Tau polarization LoI Benchmarking Study

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SiD Collaboration Meeting at SLAC for Final Preparation of the Letter of Intent

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LoI tau polarization study update

- **LoI statement**
- **Analysis components**
  - Decay mode analysis (see Ron Cassell's talk in this session)
  - Tau direction analysis
  - Polarization measurement
- **ILD Tau analysis status at LCWS08**
- **Summary**

LoI statement

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)

ILC-MEMO-2008-001

Address using

- **Tau decay mode identification**
- **Tau direction/impact parameter determination**
- **Tau polarization measurement using optimal observables**

Tau decay mode identification

Modes & branching ratios we could consider

$\tau \to e\nu\nu$ (18%), $\tau \to \mu\nu\nu$ (18%), $\tau \to \pi\nu$ (11%), $\tau \to \rho\nu$ (25%),
and $\tau \to a_1\nu$ (9%)

Status

- Work done by Subhendu until recently
  - Focused on $\tau \to \pi\nu$ and $\tau \to \rho\nu$
- Ron now working on this too (see his talk in this session)
- Hope to include a_1 mode
- Lepton mode sensitivities to τ polarization reduced due to two undetected particles

Not trivial

- Need to understand efficiencies and purities

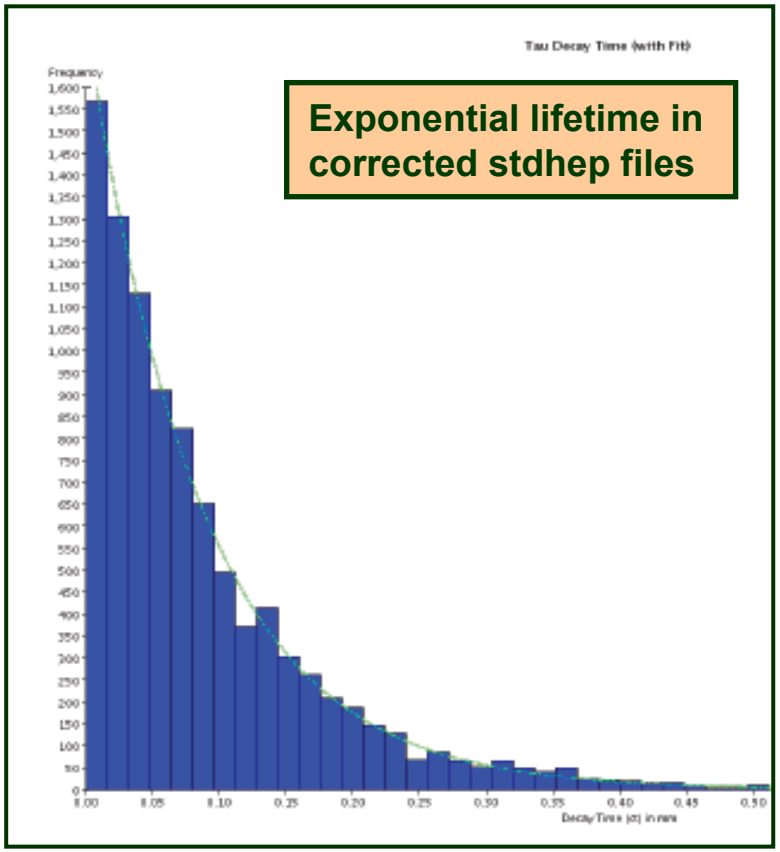
Tau direction study

Performed by Rich and Cosmin

- Cosmin's senior thesis
- Investigate use of vertexing information
- Provide a handle on tau direction
- Improves tau polarization measurement
- Perform maximum likelihood fit using vertexing parameters
- Not sure if it will be ready on the LoI timescale

First payoff already

- Discovered some samples had *τ's* decaying with zero lifetime
  - Due to configuration problem with whizard and tauola
  - Cosmin provided revised stdhep files with corrected decays
- Corrected stdhep files running through simulation and recon now



Cosmin, Jan. 27, 2009 sim/reco mtg

Polarization using optimal observables

We plan to use "optimal observables" for the tau polarization measurement

- Described in several LEP-related papers. E.g:
  - (1) M. Davier et al., "The optimal method for the measurement of tau polarization", Phys. Lett. B 306, 411 (1993)
  - (2) LEP & SLD expts, "Precision electroweak measurements on the Z resonance", Phys. Rept. 427, 257 (2006)
- along with others

