Measurement of the Branching Fraction for the Decay $\psi(3686) \to \phi K_S^0 K_S^0$

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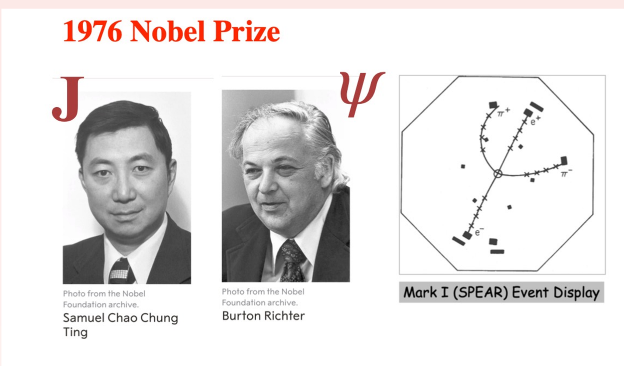
Why we study the charmonium decay

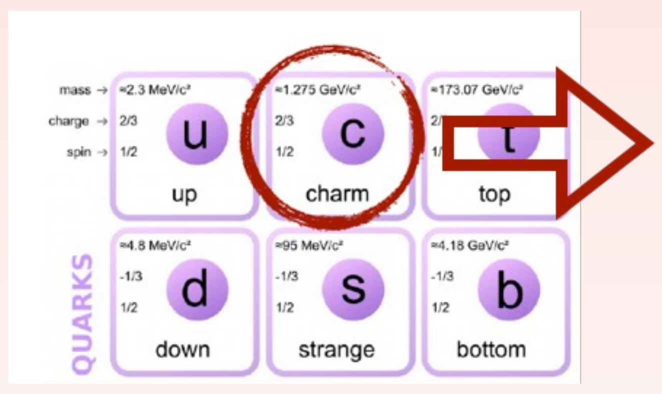
✪**Charmonium Ψ**

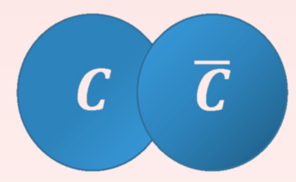
➢ J/ψ, $\psi(3686)$: non-relativistic bound states of a charm and an anti-charm quark ($c\bar{c}$)

✪**Test the properties of QCD**

➢ **Ideal laboratory** for the properties of the strong interaction using quantum chromodynamics (QCD)







J/ψ, $\psi(3686)$

Aim for this study

✪**Test the 12% rule**

➢ According to perturbative QCD, the relative ratio of Ψ decays to the same final states is expected to be a constant:

$$Q_h = \frac{\mathcal{B}(\psi(3686)\to h)}{\mathcal{B}(J/\psi\to h)} \approx \frac{\mathcal{B}(\psi(3686)\to e^+e^-)}{\mathcal{B}(J/\psi\to e^+e^-)} \approx 13.3\%$$

➢ Consistent well with many experiments result

✪**$\rho\pi$ puzzle**

➢ Violation of the12% rule was found in 1983.

➢ More experimental results are desired to test 12% rule!

$$\mathcal{B}(J/\psi \to \phi K_S^0 K_S^0) = 5.9 \pm 1.5 \times 10^{-4}$$
$$\mathcal{B}(\psi(3686) \to \phi K_S^0 K_S^0) = ?$$

Summary

Motivation · Background · Interference effect · Solution · Aim · e^- · e^+

$\psi(3686) \to \phi K_S^0 K_S^0$ is **observed for the first time !**

$\mathcal{B}(\psi(3686) \to \phi\, K_S^0\, K_S^0) = (3.53 \pm 0.20_{stat.} \pm 0.21_{syst.})\times 10^{-5}$

12% rule is strongly **violated** !

Compared with $\mathcal{B}(J/\psi \to \phi\, K_S^0\, K_S^0)$

$$\text{ratio}=\frac{\mathcal{B}(\psi(3686)\to\phi K_S^0 K_S^0)}{\mathcal{B}(J/\psi\to\phi K_S^0 K_S^0)} = 6.0 \pm 1.6\%$$

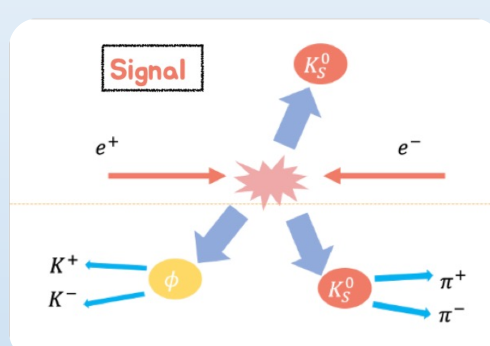
Analysis strategy

✪**BESIII experiment**

✪A symmetric electron positron collider running at tau-charm region

✪BEPCII: Electron–positron colliders: accelerate the e^+e^-

✪BESIII detector : Record the hit positions, momentum , energy of particles. `High statistic Clean background!`



✪**Cascade decay**

$\psi(3686) \to \phi K_S^0 K_S^0, \phi \to K^+K^-, K_S^0 \to \pi^+\pi^-$

✪**Branching fraction**

$N_{sig} = N_{\psi(3686)} \times \mathcal{B}_{inter} \cdot \varepsilon \cdot \mathcal{B}_{sig}$ 👈 `Our interested variables!`

⇒ We need to estimate

? ε: detection efficiency (MC simulations)

? N_{sig}: signal yields in data, also need to consider the background contaminations.

