Operating the D0 detector

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Accelerator Physics and Technology Seminar
8 August 2006

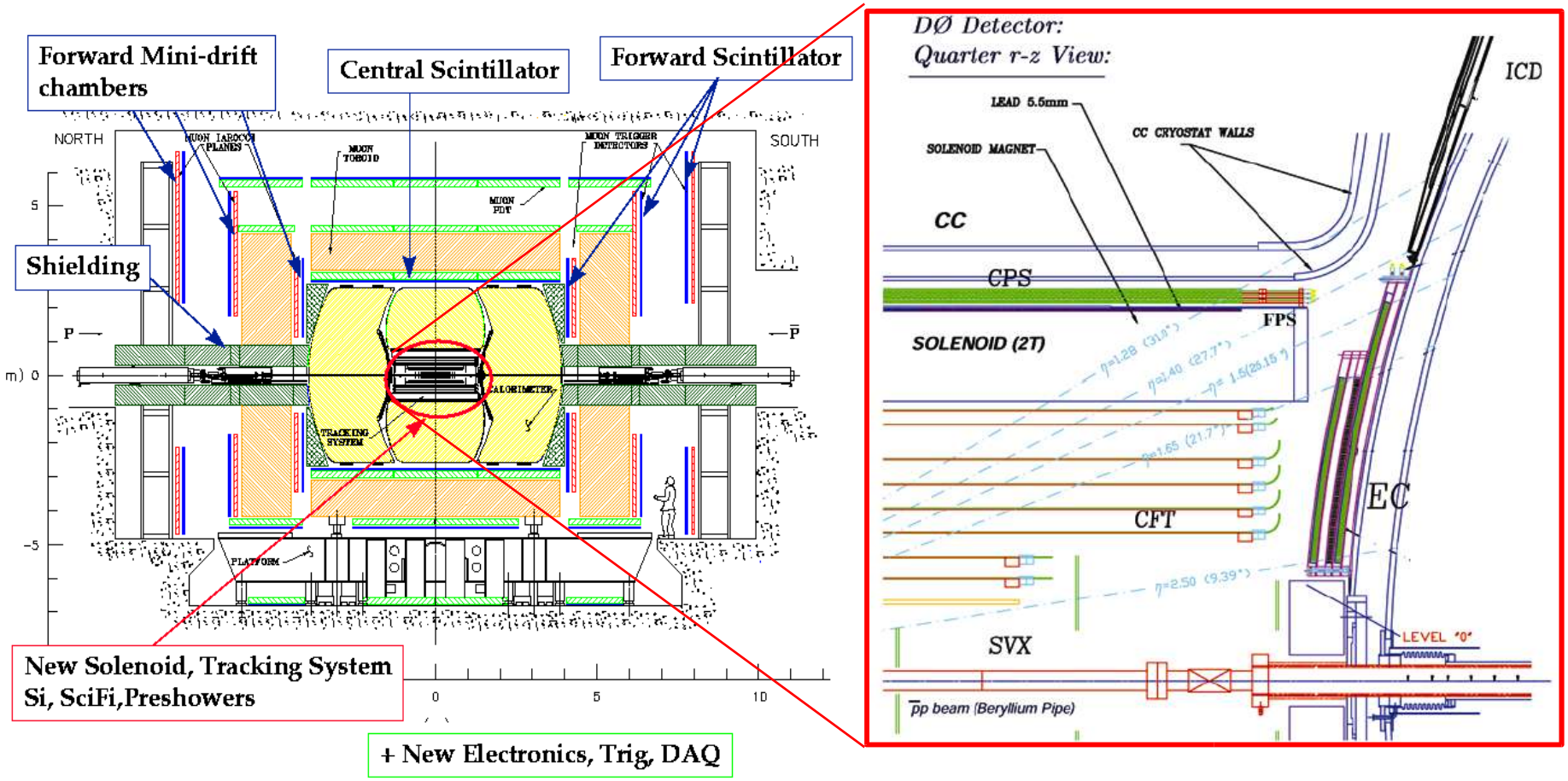
Outline

- The detector and readout
- Increasing luminosity
- Triggering and Trigger upgrades
- Operational Issues
- Efficiency

General Operational Goals

- Record all of the best possible physics quality data.
- To do this we must:
  - Keep all portions of the D0 detector in their optimal operating condition.
  - Record as much of the delivered Luminosity as possible.
    - The more integrated luminosity we receive, the more precision we will have on our measurements and the more likely that we will detect some rare process.
    - Run the detector 24/7
    - Keep our dead time to a minimum.

The D0 Run II Detector



Muon System

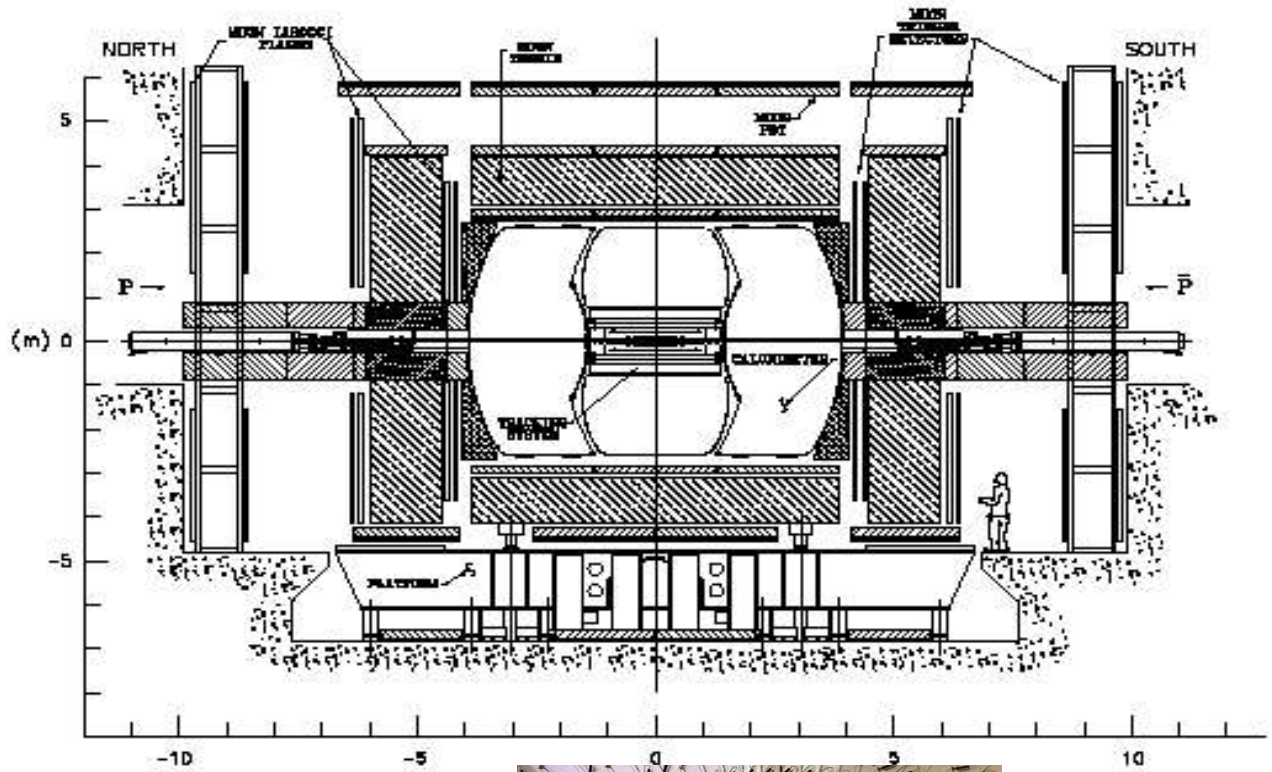
central: Central Drift Chambers Central Scintillation Counters ($|\eta| < 1$)

forward region:

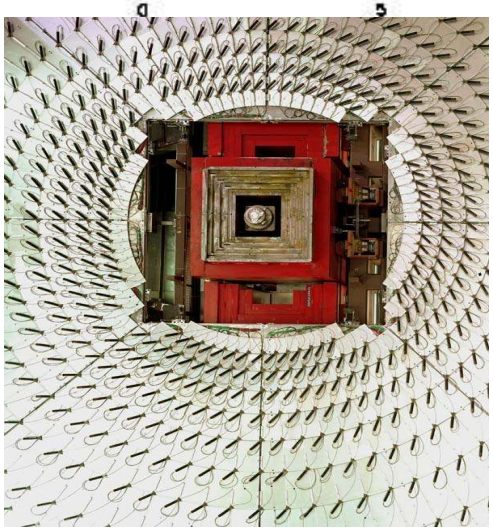
Forward
Mini-Drift Chambers

Forward
Scintillation Counters

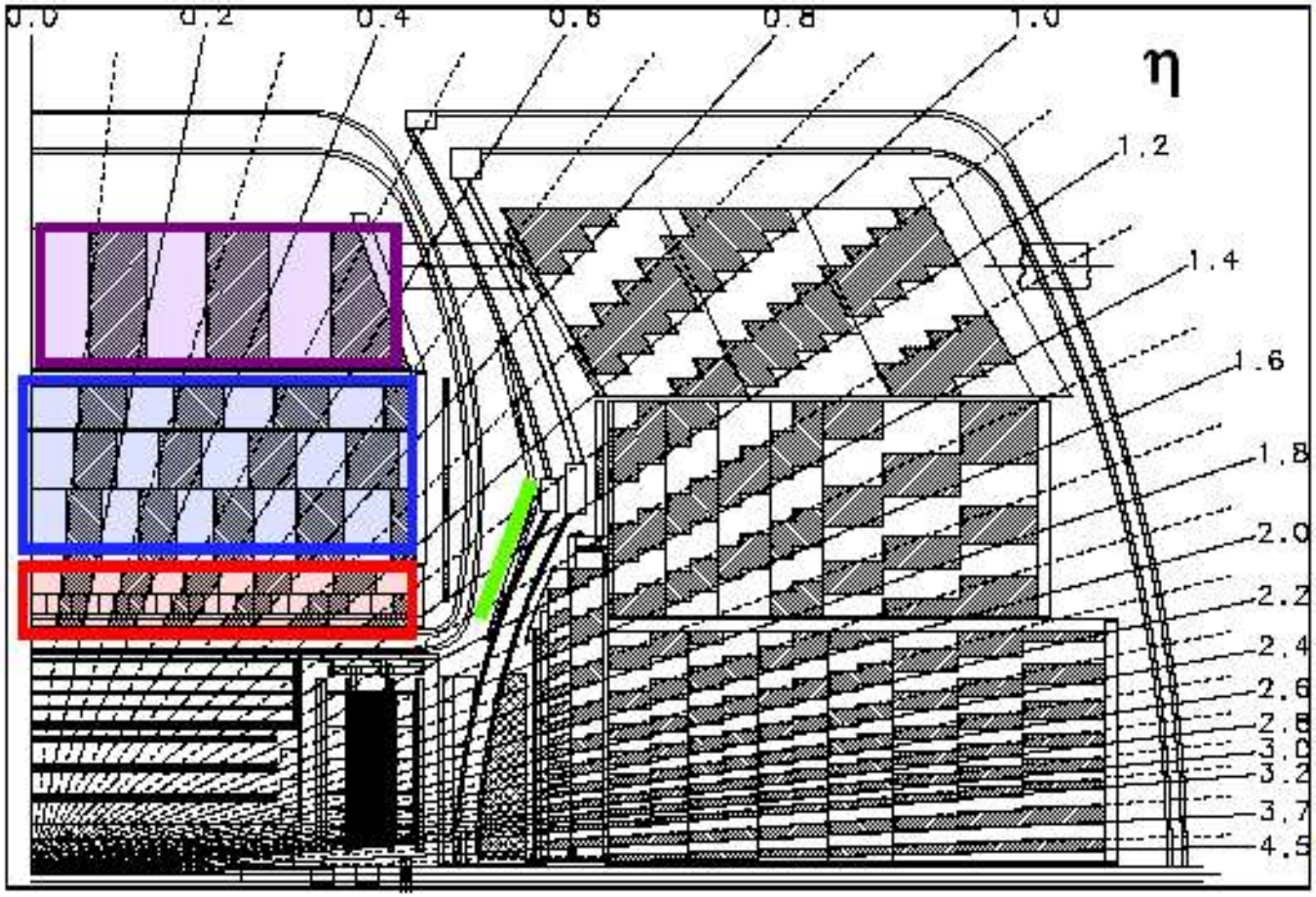
($1 < |\eta| < 2$)



