B_S Mixing Results at Tevatron

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Outline

- Introduction
- B_s mixing in the Standard Model
- Ingredients to perform a measurement
- CDF measurement
- D0 analysis and result
- New Standard Model constraints

Introduction

B_s Mixing group

Konstantin Anikeev [6], Farrukh Azfar [20], Gary Barker [8], Gerry Bauer [14], Franco Bedeschi [11], Satyajit Behari [16], Stefano Belforte [12], Alberto Belloni [14], Eli Ben-Haim [13], Juerg Beringer [5], Arkadiy Bolshov [14], Joe Boudreau [23], Massimo Casarsa [12], Pierluigi Catastini [11], Alessandro Cerri [5], Agnese Ciocci [11], David Clark [2], Saverio D'Auria [7], Christian Dörr [8], Saverio Da Ronco [21], Sandro De Cecco [10], Amanda Deisher [5], Francesco Delli Paoli [21], Gianpiero Di Giovanni [13], Simone Donati [11], Mauro Donega [17], Sinead Farrington [19], Michael Feindt [8], Armando Fella [11], Ivan Furić [4], Stefano Giagu [10], Karen Gibson [3], Kim Giolo [15], Gavril Giurgiu [3], Guillelmo Gomez-Ceballos [9], Robert Harr [26], Aart Heijboer [22], Matt Herndon [25], Todd Huffman [20], Boris Iyutin [14], Matthew Jones [15], Ulrich Kerzel [8], Ilya Kravchenko [14], Michal Kreps [8], Joe Kroll [22], Thomas Kuhr [8], Tom LeCompte [1], Claudia Lecci [8], Nuno Leonardo [14], Donatella Lucchesi [21], Johannes Mülmenstädt [5], Petar Maksimović [16], Stephanie Menzemer [14], Jeffrey Miles [14], Michael Morello [11], Reid Mumford [16], Steve Nahn [27], Rolf Oldeman [19], Manfred Paulini [3], Christoph Paus [14], Jonatan Piedra [13], Kevin Pitts [18], Giovanni Punzi [11], Jonas Rademacker [20], Azizur Rahaman [23], Marco Rescigno [10], Alberto Ruiz [9], Giuseppe Salamanna [10], Aurore Savoy-Navarro [13], Fabrizio Scuri [11], Marjorie Shapiro [5], Paola Squillacioti [11], Masa Tanaka [1], Vivek Tiwari [3], Fumi Ukegawa [24], Satoru Uozumi [24], Denys Usynin [22], Ivan Vila [9], Barry Wicklund [1], Chun Yang [27]

- Decay channels selection using Tier 1 and data stored at CNAF

  Casarsa (TS), Da Ronco, Pagan, Delli Paoli, Lucchesi

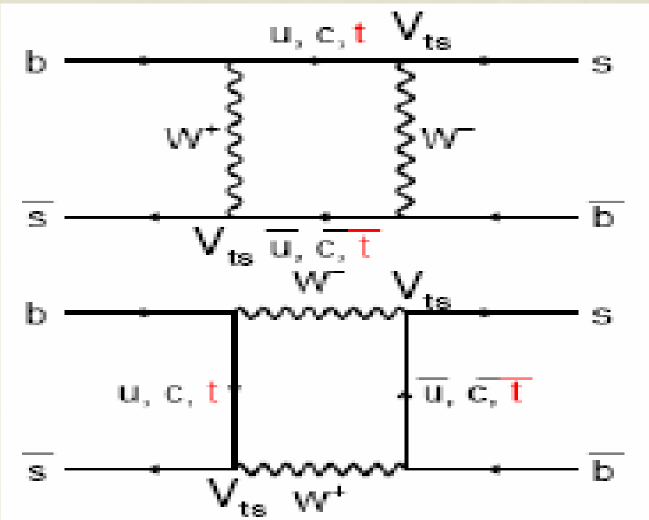
- Event by event Primary Vertex determination

  Casarsa (TS), Da Ronco, Lucchesi

- B_s lifetime measurement in hadronic decays: trigger efficiency determination used in mixing analysis

  Da Ronco, PhD thesis

B_s Mixing in The Standard Model



$$i\frac{d}{dt}\begin{pmatrix} |B(t)\rangle \\ |\bar{B}(t)\rangle \end{pmatrix} = \left(M - \frac{i}{2}\Gamma\right)\begin{pmatrix} |B(t)\rangle \\ |\bar{B}(t)\rangle \end{pmatrix}$$

$$H = \begin{pmatrix} M & M_{12} \\ M_{12}^{*} & M \end{pmatrix} - \frac{i}{2}\begin{pmatrix} \Gamma & \Gamma_{12} \\ \Gamma_{12}^{*} & \Gamma \end{pmatrix}$$

Eigenstates are:

$$|B_s^H\rangle = \tfrac{1}{\sqrt{2}}(|B_s\rangle + |\bar{B}_s\rangle)$$

$$|B_s^L\rangle = \tfrac{1}{\sqrt{2}}(|B_s\rangle - |\bar{B}_s\rangle)$$

$$M_{H,L} = M \pm \overbrace{\mathrm{Re}(M_{12} - \tfrac{i}{2}\Gamma_{12})}^{\Delta m/2}$$

$$\Gamma_{H,L} = \Gamma \pm \underbrace{2\,\mathrm{Im}(M_{12} - \tfrac{i}{2}\Gamma_{12})}_{\Delta\Gamma/2}$$

$$\Gamma = \tfrac{1}{2}(\Gamma_L + \Gamma_H) \equiv \frac{1}{\tau} \qquad \Delta\Gamma = \Gamma_L - \Gamma_H$$

B_s Mixing in The Standard Model cont'd

$$\Delta m_q = \frac{G_F^2 m_W^2 \eta S(m_t^2/m_W^2)}{6\pi^2} m_{Bq} f_{Bq}^2 B_{Bq} \left|V_{tq}^* V_{tb}\right|^2$$

From lattice-QCD, big uncertanties

$\Downarrow$

$|V_{td}|$ determined at 15%

In the ratio uncertainties cancels:

$$\frac{\Delta m_s}{\Delta m_d} = \frac{m_{Bs}}{m_{Bd}} \frac{f_{Bs}^2 B_{Bs}}{f_{Bd}^2 B_{Bd}} \frac{|V_{ts}|^2}{|V_{td}|^2} = \frac{m_{Bs}}{m_{Bd}} \xi^2 \frac{|V_{ts}|^2}{|V_{td}|^2}$$

$\xi^2 = 1.21 \pm 0.02^{+0.035}_{-0.014}$

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

Applying unitarity…

B_s Mixing constraints the Standard Model

Winter 2006

$\Delta m_s > 16.6$ at 95% C.L.

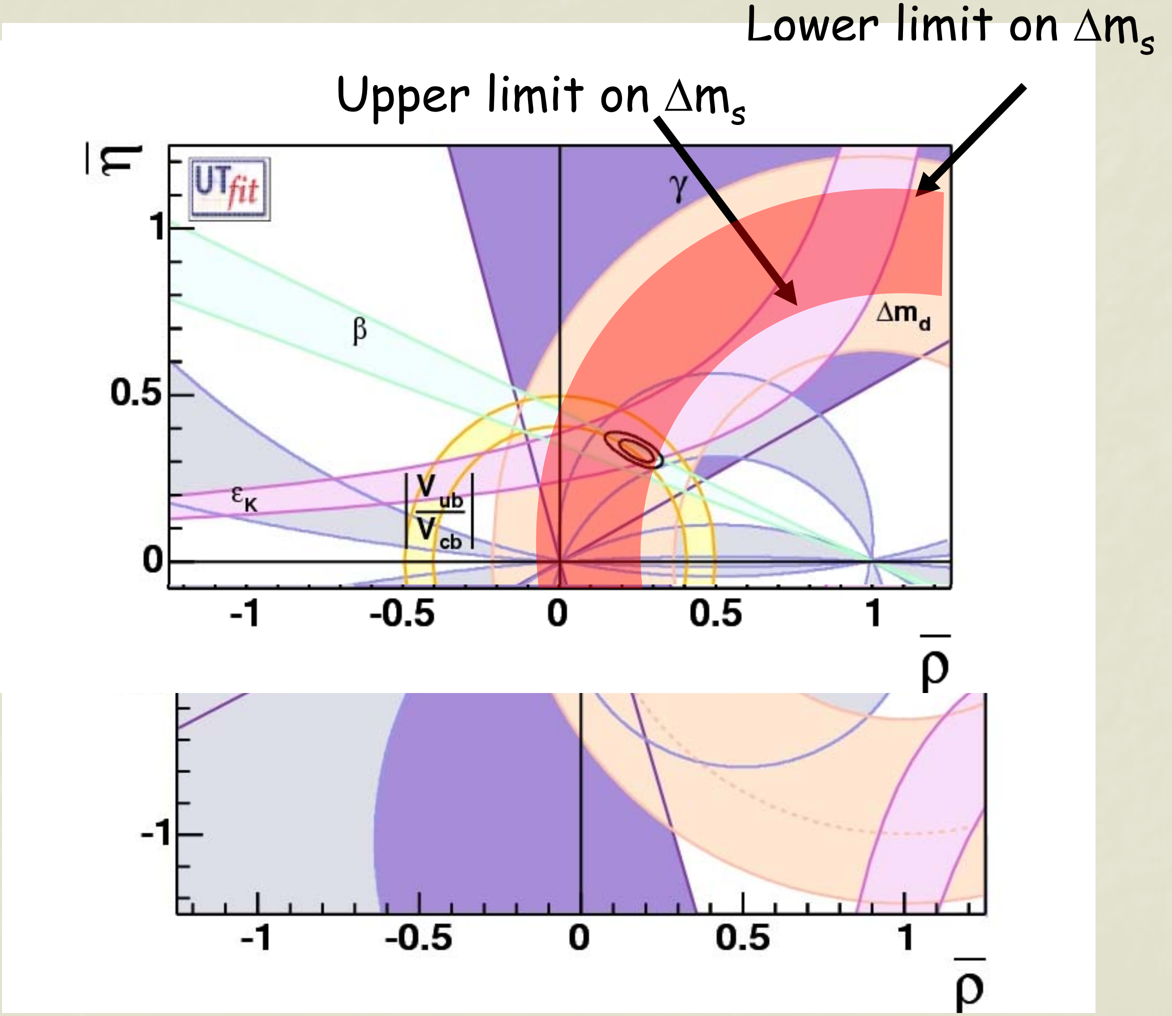
$\bar{\rho} = 0.217 \pm 0.032$

$\bar{\eta} = 0.344 \pm 0.021$

D0 results:

$17 < \Delta m_s < 21$ 90% C.L.

CDF effect in about one hour…

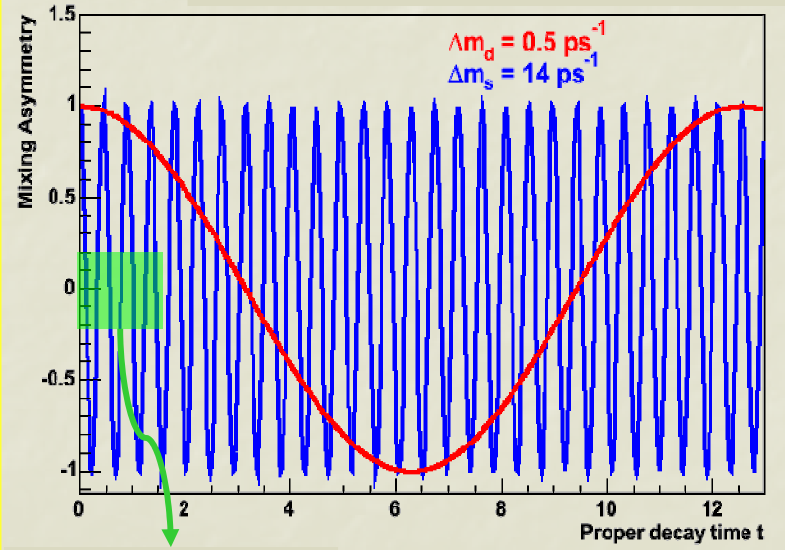


Measurement Principle in a Perfect World

$$P(t)_{B_q^0 \to \overset{(-)}{B}{}_q^0} = \frac{1}{2\tau} e^{-\frac{t}{\tau}} (1 \pm \cos(\Delta m_q t))$$

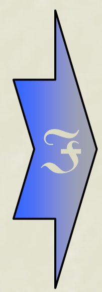
$$A = \frac{N^{nomix} - N^{mix}}{N^{nomix} + N^{mix}} = \cos(\Delta m_s t)$$

B_s vs B_d oscillation

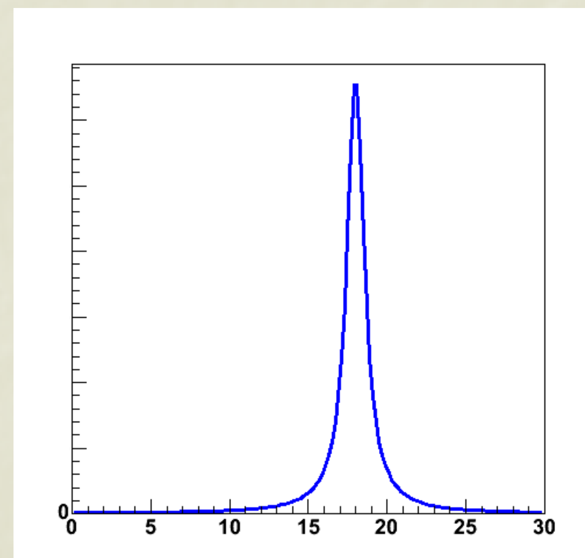


B lifetime

Rather than fit for frequency perform a 'fourier transform'



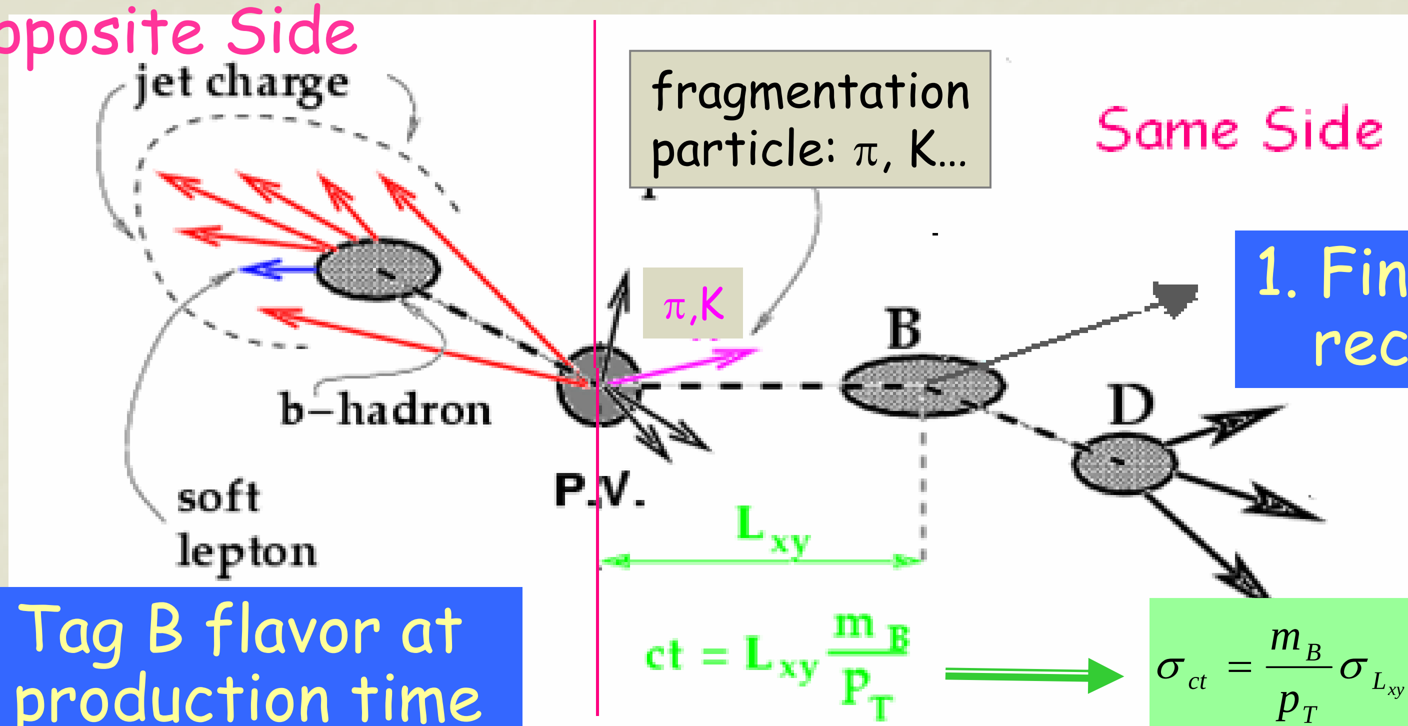
A



Δm_s [ps^{-1}]

Road Map to Δm_s Measurement

Opposite Side



1. Final state reconstruction

3. Tag B flavor at production time

$$\sigma_{ct} = \frac{m_B}{p_T}\sigma_{L_{xy}} \oplus ct\left(\frac{\sigma_{p_T}}{p_T}\right)$$

2. High resolution on proper decay length

measure efficiency ε and dilution D: εD^2 gives the "effective" number of events

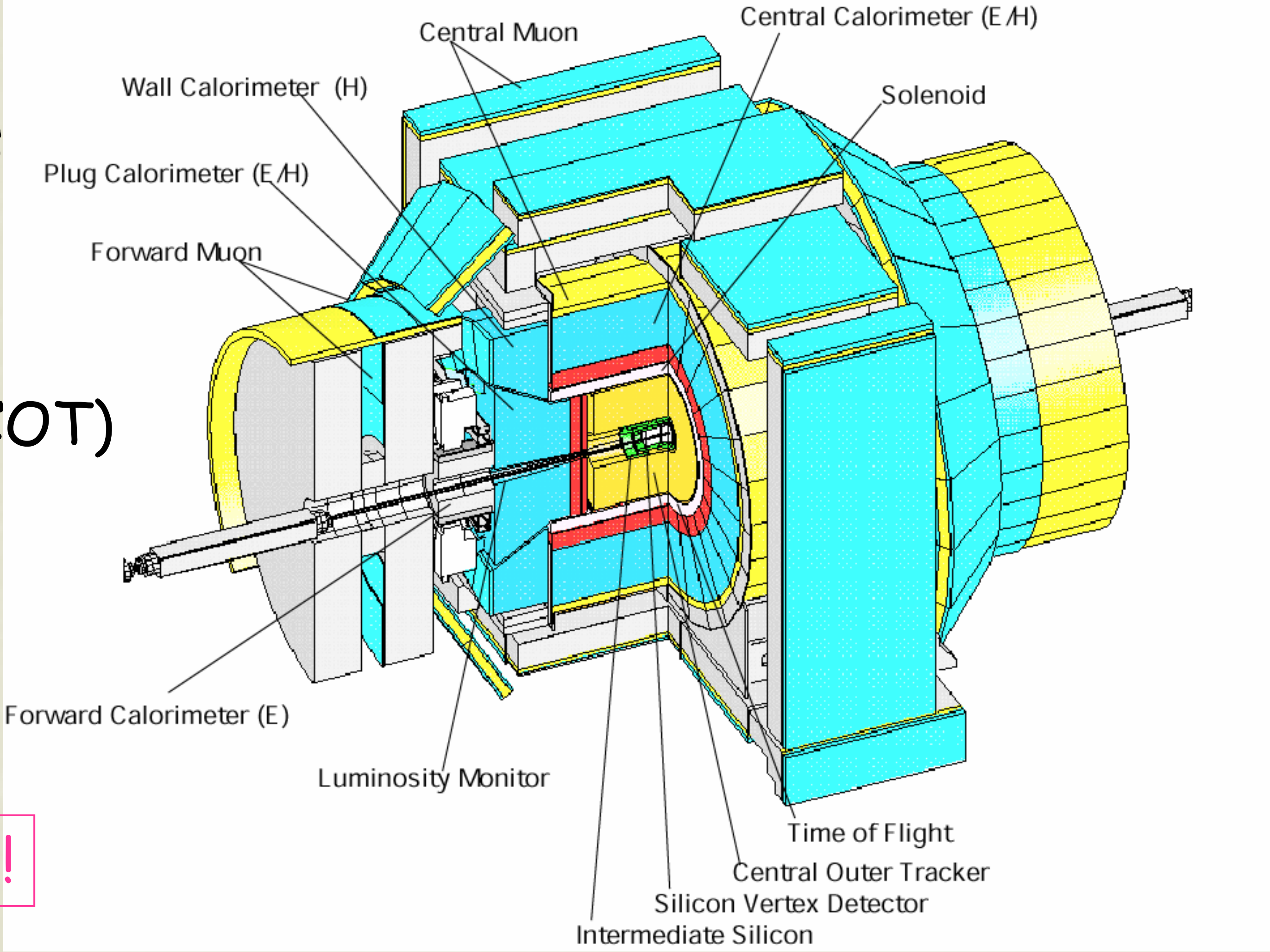
Detector for the measurement

Trigger:
displaced tracks (SVT)

