Recent result from Belle

谷口　七重(KEK)

ICEPP Symposium

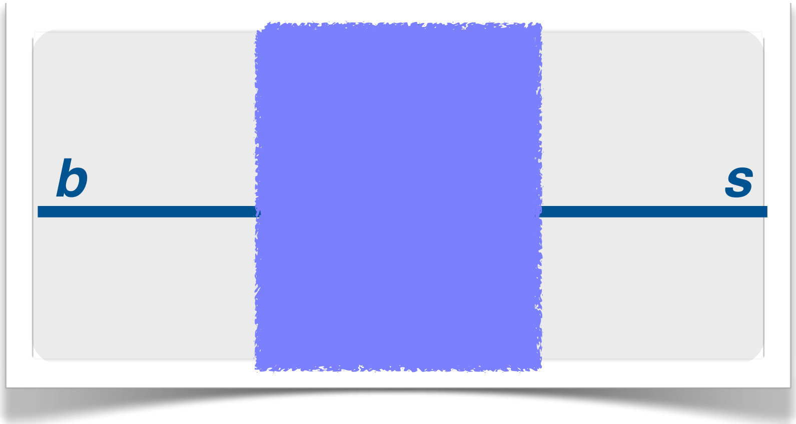
2月14日~17日

長野県白馬

contents

- Introduction
- $B \to Xsll$
  - exclusive $K^{(*)}$ ll
  - inclusive

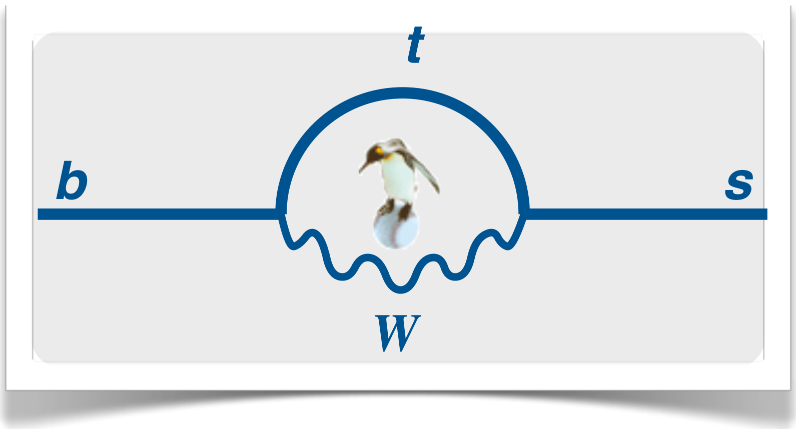
b→s transition

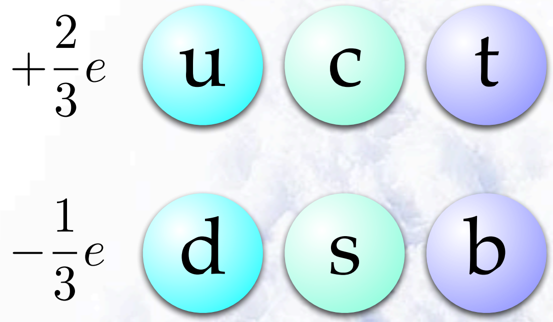


$+\frac{2}{3}e$	u	c	t
$-\frac{1}{3}e$	d	s	b

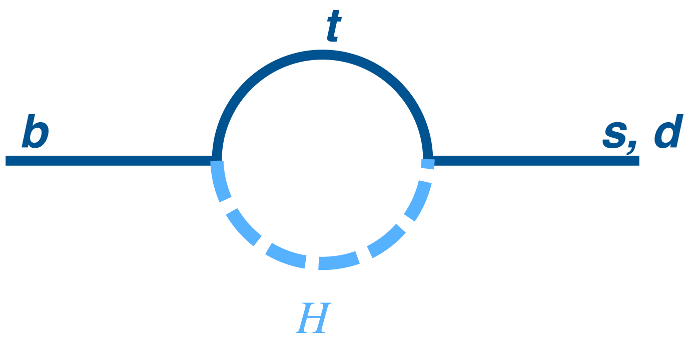
- Flavor Changing Neutral Current
    -

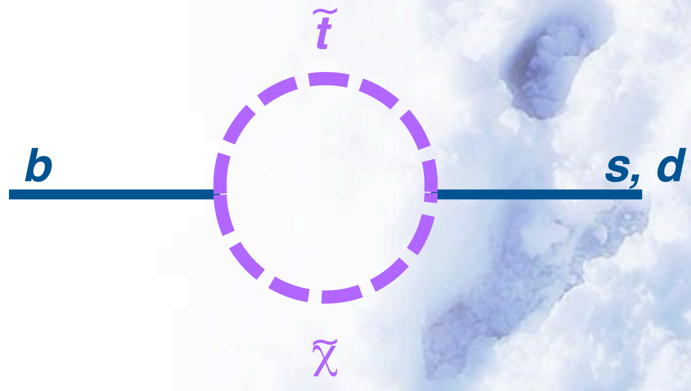
b→s transition





- Flavor Changing Neutral Current
  - 標準理論ではループダイアグラムを介して可能
  - SUSYとの結合も同じオーダー(1-loop)で可能

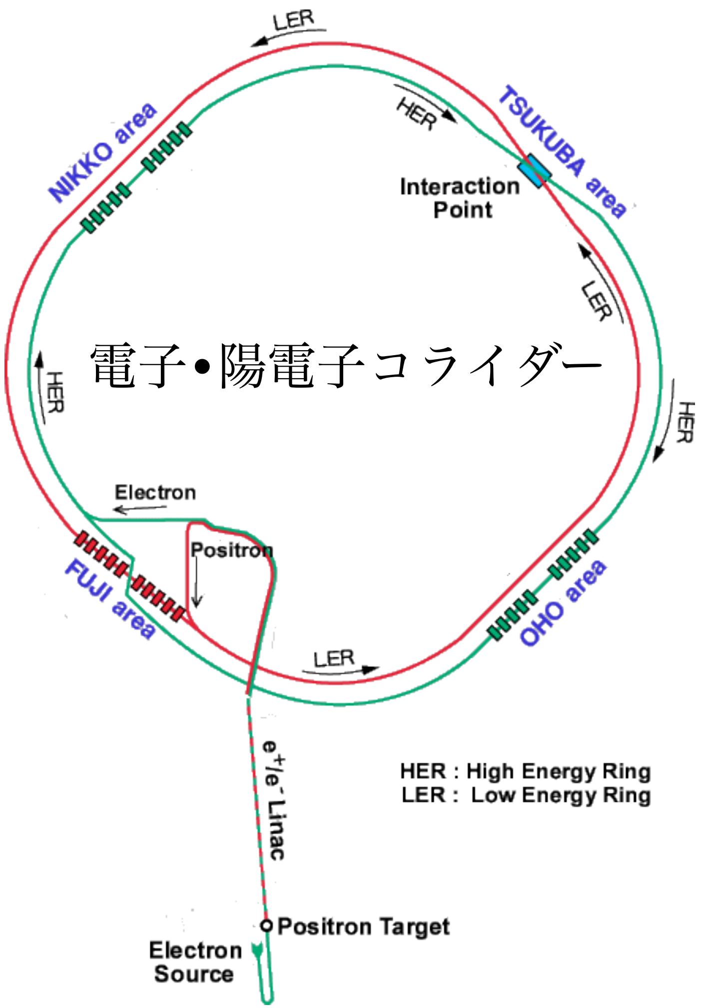




introduction

KEKB加速器

電子•陽電子コライダー



New World Record Luminosity

2.11×10^{34} cm^{-2} s^{-1}

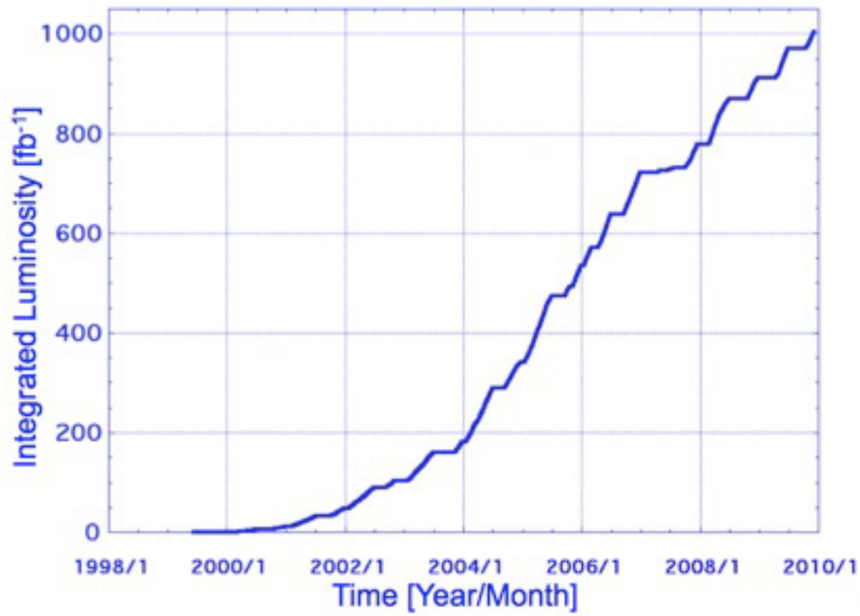
achieved with crab cavities at KEKB

(June 17, 2009, another world record since May 3rd)

[KEK press release (Japanese), interactions.org, CERN Courier]

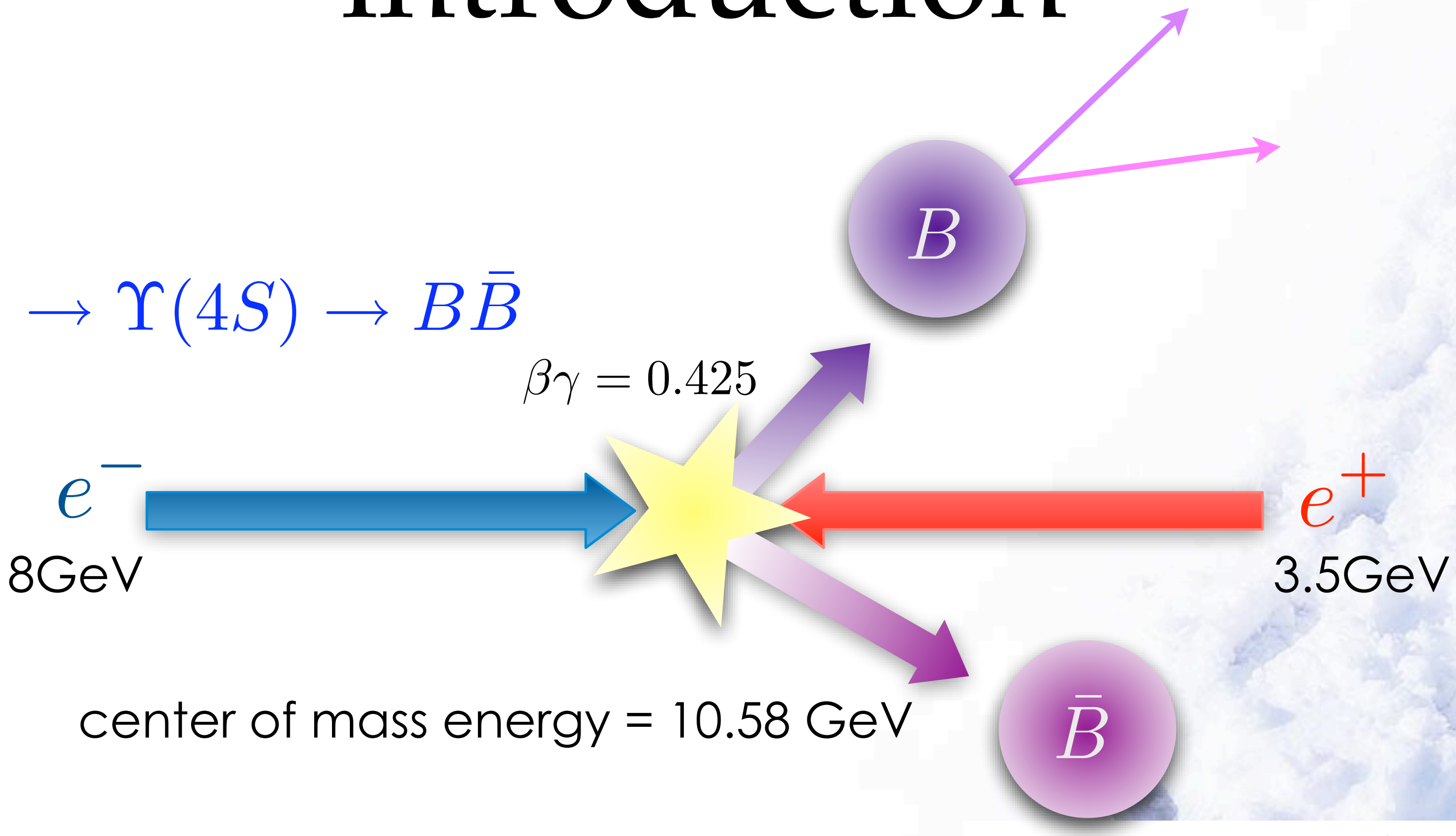
Integrated luminosity reached 1000 fb^{-1}

[KEK press release (Japanese), interactions.org]

