Tevatron







First analysis at the CDF II experiment

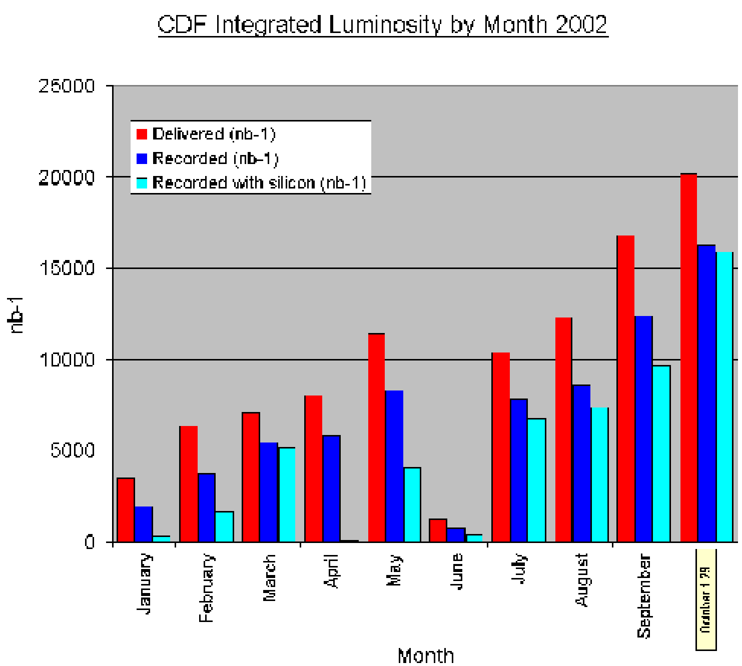
“Original Slides” on first results copied from overview talk from Ch. Paus

Little History

CDF Run I: 1992-96, $p\bar{p}$ collisions @ $\sqrt{s}$ = 1.8 TeV

CDF Run II: 2001-2009 (?), $p\bar{p}$ collisions @ $\sqrt{s}$ = 1.96 TeV

May-November 2001	:	detector commissioning, no quality data
January-June 2002	:	first 40 pb^{-1} of data, 10 pb^{-1} "quality" data
- October 2002	:	65 pb^{-1} of quality data



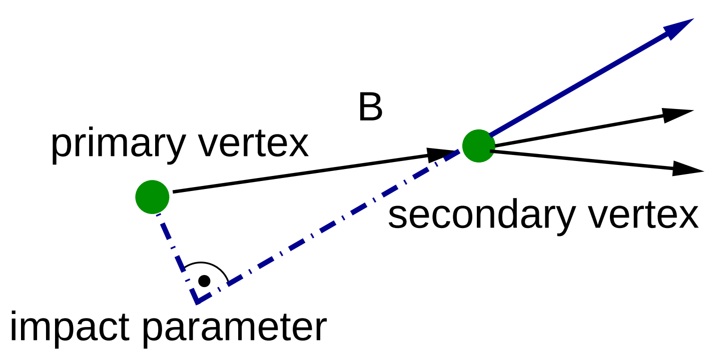
Initial luminosity was a factor 2-5 bellow expectation

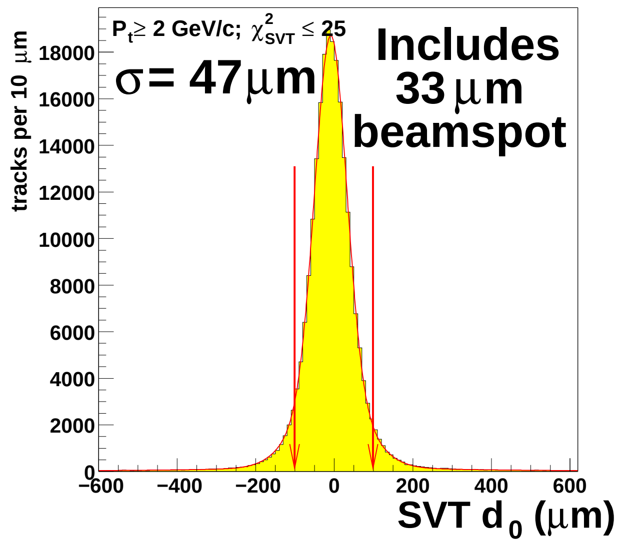
Focus on analysis presented summer 2002 & winter 2003

B Triggers

Trigger signatures: lepton (e,μ) and displaced tracks

- $B \to J/\psi X; J/\psi \to \mu^+\mu^-$ $\Rightarrow$ Di-Muon Trigger
  + muon provides easy trigger
  - small branching ratio
- Semi-leptonic B decays $\Rightarrow$ Lepton + Displaced Track Trigger
  + large branching ratios ($\approx$ 20%)
  - missing neutrino
- Fully hadronic B decays $\Rightarrow$ Two Track Trigger
  + $\approx$ 80% of branching ratio
  - requires displaced track trigger





Overview of First Results

Results shown summer 2002 (5-10 pb^{-1}):
(rely only on understanding of tracking system)

- Mass difference measurements $\Leftarrow$ 1. CDF II paper
- Prompt vs secondary D meson production $\Leftarrow$ 2. CDF II paper
- Momentum calibration $\Leftarrow$ shown in 24 conference talks
- First B mass measurements
- Lifetime in $B \rightarrow J/\psi X$ modes
- Relative BRs of Cabbibo suppressed charm decays (CLEO dominates the field here in the meantime)

Additional results winter 2003 (65 pb^{-1}):
(need additional understanding of muon trigger/reconstruction)

- BR of rare $D^0 \rightarrow \mu^+\mu^-$ decay $\Leftarrow$ 4. CDF II paper
- J/ψ production cross section $\Leftarrow$ 5. CDF II paper

