Benchmark analysis of tau-pairs

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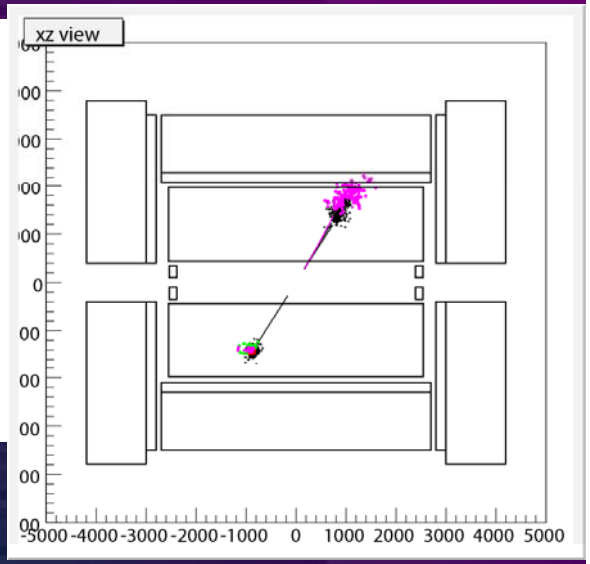
Charge of tau-pair analysis

4. $e^+e^- \rightarrow Z \rightarrow \tau^+\tau^-$ **(Ecm=500 GeV)**
   a. tau reconstruction, aspects of particle flow
   b. π^0 reconstruction
   c. tracking of very close-by tracks

Tau reconstruction is a very challenging topic at the ILC. It will stress the tracking system and the clustering in the calorimeter. In addition selecting π^0 mesons will probe the photon reconstruction ability of the detector. Observables are the efficiency and purity. Physical observables are σ, A_{FB} and Ptau (tau polarization)



Description of LOI benchmark, from ILC-MEMO-2008-001

- Themes
  - Tracking and calorimetry of concentrated particles
    - Gamma factor is around 140 for 250 GeV τs

    π_0 to 2γ decay reconstruction
    - 2γs are very closed, difficult to separate
- Observables
  - Cross section, A_{FB}, P(τ)
  - Event selection and π_0 reconstruction performance (efficiency and purity)

Events (Signal & Background)

- Signal cross sections: 2.6 pb (e_L), 2.0 pb (e_R)
  - 500 fb^{-1} is available with ILD_00
- Background
  - Full SM sample of ILD_00 is used.
    (samples downloaded to KEK by Feb. 3.
    Some of $\gamma\gamma$->$\tau\tau$ missing)
  - Event weighting is performed.
- Major backgrounds:
  - Bhabha (35000 pb in SLAC sample)
    - Preselected 2 fb^{-1} is prepared by Akiya.
      Opening angle > 165deg, $|\cos(\theta)| < 0.92$

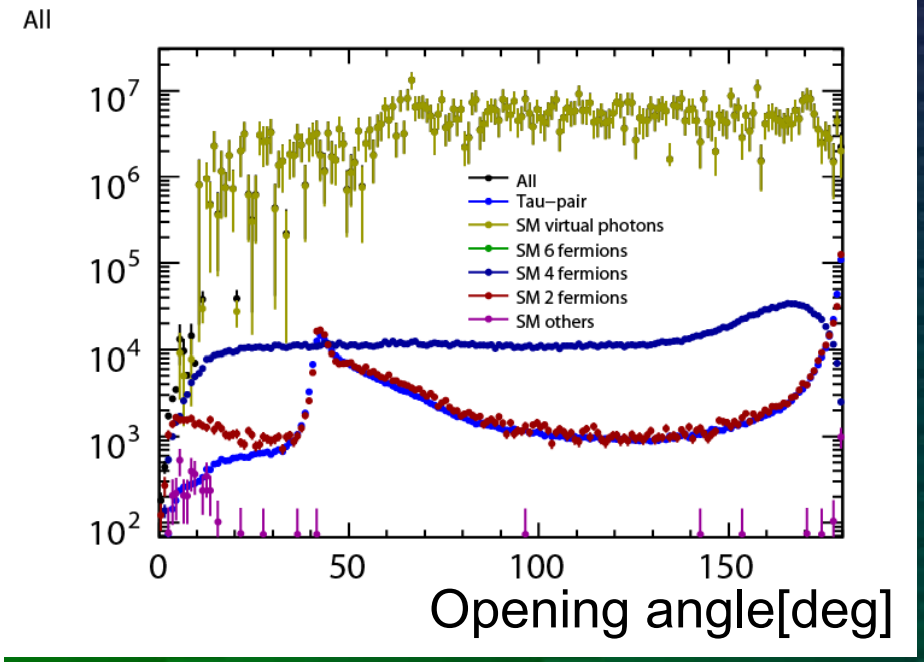
    $\gamma\gamma$ -> $\tau\tau$ (3700 pb in SLAC sample)
  - WW -> $l\nu l\nu$ (~1 pb)

