

# WG8(experiment)

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B2TiP MIAPP  
17/Nov/2016

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Thanks to Emi's Great effort, we can reach some shape. (not so bad, not yet so good)

Big changes: Golden mode  $\tau \rightarrow \mu\mu\mu \rightarrow \tau$ LFV

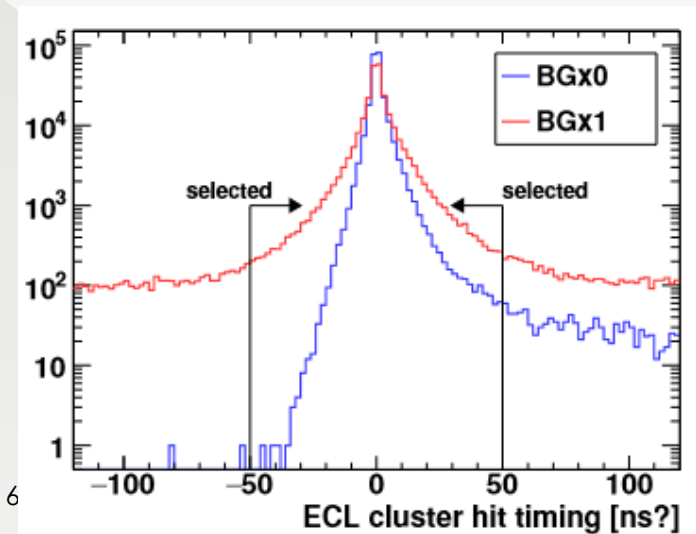
Added "Other important measurements", Event generator relating  $\tau$  physics

# Highlights of WG8 Chapter

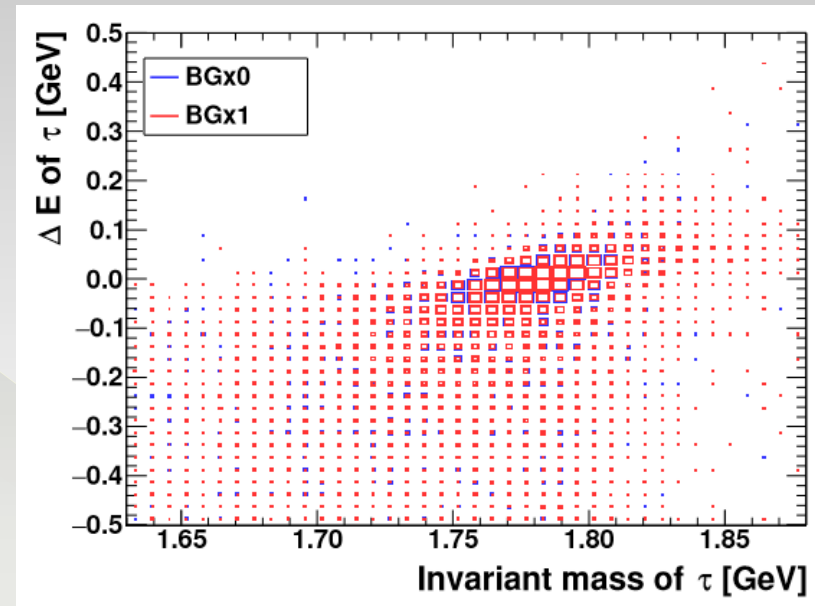
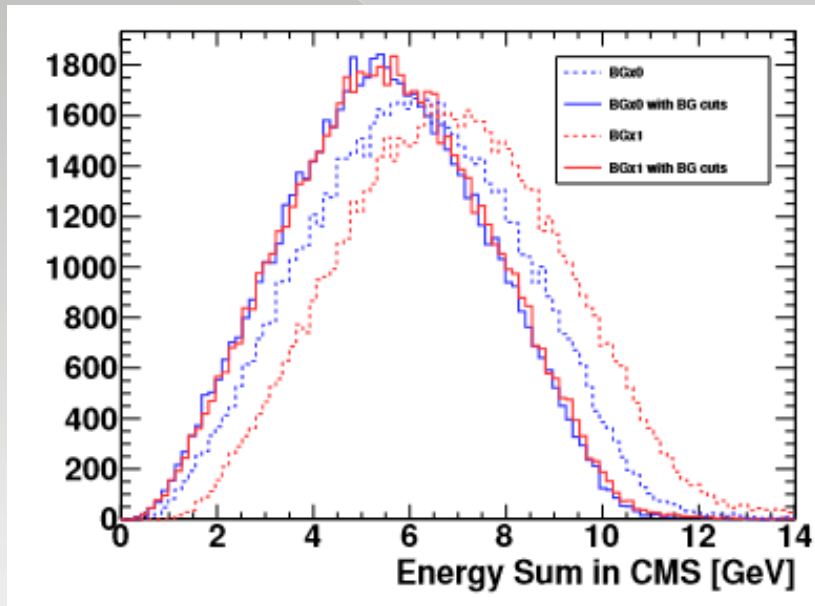
- ◎  $\tau \rightarrow \mu \gamma$ :
- ◎ CPV in  $\tau \rightarrow K_s^0 \pi \nu$ :
- ◎ Dark Photon:

# $\tau \rightarrow \mu \gamma$ MC study

- With beam BG, MC study has been performed for  $\tau \rightarrow \mu \gamma$ .
  - Here, the effect from beamBG to signal events is studied.
  - It turns out that by applying some cuts almost similar result can be obtained to the one without beam BG.



# $\tau \rightarrow \mu \gamma$ MC study

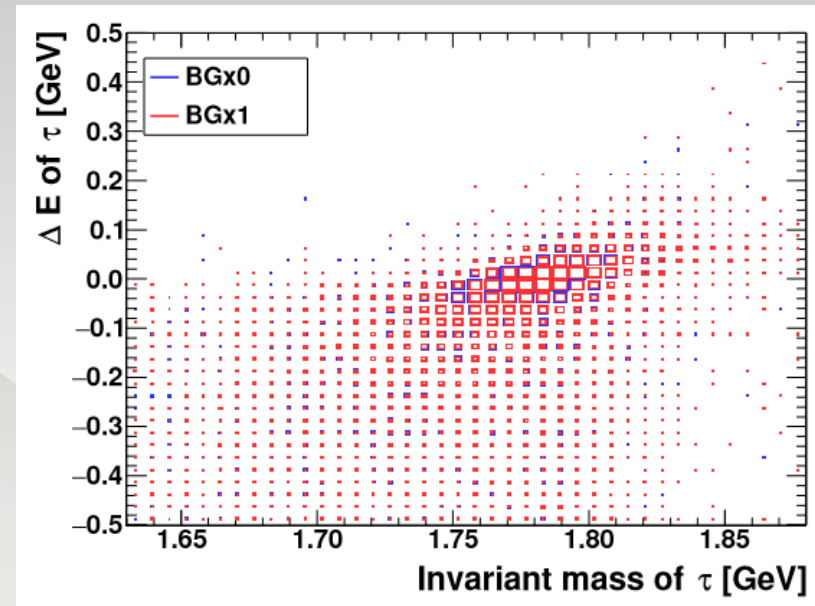
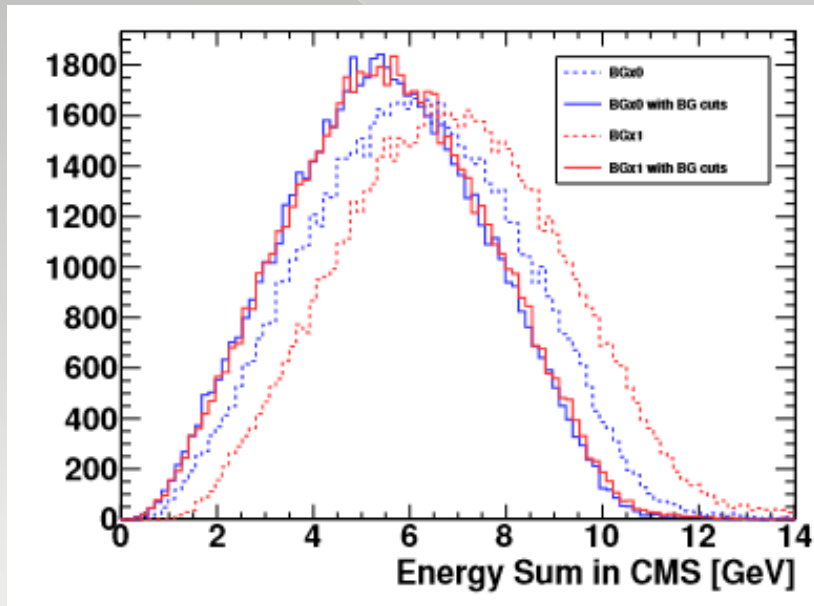


Red: with beamBG  
Blue: without beamBG

Due to the cut,  
16% signal detection  
Efficiency loss is expected.

