Rare B decays in Belle

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For Belle collaboration

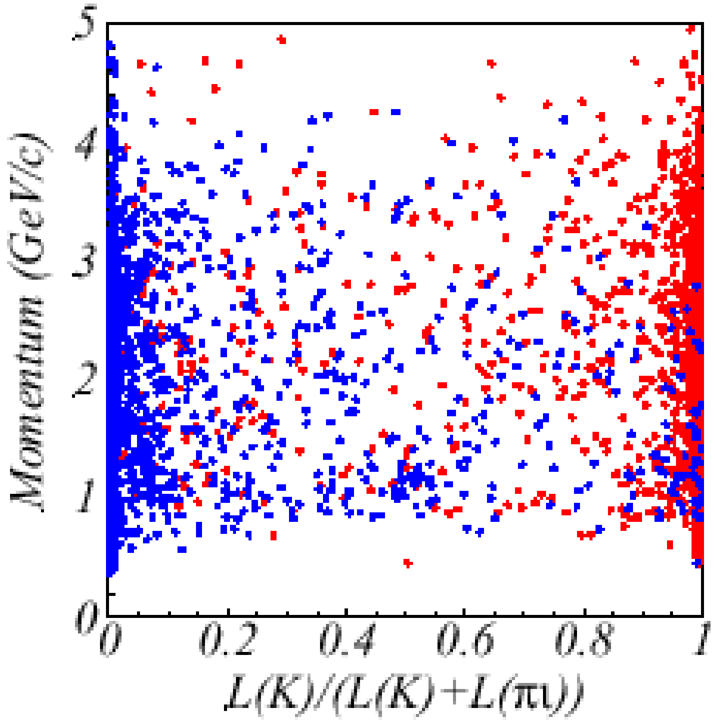
- ***$b \to s$ penguin : $b \to s\bar{s}s$ ($\phi K^{(*)}$), $b \to s\bar{s}s\bar{s}s$($\phi\phi K$), $b \to s\gamma$, $b \to sll$***

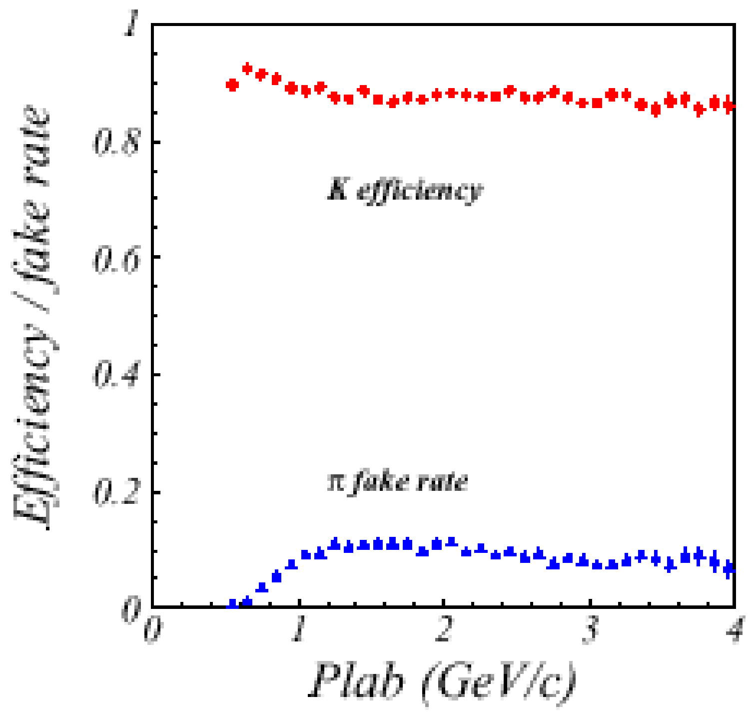
- ***$B \to hh$ charmless decays modes: $K\pi$, $\pi\pi$, KK, ρh, ωh, $\rho\rho$***

- ***New resonance $B \to K(\pi\pi J/\psi)$***

Particle Identification

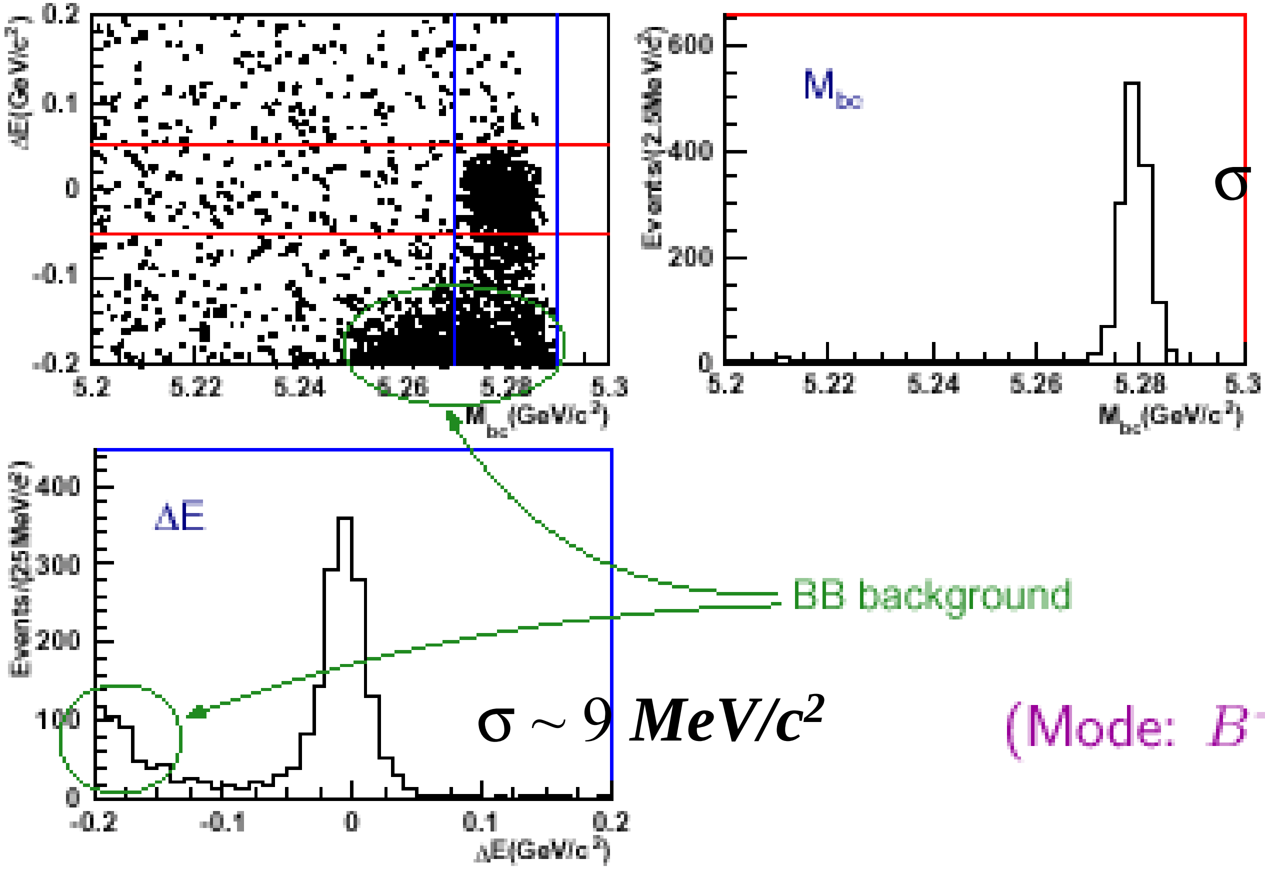
PID use dE/dx, ToF and ACC. $PID(K) = L(K)/(L(K) + L(\pi))$





Kinematic variables for the Υ (4S)

$$M_{bc} \equiv \sqrt{(E^*_{beam})^2 - |\vec{p}^*_B|^2} \quad \text{(beam constrained mass)}$$
$$\Delta E \equiv E^*_B - E^*_{beam}.$$



$\sigma \sim 2.7$ ***MeV/c²***

$\sigma \sim 9$ ***MeV/c²***

(Mode: $B^- \to D^0\pi^-$)

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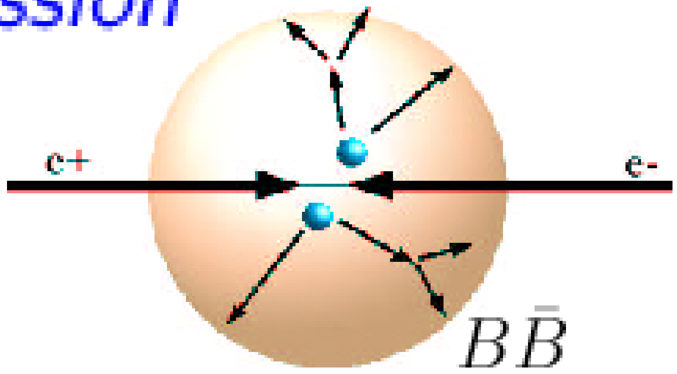
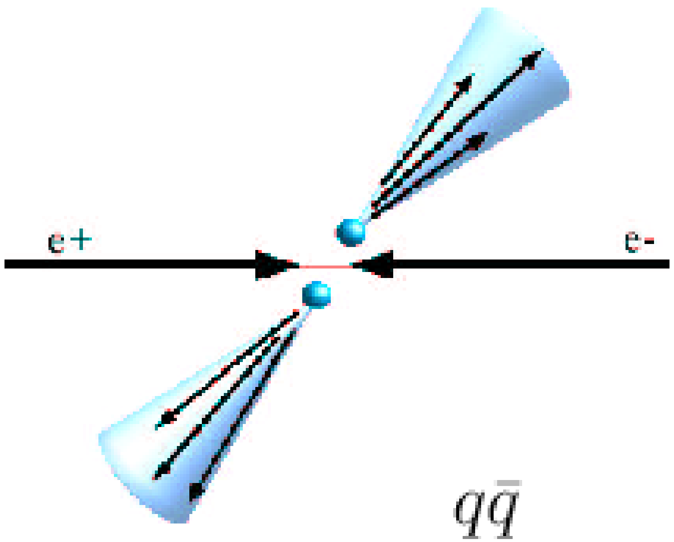
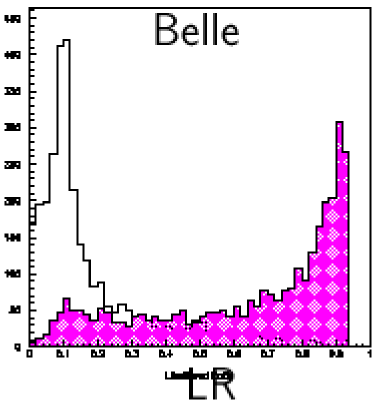
Continuum Suppression

- Distinguish spherical B events from jet-like continuum.
- Employ event topology or/and angular distribution
  - Modified Fox Wolfram moments
  - sphericity, $\cos\theta_{thr}$
  - $\cos\theta_B$
- Build Fisher Discriminants ($\mathcal{F}$):
  - Belle: Form Likelihood from $\mathcal{F}$ and $\cos\theta_B$





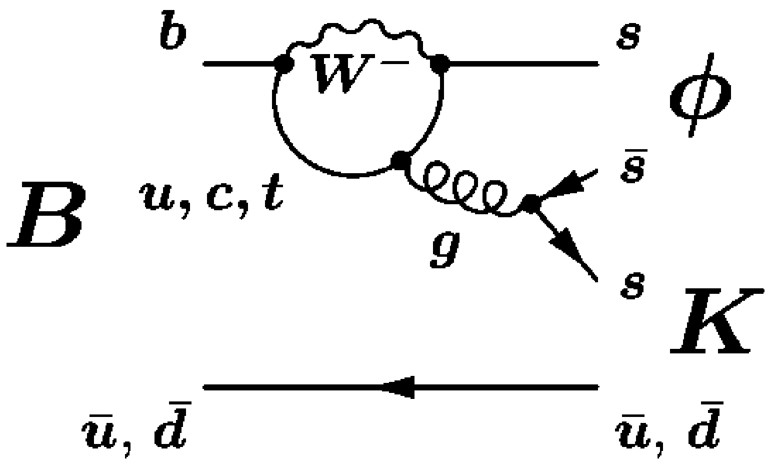


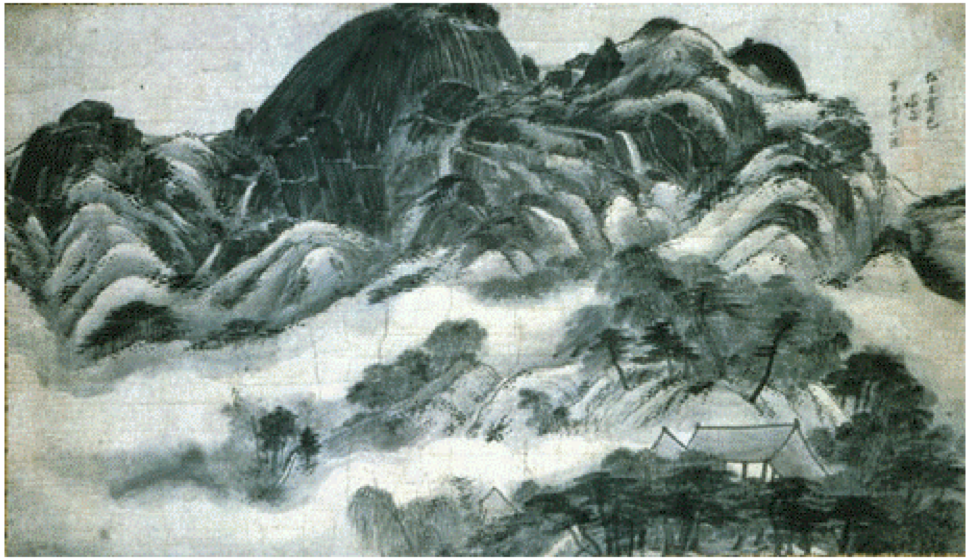
Cut on Likelihood ratio.

