Search for B_s^0 Oscillations at DØ

① Motivation

② The DØ Detector

③ Analysis Overview

④ Results

⑤ Outlook

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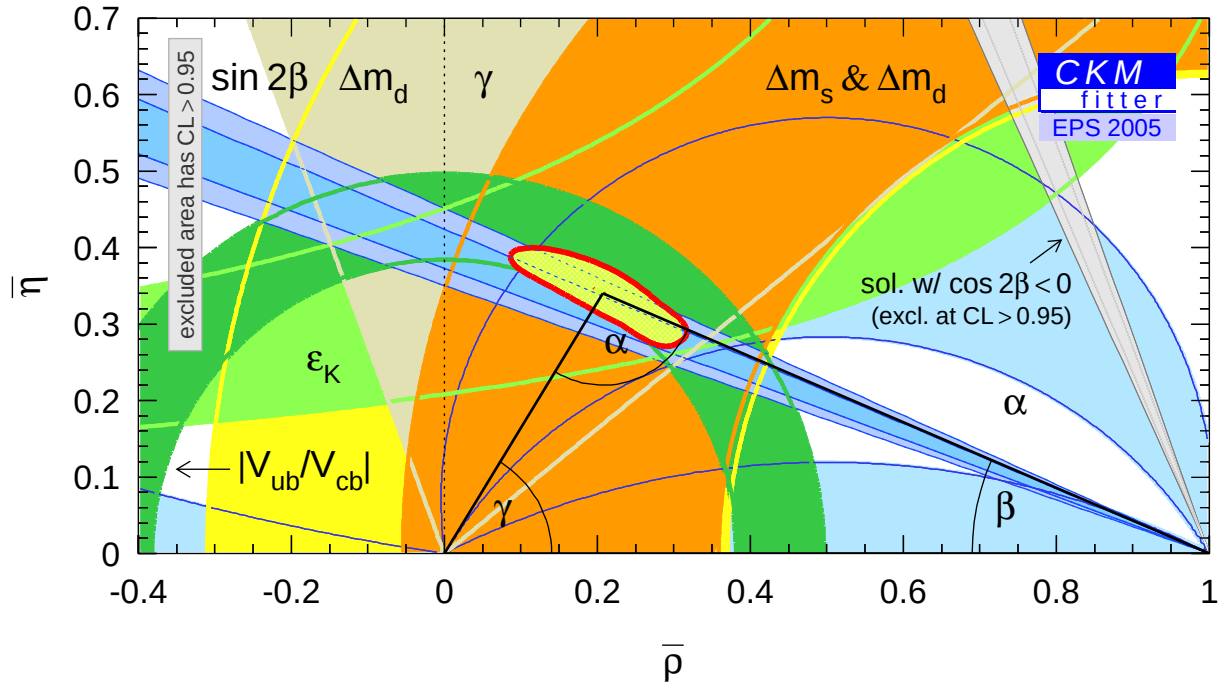
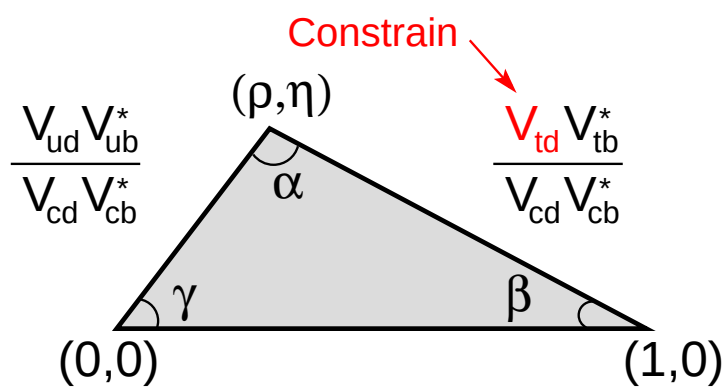
On behalf of the DØ Collaboration

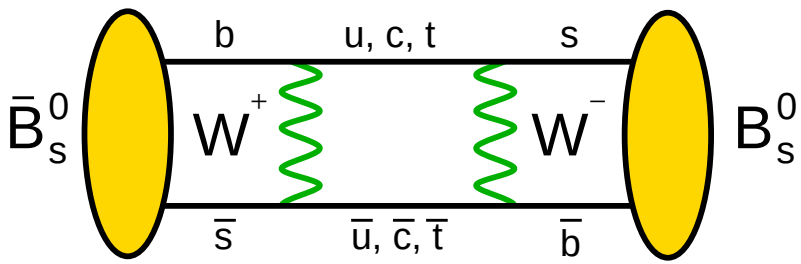
The CKM Triangle



- Measure length of all sides.
- Measure all three angles.
- Consistent?



