CDFでのBの物理

筑波大学素粒子実験研究室
三宅秀樹

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Introduction

- Tevatron as “Hadronic” B-factory
  - SM、BSMに迫るユニークな実験場
    - BSM直接探索やe^+e^- B-factoryと相補的

- あらゆるbハドロンが生成 (B^0, B^+, B_s, B_c, Λ_b, Σ_b, etc…)

- 新粒子発見から精密測定まで、多種多様なプログラム
- データ量増大中…まさに今が旬

- e^+e^- B-factoryの約1000倍のbハドロン生成断面積
  - 但しQCD背景事象はその1000倍
    - ルミノシティに応じたトリガーの改良がカギ

Topics

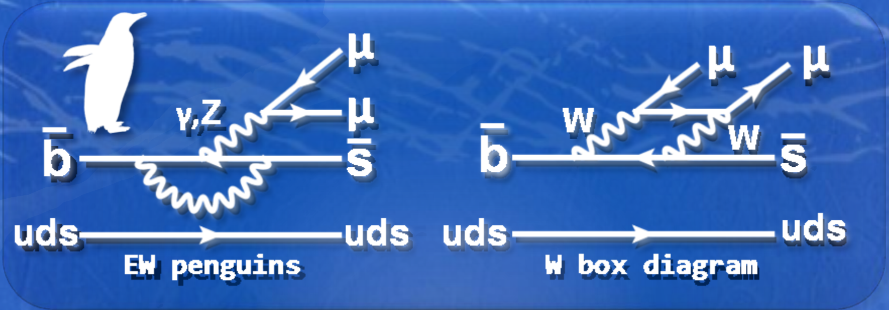
- 本年度の成果より、かいつまんで…
  - **B中間子希少崩壊（崩壊分岐比、A_{FB}）**
    - $B \to K^{(*)} \mu\mu$, $B_s \to \phi\mu\mu$, $B_{(s)} \to \mu\mu$
  - **CP非対称度測定（β_s）**
    - $B_s \to J/\psi\phi$
  - **bハドロン解析（質量、寿命、偏極度）**
    - Ω_b, $\Upsilon(1s)$

don't cover…$B_s \to \phi\phi$, Λ_b and so on

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

希少崩壊

$B\to K^{(*)}\mu\mu$, $B_s\to\phi\mu\mu$



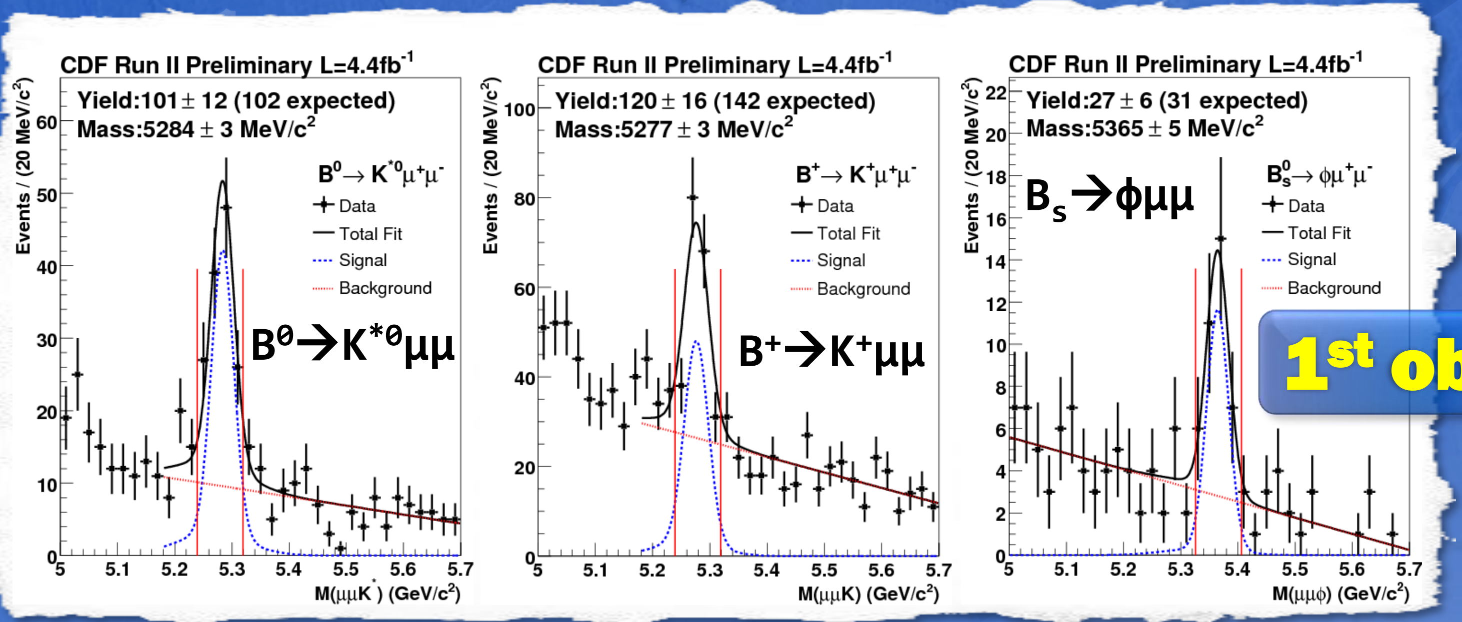
- $b\to sll$ FCNC
  - New Physicsに敏感
    - BR, A_{FB}…

$BR(B^0\to K^{*0}\mu\mu)$
$=[1.06\pm0.14(stat)\pm0.09(syst)]\times10^{-6}$

$BR(B^+\to K^+\mu\mu)$
$=[0.38\pm0.05(stat)\pm0.03(syst)]\times10^{-6}$

$BR(B_s\to\varphi\mu\mu)$
$=[1.44\pm0.33(stat)\pm0.46(syst)]\times10^{-6}$

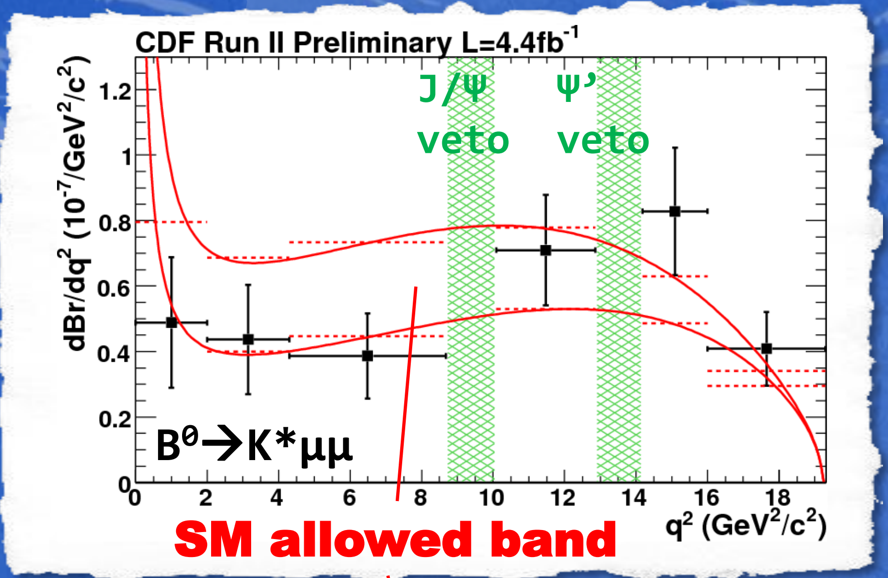
- これまでに観測された中で
  最も希少なB_s中間子崩壊の発見



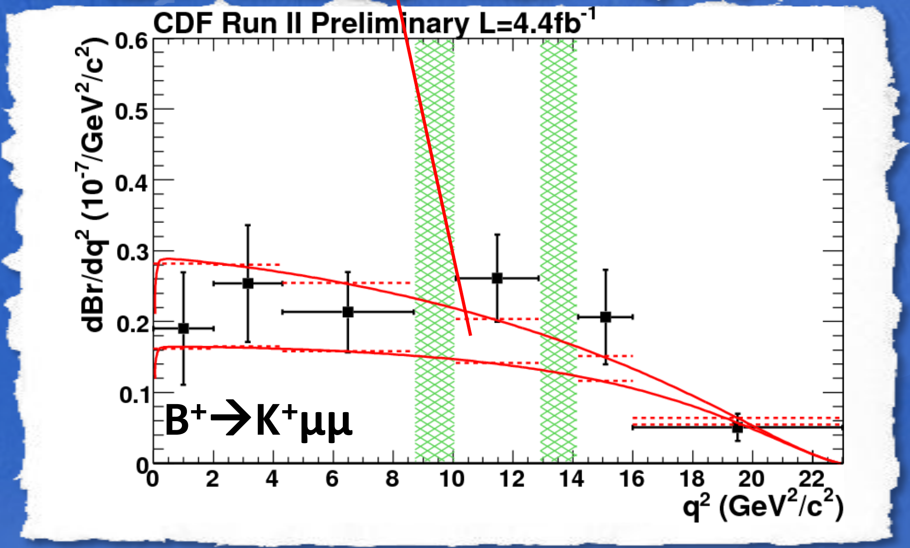
1st observation!

