CDF実験のフレーバー物理（A03総括）

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A03 「陽子反陽子衝突実験CDFによるトップとボトム･フレーバーの物理」の目的と設定目標

CDF 実験の物理解析によって，トップクォーク生成崩壊の精密測定，B ハドロン生成崩壊の精密測定を行い，本研究の目的である弱い相互作用におけるCP 対称性の破れを記述する

小林益川理論の高精度での検証

標準理論を超える物理の探索

を行う。

本計画研究を始めるにあたって，最終年度の2011 年度までに達成すべき具体的な目標として，二つの大きい目標を設定した。

***B_s* 中間子の粒子･反粒子振動の初観測:**

$|V_{ts}/V_{td}|$ 成分を5 %の精度で測定。

トップクォーク単一生成の初観測:

V_{tb} 成分を6 %の精度で測定。

このように小林益川混合行列の高精度の決定をはじめとするフレーバー物理の研究を推進する。

Tevatron 運転終了：　2011/9/30

Helen Edwards dumps the TeV beam

Fermilab Today 2011/10/3

http://www.fnal.gov/pub/tevatron/milestones/interactive-timeline.html　テバトロン30年史

CDF の始まり

TEVATRON AUTHORIZED JULY 1979

1979: Sho Ohnuma and R. Yamada indicated that K. Kondo and several other Japanese we in the U. S. looking for ways to collaborate in HEP. I met them at a Conference at BNL and told them about our plans for a colliding beams experiment at FNAL. They came to visit and met with Lederman. The collaboration with CDF was finalized at the end of the year!

...Prof. Kunitaka Kondo (second from right) visits with (L-R) Hans Jensen, Alvin V. Tollestrup and Ryuji Yamada, all with the Fermilab Colliding Detector Facility. On the table before them is a model of the colliding detector...

Fermi News: Dec 1979

1980: Italians joined CDF

1981: Conceptual Design Document

Number of Collaborators 87

1982, July 1. CDF Construction Begins!
Start construction of pbar source.

1983, July 3. First Beam in Tevatron!

1985, Oct. 13. First Collisions at CDF

CDF初期の写真

Superconducting Solenoid Coil

Superconducting solenoid coil was made at Hitachi company in a collaboration with University of Tsukuba and Fermilab.

People at University of Tsukuba, KEK and Fermilab in front of the CDF detector with a Superconducting solenoid coil installed in 1984.

Plug ElectroMagnetic Calorimeter (PEM)

The gas proportional chamber with resistive plastic tubes for PEM was developed at Tsukuba. Testbeam calibration of PEM was done by University of Tsukuba and KEK members. (Picture: PEM prototype completed in 1983.)

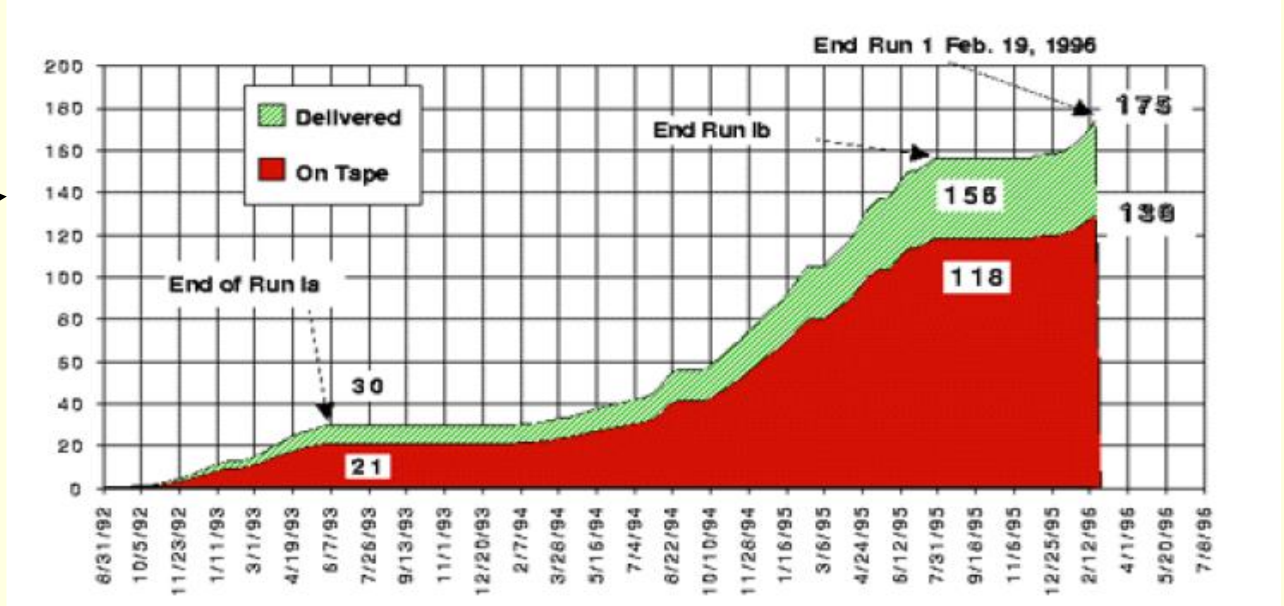
CDF積分ルミノシティー

- First Collision(1985.10)
- Engineering RUN
  (1987.1 – 1987.5) 27nb^{-1}
- RUN0
  (1988.9 – 1989.4) 4.4pb^{-1}

- **RUN1**
  (1992.8 – 1996.3) 130pb^{-1}

1994.7 Top Evidence
1995.4 Top Observation

1998.12 B_c Observation

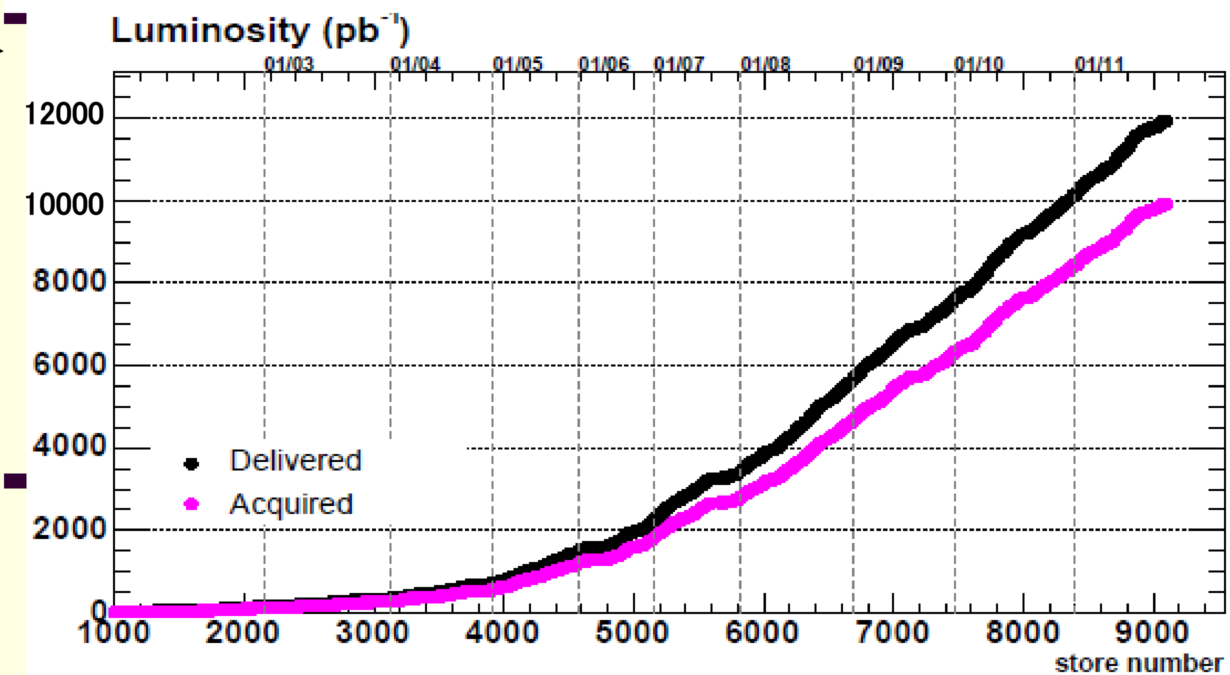


- **RUN2**
  (2001.6 – 2011.9.30)
  10.0fb^{-1}

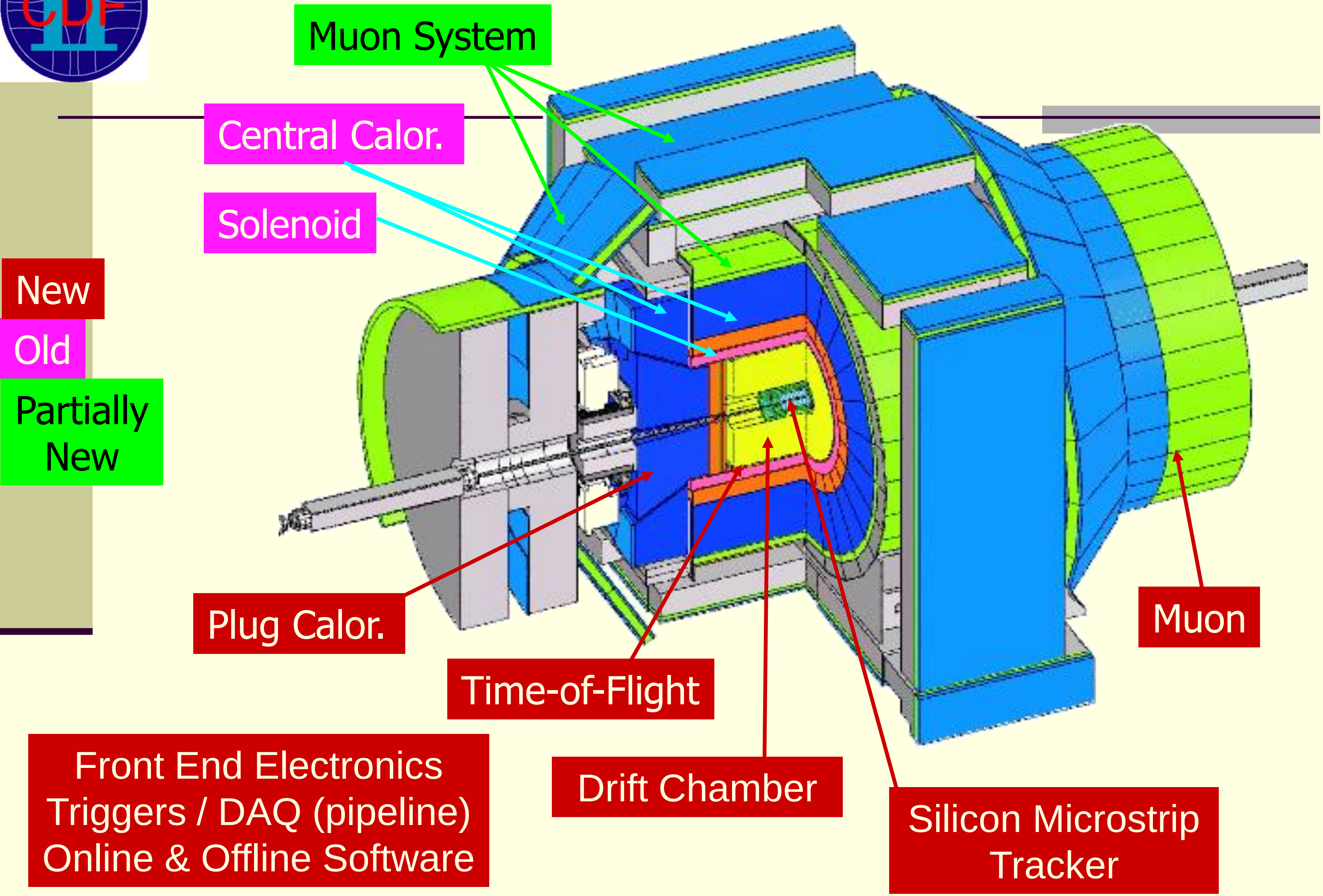
2006.3 Precision M_{top}
ΔM_{top}=3GeV→M_H<186GeV

2006.12 Observation of
B_s Oscillation

2011.7 Direct Higgs Search
Exclude M_H of
156GeV-177GeV



CDF Ⅱ 測定器　RUN Ⅱ



本特定領域研究期間のCDF実験の物理成果（２００６〜）

CDF実験 高引用数論文（2006～）

（引用数＞200）

1. *Bs* Oscillation 462, 239

Observation of B0(s) - anti-B0(s) Oscillations. Phys.Rev.Lett.97:242003,2006. | Cited 462 times
Measurement of the B^0_{s}-¥bar{B}^0_s Oscillation Frequency. Phys.Rev.Lett.97:062003,2006. | Cited 239 times

2. Search for CP Violaton in $Bs \to J/\psi\,\varphi$ Decay 254

First Flavor-Tagged Determination of Bounds on Mixing-Induced CP Violation in B^0_{s} ¥to J/¥psi ¥phi Decays. Phys.Rev.Lett.100:161802,2008. | Cited 254 times

3. Search for $Bs \to \mu\,\mu$ and $Bd \to \mu\,\mu$ Decay 232

Search for B^0_{s} ¥to ¥mu^{+} ¥mu^{-} and B^0_{d} to mu^{+} ¥mu^{-} decays with 2fb^{-1} of p ¥bar{p} collisions. Phys.Rev.Lett.100:101802,2008. | Cited 232 times

4. t tbar Forward-Backward Asymmetry 233, 168

Evidence for a Mass Dependent Forward-Backward Asymmetry in Top Quark Pair Production. Phys.Rev.D83:112003,2011. | Cited 233 times
Forward-Backward Asymmetry in Top Quark Production in $p¥bar{p}$ Collisions at $sqrt{s}=1.96$ TeV. Phys.Rev.Lett.101:202001,2008. | Cited 168 times

5. Single Top Quark Production 205, 59

First Observation of Electroweak Single Top Quark Production.Phys.Rev.Lett.103:092002,2009. | Cited 205times
Observation of Single Top Quark Production and Measurement of |Vtb| with CDF. Phys.Rev. D82: 072003,2010. | Cited 59 times

CDF実験 高引用数論文（ 2006～ ）

（引用数＞100）

6. Direct Higgs Search 109, 63

Combination of Tevatron searches for the standard model Higgs boson in the W+W− decay mode.Phys.Rev.Lett.104:061802,2010. | Cited 109 times
Combined CDF and D0 Upper Limits on Standard Model Higgs Boson Production with up to 8.2 fb^{-1} of Data.: arXiv:1103.3233 | Cited 63 times

7. Top Quark Mass 117

Top quark mass measurement using the template method in the lepton + jets channel at CDF II. Phys.Rev.D73:032003,2006.. | Cited 117 times

8. New Heavy Flavor Hadrons 104, 106, 144

Observation and Mass Measurement of the baryon *Xi b*. Phys. Rev. Lett. 99: 052002, 2007.. | Cited 104 times
First Observation of heavy Baryon Σ_b and Σ_b^* Phys. Rev. Lett. 99: 202001, 2007.. | Cited 106 times
Analysis of the Quantum Numbers of J**PC of the X(3872) Phys. Rev. Lett. 99: 132002, 2007.. | Cited 144 times

9. Polarization of J/Ψ and $\Psi(2s)$ 118

Polarization of J/Ψ and $\Psi(2s)$ Mesons produced in p pbar collisions at sqrt(s) = 1.96−TeV. Phys. Rev. Lett. 99: 132001, 2007.. | Cited 118 times