$$LR = \frac{L_B}{L_B + L_{q\bar{q}}}$$

$B \to \varphi K^+$, $B \to \varphi K_s$, $B \to \varphi K^*$

Pure $b \to s$ penguins in SM

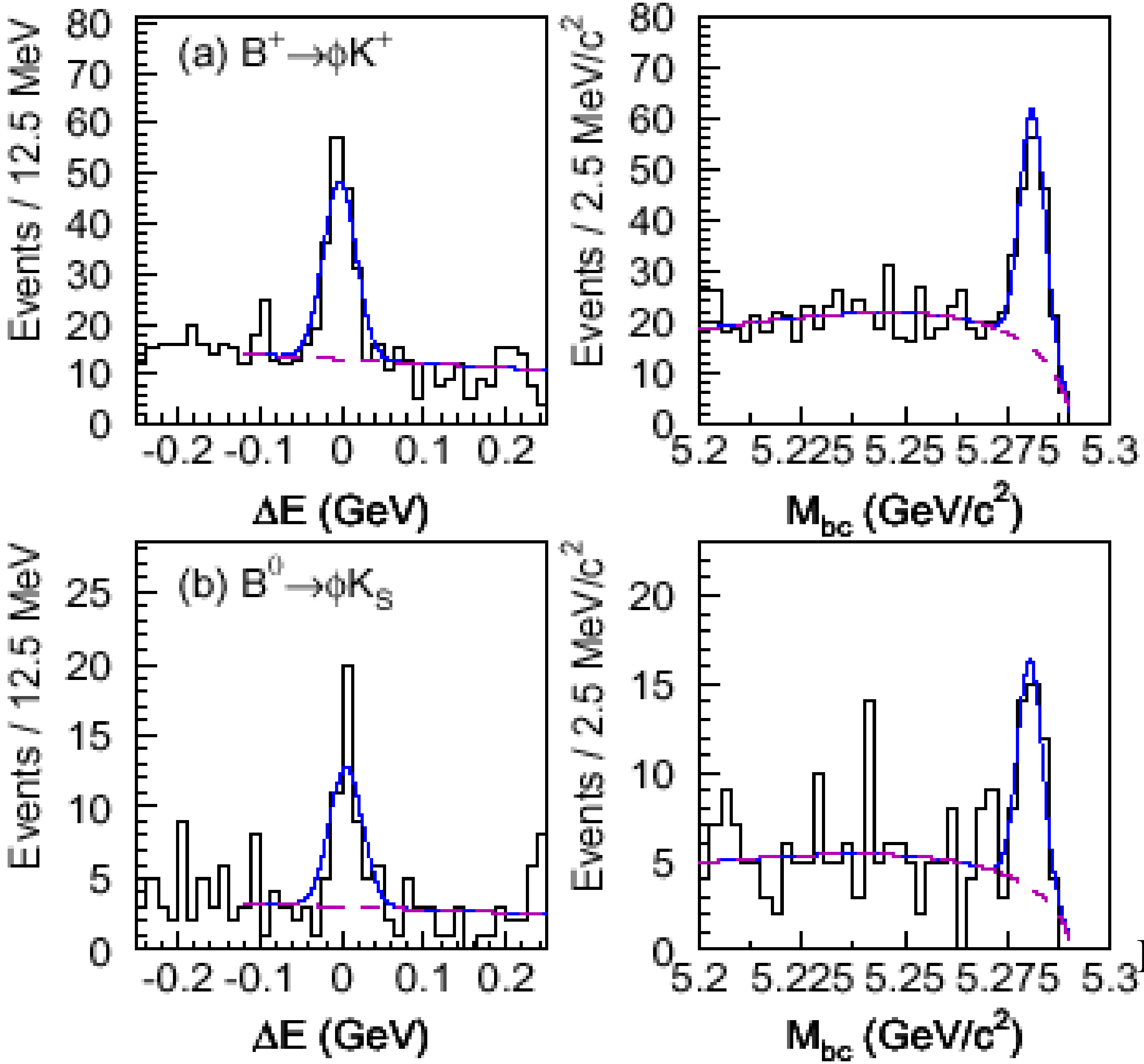




In the SM, $\sin(2\varphi_1) = \sin(2\varphi_1)\ (B \to \varphi K_S)$

interesting indirect CPV results for $B \to \varphi K^0$

$B \to \varphi\ K^+$, $B \to \varphi\ K_s$, $B \to \varphi\ K^*$



$N_s = 136^{+16}_{-15}$

significance $= 16.5\sigma$

$\varepsilon = 16.9\%$

$N_s = 35.6^{+8.4}_{-7.4}$

significance $= 8.7\sigma$

$\varepsilon = 4.6\%$

Data used : 78 fb^{-1} on Y(4S)

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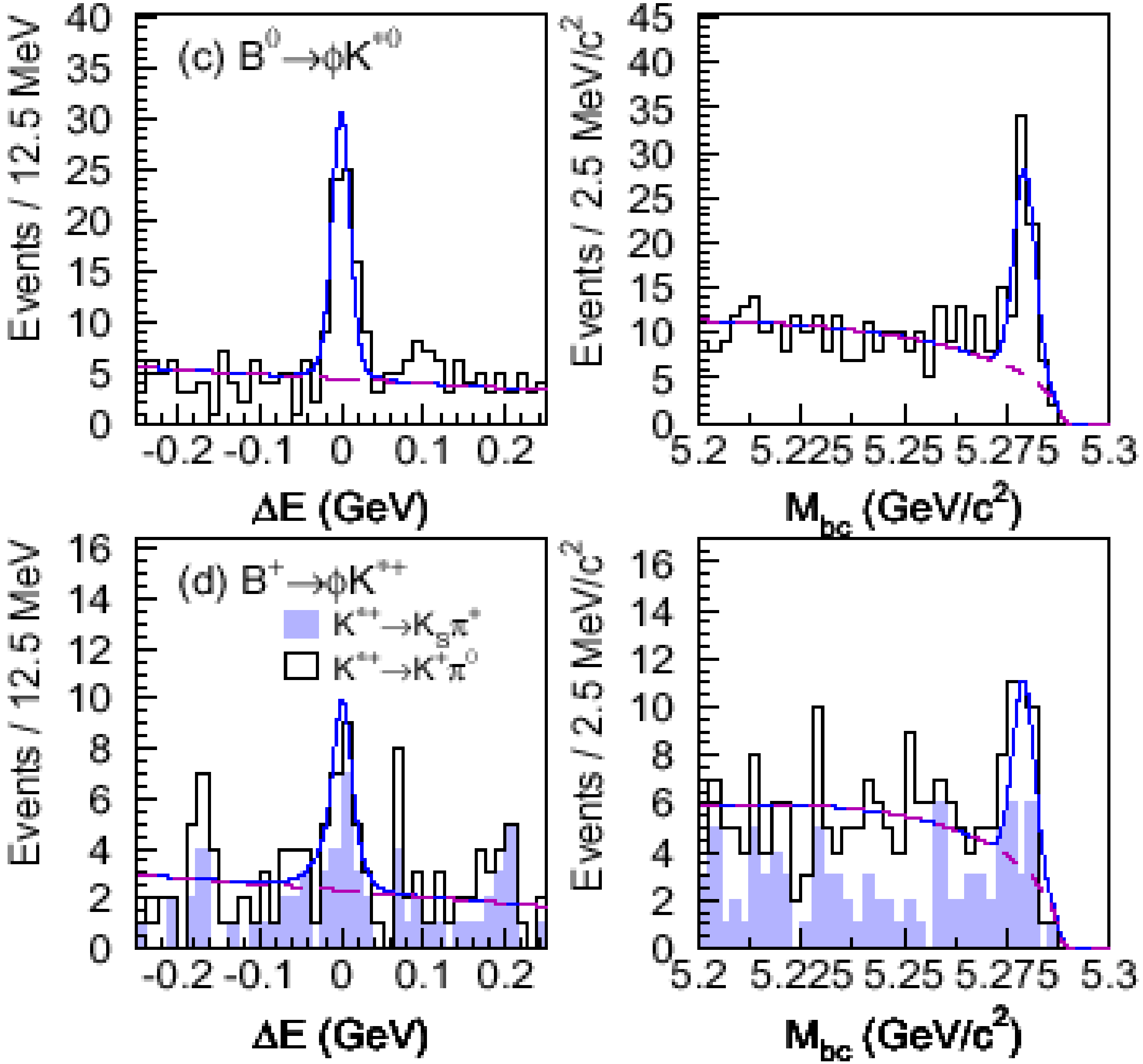
$B \to \varphi K^+$, $B \to \varphi K_s$, $B \to \varphi K^*$



$N_s = 58.5^{+9.1}_{-8.1}$

significance $= 11.3\sigma$

$\varepsilon = 6.9\%$

$N_s(K^+\pi^0) = 8.0^{+4.3}_{-3.5}$

$N_s(K_s\pi^+) = 11.3^{+4.5}_{-3.8}$

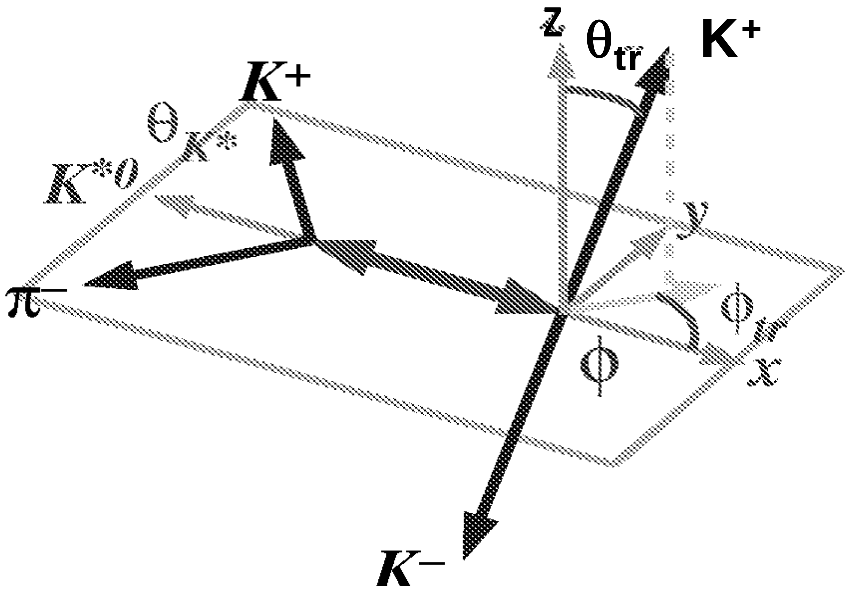
significance $= 4.9\sigma$

$\varepsilon(K^+\pi^0) = 1.4\%$

$\varepsilon(K_s\pi^+) = 2.1\%$

Data used : 78 fb^{-1} on $\Upsilon(4S)$

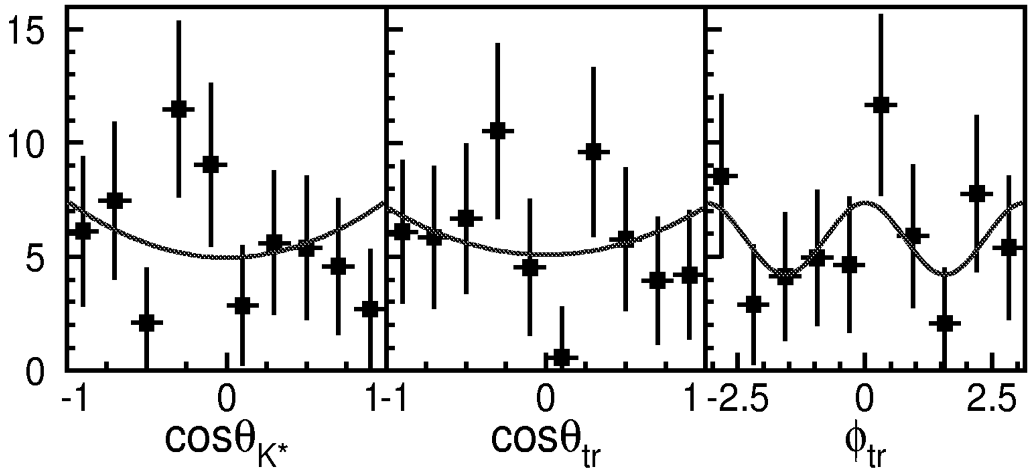
$B \to \varphi K^*$ polarization measurement



Decays amplitudes & parametres
-> A_0 , $A_\perp$, $A_\parallel$, θ_{tr} , θ_{K^*} , ϕ_{tr}
Where Ax are complex amplitudes

Amplitudes are determined by unbinned max likelihood fit:

$|A_0|^2$ = 0.43 ± 0.09 ± 0.04
$|A_\perp|^2$ = 0.41 ± 0.10 ± 0.04
(CP odd and CP even states)
and
$\arg(A_\perp)$ = 0.48 ± 0.32 ± 0.06
$\arg(A_\parallel)$ = -2.57 ± 0.39 ± 0.09



$B \rightarrow \varphi K^+$, $B \rightarrow \varphi K_s$, $B \rightarrow \varphi K^*$

mode	Signal yield	ε(%)	σ	***B(10^-6^)***
$\phi K^{\pm}$	136^{+16}_{-15}	16.9	16.6	$9.4 \pm 1.1 \pm 0.7$
ϕK^{0}	$35.6^{+8.4}_{-7.4}$	4.6	8.7	$9.0\ ^{+2.2}_{-1.8} \pm 0.7$
ϕK^{*0}	$58.5^{+9.1}_{-8.1}$	6.9	11.3	$9.0\ ^{+2.2}_{-1.8}\ ^{+0.7}_{-0.8}$
$\phi K^{*\pm}$	-	-	4.9	$6.7\ ^{+2.1}_{-1.9}\ ^{+0.7}_{-1.0}$
$K^{*+} \rightarrow K^{+}\pi^{0}$	$8.0^{+4.3}_{-3.5}$	1.4	2.8	$6.9\ ^{+3.8}_{-3.2}\ ^{+0.9}_{-1.0}$
$K^{*+} \rightarrow K_S^{0}\pi^{\pm}$	$11.3^{+4.5}_{-3.8}$	2.1	4.0	$6.5\ ^{+2.6}_{-2.3}\ ^{\mathbf{+0.6}}_{\mathbf{-0.9}}$

Yields obtained by 2 - D M_{bc} and ΔE fits.

Data used : 78 fb^{-1} on Υ(4S)

$B \to \phi\phi K$

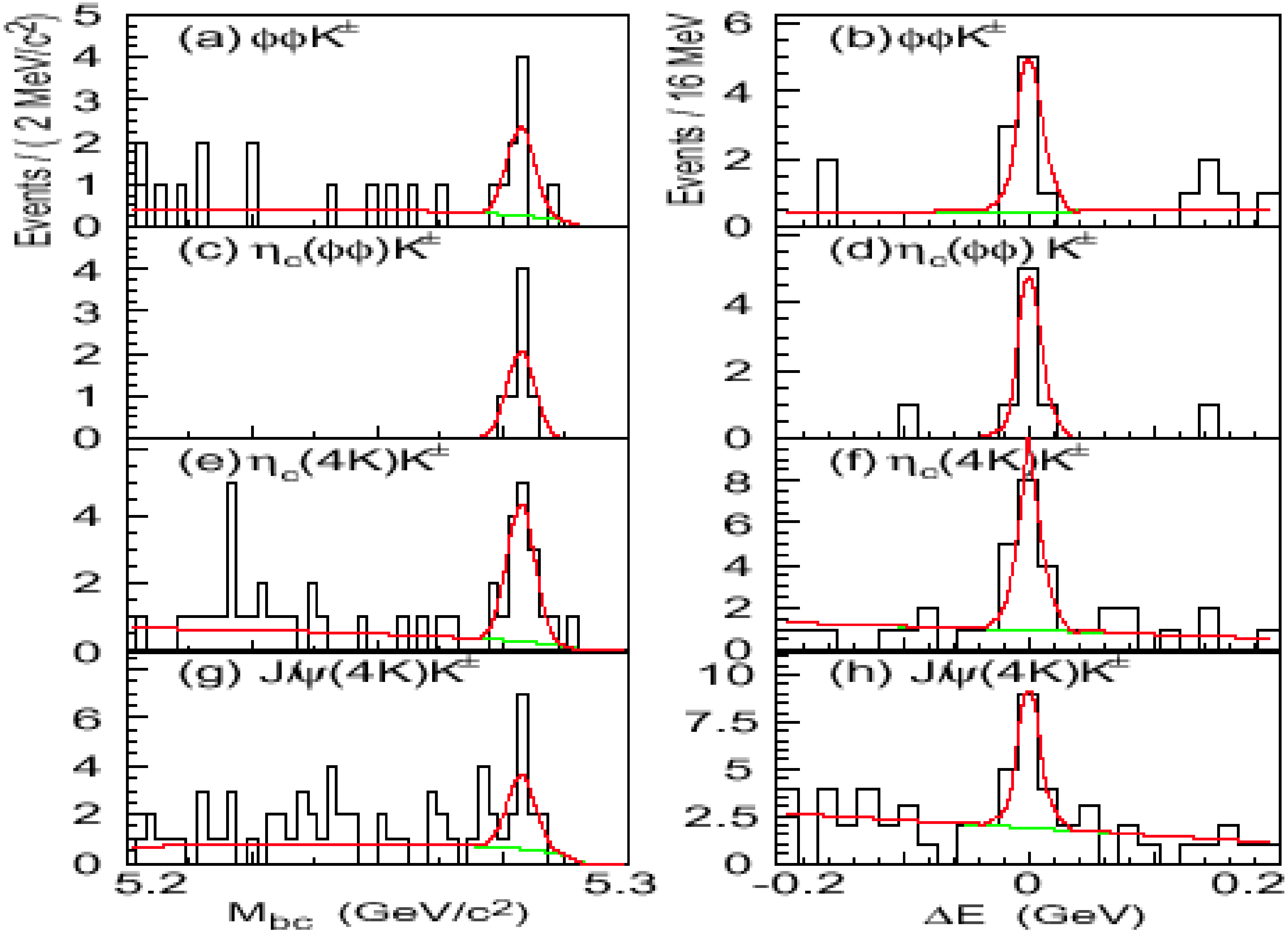
- One more ss popping from $b \to s\bar{s}s$

- Modes search: $B^+ \to \phi\phi K^+, B^0 \to \phi\phi K^0$ with $M_{\phi\phi} < 2.85 GeV/c^2$.

