The DØ Run IIb L1Cal (past, present & future)

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Why Give This Talk?

1. Introduce/Attract New Participants
2. Review Where We Are
3. Remember Constraints: Cost & Schedule
4. Start Discussion on Where We're Going

Outline

1. Overview & Review
   - Physics Goals
   - System Architecture
   - The Current Team
2. Current Status
   - Boards in the System
   - Prototype Integration Test
3. Where Do We Stand
   - Cost & Schedule
   - Where We Need Help
4. Getting to the End
   - What Should We Do (start of discussion)

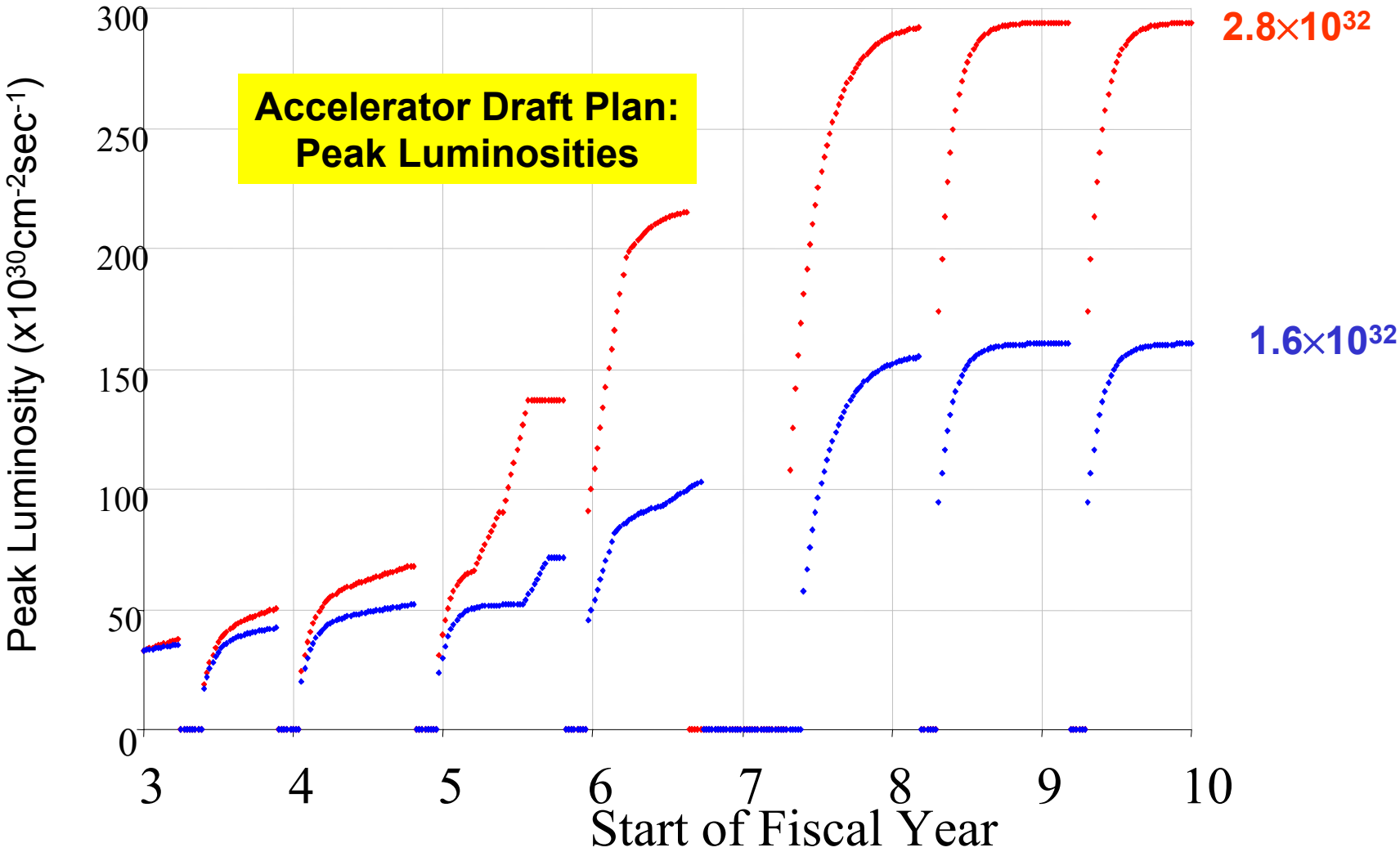
（5. Handy Glossary of Acronyms）

L1Cal is Key (Higgs or No)

L1 Calorimeter Trigger is the primary mechanism for collecting: e/γ, Jets, Invisible Particles (ME_T)

Physics	Sample Channels	Cal Triggers
Electro-Weak	$W \to \ell\nu$ / $Z \to \ell^+\ell^-$	EM, ME_T
Top	$t\bar{t} \to \ell\nu$ + jets, all jets $Z \to b\bar{b}$	EM, Jet (calibrate E-scale)
B Physics	B_s Mixing (hadronic)	EM, Cal-Track
New Phenomena	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to \tilde{\chi}_1^0\ell\nu\ \tilde{\chi}_1^0\ell^+\ell^-$ $\tilde{t}_1 \to bW^+\tilde{\chi}_1^0$, $G_{KK} \to \gamma\gamma$	EM, Jet, ME_T
Higgs	W/Z $H \to \ell\nu$ / $\nu\nu\ b\bar{b}$ $H \to W^{(*)}W$	EM, Jet, ME_T

