New Measurement of the B_s mixing phase at CDF II

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Outline

- Motivation
- Analysis Strategy
- Results
- Other CDF flavor results
- Conclusions and Outlook

Motivation

- One possible way of CP violation:
  - Interference of decays with and without mixing
  - Only for channels, that are accessible for both particle/antiparticle
  - CP violation comes in phase β_s

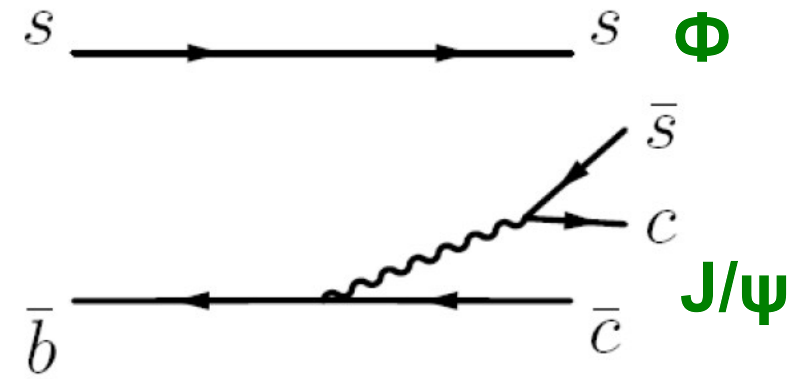
- In SM β_s is predicted to be small

  $\beta_s^{SM} = arg(-V_{ts} V_{tb}^{*} / V_{cs} V_{cb}^{*}) \approx 0.02$

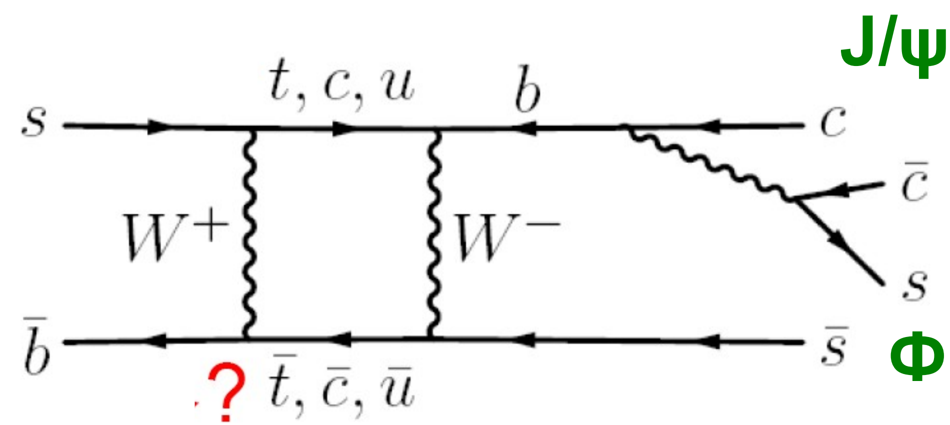
β_s value in SM indistin-guishable from 0 for us.

Significant measurement of phase -> New Physics!

Decay without mixing



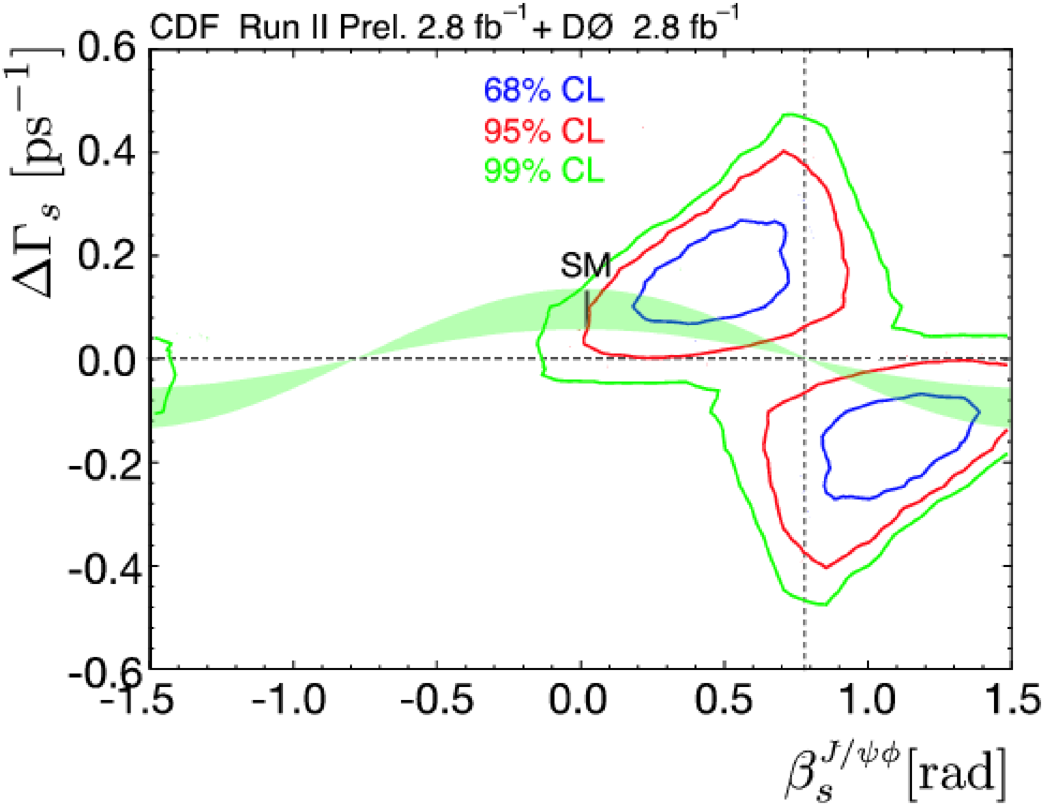
Decay after mixing



Top quark dominant contribution.

Are there SuSy particles in the loop, too?

Status with 2.8 fb^{-1} of Tevatron data



See http://tevbwg.fnal.gov/

Combination of

Abazov et al. D0 Collaboration **PRL 101, 241801 (2008)**

CDF public note 9458

Looked promising...

