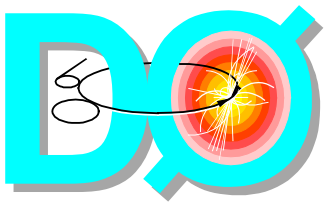


The DØ Run 2b Trigger Upgrade

Darien Wood, Northeastern University,
for the DØ collaboration

Fermilab PAC Meeting

November 2, 2001

Trigger Upgrades

Prior to L=5x10^{32} cm^{-1}s^{-1}

- SIFT replacement
- Level 2β
- Commercial DAQ system

Preparation for L=5x10^{32} cm^{-1}s^{-1}

- Level 1 Calorimeter Trigger upgrade
- Level 1 Track Trigger upgrade
- Level 1 Calorimeter-Track match
- Level 2 Silicon Track Trigger Upgrade
- Level 2β Upgrade
- Online System

All described in Trigger CDR, but only underlined upgrades mentioned in this talk.

Run 2b Trigger Upgrade Goals

- Critical need to upgrade trigger systems
  - » Increase trigger rejection to maintain existing rates with higher luminosity
  - » Ensure efficient triggering for full range of Higgs channels
- Biggest challenges at Level 1
  - » Input rate to Level 2 limited to 5 kHz (readout time)
  - » Need to get the events to level 2, where more handles are available (Silicon Track Trigger)
- Level 2 trigger rate limited to 1.8 kHz by calorimeter readout
- High p_T triggers expected to exceed these limits in Run 2b
- Need to increase trigger rejection, particularly at Level 1
  - » L1 Calorimeter trigger upgrade to sharpen thresholds
  - » L1 Tracking trigger upgrade to maintain rejection
  - » L2/L3 Processor upgrades

Run 2b Trigger Task Force

- **Run 2b Trigger Task Force in place Mon, 6/25/01:**
  - **Co-Chairs: M. Hildreth (Notre Dame), R. Partridge (Brown U)**

- Calorimeter
  - M. Abolins (MSU)
  - D. Baden (UMaryland)
  - B. Kehoe (MSU)
  - P. Le Du (Saclay)
  - E. Perez (Saclay)
  - M. Tuts* (Columbia)
  - V. Zutshi (BNL)
- Technical/Hardware
  - D. Edmunds (MSU)
  - M. Johnson* (Fermilab)
  - J. Linnemann (MSU)
  - D. Schamberger (Stony Brook)
- Tracking
  - B. Abbott (UOklahoma)
  - D. Alton (UMichigan)
  - V. Bhatnagar (Orsay)
  - F. Borcherding (Fermilab)
  - S. Chopra (BNL)
  - F. Filthaut (UNijmegen)
  - Y. Gerstein (Brown U)
  - G. Ginther* (URochester)
  - P. Petroff (Orsay)
- Muon
  - J. Butler (Boston U)
  - K. Johns* (UArizona)

