Heavy Flavor Results from the Tevatron

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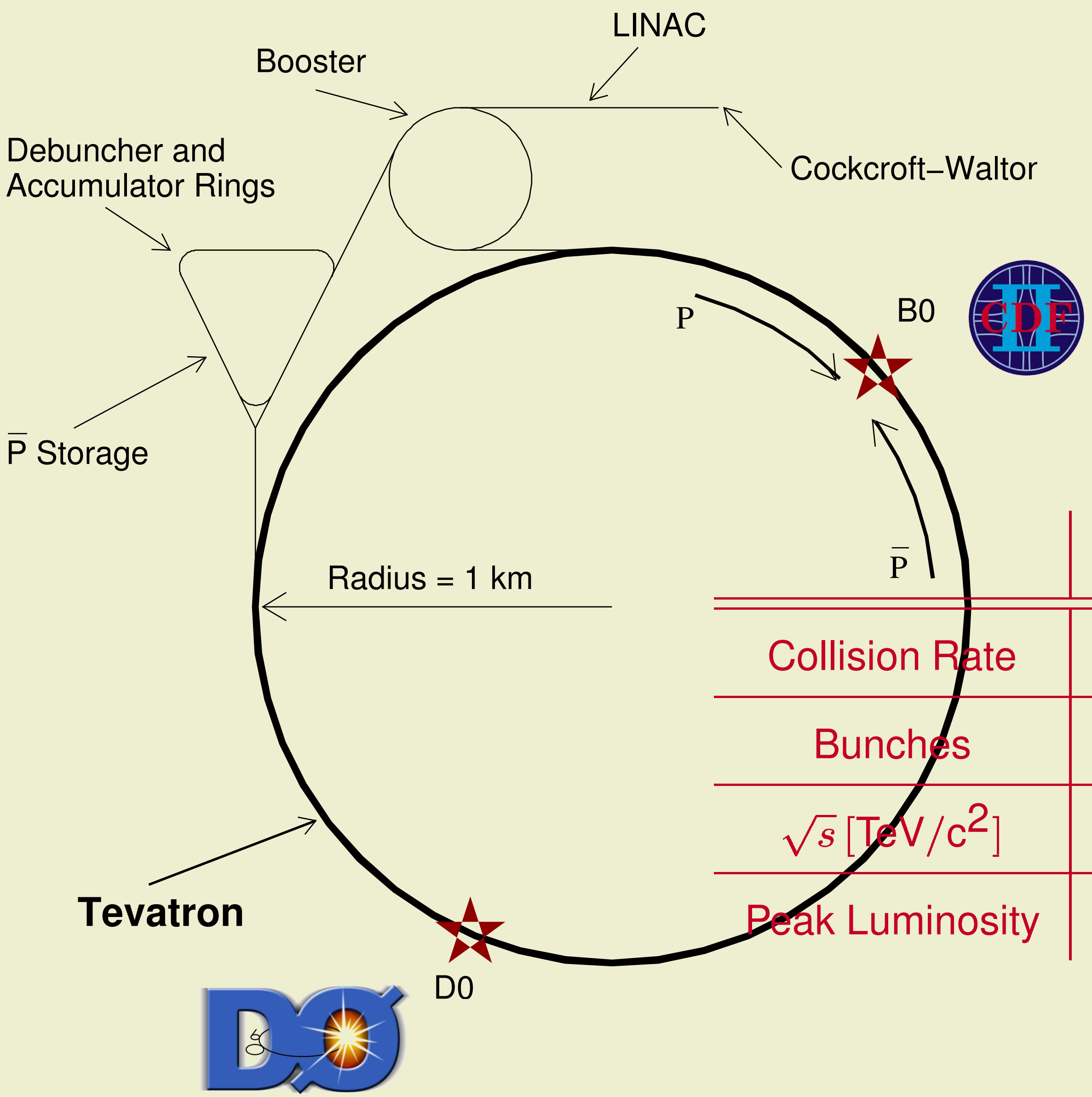
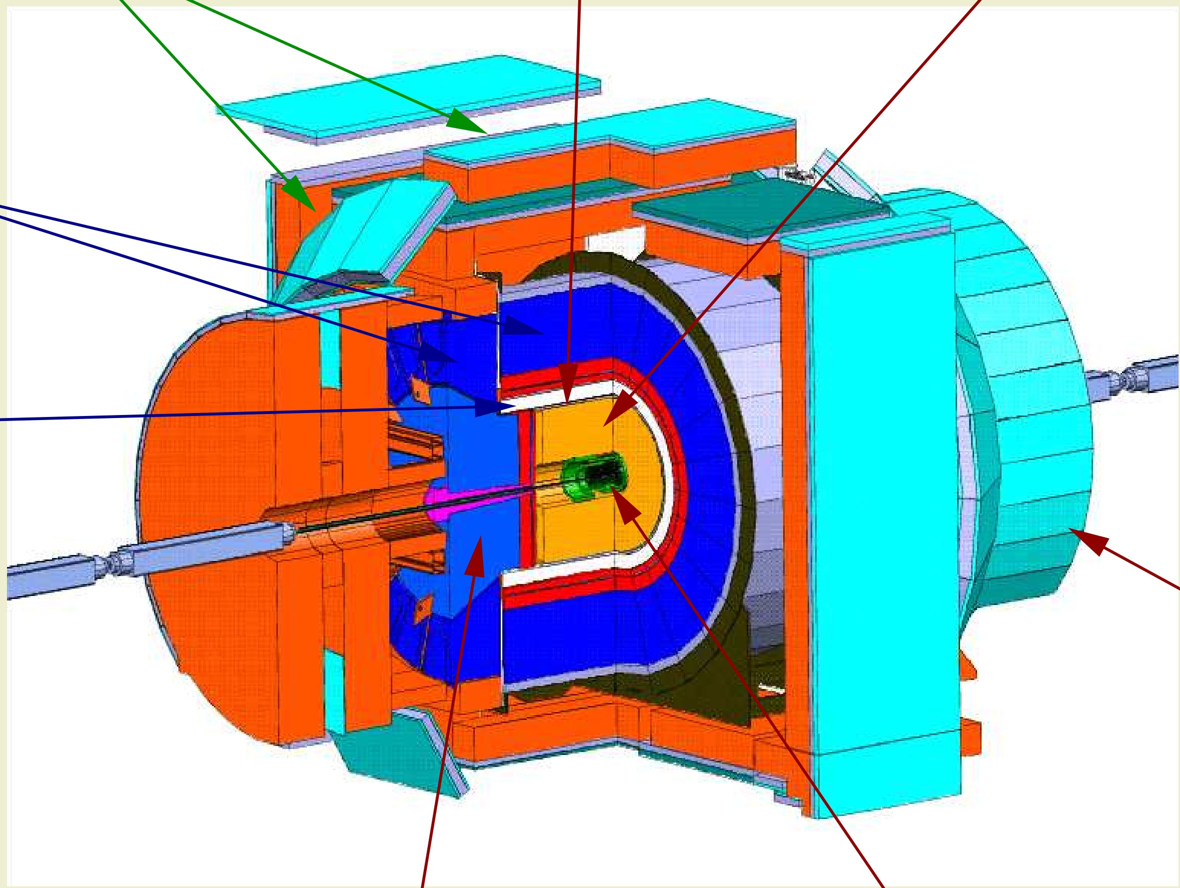
The Tevatron



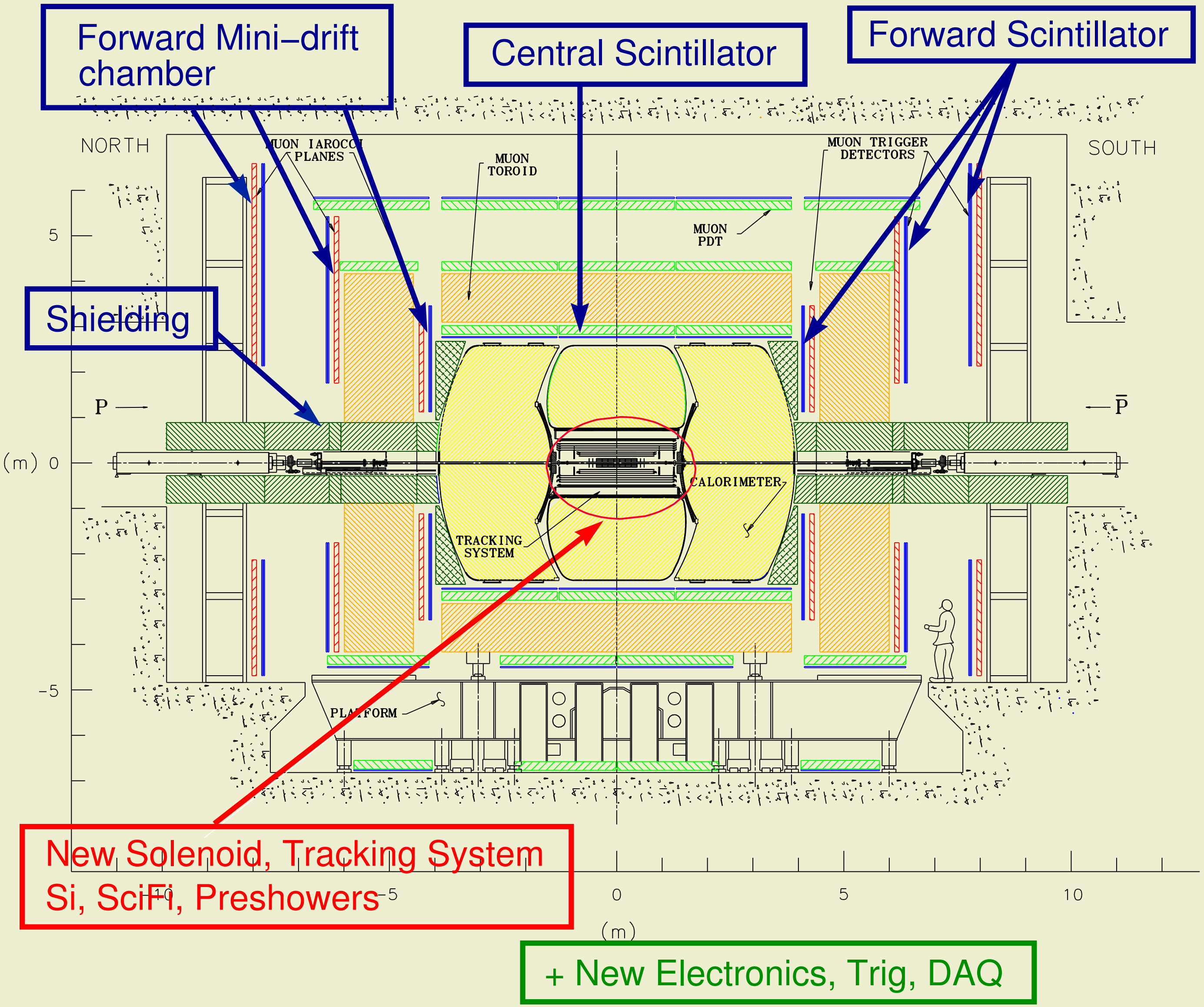
	Run I	Run II
Collision Rate	3.5 μs	369 ns
Bunches	6×6	36×36
$\sqrt{s}$ [TeV/c^2]	1.8	1.96
Peak Luminosity	2.4×10^{31}	4.4×10^{31}

