Masses, Lifetimes and Decays of B Hadrons at the Tevatron

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for the CDF and D0 collaborations

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B physics at the Tevatron

Production

- Production $\mathcal{O}(10^5)$ larger than @ Υ_{4s}/Z^0
  - though total inelastic X-section 10^3 bigger $\Rightarrow$ needs adequate trigger
- All B species: $B^+, B^0, B_s, B_c, \Lambda_b, \ldots$

Topics

- QCD
  - J/ψ cross-section
  - B cross-section
  - quarkonium states
- Production, masses and lifetimes: B^+,B^0,B_s, Λ_b, B_c
- Rare decays
- CP violation and mixing
  - B_s mixing: $B_s^0 \to D_s\pi$, $B_s^0 \to D_s l\nu X$
  - $\sin(2\beta)$ in $B^0 \to J/\psi K_s^0$
  - weak phase of V_{ts} in $B_s^0 \to J/\psi\phi$
  - CP asymmetries in $B \to h^+h^-$
  - γ: $B_s^0 \to D_s K$

Triggers and data samples

Triggers

D0 Di-Muon	CDF Di-Muon
❖ $p_T^\mu > 3.5$ GeV/c, $\|\eta^\mu\| < 1$ ❖ $p_T^\mu > 2-2.5$ GeV/c, $1 < \|\eta^\mu\| \leq 2$	❖ $p_T^\mu > 1.5$ GeV/c, $\|\eta^\mu\| \leq 1$

CDF Lepton + displaced track	CDF Two-track trigger
❖ $\mu^\pm$: $p_T > 4$ GeV/c, $\|\eta\| \leq 1$ ❖ $e^\pm$: $p_T > 4$ GeV/c, $\|\eta\| \leq 1.5$ ❖ SVT: $p_T > 2$ GeV/c, $d_0 > 120\mu$m	❖ SVT: $p_T > 2$ GeV/c, $d_0 > 100\mu$m, $\delta\varphi$ cut

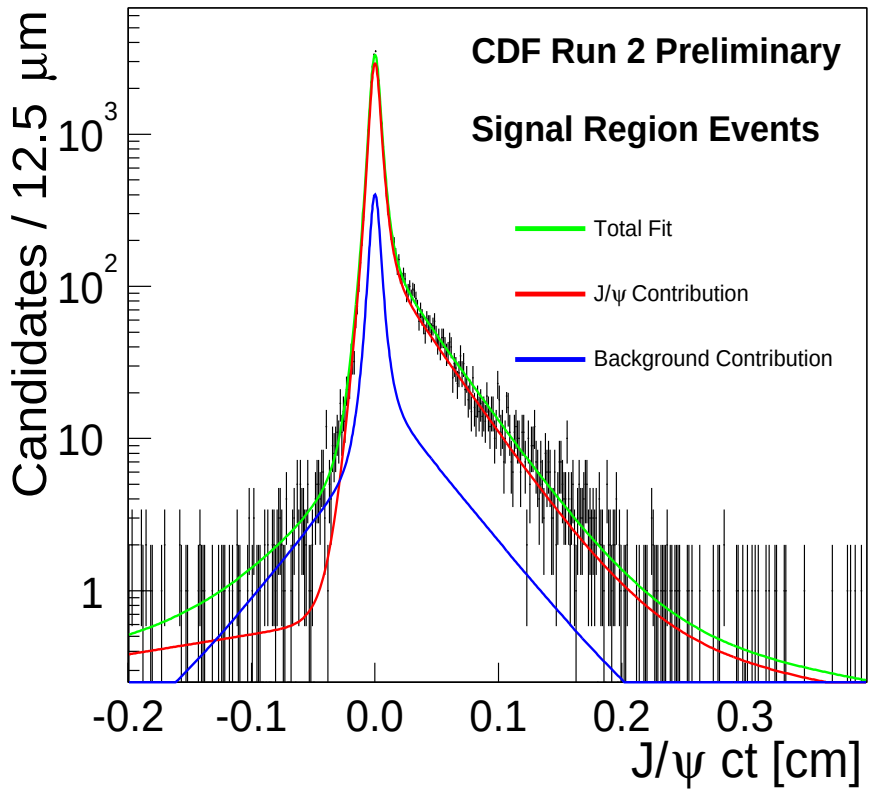
Silicon Vertex Trigger (cf. Andreas' talk)

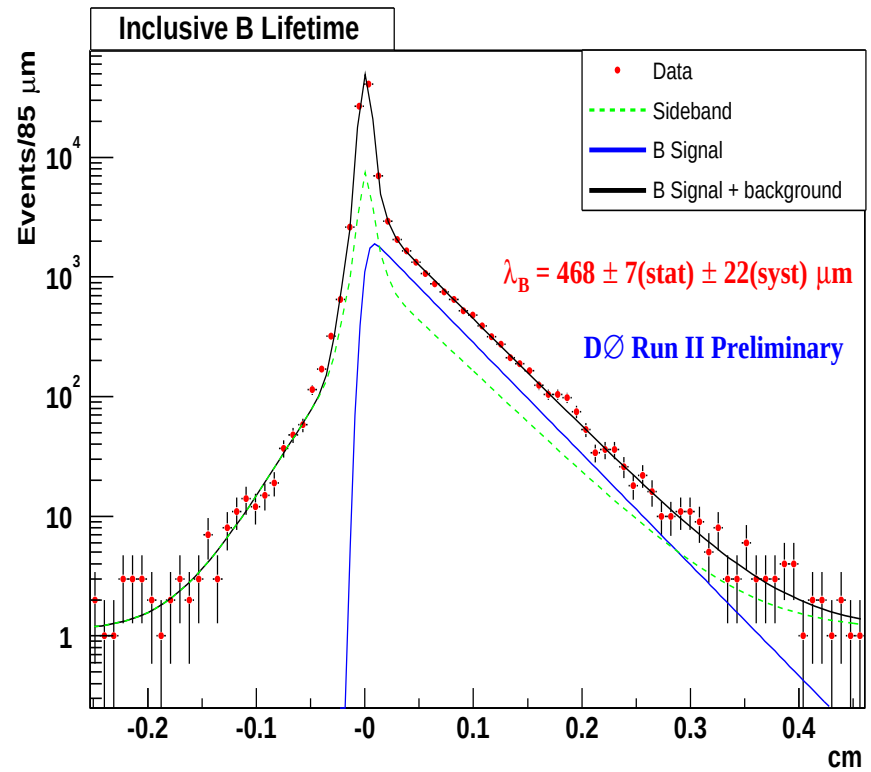
Data sample

D0: results in this talk based on 40-45 pb^{-1} (Aug 2002-Jan 2003)