Total: 110,000+ channels



Calorimeter



Liquid Argon

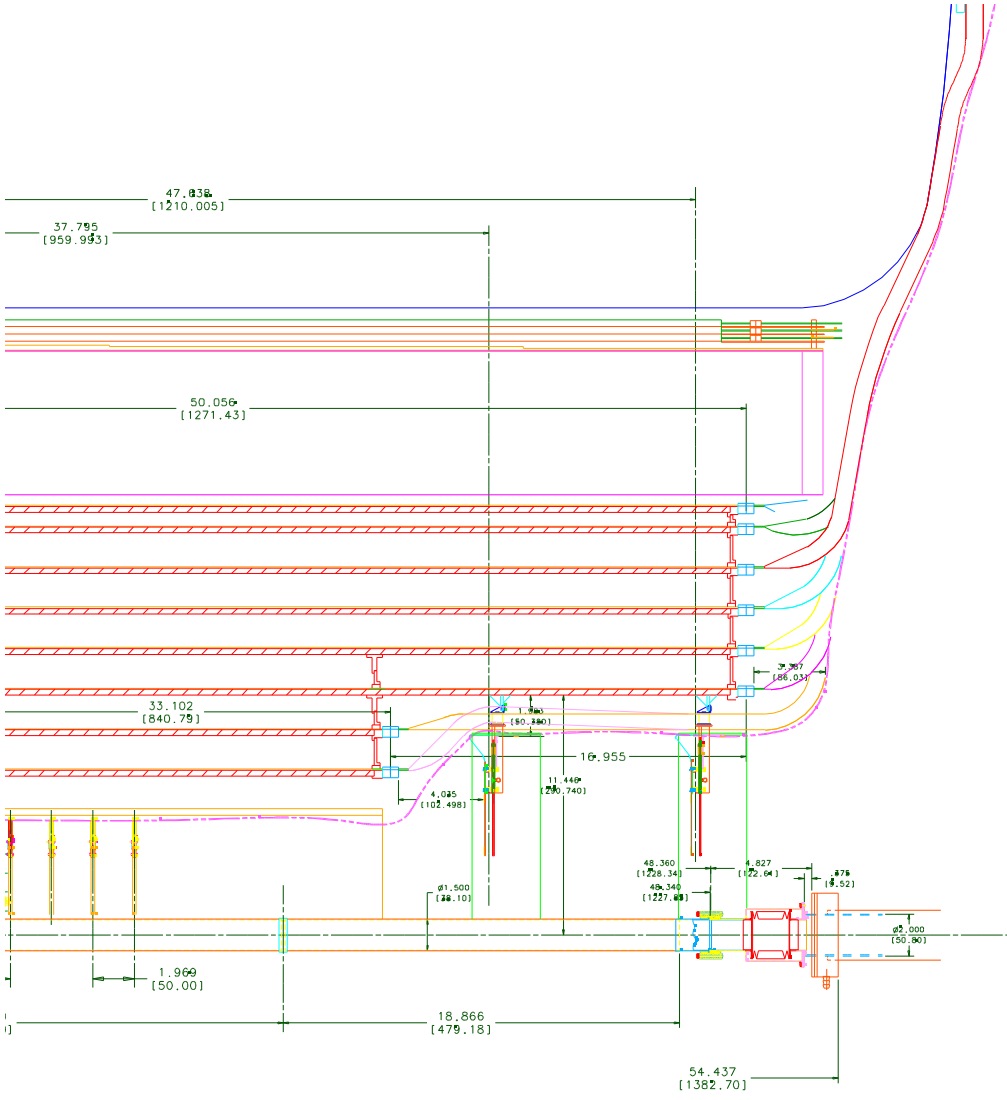
- Electromagnetic
- Fine hadronic
- Coarse hadronic

Scintillating

- Inter-cryostat detector

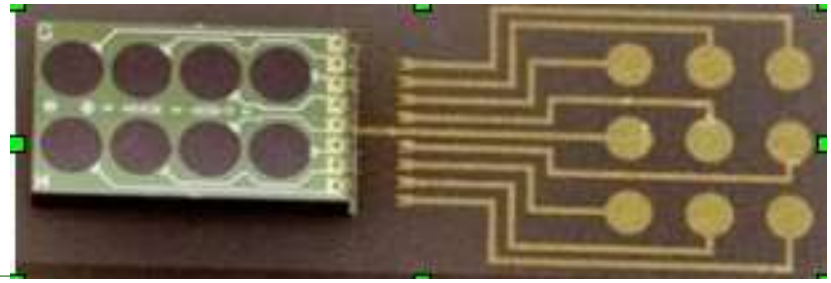
~55,000 readout channels

Central Fiber Tracker (CFT)

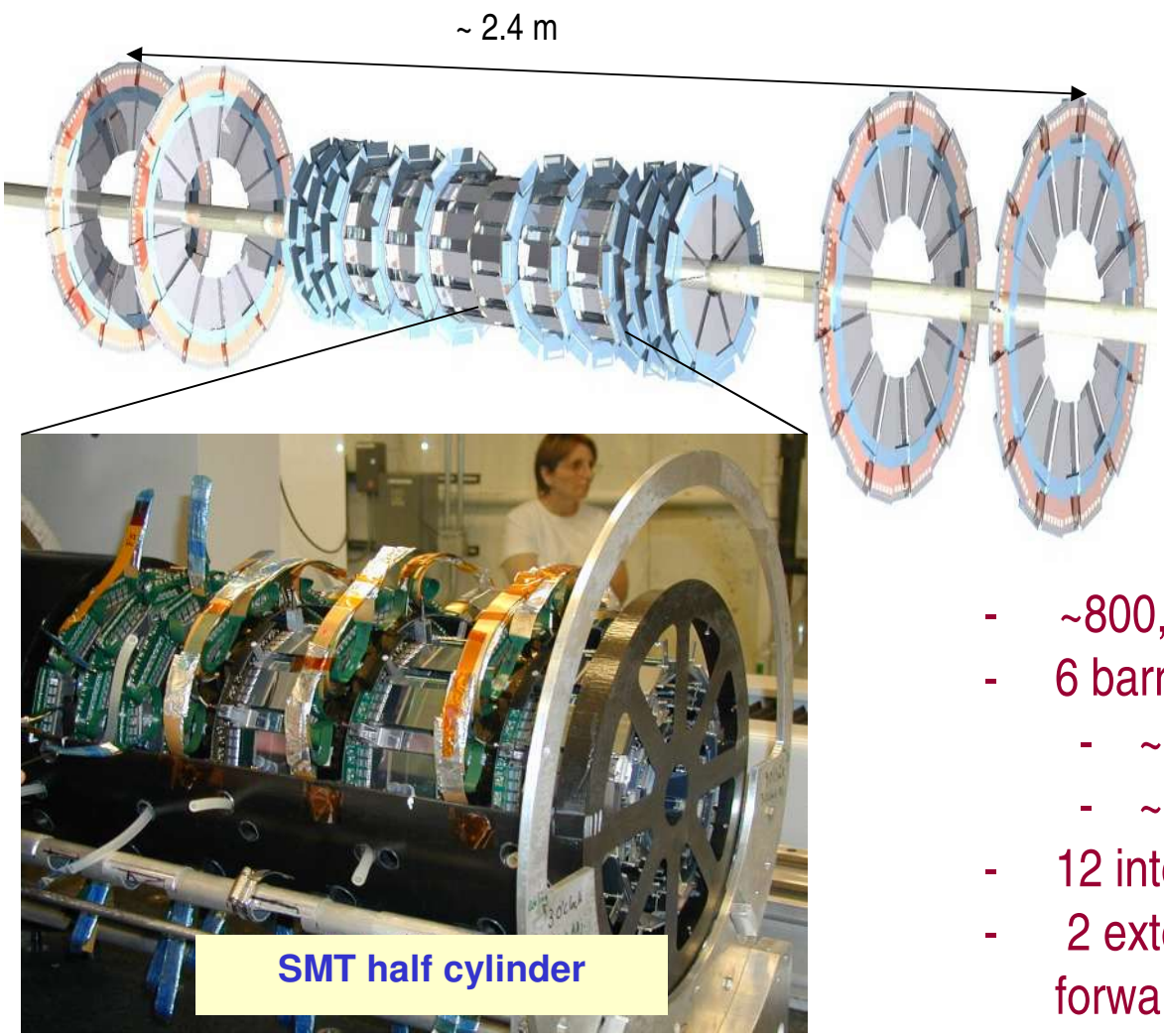


- Consists of 76 800 scintillating fibers placed on eight coaxial cylinders of radii 20 to 50 cm.
- Light generated by particles crossing fibers propagates to VLPC chips- solid state diodes cooled to 9K.
- Pre-showers and fpd: additional 24064 channels

VLPC chip



Silicon Microstrip Tracker (SMT)

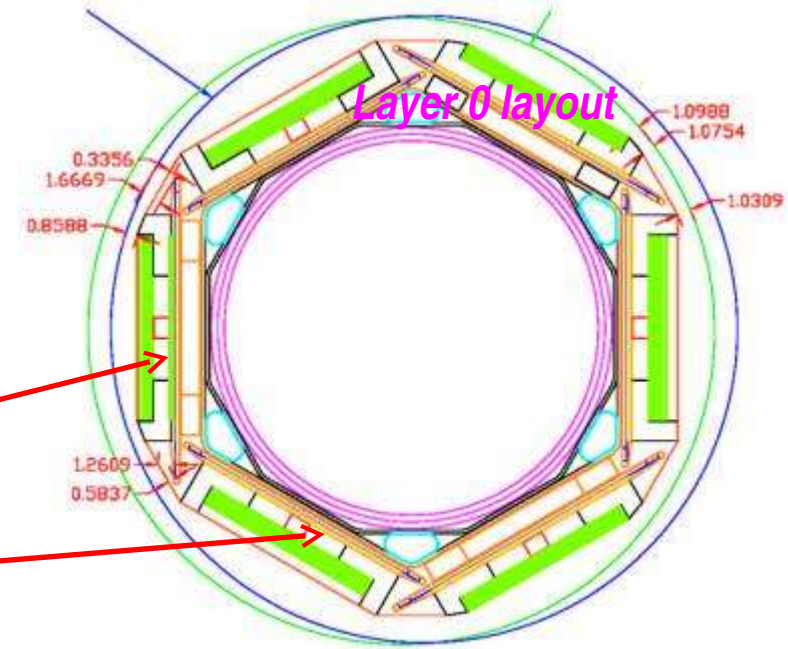


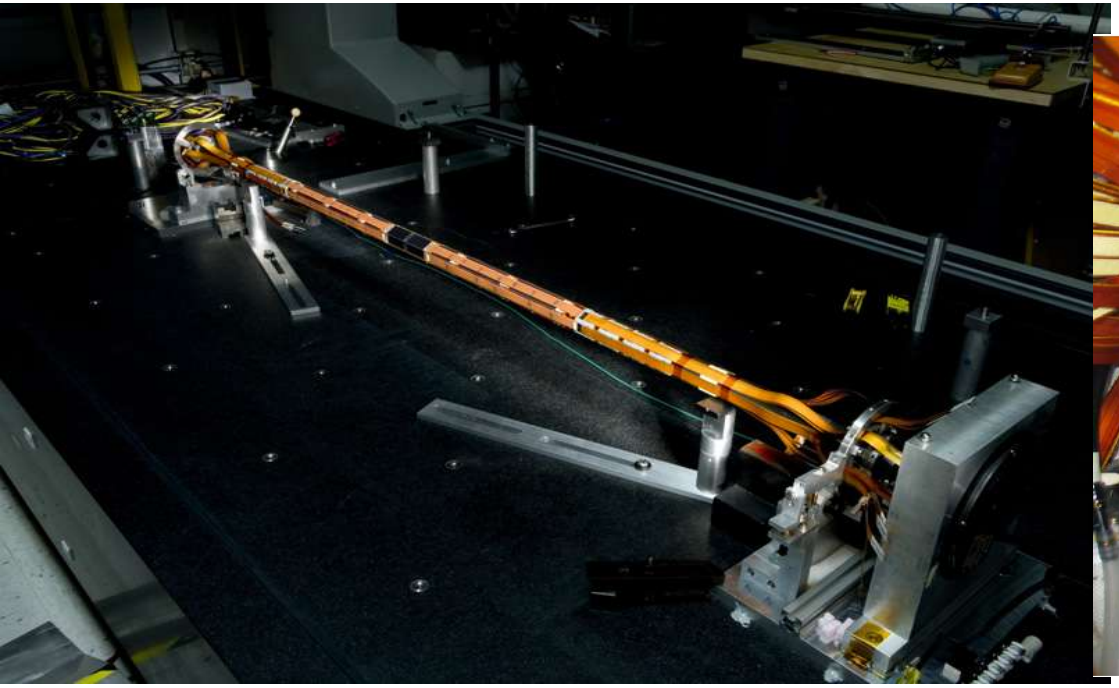
- ~800,000 total readout channels
- 6 barrels (4 layers)
  - ~390,000 axial channels
  - ~220,000 stereo channels
- 12 interspersed (F-)disks
- 2 external large area (H-)disks for forward tracking

