

# Muons in D0

The image shows the interior of the D0 detector tunnel. The walls are covered in a dense array of white, diamond-shaped scintillator tiles. In the center, a large, red, rectangular structure, likely the muon detector, is visible. The ceiling is white with various pipes and lights. A red metal railing is in the foreground. The overall scene is a large, industrial-scale scientific facility.

Martijn Mulders  
Fermilab  
for the Muon detector and Algorithm groups

# Muons in D0

## hardware / software

- Status of Forward / Central Muon detector
- PDT monitoring with HV currents and Pads
- L1, L2, L3 Muon Trigger
- Improvements in Muon reconstruction



# Forward muon detector: MDTs and Pixels

V. Abazov, Y. Chtcheglov, D. Denisov, G. Erusalimtsev, V. Tokmenin, Y. Yatsunenko, V. Evdokimov, V. Bezzubov, A. Schukin, I. Vasilyev

- Stable and very efficient ( $>99\%$  single hit efficiencies)
- Improved monitoring with single muons (D. Bandurin)
- MDT Shutdown progress (first time access to A-layer):
  - 708 (of 960) CPLDs tested and reprogrammed; the rest (252) will be done at end shutdown
  - Fixed dead channels:  $0.5\% \rightarrow 0.3\%$
  - Fixed gas leaks:  $5\% \rightarrow 2.5\%$
  - Checked HV calibration: OK
  - Checked water contamination in gas mixture: 1-2 ns increase drift time (64 ns) at 18.8 ns digitization



# The central muon detector: PDTs, scintillation counters

- Stable and efficient
- No. of dead channels  $< 0.5\%$  (wires), all scintillators are working
- SHUTDOWN progress:
  - Installation new C-hole trigger counters
  - Some wires drawing high currents have been pulled for investigation
  - Installation of 144 remote power cycle boxes for front-end electronics on schedule
  - Replaced all remaining old m68k processors in Muon readout crates by 10x faster Power PC. Rate test with L2 accept rate of 1.3 kHz looking good (D. Shpakov)



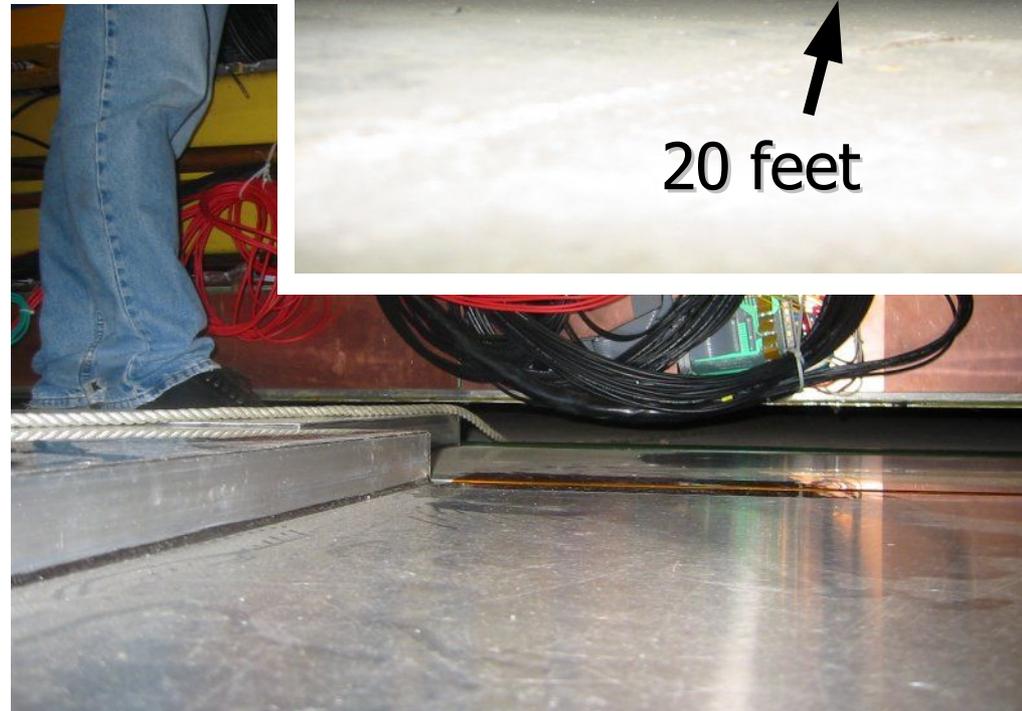
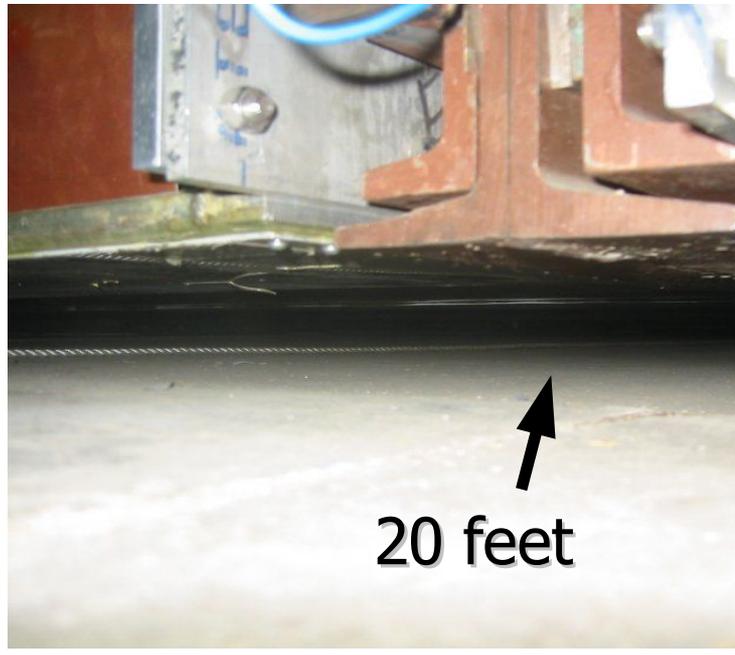
# New counters in bottom C-hole

- D0 note 4088 (T.Diehl) for hardware description. Will provide extra layer of scintillator in 'hole' in bottom of detector.
- Reco and d0gstar are ready (D. Bauer), L1 and L2 trigger to follow (soon?)



Al Ito  
Bryan Johnson  
Rolando Flores

Robert Harrington



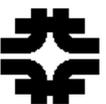
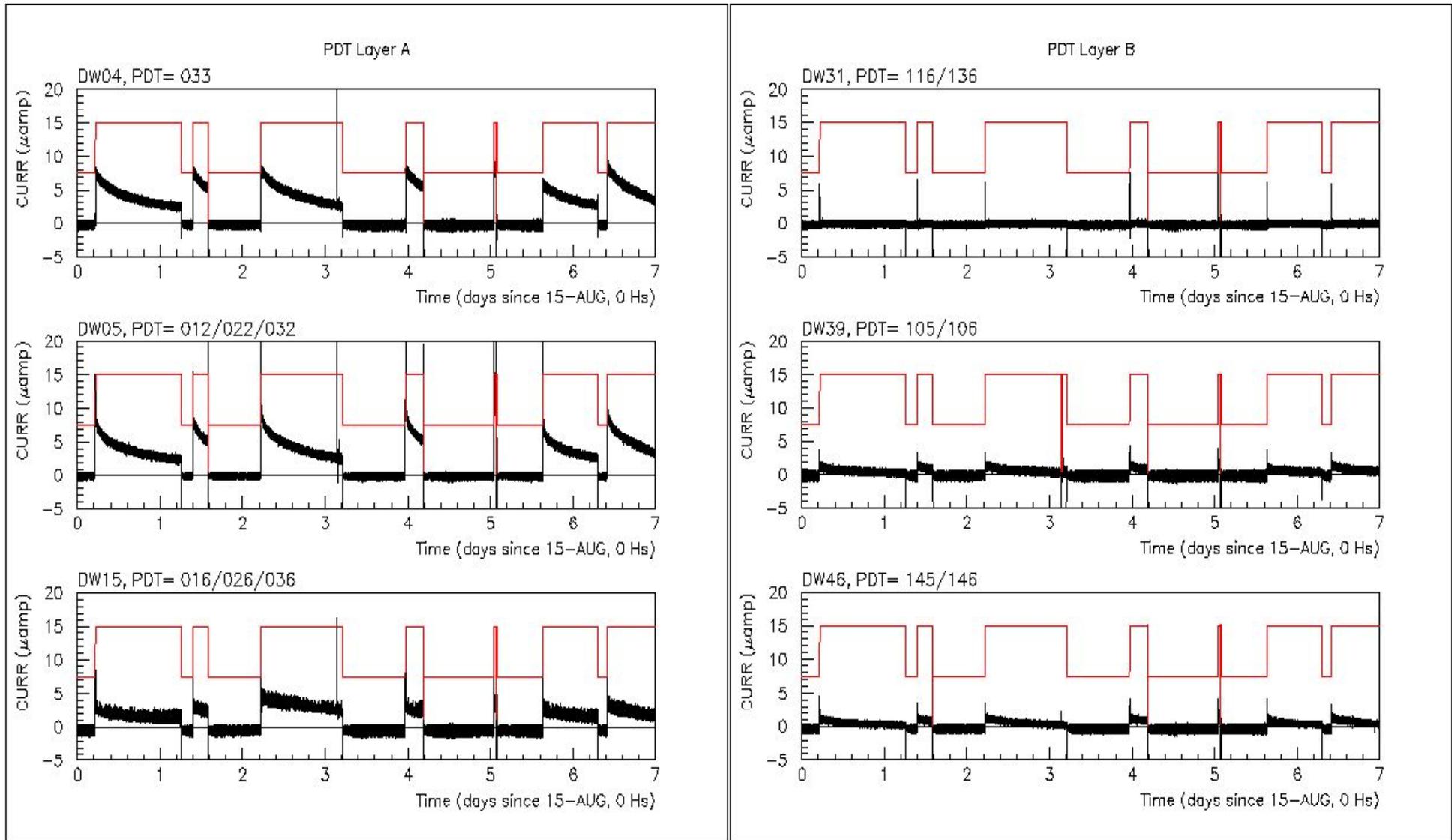
# Monitoring PDT currents

(Gaston Gutierrez)

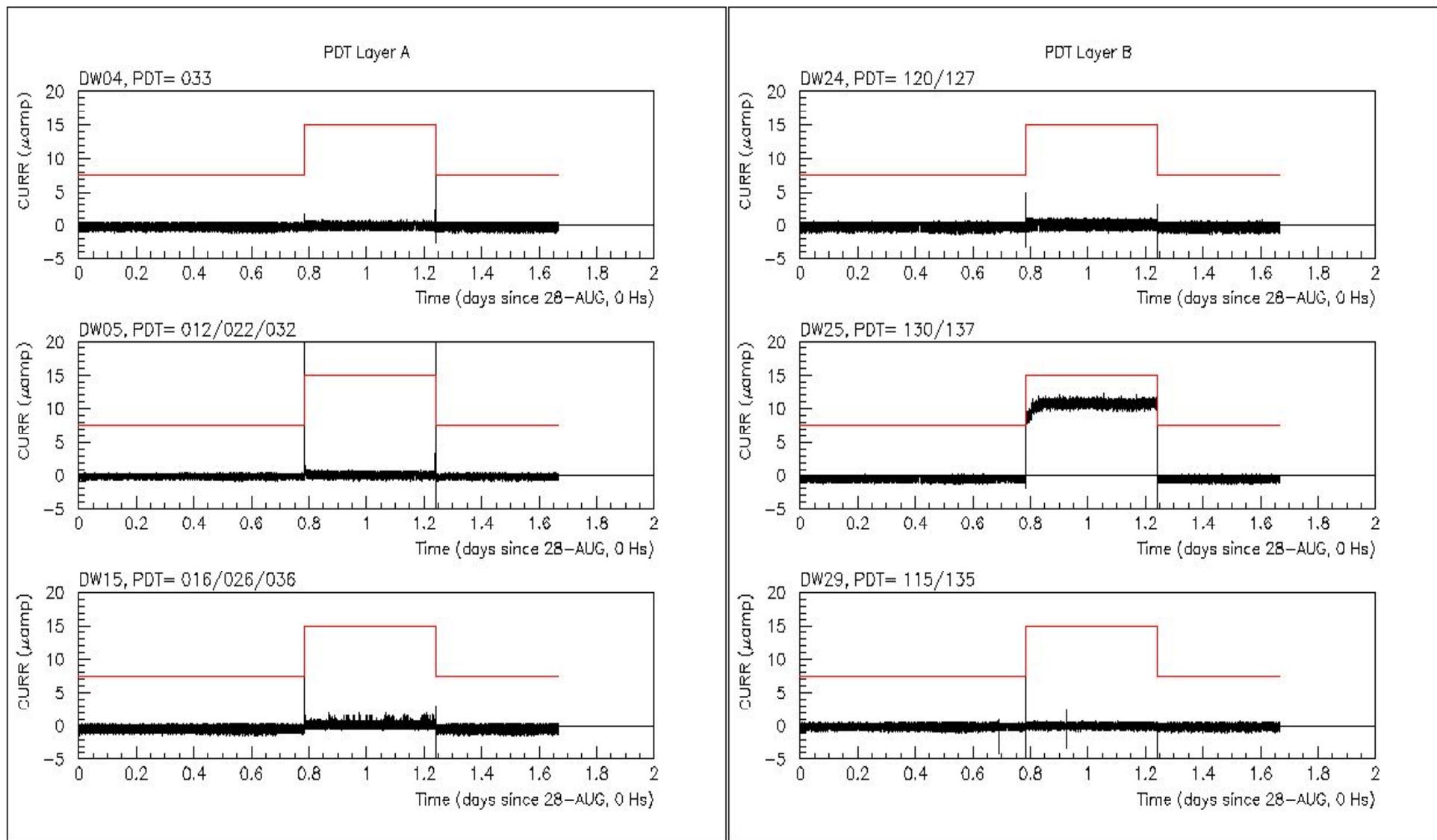
- We can gain from a better understanding of the basic properties of the PDTs (better understanding of gains, time-to-drift relations, role of electronics response in  $t_0$ 's )
- We need a better monitoring of the status of the PDTs make sure that we see potential problems before they actually happen (aging, HV, gas composition, etc.)



