B Physics at CDF

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XVII Les Rencontres de Physique de la Vallee d'Aoste
La Thuile

March 2003

Outline

Introduction - CDF

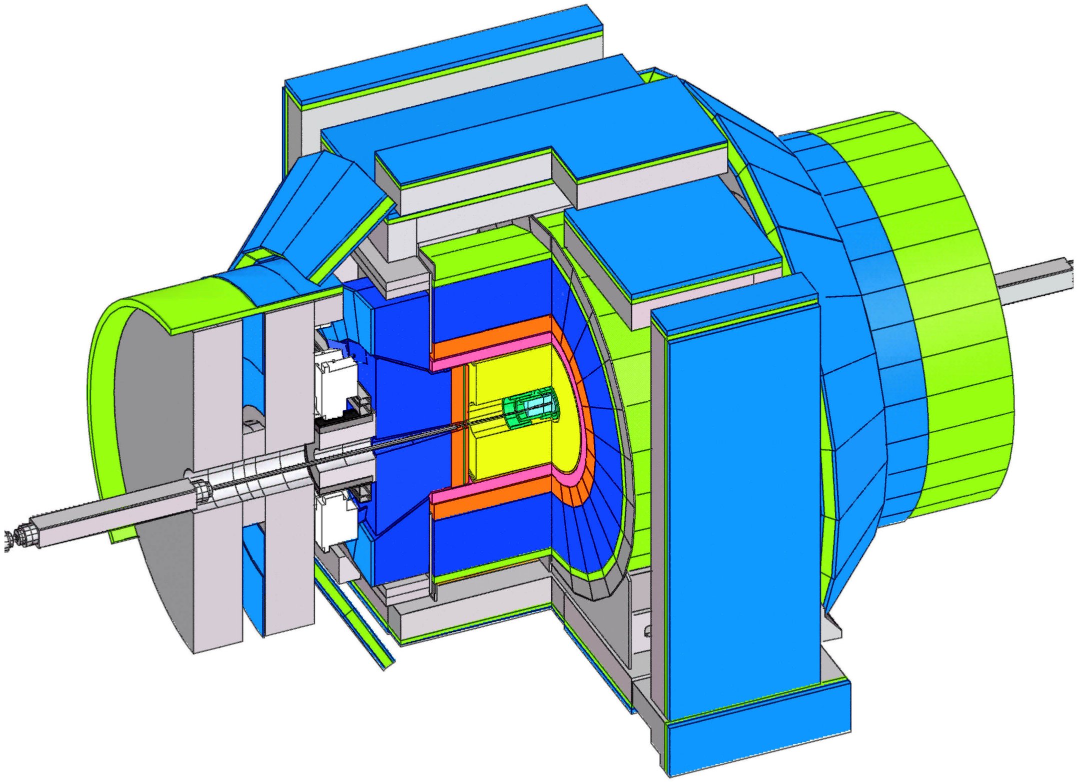
The CDF B Physics Program - Results

Conclusions

CDF Run 2 Detector

Detector improvements

- Track trigger
  - Fast turn on of track trigger just below $p_T = 1.5\text{GeV}$
- Increased silicon coverage
  - 1 meter long central detector
  - Tracking up to $|\eta| = 2$
  - Displaced track trigger at Level 2
- Increased muon coverage
  - Coverage extended to $|\eta| = 1.5$
  - Track/Muon triggers to $|\eta| = 1.0$
- Time of Flight: π K p particle ID
- Trigger
  - 50KHz Level 1 - 50Hz to tape



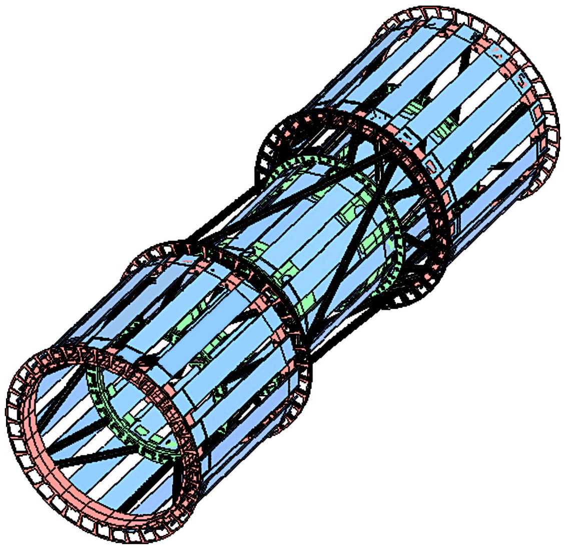
Run 2 Silicon

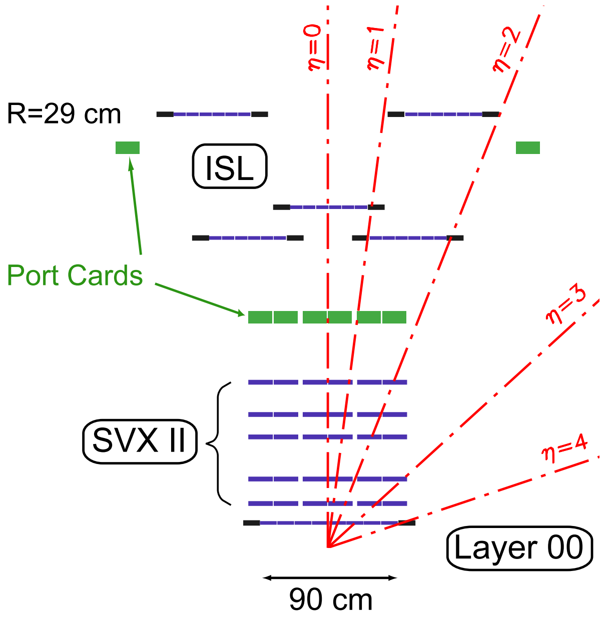
Features

- 8 layers(7 stereo)
- Standalone tracking for $|\eta| < 2.0$
  - ISL extends range
- 3D tracking - 3 layers of 90^{o} strips
- L00
  - Precision measurement point at $1.3 - 1.6\mathrm{cm}$

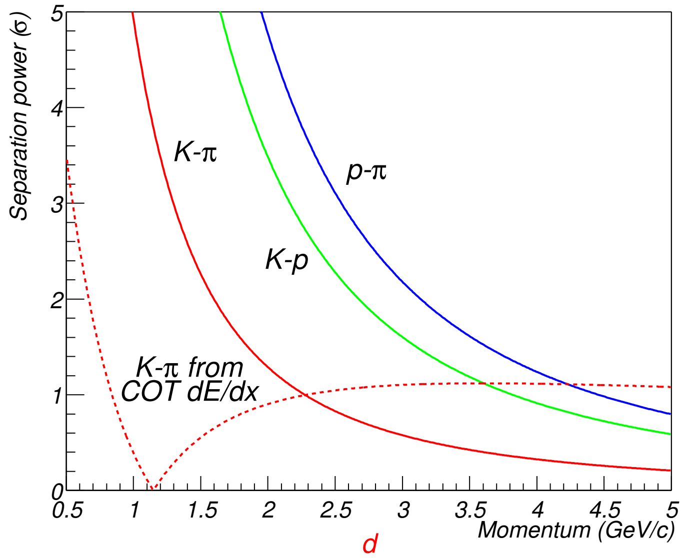
Silicon Vertex Trigger(SVT)

- 5 layer trigger
  - Displaced track trigger
  - Cuts at $120\mu m$
  - $35\mu m$ resolution ($\sim 50\mu\mathrm{m}$ with beam line)