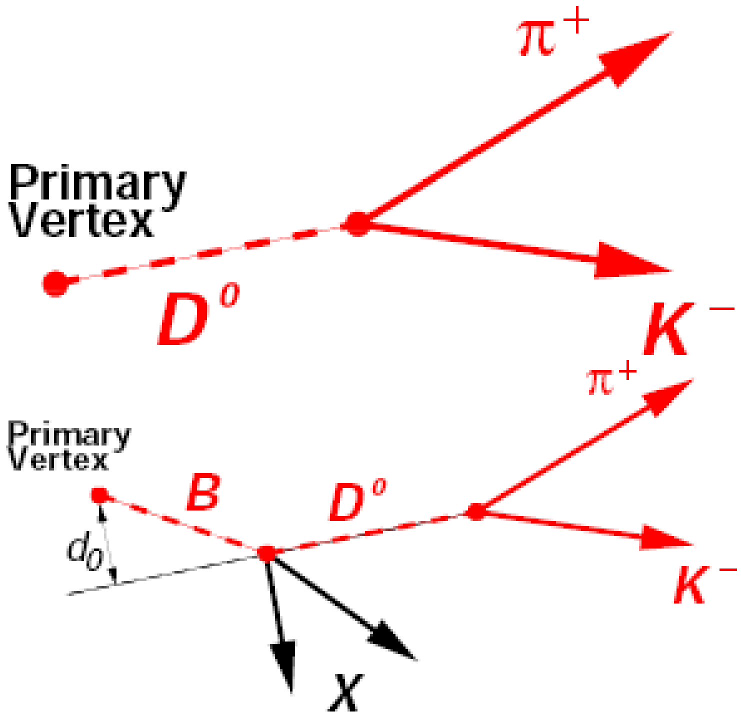
Cross Section Measurements

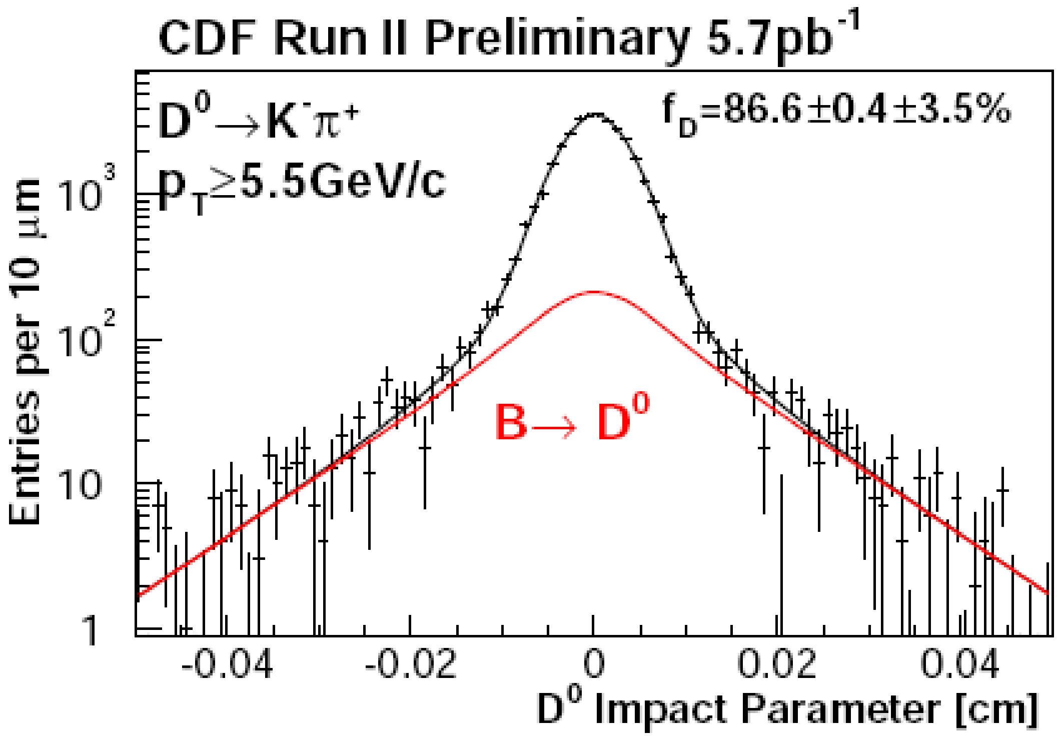
Prompt vs. Secondary Charm

distinguish prompt/secondary

discriminating variable

- meson impact parameter





most charm is prompt

$$f_D(D^0) = 86.6 \pm 0.4 \pm 3.5\%$$
$$f_D(D^{*+}) = 88.1 \pm 1.1 \pm 3.9\%$$
$$f_D(D^+) = 89.1 \pm 0.4 \pm 2.8\%$$
$$f_D(D_s^+) = 77.3 \pm 3.8 \pm 2.1\%$$

d_0 resolution function

- from $K_S^0 \to \pi^+\pi^-$ decays

Prompt vs. Secondary Charm

$$\sigma_i = \frac{N_i/2 \times f_{D,i}}{\int \mathcal{L}dt \times \epsilon_i \times BR_i}$$

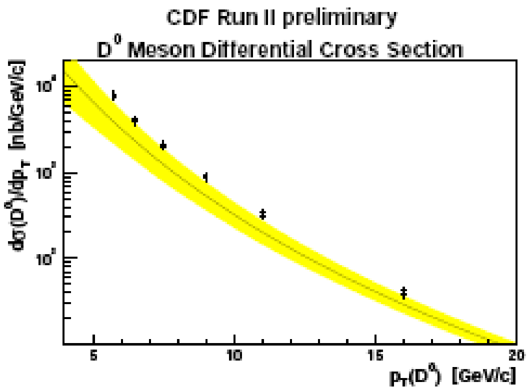
- Drift chamber (COT) tracking efficiency:
  Embedding MC tracks in data to mimic realistic occupancy
- Efficiency to attach silicon hits to COT tracks from data
- Single track trigger efficiency measured on data w/o trigger

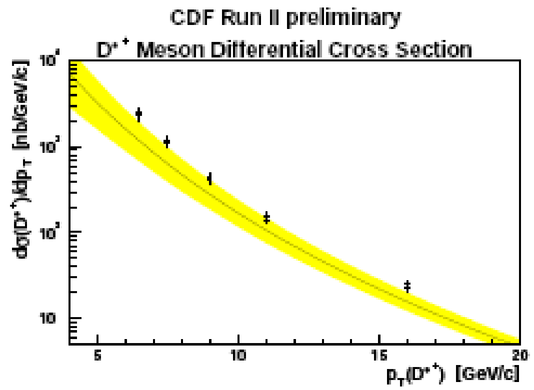
$\longrightarrow$ combined trigger & reconstruction efficiency: 0.12-1.9%
relative uncertainties 8-14%

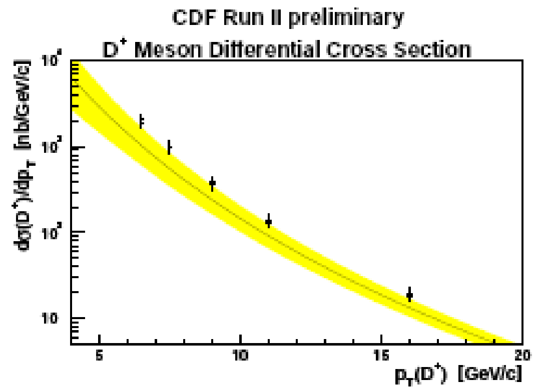
Only tracking system required for this analysis,
this is no precision measurements.

About 70k D mesons in 5.7 pb^{-1} of data;

