International Workshop
e^+e^- Collisions from ϕ to J/Ψ
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Study of $\tau \to K_S \pi \nu_\tau$ decay

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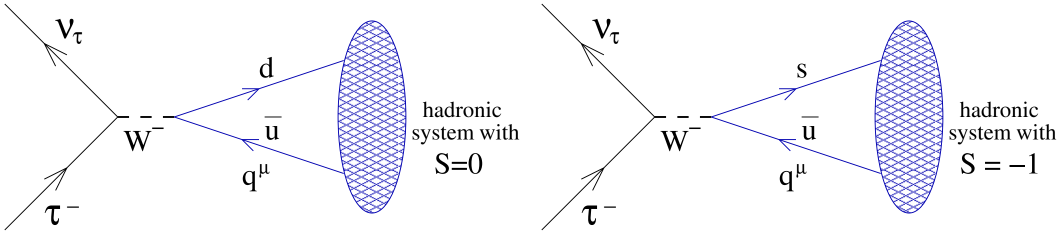
Outline:

- Physics Motivation
- Selection of $\tau \to K_S \pi \nu_\tau$ events
- Branching fraction
- Study of $K_S \pi$ spectrum
- Conclusion

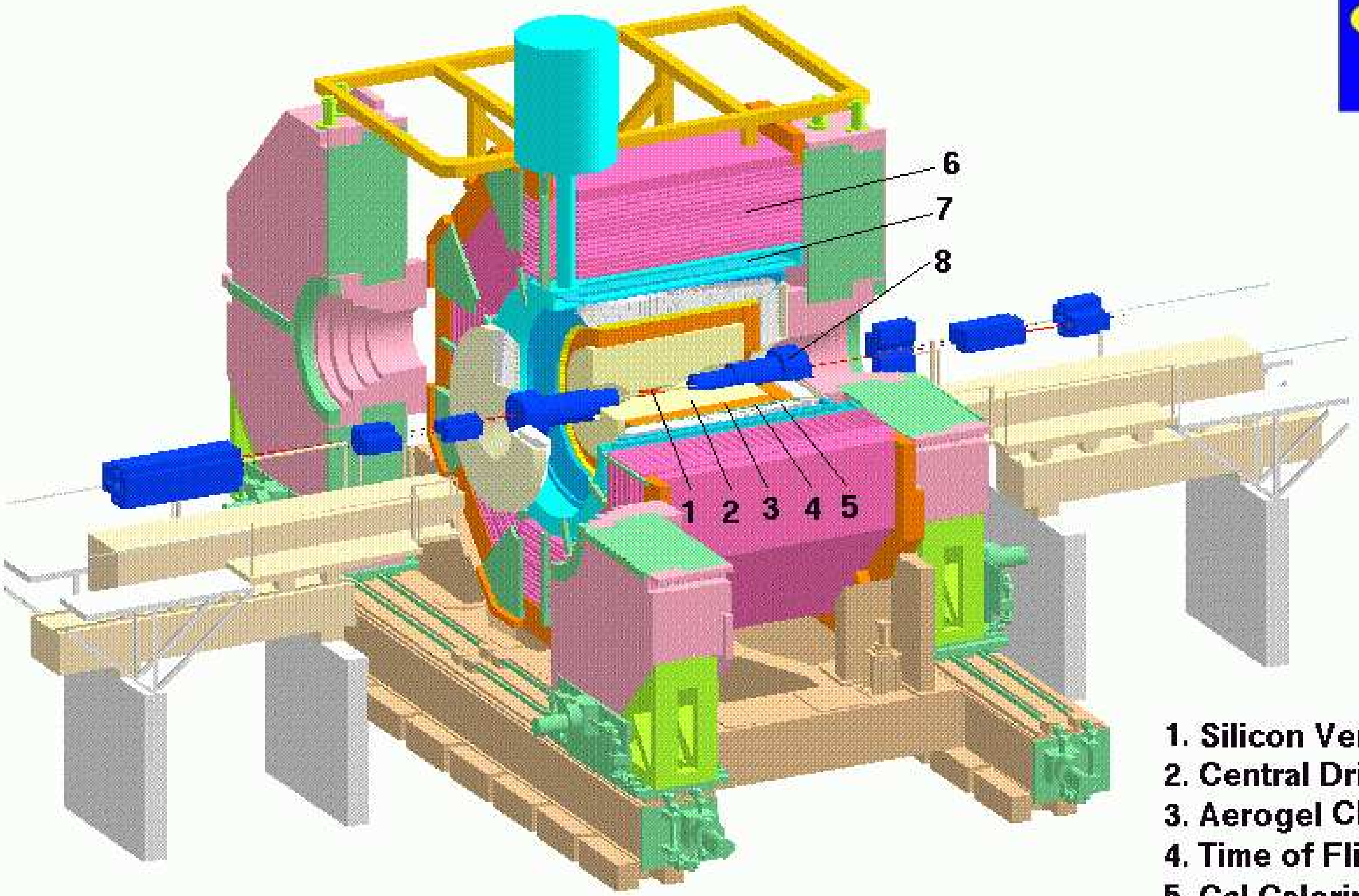
Physics Motivation



$Br \sim cos^2\theta_c$ $\qquad$ $Br \sim sin^2\theta_c$

- Measurement of $\tau \to K_S\pi\nu_\tau$ branching ratio. $\tau \to \bar{K^0}\pi\nu_\tau$ has the largest Br among decays with one kaon, so provides the dominant contribution to the s-quark mass sensitive total strange hadronic spectral function.
- $K_S\pi$ spectrum ($K^\star(800)(0^+)$, $K^\star(1430)(0^+)$, $K^\star(1410)(1^-)$)
  - M.Finkemeier, E.Mirkes, Z.Phys. **C72**, 619 (1996)
  - R. Barate *et al* (ALEPH), Eur. Phys. J. **C11**, 599 (1999)
  - P. Lichard, Phys.Rev.D **60**, 093012 (1999) (nonzero value of the slope parameter λ_0 of the $K^\pm_{\mu 3}$ and $K^0_{\mu 3}$ formfactors implies the existence of the $\tau \to K^\star_0(1430)\nu_\tau$ decay)
- CP violation in $\tau \to K_S\pi\nu_\tau$
  - J.Kuhn, E.Mirkes,Phys. Lett. **B398**, 407 (1997)
  - G.Bonvicini *et al* (CLEO), Phys.Rev.Lett.**88**, 111803 (2002)
  - I.I.Bigi, A.I.Sanda, Phys. Let. B **625**, 47 (2005)