- We also look for 4*K* from: $f_J(2200) \to \phi\phi, \eta_c \to \phi\phi, \eta_c \to \phi K^+K^-$, $\eta_c \to 2(K^+K^-), J/\psi \to \phi K^+K^-$ and $J/\psi \to 2(K^+K^-)$ decays.

- Possible large DCPV and Glueball search.

$B \to \phi\phi K$



(a) φφK±
(b) φφK±
(c) η_c(φφ)K±
(d) η_c(φφ) K±
(e) η_c(4K)K±
(f) η_c(4K)K±
(g) J/ψ(4K)K±
(h) J/ψ(4K)K±
Events / (2 MeV/c²)
Events / 16 MeV
M_bc (GeV/c²)
ΔE (GeV)
5.2
5.3
-0.2
0
0.2

$B \to \phi\phi K$

mode	yield	ε(%)	σ	B(10^-6)
$B^{\pm} \to \phi\phi K^{\pm} (M_{\phi\phi} < 2.85\, GeV/c^2)$	$7.3^{+3.2}_{-2.5}$	3.3	5.1	$2.6^{+1.1}_{-0.9} \pm 0.3$
$B \to \phi\phi K (M_{\phi\phi} < 2.85\, GeV/c^2)$	$8.7^{+3.6}_{-2.9}$	2.2	5.3	$2.3^{+0.9}_{-0.8} \pm 0.3$
$B^{\pm} \to f_J(2200) K^{\pm}, f_J(2200) \to \phi\phi$	< 3.7	3.6	.	< 1.2
$B^{\pm} \to \eta_c K^{\pm}, \eta_c \to \phi\phi$	$7.0^{+3.0}_{-2.3}$	3.7	8.8	$2.2^{+1.0}_{-0.7} \pm 0.5$
$B^{\pm} \to \eta_c K^{\pm}, \eta_c \to \phi K^+ K^-$	$14.1^{+4.4}_{-3.7}$	4.6	7.7	$3.6^{+1.1}_{-0.9} \pm 0.3$
$B^{\pm} \to \eta_c K^{\pm}, \eta_c \to 2(K^+ K^-)$	$14.6^{+4.6}_{-3.9}$	9.6	6.6	$1.8^{+0.6}_{-0.5} \pm 0.4$
$B^{\pm} \to J/\psi K^{\pm}, J/\psi \to \phi K^+ K^-$	$9.0^{+3.7}_{-3.0}$	4.4	5.3	$2.4^{+1.0}_{-0.8} \pm 0.3$
$B^{\pm} \to J/\psi K^{\pm}, J/\psi \to 2(K^+ K^-)$	$11.0^{+4.3}_{-3.5}$	9.2	4.8	$1.4^{+0.6}_{-0.4} \pm 0.2$

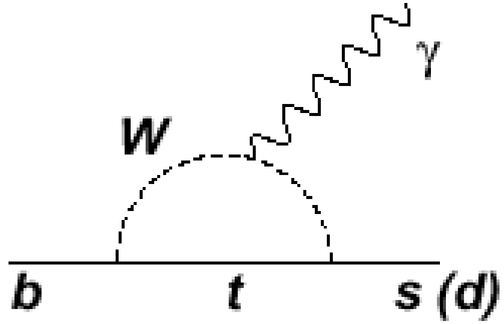
Data used: 90 fb^{-1} on Υ(4S)

Radiative and Electroweak B decays

$b \to s\gamma$ and $b \to s\ell^+\ell^-$ process: FCNC process.

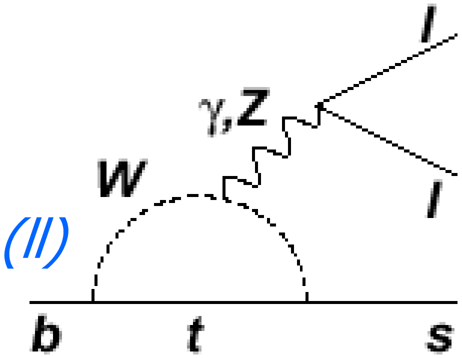
Electroweak penguin diagram.

Sensitive to physics beyond the Standard Model.



$B \to K\ell^+\ell^-$, $B \to K^*\ell^+\ell^-$

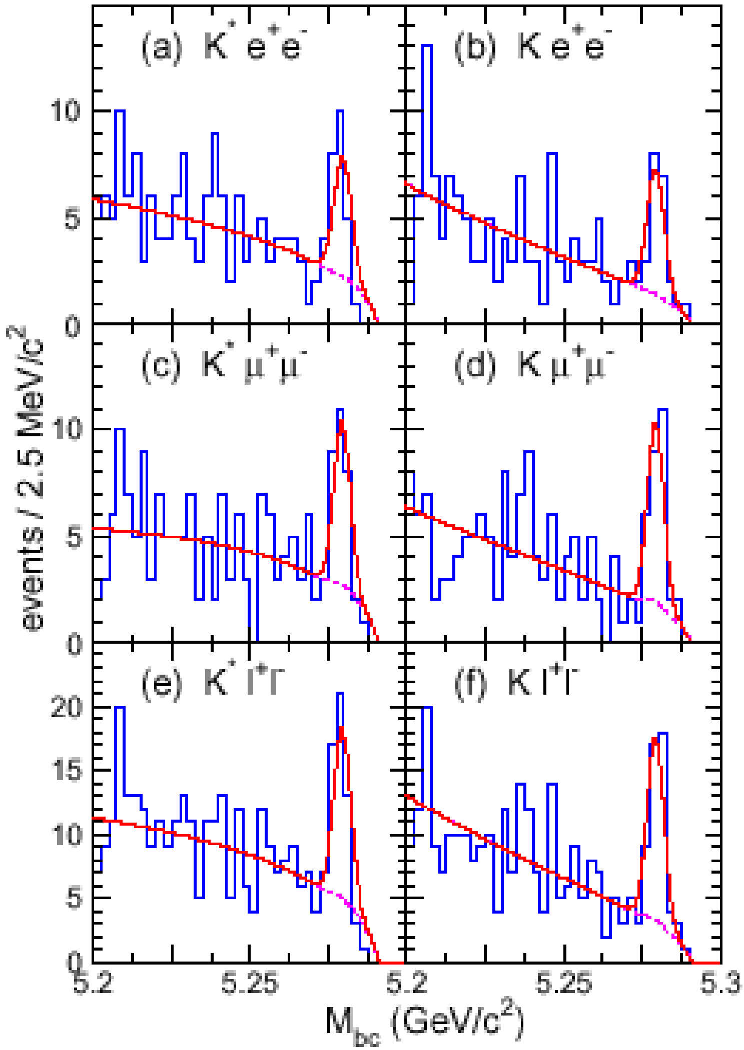
Sensitive to different types of New Physics than $X_s\gamma$
New observables : forward-backward asymmetry, **M***(ll)*



CP Asymmetry of $B \to X_s\gamma$

CP asymmetry in B→$X_s\gamma$ is expected to be small (less than 1%).
Some non-SM models allow large (up to 10%) A_{CP} without changing the **B.F.**

$B \to K\ell^+\ell^-$, $B \to K^*\ell^+\ell^-$



	(a) $K^*e^+e^-$	(b) Ke^+e^-
yield	$15.6^{+5.5}_{-4.8} \pm 1.0$	$15.9^{+5.1}_{-4.4} \pm 0.7$
eff. [%]	$3.5 \pm 0.2 \pm 0.1$	$10.8 \pm 0.5 \pm 0.2$
$\mathcal{B}(10^{-7})$	$14.9^{+5.2}_{-4.6}{}^{+1.2}_{-1.3} \pm 0.3$	$4.8^{+1.5}_{-1.3} \pm 0.3 \pm 0.1$
signif.	3.5	4.5

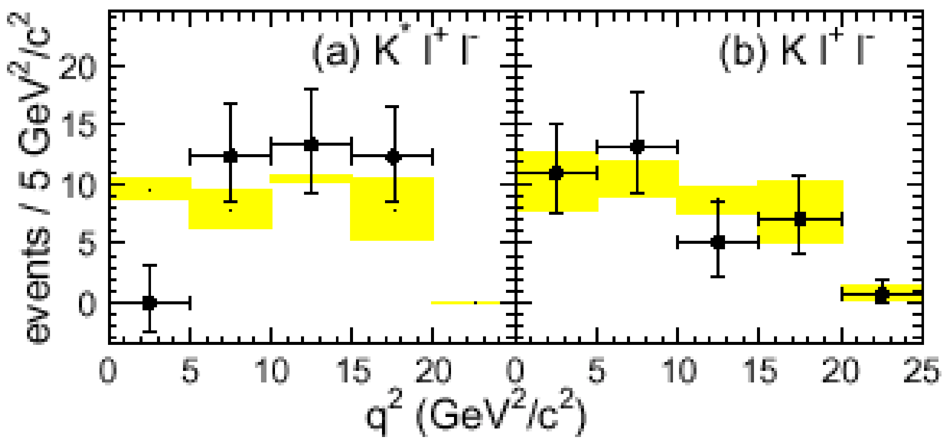
	(c) $K^*\mu^+\mu^-$	(d) $K\mu^+\mu^-$
yield	$20.0^{+6.0}_{-5.3}{}^{+1.1}_{-1.2}$	$22.0^{+5.8}_{-5.1} \pm 0.8$
eff. [%]	$5.6 \pm 0.3 \pm 0.3$	$15.2 \pm 0.7 \pm 0.5$
$\mathcal{B}(10^{-7})$	$11.7^{+3.6}_{-3.1} \pm 0.9 \pm 0.6$	$4.8^{+1.2}_{-1.1} \pm 0.3 \pm 0.2$
signif.	4.2	5.6

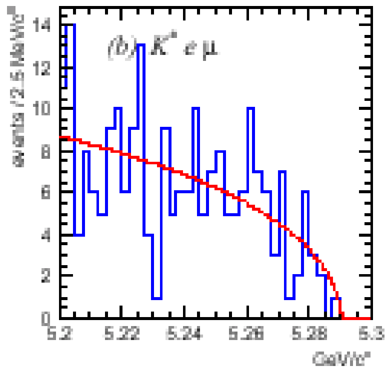
	(e) $K^*\ell^+\ell^-$	(f) $K\ell^+\ell^-$
yield	$35.8^{+8.0}_{-7.3} \pm 1.7$	$37.9^{+7.6}_{-6.9}{}^{+1.0}_{-1.1}$
eff. [%]	$5.1 \pm 0.3 \pm 0.2$	$13.0 \pm 0.6 \pm 0.2$
$\mathcal{B}(10^{-7})$	$11.5^{+2.6}_{-2.4} \pm 0.8 \pm 0.4$	$4.8^{+1.0}_{-0.9} \pm 0.3 \pm 0.1$
signif.	5.7	7.4

Analyses are based on 140 fb^{-1} data

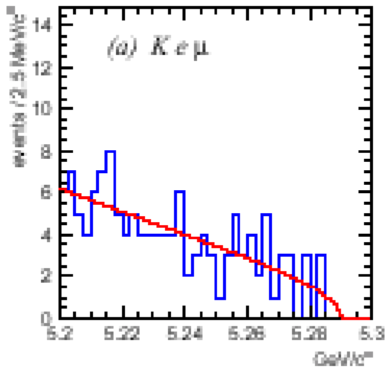
$B \to K\ell^+\ell^-$, $B \to K^*\ell^+\ell^-$

$q^2 = M^2(\ell^+\ell^-)$ distribution





M_{bc}



M_{bc}

$$\mathcal{B}(B \to K^*\ell^+\ell^-) = (11.5\,^{+2.6}_{-2.4} \pm 0.8 \pm 0.4) \times 10^{-7}$$

$$\mathcal{B}(B \to K\ell^+\ell^-) = (4.8\,^{+1.0}_{-0.9} \pm 0.3 \pm 0.1) \times 10^{-7},$$

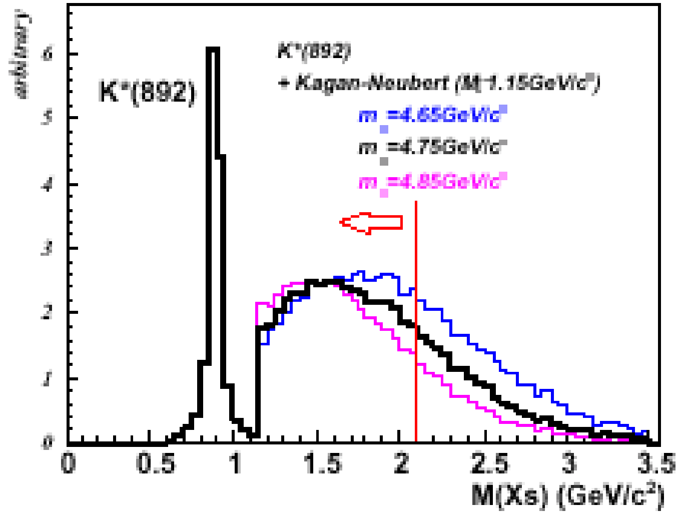
where $\mathcal{B}(B \to K^*\ell^+\ell^-) = \mathcal{B}(B \to K^*\mu\mu) = 0.75\mathcal{B}(B \to K^*ee)$ is assumed.

- First observation of $B \to K^*\ell^+\ell^-$.
- Need more data to check q^2 distribution.

CP Asymmetry of $B \to X_s \gamma$

Analysis

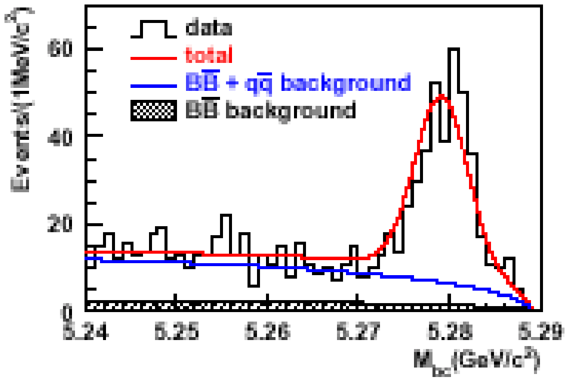
- Pseudo-reconstruction of X_s
  $K^+ \ (K_S^0) + 1 \sim 4 \ \pi$ (up to 1 π^0)
  $K^+K^-K^+(\pi^-) \ / \ K_S^0 K^+ K^-(\pi^+)$
- $M(X_s) < 2.1 \ \mathrm{GeV}/c^2$ ($\sim E_\gamma > 2.2$ GeV)
- High energy lepton from the other side B (to suppress $q\bar{q}$)
- $b \to d\gamma$ contamination is negligible.
- Signal yield by fitting $M_{\rm bc}$ to signal, $q\bar{q}$ and $B\bar{B}$ (fixed) components.



- B.F. of $B \to X_s\gamma$: large theoretical error.
- CP asymmetry in $B \to X_s\gamma$ is expected to be small (less than 1%).
- Some non-SM models allow large (up to 10%) $A_{\rm CP}$ without changing the B.F.

