Status of CDF and Prospects for Run II

Presented for the CDF Collaboration

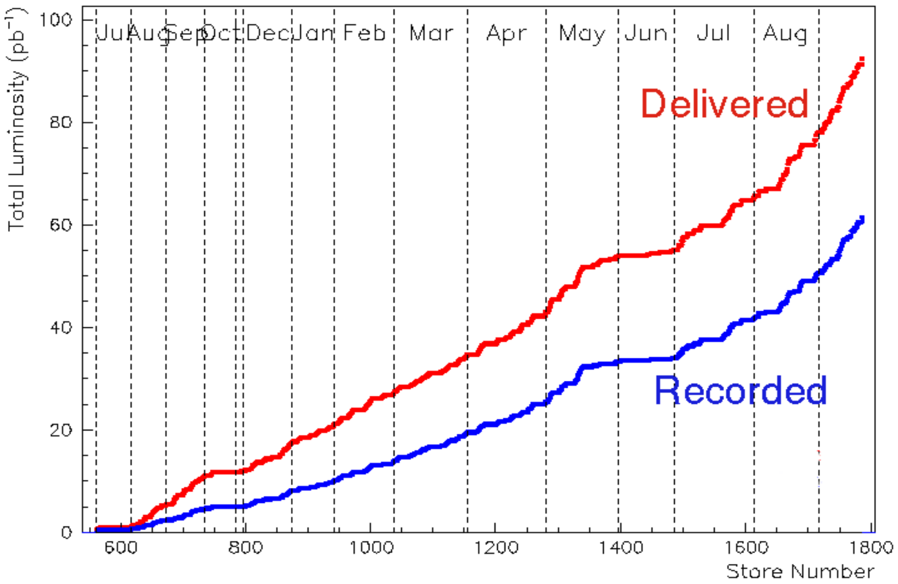
by

Frank Chlebana

(Fermi National Accelerator Laboratory)

14th Topical Conference on Hadron Collider Physics

Sept 30 2002



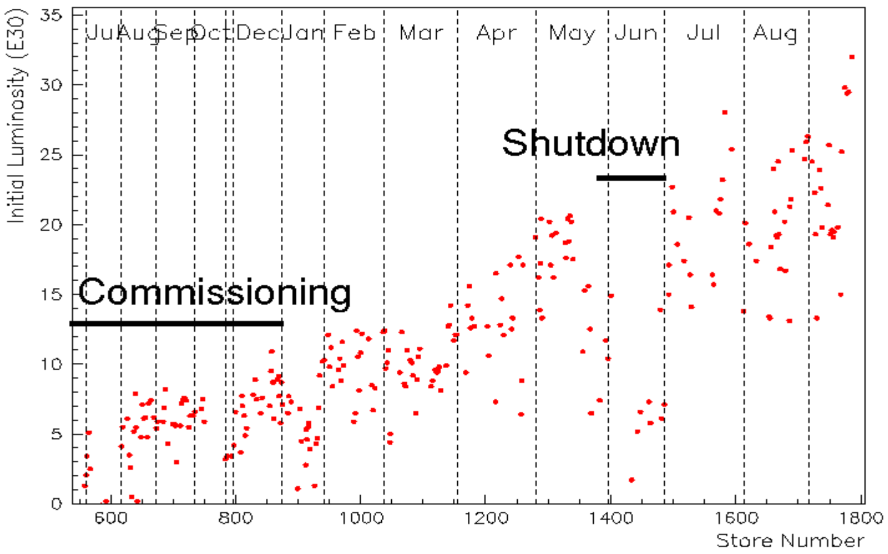
Data period Jul '01-Sep '02

Delivered 90 pb^{-1}

Recorded 60 pb^{-1}

"Good Runs" 35 pb^{-1}

Recently delivering over $4.5 pb^{-1}$ per week.



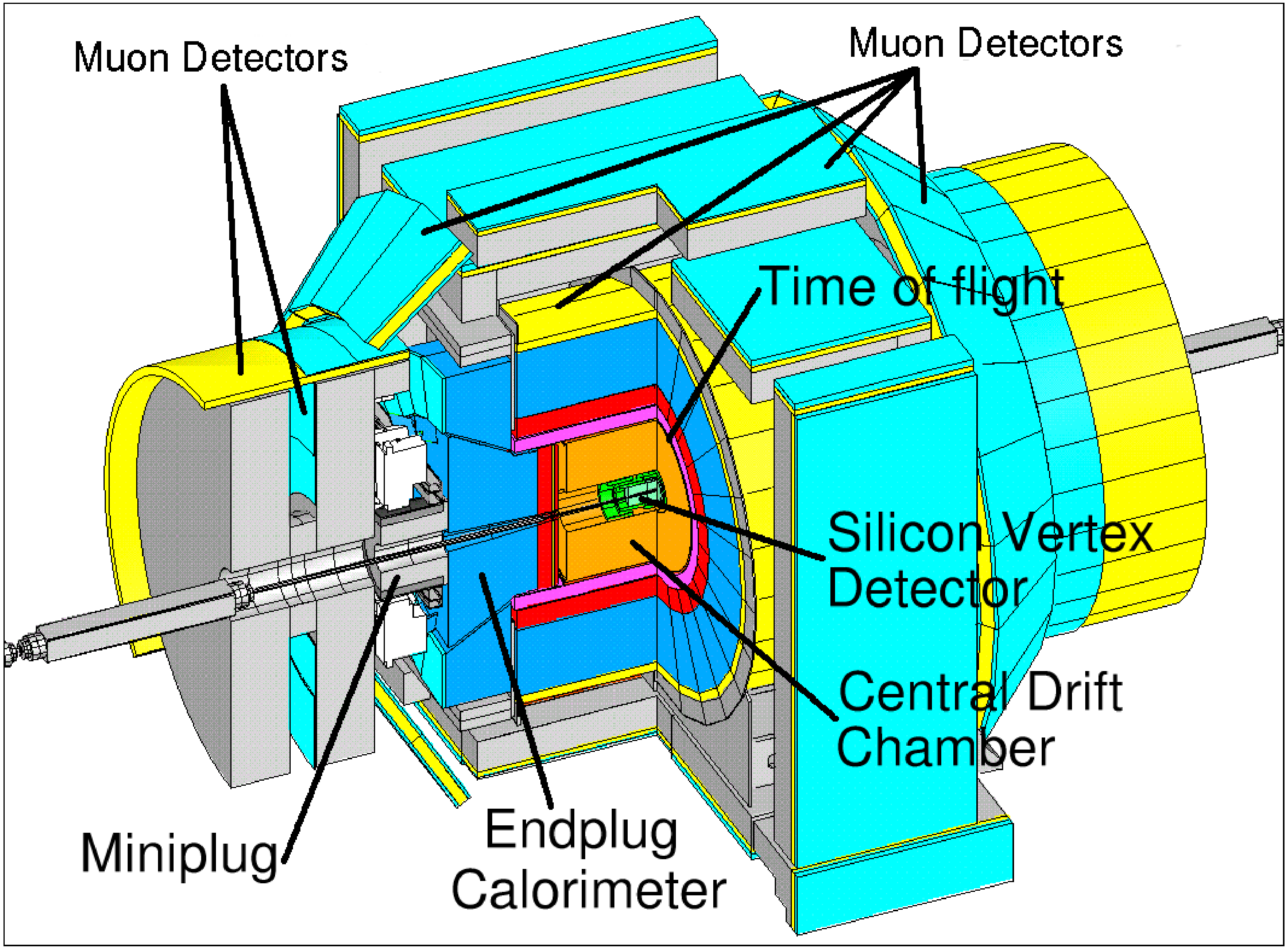
Initial luminosity has been increasing.

Routinely start with $\mathcal{L}^{inst} > 2 \times 10^{31}$.

Record initial luminosity is 3×10^{31}

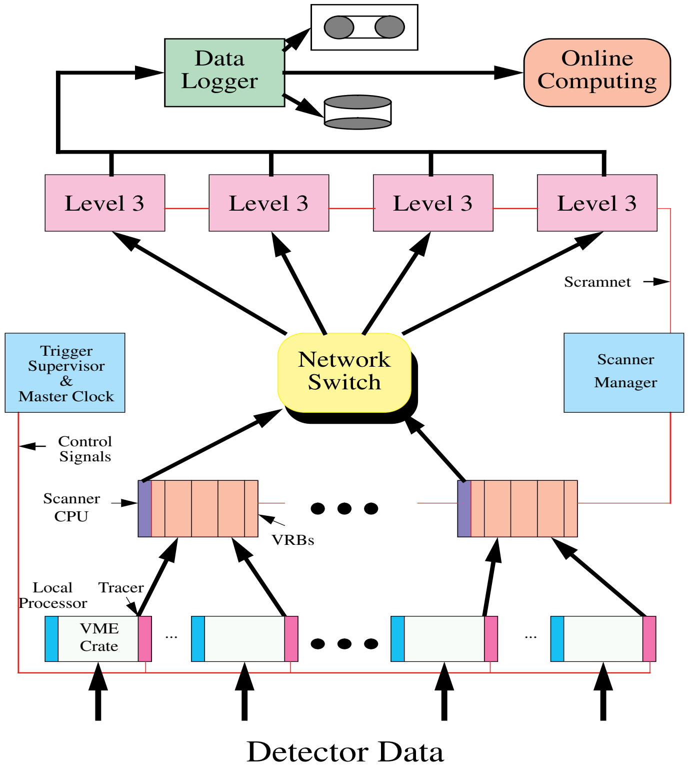
Our efficiency of recording data is also improving, have had stores with over 94% efficiency! *Getting better all the time...*

CDF Detector Upgrades for Run II



Data Acquisition Status

Upgraded to operate with shorter bunch spacing times (132 ns) and handle higher data volume and rate. Currently operating with a 396 ns bunch spacing.



Designed Capability

For $\mathcal{L} = 2 \times 10^{32}$

L1/L2/L3: $\lesssim$ 50000/300/50 Hz

Current Running Conditions

For $\mathcal{L} = 2.6 \times 10^{31}$

L1/L2/L3: 11000/290/55 Hz

Typical event sizes of 250-300 KB

Maximum logging rate of 20 MB/s

Currently running with reduced trigger thresholds to make use of the bandwidth and taking events used for calibrations

L1 Trigger

Calorimeter, Muon, Forward Detectors and Tracking triggers (XFT)

Typically about <u>40 L1 triggers</u>

L2 Trigger

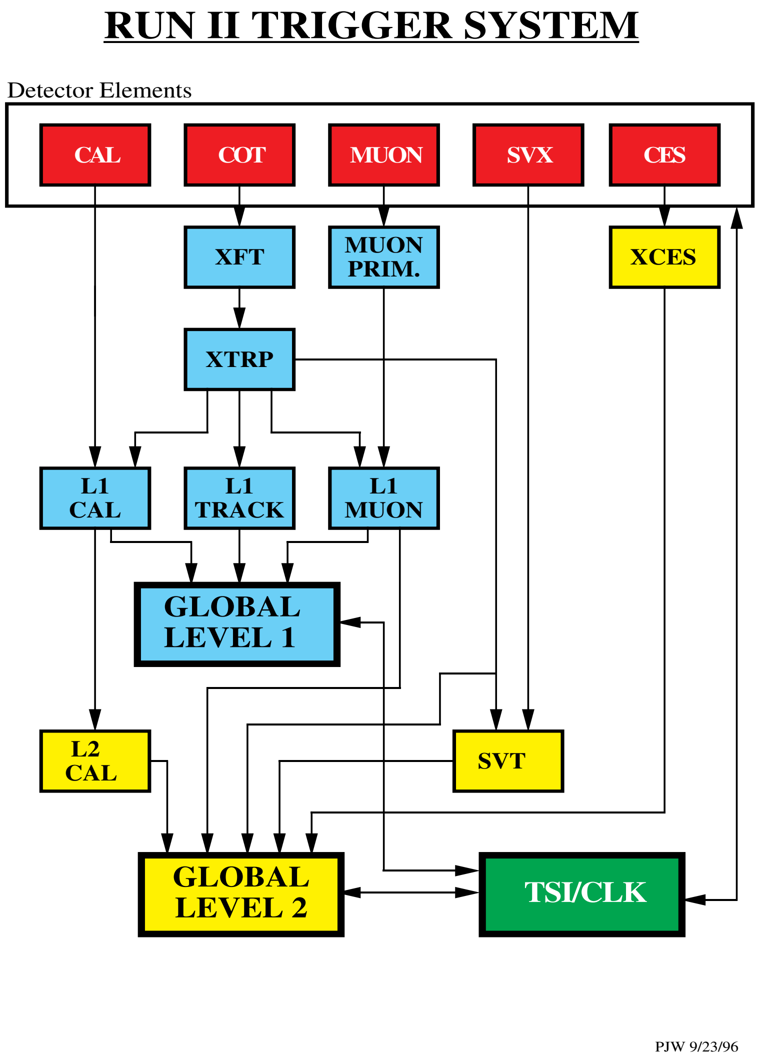
Calorimeter, *Muon* and Impact parameter triggers (SVT)