B_s中間子の粒子反粒子振動の初観測

2005年時点でのCDFのB_s振動についての展望

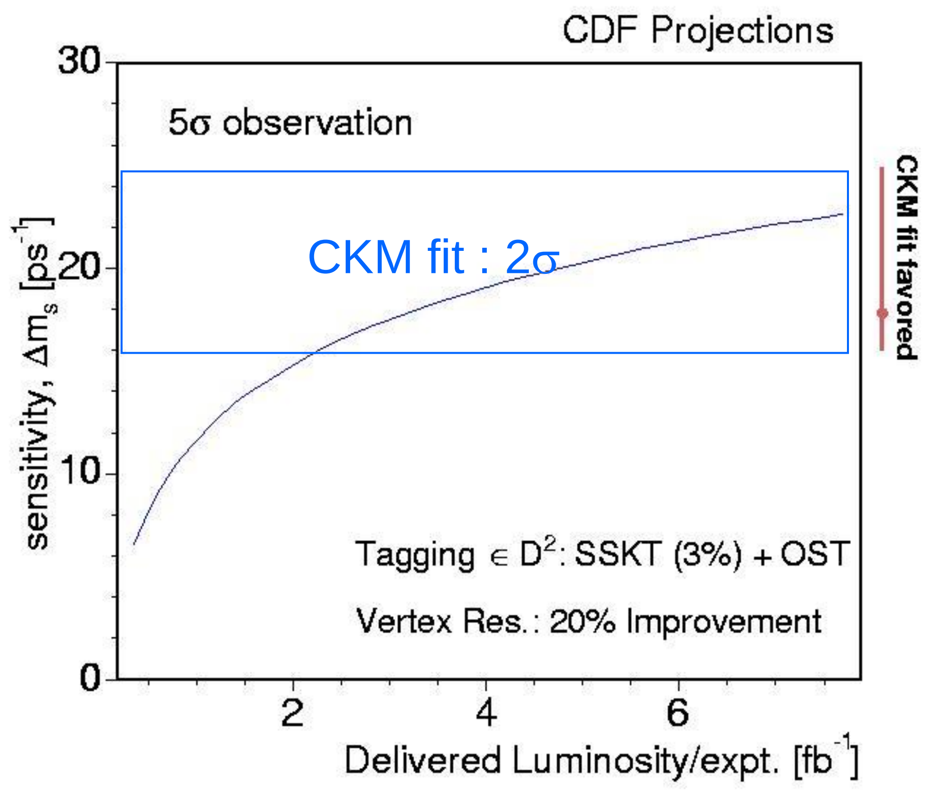
B_S mixing : future sensitivity

- This plots assume:

  – flavor tagging:
    add same–side kaon tagging
    $\varepsilon D^2 = 1.6 + 3.0\%$

  – Vertex resolution:
    improved by 20%

  – Trigger bandwidth:
    utilize 50% of CDF data



5 σ observation:

$L=2\ fb^{-1}$: $\Delta m_S < 15\ ps^{-1}$

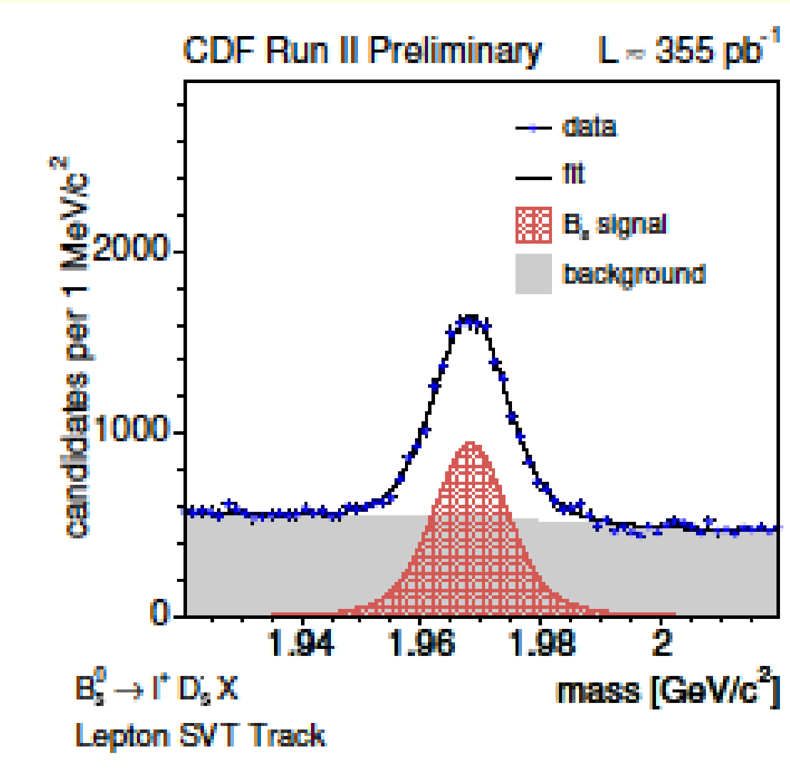
$L=8\ fb^{-1}$: $\Delta m_S < 22\ ps^{-1}$

B_s 中間子の再構成

セミレプトニック崩壊モード

$B_s \to D_s l\nu\ X$ （$D_s \to \phi\pi, K^*K, 3\pi$）

61,500 events (1.0 fb^{-1})



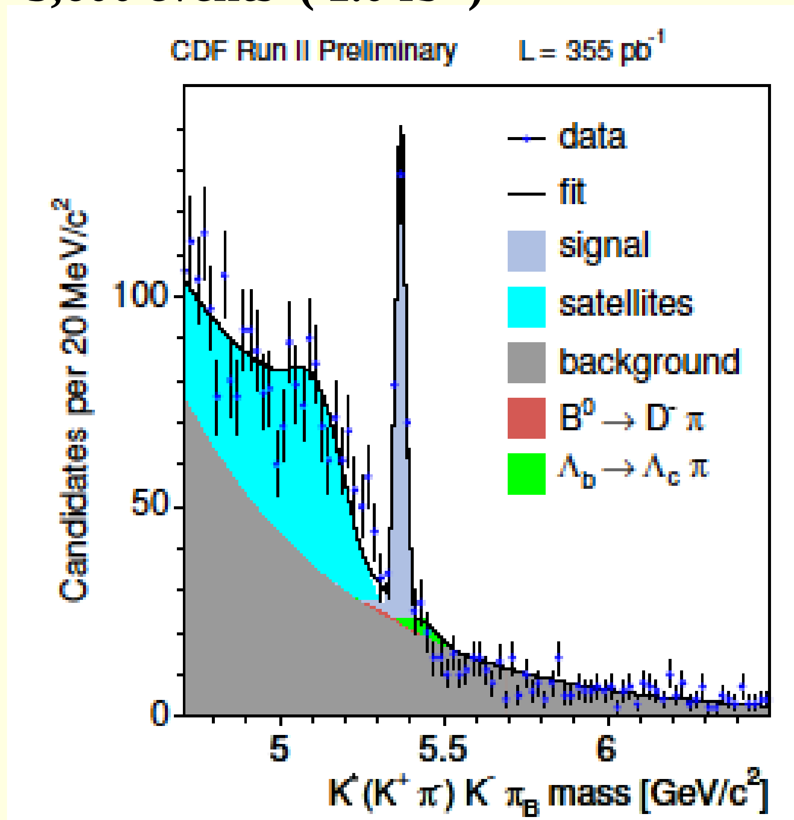
$B_s \to l\nu D_s X(D_s \to \phi\pi)$

ハドロニック崩壊モード

$B_s \to D_s\ \pi$ （ $D_s \to \phi\pi, K^*K, 3\pi$）

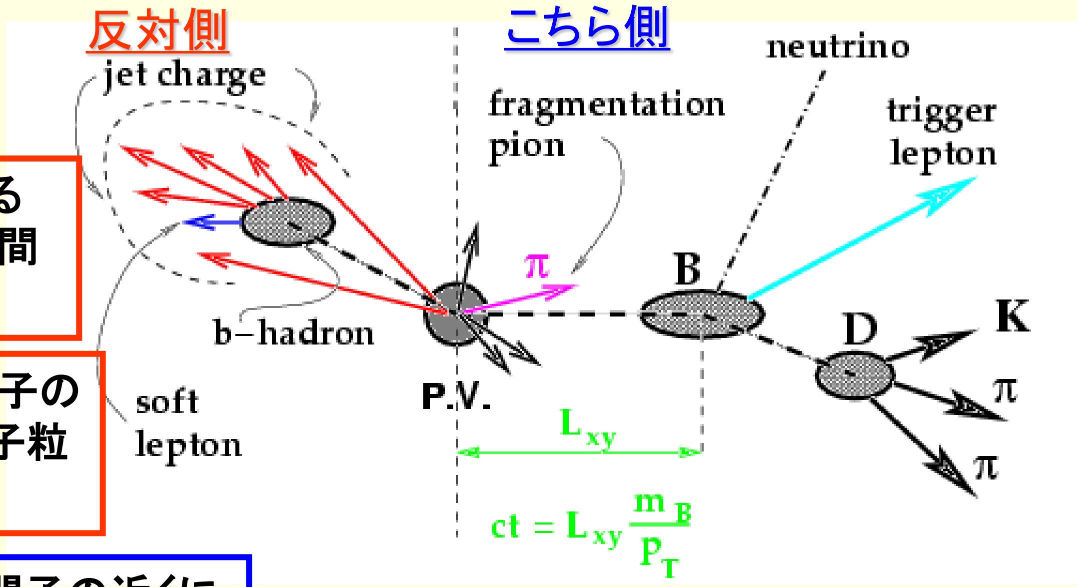
$B_s \to D_s\ 3\pi$ （ $D_s \to \phi\pi, K^*K$ ）

5,600 events (1.0 fb^{-1})



$B_s \to D_s\pi, D_s \to K^*K$

フレーバー同定

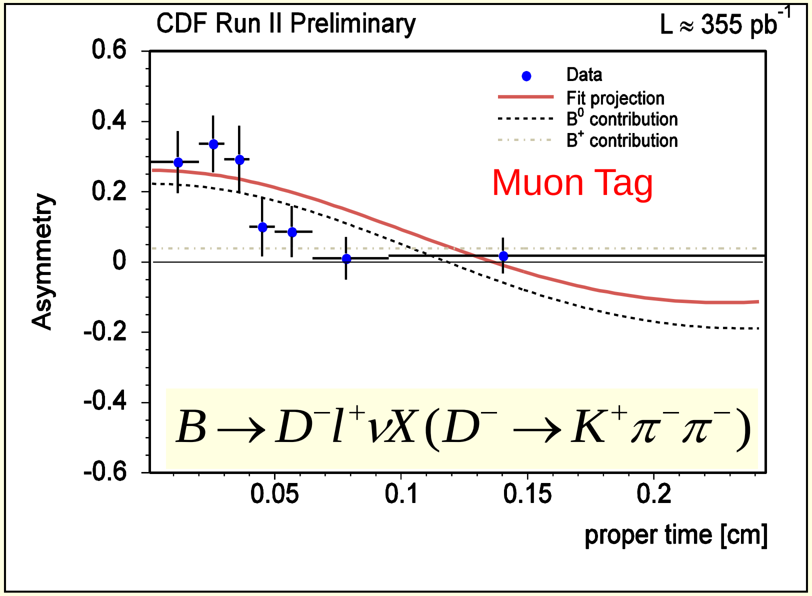


Soft Lepton (e,μ) b→ℓνX崩壊でできる soft lepton ℓ の電荷で生成時のBs中間子が粒子か反粒子かが決まる。

Jet Charge: b-Jetを構成する荷電粒子の飛跡 の電荷の和で生成時のBs中間子粒子か反粒子かが決まる。

Same Side Kaon: 再構成したBs中間子の近くに生成した K中間子の電荷で生成時のBs中間子粒子か反粒子かが決まる。
高い 実質同定効率 $\varepsilon D^2 \sim 4\%$

B_d^0 振動でフレーバー同定率を校正 →



	HADRONIC	SEMILEPTONIC
Δm_d	$(0.503 \pm 0.063 \pm 0.015)$ ps^{-1}	$(0.498 \pm 0.028 \pm 0.015)$ ps^{-1}
Tot. εD^2	$(1.12 \pm 0.23)\%$	$(1.43 \pm 0.09)\%$

Δ m_sの決定方法

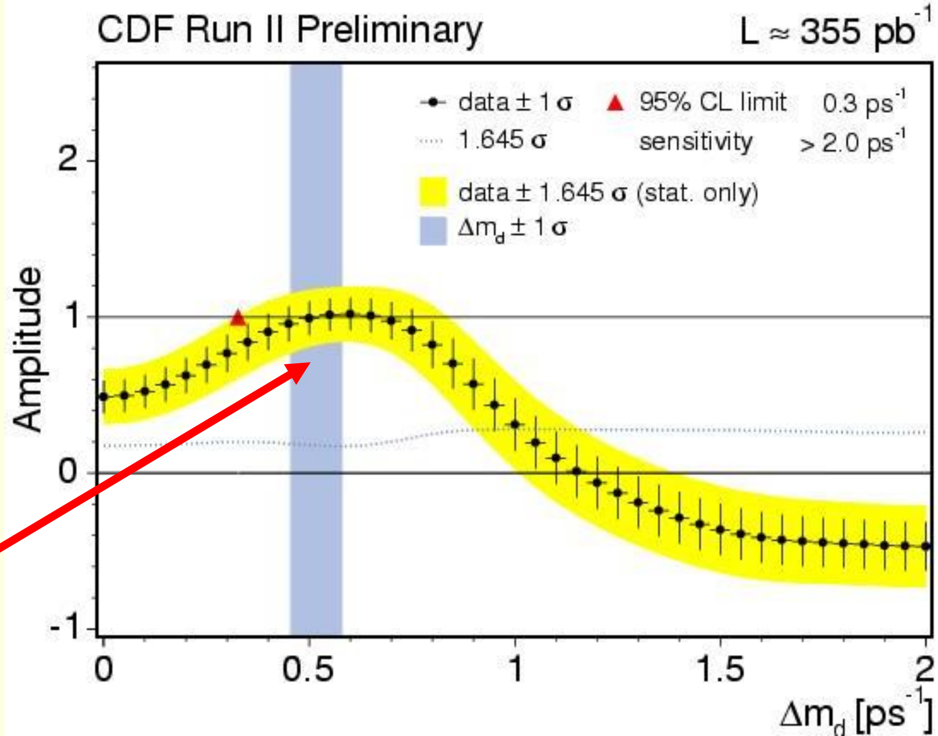
- 振動振幅Aをパラメーターにして崩壊固有時間分布にフィット：

$$\mathrm{Prob}\ (B_s^0 \to B_s^0) = \frac{1}{2\tau} e^{-\frac{t}{\tau}} (1 + A \cdot D \cos \Delta m_s t)$$

$$\mathrm{Prob}\ (B_s^0 \to \overline{B}_s^0) = \frac{1}{2\tau} e^{-\frac{t}{\tau}} (1 - A \cdot D \cos \Delta m_s t)$$

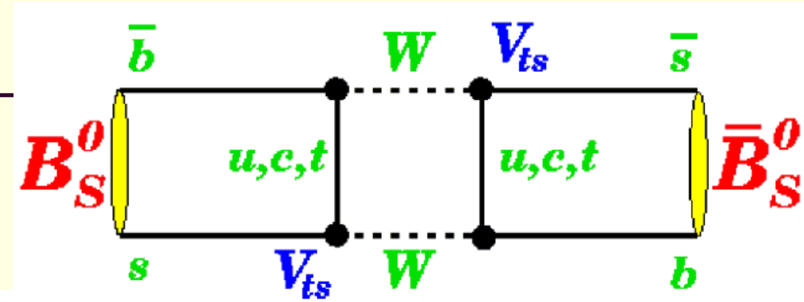
- Δm_s は変えていく
- "A" = 1　振動が起きている
  "A" = 0　振動なし

