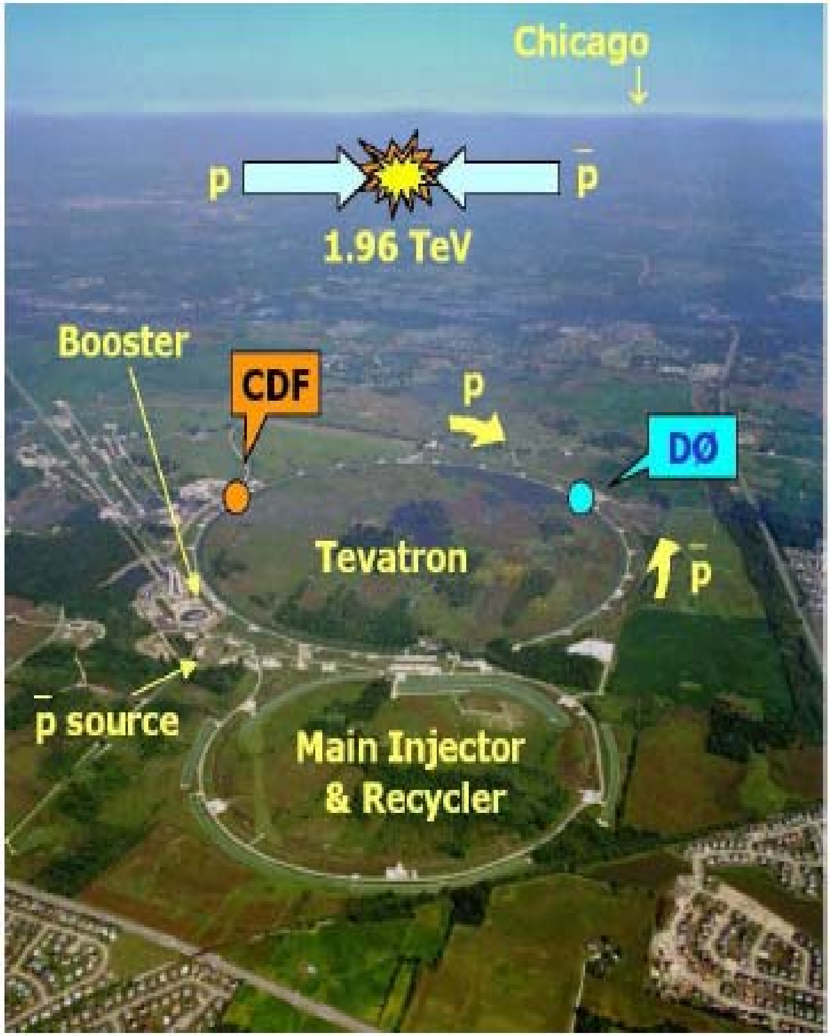
# Selected B-physics at DØ

for the DØ Collaboration
09 nov 2005 Flavour in the era of the LHC
CERN

- Tevatron and DØ
- Results and Prospects
  - $\Delta\Gamma_s/\Gamma_s$
  - $B_s$ Mixing
  - $B_s \rightarrow \mu\mu$
- Summary

Cano Ay , Johannes Gutenberg Universität , ayc@uni-mainz.de

# Tevatron




Highest Luminosity at DØ:
$1.6 \cdot 10^{32}$ $cm^{-2}s^{-1}$

Recorded Luminosity:
1.04 $fb^{-1}$

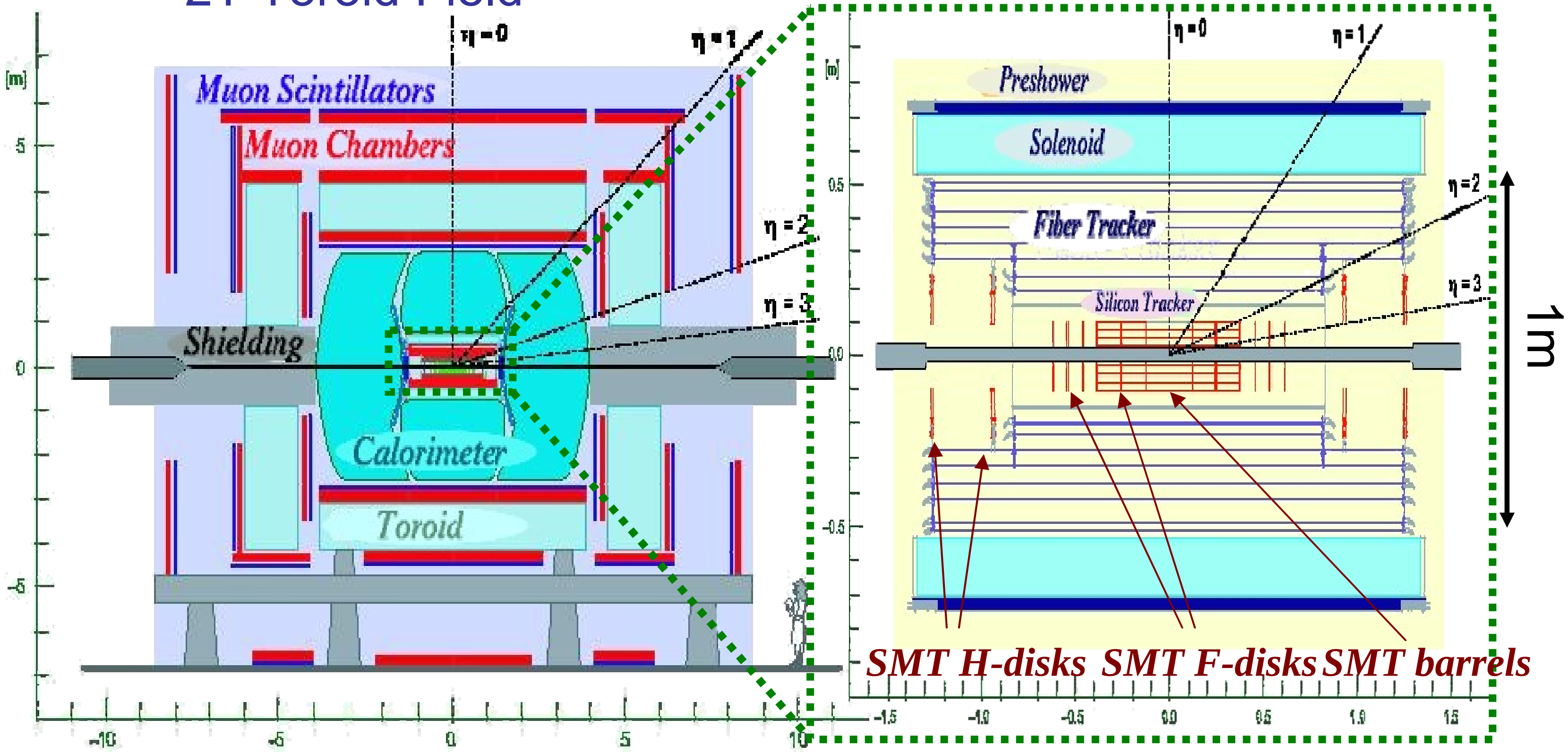
Delivered Luminosity:
1.24 fb-1

Integrated Luminosity per Experiment:
~2 $fb^{-1}$ until 2006
~8 $fb^{-1}$ until 2009