One of the originators of this method is Francois Le Diberder (paper (1) above) is at SLAC

- BaBar spokesperson
- We have discussed this approach with him

Optimal observables method

Relies on decay rate distribution

- $W = \frac{1}{2}(1 + p \cos\theta_h)$ where
  - $p = \tau$ polarization
  - θ_h is the angle between the τ helicity and the pion in the τ rest frame

This holds for the other five τ decay modes

- When using "optimal observable" ω in place of $\cos\theta_h$
- Variable ω depends on kinematic variables of each decay mode

From paper (1)

Table 1
Sensitivities of the τ decay channels for $P_\tau = -0.15$. The two first columns give the sensitivities of the standard analyses [1,4], the two last the sensitivities achieved when using all the available information without and with the τ direction $\hat{\tau}$.

Channel	Number of observables			
	1	2	all but $\hat{\tau}$	with $\hat{\tau}$
$\pi\nu$	0.58	–	0.58	0.58
$\rho\nu$	0.26	0 49	0.49	0.58
$a_1\nu$	0.10	0 23	0.45	0.58
$l\nu\bar{\nu}$	0 22	–	0.22	0.27

Sensitivities can be calculated from known decay distributions

- $S = 1/\sigma\sqrt{N}$
- σ = statistical error
- N = # events
- Model dependence for multi-body decays

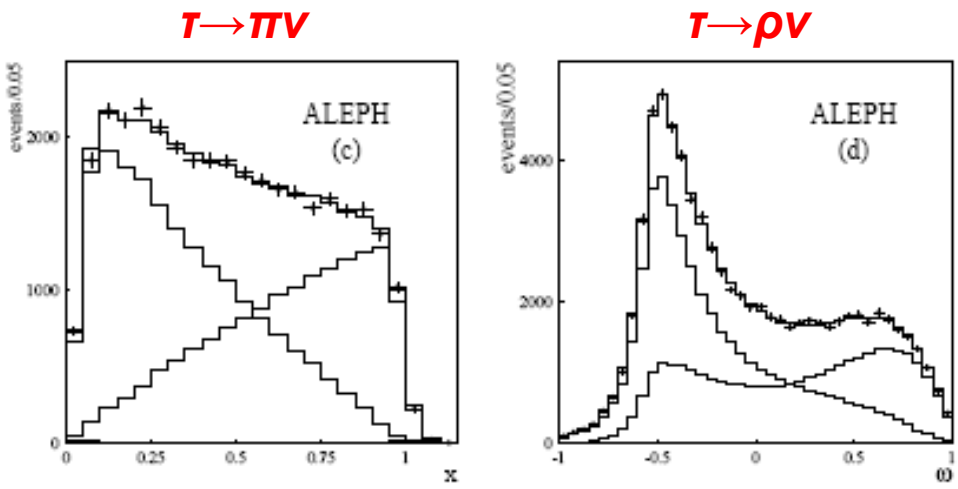
Optimal observables (2)

Distributions in ω need only be obtained for τ's with helicity +1 and -1

- These can be obtained with detailed MC simulation of full detector response
- Automatically includes detector effects
- Depends on accuracy of simulation

Fit simulated distributions directly to data

Eur. Phys. J. C 20, 401 (2001)



Dotted line: helicity −1
Dot-dashed line: helicity +1
Points: data
Solid line: fit

What's ILD doing?

