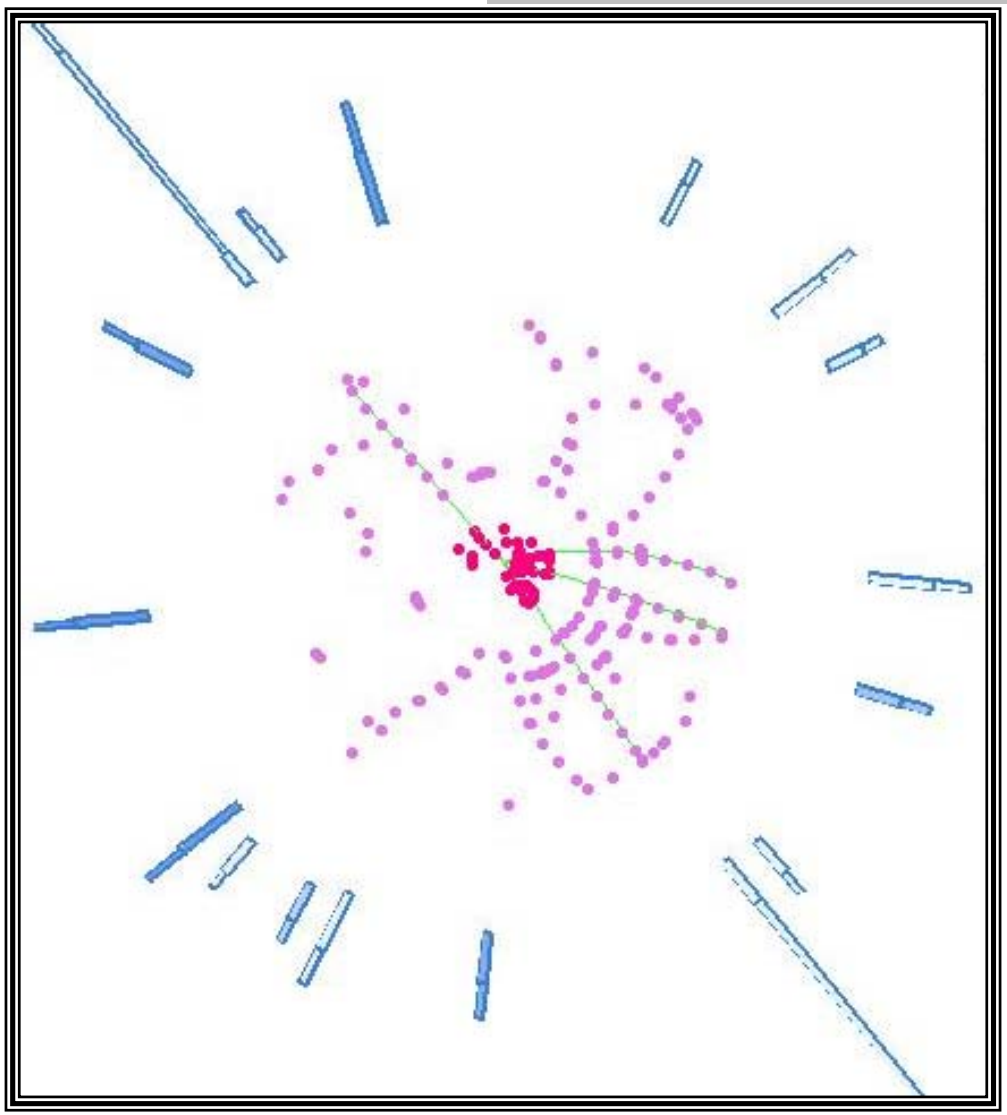
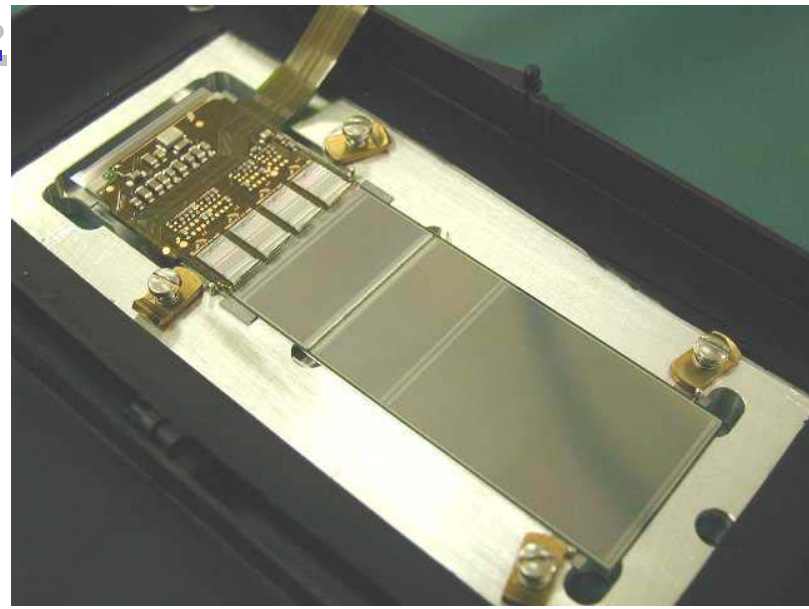
The DØ Tracking System for Run II