What Can We Expect



But Rate is a Problem

Trigger	Run IIa Definition	Example Channel	L1 Rate [kHz] (no upgrade)	L1 Rate [kHz] (w/ upgrade)
EM	1 EM TT > 10 GeV	$W \to e\nu$ $WH \to e\nu jj$	1.3	0.7
DiEM	1 EM TT > 7 GeV 2 EM TT > 5 GeV	$Z \to ee$ $ZH \to eejj$	0.5	0.1
Muon	1 Mu Pt > 11 GeV CFT Track	$W \to \mu\nu$ $WH \to \mu\nu jj$	6	1.1
Di-Mu	2 Mu Pt > 3 GeV CFT Tracks	$Z/\psi \to \mu\mu$ $ZH \to \mu\mu jj$	0.4	<0.1
e + Jets	1 EM TT > 7 GeV 2 Had TT > 5 GeV	$WH \to e\nu jj$ $tt \to e\nu$+jets	0.8	0.2
Mu + Jet	1 Mu Pt > 3 GeV 1 Had TT > 5 GeV	$WH \to \mu\nu jj$ $tt \to \mu\nu$+jets	<0.1	<0.1
Jet+MEt	2 TT > 5 GeV MEt > 10 GeV	$ZH \to \nu\nu bb$	2.1	0.8
Mu+EM	1 Mu Pt > 3 GeV + Trk 1 EM TT > 5 GeV	$H \to WW, ZZ$	<0.1	<0.1
Iso Trk	1 Iso Trk Pt > 10 GeV	$H \to \tau\tau$, $W \to \mu\nu$	17	1.0
Di-Trk	1 Iso Trk Pt > 10 GeV 2 Trk Pt > 5 GeV 1 Trk matched w/ EM	$H \to \tau\tau$	0.6	<0.1
Total Rate Cal Rate			~30 4.7	3.9 1.8

Luminosity
2×10^{32}

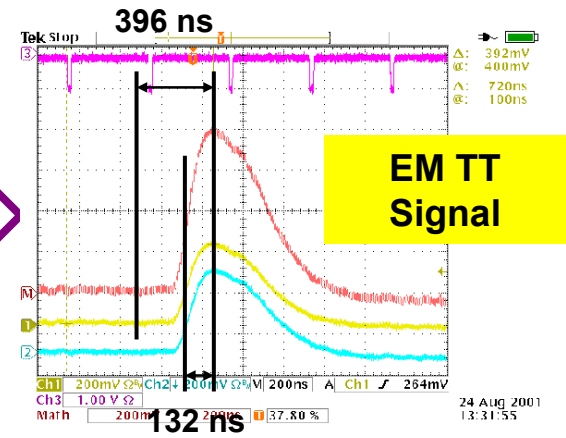
BC
396 ns

L1 Limit
~3 kHz

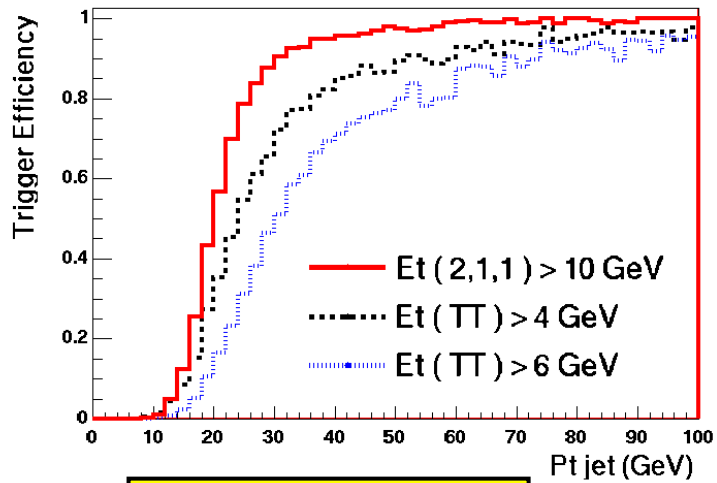
Run IIa Limitations

1. **Signal rise > 132 ns**
   - cross thrsh before peak ⇒ trigger on wrong x'ing
   - affects high-Et events
   - prevents 132 ns running

2. **Poor Et-res. (Jet,EM,MEt)**
   - slow turn-on curves
     - 5 Gev TT thresh ⇒ 80% eff. for 40 GeV jets
   - low thresholds ⇒ unacceptable rates at $\mathcal{L} = 2\times10^{32}$



Turn-on curves : 2,1,1 algo vs current trigger

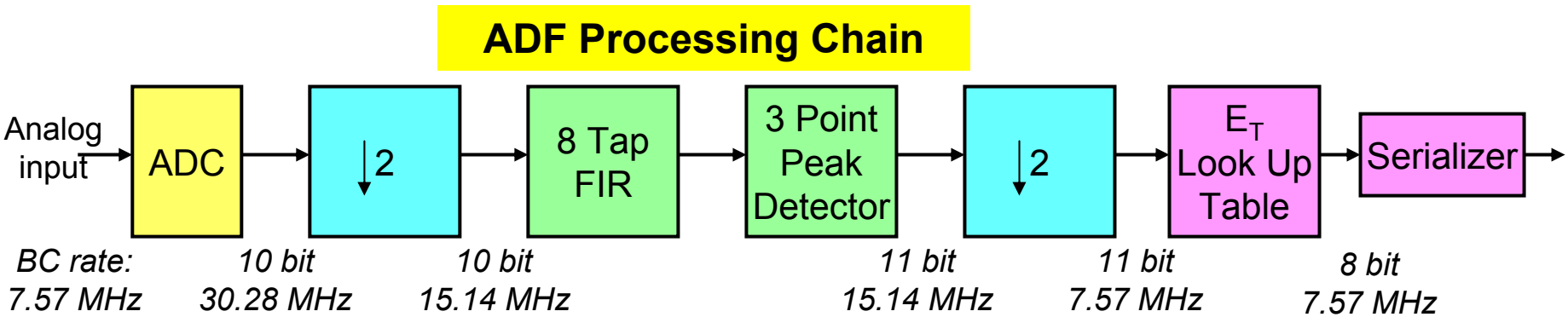


Trigger	Phys. Chan	Rate (kHz)
EM Trigger 1 TT>10 GeV	W → ev	1.3
Jet Trigger 2 TT>5 GeV + MEt>10 GeV	ZH → vvbb	2.1 (L = 2e32)

L1 Rate Limit ~3 kHz

Run IIb Solutions (1)

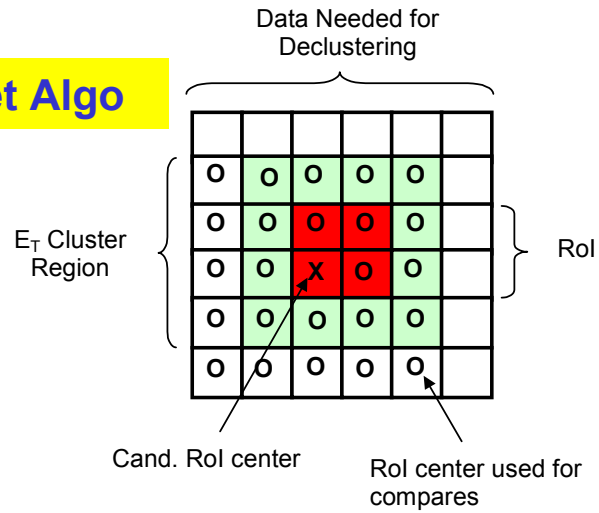
- **Solution to Signal Rise Time: Digital Filtering**
  - digitize Cal trigger signals
  - 8-tap FIR (6-bit coeff's) + Peak Detector run at BC×2
  - reformats output for transmission to physics algo stage
- **Benefits**
  - allows running at 132 ns (keeps this option open)
  - improvements in energy resolution (under study)
  - note: this stage is necessary as input to algo stage