Typically about <u>80 L2 triggers</u>

L3 Trigger

Full offline reconstruction

Typically about <u>140 L3 triggers</u>



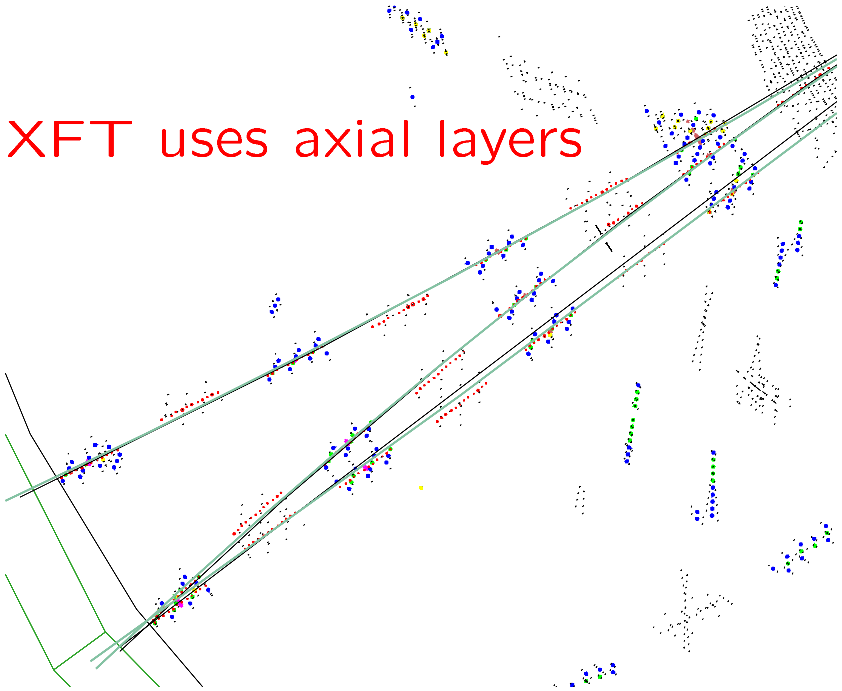
Trigger is well advanced and close to the final specification.

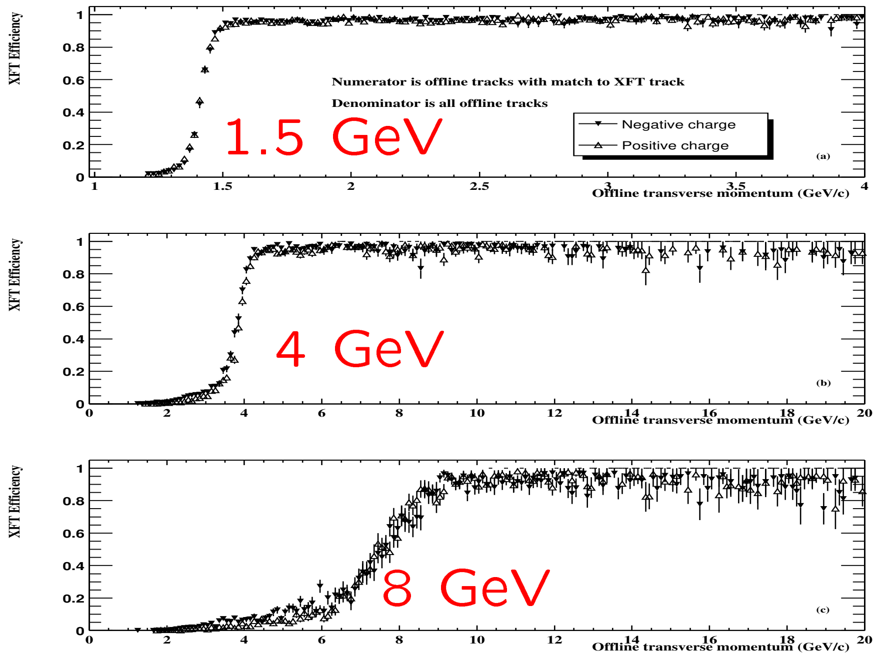
After L3 events are sorted into 20 streams, after processing data is split into more specific datasets (calibration and physics datasets).

Extremely Fast Tracker (XFT Trigger)

Tracking trigger at L1! Enhances our physics capabilities, able to collect large samples used for in situ calibration.

XFT uses axial layers





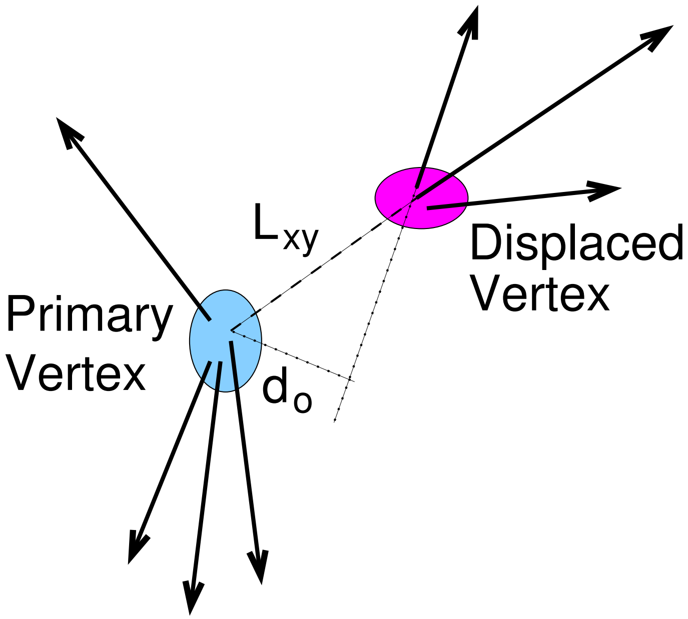
XFT tracks (green) compared with offline tracks (black).

Performance exceeds design specification.

→ Measured momentum resolution $(\Delta p_T/p_T^2) = 1.65\%$.

→ Measured angular resolution 5.1 mR.

Silicon Vertex Tracker (SVT Trigger)



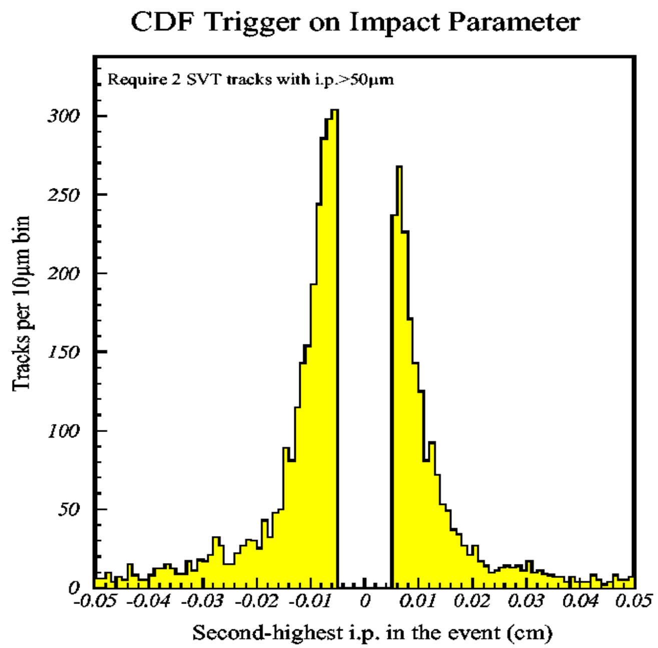
Many important physics signatures involve b quarks: Higgs searches, top studies, constraining CKM matrix...

b quarks have lifetimes $\tau(b) \sim 1.5ps \quad (c\tau \sim 450\mu m)$

Combine silicon hits with L1 tracks (XFT)

Select events with two tracks $d_o > 120\mu m$

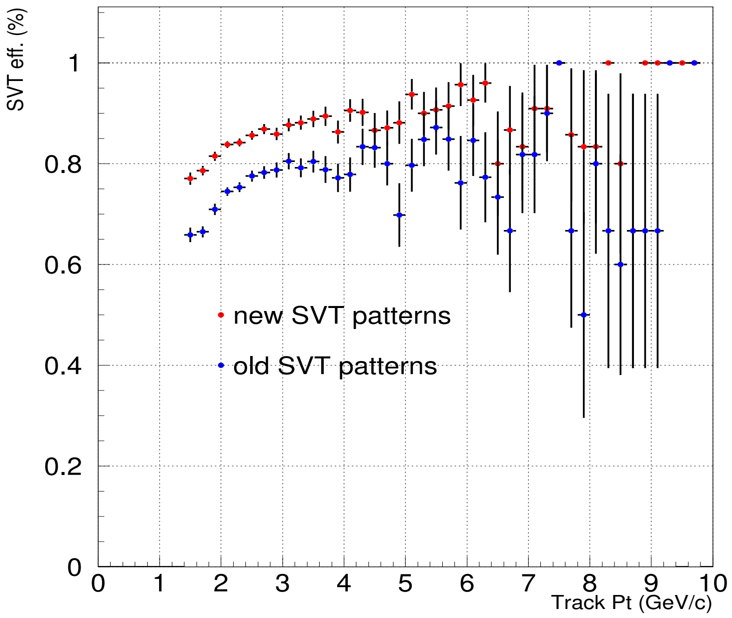
Using impact parameter (d_o) to detect secondary vertices at the Level 2 trigger significantly increases both our physics potential and calibration sample.



Able to better select $Z \to b\bar{b}$ over the QCD background. Used for resolution and mass scale systematics when determining the top mass.

B decay studies greatly improved. Allows study of hadronic decay modes ($B^o \to \pi^+\pi^-\ldots$) that are difficult to trigger on.

Allows triggering on hadronic B decays for measurements such as B_s mixing.

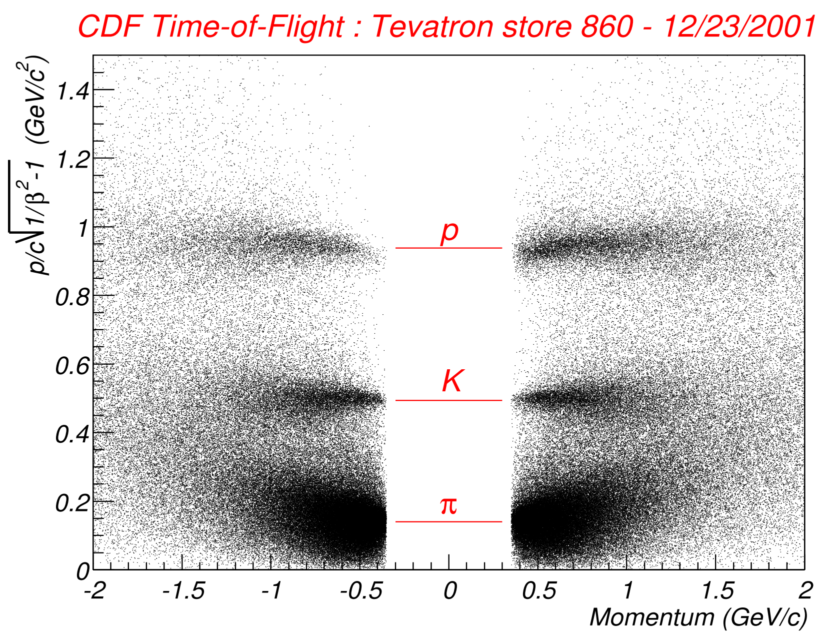


Efficiency has been improving as more of the Silicon is included.