B_s^0 Mixing and V_{td}

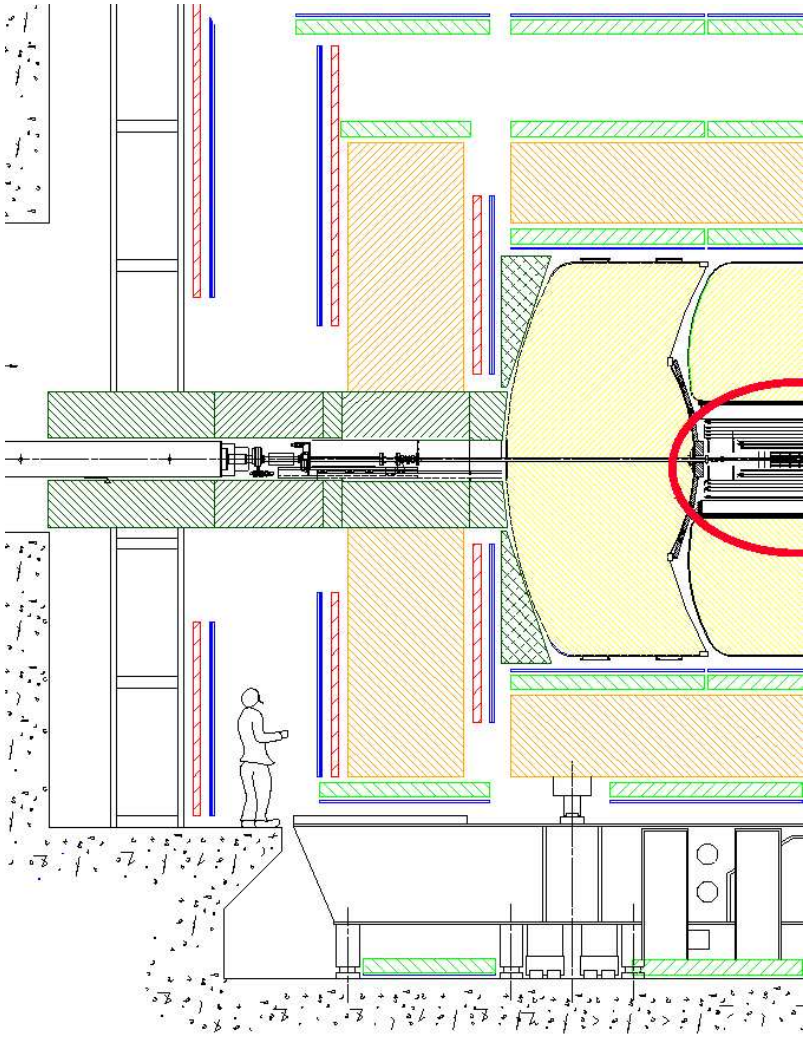


$$|B_1\rangle = \frac{1}{\sqrt{2}}\left(|B^0\rangle + |\bar{B}^0\rangle\right) = |B_H\rangle$$

$$|B_2\rangle = \frac{1}{\sqrt{2}}\left(|B^0\rangle - |\bar{B}^0\rangle\right) = |B_L\rangle$$

- From Δm_d: $\Delta m_d = \frac{G_F^2}{6\pi^2} m_W^2 m_{B_d} S\left[\frac{m_t^2}{m_W^2}\right] \eta \underbrace{f_{B_d}^2 B_{B_d}}_{\text{Large } (\sim 15\%) \text{ uncertainties}} |V_{tb}^* V_{td}|^2$

- From Δm_d and Δm_s: $\frac{\Delta m_s}{\Delta m_d} = \frac{m_{B_s}}{m_{B_d}} \underbrace{\frac{f_{B_s}^2}{f_{B_d}^2} \frac{B_{B_s}}{B_{B_d}}}_{\text{Smaller uncertainties}} \left|\frac{V_{ts}}{V_{td}}\right|^2$

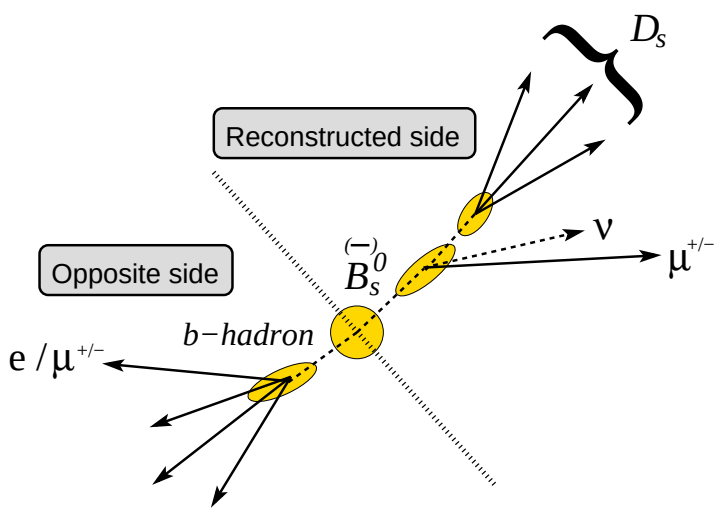


- Located at the Tevatron $p\bar{p}$ collider, operating at 1.96 TeV.
- Multipurpose detector.
- $20 \times 12 \times 12$ meters.
- Central tracking in a 2 T magnetic field:
  - Silicon tracker to $|\eta| \sim 3$.
  - Fiber tracker to $|\eta| \sim 2$.
- Calorimeter (EM + hadr.).
- Muon detectors, with 1.8 T toroid, extends to $|\eta| \sim 2$.
- Trigger system (write 50 Hz to tape).

