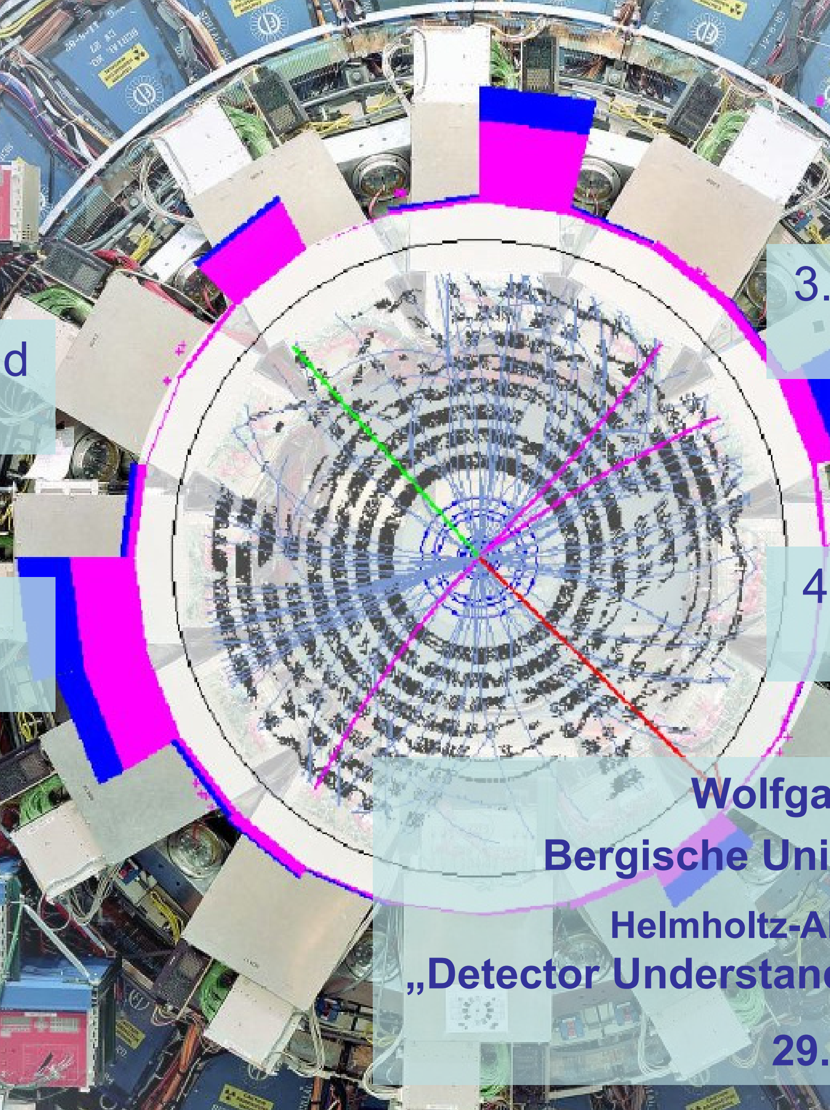
The First "Hundred" Days of the Tevatron

From the Commissioning Run to ICHEP 2002



1. The Tevatron and its Detectors
2. CDF Commisioning
3. Comedy of Challenges, Errors and Mishaps
4. Run II Physics Results at ICHEP 2002

Wolfgang Wagner
Bergische Universität Wuppertal

Helmholtz-Alliance Workshop
„Detector Understanding with First LHC Data"

29.06.2009

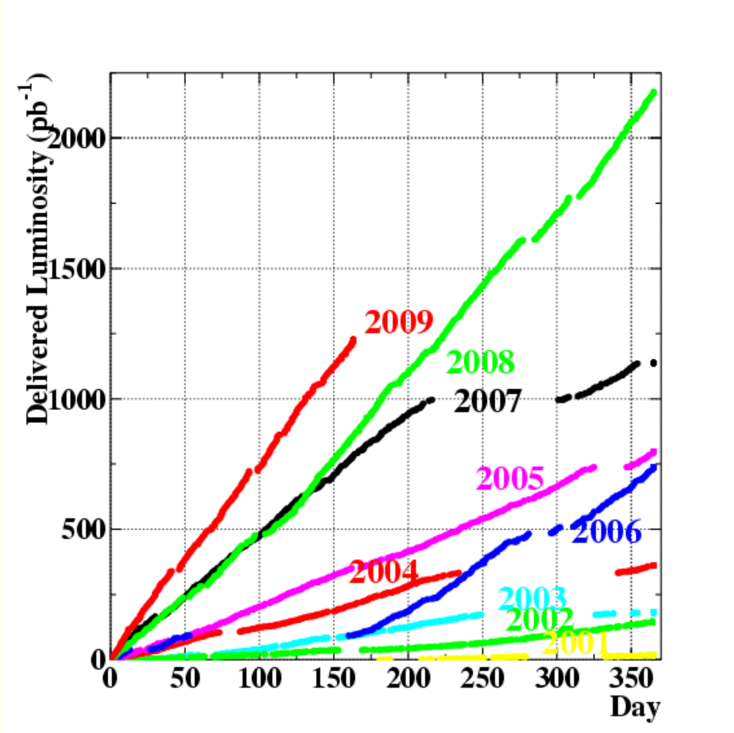
1. The Tevatron at Fermilab

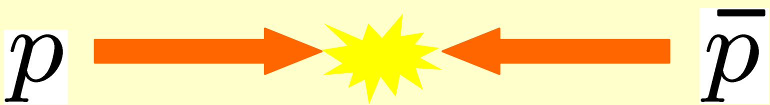
Run 1 (1992 – 1995): $\sqrt{s}$ = 1.8 TeV
L_{int} = 100 pb^{-1}

Run 2 (since 2002): **$\sqrt{s}$ = 1.96 TeV**

L_{int} > 7.0 fb^{-1}

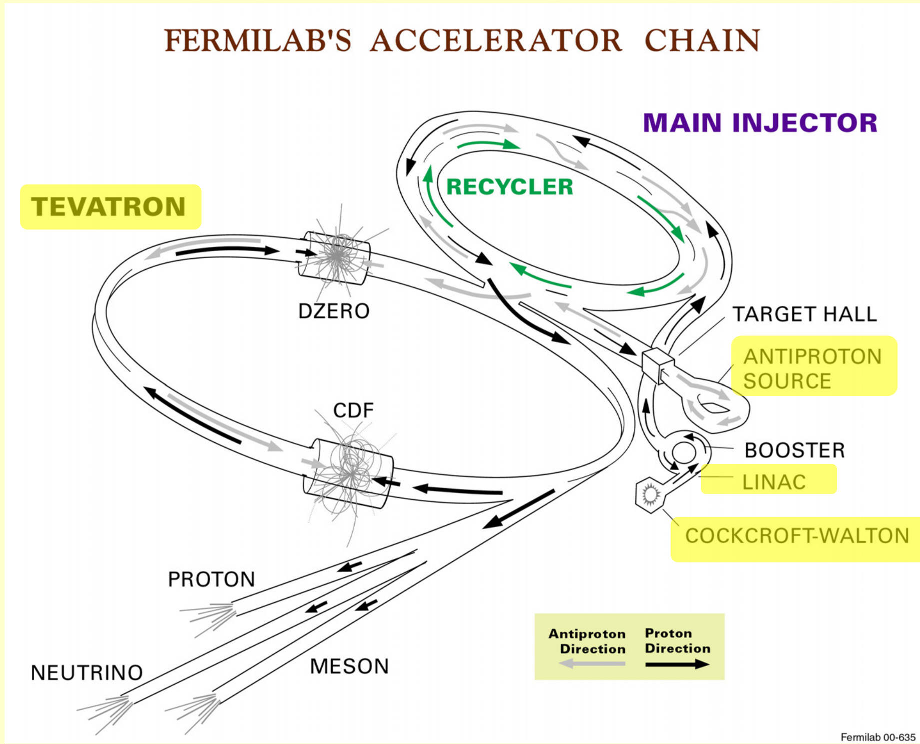
now delivering > 2 fb^{-1} / year

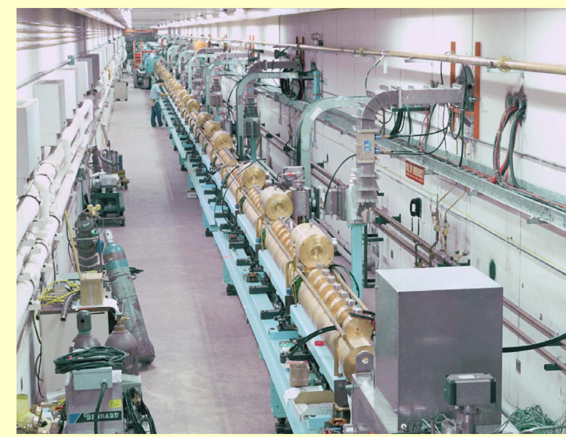


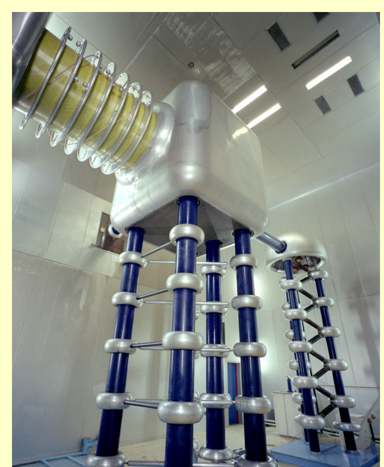


record luminosity: $\mathscr{L}$ = 3.7 · 10^{32} cm^{-2} s^{-1}
(exceeds goal of 1.6 – 2.7 · 10^{32})

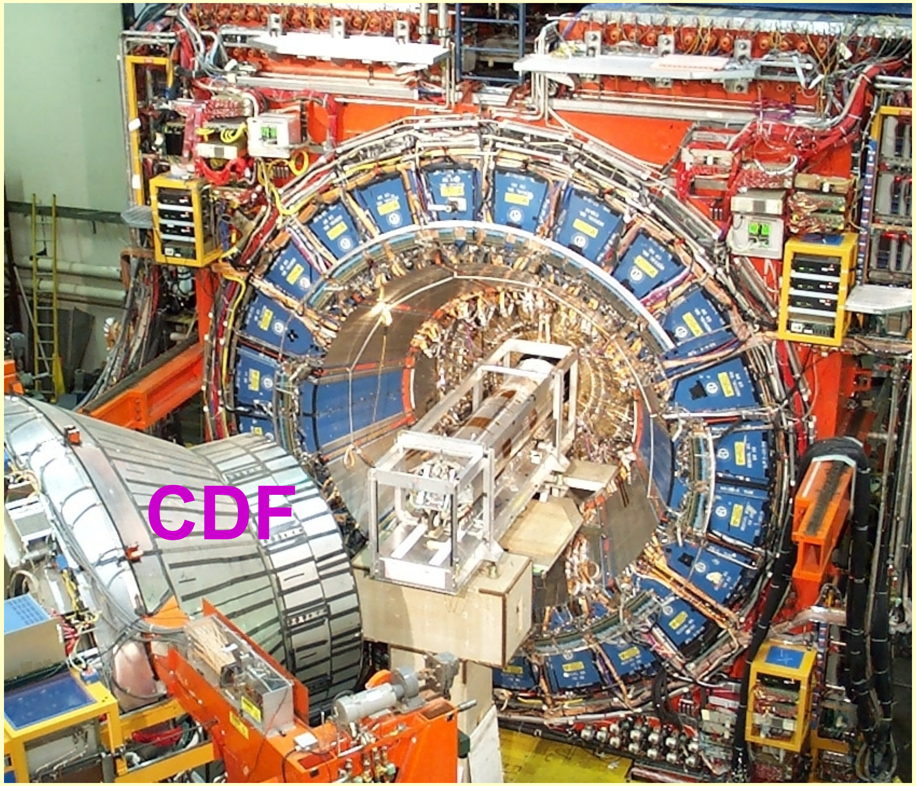
Fermilab Accelerator Chain

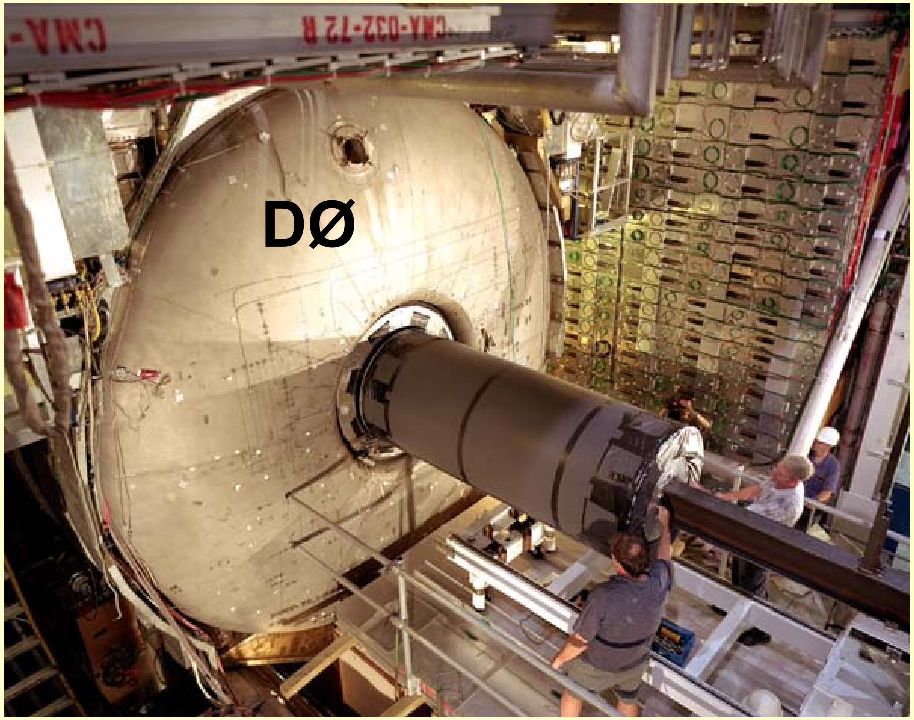






Detectors at the Tevatron





multi-purpose detectors: tracking, b-tagging, calorimeter, muon system, …

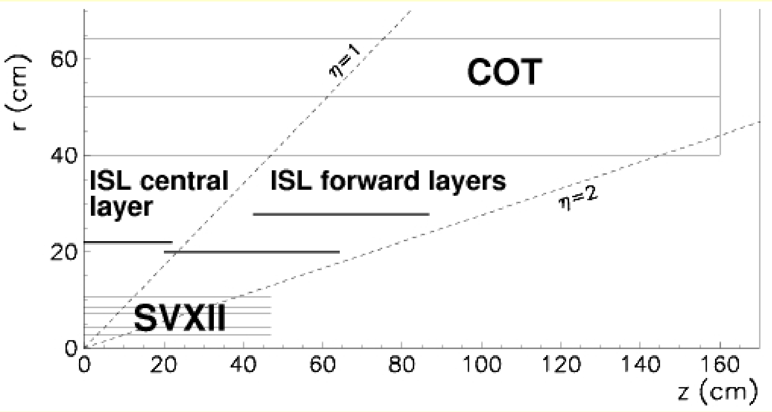
strength of CDF: momentum resolution and particle ID (K,π)
strength of DØ: muon coverage and jet energy resolution

Tevatron Collaborations

13 countries, 61 institutions
600 physicists

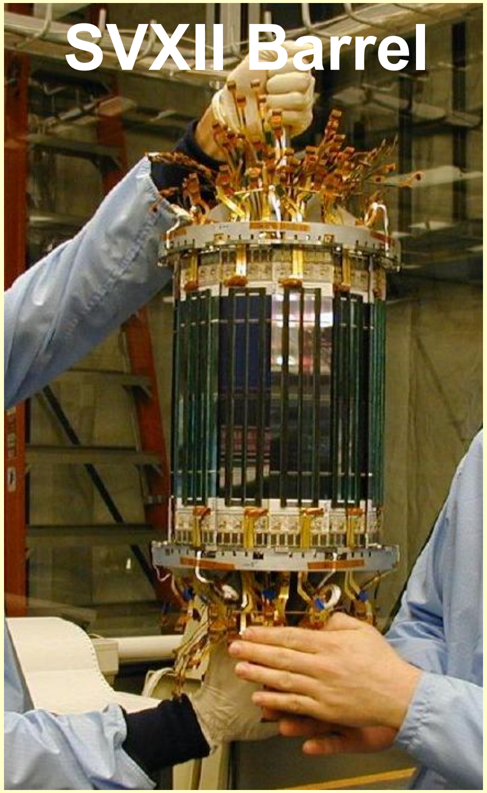
19 countries, 83 institutions
530 physicists

CDF Silicon Tracker

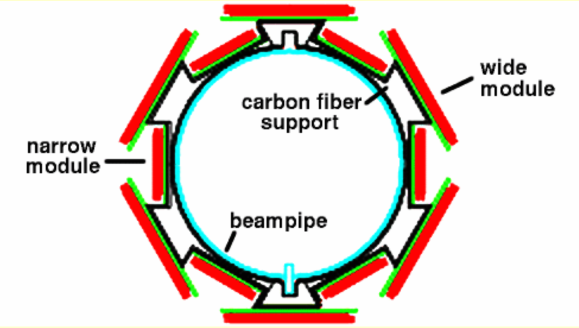


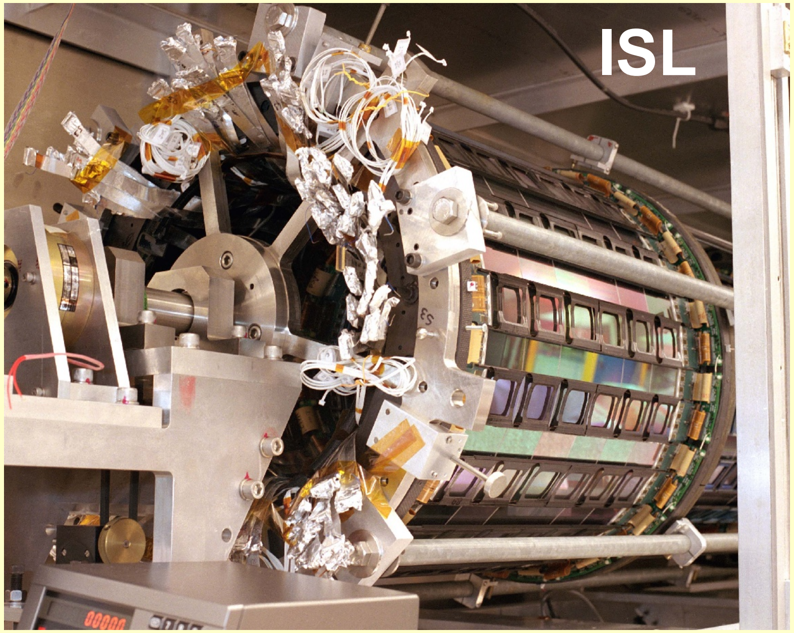
3 silicon subsystems

L00	R = 1.35, 1.6 cm
SVXII	R = 2.5 to 10.7 cm
ISL	R = 20, 22, 28 cm



Layer 00



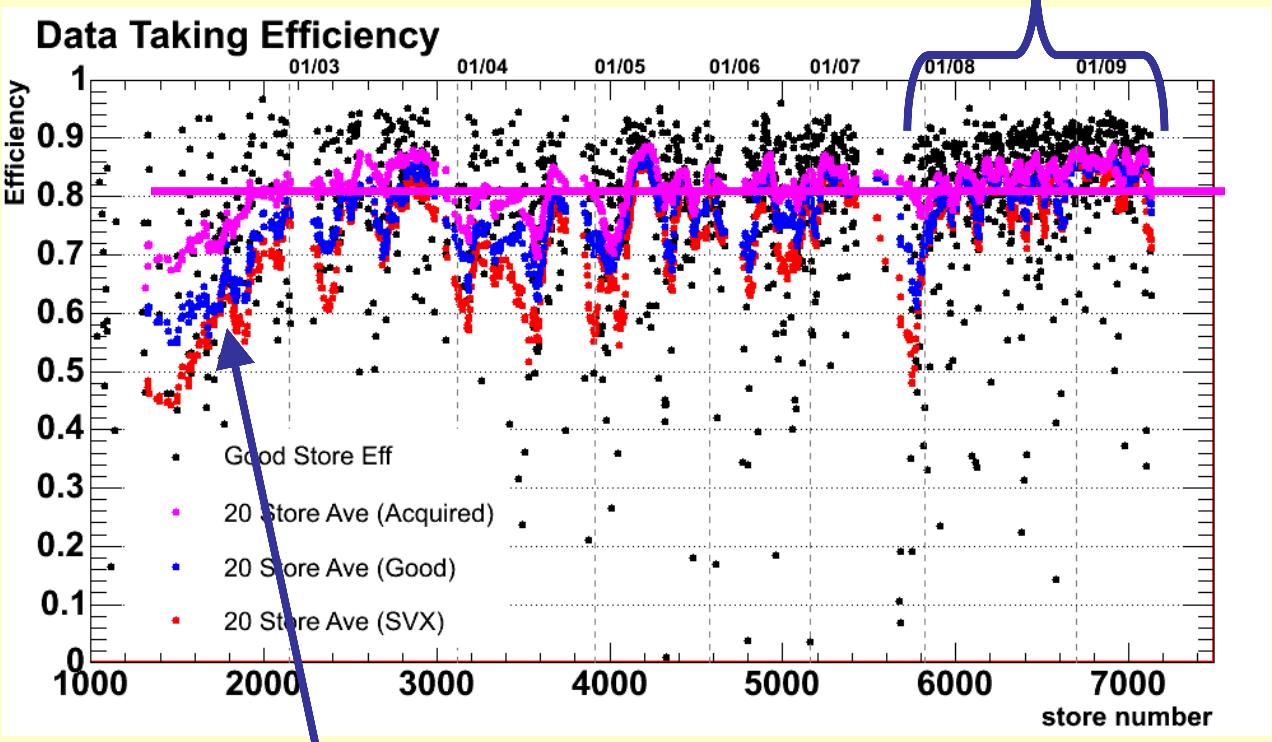


L00
- 72 single-sided sensors
- 2 layers × 6 ϕ-wedges

SVXII
- 720 double-sided sensors
- 5 layers
- 12 ϕ-wedges
- rϕ and rz measurements

Data Taking Efficiency

steadily improved in the past two years



it took about 1 year to stabilize the efficiency

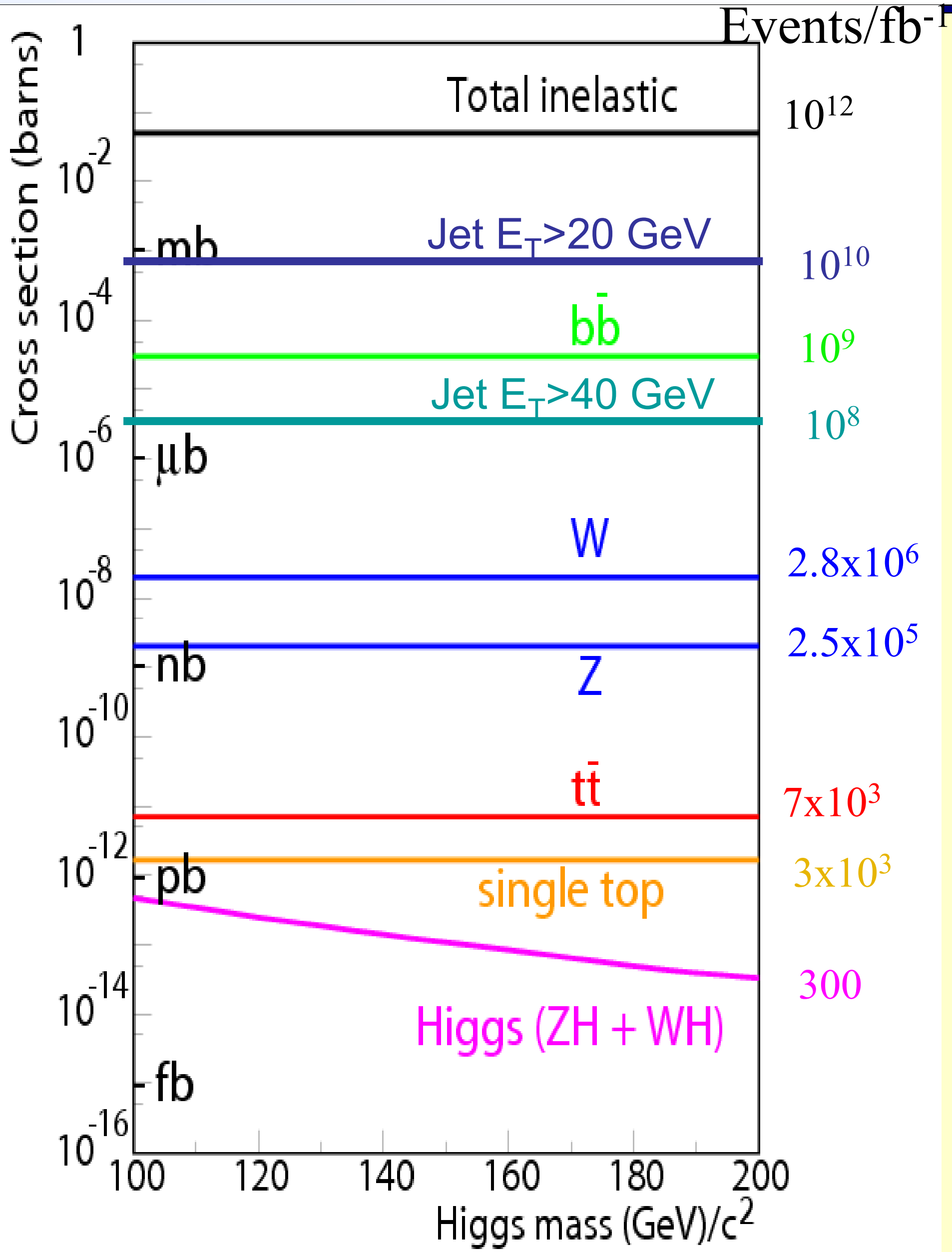
now ~ 85%

<u>Downtime sources:</u>

- Detector/trigger/DAQ ~5%
- Beam, start/end stores ~5%
- Trigger deadtime ~5% (our choice to optimize physics)

Processes and Cross Sections

- Cross section:
  - Total inelastic cross section is huge: ≈ 61 mb
  - Used to measure luminosity
- Rates at e.g. $L=1x10^{32}\ cm^{-2}s^{-1}$:
  - Total inelastic: 6.000.000
  - bb: 42000/s
  - Jets with E_T>40 GeV: 300/s
  - W: 3/s
  - Top: 6/hour
- Challenging to select the interesting events
  - Mostly fighting generic jets!