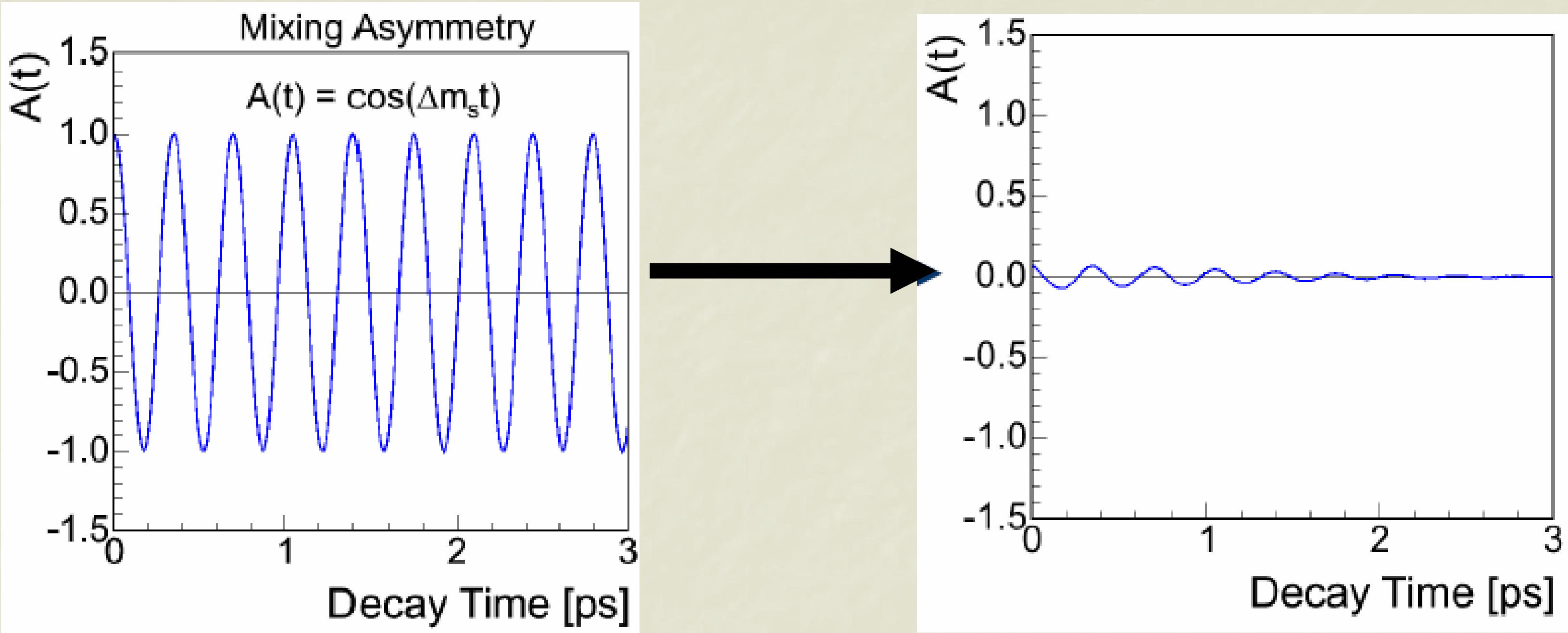
Tagging Power:
TOF & dE/dX (COT)

Proper time Resolution:
SVX and L00

Padova project!



Adding all the realistic effects



Flavor tagging power

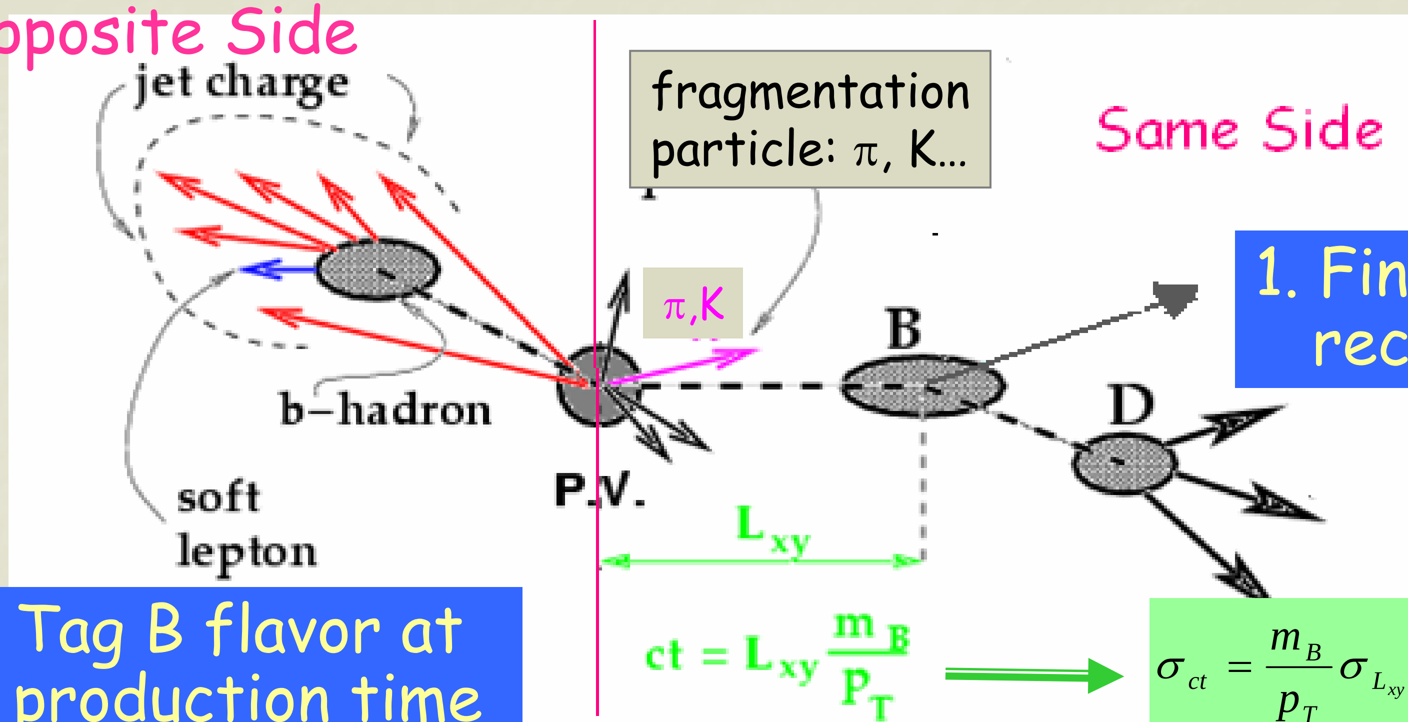
Proper time resolution

$$\frac{1}{\sigma} = \sqrt{\frac{S\epsilon D^2}{2}e^{-\frac{(\Delta m_s \sigma_t)^2}{2}}}\sqrt{\frac{S}{S+B}}$$

$$\sigma_{ct} = \frac{m_B}{p_T}\sigma_{L_{xy}} \oplus ct\left(\frac{\sigma_{p_T}}{p_T}\right)$$

Road Map to Δm_s Measurement

Opposite Side



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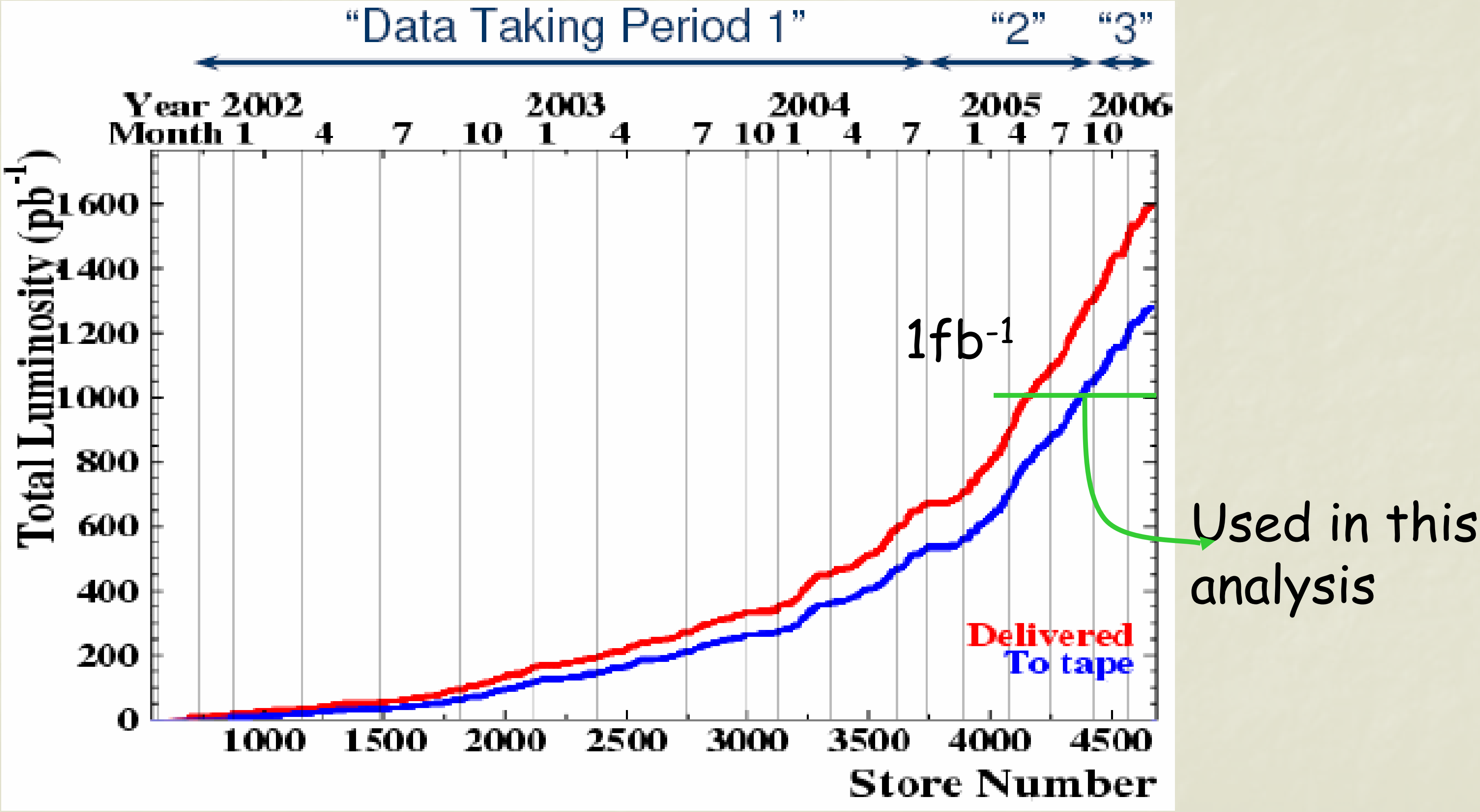
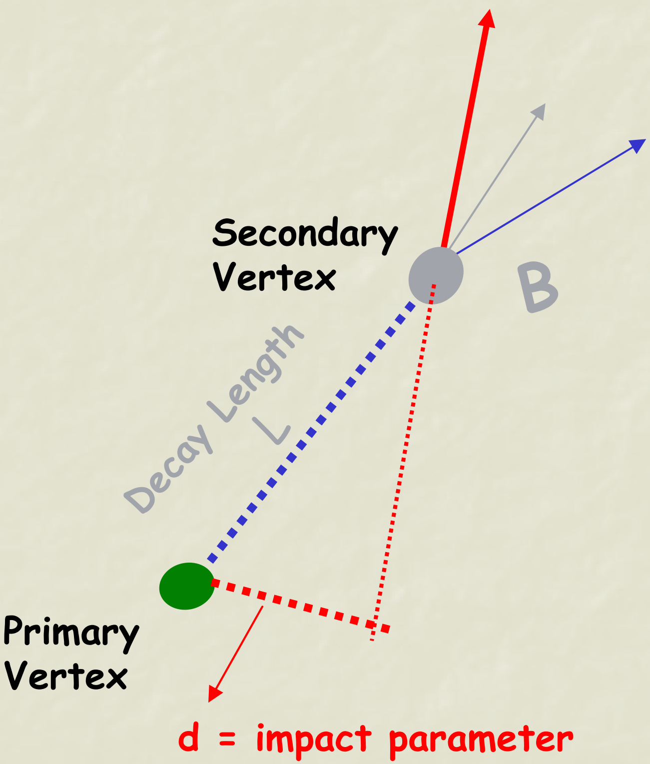
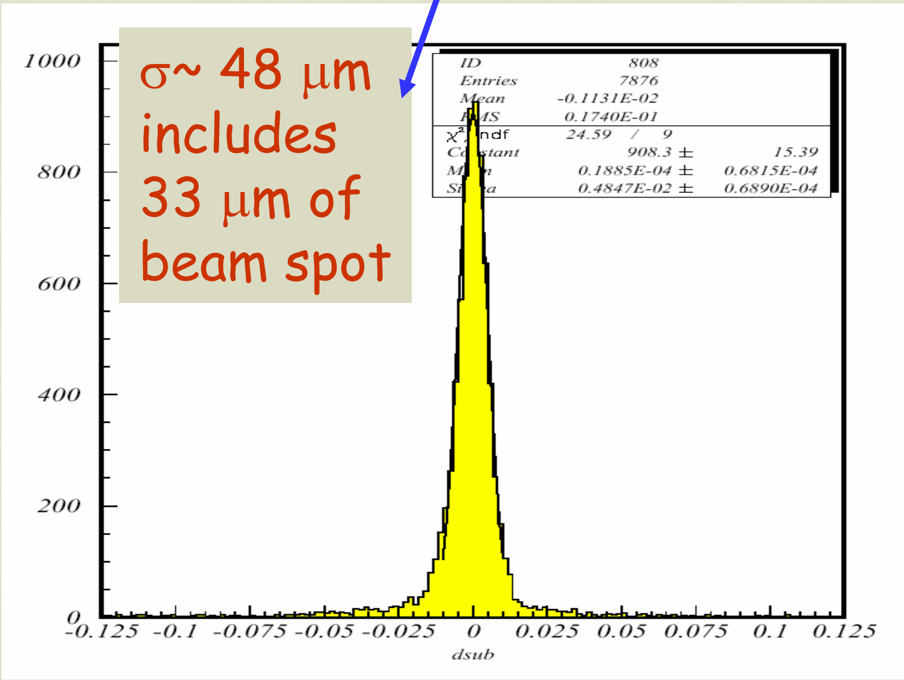
Tevatron Luminosity



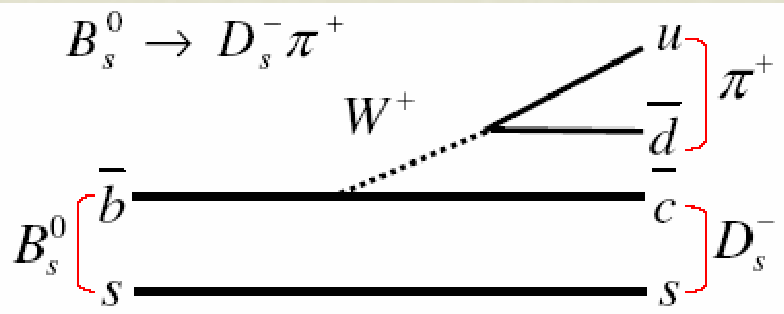
Trigger on displaced tracks: SVT



- Two tracks:
  - Pt>2 GeV/c
  - 120μm<|d|<1mm
  - minimum φ separation
- precision tracking in SVX



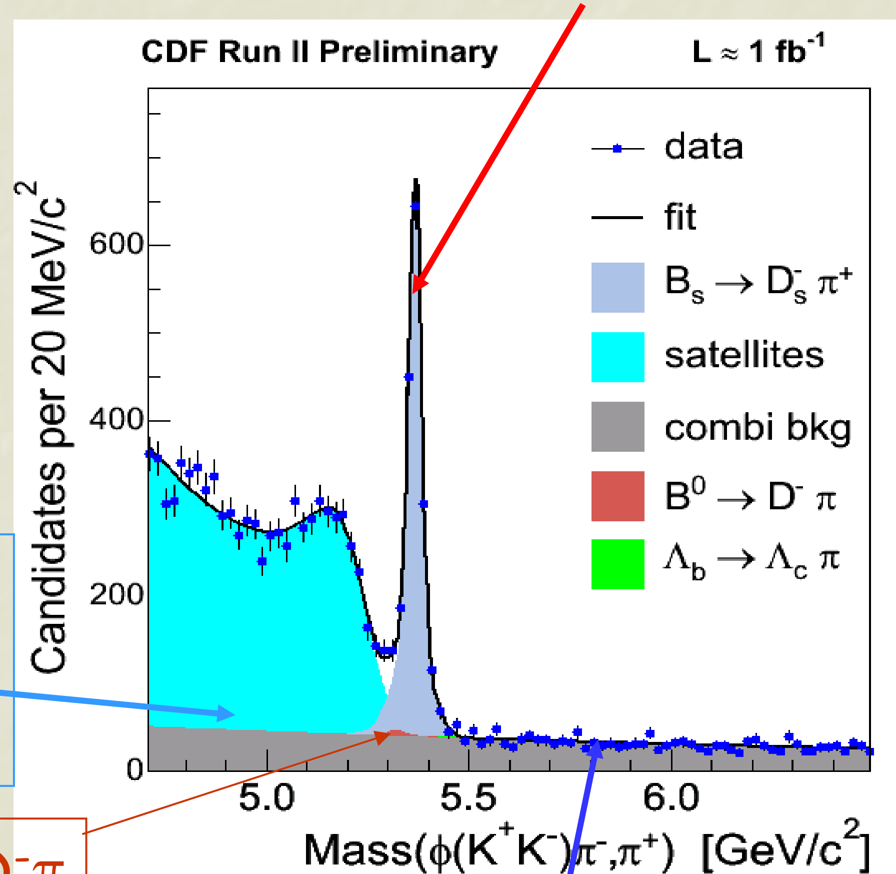
B_s Data sample



$B_s \to D_s \pi$
- $D_s \to \phi\pi$ $\phi \to KK$
- $D_s \to K^{*0}K$ $K^{*0} \to K\pi$
- $D_s \to 3\pi$

