T.M. Liss 4/28/05

# Commissioning CDF for Physics

## An Historical Look at 1999-2002

# CDFII – A New Detector

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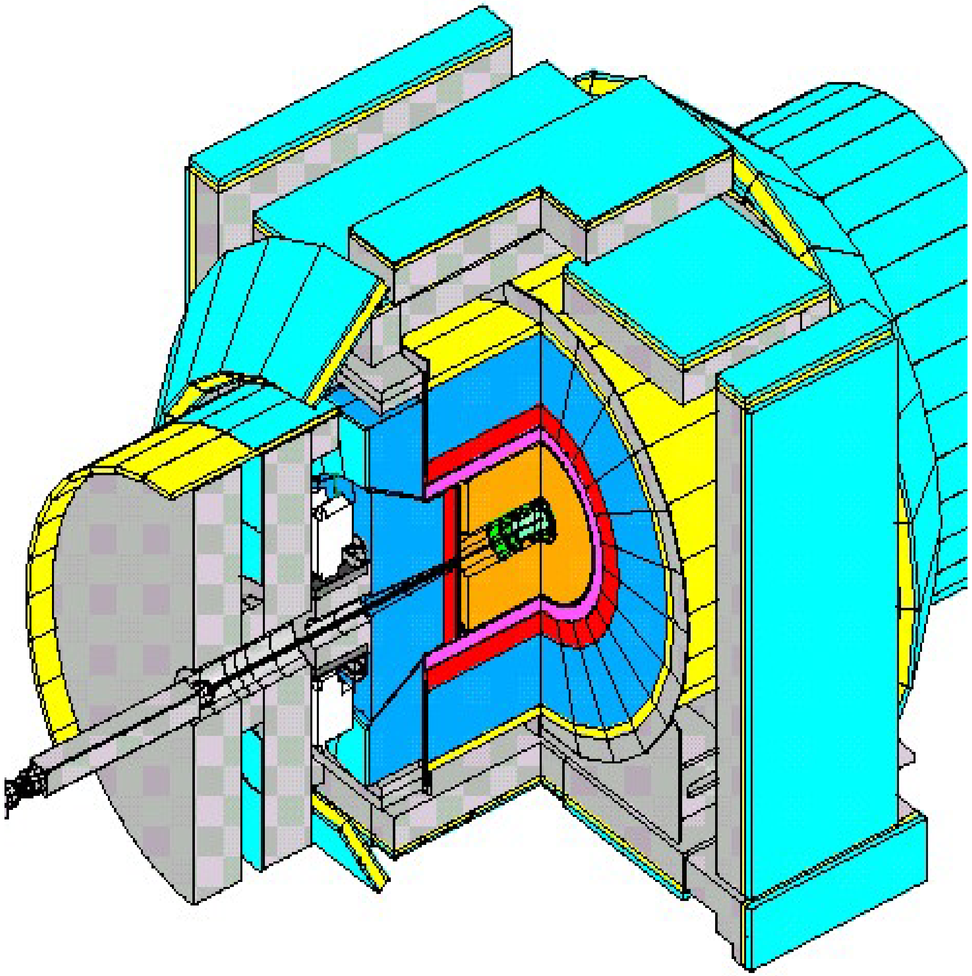

- Endplug Calorimeter
- Tracking
  - Silicon Vertex Detector
  - Intermediate Silicon Layers
  - Layer 00
  - Central Outer Tracker
- Front End Electronics
- Trigger (pipelined)
- DAQ System
- Muon systems
- Luminosity Monitor
- TOF
- Offline Software

# Detector Commissioning Stages

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- Early: 1999-2000 (detector incomplete)
  - Integration of components into DAQ
    - Daily running – pedestals, calibration runs

      November 1999: Three system readout test (DAQ w/ multiple readout systems: Calorimeter/TDC/Si DAQ

      January 2000: L1 calorimeter trigger established.
  - Cosmic Ray Running
    - Once L1 trigger established, begin timing-in of systems
    - Steady increase in fraction of components read-out

The ability to partition the DAQ is crucial during this period

# Detector Commissioning Stages

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- Sept.-Oct. 2000 Commissioning Run
  - Si “Barrel 4” only
  - Many other systems partial
  - COT just barely on-line (1st cosmics seen just days before roll-in)

The commissioning run had some of everything, and enough to allow us to shake down much of the system prior to the beginning of Run II operations.

- Nov. 2000-March 2001
  - Complete the detector
  - Continued integration work
  - Daily cosmic running
- March 2001-February 2002
  - Commission for physics data

# 1999-2000



Commissioning without Beam

# Timing-In CDF Electronics

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Major steps to timing-in CDF electronics

1. Synchronize clock and control signals to all electronics subsystems
   - Done without beam
2. Vertical Synchronization of each Front-end electronics subsystem with corresponding Trigger chain (e.g. ADMEM-L1 Calorimeter-L1 Decision). Synchronize each Front-end with Beam:
   - Coarse (132ns steps) – reading out the right clock cycle
   - Fine (1-5ns steps) – getting all the charge in the right cycle
     - Done with cosmics, tuned with beam
3. Horizontal Synchronization across Front-end and Trigger systems
   - Done with cosmics

P. Wilson/Jan. 2000

# CR Activities

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- Establish L1 calorimeter/muon triggers
- Basic Level 3 filtering established
- Steady build-up of more complete read-out
- Development of detector monitoring
  - peds, ped widths, occupancy
- Set calorimeter readout thresholds
- Measure calorimeter noise rates (e.g. 1 PMT in plug).
- Development of error handling & useful error reporting
- Establish regular, reliable running of the detector.

# Commissioning L1 Trigger w/ Cosmics

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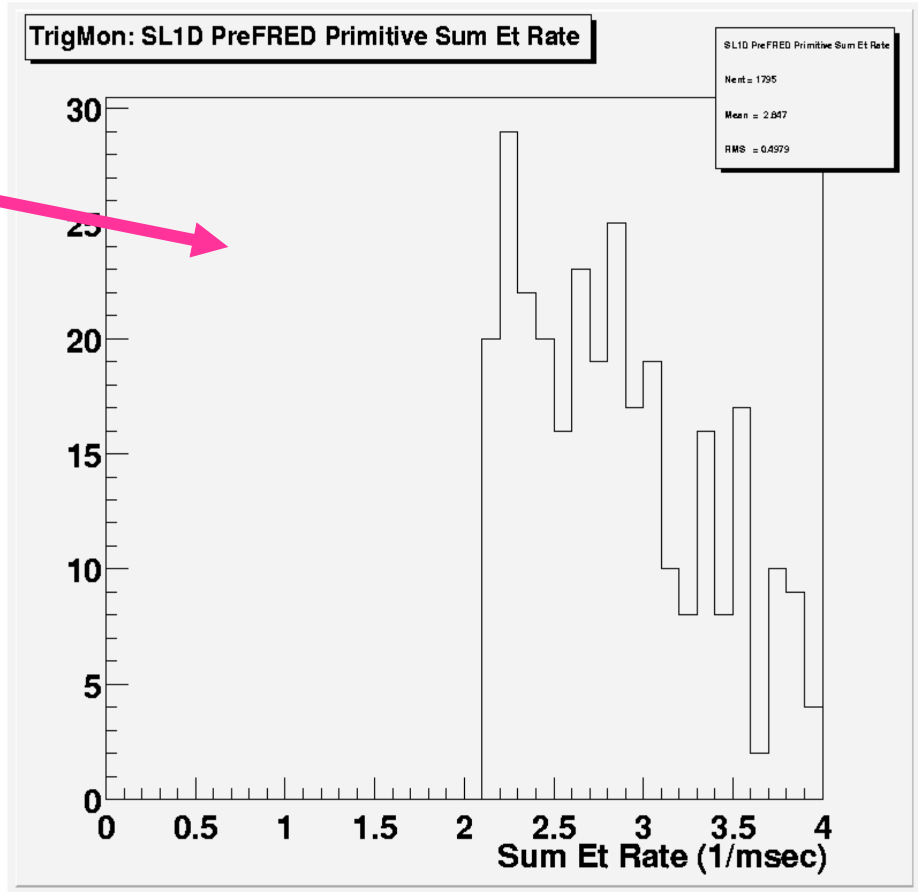
- **Level 1 Calorimeter** Triggers commissioned with cosmics
  - Sum Et,
    Single tower,
    Missing Et triggers
    Muon "primitives"

Histogram made with online monitor.