Prompt vs. Secondary Charm







Preliminary Run II measurements

$$\sigma(D^0, p_T > 5.5 \text{ GeV}) = 13.3 \pm 0.2 \pm 1.5\ \mu\text{b}$$

$$\sigma(D^{*+}, p_T > 6.0 \text{ GeV}) = 5.2 \pm 0.1 \pm 0.8\ \mu\text{b}$$

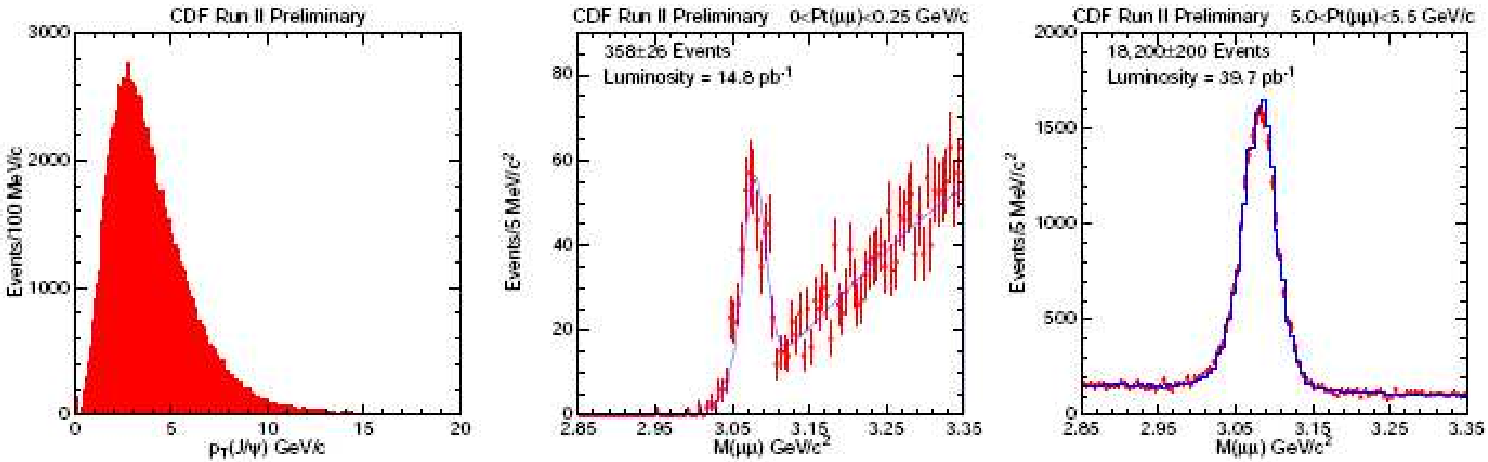
$$\sigma(D^{+}, p_T > 6.0 \text{ GeV}) = 4.3 \pm 0.1 \pm 0.7\ \mu\text{b}$$

$$\sigma(D_s^{+}, p_T > 8.0 \text{ GeV}) = 0.75 \pm 0.05 \pm 0.22\ \mu\text{b}$$

all measurements refer to rapidity range $|Y| < 1$

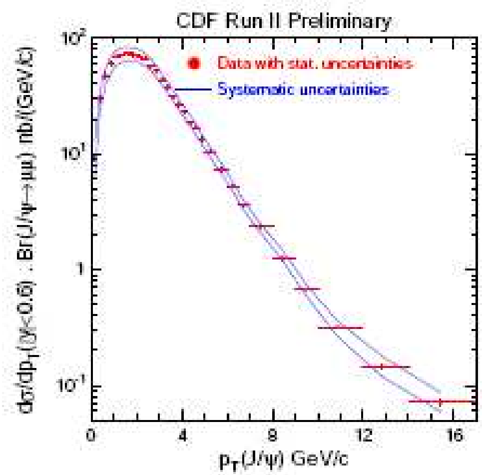
No prompt charm meson x-section measurements at large |Y|!

J/ψ Production X-Section



Use sample of 300k $J/\psi \to \mu^+\mu^-$

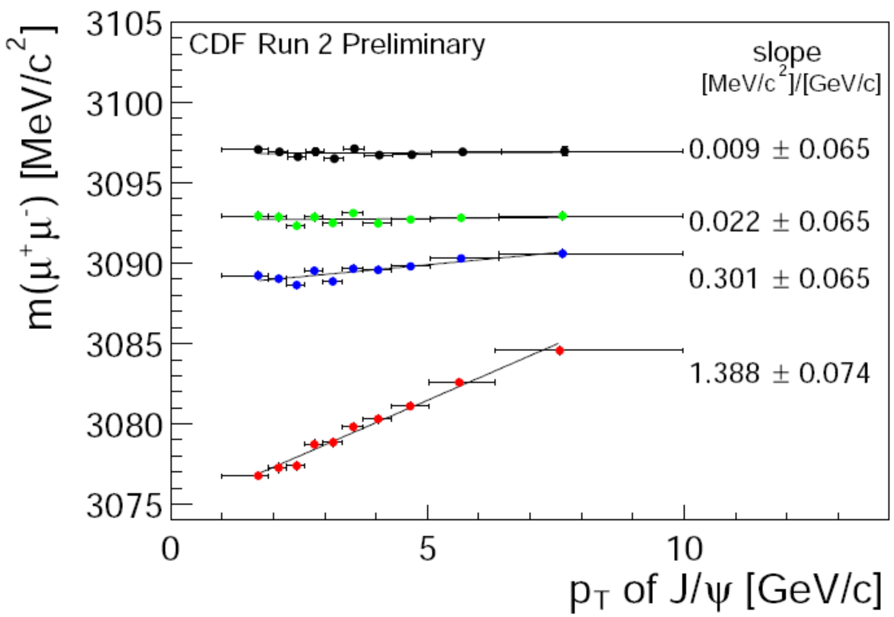
- $|y(J/\psi)| < 0.6$ as Run I but
- $p_T(\mu) > 1.5$ GeV $\to p_T(J/\psi) \geq 0$ GeV
- first time at hadron collider
- $\sigma(p_T > 0, |\eta| < 0.6) =$
  $240 \pm 1(stat) \pm 35/28(syst)$



Very similar motivation & requirements as for charm x-section. However additionally muon reconstruction and muon trigger efficiency needed.

Mass Measurements & Momentum Calibration

Momentum Calibration



raw tracks

nominal E loss

fine tuned E loss

adjusted overall B scale

500k $J/\psi \to \mu^+\mu^-$

Situation probably tougher @ LHCb:

No homogeneous B field, harder to disentangle material, B field and misalignment effects.

However all of this can be studied in MC.

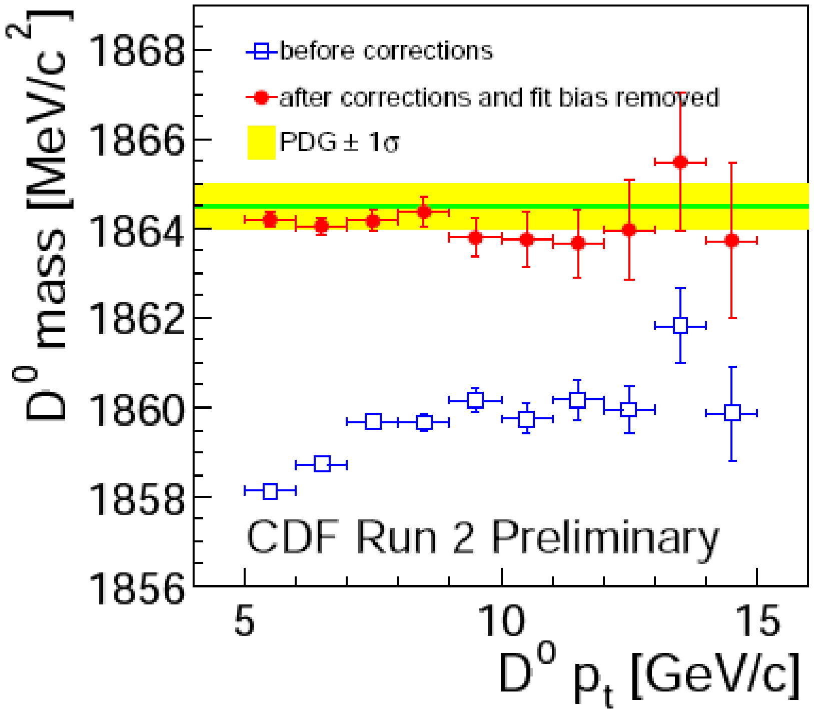
1 million reconstructed mainly prompt J/ψ events on disk.