Improving the trigger efficiency by improving the pattern matching algorithm...

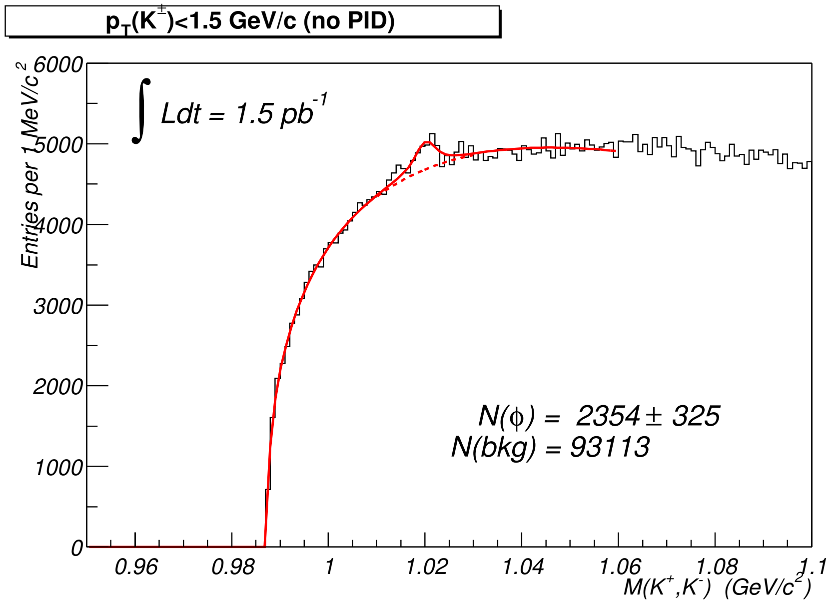
All this in a hadron collider environment... Unique to CDF...

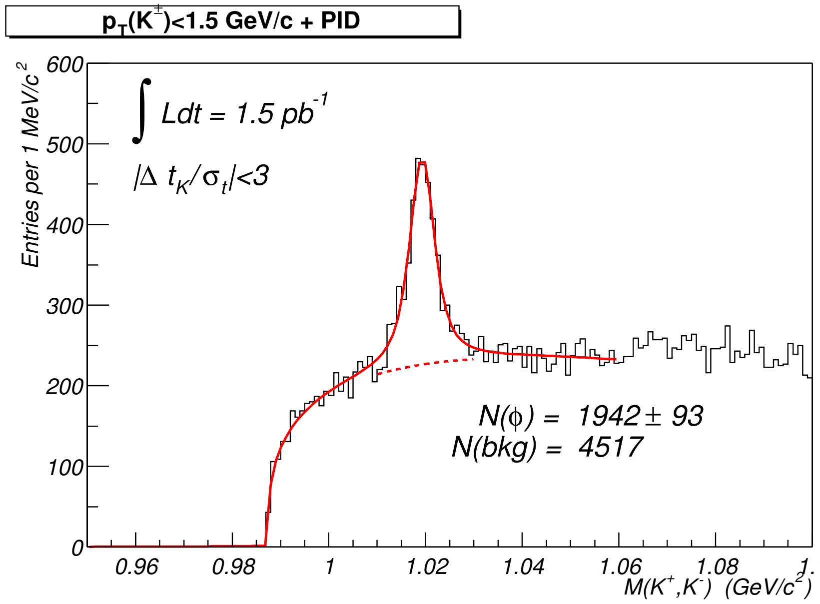
Time Of Flight



TOF resolution within 10-20% of the 100 ps design value.

Improved SN ratio for the $\phi(1020)$ using the TOF. 0.025 $\rightarrow$ 0.430 $\sim$ 18$\times$ improvement.



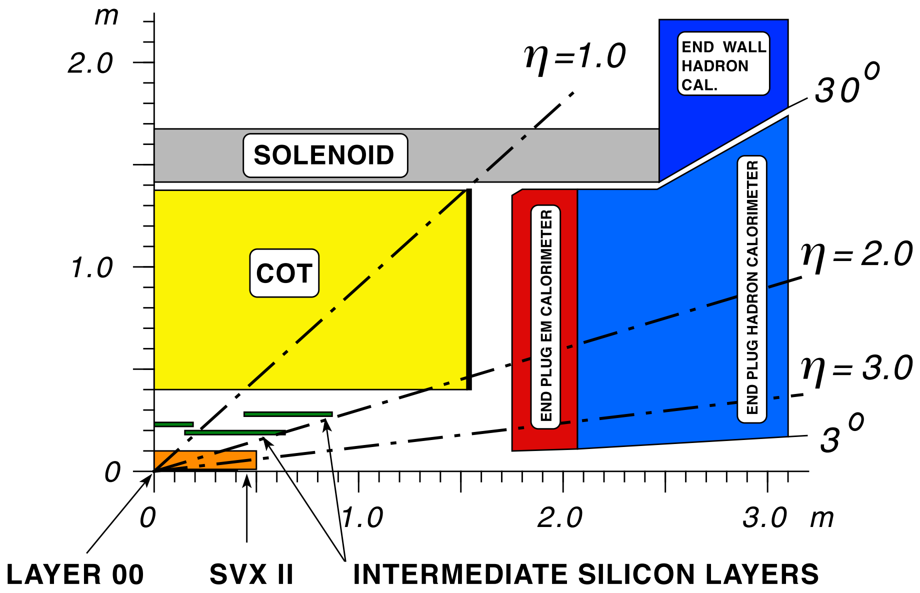


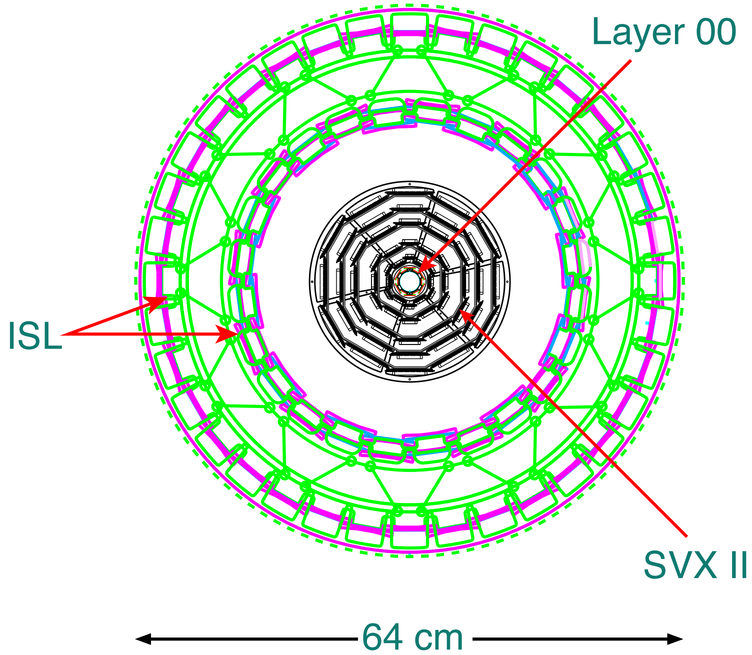
New Silicon Detectors: L00, SVXII, ISL

Covers $\sim 2.5\sigma$ of the luminous region

Extending the well measured region to $|\eta| < 2$

Doubles acceptance for particles with good tracking and vertexing.





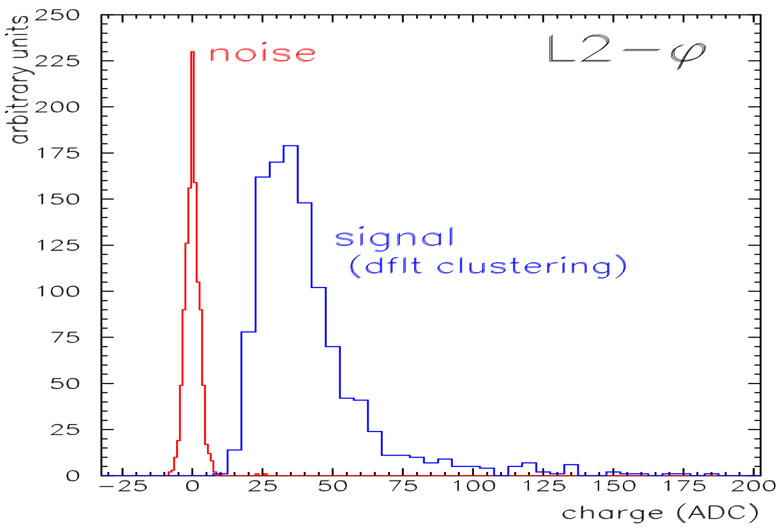
Improved b tagging for top events

Improved electron ID ($W \to e\nu$)

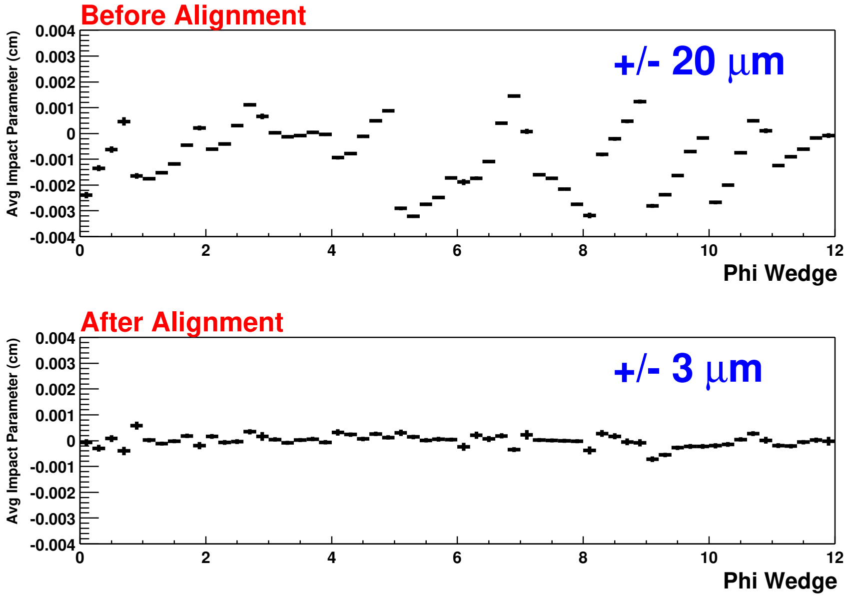
Improved soft lepton tagging

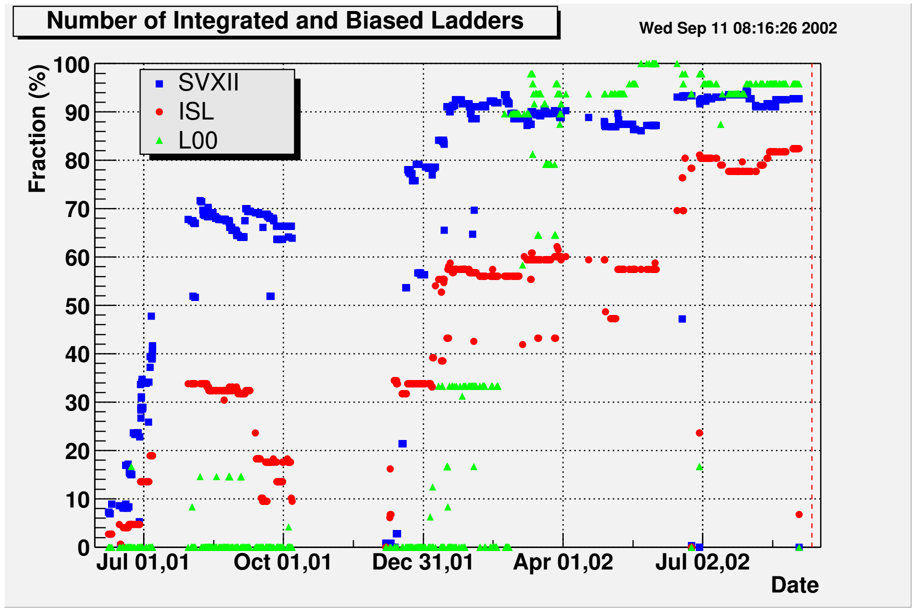
Triggering on a displaced tracks $\to$ richer B physics program

Typical SN ratio of 12.