$B_s \to D_s 3\pi$
- $D_s \to \phi\pi$
- $D_s \to K^{*0}K$

Signal $B_s \to D_s\pi$ $D_s \to \phi\pi$



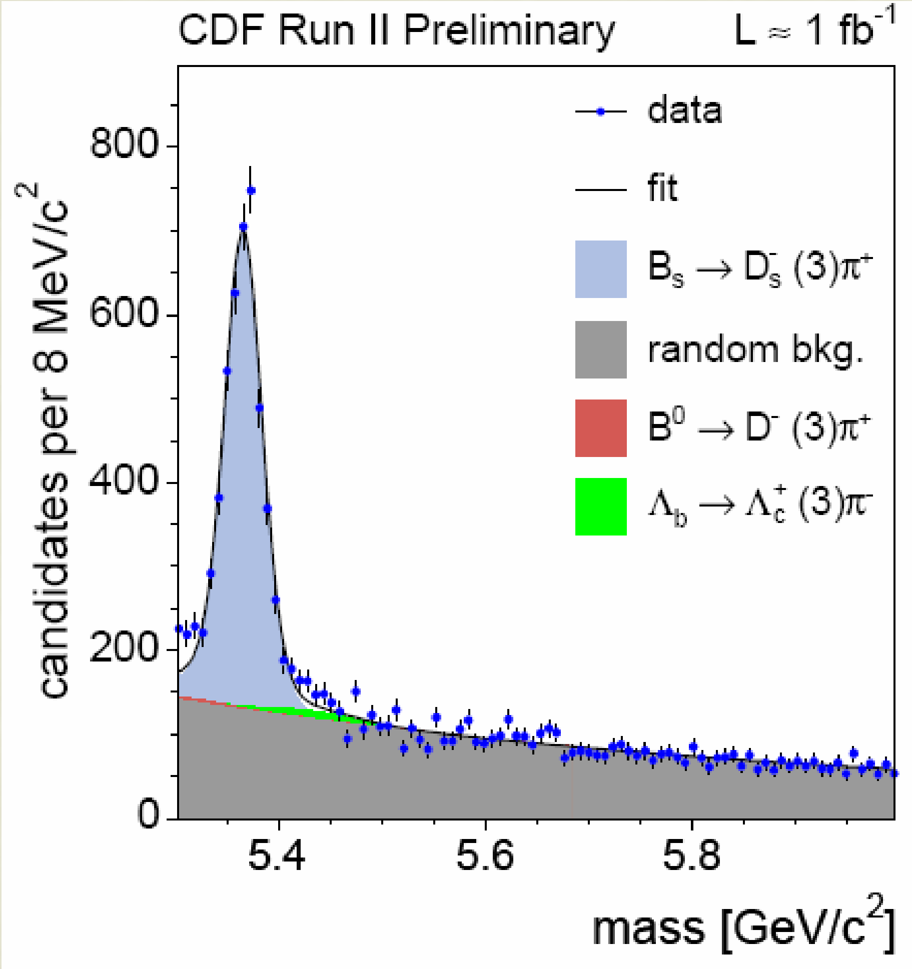
Partially reconstructed B mesons

$B^0 \to D^-\pi$

Combinatorial background

Hadronic B_s yields summary

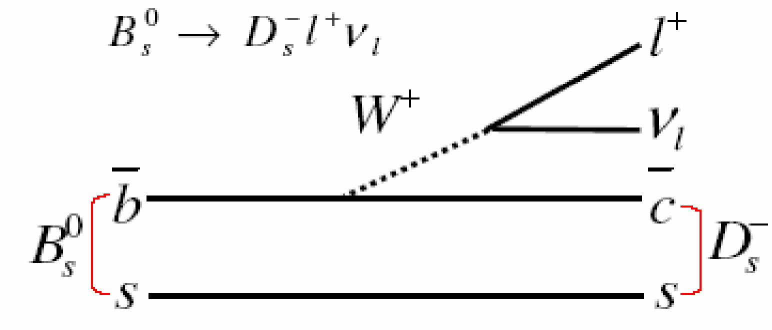
Decay channel	Yield
$B_s \rightarrow D_s\pi$ $D_s \rightarrow \phi\pi$	1570±43
$B_s \rightarrow D_s\pi$ $D_s \rightarrow K^{*0}K$	857±32
$B_s \rightarrow D_s\pi$ $D_s \rightarrow 3\pi$	612±37
$B_s \rightarrow D_s 3\pi$ $D_s \rightarrow \phi\pi$	493±37
$B_s \rightarrow D_s 3\pi$ $D_s \rightarrow K^{*0}K$	204±26
Total	3736±79



$B^+ \rightarrow D^0\pi$ ~ 26,000

$B^0 \rightarrow D^-\pi$ ~ 22,000

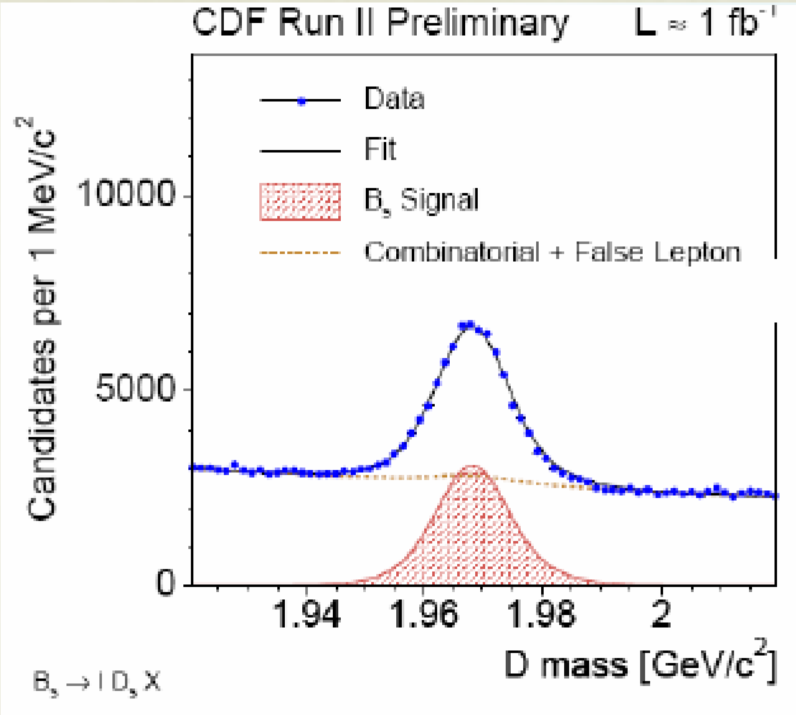
Semileptonic samples



Decay	S/B	S
$\mu D0$	3.8	409,600 ± 970
μD^+	1.3	218,500 ± 940
μD^*	≥ 50	53,900 ± 230
$\mu D_s(\phi\pi^-)$	2.1	24,100 ± 240
$\mu D_s(K^{*0}K^-)$	0.4	8,000 ± 160
$\mu D_s(\pi^+\pi^-\pi^-)$	0.2	7,500 ± 210
$eD0$	3.7	142,300 ± 540
eD^+	1.3	79,500 ± 630
eD^*	≥ 50	21,000 ± 150
$eD_s(\phi\pi^-)$	2.1	8,200 ± 130
$eD_s(K^{*0}K^-)$	0.4	2,900 ± 90
$eD_s(\pi^+\pi^-\pi^-)$	0.2	2,600 ± 130

$B_s \to D_s l X$

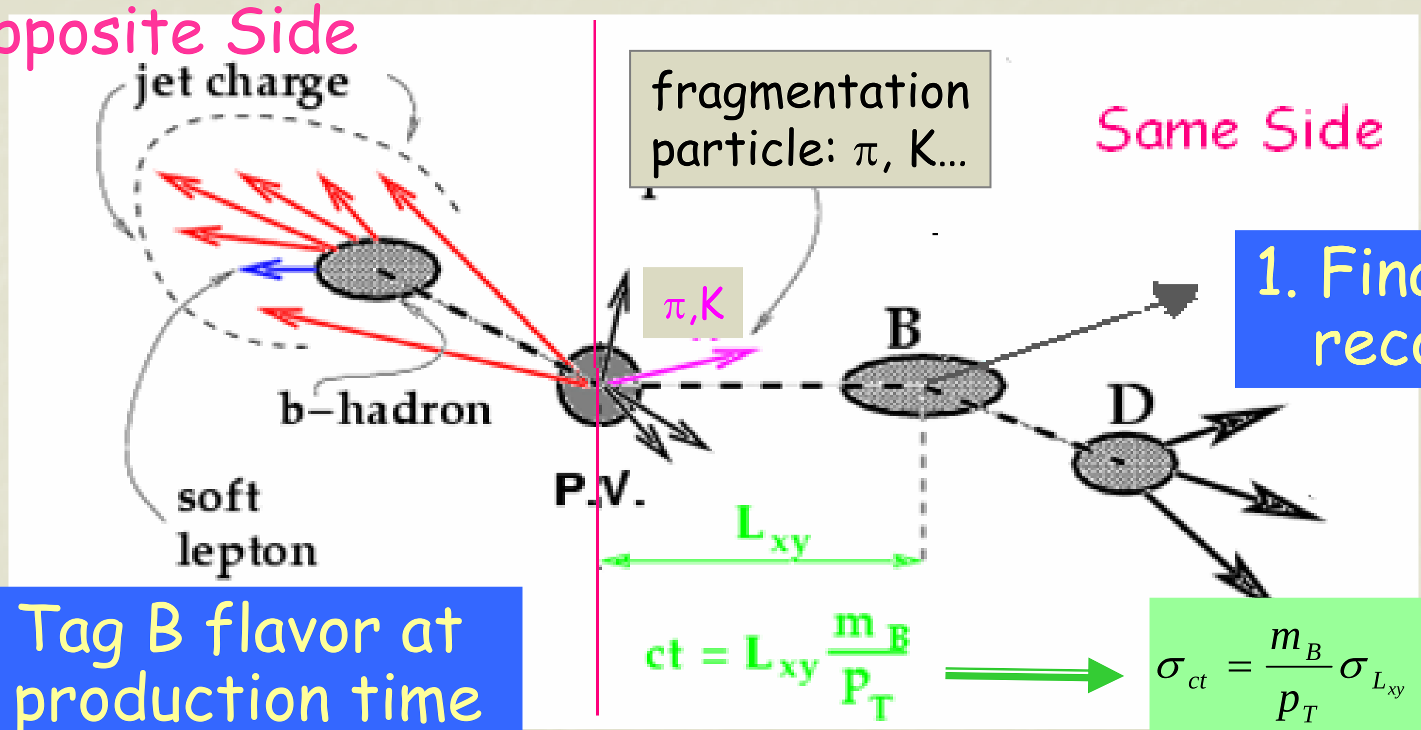
- $D_s \to \phi\pi$ $\phi \to KK$
- $D_s \to K^{*0}K$ $K^{*0} \to K\pi$
- $D_s \to 3\pi$



$D_s l \sim 53{,}000$

Road Map to Δm_s Measurement

Opposite Side



1. Final state reconstruction

$$\sigma_{ct} = \frac{m_B}{p_T}\sigma_{L_{xy}} \oplus ct\left(\frac{\sigma_{p_T}}{p_T}\right)$$

2. High resolution on proper decay length

3. Tag B flavor at production time

B Lifetime measurement

Lifetime Measurement: hadronic and semileptonic B decays

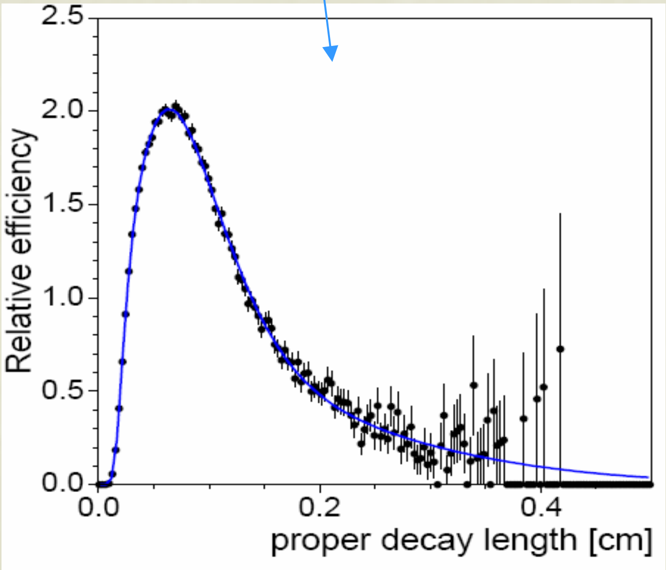
Hadronic decays: well measured

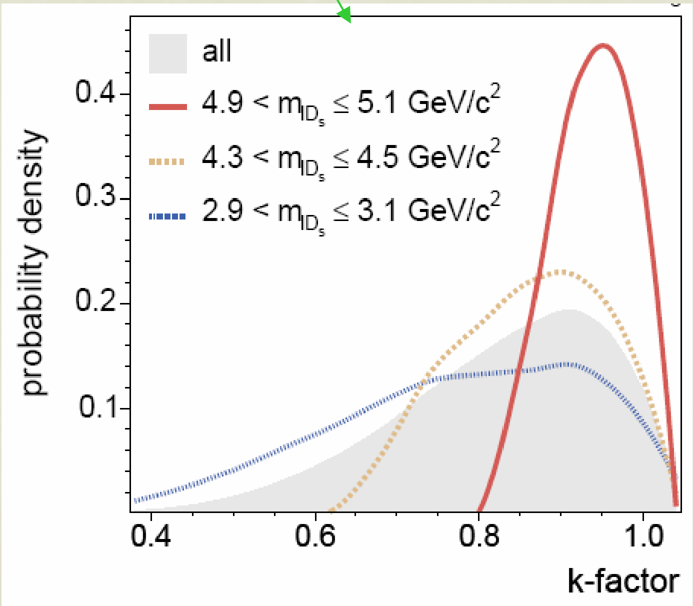
$ct = L_{xy}/\beta_t\gamma \quad \beta_t\gamma = P_t(B)/M(B)$

Semileptonic decays: missing X
need correction factor

SVT trigger bias:

$P(t) = e^{-t'/\tau} \otimes R(t',t) \cdot \varepsilon(t)$





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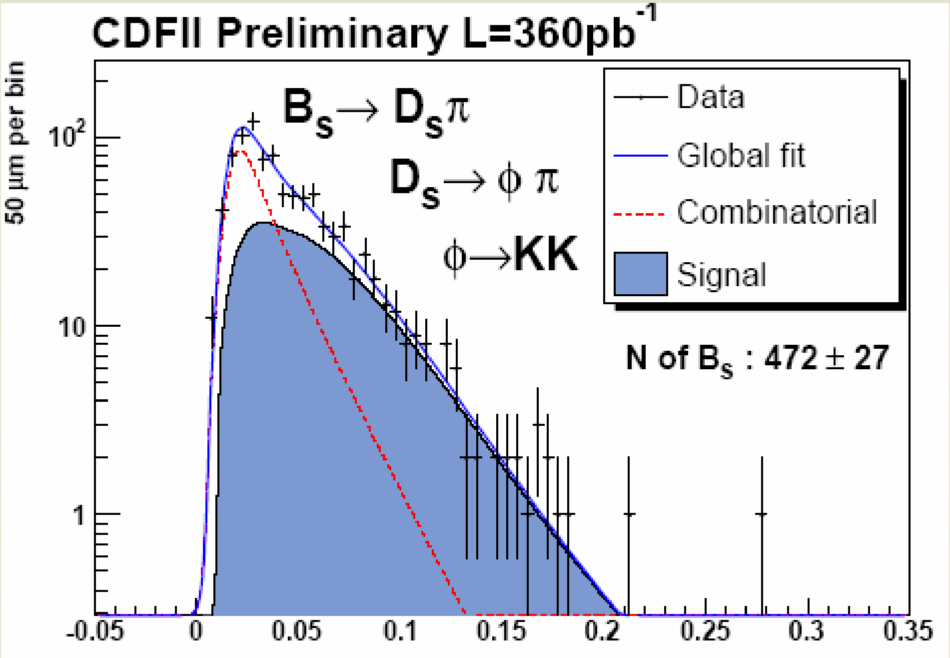
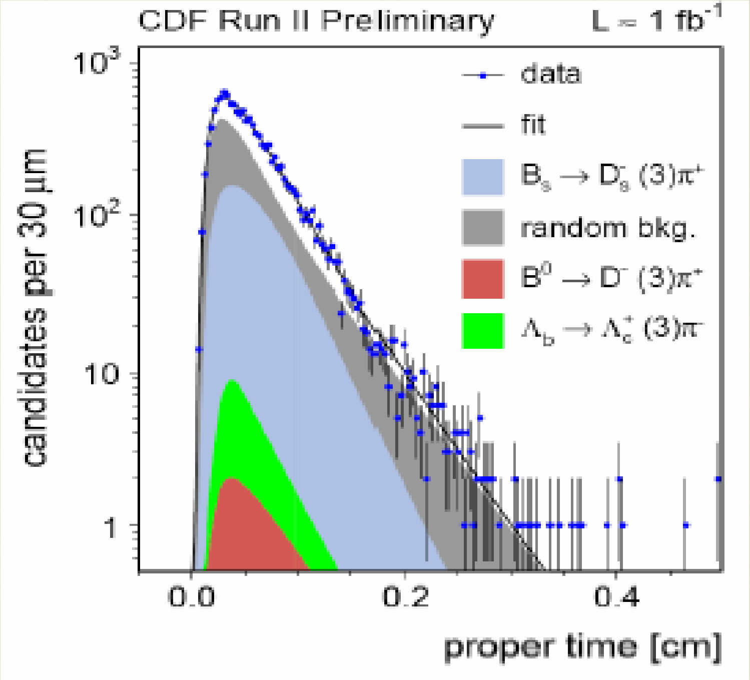




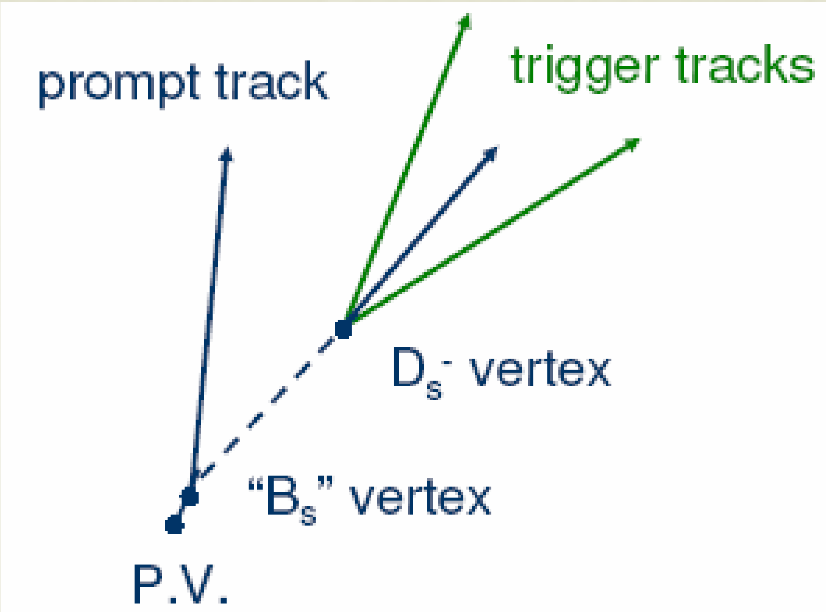
$c\tau(B_s)$=1.60±0.10(stat)±0.02(sys) ps

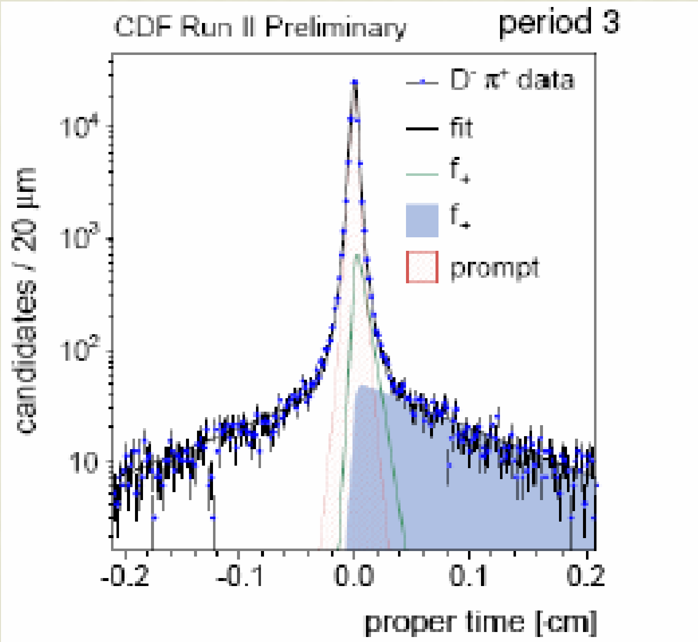
High precision measurement to be done!! ← $c\tau(B_s)$=1.538±0.040(stat) ps