CDF: results in this talk based on 60-70 pb^{-1} (Feb 2002-Dec 2002)

Di-muon: B inclusive lifetime

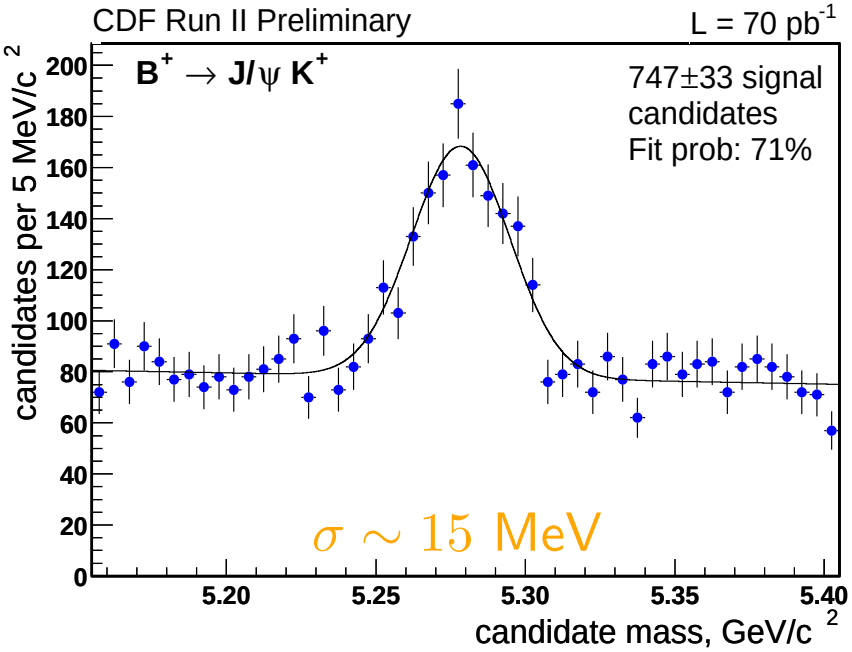


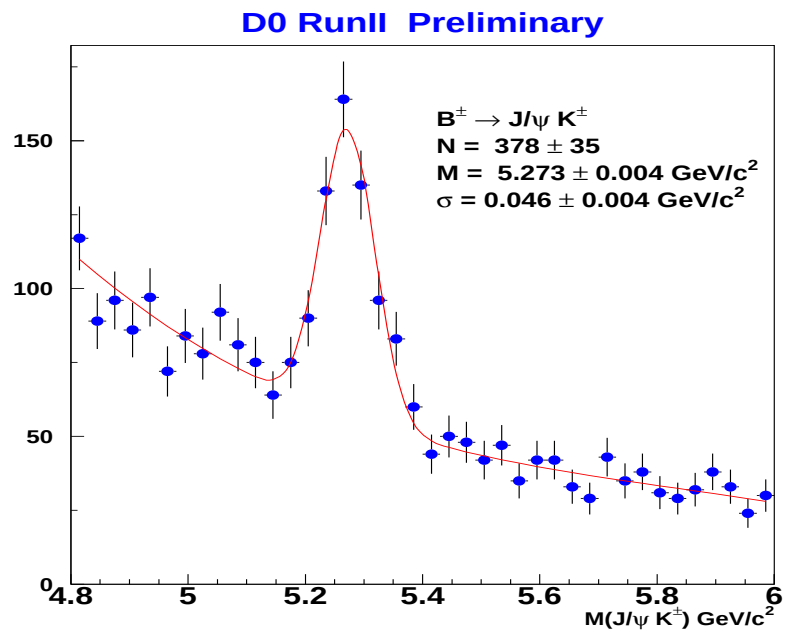


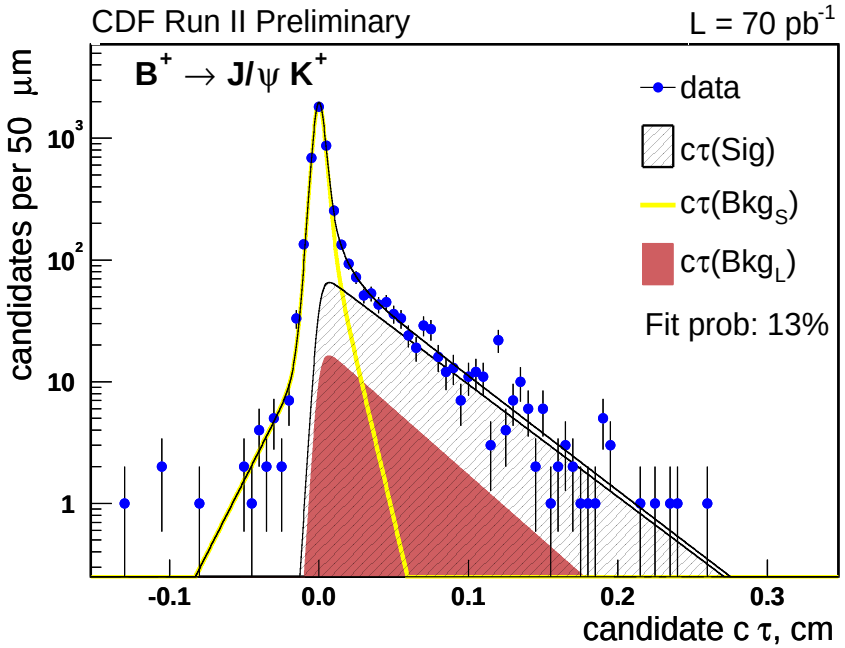
- based on the decay length $L = \beta\gamma ct = \frac{p_B}{m_B} ct$, $\beta\gamma$ from Monte-Carlo
- systematics: resol. function, background modeling, $\beta\gamma$ correction, alignment

