Heavy Flavor and QCD Results From CDF

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- B and Charm results
- QCD: jet physics
- Conclusions

Fermilab Users Meeting, June 2-3, 2003

B physics at CDF

- Major trigger strategies
- Current physics results
  - Cross-sections
  - CP asymmetries in D decays
  - Rare decays
  - B hadron masses, and lifetimes
- Preparing for flagship analyses
  - CKM matrix measurements

Major trigger strategies

Trigger: select events with interesting physics

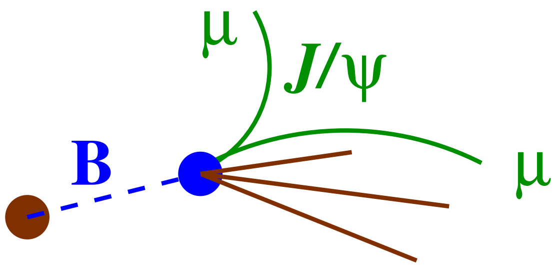
Challenging! $\sigma_{b\bar{b}}/\sigma_q \sim 1/1000$

Conventional: dimuon events

New B triggers in Run II:

- B lifetime is long: $c\tau \sim 500\mu$m; D is a few$\times 100\mu$m
- CDF tracking: $\sim 55\mu$m precision

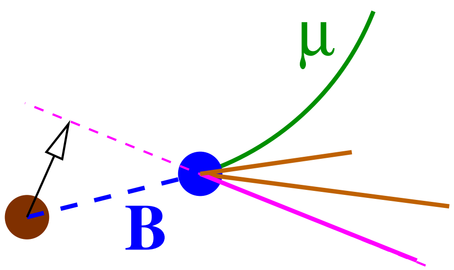
$\Rightarrow$ trigger on displaced tracks! (also get Charm!)



Dimuon trigger

Inclusive J/ψ events

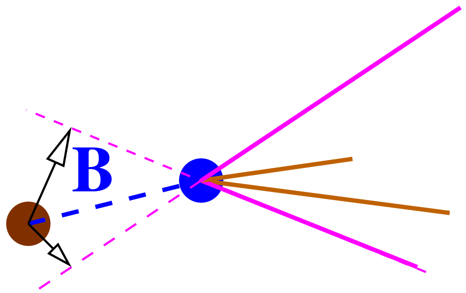
masses, lifetimes, CP−violation,...



Lepton−track trigger

Semileptonic B and D events

lifetimes, B flavor tagging, B^0 mixing, ...



Two−track trigger

Hadronic B and D events

CKM physics (B_s mixing, CP violation, ...)