Proper time resolution, σ_t

- Lifetime measurement not very sensitive
- In the Δms fit each event weighted by its resolution
- Dedicated calibration need

Prompt Charm + track sample





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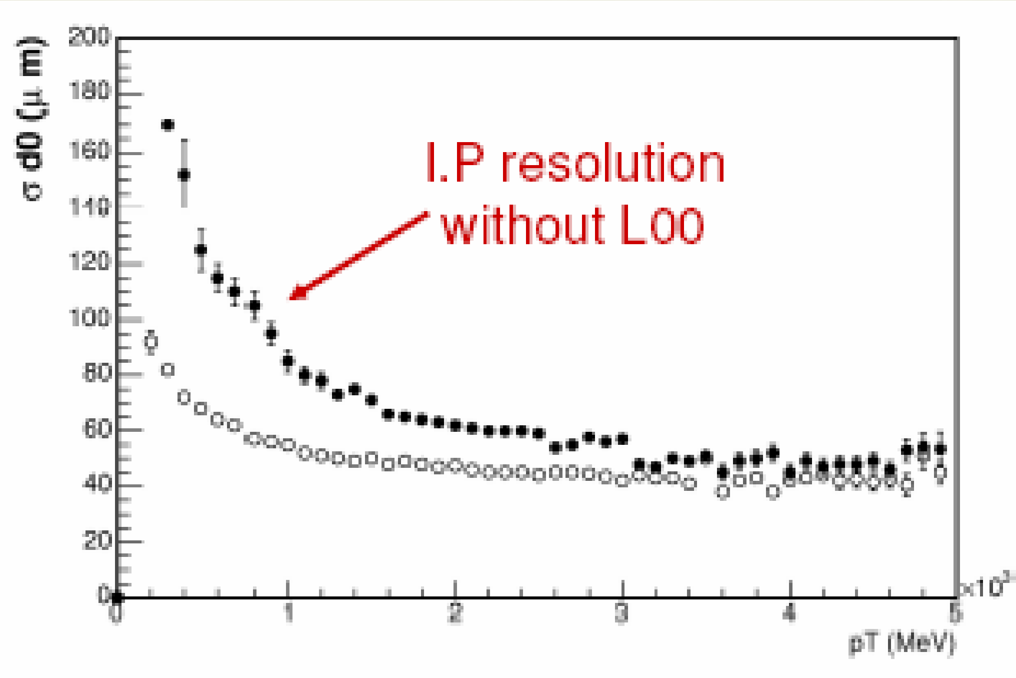
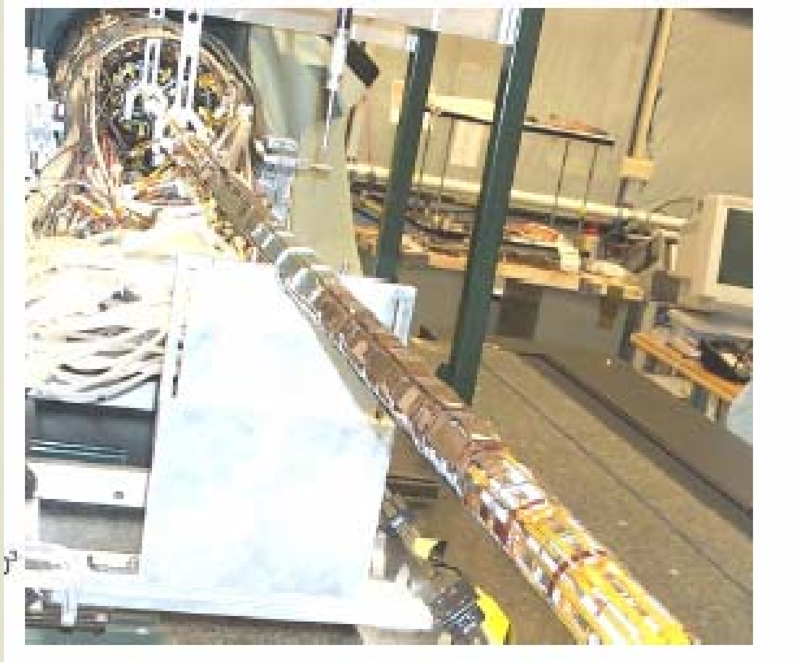
Proper time resolution, σ_t

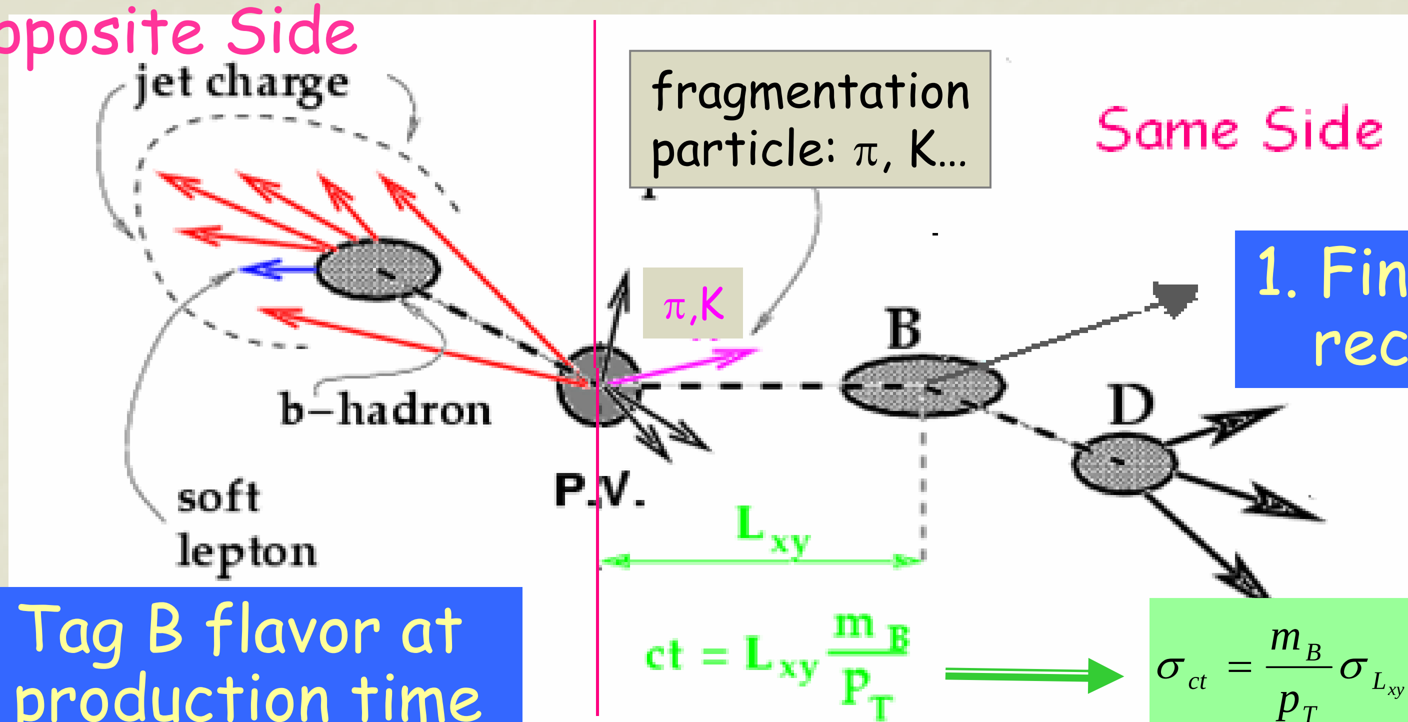




Layer00 is a layer of silicon placed directly on beam pipe
Additional impact parameter resolution, radiation hardness

Road Map to Δm_s Measurement

Opposite Side



1. Final state reconstruction

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2. High resolution on proper decay length

3. Tag B flavor at production time

measure efficiency ε and dilution D: εD^2 gives the "effective" number of events

Flavor tagger calibration: OST

Dilution $D = \frac{N^{right} - N^{wrong}}{N^{right} + N^{wrong}} = 2P^{right} - 1$

Opposite Side Tagger (OST):

- Use data to calibrate the tagger and to evaluate D
- Fit semileptonic and hadronic B_d sample to measure: D, Δm_d

Hadronic:

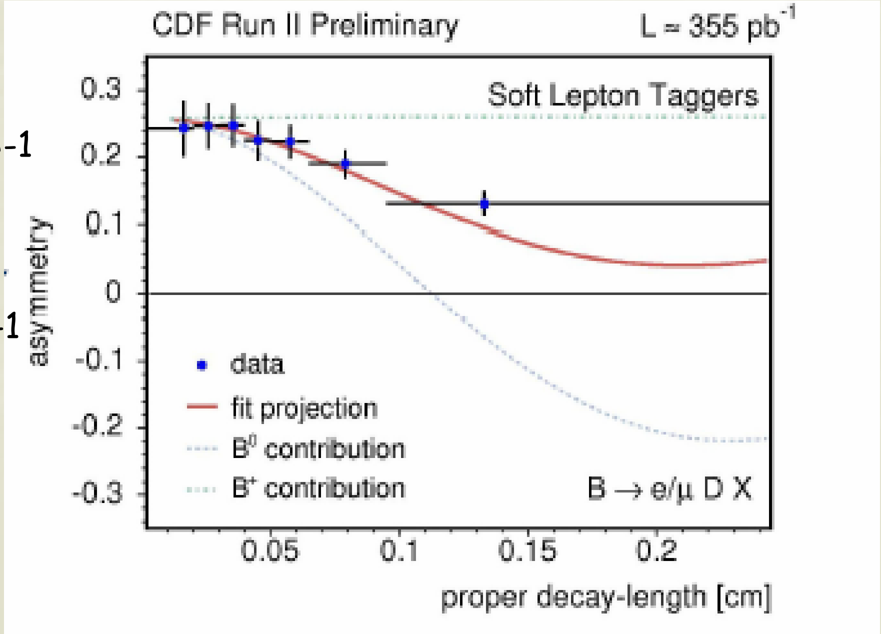
$\Delta m_d = 0.535 \pm 0.028(stat) \pm 0.006(sys)\ ps^{-1}$

Semileptonic:

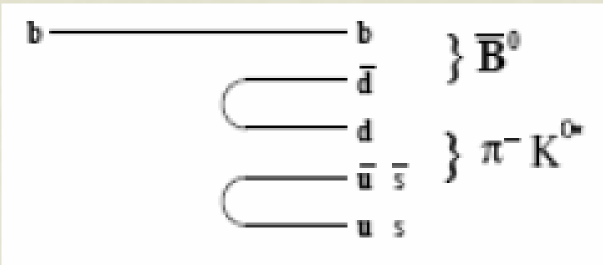
$\Delta m_d = 0.509 \pm 0.010(stat) \pm 0.016(sys)\ ps^{-1}$

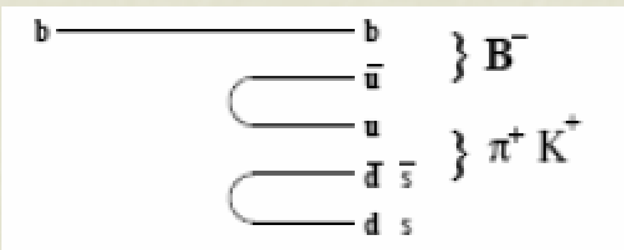
W.A. :

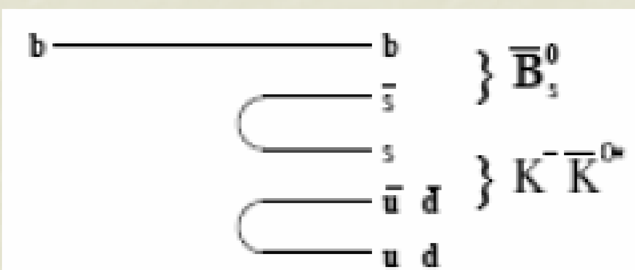
$\Delta m_d = 0.506 \pm 0.005\ ps^{-1}$



Flavor Tagger calibration: SSTK





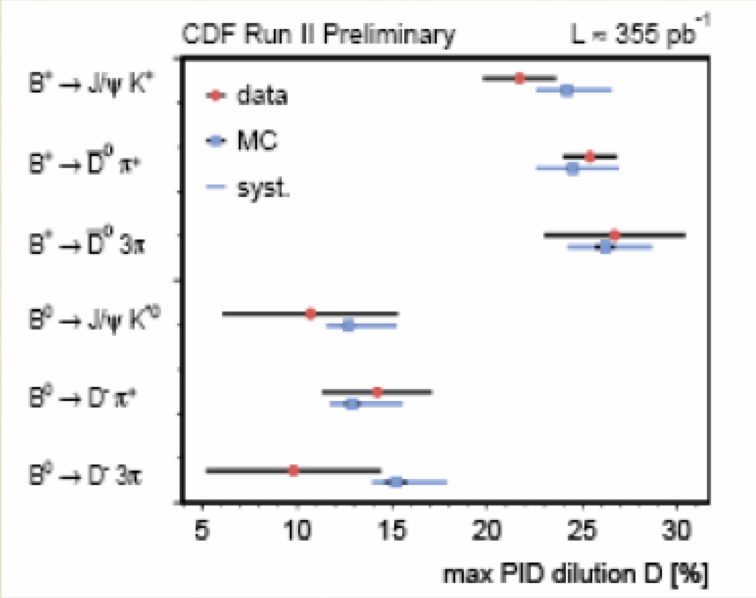


$B^0/B^{\pm}$ likely to have π nearby

B^0_s likely to have K

Use TOF and dE/dX to separate pion from kaon

Tune Monte Carlo to reproduce B^0,B^- distributions then apply to B_s



Flavor Tagger performances

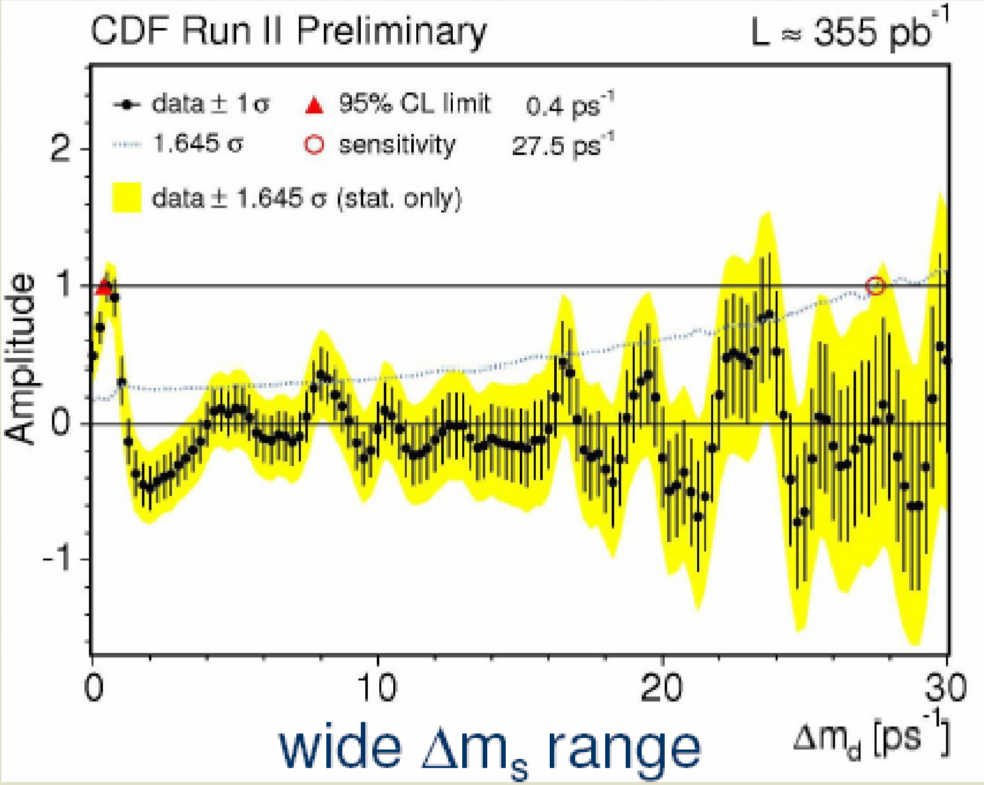
	εD^2 Hadronic (%)	εD^2 Semileptonic (%)
Muon	0.48 ± 0.06 (stat)	0.62 ± 0.03 (stat)
Electron	0.09 ± 0.03 (stat)	0.10 ± 0.01 (stat)
JQ/Vertex	0.30 ± 0.04 (stat)	0.27 ± 0.02 (stat)
JQ/Prob.	0.46 ± 0.05 (stat)	0.34 ± 0.02 (stat)
JQ/High p_T	0.14 ± 0.03 (stat)	0.11 ± 0.01 (stat)
Total OST	1.47 ± 0.10 (stat)	1.44 ± 0.04 (stat)
SSKT	3.42 ± 0.49 (syst)	4.00 ± 0.56 (syst)

- Exclusive combination of tags in OST
- SSTK-OST combination assumes independent tagging information

Amplitude Scan

- A is introduced: $P(t)_{B_q^0 \to \overset{(-)}{B}{}_q^0} = \frac{1}{2\tau} e^{-\frac{t}{\tau}} (1 \pm A\cos(\Delta m_q t))$
- A=1 when $\Delta m_s^{measured} = \Delta m_s^{true}$
- Points:
  A±σ(A) from Likelihood fit for different Δm
- Yellow band: A±1.645σ(A)
- Δm where A±1.645σ(A)<1 excluded at 95% C.L.
- Dashed line:
  1.645σ(A) vs Δm
- Measured sensitivity:
  1.645σ(A)=1

B^0 mixing in hadronic decay



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Choice of Procedure

- Amplitude scan helpful to set Δm limit and combine results
- How does an evidence of a signal look like?
- What procedure if aiming at measurement?
- These questions must be asked before performing the Analysis! Otherwise lack of coverage is the punishment!

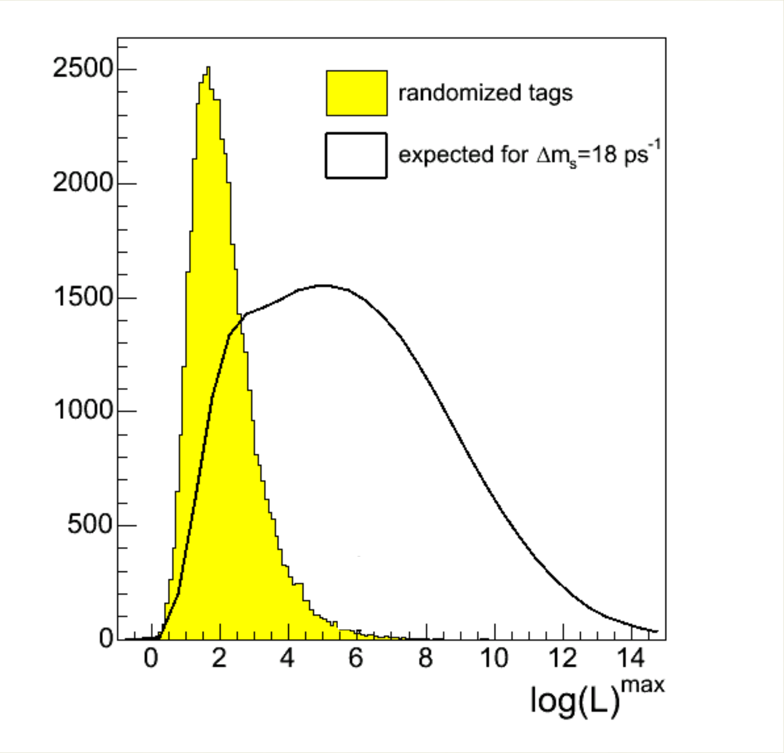
- Before un-blinding:
  p-value: probability that observed effect is due background fluctuation. No search window.