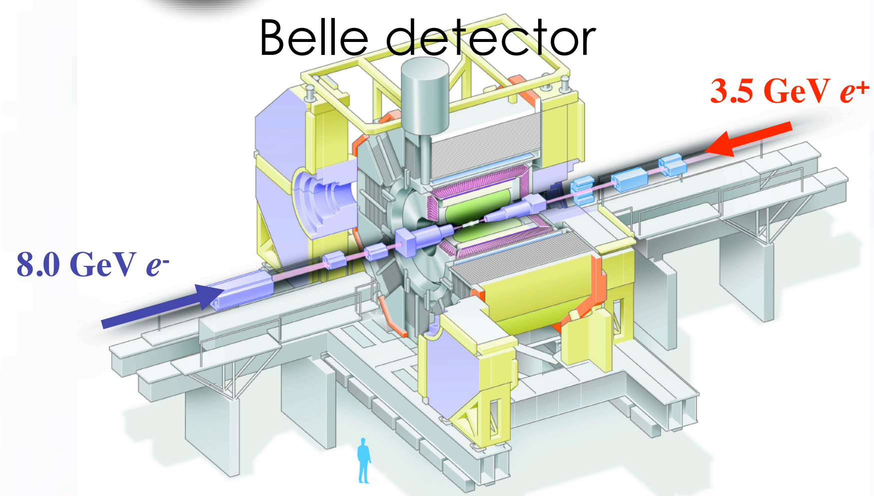


introduction

$$e^+e^- \to \Upsilon(4S) \to B\bar{B}$$



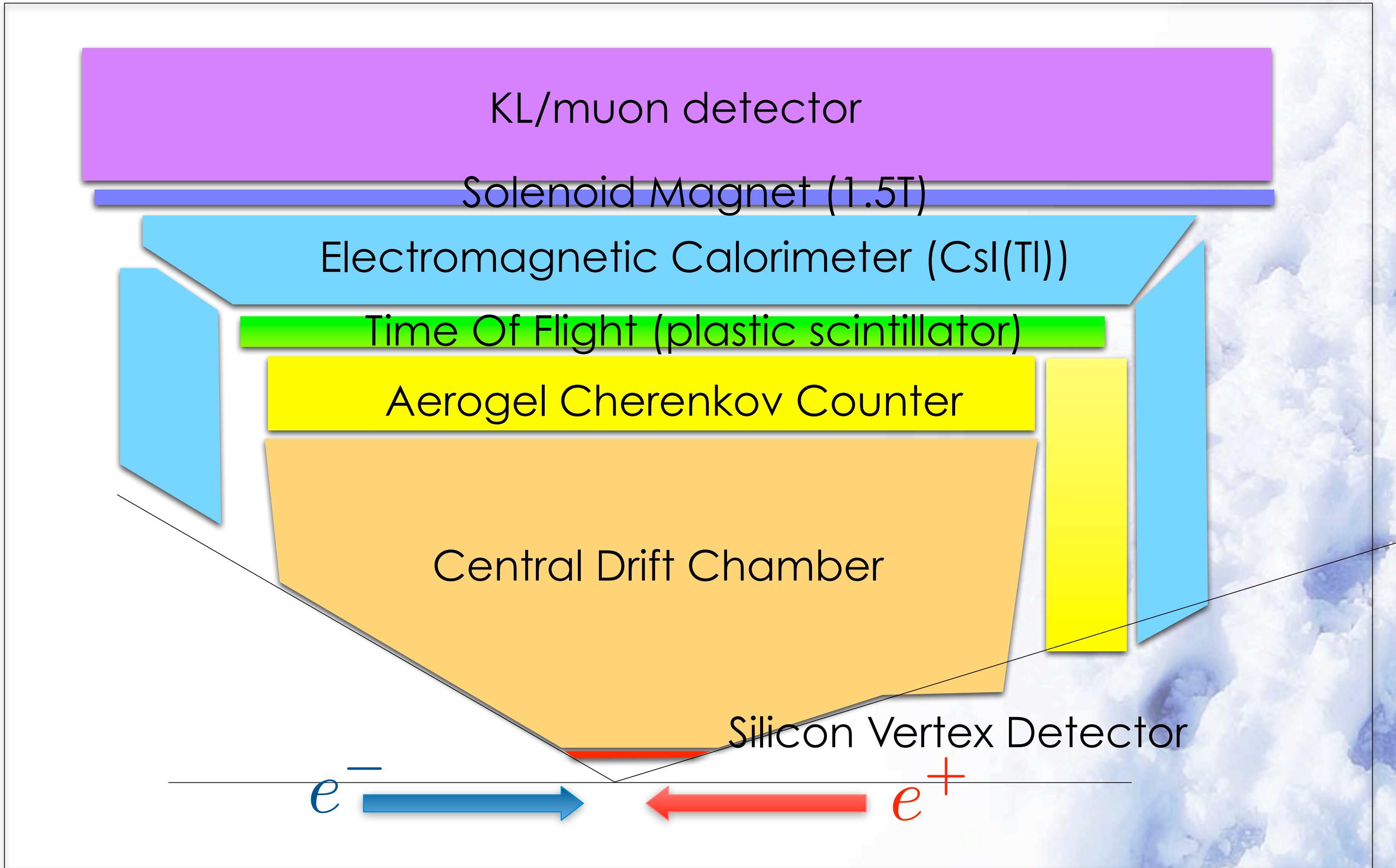
center of mass energy = 10.58 GeV



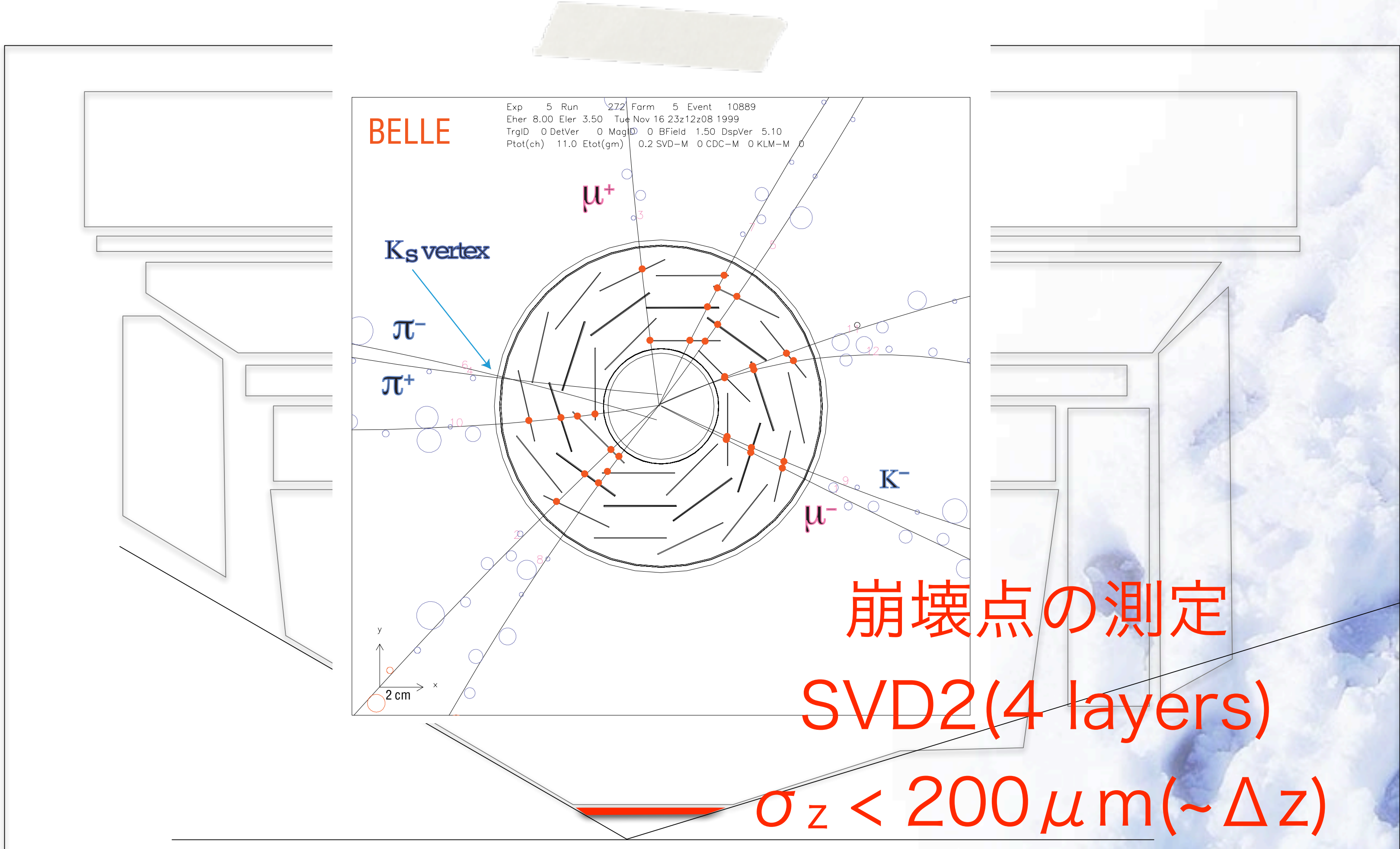
introduction

Belle detector

side view



introduction



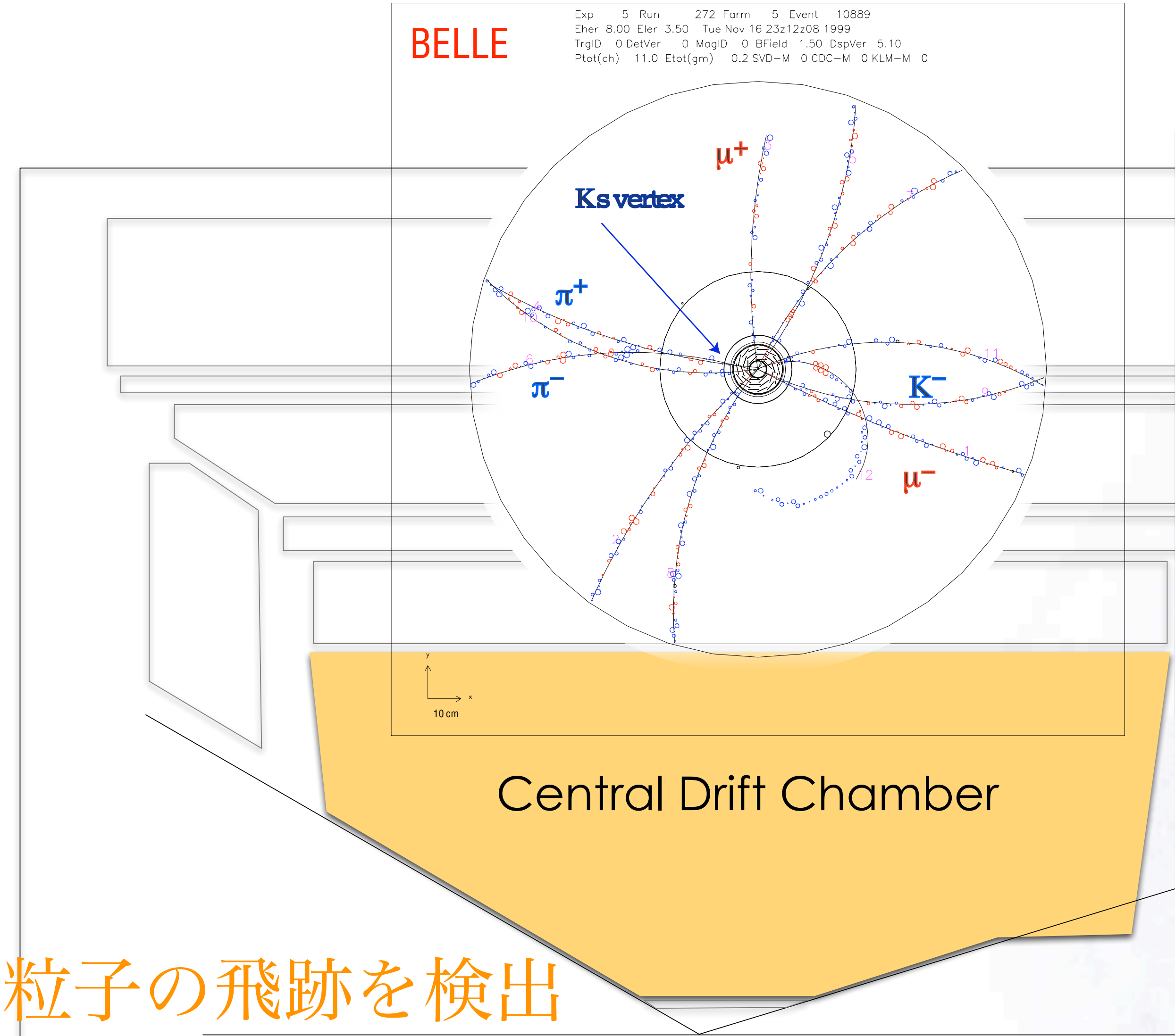
崩壊点の測定

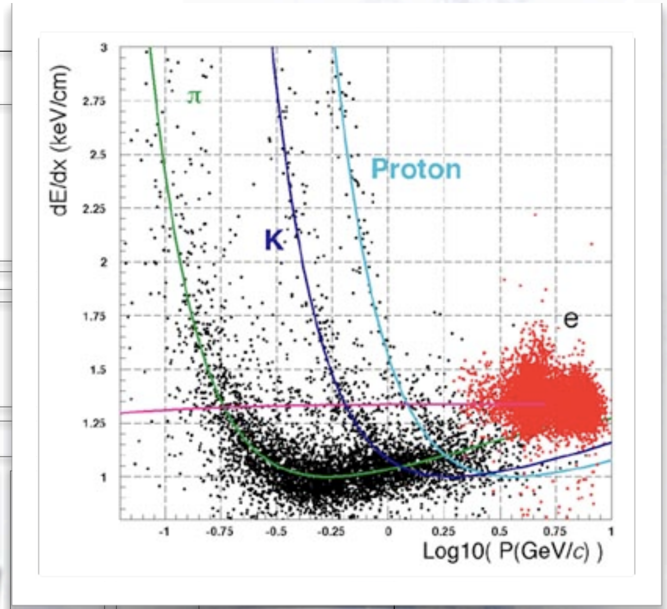
SVD2(4 layers)

$\sigma_z < 200\mu m (\sim \Delta z)$

Silicon Vertex Detector

introduction

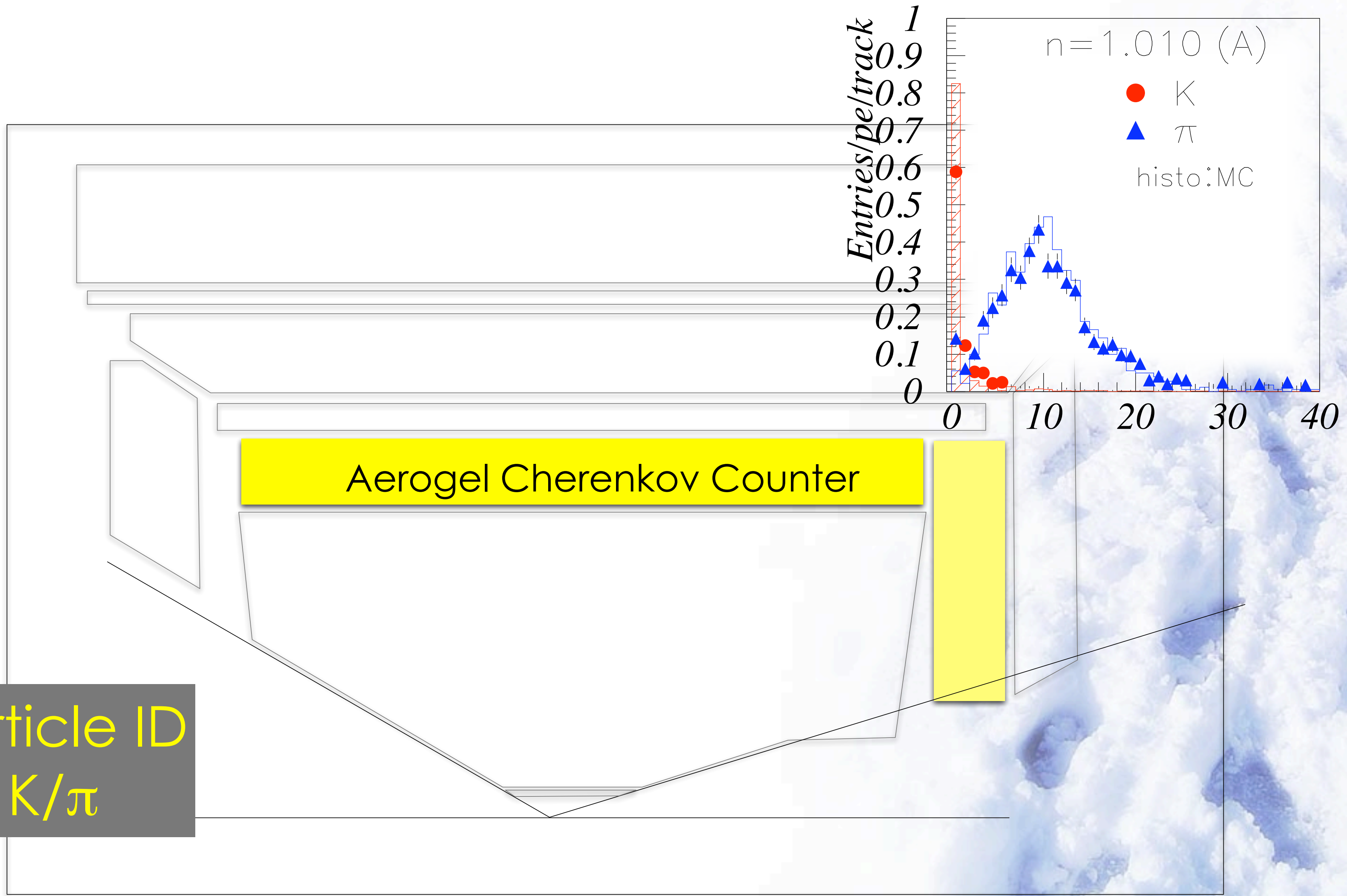




荷電粒子の飛跡を検出

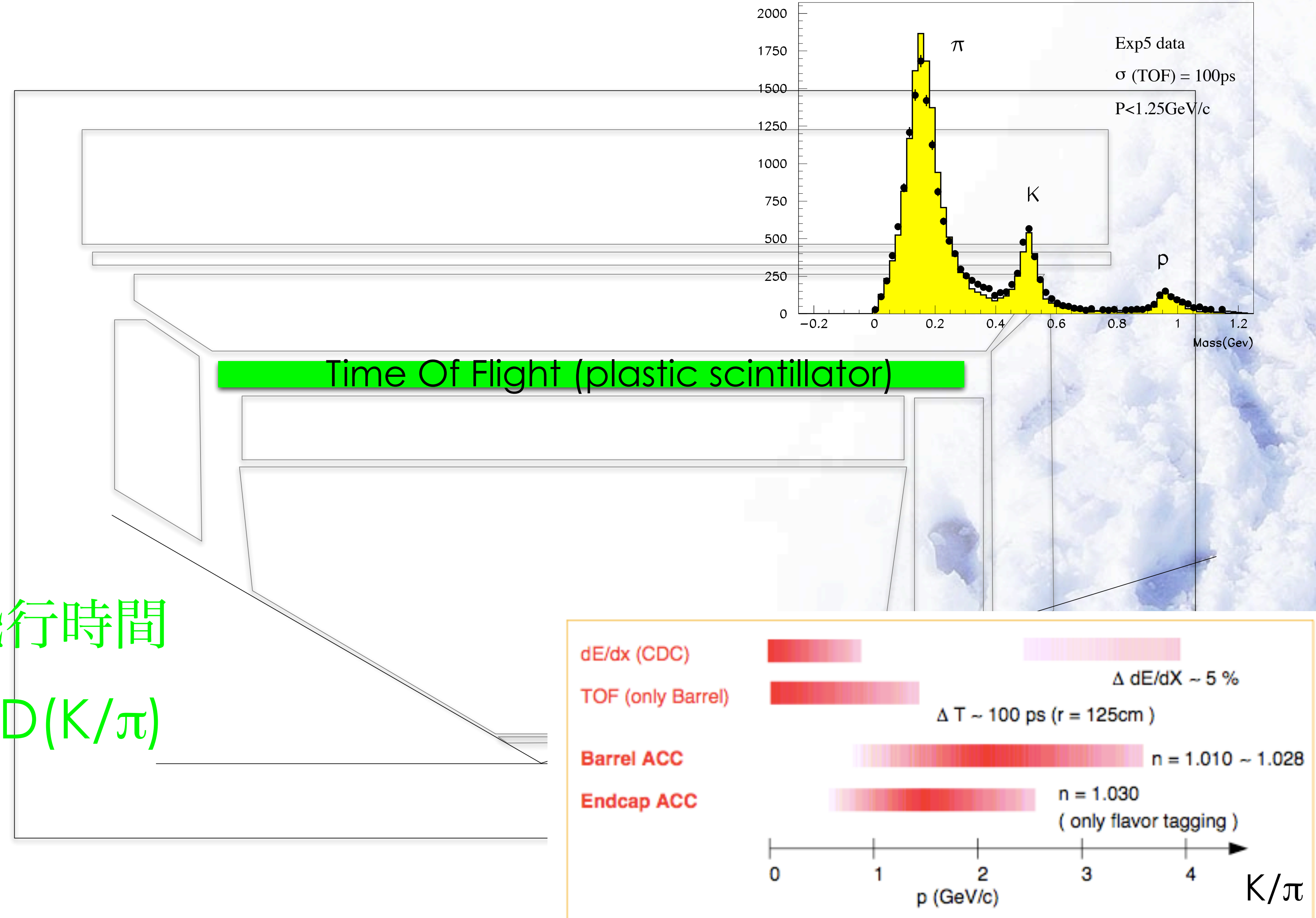
運動量、dE/dxを測定

introduction



Particle ID
K/π

introduction



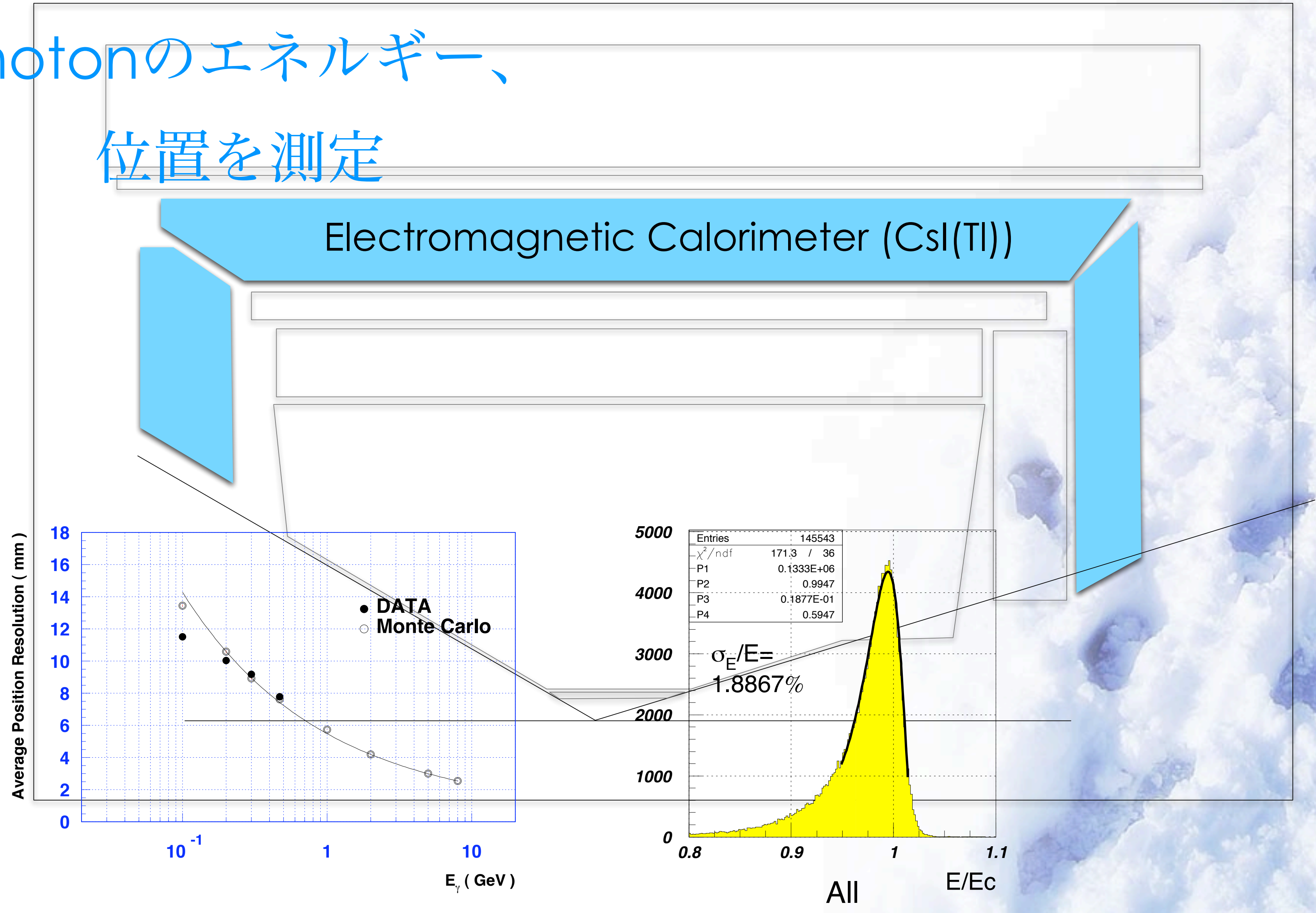
飛行時間

PID(K/π)