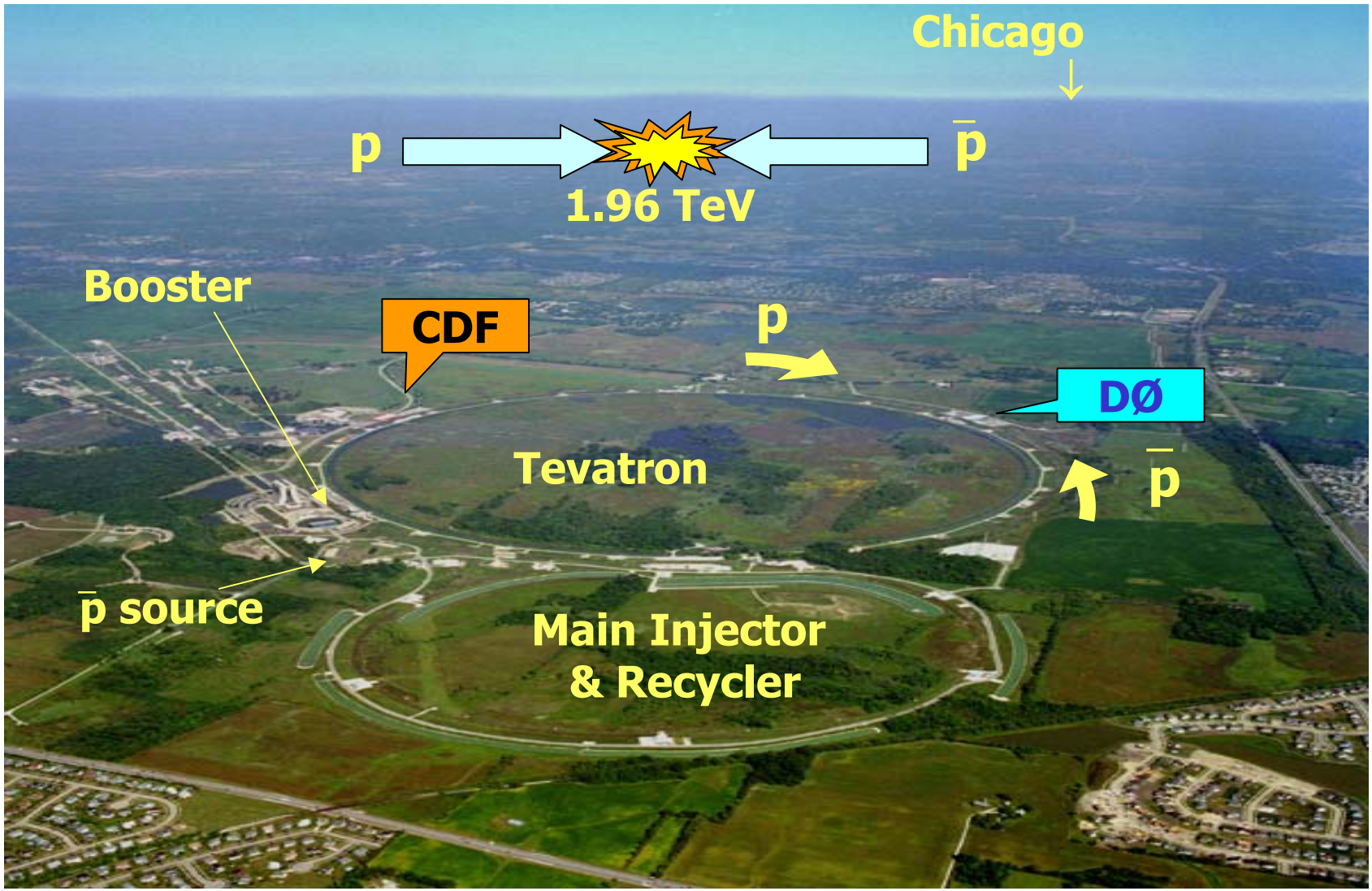




George Ginther
University of Rochester

for the DØ Collaboration

The Fermilab Tevatron Collider

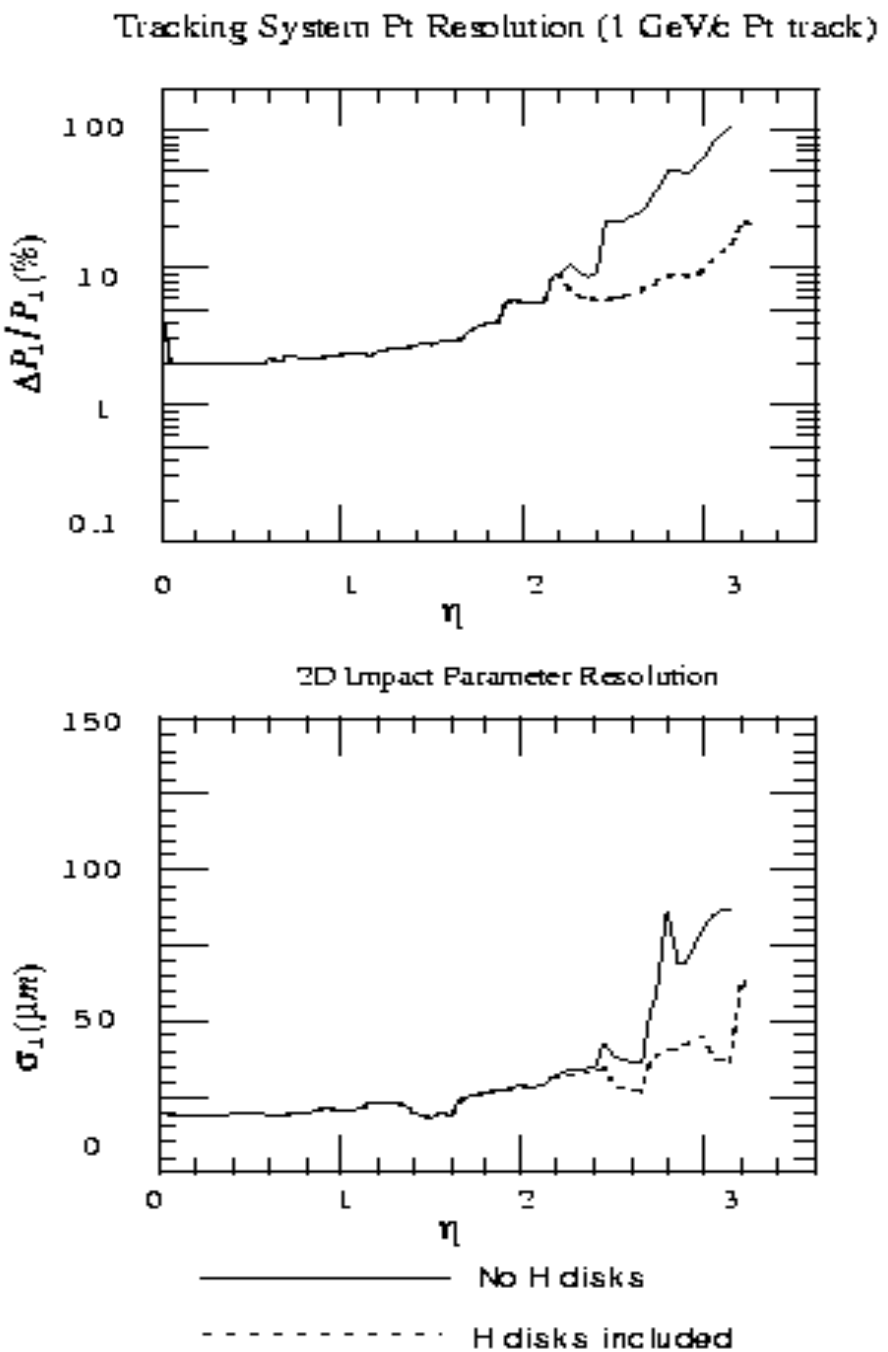


An Opportunity

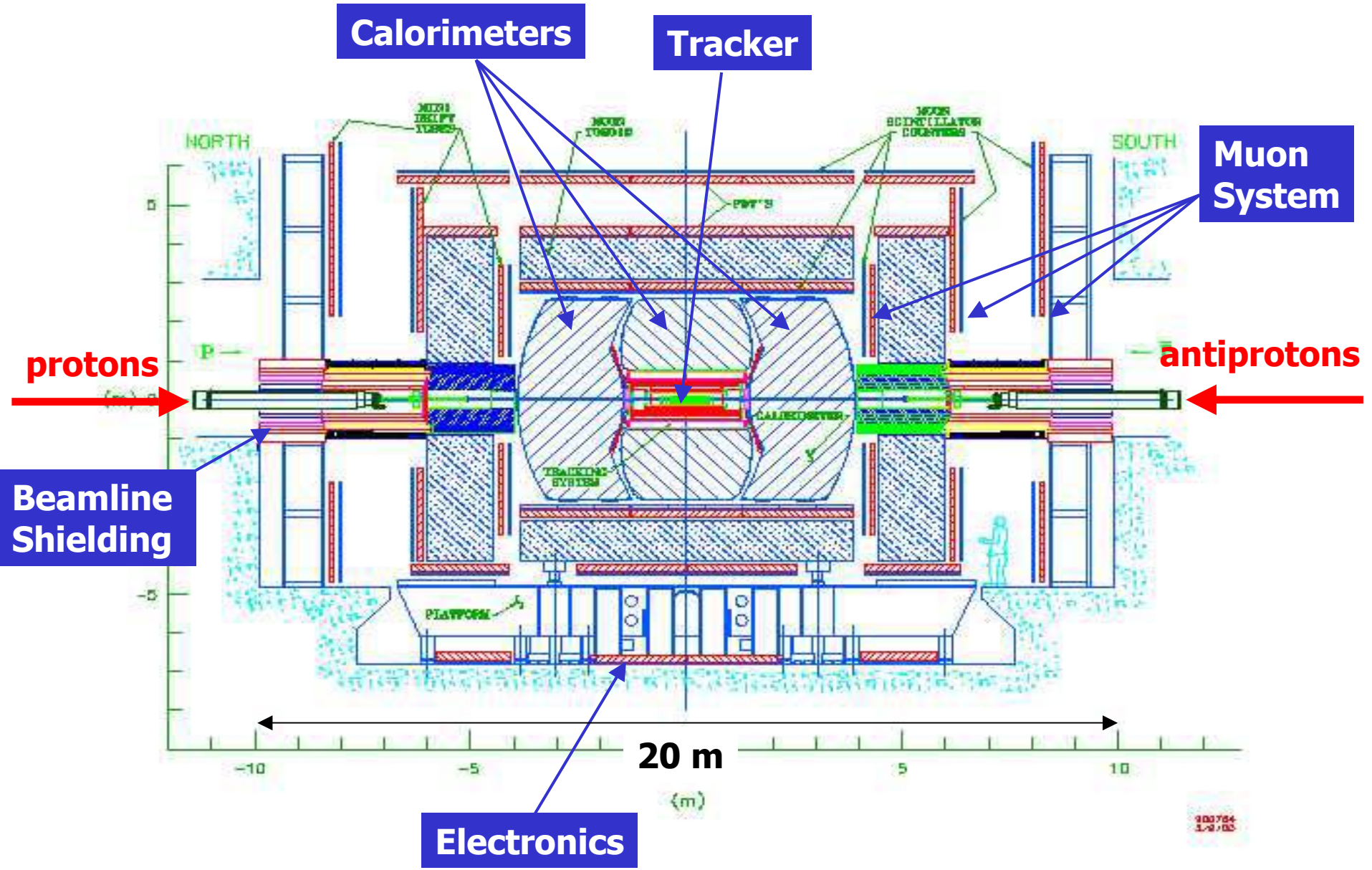
- Explore the energy frontier
  - searches
    - Higgs boson
    - supersymmetry
    - extra dimensions
    - quark or lepton compositeness
    - new dynamics
  - precision measurements of W, Z and top
  - B physics
  - QCD studies
- To take best advantage of this opportunity
  - large integrated luminosities (Run IIA $\Rightarrow$ ~ 2 fb^{-1})
  - electron, muon, tau, jet (including b jets) and missing Et measurement capabilities

DØ Tracker Design

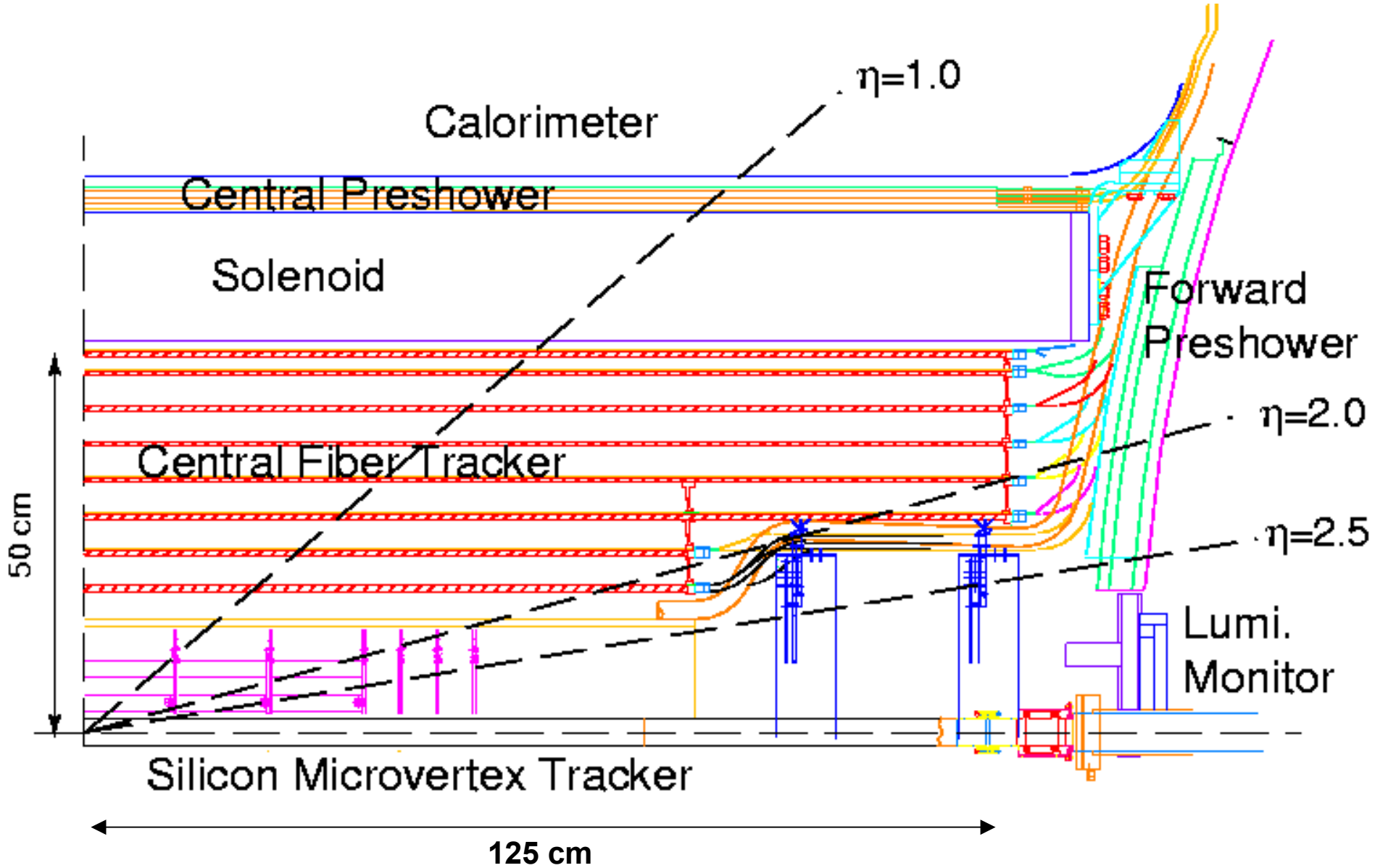
- Tracking system for Run II
  - 2 Tesla superconducting solenoidal magnet
  - Silicon Microstrip Tracker (SMT) and Central Fiber Tracker (CFT)
- Good 3D track reconstruction performance for high-p_T (top, Higgs, EW, NP) and low-p_T (B) tracks out to $|\eta| < 3$
- Momentum resolution $\approx$2% at p_T = 1 GeV/c for $|\eta| < 1$
- Impact parameter resolution within 30 μm
  - SMT H disks are employed to achieve these resolutions at high $|\eta|$



The Run II DØ Detector

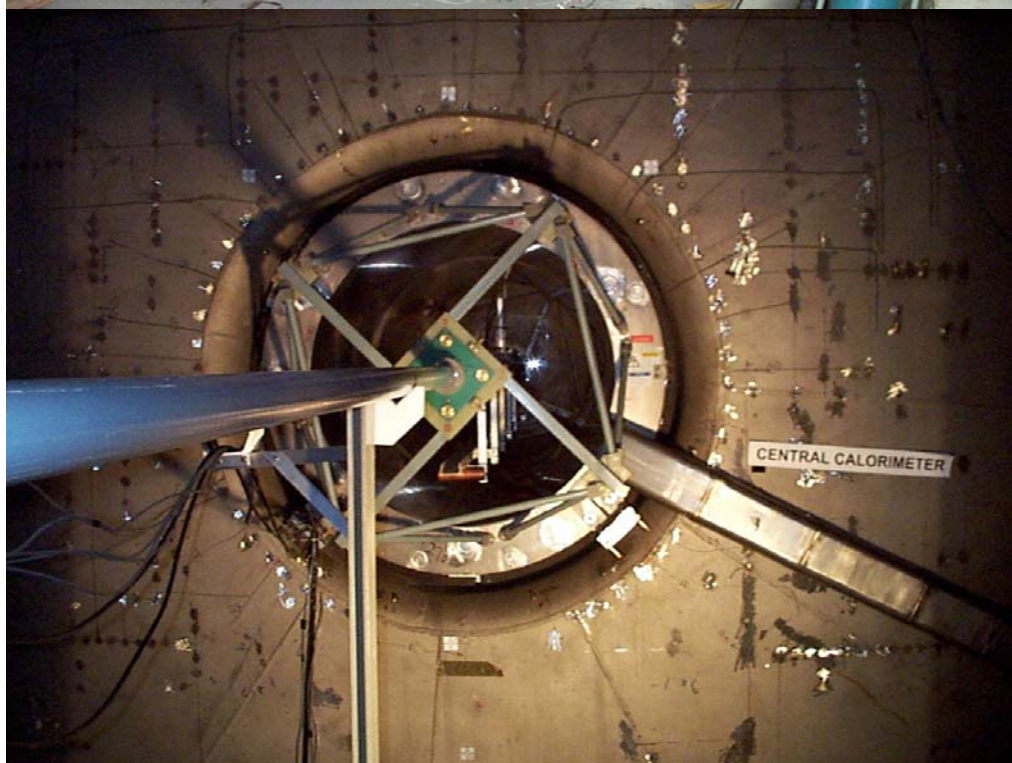


DØ Tracker

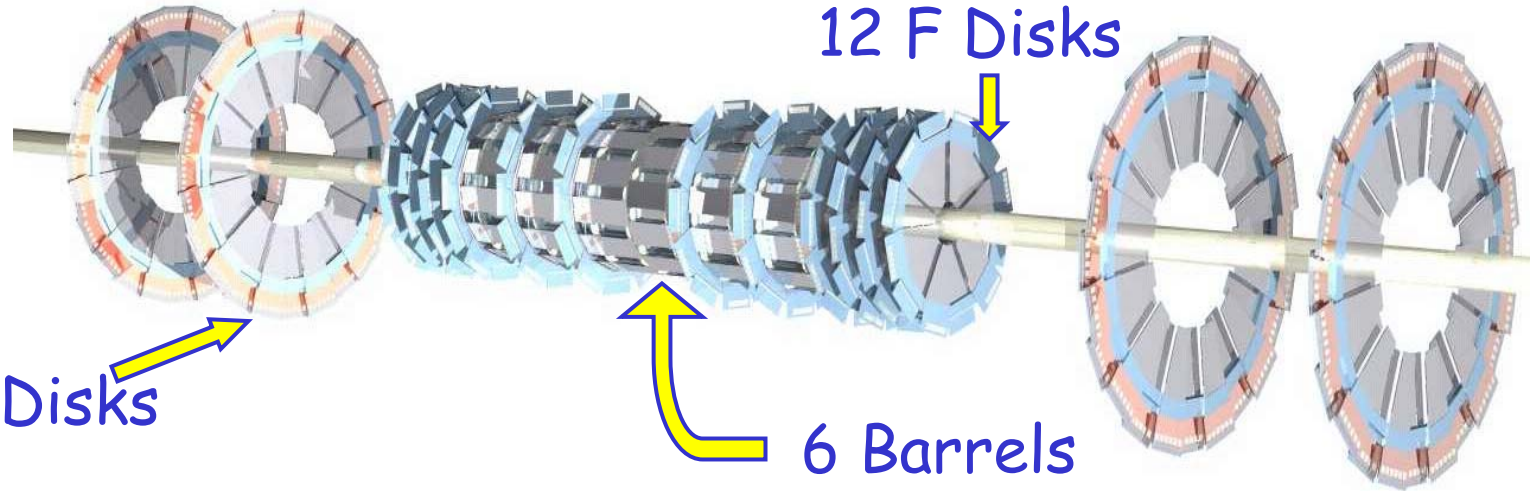

η=1.0
Calorimeter
Central Preshower
Solenoid
Forward
Preshower
η=2.0
Central Fiber Tracker
η=2.5
50 cm
Lumi.
Monitor
Silicon Microvertex Tracker
125 cm

Solenoid

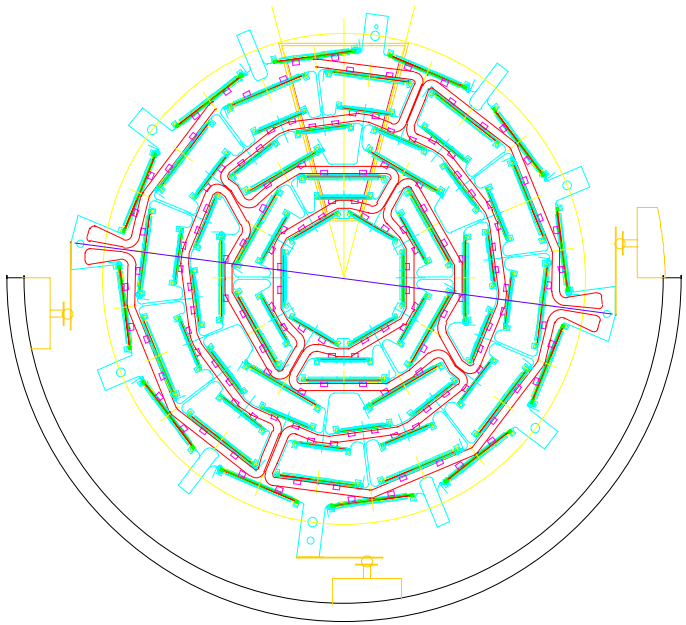
- 2.7 m long 2 Tesla field
- 5 MJ stored energy
- Two layer superconducting coil with mean radius of 60 cm
- $\sin\theta \int B_z \, dl$ is uniform to within 0.5%
  - achieved using two grades of conductors with higher densities near ends of coils
- Coil and cryostat ≈ 0.9 rad lengths
- Manufactured by Toshiba Corporation
- Delivered May 97



