B_s mixing

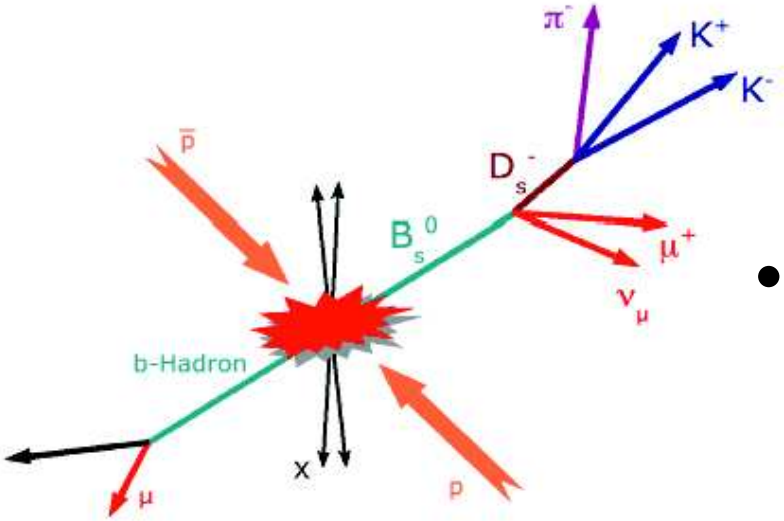
Meghan Anzelc, Steve Beale, Guennadi Borissov, Sergey Burdin,
Hal Evans, Thorsten Kuhl, Tania Moulik, Md Naimuddin,
Jacqueline Radigan, Alexander Rakitin, Derek Strom, Wendy Taylor,
Dmitri Tsybychev, Gernot A. Weber, Sung-Woo Youn

July 27, 2007

All-DØMeeting

http://www-d0.fnal.gov/~rakitin/d0_private/tex/2007.Jul.27.ADM/tr.pdf

Current status of B_s mixing:



- Published:
  - DØ ($B_s \to \mu\phi\pi$ only):
    $$17\ \text{ps}^{-1} < \Delta m_s < 21\ \text{ps}^{-1}$$
  - CDF (semileptonic + hadronic decays):
    $$\Delta m_s = 17.77 \pm 0.10(\text{stat.}) \pm 0.07(\text{sys.})$$
- Currently utilized decay modes at DØ:
  - $B_s \to \mu\nu D_s X, D_s \to \phi\pi$ (M. Anzelc *et al.*)
  - $B_s \to \mu\nu D_s X, D_s \to K^{*0}K$ (S. Beale *et al.*)
  - $B_s \to \mu\nu D_s X, D_s \to K_S K$ (G. Borissov *et al.*)
  - $B_s \to e\nu D_s X, D_s \to \phi\pi$ (T. Moulik *et al.*)
  - $B_s \to D_s\pi, D_s \to \phi\pi$ (T. Kuhl *et al.*)

Semileptonic decays:

- Simple and efficient trigger
- High event rate
- Low proper time resolution due to lost ν

Hadronic decays:

- Triggering is a challenge
- Low event rate
- Better proper time resolution due to full reconstruction

Goal: get combined measurement Δm_s at at least 3σ

Data used:

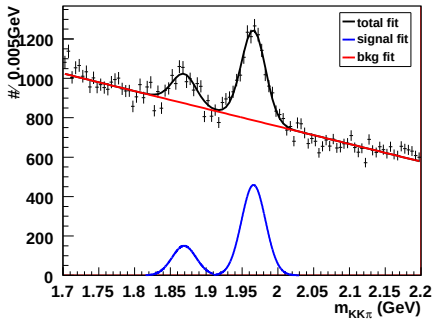
- Run IIa: 1.3 fb^{-1}, p17 reprocessing (D. Strom, M. Anzelc)
- Run IIb: 1.1 fb^{-1}, p20 reprocessing (G. Weber, S.-W. Youn)
- Total: 2.4 fb^{-1}

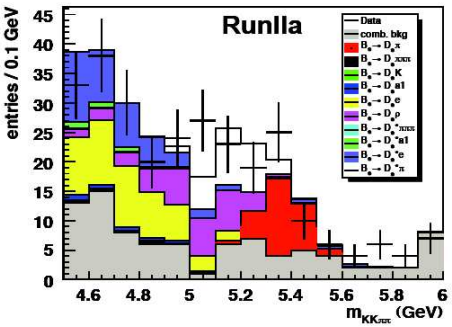
– Converted tmbfiles to special AADST format

– Created event lists with only events containing B_s candidates

D_s reconstruction:

- Combine two oppositely-charged tracks into $\phi \rightarrow KK$ or $K^{*0} \rightarrow K\pi$
- Add a third track (π or K) to complete D_s
- For semileptonic mode: add trigger lepton - μ (or e) to complete lepton+D_s system
- For hadronic mode: add fourth track (π) to fully reconstruct B_s (DØ Note **5249**)





B_s oscillation analysis:

- Find decay vertex of lepton+D_s system or of B_s (implemented in BANA package)
- Calculate B_s lifetime $ct = L_{xy} \cdot \frac{m(B_s)}{p_t(B_s)}$
- For semileptonic and partially reconstructed hadronic decays $p_t(B_s)$ not known $\Longrightarrow$ replace it with $p_t(\ell D_s) \cdot K$ where K-factors $K \equiv \langle \frac{p_t(B_s)}{p_t(\ell D_s)} \rangle$ are obtained from Monte Carlo (DØ Note **5221**)
- Tag B_s flavor at production (OST, SST - DØ Notes **4875, 5210**)
- Tag B_s flavor at decay (trigger lepton or sign of π)
- For each event calculate likelihood of observing oscillated B_s (depending on Δm_s value) (DØ Note **5017**)
- Perform amplitude scan: fix Δm_s and see if the fitted amplitude is consistent with one (DØ Note **5428**)
- Significance of observation is proportional to

