TevatronにおけるB物理の最新結果

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The time is over

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→Please ask Sato-san

Outline

- Heavy Flavor Physics @ Tevatron
- B、D物理の最新結果
  - Rare decays
  - CKM/CP violation
  - Spectroscopy
- 今後の展望

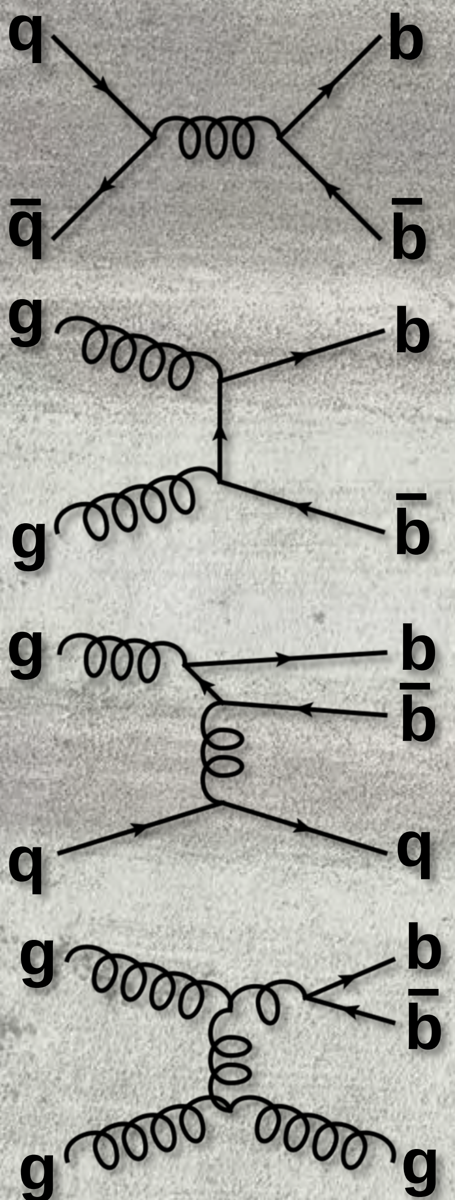
Why Heavy Flavor?

- HF approaches the structure of matter and its interactions
  - Can access energy scales **beyond** the energy frontier machines

Many results are on 浅井さん's border line (~2σ)

- There are a lot of puzzles (or hints to new physics):
  - Same sign dimuon charge asymmetry
  - CPV in B_S mixing, CPV (tree) ≠ CPV (penguin) …
  - A_{FB} in $B \to K^{(*)}\mu\mu$, large BR ($B \to \tau\nu$) …

B production@Tevatron



☺ Pros

- Large cross-section (~3-5 μbarn)
- All species of b-hadrons
  - $B_u, B_d, B_s, B_c, \Lambda_b, \Sigma_b\cdots$

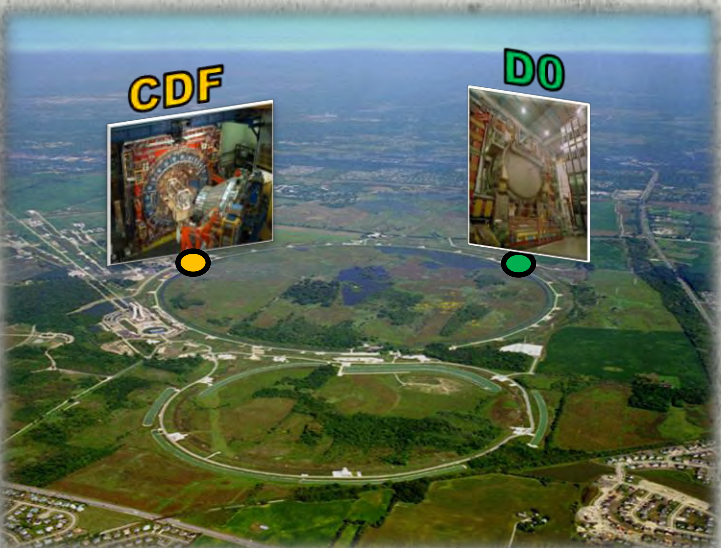
☹ Cons

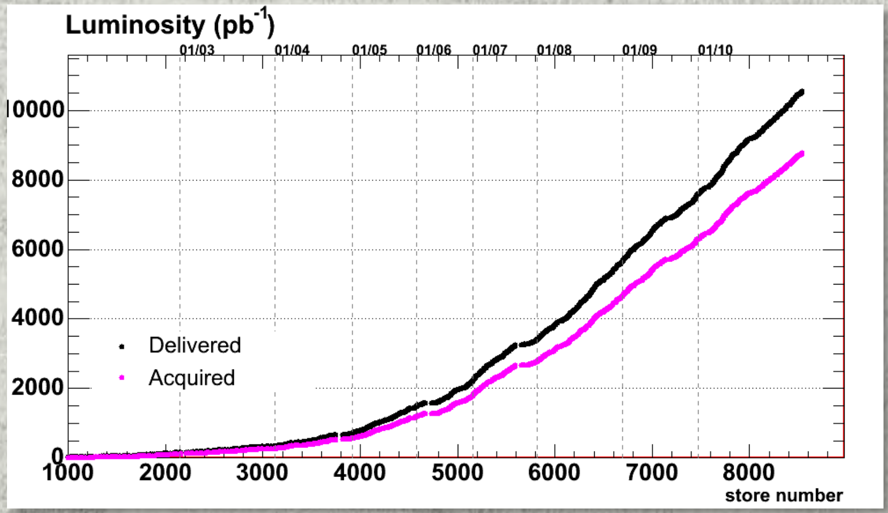
- QCD background x10^3 larger than $\sigma(b\bar{b})$
- Collision rate ~2MHz
  → tape writing limit ~100Hz
  - Sophisticated triggers are very important!

Tevatron B-production enables :
- explore various rare decays
- measure precise CPV parameters
- study wide mass range of b hadrons

Tevatron

- $p\bar{p}$ collisions at $\sqrt{s}$=1.96 TeV
  - Typical initial luminosities of $3.5 \times 10^{32} cm^{-2} s^{-1}$
  - >50 pb^{-1} collected per week (2.5fb^{-1} per year)
- >8.7fb^{-1} data on tape
  - Expect >10fb^{-1} until end of FY2011 (Sept.30)
- Today we cover 2.9-6.1fb^{-1} of data





Tevatron Experiments

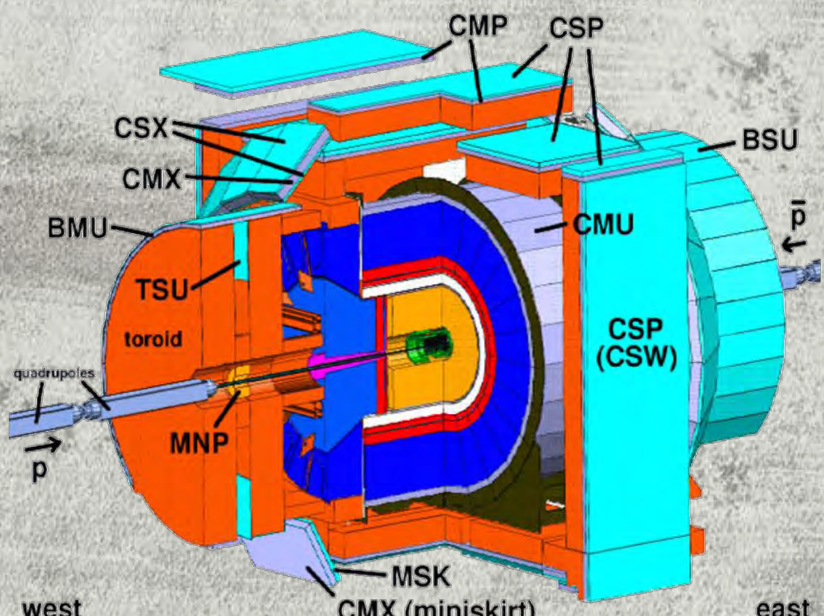
CDF II Detector

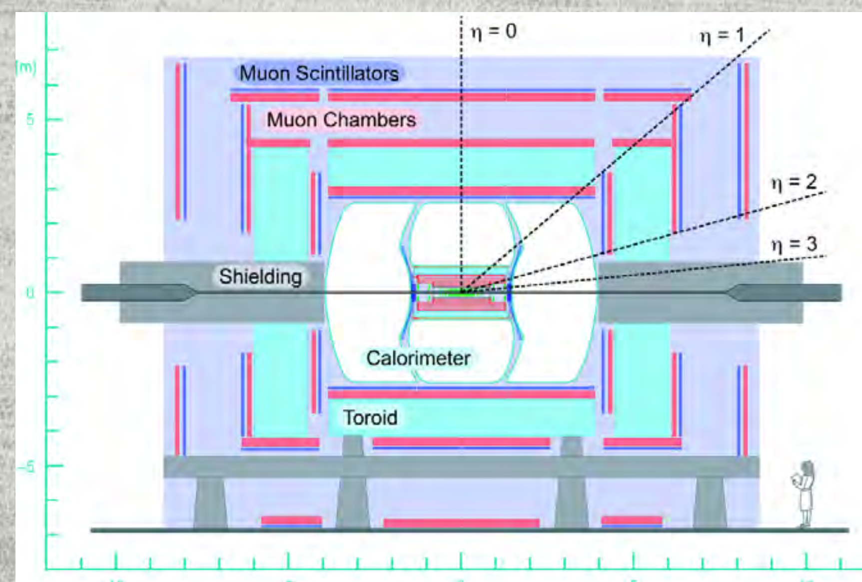
DØ Detector

- Silicon vertex detector
- Central tracking
- Calorimeter & muon systems

CDF II:
- Silicon vertex trigger
- Particle ID (TOF and dE/dx)
- Excellent mass resolution

DØ:
- Excellent electron & muon ID
- Excellent tracking acceptance





Tevatron RunII results for HF physics

CDF II

- 58 published papers
- 11 Topcite 50+
- 7 Topcite 100+
- 3 Topcite 250+

DØ

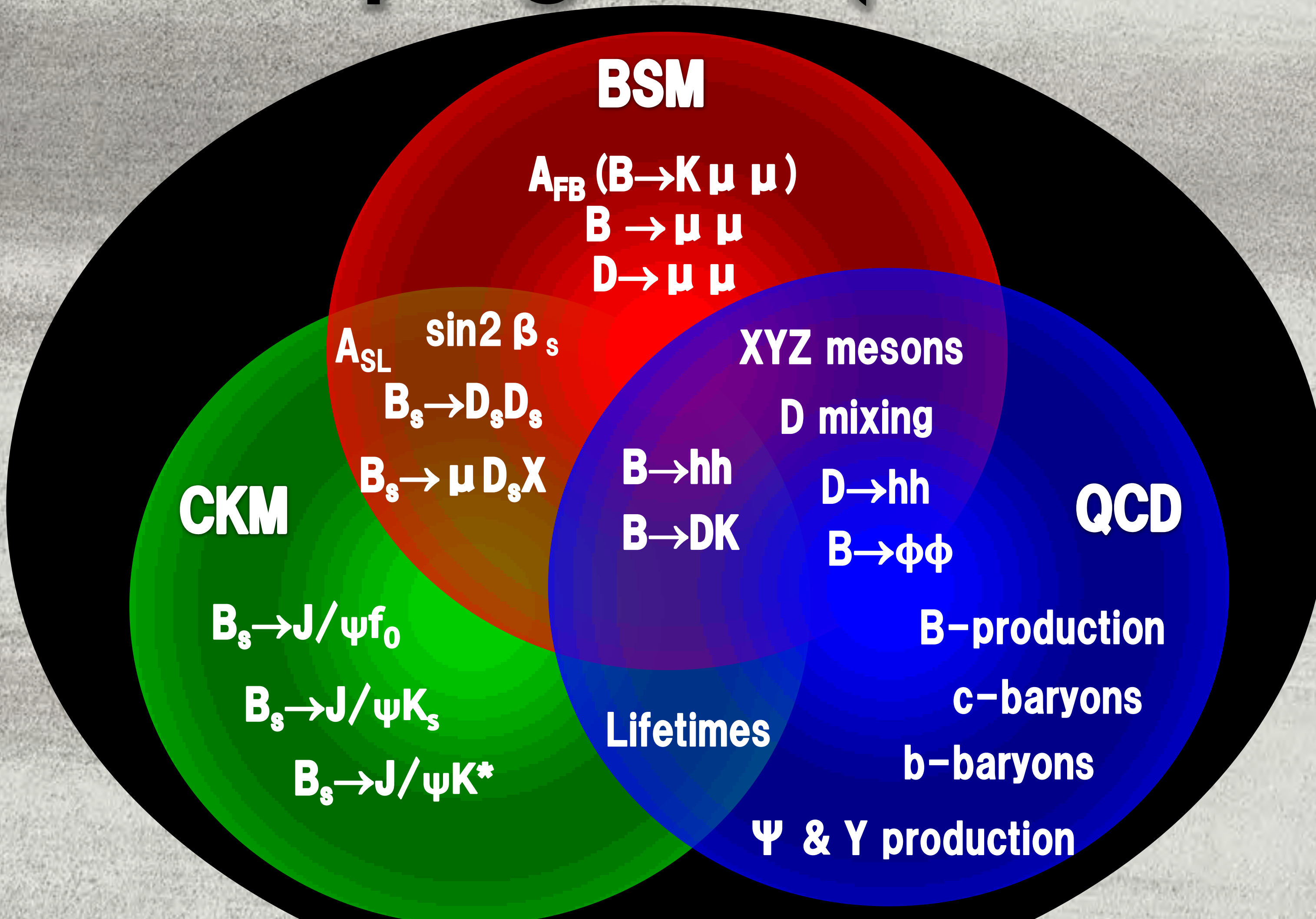
- 48 published papers
- 10 Topcite 50+
- 4 Topcite 100+
- 2 Topcite 250+

b cross section

B_s mixing

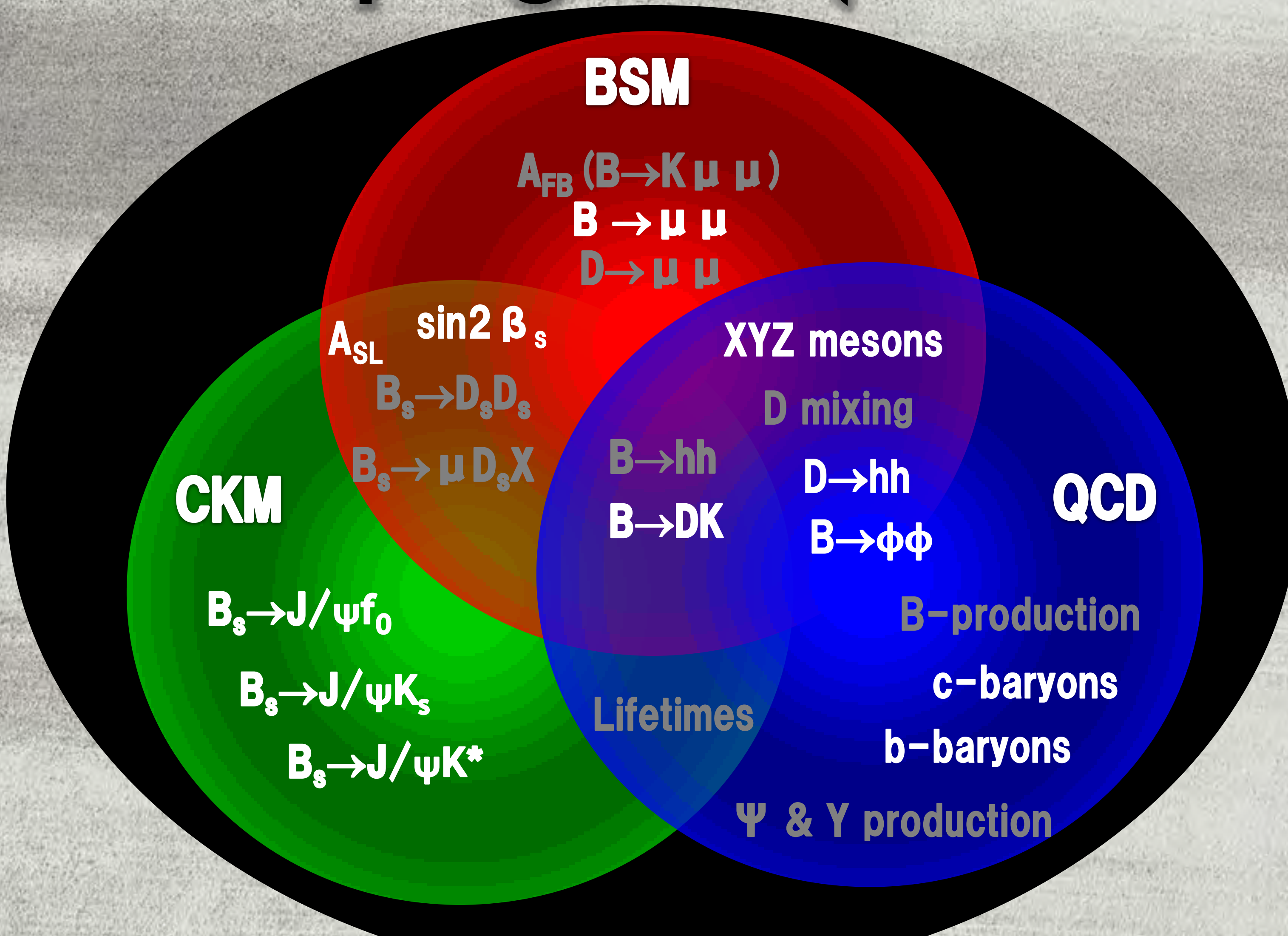
X (3872)

Active HF programs (NOT ALL!)



Many ongoing analyses!

Active HF programs (NOT ALL!)



Focus on the latest results

Rare Decays

- $B_s \rightarrow \mu\mu$
- $B_s \rightarrow \phi\phi$

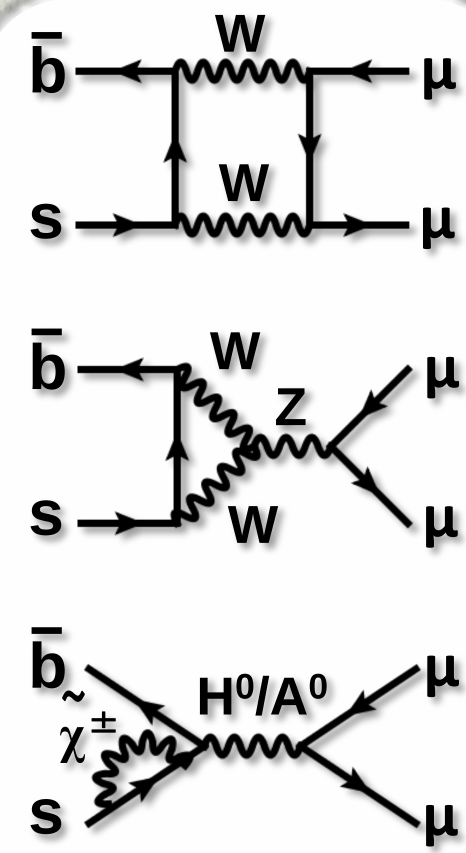
$B_{s,d} \rightarrow \mu\mu$

- Highly suppressed in the SM

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (3.6 \pm 0.3) \times 10^{-9}$$
$$\mathcal{B}(B_d^0 \to \mu^+\mu^-) = (1.1 \pm 0.1) \times 10^{-10}$$

A. J. Buras, arXiv:0904.4917v1

- Enhanced in NP (up to 100x)
  - Tree level:
    - R parity violation in SUSY
  - Loop level:
    - MFV SM extensions such as 2HDM
    - MSSM
      - BR (B→μμ) $(\tan\beta)^6$



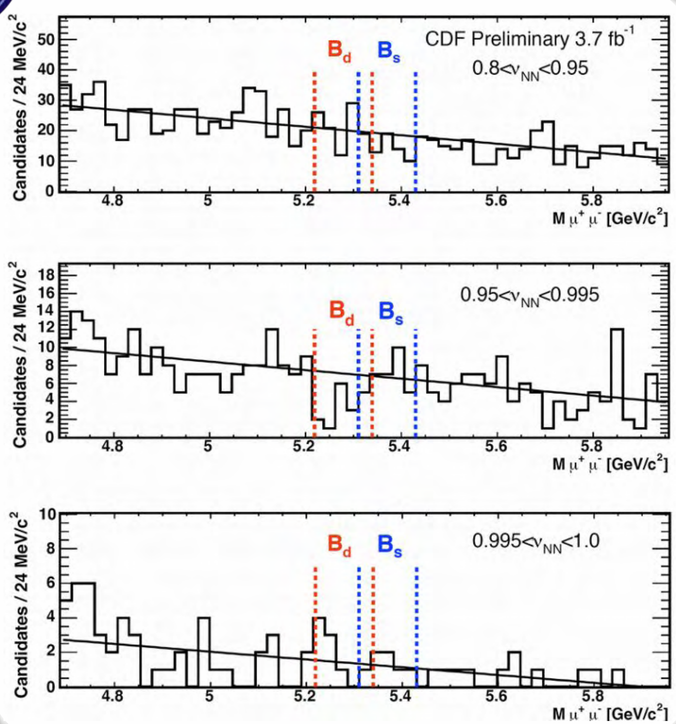
✓Previous world's best upper limit:
 ✓BR (B_s→μμ) <4.7 (5.8) x10^{-8}
 ✓BR (B_d→μμ) <1.5 (1.8) x10^{-8} 90 (95) % C.L.