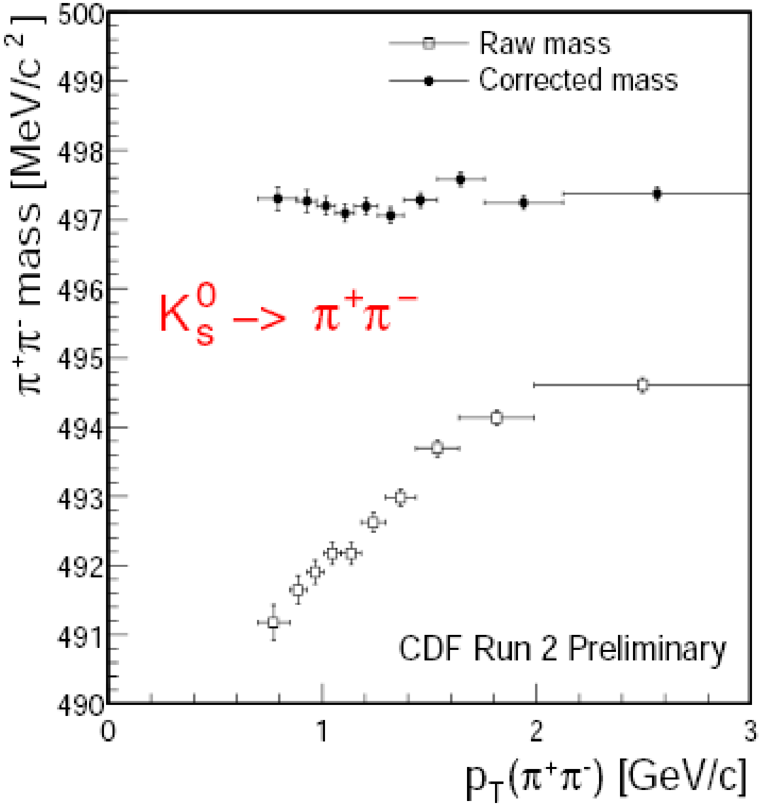
This is a high profile analysis within the tracking group.

Momentum Calibration

Using J/ψ calibration

+ low momentum (π): $K_s \to \pi^+\pi^-$
+ high stat. (K,π): $D^0 \to K^+\pi^-$
+ high momentum (μ): $\Upsilon \to \mu^+\mu^-$





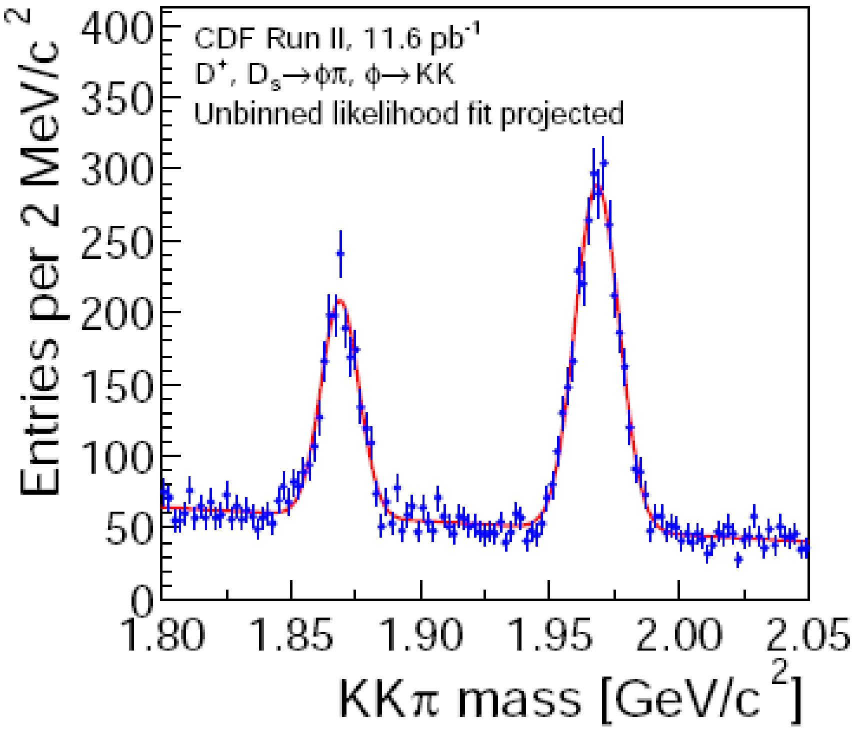
Basic input to any mass measurement performed at CDF II.

No own paper, however still cited within many B publications.

$m(D_s^+) - m(D^+)$

Conceptual idea

- $D_s^+ \to \phi\pi^+(\phi \to K^+K^-)$
- $D^+ \to \phi\pi^+(\phi \to K^+K^-)$
- almost identical kinematics
- measure difference
- basically no systematics



Result $m(D_s^+) - m(D^+)$:

99.41 ± 0.38 (stat) ± 0.21 (syst) MeV/c^2

About the measurement

- first Tevatron Run II publication
- uses new SVT trigger
- agrees with old world average 99.5 ± 0.50 MeV/c^2

Recent BaBar:

PRD 65(2002)091104

98.4 ± 0.1 (stat) ± 0.3 (syst) MeV/c^2

Maybe at bit boring topic, however first CDF II paper.

Many analysis tools established for this analysis and document in this PRD. Proof that detector & new TTT works.

B Mass Measurements

Largest J/ψ modes

+ $B^+ \to J/\psi K^+$
+ $B^0 \to J/\psi K^{*0}, B^0 \to J/\psi K^0_S$
+ $B^0_s \to J/\psi \phi$
+ $\Lambda^0_b \to J/\psi \Lambda$

B meson masses in MeV/c^2

preliminary

B^+ : 5279.32 ± 0.68 (stat) ± 0.94, (sys)

B^0 : 5280.30 ± 0.92 (stat) ± 0.92 (sys)

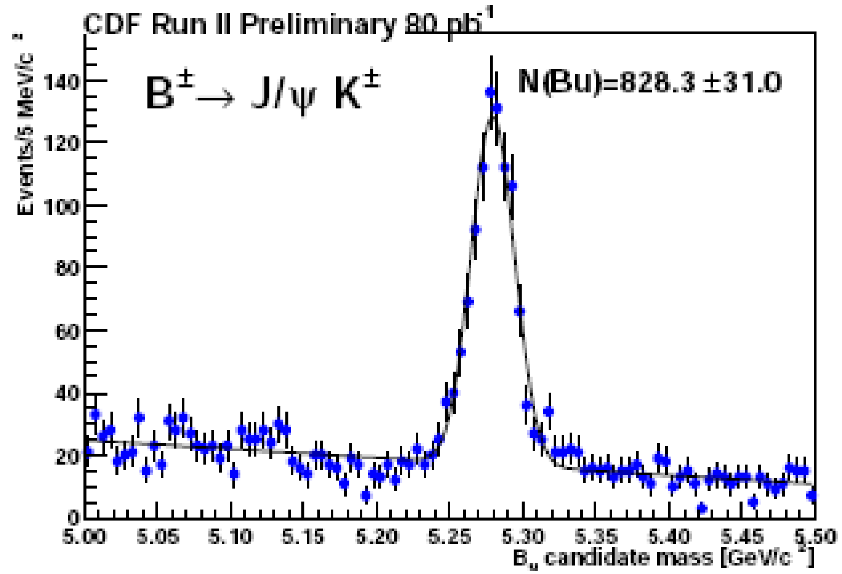
B_s : 5365.5 ± 1.3 (stat) ± 0.94 (sys)