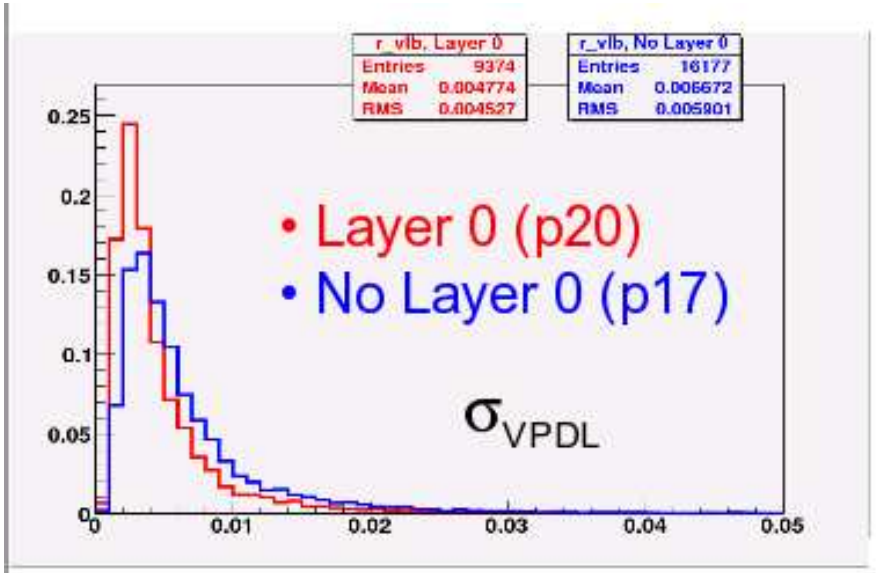
$$\sqrt{\epsilon D^2} \cdot \frac{S}{\sqrt{S+B}} \cdot \exp\{-(\Delta m_s \sigma_t)^2/2\}$$

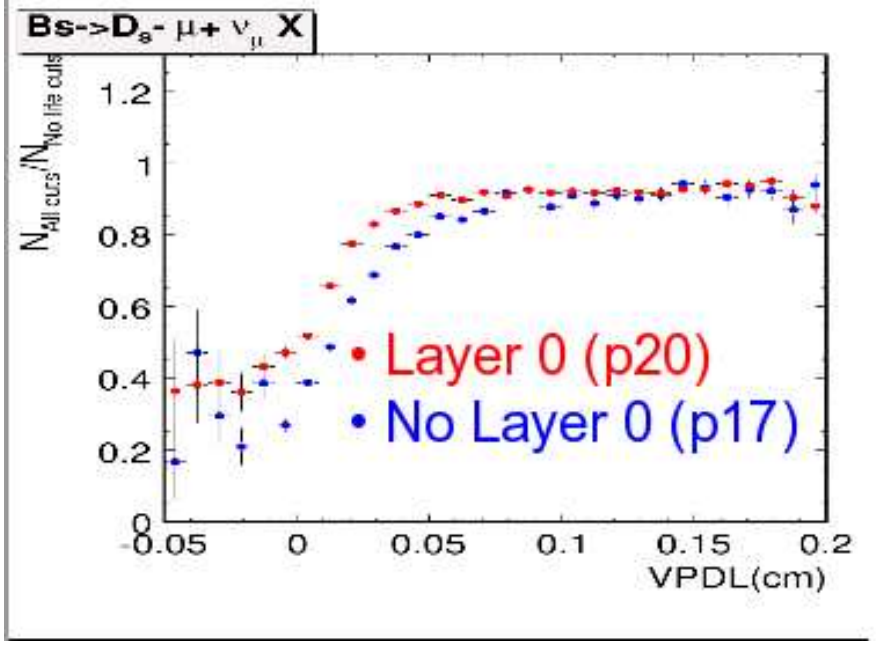
  - Improve resolution σ_t (including K-factors, scale factors...)
  - Improve tagging power ϵD^2
  - Improve signal selection $S/\sqrt{S+B}$

Resolution

Inclusion of Layer 0 improves resolution:

Large effect in the region of interest

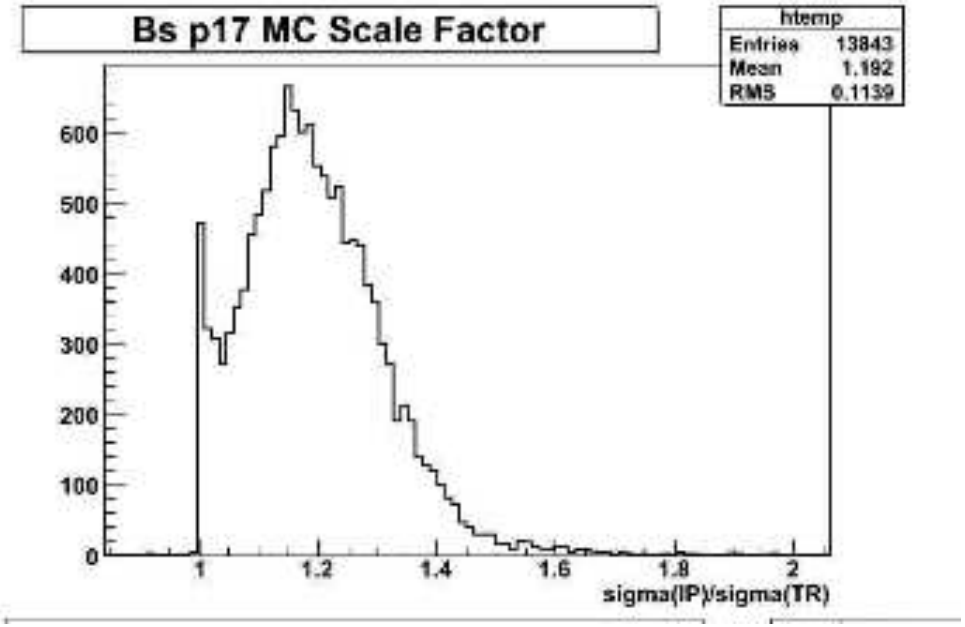


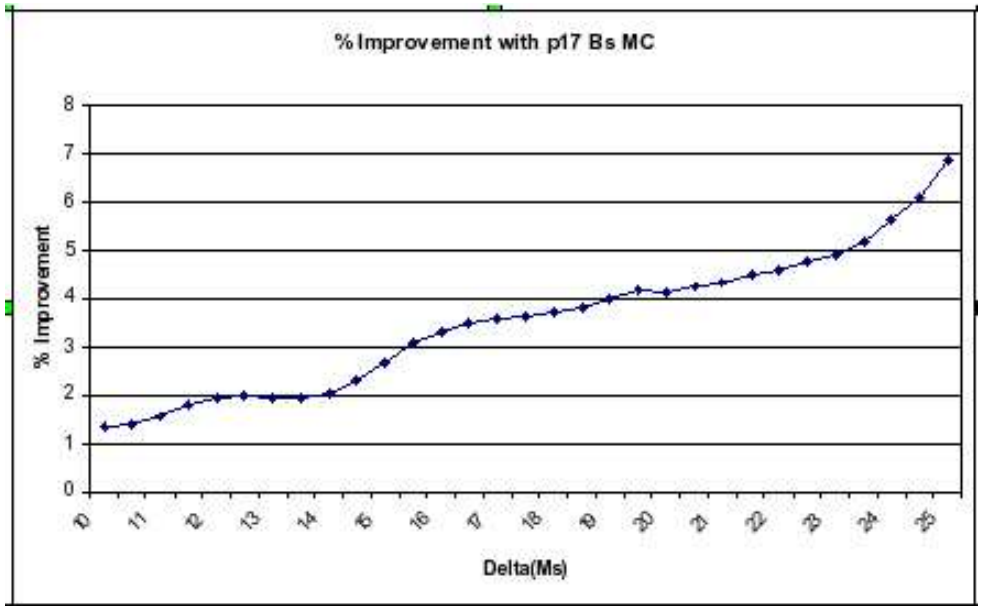


Event-by-event scaling factors

For each event (either data or MC):

- Divide all tracks into categories
- For each category get assigned track IP errors
- Compare to true IP resolution (w.r.t. PV)
- Get scaling factor as ratio: assigned/true
- Compare to average scaling factor for this category

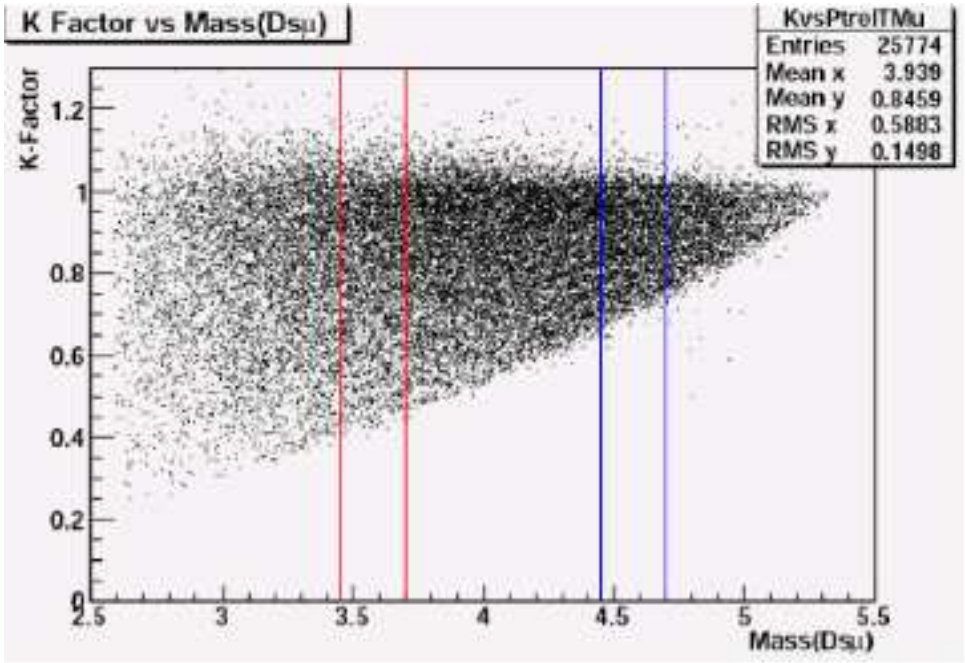




$\%Im = (1 - \frac{\sigma(A)_{event}}{\sigma(A)_{ave}}) \cdot 100$ - rises with Δm_s

- Sensitivity improvement by 3.5 - 7.3% (DØ Note **5336**, M. Anzelc, S. Burdin)
- $\sim 30\%$ decrease of amplitude errors in amplitude scan

