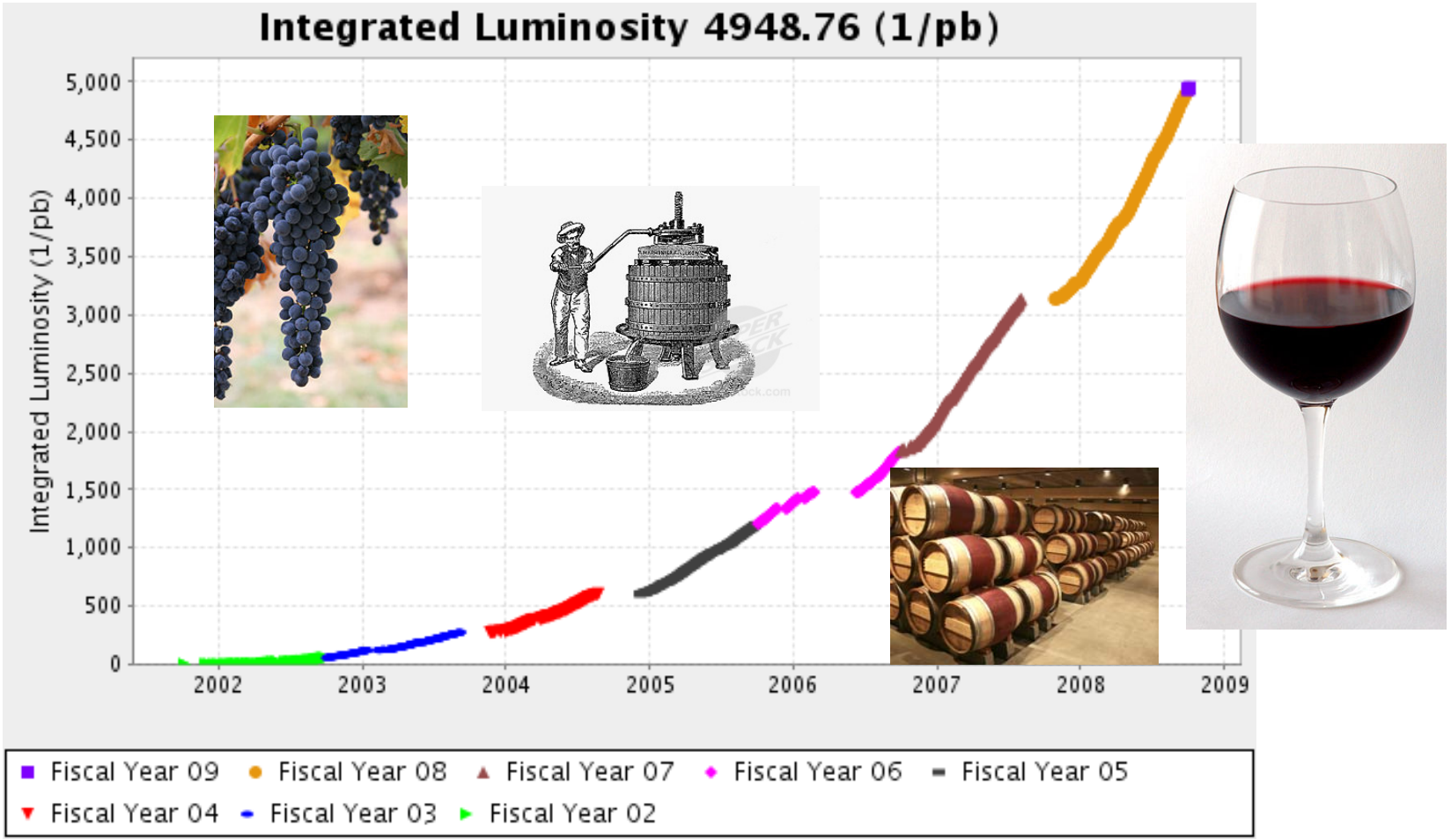
A story of good investments: Tevatron luminosity, the Run IIb upgrade, and DØ-France



Darien Wood

Northeastern University

Overview

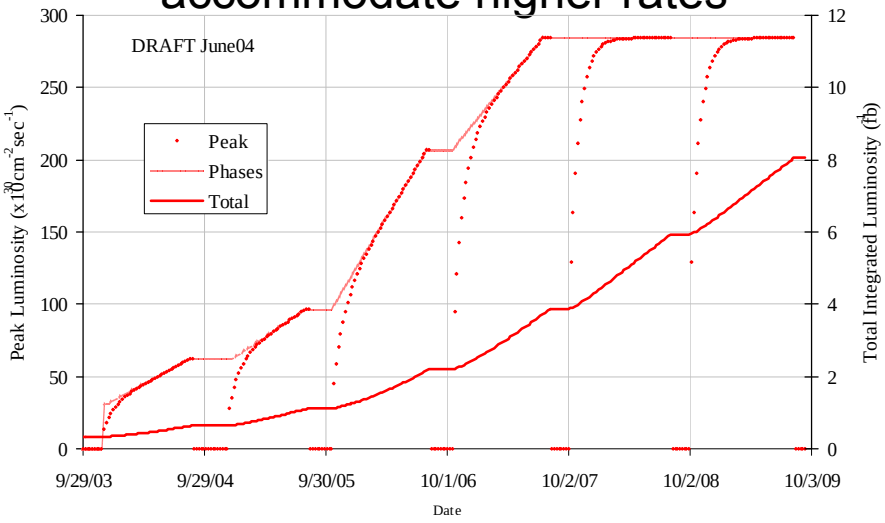
- Largely historical review
  - Luminosity expectations
  - Run IIb upgrade planning
  - Re-scoping the upgrades
  - Installation and commissioning
  - Performance today
    - Tevatron
    - D0 upgrades
  - Future outlook
- Rather trigger-centric view
- Contributions from DØ-France
  - Highlighted along the way
  - Apologies for any contributions that I fail to mention

Remembering Back to 2000/2001

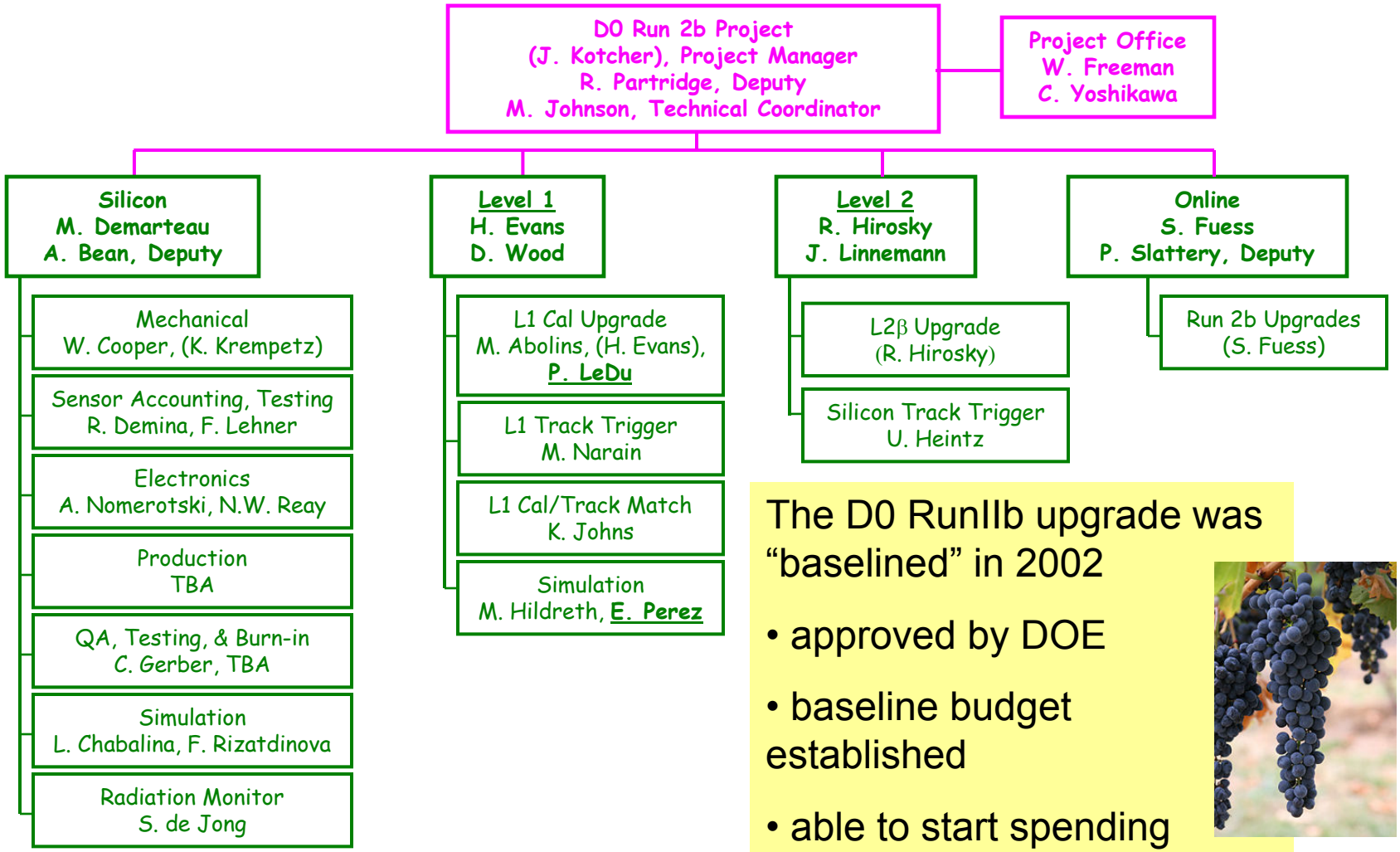
The situation

- The original Run II plan
  - total of 2 fb^{-1} total integrated luminosity
  - Maximum instantaneous luminosity of ~100e30
- The new plan from the Accelerator Division
  - New ideas using recycler, electron cooling, slip stacking, etc.
  - New projections:
    - Total of 8-15 fb^{-1} integrated
    - Maximum instantaneous luminosities of 250-500x10^{30} $cm^{-2}s^{-1}$

- The problem
  - The D0 RunII detector design had been guided by the original accelerator plan
- Response from DØ: Run IIb upgrade
  - Silicon Microstrip Tracker (SMT) upgrade to avoid radiation damage issues
  - Trigger upgrade to accommodate higher rates



Run 2b Project Organization: 2002

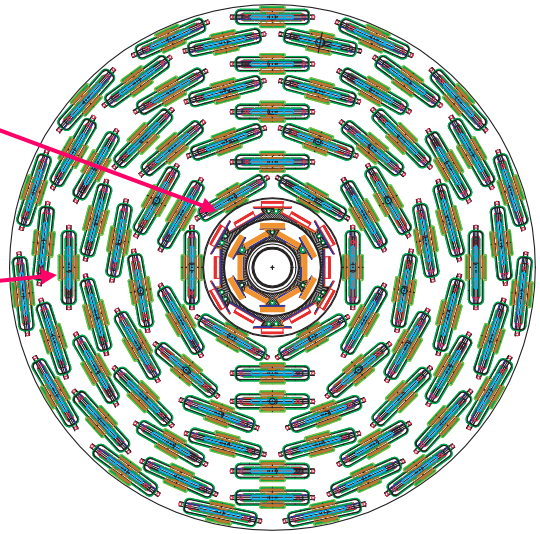


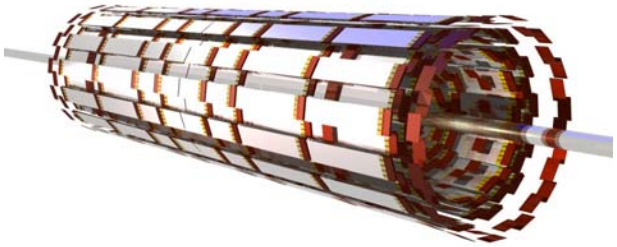
The D0 RunIIb upgrade was "baselined" in 2002

- approved by DOE
- baseline budget established
- able to start spending money

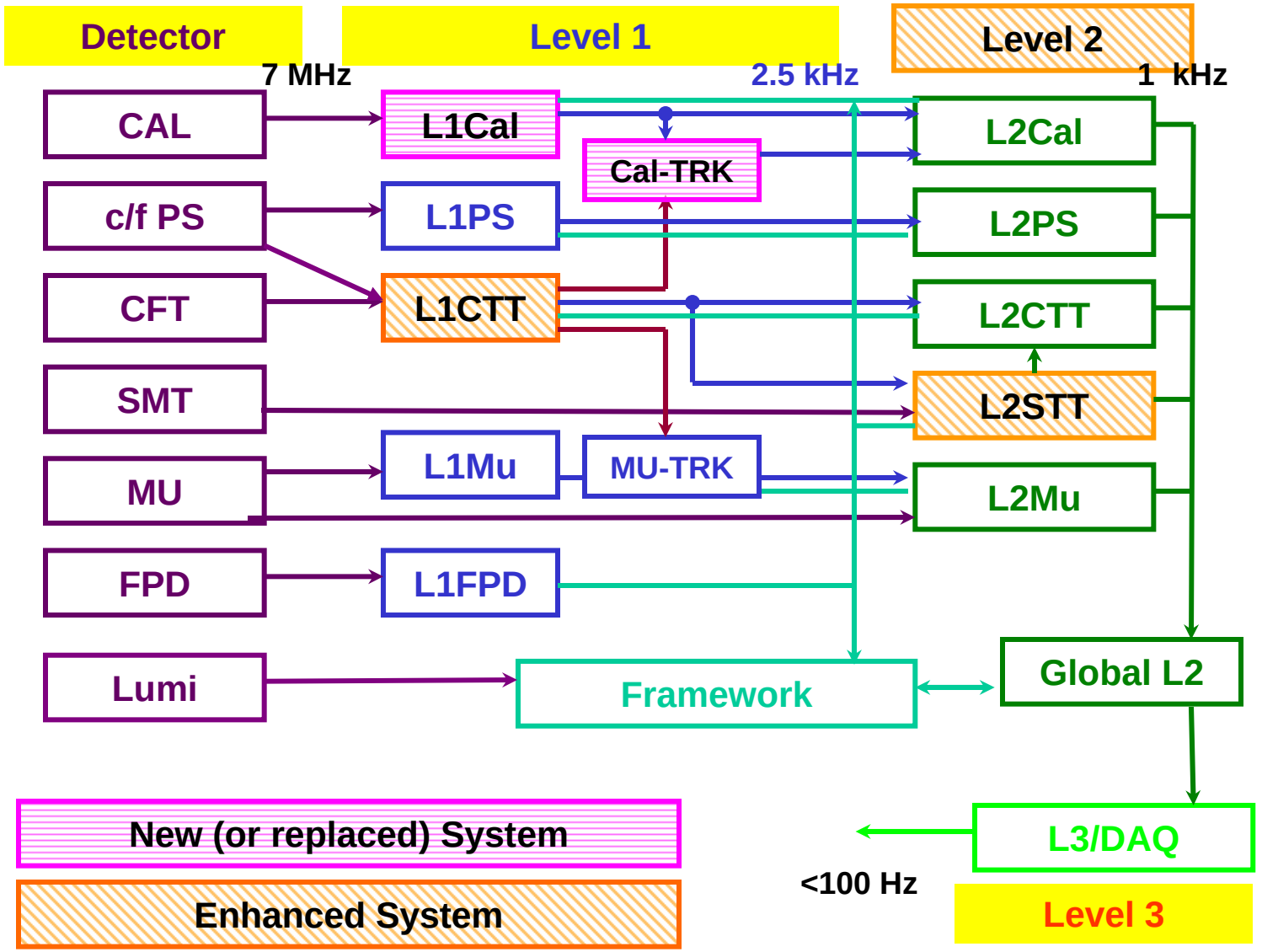
Original Run IIb Silicon Detector Design (2002)