統計有意度~6σ

$B \rightarrow K^{(*)} \mu \mu$: differential BR



SM allowed band



運動量移行の二乗(q^2)の関数で崩壊率を見る

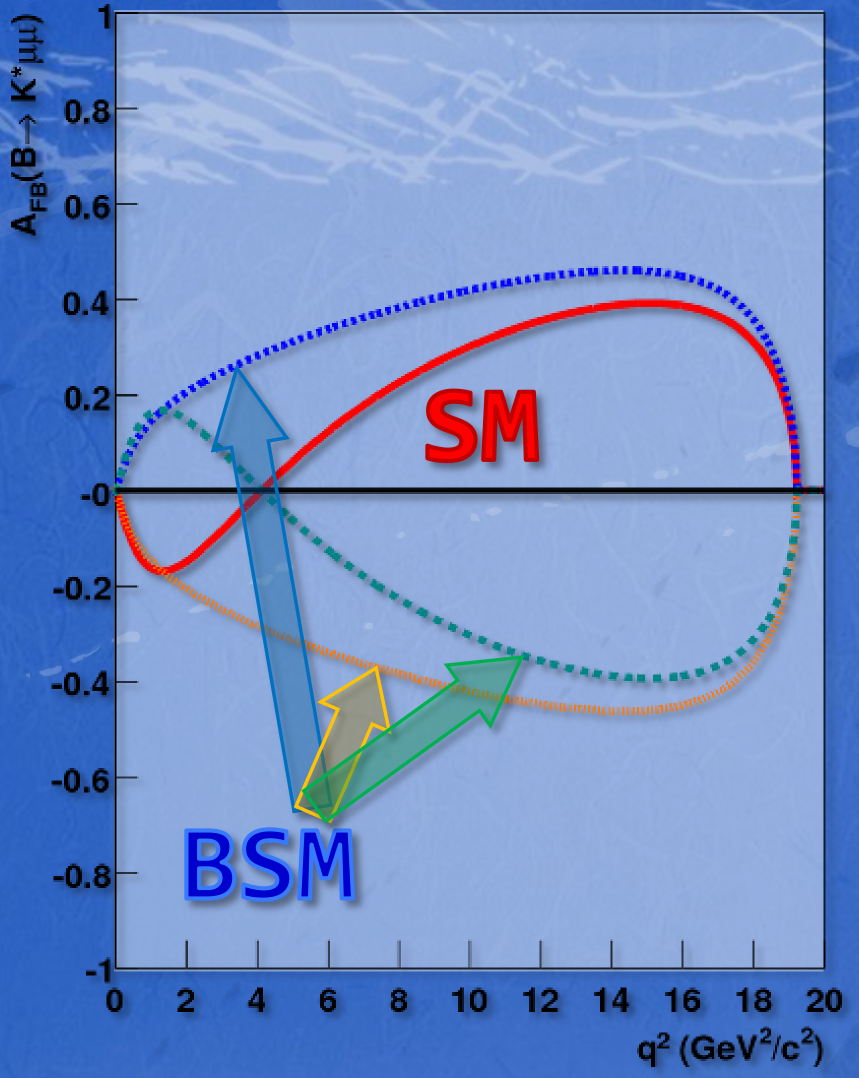
但し $q^2 = M_{\mu\mu}{}^2$

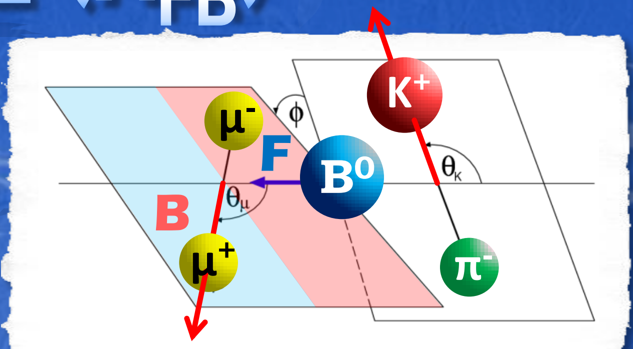
- より細密な理論構造の検証

6個のq^2 binでそれぞれ崩壊率を測定
(binの定義はBelleと同じ)

- SMと矛盾しない
- B-factory実験とも矛盾せず、同等の感度を示す
  - BaBar, PRL102:091803 (2009)
  - Belle, PRL103:171801 (2009)

ミューオン前後方非対称性 (A_{FB})





$B^0 \to K^{*0}\mu\mu$ decay plane

Forward-Backward Asymmetry :

$$A_{FB}(q^2) \equiv \frac{\Gamma(q^2, \cos\theta_\mu > 0) - \Gamma(q^2, \cos\theta_\mu < 0)}{\Gamma(q^2, \cos\theta_\mu > 0) + \Gamma(q^2, \cos\theta_\mu < 0)}$$

- 比を取る事で、
理論の不定性をキャンセル
- BSMの影響を敏感に反映

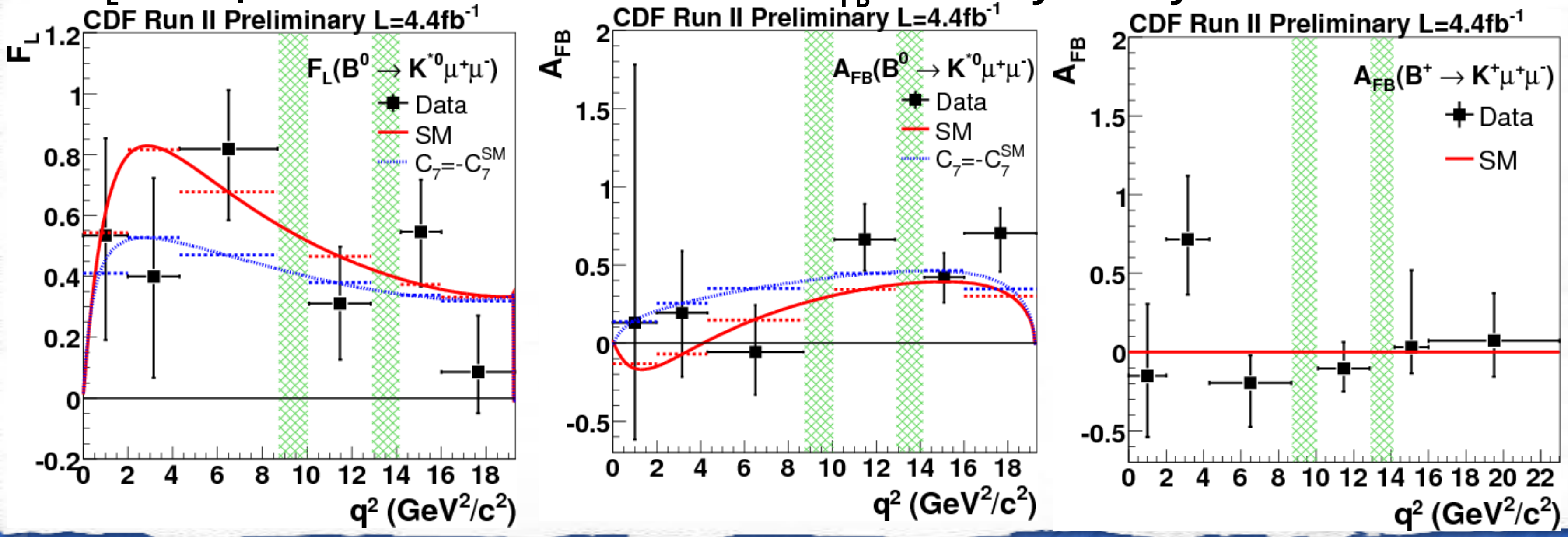
→BSM探索の有望なプローブ

Kμμの場合, $A_{FB}(K\mu\mu) \sim 0$

A_{FB} (B→$K^{(*)}$ μμ)

F_L: K* polarization

A_{FB}: FB asymmetry



$$\frac{3}{2}\boxed{F_L}\cos^2\theta_K+\frac{3}{4}(1-\boxed{F_L})(1-\cos^2\theta_K)$$

$$\frac{3}{4}F_L(1-\cos^2\theta_\mu)+\frac{3}{8}(1-F_L)(1+\cos^2\theta_\mu)+\boxed{A_{FB}}\cos\theta_\mu$$

F_L=1 for Kμμ

- B-factory実験と矛盾せず、同等の感度を示す:
  BaBar 384M BB, PRD79,031102(R) (2009) and
  Belle 657M BB, PRL103,171801(2009)

統計量の向上がカギ
→解析の改良を予定

- SM及びBSMの一例とも矛盾しない
- **三実験とも同様の傾向がみられており、非常に興味深い**

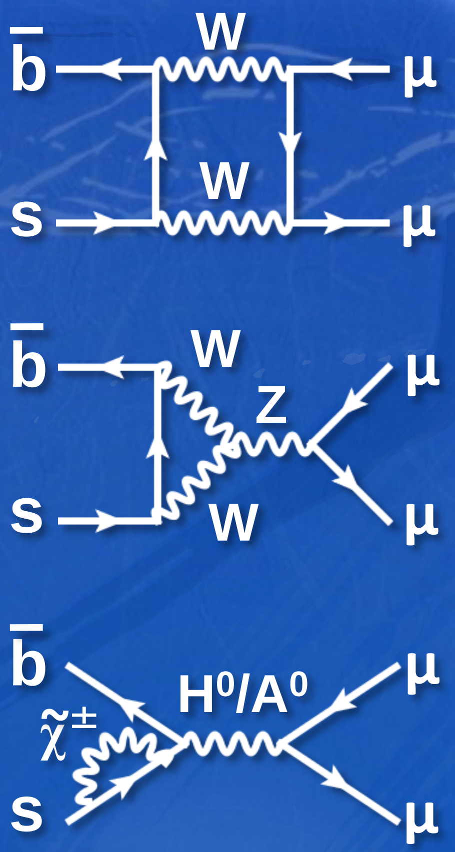
$B_{s,d} \rightarrow \mu\ \mu$

- SMにおいて極めて強く抑制

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

A. J. Buras, arXiv:0904.4917v1

- 様々なNPモデルがBRの亢進を予言
  - 特にMSSM large tan β ～BR∝ (tanβ) ^{6}
  - 逆にNPモデルのパラメータ空間に対する強力な制限を与える



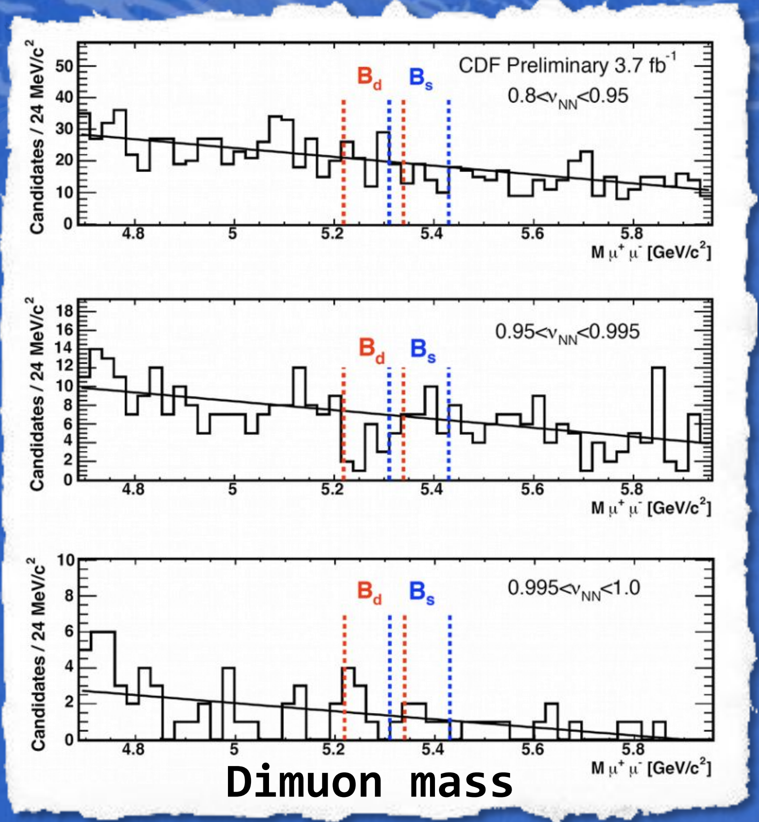
✓Current world's best upper limit:

✓BR(B_s→μμ)<4.7(5.8)x10^{-8}

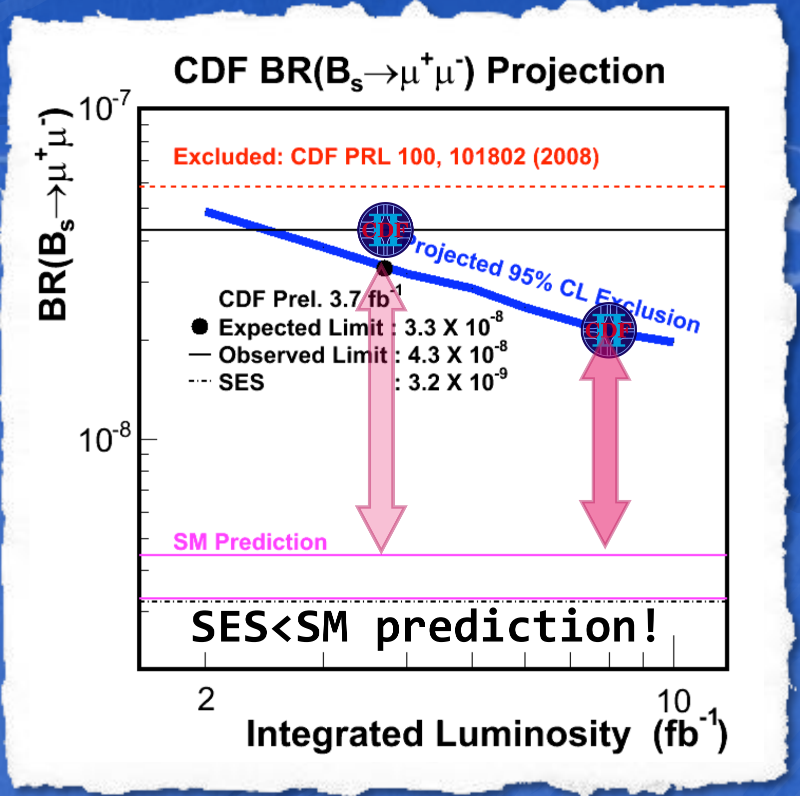
✓BR(B_d→ μμ)<1.5(1.8)x10^{-8} 90(95)% C.L.

