Bruno Casal Laraña

Istituto de Física de Cantabria (CSIC-Univ. de Cantabria)

On behalf of the CDF Collaboration

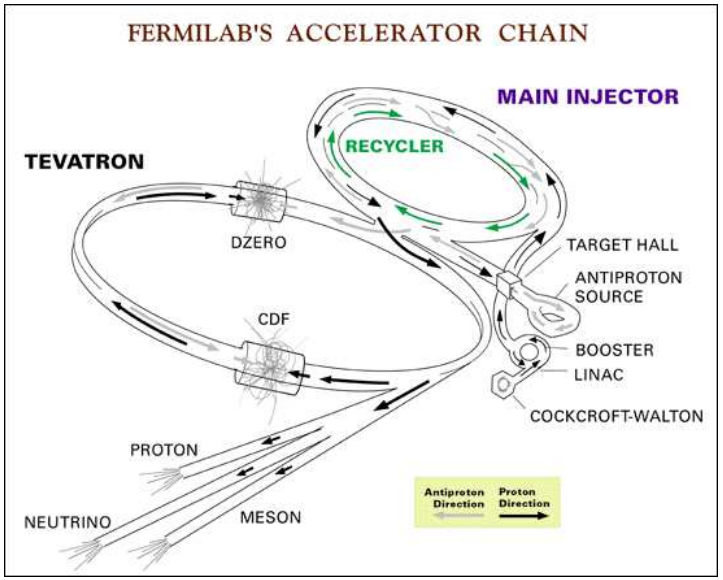
5TH FLAVOR PHYSICS & CP VIOLATION CONFERENCE | BLED, SLOVENIJA | MAY 12-16, 2007

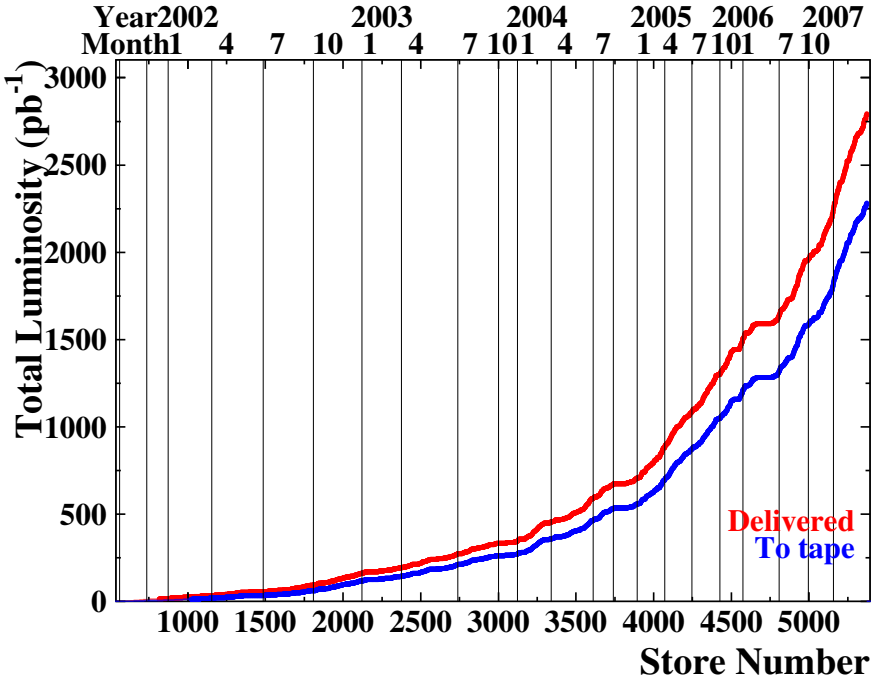
Outline

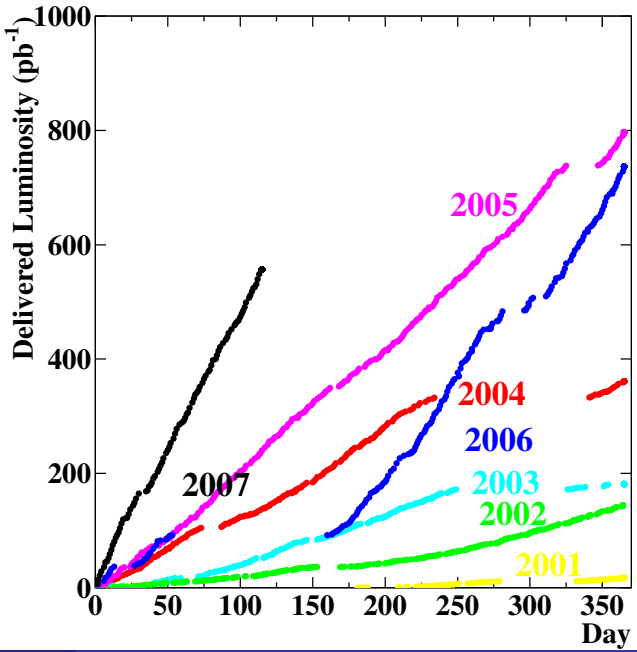
- Tevatron and CDF overview
- Heavy flavor triggers
- Recent results
  - B_s oscillations
  - Σ_b observation
  - Lifetimes
  - $B \to \mu^+ \mu^- h$
  - $B \to h^+ h'^-$
- Conclusions

Tevatron

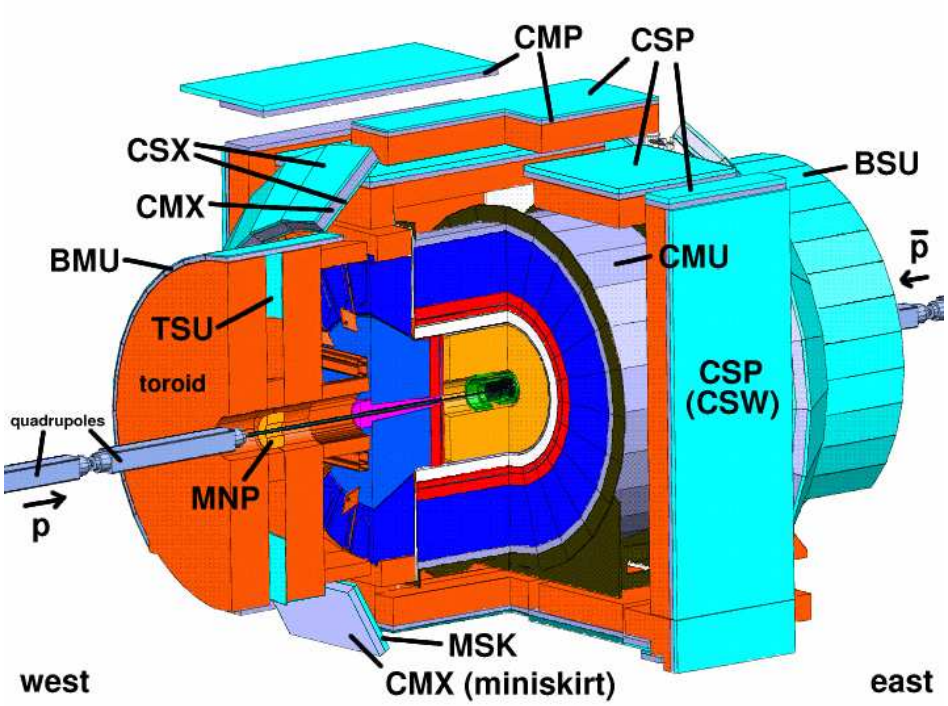
- $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV
- Peak luminosity $\sim 3 \times 10^{32}$ cm^{-2}s^{-1}
- CDF II collected > 2 fb^{-1}
  - Analyses today use ~ 1 fb^{-1}
  - ~ 2 fb^{-1} analized for the summer

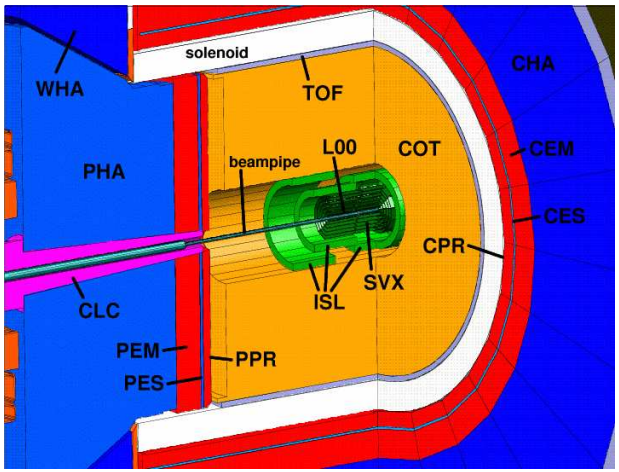






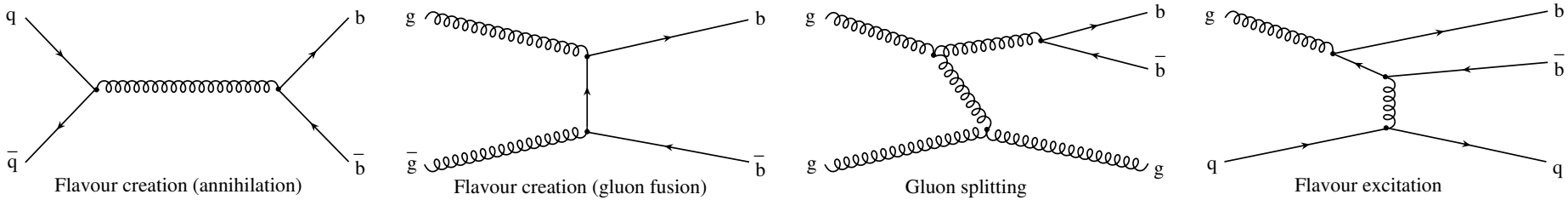
CDF II Detector





- Good tracking resolution, $\sigma(p_T)/p_T^2 \sim 0.1\%\ \text{GeV}^{-1}$
  - Precise mass resolution
- Silicon Vertex Detector
  - Excellent vertex resolution
  - Crucial for triggering
- Large acceptance and good ID for leptons
- Kaon/pion separation
  - dE/dX in the COT
  - Time of Flight