Silicon Microstrip Tracker (SMT)



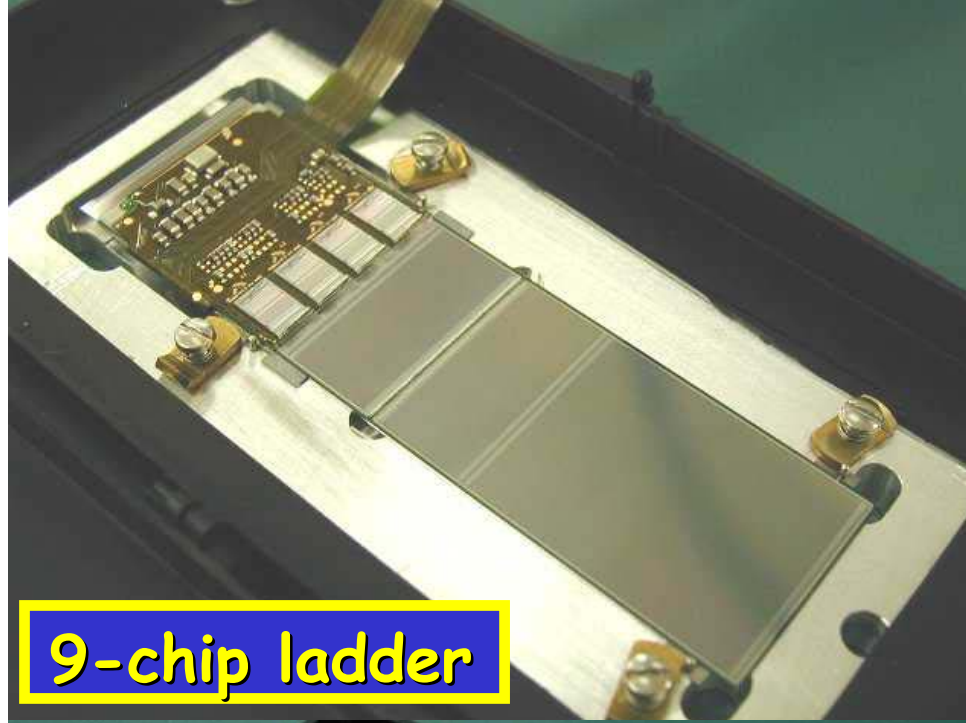
4-layer barrel cross-section

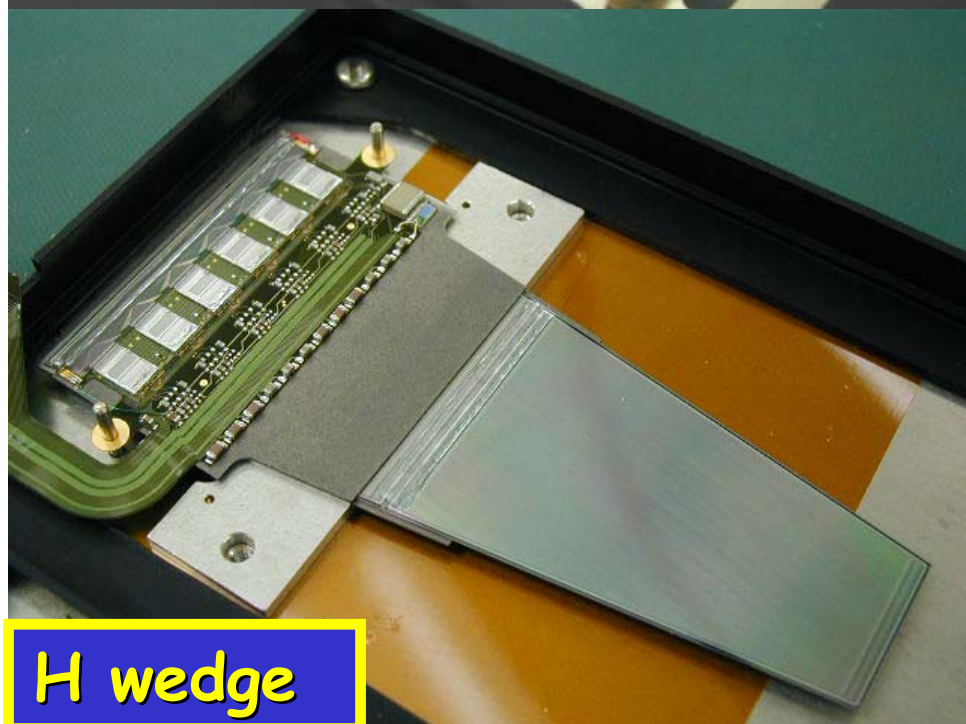


	Barrels	F-Disks	H-Disks
	sngl + dbl	double	single
Stereo	0, 2, 90	+/-15	+/-7.5
Channels	387072	258048	147456
Modules	432	144	96
Inner R	2.7 cm	2.6 cm	9.5 cm
Outer R	9.4 cm	10.5 cm	26 cm

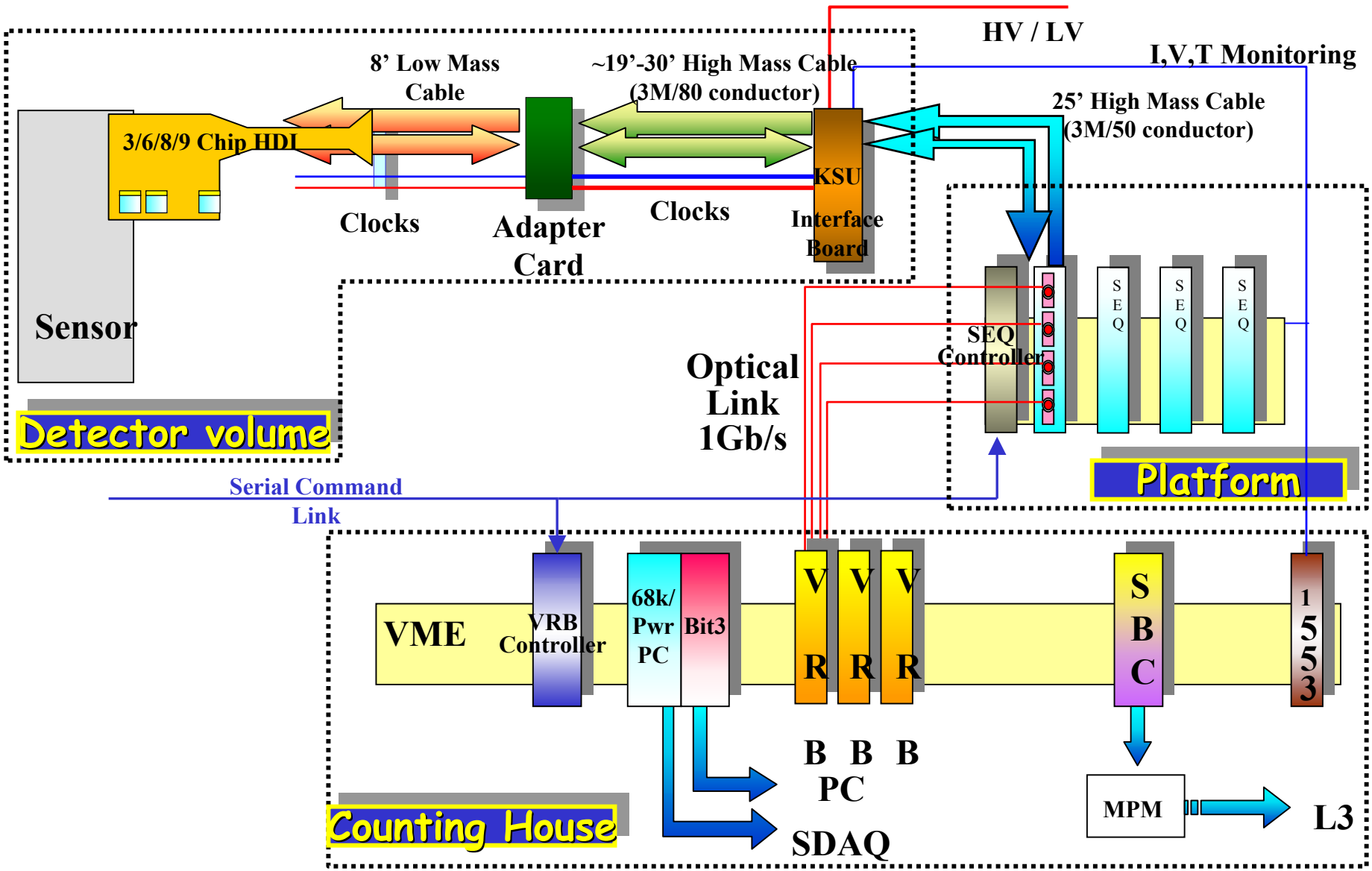
SMT

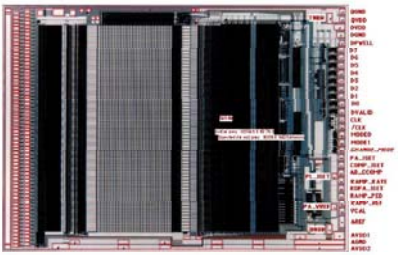
- 793K channels
- 3 m^2 of silicon
- >2.3 million wirebonds
- Ladders
  - 3-chip: 72 single-sided, axial ladders in the two outer barrels
  - 6-chip: 144 double-sided, axial/90° ladders in the four inner barrels
  - 9-chip: 216 double-sided, axial/2° ladders in all barrels
  - Mechanical accuracy of 2 to 5 μm
- Wedges
  - F Disks: 144 double-sided, ±15°, 6+8 chip wedges
  - H Disks: 96×2 back-to-back single-sided, ±7.5°, 6 chip wedges
  - Mechanical accuracy of 5 to 10 μm
- CMM aligned ladders and wedges to better than 20 μm





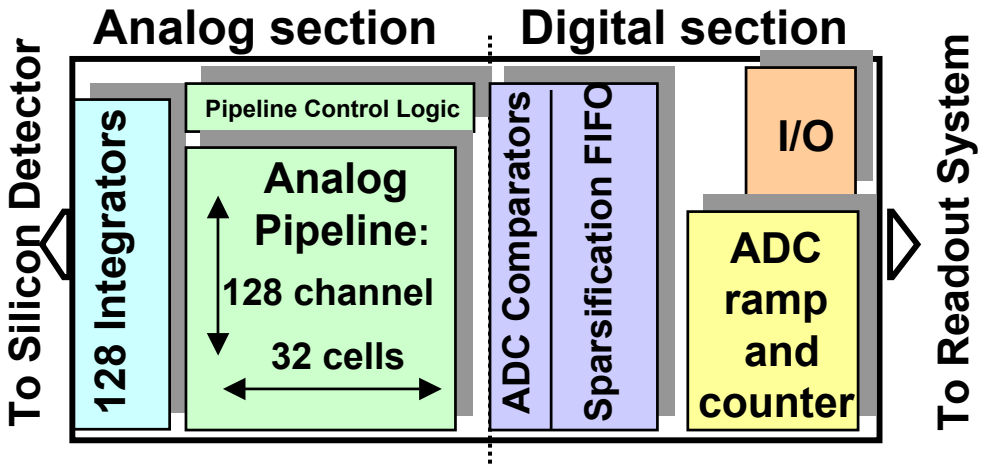
SMT Readout: Data Flow





SMT Readout Electronics

- SVX IIe Chip
  - Design by LBL and Fermilab
  - 1.2 μm radiation hard tech.
  - 128 channels per chip
  - 32 cell pipeline depth
  - 8 bit ADC with sparsification
  - 106 MHz digitization
    53 MHz readout

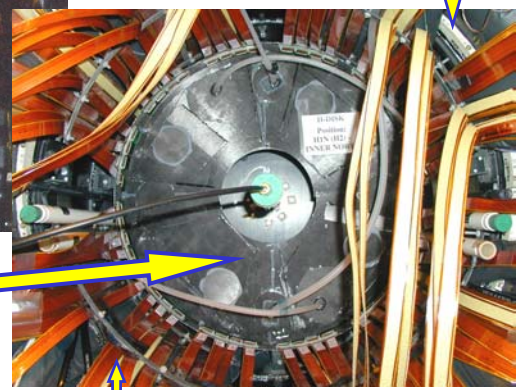


- Interface Boards
  - Refresh signals and adjust timing
  - Power management and monitoring
- SEQencers
  - Management of SVX
  - Fiber optic output
- VME Readout Buffer
  - Data buffer pending L2 trigger decision
  - ~ 50 Mb/s/channel
  - 10 kHz L1 accept
  - 1 kHz L2 accept rate

SMT Installation

- Cylinder installation completed Dec 2000
  - A ½ cylinder of 3 barrels and 6 F disks was inserted into each end of the CFT bore
- H Disk installation completed Feb 2001
- The cabling (~15,000 connections) and electronics installation was completed in May 2001