Good alignment in $R-\phi$





Percent of silicon ladders that are read out

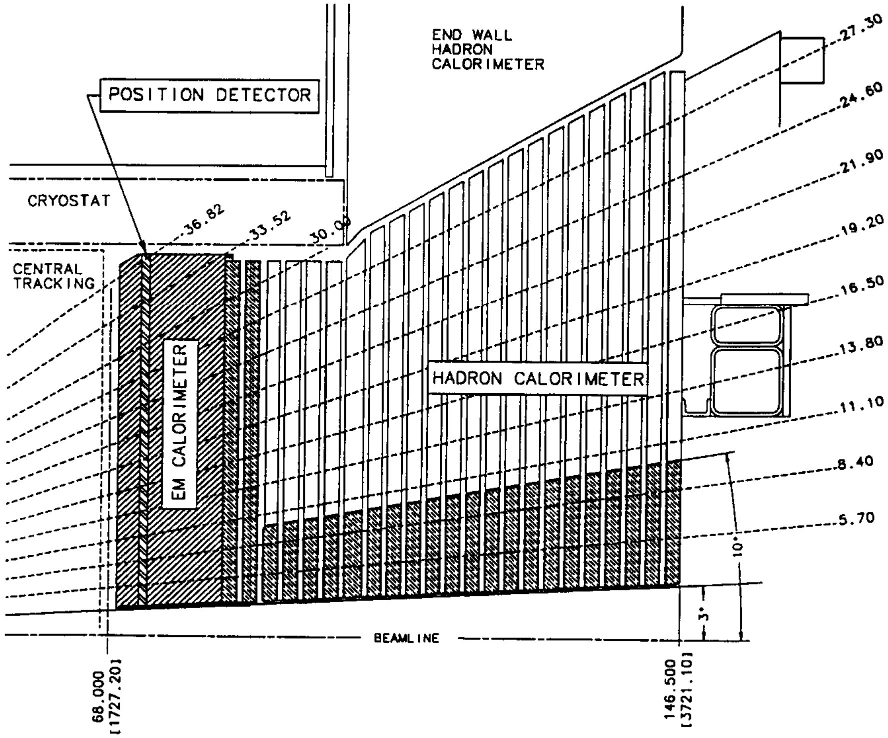
L00 $> 95\%$

SVXII $> 90\%$

ISL $> 80\%$

New Plug Calorimeter

Better forward coverage provides improved Jet energy resolution and electron identification.



Muon system: New detectors and more complete $\eta - \phi$ coverage enables better identification of primary muons from W decays and low p_T muons from semi-leptonic b decays.

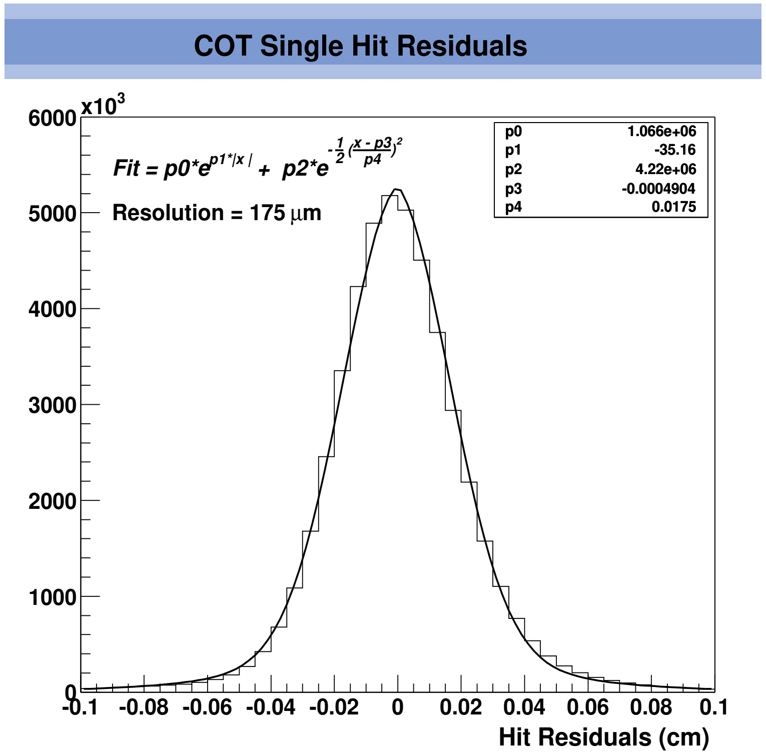
$\rightarrow$ Filled in gaps resulting in an increase in the total acceptance for top events by 12%

COT Upgrade

Reduced cell size and faster gas results in $< 100ns$ drift time

96 layers, increased number of stereo measurements from 24 to 48, full coverage up to $|\eta| < 1$

Better momentum resolution and more complete coverage



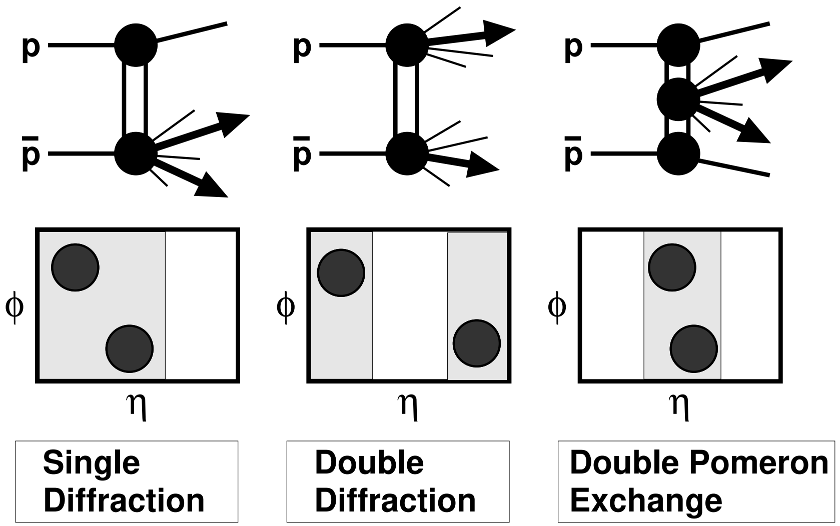
Measured tracking efficiencies:

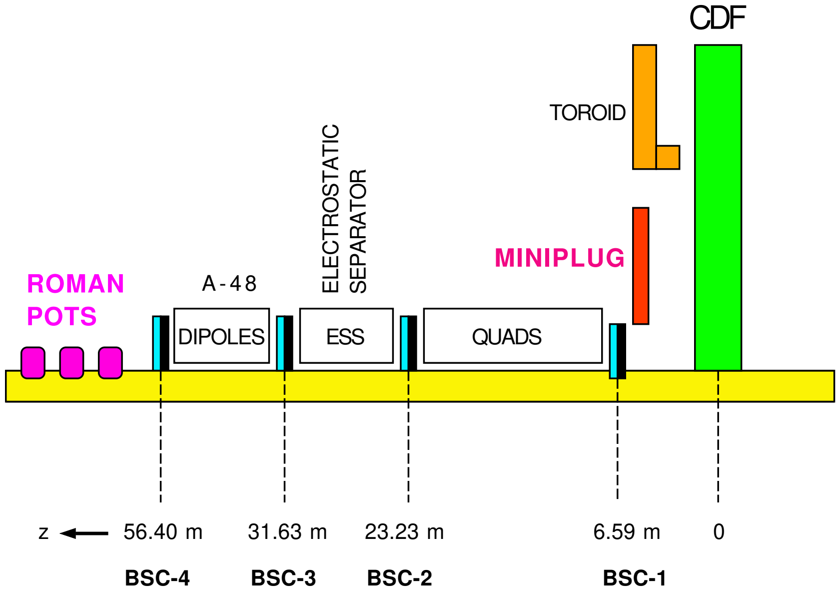
$\epsilon = 99 \pm 1\%$ (L3/offline)
$\sigma(1/p_T) < 0.13\%/\text{GeV}$ (offline)

$\epsilon = 96.1 \pm 0.1\%$ (L1 trigger)
$\sigma(1/p_T) = 1.74\%/\text{GeV}$ (L1 trigger)

Working well, used at the L1 trigger with excellent efficiency for triggering on tracks with p_T down to 1.5 GeV.

Forward Detectors





Single Diffraction
→ measurement of the diffractive structure function

Double Diffraction
→ jet-gap-jet at large η, tests of BFKL.

Double Pomeron Exchange
→ F^D_{JJ} vs gap width
→ exclusive dijet/$b\bar{b}$ production
→ low mass exclusive states

MiniPlug $3.5 < |\eta| < 5.5$
→ identify rapidity gaps and very forward jets

Beam Shower Counters $5.5 < |\eta| < 7.5$
→ detect particles at very small angles, identify rapidity gaps

Roman Pot Spectrometers
→ detect leading $\bar{p}$

See "Measurement of Diffraction..." talk by Dino Goulianos.

Understanding the Calorimeter Response

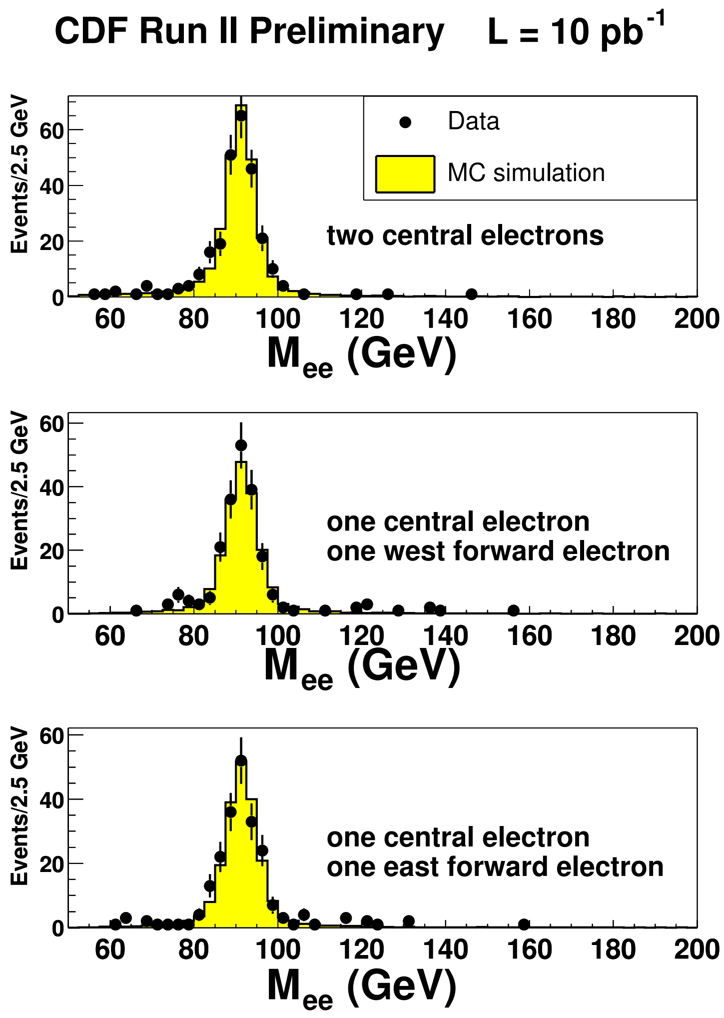
638 $Z \rightarrow e^+e^-$ in 10 pb^{-1} of data

Use $M(Z)$ to check the EM energy scale $M(Z) = 91.05 \pm 0.29$ GeV

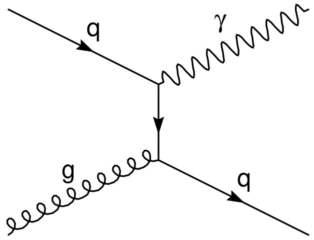
$\rightarrow$ For the central region, mean of the invariant mass is 1.2% higher

Absolute energy scale of the Plug EM checked with $Z \rightarrow e^+e^-$ with one electron in the central region.

