τ-decays at Belle

On Behalf of Belle Collaboration

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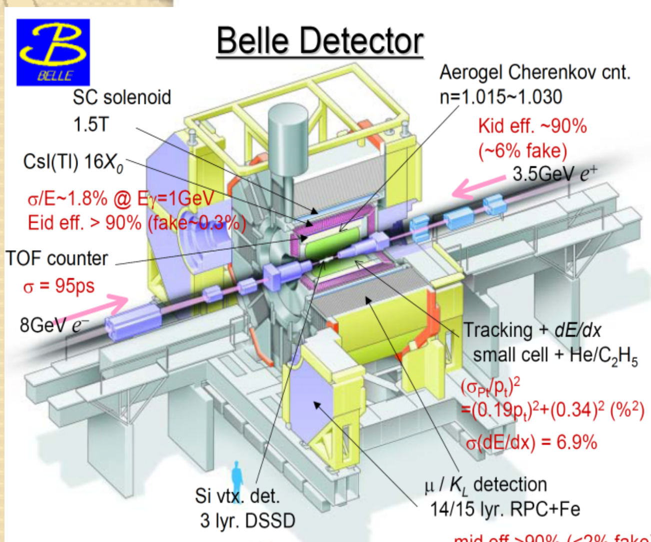
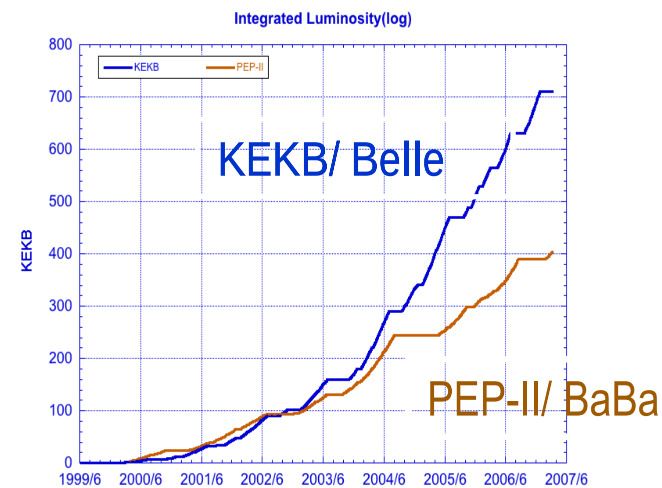




1. $\tau^- \rightarrow K_S\pi^-\nu_\tau$ **study**

- **Branching ratio**
- **Mass spectrum (vector & scalar FF: mass & width)**

2. $\tau^- \rightarrow K^-\eta\nu$, $K^-\pi^0\eta\nu$ ($K^{*-}\eta\nu$), **and** $\pi^-\pi^0\eta\nu$ **study**

- **Branching fractions**
- **(mass spectrum)**

A large amount of data samples would provide us more precise QCD information in low energy region.

1. $\tau^- \rightarrow K_S \pi^- \nu_\tau$ study

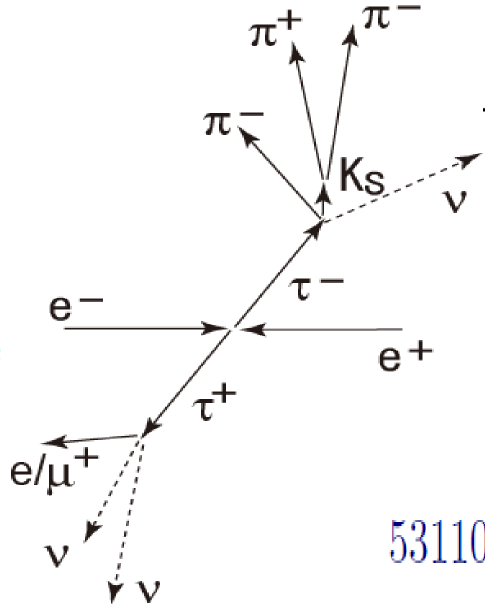
Largest Br among decays with a K, so it makes dominant contribution to the s-quark mass sensitive total strange hadronic spectrum function.

Mode	Contents, %
$\tau \rightarrow K_S \pi \nu$	79
$\tau \rightarrow K_S \pi K_L \nu$	9
$\tau \rightarrow K_S \pi \pi^0 \nu$	4
$\tau \rightarrow K_S K \nu$	2
$\tau \rightarrow 3\pi \nu$	5
non-$\tau\tau$	1

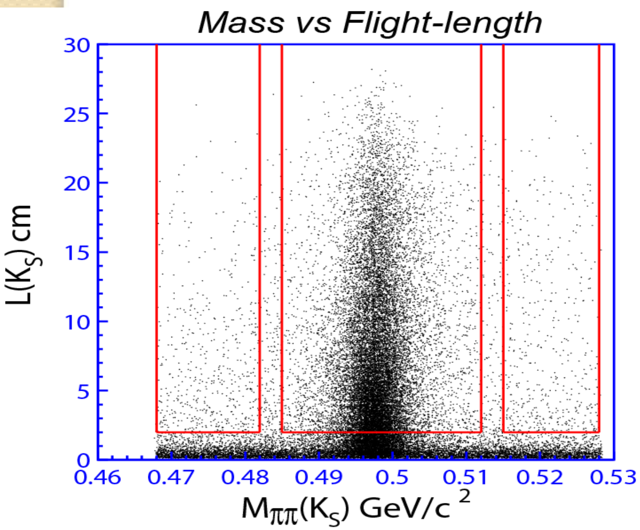
1-1 Events selections

For the K_S candidate:

- $\Delta Z_{1,2} < 1.5$ cm
- $cos(\vec{P}_\perp, \vec{r}_\perp) \geq 0.95$
- $L_{K_S} > 2$ cm
- $485 < M_{\pi\pi}(K_S) < 512$ MeV/c^2



351/fb, 310 M $\tau\tau$–pairs



53110 signal events ($\varepsilon_{det} \simeq 6\%$)

	$(e^+, K_S\pi^-)$	$(e^-, K_S\pi^+)$	$(\mu^+, K_S\pi^-)$	$(\mu^-, K_S\pi^+)$
N_{exp}	13336 ± 137	13308 ± 137	13230 ± 134	13236 ± 134
$\varepsilon(l, K_S\pi)$, %	5.70 ± 0.02	5.58 ± 0.02	5.95 ± 0.02	5.89 ± 0.02

1-2 Branching fraction $B(\tau \to K_S\pi^-\nu_\tau)$

Two lepton (e,μ) events are used for normalization.

$$\mathcal{B}(K_S\pi^\mp\nu_\tau) = \frac{N(l_1^\pm, K_S\pi^\mp)}{N(l_1^\pm, l_2^\mp)} \cdot \frac{\varepsilon(l_1^\pm, l_2^\mp)}{\varepsilon(l_1^\pm, K_S\pi^\mp)} \cdot \mathcal{B}(l_2^\mp\nu_l\nu_\tau), \quad l_{1,2} = e, \mu$$

To cancel systematic errors, relating evaluations of luminosity and σ(ττ), and track reconstruction eff.

→ Uncertainty of 3.4% is reduced.

Source of the syst. error	Contribution,%
K_S detection efficiency	2.5
$\tau^+\tau^-$ background subtraction	1.6
$\sum E_\gamma^{LAB}$	1.0
Lepton identification efficiency	0.8
Pion momentum	0.5
Non-$\tau^+\tau^-$ background subtraction	0.3
$\mathcal{B}(l\nu_l\nu_\tau)$	0.3
$\frac{\varepsilon(l_1,l_2)}{\varepsilon(l_1,K_S\pi)}$	0.2
K_S momentum	0.2
Pion identification efficiency	0.1
Total	3.3

$$\mathcal{B}(\tau^- \to K_S\pi^-\nu_\tau) = (0.404 \pm 0.002_{\rm stat} \pm 0.013_{\rm syst})\%$$

$$B(\tau^- \to \overline{K}^0\pi^-\nu) = 2.0\mathrm{x}B(\tau^- \to K_S{}^0\pi^-\nu)$$
$$= 0.808 \pm 0.004(\mathrm{stat.}) \pm 0.026(\mathrm{syst.})\ \%$$

PDG : $B(\tau^- \to \overline{K}^0\pi^-\nu) = (0.90 \pm 0.04)\ \%$

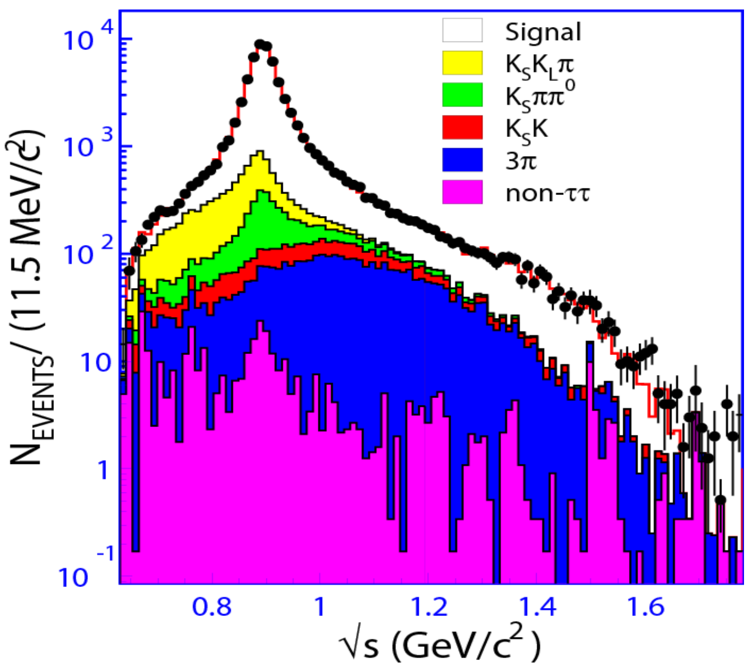
The statistical uncertainty achieved to a half a %, but the systematic is about 3%, dominated by uncertainties of Ks detection and BG subtraction.