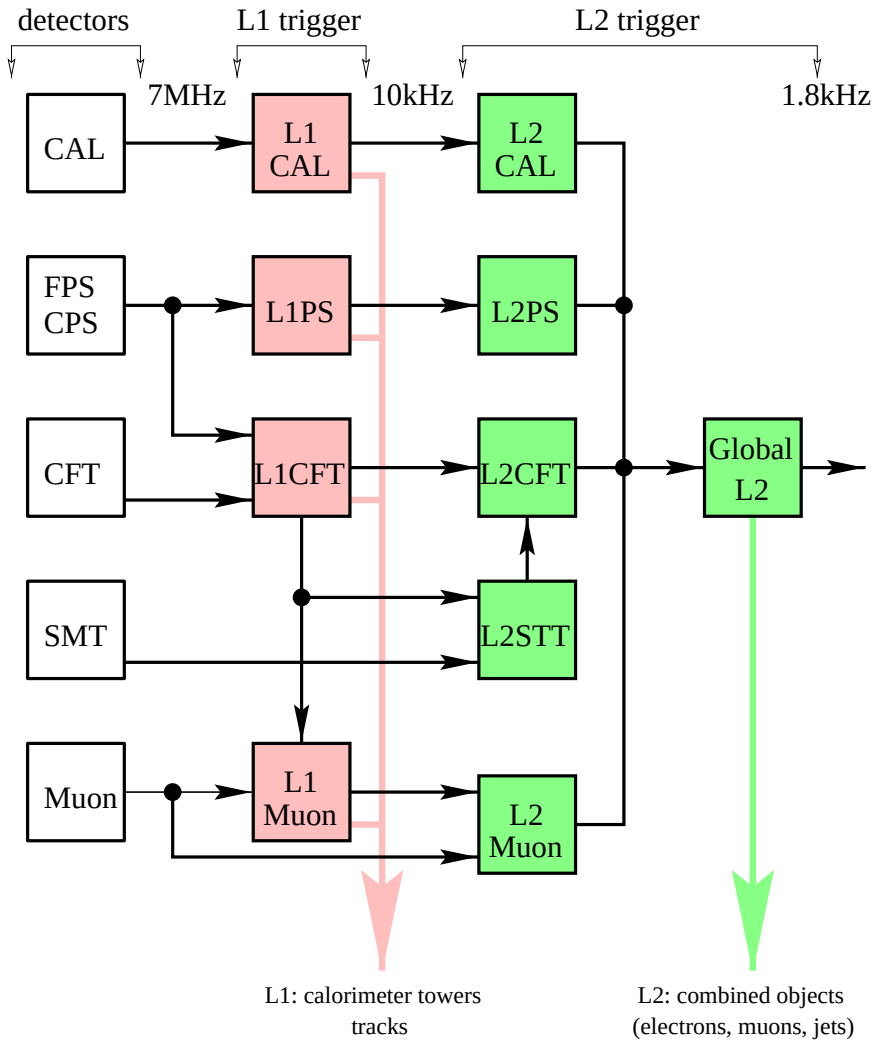
*** = Sub-Group Chair**

Trigger Task Force
(cont'd)

- Task Force Charge:
  - Develop plan for Run 2b trigger system that allows D0 to run at 132 nsec & lum 5E32 with output rates:
    - Level 1: 5 kHz
    - Level 2: 1 kHz
    - Level 3: 50 Hz
  - Installed in summer 2004
  - Reasonable cost, technical resources, development & production time, low impact on existing detector, infrastructure:
    - No tracker replacement, limited cable plant replacement, limit number additional crates in MCH, …
- Conceptual Design Proposal submitted to Run 2b Project Mgr by Sep 17, 2001
  - Given tight time constraints (3 months):
    - Focus on high-pT physics program, Higgs search
    - Estimate rates, rejection for various options (simulation)
      - Level 1 calorimeter, track match, singlets/doublets, CFT stereo,…
    - Focus on Level 1
      - Feasibility arguments for Levels 2,3 may be sufficient

DØ Trigger Architecture

- Level 1
  - » Calorimeter trigger
  - » Fiber tracker trigger
  - » Preshower (e/γ) trigger
  - » Muon trigger
- Level 2
  - » Silicon track trigger
  - » Introduce Correlations, Refine Level 1 decision
- Level 3
  - » Full event information available
  - » Farm of high-performance computing nodes