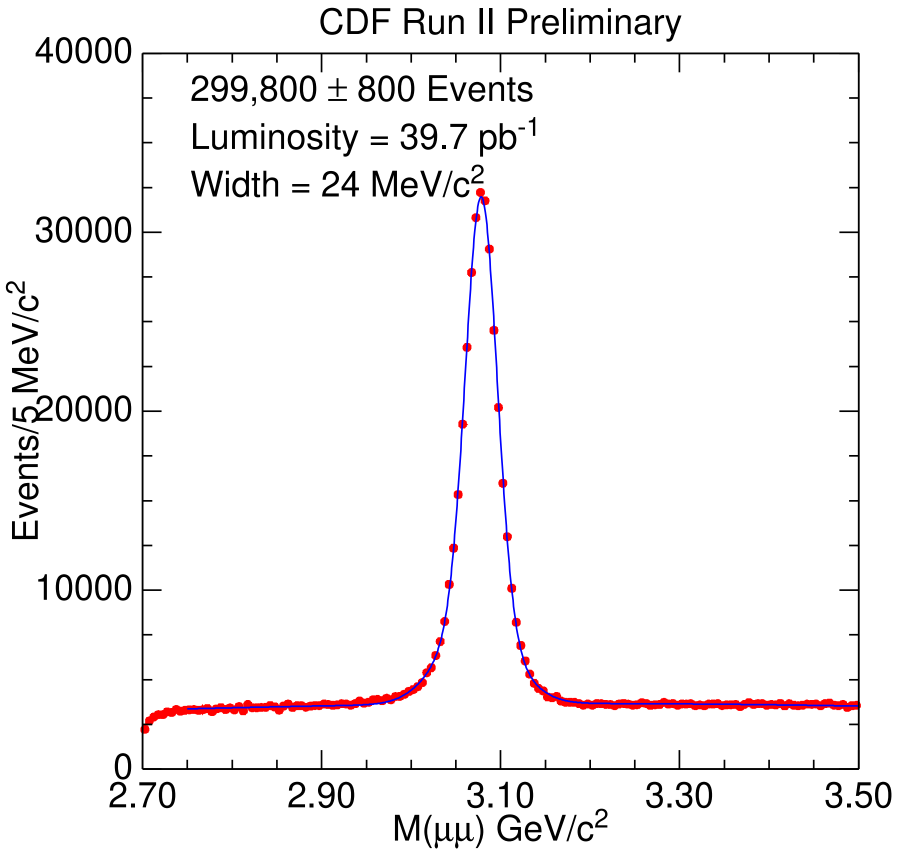
Inclusive J/ψ cross-section

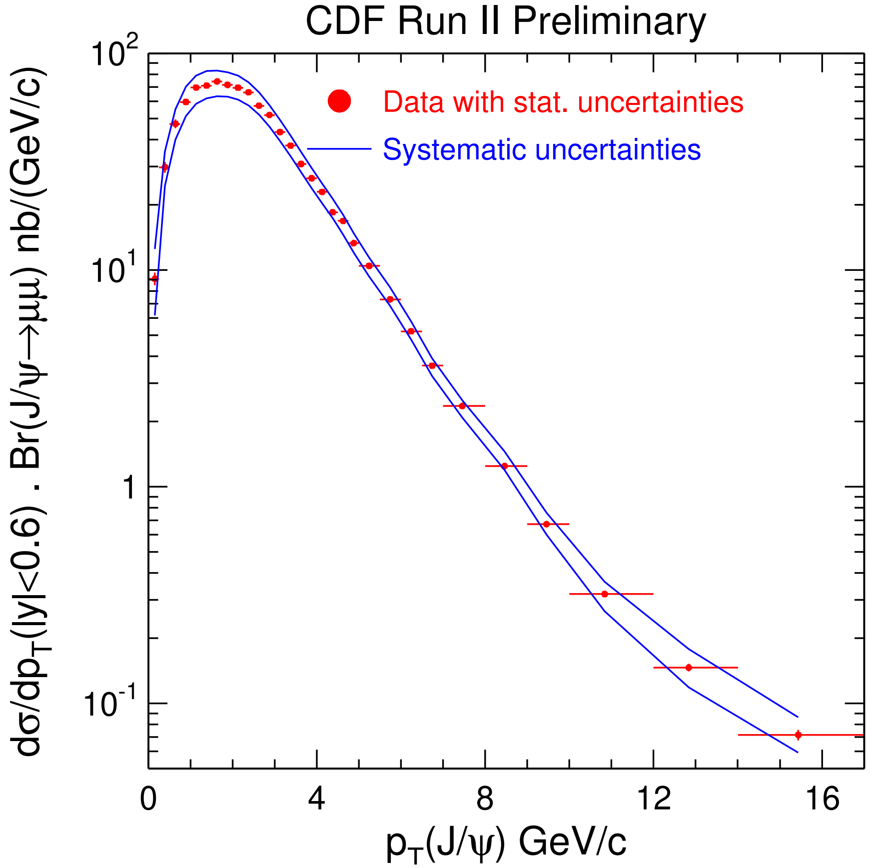
Quarkonium physics, x-section of b-production

New CDF Run II electronics: we can trigger on stopped J/ψ

Measure total x-section: first time at hadron collider!

From 300k of $J/\psi \to \mu^+\mu^-$: $\sigma(p\bar{p} \to J/\psi X) = 240 \pm 1^{+35}_{-28}$nb





Direct Charm cross-section

Powerful test of QCD

Large samples from 2-track trigger: 450k D^0, 78k D^*, etc

Full reconstruction of D^0, $D^\pm$, $D^{*\pm}$ and $D_s^\pm$

Split prompt D from B$\rightarrow$DX: exploit precision tracking

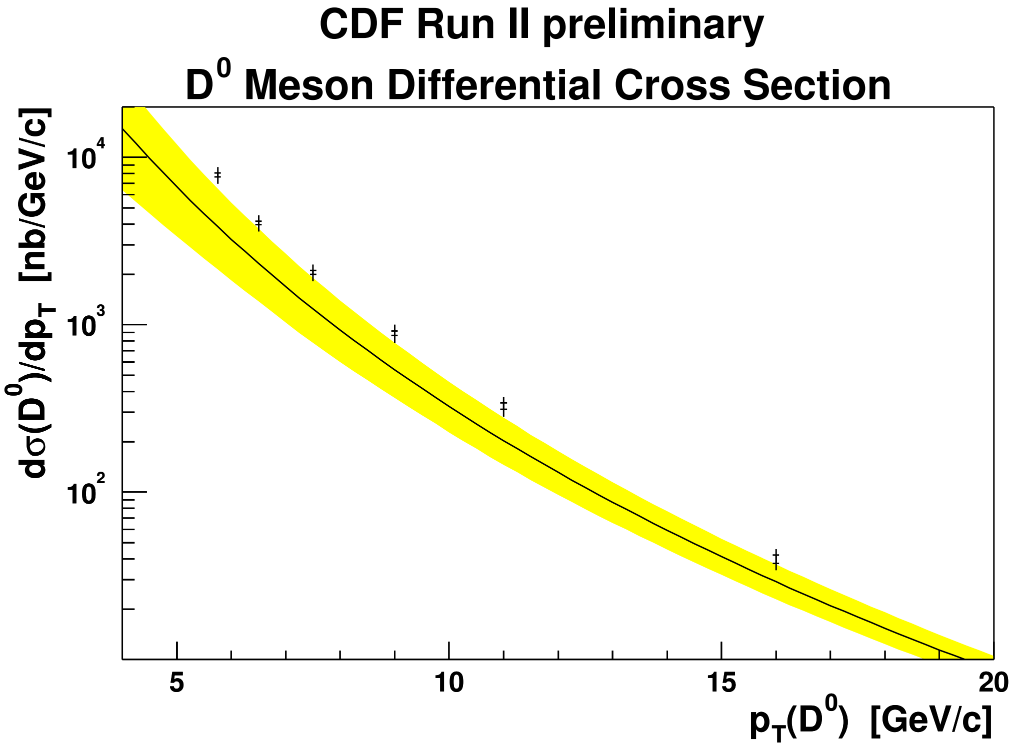
Measure differential and total x-section:

$$\sigma^{D^0}_{p_t \geq 5.5\mathrm{GeV}} = 13.3 \pm 0.2 \pm 1.5 \mu b$$

$$\sigma^{D^{*\pm}}_{p_t \geq 6\mathrm{GeV}} = 5.2 \pm 0.1 \pm 0.8 \mu b$$

$$\sigma^{D^\pm}_{p_t \geq 6\mathrm{GeV}} = 4.3 \pm 0.1 \pm 0.7 \mu b$$

$$\sigma^{D_s^\pm}_{p_t \geq 8\mathrm{GeV}} = 0.75 \pm 0.05 \pm 0.22 \mu b$$



Physics of $D^0 \to KK/\pi\pi/K\pi$ decays

D^0 mixing small: good handle on direct CP violation

$D^0 \to KK/\pi\pi$: CP eigenstates (but, Cabibbo-suppressed)