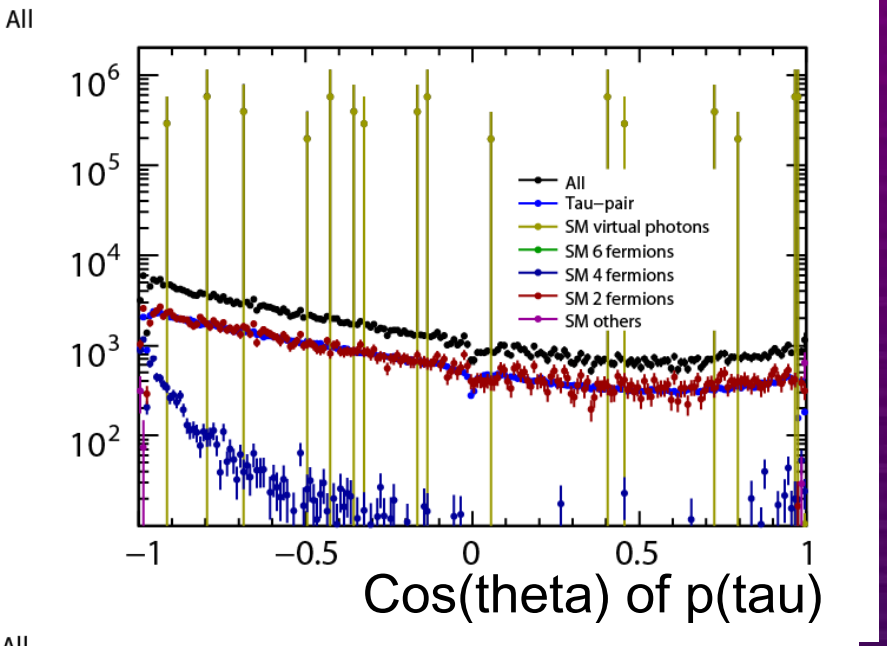
BG suppression cuts

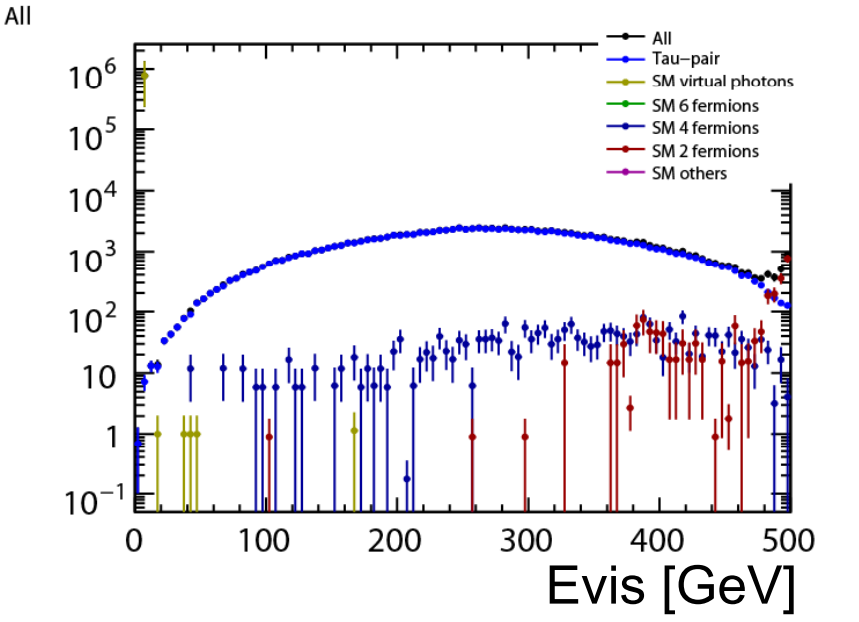
1. Number of track <= 6
   - Veto hadronic events
2. Specialized jet clustering (TaJet)
   - Customized to taus (several particles within narrow angle)
   - 1 positive & 1 negative jets required for further analyses
3. Opening angle > 178deg
   - Suppress WW to lνlν background
4. 40 < E_{vis} < 450 GeV

   $\gamma\gamma \rightarrow \tau\tau$ and Bhabha rejection
5. 2-electron and 2-muon veto
   - For bhabha and ee->μμ veto
   - E-ID by Ecal/total deposit, μ-ID by hit/track energy
6. $|\cos\theta| < 0.9$ for both jets
   - Bhabha is completely suppressed by this cut

Selections







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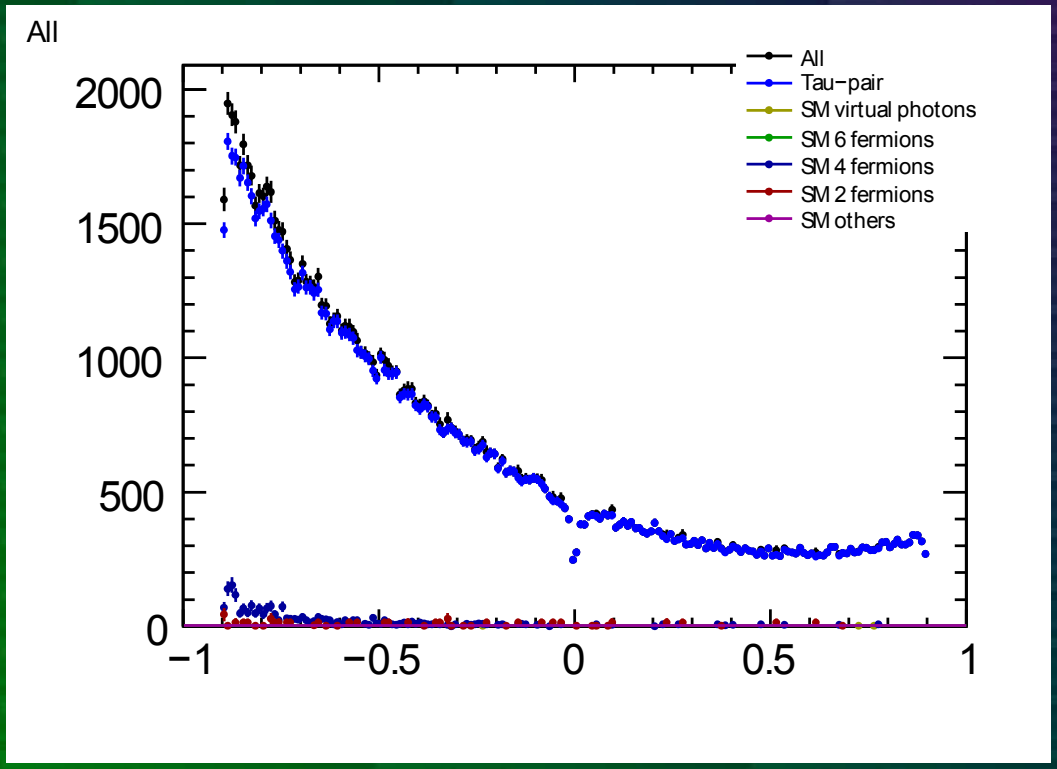
Result of SM suppression cut

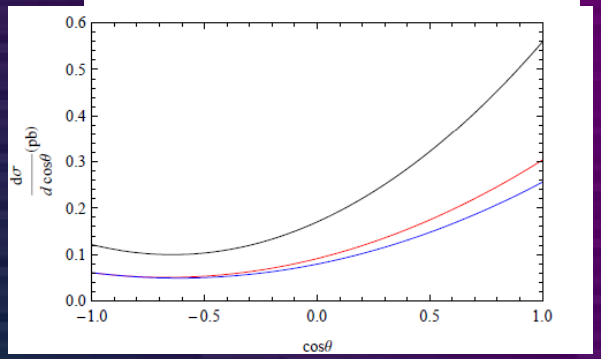
event	tautau	SM gg	SM 6f	SM 4f	SM 2f	SM other
Ntrack, jet cut	572650	7.42E+08	2005.55	2.35E+06	630123	5655.56
opening angle	152752	6.46E+06	4.00865	9523.97	157423	1048.42
thetacut	129176	5.03E+06	1.75392	3779.34	133404	0
ee,mumucut	118540	784486	0	2269.27	2616.24	0
eviscut	114811	3.15477	0	1982.1	490.532	0

- ILD_00 geometry
- Bhabha/ part of $\gamma\gamma \rightarrow \tau\tau$ are not included.
  - Bhabha was checked in LDC', not critical.
  - Preselected sample is ready, soon included.
- All background is almost negligible.