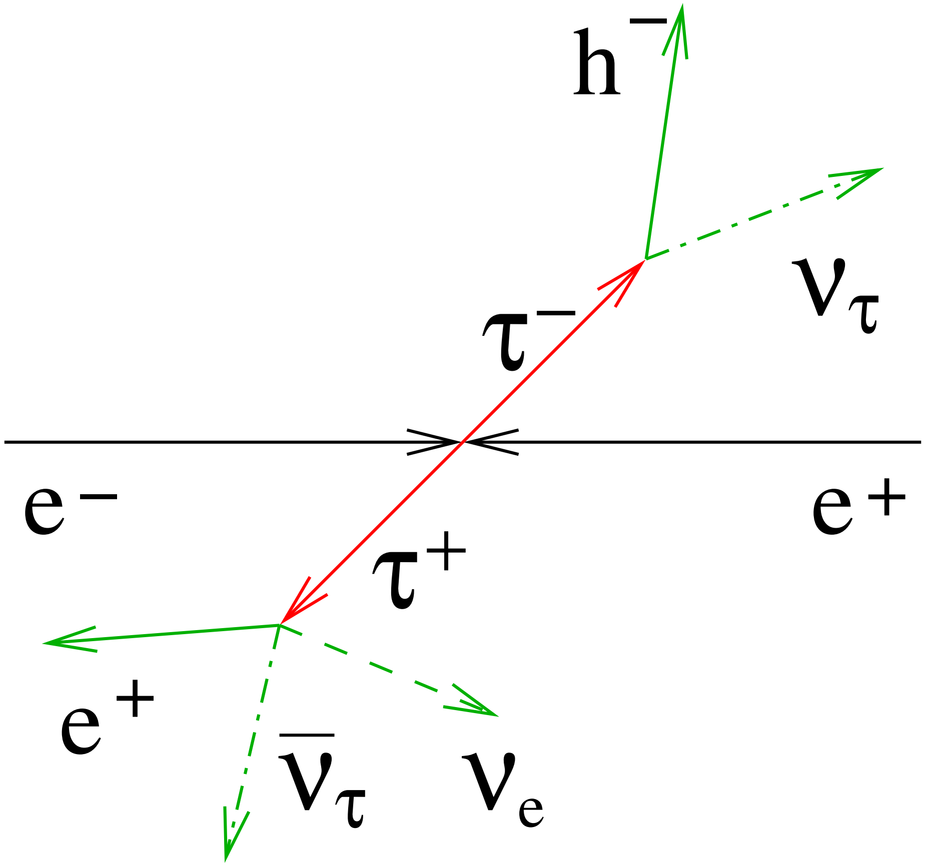
BELLE Detector



1. Silicon Vertex Detector
2. Central Drift Chamber
3. Aerogel Cherenkov Counter
4. Time of Flight Counter
5. CsI Calorimeter
6. KLM Detector
7. Superconducting Solenoid
8. Superconducting Final Focussing System

Selection criteria

Experimental data of $\int Ldt = 351 fb^{-1}$ is analyzed ($N_{\tau\tau} = 313 \times 10^6$)
TAUOLA generated MC sample $N_{\tau\tau}^{MC} = 73.6 \times 10^6$

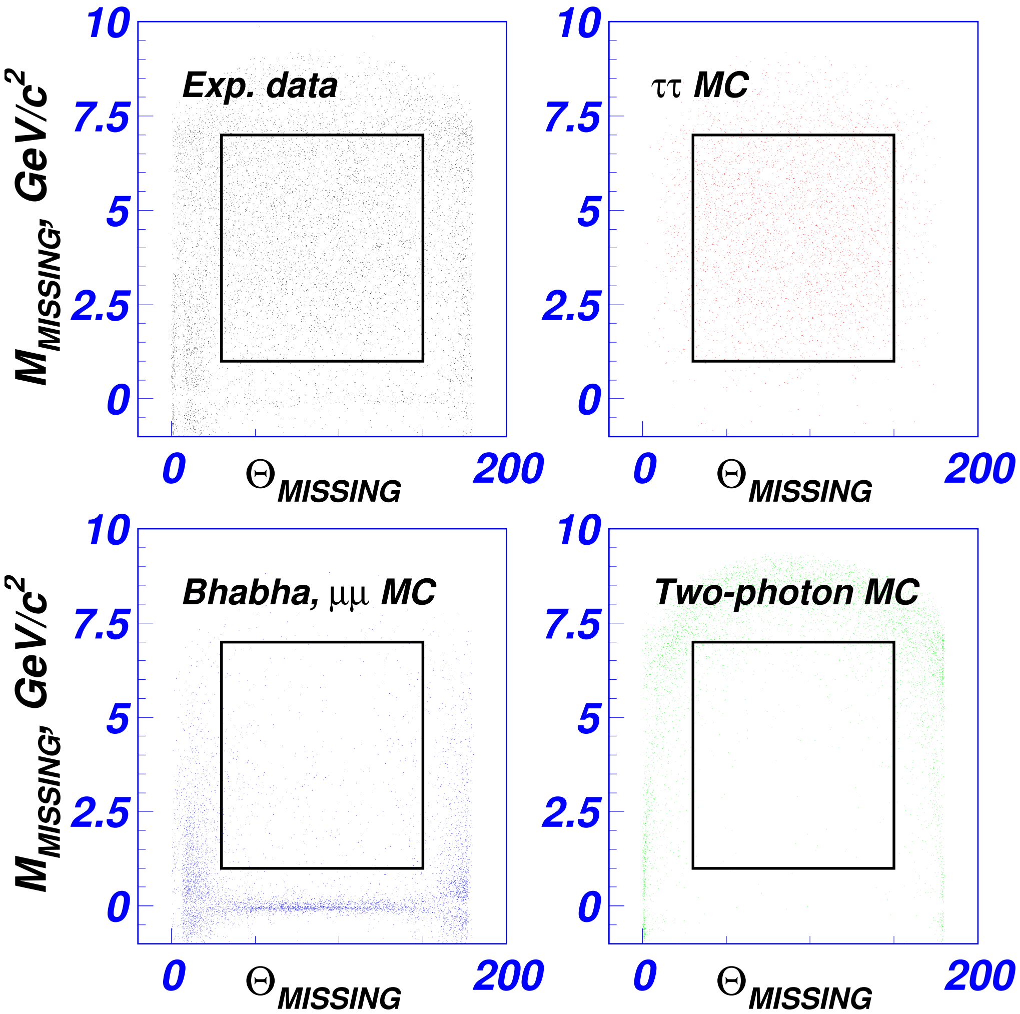


The idea is to select $\tau\tau$ events tagging one τ by its leptonic decay and to use for normalization two-lepton (e, μ) events, where background is small ($\sim 2.5\%$ $ee\mu\mu$; $\sim 3.4\%$ $\pi - \mu$ $misid$)

$$Br(hadrons) = \left(\frac{N(hadrons;lepton)}{N(lepton;lepton)}\right)^{EXP} \cdot \left(\frac{\varepsilon(lepton;lepton)}{\varepsilon(hadrons;lepton)}\right)^{MC} \cdot Br(lepton)$$

I. A sample with 70% of $\tau\tau$ events and 30% of background events ($\varepsilon_{\tau\tau} = 46\%$):

1) The number of beam-originated tracks is $2 \leq N_{tracks} \leq 4$
2) The number of photons with 80 MeV energy threshold is $N_{\gamma} \leq 5$
3) Some criteria were applied to suppress essentially the events of Bhabha, $e^+e^- \to \mu^+\mu^-$ and two-photon processes.