SM predicts: direct CP-violating asymmetry 0.1-1%

Asymmetry: count D^0 vs $\bar{D}^0$, use D^* to tag D flavor

Measured Br ratios:

$$\frac{\Gamma_{KK}}{\Gamma_{K\pi}} = 9.38 \pm 0.18 \pm 0.10\%$$

$$\frac{\Gamma_{\pi\pi}}{\Gamma_{K\pi}} = 3.686 \pm 0.076 \pm 0.036\%$$

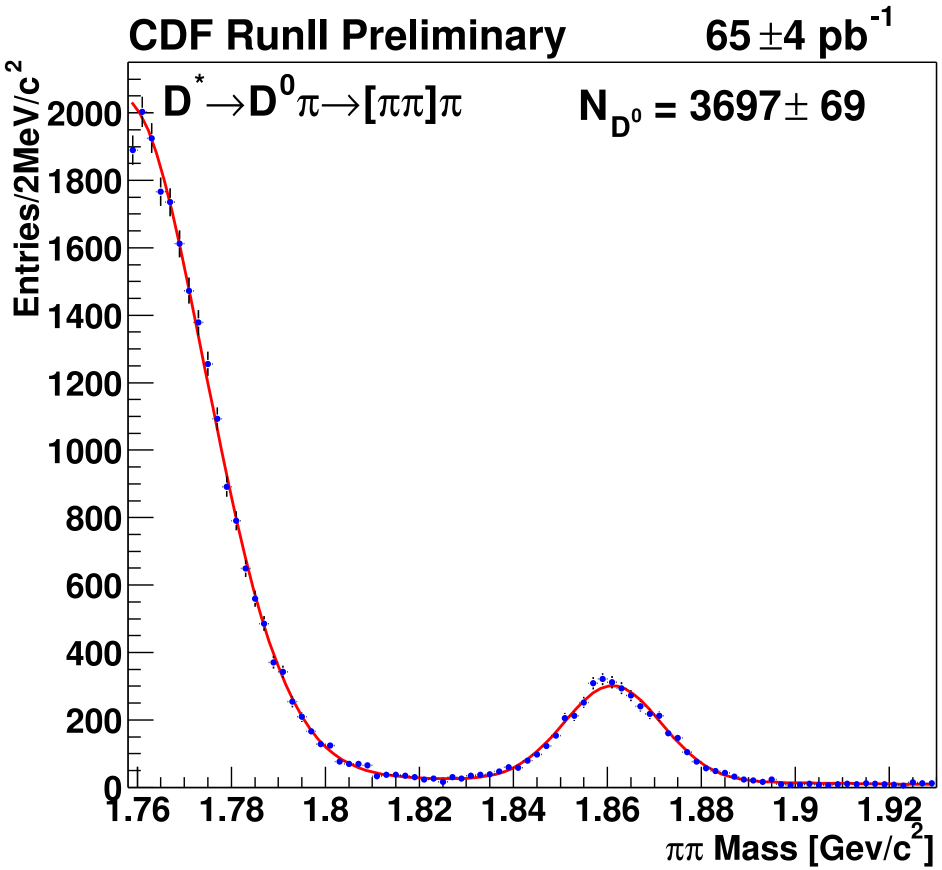
FOCUS 2003:
$\frac{\Gamma_{KK}}{\Gamma_{K\pi}} = 9.93 \pm 0.14 \pm 0.14\%$, $\frac{\Gamma_{\pi\pi}}{\Gamma_{K\pi}} = 3.53 \pm 0.12 \pm 0.06\%$

Direct CP asymmetries:

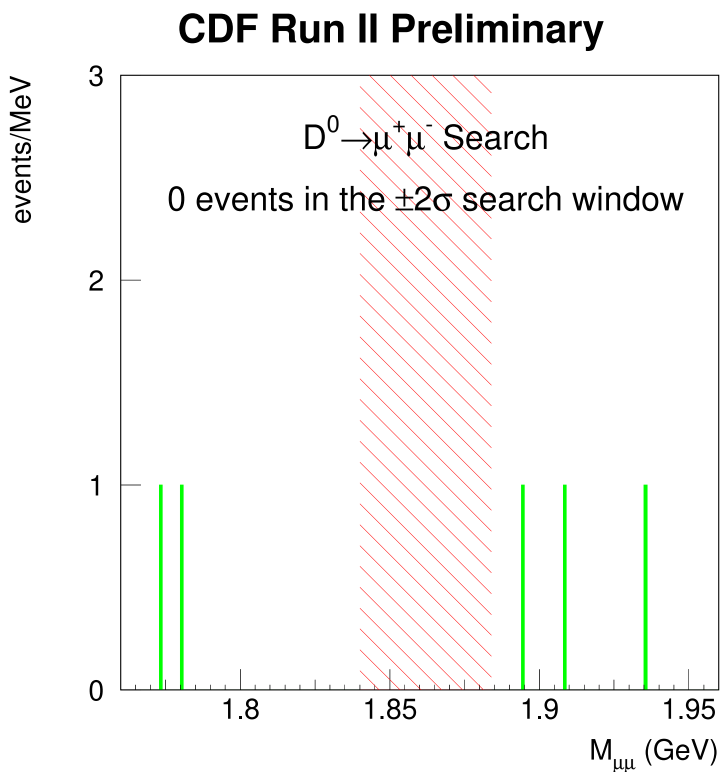
$$A_{CP}^{KK} = 2.0 \pm 1.7 \pm 0.6\%$$

$$A_{CP}^{\pi\pi} = 3.0 \pm 1.9 \pm 0.6\%$$

CLEO 2001:
$A_{CP}^{KK} = 0.0 \pm 2.2 \pm 0.8\%$, $A_{CP}^{\pi\pi} = 1.9 \pm 3.2 \pm 0.8\%$



Rare decay $D^0 \rightarrow \mu^+\mu^-$



Direct FCNC not allowed in SM

SM predicts rate 3×10^{-13}

SUSY: up to 3.5×10^{-6}

Current CDF result:

$Br(\mathbf{D}^0 \rightarrow \mu^+\mu^-) \leq 2.4 \times 10^{-6}$@90%C.L.

Previous best limit BEATRICE: $\leq 4.1 \times 10^{-6}$@90%C.L.

B meson masses and lifetimes

A step on the way to B_s mixing!