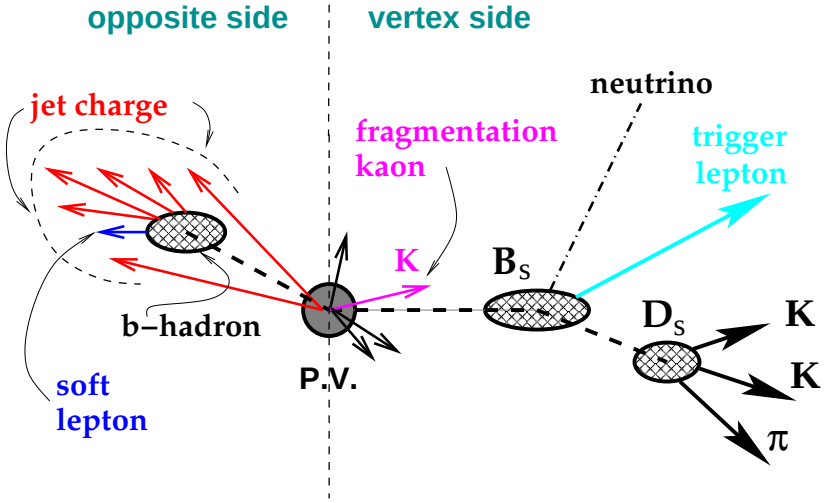
K-factors

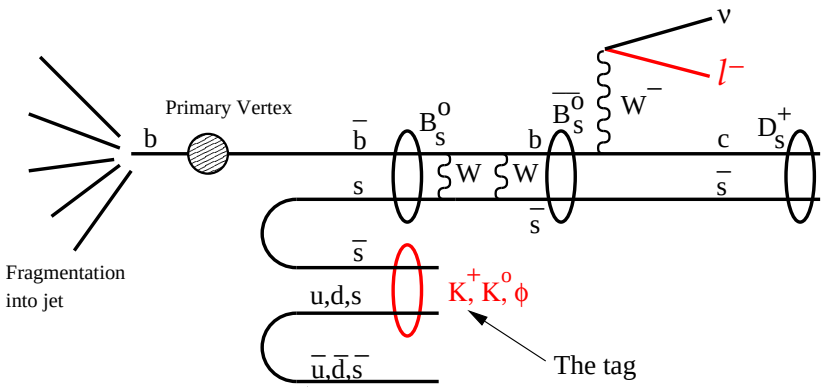


- $K \equiv \langle \frac{p_t(B_s)}{p_t(\ell D_s)} \rangle$ are obtained from MC
- K-factors may be > 1 (ratio of p_t's)
- K-factors depend on $\ell + D_s$ mass

- Improvement: 10 bins instead of 4
- Implemented for signal and background (for $B_s \to \mu\phi\pi$ and $B_s \to \mu K^{*0} K$)
- Errors on amplitudes in amplitude scan improved by 15%
- DØ Note **5221**, W. Taylor, J. Radigan

Flavor Tagging





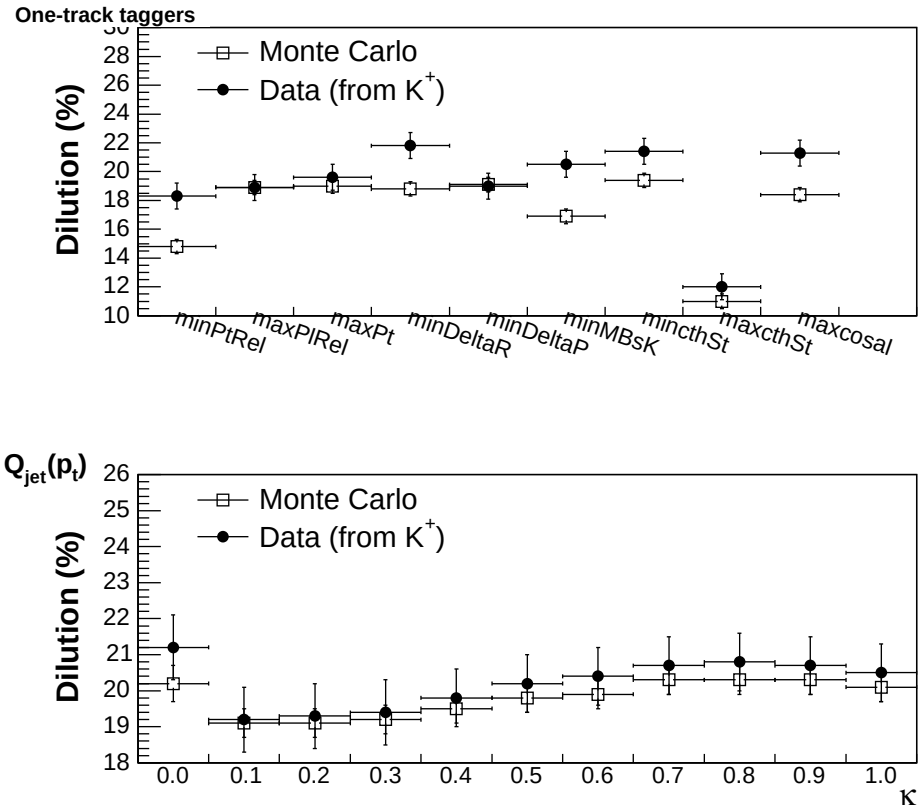
- OST looks at flavor of "the other" b-quark in the event
  - Soft μ or e, secondary vertex on the opposite side
- SST looks at charge of kaon born together with B_s (totally new addition)
  - Min. ΔR between track and $\vec{p}(B)$, p_t-weighted jet charge on same side
- If neither OST nor SST is not found we use the $\sum q_i$ of all tracks on the opposite side – "Event Charge" tagger. Tagging efficiency $\sim 100\%$

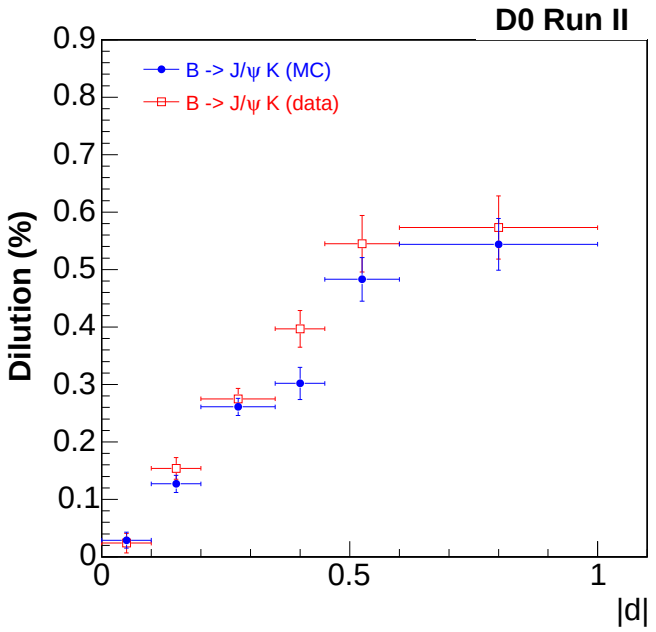
Since publication of $B_s \to \mu\phi\pi$ analysis:

- OST was verified with B^+ and B^0 decays
- Electron OST improved by 3% due to better cuts
- Combined OST improved by 12% due to addition of "Event Charge" tagger