# The Commissioning Run

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| Date | 9/5 | | 9/18 | | | | | | 10/31 |
|---|---|---|---|---|---|---|---|---|---|
| Week | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 | 6 |

| Period | Roll-in | A | B | C |
|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Lum. | 10^29 | | | | 10^30 |
| Bunches | proton | 1 x 8 | 1 x 8 | 36 x 8 | 36 x 36 |

- Period A : Proton only beam (1.5 wks)
- Period B : Observe first collision (1 wk)
- Period C : Subsystem commissioning (3.5 wks)

Y.K. Kim/Sep.2000

# What Was There

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## Status of Detectors

(at the beginning of the run)

| System | | Coverage | Limitation |
|---|---|---|---|
| Track | COT | $30° < \phi < 120°$ $210° < \phi < 330°$ | TDC |
| | Si-4 | $45° < \phi < 105°$ | |
| Muon | CMU | full | |
| | CMP | Top, Bottom, South Wall | |
| | CMX | North-West | TDC |
| | IMU | North-West | TDC |
| Calor. | CEM | full | |
| | CHA | full | |
| | WHA | full | |
| | PEM | full | |
| | PHA | full | |
| | CES | $225° < \phi < 255°$ (West) | electronics |
| | PES | $225° < \phi < 315°$ (West) | electronics |
| | HadTDC | $225° < \phi < 270°$ | electronics |
| Lum. | CLC | full | |
| Beam Loss Mon. | | full | |

## Status of Triggers

(at the beginning of the run)

| System | | Coverage |
|---|---|---|
| L1 Trigger | Calorimeter | full |
| | Muon stub | full |
| | XFT | full |
| | XTRP | $30° < \phi < 90°$ |
| | 2-Track | none |
| | Global | full |
| L2 Tagging | Cal | full |
| | SVT | $45° < \phi < 105°$ |
| | XCES | $225° < \phi < 255°$ |
| | Global | 2 / 4 processors |
| L3 Tagging | | 30 / 144 processors |

# Commissioning Run Plan

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- Period A (proton only)
  - Verify Synchronization of clock
  - Commissioning beam loss monitor (BSC-1) and CLC
  - Total proton loss measurement (BSC-1) – beam cogging
  - Establish minimum bias trigger (CLC E*W coincidence)
- Period B (1x8 bunches)
  - Luminosity measurement (bunch by bunch, & total) – CLC
  - Interaction point (z-vertex) measurement – CLC
  - Total proton, antiproton loss measurement – BSC
  - Time in Front-ends : ADMEM, TDCs (should carry over from cosmics)
    - Read out 4 "buckets" to check timing

# Commissioning Run Plan



- Period C (1x8, 36x8, 36x36 bunches)
  - Understand operation of COT with colliding beam
    - Stability of the chamber with a large amount of ionization
    - Determine hit occupancies / efficiencies per superlayer
    - Begin to understand tracking issues / t0, drift velocity
    - Synchronous noise from Silicon readout ?
  - Understand operation of Si Barrel-4, new endplugs.
  - Commission calorimetry and muon systems.
  - Commission DAQ system (Hardware Event Builder, L3, Data Logger …)
  - Establish operation of L1 Trigger system functionality
    - Calorimeter & muon stubs triggers
    - Tracking slice COT – XFT – XTRP to Muon / Calorimeter
  - Capture data in L2 processors, simple tagging/prescaling
    - Read-in L1 and XFT info, Cluster and ISO cluster operation
    - SVT for instrumented region
  - Take a few hundred k good events for the COT for the post-run

Y.K. Kim/Sep.2000

# Refining the Calorimeter Timing

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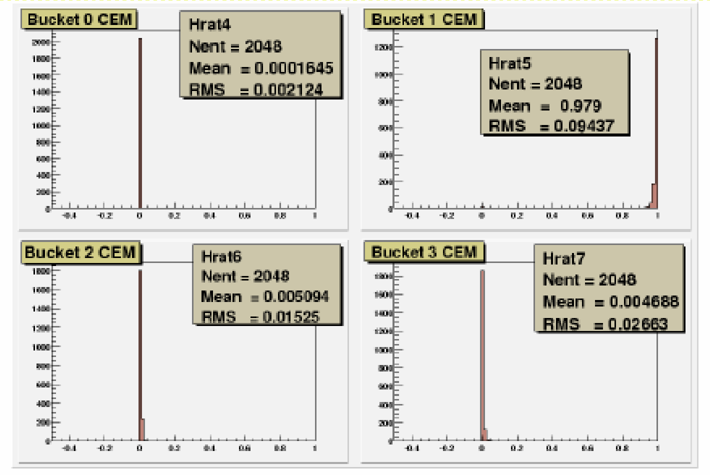
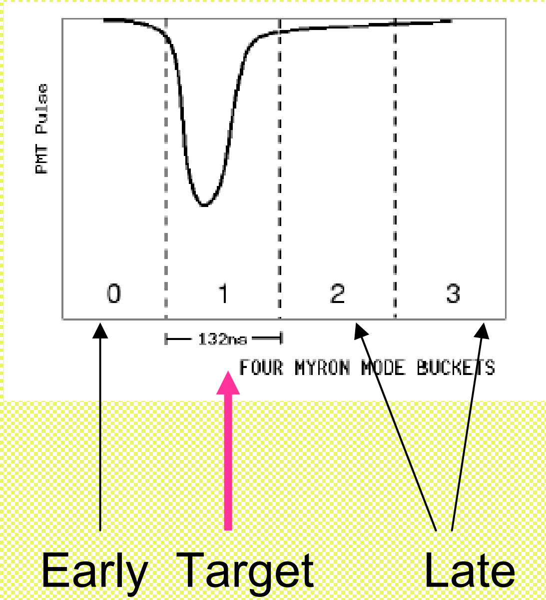
- Read out 4 132ns “buckets”

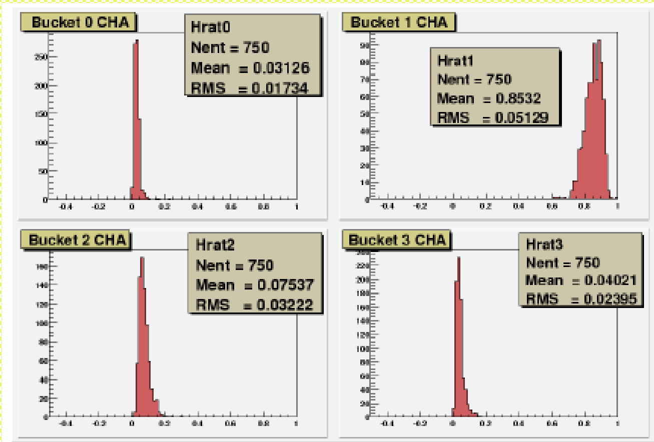



CEM

$$R_i = \frac{q_i}{\sum_{j=0-3} q_j} \quad i = 0-3$$

Fraction of total charge in each bucket.