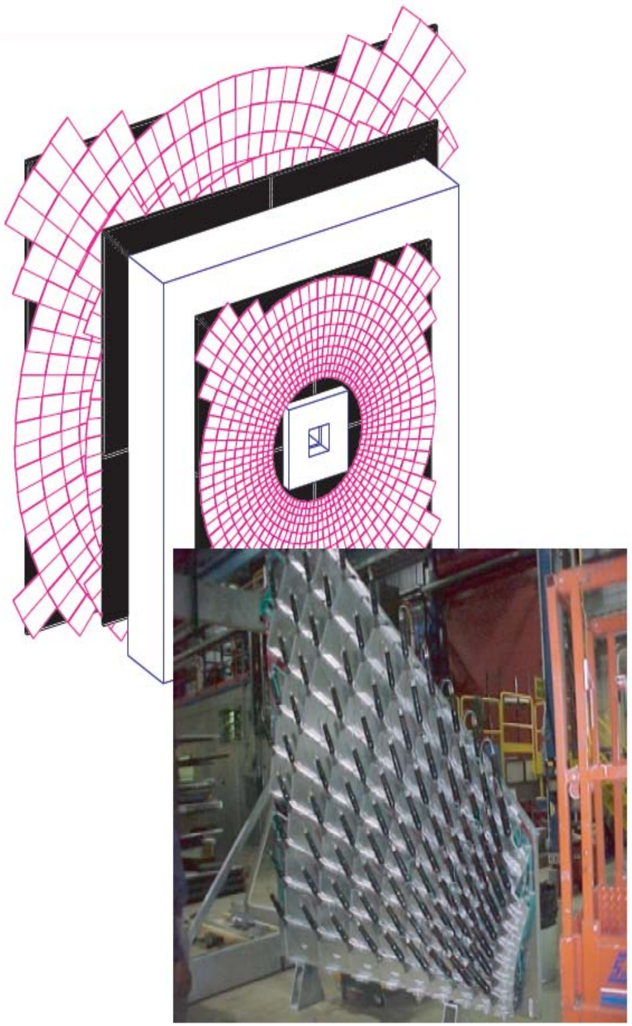
# DØ Detector

Muon system:
Coverage: $|\eta|<2$
Good shielding
2T Toroid Field

Tracking system:
Coverage: $|\eta|<3.2$
2T Solenoid Field



# Muon triggers



- single inclusive muons, $|\eta|<2.0$, $p_T>3,4,5$ GeV
  - Muon + track match at Level 1 and a muon at Level 2
  - Unbiased; prescaled or turned off depending on inst. Lumi.
  - At Level 3 also invariant mass track selections (imply impact parameter bias)

- Dimuons

**Tevatron currently only place to study $B_s$ Meson**

- SM predicts a $\Delta m_s \neq 0$ and $\Delta\Gamma_s \neq 0$

$$|B_H\rangle = \tfrac{1}{\sqrt{2}}(|B^0\rangle + |\overline{B^0}\rangle) \qquad |B_L\rangle = \tfrac{1}{\sqrt{2}}(|B^0\rangle - |\overline{B^0}\rangle)$$

$$\Rightarrow \quad \Delta m_q = m_H - m_L \approx 2 \cdot |M_{12}| \qquad \Delta\Gamma_q = \Gamma_L - \Gamma_H \approx 2 \cdot |\Gamma_{12}| \cdot \cos\phi \qquad \phi = \arg\left(\frac{-M_{12}}{\Gamma_{12}}\right)$$

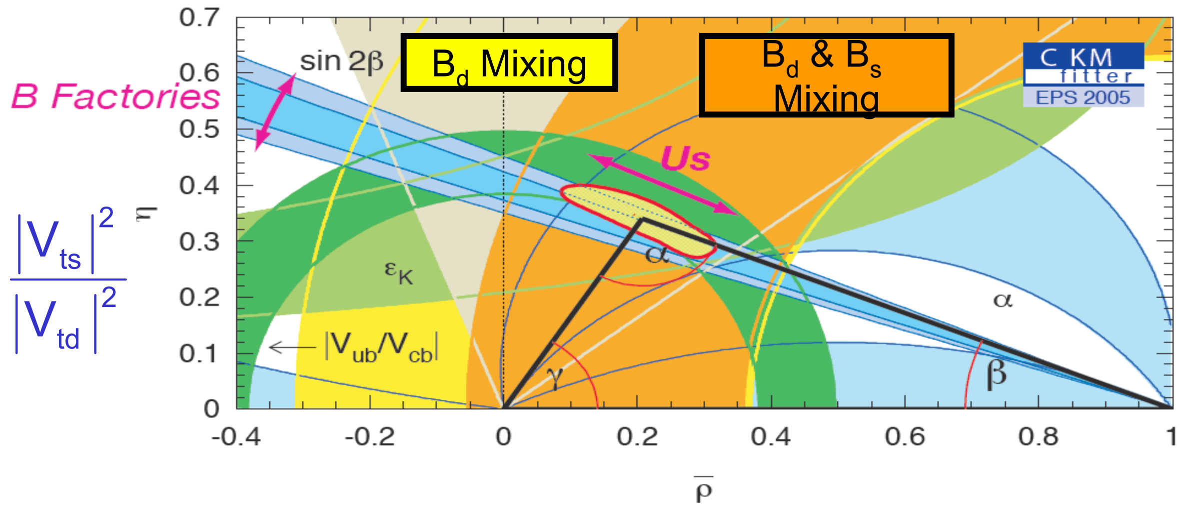
- $\Delta m_s / \Delta m_d$ constrain unitarity triangle

$$\Delta m_d \sim |V_{td}|^2$$

larger uncertainties!

$$\frac{\Delta m_s}{\Delta m_d} = \frac{m_{B_s^0}}{m_{B_d^0}} \cdot \frac{B_{B_s^0} \cdot f_{B_s}^2}{B_{B_d^0} \cdot f_{B_d}^2} \cdot \frac{|V_{ts}|^2}{|V_{td}|^2}$$

smaller uncertainties!



# Motivation

- Expectation for lifetime difference $\Delta\Gamma_s/\Gamma_s$ (with experimental input)

$$\Delta\Gamma_s/\Gamma_s = 0.12 \pm 0.05$$

A.Lenz hep-phy / 0412007

- Discrepancies to SM Expectation $\rightarrow$ new physics

- decay Bs $\rightarrow \mu\mu$ : example indirect search for New physics
    - FCNC process $\rightarrow$ highly suppressed in SM
    - Observing the decay would indicate new physics (SUSY, MSSM, etc)

Standard Model Predictions

| | $\mathcal{B}(B_d^0 \to \ell^+\ell^-)$ | $\mathcal{B}(B_s^0 \to \ell^+\ell^-)$ |
|---|---|---|
| $\ell = e$ | $(2.40 \pm 0.34) \times 10^{-15}$ | $(8.15 \pm 1.29) \times 10^{-14}$ |
| $\ell = \mu$ | $(1.00 \pm 0.14) \times 10^{-10}$ | $(3.42 \pm 0.54) \times 10^{-9}$ |
| $\ell = \tau$ | $(2.90 \pm 0.41) \times 10^{-8}$ | $(9.86 \pm 1.55) \times 10^{-7}$ |