✪**Data sets**

✓ Obtain signal yields : using $(448.1 \pm 2.9)\times 10^6$ $\psi(3686)$events

✓ Estimate the backgrounds

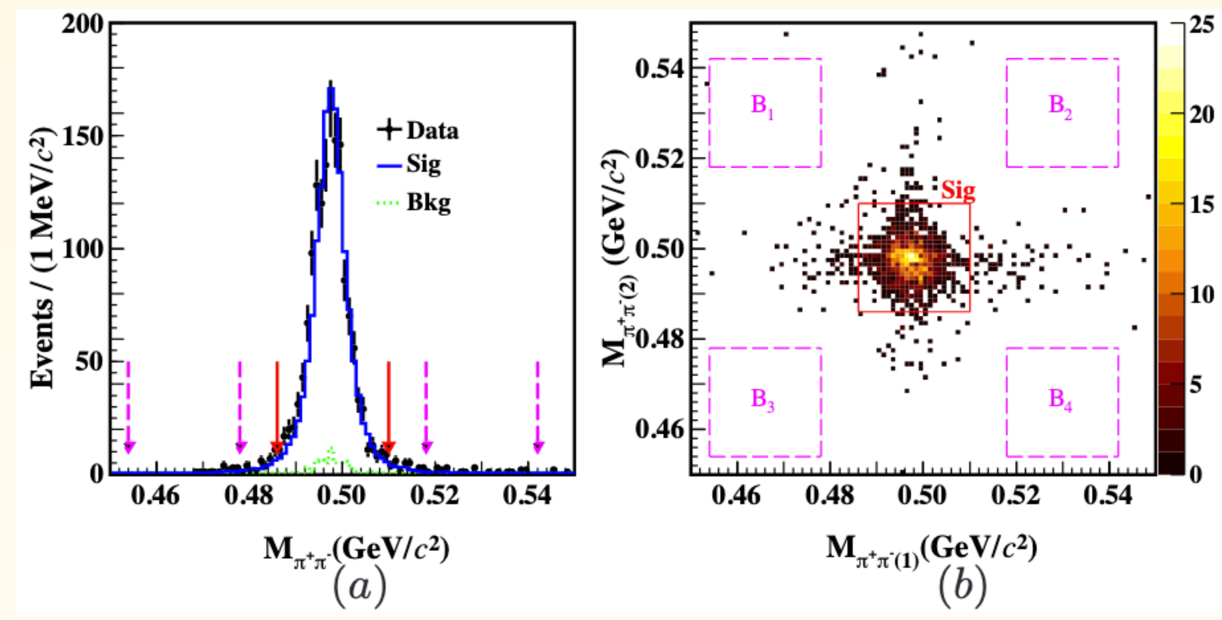
✓ Estimate the interference contributions between resonance & non-resonant

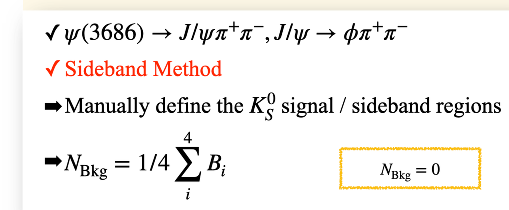
Background estimation

✪**Two sorts of backgrounds**

➢ **1.** Same final states channel decayed from $\psi(3686)$

✓ Estimate them using the sideband method





✪**Two sorts of backgrounds**

➢ **2.** Decays from QED process

✓ Contributions of the continuum processes

✓ Weighted average method

$$\overline{N_{QED}} = 108 \pm 5$$

E_{CM}(GeV)	$\mathcal{L}_{cont.}$(pb^{-1})	N_{net}	f_c	N_{QED}
3.508	183.64	32 ± 6	3.30	106 ± 20
3.510	181.79	28 ± 7	3.34	94 ± 23
3.539	25.50	7 ± 3	24.17	169 ± 72
3.553	42.56	10 ± 3	14.59	146 ± 44
3.554	27.24	1 ± 1	22.81	23 ± 23
3.650	43.88	14 ± 4	14.94	209 ± 60
3.773	2931.80	465 ± 22	0.24	112 ± 5

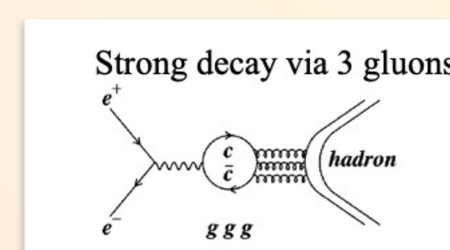
Interference effect

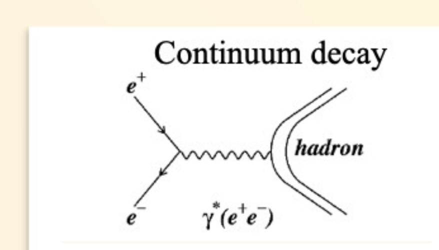
✪ **Why we need to consider the interference?**

➢ The total cross section of $e^+e^- \to \phi K_S^0 K_S^0$ includes three parts

⇒ Resonances ($\psi(3686)$), Continuum, interference term

$$\sigma_{tot}(s) = \sigma_{cont.}(s) + \sigma_{Res}(s) + \sigma_{inter}(s)$$





➢ Measure the line shape of $\sigma(e^+e^- \to \phi K_S^0 K_S^0)$ in the vicinity of $\psi(3686)$

➢ Obtain the relative phase φ from fitting to $\sigma(e^+e^- \to \phi K_S^0 K_S^0)$

✪ **Two solutions**

➢ The fit yields two solution with the same $\frac{\chi^2}{ndf} = \frac{9.88}{6}$

➢ However, the destructive solution can be excluded by the isospin symmetry.

$$\frac{\mathcal{B}(\psi\to\phi K_S^0 K_S^0)}{\mathcal{B}(\psi\to\phi K^+K^-)} = \frac{1}{2}$$

➢ The constructive solution will be treated as physical solution.