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Measurement of the CP Violation Parameter $\sin 2\phi_1$ in B^0 Meson Decays

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for
the Belle Collaboration

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Measurement of the CP Violation Parameter $\sin 2\phi_1$ in B^0_d Meson Decays

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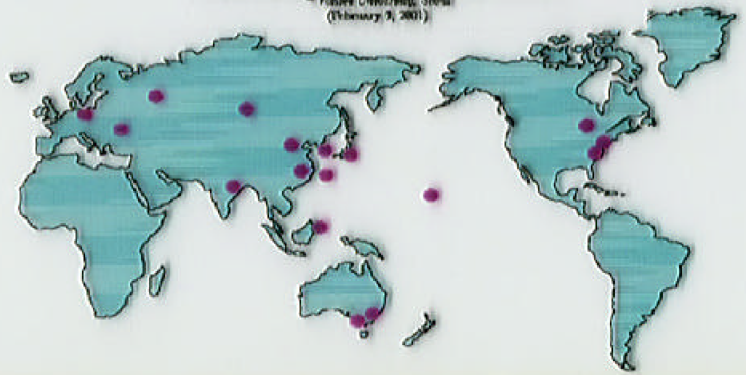


The Belle Collaboration

274 Authors from 45 Institutions

Outline

1. Introduction
2. Reconstruction of B mesons
3. Flavor Tagging
4. Proper Decay Time and CP Fit
5. Conclusion

1. Introduction

Mixing-induced CP Violation in B → CP eigenstate (fcp)

$$A(\Delta t) \equiv \frac{\Gamma(\overline{B_d}^0 \to f_{CP}) - \Gamma(B_d^0 \to f_{CP})}{\Gamma(\overline{B_d}^0 \to f_{CP}) + \Gamma(B_d^0 \to f_{CP})} = -\xi_f \sin 2\phi_1 \sin \Delta m_d \Delta t,$$

Δt : $\equiv t_{CP} - t_{tag}$

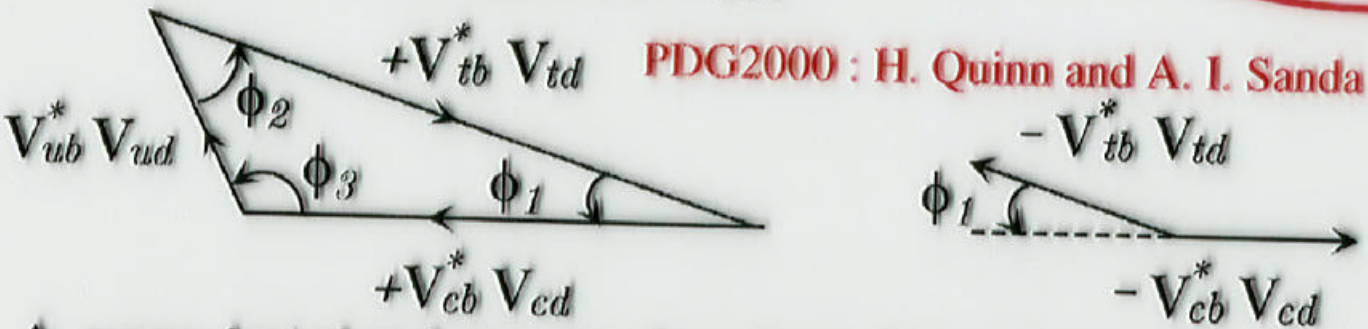
f_{CP} : CP eigenstate

$\Gamma(\overline{B_d}^0(B_d^0) \to f_{CP})$: decay rate for a $\overline{B_d}^0(B_d^0)$ to f_{CP} at Δt

ξ_f : CP-eigenvalue of f_{CP}

$$\phi_1 \equiv \pi - \arg\left(\frac{-V_{tb}^* V_{td}}{-V_{cb}^* V_{cd}}\right) = \beta$$