- まずB_d中間子の粒子反粒子振動でこの方法をチェックする。

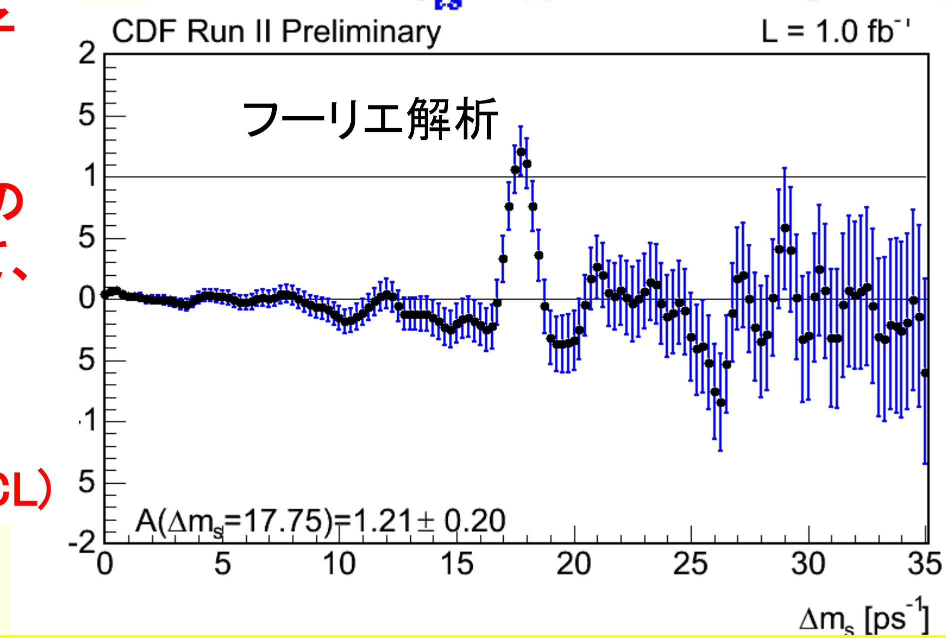


B_d中間子の粒子反粒子振動の信号

B_s中間子振動の観測



CDF実験では，2006年春にB_s中間子の粒子反粒子振動を観測した(多数の新聞報道)。



B_s中間子振動の振動数は、B中間子振動の振動数の40倍程度と理論で予測されていて、観測は非常に難しいと考えられていた。

PRL 97 (2006) 062003　3.1σ（99.8% CL）
PRL 97 (2006) 242003　5.4σ（1−8x10^{-8} CL）

B_s 中間子の粒子反粒子振動の角振動数

Δm_s ＝17.77 ±0.10(統計誤差)±0.07(系統誤差)毎ピコ秒。(ピコ秒＝10^{-12}秒)

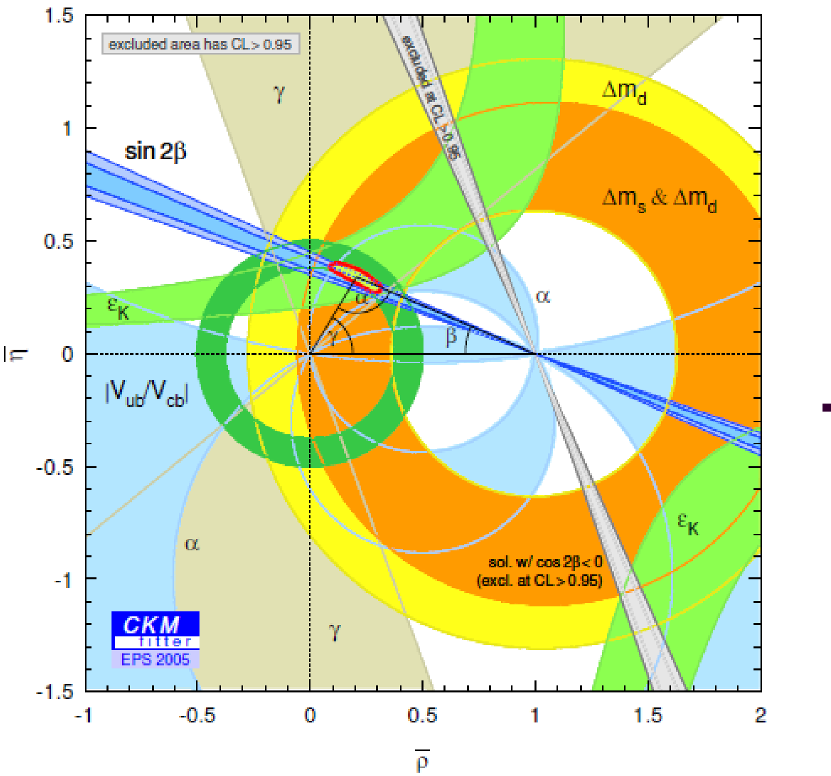
標準理論(小林益川理論)の非常に高い精度の検証。

魚住　聖（筑波大）博士論文 「 B_s中間子の寿命測定」

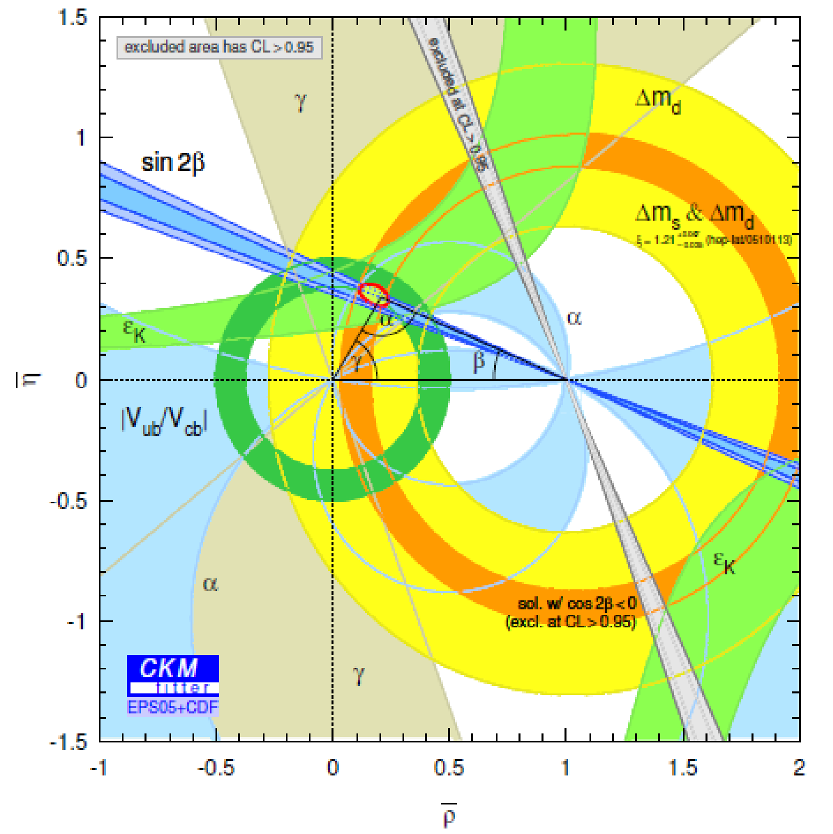
B_s中間子振動の観測

ユニタリ三角形

2005年夏



Δm_s測定後(2006年)

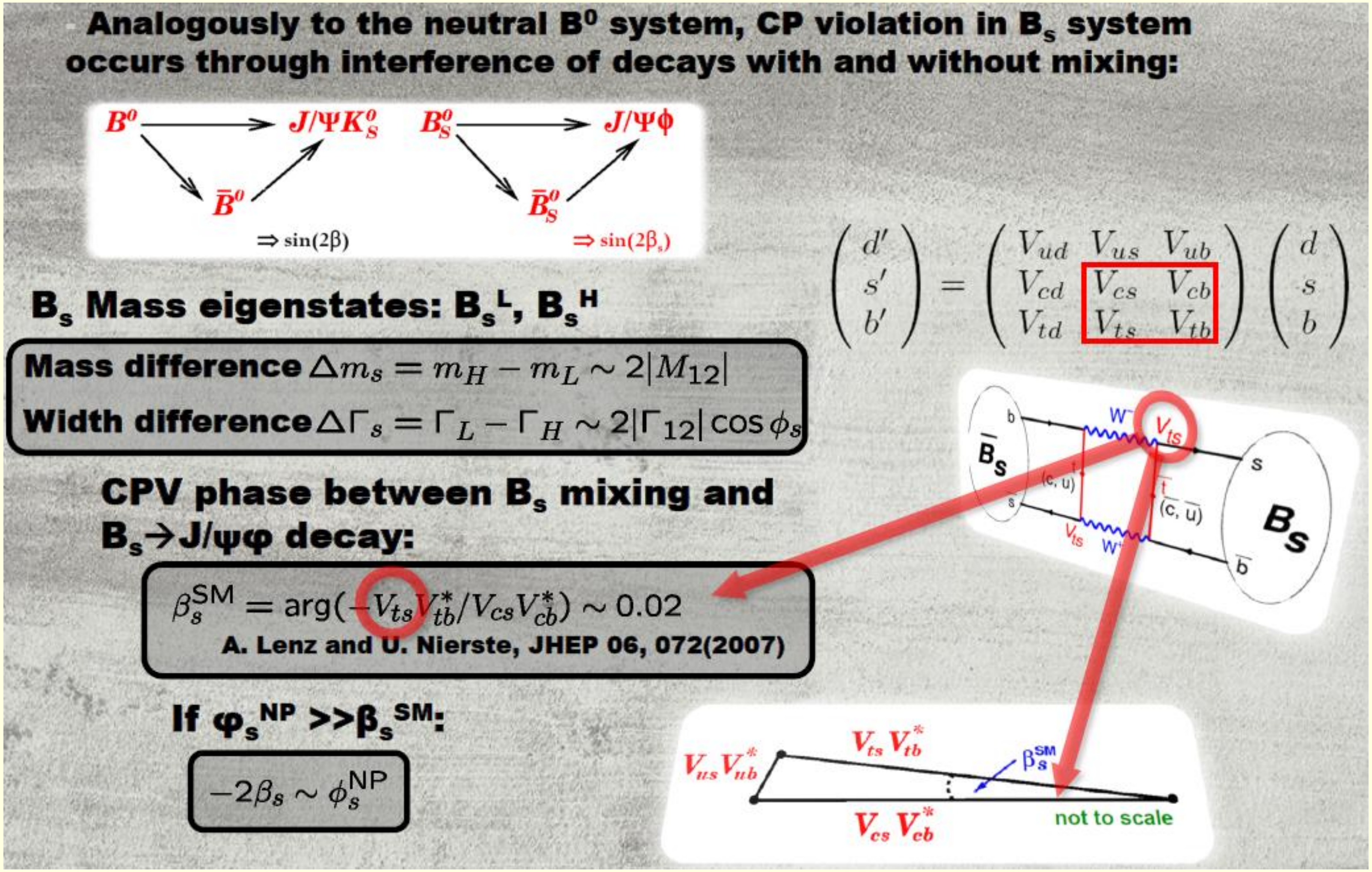


Δm_s ＝17.77 ±0.10(統計誤差)±0.07(系統誤差)毎ピコ秒。(ピコ秒＝10^{-12}秒)

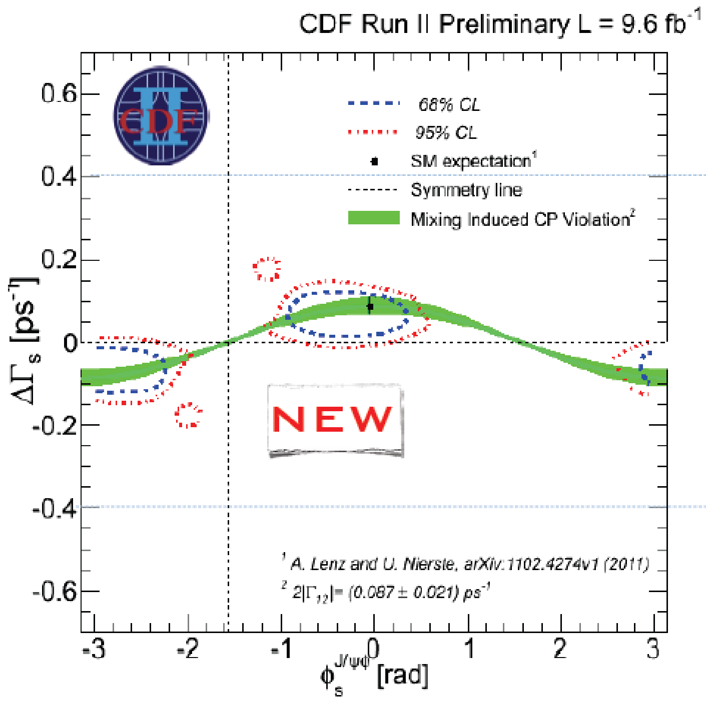
$|V_{td}/V_{ts}|$ = 0.2060±0.0007 (実験) +0.0081/−0.0060 (理論)

標準理論(小林益川理論)の非常に高い精度の検証。

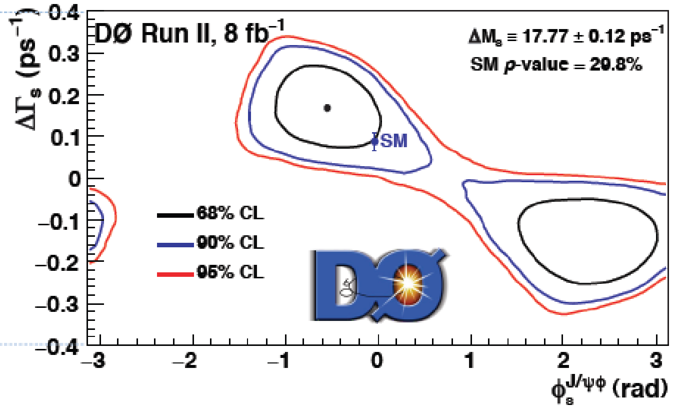
$B_s \to J/\Psi\ \phi$におけるCPの破れの探索



$B_s \to J/\Psi\ \phi$におけるCPの破れの探索



PRD 85, 032006 (2012)



Strong phases fitting range restricted based on $B^0 \to J/\psi K^*$

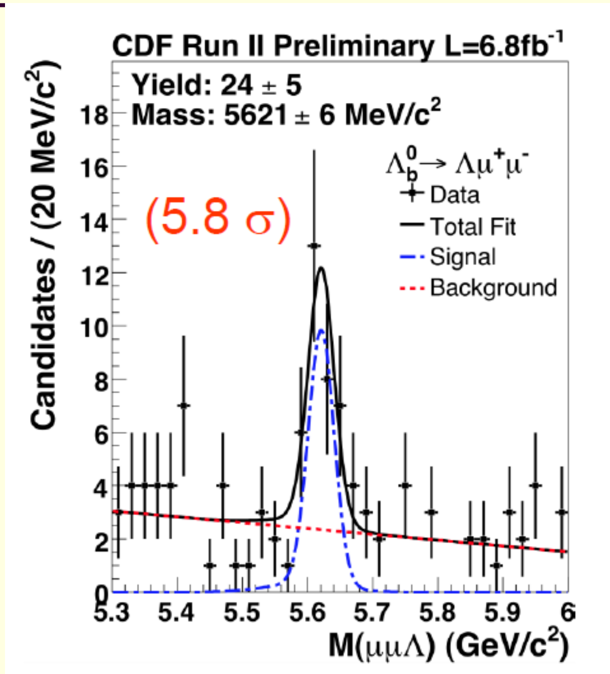
ϕ_s in [-0.60, 0.12] rad @ 68% C.L.