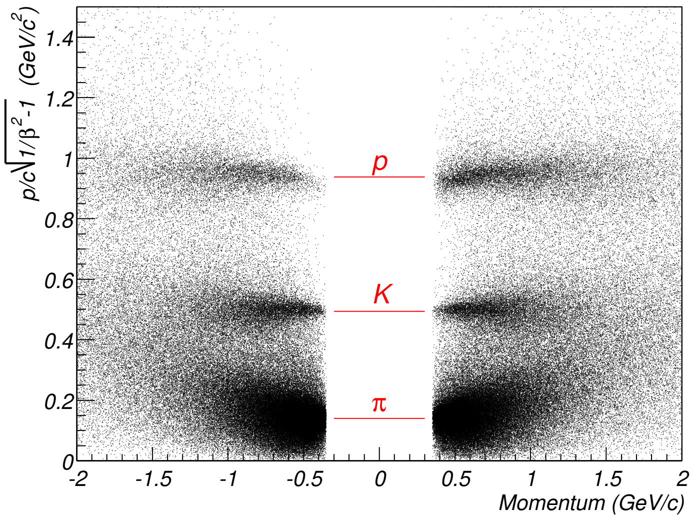




PID: dE/dx and Time of Flight



CDF Time-of-Flight : Tevatron store 860 - 12/23/2001



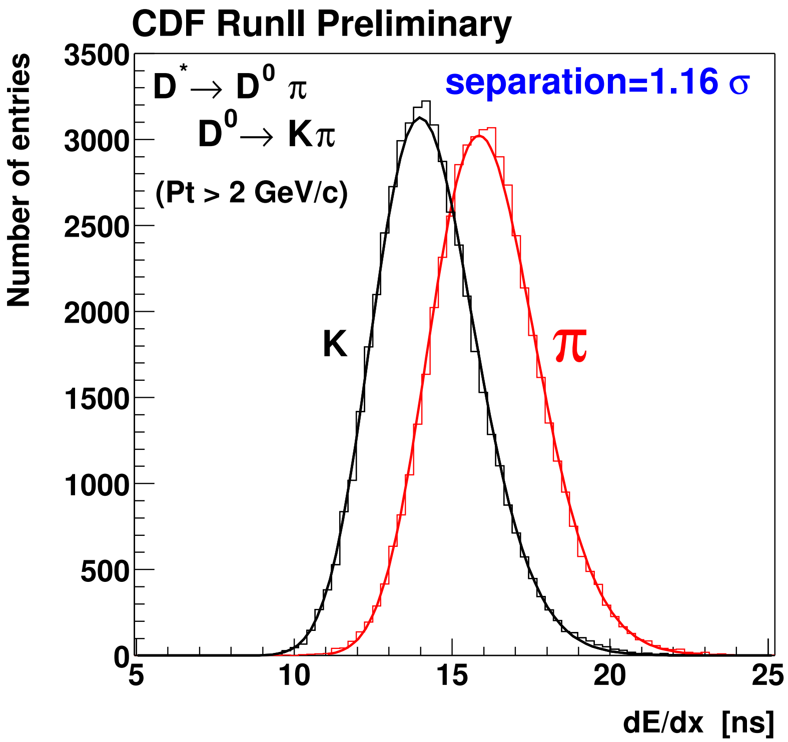
Combined PID system

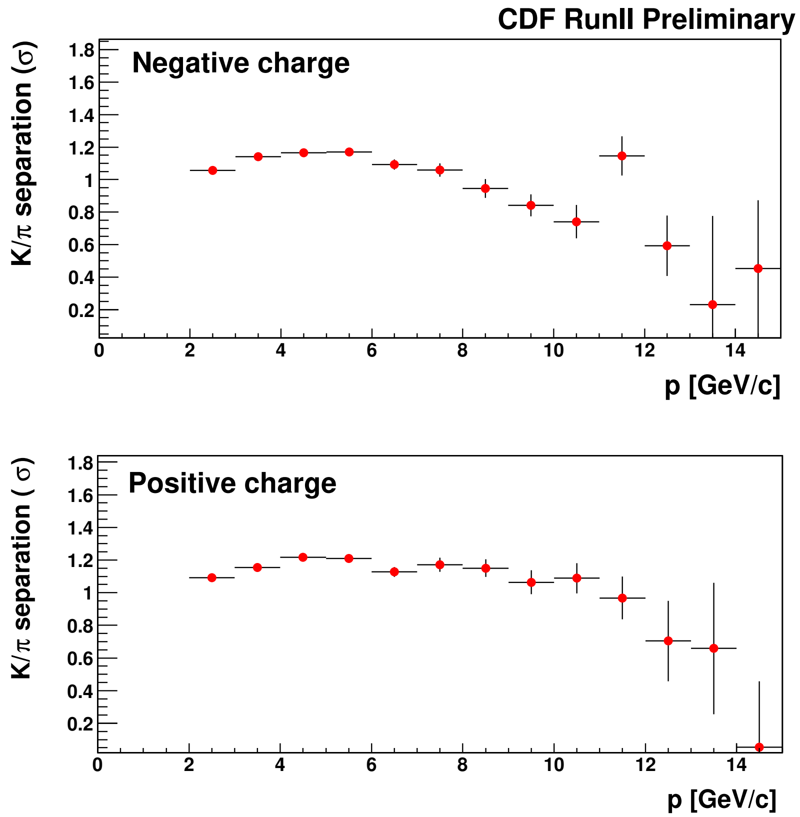
- Time of Flight: TOF
  - 100ps time resolution at 1.4m (at PMT face)
  - 2σ separation for $\mathrm{K}\ \pi$ below $1.6\mathrm{GeV}$
  - Separation for protons out to 2.7-$3.2\mathrm{GeV}$
  - Currently achieving 110ps resolution $\sim$125ps averaged over all z
- dE/dx using the drift chamber
  - All wires instrumented for dE/dx
  - Separation at higher momentum where TOF has no sensitivity

PID: dE/dx

dE/dx using the drift chamber

- Evaluated dE/dx performance using $D^* \to D^0\pi$ signal
  - K purity $\sim 95\%$ (from charge correlation)





- Fit using Log-Normal fit function
  - Separation based on variance

B Physics with Run 2 CDF

B physics at the Tevatron

- All B species: B^+, B^0, B_s, B_c, Λ_b ...
- Production: $10\mu b$ for $p_T > 6.0GeV$ and $|y| < 1$
  - 1000 b's per second at design luminosity