Analysis Overview

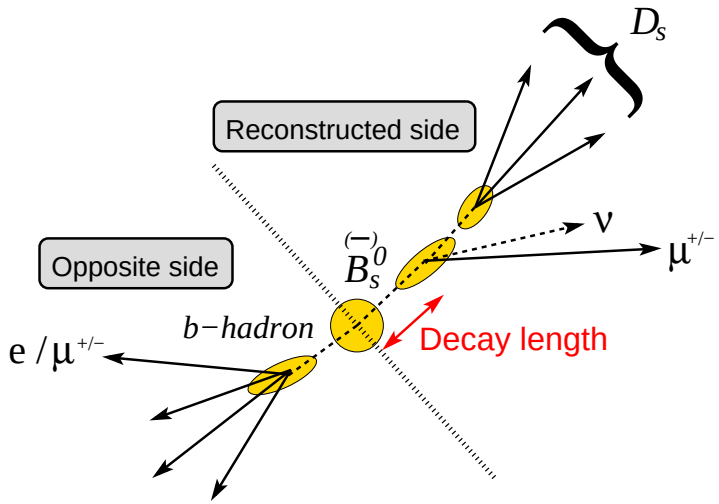
Use two semileptonic decay channels:

$$B_s^0 \rightarrow D_s^- \mu^+ X, \ (D_s^- \rightarrow \phi\pi)$$
$$B_s^0 \rightarrow D_s^- \mu^+ X, \ (D_s^- \rightarrow K^{*0} K^-)$$



- Charge of muon gives flavor at decay time.
- Jet charge, secondary vertex, muon or electron at opposite side (production time).
- Same sign - one oscillated, opposite sign - none (or both) oscillated.

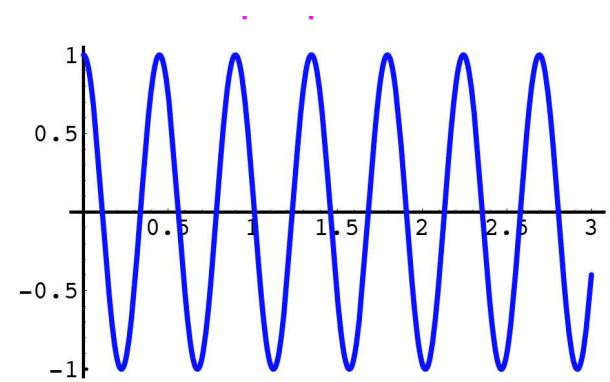
Asymmetry and Decay Length



- Measure decay length ($\vec{L}_{xy}$).
- Include boost to form Visible Proper Decay Length (VPDL).

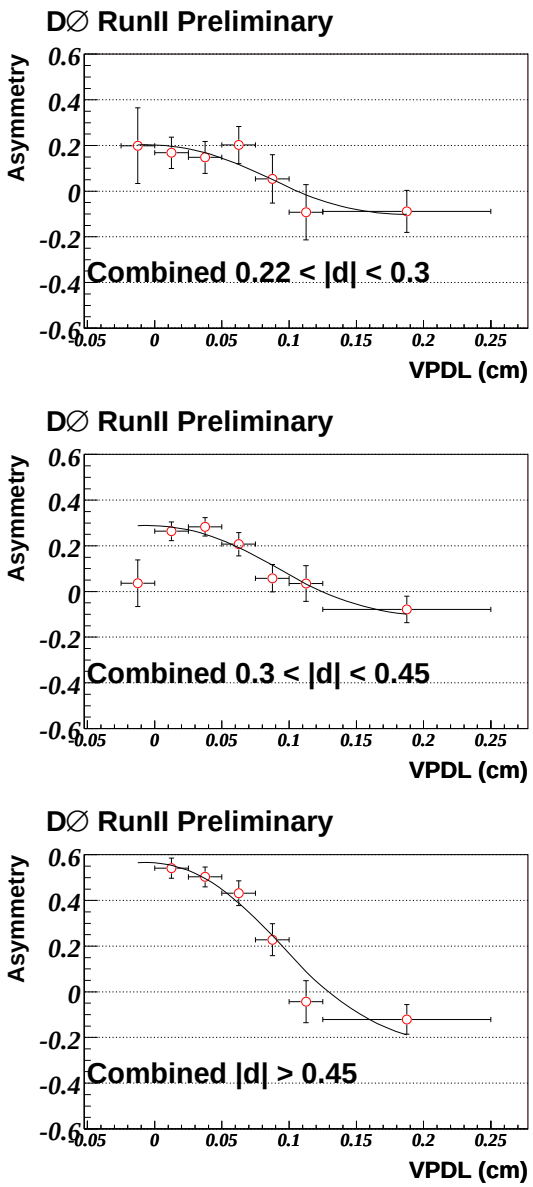
$$VPDL = (\vec{L}_{xy} \cdot \vec{p}_{xy}^{D_s\mu})/(p_T^{D_s\mu})^2 m_{B_s}$$

- Form asymmetry $A = \frac{N_{non-osc} - N_{osc}}{N_{non-osc} + N_{osc}}$ as a function of VPDL.
- Compare with the expected asymmetry for a given Δm_s.
- $ct_{B_s} = VPDL \cdot K$.
- $K = p_T^{D_s\mu}/p_T^{B_s}$ from MC.