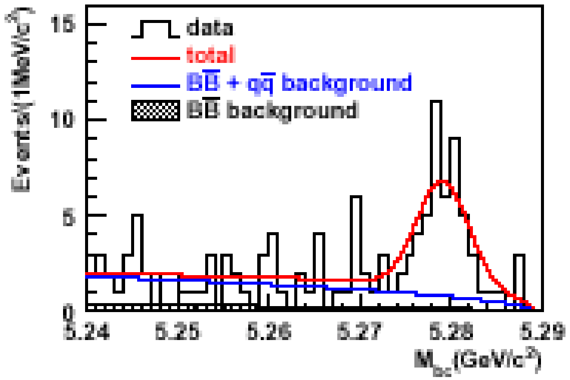
CP Asymmetry of $B \to X_s\gamma$

b



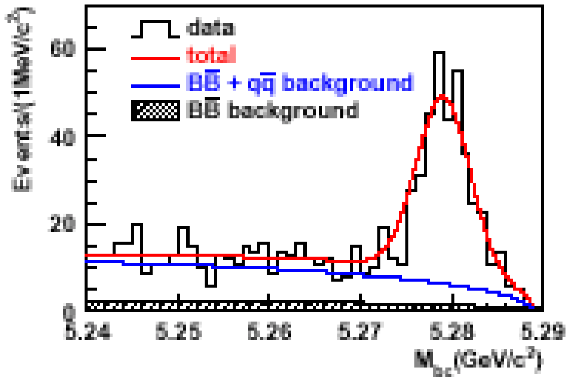
$342 \pm 23 ^{+7}_{-14}$

ambiguous



$47.8 \pm 8.7 ^{+1.4}_{-1.8}$

$\bar{b}$



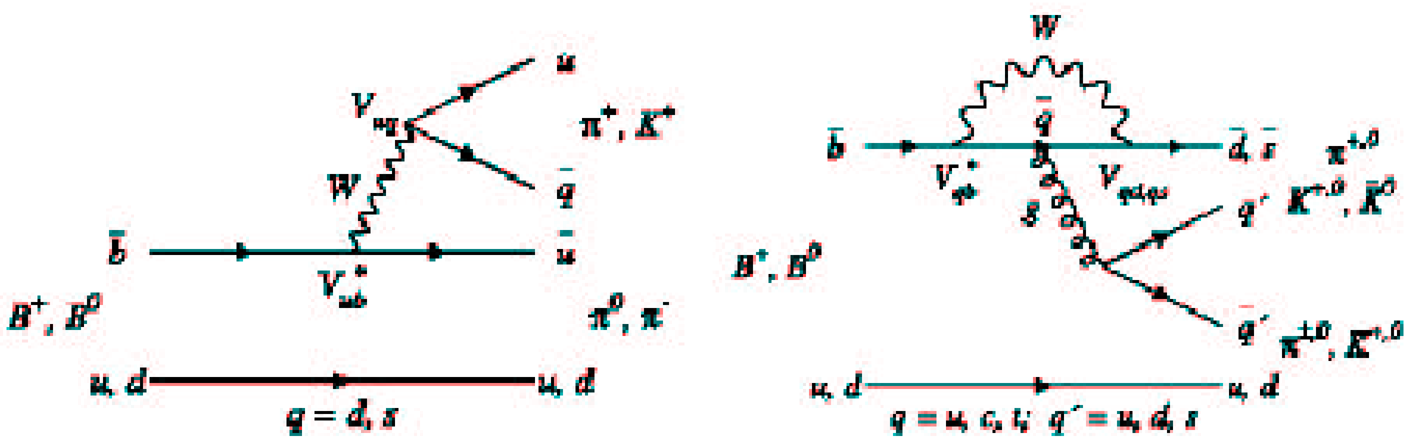
$349 \pm 23 ^{+7}_{-14}$

$$A_{\rm CP}(B \to X_s\gamma; M(X_s) < 2.1\ {\rm GeV}/c^2) = -0.004 \pm 0.051({\rm stat.}) \pm 0.038({\rm syst.})$$

$$-0.107 < A_{\rm CP}(B \to X_s\gamma; M(X_s) < 2.1\ {\rm GeV}/c^2) < 0.099 \qquad (90\%\ {\rm CL})$$

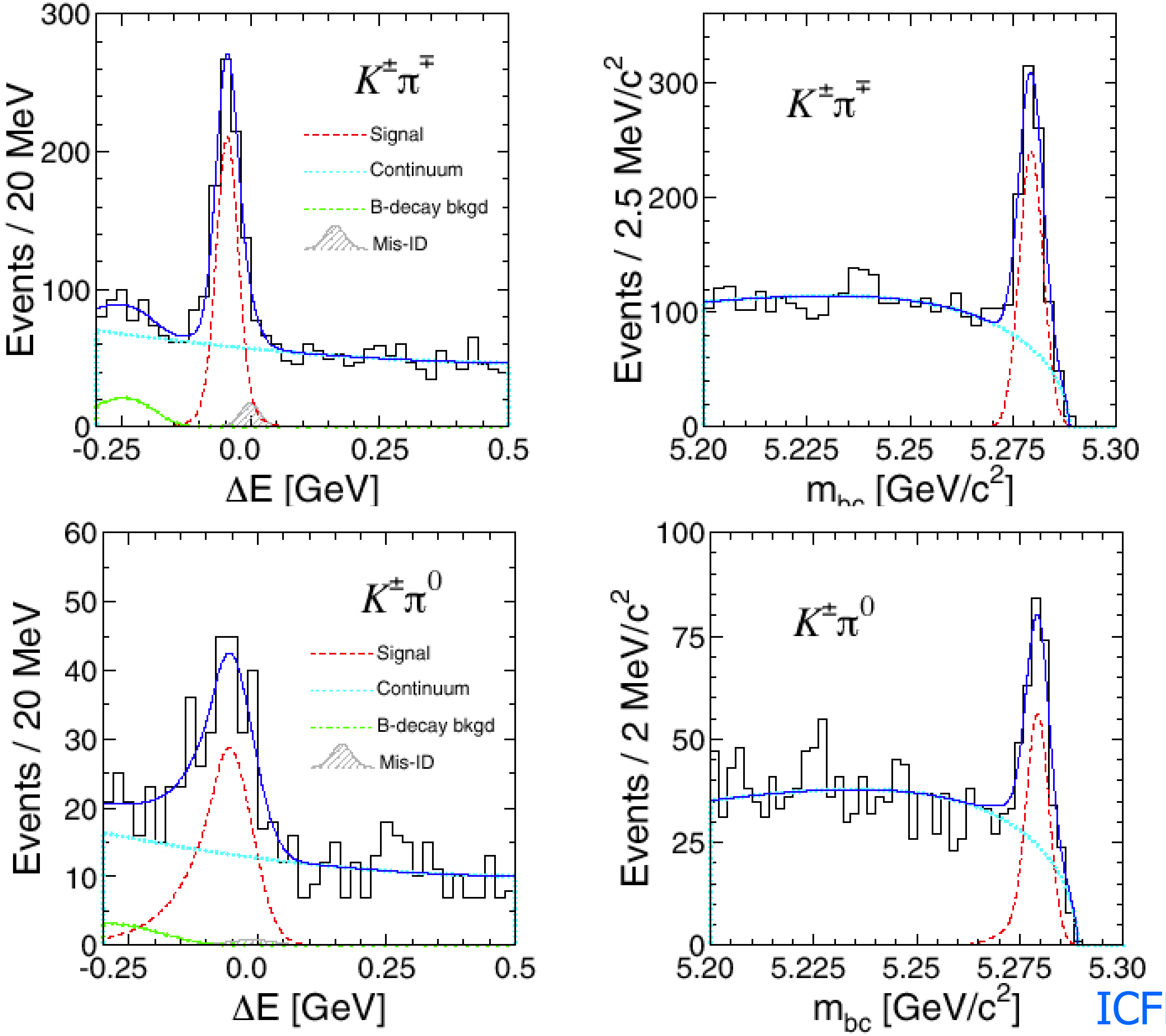
Analyses are based on $140\ {\rm fb}^{-1}$ data

$B \to K\pi,\ \pi\pi,\ KK$



- ***B→Kπ,ππ,KK*** proceeds through tree and penguin diagram.
- Interference of the tree and penguin diagram can leed to Direct CP Violation.
- Branching fraction and CP asymetries of these mode provide information for the CKM angle ϕ_2 and ϕ_3 (but not straightforward because of complicated hadronic effects).
- Each B.F. of ***B→ππ*** ($B^0 \to \pi^+\pi^-$, $B^+ \to \pi^+\pi^0$, $B^0 \to \pi^0\pi^0$, ***B→***… etc.) is necessary for the isospin analysis to extract ϕ_2 using ***B→ππ***.

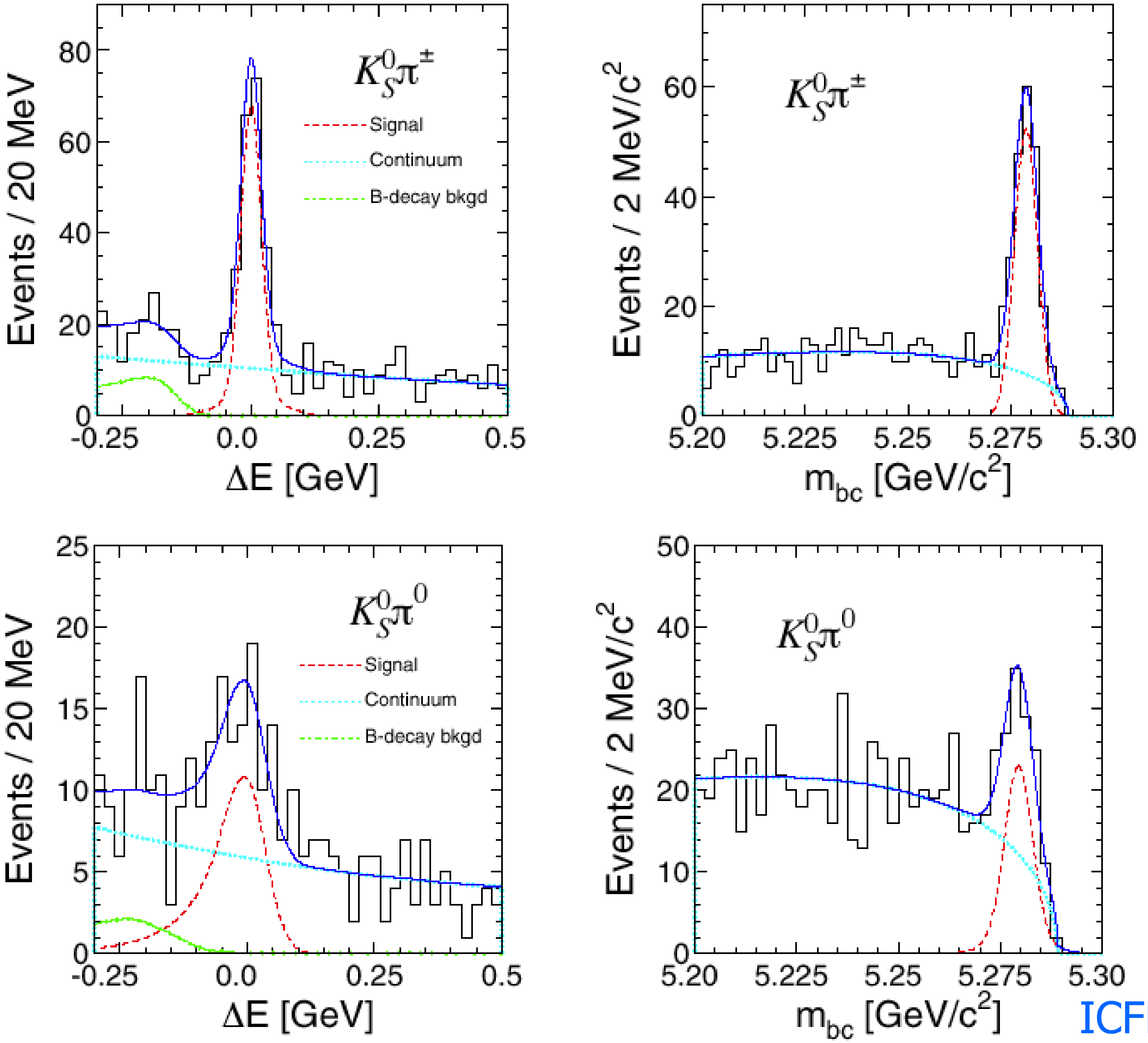
$B \to K\pi,\ \pi\pi,\ KK$



$$N_s = 596 \pm 33$$
$$\text{Significance} = 24.1\sigma$$
$$\varepsilon = 37.9\%$$

$$N_s = 199 \pm 22$$
$$\text{Significance} = 10.8\sigma$$
$$\varepsilon = 18.3\%$$