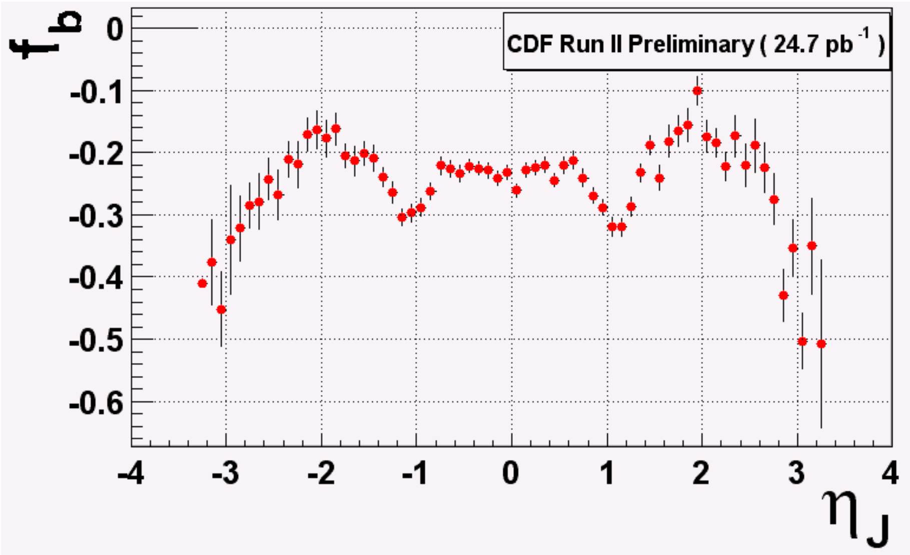
$\rightarrow$ For the forward region, mean is +10/+6.6% higher.



Use photon-jet balancing to find jet scale, $f_b = (P_T^{Jet} - P_T^{\gamma})/P_T^{\gamma}$



Require a photon in the central η region and look at the E_T of the Jet for different η



Corrections applied to the γ

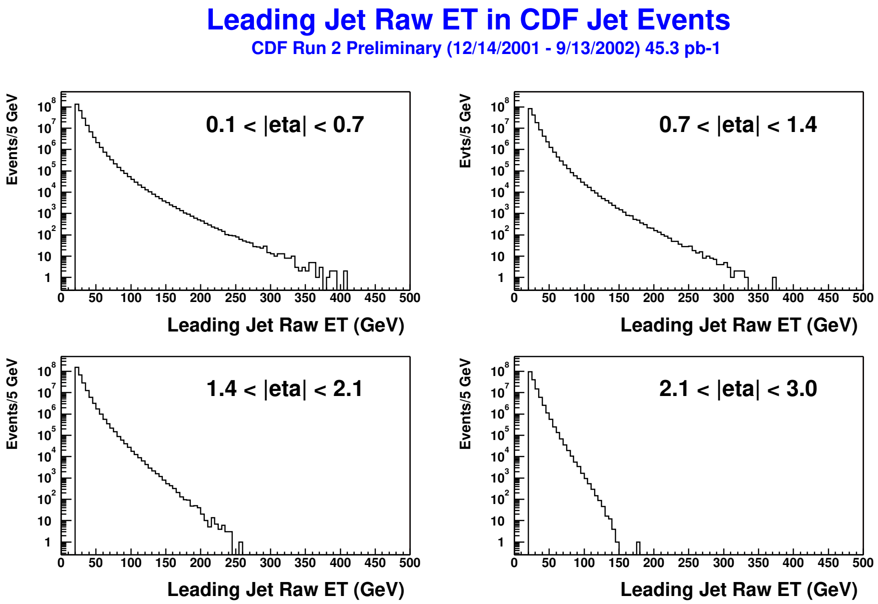
$\rightarrow$ Face map

$\rightarrow$ Tower-by-tower

$\rightarrow$ run-by-run

See a $(4.5 \pm 0.3)\%$ difference when compared to Run I.

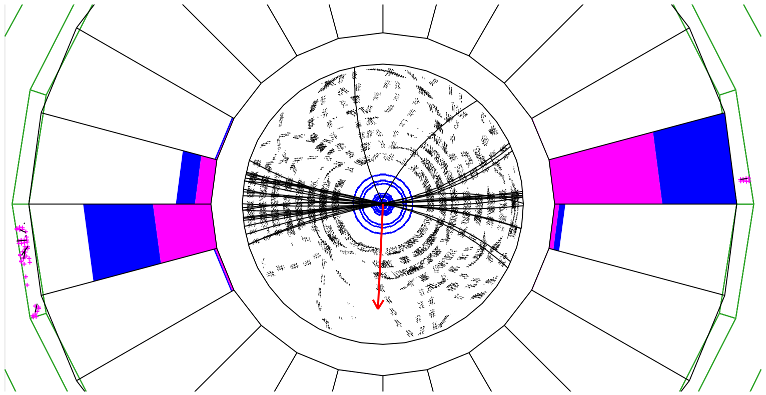
Also see a larger than expected gain reduction as a function of integrated luminosity in the most forward η region.



Raw leading Jet Raw E_T distribution (JetClu cone 0.7).

See high Et Jets!

Jet 1 Raw $E_T = 403$ GeV
Jet 2 Raw $E_T = 321$ GeV



Tests of perturbative QCD at NLO and Large Q^2

- Measure Jets with E_T out to 550 GeV.
- Use forward jets to study the proton structure at high x.
- Measure the running of α_s, better constraints on the PDFs.
- Study of the production properties of W/Z bosons, Drell-Yan lepton pairs and direct photons.

See "Jet Production..." talk by Mario Martinez.

Rich b physics program, constraint of the CKM matrix with high statistics B decays

- Copious production of various species of b hadrons at the Tevatron and unique triggering capabilities at CDF.

- The Tevatron provides the unique opportunity to study heavier b hadrons such as B_c.

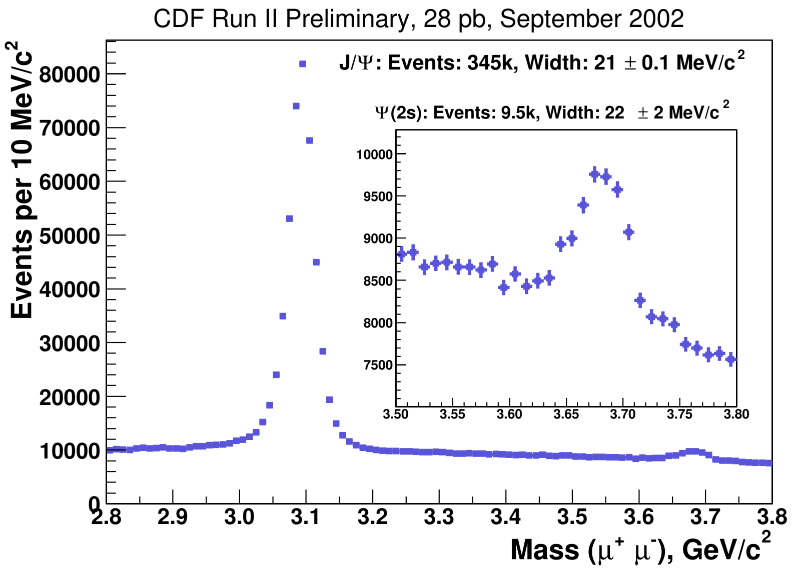
- Pursue the observation of rare decays (*e.g.* $B \to K^{*o}\mu^+\mu^-$).

Improvements in the trigger and acceptance

$p_T^{\mu} > 2 \to 1.5$ MeV

$\Delta\phi > 5^o \to 2.5^o$

COT only	$\sigma = 21$ MeV
with Silicon	$\sigma = 15$ MeV



Large sample used for the tracking calibration

345K events in 18 pb^{-1}!

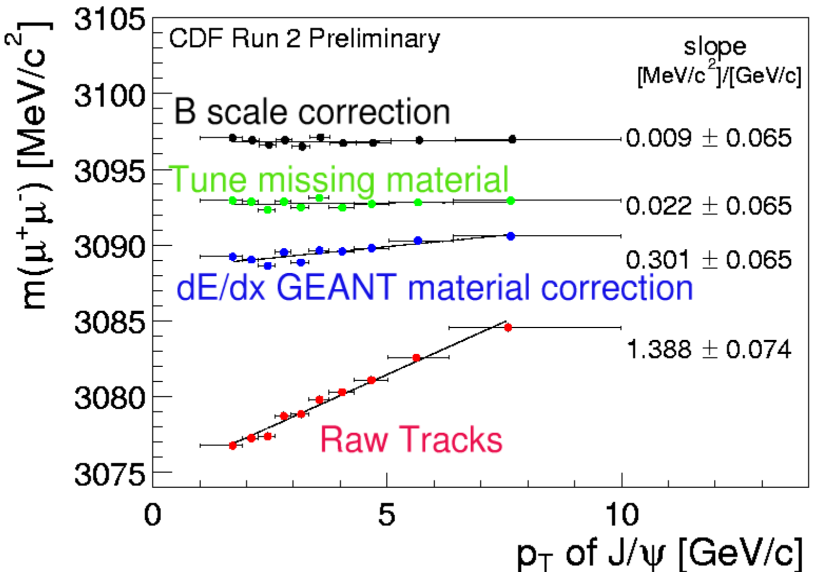
Tracking Calibration Using the J/ψ Sample

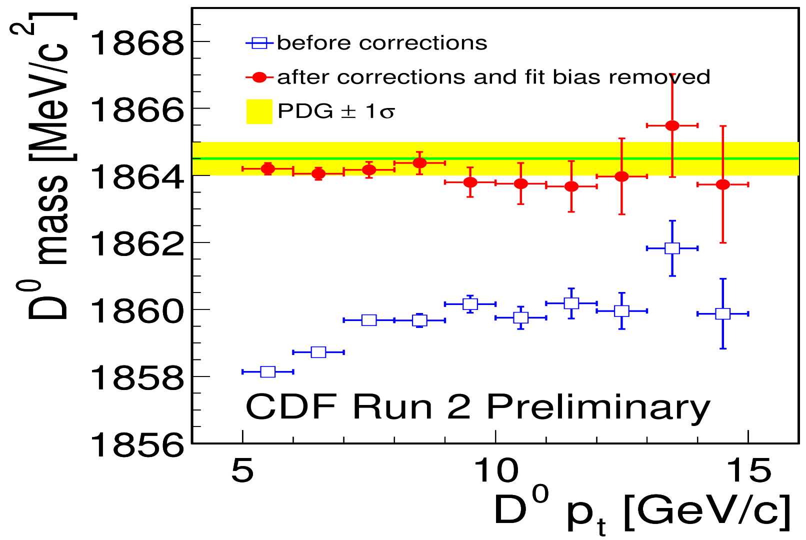
→ Apply GEANT dE/dx corrections
→ Measure missing material from $m_{J/\psi}(p_T)$
→ Add Magnetic Field correction

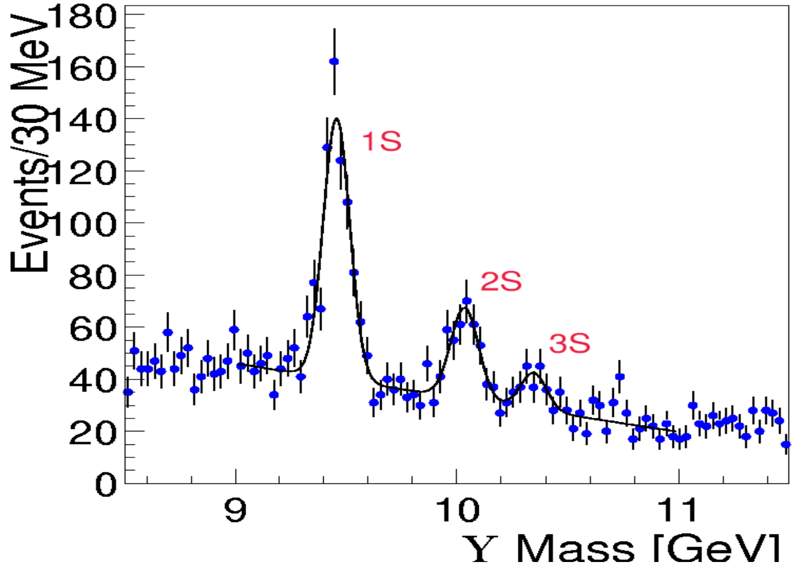
Tune to the J/ψ mass

Check corrections with other particles.

Agrees at the sub MeV level...