2. The CDF Commissioning Phase

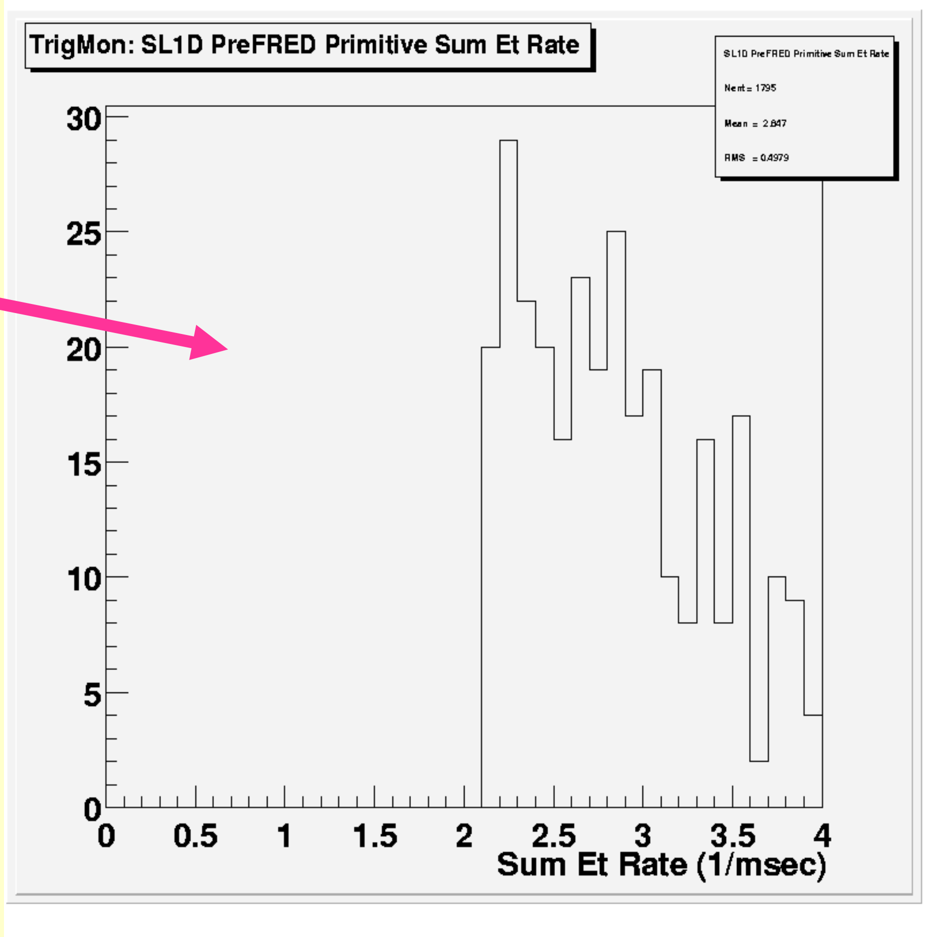
Commissioning Stages 1999 – 2002

- Nov. 1999 – August 2000: Commissioning without Collisions
  - Integration of components into the DAQ
  - Daily running: calibration and pedestals
  - Cosmic ray runs
  - Timing-in of systems
- 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)
- Nov. 2000 - March 2001
  - Complete the detector
  - Continued integration work
  - Daily cosmic running
- March 2001 - February 2002
  - Commission for physics data (using collision data)

Commissioning L1 Trigger w/ Cosmics

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

Histogram made with online monitor.



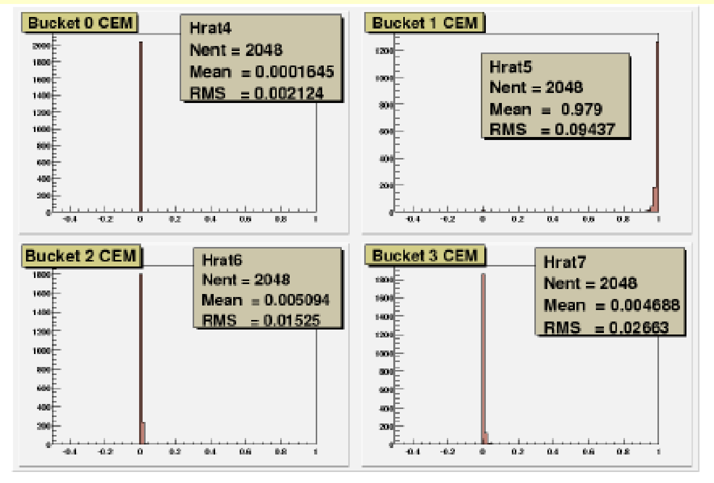
The Commissioning Run

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

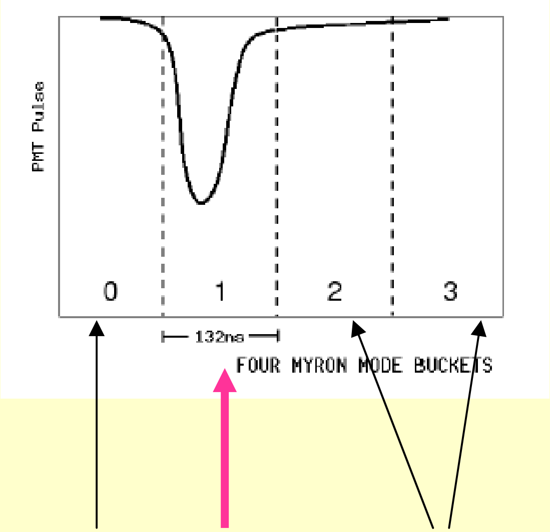
- Period A : Proton only beam (1.5 wks)
- Period B : Observe first collision (1 wk)
- Period C : Subsystem commissioning (3.5 wks)

Refining the Calorimeter Timing

- Read out 4 132ns “buckets”



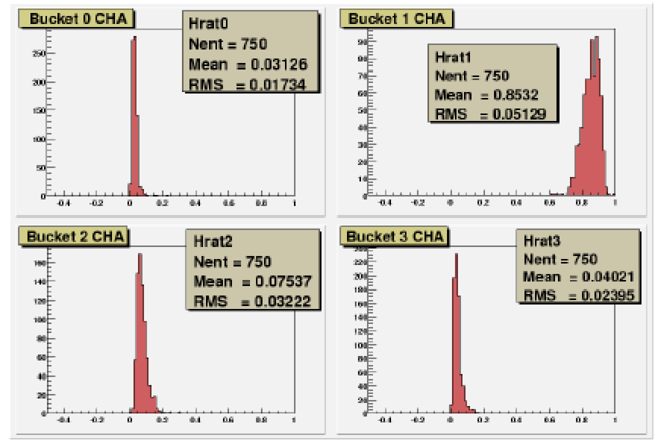
CEM



Early Target Late

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

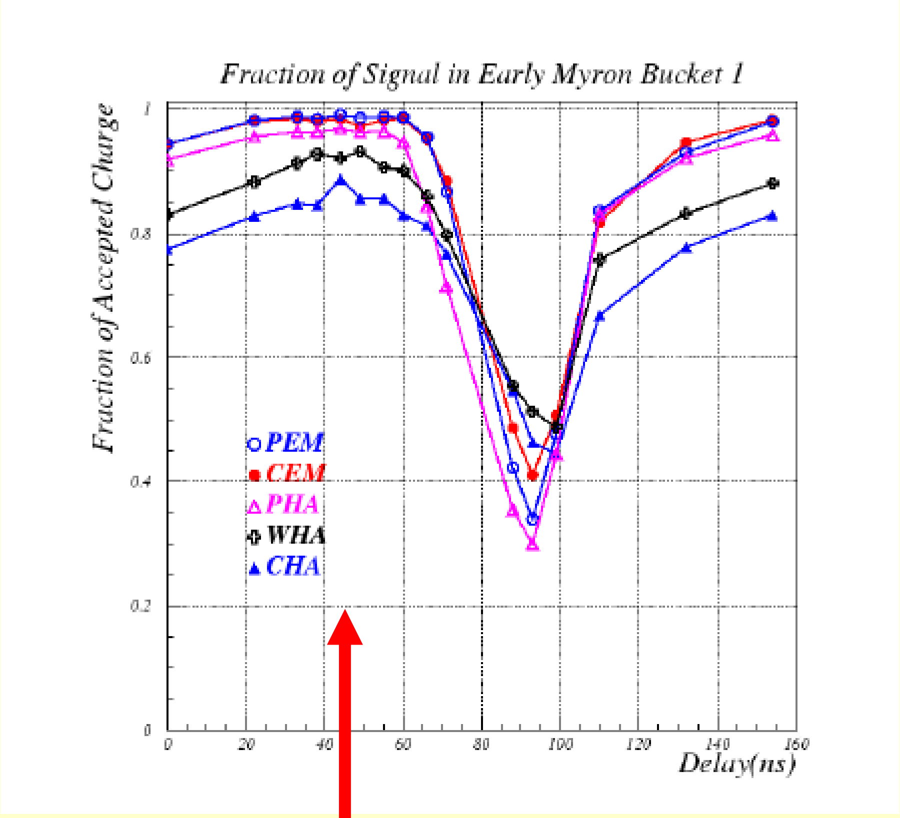
Fraction of total charge in each bucket.



CHA

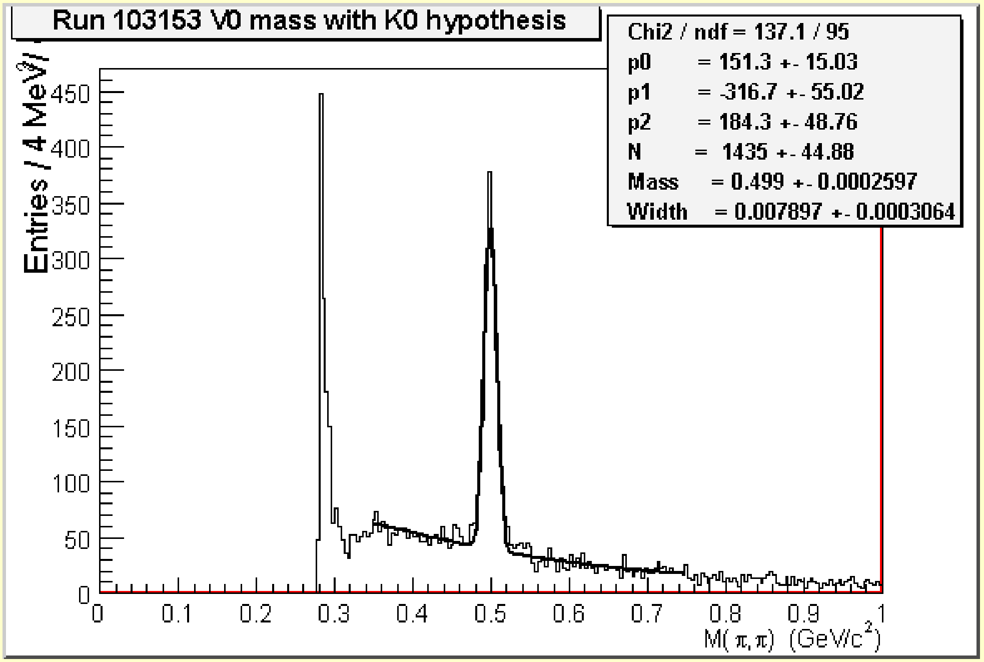
Refining Calorimeter Timing

delay scan

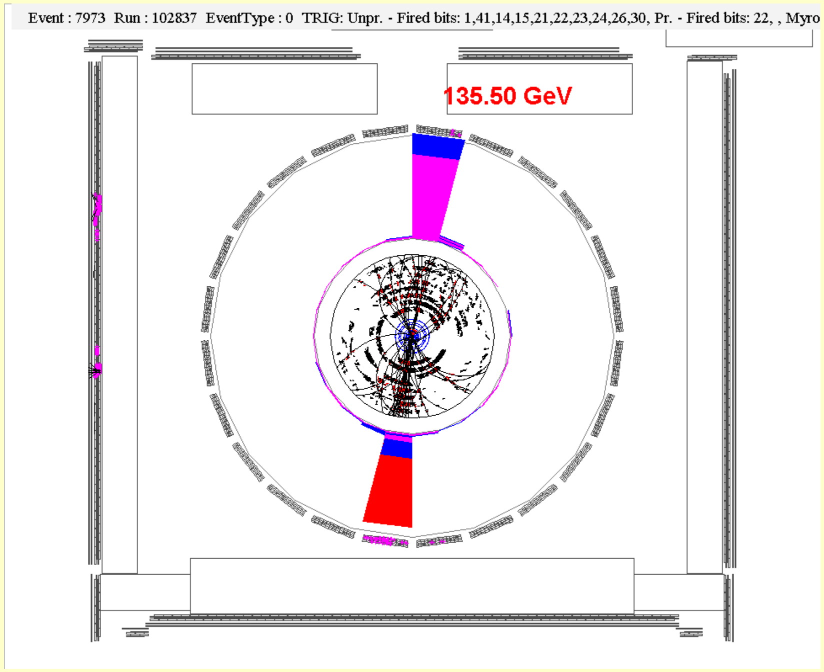


Delay set here

Data From the Commissioning Run



K short peak

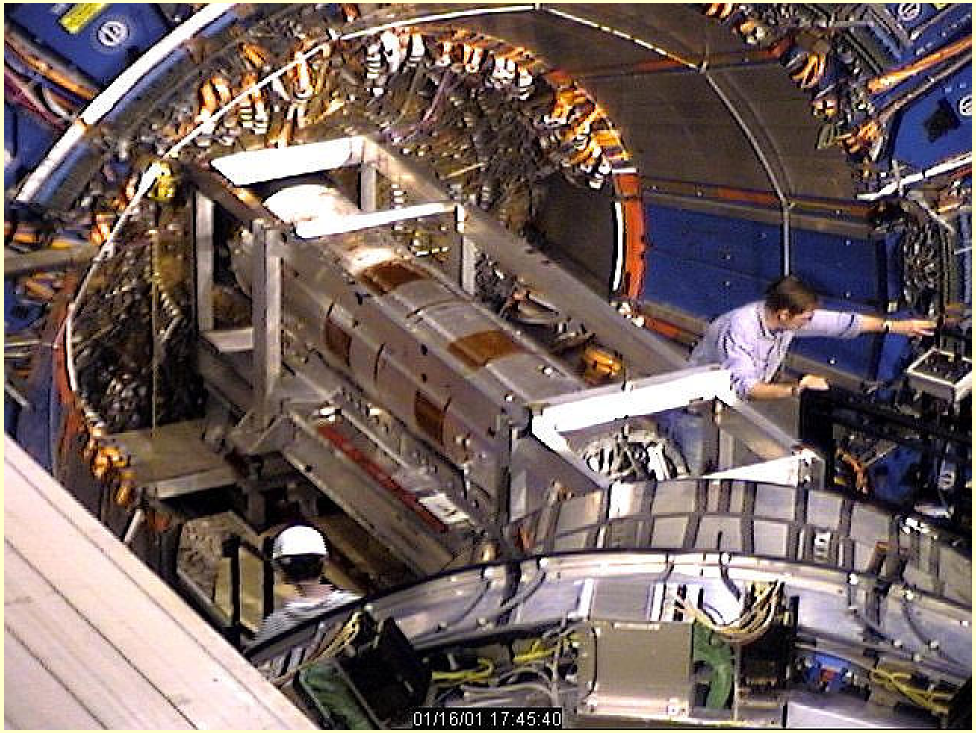


ΣE_T = 500 GeV di-jets

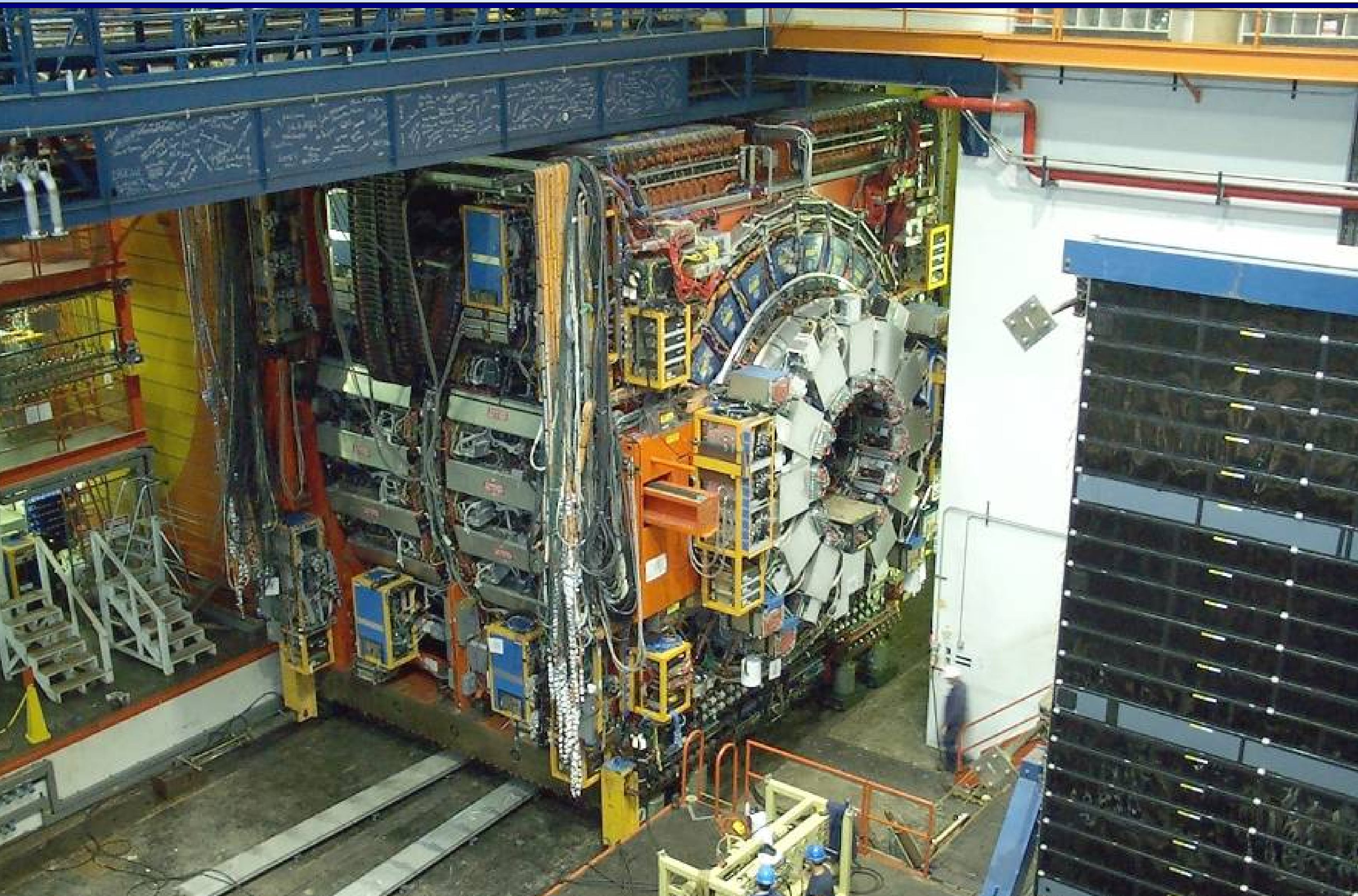
Silicon Commissioning

- 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
  (not CMS or ATLAS, but it's enough)
- silicon was not connected to readout before rolling in



Detector Roll-In in February 2001



Physics Commissioning

Issues for physics readiness

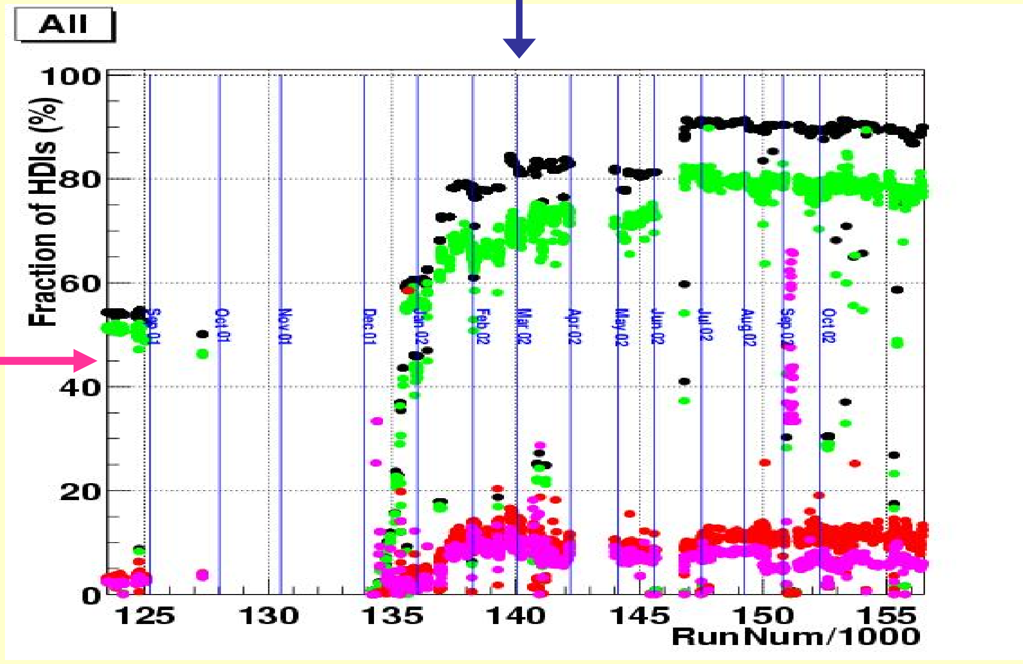
- Is the detector timed-in properly?
  - Is all the charge read out?
- Is the detector properly calibrated?
  - Are trigger thresholds where they're supposed to be?
  - Is pedestal subtraction working properly?
- Is the detector fully efficient?
- Is the detector configuration stable?
  - Doing physics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

Silicon Commissioning w/ Beam

Bit errors in data due to a variety of sources

- Data clock problems
- Optical system problems due to
  - Light output
  - Mechanical damage to fibers
  - Electrical contact at receiver end

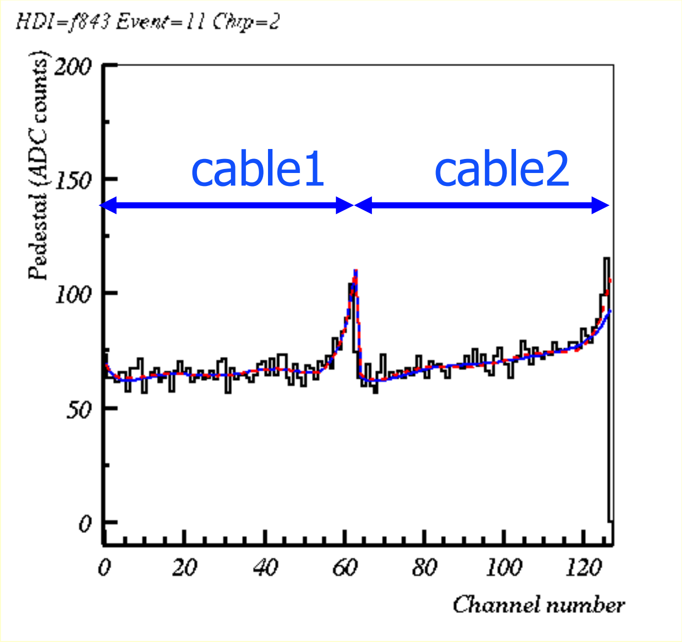
March 2002

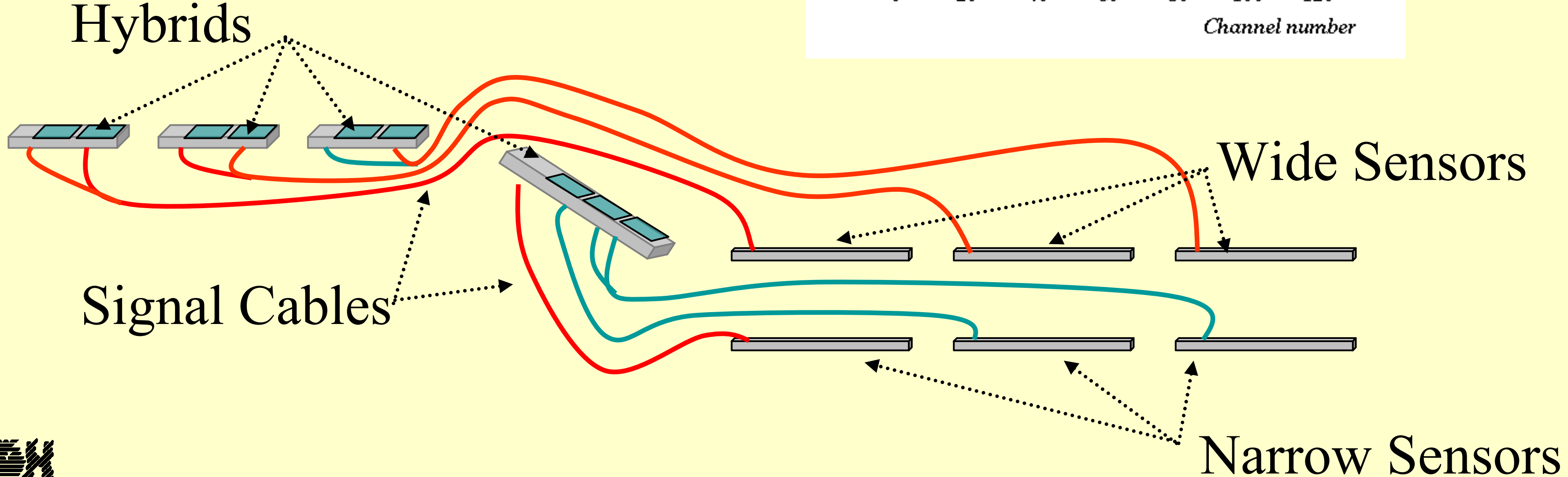


BLACK - fraction of the detector used in any given run
GREEN - fraction of the detector used with < 1% errors of any kind

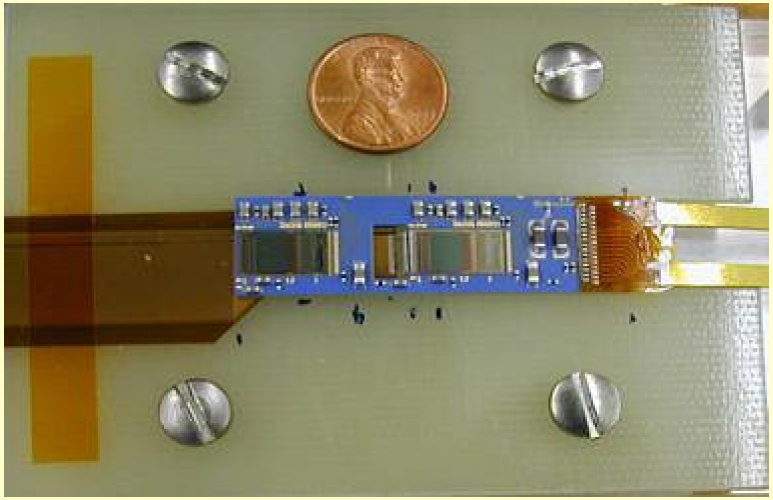
Pickup on L00 Signal Cables

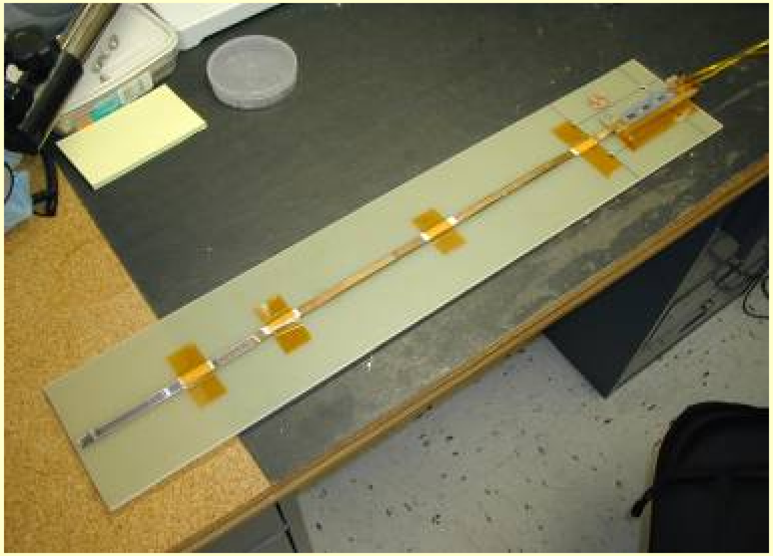
- Noise picked up by analog signal cables
  - Effects are seen at edges of cables, within one sensor
  - Both coherent and incoherent sources
    - Noise shapes
    - Pedestal shifts
    - Common Mode