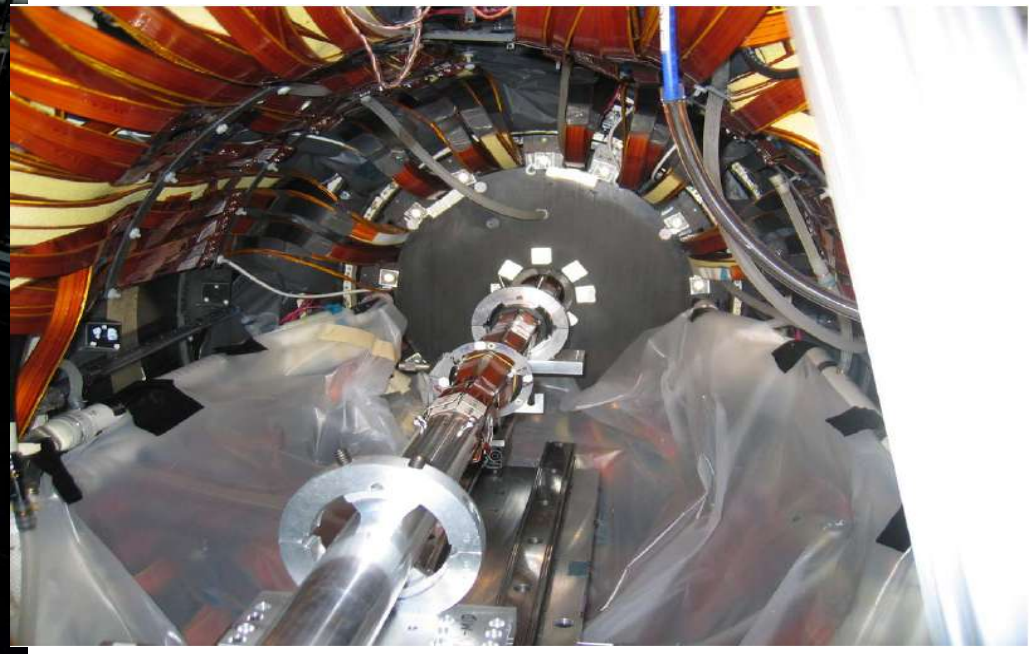
Layer 0

Relied heavily on Run IIb silicon design

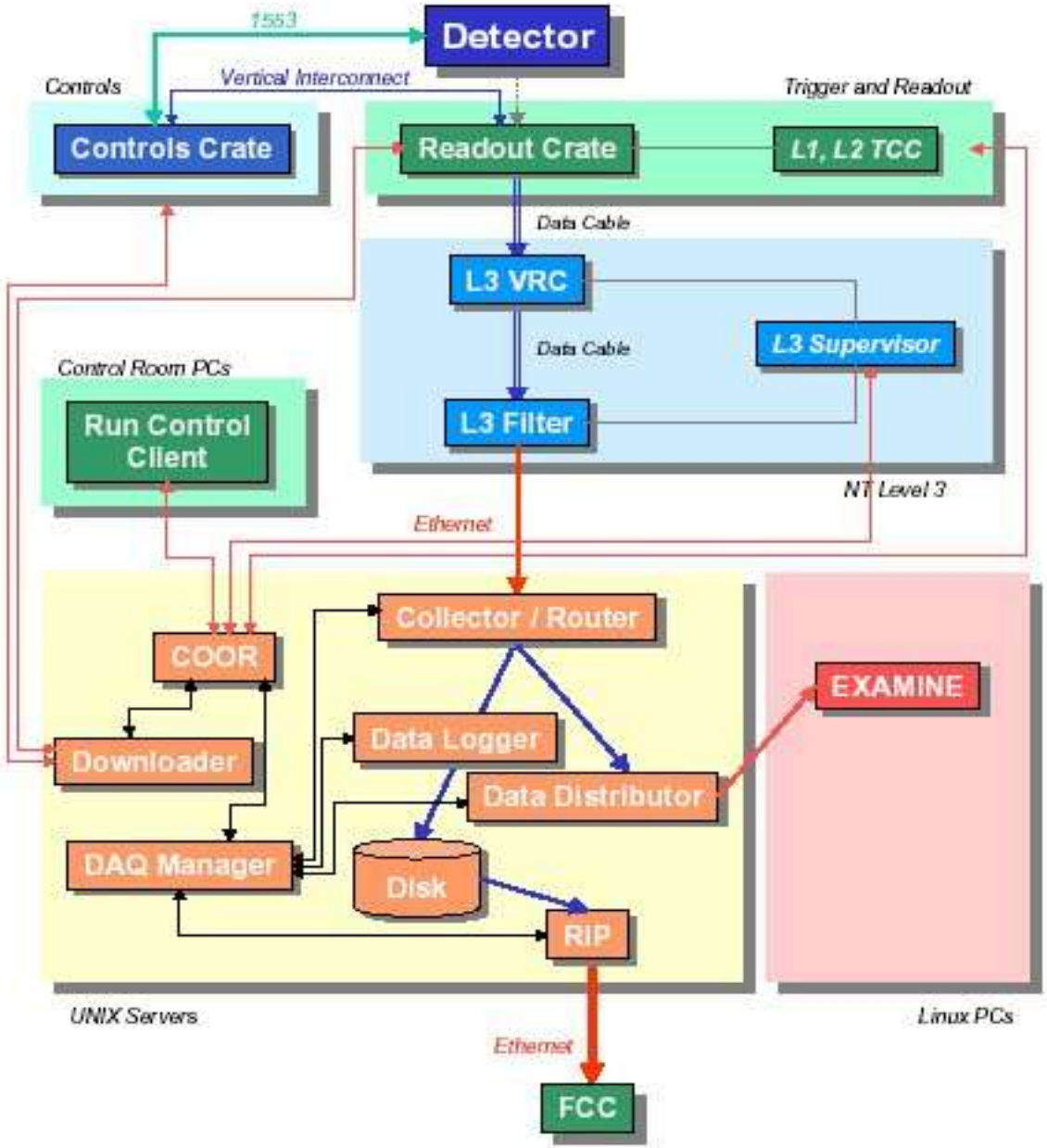
- 48 modules
  - 6 ϕ–segments, 8 z-segments
- Four sensor types provide 98.4% ϕ acceptance
  - 2x70mm + 2 x120 mm (one z half)
  - Sensor pitch 81 and 71 um with intermediate strips



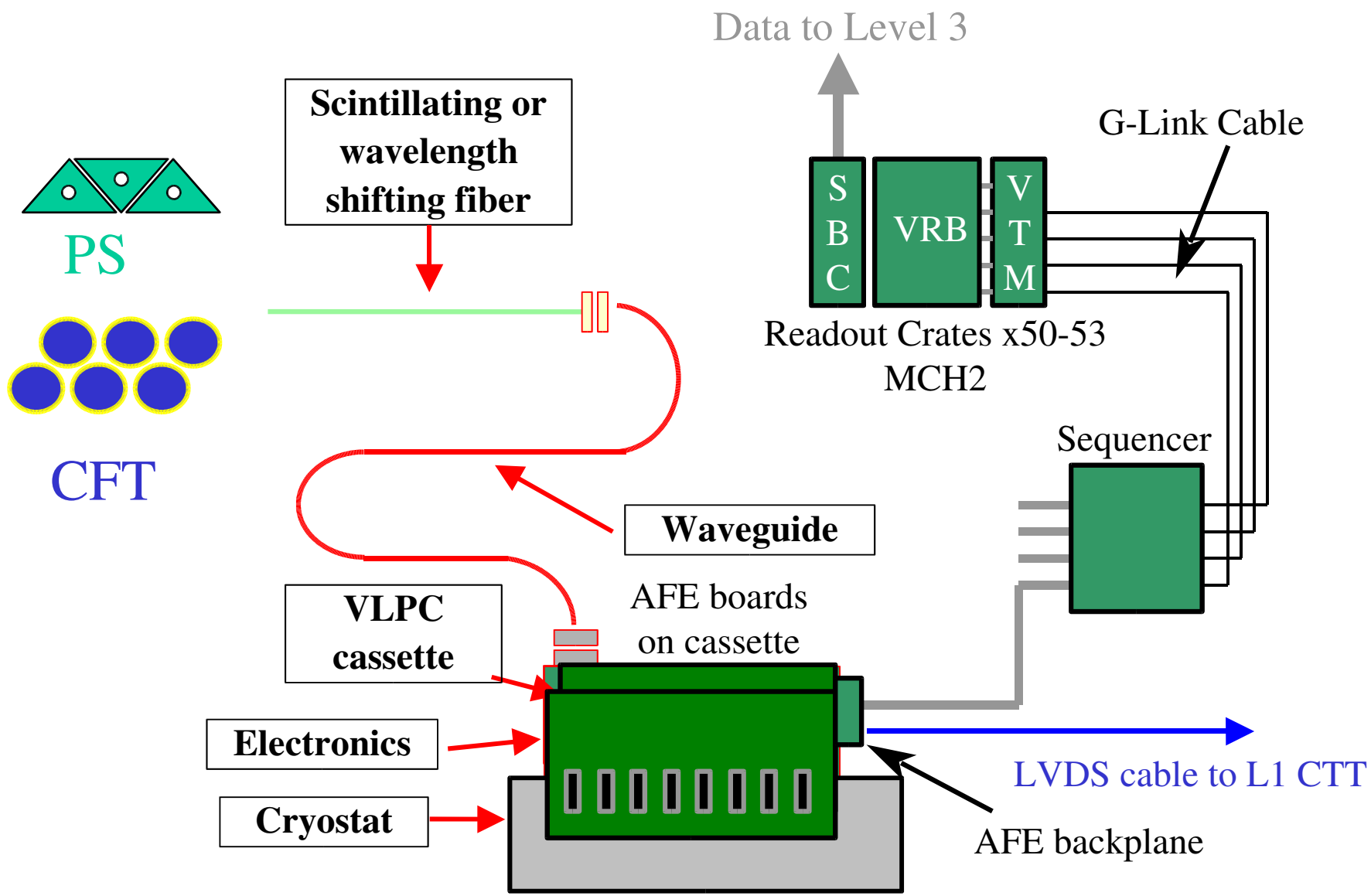




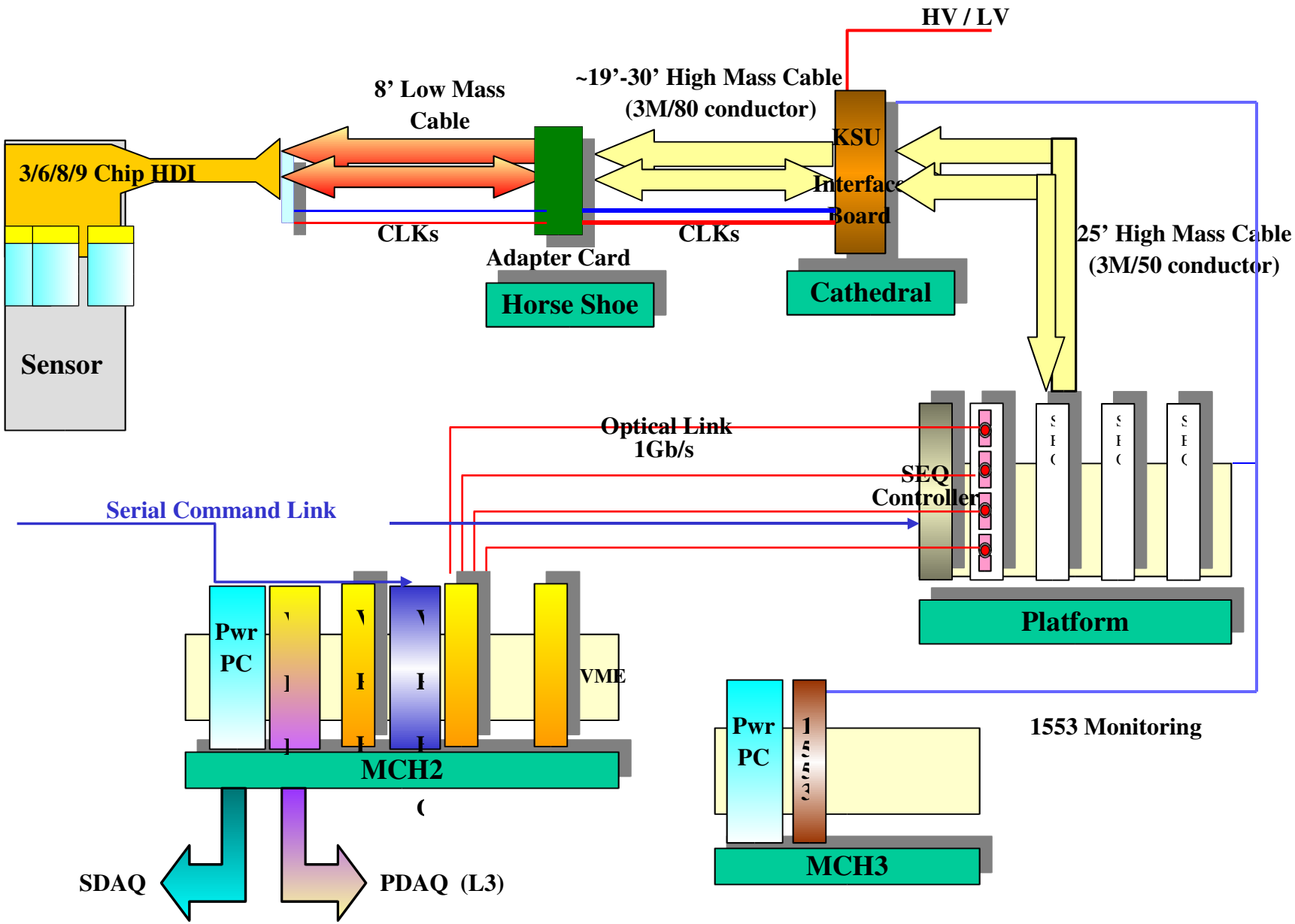
Run Control and Configuration



CFT Readout


Data to Level 3
Scintillating or wavelength shifting fiber
G-Link Cable
PS
CFT
S B C
VRB
V T M
Readout Crates x50-53
MCH2
Sequencer
Waveguide
AFE boards on cassette
VLPC cassette
Electronics
Cryostat
LVDS cable to L1 CTT
AFE backplane