II. Selection of pure τ^- decay channels tagging the τ^+, charge conjugate states are implied.

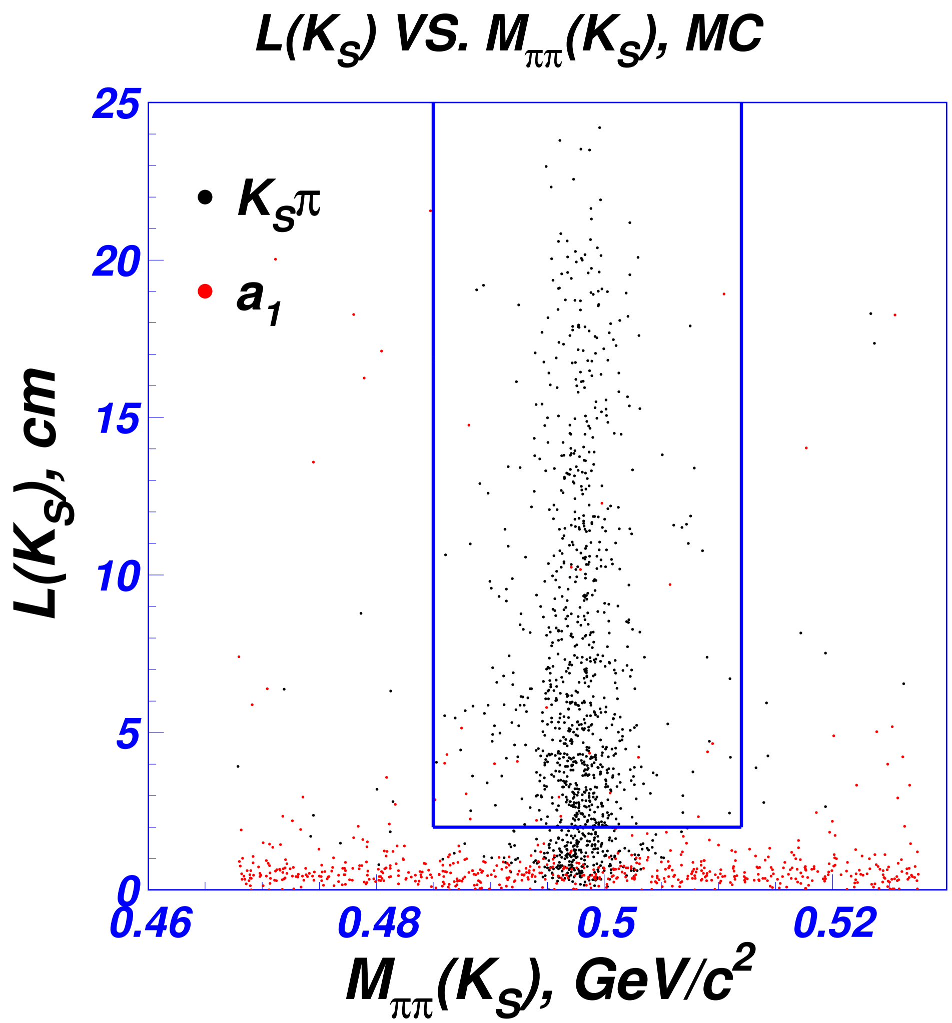
Selection of $\tau^\pm \to K_S \pi^\pm \nu_\tau$

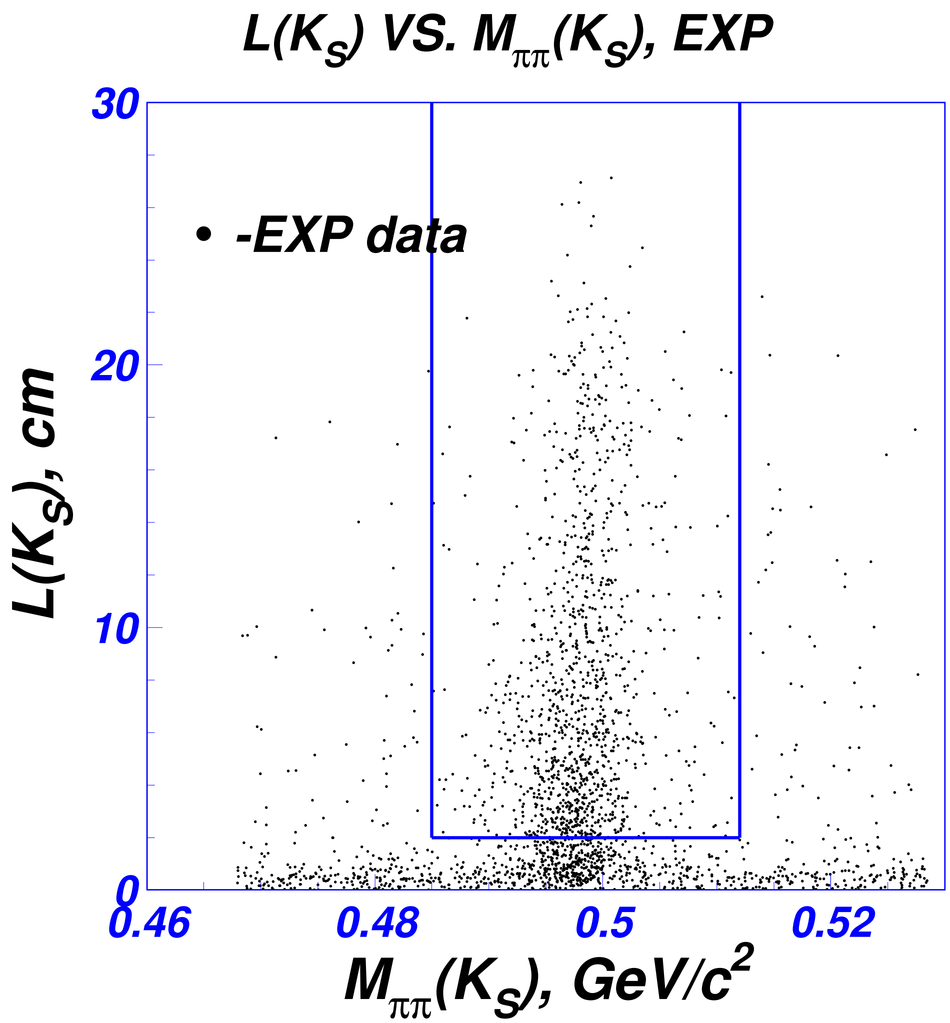
$e^\pm$ is identified by $\mathcal{L}_e$ which includes dE/dx measurement by CDC and the ratio of the ECL cluster energy to the CDC track momentum