Flavor Tagging

- OST was calibrated directly on $B^0 \to \mu\nu D^*$ data
- SST was calibrated on $B_s \to \mu\nu \mathrm{D_s}, \mathrm{D_s} \to \phi\pi$ Monte Carlo
- To justify using Monte Carlo for $B_s \to \mu\phi\pi$ we plot data – Monte Carlo match for $B^+ \to J/\psi K^+$ decay mode for different individual SST taggers (left) and for combined one (right)





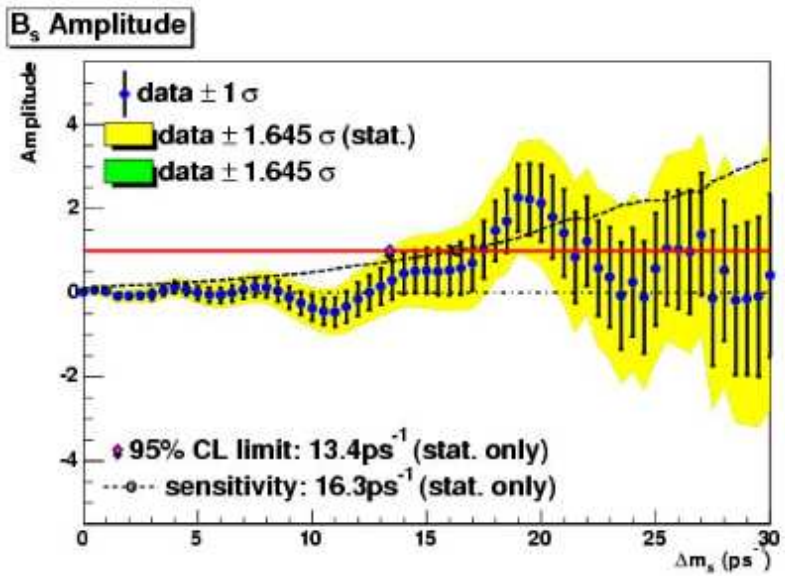
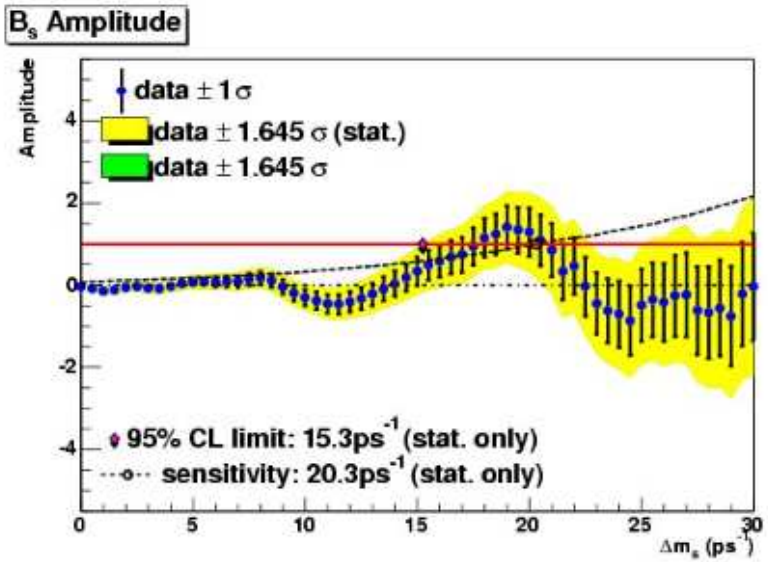
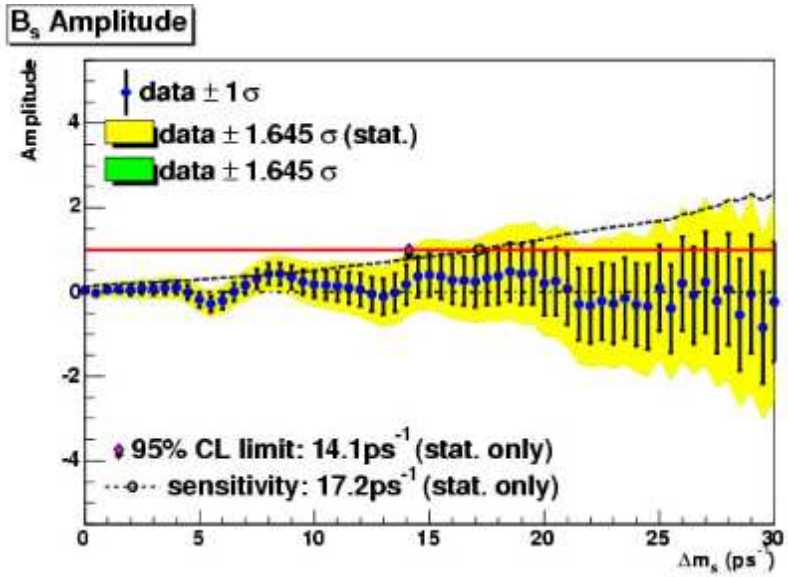
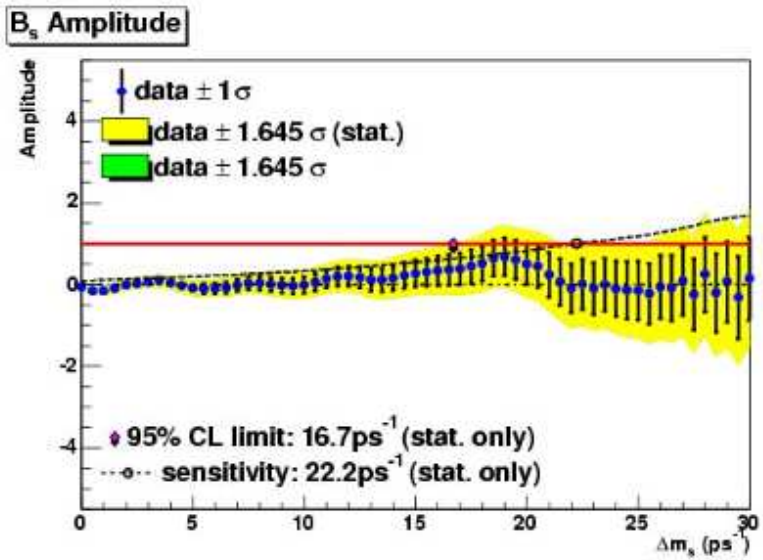
Flavor Tagging