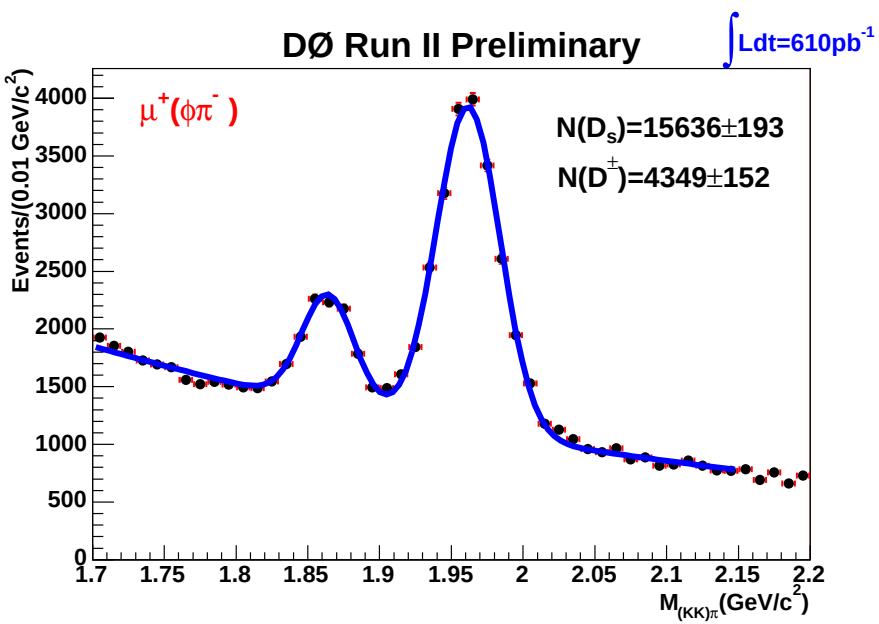


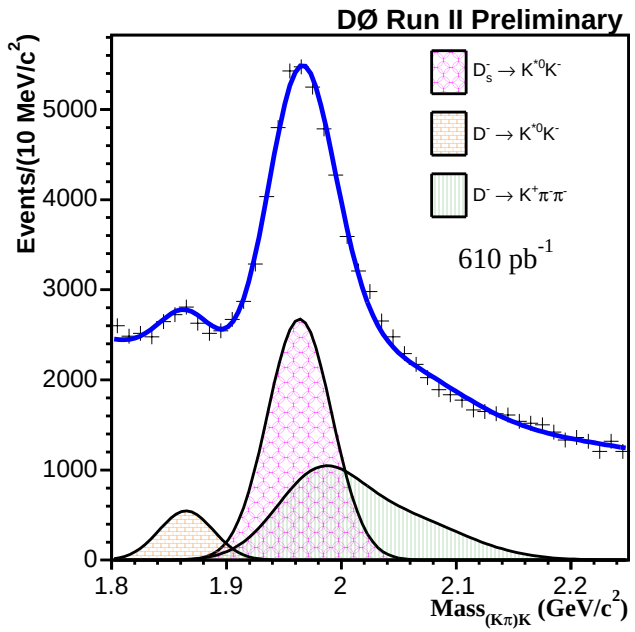
Dilution

- $\mathcal{D} = 2\eta - 1$, $\eta = \frac{N_{correct\ tags}}{N_{total\ tags}}$.
- Multiplier of the ideal ± 1 asymmetry amplitude.
- Measured in data using B_d^0 oscillations.
- Amplitude gives $\mathcal{D}$.
- MC shows that dilutions for B_d^0 and B_s^0 agree.
- Dilutions for B_d^0 agree in data and MC.
- $\mathcal{D} = 0.384 \pm 0.013$.