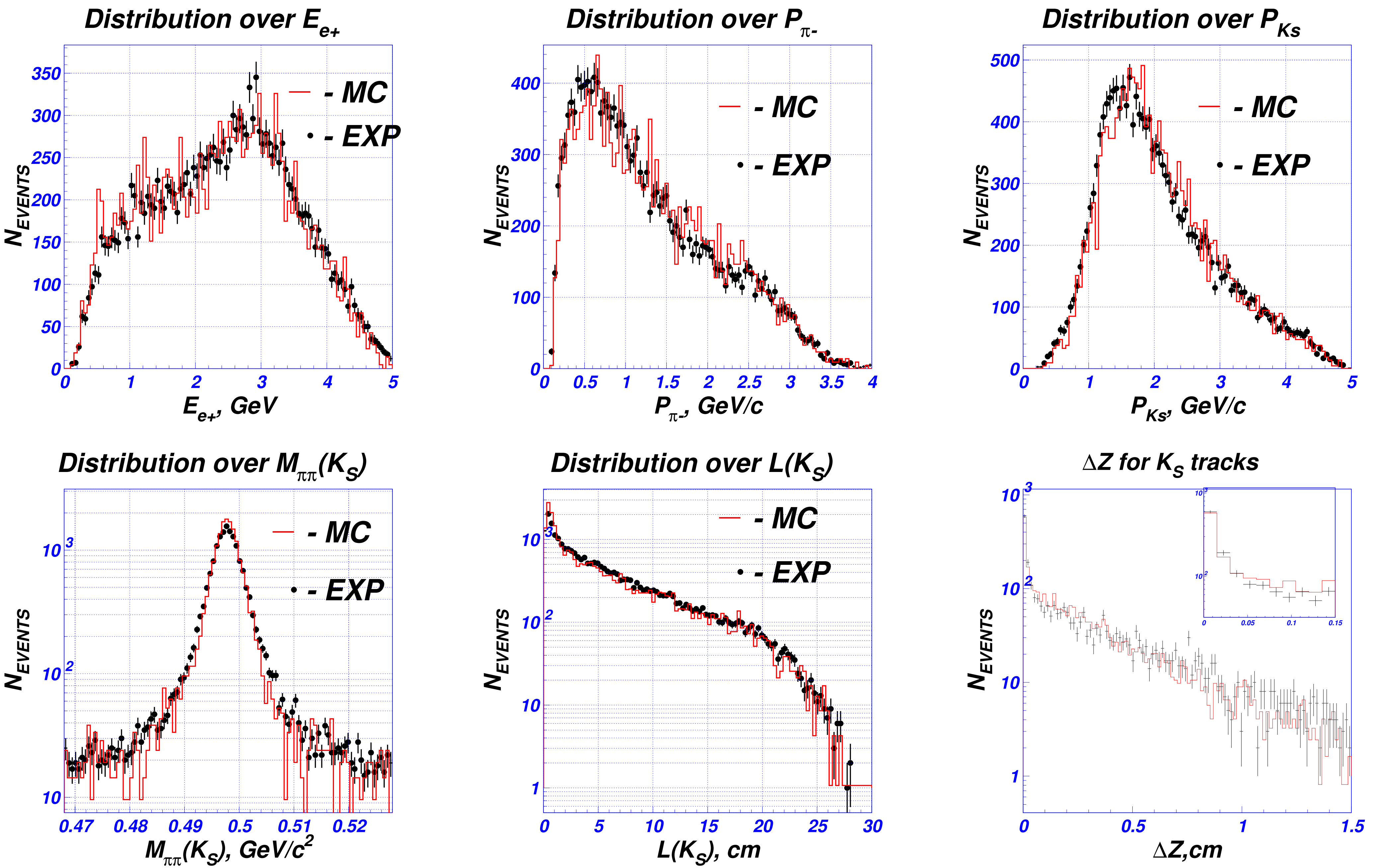
$\mu^\pm$ is identified by $\mathcal{L}_\mu$ which is evaluated from two variables - the difference between the range calculated from the momentum and the range measured by KLM, the χ^2 of the KLM hits with respect to the extrapolated track.

To separate pions from kaons we determine the pion ($\mathcal{L}_\pi$) and kaon ($\mathcal{L}_K$) likelihoods from ACC response, the specific ionization (dE/dx) measurement in the CDC and the TOF flight-time measurement for each track, and form a likelihood ratio $\mathcal{L}_{K/\pi} = \mathcal{L}_K/(\mathcal{L}_\pi + \mathcal{L}_K)$

- 1 lepton (e/μ) with $\mathcal{L}_e, \mathcal{L}_\mu > 0.8$
- 1 charged pion π with $\mathcal{L}_K/(\mathcal{L}_K + \mathcal{L}_\pi) < 0.3$
- 1 K_S candidate reconstructed from $K_S \to \pi^+\pi^-$
  - $\Delta Z_{1,2} < 1.5cm$
  - $0.1 < l_{\rho-\phi}(K_S) < 20cm$
  - $cos(\vec{P}_\perp, \vec{r}_\perp) \geq 0.95$
  - $L_{K_S} > 2\ cm$, $485 < M_{\pi\pi}(K_S) < 512\ MeV/c^2$ ($\pm 5\sigma$)

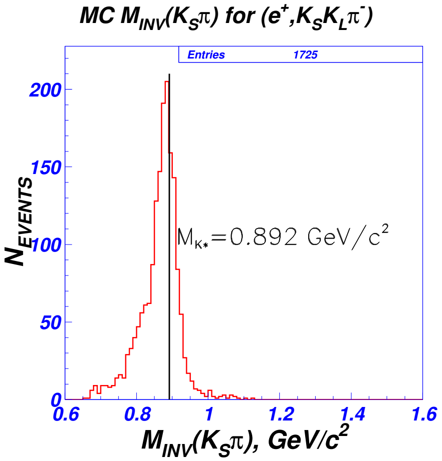

$L(K_S)$ VS. $M_{\pi\pi}(K_S)$, MC
$K_S\pi$
a_1
$L(K_S)$, cm
$M_{\pi\pi}(K_S)$, GeV/c^2
0
5
10
15
20
25
0.46
0.48
0.5
0.52


$L(K_S)$ VS. $M_{\pi\pi}(K_S)$, EXP
-EXP data
$L(K_S)$, cm
$M_{\pi\pi}(K_S)$, GeV/c^2
0
10
20
30
0.46
0.48
0.5
0.52

