The D0 Silicon Operations Experience

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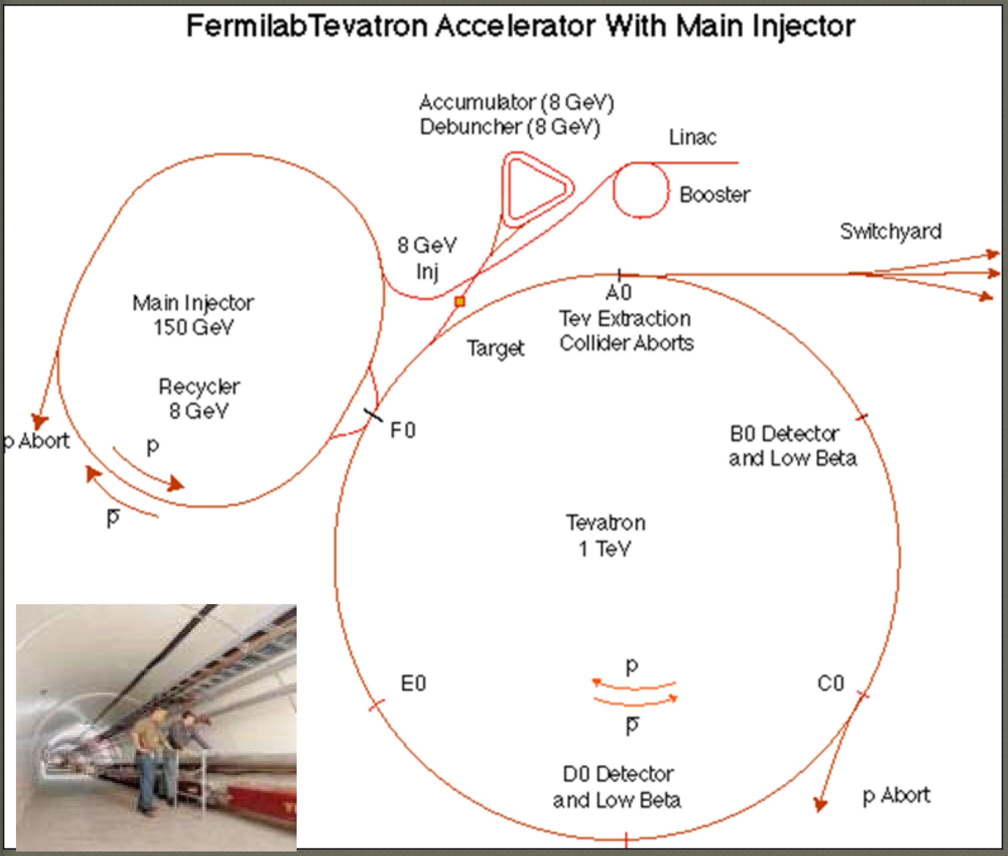
for the D0 collaboration

Vertex 2008

Outline

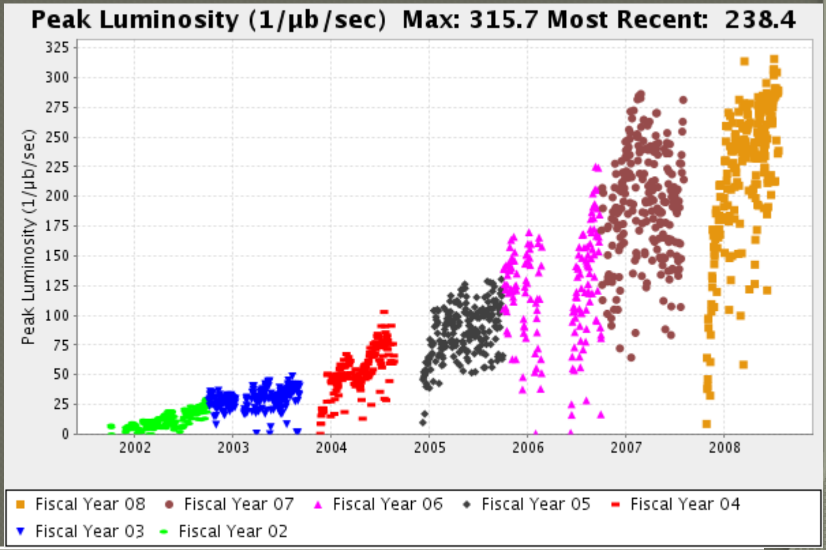
- Tevatron and D0
- The D0 tracker
- Layer 0
- Operations
  - Detector monitoring
  - Radiation protection
  - Maintenance

Fermilab Accelerator Complex



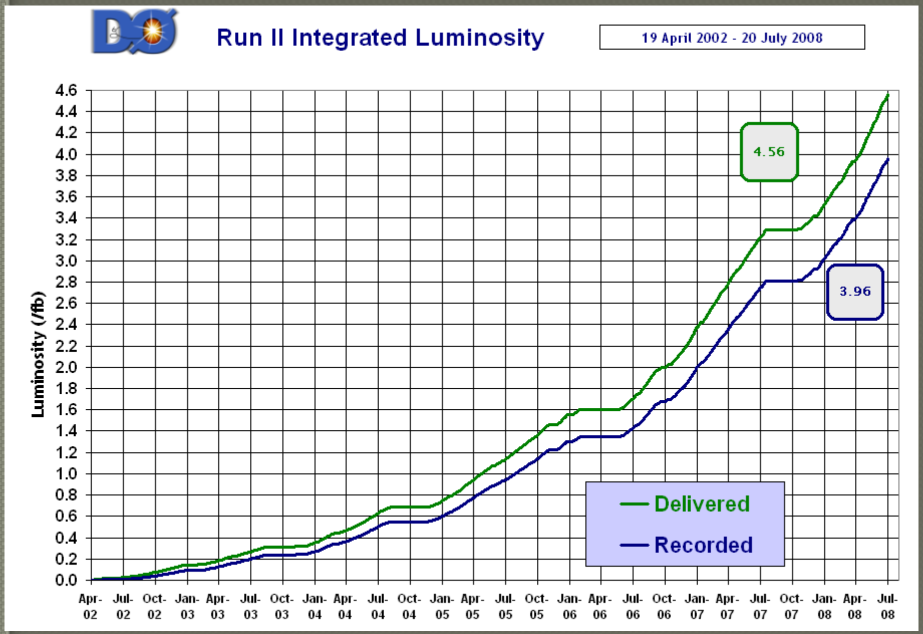
Tevatron parameters

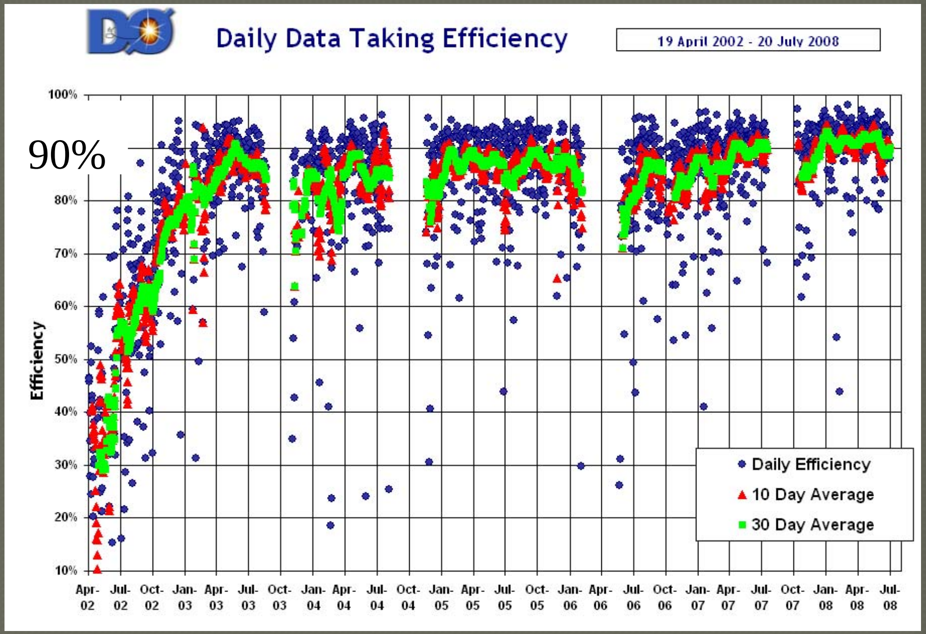
- Sqrt(s) = 1.96 TeV
- 36 x 36 bunches
- 396 ns bunch crossing
- Peak inst. Lumi > $3*10^{32}/cm^2/s$
- 3-8 interactions/crossing
- 50/pb per week



TeV/D0 performance

- The Tevatron is running very well
- Delivered 1.5 fb^{-1} to D0 in the last year (to CDF too ☺)