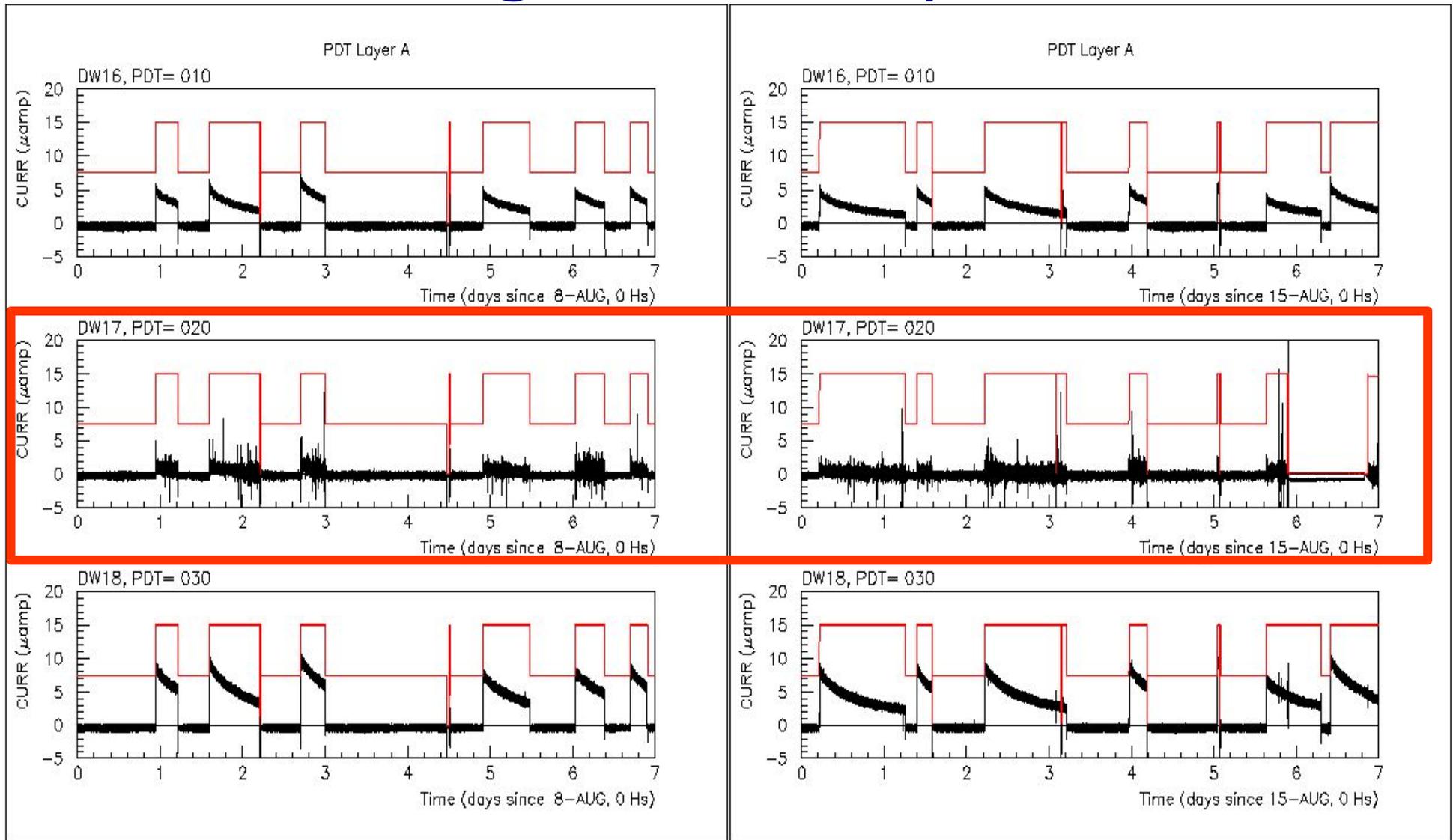
# PDT HV currents as a function of time



# PDT HV currents with no beam

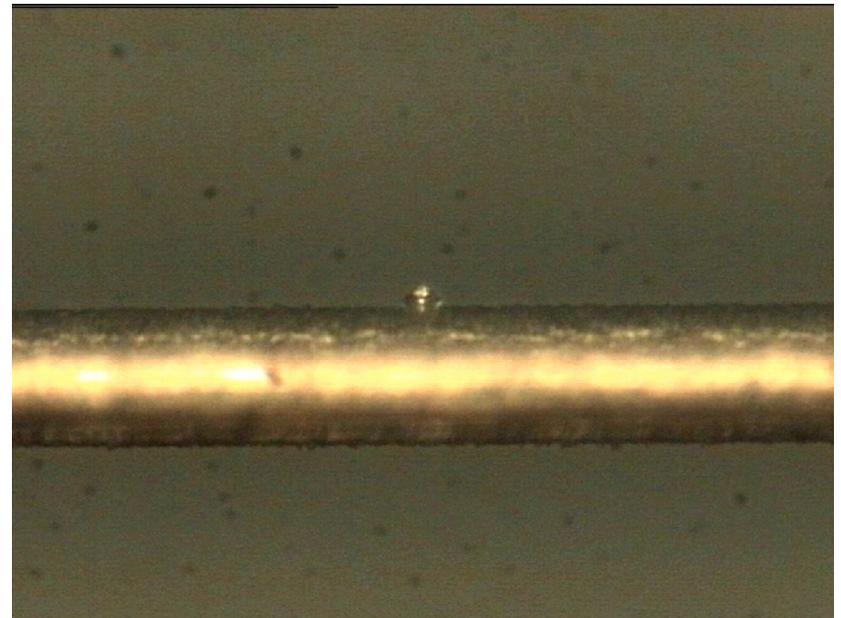
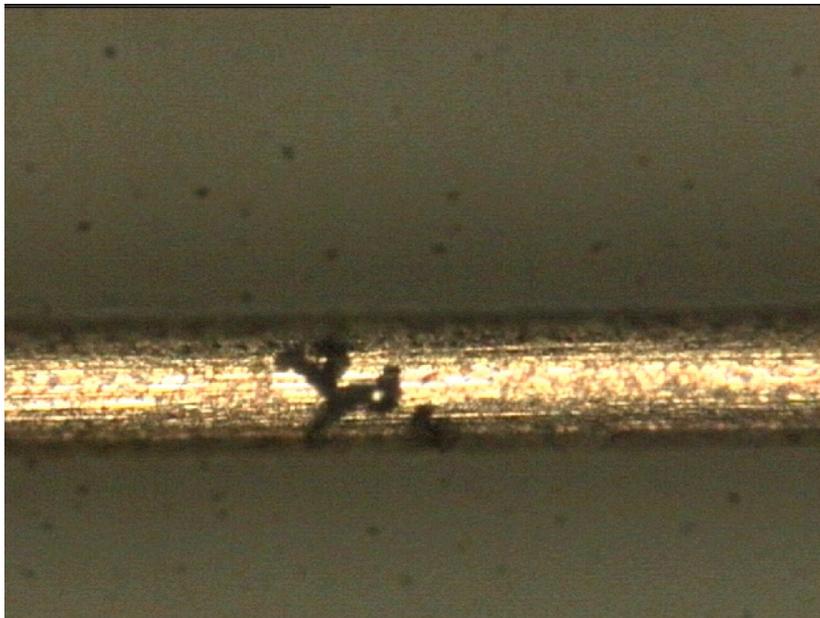
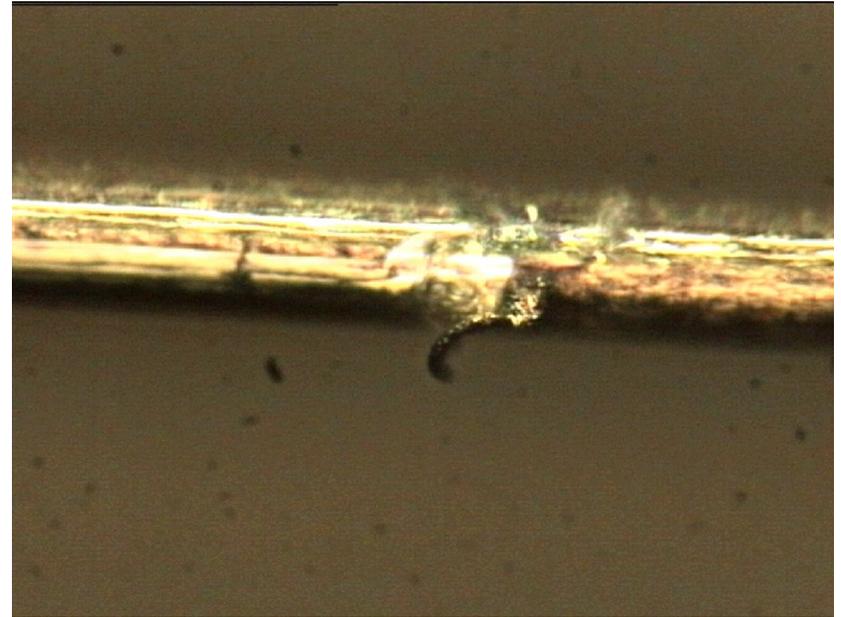
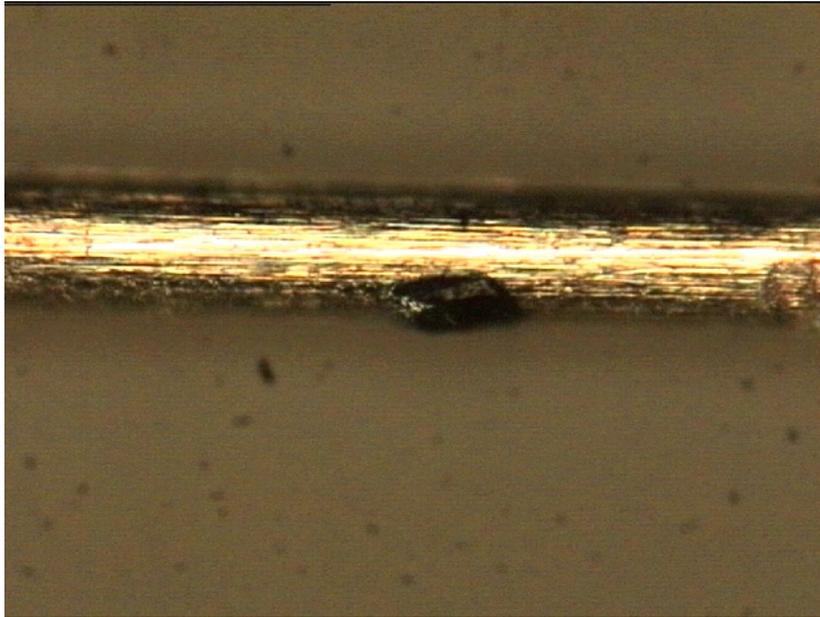