Measurement of B Masses in Exclusive J/ψ Channels

Cross check of tracking calibration

$m(\psi(2S))$ $3686.43 \pm 0.54(stat)\ MeV/c$
PDG: $3685.96 \pm 0.09\ MeV/c$

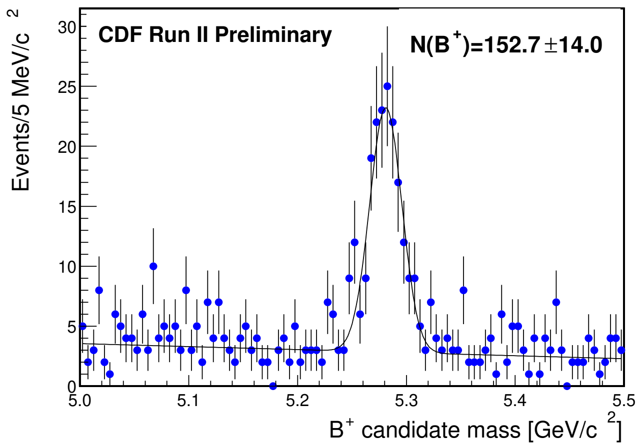
$m(B^+)$ $5280.6 \pm 1.7(stat) \pm 1.1(sys)\ MeV/c$
PDG: $5279.0 \pm 0.5\ MeV/c$

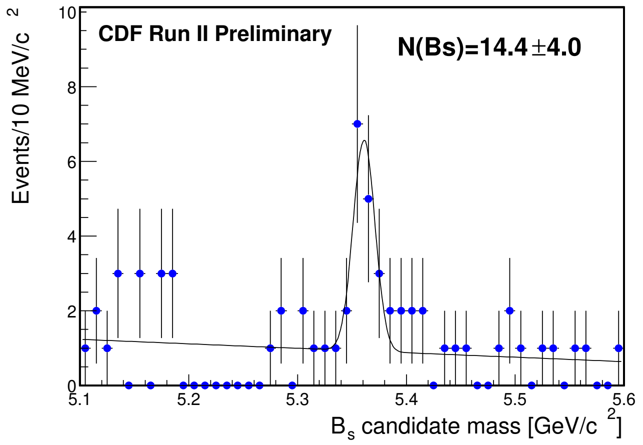
$m(B^o)$ $5279.8 \pm 1.9(stat) \pm 1.4(sys)\ MeV/c$
PDG: $5279.4 \pm 0.5\ MeV/c$

Improving previous measurements...

$m(B_s^o)$ $5360.3 \pm 3.8(stat)\ ^{+2.1}_{-2.9}\ (sys)\ MeV/c$
PDG $5369.6 \pm 2.4\ MeV/c$

See "B mass..." talk by Sandro Dececco.

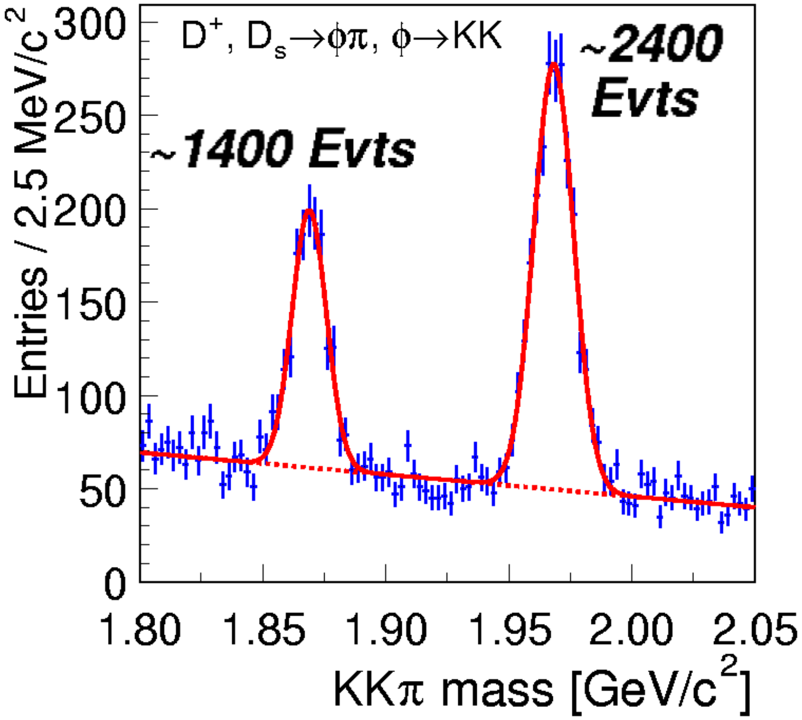




Measurement of the mass difference of D_s and D^+ mesons reconstructed from the $\phi\pi$ channel.

Reduced systematics since the decay kinematics of $D_s^{\pm}$ and $D^{\pm}$ are similar.

Dominated by background modeling



$m(D_s^{\pm}) - m(D^{\pm}) = 99.28 \pm 0.43(stat) \pm 0.27(sys)\ MeV/c^2$

PDG: 99.2$\pm$0.5 MeV/c^2

Improving previous results...

Make use of the *L1 XFT trigger* and *L2 SVT trigger*.

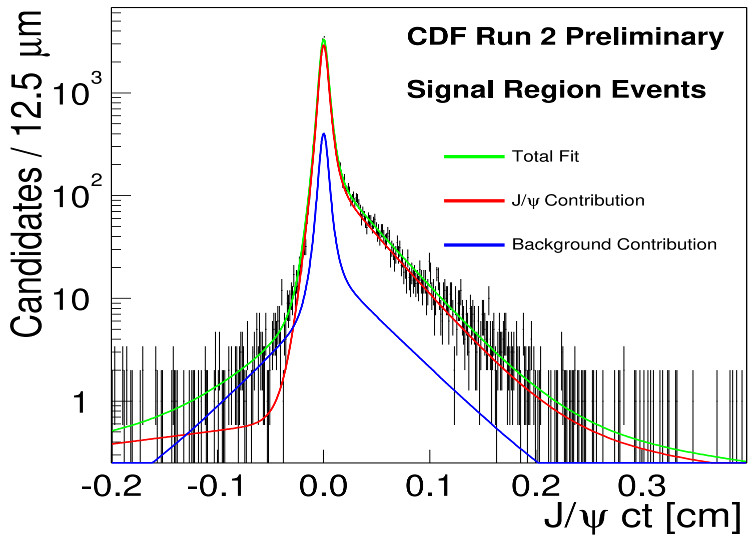
Inclusive B lifetime from J/ψ decays, $B \to J/\psi + X$

Collected using the *dimuon trigger*

$c\tau_B = 458 \pm 10(stat) \pm 11(sys)\ \mu m$

$\tau_B = 1.526 \pm 0.034(stat) \pm 0.035(sys)\ ps$

$c\tau_B(PDG) = 469 \pm 4\mu m$



Exclusive B lifetime measurements. $B^+ \to J/\psi K^+$

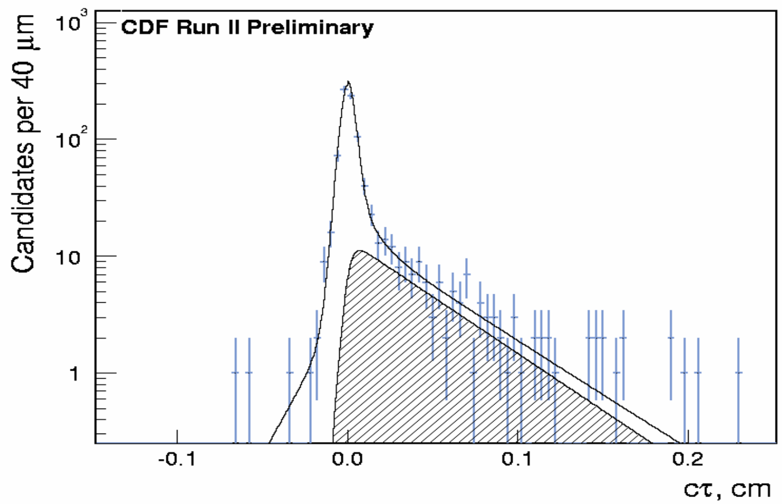
Integrated luminosity of 18 pb^{-1}

154 signal events

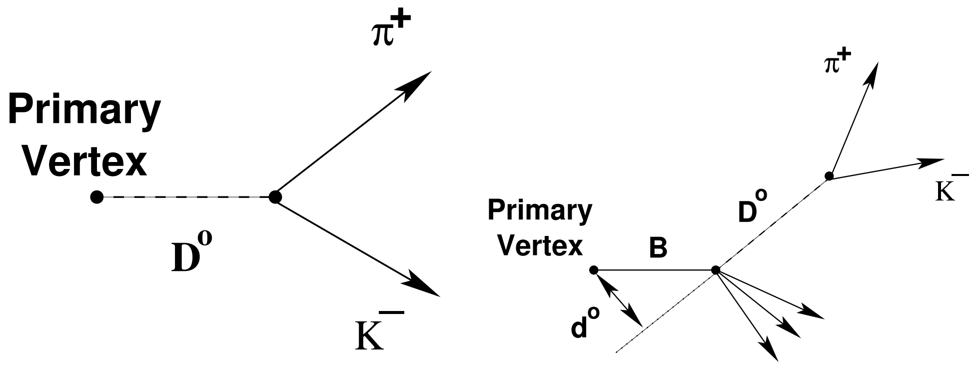
$c\tau_{B^+} = 446 \pm 43(stat) \pm 13(sys)\mu m$

$\tau_B = 1.49 \pm 0.14(stat) \pm 0.04(sys)ps$

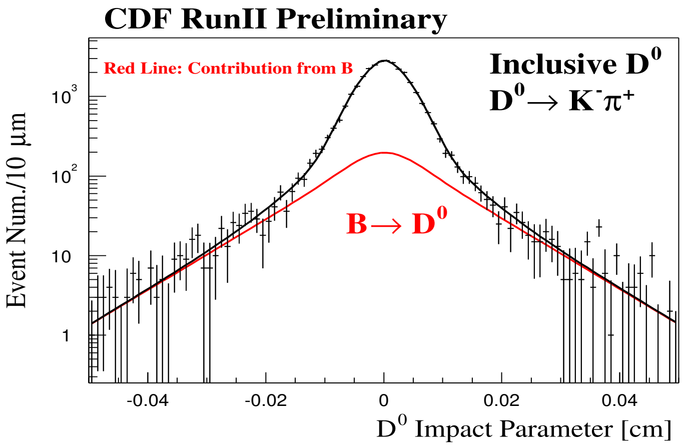
$c\tau_{B^+}(PDG) = 502 \pm 5\mu m$



Measurement of Direct and Secondary Charm Production



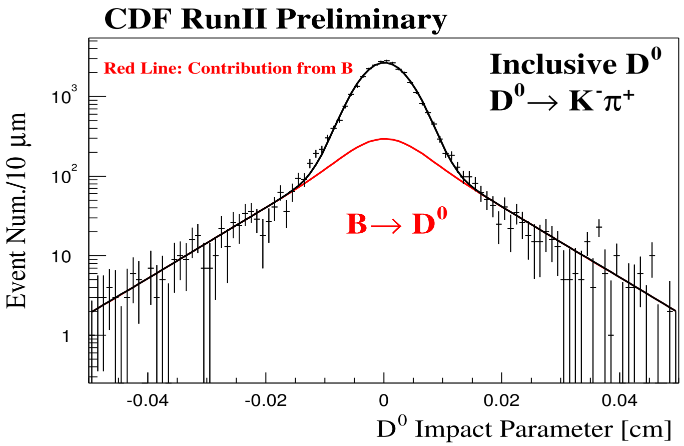
Detector resolution



Inclusive B fraction, fB.