By applying some cuts to reject beamBG,  
Similar distribution is obtained to  
the one without beamBG.

# $\tau \rightarrow \mu \gamma$ MC study



Red: with beamBG  
Blue: without beamBG

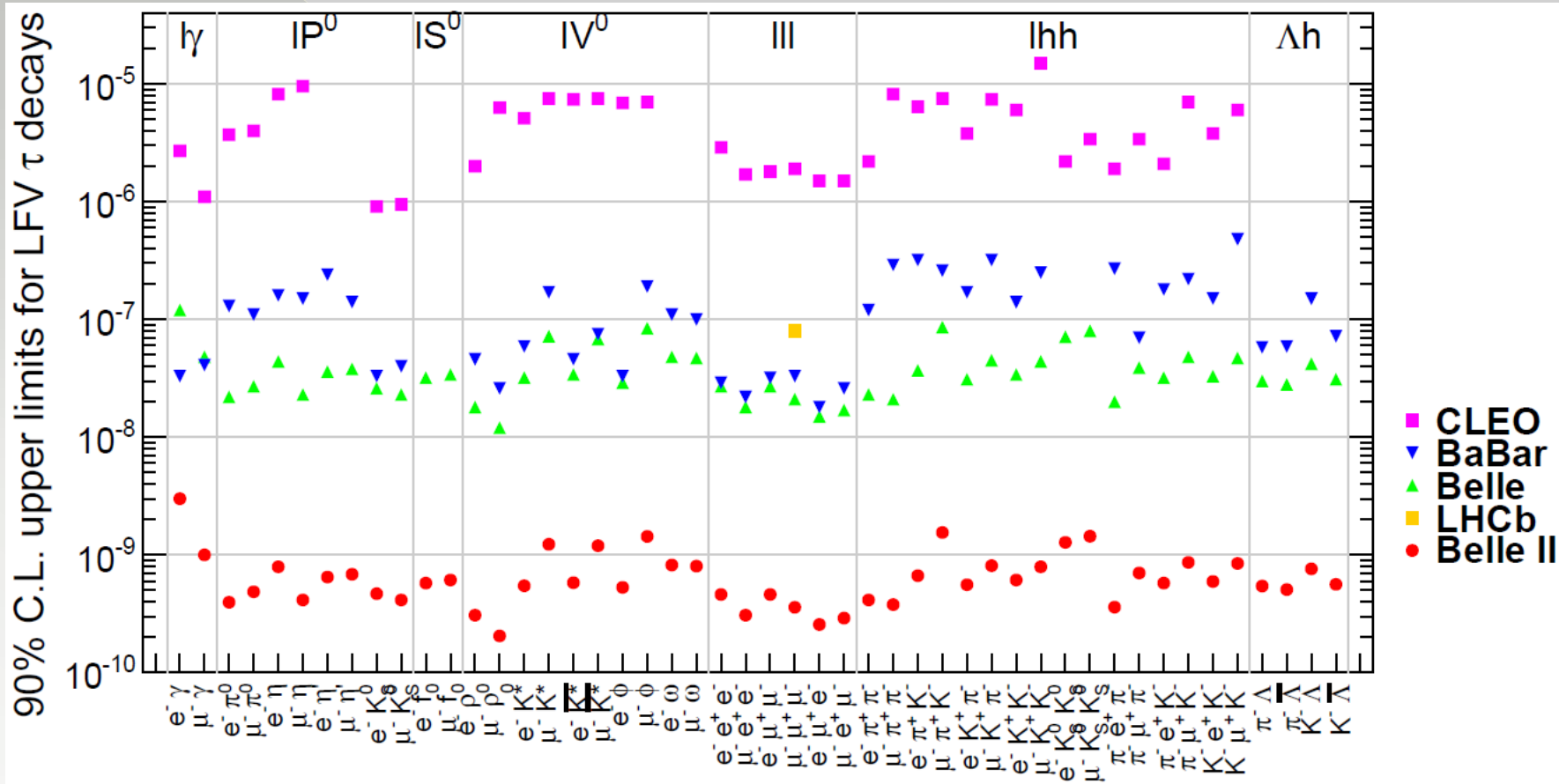
By applying some cuts to reject beamBG,  
Similar distribution is obtained to  
the one without beamBG.