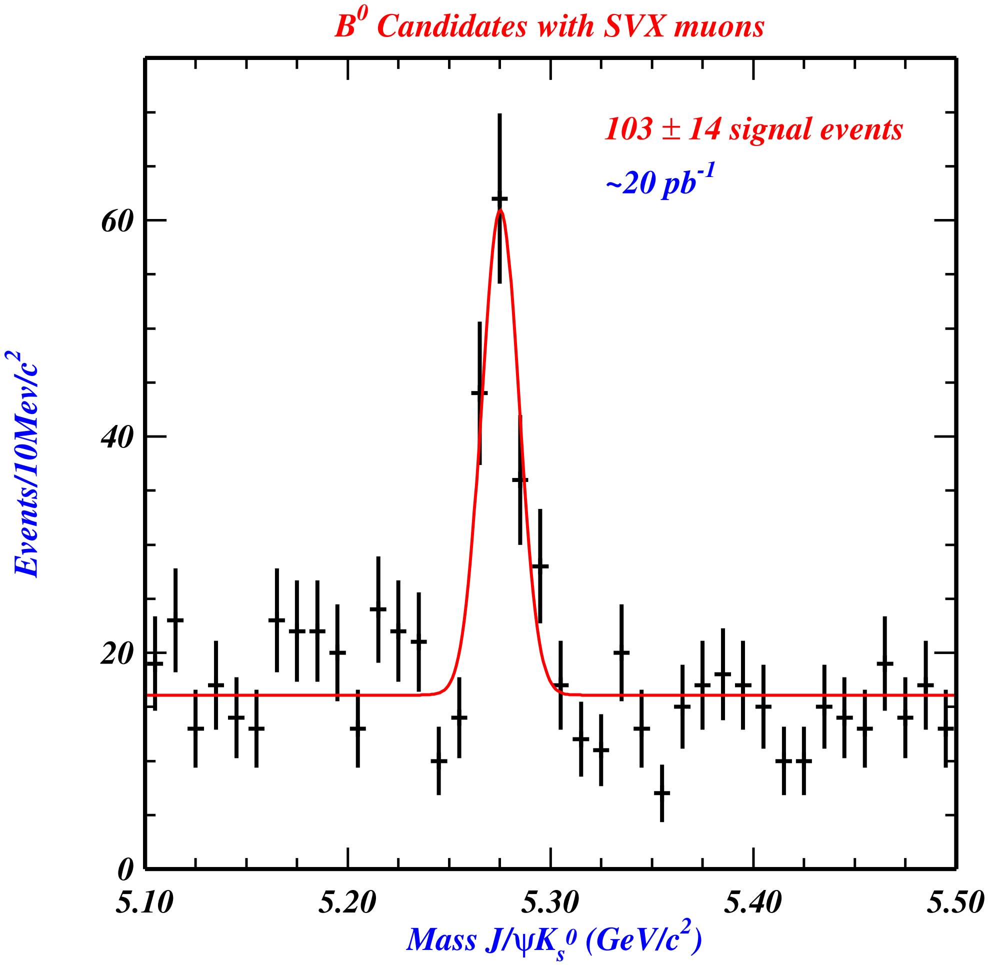
B physics signatures

- QCD physics
  - J/ψ cross section and B fraction Down to $0GeV$: μ trigger goes to $1.5GeV$
  - Total B production cross section
  - Quarkonium states: $\Upsilon(1S)$ and $\chi_b \to Upsilon(1S)$ feeddown
- CP violation and mixing
  - B_s mixing, x_s: $B_s^0 \to D_s\pi$
  - $\sin(2\beta)$: $B^0 \to J/\psi K_s^0$
  - Weak phase of V_{ts}: $B_s^0 \to J/\psi\phi$
  - CP asymmetry: $B^0(B_s^0) \to hh$
  - γ: $B_s^0 \to D_s^- K^+ ...$
- Properties of B_s, B_c, Λ_b...
  - Production, Mass and lifetime
- Rare Decays
  - $B \to \mu\mu K^{(*)}$
  - Even beyond the standard model physics: $B^0, B_s \to \mu\mu$ and $B_s \to e\mu$

J/ψ **Signatures:** B^0

$\mathrm{B}^0 \rightarrow \mathrm{J}/\psi \mathrm{K}^0_\mathrm{s}$, $\mathrm{K}^0_\mathrm{s} \rightarrow \pi^+\pi^-$

- Measures $\sin(2\beta)$
  - Look at the CP asymmetry in the decay rates of B^0 and $\bar{\mathrm{B}}^0$
  - Will need to tag the original flavor
- Using dimuon trigger
  - Similar to run 1
  - Muon/track trigger now efficient down to $1.5\mathrm{GeV}$and out to $|\eta| = 1$
- Analysis Cuts
  - Silicon on J/ψ legs
  - $2.99 < \mathrm{m}_{\mathrm{J}/\psi} < 3.17\mathrm{GeV}$
    $0.478 < \mathrm{m}_{\mathrm{K}^0_\mathrm{s}} < 0.517\mathrm{GeV}$
  - $\mathrm{p_{T_B}} > 4.5\mathrm{GeV}$, $\mathrm{p_{T_\phi}} > 0.7\mathrm{GeV}$
  - $\mathrm{Prob}(\chi^2_{2\mathrm{D}}) > 0.001$, J/ψ and K^0_s