Mode	fB	fB (Gaussian)
D^o	$16.4 \pm 0.7\%$	$23.1 \pm 0.6\%$
D^{*+}	$11.4 \pm 1.4\%$	$20.0 \pm 1.2\%$
D^+	$11.3 \pm 0.5\%$	$17.3 \pm 0.5\%$
D_s^+	$34.8 \pm 2.8\%$	$37.8 \pm 2.6\%$

Gaussian

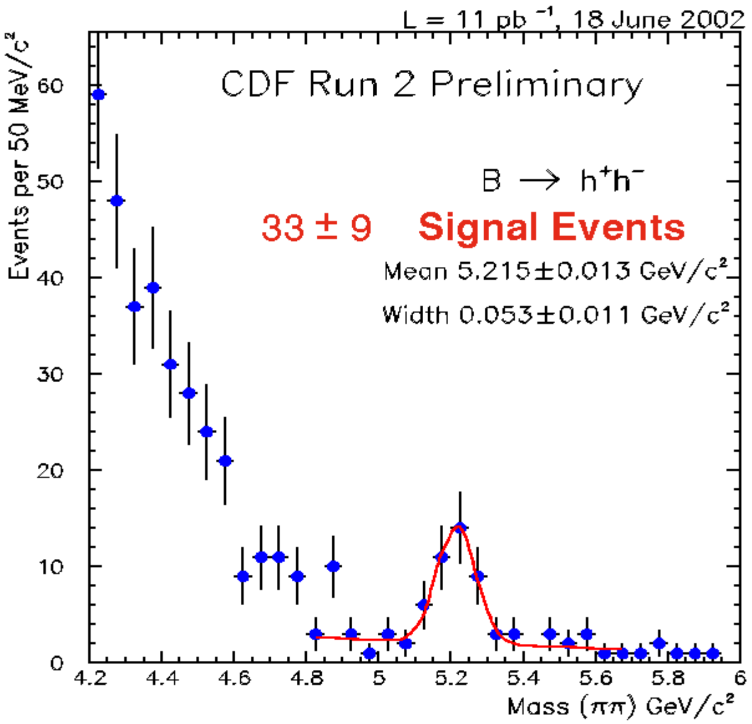


Most of the charm mesons originate from direct production.

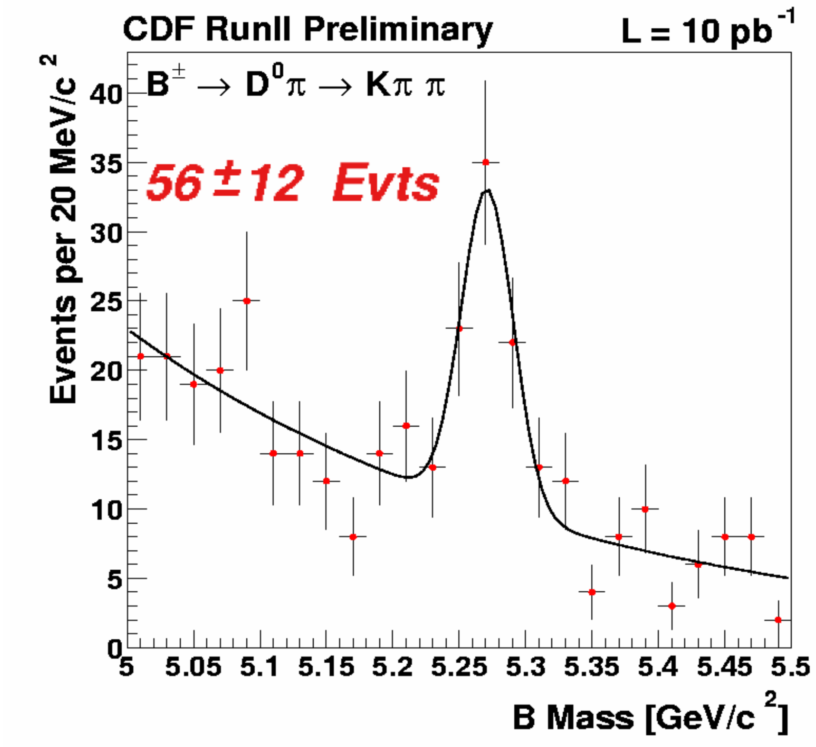
See "Heavy Quark..." talk by Mary Bishai.

Fully hadronic B decay modes collected with SVT trigger

$B \to h^+h^-$



$B \to D\pi$



$B \to h^+h^-$ includes $B_d \to K\pi$, $B_d \to \pi\pi$, $B_s \to KK$ and $B_s \to K\pi$.

With improvements in triggering and silicon coverage expect more than a factor of 3 increase in the yield.

New capability at CDF!

Global Precision Electroweak Program

• New detectors and increased coverage extends the measurable region to $|\eta| < 2$, better lepton identification.

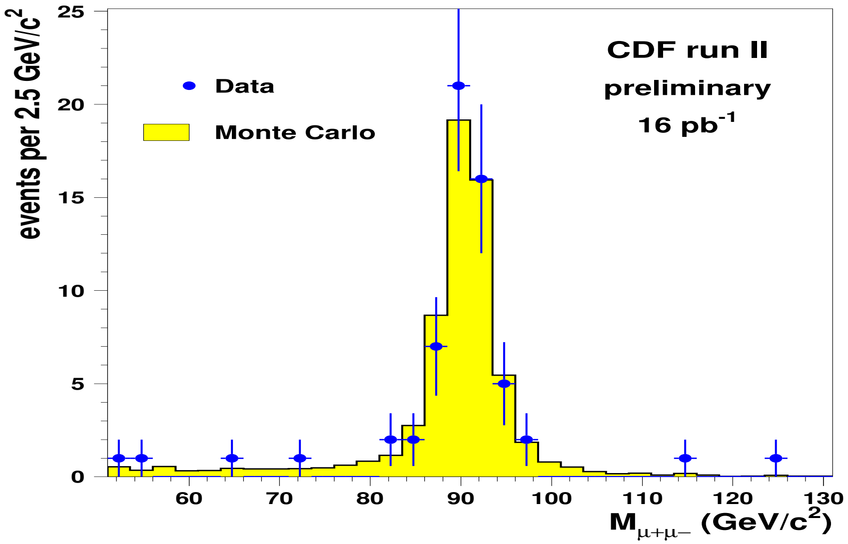
• Precision measurement of m_W to $\pm$40MeV

• W decay width is expected to be measured to 30 MeV, a factor of 6 improvement over LEP-II.

Observe a $Z \to \mu^+\mu^-$ signal

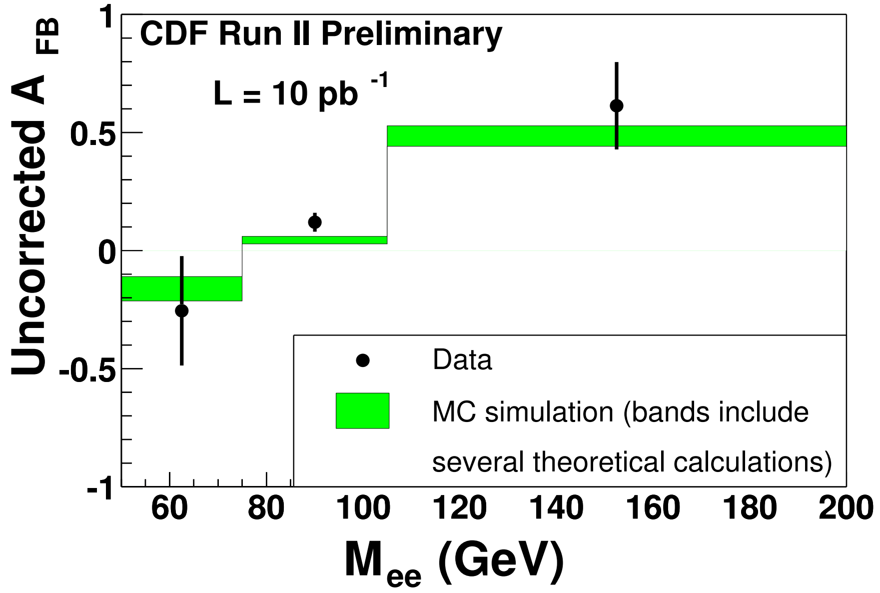
57 candidates in 16 pb^{-1}
$66 < M_{\mu\mu} < 116$ GeV

Utilizes COT×CMU×CMP



Forward Backward Charge Asymmetry

$p\bar{p} \rightarrow Z/\gamma + X \rightarrow e^{+}e^{-} + X$



N_F: # events with cos$(\theta^*) > 0$
N_B: # events with cos$(\theta^*) < 0$
$A_{FB} = (N_F - N_B)/(N_F + N_B)$

Measures the relative strength of the vector and axial-vector couplings.

Search for non standard model heavy neutral gauge bosons (Z').

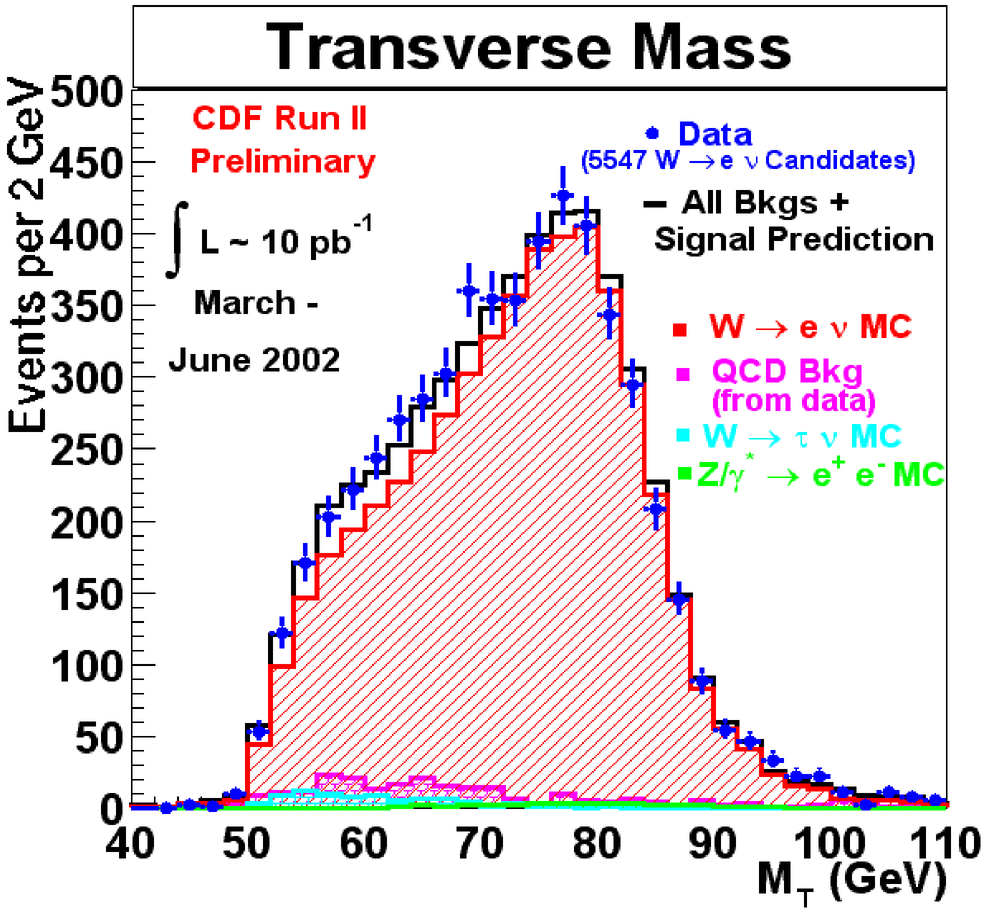
$W \rightarrow e\nu$

Based on $\mathcal{L} = 10\ pb^{-1}$

5547 Candidates

Background (8%)

QCD	$260 \pm 34 \pm 78$
$Z \rightarrow ee$	$54 \pm 2 \pm 3$
$W \rightarrow \tau\nu$	$95 \pm 6 \pm 1$



Uses XFT trigger at L1.