PRL 100,101802 (2008)

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



Dimuon mass



SES<SM prediction!

- ✓ Preliminary @3.7fb^{-1} (CDF public note 9892)
  - ✓ BR($B_s \rightarrow \mu\mu$)<3.6(4.3) x10^{-8} 90%(95%)C.L.
  - ✓ BR($B_d \rightarrow \mu\mu$)<6.0(7.6) x10^{-9} 90%(95%)C.L.

- □ **既に実験感度はSM予言値に到達**
  （limitは背景事象で制限）
  - □ NP事象が見え出す可能性

- □ 2010年度にSMの6倍、D0とのcombinationで4～5倍程度の分岐比測定を期待

CPの破れ

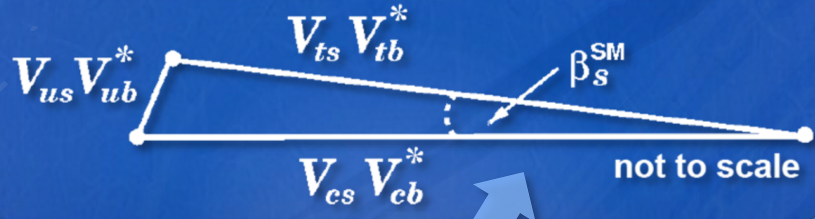
B_s中間子系におけるCP非対称度測定

$B\bar{B}$混合に誘起される、時間に依存したCPの破れ～same as $B^0\rightarrow J/\psi K_s$

$$\begin{tikzcd}
B^0 \arrow[rr] \arrow[dr] & & J/\Psi K^0_S \\
& \bar{B}^0 \arrow[ur] &
\end{tikzcd}
\qquad
\begin{tikzcd}
B^0_S \arrow[rr] \arrow[dr] & & J/\Psi\phi \\
& \bar{B}^0_S \arrow[ur] &
\end{tikzcd}$$

$\Rightarrow \sin(2\beta)$ $\Rightarrow \sin(2\beta_s)$

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



B_s中間子質量固有状態: B_s^L, B_s^H

質量差: $\Delta m_s = m_H - m_L \sim 2|M_{12}|$

崩壊幅差: $\Delta\Gamma_s = \Gamma_L - \Gamma_H \sim 2|\Gamma_{12}|\cos\phi_s$

CP非保存位相:

$$\phi_s = \arg(-\frac{M_{12}}{\Gamma_{12}})$$

β_s

$\phi_s^{SM} \sim 0.004$

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

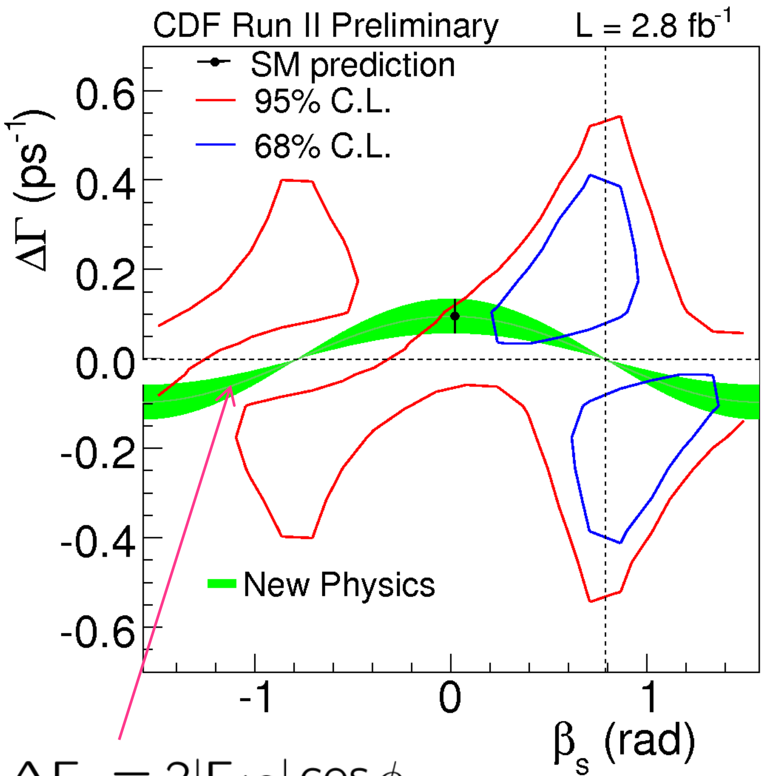
A. Lenz and U. Nierste, JHEP 06, 072(2007)

- ϕ_s^{NP} はϕ_sとβ_sの両方に寄与する

$-2\beta_s = -2\beta_s^{SM} + \phi_s^{NP}$ If φ_s^{NP} dominates : $-2\beta_s \sim \phi_s^{NP}$

大きなCP位相の測定→NPの発見及びCP位相の決定

CDF β_s result@2.8fb^{-1}



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

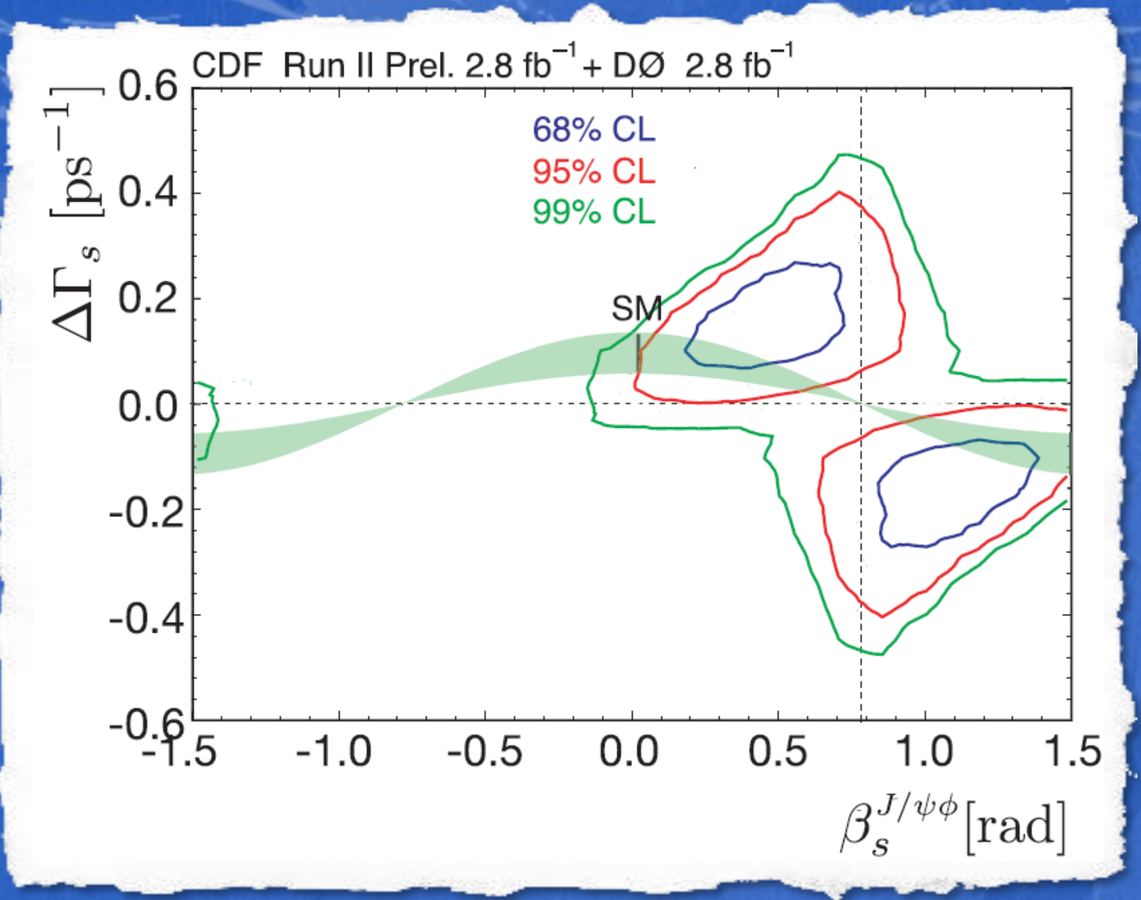
CDF note 9458
(2.8fb^{-1})

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

SM p-value=7%

標準理論からのずれ: 1.8σ

Tevatron combination



DØ note 5928,
CDF note 9787

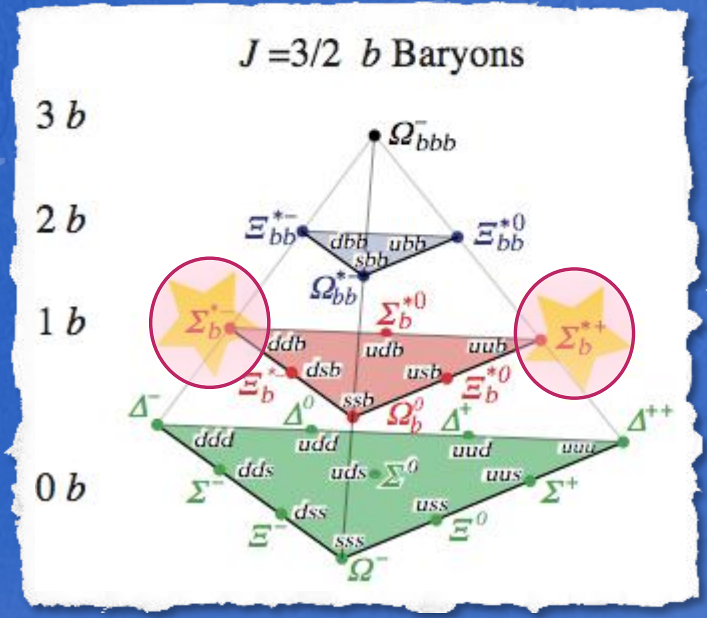
Combined likelihood finds 2.1σ deviation from SM