CHA

# Refining Calorimeter Timing

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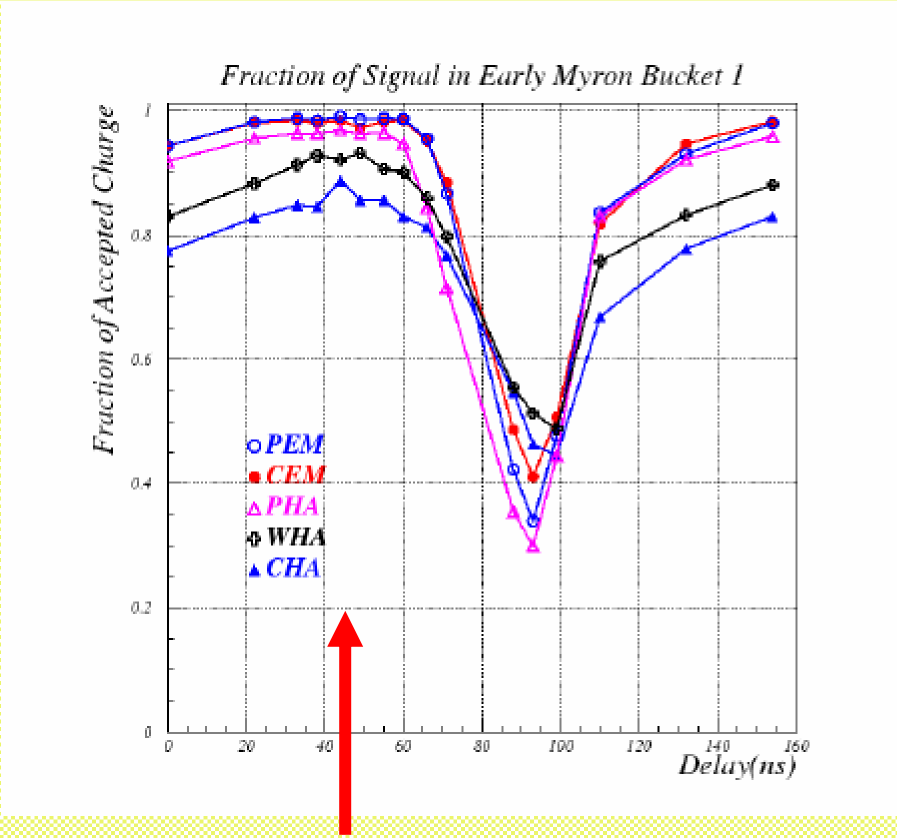
- Delay scan




Delay set here

# Data From the Commissioning Run

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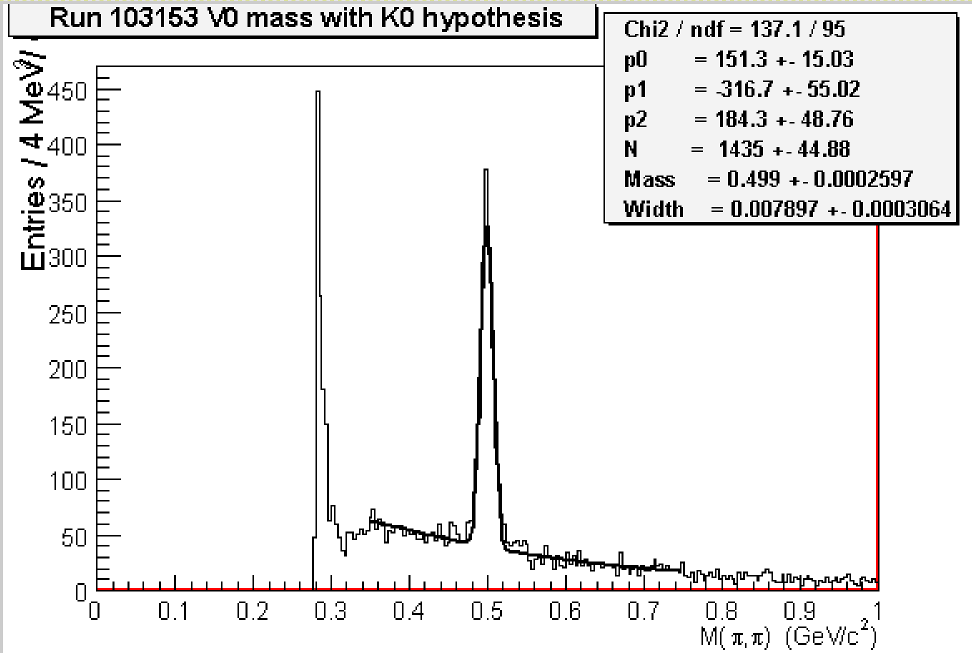
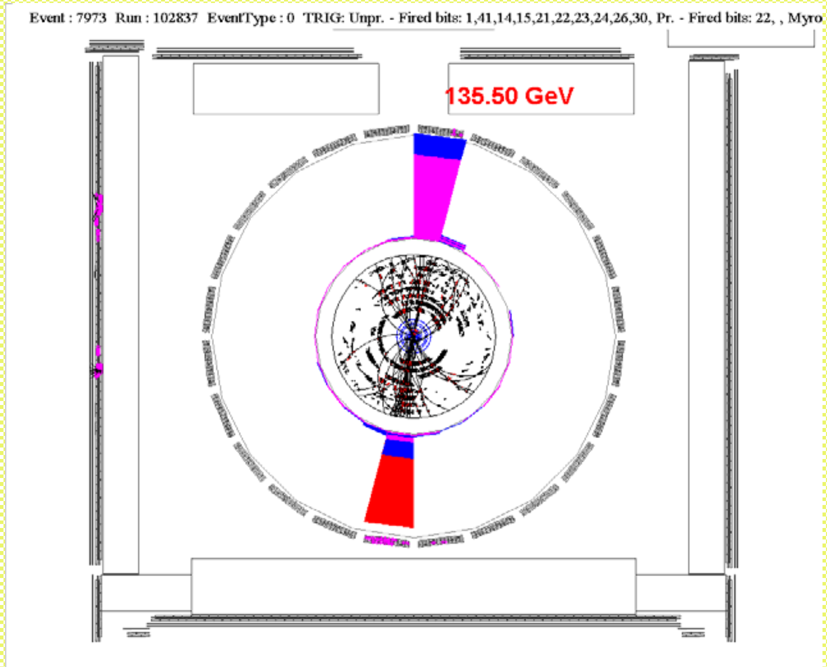



K short peak

$\Sigma E_T$=500 GeV di-jets

# March 2001-February 2002

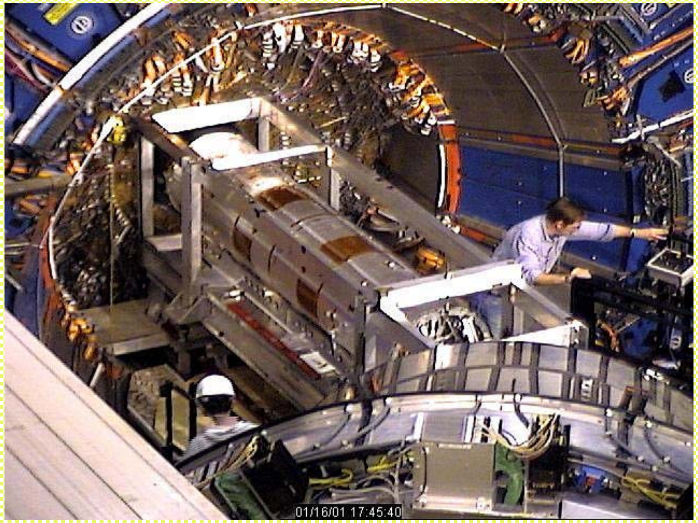


The Official Start of Run II to Run II Physics

# Si Commissioning



- Only prototype Si installed for commissioning run
  - Allowed nominal Si DAQ commissioning.
  - Established that Si readout did not cause noise problems elsewhere.
  - Left most of Si commissioning still to be done.
- Si was installed in January 2001 with just 2 months to start of Run II
  - 722K channels
    (maybe not CMS or ATLAS, but it's enough)



# Si Commissioning

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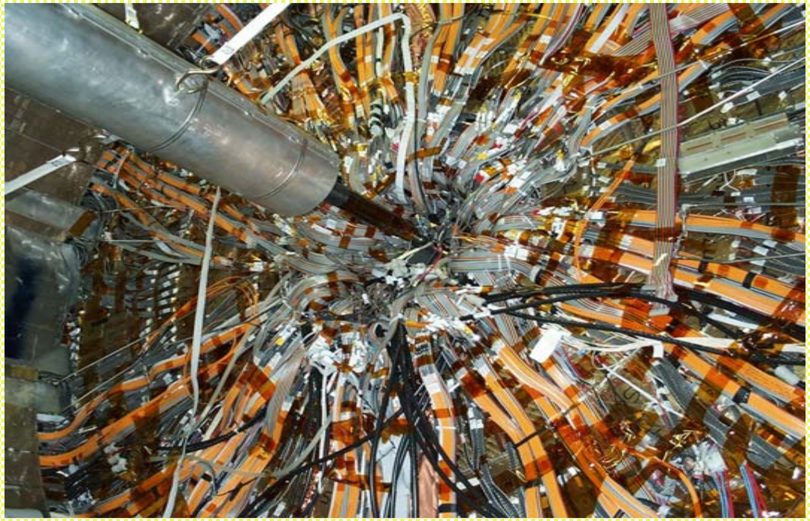
- **Installation completed May 2001**
- Not so simple, why?
  - Schedule complicated because Run II began March '01
    - Access to collision hall restricted before connection complete
  - Took 7 weeks employing shifts 24 hours a day, 7 days a week
    - 7 page checklist
      - Needed for safety of detector
      - Whole system was being shaken down simultaneously for the first time!
    - Lots of stiff, heavy cables
      - Interfere with one another
      - Weight tends to disconnect
    - Not easy to verify connections
      - Used mirrors+boroscope