Confidence region instead of value + uncertainty, because of non-Gaussian uncertainty behavior

β_s analysis often cited by SuSy papers, random examples:

Biggio, Calibbi, **arXiv 1007.3750**

Wang, Zu, Li, **arXiv:1007.2944**

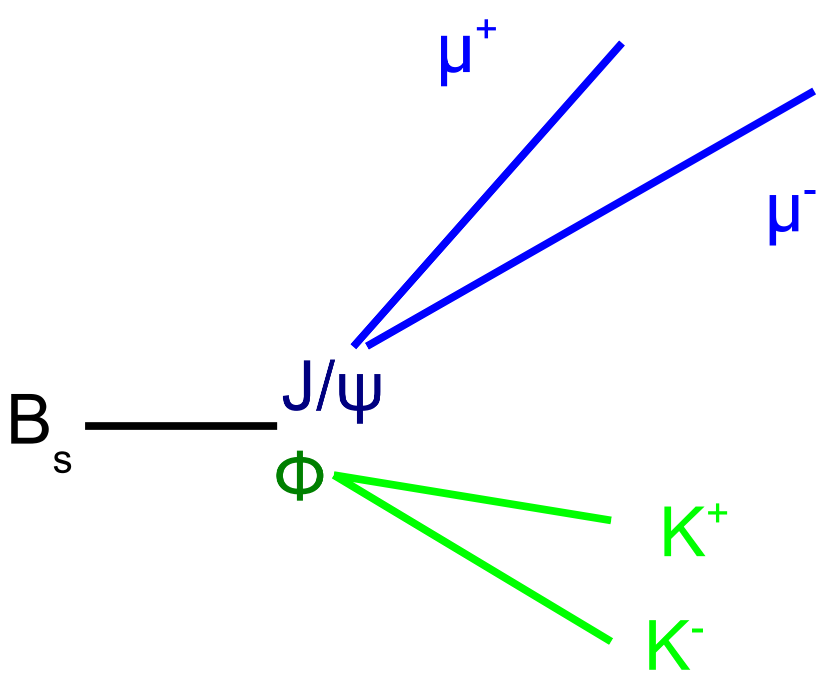
Kubo, Lenz, **arXiv:1007.0680**

Altmannshofer et. al.,a**rXiv:0909.1333**

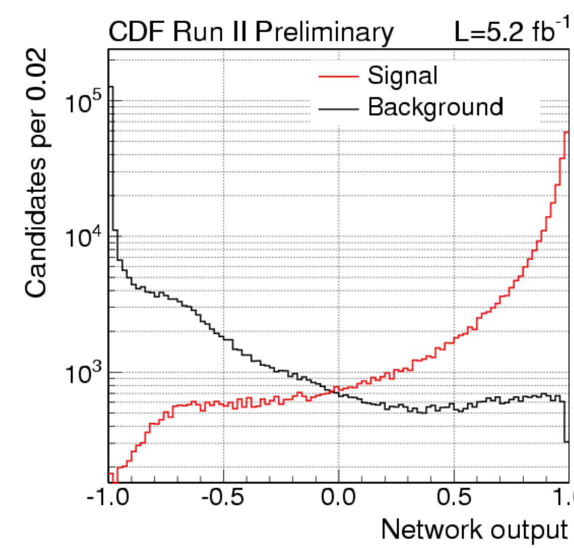
Analysis Strategy

- Measure
  - B_s life time
  - Decay width $\Delta\Gamma$ difference between CP even and odd B_s
  - CP violation phase β_s

CDF public note 10206



Di-muon Trigger

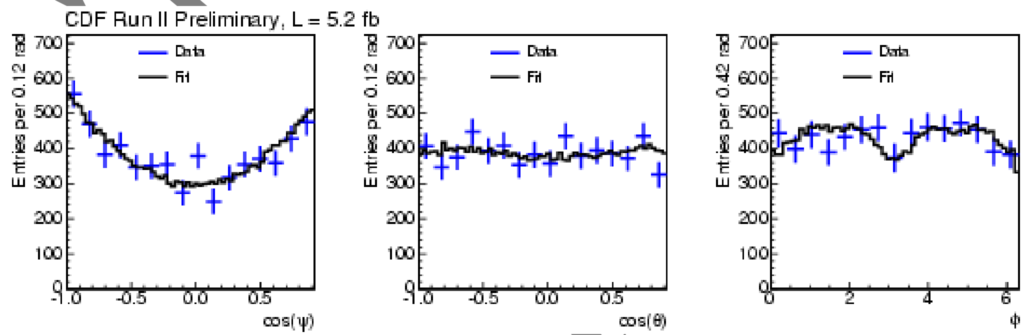


NN Selection

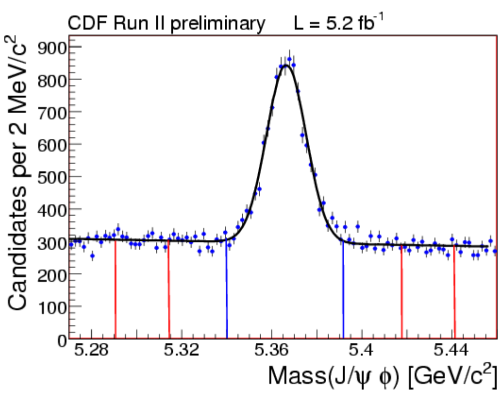
multidimensional likelihood-fit

$$f_s P_s(m|\sigma_m) P_s(t,\rho,\xi|D,\sigma_t) P_s(\sigma_t) P_s(D)$$

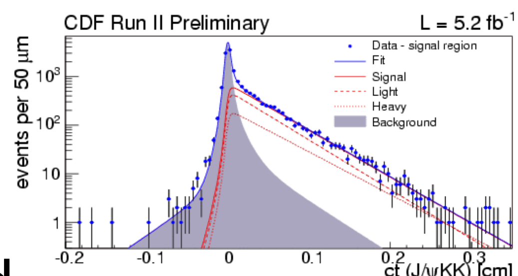
Angles
separate CP even and odd final states