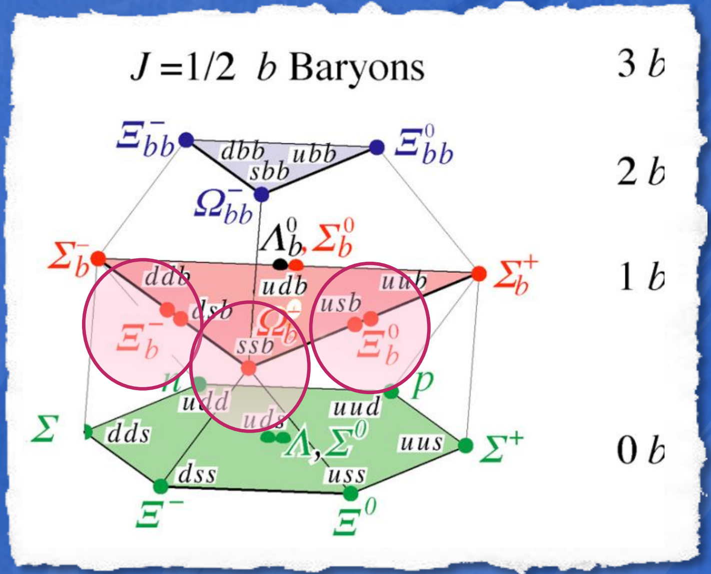
データ量を増やした解析が両実験で進行中…
乞うご期待

bハドロン

Bottom baryons

- Bottom spectroscopyはここ数年で急速に発展
  - 2006 $\Sigma_b^{(*)+}$ and $\Sigma_b^{(*)-}$
  - 2007 Ξ_b^-
  - 2008 Ω_b^-
- 発見から各種性質（質量、寿命…）の測定へ





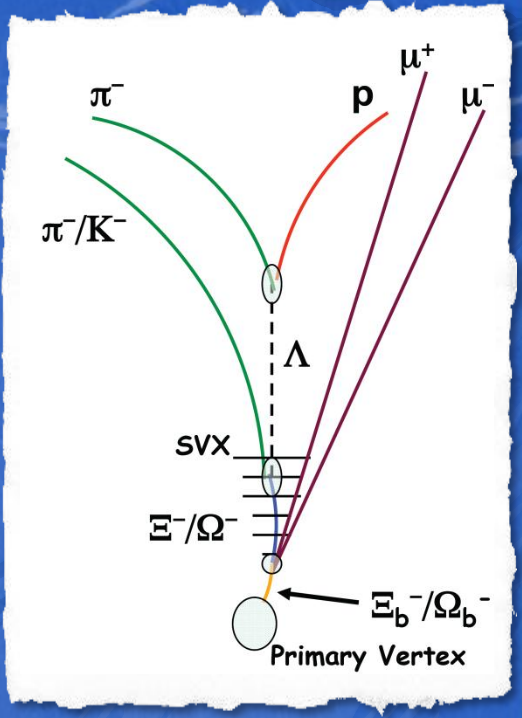
$\Omega_b \to J/\Psi\,\Omega$, $\Xi_b \to J/\Psi\,\Xi$

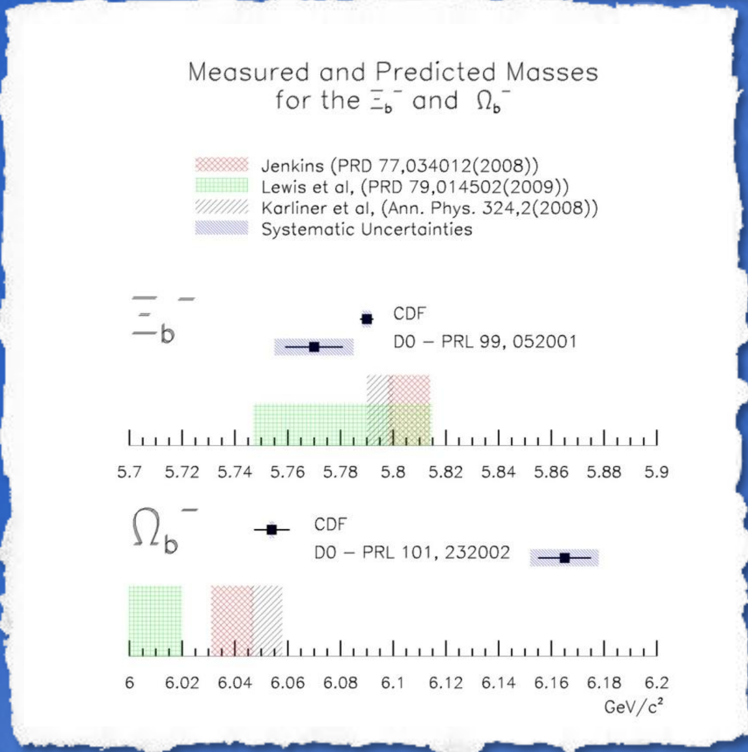
- D0は18 Ω_b（15 Ξ_b）事象を観測@1.3fb^{-1}
  - 質量: 6165±10±13（5774±11±15）MeV/c^2

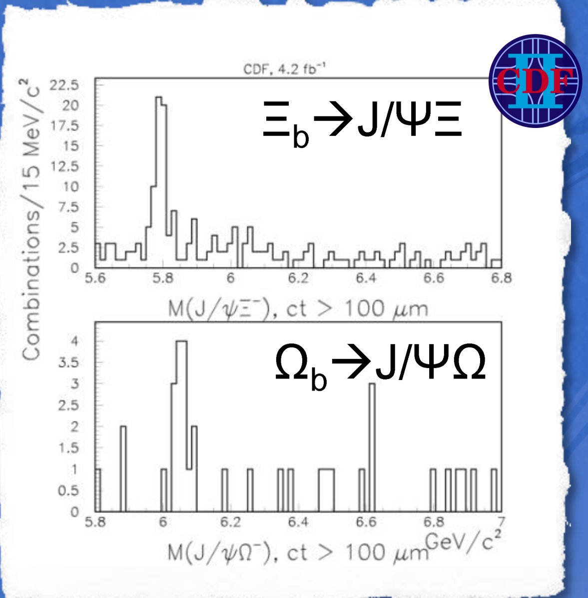
PRL101,232002（PRL99,052001）

- CDFは16 Ω_b（66 Ξ_b）事象を観測@4.2fb^{-1}
  - 質量: 6054.4±6.8±0.9（5790.9±2.6±0.8）MeV/c^2
  - 寿命: $1.13^{+0.53}_{-0.40} \pm 0.02$（$1.56^{+0.27}_{-0.25} \pm 0.02$）ps

arXiv:0905.3123



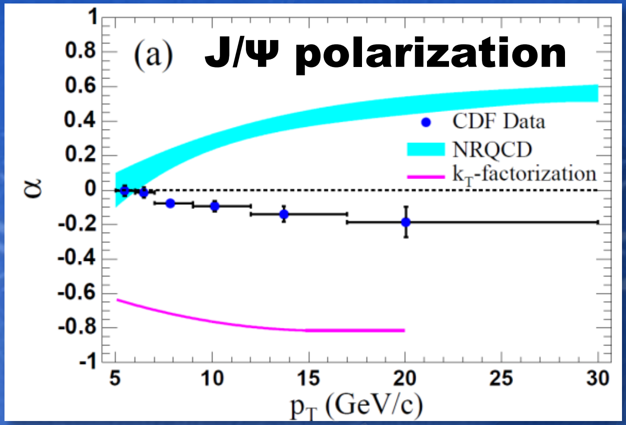




- **Ξ_b mass: 一致**
- **Ω_b mass: 不一致**

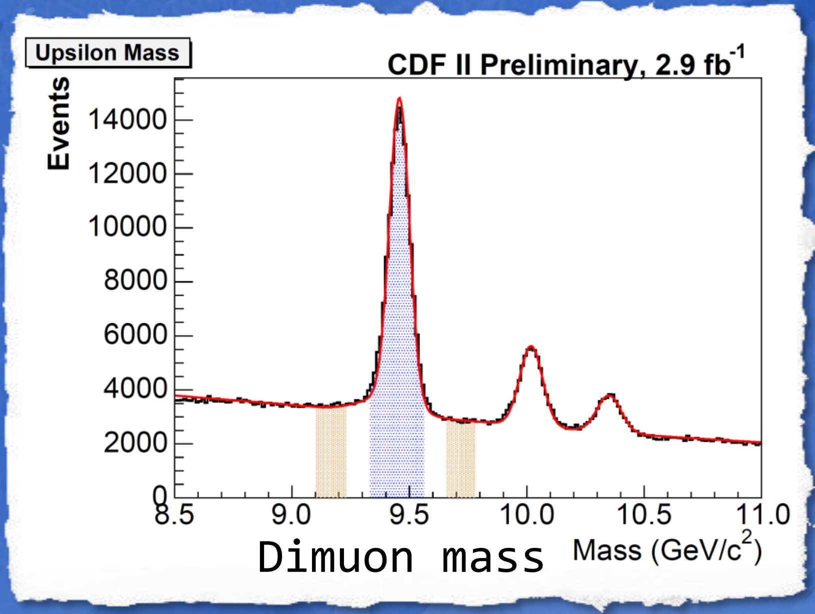
Puzzle!

Υ偏極度測定



PRL99,132001(2007)

- 一次生成vector中間子偏極度測定
  - NRQCDの検証（color-octet model)
    - Ψ(nS)において、実験と不一致
    - 重い$b\bar{b}$系であるΥ(nS)でなら一致するかも?



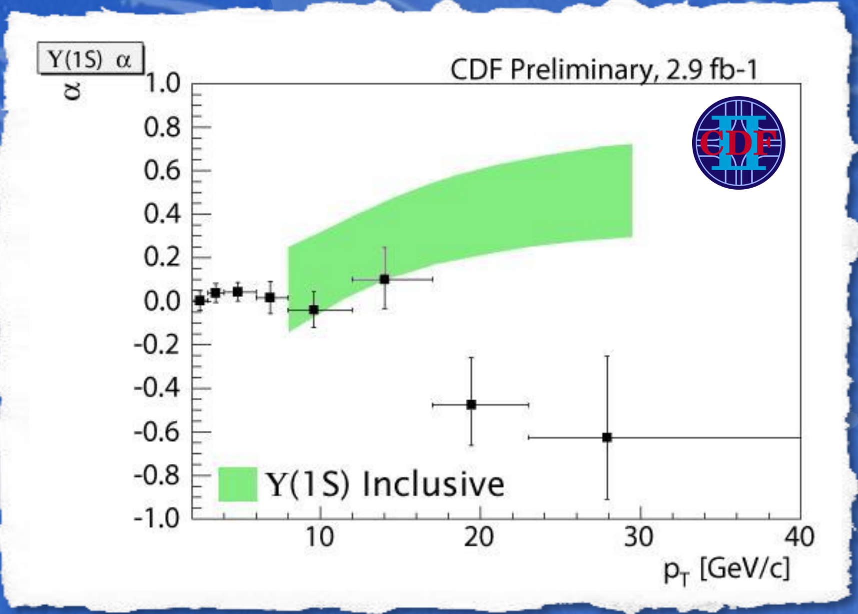
$$\frac{d\,\Gamma}{d\cos\theta^*} \propto 1 + \alpha\cos^2\theta^*.$$