Cross section and A_{FB}



$$A_{FB} = \frac{N_F - N_B}{N_F + N_B}$$



SM calculation
(Red: left, Blue: right)

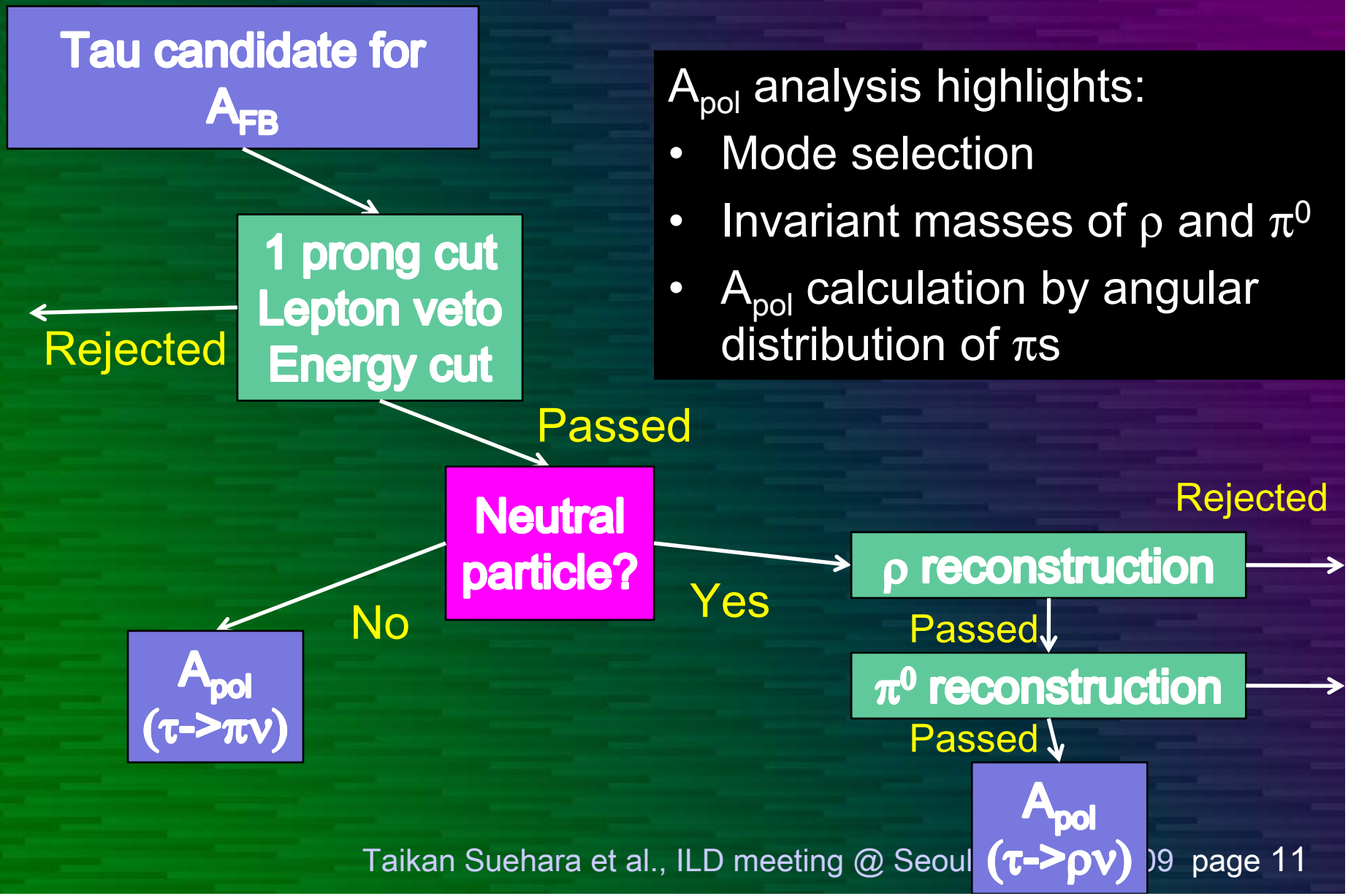
- Cross section precision: 0.3% (count based).
- AFB precision: 50.5 ± 0.25%.
  (statistical error of signal only).

Status on Polarization analysis (ILD_00 is ongoing…)

Decay modes in A_{pol} analysis

$\tau \to e\nu\nu$	• Branching ratio: 17.8% • 3 body decay; pol. info is smeared
$\tau \to \mu\nu\nu$	• Branching ratio: 17.4% • 3 body decay; same as $e\nu\nu$ mode
$\tau \to \pi\nu$	• Branching ratio: 10.9% • Pol. can be directly observed by π distribution
$\tau \to \rho\nu$, $\rho \to \pi\pi$	• Branching ratio: 25.2% • Pol. of ρ can also be obtained by π distribution in ρ-rest frame (pol. of ρ is connected to pol. of τ)
$\tau \to a_1\nu$, $a_1 \to \pi\pi\pi$	• Branching ratio: 9.3% • Currently not used because statistics is low

Analysis flow



A_{pol} analysis highlights:

- Mode selection
- Invariant masses of ρ and π^0
- A_{pol} calculation by angular distribution of πs

$\tau \rightarrow \pi\nu$ selection cuts

1. 1 prong cut
   Jets with >2 charged particle rejected.
2. Lepton veto
   Events containing e/μs are rejected.
   (criteria is the same as A_{FB} lepton-pair veto)
3. Energy cut
   Jets with energy < 10 GeV rejected.
   (e/μ/π separation is inefficient in low energy)
4. Events with > 1 GeV neutral particles are rejected.
   In “tight cut” event with any neutrals are rejected.