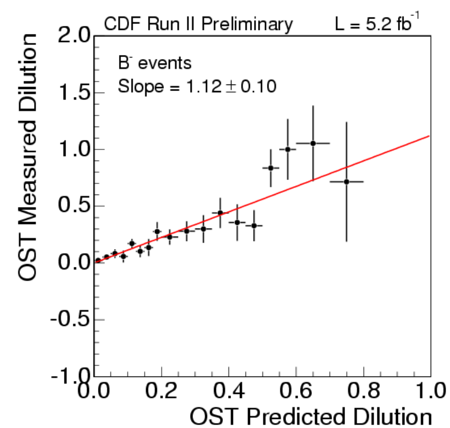
$$\rho = (\theta, \varphi, \psi)$$



Mass
discriminate signal/background



Lifetime
lifetime of each mass eigenstate



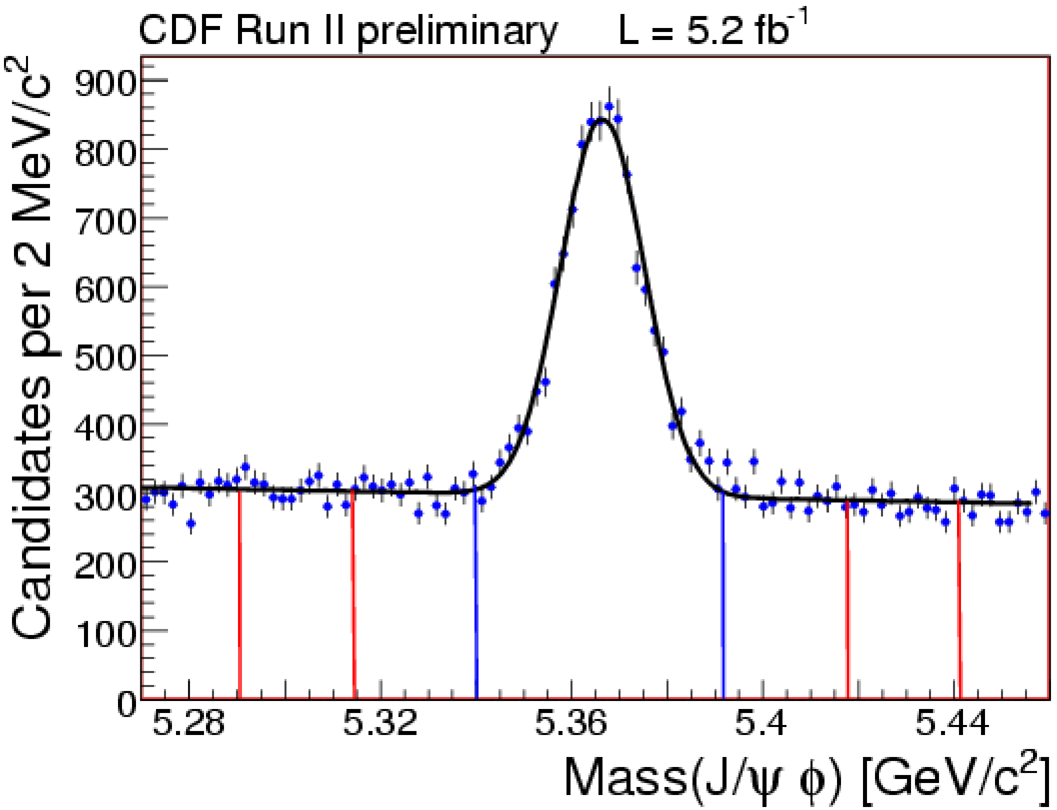
tagging
flavour of initial B_s state

$$\xi = \begin{cases} +1 & \text{for } B_s \\ -1 & \text{for } \bar{B}_s \end{cases} \text{ at production time}$$

Reconstruct B_s candidates in 5.2 fb^{-1} of data triggered on a di-muon pattern with J/ψ characteristics.

Combine kinematic and particle ID variables in neural network to enrich signal.

Chose cut based on simulation in such a way, that uncertainty on β_s is minimized.



~6500 Bs mesons compared with ~3150 in old analysis.

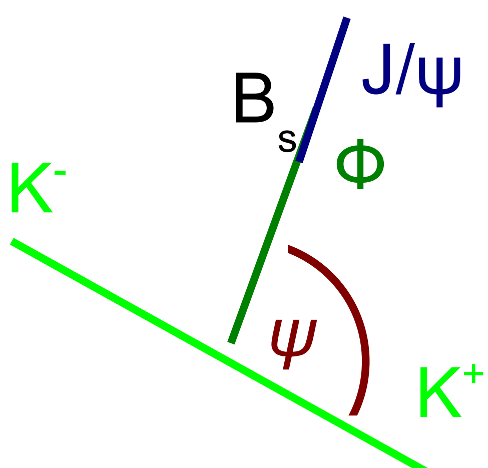
- Propagating B_s mesons are almost CP eigenstates.
- This dominates the lifetime difference (think as well K_{short}, K_{long})
- CP violation means, sometimes dominantly CP even decays in CP odd final state and vice versa (like K_{long} decaying into 2 pions)

==> necessary to know CP value of final state.

CP even (light if no New Physics) states decay in S- or D-waves
CP odd (heavy) states decay in P-waves

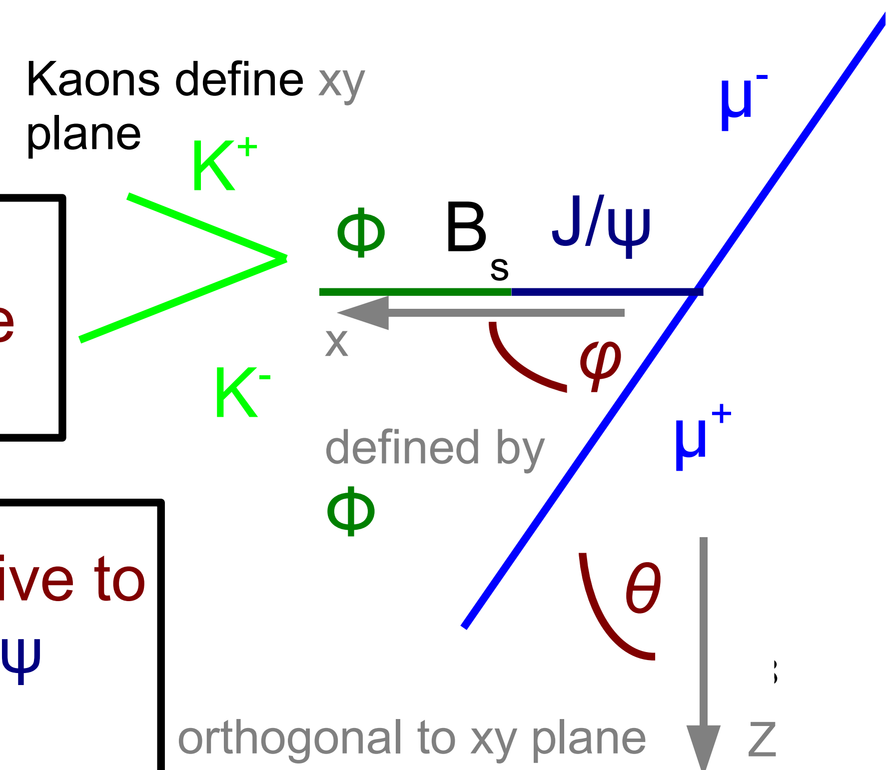
This allows statistical discrimination by measuring the angular distribution ($\rho = (\theta, \varphi, \psi)$)