# Detecting Muon POD problems

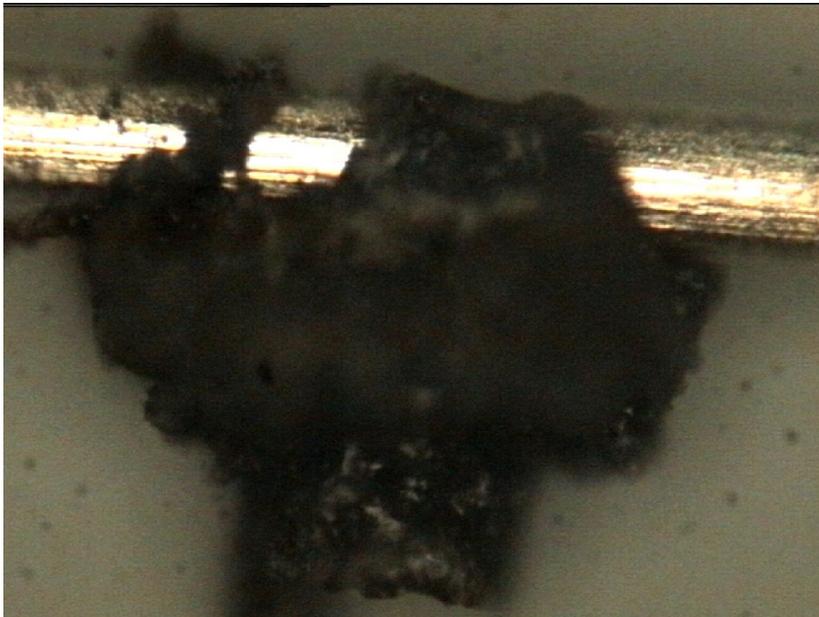
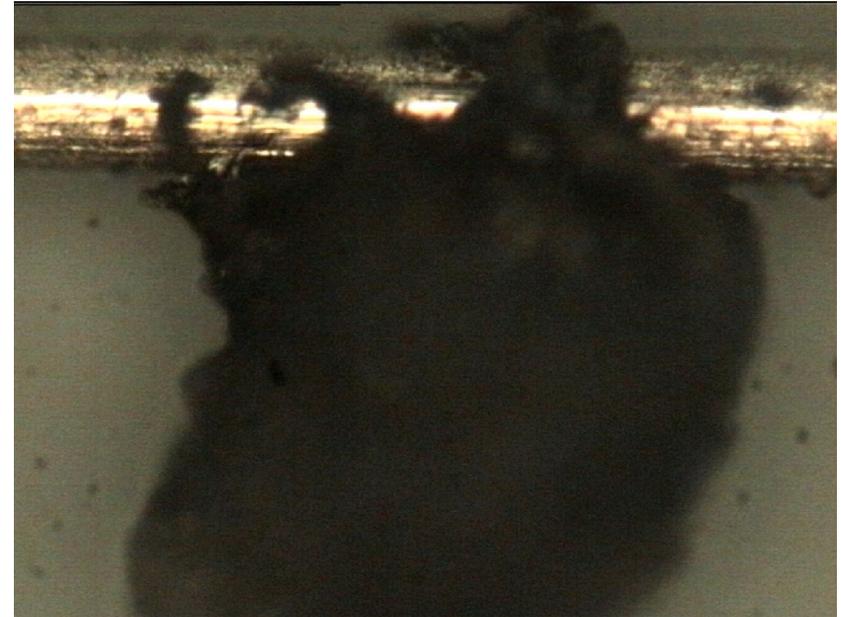
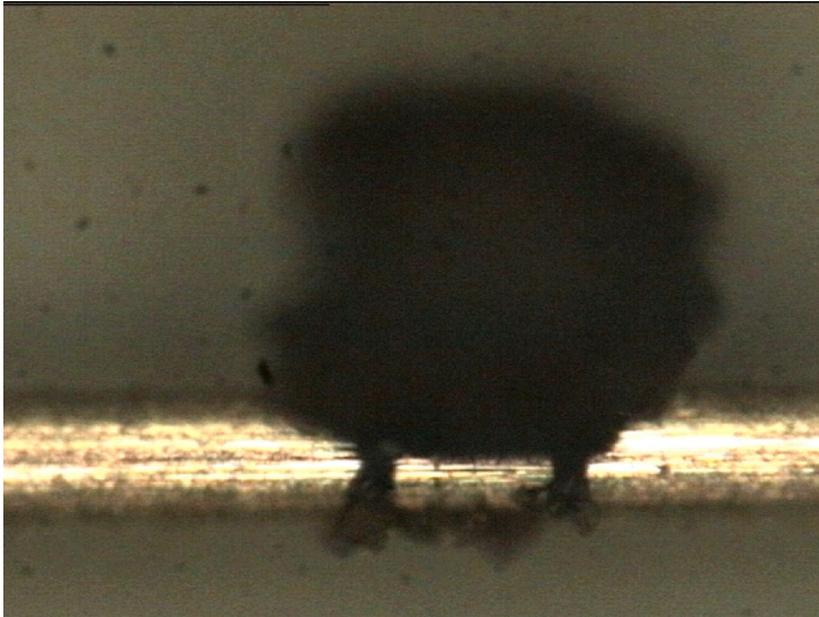


Similarly: wire about to break, Service Card problem ...  
detectable days / weeks before failure

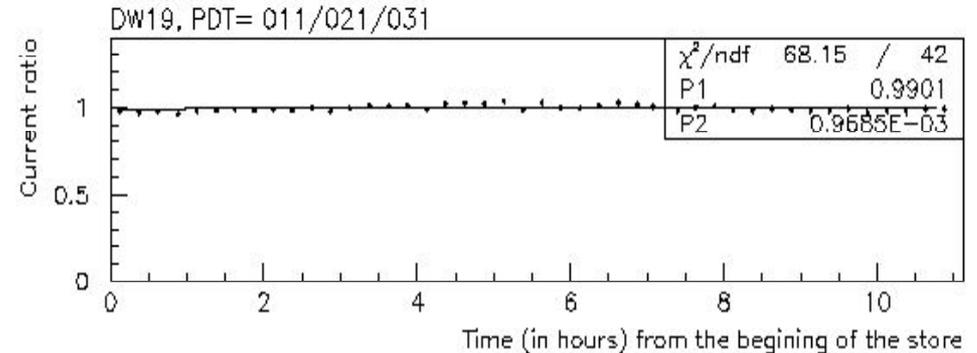
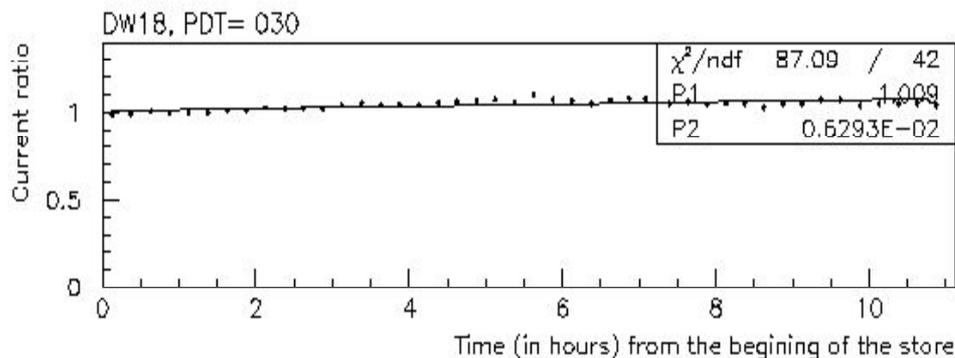
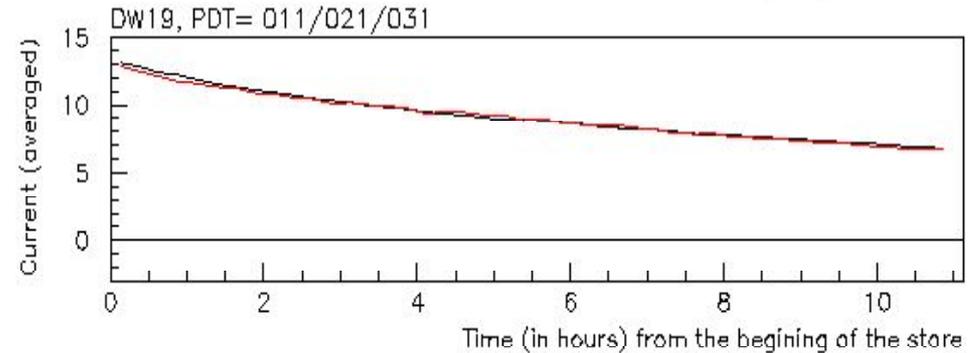
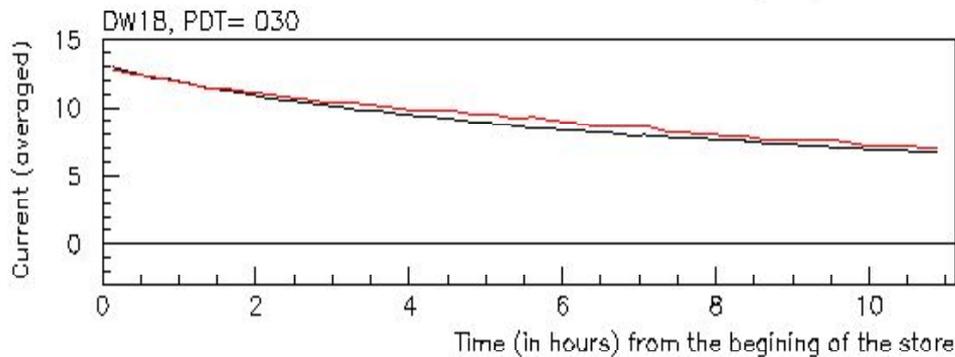
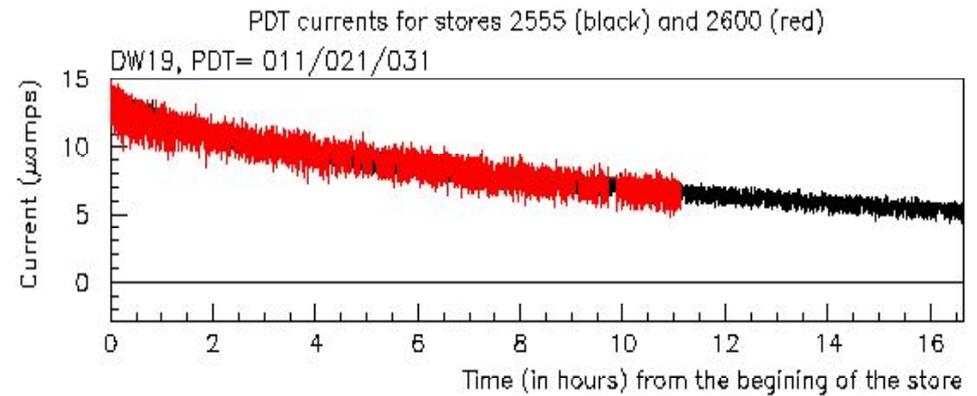
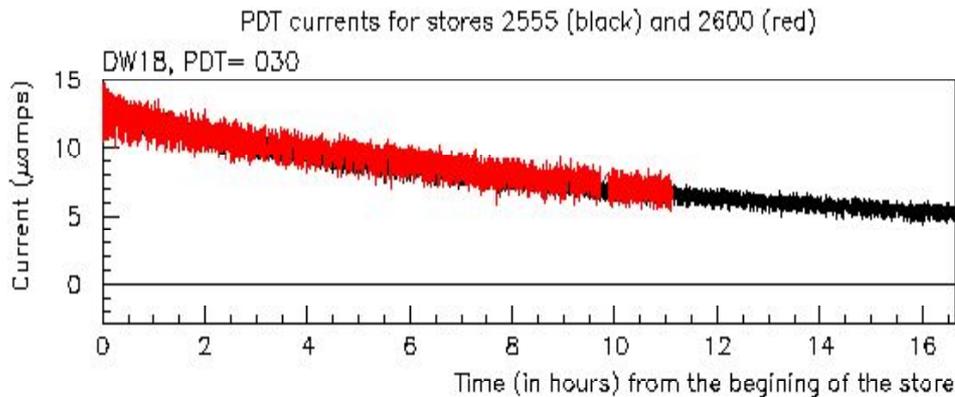
# Wire from PDT 237, channel 33