τ -> $\rho\nu$ selection cuts

1. 1 prong cut
2. Lepton veto
3. Energy cut (jet energy must be > 10 GeV)

Above are same as τ->$\pi\nu$ cuts

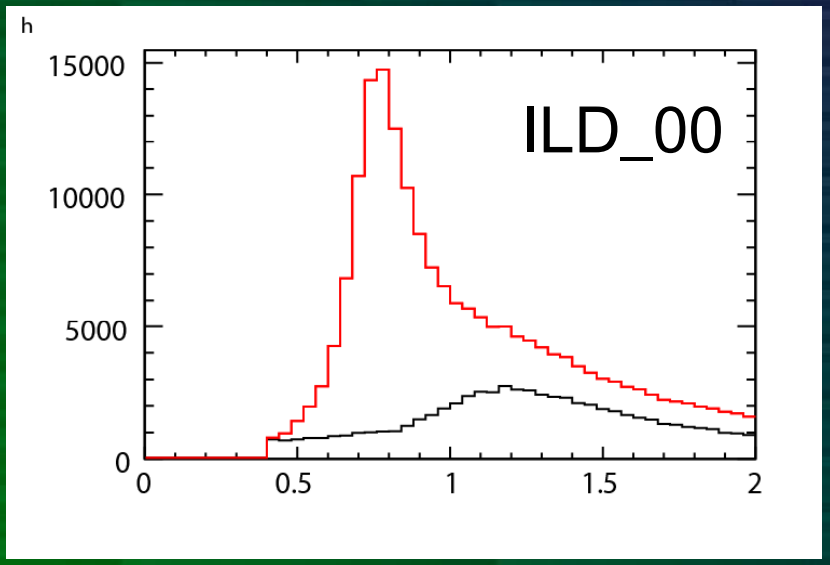
4. Events with > 10 GeV from neutrals (in total) are selected.
5. Mass of ρ is reconstructed, must be within 200 MeV from actual mass (770 MeV).
6. Mass of p0 is reconstructed with neutral particles.
   If # of neutrals >=3, nearest (in angle) two are combined until 2 particles are left.
   Application of this cut is discussed later.

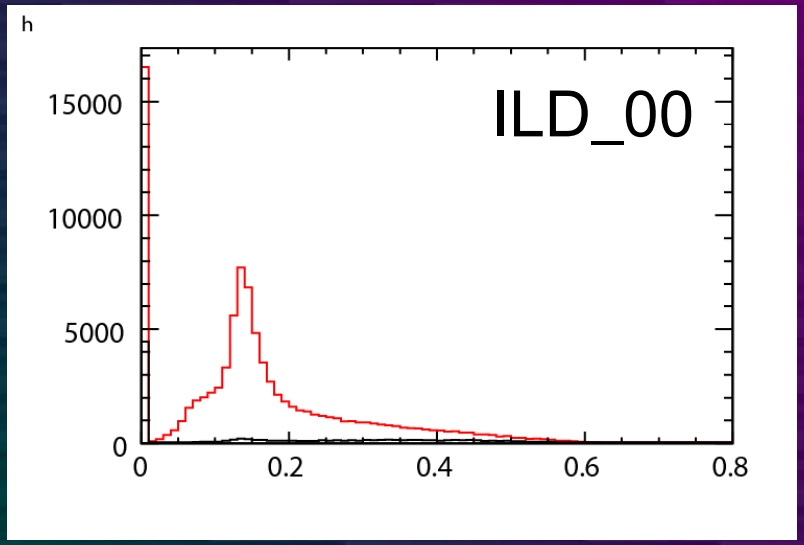
Selection results (mode BG only)

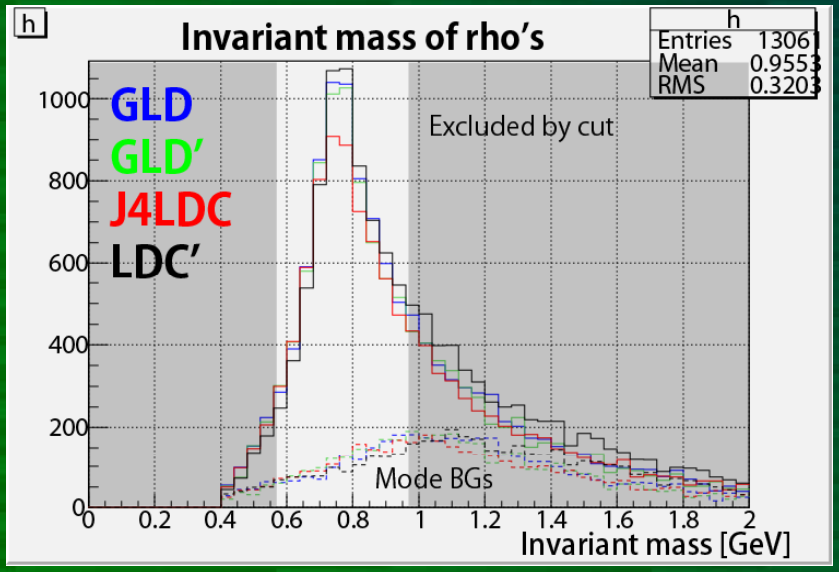
	all tau	pinu			rhonu		
	N	N	e	p	N	e	p
No cut	2294875	250141	1	0.109	578308	1	0.252
afb cut	670700	79118	0.316294	0.117963	186002	0.321631	0.277325
1 prong	564110	78931	0.315546	0.139921	174357	0.301495	0.309083
energy cut	556681	77964	0.31168	0.140051	174325	0.30144	0.313151
mu,e veto	332444	75656	0.302453	0.227575			
no gamma	53794	49443	0.197661	0.919117			
ng (tight)	43173	39870	0.15939	0.923494			
mu,e veto	339776				167575	0.289768	0.493193
any gamma	258777				159036	0.275002	0.614568
rhomass200	93217				81949	0.141705	0.879121
pi0mass	67300				61000	0.10548	0.906389
pi0masst	50825				48975	0.084687	0.963601