- Six layer silicon tracker, divided into two radial regions
  - Inner layers: Layers 0 and 1
    - Axial readout only
    - Mounted on integrated support
    - Assembled into one unit
    - Designed for V_{bias} up to 700 V
  - Outer layers: Layers 2-5
    - Axial and stereo readout
    - Stave support structure
    - Designed for V_{bias} up to 300 V
- Employ single sided silicon only, 3 sensor types
  - 2-chip wide for Layer 0
  - 3-chip wide for Layer 1
  - 5-chip wide for Layers 2-5
- No element supported from beampipe





Trigger System Upgrades



Ingredients of the Trigger Upgrade

- Level 1
  - Calorimeter trigger upgrade
    - sharpens turn-on trigger thresholds
    - more topological cuts
  - Calorimeter track-match
    - fake EM rejection
    - tau trigger
  - L1 tracking trigger upgrade (CTT)
    - improved tracking rejection especially at higher occupancies
- Level 2
  - L2 Processor upgrades for more complex algorithms
  - Silicon Track Trigger expansion
    - More processing power
    - use trigger inputs from new silicon layer 0

Slide from Paris L1cal workshop – Nov 2002

Run IIb Trigger Priorities

- Main physics driver for Run IIb: Higgs search
  - Need efficient triggers for Higgs production/decay in all major modes
  - Trigger objects:
    - Leptons
    - b-jets
    - taus
    - Missing E_T
- SUSY
  - Trigger objects
    - Leptons
    - Missing E_T
    - taus
- Top, W, Z
  - Trigger objects:
    - Leptons
    - Jets
    - Missing E_T
  - precision mass measurement to understand EWSB
  - Also important for background & calibration for Higgs search
- Background/calibration channels
  - $Z \rightarrow b\bar{b}$, reduce top syst error x2
- Some trigger load can be relieved by elimination of low-pt physics menu (lower energy QCD, b-physics, …), but this is not sufficient

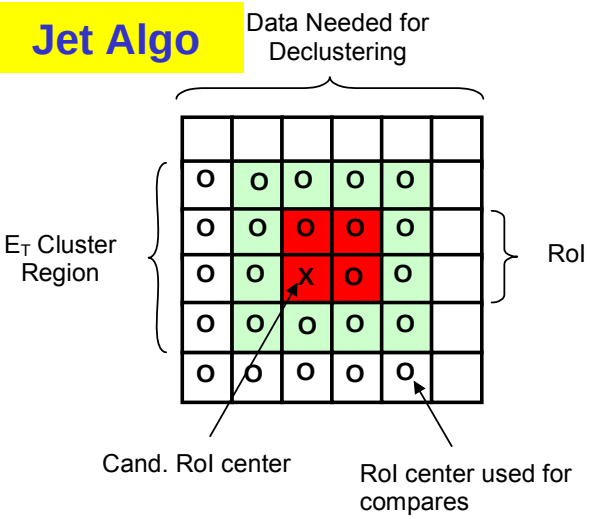
3

Saclay Trigger Workshop
4-6 Nov, 2002

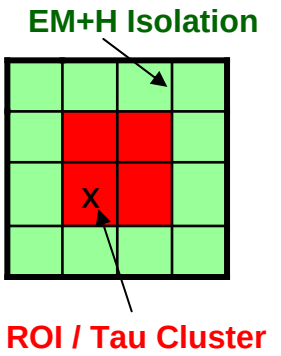
Run IIb L1Cal Concept: Sliding windows and topological capabilities

Clustering

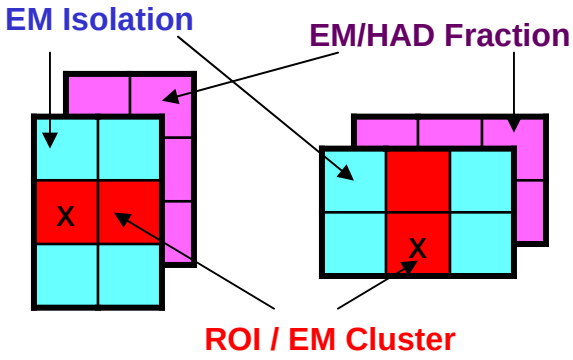
Jet Algo



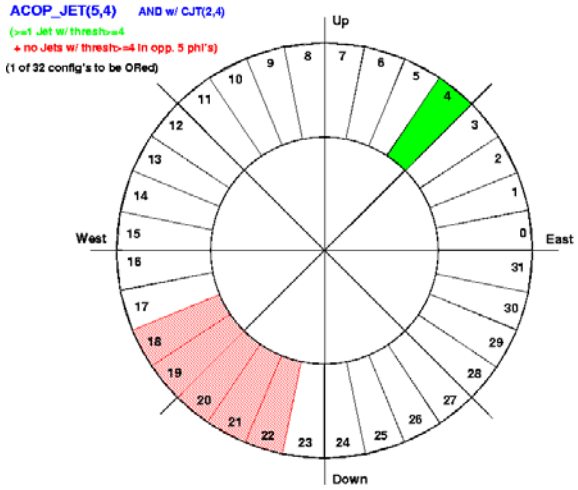
Tau Algo



EM Algo

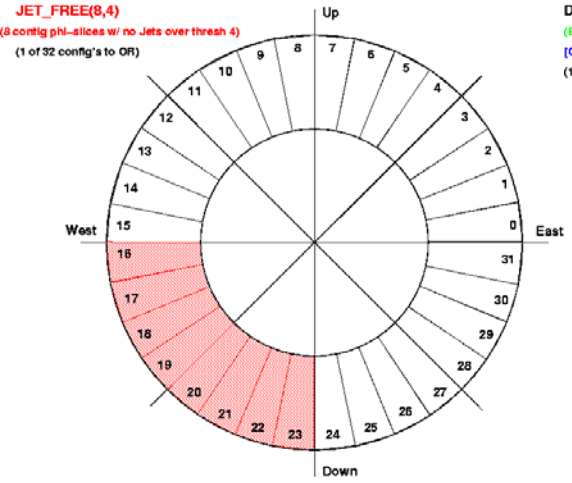


Topological



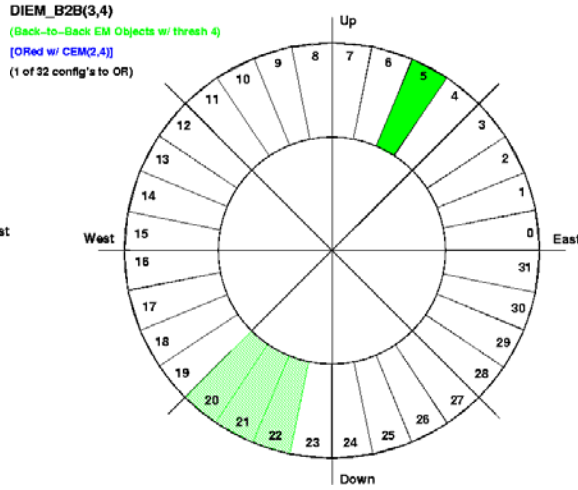
ACOP_JET(n,thr)

- **used w/ CJT(2,thr)**



JET_FREE(n,thr)

- **used w/ CJT(1,thr)**



DIEM_B2B(n,thr)

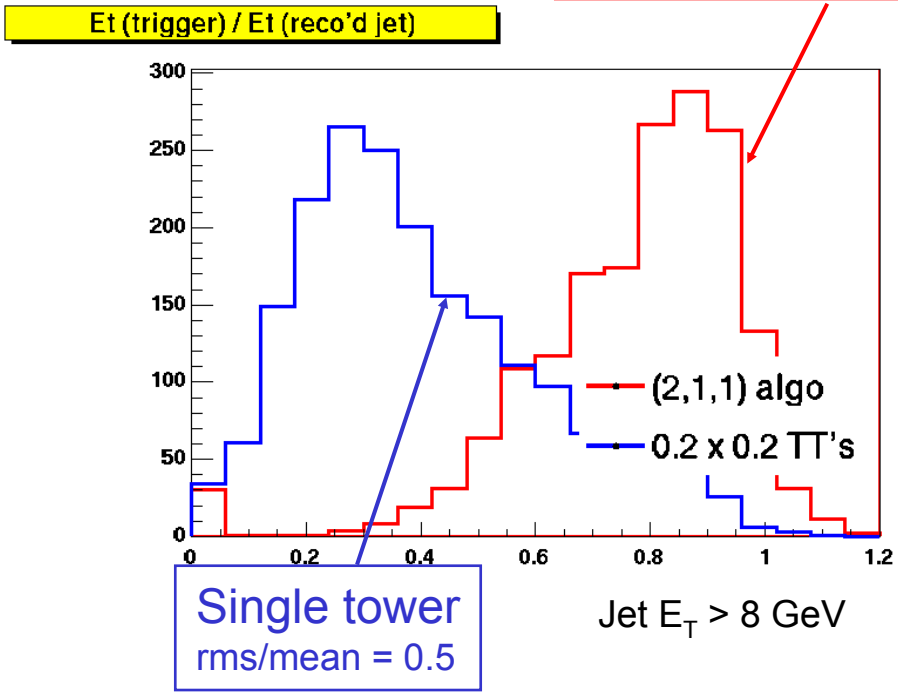
- **used w/ CEM(2,thr)**

Level 1 Calorimeter Trigger

- Most extensive of trigger upgrades
- *Required the removal of existing Cal trigger*
  - *Posted the biggest risk of spoiling the whole vintage*