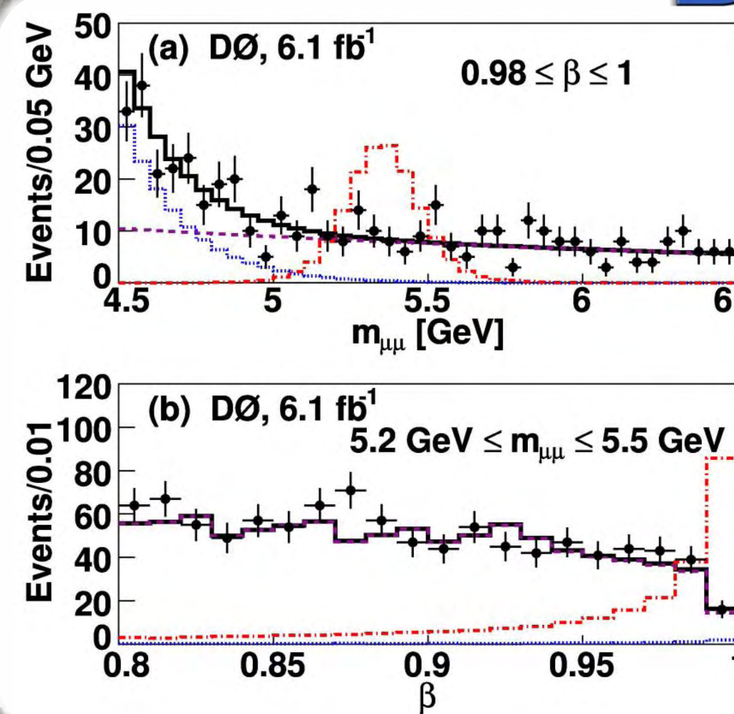
PRL 100, 101802 (2008)

~16×SM

$B_{s,d} \rightarrow \mu\mu$: result

- Utilize neural network to optimize event selection





✓BR ($B_s \rightarrow \mu\mu$) <3.6 (4.3) x10^{-8}
✓BR ($B_d \rightarrow \mu\mu$) <6.0 (7.6) x10^{-8} 90 (95) % C.L.

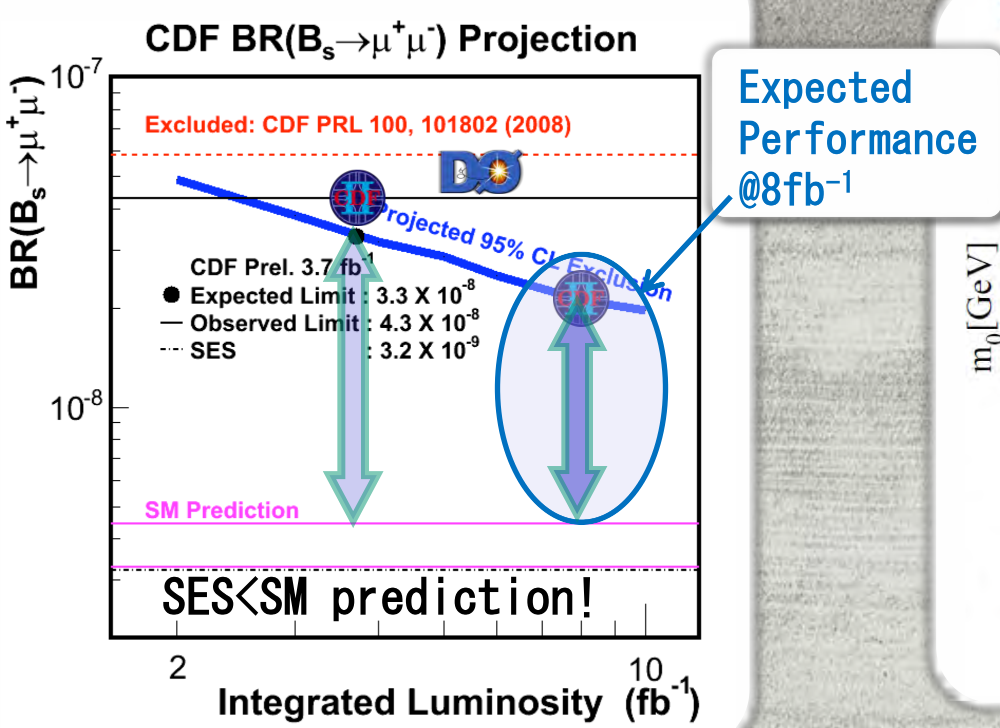
@3.7fb^{-1}
CDF public note 9892

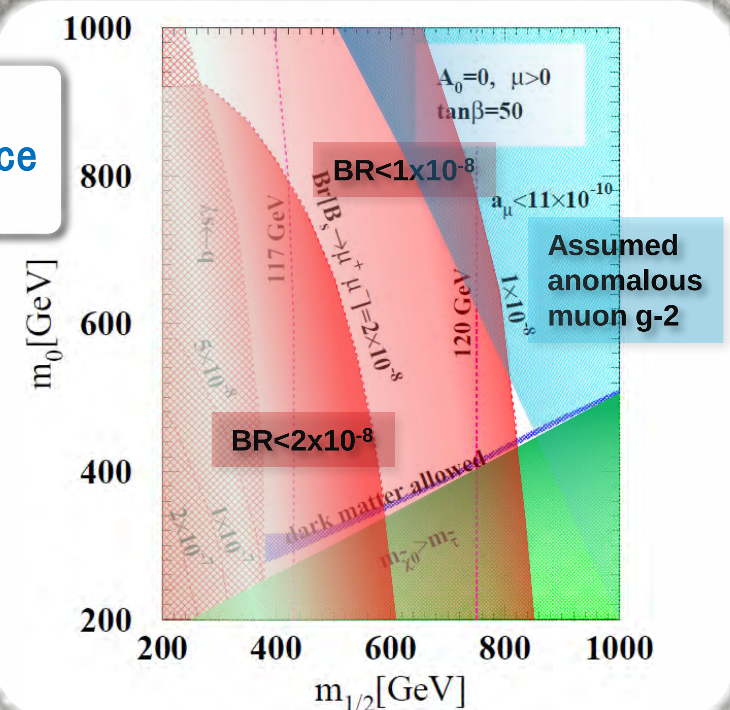
✓BR ($B_s \rightarrow \mu\mu$) <5.1x10^{-8} 95%C.L.

@6.1fb^{-1}
PLB693,539 (2010)

$B_s \to \mu\mu$: prospects

mSUGRA, D. Toback, arXiv:0911.0880v1 (2009)



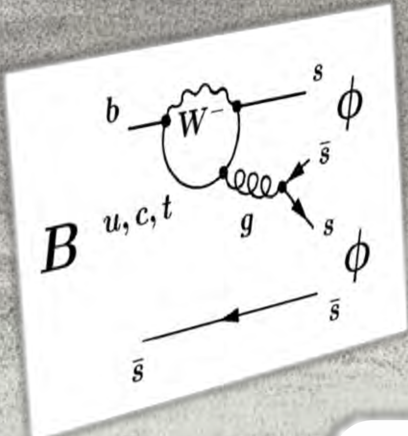


- 8fb^{-1} expectation (**w/o no improvement**)
  - CDF Expected limit: 2x10^{-8}@8fb^{-1} (6xSM)
  - Combined with DØ→5xSM

Strong constraint on NP parameters : Could rule-out mSUGRA with Tevatron combination at 10fb^{-1}

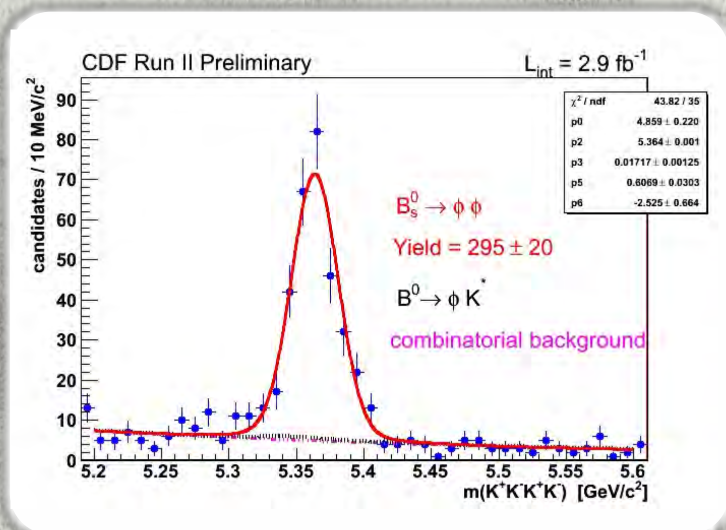
間もなくCDF update@6.9fb^{-1}

$B_s \rightarrow \varphi\varphi$: gluonic penguin



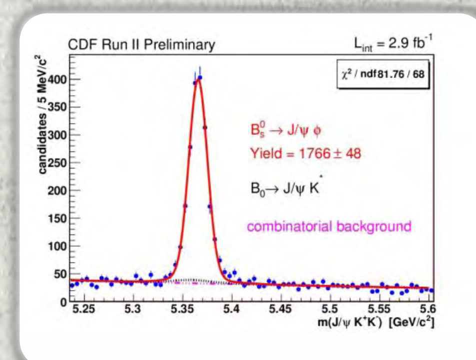
CDFnote 10064

- Dominated by $b \rightarrow s\bar{s}s$ (same as $B \rightarrow \varphi K^{(*)}$)
  - BR is sensitive to NP due to the loop diagram
    - Previous result: $(1.4^{+0.6}_{-0.5} \pm 0.6) \times 10^{-5}$ by 8 signal@180pb^{-1}



~x37 signal!

Control channel: $J/\Psi\varphi$

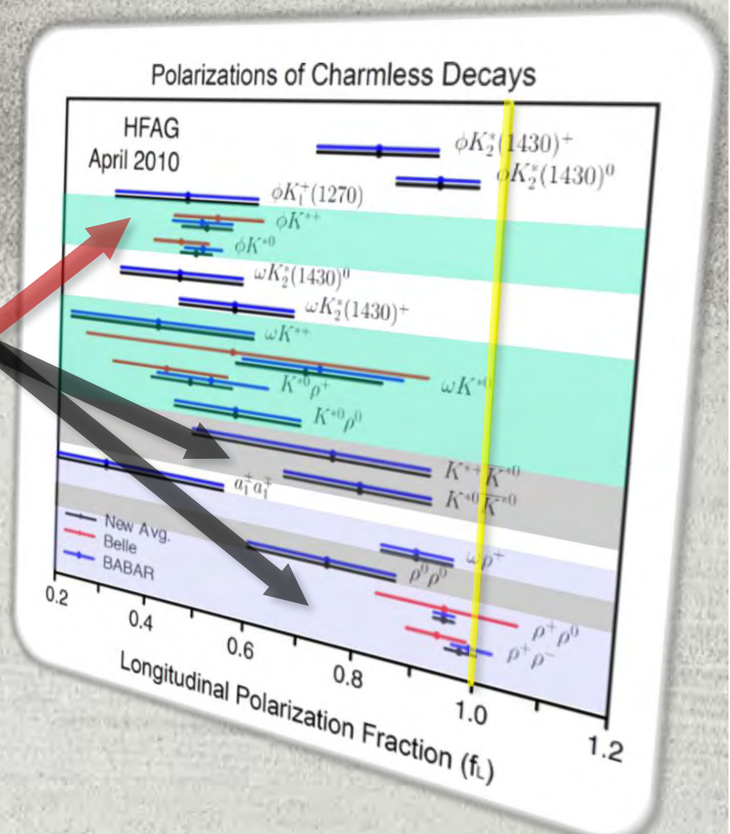


$$BR(B_s^0 \rightarrow \phi\phi) = [2.40 \pm 0.21(stat) \pm 0.27(syst) \pm 0.82(BR)] \cdot 10^{-5}$$

Significant improvement from previous results

$B_s \to \phi\phi$: polarization

- B→VV Polarization puzzle
  - Naïve QCD expectation: $f_L >> f_T$
    - Confirmed b→u tree (e.g. $B^0 \to \rho^+\rho^-$)
    - Evidence b→d penguin (e.g. $B^0 \to \rho^0\rho^0$)
  - while b→s penguin: $f_L \sim f_T$
    - $f_L(B^0 \to \phi K^{*0}) = 0.48 \pm 0.03$ (HFAG ave.)
    - $f_L(B^+ \to \phi K^{*+}) = 0.50 \pm 0.05$ (HFAG ave.)

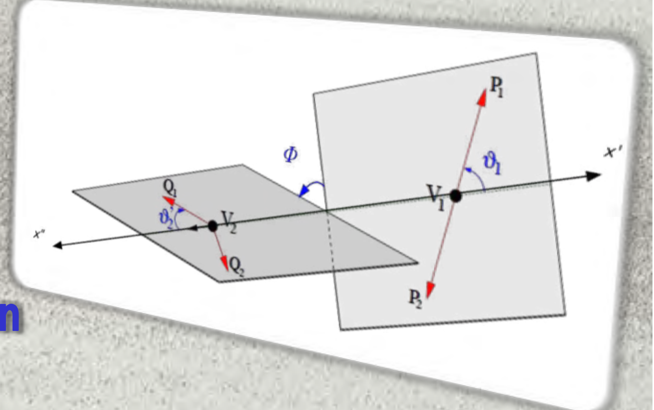


http://www.slac.stanford.edu/xorg/hfag/rare/index.html

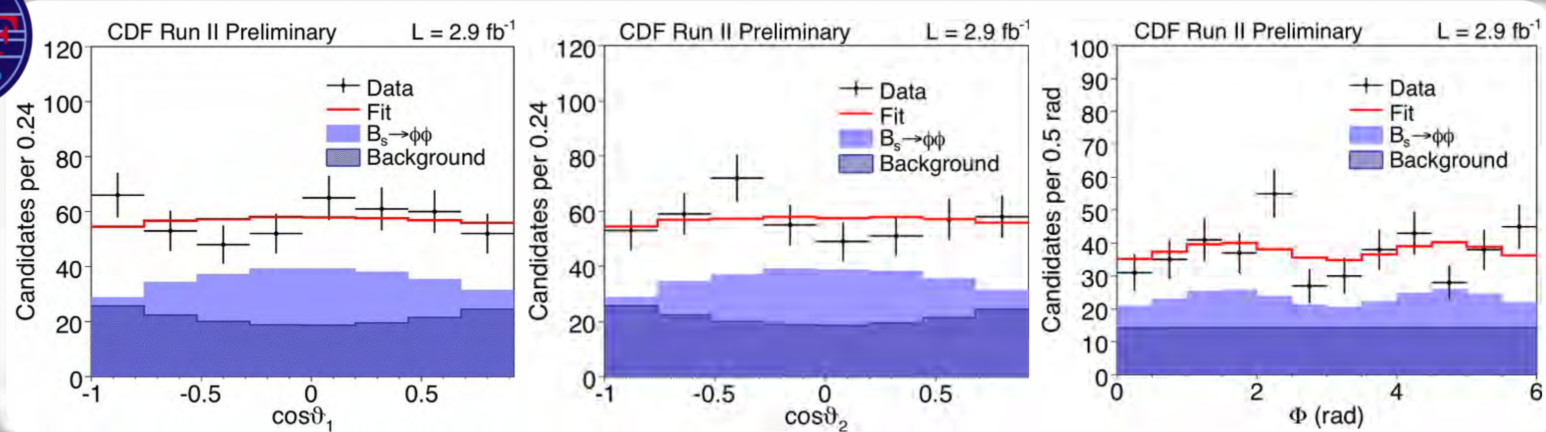
- Sign of NP?
- or within SM framework?

Information from penguin dominated $B_s \to VV$ is quite interesting

$B_s \to \varphi\varphi$: polarization fit



- 3 angular distributions ($\cos\theta_1$, $\cos\theta_2$, ϕ)
- Unbinned maximum likelihood fit
  - Time-integrated, B_s flavor untagged, no CPV assumption
  - 3 transversity amplitudes and 1 phase difference



$$|A_0|^2 = 0.348 \pm 0.041(\text{stat}) \pm 0.021(\text{syst}),$$
$$|A_\parallel|^2 = 0.287 \pm 0.043(\text{stat}) \pm 0.011(\text{syst}),$$
$$|A_\perp|^2 = 0.365 \pm 0.044(\text{stat}) \pm 0.027(\text{syst}),$$
$$\cos\delta_\parallel = -0.91^{+0.15}_{-0.13}(\text{stat}) \pm 0.09(\text{syst}).$$

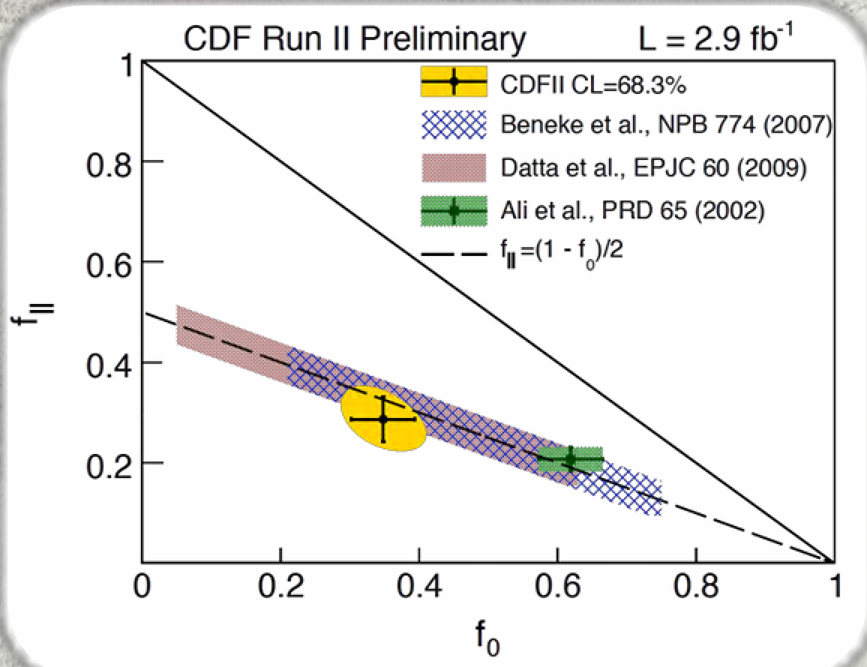
First polarization measurement of the decay!

$B_s \to \varphi\varphi$: discussion

$$|A_0|^2 = 0.348 \pm 0.041(\text{stat}) \pm 0.021(\text{syst}),$$
$$|A_\parallel|^2 = 0.287 \pm 0.043(\text{stat}) \pm 0.011(\text{syst}),$$
$$|A_\perp|^2 = 0.365 \pm 0.044(\text{stat}) \pm 0.027(\text{syst}),$$
$$\cos\delta_\parallel = -0.91^{+0.15}_{-0.13}(\text{stat}) \pm 0.09(\text{syst}).$$

$$f_{\text{L}} = 0.348 \pm 0.041(\text{stat}) \pm 0.021(\text{syst}),$$
$$f_{\text{T}} = 0.652 \pm 0.041(\text{stat}) \pm 0.021(\text{syst}).$$

$f_L << f_T$!!



QCD factorization
QCD factorization
Perturbative QCD

This first measurement in the B_s sector seems to strengthen the puzzle!