$\phi_s = -0.55^{+0.38}_{-0.36}$ rad

Both experiments consistent with SM ($< 1\sigma$).

$b \to s\ \mu\ \mu$ 崩壊

$\Lambda_b \to \Lambda\ \mu\mu$ 崩壊モードの初観測



$BR(\Lambda_b \to \Lambda\mu^+\mu^-) = [1.73 \pm 0.42(stat) \pm 0.55(syst)] \times 10^{-6}$

QCD理論計算

$BR(\Lambda_b \to \Lambda\mu^+\mu^-) = (4.0 \pm 1.2) \times 10^{-6}$ (sum rule model)

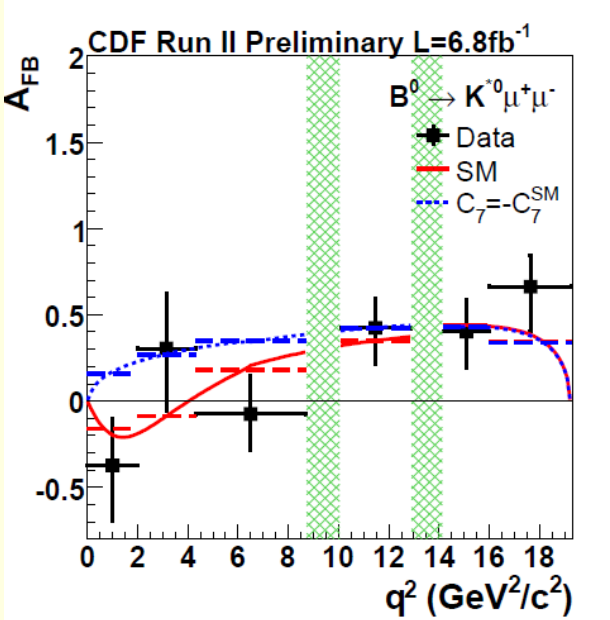
T.M.Aliev et al. PRD 81, 056006 (2008)

$BR(\Lambda_b \to \Lambda\mu^+\mu^-) = (2.08 \sim 3.19) \times 10^{-6}$ (HQET model)

C. H. Chen, C. Q. Ceng, PRD 64, 074001 (2001)

本計画研究の三宅秀樹研究員による解析

$B_d \to K^*\mu\mu$ 崩壊のμ前後方非対称性



In the theoretically cleanest range $1<q^2<6$:

$$A_{FB}^{CDF}(1 < q^2 < 6\,\mathrm{GeV}^2/c^4) = 0.29^{+0.20}_{-0.27} \pm 0.07$$

better than Belle 660x10⁶ B

$$A_{FB}^{Belle}(1 < q^2 < 6\,\mathrm{GeV}^2/c^4) = 0.26^{+0.27}_{-0.30} \pm 0.07$$

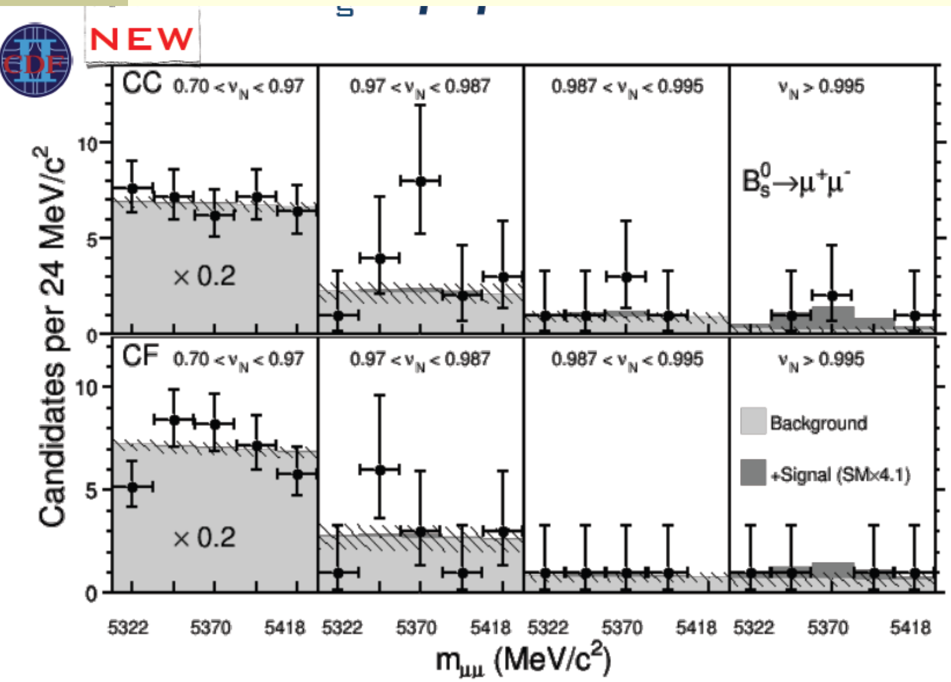
Comparable to LHCb 300 pb^{-1}

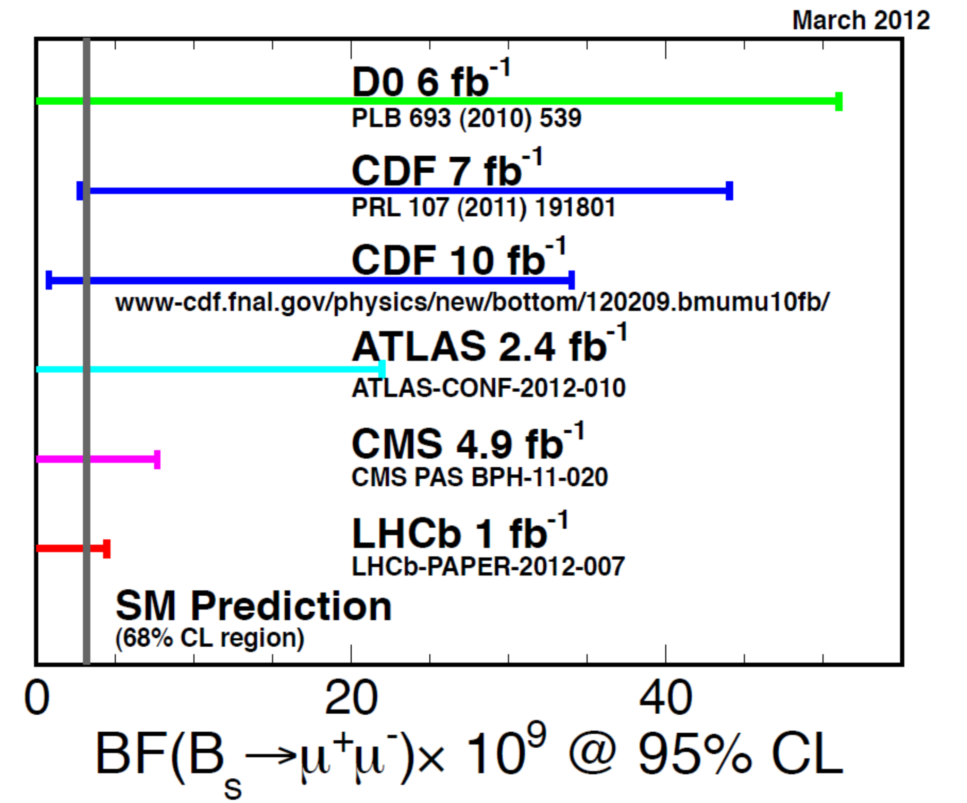
$$A_{FB}^{LHCb}(1 < q^2 < 6\,\mathrm{GeV}^2/c^4) = -0.10 \pm 0.14 \pm 0.05$$

$B_s \rightarrow \mu\mu$ 崩壊探索

$0.8 \times 10^{-9} < BR(B_s \rightarrow \mu\mu) < 3.4 \times 10^{-8}$ @95% C.L. 〔 $BR = (1.3^{+0.9}_{-0.7}) \times 10^{-8}$ 〕

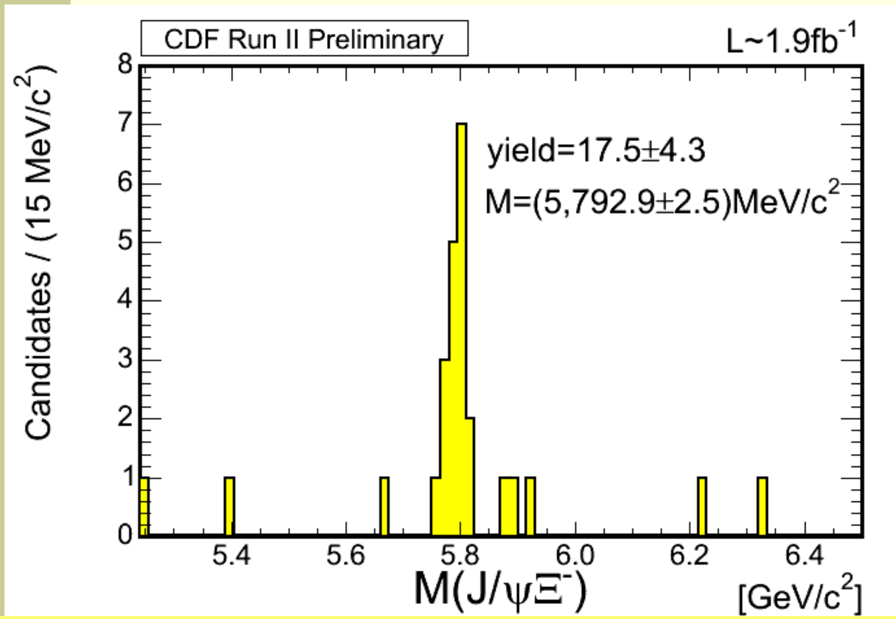
Bkg+SM p-value 7.1%. Bkg-only p-value 0.94%

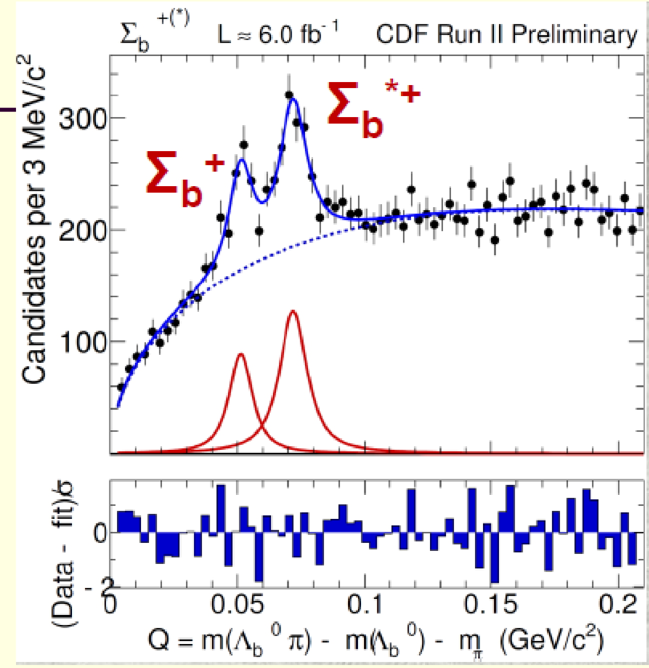




Neural Network解析で$B_s \rightarrow \mu\mu$ 崩壊事象を探索。信号領域： $\nu_N > 0.995$

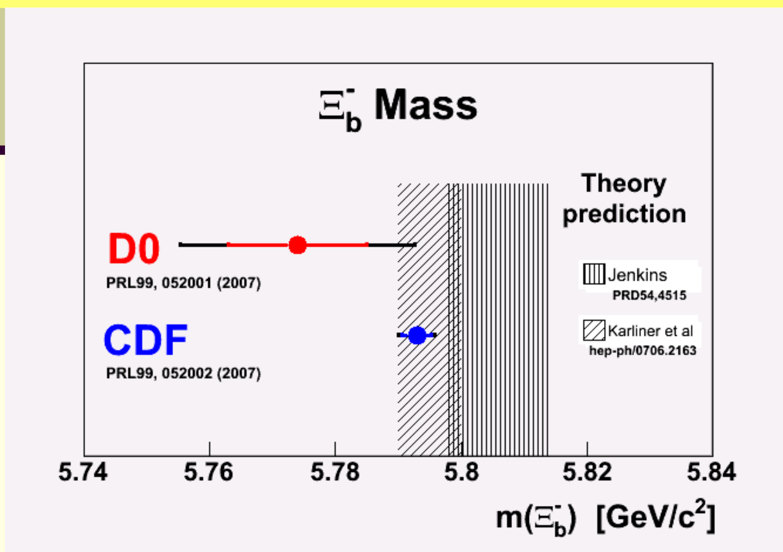
Ξ_b , Σ_b の初観測





$\Xi_b^- \rightarrow J/\Psi\ \Xi^-$; $J/\Psi \rightarrow \mu^+\mu^-$; $\Xi^- \rightarrow \Lambda^0\ \pi^-$; $\Lambda^0 \rightarrow p\ \pi^-$

$\Sigma_b^+ \rightarrow \Lambda_b\ \pi^-$; $\Lambda_b \rightarrow \Lambda_c^+\ \pi^-$; $\Lambda_c^+ \rightarrow p\ K^-\ \pi^+$

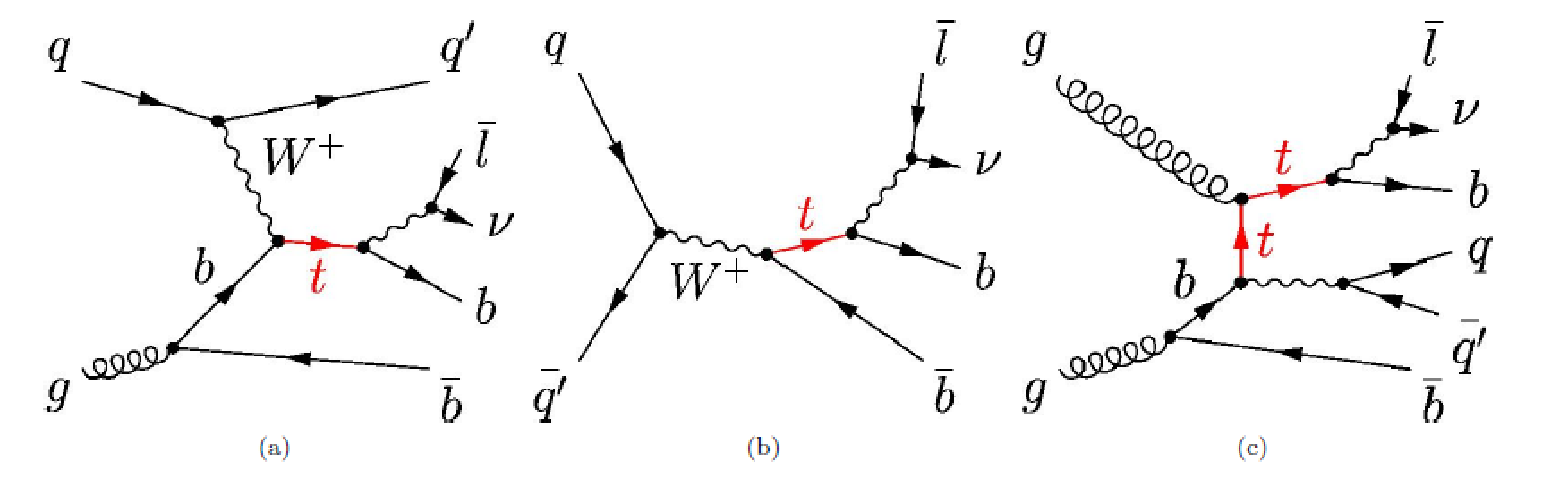


State	M, MeV/c^2	Γ_0, MeV/c^2
Σ_b^+	$5811.2^{+0.9}_{-0.8}$ (stat) $\pm$ 1.7 (syst)	$9.2^{+3.8}_{-2.9}$(stat)$^{+1.0}_{-1.1}$(syst)
Σ_b^{*+}	5832.0 ± 0.7 (stat) $\pm$ 1.8 (syst)	$10.4^{+2.7}_{-2.2}$(stat)$^{+0.8}_{-1.2}$(syst)
Σ_b^-	$5815.5^{+0.6}_{-0.5}$ (stat) $\pm$ 1.7 (syst)	$4.3^{+3.1}_{-2.1}$(stat)$^{+1.0}_{-1.1}$(syst)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

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

トップクォーク単一生成の初観測

Single Top Quark Production



t-channel

$\sigma = 2.10 \pm 0.19$ pb

s-channel

$\sigma = 1.05 \pm 0.07$ pb

W t associated production

$\sigma = 0.22 \pm 0.08$ pb

Cross section calculated with NNNLO
and $M_{top} = 172.5$ GeV

Run1 Analysis

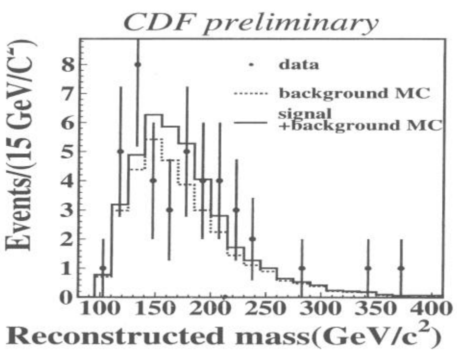
s-channel
W + 2 jets (at least 1 b-tag)

W^* single top search

Candidate	: 42 events
Expected background	($Wb\bar{b}$, $t\bar{t}$ ...)
	: 29.7 ± 4.7 events
Expected signal	: 1.8 ± 0.3 events

Perform a likelihood fit of reconstructed top mass distribution:

Number of fitted signal events = $6.4\ ^{+7.3}_{-6.4}$
$\sigma_{W^*} < 12.9$ pb at 95% C.L.