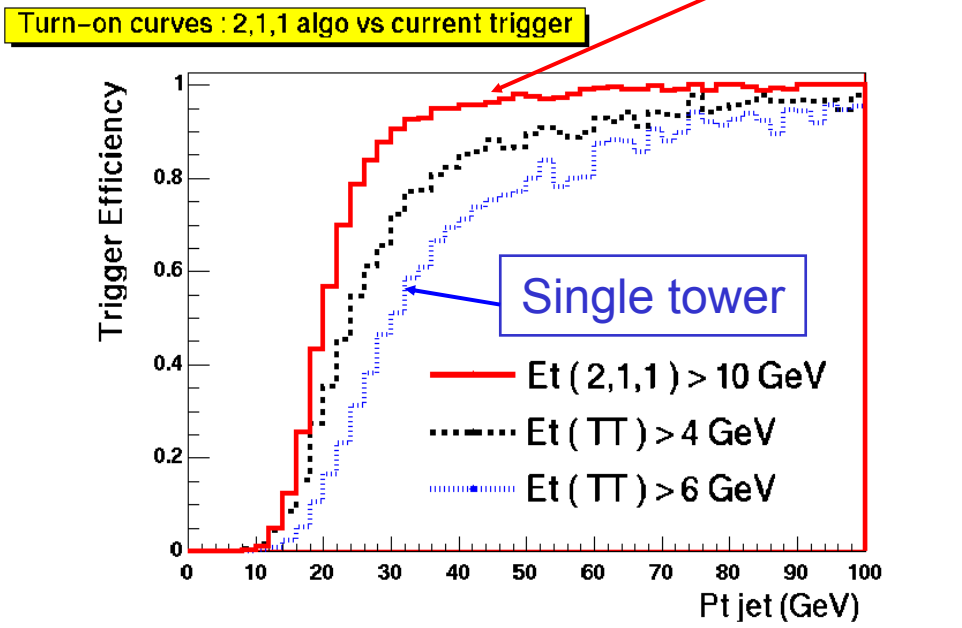
Run IIa data

Sliding window
rms/mean = 0.2

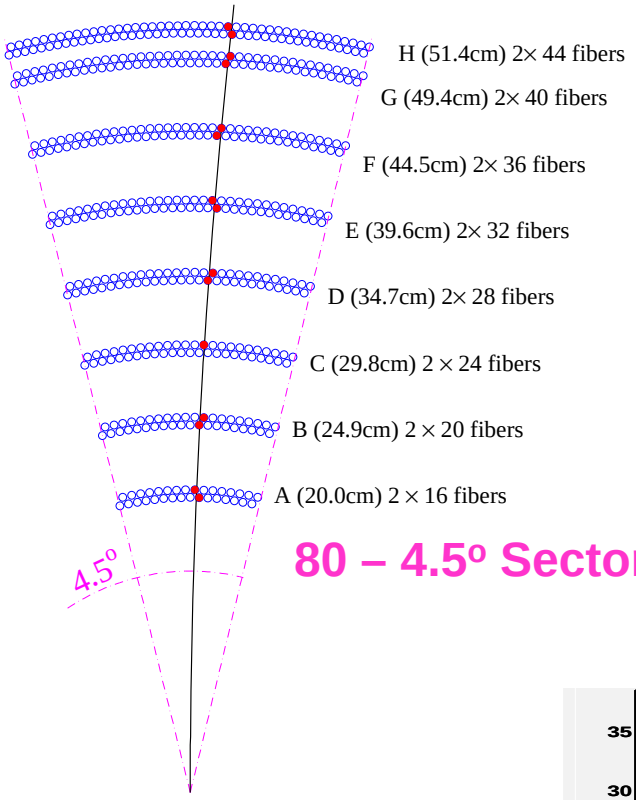


Single tower
rms/mean = 0.5

Sliding window

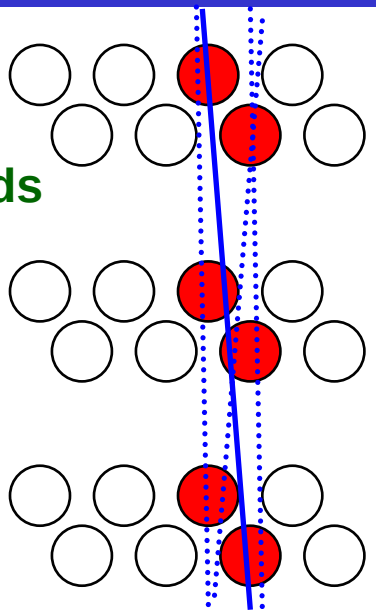


L1CTT Upgrade : Narrower Roads

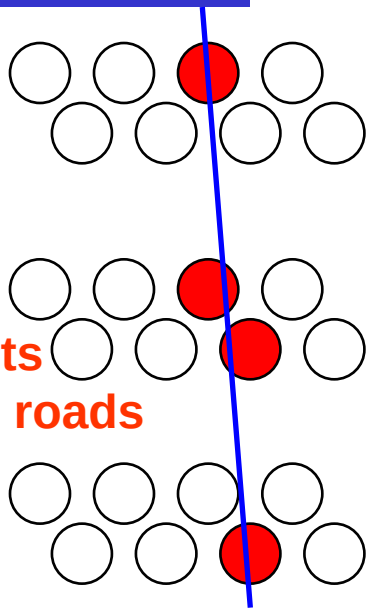


80 – 4.5° Sectors

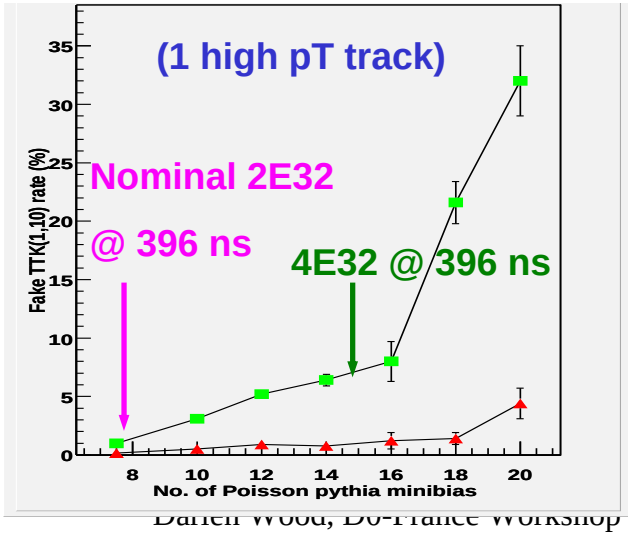
Run IIa
- doublets define roads

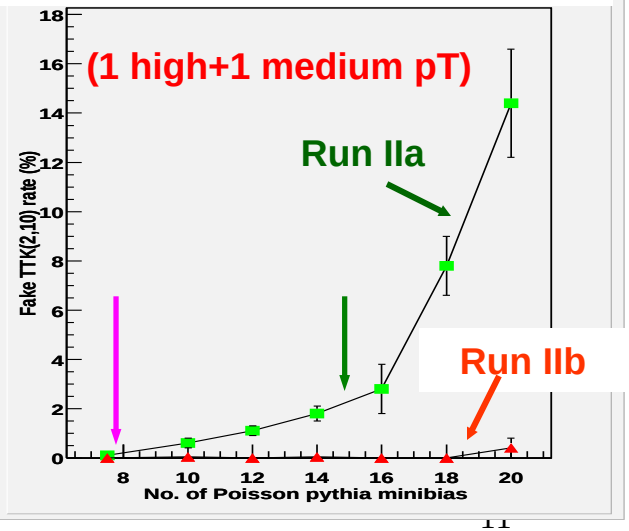


Run IIb
- singlets define roads



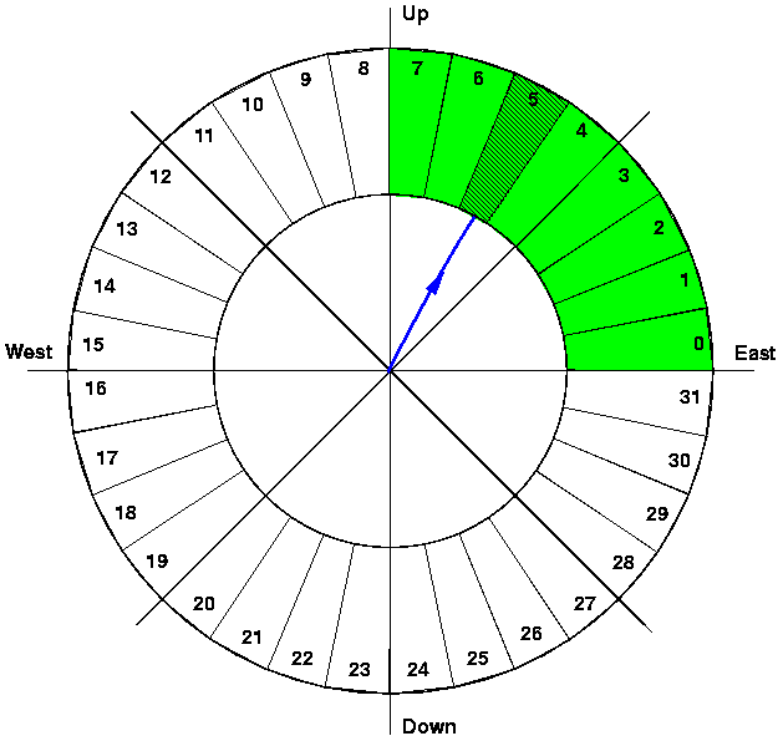
Fake Rate Reduction: x20 @ P_t=10GeV (2e32)





Cal-Track Matching at L1

Condition		CTT	Cal-Match	
Run IIa	no P-terms	4°	360°	(all Cal)
	P-terms	4°	90°	(quadrant)
Run IIb	Cal-Track	4°	11.25°	(TT)



Improvements in Bgrd Rej.

- Tau x10
- EM x2 (if desired)

Especially useful for Higgs

- $H \rightarrow \tau^+ \tau^-$; $H^+ \rightarrow \tau^+ \nu$
- electrons in WH & H→WW

Modest Effort

- based on existing L1Muon

Silicon Track Trigger and Level 2

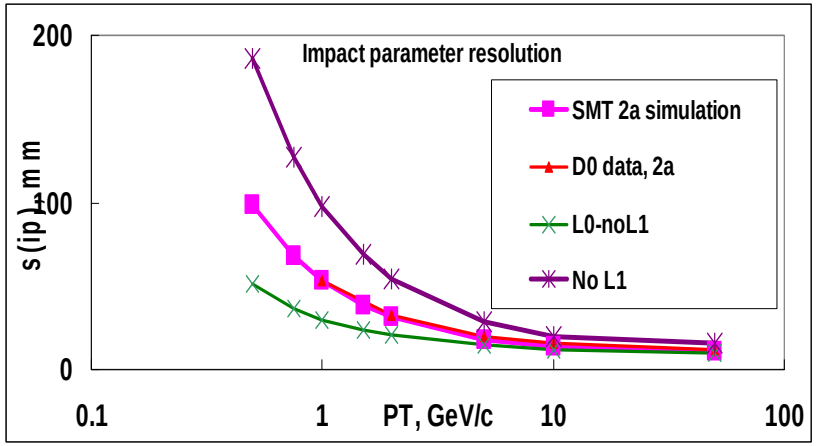
- STT
  - Additional production of the same boards is needed to accommodate new Layer 0 channels
- Level 2
  - A new generation of Level 2 “Beta” processors to provide more power and rate capability to the Level 2 trigger
  - Engineering for hard drive adapters for Beta processors from LAL Orsay

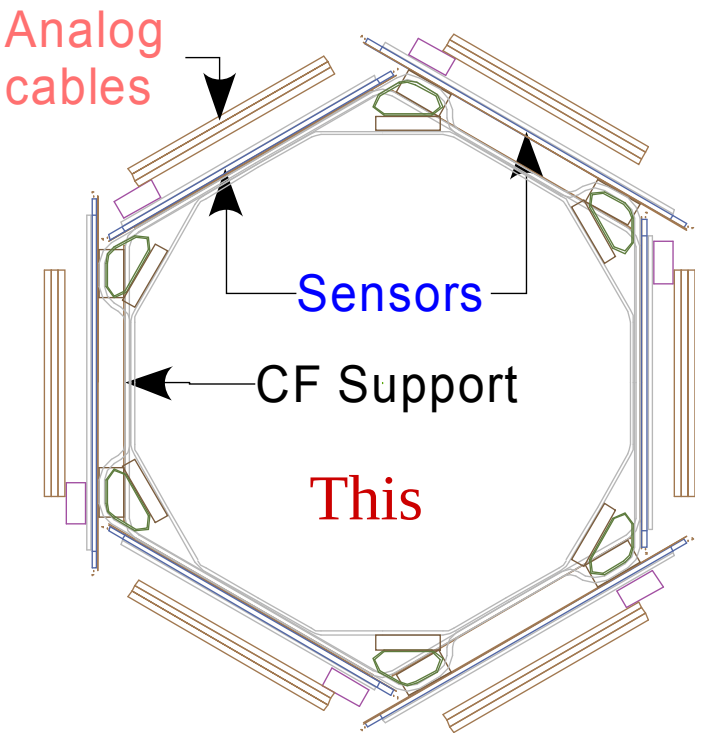
2003: The Drought Year

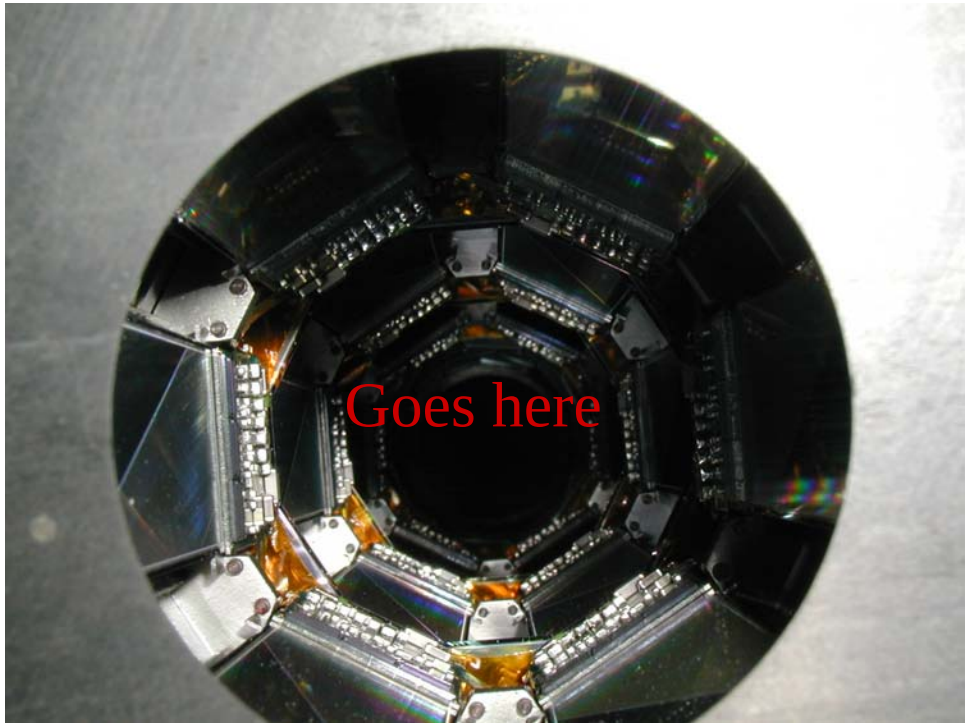
- July 2003 Fermilab PAC report
  - "The luminosity is still below expectations, resulting in considerable frustration and uncertainty. "
- New Tevatron Run II projections with reduced expectations
  - 4.4 fb^{-1} base goal
  - 8.8 fb^{-1} design goal
- September 2003: Fermilab director Mike Witherell cancels full silicon upgrades for CDF and DØ
- October 2003: DØ proposes a reduced silicon upgrade:
  - Addition of inner layer (Layer 0) inside the existing SMT

Silicon Tracker Layer 0

- Uses existing R&D on grounding, hybrids, sensors, supports, and cables
- Improve tracker performance even with radiation damage to other inner layers
- Difficult mechanical problem …



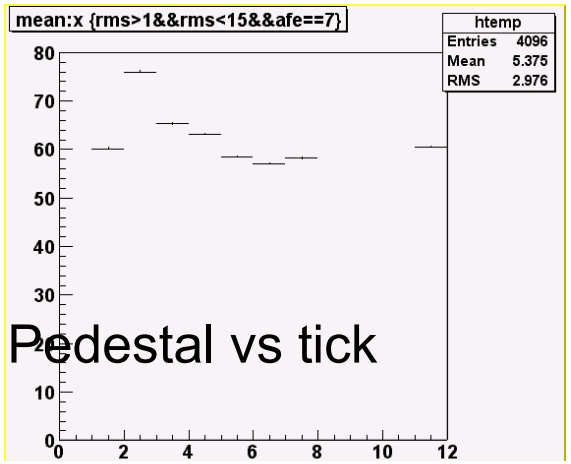


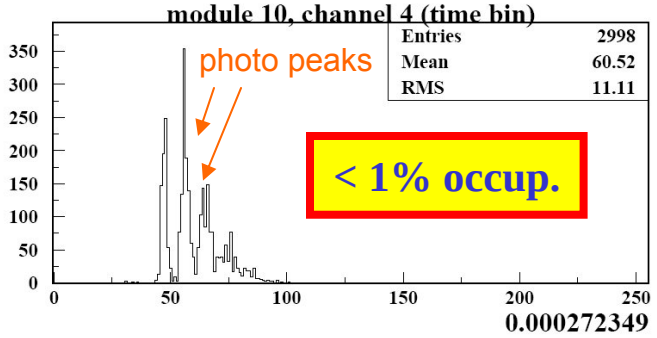


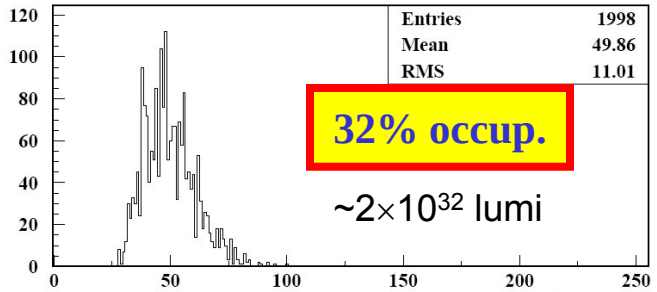
Additional Upgrade - Replacement of CFT Read-out: AFE II