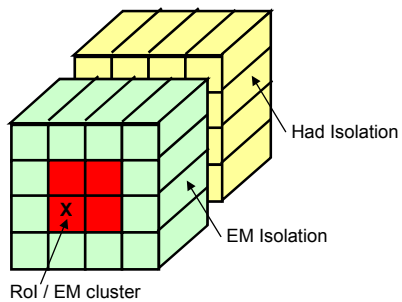
Run IIb Solutions (2)

- **Solution for Rates:**
  Sliding Windows Algorithm
  - Et cluster local max. search on 40×32 (η×φ) TT grid
  - Jet, EM & Tau algo's
  - Better calc of missing Et
  - Topological Triggers
  - Jet, EM clust output for matching with L1 Tracks
- **Benefits**
  - ×2.5–3 Jet Rate reduction at const. eff.
    - ZH→*vv*bb Rate: 2.1→0.8 kHz
  - Similar gains for EM &Tau
  - MEt, Topological Triggers under study

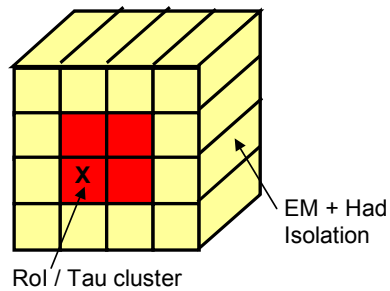
Jet Algo



EM Algo

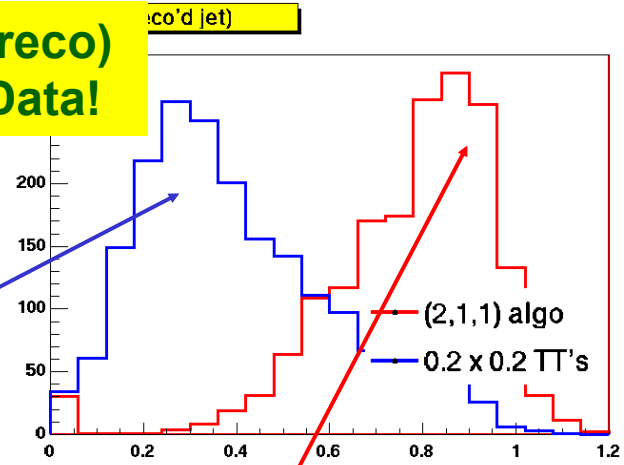


Tau Algo



Algorithm Results

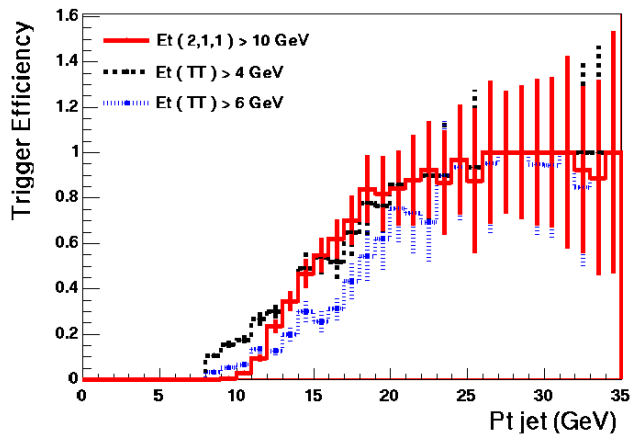
Et(trig) / Et(reco) w/ Run IIa Data!