where cosθ*: μ^+ angle

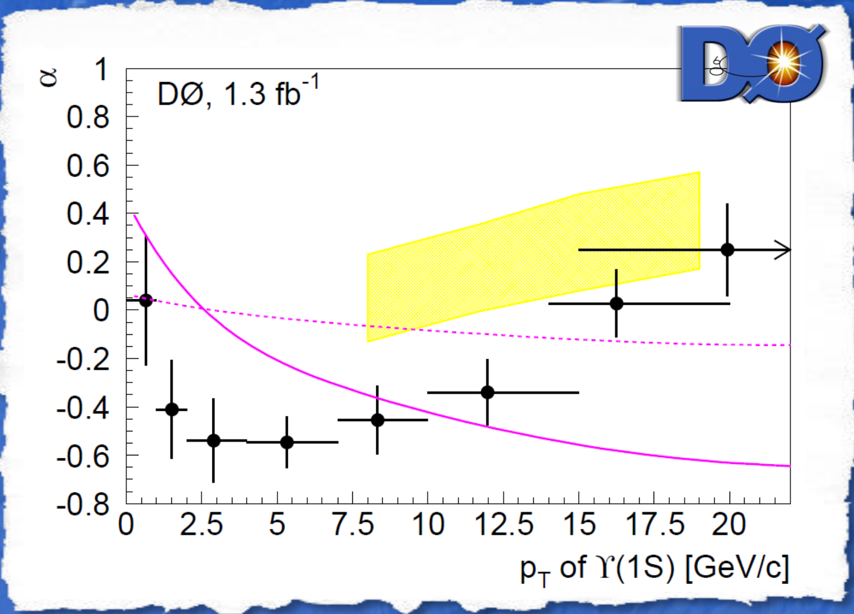
α=+1: transverse

α=-1: longitudinal

ϒ偏極度測定結果



CDF Public Note 9966



PRL101, 182004 (2008)

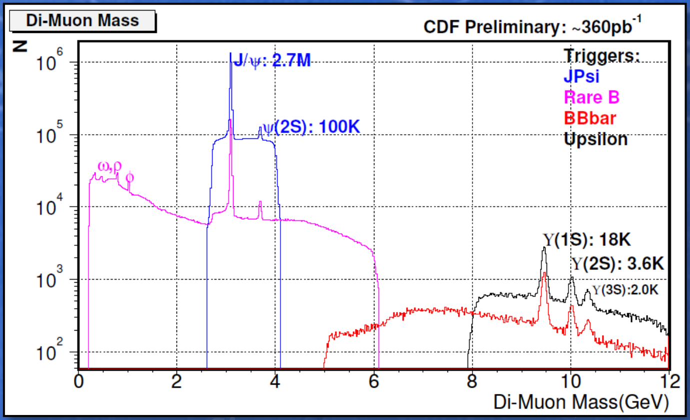
- D0はϒ(1S)とϒ(2S)を用いて偏極度を測定@1.3fb^{-1}
- 今回、CDFはϒ(1S)を2.9fb^{-1}のデータで測定
  - NRQCDとの不一致
  - CDFとD0も不一致(…BG偏極度の問題?)
- 両実験共ϒ(nS)及びΨ(nS)を測定し、結果を比較する予定
- D0からのJ/Ψ測定結果が間もなく出るそうです

Summary

- 現在CDFでは様々な
  ボトム解析プログラムが遂行中
  - 希少崩壊（崩壊分岐比, A_{FB}）
  - CP非対称度測定（β_s）
  - bハドロン解析（質量、寿命、偏極度）
- その特性を生かした、
  B-factory実験や直接探索実験と競合
  もしくは相補的な結果が多く出ている
- 2010年度において、統計の大幅な向上が期待される
  - 2011年度データ取得が認可されれば、さらなる精度向上

Backup

B triggers



Di-Muon

- **Conventional trigger at hadron collider**
- **Wide mass range**

1-Displaced track + *lepton* (*e*, *μ*)

120 μm < I.P.(trk) < 1mm

P_T(*lepton*) > 4 GeV

Semileptonic modes

Sillicon Vertex Trigger: SVT

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

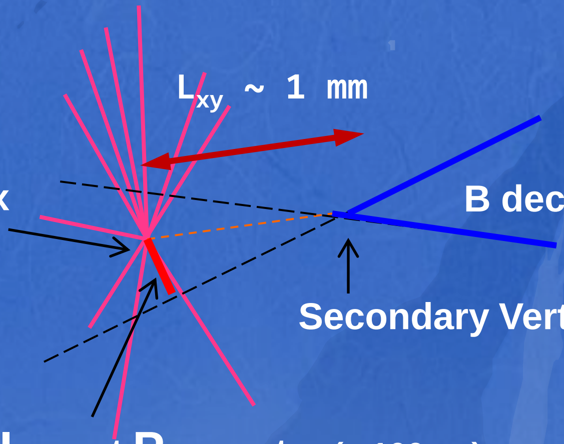
2-Displaced tracks

P_T(trk) > 2 GeV

120 μm < I.P.(trk) < 1mm

Σp_T > 5.5 GeV

fully hadronic modes



Primary Vertex

B decay

Secondary Vertex

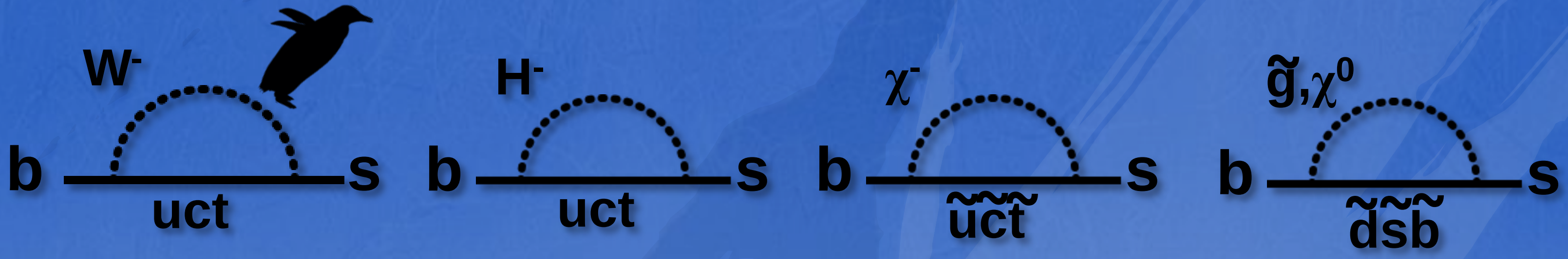
Impact Parameter (~100μm)

`Level-2 SVT trigger`

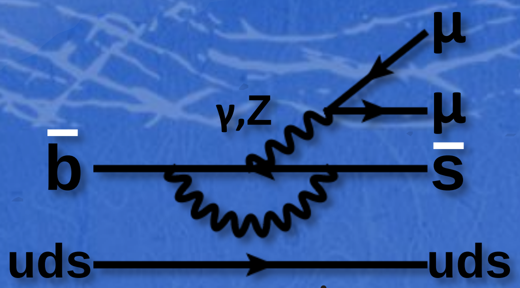
Flavor Changing Neutral Current

- b→s FCNC
  - Promising tool to search for new physics
  - Tree diagram is forbidden in the SM
  - May occur via higher order loop diagram
  - NP could enhance the amplitude
    - Interference with SM amplitude

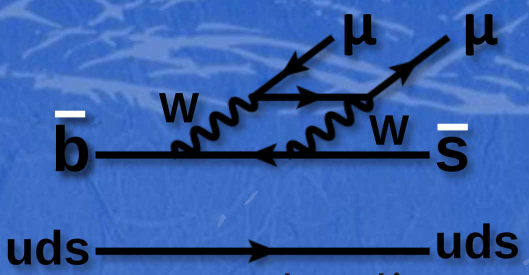
- **Various observables are available**
  - **BR, K* polarization, and A_{FB}**



$B\to K^{(*)}\mu\mu$, $B_s\to\phi\mu\mu$



EW penguins



W box diagram

Rare decay : $b\to sll$

- $B^+\to K^+\mu^+\mu^-$: $[0.52^{+0.08}_{-0.07}]\times 10^{-6}$ (HFAG)
- $B^0\to K^{*0}\mu^+\mu^-$:$[1.05^{+0.15}_{-0.13}]\times 10^{-6}$ (HFAG)
- $B_s\to \varphi\mu^+\mu^-$:1.61×10^{-6} (C.Q.Geng and C.C.Liu, J.Phys.G29:1103-1118,2003)
  - $BR(B_s\to\varphi\mu\mu)/BR(B_s\to J/\Psi\varphi)$
    $<2.3(2.6)\times 10^{-3}$ @90(95%) C.L. CDF 0.92fb^{-1}
    $<4.4\times 10^{-3}$ @95% C.L. DØ 0.45fb^{-1}
- **CDF updated the analysis with 4.4fb^{-1}**
  - **BR**
  - **A_{FB}**

B→K$^{(*)}$ μ μ : BR

- ✓ **Relative BR : normalized BR by control channel (J/Ψh)**

h=K,K*

Rare channel yield

$$\frac{\mathcal{B}(B\to h\mu^+\mu^-)}{\mathcal{B}(B\to J/\Psi h)} = \frac{N^{\mathrm{NN}}_{h\mu^+\mu^-}}{N^{\mathrm{pre}}_{J/\Psi h}} \boxed{\frac{\epsilon^{\mathrm{pre}}_{J/\Psi h}}{\epsilon^{\mathrm{pre}}_{h\mu^+\mu^-}}\frac{1}{\epsilon^{\mathrm{NN}}_{h\mu^+\mu^-}}} \times \mathcal{B}(J/\Psi\to\mu^+\mu^-),$$

Control channel yield

Reconstruction efficiency

- ✓ **Absolute BR**

(x10^{-6})

	BaBar (384M BB)	Belle (657M BB)	CDF (4.4fb^{-1})
K$^+$μμ	$0.41^{+0.16}_{-0.15}$(stat)±0.02(syst)	$0.53^{+0.08}_{-0.07}$(stat)±0.03(syst)	0.38±0.05(stat)±0.03(syst)
K*^{0} μμ	$1.35^{+0.40}_{-0.37}$(stat) ±0.10(syst)	$1.06^{+0.19}_{-0.14}$(stat) ±0.07(syst)	1.06±0.14(stat)±0.09(syst)
Kll	0.39±0.07(stat)±0.02(syst)	$0.48^{+0.05}_{-0.04}$(stat)±0.03(syst)	Same as K$^+$μμ
K*ll	$1.11^{+0.19}_{-0.18}$(stat)±0.07(syst)	$1.07^{+0.11}_{-0.10}$(stat)±0.09(syst)	Same as K^{*0}μμ

PRL102:091803 (2009)

PRL103:171801 (2009)

The best measurement for single final state!!