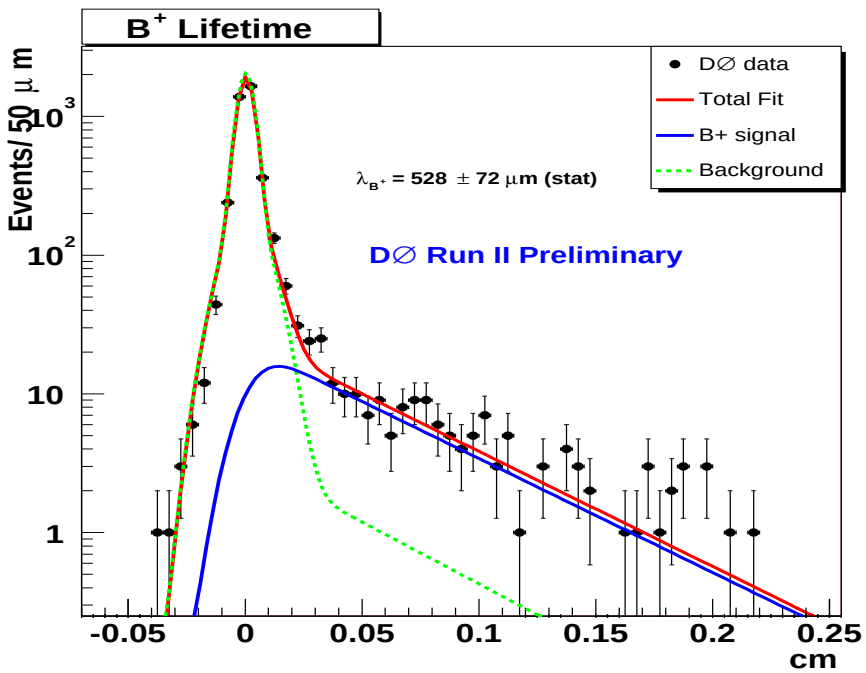
CDF July 2002 (18 pb^{-1})	τ	$= 1.526 \pm 0.034(stat.) \pm 0.035(syst.)$ ps
D0 March 2003 (40 pb^{-1})	τ	$= 1.561 \pm 0.024(stat.) \pm 0.074(syst.)$ ps
PDG 2002	τ	$= 1.564 \pm 0.014$ ps

Di-muon: B exclusive lifetime





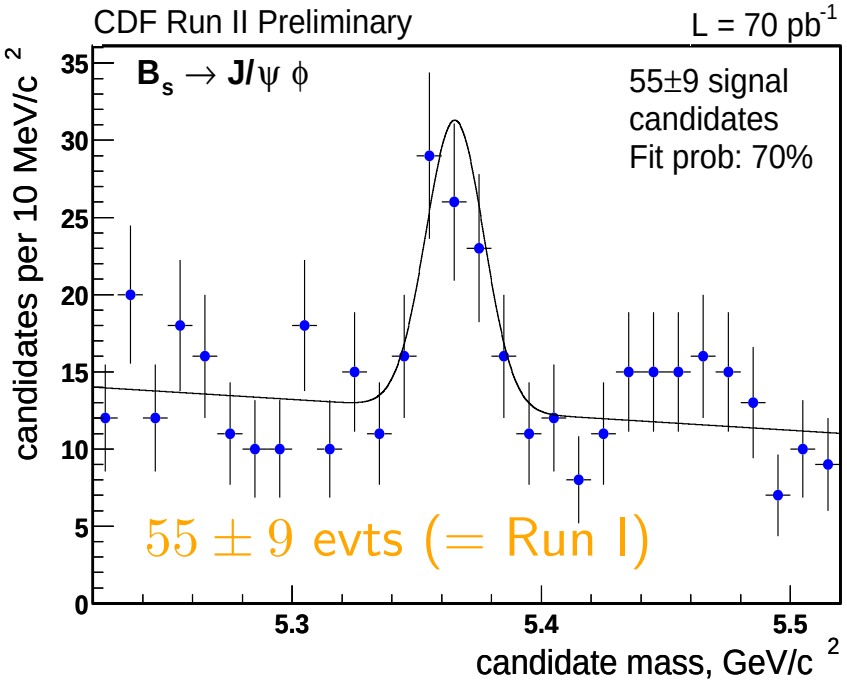


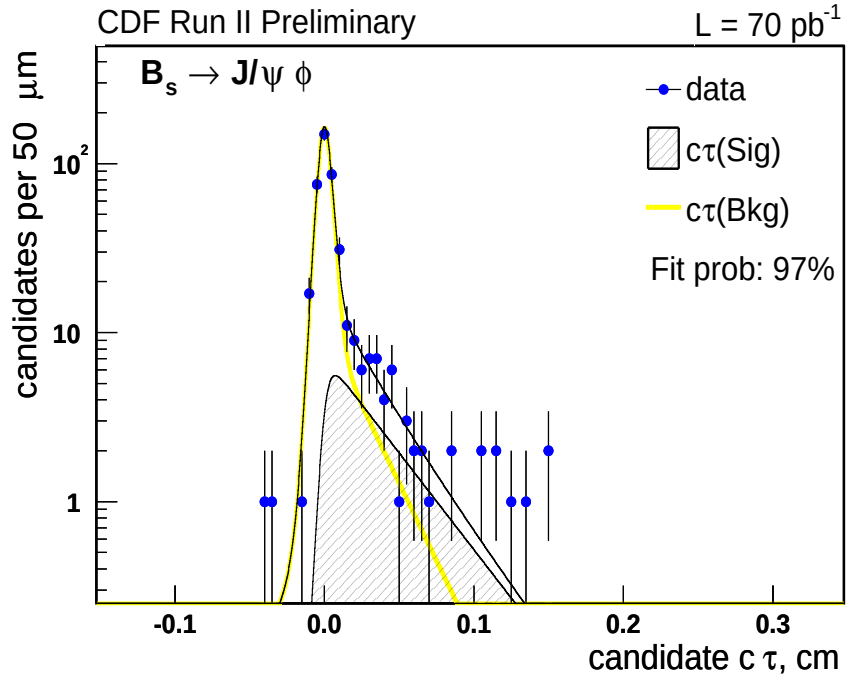


Di-muon: B exclusive lifetime

⇒ $B^+ \to J/\psi K^+$ and $B^0 \to J/\psi K^{*0}$: control sample for systematics.