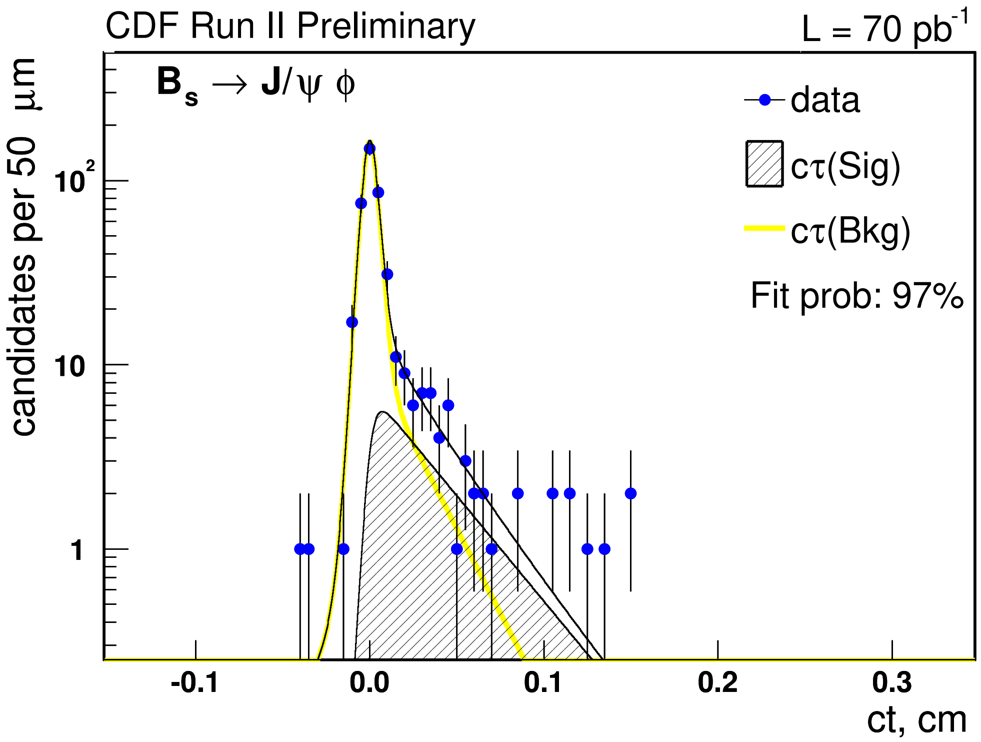
B_s available only at Tevatron!

Focus on B_s properties

Test HQET predictions for $\frac{\tau_{B_s}}{\tau_{B^0}}$

$B^0/B^{\pm}$: engineering numbers

Prereq: detector calibration



Best world measurements of B_s mass and lifetime:

	signature	mass, GeV/c^2	lifetime, ps
B^+	$J/\psi K^+$	5279.32±0.68±0.64	1.57±0.07±0.02
B^0	$J/\psi K^{*0}$	5280.30±0.92±0.96	1.42±0.09±0.02
B_s	$J/\psi\phi$	5365.50±1.29±0.94	1.26±0.20±0.02

First CDF Run II paper

Measurement of the Mass Difference $m(D_s^+) - m(D^+)$ at CDF II

We present a measurement of the mass difference $m(D_s^+) - m(D^+)$, where both the D_s^+ and D^+ are reconstructed in the $\phi\pi^+$ decay channel. This measurement uses 11.6 pb^{-1} of data collected by CDF II using the new displaced-track trigger. The mass difference is found to be

$$m(D_s^+) - m(D^+) = 99.41 \pm 0.38(\mathrm{stat.}) \pm 0.21(\mathrm{syst.})\ \mathrm{MeV/c^2}.$$

PACS numbers: 13.25.Ft, 14.40.Lb

I. INTRODUCTION

Meson masses are predicted by different models of quark interactions and the inter-quark potential. Analytically, the spectrum of heavy-light mesons can be described in the QCD framework using the principles of Heavy Quark Symmetry and Heavy Quark Effective Theory [1, 2]. These theories state that in the limit of infinitely heavy quark mass, the properties of the meson are independent of the heavy quark flavor and that the heavy quark does not contribute to the orbital degrees of freedom. The theory predicts that up to corrections of order $1/m_{b,c}$, $m(B_s^0) - m(B_d^0) = m(D_s^+) - m(D^+)$ [3]. Recently, lattice QCD calculations have also given their predictions for the meson mass spectrum [4–6]. By measuring the masses of mesons precisely, we narrow the range of parameters and approximations that theoretical models use to make predictions. For charm meson masses, a simultaneous fit [7] of all measurements including the mass difference between the D_s^+ and D^+ is used to compare experimental measurements with theoretical predictions. In this paper a measurement of the mass difference $m(D_s^+) - m(D^+)$ in the decay channels $D_s^+ \to \phi\pi^+$ and $D^+ \to \phi\pi^+$ where $\phi \to K^+K^-$ is presented [8]. The advantage of measuring the mass difference in a common final decay state is that many of the systematic uncertainties cancel. Gathering the large sample of charmed mesons used in this analysis is done using a novel displaced-track trigger, the Silicon Vertex Tracker (SVT) [9], which enables recognition of the decay of long-lived particles early in the trigger system.

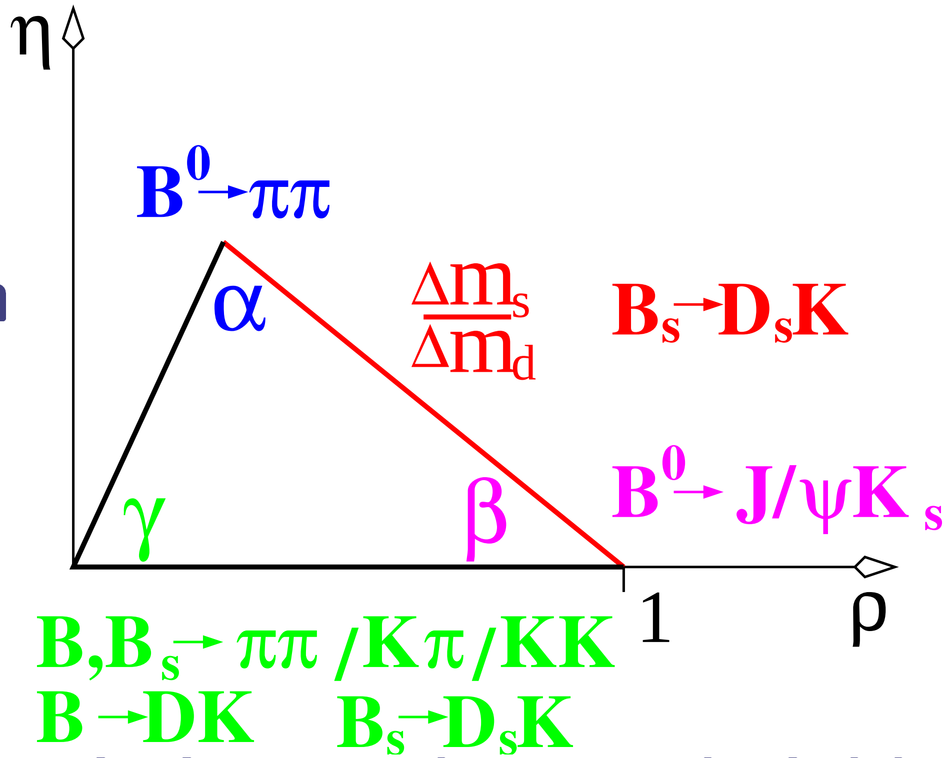
Primary targets in Run II

Physics of CKM matrix

- Overconstrain SM unitarity triangle
- Measure all angles: α, β and γ
- From B$_s$ mixing determine $|V_{td}/V_{ts}|$
- For B$_s$ measure $\Delta\Gamma_s$ and test its SM relation to Δm_s