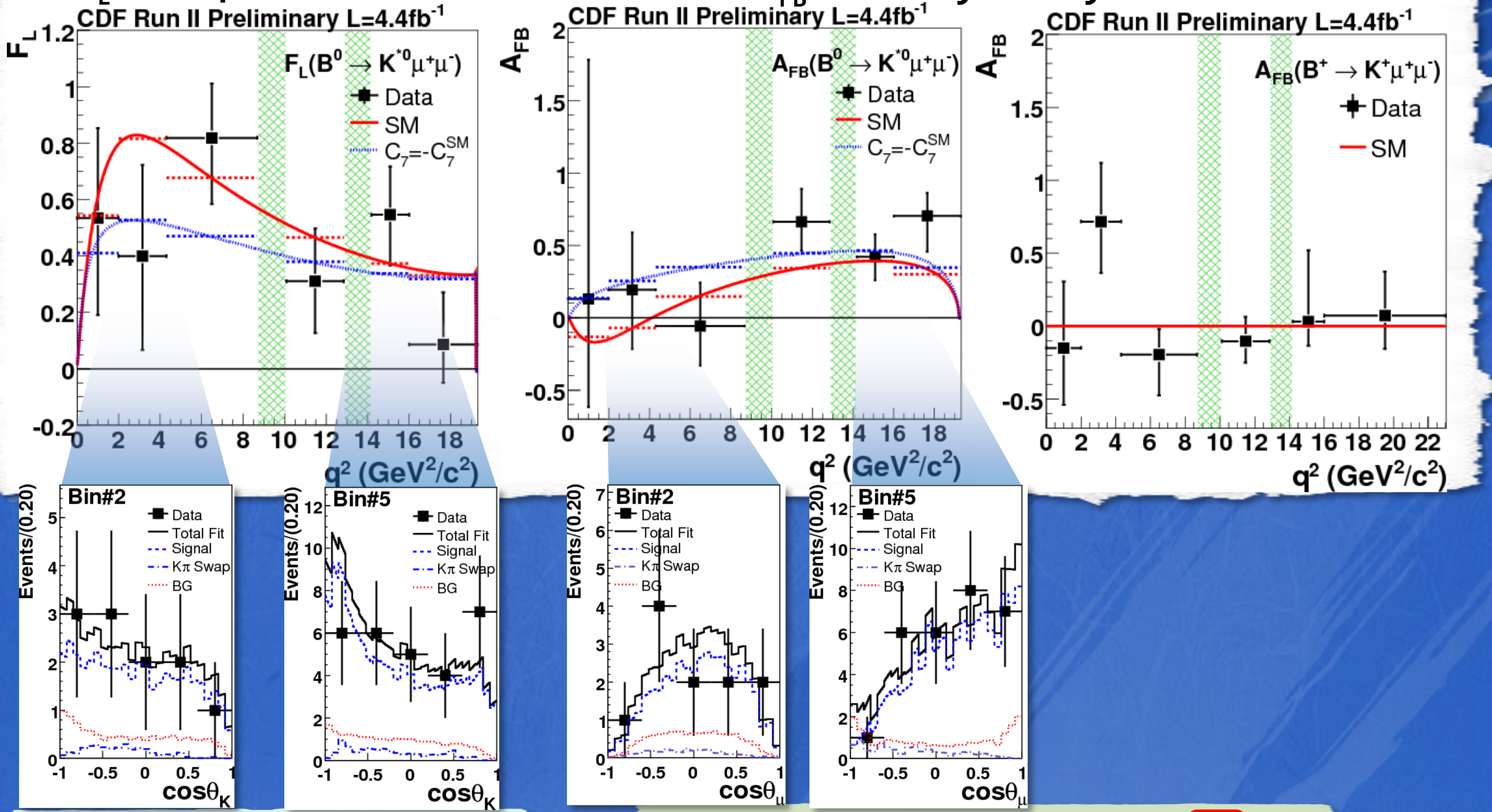
{Kπ, K$_s$π, Kπ^0}*{ee, μμ}

{K, K$_s$}*{ee, μμ}

A_{FB} ($B \to K^{(*)} \mu\mu$)

F_L: K* polarization

A_{FB}: FB asymmetry



$$\frac{3}{2}\boxed{F_L}\cos^2\theta_K + \frac{3}{4}(1-\boxed{F_L})(1-\cos^2\theta_K)$$

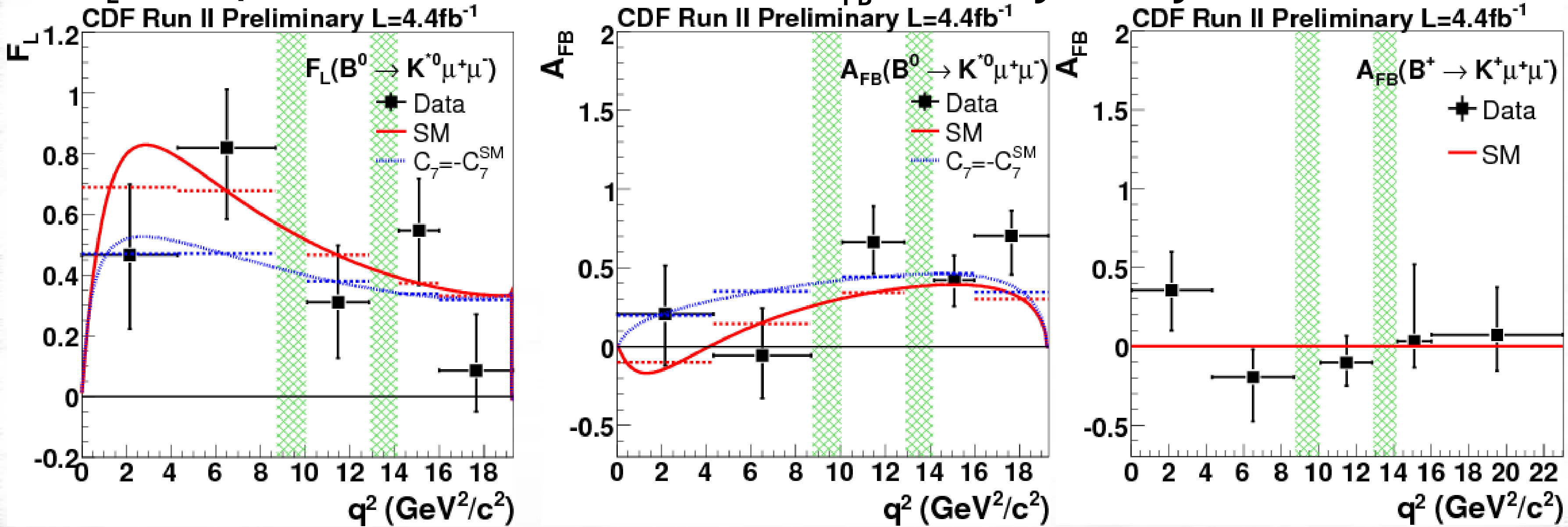
$$\frac{3}{4}F_L(1-\cos^2\theta_\mu)+\frac{3}{8}(1-F_L)(1+\cos^2\theta_\mu)+\boxed{A_{FB}}\cos\theta_\mu$$

F_L=1 for Kμμ

A_{FB} (B→K(*) μ μ) : 5 bin analysis

F_L: K* polarization

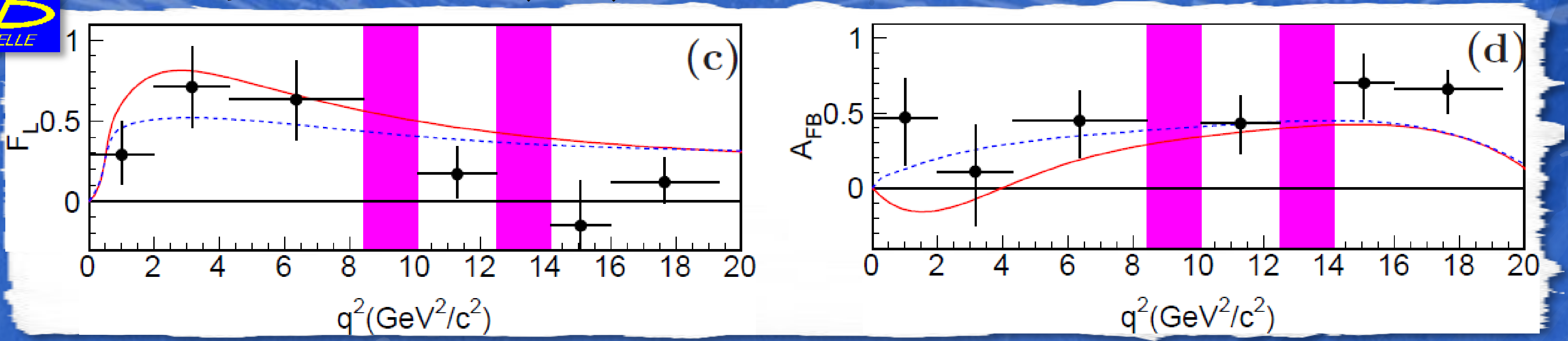
A_{FB}: FB asymmetry



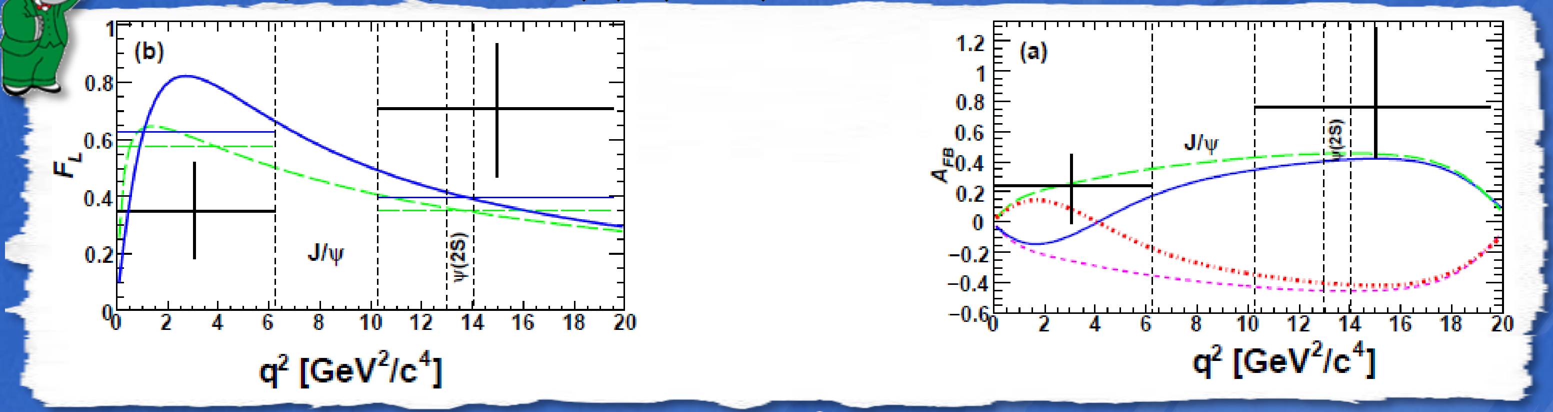
- 1st and 2nd bin are merged (prior unblinding A_{FB} and F_L)

$A_{FB}\,(B \to K^{(*)} \mu\, \mu)$

657M BB, PRL103:171801 (2009)

