Upgraded D0 Central Fiber Tracker

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for the D0 Collaboration

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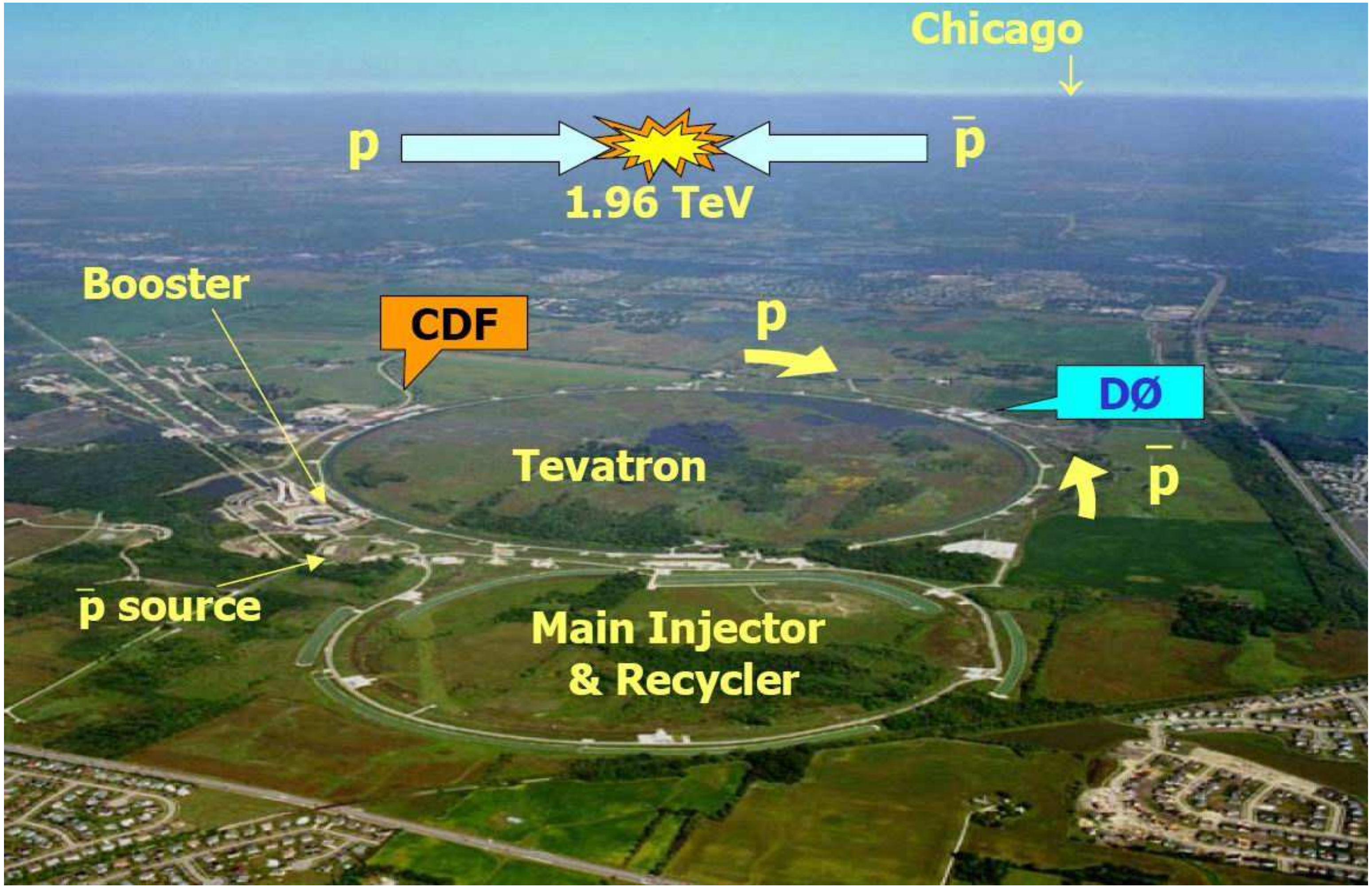
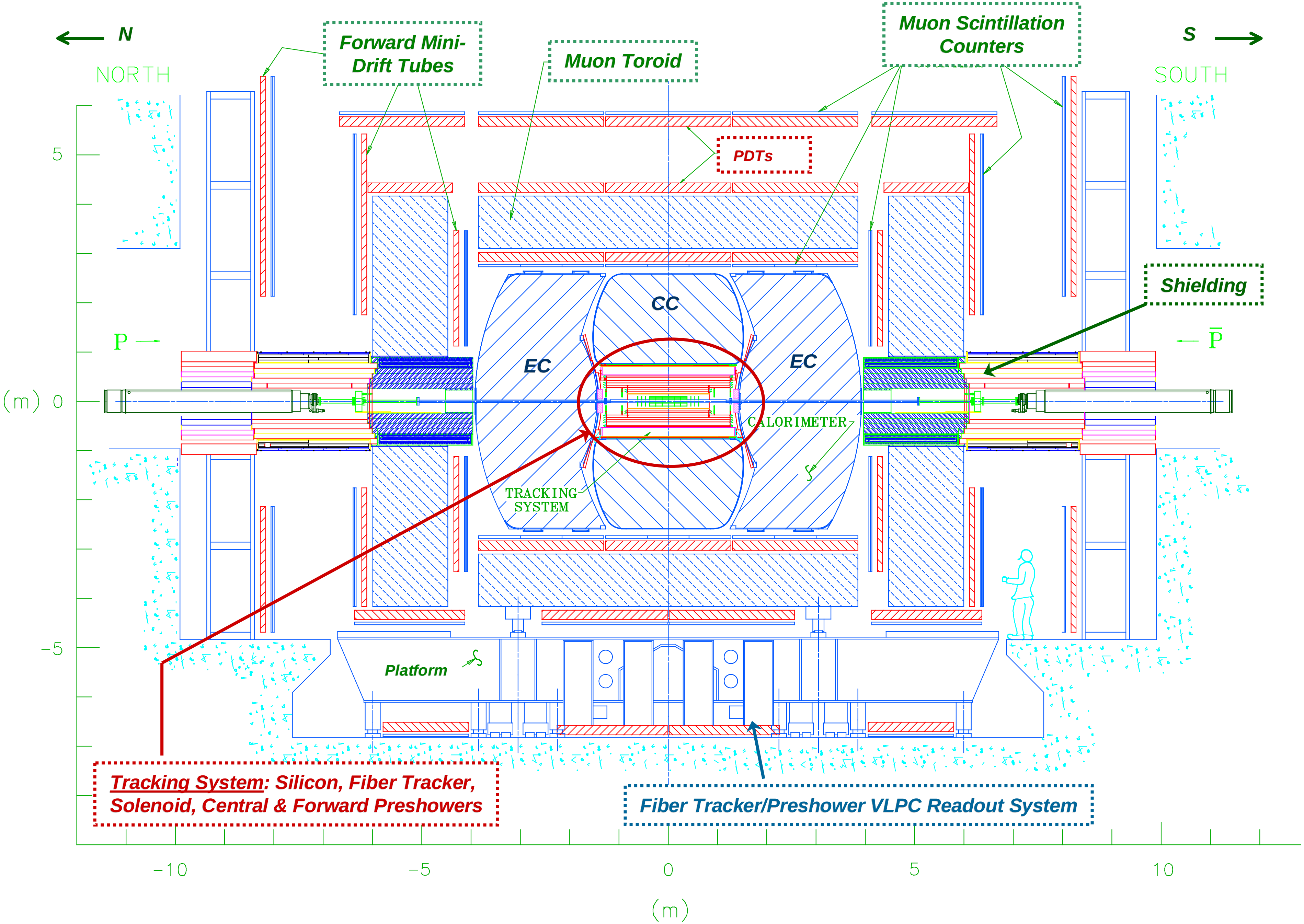
The Fermilab Tevatron Collider



- Tevatron is a superconducting synchrotron 2 km in diameter.
- High energy physics:
  - Precision measurements of W, Z bosons and top quark
  - Searches for Higgs boson, supersymmetry, extra dimensions
  - B physics and QCD studies