# B-physics program at DØ

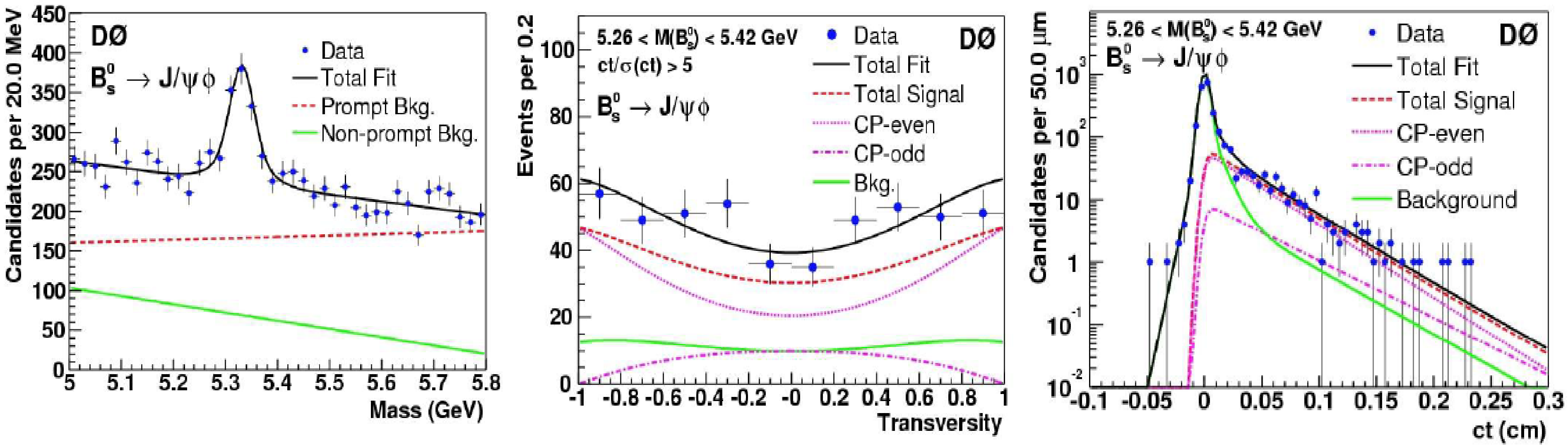
- Reconstruction of $\Lambda_b$ in semileptonic Decays
- Reconstruction of $B_s \rightarrow \mu D_s X$ decays
- Reconstruction of B Hadron Signals at D0
- Evidence of $B_s \rightarrow D_s(2536)\mu\nu X$
- Observation of the $B_c$ Meson and study of ist properties
- Study of exited B Mesons (B**)
- A high statistics measurement of the $B_s^0$ lifetime
- Observation of $B_s \rightarrow \psi(2s)\phi$ and a measurement of $B(B_s \rightarrow \psi(2s)\phi$ ))/B( $B_s \rightarrow \psi(2s)\phi$ )
- **Search for $B_s \rightarrow \mu\mu$ rare decays**
- FCNC charm decays and Observation of $D_s \rightarrow \phi\pi \rightarrow \pi\mu\mu$
- **$B_s$ mixing with $B_s \rightarrow D_s \mu X$, $D_s \rightarrow \phi\pi$ and opposite-side flavor tagging**
- **$B_s$ mixing with $B_s \rightarrow D_s \mu X$, $D_s \rightarrow K^*K$ and opposite-side flavor tagging**
- Flavor oscillations in $B_d$ Mesons with 3 combined Taggers
- Measurement of upsilon differential cross section
- Measurement of the ratio $B^+$ and $B^0$ meson lifetimes
- Measurement of the $\Lambda$b lifetime in the decay $J/\psi\Lambda$ decays
- Measurement of the $B_s$ lifetime in the exclusive decay channel $B_s \rightarrow J/\psi\phi$
- **Measurement of the lifetime difference in the $B_s$ system**
- Measurement of the semileptonic branching fractions of B mesons to narrow D** states
- Observation and Properties of the X(3872) Decayoing to $J/\psi\pi^+\pi^-$

- $\Delta\Gamma_s/\Gamma_s$
- $B_s$ Mixing
- $B_s \rightarrow \mu\mu$

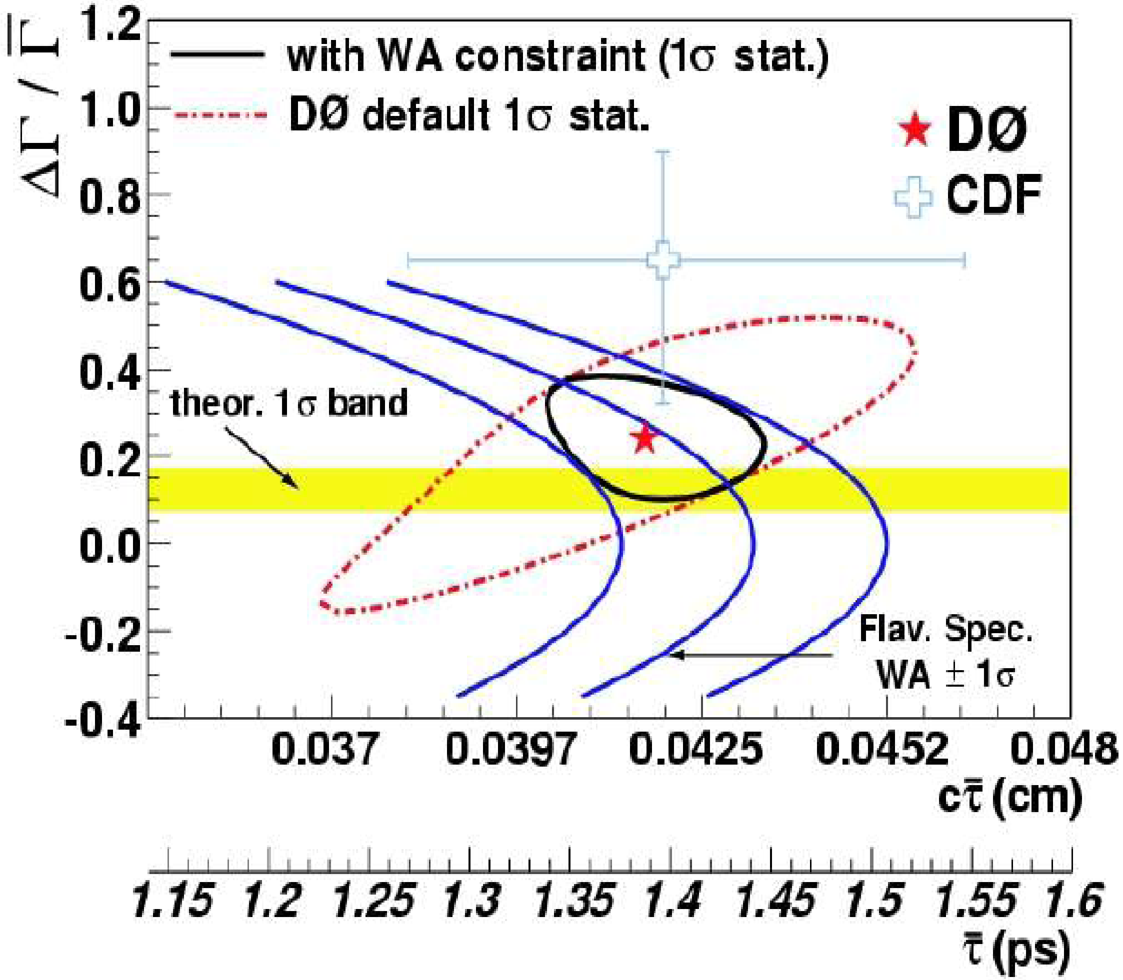
# $\Delta\Gamma_s/\Gamma_s$ Analysis

- Reconstruct $B_s \rightarrow J/\psi\ \phi$, with $\phi \rightarrow K^+K^-$ and $J/\psi \rightarrow \mu^+\mu^-$

- the polarisation state of the vector mesons in the final states are different for CP eigenstates
- Simultaneous fit to