C. Hill/Jan. 2003

# ISL Cooling Blockage

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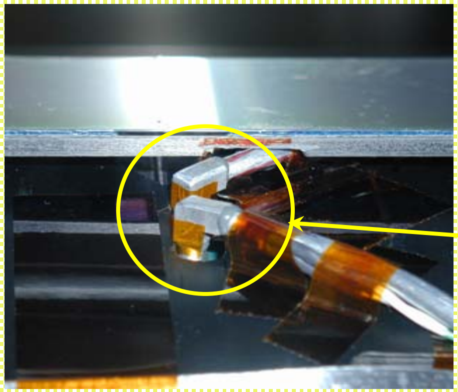
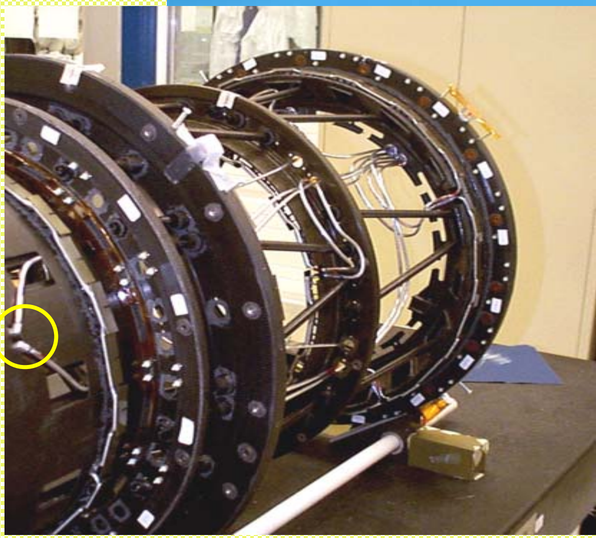
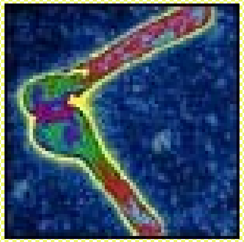
- ISL cooling lines blocked
  - Initially could not operate detector
  - Blockage due to epoxy in 90 degree bends
  - Eventually cleared using Yag LASER + prism





What's this?



# Si Commissioning w/ Beam

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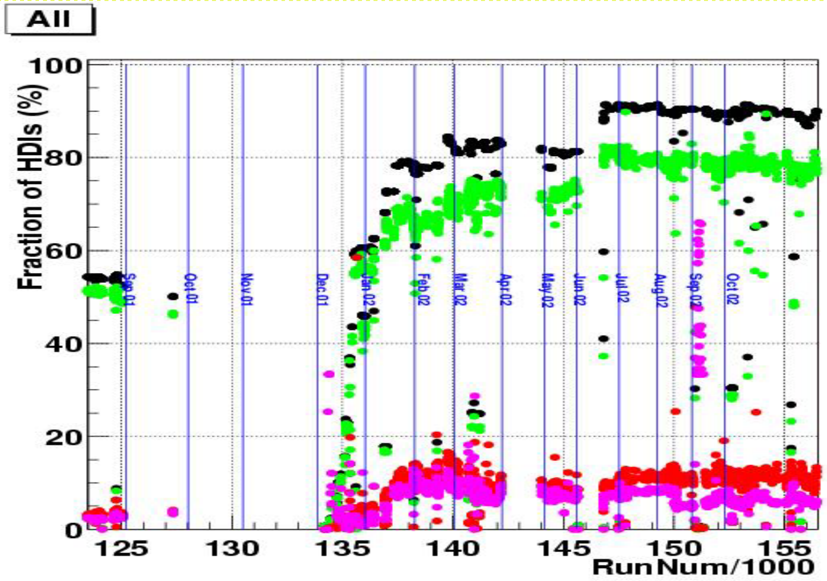
- Bit errors in data due to a variety of sources
  - Data clock problems
    - Modified all 58 FIBs (collision hall)
  - Optical system problems due to

    Light output

    Mechanical damage to fibers

    Electrical contact at receiver end

BLACK - fraction of the detector used in any given run
GREEN - fraction of the detector used with < 1% errors of any kind



# Si Commissioning w/ Beam: L00 Noise

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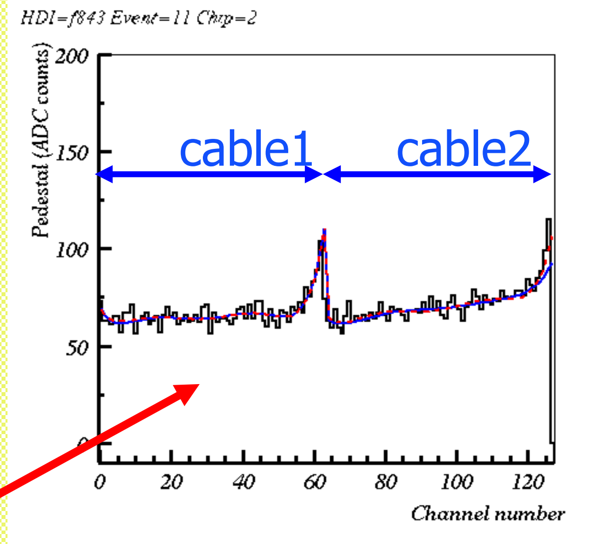
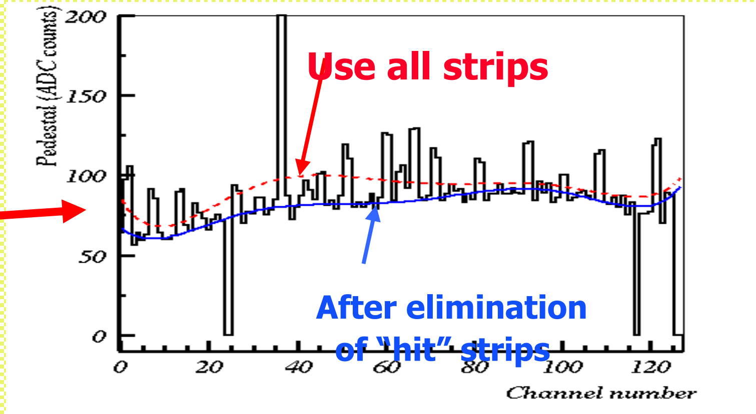
- A significant fraction of L00 detectors have non-uniform pedestals
  - Magnitude of effect varies from event-to-event, module-to-module and within a sensor
  - DPS no help
- Reason: Noise picked up by analog signal cables
  - Effects are seen at edges of cables, within one sensor
- Solution: Learn to live with it
  - Readout all strips in L00
  - Use this information to fit for an event-by-event pedestal



# Physics Commissioning



- Issues for physics readiness
  - Is the detector timed-in properly?
    - Is all the charge read out?
  - Is the detector properly calibrated?
    - Are trigger thresholds where they're supposed to be?
    - Is pedestal subtraction working properly?
  - Is the detector fully efficient?
  - Is the detector configuration stable?
    - Doing physics with an evolving detector configuration is very painful (though not impossible)