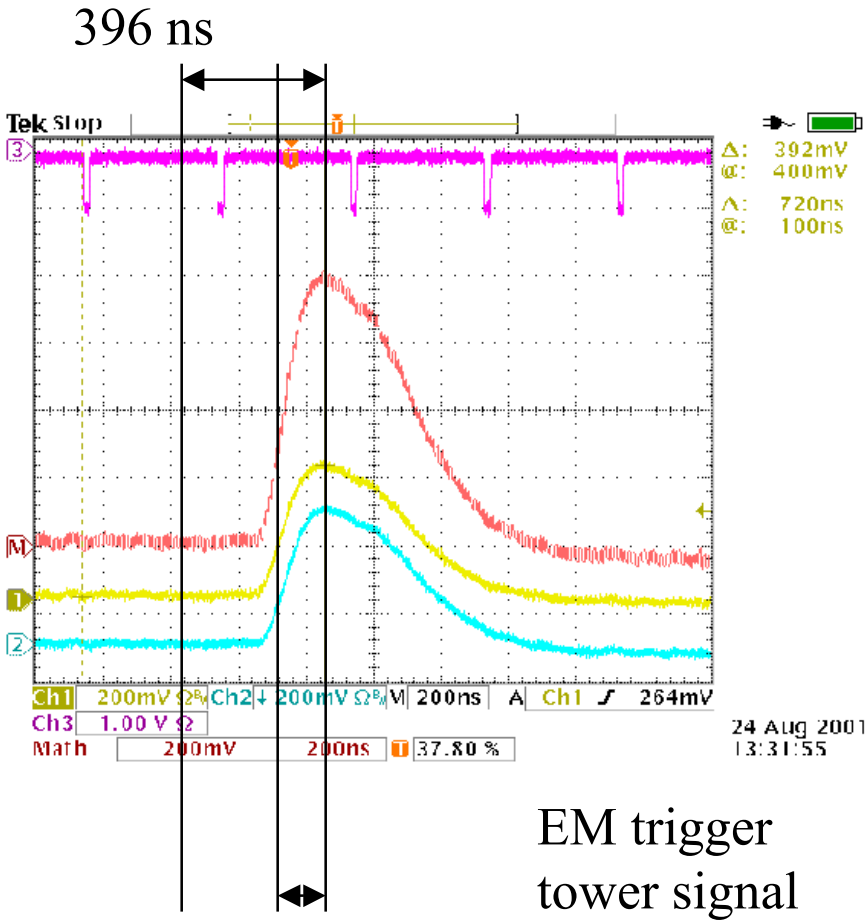


Sample run 2b Trigger rates

- $5x10^{32}$ $cm^{-2}s^{-1}$, assuming no trigger upgrades
- High p_T trigger menu exceeds available bandwidth

Trigger	Physics	Level 1 rate (kHz)
EM tower > 10 GeV	$W \rightarrow e\ \nu$	5
2 Tracks (>10 & 5 GeV) +isolation + EM>2 GeV	$H \rightarrow \tau^+\tau^-$	10
2 Had+EM towers, sum > 4 GeV	$ZH \rightarrow \nu\bar{\nu}b\bar{b}$	2

Calorimeter Trigger Upgrade

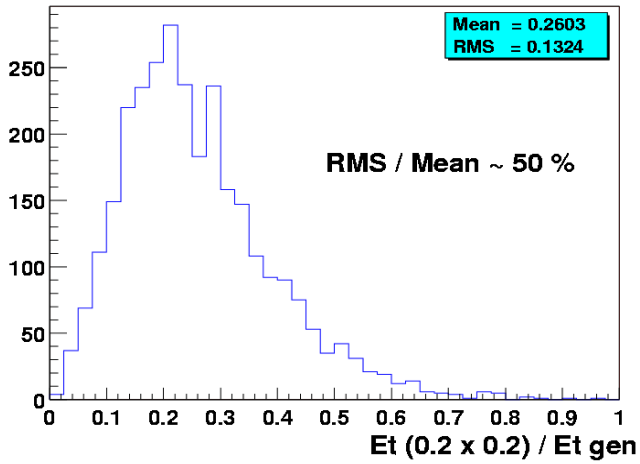


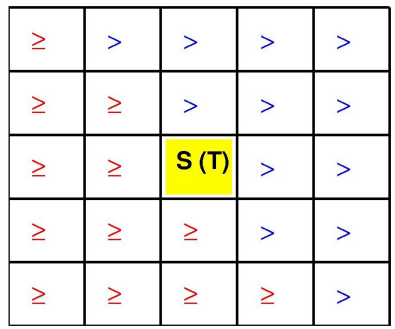
EM trigger tower signal

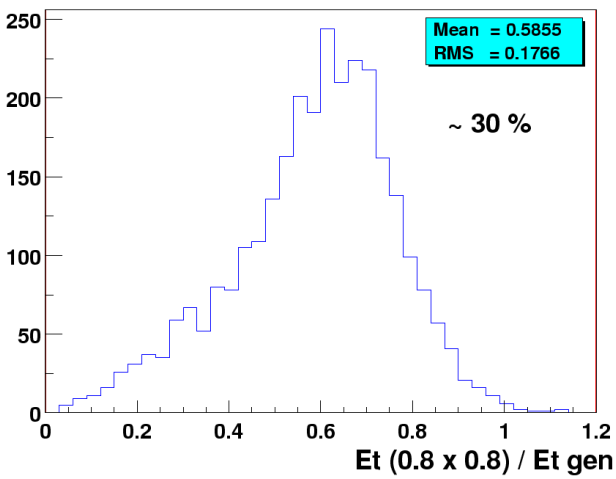
- Introduce digital filter on trigger tower signals
- Suppress pile-up effects
- Improve energy resolution
- Avoid triggering on wrong crossing (signal rise time > 132 ns)
  - » Sample at peak to avoid timing variations
  - » Previous crossing will often be above threshold
  - » It would be the highest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