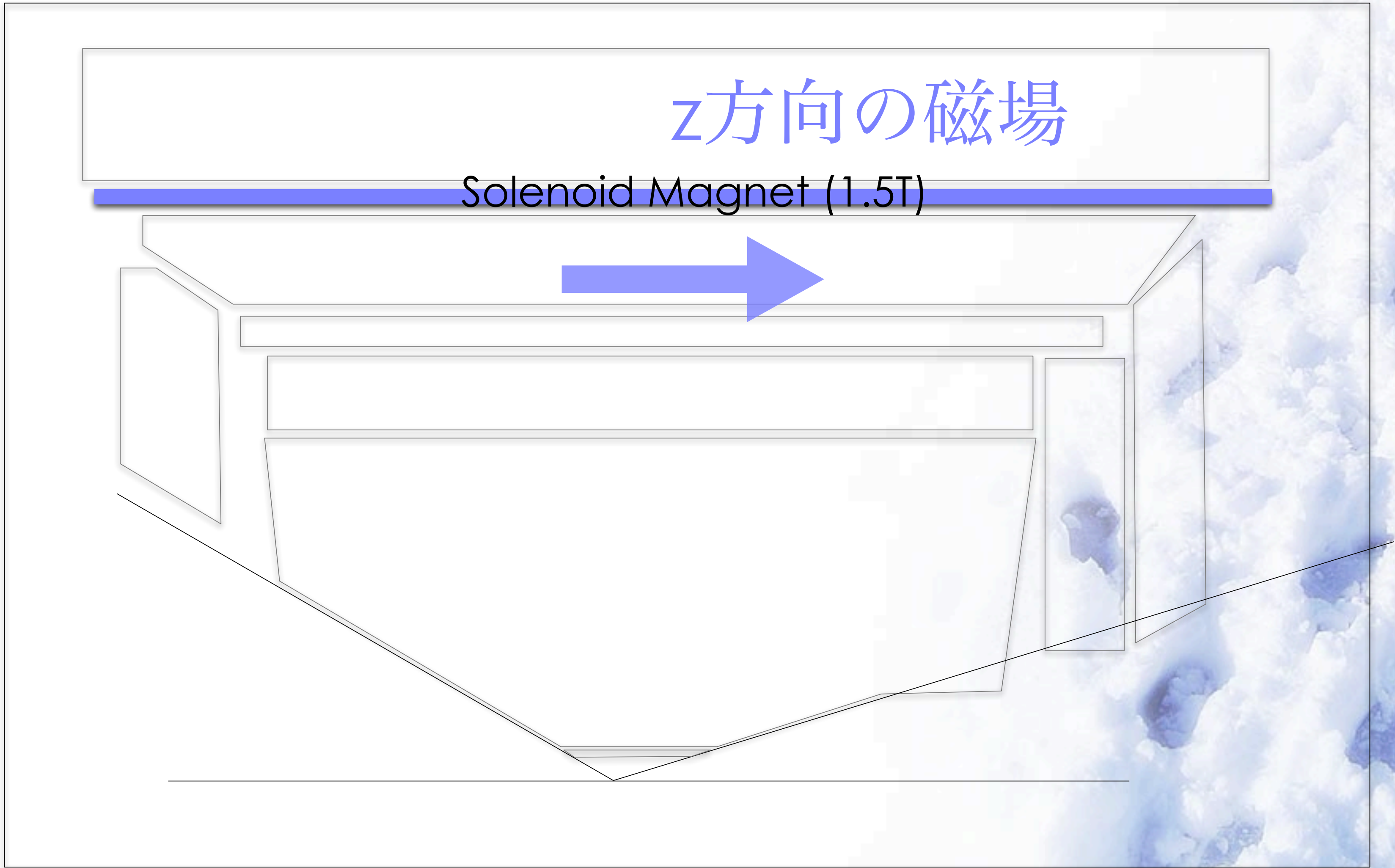
introduction

photonのエネルギー、

位置を測定



introduction



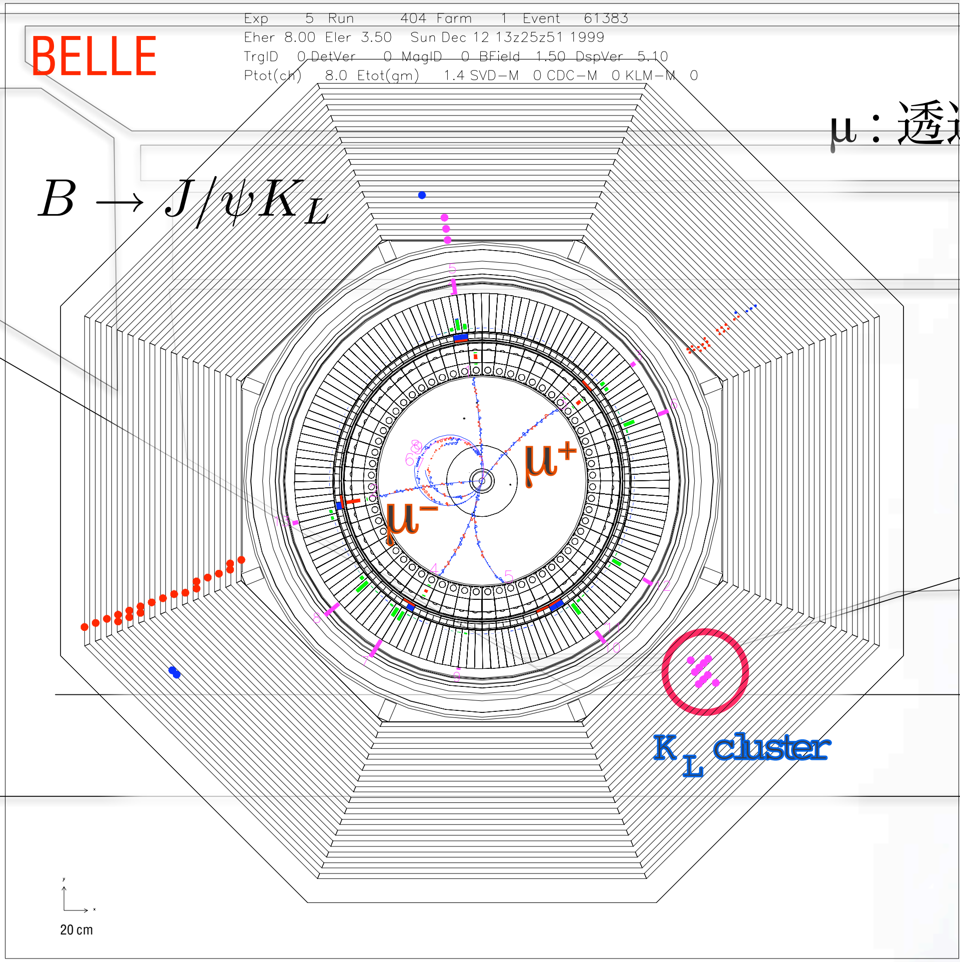
introduction

鉄+RPC(スパークチェンバーのようなもの)の層

KL/muon detector

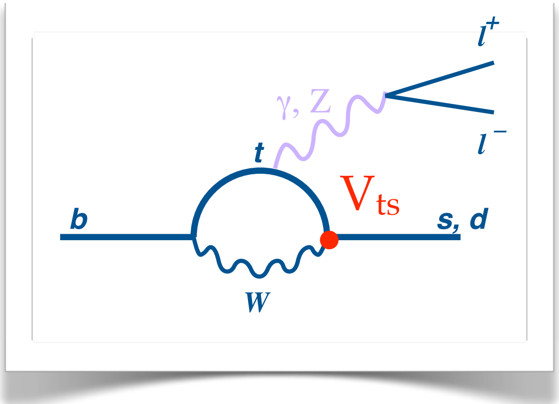
K_L : 鉄でハドロンシャワー

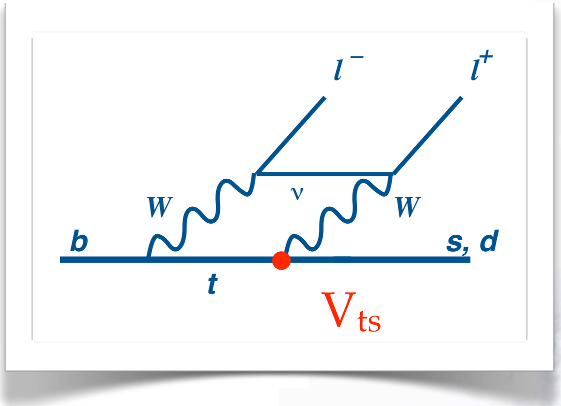
μ : 透過力があるので何層も突き抜ける



$B \to Xsll$

B→Xsll





$V_{ts} \sim 10^{-2}$

- ペンギン or ボックス　ダイアグラム
- 豊富な観測量
  - Branching fraction ($10^{-7} \sim 10^{-6}$)
  - Isospin Asymmetry
  - Forward-Backward Asymmetry

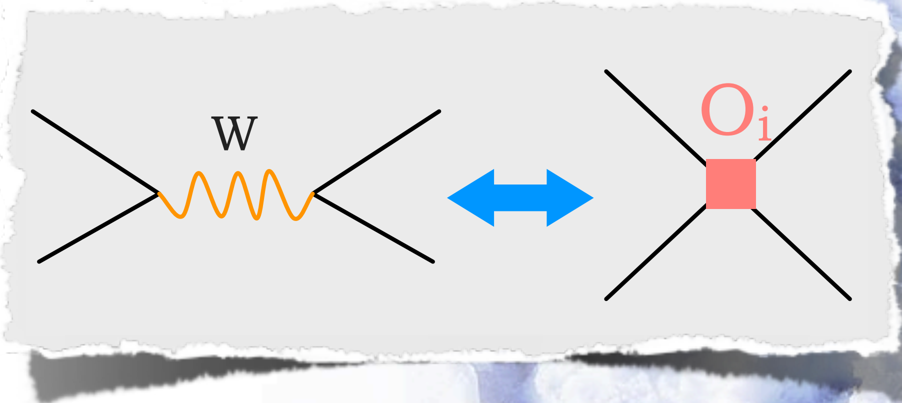
B→Xsll

- Wilson係数にも感度がある
  - Wilson係数はSMでは精度よく計算されている
  - new physicsの寄与はそこからのずれとして現れる
- ３つのWilson係数が寄与

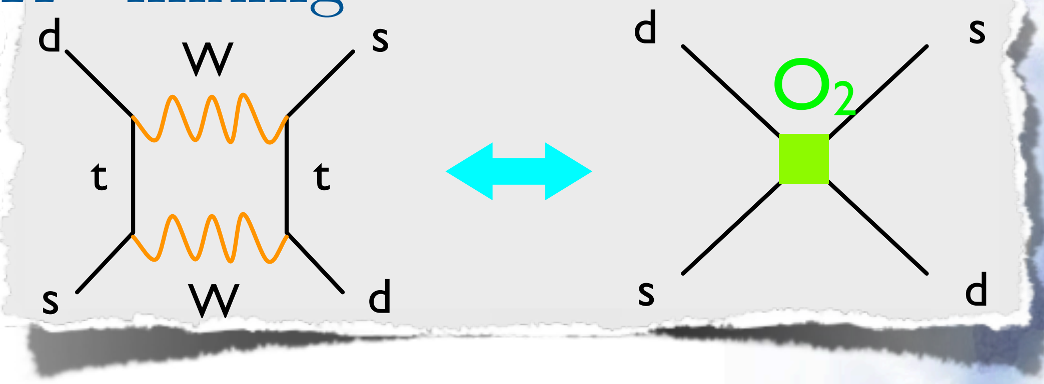
Operator Product Expansion

- Operator Product Expansion
  - 実効オペレータO_iとWilson係数C_iを使ってハミルトニアンを書き下す

$$H \sim \sum_i C_i O_i$$



$K^0 - \bar{K^0}$ mixing



B→Xsll

- Wilson係数にも感度がある
  - Wilson係数はSMでは精度よく計算されている
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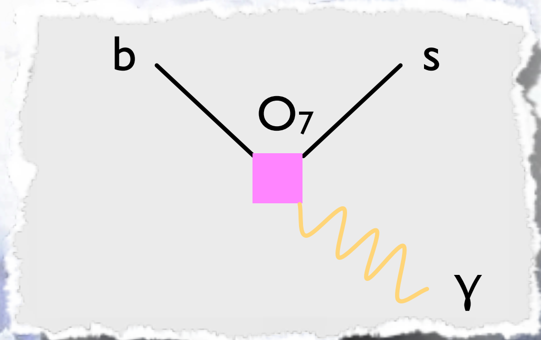
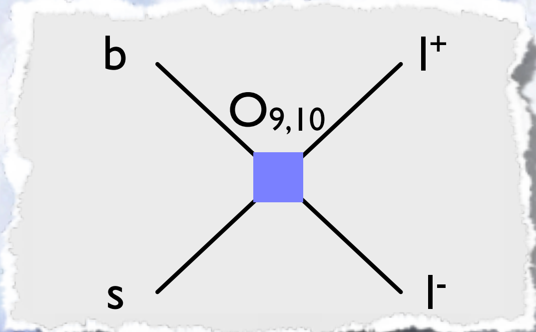
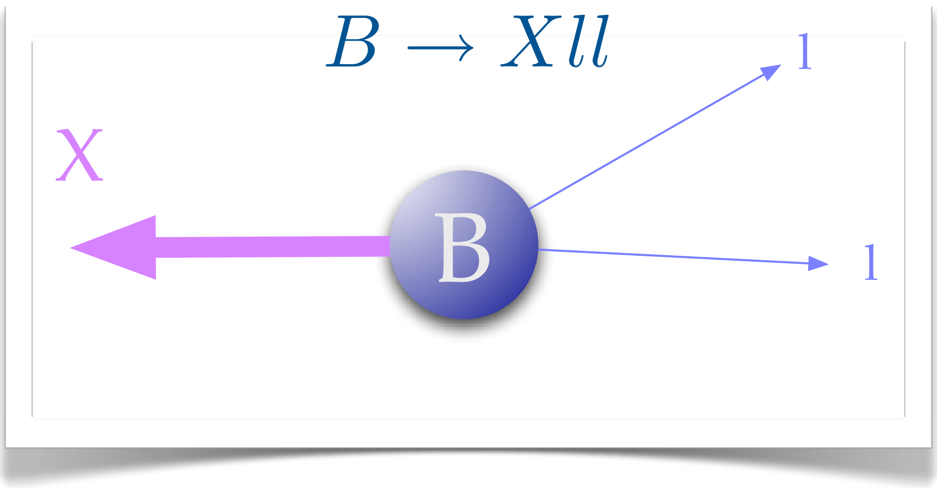
- ３つのWilson係数が寄与
  - C_7 : electromagnetic penguin diagram
    - ✦ $|C_7| \sim 0.33$ from B.F($B \to Xs\gamma$)
    - ✦ b→sll はC_7の符号に感度がある
  - C_9 : vector part of weak diagram
  - C_{10} : axial vector part of weak diagram