***ψ**: K angle in Φ rest frame*



***φ**: μ angle of projection to Φ plane in J/ψ rest frame*

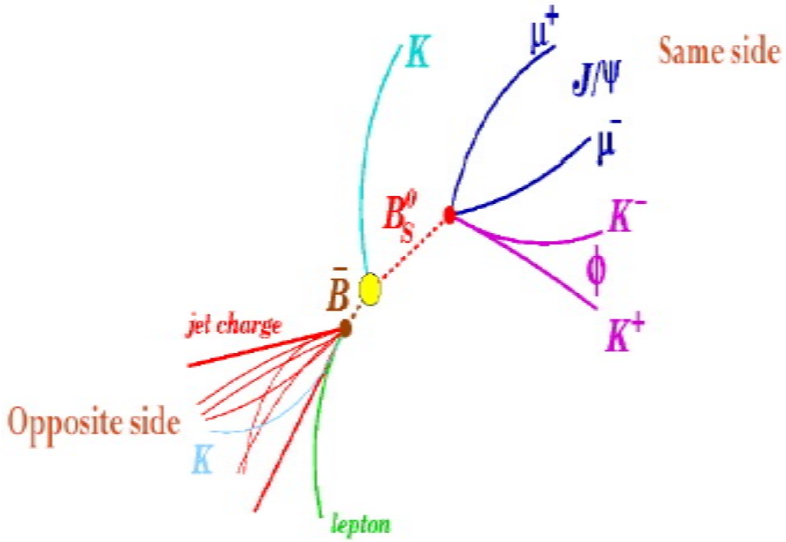
***θ**: μ angle relative to z direction in J/ψ rest frame*



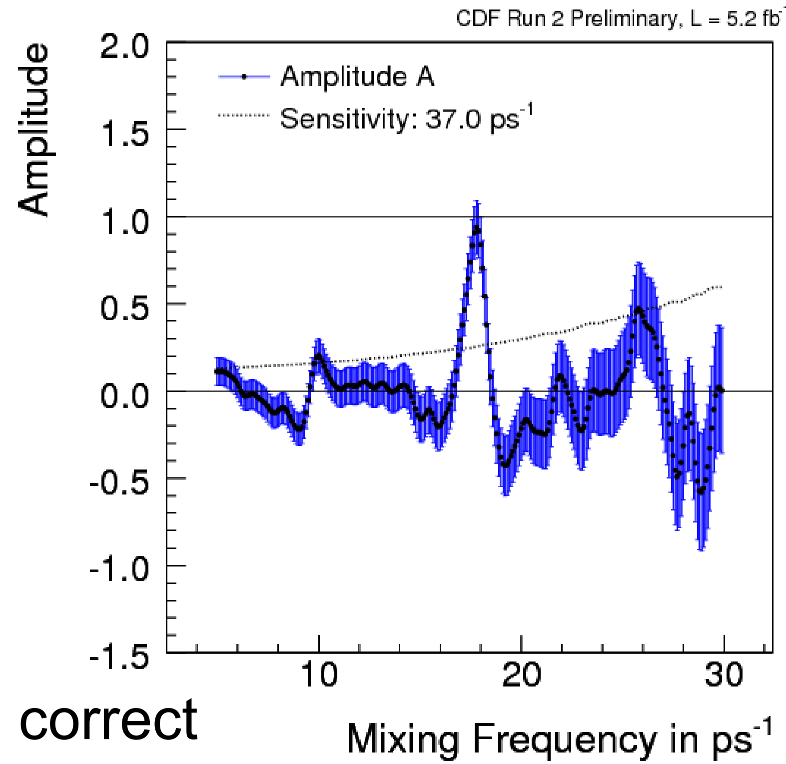
We are searching for effect in mixing. Tagging production flavor tells us, if mixing happened or not.

Tagging is possible due to two effects

1. dominant b production is in bottom anti-bottom pairs
   -> find flavour of "opposite side" bottom
2. fragmentation means, the strange quark has usually a nearby kaon partner
   -> find the fragmentation partner on the "same side"



Output of flavour tagger
- flavour decision
- probability that the decision is correct



At correct εD^2 amplitude scan reaches exactly 1

For the first time the CDF II same side kaon Tagger has been calibrated on data for this analysis.

Efficiency times Dilution^2 (εD^2) is measured as 3.2 ± 1.4% (~reduced statistics)