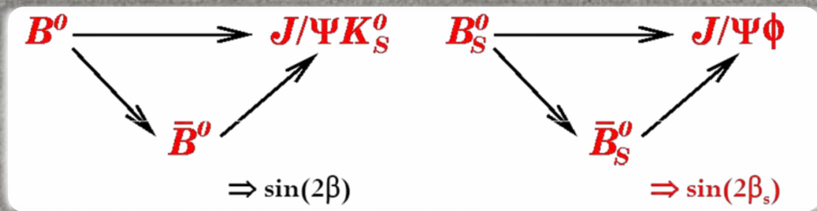
CKM/CPV

- β_s measurement
- A_{SL}
- $B_s \rightarrow J/\psi K_S/K^{*0}$
- $B_s \rightarrow J/\psi f_0$
- γ measurement
- $D \rightarrow hh$ CPV

CP violation in $B_s \to J/\psi\phi$

Interference of neutral B (d,s) decays **with** and **without mixing**:

→CPV

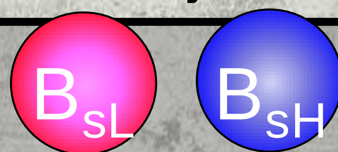


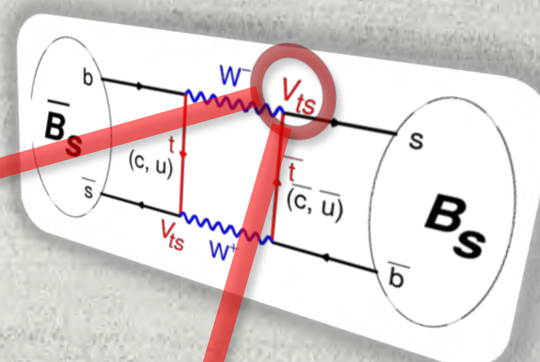
$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

Tools to measure CPV induced by mixing:

Mass difference: ΔM

Width difference: ΔΓ

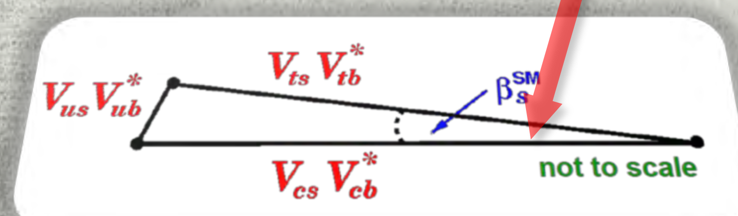




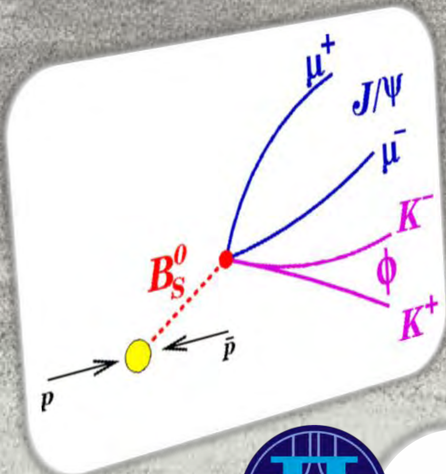
CPV phase between B_s mixing and $B_s \to J/\psi\phi$ decay:

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

A. Lenz and U. Nierste, JHEP 06, 072(2007)

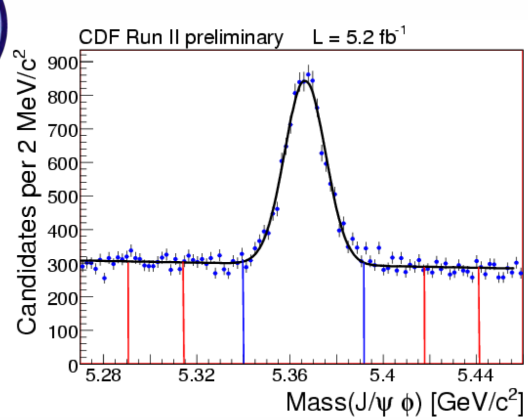


$B_s \to J/\psi\phi$ signal

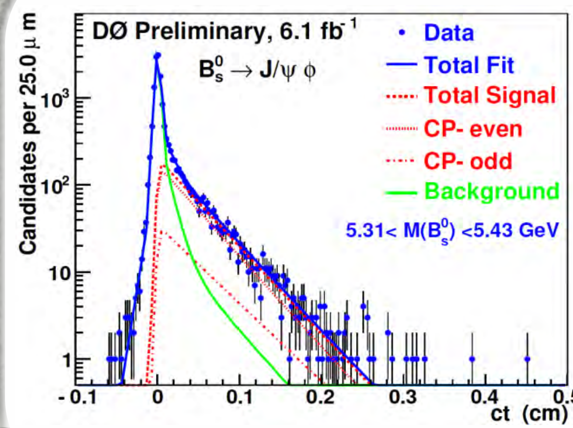


- The golden channel to measure β_s
  - dominated by b→ccs tree ~theoretically clean
- B→VV decay: three partial waves
  - L=0,2 (CP even)
  - L=1 (CP odd)

Need angular analysis



$N(B_s^0) \sim 6500$

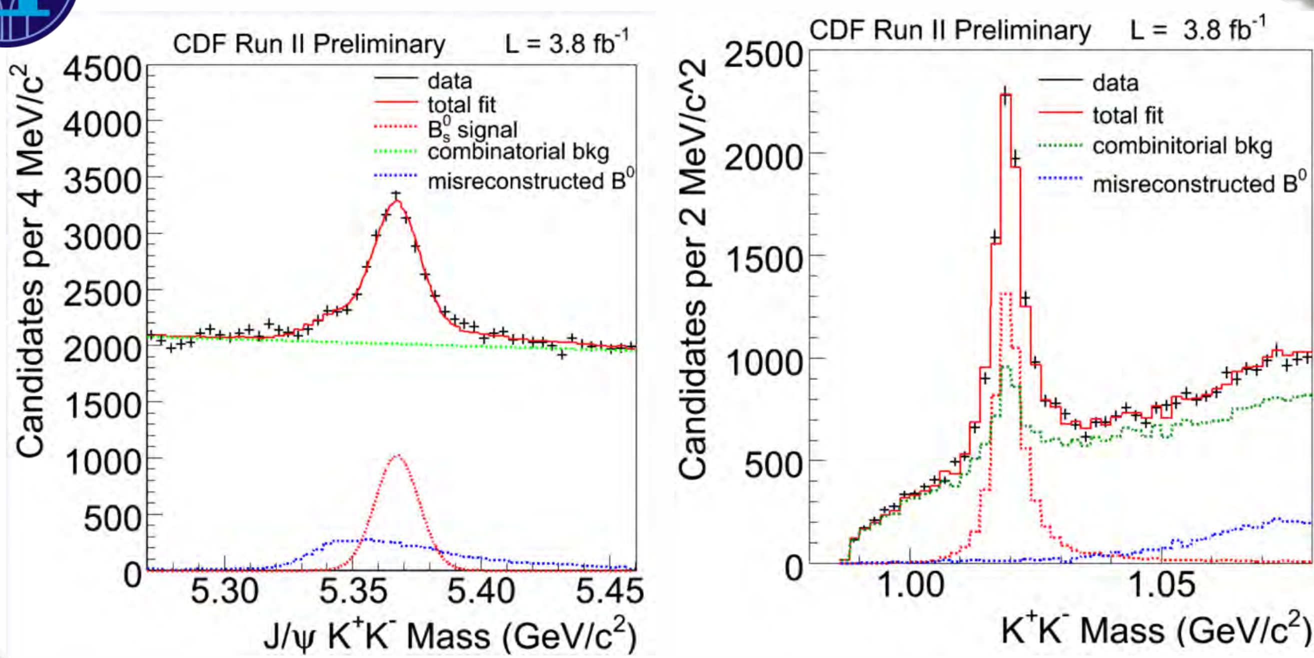


$N(B_s^0) \sim 3400$

β_s=0, no flavor tag :
$c\tau(B_s^0)$ = 458.6±7.6 (stat)±3.6 (syst) um
$\Delta\Gamma$ = 0.075±0.035 (stat)±0.01 (syst) ps^{-1}

S-wave contamination

- Potential contamination of $B_s \rightarrow J/\psi\varphi$ signal by $B_s \rightarrow J/\psi KK$ (KK non-resonant) and $B_s \rightarrow J/\psi f_0$ are S-wave states
- Contamination could bias SM value of β_s



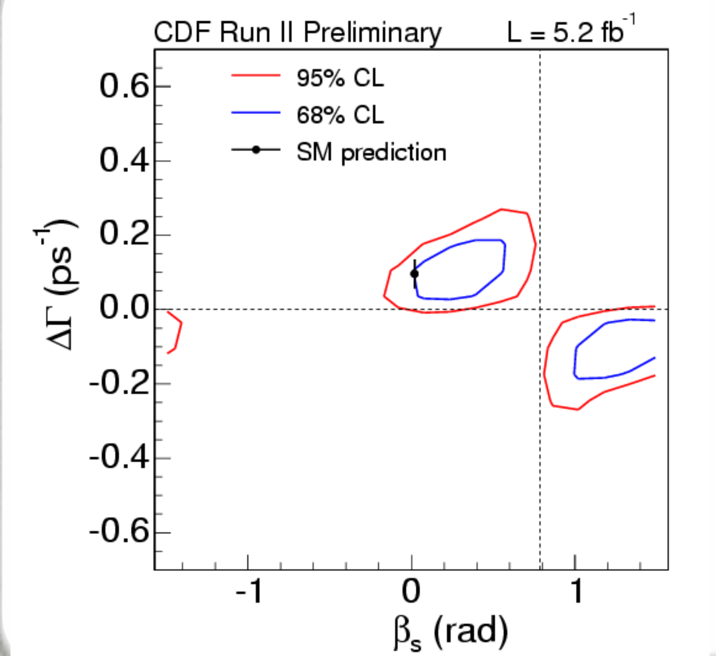
The fitted fraction of KK S-wave contamination in the signals is <6.7% at the 95% CL

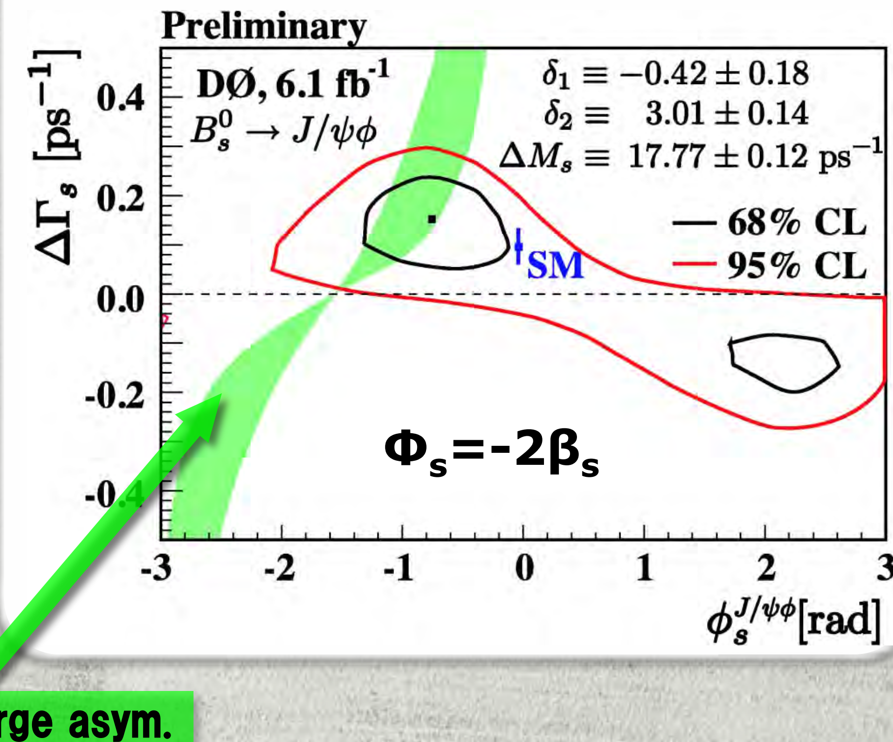
β_s new results

CDF note 10206 ($5.2fb^{-1}$)

DØ note 6098 ($6.1fb^{-1}$)

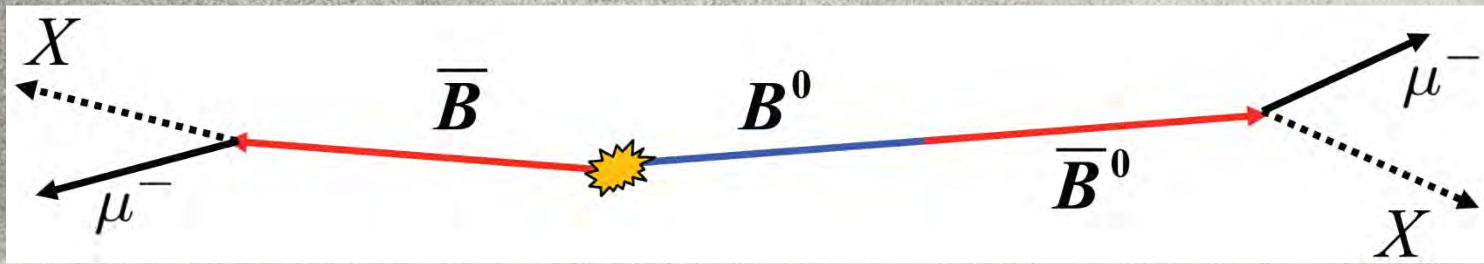
- Significant improvements from last publication
  - S-wave consideration, PID, multi variate analysis…





Both experiments see SM consistency at ~1σ

Dimuon charge asymmetry



- Search for CPV in B mixing from **same sign semileptonic** B decays:

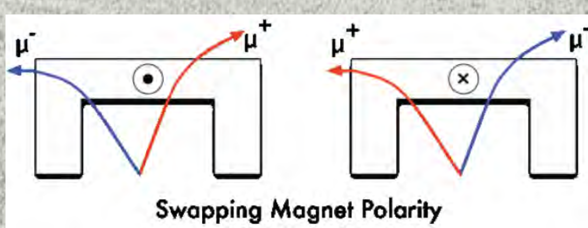
$$A_{sl}^{b} \equiv \frac{N_b^{++} - N_b^{--}}{N_b^{++} + N_b^{--}}$$

$$N_b^{--} = \begin{cases} b \rightarrow \mu^- X \\ \overline{b} \rightarrow b \rightarrow \mu^- X \end{cases}$$

Major issues:

1. Asymmetric backgrounds from kaon faking muon
2. Asymmetric μ^+ and μ^- acceptance/efficiecny

$$K^{*0} \rightarrow K^+\pi^-$$
$$\varphi(1020) \rightarrow K^+K^-$$



D0 can swap polarity!

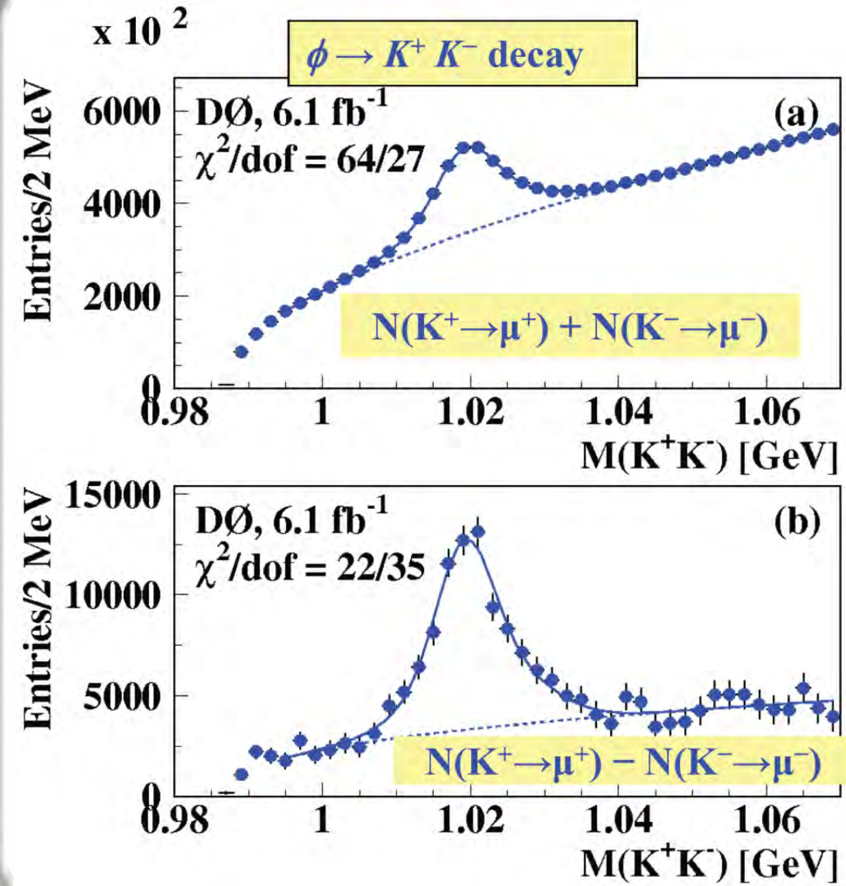
Fake muon backgrounds

- $\sigma(K^+N) < \sigma(K^-N)$
  - More K^+ make fake μ
- Kaon's properties are investigated by:

$$K^{*0} \to K^+\pi^-$$
$$\varphi(1020) \to K^+K^-$$

→ Fake μ

- Compute asymmetry from observed +/− yields



μμ charge asymmetry result

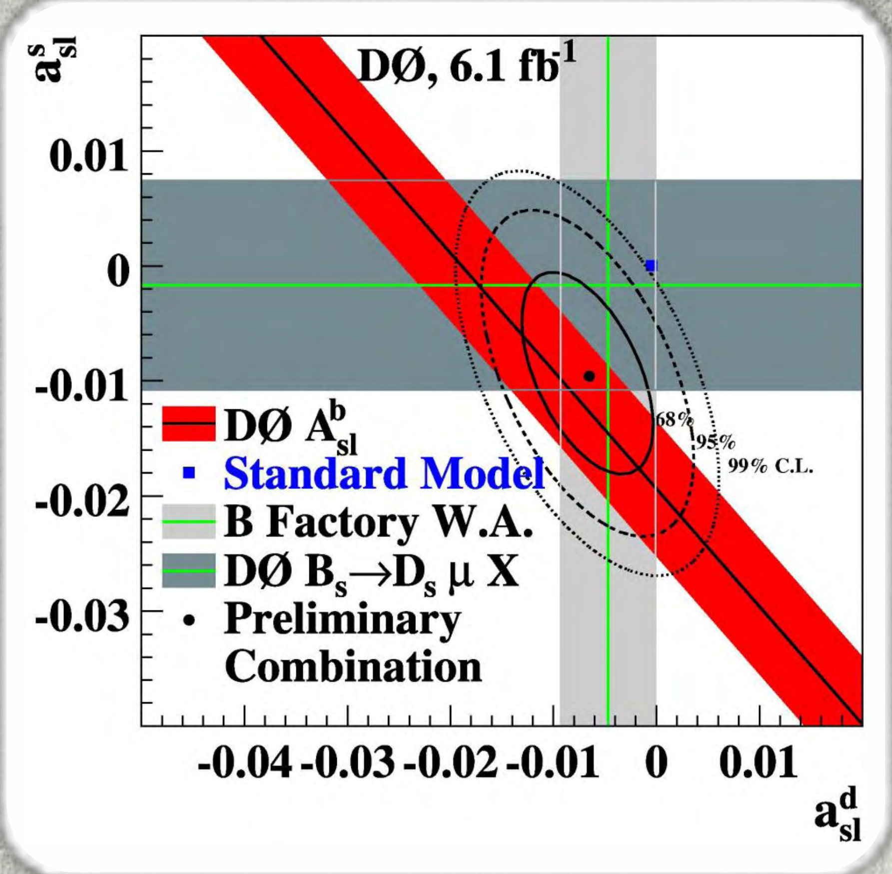
- DO 6.1fb^{-1} analysis yields:

$$A_{sl}^{b} = (-0.957 \pm 0.251\,(\text{stat}) \pm 0.146\,(\text{syst}))\%$$

- SM prediction:

$$A_{sl}^{b}(SM) = (-0.023^{+0.005}_{-0.006})\%$$

⇒ using prediction of a^d_{sl} and a^s_{sl} from A. Lenz, U. Nierste, hep-ph/0612167



Differs from SM by ~3.2 σ

CDF 1.6fb^{-1} CDF update is ongoing

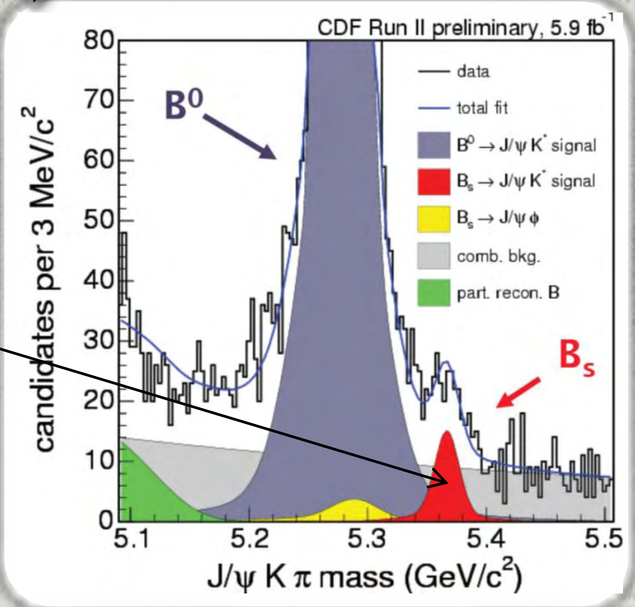
A_{SL}=0.0080±0.0090(stat)±0.0068(syst)

$B_s \rightarrow J/\psi K_s (K^{*0})$

- Cabibbo suppressed $b \rightarrow c\bar{c}d$

$B_s \rightarrow J/\psi K^{*0}(892)$

- Analogous to $B_s \rightarrow J/\psi\phi$



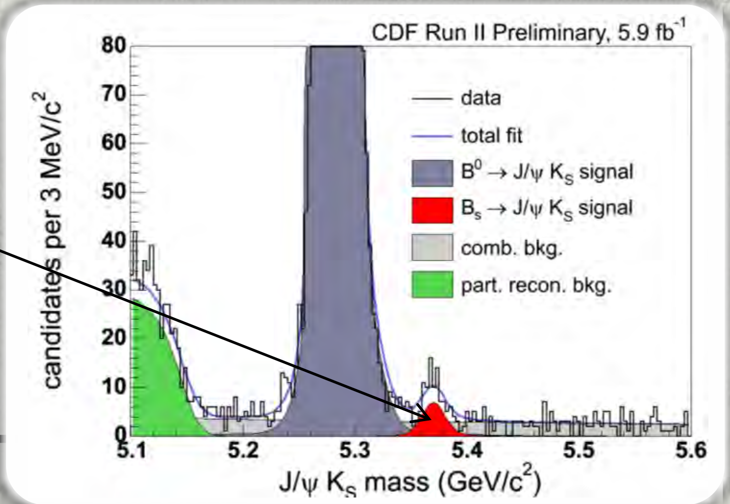
$BR(B_s \rightarrow J/\psi K^{*0})$ =
$[8.3 \pm 1.2(stat) \pm 3.3(syst) \pm 1.0(frag) \pm 0.4(PDG)] \times 10^{-5}$

1st observation!