- Replacement for the old AFE CFT readout board
  - Replace SIFT/SVX II with TRiP-t + Commercial ADC
  - Gain: TRiP-t will allow timing (z information) from CFT
    - 2ns resolution → ~30cm
- Benefits
  - Lower noise → lower thresholds.
  - Stable pedestals

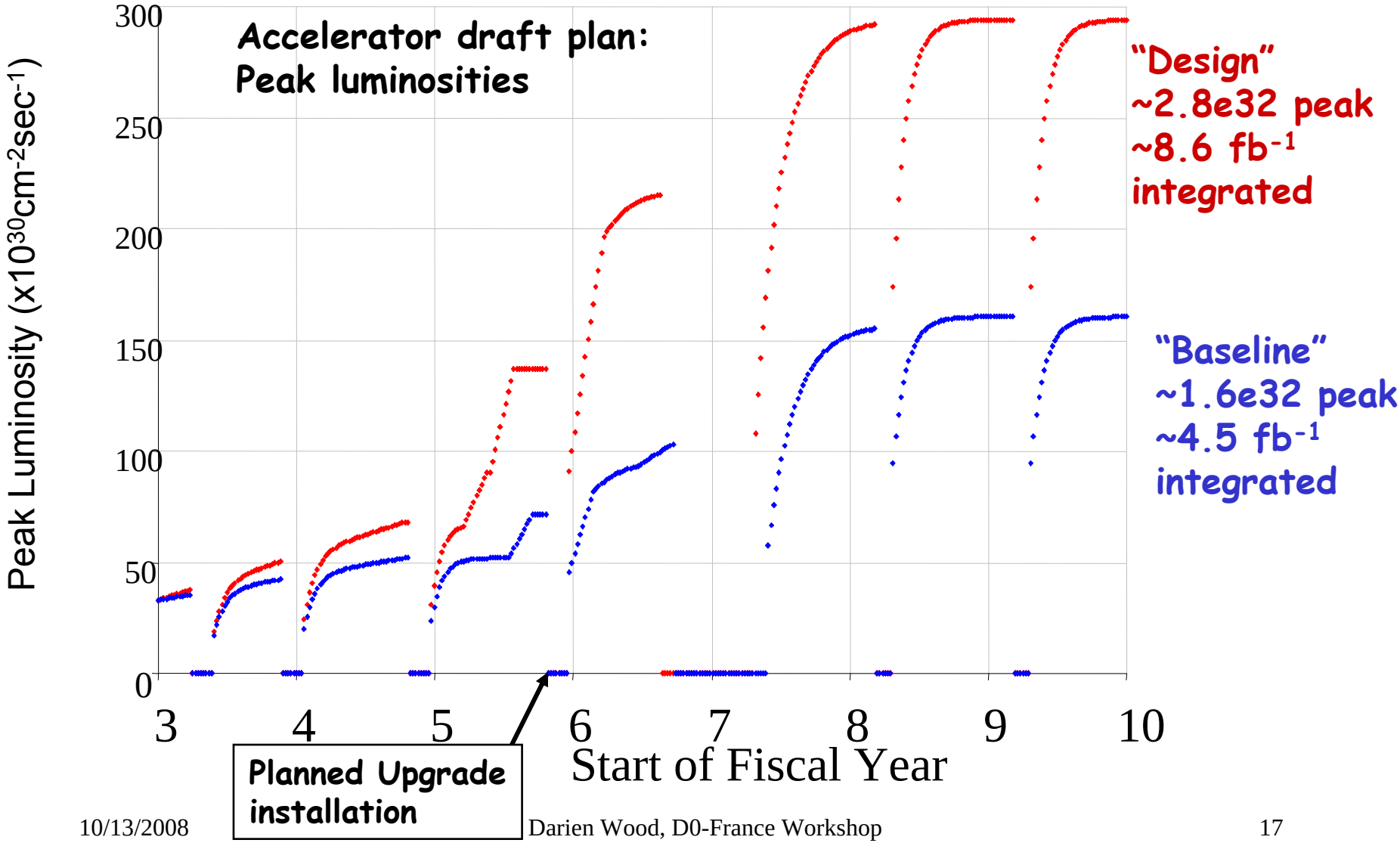
    We can recover signal that would be lost at high luminosity
  - Z information → easier pattern recognition. Decrease fake rate and maintain efficiency







Run IIb Luminosity Projections in 2003



Upgrade Project Structure after Re-scoping

Run IIb Project
V. O'Dell, *Project Manager* , R. Lipton, *Deputy*
M. Johnson, *Technical Coordinator*
T.J. Sarlina, *Asst Project Manager*, D. Knapp, *Budget Officer* T. Erickson, *Adminstration*

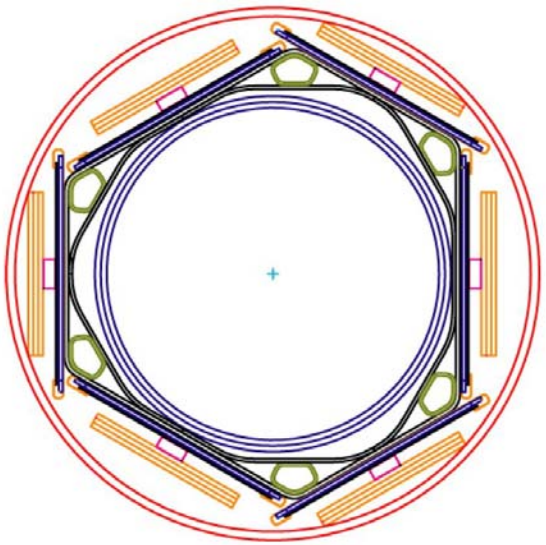
- **Silicon Layer 0** — A. Bean (R. Lipton)
  - **Sensors** — M. Demarteau, R. McCarthy
  - **Readout** — A. Nomerotski, R. Sidwell
  - **Mechanical Design & Fabrication** — W. Cooper
  - **Detector Modules & Integration** — J. Fast, L. Bagby
  - **Administration** — (A. Bean)
- **Trigger** — P. Padley, D. Wood
  - **L1 Cal Upgrade** — M. Abolins, H. Evans
  - **L1 Track Trigger** — M. Narain
  - **L1 Cal/Track Match** — K. Johns
  - **L2β upgrade** — R. Hirosky
  - **Silicon Track Trigger** — U. Heintz
  - **Simulation** — E. Barberis, M. Hildreth
  - **Administration** — (D. Wood)
  - **AFE/TriP** — A. Bross
- **DAQ/Online** — S. Fuess
  - **L3 Systems** — D. Chapin, G. Watts
  - **Network & Host Systems** — J. Fitzmaurice, S. Krzywdzinski
  - **Control Systems** — F. Bartlett, G. Savage, V. Sirotenko
  - **DAQ/Online Management** — (S. Fuess)
- **Installation** — R. Smith
  - **Silicon Installation** — Mechanical: W. Cooper; Electrical: L. Bagby
  - **Trigger Installation** — D. Edmunds

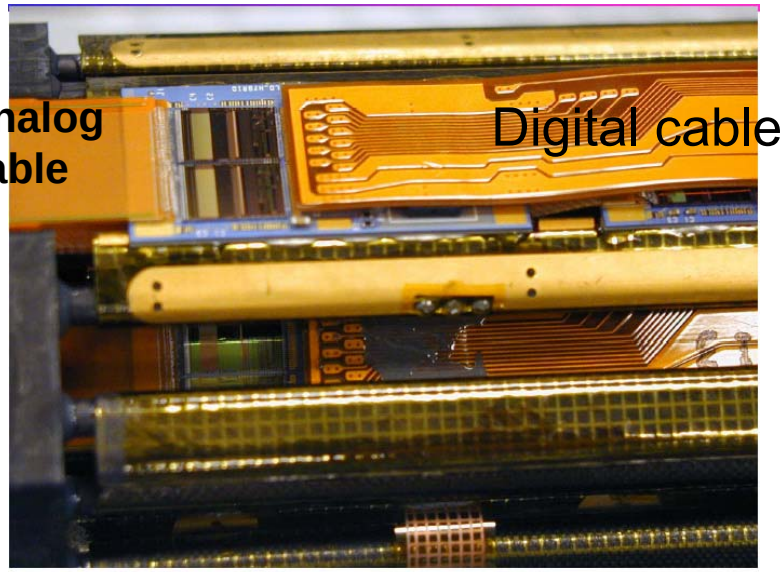
Gina Mikel, http://www.scientificillustrator.com

- **This outlines the upgrade that was actually implemented**
- **Ready for installation in 2005**
- **Actual installation delayed until 2006 due to zebra mussel infestation in accelerator cooling water**

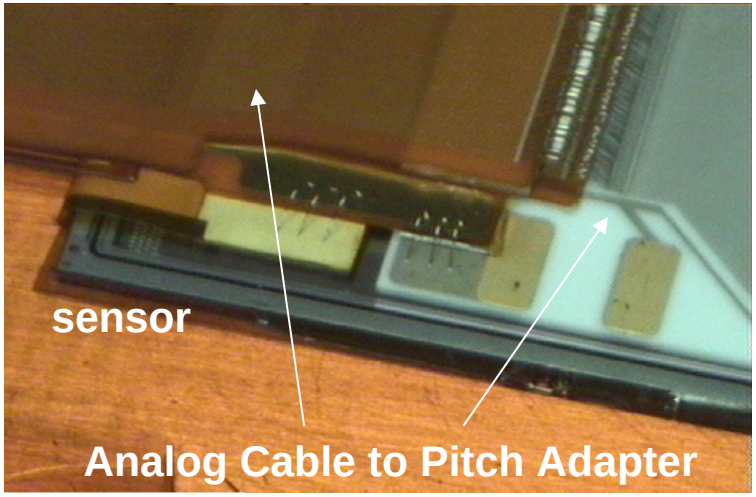
Layer 0 Hardware

- 6-fold symmetry
- 4 sensors /z half (2x7cm, 2x12cm)
- 71μm readout pitch (inner) and 81μm (outer)
- 98.4% ϕ acceptance
- 48 hybrids
- SVX4 chip
- extensive study of grounding issues to

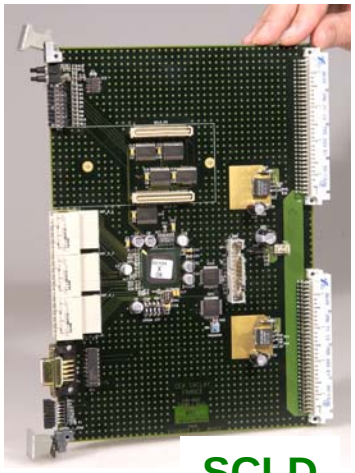




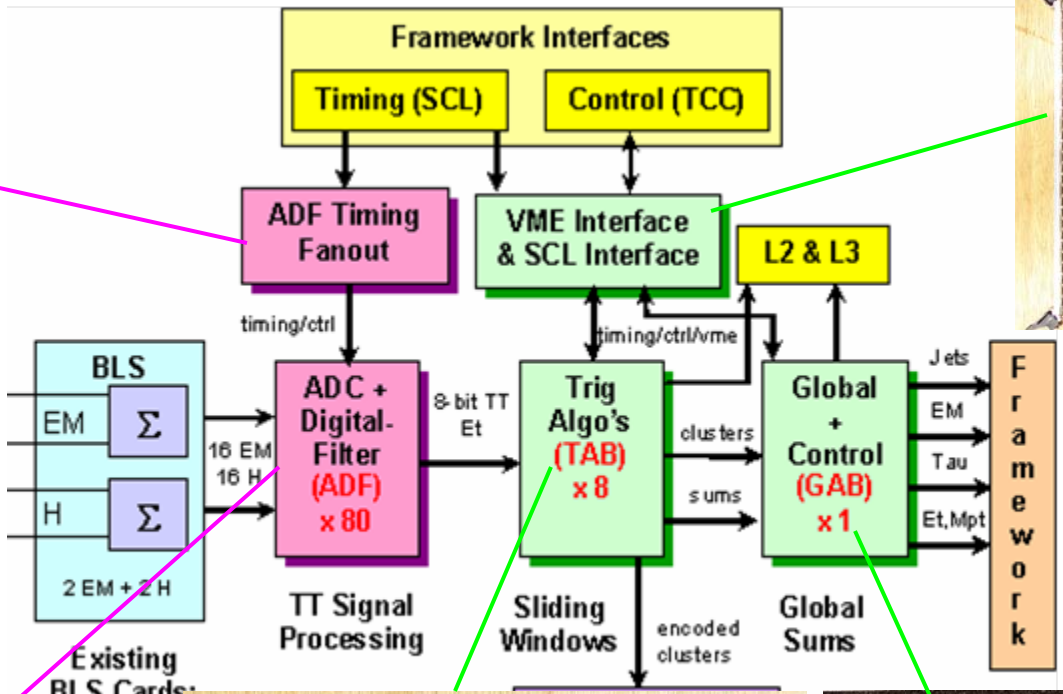
Hybrid region with co-cured kapton circuit