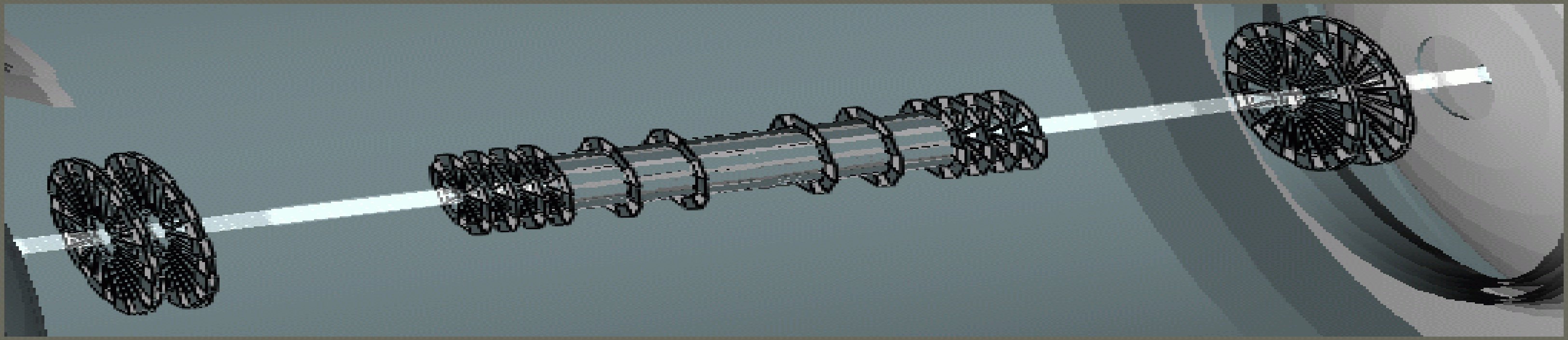


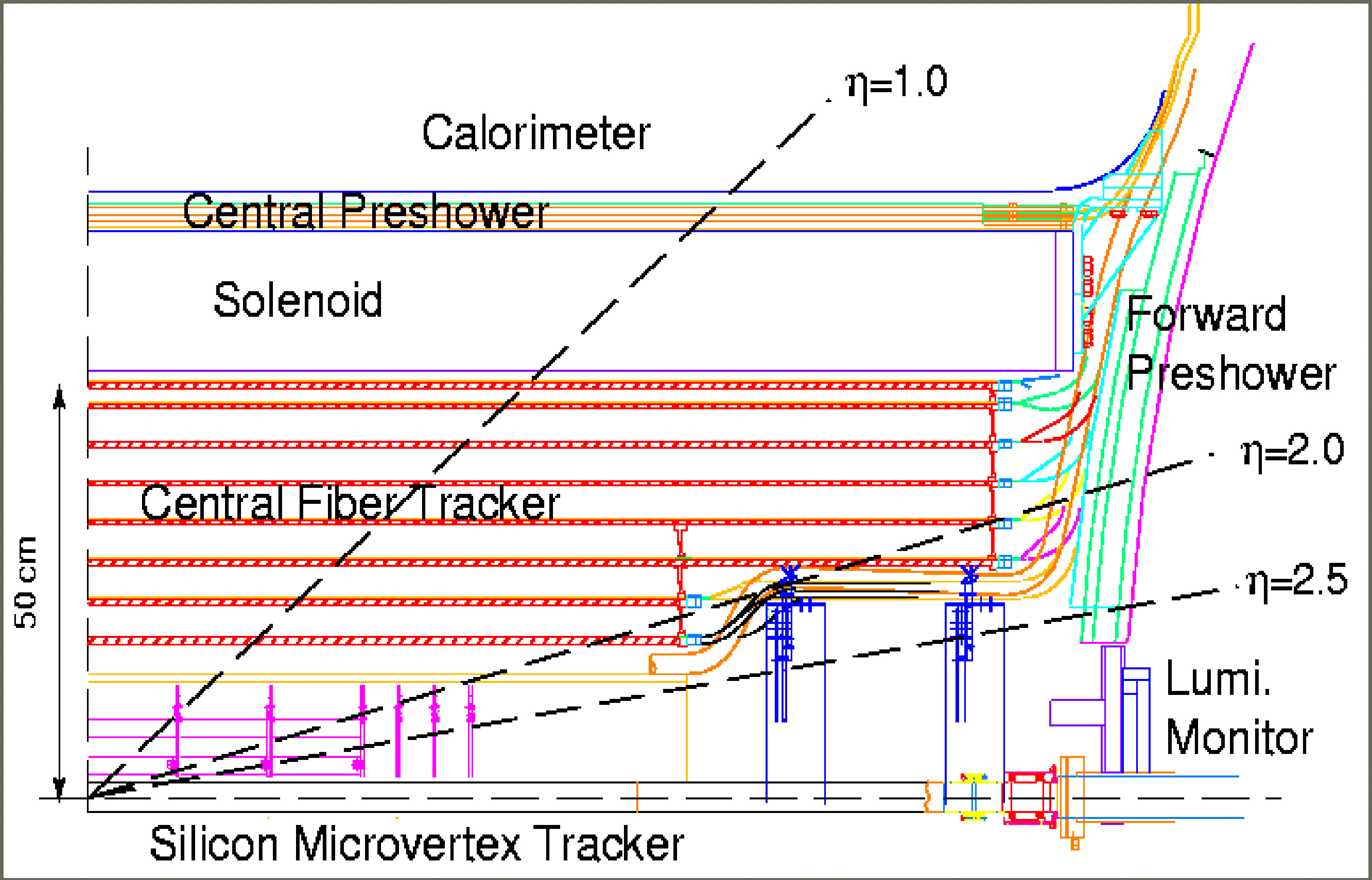


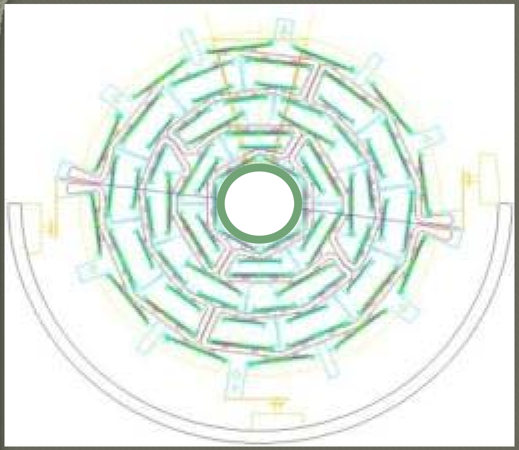
Tracker Design at D0

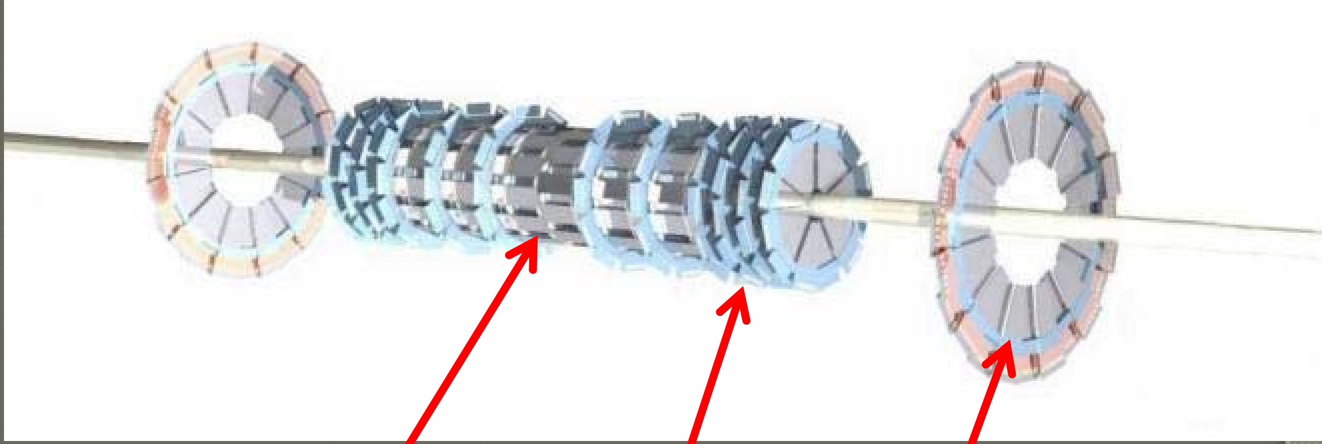
- Driven by large interaction region (about 50 cm FWHM)
- 3D track reconstruction capability
- Excellent vertexing for high pT-tracks
- Acceptance up to eta of about 3.

