Study of $\tau \to K^{*0} K \nu$ and $\tau \to \eta + X$ Decay at Belle

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PhiPsi08

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Belle collaboration
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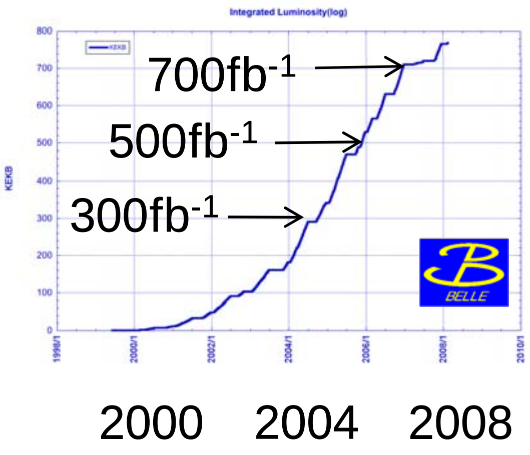
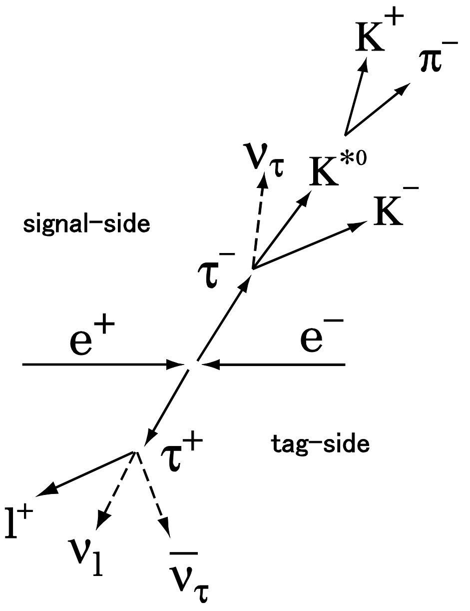
Introduction



- Belle detector has collected the τ-pair data with the highest statistics in the world.

  At the present, about 800fb^{-1} of data has collected. It corresponds to 7.0×10^8 τ-pairs!

- τ hadronic decay from $e^+e^- \to \tau^+\tau^-$ process is very clean.
- τ hadronic decay is good for studying low energy QCD phenomena.



By using $\tau \to K^{*0}K\nu$ and $\tau \to \eta + X$,
we can test VMD and CVC with high accuracy.
(using $M_{KK\pi}$, $M_{\pi\pi 0}$ and $M_{\pi\pi 0\eta}$ distributions)

We report on $Br(\tau \to K^{*0}K\nu)$, $Br(\tau \to \eta + X)$, M_{K*0} and Γ_{K*0} measurement.

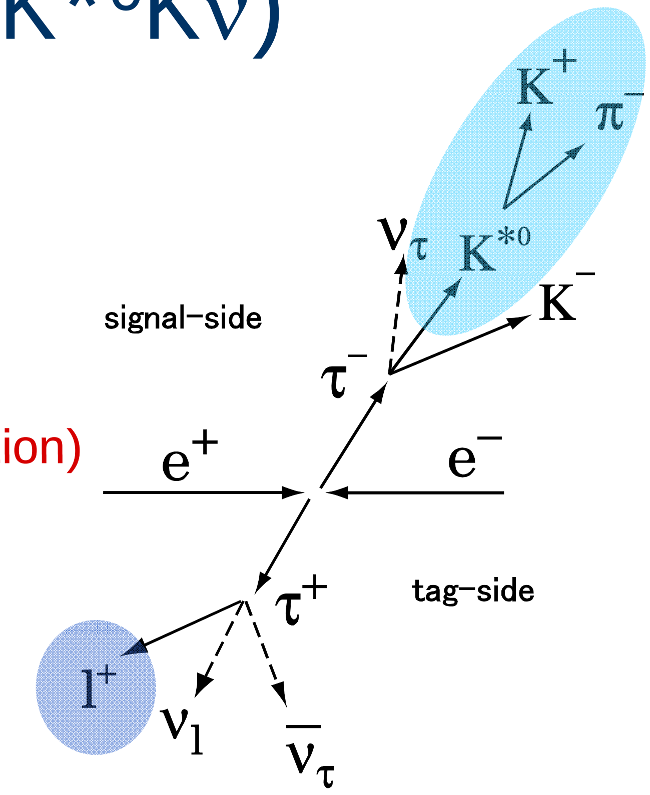
Study of
$\tau \to K^{*0} K \nu$ Decay

Event selection ($\tau \to K^{*0} K \nu$)

Data set : 5×10^8 τ–pairs($545 fb^{-1}$)

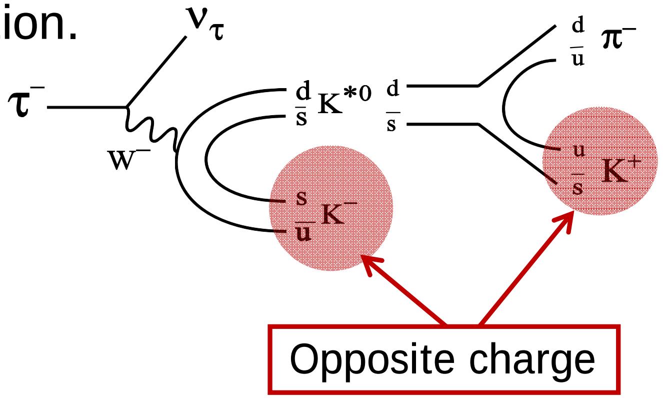
- select 1-3 prong event (divided by thrust vector)
  (3 prong side=signal side/ 1 prong side=tag side)
- Select $\tau \to KK\pi\nu$ for signal event(K-ID,π-ID)
- K^{*0} is reconstructed from only charged K and π.
- Correct charge assignments(strangeness conservation)
- Require $\tau \to e\nu\nu / \mu\nu\nu$ events for tag-side(35%)
  (suppress $q\bar{q}$ events: $q\bar{q}$ process contains many K^{*0})
- Select τ-pair events
  - $M_{\text{signal-side}} < 1.8 GeV/c^2$
  - τ decay including $\nu(p_{\text{miss}}, \cos\theta_{\text{miss}})$
- others ($P_{K^{*0}K}$,$\cos\theta(K^{*0}\text{-}K)^{CM}$ etc.)

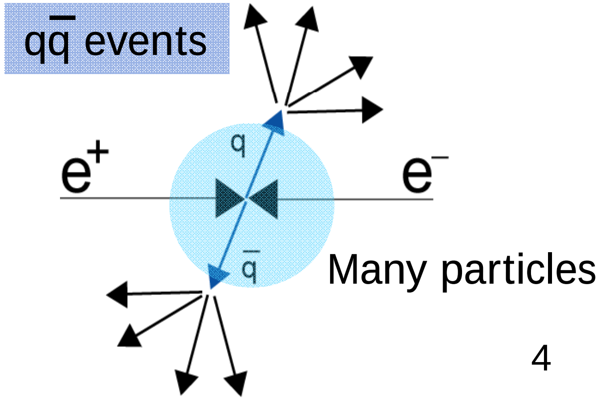
We estimate the number of signal events
from $K\pi$ mass distribution.



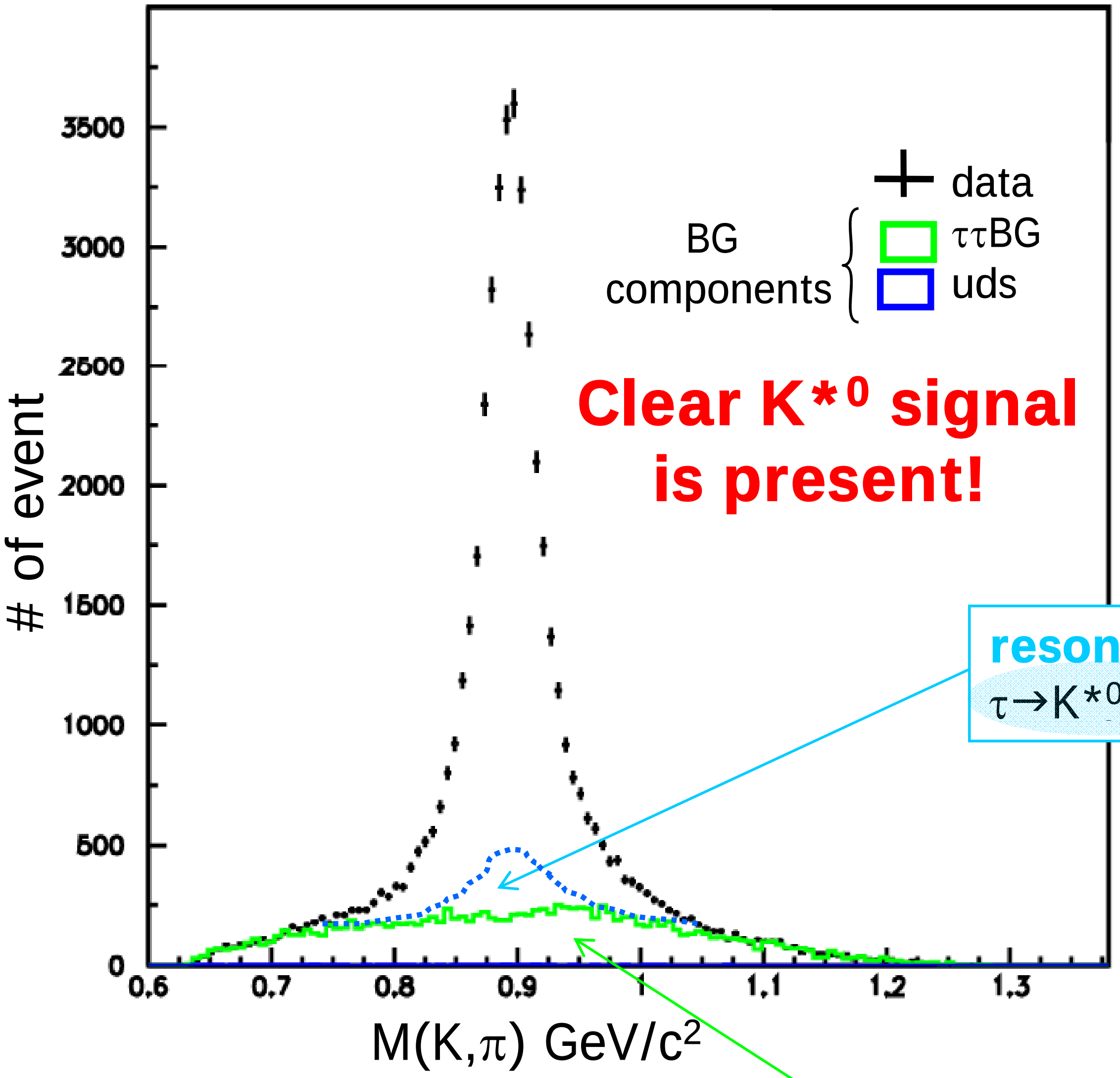
<decay modes of K^{*0}>

$K\pi$	∼100%
$K^+\pi^-$	2/3
$K^0\pi^0$	1/3





$M_{K\pi}$ after all selection



Clear K^{*0} signal is present!

- $N_{data}=5.10\times10^4$
  We obtained a large number of data events.
- $eff_{sig}=2.15\%$
  reasonably good

resonant BG mode
$\tau\to K^{*0}K\pi^0\nu$/qq(negligible)

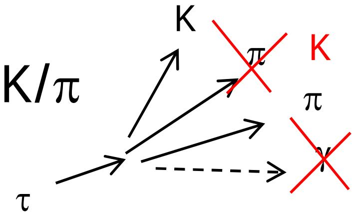
$Br(\tau\to K^{*0}K\pi^0\nu)$ has not been measured yet.→ We measure it!

80% of all BG

non-resonant BG mode
$\tau\to KK\pi n\pi^0\nu/K\pi\pi n\pi^0\nu/\pi\pi\pi n\pi^0\nu/KKKn\pi^0\nu$

We distinguish non-resonant $\tau\to KK\pi\nu$ mode from resonant $\tau\to K^{*0}K\nu$ mode (signal) by making K^{*0} peak or not.

Non-resonant **BG** mode ($\tau \to K\pi\pi n\pi^0\nu, \pi\pi\pi n\pi^0\nu$)



$K\pi\pi n\pi^0\nu, \pi\pi\pi n\pi^0\nu$ components remain because of mis K/π identification(π as K).

Change particle identification for **h1**

signal

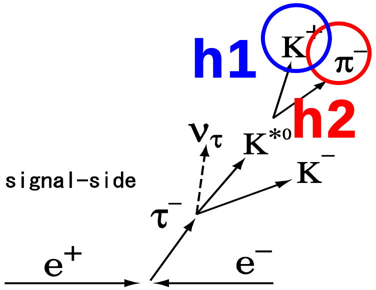
K **K** π selection

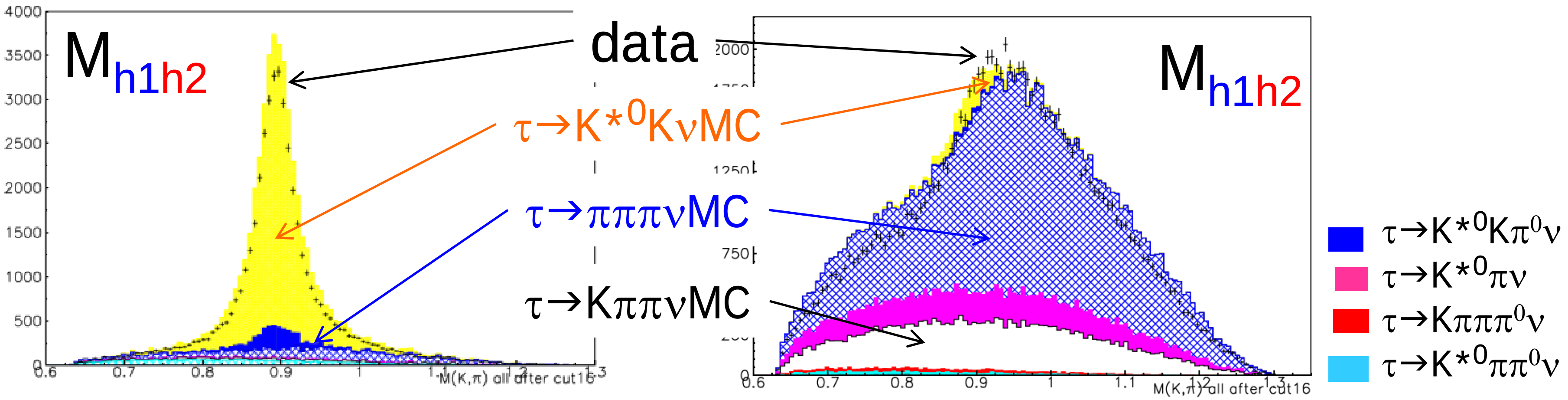
(K-ID$_{h1}$>0.8 , π-ID$_{h2}$>0.8)

BG

K π π selection

(K-ID$_{h1}$<0.2 , π-ID$_{h2}$>0.8)



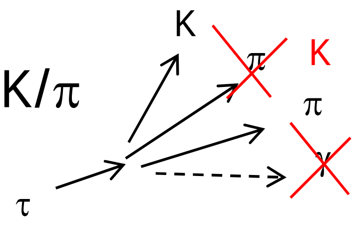


We obtain enriched BG samples

We obtain enriched BG samples by changing the selection criteria for P-ID(K to π), and estimate the contribution from $K\pi\pi n\pi^0\nu, \pi\pi\pi n\pi^0\nu$ to $K^{*0}K\nu$.

Non-resonant **BG** mode ($\tau \to K\pi\pi n\pi^0\nu, \pi\pi\pi n\pi^0\nu$)

$K\pi\pi n\pi^0\nu, \pi\pi\pi n\pi^0\nu$ components remain because of mis K/π identification(π as K).