Heavy Flavor Physics at Tevatron



- ✔ Large $b\bar{b}$ pair production cross-section: $\sim 100\,\mu$b
  - 10^4 interactions/s at peak luminosity
- ✔ All b species produced: B_u, B_d, B_s, B_c, Λ_b, Σ_b, ...
  - Branching ratios of rare decays are $O(10^{-6})$ or lower
- ✘ Inelastic background (QCD): $\sim 1000 \times \sigma(b\bar{b})$
- ✘ Low acceptance for opposite side B
- ➥ Trigger is challenging!

Trigger Strategies

Di-muon

$J/\Psi \rightarrow \mu\mu$, $B \rightarrow \mu\mu$

- $p_T(\mu) > 1.5$ GeV

One displaced track + lepton

$B \rightarrow \ell\nu X$

- $p_T(\ell) > 4.0$ GeV
- $p_T(track) > 2.0$ GeV
- $120 < d_0 < 1000\ \mu$m

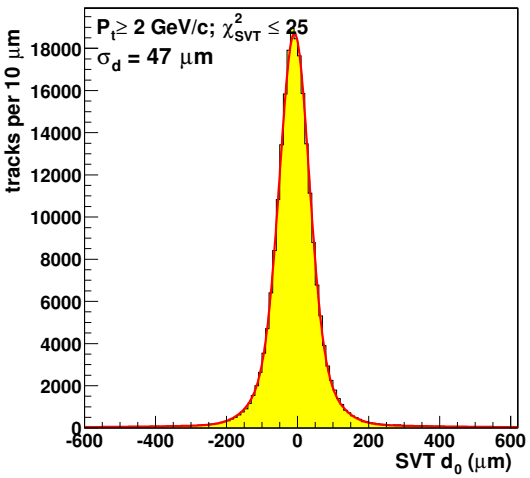
Two displaced tracks

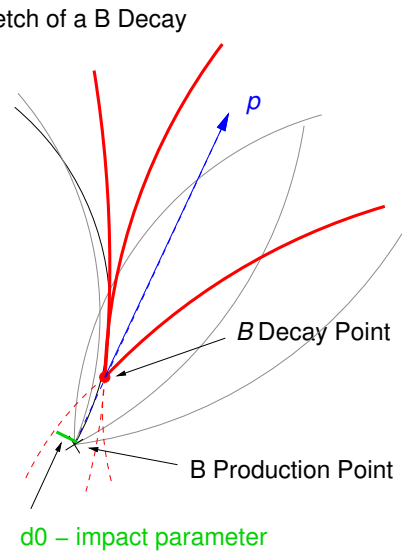
$B \rightarrow hh$, Σ_b, B_s mixing

- $p_T > 2.0$ GeV
- $\sum p_T > 5.5$ GeV
- $120 < d_0 < 1000\ \mu$m

Silicon Vertex Trigger (SVT)

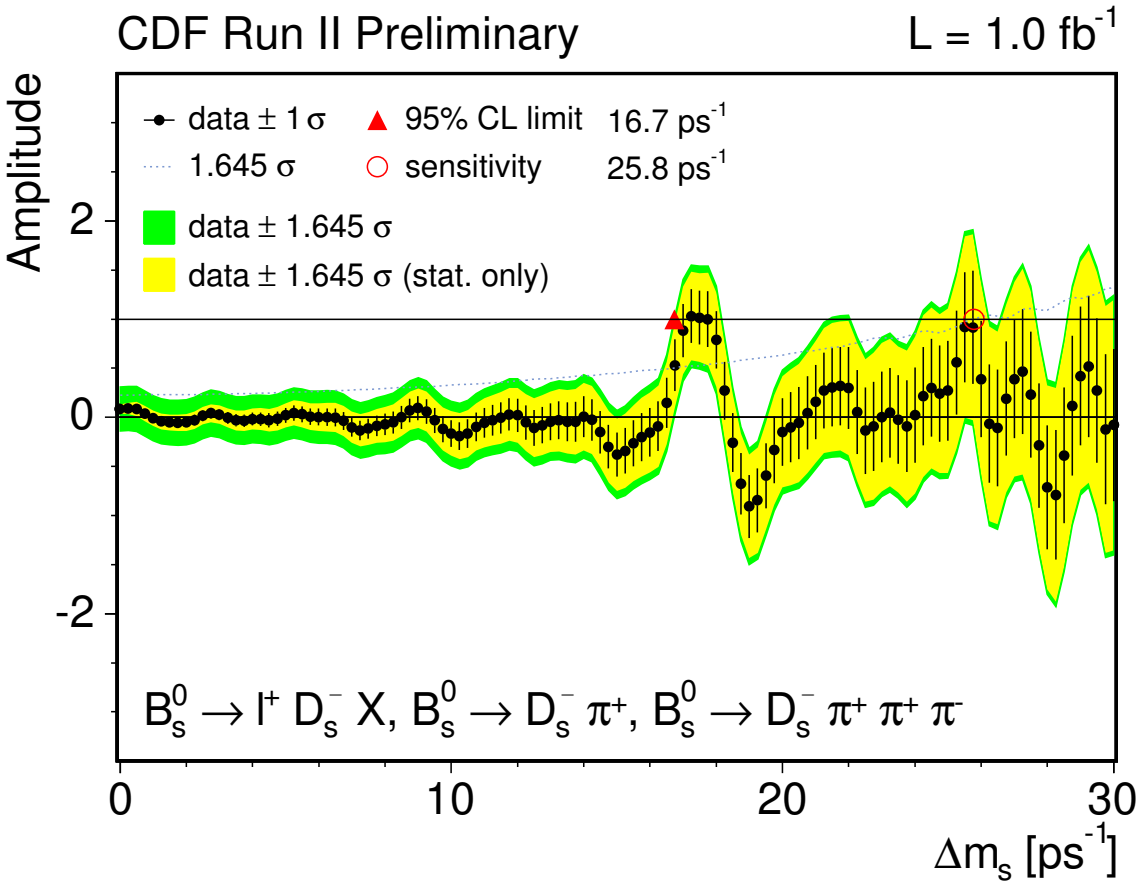
- Exploits long B lifetimes
- d_0 resolution $\sim 50\ \mu$m (includes beam width)
- Very fast response at L2