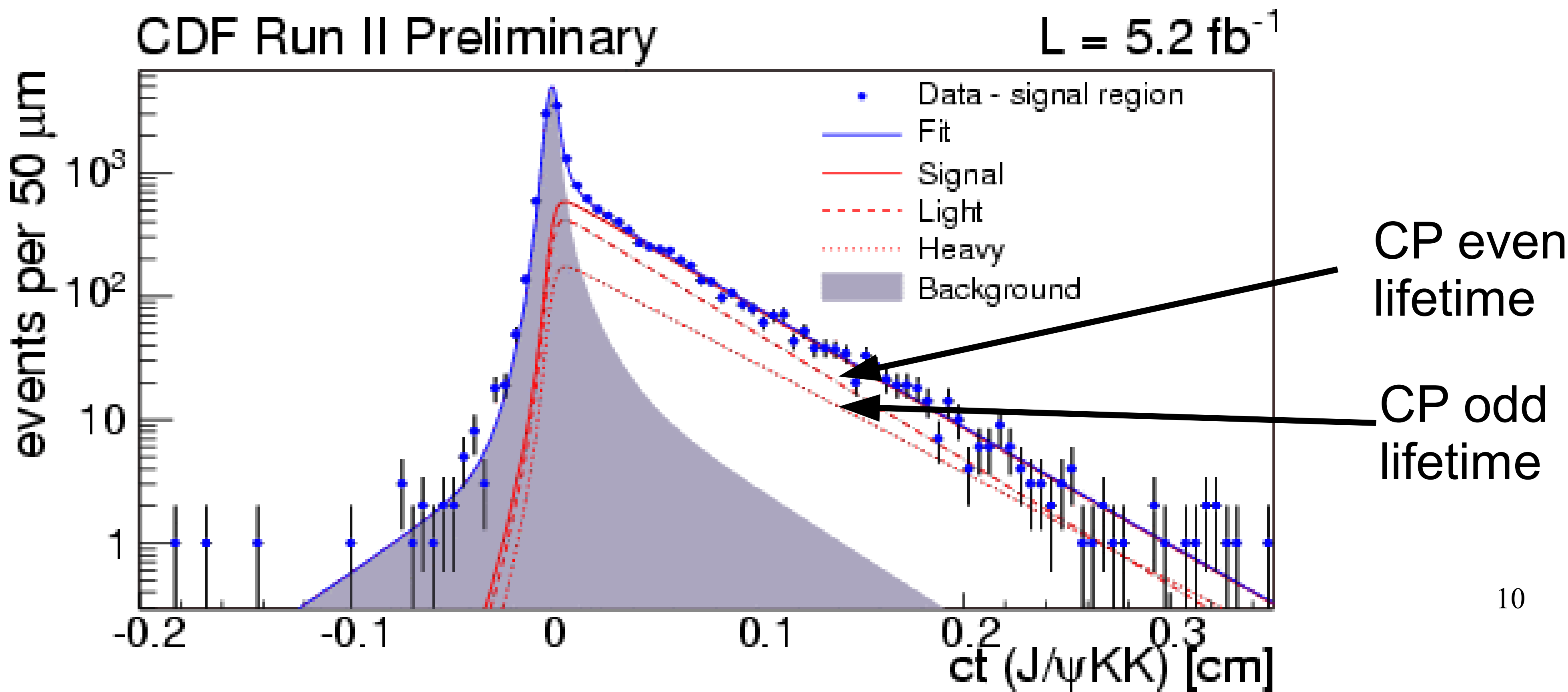
Results

Lifetime and decay width difference

Assuming no CP violation, most precise single measurements

$$\tau_s = 1.530 \pm 0.025\ \text{(stat)} \pm 0.012\ \text{(sys) ps}$$

$$\Delta\Gamma_s = 0.075 \pm 0.035\ \text{(stat)} \pm 0.01\ \text{(sys) ps}$$

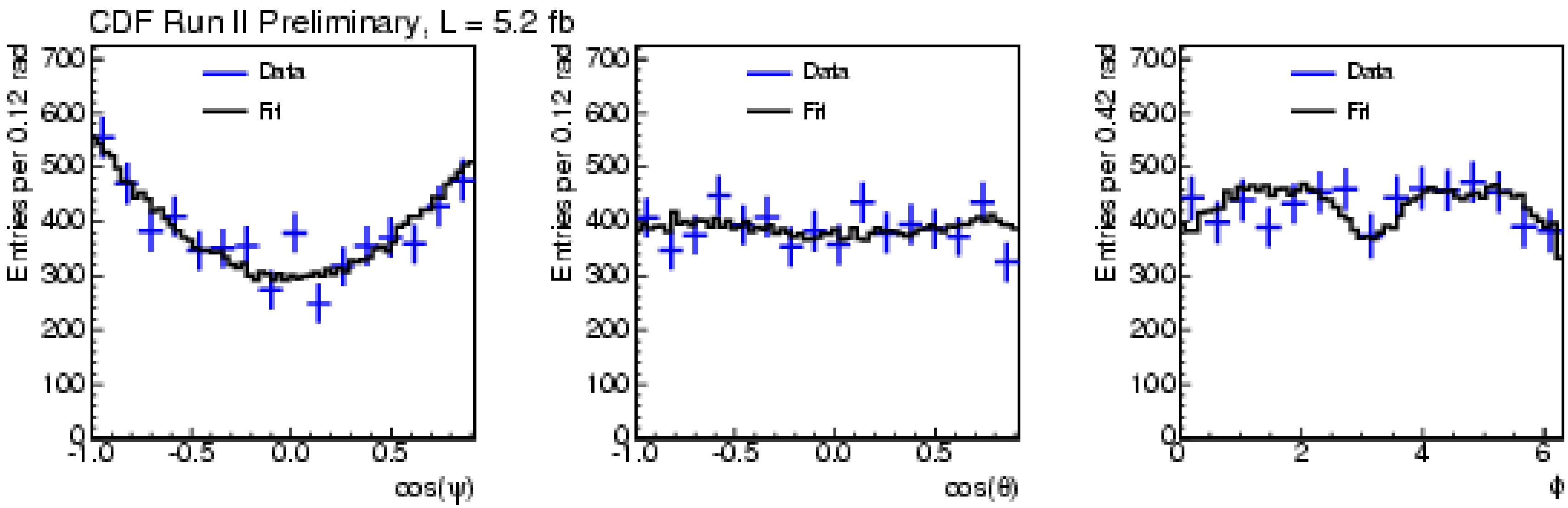


Polarization amplitudes

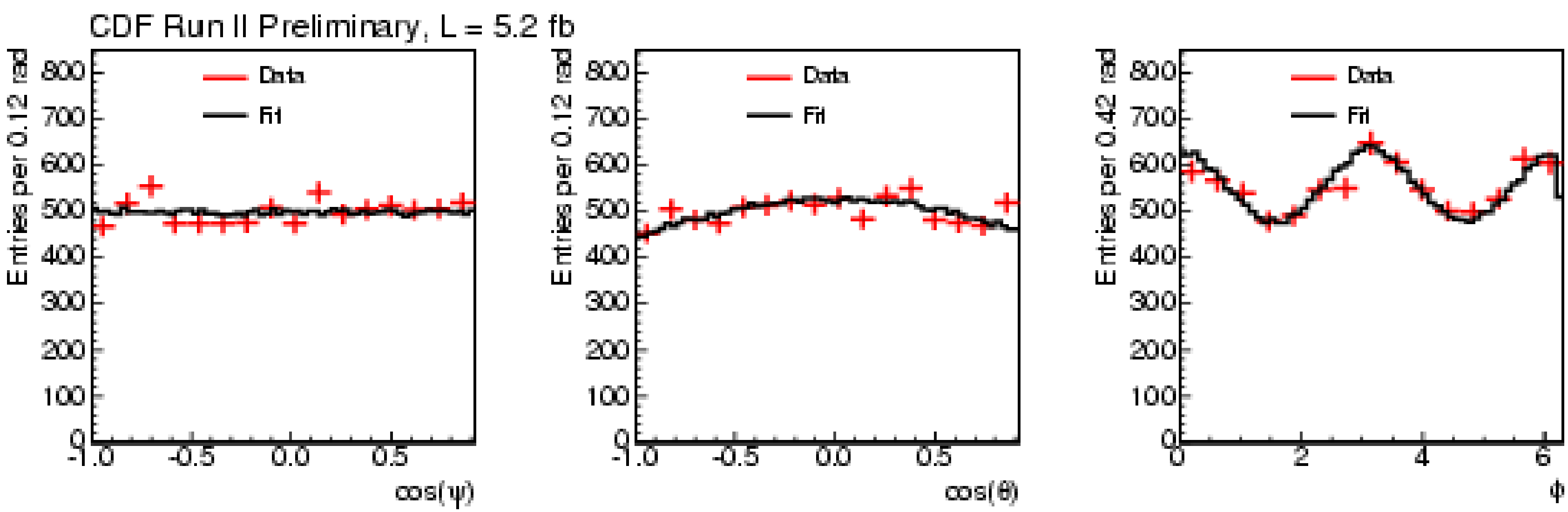
$$|A_{\parallel}(0)|^2 = \text{٠.٢٣١} \pm \text{٠.٠١٤}\,(stat) \pm \text{٠.٠١٥}\,(syst)$$

