DØ Run IIb L1Cal Overview
(the stuff you already know)

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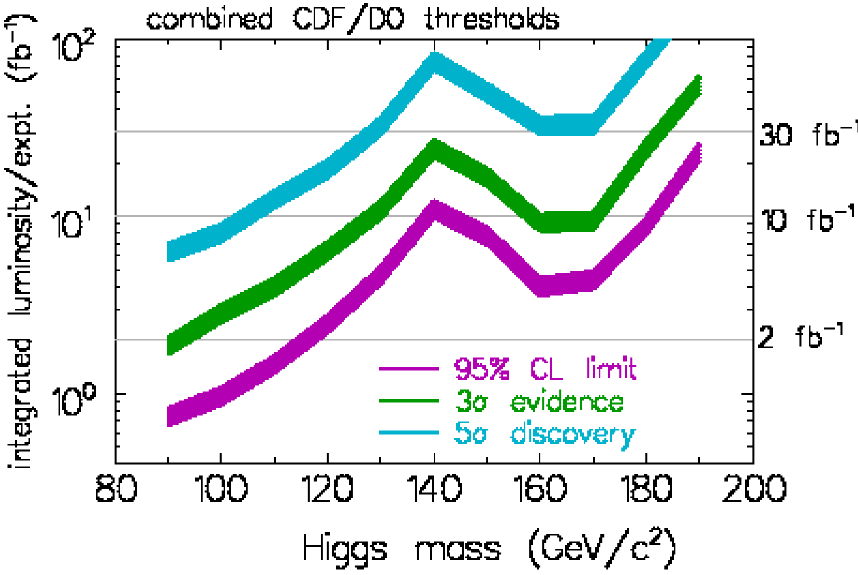
Why Give This Talk?

1. **Recall Problems & Solutions**
2. **Reminder of System Architecture & Confusing Acronyms**
3. **Overview of Issues to Discuss During the Meeting**
4. **Remember Constraints: Cost & Schedule**

Seizing the Moment

The Higgs is w/in our grasp! If…

- enough luminosity (~15 fb^{-1})
- performant detector (b-tag)
- strong trigger
  - leptons, b-jets, taus, Et-miss
  - Trig eff assumed for Higgs
    Lepton 100%
    Jet+Met 100%



And don't forget other physics

Tevatron plans

Scheme	Lumi ($x10^{32}$ $cm^{-2}s^{-1}$)	BC [ns]	$\langle N_{int} \rangle$	*L* Level
baseline	2	396	5.5	yes
no *L* level	4	396	11.1	no
still alive	5	132	4.1	no

DØ Changes

- Integ Lumi ⇒ New Si
- Inst Lumi ⇒ Upgr Trigger

Focus on High Pt Phys

- frees trig bandwidth
- but not enough…

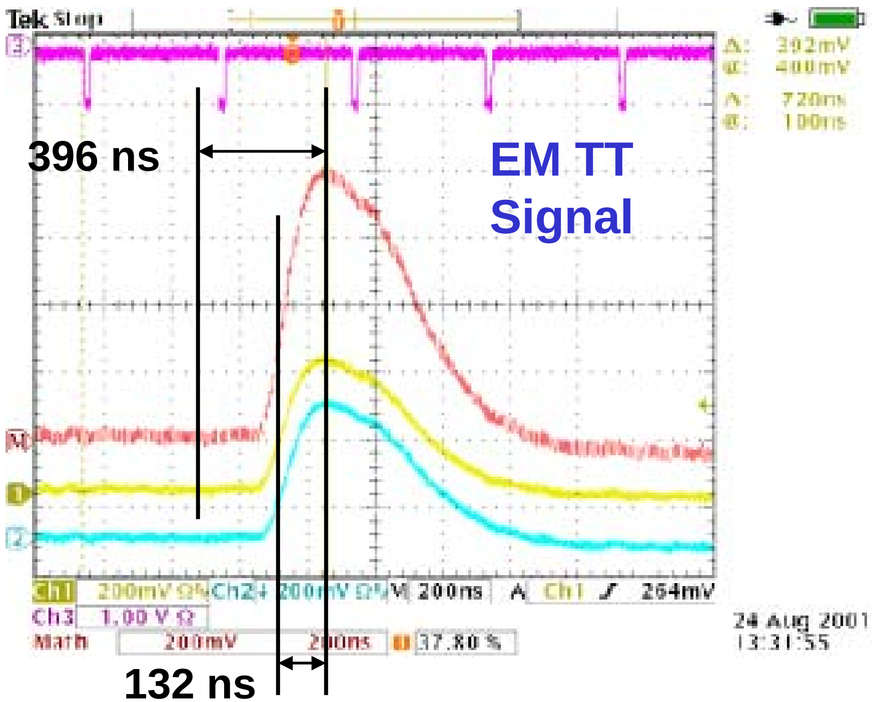
L1Cal is the Key

- **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	$t\bar{t} \to \ell\nu + \text{jets}$ $t\bar{t} \to \text{all jets}$ $Z \to b\bar{b}$	EM, Jet (calibrate E-scale)
Higgs	$WH \to \ell\nu b\bar{b}$ $ZH \to \nu\nu b\bar{b}$ $H \to W^{(*)}W$	EM, Jet, ME_T
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

But there are Problems…

L1Cal Signals



Signal Shape

- Rise Time > 132 ns
  - not entirely understood – dispersion in cables?
  - can cross threshold before peak
- Trigger on Wrong Crossing
  - affects interesting high-E events
- Note: this is only an issue at 132 ns BC

Solution

- Digital Filtering of BLS of input signals
  - more flexible than analog shaping
- Baseline: Match Filt. + Peak Det.

Advantages

- allows running at 132 ns
- tunable response
- improved energy resolution

...and More Problems

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

Core Trigger Menu

- $L = 2 \times 10^{32}\ \mathrm{cm^{-2}s^{-1}}$
- BC = 396 ns

Total L1 Bandwidth Limit = 5 kHz

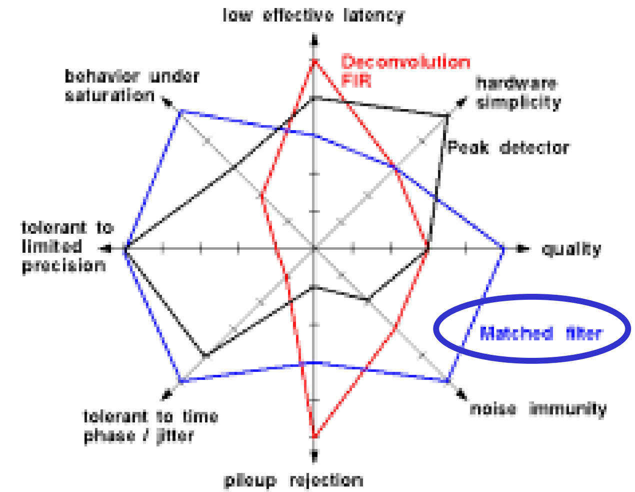
Solution (L1Cal)