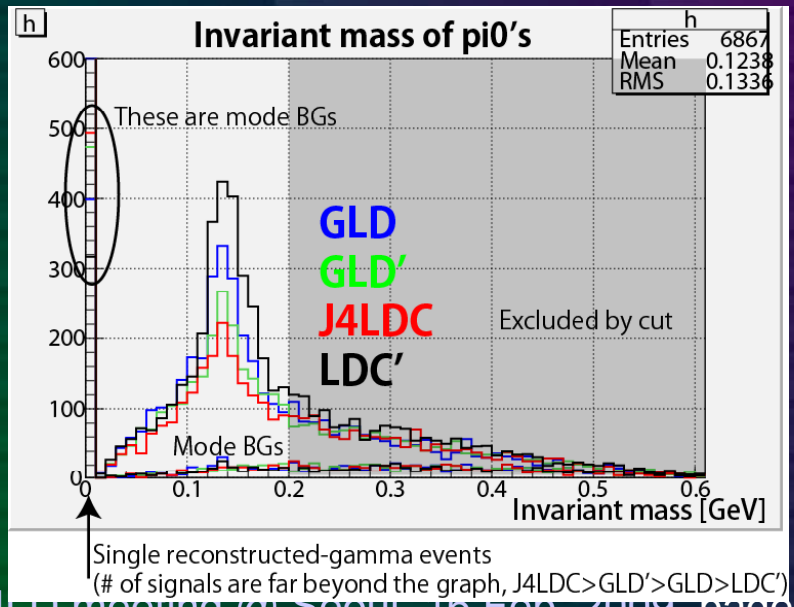
- Efficiency and purity are changed from LDC'
  - There might be effects of change of PandoraPFA?
  - Cut criteria needs to be reconsidered.

ρ and π^0 reconstruction

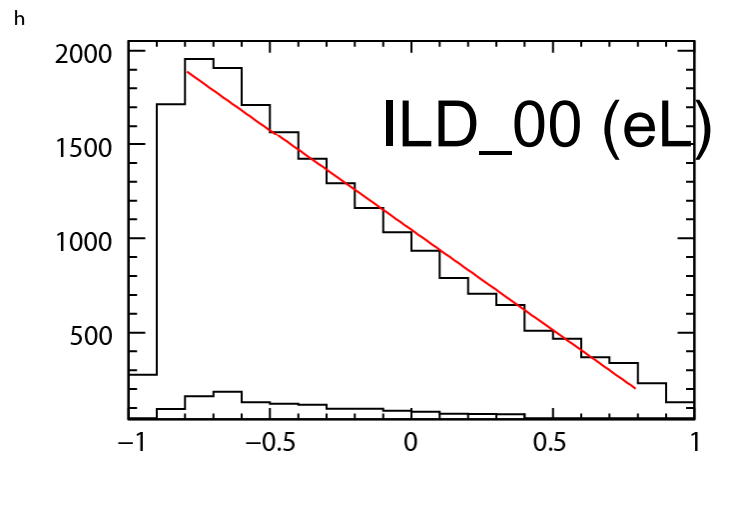


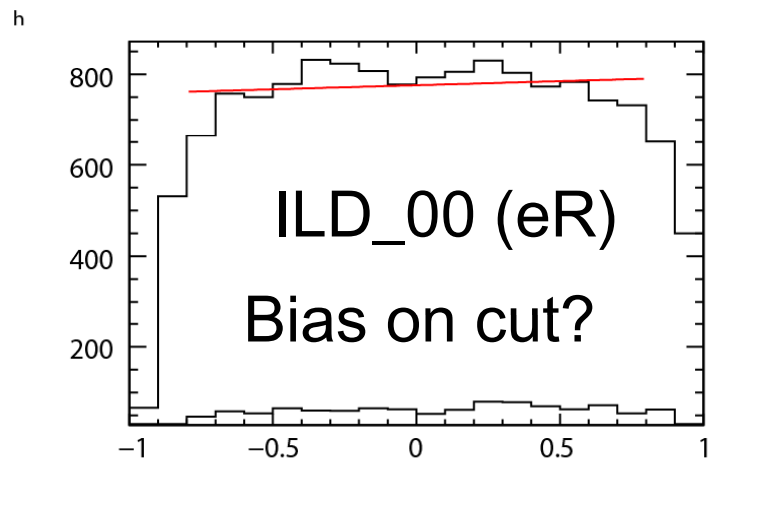


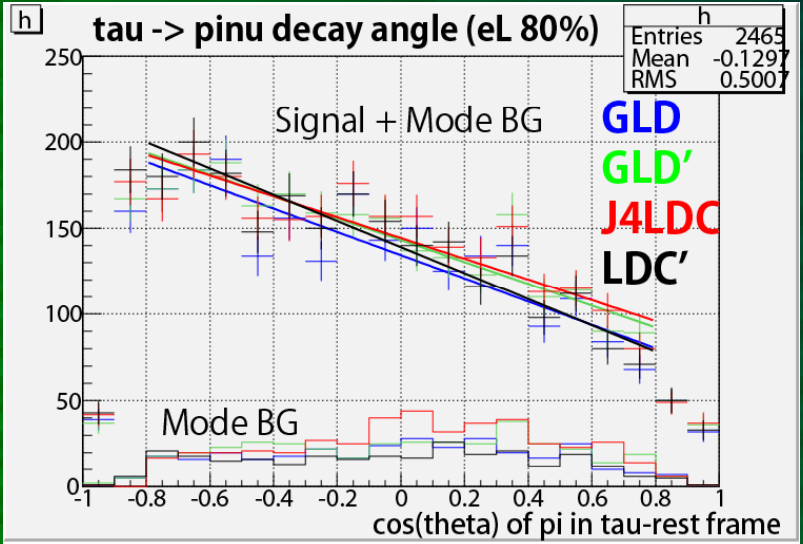


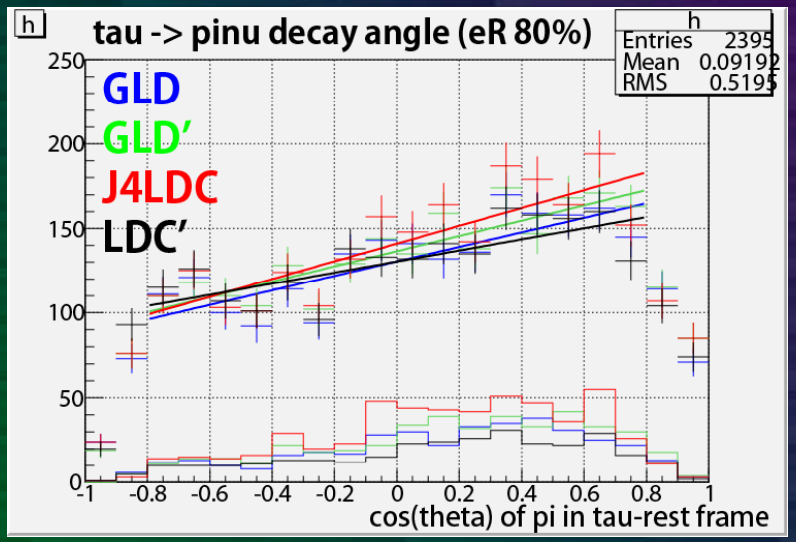


A_{pol} ($\pi\nu$ mode) PRELIMINARY!