$$|A_0(0)|^2 = 0.524 \pm 0.013\,(stat) \pm 0.015\,(syst)$$

$$\Phi_{\perp} = 2.95 \pm 0.64\,(stat) \pm 0.07\,(syst)$$

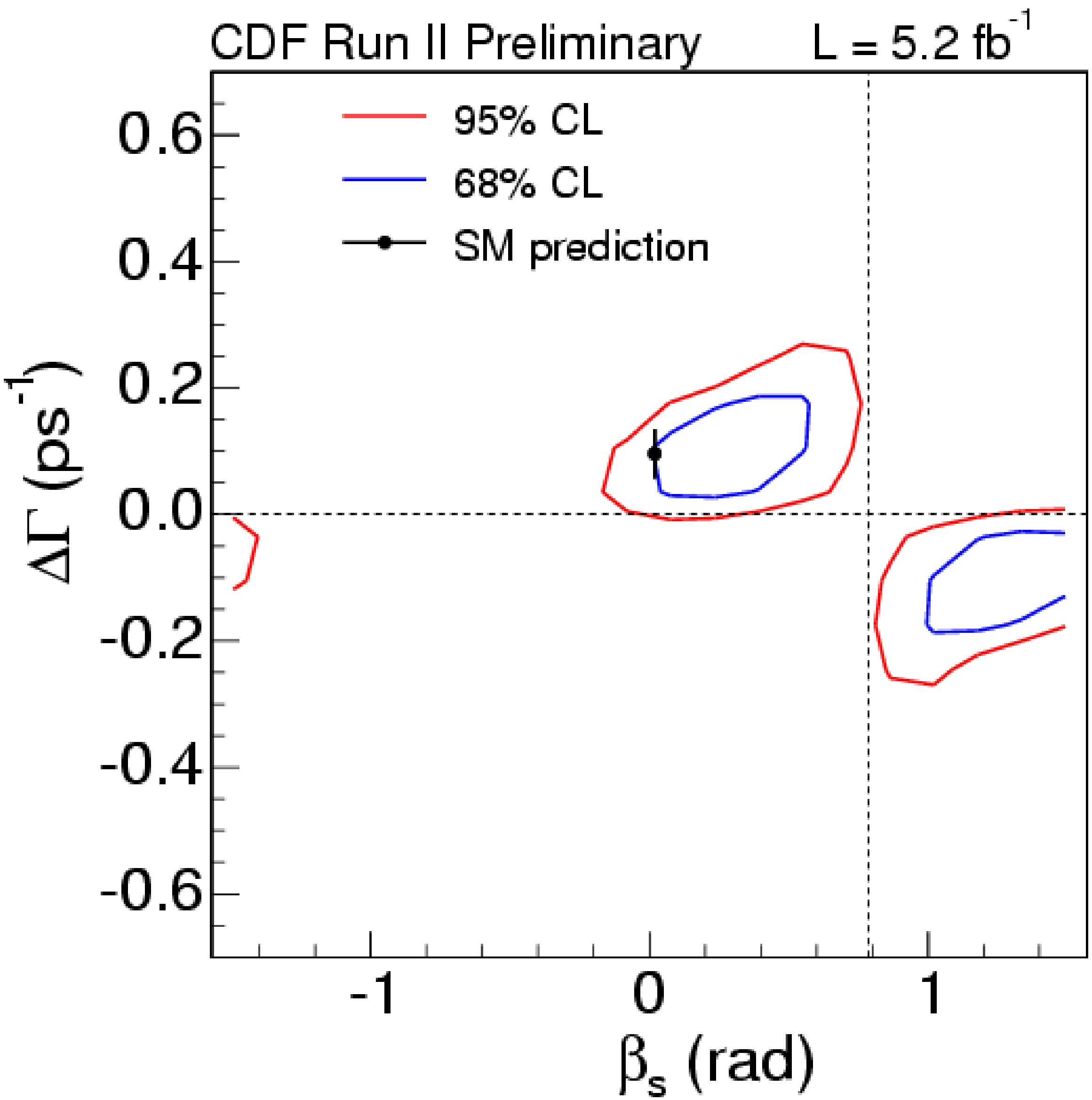


Signal fit projections



background fit projections

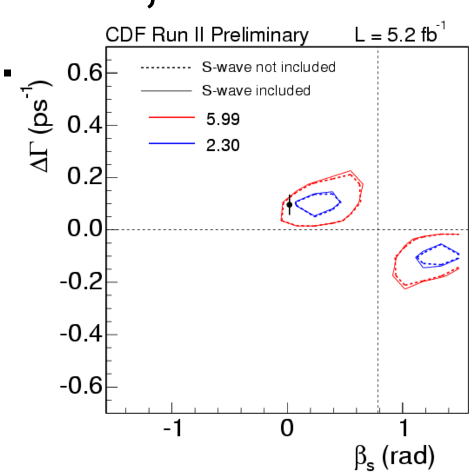
CP violating phase



Allowed are β_s [0.02, 0.52] or [1.08,1.55] at 68% CL

Improvement in this analysis:
S-wave contributions with $B_s \to J/\psi\ K^+ K^-$ are included.

The effect of the contributions is as expected rather small, so old analysis still OK.