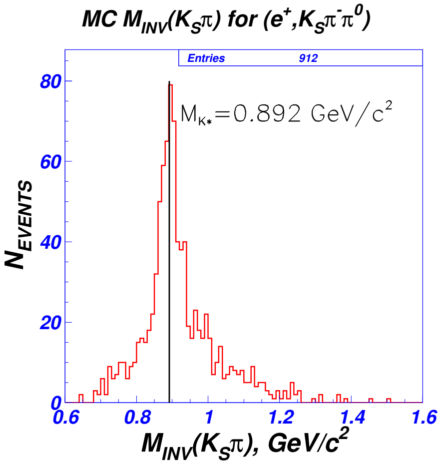


68100 selected events

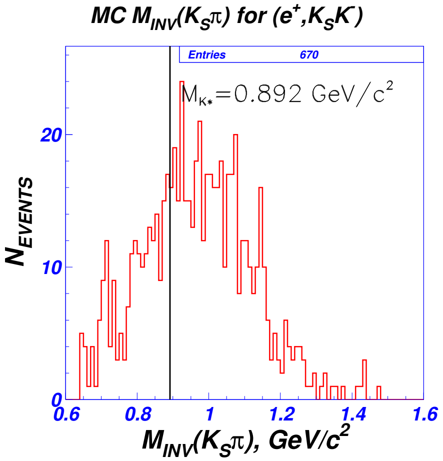
Background



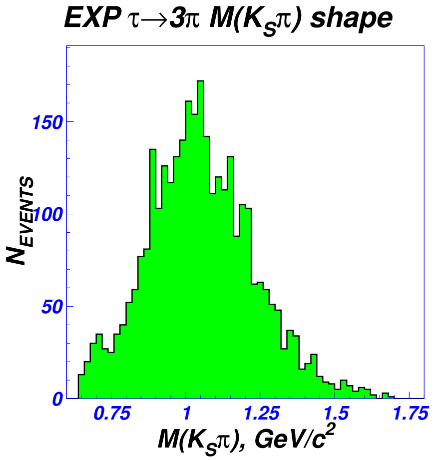
$\tau \to K_S K_L \pi \nu$



$\tau \to K_S \pi^0 \pi \nu$



$\tau \to K_S K \nu$



$\tau \to \pi^+ \pi^- \pi \nu$

Mode	Efficiency(MC),%	Contents, %
$K_S\pi$	6.2	81
$K_S\pi K_L$	3.5	8
$K_S\pi\pi^0$	0.9	4
$K_S K$	0.7	2
3π	(0.04)	5

55017 signal events

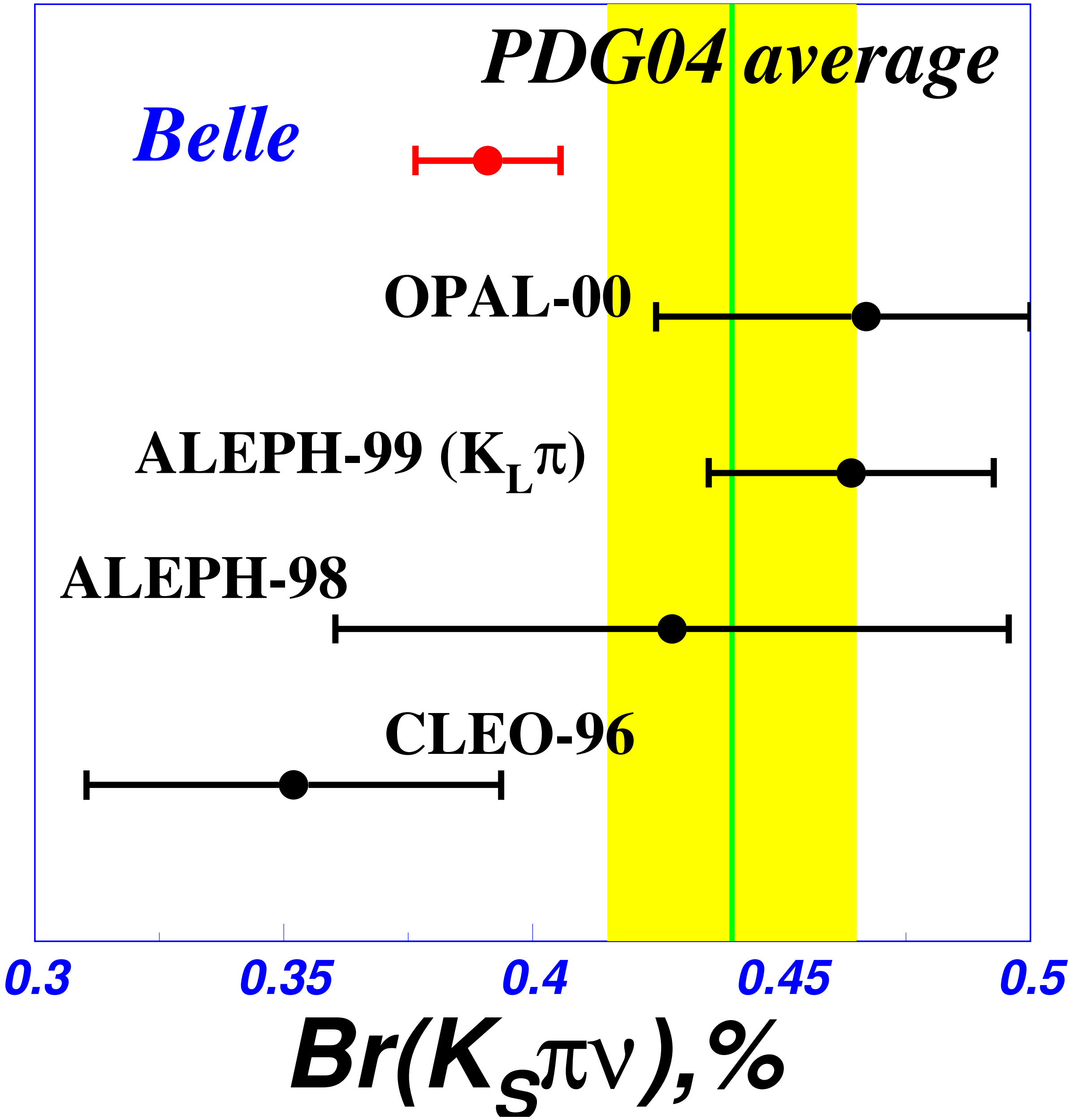
Branching fraction

	e-tag	μ-tag
+	$(0.390 \pm 0.008)\%$	$(0.387 \pm 0.008)\%$
-	$(0.390 \pm 0.008)\%$	$(0.398 \pm 0.008)\%$
avg(+&-)	$(0.390 \pm 0.006)\%$	$(0.393 \pm 0.006)\%$

$$Br(\tau \to K_S \pi \nu_\tau) = (0.391 \pm 0.004)\%$$

Type	Contribution,%
Br(e,μ)	**0.3**
PID(K/π)	**1**
P_π (**0.1**;0.3 GeV/c)	**0.5**
PID(leptons)	**1**
$\varepsilon(K_S)$	2.3%trk$\bigoplus$0.6%$M_{\pi\pi}$ $\bigoplus$0.9%$\Delta Z_{1,2}$=**2.5**
P_{K_S} (**0.1**;0.5 GeV/c)	**0.2**
K_S-bkg. subtr.	0.8%$KK\pi$ $\bigoplus$1.1%$K\pi\pi^0$ $\bigoplus$0.6%K_SK=**1.5**
3π-bkg.,L(K_S)=(1.5;**2.0**;2.5 cm)	**0.5**
$E^{LAB}_{\gamma,rest}$ =0.1;**0.2**:0.3 GeV/c^2	**1**
Total	**3.5**

$$Br(\tau \to K_S \pi \nu_\tau) = (0.391 \pm 0.004_{stat} \pm 0.014_{syst})\%$$



Study of $K_S\pi$ spectrum

$$\frac{d\Gamma}{d\sqrt{s}} \sim \frac{1}{s}\left(1-\frac{s}{m_\tau^2}\right)^2\left(1+2\frac{s}{m_\tau^2}\right)P\left\{P^2|F_V|^2+\frac{3(m_K^2-m_\pi^2)^2}{4s(1+2\frac{s}{m_\tau^2})}|F_S|^2\right\}$$

$$F_V = \frac{1}{1+\beta}\left[BW_{K*(892)}(s)+\beta BW_{K*(1410)}(s)\right]$$

$$F_S = \frac{1}{1+\beta}\left[\left(1-\frac{s}{m_{892}^2}\right)BW_{K*(892)}(s)+\beta\left(1-\frac{s}{m_{1410}^2}\right)BW_{K*(1410)}(s)\right]+$$
$$\gamma\frac{s}{m_{1430}^2}BW_{K_0*(1430)}(s)+\kappa\frac{s}{m_{800}^2}BW_{K_0*(800)}(s)+\delta_{LASS}A_S$$