Due to the cut,  
16% signal detection  
Efficiency loss is expected.

Now, we also have  
Phill's student result: will be

# Expected ULs plot

● Phill kindly prepares plots



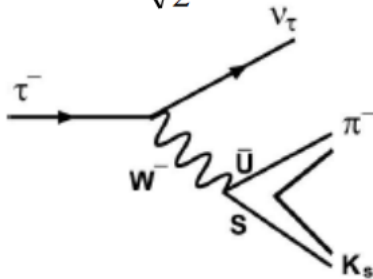




# CPV in $\tau \rightarrow K_S^0 \pi \nu$

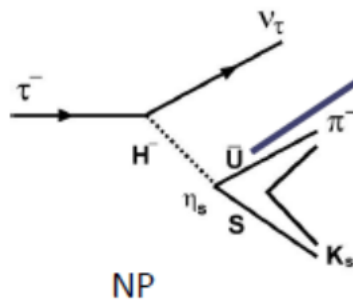
## -Effective Hamiltonian

$$H_{SM} = \sin \theta_c \frac{G}{\sqrt{2}} (\bar{\nu} \gamma^\mu (1 - \gamma_5) \tau) (\bar{s} \gamma_\mu (1 - \gamma_5) u)$$



Scalar Boson

$$H_{NP} = \sin \theta_c \frac{G}{\sqrt{2}} (\bar{\nu} (1 + \gamma_5) \tau) \eta_s \bar{s} u$$



When NP is considered, this scalar interaction is possible and induces CP violation.

# CPV in $\tau \rightarrow K_s^0 \pi \nu$

## -Effective Hamiltonian

Scalar Boson  
 $H_{SM} = \sin \theta_s \frac{G}{\sqrt{2}} (\bar{\nu}(1 + \gamma_5)\tau) n \bar{s} u$

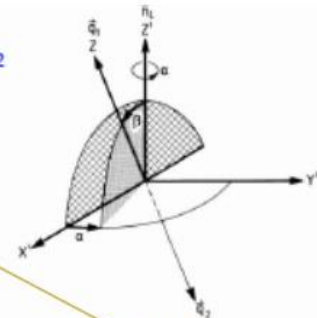
$H_{SM} =$

- The effect from CPV appears via the interference between SM term and NP term.

$\tau^-$

$$\frac{d\Gamma(\tau^-)}{dQ^2 d\cos\theta d\cos\beta} = [A(Q^2) - B(Q^2)(3\cos^2\Psi - 1)(3\cos^2\beta - 1)] \cdot |F|^2 + m_\tau^2 |F_s|^2$$

$- C(Q^2) \cos\beta \cos\psi \cdot \text{Re}(FF_s^*(\eta_s))$  ← **Contain CPV terms**



$Q^2 = M_{K\pi}^2$ ,  $A(Q^2), B(Q^2), C(Q^2)$ : known function.

$\beta$ : direction of  $K_s$  in  $K_s \pi$  rest frame

$F$ : Vector form factor

$\Psi$ : direction of  $\tau$  in the  $K_s \pi$  rest frame.

$F_s$ : Scalar form factor

( $\theta$ : direction of  $K_s \pi$  system in the  $\tau$  rest frame. Correlated with  $\Psi$ )

This term will vanish when it is integrated over  $Q^2$ .

$$A_i^{cp} = \frac{\iiint_{Q_{1,i}^2}^{Q_{2,i}^2} \cos\beta \cos\psi \left( \frac{d\Gamma_{\tau^-}}{d\omega} - \frac{d\Gamma_{\tau^+}}{d\omega} \right) d\omega}{\frac{1}{2} \iiint_{Q_{1,i}^2}^{Q_{2,i}^2} \left( \frac{d\Gamma_{\tau^-}}{d\omega} + \frac{d\Gamma_{\tau^+}}{d\omega} \right) d\omega}$$

$$\simeq \langle \cos\beta \cos\psi \rangle_{\tau^-}^i - \langle \cos\beta \cos\psi \rangle_{\tau^+}^i$$

This is an experimental observable extracting CPV term from the differential decay width.

with  $d\omega = dQ^2 d\cos\theta d\cos\beta$ .