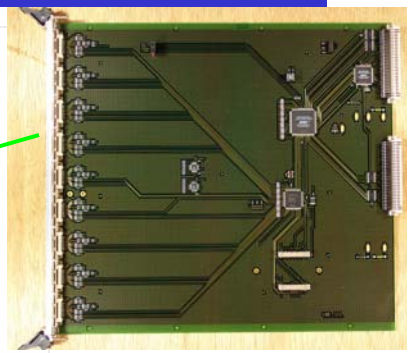


L1Cal Trigger Hardware

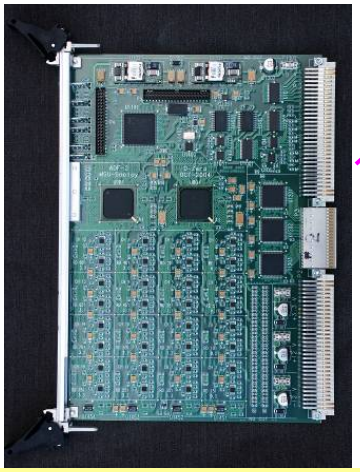


SCLD



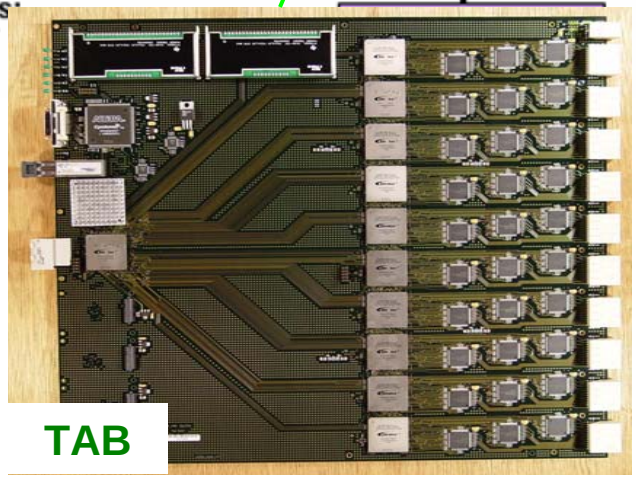


VME/SCL



ADF v2

(note: v1 designed and produced by Saclay)



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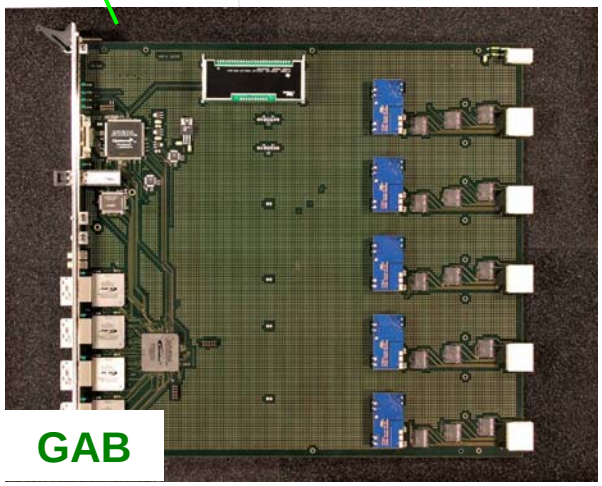
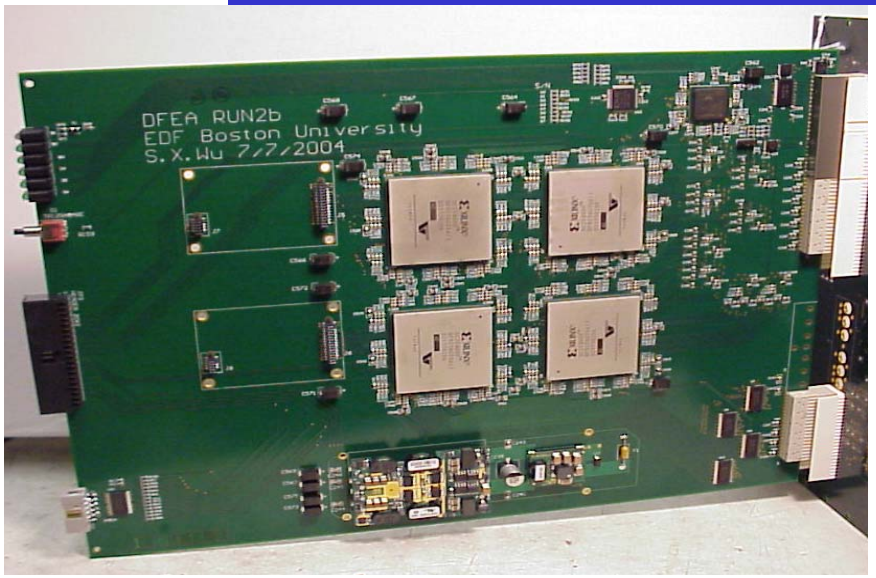


GAB

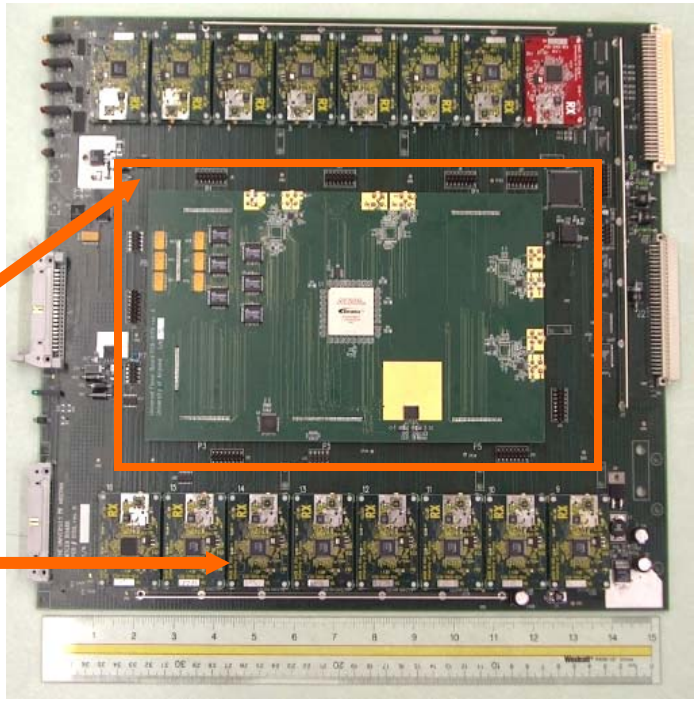
Hardware: L1CTT and L1 cal-track



L1CTT Digital Front End with large FPGA's:

(Xilinx Virtex-II XC2V6000)

Cal-track matching board

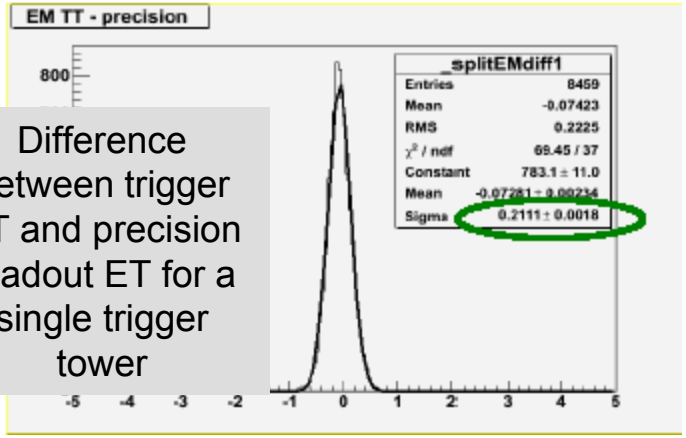


Universal Flavor board (daughter)

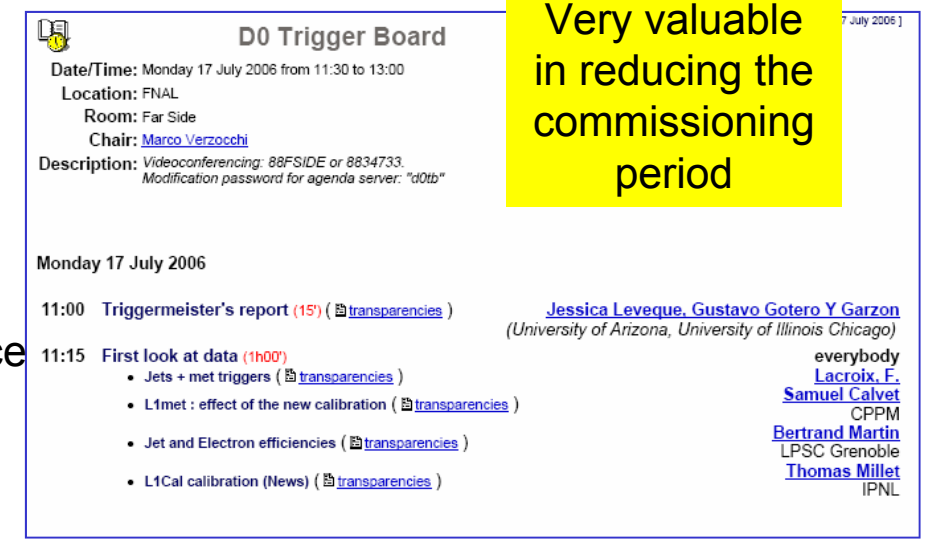
MTCxx (mother board)

2006: Turning Trigger hardware into a functioning trigger for the experiment

- New trigger list: “Version 15”: Trigger List Task Force and Trigger Board led by Marco Verzocchi
  - Major work on Missing ET triggers from Arnaud Duperrin and Thomas Millet (IPNL)
- Calibration/commissioning of L1cal with data - special French task force set up
  - Thomas Millet, IPNL (data), Fabrice Tissandier, LPC (MC)
    - Tower-by-tower calibration
  - Samuel Calvet, CPPM
    - Missing ET efficiency
  - Florent Lacroix, LPC, Christophe Ochando, LAL Orsay
    - Jet + MET Triggers
  - Bertrand Martin, LPSC Grenoble
    - Jet efficiencies
  - Jan Stark, Arnaud Duperrin, Patrice Verdier
    - guidance

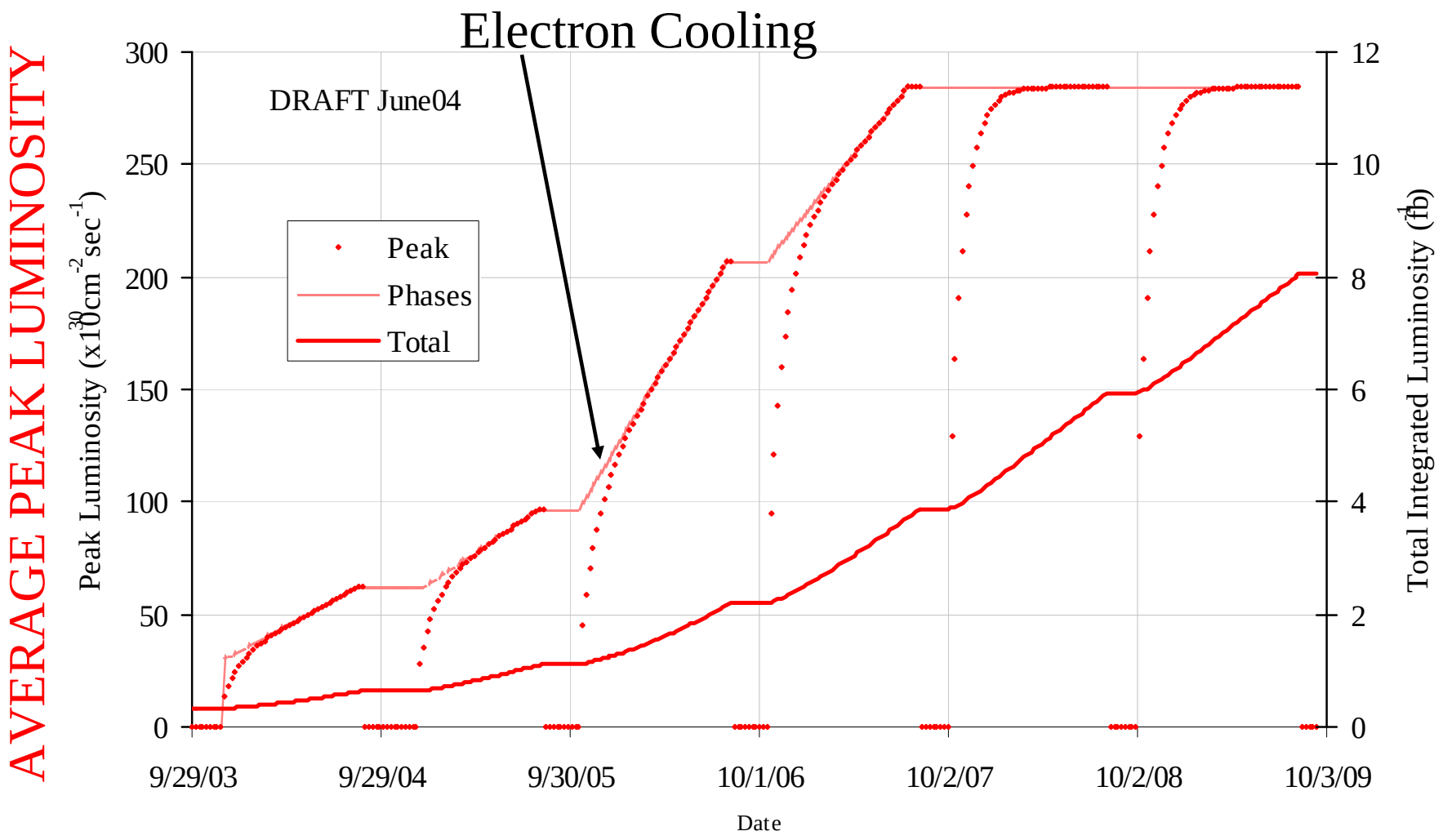


Difference between trigger ET and precision readout ET for a single trigger tower