The CDF Detector Upgrade



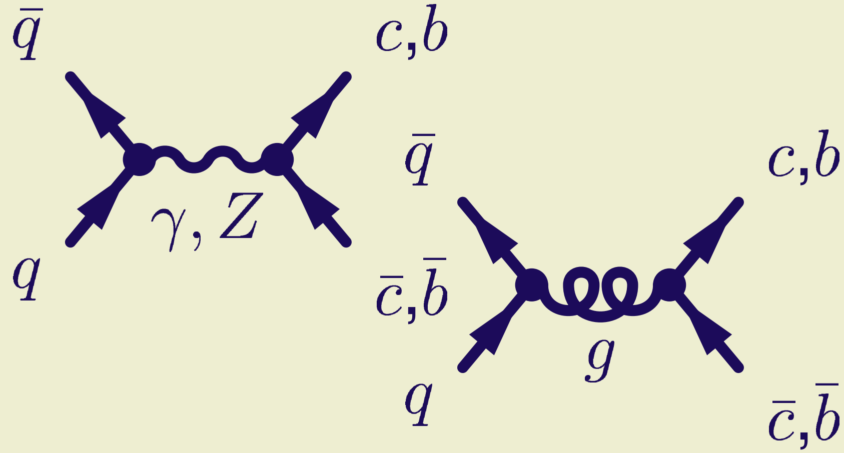
- New
- Old
- Partially New

The DØ Detector Upgrade

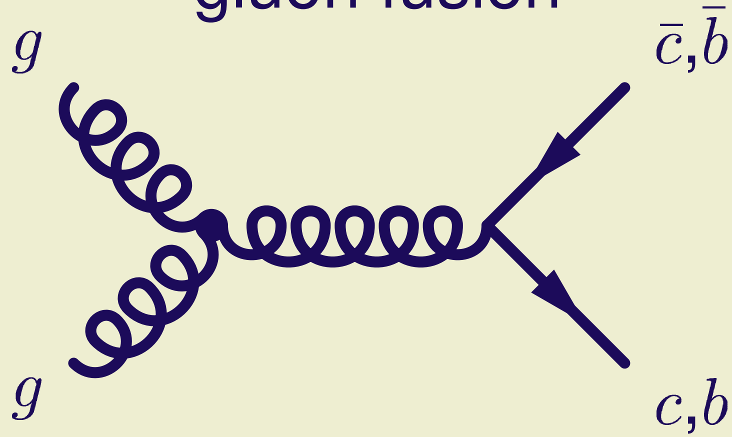


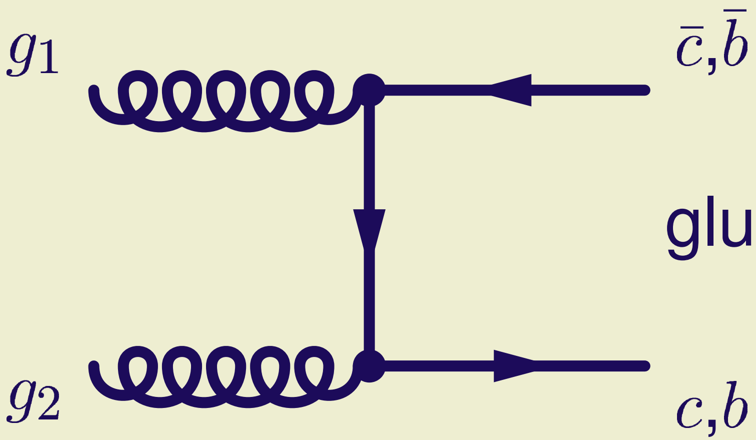
Charm and Beauty Production

$q\bar{q}$ annihilation

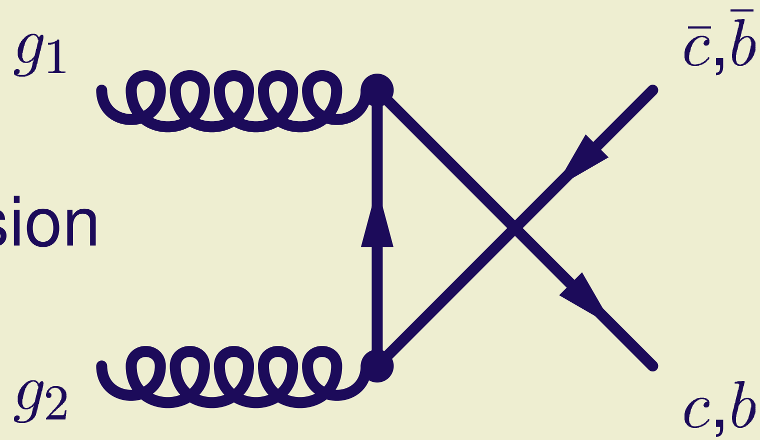


gluon fusion

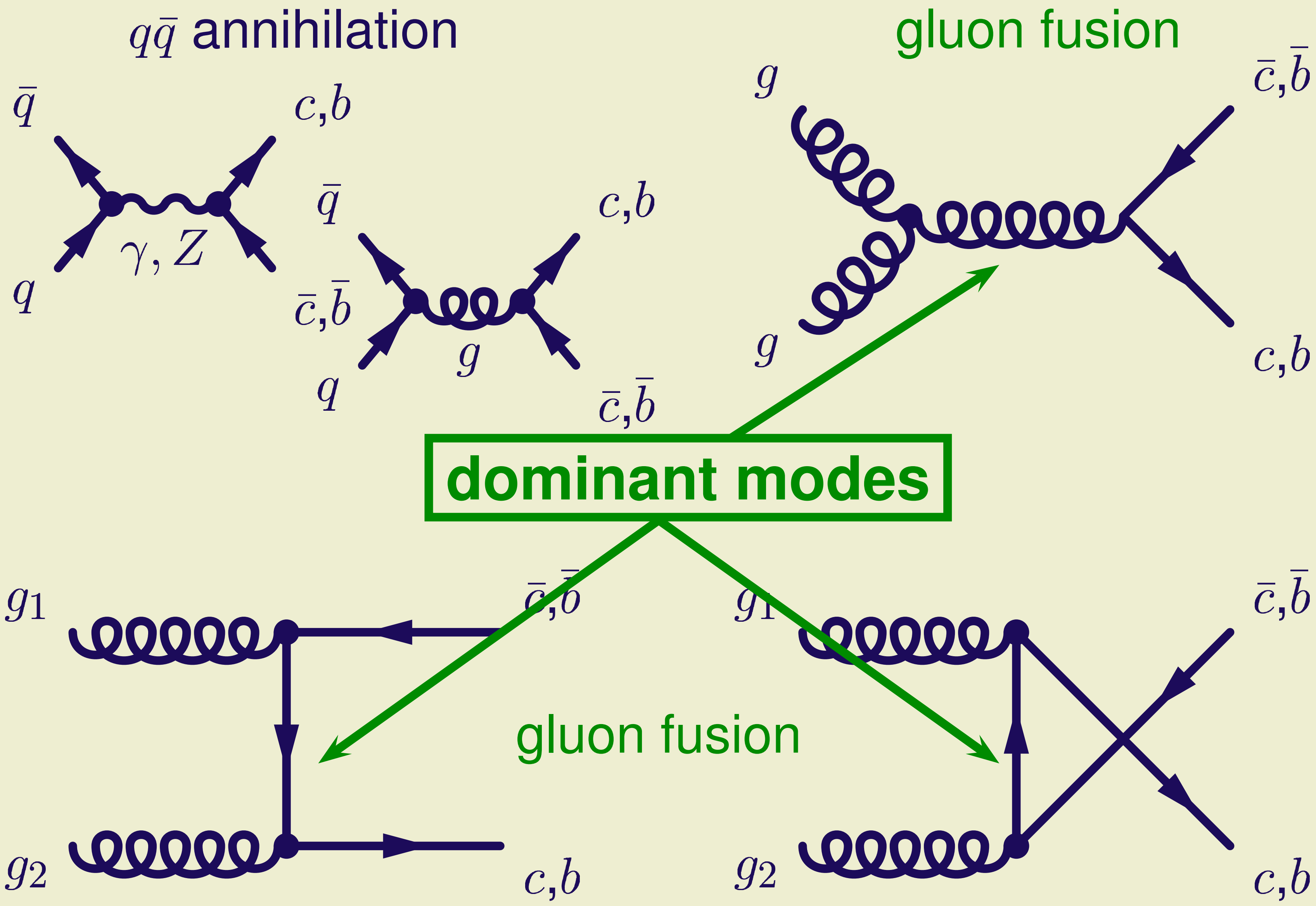




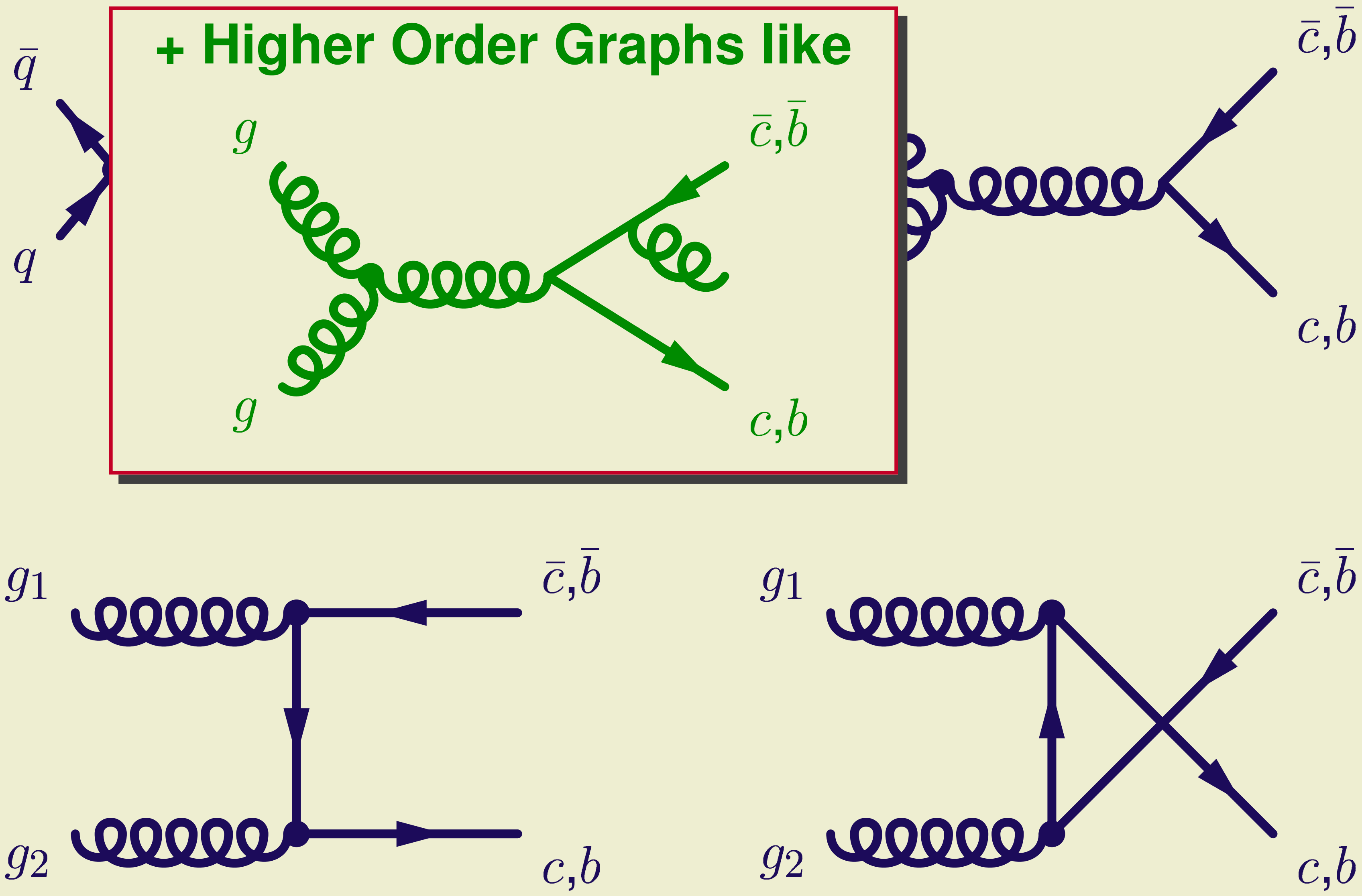
gluon fusion



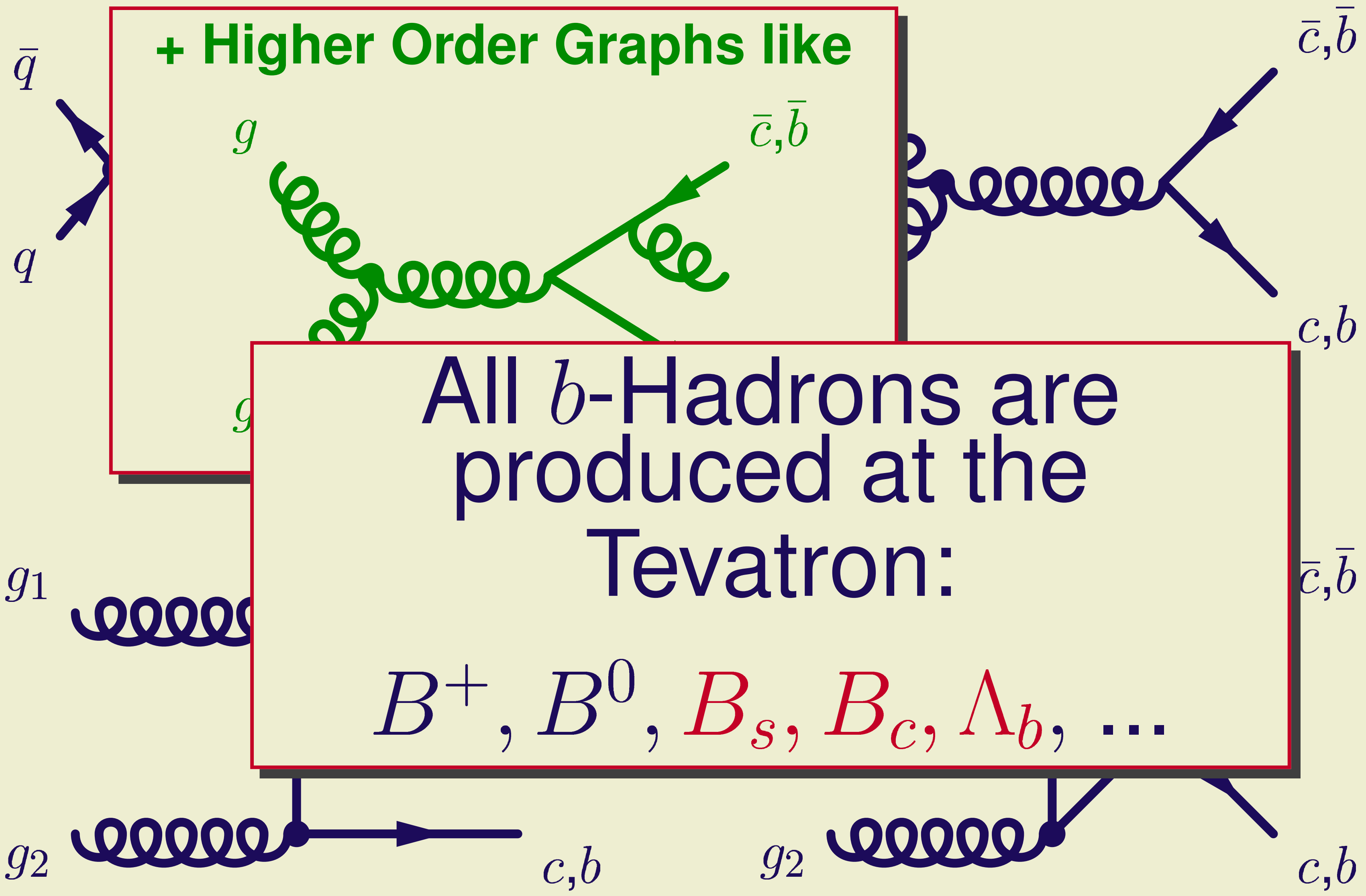
Charm and Beauty Production



Charm and Beauty Production



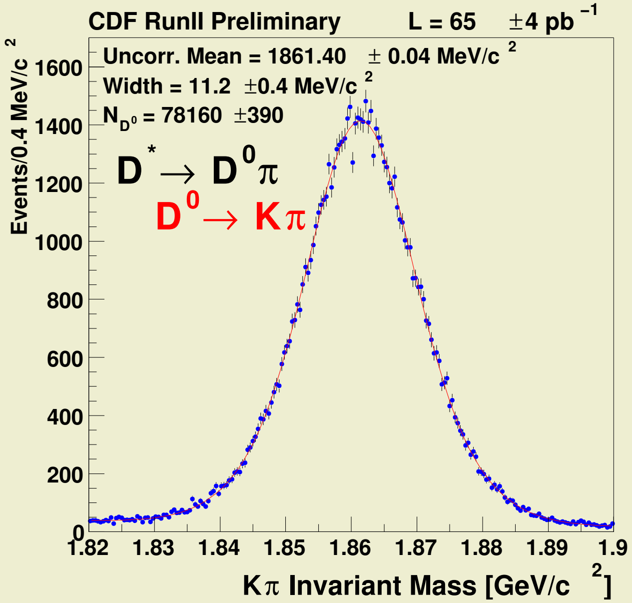
Charm and Beauty Production

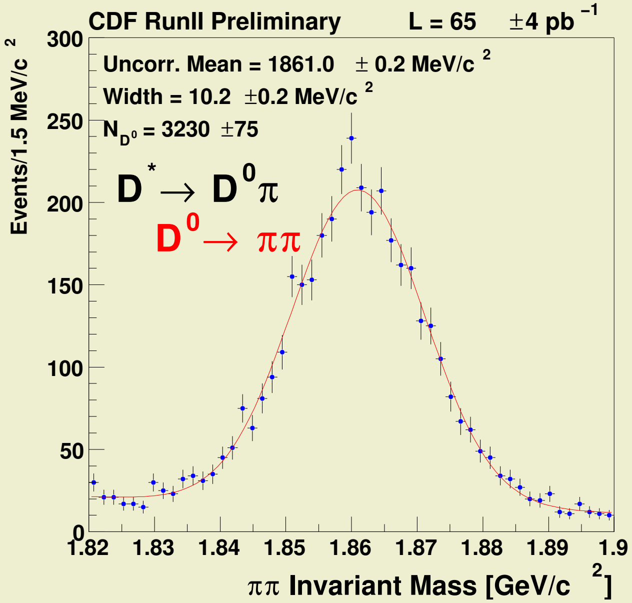


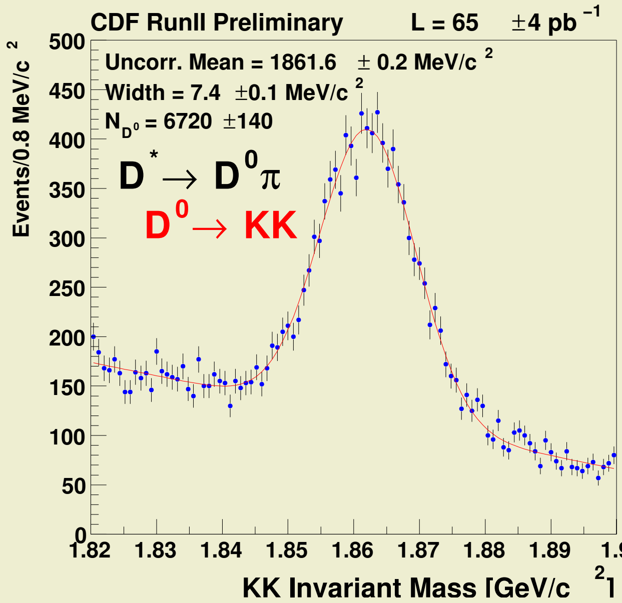