$B \to K\pi,\ \pi\pi,\ KK$



$N_s = 187 \pm 16$

$\text{Significance} = 16.4\sigma$

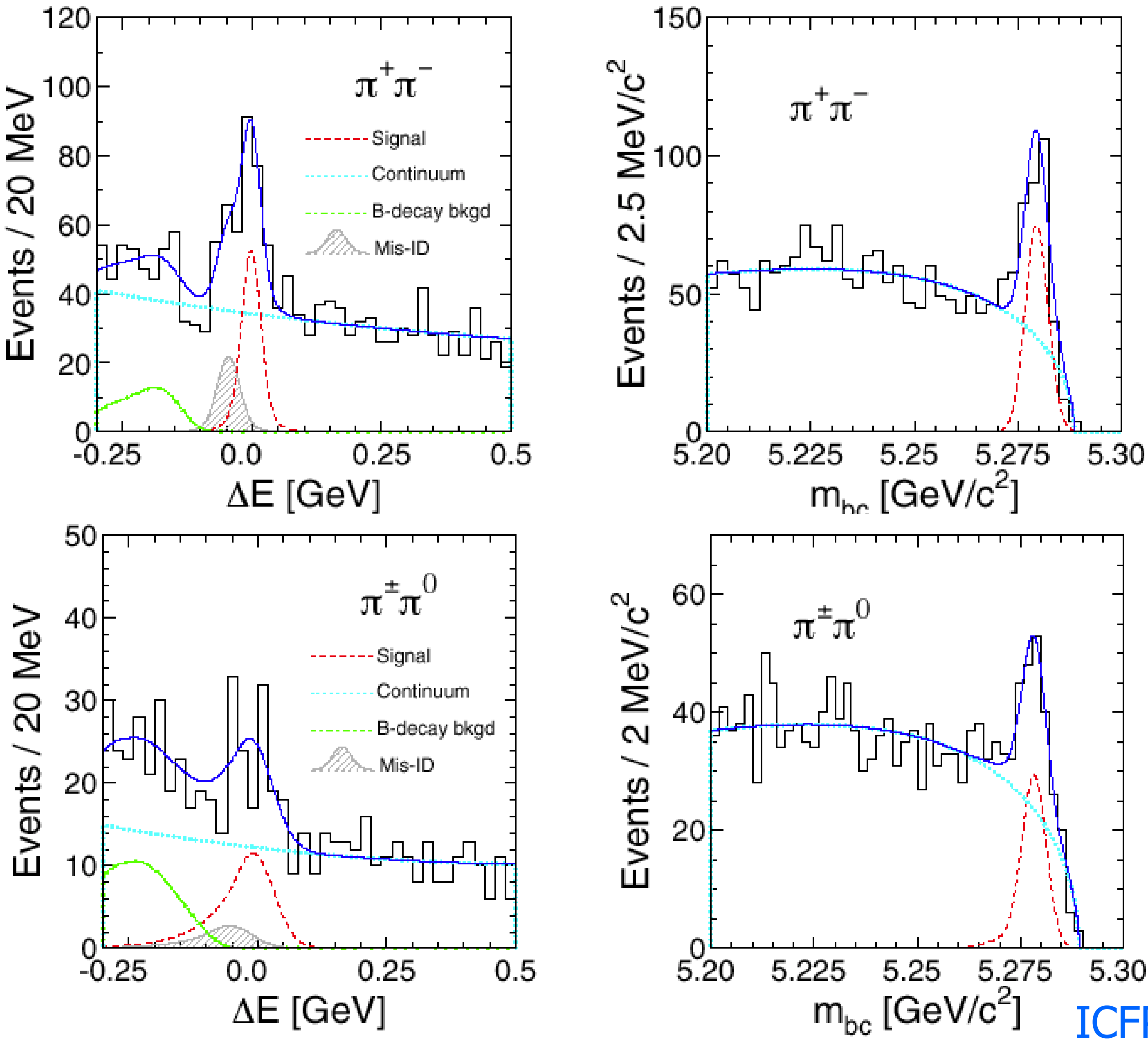
$\varepsilon = 10.0\%$

$N_s = 73 \pm 14$

$\text{Significance} = 5.8\sigma$

$\varepsilon = 6.8\%$

$B \to K\pi,\ \pi\pi,\ KK$



$N_s = 133 \pm ^{19}_{18}$

$\text{Significance} = 8.5\sigma$

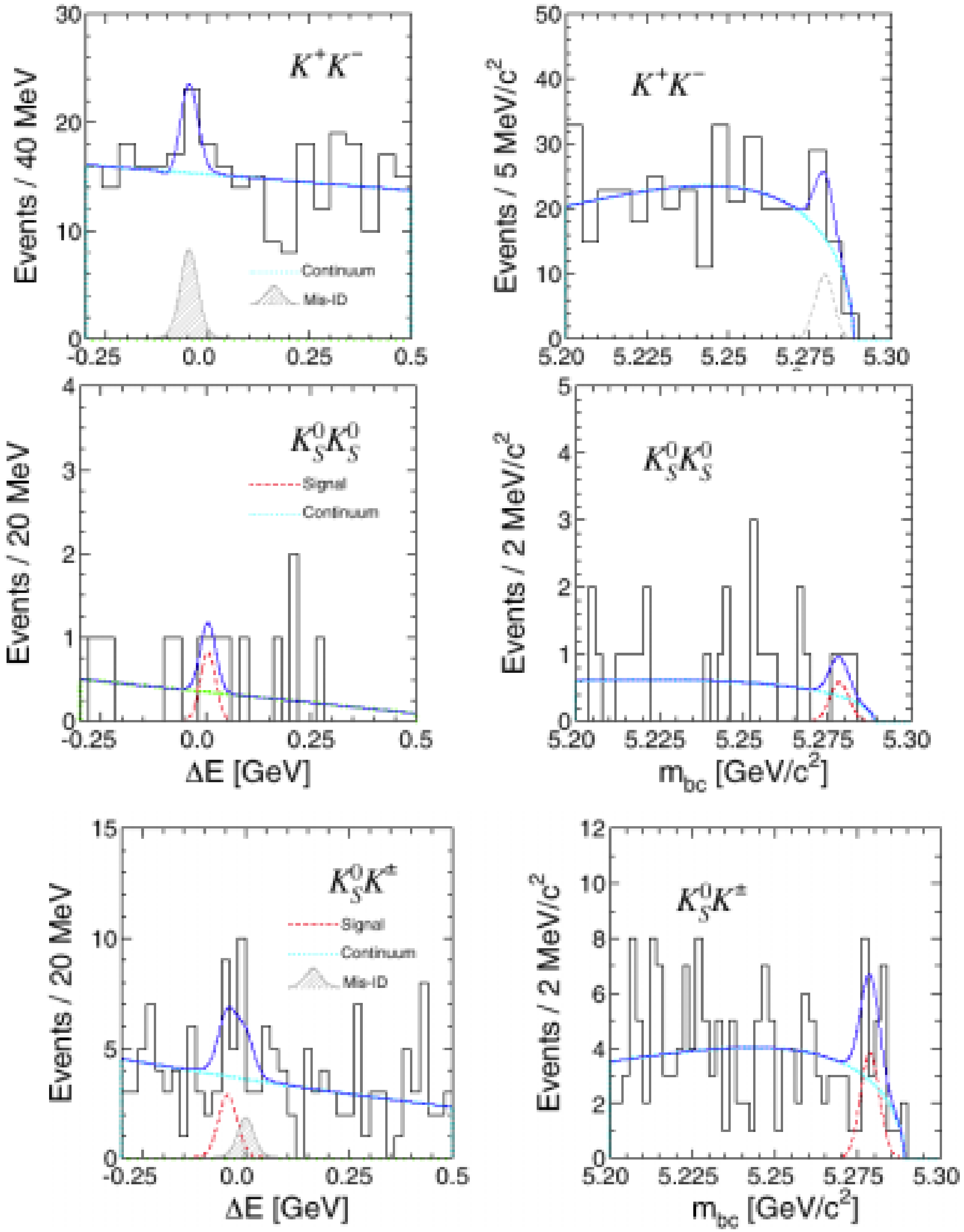
$\varepsilon = 35.2\%$

$N_s = 72 \pm 17$

$\text{Significance} = 4.5\sigma$

$\varepsilon = 16.1\%$

$B \to K\pi,\ \pi\pi,\ KK$



$$N_s = -1 \pm^{7}_{6}$$
$$\text{Significance} = 0$$
$$\varepsilon = 20.1\%$$

$$N_s = 9 \pm 6$$
$$\text{Significance} = 1.6\sigma$$
$$\varepsilon = 5.9\%$$

$$N_s = 2 \pm 2$$
$$\text{Significance} = 1.3\sigma$$
$$\varepsilon = 2.9\%$$

$B \to K\pi,\ \pi\pi,\ KK$

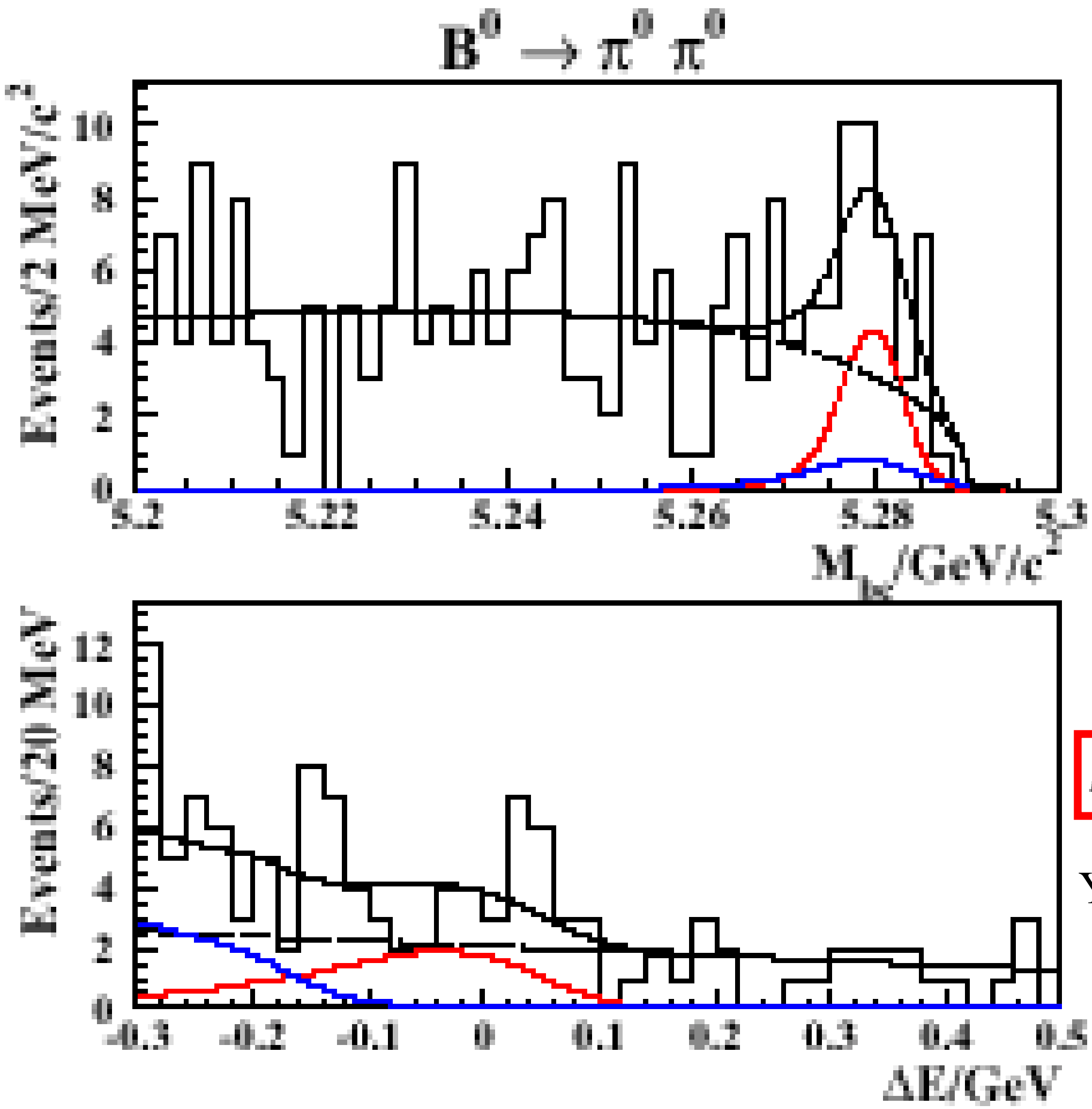
Belle Result with 78 fb^{-1}.

Mode	$B(x10^{-6})$	σ
$B^0 \to K^+\pi^-$	$18.5 \pm 1.0 \pm 0.7$	24.1
$B^+ \to K^+\pi^0$	$12.8 \pm 1.4^{+1.4}_{-1.0}$	10.8
$B^+ \to K^0\pi^+$	$22.0 \pm 1.9 \pm 1.1$	16.4
$B^0 \to K^0\pi^0$	$12.6 \pm 2.4 \pm 1.4$	5.8
$B^0 \to \pi^+\pi^-$	$4.4 \pm 0.6 \pm 0.3$	8.5
$B^+ \to \pi^+\pi^0$	$5.3 \pm 1.3 \pm 0.5$	4.5
$B^0 \to K^+K^-$	< 0.7	0.0
$B^+ \to K^+K^0$	< 3.4	1.6
$B^0 \to K^0K^0$	< 3.2	1.2

Yields obtained from ΔE fits.

Evidence for $\pi^0\pi^0$

$B \to K\pi,\ \pi\pi,\ KK$



$25.6^{+9.3}_{-8.4}{}^{+1.6}_{-1.4}$ events.

$\mathcal{B}(B^0 \to \pi^0\pi^0)$
$= (1.7 \pm 0.6 \pm 0.2) \times 10^{-6}$.

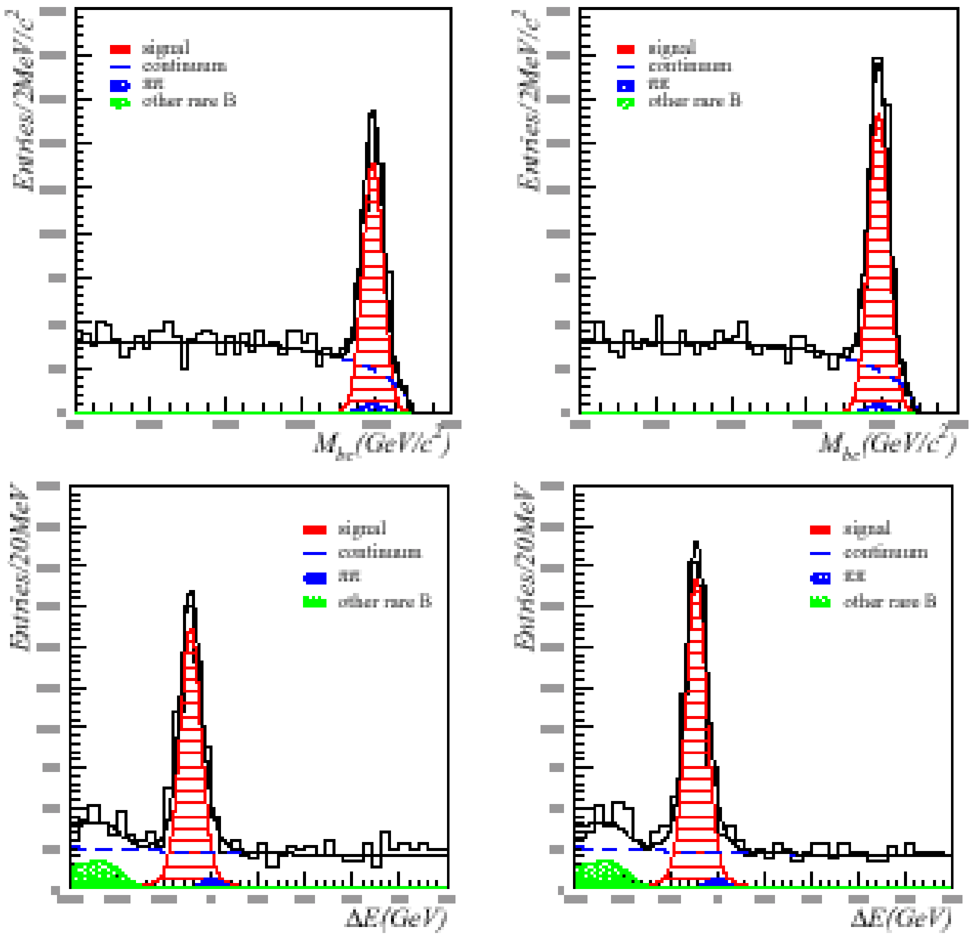
Significance 3.4σ.

Analyses are based on 140 fb^{-1} data

Yields obtained by 2 - D M_{bc} and ΔE fits.

$B \to K\pi,\ \pi\pi,\ KK$

$\bar{B}^0 \to K^-\pi^+$ $\qquad$ $B^0 \to K^+\pi^-$



470.6 ± 24.2 events $\qquad$ 559.2 ± 26.3 events

- Sizable $A_{\rm CP}$ is allowed in $B^0 \to K^+\pi^-$.
- Perturbative QCD vs. QCD factorization.

$$A_{\rm CP} = -0.088 \pm 0.035 \pm 0.018$$

$$-0.152 < A_{\rm CP} < 0.024 \quad (90\%\ \text{CL}).$$

Yields obtained by 2-D M_{bc} and ΔE fits.

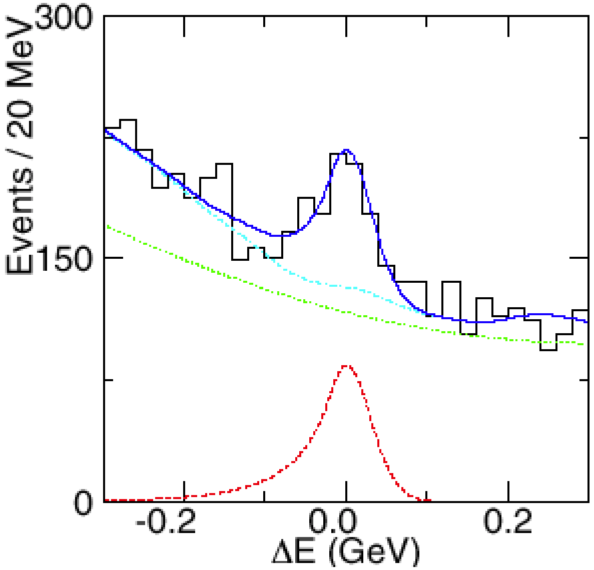
$M_{\rm bc}$, ΔE simultaneous fit.

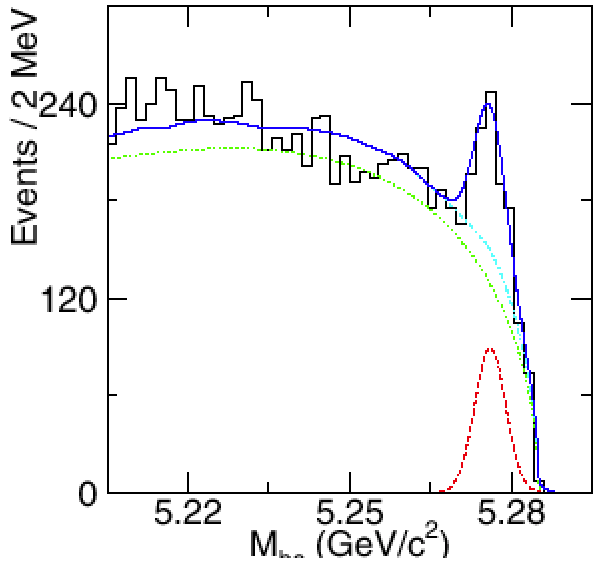
Components: signal + $q\bar{q}$ + $\pi^+\pi^-$ + rare B

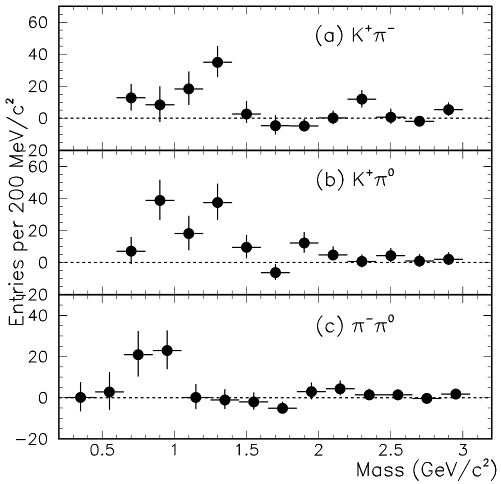
$\pi^+\pi^-$ component is fixed based on the K/π fake rate.