1-3 $K_S\pi^-$ mass spectrum

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

$$F_V = \frac{BW_{K^*(892)} + a(K^*(1410))\cdot BW_{K^*(1410)} + a(K^*(1680))\cdot BW_{K^*(1680)}}{1 + a(K^*(1410)) + a(K^*(1680))}$$

$$F_S = a(K_0^*(800))\cdot BW_{K_0^*(800)} + a(K_0^*(1430))\cdot BW_{K_0^*(1430)} + a(LASS)\cdot \mathcal{A}_{LASS}$$



$K_0^*(800) + K^*(892) + K^*(1410)$ model	
$M_{K^*(892)}$	$= 895.47 \pm 0.20\ \mathrm{MeV}/c^2$
$\Gamma_{K^*(892)}$	$= 46.19 \pm 0.57\ \mathrm{MeV}$
$\lvert a(K^*(1410))\rvert$	$= (75 \pm 6) \times 10^{-3}$
$\arg(a(K^*(1410)))$	$= 1.44 \pm 0.15$
$\lvert a(K_0^*(800))\rvert$	$= 1.57 \pm 0.23$
$\chi^2/\mathrm{n.d.f.} = 90.2/84,\ P(\chi^2) = 30\%$	

Best fit is achieved in $K^*_0(800)$+$K^*(892)$+$K^*(1410)$/ $K^*_0(1430)$ but not $K^*(892)$ alone.

1-4 K*(892) mass & width

$$M(K^*(892)^-) = 895.47 \pm 0.20(\text{stat.}) \pm 0.44(\text{syst.}) \pm 0.59(\text{mod.}) \quad \text{MeV}/c^2$$
$$\Gamma(K^*(892)^-) = 42.2 \pm 0.6(\text{stat.}) \pm 1.0(\text{syst.}) \pm 0.7(\text{mod.}) \quad \text{MeV}$$

	$M(K^*(892)^-)$, MeV/c^2	$\Gamma(K^*(892)^-)$, MeV	Comments
ALEPH	895 ± 2	55 ± 8	$K^-\pi^0$, syst. errors not est.
CLEO	896.4 ± 0.9		$K_S\pi^-$, syst. errors not est.
PDG $K^{*\pm}$ (K^{*0})	891.66 ± 0.26 (896.00 ± 0.25)	50.8 ± 0.9 (50.3 ± 0.6)	

2. $\tau \to K^- \eta \nu$, $K^- \pi^0 \eta \nu$ ($K^{*-} \eta \nu$), and $\pi^- \pi^0 \eta \nu$

Analyze τ-decay modes, involving an η,

Because of poor statistics, previous measurements have large uncertainty.

Data used are 485/fb (433M τ pairs), x ∼100 larger than previously.

Physics motivations

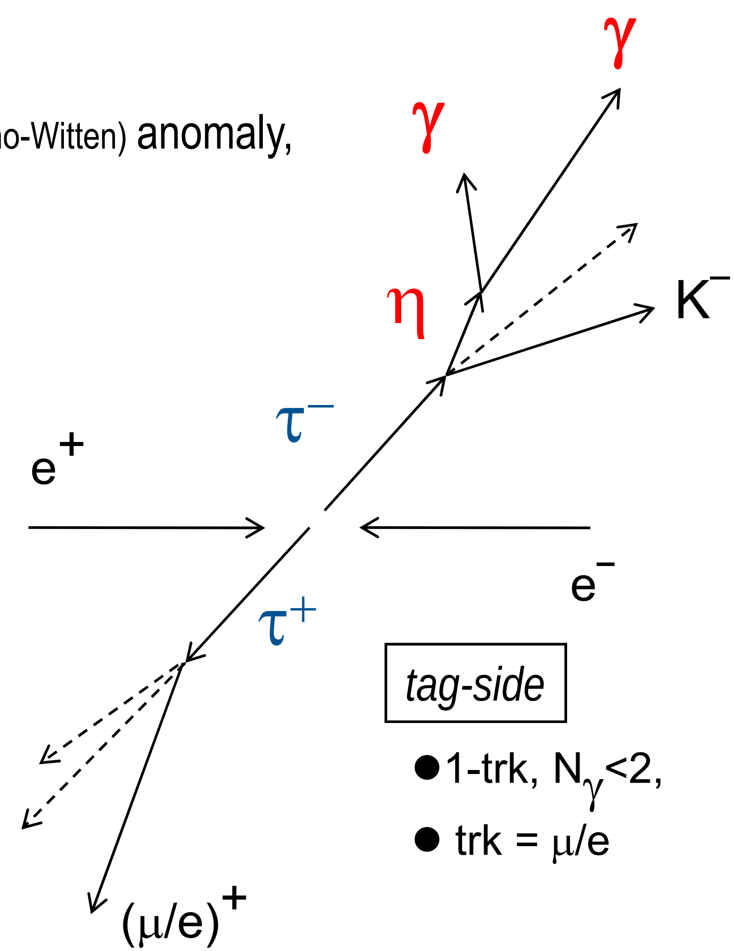
- CVC hypothesis,
- chiral Lagrangian approach with WZW (Wess-Zumino-Witten) anomaly,
- High mass resonance.