PDG2000 : H. Quinn and A. I. Sanda

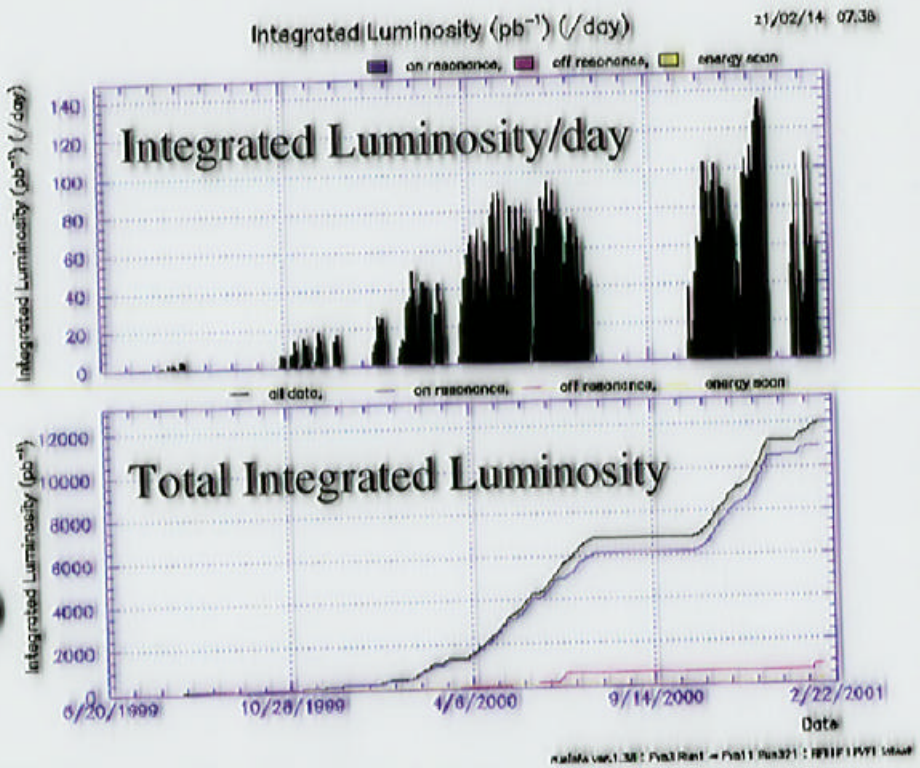


A very intriguing mechanism based on the Kobayashi-Maskawa ansatz in the Standard Model

KEKB Collider

e- 8GeV → ← e+ 3.5GeV

$\beta\gamma = 0.425$



Luminosity records

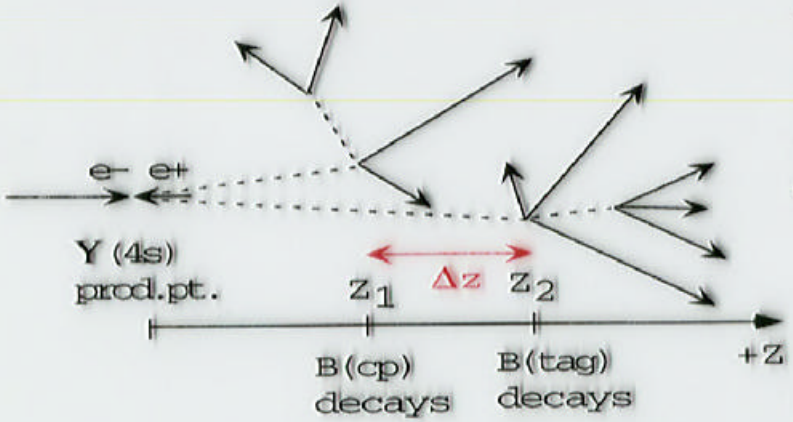
- 2.27×10^{33} cm^{-2}sec^{-1} (peak)
- 129pb^{-1}/day
- 805pb^{-1}/week
- 11.1fb-1 by the end of 2000

10.5fb^{-1} (on resonance)
0.6fb^{-1} (off resonance)
used in this analysis

→Talk by Prof. Kurokawa for detail (Session 19-IV)