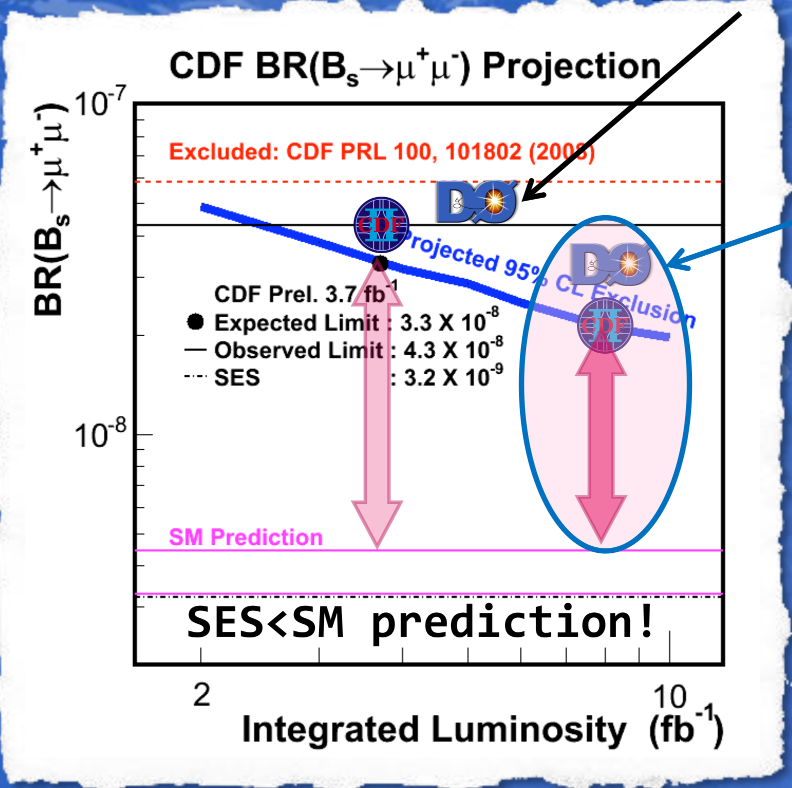


384M BB, PRD79,031102(R) (2009)



$B_s \to \mu\,\mu$: prospects

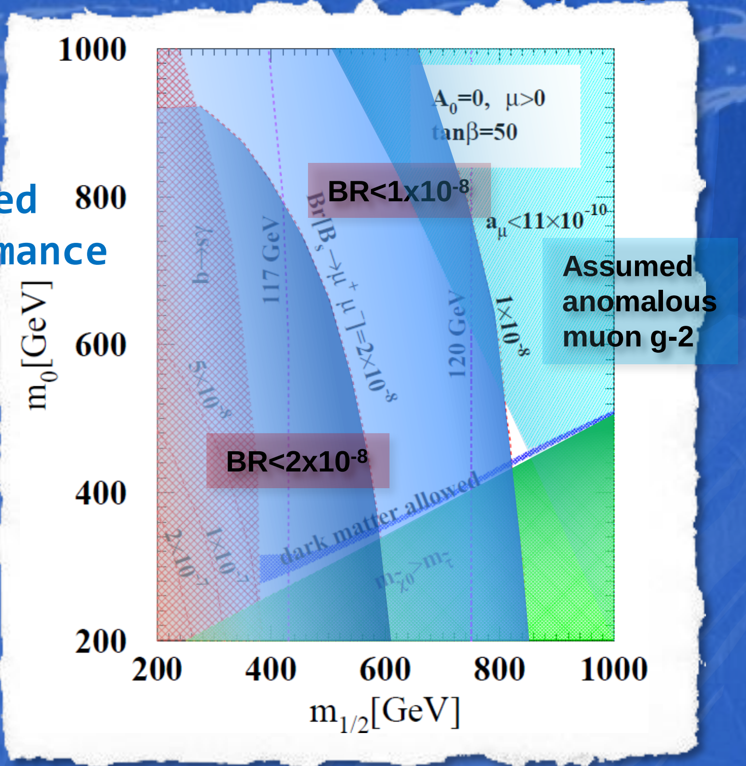
DØ expected@5fb^{-1}



SES<SM prediction!

Expected performance @8fb^{-1}

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



BR<1×10^{-8}

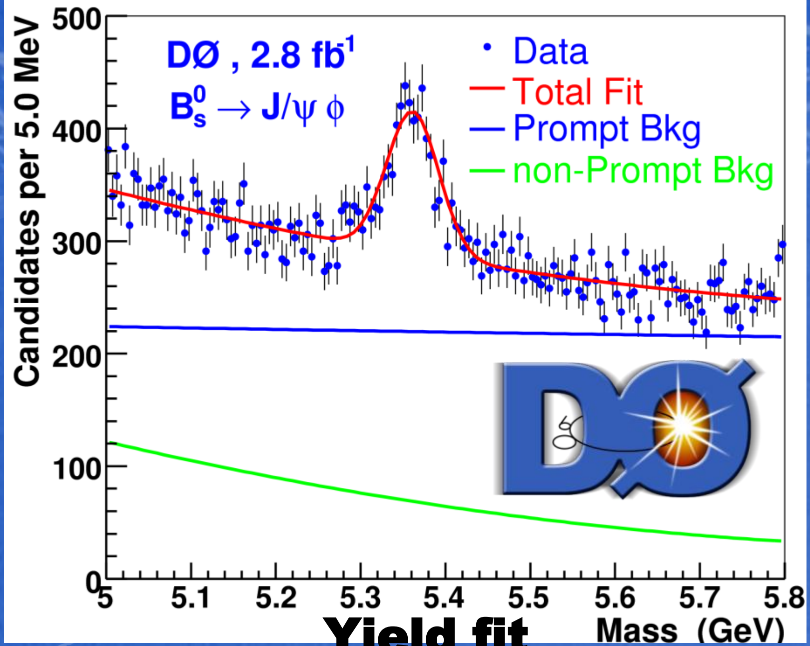
BR<2×10^{-8}

Assumed anomalous muon g-2

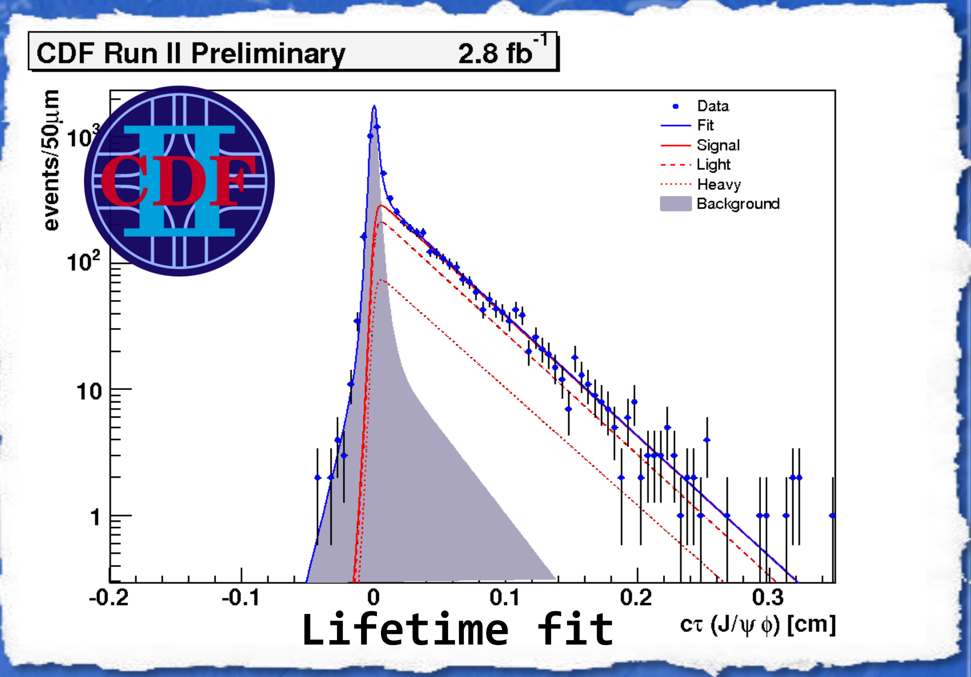
Strong constraint on NP parameters :
Could rule-out mSUGRA with Tevatron combination at 10fb^{-1}

- 2010 (approved, ongoing : ~8fb^{-1})
  - CDF Expected limit: 2×10^{-8}@8fb^{-1} (6xSM)
  - Combined with DØ→5xSM
- 2011 (proposal, likely 10fb^{-1})
  - Combined limit ~O (10^{-8})

$B_s \rightarrow J/\Psi\ \Phi$@2.8fb^{-1}



Yield fit



Lifetime fit

$N(B_s^0)^{DØ} \sim 2000$

$N(B_s^0)^{CDF} \sim 3200$

β_s=0, no flavor tag :

$\tau(B_s^0) = 1.53 \pm 0.04\ (stat) \pm 0.01\ (syst)\ ps$

$\Delta\Gamma = 0.02 \pm 0.05\ (stat) \pm 0.01\ (syst)\ ps^{-1}$

PRL 102, 032001 (2009)

$\tau(B_s^0) = 1.487 \pm 0.060\ (stat) \pm 0.028\ (syst)\ ps$

$\Delta\Gamma = 0.085^{+0.072}_{-0.078}\ (stat) \pm 0.006\ (syst)\ ps^{-1}$

$B_s \to J/\Psi\,\Phi$ Decay Rate

- $B_s \to J/\Psi\Phi$ decay rate as function of time, decay angles and initial B_s flavor:

time dependence terms

$$\begin{aligned}\frac{d^4P(t,\vec{\rho})}{dt\,d\vec{\rho}} \propto\ & |A_0|^2\mathcal{T}_+ f_1(\vec{\rho}) + |A_\parallel|^2\mathcal{T}_+ f_2(\vec{\rho})\\ &+ |A_\perp|^2\mathcal{T}_- f_3(\vec{\rho}) + |A_\parallel||A_\perp|\mathcal{U}_+ f_4(\vec{\rho})\\ &+ |A_0||A_\parallel|\cos(\delta_\parallel)\mathcal{T}_+ f_5(\vec{\rho})\\ &+ |A_0||A_\perp|\mathcal{V}_+ f_6(\vec{\rho}),\end{aligned}$$

angular dependence terms

terms with b_s dependence

$$\begin{aligned}\mathcal{T}_\pm = e^{-\Gamma t} \times\ & [\cosh(\Delta\Gamma t/2) \mp \cos(2\beta_s)\sinh(\Delta\Gamma t/2)\\ &\mp \eta\sin(2\beta_s)\sin(\Delta m_s t)],\end{aligned}$$

terms with Dm_s dependence present if initial state of B meson (B vs anti-B) is determined (flavor tagged)

$$\begin{aligned}\mathcal{U}_\pm = \pm e^{-\Gamma t} \times\ & [\sin(\delta_\perp - \delta_\parallel)\cos(\Delta m_s t)\\ &- \cos(\delta_\perp - \delta_\parallel)\cos(2\beta_s)\sin(\Delta m_s t)\\ &\pm \cos(\delta_\perp - \delta_\parallel)\sin(2\beta_s)\sinh(\Delta\Gamma t/2)]\\ \mathcal{V}_\pm = \pm e^{-\Gamma t} \times\ & [\sin(\delta_\perp)\cos(\Delta m_s t)\\ &- \cos(\delta_\perp)\cos(2\beta_s)\sin(\Delta m_s t)\\ &\pm \cos(\delta_\perp)\sin(2\beta_s)\sinh(\Delta\Gamma t/2)].\end{aligned}$$