2-1 Event selection with $\eta \to \gamma\gamma$

sig-side

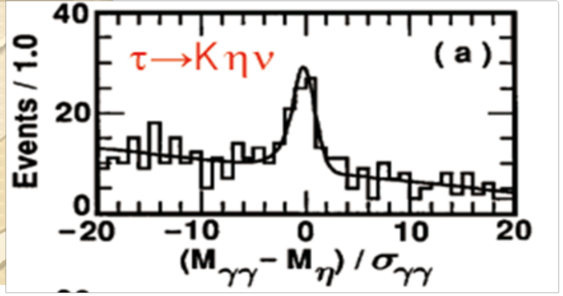
	$K\eta\nu$	$K\pi^0\eta\nu$	$\pi\pi^0\eta\nu$
●1-trk	K		π
●N_γ	2	4	
●2γ	η	η & π^0	

- $|V_{thrust}|>0.8$;
- $M_{sig}<M_\tau$; $M_{tag}<M_\tau$



tag-side

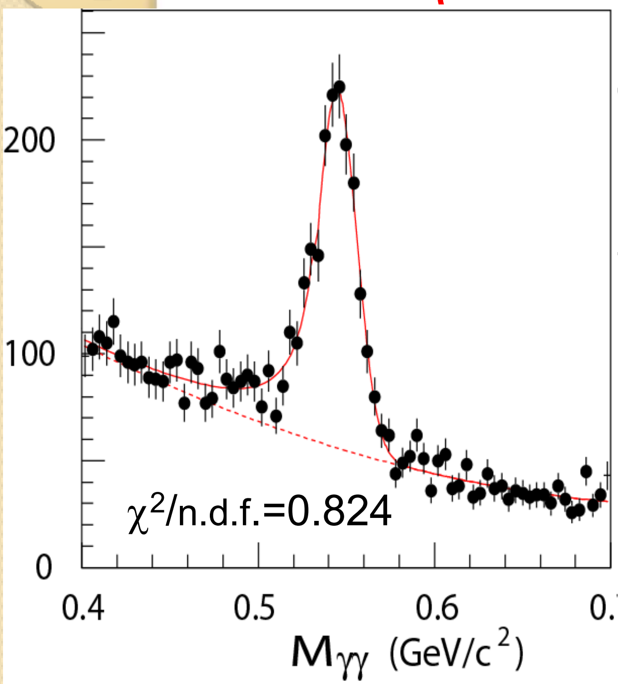
- 1-trk, N_γ<2,
- trk = μ/e



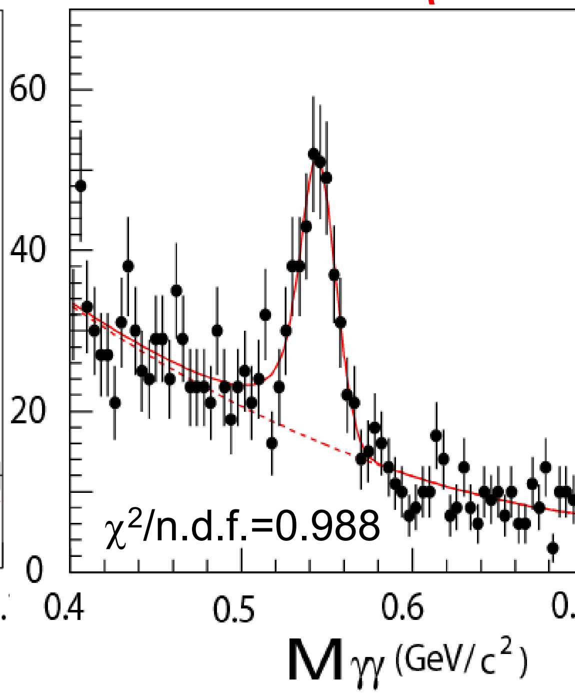
2-2 $\eta\to\gamma\gamma$ yield measurement

Fit data with (signal=Crystal Ball function + BG=second-order polynomial function)

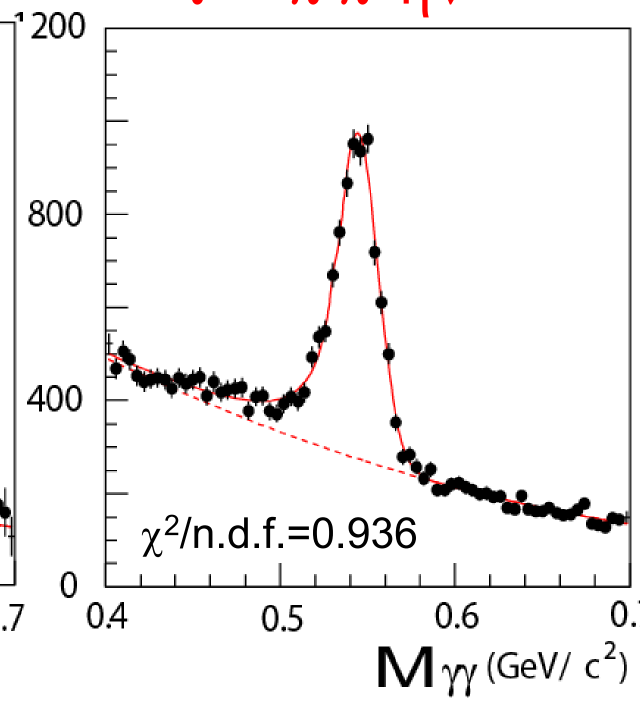
$\tau^-\to K^-\eta\nu$



$\tau^-\to K^-\pi^0\eta\nu$



$\tau^-\to \pi^-\pi^0\eta\nu$



	$K\eta\nu$	$K\pi^0\eta\nu$	$\pi\pi^0\eta\nu$
yields	1387 ± 44	270 ± 33	5959 ± 105
mass (MeV/c^2)	544.9 ± 0.6	544.4 ± 1.0	544.3 ± 0.4
resolution (MeV/c^2)	11.0 ± 0.6	10.7 ± 1.5	11.6 ± 0.3