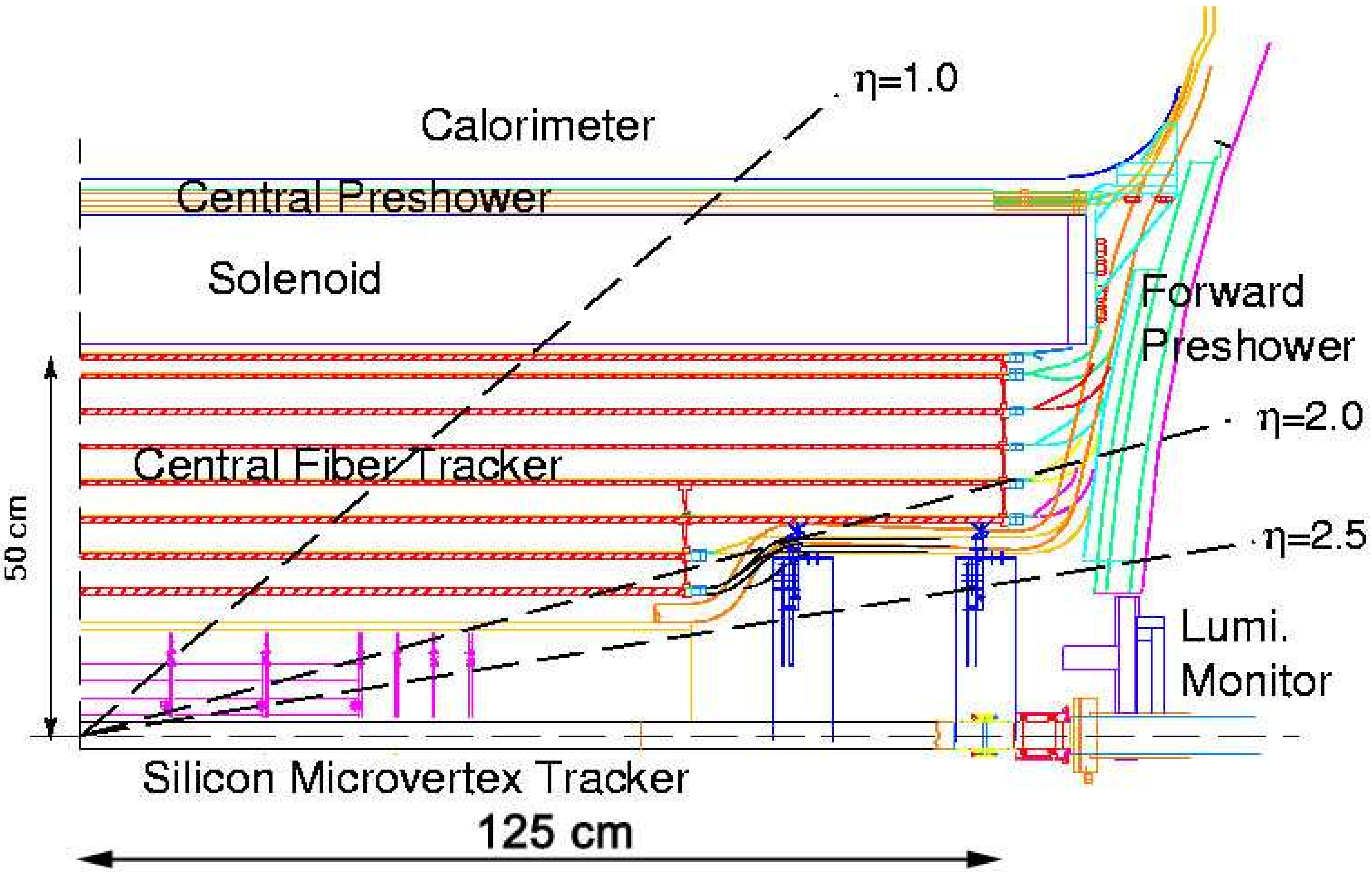
	$\sqrt{s}$	Num. of Bunches	Spacing	Inst. Luminosity	Interactions
Run II	1.96 TeV	36×36	396 ns	$\lesssim 3 \times 10^{32}$ cm^{-2}s^{-1}	~ 5

The RunII D0 Detector



- Tracking system submerged in uniform 2 Tesla magnetic field created by superconducting solenoidal magnet with mean radius of 60 cm

Central Fiber Tracker & Preshower Detectors

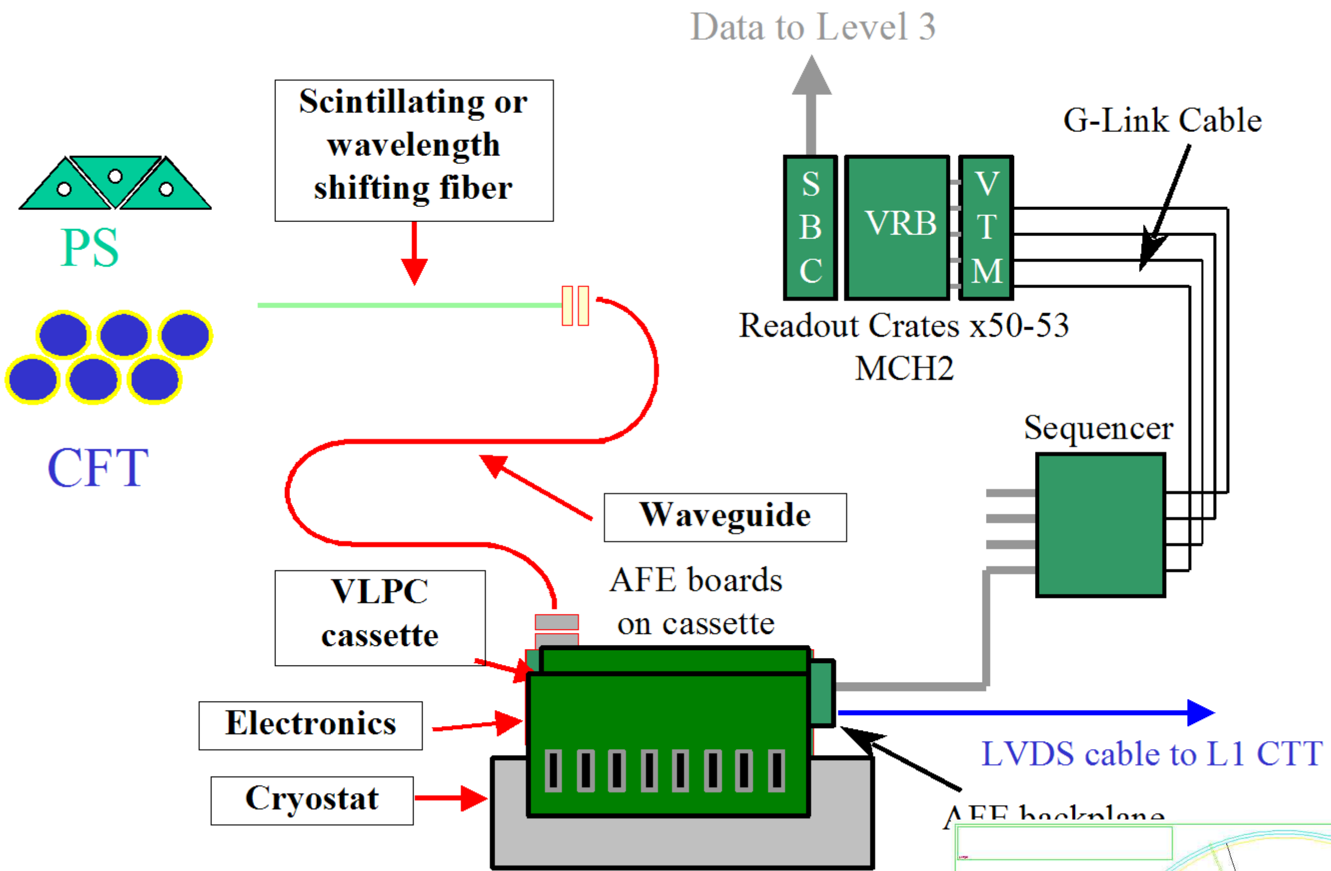


Central Fiber Tracker (CFT), Central and Forward Preshower (CPS, FPS) detectors utilize a similar readout:

Particles crossing scintillating fibers or triangle scintillators generate light which propagates to solid state diodes, **Visible Light Photon Counters** (VLPCs)

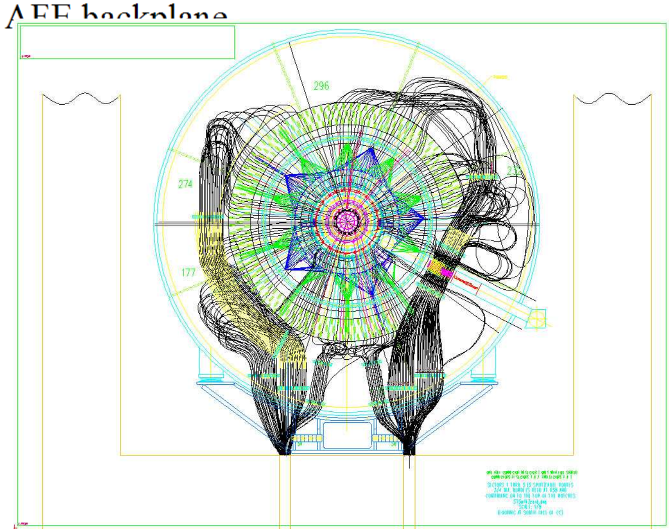
	Layers	Coverage	Num. of Channels
CFT	8 axial and 8 stereo	$\|\eta\| < 2.0,\ 0 < \phi < 2\pi$	$\approx 77,000$
CPS	1 axial and 2 stereo	$\|\eta\| < 1.25,\ 0 < \phi < 2\pi$	$\approx 7,700$
FPS	2 MIP and 2 shower	$1.4 < \|\eta\| < 2.5,\ 0 < \phi < 2\pi$	$\approx 15,000$