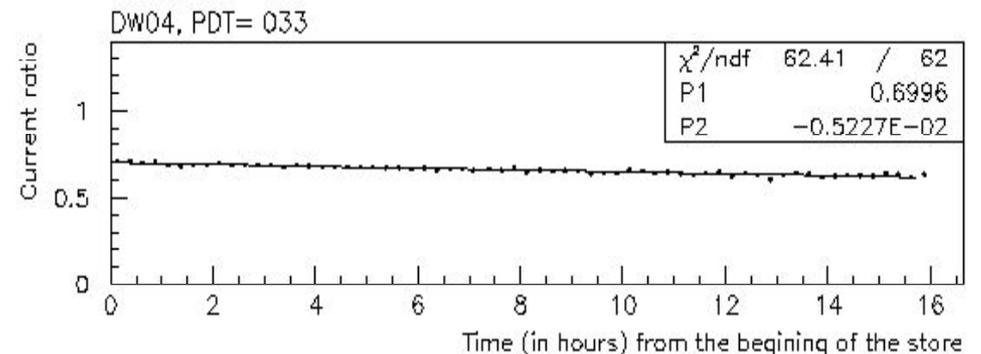
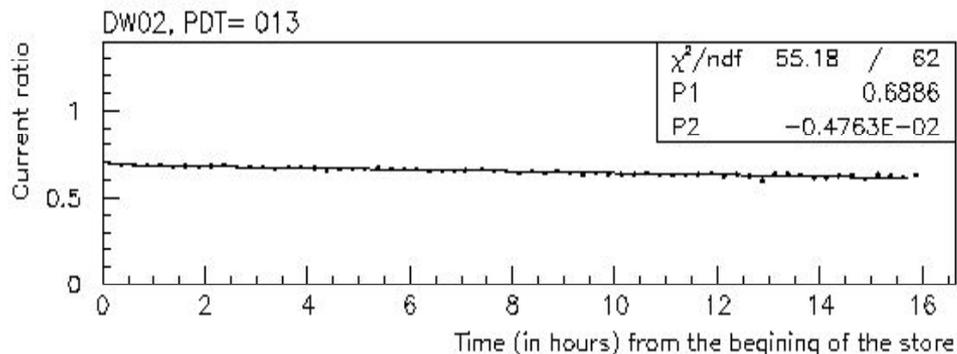
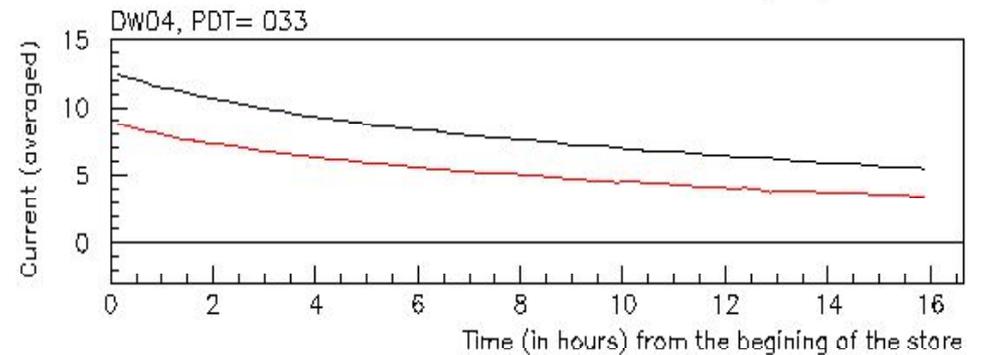
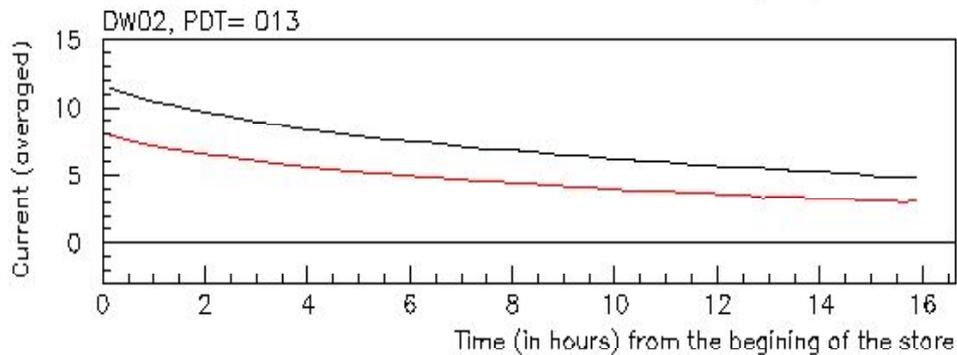
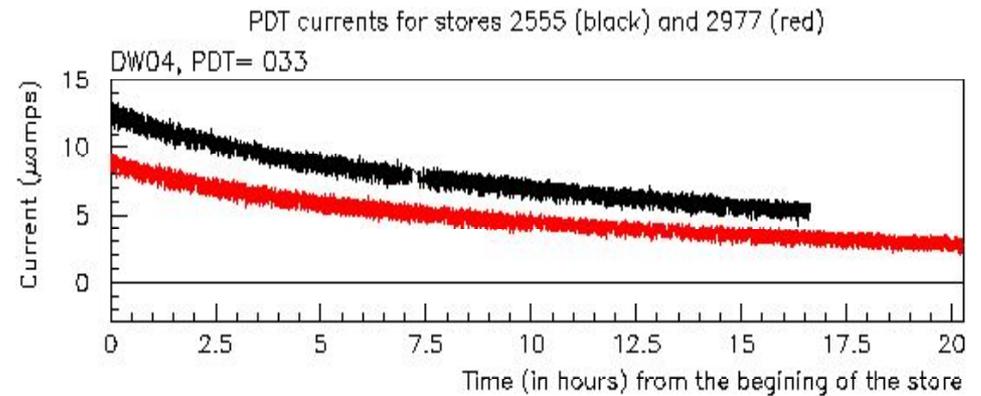
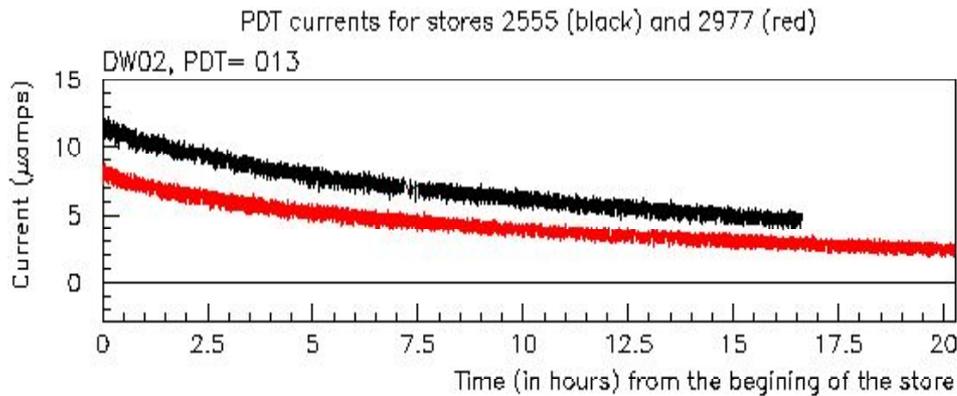
# Wire from PDT 237, channel 33



# 'luminosity normalized' PDT currents 2 stores in May (2555 vs. 2600):

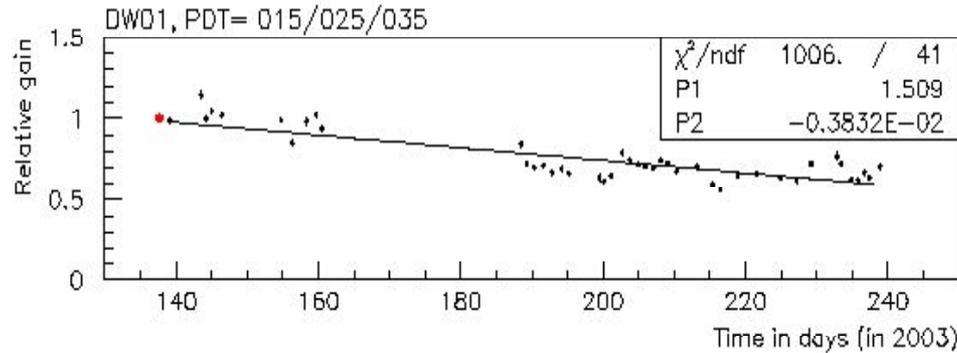


# Compared to Sept. 1 (2555 vs. 2977):

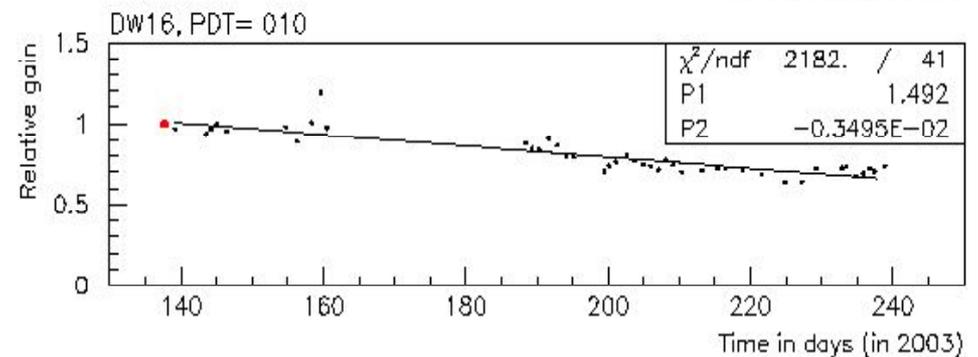
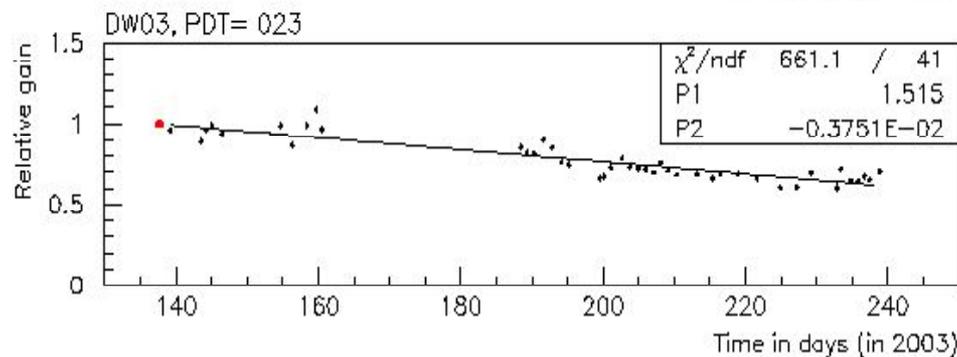
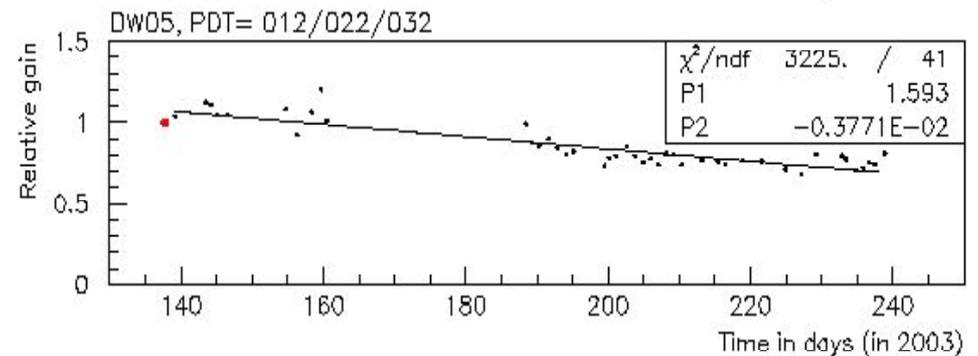
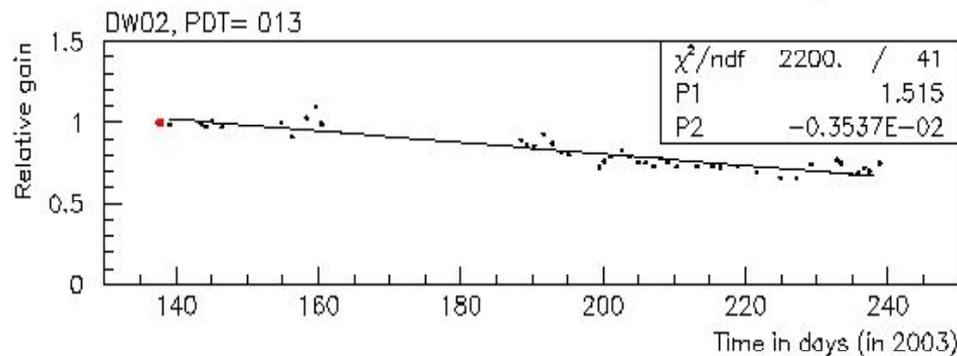
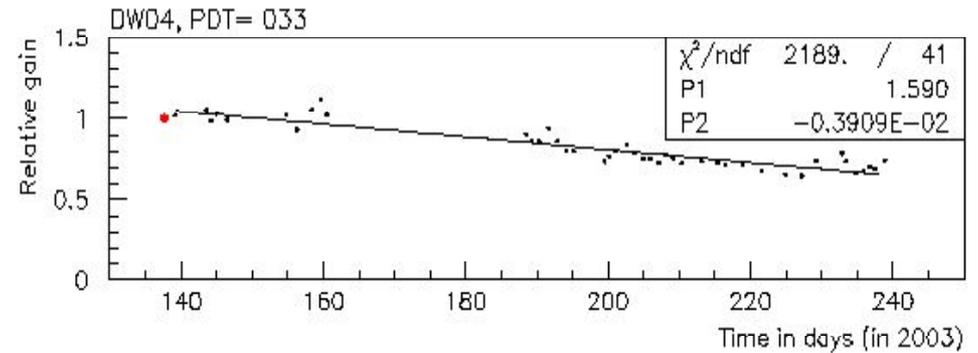