$B_s \rightarrow J/\psi K_s$

- CP eigenstate, 100% B_s heavy

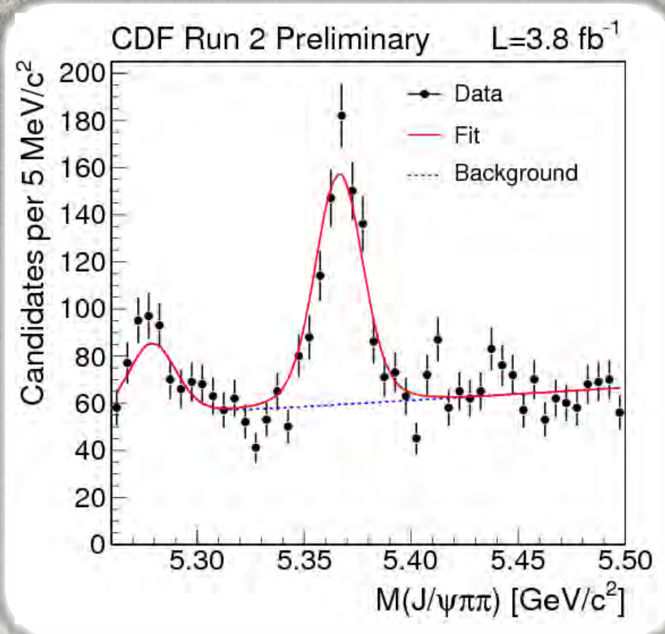
1st observation!



$BR(B_s \rightarrow J/\psi K^0)$ =
$[3.53 \pm 0.61(stat) \pm 0.35(syst) \pm 0.43(frag) \pm 0.13(PDG)] \times 10^{-5}$

$B_s \rightarrow J/\psi f_0(980)$

- S-wave contribution to $B_s \rightarrow J/\psi\phi$ ($\rightarrow K^+K^-$)
- $\sin 2\beta_s$ measurement w/o angular analysis
- Reconstruct with $f_0 \rightarrow \pi^+\pi^-$
- LHCb and Belle also claim the observation



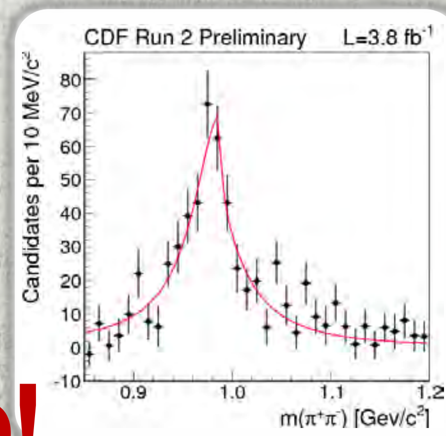
CDF: $N_{signal}=571\pm37(stat)\pm25(syst)$

LHCb: $N_{signal}=169^{+31}_{-21}$ (arXiv:1102.0206)

Belle: $N_{signal}=63^{+16}_{-10}$ (arXiv:1102.2759)

$R_{f0/\varphi}=[BR(B_s\rightarrow J/\psi f_0(980))BR(f_0(980)\rightarrow\pi^+\pi)]/[BR(B_s\rightarrow J/\psi\varphi)BR(\varphi\rightarrow K^+K^-)]=$
$0.290\pm0.020(stat)\pm0.017(sys)$

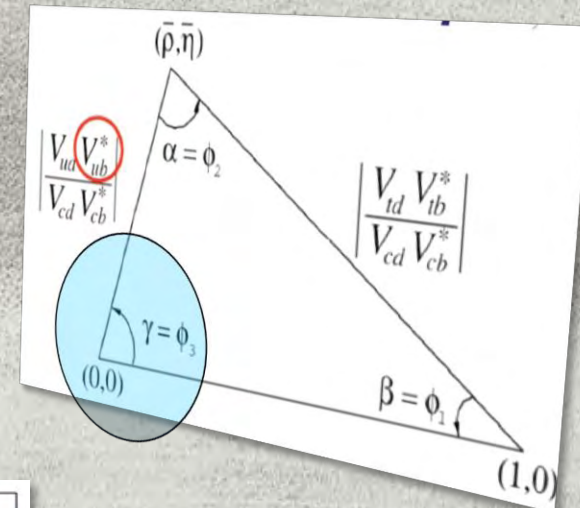
Most precise!



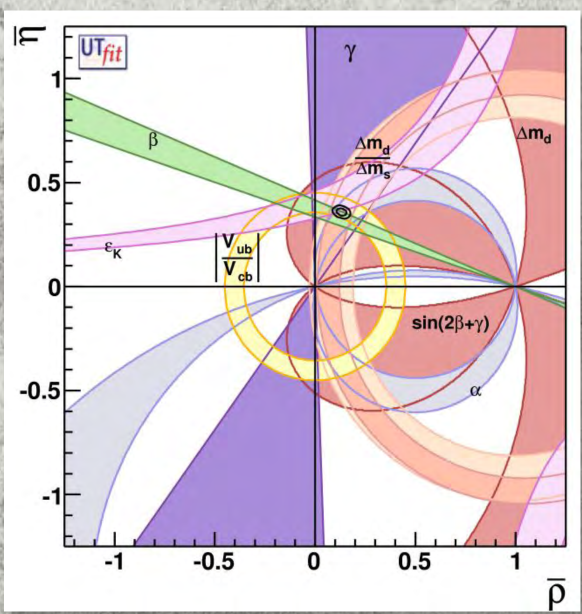
Dipion mass

CKM angle γ

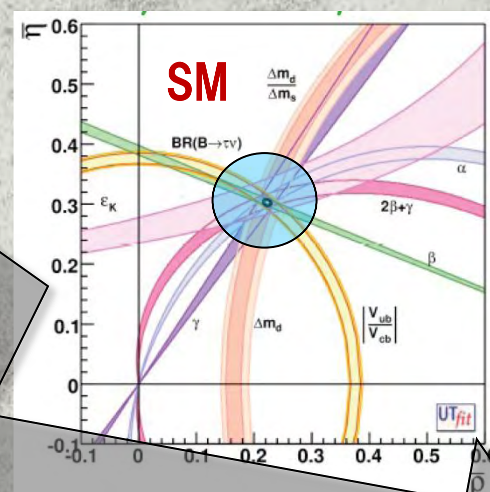
$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$



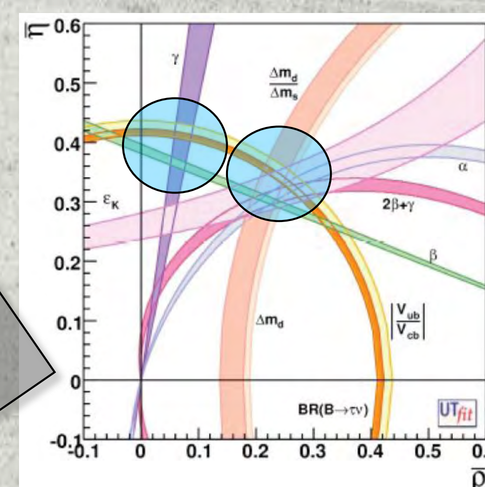
- CKM angle γ: still large uncertainty
- Does Unitarity triangle close?



2010 constraint

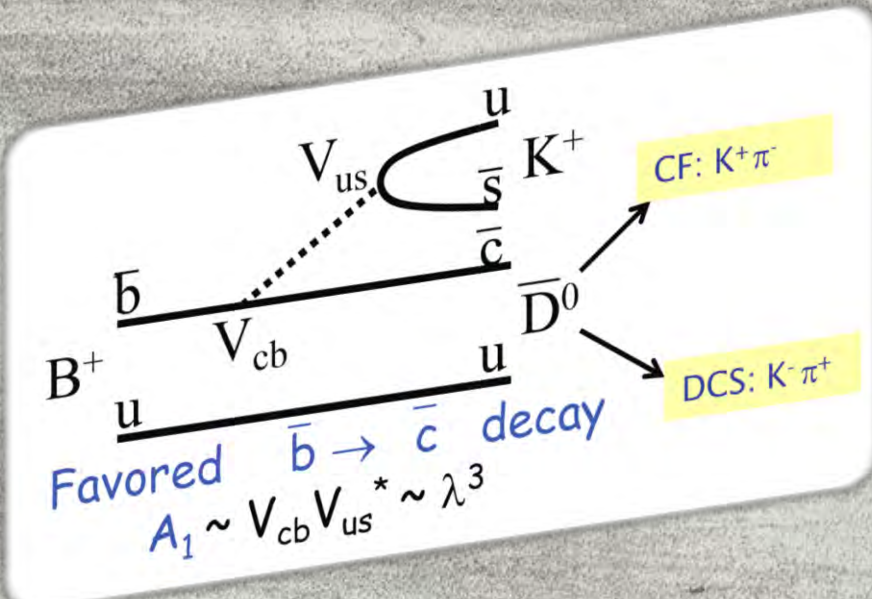


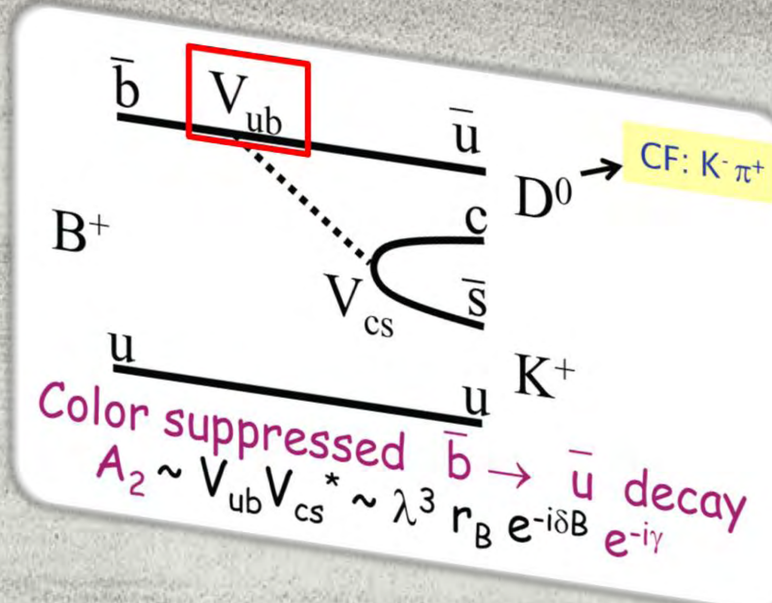
NP scenario



γ by ADS

- CKM angle γ could be extracted by exploiting the interference between $\bar{b}\to\bar{c}u\bar{s}$ ($B^+\to\bar{D}^0K$) and $\bar{b}\to\bar{u}c\bar{s}$ ($B^+\to D^0K$), while D's decay into the same final state

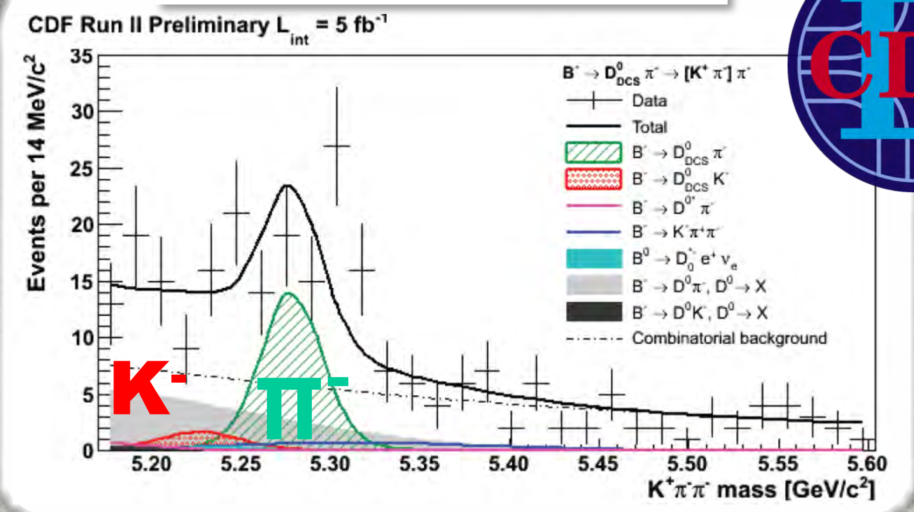




- ADS (Atwood-Dunietz-Soni) method
  - Uses $B^\pm\to DK^\pm$ decays with $D^0\to K^+\pi^-$ (doubly-cabibbo suppressed)
  - No flavor tag, no time dependence

ADS results

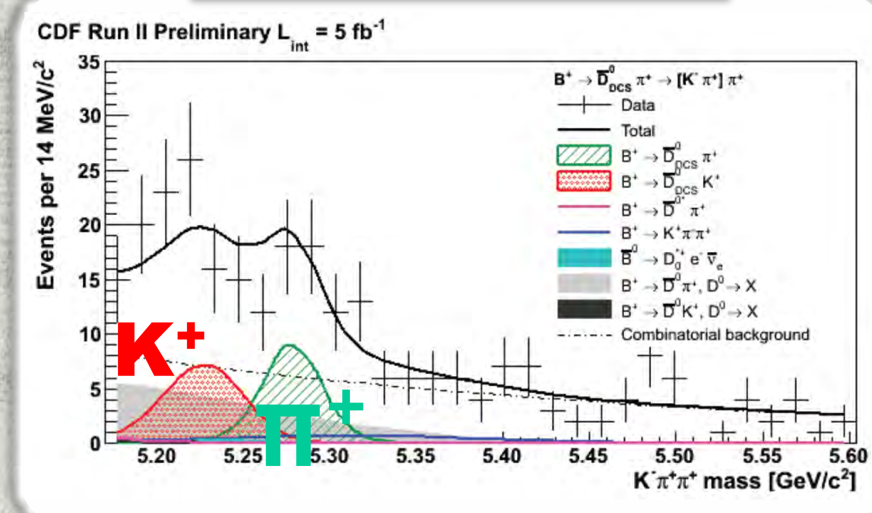
$B^- \to D^0_{DCS}\,\pi^- \to [K^+\,\pi^-]\,\pi^-$



$$R_{ADS}(K) = \frac{N(B^- \to D^0_{DCS}K^-) + N(B^+ \to D^0_{DCS}K^+)}{N(B^- \to D^0_{CF}K^-) + N(B^+ \to D^0_{CF}K^+)}$$

$$\mathcal{A}_{ADS}(K) = \frac{N(B^- \to D^0_{DCS}K^-) - N(B^+ \to D^0_{DCS}K^+)}{N(B^- \to D^0_{DCS}K^-) + N(B^+ \to D^0_{DCS}K^+)}$$

$B^+ \to \bar{D}^0_{DCS}\,\pi^+ \to [K^-\,\pi^+]\,\pi^+$



$$R_{ADS}(\pi) = 0.0041 \pm 0.0008(stat) \pm 0.0004(syst)$$

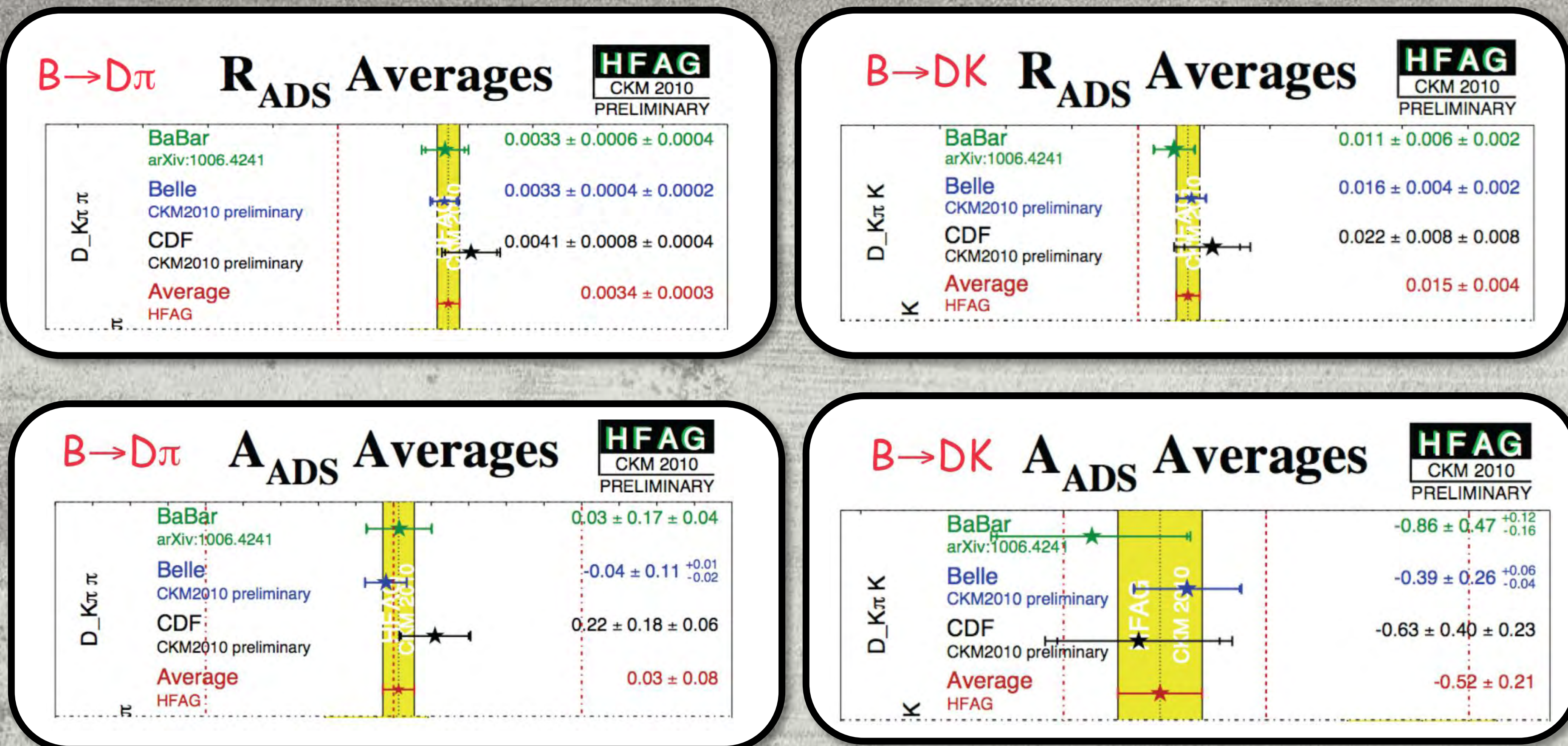
$$A_{ADS}(\pi) = 0.22 \pm 0.18(stat) \pm 0.06(syst)$$

$$R_{ADS}(K) = 0.0225 \pm 0.0084(stat) \pm 0.0079(syst)$$

$$A_{ADS}(K) = -0.63 \pm 0.40(stat) \pm 0.23(syst)$$

ADS comparison

- CDF results are in agreement with B-factories



CPV in $D^0 \to \pi^+\pi^-$

- Charm is a unique window toward NP:
  - only one probe to measure CPV in up-quarks

$$A_{CP}(D^0 \to \pi^+\pi^-) = \frac{\Gamma(D^0 \to \pi^+\pi^-) - \Gamma(\overline{D}^0 \to \pi^+\pi^-)}{\Gamma(D^0 \to \pi^+\pi^-) + \Gamma(\overline{D}^0 \to \pi^+\pi^-)}$$

