The Central Outer Tracker for Run II at CDF

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9^{th} Pisa Meeting
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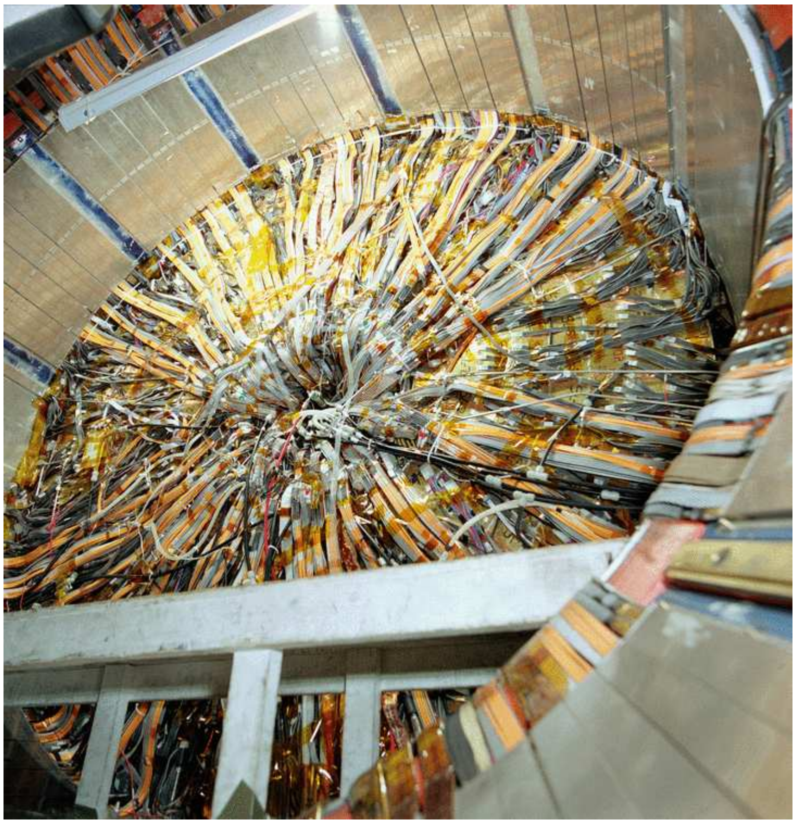

Outline:

- ▷ overview
- ▷ design for Run II upgrade
- ▷ components and construction
- ▷ Run II performance and outlook

COT Collaboration

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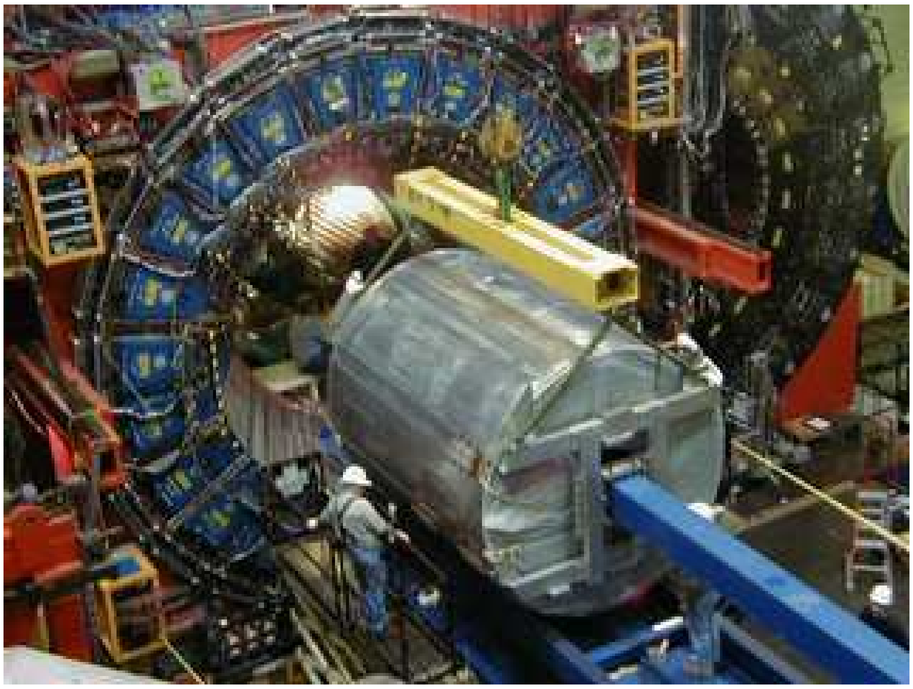
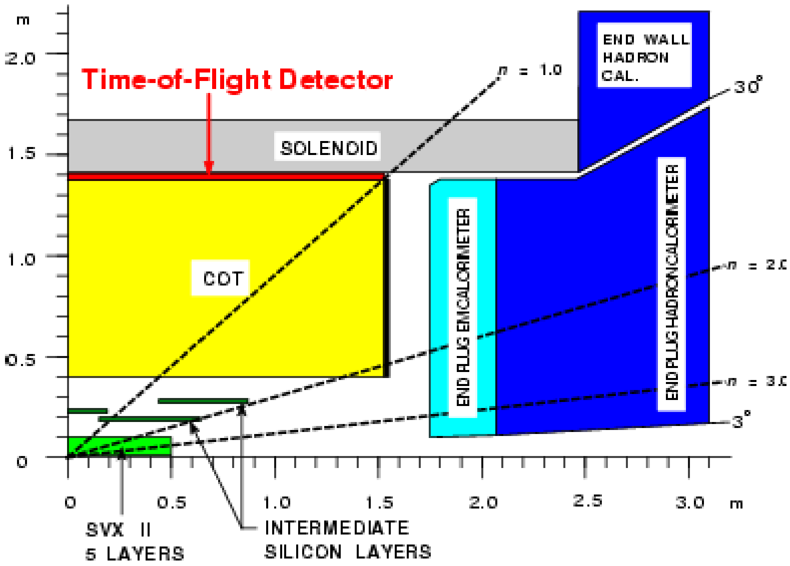
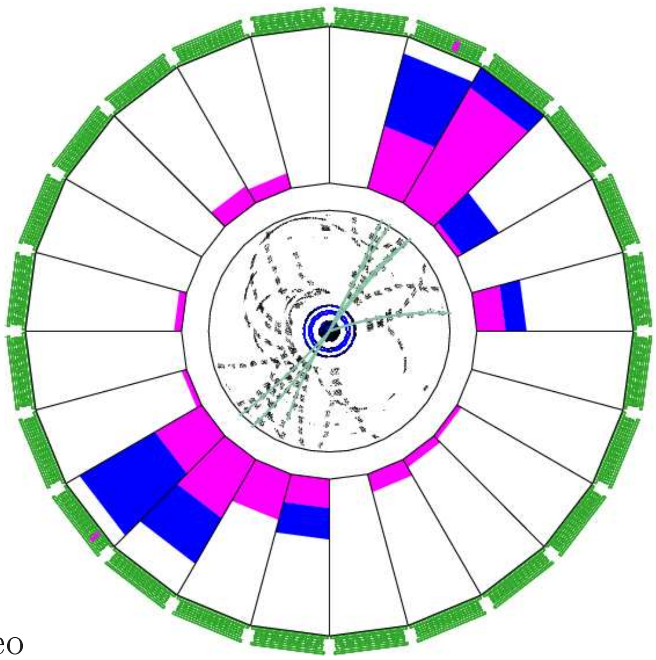


Central Outer Tracker: Overview





- ▷ large, open-cell cyl. drift chamber
- ▷ within 1.4 T solenoid magnet
- ▷ active region:
  - ⇒ 310 cm along beamline
  - ⇒ 43 cm inner radius
  - ⇒ 132 cm outer radius
- ▷ precision r-ϕ tracking, momentum measurement
- ▷ r-z tracking with small-angle stereo
- ▷ fast hit signals for Level 1 track triggers

Design for Run II Upgrade

▷ primary goal:

reproduce Run I CTC performance for Run II luminosity

▷ primary design constraint:

100 ns maximum drift time $\Longrightarrow$ 1/4 cell size of CTC

	Run I	**Run II**	**Run IIb**
bunches	6	36	108
spacing	3500 ns	396 ns	132 ns

▷ more bunches, smaller cell size give similar occupancies at:

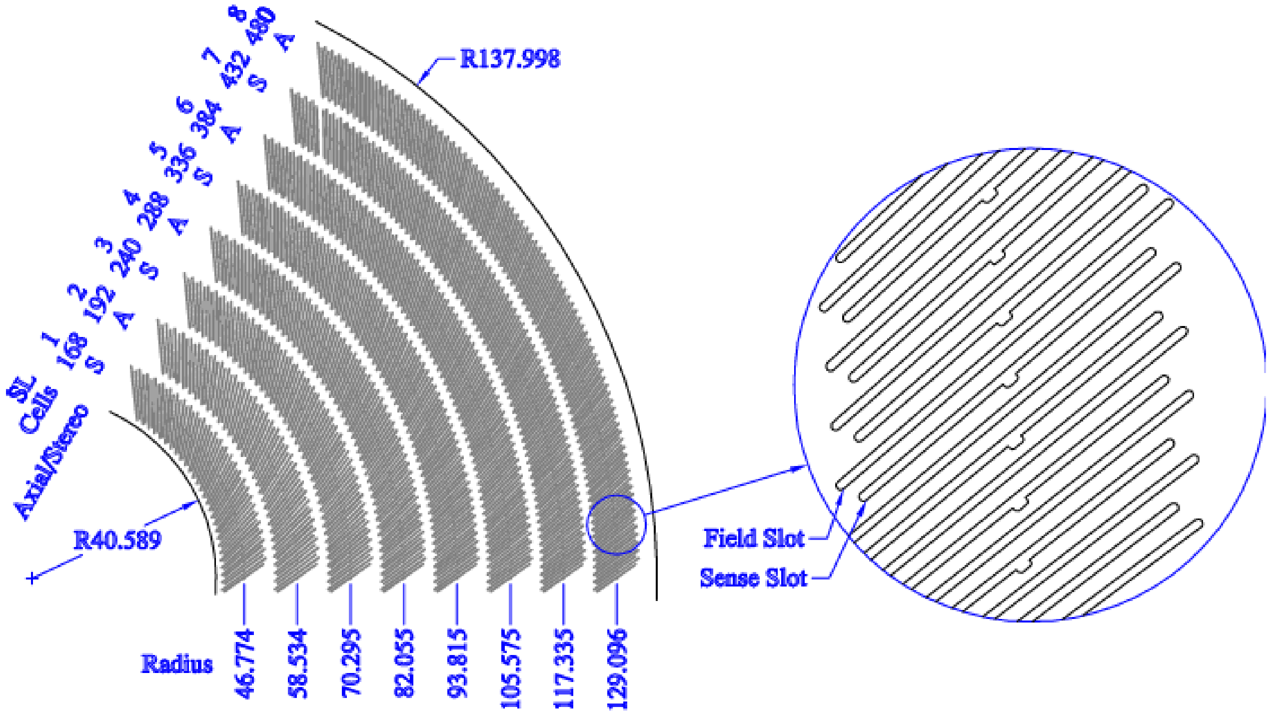
$$\mathcal{L} = 1.6 \times 10^{32}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}\ (36\ \text{bunch})$$
$$\mathcal{L} = 4.0 \times 10^{32}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}\ (108\ \text{bunch})$$

▷ cathode field sheets allow smaller cell (higher field, reduced mass)

▷ improve stereo capability over Run I CTC

	Run I CTC	**Run II [IIb] COT**
drift gas	50:50 Ar/Et + Ethyl	50:50 Ar/Et + Isopropyl
		[50:35:15 Ar/Et/CF_4 + Iso]
max drift distance	3.6 cm	0.88 cm
max drift time	706 ns	177 ns [100 ns]
Lorentz angle (cell tilt)	$\sim 45°(45°)$	$\sim 31°(35°)$ [$\sim 31°(35°)$]
drift field	$\sim$1.3 kV/cm	1.9 kV/cm [2.1 − 2.4 kV/cm]
radiation lengths	1.7%	1.7%
sense-wire layers (SL)	84 (9)	96 (8)
sense-wires/SL	12 (odd SL), 6 (even SL)	12 (all SL)
stereo-angle/SL	$\pm 3°$ (even SL)	$\pm 2°$ (odd SL)
total sense-wires	6156	30240
total wires	36504	63000
endplate load	25 tons	40 tons

COT Endplate



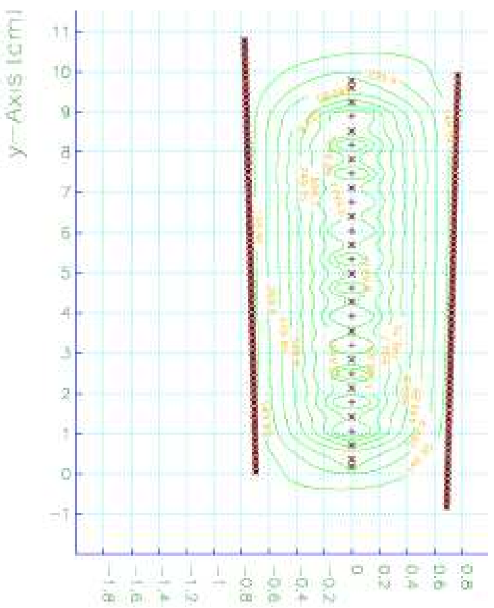
- ▷ composed of 6061-T651 aluminum, 4.128 cm thick, 409 kg
- ▷ machined with end mill due to radius
- ▷ wire planes and field sheets positioned with machined slots
- ▷ # of precision edges kept small (one surface per slot, one edge per notch)
- ▷ 2°-stereo by stepping 6 cells (12 slots)
- ▷ endplate deflection under load tested with vacuum, 0.538 cm at maximum

SL	Cells	Sense Wires
1	168	2016
2	192	2304
3	240	2880
4	288	3456
5	336	4032
6	384	4608
7	432	5184
8	480	5760
	2520	30240

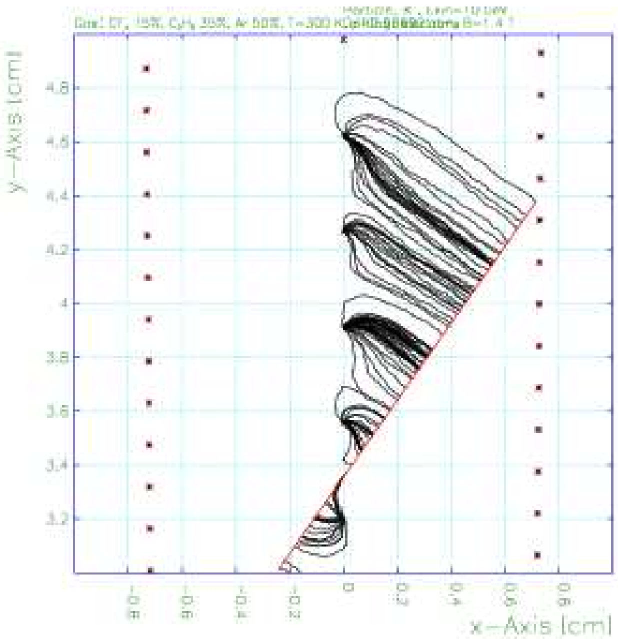
COT "Can" Assembly

- ▷ inner cylinder:
  - ⇒ 0.251 cm thick carbon fiber / epoxy composite (0.99% rad length)
  - ⇒ 25.4 μm outer aluminum shielding
  - ⇒ carries $14,000$ kg of load
- ▷ outer cylinder:
  - ⇒ 8 ϕ-sections of 0.635 cm thick 6061-T651 aluminum (cover plates)
  - ⇒ precision staves set z-distance between endplates
  - ⇒ hatches allow access during stringing
  - ⇒ carries $22,000$ kg of load
- ▷ "Can" assembled vertically with alignment fixture
- ▷ slots pre-strung for pulling wire planes, field sheets

COT Wire Cell Design

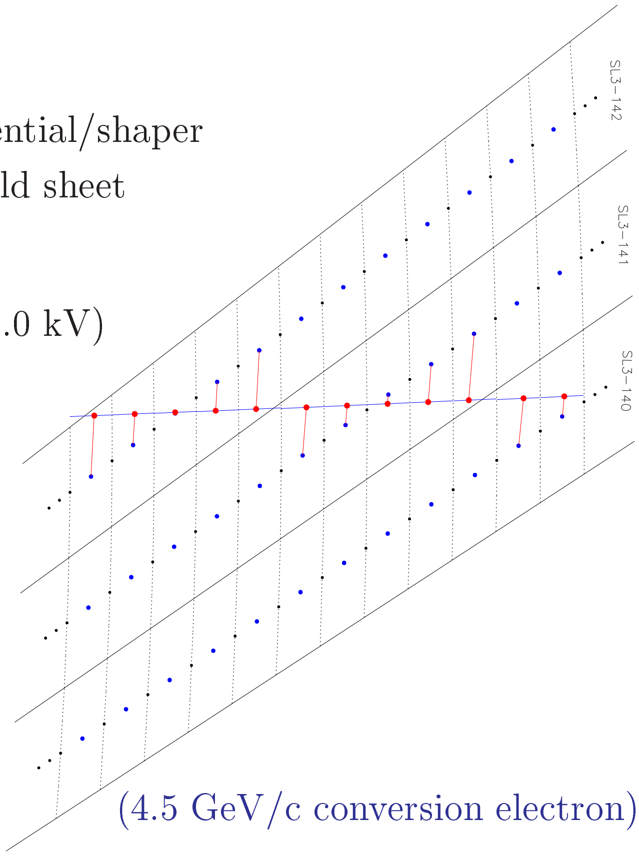


(equipotential contours)