All b-Hadrons are produced at the Tevatron:

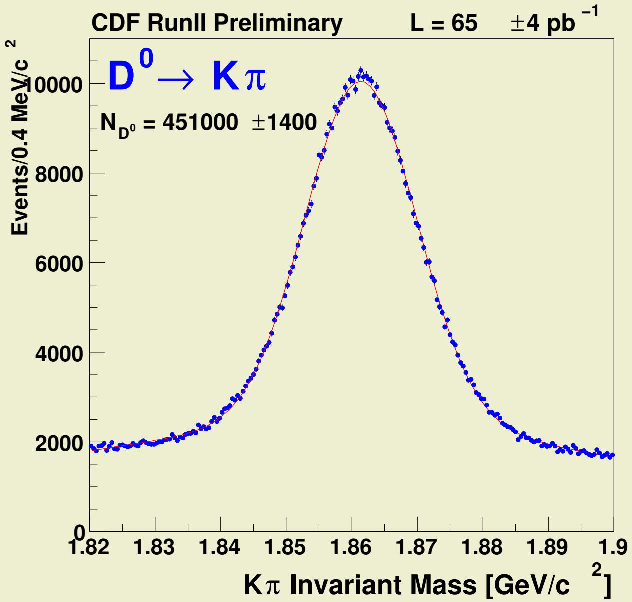
$B^+, B^0, B_s, B_c, \Lambda_b, \ldots$

Charm in Displaced Vertex Trigger







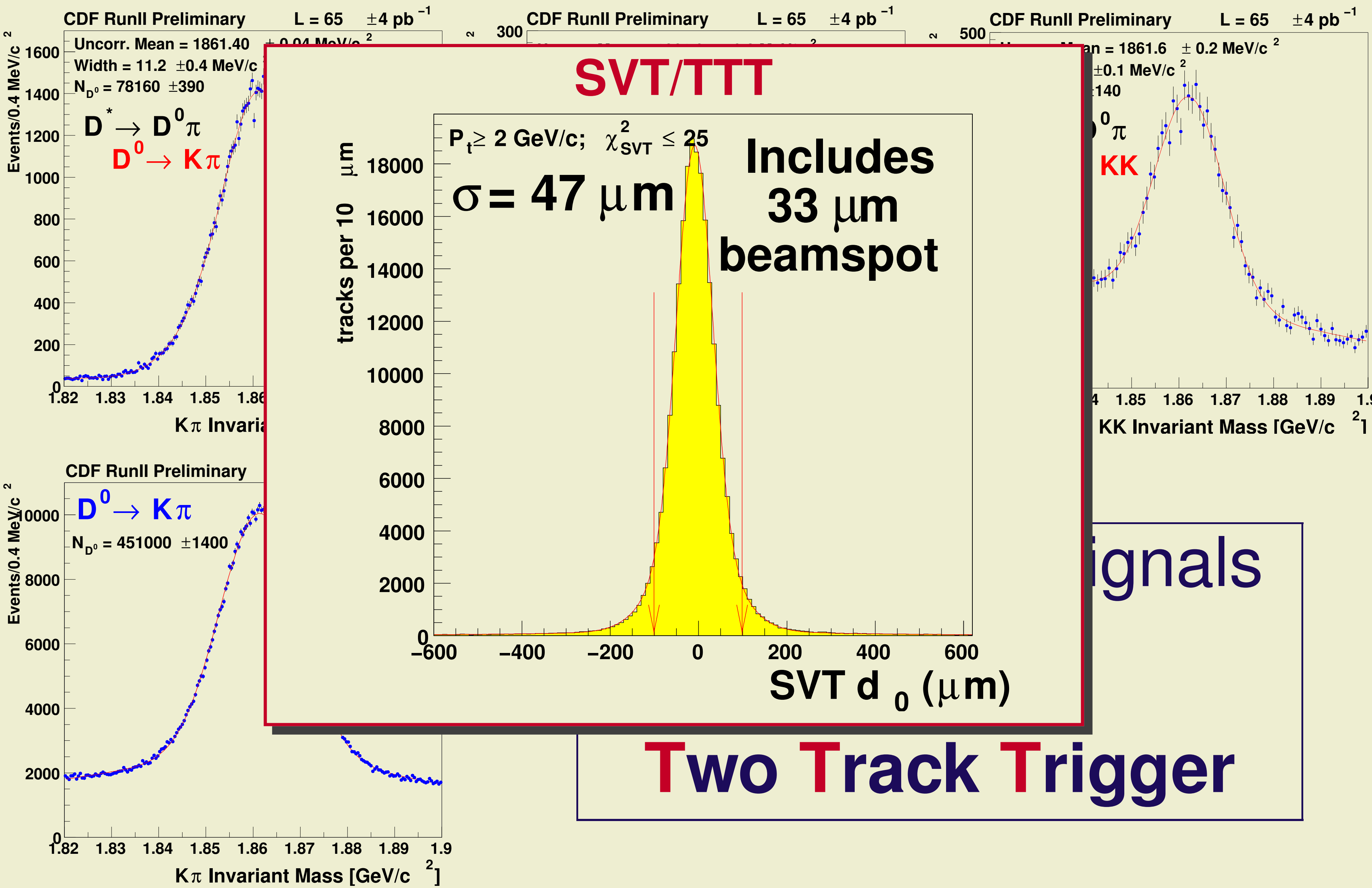


Clean Charm Signals

in

Two Track Trigger

Charm in Displaced Vertex Trigger

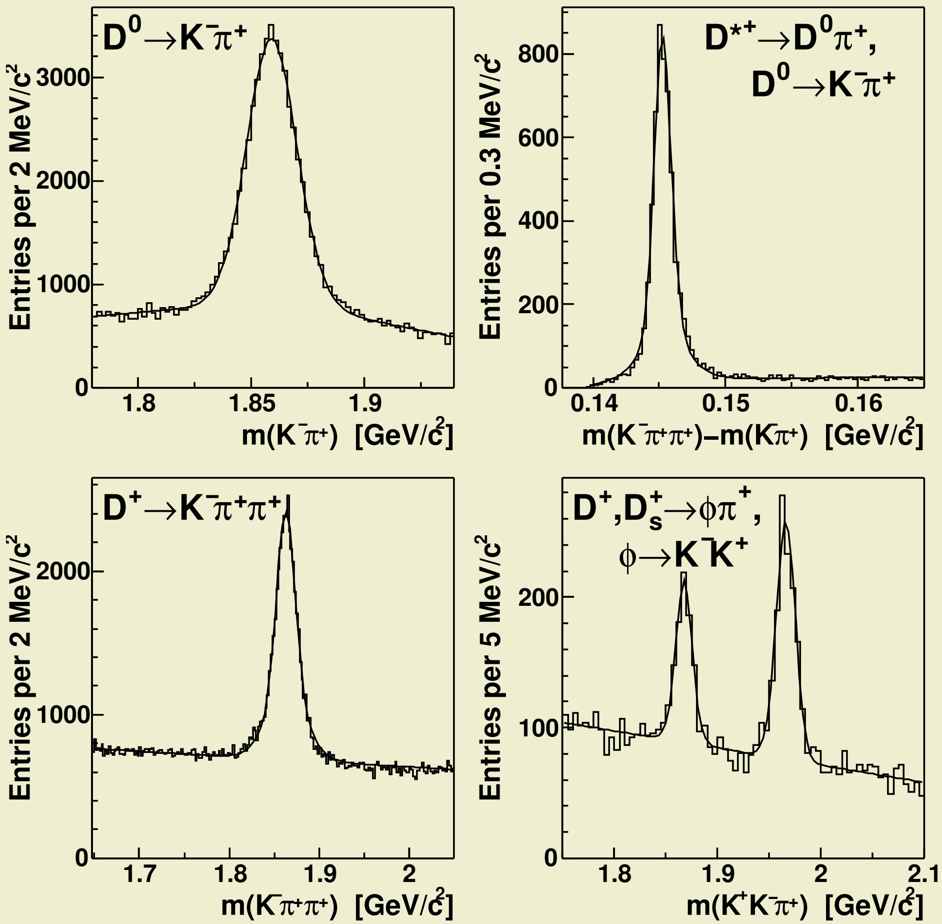


ignals

Two Track Trigger

Charm Meson X-Section – Method

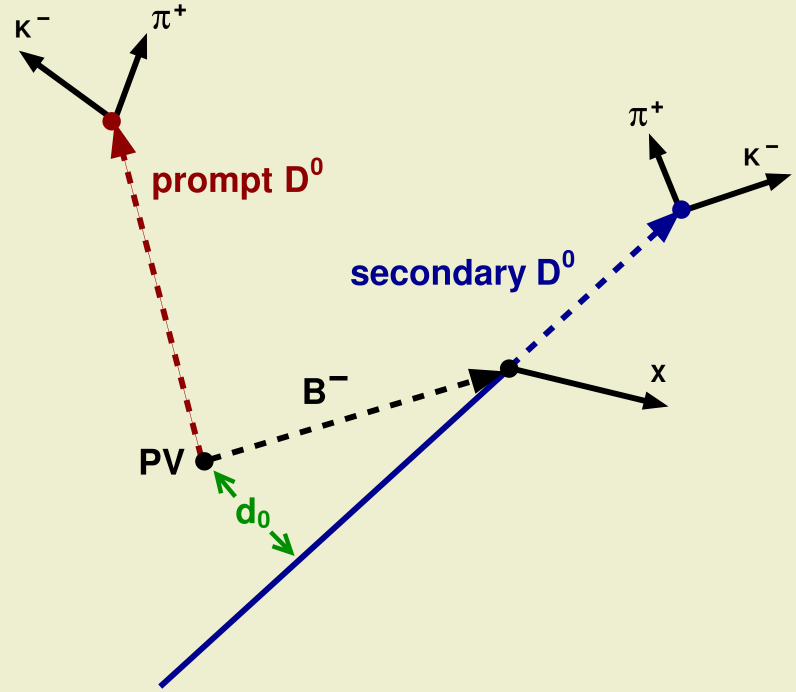
- differential $d\sigma(|y| \leq 1)/dp_T$
- data collected in TTT
- channels used $(+c.c.)$:
  - $D^0 \to K^-\pi^+$
  - $D^{*+} \to D^0\pi^+$
  - $D^+ \to K^-\pi^+\pi^+$
  - $D_s^+ \to \phi\pi^+$, $\phi \to K^+K^-$
- trigger pair required