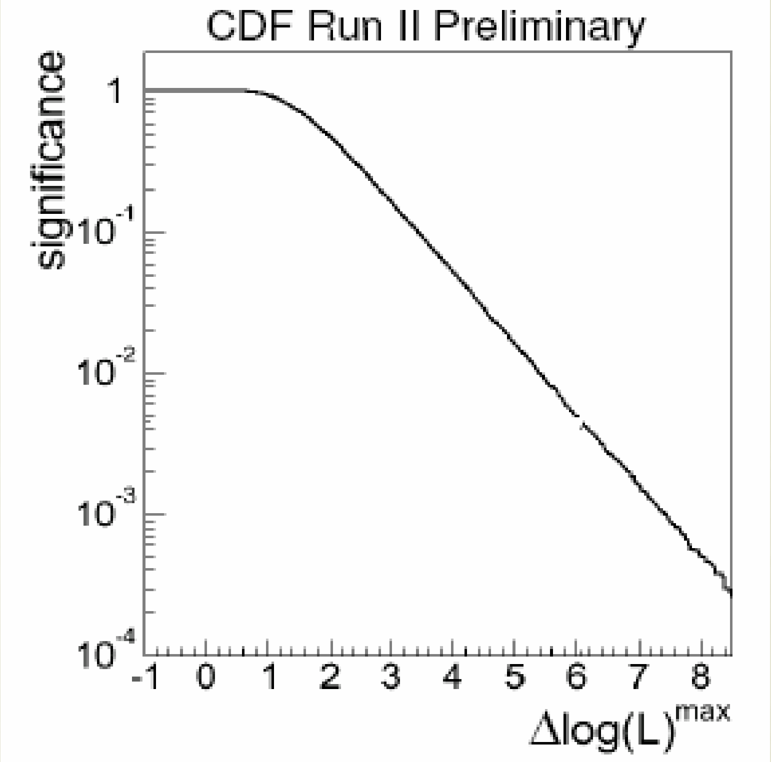
p-value<1%?

yes → make double sided confidence interval from $\Delta(\ln(L))$, measure Δm_s

no → set 95% C.L. based on Amplitude Scan

p-value Estimation

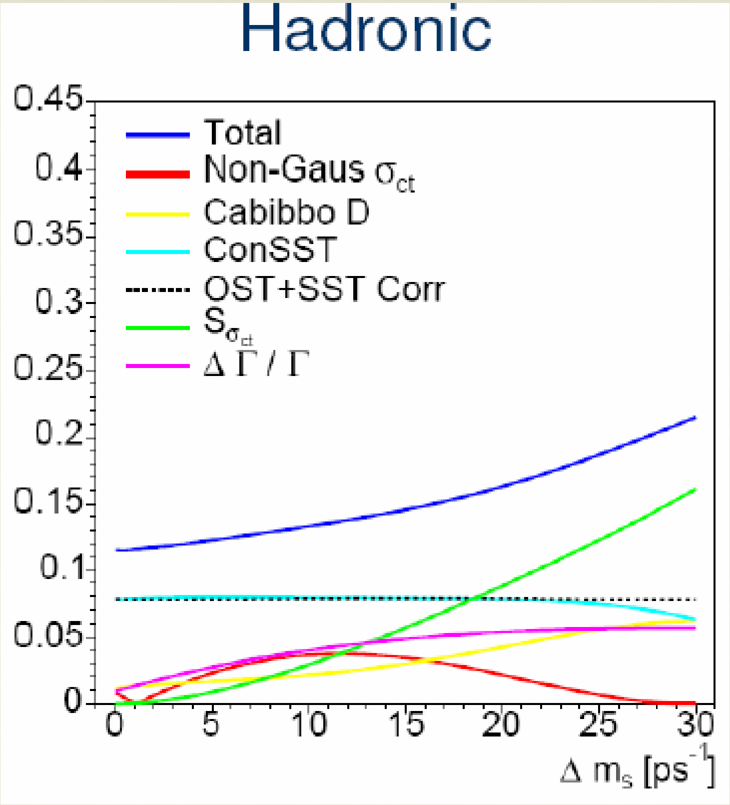


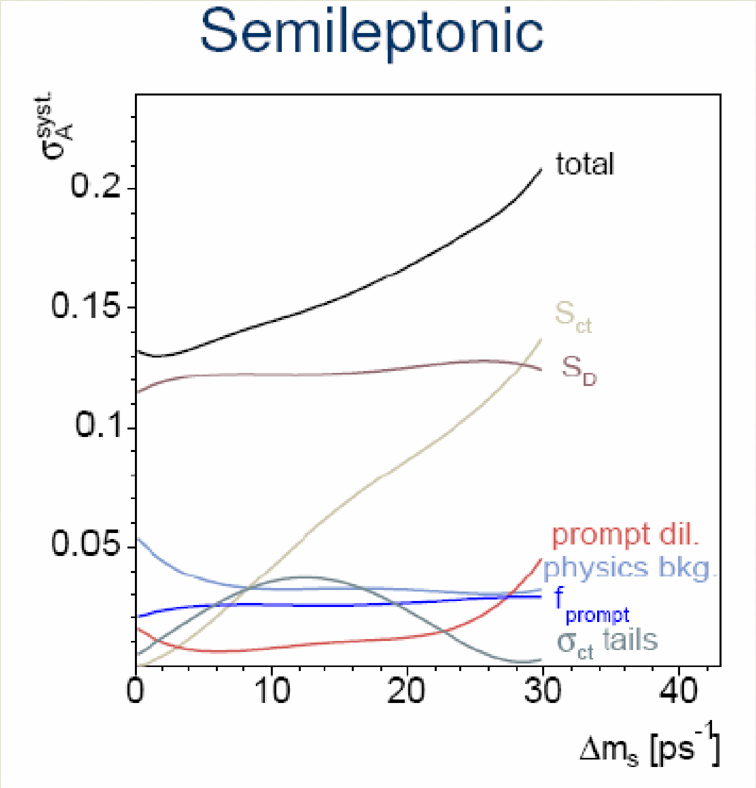


$\Delta(\ln(L)) = \ln[L(A=1)/ \ln L(A=0)]$

Probability of random tag fluctuation estimated on data (randomized tags) and checked with toy Monte Carlo