Change particle identification for **h1**

signal

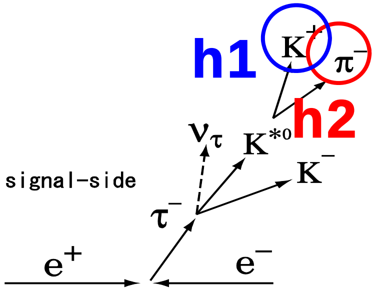
K K π selection

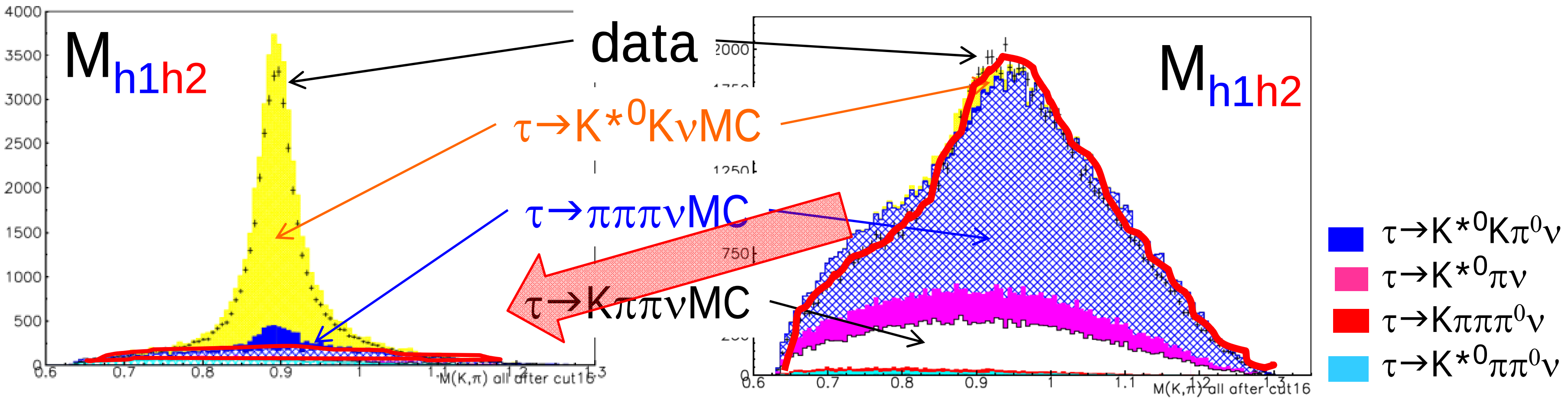
(K-ID$_{h1}$>0.8 , π-ID$_{h2}$>0.8)

BG

K π π selection

(K-ID$_{h1}$<0.2 , π-ID$_{h2}$>0.8)

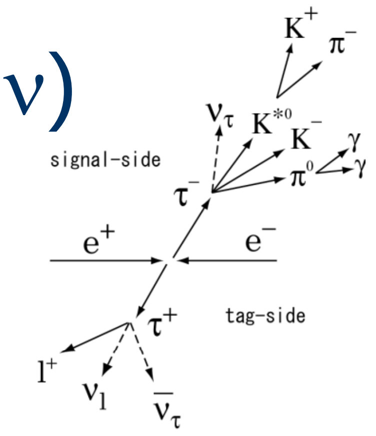




We obtain enriched BG samples

We obtain enriched BG samples by changing the selection criteria for P-ID(K to π), and estimate the contribution from $K\pi\pi n\pi^0\nu, \pi\pi\pi n\pi^0\nu$ to $K^{*0}K\nu$.

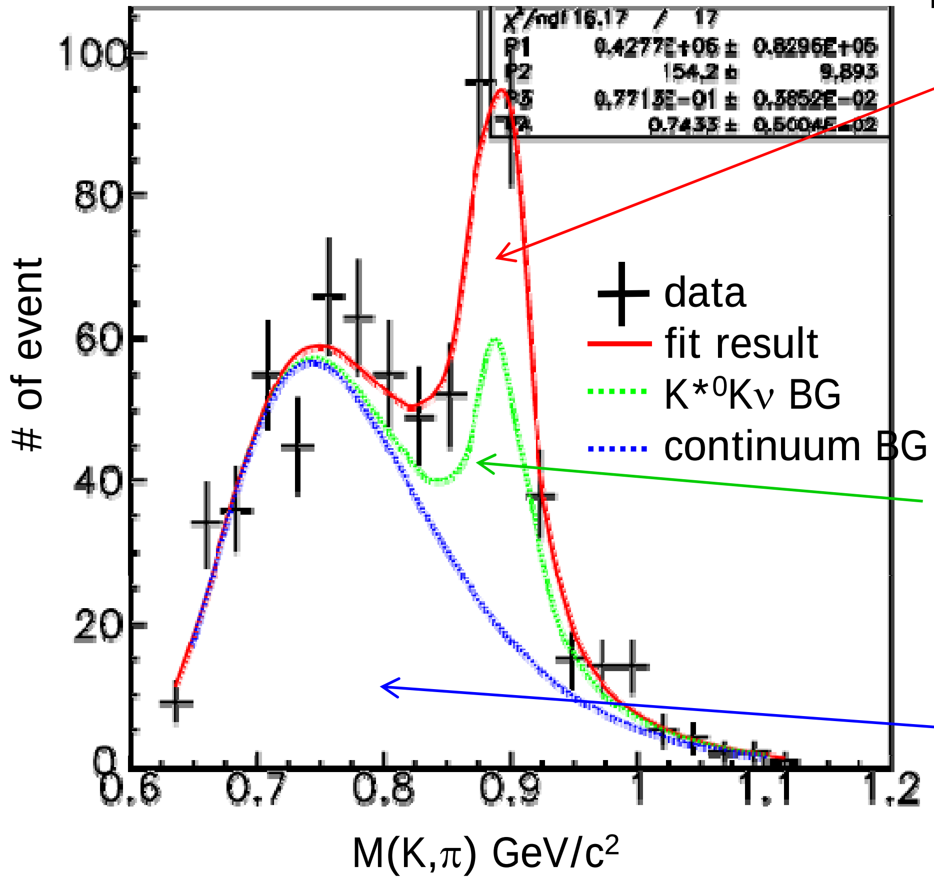
Resonant **BG** mode($\tau \to K^{*0} K \pi^0 \nu$)



$\tau \to K^{*0} K \pi^0 \nu$ Br has not been measured yet.
⇨ Measure the Br and evaluate the contamination for $\tau \to K^{*0} K \nu$.

Selection criteria are almost same as those of $\tau \to K^{*0} K \nu$ mode.

- require $N\gamma=2$ for signal side , $M\pi^0$ region



function: BW($K^{*0} K \pi^0 \nu + K^{*0} K \nu$BG)+ Landau

- \# of signal($K^{*0} K \pi^0 \nu$)

$N_{K^{*0}}^{K^{*0} K \pi^0} = 129.2 \pm 25.1$

signal efficiency=0.54%

Belle preliminary

$Br(\tau \to K^{*0} K \pi^0 \nu) = (2.39 \pm 0.46) \times 10^{-5}$
(stat.)

➢ This is the first measurement!

- peaking BG component : $K^{*0} K \nu$

$N_{K^{*0}}^{K^{*0} KMC} = 113.7 \pm 10.0$

This uncertainty mainly comes from
Br($\tau \to K^{*0} K \nu$) and statistics of $K^{*0} K \nu$MC.

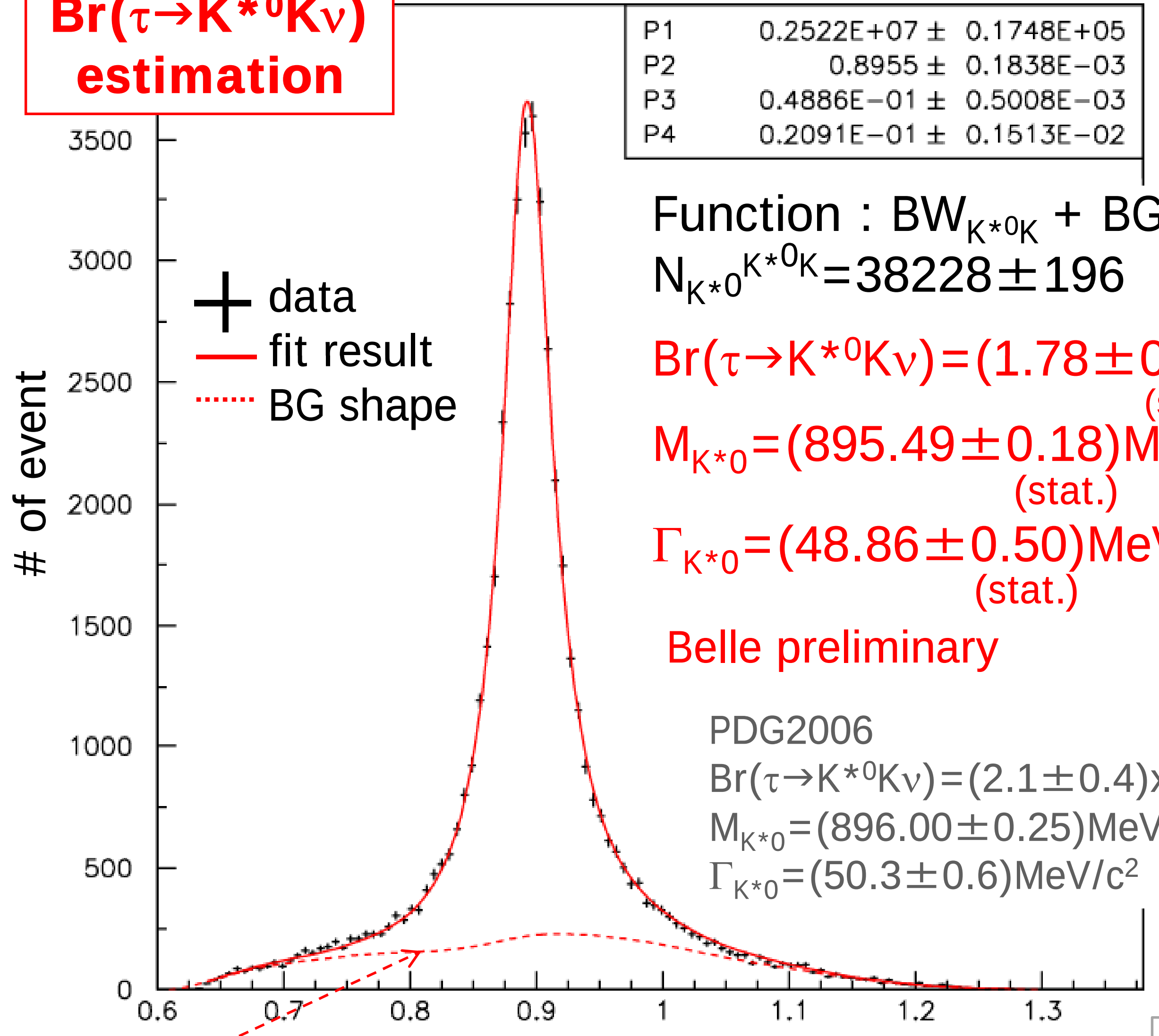
- continuum BG component

$N_{K^{*0}}^{continuum} = 482.6 \pm 8.2$

This uncertainty comes from the
shape of continuum BG.

Fit to data @$K^{*0}K\nu$ analysis

$Br(\tau \to K^{*0}K\nu)$ estimation



M(K,π) GeV/c²

Function : $BW_{K^{*0}K}$ + BG function

$N_{K^{*0}}^{K^{*0}K}=38228\pm196$

$Br(\tau \to K^{*0}K\nu)=(1.78\pm0.01)\times10^{-3}$ (stat.)

$M_{K^{*0}}=(895.49\pm0.18)\text{MeV}/c^2$ (stat.)

$\Gamma_{K^{*0}}=(48.86\pm0.50)\text{MeV}/c^2$ (stat.)

Belle preliminary

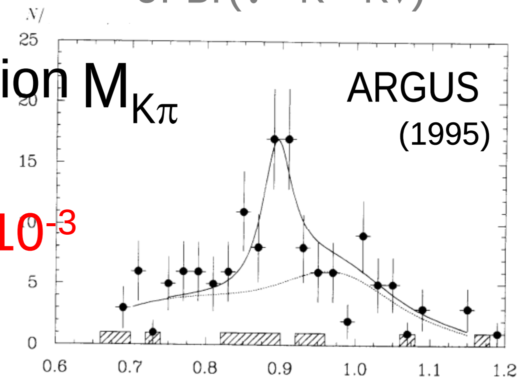
PDG2006

$Br(\tau \to K^{*0}K\nu)=(2.1\pm0.4)\times10^{-3}$

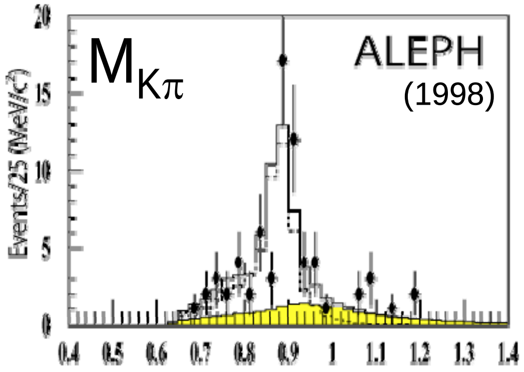
$M_{K^{*0}}=(896.00\pm0.25)\text{MeV}/c^2$

$\Gamma_{K^{*0}}=(50.3\pm0.6)\text{MeV}/c^2$

Previous measurement of $Br(\tau \to K^{*0}K\nu)$



H.Albrecht et al. ZP C68 215



R.Barate et al. EPJ C1 65

This BG shape is explained before.
Of course $K^{*0}K\pi^0\nu$ component is included.
(contamination from $K^{*0}K\pi^0\nu$ is negligible:~0.2%)

Charged K* has already analyzed via τ decay at Belle.
D.Epifanov, PLB 654 (2007) 65-73

Systematic error

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	Systematic error(%)	
	Br($\tau \to K^{*0} K \nu$)	Br($\tau \to K^{*0} K \pi^0 \nu$)
Luminosity	1.4	1.4
τ-pair cross section	0.3	0.3
Track finding efficiency	3.0+0.3	3.0+0.3
Trigger efficiency	0.7	0.1
Lepton-ID	2.9	2.9
Kaon-ID/fake	2.6	3.8
MC statistics	0.2	0.5
π^0 efficiency	—	1.7
BG estimation	1.3	9.0
Total	**5.6**	**10.9**

	Systematic error(MeV/c²)	
	$M_{K^{*0}}$	$\Gamma_{K^{*0}}$
BG estimation	0.22	0.68
Momentum calibration	0.2	0.09
Total	**0.30**	**0.69**

Br($\tau \to K^{*0} K \nu$)=
$(1.78 \pm \underset{\text{(stat.)}}{0.01} \pm \underset{\text{(syst.)}}{0.10}) \times 10^{-3}$

Br($\tau \to K^{*0} K \pi^0 \nu$)=
$(2.39 \pm \underset{\text{(stat.)}}{0.46} \pm \underset{\text{(syst.)}}{0.26}) \times 10^{-5}$

$M_{K^{*0}}$=
$(895.49 \pm \underset{\text{(stat.)}}{0.18} \pm \underset{\text{(syst.)}}{0.30})$ MeV/c^2

$\Gamma_{K^{*0}}$=
$(48.86 \pm \underset{\text{(stat.)}}{0.50} \pm \underset{\text{(syst.)}}{0.69})$ MeV/c^2

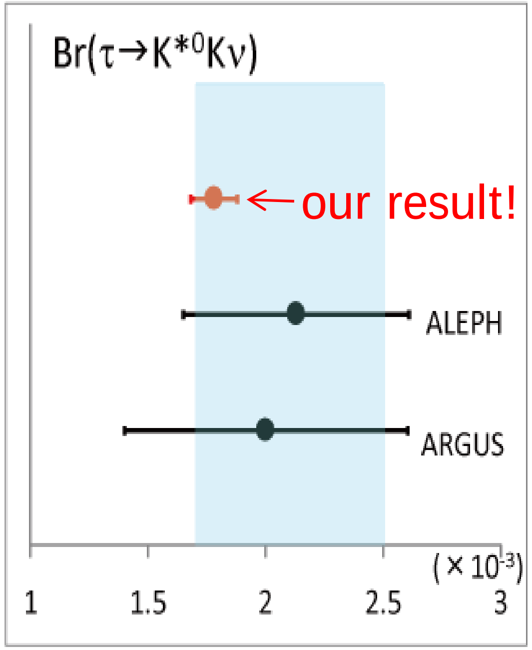
@PDG2006
Br($\tau \to K^{*0} K \nu$)=$(2.1 \pm 0.4) \times 10^{-3}$
$M_{K^{*0}}$=(896.00 ± 0.25)MeV/c^2
$\Gamma_{K^{*0}}$=(50.3 ± 0.6)MeV/c^2