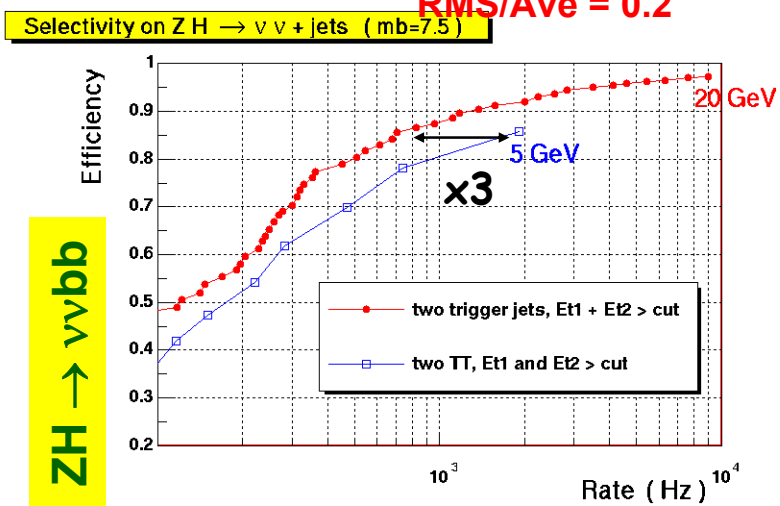


TTs
Ave = 0.4
RMS/Ave = 0.5

Sliding Windows
Ave = 0.8
RMS/Ave = 0.2

Turn-on Curves from data

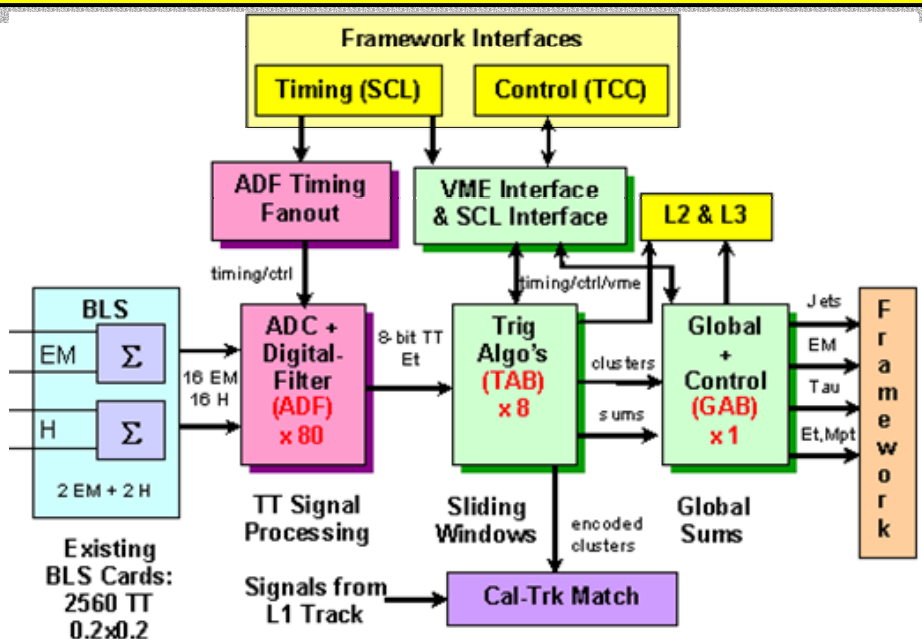




ZH → ννbb

Algorithm Study Status		
Algo	**Rate Red. @ const eff**	**Comments**
Jet	2.5 – 3	most studied
EM	?	gains possible ???
Tau	*O*(2)	very preliminary
ICR	?	tools available

The Run IIb L1Cal System



Custom Board	No	Purpose
ADF: ACD/Dig. Filt.	80	digitize, filter, E-to-Et
ADF Timing F'out	4	ADF control/timing
TAB: Trig Algo Board	8	algo's, Cal-Trk out, sums
GAB: Global Algo Board	1	sums, trigs to FWK
VME/SCL Board	1	VME comm & timing f'out to TAB/GAB

The L1Cal Team

Saclay — **ADFs/ADF Timing/Splitters**

- **Physicists:** J.Bystricky, P.LeDu*, E.Perez
- **Engineers:** D.Calvet, Saclay Staff

Columbia/Nevis — **TABs/GABs/VME-SCL**

- **Physicists:** H.Evans*, C.Johnson, J.Parsons, J.Mitrevski
- **Engineers:** J.Ban, B.Sippach, Nevis Staff

Michigan State — **Framework/Online Software**

- **Physicists:** M.Abolins*, C.Brock, H.Weerts
- **Engineers:** D.Edmunds, P.Laurens