# Clear downward trend 'gain' (30% in 3 months):

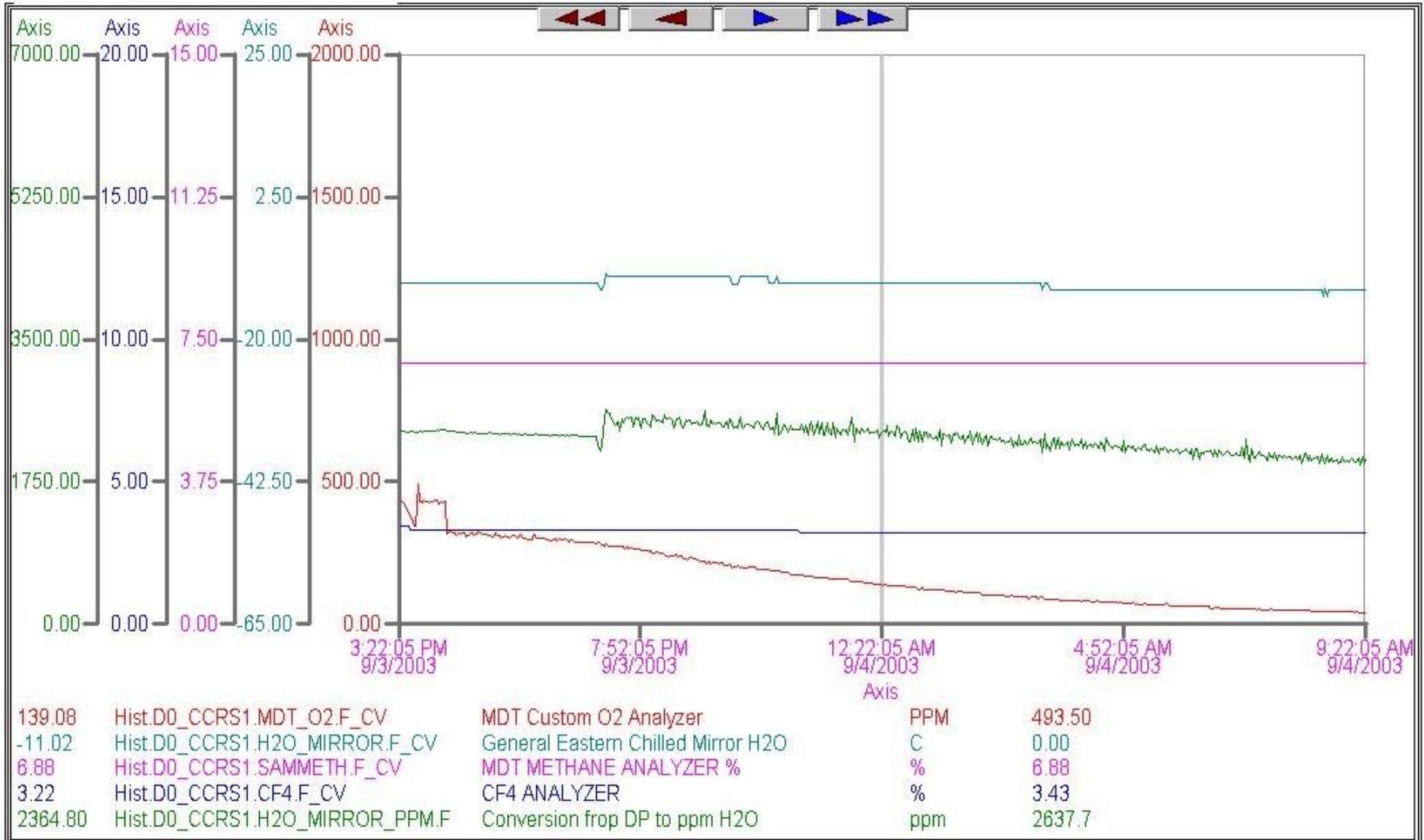
Gain relative to store 2555 (red dot) as a function of time



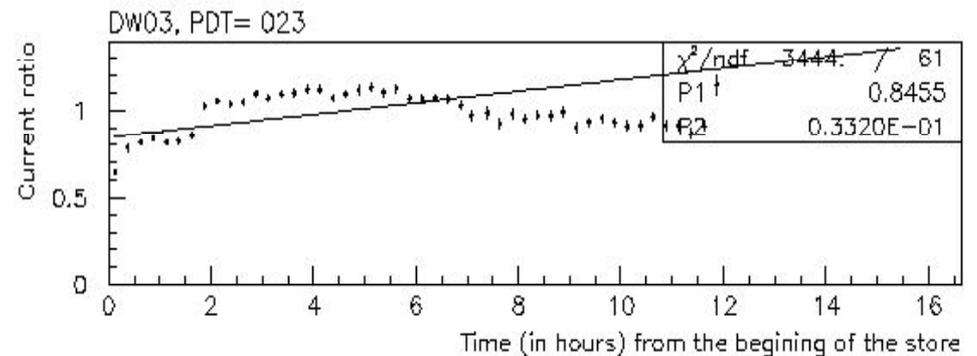
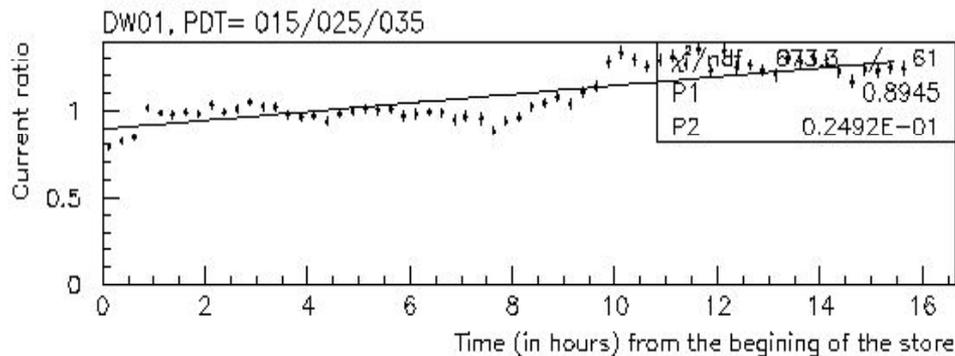
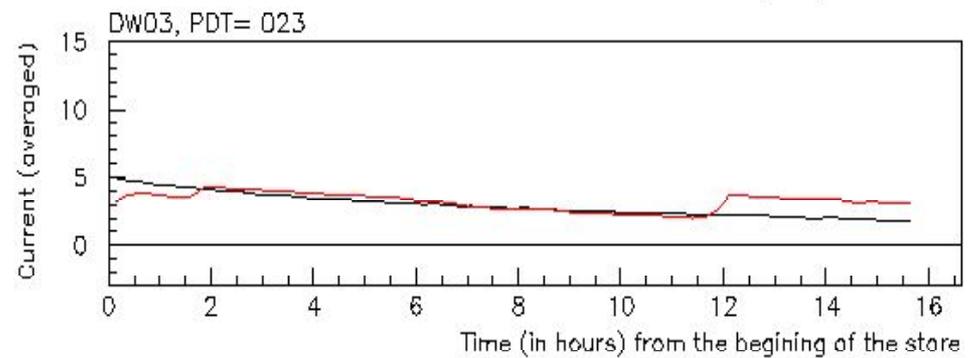
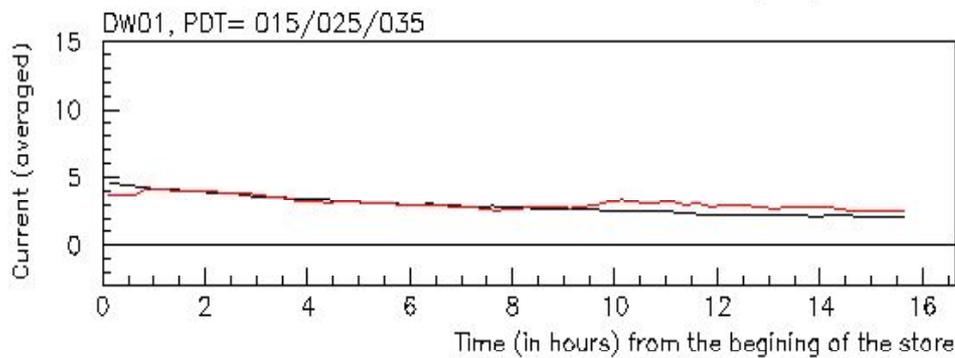
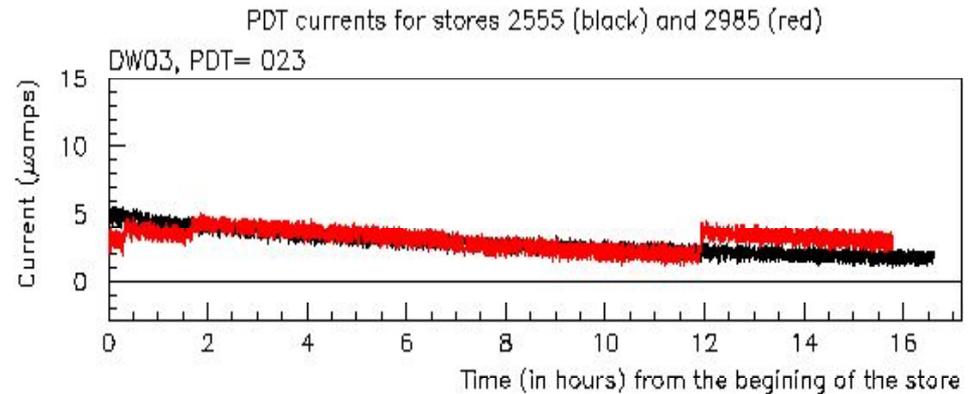
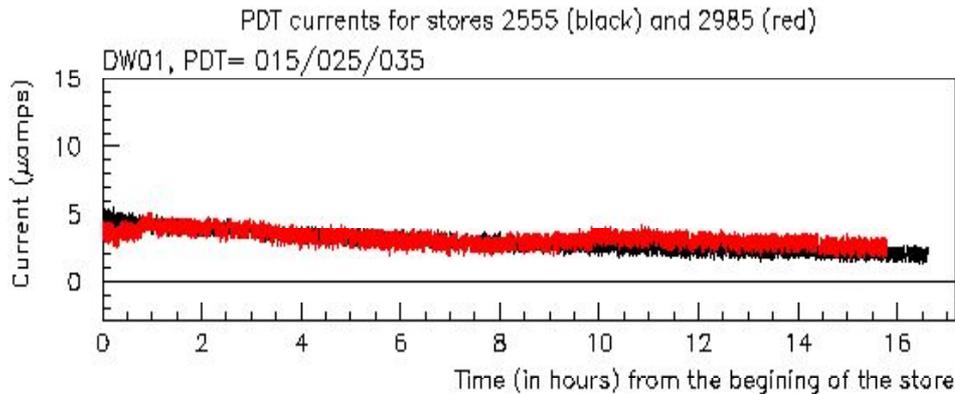
Gain relative to store 2555 (red dot) as a function of time



# Purge gas (high flow) in A-layer PDTs:



# Immediate effect 'gain' (in A-layer only):



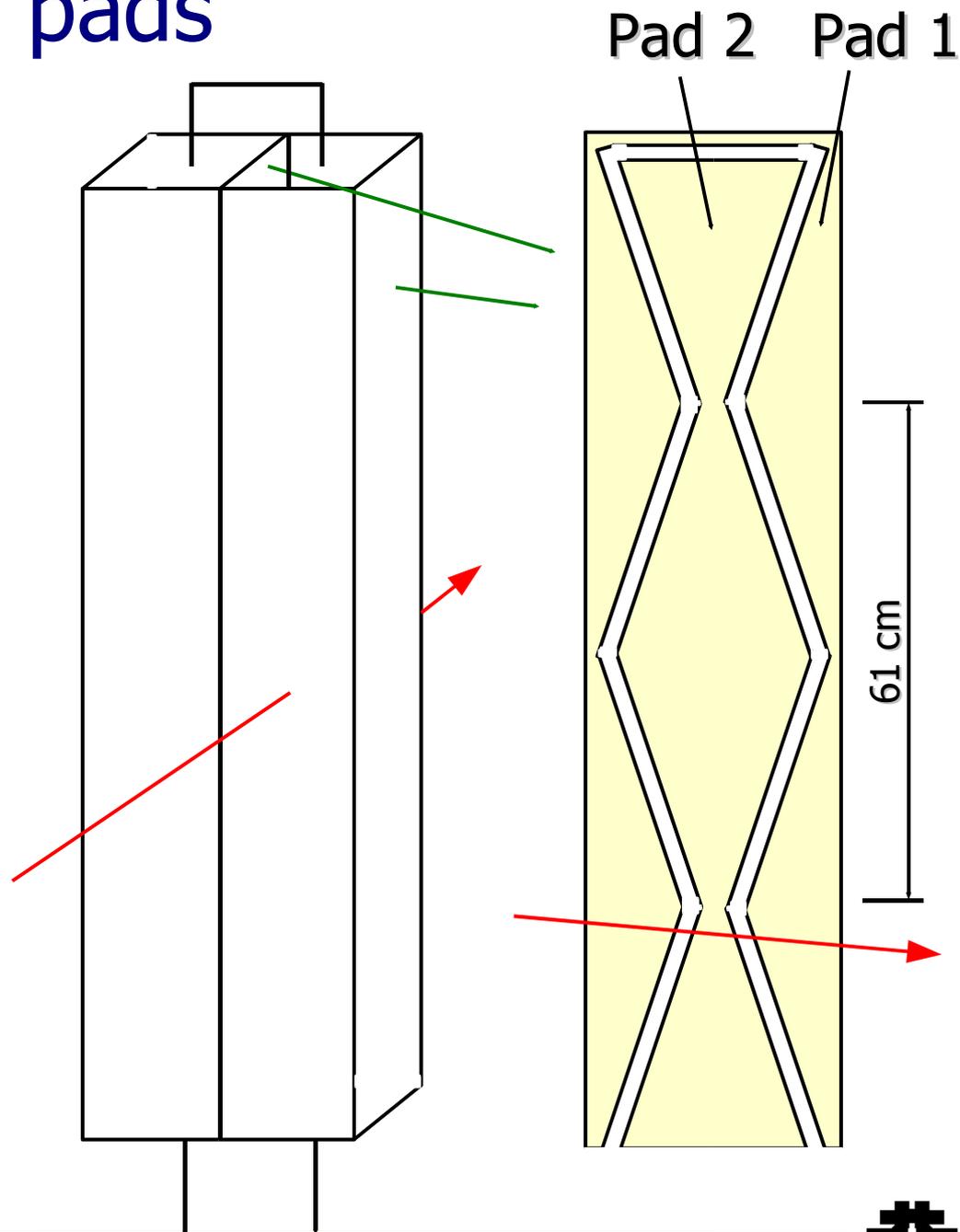
# Really 30% reduction in gain for all PDTs?