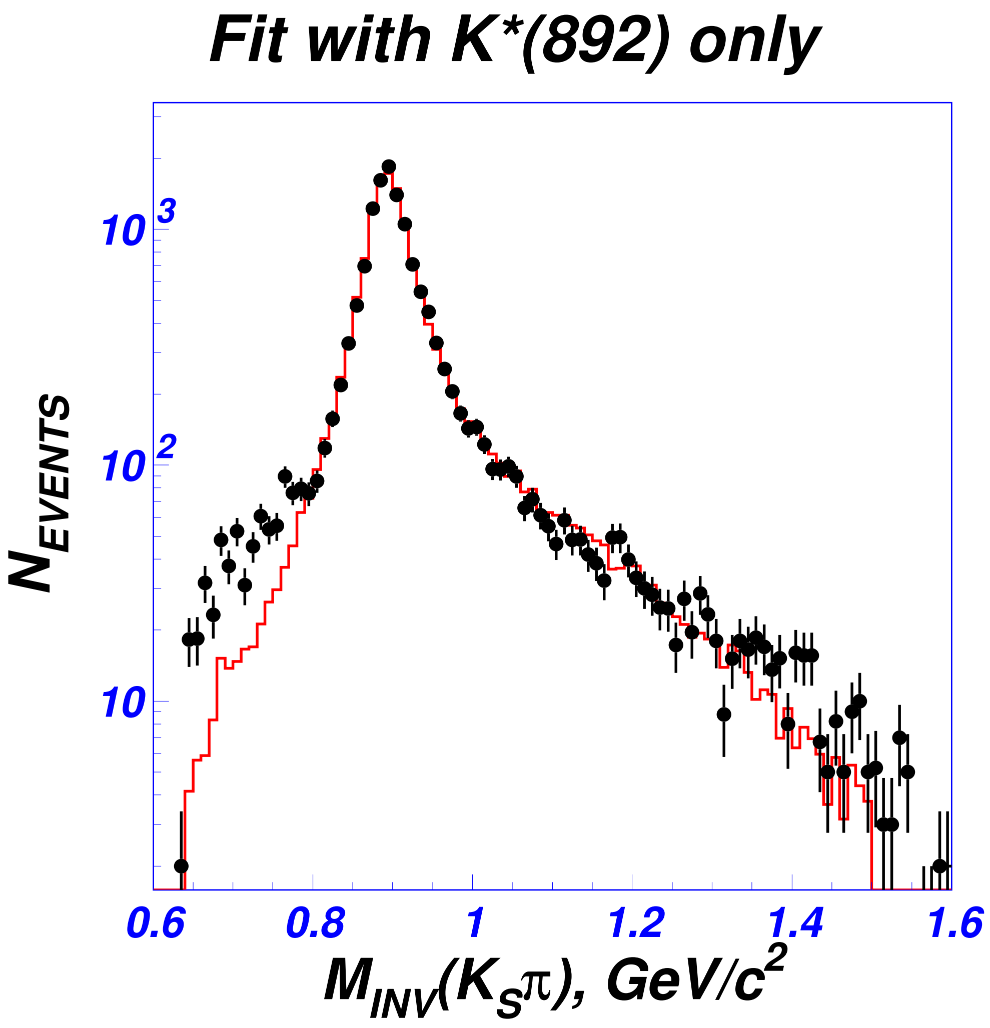
LASS parametrization

$$A_S = \frac{\sqrt{s}}{P}(sin\delta_B e^{i\delta_B}+e^{2i\delta_B}BW_{K_0^*(1430)}(s))$$

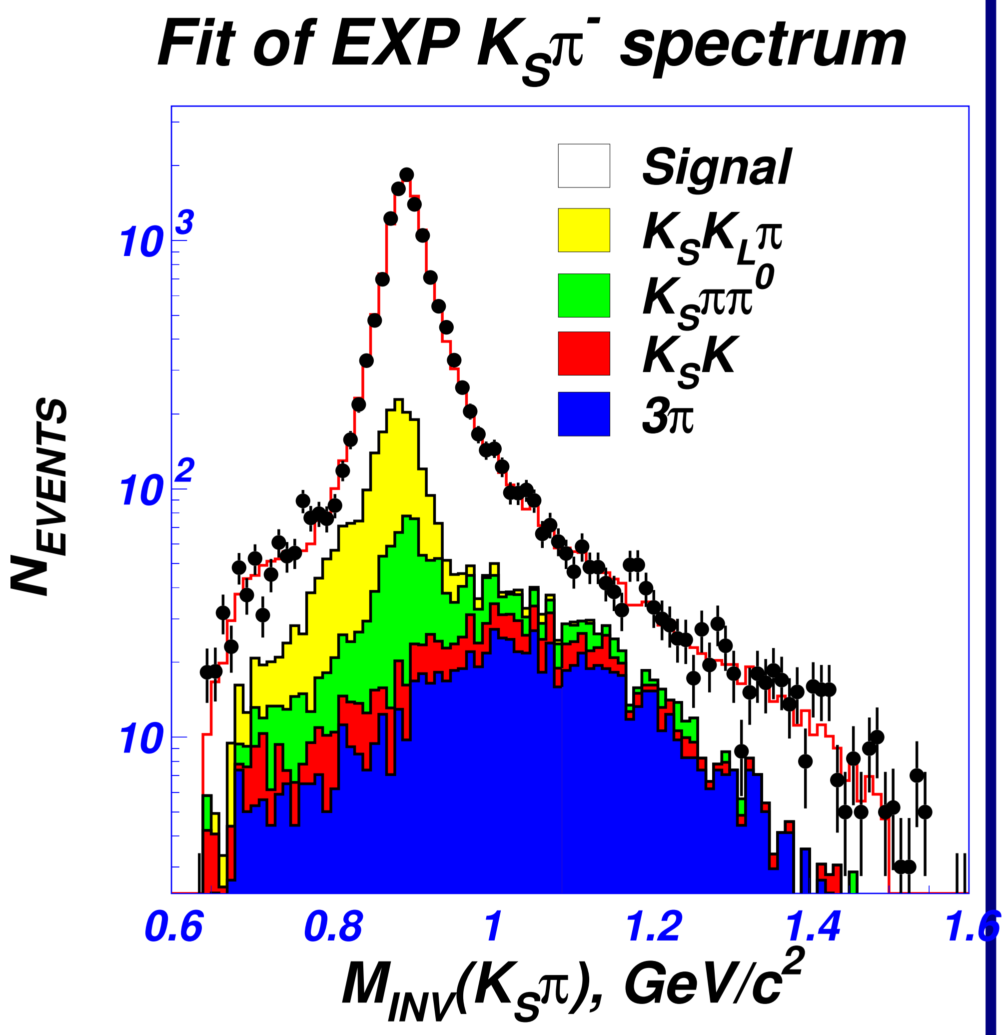
$$ctg\delta_B = \frac{1}{aP}+\frac{bP}{2},\ \ a=2.07\pm0.10(GeV/c)^{-1},\ \ b=3.32\pm0.34(GeV/c)^{-1}$$