Northeastern — **Online Software**

- **Physicists:** D.Wood

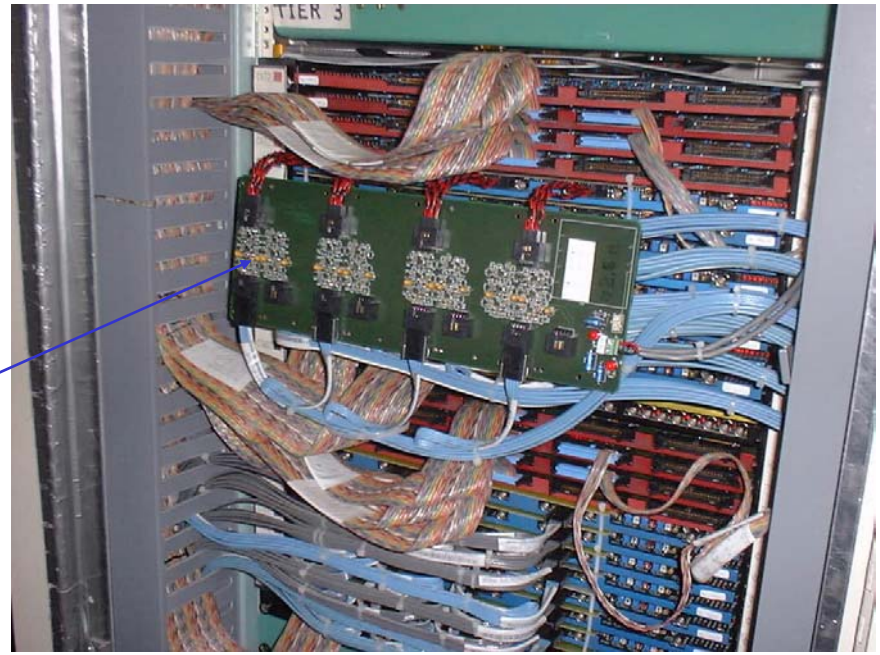
Fermilab — **Test Waveform Generator**

- **Engineers:** G.Cancelo, V.Pavlicek, S.Rapisarda

*** L1Cal Project Leaders**

Signal Splitter

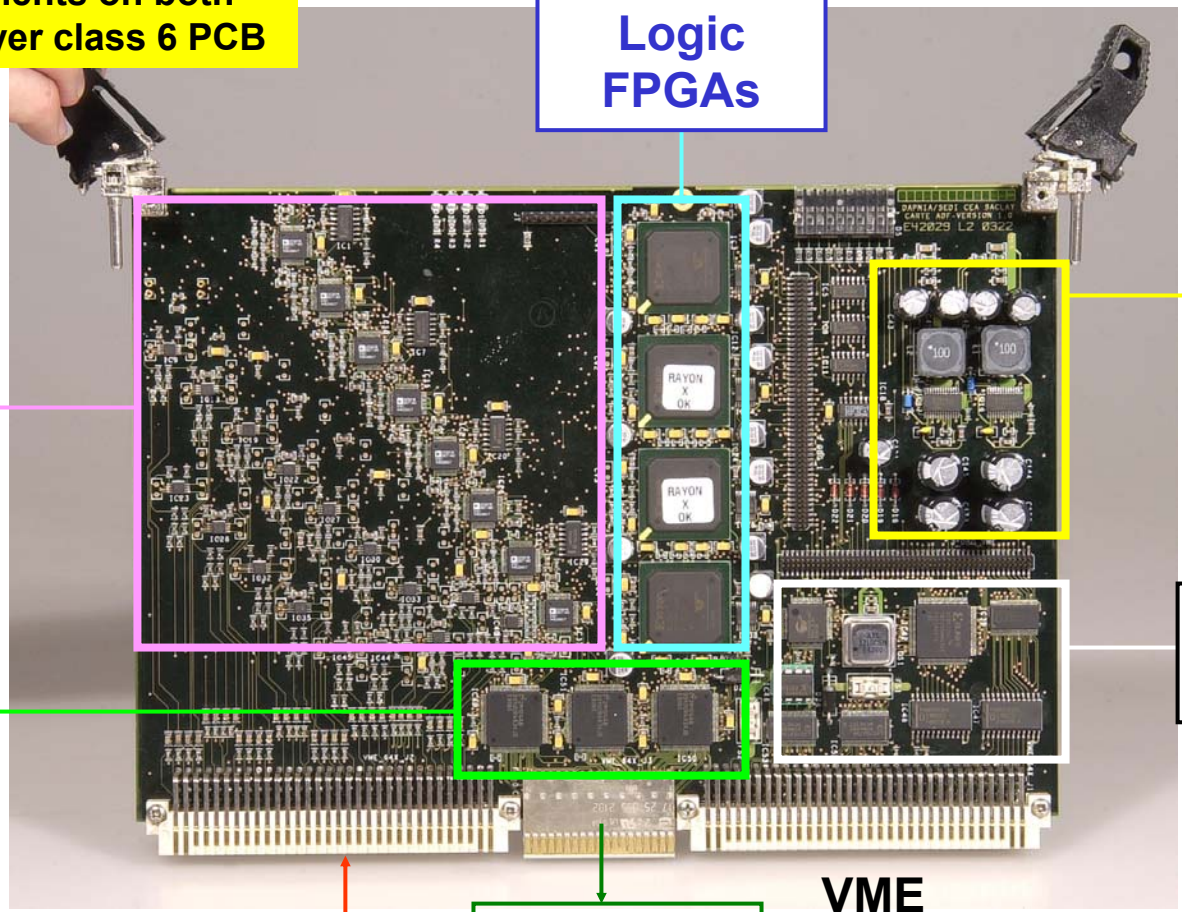
- **Access to Real TT Data using "Splitter" Boards**
  - designed/built by Saclay
  - active split of analog signals at CTFE input
  - 4 TTs per board
  - installed: Jan. 2003



- **Splitter Data**
  - no perturbation of Run IIa L1Cal signals
  - allows tests of digital filter algorithm with real data