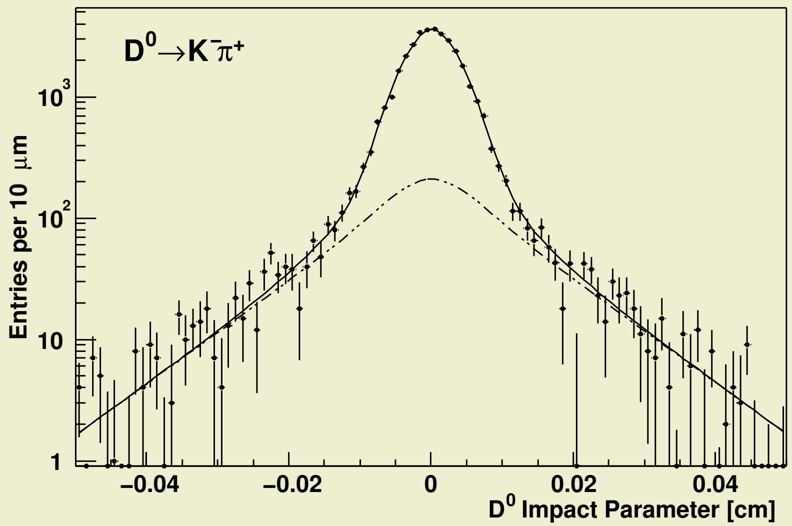


Get trigger and reconstruction efficiencies from measured tracking efficiencies and reweighted MC

Charm Meson X-Section – Method

- differential $d\sigma(|y| \leq 1)/dp_T$
- data collected in TTT
- channels used $(+c.c.)$:
  - $D^0 \to K^-\pi^+$
  - $D^{*+} \to D^0\pi^+$
  - $D^+ \to K^-\pi^+\pi^+$
  - $D_s^+ \to \phi\pi^+,\ \phi \to K^+K^-$
- trigger pair required
- need to seperate *prompt charm* from charm from B decays (*secondary charm*)





Charm Meson X-Section – Results

- i enumerates p_T bins
- N_i number of charm mesons per bin
- $\int \mathcal{L}dt$ from $\sigma_{p\bar{p}} = 60.7 \pm 2.4$mb (6% uncertainty)
- B from K. Hagiwara *et. al*, PDG, Phys. Rev. D **66**, 010001 (2002)

$$\boxed{\sigma_i = \frac{N_i/2 \cdot f_{D,i}}{\int \mathcal{L}dt \cdot \epsilon_i \cdot \mathcal{B}}}$$

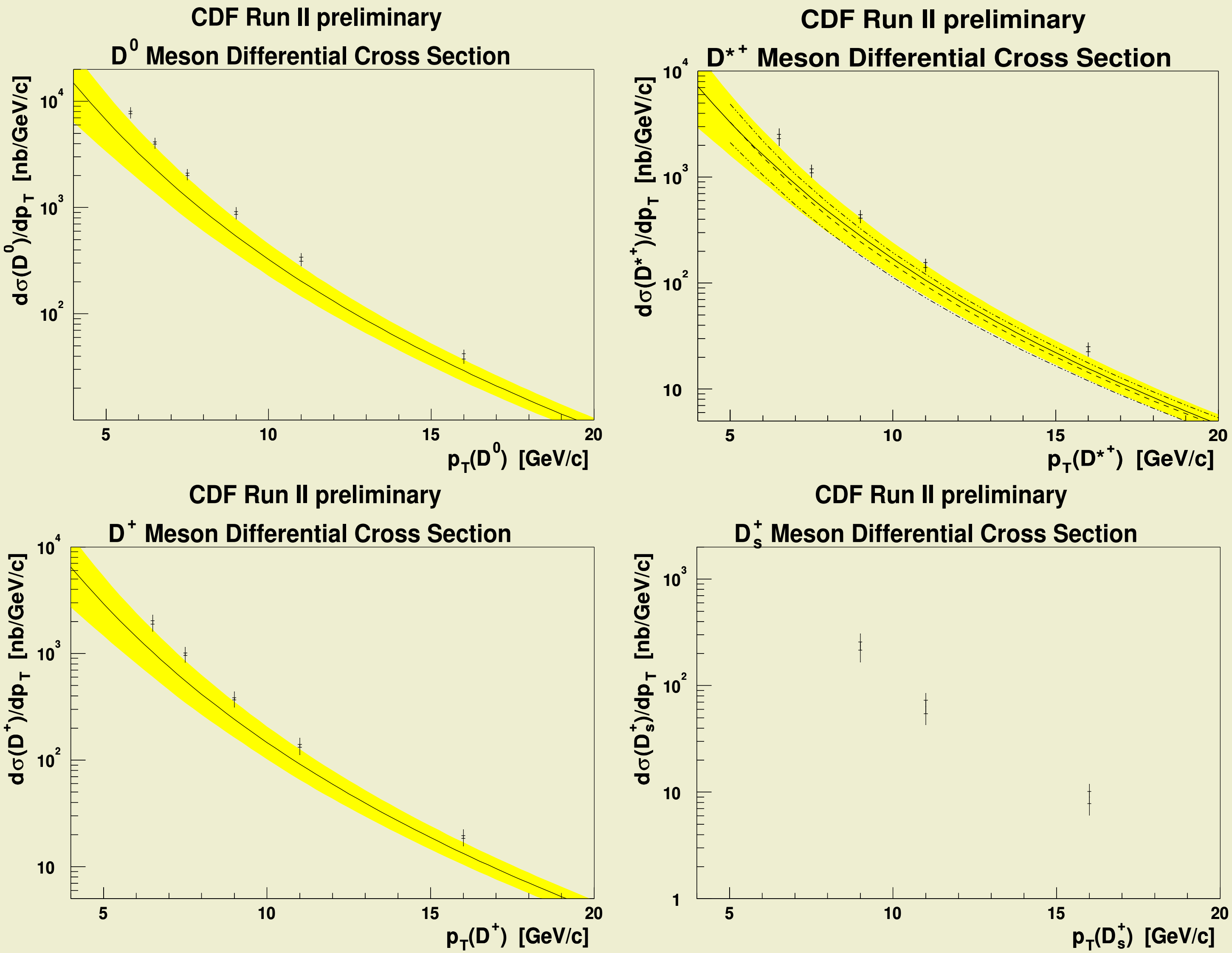
5.8±0.3pb^{-1}

p_T range [Gev/c]	D^0	D^{*+}	D^+	D_s^+
		$d\sigma(\lvert y\rvert \leq 1)/dp_T$	[nb/(Gev/c)]	
5.5–6	7837±220±884	–	–	–
6–7	4056±93±441	2421±108±424	1961±69±332	–
7–8	2052±58±227	1147±48±145	986±28±156	–
8–10	890±25±107	427±16±54	375±9±62	236±20±67
10–12	327±15±41	148±8±18	136±4±24	64±9±19
12–20	39.9±2.3±5.3	23.8±1.3±3.2	19.0±0.6±3.2	9.0±1.2±2.7

Charm Meson X-Section – Results

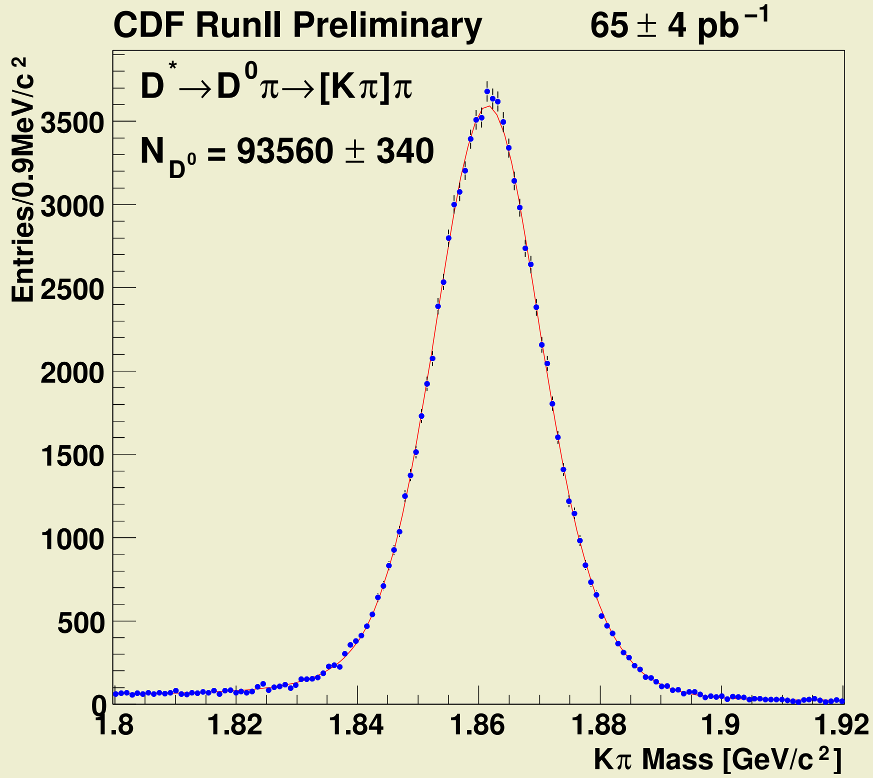
Comparison with Theory

M. Cacciari and P. Nason, arXiv:hep-ph/0306212



Branching Fractions in D^0 Decays

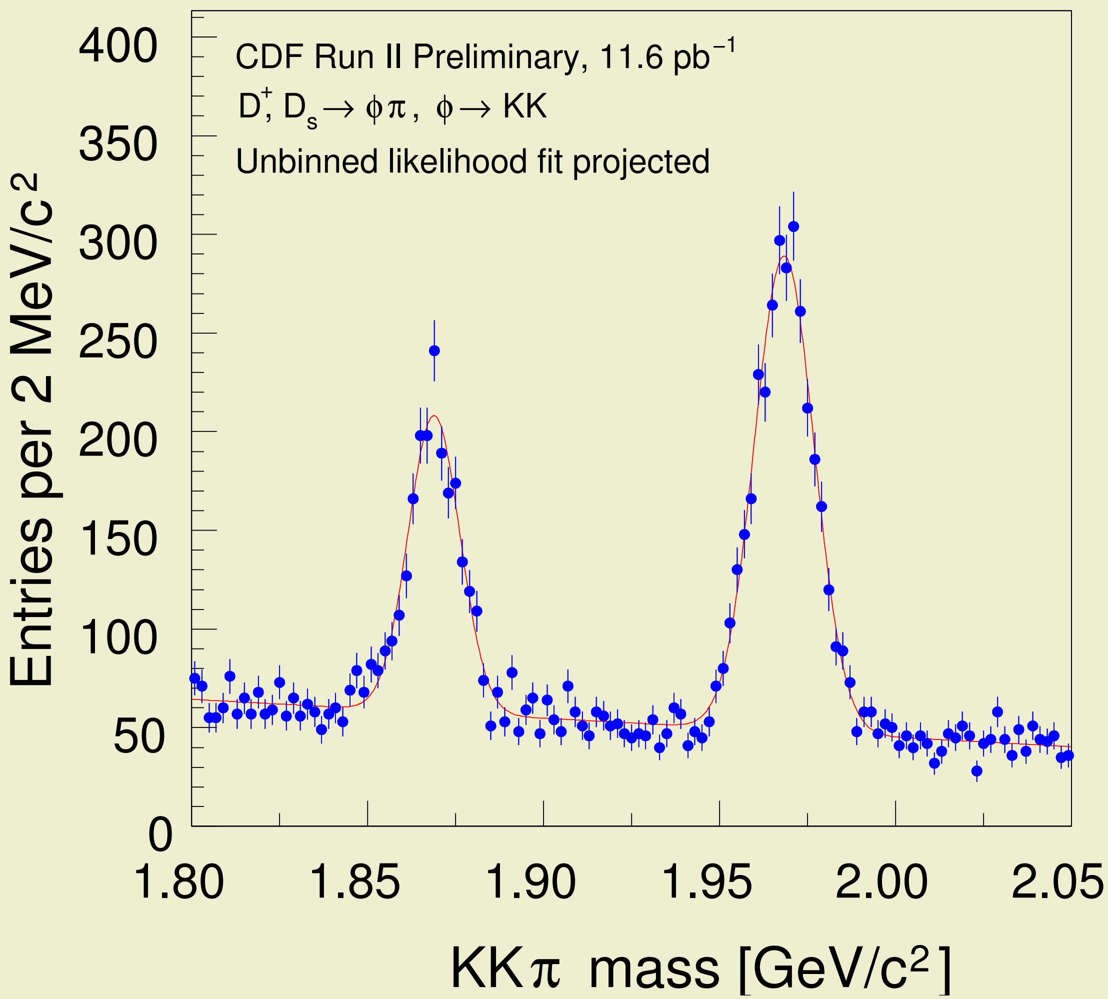
- collected by TTT
- $D^* \to D^0 \pi_s \to [K\pi]\pi_s$
- Systematics cancel (almost)



$$\frac{\Gamma(D^0 \to K^+K^-)}{\Gamma(D^0 \to K\pi)} = 9.38 \pm 0.18 \pm 0.1\%$$ (PDG 02: 10.83±0.27%)

$$\frac{\Gamma(D^0 \to \pi^+\pi^-)}{\Gamma(D^0 \to K\pi)} = 3.686 \pm 0.076 \pm 0.036\%$$ (PDG 02: 3.76±0.17%)