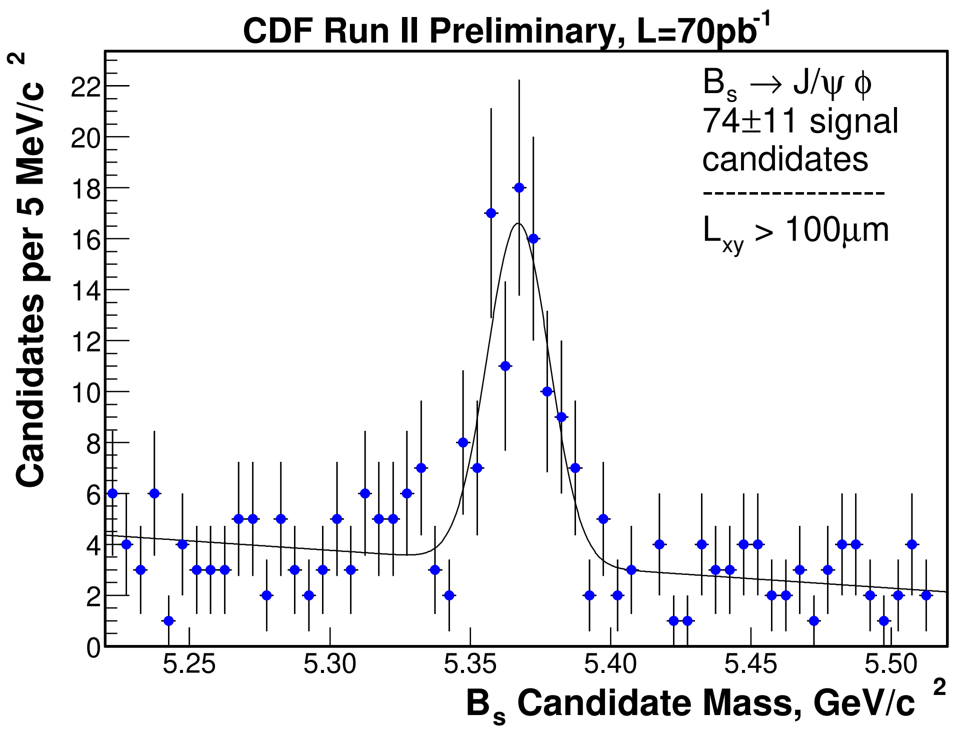


~ 200 events with $110\mathrm{pb}^{-1}$ in Run 1

J/ψ Signatures: B_s^0

$B_s^0 \to J/\psi\phi$, $\phi \to K^+K^-$

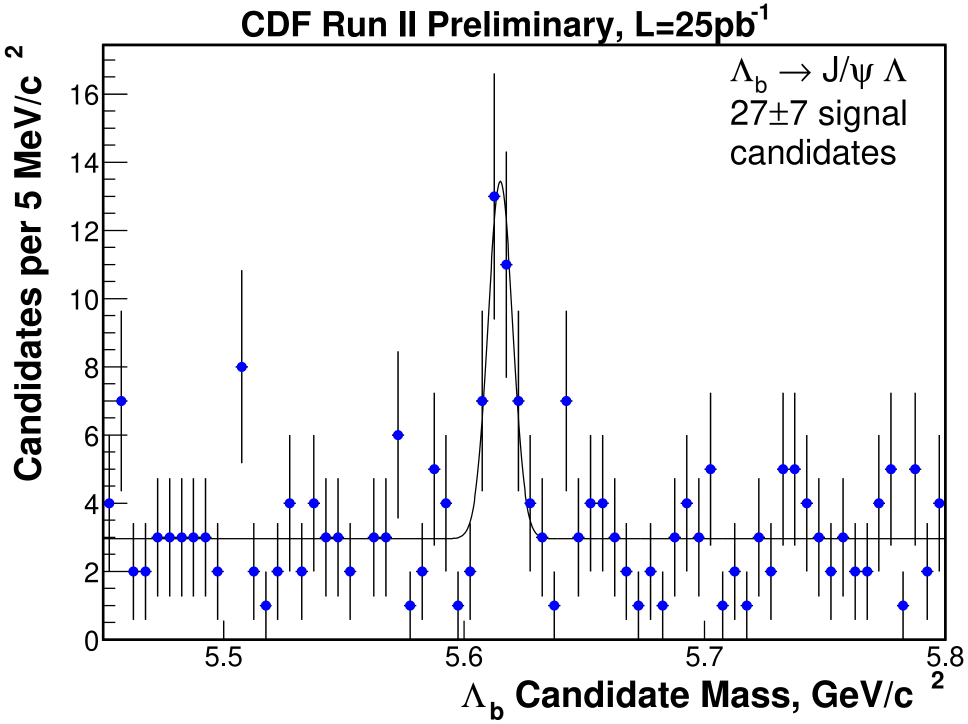
- Measures weak phase of V_{ts}
  - Look at the CP asymmetry in the decay rates of B_s^0 and $\bar{B}_s^0$
  - Will need to tag the original flavor
  - Time dependent
- Using dimuon trigger
  - Also benefits from Muon/track trigger improvements
  - Improved silicon precision using inner layer to extract time dependence
- Analysis cuts
  - Silicon on all legs
  - $1.004 < m_\phi < 1.034\text{GeV}$
  - $p_{T_B} > 4.0\text{GeV}$, $p_{T_\phi} > 1.75\text{GeV}$
  - $L_{xy} > 100\mu\text{m}, \text{Prob}(\chi^2_{2D}) > 0.001$



J/ψ Signatures: Λ_b

$\Lambda_b \to J/\psi\Lambda,\ \Lambda \to \mathrm{p}\pi$

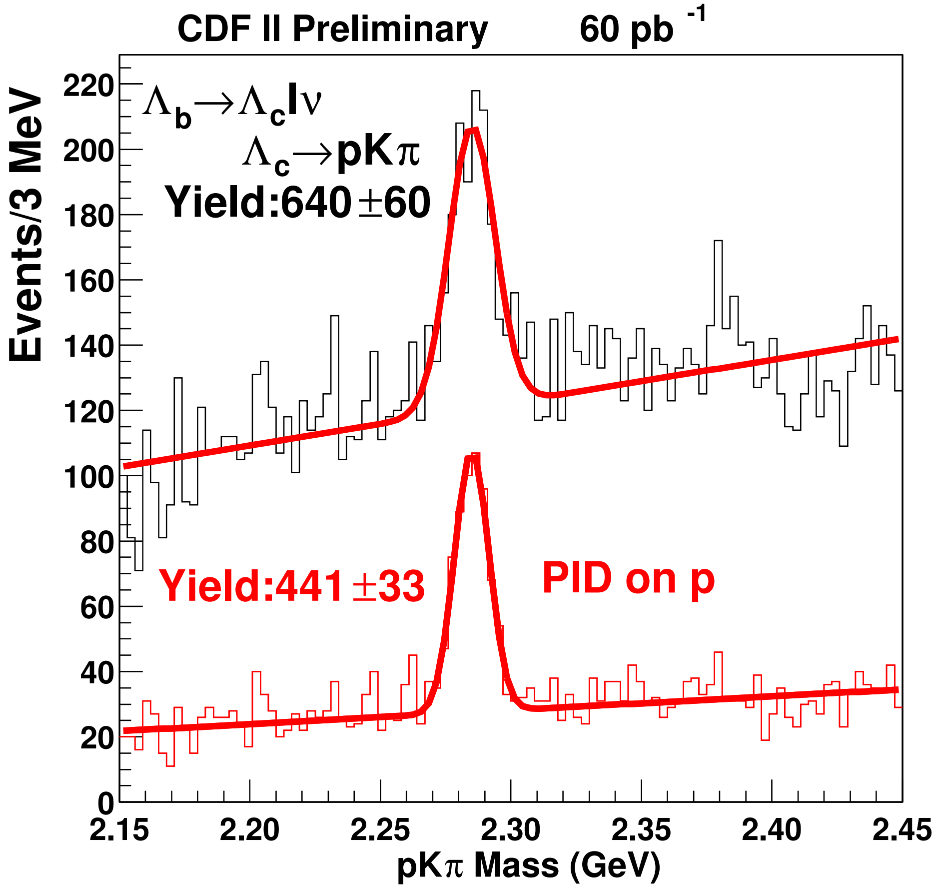
- Measure Λ_b mass and lifetime
- Using dimuon triggers
  - Trigger now goes to lower momentum and higher eta
- Using dimuon trigger
  - Silicon acceptance improves statistics for lifetime measurement
- Analysis cuts
  - Silicon on J/ψ legs
  - $2.99 < \mathrm{m_{J/\psi}} < 3.17\mathrm{GeV}$
    $1.107 < \mathrm{m_\Lambda} < 1.124\mathrm{GeV}$
  - $\mathrm{p_{T_B}} > 4.5\mathrm{GeV},\ \mathrm{p_{T_\Lambda}} > 0.7\mathrm{GeV}$
  - $\mathrm{Prob}(\chi^2_{\mathrm{2D}}) > 0.001$, J/ψ and Λ