- Six 12cm barrel modules (4 layers) with interspersed disks for forward tracking
- external large area disks for forward momentum resolution
- detectors and inboard electronics radiation hard up to 3 MRad




η=1.0
Calorimeter
Central Preshower
Solenoid
Forward
Preshower
η=2.0
Central Fiber Tracker
η=2.5
50 cm
Lumi.
Monitor
Silicon Microvertex Tracker

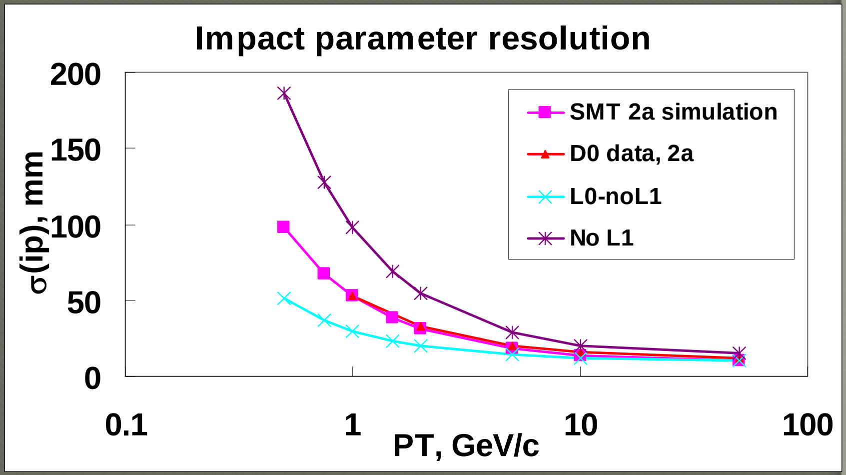




D0	Layer0	Barrels	F-Disks	H-Disks
Layers/planes	1	4	12	2
Readout chip	SVX4	SVX2	SVX2	SVX2
Channels	12288	387120	258000	73728
Modules	48	432	144	96
Sensor Length	7 – 12 cm	12 cm	7.5 cm	14.6 cm
Inner Radius	1.6 cm	2.7 cm	2.6 cm	9.5 cm
Outer Radius		10 cm	10.5 cm	26 cm

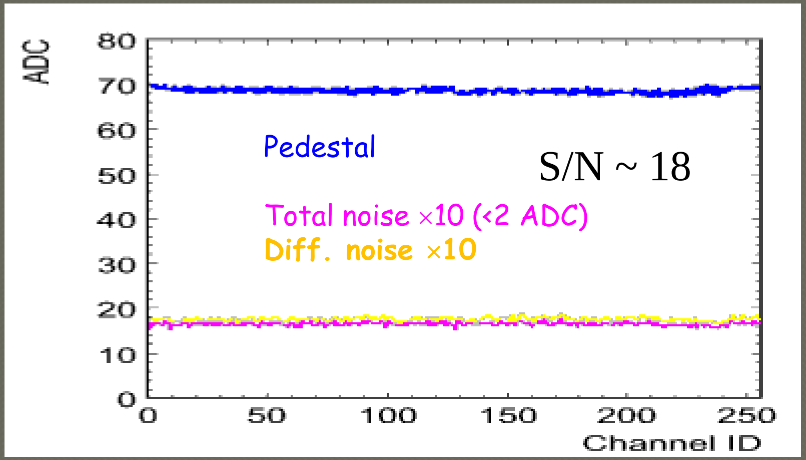
Layer 0

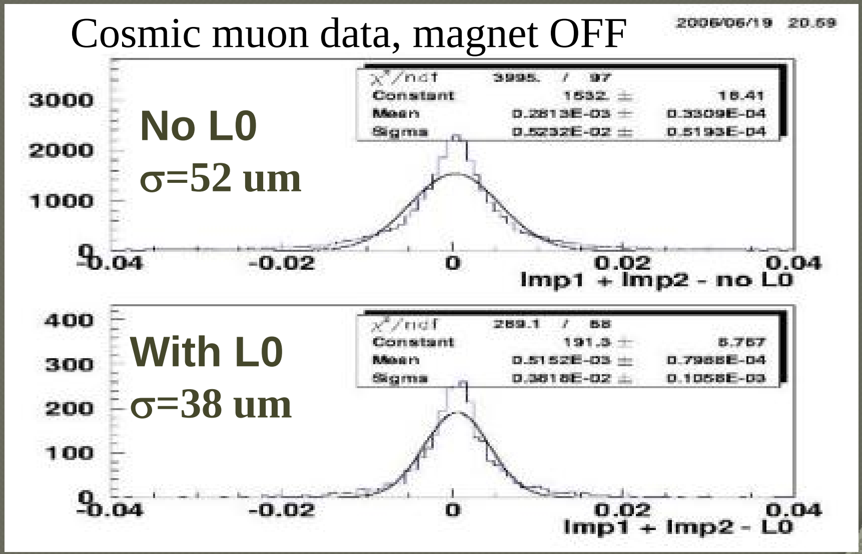
- Barrels and disks installed before the start of RunII, no replacement
- A radiation hard inner layer detector was proposed, built and installed (2003 — 2006):
  - Extends the lifetime of the SMT by compensating possible reduced performance of L1
  - Smaller radius improves the impact parameter resolution and b-jet tagging
  - Provides an additional hit for pattern recognition
- Difficult installation, very successful
  - Fit a 2 m cantilevered object to the center of the detector with 1 mm radial clearance
  - Installation path through the beampipe in the endcap calorimeter



Layer-0 installed 2006

- All 48 modules reading out, one module with an open HV line, possibly repairable
- Excellent noise performance
- Integrated in the tracking with good efficiency of hits on tracks
- 30% improvement in impact parameter resolution for low momentum tracks





Operations

- Monitoring the detector in the control room / data quality
- Radiation protection
(separate talk on radiation damage studies to sensors, S. Desai on Tue)
- Some issues / Maintenance / Repairs
  – D0 has been able to find the right balance between 'stable operations' and maintenance.
  – Continued studies with the system also fostered new experts to keep up with system knowledge

In operation since 2001

- 24/7 operation
- 24/7 on-site coverage with a shifter
- Support of a team of experts (both silicon and technical)

- In general very stable operations and quick recovery times, considering some significant access limitations

Online detector monitoring

- A dedicated shifter
  (over the years reduced to one shifter for inner tracking and track triggers):
  - Monitor the system hardware
  - Fix dataflow hang-ups
  - Monitor system data quality (from r/o errors to physics)
  - Page the experts
  - Document in electronic logbook
- Monitoring tools at several levels (see next slide)
  - It has shown to be a great advantage to have monitoring tools from low level hardware to "just a green light"
- Alarm displays
  audible alarms/messages (archived)

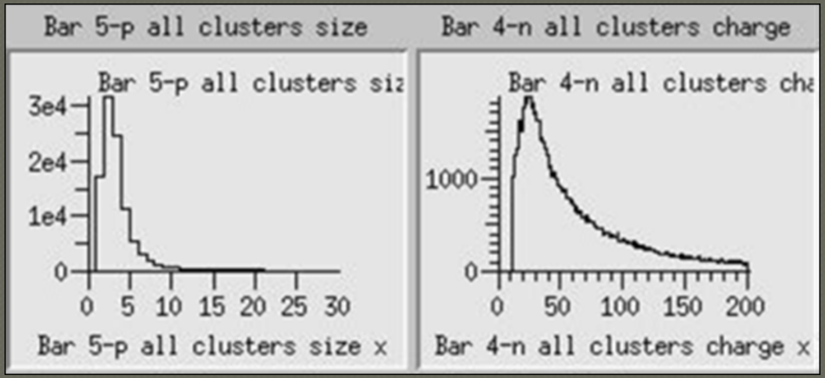
File View Settings Help

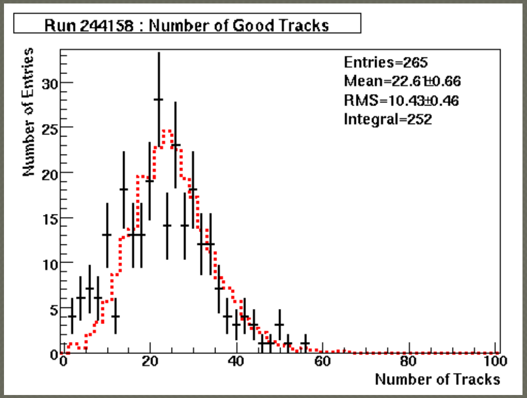
	MAJOR	MINOR	INVALID	ACKED	DISABLED	GOOD
CAL and ICD	0	9	0	15	43	22
CFT	0	37	0	0	17	3
L1CTT	0	0	0	0	40	0
L1CTK	0	0	0	0	0	0
MUO	0	2	0	0	0	1
SMT	11	0	2	65	124	3

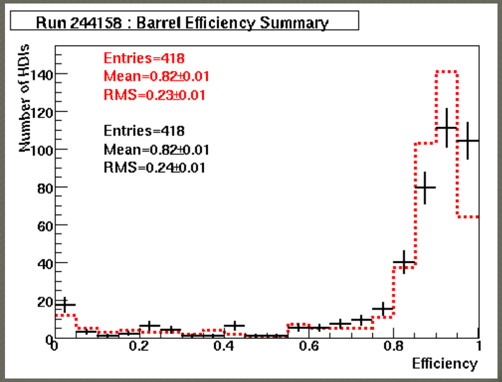
- Many dedicated experts
  - Primary silicon pager, rotates weekly
  - Two silicon group leaders with backup pagers
  - Pool of experts

Online detector monitoring

- Some examples:
  - Cluster size and charge
  - Number of tracks
    - Reference histograms are also provided to compare to data points
  - Efficiencies

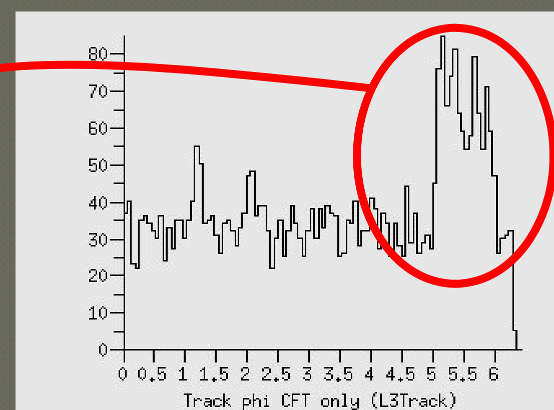






- Readout errors
- Overall error display “quick and simple”, is quite involved in automatic checks: requires a lot of experience to program

- Problems do get spotted ! Need a set of tools !