2-3 Extract Branching fractions

Consider cross-feed among the decays,

$$N_{K\eta\nu} = 2N_{\tau\tau}\left(B_{K\eta\nu}\cdot\varepsilon^{K\eta\nu}_{K\eta\nu} + B_{K\pi^0\eta\nu}\cdot\varepsilon^{K\eta\nu}_{K\pi^0\eta\nu} + B_{\pi\pi^0\eta\nu}\cdot\varepsilon^{K\eta\nu}_{\pi\pi^0\eta\nu}\right)$$

$$N_{K\pi^0\eta\nu} = 2N_{\tau\tau}\left(B_{K\eta\nu}\cdot\varepsilon^{K\pi^0\eta\nu}_{K\eta\nu} + B_{K\pi^0\eta\nu}\cdot\varepsilon^{K\pi^0\eta\nu}_{K\pi^0\eta\nu} + B_{\pi\pi^0\eta\nu}\cdot\varepsilon^{K\pi\eta\nu}_{\pi\pi^0\eta\nu}\right)$$

$$N_{\pi\pi^0\eta\nu} = 2N_{\tau\tau}\left(B_{K\eta\nu}\cdot\varepsilon^{\pi\pi^0\eta\nu}_{K\eta\nu} + B_{K\pi^0\eta\nu}\cdot\varepsilon^{\pi\pi^0\eta\nu}_{K\pi^0\eta\nu} + B_{\pi\pi^0\eta\nu}\cdot\varepsilon^{\pi\pi^0\eta\nu}_{\pi\pi^0\eta\nu}\right)$$

(η-yield)-($q\bar{q}$+others)

Cross-feed rates

Detection efficiencies

Efficiencies (ε's) include $B(\eta \to \gamma\gamma)$.

Selection	$K\eta\nu$	$K\pi0\eta\nu$	$\pi\pi^0\eta\nu$
$K\eta\nu$	9.41×10^{-3}	3.71×10^{-4}	1.50×10^{-5}
$K\pi^0\eta\nu$	1.14×10^{-4}	3.46×10^{-3}	7.09×10^{-5}
$\pi\pi^0\eta\nu$	1.74×10^{-5}	2.32×10^{-4}	4.71×10^{-3}

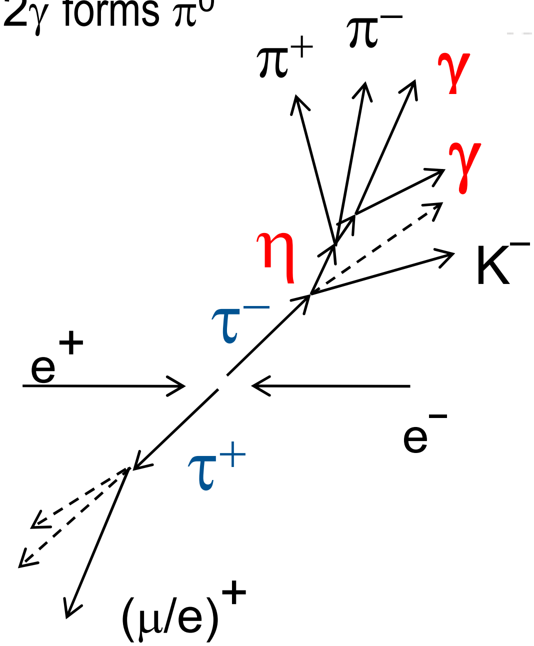
	η-yield	$q\bar{q}$	others	$K\eta\nu$	$K\pi^0\eta\nu$	$\pi\pi^0\eta\nu$
$K\eta\nu$	1387±43 (ev)	30.6±15.6	1.1±0.2		15.1±3.8	18.0±1.0
$K\pi^0\eta\nu$	270±33	27.0±8.5	1.2±0.4	16.0±0.9		85.3±4.6
$\pi\pi^0\eta\nu$	5959±105	212±29	71.6±20	2.4±0.1	9.4±2.4	