# $\Delta\Gamma_s/\Gamma_s$ Results




DØ : 450pb$^{-1}$

$$\frac{\Delta\Gamma}{\overline{\Gamma}} = 0.24^{+0.28}_{-0.38}$$

$$\overline{\tau} = 1.39^{+0.13}_{-0.16}\ ps$$

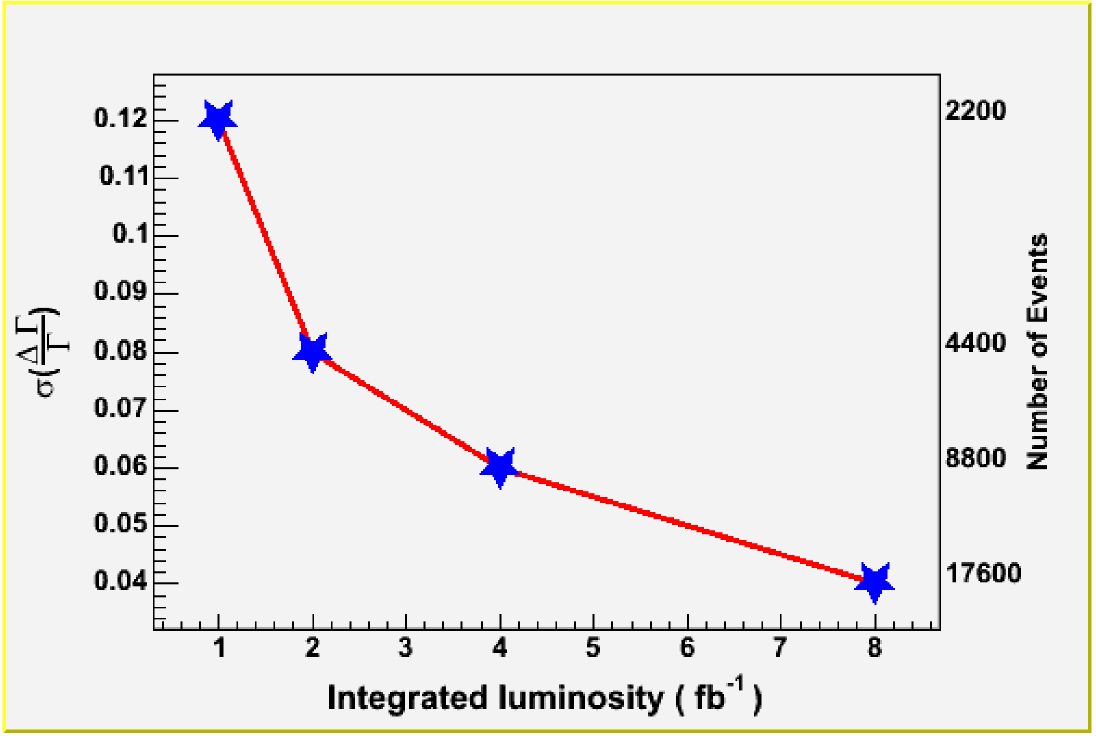
**With F.S. Constraint**

$$\frac{\Delta\Gamma}{\overline{\Gamma}} = 0.25^{+0.14}_{-0.15}$$

$$\overline{\tau} = 1.39 \pm 0.06\ ps$$

# Prospects $\Delta\Gamma_s/\Gamma_s$

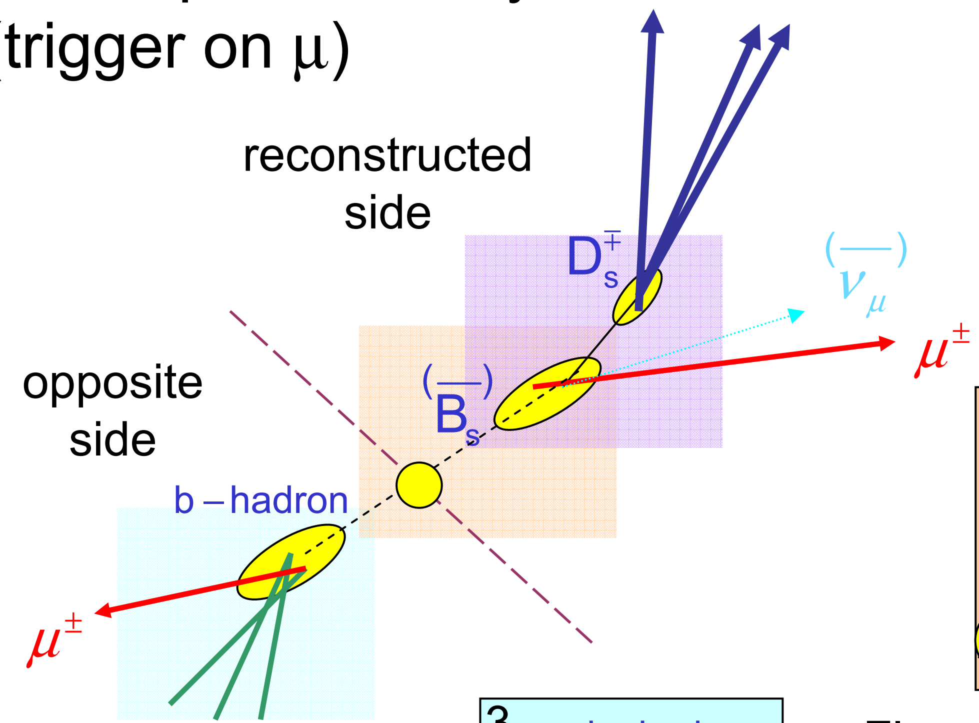
- Analysis improvement
  - Fit all 3 angles in transversity, not only 1 angle
  - update silicon Layer 0
  - extrapolate forwards to higher luminositiy

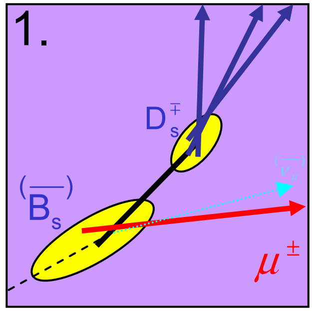


- $\Delta\Gamma_s/\Gamma_s$
- <u>$B_s$ Mixing</u>
- $B_s \rightarrow \mu\mu$

# $B_s$ Mixing: Analysis

Semileptonic decays:
(trigger on μ)



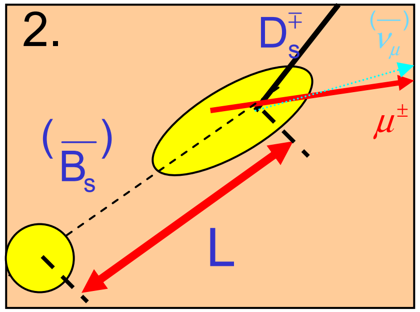




Signal selection:

$D_s^{\pm} \to \phi(K^+K^-)\pi^{\pm}$

$D_s^{\pm} \to K^*(K^{\pm}\pi^{\mp})K^{\pm}$

$\to$ 34k Candidates

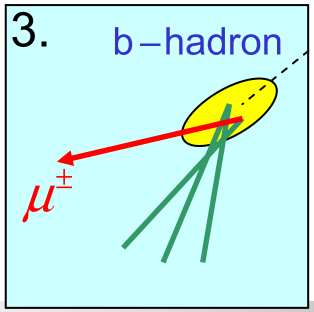



Proper decay time:

$$c\tau = m_B \frac{L_{xy}}{P_T(B)}$$

$$P_T(B) = P_T(D\mu)\cdot K$$

$$\sigma_\tau \approx 150\text{fs}$$

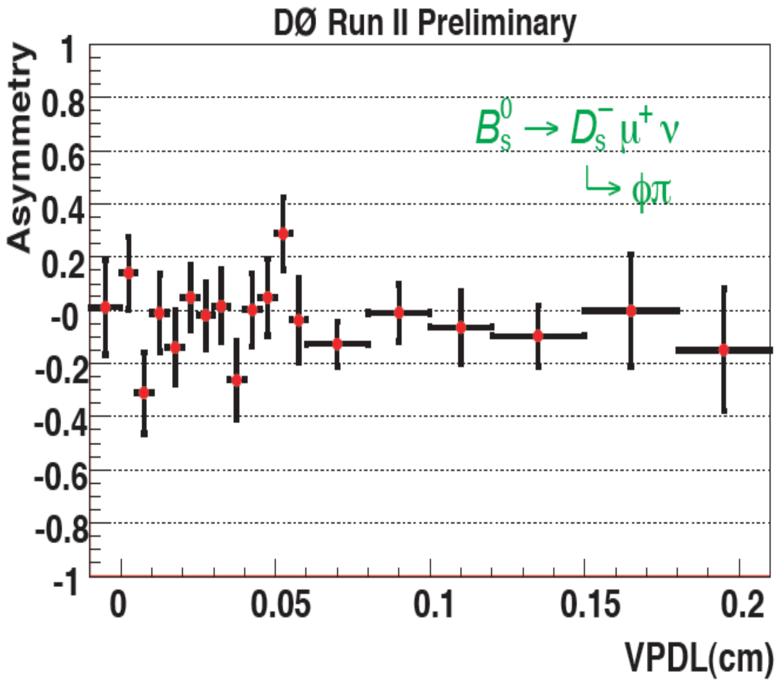



Flavor at time of production
(Flavor tagging):