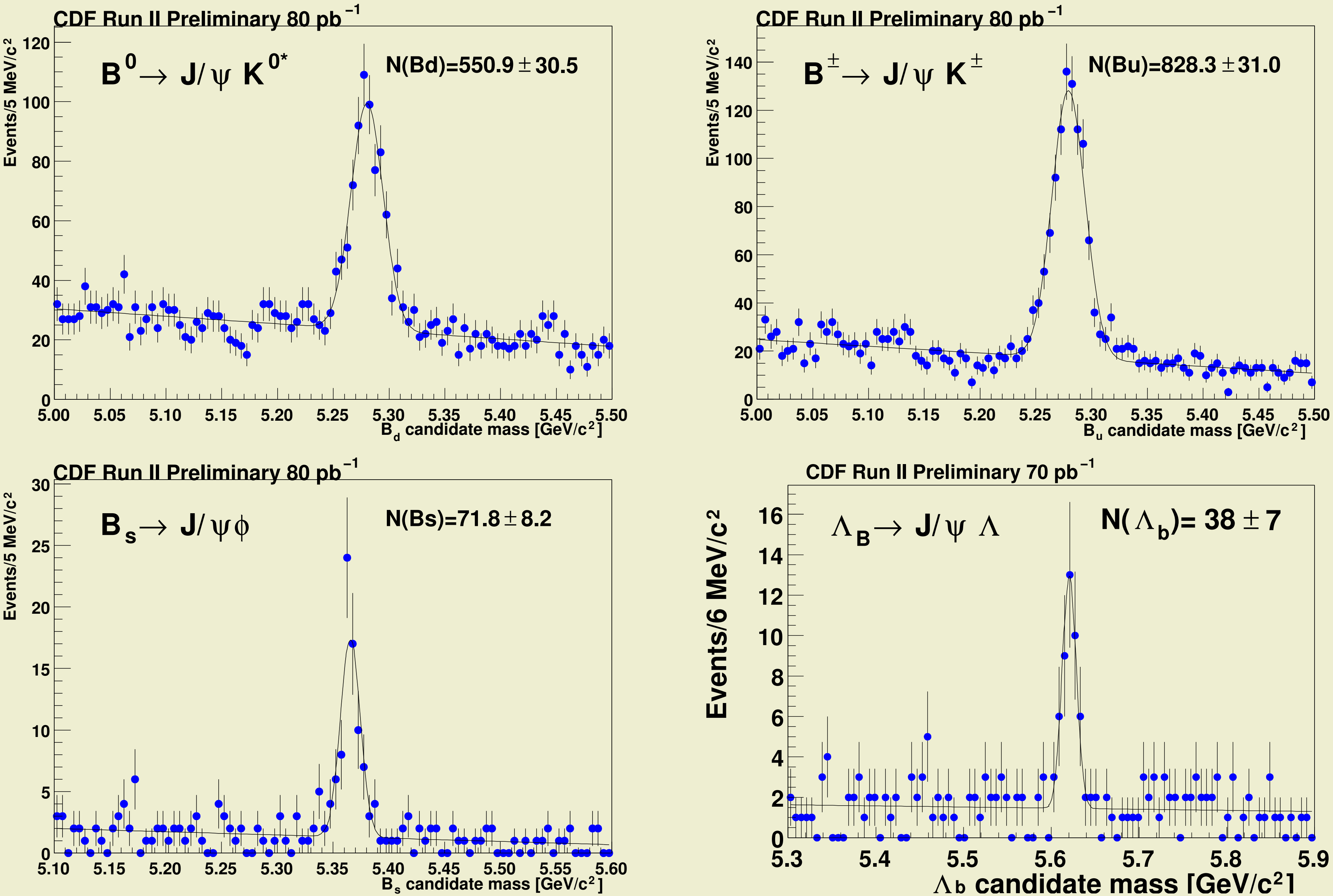
$D_s^+ - D^+$ Mass Difference



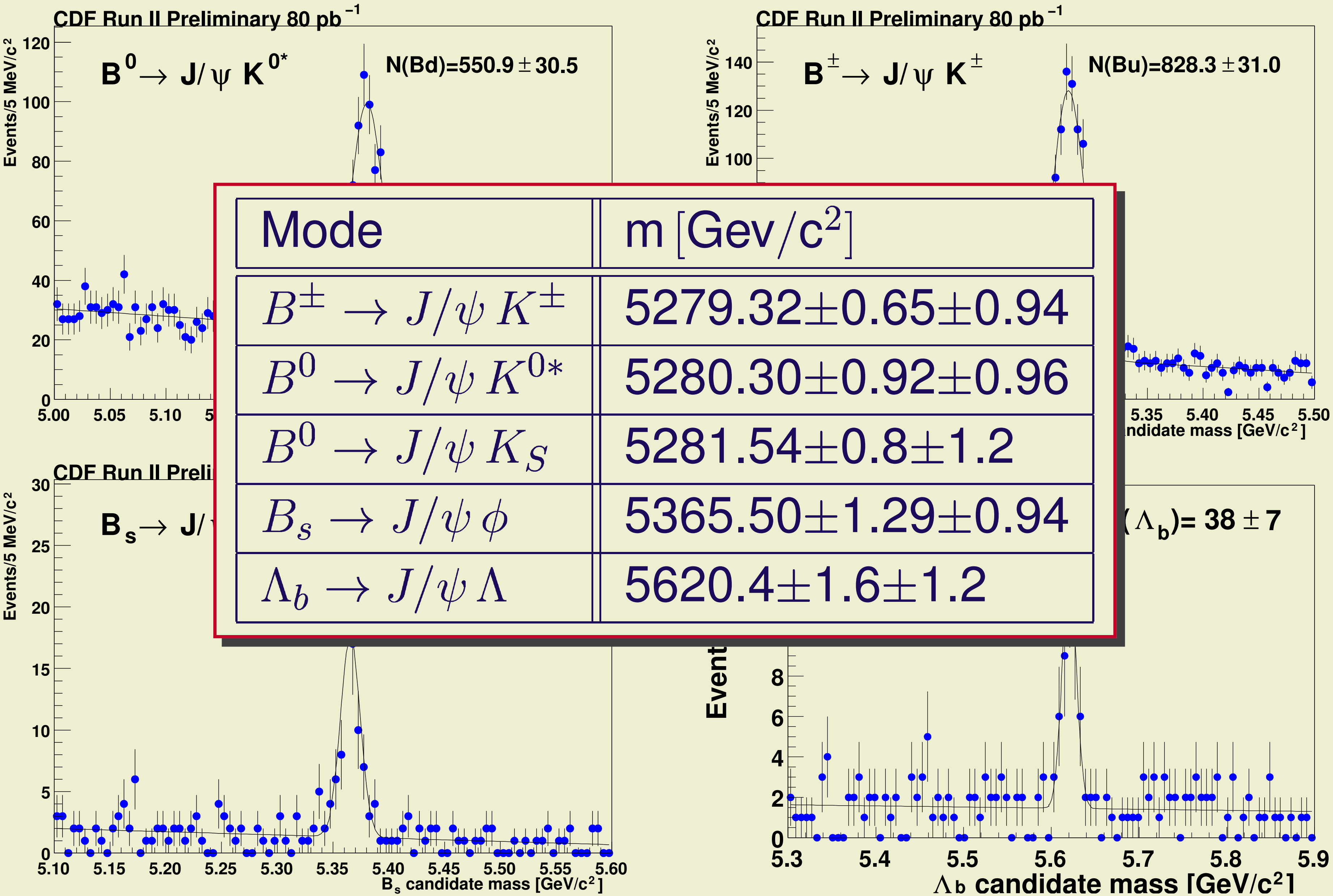
- PDG '02
  99.2 ± 0.5 MeV/c^2
- CLEO 1998
  $99.5 \pm 0.6 \pm 0.3$ MeV/c^2
- BaBar 2002
  $98.4 \pm 0.1 \pm 0.3$ MeV/c^2

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

B and Λ_b Masses



B and Λ_b Masses

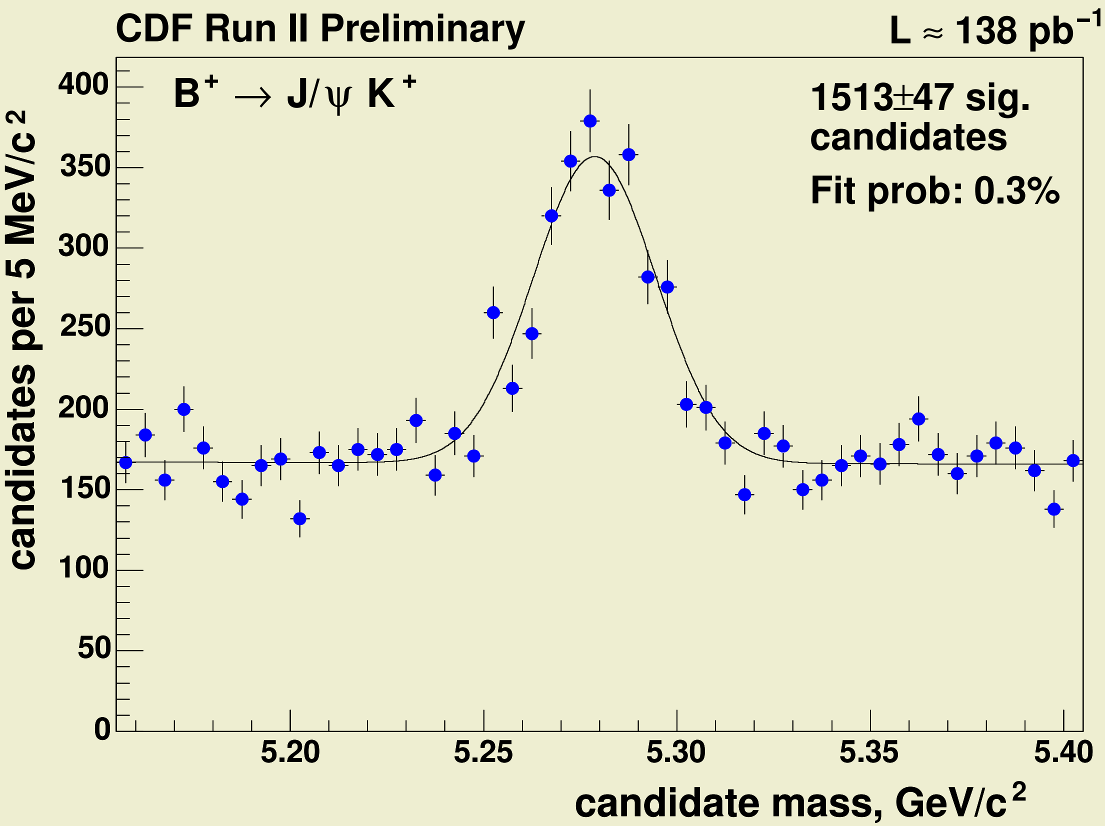


Mode	m [Gev/c^2]
$B^{\pm} \to J/\psi\, K^{\pm}$	5279.32±0.65±0.94
$B^{0} \to J/\psi\, K^{0*}$	5280.30±0.92±0.96
$B^{0} \to J/\psi\, K_S$	5281.54±0.8±1.2
$B_s \to J/\psi\, \phi$	5365.50±1.29±0.94
$\Lambda_b \to J/\psi\, \Lambda$	5620.4±1.6±1.2

Method of Lifetime Measurements

$$B^+ \to J/\psi\, K^+$$

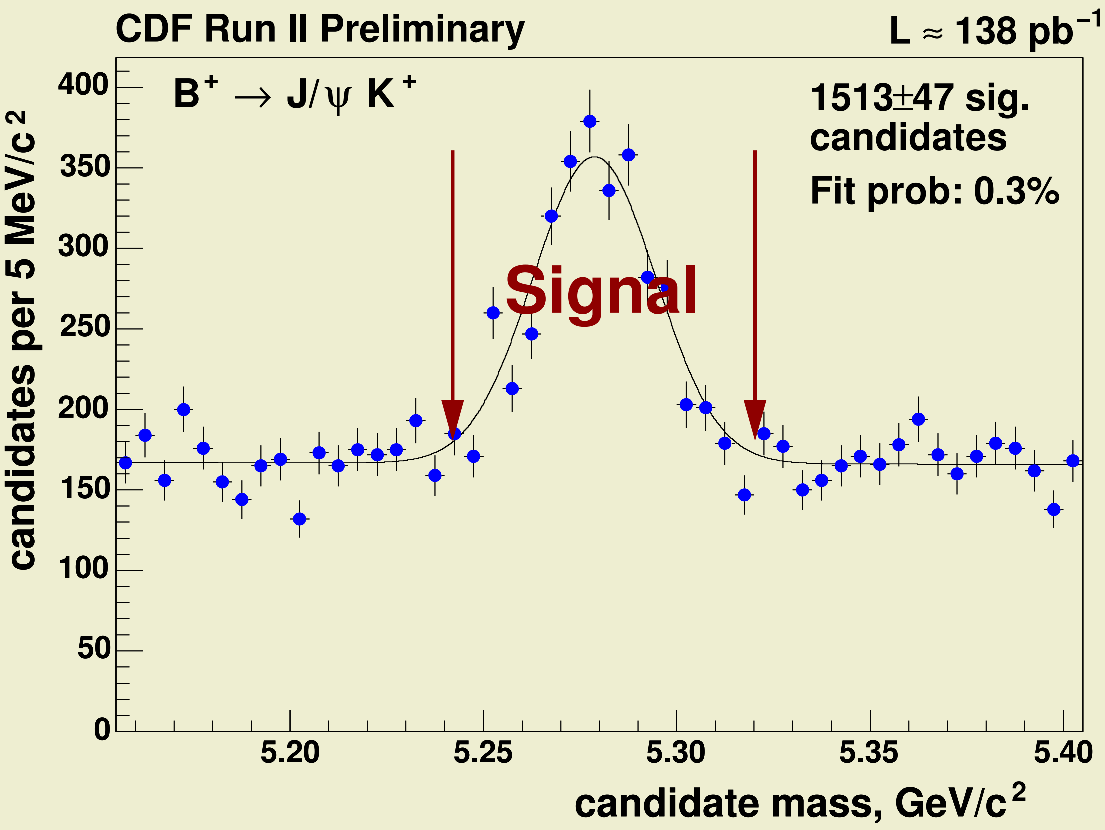
- di-μ trigger: $J/\psi \to \mu^+\mu^-$
- add K^+, apply quality cuts
- compute $m(B^+)$