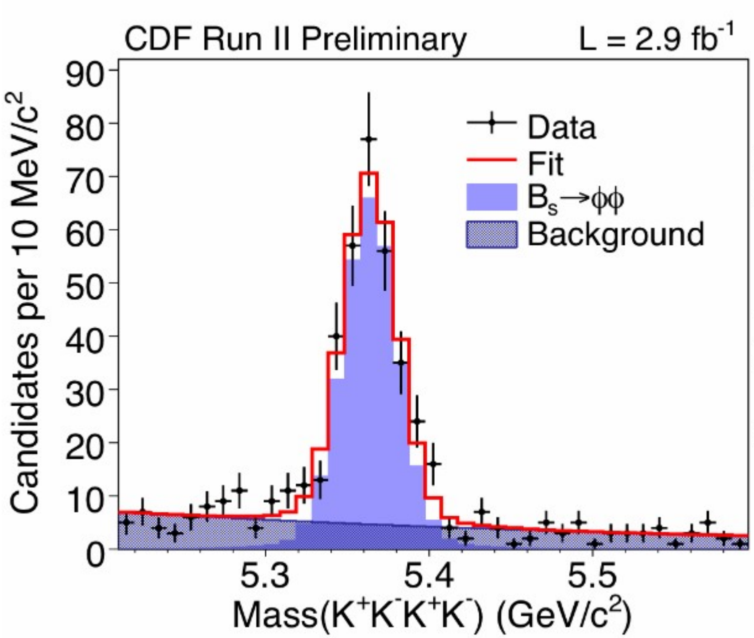


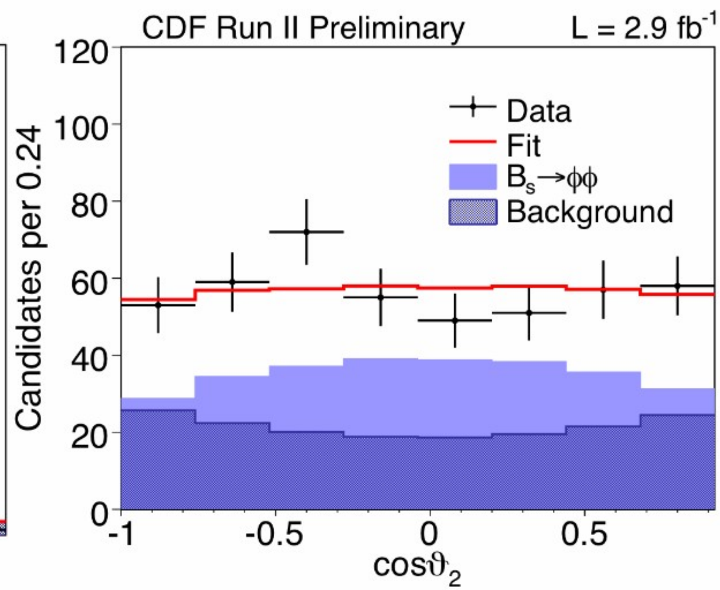
Improved agreement with standard model.

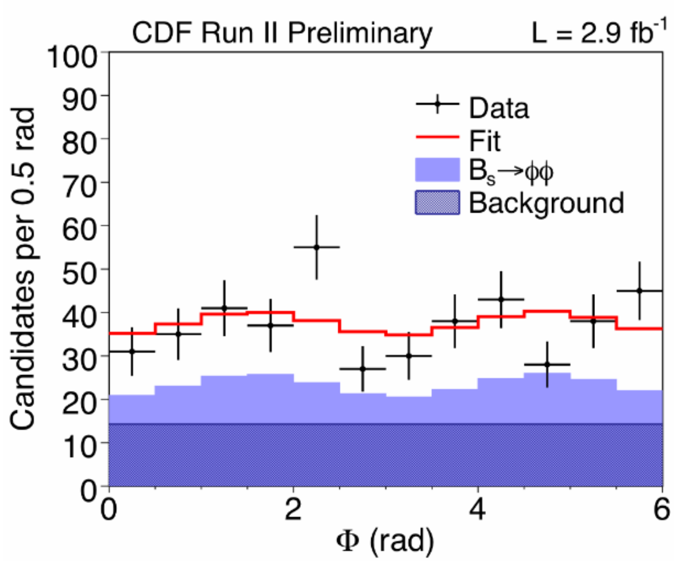
Other CDF Flavour Results

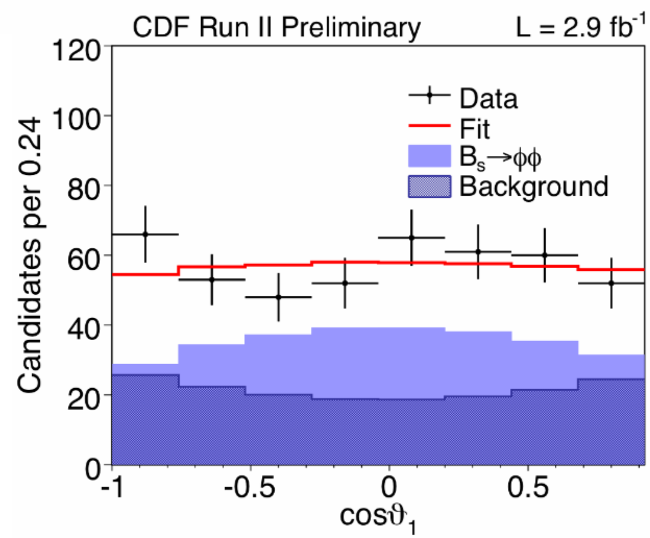
First measurement of polarization angles in
$B_s \to \Phi\Phi$

Confirms puzzling behavior in b->s penguin polarizations









Parameter	Fit value
M [GeV/c^2]	5.3636 ± 0.0012
σ [GeV/c^2]	0.0165 ± 0.0011
$f_{\rm b}$	0.381 ± 0.030
b [c^2/GeV]	2.68 ± 0.67
$\lvert A_0\rvert^2$	0.348 ± 0.041
$\lvert A_{\parallel}\rvert^2$	0.287 ± 0.043
$\cos\delta_{\parallel}$	$-0.91^{+0.15}_{-0.13}$
B	$0.49^{+0.31}_{-0.26}$