Layer 00 Components



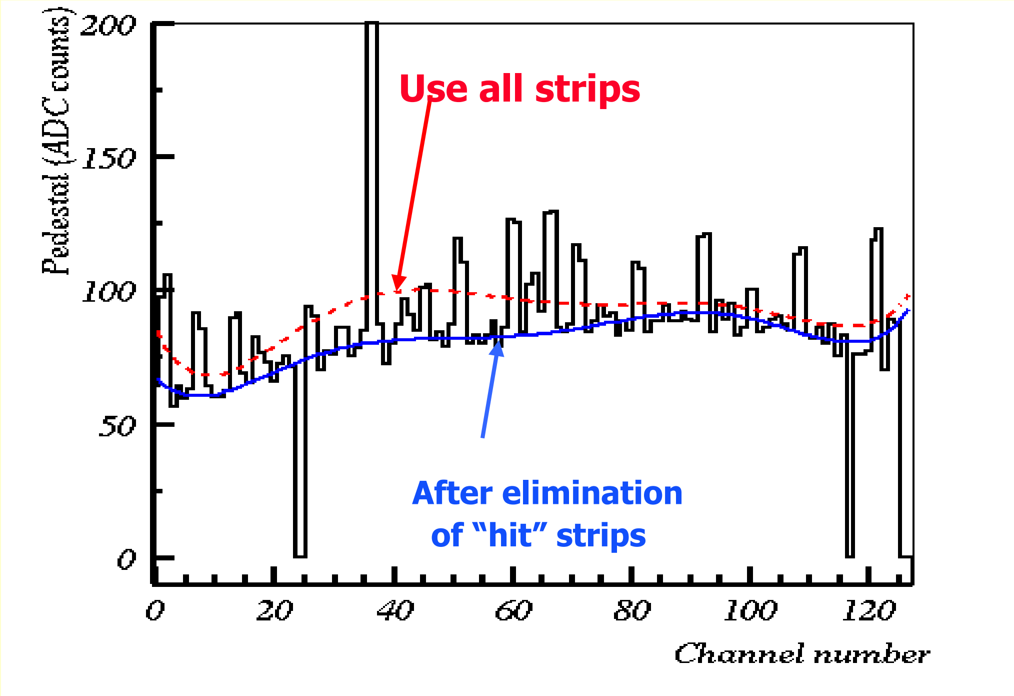


- CMS-type silicon (Hamamatsu, Micron, Micron oxygenated)
- Long Signal Cables:

  Electronics separated from Silicon by Kapton cables (up to ~ 40 cm long)
- Silicon Cooled to -6 °C using water/glycol mixture

Solution: Fit for Pedestal

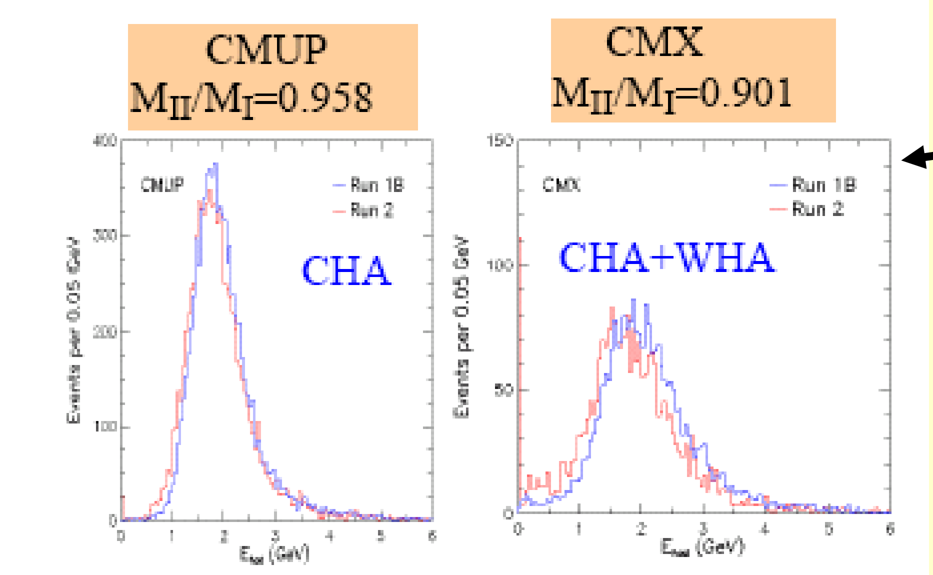
- Problem solved offline
  - Readout all strips in L00
  - Use this information to fit for an event-by-event pedestal
    - χ^2 fit to Chebyshev polynomials
  - Tested by embedding MC clusters in data
    - 95% efficiency with 95% purity
  - Implications for CDF
    - L00 can't be in online track trigger
    - Readout time may be a bottleneck



Calorimeter Energy Scale

Before Dec 10, 2001 the central hadron calorimeter E scale was based on 2000 Cs source calibration

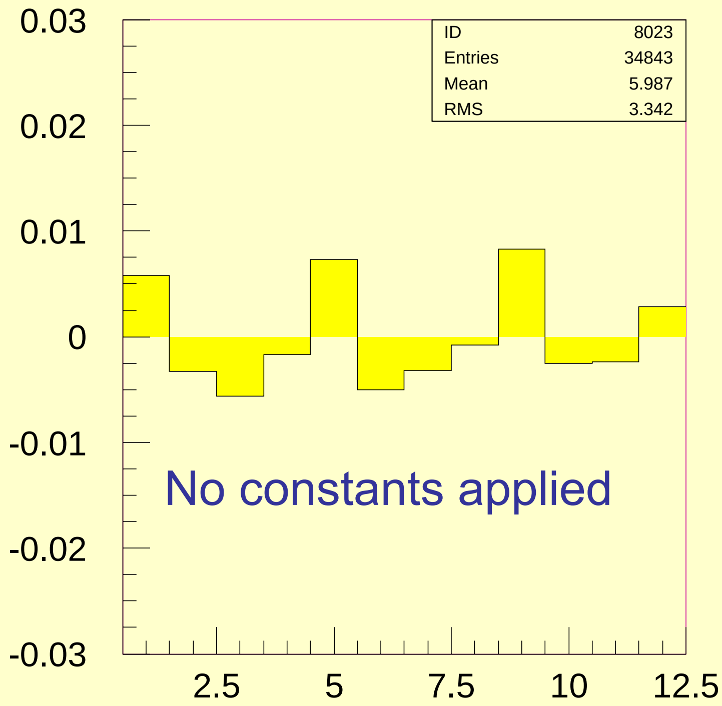
- μ MIPs (high Pt, J/Psi) ⇒ **E scale ~16% low**
  - **Due to problem with original calibration**
  - **No accounting for energy outside integration window**



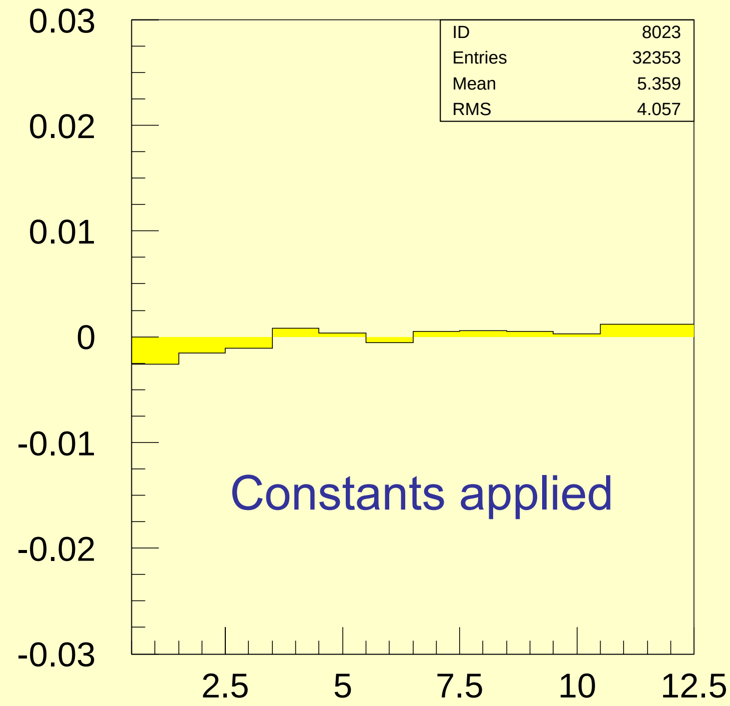
After fixes. Still not quite there.

Tracking Chamber

- T_0's from pulsing the front end
  - Constants stored in DB, applied to raw hit times
  - Need proper length calibration



SL3 Res vs Wire



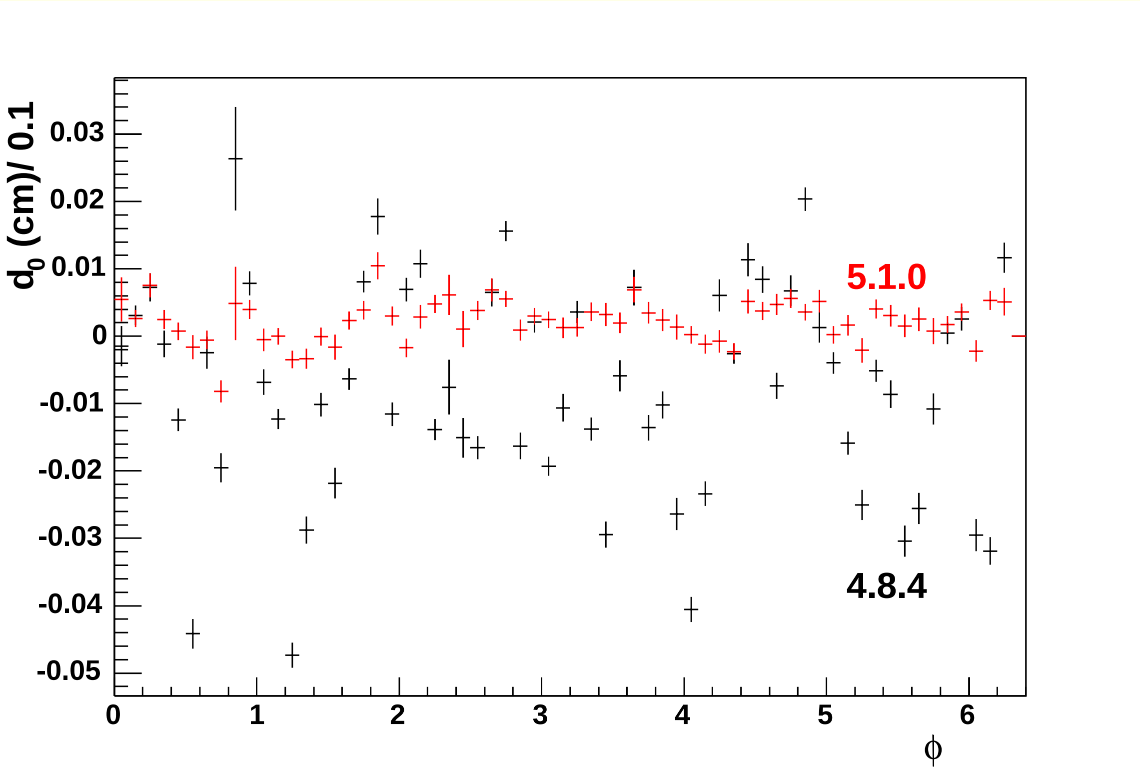
SL3 Res vs Wire

Tracking Chamber Alignment

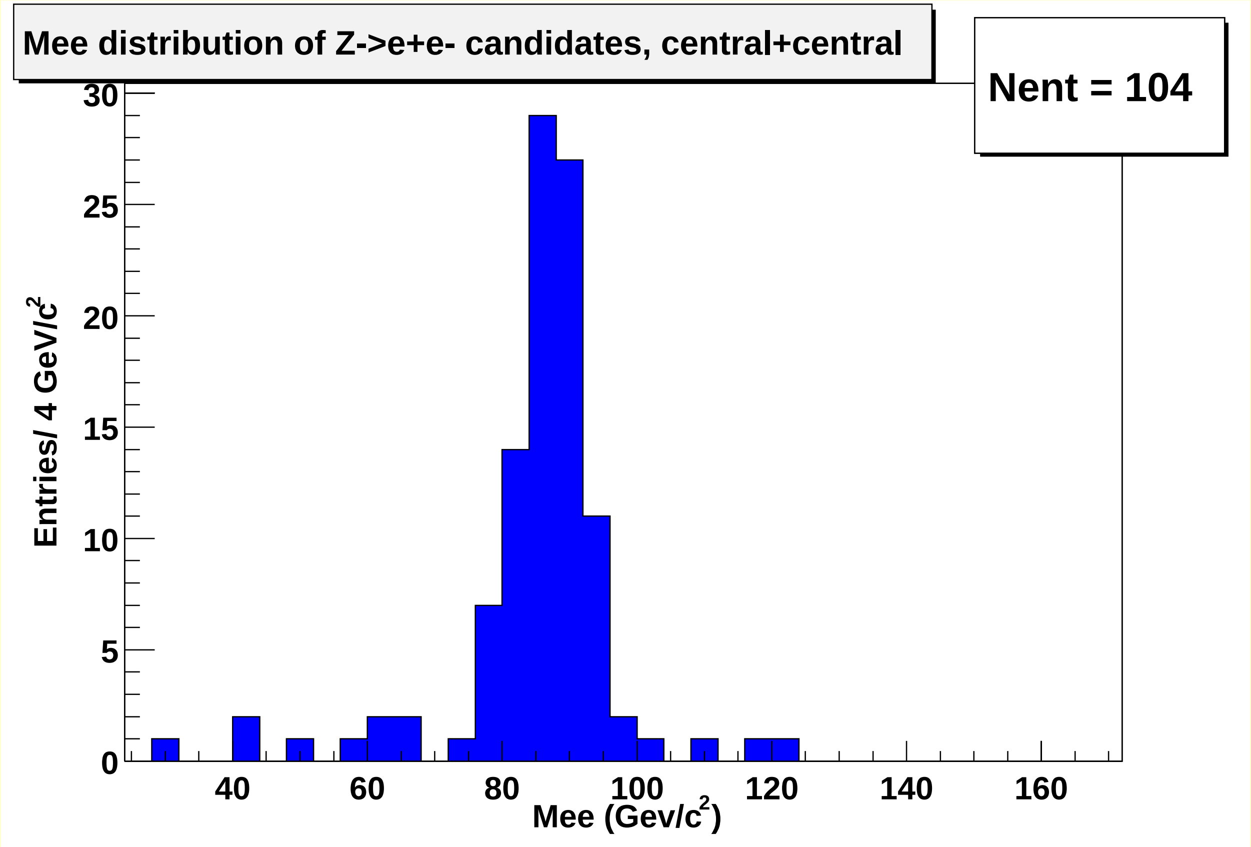
Cosmic ray based alignment: Cell tilts/shifts

– Includes corrections for electrostatics and gravity

Impact parameter vs. phi



Commissioning with Data



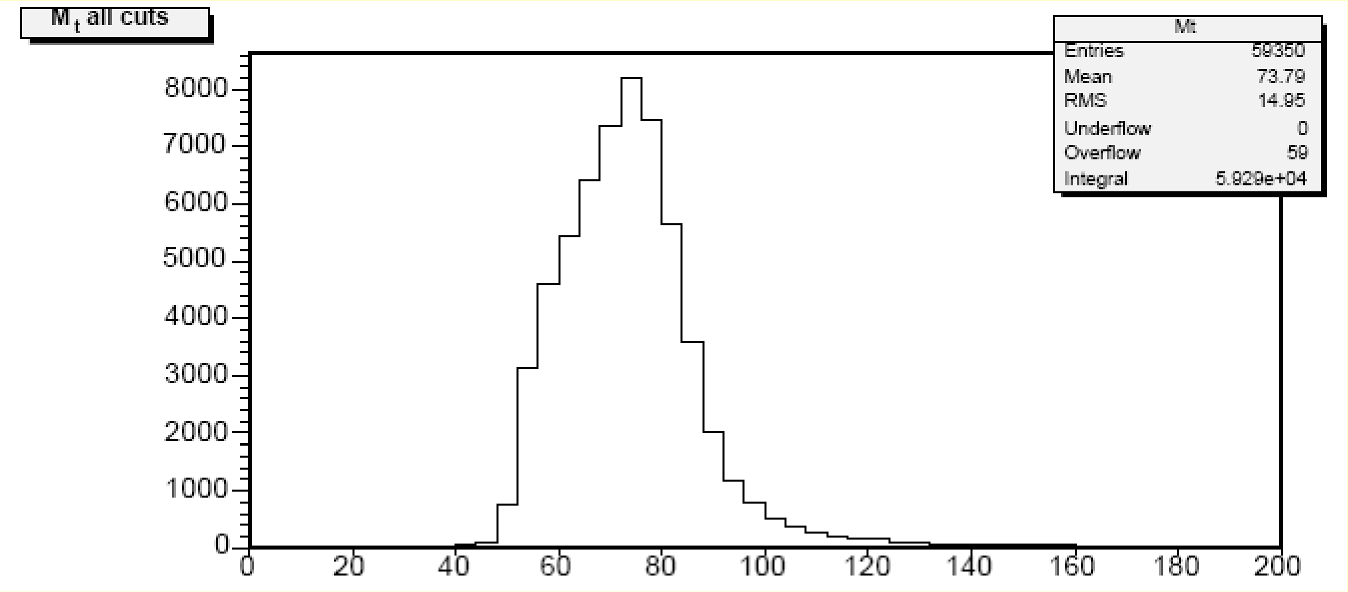
Jan. 2002
CEM (Central Electromagnetic Calorimeter) E scale established to ~1% with < 10 pb^{-1}

PEM (Plug ElectroMagnetic Calorimeter) E scale established to be 7% low with same data

(M_Z = 88 GeV/c^2)

Commissioning with Data

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



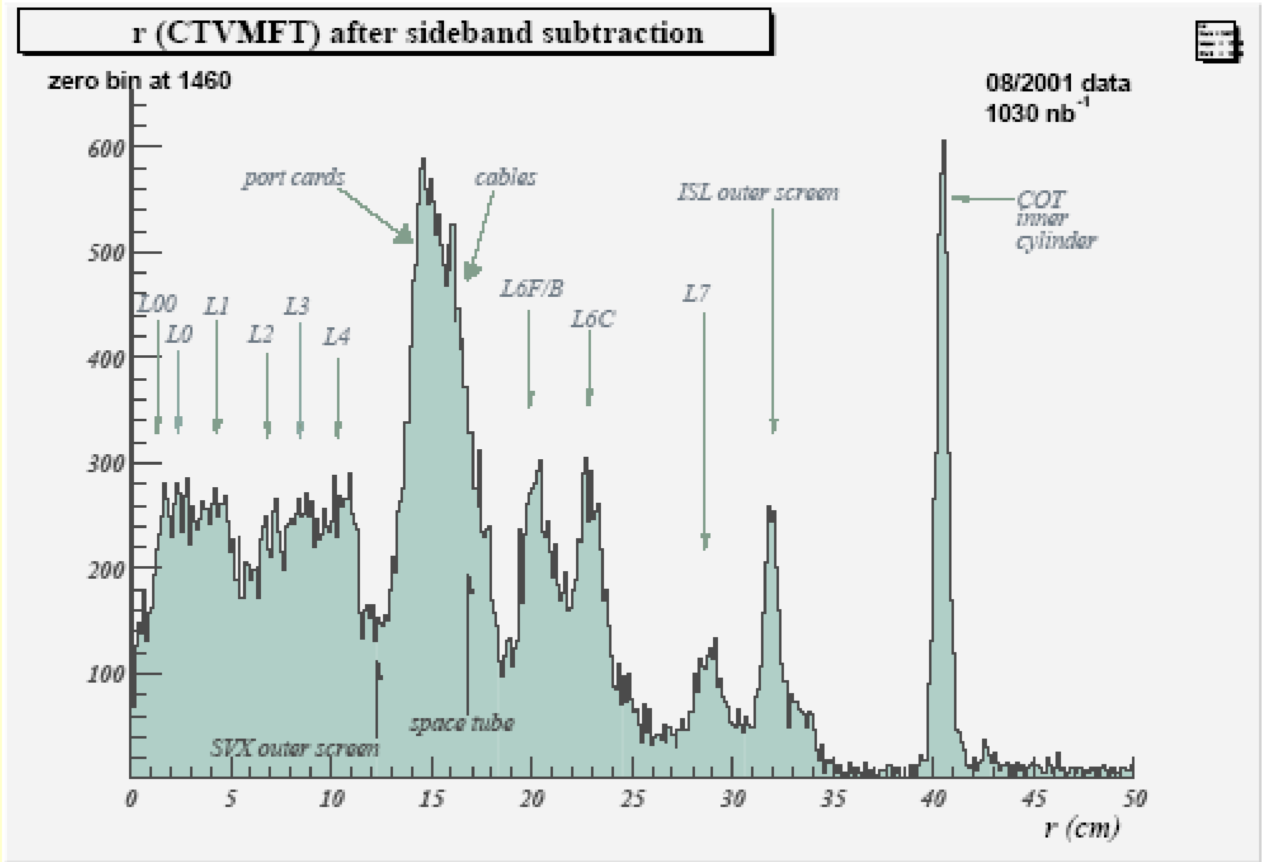
High-Pt Isolated track efficiency >99%

Commissioning with Data

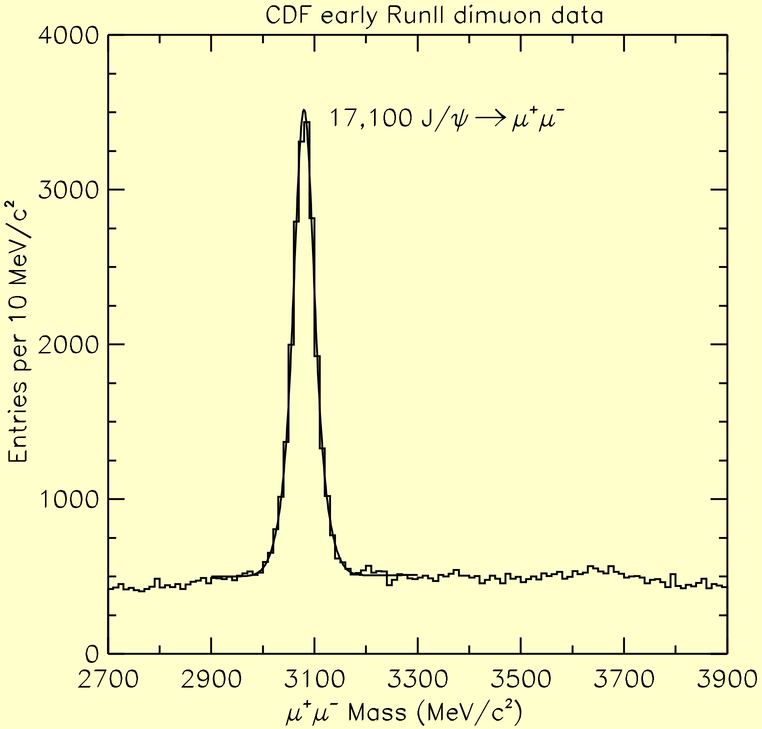
- Photon conversions used to understand the radial material distribution

August 2001

1 pb^{-1}



Commissioning with Data



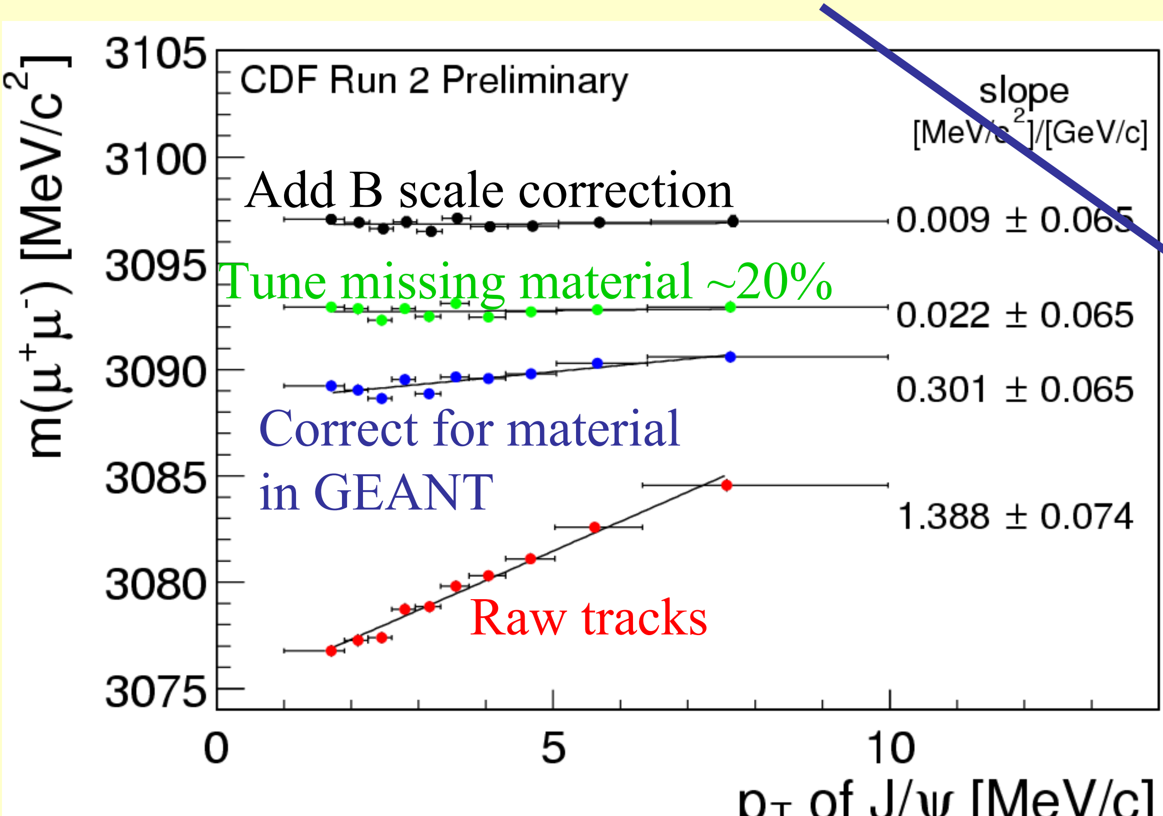
Very early J/ψ data (few pb^{-1})

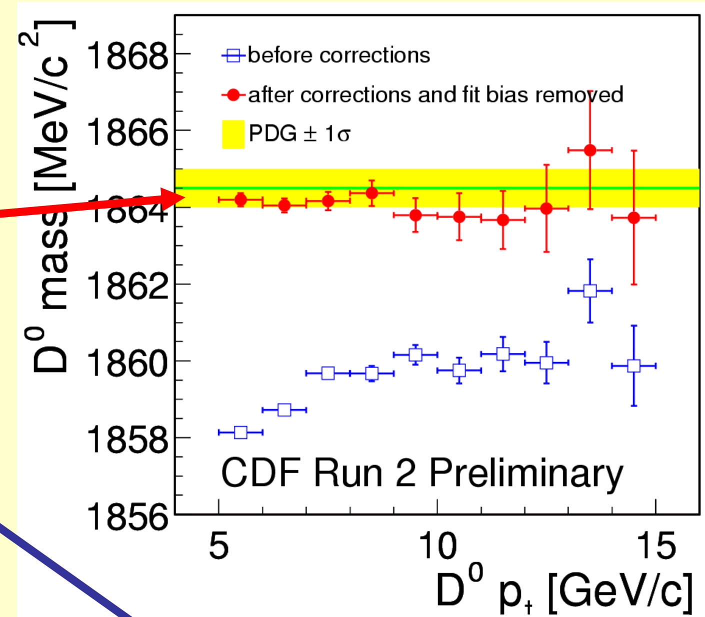
- Established basic momentum scale for tracking
- Used to measure muon chamber efficiencies
- Used to measure vertex resolution of SVX
- Used to measure energy scale of hadron calorimeter

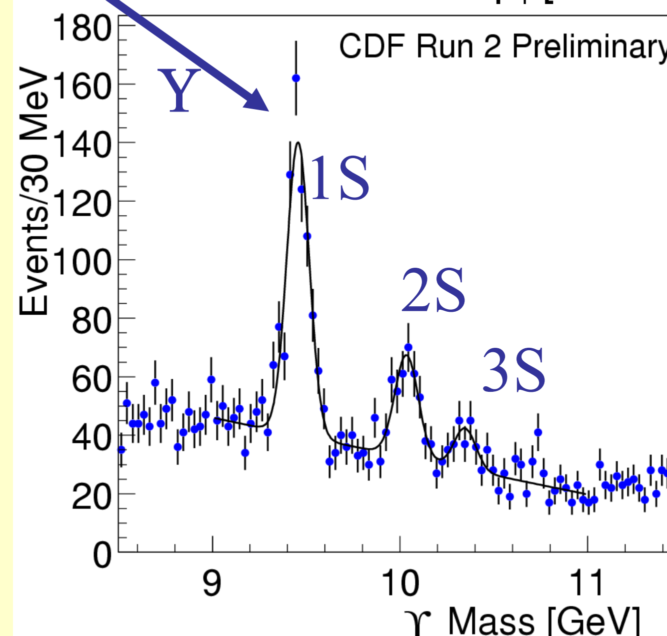
Calibration of B-Field and Material

- Use ψ's to understand E-loss and B-field corrections
- Check with other known signals