# Calorimeter Energy Scale

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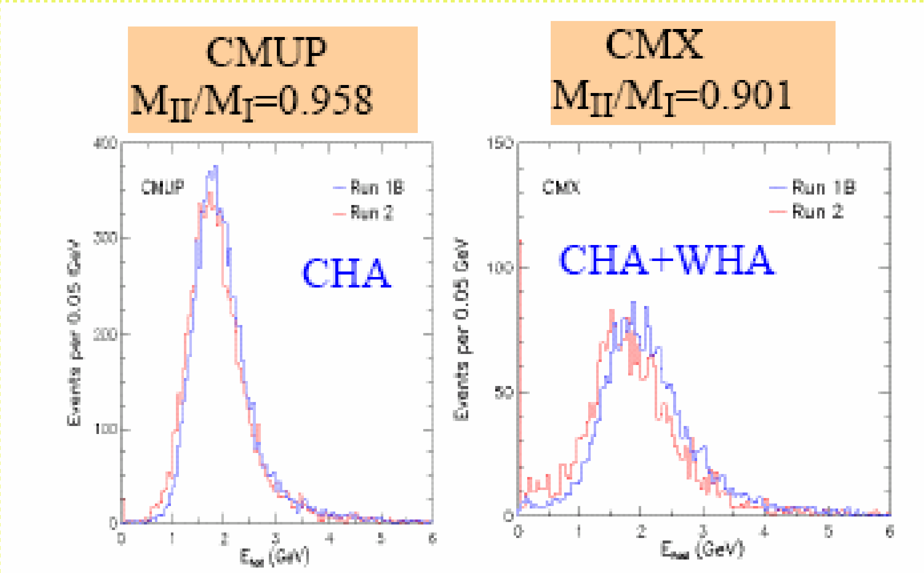
- Before Dec 10, 2001 the central hadron calorimeter E scale was based on 2000 Cs source calibration
  - μ MIPs (high Pt, J/Psi) ⇒ **E scale ~16% low**
    - **Due to problem with original calibration**
    - **No accounting for energy outside integration window**




**After fixes. Still not quite there**

# Tracking Chamber

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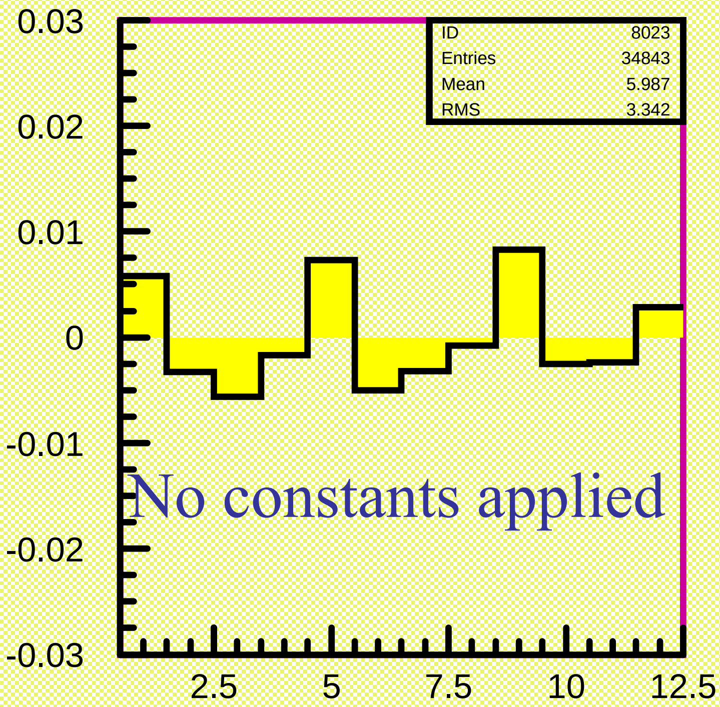
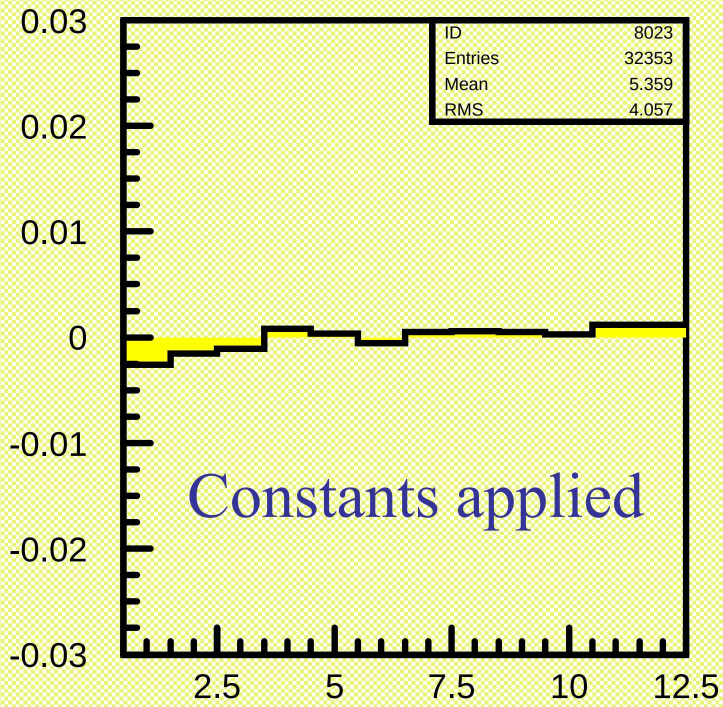
- T0's from pulsing the front end
  - Constants stored in DB, applied to raw hit times
  - Need proper length calibration




SL3 Res vs Wire




SL3 Res vs Wire

A. Yagil/Jan. 2002

# Tracking Chamber



- COT online "Stage0" calibration
  - Select good hits from good tracks.
  - Drift model with:
    - Constant drift velocity (except near wire)
    - aspect angle correction
    - time slewing correction (based on Penn sim.)
    - 7 parameters (v, $\beta$, t0, w, $\rho$, 2 near wire)
  - Fit (for each run) drift velocity, drift angle , t0

➔ study residual distribution

# Tracking Chamber Alignment

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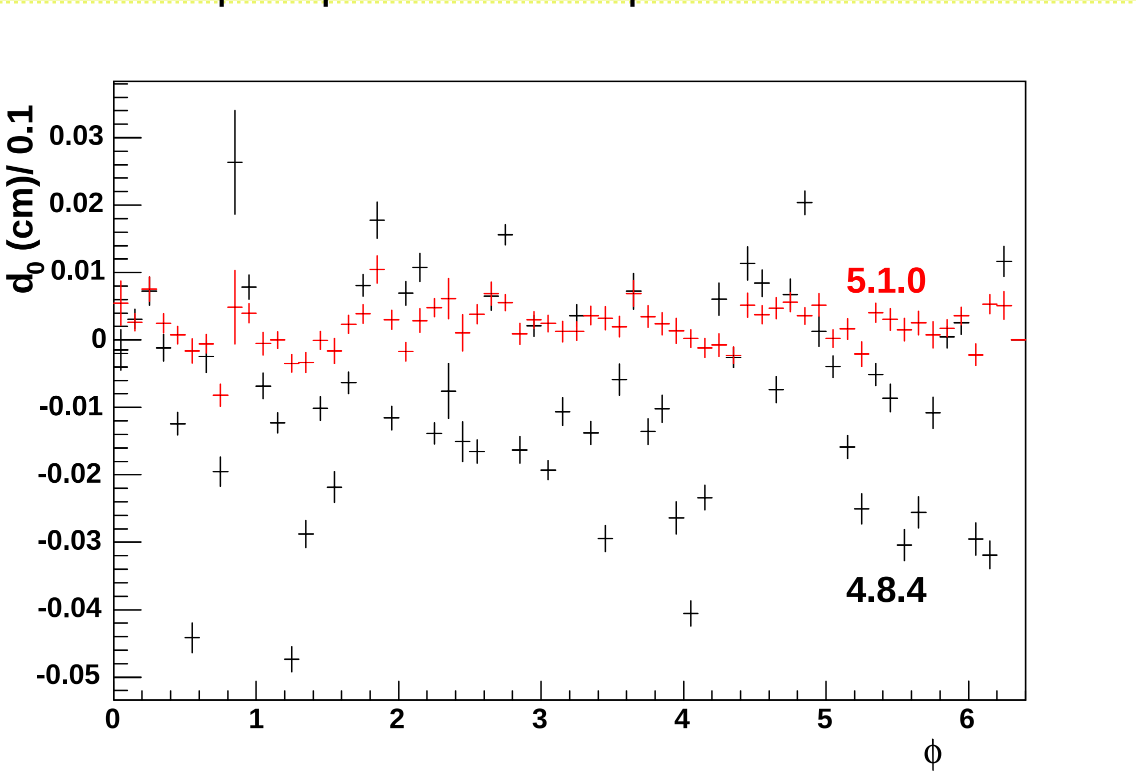
- Cosmic ray based alignment: Cell tilts/shifts
  - Includes corrections for electrostatics and gravity