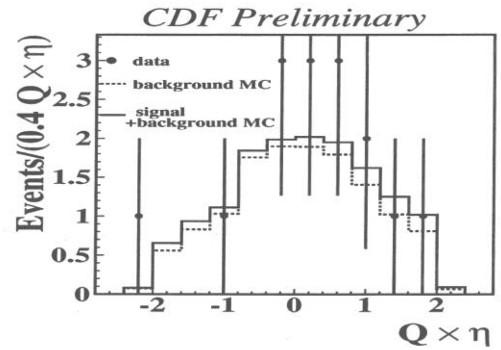
t-channel
W + 2 jets (1 b-tag and 145<M_t <245 GeV)

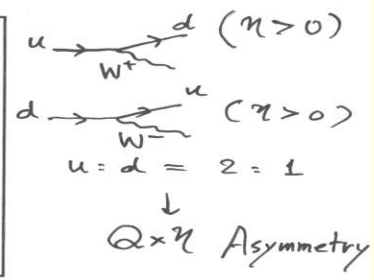
W-gluon fusion single top search

Candidate	: 15 events
Expected background	: 13.1 ± 2.1 events
Expected signal	: 1.4 ± 0.3 events

Perform a likelihood fit of $Q\times\eta$ distribution:
Q: lepton charge (± 1), η: untagged jet pseudo-rapidity.

Numeber of fitted signal = $1.3\ ^{+4.2}_{-1.3}$
$\sigma_{Wg} < 13.5$ pb at 95% C.L.



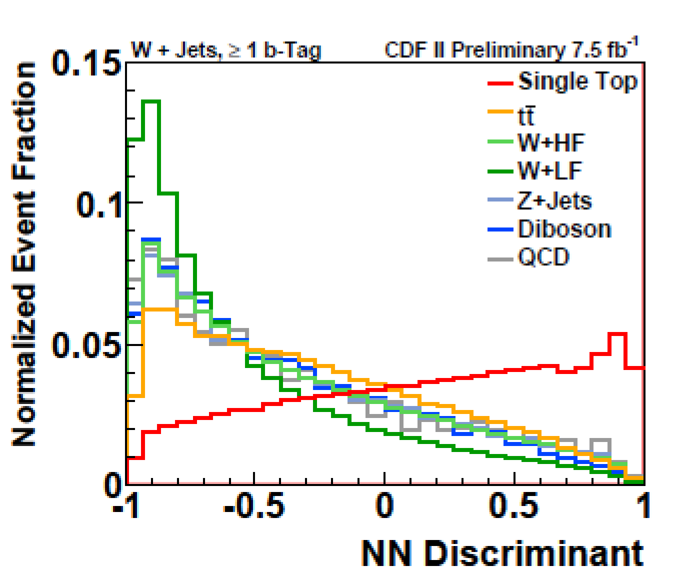


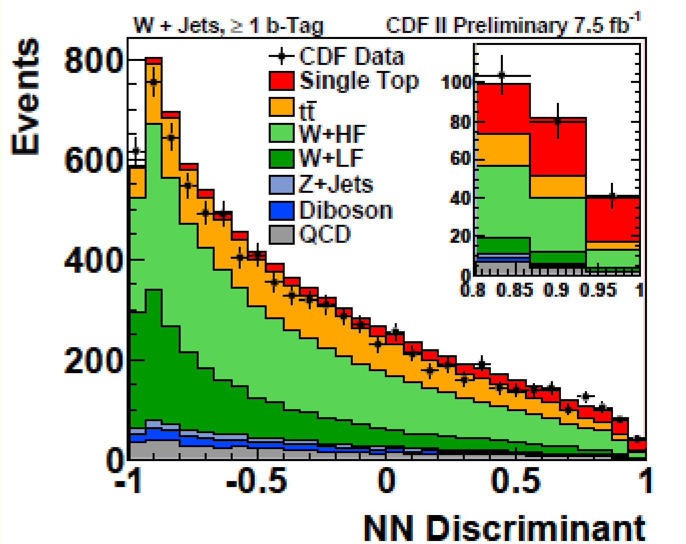
Combined Cross Section Limit

$\sigma_{W^*} + \sigma_{Wg} = 5.9\ ^{+4.9}_{-3.4}$(stat)±1.4(syst) pb
$\sigma_{W^*} + \sigma_{Wg} < 18.6$ pb at 95% C.L.

菊地俊章（筑波大）博士論文
“ Search for Single Top Quark Production in 1.8-TeV Proton-Antiproton Collisions ”

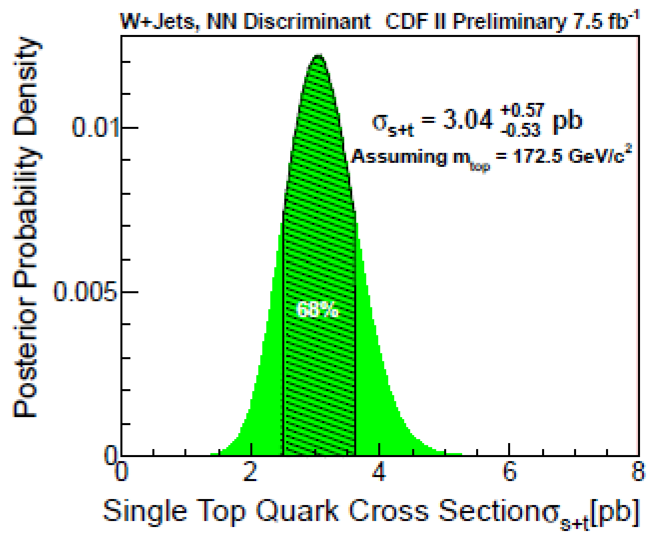
Neural Network Analysis (Run 2)

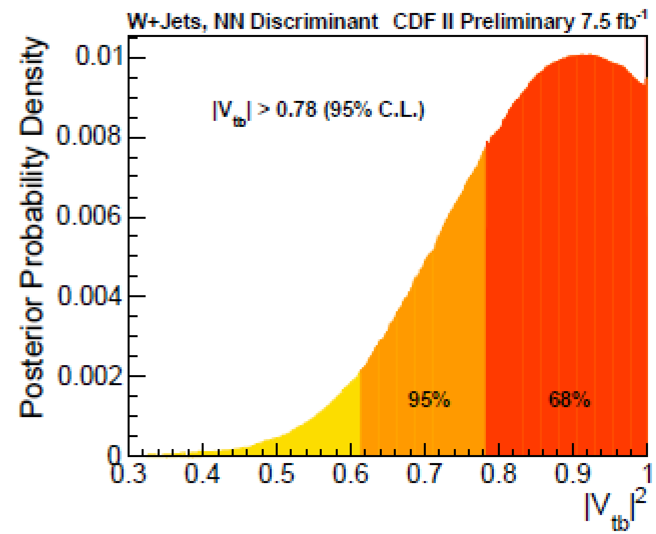


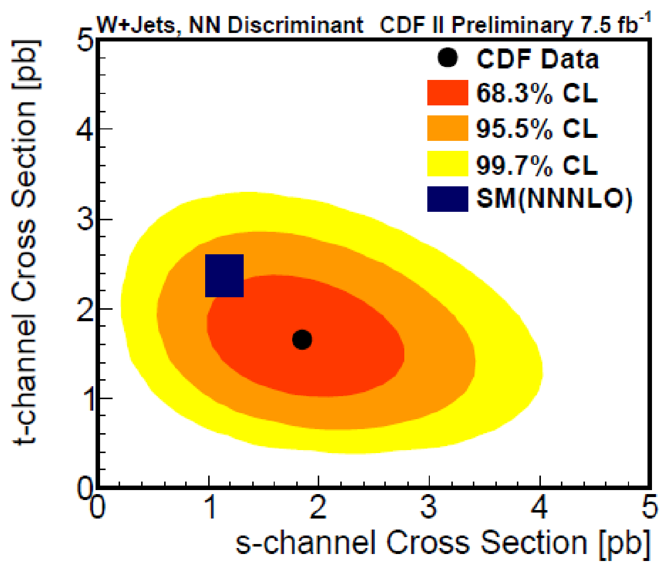


variable	2-jet 1-tag	2-jet 2-tag	3-jet 1-tag	3-jet 2-tag
$M_{\ell\nu b}$	✓	✓	✓	
$M_{\ell\nu bb}$		✓		✓
$M_t^{\ell\nu b}$	✓	✓	✓	✓
M_{jj}	✓	✓	✓	✓
M_t^w	✓	✓		
$E_t^{b_{top}}$		✓	✓	
$E_t^{b_{other}}$				✓
$\sum e_t^{jj}$			✓	✓
E_t^{light}	✓			✓
p_t^{ℓ}	✓			
$p_t^{\ell\nu jj}$			✓	✓
H_t	✓		✓	
$\not{E}_T$		✓		
$\not{E}_{T\,sig}$			✓	
$\cos\theta_{\ell j}$	✓		✓	✓
$\cos\theta^w_{\ell w}$	✓			
$\cos\theta^t_{\ell w}$	✓			
$\cos\theta^t_{jj}$		✓		✓
$Q \times \eta$	✓		✓	✓
η_ℓ		✓		
η_w	✓	✓		
$\sum \eta_j$	✓		✓	
$\Delta\eta_{jj}$			✓	✓
$\Delta\eta_{t,light}$			✓	
$\sqrt{\hat{s}}$				✓
Centrality				✓
Jet flavor separator	✓	✓	✓	

Single Top Cross Section and $|V_{tb}|$







$$|V_{tb}| = 0.96 \pm 0.09(\mathrm{stat+sys}) \pm 0.05(\mathrm{theory})$$

$$\sigma_t = 1.49^{+0.47}_{-0.42} \text{ pb}$$

$$\sigma_s = 1.81^{+0.63}_{-0.58} \text{ pb}$$

Theoretical prediction

($\sigma_{t+wt} = 2.32 \pm 0.27$ pb and $\sigma_s = 1.05 \pm 0.07$ pb)

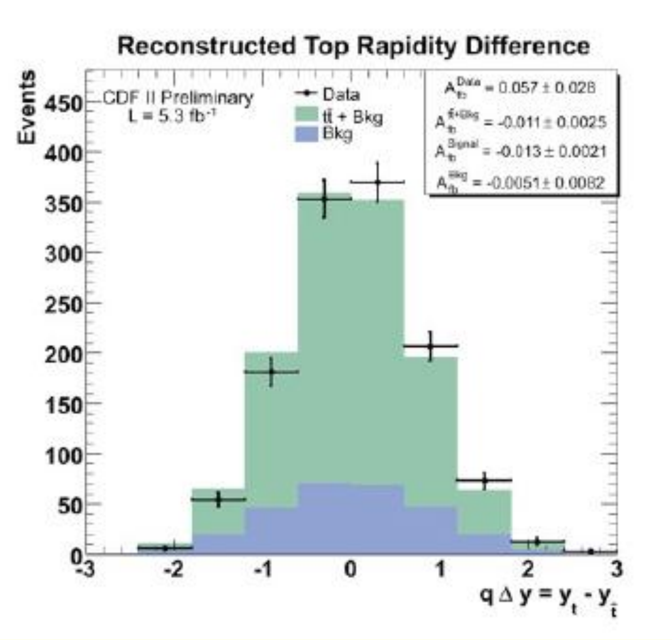
中村浩二（筑波大）博士論文 “ Measurement of the Single Top Quark Production Cross Section in 1.96-TeV Proton-Antiproton Collisions ”

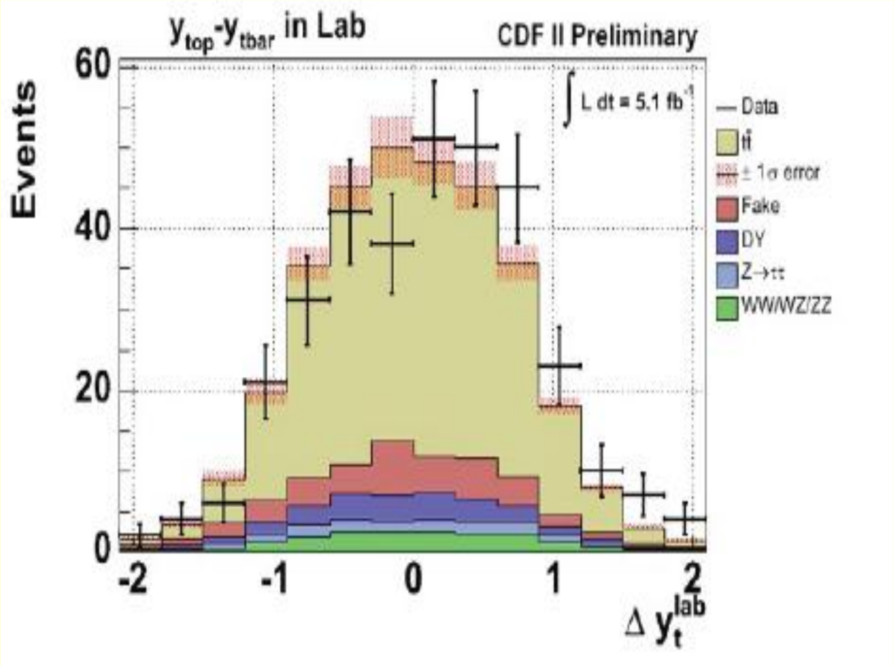
トップクォーク対生成の前後方非対称性

トップ対生成の前後方非対称性

Lepton + jets channel

Dilepton channel





$A_{FB} = 16 \pm 7_{stat} \pm 2_{syst}$ %

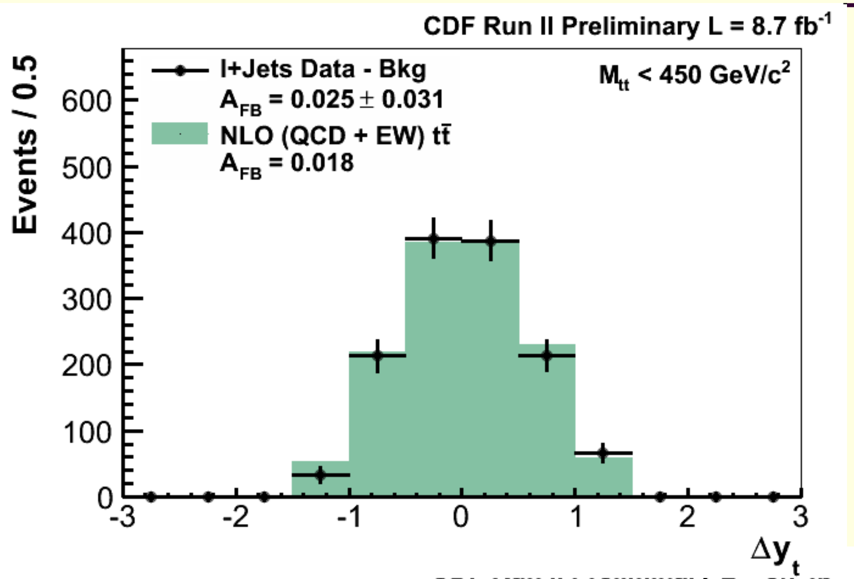
$A_{FB} = 42 \pm 15_{stat} \pm 5_{syst}$ %