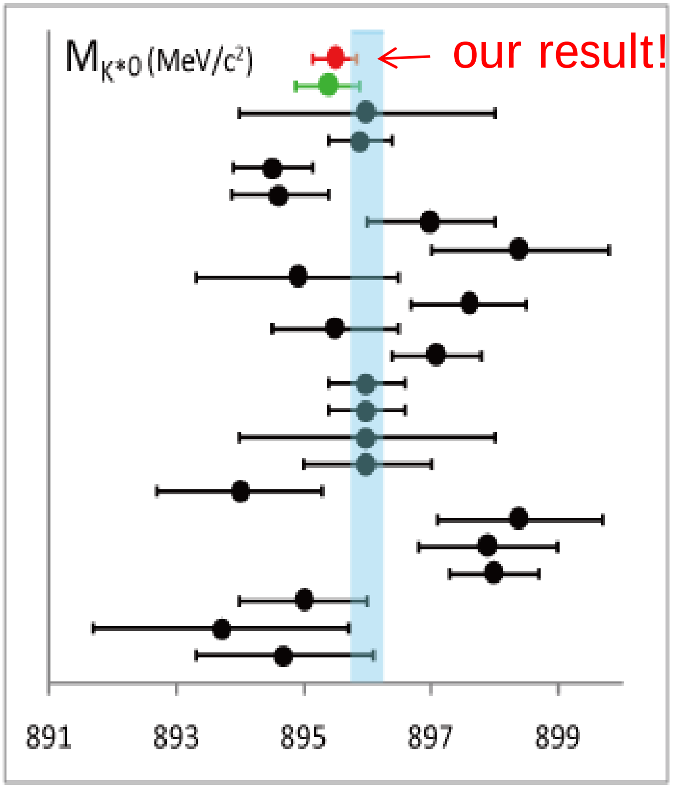
※doesn’t yet include the systematic error for the BW function model.

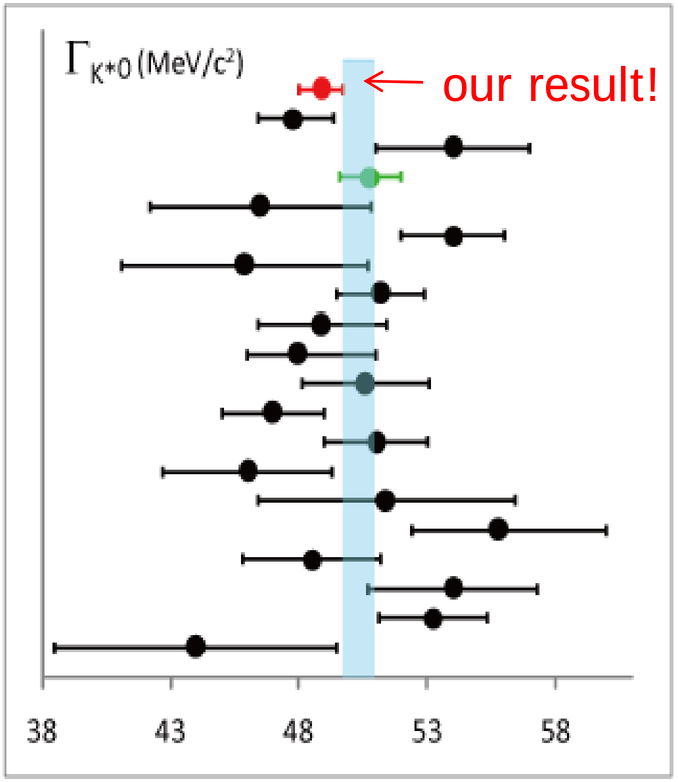
Br($\tau \to K^{*0} K \nu$) , K*(892)^0 mass & width

This is the first measurement of $M_{K^{*0}}$ and $\Gamma_{K^{*0}}$ via τ decay.

▨ PDG average







	Br($\tau \to K^{*0} K \nu$)
Our result	**1.78±0.01±0.10**
PDG2006	**2.1±0.4**
ALEPH (1998)	0.13±0.48
ARGUS (1995)	2.0±0.5±0.4

	$M_{K^{*0}}$ (MeV/c^2)	$\Gamma_{K^{*0}}$ (MeV/c^2)
Our result	**895.49±0.18±0.30**	**48.86±0.50±0.69**
PDG2006	**896.00±0.25**	**50.3±0.6**
Most precise before	$895.41 \pm 0.32^{+0.35}_{-0.43}$	50.8±0.8±0.9

Belle preliminary

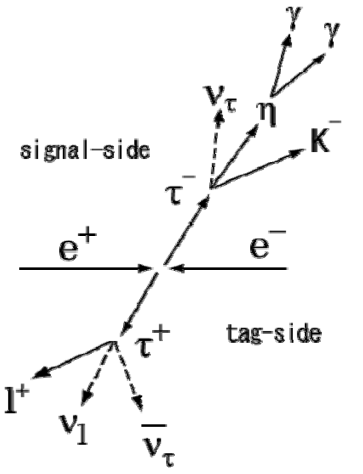
Most precise before

$M_{K^{*0}}$: from $D^+ \to K^- \pi^+ \mu^+ \nu$ with 18k events measured by FOCUS(at Fermi lab)

$\Gamma_{K^{*0}}$: from $K^- p \to K^- \pi^+ n$ measured by LASS(at SLAC)

Study of $\tau \to \eta + X$ Decay

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

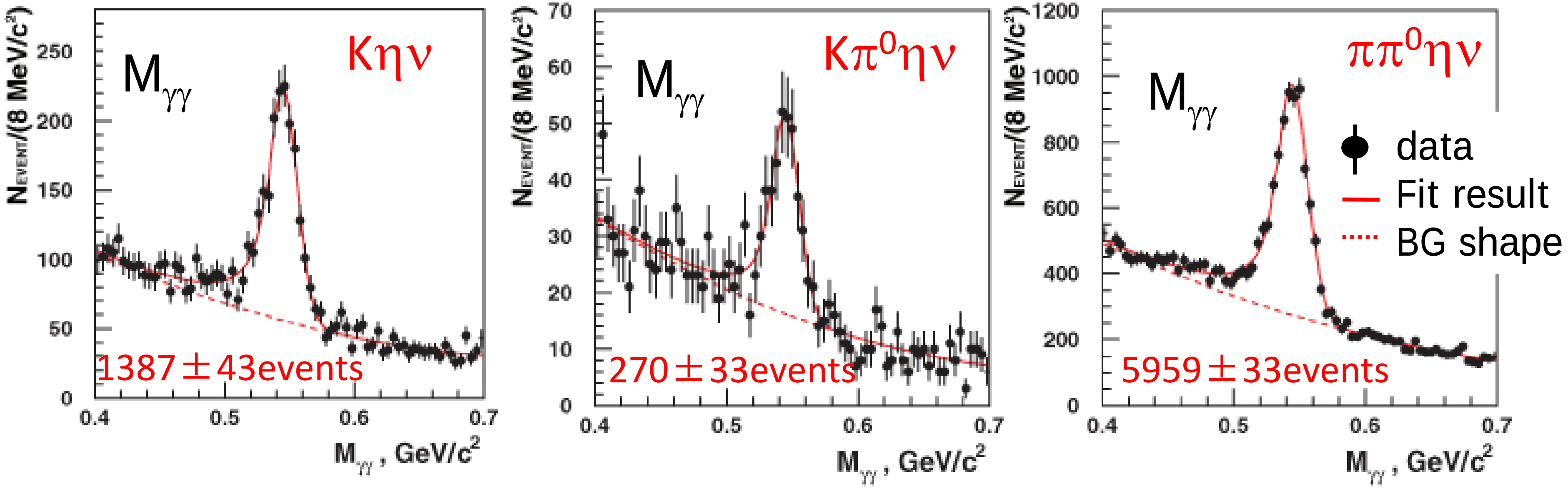


We analyzed $\tau \to \eta + X$ decay with 4.5×10^8 τ-pair data($485 fb^{-1}$).

- η is reconstructed from only $\gamma\gamma$.
- We estimate the signal yield from the $M_{\gamma\gamma}$ distribution.

I explain here $\tau \to K\eta\nu$, $\pi\pi^0\eta\nu$, $K\pi^0\eta\nu$ estimation.

fit function: Crystal ball(signal)+second-order polynomial(BG)



Main BG components for $\tau \to K\eta\nu$ is $\tau \to K\pi^0\eta\nu, \pi\pi^0\eta\nu, ee \to qq$.

By evaluating the number of η, Br($\tau \to K\eta\nu$) is measured.

But the signal η peak is contaminated by $K\pi^0\eta\nu$, $\pi\pi^0\eta\nu$.

➡ Simultaneously, their BRs are evaluated.

Result for $\tau \to \eta + X$

Belle preliminary

We obtain precise results in each τ decay mode including η.

Modes	Our Br(x10^{-3})	CLEO's Br(x10^{-3})	Error ratio δ(CLEO) / δ(Belle)
$\tau \to K\eta\nu$	$0.158 \pm 0.005 \pm 0.009$	$0.26 \pm 0.05 \pm 0.05$	7.0
$\tau \to K\pi^0\eta\nu$	$0.046 \pm 0.011 \pm 0.004$	$0.177 \pm 0.056 \pm 0.071$	7.5
$\tau \to \pi\pi^0\eta\nu$	$1.35 \pm 0.03 \pm 0.08$	$1.7 \pm 0.2 \pm 0.2$	3.3
$\tau \to K_s\pi\eta\nu$	$0.044 \pm 0.007 \pm 0.002$	$0.100 \pm 0.035 \pm 0.011$	5.3
$\tau \to K^*\eta\nu$	$0.130 \pm 0.013 \pm 0.011$	$0.290 \pm 0.080 \pm 0.042$	5.3

Modes	Upper limit
$\tau \to K_sK\eta\nu$	$<4.5 \times 10^{-6}$ @90% CL
$\tau \to K_s\pi\pi^0\eta\nu$	$<2.5 \times 10^{-5}$ @90% CL
$\tau \to K\eta\eta\nu$	$<3.0 \times 10^{-6}$ @90% CL
$\tau \to \pi\eta\eta\nu$	$<7.4 \times 10^{-6}$ @90% CL

High statistics enable us to **reliably estimate** BG contributions for each mode using data.

Result for $\tau \to \eta + X$

Belle
preliminary

We can compare our result and theoretical predictions of each Br.

Modes	Our Br(x10^{-3})	Theoretical predictions of Br(x10^{-3})
$\tau \to K \eta \nu$	0.158±0.005±0.009	0.12(Pich) , 0.22(Li)
$\tau \to K \pi^0 \eta \nu$	0.046±0.011±0.004	0.088(Pich)
$\tau \to \pi \pi^0 \eta \nu$	1.35±0.03±0.08	3(Pich) , 1.9(Li) , 1.3±0.2(Eidelman)
$\tau \to K_s \pi \eta \nu$	0.044±0.007±0.002	0.011(Pich)
$\tau \to K^* \eta \nu$	0.130±0.013±0.011	0.1(Lee)

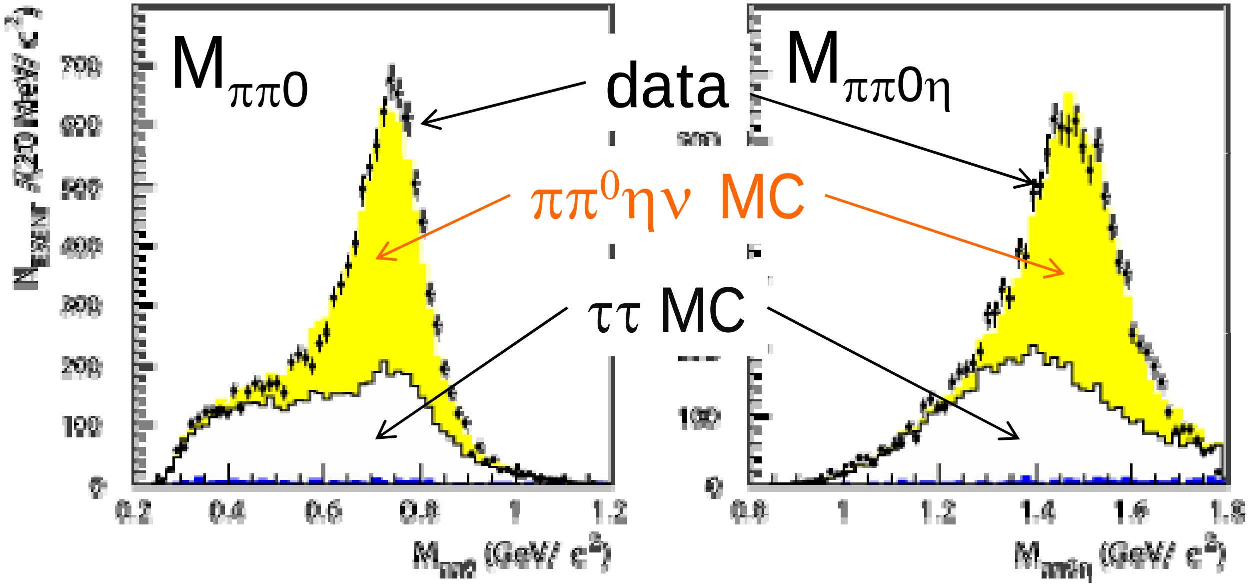
Modes	Upper limit	Theoretical predictions of Br(x10^{-3})
$\tau \to K_s K \eta \nu$	<4.5X10^{-6} @90% CL	3.1X10^{-7}(Pich)
$\tau \to K_s \pi \pi^0 \eta \nu$	<2.5X10^{-5} @90% CL	———
$\tau \to K \eta \eta \nu$	<3.0X10^{-6} @90% CL	1.6X10^{-9}(Pich)
$\tau \to \pi \eta \eta \nu$	<7.4X10^{-6} @90% CL	1.1X10^{-9}(Pich)

A.Pich, PLB 196 (1987) 561
B.A.Li, PRD 55 (1997) 1436
S.I.Eidelman, PLB 257 (1991) 437

Our results show that theory predicts these BRs to better than an order of magnitude.

Check for CVC

$\tau \to \pi\pi^0\eta\nu$ MC generations designed based on $\sigma(e^+e^- \to \pi^+\pi^-\eta)$ measured more than 10 years ago, assuming CVC.



data

$\pi\pi^0\eta\nu$ MC

$\tau\tau$ MC

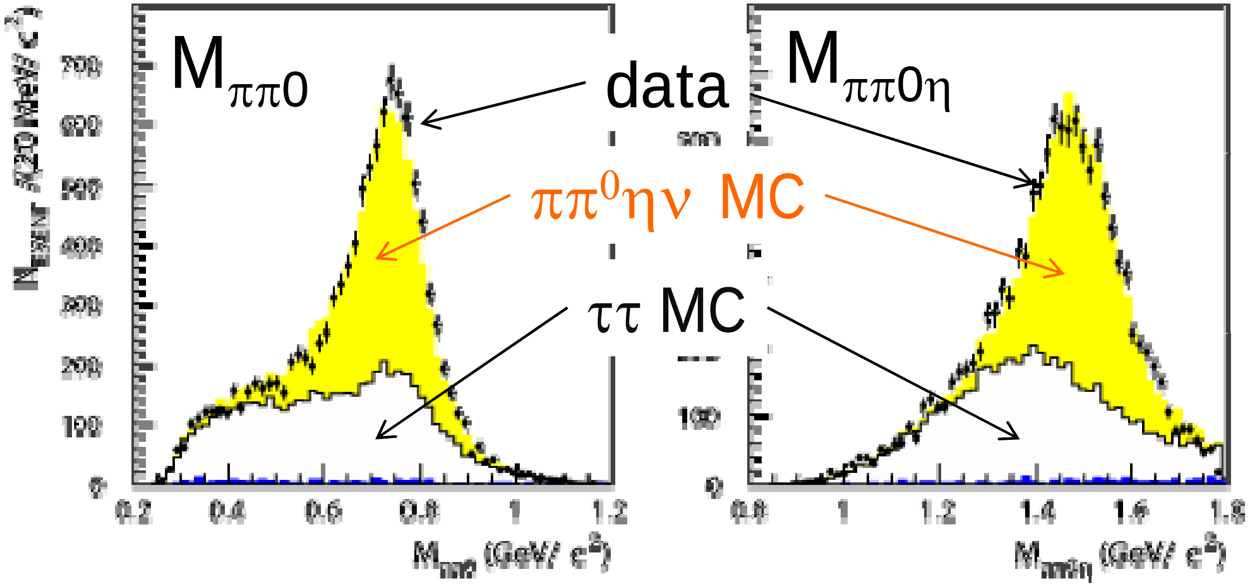
The distributions for the observed data and MC agree well.