Tagging the D^0 with D^*: $\begin{cases} D^{*+} \to D^0 \pi_s^+ \\ D^{*-} \to \overline{D}^0 \pi_s^- \end{cases}$

- CP symmetric initial state ($p\bar{p}$) ensures charge symmetric production
- We have world's largest charm sample:
  - ~215,000 $D^{*+} \to D^0(\to \pi^+\pi^-)\pi^+$ @5.94fb^{-1}

$D^0 \to \pi^+\pi^-$: Methodology

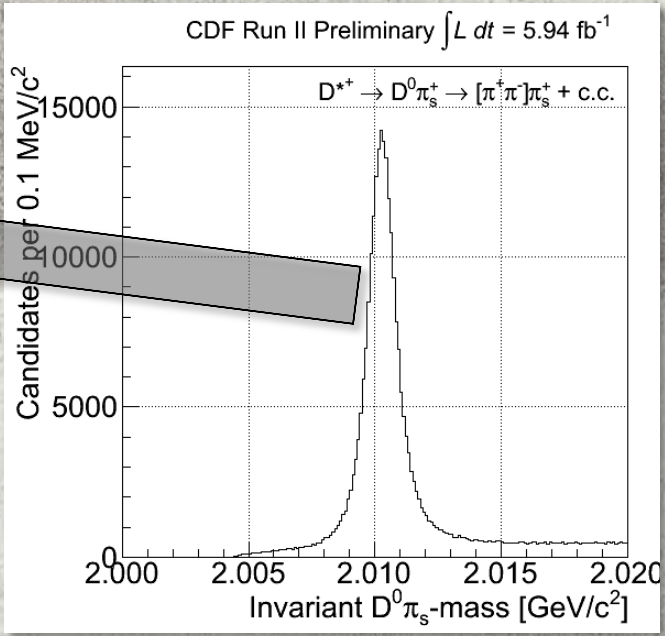
$$D^\star \to D^0\pi_s \to [\pi\ \pi]\ \pi_s$$

$$D^\star \to D^0\pi_s \to [K\pi]\ \pi_s$$

$$D^0 \to [K\pi]$$

$D^0 \to \pi^+\pi^-$: Methodology

$$D^\star \to D^0\pi_s \to [\pi\ \pi]\ \pi_s$$



$$D^\star \to D^0\pi_s \to [K\pi]\ \pi_s$$

$$D^0 \to [K\pi]$$

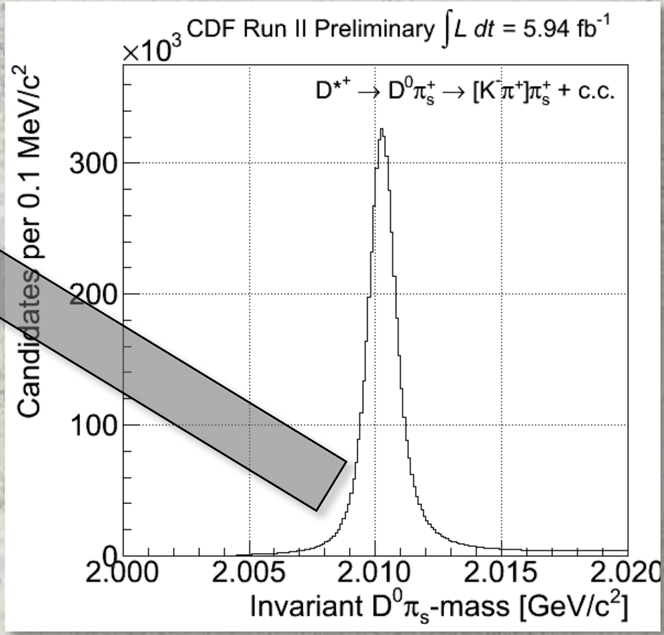
$D^0 \to \pi^+\pi^-$: Methodology

$$D^\star \to D^0\pi_s \to [\pi\ \pi]\ \pi_s$$

$$A_{CP}^{raw}(\pi\pi^\star) = A_{CP}(\pi\pi) + \delta(\pi_s)$$

cancel asymmetry due to π_s^+/π_s^-
different reconstruction efficiencies

$$D^\star \to D^0\pi_s \to [K\pi]\ \pi_s$$

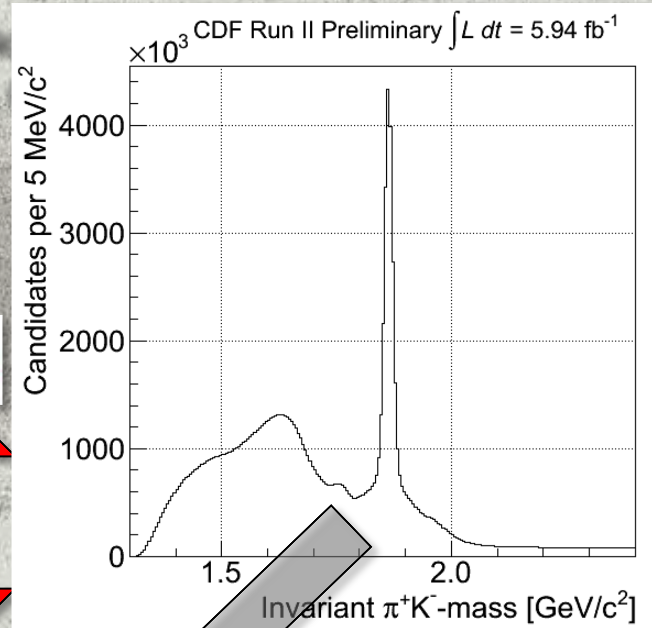


$$D^0 \to [K\pi]$$

$D^0 \rightarrow \pi^+\pi^-$ gy

$D^\star \rightarrow D^0\pi_s \rightarrow [\pi\ \pi]\ \pi_s$

$(\pi\pi) + \delta(\pi_s)$



$/\pi_s^-$

ncies

$D^\star \rightarrow D^0\pi_s \rightarrow [K\pi]\ \pi_s$

$A_{CP}^{raw}(K\pi^\star) = A_{CP}(K\pi) + \delta(\pi_s) + \delta(K\pi)$

cancel asymmetry due to K^+/K^- different interaction with matter + possible CPV in $D^0 \rightarrow K\pi$

$D^0 \rightarrow [K\pi]$

$A_{CP}^{raw}(K\pi) = A_{CP}(K\pi) + \delta(K\pi)$

$D^0 \rightarrow \pi^+\pi^-$: Methodology

$D^\star \rightarrow D^0\pi_s \rightarrow [\pi\ \pi]\ \pi_s$

$A_{CP}^{raw}(\pi\pi^\star) = A_{CP}(\pi\pi) + \delta(\pi_s)$

cancel asymmetry due to π_s^+/π_s^-
different reconstruction efficiencies

$D^\star \rightarrow D^0\pi_s \rightarrow [K\pi]\ \pi_s$

$A_{CP}^{raw}(K\pi^\star) = A_{CP}(K\pi) + \delta(\pi_s) + \delta(K\pi)$

cancel asymmetry due to K^+/K^-
different interaction with matter
+
possible CPV
in $D^0 \rightarrow K\pi$

$D^0 \rightarrow [K\pi]$

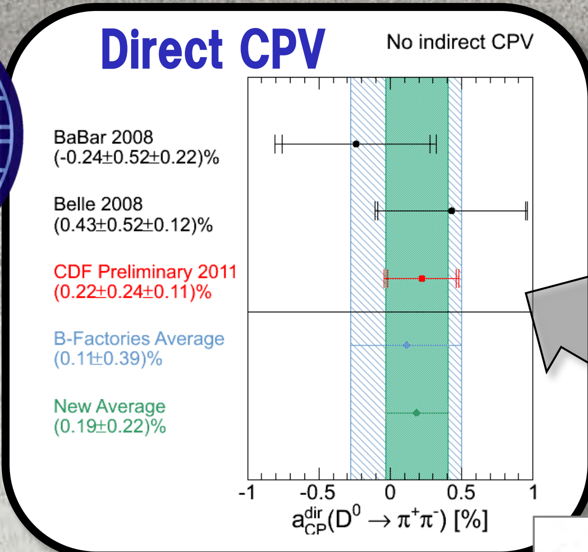
$A_{CP}^{raw}(K\pi) = A_{CP}(K\pi) + \delta(K\pi)$

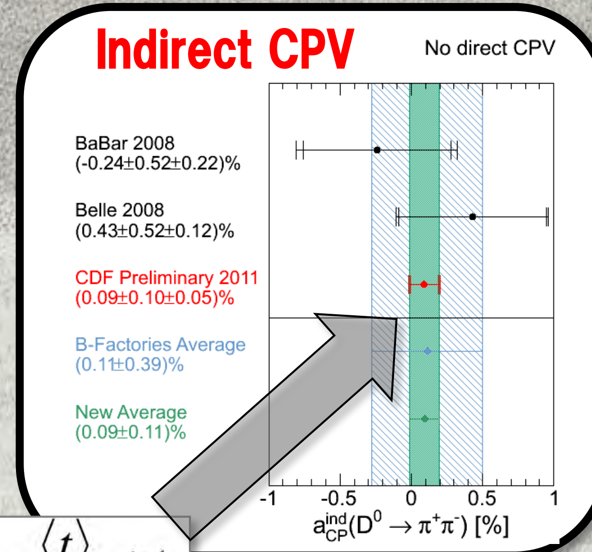
$$A_{CP}(\pi\pi) = A_{CP}^{raw}(\pi\pi^\star) - A_{CP}^{raw}(K\pi^\star) + A_{CP}^{raw}(K\pi)$$

$D^0 \rightarrow h^+h^-$ results

- Agreement with B-factories and most precise so far

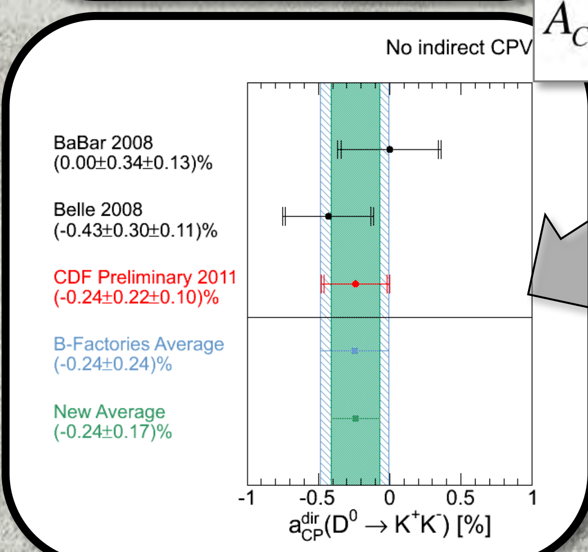
$\pi^+\pi^-$

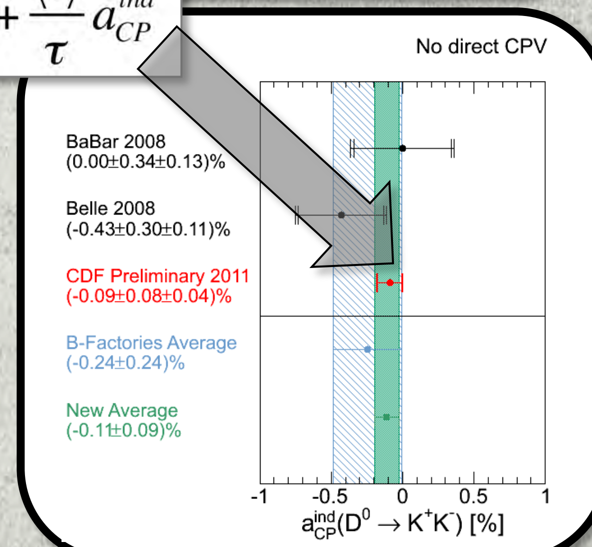




$$A_{CP}(D^0 \rightarrow \pi^+\pi^-) \approx a_{CP}^{dir} + \frac{\langle t \rangle}{\tau} a_{CP}^{ind}$$

K^+K^-

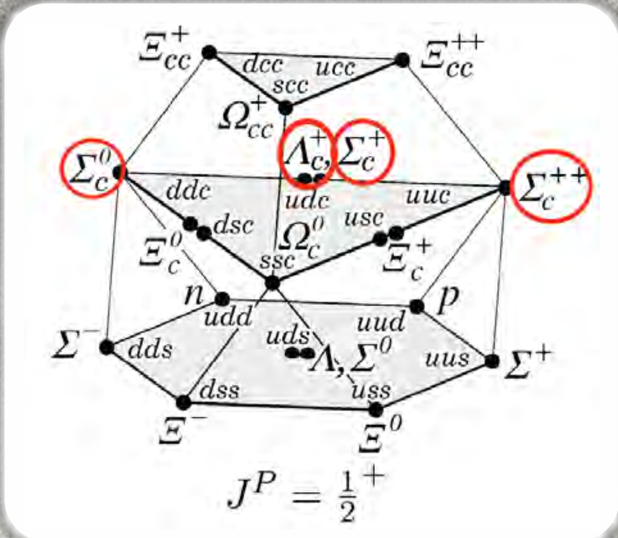


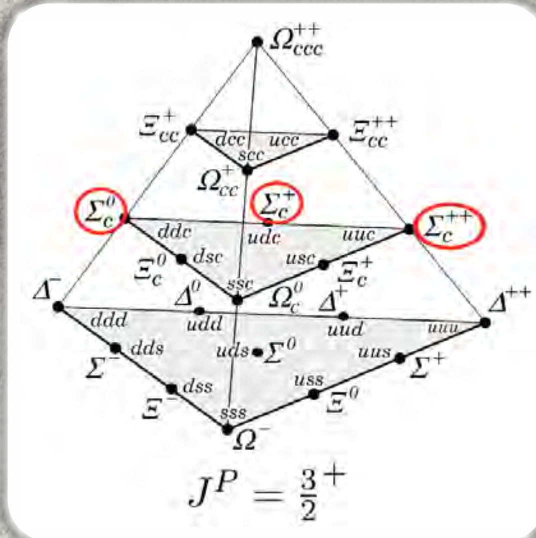


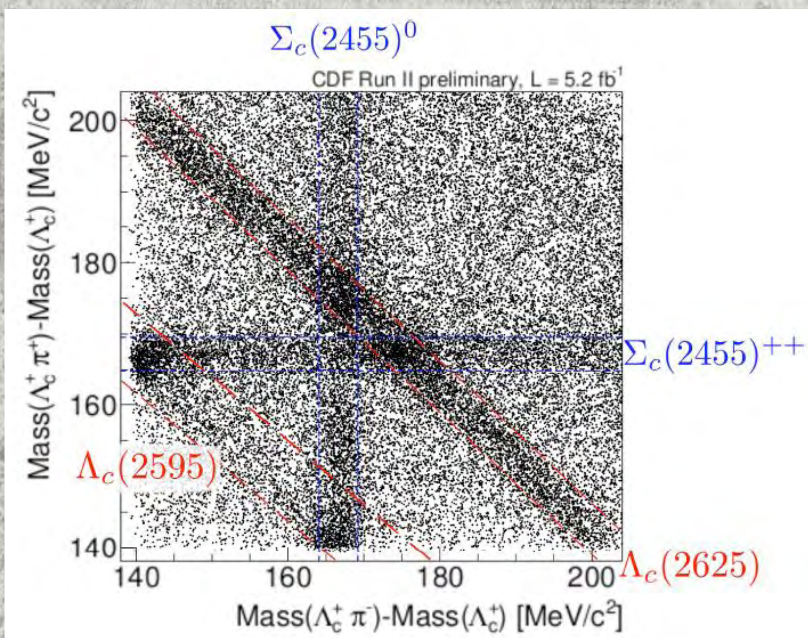
Spectroscopy

- Charm Baryons
- Bottom Baryons
- Y(4140)

Charm Baryons: $\Sigma_c^{0(++)}$ and Λ_c^{*+}

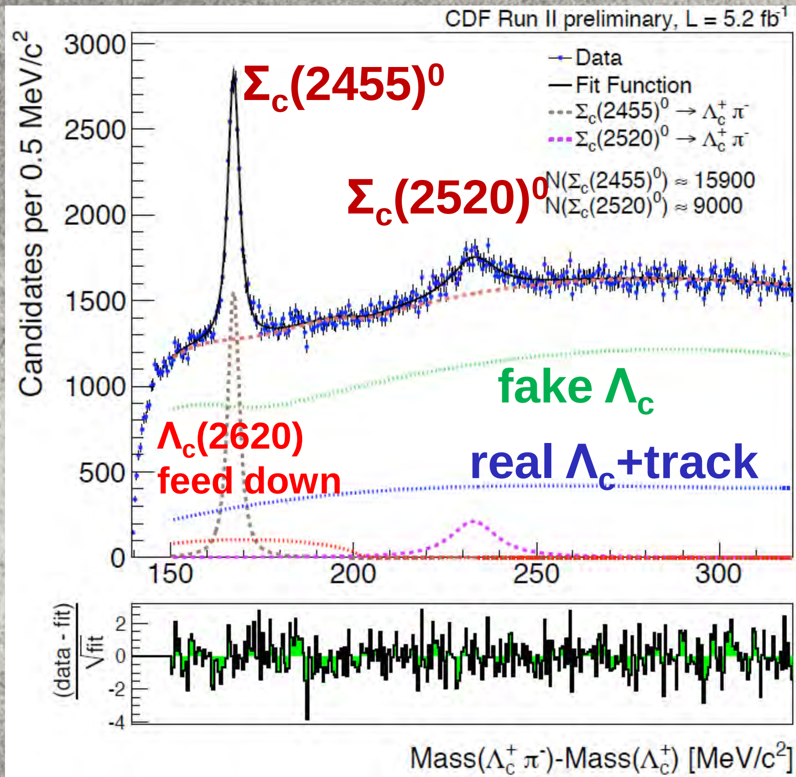


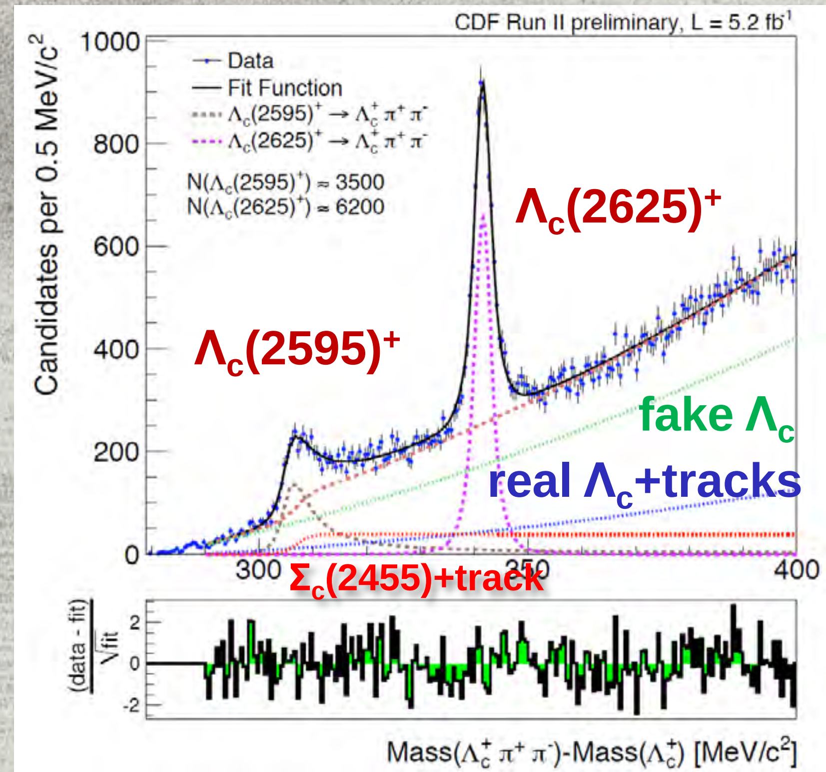




- High statistics >~30xCLEO
- Test for heavy quark symmetry
  - Rich mass spectrum
- $\Lambda_c^+ \rightarrow p^+ K^- \pi^+$: lightest c-baryon
- $\Sigma_c^{0(++)} \rightarrow \Lambda_c^+ \pi^{-(+)}$
- $\Lambda_c^{*+} \rightarrow \Lambda_c \pi^+ \pi^-$

