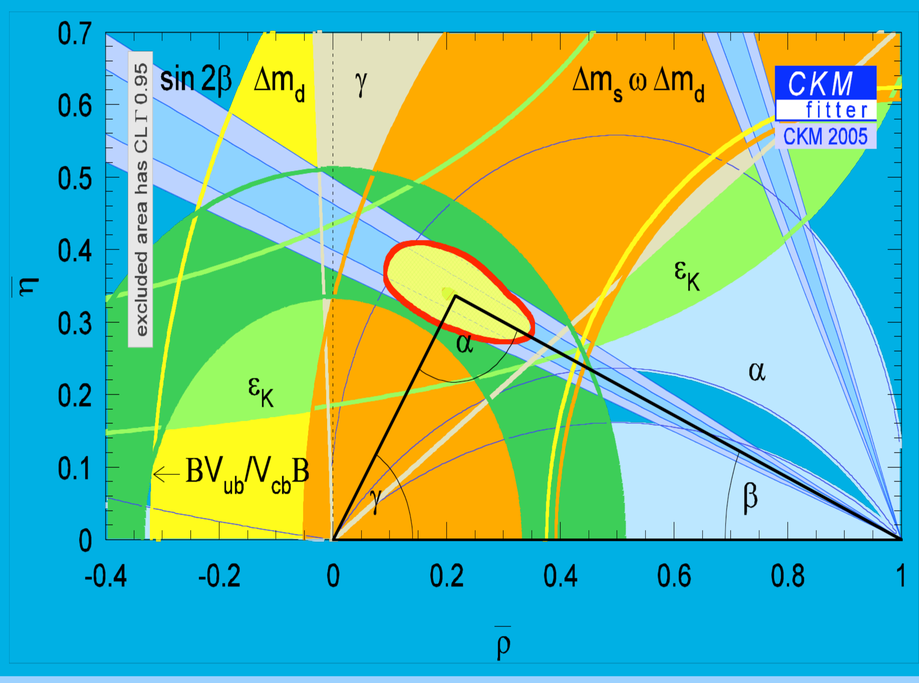
Bs Mixing at CDF

CP violation in the Standard Model

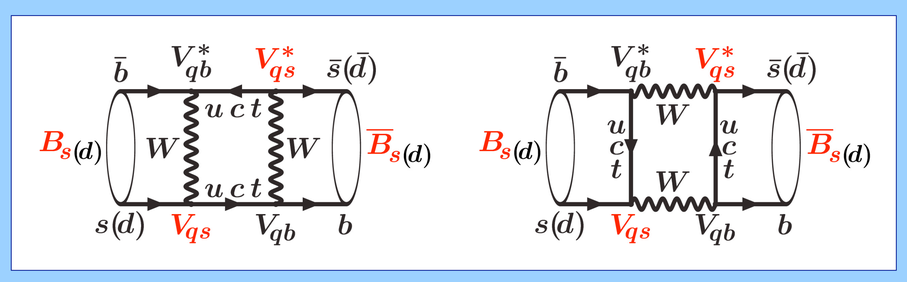
- ✓ Only source of CP violation in the SM: complex phase in the CKM matrix
- ✓ but "not enough" to explain baryon - anti-baryon asymmetry

$$\begin{bmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{bmatrix}$$

To probe CP violation deeper, check CKM matrix unitarity by over-constraining the Unitarity Triangle



Neutral B meson mixing



- ✓ occurs via 2nd order weak diagrams
- ✓ 2 eigenstates of definite mass and width: H(eavy) and L(ight)
- ✓ extract V_{td}, V_{ts} and (more precisely) the ratio V_{td}/V_{ts}:
  - $\Delta M_{s(d)} = M^H - M^L \sim |V_{ts(d)}|^2$
  - $\Delta\Gamma = \Gamma^H - \Gamma^L$, $\frac{\Delta\Gamma}{\Delta M} = -3.7^{+1.5}_{-0.8} \times 10^{-3}$

✓ $P(B \to \bar{B}) = \frac{1}{2} e^{-\Gamma t}\left[\cosh(\Delta\Gamma t/2) - \cos(\Delta M t)\right]$