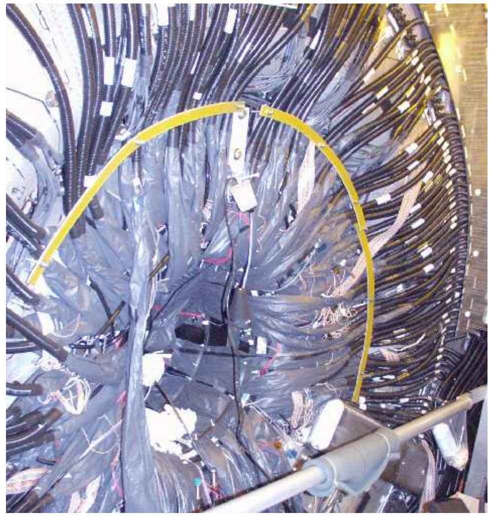
Central Fiber Tracker & Preshower Readout



- Long clear fibers (waveguides) transport light to VLPCS
- Waveguide length ranges from 8.2 to 11.4 meters
- Analog Front End (AFE) boards amplify and digitize the signal
- Discriminator output is formed f the trigger system every crossing

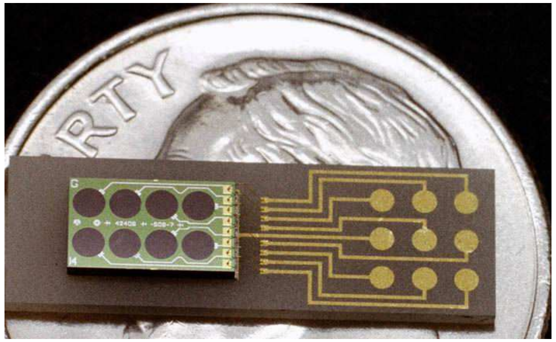
- The raw data is buffered in the VME Readout Buffer (VRB) and then send to the processing farm



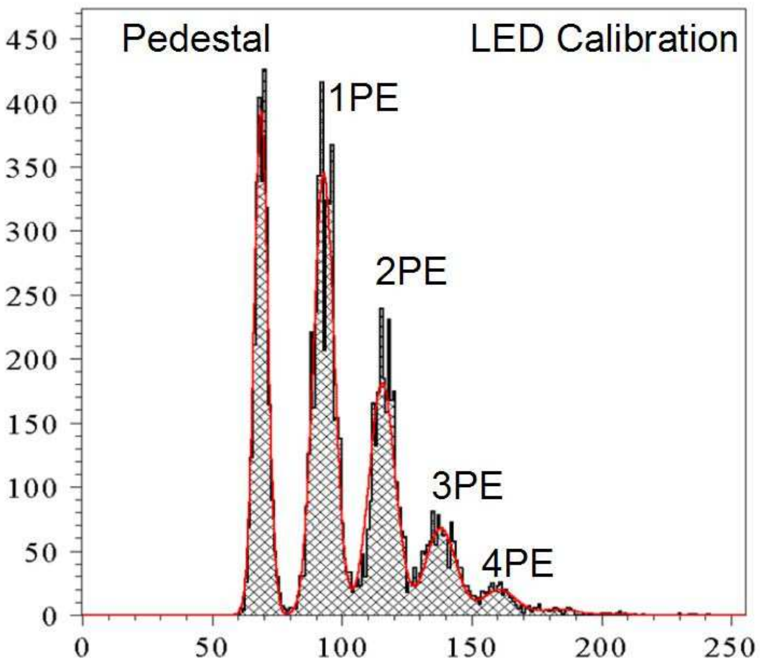


Visible Light Photon Counters (VLPC)

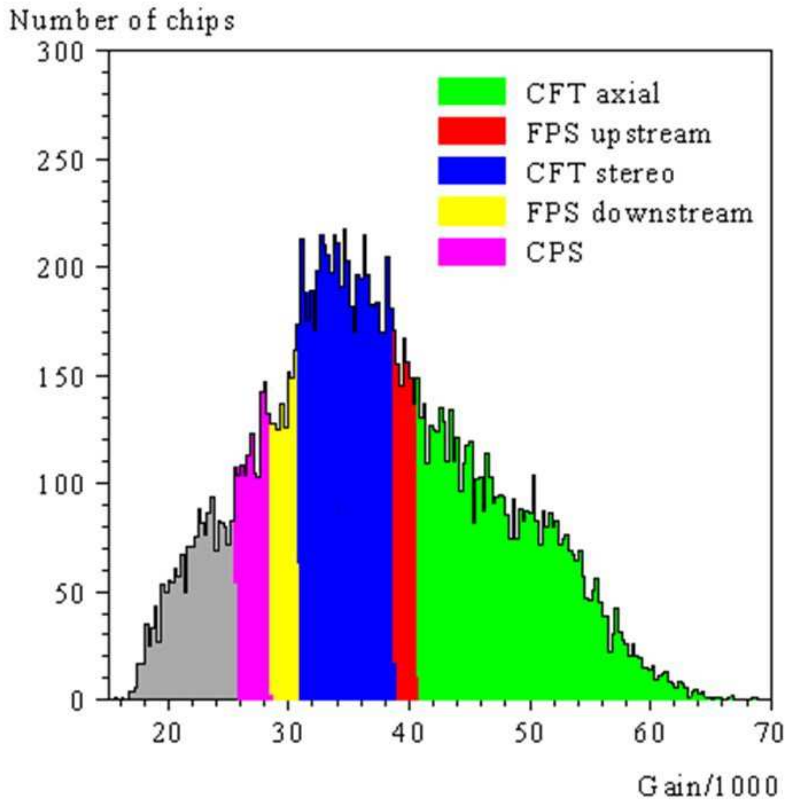
- VLPC is a solid state photo-detector with 8 input pixels 1 mm in diameter each



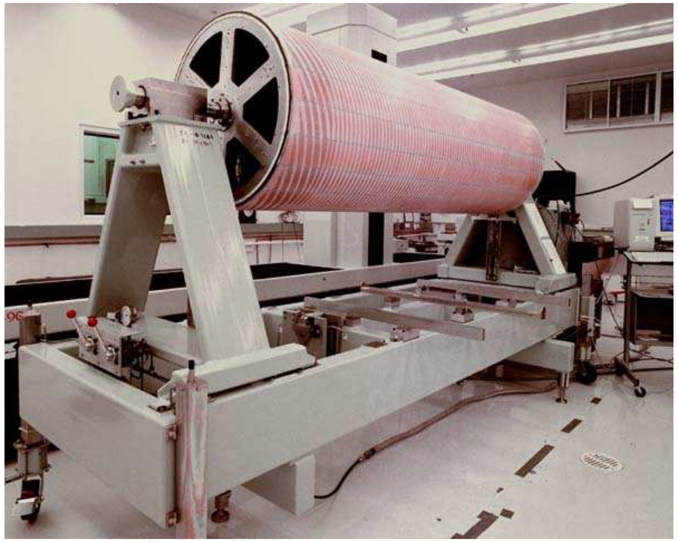
- Pulse height distributions from an LED run

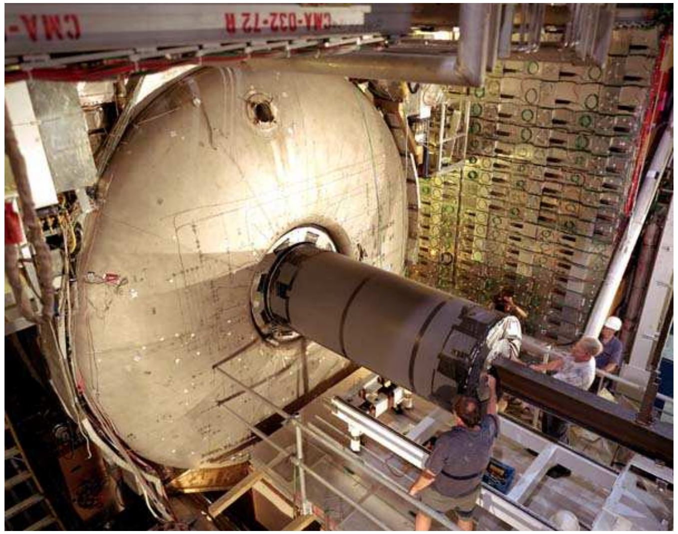


- VLPC is operated at 9 ± 0.05 K with bias voltages 6–8 V
- VLPC provides high gain of 25,000 – 60,000 electrons per detected photon
- Quantum Efficiency (QE) $\sim 80\%$
- Optimal bias voltages, gain, and relative QE vary among VLPC chips
- VLPCs with similar properties grouped together to optimize performance