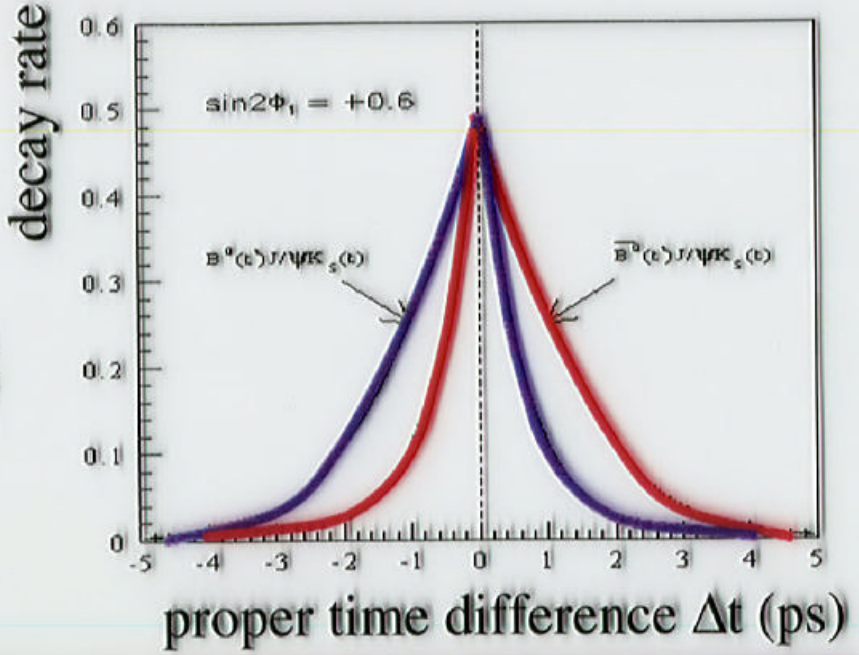
Experimental Challenges

1) Copious BB production, efficient B reconstruction
2) Efficient and correct flavor tagging
3) Observation of time-dependent CP asymmetry in B decays to fcp with good vertex resolution



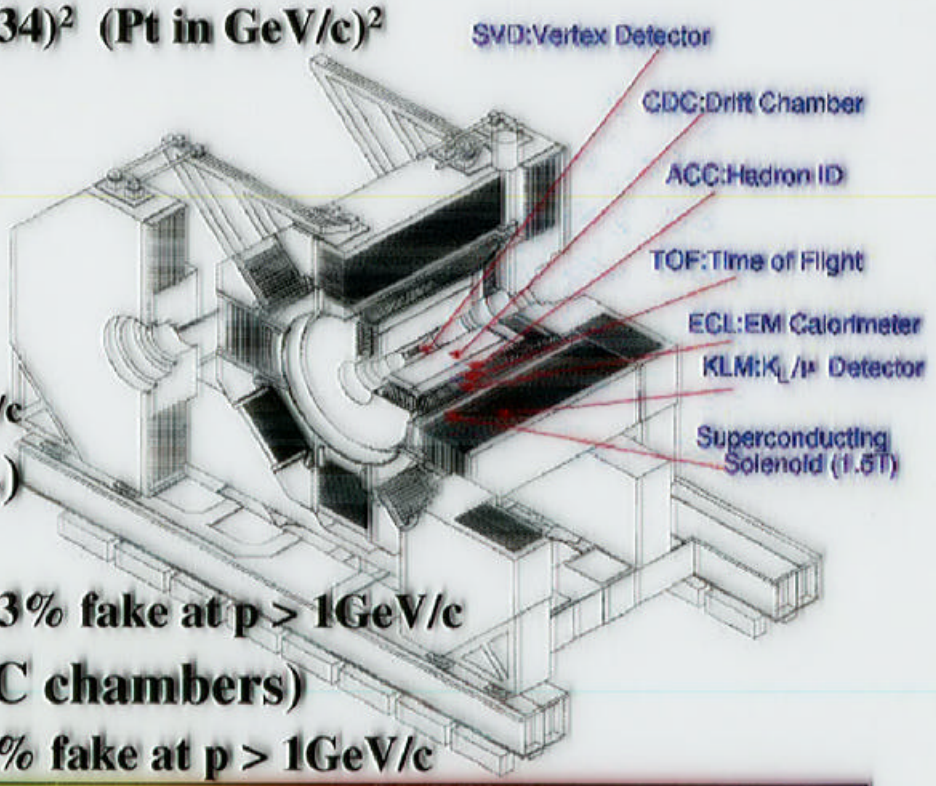
$$\Delta z \approx c\beta\gamma\Delta t$$

τ_B : B lifetime



Belle Detector

- **Silicon Vertex Detector (SVD)**
  - Impact parameter resolution : 55μm for p=1GeV/c at normal incidence
- **Central Drift Chamber (CDC)**
  - $(\sigma_{P_t}/Pt)^2 = (0.0019Pt)^2 + (0.0034)^2$ (Pt in GeV/c)^2
- **K/π separation with**
  - dE/dx in CDC ($\sigma_{dE/dx}$ =6.9%)
  - TOF (σ_{TOF} = 95ps)
  - Aerogel Cerenkov (ACC)
    - Efficiency = ~85%,
      Fake rate = ~10% up to 3.5GeV/c
- **γ, $e^{\pm}$ with CsI crystals (ECL)**
  - σ_E ~ 1.5% for E=1GeV
  - $e^{\pm}$: efficiency > 90% with ~0.3% fake at p > 1GeV/c
- **KL and $\mu^{\pm}$ with KLM (RPC chambers)**
  - $\mu^{\pm}$: efficiency > 90% with ~2% fake at p > 1GeV/c



2. Reconstruction of B mesons

As many as possible (as far as background is small) !