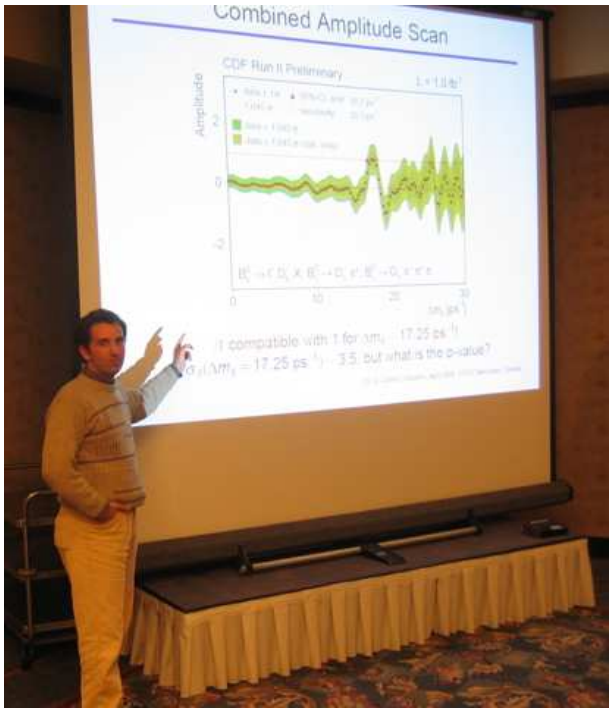




B_s Oscillations

Last Year in FPCP 2006





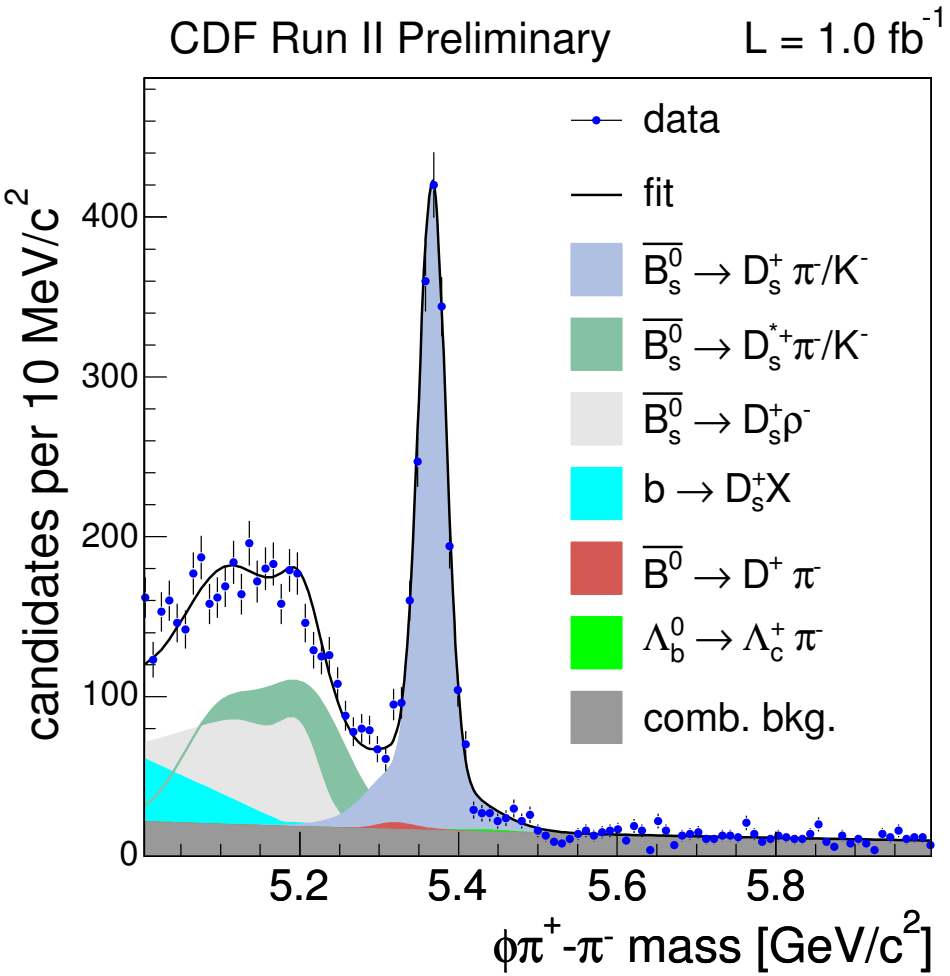
Evidence of B_s oscillations at 3σ significance shown

$$\Delta m_s = 17.31^{+0.33}_{-0.18}(\text{stat.}) \pm 0.07(\text{syst.})\ \text{ps}^{-1}$$

B_s Oscillations

Improvements

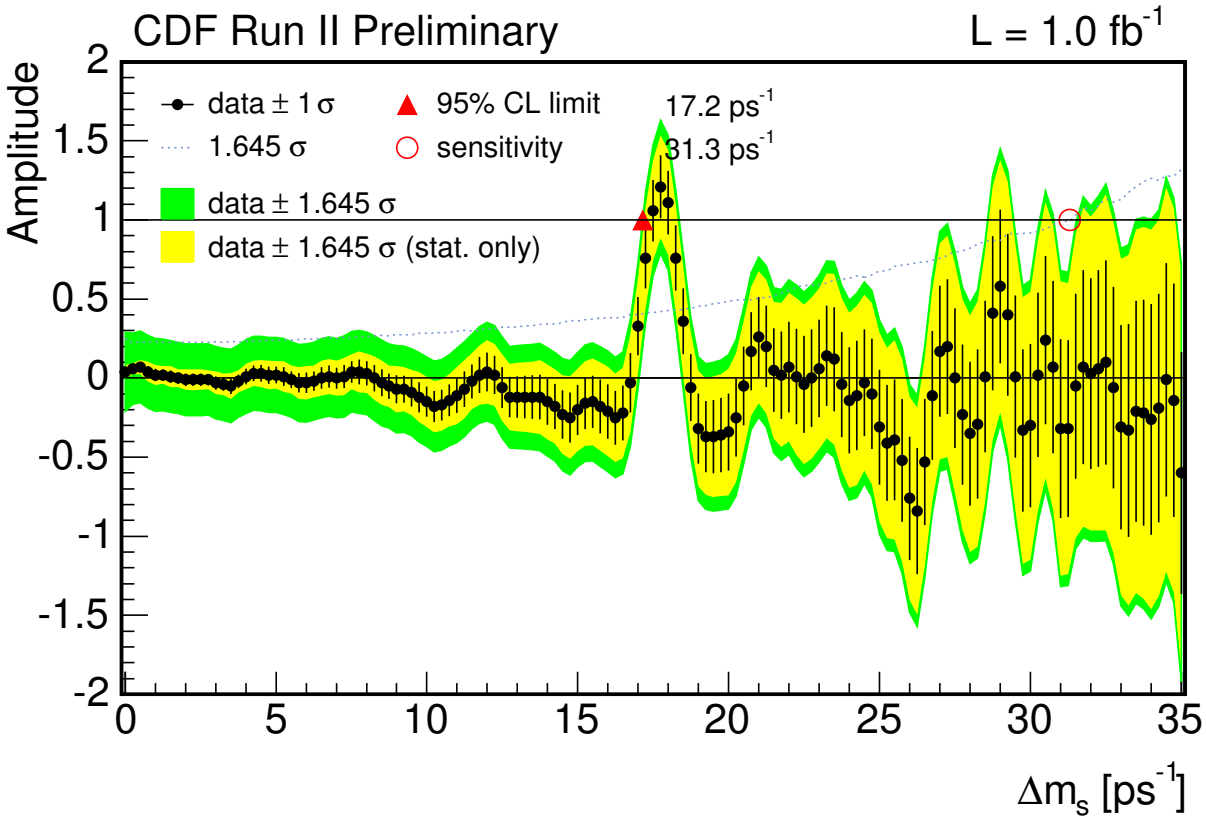
Are we able to reach a 5σ observation with the same data sample of 1fb^{-1} but improved tecniques?



- PID information to reject background from D^- mass missassignments
- New trigger paths for semileptonic analysis: 37,000 $\longrightarrow$ 61,500
- Neural Network selection for hadronic modes: 3,600 $\longrightarrow$ 5,600
- Inclusion of partially reconstructed hadronic modes: 3,100
- Neural Network to combine OS taggers: 15 % improvement in ϵD^2
- Neural Network SSK tagger: 8 % improvement in ϵD^2

B_s Oscillations

Results



Observed signal consistent with B_s oscillations at significance $> 5\sigma$

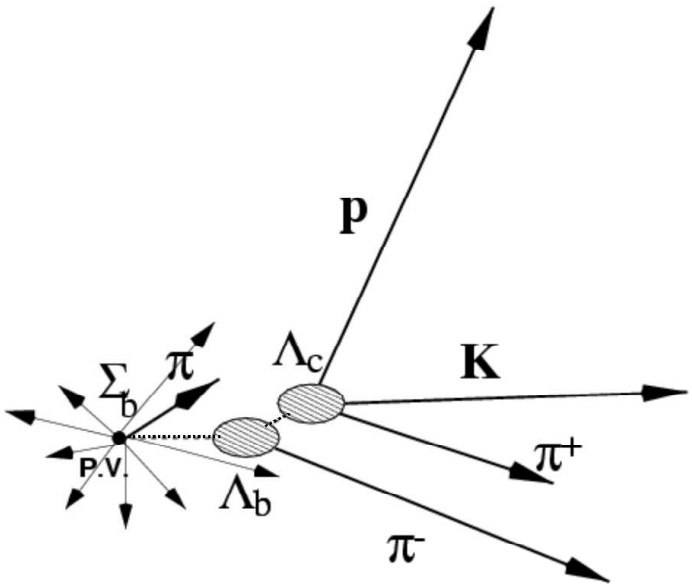
$$\Delta m_s = 17.77 \pm 0.10(\text{stat.}) \pm 0.07(\text{syst.})\ \text{ps}^{-1}$$

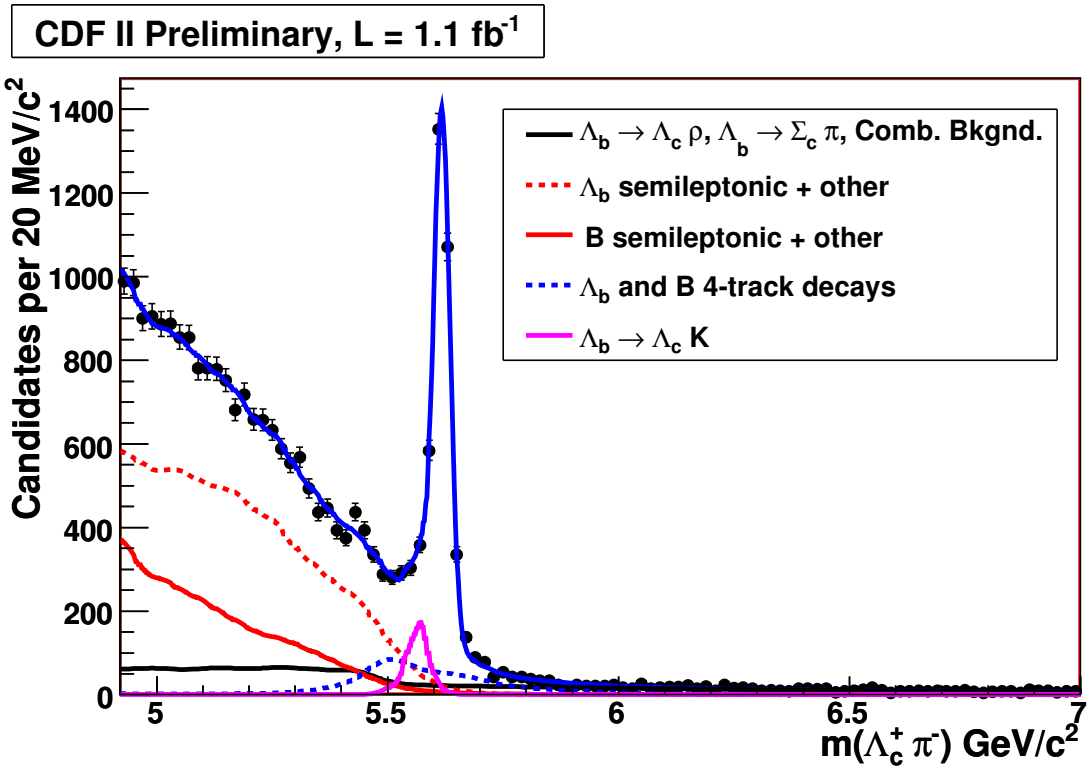
$$\left|\frac{V_{td}}{V_{ts}}\right| = 0.2060 \pm 0.0007(\text{exp.})^{+0.0080}_{-0.0060}(\text{theor.})$$