By normalizing numbers of tau+ and tau- to be same,  $K^0$ - $\bar{K}^0$  mixing does not affect this analysis.

# Systematic source of CPV in

$$\tau \rightarrow K_s^0 \pi \nu$$

$W$ (GeV/c <sup>2</sup> )	Systematic uncertainties (10 <sup>-3</sup> )			Total
	Detector	Backgr.	MC stat.	
0.625–0.890	2.76	0.59	0.15	2.83
0.890–1.110	1.40	0.04	0.10	1.40
1.110–1.420	1.50	0.25	0.79	1.71
1.420–1.775	5.18	0.96	1.38	5.45

- ⊙ Main contribution comes from Detector bias
  - > Control sample:  $\tau \rightarrow \pi \pi \pi \nu$
  - >  $A^{\text{CP}}$  obtained using control sample is considered as a detector bias. (noCPV)
  - > This strongly depends on statistics of control sample. → Belle II systematics also depends on L!

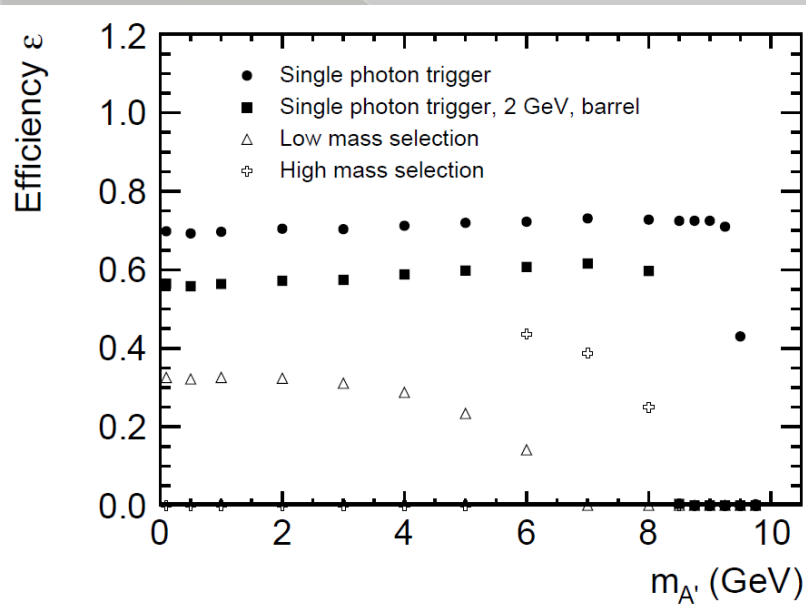
# Expected result on Belle II

- So, we make an expectation for Belle II using extrapolation (squared root) for statistics as well as systematics.
- $A^{CP_j} < |0.5-3.8| \times 10^{-4}$  at 90%
  - $(A^{CP_j} < |4-30| \times 10^{-3}$  at 90% at Belle)

# Dark Photon search (1)

- ⊙ main competition: **not mainly LHC** but other ee colliders and experiments like NA64 as well as dedicated experiments.
- ⊙ Process:  $e^+e^- \rightarrow A' \gamma$  ( $A'$  : dark photon)  
 $A' \rightarrow \chi\chi$  ( $\chi$ : dark matter)
- ⊙ Experimental signal:  $\gamma$  **That's all!!!**
- ⊙ Expected BG: radiative Bhabha,  $e^+e^- \rightarrow \gamma\gamma(\gamma)$
- ⊙ Newly, one photon trigger introduced!
  - > This is very challenging.
  - > MC study has been performed.