⇒ Measurements: $\tau(B_s)$, $\tau(B^0)/\tau(B^+)$, $\tau(B_s)/\tau(B_d)$, (+ β_s phase)





CDF results

$$\tau_{B^+} = 1.57 \pm 0.07\ (stat.) \pm 0.02\ (syst.)\ \text{ps}$$
$$\tau_{B^0} = 1.42 \pm 0.09\ (stat.) \pm 0.02\ (syst.)\ \text{ps}$$
$$\tau_{B_s} = 1.26 \pm 0.20\ (stat.) \pm 0.02\ (syst.)\ \text{ps}$$

$$\tau_{B^+}/\tau_{B^0} = 1.11 \pm 0.09$$
$$\tau_{B_s}/\tau_{B_d} = 0.89 \pm 0.15$$

Di-muon: opposite-side tagging

Next step: tagging of the B flavor at production

Opposite-side tagging:

- semileptonic decay of other B: $b \to c l^- \bar{\nu}$
- jet charge: $\sum Q_i p_T^i$
- kaon tagging

Figures of merit:

$$\epsilon = \frac{N_{correct} + N_{wrong}}{N_{correct} + N_{wrong} + N_{notag}}$$

$$D = \frac{N_{correct} - N_{wrong}}{N_{correct} + N_{wrong}}$$

- tag always right: $D = 1$
- tag right 50% of the time: $D = 0$

Effective tagging efficiency: ϵD^2

D0 Run-II Preliminary

Soft Muon Tagging

- highest p_T muon
- ΔR(reconstructed B) > 2
- $p_T > 1.9$ GeV$/c$

$$\begin{aligned} \epsilon &= 8.2 \quad \pm 2.2\% \\ D &= 63.9 \quad \pm 30.1\% \\ \epsilon D^2 &= 3.3 \quad \pm 1.8\% \end{aligned}$$

Jet Charge Tagging

- tracks away from the B
- $|Q| > 0.2$

$$\begin{aligned} \epsilon &= 55.1 \quad \pm 4.1\% \\ D &= 21.0 \quad \pm 10.6\% \\ \epsilon D^2 &= 2.4 \quad \pm 1.7\% \end{aligned}$$

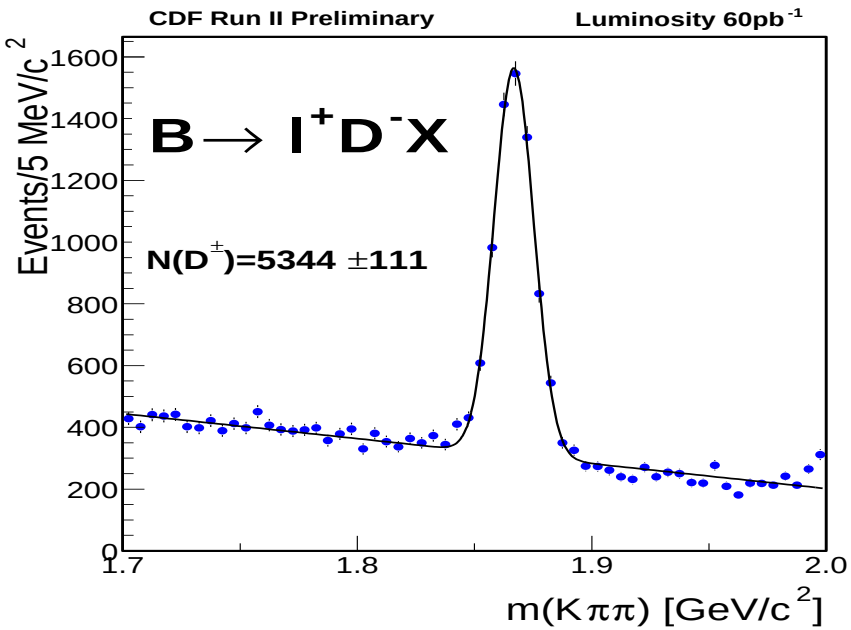
Lepton + displaced track: semi-leptonic decays

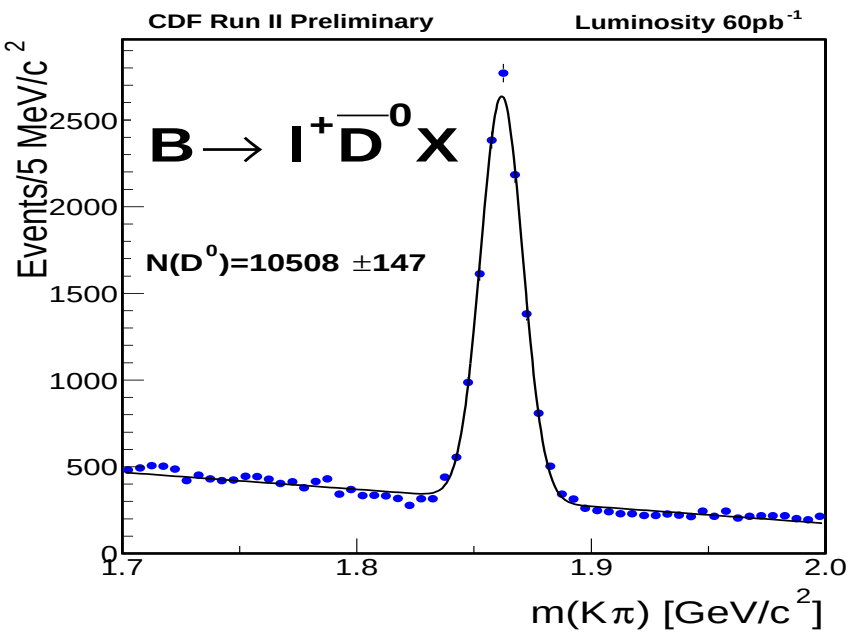
Unbiased sample for tagging studies:

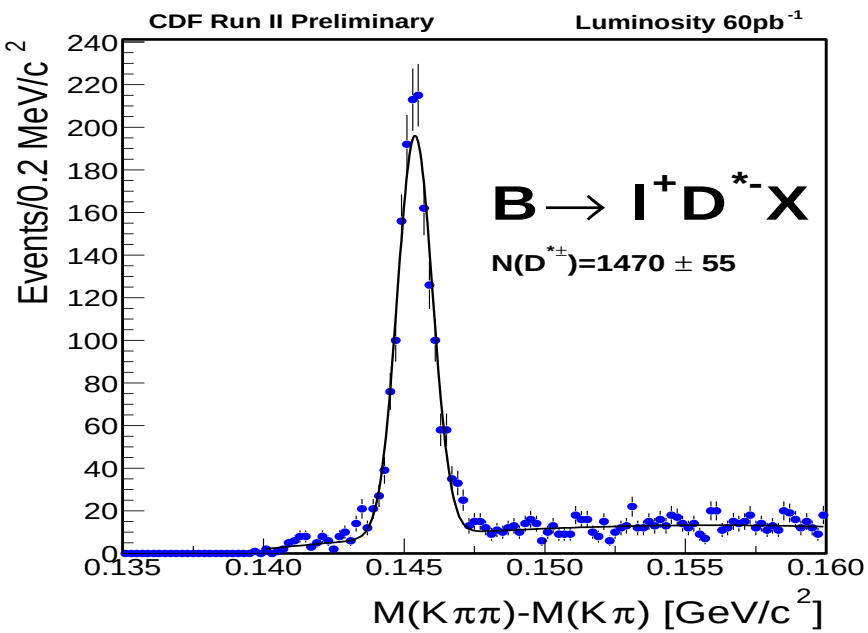
- flavor tagged
- high B contents
- large statistics