Latest information I have is from LCWS08

"Tau-pair performance in ILD detectors" **by T. Suehara**

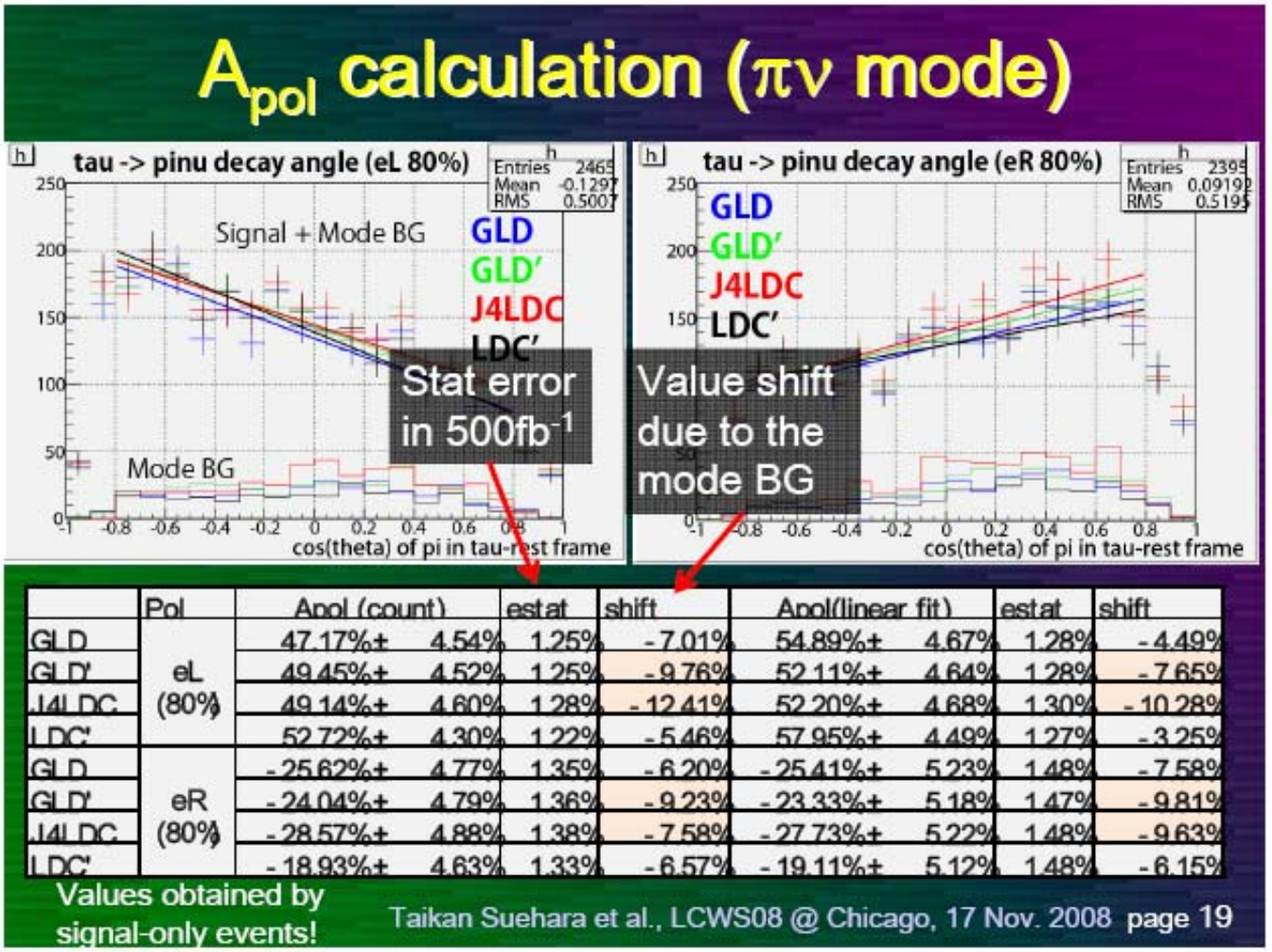
Showed results for LDC', GLD', GDL, J4LDC