Semileptonic Signatures: Λ_b

$\Lambda_b \to \Lambda_c l\nu$, $\Lambda_c \to pK\pi$

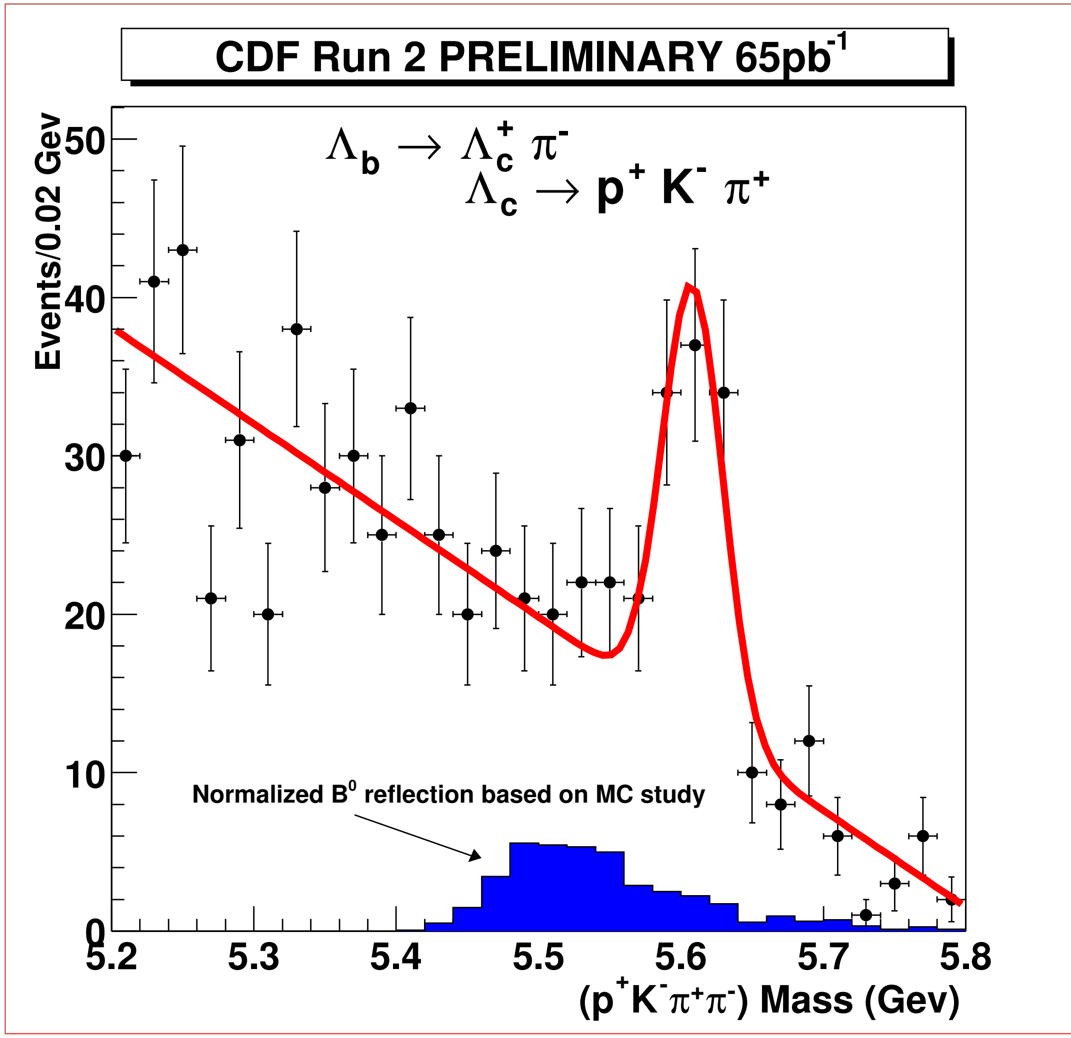
- Measure Λ_b lifetime and branching ratios
- Using inclusive lepton plus SVT data
  - 4GeV e or μ + 2GeV SVT track
  - SVT track can be any of the three hadrons
  - dE/dx and TOF used for proton ID
- Analysis cuts
  - Silicon on all legs
  - $3.5 < m_{l+\Lambda_c} < 5.6\text{GeV}$
  - $p_{T_B} > 9.0\text{GeV}$, $p_{T_{\Lambda_c}} > 5.0\text{GeV}$



Hadronic Signatures: Λ_b

$\Lambda_b \to \Lambda_c \pi$, $\Lambda_c \to pK\pi$

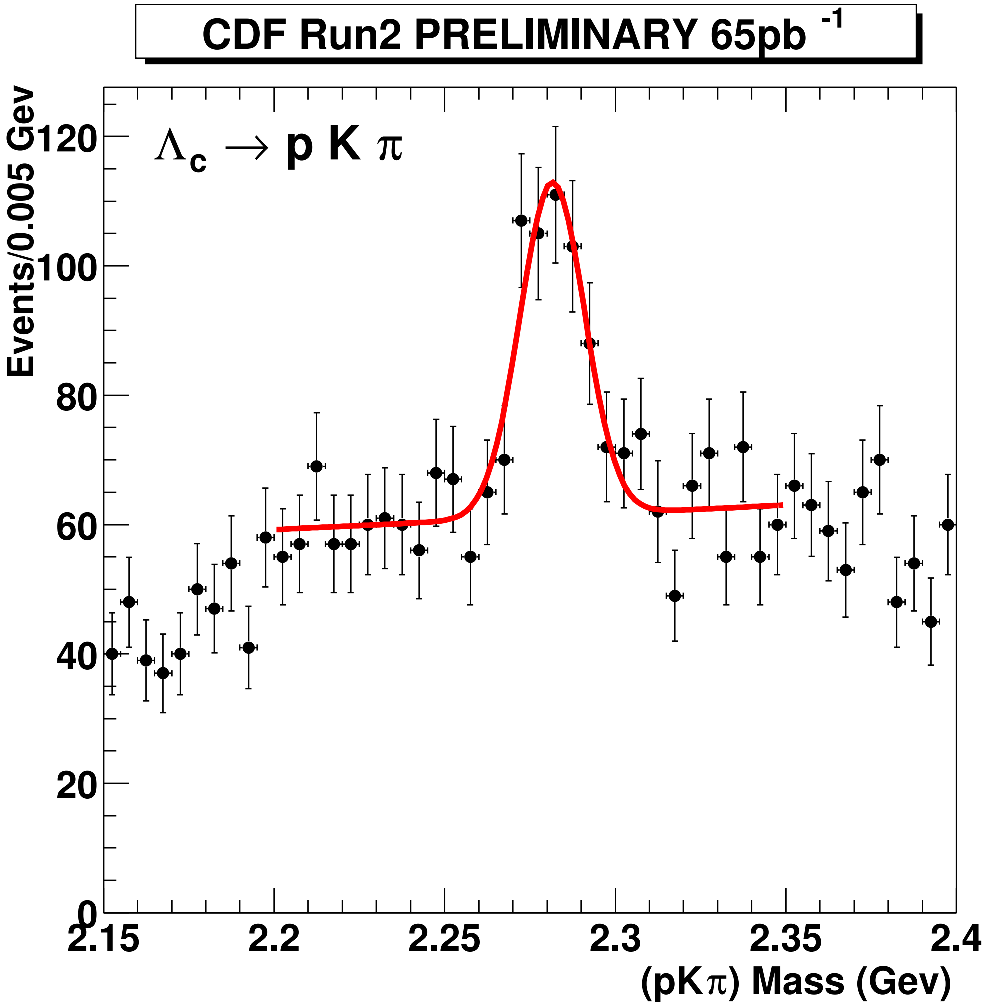
- Measure Λ_b lifetime and branching ratios
- Using hadronic trigger: SVT
  - Two tracks with displaced impact parameter
  - Can be any of the four tracks
  - Could use TOF and dE/dx for proton ID
- Analysis cuts
  - Silicon on all legs
  - $2.264 < m_{\Lambda_c} < 2.305\mathrm{GeV}$
  - $p_{T_B} > 7.5\mathrm{GeV}$, $p_{T_{\Lambda_c}} > 4.5\mathrm{GeV}$
  - $d0(\Lambda_b) < 85\mu m$



Hadronic Signatures: Λ_c from Λ_b

$\Lambda_b \to \Lambda_c \pi$, $\Lambda_c \to pK\pi$

- m_{Λ_c} from Λ_b
- Λ_b selection applied
- Wide mass cut around Λ_b
  - $5.2 < m_{\Lambda_b} < 5.8\mathrm{GeV}$