Measurements:

- lifetime measurements
- test of HQET+OPE (hadronic mass moments)







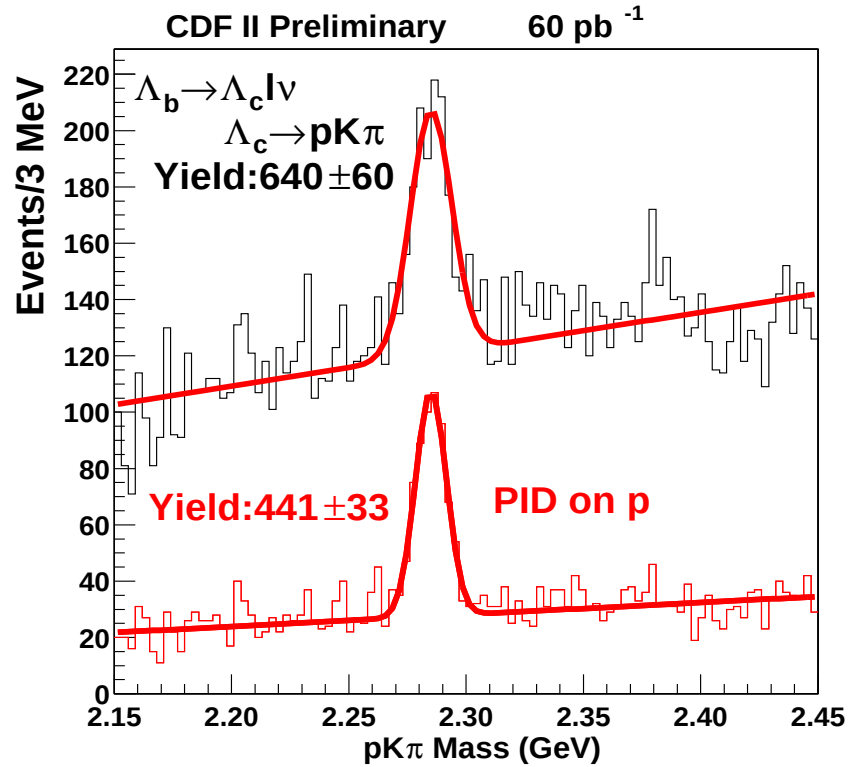
Lepton + displaced track: Λ_b

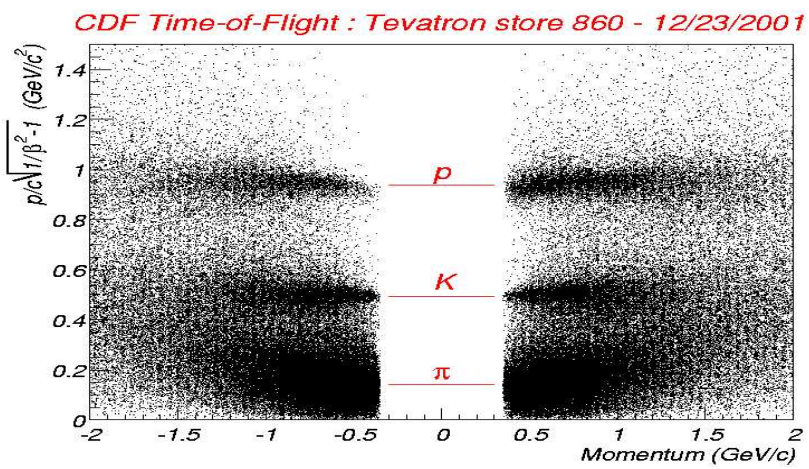
Measurement:

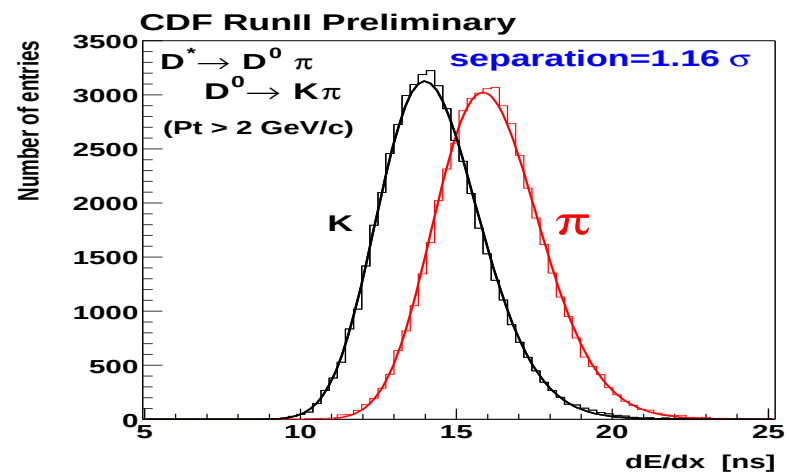
- Λ_b lifetime
- Λ_b branching ratios
- test of HQET (/ B)

Proton ID:

- dE/dx (drift chamber)
- TOF
  - 100 ps @ 140 cm





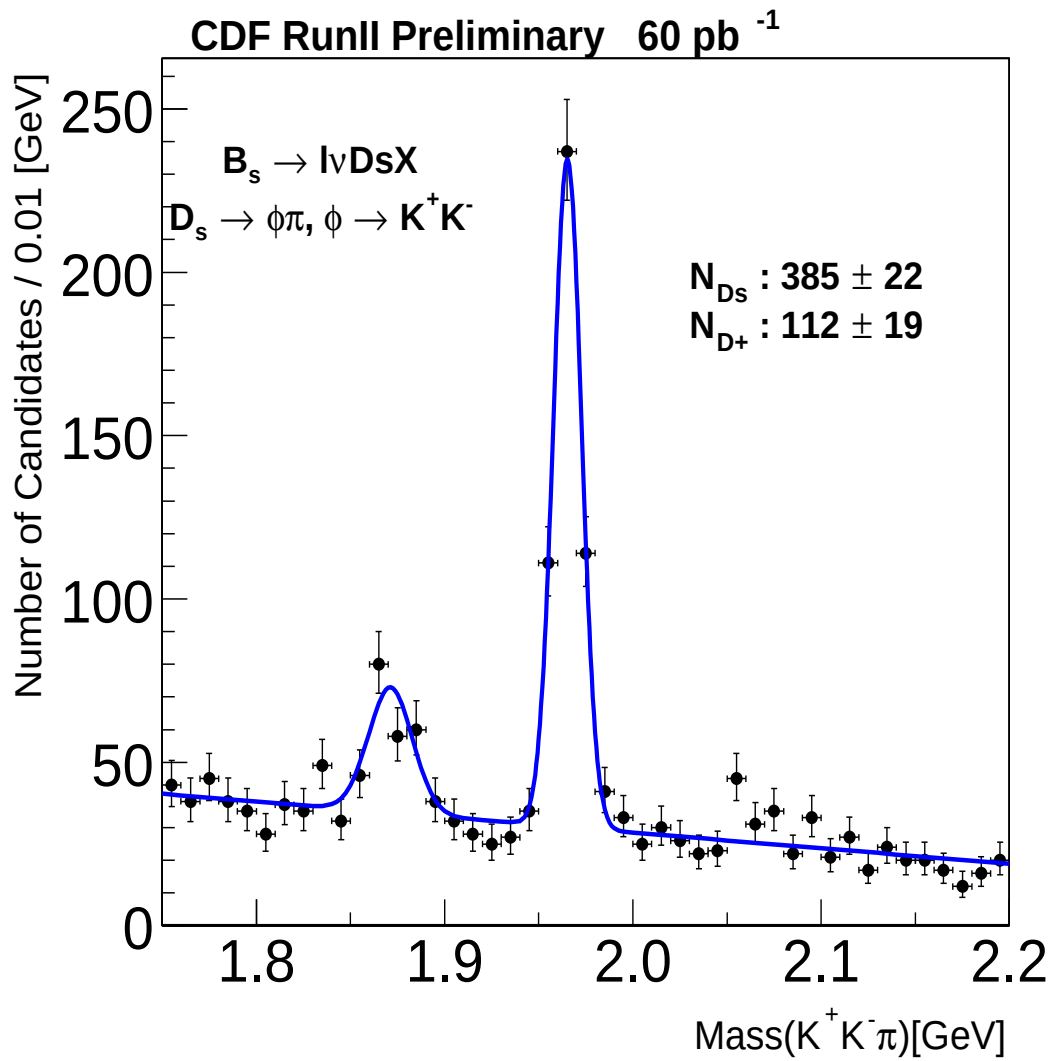


Lepton + displaced track: inclusive B_s

$$B_s \to D_s l\nu X \to [\phi\pi] l\nu X \to [[K^+K^-]\pi] l\nu X$$

385 ± 22

- high statistics
- lifetime $\tau(B_s)/\tau(B_d)$
- mixing:
  - good S/N
  - partial reconstruction
  - $\Rightarrow$ limited time resolution
  - $\Rightarrow$ for moderate x_s
  - $\Rightarrow$ back-up sample

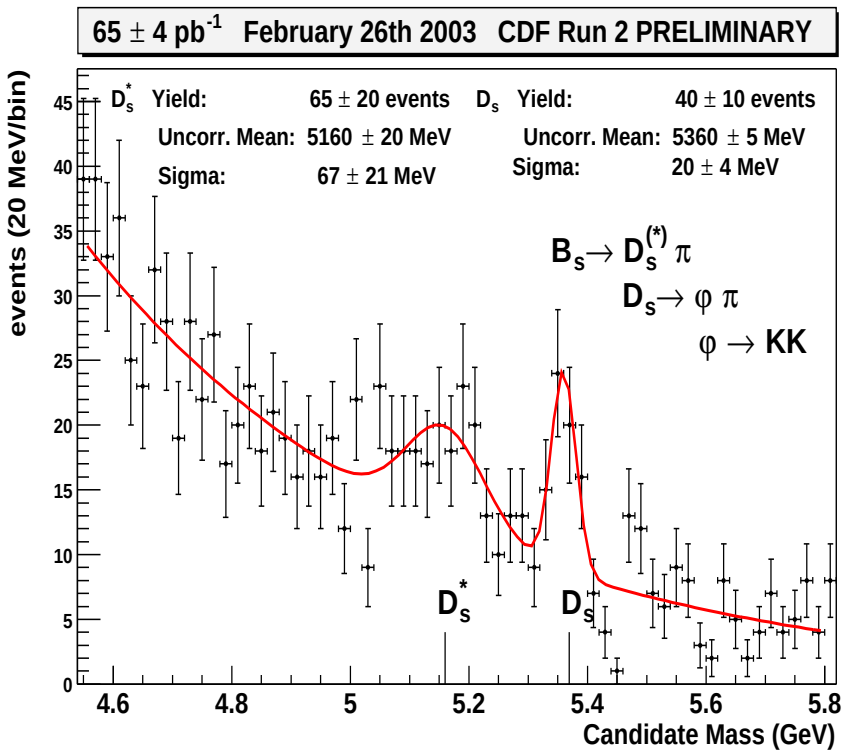


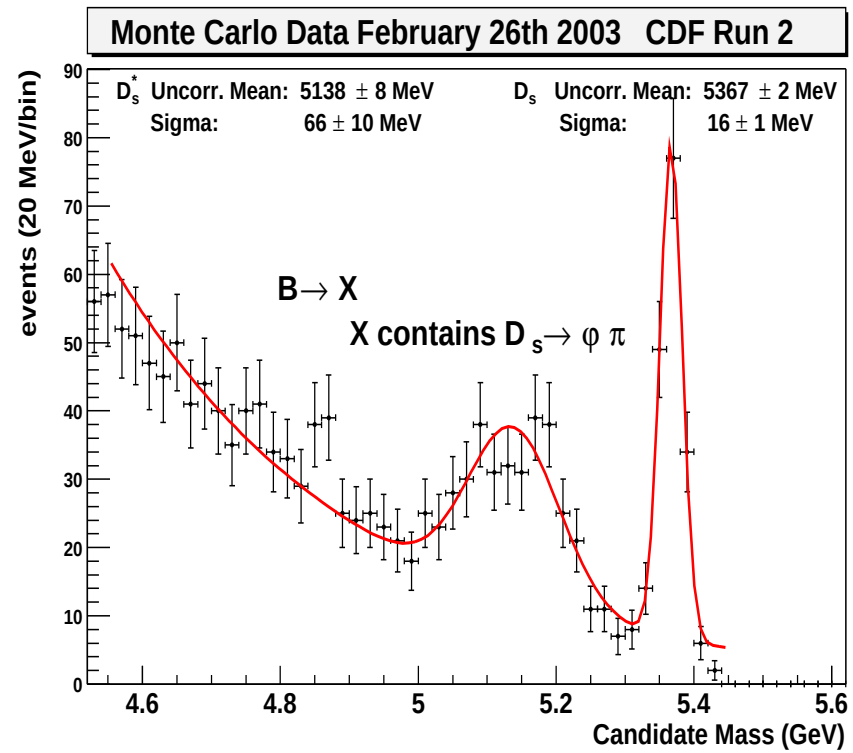
Two-track trigger: B_s

$$B_s \to D_s^{(*)-}\pi^+, \quad B_s \to D_s^{(*)-}3\pi, \quad B_s \to D_s^{(*)-}D_s^{(*)+}$$