Charm Baryons: Mass Spectrum





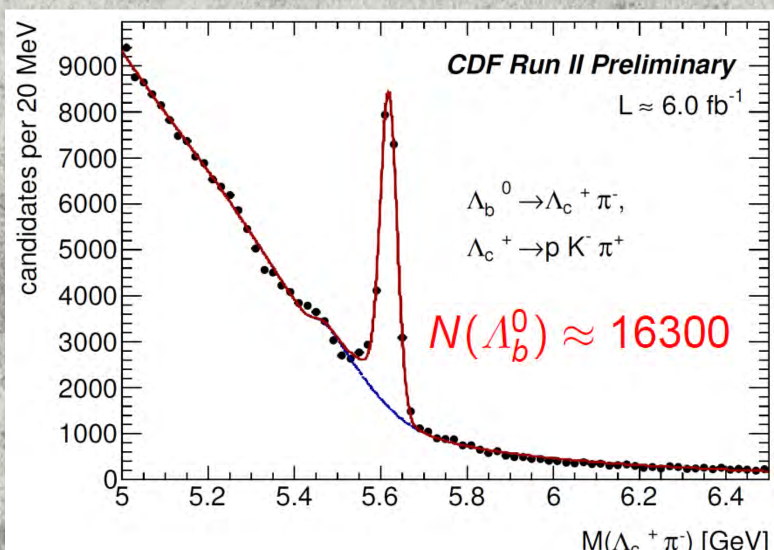
	$m - m(\Lambda_c^+)$[MeV/c^2]	PDG	Γ[MeV/c^2]	PDG
$\Sigma_c(2455)^0$	167.28 ± 0.12	(167.30 ± 0.11)	1.65 ± 0.50	(2.2 ± 0.4)
$\Sigma_c(2455)^{++}$	167.44 ± 0.13	(167.56 ± 0.11)	2.34 ± 0.47	(2.23 ± 0.30)
$\Sigma_c(2520)^0$	232.88 ± 0.46	(231.6 ± 0.5)	12.51 ± 2.28	(16.1 ± 2.1)
$\Sigma_c(2520)^{++}$	230.73 ± 0.58	(231.9 ± 0.6)	15.03 ± 2.52	(14.9 ± 1.9)
$\Lambda_c(2595)^+$	305.79 ± 0.24	(308.9 ± 0.6)(*)	2.59 ± 0.56	$(3.6^{+2.0}_{-1.3})$
$\Lambda_c(2625)^+$	341.65 ± 0.13	(341.7 ± 0.6)	$< 0.97(90\%CL)$	$(< 1.9(90\%CL))$

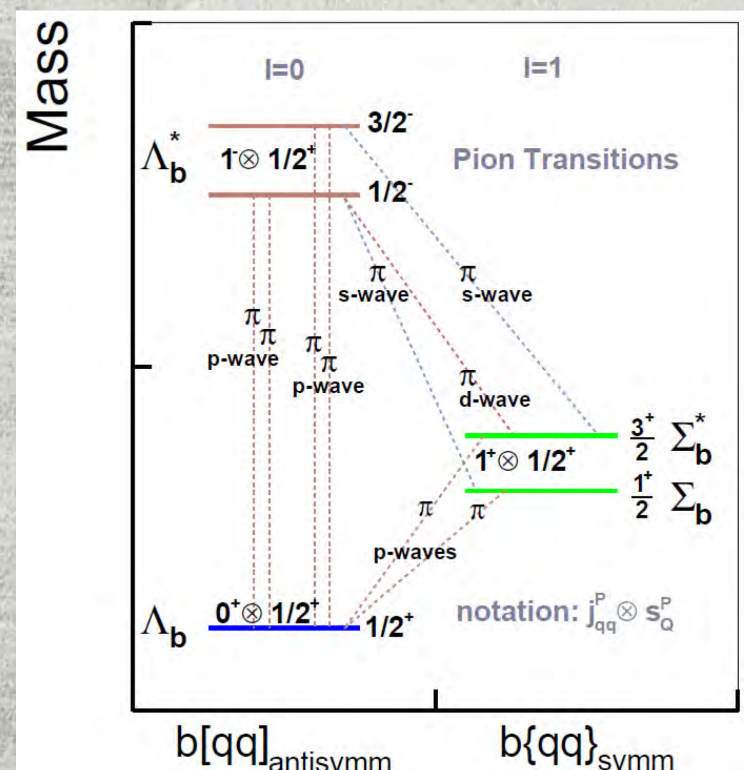
PDG

(*) Due to proper treatment of mass width near threshold

Bottom Baryons: $\Sigma_b^{(*)}$

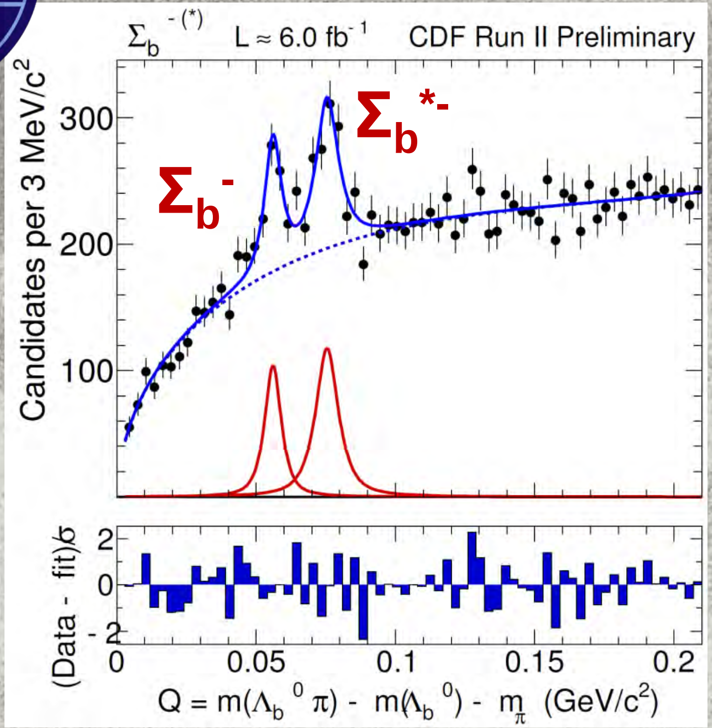
- 2006: Evidence for new bottom baryons (1.1fb^{-1})
  - $\Sigma_b^{(*)\pm} \to \Lambda_b^0 \pi^\pm ; \Lambda_b^0 \to \Lambda_c^+ \pi^- ; \Lambda_c^+ \to pK^- \pi^+$
- Confirm the discovery and measure their resonance properties with 6.0fb^{-1} of data
  - Test various non-perturbative QCD (HQET, potential models…)

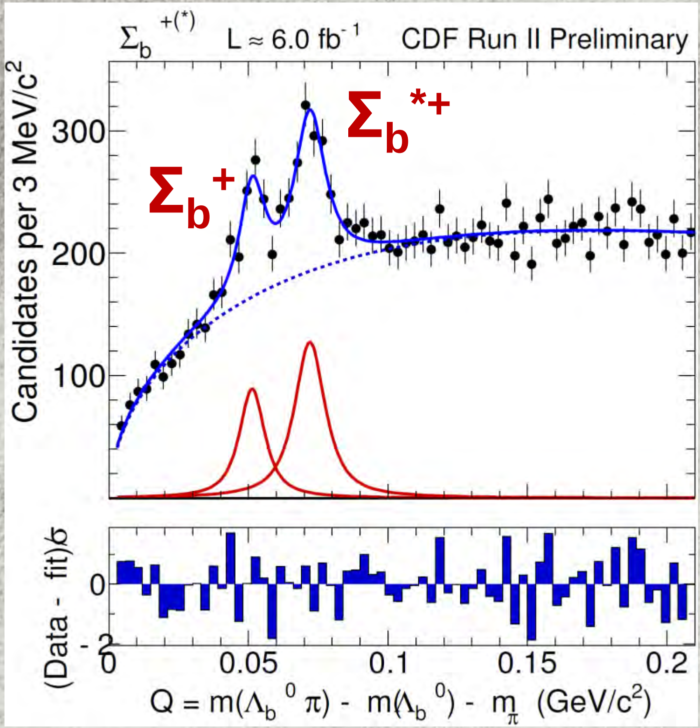




uud,
udb,
ddb

$\Sigma_b^{(*)}$: results





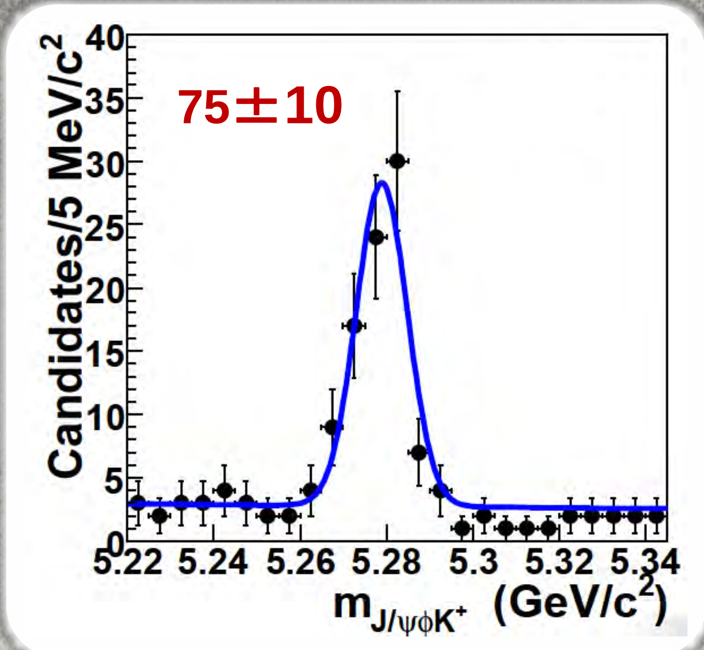
State	M, MeV/c^2	Γ_0, MeV/c^2
Σ_b^+	$5811.2^{+0.9}_{-0.8}\,(\mathrm{stat}) \pm 1.7\,(\mathrm{syst})$	$9.2^{+3.8}_{-2.9}(\mathrm{stat})^{+1.0}_{-1.1}(\mathrm{syst})$
Σ_b^{*+}	$5832.0 \pm 0.7\,(\mathrm{stat}) \pm 1.8\,(\mathrm{syst})$	$10.4^{+2.7}_{-2.2}(\mathrm{stat})^{+0.8}_{-1.2}(\mathrm{syst})$
Σ_b^-	$5815.5^{+0.6}_{-0.5}\,(\mathrm{stat}) \pm 1.7\,(\mathrm{syst})$	$4.3^{+3.1}_{-2.1}(\mathrm{stat})^{+1.0}_{-1.1}(\mathrm{syst})$
Σ_b^{*-}	$5835.0 \pm 0.6\,(\mathrm{stat}) \pm 1.8\,(\mathrm{syst})$	$6.4^{+2.2}_{-1.8}(\mathrm{stat})^{+0.7}_{-1.1}(\mathrm{syst})$

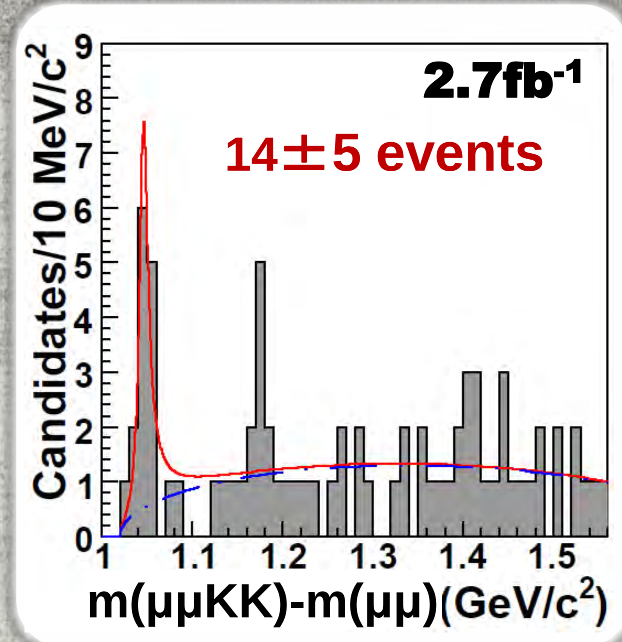
State	ΔM^{+-}, MeV/c^2
$\Sigma_b^+ - \Sigma_b^-$	$-4.2^{+1.1}_{-0.9}(\mathrm{stat})^{+0.07}_{-0.09}(\mathrm{syst})$
$\Sigma_b^{*+} - \Sigma_b^{*-}$	$-3.0 \pm 0.9\,(\mathrm{stat})^{+0.12}_{-0.13}(\mathrm{syst})$

- Established existence of these states
- First measurements of width and isospin mass splitting

Y(4140): Recap

- 2009: Evidence of J/ψφ structure at 4140MeV in exclusive $B^+ \to J/\psi\phi K^+$



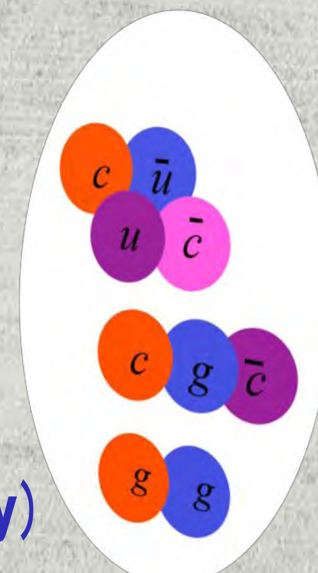


$M = 4143 \pm 2.9 \pm 1.2$MeV

$\Gamma = 11.7^{+8.3}_{-5.0} \pm 3.7$MeV

(above open charm)

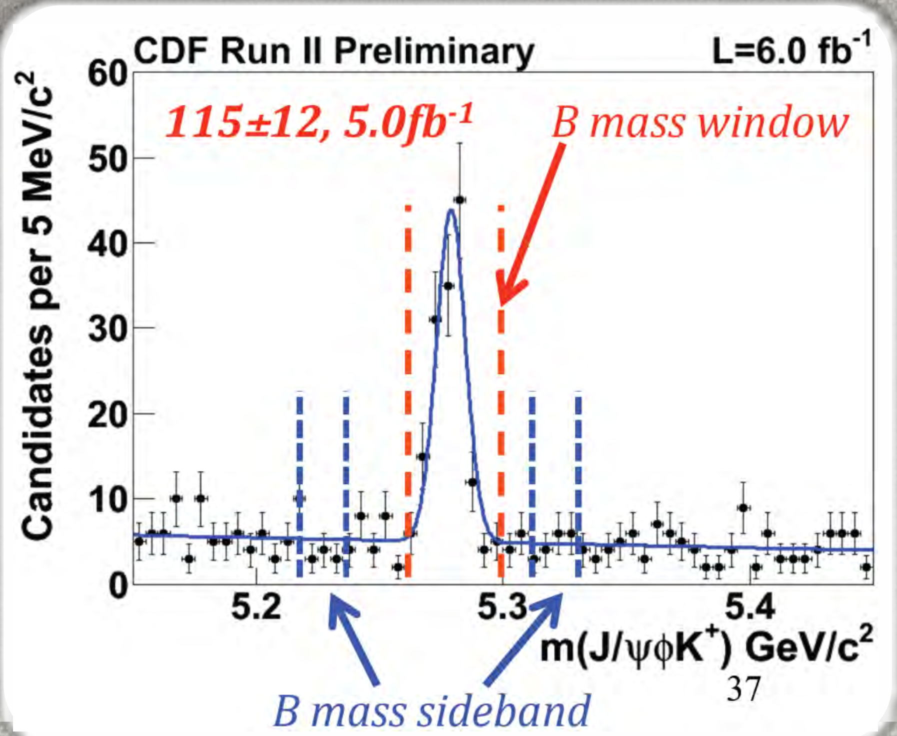
(probably a strong decay)

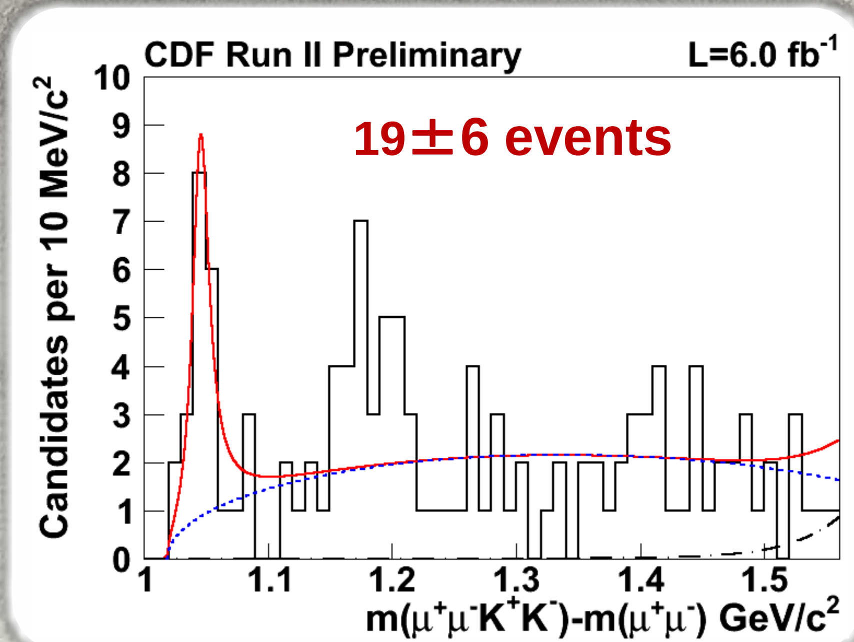


Tetraquark, Charmonium hybrid, Molecule…

Y(4140): Update

- Up to 6.0fb^{-1} with same requirements





$M=4143^{+2.9}_{-3.0}\pm0.6$MeV

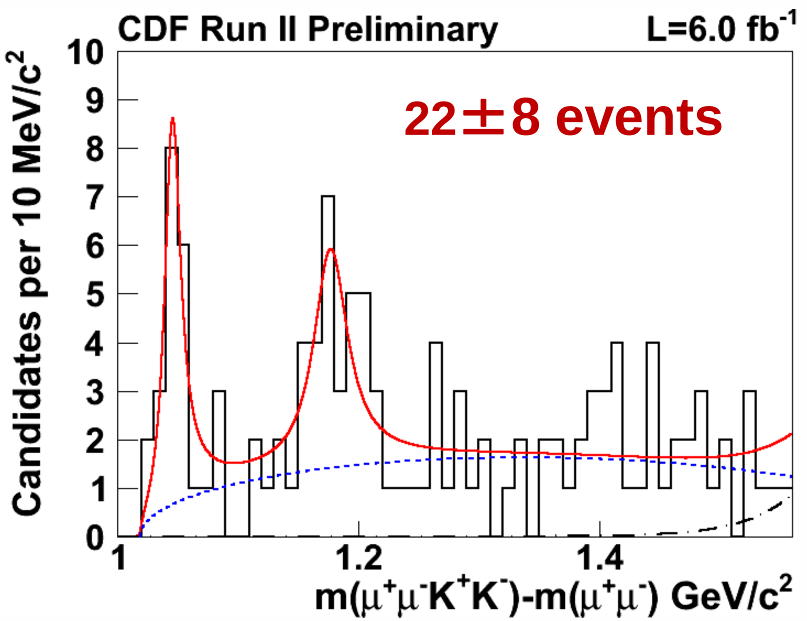
$\Gamma=15.3^{+10.4}_{-6.1}\pm2.5$MeV

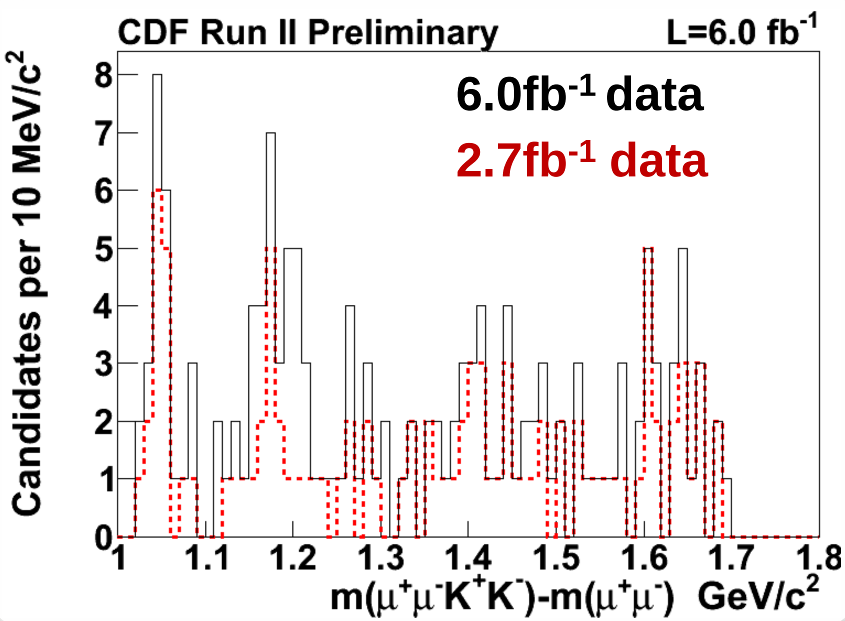
>5 σ significance

1st observation!