$$P = \frac{\sqrt{(s-(M_K+M_\pi)^2)(s-(M_K-M_\pi)^2)}}{2\sqrt{s}}$$

Only K^*

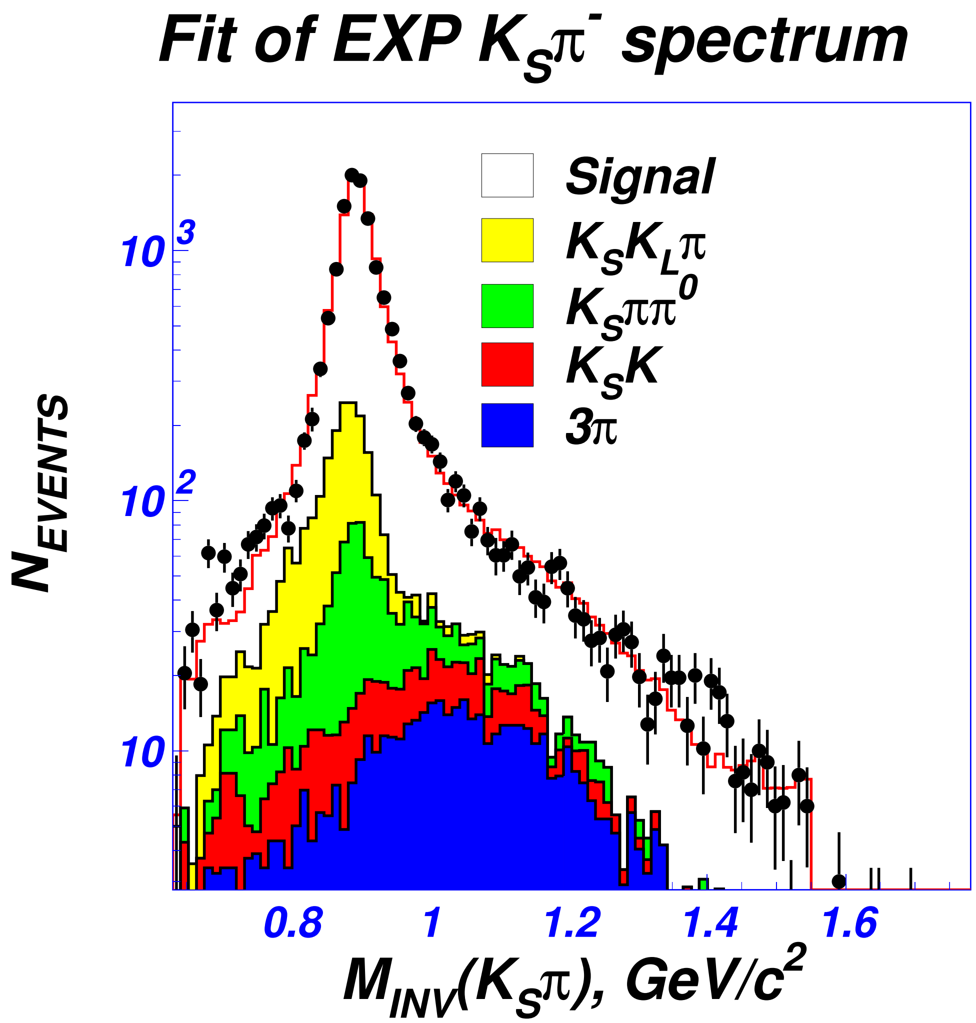


$K^* + \kappa + K^*(1410)$

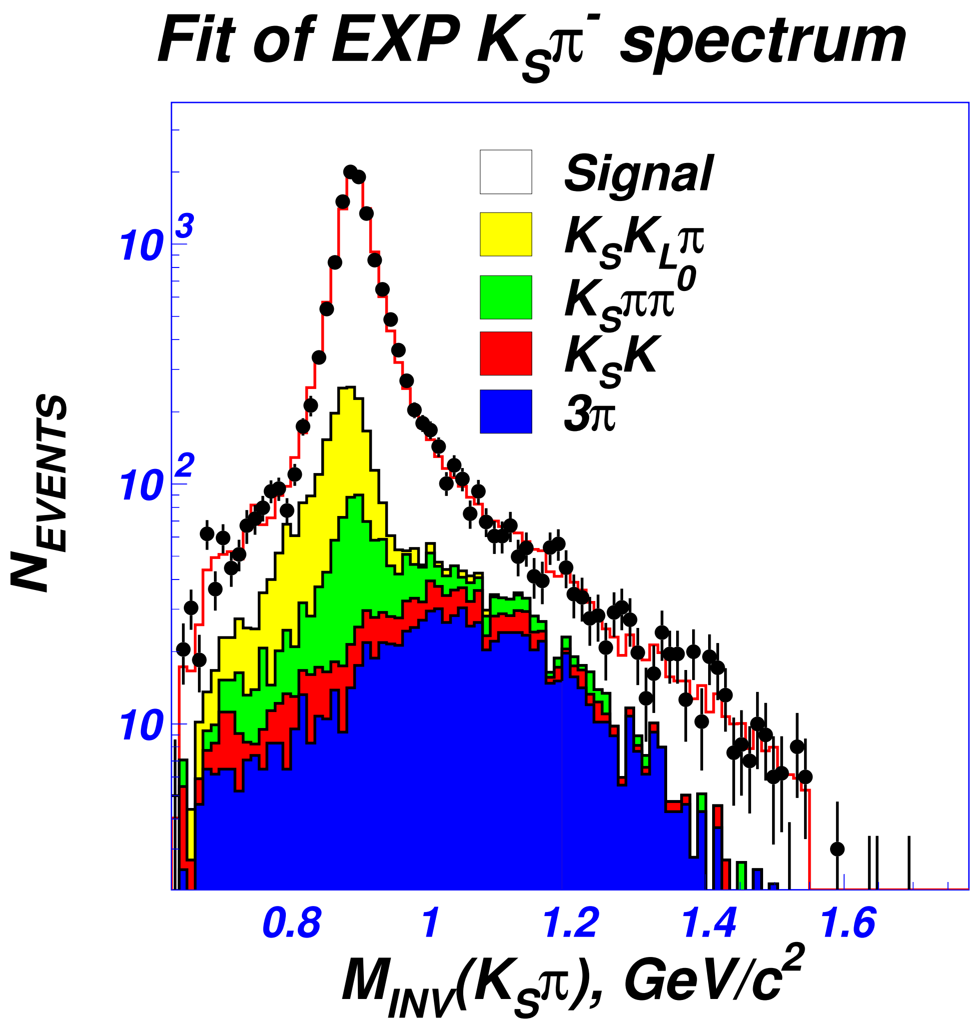


Efficiency nonuniformity, finite resolution were taken into account

LASS parameters are fixed



LASS parameters are free



	only-$K^\star(892)$	$K^\star(892) + A_{LASS} +$ $+ K_0^*(1430)$		$K^\star(892) + \kappa +$ $+ K^*(1410)$
$M_{K^\star(892)}$, MeV/c^2	895.6 ± 0.4	896.4 ± 0.4	896.1 ± 0.4	896.4 ± 0.4
$\Gamma_{K^\star(892)}$, MeV	48.2 ± 1.1	47.2 ± 1.2	48.3 ± 1.2	48.0 ± 1.1
$\lvert\beta\rvert$				0.039 ± 0.011
$arg(\beta)$				0.96 ± 0.55
$\lvert\gamma\rvert$		-2.8 ± 0.3	$-0.5 \pm {}^{0.2}_{0.5}$	
$arg(\gamma)$		1.3 ± 0.3	$1.9 \pm {}^{1.0}_{1.8}$	
$\lvert\kappa\rvert$				0.53 ± 0.08
$\lvert\delta_{LASS}\rvert$		0.81 ± 0.07	0.40 ± 0.03	
$arg(\delta_{LASS})$		-2.1 ± 0.2	1.4 ± 0.5	
$a(LASS)$, $(Gev/c)^{-1}$		$2.07 - fixed$	$4.09 \pm {}^{1.21}_{0.84}$	
$b(LASS)$, $(Gev/c)^{-1}$		$3.32 - fixed$	-21.4 ± 4.3	
χ^2/ndf	$282.8/76$	$176.0/72$	$122.5/72$	$122.5/72$

Our $K^*(892)$ mass differs from the PDG value $M_{K*} = 891.66 \pm 0.26$, the last is dominated by measurements in experiments with hadronic environment.

Conclusion

I. The branching fraction of the $\tau \to K_S \pi \nu$ decay has been measured using a data sample of 351.4 fb^{-1} collected with the Belle detector. Our result:

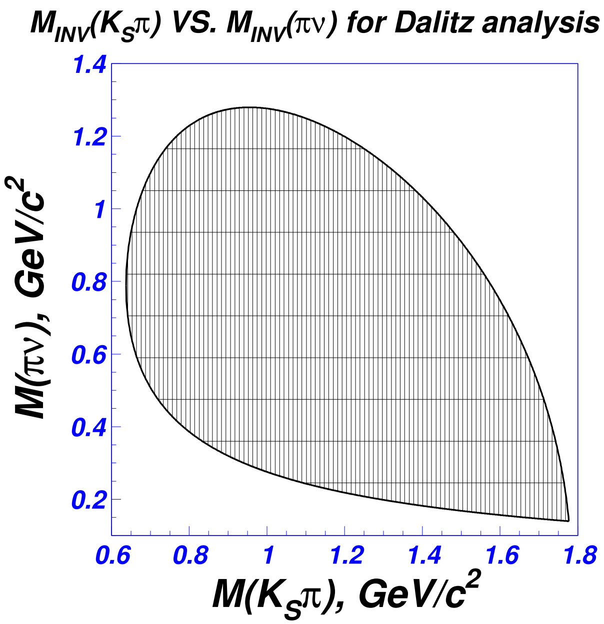