Only at CDF:

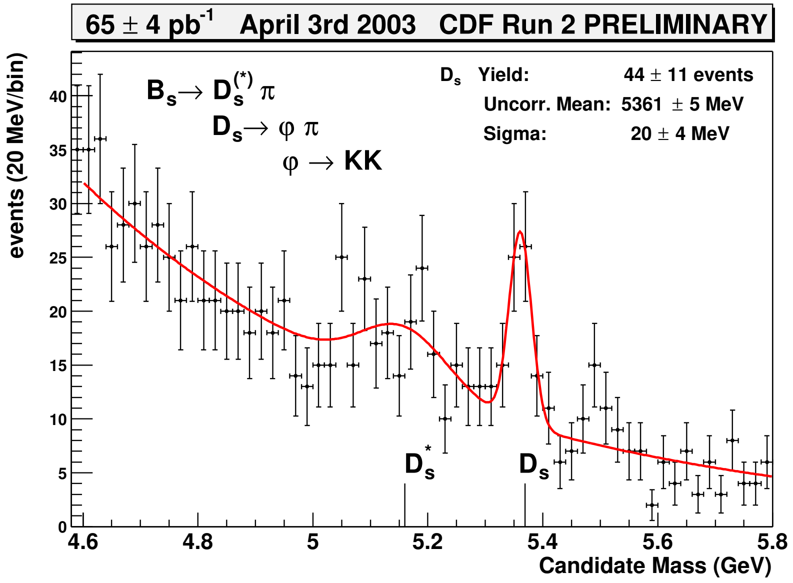
- rich physics of B$_s$ meson
- lifetime, mass of Λ_b
- study B$_c$



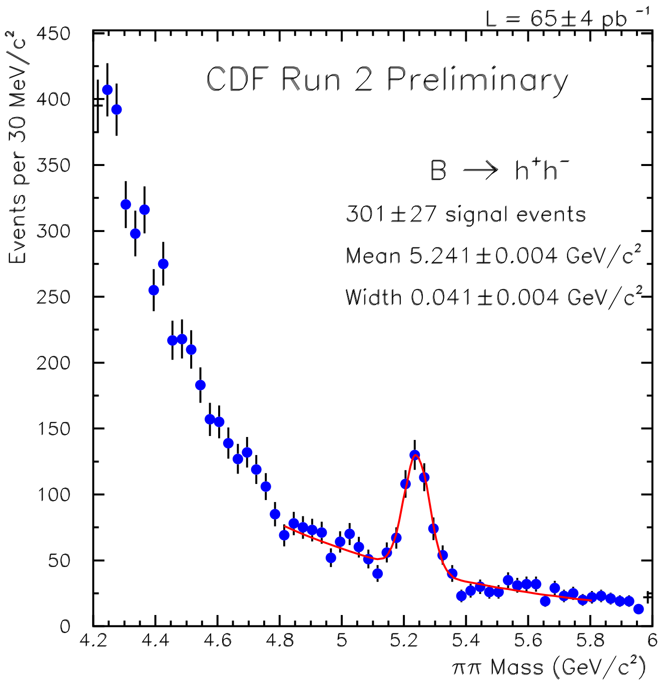
At present: accumulate statistics, understand yields

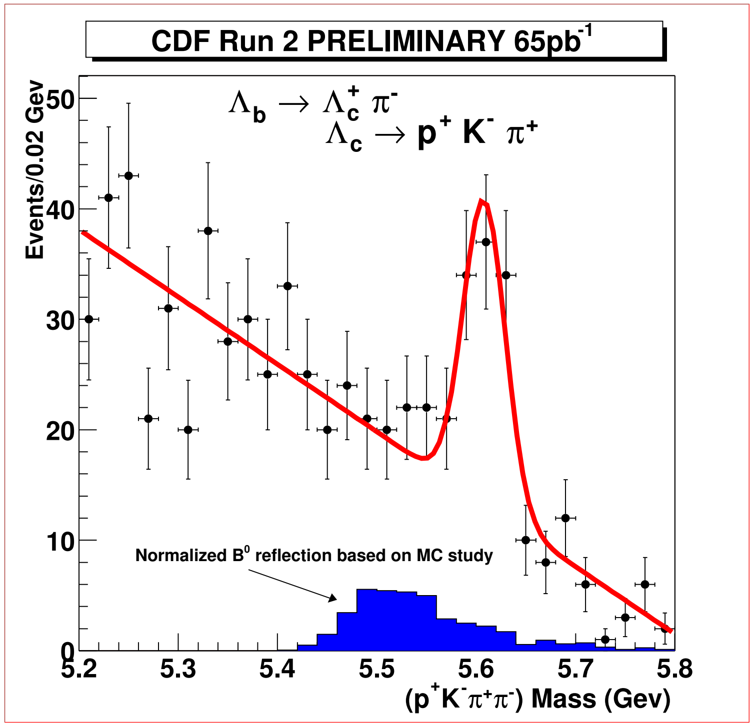
Signals established

Decay	Yield, events
$B \to hh$	301 ± 27
$B^0 \to J/\psi K_s^0$	220 ± 18
$B_s \to D_s \pi$	41 ± 11
$\Lambda_b \to \Lambda_c \ell \nu$	640 ± 60



More statistics soon!





QCD physics at CDF

$p\bar{p}$ environment at the Tevatron:

- all interactions start with QCD!