- Better Algorithms
  - Jet, EM, Tau
  - Clustering similar to what is done at L2 now
  - Implies that L2 must improve as well
- Baselines Chosen: Atlas sliding windows

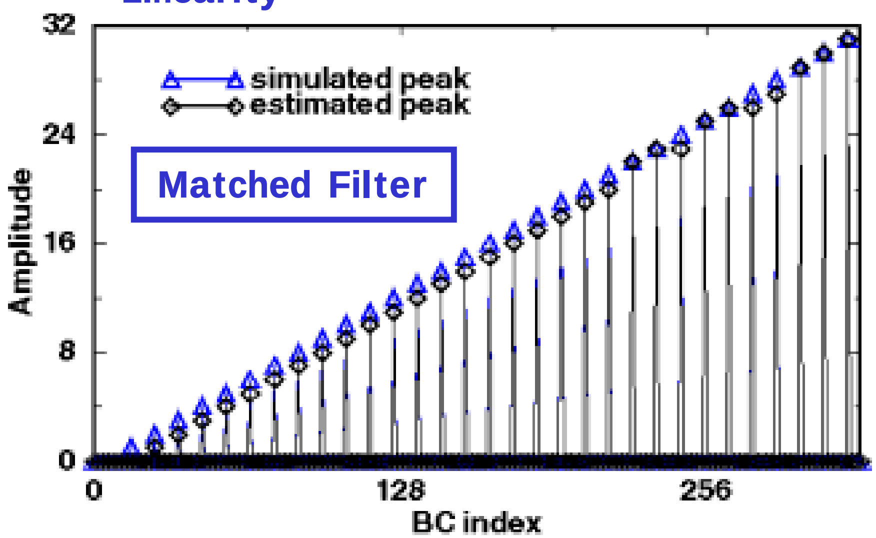
Digital Filter

- **Performance Criteria**
  - latency, #params, satur.
  - Et-res, BC mis-ID, Δt
  - noise, phase, jitter, shape
- **Algorithms Studied**
  - Deconvolution FIR
  - Peak Detector
  - Matched Filt + Peak Det

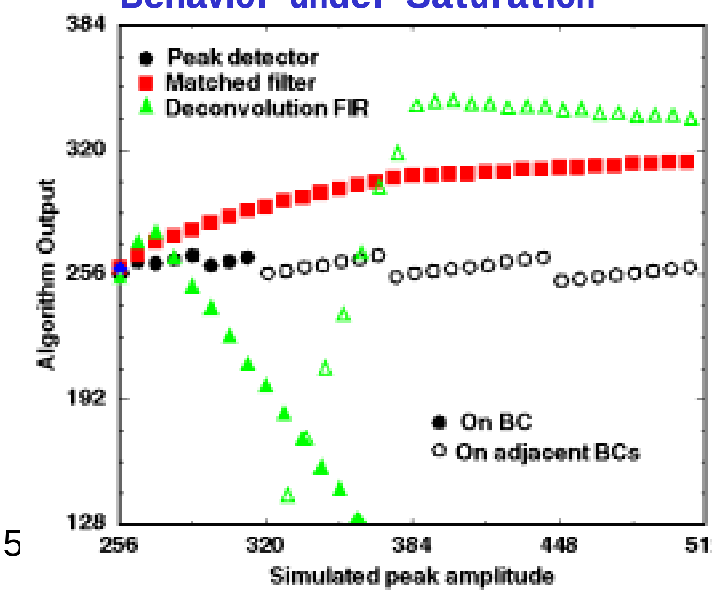
baseline



Linearity



Behavior under Saturation



Digital Filter Algorithm

Matched Filter + Peak Detector

1. Impulse filter ⇒ Et
2. 3-Point Peak Detector ⇒ Find peak

– Strengths
  * linearity
  * robust against signal phase shift [-32ns – +32ns]
  * stable under modest saturation
– Relative Weaknesses
  * latency can be large
  * does not resolve signals very close in time (few BC)

Testing the Algorithm

– current: a few digital scope traces of signals
– soon: real data using “Splitter Boards”

More Details in Talk by Denis Calvet

Sliding Windows

Jet Algorithm Parameters

- RoI Size *(a)*
- Declustering Region
  RoI's comp to find local max
  ⇒ effective sep. b/w LM's (*b*)
- Et cluster region (*c*)
- Naming: *a,b,c*

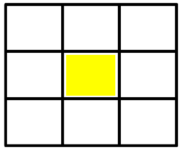
EM Algorithm

- Sliding Windows LM (*a,b*)
  - using only EM
- Isolation Region (*d*)
  - EM isolation
  - Had Veto
- Naming: *a,b,d*

Tau Algorithm

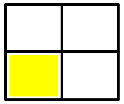
- Sliding Windows LM (*a,b*)
  - use EM+Had
- Isolation Region (*d*)
  - Et(2x2) / Et(4x4) > cut
- Naming: *a,b,d*

(a)



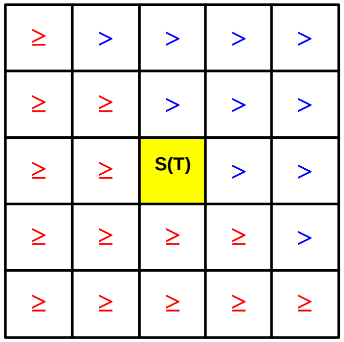
3x3 RoI

(b)