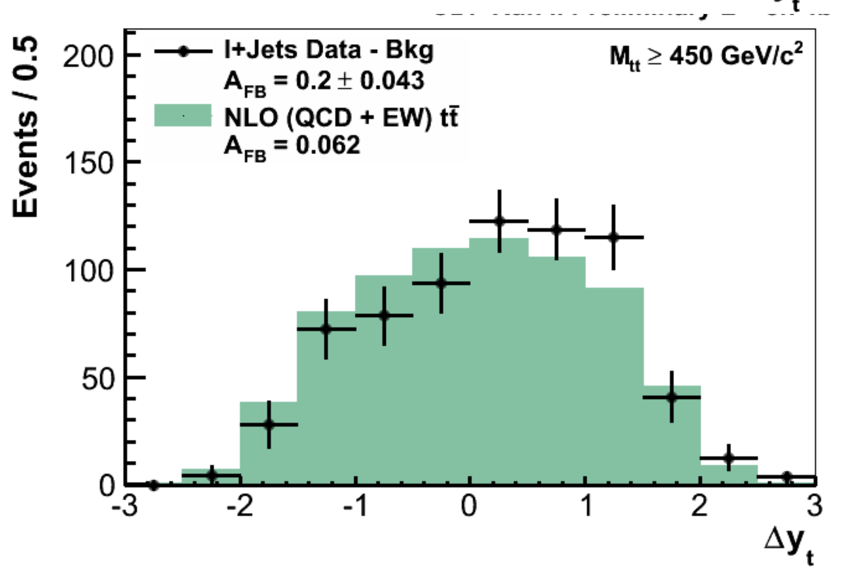
Combined $A_{FB} = 20 \pm 7_{stat} \pm 2_{syst}$ %

(2.9σ from zero asymmetry, 1.9σ from A_{FB}^{Theory})

($A_{FB}^{Theory} = 6 \pm 1$% by Higher Order QCD calculation)

トップ対生成の前後方非対称性(M_{tt}依存性)





For M_{tt} ＞ 450 GeV

A_{FB} =0.200±0.043

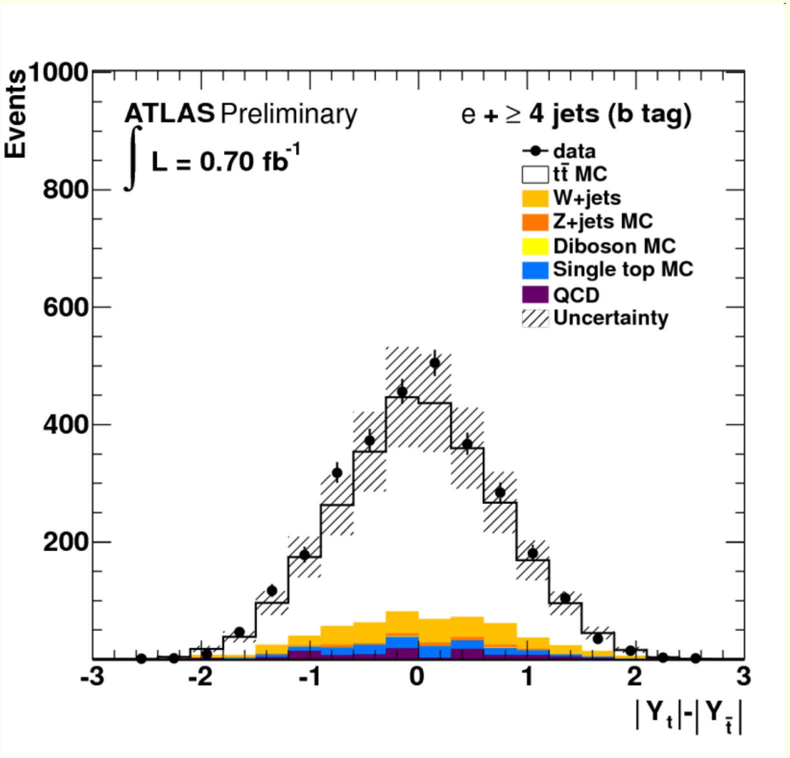
A_{FB}^{Theory} ＝ 0.062

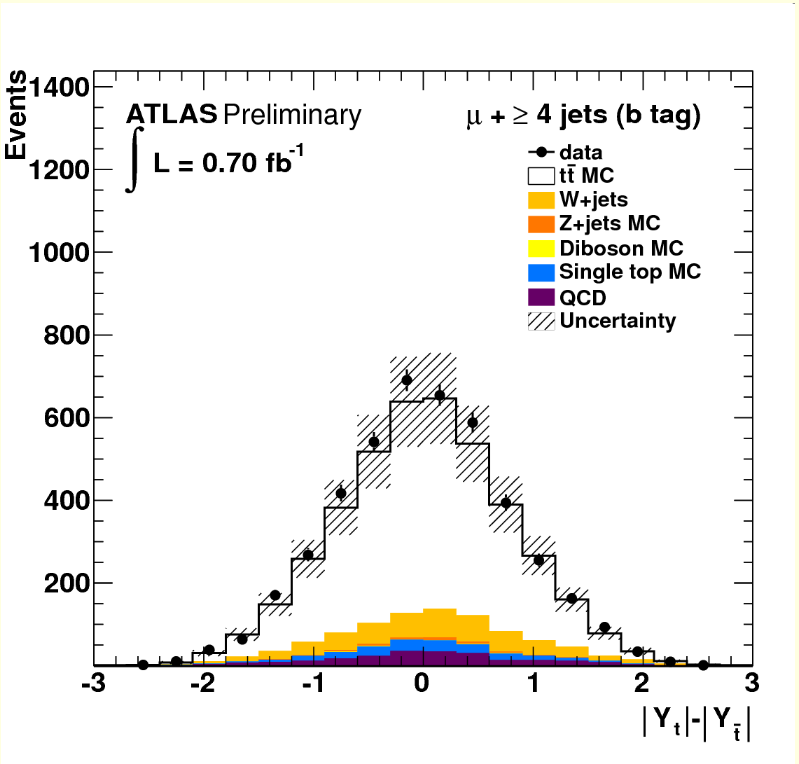
3.2σ away from A_{FB}^{Theory}

(A_{FB} Mass slope 2.4σ away from theoretical prediction)¥

トップ対生成の前後方非対称性（ATLAS）

ATLAS-CONF-2011-106



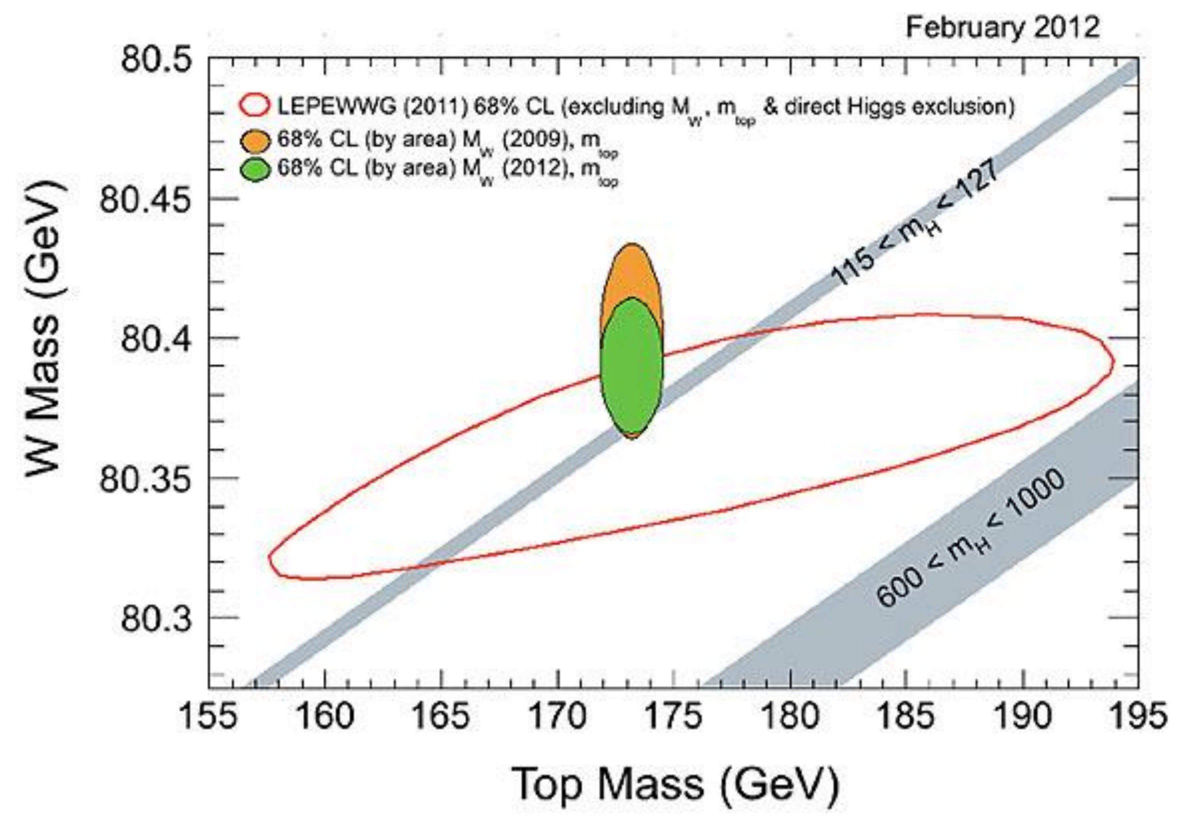


A_C = {N(Δ |Y|>0)−N(Δ |Y|<0)} / {N(Δ |Y|>0)+N(Δ |Y|<0)}

A_C = −0.024±0.016 (stat)±0.023 (syst),
in agreement with the Standard Model prediction: A_C=0.006.

トップクォークとWボソンの質量測定
（ヒッグス粒子の間接探索）

トップとWの質量測定によるヒッグス粒子の間接探索



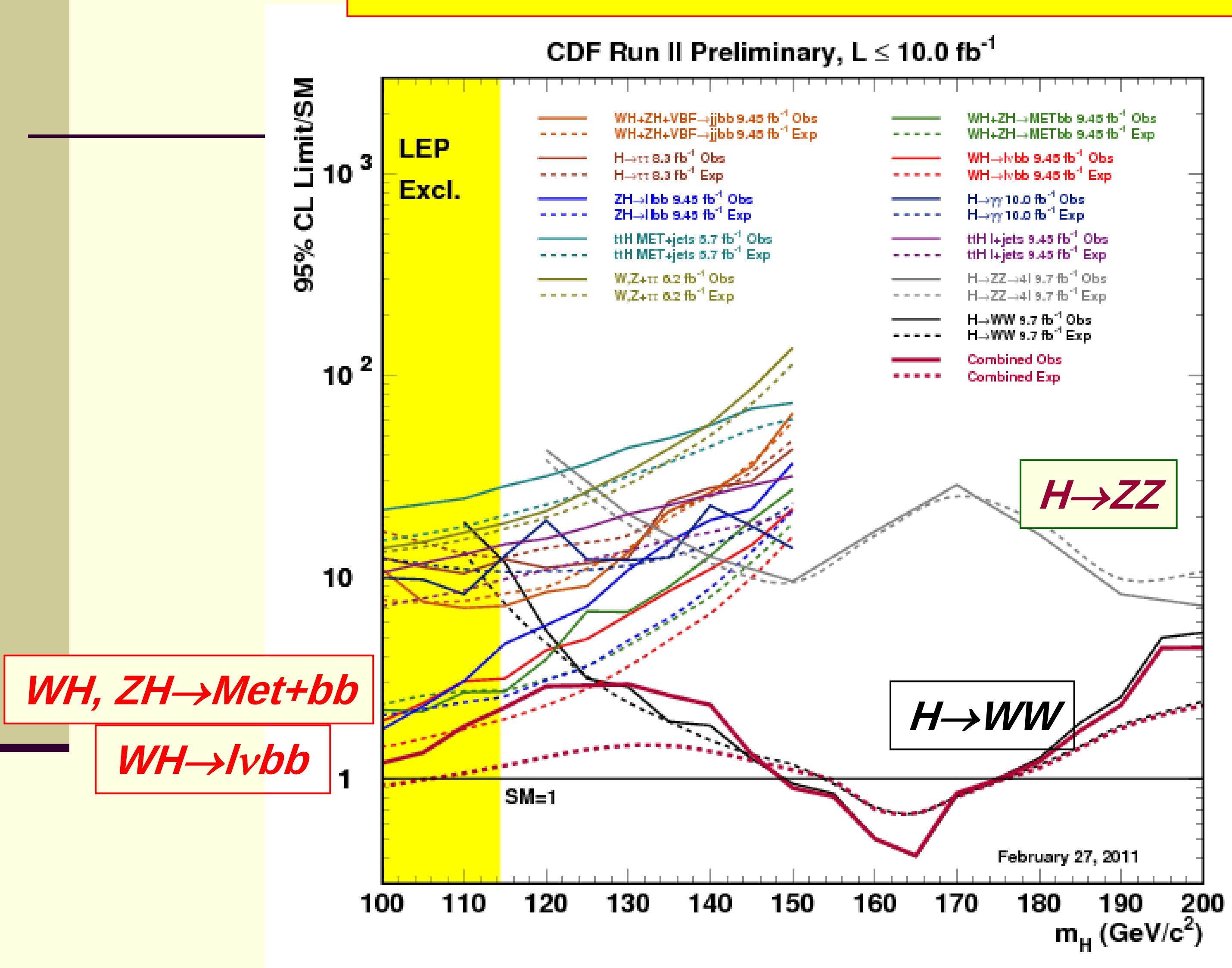
質量の輻射補正計算より，ヒッグス粒子の質量はトップクォークの質量とWボソンの質量に左図のように関係づけられる。
トップとWの質量測定→ヒッグスの質量決定

トップクォークの質量(Tevatron): M_{top} = 173.1 ± 0.9 GeV/c^2
Wボソンの質量(LEP2 + Tevatron): M_W = 80.390 ± 0.016 GeV/c^2