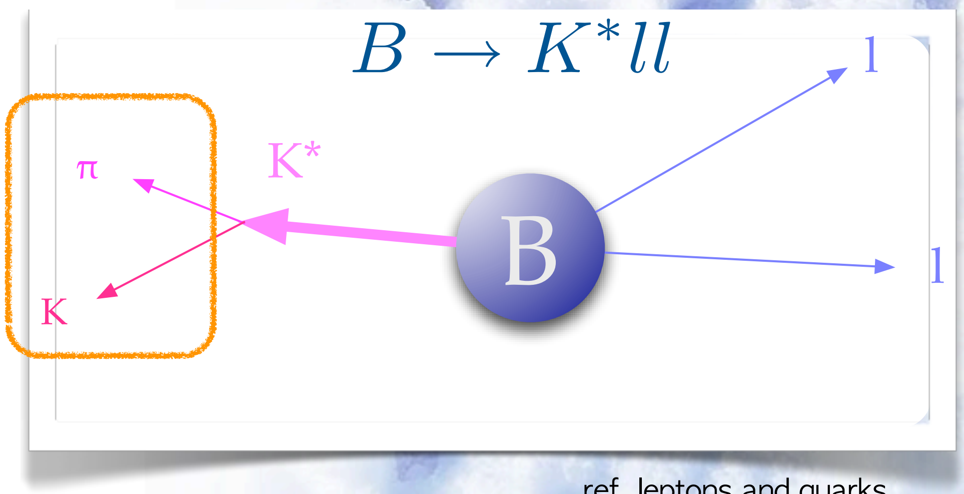




inclusive / exclusive

- Inclusive
  - 反応 a + b → c + Xにおいて、cのみを観測してXに含まれているいろいろな粒子を観測しないときこれをinclusive反応と呼ぶ
- Exclusive
  - これに対して、a + b → $c_1 + c_2 + .. c_n$ のように終状態の限定した粒子は全て観測する反応をexclusive反応と呼ぶ





ref. leptons and quarks

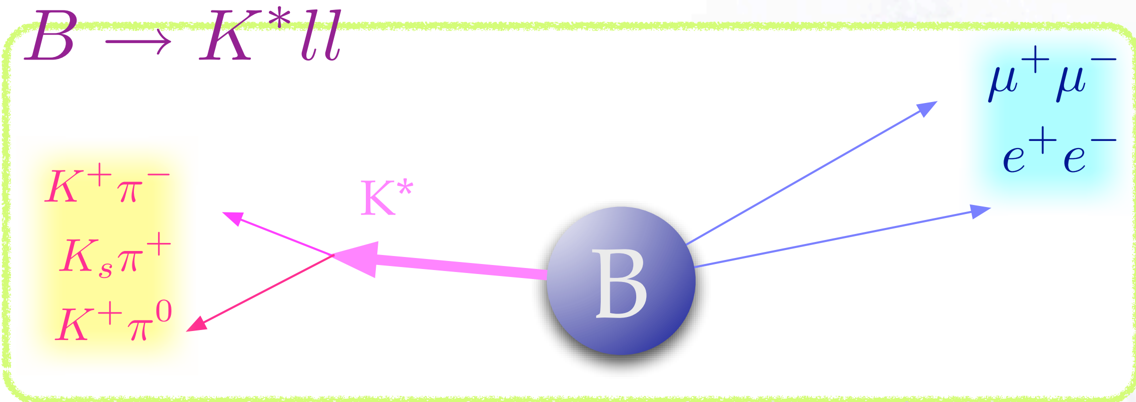
exclusive $B \rightarrow K^{(*)}ll$

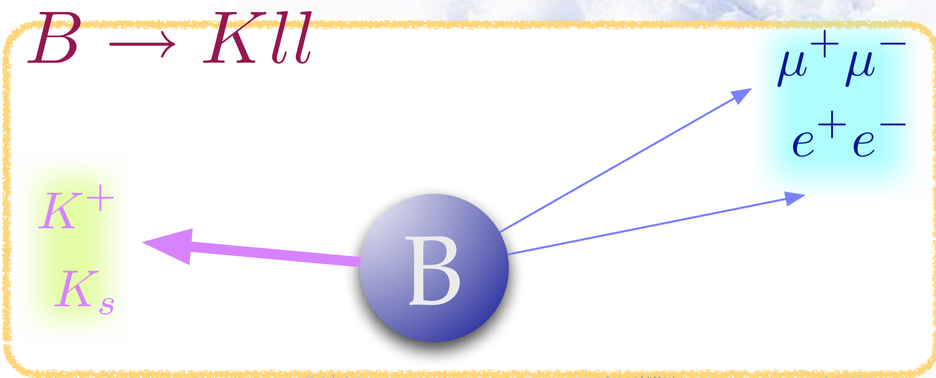
outline

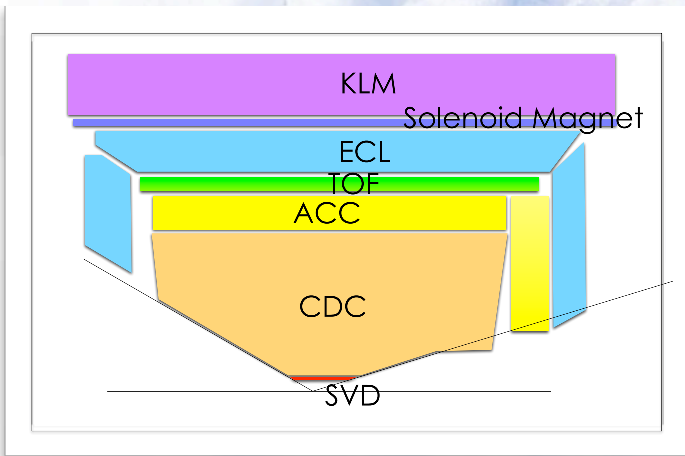
- Event selection and reconstruction
- Background suppression
- Branching fraction
- Isospin Asymmetry
- Forward-backward asymmetry

exclusive mode B→K$^{(*)}$ll

- Particle ID
  - K/π
    - CDC (dE/dx)
    - TOF
    - ACC (number of photoelectron:N_{pe})
  - electron ID
    - ECL (position, shower shape)
    - CDC (dE/dx)
    - ACC (N_{pe})
  - muon ID
    - KLM (range, hit position)
    - CDC (tracking)

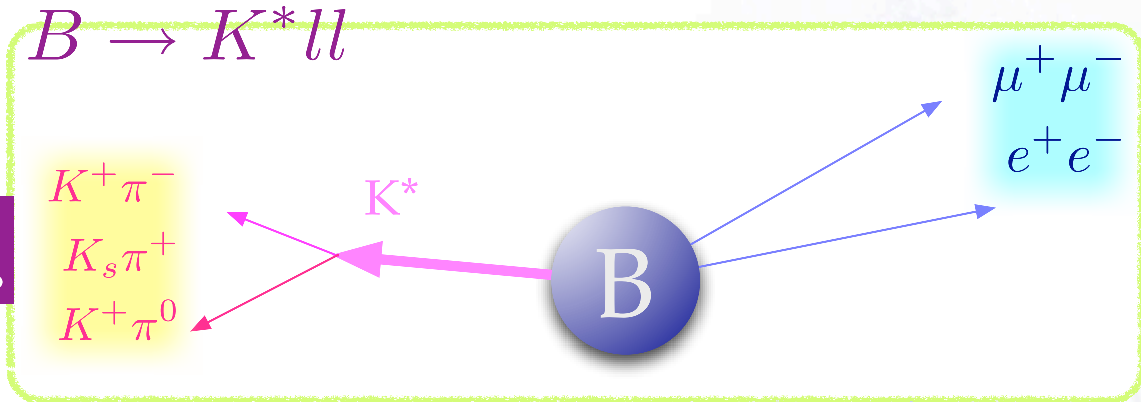


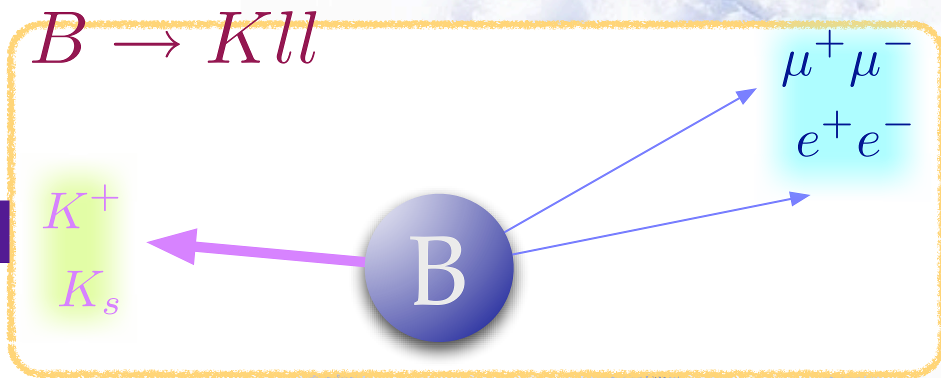


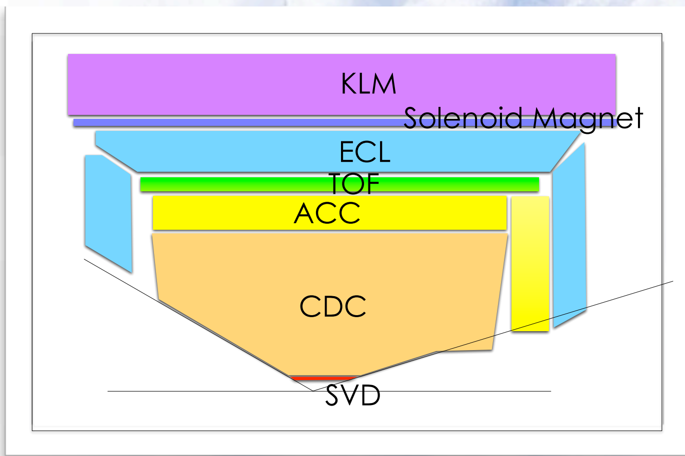


exclusive mode B→K(*)ll

- Particle ID
  - K/π — pion : eff. 85%/ fake rate 3%; kaon : eff.~ 90%/ fake rate 9%
    - ✦ CDC (dE/dx)
    - ✦ TOF
    - ✦ ACC (number of photoelectron:N_{pe})
  - electron ID — eff. 90% /fake rate 0.3% (as pion)
    - ✦ ECL (position, shower shape)
    - ✦ CDC (dE/dx)
    - ✦ ACC (N_{pe})
  - muon ID — eff. 80% /fake rate 1.5% (as pion)
    - ✦ KLM (range, hit position)
    - ✦ CDC (tracking)







Reconstruction

- Ks
  - ππのうち崩壊点がIPから離れたもの
  - $|M_{\pi\pi} - M_{Ks}| < 15\mathrm{GeV}/c^2$
- neutral pion
  - 2γから再構成
  - $115 < M_{\gamma\gamma} < 152\ \mathrm{GeV}/c^2$
- K*
  - $M_{K\pi}$
- B meson

Fitに用いる

(分岐比測定)

$$5.27\mathrm{GeV}/c^2 < M_{\mathrm{bc}} < 5.29\mathrm{GeV}/c^2$$
$$|M_{K\pi} - M_{K^*}| < 80\mathrm{MeV}/c^2$$

$$5.2\mathrm{GeV}/c^2 < M_{\mathrm{bc}} < 5.29\mathrm{GeV}/c^2$$
$$M_{K\pi} < 1.2\mathrm{GeV}/c^2$$

$$M_{\mathrm{bc}} = \sqrt{(E^*_{\mathrm{beam}}/c^2)^2 - |\vec{p^*_B}/c|^2}$$
$$\Delta E = E^*_B - E^*_{\mathrm{beam}}$$

$$|\Delta E| < 35 \text{ MeV for } K^{(*)}\mu^+\mu^-$$
$$-55 < \Delta E < 35 \text{ MeV for } K^{(*)}e^+e^-$$

Background suppression

- continuum
- Bのセミレプトニック崩壊
- $B \to J/\psi(\to ll)K^{(*)}$, $\psi(\to ll)K^{(*)}$

Background suppression

- continuum background
  - ee → qq (q=u,d,s,c)
  - 終状態に運動量の大きなKaonやpionをたくさん作る
  - 数が多い(~x3)

	BB event	continuum event
崩壊点の差 Δz	$c\tau\beta\gamma$ ~ 200μm	~0 (ほぼ一点から)
崩壊生成物 (event shape)	等方的(Bは重いのでほぼ静止)	2ジェット状(軽いクォークが大きな運動量を持つ)
崩壊角分布 θ_B	$\sin^2\theta$ (Υ(4S)(J=1),B(J=0))	~uniform (ランダムな組み合わせ)

Background suppression

- Event shape
  - 終状態粒子の運動量の情報を使う
  - Fox-Wolfram momentを応用して、18個の変数(x_k)を定義、signalとbackgroundの分離が最適となる係数(Fisher discriminant: F)を計算($F=\Sigma\alpha_k x_k$)

Fox-Wolfram moment

$$R_l = \frac{\sum |p_i||p_j|P_l(\cos\theta_{ij})}{\sum |p_i||p_j|}$$

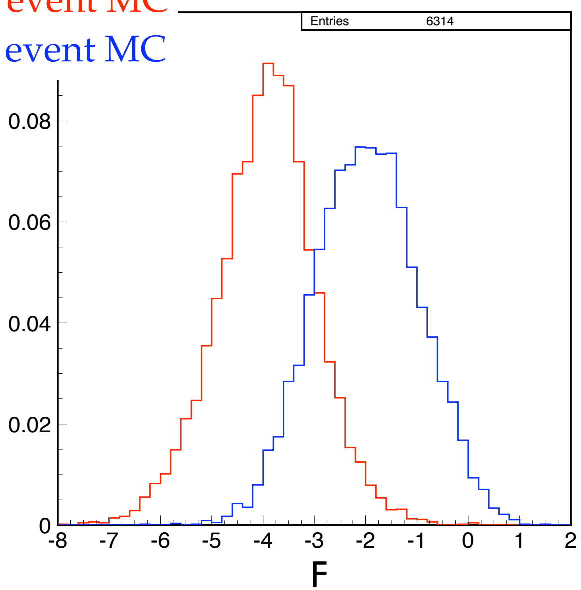
$$R_2 = \frac{\sum |p_i||p_j|\cos\theta_{ij}}{\sum |p_i||p_j|} = \frac{\sum p_i \cdot p_j}{\sum |p_i||p_j|}$$

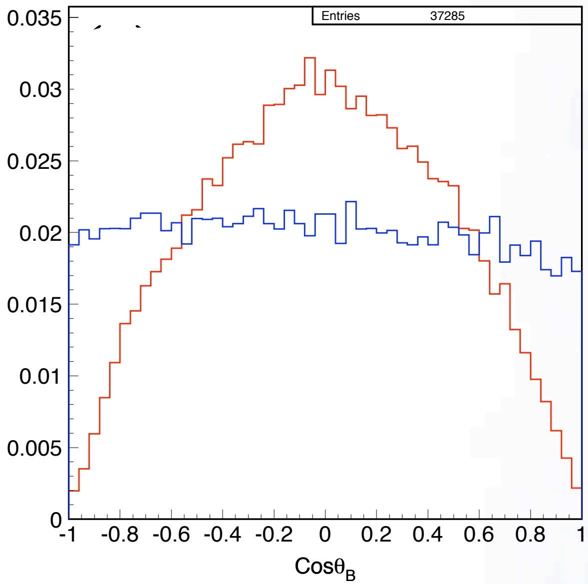
$R_2 = 0$ for BB event

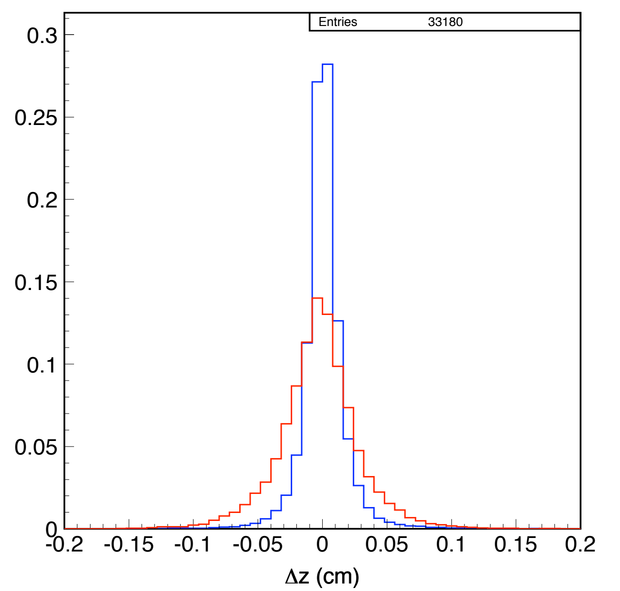
$R_2 = 1$ for qq event

BB event MC

qq event MC







Background suppression

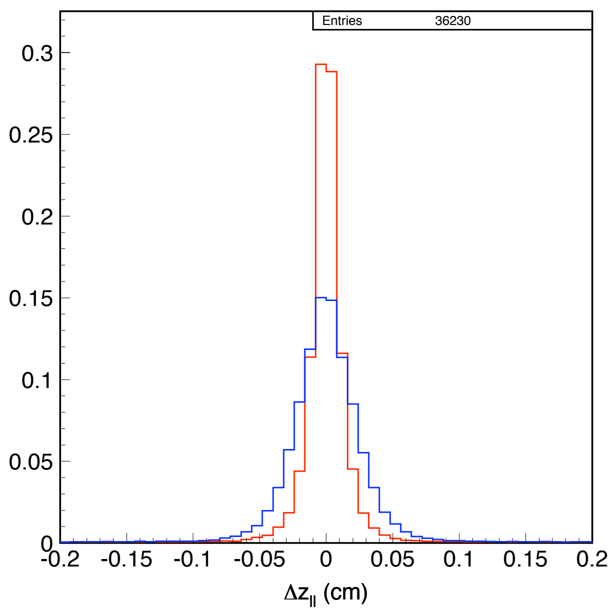
- Bのセミレプトニック崩壊
  - ニュートリノが２つ以上
  - missing massが有効な変数
  - lepton vertex, Fisher

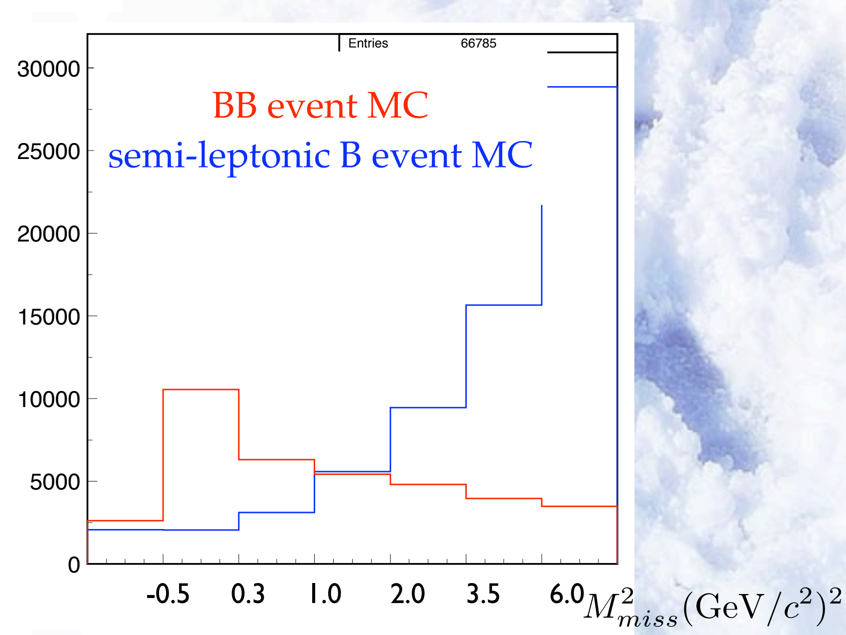
$B\bar{B}$ が...