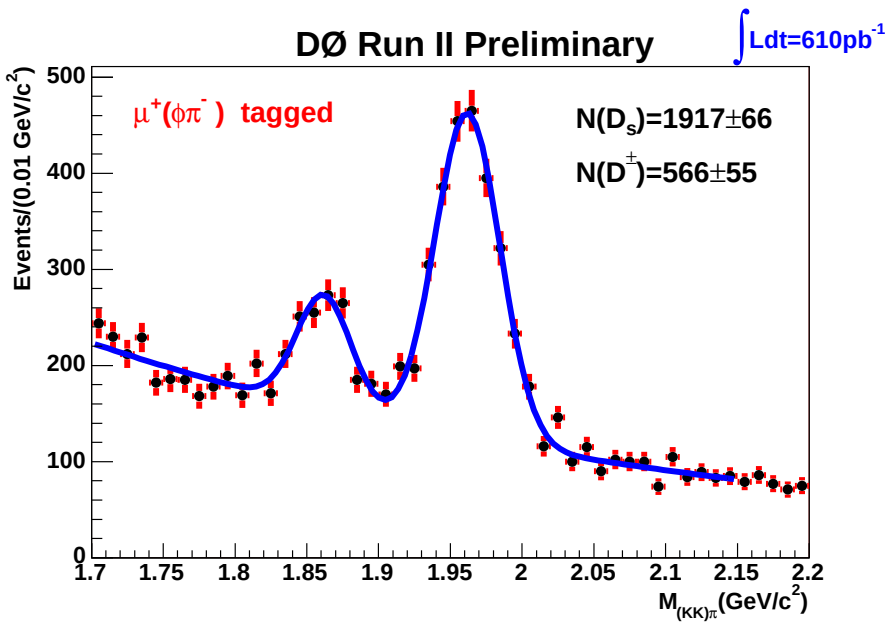


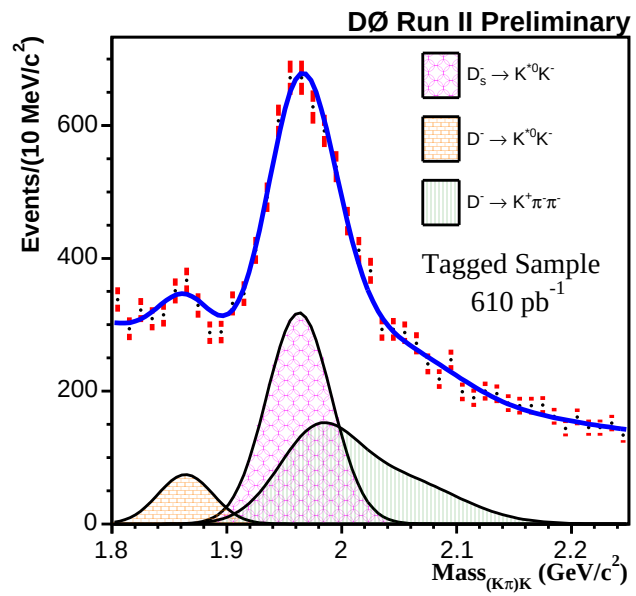
Signal Samples





- Impressively large semileptonically decaying B_s^0 sample.
- Based on 610 pb^{-1} of data, processed up to June 2005.



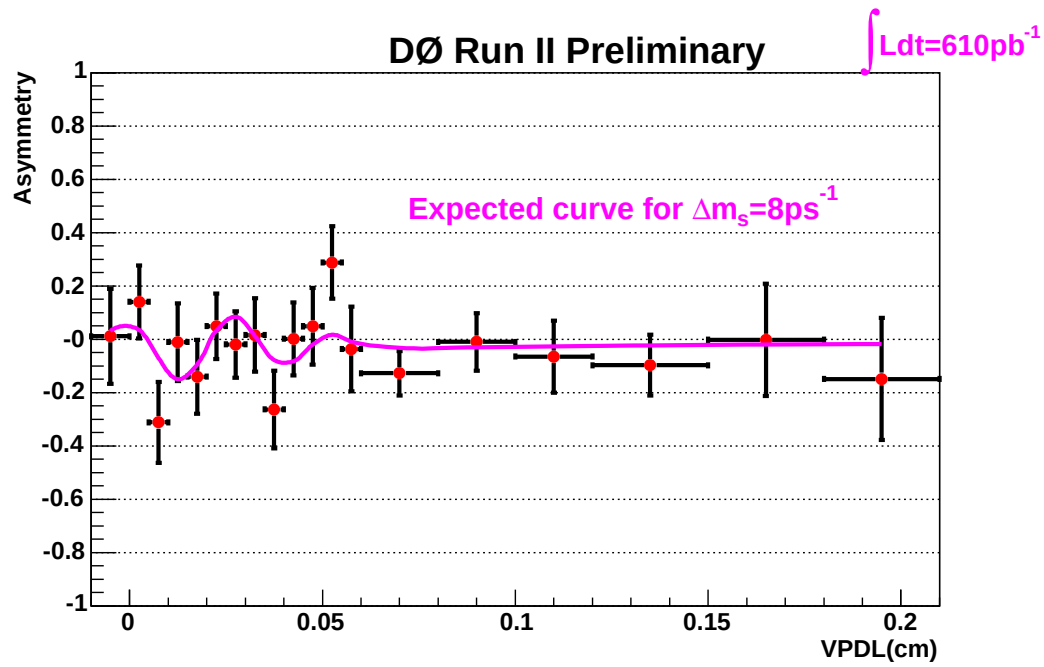


- Flavor-tagging efficiency for combined opposite-side tag is 12.3%.
- $\sim$ 4.2 k candidates after flavor tagging.
- Useful signal fraction is 88.3%.

The Amplitude Method

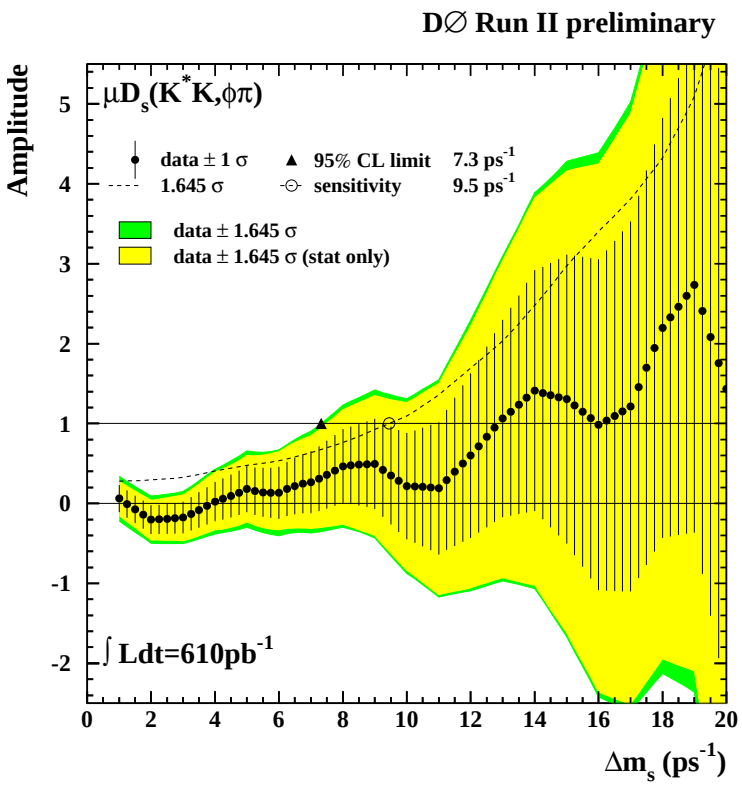
$$n_s^{osc,non-osc}(x) = \frac{K}{c\tau} \cdot 0.5 \cdot [1 \mp \mathcal{D} \cdot \mathcal{A} \cdot \cos(\Delta m_s \cdot Kx/c)]$$