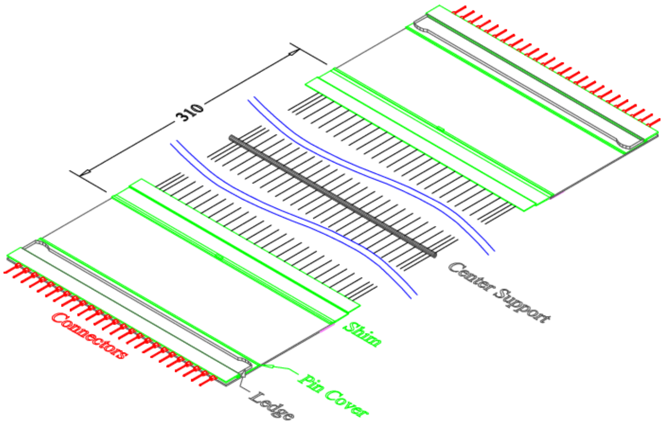
(simulated drift trajectories)

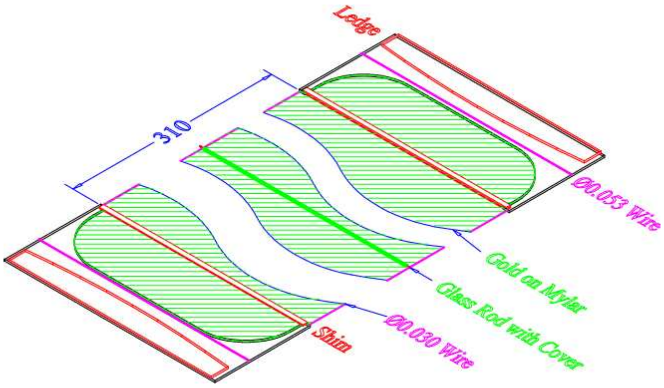
- ▷ "super-cell":
  - ⇒ wire plane of 12 sense, 15 potential/shaper
  - ⇒ separated by cathode plane field sheet
- ▷ cell electrostatics:
  - ⇒ incremented HV for sense (∼3.0 kV) and potential (∼2.2 kV)
  - ⇒ shaper wires (at higher HV) reduce edge effects
  - ⇒ produces uniform drift field $\sim$1.9 kV/cm, $\sim 2\times10^4$ gain
  - ⇒ Lorentz angle near 35° (cell tilt), creates drift trajectory perpendicular to radial track

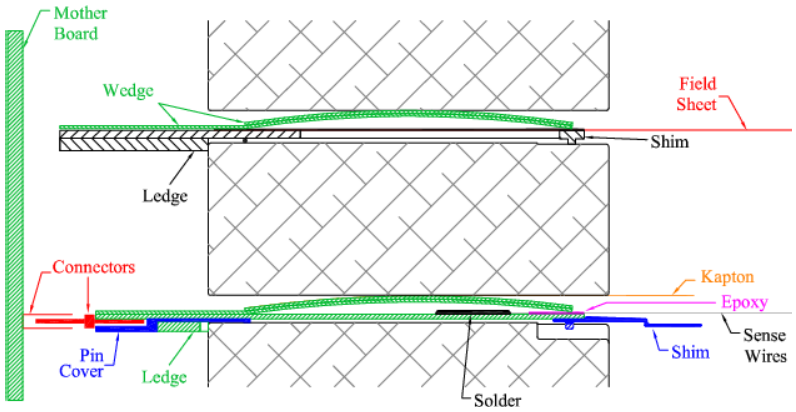


(4.5 GeV/c conversion electron)

COT Wireplanes and Fieldsheets



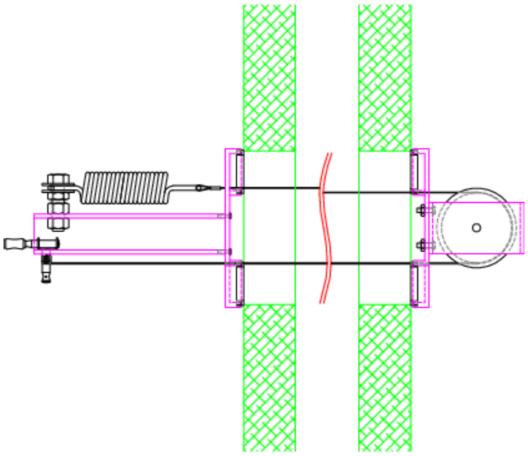


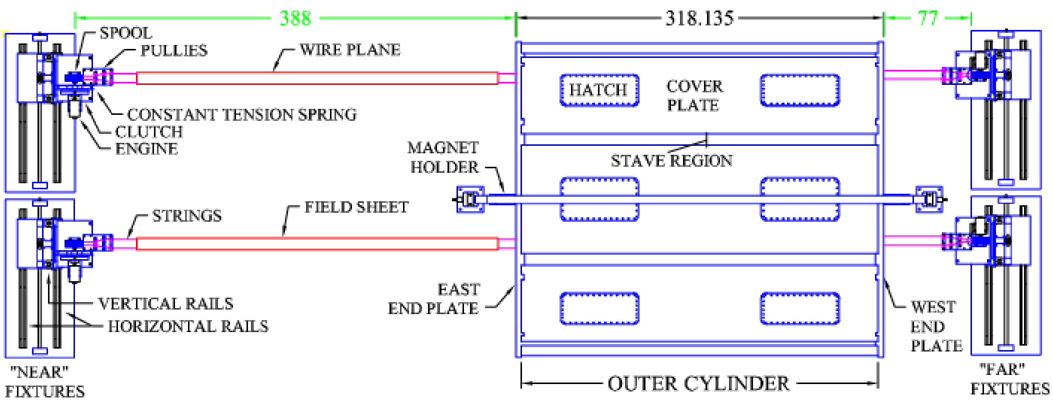


- ▷ wire planes:
  - ⇒ 40 μm diameter gold plated tungsten for all wires
  - ⇒ fiberglass center support ($\sim$12 mg) reduces electrostatic repulsion
  - ⇒ assembled with winding machine, wires attached to G10 end board
  - ⇒ tested for tension and HV (with Sr^{90} source) before installation
- ▷ field sheets:
  - ⇒ gold vapor deposited on 6.35 μm Mylar, aluminum end boards
  - ⇒ 305 μm parabolic SS edge wires to prevent ripple
  - ⇒ 2.4 mm diameter glass tube center support reduces deflection
- ▷ mounted in slots with end board ledges, precision shims, G10 wedges

Wireplane and Fieldsheet Installation

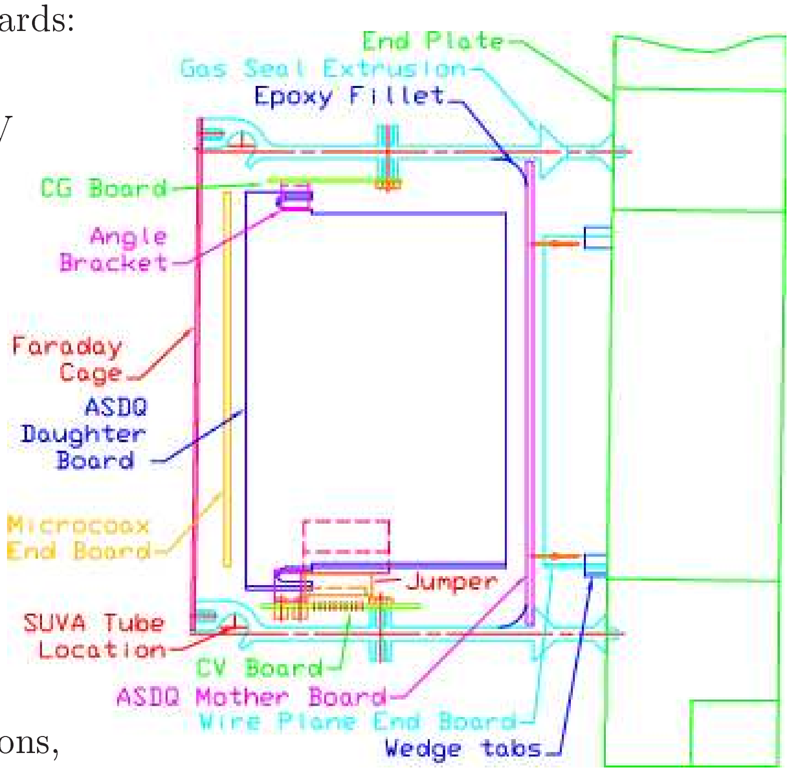
- ▷ chamber placed on rotating fixture
- ▷ end plates pre-tensioned with piano wire, tuner
- ▷ two stringing engines with controllable speed/tension
- ▷ wire planes, field sheets pulled through with pre-strung lines