Belle preliminary

$e^+ + e^- \to$ hadrons $\xrightarrow{\text{CVC}}$ $\tau^- \to$ hadrons + ν

Check for CVC

$\tau \to \pi\pi^0\eta\nu$ MC generations designed based on $\sigma(e^+e^- \to \pi^+\pi^-\eta)$ measured more than 10 years ago, assuming CVC.



The distributions for the observed data and MC agree well.

Belle preliminary

$e^+ + e^- \to$ hadrons $\xrightarrow{\text{CVC}}$ $\tau^- \to$ hadrons + ν

Check in high accuracy

Now, we can compare $\tau \to$ hadrons+ν and $e^+e^- \to$ hadrons with high accuracy to check CVC.

Summary

Belle preliminary

We perform a high-precision study of $\tau \to K^{*0}K\nu$ and $\tau \to \eta + X$ modes based on 5.0×10^8 and 4.5×10^8 τ-pairs, respectively.

For $\tau \to K^{*0}K\nu$ mode

Previous experiment(ARGUS 1995)
$Br(\tau \to K^{*0}K\nu) = (2.0 \pm \mathbf{0.5} \pm \mathbf{0.4}) \times 10^{-3}$, $N_{sig} = 47.1$

- **$Br(\tau \to K^{*0}K\nu) = (1.78 \pm 0.01 \pm 0.10) \times 10^{-3}$**
  - We improve statistical error by a factor of **45**, as well as systematic error by a factor of **3.6**.
    - We obtain 38,228 signal events, **800** times more than in any previously published result.
    - 80% of BG components are evaluated by using data samples.
    - We measure $\tau \to K^{*0}K\pi^0\nu$: **$Br(\tau \to K^{*0}K\pi^0\nu) = (2.39 \pm 0.46 \pm 0.26) \times 10^{-5}$**
      - This is the first measurement!
- We also measure $M_{K^{*0}}$ and $\Gamma_{K^{*0}}$.
  - **$M_{K^{*0}} = (895.49 \pm 0.18 \pm 0.30)\mathrm{MeV}/c^2$, $\Gamma_{K^{*0}} = (48.86 \pm 0.50 \pm 0.69)\mathrm{MeV}/c^2$**
    - We improve the uncertainty by a factor of **1.7** for $M_{K^{*0}}$ and **2.7** for $\Gamma_{K^{*0}}$.
    - This is the first measurement of $M_{K^{*0}}$ and $\Gamma_{K^{*0}}$ via τ decay.

Previous experiment(FOCUS 2005)
$M_{K^{*0}} = (895.41 \pm 0.32^{+0.35}_{-0.43})\mathrm{MeV}/c^2$
Previous experiment(LASS 1988)
$\Gamma_{K^{*0}} = (50.8 \pm 0.8 \pm 0.9)\mathrm{MeV}/c^2$

For $\tau \to \eta + X$ modes

- We improve the uncertainty of $\tau \to K\eta\nu$ by a factor of **7.0**.
  Other $\tau \to \eta + X$ modes are improved **3.3~7.5** times.
- We **check CVC** to high accuracy through the precise measurements of $\tau \to \pi\pi^0\eta\nu$.
  - There is good agreement between data and CVC.

Back up

BW function

We use Jackson’s BW function.

$$\mathrm{BW} \sim \frac{\Gamma(M)}{(M_{K*}{}^{2} - M^{2})^{2} + M_{K*}{}^{2}\Gamma^{2}(M)}$$

$$\Gamma(M) = \Gamma_{K*}\left(\frac{p}{p_{K*}}\right)^{3}\frac{M_{K*}}{M} \qquad (1^{-}\rightarrow 0^{-}0^{-}\text{ case})$$

$$p = \frac{\sqrt{(M+M_{\pi}+M_{K})(M+M_{\pi}-M_{K})(M-M_{\pi}+M_{K})(M-M_{\pi}-M_{K})}}{2M}$$

$$p_{K*} = \frac{\sqrt{(M_{K*}+M_{\pi}+M_{K})(M_{K*}+M_{\pi}-M_{K})(M_{K*}-M_{\pi}+M_{K})(M_{K*}-M_{\pi}-M_{K})}}{2M_{K*}}$$

J.D.Jackson Nuovo Cim.34 1644(1964)

spectral function

The spectral function v(s) is defined as follows,

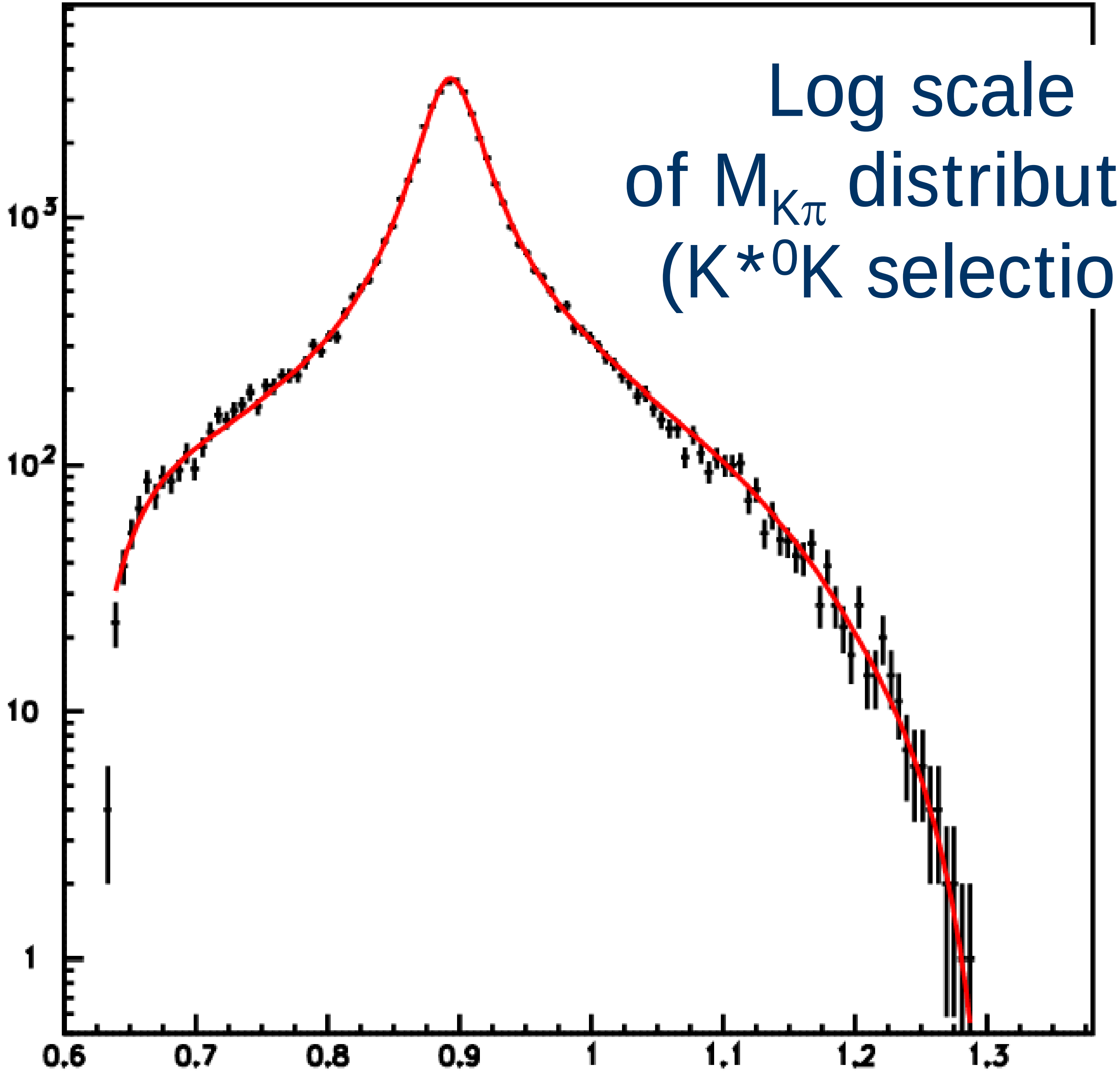
$$v(s) = \frac{32\pi^2 M_\tau^3}{G_F^2 \, |V_{ud}|^2 \, (M_\tau^2 - M_{KK\pi})^2 (M_\tau^2 + 2M_{KK\pi})} \frac{d\Gamma}{dM_{KK\pi}}$$

We can obtain spectral function v(s) from $M_{KK\pi}$ distribution.

Previous measurements

	Belle（our result）	**ARGUS(1995)**	**ALEPH(1998)**
Br	$(1.78\pm0.01\pm0.10)\times10^{-3}$	$(2.0\pm0.5\pm0.4)\times10^{-3}$	$(2.1\pm0.48)\times10^{-3}$
# of $\tau\tau$	5×10^{8}	4×10^{5}	2×10^{5}
#of signal	38228	47.1	52

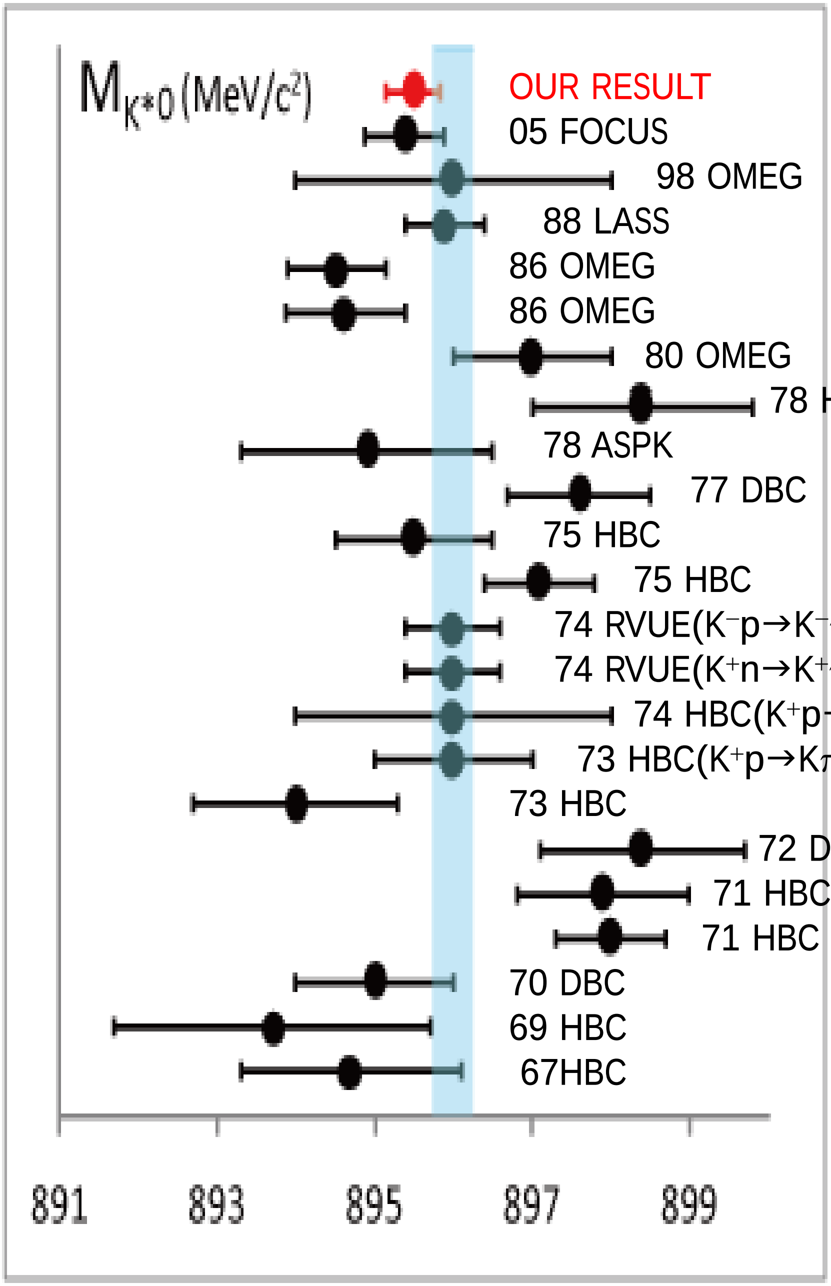
	Belle（our result）	**Most precise before**
$M_{K^{*0}}$	$895.49\pm0.18\pm0.30$	$895.41\pm0.32^{+0.35}_{-0.43}$(FOCUS 2005)
$\Gamma_{K^{*0}}$	$48.86\pm0.50\pm0.69$	$50.8\pm0.8\pm0.9$(LASS 1988)
Systematic error for $M_{K^{*0}}$	BG estimation 0.22MeV	Momentum calibration 0.30MeV
Systematic error for $\Gamma_{K^{*0}}$	BG estimation 0.68MeV	BG estimation etc. 0.9MeV

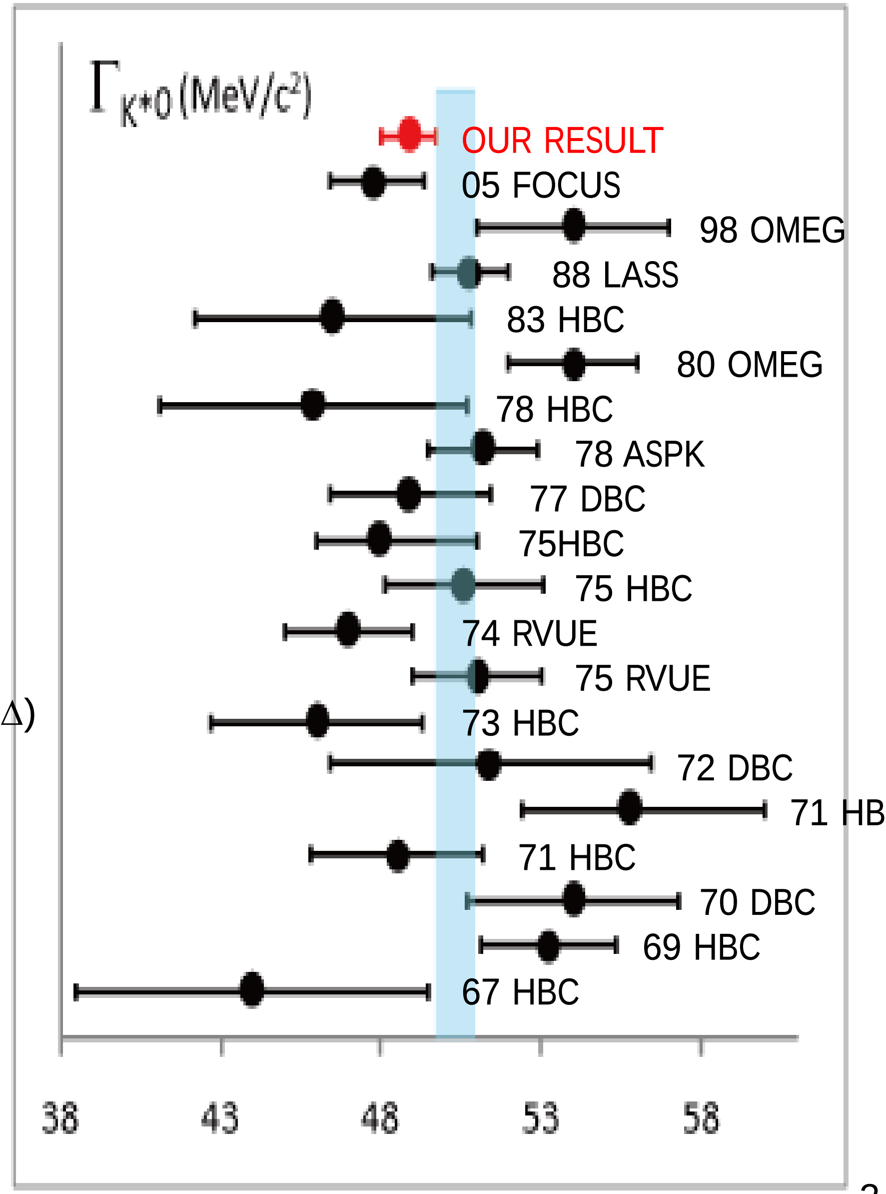


Log scale of $M_{K\pi}$ distribution ($K^{*0}K$ selection)