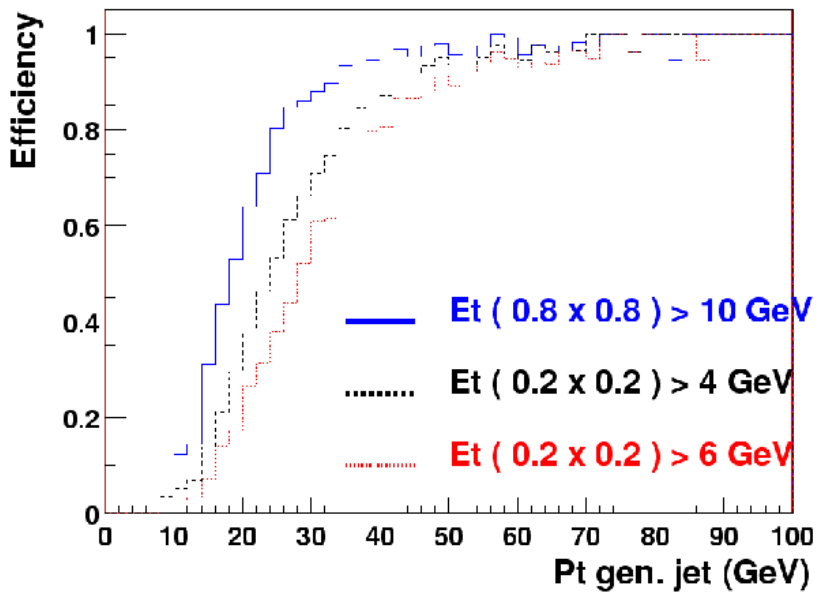
Calorimeter Trigger Upgrade

- Sharpen thresholds by introducing EM, Jet clustering



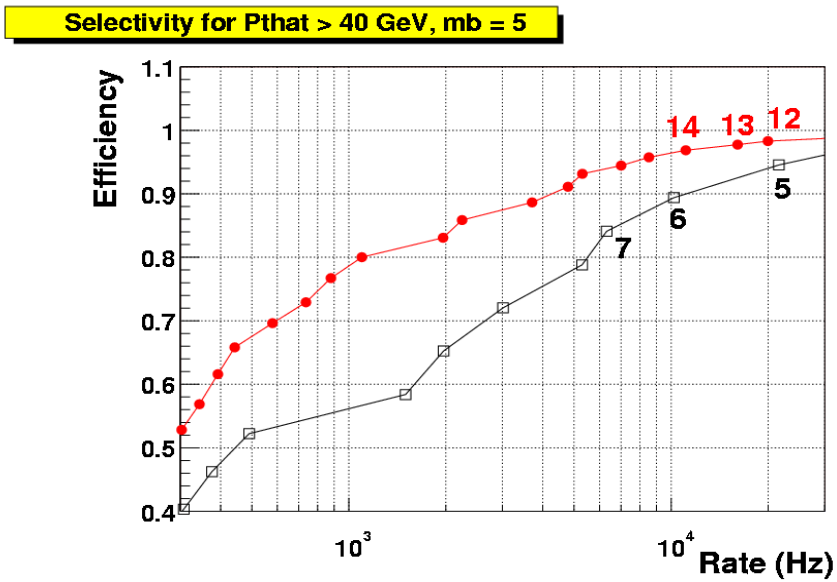


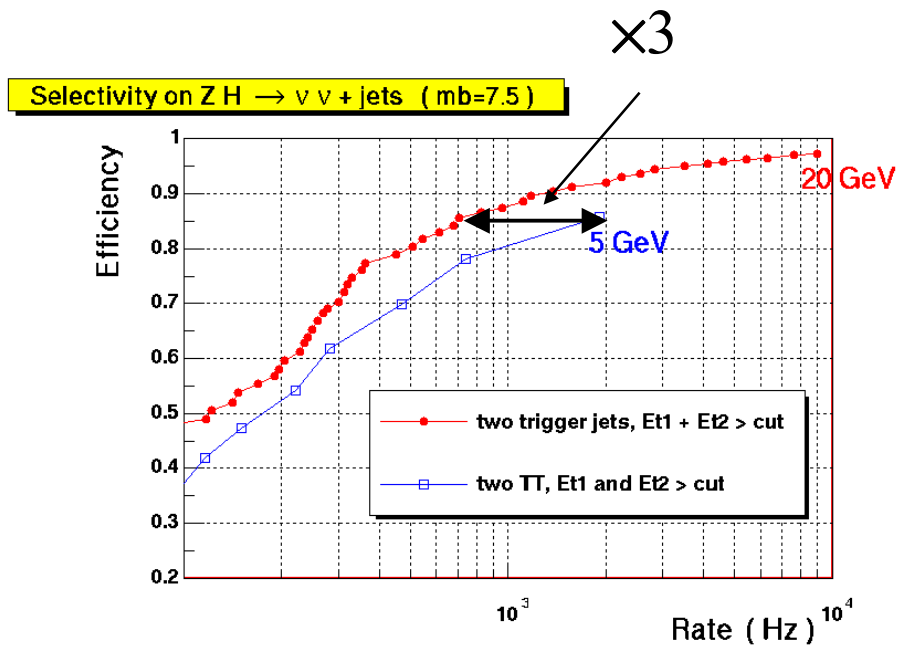




Calorimeter Trigger Upgrade

- Rate improvements from cluster thresholds vs. tower thresholds



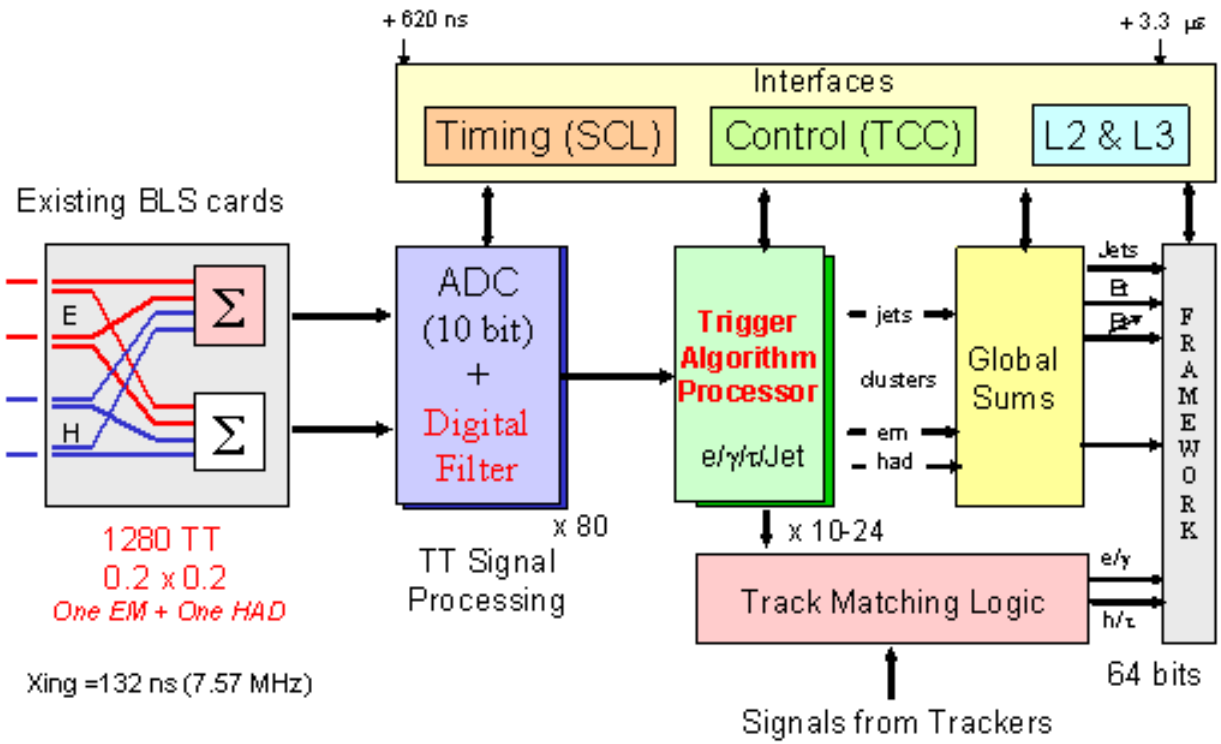


Single jet

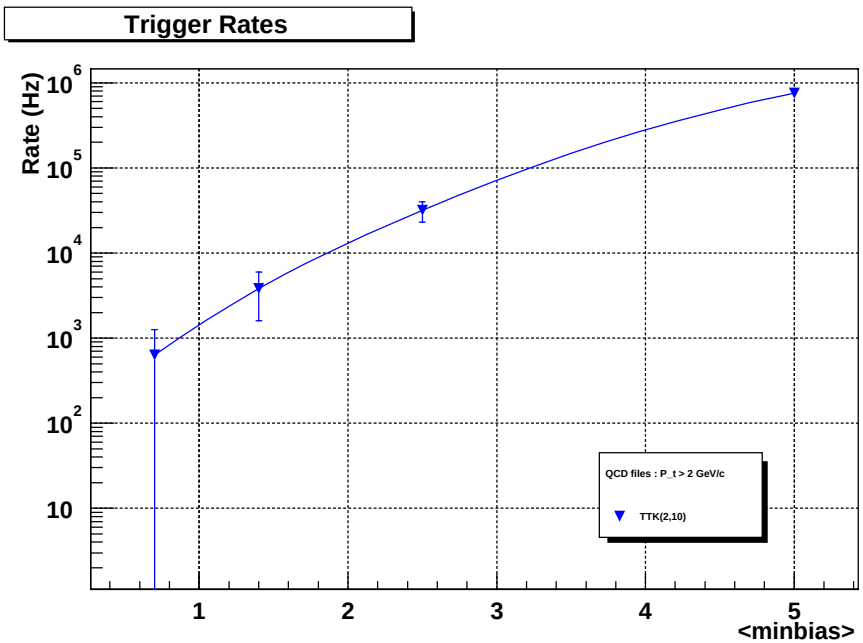
$$ZH \rightarrow \nu\bar{\nu}b\bar{b}$$

Calorimeter Trigger Upgrade