QCD important to most physics analyses

- parton distribution functions, underlying event
- QCD processes as backgrounds

Studies of jets, selected topics:

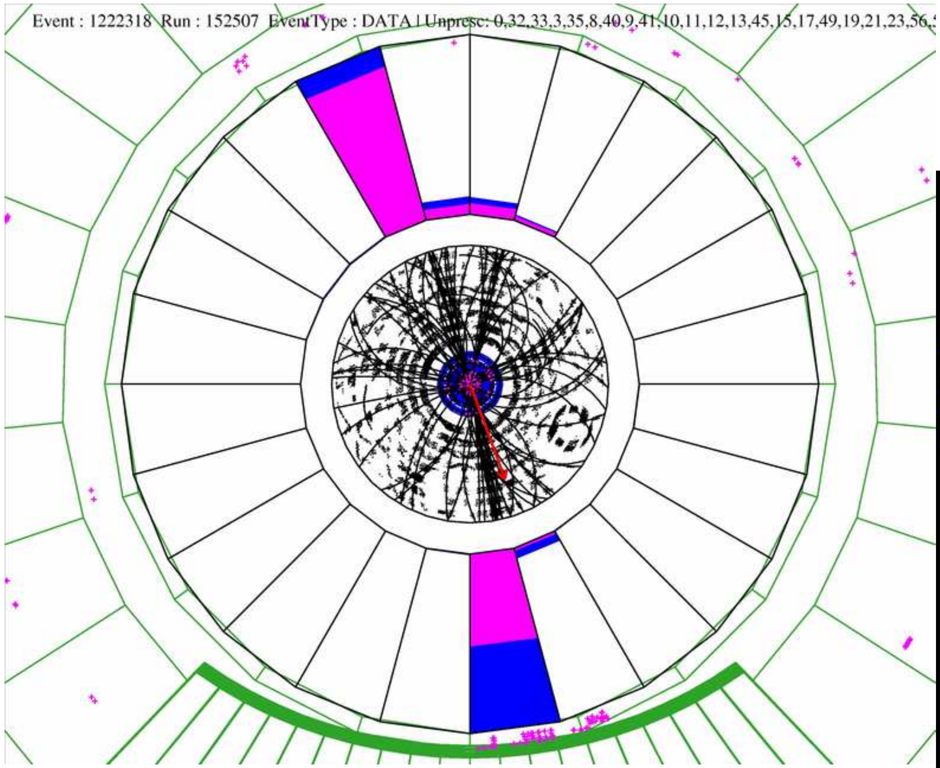
- high-E_t jet events
- cross-sections
- dijet mass distributions
- jet shape
- diffractive jet production

High-E_t jets

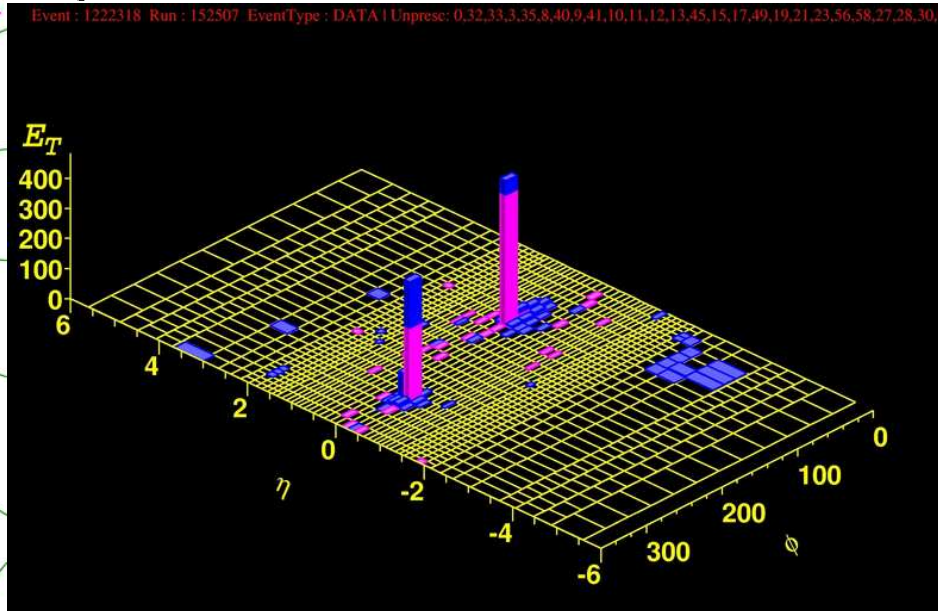
High E_t jets probe the smallest distance scales!

Run II c.m. energy: $\sqrt{s}$ $1.8 \rightarrow 1.96$ TeV
Higher jet x-section: x5 at 600 GeV Run II vs Run I
Highest E_t jets: Run I - 400 GeV, Run II - 600 GeV

Best event to date at CDF in Run II:

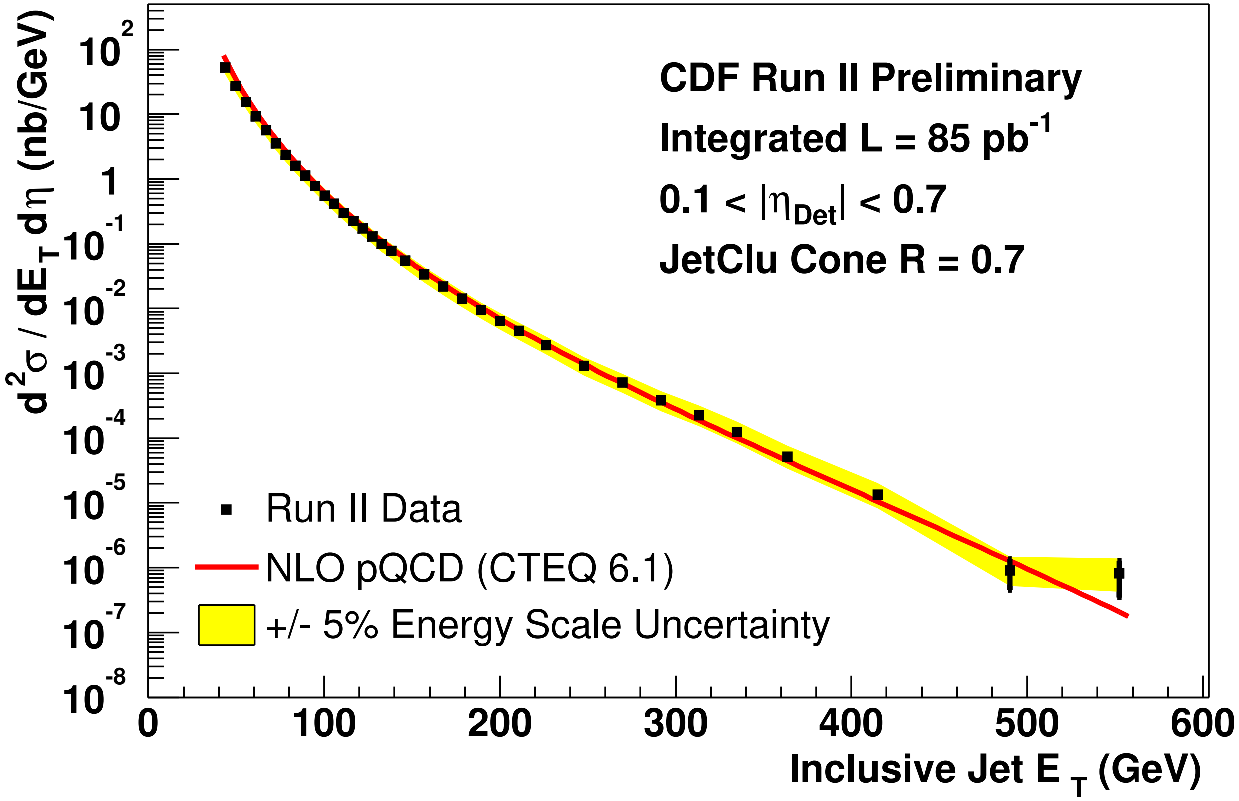


E_t^{jet1}=633GeV, E_t^{jet2}=666GeV
Dijet mass 1364GeV



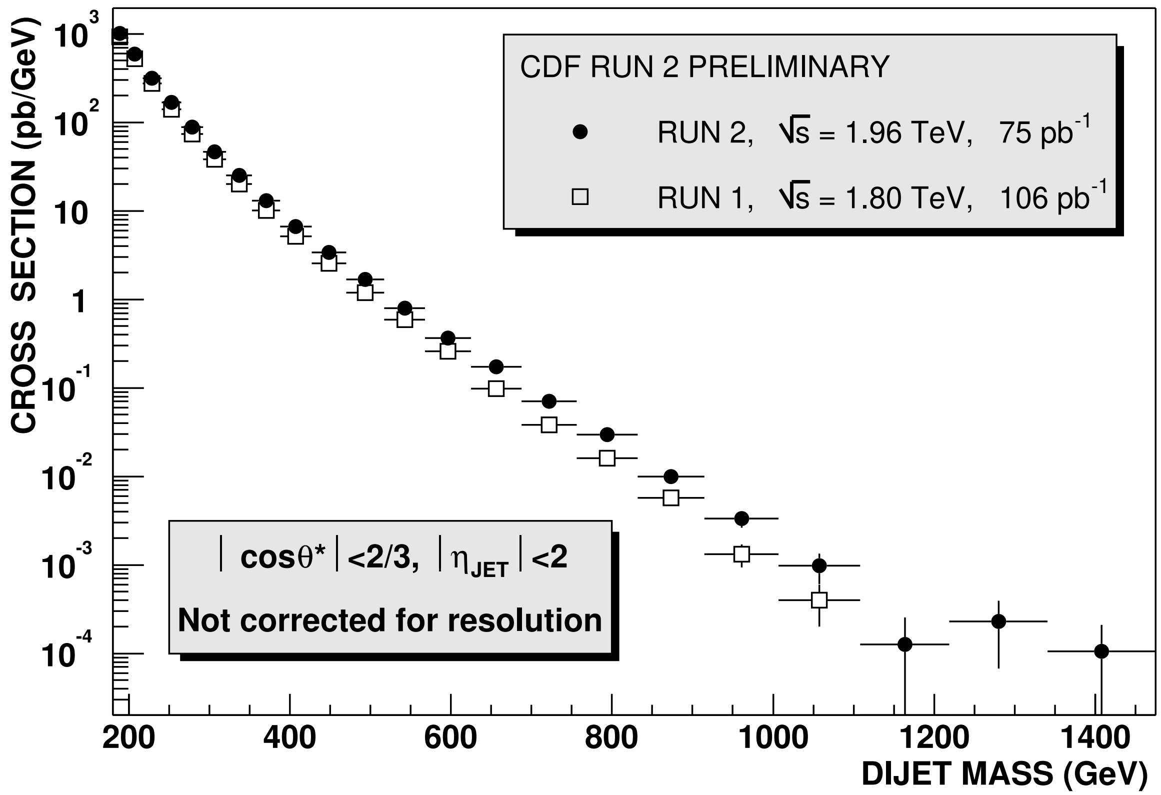
Inclusive jet cross-section

- Run II extends Run I results by 150 GeV
- Spans 8 orders of magnitude!
- Good agreement with NLO CTEQ6.1 predictions



Dijet mass distribution

- Search for resonances in dijet mass
- Present CDF data extend reach to 1.4 TeV
- No new particles, no sign of new physics so far
- Limits on specific particles are in preparation