$$b \to c l^- \bar{\nu}$$
$$\bar{b} \to \bar{c} l^+ \nu$$

ひとつの B が

$$b \to c l^- \bar{\nu}$$
$$c \to s l^- \nu$$





Background suppression

- $B \to J/\psi(\to ll)K^{(*)}$, $\psi(\to ll)K^{(*)}$
  - 終状態の粒子の組み合わせがsignalと同じ
  - 運動学的な変数が signal に似たピークを作る
  - フィットで分離しにくい
  - di-leptonのinvariant mass がJ/ψやψの付近にある事象は除く

Results

- data set = 657x10^6 B中間子対

- Branching fraction
  - q^2=(M_{ll})の関数として微分分岐比を求めるためq^2を6ビンに分割
- Isospin asymmetry
- Forward-backward asymmetry
-

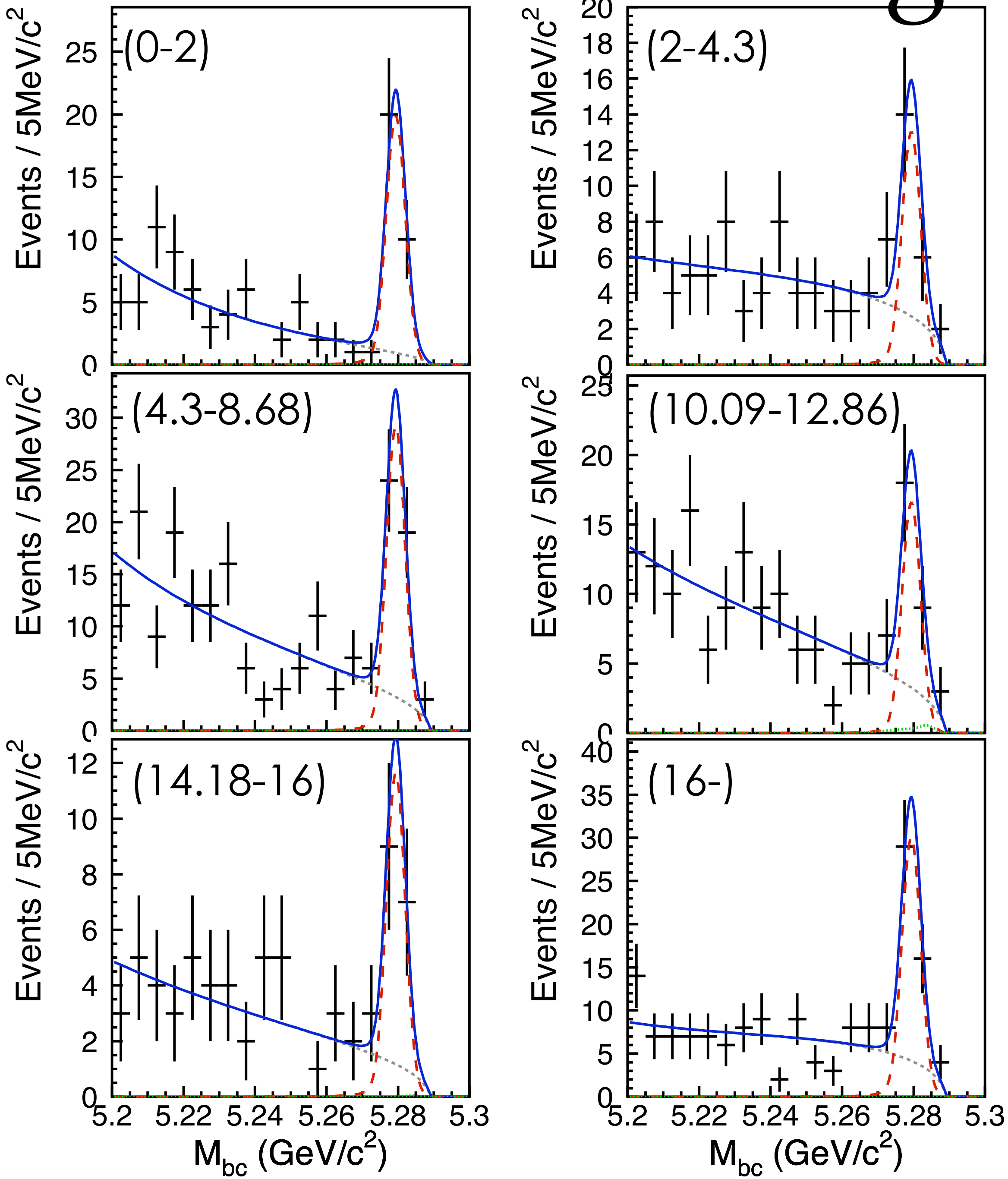
Results

- data set = 657×10^6 B中間子対
- Branching fraction
  - $q^2=(M_{ll}c^2)$の関数として微分分岐比を求めるためq^2を6ビンに分割
- Isospin asymmetry
- Forward-backward asymmetry
-

比をとることで理論の不定性を
ある程度キャンセルできる
(系統誤差も)

$B \to Kll$

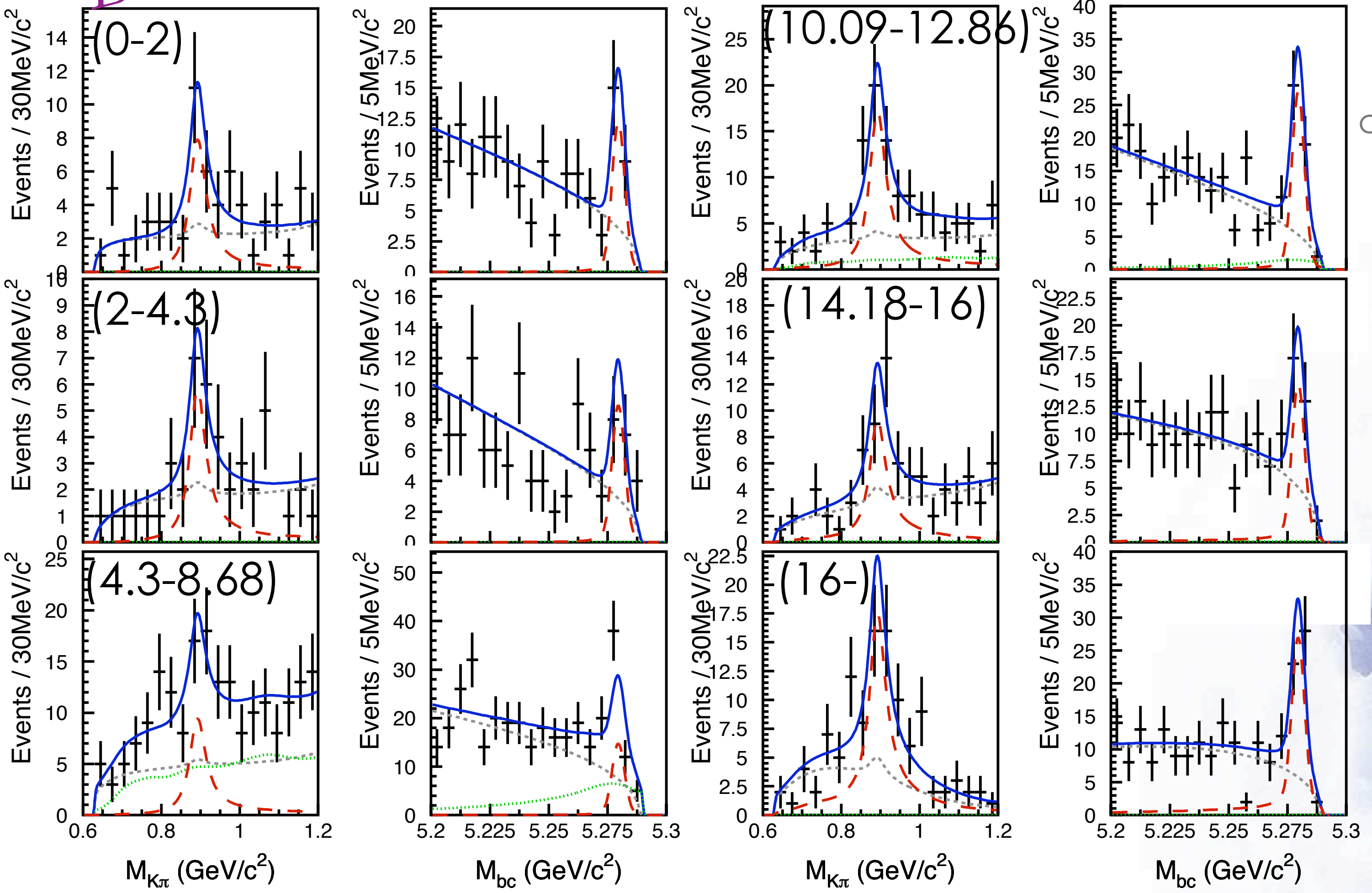
Branching fraction



total
signal (ガウス分布)
continuum+semi-leptonic B decay
(threshold関数(ARGUS))
J/ψ(ψ)X background
(MC)

Branching fraction

$B \to K^* ll$



For $M_{K\pi}$

total

signal (Breit-Wigner)

continuum+semi-leptonic B decay
(threshold関数+Breit-Wigner)

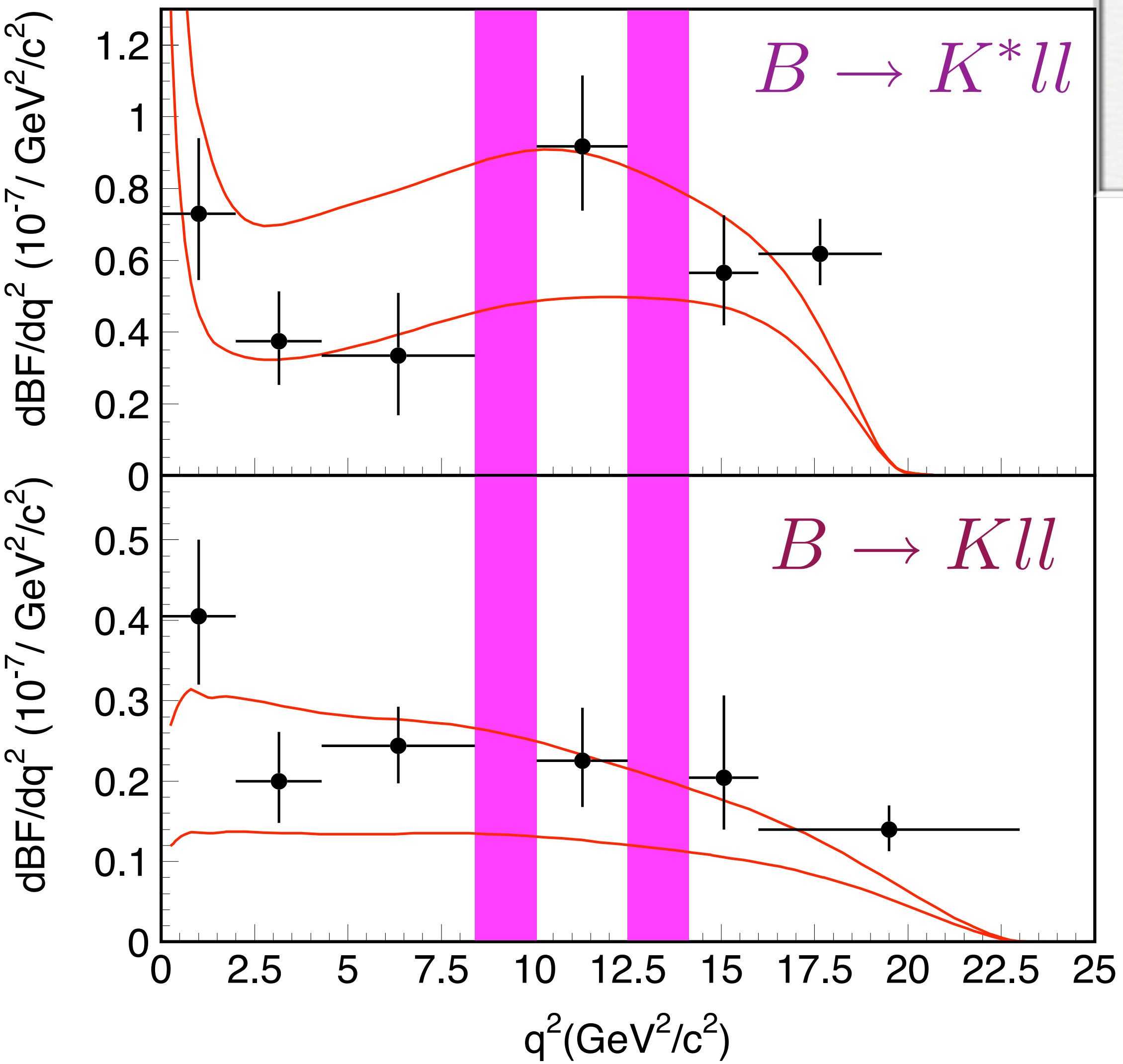
$J/\psi(\psi)X$ background
(MC)

BELLE : PRL 103, 171801 (2009)

Branching fraction

photon pole
($B \to K^*\gamma$)

— 理論値(SM)の上限と下限



entire region

$$\mathcal{B}(B \to Kll) = (4.8^{+0.5}_{-0.4} \pm 0.3) \times 10^{-7}$$
$$\mathcal{B}(B \to K^*ll) = (10.7^{+1.1}_{-1.0} \pm 0.9) \times 10^{-7}$$

BELLE : PRL 103, 171801 (2009)

BABAR: ARXIV: 0804.4119 (2008) 384M BB

CDF: AEXIV: 0804.3908 (2006) 924/PB

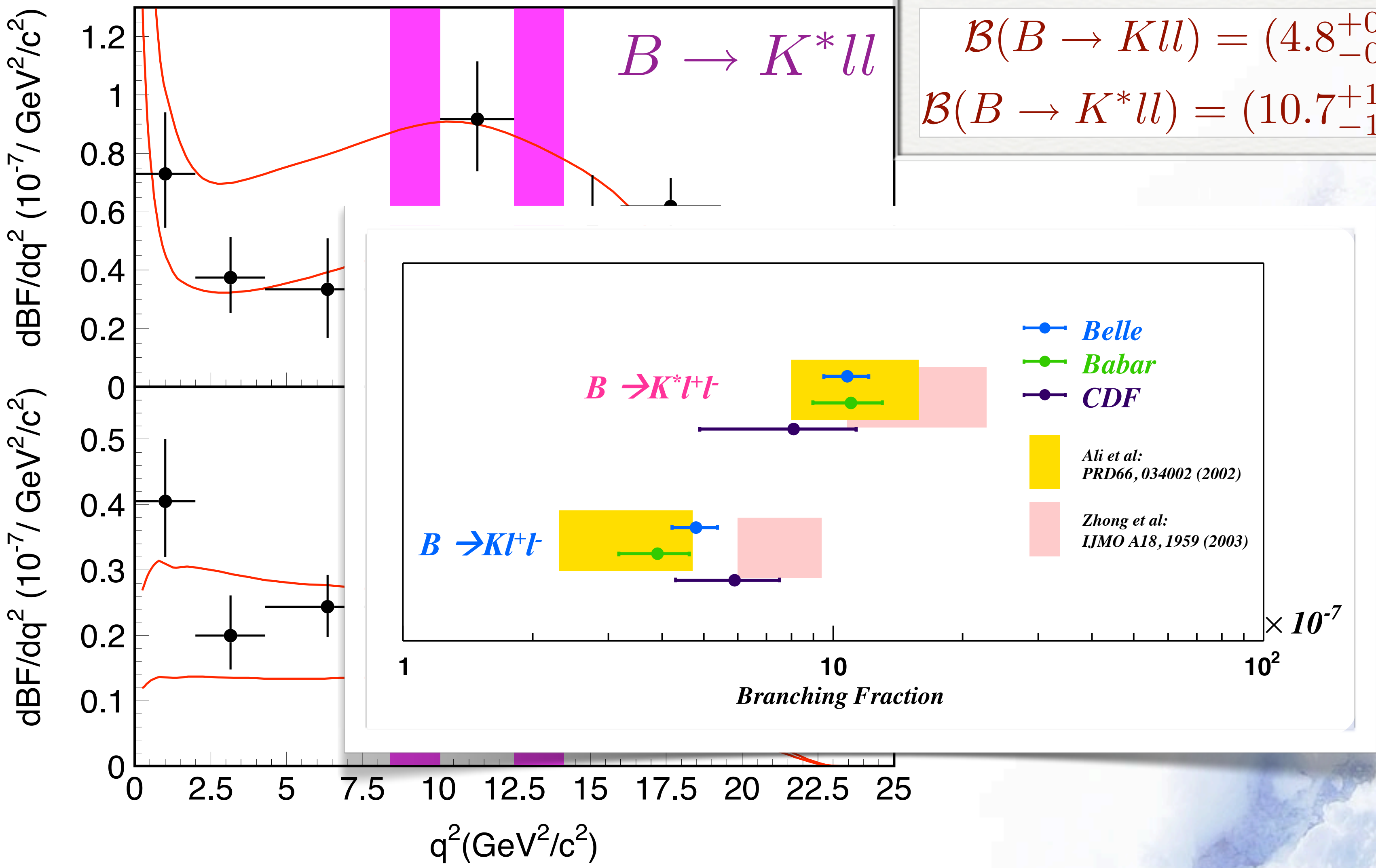
Branching fraction

— 理論値(SM)の上限と下限

entire region

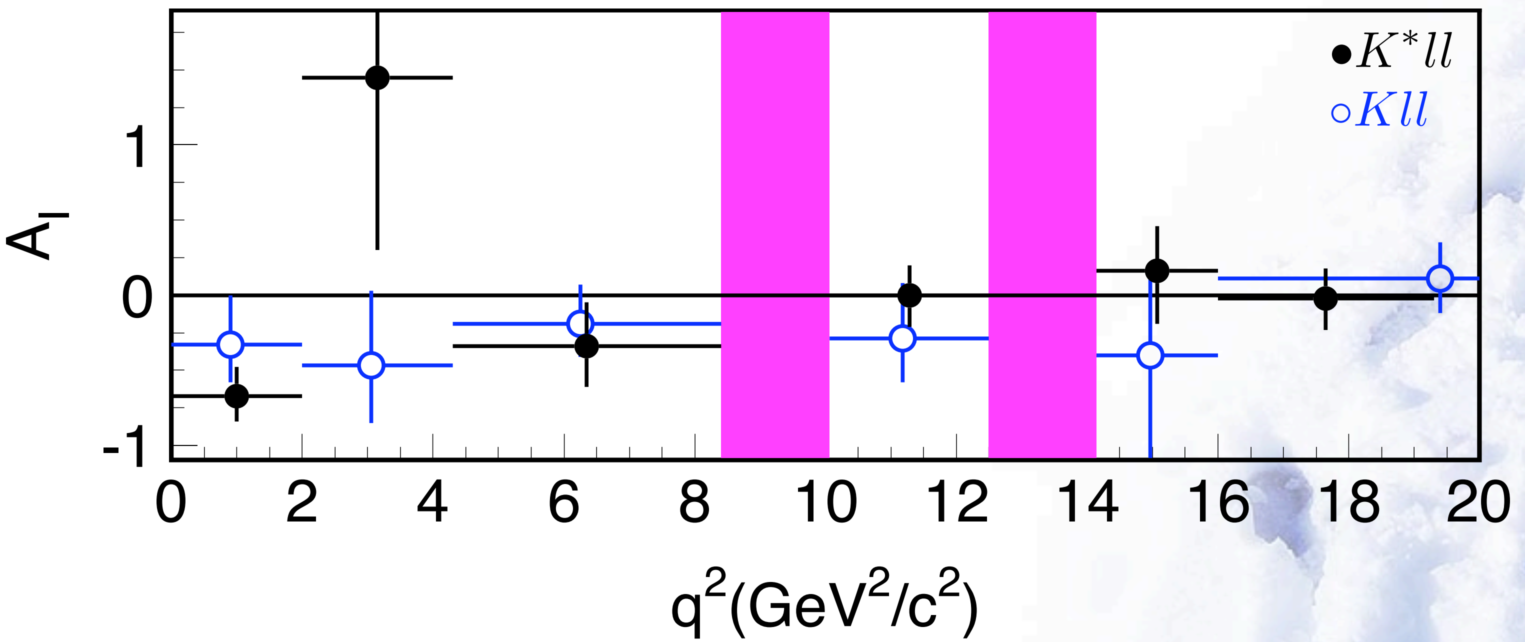
$$\mathcal{B}(B \to Kll) = (4.8^{+0.5}_{-0.4} \pm 0.3) \times 10^{-7}$$

$$\mathcal{B}(B \to K^*ll) = (10.7^{+1.1}_{-1.0} \pm 0.9) \times 10^{-7}$$



isospin asymmetry

$$A_I = \frac{(\tau_{B^+})/(\tau_{B^0})\mathcal{B}(K^{(*)0}l^+l^-) - \mathcal{B}(K^{(*)\pm}l^+l^-)}{(\tau_{B^+})/(\tau_{B^0})\mathcal{B}(K^{(*)0}l^+l^-) + \mathcal{B}(K^{(*)\pm}l^+l^-)}$$