- If oscillation signal with Δm_s then $\mathcal{A}$ reaches 1, else $\mathcal{A} < 1$.
- Scan Δm_s and fit $\mathcal{A} \pm \Delta\mathcal{A}$ by minimizing the χ^2 between the expected and observed asymmetry.



Results

- Limit: Where $\mathcal{A} = \mathcal{A}^{fit} + \Delta\mathcal{A}^{tot}$ could fluctuate to $\mathcal{A} = 1$.
- Sensitivity: Where $\mathcal{A} = 0 + \Delta\mathcal{A}^{tot}$ could fluctuate to $\mathcal{A} = 1$.

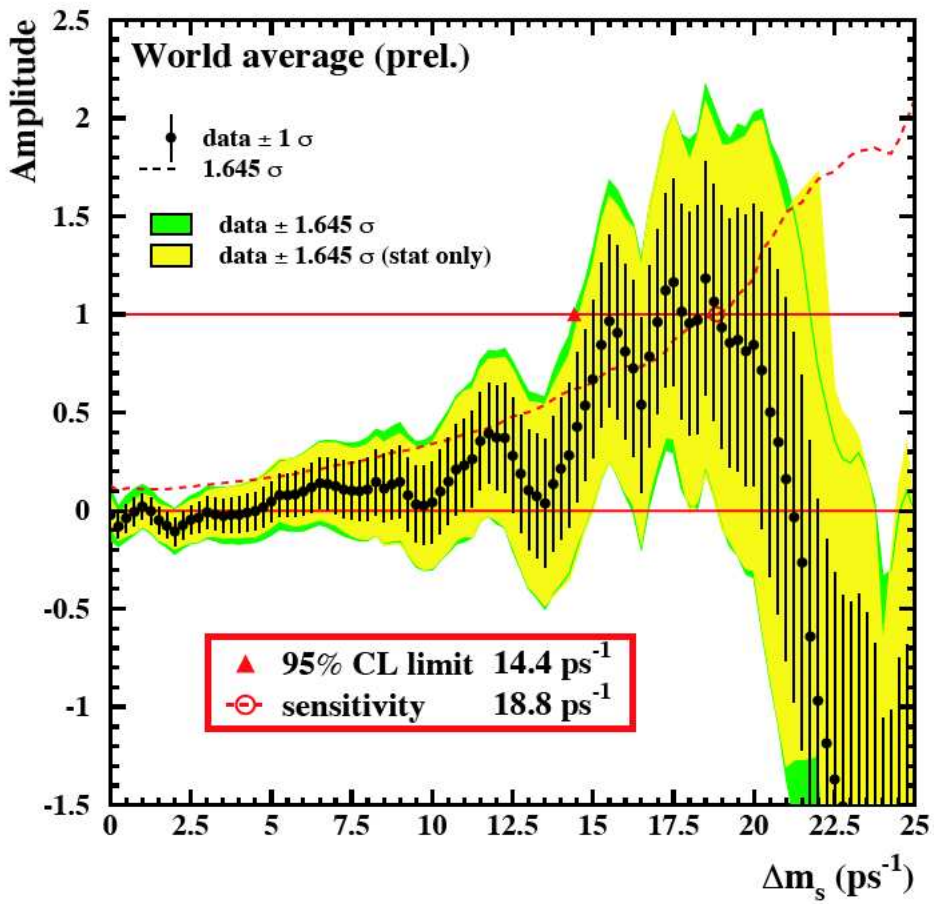


- Combined limit:
  $\Delta m_s > 7.3$ ps^{-1} at 95% C.L.
- Combined sensitivity:
  $\Delta m_s > 9.5$ ps^{-1} at 95% C.L.