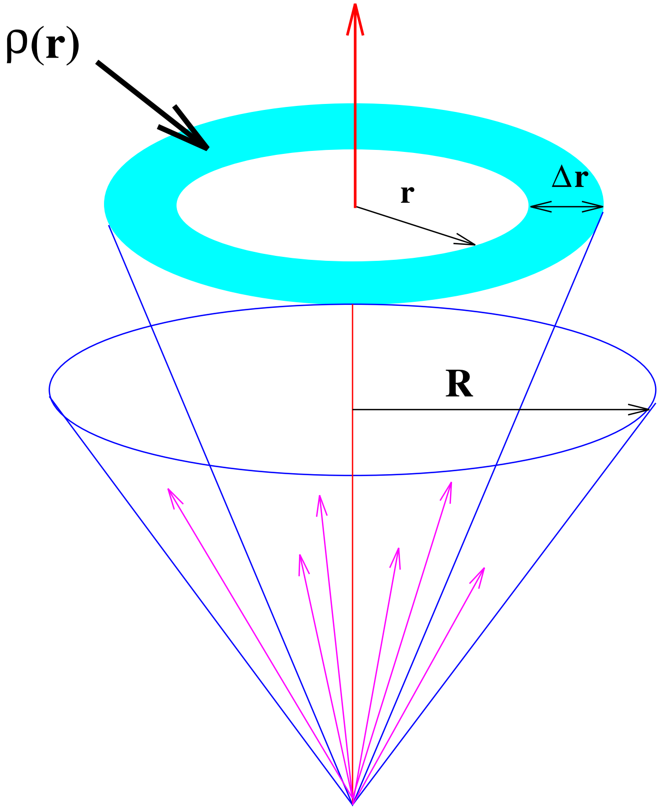


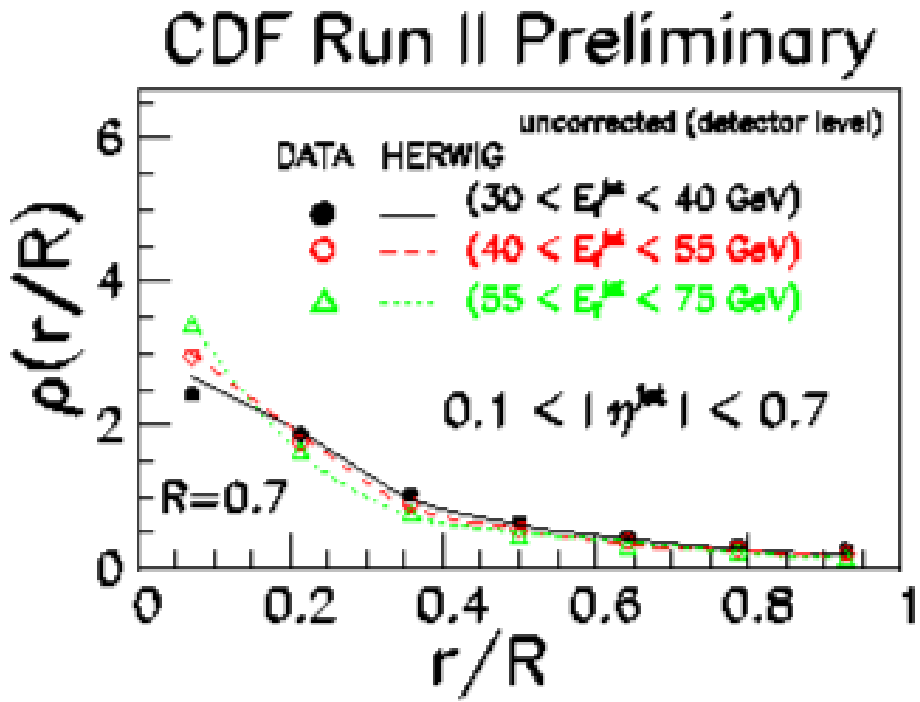
Jet shapes

Shape of the jets: test Pythia/Herwig predictions

Examine energy density distributions $\rho(r/R)$
Observe: jets narrow at higher E_t, lower η

Data agrees well with Pythia/Herwig





Hard diffractive dijet processes

Detection:

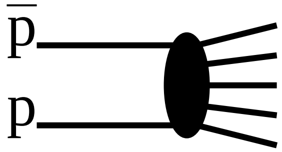
- directly detect antiproton
- observe "rapidity gaps"

For single diffractive events:

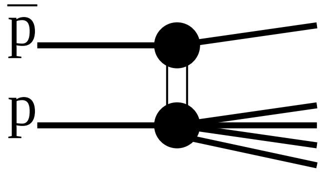
- $\bar{p}$ momentum loss function
- diffractive struct. functions

For double pomeron exchange:

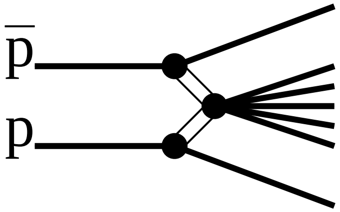
- dedicated trigger
- study kinematics
- 300k events collected!



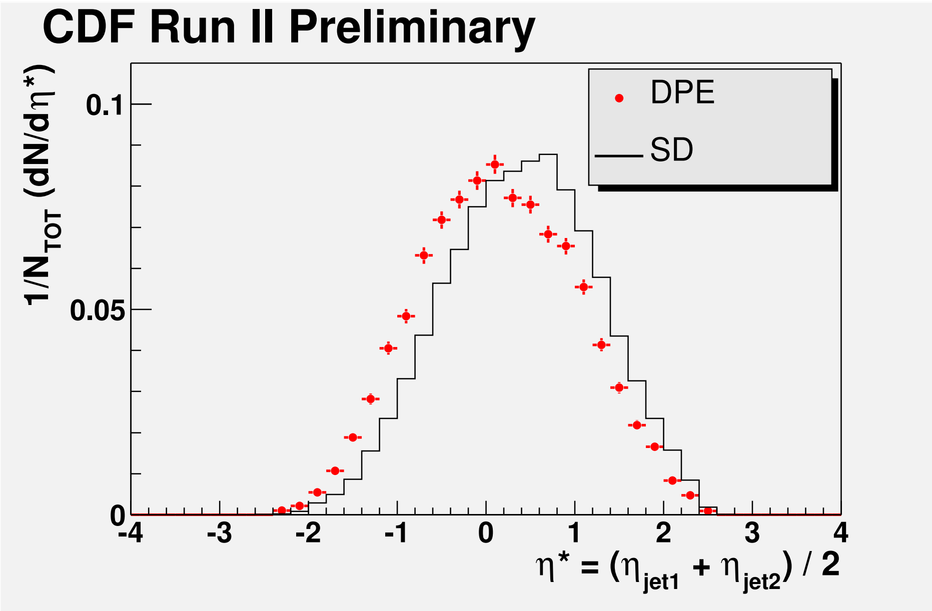
non−diffractive



single diffractive



double pomeron exchange



Conclusions

CDF accumulated sizable datasets:

- $\sim$ 85 pb^{-1} available for QCD analyses
- $\sim$ 70 pb^{-1} for B and Charm physics

Detector and triggers are well calibrated and understood

Unique Run II features:

- higher c.m. energy: great advantage to QCD, already recorded higher statistics than Run I
- new hadronic triggers at CDF: large hadronic B, charm samples

Current results on masses, lifetimes, cross-sections:

- competitive or better with Run I and world averages

Future: exciting!

- B_s mixing, CP violation in B, D decays,...
- B jet, W+jet cross-sections,...