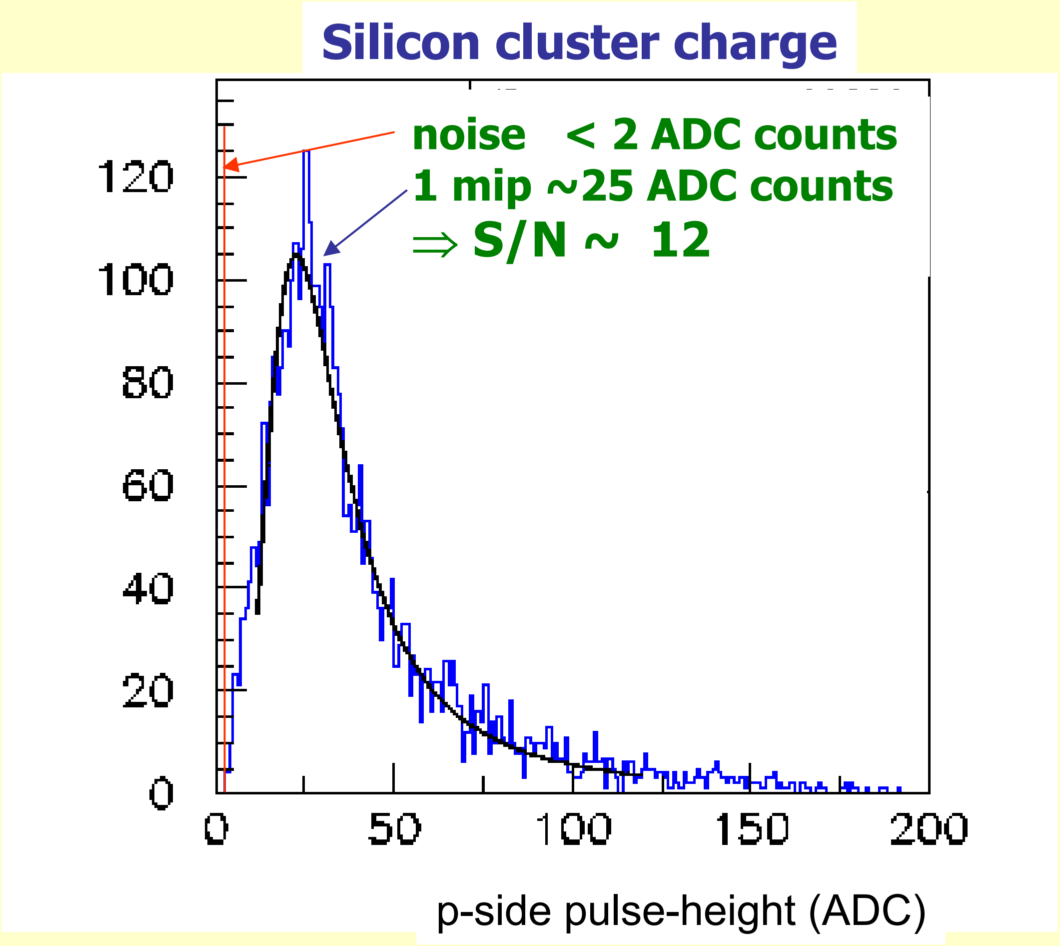
D0



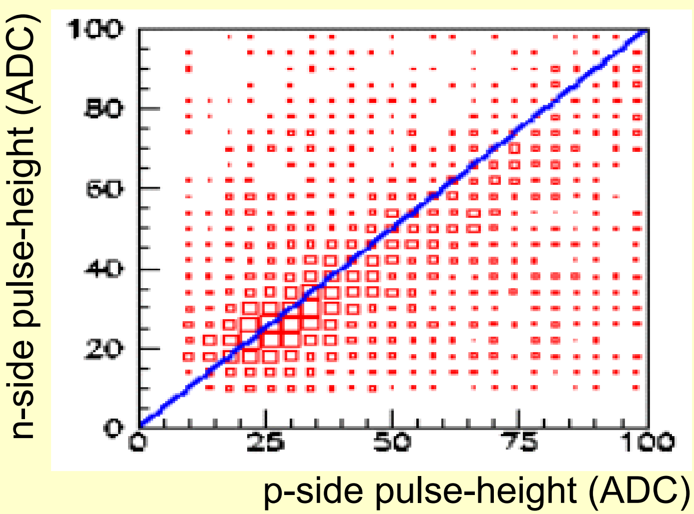




Silicon Tracker Performance

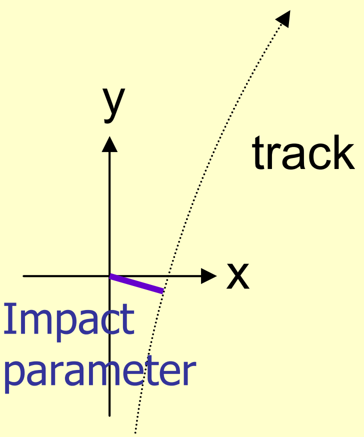


Charge correlation between p and n-side of a silicon detector

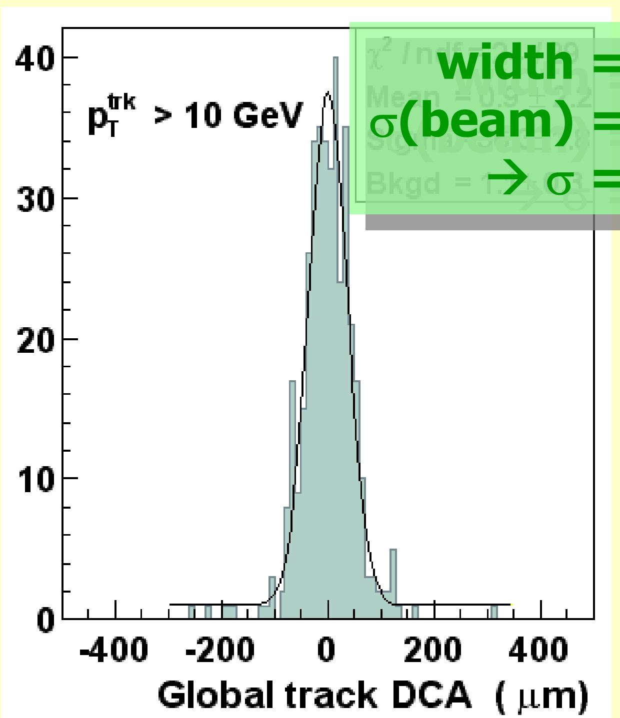


Hit efficiencies > 97%

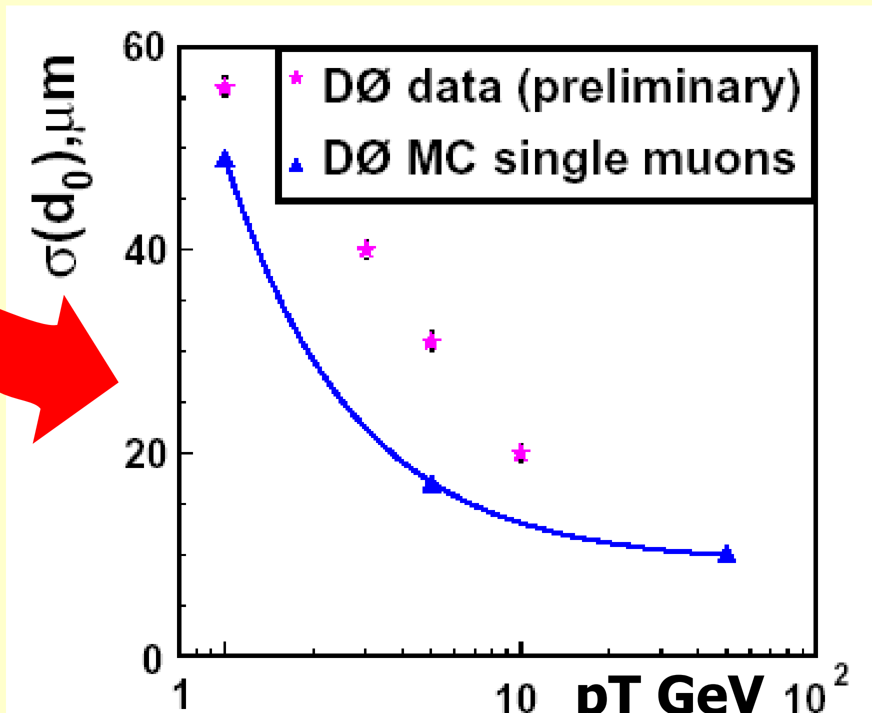
Impact Parameter Resolution



Survey-only alignment constants

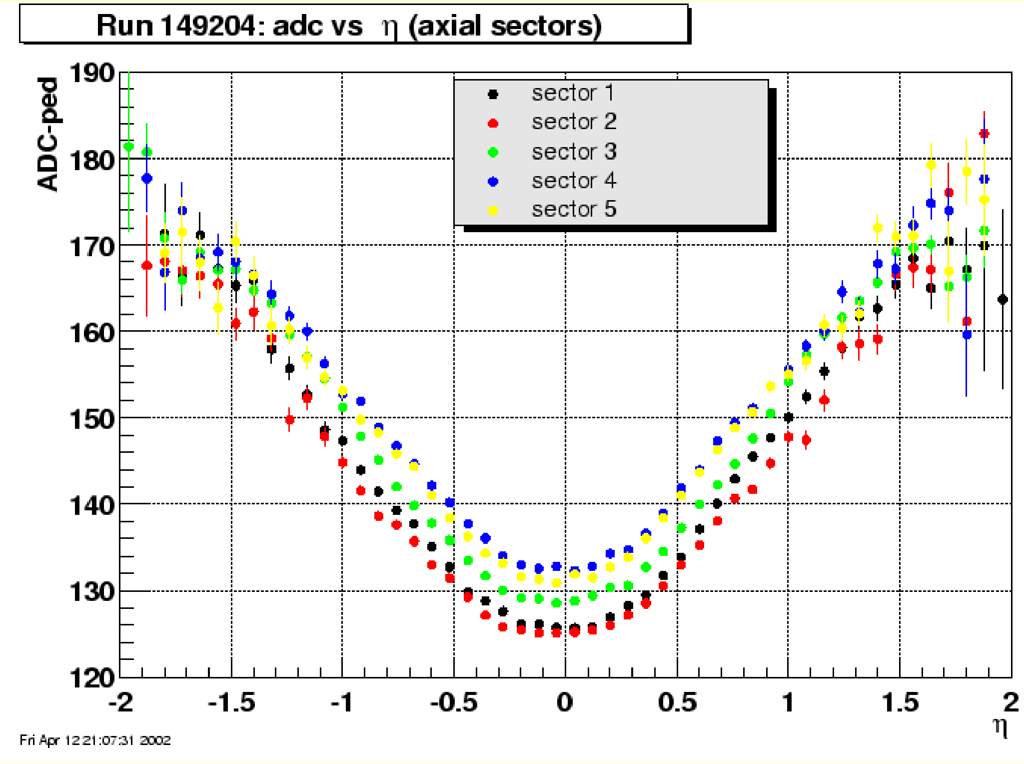


width = 36 μm
σ(beam) = 30 μm
→ σ = 20 μm

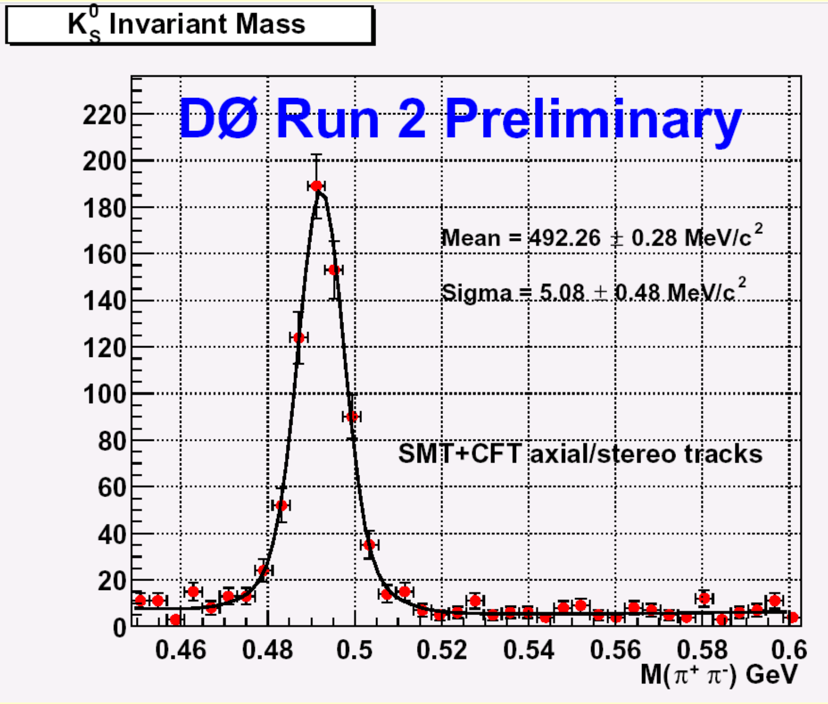


Fiber Tracker Performance

light yield vs pseudorapidity η



$K_s^0 \rightarrow \pi^+\pi^-$

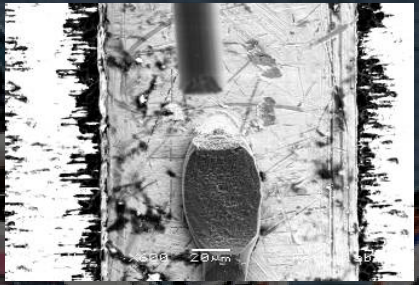


Hit efficiency $\approx$ 98%

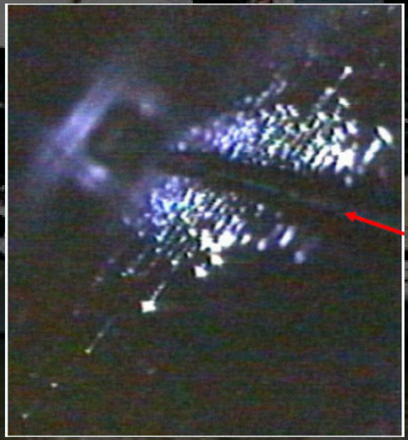
3. Comedy of Unanticipated Problems

1. ISL Cooling Lines

2. Jumper Failures due to Lorentz Forces



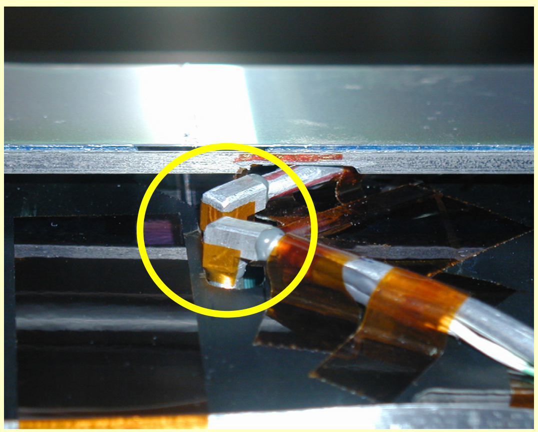
3. Beam Incidents

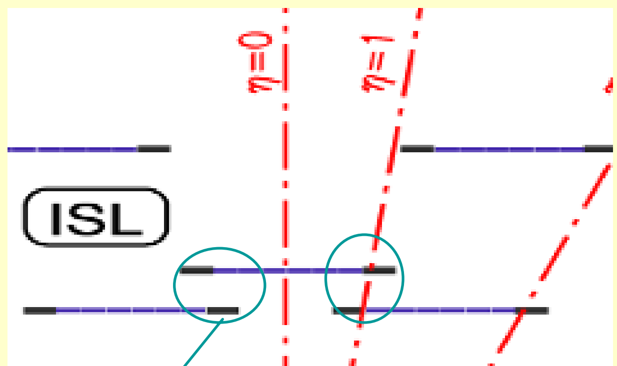


3.1 ISL Cooling Blockage

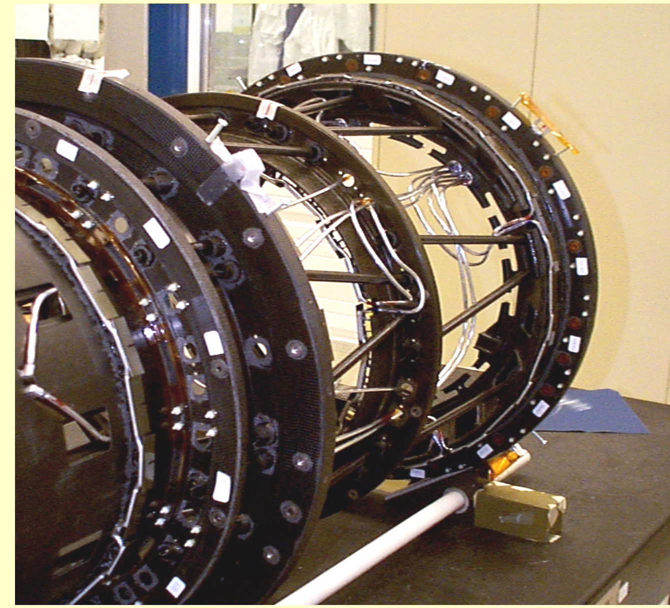
ISL cooling lines blocked

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

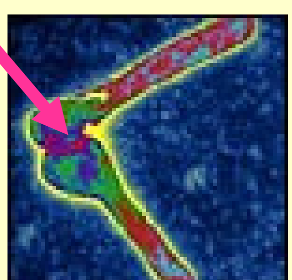




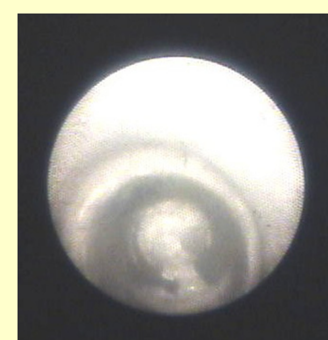
cooling problem



What's this?

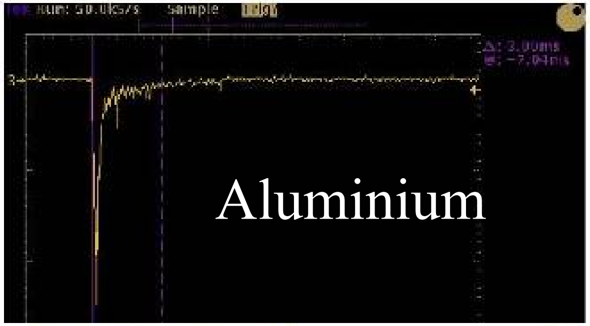


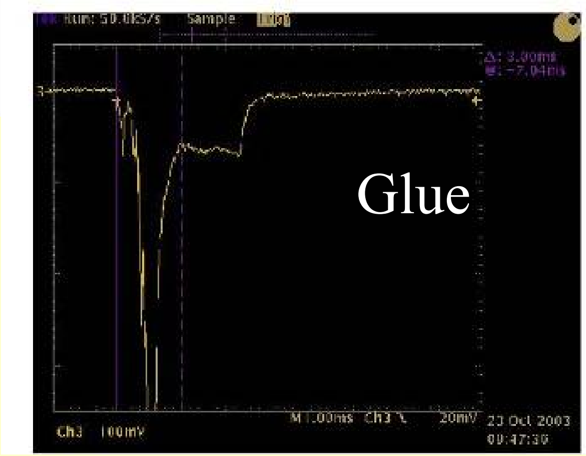
optical inspection



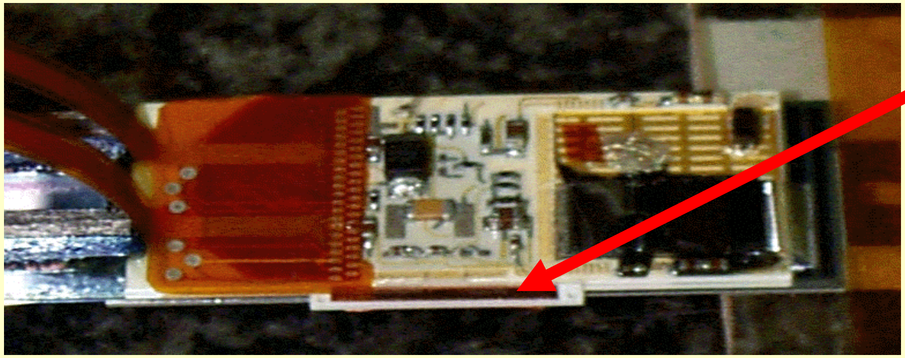
Finding and Removing the Epoxy

40W IR laser was used to find and remove the glue
- Fused silica fiber optics & prisms used to direct the light
- Targeted with **2 Joule** pulses (determined safe for Al lines on bench)
- Scattered light was observed with PMT
  - Glue burning had 'afterglow'
- Glue was burned out with **6 Joule**, 3 ms pulses
- No lines were damaged
- 11/12 lines cleared
  - Last line blocked by stuck prism



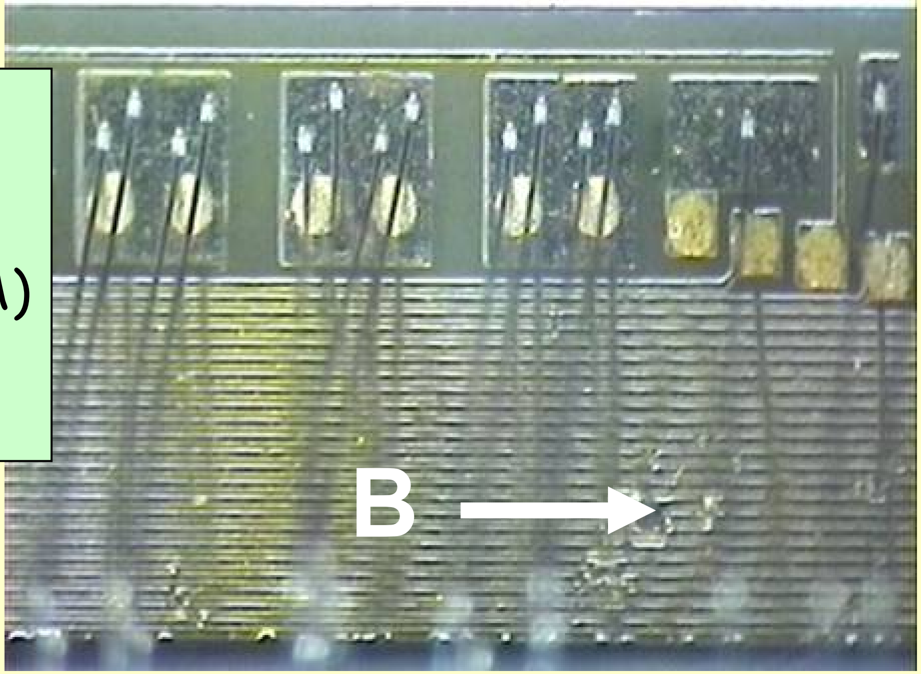


3.2 Losses Due to Jumper Failures



"Jumper" connects r-ϕ and r-z sides of hybrid (data, power lines)

Observed loss of digital power for 12/360 SVX z sides



Crazy theory: Lorentz forces on wirebonds which connect jumper?

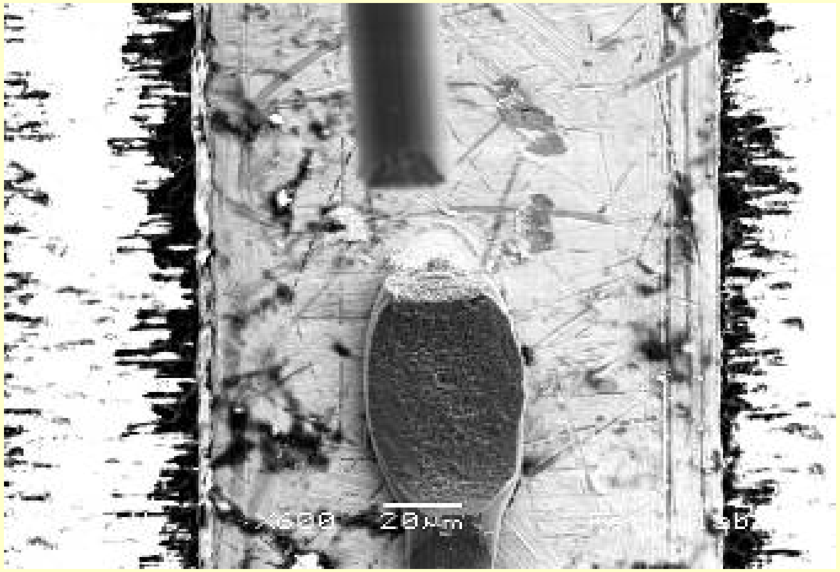
- 1.4 T field perp. to bond
- Dynamic digital current draw (200mA)
- Trigger rate may induce resonance
- Bonds are not encapsulated

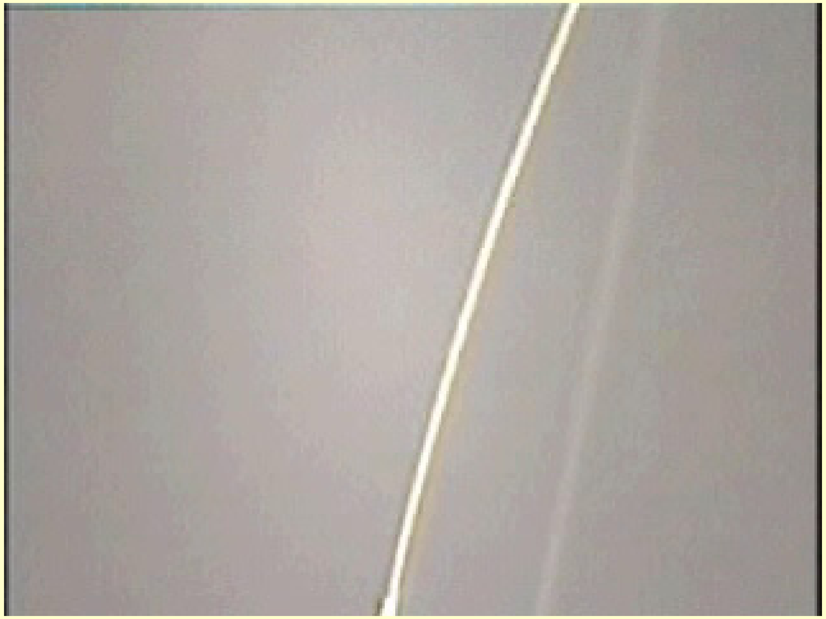
"So crazy that it might be true!"