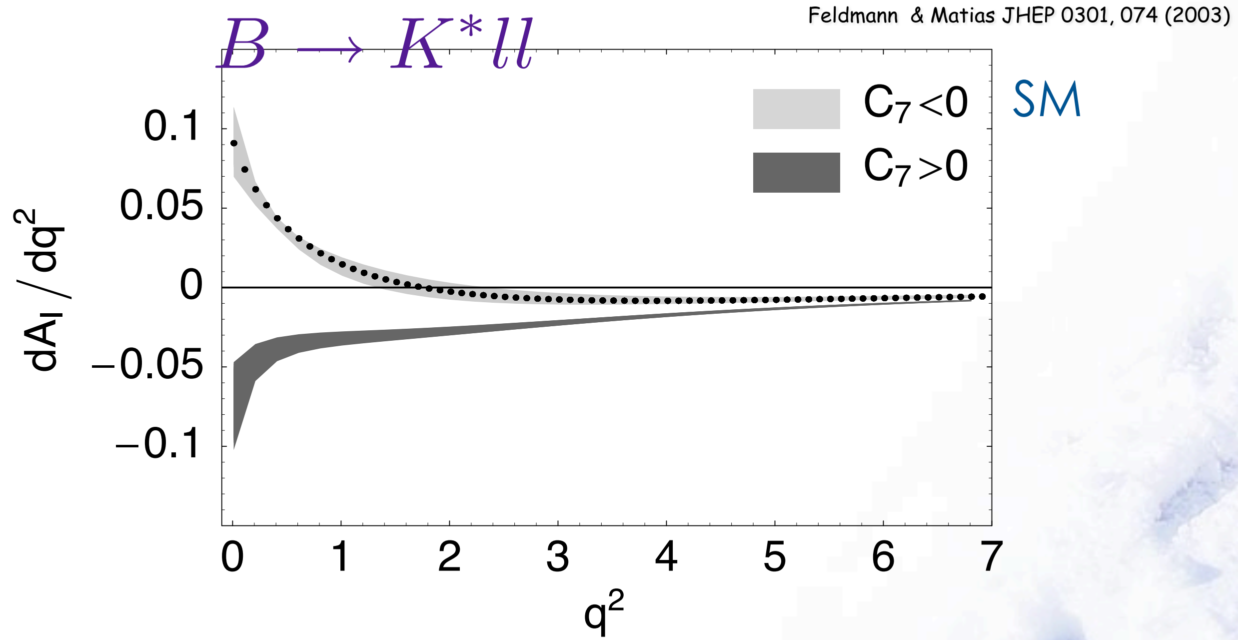


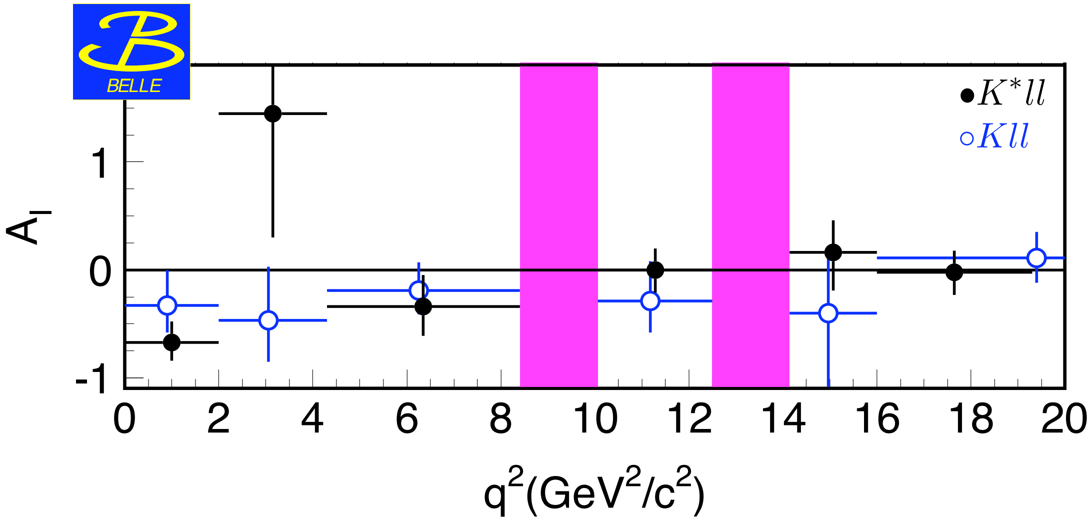
- SMではA_Iは小さい<10%

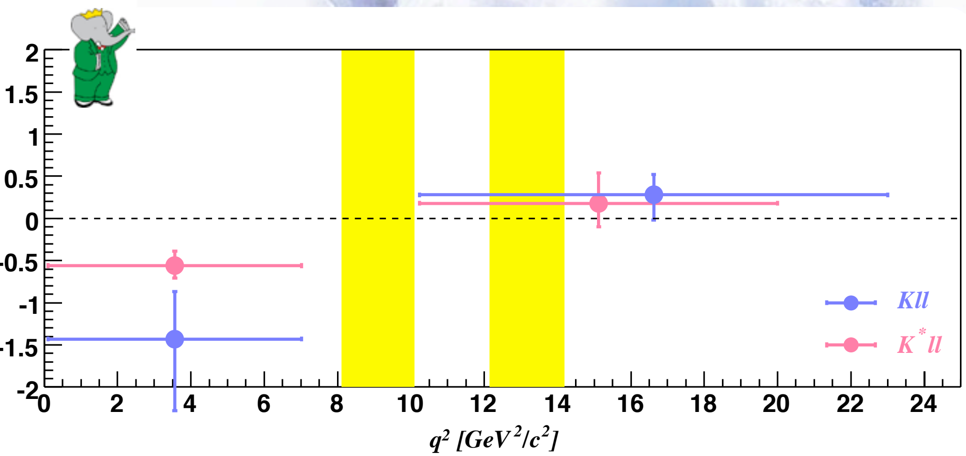
BELLE : PRL 103, 171801 (2009)

BABAR: ARXIV: 0804.4119 (2008) 384M BB

isospin asymmetry







B→K*ll angular analysis

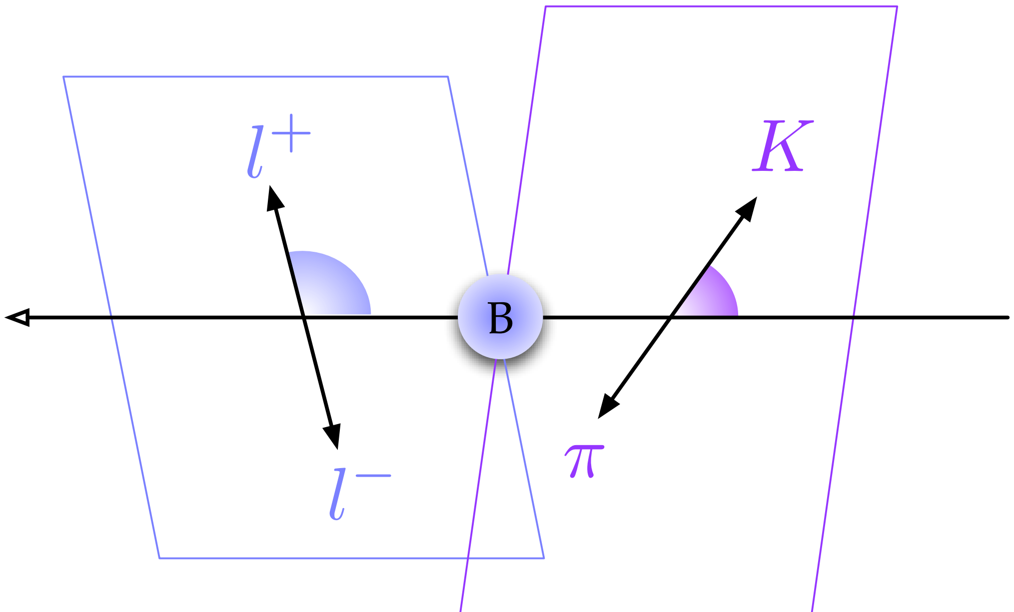
FLやAFBからWilson係数を
決定することができる

- K* 偏極度(FL)

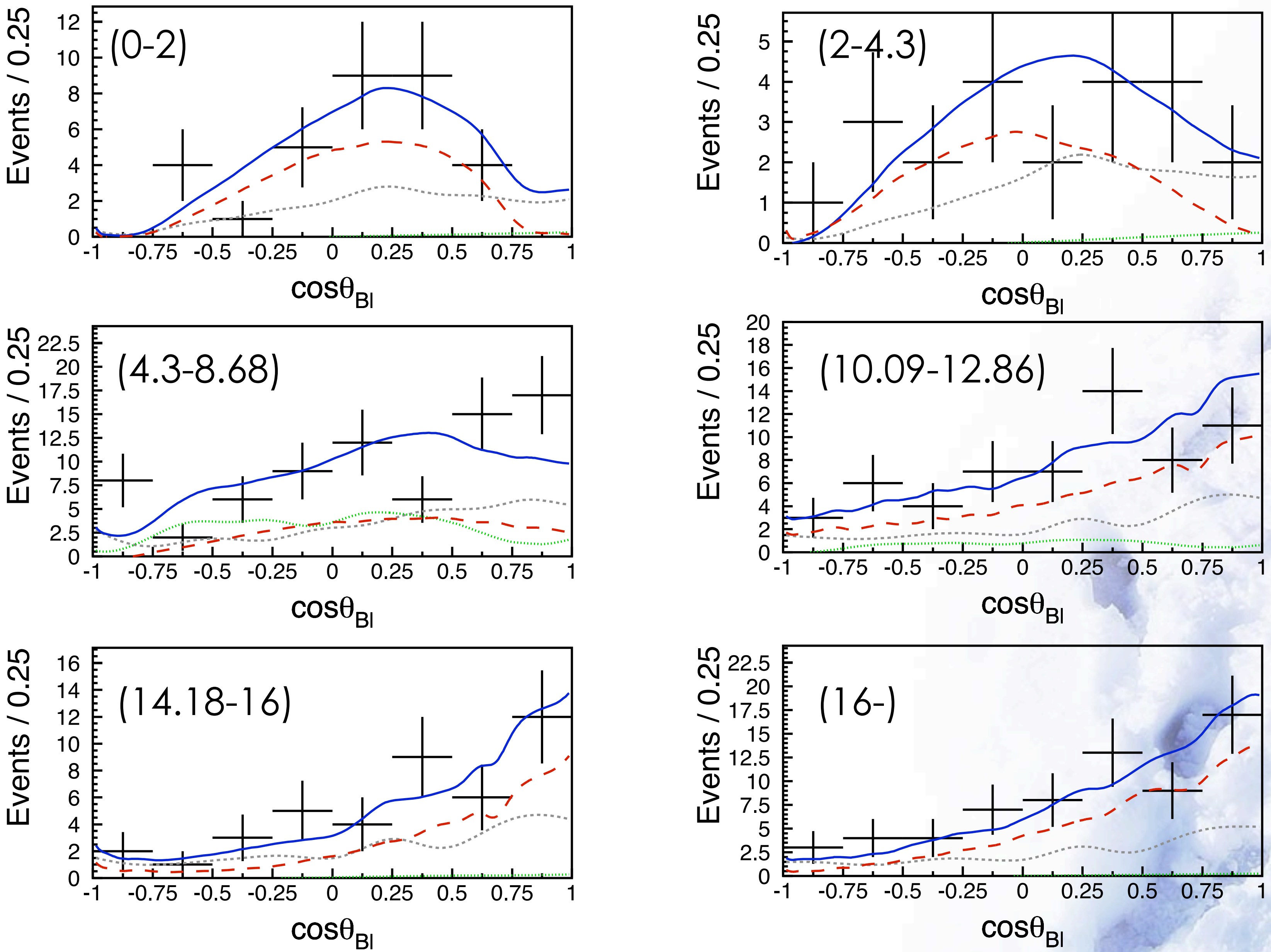
$$\frac{d\Gamma}{d\cos\theta_{K*}} = \frac{3}{2}F_L\cos^2\theta_{K^*} + \frac{3}{4}(1-F_L)\sin^2\theta_{K*}$$

- Forward-backward Asymmetry (AFB)

$$\frac{d\Gamma}{d\cos\theta_{Bl}} = \frac{3}{4}F_L\sin^2\theta_{Bl} + \frac{3}{8}(1-F_L)(1+\cos^2\theta_{Bl}) + A_{FB}\cos\theta_{Bl}$$