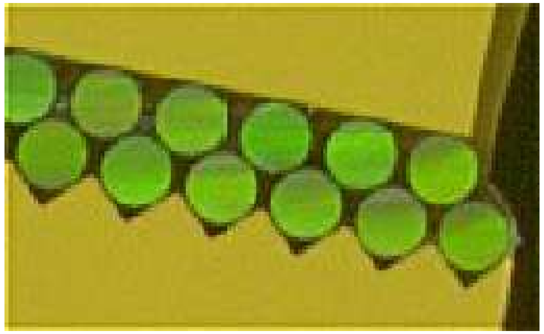


The Central Fiber Tracker Detector



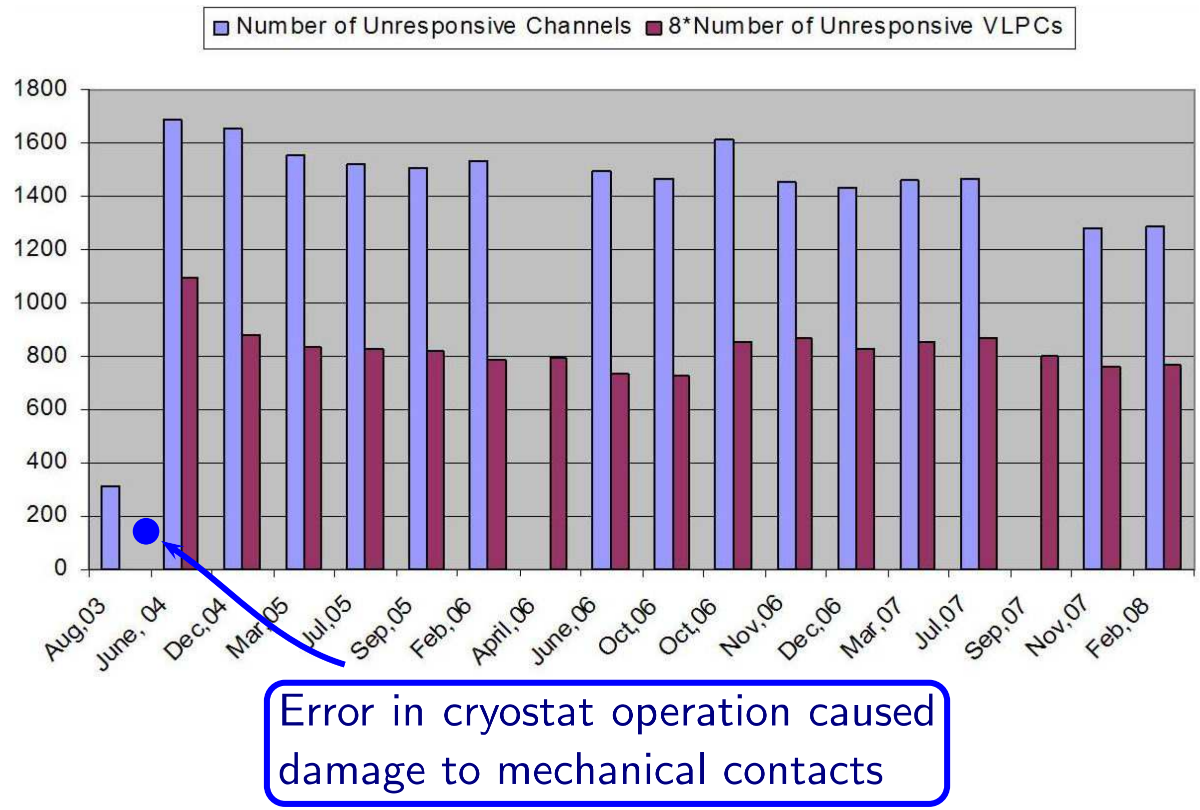


- Multiclad CFT scintillating fibers arranged into precisely positioned ribbons of interlocked **fiber doublets**
- **Fiber diameter is 0.835 mm**
- Fiber doublet radiation length is ~ 0.28 %



- CFT has 8 coaxial carbon cylinders, each supporting 2 doublet layers on their outside surface
- 8 axial layers are formed by fibers oriented along the cylinder axis
- 4 stereo layers are formed by fibers oriented at $+3^\circ$ and 4 stereo layers at -3° angle
- Position resolution of fiber doublet is $\approx 100\ \mu$m

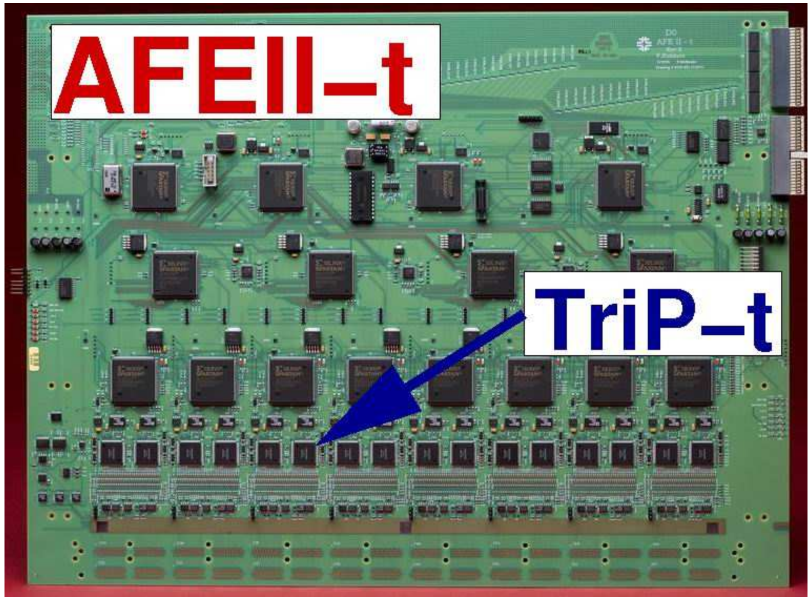
VLPC Cassette and Cryostat



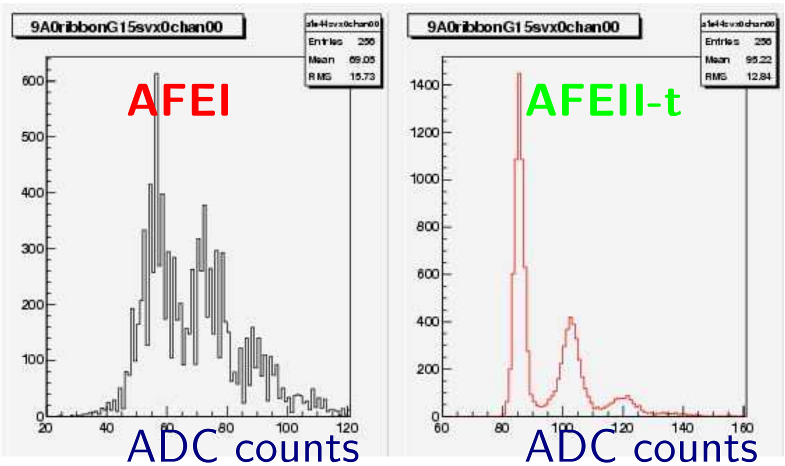
- Initial fraction of unresponsive channels was ≈ 0.3 %; Today it is ≈ 1.6 %
- VLPC cassettes provide mechanical support, optical alignment, and appropriate operating services for proper operation and readout of the VLPCs
- Lower portion of VLPC cassets is immersed in gas Helium, while the upper portion supports a pair of AFE boards
- During the lifetime cryostat was never warmed up above 60 K

- **1992: Compact** D0 scintillating fiber tracker proposed
- **2000:** CFT installed
- **2001:** Data taking begins
- **2008:** Stable operation continues

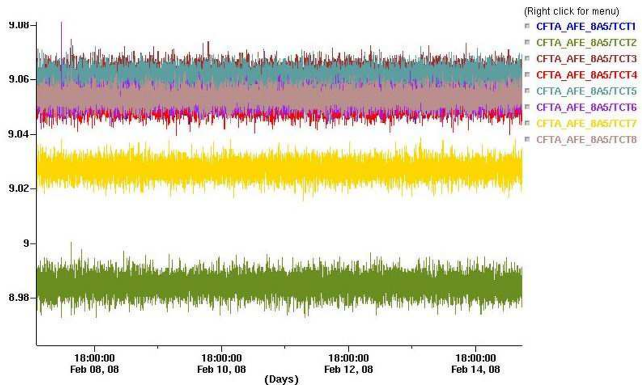
Analog Front End (AFE) Boards



- Two plots below show pulse height distributions from a LED run for the same channel readout with AFEI and AFEII-t