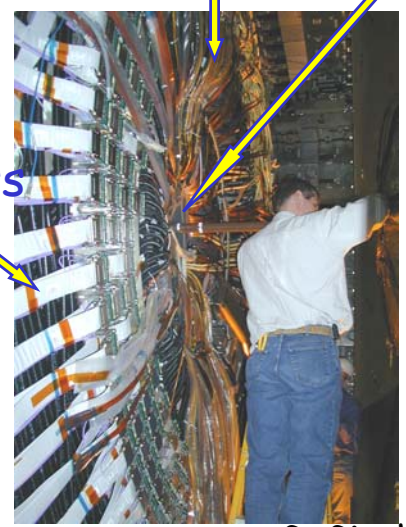
Fiber Tracker



Calorimeter

Low Mass Cables

SMT

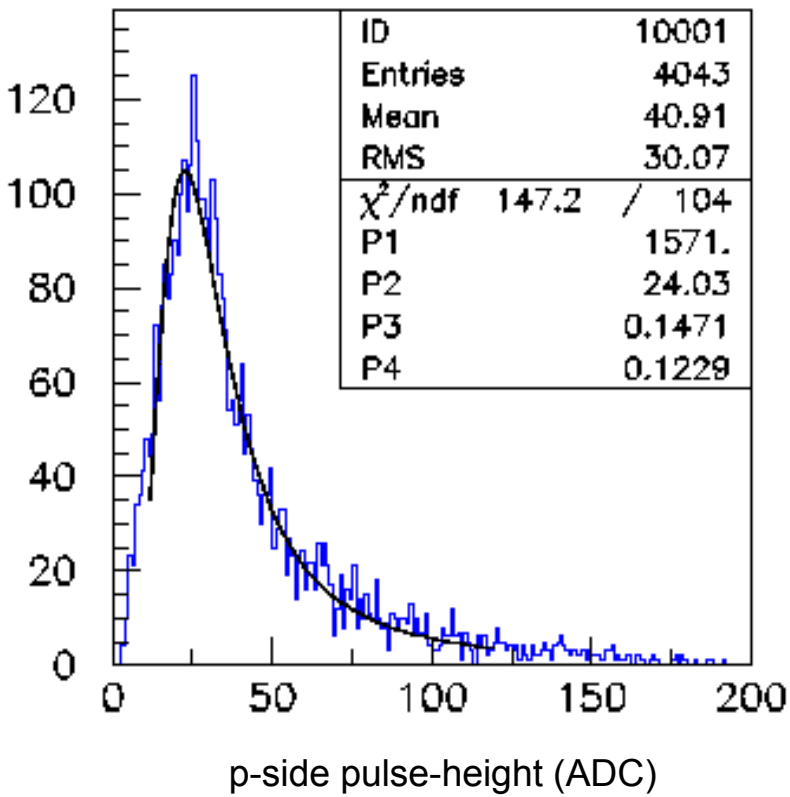


High Mass Cables

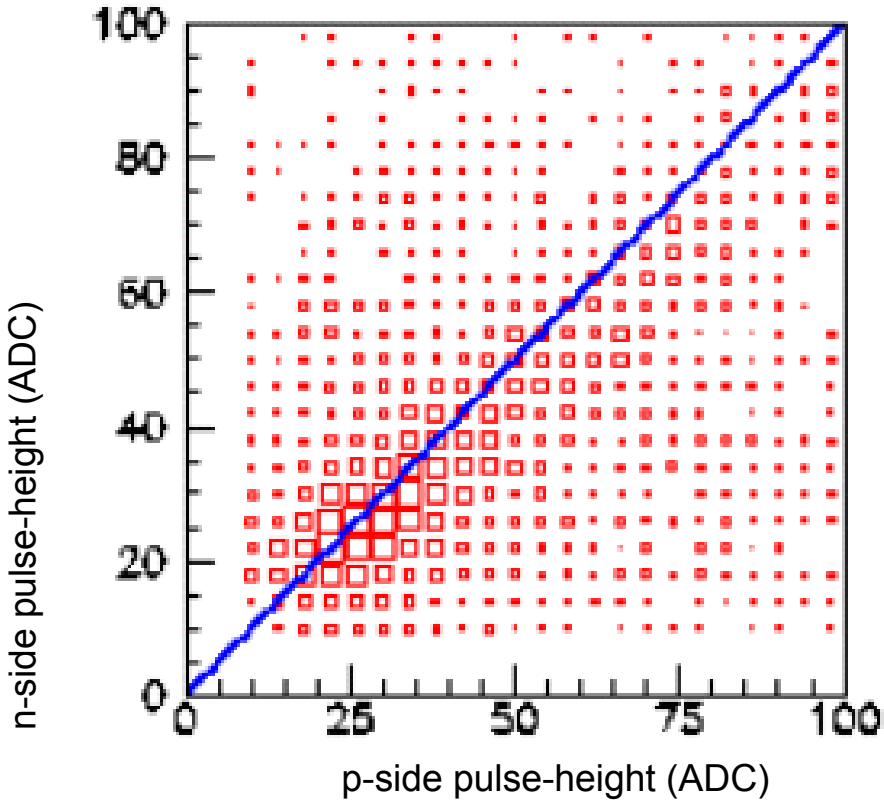
Interface Boards

SMT Charge Collection

- Cluster charge (corrected for track angle):
  - 1 mip ⇒ ~ 4fC ⇒ 25 ADC counts
  - Noise < 2 ADC counts

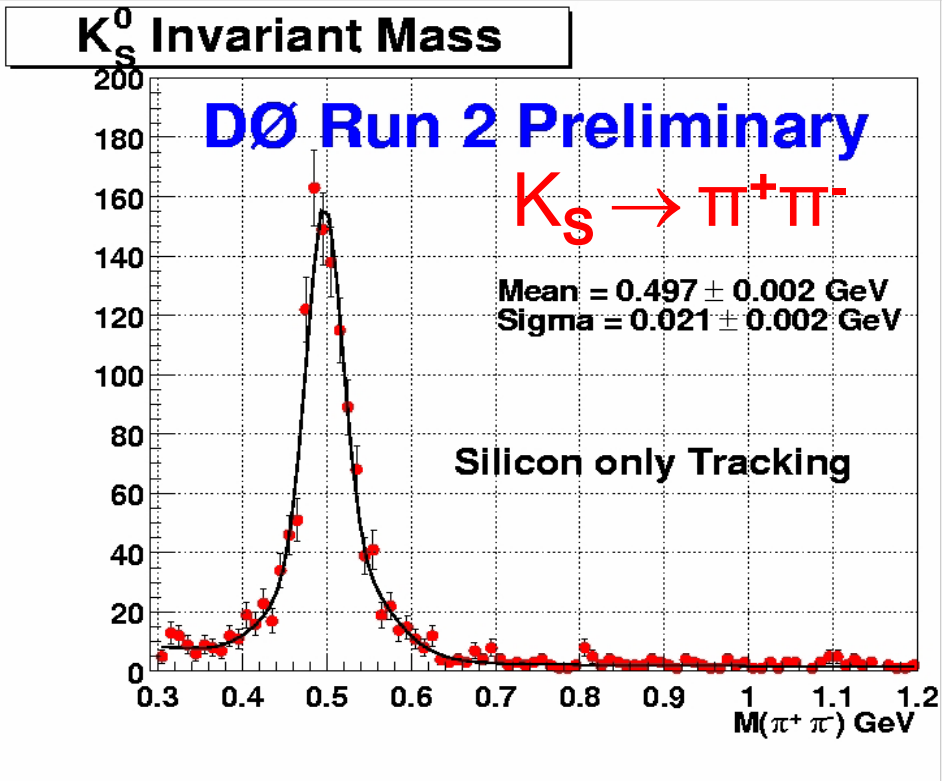


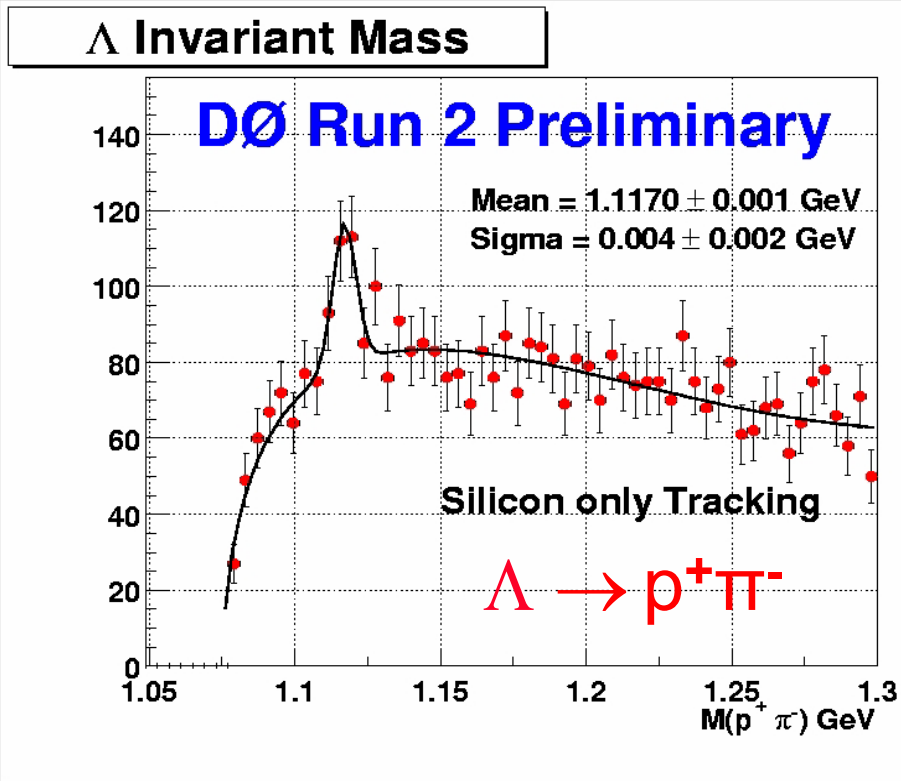
- Charge correlation between p- and n-side of a detector



SMT Results

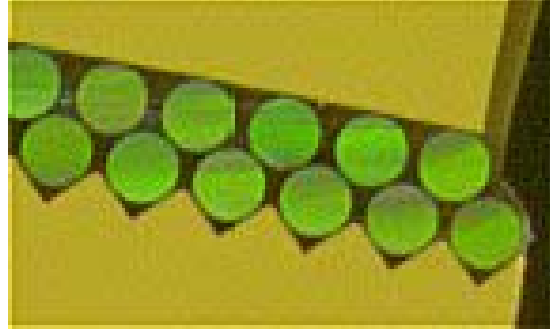
- ≈95% of SMT channels available for readout
- Hit efficiencies for good single silicon detectors > 97%
- Explicit V^0 reconstruction using SMT only tracks



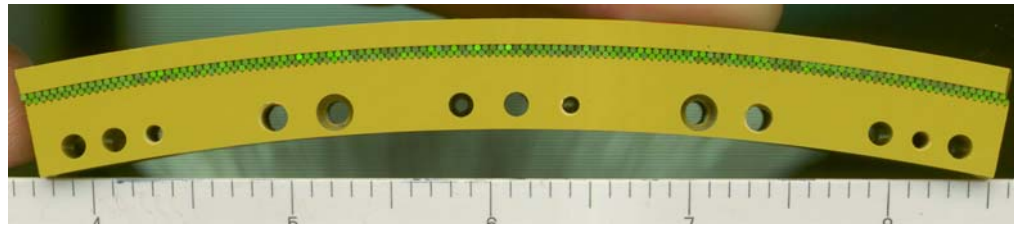


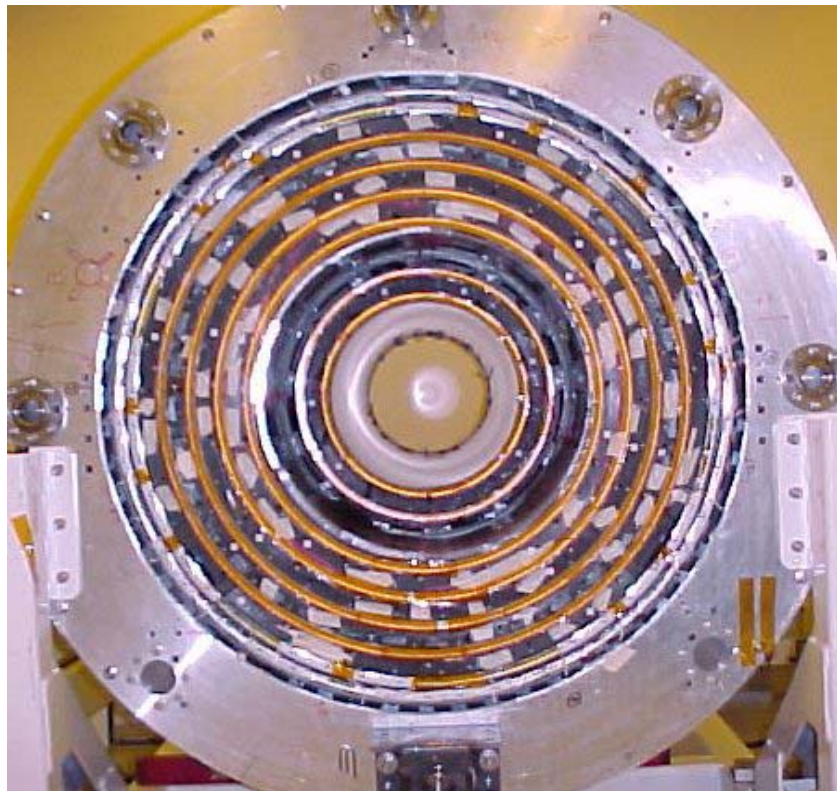
- Work in progress on geometry and alignment, charge sharing and clustering to improve resolutions, and performance

Central Fiber Tracker (CFT)



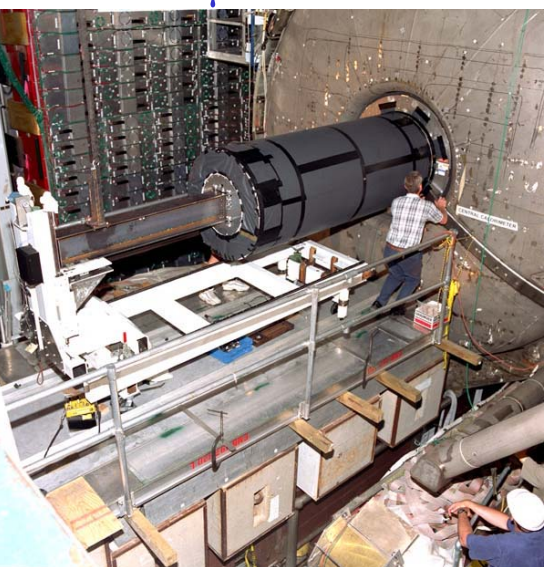
- 835 μm diameter multi-clad scintillating fibers arranged into precisely positioned ribbons of interlocked fiber doublets
- 256 fibers per ribbon
- Pairs of ribbons mounted on outside surface of eight carbon fiber support cylinders
- Inner ribbons on each cylinder have fibers oriented along the cylinder axis (axial view)
- Outer ribbons on each cylinder have fibers oriented at ±3° angle (stereo view)
- Scintillating fibers on outer six cylinders are 2.5 m long