Resonant Lorentz Forces

- Resonance effect established at a test stand:
  - Fundamental frequency for 2 mm AlSi bond ~ 15 kHz
  - Drive w/ sinusoidal AC
  - Scan current (10mA - 150mA)
  - with real modules driven by real DAQ

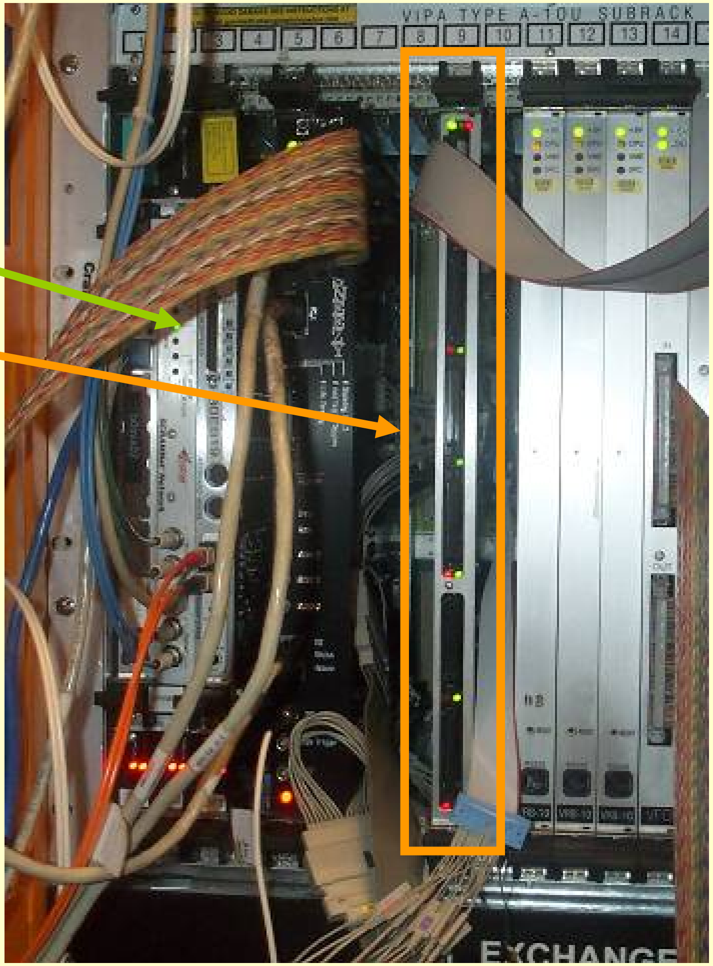
- After exposure to resonance for minutes-hours, bonds break





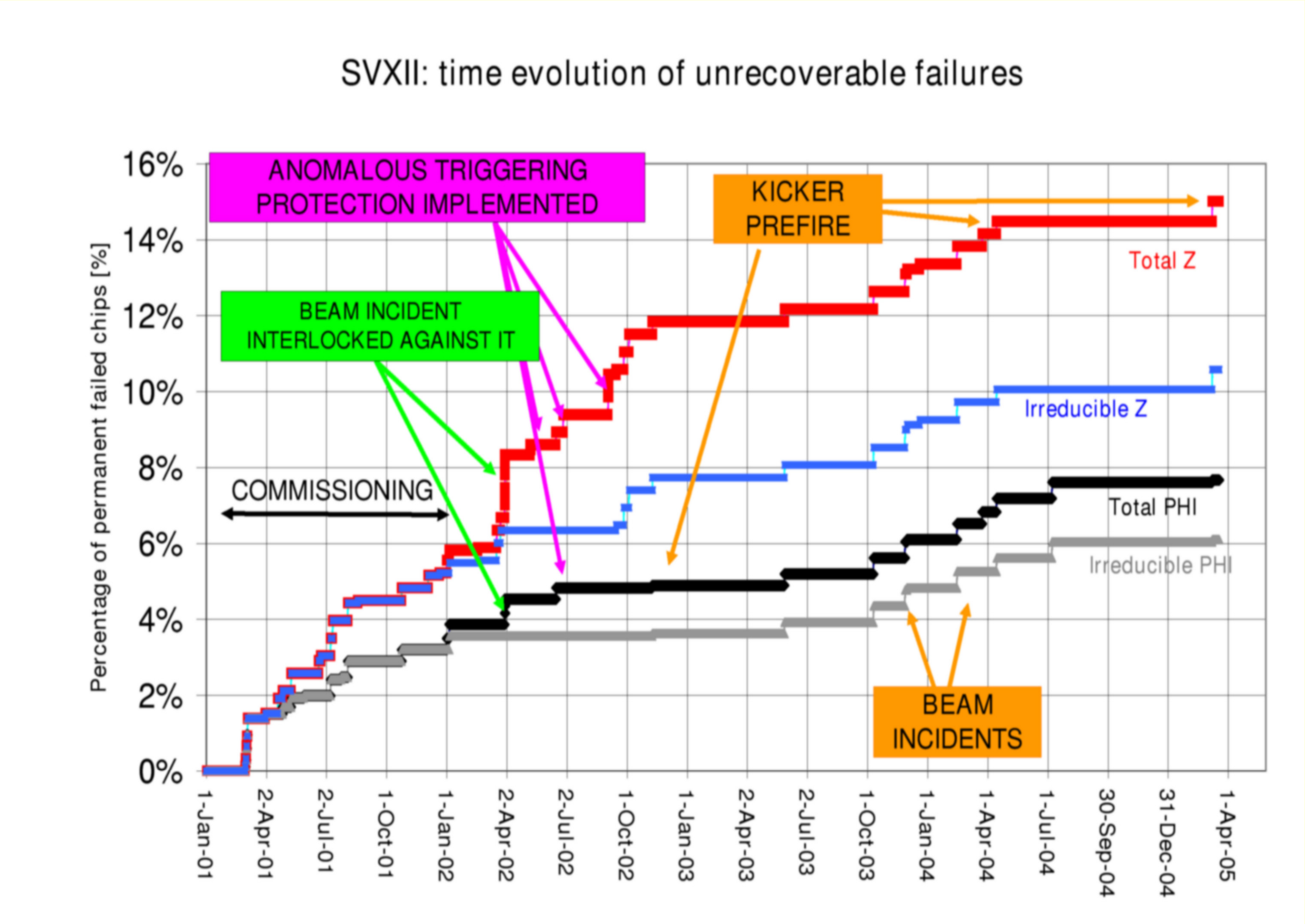
Wirebond Resonance Mitigation

- A synchronous trigger condition detector avoids wire bond resonances
  - Performs FFT analysis of of L1 trigger rates
  - Halts DAQ via **Silicon Readout Controller**
  - Based on SVT **ghostbuster** board
  - DAQ code analyzes possible cause of synch. trigger conditions.



3.3 Beam Incididents

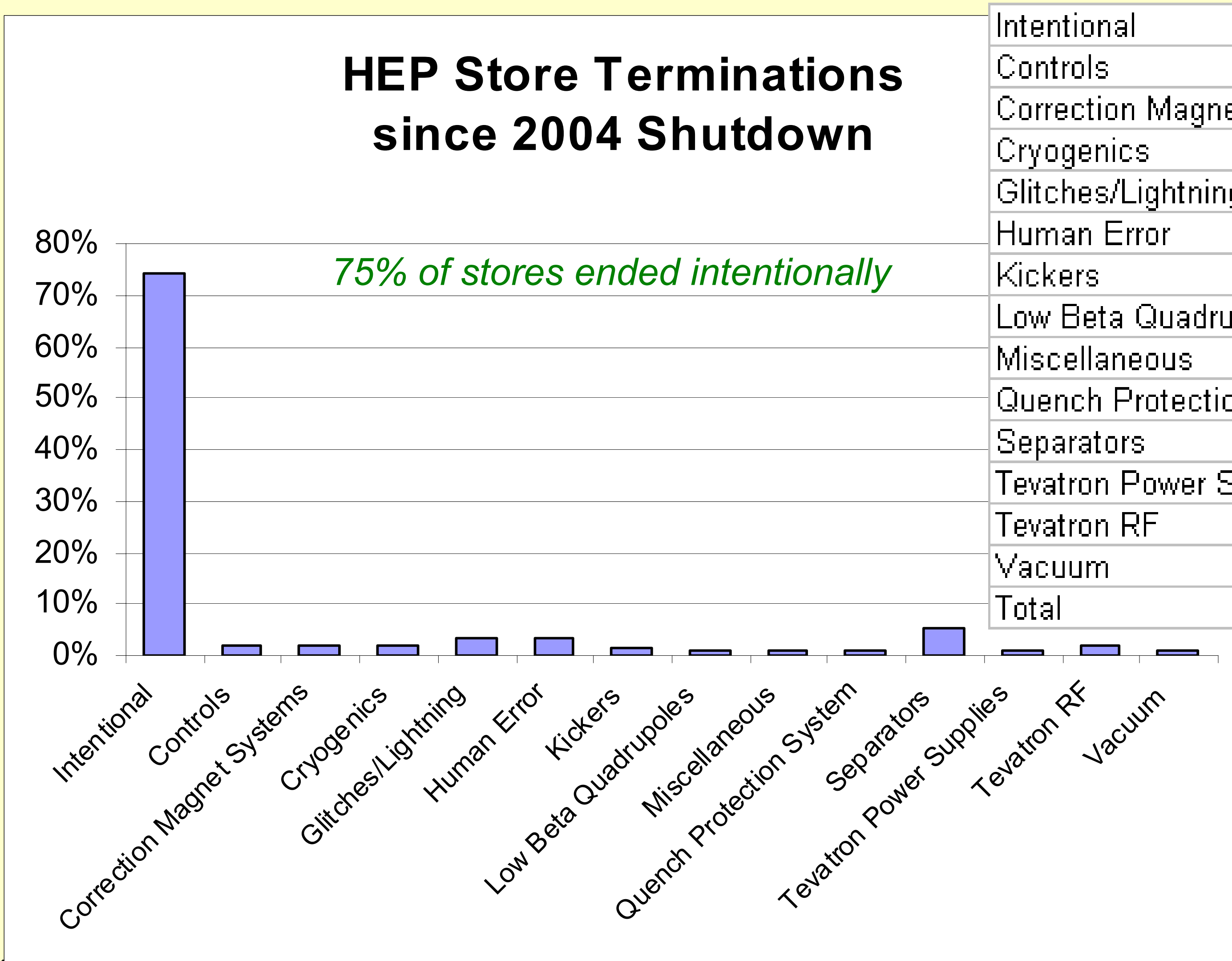
- Abort kicker pre-fire
- Loss of Tevatron RF



What Can Go Wrong With the Tevatron …

- Thunderstorms, power glitches: can't control Mother Nature or Commonwealth Edison
- Cryogenic failure, *e.g.* wet engine: usually enough time to abort beam before quench
- Magnet power supply failure: most supply trips cause automatic abort
- Tev electron lens trip: DC beam accumulates in abort gap
- RF cavity trip: increase bunch lengths (decrease luminosity), dump beam into abort gap
  - Automatic abort if >1 cavity trips
- Separator spark: drive beam into collimators causing a quench, loss of store
    - Very fast, can have bad results (indirectly)
- Abort kicker pre-fire: 1 kicker tube fires at random time, possibly in middle of train
  - Very fast, possibly very bad $\Rightarrow$ kick protons into CDF, fry some ladders
  - 1 kicker insufficient to kick beam into abort dump, beam circulates with large oscillation

Store Termination by Category

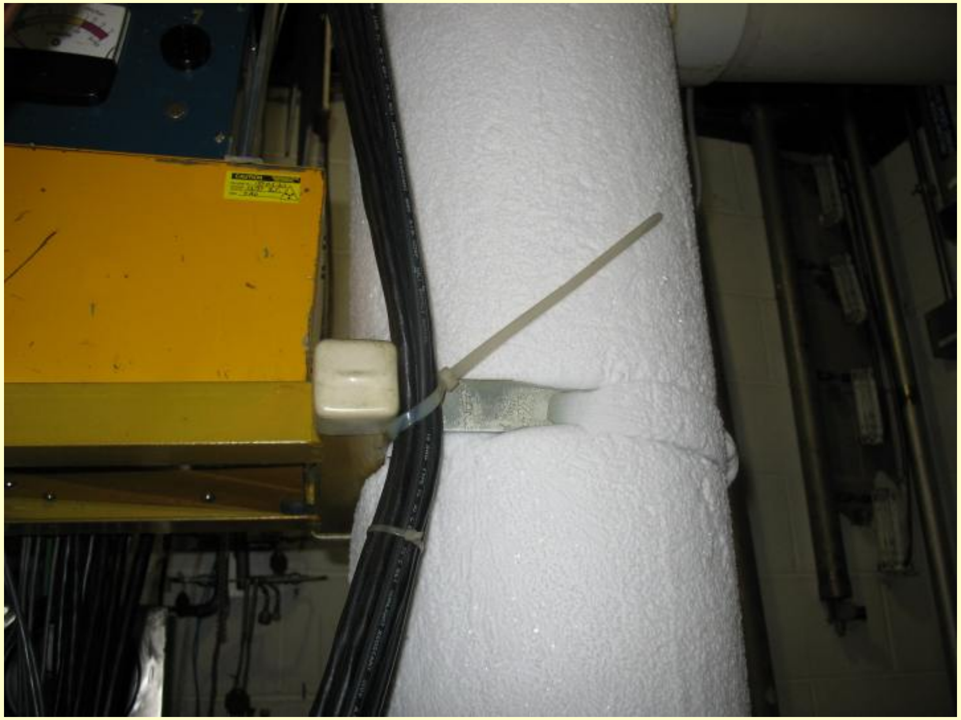


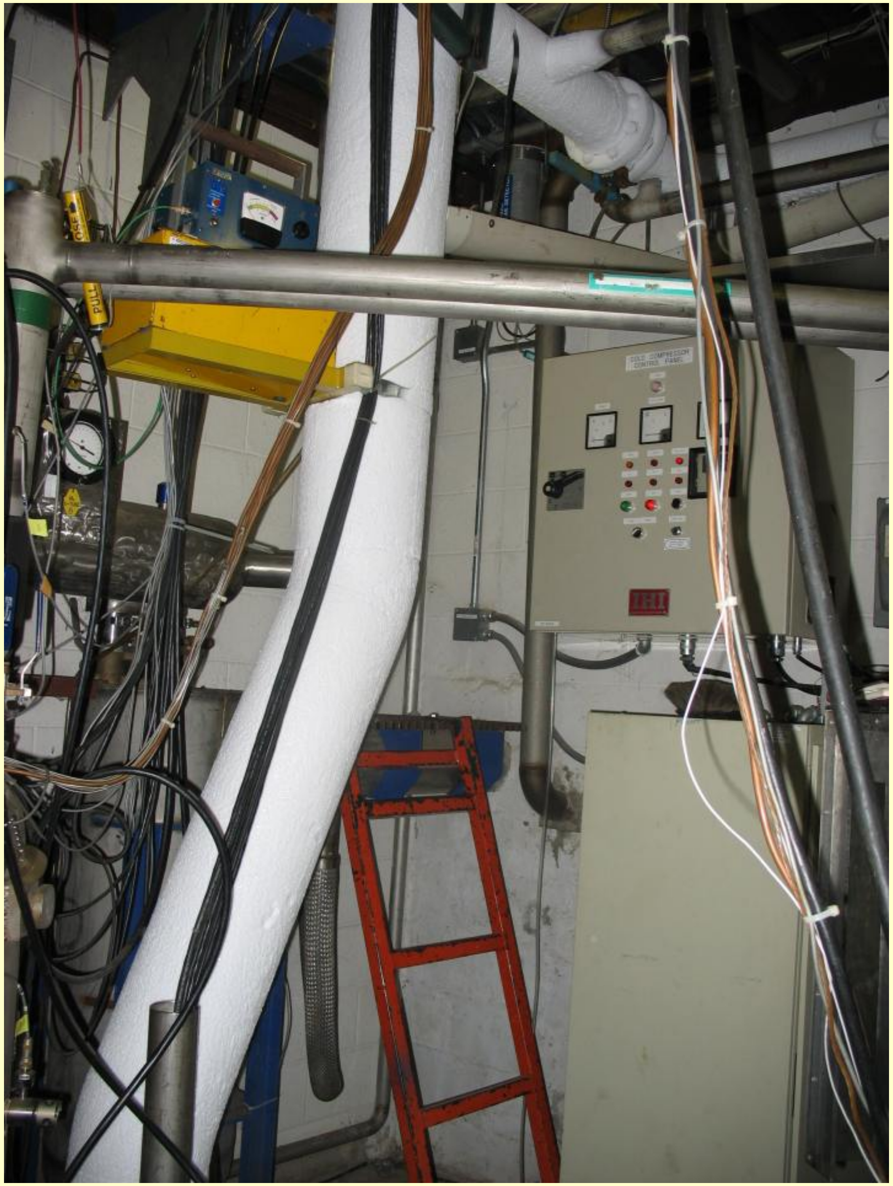
Intentional	74%
Controls	2%
Correction Magnet Systems	2%
Cryogenics	2%
Glitches/Lightning	3%
Human Error	3%
Kickers	1%
Low Beta Quadrupoles	1%
Miscellaneous	1%
Quench Protection System	1%
Separators	5%
Tevatron Power Supplies	1%
Tevatron RF	2%
Vacuum	1%
Total	100%

Frozen Pipes Cause Wet Engine Failure

Quench in house A32U (Dec. 2007).

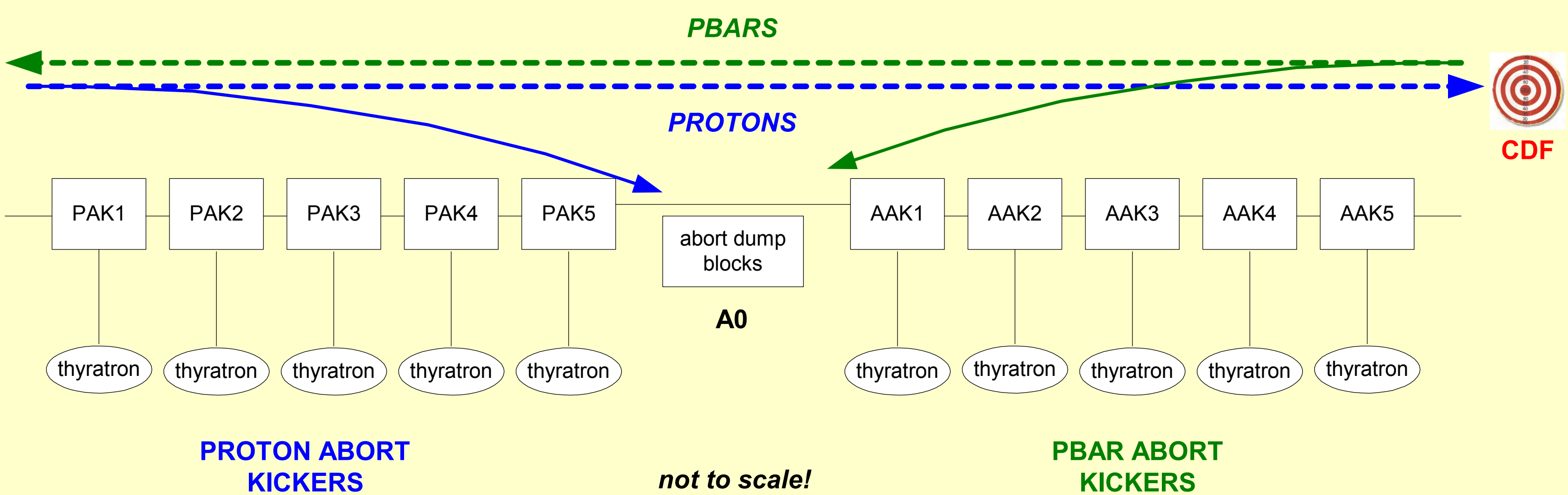
Pipe (suction header) was covered with a 2 cm thick ice layer..





Aborting the Beam

- Abort kickers ramp up synchronously in gap between P24/P25 (A36/A1)
  - 70% full voltage when next bunch passes by; enough to kick into dump
- Beam in abort gap while kickers rising gets kicked, but not into dump
  - Can circulate with large distortion, strike apertures downstream, cause quenches, …
  - Collimators at A11, A48 help protect CDF
- Abort kicker pre-fires happen when 1 thyratron breaks down spontaneously
  - Other abort kickers automatically fire < 1 turn later to kick rest of beam into dump
  - Tubes holding off 36 kV @ 980 GeV over entire store – many hours
  - Thyratrons are conditioned at higher voltages, but pre-fires can (will) still occur

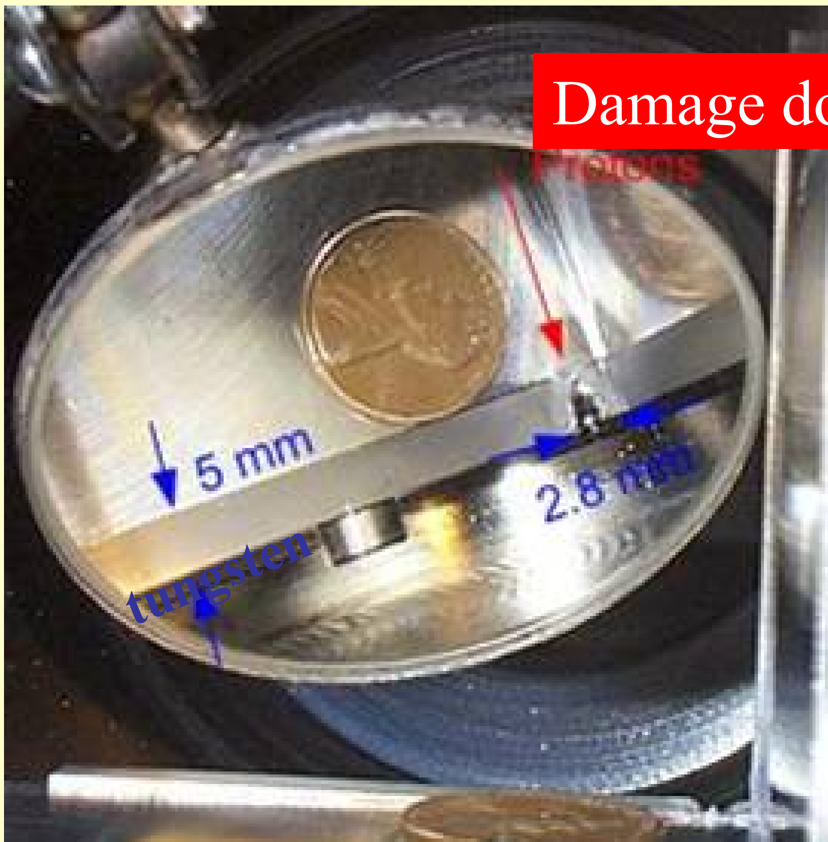


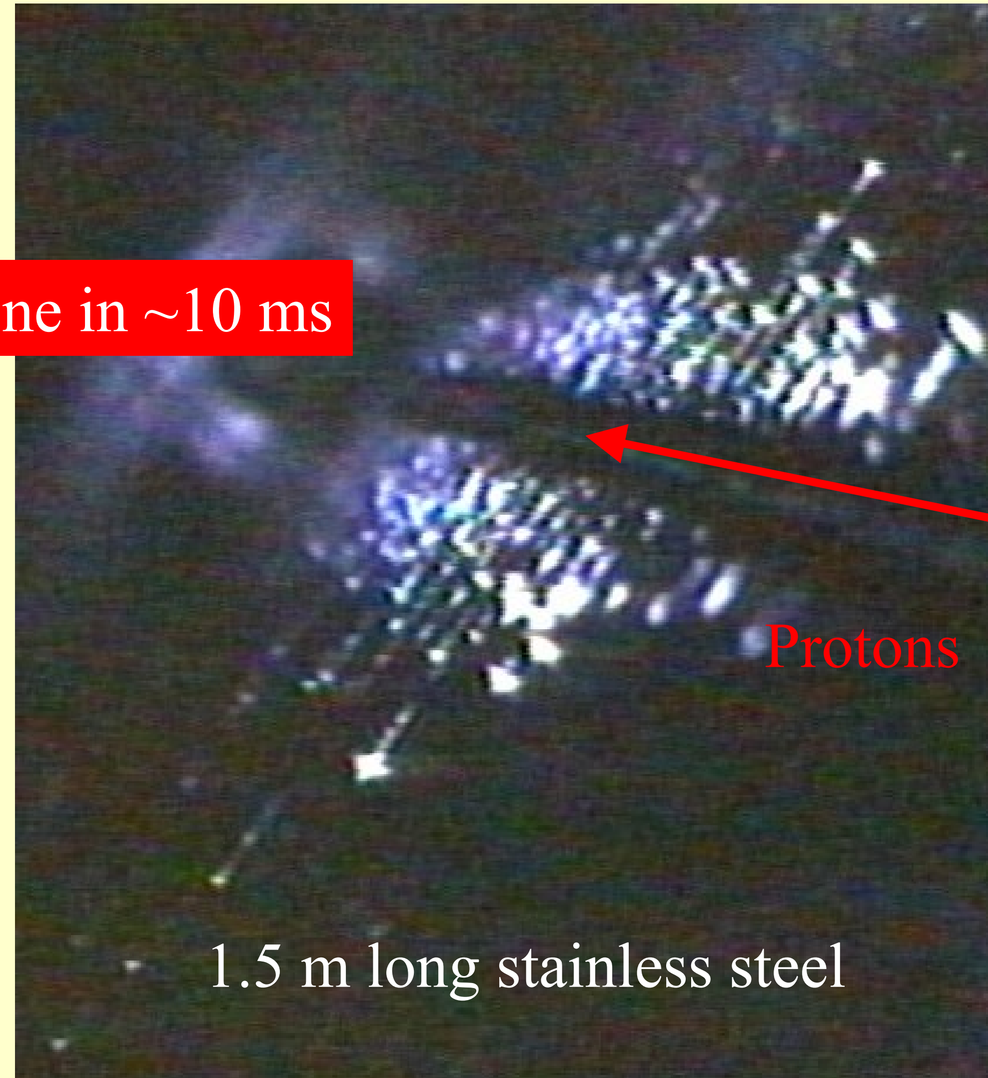
Destroyed Collimators in Tevatron

stored beam energy

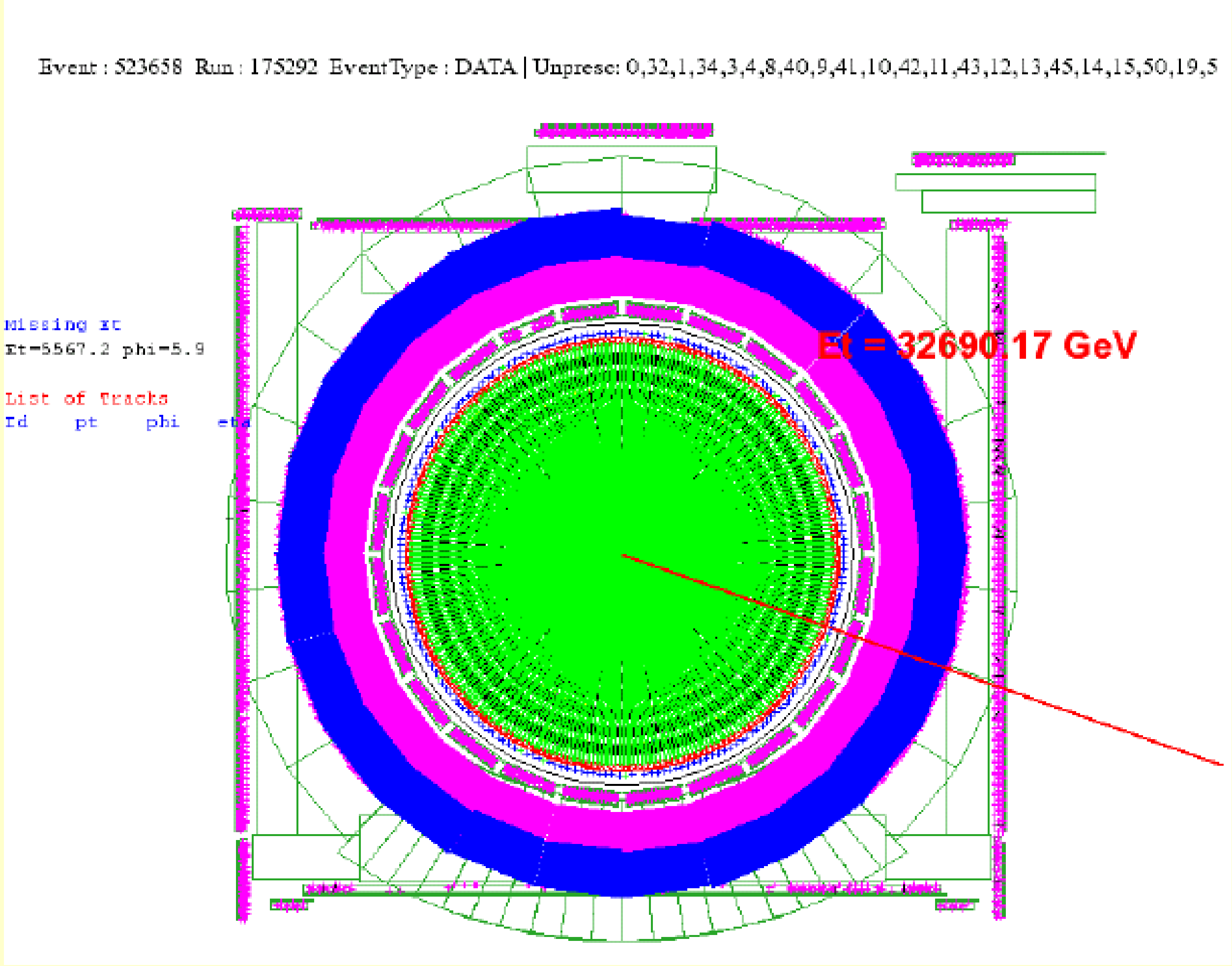
10^{13} *protons @ 1 TeV ≈ 1.6 MJ*

Damage done in ~10 ms





CDF Glowing

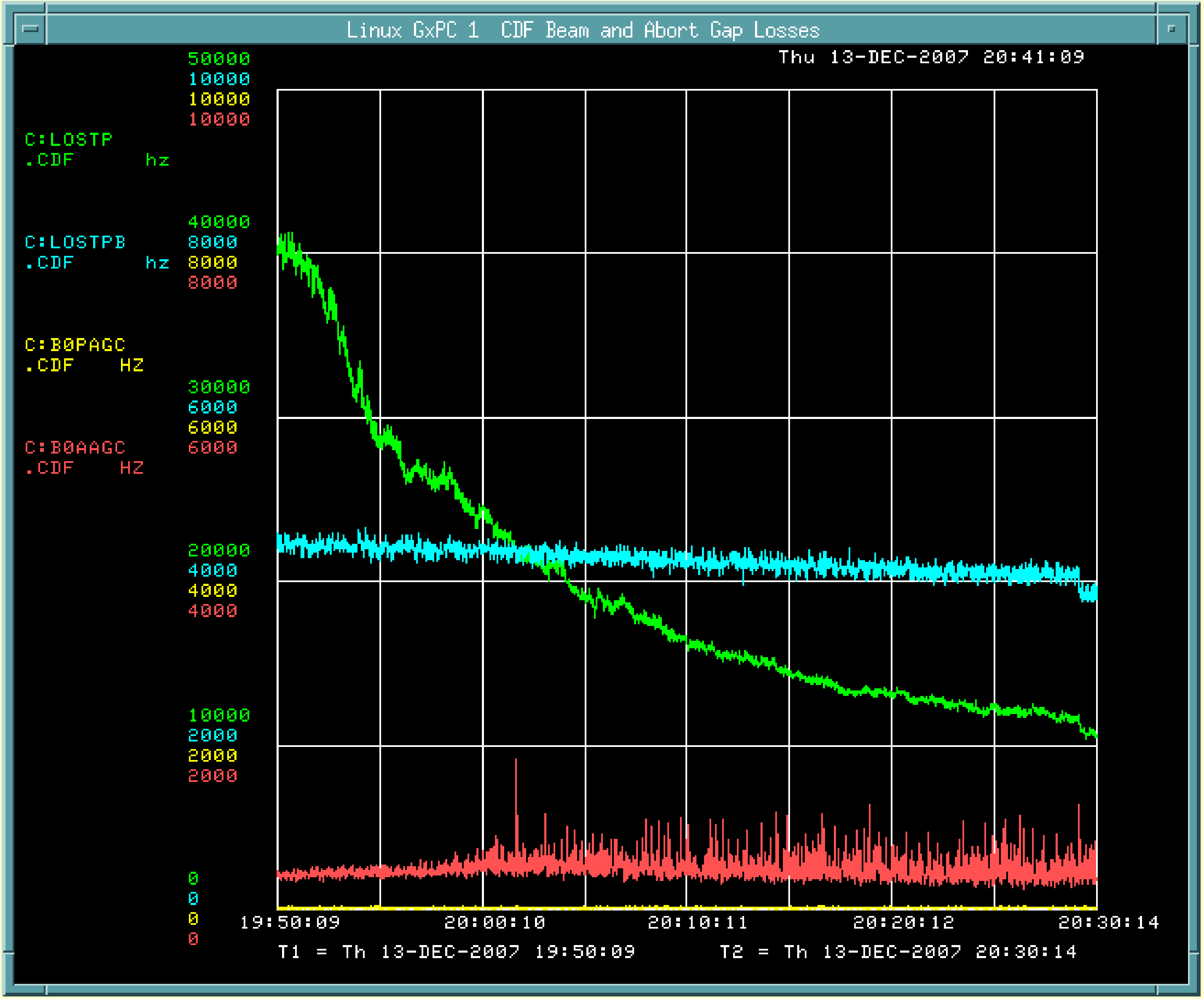


- Beam incidents are a major threat the silicon system
- Several interlock systems in place to mitigate risks