$B_{CP} \rightarrow J/\psi\ Ks(\rightarrow \pi^+\pi^-\ or\ \pi^0\pi^0)$
$\psi(2S)(\rightarrow l^+l^-\ or\ J/\psi\pi^+\pi^-)\ Ks$
$\chi_{c1}(\rightarrow J/\psi\gamma)\ Ks$
$\eta_c(\rightarrow K^+K^-\pi^0\ or\ KsK^{\pm}\pi^{\mp})\ Ks$
$J/\psi\ \pi^0$
$J/\psi\ K_L$

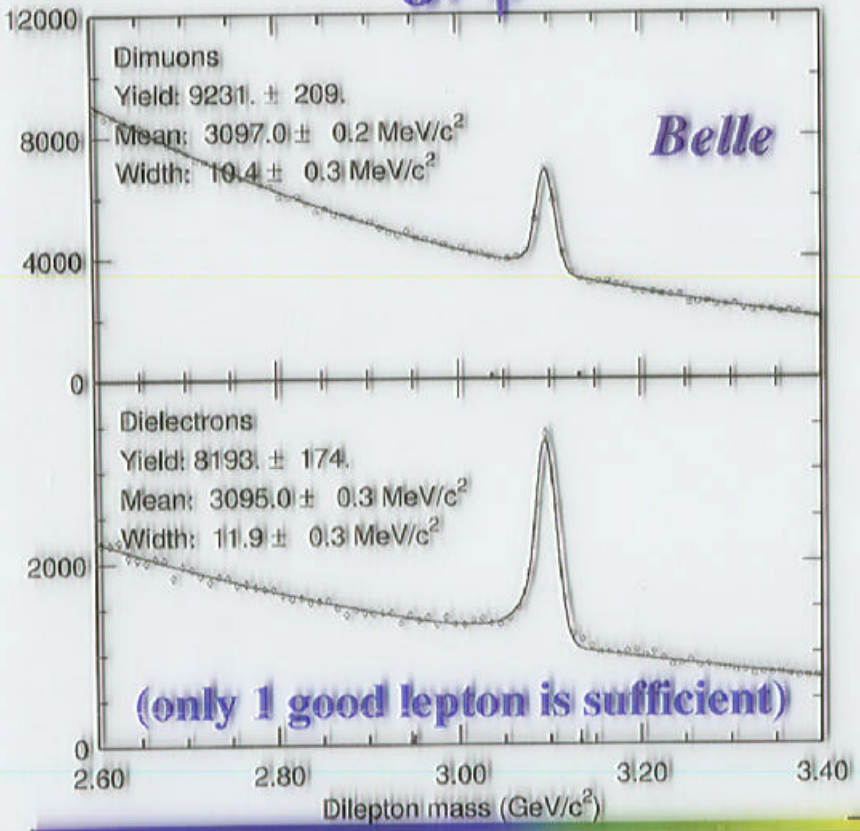
$CP = -1$
$CP = +1$

$(J/\psi \rightarrow l^+l^-\ , Ks \rightarrow \pi^+\pi^-\ , \pi^0 \rightarrow \gamma\gamma$ *unless otherwise noticed* $)$