- Different algorithms for both SST and OST $\Longrightarrow$ combine them to get maximum tagging power ϵD^2
- Further, "Combined SST", "Combined OST" and "Event Charge" are all combined into a single tagger (DØ Note **5210**)

Tagger	ϵD^2
Comb. SST	$1.7 \pm 0.6\%$
Comb. OST	$2.5 \pm 0.2\%$
Evt. Charge	$1.5 \pm 0.5\%$
All	$4.5 \pm 0.9\%$

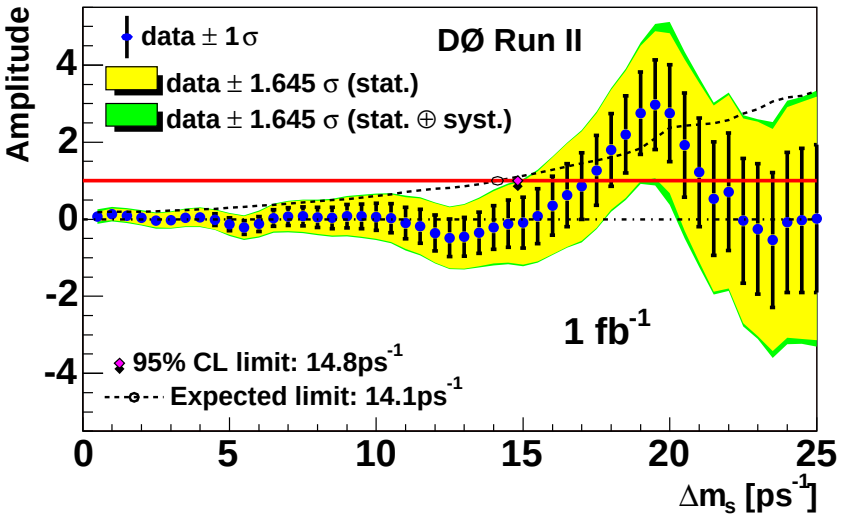
Flavor Tagging

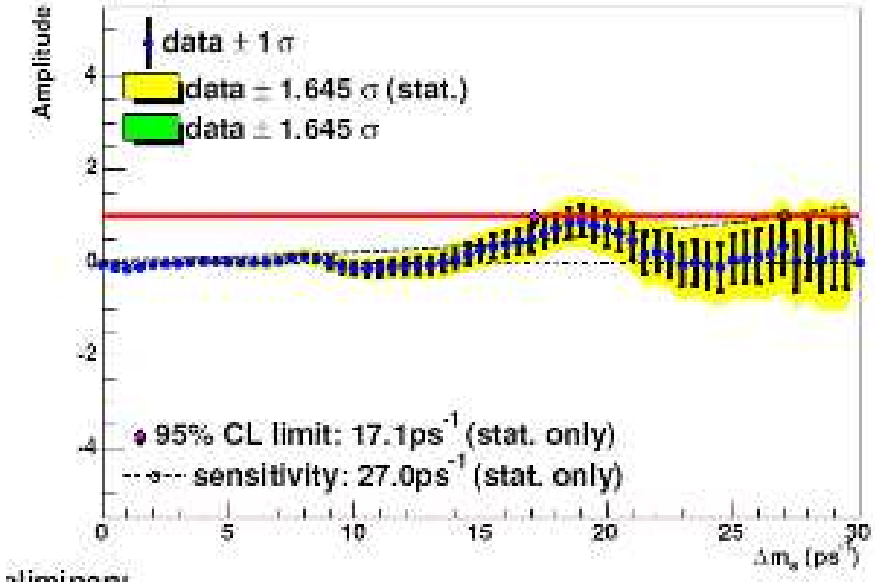
- Addition of SST and Event Charge increases sensitivity

	OST only	OST + SST + Event Charge
p17		
p20		

Results for single $\mu\phi\pi$ mode

Overall Δm_s sensitivity changed from 14.1 ps^{-1} to 27.0 ps^{-1} due to improvements in resolution (scale factors, K-factors), flavor tagging and addition of new data (Run IIb):