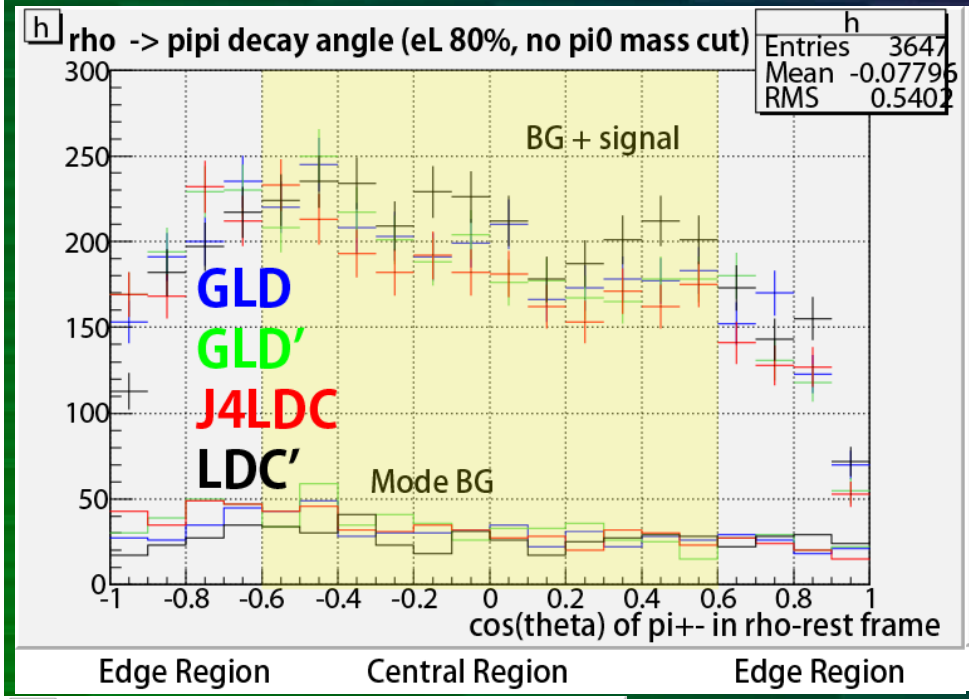


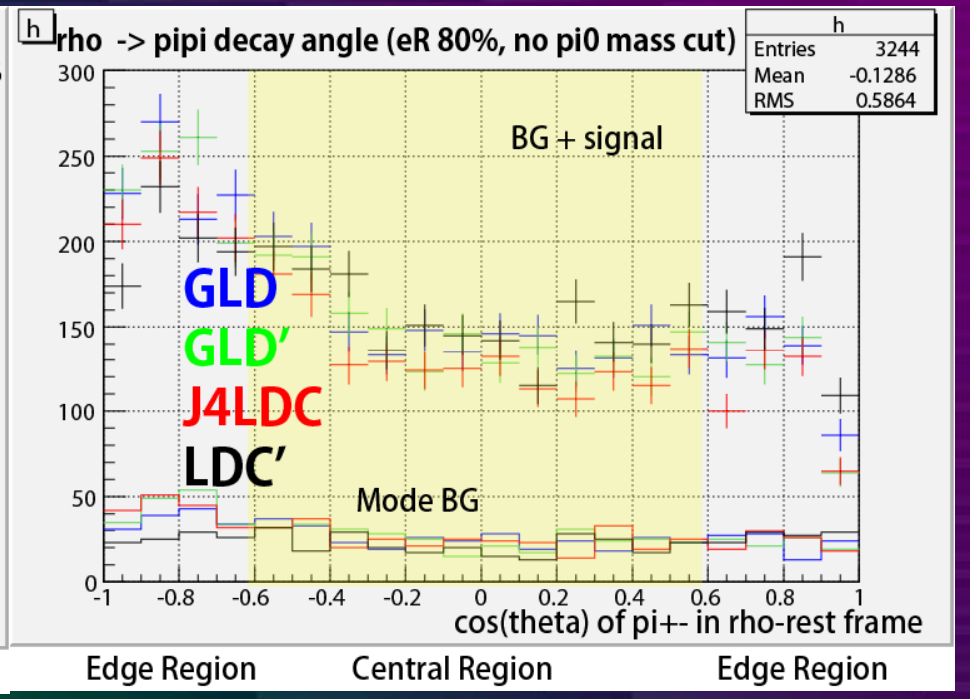


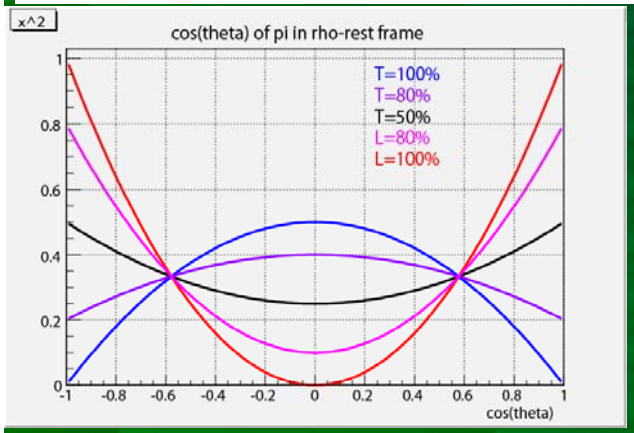
Values obtained by signal-only events!

ILD is all for now.
Following is the old result.