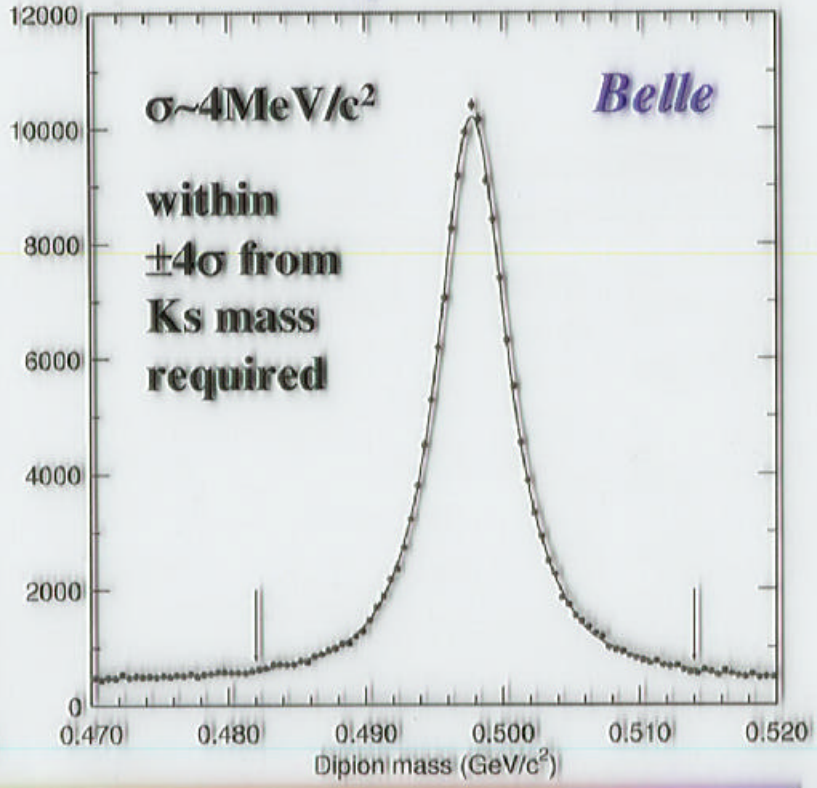
Reconstruction of $B^0 \to J/\psi\, Ks(\to \pi^+\pi^-)$

Greatest contribution among all the fcp states

J/ψ



$Ks(\to \pi^+\pi^-)$



Reconstruction of $B^0 \to J/\psi\, Ks(\to \pi^+\pi^-)$

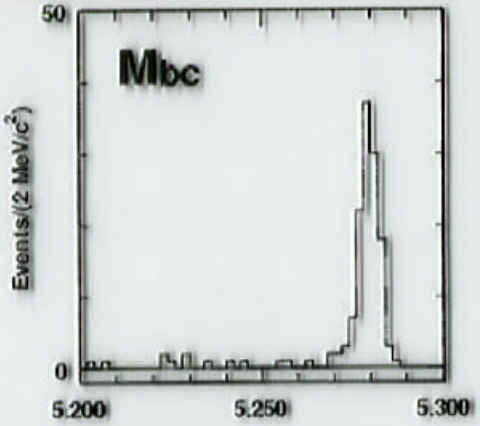
Energy difference : $\Delta E \equiv E_B^{cms} - E_{beam}^{cms}$

Beam-constrained mass : $M_{bc} \equiv \sqrt{(E_{beam}^{cms})^2 - (p_B^{cms})^2}$

cms : the $\Upsilon(4S)$ center of mass system,

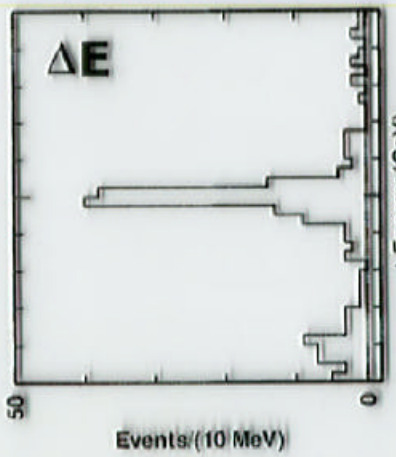
E_{beam}^{cms} : the cms beam energy,

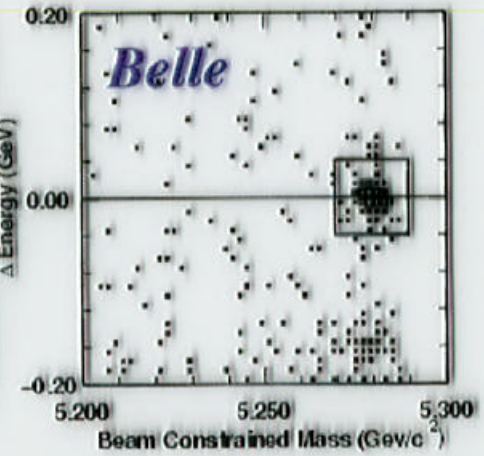
E_B^{cms} and p_B^{cms} : the cms energy and momentum of the B candidate.