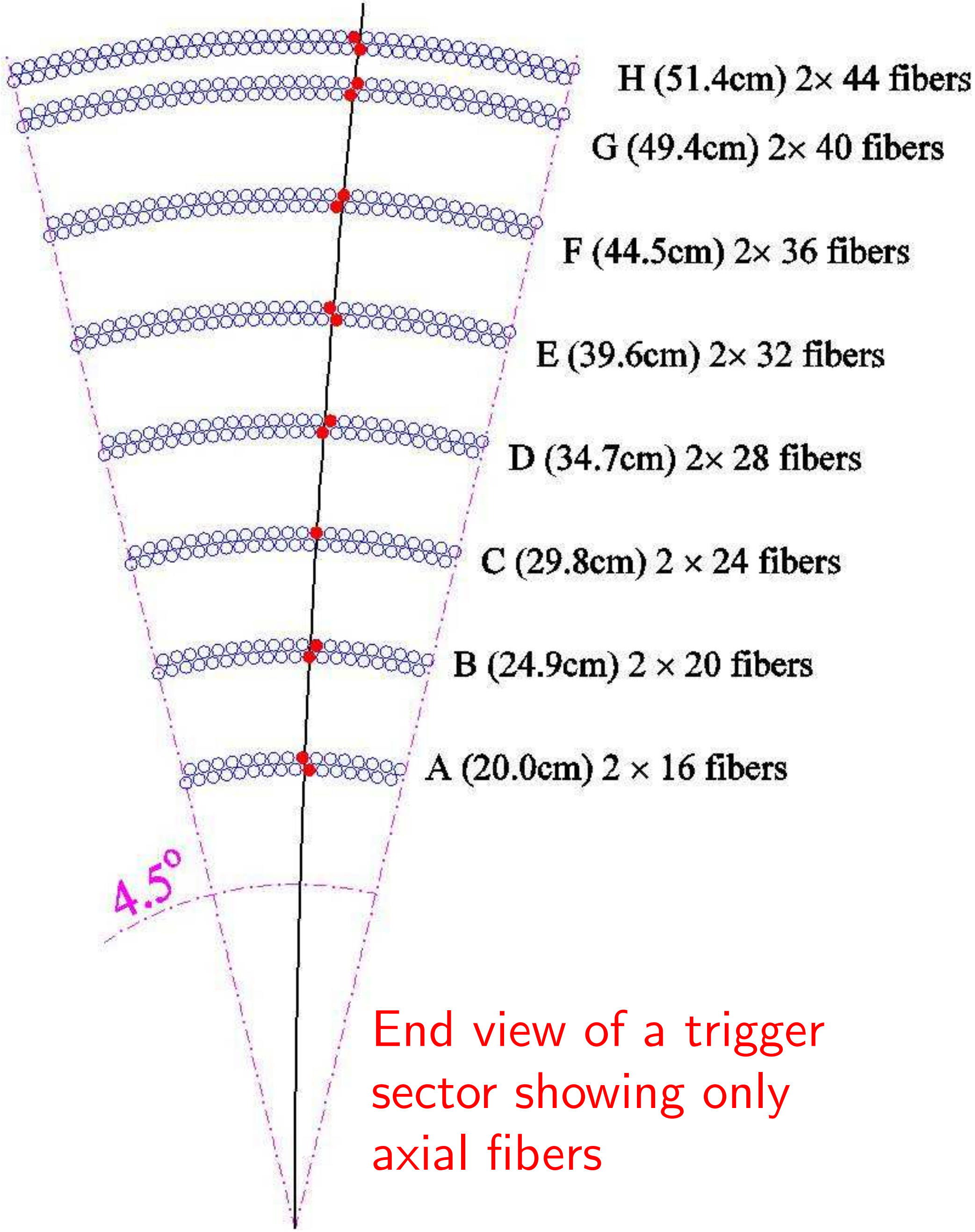
- Each AFE has 8 modules that readout 64 channels each (512 channels/AFE)
- ~ 8 photoelectrons per MIP (signal charge of ~ 50 fC)
- AFE controls VLPC bias voltage and temperature with precision of ± 30 mV and ± 0.05 K respectively
- Measurements of VLPC temperature, bias voltage, and heater currents fluctuate within allowed limits (below)



- AFE amplifies VLPC signal, digitize it to 8 bits, suppress pedestal, and discriminate output for trigger
- AFEII-t's are stable and require less frequent calibrations
- CFT, CPS, and FPS are fully instrumented with AFEII-t (April 2007)
- AFEII-t provides new information about time of hit arrival
- More details on AFEII-t in the talk on March 5

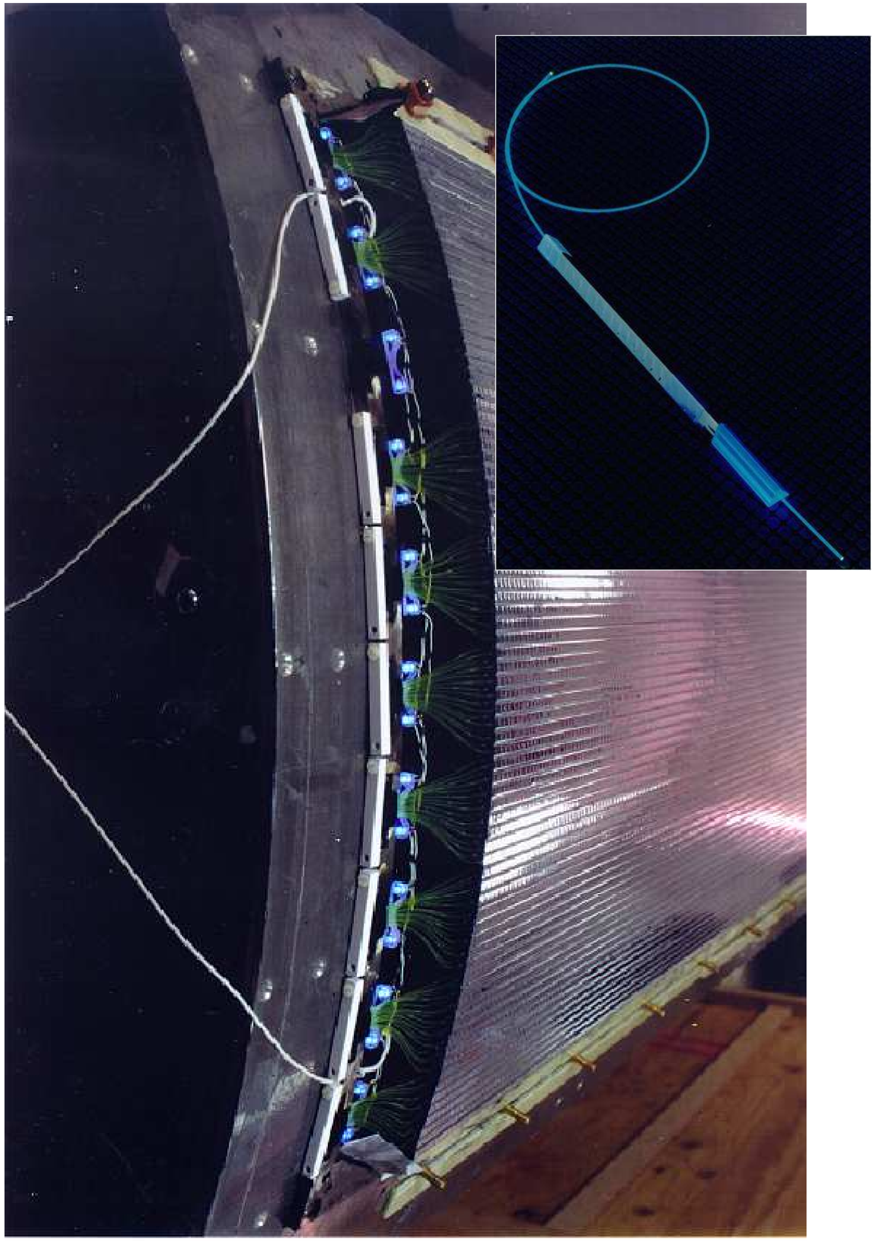
Central Track Tigger (CTT)

- Counts track candidates identified in axial view of CFT by looking for hits in all 8 axial layers within predetermined roads above four Pt thresholds (1.5, 3, 5, and 10 GeV/c)
- Combines tracking and preshower information to identify electron and photon candidates
- Generates track lists allowing other trigger systems to perform track matching