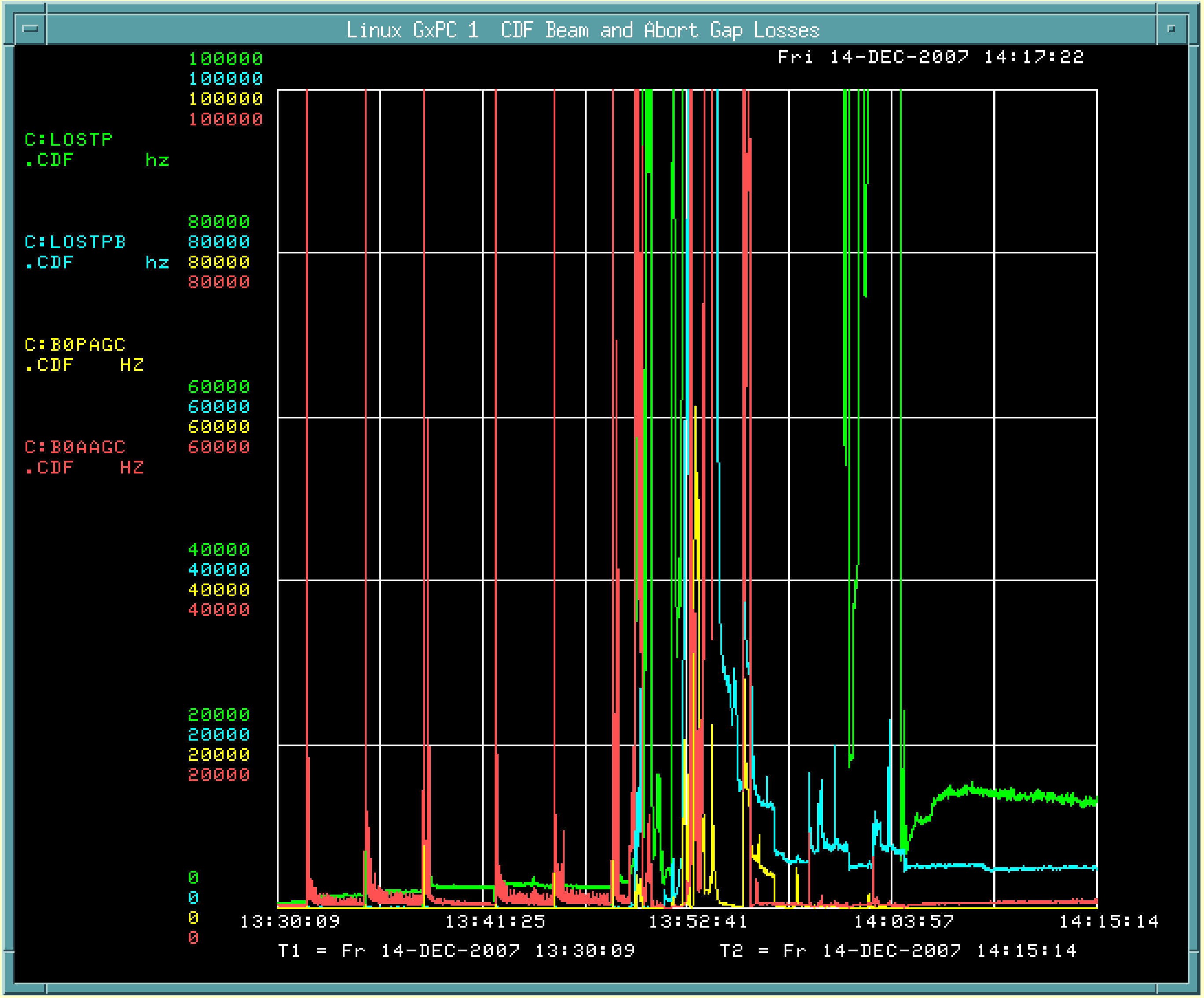
Monitoring Proton Losses

ACNET real time plotter in control room

Silicon detector only turned on, if lostp und lostpbar rates are below 10 kHz.



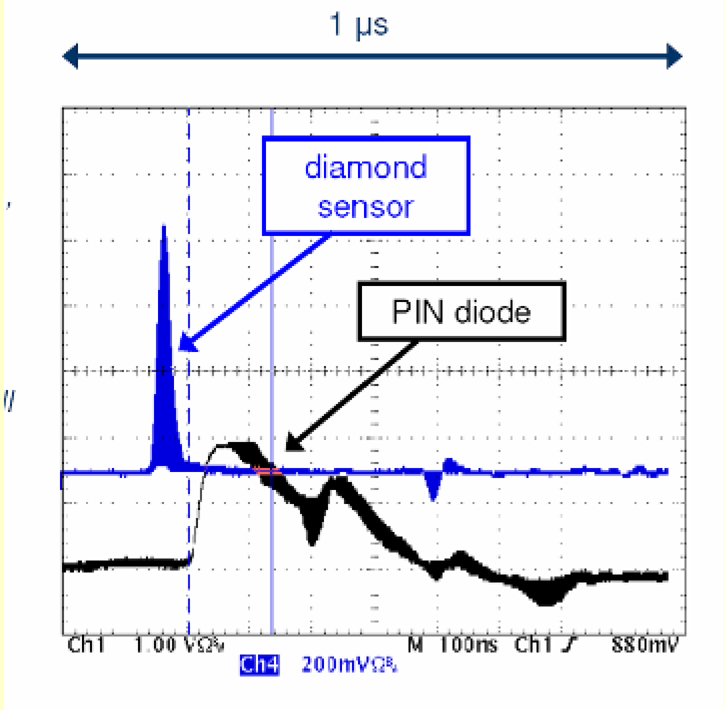
Beam Scraping

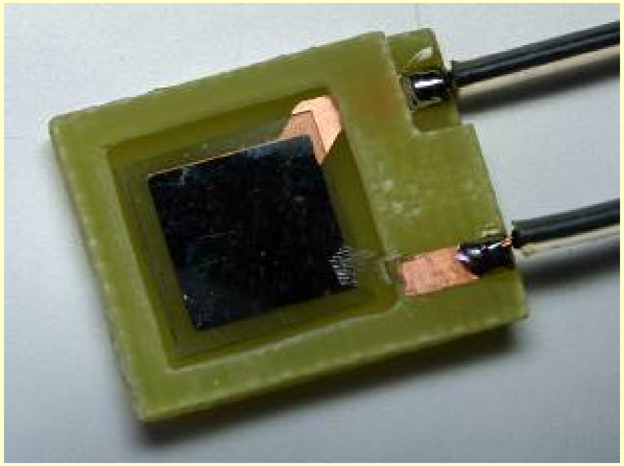


Improved Beam Condition Monitor and Abort System

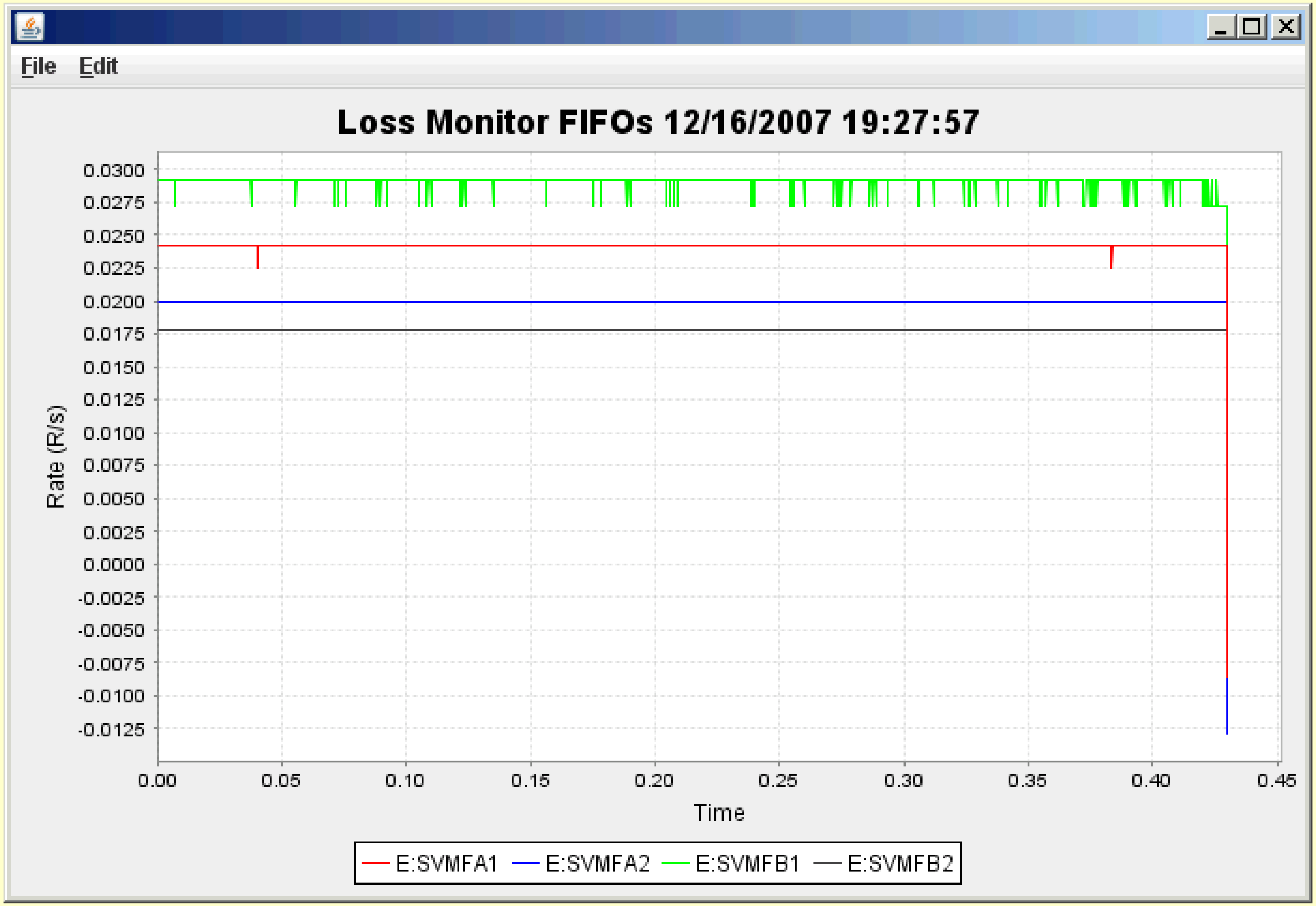
Original beam abort system (based on ionization chambers) had 200μs latency
⇒Upgrade to **CVD Diamond Detectors** for **Beam Abort** and **Beam Condition Monitoring:**
- signal and noise comparable to silicon.
- **radiation hard** (10x LHC)
- **fast! O(100 ns)**

BaBar diamond abort system

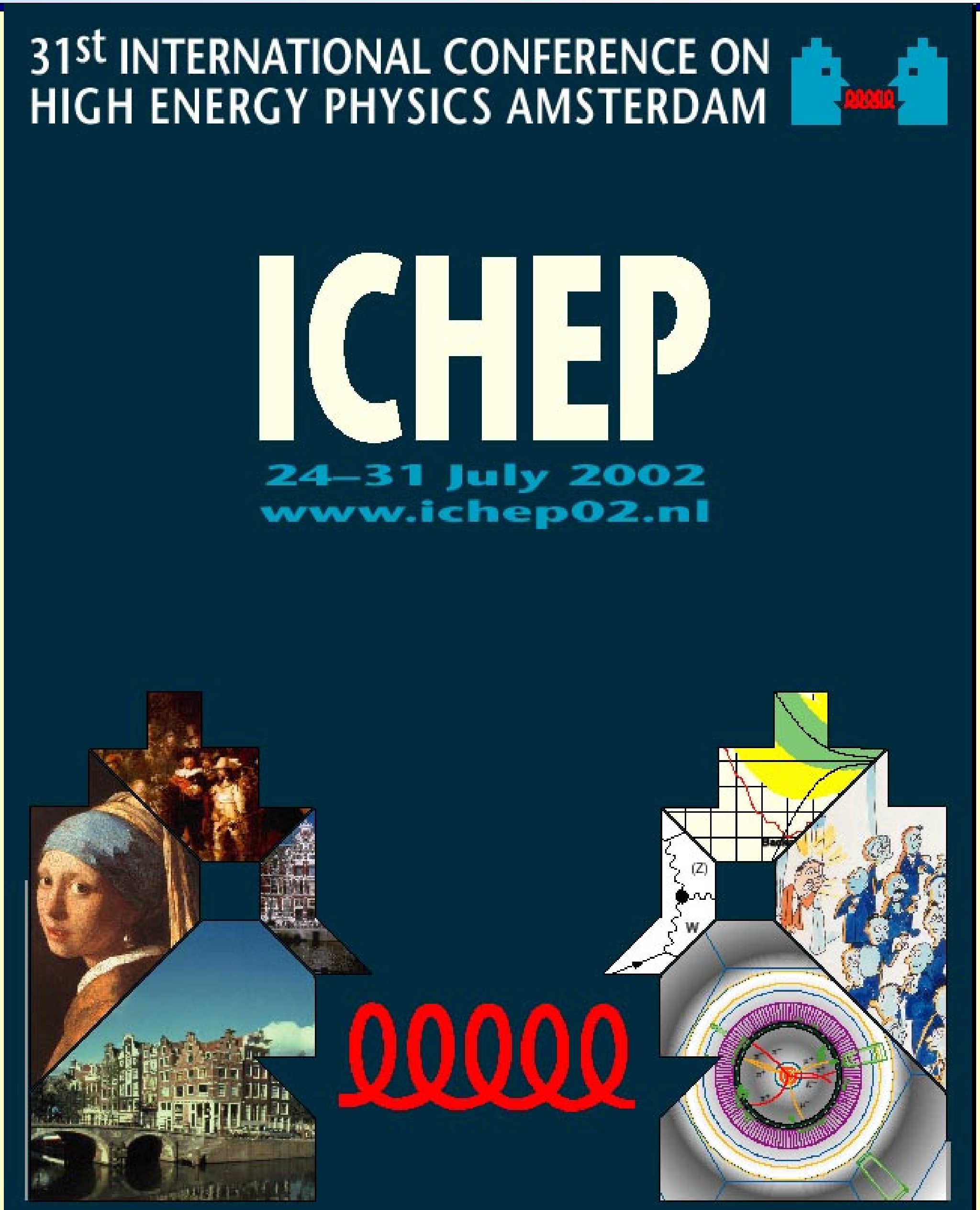




Beam Abort Sunday 16.12.2007

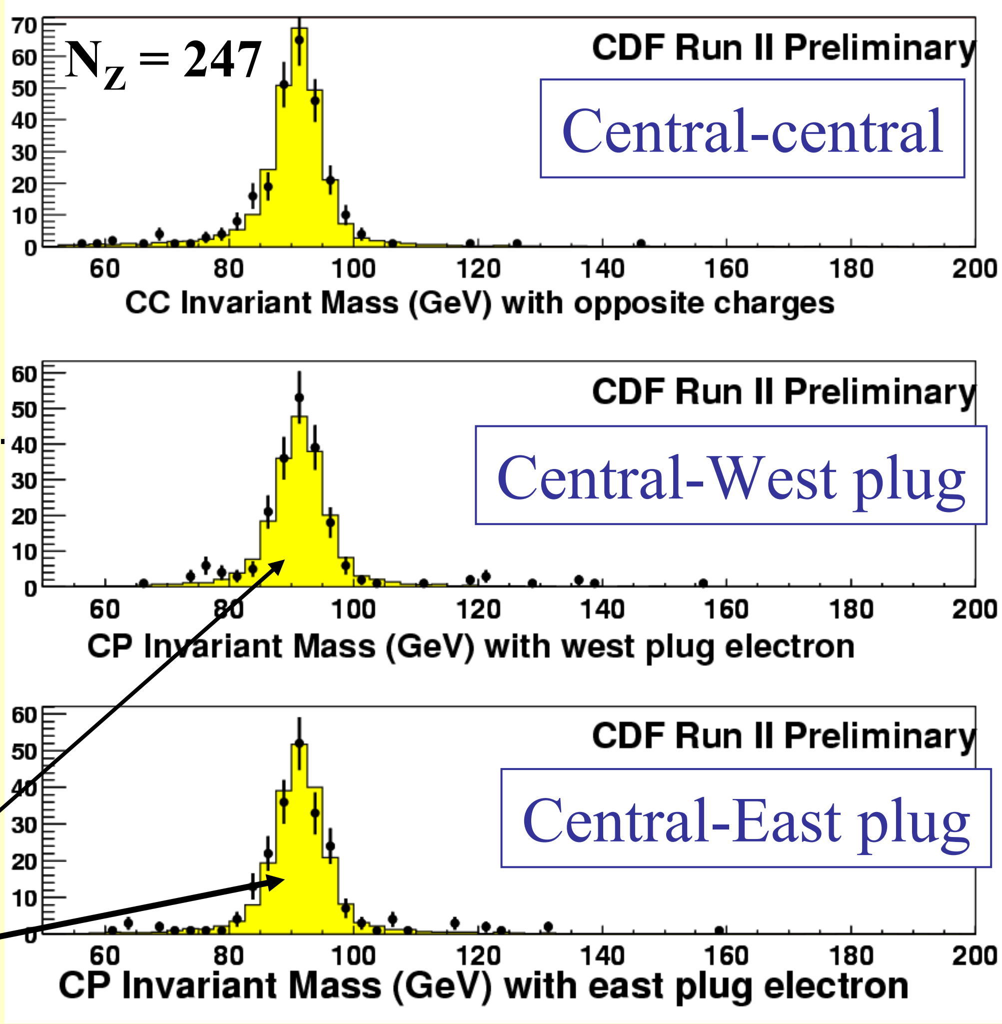


4. CDF and DØ at ICHEP 2002



EM Calorimeter scale

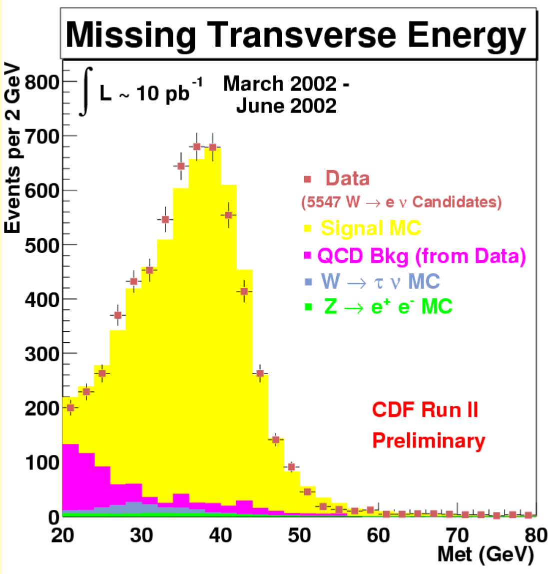
- **638 Z → e^+e^-** in 10 pb^{-1}
  $\Delta\sigma(M) \sim 4$ GeV
- Check **Z mass** in data and simulation after corrections
  - Central region:
    - Mean: +1.2% data, -0.6% sim.
    - Resolution: +2% simulation
  - Forward region (Plug):
    - Mean: +10/6.6% data, +2.0% simulation
    - Resolution: +4% simulation

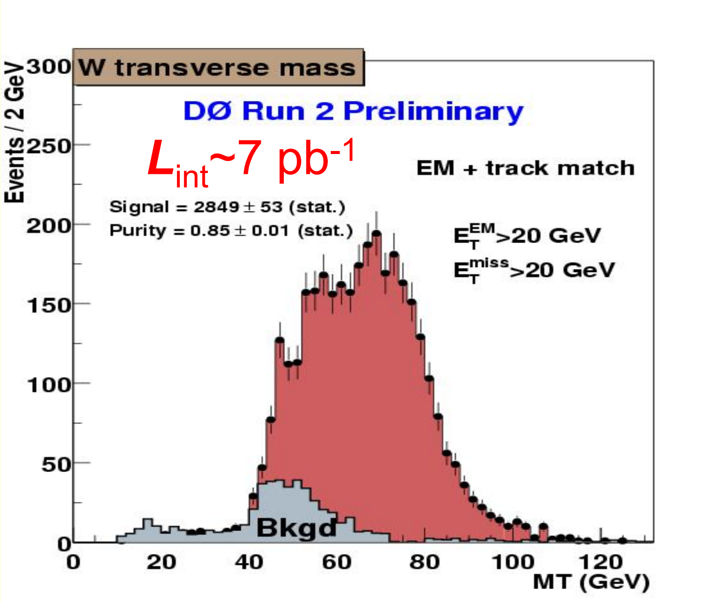


N_Z (W+E) = 391

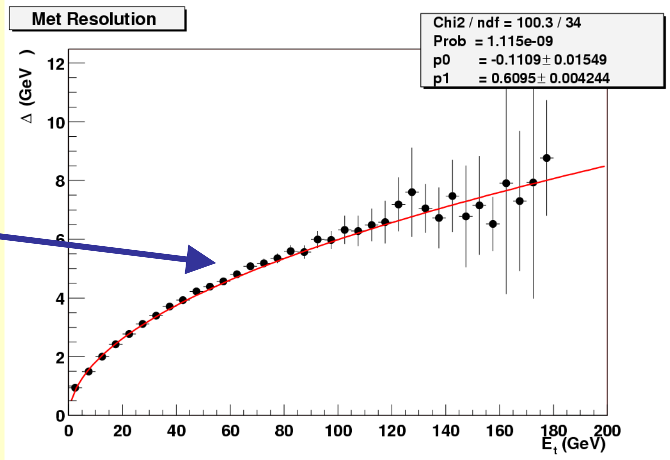
W → e ν Candidate Events

- W transverse mass spectrum in e + missing E_T inclusive sample.
- QCD background derived from the data

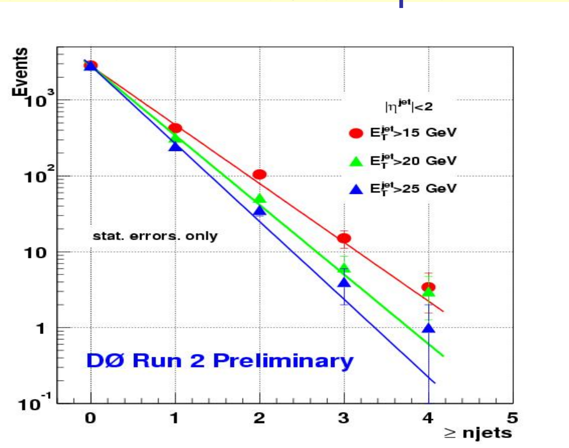




Inclusive jet multiplicity in background subtracted W→eν sample



MET resolution from MB data consistent with Run 1



linear in log N (Berends scaling)

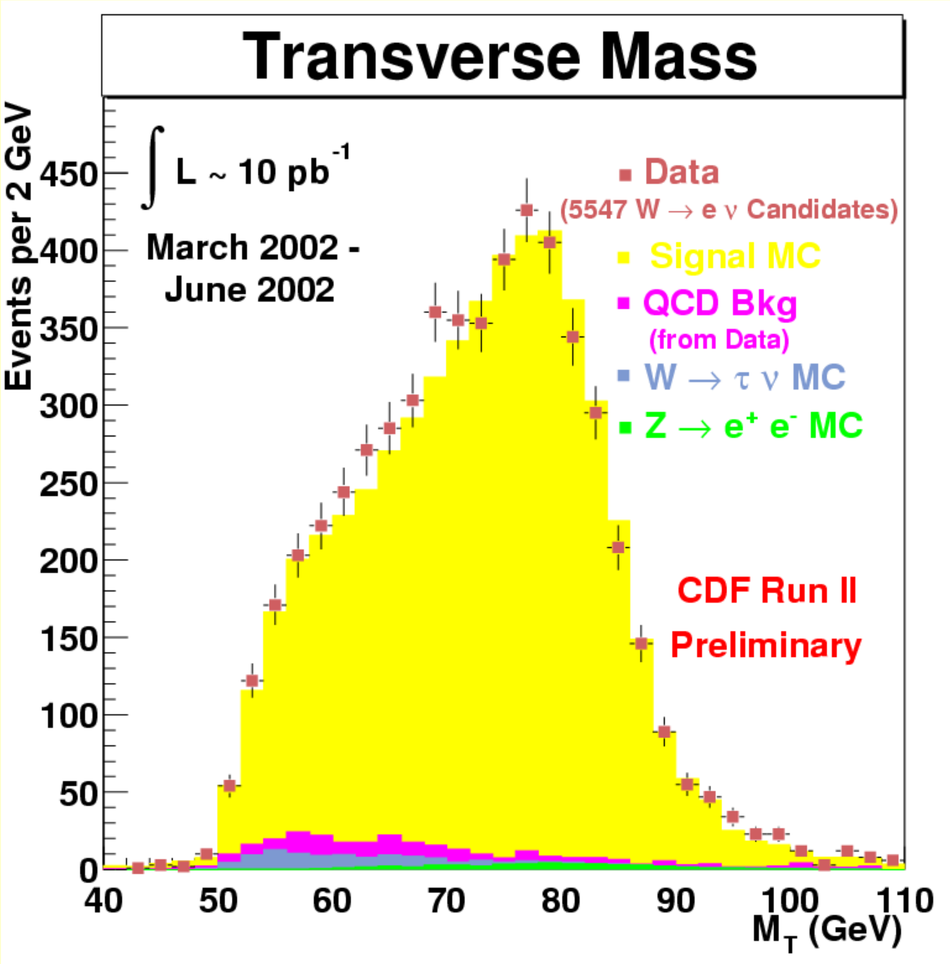
Measurements with high E_T $e^{\pm}$

W cross section:

- σ_W*BR(W→eν) (nb) = $2.60 \pm 0.07_{stat} \pm 0.11_{syst} \pm 0.26_{lum}$

initially 10%, later 5.8%

- – Consistent with Run 1 results rescaled for higher energy: $2.72 \pm 0.02_{stat} \pm 0.08_{syst} \pm 0.09_{lum}$ (use Sterling et al. NNLO predictions)



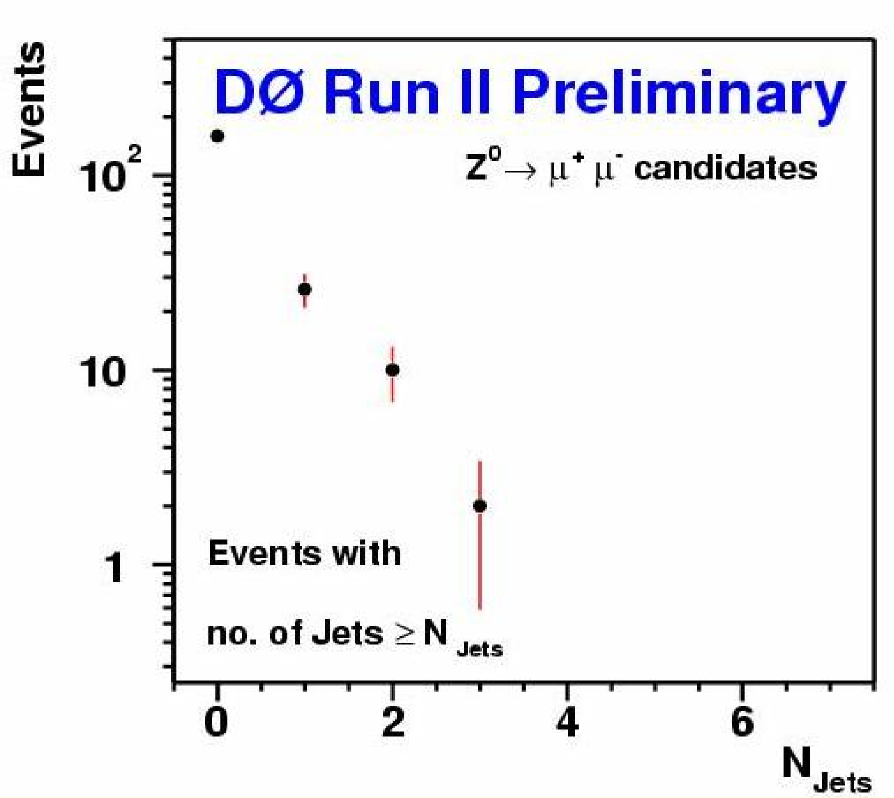
Nr. Candidates:

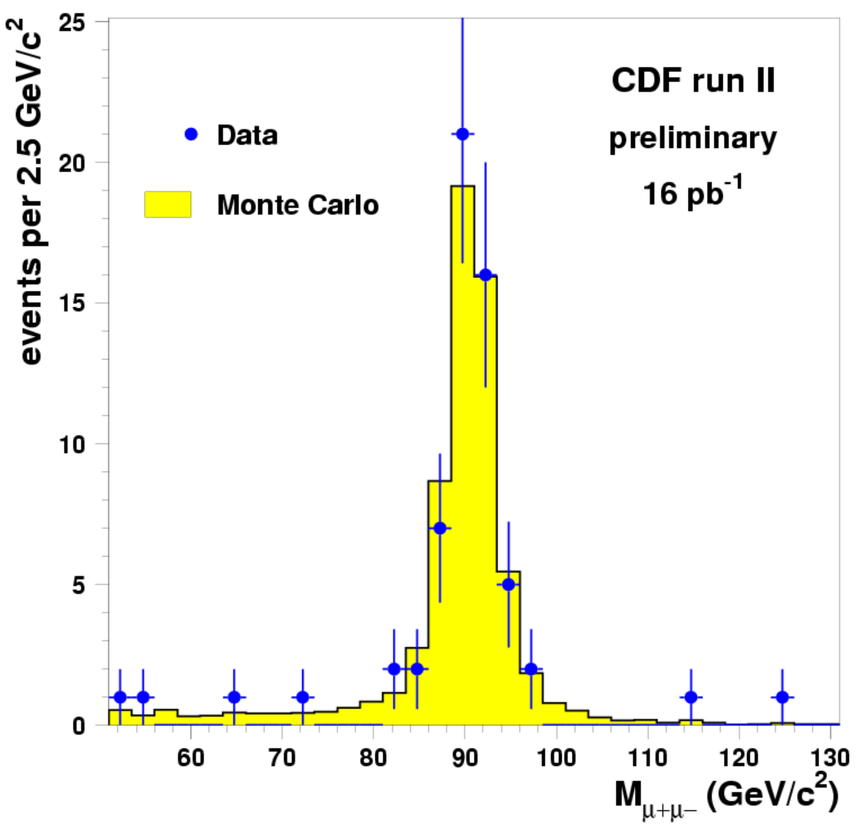
- **5547 in 10 pb⁻¹**

Background:

- **QCD:** 260 ± 34 ± 78
- **Z →ee:** 54 ± 2 ± 3
- **W→τν:** 95 ± 6 ± 1

$Z^0 \rightarrow \mu^+ \mu^-$ Candidate Events

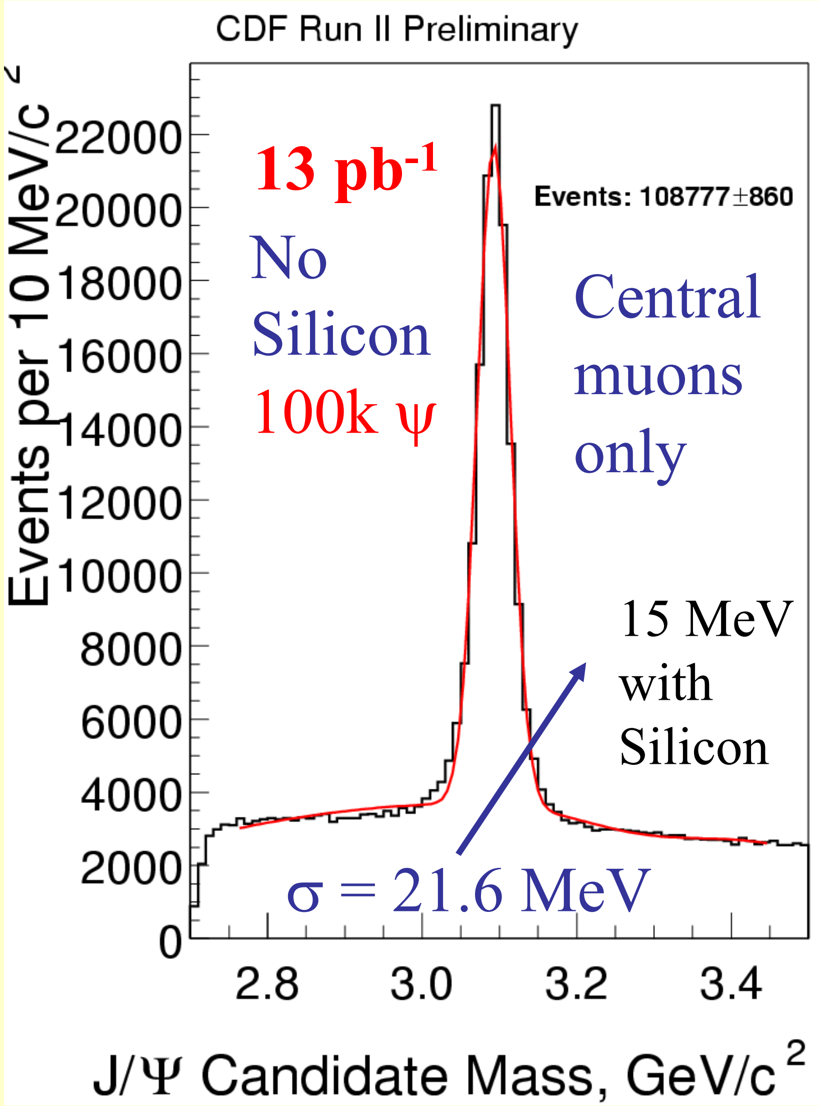




- 57 candidate events in $66 < M_{inv} < 116$ range
- $N_Z = 53.2 \pm 7.5 \pm 2.7$

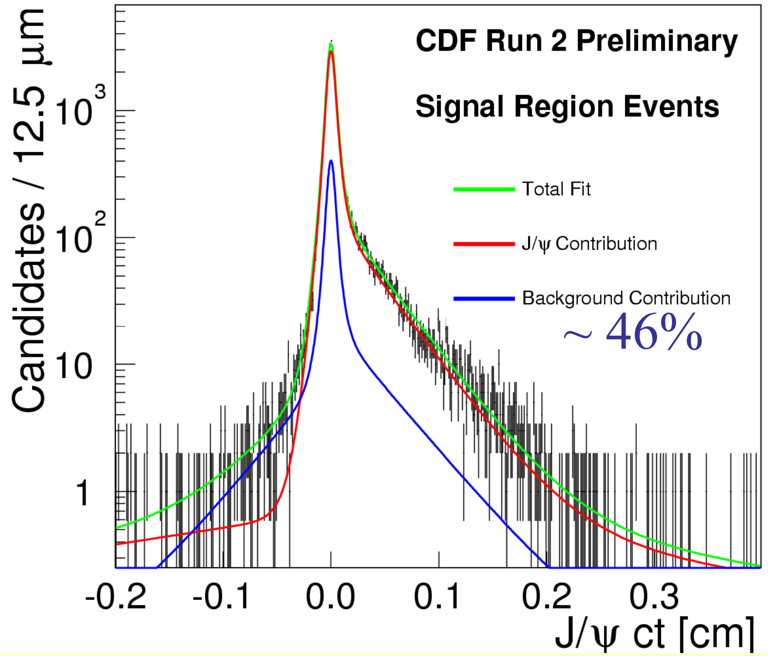
Measurements with low E_T $\mu^{\pm}$

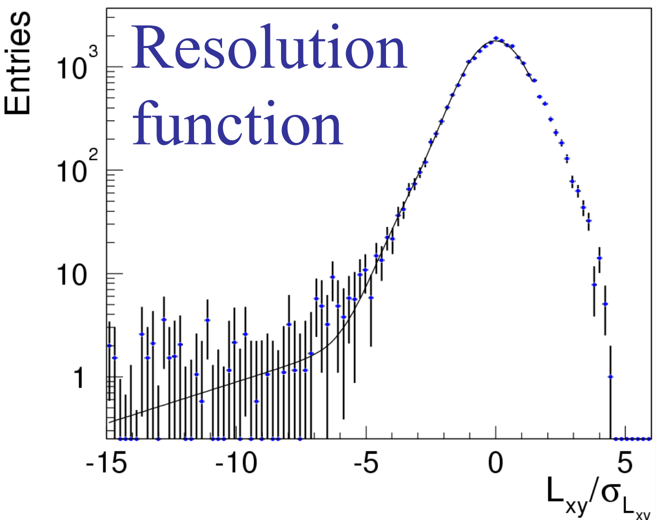
- J/ψ trigger improved
  - p_T^{μ} > 2.0 → 1.5 GeV
  - $\Delta\phi$ > 5° → 2.5°
- Observed ψ rates are consistent with expected increase due the lowering of the thresholds



B-Lifetime Measurements

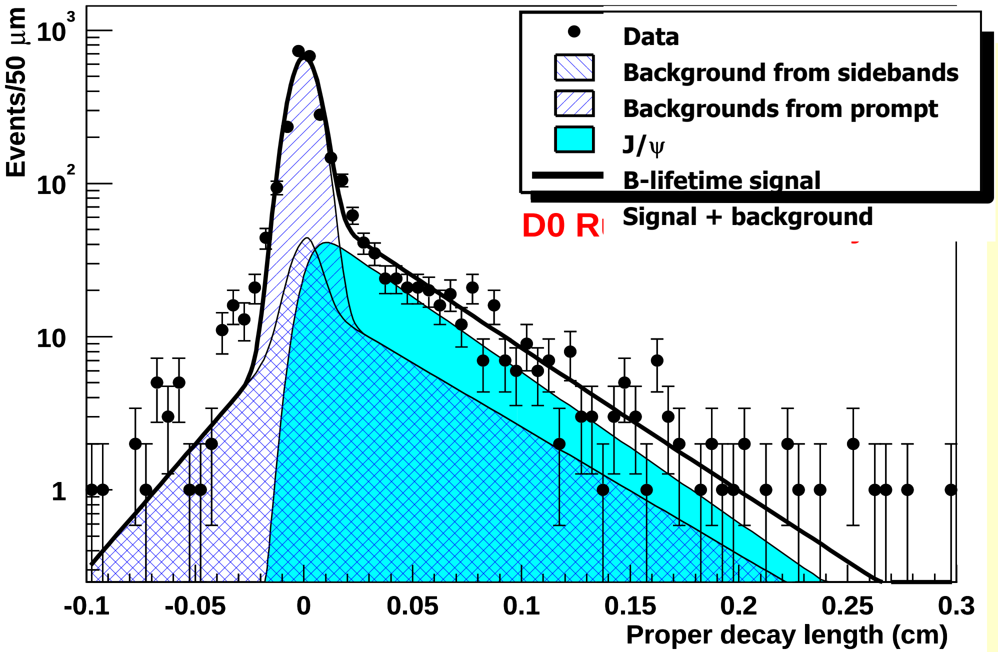
- Inclusive B lifetime with ψ's
  - Fit pseudo-cτ = $L_{xy}^{\psi} * F_{MC} * M^{\psi} / p_T^{\psi}$ distribution
    - Output: b lifetime, fraction of ψ from B
      - cτ=458±10 stat. ±11 syst. μm (PDG: 469±4 μm)
      - ➢ ψ from B = 17% (p_T^{ψ} > 4 GeV)
- Resolution function from large prompt component
  - R = narrow + wide Gaussian (19%) + exponential tails (1.2%)
  - Scale factor on error returned from vertex fit **1.069**



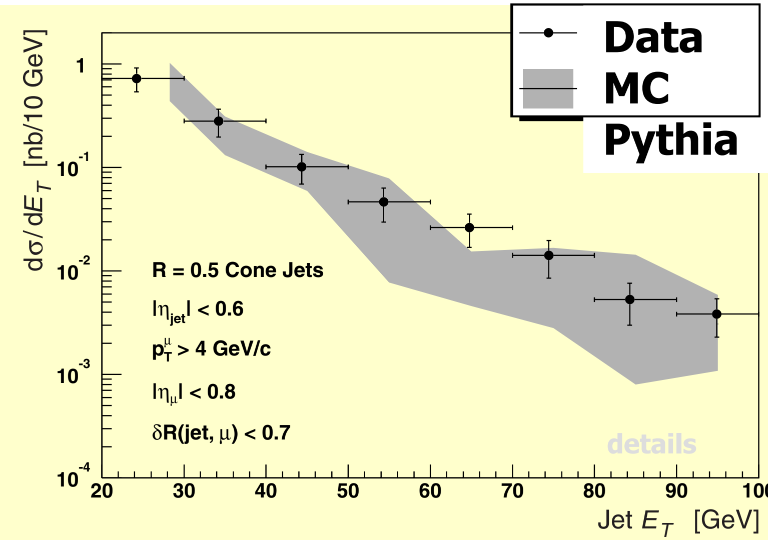


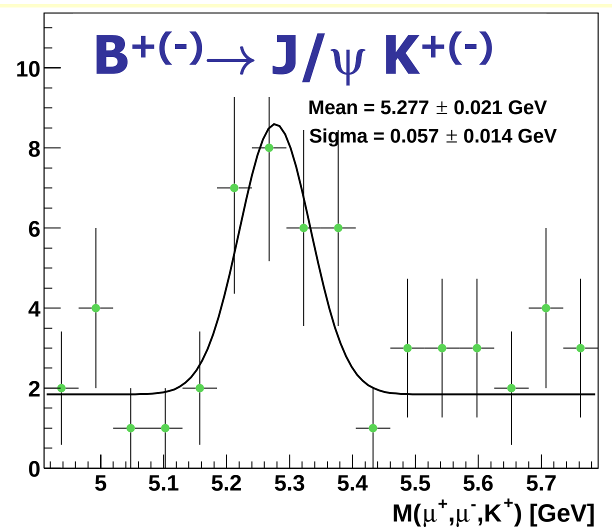
B-Mesons

Average B Lifetime (B→ J/ψ+X)

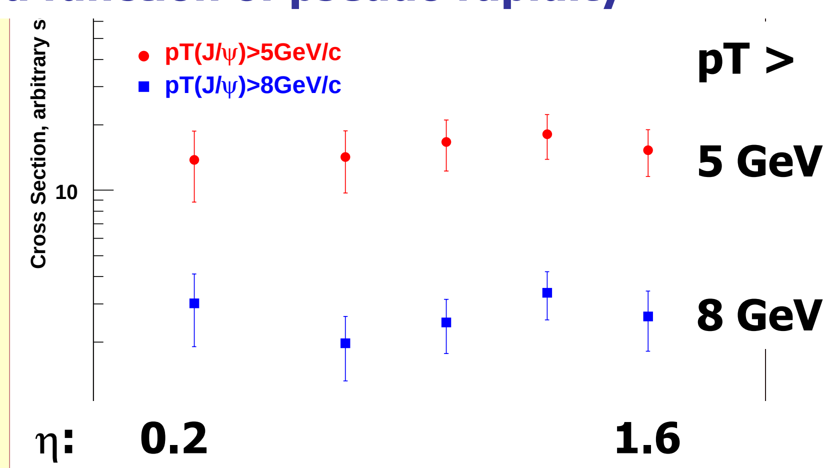


μ+jet Production Cross Section



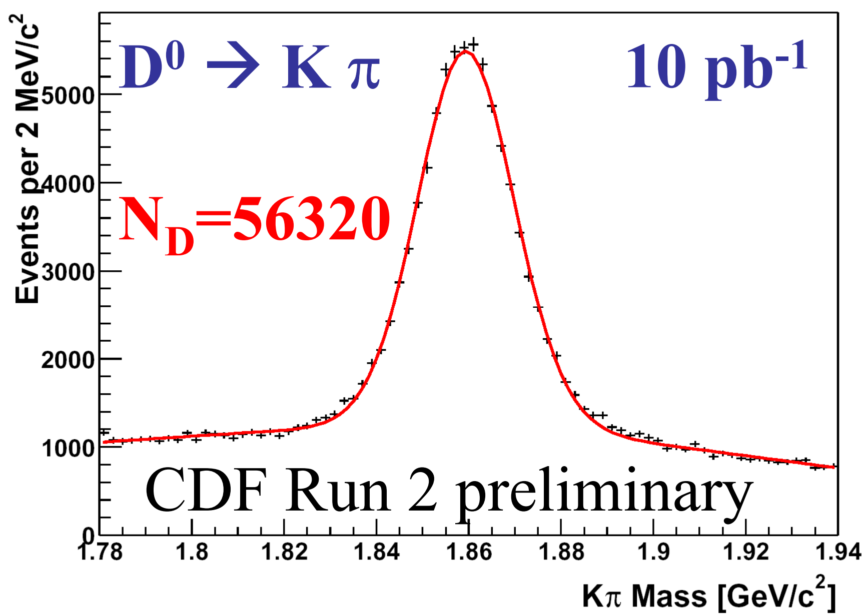


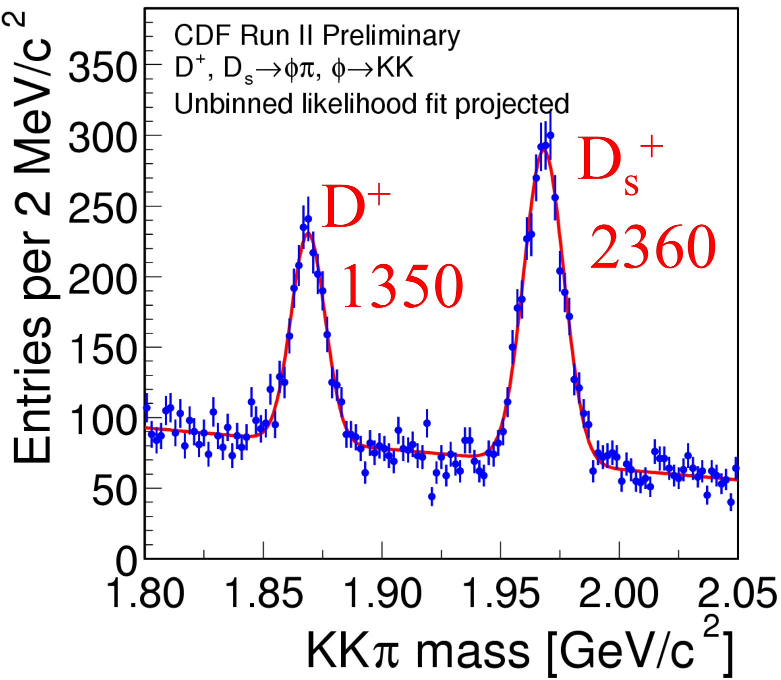
J/ψ production cross section as a function of pseudo rapidity



Measurements with Hadronic b Triggers

- L2 trigger on 2 tracks:
  - pt > 2 GeV
    - |D| > 100 μm (2 body)
    - |D| > 120 μm (multibody)
- Swamped by D mesons!
  - But see B's as well….



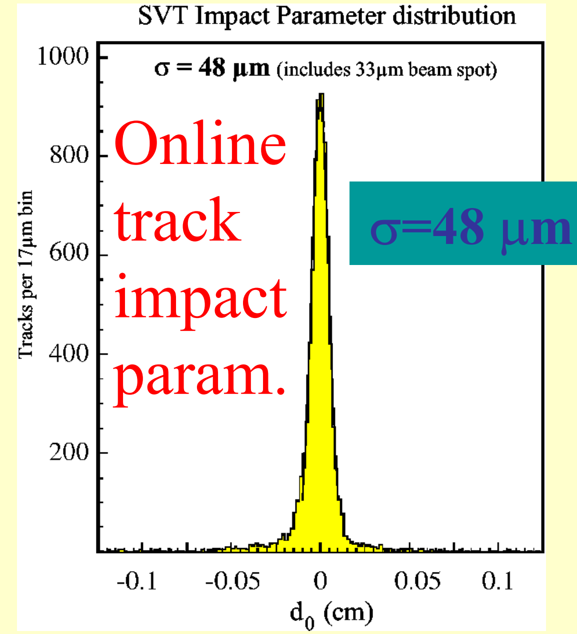


- $D_s^{\pm}$ - $D^{\pm}$ mass difference
  - Both D → ϕπ (ϕ→KK)
  - Δm=99.28±0.43±0.27 MeV
    - PDG: 99.2±0.5 MeV
  - Systematics dominated by background modeling

Secondary Vertex Trigger

8 VME crates

Find tracks in Si in 20 μs with offline accuracy



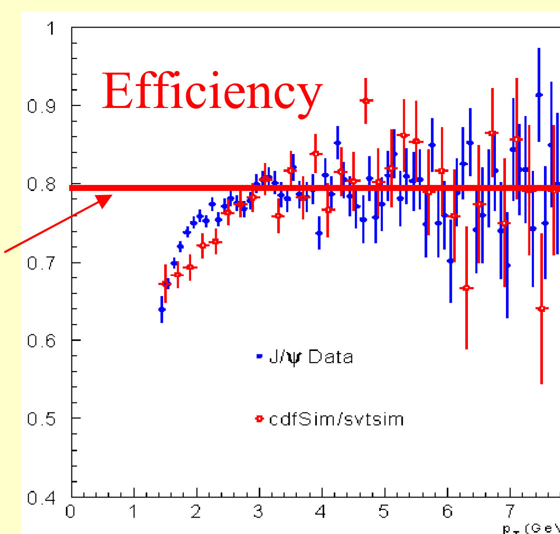
❖ **S**econdary **V**er**T**ex L2 trigger

- ➢ Online fit of primary Vtx
- ➢ Beam tilt aligned
- ➢ D resolution as planned
  - **48 μm** (**33 μm** beam spot transverse size)