'strong' phases:

$$\delta_\parallel \equiv \mathrm{Arg}(A_\parallel(0)A_0^*(0))$$

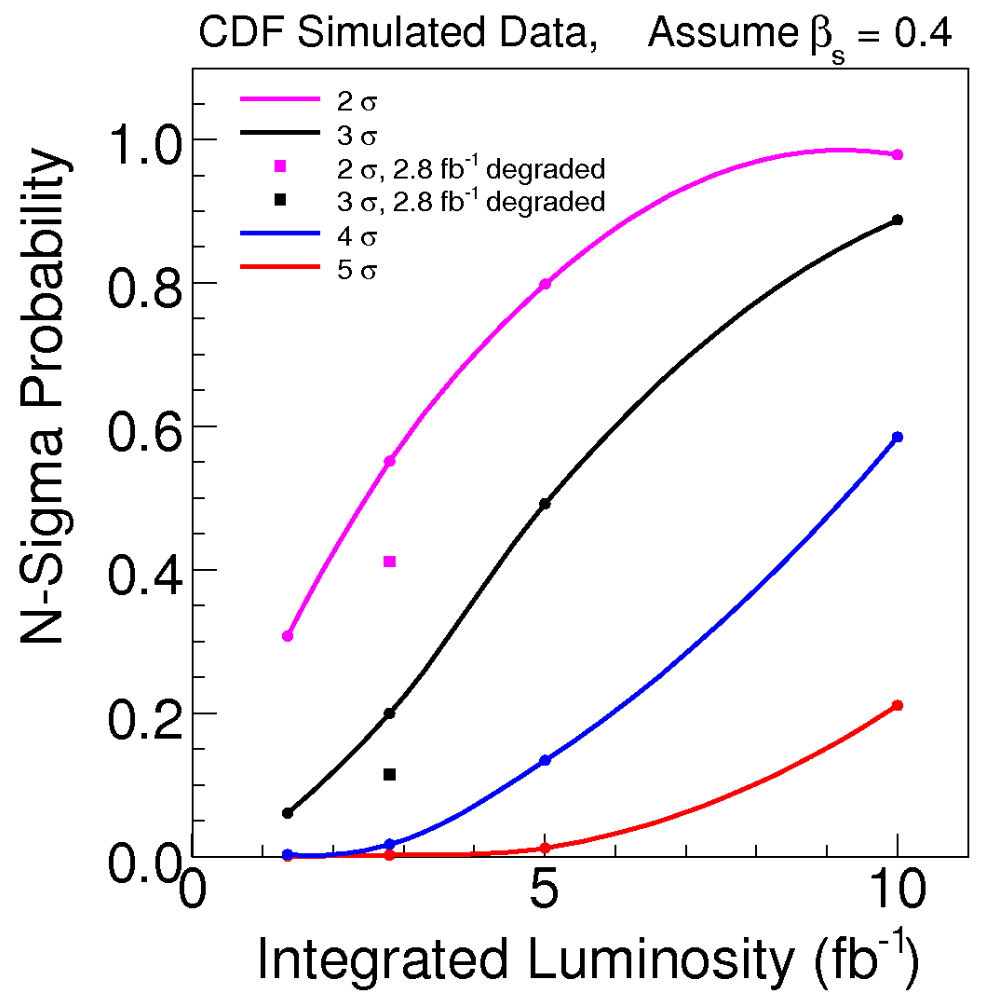
$$\delta_\perp \equiv \mathrm{Arg}(A_\perp(0)A_0^*(0))$$

- Identification of B flavor at production (flavor tagging) → better sensitivity to b_s

Present CDF result doesn’t fully utilize data

⇒ No particle ID in Neural Network selection

⇒ No SSKT after 1.3 fb^{-1}

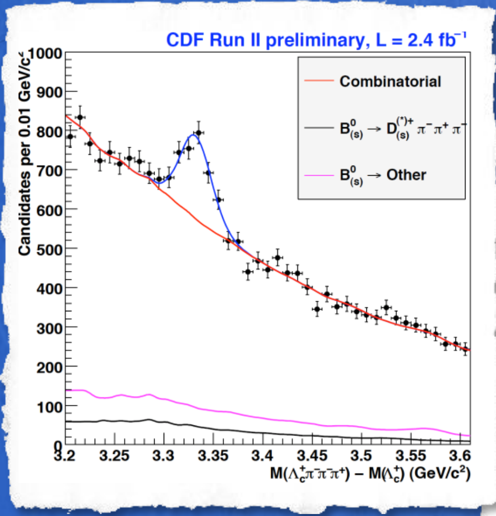


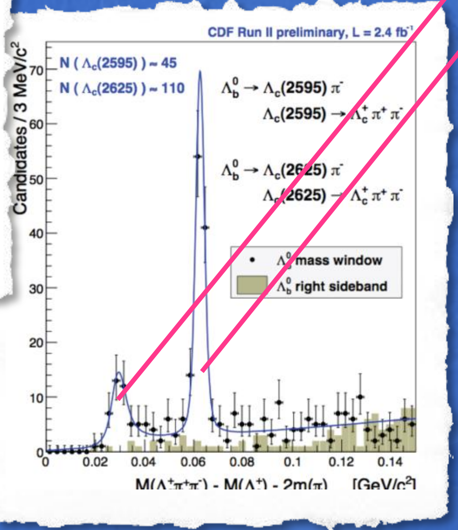
$\Delta_b \rightarrow X_c n \pi \rightarrow \Delta_c^+ \pi^- \pi^+ \pi^-$

- Charm resonant decay channel
  - CDF observed resonant semileptonic decay channel: $\Delta_b \rightarrow X_c (\pi) \mu \nu$

PRD 79, 032001 (2009)

- First observation of $\Delta_b \rightarrow \Delta_c^+ \pi^- \pi^+ \pi^-$





Λ_b^0 Decay Mode	Yield
$\Lambda_b^0 \rightarrow \Lambda_c(2595)^+\pi^- \rightarrow \Lambda_c^+\pi^-\pi^+\pi^-$	46.6±9.7
$\Lambda_b^0 \rightarrow \Lambda_c(2625)^+\pi^- \rightarrow \Lambda_c^+\pi^-\pi^+\pi^-$	114±13
$\Lambda_b^0 \rightarrow \Sigma_c(2455)^{++}\pi^-\pi^- \rightarrow \Lambda_c^+\pi^-\pi^+\pi^-$	81±15
$\Lambda_b^0 \rightarrow \Sigma_c(2455)^0\pi^+\pi^- \rightarrow \Lambda_c^+\pi^-\pi^+\pi^-$	41.5±9.3
$\Lambda_b^0 \rightarrow \Lambda_c^+\rho^0\pi^- + \Lambda_c^+3\pi(other) \rightarrow \Lambda_c^+\pi^-\pi^+\pi^-$	610±88

848 signals@2.4fb⁻¹

Relative BR

$$\frac{BR(\Lambda_b^0 \rightarrow \Lambda_c(2595)^+\pi^- \rightarrow \Lambda_c^+\pi^-\pi^+\pi^-)}{BR(\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-\pi^+\pi^-(all))} = (2.5 \pm 0.6(stat) \pm 0.5(syst)) \cdot 10^{-2}$$

$$\frac{BR(\Lambda_b^0 \rightarrow \Lambda_c(2625)^+\pi^- \rightarrow \Lambda_c^+\pi^-\pi^+\pi^-)}{BR(\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-\pi^+\pi^-(all))} = (6.2 \pm 1.0(stat) \pm 1.2(syst)) \cdot 10^{-2}$$

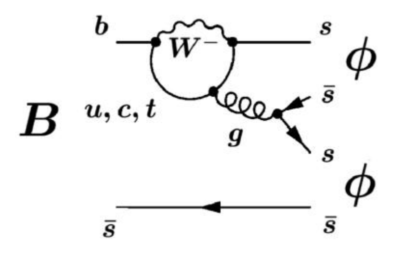
$$\frac{BR(\Lambda_b^0 \rightarrow \Sigma_c(2455)^{++}\pi^-\pi^- \rightarrow \Lambda_c^+\pi^-\pi^+\pi^-)}{BR(\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-\pi^+\pi^-(all))} = (5.2 \pm 1.1(stat) \pm 0.9(syst)) \cdot 10^{-2}$$

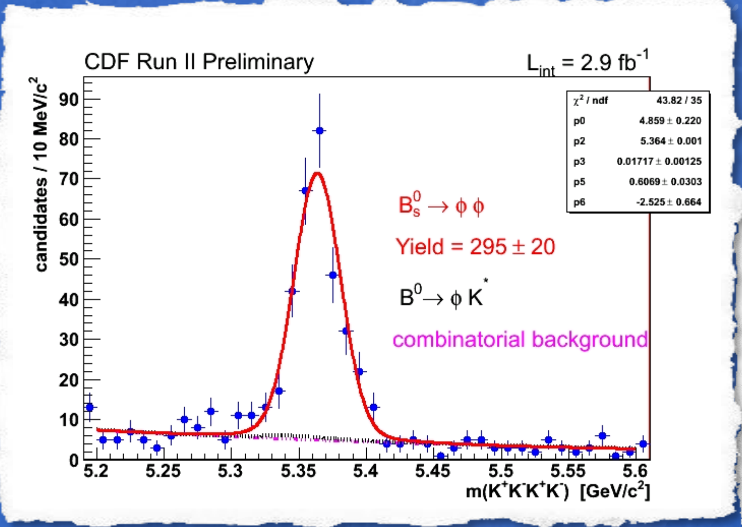
$$\frac{BR(\Lambda_b^0 \rightarrow \Sigma_c(2455)^0\pi^+\pi^- \rightarrow \Lambda_c^+\pi^-\pi^+\pi^-)}{BR(\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-\pi^+\pi^-(all))} =$$

$$(8.9 \pm 2.1(stat) + 1.5 - 1.0(syst)) \cdot 10^{-2}$$

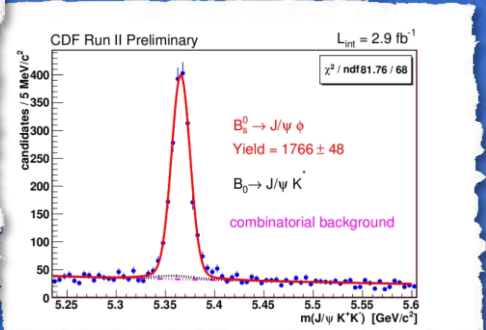
$B_s \to \phi\ \phi$: gluonic penguin

- Dominated by $b \to s s \bar{s}$ (same as $B \to \phi K^{(*)}$)
  - 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}
  - Various BR expectations
    - QCDF: $(2.18 \pm 0.1^{+3.04}_{-1.78}) \times 10^{-5}$ NPB774,64 (2007)
    - pQCD: $(3.53^{+0.83}_{-0.69}{}^{+1.67}_{-1.02}) \times 10^{-5}$ PRD76,074018 (2007)





Control channel: J/Ψφ



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

- **Updated by 2.9fb^{-1} from 180pb^{-1}~significant improvement**
- **BR: Consistent with SM**

Next step: Polarization measurement