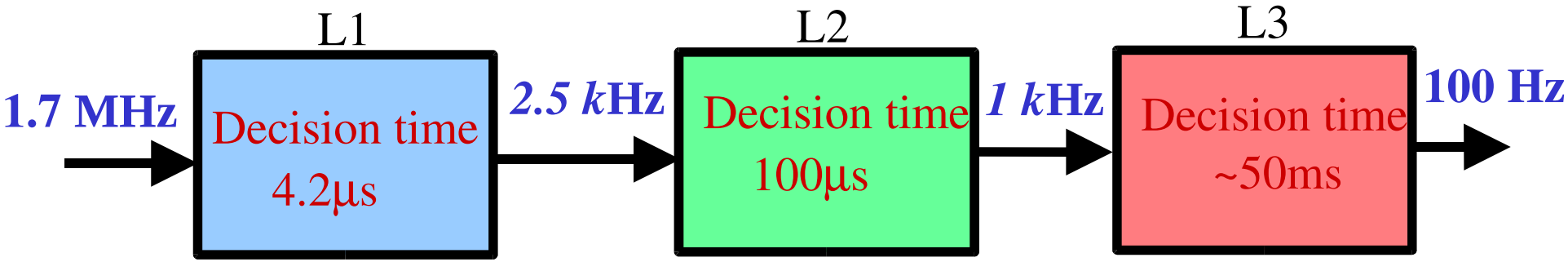
Silicon Readout Data Flow



The D0 RunII Trigger System

But data acquisition rate is limited to 100 Hz

⇒ 3 Level Trigger System

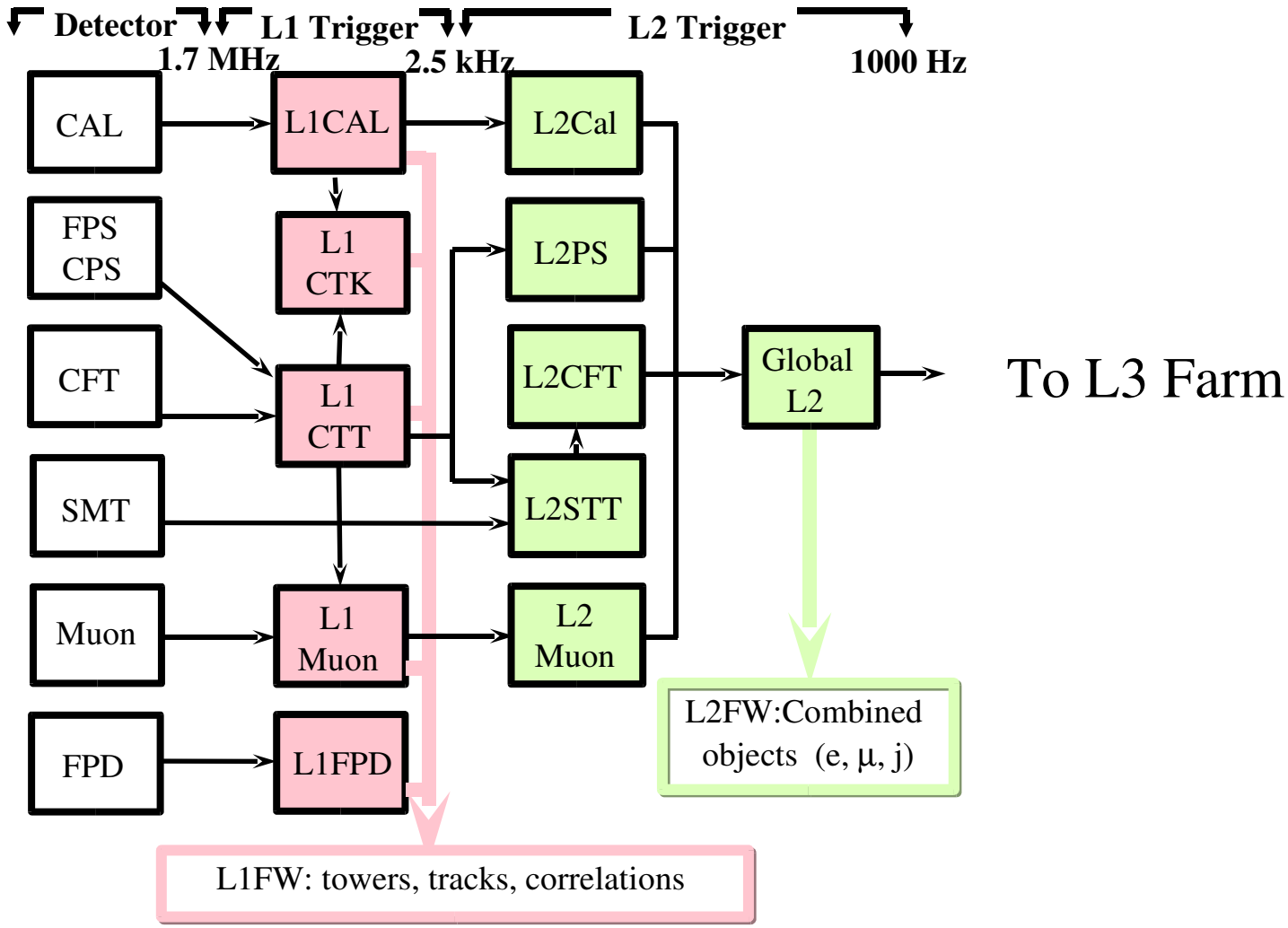


- **Hardware based**
- **Simple Signatures in each Sub-Detector**

- **Software and Firmware based**
- **Physics Objects e,μ,jets, tracks**

- **Software based**
- **Simple versions of reconstruction algorithms**

The D0 Trigger - L1/L2

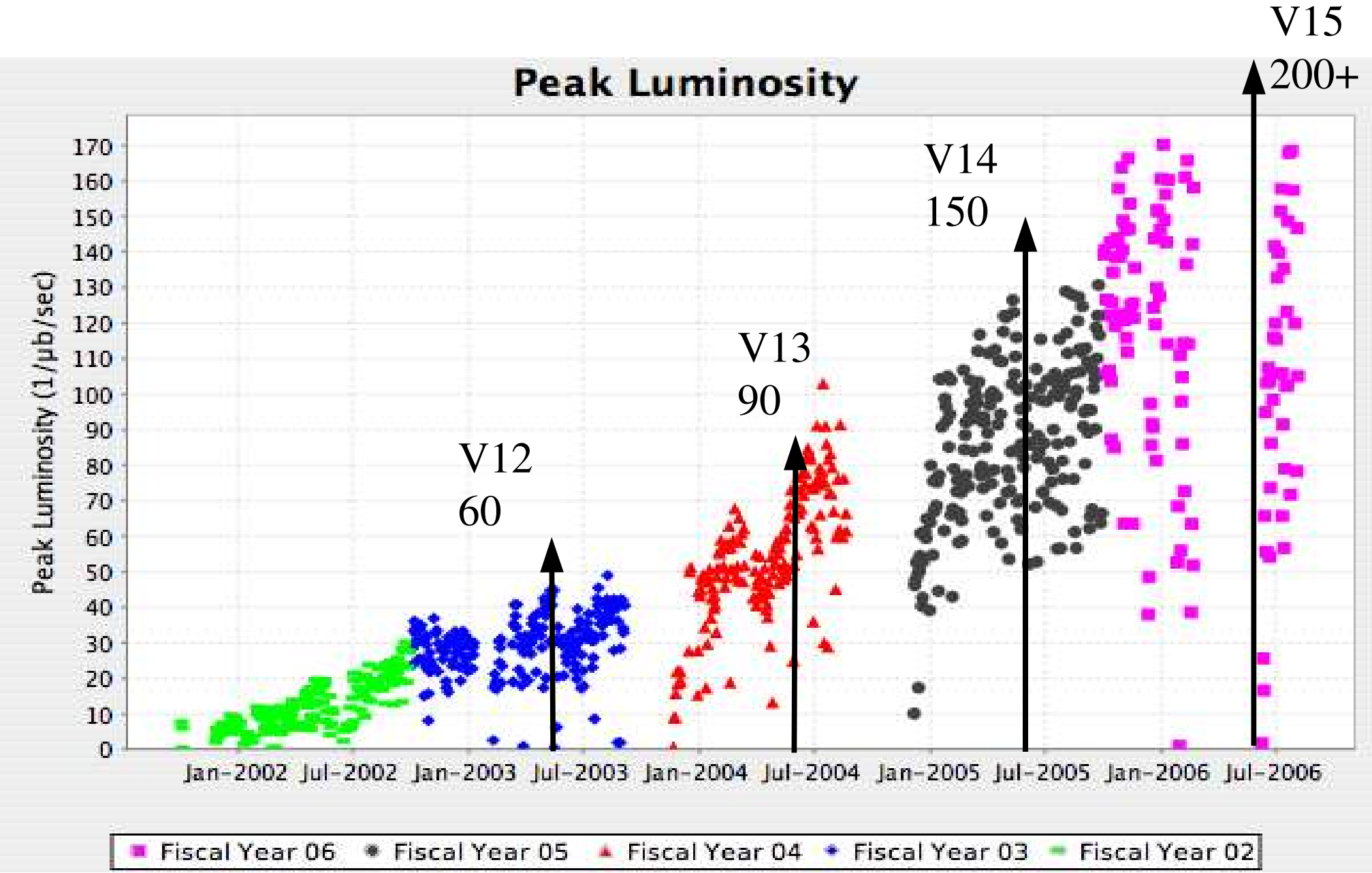


Progression of Initial Luminosity

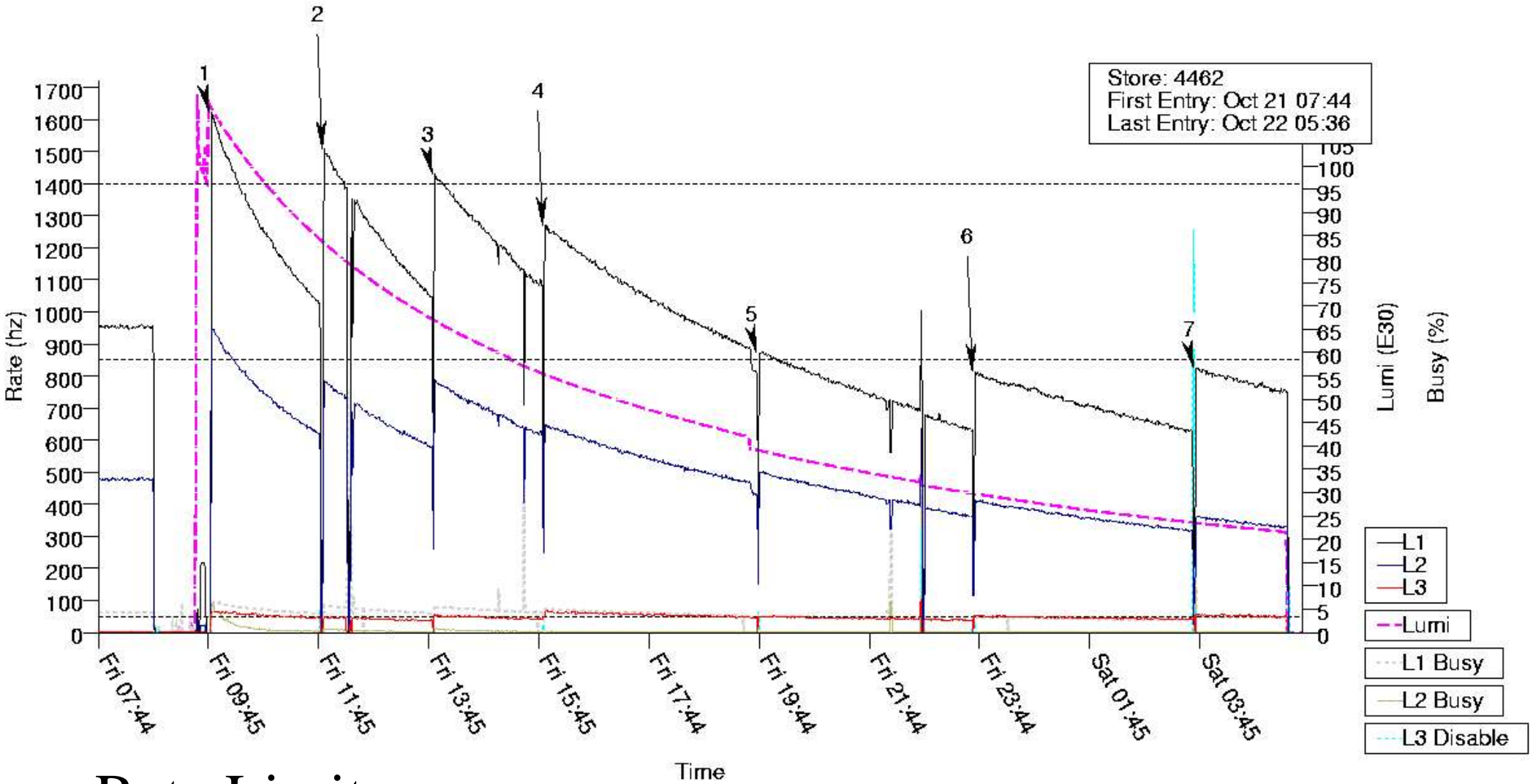
Initial Luminosity (E30)	Store	Start Time
159.95	4859	2006 Jul 27 07:59
158.86	4581	2006 Jan 06 03:29
157.99	4477	2005 Oct 31 09:25
149.91	4473	2005 Oct 27 02:53
136.69	4468	2005 Oct 25 03:29
136.40	4465	2005 Oct 23 19:20
123.83	4401	2005 Sep 25 11:19
119.12	4318	2005 Aug 04 17:18
117.57	4138	2005 May 12 17:42
115.24	4118	2005 Apr 29 09:49
111.48	4116	2005 Apr 27 18:51
109.17	4053	2005 Mar 21 10:26
105.99	4048	2005 Mar 18 13:17
96.09	4002	2005 Feb 23 19:03

Initial Luminosity (E30)	Store	Start Time
93.85	3952	2005 Jan 29 20:07
93.57	3657	2004 Jul 16 11:53
84.32	3621	2004 Jul 6 23:21
77.20	3588	2004 Jun 22 11:36
75.46	3586	2004 Jun 21 00:58
71.88	3574	2004 Jun 14 15:16
70.98	3562	2004 Jun 7 15:18
68.21	3534	2004 May 26 18:09
65.70	3532	2004 May 25 07:54
64.06	3261	2004 Feb 27 16:42
59.47	3245	2004 Feb 18 22:06
56.04	3219	2004 Feb 5 15:56
52.65	3217	2004 Feb 4 04:16
52.46	3214	2004 Feb 2 11:28

Trigger Lists and Target Lumi



DAQ Rates



- Rate Limits
  - L1 – 1500 Hz L2 – 1000 Hz L3 – 100 Hz

L1 Rate

- Rate Limit of 1500 Hz
  - L1 busy (deadtime) is proportional to L1 rate.
  - 1500 Hz keeps our L1 busy to below 6%.
- L1 issues
  - L1 trigger rates are non-linear.
  - As we go to higher luminosity, we tend to violate the 1500 Hz limit choosing to run at a higher FEB
    - This keeps more physics triggers running, but all triggers experience a higher deadtime.

L2 and L3 Rate

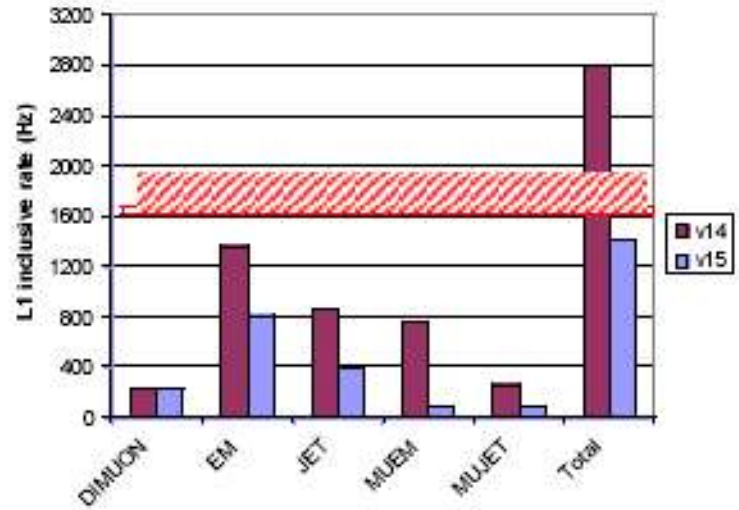
- L2
  - Rate Limit 1000 Hz
    - Design limit