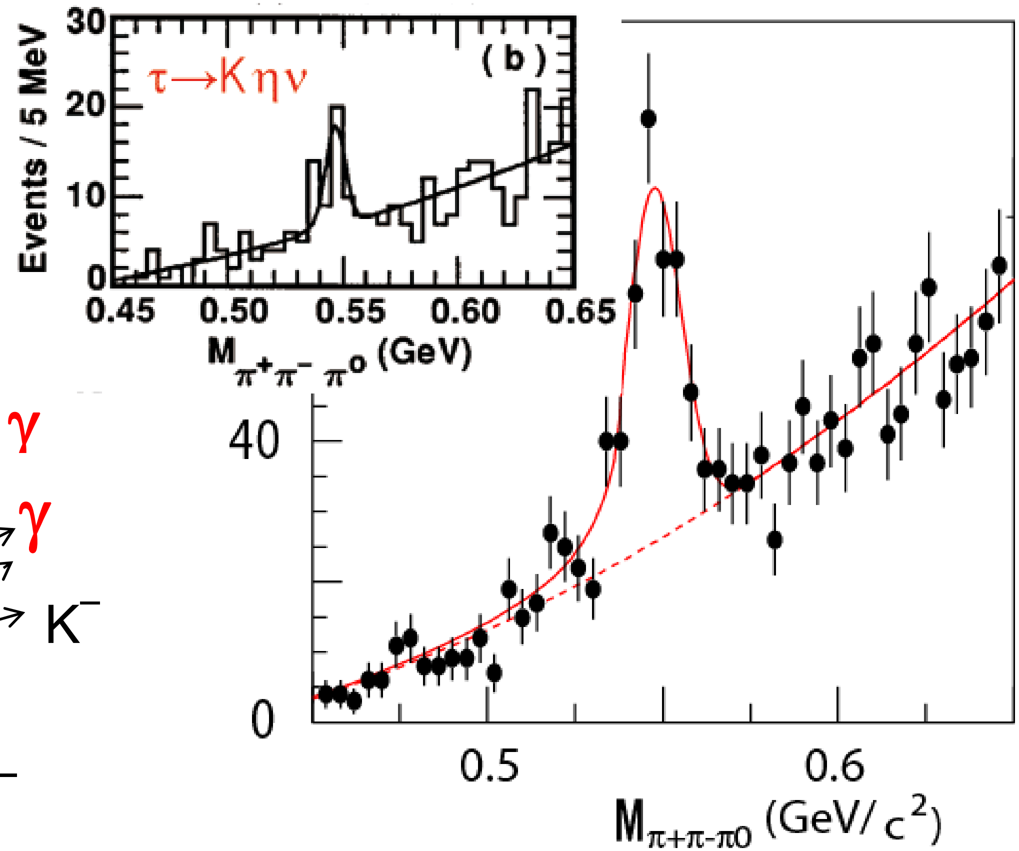
$\pi^-\pi^0\pi^0\eta\nu$, $\pi^-\pi^+\pi^-\eta\nu$

2-4 B($\tau^- \to K^- \eta \nu$) with $\eta \to \pi^+ \pi^- \pi^0$

- 3-trk & Nγ=2
- 1-trk = K
- 2γ forms π^0

sig-side





	result of fitting
yield	241±21
mass (MeV/c^2)	547.4±0.7
resolution(MeV/c^2)	7.5±0.4

Efficiencies (ε's) include B($\eta \to \pi\pi\pi$).

	η-yield	$q\bar{q}$	others	$K\eta\nu$	$K\pi^0\eta\nu$	$\pi\pi^0\eta\nu$
ε's				1.56×10^{-3}	8.18×10^{-5}	4.82×10^{-6}
$K\eta\nu$	241±21 (ev)	9.1±2.2	<1.18		3.3±0.8	5.8±1.3

2-5 Systematic uncertainties (%)

	$K\eta\nu$ ($\eta\to\gamma\gamma$)	$K\eta\nu$ ($\eta\to\pi\pi\pi$)	$K\pi^0\eta\nu$	$\pi\pi^0\eta\nu$
contaminations of $K\eta\nu$	–	–	0.6	0.0018
contaminations of $K\pi^0\eta\nu$	0.3	0.4	–	0.042
contaminations of $\pi\pi^0\eta\nu$	0.075	0.1	3.3	–
contaminations of $\pi\pi^0\pi^0\eta\nu$	–	–	–	0.4
contaminations of qq	1.5	1.5	6.0	0.5
K/p ID	3.3	2.8	2.2	1.0
lepton ID	2.3	2.6	2.8	2.6
tracking	1.3	3.3	1.3	1.3
luminosity	1.6	1.6	1.6	1.6
π^0 detection	–	2.0	2.0	2.0
π^0 veto	2.8	–	2.8	2.8
signal MC	0.5	1.3	1.7	0.7
$B(\eta\to\pi^-\pi^+\pi^0)$	–	1.8	–	–
Total	5.6	6.1	8.9	5.0

2-6 Branching fractions

	Our results
$K^-\eta\nu$ ($\eta\to\gamma\gamma$)	$(1.61\pm0.05\pm0.09)\times10^{-4}$
$K^-\eta\nu$ ($\eta\to\pi^-\pi^+\pi^0$)	$(1.65\pm0.16\pm0.10)\times10^{-4}$
$K^-\eta\nu$ combined	$(1.62\pm0.10)\times10^{-4}$
$K^-\pi^0\eta\nu$	$(4.7\pm1.1\pm0.4)\times10^{-5}$
$\pi^-\pi^0\eta\nu$	$(1.39\pm0.03\pm0.07)\times10^{-3}$