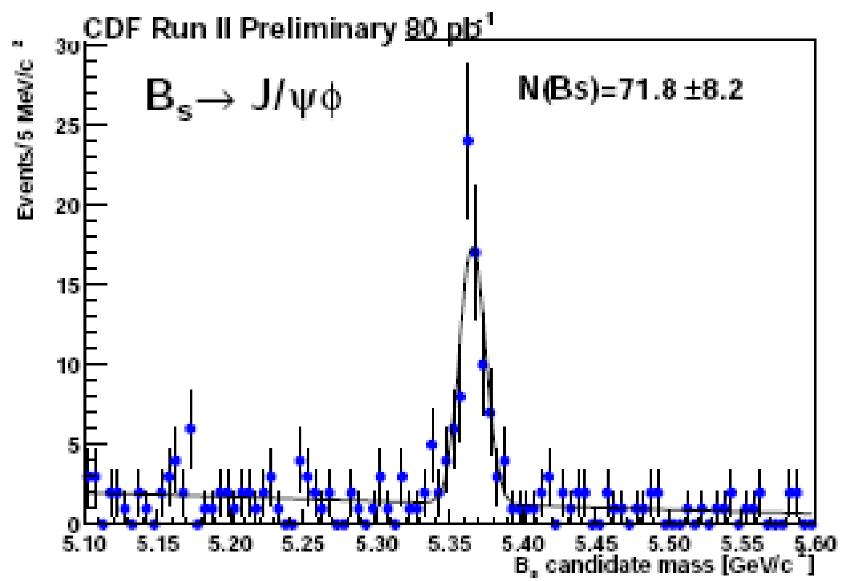
in the pipeline: Λ_b, $B^0 \to J/\psi K^0_S$

publishing soon!!

CDF Momentum scale

+ best B_s in the world (soon Λ_b)
+ best systematic around ..
+ excellent prerequisite





Systematics

TABLE I: Summary of systematic uncertainties for the B meson mass measurements in MeV/c^2.

Source	$B^0 \to J/\psi K^{*0}$	$B^\pm \to J/\psi K^\pm$	$B_s^0 \to J/\psi \phi$
Tracking			
Momentum scale	0.20	0.22	0.20
Alignment	0.18	0.18[a]	0.18[a]
False Curvature	0.02[b]	0.02	0.02[b]
Vertex Fitting	0.10	0.10[a]	0.10[a]
Resolution bias	0.13	0.13	0.13
Bkg Systematics			
K-π swap in K^{*0}	0.06	—	—
$J/\psi\pi$ contamin.	—	0.13	—
Total Uncertainty	0.33	0.36	0.33

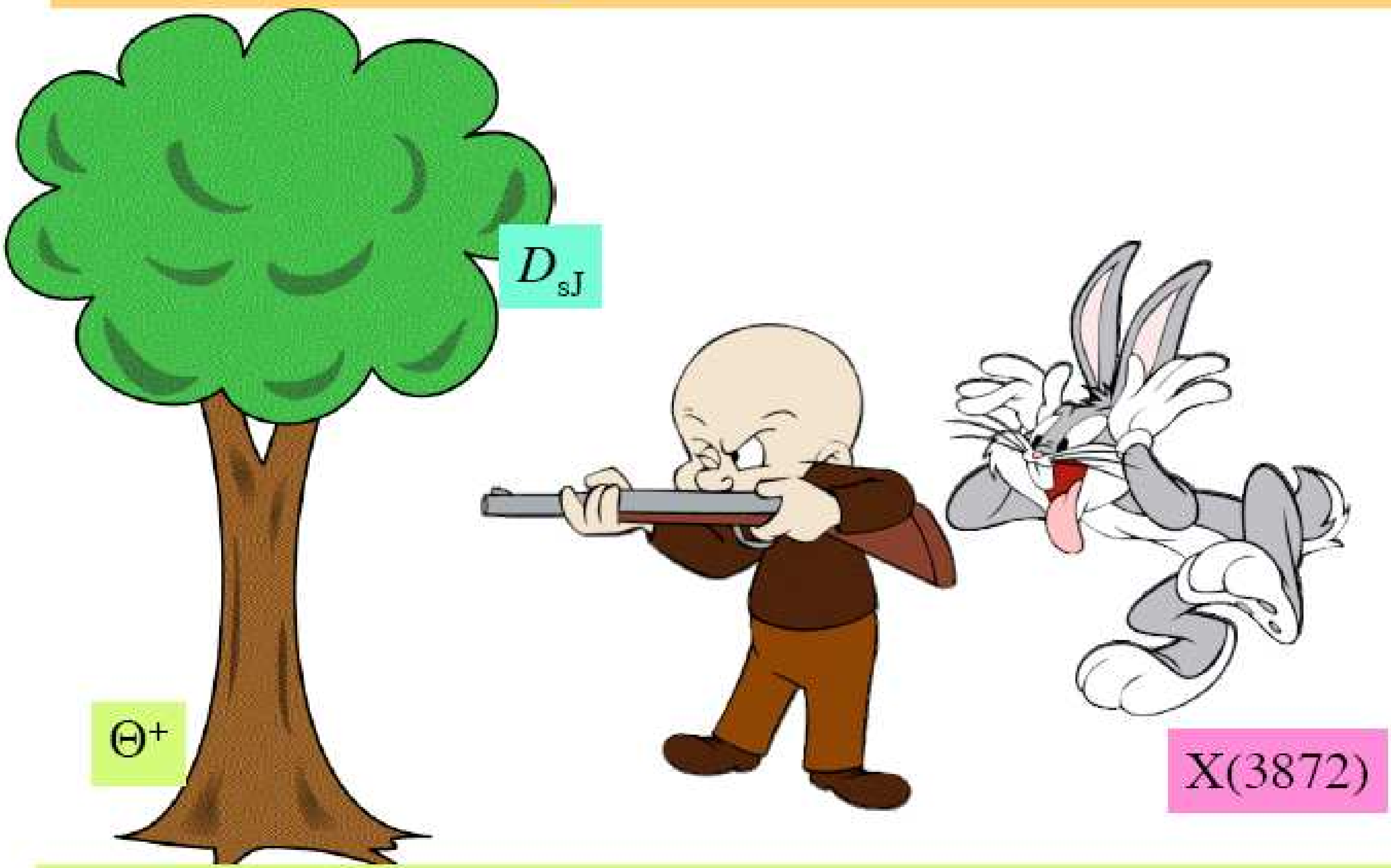
TABLE III: Summary of systematic uncertainties for the b hadron mass differences in MeV/c^2.

mass difference	mom. scale	fit model	total uncert.
$m(B^\pm)$ - $m(B^0)$	0.00	0.14	0.14
$m(B_s^0)$ - $m(B^0)$	0.01	0.06	0.06
$m(B_s^0)$ - $m(B^\pm)$	0.01	0.13	0.13
$m(\Lambda_b^0)$ - $m(B^0)$	0.05	-	0.05