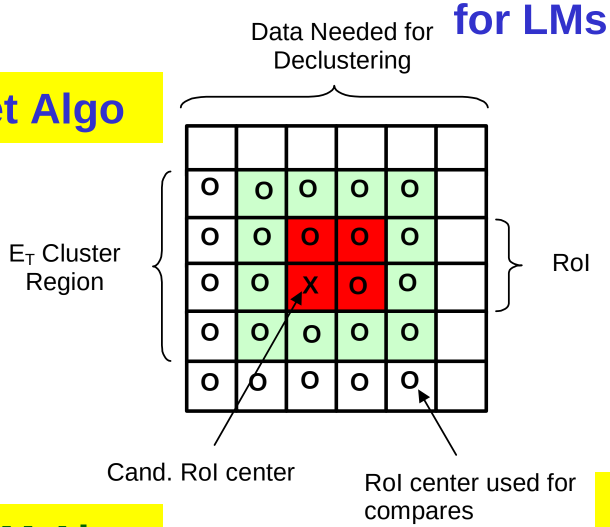


2x2 RoI

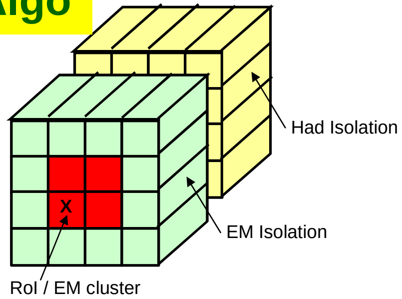
5x5 RoI declust reg. ⇒ 1 TT sep for LMs



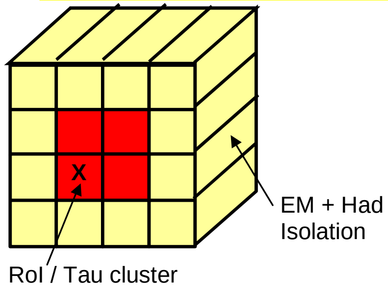
2,1,1 Jet Algo



2,1,1 EM Algo

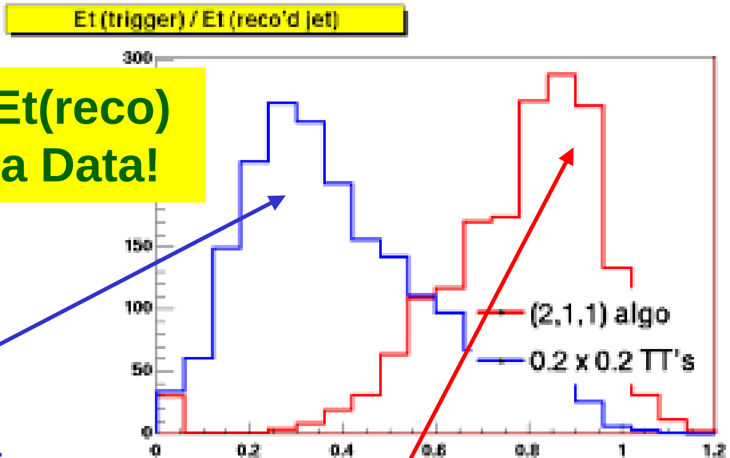


2,1,1 Tau Algo



Algorithm Results

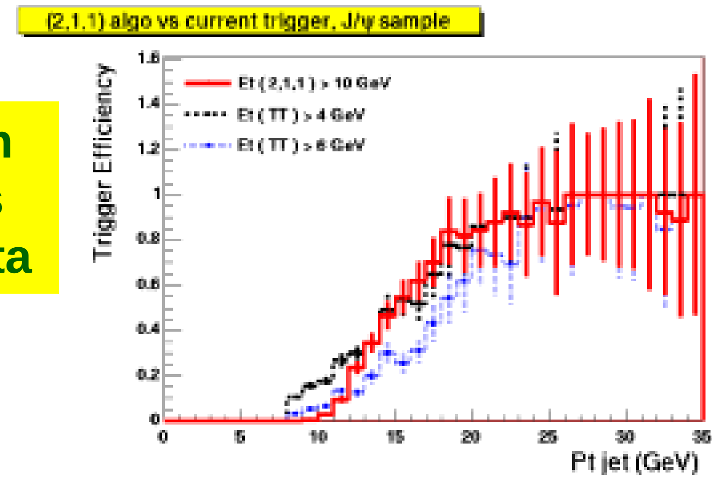
Et(trig) / Et(reco) w/ Run IIa Data!