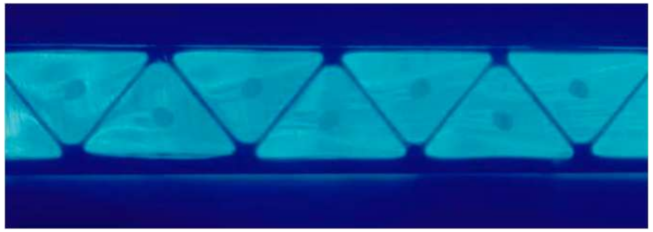


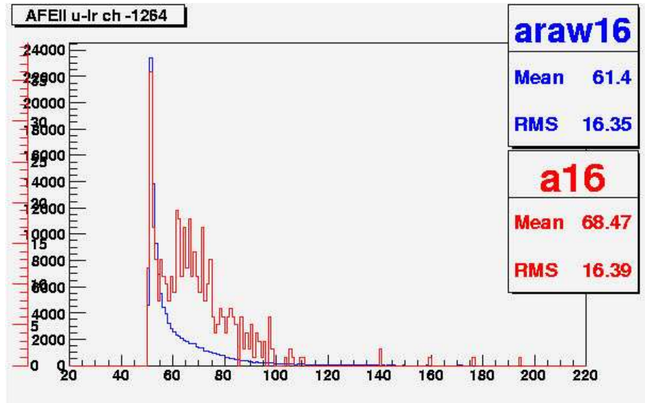
End view of a trigger sector showing only axial fibers

Central Preshower Performance

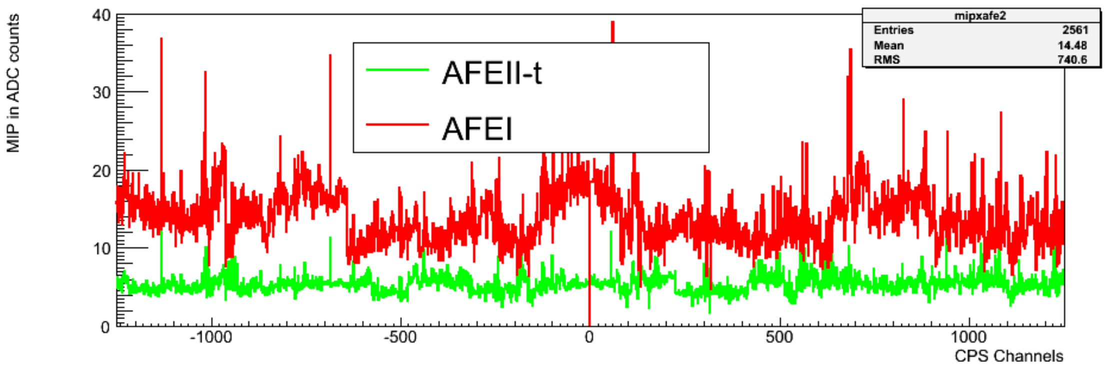


- The PS detectors are made of extruded scintillator with wavelength shifting fibers running through the center





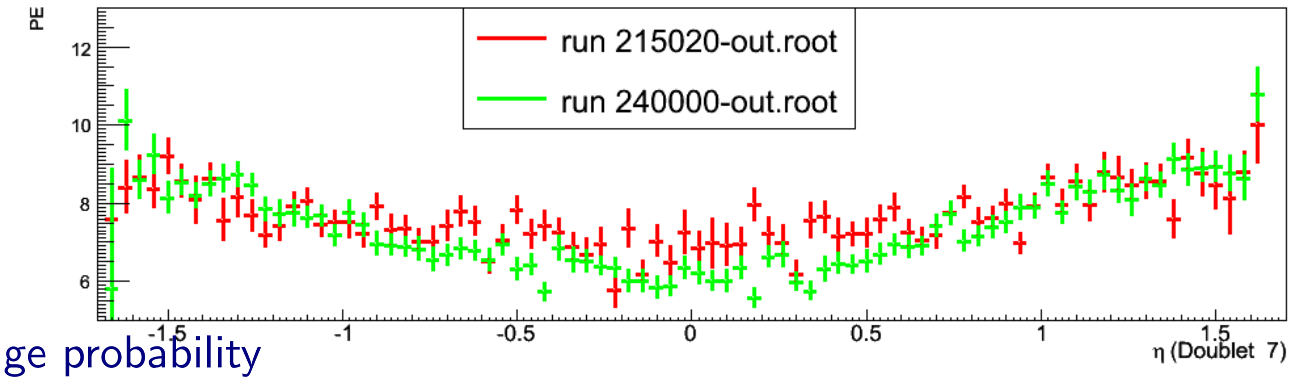
- MIP peak measured with AFEII-t is more pronounced in CPS channels $\longrightarrow$ more uniform and reliable fits

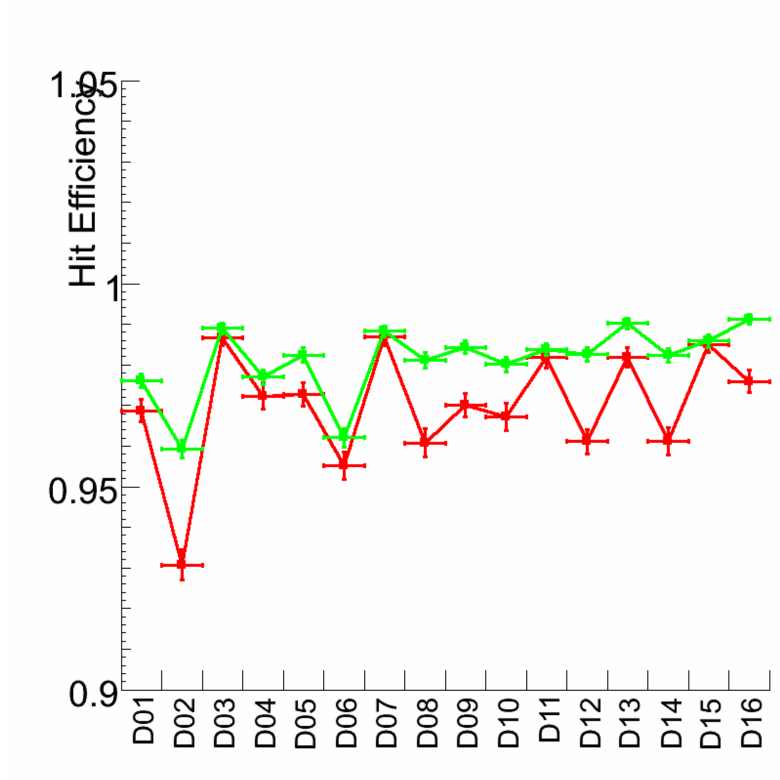


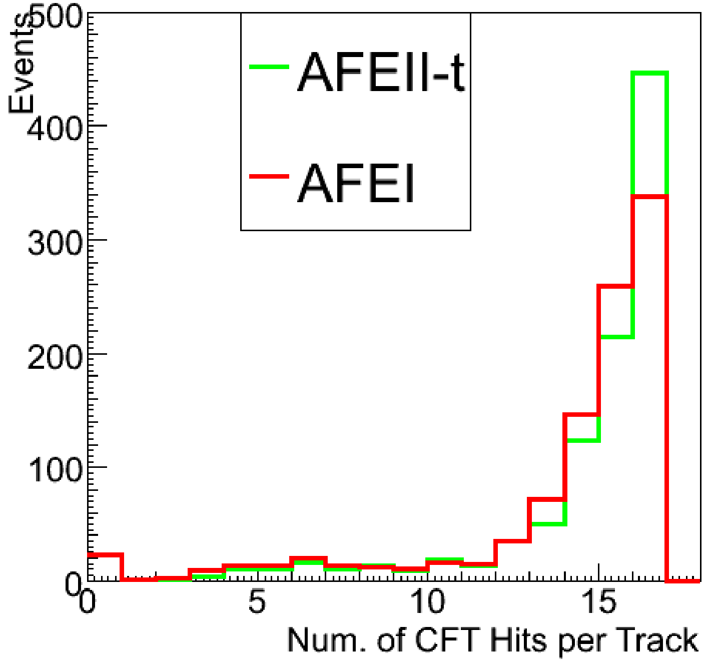
- Using AFEII-t capabilities increased CPS dynamic range from 13 to 54 MIP

Central Fiber Tracker Performance

- Average **light yield** depends upon path length through scintillator. It is shown as a function of pseudo-rapidity $\eta = -\ln\left[\tan\left(\frac{\theta}{2}\right)\right]$ (right)
- On average 8 photons produced per hit.
- Using good 15 hit CFT tracks, the average probability of a cluster in excluded layer is $98\ \%$