Observation of New Σ_b Baryon

More details in Michal Krep's talk

- So far, Λ_b only established b-baryon
- Next accessible b-barions are Σ_b $\left(J^P = \frac{1}{2}^+\right)$ and Σ_b^* $\left(J^P = \frac{3}{2}^+\right)$





- World largest sample of Λ_b: ~ 3000 $\Lambda_b^0 \to \Lambda_c^+ \pi^-$, $\Lambda_c^+ \to pK^-\pi^+$
- Search for $\Sigma_b^{(*)\pm} \to \Lambda_b^0 \pi^\pm$
  - Combine Λ_b with a prompt track

Observation of New Σ_b Baryon

Results

- Four peaks consistent with $\Sigma_b^{(*)\pm}$ states found in signal region
  - $> 5\sigma$ significance level
- Unbinned likelihood fit:

$$m(\Sigma_b^-) = 5816^{+1.0}_{-1.0}(stat.) \pm 1.7(syst.)\ \mathrm{MeV}$$

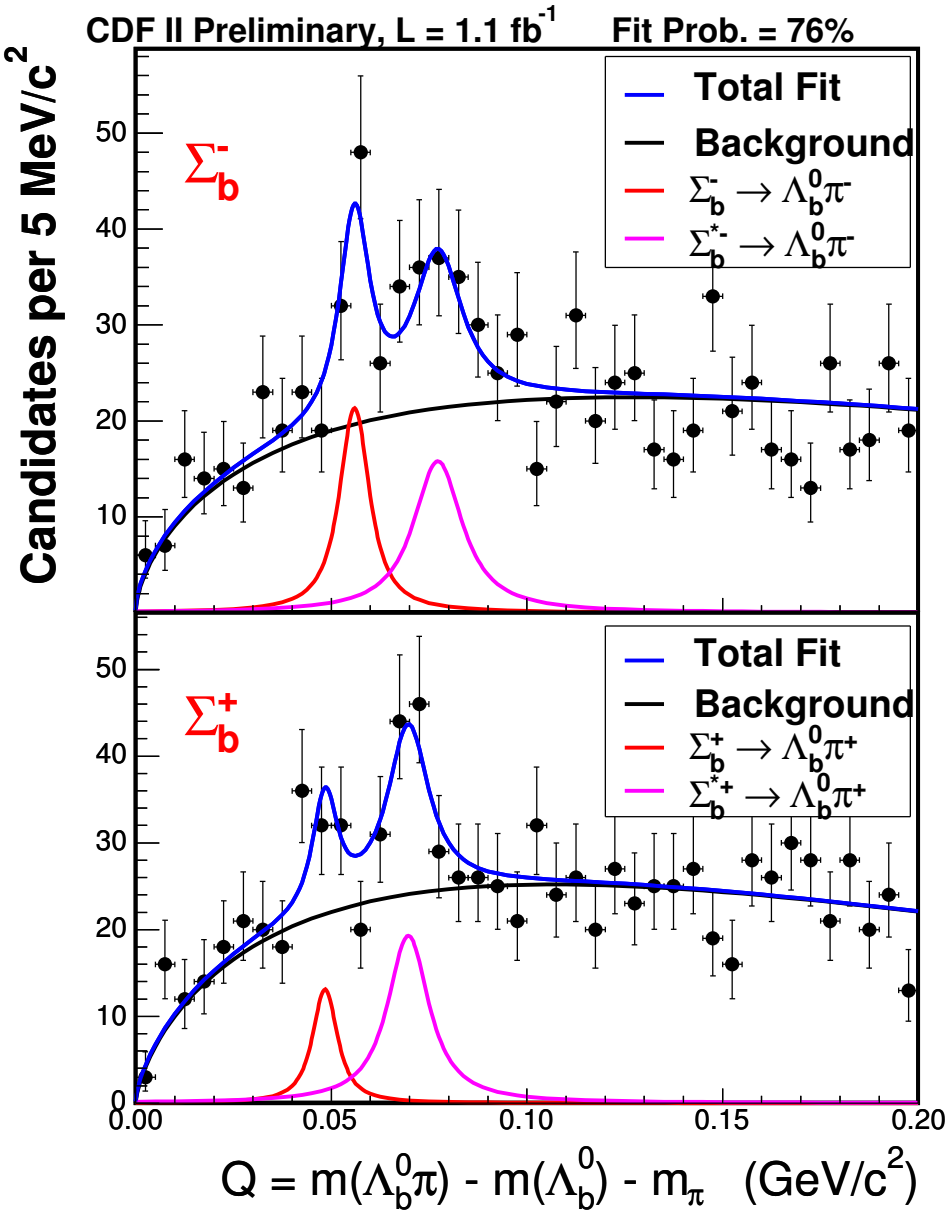
$$m(\Sigma_b^+) = 5808^{+2.0}_{-2.3}(stat.) \pm 1.7(syst.)\ \mathrm{MeV}$$

$$m(\Sigma_b^{*-}) = 5837^{+2.1}_{-1.9}(stat.) \pm 1.7(syst.)\ \mathrm{MeV}$$

$$m(\Sigma_b^{*+}) = 5829^{+1.6}_{-1.8}(stat.) \pm 1.7(syst.)\ \mathrm{MeV}$$

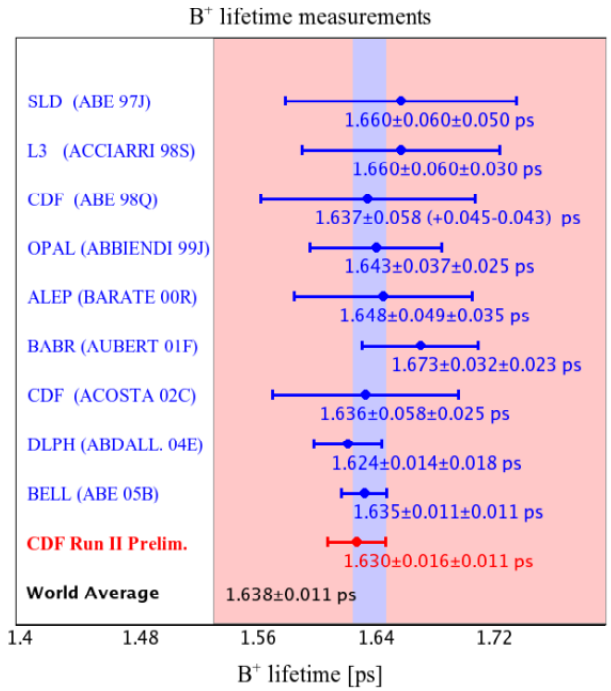
Plans:

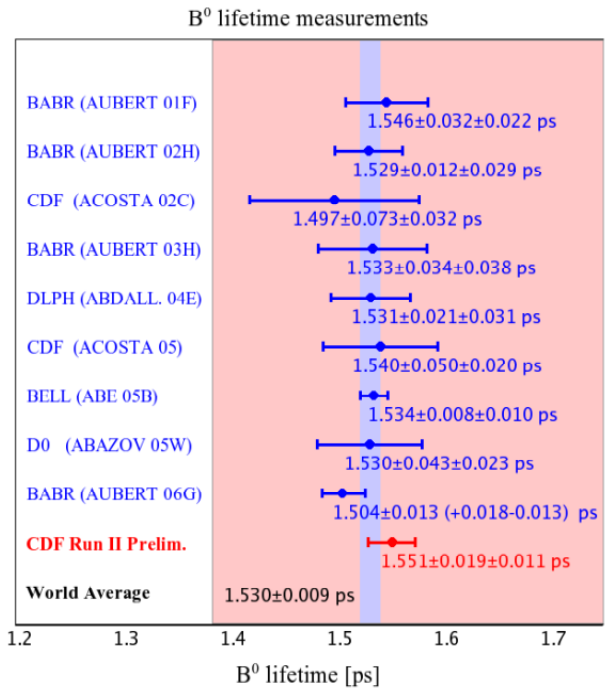
- Increase sample: alternate trigger paths, and adding other Λ_b modes
- Measure Σ_b properties: polarization, quantum numbers,...