- golden sample for B_s mixing: resolve fast oscill.
- already some channels fully reconstructed: $40 \pm 10\ D_s$, $65 \pm 20\ D_s^*$

$B_s \to D_s\pi \to [\phi\pi]\pi \to [[K^+K^-]\pi]\pi$ MC: $B \to X \to D_sX \to [\phi\pi]X$

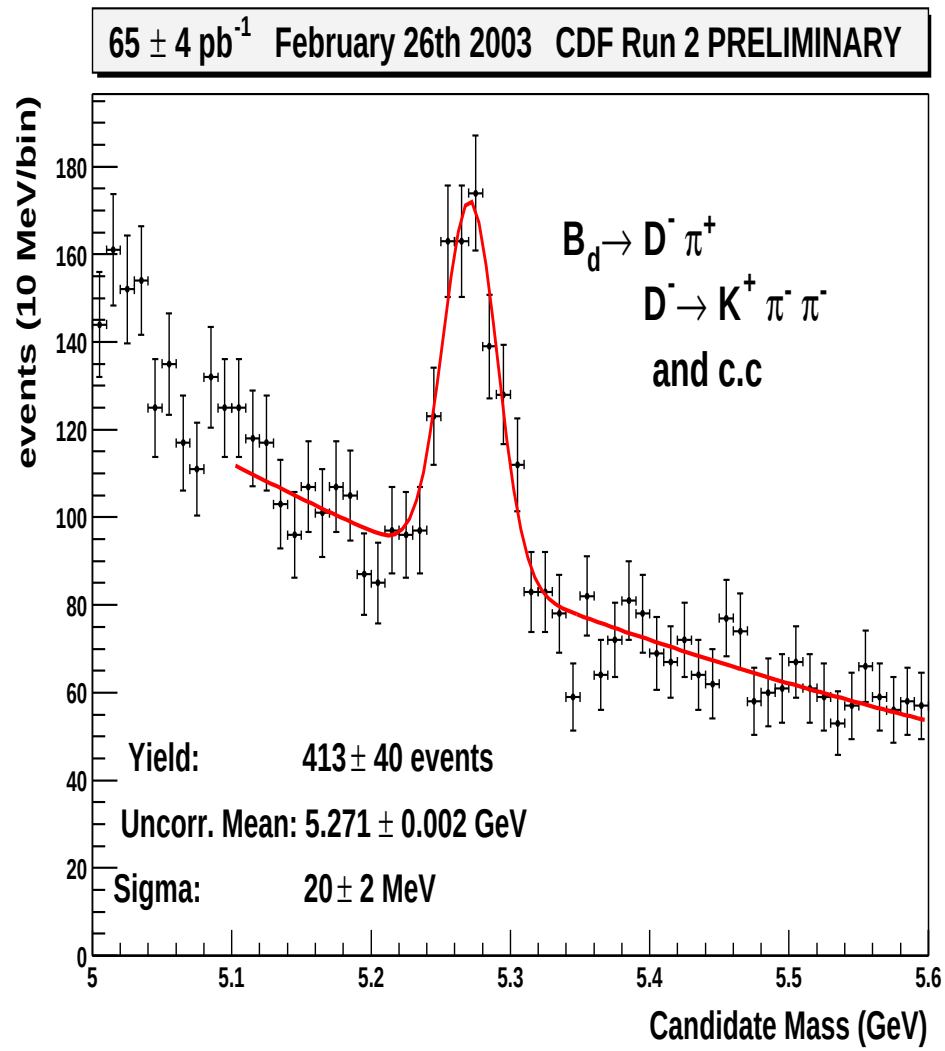




Two-track trigger: B_s

$$B^0 \to D^- \pi^+ \to [K^+ \pi^- \pi^-] \pi^+$$

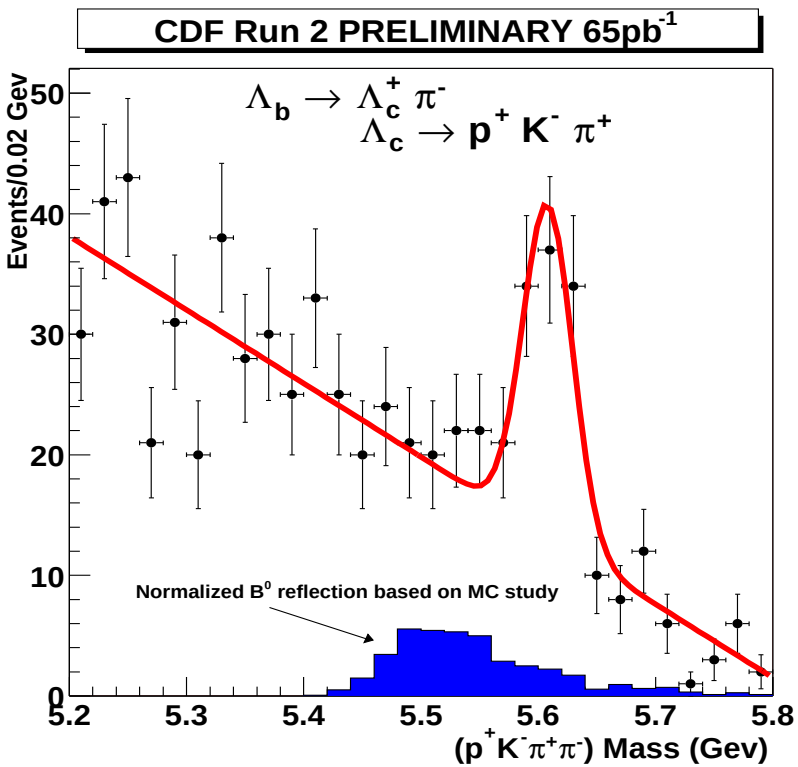
- control sample for $B_s \to D_s^{(*)-} \pi^+$
- $B \to D\pi$ gives the normalization for B_s branching ratio
  - same trigger
  - same reconstruction