Systematic Uncertanties in Amplitude Scan



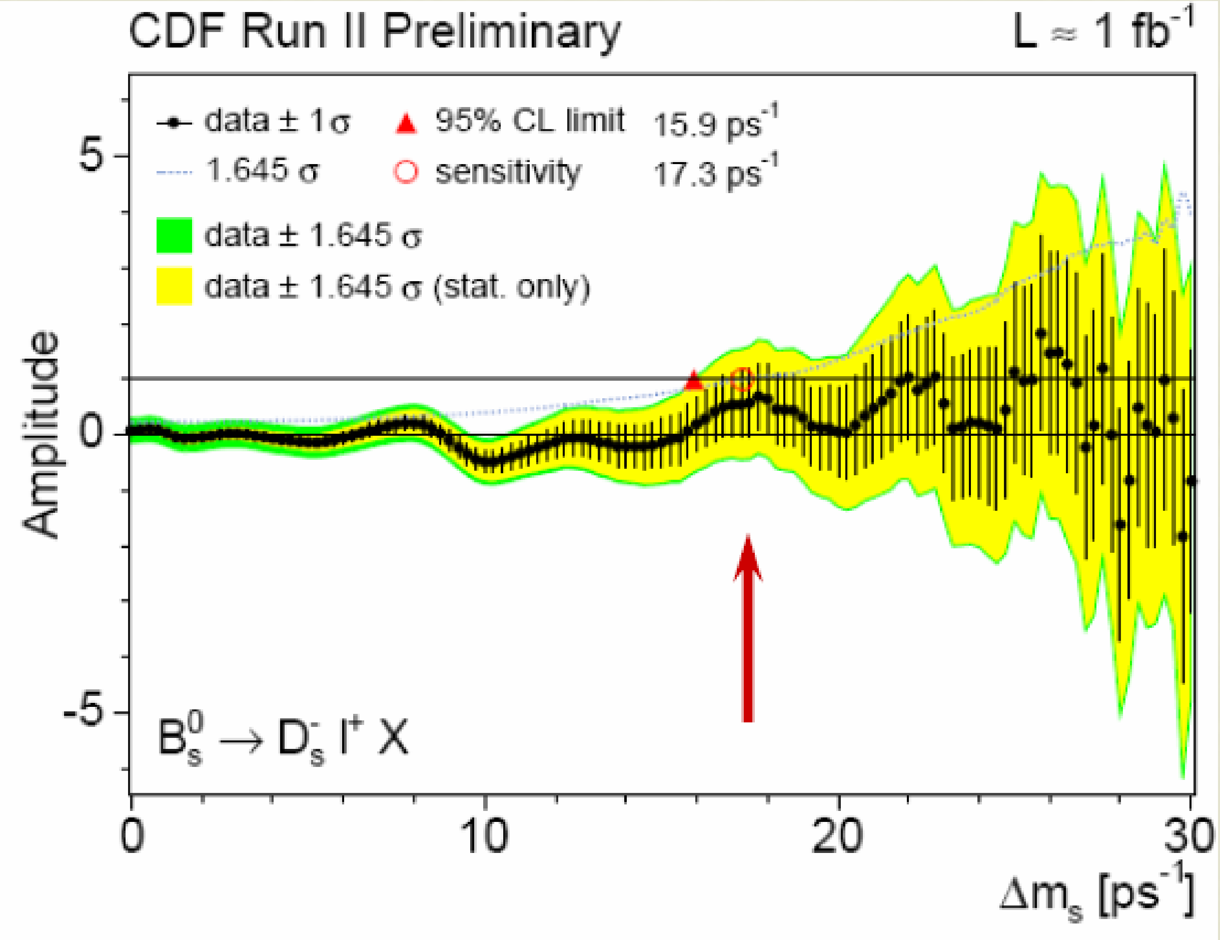


Related to absolute value of A important when setting a limit

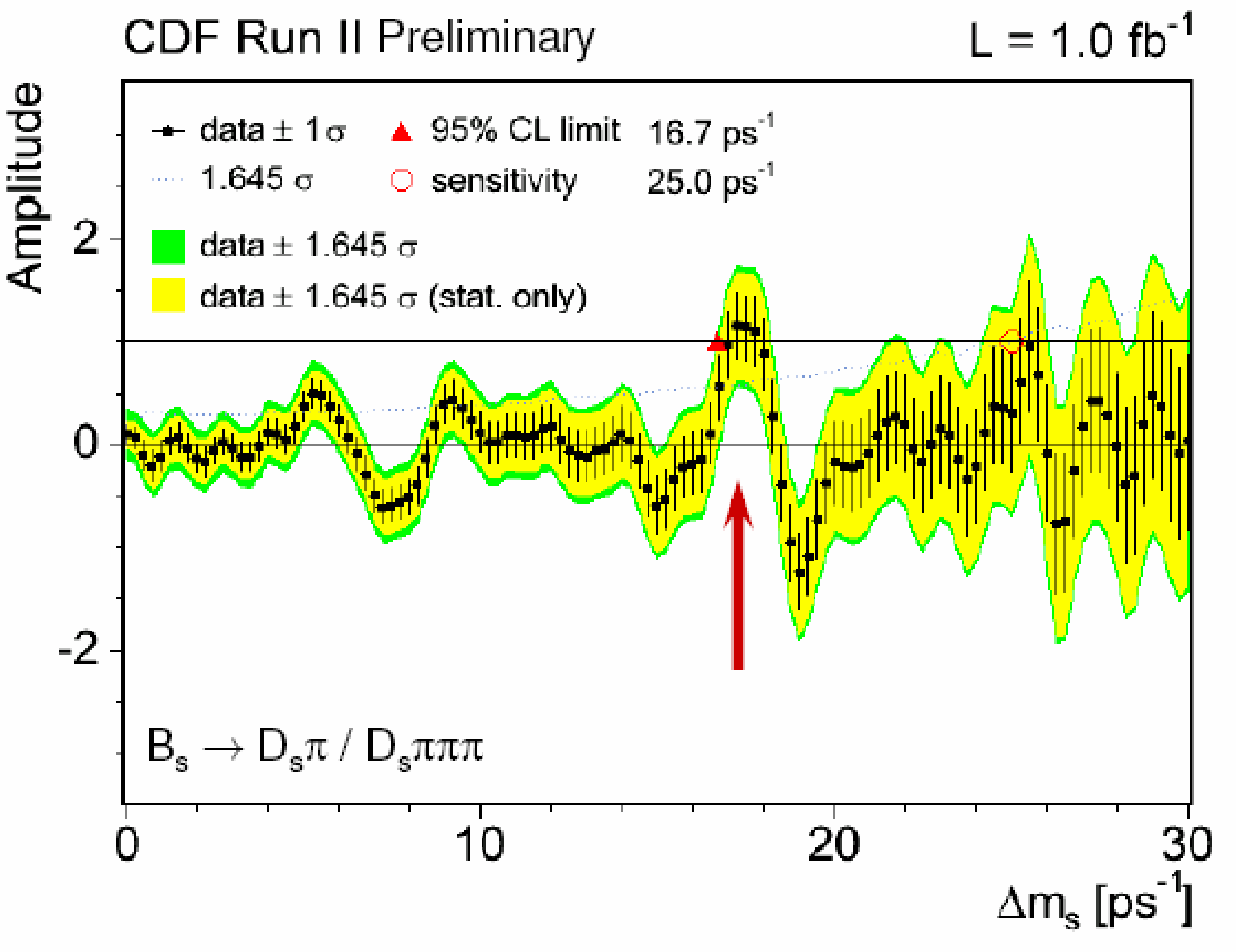
Cancel out in A/σ_A

Very small compared to statistical error

Amplitude Scan: Semileptonic decays

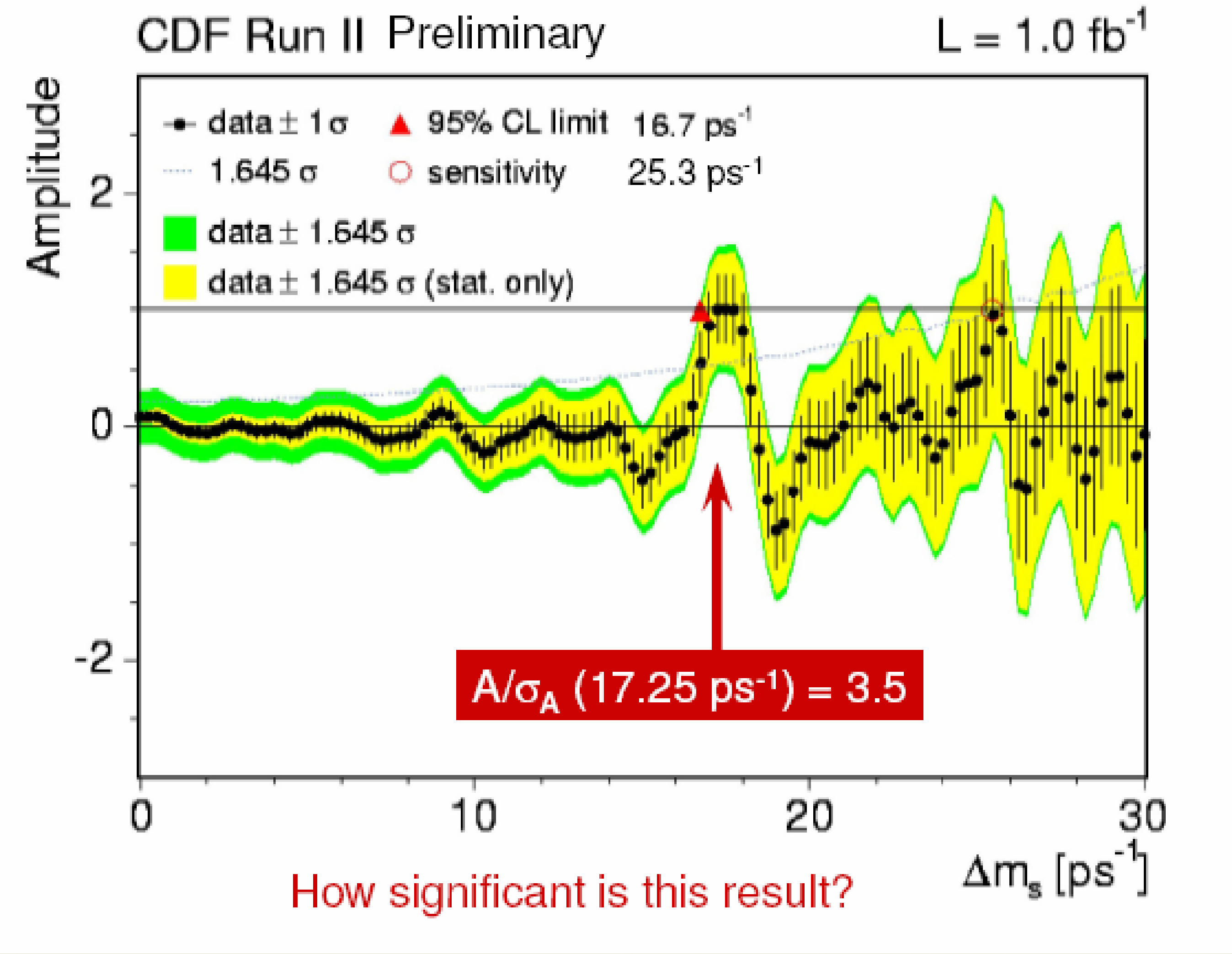


Amplitude Scan: Hadronic decays

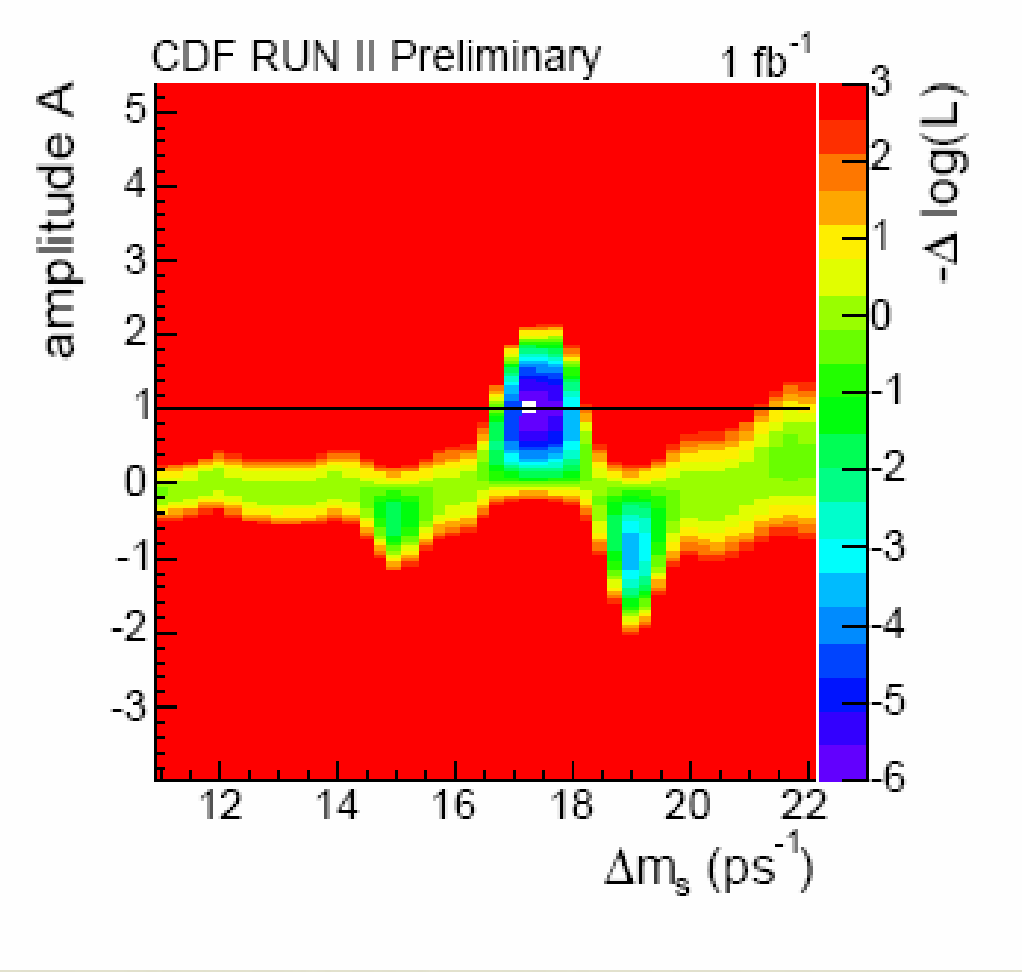


Amplitude Scan: Combined

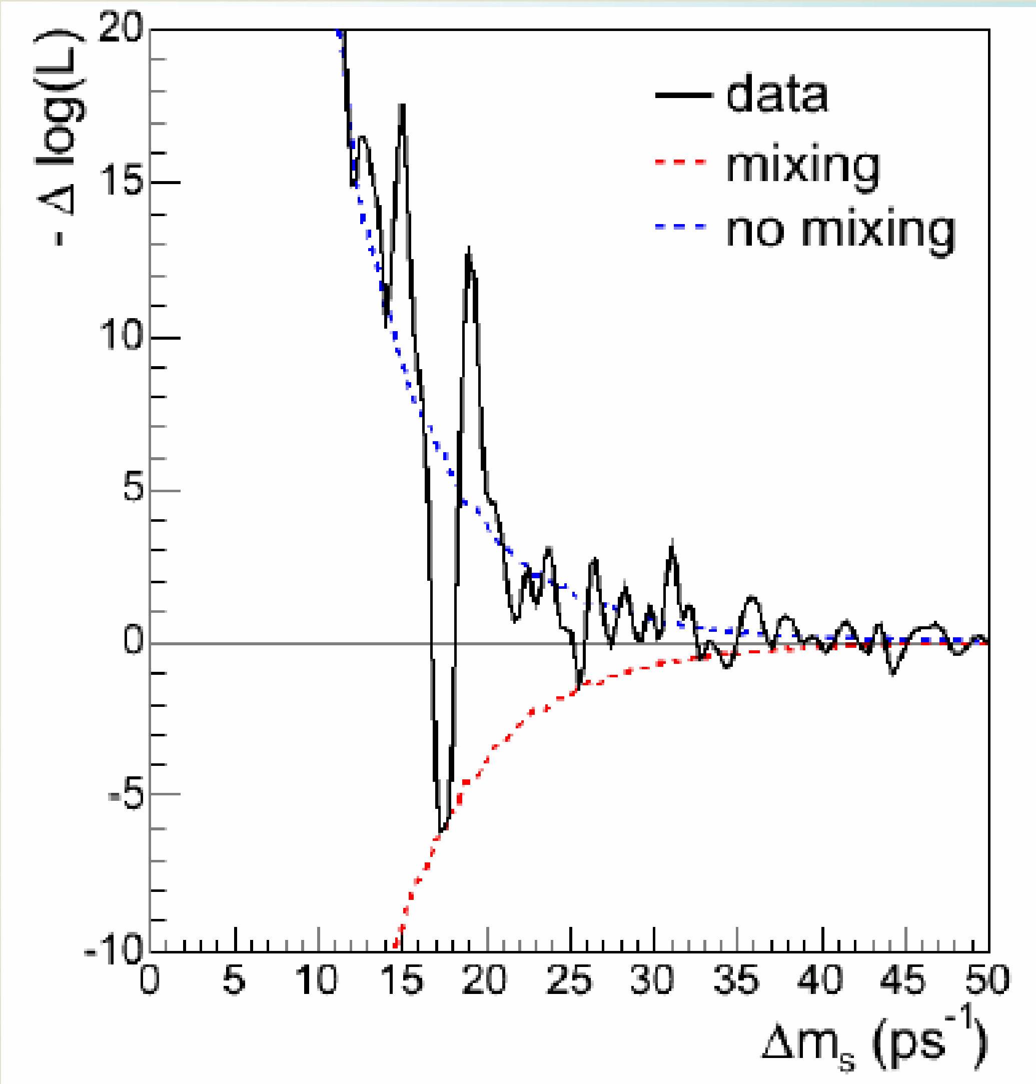
Sensitivity better than the W.A. 20.1 ps^{-1}
Rare case!!



Combined Amplitude Scan: an other view

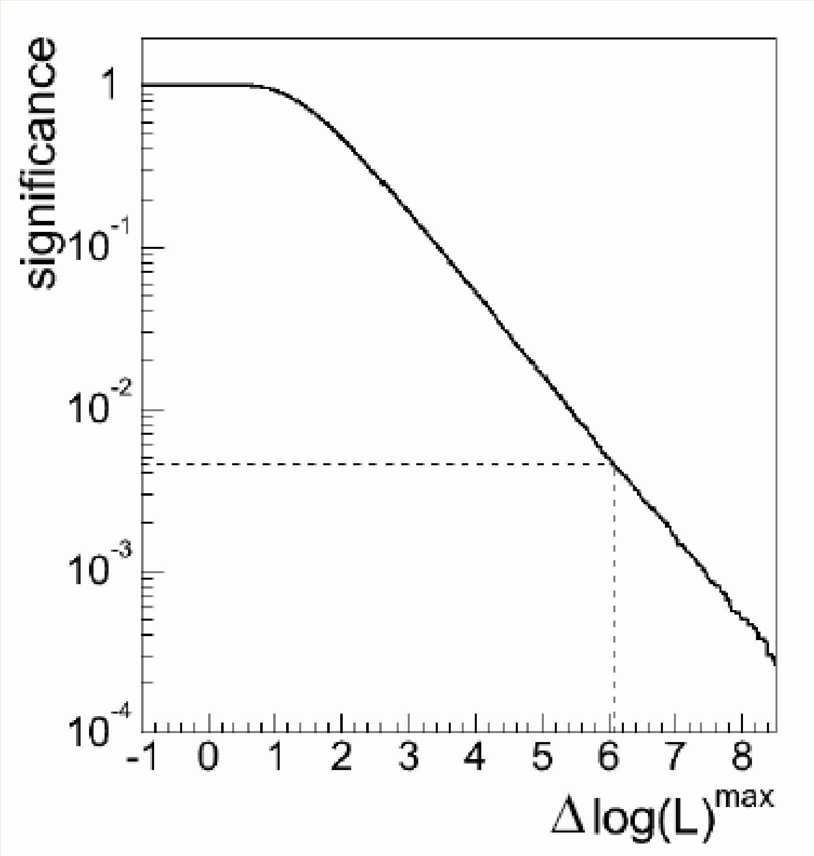


Likelihood Profile



How often random tags produce a likelihood deep this dip?

Likelihood significance



- Find maximum $\Delta(\ln(L))$ in data randomizing 50,000 times tags
- In 228 experiments found $\Delta(\ln(L))>6.06$ Probability of fake, p-value=0.5%

Measure Δm_s !!!

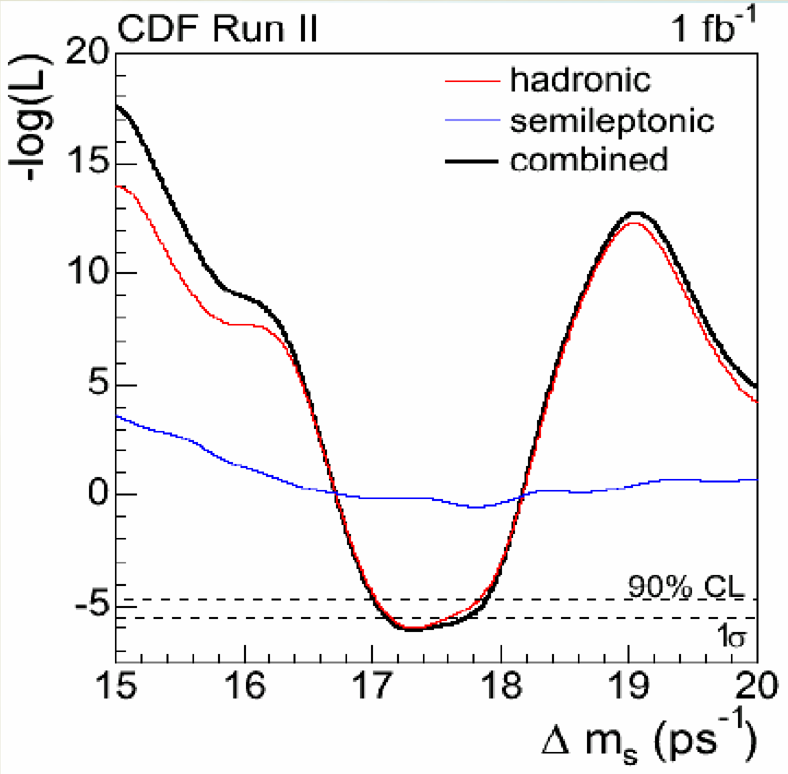
Systematic Uncertanties on Δm_s

	Syst. Unc
SVX Alignment	0.04 ps^{-1}
Track Fit Bias	0.05 ps^{-1}
PV bias from tagging	0.02 ps^{-1}
All Other Sys	< 0.01ps^{-1}
Total	0.07 ps^{-1}

Fit Model: negligible

Relevant only lifetime scale

Measurement of Δm_s



$$\Delta m_s = 17.33^{+0.42}_{-0.21} \pm 0.07 \text{ ps}^{-1}$$

$17.00 < \Delta m_s < 17.91 \text{ ps}^{-1}$ at 90% C.L. $16.94 < \Delta m_s < 17.97 \text{ ps}^{-1}$ at 95% C.L.

$|V_{td}|/|V_{ts}|$ Determination

$$\frac{\Delta m_s}{\Delta m_d} = \frac{m_{Bs}}{m_{Bd}} \xi^2 \frac{|V_{ts}|^2}{|V_{td}|^2}$$

Used as inputs:

- $m_{Bs}/m_{Bd} = 0.9830$ PDG 2006
- $\xi^2 = 1.210^{+0.47}_{-0.35}$ (M. Okamoto, hep-lat/0510113)
- $\Delta m_d = 0.507 \pm 0.005$ PDG 2006

$$|V_{td}|/|V_{ts}| = 0.208\,^{+0.008}_{-0.007}\ \text{(stat.+syst.)}$$

Latest Belle result $b \rightarrow s\gamma$ (hep-ex/050679):

$$|V_{td}|/|V_{ts}| = 0.199\,^{+0.026}_{-0.025}\ \text{(stat)}\ ^{+0.018}_{-0.015}\ \text{(syst)}$$

D0 Analysis

Trigger: single muon p_t>2 GeV/c

N_{Bs} = 26,710 ± 556(stat)

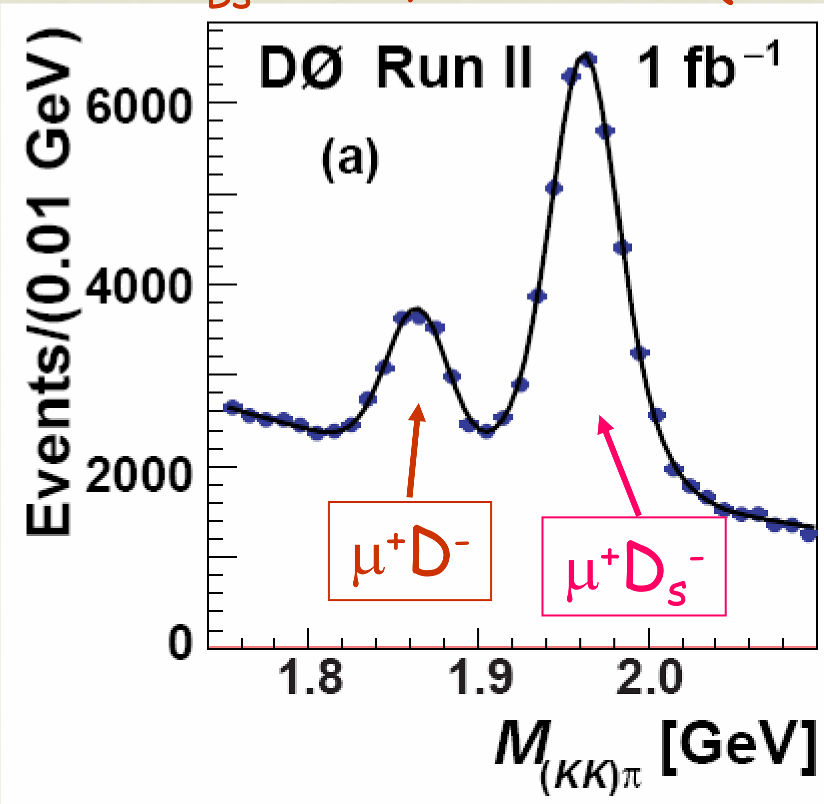
Decay channel:

$B_s \rightarrow \mu^+ D_s^- X$

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

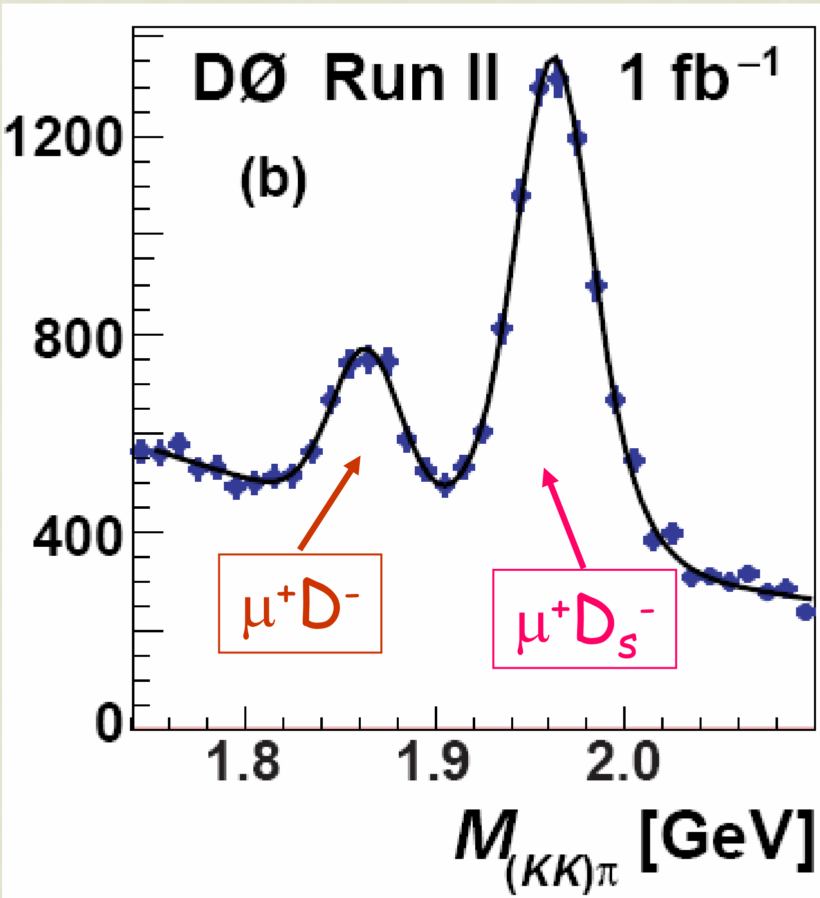
Cuts selected maximize

$$S/\sqrt{S+B}$$



D0 Analysis

N = 5601 ± 102 (stat)



Opposite Side Tagging:

-lepton (electron or muon)

$$Q_J^\ell = \sum_i q^i p_T^i / \sum_i p_T^i$$

- Secondary Vertex

$$Q_{SV} = \sum_i (q^i p_L^i)^{0.6} / \sum_i (p_L^i)^{0.6}$$

- Event Charge

$$Q_{EV} = \sum_i q^i p_T^i / \sum_i p_T^i$$

Tags combined:

$$d_{tag} = \frac{1-z}{1+z} \qquad z = \prod_{i=1}^{n} \frac{f_i^{\bar{b}}(x_i)}{f_i^b(x_i)}$$

$d>0$ b tag

$d<0$ $\bar{b}$ tag

D0 Procedure

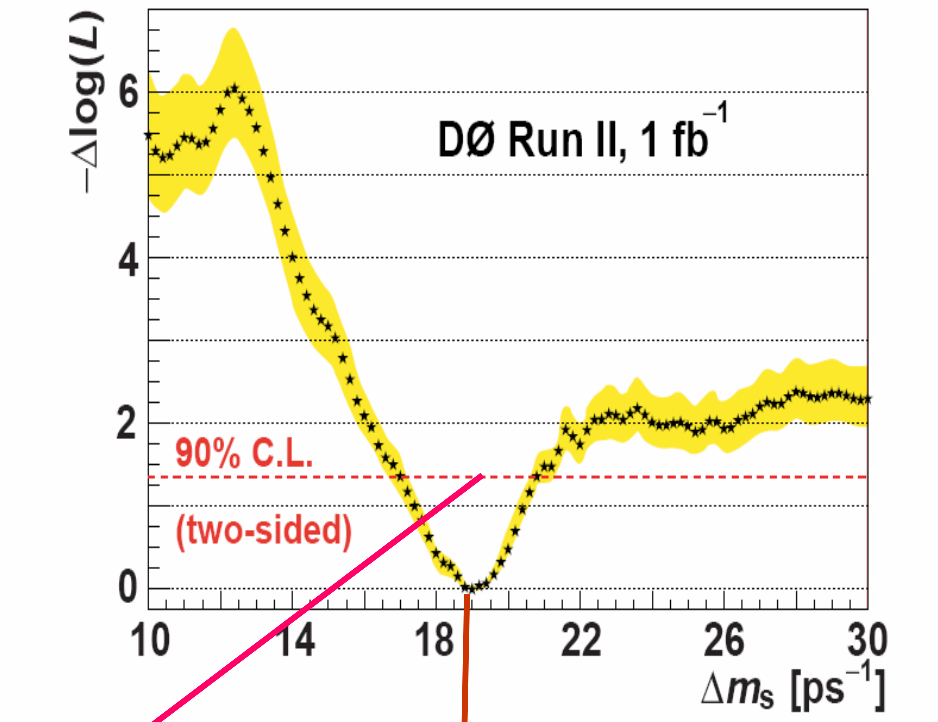
$$p_s^{\mathrm{nos/osc}}(l, K, d_{\mathrm{tag}}) = \frac{K}{c\tau_{B_s^0}} \exp(-\frac{Kl}{c\tau_{B_s^0}})[1 \pm \mathcal{D}(d_{\mathrm{tag}}) \cos(\Delta m_s \cdot Kl/c)]/2.$$

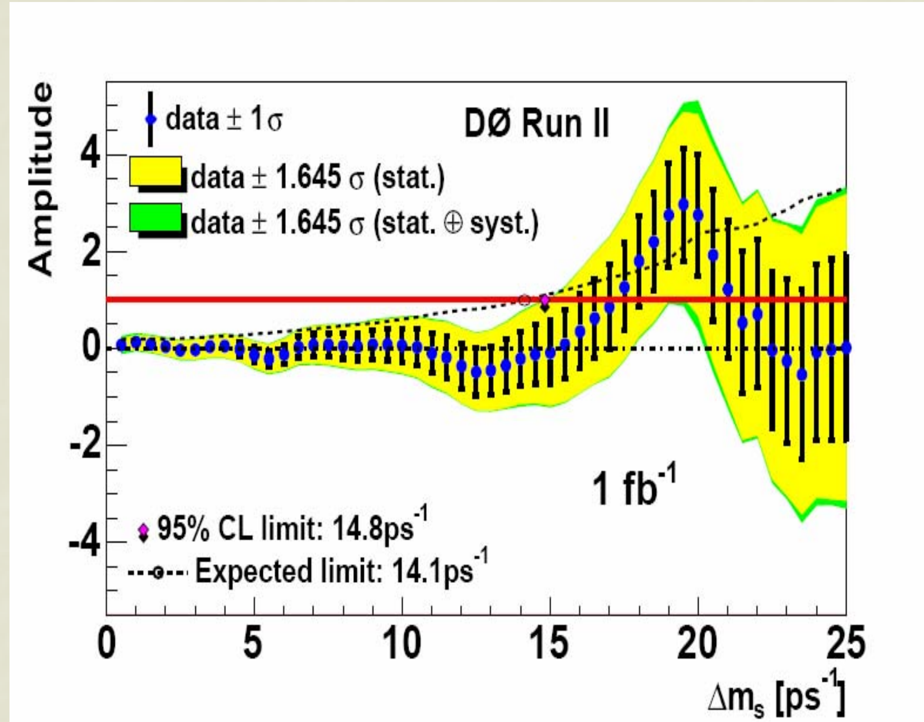
Correction factor due to missing neutrino

Several effects taken into account:

- Resolution scale factor for detector mismodeling
- Reconstruction efficiency as function of decay length
- Physical and combinatorial background contributions

D0 Results





"favored value" = 19 ps^{-1}

$17<\Delta m_s<21\ ps^{-1}$ at the 90% C.L.