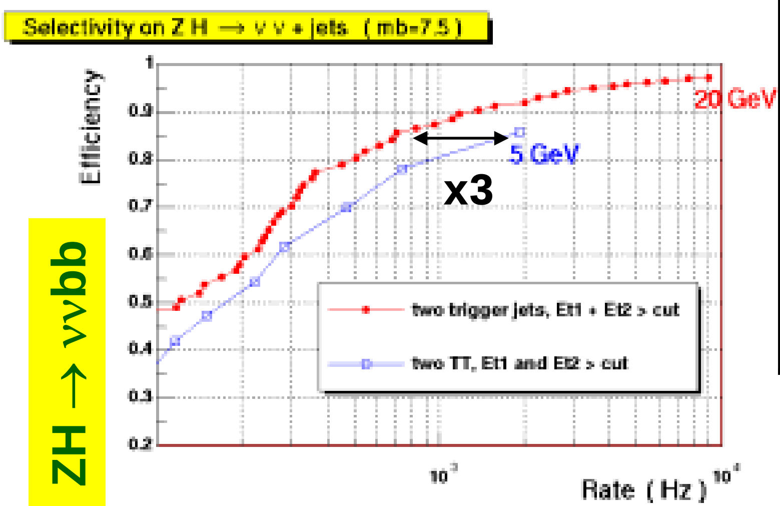
TTs
Ave = 0.4
RMS/Ave = 0.5

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

More Details in Talks by Emmanuelle Perez & Jovan Mitrevski

The Bottom Line

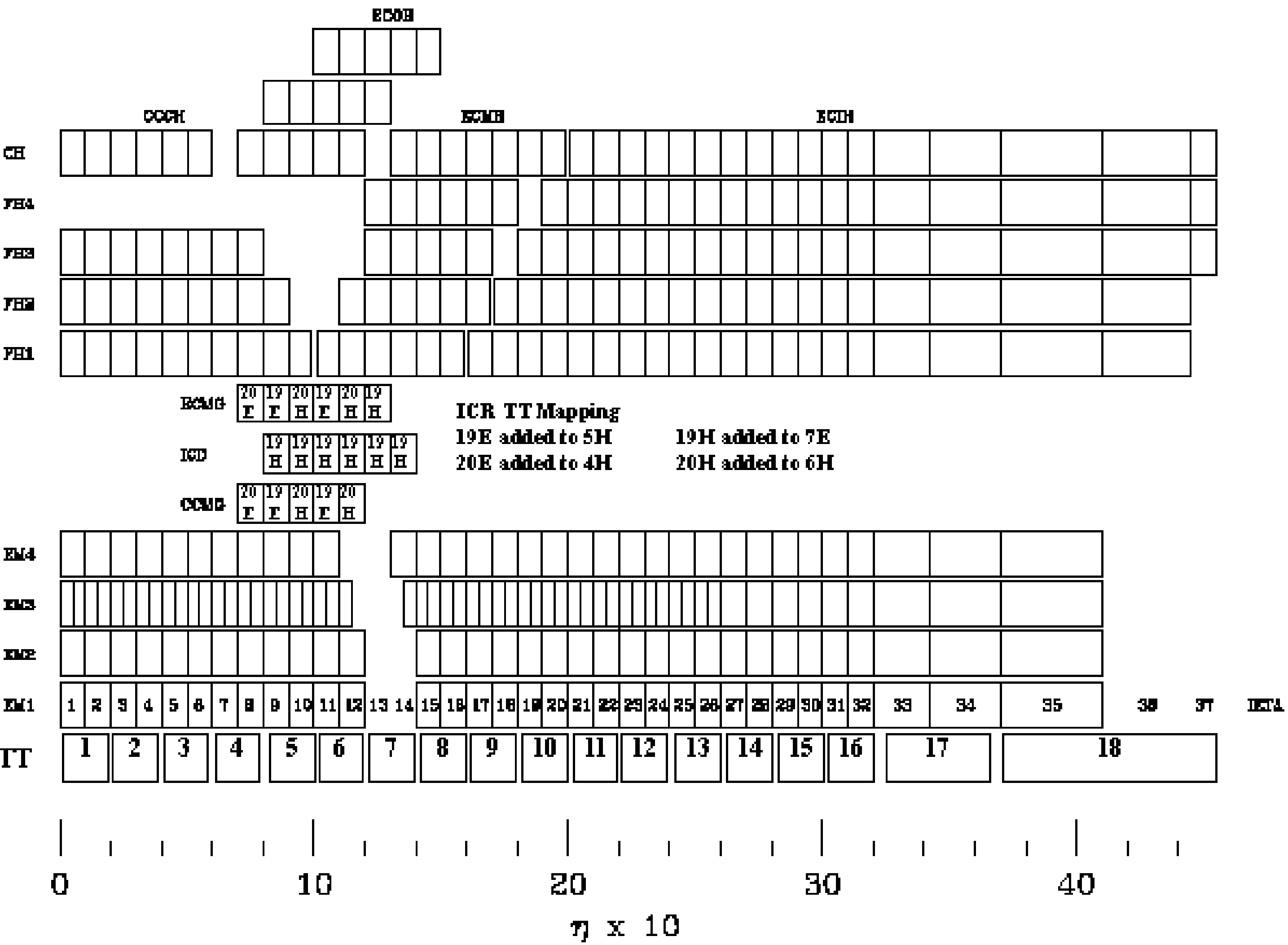
Trigger	Run IIa Definition	Example Channel	L1 Rate [kHz] (no upgrade)	L1 Rate [kHz] (w/ upgrade)
EM	1 EM TT > 10 GeV	$W \to e\nu$ $WH \to e\nu jj$	1.3	0.7
DiEM	1 EM TT > 7 GeV 2 EM TT > 5 GeV	$Z \to ee$ $ZH \to eejj$	0.5	0.1
Muon	1 Mu Pt > 11 GeV CFT Track	$W \to \mu\nu$ $WH \to \mu\nu jj$	6	1.1
Di-Mu	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			~30	3.9

Core Trig Menu
- $L = 2\text{x}10^{32}$
- BC = 396 ns

Not Yet Included
- L1Cal Topo cuts
- EM Algo
- Tau Algo
- MEt w/ ICR

Total L1 Bandwidth = 5 kHz

DØ Calorimeter



Hermetic

- |η| < 4.2

E-Res

- EM: ~14%/√E ⊕ <1%
- Jet: ~80%/√E

Cells

- Δη×Δϕ=0.1×0.1

Sampling

- 4 EM
- 4-5 Had

Trigger

- 32 ϕ x 40 η
- ICR at ±19,20

The Run IIa Trigger System

Level-1

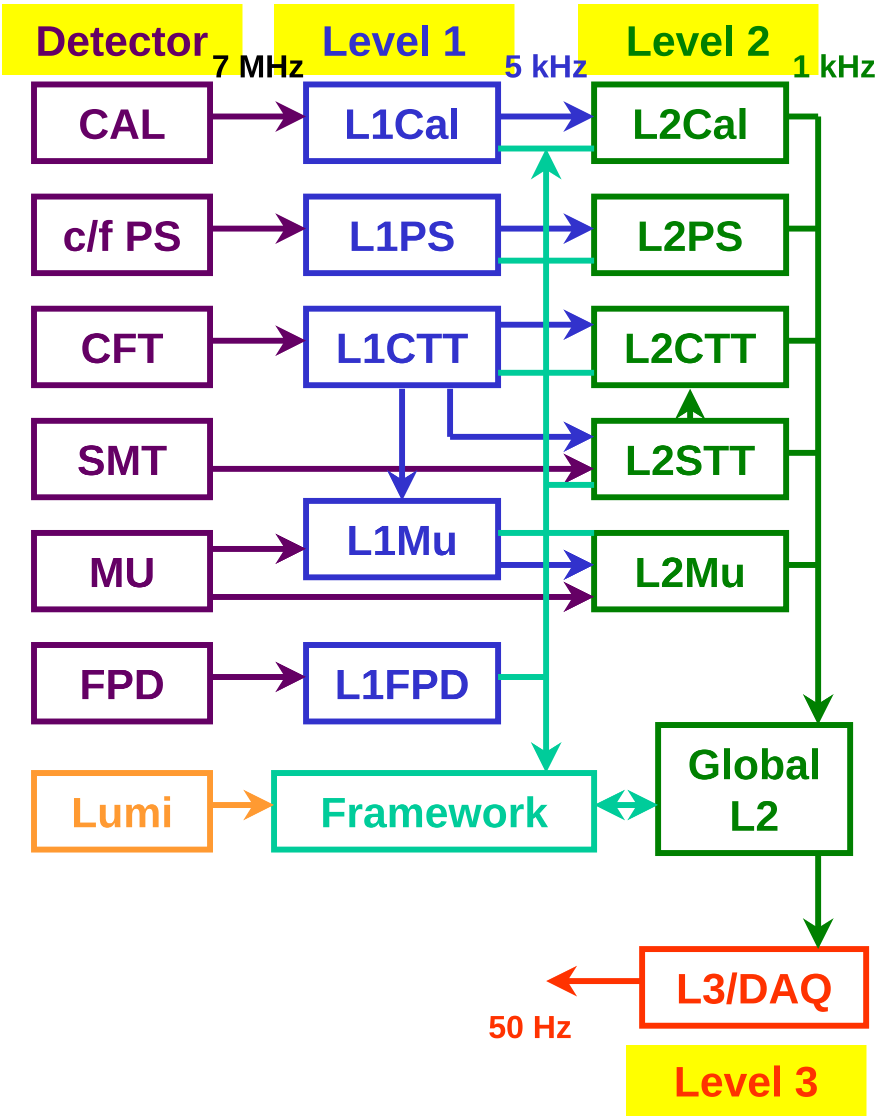
- Mainly detector-based
- Correlations
  - Cal-Trk: quadrant level
  - Mu-Trk: L1trk info → L1Mu
- Not deadtimeless
  - Out rate ~5 kHz (r'dout time)

Level-2

- Calibrated data
- Extensive correlations
- Physic objects out (e,μ,τ,j…)
- Out rate ~1kHz (cal r'dout)

Accept Rate Limits

- L1 = 5 kHz   L2 = 1 kHz
- Cannot change
- Improve triggering by increasing bgrd rej. at same eff.