ヒッグス粒子の質量: M_{Higgs} < 145 GeV/c^2 (95%信頼度)

ヒッグス粒子の直接探索

ヒッグス粒子の直接探索

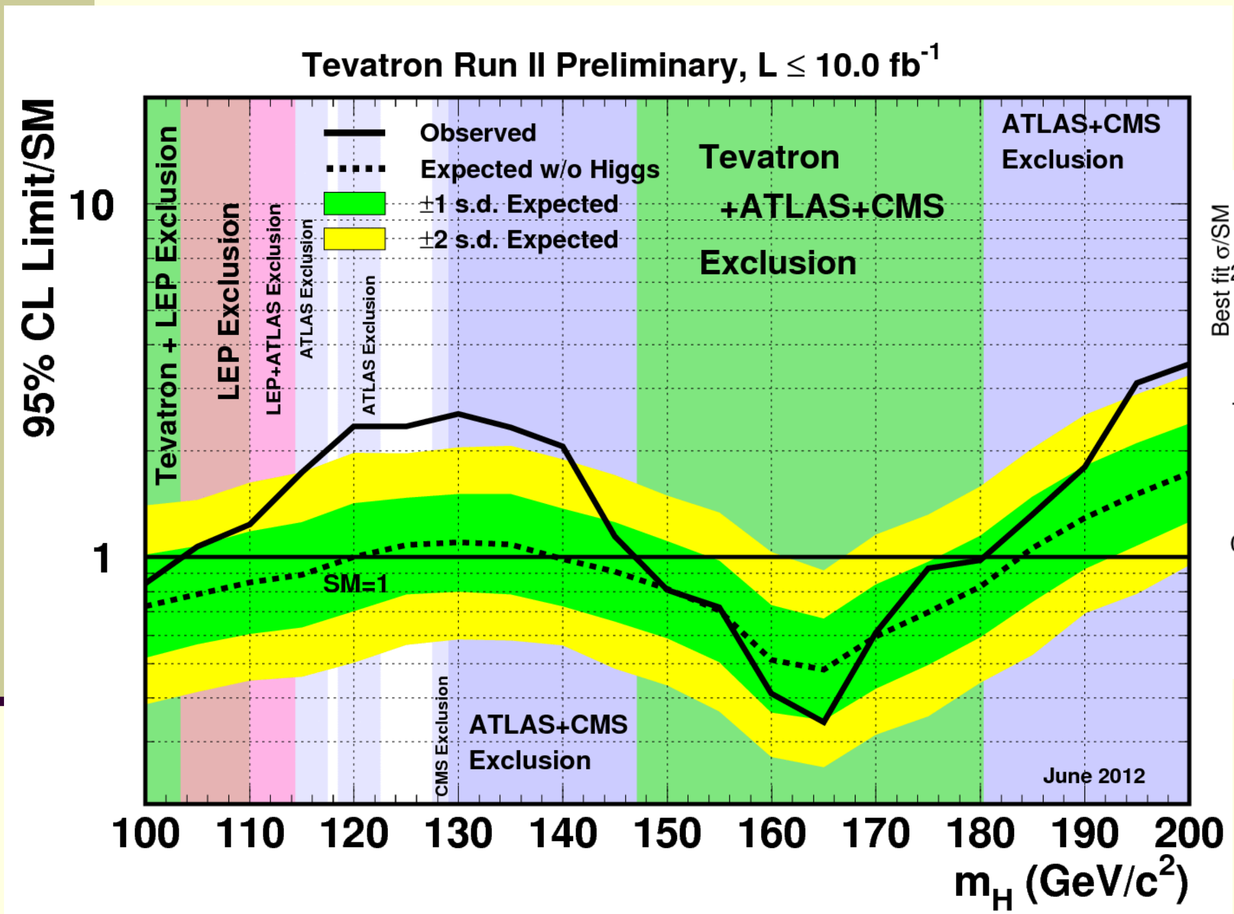


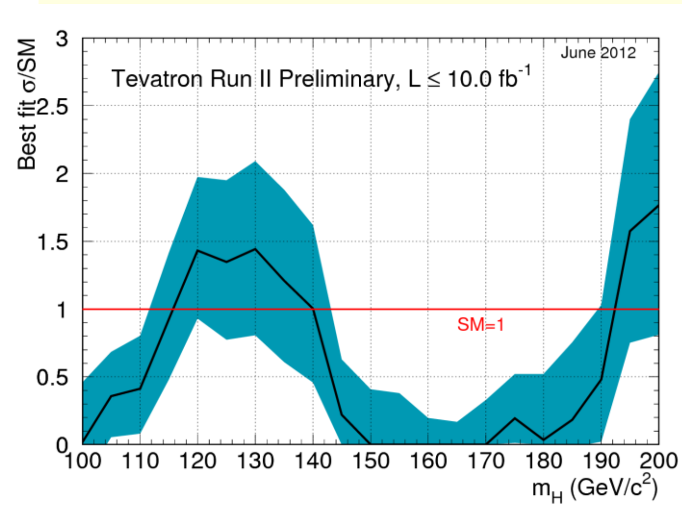
- $M_H < 130$ GeV/c^2 $\quad pp \rightarrow WHX \rightarrow l\ \nu + bb + X$

博士論文:　増渕達也(筑波大), 永井義一(筑波大)

ヒッグス粒子探索

10fb^{-1}　Tevatron





2012年7月2日　147＜m_H ＜180 GeV/c^2, 100＜m_H＜103 GeV/c^{2}を95%C.L.で排除。

115 ＜m_H ＜ 135 GeV/c^{2}のexcessの有意性 2.5σ

2006年度以降の
CDF日本グループ博士論文 (11篇)

2006年度以降

Y. Kusakabe Search for Higgs Boson Production in Proton-Antiproton Collisions at sqrt{s}=1.96TeV (2006.12)
PRD78 (2008) 032008; citation 13

T. Akimoto Search for Third Generation Vector Leptoquarks in 1.96-TeV Proton-antiproton Collisions (2007.2)
PRD77 (2008) 091105; citation 11

T. Kubo Measurement of the Top Quark Mass by Dynamical Likelihood Method using the Lepton+Jets Events with the Collider Detector at Fermilab (2008.2)

T. Masubuchi Search for Higgs Boson Production in Association with a W Boson in 1.96-TeV Proton-Antiproton Collisions (2008.2) PRL103 (2009) 101802; citation 33

A. Nagano Measurement of W+Photon Production in Proton-Antiproton Collisions at 1.96 TeV (2008.2)

J. Naganoma Study on the Top Quark Pair Production Mechanism in 1.96TeV Proton-Antiproton Collisions (2008.3) PL B691 (2010) 183; citation 13

N. Kimura Study of the Top Quark Production Mechanism in 1.96-TeV Proton-Antiproton Collisions (2009.2)

K. Nakamura Measurement of the Single Top Quark Production Cross Section in 1.96-TeV Proton-Antiproton Collisions(2009.2) PRL 103 (2009)092002; citation 171

Y. Nagai Search for the Standard Model Higgs Boson in the WH -> l nu b b-bar Channel in 1.96-TeV Proton-Antiproton Collisions(2009.2) PRL 104 (2010)081802; citation 86

Y. Sudo Search for the Standard Model Higgs Boson in $H \rightarrow WW \rightarrow \ell\nu jj$ Channel in 1.96-TeV Proton-Antiproton Collisions (2012.2)

K. Takemasa Measurement of the Spin Correlation in the Top Quark Pair Production using the Dilepton Events in 1.96-TeV Proton-Antiproton Collisions (2012.2)

まとめ

- CDF実験で. 多くの重要なフレーバー物理の成果を得た。
  - B_s中間子振動の観測
  - トップ単一生成の観測
  - トップ対生成の前後方非対称性の測定
  - ヒッグス粒子の質量範囲の決定

- 大型国際協力実験の経験で成長した若手研究者人材を多く輩出した。

BACKUP

$B_s \to J/\Psi\ \phi$におけるCPの破れの探索

Assuming SM CP-violation, new CDF measurement with full Run II dataset

$\Delta\Gamma_s = 0.068 \pm 0.026 \pm 0.007\ \mathrm{ps}^{-1}$

$\tau_s = 1.528 \pm 0.019 \pm 0.009\ \mathrm{ps}$

NEW

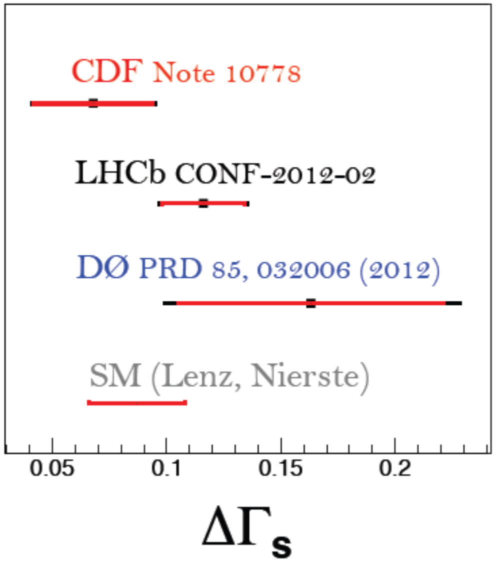
CDF Note 10778

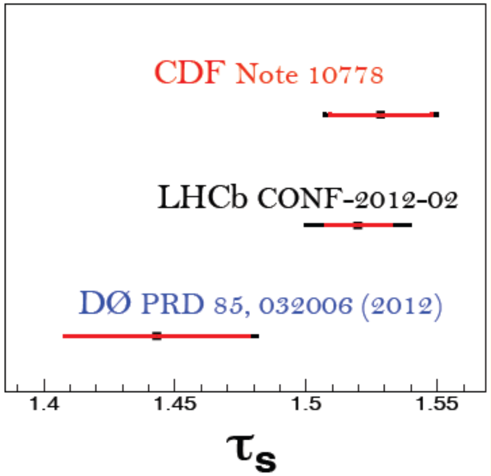
DØ: $\Delta\Gamma_s = 0.163\ ^{+0.065}_{-0.064}\ \mathrm{ps}^{-1}$

$\tau_s = 1.443\ ^{+0.038}_{-0.035}\ \mathrm{ps}$

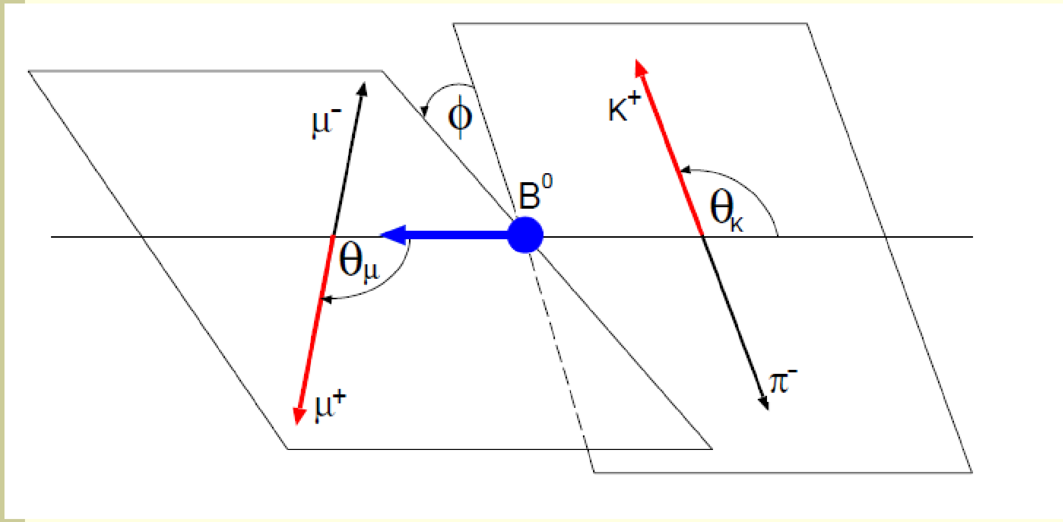
PRD 85, 032006 (2012)

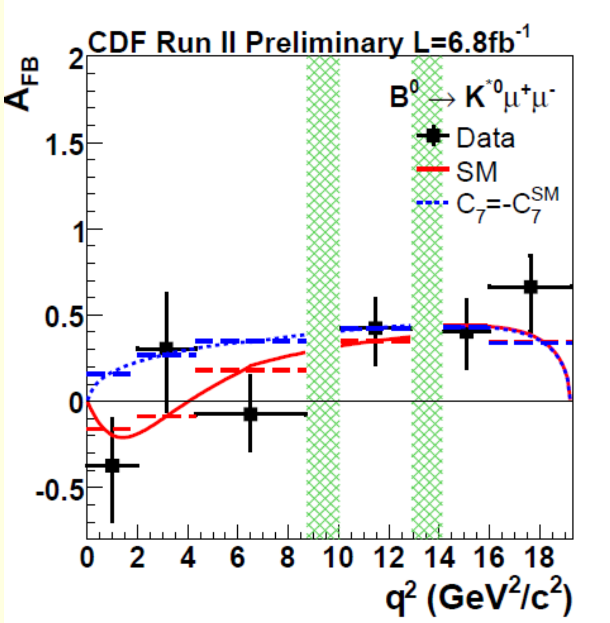
Very interesting to constrain A_{SL} (for instance, A. Lenz @Moriond EW 2012)





$B_d \to K^*\mu\mu$ 崩壊におけるμ前後方非対称性





In the theoretically cleanest range $1<q^2<6$:

$$A_{FB}^{CDF}(1<q^2<6\,\text{GeV}^2/c^4) = 0.29^{+0.20}_{-0.27} \pm 0.07$$

better than Belle 660×10^6 B

$$A_{FB}^{Belle}(1<q^2<6\,\text{GeV}^2/c^4) = 0.26^{+0.27}_{-0.30} \pm 0.07$$

Comparable to LHCb 300 pb^{-1}

$$A_{FB}^{LHCb}(1<q^2<6\,\text{GeV}^2/c^4) = -0.10 \pm 0.14 \pm 0.05$$

$$\frac{1}{\Gamma}\frac{d\Gamma(B^0 \to K^{*0}\mu^+\mu^-)}{d\cos\theta_\mu} = \frac{3}{4}\mathrm{F_L}(1-\cos^2\theta_\mu) + \frac{3}{8}(1-\mathrm{F_L})(1+\cos^2\theta_\mu) + \mathrm{A_{FB}}\cos\theta_\mu .$$

本研究計画の三宅秀樹研究員による解析

*D*中間子崩壊におけるCP対称性の破れ

Optimize off-line selection for ΔA_{CP}

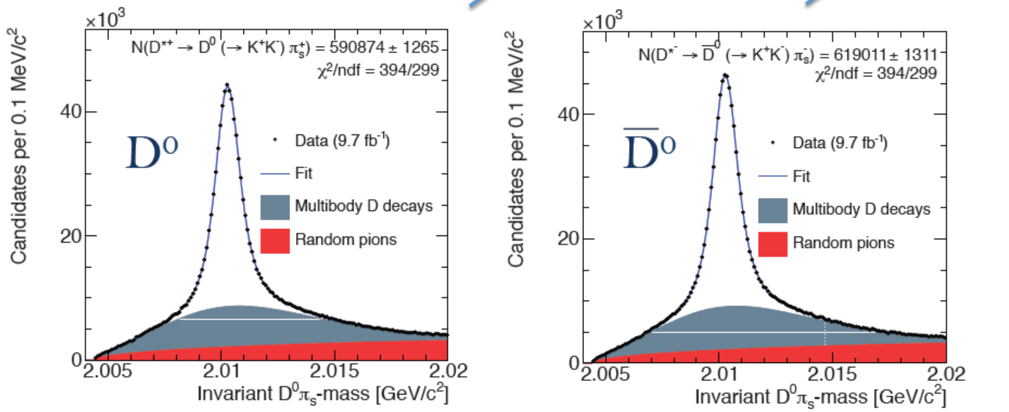
- ✓ loosen selection requirements (no D^0 I.P. cut) w.r.t. 5.9 fb^{-1} analysis: no need of $D^0 \to K\pi$.
- ✓ about double signal events.

