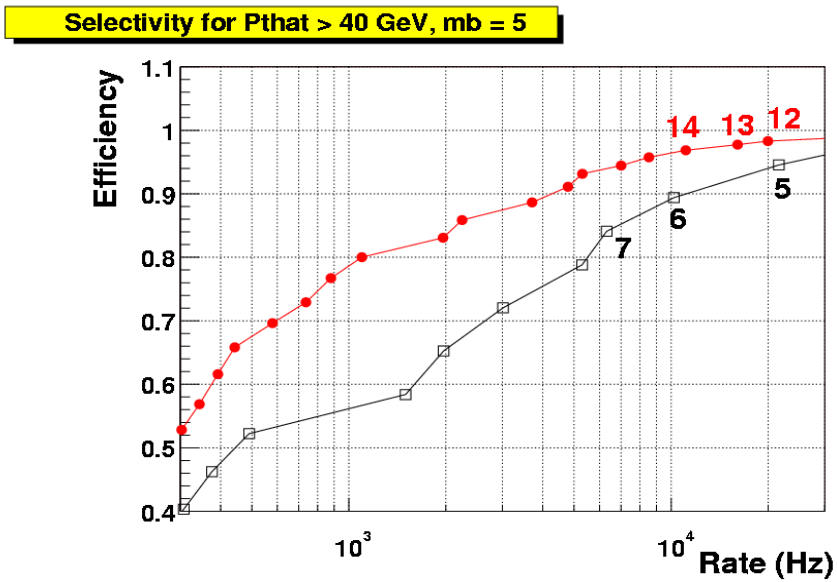


- Sharpen thresholds by introducing EM, Jet clustering

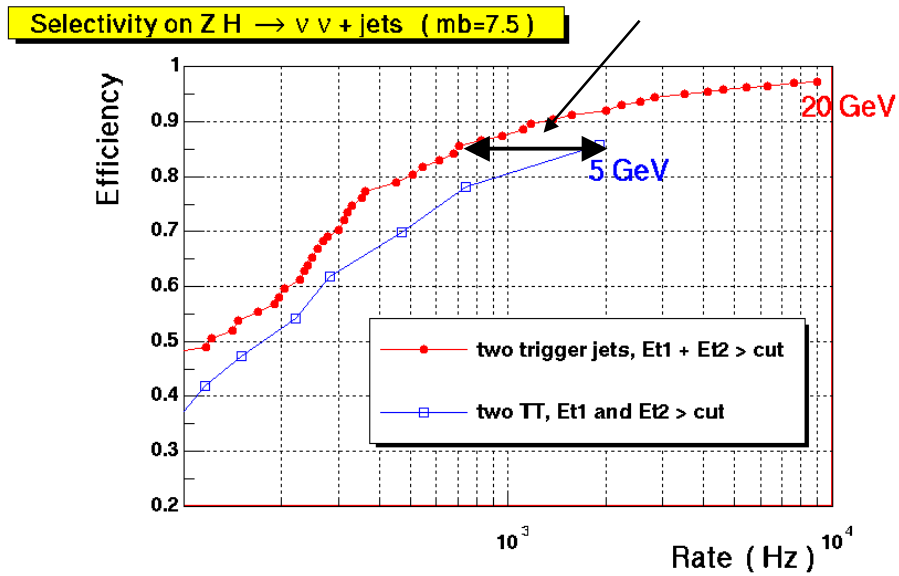


Calorimeter Trigger Upgrade

- Rate improvements from cluster thresholds vs. tower thresholds



×3

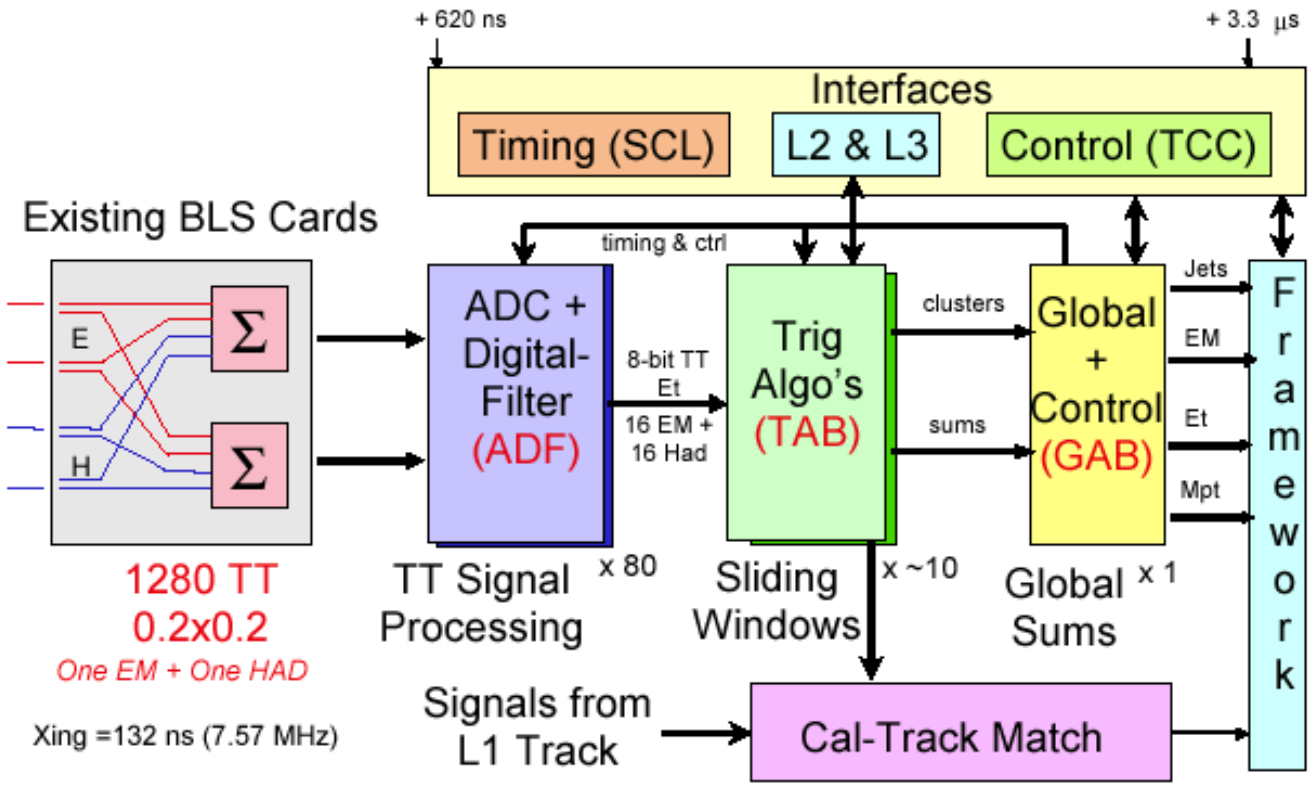


Single jet

$$ZH \rightarrow \nu\bar{\nu}b\bar{b}$$

Calorimeter Trigger Upgrade

- Clustering algorithm gets implemented in FPGA's
- Similar to ATLAS sliding-window algorithm



Calorimeter-Track matching

- Present calorimeter trigger allows calorimeter-track matching only by quadrant in azimuth
- Upgrade L1 Cal trigger would provide calorimeter matching information with 8 times finer granularity

- Additional factor of ~2 in background rejection for electron triggers (confirming EM clusters with high-p_T tracks)
- Additional factor of ~3 in background rejection for tau's (confirming high-p_T isolated tracks with EM+had energy)

Additional features

- Muon triggers – No change needed to muon trigger system, but most muon triggers would gain needed rejection from upgrade of the CTT FPGA's.
- Global calorimeter sums – better missing E_T with incorporation of intercryostat detector and massless gaps
- EM shape and isolation – these cuts can be implemented in Level 1 after cluster finding, giving an additional factor of 2 rejection for electron & photon triggers
- Topology – flexibility to require acoplanar jets, etc.
- Flexibility: New clustering and tracking algorithms can be implemented with FPGA downloads

Level 1 upgrade:Limited scope

- Studied and eliminated several upgrade options in favor of lower schedule-risk and/or cost:
  - Level 1 stereo tracking
  - Preshower as 9th tracking layer
  - Finer granularity of calorimeter towers (0.1x0.2)
- Use existing hardware (or minor modifications thereof) for new applications
  - Muon Trigger Cards for calorimeter-track matching
  - Existing DFE motherboards with daughter board replacement for tracking upgrade