Method of Lifetime Measurements

$$B^+ \to J/\psi\, K^+$$

- di-μ trigger: $J/\psi \to \mu^+\mu^-$
- add K^+, apply quality cuts
- compute $m(B^+)$
- define signal region



Method of Lifetime Measurements

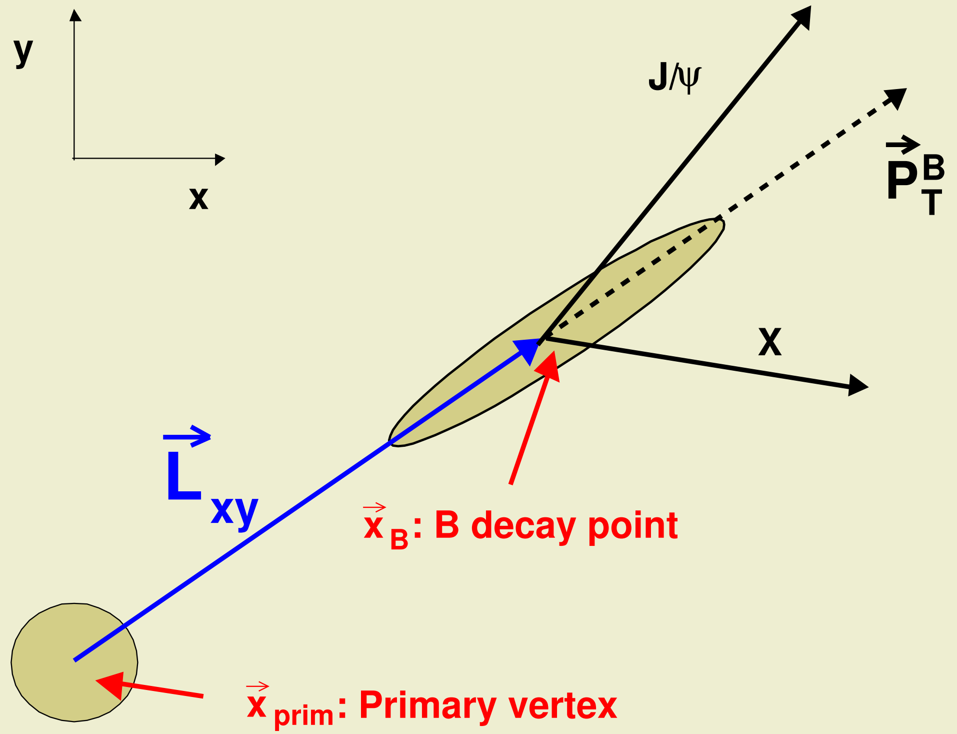
$$B^+ \to J/\psi \, K^+$$

- di-μ trigger: $J/\psi \to \mu^+\mu^-$
- add K^+, apply quality cuts
- compute $m(B^+)$
- define signal region
- proper decay length in x-y:

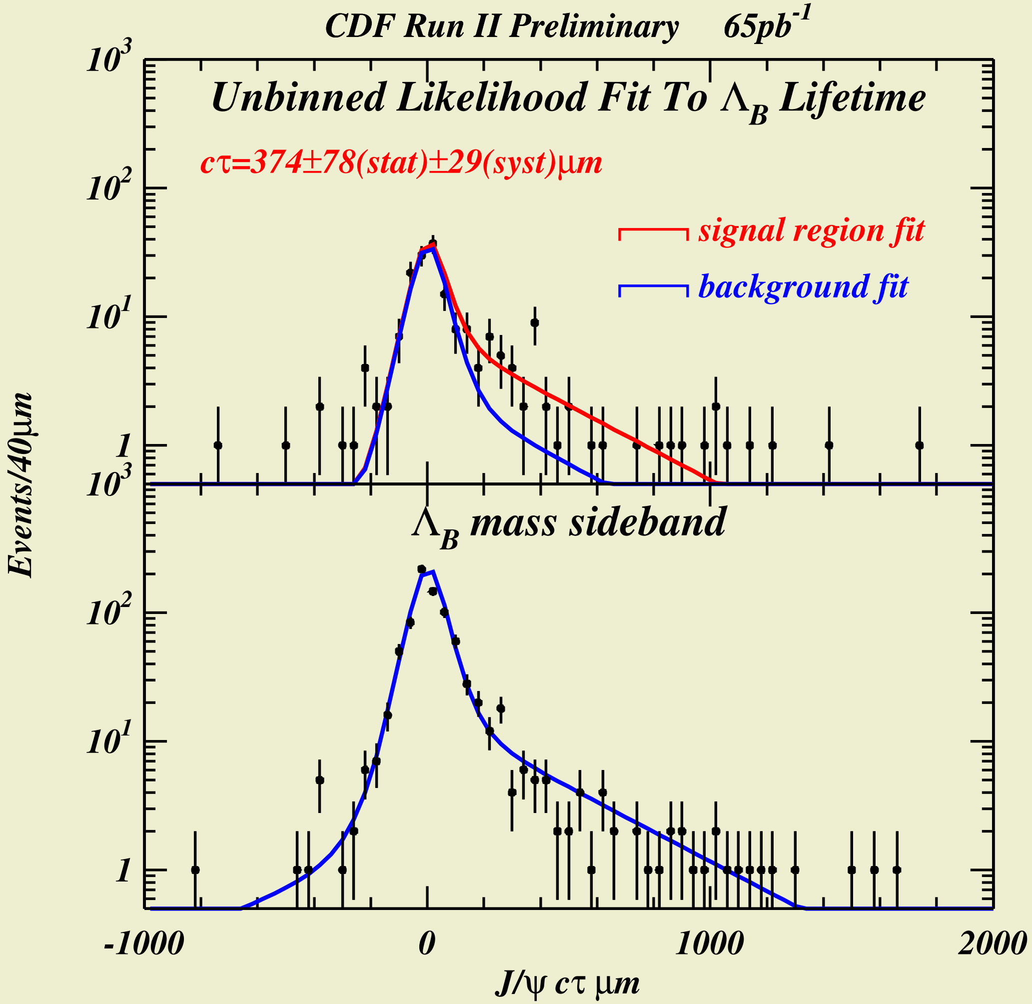
$$\vec{L}_{xy} = \vec{x}_B - \vec{x}_{prim}$$

$$L^B_{xy} = \frac{\vec{L}_{xy} \cdot \vec{p}^B_T}{|\vec{p}^B_T|}$$

$$\boxed{c\tau = \frac{L^B_{xy}}{(\beta\gamma)^B_T} = \frac{M_B}{|\vec{p}^B_T|}}$$



Λ_b Lifetime

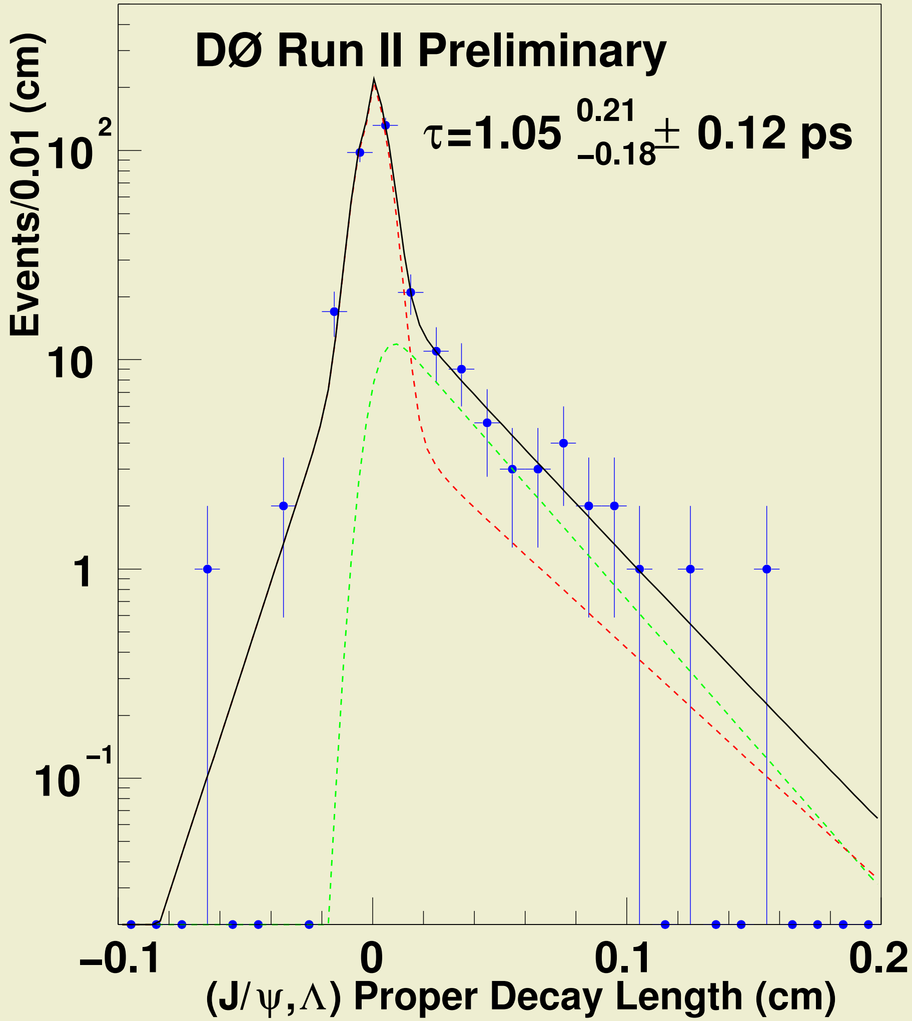


- fully reconstructed mode
- $\Lambda_b \to J/\psi\Lambda$
  - $\Lambda \to p^+\pi^-$
  - $J/\psi \to \mu^+\mu^-$

$$\boxed{\tau(\Lambda_b) = 1.25 \pm 0.26(stat) \pm 0.10(syst)ps}$$

PDG 2002: $\tau(\Lambda_b) = 1.229 \pm 0.08ps$

Λ_b Lifetime

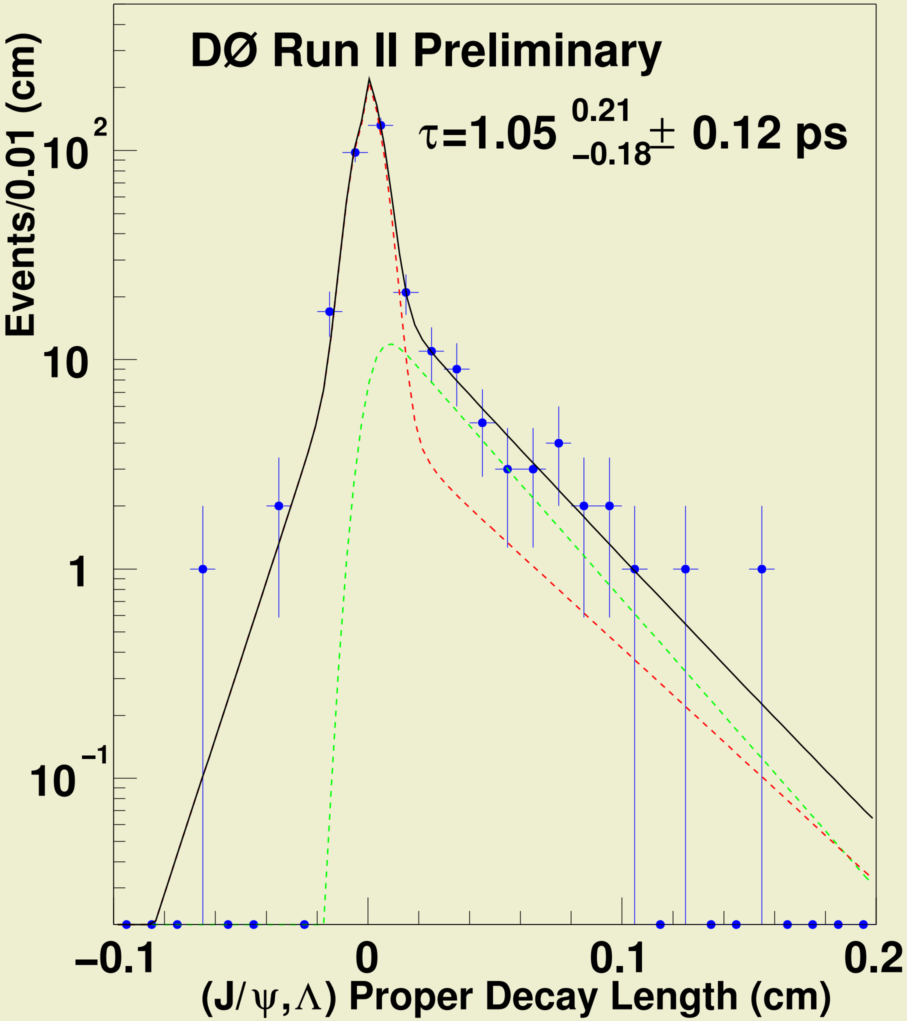


- fully reconstructed mode
- $\Lambda_b \to J/\psi\Lambda$
  - $\Lambda \to p^+\pi^-$
  - $J/\psi \to \mu^+\mu^-$

$$\boxed{\tau(\Lambda_b) = 1.05^{+0.21}_{-0.18} \pm 0.12(syst)ps}$$

PDG 2002: $\tau(\Lambda_b) = 1.229 \pm 0.08ps$

Λ_b Lifetime



$$\tau(\Lambda_b) = 1.05^{+0.21}_{-0.18} \pm 0.12(syst)ps$$

PDG 2002: $\tau(\Lambda_b) = 1.229 \pm 0.08ps$

- fully reconstructed mode
- $\Lambda_b \to J/\psi \Lambda$
  - $\Lambda \to p^+\pi^-$
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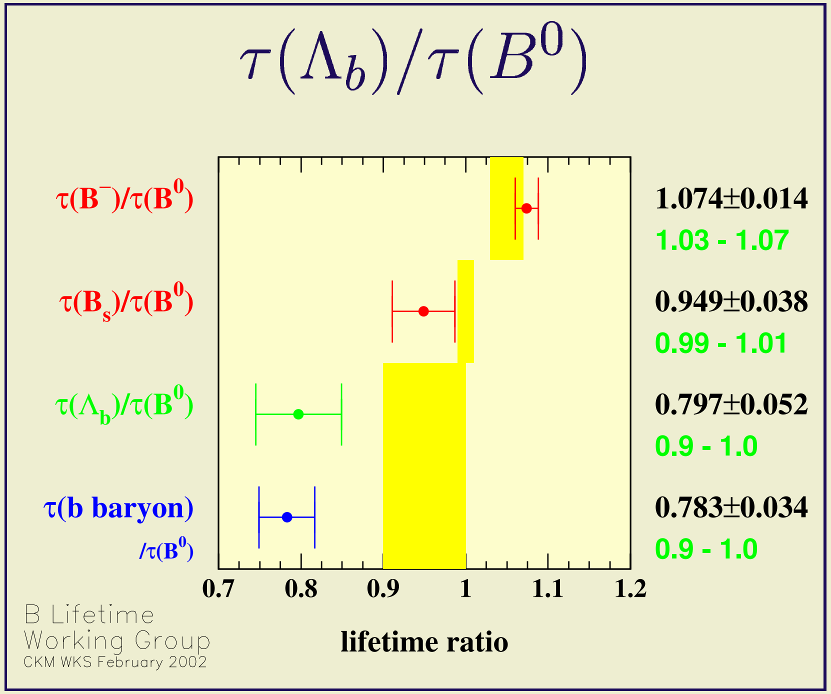