123 candidates
3.7 background

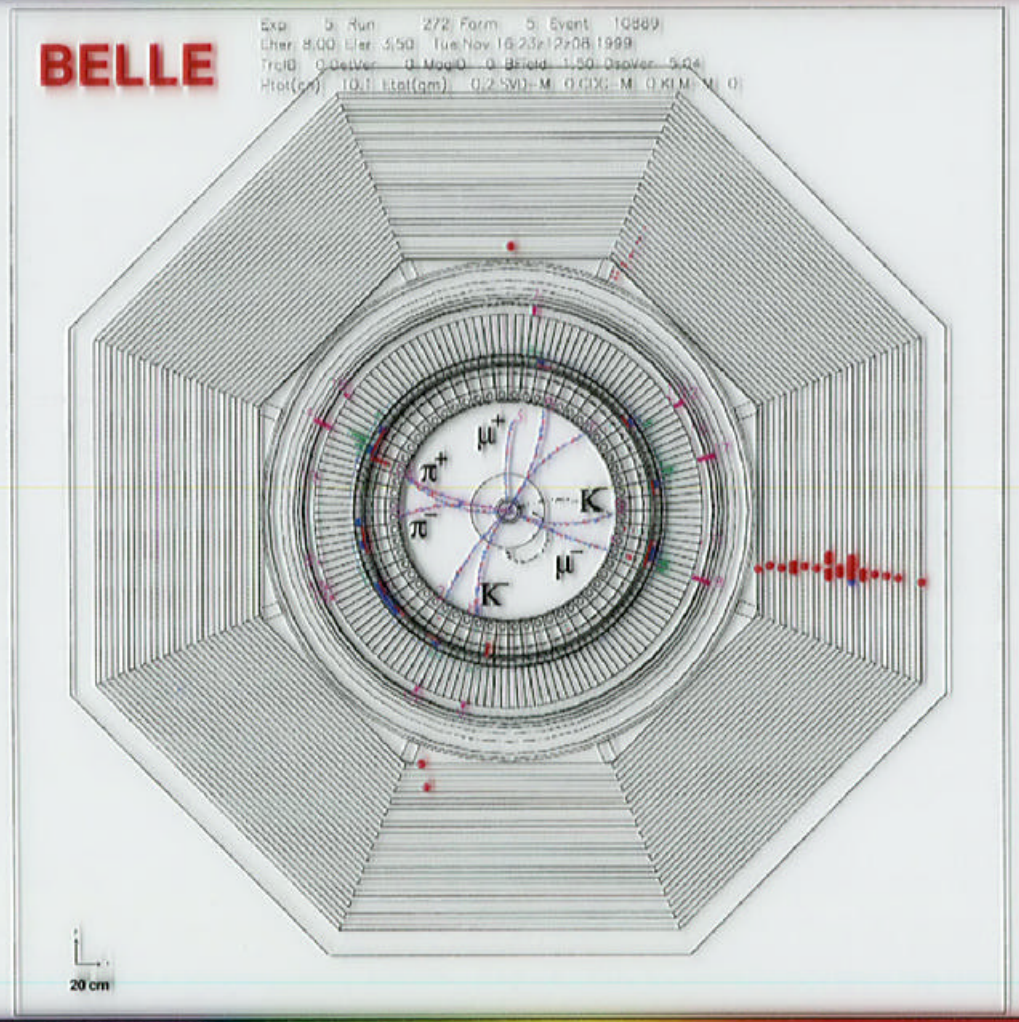
Purity = 97%





ΔE vs Mbc

$B^0 \to J/\psi\ Ks(\to \pi^+\pi^-)$



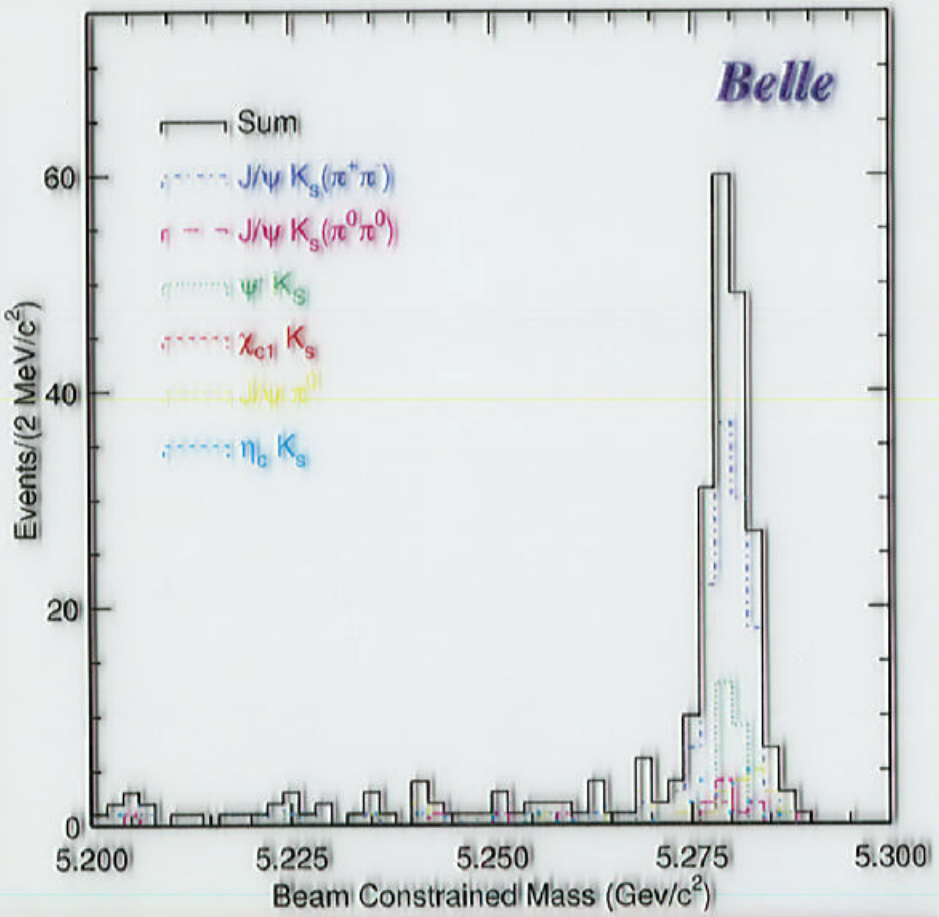
All modes combined (other than $B^0 \to J/\psi\, K_L$)

$B^0 \to$ other modes

71 candidates
7.3 background
(Purity = 90%)

$B^0 \to J/\psi\, Ks(\to\pi^+\pi^-)$

123 candidates