Run 2b Level1 Trigger rates with upgrade

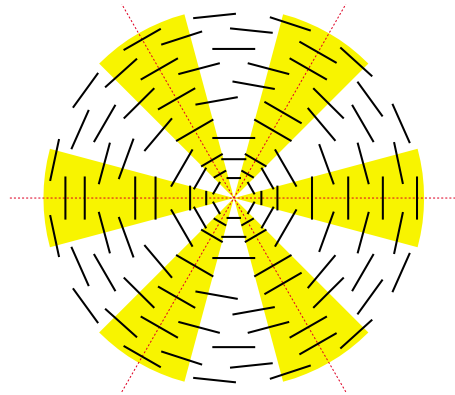
- Run2b: Δt=132ns, L=5x10^{32} cm^{-2}s^{-1}

Trigger	Example Physics Channel	Rate (no upg.)	Rate (w/ upgrade)
EM Trigger (1 EM tower > 10 GeV)	$W \to e\nu$	9 kHz	0.5 kHz
Jet Trigger (2 trigger towers > 4 GeV)	$ZH \to \nu\bar{\nu}b\bar{b}$	2 kHz	0.5 kHz
Track Trigger (2 trk > 10, 5 GeV, iso, EM)	$H \to \tau\tau$	60 kHz	0.7 kHz
Muon Trigger (muon > 10 GeV)	$W \to \mu\nu$	6 kHz	2 kHz
TOTAL		77 hKz	3.7 kHz

Total rate into Level 2 limited to 5 kHz

Level 2 Trigger

- Silicon Track Trigger
  - Vital for triggering on b-quarks
    - $ZH \rightarrow \nu\nu bb$
    - $Z \rightarrow bb$ (top mass jet energy scale)
  - Improves track trigger
    - Sharper p_T turn-on
    - Reduced fake rate
  - Upgrade needed to accommodate design of new silicon detector



- Level 2 β processors
  - Add 12 additional processors for higher Run2b luminosity
  - This additional processing power (X 2-3 increase over run2a) is needed to take advantage of the increased power at Level 1

Trigger Upgrade Project

- Summer 2001: DØ Trigger Task force studies upgrade options for trigger
- October 2001: Conceptual Design report produced, trigger upgrade presented to the Fermilab PAC
- December 2001: Reviewed by Director's Technical review committee. Scope approved:
  - "The proposed Level 1 trigger/DAQ upgrades are needed for the D0 experiment to function at an instantaneous luminosity of 5×10^{32} and a bunch spacing of 132ns. Without these improvements D0 will not be able to take useful data under Run 2b running conditions. "

Trigger Upgrade Project (cont.)

- Jan 2002: MRI proposal submitted for trigger upgrade
  - $2.6 M requested ($2.0 M from NSF)
- April 2002: Technical design report draft, cost estimate, resource-loaded schedule prepared for Director's Review Committee.

Trigger Upgrade Project

Sub-project	Institution(s)
Calorimeter: ADF	Saclay, MSU
Calorimeter: TAB	Columbia
Track trigger	Boston University, FNAL
Cal-Track match	U. of Arizona
Simulation & algorithms	Notre Dame, Saclay, Kansas, Manchester, Brown
Online software & integration	MSU, Northeastern, FSU,Langston
Level 2β	Orsay, Virginia
STT upgrade	Boston, Columbia, Stony Brook, FSU

- Strong, active institutions
- Largely University-driven
- Combination of Run2a experience and new ideas
- Other institutions expressing interest

Schedule Contingency

scenario	All production and testing complete	Trigger slippage (days)
default	12/10/04	0
extra ADF prototype revision & test	03/04/04	84
extra TAB prototype revision & test	03/04/05	84
extra GAB prototype revision & test	12/10/04	0
double time for all in-situ and integration tests	04/29/05	140
3rd prototype cycle for DFEAs	02/04/05	56
Cal-trk redesign after internal review	12/10/04	0
All of the above	06/24/05	196

Note: Shutdown period = 3/14/05 – 10/27/05
All scenarios leave at least 4 months for installation and commissioning

Conclusions

- Trigger Upgrades needed for:
  - Increased rejection at level 1 (x2-3)
  - Controlling rates with multiple interactions
  - Triggering on correct beam crossing at 132 ns
  - More sophisticated event selection at Level 2
  - **Selecting the events needed to discover the Higgs boson**