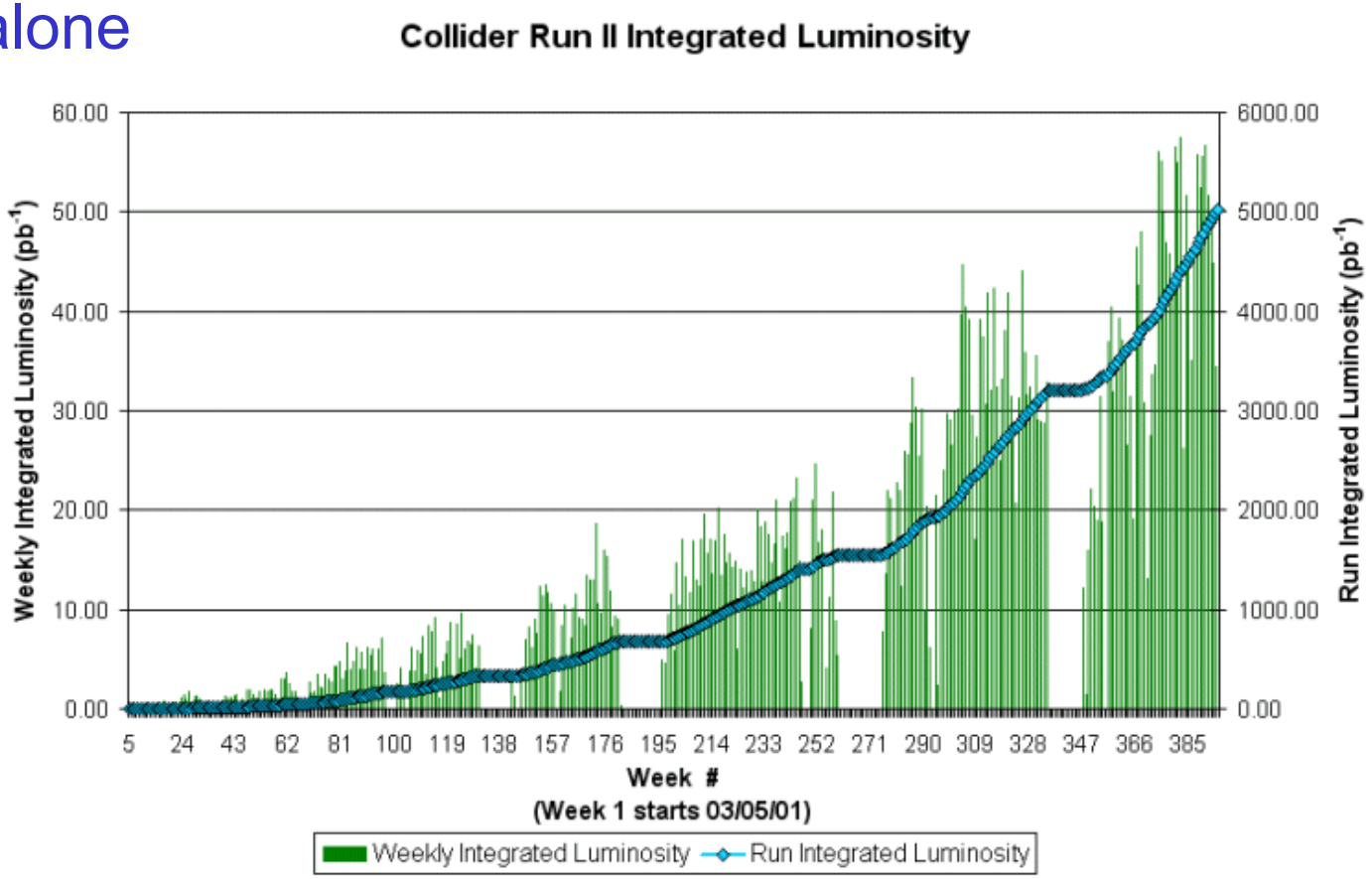
Very valuable in reducing the commissioning period

AD Design Goals

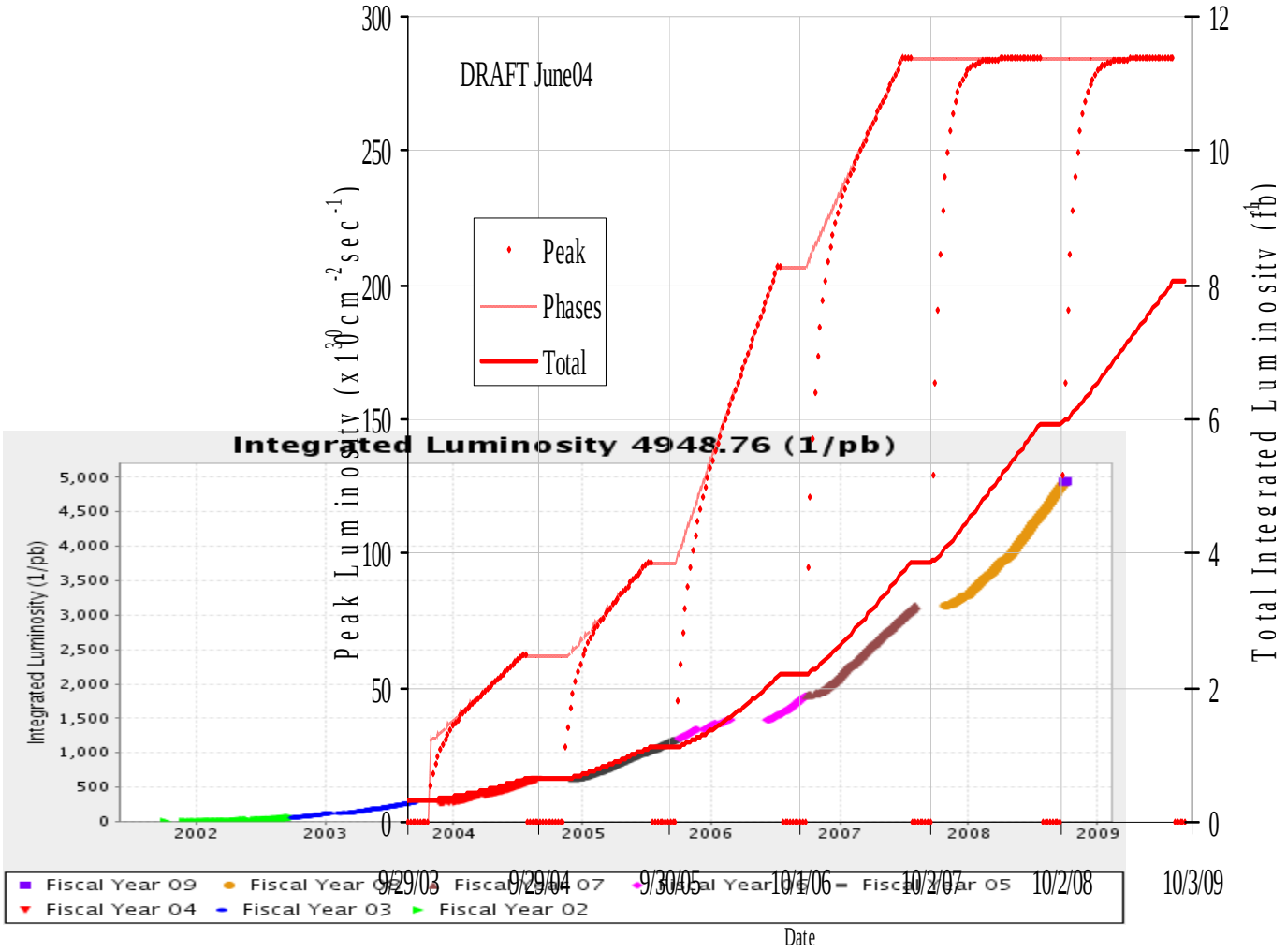


Current Tevatron Performance: integrated luminosity

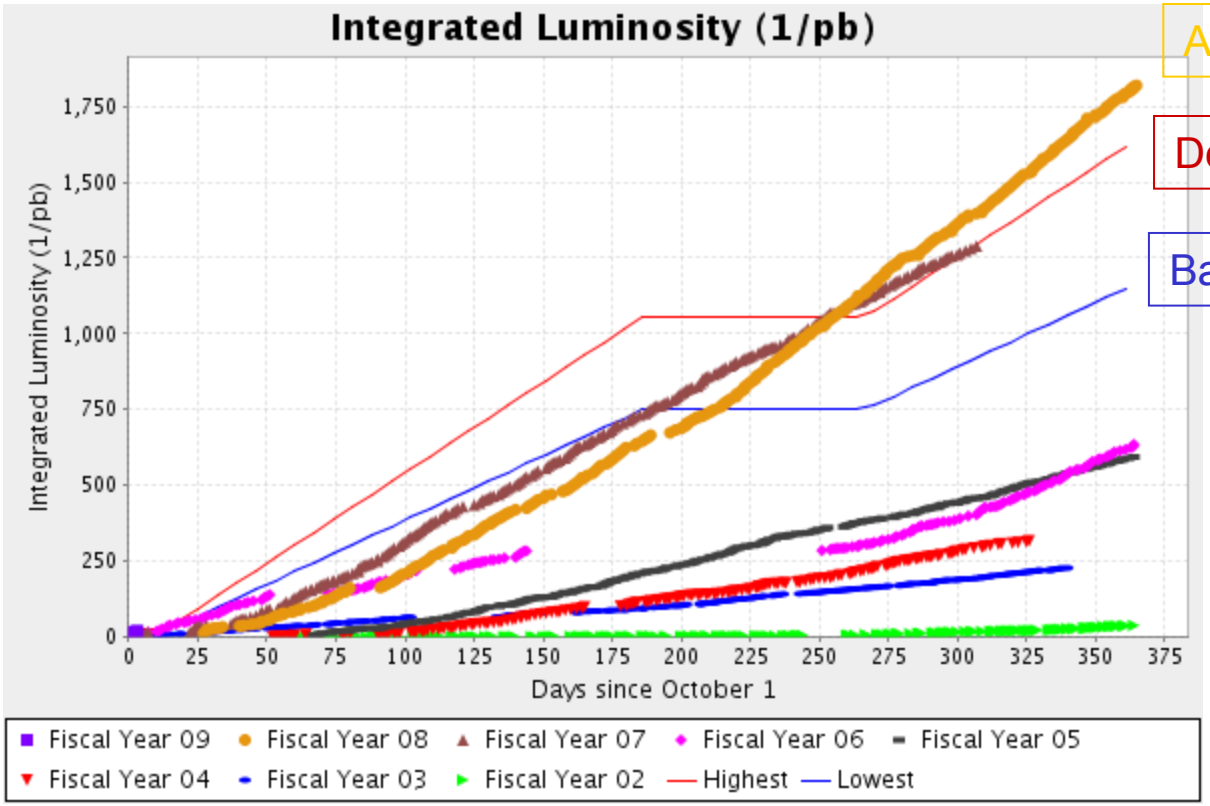
- More than 5 fb^{-1} delivered to each experiment since the start of Run II
- Delivered 1.77 fb^{-1} in the last year (Oct 1 – Sep 30) alone