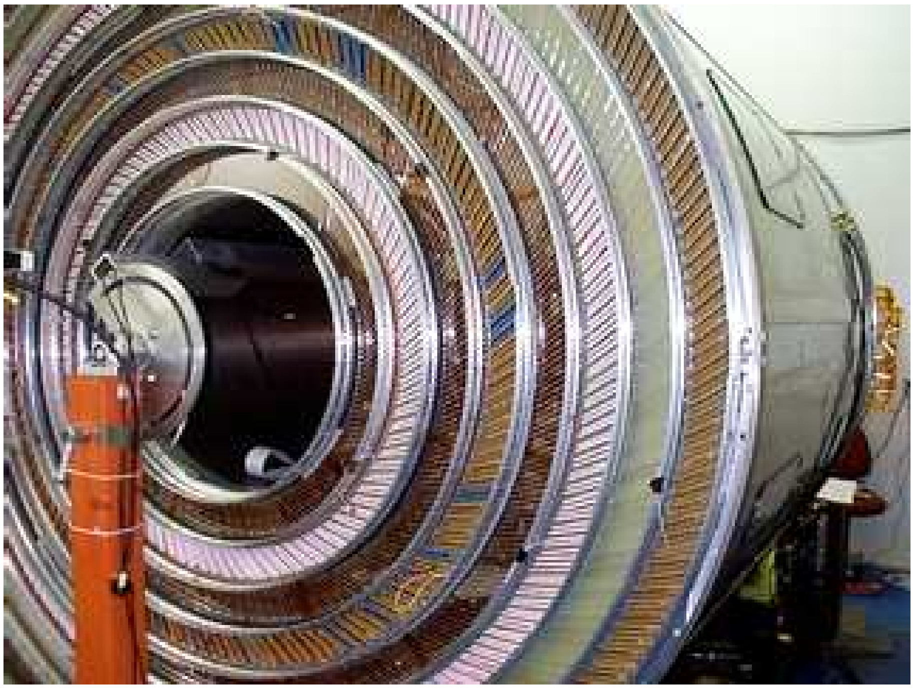




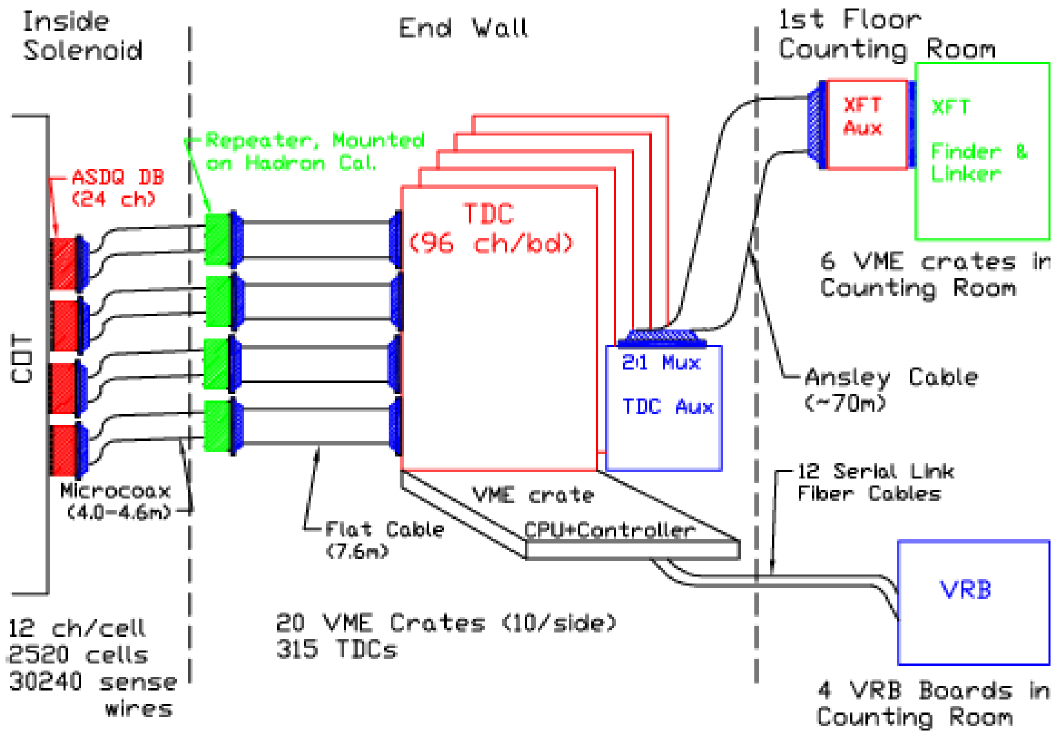
COT Gas Seal

- ▷ HV, readout G10 motherboards:
  - ⇒ form endplate gas seal
  - ⇒ feed-thru sockets for HV
  - ⇒ feed-thru plus blocking capacitors for readout
- ▷ aluminum extrusions:
  - ⇒ mounted on endplate
  - ⇒ base for motherboards
  - ⇒ grounded frame for HV, readout boards
  - ⇒ hold cooling lines and Faraday cages
- ▷ epoxy seals between extrusions, motherboards (leak rate ∼1 SCFH)



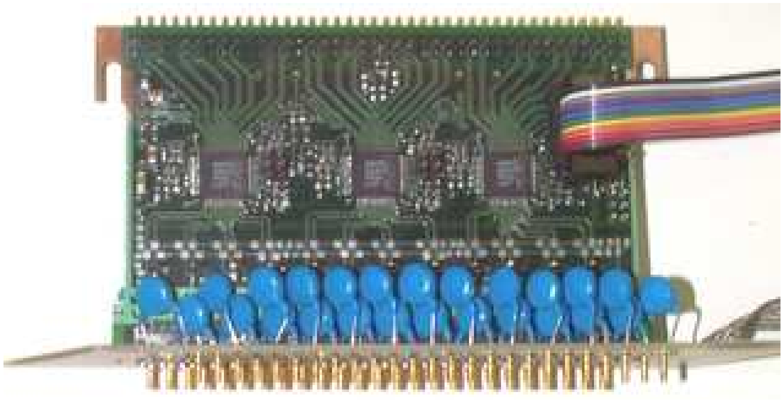


Front-end Electronics



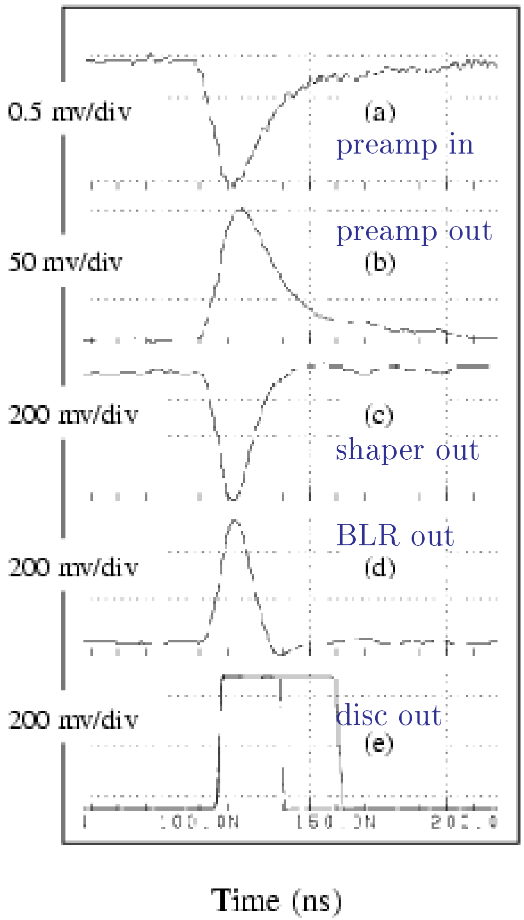
- ▷ alternating readout (SL1,4,5,8 on East; SL2,3,6,7 on West)
- ▷ signal processing, discrimination at chamber face with ASDQ boards
- ▷ differential signals exit solenoid via μ-coaxial cables
- ▷ “repeater” boards echo signals along flat cables to TDC crates
- ▷ TDC’s send multiplexed signals to Level 1 track trigger (XFT), then store signals in Level 1 pipeline and Level 2 buffer
- ▷ accepted event hits digitized, sent to VME readout boards

COT ASDQ



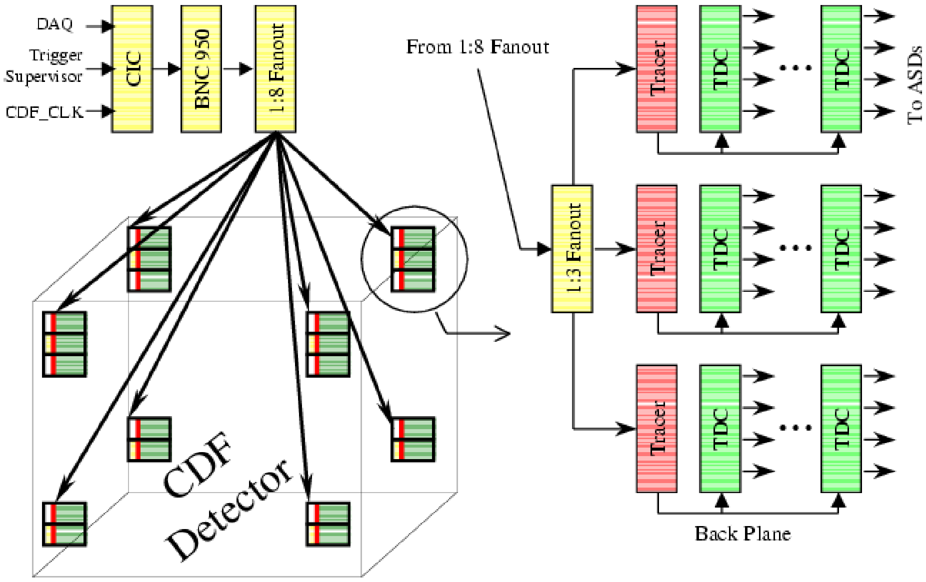
- ▷ 8-channel ASDQ chip:
  - ⇒ resistor and diode input protection
  - ⇒ preamplifier (pseudo-differential, 1.5 mv/fC gain)
  - ⇒ two-stage multipole shaping to cancel positive ion tail (optional attenuation for high gain operation)
  - ⇒ baseline restorer maintains uniform threshold at high rate
  - ⇒ analog monitor output after BLR
  - ⇒ discriminator with 2-10 fC threshold
  - ⇒ charge encoded in LVDS output width
  - ⇒ separate even/odd channel calibration input for channel t_0, Q-to-width
- ▷ 24-channel ASDQ daughterboard:
  - ⇒ houses 3 ASDQ chips (handles 2 cells)
  - ⇒ added input protection, distributes power and control voltages, calibration signals