    - This limit is mainly due to the amount of time it takes the calorimeter to digitize its data to send to L3.
  - L2 Issues
    - L2 rates can be limited by L3's ability to process data.
- L3
  - Rate Limit 100 Hz (2X design), but can actually write much faster.
  - L3 Issues
    - Processing time
    - Event size (increases with higher Luminosity)
      - If L2 rate and event size get too large, can reach ethernet limit.

High Luminosity Running

- For most of Run II, D0's ability to run at higher Luminosity has been a function of the quality of the trigger list being used.
  - In order to run at a given luminosity, a new set of triggers needs to be created to keep the rates within the allowed limits.
    - This will require the development of new tools to increase rejection without losing efficiency.
  - Another method of keeping a high efficiency is to use multiple triggers to cover a larger phase space.
- So far, D0 has been able to develop trigger lists to keep up with the higher luminosity.
- For RunIIb, D0 has also upgraded the L1 portion of the trigger.
  - This will allow us to lower the L1 rates without losing efficiency.

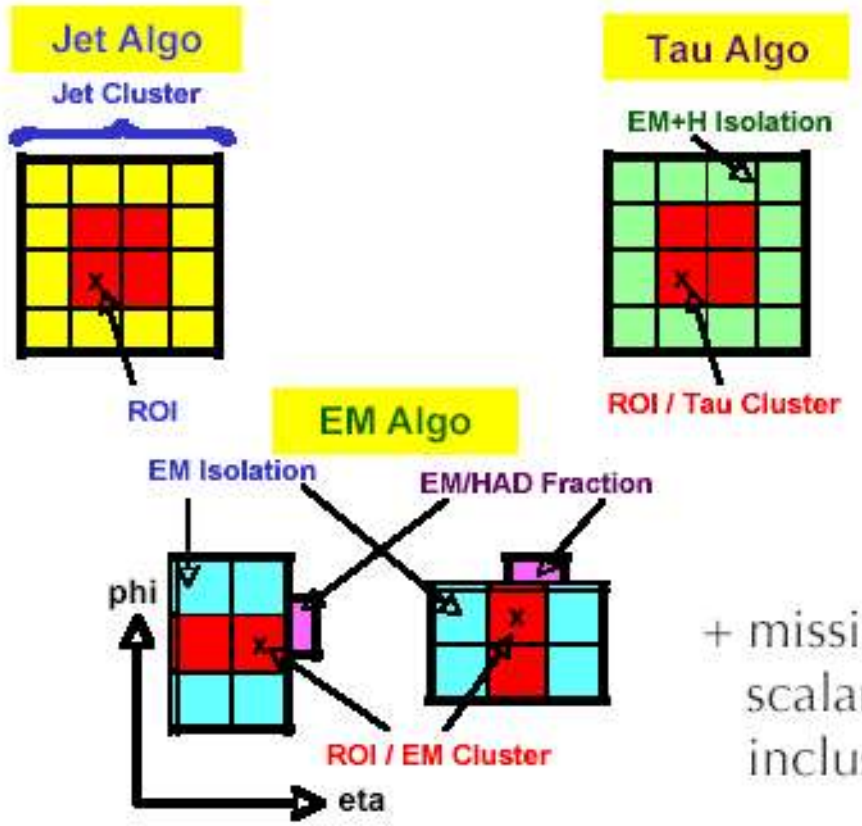
L1Cal upgrade

Run2a L1 Calorimeter trigger would not survive very high luminosity running planned for run2b without massive prescaling.



E.Barberis, SFU Workshop, June 2005

Introduce clustering algorithms at L1:

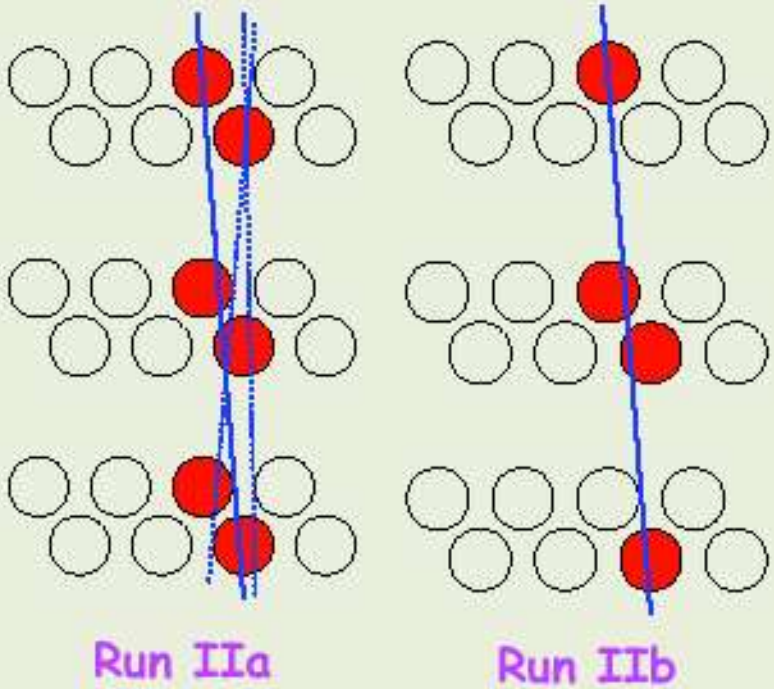


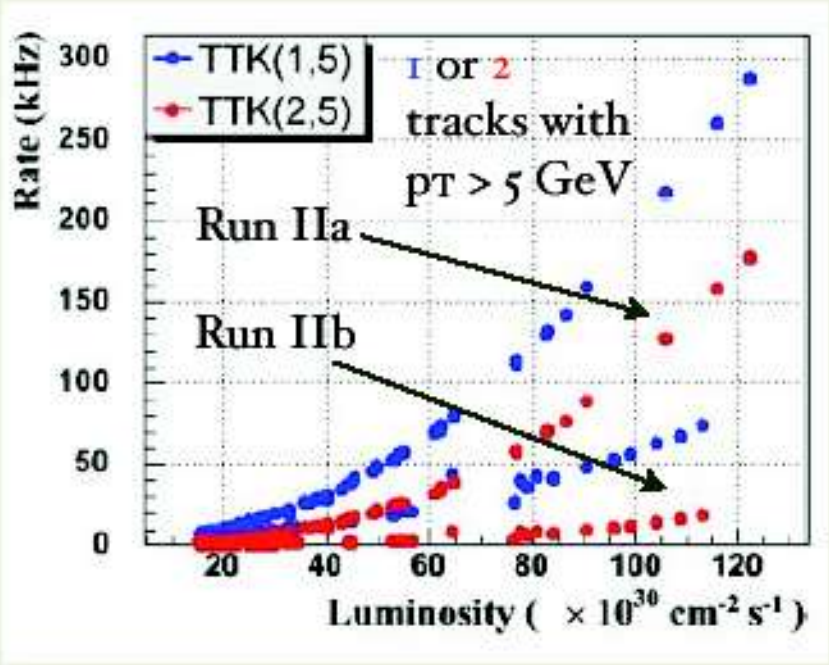
Topological Terms:

+ missing ET,
scalar ET
inclusion of ICR in algos

Central Track Trigger Upgrade

- Replaced track finding hardware (DFEA)
  - More powerful FPGAs allow exploitation of full granularity of the axial CFT
    ⇒ Reduction in fake rate





L1 Cal Track

- D0 is also in the process of adding a trigger such that at L1 we can match Calorimeter towers with CTT tracks.
  - The time required to make this match required an additional three tick latency in the L1 trigger system.
  - During the shutdown, the Muon system clock was decreased to 6/7 RF in order to accommodate this latency.
  - However this introduced noise in the calorimeter.