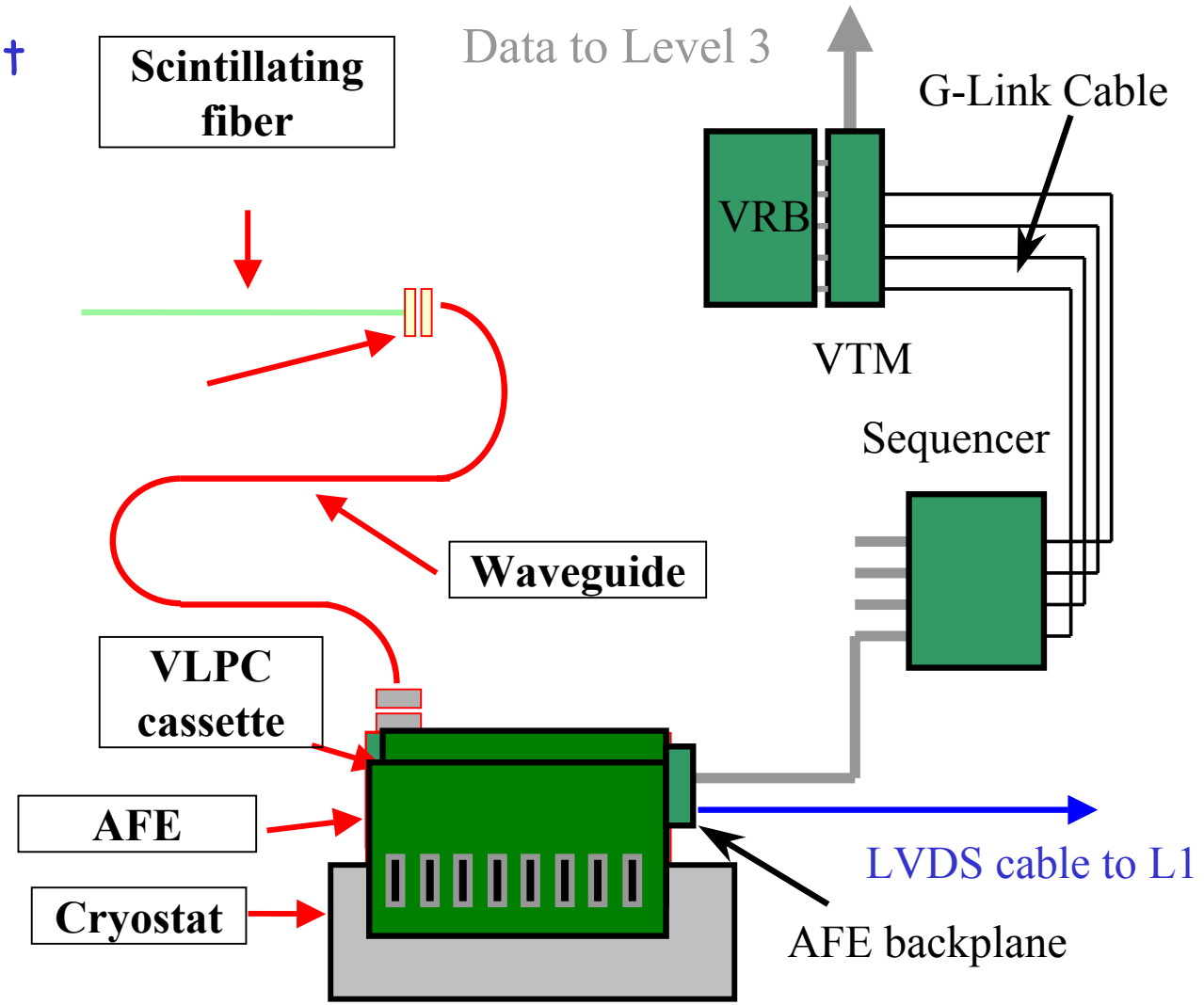




CFT Readout

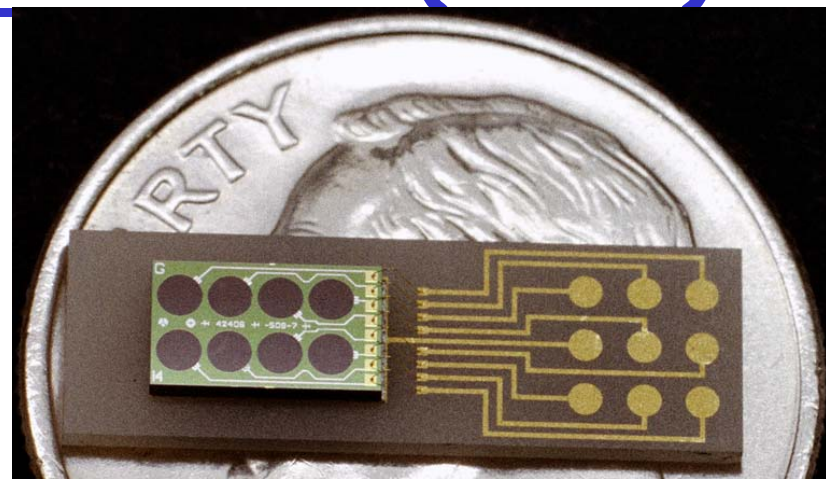
- Total of 76800 scintillating fibers
- Bundles of 8.2 to 11.4 m long clear fibers (waveguides) pipe light to individual light sensitive detectors (Visible Light Photon Counter pixels)
- ≈10 photons to VLPCs
- Position resolution of fiber doublet is ≈100μm



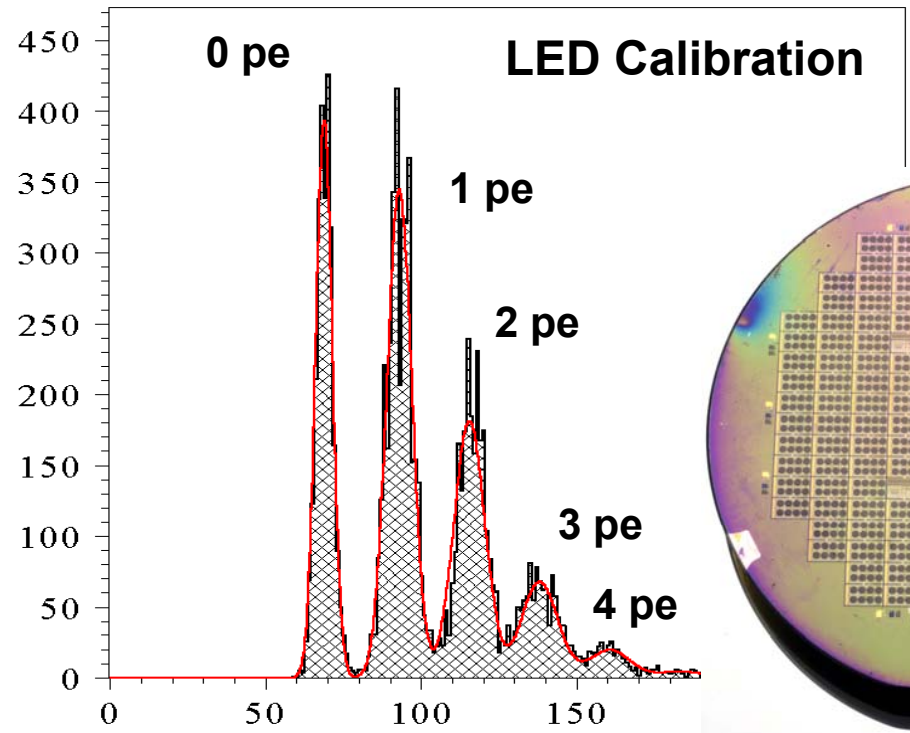


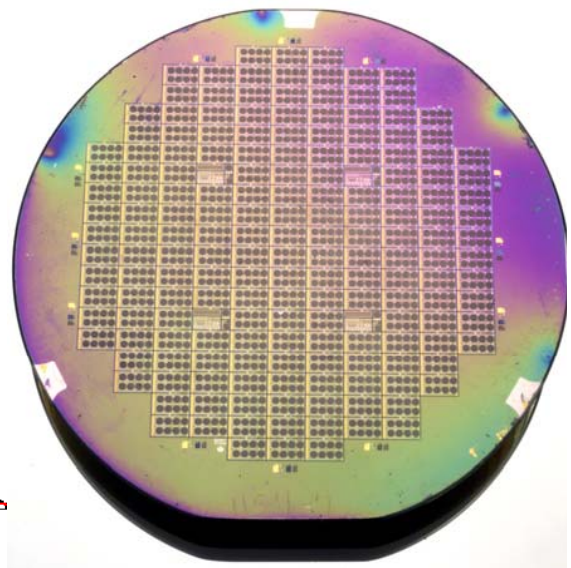
Visible Light Photon Counters (VLPC)

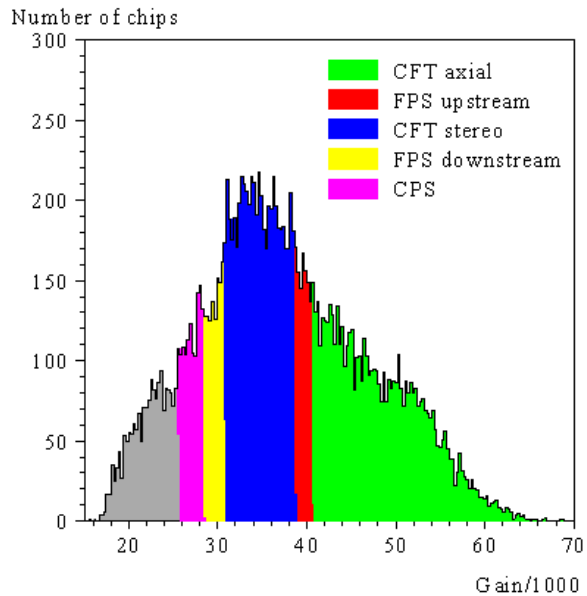
- solid state photo-detectors
  - 1 mm diameter pixels arranged in 2x4 array
  - function at high rates
  - quantum efficiency ≈80%
  - low gain dispersion
  - operated at 9K ± 0.05K



- VLPC fabricated in wafers of 176 chips
  - gain, optimal bias voltage, relative QE, and rate effects vary among and across wafers