Number of tracks w/o silicon information vs phi

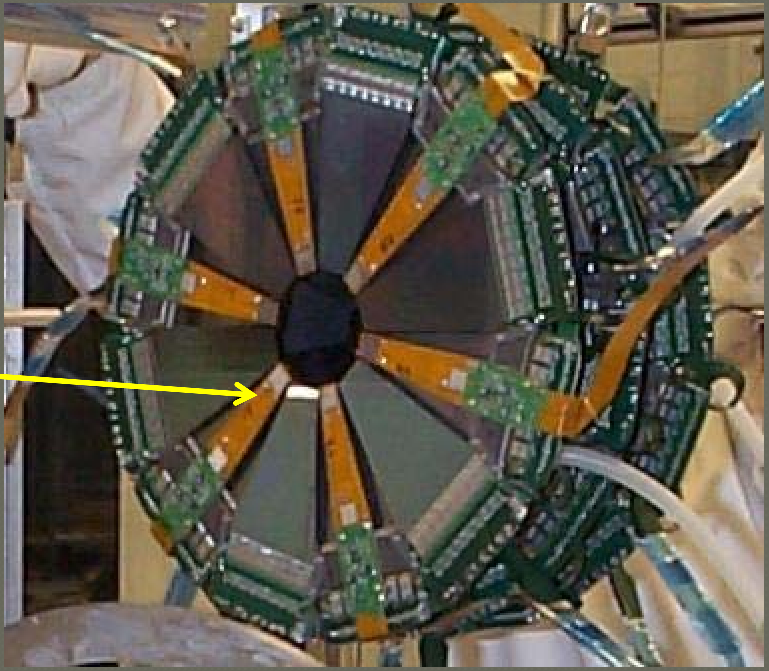
Data quality / lost data

- Overall only 2.5% of luminosity declared bad for silicon data
- Almost all losses due to various power supply failures

	Good	Bad	Special
May '07	98.0%	1.6%	0.4%
June '07	95.7%	4.3%	0.0%
July '07	99.7%	0.0%	0.3%
August '07	100.0%	0.0%	0.0%
October '07	99.5%	0.5%	0.0%
November '07	99.8%	0.2%	0.0%
December '07	99.8%	0.2%	0.0%
January '08	100.0%	0.0%	0.0%
February '08	95.4%	4.6%	0.0%
March '08	95.4%	4.6%	0.0%
April '08	99.5%	0.0%	0.5%
May '08	99.6%	0.4%	0.0%
June '08	95.9%	4.1%	0.0%

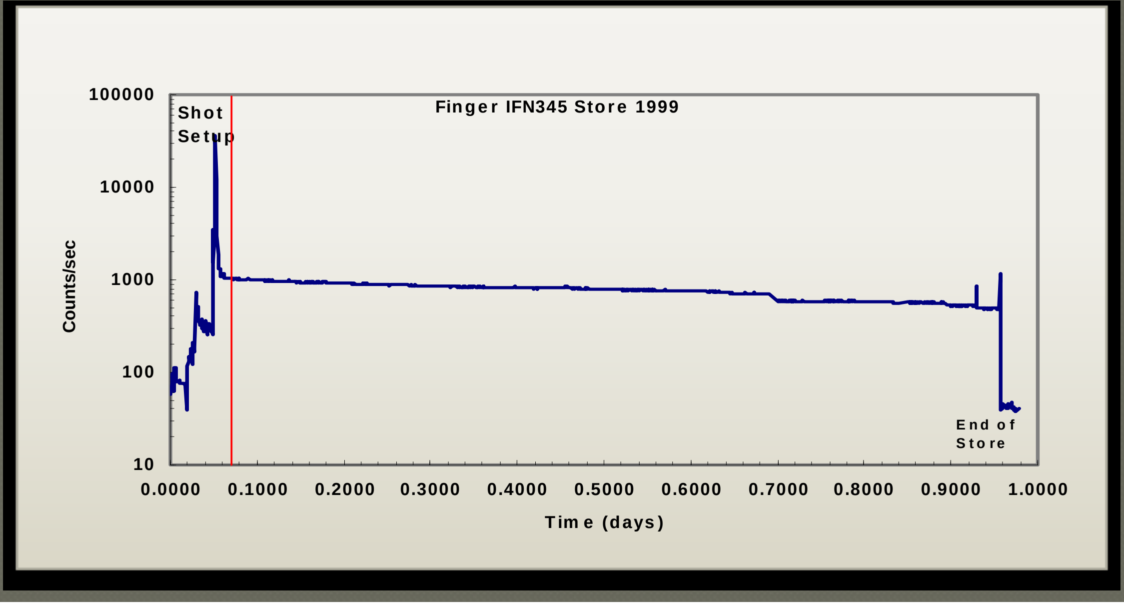
Silicon radiation protection

- **Beam Loss Monitors**
  - Ionization chambers
  - "Simple" devices, standard Tevatron
  - Logarithmic response, large dynamic range, lower precision at low rates
  - 8 specifically used for D0 silicon, in the Tevatron beam abort system
  - Rather far from the silicon, around the beam pipe in the forward region
- **Fingers diodes**
  - Alternative dose measurement
- **Luminosity counters**
  - Measure beam halo rates
  - Used to declare safe conditions for physics data taking



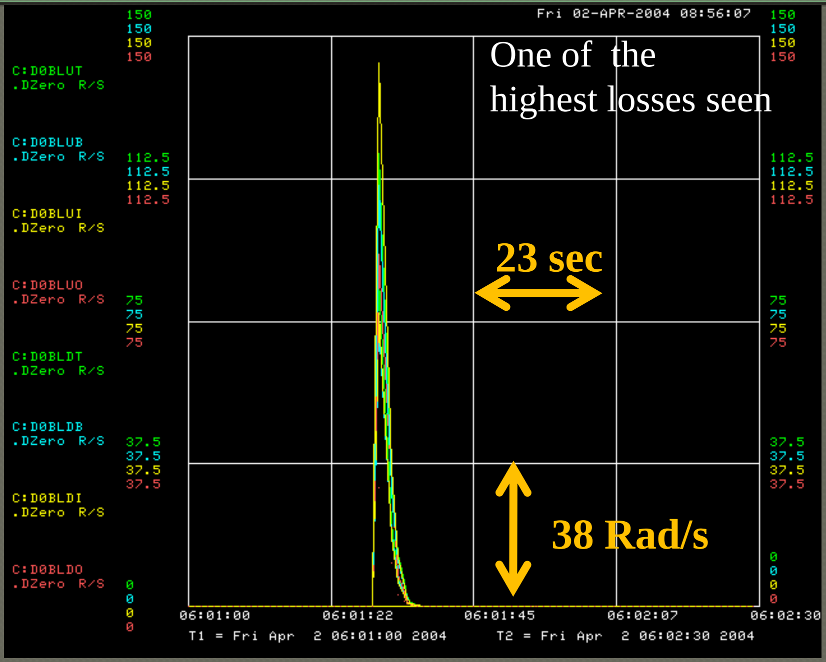
Typical doses

- For a "store"
  (one filling the tevatron with p and pbar):
  – O(100) Rad during beam setups to collisions
  – O(1000) Rad during physics data taking



Radiation issues / Operations

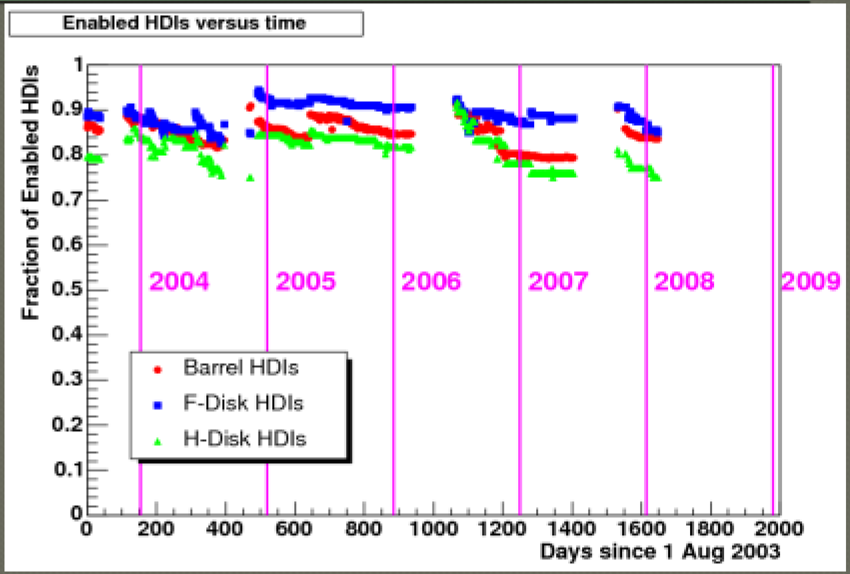
- Radiation is a concern
- Several safe beam aborts
- Very few "unclean" aborts (O(kRad), see figure)
- Some unusually intense splashes from upstream beam losses during beam setup and studies
  - High currents in detectors
  - Tripped HV, LV
  - Power supply problems