⟶ ΔM sets the frequency of the flavor oscillations

Measuring ΔM_s

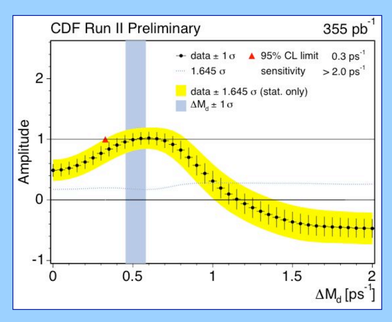
Necessary ingredients:

- ✓ flavor at decay [consider flavor specific decays $D_s^- \pi^+$, $D_s^- l^+ \nu X$, …]
- ✓ proper decay time
- ✓ flavor at production, i.e. "tagging":
  - ε = tagger efficiency
  - D = tagger dilution = 1 – 2w [w is the wrong tag probability]

$\Delta M_d = 0.510 \pm 0.005\ ps^{-1}$ → small → easy to resolve oscillations
$\Delta M_s > 14.4\ ps^{-1}$ @95% C.L. → large → use **AMPLITUDE SCAN** method

1) $\text{Asymmetry}(t) = \frac{N^{\text{unmixed}} - N^{\text{mixed}}}{N^{\text{tagged}}} = A D \cos(\Delta M_s t)$

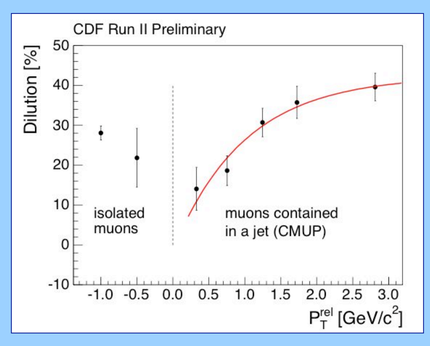
2) Scan:
A ~ 1 → $\Delta M_s = \Delta M_s^{\text{real}}$
A ~ 0 otherwise



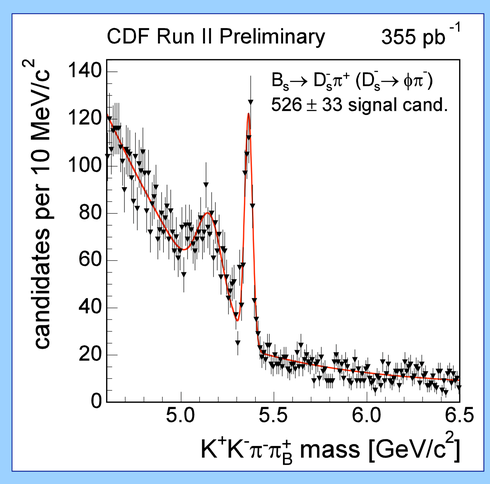
3) Signal significance: $\frac{A}{\sigma_A} = \sqrt{\frac{\varepsilon D^2}{2} S \frac{S}{S+B}} e^{-\frac{\Delta M_s^2 \sigma_{ct}^2}{2}}$

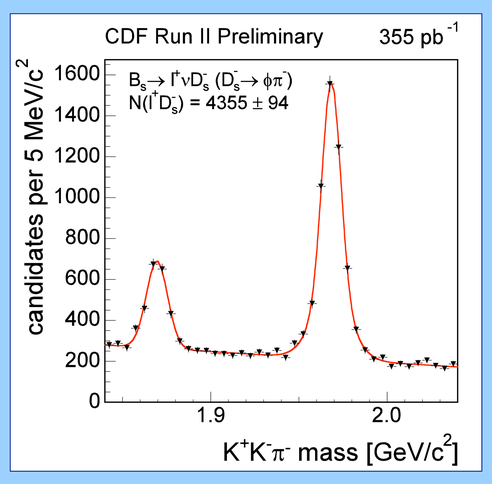
✓ εD^2 -- dilutions and efficiencies from data

Tagger	ε	D	εD^2
Soft Muon	5%	36%	0.56%
Soft Electron	4%	30%	0.29%
Jet Charge	75%	8%	0.58%
Total	84%	---	1.43%