L1 Cal in Run IIa

Level-1 Calorimeter Trigger

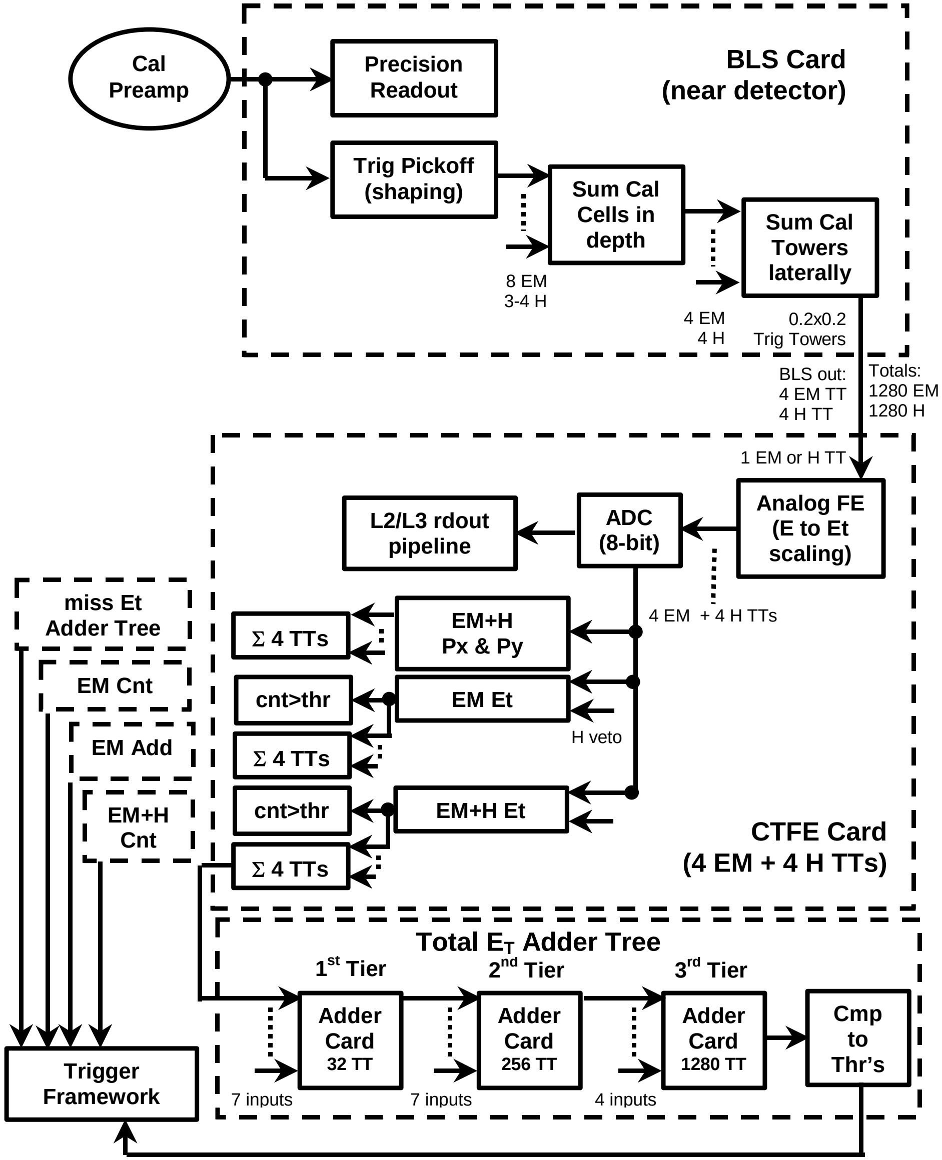
- Using Run Ib System (1990)
- Unit = Trigger Tower (TT)
  - $\Delta\eta \times \Delta\phi = 0.2 \times 0.2 \Rightarrow 40 \times 32$

$\Rightarrow$ 1280 EM + 1280 Had

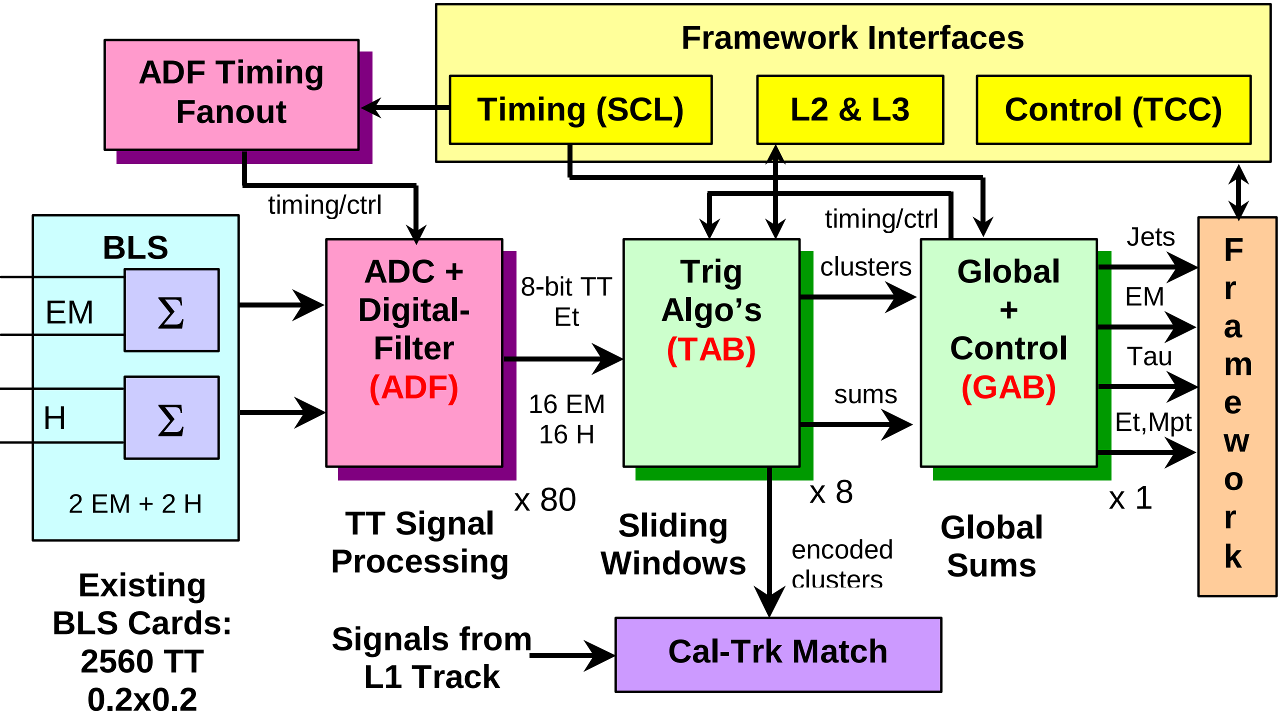
- Compromise b/w Jet & EM
  - EM Molière Radius ~0.02
  - Jet Radius ~0.5