2004 projection vs. today: integrated Luminosity



Comparative Performance

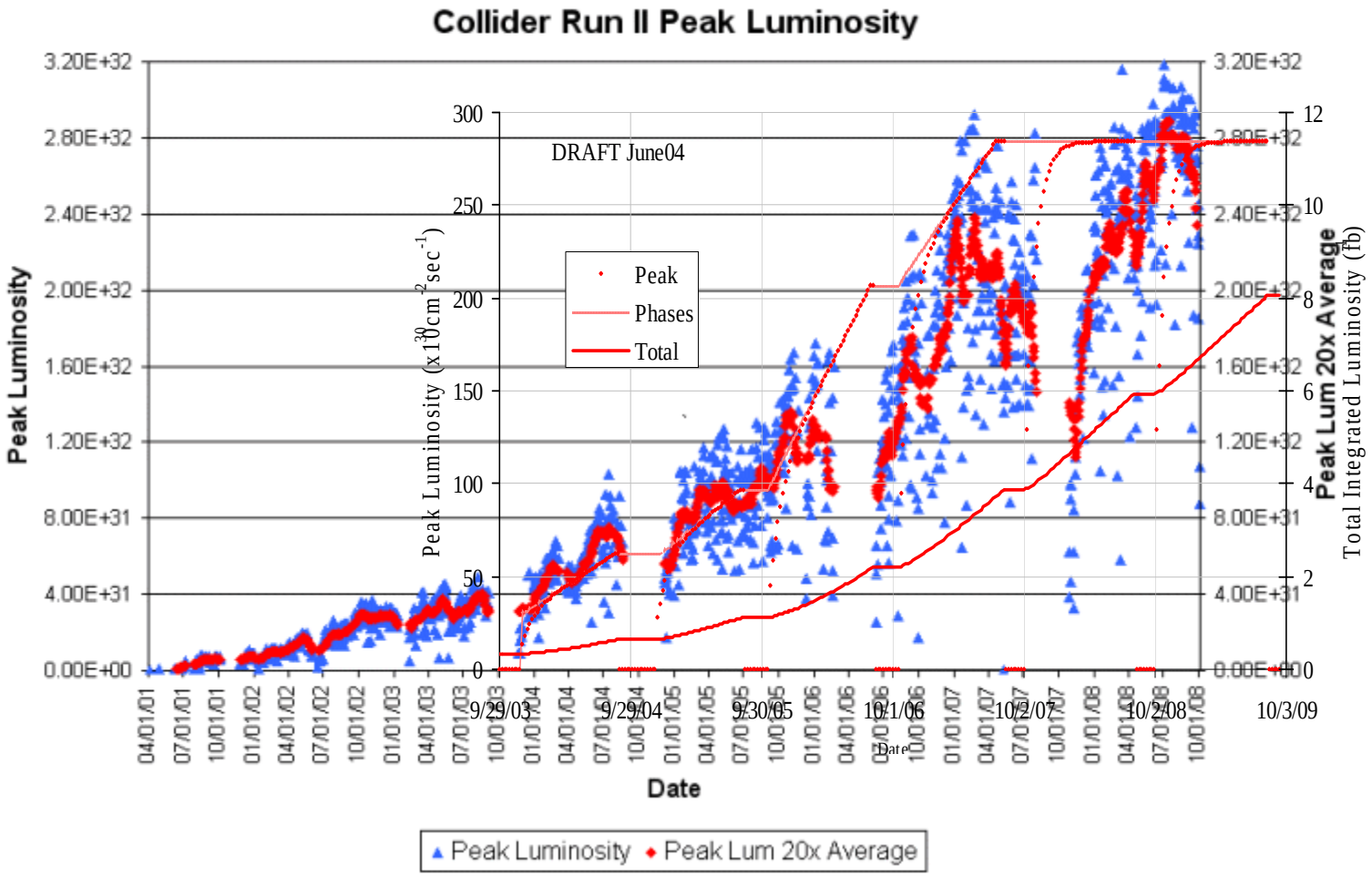


Actual delivered lum

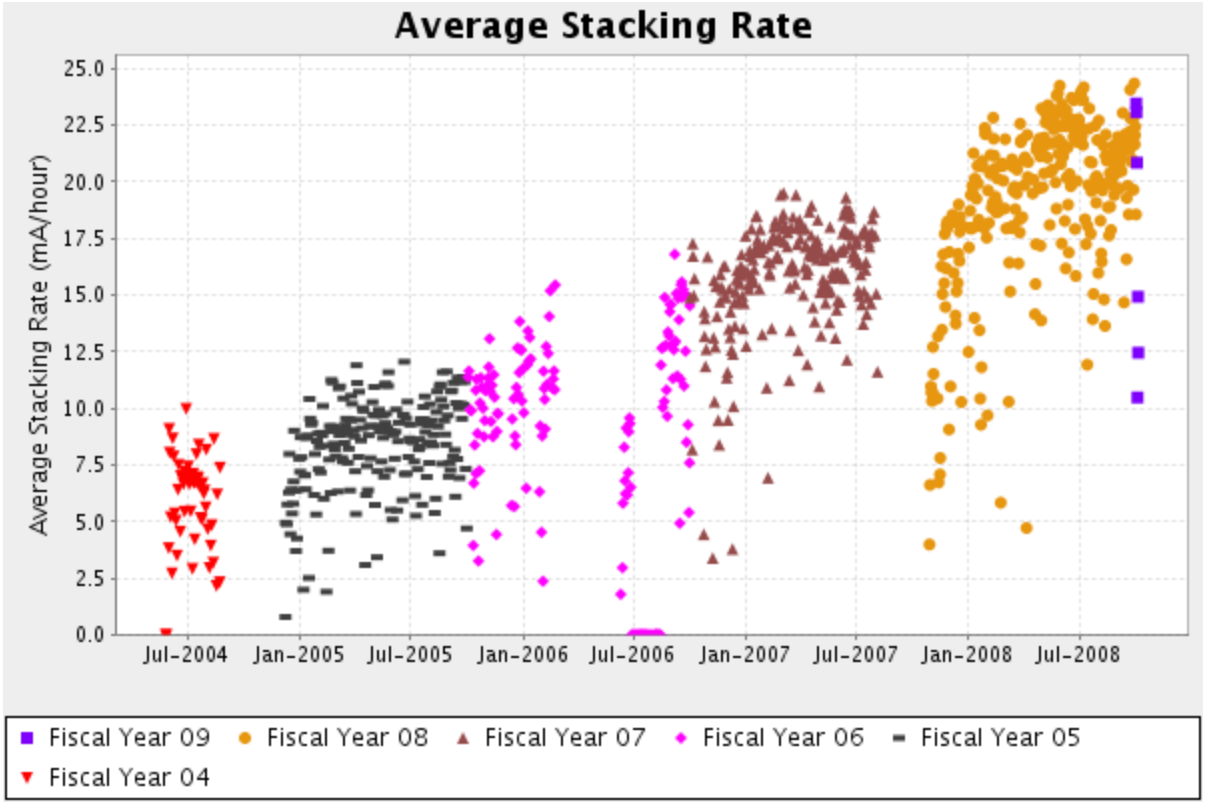
Design goal for FY08

Baseline goal for FY08

Peak luminosities: prediction vs. reality



Antiproton Stacking



Tevatron Reliability

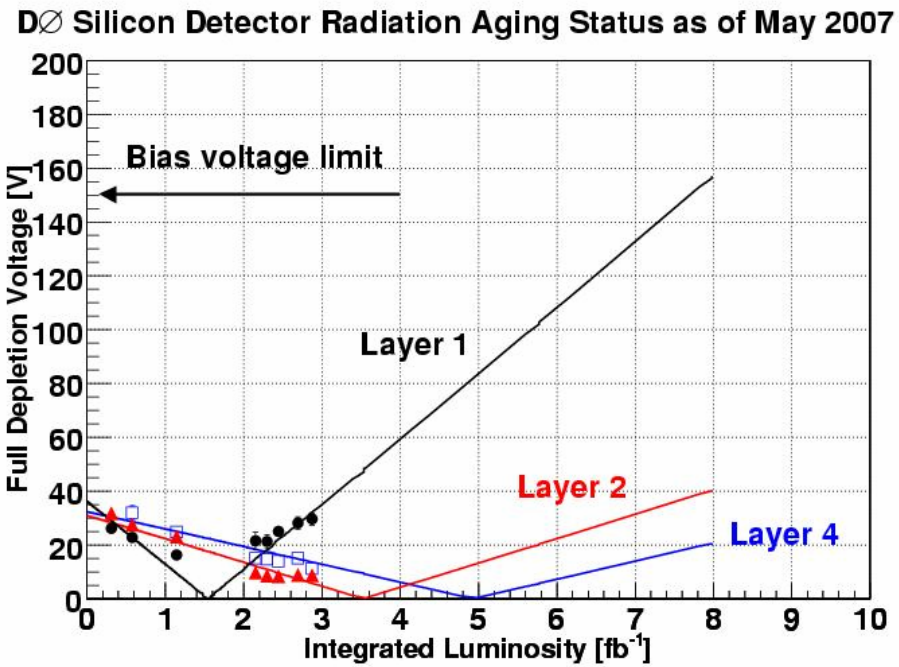
- Table from Roger Dixon (head of Fermilab Accelerator Division):

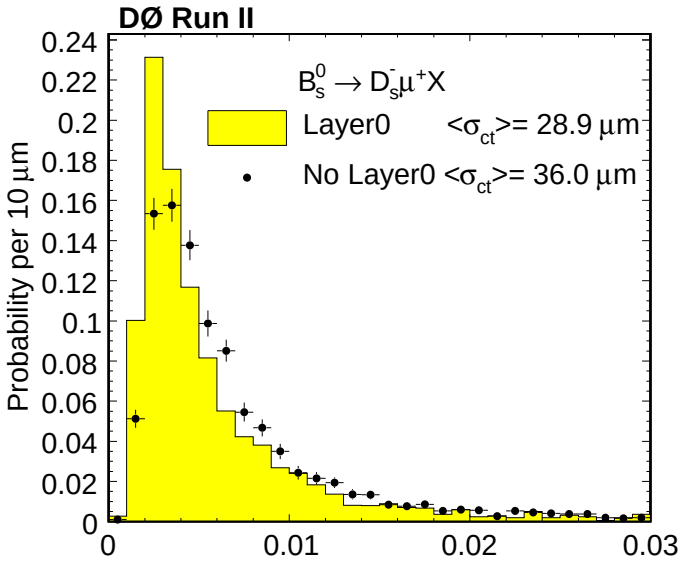
Year	Stores	Normal Terminations	%Normal Terminations
2003	186	55	30%
2004	166	110	66%
2005	243	170	69%
2006	171	107	63%
2007/8	247	197	80%

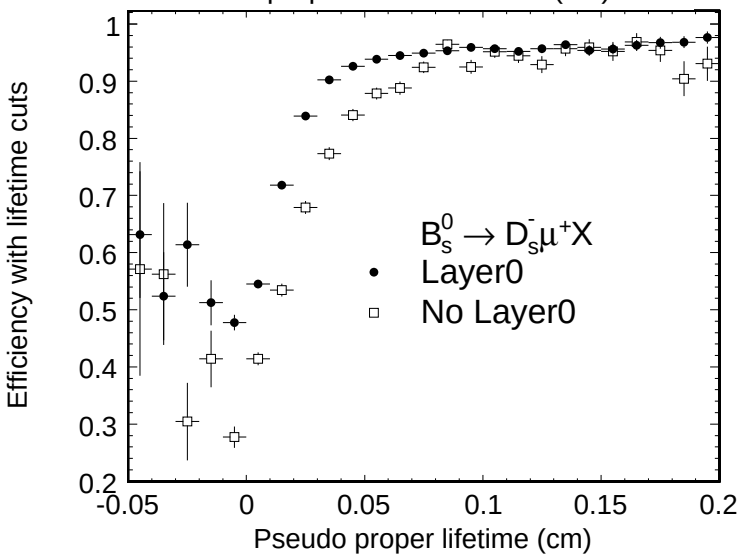
(from February 2008)

Layer 0 Performance on real data

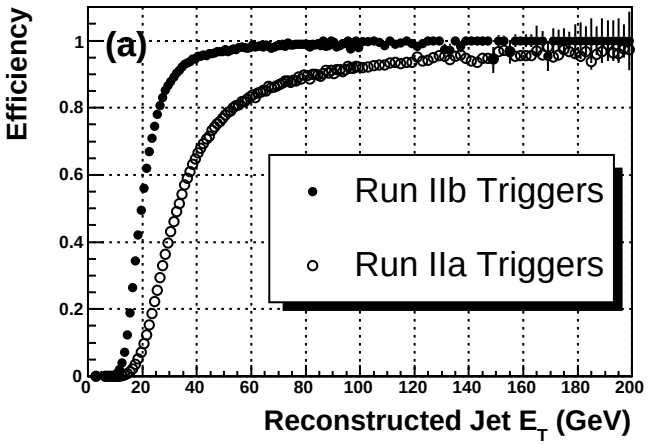
- Two examples of performance enhancements in Bs mixing →
- And in the mean time, the radiation damage on the old SMT layers is not bad ↓