✓ S, S/(S+B) and σ_{ct} -- reasonable values achieved with SILICON TRACKER





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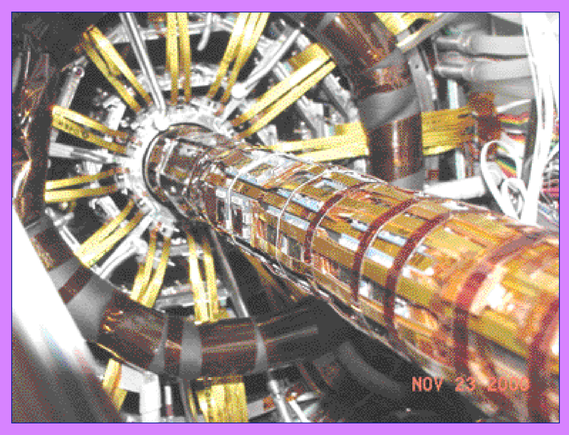
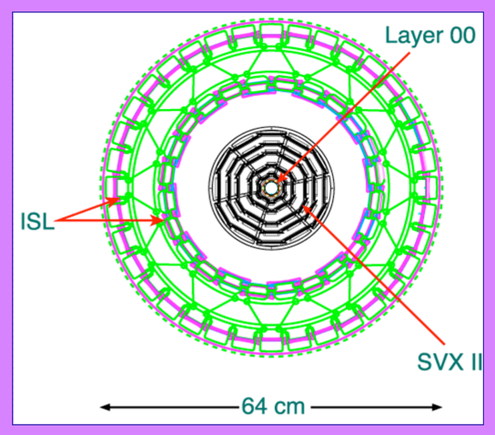
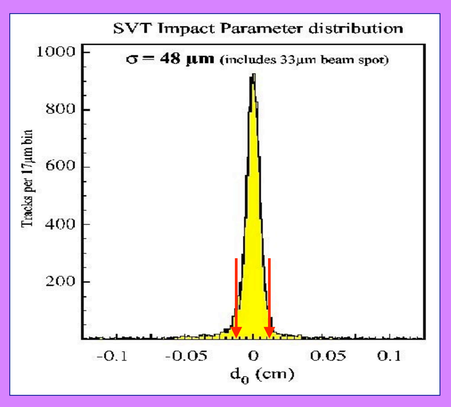
Bs Mixing at CDF

Silicon Tracker





L00+SVXII+ISL: 7-8 silicon layers *
* 722K channels * rϕ and rz views * 1.3cm < r < 28cm



SVT

ONLINE track processor that uses SVX information to select tracks with large impact parameter w.r.t. the beam line -- a signature of B and D meson decays

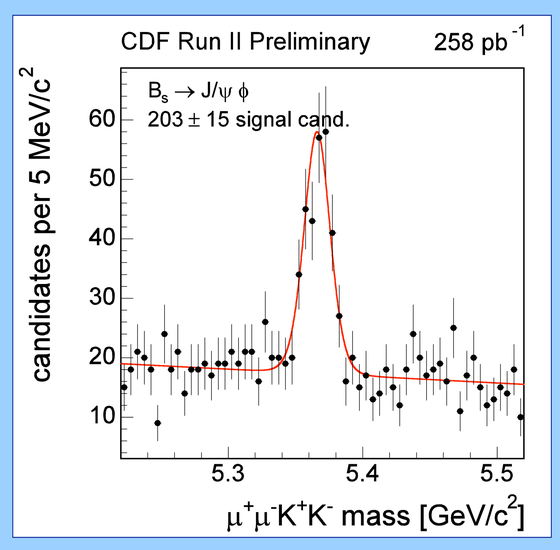
Measuring $\Delta\Gamma_s$

✓A larger ΔM_s is more difficult to measure, but a larger $\Delta\Gamma_s$ is easier to measure

$\Delta\Gamma_s$ is an insurance we have if ΔM_s turns out to be too large ($\Delta\Gamma \sim \Delta M$)

✓ H and L eigenstates are nearly CP eigenstates → measuring the lifetime in a B_s decay to a CP final state ≡ measuring the lifetime of the corresponding H or L eigenstate

$B_s \to J/\psi\phi$ is P → VV decay
J = 0, S = 0,1,2 → L = 0,1,2 i.e.
S, P, and D partial waves:
S,D-waves ⇔ B_s^L
P-wave ⇔ B_s^H