(simulated radial track)

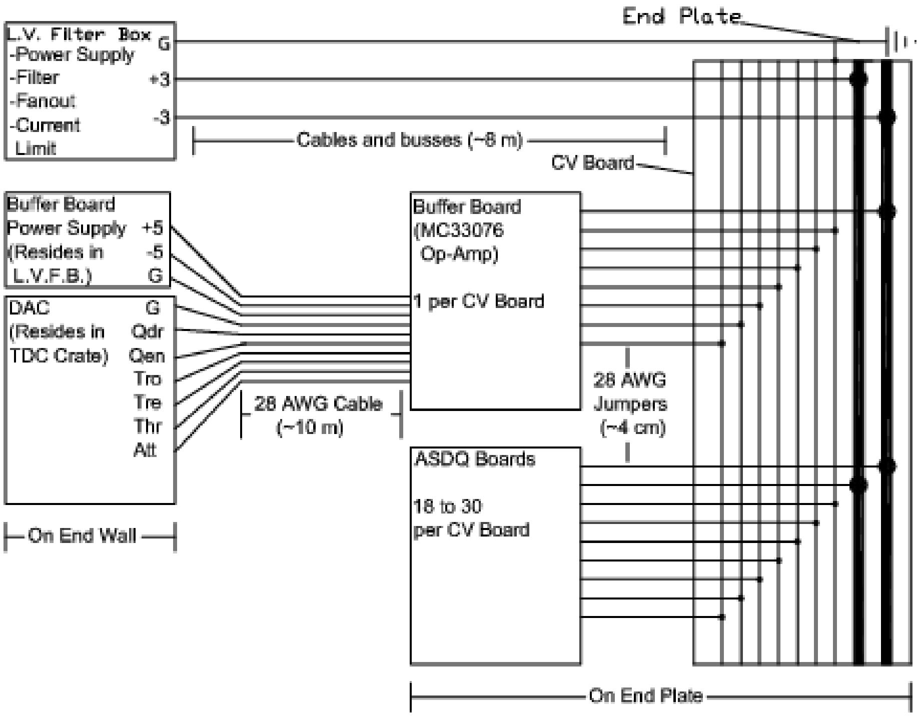


Repeater, TDC, and Calibration

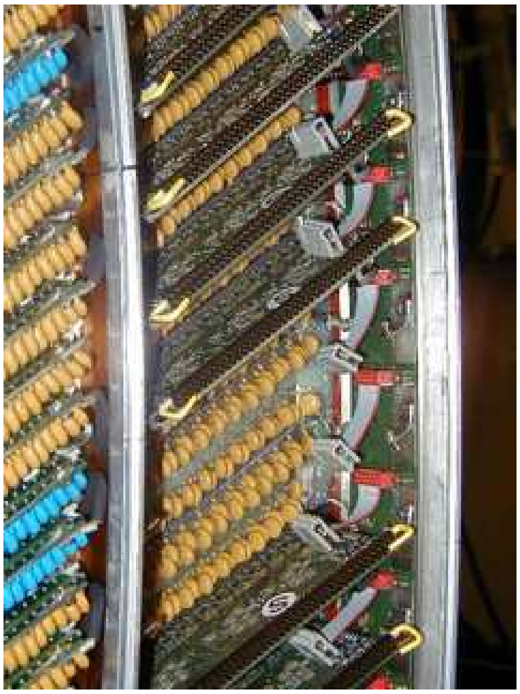
- ▷ "repeater" boards:
  - ⇒ provide ASDQ/TDC ground break
  - ⇒ amplify μ-coax signals onto larger conductor flat cables
  - ⇒ receive -3 V power from TDC via FC
- ▷ University of Michigan TDC96C TDC:
  - ⇒ also used for calorimeter, muon chambers
  - ⇒ JMC96 ASIC measures hit leading/ trailing edges in 1 ns bins
  - ⇒ daughter board sends multiplexed axial hits (in two time bins) to eXtremely Fast Tracker (XFT) for Level 1 trigger
  - ⇒ hits enter 5.6 μsec delay pipeline for L1, stored in L2 4-fold buffer
  - ⇒ JMC96 digitizes 2 μsec of hits (8 max) into drift time, width
  - ⇒ DSP performs individual channel t_0 correction
- ▷ common calibration signal fanned-out to 20 crates of 315 TDC's



Low Voltage Distribution



- ▷ low voltage filter boxes:
  - ⇒ provide ±3 V ASDQ power for each SL/quadrant
  - ⇒ perform voltage regulation and filtering for switching noise
  - ⇒ distribute ASDQ control voltages (CV) from VME DAC modules
- ▷ ASDQ buffer boards drive CV's for each quadrant/octant:
  - ⇒ discriminator threshold
  - ⇒ attenuation/Q-enable switches
  - ⇒ output width control
  - ⇒ even/odd calibration reference



- ▷ circumfrential voltage boards distribute power, CV along ϕ to ASDQ's

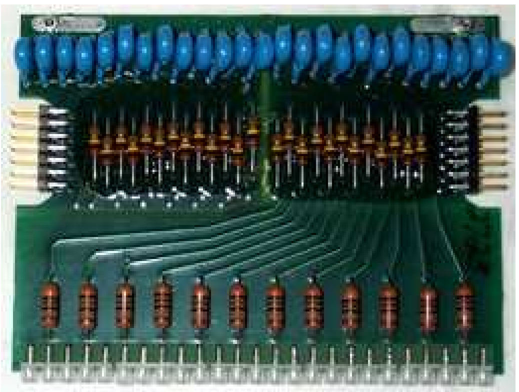
High Voltage Distribution

▷ HV for 200 sense/potential in 8 SL from BiRa VME 4877 crates

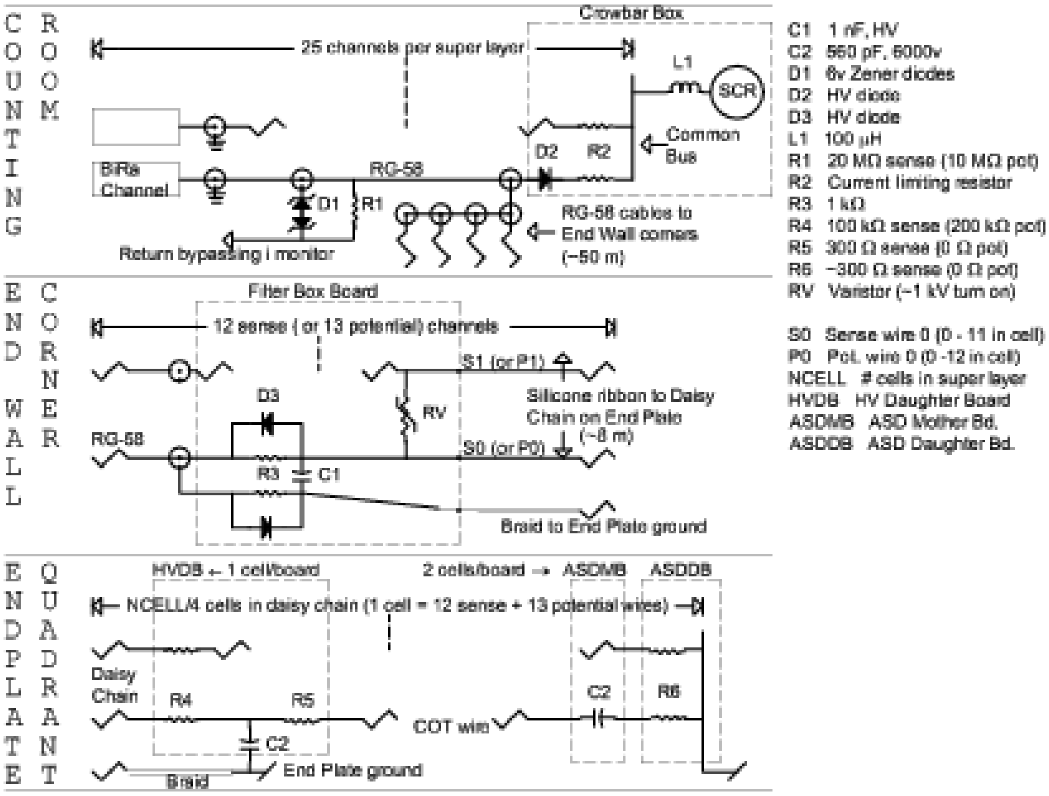
▷ HV crowbar boxes prevent multiple discharge during trips, fan-out HV to quadrants