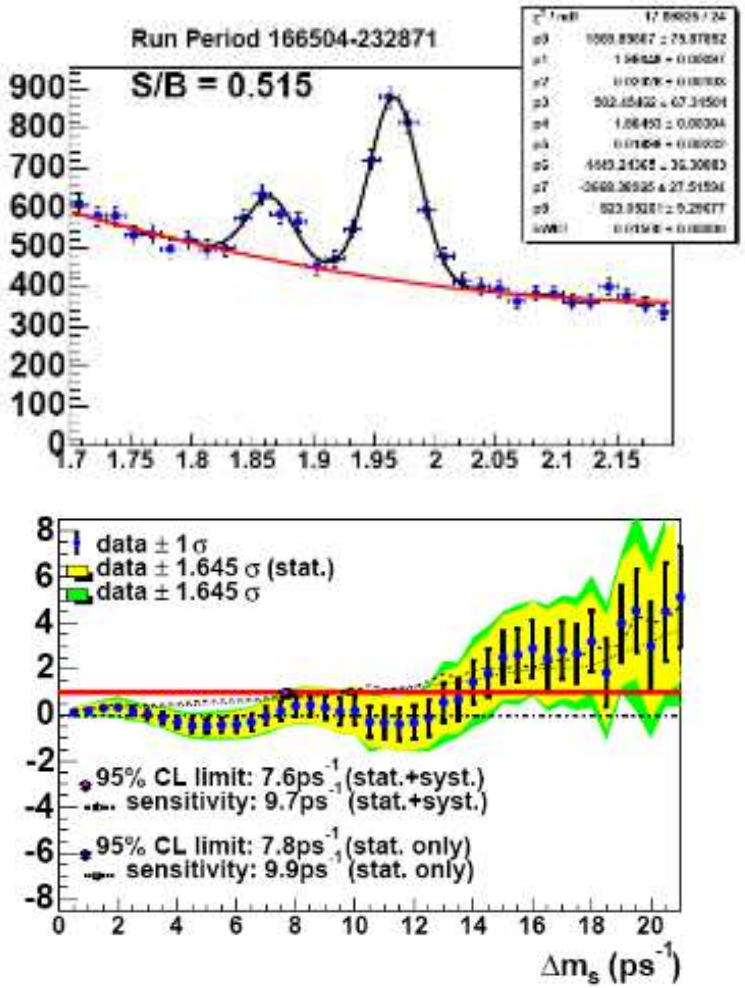




B_s lifetime fit (input for amplitude scan) and systematics are not finished yet

Other single modes

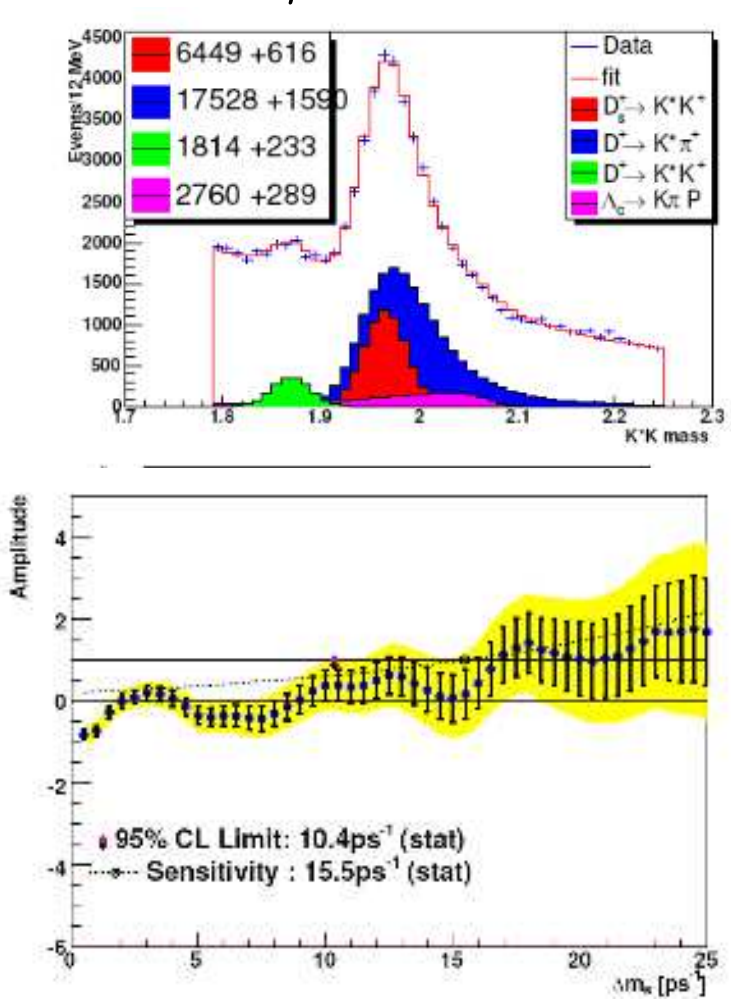
$e\phi\pi$



Sensitivity is 9.7 ps^{-1}

Scale factors and K-factors are not finished yet

$\mu K^{*0} K$

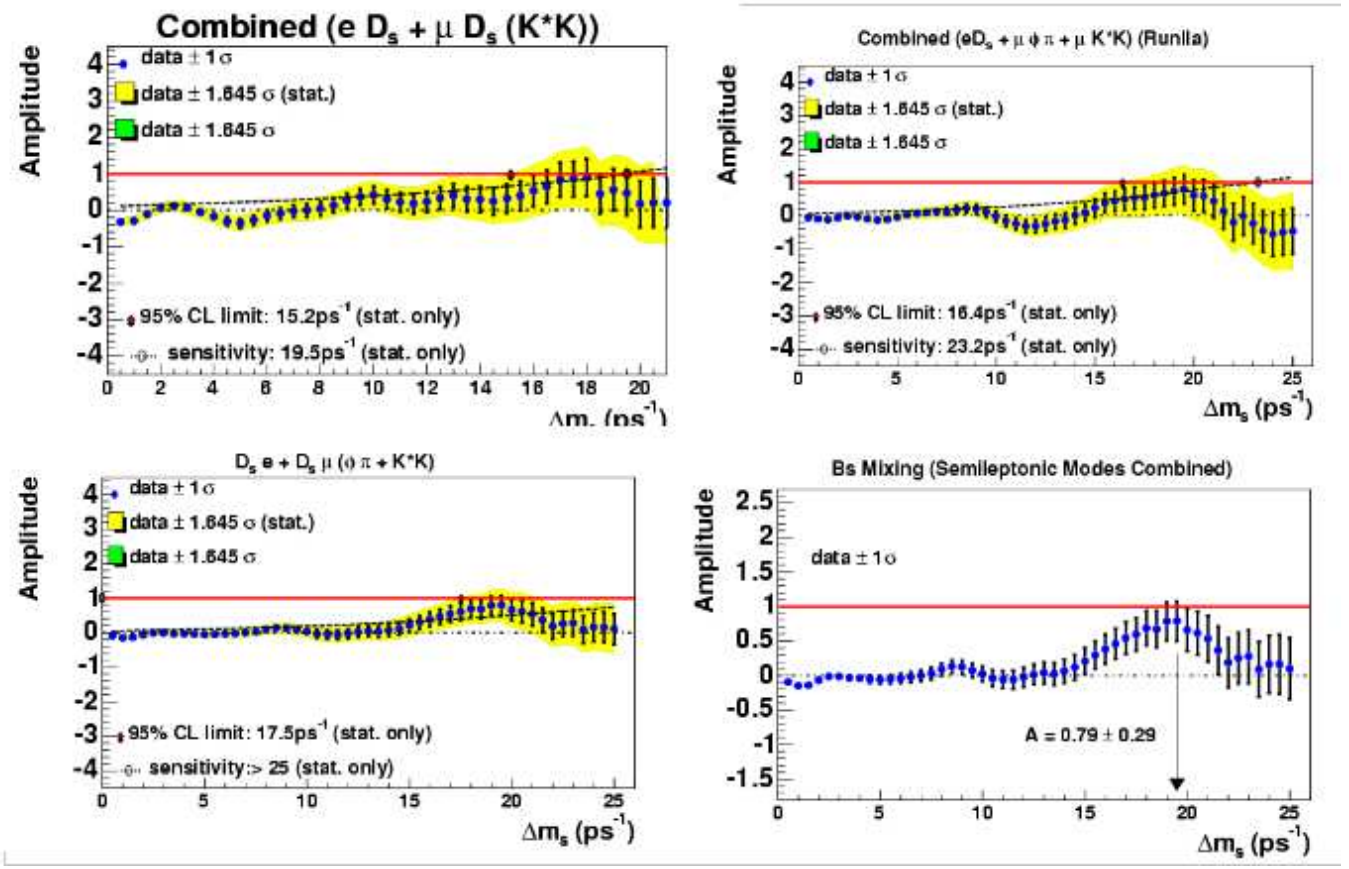


Sensitivity is 15.5 ps^{-1}

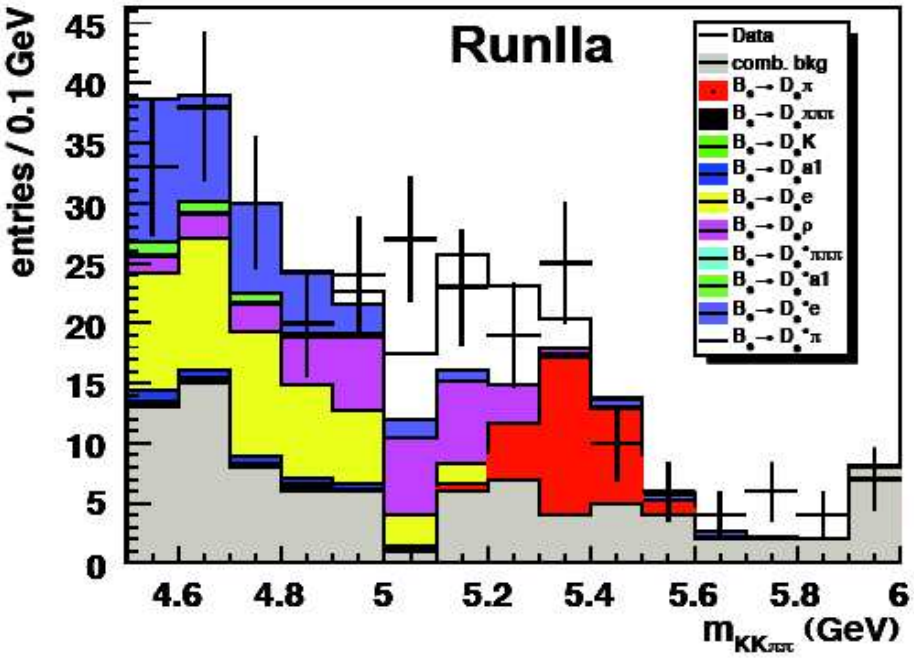
B_s lifetime fit not finished yet

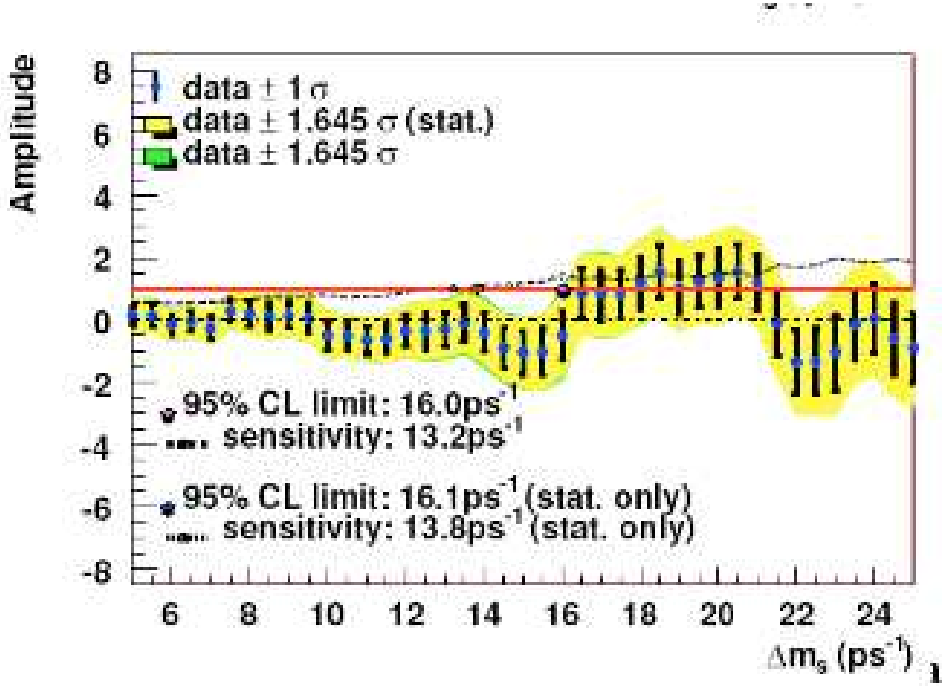
Combinations of semileptonic modes

- Addition of $e(\phi\pi)$ to $\mu(\phi\pi)$ increases sensitivity by 4%
- Addition of $\mu(K^{*0}K)$ to $\mu(\phi\pi)$ increases sensitivity by 15%
- Combined $e(\phi\pi)+\mu(\phi\pi)+\mu(K^{*0}K)$ sensitivity is $\mathbf{17\%}$ higher than single $\mu(\phi\pi)$ mode



Hadronic mode $B_s \longrightarrow D_s\pi$:





SST is not added yet, systematics is not finished yet

Conclusion:

- Semileptonic B_s mixing is in good progress
- All modes are almost finished (except for a few small details)
- Hadronic mode is also in good shape
- Combination of all semileptonic and hadronic modes is to be done
- Results are under EB review
- Hope to present results at Lepton-Photon'07