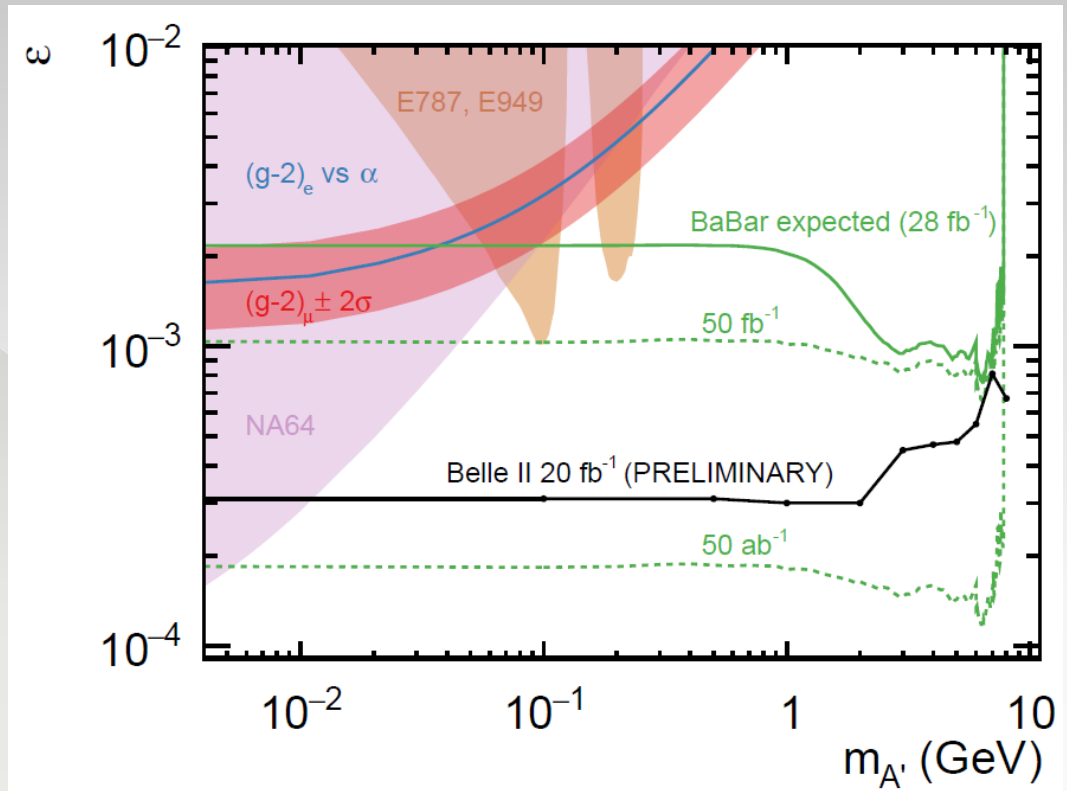
# Dark Photon search (2)



Trigger study is on-going well  
Using BG samples (radiative Bhabha,  $ee \rightarrow 2/3\gamma$ )

Since trigger simulate has not yet been ready, this study should be continued.

Anyway, well-understandings is being obtained.



Expected rejectable region

# 5 Golden modes

- ◎ Tau LFV search
- ◎ Tau CPV search
- ◎ Pion TFF
- ◎ ISR  $ee \rightarrow \pi\pi$
- ◎ Dark photon search

# Prospect for 5 Golden modes

- ◎ Tau LFV search : simple extrapolation
- ◎ Tau CPV search : simple extrapolation
- ◎ Pion TFF : not yet
- ◎ ISR  $ee \rightarrow \pi\pi$  : not yet
- ◎ Dark photon search: Evaluated

# Beyond the Golden Channels: wish-list for the future

- $\alpha_s$ , Vector/Axial vector contribution from Weak current has not been update using tau.(By ALEPH)
- To evaluate them, inclusive measurement is required.
- They will be obtained from sum-up of exclusive result.
- So, before hand, to sum up the results future, measurement should have same format, bin-width, error matrix and so on.

- ⦿ Also, individual tau hadronic decay is fruitful for Form Factor evaluation, hadron spectroscopy and so on.
- ⦿ SCC search as well.
- ⦿ So, Add inclusive/exclusive hadronic tau decay section.

# Homework...

- ⊙ Complete author list
- ⊙ ULs plot for tau LFV
- ⊙ Pion FF experiment part?
- ⊙ Inclusive/Exclusive hadronic tau decay experiment part
- ⊙ Of course, ask review...