- Intense collaboration with machine people to avoid radiation and/or improve operation procedures and hardware

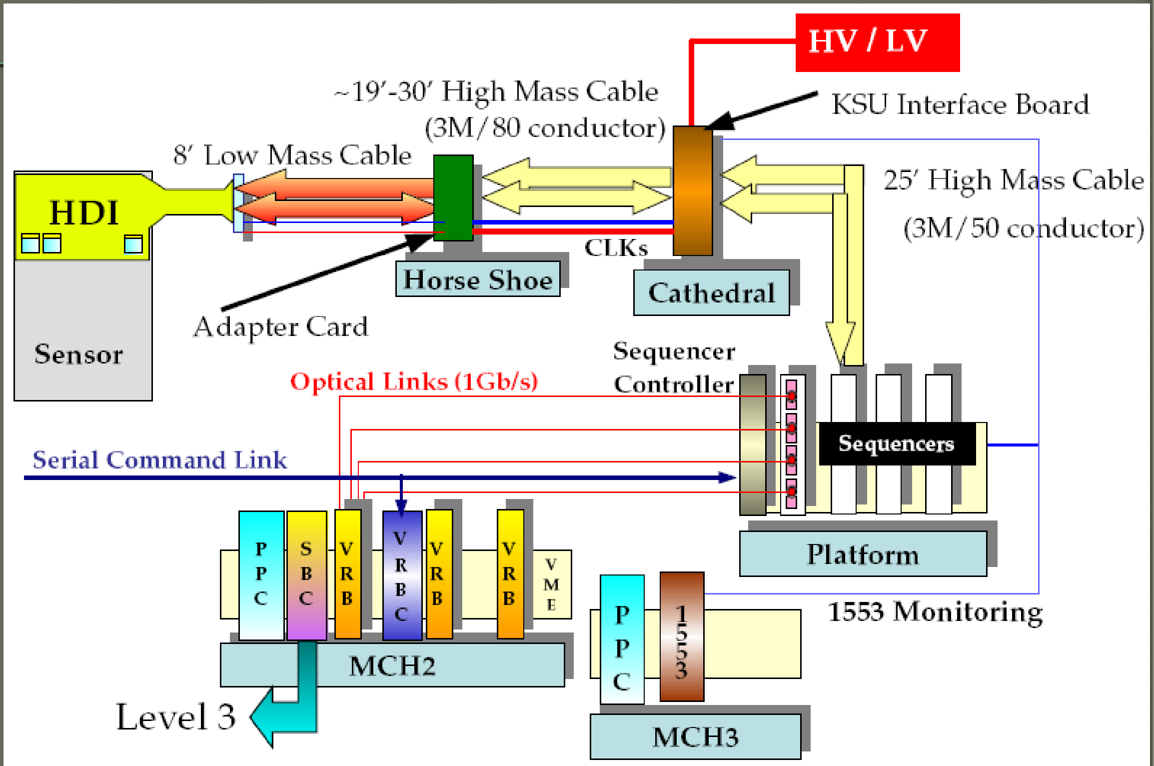
Maintenance work

- Obviously there is no "one number" to qualify a system health (ultimately physics performance)
- Useful monitor: fraction of powered sensor modules (HDIs)
- Note the recovery efforts
  - Tireless routine fixes during shutdowns
  - Continued and dedicated studies by experts to eliminate causes or recover



Key to successful long-term support:
put young and motivated physicists in charge with strong support from very experienced people

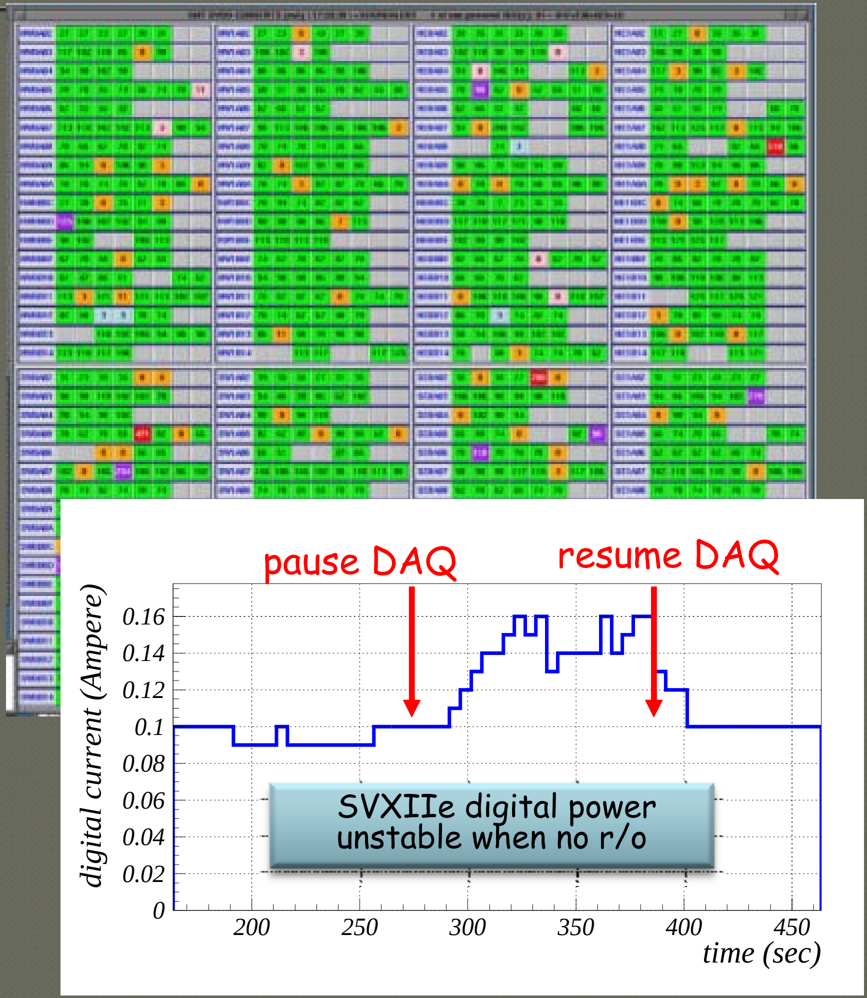
Readout chain / accessibility



- Horse Shoe
  - Accessible during long shutdowns
  - 1 access / year
- Cathedral
  - 10h access
  - LV Power supplies
  - couple / year
- Platform
  - In the experimental hall, underneath D0
  - Access about monthly for SMT (failures, maintenance)
  - Readout control hardware and PS, few failures / year
- Movable counting houses (MCH)
  - Only operational access restriction

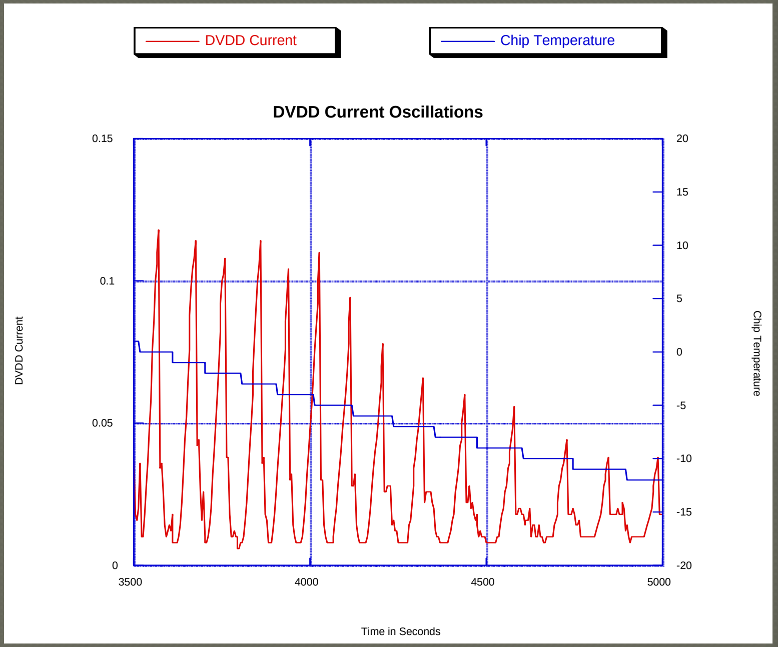
Digital power (DVDD) issue of the SVXII chip

- Known behavior of SVX2 chip: no readout causes high current draw (DVDD)
- Shifters are continuously monitoring the readout and digital currents
- Developed a heartbeat of backup readout strobes, that are generated when the data acquisition is halted
- Complicates operations
- Failures caused significant module loss