$\Delta m \approx 19\ ps^{-1}$:

$A/\sigma A=2.5$ and $A-1/\sigma A=1.6$

Sensitivity = $14.1 ps^{-1}$

$\Delta m_s>14.8$ at the 90% C.L.

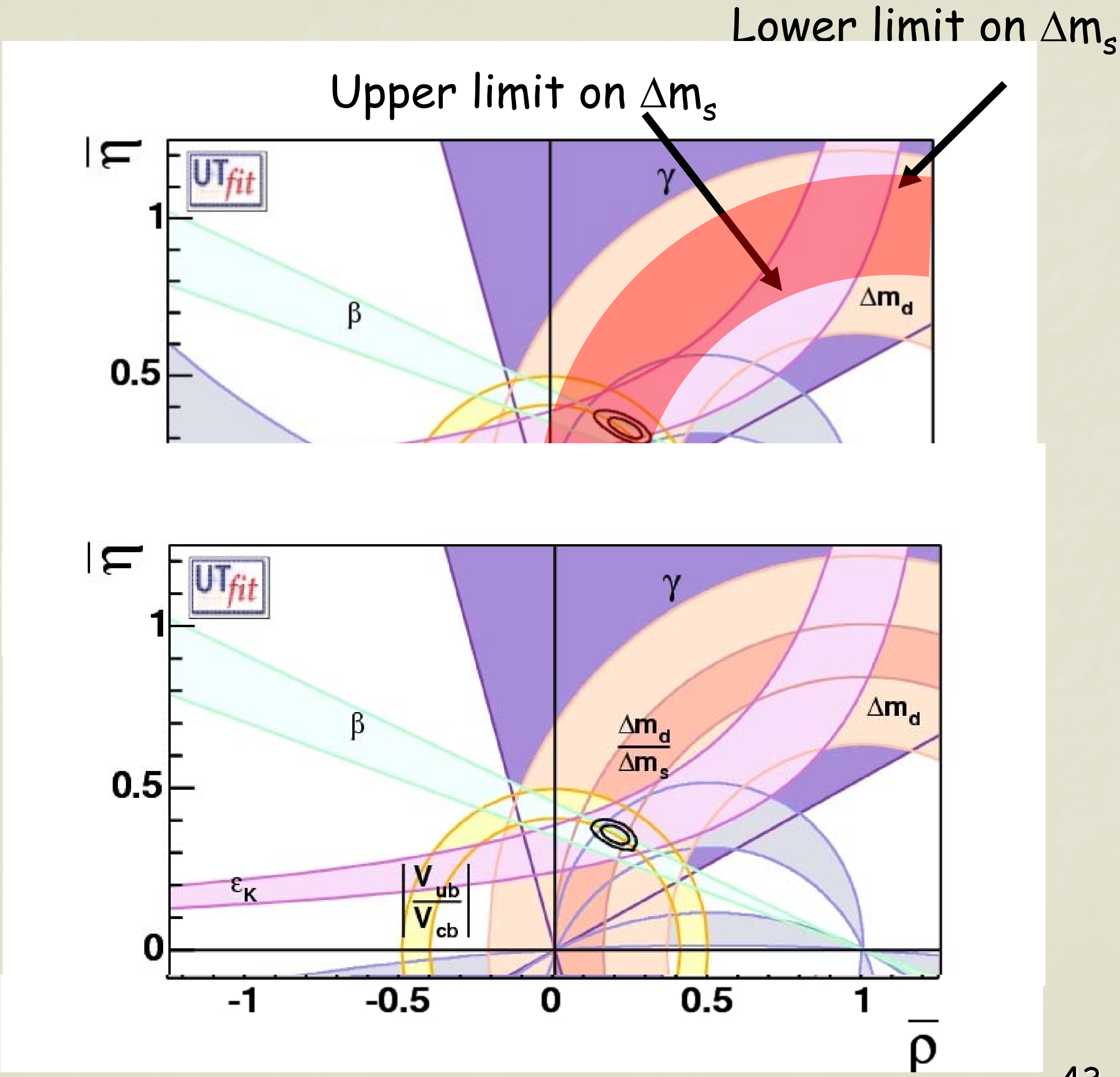
Unitarity Triangle fit with Δm_s

Old:

$\bar{\rho} = 0.217 \pm 0.032$
$\bar{\eta} = 0.344 \pm 0.021$

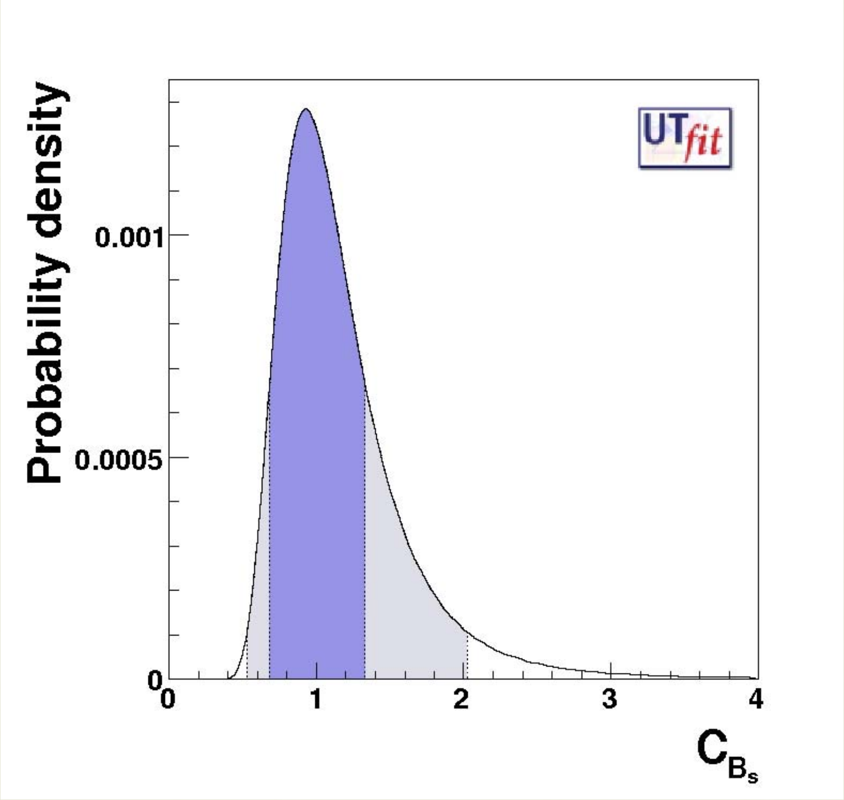
New:

$\bar{\rho} = 0.193 \pm 0.029$
$\bar{\eta} = 0.355 \pm 0.019$



New Physics Limit UTfit

Model independent approach $|\Delta F|=2$ Hamiltonian



$$C_{Bs} = \Delta m_s^{SM+NP} / \Delta m_s^{SM} = 1.01 \pm 0.33$$

[0.33,2.04] @ 95% C.L.

Conclusions

- CDF has an experimental signature for B_s-$\overline{B}_s$ oscillations
- Probability of random fluctuation is 0.5%

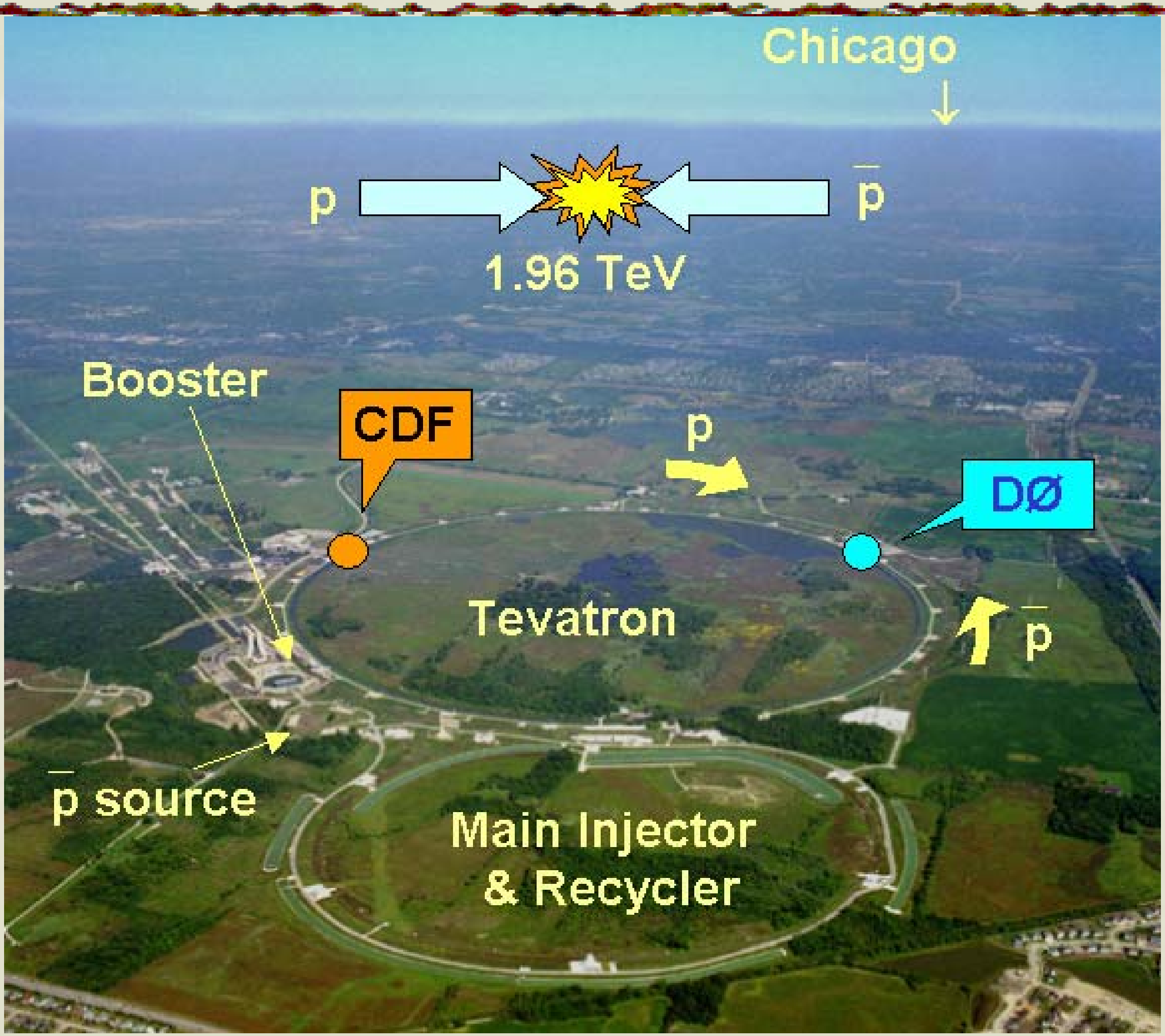
First direct measurement of:

$$\Delta m_s = 17.33^{+0.42}_{-0.21} \pm 0.07 \text{ ps}^{-1}$$

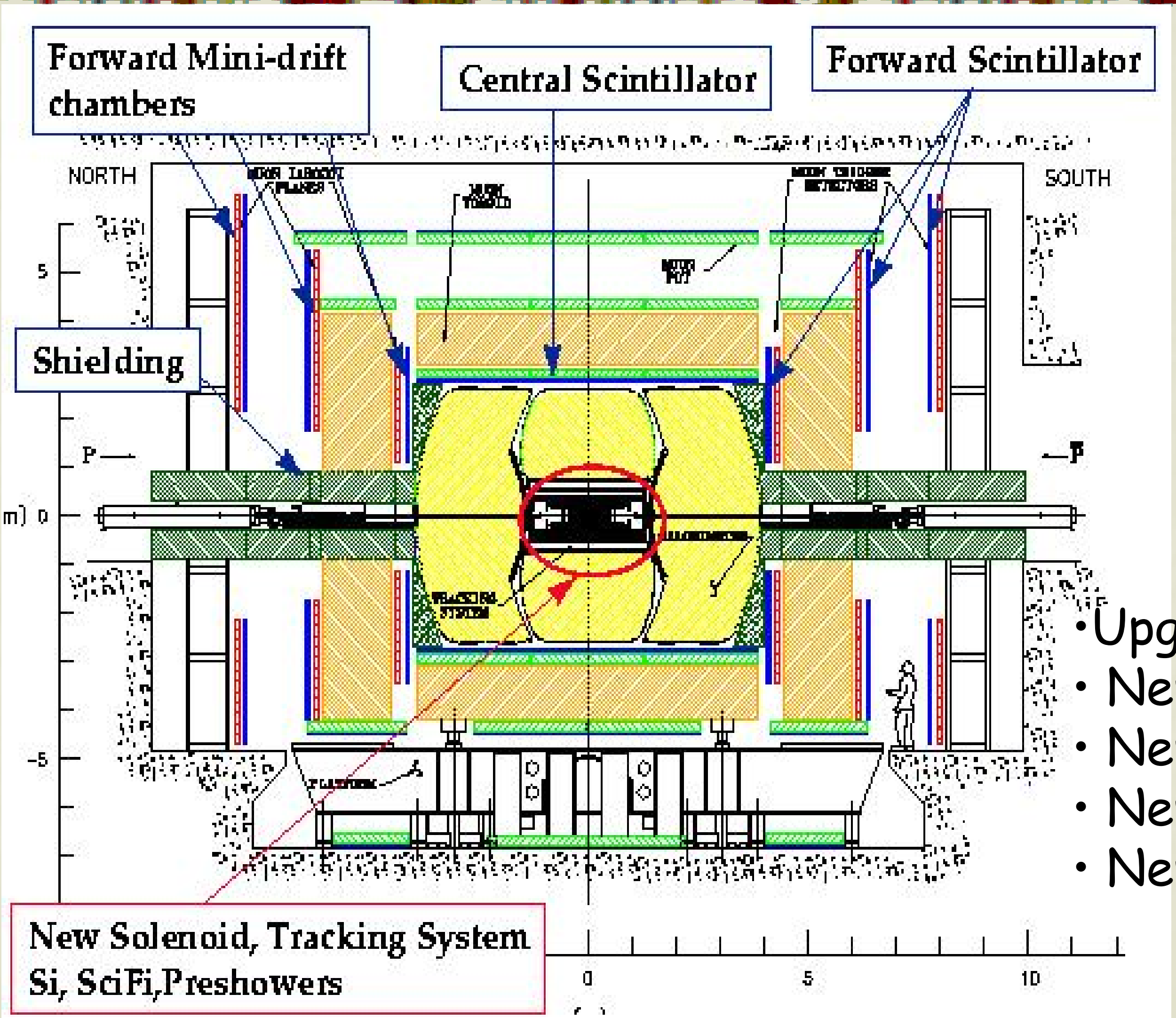
$$|V_{td}|/|V_{ts}| = 0.208^{+0.008}_{-0.007} \text{ (stat.+syst.)}$$

BACKUP

The Accelerator

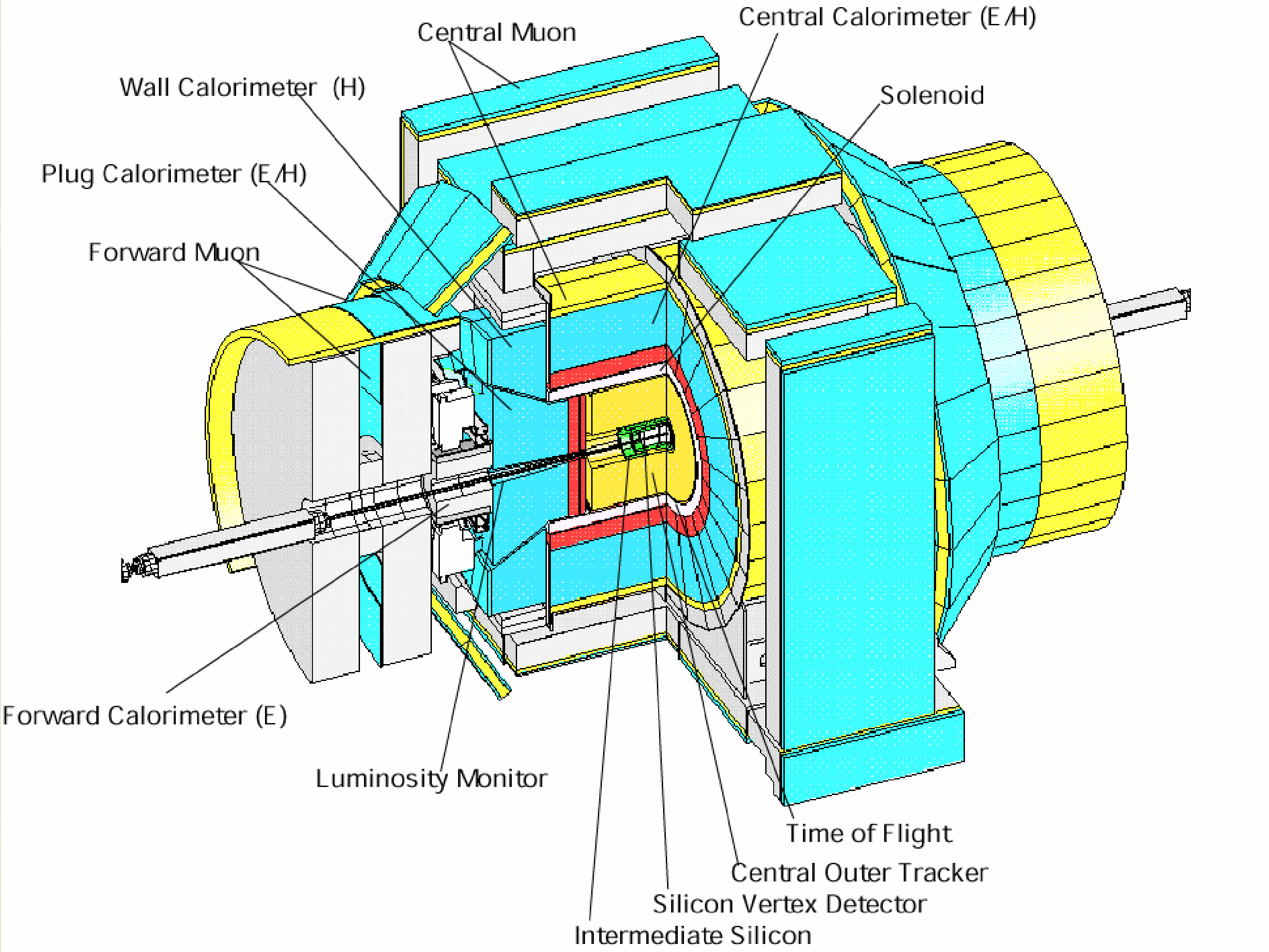


Detectors



- Upgraded muon coverage
- New Tracking System
- New Silicon Micro-vertex
- New Solenoid
- New Pre-showers

Detectors


Central Muon
Central Calorimeter (E/H)
Wall Calorimeter (H)
Solenoid
Plug Calorimeter (E/H)
Forward Muon
Forward Calorimeter (E)
Luminosity Monitor
Time of Flight
Central Outer Tracker
Silicon Vertex Detector
Intermediate Silicon