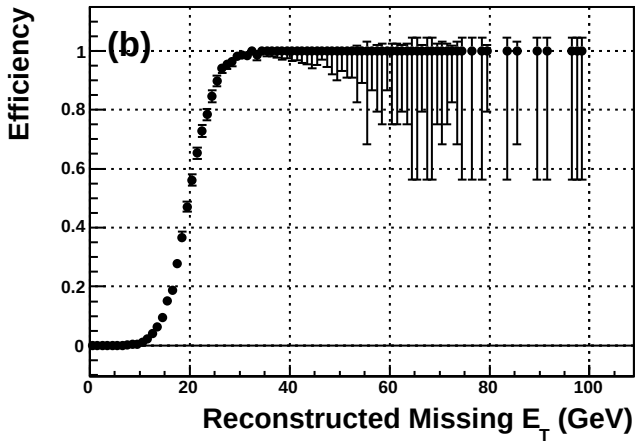


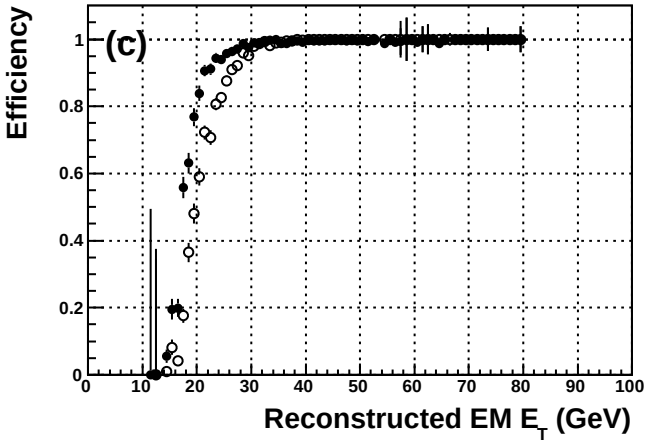


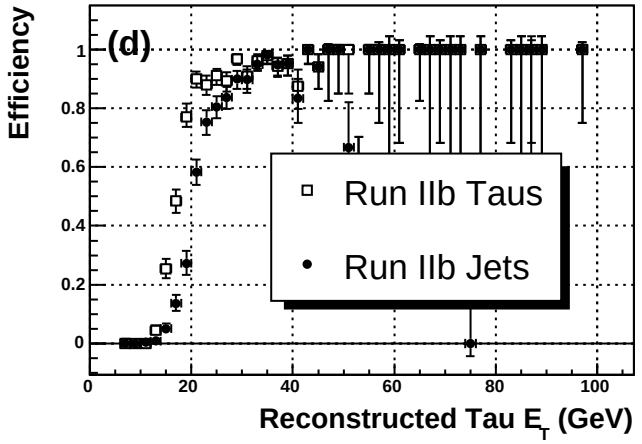


Trigger Performance on real data: L1Cal



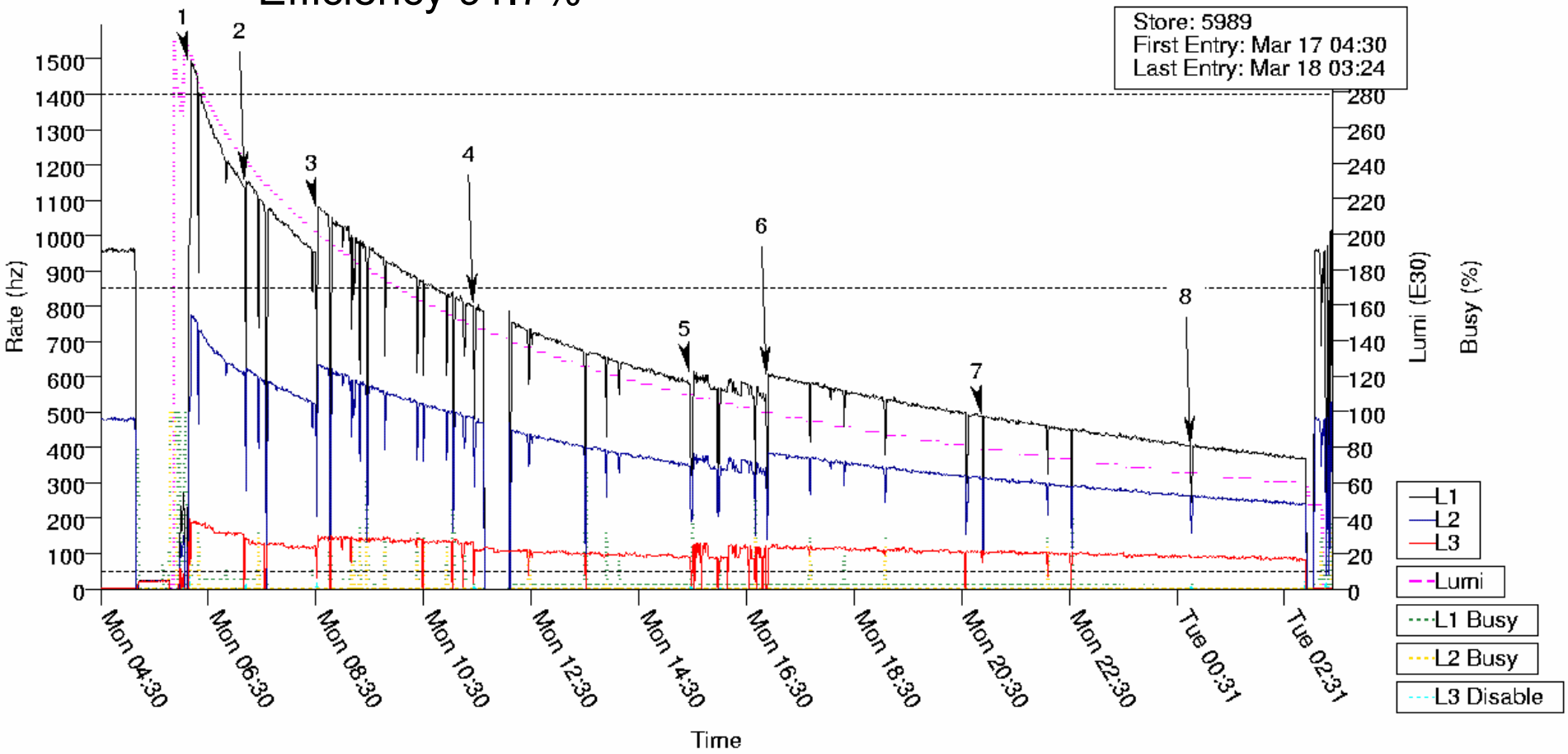






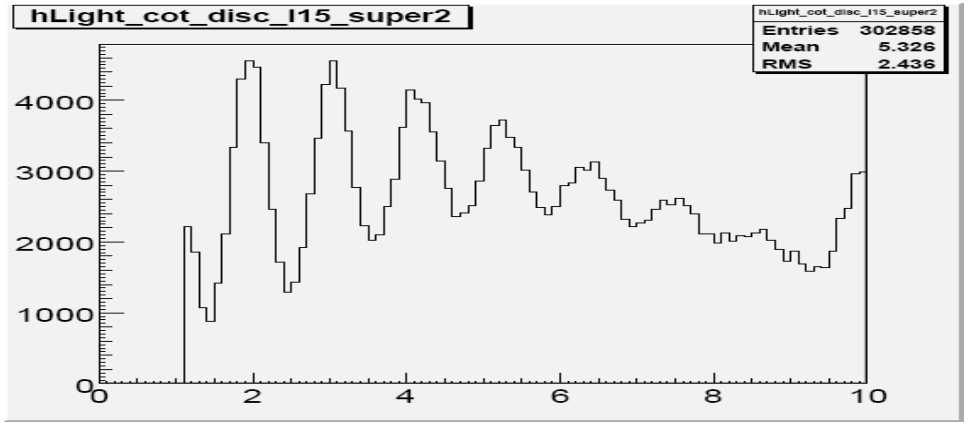
Overall Trigger performance example

- Record luminosity store 5989: starting luminosity = 312e30 $cm^{-2}s^{-1}$
- First run of store, Run 240822 Duration 1.04 hours
  - Efficiency 91.7%



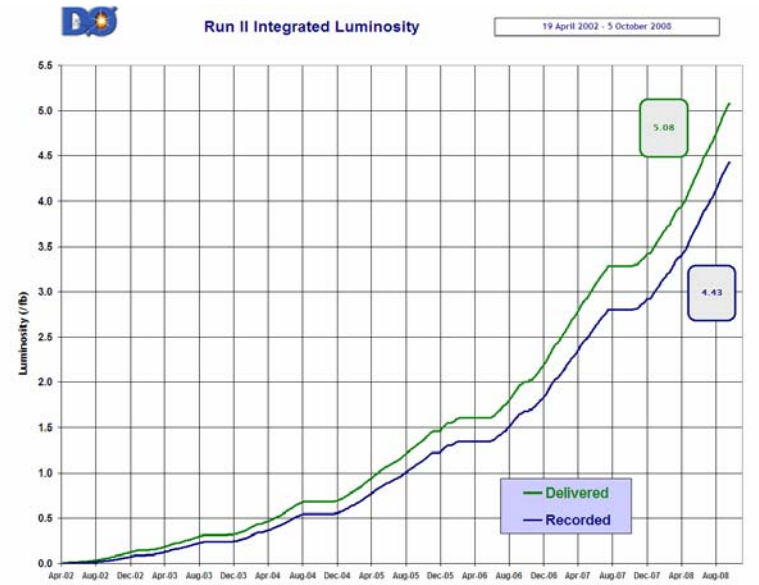
AFEII Performance

- Beautiful photoelectron peaks from real collider data



- Timing calibration nearly complete – being tested for fake-track killing

Overall D0 Data Taking Performance

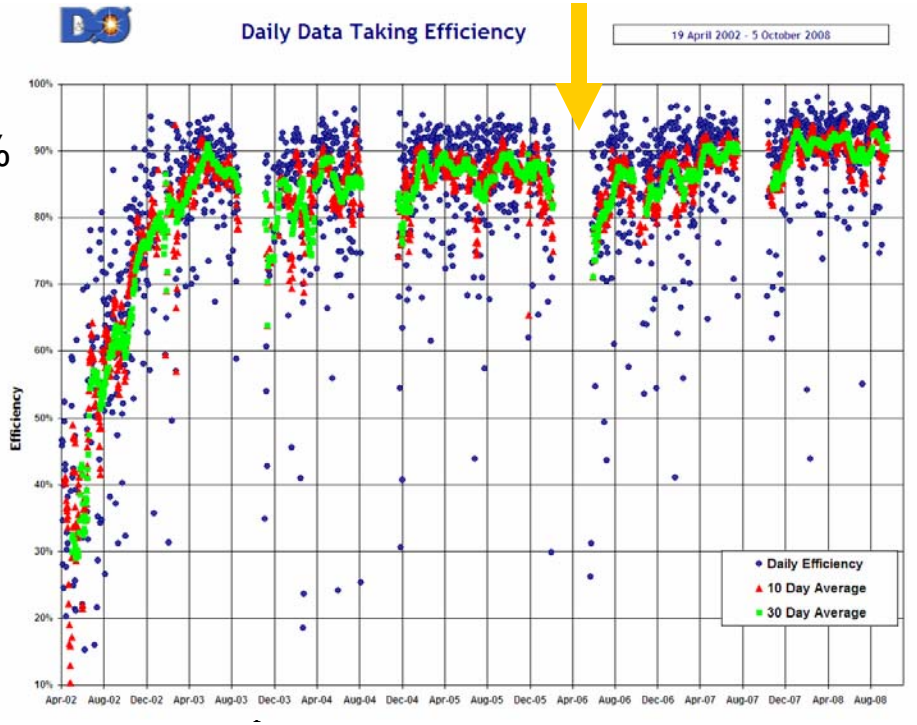


5.08 fb^{-1} delivered

4.43 fb^{-1} recorded

Run IIb upgrades installed

90%

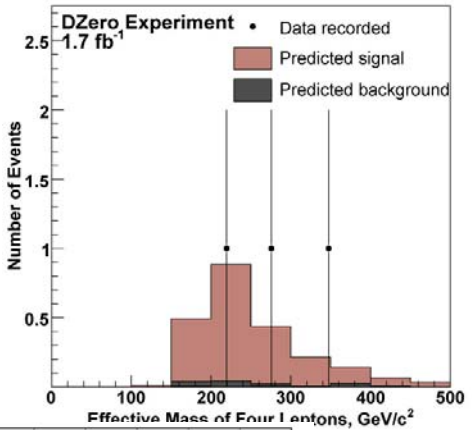


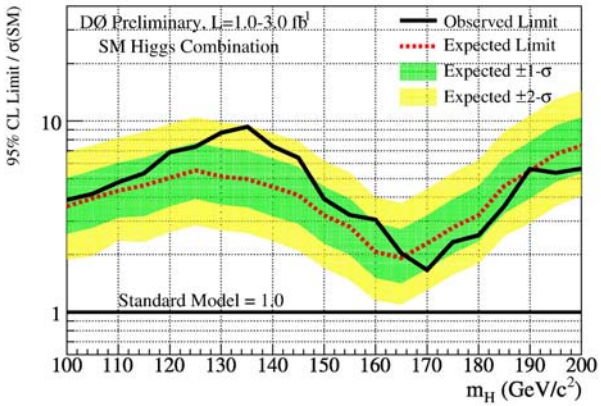
87% average efficiency for Run II

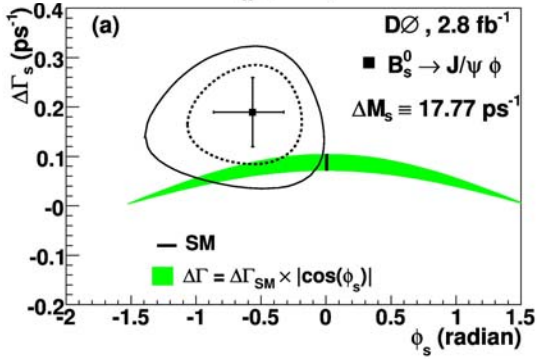
>90% efficiency over the last year

Physics Performance

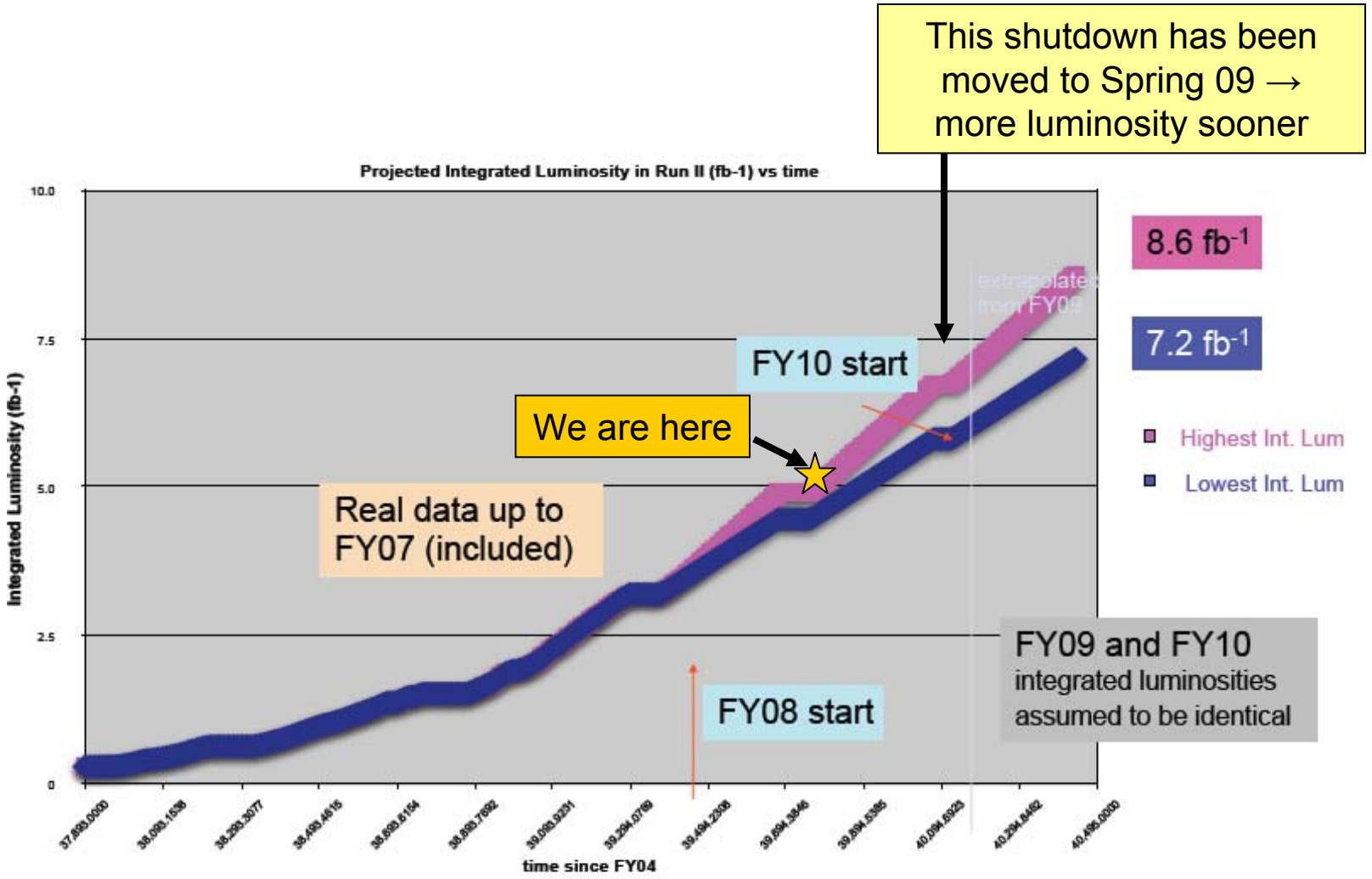
- Many new result have come out of the Run IIb data already. A few examples:
  - Observation of ZZ production (2.7 fb^{-1} total, 60% from Run IIb)
  - Preliminary High mass SM Higgs limits (3.0 fb^{-1} total, 65% from Run IIb)
  - B_s mixing parameters (2.8 fb^{-1} total, 55% from Run IIb)
- Most results in progress now are dominated by Run IIb data







Tevatron Projections



Conclusions

- The Tevatron had a stormy path to Run IIb, but is now performing superbly
- The DØ Run II b upgrade plans underwent some major changes along the way to completion, but the installation and performance were remarkably smooth
  - We would not be in this position without investments made years ago, some of them risky
- DØ-France made significant contributions to the upgrades, especially to the trigger
- We have just begun to taste the physics potential of Run II
  - The cave is well stocked, and the collection continues to grow
  - The finest vintages still await us