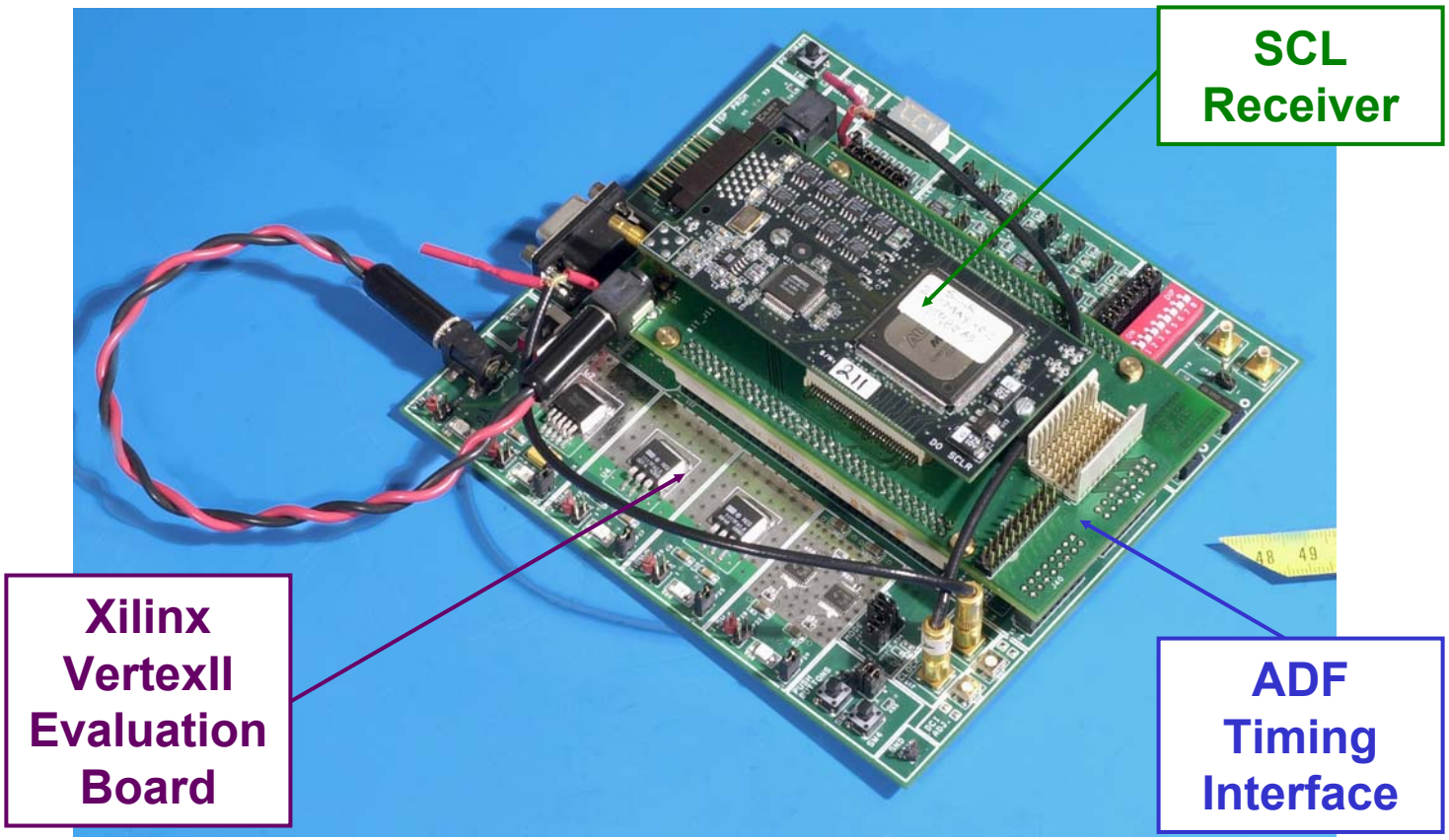
ADF Prototype

~1300 components on both sides of a 14-layer class 6 PCB

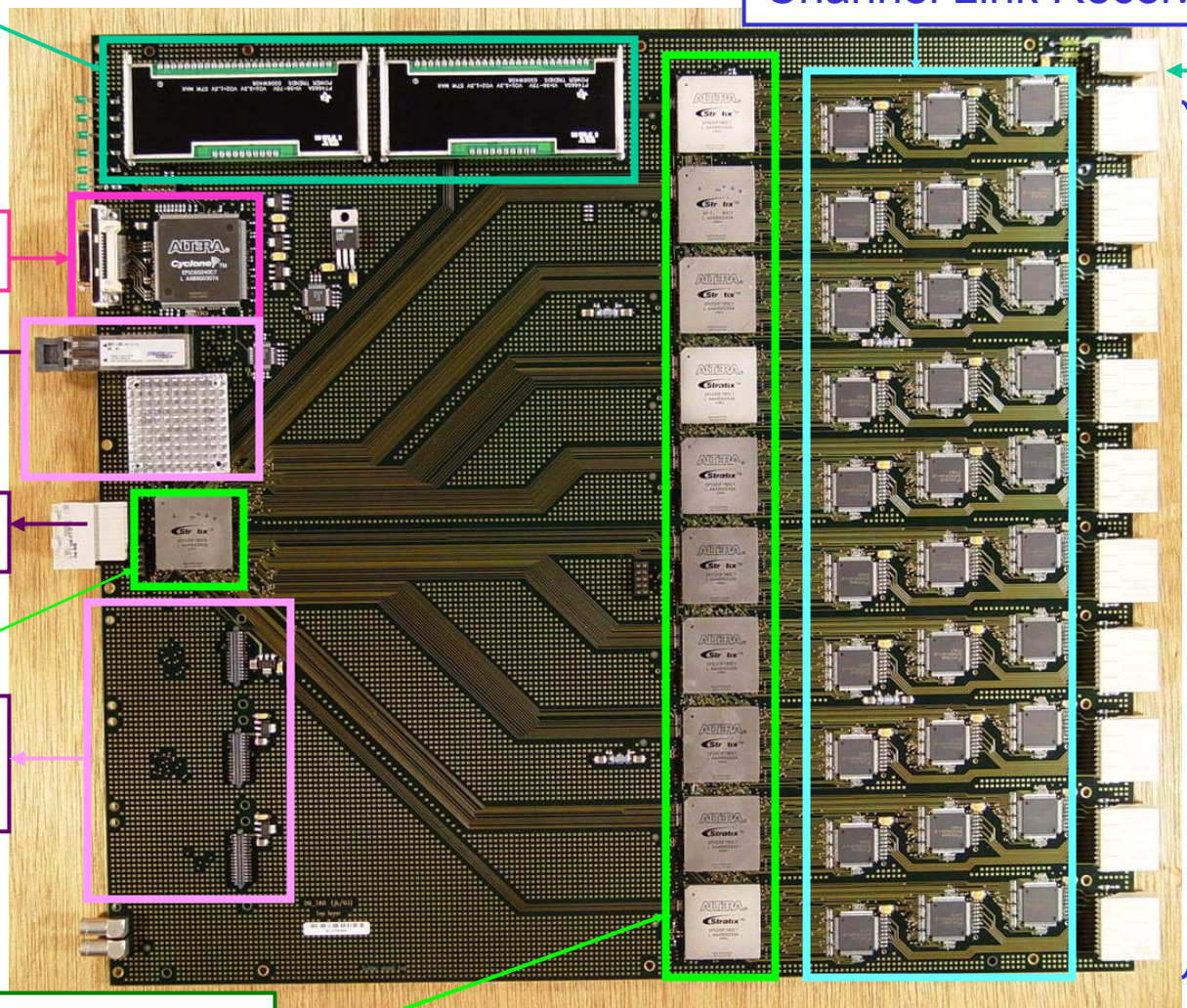


Internal Functionality mainly tested

ADF Timing Test Card



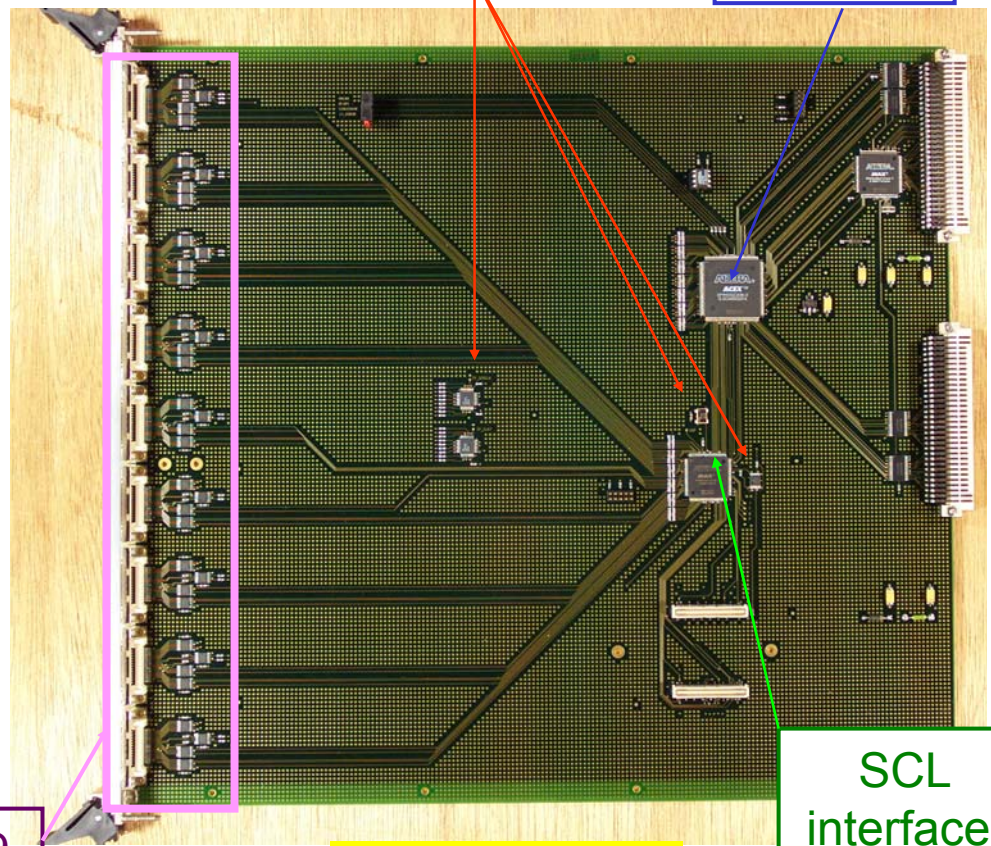
TAB Prototype



Internal Functions ~Fully Tested

VME/SCL Board

- New Comp. of TAB/GAB system
  - proposed: Feb 03
  - change control: Mar 03
- Interfaces to
  - VME (custom protocol)
    - not enough space on TAB for standard VME
  - D0 Trigger Timing (SCL)
  - (previously part of GAB)
- Why Split off from GAB
  - simplifies system design & maintenance
  - allows speedy testing of prototype TAB
- Fully Tested: Jun 12