Analyses are based on 140 fb^{-1} data

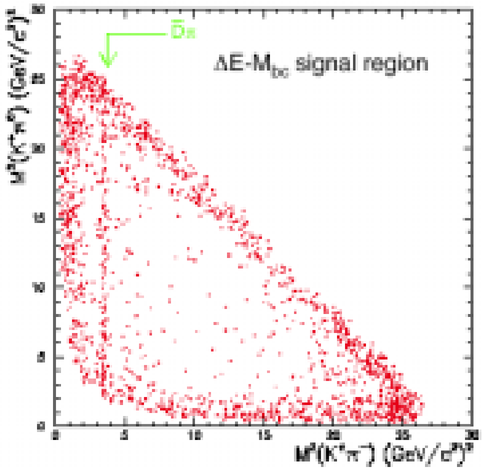
$B^0 \to K^+ \pi^- \pi^0$



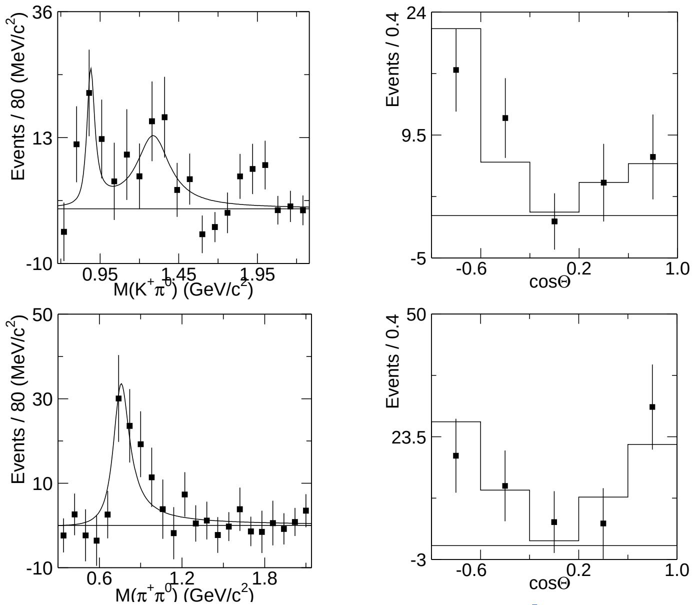




$B^0 \to (K^+ \pi^0)\, \pi^-$ and $K^+ (\pi^+ \pi^0)$ Yields and Helicity



Remove $B^0 \to \bar{D}^0 \pi^0$ contamination by requiring $|M(K^+\pi^-) - M(D^0)| > 50\ \mathrm{MeV}/c^2$



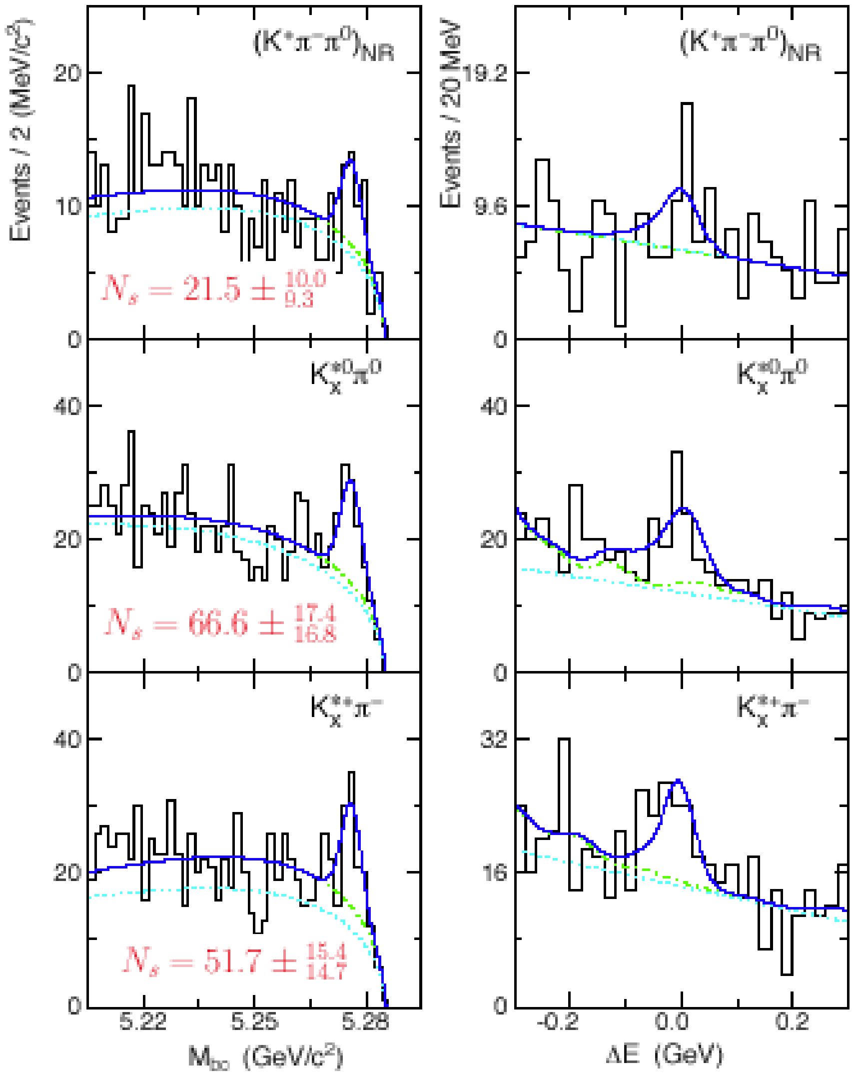
Signal candidates populate edges of Dalitz plot

⇒ two-body intermediate states

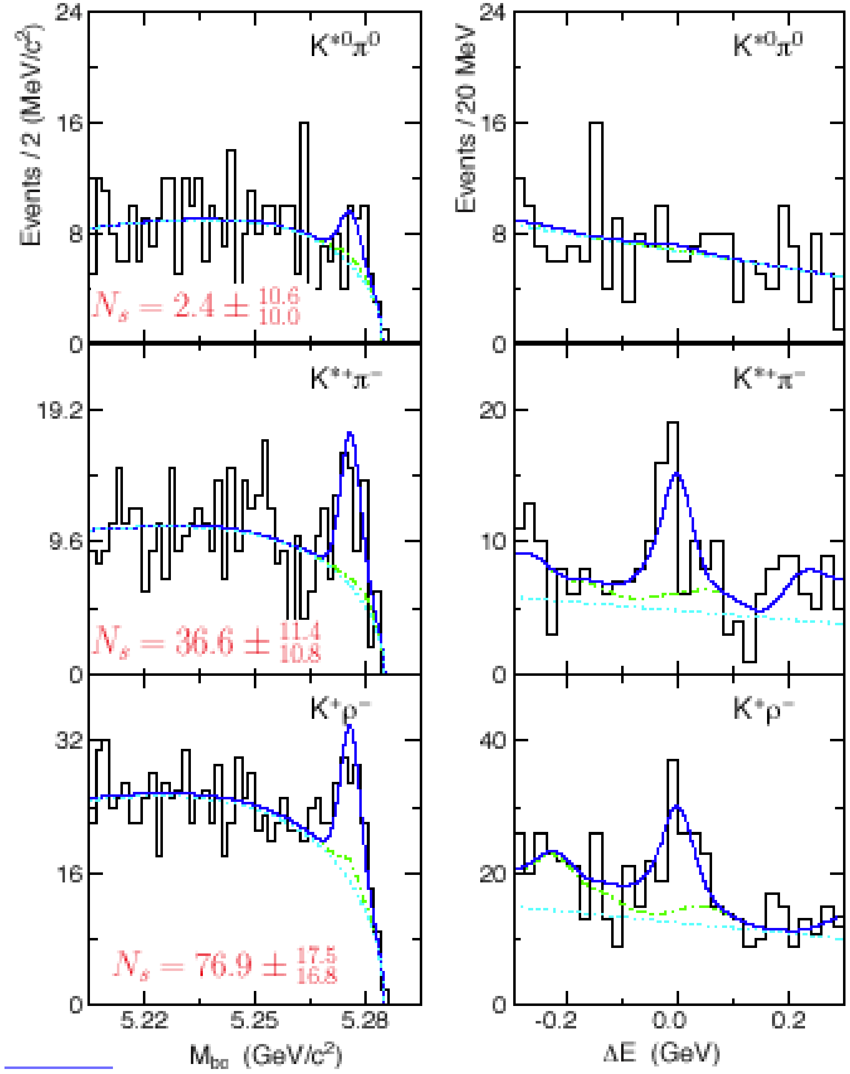
Data used: 78 fb^{-1} on $\Upsilon(4S)$

$B^0 \to K^+ \pi^- \pi^0$

$B^0 \to (K^+ \pi^- \pi^0)_{NR}$ and $K_x^*(1400)\,\pi$



$B^0 \to K^*(892)\,\pi$ and $K\,\rho(770)$



Data used: 78 fb^{-1} on $\Upsilon(4S)$

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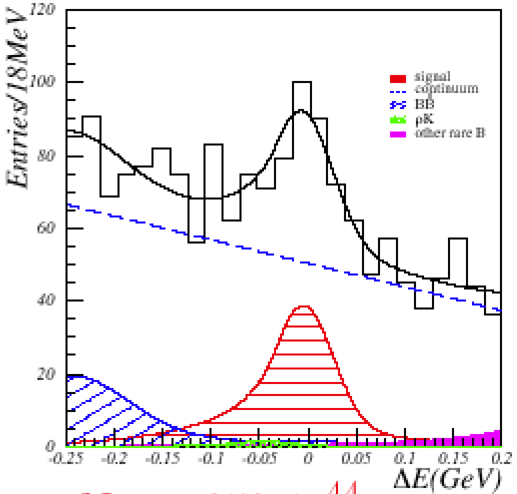
$B^0 \to K^+ \pi^- \pi^0$

mode	yield	ε(%)	σ	B(10^-6)
$B^0 \to K^+\pi^-\pi^0$	386 ± 44	12.4	9.4	$36.6\,^{+4.2}_{+4.1} \pm 3.0$
$B^0 \to K^*(892)^0\pi^0$	$2.4^{+10.6}_{-10.0}$	6.7	0.3	< 3.5
$B^0 \to K^*(892)^+\pi^-$	$36.6^{+11.4}_{-10.8}$	2.9	3.8	$14.8\,^{+4.6}_{-4.4}\,^{+1.5}_{-1.0}\,^{+2.4}_{-0.9}$
$B^+ \to K^+\rho(770)$	$76.9^{+17.5}_{-16.9}$	6.0	4.9	$15.1\,^{+3.4}_{-3.3}\,^{+1.4}_{-1.5}\,^{+2.0}_{-2.1}$
$B^0 \to K^*_x(1400)^0\pi^0$	$66.6^{+17.4}_{-16.8}$	12.9	4.2	$6.1\,^{+1.6}_{-1.5}\,^{+0.5}_{-0.6}$
$B^0 \to K^*_x(1400)^+\pi^-$	$51.7^{+15.4}_{-14.7}$	11.9	3.7	$5.1\,^{+1.5}_{-1.5}\,^{+0.6}_{-0.7}$
$B^0 \to (K^+\pi^-\pi^0)_{NR}$	$21.5^{+10.0}_{-9.3}$	4.4	2.5	< 9.4

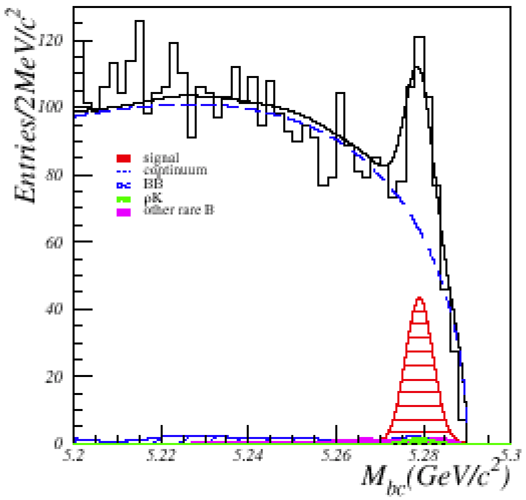
Data used: 78 fb^{-1} on Υ(4S)

$B^0 \rightarrow (\pi^\pm \pi^0)\, \pi^\mp$

$B^0 \rightarrow \rho^+ \pi^-$

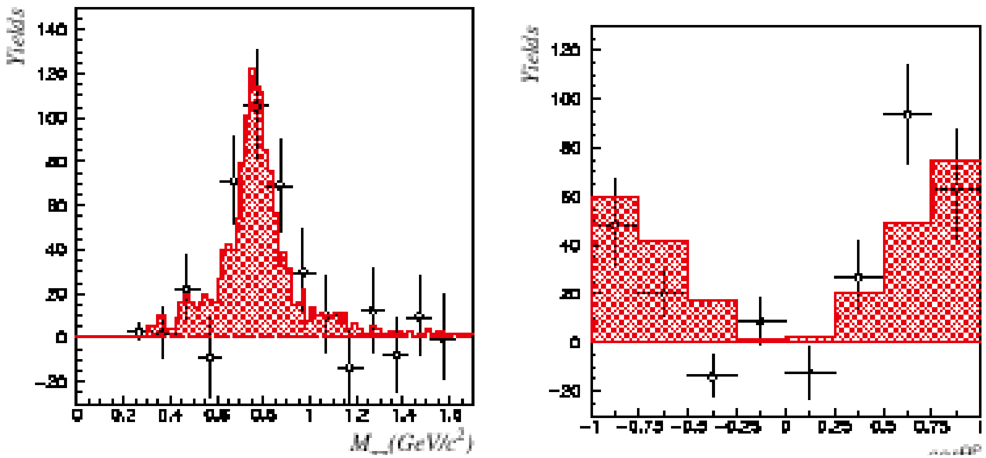


$N_s = 258 \pm ^{44}_{43}$



$$\mathcal{B} = (29.1 \pm ^{5.0}_{4.9} \pm 4.0) \times 10^{-6}$$

$\pi\pi$-mass and Helicity Yields



Signal yields are consistent with $B^0 \rightarrow \rho^\pm \pi^\mp$

Data used: 78 fb^{-1} on Y(4S)

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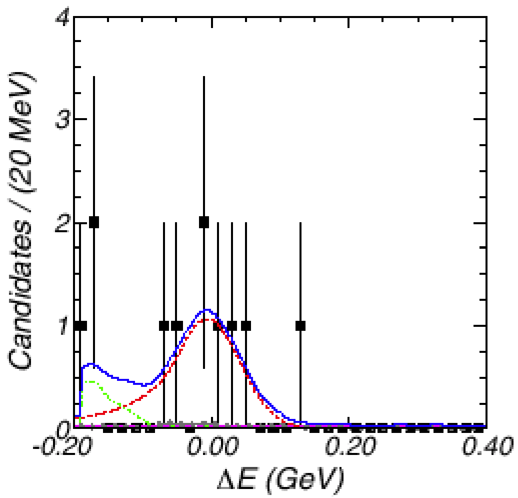
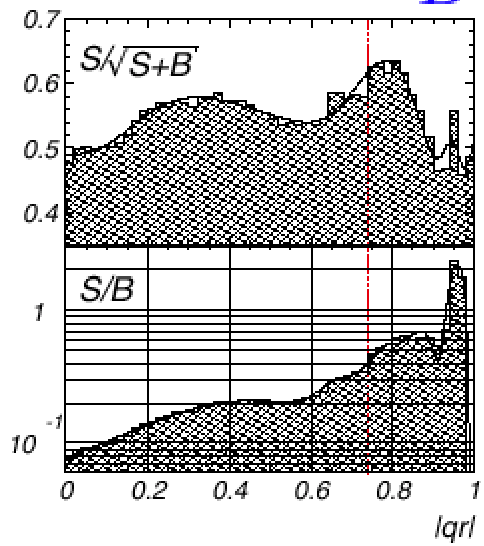
$B^0 \to (\pi^+ \pi^-)\, \pi^0$