$\tau \rightarrow \rho\nu$, $\rho \rightarrow \pi\pi$ distribution (1) no π^0 cut



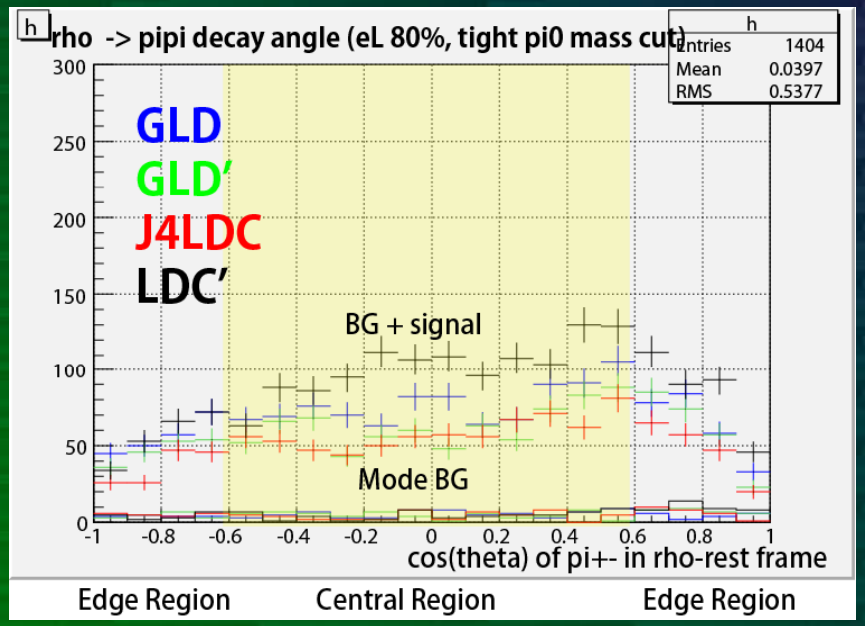


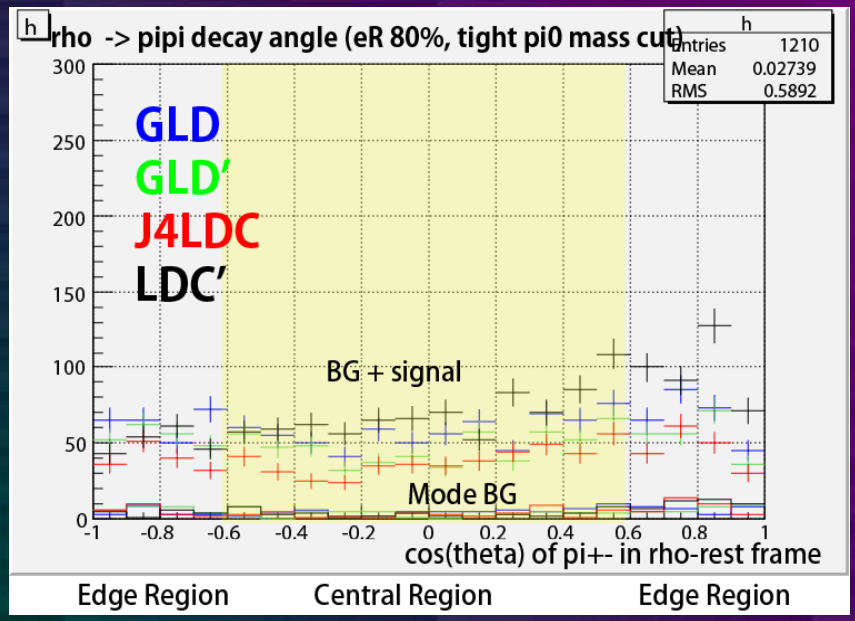


P_{pol} vs dist. calc

- Clear difference between e_L and e_R observed.
- Distribution is degraded due to the cut effects.

$\tau \rightarrow \rho\nu$, $\rho \rightarrow \pi\pi$ distribution (2) tight π^0 cut





- Number of signal is about a half.
- Difference between geometry enhanced.
  - J4LDC is not realistic with this cut?
- Background is quite low, negligible level.

Obtaining P(τ) value

τ POLARIZATION MEASUREMENTS AT LEP AND SLC

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$$y = \frac{|E_{\pi^0} - E_{\pi^-}|}{E_{\text{beam}}}, \qquad (23)$$

to be a good τ polarization analyzer. The y distribution is shown in fig. 2 for three values of the τ^- polarization: $P_\tau = -1, 0$ and $+1$. Indeed a large sensitivity to the τ polarization is found.

In order to quantify this sensitivity we consider the y symmetry

$$A_y(P_\tau) = \frac{\Gamma(y > y_c; P_\tau)}{\Gamma(y > y_c; P_\tau = 0)} - \frac{\Gamma(y < y_c; P_\tau)}{\Gamma(y < y_c; P_\tau = 0)} \qquad (24)$$