$K^*(892)^0$ mass & width

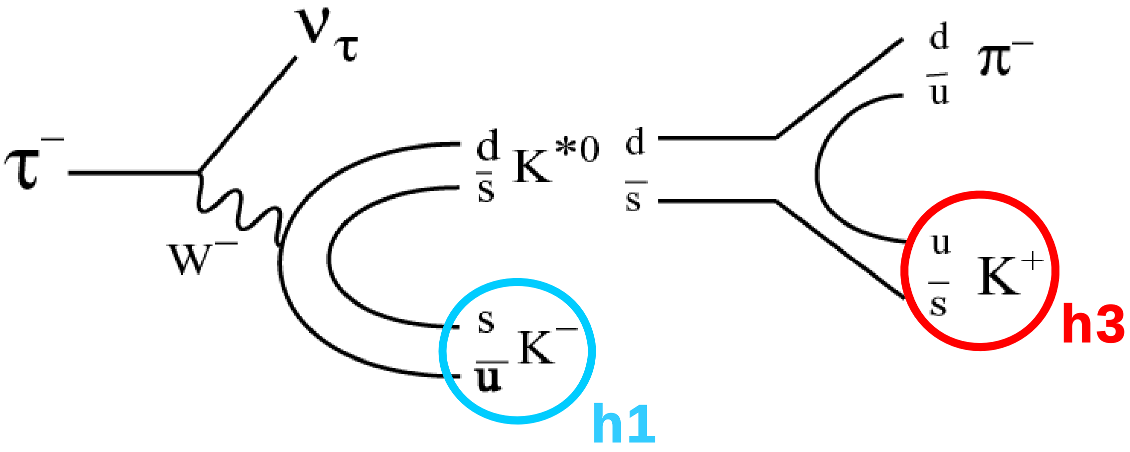
🟦 PDG average



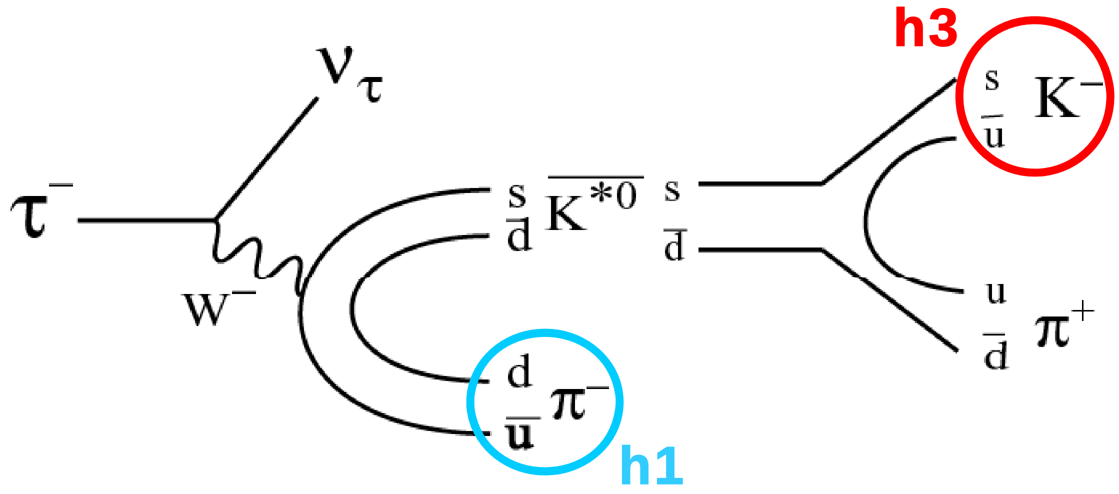


$K^{*0}K\nu$ and $K^{*0}\pi\nu$

$\tau \to K^{*0}K\nu$



$\tau \to K^{*0}K\pi^0\nu$



We assign opposite charge between h1 and h3.
(strangeness conservation)

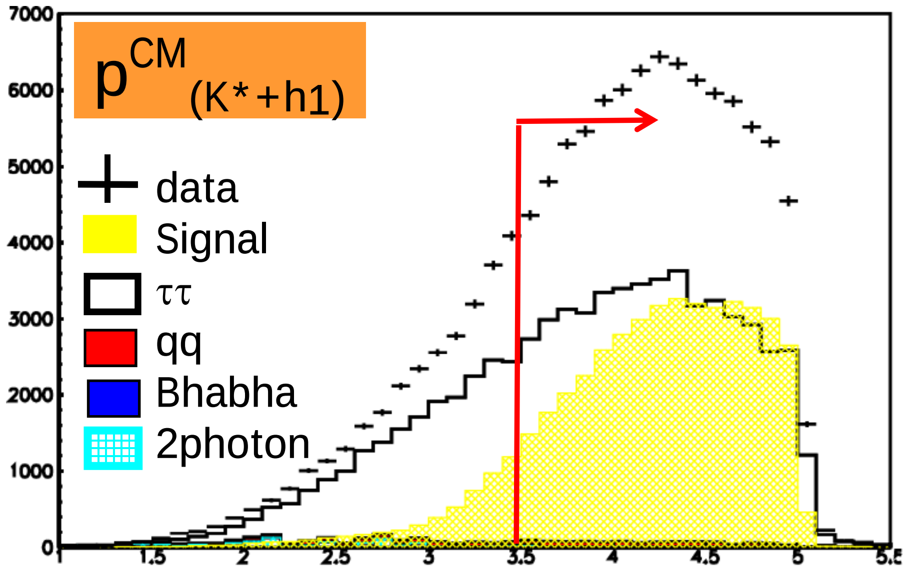
↑

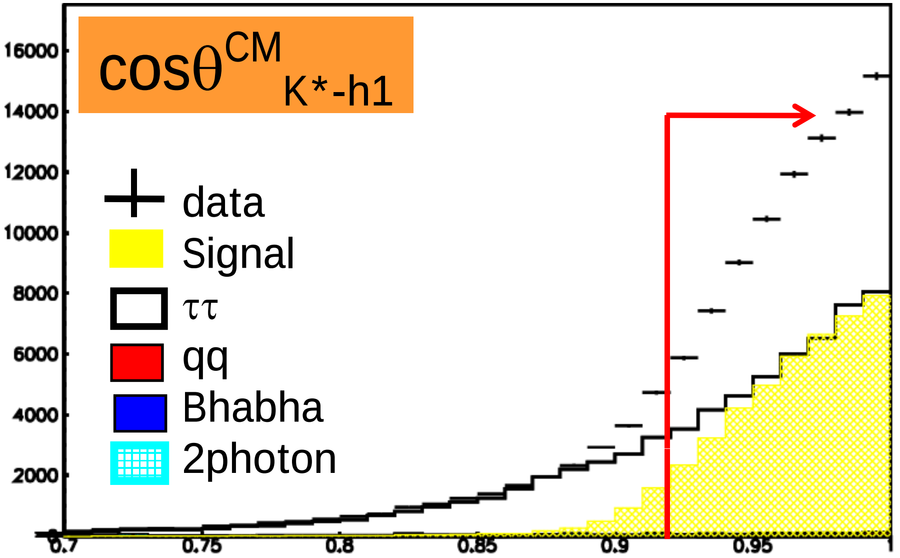
By assuming this selection, we can suppress $\tau \to K^{*0}\pi\nu$ component.

procedure of $K^{*0}K\nu$ analysis

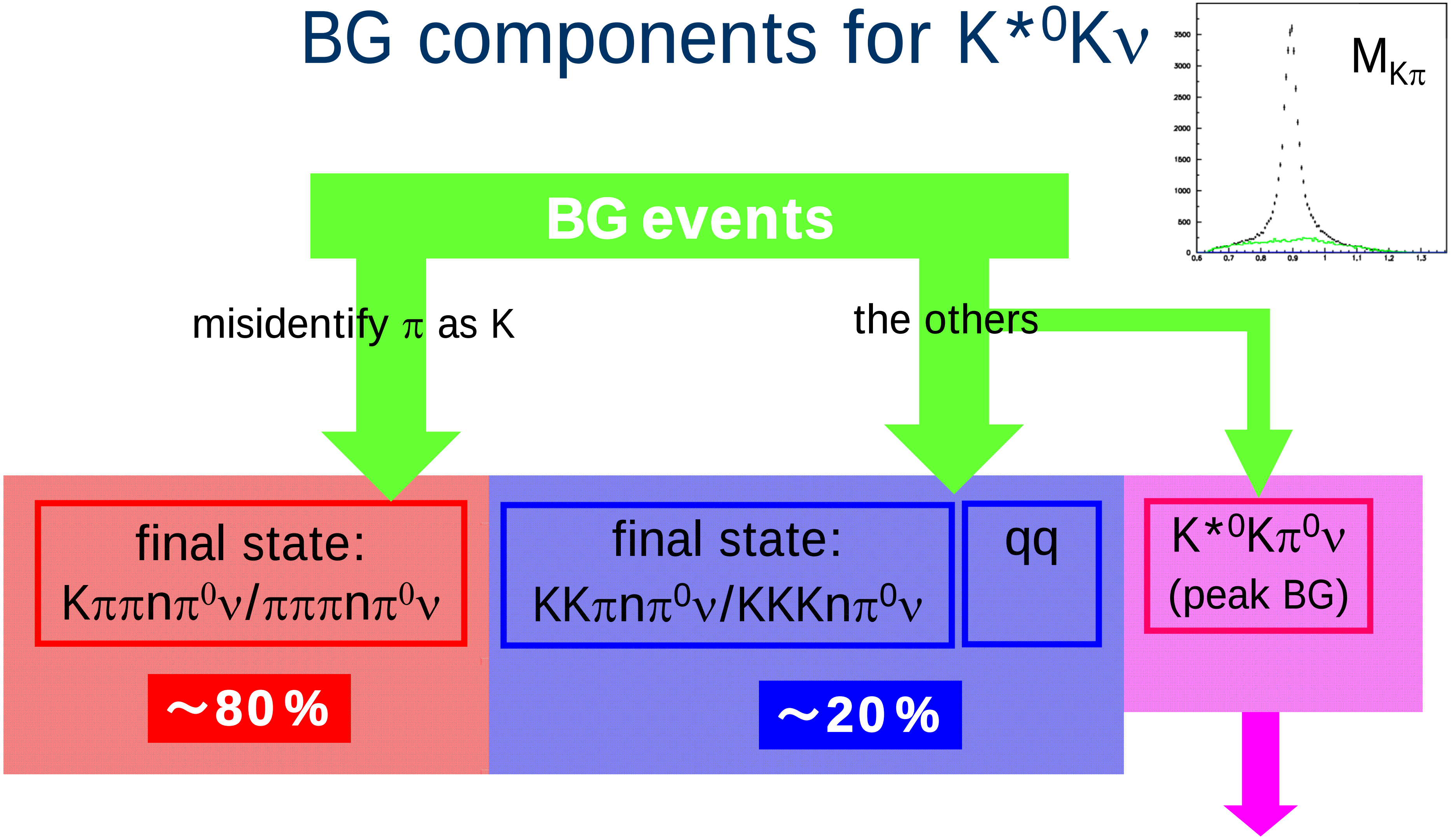
- $K^{*0}K\nu$ analysis
  - Selection
  - BG estimation
    - $\pi \rightarrow K$ mis-ID component
    - $\phi K\nu, \phi\pi\nu$ etc.
    - qq component (include peaking component)
    - $K^{*0}K\pi^0\nu$ component (peaking BG)
      - $Br(K^{*0}K\pi^0\nu)$
      - Systematic error
  - Systematic study
  - Measure $Br(\tau \rightarrow K^{*0}K\nu)$
  - $M_{K^{*0}}, \Gamma_{K^{*0}}$ study

Event selection ($K^{*0}K\nu$)





BG components for $K^{*0}K\nu$



BG events

misidentify π as K

the others

final state:
$K\pi\pi n\pi^0\nu/\pi\pi\pi n\pi^0\nu$

～80％

final state:
$KK\pi n\pi^0\nu/KKKn\pi^0\nu$

qq

～20％

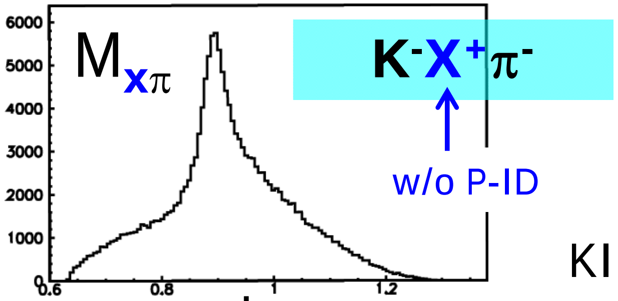
$K^{*0}K\pi^0\nu$
(peak BG)

We estimate these components from data

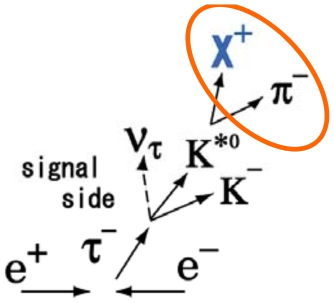
from MC samples

measure $Br(\tau\to K^{*0}K\pi^0\nu)$

data distribution

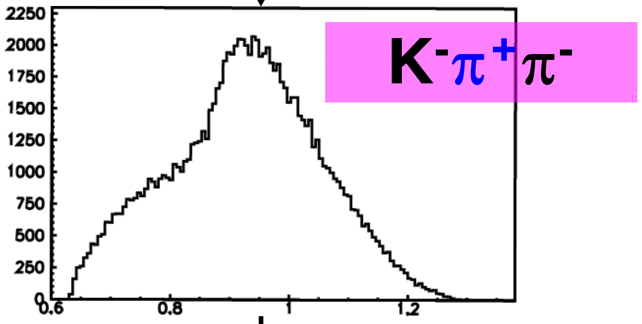


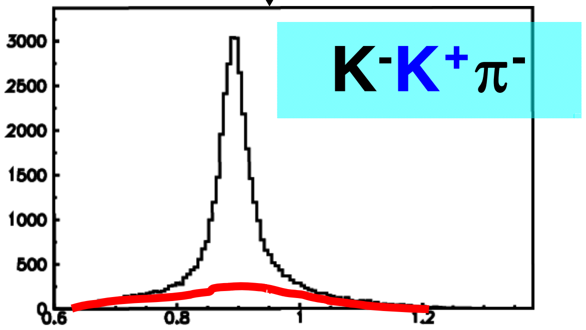
w/o P-ID



KID<0.2
$=1-\text{fakerate}^{DATA}(\pi\to K)^{0.2}$

KID>0.8
$=\text{fakerate}^{DATA}(\pi\to K)^{0.8}$ for BG

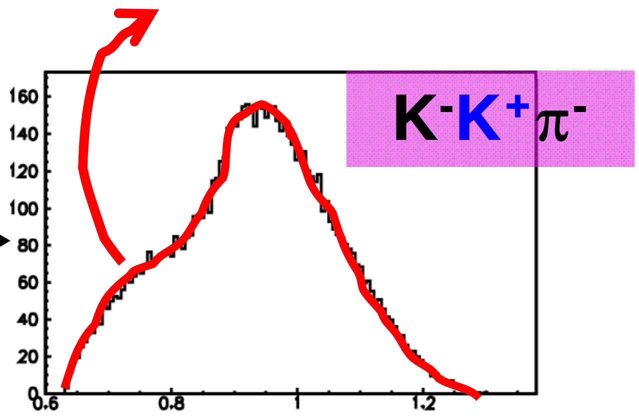




1.13% uncertainty

$$\times\left(\frac{\text{fakerate}^{DATA}(\pi\to K)^{0.8}}{1-\text{fakerate}^{DATA}(\pi\to K)^{0.2}}\right)$$

a kind of efficiency



We use this shape for
$K\pi\pi n\pi^0\nu/\pi\pi\pi n\pi^0\nu$ components.