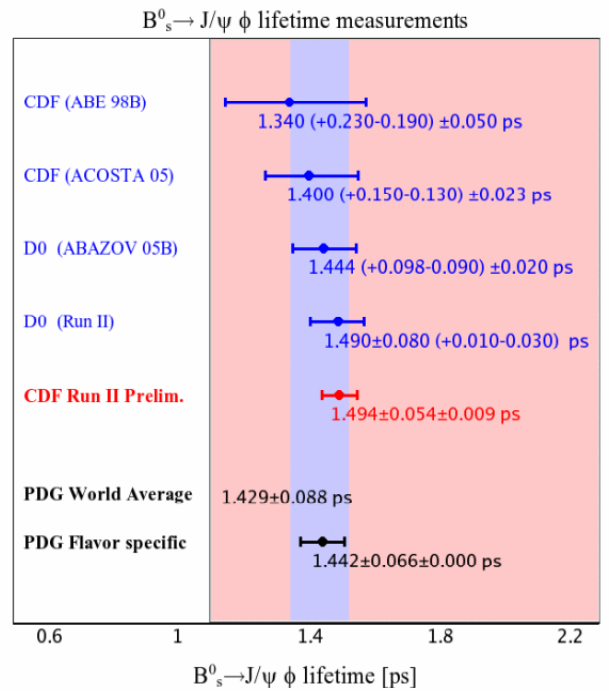


Lifetimes Measurements

- Update on B^+, B^0, B_s and Λ_b lifetimes using exclusive decays containing a J/Ψ



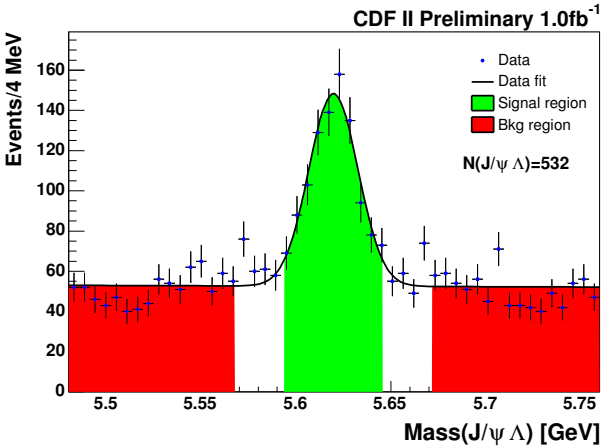


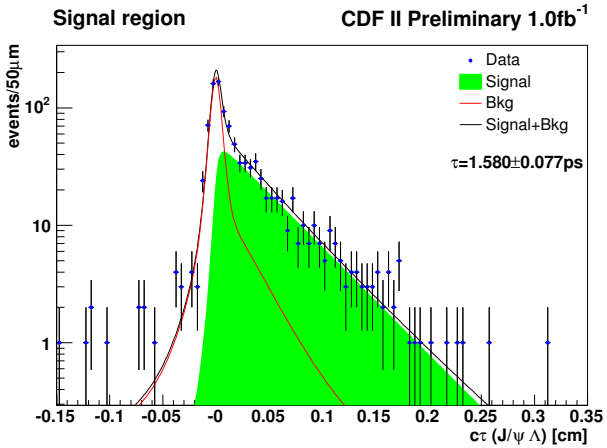


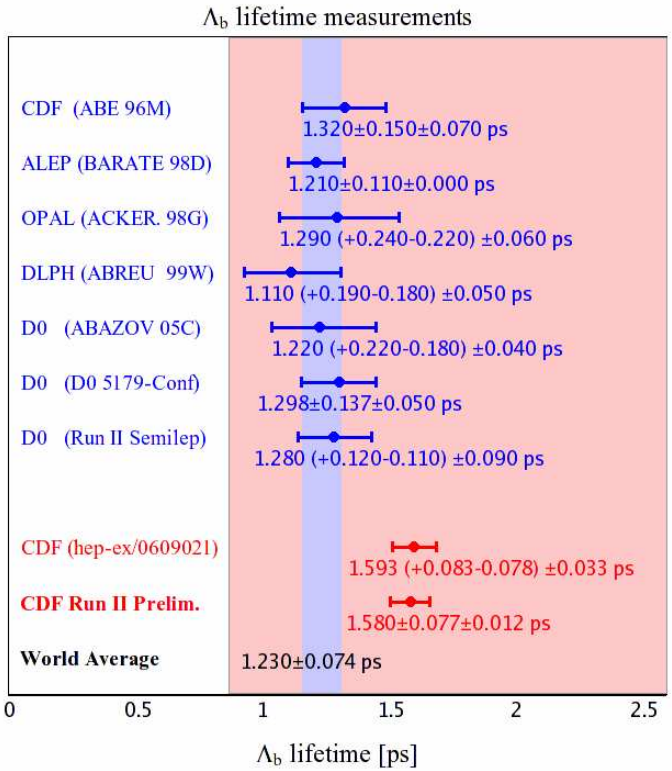
➥ Measurement for B_s more precise than PDG value

- Next: Measure $\sin 2\beta$ on $B^0 \to J/\Psi K_s$ and $B_s \to J/\Psi\phi$

Λ_b Lifetime in $J/\Psi\Lambda$





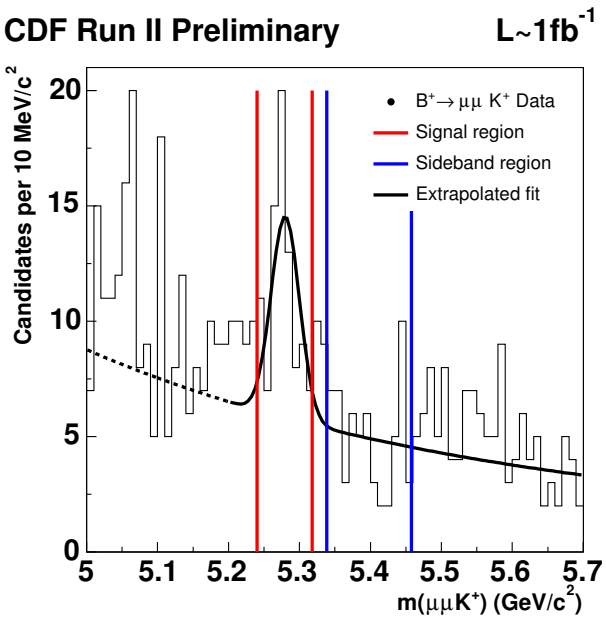


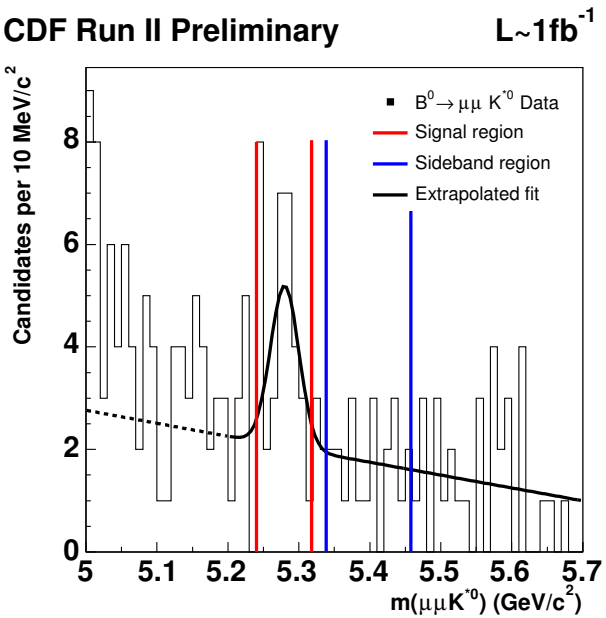
$$\tau(\Lambda_b) = 1.580 \pm 0.077(stat) \pm 0.012(syst)\ \text{ps}$$

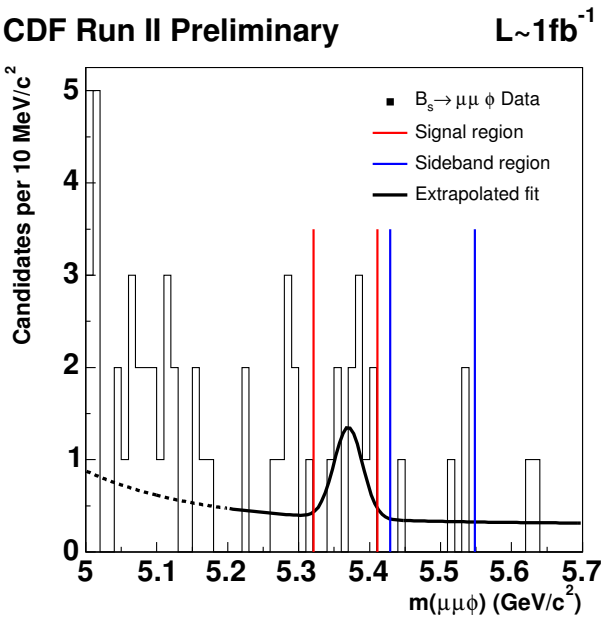
- Most precise measurement
- Consistent with independent CDF result
- $\sim 3\sigma$ above world average
- Need more experimental inputs
- Plan to use $\Lambda_b \rightarrow \Lambda_c \pi$ sample