Impact parameter vs. phi



# Commissioning with Data

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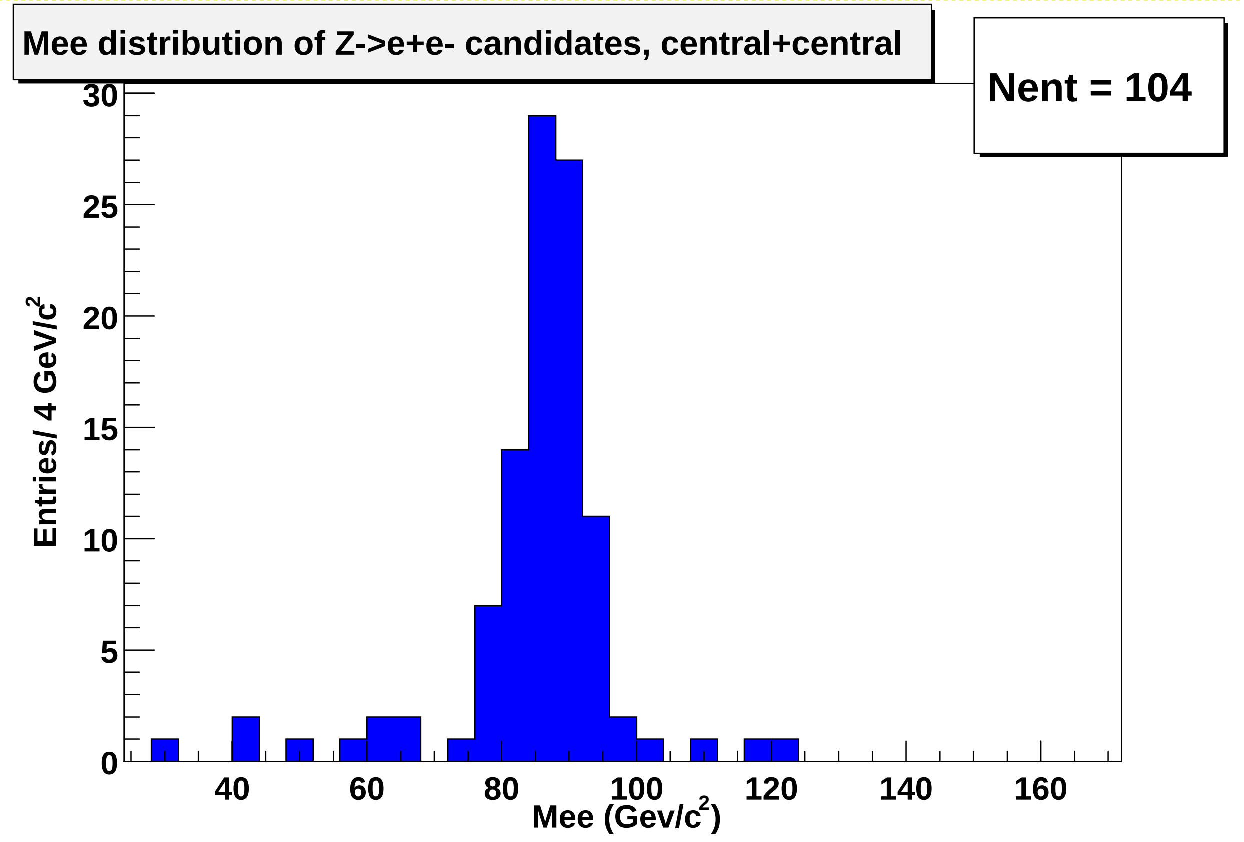


**Jan. 2002 CEM E scale established to ~1% with <10pb$^{-1}$**

**PEM E scale established to be 7% low with same data**

**(M(Z)=88 GeV/c$^2$)**

# Commissioning with Data

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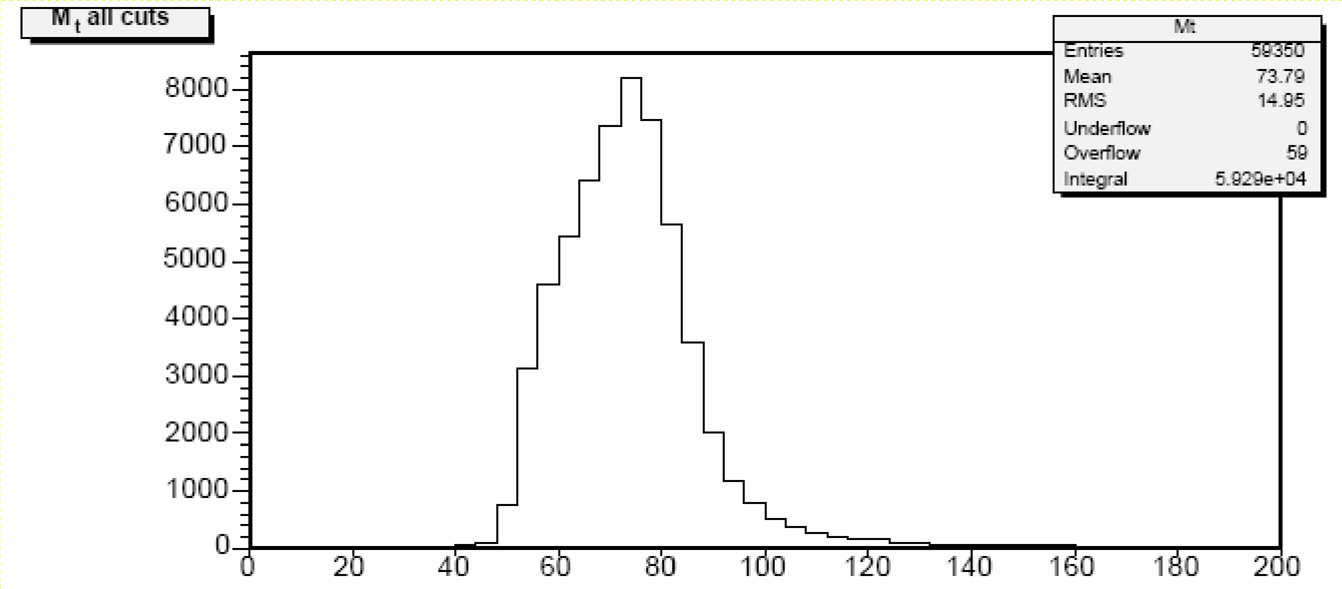
- Tracking efficiency established with calorimeter-based W trigger ("W-no track")