3.7 background
(Purity = 97%)



Reconstruction of $B^0 \to J/\psi\, K_L$

1) $J/\psi \to l^+l^-$ requiring two leptons

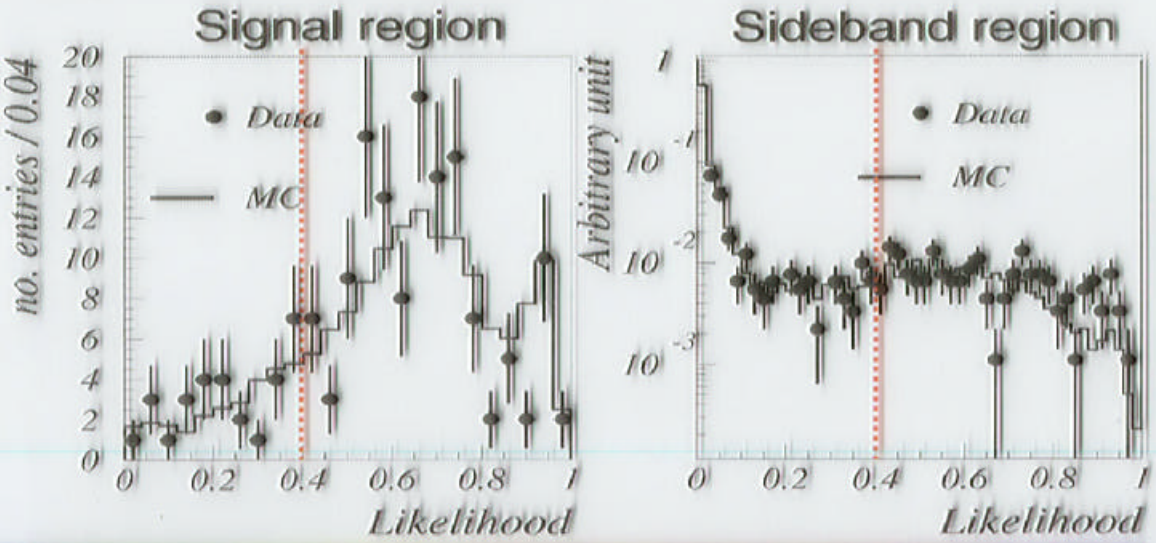
2) K_L cluster and P_B(cms). $(0.2 < P_B(\text{cms}) < 0.45\text{GeV/c})$

3) Remove fully reconstructed $B^0 \to J/\psi$ Ks, $J/\psi\, K^{*0}$,
$B^\pm \to J/\psi\, K^\pm$, $J/\psi\, K^{*\pm}$