Trigger Outputs

- \# EM TTs > 4 Thr
  - H Et veto avail. – not used
  - also avail. by quadrant
- \# EM+H TTs > 4 Thr
  - also avail. by quadrant
- Global E_T Sum
- Missing E_T (E_x & E_y)



L1Cal in Run IIb

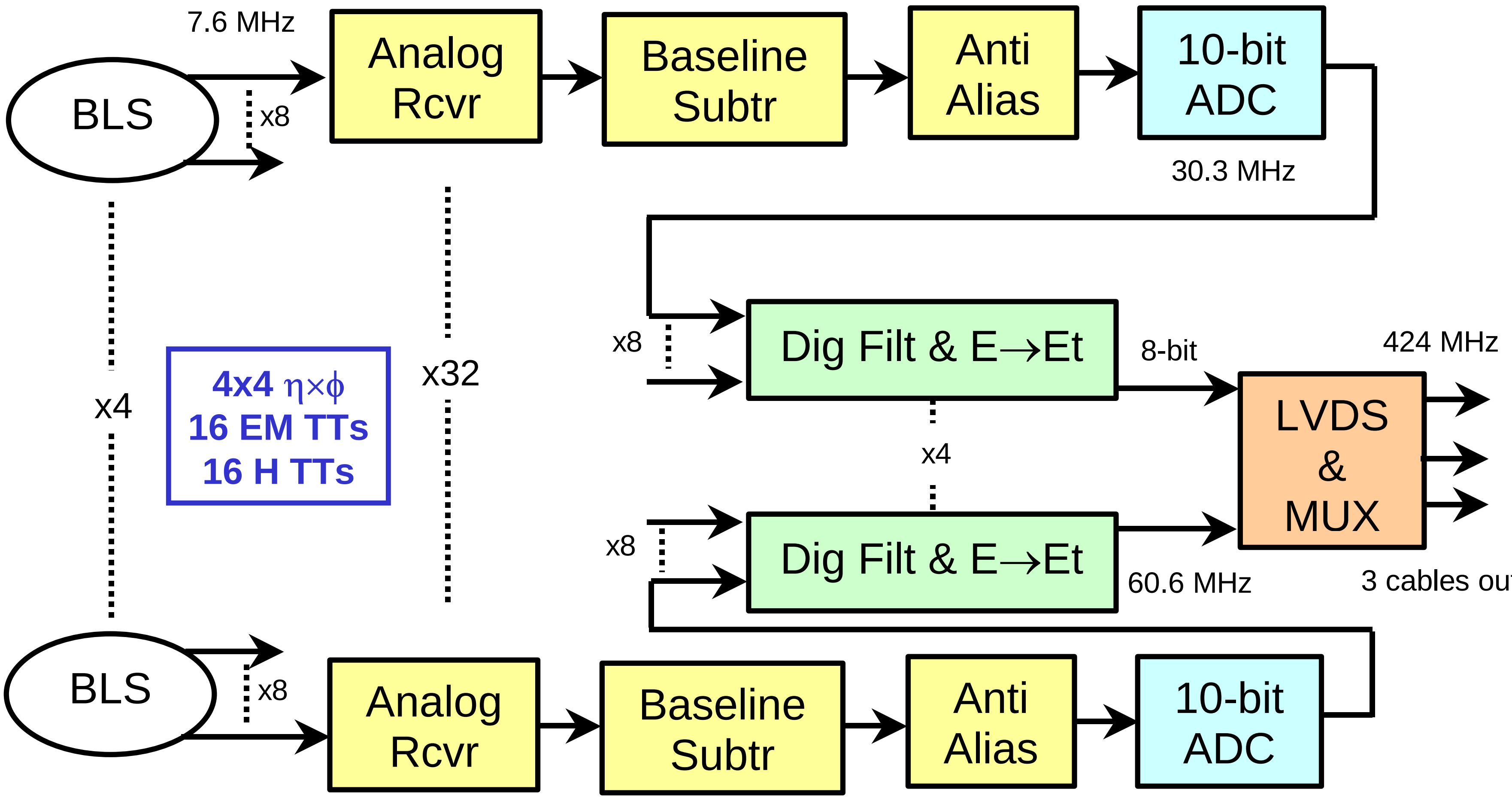


New Features

- Digital Filter
- Jet,EM,Tau Clusters
  - topology & isolation
- ICR in Global Sums & Clusts
- Clusts output to Cal-Trk Match

Board	No	Input ($\eta\times\phi$)	Output ($\eta\times\phi$)	Purpose
ADF: ACD/Dig. Filt.	80	4x4	4x4	digitize, filter, E-to-Et
ATF: ADF Timing F'out	1	all	all	ADF control/timing
TAB: Trig Algo Board	8	40x12	31x4	algo's, Cal-Trk out, sums
GAB: Global Algo Board	1	all	all	TAB ctrl/time, sums, trigs to FWK