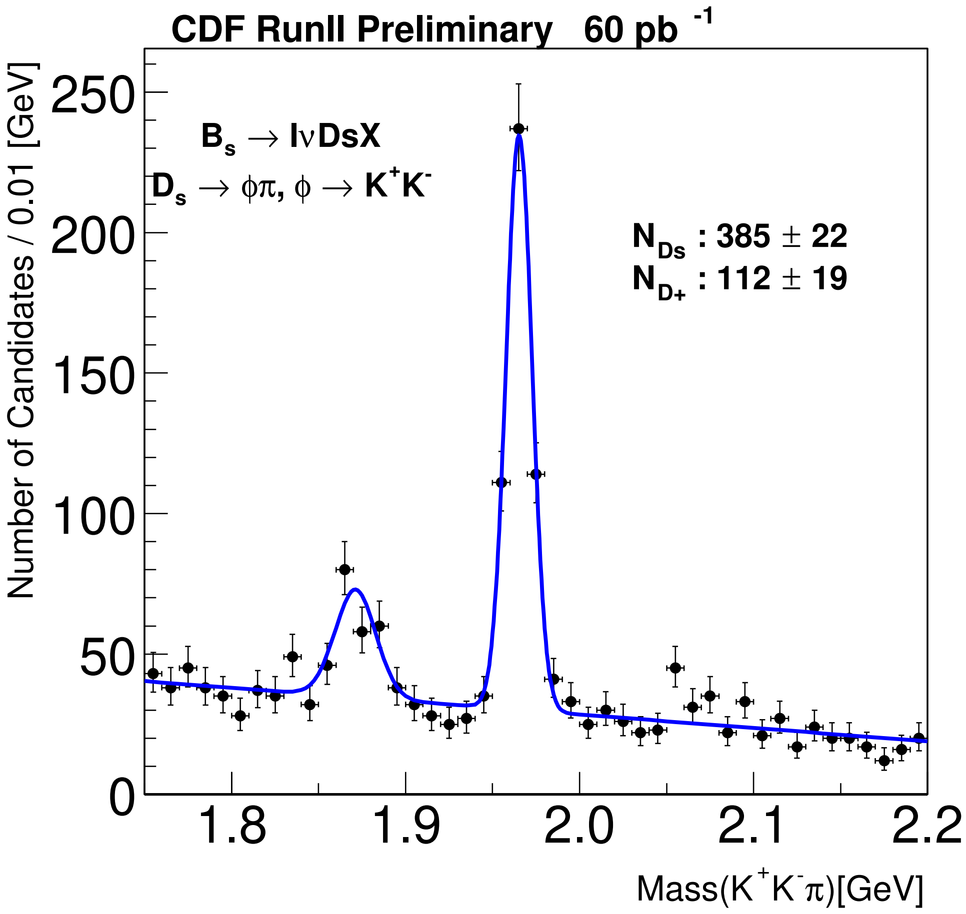


Semileptonic Signatures: $\mathrm{B_s^0}$

$\mathrm{B_s^0 \rightarrow D_s l \nu X}$

$\mathrm{D_s} \rightarrow \phi\pi$ and $\phi \rightarrow \mathrm{K^+K^-}$

- Measurements
  - Lifetime
  - Could be used for $\mathrm{B_s}$ mixing: $\mathrm{x_s}$ (less sensitivity than fully reconstructed modes)
- Using Lepton + SVT trigger
  - $\mathrm{4GeV\ e\ or\ } \mu + \mathrm{2GeV\ SVT\ track}$
  - Silicon improves acceptance for lifetime measurements
- Analysis cuts
  - Silicon on all legs
  - $1.011 < \mathrm{m}_\phi < 1.027\mathrm{GeV}$ $3.0 < \mathrm{m_{D_s\ell}} < 5.0\mathrm{GeV}$
  - $\mathrm{L_{xy(B_s-D_s)}} < 400\mu\mathrm{m}$

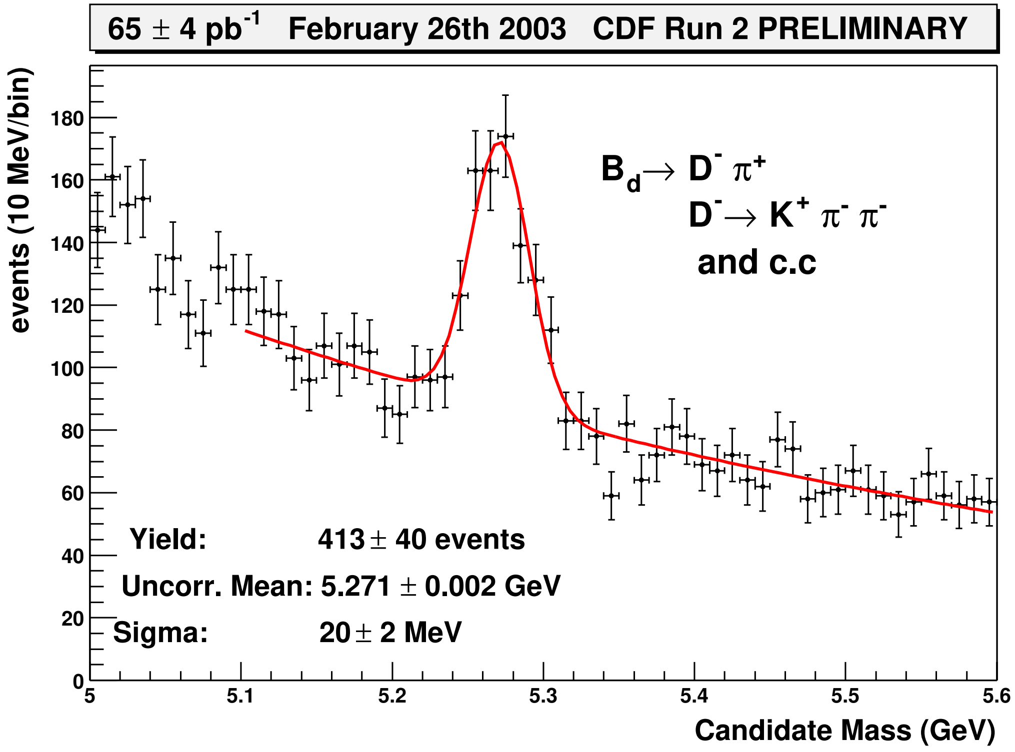


Hadronic Signatures: B^0

$\mathrm{B}^0 \to \mathrm{D}^-\pi^+$

$\mathrm{D}^- \to \mathrm{K}^+\pi^-\pi^-$ and cc

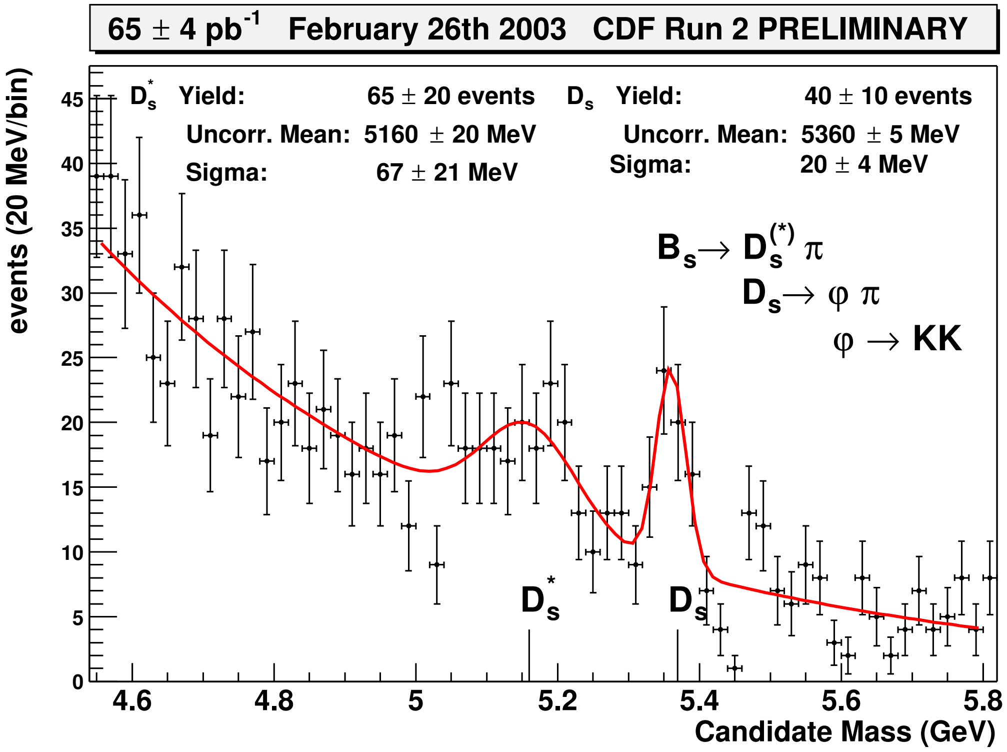
- For normalization of B^0_s branching ratio
- Using hadronic trigger: SVT
  - Two tracks with displaced impact parameter
  - Can be any of the four tracks
- Analysis cuts
  - Silicon on all legs
  - $\mathrm{p_{T_B}} > 6.0\mathrm{GeV}$, $\mathrm{p_{T_D}} > 4.0\mathrm{GeV}$
  - 2D vertex of D and B with χ^2 cuts
  - $\mathrm{L_{xy}(B)} > 100\mu\mathrm{m}$, $\mathrm{d0(B)} < 100\mu\mathrm{m}$ $\mathrm{L_{xy}(D)} > 400\mu\mathrm{m}$
  - Constrain D^- mass to PDG value