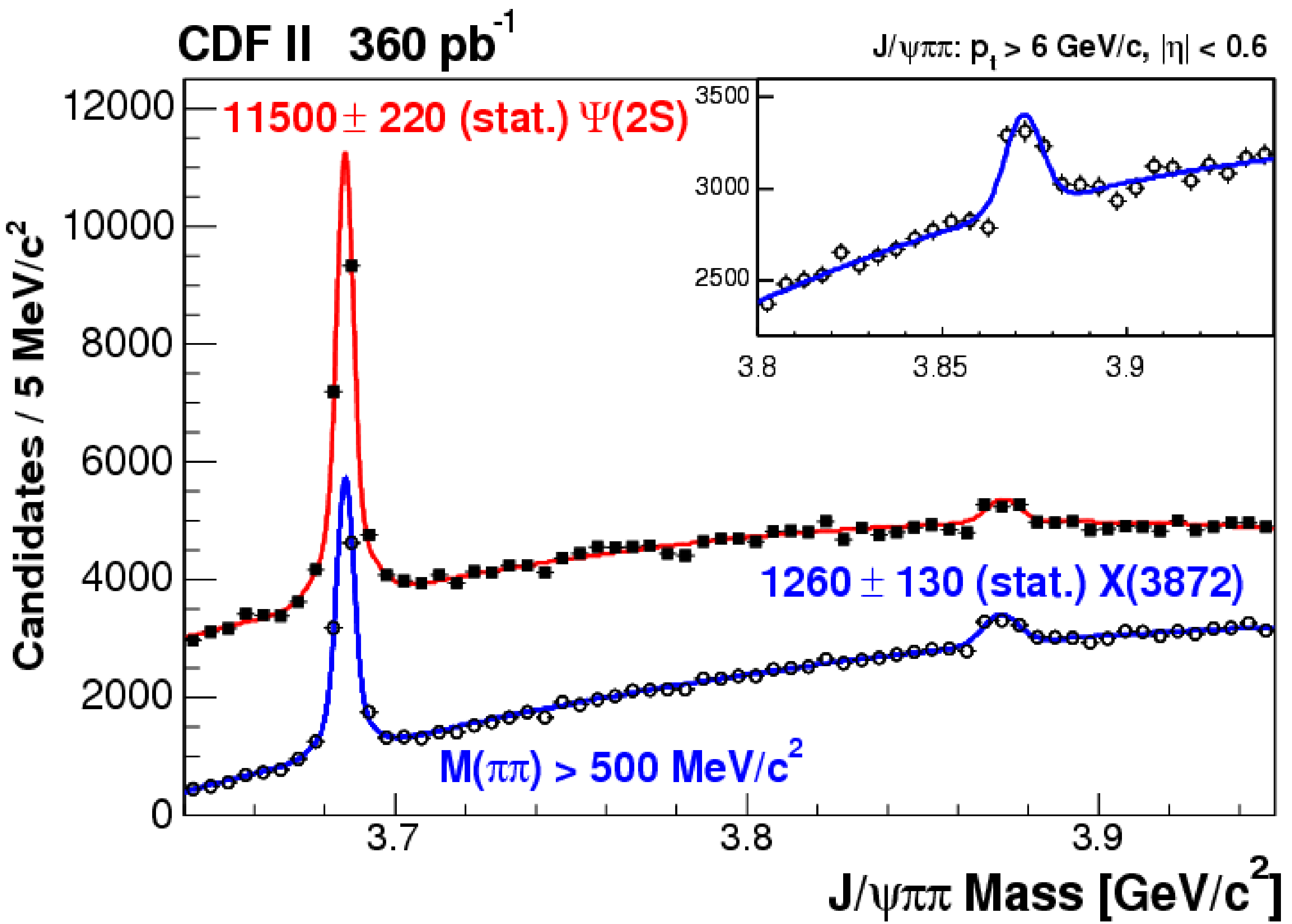
- Momentum scale: Comparing control masses to PDG
- Alignment: Comparing COT only mass w. COT+SVX mass
- False Curvature (misalignment): Comparing B^+ to B^- masses
- Vertex Fit: Test diff. mass and pointing constraints
- Resolution Bias: Resolution on Curvature has impact on vertex position, cut on B impact parameter introduces asymmetrie in curvature resolution, thus in mass.

All of those effects cancel in mass difference measurements.

Hunting For New States



- Sssshhhh.......Wabbit hunting.



3rd CDF II paper

Precision Vertexing

Lifetime in $B \to J/\psi X$

Large sample of $J/\psi \to \mu^+\mu^-$ events

- calibrate resolution
- understand alignment
- measure inclusive B lifetime
- so far only r-ϕ silicon used

Inclusive J/ψ (preliminary)

$c\tau_{incl} = 458 \pm 10\,\text{(stat)} \pm 11\,\text{(sys)}\ \mu\text{m}$

Exclusive J/ψ (preliminary)

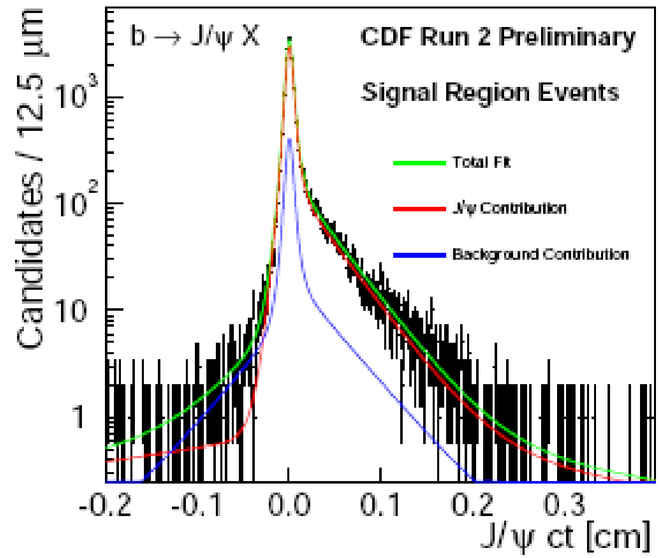
$c\tau_{B^+} = 470 \pm 20\,\text{(stat)} \pm 6\,\text{(sys)}\ \mu\text{m}$

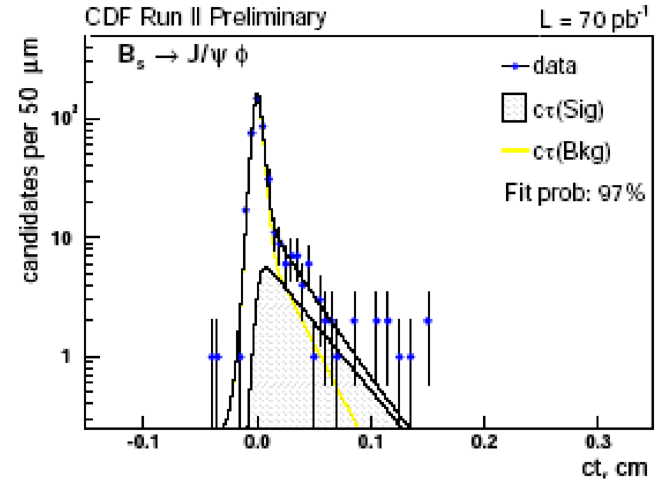
$c\tau_{B^0} = 425 \pm 28\,\text{(stat)} \pm 6\,\text{(sys)}\ \mu\text{m}$