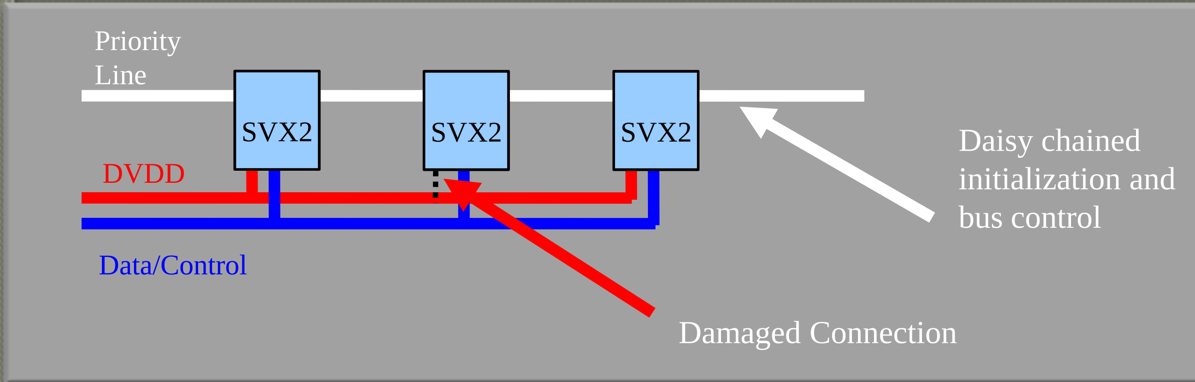


Recent progress and recovery

- Intense investigations:
  - Test stand measurements: actually seen large current oscillations
  - Depend on temperature
  - Indentified as CMOS dynamic memory latch-up
- Causes wire bonds to fail. Current thinking, based on the failure mode. Usually only one or two chips per hybrid.
- Interrupts the readout priority daisy chain between chips of one module
- Hardware recovery has been designed and implemented to save healthy chips



Recovery



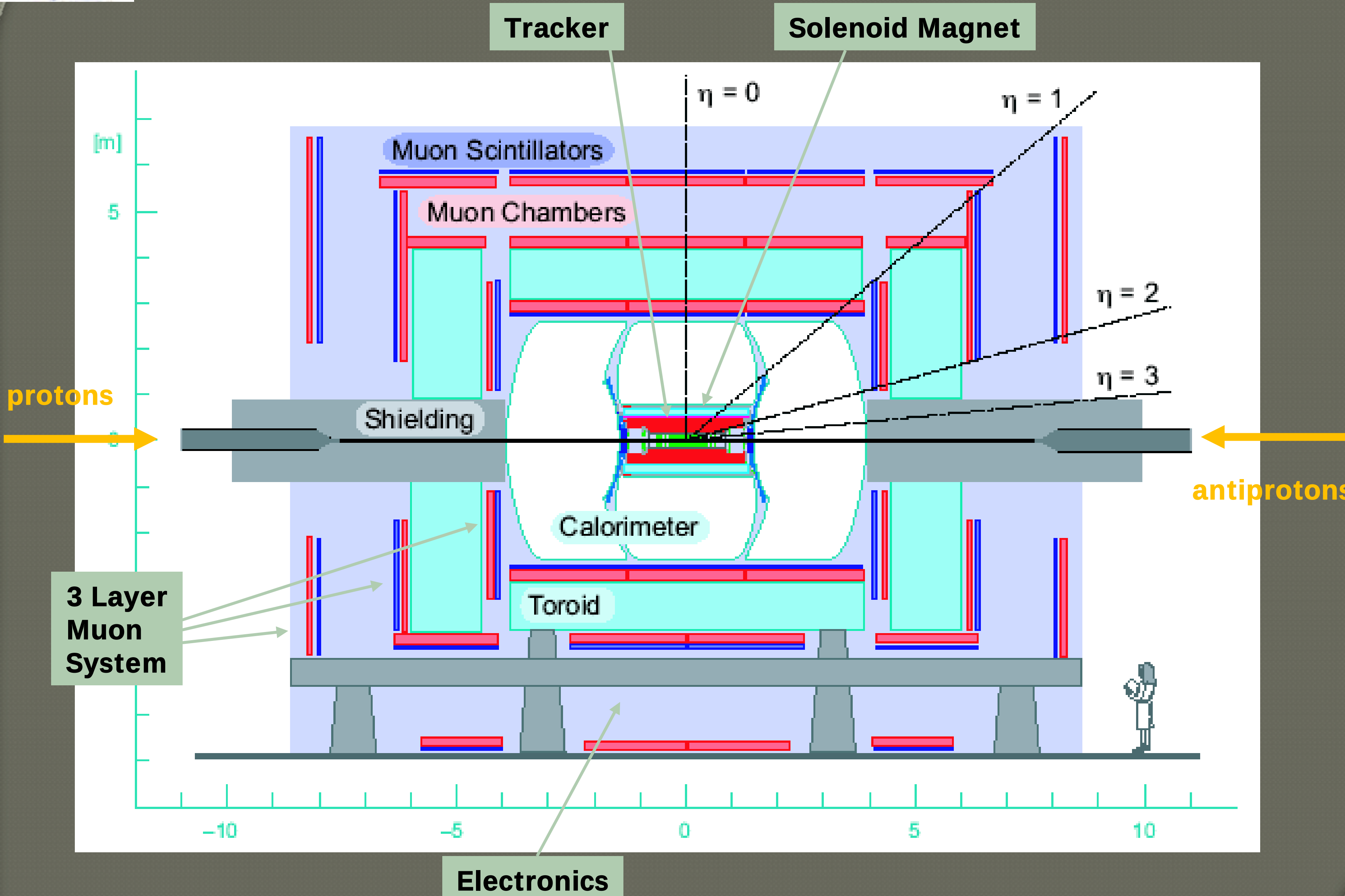
- Recovery requires alternate power path.
  - Such a path exists!
  - All digital lines have protection diodes to DVDD
  - Power the chip via data lines: special hardware board designed supply power to the data lines for affected chips
  - Not possible to readout the chips, but the daisy chain for the readout priority line is restored

- Recovered 514 (60%) out of 914 chips in faulty modules

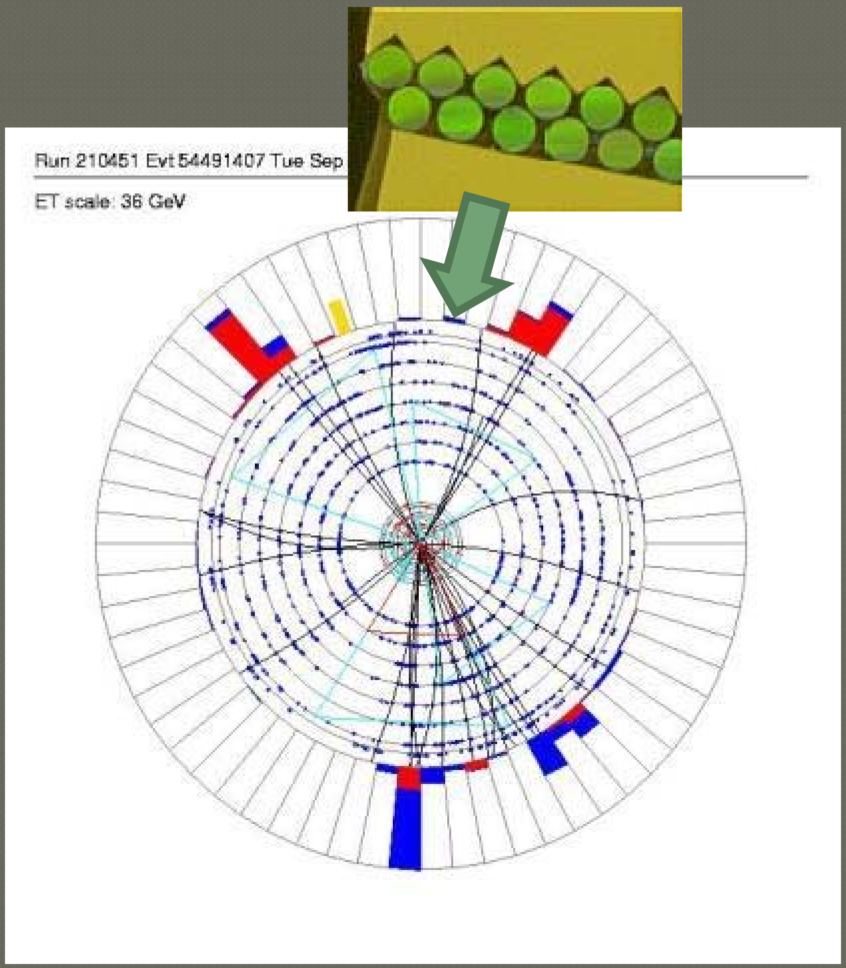
Show here also as example of recovery possible in the 7th operation year, if the expertise is kept, fostered