Y(4140): And more!

- Suggestive evidence of a second peak





$M=4274^{+8.4}_{-6.7} \pm 1.9$MeV

$\Gamma=32.3^{+21.9}_{-15.3} \pm 7.6$MeV

3.1 σ significance

All done?

All done?

- No! There are many analyses in pipeline
  - A_{SL}
  - $B_s \rightarrow \mu\mu$
  - $B_s \rightarrow D_s D_s$
  - $B \rightarrow K^*\mu\mu$ A_{FB}
  - $B \rightarrow hh$
  - $B_s \rightarrow \phi\phi$
  - Y polarization
  - …

Please look forward winter/spring conferences!


Interesting results...
Coming!

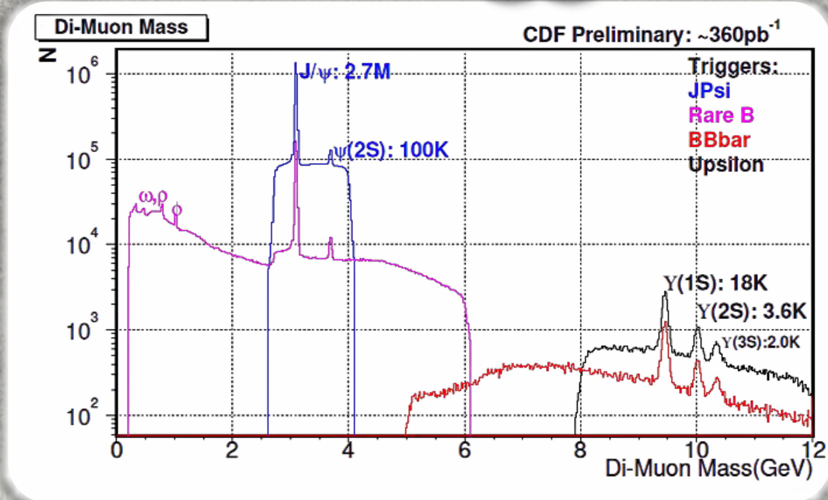
Conclusion

- Tevatron heavy flavor program has reached maturity
  - Tevatron is scheduled to shutdown at the end of FY2011 (Sept. 30)
  - Various important and interesting results are produced and coming in a few months
  - We can still play a game with LHCb and B-factories, especially by well understood detector and symmetric $p\bar{p}$ production

Thank you!

backup

B triggers



Di-Muon

- Conventional trigger at hadron collider
- Wide mass range

2-Displaced tracks

$P_T(trk) > 2$ GeV

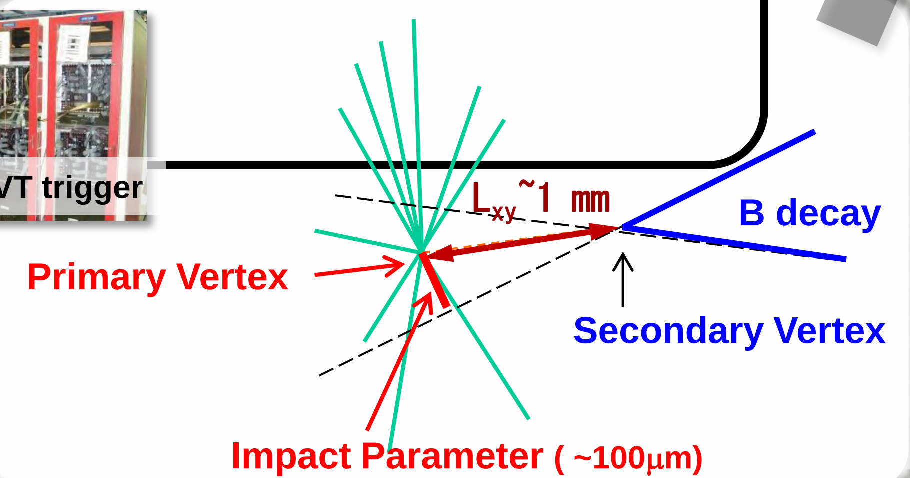
120 μm < I.P.(trk) < 1mm

$\Sigma p_T > 5.5$ GeV

fully hadronic modes

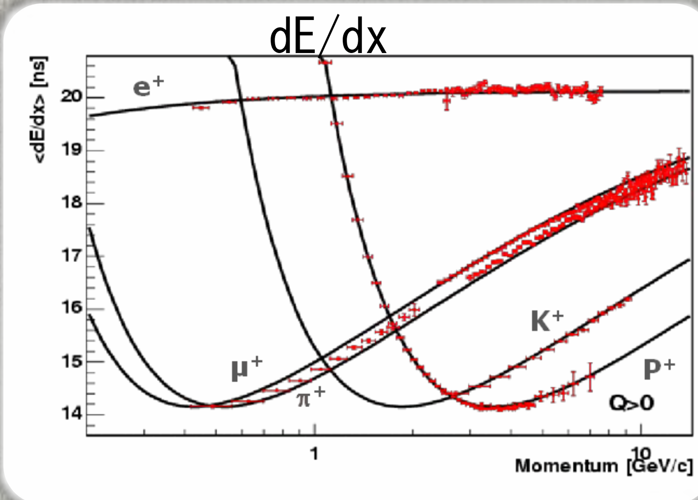
Sillicon Vertex Trigger: SVT

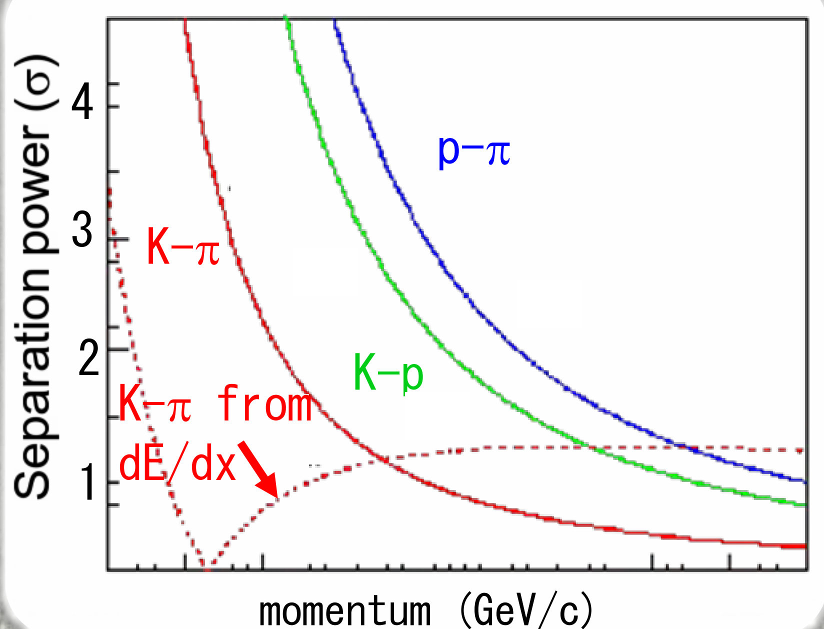
- Online selection of displaced tracks
- **UNIQUE** at hadron colliders

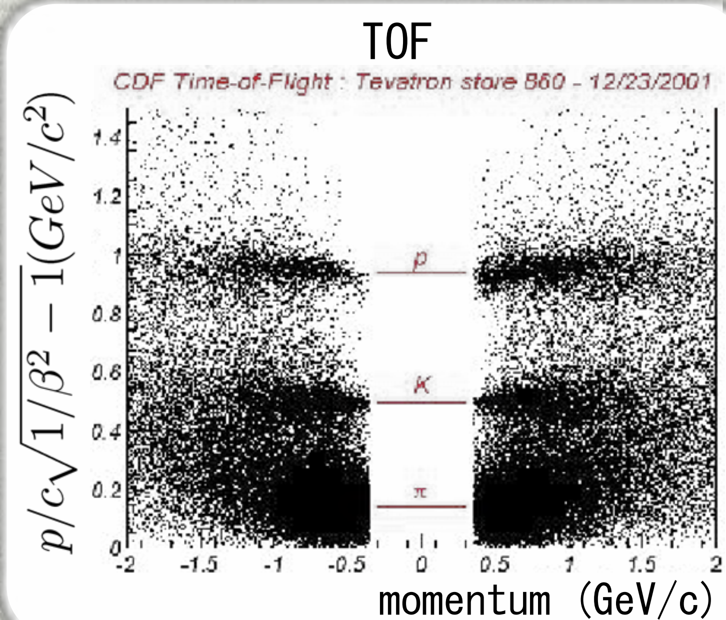


Particle Identification

- **Separate kaons from pions**
  - dE/dx gives 1.5σ separation for p>2 GeV
  - TOF gives better separation at low p
- **Used for:**
  - Kaon/pion separation
  - Electron tagging

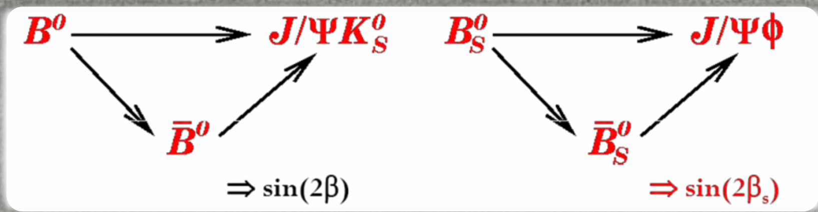






CP violation in $B_s \to J/\psi\varphi$

- Analogously to the neutral B^0 system, CP violation in B_s system occurs through interference of decays with and without mixing:

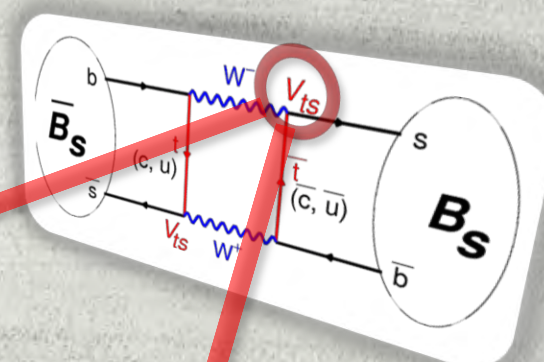


$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

B_s Mass eigenstates: B_s^L, B_s^H

Mass difference $\Delta m_s = m_H - m_L \sim 2|M_{12}|$

Width difference $\Delta\Gamma_s = \Gamma_L - \Gamma_H \sim 2|\Gamma_{12}| \cos\phi_s$



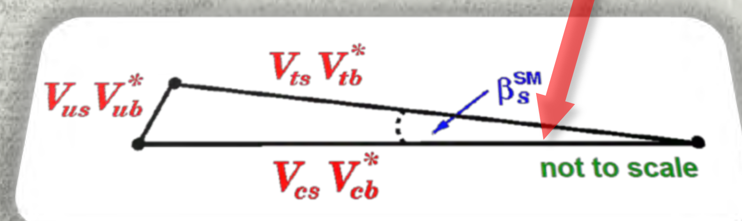
CPV phase between B_s mixing and $B_s \to J/\psi\varphi$ decay:

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

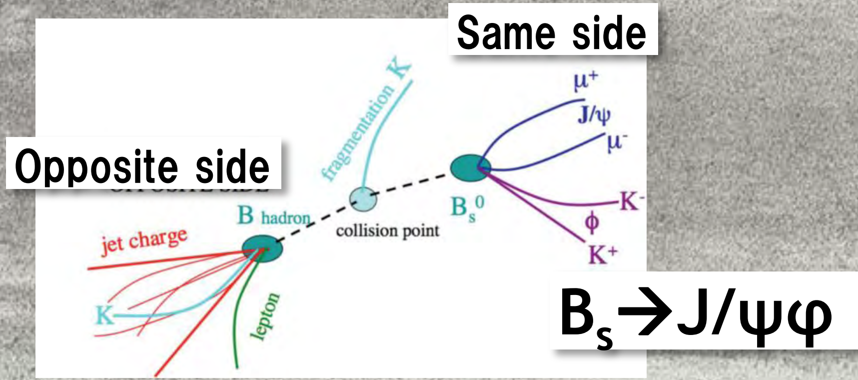
A. Lenz and U. Nierste, JHEP 06, 072(2007)

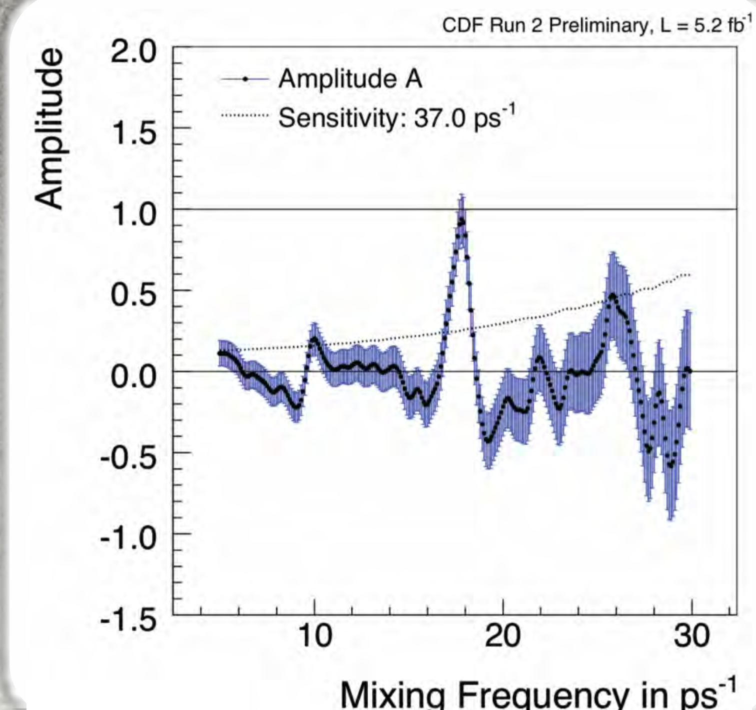
If $\varphi_s^{NP} \gg \beta_s^{SM}$:

$$-2\beta_s \sim \phi_s^{NP}$$



B_s flavor tagging

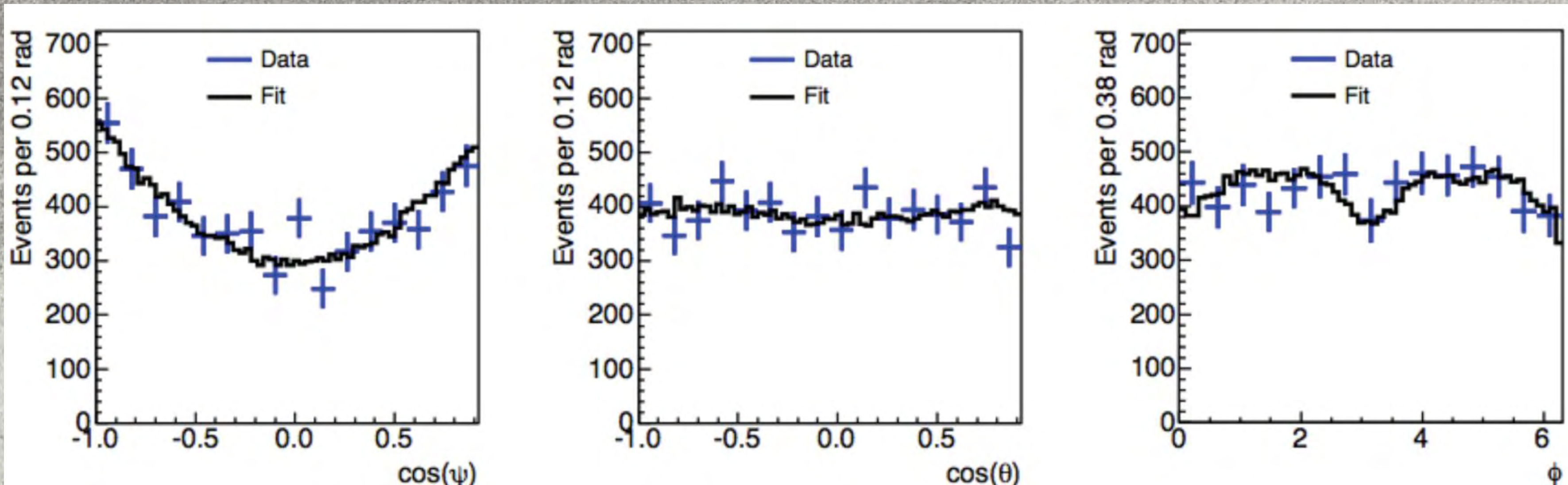




- Need to know B_s flavor since $B_s \to J/\psi\varphi$ decays into CP eigenstate
- Tag same side (εD^2~3.2%) or opposite side (εD^2~1.2%) events based on jet/track charge
- Test the performance with B_s-B_s oscillation ($5.2 fb^{-1}$):
  - Mixing amplitude A~1 indicates accurate flavor tagging
  - Consistent with past publications

$$\mathcal{A} = 0.94 \pm 0.15\ (\text{stat.}) \pm 0.13\ (\text{syst.})$$

$$\Delta m_s = 17.79 \pm 0.07\ ps^{-1}$$



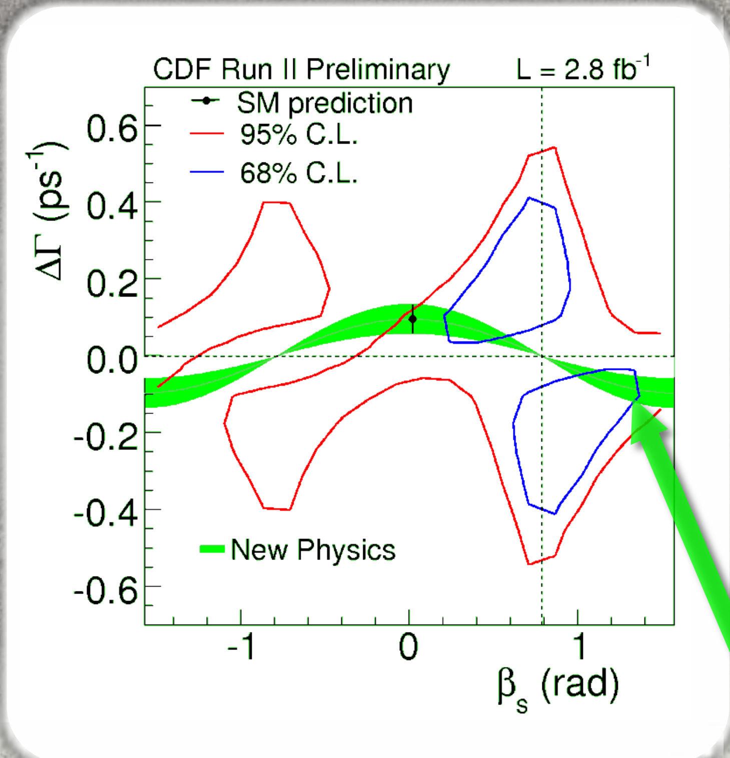
$$
\begin{aligned}
|A_{\parallel}(0)|^2 &= 0.231 \pm 0.014\ (\text{stat}) \pm 0.015\ (\text{syst.}) \\
|A_0(0)|^2 &= 0.524 \pm 0.013\ (\text{stat}) \pm 0.015\ (\text{syst.}) \\
\phi_{\perp} &= 2.95 \pm 0.64\ (\text{stat}) \pm 0.07\ (\text{syst.})
\end{aligned}
$$