$c\tau_{B^0_s} = 379 \pm 59\,\text{(stat)} \pm 6\,\text{(sys)}\ \mu\text{m}$

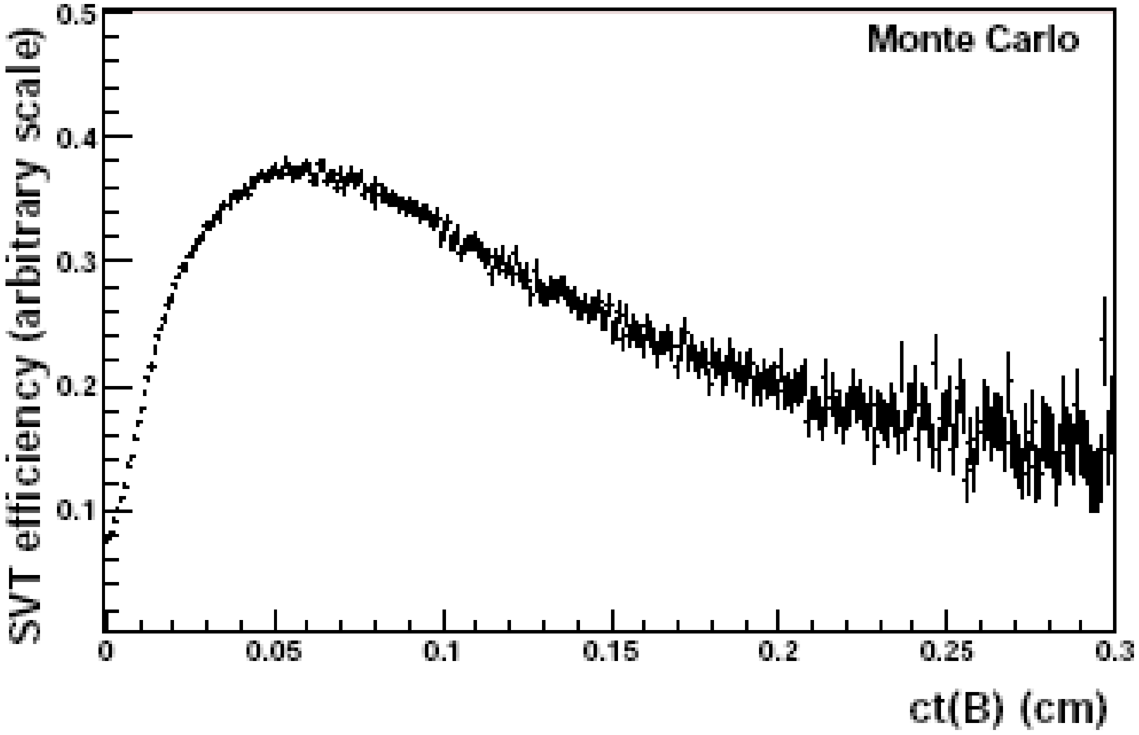
About results

- silicon already well understood
- prerequisite for $\Delta\Gamma_s$
- major improvements expected: Layer 00, 3D tracking, alignments
- important for B_s mixing





Cut on IP @ LHCb Trigger?



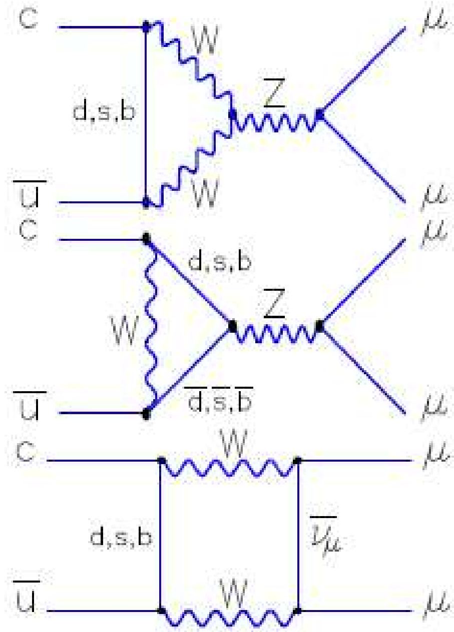
Lifetime (& lifetime resolution) analysis might become a bit more complicated with impact parameter significance cut on HLT.

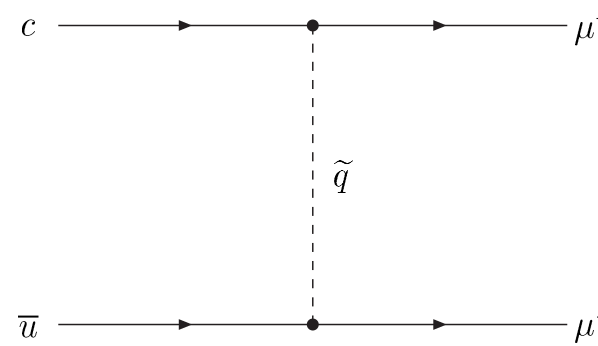
Rare Decays

Rare Decays: $D^0 \to \mu^+\mu^-$

SM prediction very small:
BR $\approx 10^{-13}$

Some R-parity violation SUSY:
BR $\approx 10^{-6}$





Measurement relative to kin. similar decay $D^0 \to \pi\pi$:

$$BR(D^0 \to \mu^+\mu^-) = \frac{N(\mu^+\mu^-)}{N(\pi^+\pi^-)} \frac{\epsilon(\mu^+\mu^-)}{\epsilon(\pi^+\pi^-)} BR(D^0 \to \pi^+\pi^-)$$

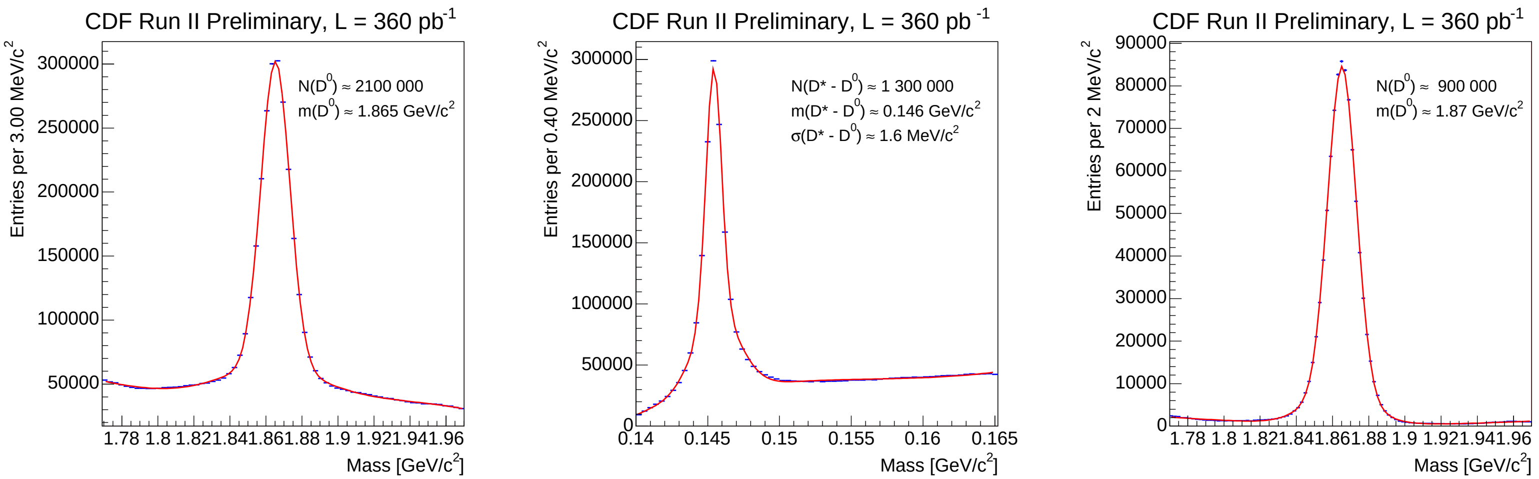
CDF limit based on 65 pb^{-1} current best limit:
$BR(D^0 \to \mu^+\mu^-) \leq 3.3 \times 10^{-6}$ @ 95% C.L.