The ADF

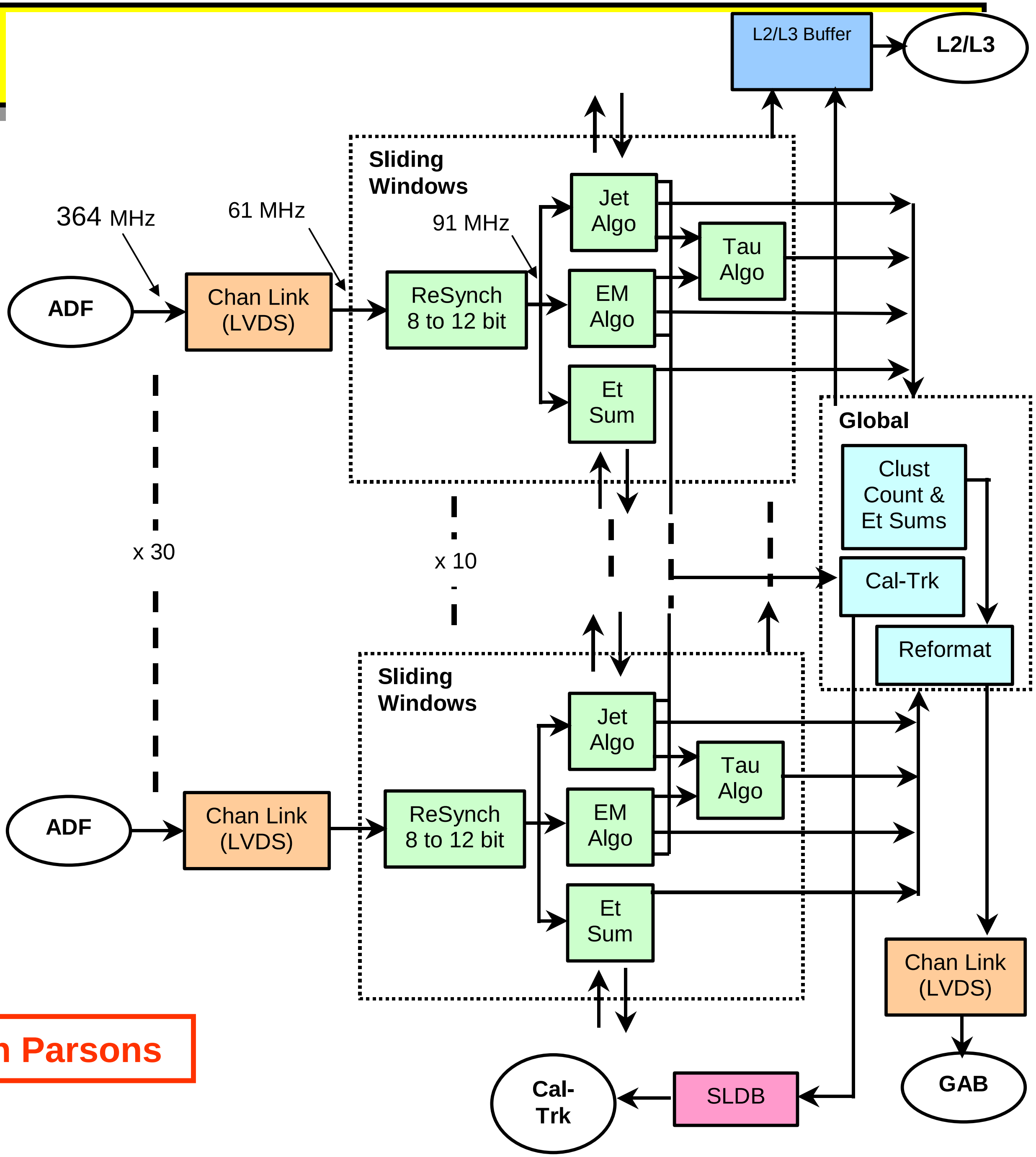


More Details in Talk by Denis Calvet

TAB

TAB Components

- 30 Chan Link Rcv
  - 40x12 $\eta \times \phi$
  - 960 TTs in
- 10 Sliding Windows Chips
  - Algo's here
  - ~9x9 TTs in
  - ~4x4 LM out
- 1 Global Chip
  - 31x4 LMs out
    - η edge effects
  - clust counts
  - Et sums
  - Cal-Trk out
- 3 SLDBs
  - xmit to Cal-Trk



More Details in Talk by John Parsons

H.Evans

Global Design Issues to Discuss

1. Data Out to Cal-Trk
   - latency
2. ADF-to-TAB Data Transfer
   - baseline:
     - National Channel-Link LVDS drivers/receivers w/ AMP 2mm HM cables
     - each ADF has 3 identical outputs
   - ADF-to-TAB transfer protocol
     - clocks, error detection, etc.
3. Monitoring Data Quality
   - raw data to ADF ?
     - 10-bit data transfer to TAB ?
   - filter coefficients ?
   - algorithm performance ?
   - dead/noisy channels… ?
   - (see talk by Philippe Laurens)
4. Data to Outside World
   - Cal-Trk content
   - L2/L3 content
   - Triggers to TFW
5. Testing and Commissioning
   - digital filter tuning w/ data
     - Splitter Boards
     - (see talk by Denis Calvet)
   - ADF-to-TAB xfer scheme
     - Cable Tester
     - (see talk by Jovan Mitrevski)
   - Integration Tests
     - (see talks by Dan Edmunds and Philippe Laurens)
   - Parasitic Running
7. Algorithm Choices
   - Finalize Jet Algo Studies
   - Finish ICR Studies
   - Set Params for EM & Tau Algo’s
   - (see talk by Emmanuelle Perez)

L1Cal Latency

- Latency budget is rather tight
  - increase available time by lengthening depth of FE pipelines
    - Muon system scintillators and PDTs are the bottleneck
  - Change clock frequency on readout electronics
    - small degradation in time resolution
    - gain 6, 132 ns ticks in pipeline depth

Step	Δt [ns]	Elapsed t [ns]	Comments
BC to ADF	650	650	calo to ADF in
Digitization	347	997	ADF
Digital Filter	594	1591	
Output to TAB	206	1797	
Resynch Inputs	132	1929	TAB
Input Data Checks	66	1995	
Jet/EM Algorithms	242	2237	
Construct Output	198	2435	
SLDB	90	2525	
Cal-Trk requires		2571	“as is” system
		3363	pipeline depth increased

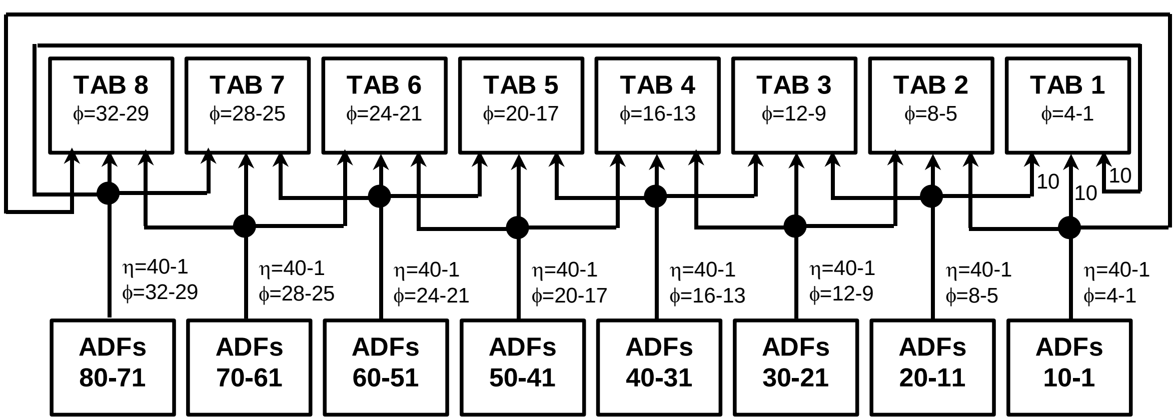
ADF-to-TAB Data Routing

- **System Design driven by data sharing req's of jet algorithm**
  - **2,1,1 algo**
    ⇒ data from 6x6 TTs for 1 LM
  - **include ICR in jets**
    ⇒ each TAB gets all data in η
- **Minimize Data Sharing/Cabling**
  - **⇒ only certain config's possible**
- **Large number of signals well matched to serial data xfer**
  - **and serial algo's**

Board	Cables In	Cables Out
ADF	• 4 BLS • 1 ATF ?	• 3/1? TAB (4x4)
TAB (2,1,1)	• 30 ADF • 1 GAB ?	• 1 GAB (31x4) • 3 Cal-Trk • 1 L2

Question to Discuss:

• ADF data duplication – at ADF or TAB?