High-Pt Isolated track efficiency >99%

# Commissioning with Data

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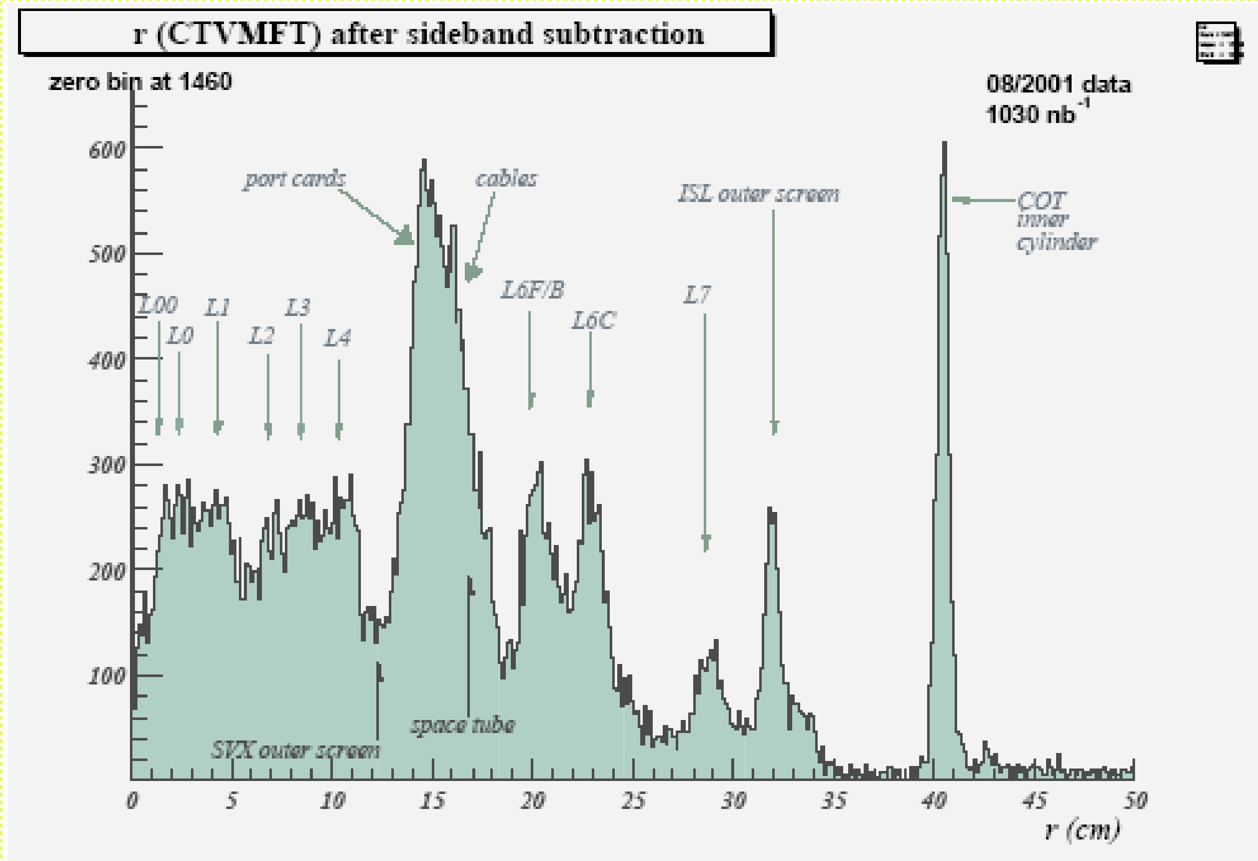
- Photon conversions used to understand the radial material distribution

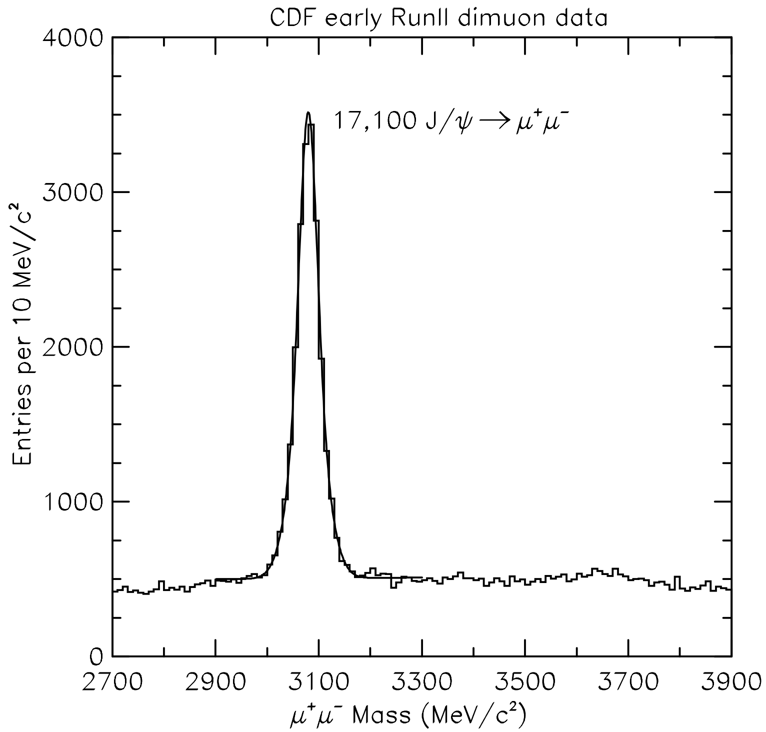
August 2001

1pb$^{-1}$



# Commissioning with Data






- Very early $J/\psi$ data (few $pb^{-1}$)
  - Established basic momentum scale for tracking
  - Used to measure muon chamber efficiencies
  - Used to measure vertex resolution of SVX
  - Used to measure energy scale of hadron calorimeter

# Commissioning with Data

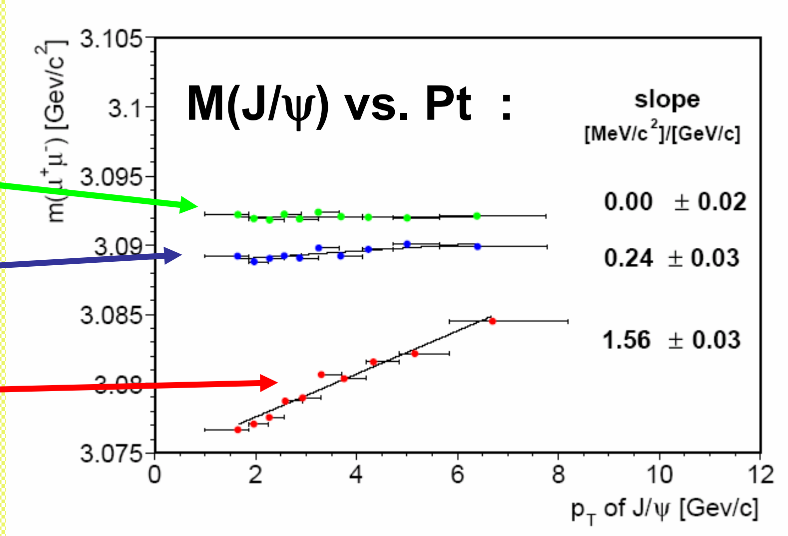


- Additional J/ψ data used to understand material

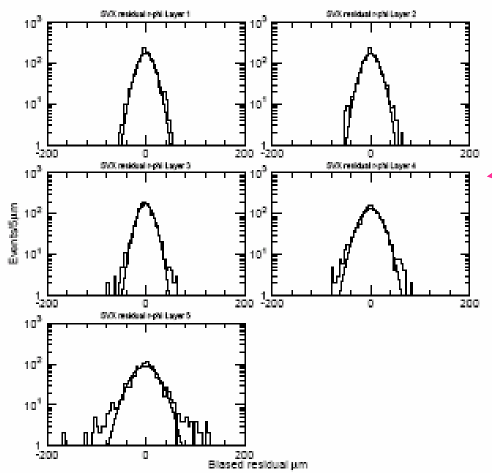
Additional 0.455 g/cm²

Corrected for nominal material in simulation

No corrections




- And alignment




**Residuals in 5 SVXII layers**

# Unanticipated Problems

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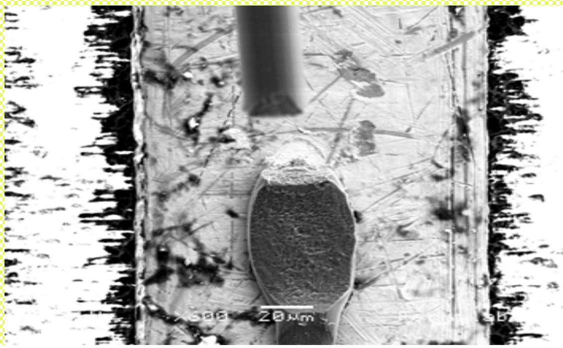
- Early TeV beam had high losses
  - Si frequently off for protection
  - Muon chamber currents very high
    - Installed shielding
- Power supply failures with beam
  - Transistor deaths due to "single event burnout"
    - Reduced bias/more resistant transistors/shielding
- TDC production problems (bad vias)
  - Slowly replaced boards (access required)
- Silicon jumper failures
  - Jumpers rout signals from phi side to z side
  - Failures due to resonant oscillation from Lorentz forces during abnormal trigger conditions.
  - Reduced current through jumper
  - Eliminated guilty trigger test mode
  - Lost some z-side sensors