$B \to \mu^+\mu^- h$

- $b \to s\,\mu^+\mu^-$ transition requires FCNC, strongly suppresed in SM
  - New physics models allow significant deviations
- Search for $B^+ \to \mu^+\mu^- K^+$, $B^0 \to \mu^+\mu^- K^{*0}$, $B_s^0 \to \mu^+\mu^- \phi$
- Normalize each signal to analogous $B \to J/\Psi h$ decays
  - Many systematic uncertainties cancel in the ratio

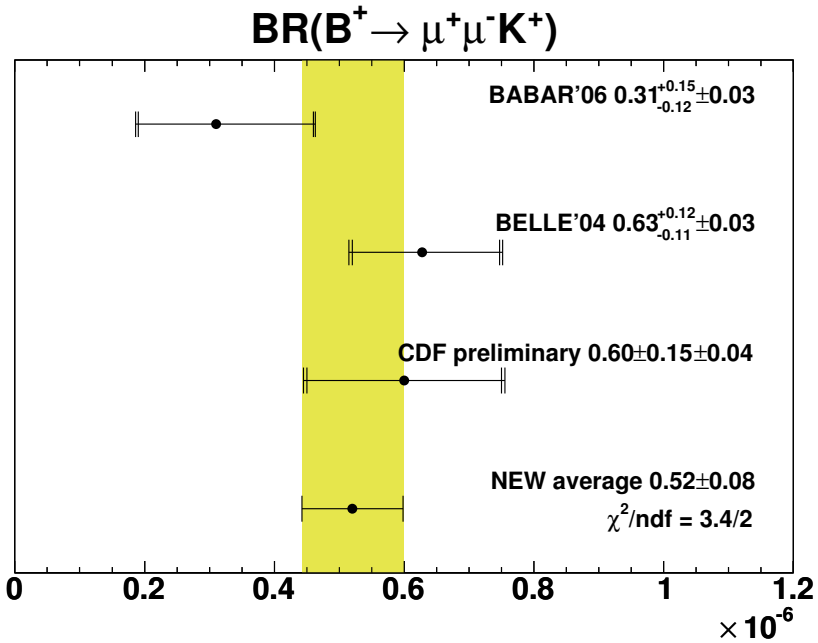


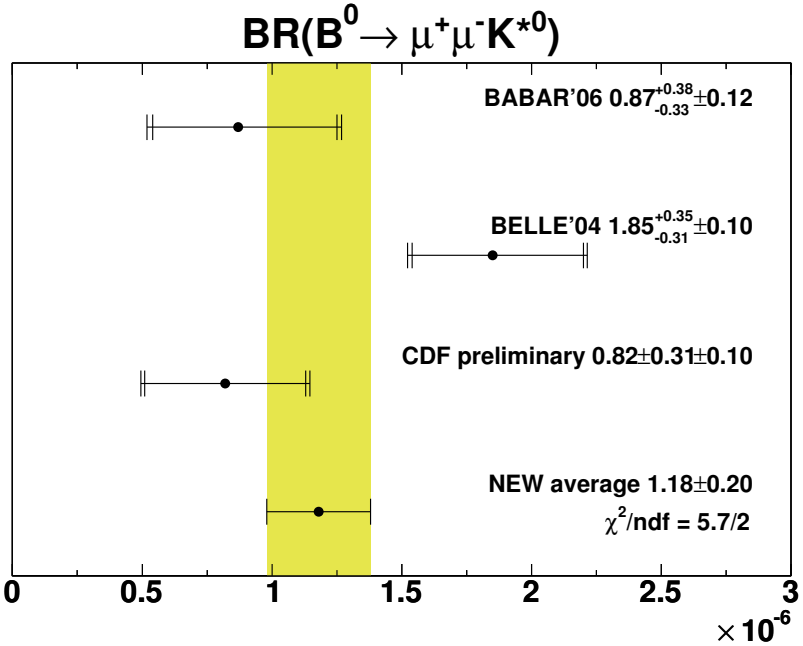




$B \to \mu^+\mu^- h$

Results





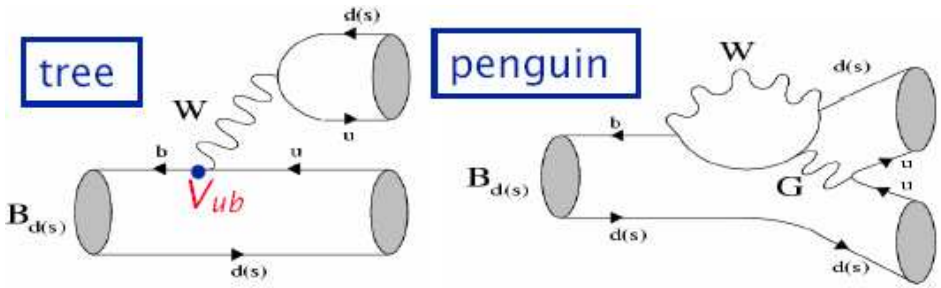
- Good agreement and similar uncertainty for B-Factories & CDF
- Found $B_s^0 \to \mu^+\mu^-\phi$ excess with 2.4σ significance
  - Most stringent limit on B_s mode (Bayesian approach)

$$\frac{\mathcal{B}(B_s^0 \to \mu^+\mu^-\phi)}{\mathcal{B}(B_s^0 \to J/\Psi\phi)} < 2.30 \times 10^{-3} \text{ at } 90\% \text{ CL}$$

- Plans: NN-based selection, incorporate additional channels: $B_d \to \mu\mu K_s$, $B^+ \to \mu\mu K^{*+}$ and $\Lambda_b \to \mu\mu\Lambda$

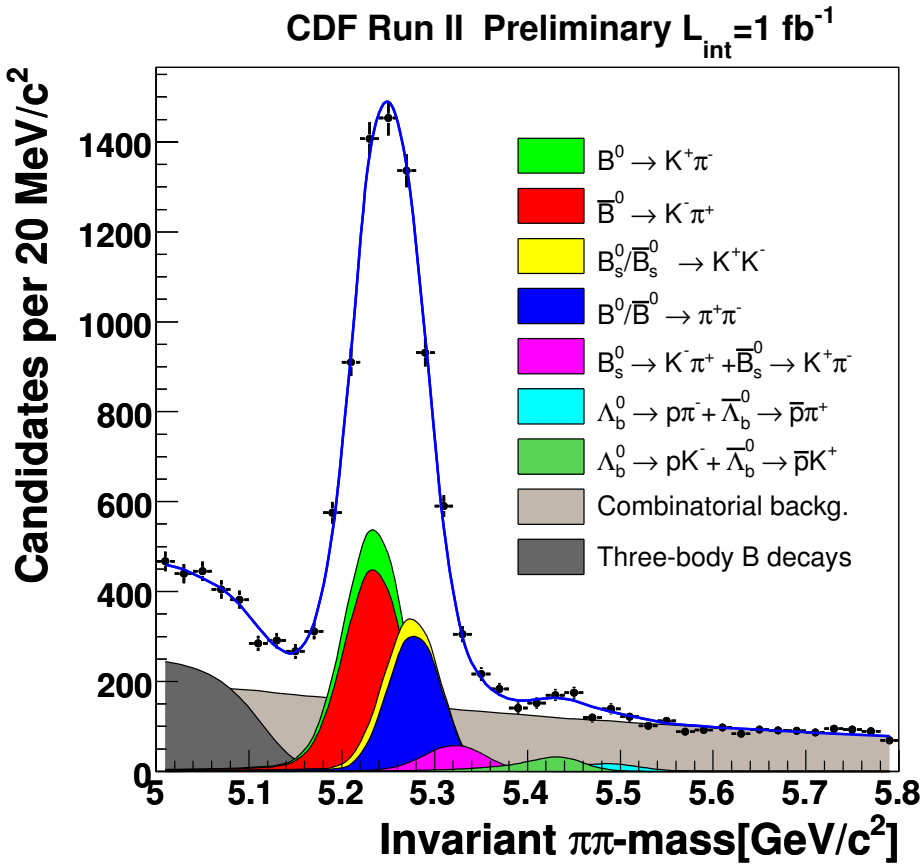
Charmless Two-Body B Decays: $B^0 \to h^+ h'^-$

- Very rich physics: BR and CP asymmetries
  - Useful for probing CKM matrix
  - Sensitive to new physics



- Invariant mass under $\pi\pi$ hypothesis
  - Excellent mass resolution but still several overlapping modes
- Likelihood fit performed to separate signal components
  - Information from mass, kinematics and particle ID (dE/dX)