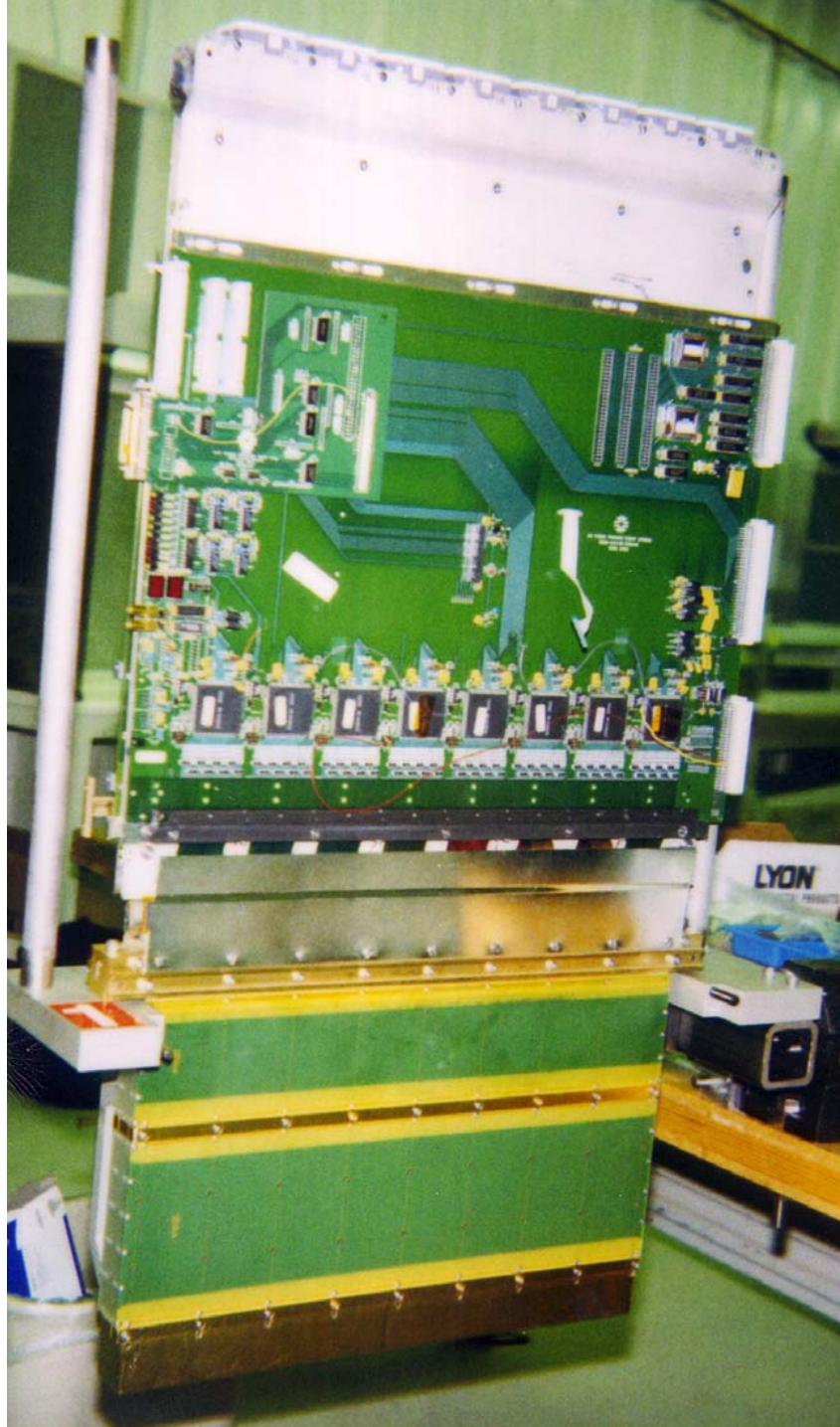




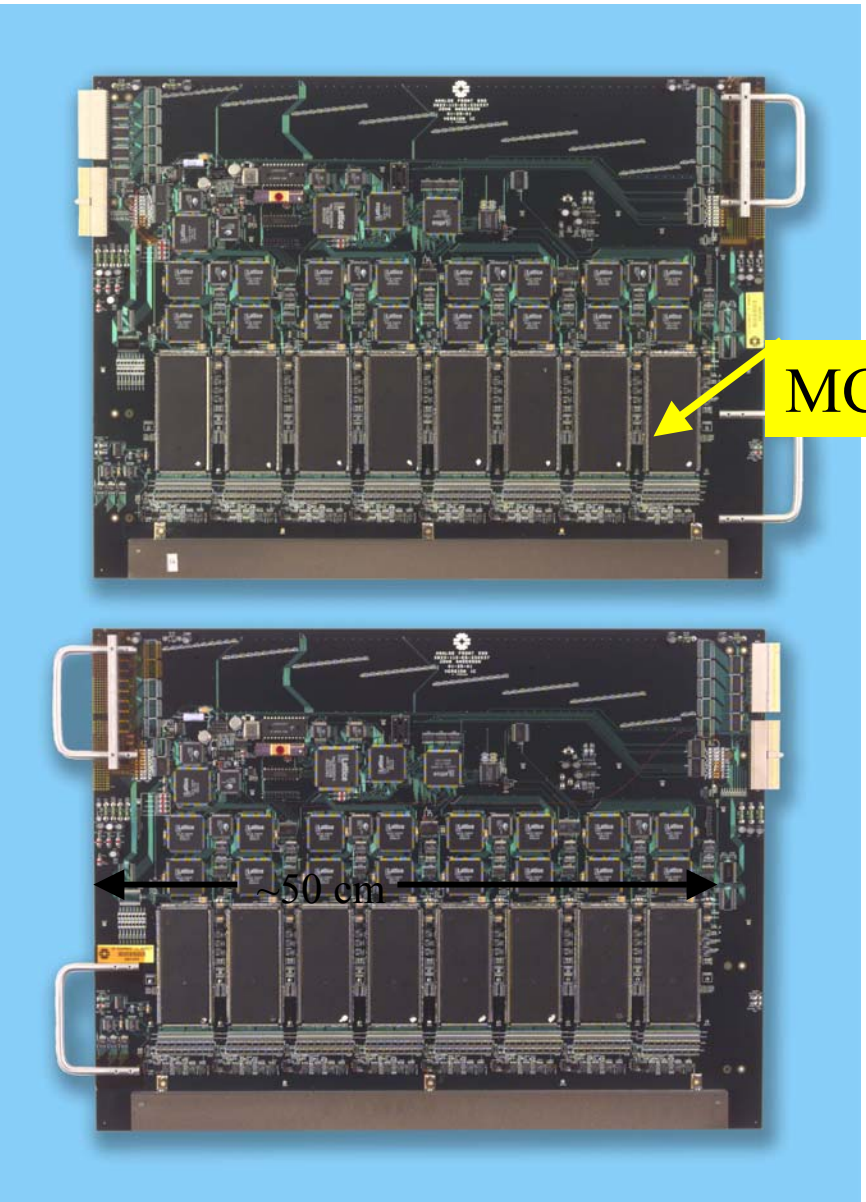


VLPC Cassette

- VLPC performance is sensitive to the operating temperature, bias voltage, and the background rate
- Optimize VLPC performance by grouping chips which exhibit similar characteristics
- Cassettes provide mechanical support, optical alignment, and appropriate operating services for proper operation and readout of the VLPCs
- 1024 channels of VLPC readout per cassette organized into eight independent modules of 128 channels
- Lower portion immersed in gas Helium
- Upper portion supports printed circuit board for trigger and readout



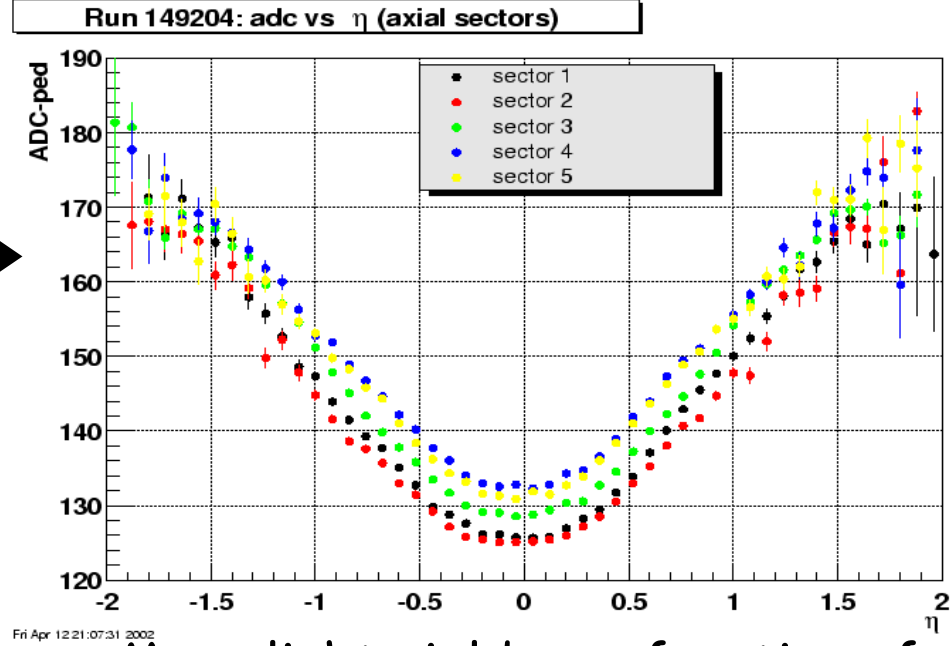
Analog Front End Boards (AFE)



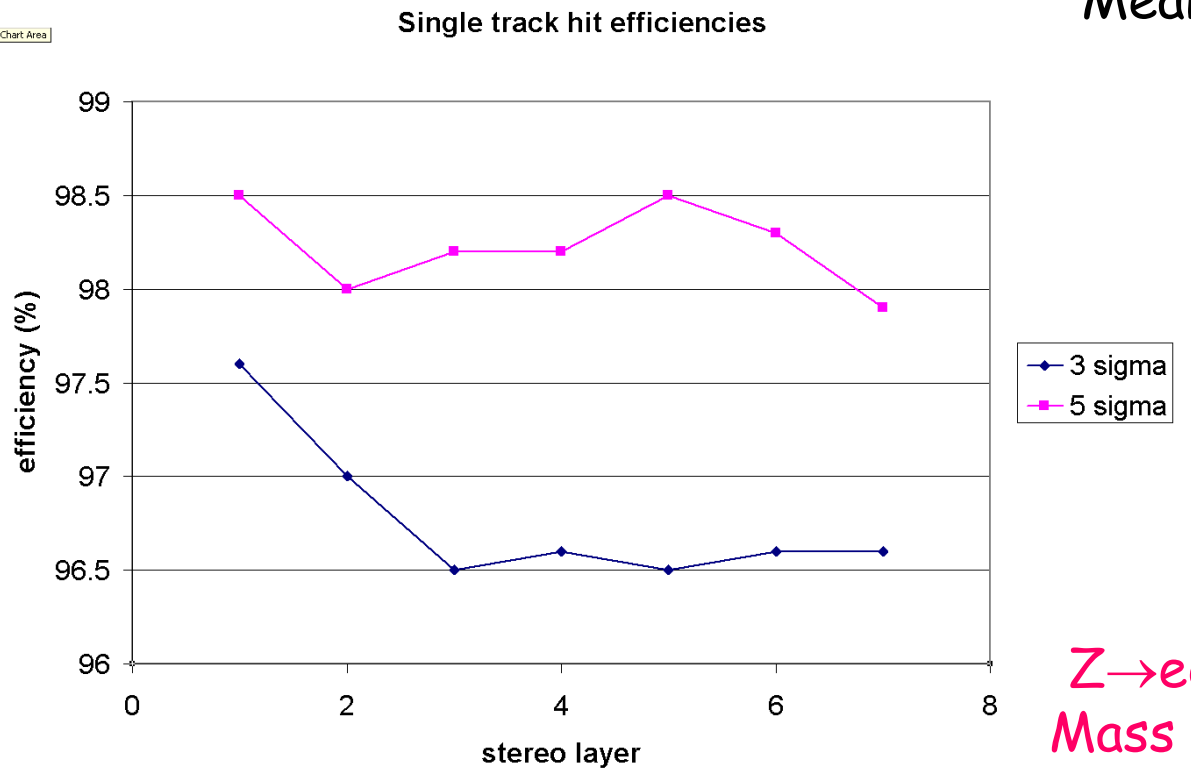
- 512 channels per AFE board
  - ~8 photoelectrons per MIP → ~50 fC signal
  - SVX IIe chip for pulse height information
  - discriminated output for trigger
  - VLPC temperature control and monitoring
    - 9K with ± 0.050K precision
  - VLPC bias voltage control and monitoring
    - 6 to 8 V with ± 0.050V precision
- AFE boards controlled by SEQuencers and data is readout to VRBs (similar to SMT readout)
- CFT axial fully instrumented by Jan 2002
- CFT stereo fully instrumented by April 2002

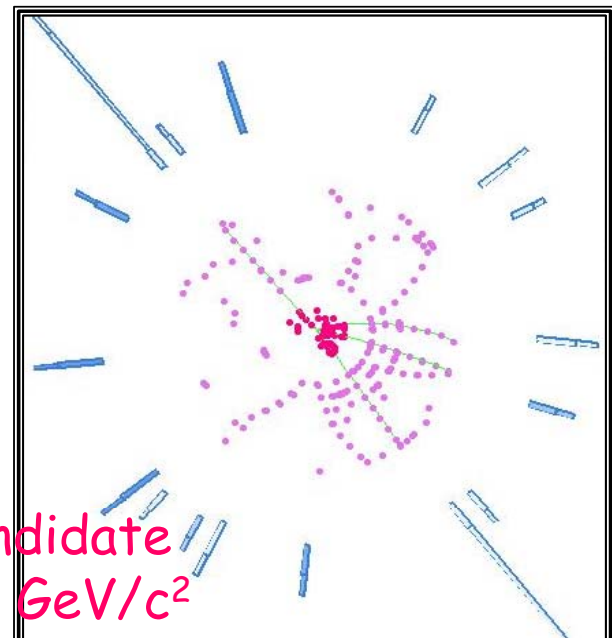
CFT Performance

- Light yield depends upon path length through scintillator
- Using good 15 hit CFT tracks, the probability of a cluster within a 3 or 5 σ search window of track in excluded layer is better than 96.5% or 98% respectively