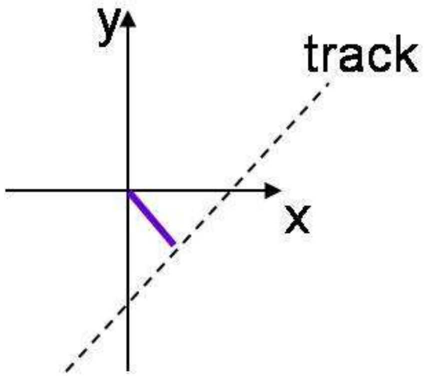


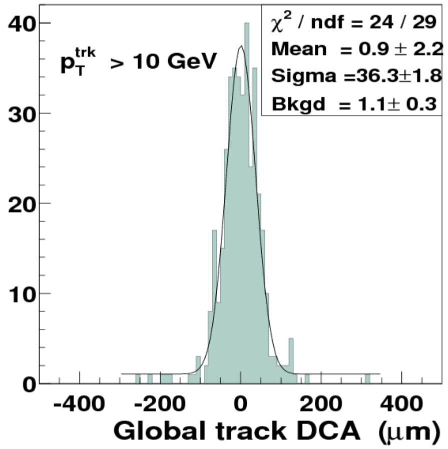


Distribution of number of hits on track agrees with naive model given by binomial probability function $f = C_k^{16} p^k (1-p)^{16-k}$ where $p \approx 0.98$

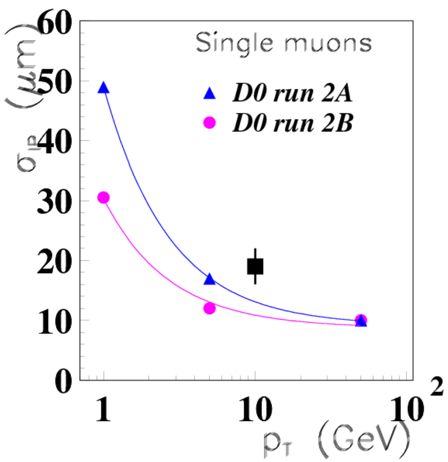
Tracking Performance and Physics Results

- Many physics analysis depend on tracker performance
- Global track DCA:

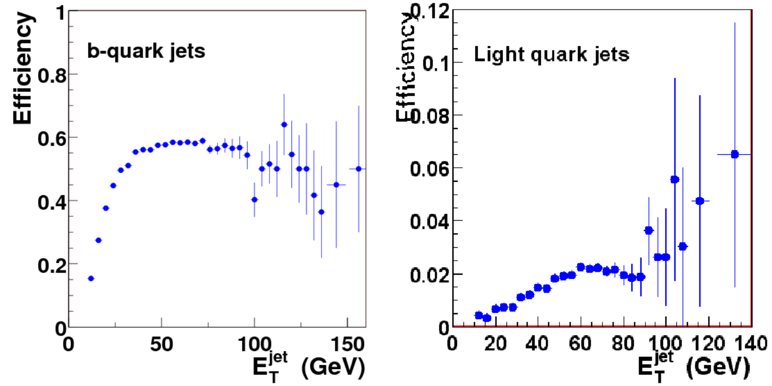




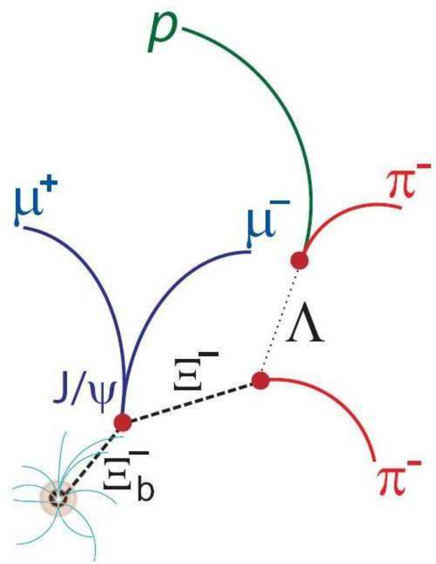
- With beam $\sigma \approx 30\ \mu m$ and DCA width $\approx 36\ \mu m$ the impact parameter resolution $\approx 20\ \mu m$
- The impact parameter is P_t dependant:

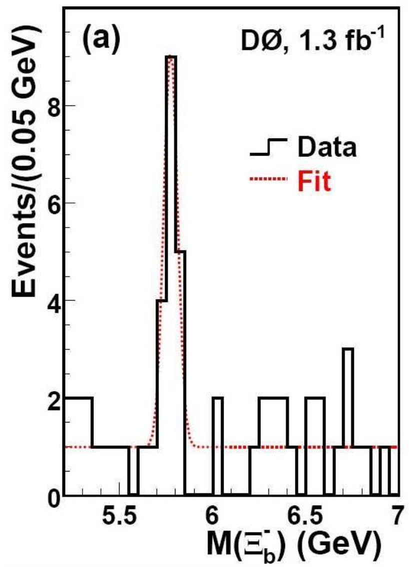


- b-tagging very crucial for the analysis to reject contribution from light quarks
- Efficiency and fake rate is determined by the impact parameter resolution