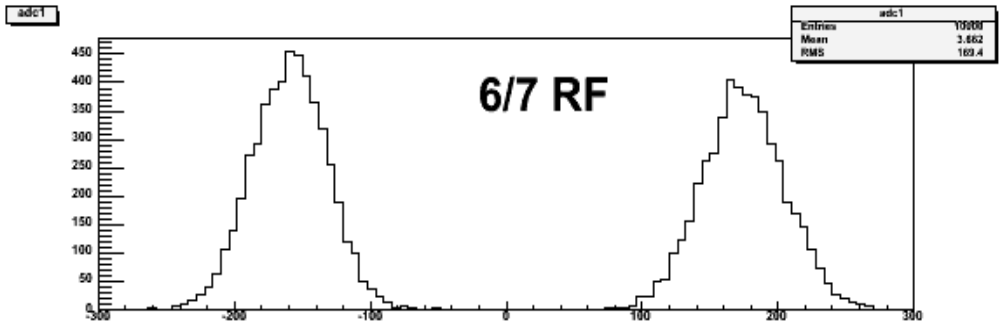
Calorimeter Noise

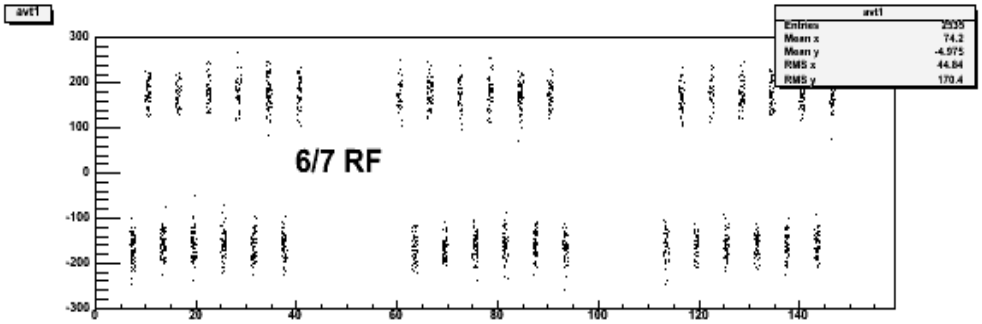
- After the 2006 shutdown a low amplitude high occupancy noise was seen ing the calorimeter and correlated to the A-layer PDT's operation.
  - The 6/7 RF was suspected, so the PDT control board firmware was modified to also operate at 7/7 RF.
  - This eliminated the noise, but at 7/7 RF we could not use CalTrk.
  - It was determined that 4/7 RF would allow both.
    - This was implemented this last Saturday.

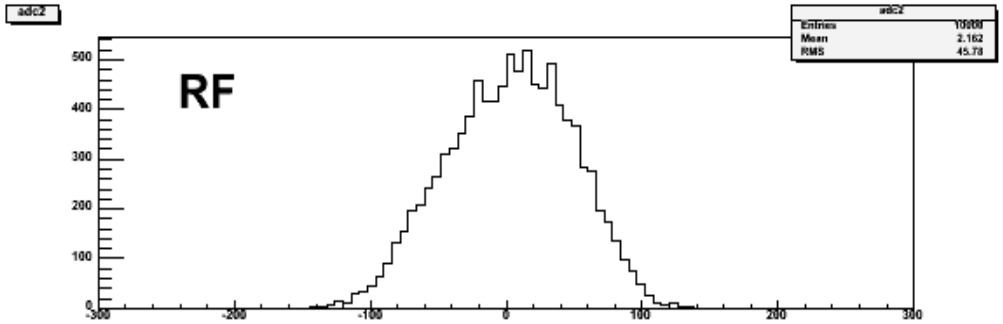
Calorimeter ADC

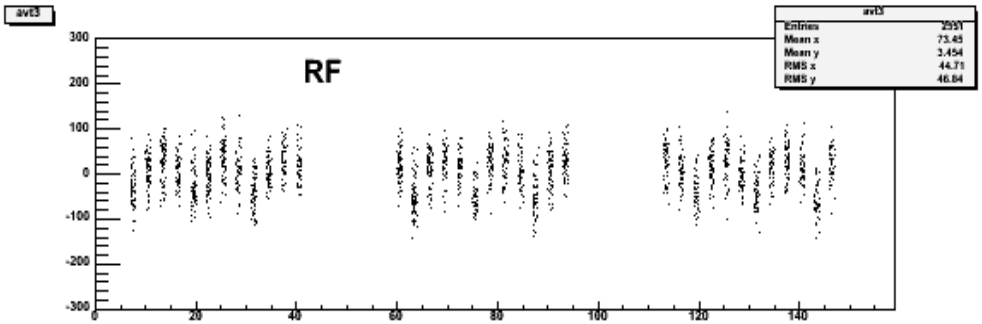
Pedestal subtracted sum of 12 course hadronic channels.

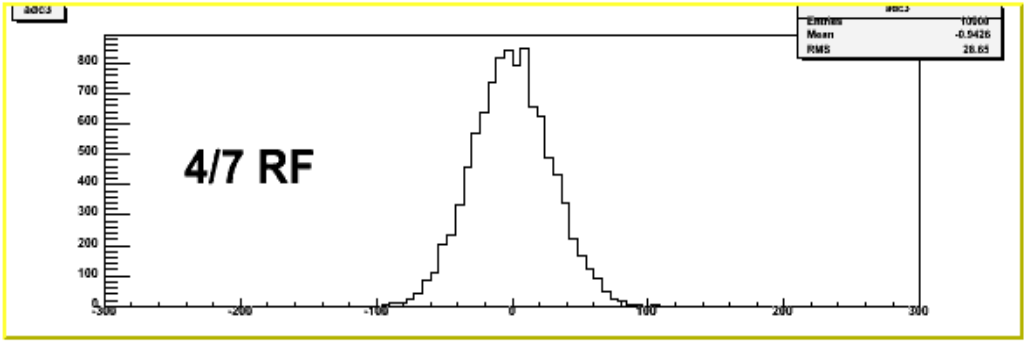
Vs tick

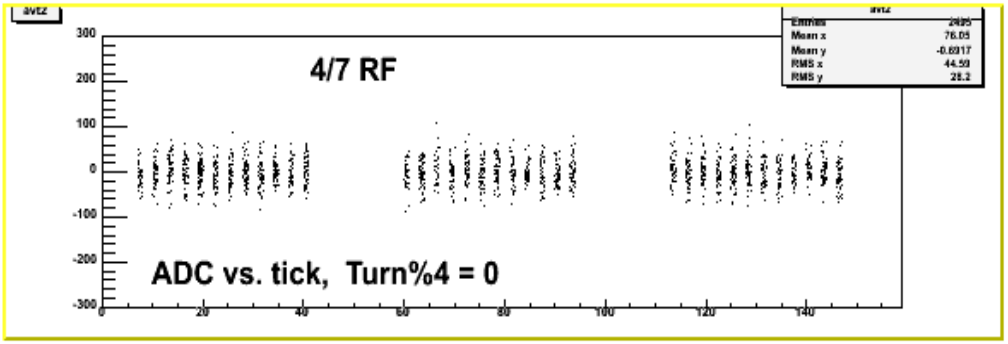






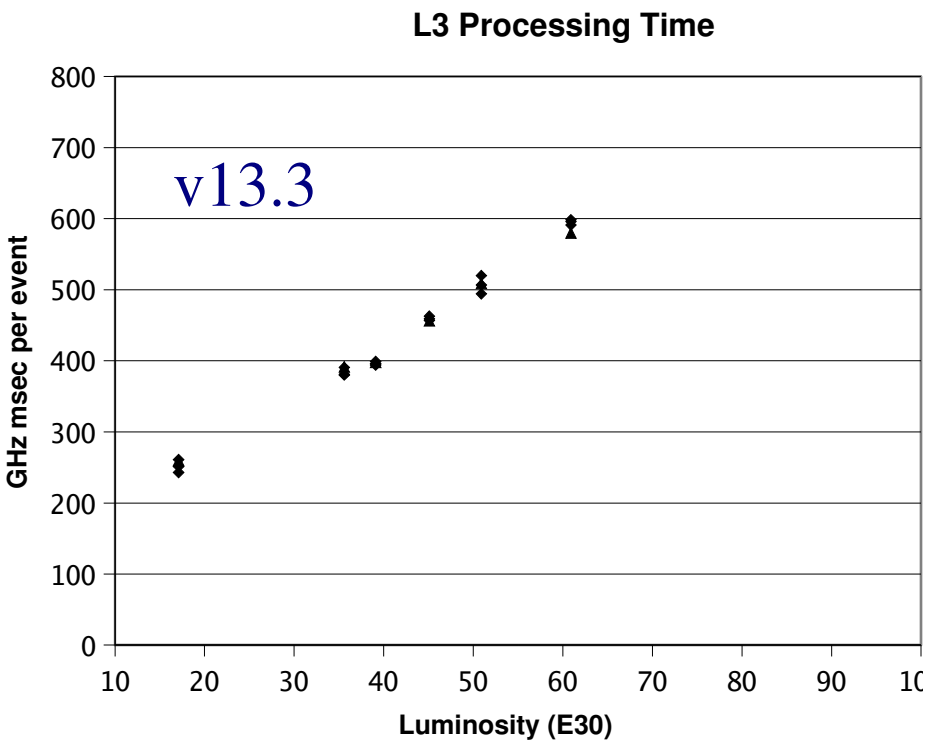


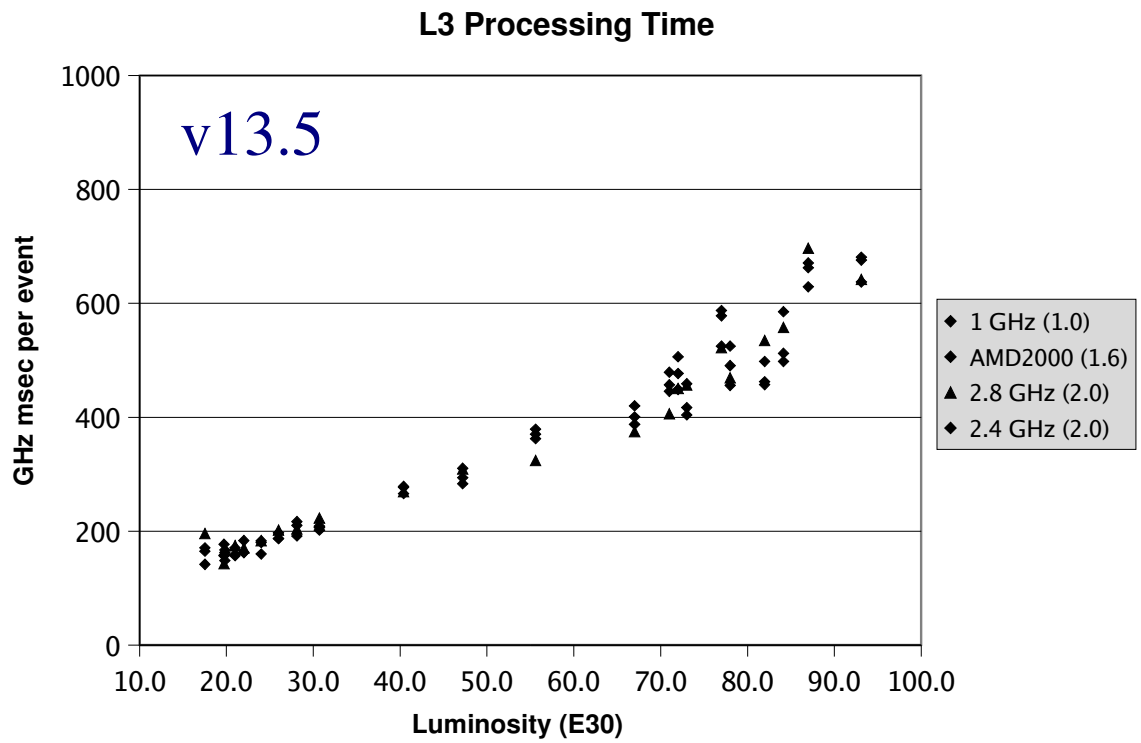




L3 Processing Time

Coming out of the 04-05 shutdown, disables occurred because L3 could not process the data fast enough to keep up with the L2 rate.