$B^0 \to \rho^0 \pi^0$

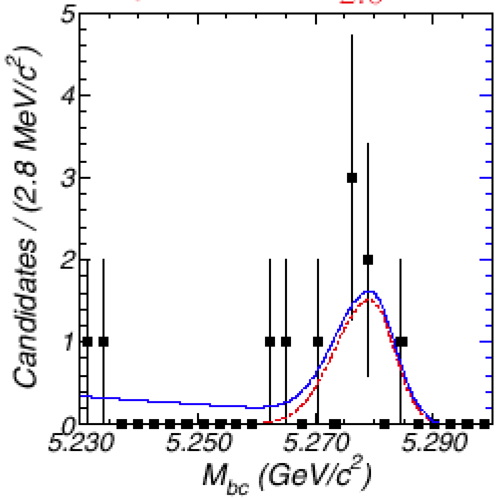


$B^0 \to \rho^0 \pi^0$ Cut Optimization

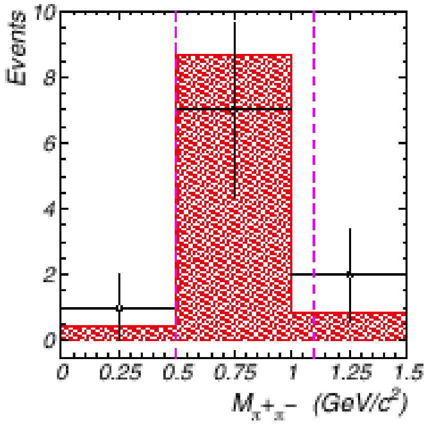


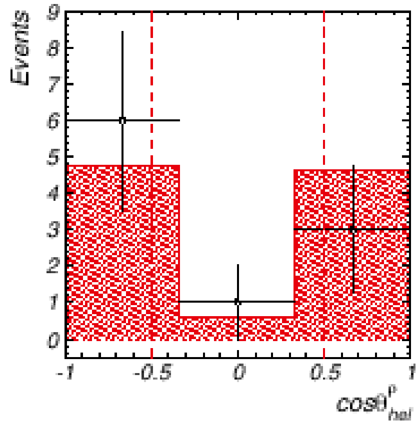
Include B-flavor-tagging information r for better continuum suppression

$N_s = 6.6 \pm^{3.2}_{2.6}$



$\mathcal{B} = (6.0 \pm^{2.9}_{2.3} \pm 1.2) \times 10^{-6}$





Signal yields are consistent with $B^0 \to \rho^0 \pi^0$

Data used: 78 fb^{-1} on Y(4S)

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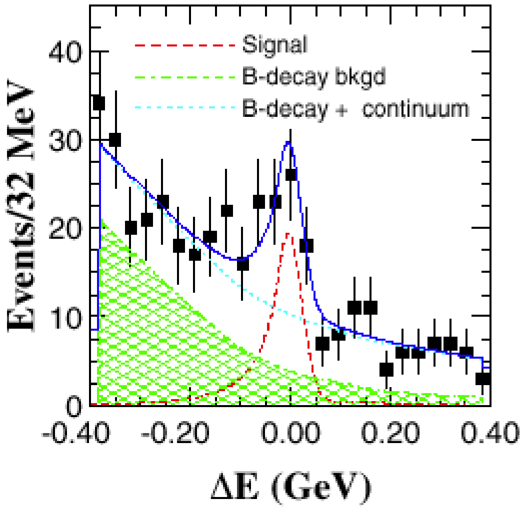
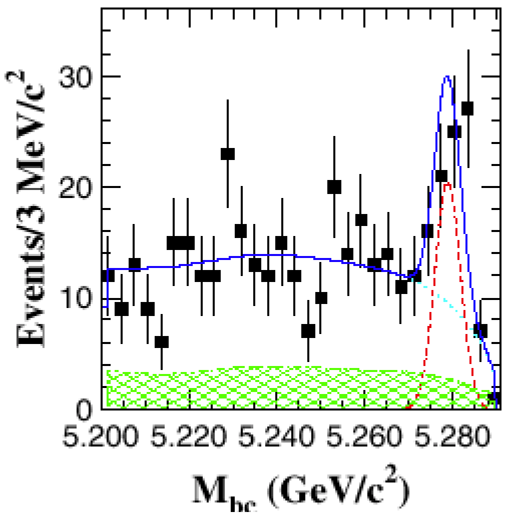
$$B^{\pm} \to \rho^{\pm}\rho^{0} \to (\pi^{\pm}\pi^{0})(\pi^{+}\pi^{-})$$ **first observation**

$$\mathcal{B} = (31.7 \pm 7.1\,(\mathrm{stat}) \pm {}^{3.7}_{6.4}\,(\mathrm{syst}) \pm {}^{1.0}_{2.1}\,(\mathrm{pol})) \times 10^{-6}$$

First observation of charmless & strangless vector-vector mode

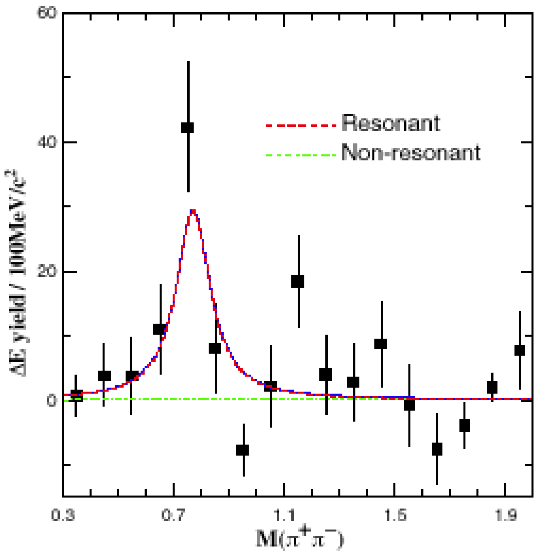


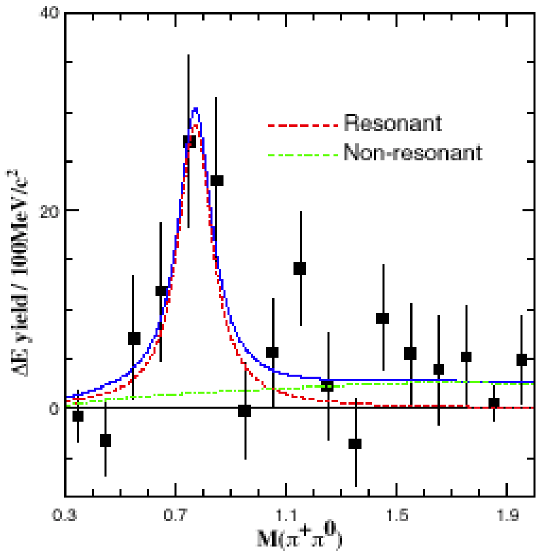
$N_s = 58.7 \pm 13.2$



$N_s = 49.1 \pm 9.7$

Background-subtracted $M_{\pi\pi}$ Distributions





	$M(\pi^+\pi^-)$	$M(\pi^+\pi^0)$
Breit-Wigner:	44.6 ± 12.8	43.7 ± 12.2
Non-resonant:	0.2 ± 3.0	3.7 ± 2.6

good agreement between background-subtracted data and $B \to \rho\rho$

Data used: 78 fb^{-1} on Y(4S)

$$B^{\pm} \to \rho^{\pm}\rho^{0} \to (\pi^{\pm}\pi^{0})(\pi^{+}\pi^{-})$$

ρρ final state is vector-vector system -> give S ,P or D wave

Both ρ mesons can be

longitudinally polarized: $\lambda = 0$, designated H_{00}

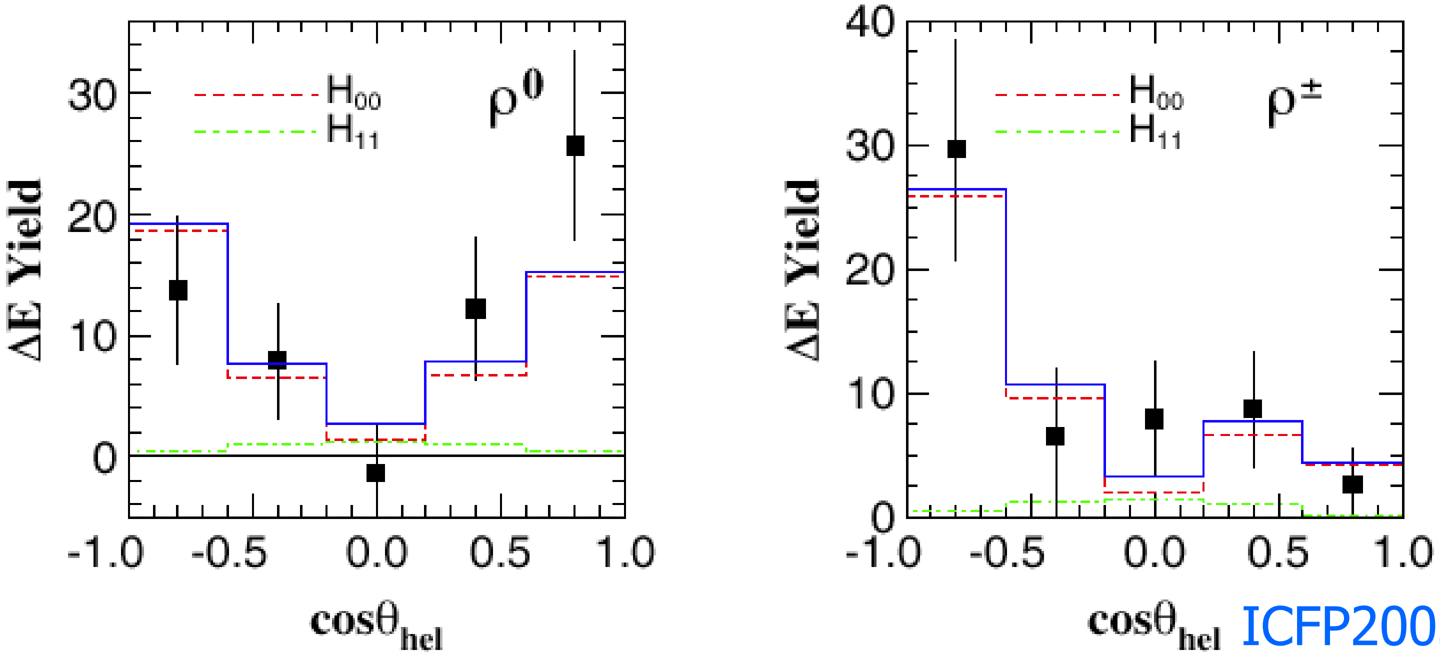
transversely polarized: $\lambda = \pm 1$, designated H_{11}

$$H_{00} = 48.3 \pm 10.8$$

$$H_{11} = 4.3 \pm 8.7$$

$$\frac{\Gamma_L}{\Gamma} = (94.8 \pm 10.6 \pm 2.1)\%$$

Data used: 78 fb^{-1} on Y(4S)



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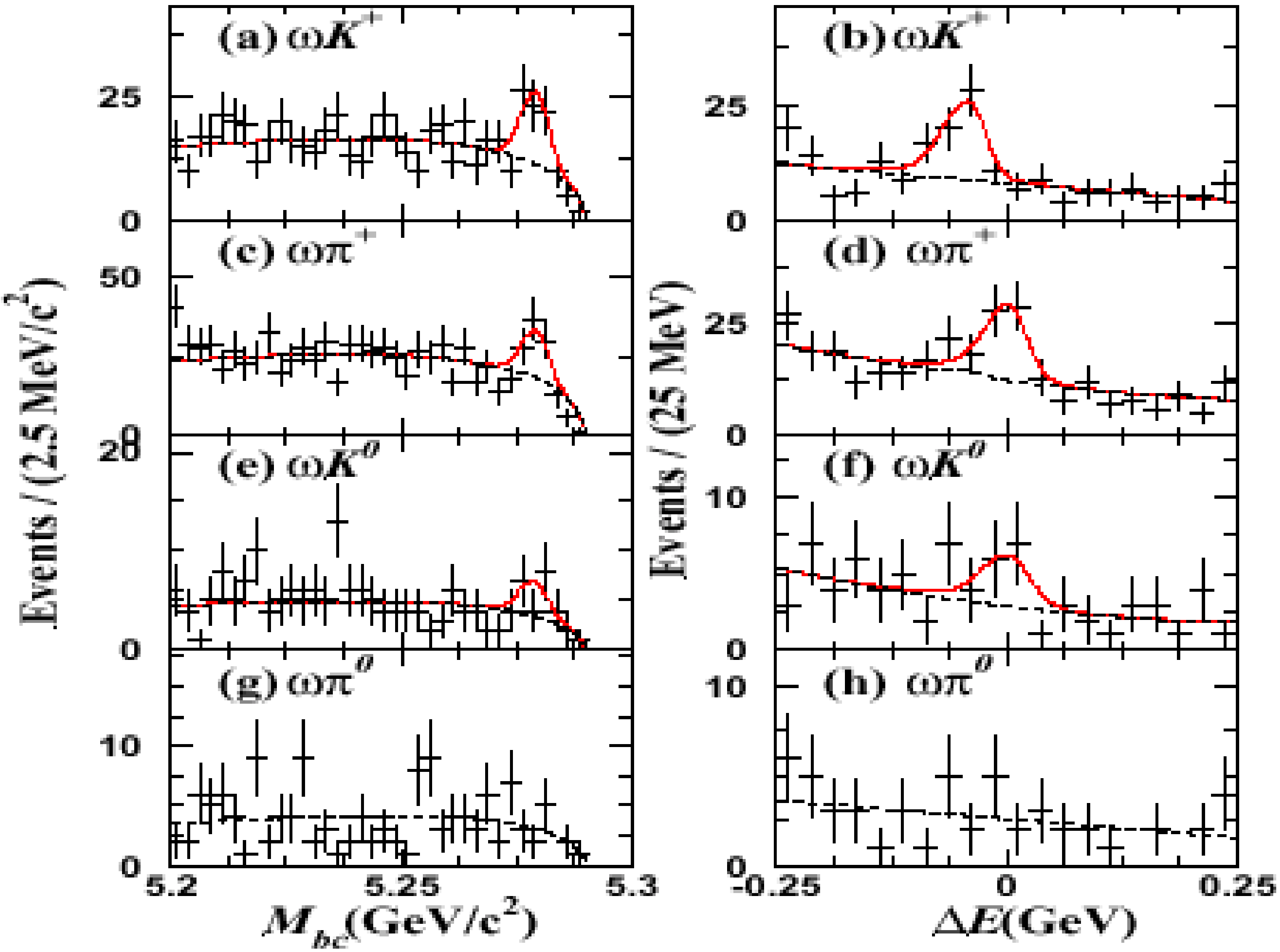
$B \to \omega h$



Data used: 78 fb^{-1} on Υ(4S)