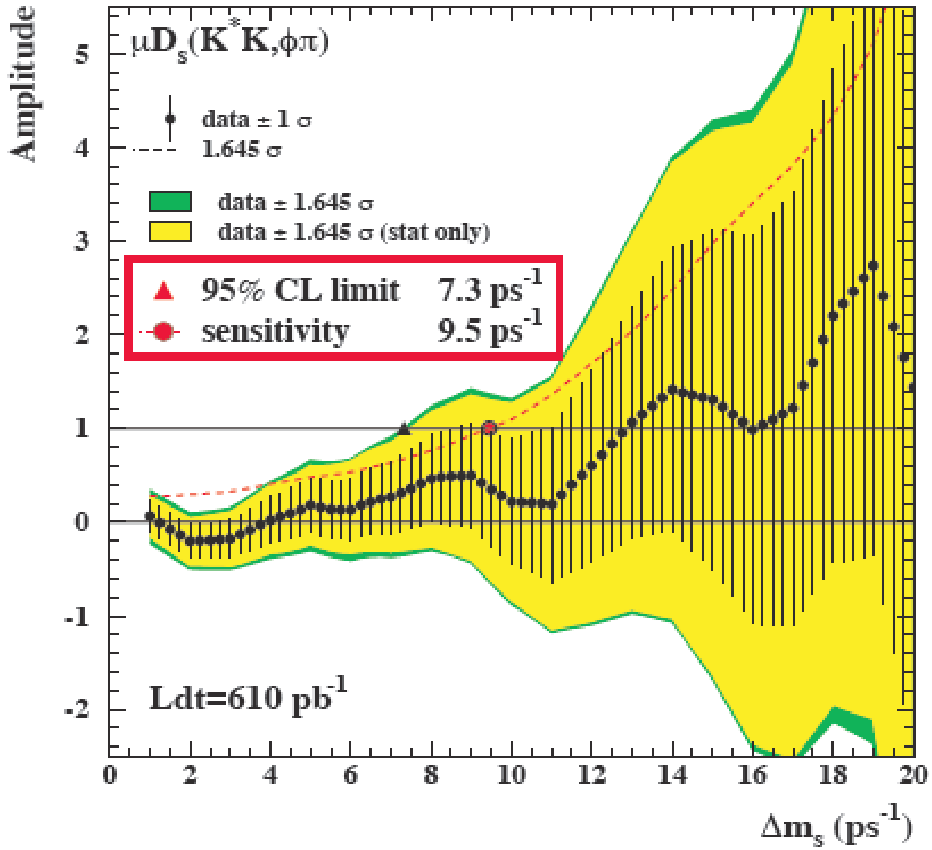
- lepton charge
- secondary vertex Jet charge

$\varepsilon D^2 = (1.94 \pm 0.14 \pm 0.09)\%$

- very large semileptonically decaying sample (~34k) in 610pb$^{-1}$
- after flavour tagging (~4.2k)




**Limit for both channels**



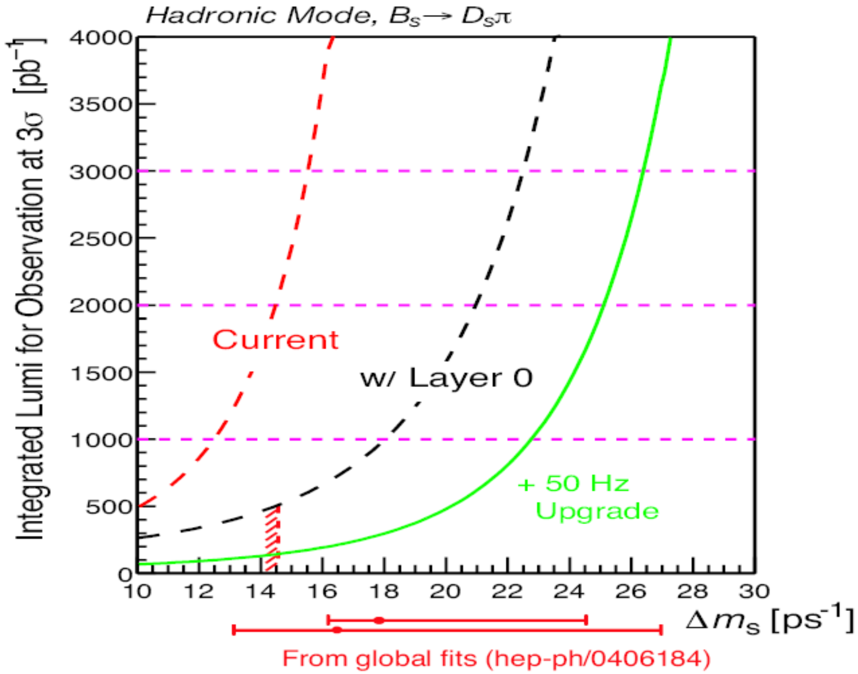
# Prospects $\Delta m_s$

- more data

- General Analysis improvements
  - hadronic channel, other semileptonic channels
  - Event-by-event fit, not binned likelihood
  - improved flavour tagging

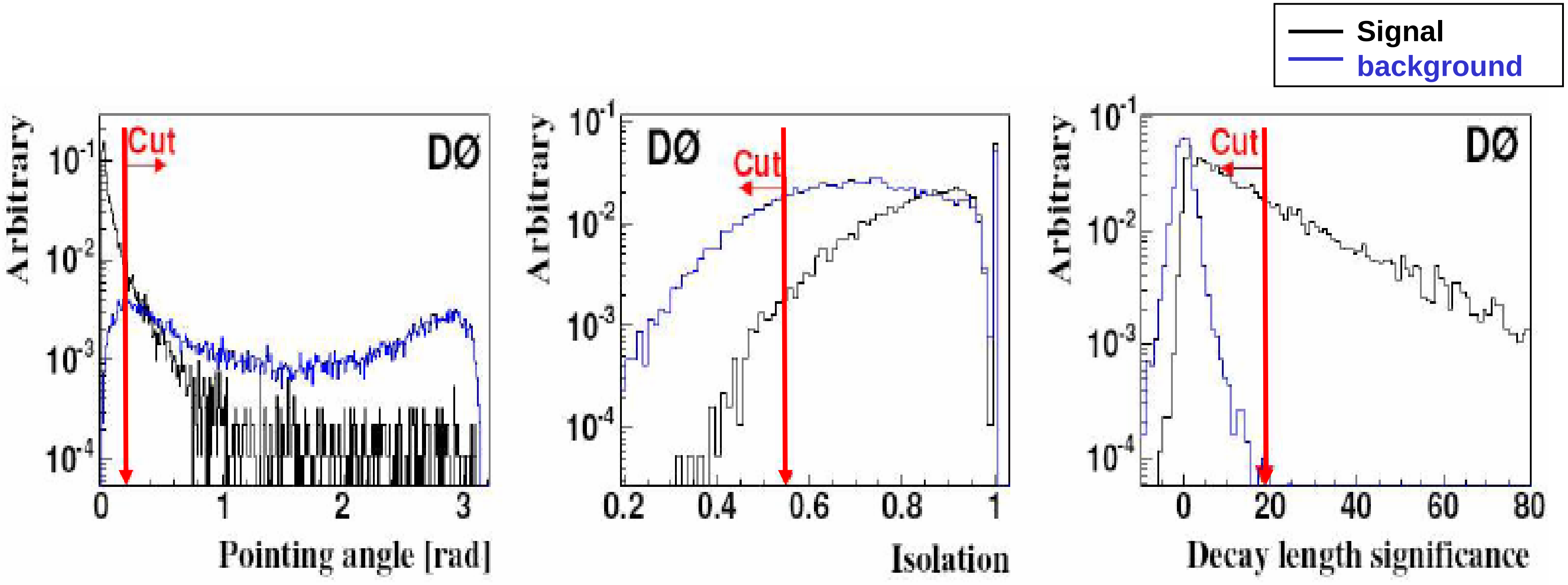
- Upgrades
  - layer 0 silicon, improved vertex resolution
  - L3 bandwidth 50Hz to 100Hz