ADF-to-TAB Data Protocol

- Data Transmission Hardware
  - Channel-Link MUX – 48:8
    - Chan-Link DS90CR483 / 4
    - 8 output pairs – 7-bits/cycle
    - 1 clock pair
    - total: 18 lines
  - Cable – 4x5 2mm HM
    - AMP 621410-6
    - total: 20 connectors
- Normal Mode – ADF output
  - 32 x 8-bit filtered TT Et's
- Monitor Mode – ADF output
  - 32 x 10-bit BLS input E

Possible Signals to Send		
Pins	Signal	Input Data (0-31) (w/ DC Balance)
2	Diff. Data Out 0	0,1,2,3,4,5
2	Diff. Data Out 1	8,9,10,11,12,13
2	Diff. Data Out 2	16,17,18,19,20,21
2	Diff. Data Out 3	6,7,14,15,22,23
2	Diff. Data Out 4	24,25,26,27,28,29
2	Diff. Data Out 7	30,31
2	Diff. Clock	
1	Framing Bit	
1	8/10 Bit Select ?	
1	Parity ?	
1	Other Signals ?	
2	Grounds ?	

Question to Discuss:

- error/synch detection
- monitoring inputs

TAB Data Formats

12-bit Sliding Windows to Global Chip Data					
No	Type	11-09	08-06	05-03	02-00
1	EM highest thresh [0=fail or 1-7]	η=4,ϕ=1	3,1	2,1	1,1
2	Jet highest thresh [0=fail or 1-7]	4,1	3,1	2,1	1,1
3	Tau highest thresh [0=fail or 1-7]	4,1	3,1	2,1	1,1
12	Tau highest thresh [0=fail or 1-7]	4,4	3,4	2,4	1,4
13	EM: Sum Et	Sum EM Et over η: ϕ=1			
20	EM+H: Sum Et	Sum EM+H Et over η: ϕ=4			

12-bit Global Chip to GAB Data		
No	11-06	05-00
1	Jet Count: Thr=1	EM Count: Thr=1
7	Jet Count: Thr=7	EM Count: Thr=7
8	Tau Count: Thr=2	Tau Count: Thr=1
9	Sum EM Et over η: ϕ=1	
16	Sum EM+H Et over η: ϕ=4	
17	EM+H Ex	
18	EM+H Ey	

Formats set by Architecture

- changes can be difficult
- constrain possible trigger terms that GAB can construct
  - need to start thinking about these

Data to Cal-Trk

12-bit Sliding Windows to Global Chip – Cal-Trk Data					
No	Type	11-09	08-06	05-03	02-00
1	EM: count over thresh – 4 η	thr=4,ϕ=1	3,1	2,1	1,1
8	Jet: count over thresh – 4 η	thr=4, ϕ= 4	3,4	2,4	1,4

No Tau Info Sent

- would increase latency

Et info only in Thr passed

- reduce transfer time

Need to Verify that this scheme is acceptable

16-bit Cal-Trk Data from TAB				
No	P	E	15-08	07-00
…	0	0	NULL	NULL
1	0	1	Jet: count + Et: ϕ=1,all η	EM: count + Et: ϕ=1,all η
4	0	1	Jet: count + Et: ϕ=4,all η	EM: count + Et: ϕ=4,all η
5	1	1	Longitudinal Parity	

Count + Et Word:

- bits 07-04: count thr n
- bits 04-00: thr’s passed

Data to L2/L3

Minimum L2/L3 Data from TAB		
No	15-08	07-00
1	EM+H TT Et: η=1, ϕ=1	EM TT Et: η=1, ϕ=1
40	EM+H TT Et: η=40, ϕ=1	EM TT Et: η=40, ϕ=1
160	EM+H TT Et: η=40, ϕ=4	EM TT Et: η=40, ϕ=4

L2/L3 Data from GAB	
No	15-00
1	Mask EM clust's over L2 thr: η=5, ϕ=1-16
2	Mask EM clust's over L2 thr: η=5, ϕ=17-32
123	Mask EM+H clust's over L2 thr: η=35, ϕ=1-16
124	Mask EM+H clust's over L2 thr: η=35, ϕ=17-32
125	EM Sum Et
126	EM+H Sum Et
127	EM+H Sum Ex
128	EM+H Sum Ey

L2/L3 Data from TAB

- Run IIa: all TT Et's
- is cluster info useful?
  - adds a lot of data

L2/L3 Data from GAB

- note: only 35 possible cluster positions in eta because of edge effects

Is this a sensible set?

Run IIa L2/L3 Format		
Start	# Bytes	Data
1	12	L2 Header
13	16	EM TT seed mask
29	16	EM+H TT seed mask
45	128	EM TT Et's
173	128	EM+H TT Et's
301	4	L2 Trailer

The Schedule

Project	Task	End Date
ADF & Co	• Analog Splitter built & tested	9/17/02
	• ADF Timing Fanout built & tested	1/3/03
	• Fabricate/Assemble prototype ADF	2/28/03
	• *ADF prototype shipped to Fermilab*	*5/2/03*
	• *Production & Testing complete*	*12/8/04*
ADF Crates	• *Prototype Crate built & tested*	*5/29/03*
	• Final Crates built & tested	11/19/03
TAB	• Fabricate/Assemble prototype	1/9/03
	• *TAB prototype complete*	*5/16/03*
	• Production & Testing complete	10/18/04
GAB	• *GAB prototype complete*	*7/16/03*
	• *Production & Testing complete*	*2/7/05*
Cables	• Test ADF to TAB cables	11/1/02
Integration	• Prototype Integration	10/9/03
	• Pre-Production Integration	5/12/04

Silicon Ready
July 2005

We will be held strictly to this schedule !

The Bill

Project Costs [FY02 k$]	M&S equip	Labor	Total
ADF + Splitter + Timing	229	530	759
ADF Crates	54	69	123
TAB	109	164	273
GAB	20	97	117
Cables	21	12	32
TAB Crates & Services	24	12	35
Integration	0	62	62
Totals	1,430	1,425	2,855

Contingency

- **Our Estimate:** **45%**
- **Lehman Committee** **lower – still being finalized**

Again – we will be held to these numbers !

Summary

Thanks to the efforts of Everyone

We have an approved Project !!!

Now we have to make it Work

Let's get to It !!!