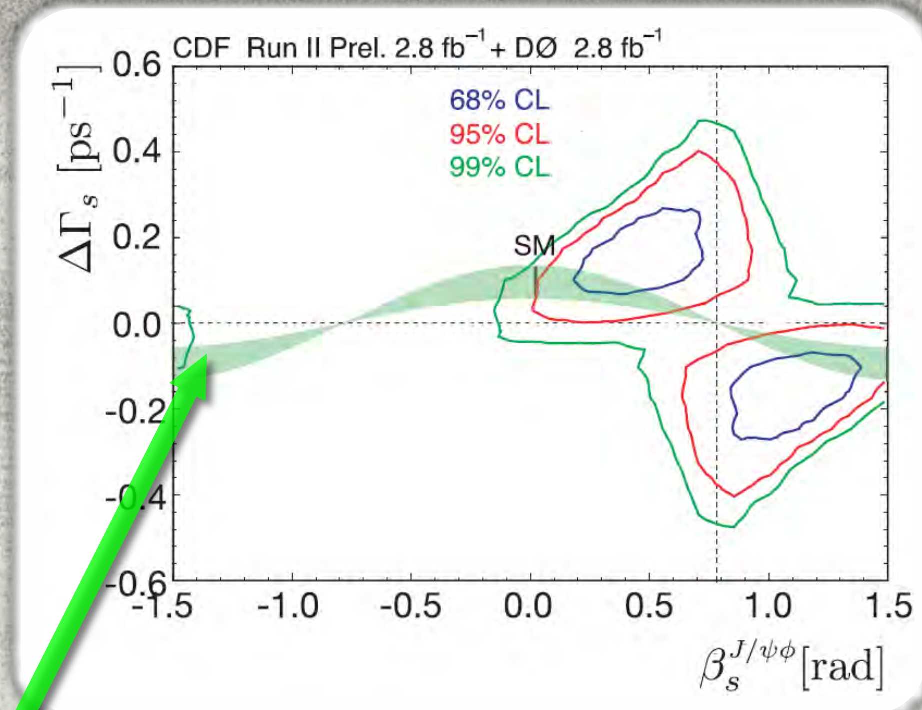
β_s results@2.8fb^{-1}

CDF note 9458 (2.8fb^{-1})

PRL100,161802 (2008) (1.35fb^{-1})

DØ note 5928, CDF note 9787





SM p-value=7%

$\Delta\Gamma_s = 2|\Gamma_{12}|\cos\phi_s$

SM p-value=3.4%

1.8σ deviation from SM

2.1σ deviation from SM

ADS parameters

Observables

$$R_{ADS}(K) = \frac{N(B^- \to D^0_{DCS}K^-) + N(B^+ \to D^0_{DCS}K^+)}{N(B^- \to D^0_{CF}K^-) + N(B^+ \to D^0_{CF}K^+)}$$

$$\mathcal{A}_{ADS}(K) = \frac{N(B^- \to D^0_{DCS}K^-) - N(B^+ \to D^0_{DCS}K^+)}{N(B^- \to D^0_{DCS}K^-) + N(B^+ \to D^0_{DCS}K^+)}$$

$D^0_{CF} \to K^-\pi^+$, $D^0_{DCS} \to K^+\pi^-$

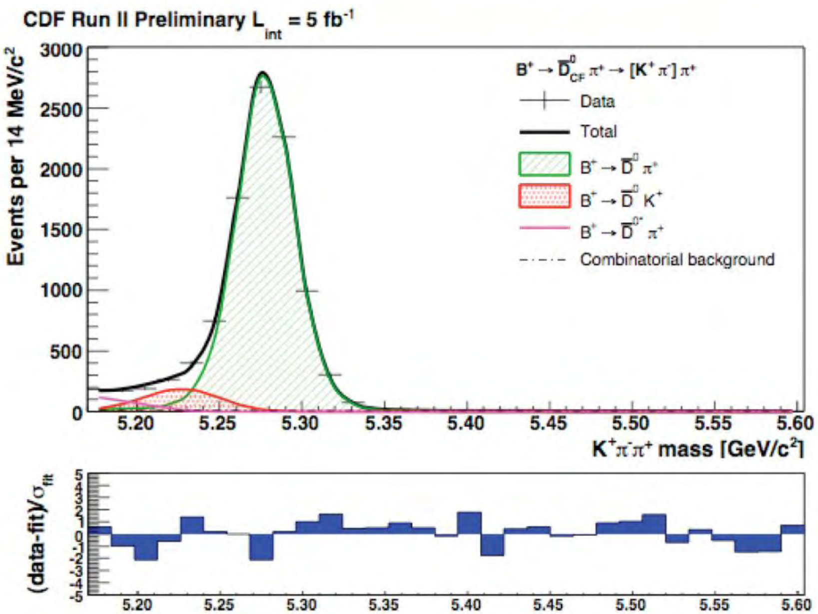
From theory:

$R_{ADS}(K) = r_D^2 + r_B^2 + 2r_B r_D \cos(\delta_B+\delta_D) \cos\gamma$

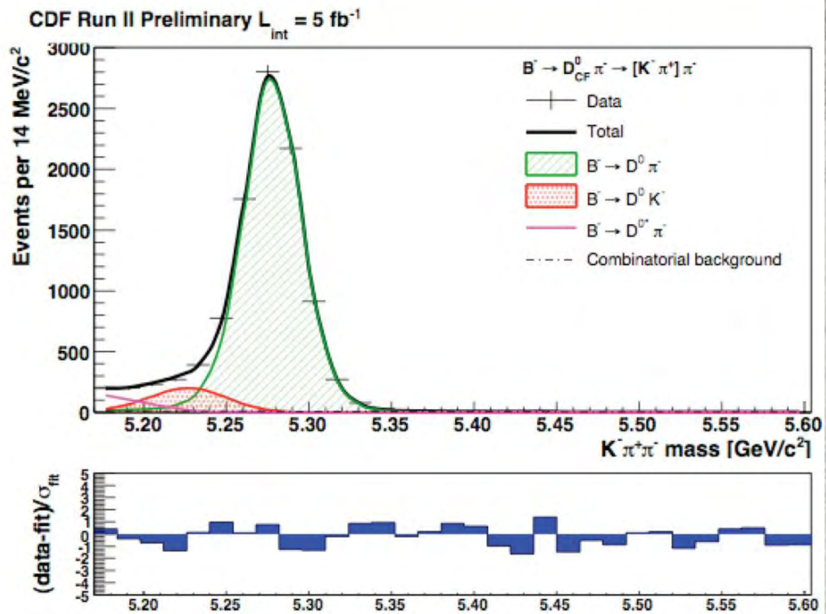
$A_{ADS}(K) = 2r_B r_D \sin(\delta_B+ \delta_D)\sin\gamma/R_{ADS}(K)$

B→Dh: CF

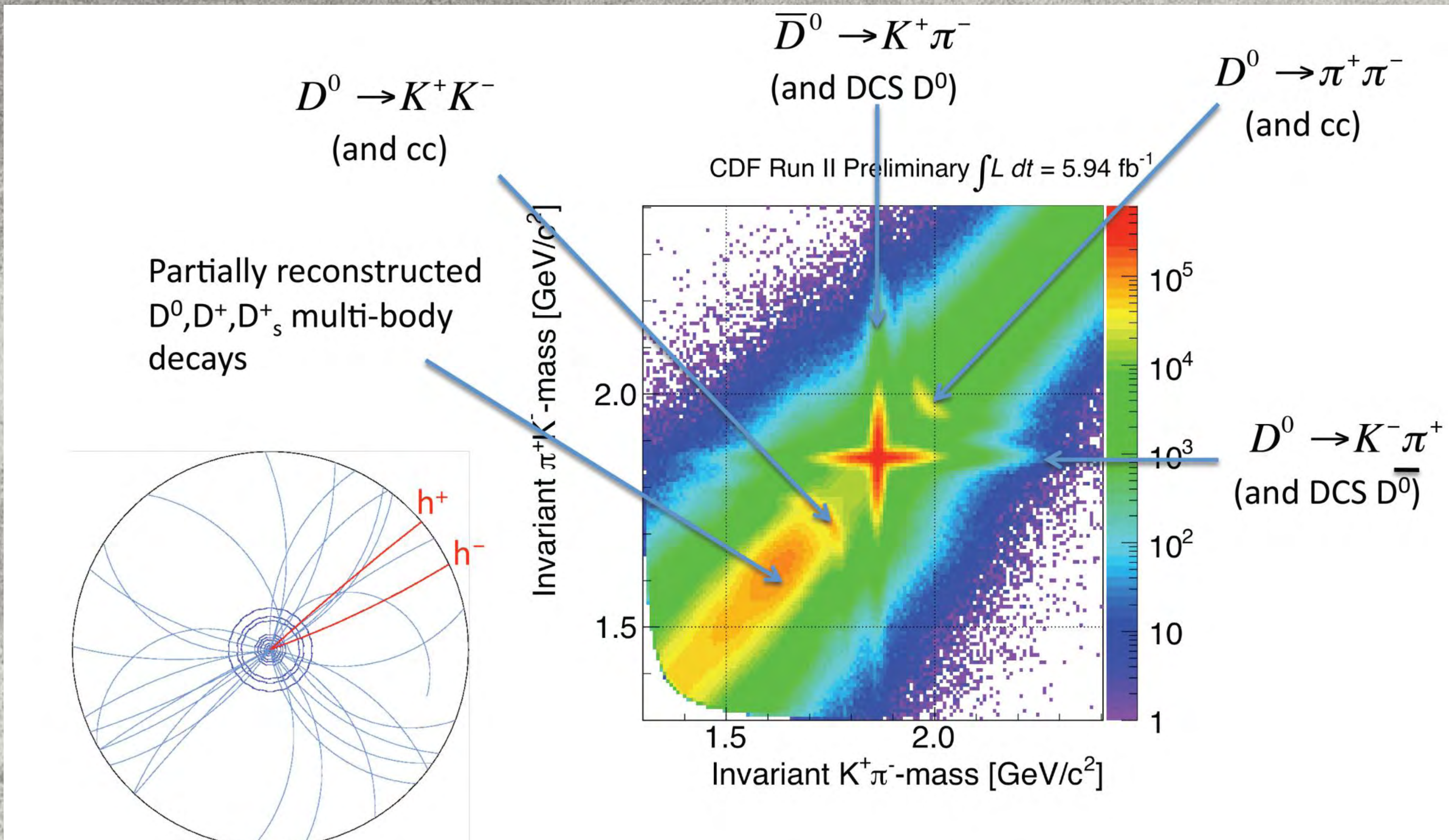
$B^+ \to \bar{D}^0_{CF}\,\pi^+ \to [K^-\pi^+]\,\pi^+$



$B^- \to D^0_{CF}\,\pi^- \to [K^+\pi^-]\,\pi^-$



Yield ($B \to D_{CF}K$) = 1513 ± 68 (5 fb^{-1})
Yield ($B \to D_{CF}\pi$) = 17677 ± 146 (5 fb^{-1})


$\overline{D}^0 \to K^+\pi^-$
(and DCS D⁰)
$D^0 \to K^+K^-$
(and cc)
$D^0 \to \pi^+\pi^-$
(and cc)
CDF Run II Preliminary $\int L\,dt = 5.94\ fb^{-1}$
Partially reconstructed
D^0,D^+,D^+_s multi-body
decays
$D^0 \to K^-\pi^+$
(and DCS $\overline{D^0}$)
h⁺
h⁻
Invariant π^+K^--mass [GeV/c²]
Invariant $K^+\pi^-$-mass [GeV/c²]
1.5
2.0
1.5
2.0
10^5
10^4
10^3
10^2
10
1

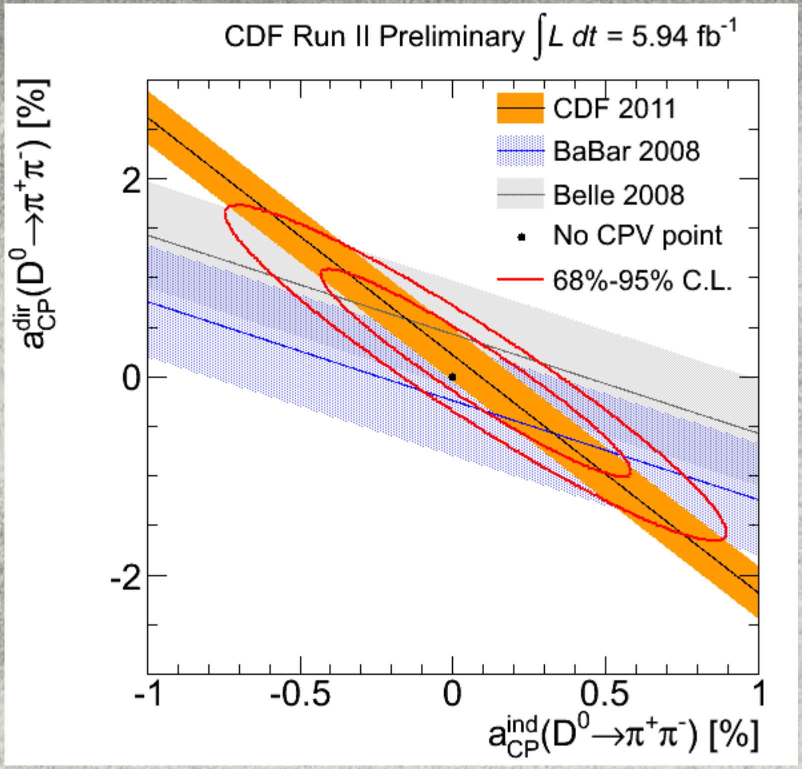
$$A_{CP}^{raw}(\pi\pi^*) = (-1.86 \pm 0.23)\%$$

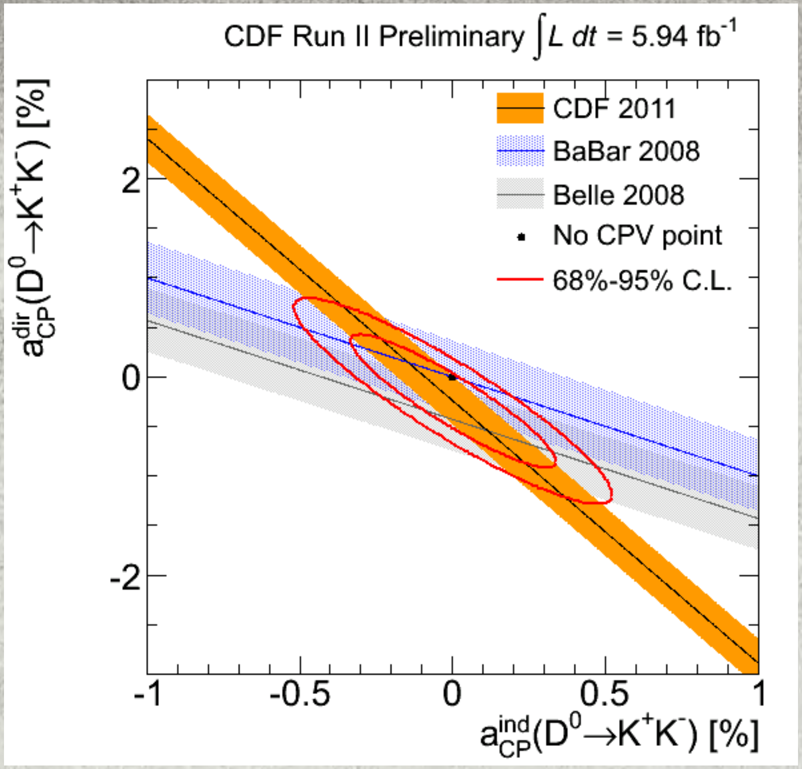
$$A_{CP}^{raw}(K\pi^*) = (-2.91 \pm 0.05)\%$$

$$A_{CP}^{raw}(K\pi) = (-0.83 \pm 0.03)\%$$

$$A_{CP}(D^0 \to \pi^+\pi^-) = (+0.22 \pm \underbrace{0.24}_{\text{stat}} \pm \underbrace{0.11}_{\text{syst}})\%$$

- BaBar on 386 fb^{-1} [−0.24 ± 0.52 ± 0.22]% PRL 100, 061803 (2008)
- Belle on 540 fb^{-1} [−0.43 ± 0.52 ± 0.12]% PLB 670, 190 (2008)
- CDF on 120 pb^{-1} [+1.0 ± 1.3 ± 0.6]% PRL 94, 122001 (2005)



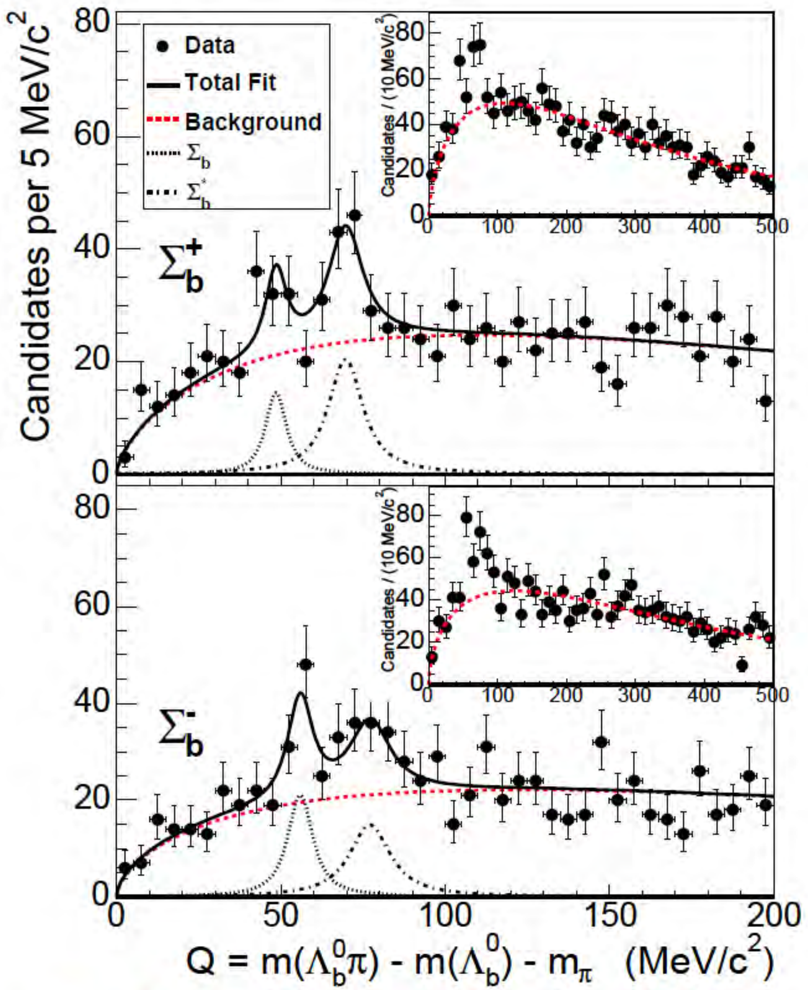


At CDF : $\langle t\rangle \approx [2.40 \pm 0.03]\,\tau$

While at B-factories $\langle t\rangle = \tau$

2.65(KK)

Discovery of $\Sigma_b^{(*)}$



- PRL **99**, 202001 (2007)
- *SPIRES topcite 50+ paper*