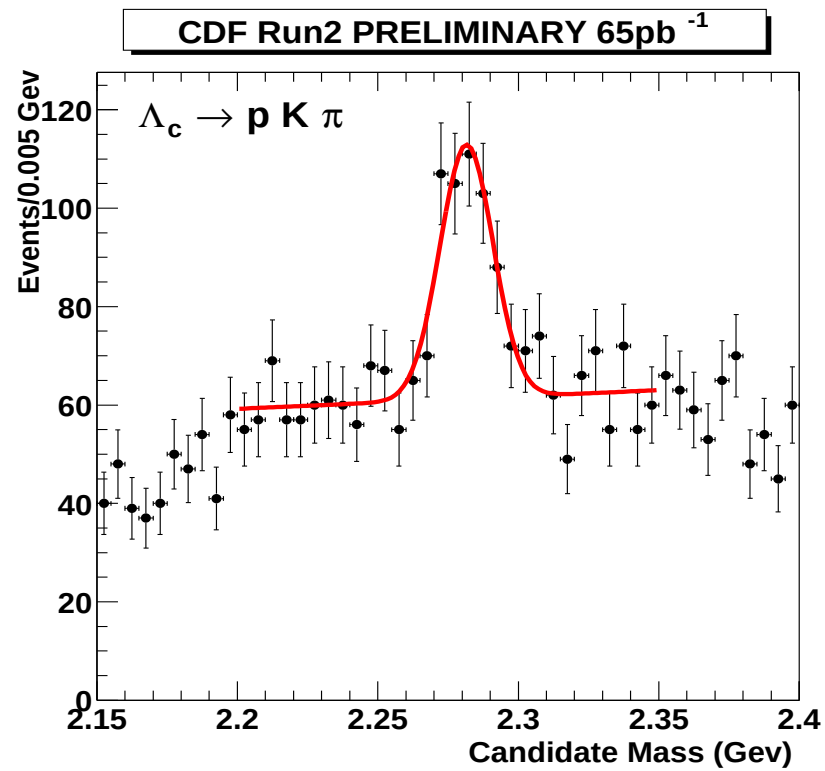


Two-track trigger: Λ_b

$$\Lambda_b^0 \to \Lambda_c^+ \pi^- \to [p^+ K^- \pi^+]\pi^-$$

- Lifetime and branching ratios
- No PID



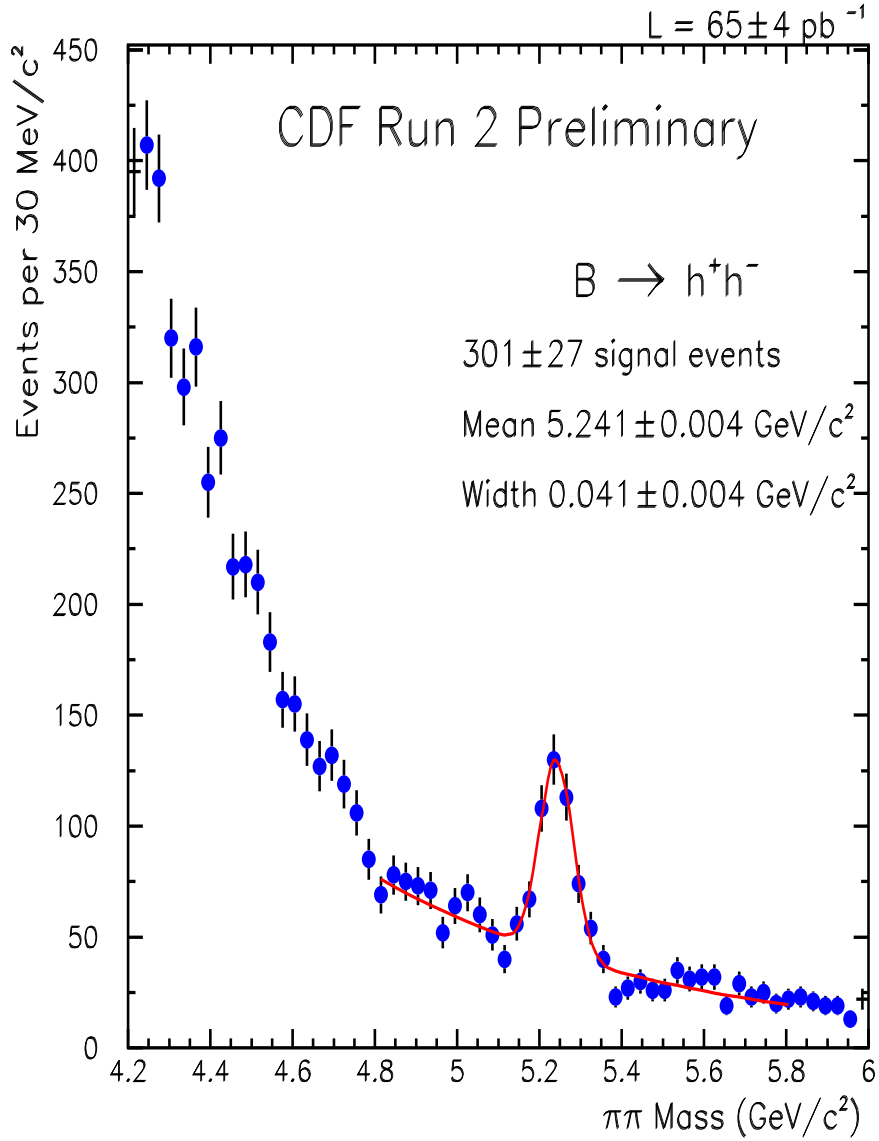


Two-track trigger: $B \to h^+h^-$

$$B_d^0 \to K^+\pi^-, \pi^+\pi^-$$

$$\bar{B}_s^0 \to K^+K^-, K^+\pi^-$$

- $B^0 \to \pi^+\pi^-$: $\sin 2(\beta+\gamma)$
- however: penguin pollution
- measuring both B_d and B_s
- very good signal/noise
- rates understood
- on-going: disentangle channels (kinematics + dE/dx)
- direct $\not{C}$P in $B_d \to K\pi$?



Conclusion

Detectors understanding and calibration well advanced

Build-up confidence with exclusive $B^+, B^0, \ldots$
First almost competitive analyses: B_s mass, lifetime
Signals seen in many channels for flagship analyses, need more statistics

Displaced track trigger at CDF:

- a great success !
- very promising for hadronic decays
- many more uses ($l + SVT$,...)
- access to Δm_s via $B_s \to D_s(3)\pi$
- $\Delta\Gamma_s$ via $B_s \to D_s D_s$ ($+ B_s \to J/\psi\phi$)

A lot of exciting physics !