soon to come (360 pb^{-1}): $BR(D^0 \to \mu^+\mu^-) \leq 0.53 \times 10^{-6}$ @ 95% C.L.

How to reduce Background?

Focus on D^0 from $D^* \to D^0\pi$ decays

clean selection via $\Delta m(D^* - D^0)$ mass cut

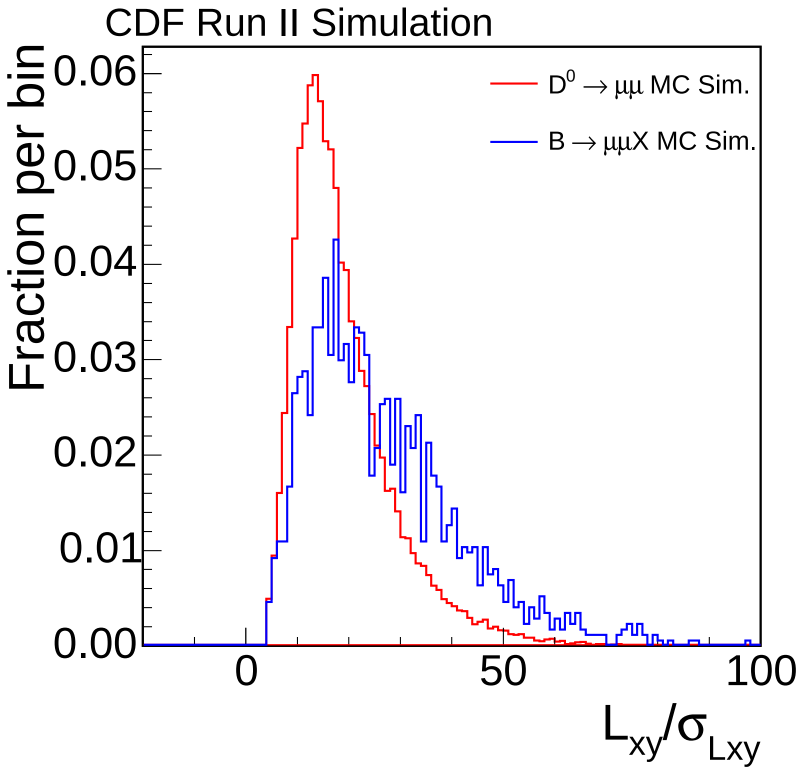


Remaining largest background:

Detector	CMU-CMU	CMU-CMX	CMX-CMX
Combinatorial Background	0.040 ± 0.007	0.008 ± 0.001	0.0007 ± 0.0001
$D^0 \to \pi\pi$ Double Tags	0.530 ± 0.005	0.057 ± 0.001	0.012 ± 0.002
$D^0 \to K\pi$ Double Tags	< 0.01	< 0.01	< 0.01
Semileptonic D^0 Decays	< 0.36	< 0.20	< 0.10
B Decays Involving One Real Muon	0.54 ± 0.06	0.13 ± 0.03	0.07 ± 0.02
B Decays Involving Two Real Muons	3.8 ± 1.3	2.5 ± 1.0	1.0 ± 0.5
Total Expected Background	4.9 ± 1.3	2.7 ± 1.0	1.0 ± 0.5
Observed Events	**3**	**0**	**1**

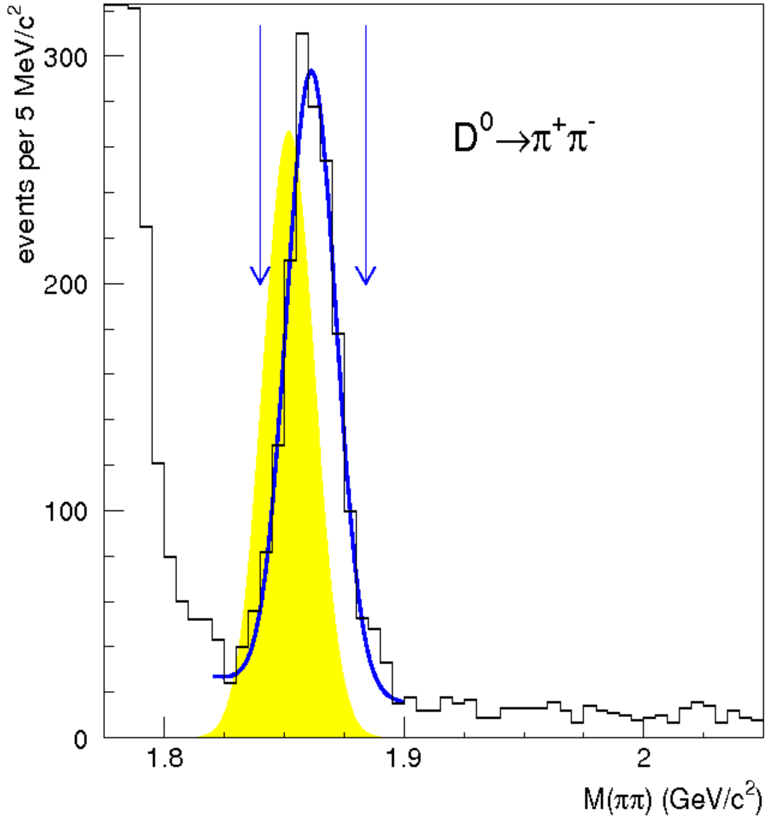
How to reduce Background?

Rejection of bkg from $B \rightarrow \mu\mu X$ via impact parameter:



About $\times$ 3 better $\frac{ct}{\sigma_{ct}}$ @ LHCb

Mis-identified $D \rightarrow \pi\pi$ events:



Mass resolution about a factor 1.6 better @ LHCb

Topics for LHCb

- Momentum Calibration (we have tracking expertise to do it!)
  Extremely high visibility analysis,
  potential thesis topic: B mass measurements
- Charm Meson production X-sections
  Haven't been measured before at large $|\eta|$
- $B \to J/\psi X$ lifetimes
  First step towards measurement of ϕ_s ($B_s \to J/\psi\phi$)
- $D^0 \to \mu^+\mu^-$
  Potential to improve world limit, good exercise for $B \to \mu^+\mu^-$

Other then that:

Get ready to reconstruct in automatized way generic mass peaks
($D \to SS$, $D \to DS$, $D \to SSS$ $D \to DD$, $D \to DDS$)

Make sure that our signals are in the trigger.