B Lifetimes at a Glance

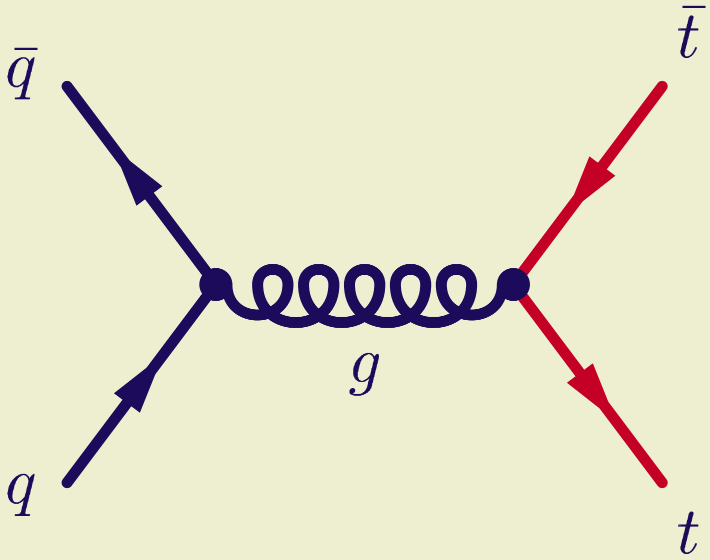
Exclusive

Mode	CDF $\tau[ps]$	DØ $\tau[ps]$
$B_s \to J/\psi\,\phi$	$1.33 \pm 0.14 \pm 0.02$	$1.19^{+0.19}_{-0.16} \pm 0.14$
$B^+ \to J/\psi\,K^+$	$1.63 \pm 0.05 \pm 0.04$	$1.65 \pm 0.083^{+0.096}_{-0.1233}$
$B^0 \to J/\psi\,K^*$	$1.51 \pm 0.06 \pm 0.02$	$1.51^{+0.19}_{-0.17} \pm 0.2$

Inclusive

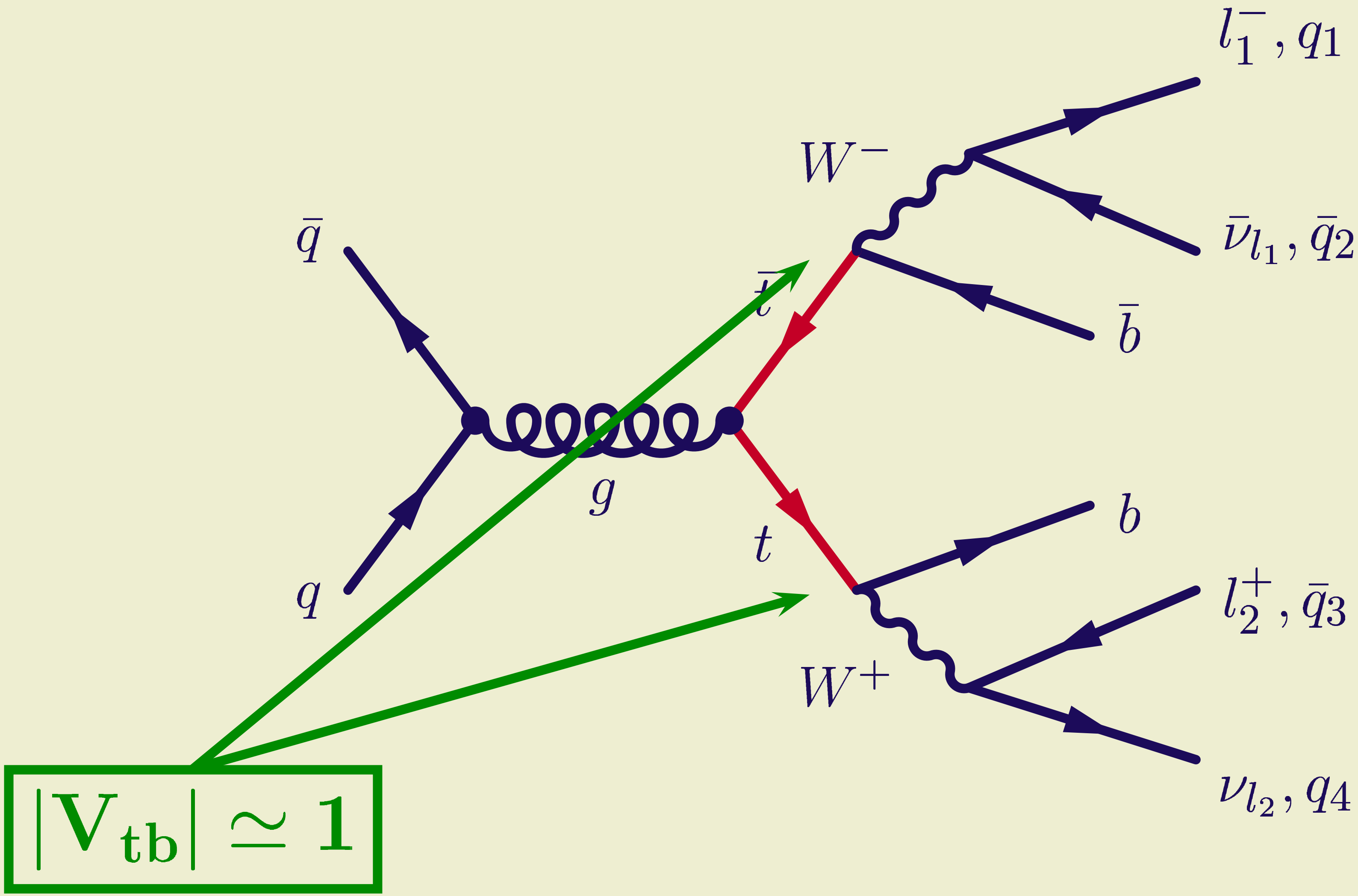
Mode	CDF $\tau[ps]$	DØ $\tau[ps]$
$B, \Lambda_b \to J/\psi\,X, J/\psi \to \mu^+\mu^-$	n/a	$1.561 \pm 0.024 \pm 0.074$

Top Production and Signatures



$\sim \mathbf{85}\%$

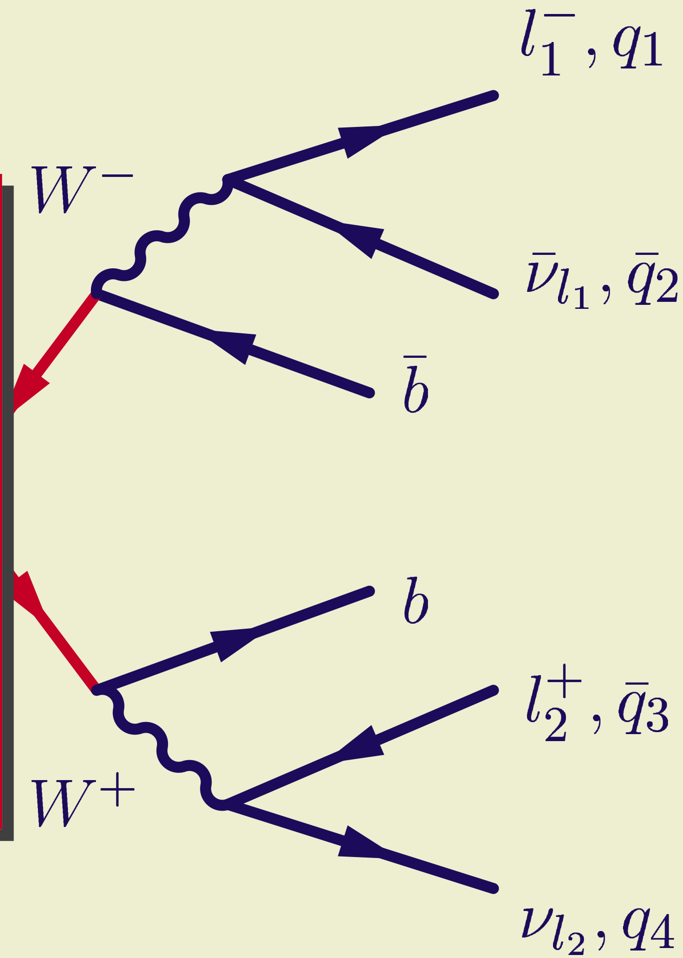
Top Production and Signatures



Top Production and Signatures

Signatures

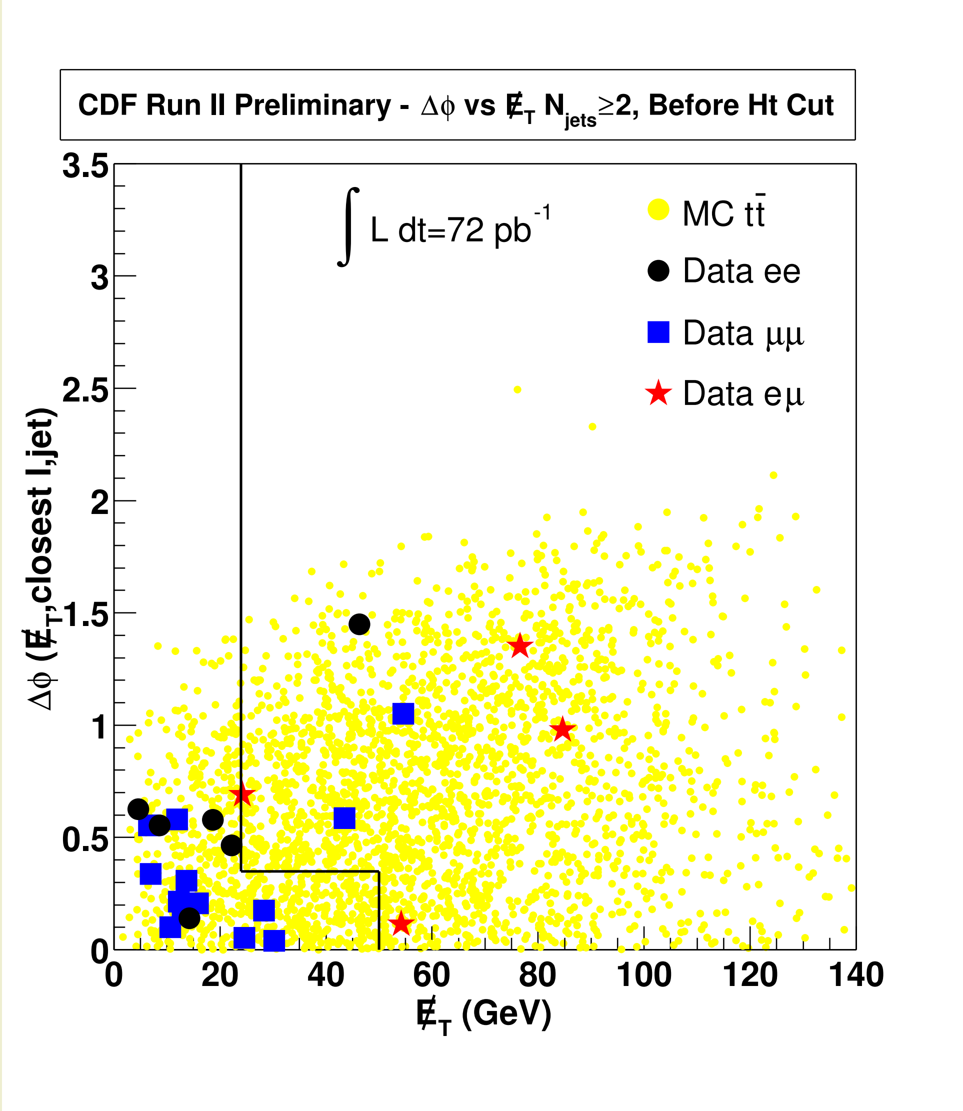
- dilepton (no τ) ~5%
  $\rightarrow$ 2 high-p_T l, 2 jets, large $\not\!\!E_T$
- lepton (no τ) + jets ~30%
  $\rightarrow$ 1 high-p_T l, 4 jets, large $\not\!\!E_T$
- all-jets ~44%
  $\rightarrow$ 6 jets