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$B \to \omega h$

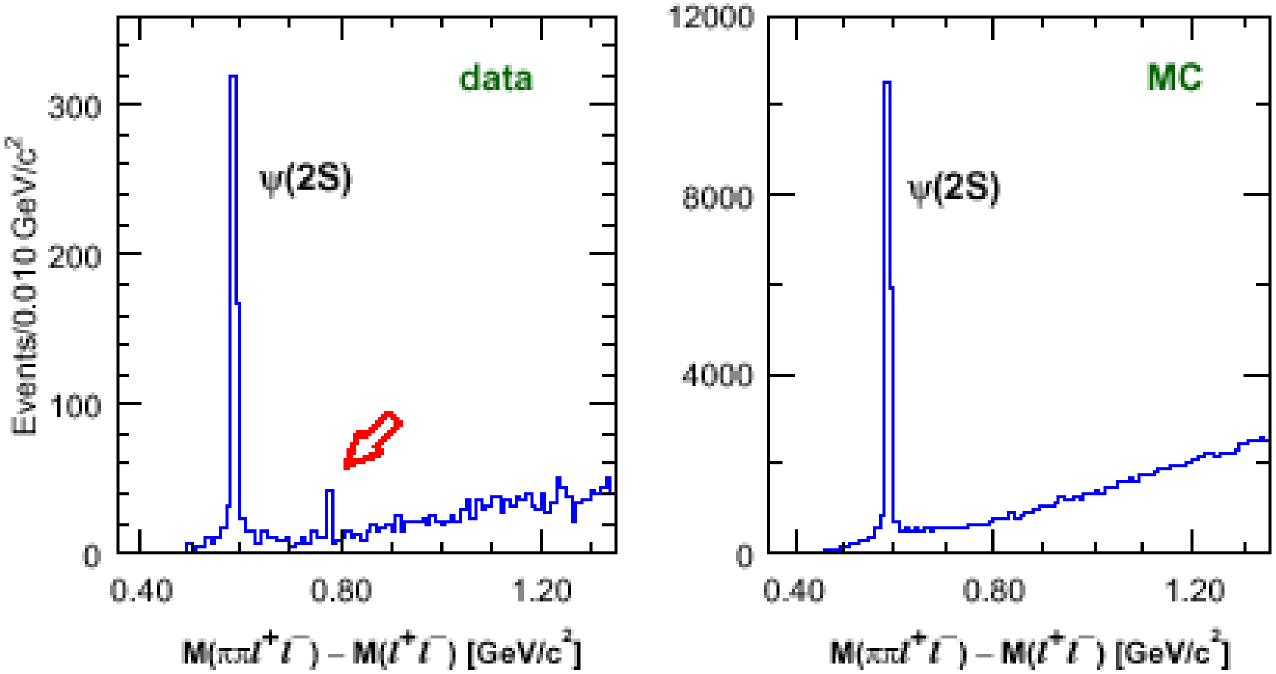
mode	yield	ε(%)	σ	*B(10^-6)*
$B^+ \to \omega K^+$	$46.1^{+9.1}_{-8.4}$	8.1	7.8	$6.7\ ^{+1.3}_{+1.2} \pm 0.6$
$B^+ \to \omega \pi^+$	$42.1^{+10.1}_{-9.3}$	8.4	6.0	$5.7\ ^{+1.4}_{+1.3} \pm 0.6$
$B^0 \to \omega K^0$	$11.1^{+5.2}_{-4.4}$	3.3	3.2	$4.0\ ^{+1.3}_{+1.6} \pm 0.5$
$B^0 \to \omega \pi^0$	$0.0^{+2.1}_{-0}$	5.2	-	< 1.9

Belle have confirmed previous observation of $\omega K^+ > \omega \pi^+$

Data used: 78 fb^{-1} on Υ(4S)

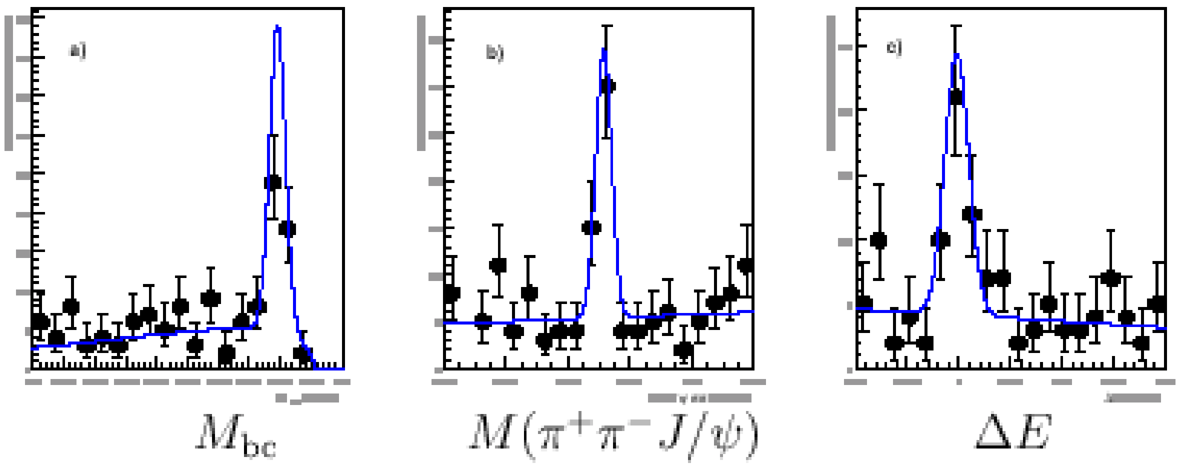
Narrow chamonium state in $B^+ \to K^+\pi^+\pi^- J/\psi$

A narrow peak (X) is found in $M(\pi^+\pi^- J/\psi)$ distribution in $B^+ \to K^+\pi^+\pi^- J/\psi$.



Analyses are based on $140\ \mathrm{fb}^{-1}$ data

$B^+ \to K^+ X$ fit results



- M_{bc}, ΔE, $M(\pi^+\pi^- J/\psi)$ simultaneous fit.
- Comparison with $B^+ \to K^+\psi(2S) \to K^+\pi^+\pi^- J/\psi$.

- 35.7 ± 6.8 events with significance 10.2σ.
- $M(X) = 3872.0 \pm 0.6 \pm 0.5$ MeV$/c^2$.
- $\sigma(X) \sim 2.5$ MeV$/c^2$ (consistent with detector resolution)

Analyses are based on 140 fb^{-1} data

$$\frac{\mathcal{B}(B^+ \to K^+X) \times \mathcal{B}(X \to \pi^+\pi^- J/\psi)}{\mathcal{B}(B^+ \to K^+\psi(2S)) \times \mathcal{B}(\psi(2S) \to \pi^+\pi^- J/\psi)} = 0.063 \pm 0.012 \pm 0.007$$

What's this ?

$$\frac{BF(X \to \chi_{c1}\gamma)}{BF(X \to J/\psi\pi^+\pi^-)} < 0.89$$

(1) $\psi(1^3D_2)$ state

- $\psi(1^3D_2) \to D\bar{D}$ is inhibited by parity.
- $) \to D\bar{D}^*$ is allowed if it's above d.
  narrow resonance if it's below threshold)
- $\psi(1^3D_2) \to \pi^+\pi^- J/\psi$ is predicted in some model.
- But $\psi(1^3D_2) \to \gamma\chi_{c1} \to \gamma\gamma J/\psi$ should be seen.

(2) Molecular charmonium

- Mass is at $D^0\bar{D}^{*0}$ threshold $(3871.5 \pm 0.7$ MeV$/c^2)$.
- Loosely bound $D^0\bar{D}^{*0}$ states.

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Summary

- Great performance of KEK-B. (Reached to 10^{34}cm^{-2}s^{-1}: 158 fb $^{-1}$)

- With ~ 78 fb^{-1} on $\Upsilon(4S)$ data, we have
  - updated $B \to \phi K$ and observed $B \to \phi K^*$ ($b \to sss$) decays
  - observed $b \to s\bar{s}s\bar{s}s$ ($B \to \phi\phi K$) decays.
  - measured $\eta_c \to \phi K^+ K$ decays.

- ***Update B→ Kπ,ππ,KK,ρh,ωh***
- ***First obserwation of B→ VV charmless & strangless decay: B→*** ρρ.

- $A_{CP}(K^+\pi^-) = -0.088 \pm 0.035 \pm 0.018$. DCPV in near future?
- Evidence for $B^0 \to \pi^0\pi^0$. Important information for ϕ_2 measurement.
- Observation of $B \to K^*\ell^+\ell^-$.
- Null asymmetry for $B \to X_s\gamma$.
- New resonance is observed in $\pi^+\pi^- J/\psi$ system
  $\Longrightarrow$ "molecular charmonium"?

Results obtained on full data sample 140fb^{-1}

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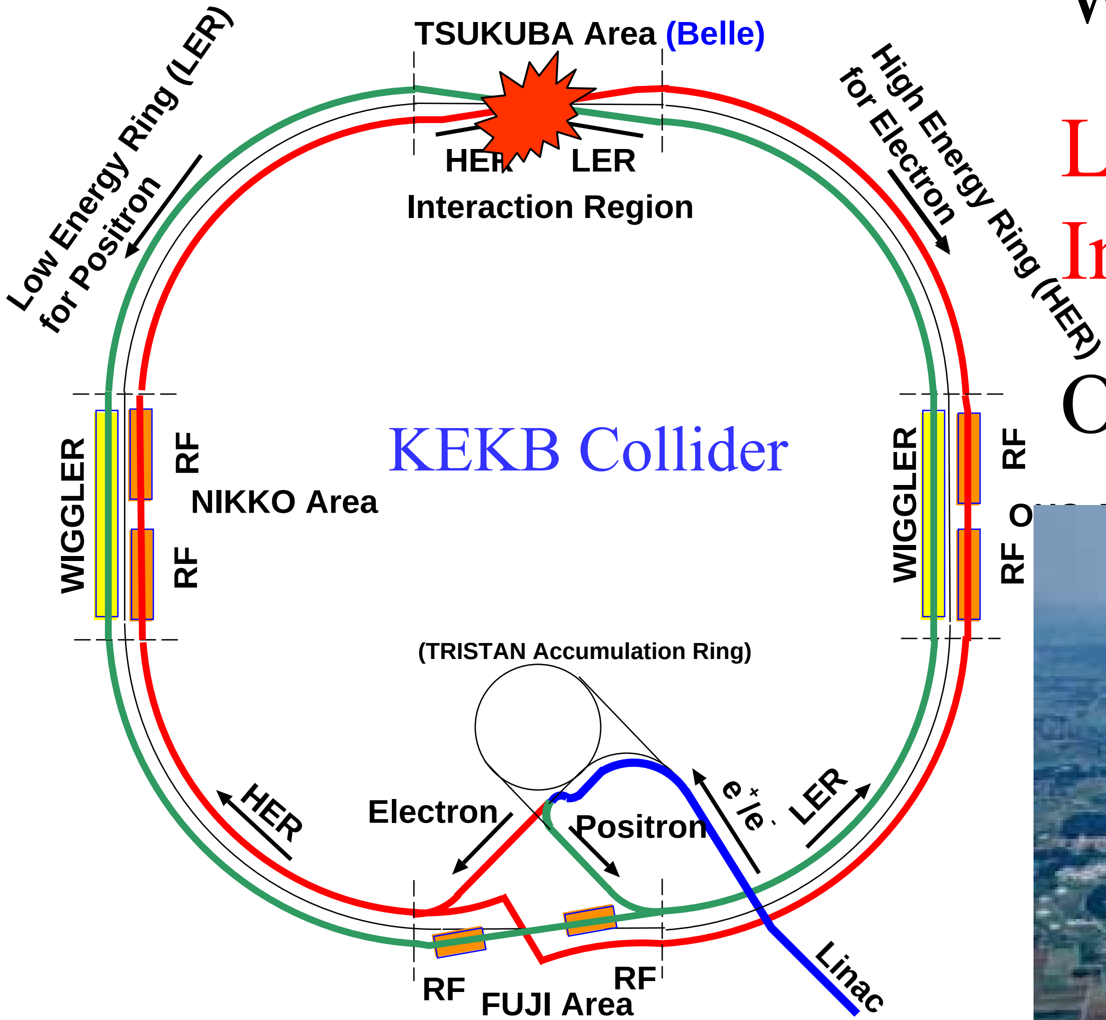
Backup Slides

The KEKB Collider (8 x 3.5 GeV, X angle)



World record:

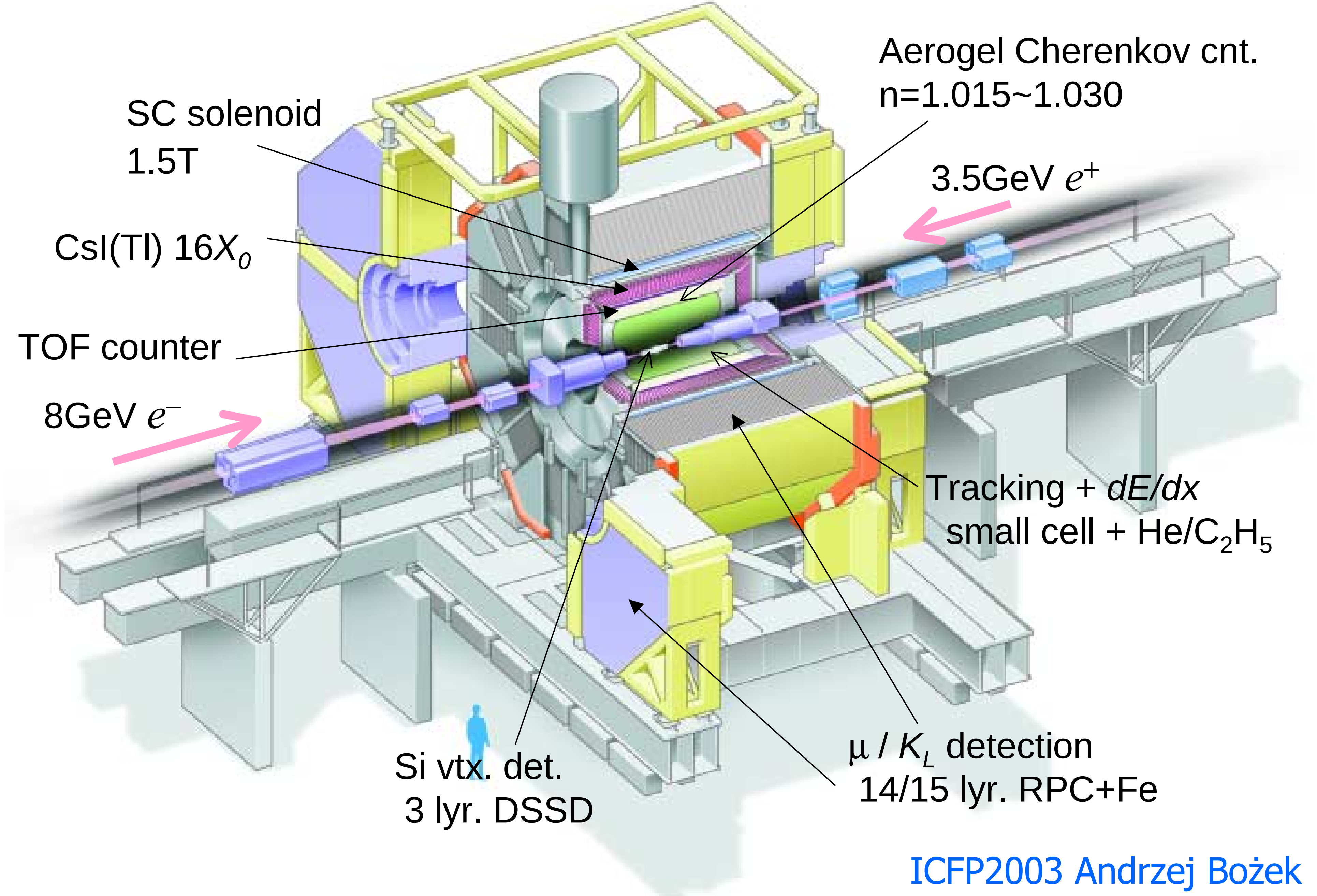
L=(1.0 x 10^{34})/cm^2/sec

Int(L dt)= 158 fb^{-1}

On-resonance 140 fb^{-1}

12

Belle Detector



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New Resonances

What's this ?

(1) $\psi(1^3D_2)$ state

- $\psi(1^3D_2) \to D\bar{D}$ is inhibited by parity.
- $\psi(1^3D_2) \to D\bar{D}^*$ is allowed if it's above threshold.
  (narrow resonance if it's below threshold)
- $\psi(1^3D_2) \to \pi^+\pi^- J/\psi$ is predicted in some model.
- But $\psi(1^3D_2) \to \gamma\chi_{c1} \to \gamma\gamma J/\psi$ should be seen.

(2) Molecular charmonium

- Mass is at $D^0\bar{D}^{*0}$ threshold $(3871.5 \pm 0.7\ \mathrm{MeV}/c^2)$.
- Loosely bound $D^0\bar{D}^{*0}$ states.