D^0 flavor through $D^* \to D^0 \pi_s$

- ✓ soft pion induce O(1%) artificial asymmetries.

  Cancel detector effects by differences of raw asymmetries:

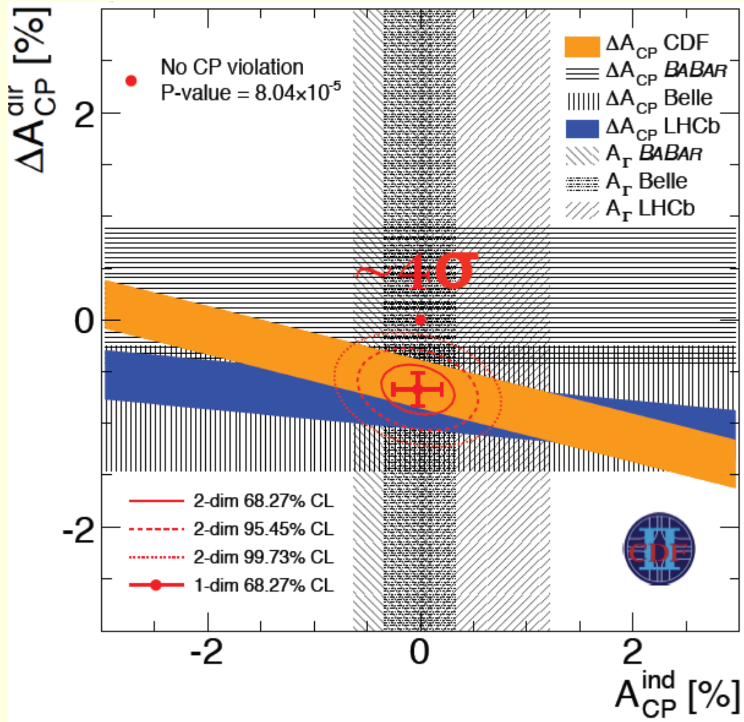
$$\Delta A_{CP} = (A(K^+K^-) + \delta(\pi_s)) - (A(\pi^+\pi^-) + \delta(\pi_s))$$



$\Delta A_{CP} = (-0.62 \pm 0.21(stat) \pm 0.10(syst))\%$

Confirm LHCb result

$\Delta A_{CP} = (-0.82 \pm 0.21 \pm 0.11)\%$



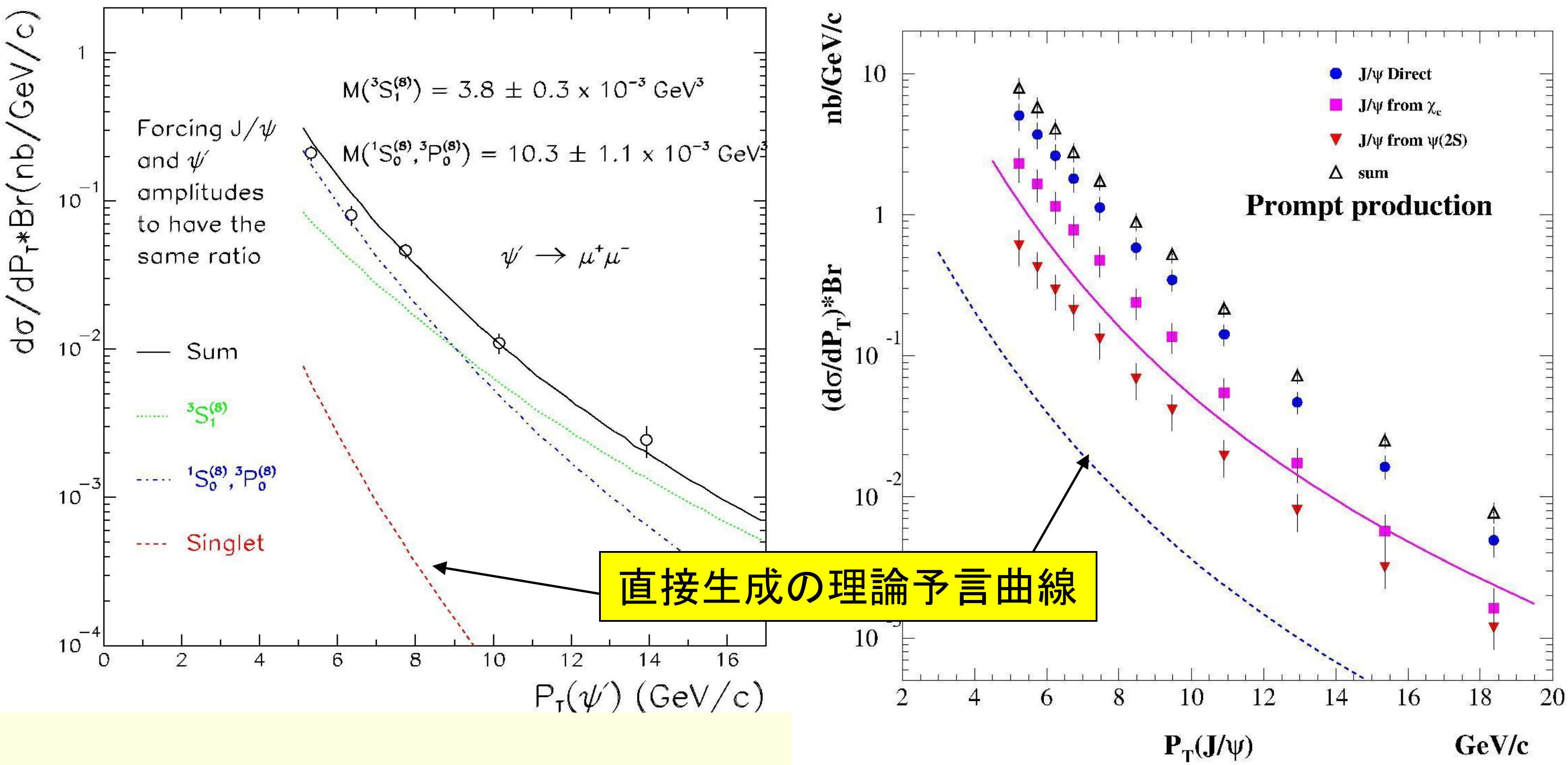
When combining à la HFAG
No CPV point is at
~4σ from zero

$\Delta A_{CP}^{dir} = (-0.67 \pm 0.16)\%$

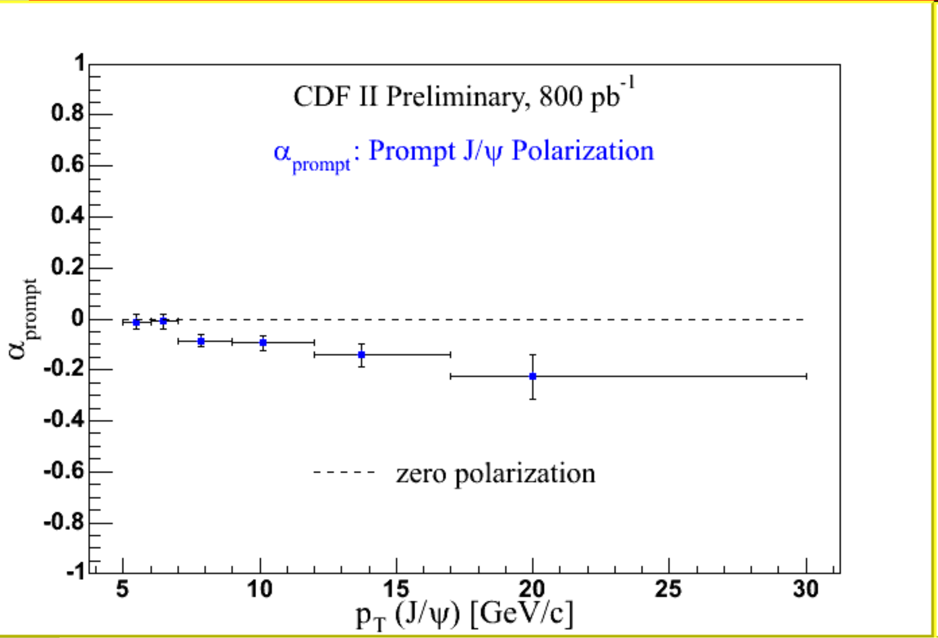
$A_{CP}^{ind} = (-0.02 \pm 0.22)\%$

Anomalous Prompt J/ψ Production

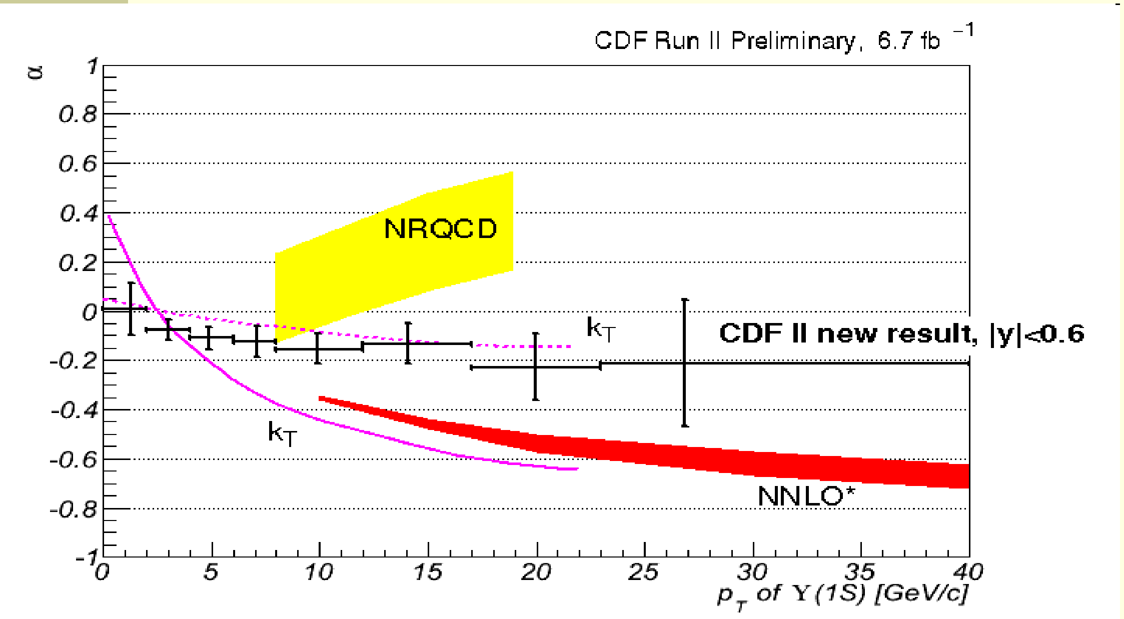
- ***J/ψ* と*ψ*(2s) の直接生成がQCD理論予言の50倍**
  PRL 79 (1997) 572,　PRL 79 (1997) 578
- ***J/ψ* と*ψ*(2s) の偏極度はColor Octet Model を否定**



Polarization of Prompt *J/ψ* and Upsilon at CDF



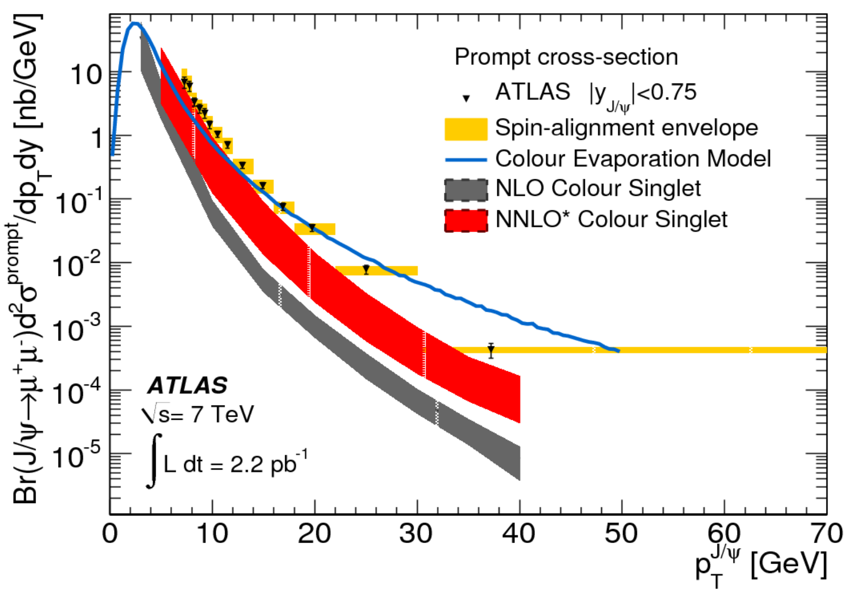
Prompt J/ψ の偏極はCOLOR OCTET MODEL(CEM)の予言（偏極0）と一致しない。
PRL 99 (2007) 132001

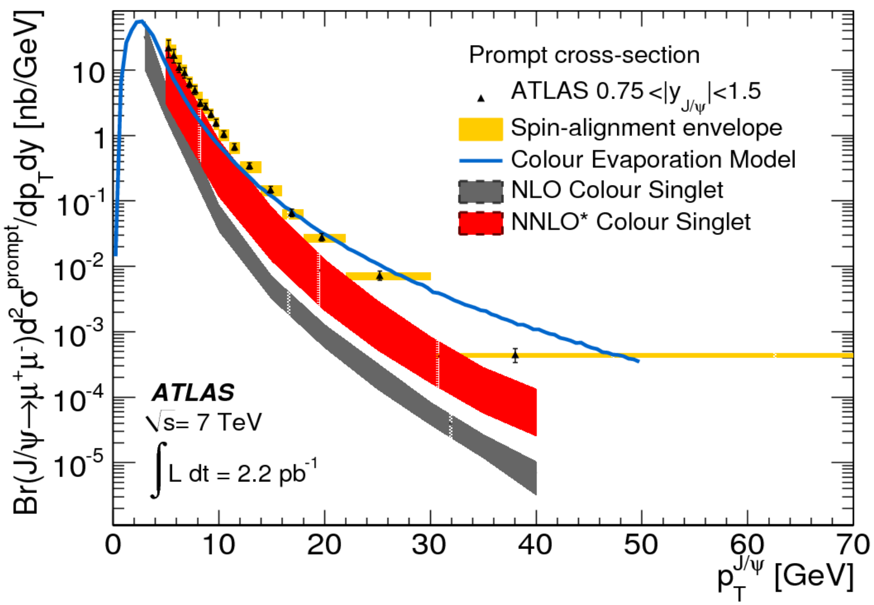


Upsilonの偏極はNRQCD (COLOR OCTET MODEL)計算ともNNLO計算とも一致しない。
arXiv:1112.1591 (2011)

Prompt J/ψ production at ATLAS

J/ψの直接生成がNLO Color Singlet Model予言の10倍以上。
NNLO(Color Singlet Model) 予言、CEM(Color Octet Model)予言はデータに近いが、未だ有意なずれがある。
Nucl.Phys. B 850 (2011) 387





Upsilon(1s) production at ATLAS

Upsilon(1s)生成がNLO Color Singlet Model予言の10倍程度。NRQCD (Color Octet Model)予言はデータに近いが、未だ有意なずれがある。
Phys. Lett. B 705 (2011) 9