▷ RG58 cables carry HV to endwall filter boxes with diode protection

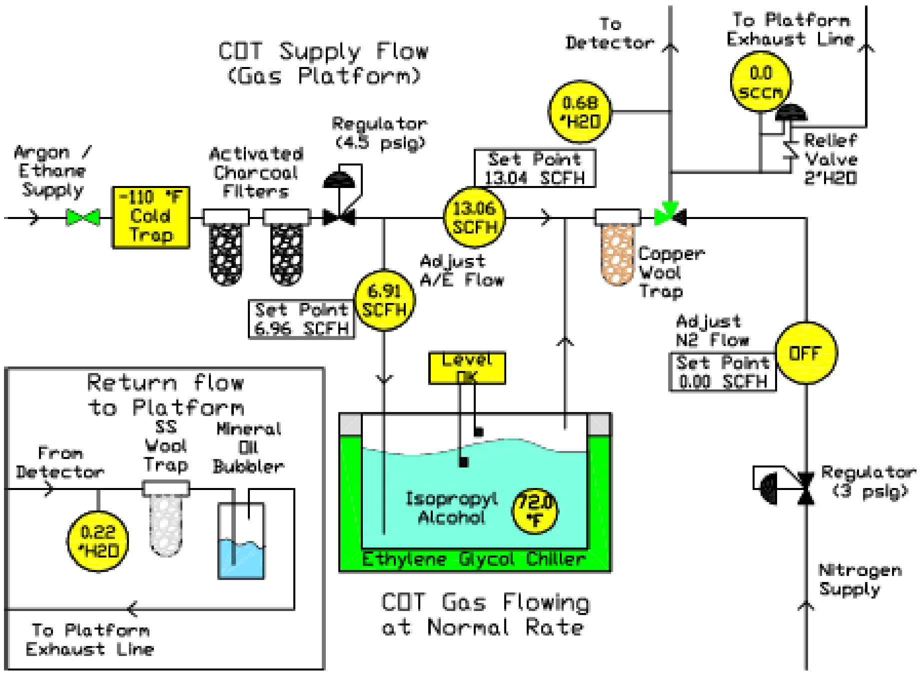
▷ HV traverses silicone ribbon cable to endplate daisy chain



▷ HV daughter boards distribute voltage to wire plane end boards, provide sense wire termination



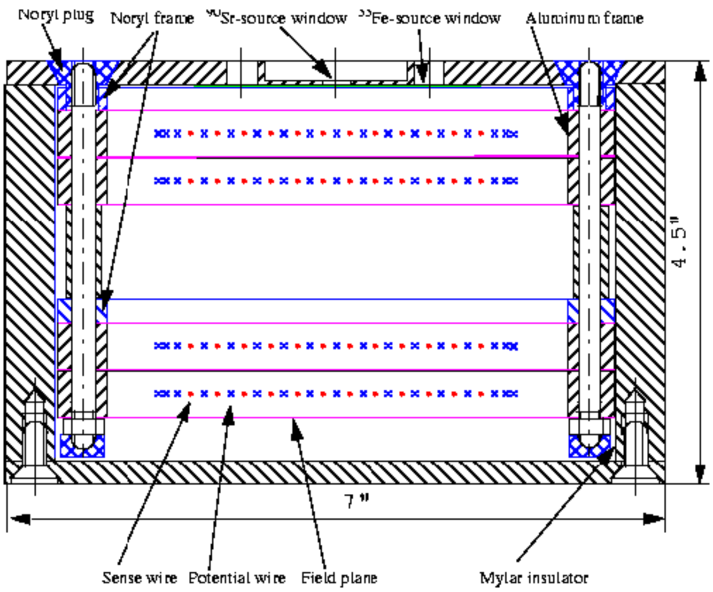
Drift Gas System

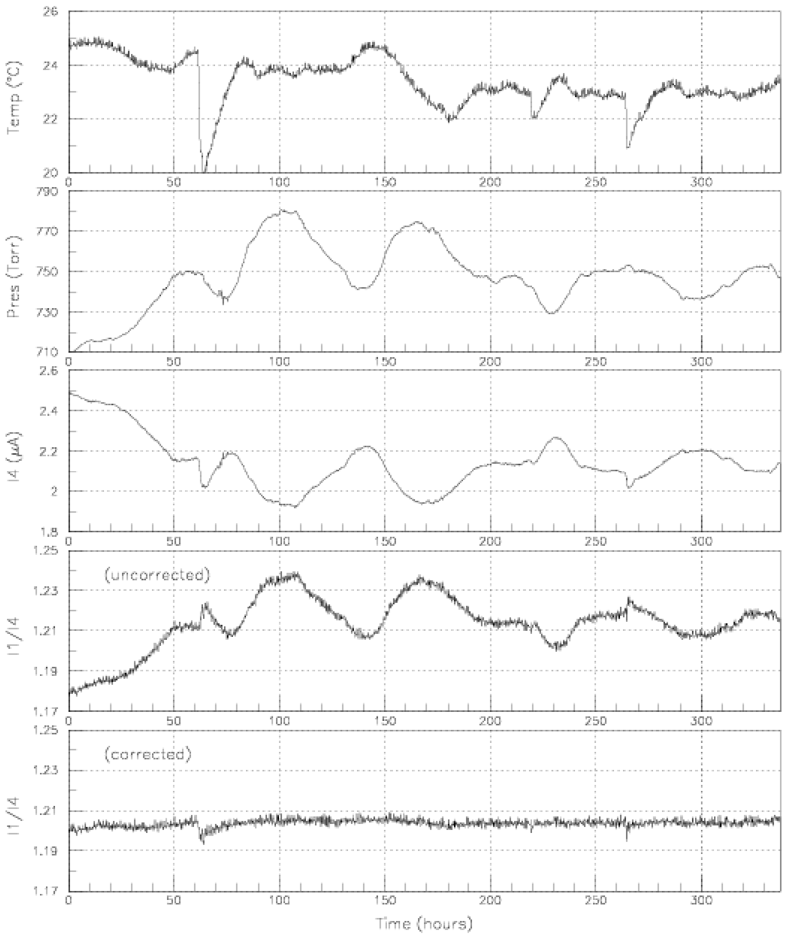


- ▷ −80 °C cold trap (using liquid nitrogen) and activated charcoal filters remove impurities from Ar/Et supply
- ▷ 1/3 of supply sent through isopropyl alcohol bubbler at 22 °C (for 1.7% alcohol concentration) to reduce aging effects
- ▷ heated copper wool trap removes aerosols from bubbler
- ▷ stainless steel tubing delivers Ar/Et to chamber face
- ▷ nitrogen purge tents over endplate prevent flammable gas buildup, maintain low humidity for electronics

Chamber Monitoring and Aging

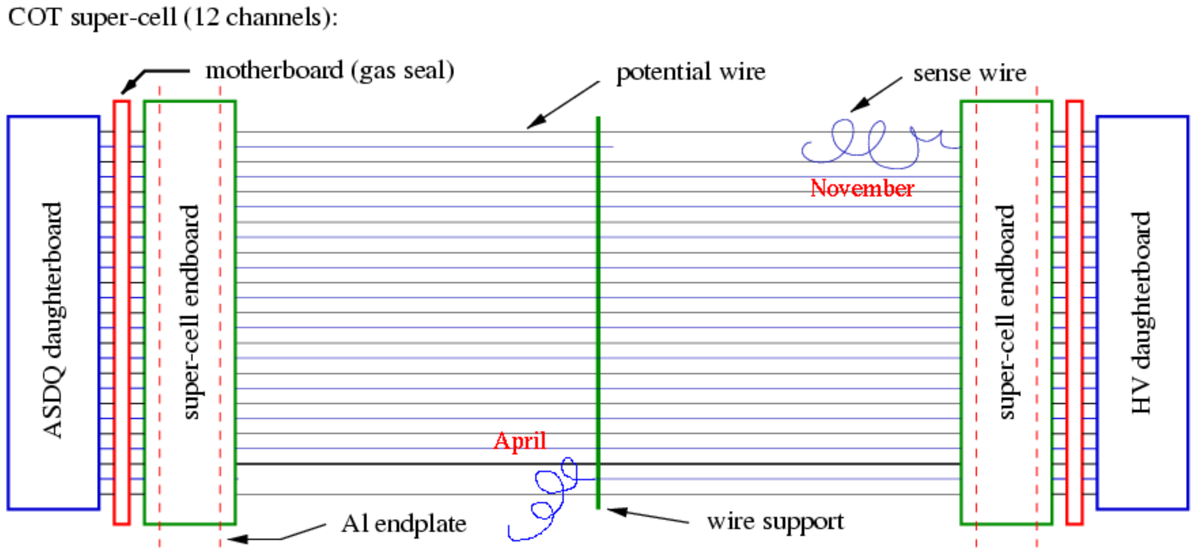
- ▷ gas monitor chambers sample drift gas at several points
- ▷ contain four 12 cm wire planes under HV with Sr^{90} source
- ▷ drop in gain due to aging measured from wire currents
- ▷ use ratio of currents to remove T/P dependence
- ▷ current aging measurement: < 5 %/C/cm