4) Cut on likelihood, *L*, for better S/N

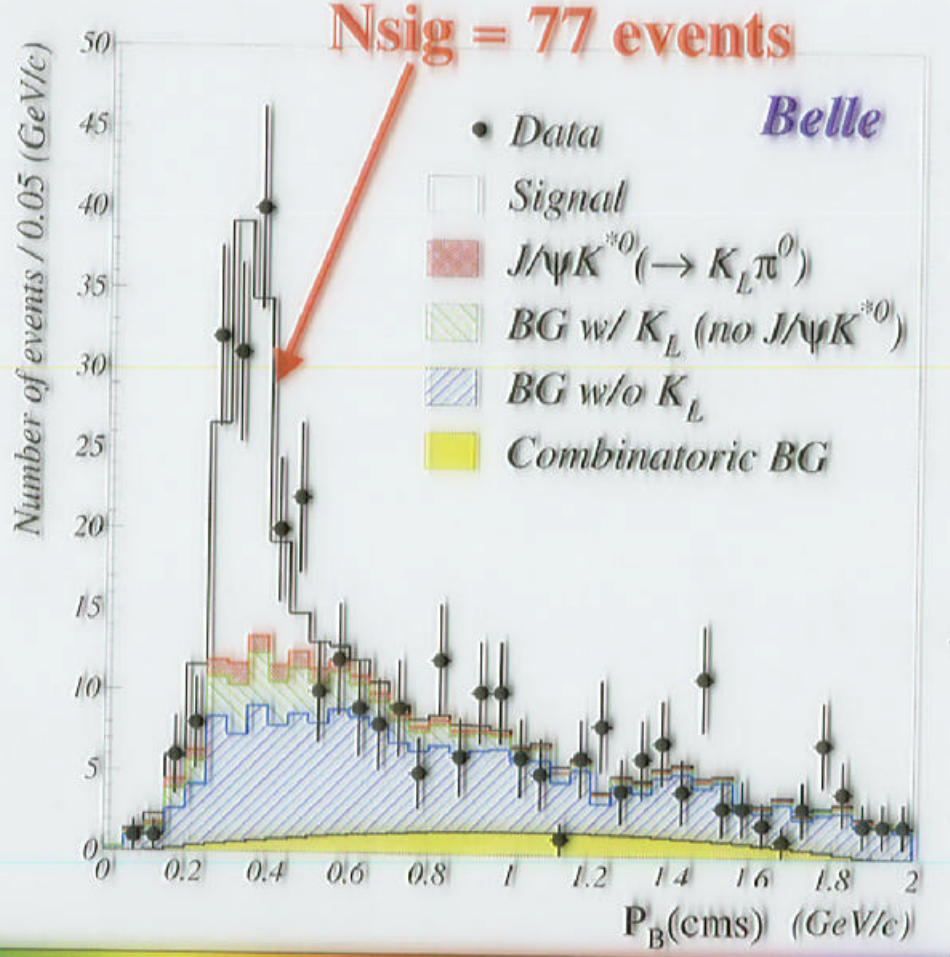
***L* is made of kinematical and topological information**

$L > 0.4$ required



Signal yield of $B^0 \to J/\psi\, K_L$

- Fit $0 < P_B(\text{cms}) < 2$ (GeV/c)
  - Four background components
  - Combinatoric J/ψ modeled with $e\mu$ combination in data
  - Other BG modeled with Monte Carlo



$B^0 \to J/\psi\, K_L$

131 candidates
54 background
(Purity = 59%)

B meson reconstruction: Summary

Mode	N_{ev}	N_{bkgd}
$J/\psi(\ell^+\ell^-)K_S(\pi^+\pi^-)$	123	3.7
$J/\psi(\ell^+\ell^-)K_S(\pi^0\pi^0)$	19	2.5
$\psi(2S)(\ell^+\ell^-)K_S(\pi^+\pi^-)$	13	0.3
$\psi(2S)(J/\psi\pi^+\pi^-)K_S(\pi^+\pi^-)$	11	0.3
$\chi_{c1}(\gamma J/\psi)K_S(\pi^+\pi^-)$	3	0.5
$\eta_c(K^+K^-\pi^0)K_S(\pi^+\pi^-)$	10	2.4
$\eta_c(K_SK^+\pi^-)K_S(\pi^+\pi^-)$	5	0.4
$J/\psi(\ell^+\ell^-)\pi^0$	10	0.9
Sub-total	194	11
$J/\psi(\ell^+\ell^-)K_L$	131	54

Next is the flavor-tagging for these 325 events.