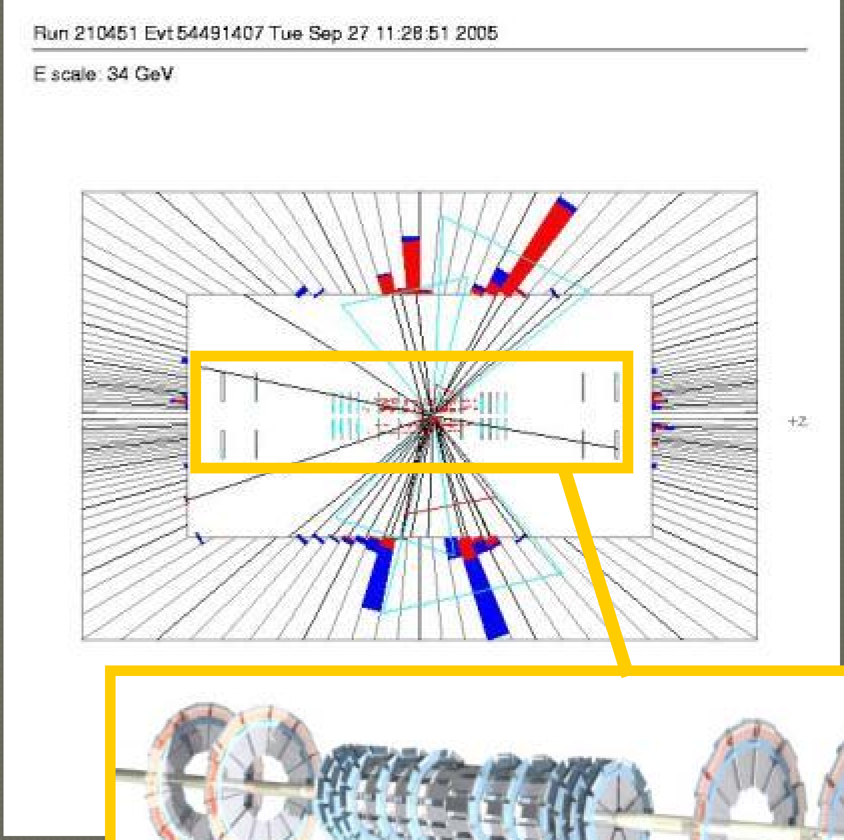
Conclusions

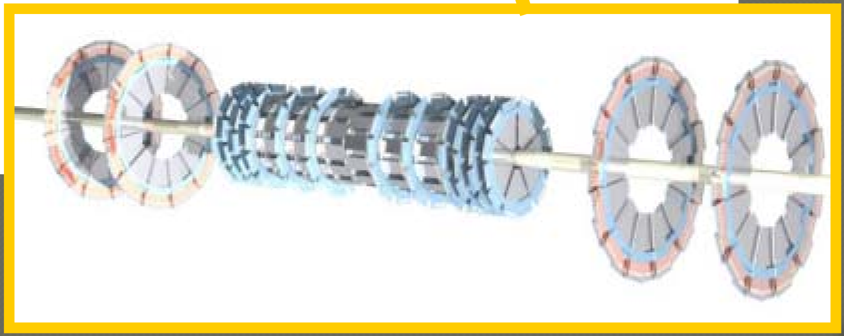
- Operated a silicon detector over 7 years in a hadron collider
- D0 has found the right balance between ‘operation’ and ‘maintenance’
- A strong support team of young leaders with excellent senior support: long term operation possible
- D0 silicon is, and will be, efficiently providing high quality physics data

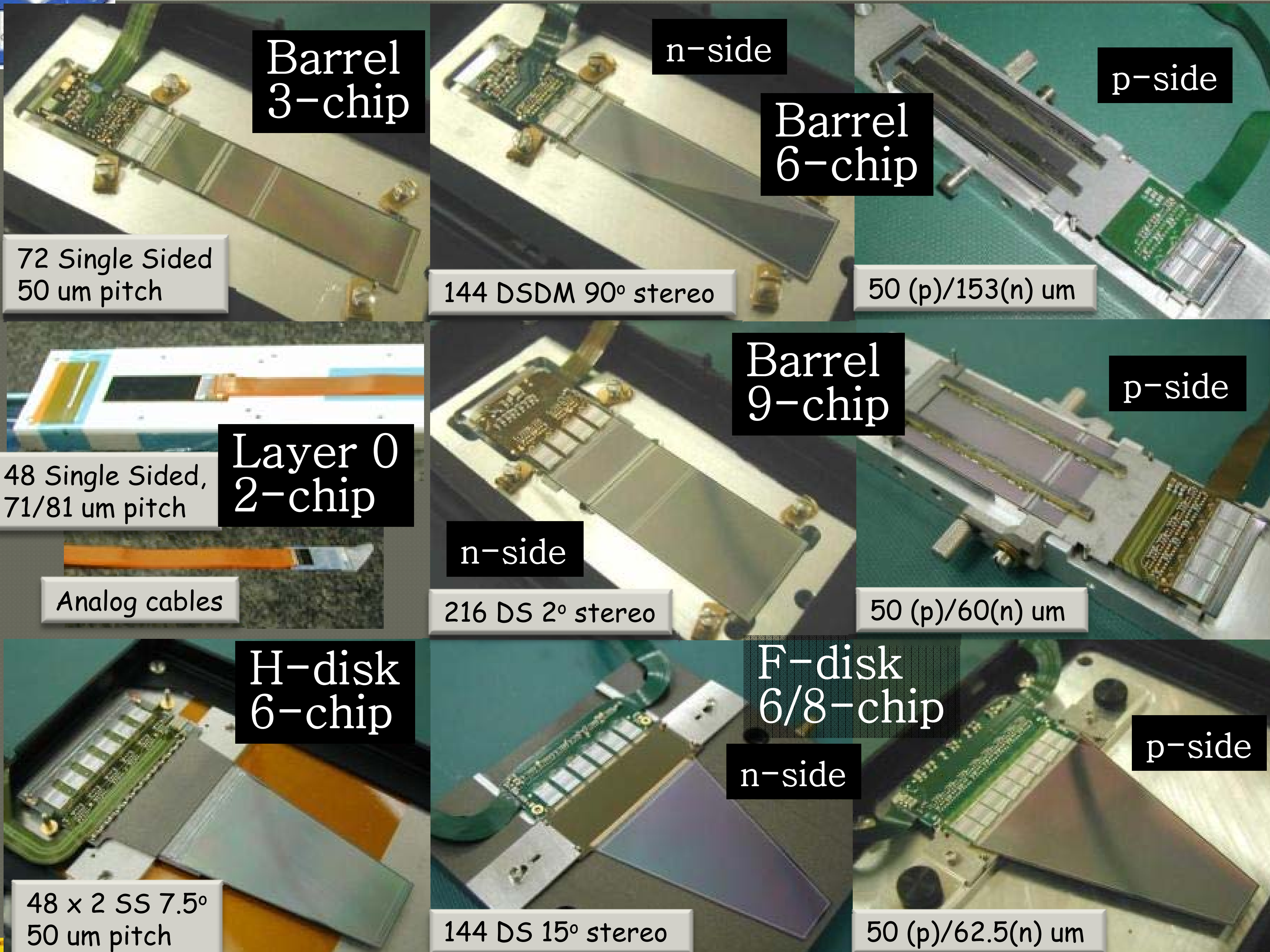

Tracker
Solenoid Magnet
η = 0
η = 1
η = 2
η = 3
[m]
5
0
Muon Scintillators
Muon Chambers
protons
Shielding
antiprotons
Calorimeter
Toroid
3 Layer Muon System
–10
–5
0
5
10
Electronics