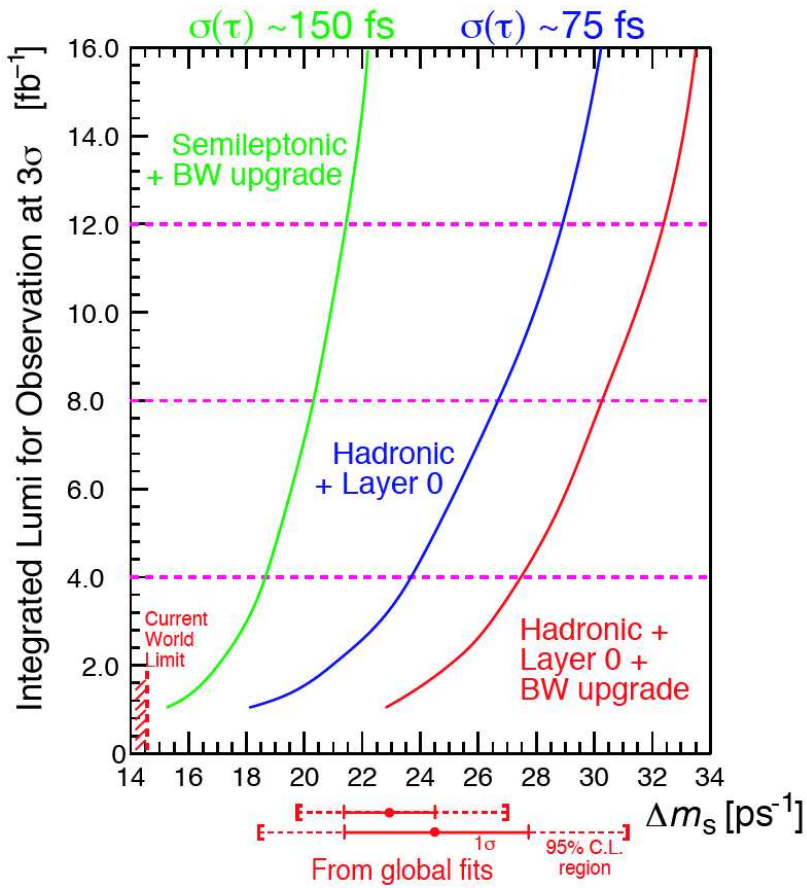
- Largest systematic errors:
  - Tagging purity.
  - $c\bar{c}$ contamination.
  - $Br(B_s \to D_s \mu X)$.
  - Resolution SF.
  - K-factor uncertainties.

New World Average

- Includes preliminary RunII CDF and DØ results.



Outlook



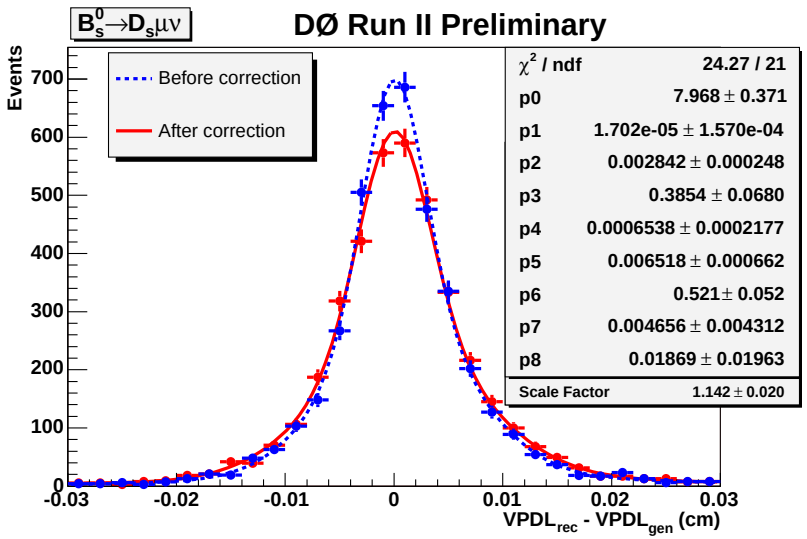
- The Tevatron is entering a new b-physics era.
- New silicon layer (Layer 0).
- Increased bandwidth for b-physics.
- Include hadronic decay modes.
- Will reach sensitivities well beyond 20 ps^{-1}.

The Tevatron = high p_T physics + B_s factory!

Backup Slides

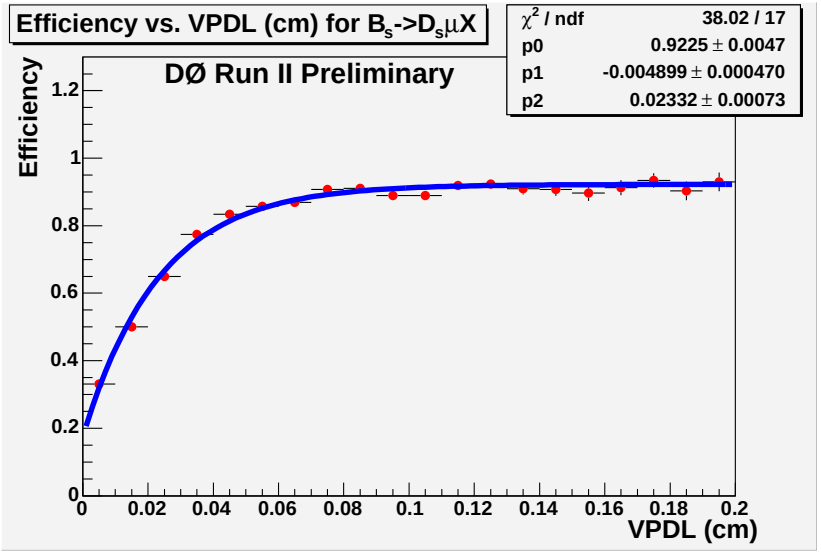
Visible Proper Decay Length Resolution

- The VPDL resolution is taken from full detector simulation.
- Adjusted by one global scale factor derived from data/simulation comparison.