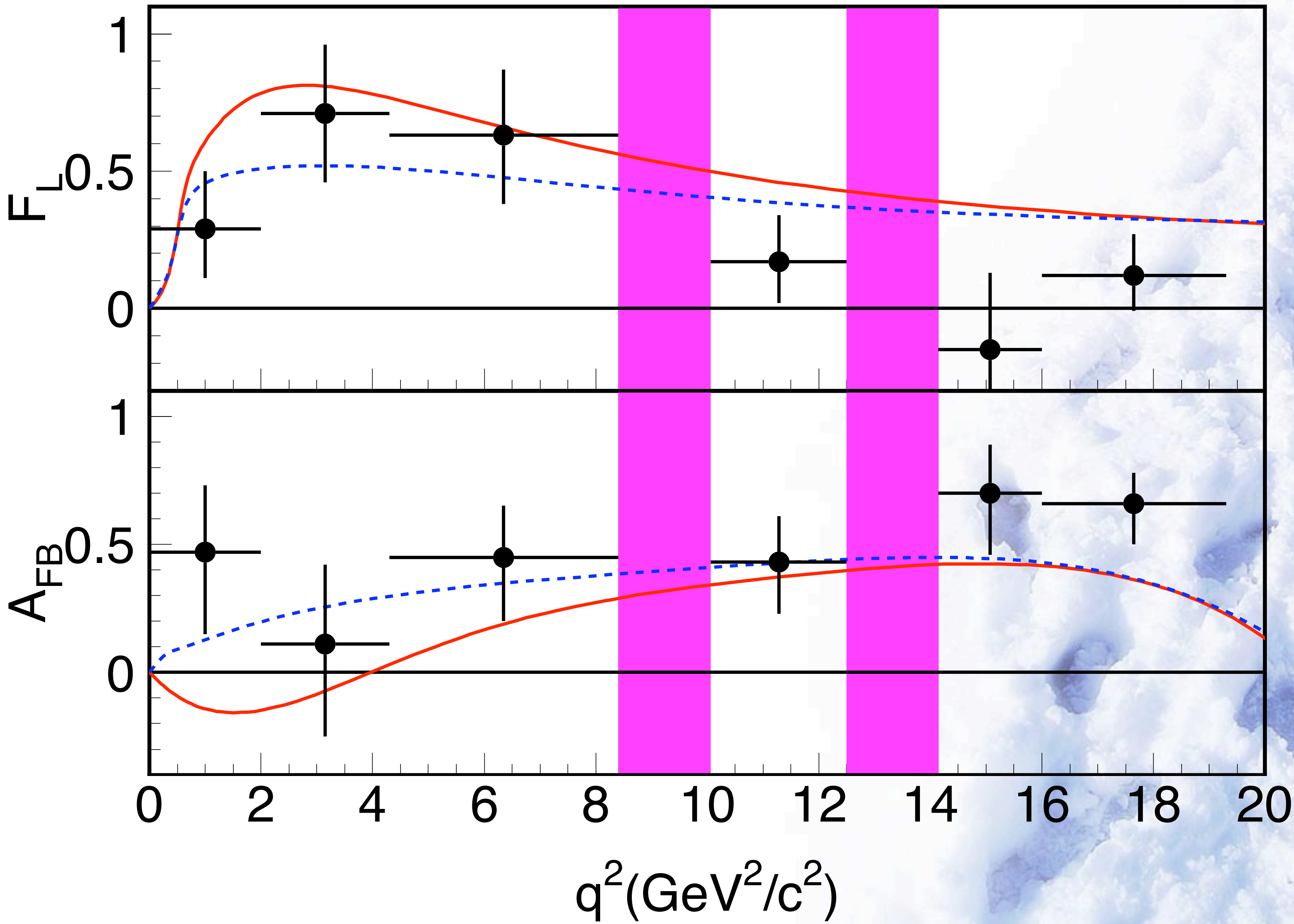


angular analysis

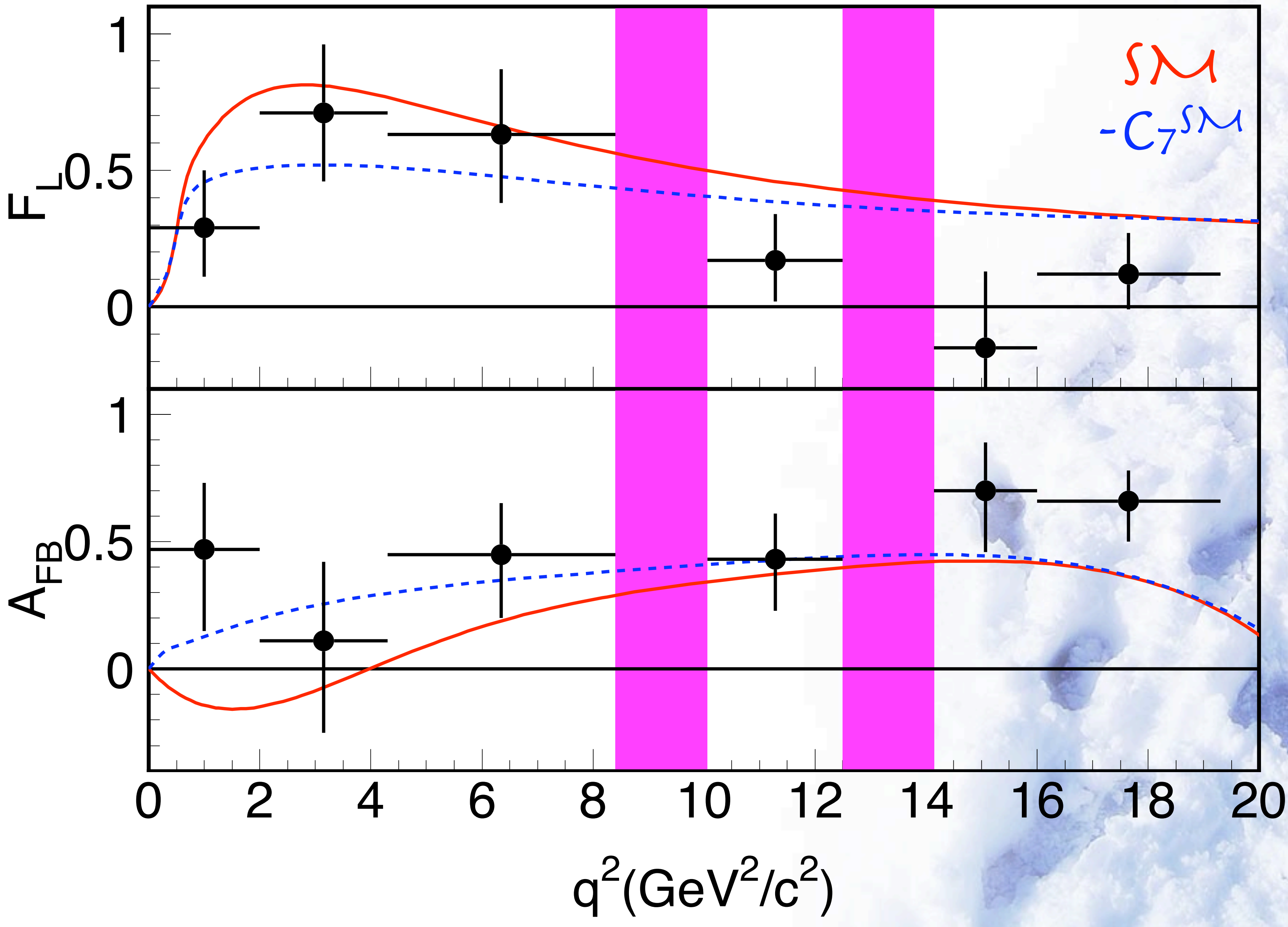


F_{AB}のみ
float

F_L and A_{FB}



F_L and A_{FB}

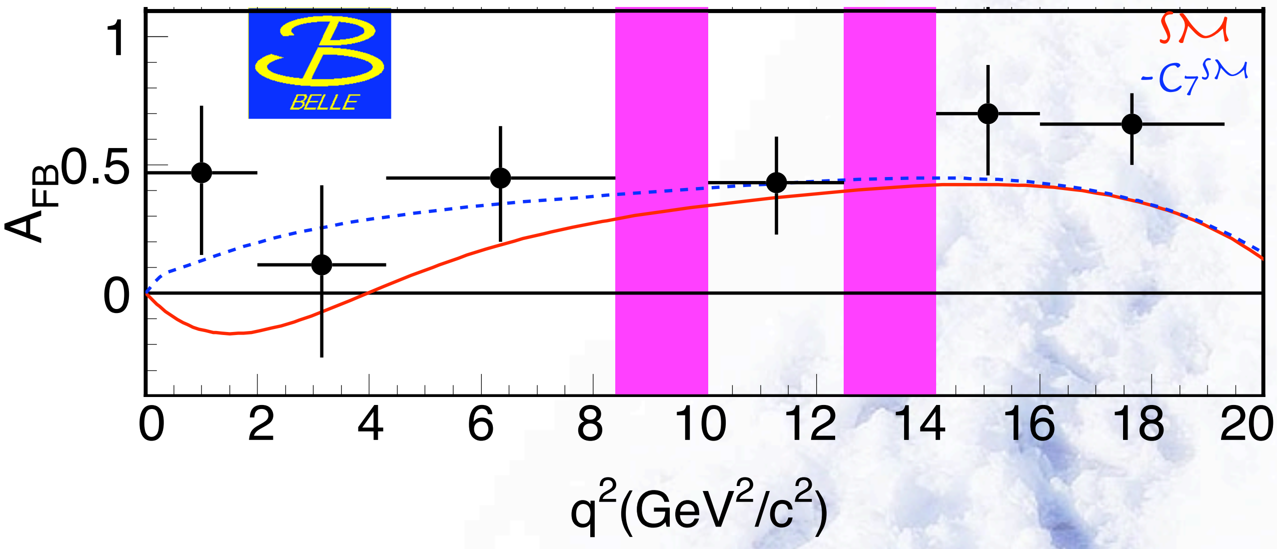


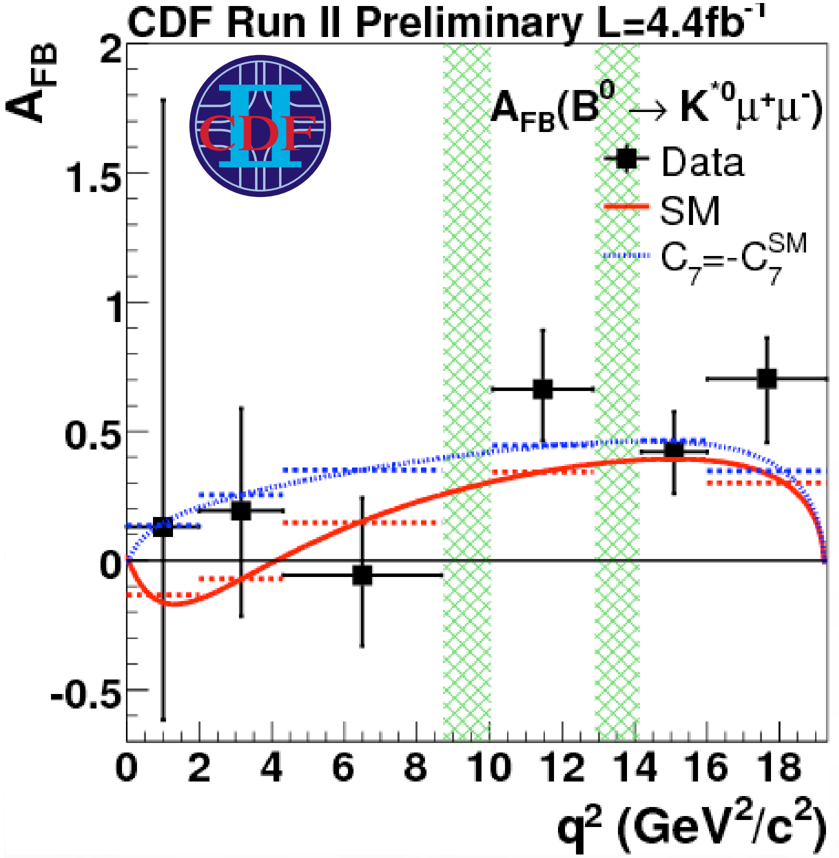
comparison

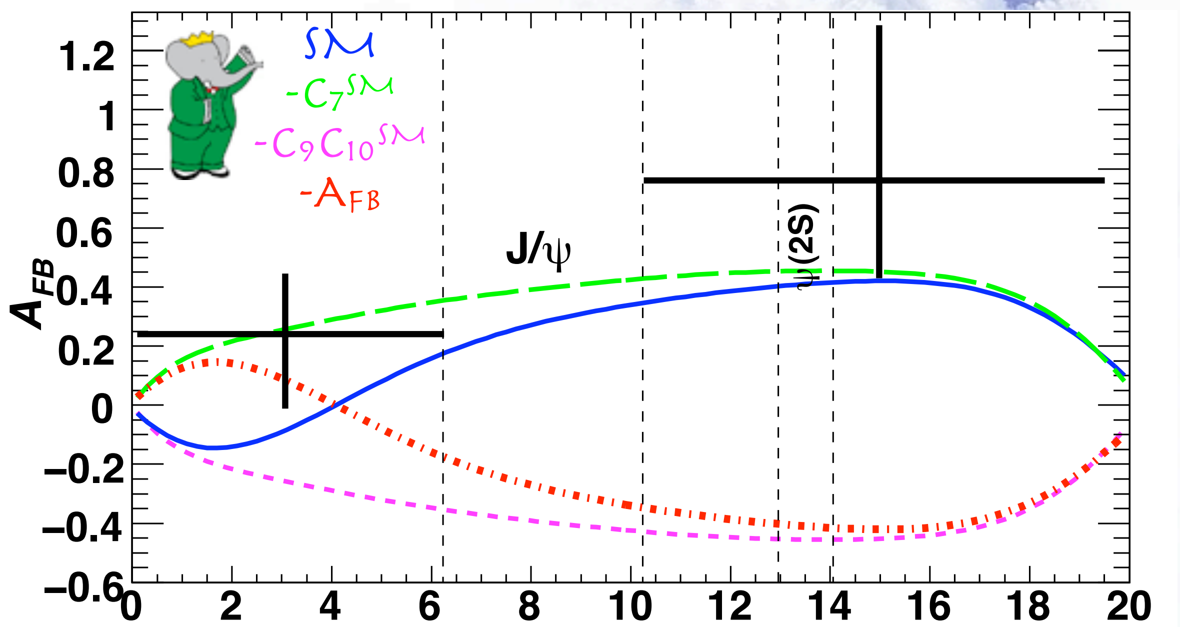
BELLE : PRL 103, 171801 (2009) 657M BB

BABAR: PRD 79, 031102(R) (2009) 384M BB

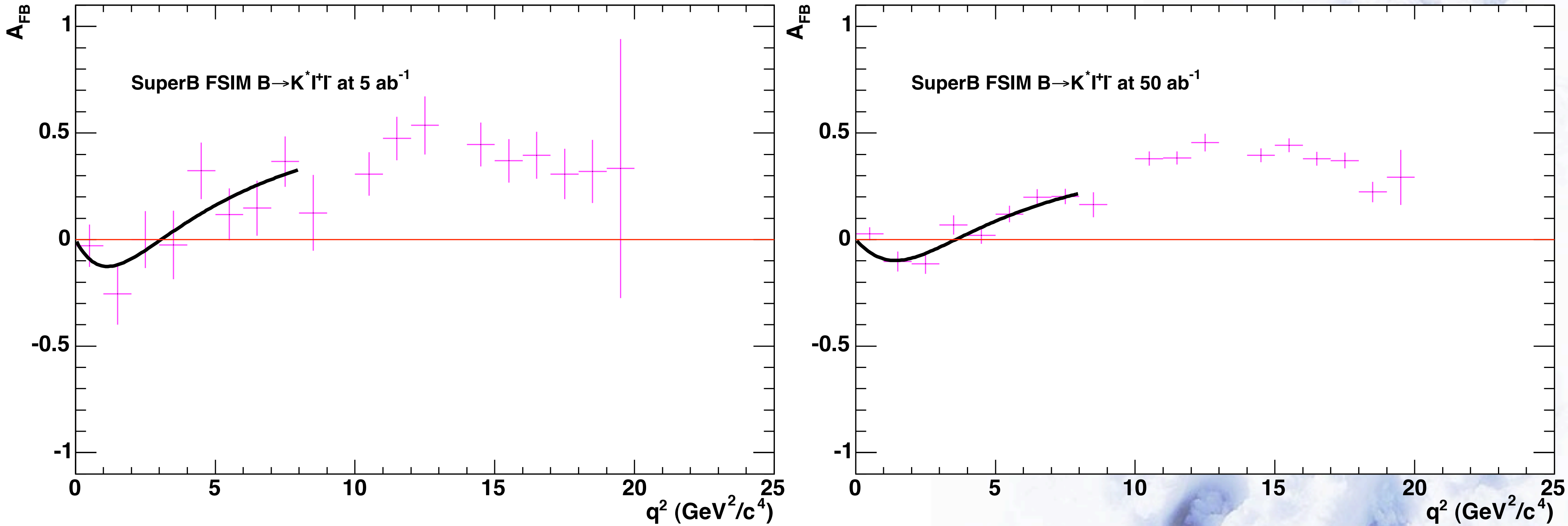
CDF: HCP SYMPOSIUM '09

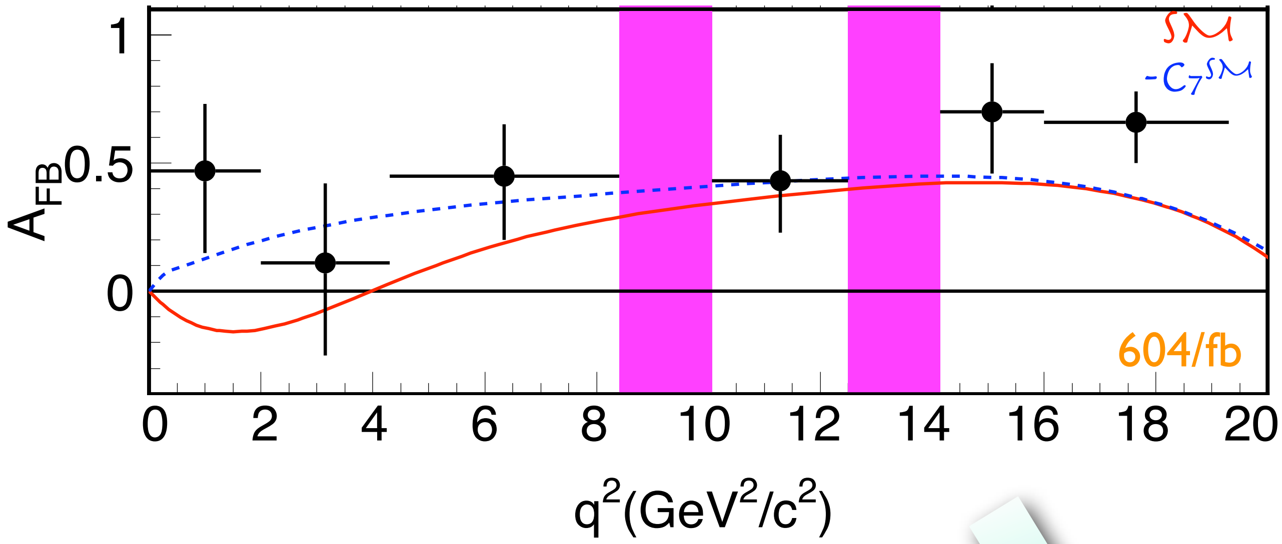




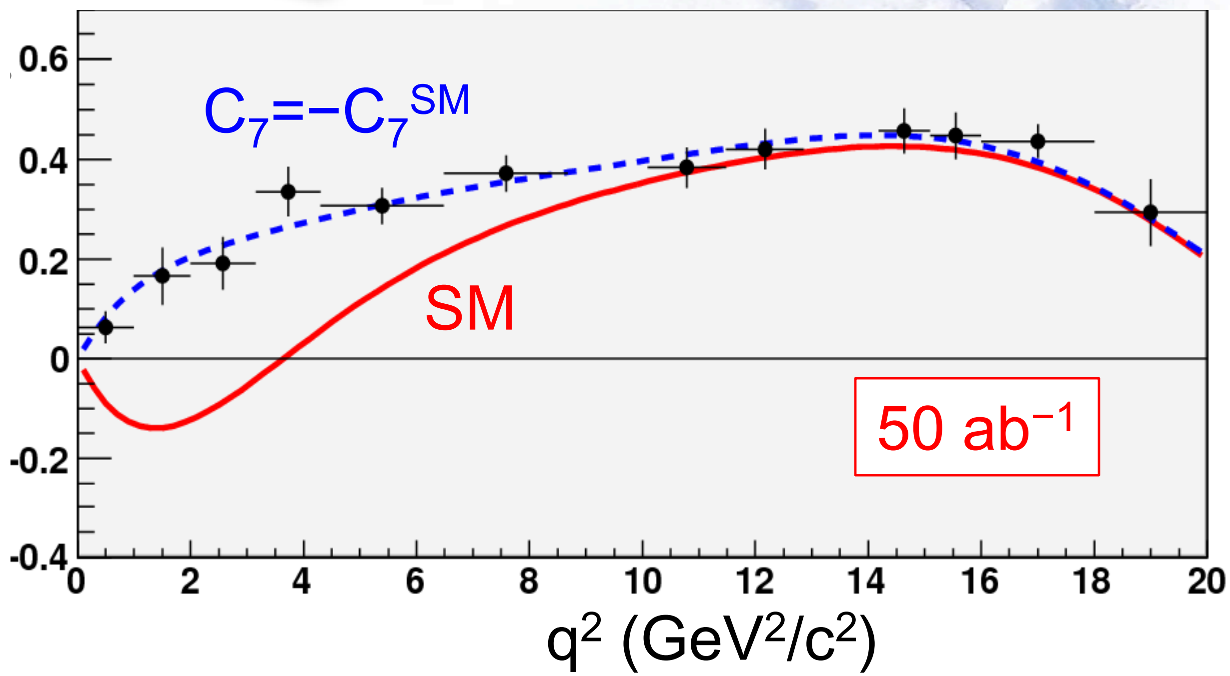


SuperKEKB / Belle II



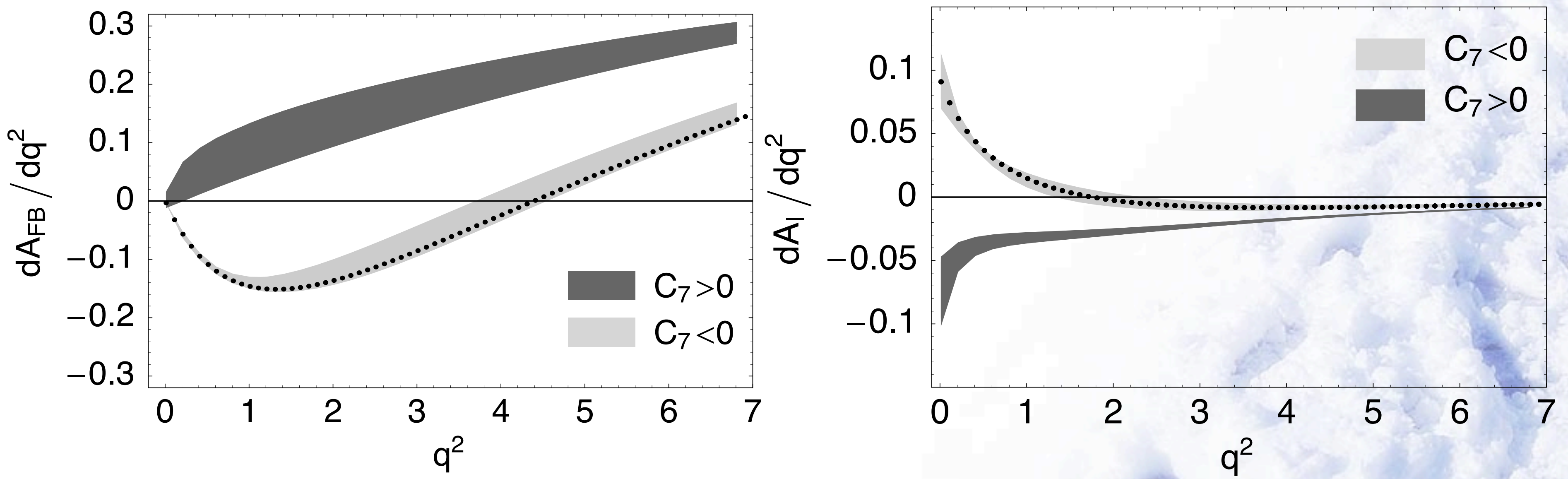


1
A_{FB} 0.5
0
SM
$-C_7^{SM}$
604/fb
0 2 4 6 8 10 12 14 16 18 20
$q^2(GeV^2/c^2)$



$C_7=-C_7^{SM}$
SM
50 ab^{-1}
0.6 0.4 0.2 0 -0.2 -0.4
0 2 4 6 8 10 12 14 16 18 20
q^2 (GeV^2/c^2)

New Physics Scenario

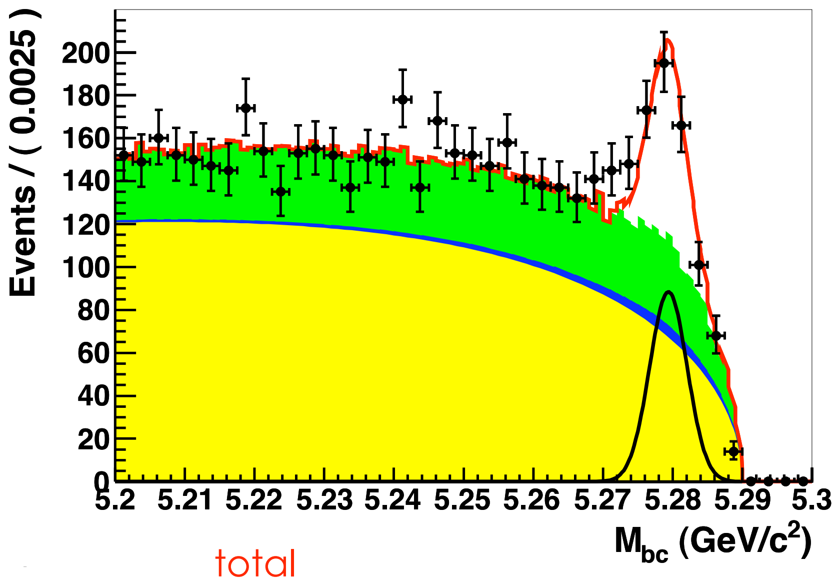


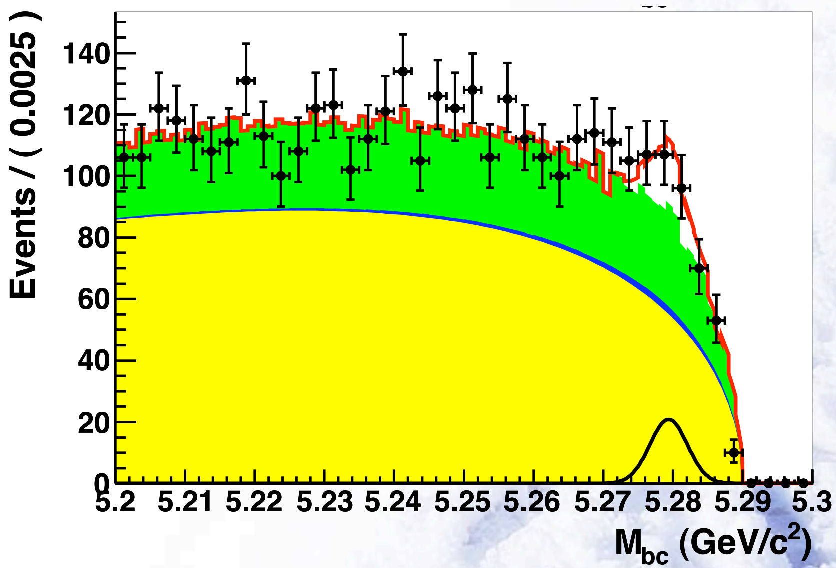
- Minimum Flavor Violation
  - flavor transitionはCKM起源, 最低限のSUSY