D0 central tracker

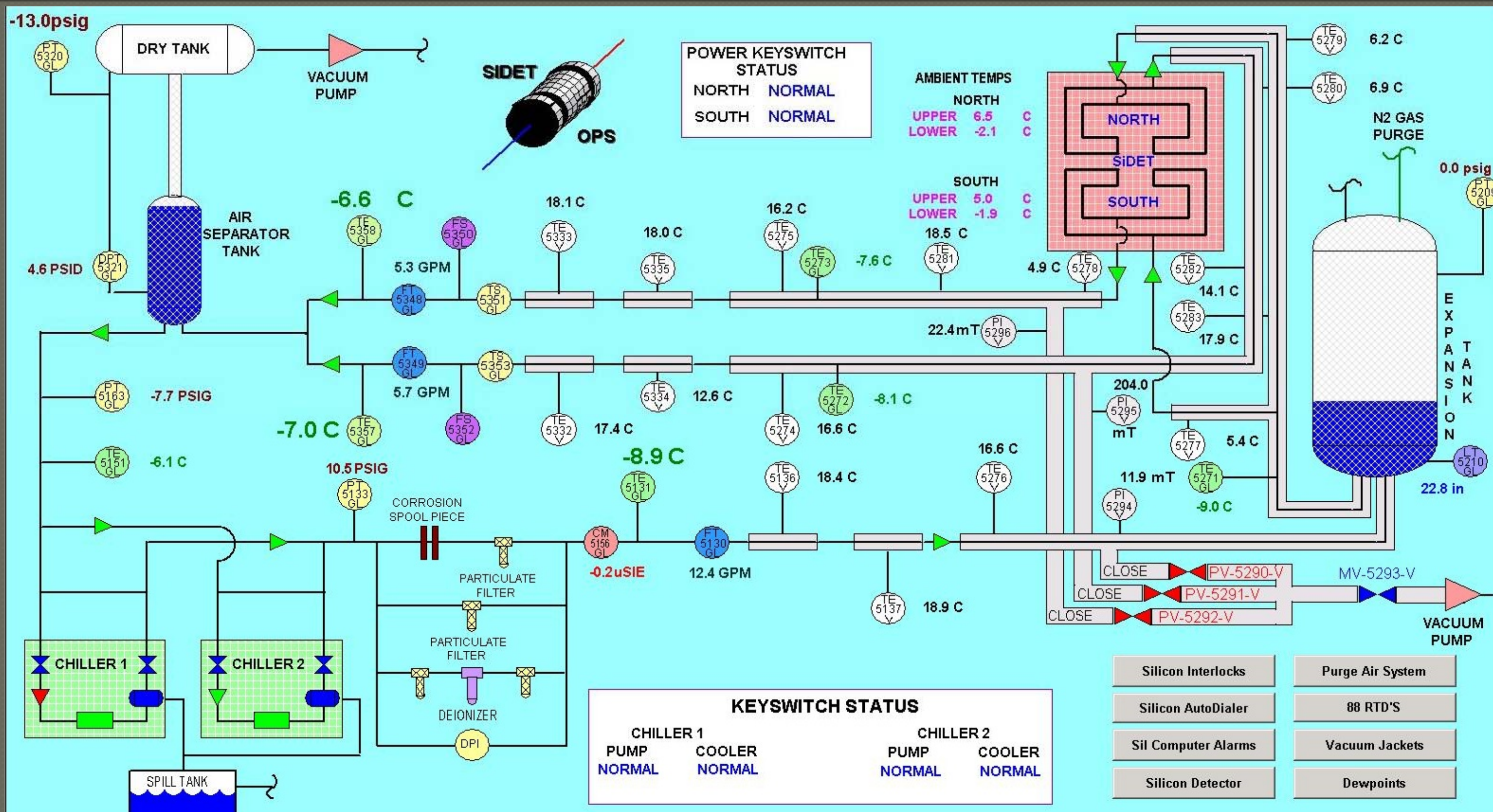







Barrel 3-chip
72 Single Sided
50 um pitch
n-side
Barrel 6-chip
144 DSDM 90° stereo
p-side
50 (p)/153(n) um
Layer 0 2-chip
48 Single Sided,
71/81 um pitch
Analog cables
Barrel 9-chip
n-side
216 DS 2° stereo
p-side
50 (p)/60(n) um
H-disk 6-chip
48 x 2 SS 7.5°
50 um pitch
F-disk 6/8-chip
n-side
144 DS 15° stereo
p-side
50 (p)/62.5(n) um

Cooling system

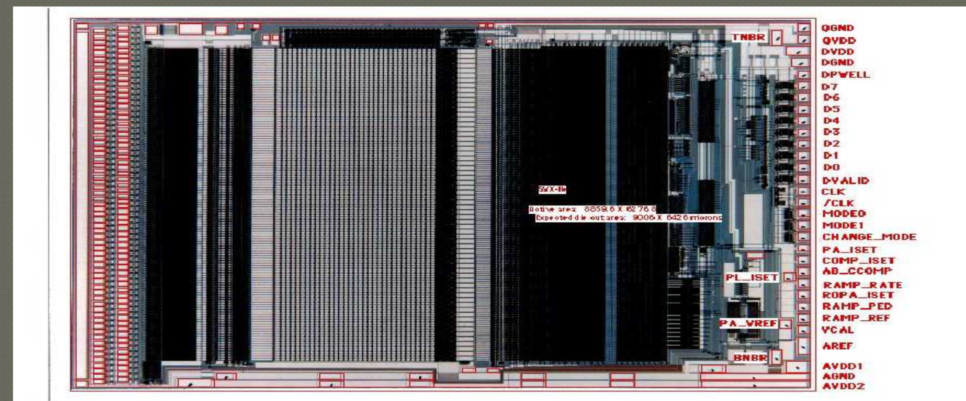


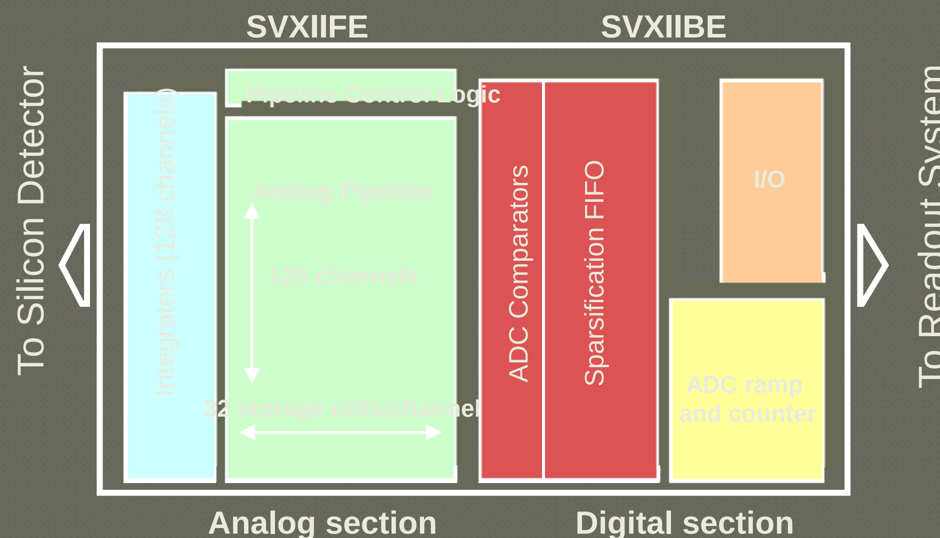
30% glycol + water at –10 °C (=> detectors between –5 and 0 °C)

The tracking volume is purged with dry air to prevent condensation

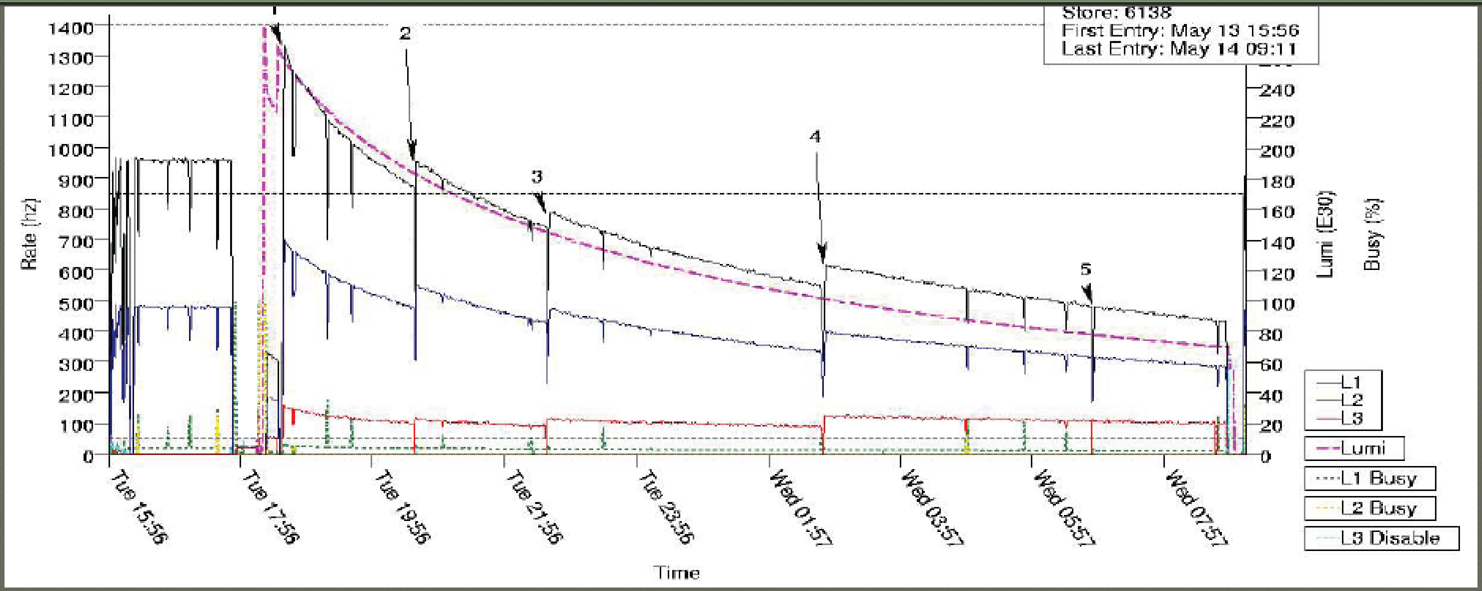
SVX-II chip

- 1.2 mm CMOS amplifier/analog delay/ADC chip fabricated in the UTMC rad hard process
- LBL/Fermilab group
- Features:
  - 128 channels (5 mW/channel)
  - 32 cell pipeline /channel
  - 8-bit Wilkinson ADC with sparsification /channel
  - Programmable test pattern, ADC ramp+pedestal, preamp bandwidth, calibration, polarity…
  - 53 MHz readout
  - 06 MHz digitization
  - Dimensions: ~ 6.4 x 9.7 mm2
  - ~ 85,000 transistors





A “store”



- HV ramped up at the beginning and down at the end of the store, takes a few minutes each (1-2 % luminosity without recording physics data)
- Silicon readout introduces readout dead time (2-3%)
- Run transitions (40 sec) and DAQ resets (15 sec) amount to less than 1 %

- Regular calibrations (pedestal and width) in the time without beam between stores

- For this store we recorded 95% of the delivered luminosity