- Had to make sure that muon efficiency was not affected
- Darien Wood & Andrzej Ziemiński quick to establish that drift velocity and muon hit efficiencies appeared stable over last few months
- Darien used muon hits in the thumbnail to do this study
  
- Still not clear what is going on exactly!
- Understand if possible before end of shutdown
  
- Urgently needed: PDT pad information to monitor PDT gain directly



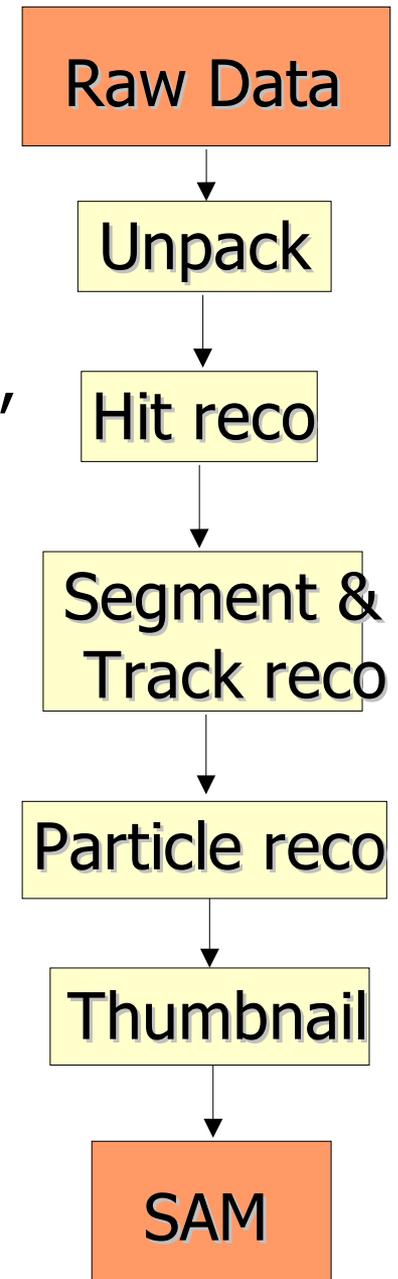
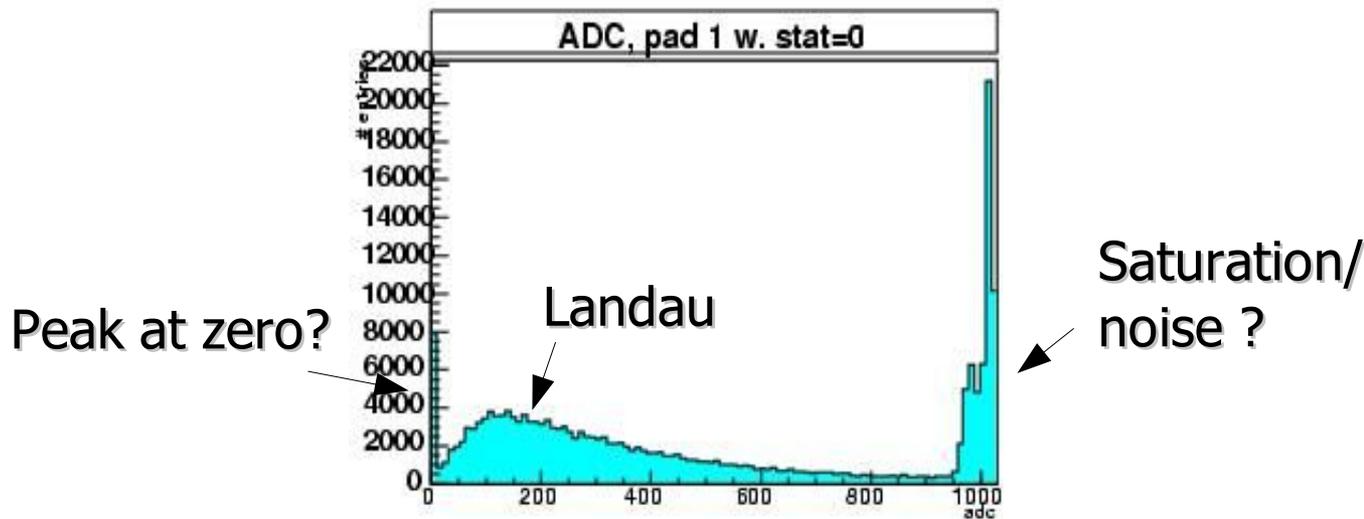
# PDT pads

- Instrumented in A-layer and 10% of B & C layer
- Anode pads cover 2 sides of PDT cells
- Measurement of coordinate along wire:
  - Relative hit times
  - Scintillator position
  - Ratio of charges on each pad
- Monitor aging (gain) from total charge collected on pads

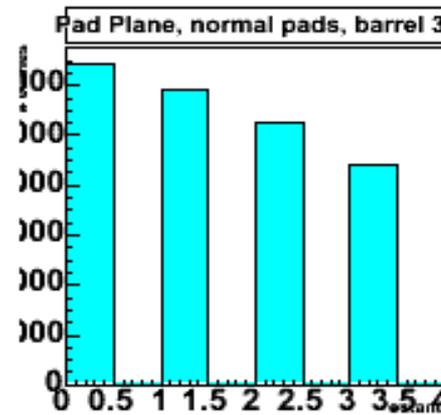
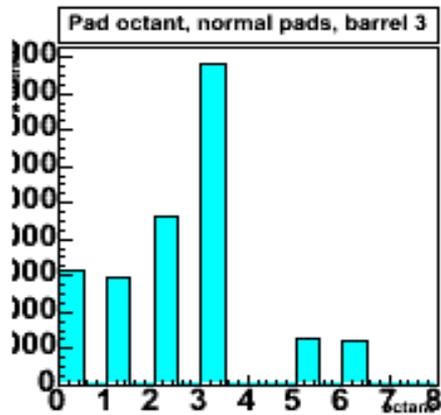
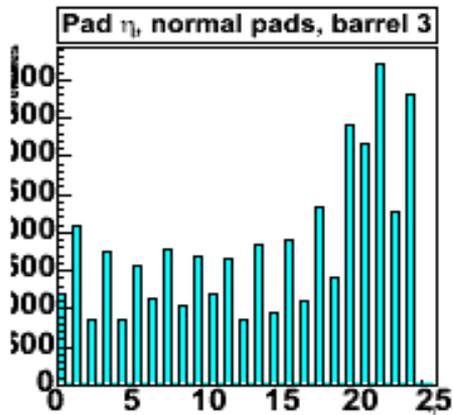
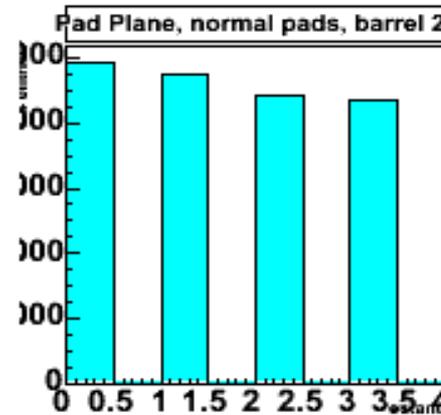
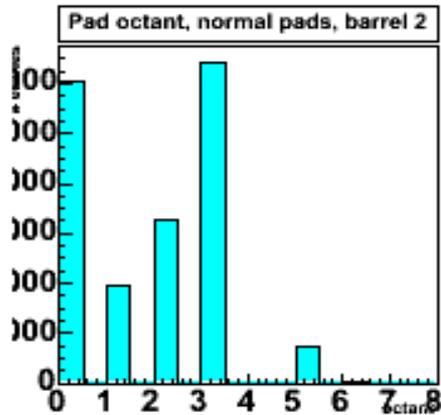
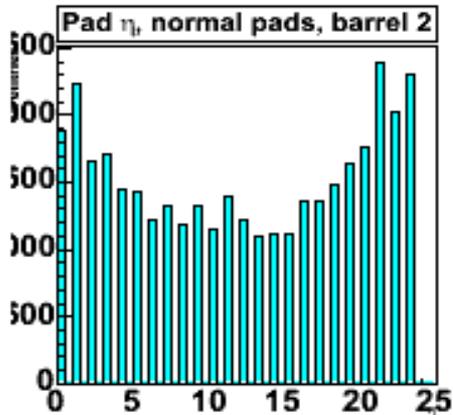
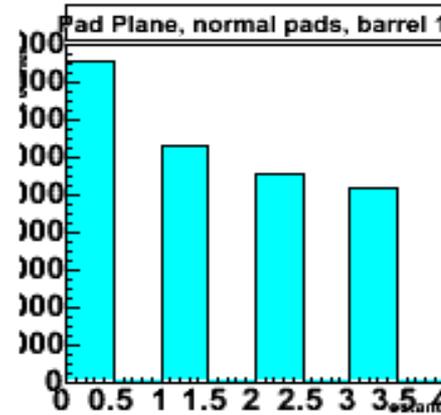
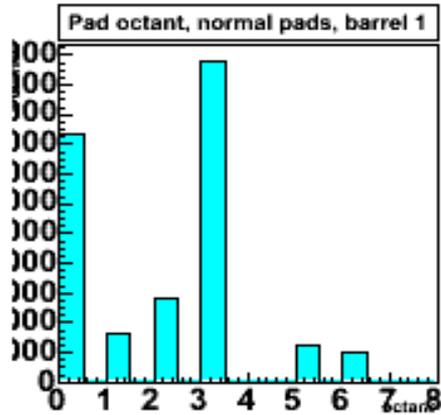
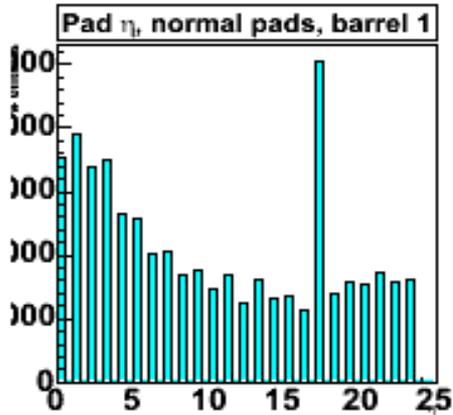


# PDT pads

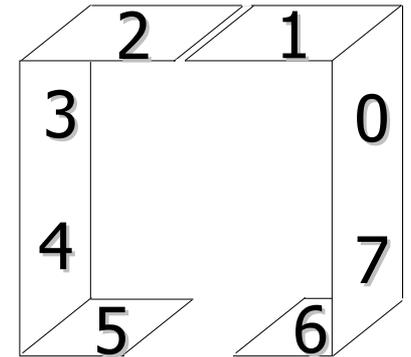
- First look by Gavin Heskett
- Already unpacked... add to PDTHit, MuonParticle, thumbnail (currently in test release --> p16)
- Pads have ADC count and status bit. Distribution of ADC counts ( $0 < 1056$ ) for pads with 'good' status:



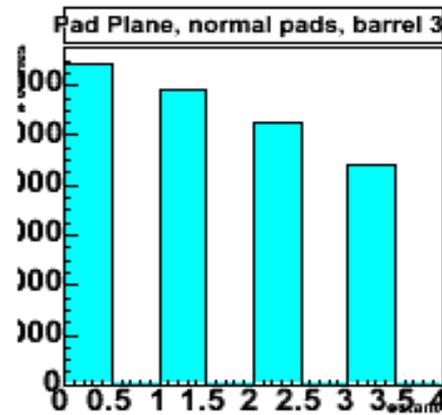
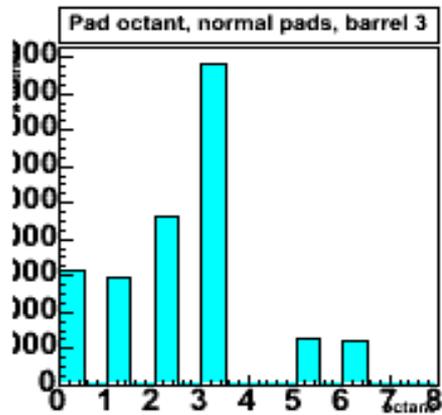
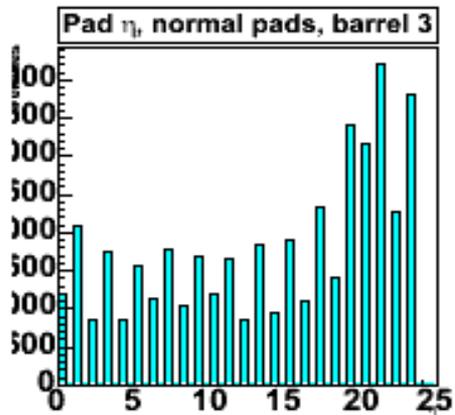
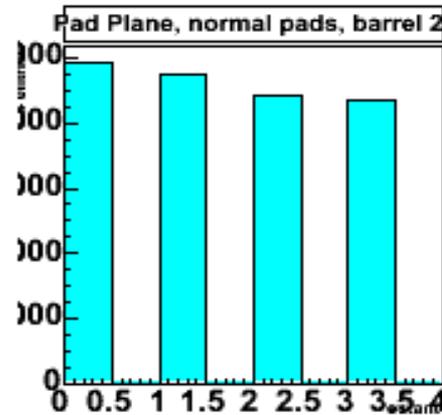
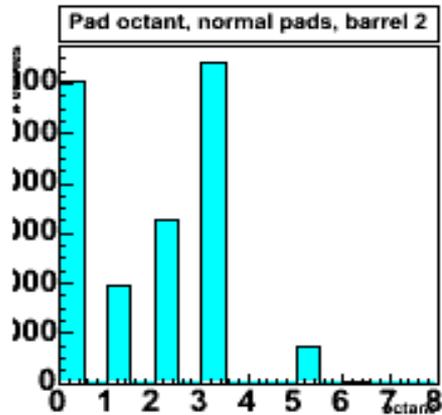
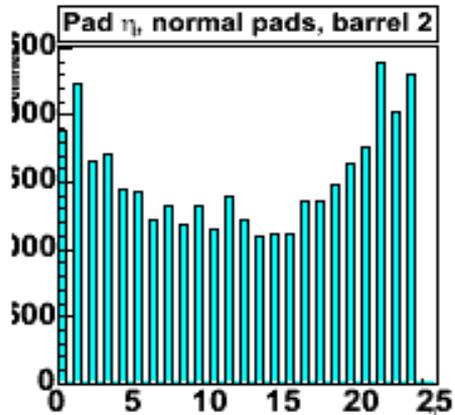
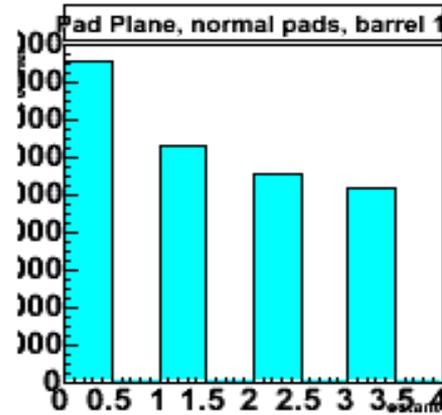
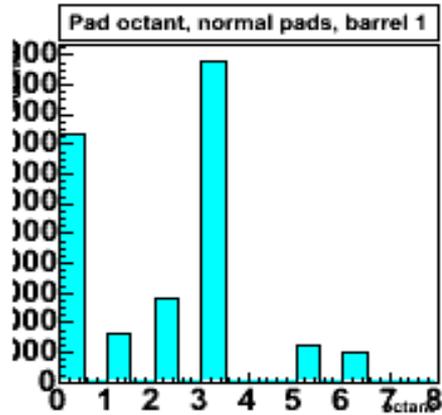
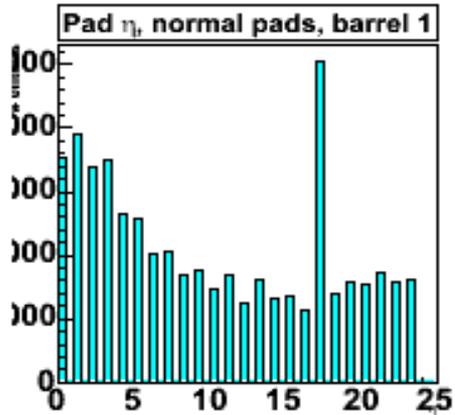
# Where are 'Landau' pad hits?



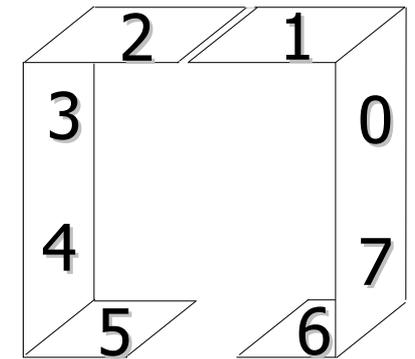
Octant Numbers



# Where are 'noisy' pad hits?

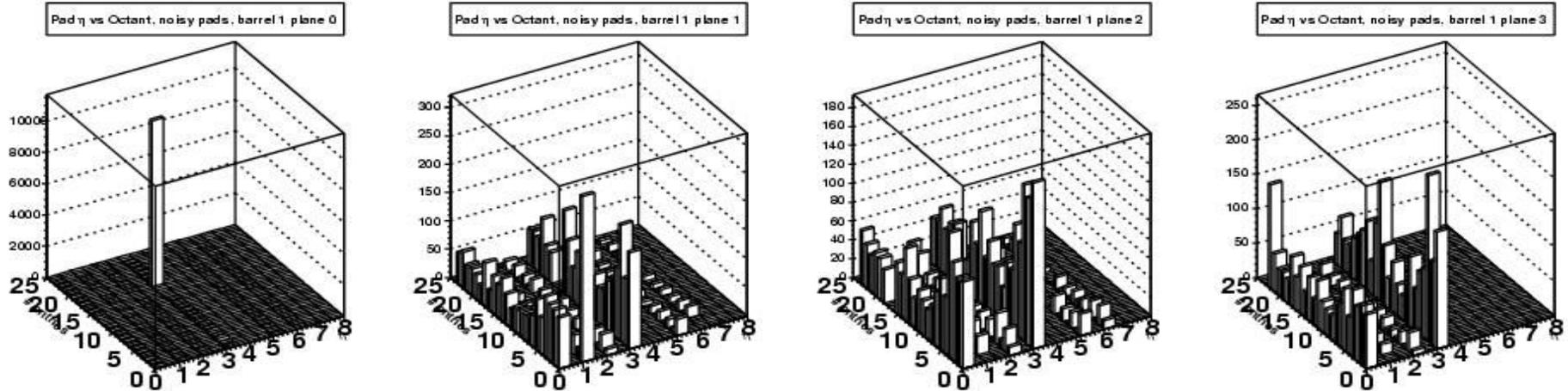


Octant Numbers

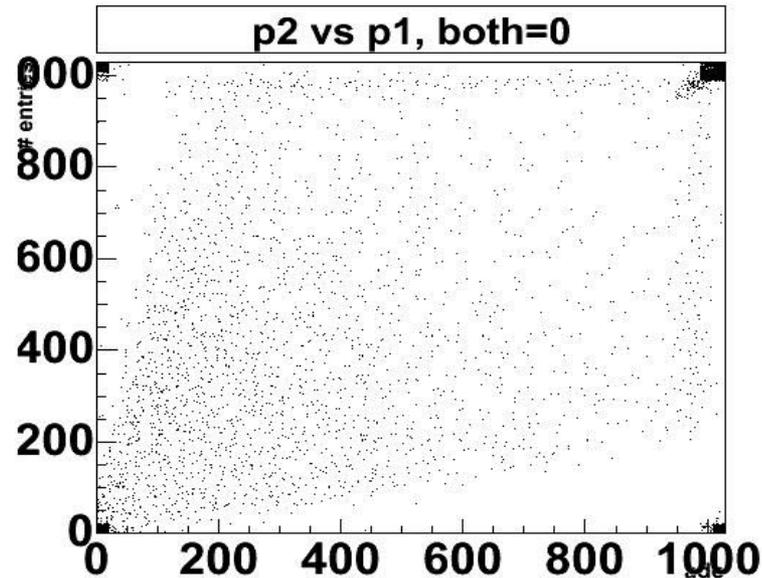
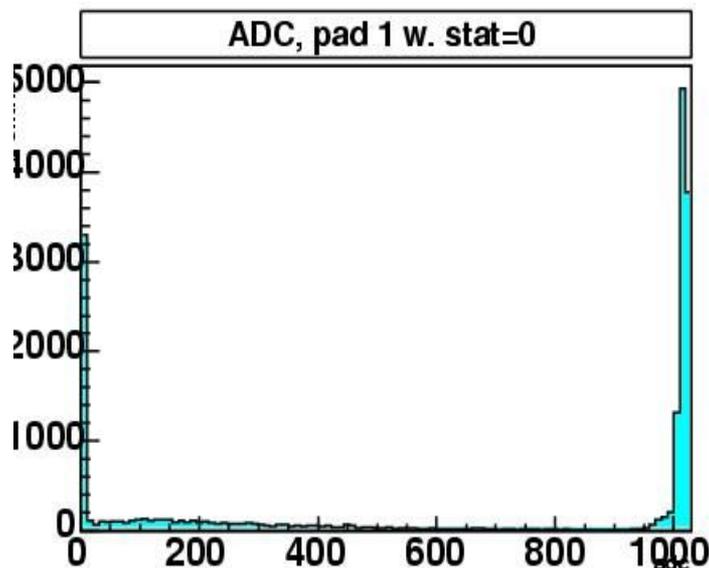


# Noisy pad PDT cell

Look at Barrel 1, plot eta vs octant for each plane:



Look at the ADC for plane 1, octant 3, eta 17, pad 1:

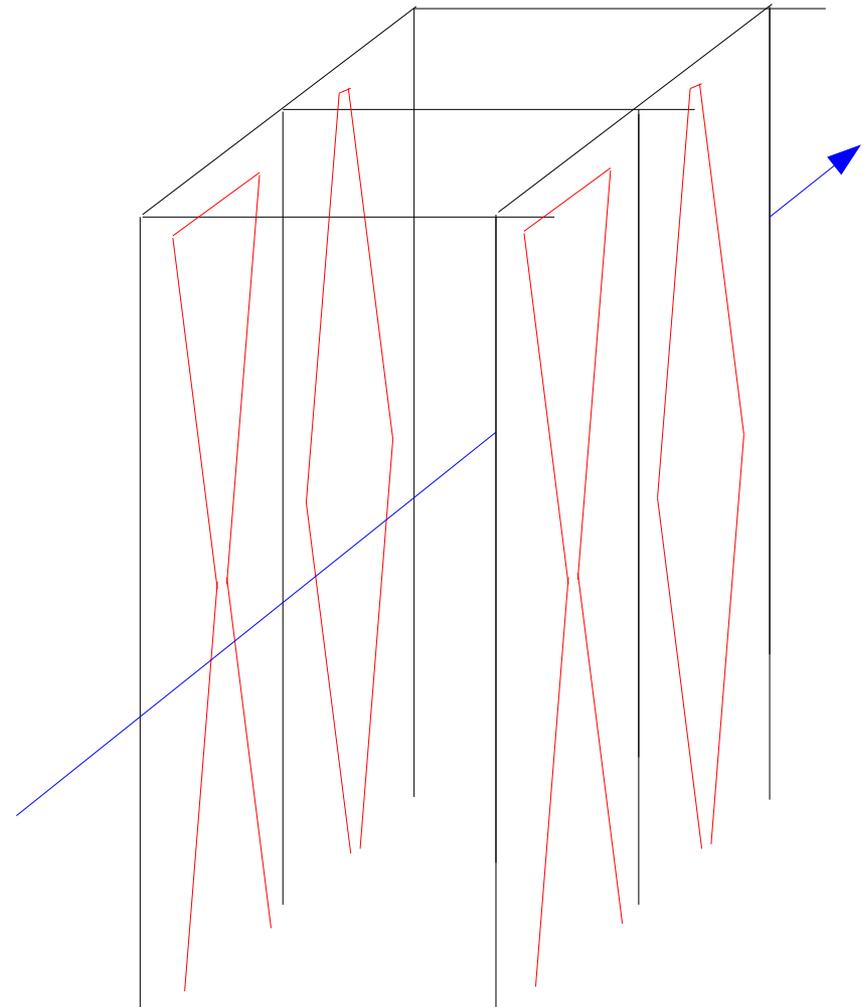


some 'normal' events,  
mostly saturated or 0

See similar  
behaviour in all  
pads!