Mean light yield as a function of pseudorapidity

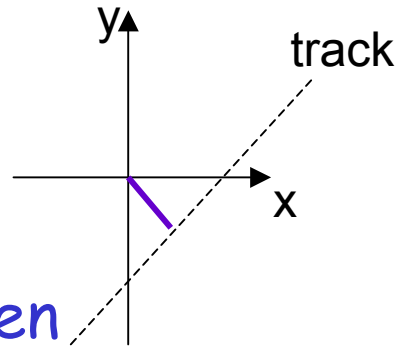


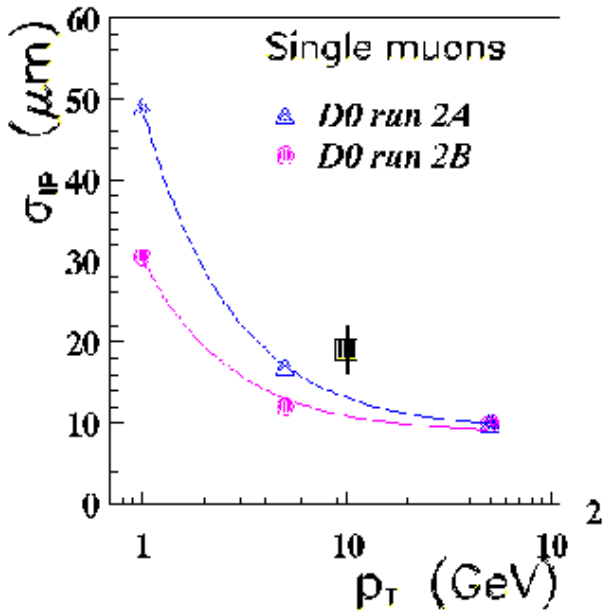


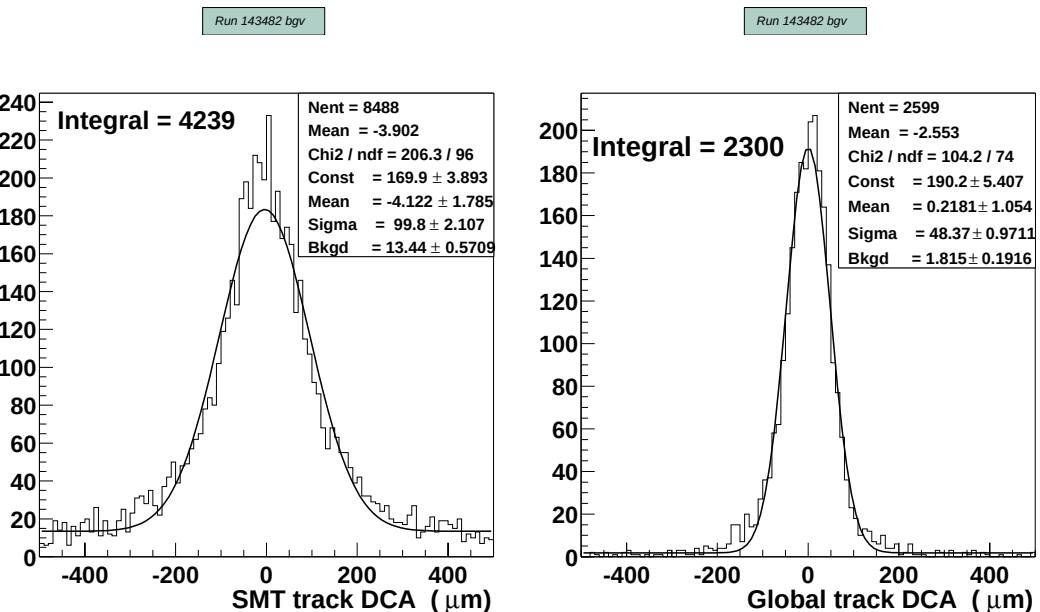
Z→ee candidate
Mass 89.9 GeV/c^2

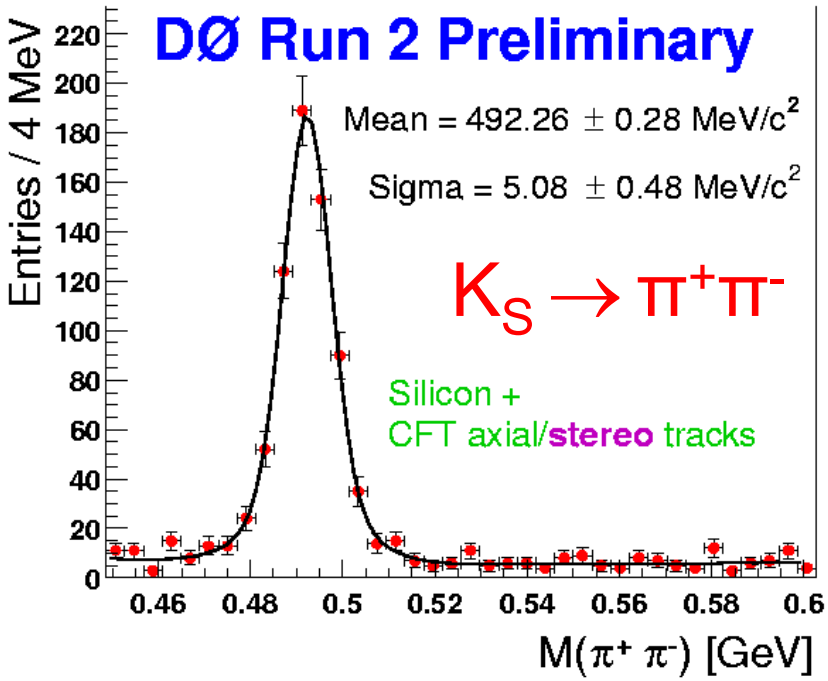
Tracking Performance

- p_T dependent impact parameter resolution at vertex is ≈100 μm using SMT only tracks and improves to ≈ 48 μm when CFT data is combined with SMT data--and is expected to improve further as studies progress

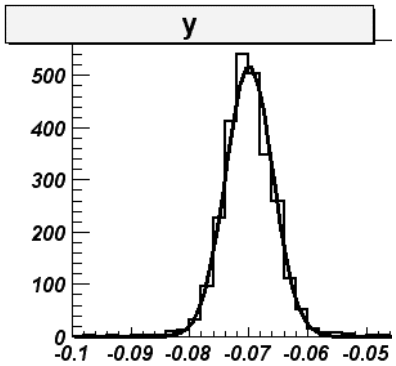


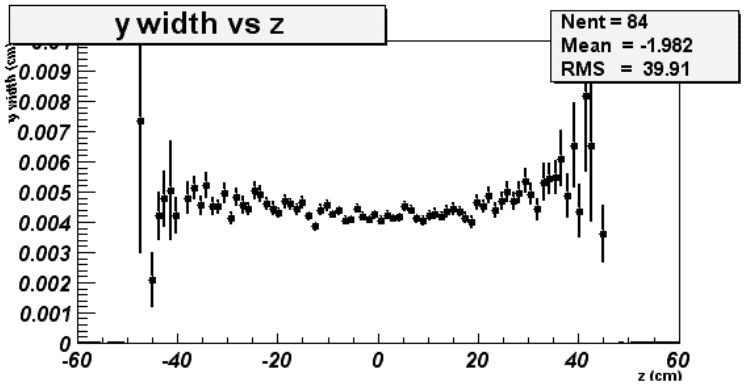


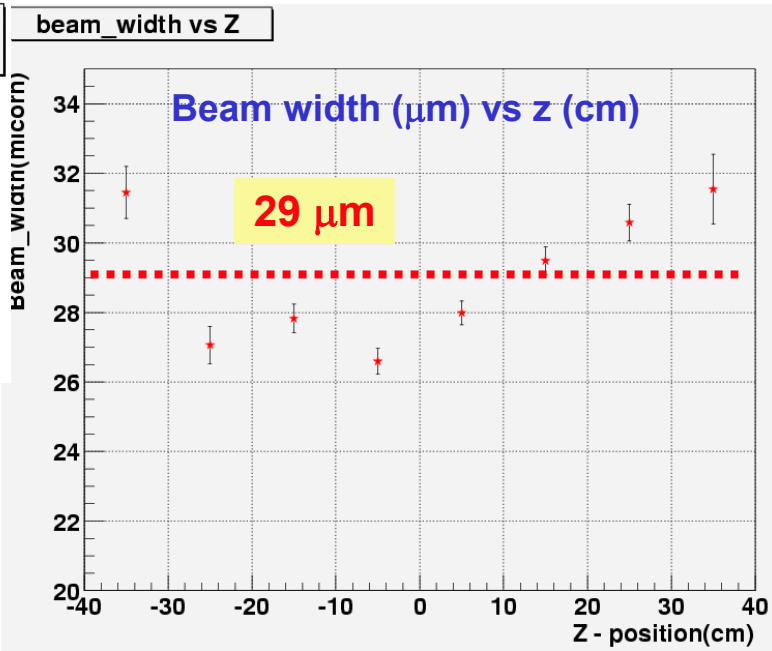




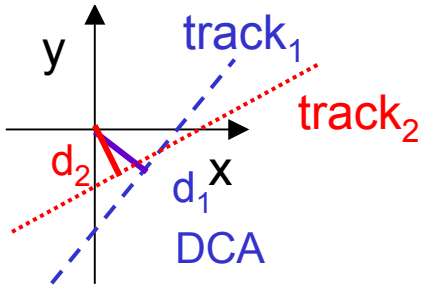
Beam Position and Alignment

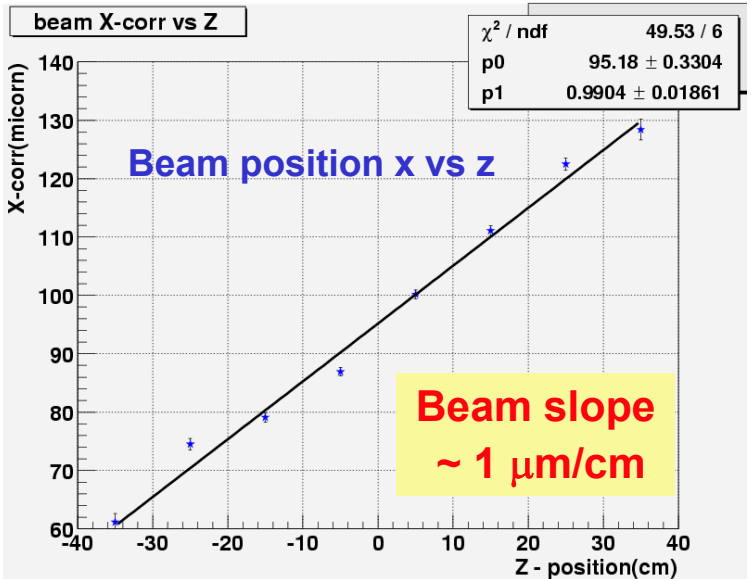


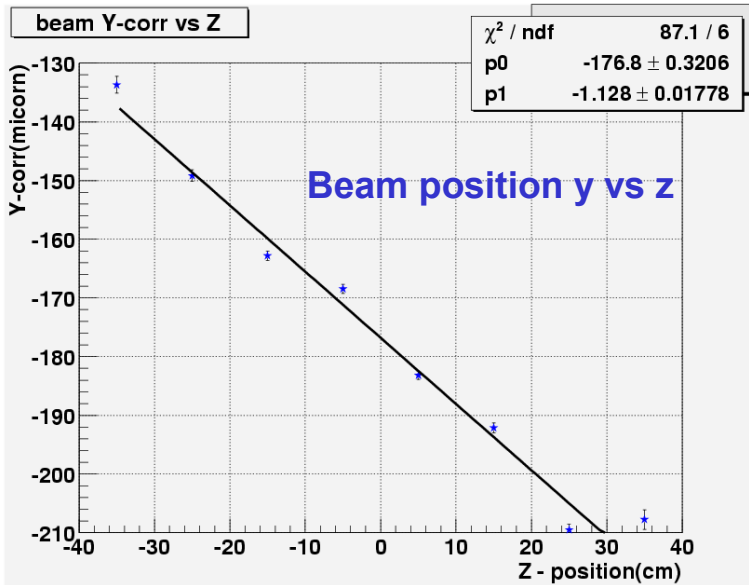




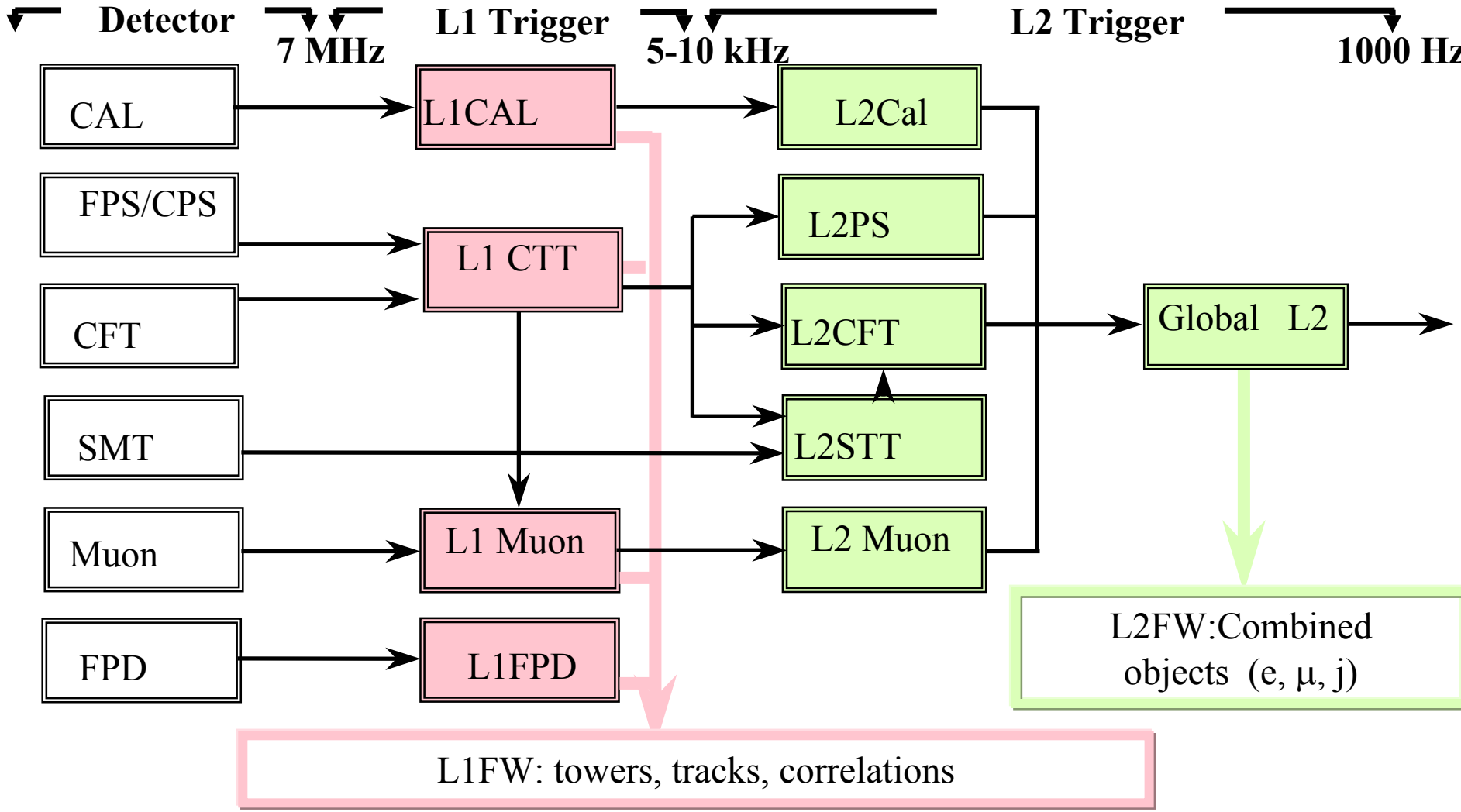
- Impact parameter resolution (DCA) for global tracks (CFT axial + stereo + SMT)
- Compare $d_1 d_2$ vs cos φ_{12} to extract beam width