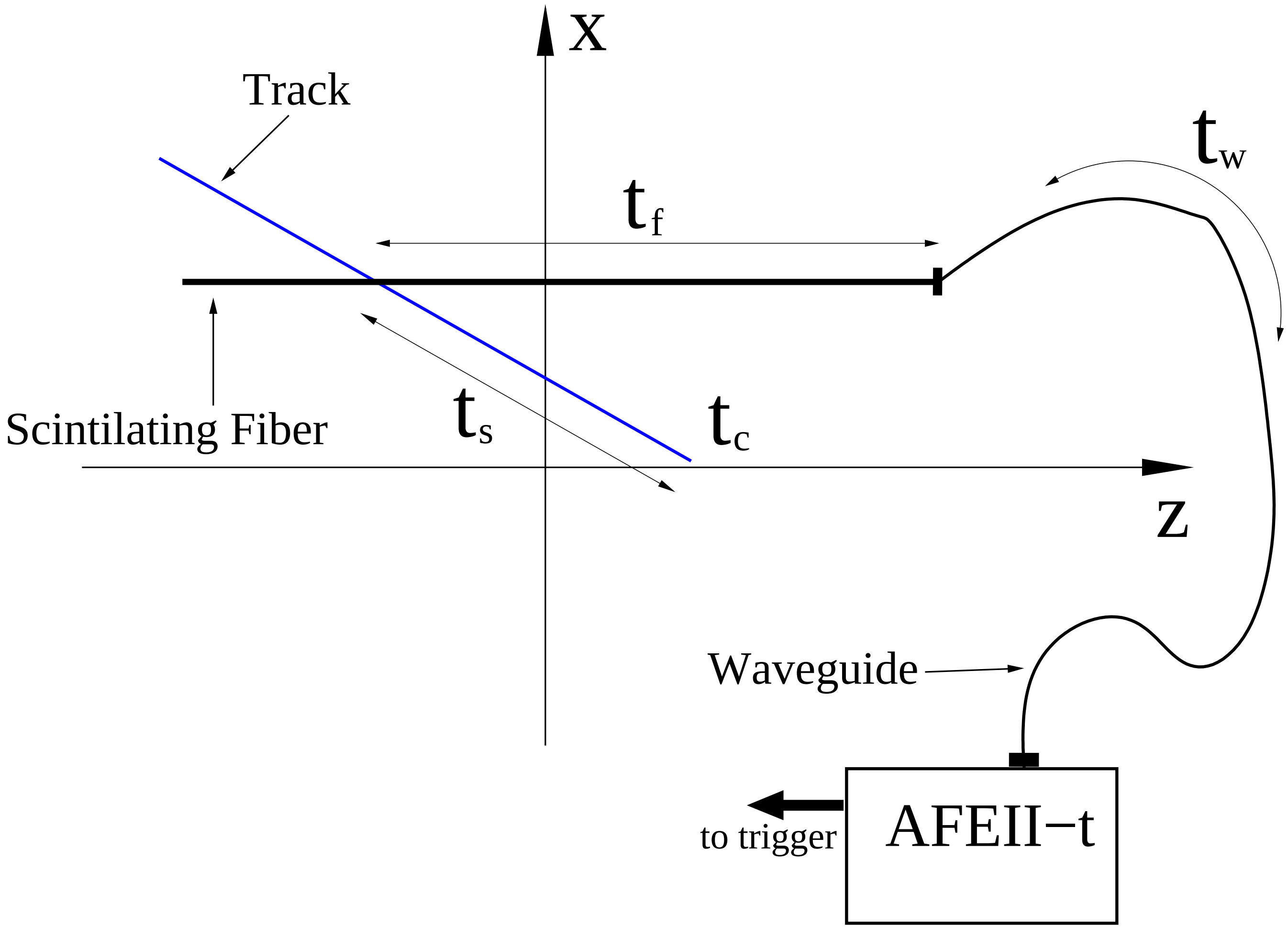


- First direct observation of the strange b baryon Ξ_b^-





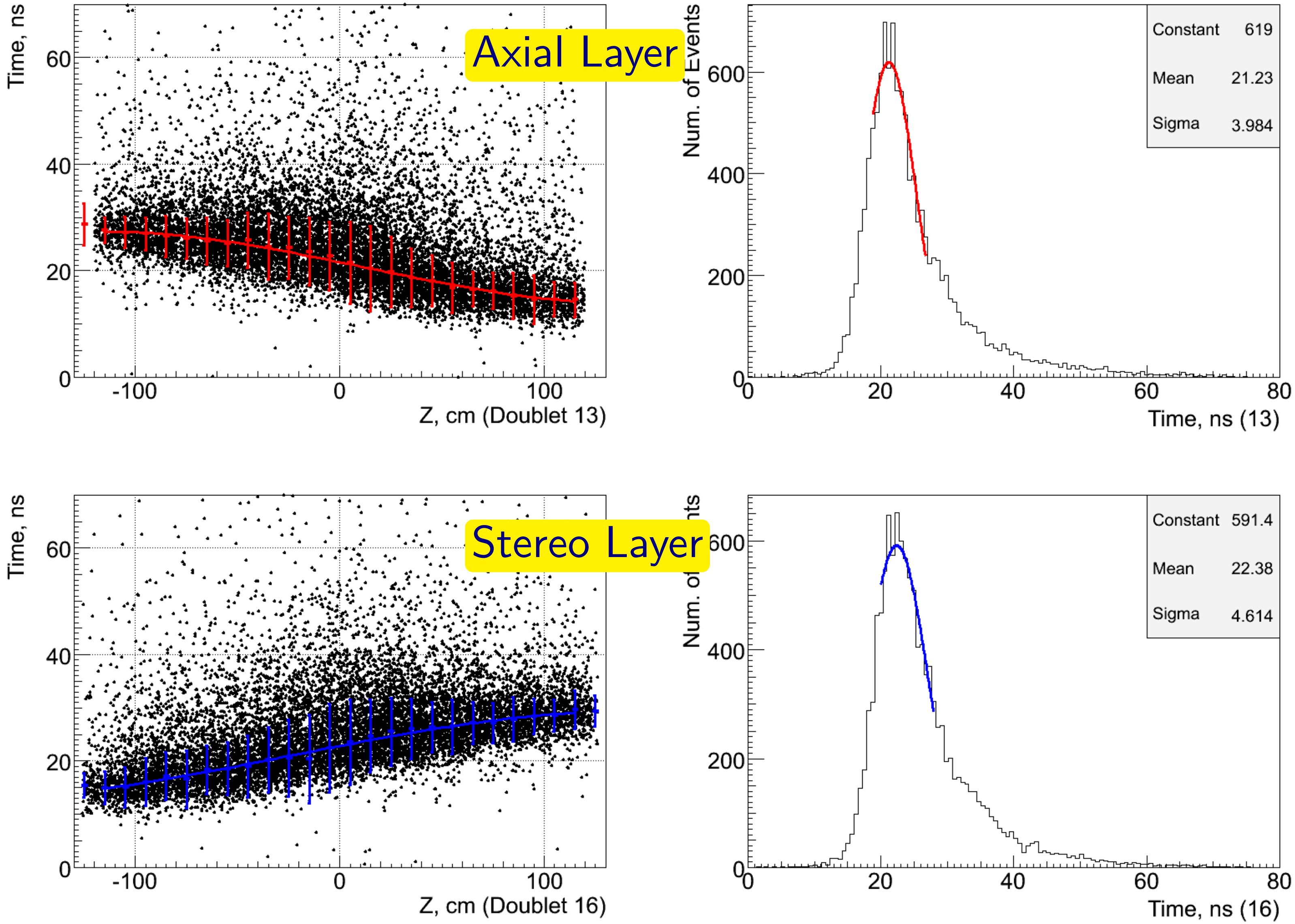
Measuring Time with AFEII-t



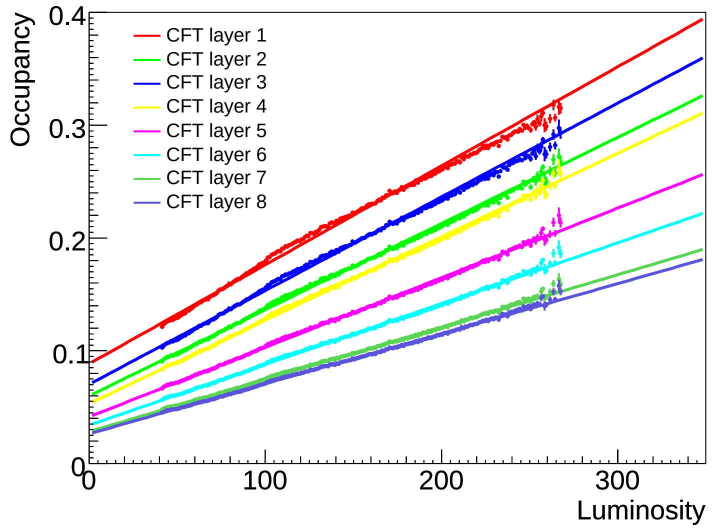
- Schematics shows different segments traveled by the signal before it reaches VLPC:
  - t_c – time when collision occured
  - t_s – time of flight ($v_s \approx c \approx 30$ cm/ns)
  - t_f – time of travel in the fiber ($v_f \approx \frac{2}{3} \times c \approx 20$ cm/ns)
  - t_w – time of travel in the waveguide. Variation in waveguide length is ≈ 3 m

Measuring Time with AFEII-t

- Time of signal arrival depends on hit's z coordinate
- Waveguides for axial and stereo layers located on opposite sides of the detector
- Average slope is consistent with the nominal speed of light in the fiber (≈ 18 cm/ns)
- Average time resolution is ~ 4 ns or ~ 60 cm

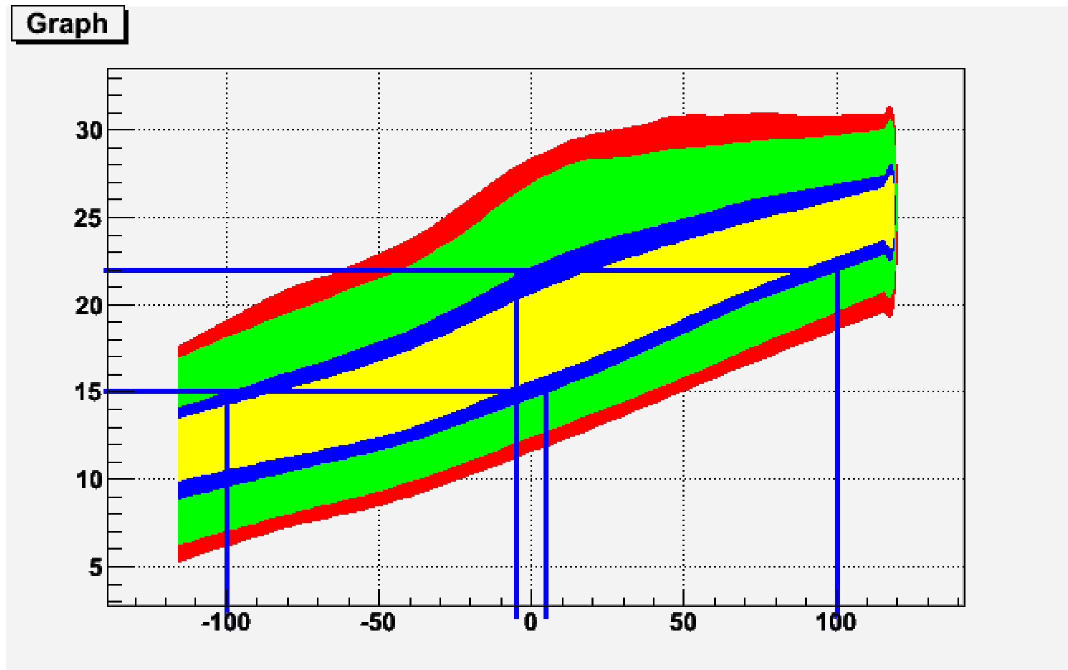


Using Time (Preliminary)



- Occupancy of the innermost layer can be upto ≈ 35 % at high luminosities
- Track reconstruction algorithm suffers from increased number of fake hits

- Before track reconstruction we can try to reject fake hits with fibers having large diference in time
- Using reconstructed tracks can create a PDF that matches z to t
- Confidence level bands: 50%, 68%, 95%, and 98%
- Resolution at 68% C.L. is $\approx$ 53 cm



Conclusions

- The Central Fiber Tracking system is a key component of the D0 experiment
- Currently all VLPC detectors read out by AFEII-t boards
- Readout system is generally stable and well behaved
- The detector is performing well
- > 98 % of the CFT channels are currently readout
- Many interesting recent physics results would not be possible without the CFT
- New timing information as well as its online and offline calibrations is available. Can be used to improve efficiency of track reconstruction algorithms