TAB/GAB Test Card

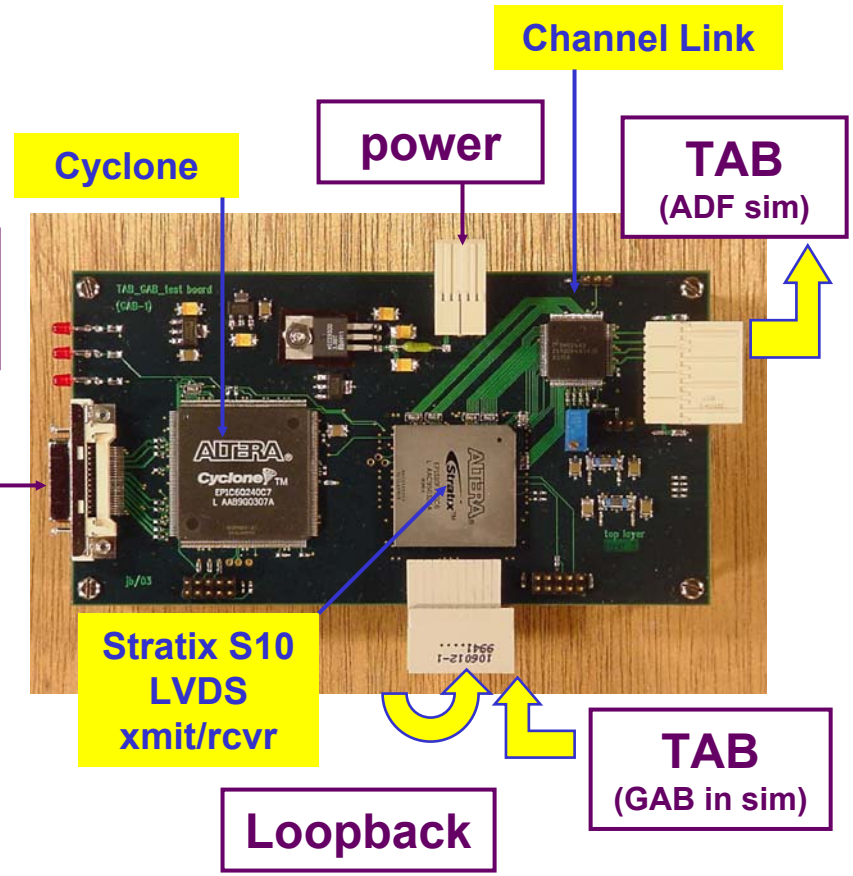
TAB/GAB Data Rates

- TAB: LVDS 424 MHz
  - (channel link)
- GAB: LVDS 636 MHz
  - (stratix)

Test Card at Nevis

- Start Design mid-Aug
- Board at Nevis 29-Sep
- Cost $790

- **Status**
  - ADF-to-TAB xmit tested before integration
  - Will test TAB-to-GAB before sending out GAB for fabrication