$$Br(\tau \to K_S \pi \nu_\tau) = (0.391 \pm 0.004_{stat} \pm 0.014_{syst})\%$$

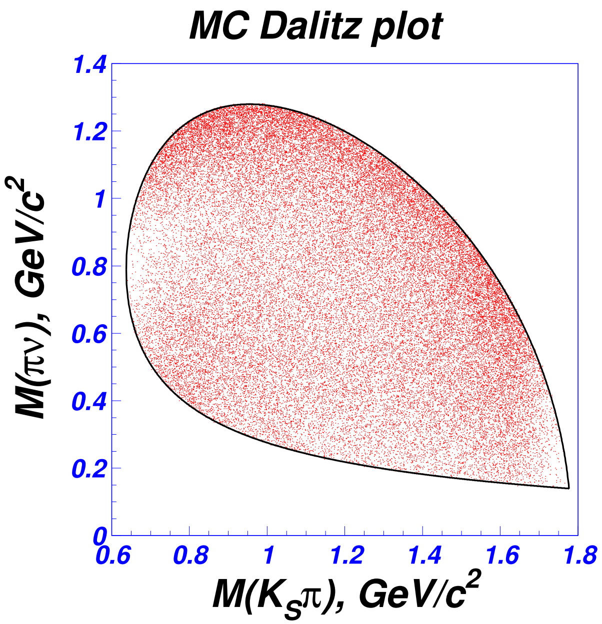
is in good agreement with the CLEO96 and ALEPH98 values and has a significantly smaller uncertainty, however, we observe $\sim 2\sigma$ difference between ALEPH99,OPAL00 values and our result.

II. Only $K^\star(892)$ is not enough to describe $K_S\pi$ invariant mass spectrum. We tried to use several parametrizations, but still have not found proper description.
A better model is needed.

III. The results shown today are preliminary. Work on the branching fraction and $K_S\pi$ mass spectrum is on-going.

Backup slides





The detector apparatus function is taken into account by 100×1000 efficiency matrix:

$$\varepsilon_{ij}(MC) = \frac{N_i(reconstructed)}{N_j(generated)}, \;\; i = 1 \div 100, \;\; j = 1 \div 1000$$

$$\chi^2 = \sum_{bins} \frac{(N_i - \varepsilon_{ij}(MC)N_j(model))^2}{N_i + \sigma^2}$$

$$N_j(model) = \int_j \frac{d\Gamma}{dm_{12}dm_{23}} dm_{12}dm_{23}$$

CP violating asymmetry

I.I.Bigi, A.I.Sanda, Phys. Let. B **625**, 47 (2005)

A known CP violation in neutral kaon decays induces asymmetry in τ decays with K_S:

$$A_{CP} = \frac{\Gamma(\tau^+ \to K_S \pi^+ \bar{\nu}) - \Gamma(\tau^- \to K_S \pi^- \nu)}{\Gamma(\tau^+ \to K_S \pi^+ \bar{\nu}) + \Gamma(\tau^- \to K_S \pi^- \nu)} = (3.27 \pm 0.12) \times 10^{-3}$$

$$A_{CP} = (7 \pm 5) \times 10^{-3}$$