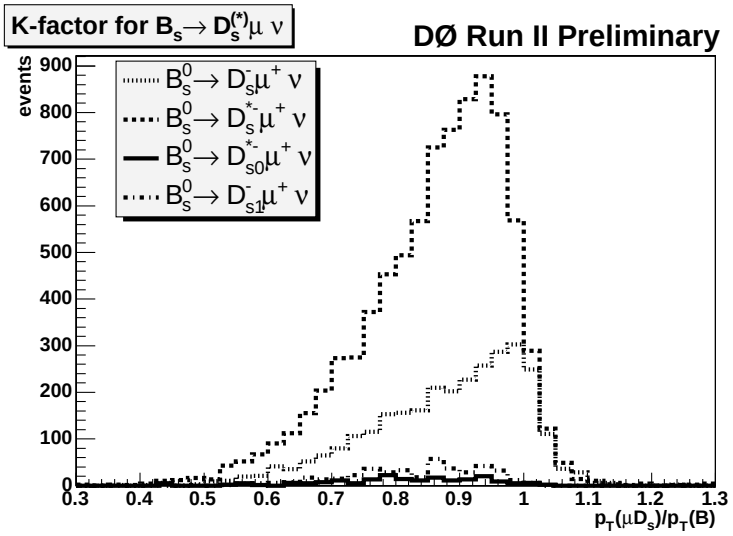
Efficiency vs VPDL

- Due to lifetime cuts in the B_s reconstruction the reconstruction efficiency depends on VPDL.
- Efficiency curve done for each mode, and the different decay modes have similar turn-on curves.

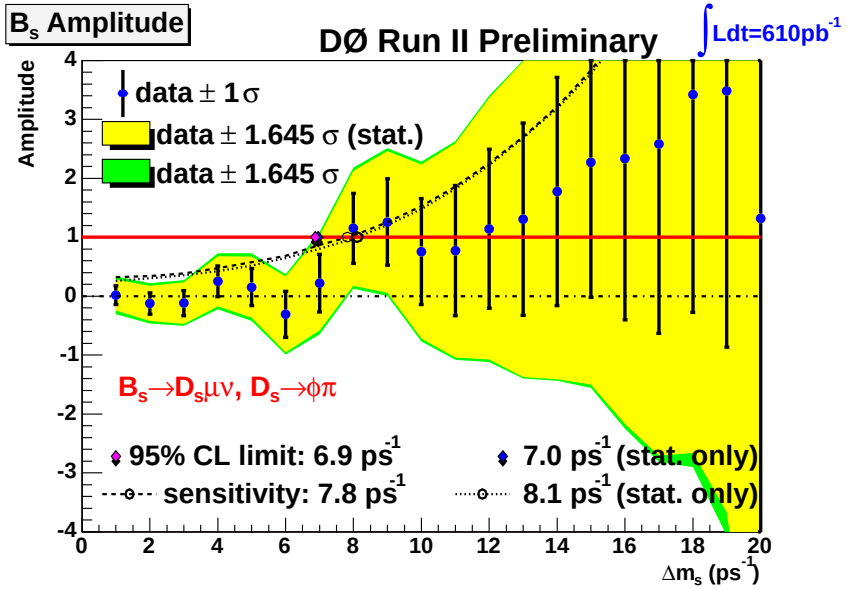
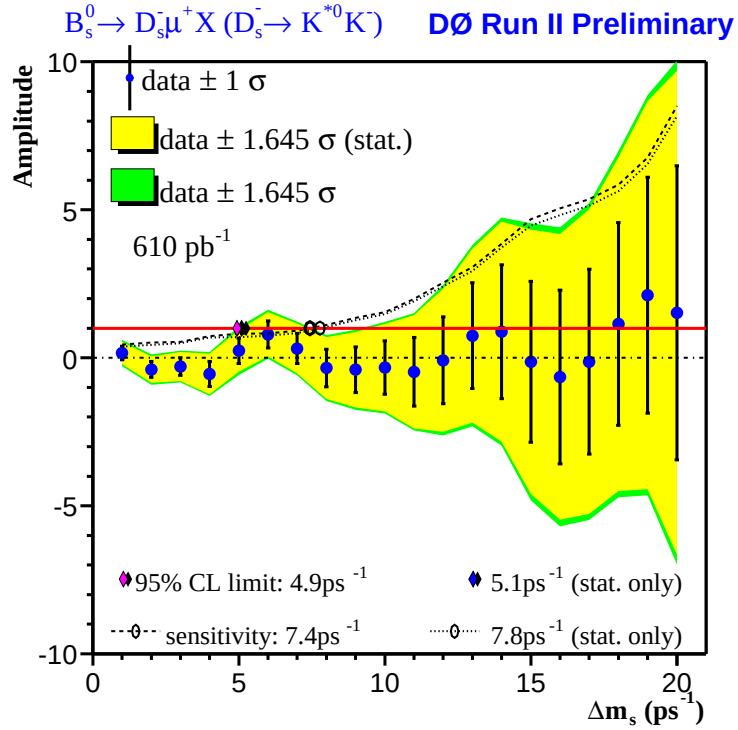


The K-factor (Non-reconstructed Particles)

- $ct_{B_s} = VPDL \cdot K$.
- $K = p_T^{D_s\mu}/p_T^{B_s}$ from MC.



- For each decay mode, the distribution of the K-factor is taken from a simulation.

Results per Decay Channel

$$B_s^0 \to D_s^- \mu^+ X,\ (D_s^- \to \phi\pi) \qquad B_s^0 \to D_s^- \mu^+ X,\ (D_s^- \to K^{*0} K^-)$$