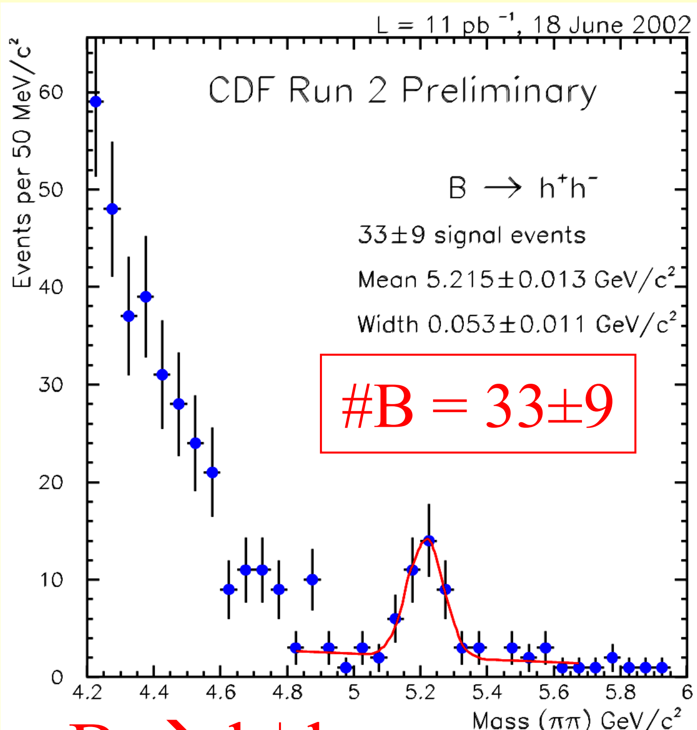
90%

soon

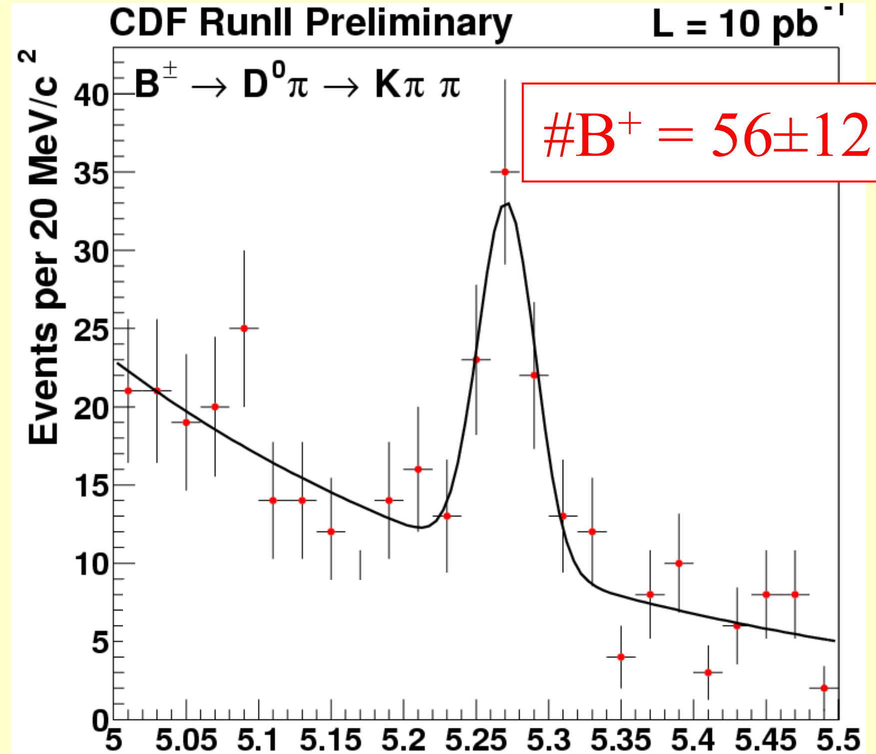
80%



Measurements with Hadronic b Triggers



B → h$^+$ h$^-$

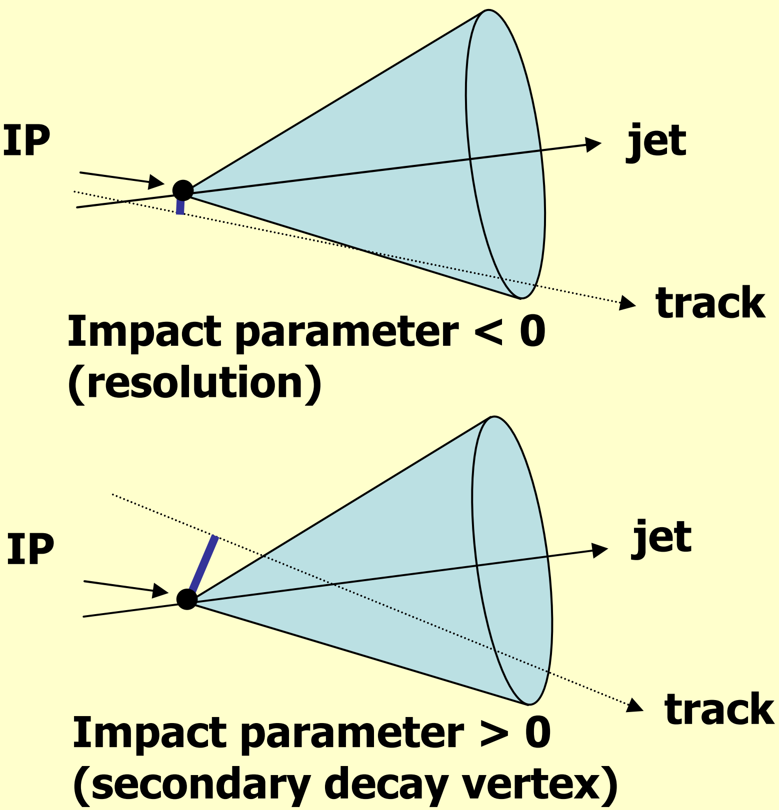


B$^+$ → D^0 π$^+$

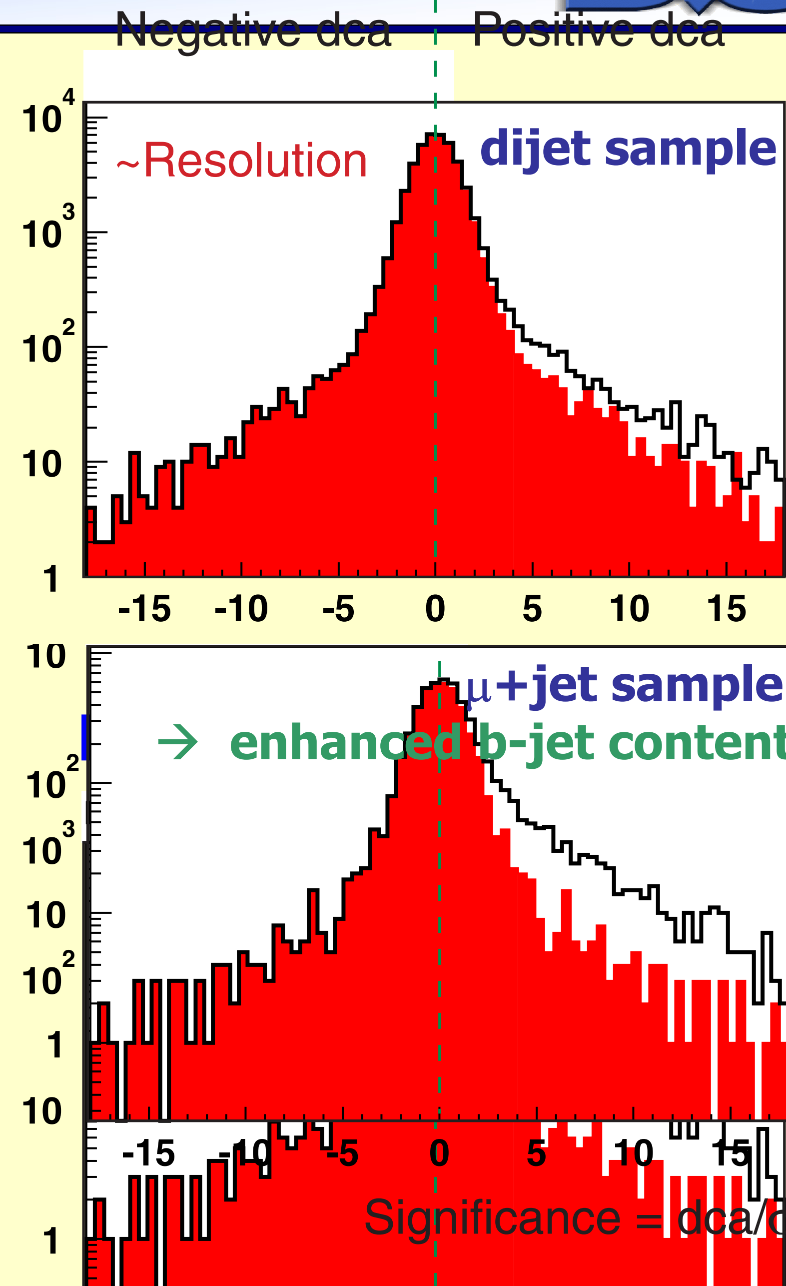
- Hadronic B decays observed
  - Yield lower than expected (silicon coverage/SVT efficiency > x 3)
  - S/N better than expected
    - Better S/N dilution compensates reduced statistics

Identyfying b-Quarks

- Signed impact parameter

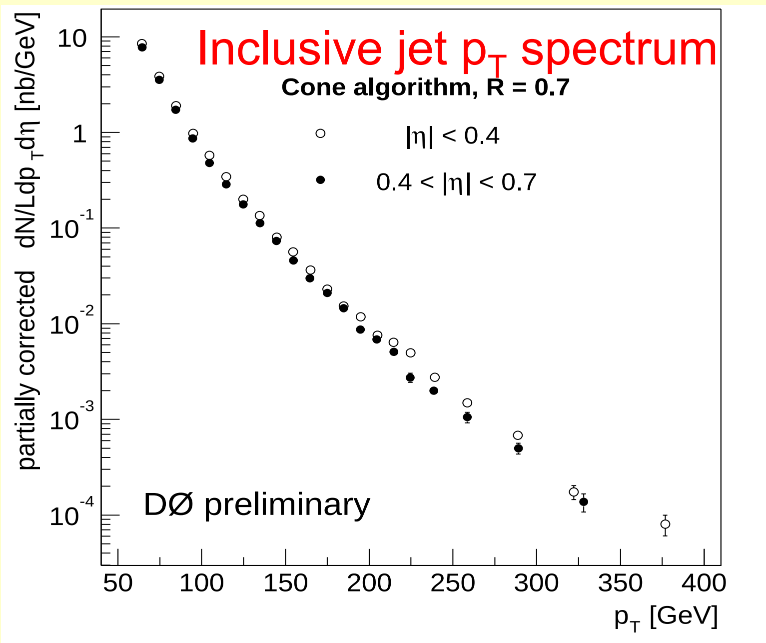


→ **Reconstruct secondary vertex**
→ **Also use semileptonic decays**



Jet Physics

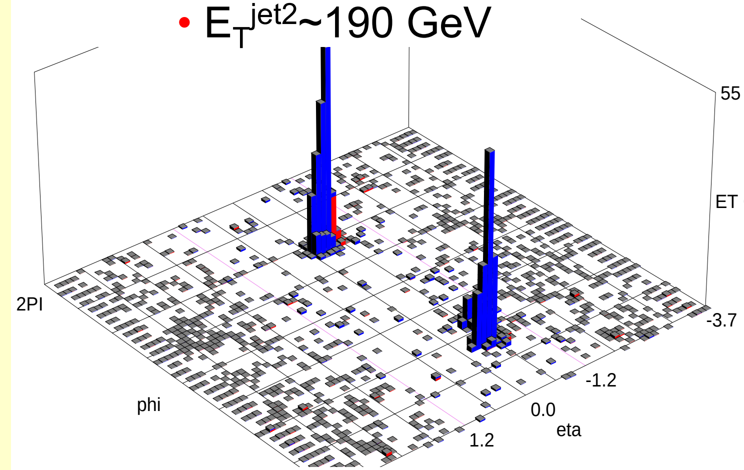
- At √s=1.96 TeV, cross section 2x larger compared to 1.8 TeV (Run I) for jets with p_T > 400 GeV

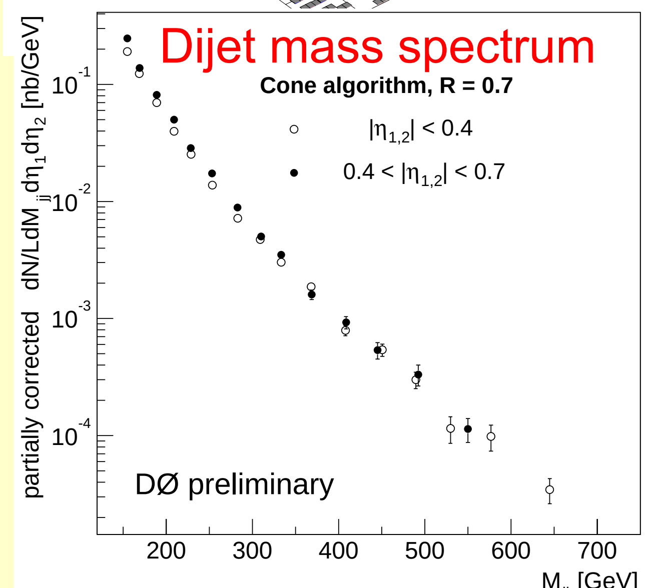


Luminosity 5.8 pb^{-1}

2-jet event

- E_T^{jet1}~230 GeV
- E_T^{jet2}~190 GeV

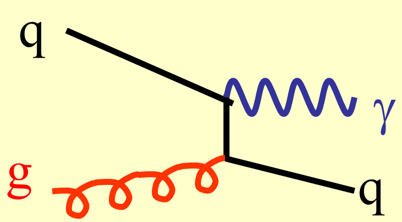


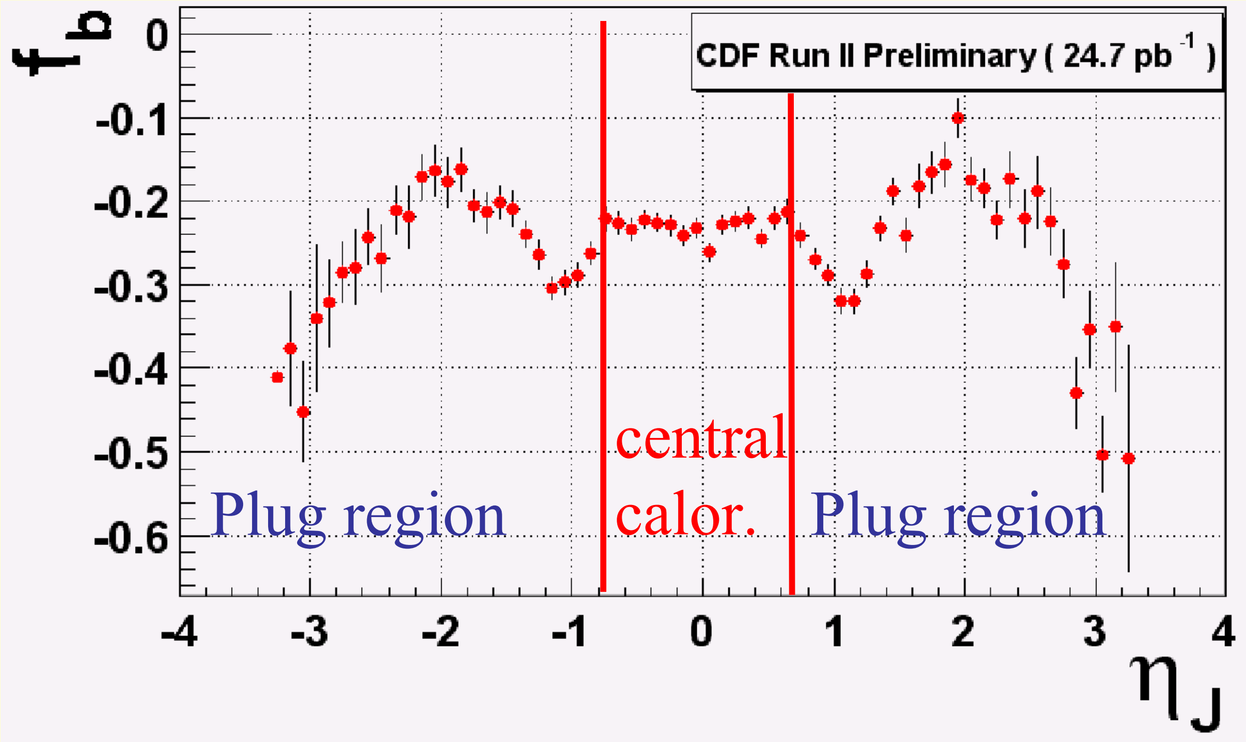


- Only statistical errors
- Preliminary jet energy scale

Hadronic Energy Scale

- Use J/ψ muons to measure MIP in hadron calorimeters
  - (Run II)/(Run 1) = 0.96±0.05





❖ Gamma-jet balancing to study jet response

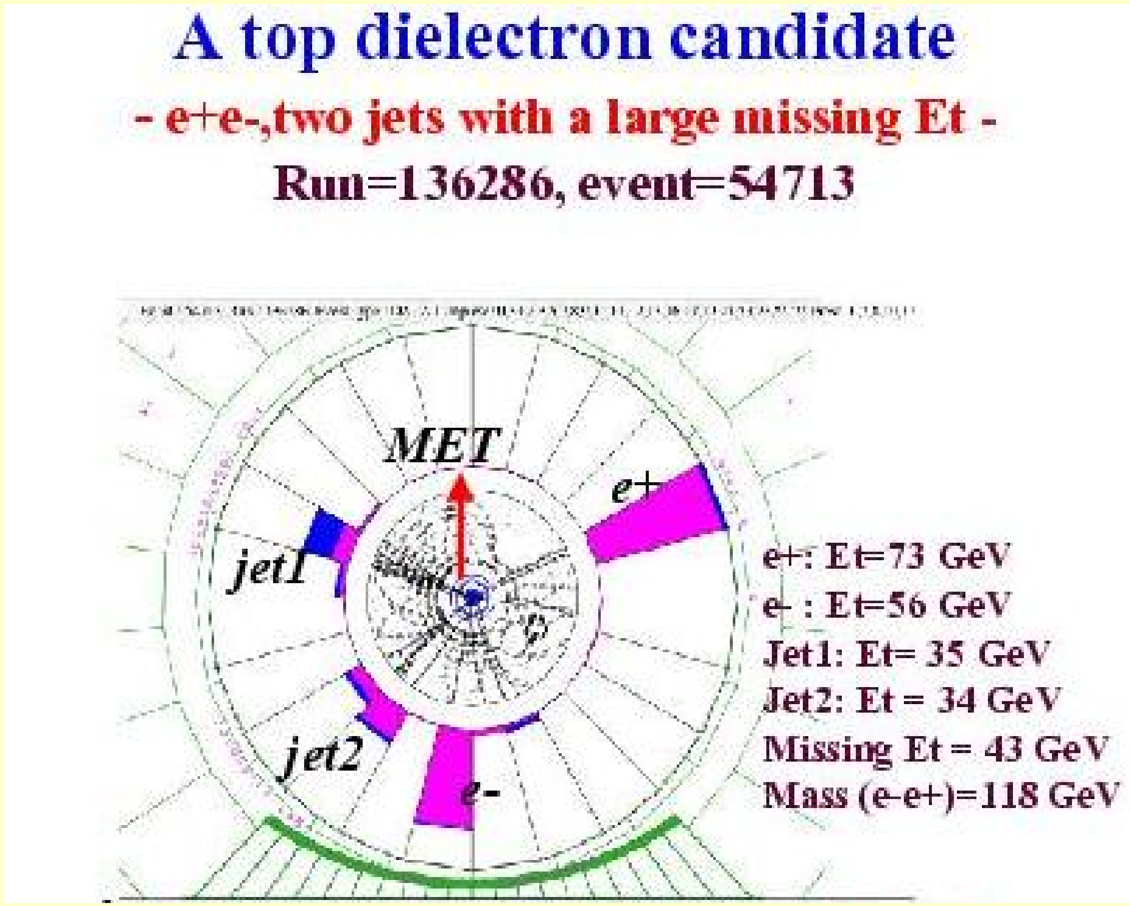
➢ $f_b = (p_T^{jet} - p_T^{\gamma})/p_T^{\gamma}$

- Run Ib (central): $f_b = -0.1980 \pm 0.0017$
- Run II (central): $f_b = -0.2379 \pm 0.0028$

$\Delta f_b = (4.0 \pm 0.4)\%$

Nothing on Top-Quarks …

… except a candidate event

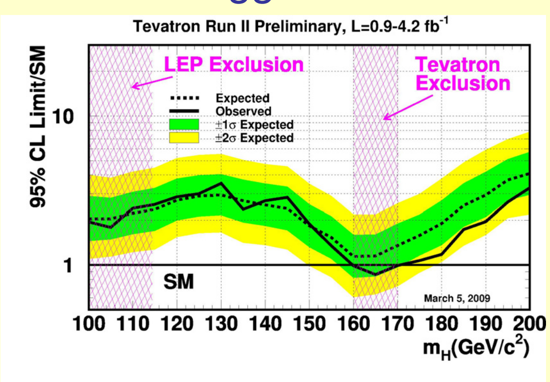


The Tevatron Legacy

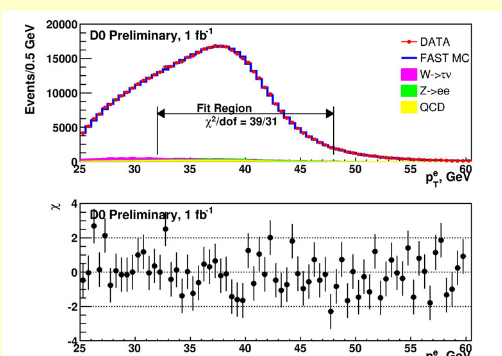
Despite a somewhat sluggish start has made many important measurement which will stand for quite a while even in the LHC era.

- Precision measurement of the top-quark mass ($\Delta m/m = 0.8\%$).
- First observation of B_s oscillations and measurement of Δm_s.
- Precision Measurement of m_W.
- First observation of single-top-quark production.
- Observation of diboson production (WW, WZ and ZZ).
- First observation of the b baryons: Σ_b, Ω_b,
- Higgs-Boson Searches and Limits
- …

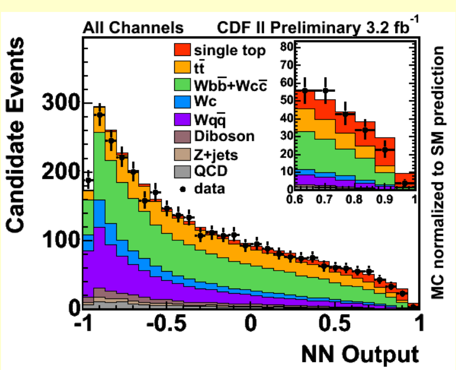
Higgs Limits



W Mass



Single Top



Summary and Outlook

Summary and Outlook

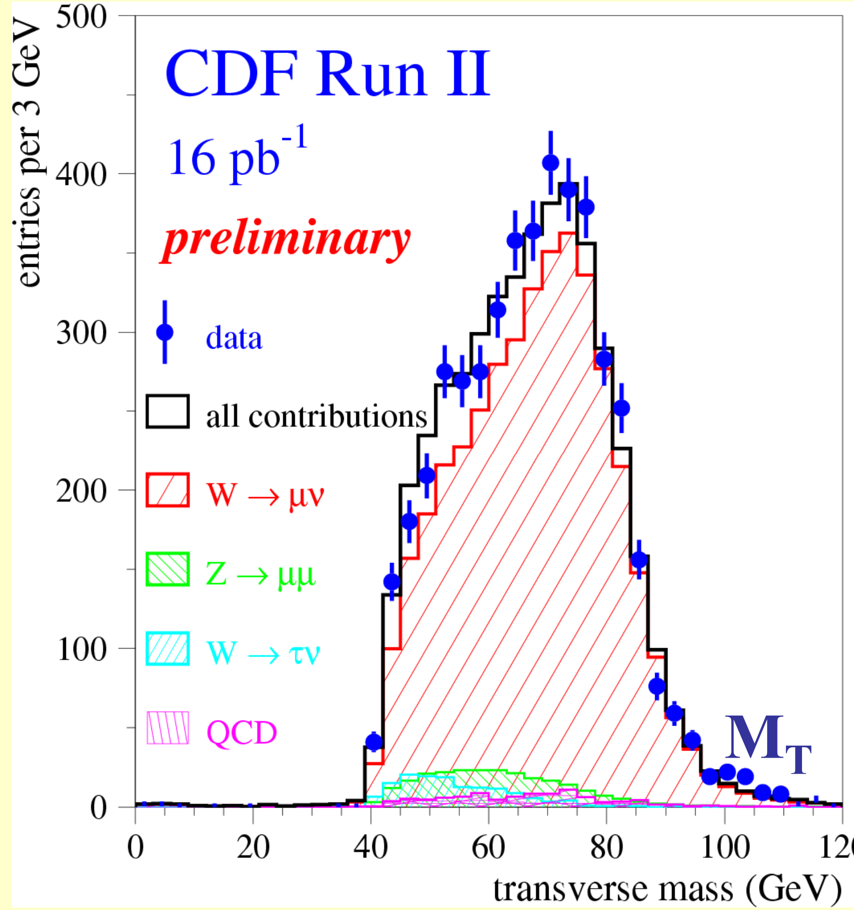
1. The Tevatron program has been a tremendous success yielding world class measurements and will still yield interesting results in the future (Higgs!).
2. The aim of this talk is to show:
   The measurements coming out now and in the recent past are the based on many years of hard work on many basic issues (calibration, reconstruction, …).
3. On a point-by-point basis we cannot extrapolate from the Tevatron experience to the LHC. ATLAS and CMS are different and will provide us with their own challenges.
4. Unanticipated problems will arise and we have to tackle them one-by-one.
5. The challenges in some „low-tech“ components are generally underestimated, e.g. cables, supports, cooling, …
6. ATLAS and CMS are well prepared, in a better state than CDF and DØ were at the start of Run 2. A lot of calibration has already been done.
   We can look forward to the start of LHC!

Thank you to my colleagues Rob Roser, Rainer Wallny, Gino Bolla, Franco Bedeschi, Ia Iashvili, Meenakshi Narain for allowing me to use transparencies from their talks or providing material.

Backup

Measurements with high E_T $\mu^{\pm}$

- W cross section:
  - σ_W*BR(W→$\mu\nu$) (nb) = Details
    $2.70 \pm 0.04_{stat} \pm 0.19_{syst} \pm 0.26_{lum}$
  - Consistent with Run 1 results rescaled for higher energy: $2.41 \pm 0.08_{stat} \pm 0.15_{syst} \pm 0.16_{lum}$ (use Sterling et al. NNLO predictions)



Nr. Candidates:

- 4561 in 16 pb^{-1}

Background:

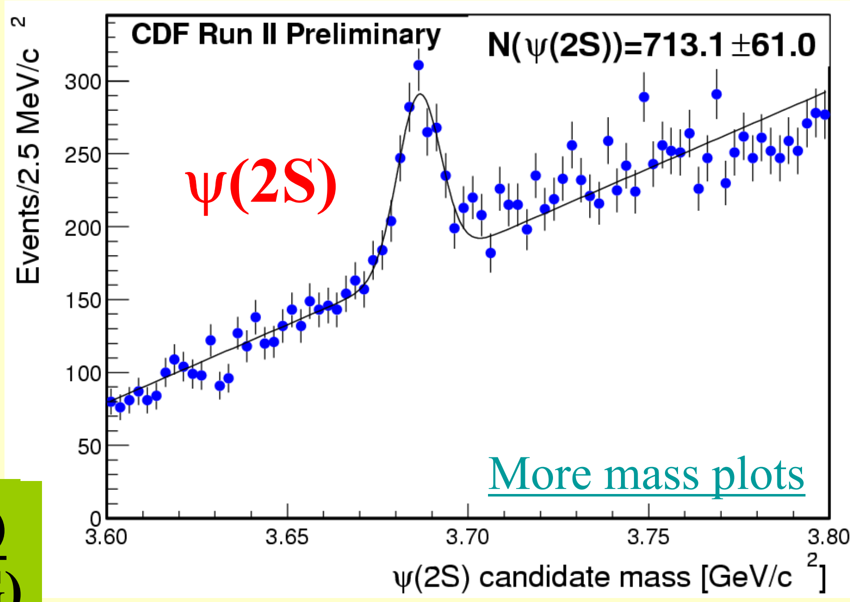
- **QCD:** 104 ± 53
- **Cosmics:** 73 ± 30
- **Z →μμ:** 247 ± 13
- **W→τν:** 145 ± 10

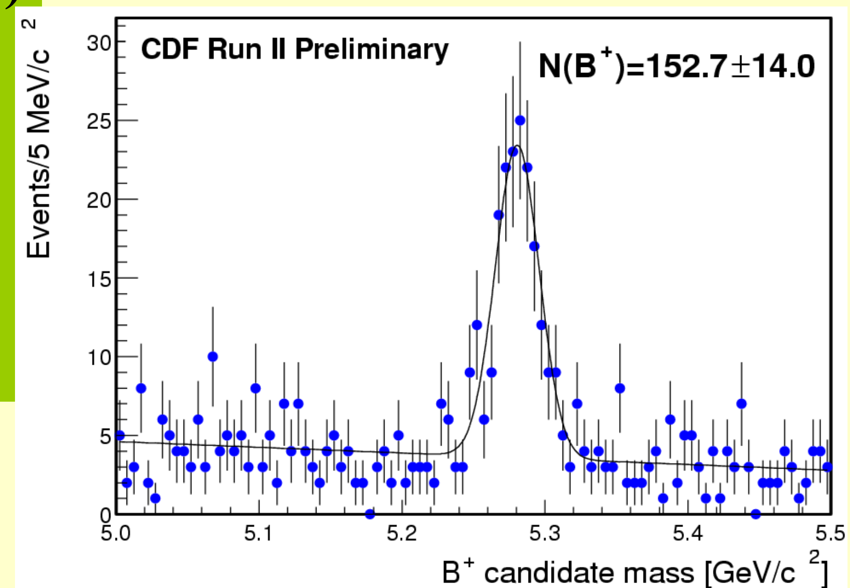
- R=σ(W→μν)/σ(Z→μμ) = $13.66 \pm 1.94_{stat} \pm 1.12_{syst}$
  - Consistent with Run 1 results

B Spectroscopy in J/ψ Channels

- B masses:
  - $\psi(2S) \rightarrow J/\psi\ \pi^+\pi^-$ (control)
  - $B_u \rightarrow J/\psi\ K^+$
  - $B_d \rightarrow J/\psi\ K^{0*}$ $(K^{0*} \rightarrow K^+\pi^-)$
  - $B_s \rightarrow J/\psi\ \phi$ $(\phi \rightarrow K^+K^-)$

	CDF 2002	ΔPDG/σ	σ(CDF) / σ(PDG)
ψ(2S)	3686.43±0.54	0.86	
Bu	5280.60±1.70±1.1	0.77	4.05
Bd	5279.80±1.90±1.4	0.17	4.72
Bs	5360.30±3.80± 2.10 / 2.90	-1.81	1.90





Jet Production

- Raw Et only:
  - Jet 1: ET = 403 GeV
  - Jet 2: ET = 322 GeV