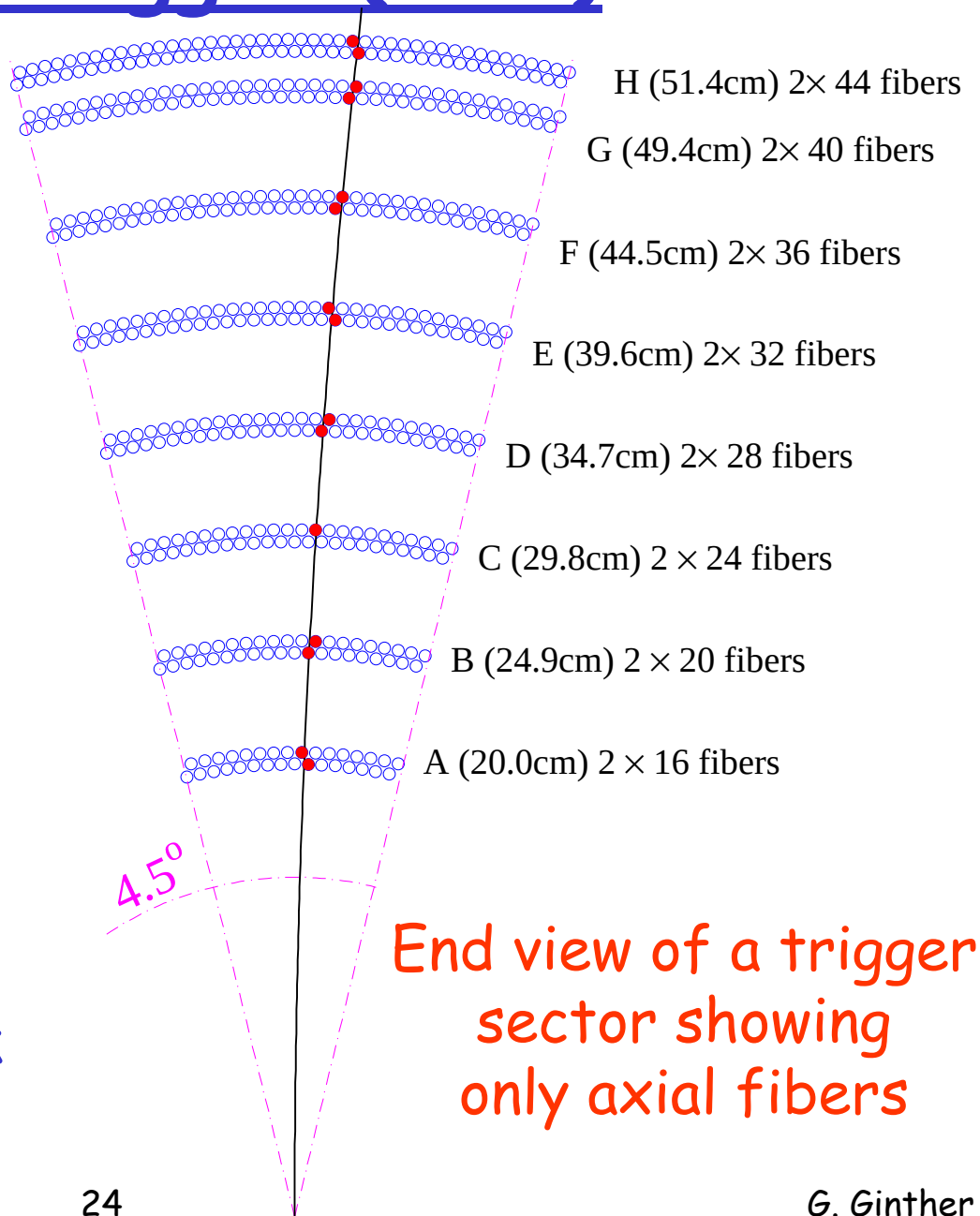


DØ Trigger System



Central Track Trigger (CTT)

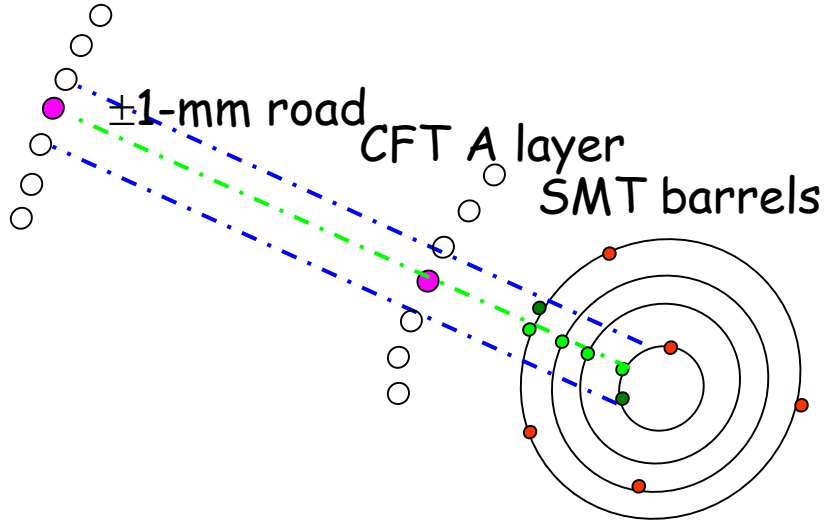
- Counts track candidates identified in axial view of CFT by looking for hits in all 8 axial layers within predetermined roads above four Pt thresholds (1.5, 3, 5, and 10 GeV/c)
- Combines tracking and preshower information to identify electron and photon candidates
- Generates track lists allowing other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

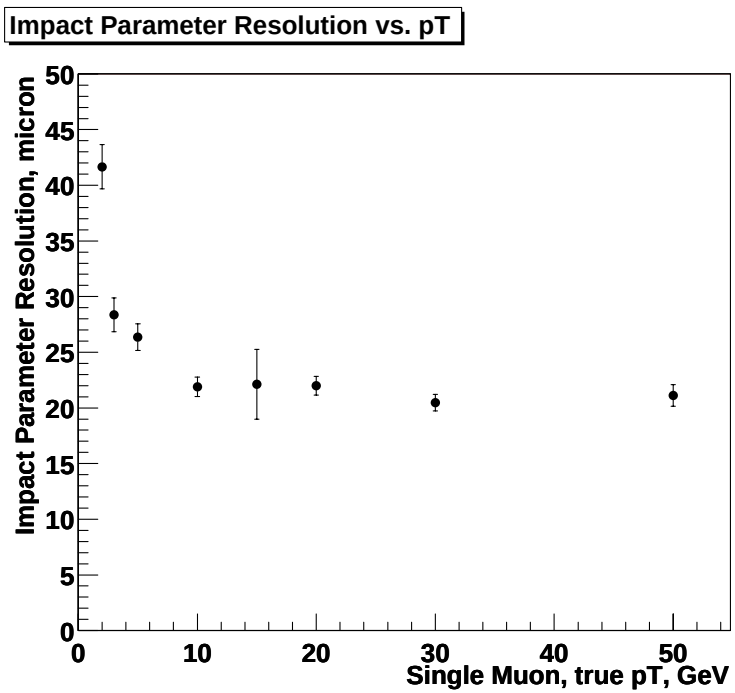


End view of a trigger sector showing only axial fibers

Silicon Track Trigger

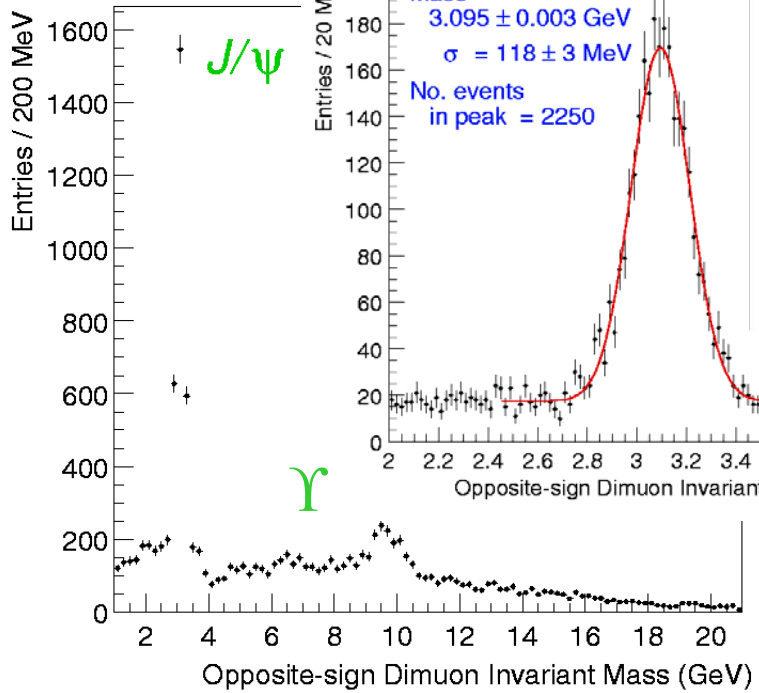
- Combines inputs from CFT and SMT at Level 2 to select events
- Axial clusters matched to ±1 mm wide roads around each CFT axial track via precomputed look up table

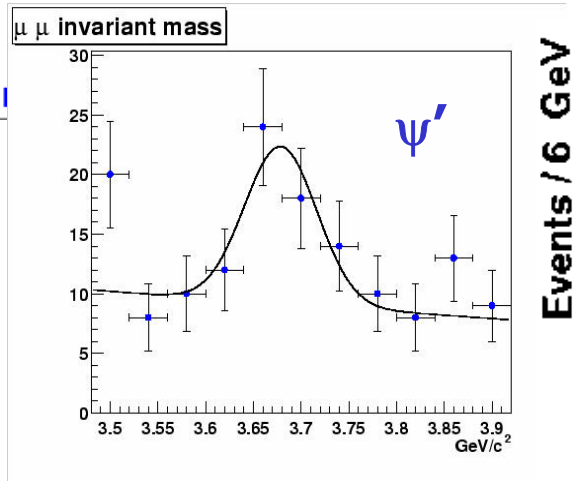




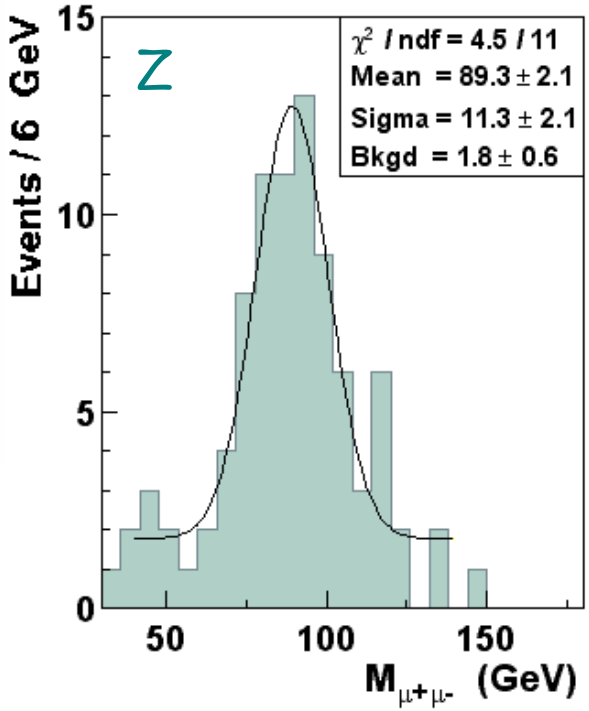
- Track fitting in Digital Signal Processors
- Prototypes of all boards in hand
- Hardware design complete and production in progress
- Firmware and integration tests ongoing

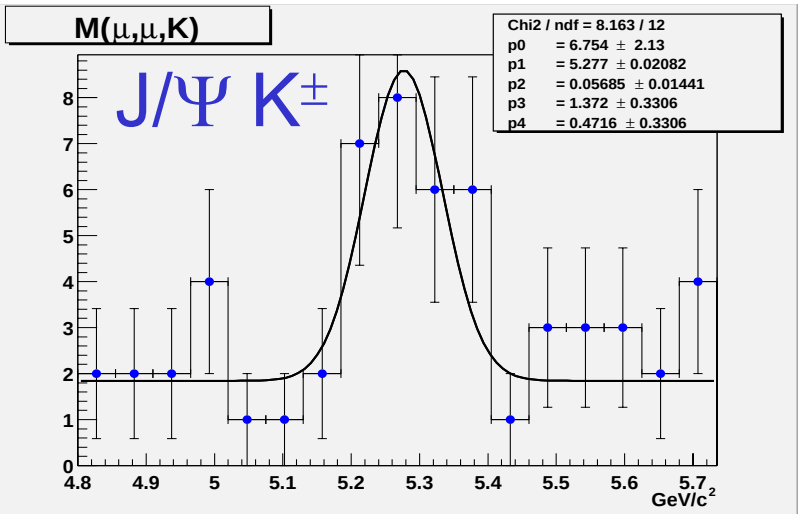
Physics Signals



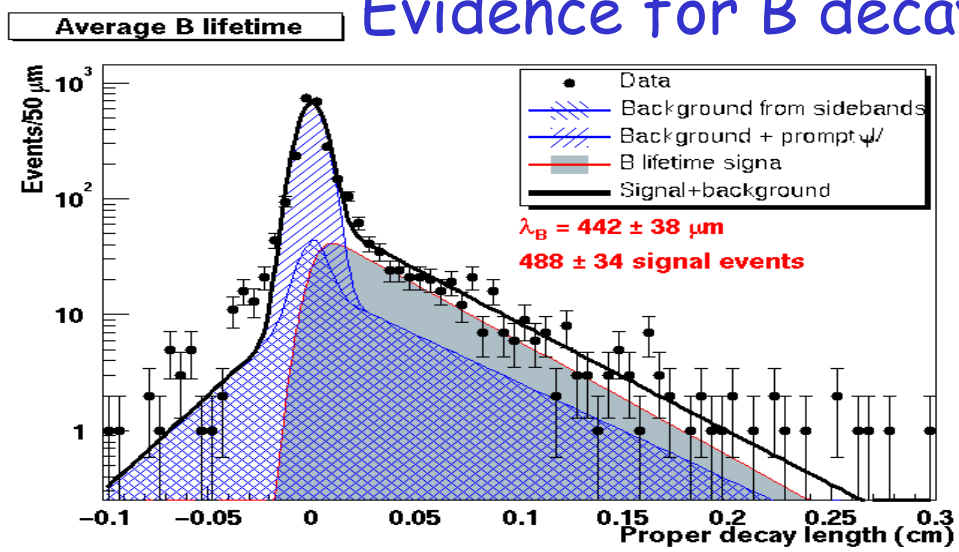


$\mu^+\mu^-$ mass





Evidence for B decays



DØ

The work of many people including some shown here ⇒

Thanks to all of them!

The DØ Tracking System for Run II

- The Silicon Microstrip and Central Fiber Tracking systems are key components of the DØ Upgrade
  - Tracking detectors designed to have good impact parameter resolution over wide range of η
  - Readout system is generally stable and well behaved
  - Detectors are performing well
  - ≈95% of the SMT channels are available for readout
  - > 98% of the CFT channels are currently readout
  - Optimization and tracking refinements continue
  - CFT based triggering is currently being commissioned
  - Silicon Track Trigger hardware and firmware developing
  - Accumulation of data is in progress
  - Physics results are coming in

Additional Related Information

- Silicon detector upgrades for TeV Run II B
  Mark Kruse later in this session
- For an overview of the DØ detector for Run II
  Levan Babukhadia in session RD-2 later today
- For a summary of recent results from DØ
  Meena Narain in Monday morning plenary session

Multiple Interactions