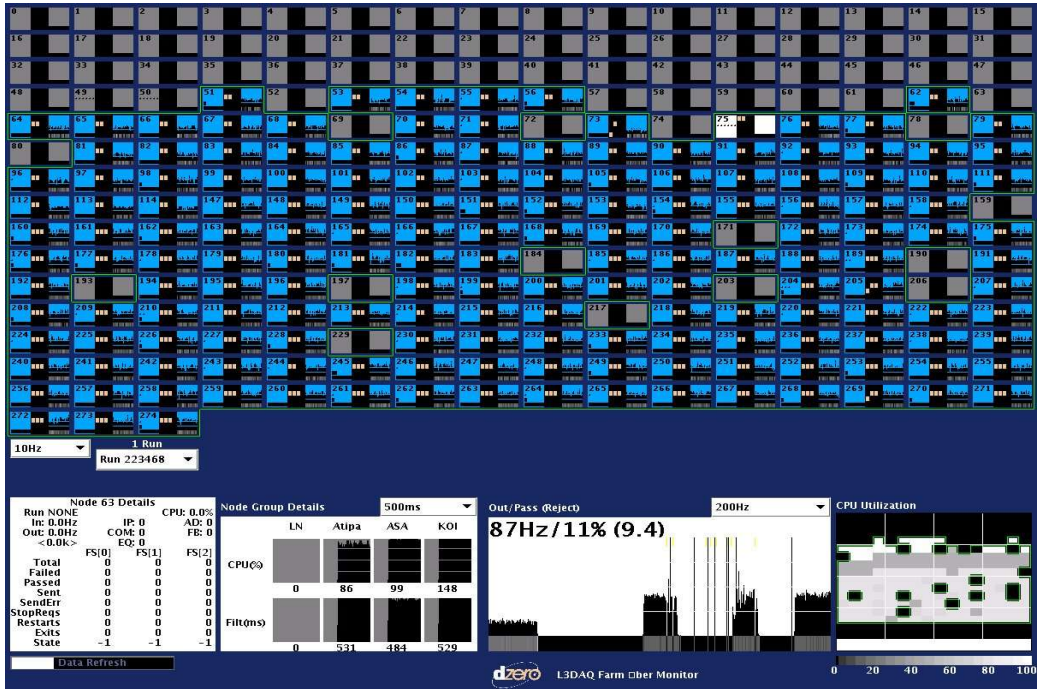


Times were reduced by:

- Improving L3 algorithms, triggers
- Reordering triggers to run faster triggers first

In addition we increased the capacity of our L3 Farm.

Current L3 Limits

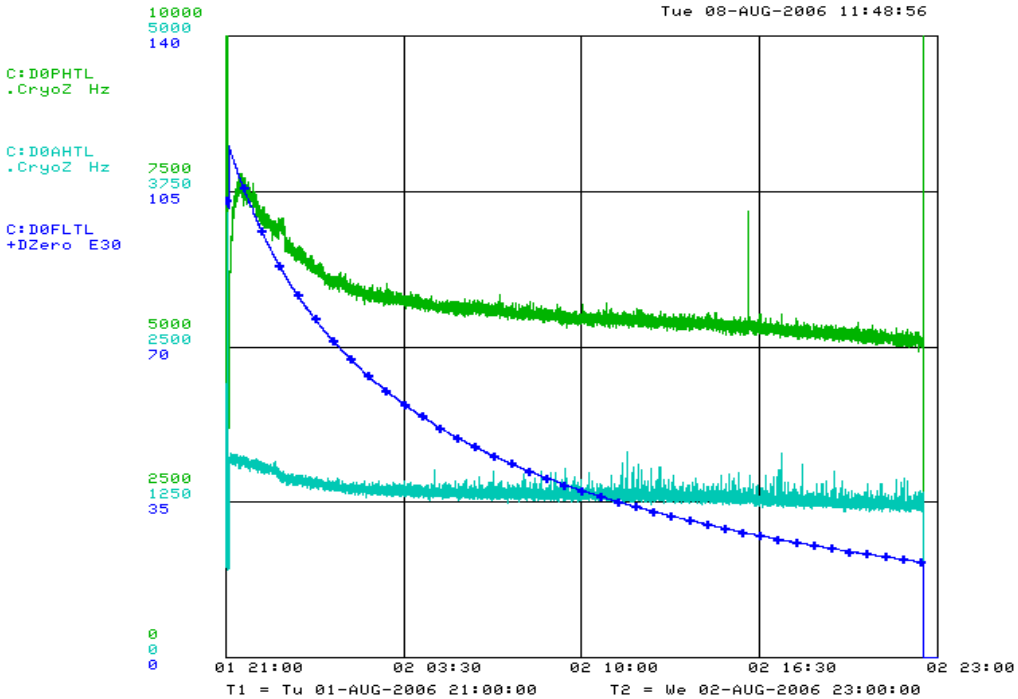


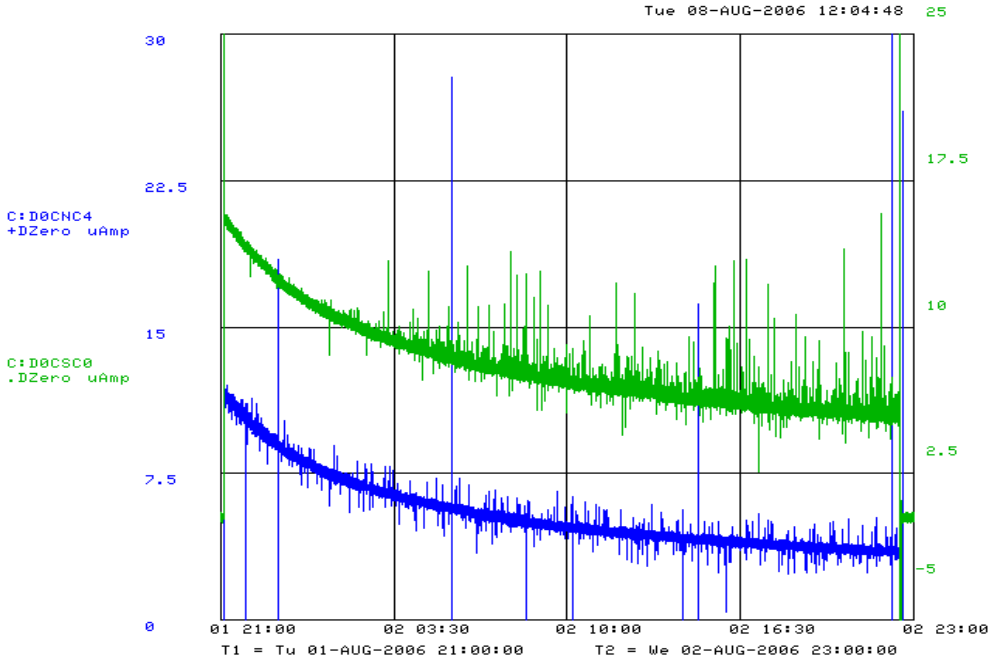
- Currently we can run up to 155 E30 with the current trigger before we run into our L3 limitations.
  - The trigger list is being investigated for inefficiencies,
  - There are 48 additional L3 nodes on order to replace our oldest nodes.

Leveling – What the AD can do.

- Bunch to bunch leveling is most important to D0.
  - It has been seen during stores with wide variations in bunch population that out prescale sets no longer apply to the given luminosity. This is because of the nonlinearity of our trigger rates.
- Leveling during a store (not a priority)
  - Reduces the need to change prescale sets.
  - Reduces the number of high multiple interaction events.
  - High instantaneous luminosity impacts our efficiency in detecting many physics processes.
    - Muon isolation
    - Track multiplicity

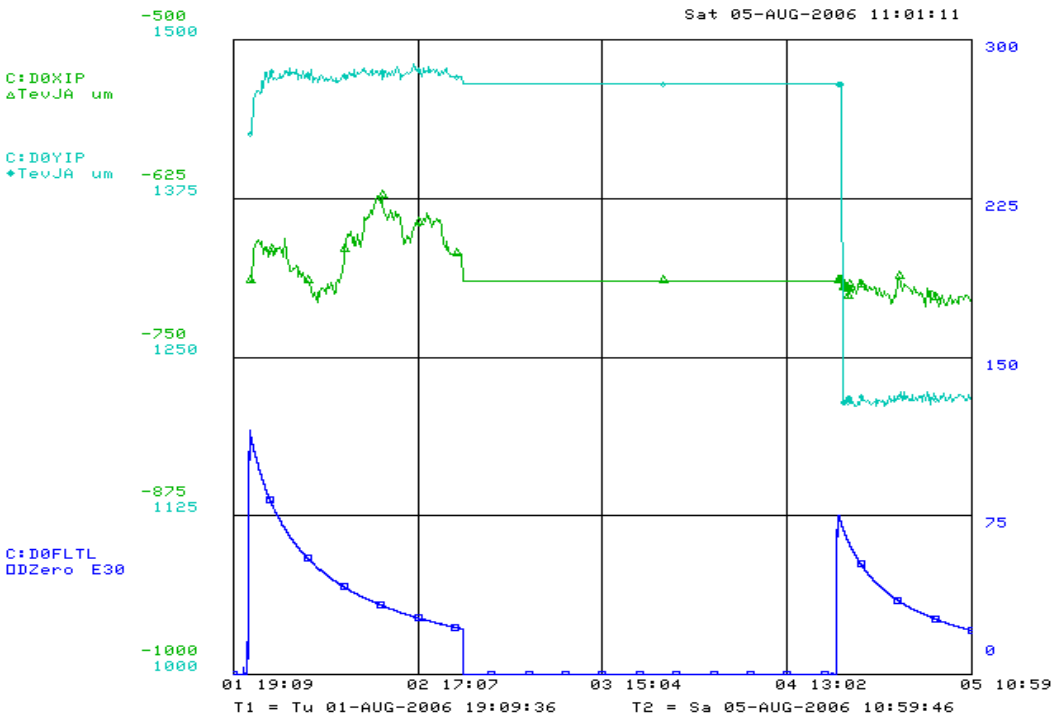
Beam Stability and Quality

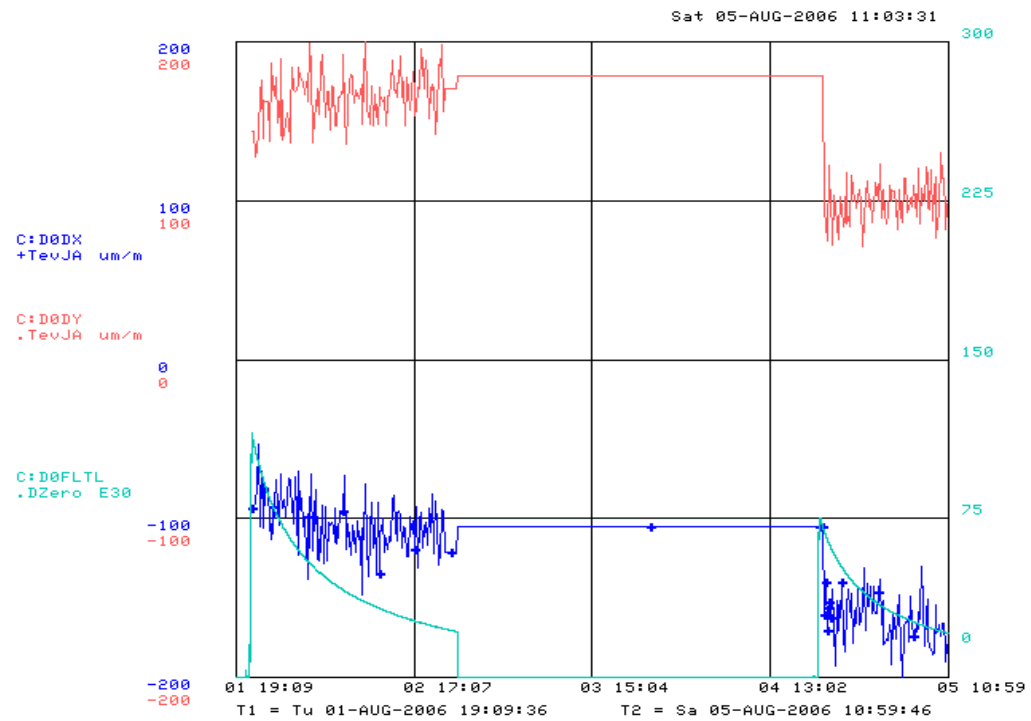




- Since the shutdown, the halo rates have been higher
  - Due to worse vacuum at D0, needs two days to bake.
- Spikes in the beam can trip off detectors.
  - Can be seen in the detectors and MDT currents.
  - Can effect data quality.
  - Often due to a slightly wandering beam.

Beam Position





- The nominal beam spot position for D0 is (x,y) = (-0.72, 1.2). The beam tilt should be kept less than 200 microradians.
  - These values need to remain as constant as possible.
    - Movements of more that 100 microns require a redownload.
  - Efficiency is maintained as long as the beam spot is within 300 microns of nominal.

Shifters

- D0 is manned around the clock by
  - Captain – also watches real time data quality
  - DAQ Shifter – keeps the DAQ running
  - Three Detector shifters
    - CFT, SMT, and CALMUO
  - Operations Shifter
  - Countless experts
    - carrying pagers 24/7

- Many thanks go out to these people who help keep our detector running.