➜ More details in Simone Donati's talk



$B^0 \to h^+ h'^-$

Results

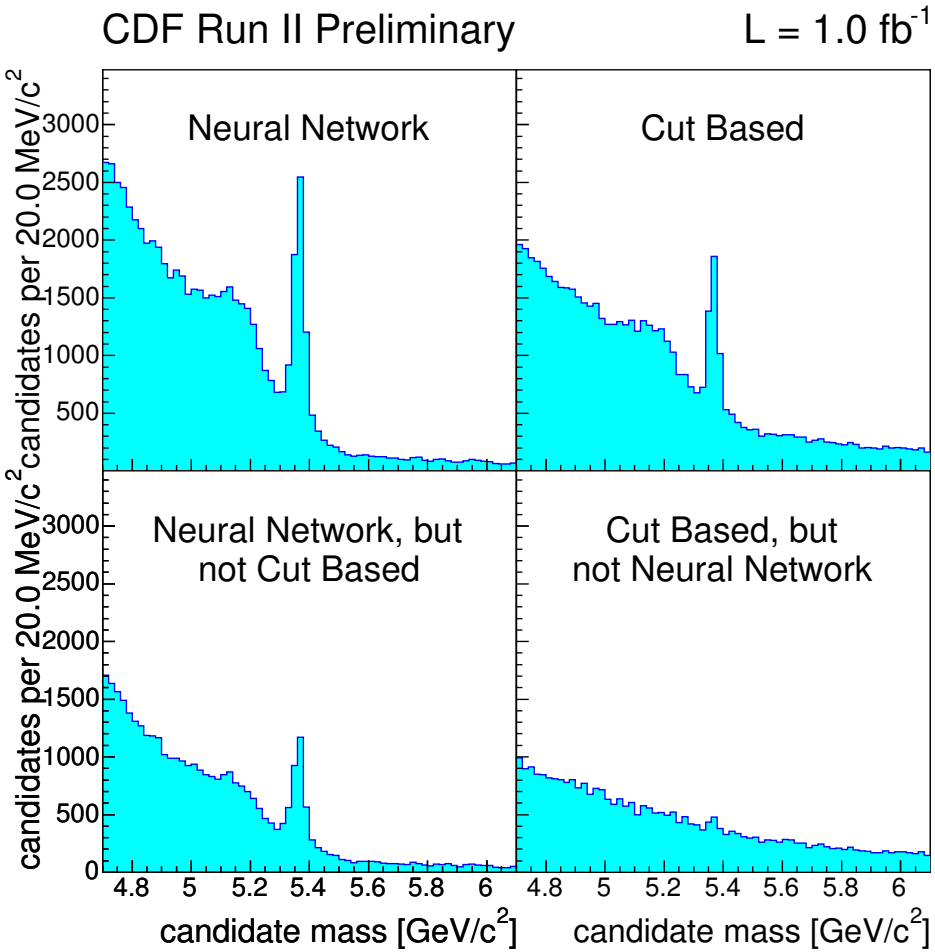
- First observation of 3 new rare decays (first charmless decays of Λ_b)
  - $N_{raw}(B_s^0 \to K^- \pi^+) = 230 \pm 34(stat.) \pm 16(syst.) \quad (8\sigma)$
  - $N_{raw}(\Lambda_b^0 \to p\pi^-) \quad = 110 \pm 18(stat.) \pm 16(syst.) \quad (6\sigma)$
  - $N_{raw}(\Lambda_b^0 \to pK^-) \quad = 156 \pm 20(stat.) \pm 11(syst.) \quad (11\sigma)$
- CP asymmetry measurement on B^0 system
  - $A_{CP} = \frac{N(B^0 \to K^- \pi^+) - N(B^0 \to K^+ \pi^-)}{N(B^0 \to K^- \pi^+) + N(B^0 \to K^+ \pi^-)} = 0.086 \pm 0.023(stat.) \pm 0.009(syst.)$
- First measurement of CP asymmetry on B_s system
  - $A_{CP} = \frac{N(B_s^0 \to K^+ \pi^-) - N(B_s^0 \to K^- \pi^+)}{N(B_s^0 \to K^+ \pi^-) + N(B_s^0 \to K^- \pi^+)} = 0.39 \pm 0.15(stat.) \pm 0.08(syst.)$
- No significant signal found for $B^0 \to K^+ K^-$ and $B_s \to \pi^+ \pi^-$
  - $\mathcal{B}(B^0 \to K^+ K^-) < 0.7 \times 10^{-6}$ at 90% CL
  - $\mathcal{B}(B_s \to \pi^+ \pi^-) < 1.36 \times 10^{-6}$ at 90% CL
- Coming next: measure time-dependent assimetry of $B_d \to \pi\pi$ and $B_s \to KK$

Conclusions

- Heavy flavor physics program at CDF is being very productive
- Complementary and competitive with B-Factories
- Great results obtained so far
  - Observation of B_s oscillations
  - Σ_b baryon discovery
  - New B hadron decays
  - ...
- New results with larger dataset coming soon, stay tuned!

BACKUP

ANN-vs-Cut and Signal Yield

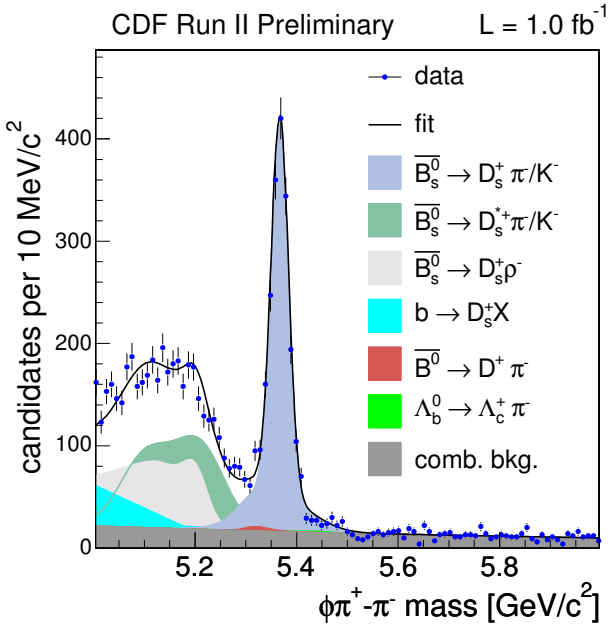


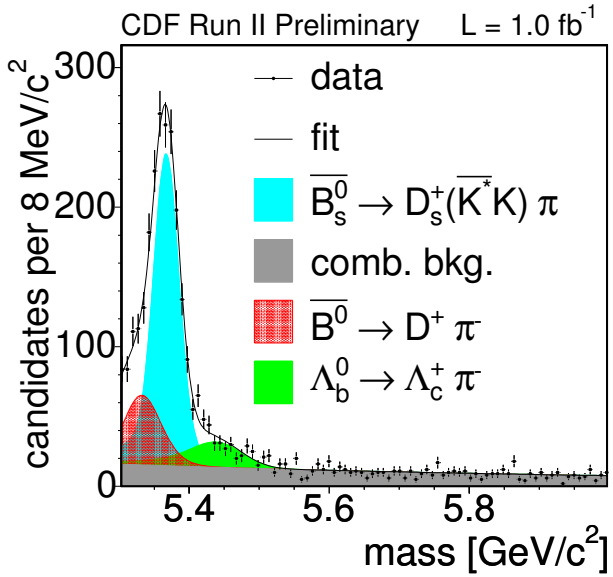
Neural Network improvements:

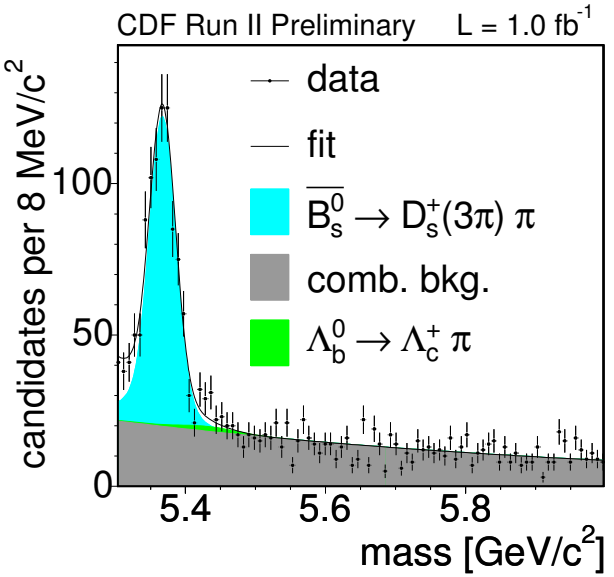
- Large signal with lower background
- Makes it possible to add a new mode $\bar{B}_s^0 \to D_s^+ \pi^- \pi^+ \pi^-$ with $D_s^+ \to \pi^+ \pi^- \pi^+$

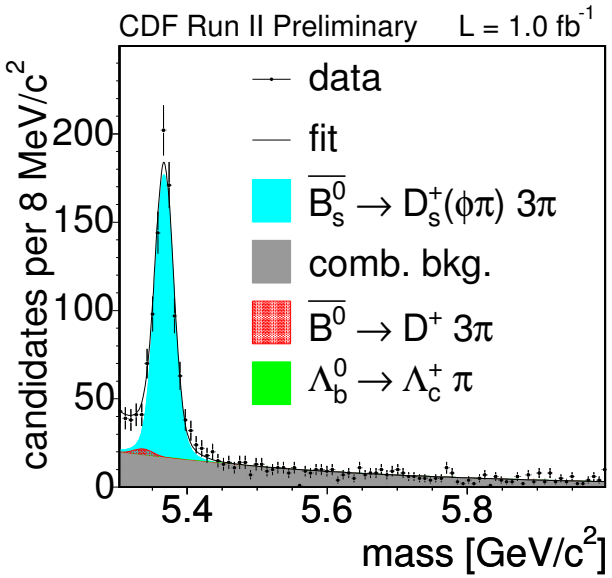
$\bar{B}_s^0$ Decay Chain	Signal	S/B	gain [%]
$D_s^+[\phi\pi^+]\pi^-$	1900	11.3	13
$D_s^+[K^{*0}K^+]\pi^-$	1400	2.0	35
$D_s^+[(3\pi)^+]\pi^-$	700	2.1	22
$D_s^+[\phi\pi^+](3\pi)^-$	700	2.7	92
$D_s^+[K^{*0}K^+](3\pi)^-$	600	1.1	110
$D_s^+[(3\pi)^+](3\pi)^-$	200	2.6	new