Hadronic Signatures: B_s^0

$B_s^0 \to D_s\pi$
$D_s \to \phi\pi$ and $\phi \to K^+K^-$

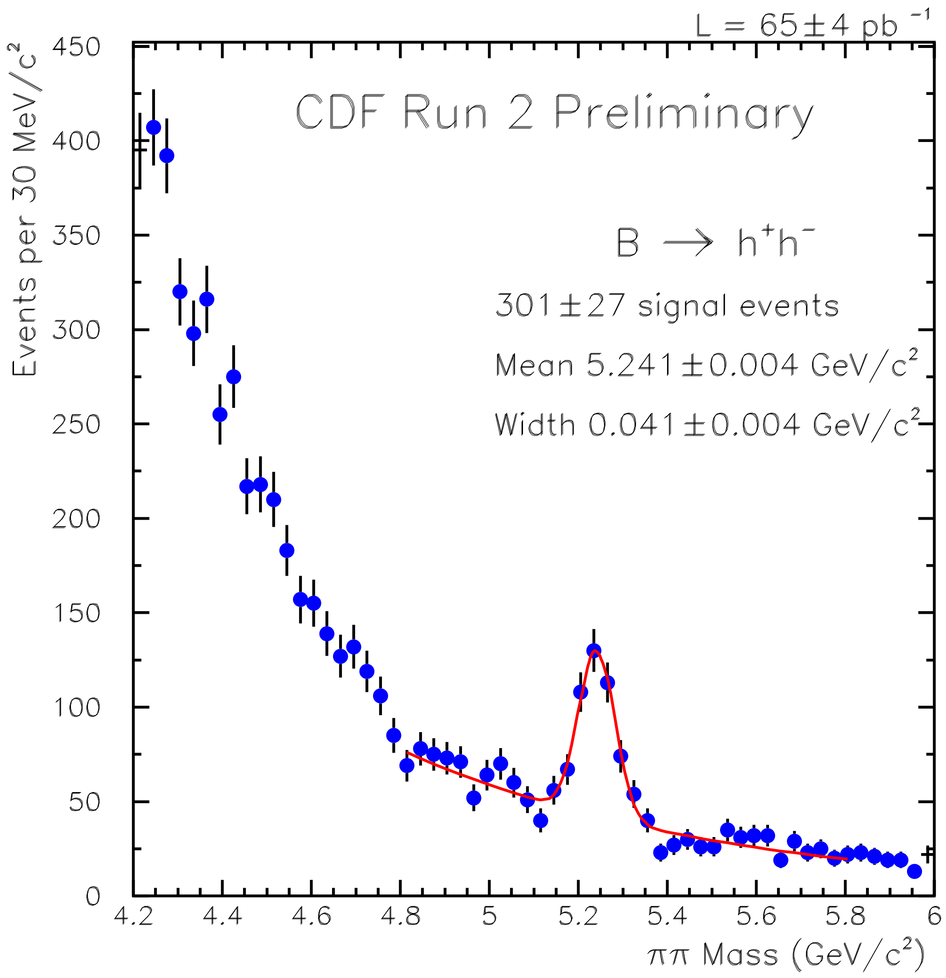
- Measurement
  - BR Relative to $B_d \to D\pi$
  - B_s mixing: x_s
- Using hadronic trigger: SVT
  - Two tracks with displaced impact parameter
  - Can be any of the four tracks
- Analysis cuts
  - Same cuts as in B^0 mode
  - $1.013 < m_\phi < 1.028\mathrm{GeV}$
- B^0 yield was 413 ± 40 events



Hadronic Signatures: $\mathrm{B} \to \mathrm{hh}$

$\mathrm{B}^0 \to \pi\pi$, $\mathrm{B}^0 \to \pi\mathrm{K}$ and
$\mathrm{B}_s^0 \to \mathrm{KK}$, $\mathrm{B}_s^0 \to \mathrm{K}\pi$

- CP asymmetries
  - Direct $\mathrm{B}^0 \to \pi\mathrm{K}$(short term)
  - Time dependent γ: $\mathrm{B}^0 \to \pi\pi$ and $\mathrm{B}_s^0 \to \mathrm{KK}$(longer term)
- Using hadronic trigger: SVT
  - Two tracks with displaced impact parameter
  - Distinguish other $\mathrm{B} \to \mathrm{hh}$ decays by mass diff and PID
- Analysis cuts
  - $\mathrm{p_{T}}_{\mathrm{h1+h2}} > 5.5\mathrm{GeV}$
  - $\mathrm{d(B)} < 80\mu\mathrm{m}$, $\mathrm{d(h)} > 150\mu\mathrm{m}$
  - $\mathrm{L_{xy}(B)} > 300\mu\mathrm{m}$
  - Use Isolation cut



Conclusions

CDF detector performing well

See physics signals for flagship B analyses

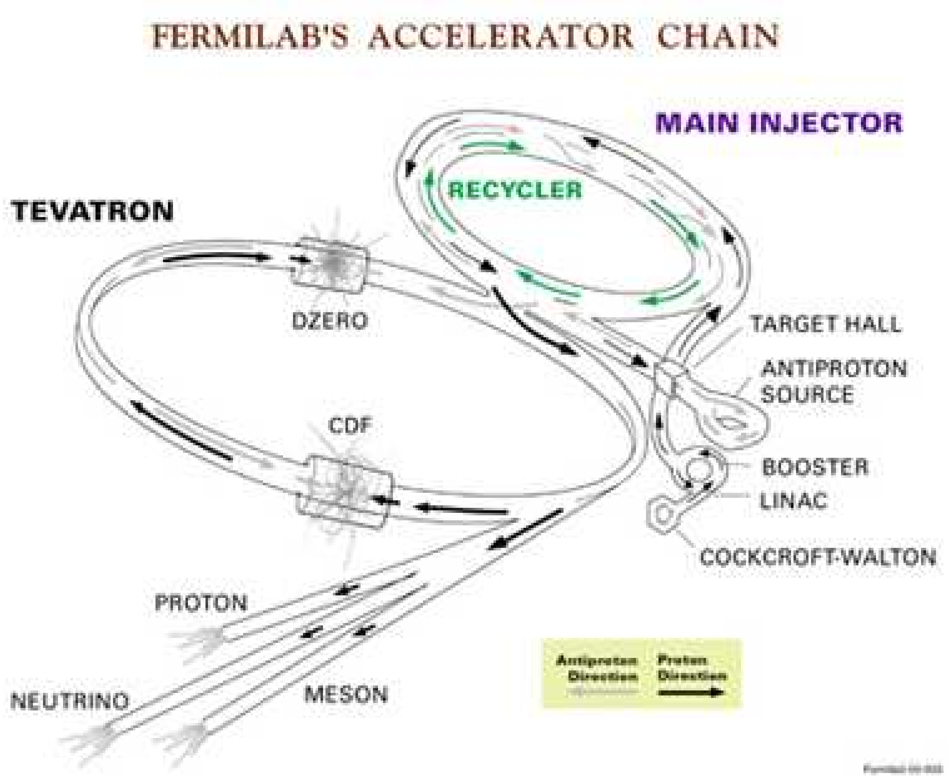
Simpler analysis being polished up for presentation

Definitely a great time to be at CDF!