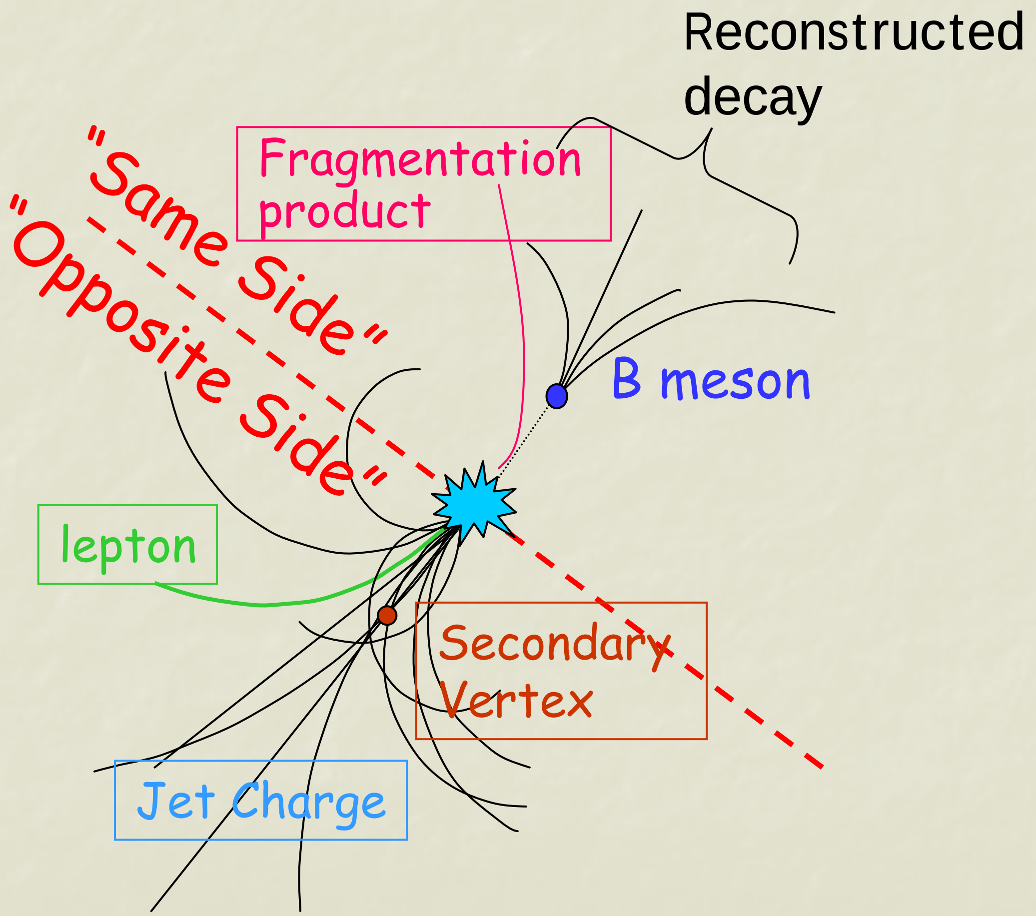
Introduction

Made Possible By the CDF Detector

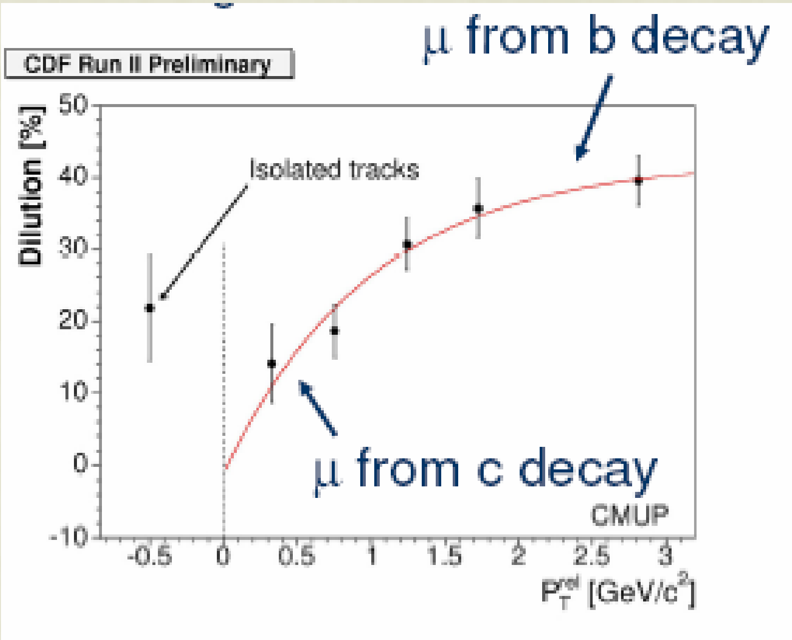
- Trigger
  - high bandwidth & tremendous flexibility
  - XFT and SVT
- Exquisite charged particle tracking
  - excellent pattern recognition & mass resolution (COT, solenoid)
  - precise production & decay point reconstruction (L00, SVX)
- Particle identification
  - Time of Flight (TOF) and dE/dx in COT
- Extremely dedicated collaborators for operations
  - a lot of sleepless nights for analysis but many more for operations
  - many of the analyzers spent sleepless nights working on critical detector components too.

Designed by Padova group and detectors tests done in Padova

Flavor tagger calibration



Parametrizing tag decision



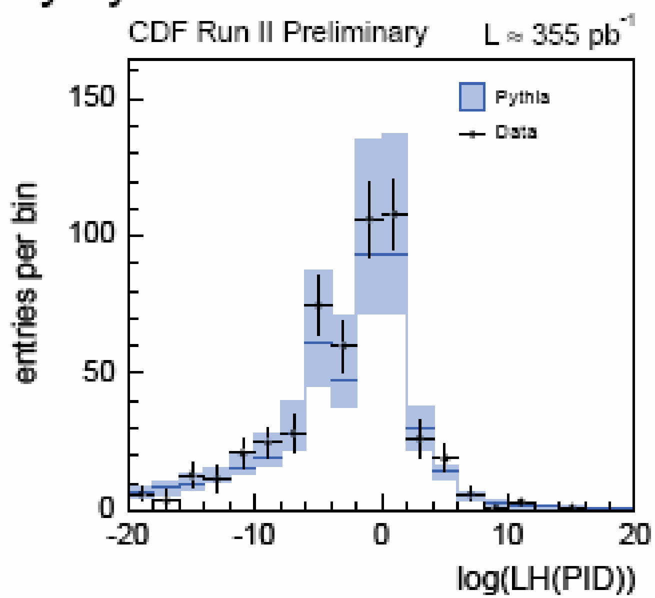
Opposite Side Taggers calibrated in our very high statistics $\ell + SVT$ samples Dependence on several variables used to increase the tagging power

Overall scale factor measured on $B^{0/+}$ candidates to take care a possible overall (small) shift

Similar performace of semileptonic hadronic modes

Calibrating SSTK

Small discrepancies covered by systematics



Systematic studies cover:

- + Fragmentation Model
- + *bb* Production Mechanisms
- + *B*** content
- + Detector/PID resolution
- + Multiple interactions
- + PID content around *B*
- + Data/MC agreement

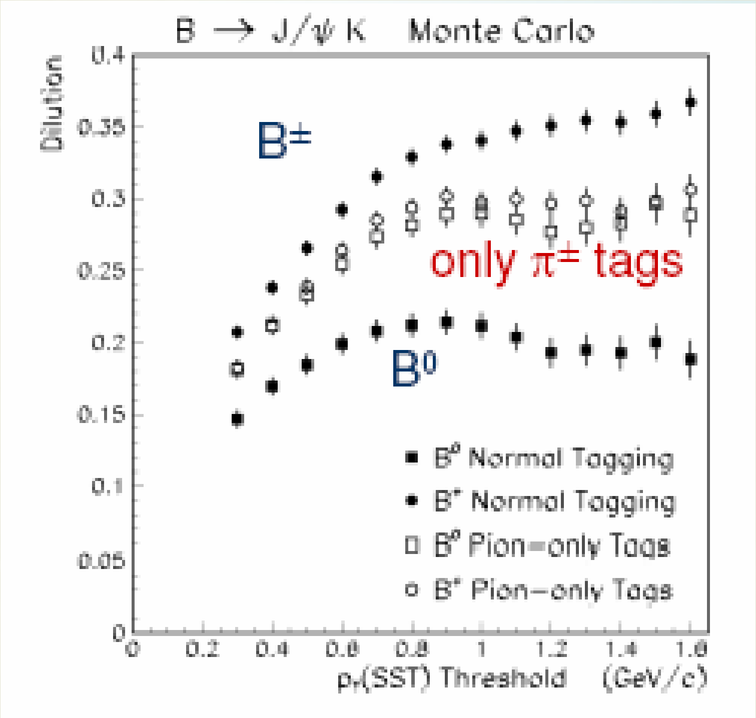
Select the most likely kaon track (PID *) as tagging track

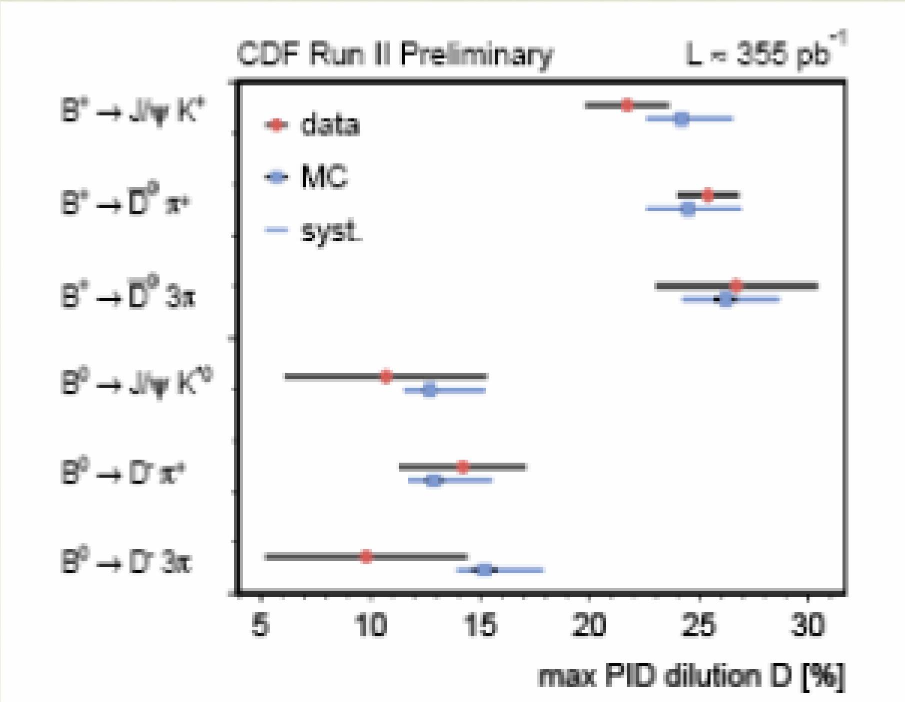
SS(K)T performance estimated from MC:

$\varepsilon D^2(B_s \to D_s(\phi\pi)\pi) = 4.0^{+0.8}_{-1.2}\%$ (1rst period of the data)

*) TOF & dE/dx are used for particle identification

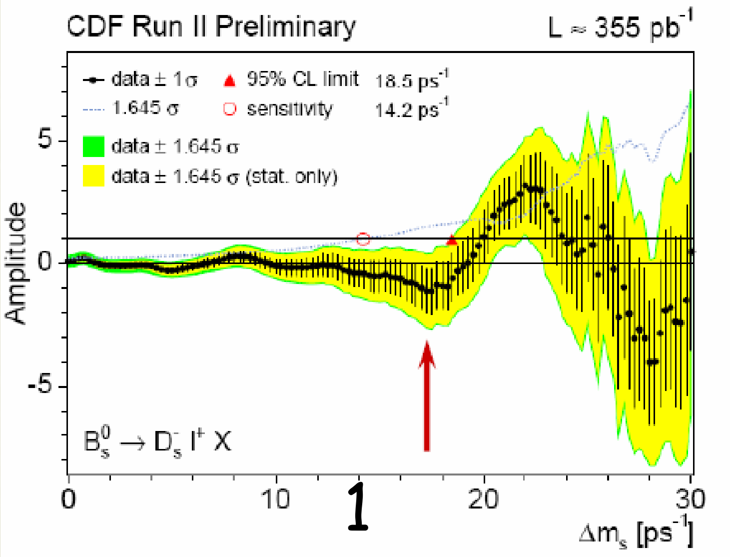
Calibrating SSTK



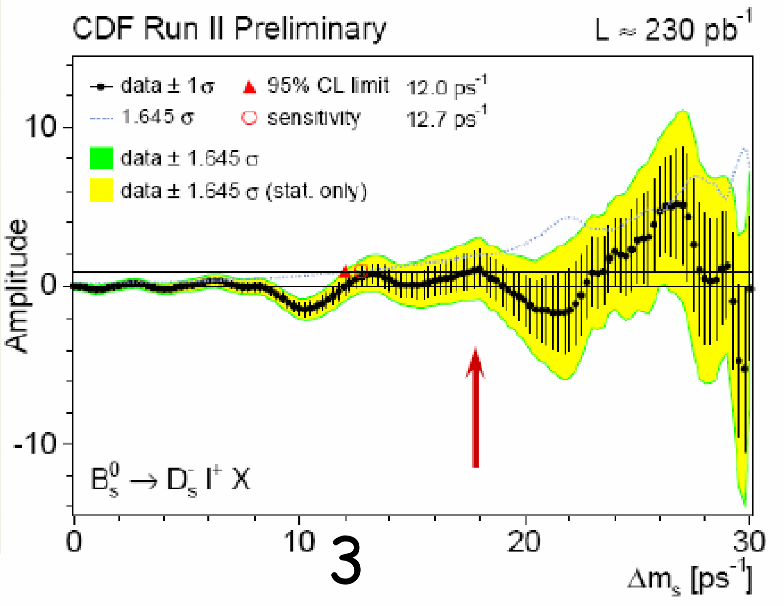


Tune MC to reproduce $B^{0/\pm}$ dilution and then measure it for SSTK

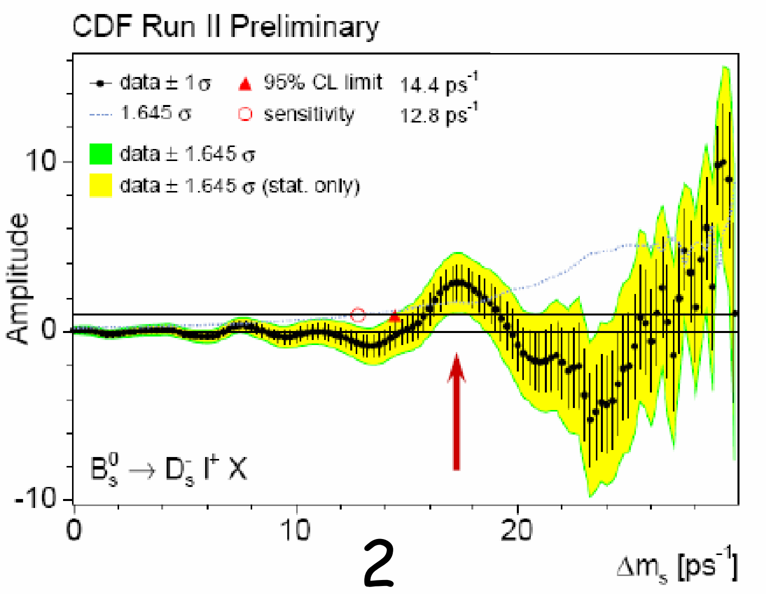
Amplitude scan semileptonic



1

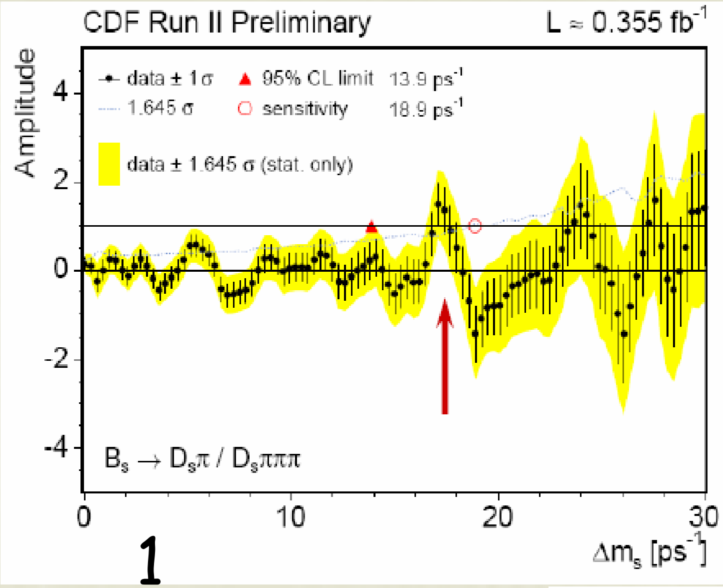


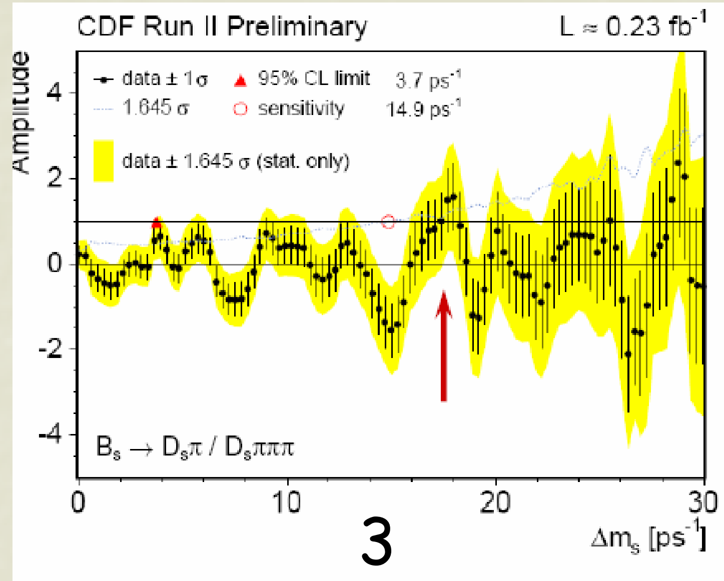
3

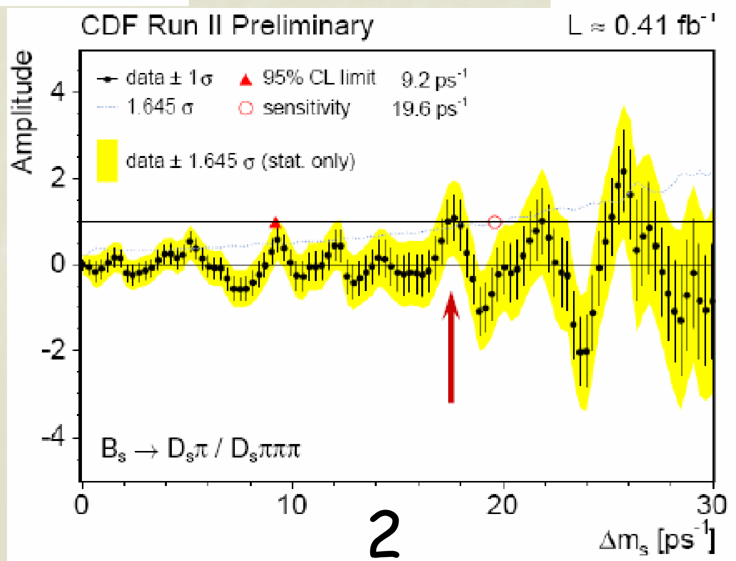


2

Amplitude scan hadronic







Sequence of CDF Run II Results on B_s Mixing

- 1^{st} result March 2005 – presented at Moriond QCD
  - hadronic modes from two-track trigger
  - semileptonic modes from lepton + SVT trigger
  - opposite-side flavor tags: muons, electrons, jet-charge
  - combined sensitivity $\Delta m_s > 8.4\ ps^{-1}$
- 1^{st} update: October 2005 – presented at PANIC 2005
  - substantial increase in semileptonic signal from TTT
  - several analysis improvements, e.g.,
    - neural net based jet-charge opposite side flavor tag
    - improved opposite side flavor tag calibration
    - improved boost resolution on semileptonic decays
  - combined sensitivity $\Delta\ m_s > 13.0\ ps^{-1}$

These results based on 360 pb^{-1} (0d data)