By using fakerate, We can estimate contribution of mis P-ID mode($\pi\to K$) for $KK\pi$ selection.

Fake rate is measured by using hadronic sample and so on.
$\text{fakerate}^{DATA}(\pi\to K)$: fakerate for miss identify π as K

BG from $KK\pi n\pi^0\nu$,$KKKn\pi^0\nu$

We estimated these BG contaminations with MC samples.

■$\phi\pi\nu$, $\phi K\nu$, $KK\pi\pi^0\nu$(ex.K^{*0}) modes

We estimate these BG contaminations individually by using Br.
Uncertainty for K^{*0} signal yield is due to the uncertainty of Br.

$Br(\tau\rightarrow\phi K\nu)=(4.05\pm0.25\pm0.26)\times10^{-5}$ (our result)
$Br(\tau\rightarrow\phi\pi\nu)=(6.07\pm0.71)10^{-5}$ (our result)
$Br(\tau\rightarrow KK\pi\pi^0\nu)=(6.1\pm2.0)\times10^{-5}$ (PDG2006)

Mode	$\phi\pi\nu$	$\phi K\nu$	$KK\pi\pi^0\nu$(ex.K^{*0})
Uncertainty for K^{*0} signal yield	0.047%	<0.01%	0.12%

■$KK\pi\nu$(ex.K^{*0}) mode

We estimate this contamination by fitting to $M_{K\pi}$ distribution of data.
This mode gives 0.24% uncertainty of K^{*0} signal yield because of the uncertainty of $KK\pi\nu$MC shape.

BG from qq

Check with qq enriched data

qqMC is not good agreement in low multiplicity region.

(ex.$\tau \rightarrow \phi K \nu$ analysis: scale factor ~2)

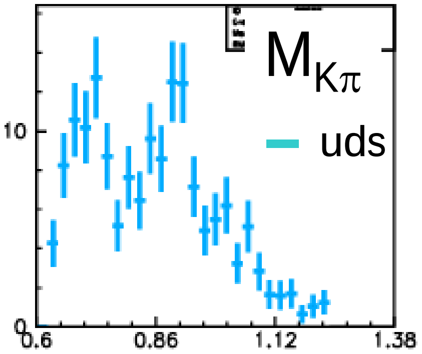
- Change criteria in tag side

$N_{\gamma}^{tag} \leqq 1$
Lepton tag
$M_{tag} < 1.8 GeV/c^2$

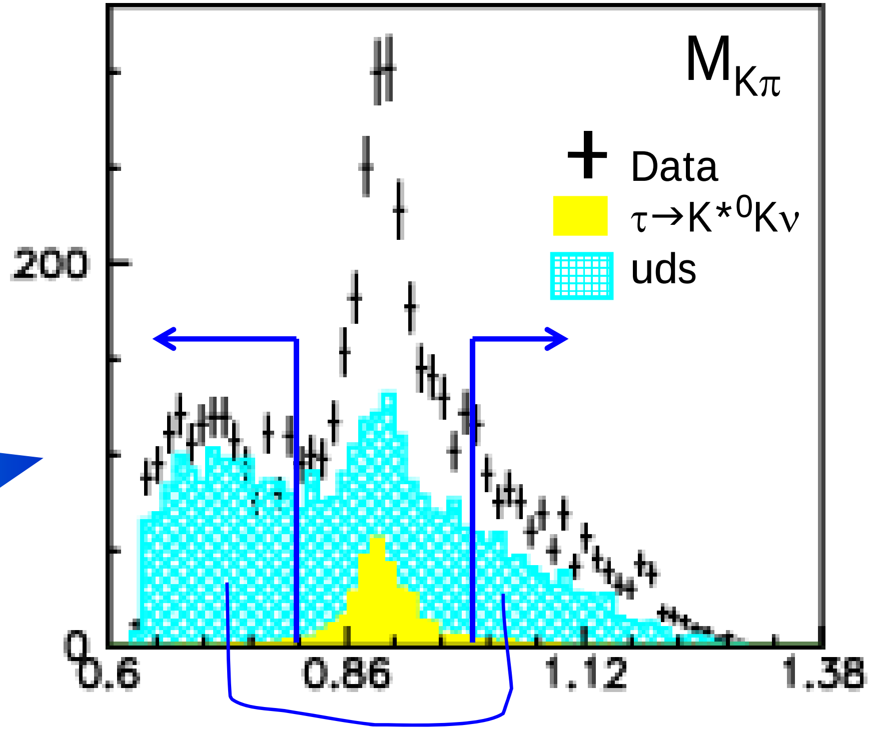
→

$N_{\gamma}^{tag} \geqq 2$
No lepton tag
$M_{tag} > 1.8 GeV/c^2$

Signal selection



qq enriched selection



side band region

We compared MC results(**uds**,**$K^{*0}K\nu$**) with **data** by choosing enriched qq samples.

We estimate the scale factor for **udsMC** in side band region and K^{*0} peak region individually.

<scale facxtor>

- Side band : data/udsMC=1.34±0.03
- K^{*0} peak : ($data-K^{*0}KMC$)/udsMC=2.02±0.26

BG from qq

Check with qq enriched data

qqMC is not good agreement in low multiplicity region.

(ex.τ→φKν analysis: scale factor ~2)

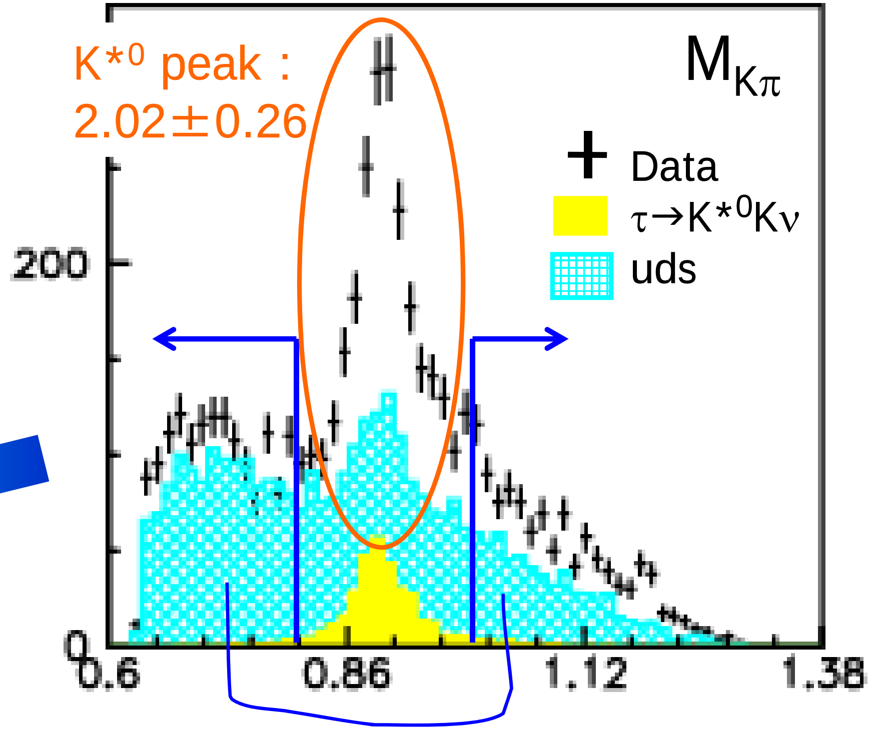
- Change criteria in tag side

$N_{\gamma}^{tag} \leqq 1$
Lepton tag
$M_{tag} < 1.8\mathrm{GeV}/c^2$

←

$N_{\gamma}^{tag} \geqq 2$
No lepton tag
$M_{tag} > 1.8\mathrm{GeV}/c^2$

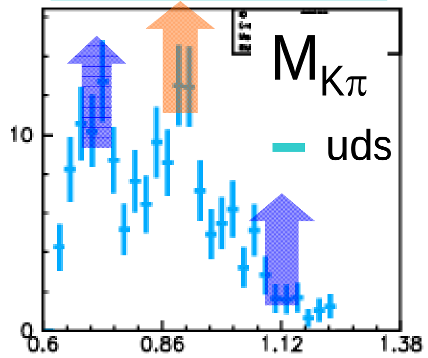
qq enriched selection



K^{*0} peak : 2.02±0.26

Side band : 1.34±0.03

Signal selection



We estimate the contamination due to uds component with these scale factors.

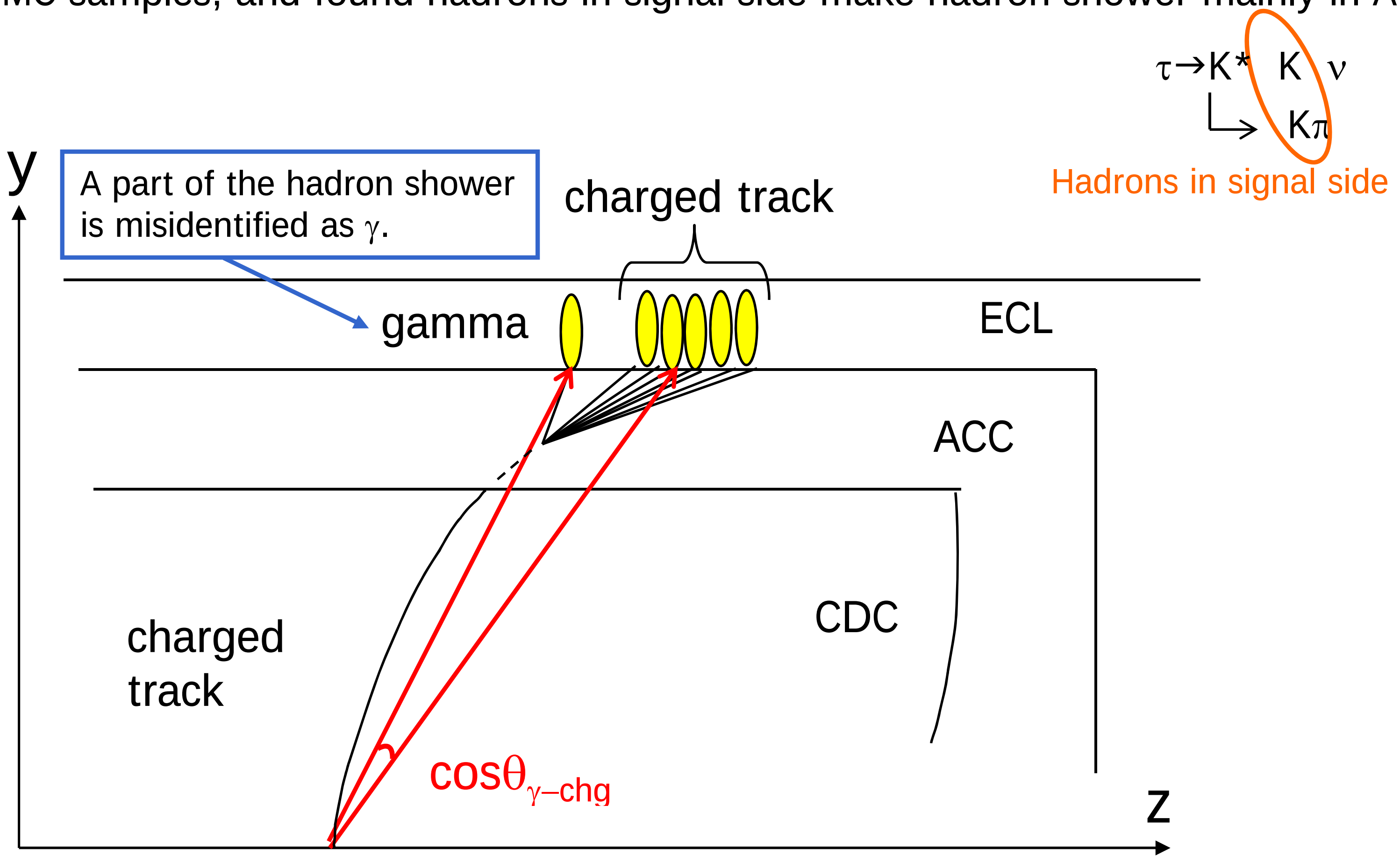
Cross-feed for $K^{*0}K\nu$: $N^{qq}_{K^{*0}peak} = 29 \pm 15$

Uncertainty for K^{*0} signal yield is due to the statistical error of qq events at $K^{*}K\nu$ selection.

Mode	qq(side band)	qq(K^{*0} peak)
Uncertainty for K^{*0} signal yield	0.040%	0.046%

$\cos\theta_{\gamma\text{-chg}}$

We checked MC samples, and found hadrons in signal side make hadron shower mainly in ACC.



$\tau \to K^* \; K \; \nu$

$\hookrightarrow K\pi$

Hadrons in signal side

A part of the hadron shower is misidentified as γ.