Tevatron Upgrade

Main Injector

- New injection stage for Tevatron
  - Ability to accelerate and deliver higher intensity of protons
  - More efficient transfer of anti protons
  - Recycler for anti protons(in progress)



Higher Collision rate

- 396ns (36x36 bunches)

$\rightarrow$ 5-10 Higher Luminosity than run 1

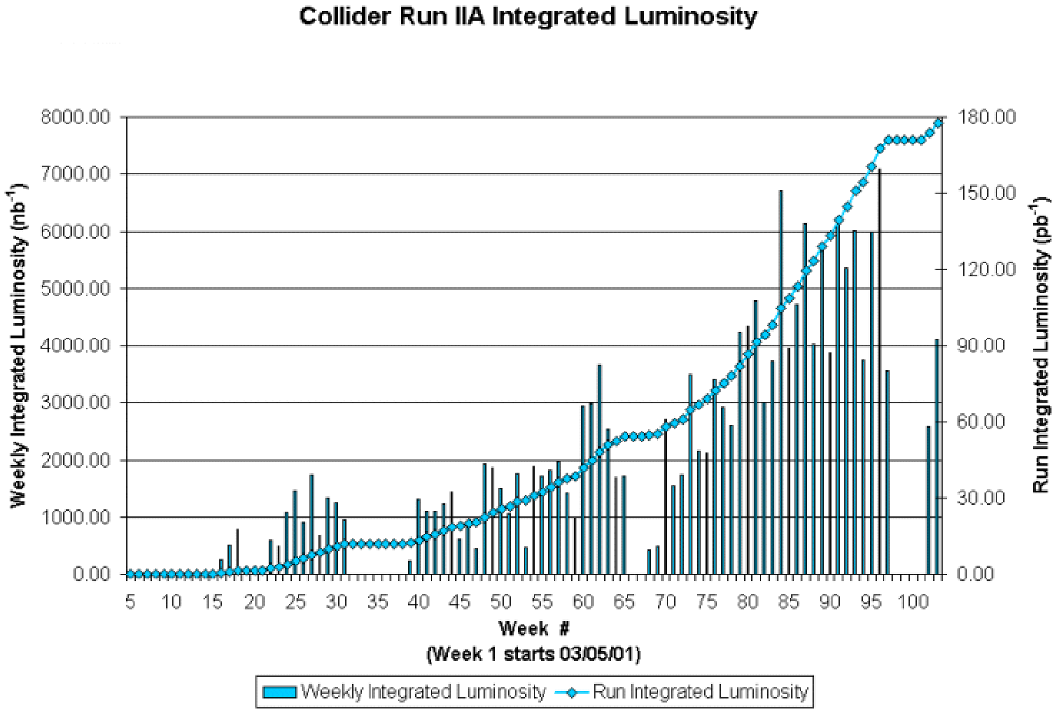
Higher C.M. Energy

- $1.8 \rightarrow 1.96\text{TeV}$

Luminosity

Current Tevatron Performance

- Below expectation but improving
  - Record luminosity: $3.6 \times 10^{31} \mathrm{cm}^{-2} \mathrm{s}^{-1}$
  - Now consistently 4-7pb^{-1}per week
  - Expect $\sim 10\% - 20\%$ improvement due to work performed in January shutdown



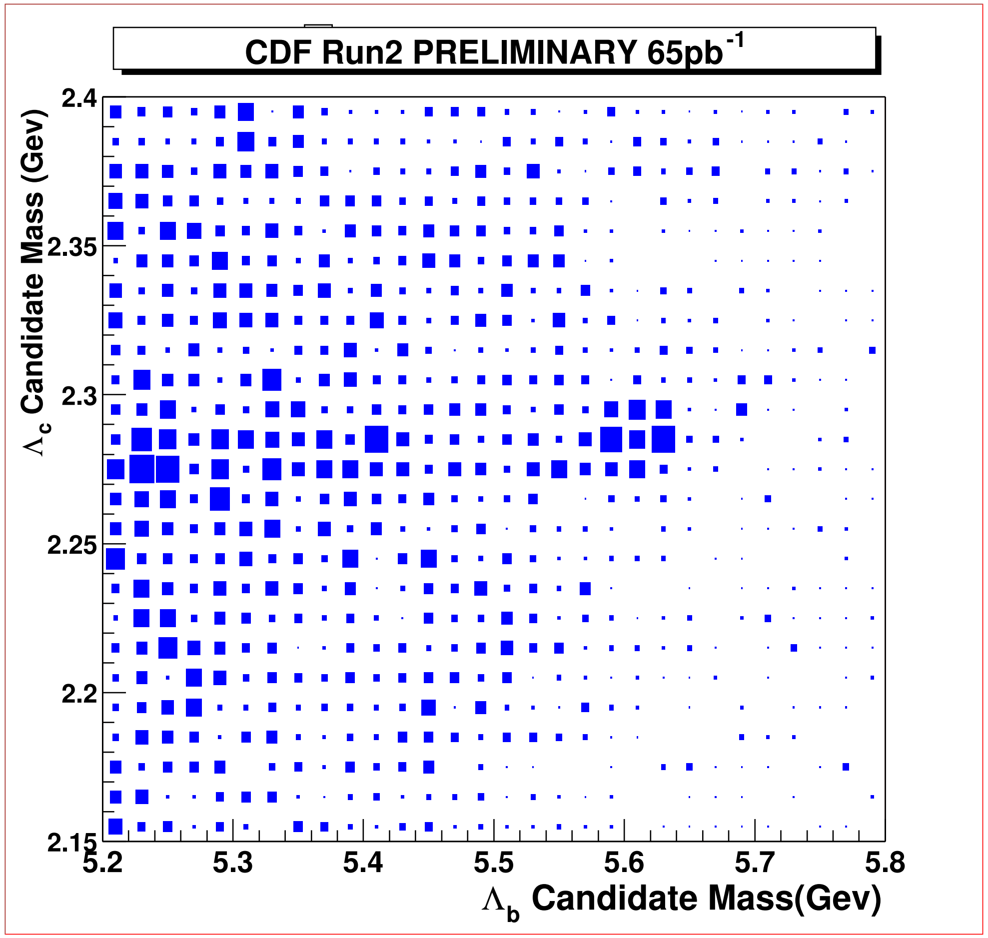
CDF

- $180\mathrm{pb}^{-1}$ delivered
  - $130\mathrm{pb}^{-1}$ recorded
  - $65\mathrm{pb}^{-1}$ all critical systems on - after commissioning period

Hadronic Signatures: Λ_c from Λ_b

$\Lambda_b \to \Lambda_c\pi$, $\Lambda_c \to pK\pi$

- m_{Λ_c} from Λ_b
- Λ_b selection applied
- Correlations between Λ_b and m_{Λ_c}
  - Strong correlation around the Λ_b,Λ_c masses



Hadronic Signatures: B_s^0

$B_s^0 \to D_s\pi$

$D_s \to \phi\pi$ and $\phi \to K^+K^-$

- Understanding of contributions to $B \to X$ where X contains $D_s \to \phi\pi$
  - Contributions from D_s^* and D_s
  - Results of MC study of signal shape