  - SUSY mass ~1TeV(heavy)
    - ✦ charged Higgs, stop ~ 数百GeV

inclusive $B \to X_s ll$

preliminary

inclusive B→$X_s$ll





total
signal
continuum+semi-leptonic B decay
J/ψ(ψ)X background

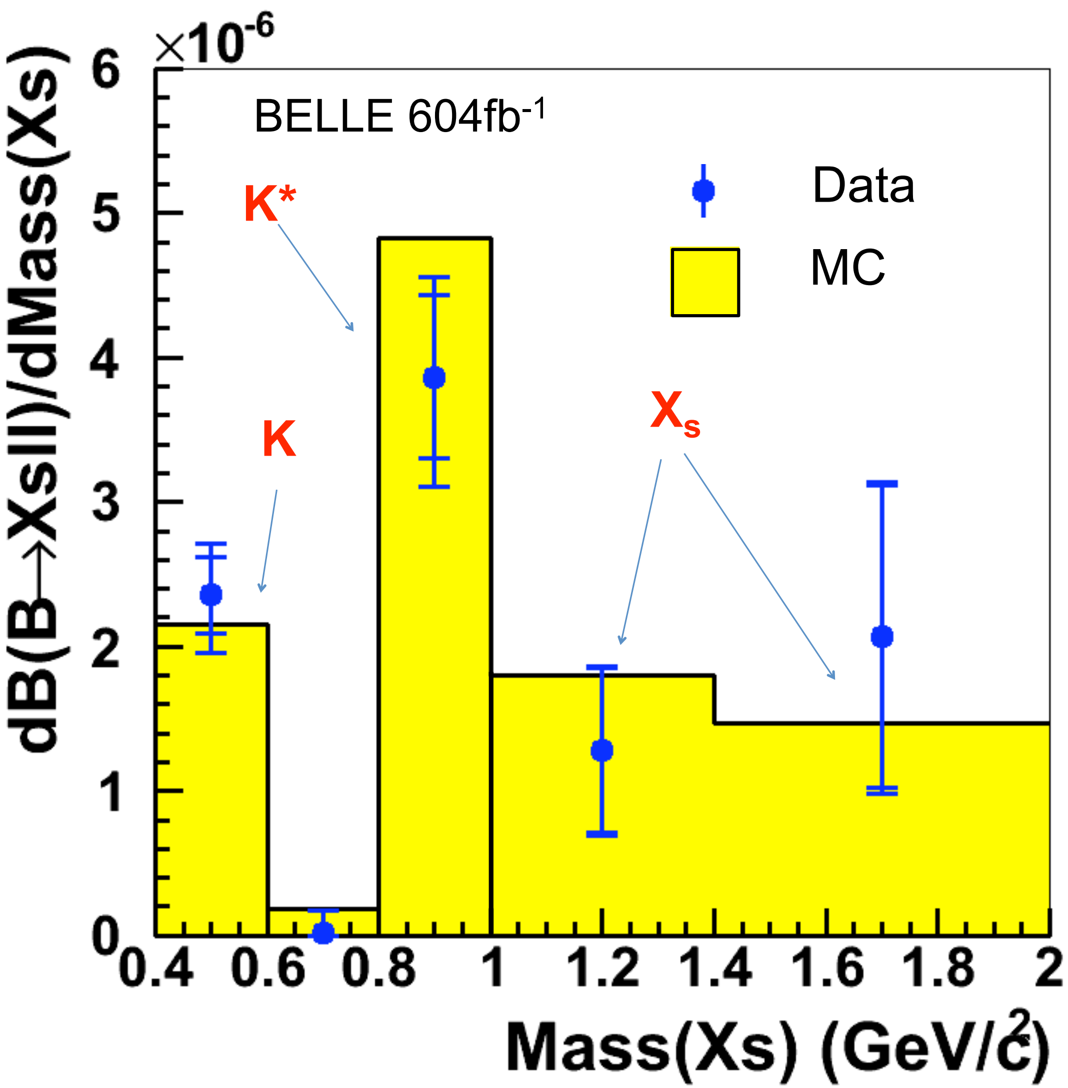
M_{Xs} > 1.0GeV
(Kll, K*llを除く)

- semi-inclusive
  - 36のexclusiveモードの和: K/Ks + 0-4π + lepton pair

M_{Xs} > 1.0GeVで初めて3σのeventを観測

inclusive B→X$_s$ll

preliminary

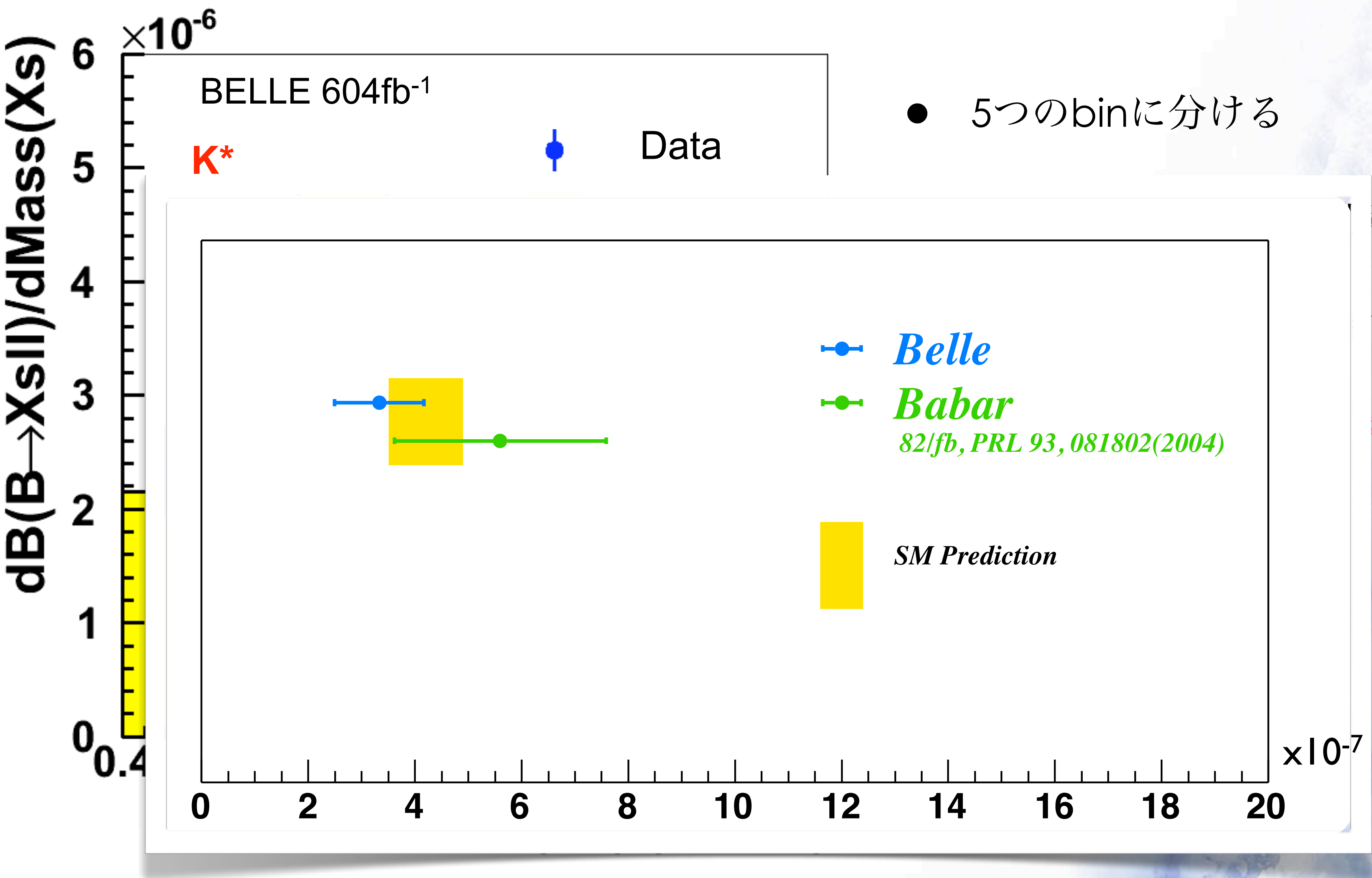


- 5つのbinに分ける
- それぞれの分岐比を測定
- 5つの結果をcombineする
- systematic errorを小さくできる

$$\mathcal{B}(B \to X_s ll) = (3.33 \pm 0.80^{+0.19}_{-0.24}) \times 10^{-6}$$

preliminary

inclusive $B \to X_s ll$



- 5つのbinに分ける

定

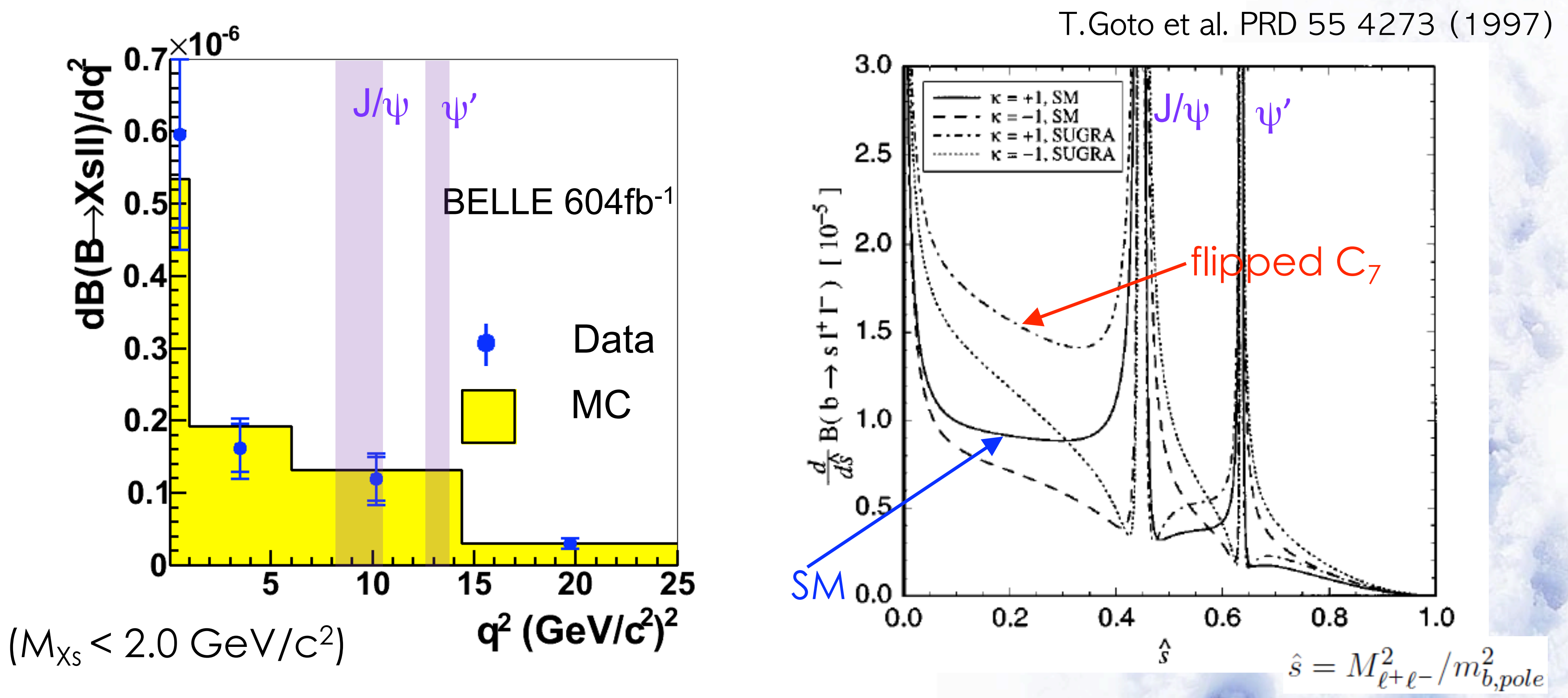
する

くできる

$$\mathcal{B}(B \to X_s ll) = (3.33 \pm 0.80^{+0.19}_{-0.24}) \times 10^{-6}$$

preliminary

inclusive B→$X_s$ll



- SMの予想とよく合っている

summary

b→sの遷移

- new physics のプローブとして注目

B→Xsll analysis

- 豊富な観測量
- F_{AB}(q^2~小)にずれ？　flipped-C_7 like
- inclusive modeではSM like
-