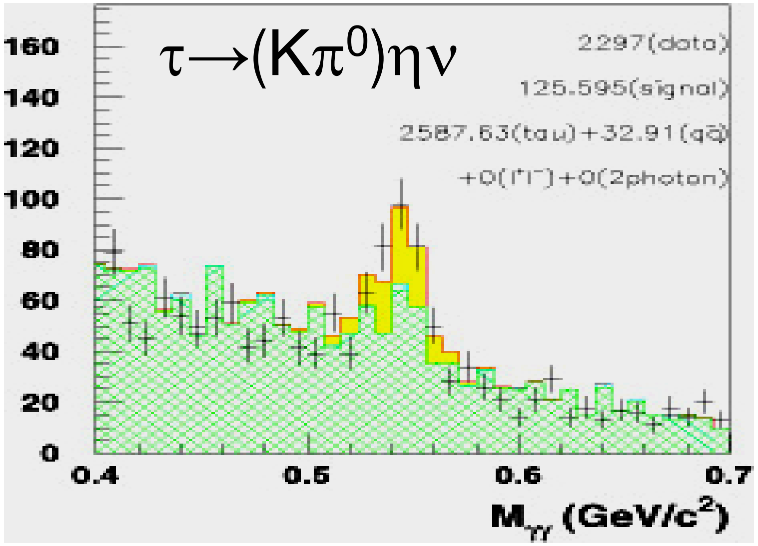
2-7 $\tau^- \to K(892)^{*-}\eta\nu$ analysis

With use of $\tau \to K\pi^0\eta\nu$ samples,

- Signal-band:0.50 < $M_{\gamma\gamma}$ < 0.58 (GeV/c^2)
- Side-bands: 0.43<$M_{\gamma\gamma}$<0.48, 0.60<$M_{\gamma\gamma}$< 0.65

(lower and higher sides show a same $M_{K\pi^0}$ dist.)

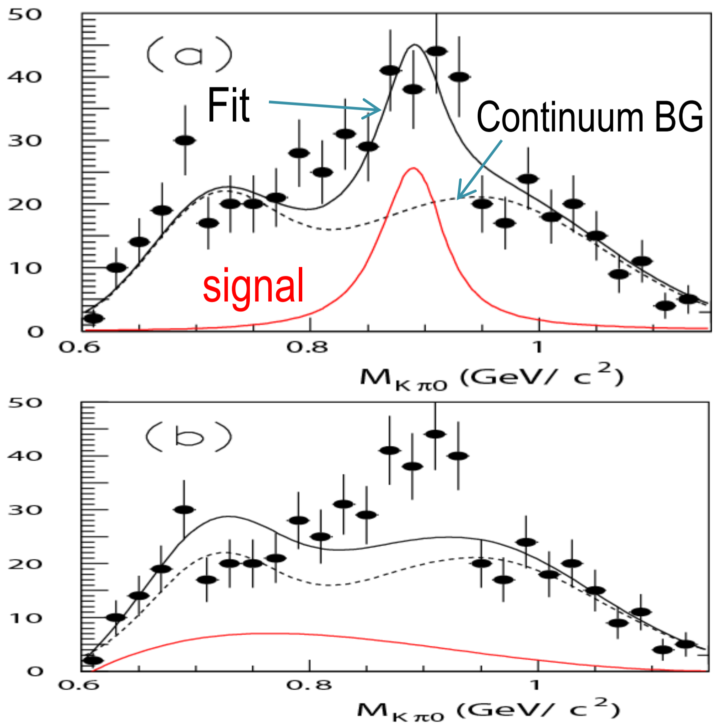
- Continuum BG estimated from side-bands.
- $K(892)^{*-}$ peaking BG estimated by MC: $\tau \to \pi\pi^0\eta\nu$, $\tau \to K(892)^{*-}\nu$ and $q\bar{q}$



2-8 $K^{*-}(892)$ yields

- Fit data with
  (a) K^{*-} resonance (BW) + BG,
  (b) V-A phase-space dist. + BG,
- Continuum (dashed curve):
  χ^2/n.d.f.=1.061, N_{BG}=427±21 events
- No significant contribution from non-resonant comp.
  Therefore, we take (a).

	N_{K*}	N_{phase}	χ^2/dof.	prob.
(a)	119±19	—	1.154	0.265
(b)	—	102±21	2.088	0.0008



No significant non-resonance component is found,
so we consider the final state to be purely K*+eta.

2-9 Branching fraction

$B(K^{*-}\eta\nu)=$

$(1.10\pm0.19\pm0.07)\times10^{-4}$

Systematic errors

	error (%)
peaking BG ($\tau\tau$)	0.94
peaking BG (qq)	2.4
K/π ID	2.2
lepton ID	2.5
tracking	1.3
luminosity	1.6
π^0 detection	2.0
π^0 veto	2.8
Signal MC	1.7
Total	6.1

Efficiency (ε) include $B(K^{*-}\to K^-\pi^0)=0.333$, $B(\eta\to\gamma\gamma)=0.394$, and $B(\tau\to l\nu\nu)=0.352$.