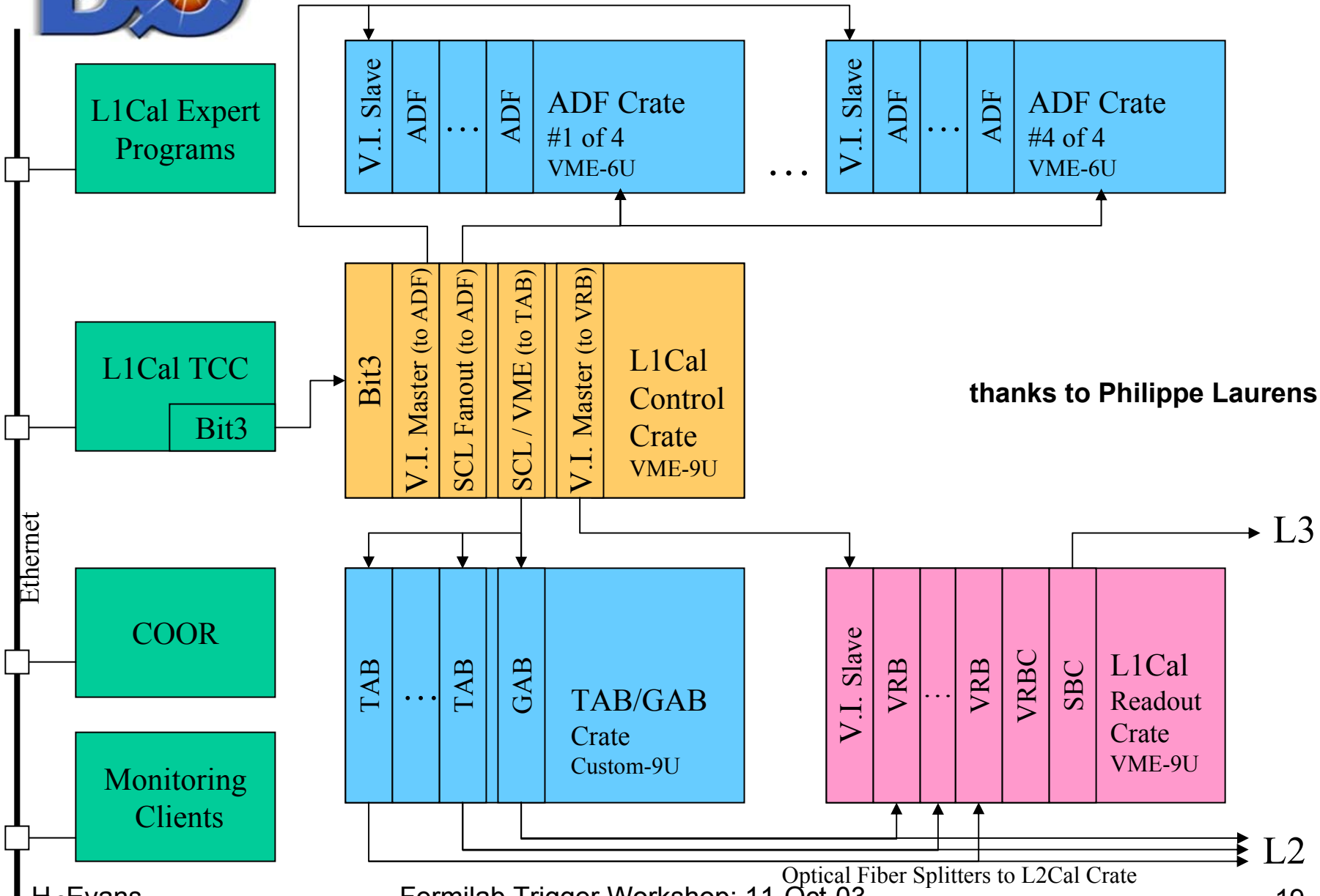
Prototype Integration Tests

- **Stage I** — **29-30 July**
  - Receive SCL trigger/timing information from SCL Hub to VME/SCL Card

- **Stage II** — **8-17 October**
  - SCL → ADF Timing Card → ADF — done
  - SCL → VME/SCL Card → TAB — done
  - ADF → TAB Data transfer — 1st data seen
  - TAB → Cal-Track — timing & data checked

- **Future Stages**
  - ADF → TAB with full timing
  - BLS → ADF
  - TAB → L2
  - BLS → ADF → TAB → GAB
  - Test Area should operate ~DC at some point

Run IIb L1 Calorimeter Trigger Control Path



thanks to Philippe Laurens

Selected Schedule Milestones

Milestone	Curr. Sched End	Lehman End
TAB Prototype (bench tested)	8/29/03	5/16/03
ADF Prototype (bench tested)	10/7/03	5/2/03
VME/SCL (bench tested)	6/17/04	—
GAB Prototype (bench tested)	1/30/04	7/16/03
Prototype Integration Tests	1/26/04	10/9/03
Pre-Production Integration	10/1/04	5/5/04
Production Readiness Review	10/8/04	5/12/04
TAB Production (bench tested)	3/25/05	10/18/04
ADF Production (bench tested)	5/13/05	12/8/04
GAB Production (bench tested)	7/5/05	2/7/05
L1Cal Production Complete	7/5/05	2/7/05

- **Main Cause of Delays** Complicated Design & Layout of ADF & TAB
- **Integration Success** More time at Prototype Stage Worth the Effort

Costs (my interpretation)

Item (*)	Equipment	Labor	Main Source
ADF Prototype & Splitter	$59K	$360K	Saclay
SCL Interface	$4K	$53K	?
ADF Production	$167K	$118K	Project
ADF Crates	$54K	$69K	Project/Saclay
TAB Prototype	$26K	$132K	Nevis
TAB Production	$83K	$32K	Project
GAB & VME/SCL Prototype	$17K	$89K	Nevis
GAB & VME/SCL Production	$11K	$20K	Project
TAB Cables, Crate, Services	$44K	$23K	Project/Nevis
TOTAL(*)	$464K	$950K	$1,414K

* Taken from Aug. 03 Schedule (to the best of my ability)

** Total includes some other misc. items

Costs (how are we doing?)

Item	Est. Unit Cost	Actual Unit Cost
TAB proto components	$7,900	$4,700
fabrication	$2,000	$310
assembly	$3,000	(incl. setup) $3,500
VME/SCL components	(GAB proto) $7,500	$350
fab/assemb	$4,500	$440
Cables (full purchase)	$17,780	$19,700

- Note: enough TAB (13) & VME/SCL (5) pcb's for full production already procured
- No problems found with either prototype

The Future – Discussion

- **Saclay unable to continue in Project after Prototype Phase**
  - **BIG THANKS for their EXCELLENT work**
- **Migration of Saclay Responsibilities**
  - **ADF Production** — **MSU**
  - **ADF Timing** — **interest expressed**
  - **Digital Filtering** — **interest expressed**
  - **Simulation Software** — **???**
- **Other Issues to Consider**
  - **Commissioning/Infrastructure** — **UIC leads here**
  - **Calibration & Monitoring** — **MSU + ???**
  - **Physics Studies** — **???**
    - **algo optimization, trigger terms, etc.**
  - **Anything Else?**

More Discussion Points

1. **Group Responsibilities**
   - any requests for rebaselining
2. **Physics Studies Needed**
3. **Online Structure**
4. **Future Integration Plans**
5. **Anything I've Missed**

Alphabet Soup

- **ADF: ADC & Digital Filter Card**
  - Run IIb L1Cal card that digitizes and filters analog signals from BLS
- **ADF Timing (aka SCL Interface)**
  - Run IIb L1Cal card that distributes SCL signals to ADFs
- **BLS: BaseLine Subtractor Card**
  - Run IIa/IIb card that constructs analog TT signals from calorimeter cell signals (in collision hall)
- **CTFE: Calorimeter Trigger Front End Card**
  - Run IIa card that digitizes BLS signals, counts TTs over threshold and does first stage of Et summing (in MCH1)
- **GAB: Global Algorithm Board**
  - Run IIb card that collects TAB outputs, constructs trigger terms and transmits them to the TFW
- **LVDS: Low Voltage Differential Signal**
  - Serial data transmission protocol used for communication between Run IIb L1Cal components
- **MCH: Movable Counting House**
  - MCH-1 (1st floor) houses L1Cal. This is accessible during data taking.
- **SCL: Serial Command Link**
  - Means of communicating D0 TFW timing and control signals to all parts of D0 Trigger/DAQ
- **Splitter**
  - Splits analog signals from BLS (at CTFE) for Run IIb L1Cal studies
- **TAB: Trigger Algorithm Board**
  - Run IIb card that performs sliding windows and Et summing algorithms on ADF outputs
- **TFW: Trigger Framework**
  - System that collects trigger terms from all D0 trigger systems, makes final trigger decisions and distributes timing and control
- **TT: Trigger Tower**
  - 0.2x0.2 (ηxϕ) region of calorimeter cells (EM or Hadronic) used as input to L1Cal
- **VME/SCL Card**
  - Run IIb card that interfaces TABs/GABs to VME using a custom serial protocol and distributes SLC signals to the TABs/GABs