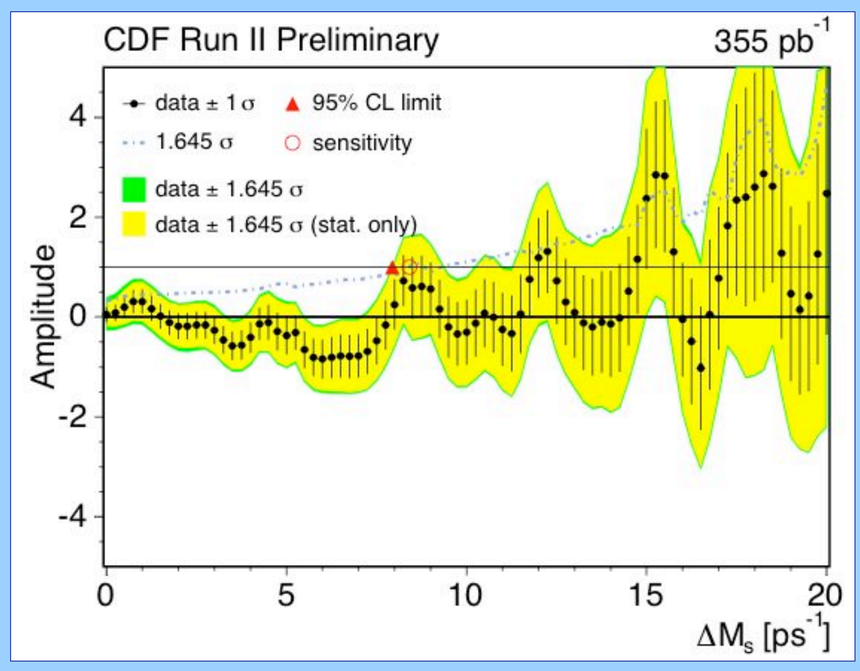


✓ Angular analysis → isolates P-wave from S- and D-waves → separates H and L eigenstates

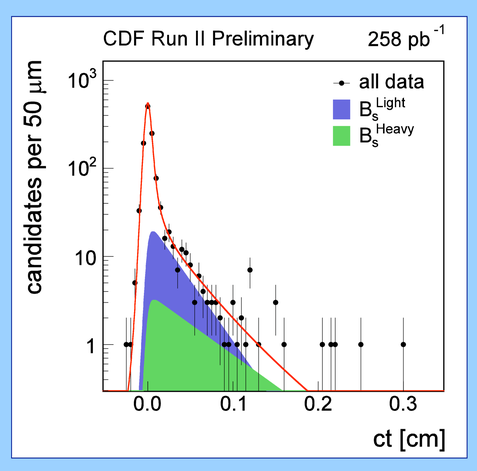
✓ Extract distinct lifetime for each → $\Delta\Gamma_s$ measurement

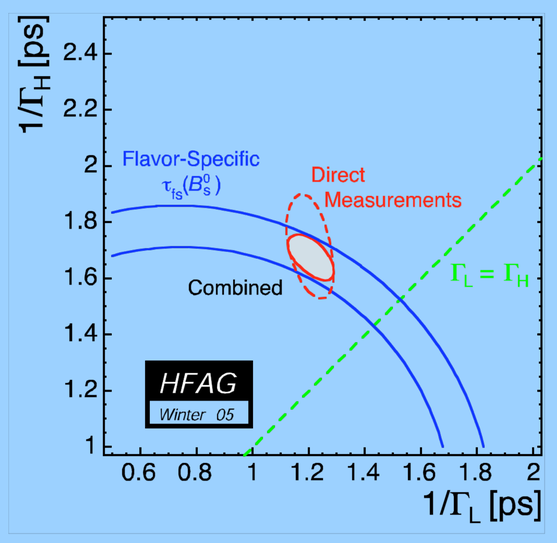
Results

Extract ΔM_s from 2 independent samples:
$B_s \to D_s l\nu X$ [larger S] and $B_s \to D_s\pi$ [better σ_{ct}]



Combined result: $\Delta M_s > 7.9\ ps^{-1}$@95% C.L.
Sensitivity: 8.4 ps^{-1}





$\Delta\Gamma_s/\Gamma_s = -0.65^{+0.33}_{-0.25}$ $\quad \Delta\Gamma_s = -0.47^{+0.24}_{-0.19}$

✓ **Statistical** uncertainties dominate the measurements
✓ Large B_d samples are used as checks/calibrations

Coming Improvements

ΔM_s:
✓ include Same-Side K Tagging using new TOF system → double tagging power
✓ "event by event" primary vertex reconstruction → improve σ_{ct}
✓ additional channels and trigger paths → larger S
✓ more statistics

$\Delta\Gamma_s$:
✓ alternative approaches [Br($B_s \to D_s^{(*)-} D_s^{(*)+}$), lifetime in CP-even dominated samples]
✓ more statistics

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