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

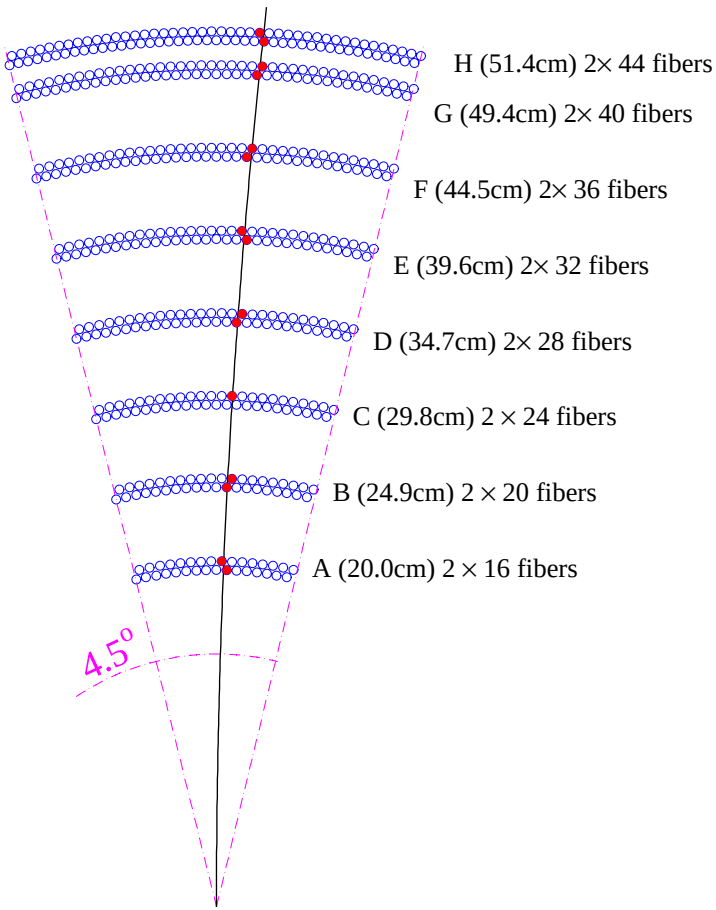


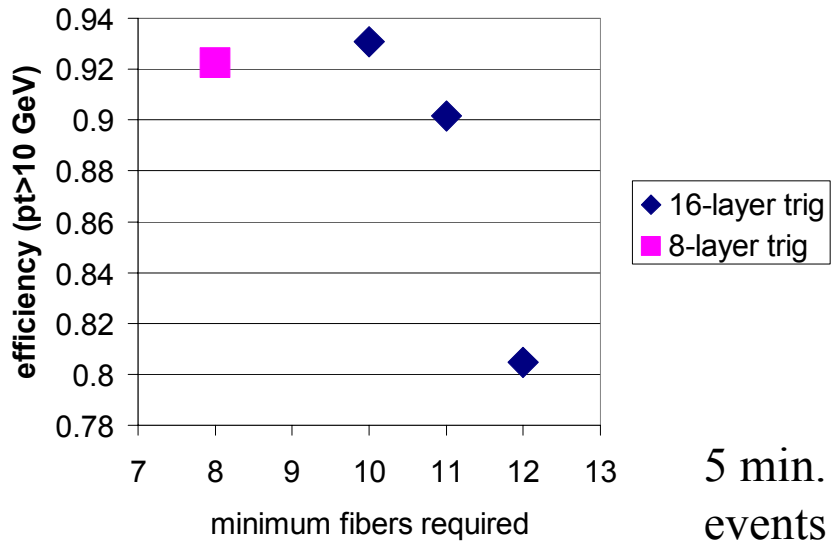
Tracking Trigger Upgrades



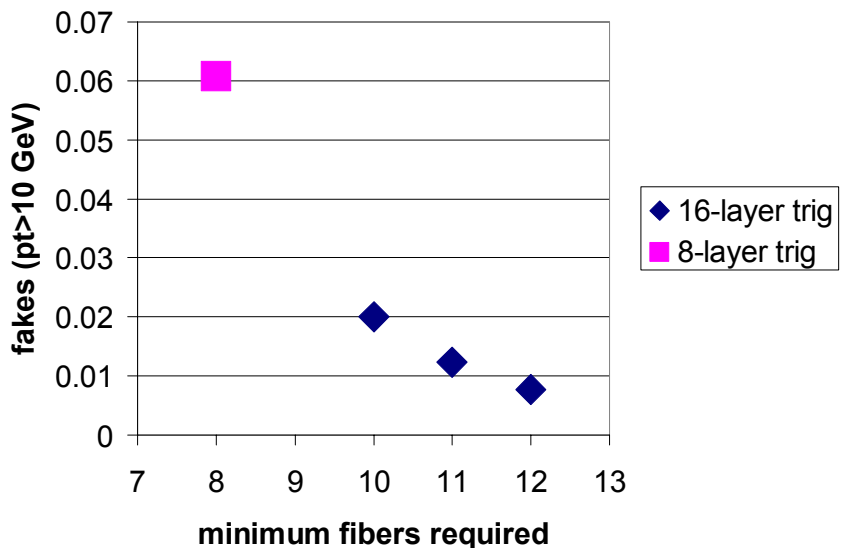
- Level 1 Central Track Trigger (CTT) essential for electrons, muons, taus (WH→lνjj)
- Tracking trigger rates sensitive to occupancy
- Upgrade proposal:
  - Narrow tracker roads by using individual fiber hits (singlets) rather than pairing adjacent fibers (doublets)
  - Cal-track matching

Tracking Trigger Upgrades





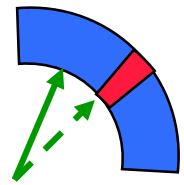
5 min. bias events



Review of SIFT Replacement

- Fiber Tracker Trigger Chip (SIFT) must be replaced for 132 nsec running
  - Required 50-70 nsec charge collection times result in inefficiencies with current chip at 132 nsec
  - Costly, some technical challenges
- Review of design, implementation: September 25, 2001
- Committee consisted of 2 D0 physicists, 3 non-D0 engineers:
  - M. Bowden, V. Buescher, M. Larwill, R. Lipton (chair), V. Pavlicek
- Findings:
  - Endorse overall design
    - With caveat that many details remain
  - Performance should equal that of present chip at 396 nsec
  - Recommend option that includes AFE board replacement
  - If single ASIC submission, schedule reasonable for November '02 changeover to 132 nsec
  - For dual submission, schedule tight, assuming changeover remains on above schedule
- Firm schedule for 132 nsec changeover not yet established