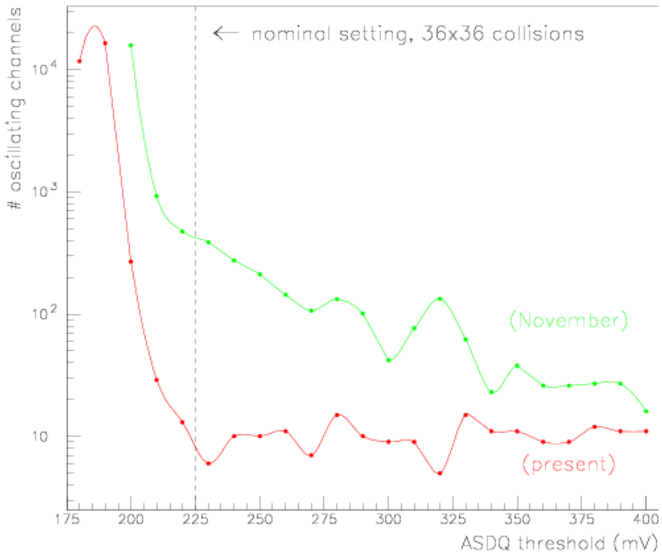
COT Run II Operation

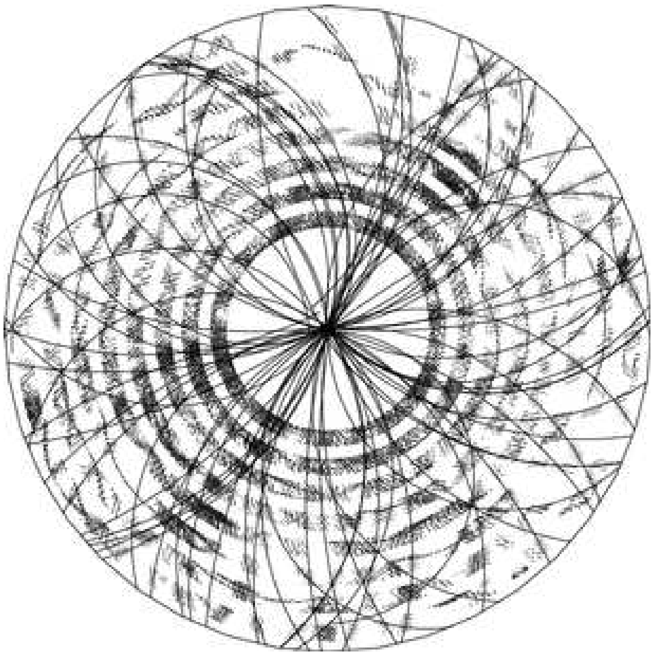
- ▷ tested during November 2000 commissioning run with partial TDC's
- ▷ fully operational for beginning of Run II, March 2001
- ▷ $>$ 99% of channels have nominal functioning
- ▷ occasional HV tripping mitigated by disabling single sense wire
- ▷ Fall 2001: problems with failing TDC crate PS due to beam loss, fixed
- ▷ two broken wires (11/01 and 04/02) fixed within few-day accesses

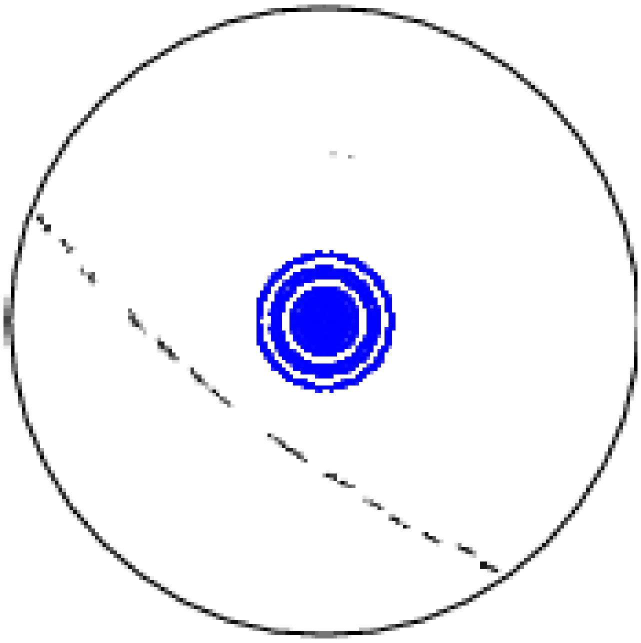


Chamber Performance: Threshold

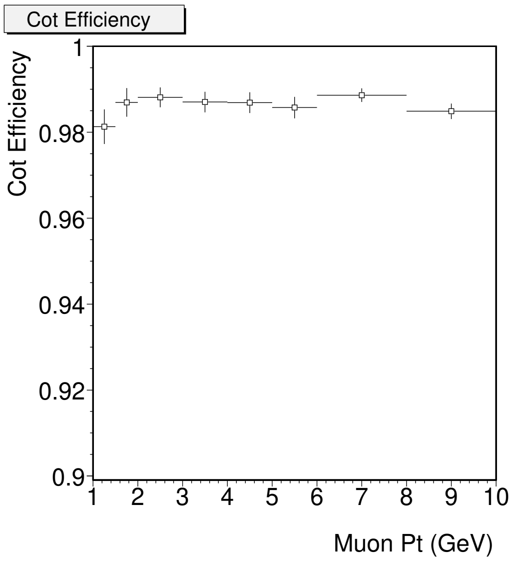
- ▷ design goal of 3 fC ($\sim$ 270 mV)
- ▷ grounding improvements to HVDB after November 2000 commissioning run
- ▷ present threshold: 2.3 fC (225 mV)