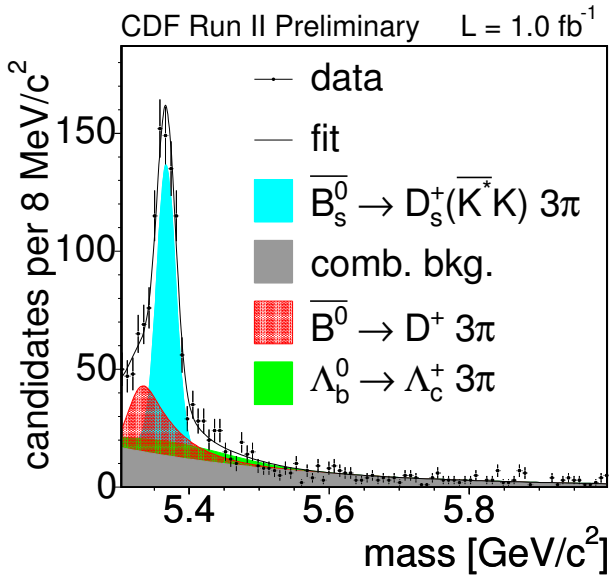
Mass Fits

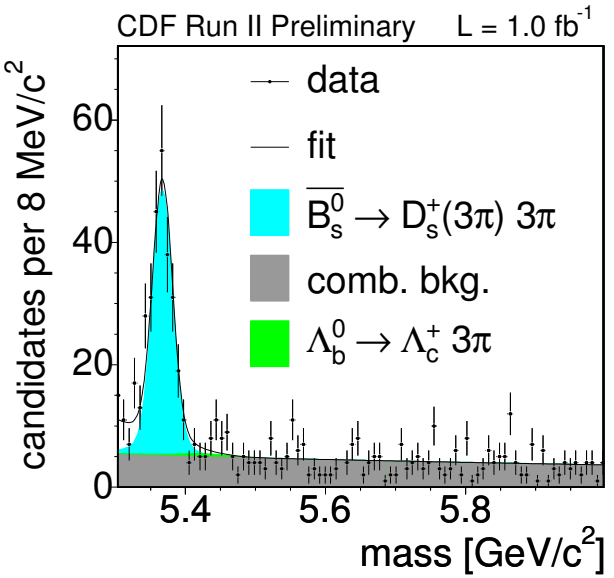

CDF Run II Preliminary
L = 1.0 fb-1
data
fit
$\overline{B_s^0} \to D_s^+ \pi/K$
$\overline{B_s^0} \to D_s^{*+} \pi/K$
$\overline{B_s^0} \to D_s^+ \rho$
$b \to D_s^+ X$
$\overline{B^0} \to D^+ \pi$
$\Lambda_b^0 \to \Lambda_c^+ \pi$
comb. bkg.
candidates per 10 MeV/c2
$\phi\pi^+\text{-}\pi^-$ mass [GeV/c2]


CDF Run II Preliminary
L = 1.0 fb-1
data
fit
$\overline{B_s^0} \to D_s^+(\overline{K^*}K)\ \pi$
comb. bkg.
$\overline{B^0} \to D^+ \pi$
$\Lambda_b^0 \to \Lambda_c^+ \pi$
candidates per 8 MeV/c2
mass [GeV/c2]


CDF Run II Preliminary
L = 1.0 fb-1
data
fit
$\overline{B_s^0} \to D_s^+(3\pi)\ \pi$
comb. bkg.
$\Lambda_b^0 \to \Lambda_c^+ \pi$
candidates per 8 MeV/c2
mass [GeV/c2]

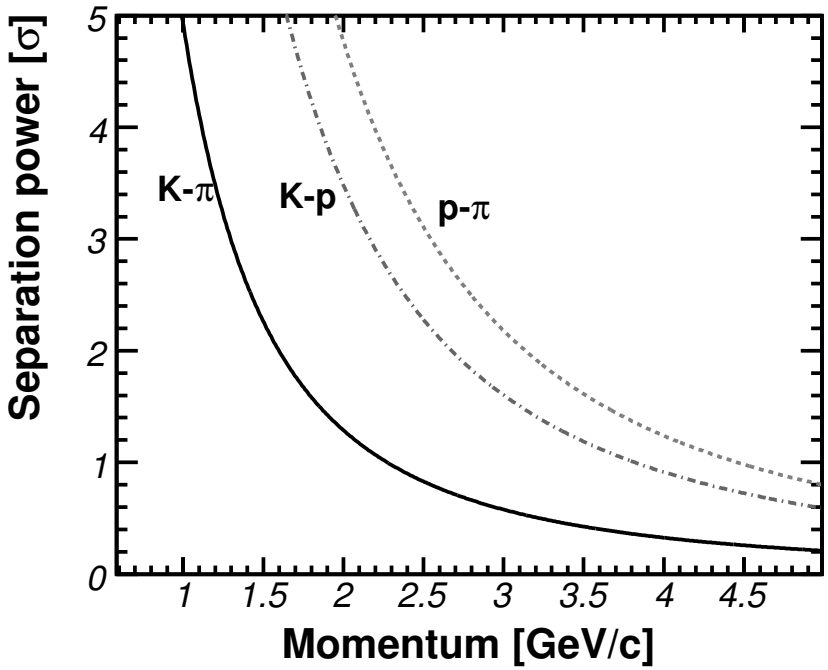

CDF Run II Preliminary
L = 1.0 fb-1
data
fit
$\overline{B_s^0} \to D_s^+(\phi\pi)\ 3\pi$
comb. bkg.
$\overline{B^0} \to D^+ 3\pi$
$\Lambda_b^0 \to \Lambda_c^+ \pi$
candidates per 8 MeV/c2
mass [GeV/c2]


CDF Run II Preliminary
L = 1.0 fb-1
data
fit
$\overline{B_s^0} \to D_s^+(\overline{K^*}K)\ 3\pi$
comb. bkg.
$\overline{B^0} \to D^+ 3\pi$
$\Lambda_b^0 \to \Lambda_c^+ 3\pi$
candidates per 8 MeV/c2
mass [GeV/c2]

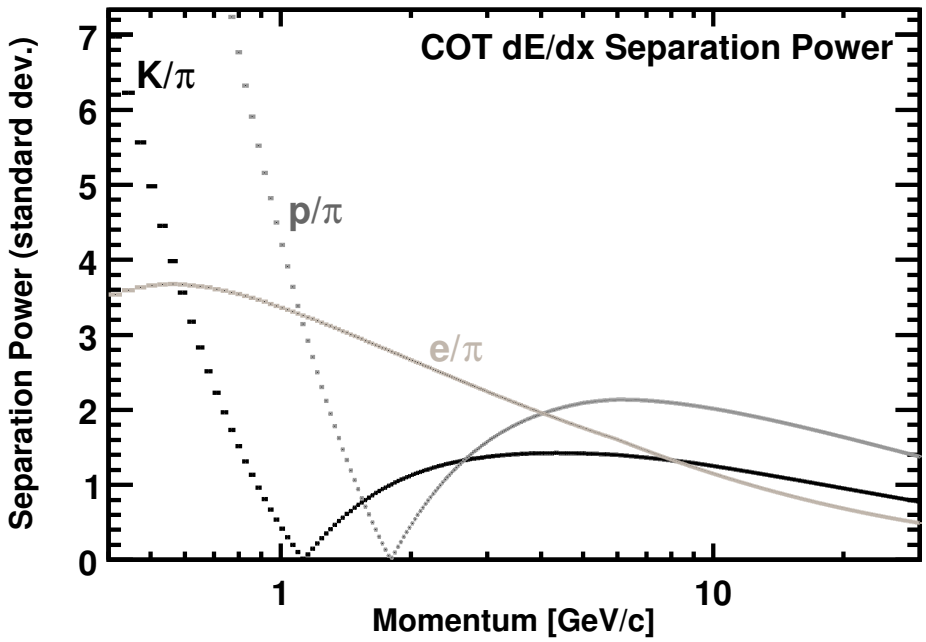

CDF Run II Preliminary
L = 1.0 fb-1
data
fit
$\overline{B_s^0} \to D_s^+(3\pi)\ 3\pi$
comb. bkg.
$\Lambda_b^0 \to \Lambda_c^+ 3\pi$
candidates per 8 MeV/c2
mass [GeV/c2]

PID

TOF separation power



dE/dx separation power



Combined log likelihood:

$$CLL(K) = \log\left(\frac{P_{TOF}(K)P_{dE/dx}(K)}{f_p P_{TOF}(p)P_{dE/dx}(p) + f_\pi P_{TOF}(\pi)P_{dE/dx}(\pi)}\right)$$