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)
- Modest extension to proposed calorimeter trigger upgrade
  - » Can use same hardware (Muon Trigger Cards) that presently does Level1 muon-CTT match
  - » Can possibly just send CTT information to last stage of Level 1 calorimeter algorithm boards

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)
- Studying use of existing hardware for new applications
  - Muon Trigger Cards for calorimeter-track matching
  - Tracker Digital Front Ends (DFE) for calorimeter cluster algorithms
  - Existing DFE motherboards with daughter board replacement for tracking upgrade

Additional features

- Muon triggers – No change needed to muon trigger system, but most muon triggers would gain 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 1Trigger rates comparison

- $L = 5x10^{32}\ cm^{-2}s^{-1}$

Trigger	Physics	Level 1 rate, no upgrades (kHz)	Level 1 rate, w/ upgrades (kHz)
EM tower > 10 GeV	$W \rightarrow e\ \nu$	5	0.3 (track matching, 16-layer, EM fraction)
2 Tracks (>10 & 5 GeV) +isolation + EM>2 GeV	$H \rightarrow \tau^+\tau^-$	10	1 (calorimeter matching)
2 Had+EM towers, sum > 4 GeV	$ZH \rightarrow \nu\bar{\nu}b\bar{b}$	2	0.6 (calorimeter clustering)

Costs

(Intend to submit trigger MRI this Winter)

Level 1calorimeter upgrade

Item/process	Unit Cost ($)	# Require	Total Cost ($k)	Total Cost + 100% Contingency
ADC/digital filter system				
ADC/filter cards	3500	105	368	
Crates & power supplies	7100	8	57	
Controller cards	2000	8	16	
VME masters	2300	10	23	
Subtotal			*464*	*928*
Digital Algorithm System				
Trigger algorithm cards	7500	30	225	
Crates & power supplies	3000	3	9	
Controller cards	500	4	2	
Subtotal			*236*	*472*
LVDS cables	75	350	26	52
TOTAL			*$726*	***$1,452***

Level 1 tracking upgrade

Item/process	Unit Cost ($)	# Require	Total Cost ($k)	Total Cost + 50% Contingency ($k)
Fabricate Daughter Boards	500	88	44	66
Purchase new FPGA	900	350	315	473
TOTAL			*$360*	***$540***

Item/process	Unit Cost ($)	# Require	Total Cost ($k)	Total Cost + 50% Contingency ($k)
Mu Trig Cards	3300	9	30	45
Serial Link Daughters	100	256	26	39
Crates, cables, etc.	44000	1	44	66
TOTAL			*$100*	***$150***

Cal-track matching

Schedules & Manpower

calorimeter

Milestone date	Task
03/02	Performance specification defined, major design choices made
08/02	Prototype design complete
12/02	Prototyping complete (ADC, TAP,…)
06/03	Prototype testing complete
09/03	Preproduction complete
12/03	Preproduction testing complete
06/04	Production complete, testing begins
07/04	Installation & commissioning starts
01/05	Commissioning complete

tracking

Prototype algorithm coded and simulated using FPGA simulation tools	2/02
Target algorithm coded and simulated using FPGA simulation tools	6/02
Prototype boards delivered	1/03
Production boards delivered	10/03
Daughter boards tested and ready for installation	4/04

- Fully loaded schedule under preparation to estimate manpower
- Large project
- Many groups in the collaboration have expressed interest in participating, and have resources becoming available (engineering, technicians, physics):
  - Saclay,LAL Orsay, Paris VI, MSU, Columbia/Nevis, Arizona, Boston, Northeastern, Notre Dame, Manchester,…

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)
  - » Upgrade needed to accommodate design of new silicon detector
  - » Most efficient to include additional modules in early '02 production
- Level 2 β processors
  - » Replace unreliable alpha processors
  - » Add additional processing power for higher Run2b luminosity

Conclusions

- Upgrades needed at level 1 to cope with:
  - need for increased rejection at level 1
  - Controlling rates even with multiple interactions
  - Triggering on correct beam crossing at 132 ns
- Since last PAC meeting, extensive study of triggering options has been completed, resulting in a conceptual design for calorimeter and tracking upgrades
  - Scope has been limited due to constraints in schedule, manpower, and costs
  - Design offer considerable flexibility to deal with unanticipated physics requirements
  - We are ready to begin the detailed design and assemble the project
- We request Stage 1 approval for the trigger upgrades