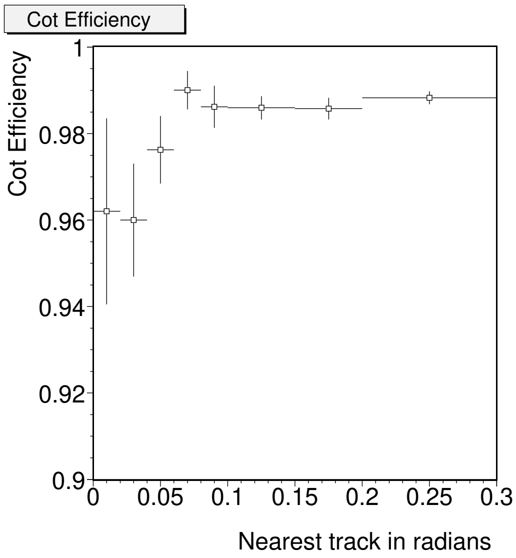




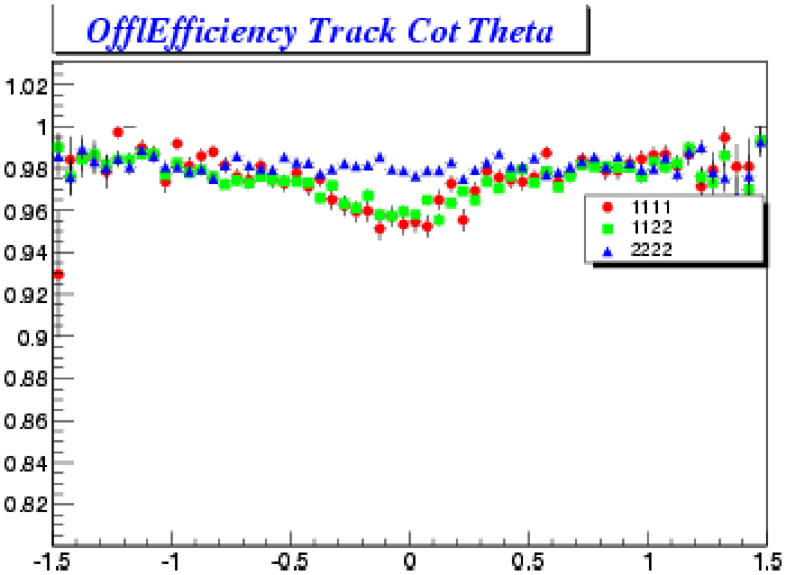


Chamber Performance: Efficiency

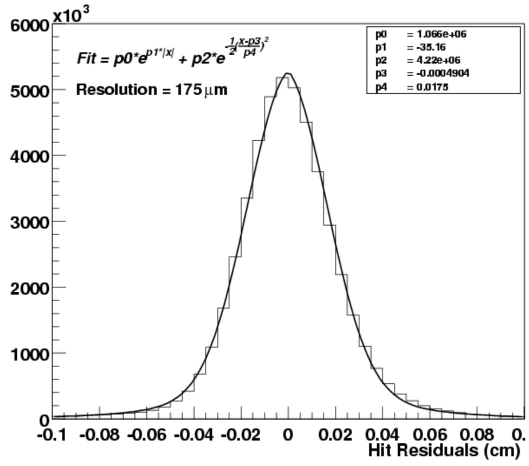


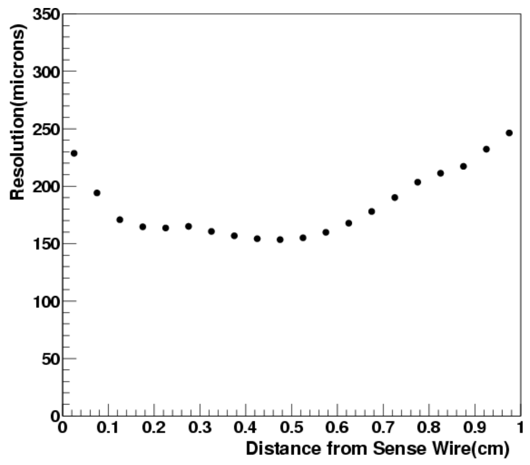


- ▷ high single-hit efficiency provides ∼99% tracking efficiency
- ▷ uniform for track $p_T > 2$ GeV/c, depends on track isolation
- ▷ more restrictive L1 track trigger shows drop at small η, mitigated by reducing thresholds

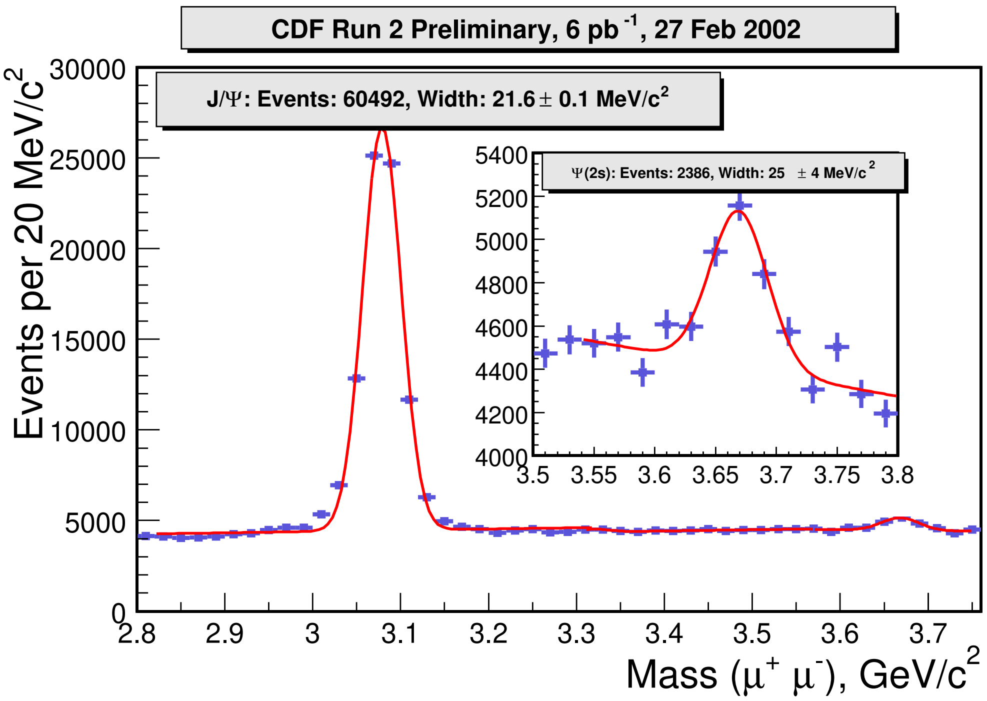


Chamber Performance: Resolution





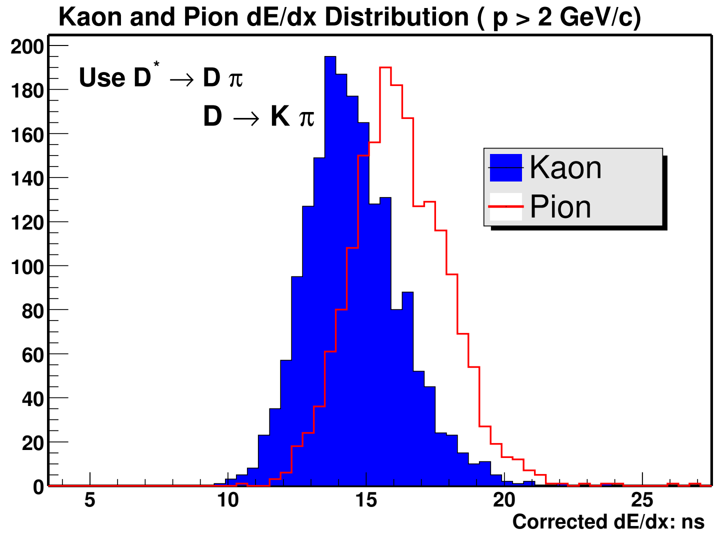
- ▷ measured COT resolution: 175 μm
- ▷ meets design goal, similar to 180 μm Run I CTC
- ▷ degrades with track aspect angle, proximity to sense wire and field sheet
- ▷ providing excellent event reconstruction for Run II physics



COT dE/dx measurement

▷ K-π separation: 1.7 ns ($\sigma = 1.6$ ns)

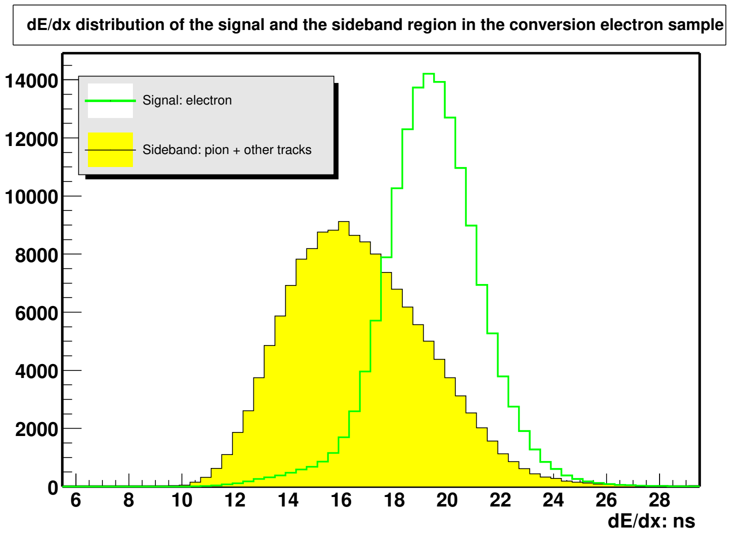
⇒ 1-σ separation up to 10 GeV/c, decreases to 0.75-σ by 30 GeV/c



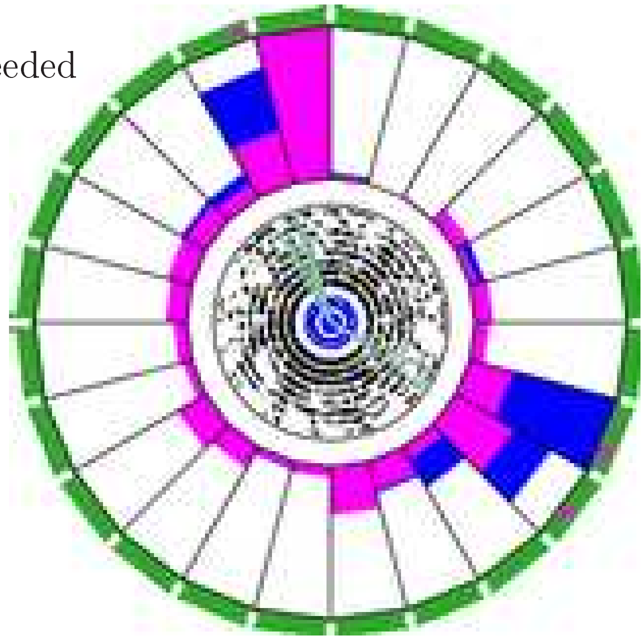
▷ e-π separation:

⇒ compare conversion electrons with $\Delta \cot\theta > 0.06$ sideband

⇒ 2.7 ns separation ($\sigma = 2$ ns) below 4 GeV/c, decreases with p



Summary and Run IIb Outlook



▷ the CDF COT has met or exceeded Run II design goals for:

⇒ discriminator threshold

⇒ hit position and momentum resolution

⇒ dE/dx separation power

⇒ chamber aging

▷ planning for Run IIb luminosities:

⇒ will reach eventual bottleneck with readout rate:

- may need new VME readout sheme
- investigating replacement TDC's using FPGA

⇒ handling high rates on inner superlayers:

- "projective" geometry by deadening inner layers at large $|z|$
- apply two-sided readout to select hits by z-position