# Unanticipated Problems

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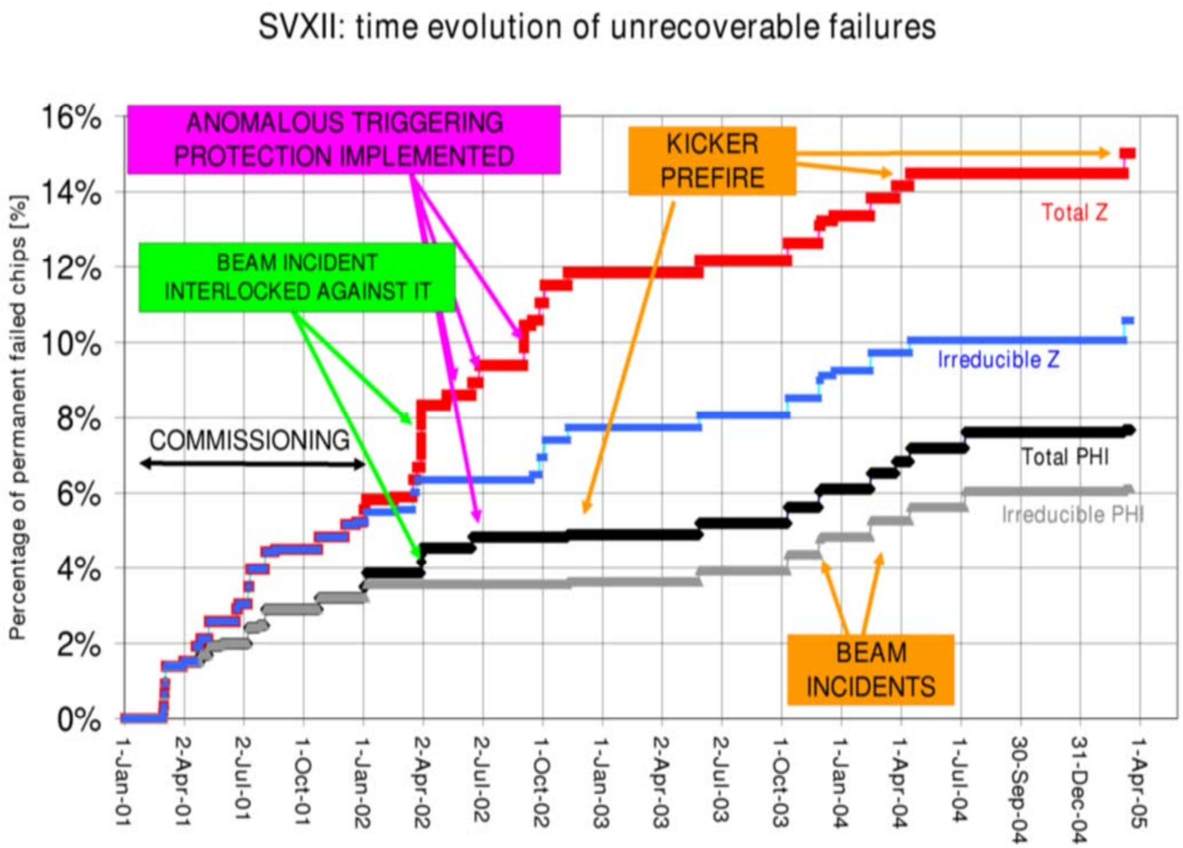
- Beam Incidents
  - Abort kicker pre-fire
  - Loss of TeV rf



# Unanticipated Problems

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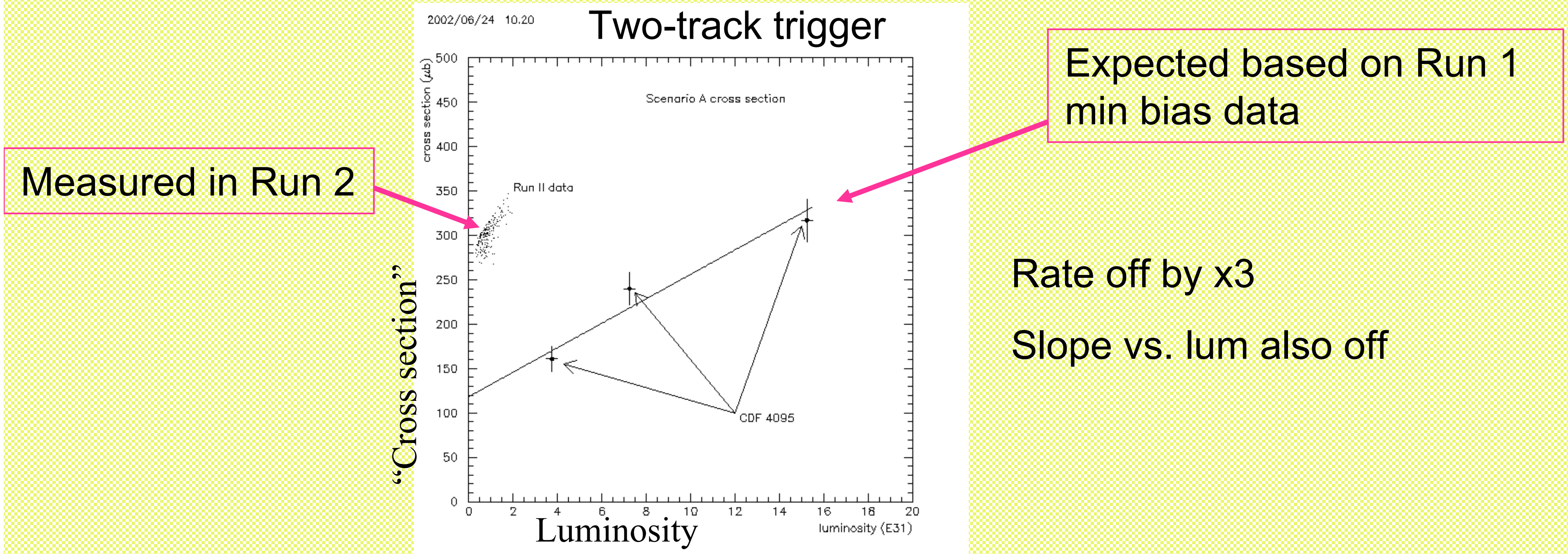
- COT Occupancy much higher than expected
  – Not completely understood – presumably due to additional material
- Many trigger rates higher than expected
  – Event those that were based on data from Run 1




Rate off by x3

Slope vs. lum also off

# Lessons



- Commissioning Run (October 2000)
  - Months of integration work and CR running was well worth it.
  - Ease of use and stability of consumer server was a major plus
    - Easy to write and integrate on-line monitors that were crucial to understanding operation with beam.
  - Could have done more with more TDCs
- Run II Commissioning Period (March 2001-February 2002)
  - Even a short 1 month commissioning run was well worth it.
  - Could have done better at establishing performance benchmarks for each system.
    - Which histograms are the key to each system's health?
    - What is "normal"?
  - A good trigger simulation is an essential tool
  - Late arrival of TDCs cost us
    - TDCs had many problems that were uncovered/fixed slowly.

# Lessons



- Run II Commissioning Period (cont)
  - Downtime accounting is a powerful tool for increasing data taking efficiency
  - A good *and flexible* simulation is worth the effort up front
    - You will have work to do when the data arrives
  - Don't believe your simulation until it has been tuned on the data.
  - Establish standard data quality monitoring *early* and produce good run lists in ~real time
    - Establishing physics readiness would have gone quicker had we done better at establishing good and bad runs.
  - Quick access to key datasets (Z, J/$\psi$,...) is essential for commissioning

# Lessons



- Silicon (clearly the most difficult commissioning effort)
  - Should have connected silicon before detector rolled into Collision Hall
  - All electrical connections through single 96 pin connector – simple connection but single-point failure
    - Connectors should lock in place and/or give feedback when not properly connected (e.g. LED)
    - Cable weight/rigidity needs to be accounted for
  - All external components need to be commissioned before silicon is connected
    - Not enough to test components individually. Need to test *entire* system.

# Despite All This Pain

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$$M_{TOP} = 173.5^{+4.1}_{-4.0}\ GeV/c^2$$