$\Delta m_s$ sensitivity

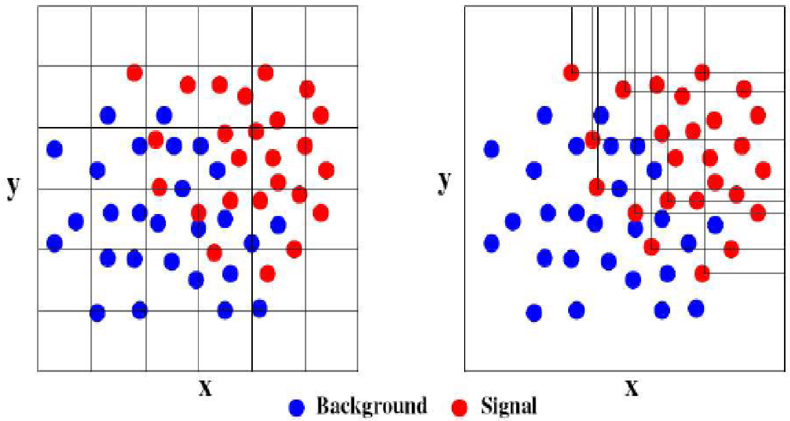


- $B_s$ Mixing
- $\Delta\Gamma_s/\Gamma_s$
- $B_s \rightarrow \mu\mu$

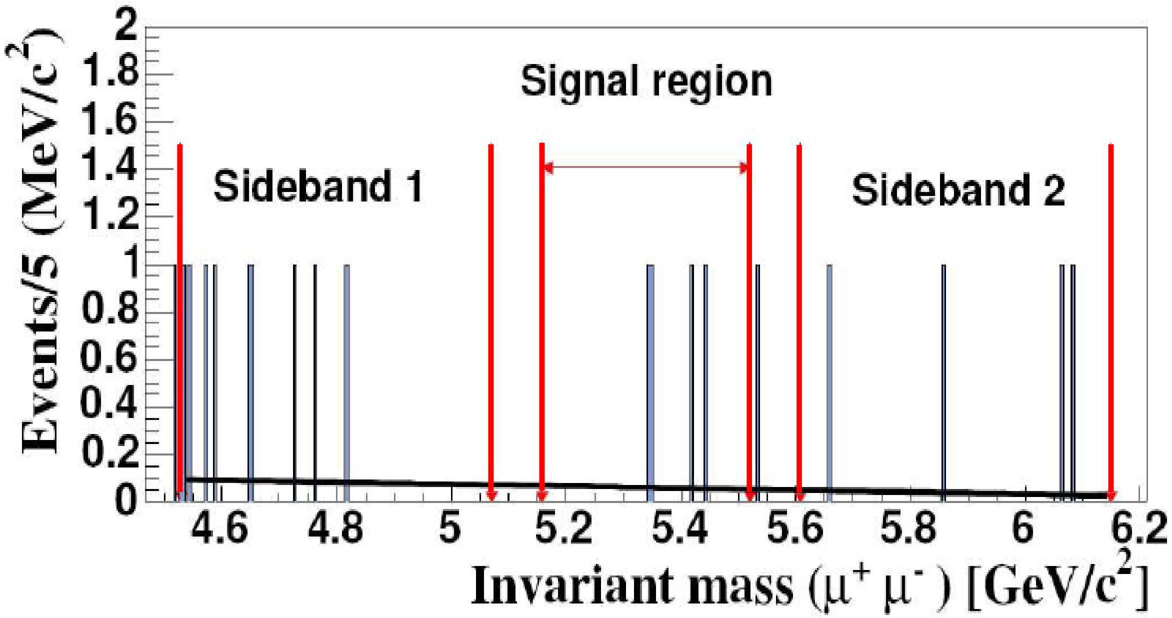
# Search for rare decay $B_s \rightarrow \mu\mu$




- ‘blind’ analysis with 300 $pb^{-1}$
- Signal selection was optimized with random grid search



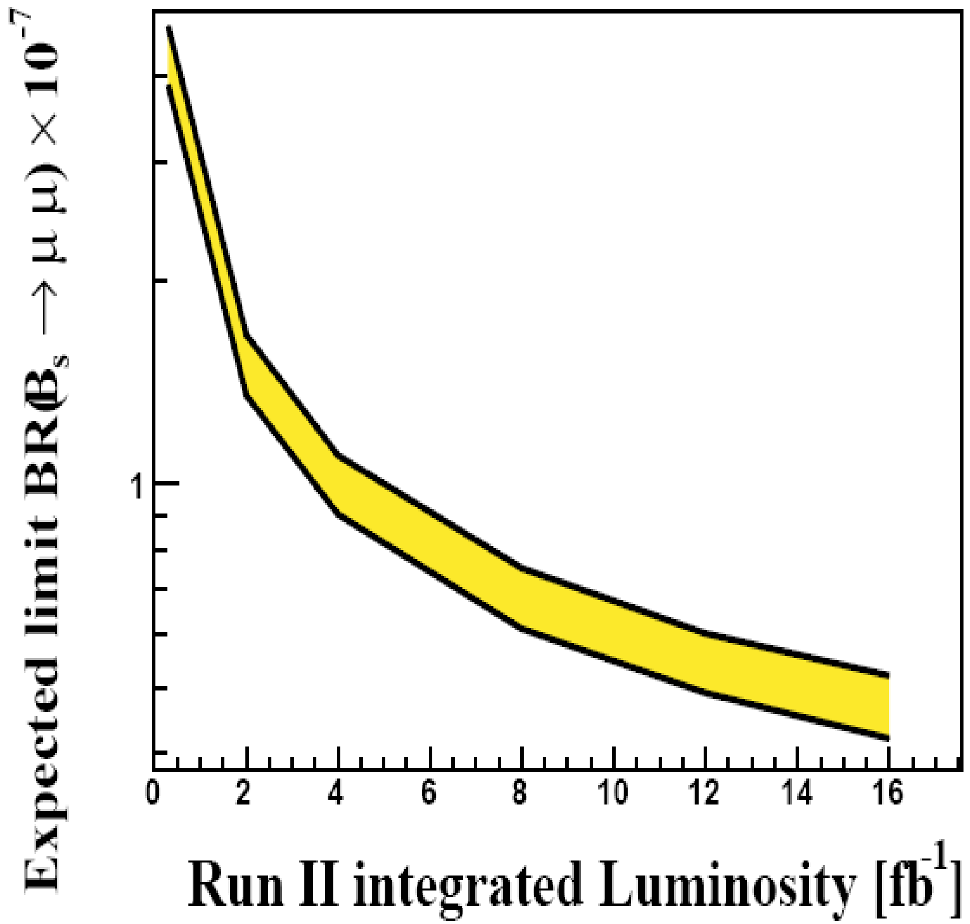
# Search for rare decay $B_s \to \mu\mu$




- After selection 4.3±1.2 background events were expected and 4 events were found in the signal region
- Calculate BR Limit using the $B^+ \to J/\psi K^+$ as normalisation channel

$$\Rightarrow \quad \mathcal{B}(B_s \to \mu^+\mu^-) \le 3.7 \cdot 10^{-7} (3.0 \cdot 10^{-7}) \text{ at } 95\% \ (90\%) \text{ C.L.}$$

# Prospects $B_s \rightarrow \mu\mu$




- Based on DØ results at ~300pb$^{-1}$
- Scale to higher luminositiy
- Bands indicate 10% variation of events

# Summary

- Currently Tevatron is the best place to study $B_s$ Meson
- Presented three preliminary results (only fraction of B-physics program at DØ )
  - Lifetime difference $\Delta\Gamma_s/\Gamma_s$ with more statistics error will be reduced by a factor ~10

$$\frac{\Delta\Gamma_s}{\Gamma_s} = 0.24^{0.28}_{-0.38}$$

  - Mass difference $\Delta m_s$ (only semileptonic) With improved analysis, upgrades and more data push sensitivity above the SM expectation

$$\Delta m_s > 7.3 ps^{-1} \quad (CL 95\%)$$

  - rare decay $B_s \rightarrow \mu\mu$ Not sensitiv for SM Prediction, but maybe for new physics

$$B(B_s \rightarrow \mu^+\mu^-) \leq 3.7 \cdot 10^{-7} (3.0 \cdot 10^{-7})$$
at 95%(90%) CL