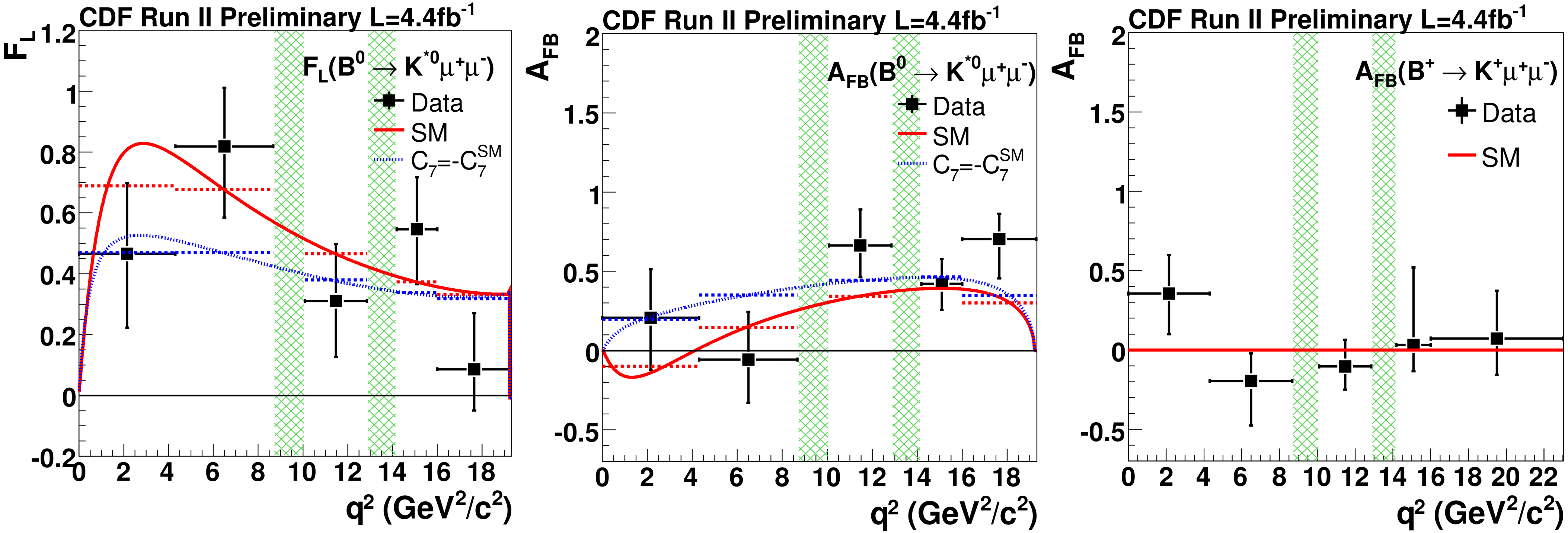
CDF public note 10064

Updated measurement

B-> K*μμ

competitive B factory results

CDF public note 10047



$$A_{FB}(q^2 = 1-6\,\mathrm{GeV}^2) = 0.43^{+0.36}_{-0.37}(\mathrm{stat}) \pm 0.06\,(\mathrm{syst})$$

More details on this analysis and many more on

http://www-cdf.fnal.gov/physics/new/bottom/

Conclusion

- CP violation measurement updated with 5.2 fb^{-1}
- Tightened constraints in β_s space
  [0.02, 0.52] or [1.08, 1.55] at 68% CL
- Agreement with SM has increased
- Best measurement of
  - B_s life time
  - $\Delta\Gamma_s$
  - Polarization amplitudes

- Several other measurement
  - B_s -> ΦΦ polarization
  - B-> K*μμ: $A_{FB}(q^2 = 1 - 6\,\mathrm{GeV}^2) = 0.43^{+0.36}_{-0.37}(\mathrm{stat}) \pm 0.06\,(\mathrm{syst})$

Outlook

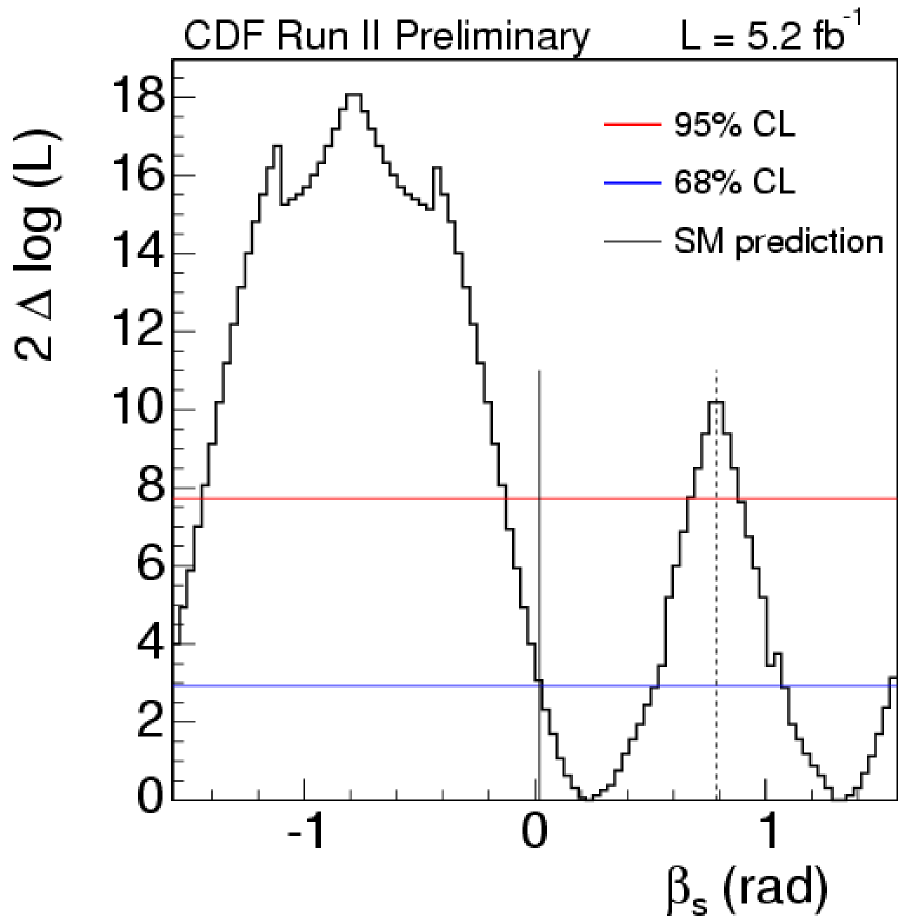
- Possible further improvements with more data and channels: factor ~2-3

- β_s measurement is one of the most promising B physics cases today (see as well D0 A_{SL} measurement)
  ==> stay tuned for updates

- Update on $B_s \rightarrow \mu\mu$ is going to be ready soon.

Backup

One dimensional likelihood profile



Detector angular efficiency has to be taken into account to separate CP even and CP odd states by their decay angular distribution.

Use simulation to determine angular efficiency

Compare with background (expectation is flat primary distribution)
==> simulation is in good agreement with background shape.