Efficiency (%)	K^{*-} yields	$K^{*-}\nu$ BG	qq BG
0.115	119±19	2.3±0.9	6.5±2.3

3 Summary

preliminary

- Ksπ^- mass spectrum is very well represented, including $K_0^*(800)^-$ and $K^*(1410)^-$ resonances along with $K^*(892)^-$.
- Highly precise $B(\tau^-\to K^0\pi^-\nu)$ measurement is performed.
- High statistical measurement results in different values on Br, M and Γ, compared to PDG07. Need more study.

	Our results	PDG-2007
$B(\tau^-\to \bar{K}^0\pi^-\nu)$	(0.808±0.004±0.026) %	(0.90±0.04) %
$M(K^*(892)^-)$	(895.47±0.20±0.44±0.59) MeV	(891.66±0.26) MeV
$\Gamma(K^*(892)^-)$	(46.2±0.6±1.0±0.7) MeV	(50.8±0.9) MeV

	$M(K^*(892)^-)$, MeV/c^2	$\Gamma(K^*(892)^-)$, MeV	Comments
ALEPH	895 ± 2	55 ± 8	$K^-\pi^0$, syst. errors not est.
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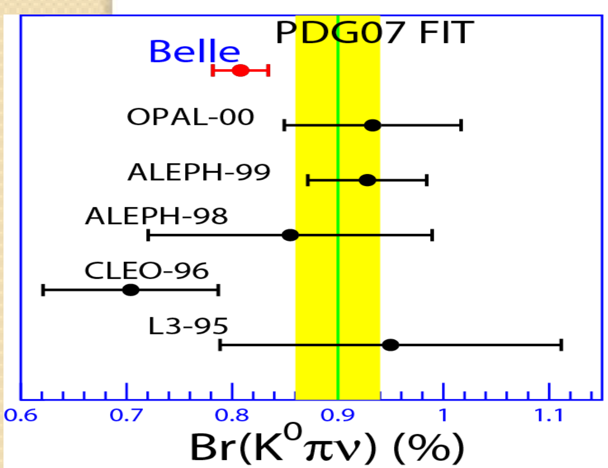

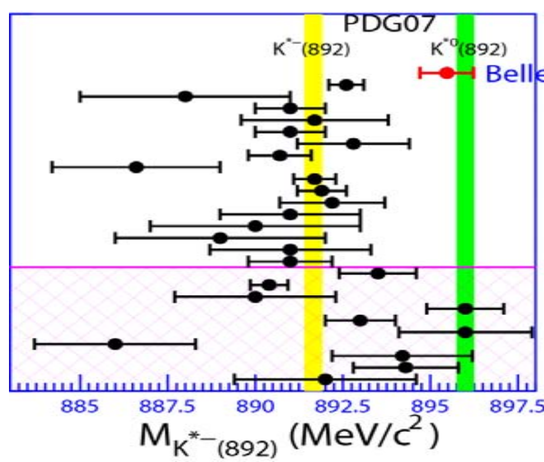

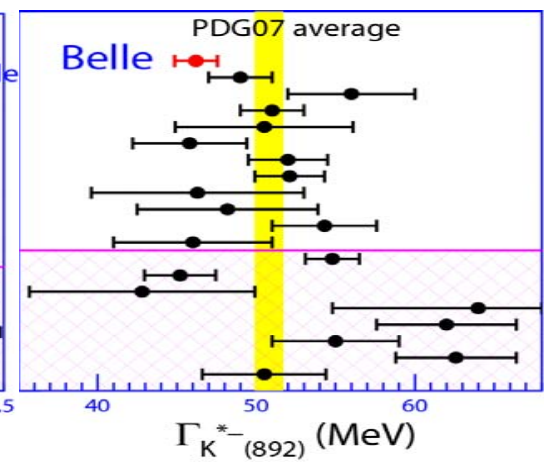

3 Summary

preliminary

- Precise $B(\tau^- \to K^- \eta\nu;\ K^-\pi^0\eta\nu;\ K^{*-}\eta\nu;\ \pi^-\pi^0\eta\nu)$ measurements largely improve PDG07 data.
- $B(\tau^- \to \pi^-\pi^0\eta\nu)$ agrees with a CVC calculation, $1.3\text{x}10^{-3}$ by Eidelman.
- Systematic theoretical study is awaited, along with new data, presented here and about other decay modes being analyzed.

Not only these data, presented here, but also others of different decay-modes, being analyzed, will be reported, soon from Belle.
So, it is now time to carry out revised theoretical studies on hadronic QCD system.

	Our results	PDG-2007
$B(\tau^- \to K^- \eta\nu)$	$(1.62 \pm 0.10) \times 10^{-4}$	$(2.7 \pm 0.6) \times 10^{-4}$
$B(\tau^- \to K^- \pi^0 \eta\nu)$	$(0.47 \pm 0.11 \pm 0.04) \times 10^{-4}$	$(1.8 \pm 0.9) \times 10^{-4}$
$B(\tau^- \to K*(892)^- \eta\nu)$	$(1.10 \pm 0.19 \pm 0.07) \times 10^{-4}$	$(2.9 \pm 0.9) \times 10^{-4}$
$B(\tau^- \to \pi^- \pi^0 \eta\nu)$	$(1.39 \pm 0.03 \pm 0.07) \times 10^{-3}$	$(1.77 \pm 0.24) \times 10^{-3}$