charged track

y

gamma

ECL

ACC

CDC

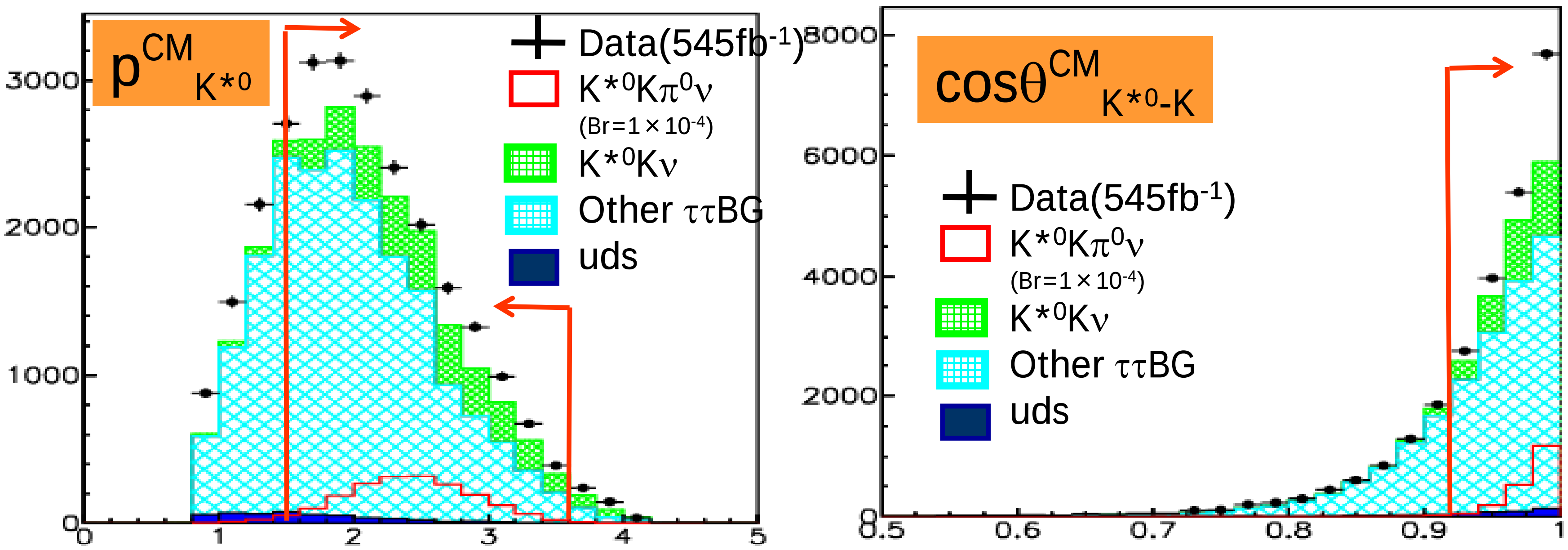
charged track

$\cos\theta_{\gamma-\text{chg}}$

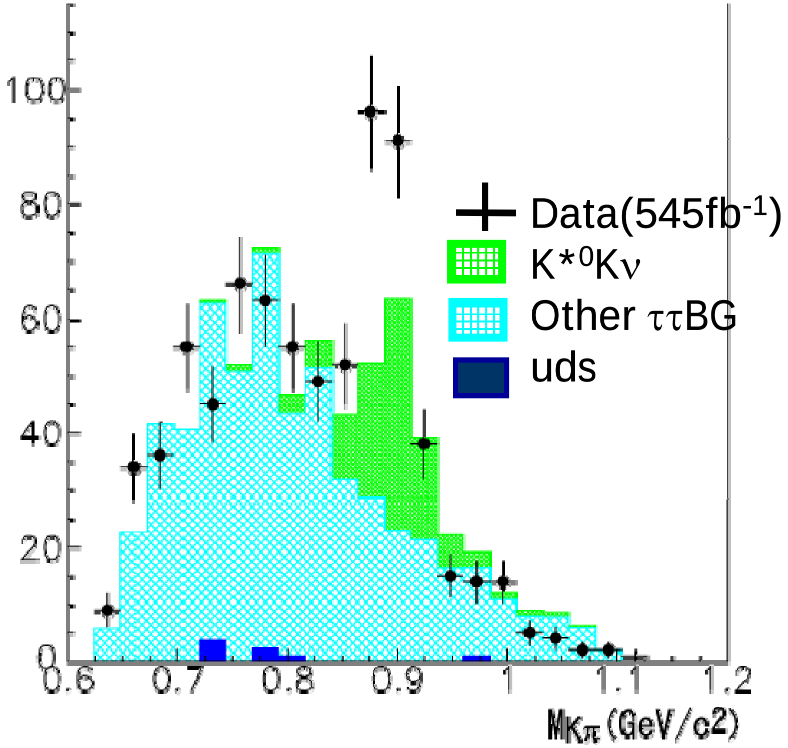
z

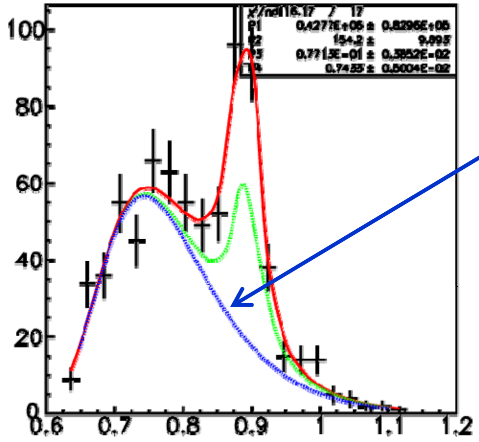
Event selection ($K^{*0}K\pi^0\nu$)

Apply almost same requirements as those of $\tau \to K^{*0}K\nu$ mode.



Estimation of BG components($K^{*0}K\pi^0\nu$)





- $K^{*0}K\nu$ component (peaking BG)
  - We estimate this component from $K^{*0}K\nu$ MC samples.
  - Uncertainty for signal yield
    - $K^{*0}K\nu$ MC statistics:6.0%
    - Error of Br($\tau \to K^{*0}K\nu$) :5.6% (our result)
    - Error of correction factor for MC:3.2%

    →Total **8.8%**
- Continuum BG component
  - We estimate this component by fitting Landau function to data($M_{K\pi}$ dist.)
    - Y=A*exp{{-(X-C)/B}-exp{-(X-C)/B}}
    - A,B and C are set as free parameter (A:scale, B:width, C:center value)
  - Uncertainty for signal yield
    - Uncertainty of BG shape:**1.7%**

→ Total systematic error from BG estimation is **9.0%**.

Br(tau→K*Kpi0nu)

Branching ratio of $\tau \to K^{*0} K \pi^0 \nu$ mode has not been measured yet.

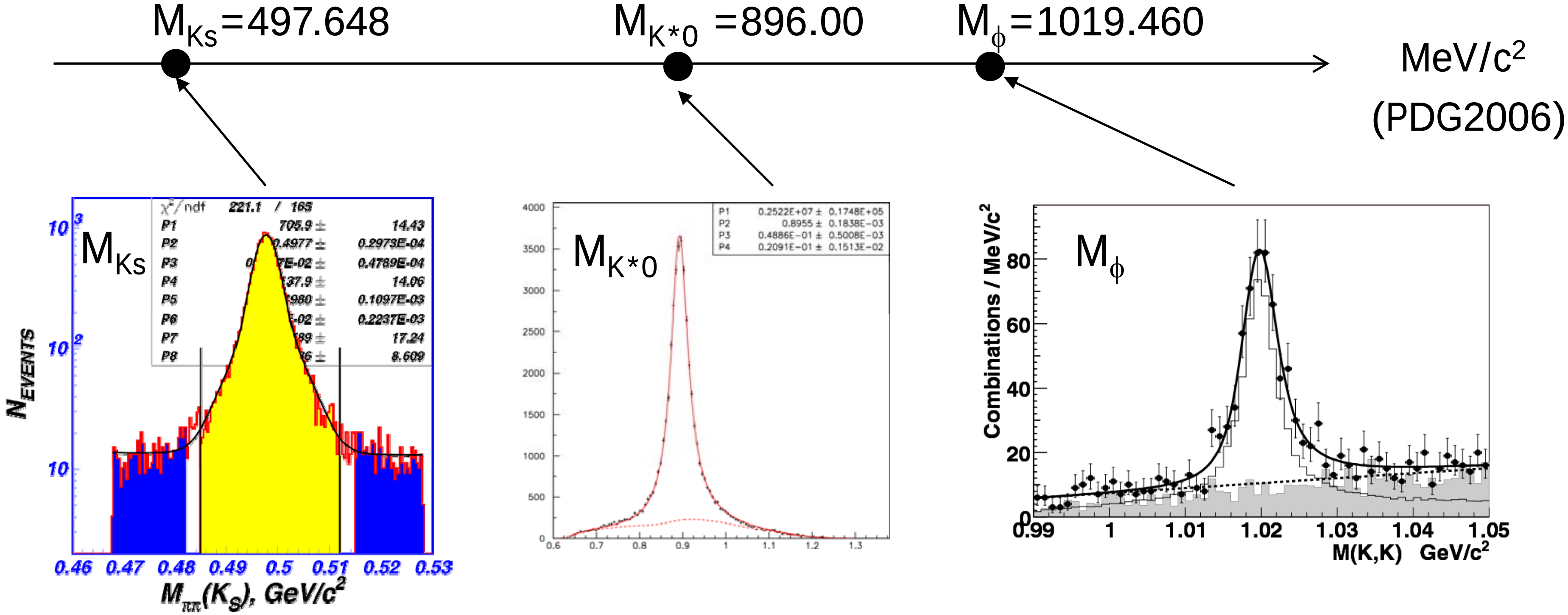
Mode	Br	measurement
$\tau \to K^{*0} K \geqq 0$ neutrals ν ①	$(3.2 \pm 0.8 \pm 1.2) \times 10^{-3}$	CLEO
$\tau \to K^{*0} K \nu$ ②	$(2.1 \pm 0.4) \times 10^{-3}$	PDG2006 Ave.
①−② $\tau \to K^{*0} K \geqq 1$ neutrals ν	$(1.1 \pm 1.5) \times 10^{-3}$ This value has too large uncertainty. We can't use this value for $K^{*0} K \pi^0 \nu$ Br.	

Idea of the systematics for $M_{K^{*0}}$ and $\Gamma_{K^{*0}}$

How to evaluate systematics for $M_{K^{*0}}$ and $\Gamma_{K^{*0}}$

- The systematics from detector mass/momentum calibration is the most biggest one.
  - We use ϕ and K_s mass peak and resolution.

    ϕ and K_s mass spectrum have already studied at Belle.
    - $\tau \to \phi K \nu$ Inami-san
    - $\tau \to K_s \pi \nu$ D.A.Epifanov



M_{Ks}=497.648

$M_{K^{*0}}$ =896.00

M_{ϕ}=1019.460

MeV/c^2

(PDG2006)

Systematics for $M_{K^{*0}}$

Estimation for $M_{K^{*0}}$

- Check the difference between data and PDG2006 value of M_{ϕ} and M_{Ks}.

	M_{Ks}	$M_{K^{*0}}$	M_{ϕ}
Data(MeV/c^2)	497.729±0.015 ~Δ0.1	895.49±0.18	1019.6±0.2 ~Δ0.2
PDG2006(MeV/c^2)	497.648±0.022	896.00±0.25	1019.460±0.019

For $M_{K^{*0}}$, the systematics from detector resolution is 0.2MeV/c^2.

$$M_{K^{*0}}=(895.49\pm0.18\pm0.2)\ \mathrm{MeV}/c^2$$

@PDG2006
$M_{K^{*0}}=(896.00\pm0.25)\mathrm{MeV}/c^2$
@FOCUS collaboration(2005)
$M_{K^{*0}}=(895.41\pm0.32^{+0.35}_{-0.43})\mathrm{MeV}/c^2$

Most precise one is obtained from $D^+\rightarrow K^-\pi^+\mu^+\nu$ with 18k events measured by FOCUS Collaboration at Fermi lab.

Systematics for $\Gamma_{K^{*0}}$

Estimation for $\Gamma_{K^{*0}}$

- Check the resolution of M_{ϕ} and M_{Ks}.

  σ_{ϕ} and σ_{Ks} are almost same? → check the consistency at the same experiment.
  - $\sigma_{Ks}=(2.93\pm0.13)$ MeV/c^2
  - $\sigma_{\phi}=(1.2\pm0.3)$ MeV/c^2
- $\Gamma_{K^{*0}}$ is very wide(~50MeV). So we expect that $\sigma_{K^{*0}}$ can be ignored.

  (We don't consider K^{*0} mass resolution when we fit to $M_{K\pi}$ distribution of data.)
- Can we ignore $\sigma_{K^{*0}}$? → $(\Gamma_{K^{*0}}{}^2+\sigma_{Ks}{}^2)^{1/2} \sim \Gamma_{K^{*0}}$?

  $(\Gamma_{K^{*0}}{}^2+\sigma_{Ks}{}^2)^{1/2} = 48.95 \longleftarrow \Delta 0.09 \longrightarrow \Gamma_{K^{*0}} = 48.86\pm0.50$

For $\Gamma_{K^{*0}}$, the systematics from detector resolution is 0.09MeV.

$$\Gamma_{K^{*0}}=(48.86\pm0.50\pm0.09)\ \text{MeV}$$

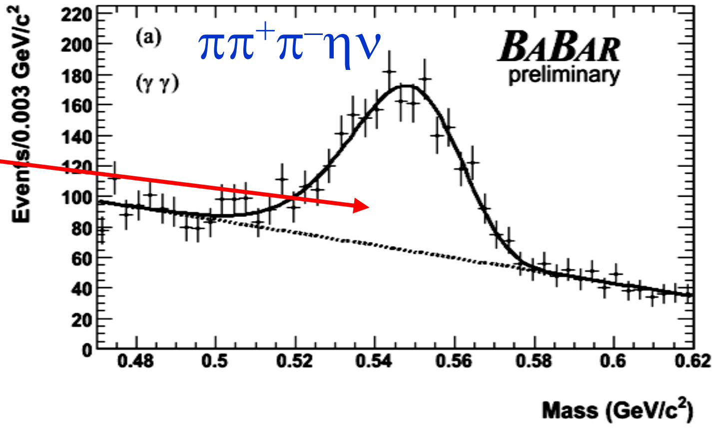
@PDG2006
$\Gamma_{K^{*0}}=(50.3\pm0.6)$MeV
@FOCUS collaboration(2005)
$\Gamma_{K^{*0}} = (47.79\pm0.86^{+1.32}_{-1.06})$MeV

Current status

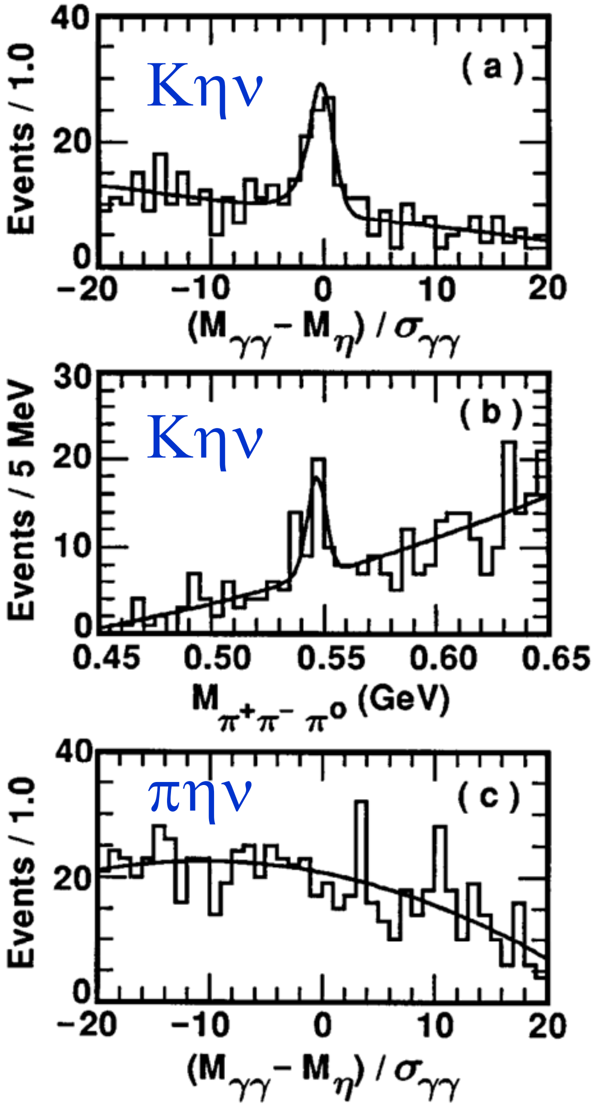
BaBar **Preliminary for tau06**

- Integrated luminosity of 220 fb^{-1} was analyzed.
- $\mathrm{Br}(\pi\pi^{+}\pi^{-}\eta\nu) = (1.84 \pm 0.09 \pm 0.13) \times 10^{-4}$
- $\mathrm{Br}(\pi\eta'\nu) < 1.2 \times 10^{-5}$

BaBar studied another second-class-current mode and set upper limit.



Kην (CLEO)



Phys. Rev. Lett. 76, 4119–4123 (1996)

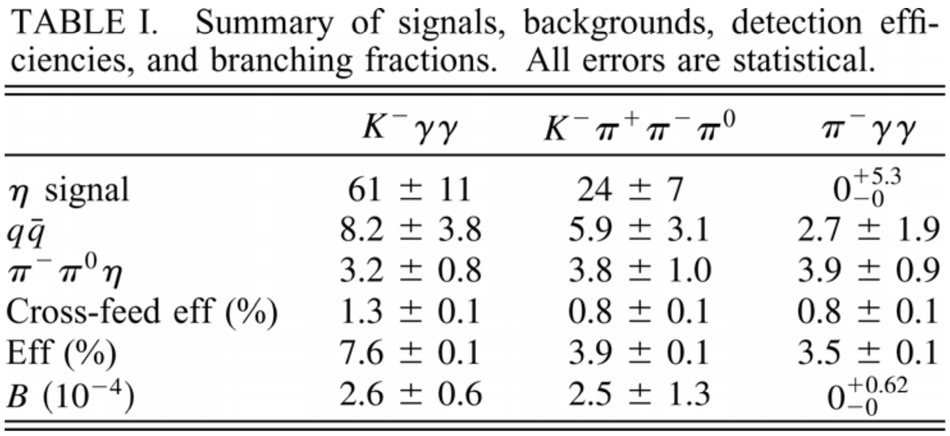


TABLE I. Summary of signals, backgrounds, detection efficiencies, and branching fractions. All errors are statistical.