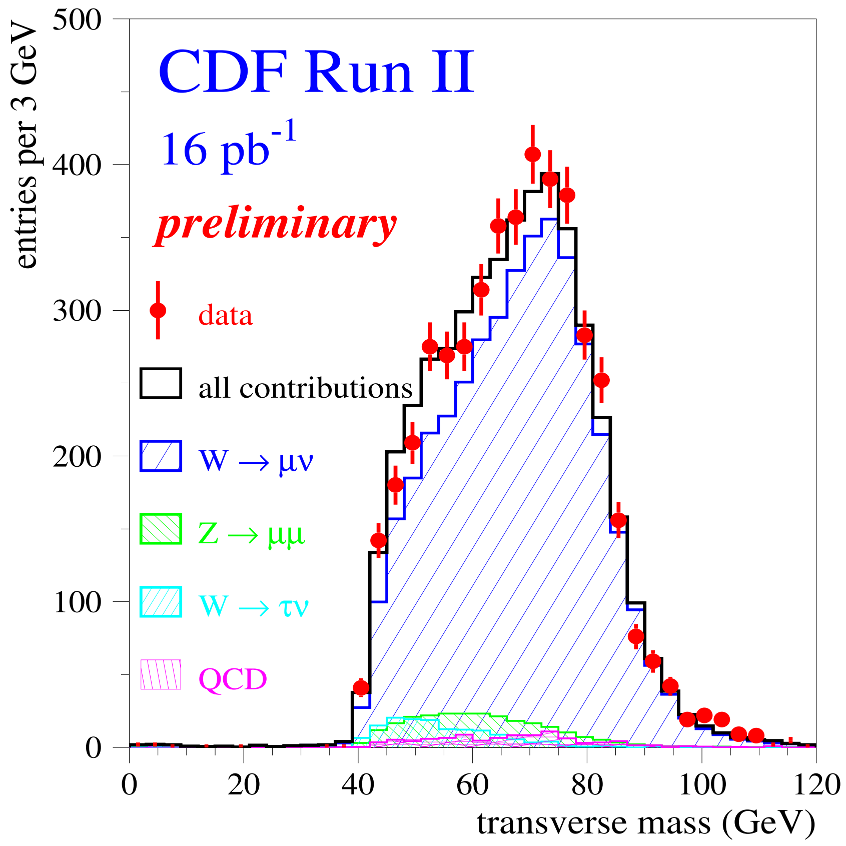
$\sigma(W \rightarrow e\nu) = 2.60 \pm 0.07(stat) \pm 0.11(sys) \pm 0.26(lum)\quad nb$

Expect that error on luminosity $\rightarrow$ 0.16.

Consistent with Run I results (after rescaling for high center of mass)

$\sigma(W \rightarrow e\nu)_{RunI} = 2.72 \pm 0.02(stat) \pm 0.08(sys) \pm 0.09(lum)\quad nb$

Inclusive W production cross section, $W \to \mu\nu$



Based on $\mathcal{L} = 16\ pb^{-1}$

5461 candidates

Background (11%)

QCD	104 ± 53
Cosmics	73 ± 30
$Z \to \mu\mu$	247 ± 13
$Z \to \tau\mu$	145 ± 13

Events selected using the Central Muon Detector (CMU) and Central Muon Upgrade (CMP)

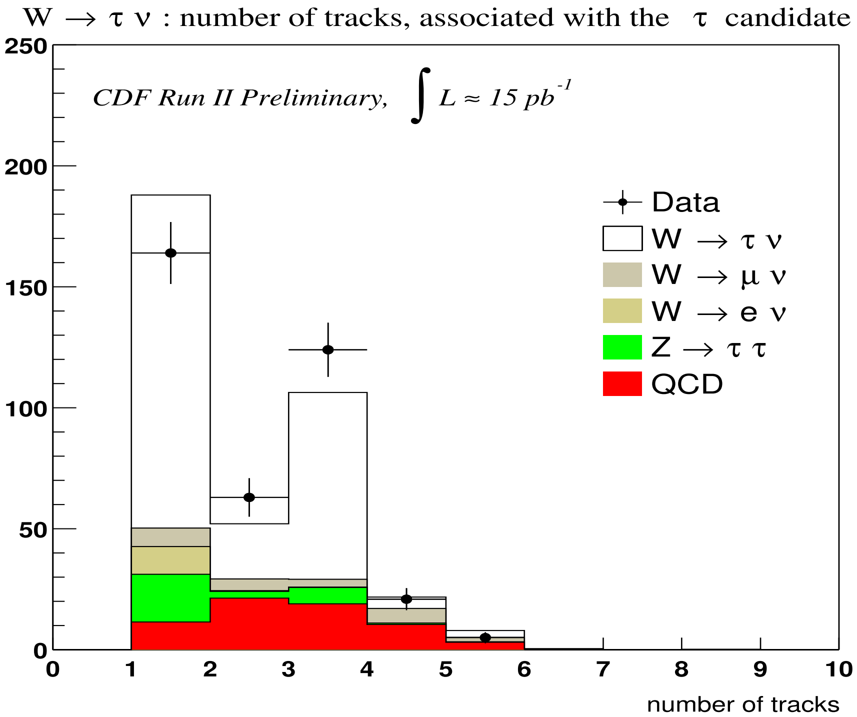
$\sigma(W \to \mu\nu) = 2.70 \pm 0.04(stat) \pm 0.19(sys) \pm 0.26(lum)nb$

Consistent with Run I results (after scaling).

$\sigma(W \to \mu\nu)_{RunI} = 2.41 \pm 0.08(stat) \pm 0.15(sys) \pm 0.16(lum)nb$

$R_\mu = \sigma(W \to \mu\nu)/\sigma(Z \to \mu\mu) = 13.66 \pm 1.94(stat) \pm 1.12(sys)$

See "W/Z Production..." talk by Eric James.



Observe more rare decays...

Evidence for $W \to \tau\nu$ decay.

τ channel important for searches of new physics (Higgs).

See "Higgs search..." talk by Pasha Murat

Direct Searches For New Phenomena

- Sensitive to charginos up to 130 GeV and gluinos up to 270 GeV.

- Second generation lepto-quarks up to 300 GeV, new vector bosons can be probed up to 800 GeV.

- Quark compositness can be probed up to a scale of 5 TeV.

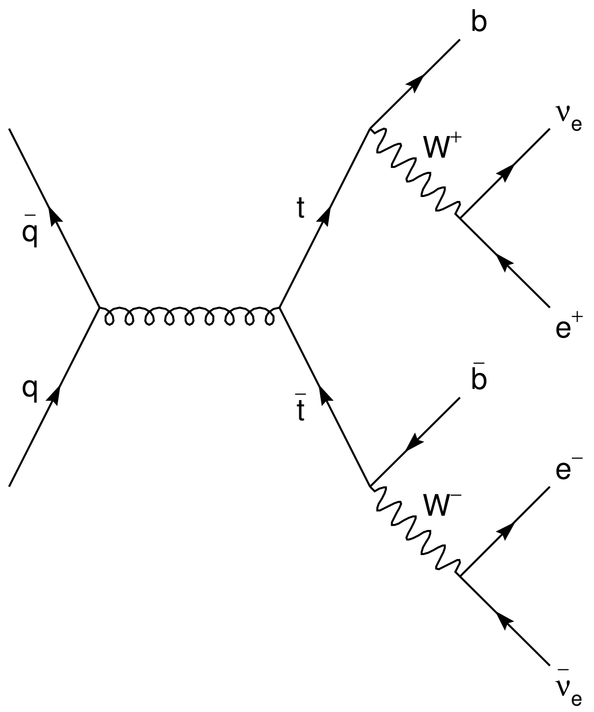
See "Searches..." talk by Hyunsoo Kim

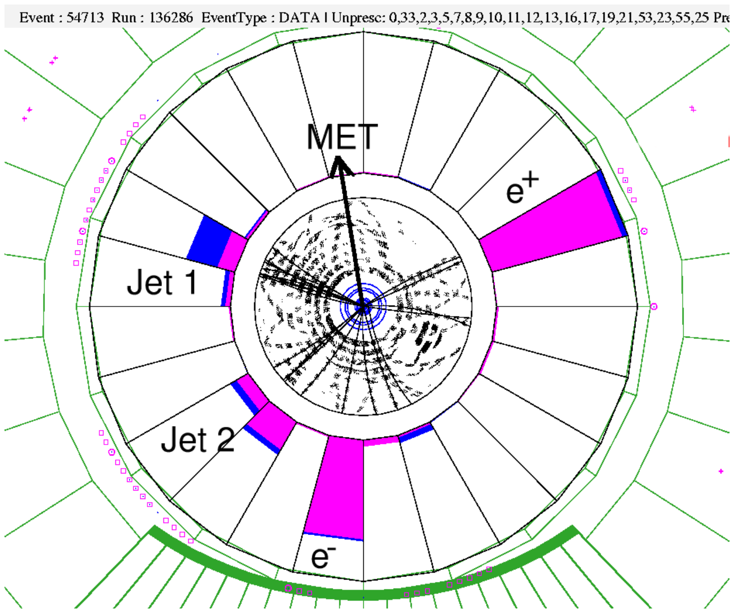
Characterization of the Properties of the Top Quark

With $2fb^{-1}$ expect 1000 b tagged events $\rightarrow$ able to measure top mass to about 3 GeV, total cross section to 9%

Search for non-standard production mechanisms resolvable to total cross sections of 90 fb

Event Having Signature Consistent With Top Production





See "Top quark..." talk by Wolfgang Wagner.

Conclusions

Run II upgrades build on the experience from Run I

$\rightarrow$ Improved acceptance
$\rightarrow$ New trigger capabilities
$\rightarrow$ Better detectors
$\rightarrow$ *More precise measurements*

New detectors and trigger hardware are working well, *taking physics quality data since Jan 2002*

Currently running with $\sim$ 40/80/140 triggers at L1/L2/L3

Already benefitting from *new triggers* and *new detectors*

$\rightarrow$ Tracking trigger at L1 (XFT)
$\rightarrow$ Displaced vertex trigger at L2 (SVT)

First results are already competitive despite the low statistics

Should see the first Run II publication soon!

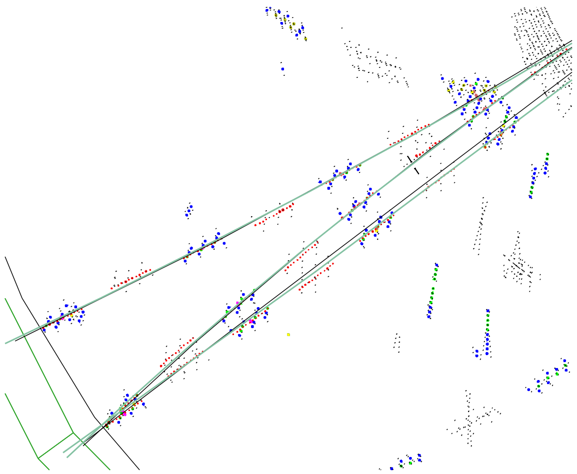
Status of CDF and Prospects for Run II

Run II upgrades build on the experience from Run I

→ Improved acceptance
→ New trigger capabilities
→ Better detectors

Detector and Trigger are commissioned and working well, taking Physics Quality data since Jan 2002

Currently running with $\sim$ 40/80/140 triggers at L1/L2/L3

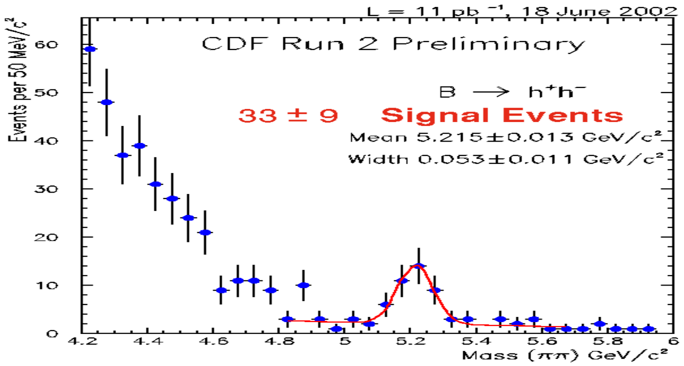


The Extremely Fast Tracking trigger (XFT) able to select tracks with p_T as low as 1.5 GeV at *L1!*

Silicon Vertex Tracker (SVT) working well, selects events with displaced tracks at *L2!*

New capabilities greatly expand the physics possibilities at CDF

Enables us to collect large samples for in situ calibration



Understanding of the detector is progressing and analysis efforts are well underway

Many results shown covering the major areas of the Run II program

- *Characterization of the properties of the top quark*
- *Global precision electroweak program*
- *Tests of perturbative QCD at NLO and large Q^2*
- *Constraint of the CKM matrix with high statistics B decays*
- *Direct search for new phenomena*
- *Diffractive Physics*

First results are already competitive despite the low statistics

Should see the first Run II publication soon!