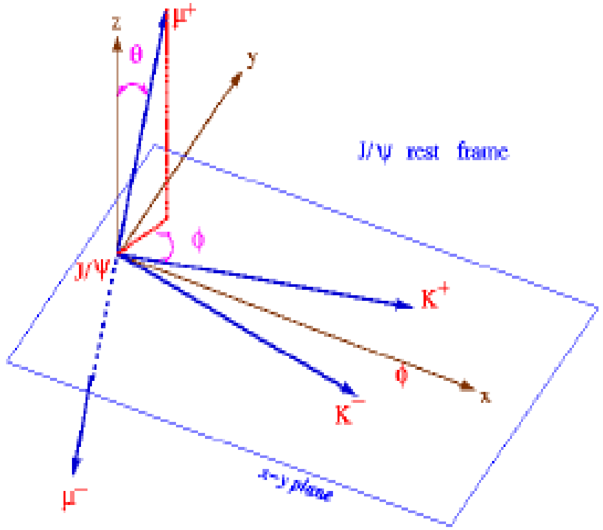
# Backup

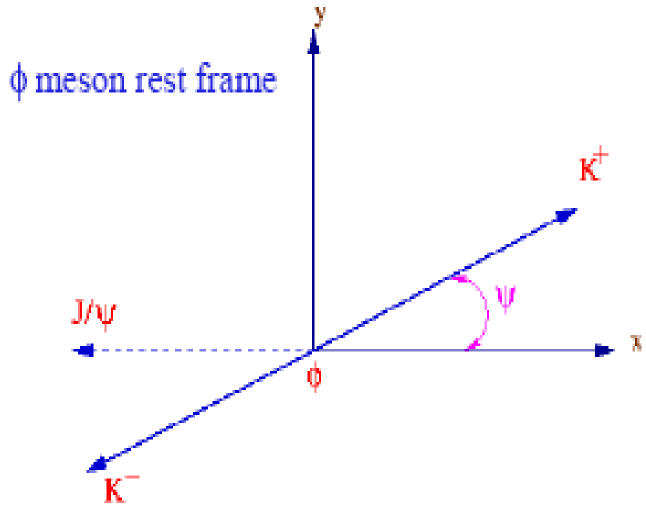
# Transversity

The $B_s \rightarrow J/\psi(\mu^+\mu^-)\ \phi(K^+K^-)$ channel can be parameterised by three angles

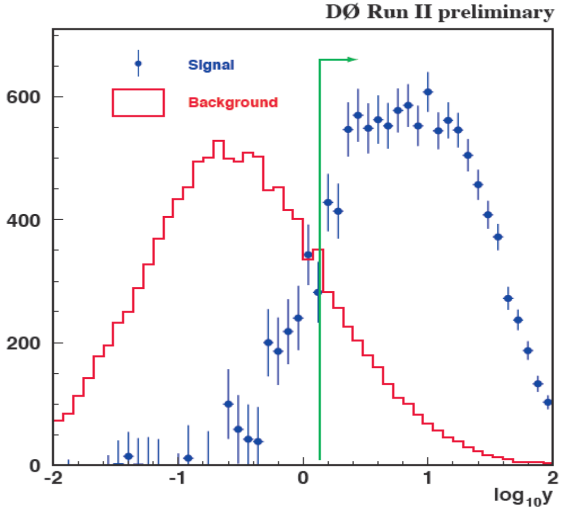
cos θ ≡ transversity

- Azimuthal (ϕ) and polar angle (θ) wrt proton beam of the μ+ in the J/ψ rest frame
- Polar angle (ψ) wrt J/ψ of $K^+$ in ϕ rest frame



# Combined Likelihood




- Set of discriminating variables $x_i$ constructed for each event
- Cut on combined variable, product of likelihood ratios (PDF for background and PDF for signal):

$$y = \prod_i^n y_i \; ; \quad y_i = \frac{PDF_i^s(x_i)}{PDF_i^b(x_i)}$$

The following discriminating variables were used:

- Helicity angle, defined as the angle between the $D_s$ and $K_1$ momenta in the $(K_1, K_2)$ center of mass system;
- Isolation, computed as $Iso = p^{tot}(\mu D_s)/(p^{tot}(\mu D_s) + \sum p_i^{tot})$. The sum $\sum p_i^{tot}$ was taken over all charged particles in the cone $\sqrt{(\Delta\phi)^2 + (\Delta\eta)^2} < 0.5$, where $\Delta\eta$ and $\Delta\phi$ are the pseudorapidity and the azimuthal angle with respect to the $(\mu D_s)$ direction. The $\mu$, $K_1$, $K_2$ and $\pi$ were not included in the sum;
- $p_T(K_1 K_2)$;
- Invariant mass, $M(\mu D_s)$;
- $\chi^2$ of the $D_s$ vertex fit;
- $M(K_1 K_2)$.

For $D_s \to \phi\pi$, $\phi \to K^+K^-$

# Proper decay length

- Measure decay length in *x*-*y* plane (and error from track parameter errors), need boost, but due to escaping neutrino, can only reconstuct partially:

$$x^M = \left(\vec{L}_{xy} \cdot \vec{p}_{xy}^{\,D_s\mu}\right) / \left(p_T^{D_s\mu}\right)^2 m_{B_s}$$

*Measured* visible proper decay length, VPDL

$$K = p_T^{D_s\mu} / p_T^{B_s}$$

"K Factor"