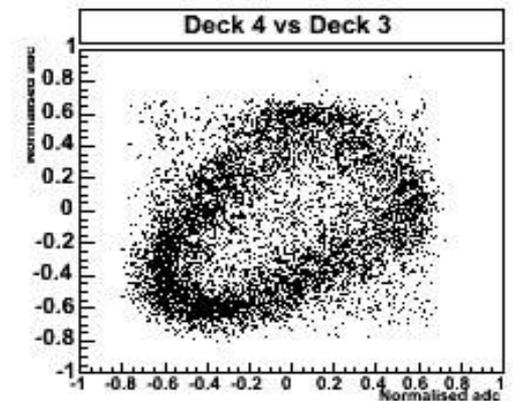
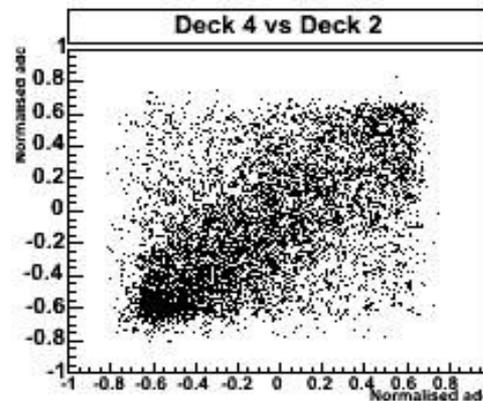
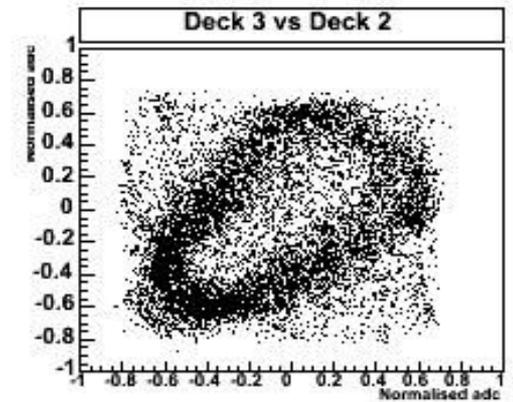
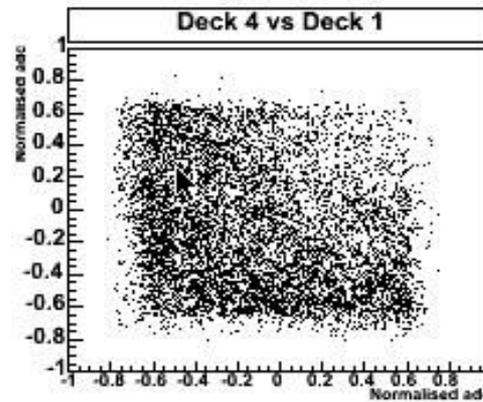
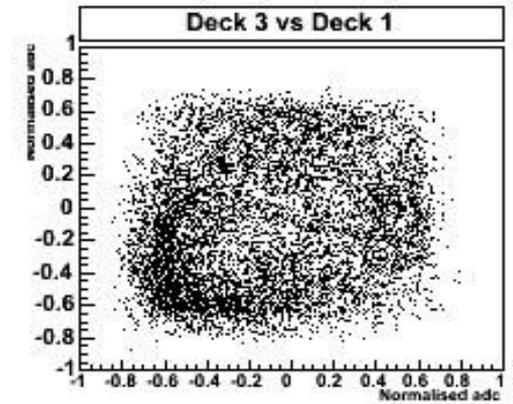
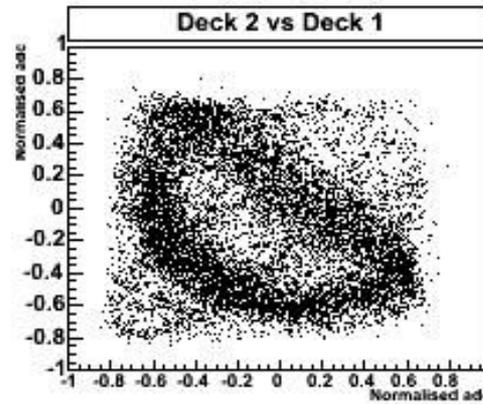
# Using the pad information

- Pad ratio  $(p1-p2)/(p1+p2)$  should give measure of position along wire
- Could check with position muon from central track extrapolation
- Or: compare ratios in different planes for one muon
- Look at A-layer only, pads associated to same muon, same barrel, same octant



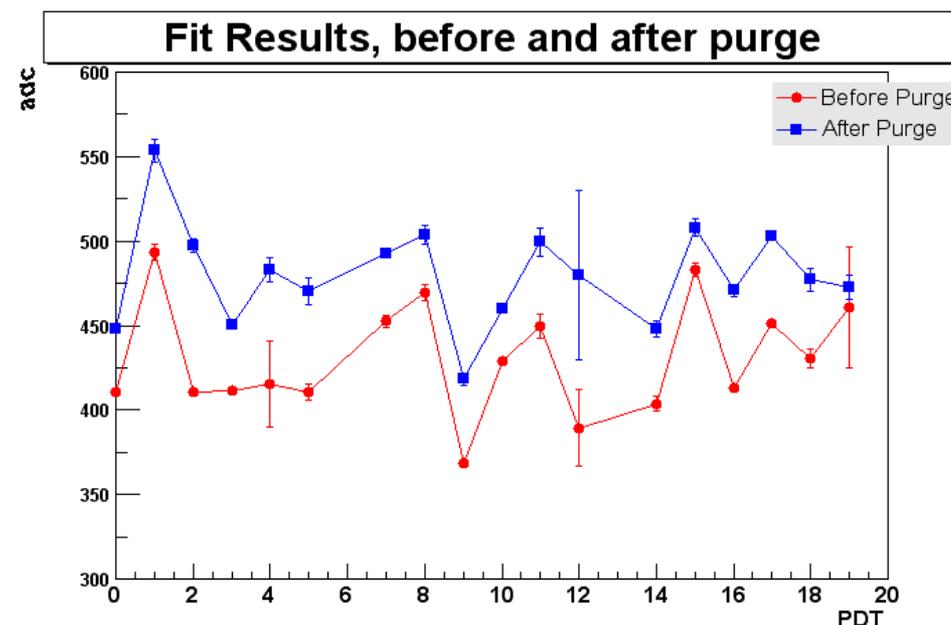
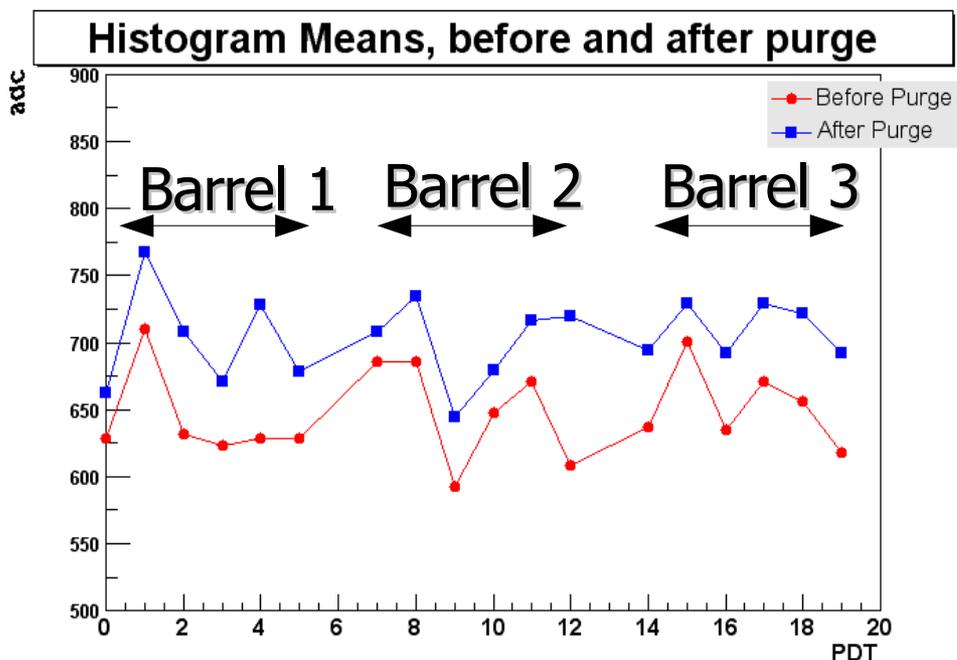
# Wow !

- There clearly is a correlation!
- Still a lot of questions to be answered, but looks very promising
- This means that the pad values make sense
- Think about using them in muon reconstruction!!
- Could help with matching muons to central tracks



# What about pad sums?

- See increase of  $\sim 10\%$  before / after gas purge
- Smaller than the observed rise in gain (current) by Gaston



- Work in progress

# The muon trigger: L1

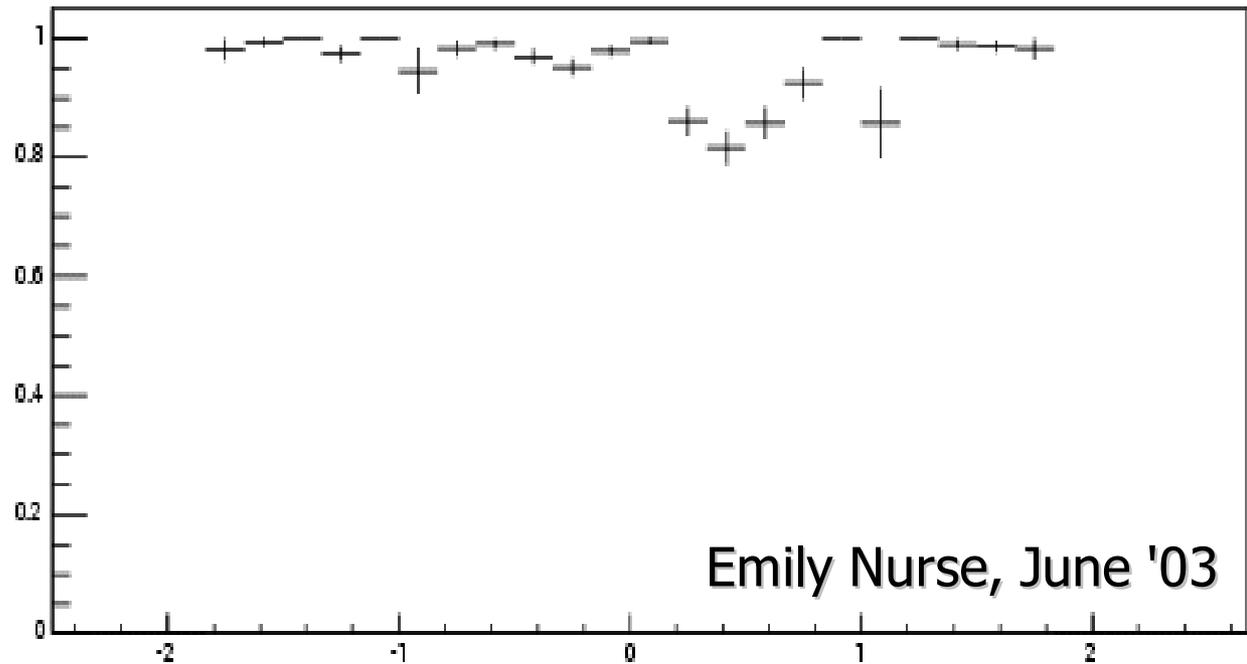
Jeff Temple, Rob McCrosskey

- Shutdown Progress:
  - Replaced/reprogrammed receivers to enable correct parity checking (helpful in finding bad inputs to L1)
  - Upgraded logic so that individual L1 Muon cards can now be read out
  - Added some jumpers and quick connects to make board and power supply replacement faster in the future
- Post shut-down plans include:
  - Commissioning tight wire triggers (that is, triggers using both A and B/C layer wire chambers)
  - Add new bottom counters to trigger



# The muon trigger: L2

- Latest ( $\sim$ april) d0gstar has realistic positions central detector --> Updated L2 Look-Up Tables, should go on-line after shut-down; study new performance in progress (Sergey Uzunyan, Christos Leonidopoulos)
- May help to solve asymmetric dip in L2M5/L2M0 efficiency seen before:



# The muon trigger: L3

- New L3 Muon Coordinator: Daniela Bauer
  - General cleanup C++ code – Angela Bellavance
  - Improve local muon rejection:
    - Better understand fake rates – Norm Buchanan
    - Improve local muon resolution – Andrzej Ziemiński
  - Low pT central track matching – Rick, Daniela
  - Fix reporting of matched track ID – Rick
  - Calorimeter conformation – ??
  - Muon – cal isolation – Christian Autermann



# Muon Reconstruction

- Everything mentioned before will benefit muons in your analysis !
- Improvements in muon reconstruction code for p16:
  - PDT wire hit resolution was used by default (1 cm instead of  $\sim 1\text{mm}$ ). Fixing this bug and tuning related segment reconstruction parameters improves local muon resolution (50% at 50 GeV? To be confirmed) - Andrzej
  - Include PDT pads in thumbnail - Gavin
  - Better handling muons with multiple scintillator hit times
  - Improved matching between central tracks and BC stubs – Boris Tuchming



# MuoCandidate p14

- P14 version MuoCandidate is ready and documented at [http://www-d0.fnal.gov/phys\\_id/muon\\_id/d0\\_private/certif/p14/index.html](http://www-d0.fnal.gov/phys_id/muon_id/d0_private/certif/p14/index.html)
- Please use it and give feedback to the Muon ID/Algorithms group
- P14 definitions of muon quality criteria better than the p13 equivalents. For example efficiency for high pt medium muons improved by  $\sim 10\%$  (see Beaune talk Frederic Deliot)
- We are very much interested in further improvement of the object definitions. Let's make sure that this is not done separately in different physics groups, but under the umbrella of the Muon ID/Algorithms group.



# Conclusions

- Thanks to hard work of many people the detection, triggering, and reconstruction of muons will continue to improve
- Focus is shifting from Firemen tactics to improved monitoring of detector, data quality
- Still some mysteries in muon detection and reconstruction to be solved, and room for improvement
- Please come and help to make D0 muons even better!!
- Make sure your analysis fully exploits the muon detection capabilities we have !