$t\bar{t}$ X-Section in ll and l+Jets

Dilepton

- Background:
  - $\gamma/Z^0 \to e^+e^-, \mu^+\mu^-$, $Z^0 \to \tau^+\tau^-, W^+W^-/W^\pm Z^0$
  - fake lepton from track or jet
- require 2 oppositely charged l
  - $P_T > 20$ GeV/c
  - exclude mass window around Z^0
  - $\not{E}_T > 25$ GeV
  - large $H_T = \sum |\vec{E}_T|$
  - reduce fake $\not{E}_T$ by cutting in $\not{E}_T$-$\Delta\phi(\not{E}_T$, closest l or jet) plane



$t\bar{t}$ X-Section in ll and l+Jets

Dilepton

- Background:
  - $\gamma/Z^0 \to e^+e^-, \mu^+\mu^-$, $Z^0 \to \tau^+\tau^-, W^+W^-/W^\pm Z^0$
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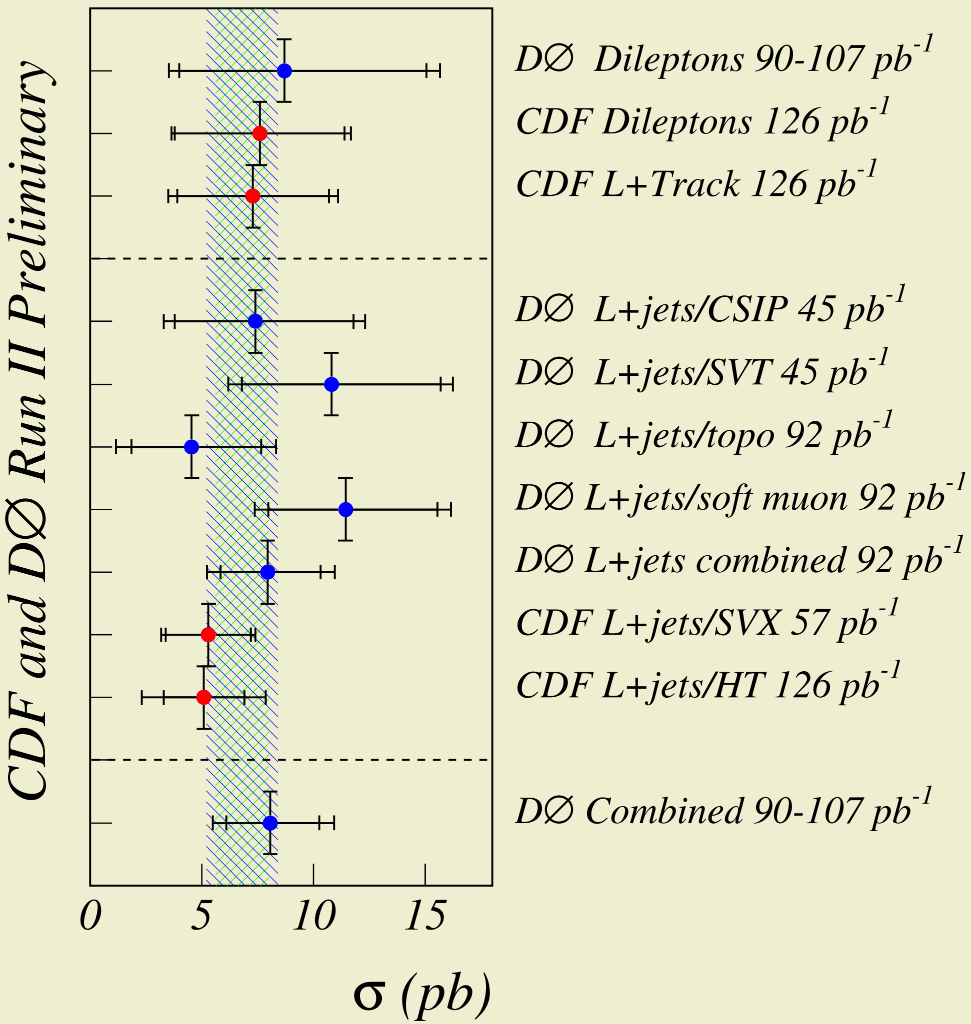
  - reduce fake $\not{E}_T$ by cutting in $\not{E}_T$-$\Delta\phi(\not{E}_T$, closest l or jet) plane

lepton + Jets

- Background:
  - Cosmic Rays
  - Drell-Yan
  - γ conversions
  - $t\bar{t}$ dilepton
- require 1 isolated high-P_T l, large $\not{E}_T$
- b-Tagging
  - CDF: displaced secondary vertex (SECVTX)
  - DØ: displaced secondary vertex (SVT)
  - DØ: large impact parameter (CSIP)
  - DØ: soft μ tag
  - DØ: topological:
    - $\rightarrow$ $\geq$4 large E jets
    - $\rightarrow$ large H_T and $\mathcal{A}$

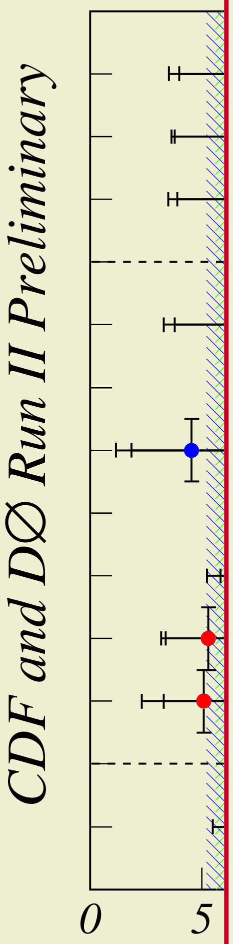
$t\bar{t}$ X-Section Summary

$$\sigma_{t\bar{t}} = \frac{N_{obs} - N_{bkg}}{A \cdot \int \mathcal{L}}$$

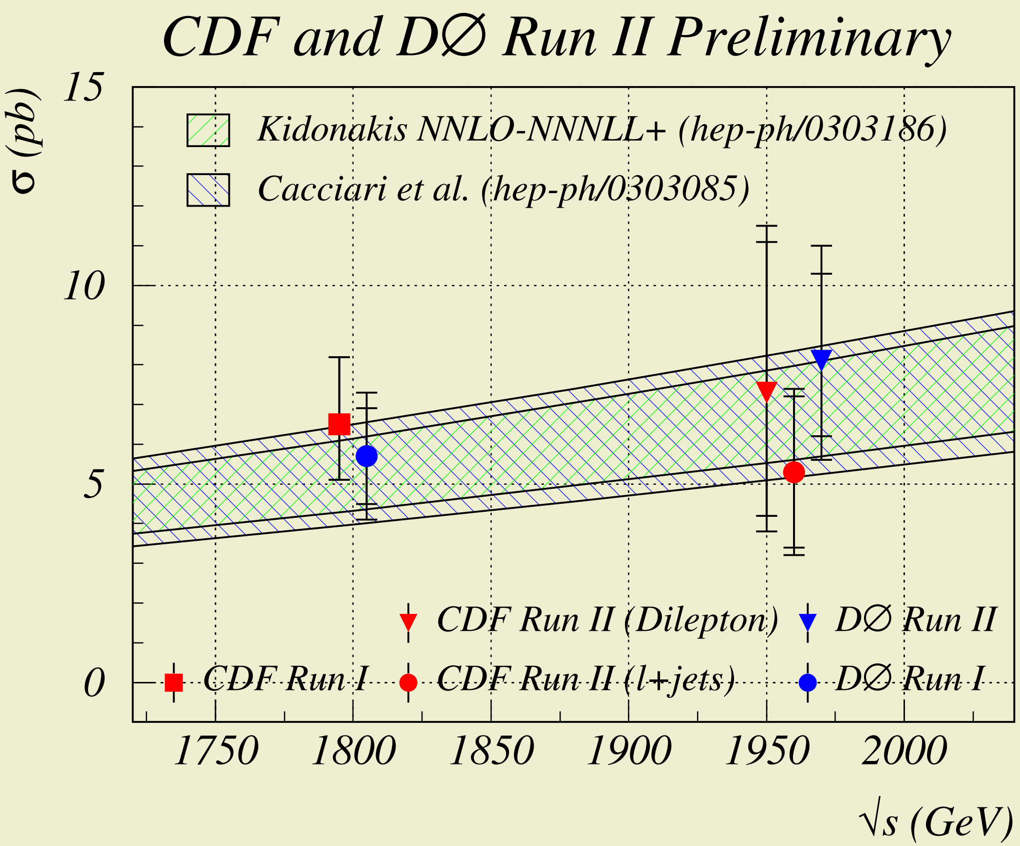


Exp. / channel	$\sigma_{t\bar{t}} \pm$ stat $\pm$ sys $\pm$ lum[pb]
DØ / ll	$8.7^{+6.4}_{-4.7}{}^{+2.7}_{-2.0} \pm 0.9$
CDF / ll	$7.6^{+3.8}_{-3.1}{}^{+1.5}_{-1.9}$
CDF / l + track	$7.3 \pm 3.4 \pm 1.7$
DØ / $l + j$, CSIP	$7.4^{+4.4}_{-3.6}{}^{+2.1}_{-1.8} \pm 0.7$
DØ / $l + j$, SVT	$10.8^{+4.9}_{-4.0}{}^{+2.1}_{-2.0} \pm 1.1$
DØ / $l + j$, topo	$4.6^{+3.1}_{-2.7}{}^{+2.1}_{-2.0} \pm 0.5$
DØ / $l + j$, soft μ	$11.4^{+4.1}_{-3.5}{}^{+2.0}_{-1.8} \pm 1.1$
DØ / $l + j$, comb.	$8.0^{+2.4}_{-2.1}{}^{+1.7}_{-1.5} \pm 0.8$
CDF / $l + j$, SVX	$5.3 \pm 1.9 \pm 0.9$
CDF / $l + j$, H_T	$5.1 \pm 1.8 \pm 2.1$
DØ / comb.	$8.1^{+2.2}_{-2.0}{}^{+1.6}_{-1.4} \pm 0.8$

$t\bar{t}$ X-Section Summary



NLO Prediction: $6.70^{+0.71}_{-0.88}$ pb



s ± lum[pb]

.9

.7

1.1

.5

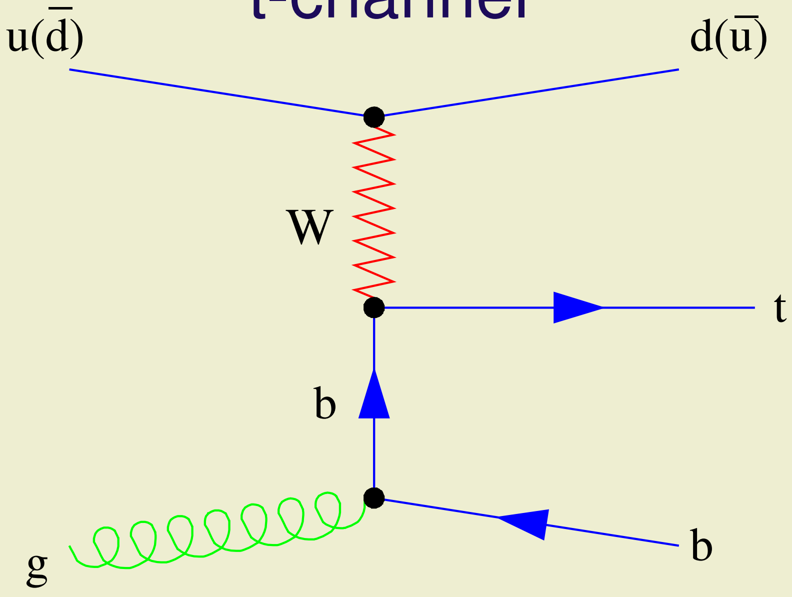
1.1

.8

.8

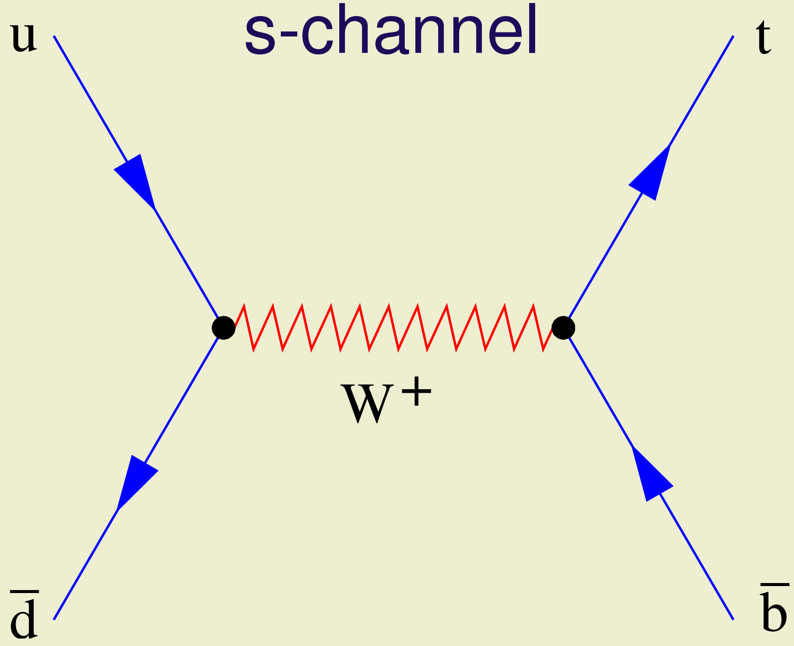
Single Top Production

t-channel



- Hard b-jet, W decay products, soft b-jet(usually lost), light q jet
- $\sigma = 1.70 \pm 0.09$ pb (Stelzer 1998)

s-channel



- 2 hard b-jets, W decay products
- $\sigma = 0.73 \pm 0.04$ pb (Smith 1996)

CDF 2 Preliminary
σ (t + s-Channel) < 17.5 pb @ 95% C.L.

Conclusions

- CDF and DØ already did competitive measurements with Tevatron Run II data
- Higher statistics and improved detector understanding will allow for even more interesting results in the near future:
  - HF X-sections
  - t quark mass
  - single top
  - B_c lifetime, B_s mixing
  - ...