with respect to the crossover point at $y_c = 0.316$. One

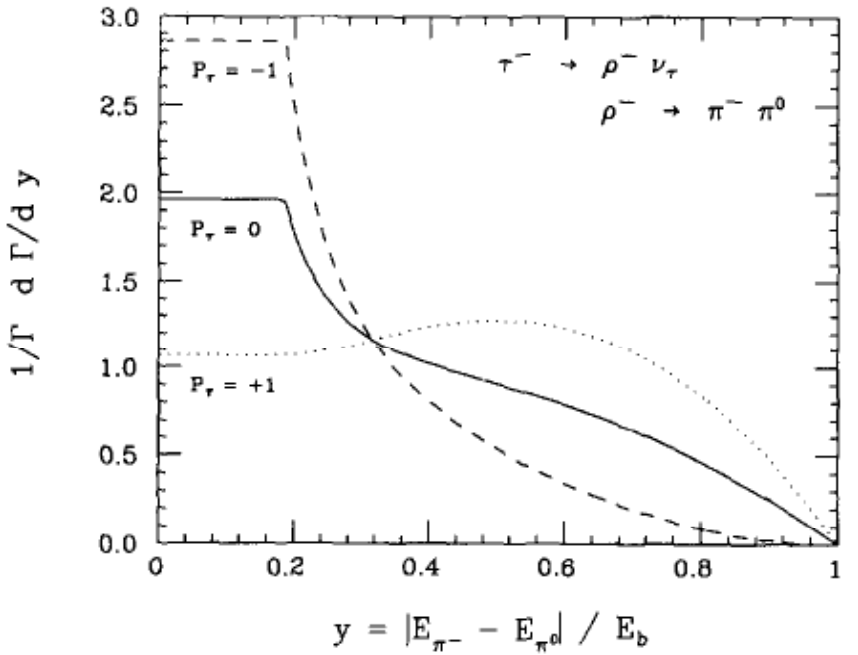
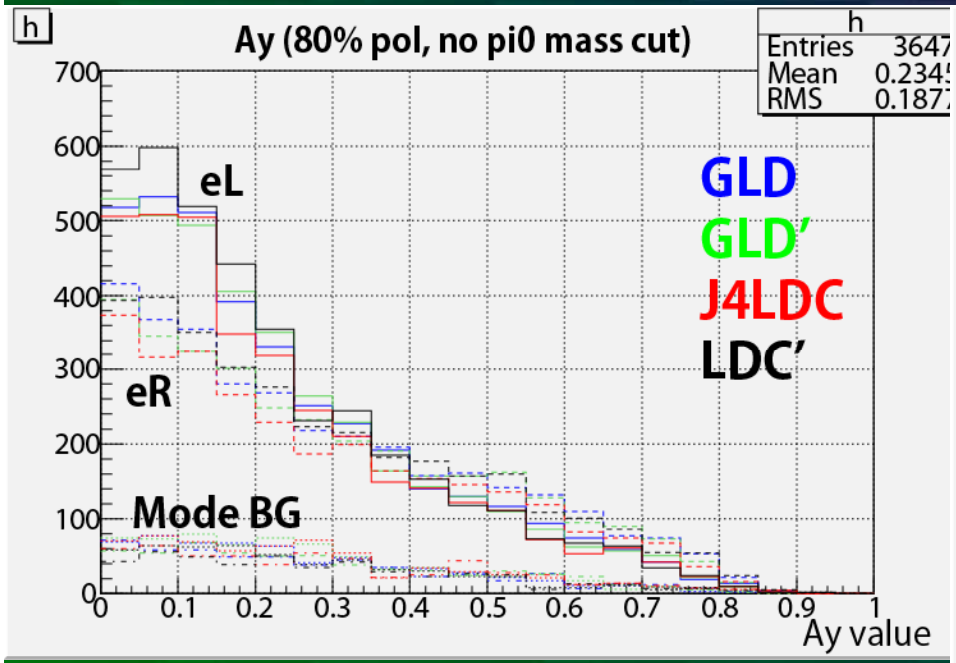
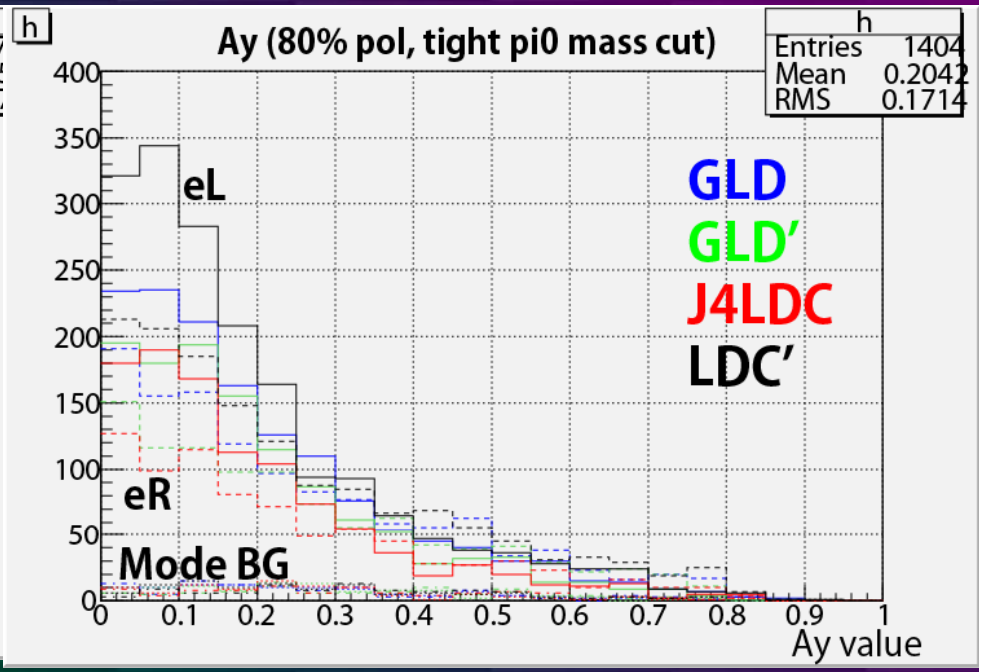


Fig. 2. Distribution of the energy difference of the two decay pions in the process $\tau^- \to \rho^- \nu_\tau$, $\rho^- \to \pi^- \pi^0$ for three values of the τ^- polarization. The common crossover point of the curves at $y_c = 0.316$ is due to the linear dependence of $d\Gamma/dy$ on the τ polarization.

- Combined information of τ -> ρν and ρ -> ππ decay can be used in this method.

A_{pol} calculation ($\rho\nu$ mode)





	Pol	Apol (nopi mass cut)	estat	shift	Apol (wpi mass cut)	estat	shift
GLD	eL (80%)	34.06% ± 4.26%	1.17%	−2.68%	34.53% ± 6.78%	1.86%	−1.66%
GLD'		38.66% ± 4.30%	1.19%	−3.59%	42.62% ± 7.36%	2.04%	−1.10%
J4LDC		34.86% ± 4.47%	1.24%	−4.24%	36.30% ± 8.24%	2.29%	0.79%
LDC'		35.62% ± 4.13%	1.17%	−3.36%	36.81% ± 6.05%	1.72%	−0.99%
GLD	eR (80%)	−28.33% ± 4.87%	1.37%	4.91%	−30.89% ± 8.32%	2.35%	3.70%
GLD'		−30.87% ± 5.00%	1.42%	3.67%	−34.26% ± 9.36%	2.66%	0.88%
J4LDC		−35.34% ± 5.38%	1.52%	2.53%	−36.45% ± 11.18%	3.16%	−1.90%
LDC'		−32.70% ± 4.89%	1.41%	2.89%	−32.46% ± 7.86%	2.27%	−0.49%

Values obtained by signal-only events!

Summary

- SM separation cuts were developed.
  - Most of the SM process can be suppressed by the cuts efficiently.
  - We need to check bhabha/ ($\gamma\gamma$->$\tau\tau$?) for confirmation.
  - Cross section and A_{FB} are obtained.
- Polarization
  - ILD_00 analysis is ongoing.

Thank you for your attention.

Backup