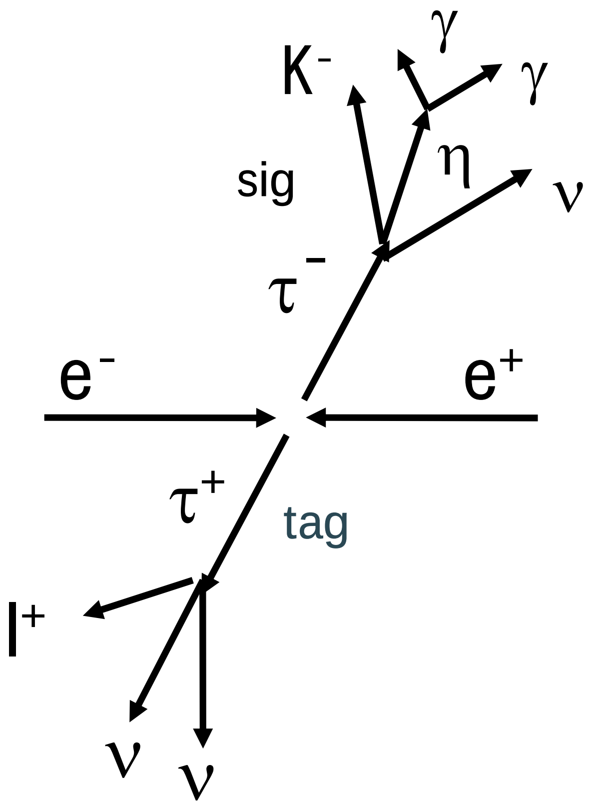
	$K^-\gamma\gamma$	$K^-\pi^+\pi^-\pi^0$	$\pi^-\gamma\gamma$
η signal	61 ± 11	24 ± 7	$0^{+5.3}_{-0}$
$q\bar{q}$	8.2 ± 3.8	5.9 ± 3.1	2.7 ± 1.9
$\pi^-\pi^0\eta$	3.2 ± 0.8	3.8 ± 1.0	3.9 ± 0.9
Cross-feed eff (%)	1.3 ± 0.1	0.8 ± 0.1	0.8 ± 0.1
Eff (%)	7.6 ± 0.1	3.9 ± 0.1	3.5 ± 0.1
B (10^{-4})	2.6 ± 0.6	2.5 ± 1.3	$0^{+0.62}_{-0}$

- Integrated luminosity of 3.5 fb^{-1} was analyzed.
- Totally, 50 events were observed.
- They assume branching ratio of $K\pi^0\eta\nu$, ~ 10^{-6} from theory
- $\text{Br}(K\eta\nu) = (2.6 \pm 0.5 \pm 0.4) \times 10^{-4}$
  $\text{Br}(\pi\eta\nu) < 1.4 \times 10^{-4}$

$\tau \to K\eta\nu, K\eta\pi^0\nu, \pi\pi^0\eta\nu$ selection

Data set：$485 fb^{-1}$

- tag side τ:$\tau \to l\nu\nu$; 1 track
- signal side τ: $\tau \to K\gamma\gamma\nu$; 1 tracks
    - $\eta \to \gamma\gamma$
      $105 < M\gamma\gamma < 165 MeV/c^2$
- other requirements
    - π^0 veto
    - missing momentum



Main BG:

with η

$\tau \to K\eta\pi^0\nu, \pi\pi^0\eta\nu, ee \to \mathbf{q\bar{q}}$

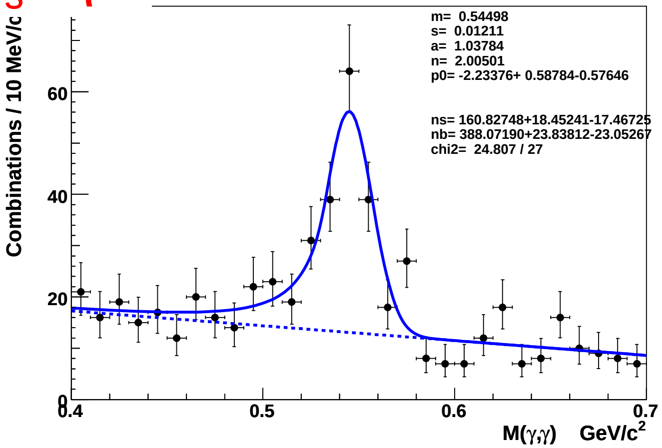
w/o η $\tau \to KK_s^0\pi^0\nu$ $(K_s^0 \to \pi^0\pi^0)$

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

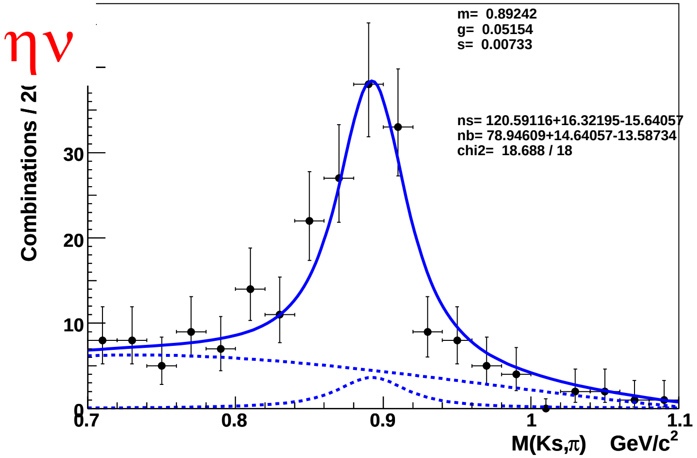
We estimate the number of signal events from η mass distribution.

$\tau \to K_s\pi\eta\nu, K^*\eta\nu$

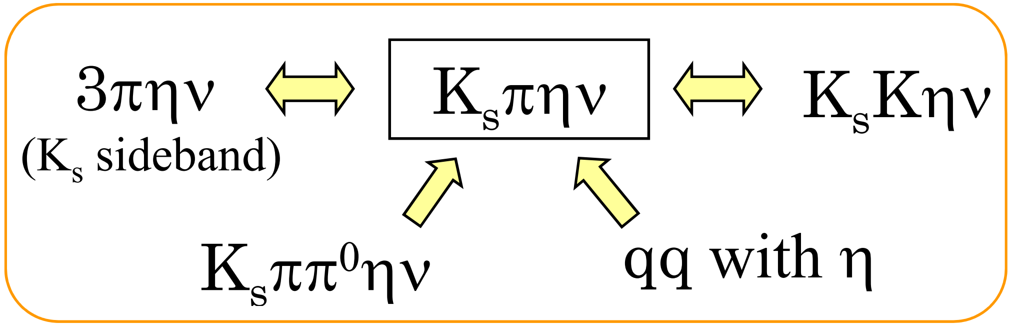
$K_s\pi\eta\nu$



$K^*\eta\nu$



- Calculate with peaking BGs
  - Cross-feed among $\tau^- \to K_s\pi^-\eta\nu$, $\tau \to 3\pi\eta\nu$ in K_s sideband, $\tau^- \to K_s\pi^-\eta\nu$
  - Contribution of qq and $\tau \to K_s\pi\pi^0\eta\nu$
  - Errors from efficiency and cross-feed rate are included as statistical error.



$3\pi\eta\nu$ (K_s sideband) ⇔ $K_s\pi\eta\nu$ ⇔ $K_sK\eta\nu$

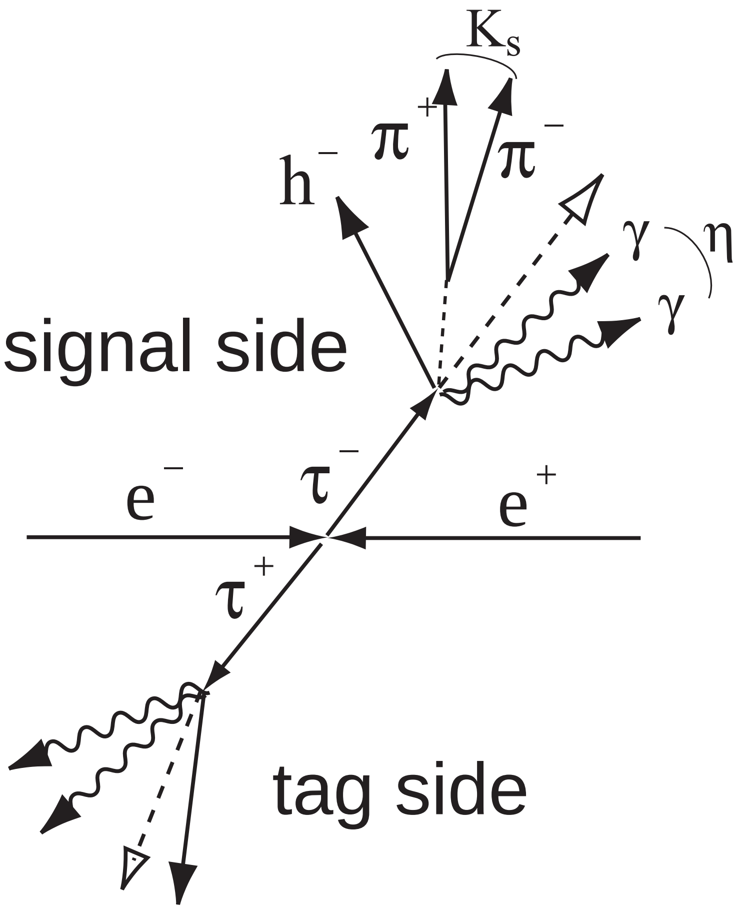
$K_s\pi\pi^0\eta\nu$

qq with η

Event selection

- $\tau^- \rightarrow K_s(\rightarrow \pi^-\pi^+)\pi^-\eta\nu$

- 3-1 topology
- Signal side
  - $N\gamma=2$
  - $0.45<M_{\pi\pi}<0.55$
    - Vertex const. fit
  - $0.5<r<30$ cm for K_s vertex
  - Electron veto for hadrons
    - Remove Bhabha BG with shower
  - $E\gamma>0.3$ for eta daughters
- Tag side
  - Lepton tag
  - $N\gamma<3$



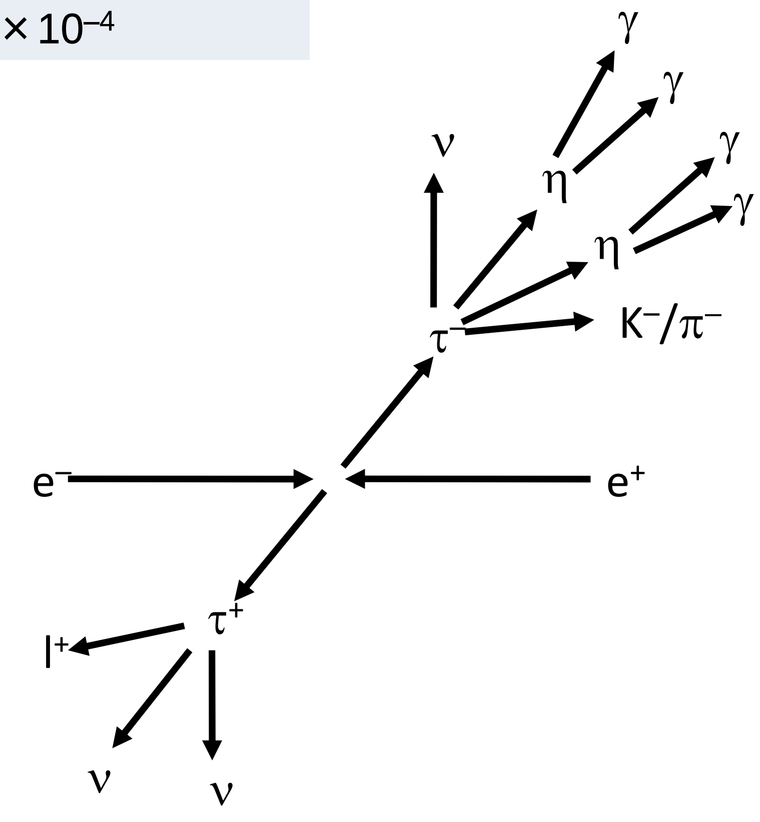
$K\eta\eta\nu$ and $\pi\eta\eta\nu$ analysis

by H.Kaji

- Strongly suppressed and not observed yet.

	Theory	Current limit
$K\eta\eta\nu$	1.1×10^{-9}	---
$\pi\eta\eta\nu$	1.9×10^{-9}	$<1.1\times10^{-4}$

- Event Selection
  - 1-1 topology, $\eta\to\gamma\gamma$
  - Signal-side
    - $N_\gamma=4$
    - K/π ID for track
    - ☐ π^0 veto for γ_η
    - P_η^τ selection in "τ rest frame" for $K\eta\eta\nu$
    - $E_\gamma>0.1$ (0.3) GeV for $K\eta\eta\nu$ ($\pi\eta\eta\nu$)
  - Lepton tag

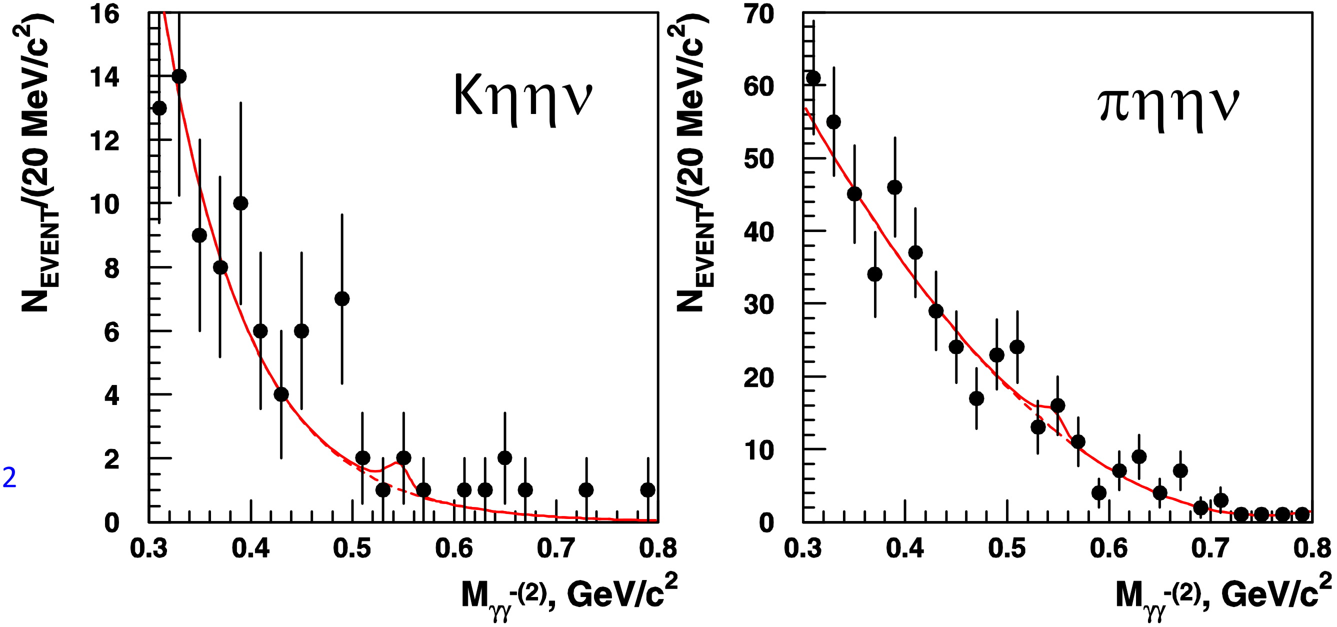


- Efficiency
  - 0.19 % for $K\eta\eta\nu$, 0.22 % for $\pi\eta\eta\nu$

Extraction of η yield

Data : 485 fb^{-1}

$0.48 < M_{\gamma\gamma}^{-(1)} < 0.58\,\mathrm{GeV}/c^2$
(η mass region)



- Crystal ball function is fitted to $M_{\gamma\gamma}^{-(2)}$ distribution
  - The shape is fixed with the result of previous analysis