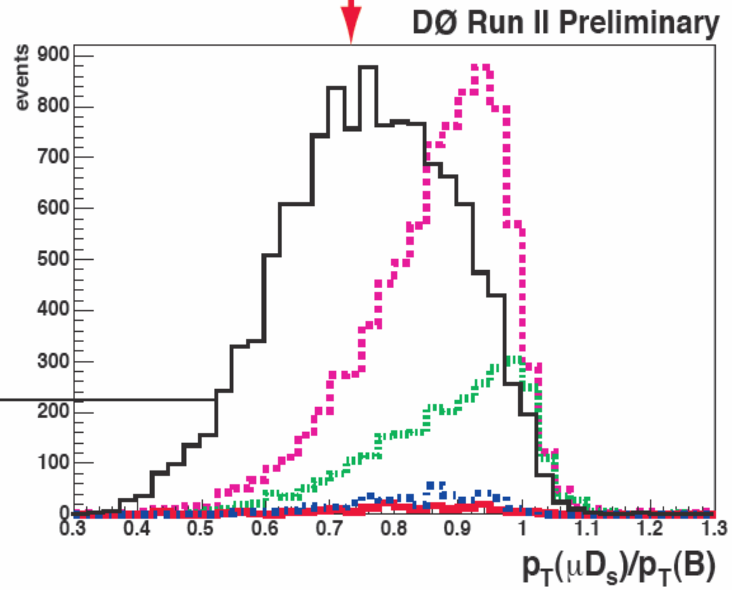
$$ct_{B_s} = x^M K$$

Measured Proper Decay Length

- From MC, each decay mode
- Also takes into account other missing particles

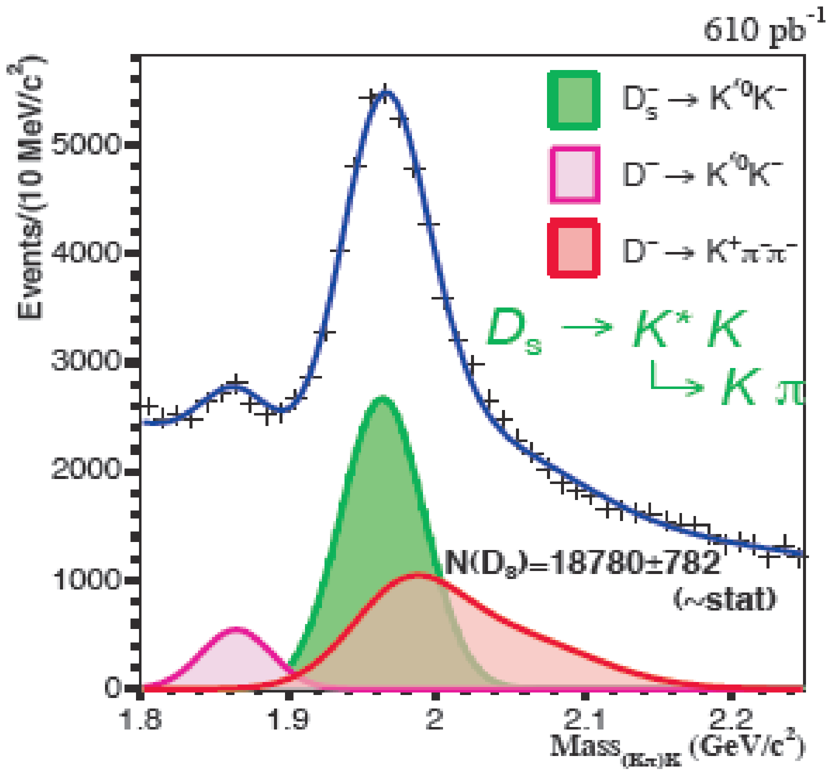
$B_s^0 \to D_s^- D_s^+ X$

$\hookrightarrow \mu \nu X$

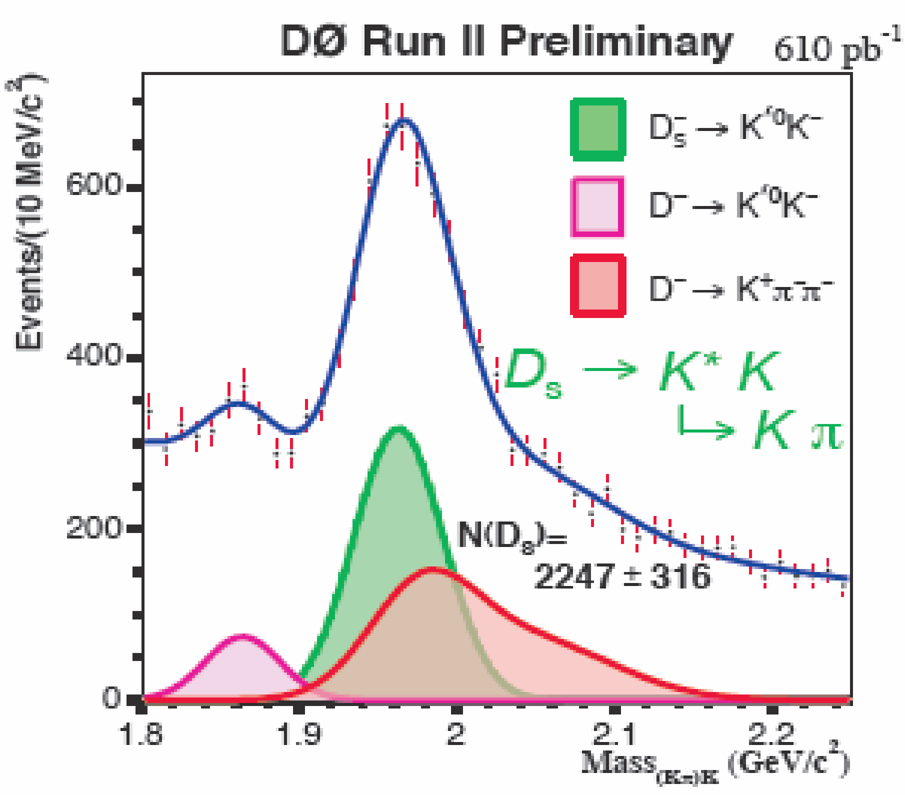


# K*K data sample

untagged



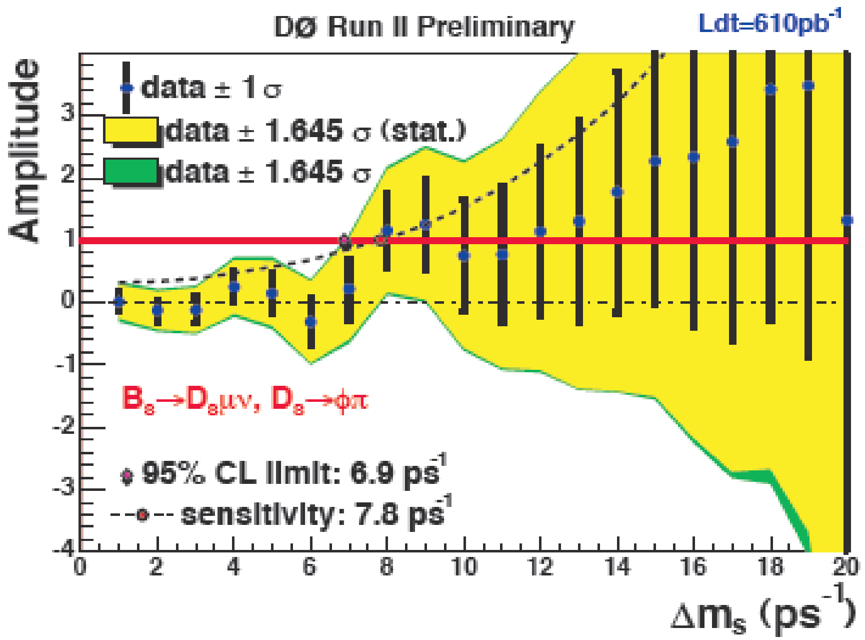

tagged



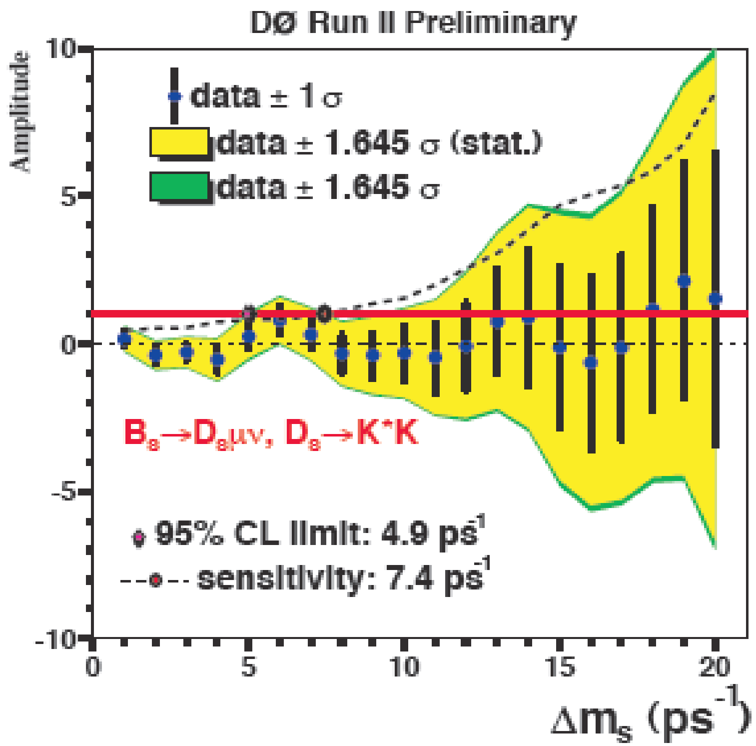
# Limits $\phi\pi$, K*K

Limit only for

$D_s^{\pm} \to \phi(K^+K^-)\pi^{\pm}$




$D_s^{\pm} \to K^*(K^{\pm}\pi^{\mp})K^{\pm}$



# Discriminating variables $B_s \to \mu\mu$

- Opening angle between the vertex direction and the muon pair "Pointing consistency"
- Decay length signifcance ($L_{xy}/\sigma(L_{xy})$)
- Isolation of the B candiate

$$\mathrm{Iso} = \frac{p_{B_s}}{p_{B_s} + \sum_{\mathrm{allTracks}\,\Delta R \leq 1} p}$$

with $\Delta R = \sqrt{(\Delta\Phi)^2 + (\Delta\eta)^2} \leq 1$