Efficiency

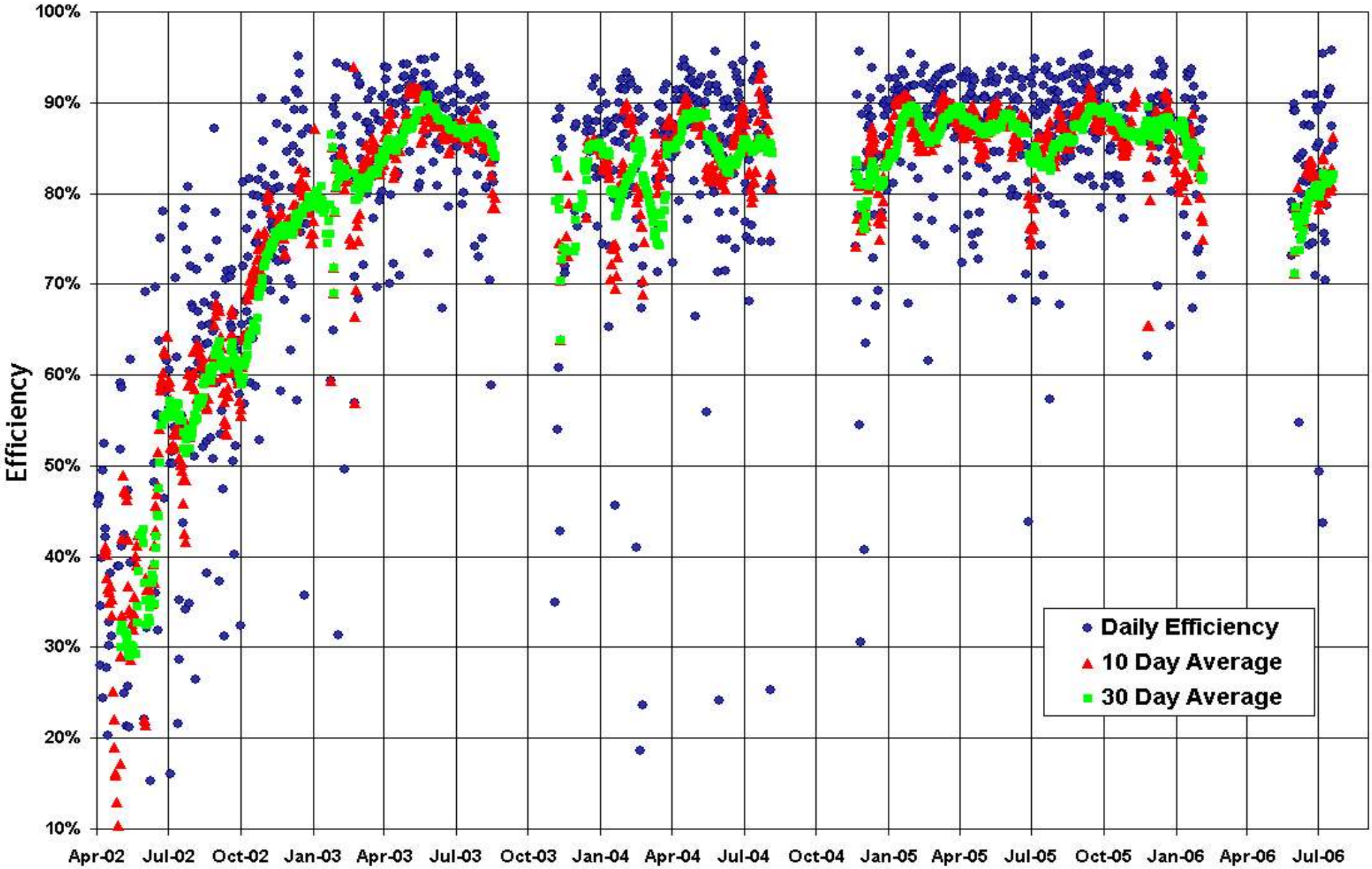
- Efficiency for D0 is simply defined as recorded luminosity divided by delivered luminosity.
- Efficiency is limited by:
  - Dead time in the Data acquisition system.
  - Down time from faulty systems
    - and the speed of recovery
  - Transitions at the start of a store and changing runs.
  - Commissioning, trigger, and detector studies.

Data Taking

Day	Delivered Lum (pb^{-1})	Recorded Lum (pb^{-1})	Efficiency (%)	Comment
31 July	1.94	1.76	91	STT special runs
1 Aug	1.25	1.14	91	Two Accesses
2 Aug	3.20	2.92	91	STT special runs
3 Aug	0.00	0.00	0	11 hour access
4 Aug	0.96	0.84	87	D0 beam spot moved back to nominal position
5 Aug	1.43	1.36	96	2nd Best daily efficiency
6 Aug	2.96	2.52	85	Two Accesses
31 Jul – 6 Aug	11.7	10.6	90	

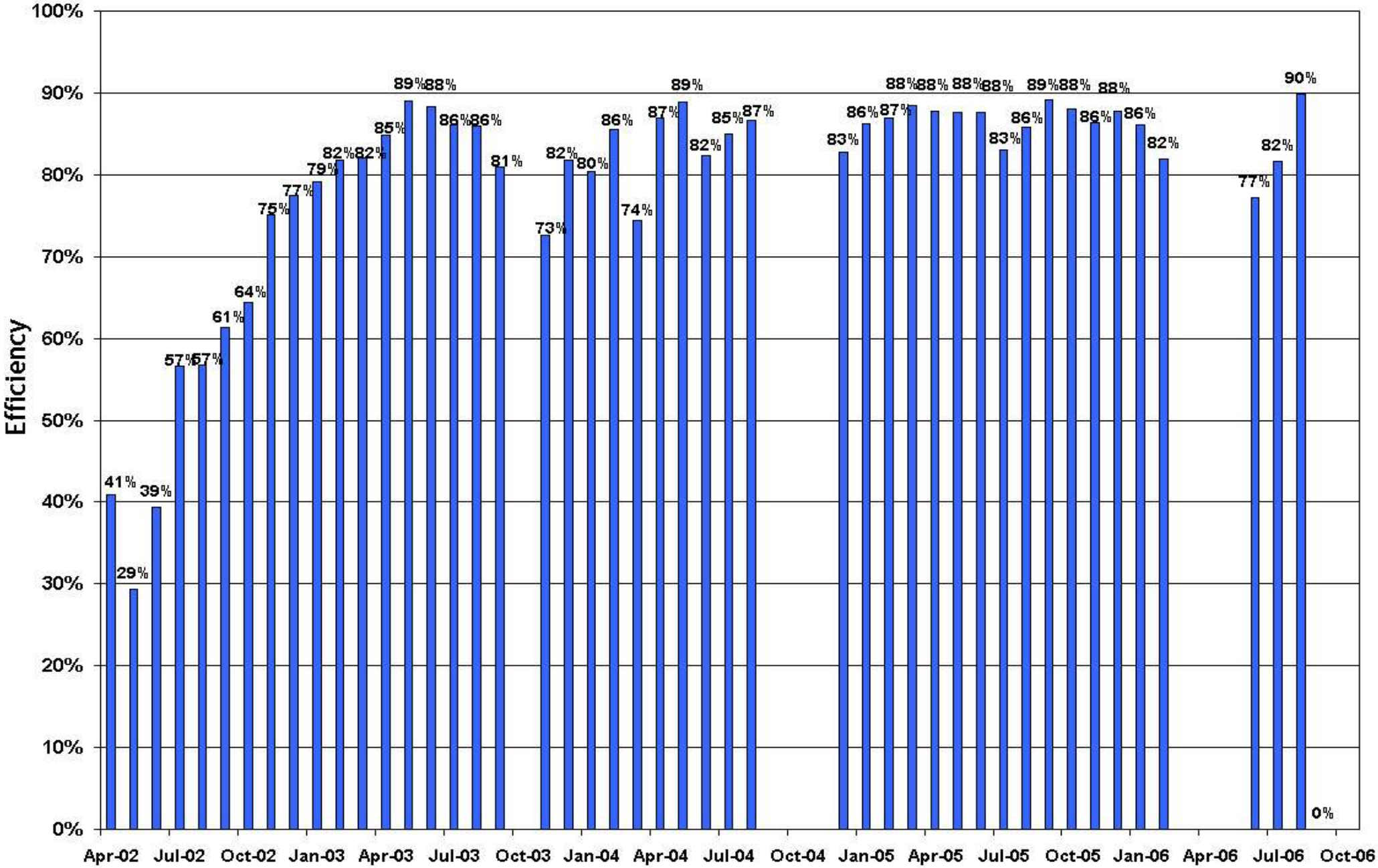
Daily Data Taking Efficiency

19 April 2002 - 6 August 2006



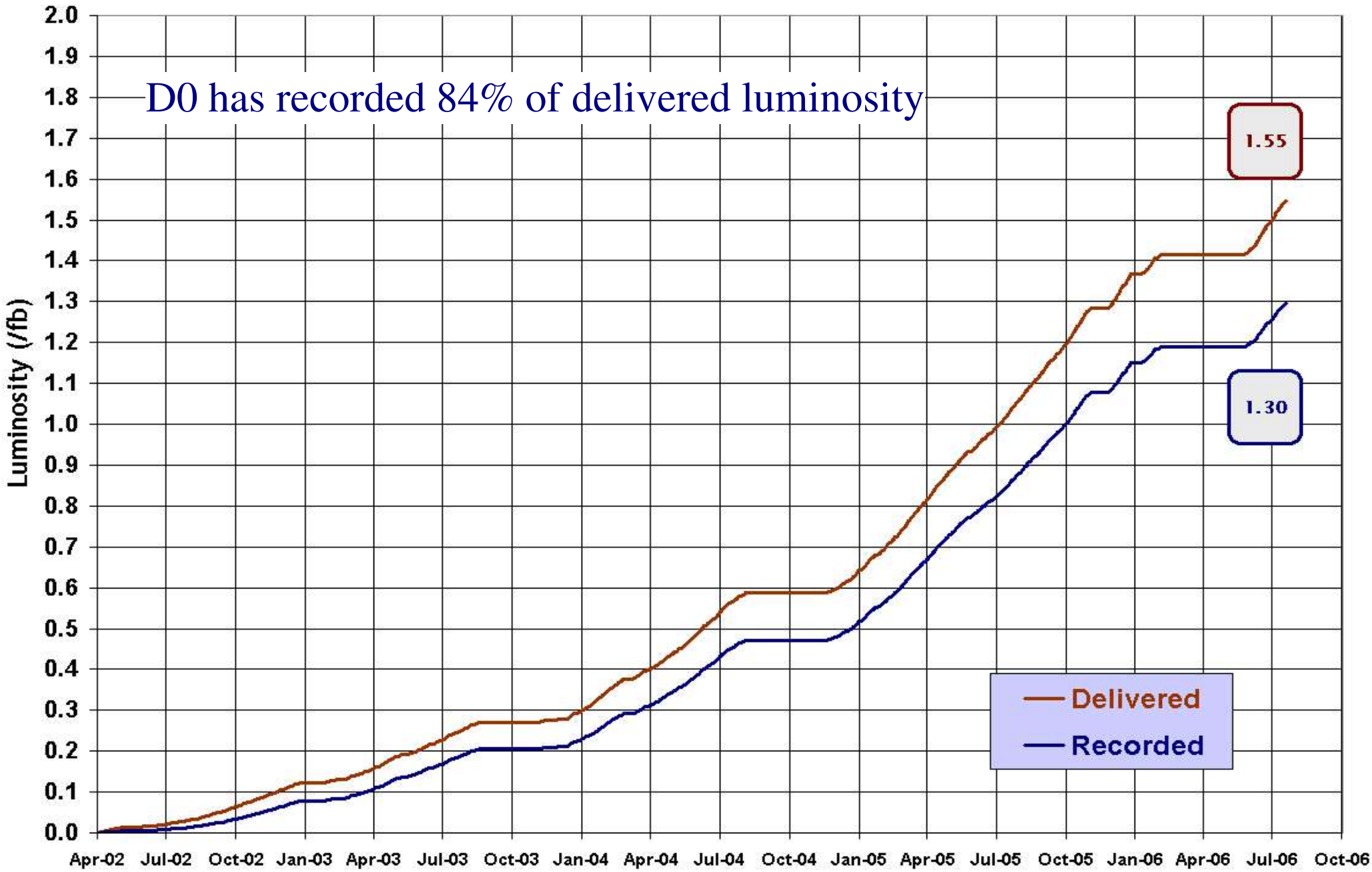
Monthly Data Taking Efficiency

19 April 2002 - 5 August 2006



Run II Integrated Luminosity

19 April 2002 - 6 August 2006



Summary

- D0 needs high Luminosity in order to probe the most interesting Physics.
  - Higher luminosities have pointed out limitations of our detector, but we have so far been able to solve them.
    - We hope that even higher luminosities will continue to help us find and address detector issues.
- It is mainly choosing a good set of triggers that will allow D0 to run efficiently and at high luminosity.
- It is very important to D0 to have per bunch leveling.
- Our sincere thanks go out to all of you who put so much effort in providing D0 quality beam.
  - We do our best to make the greatest use of it.