ILD data production was underway at that time

Presented results using signal events only

For modes $\tau \rightarrow \pi\nu$ and $\tau \rightarrow \rho\nu$

ILD study: $\tau \rightarrow \pi\nu$

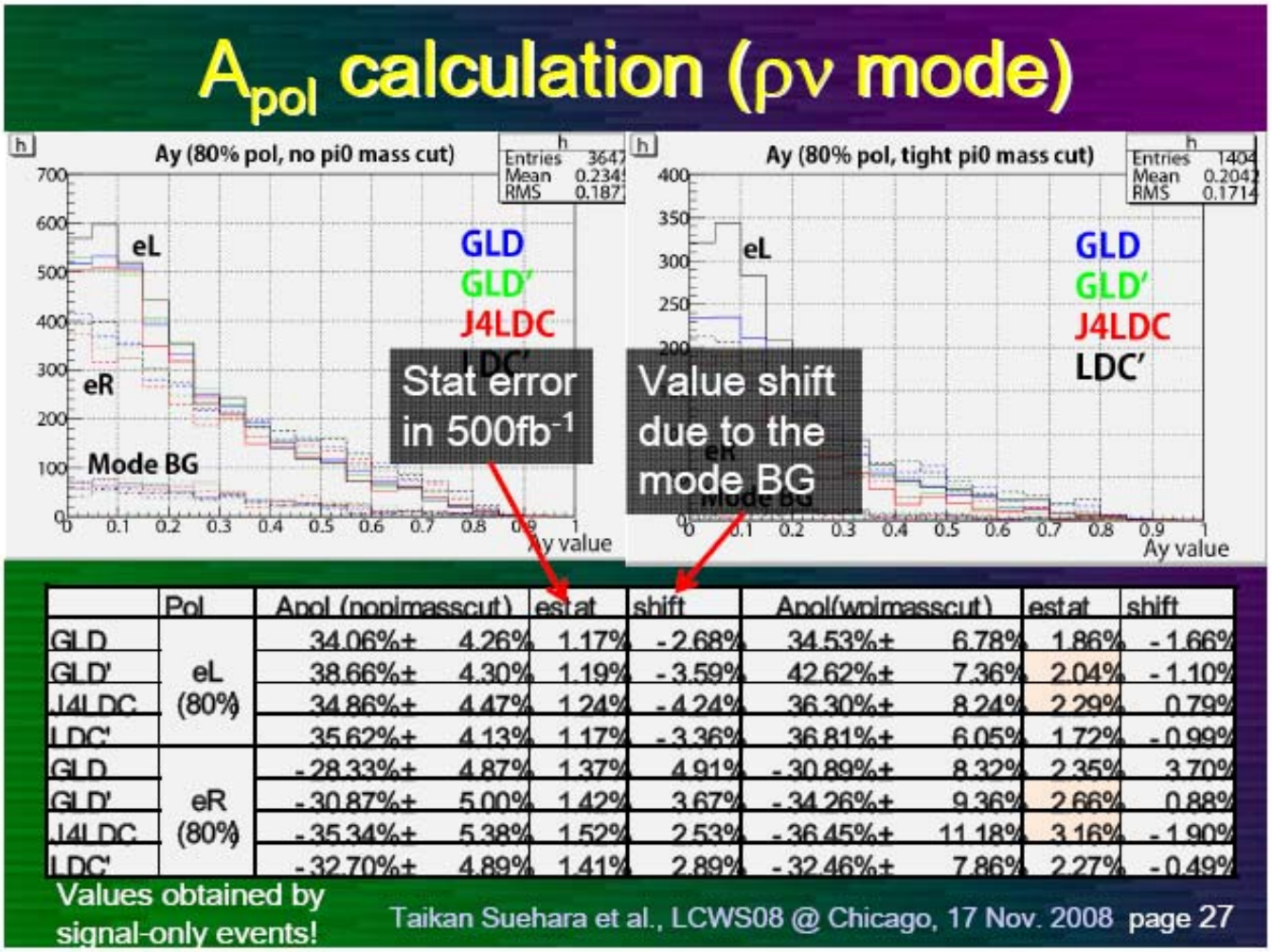


	Pol	Apol (count)	estat	shift	Apol(linear fit)	estat	shift
GLD	eL (80%)	47.17%± 4.54%	1.25%	-7.01%	54.89%± 4.67%	1.28%	-4.49%
GLD'		49.45%± 4.52%	1.25%	-9.76%	52.11%± 4.64%	1.28%	-7.65%
J4LDC		49.14%± 4.60%	1.28%	-12.41%	52.20%± 4.68%	1.30%	-10.28%
LDC'		52.72%± 4.30%	1.22%	-5.46%	57.95%± 4.49%	1.27%	-3.25%
GLD	eR (80%)	-25.62%± 4.77%	1.35%	-6.20%	-25.41%± 5.23%	1.48%	-7.58%
GLD'		-24.04%± 4.79%	1.36%	-9.23%	-23.33%± 5.18%	1.47%	-9.81%
J4LDC		-28.57%± 4.88%	1.38%	-7.58%	-27.73%± 5.22%	1.48%	-9.63%
LDC'		-18.93%± 4.63%	1.33%	-6.57%	-19.11%± 5.12%	1.48%	-6.15%

Values obtained by signal-only events!

Taikan Suehara et al., LCWS08 @ Chicago, 17 Nov. 2008 page 19

ILD study: $\tau \rightarrow \rho\nu$



	Pol	Apol (nopimasscut)		estat	shift	Apol(wpimasscut)		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!

Taikan Suehara et al., LCWS08 @ Chicago, 17 Nov. 2008 page 27

Summary

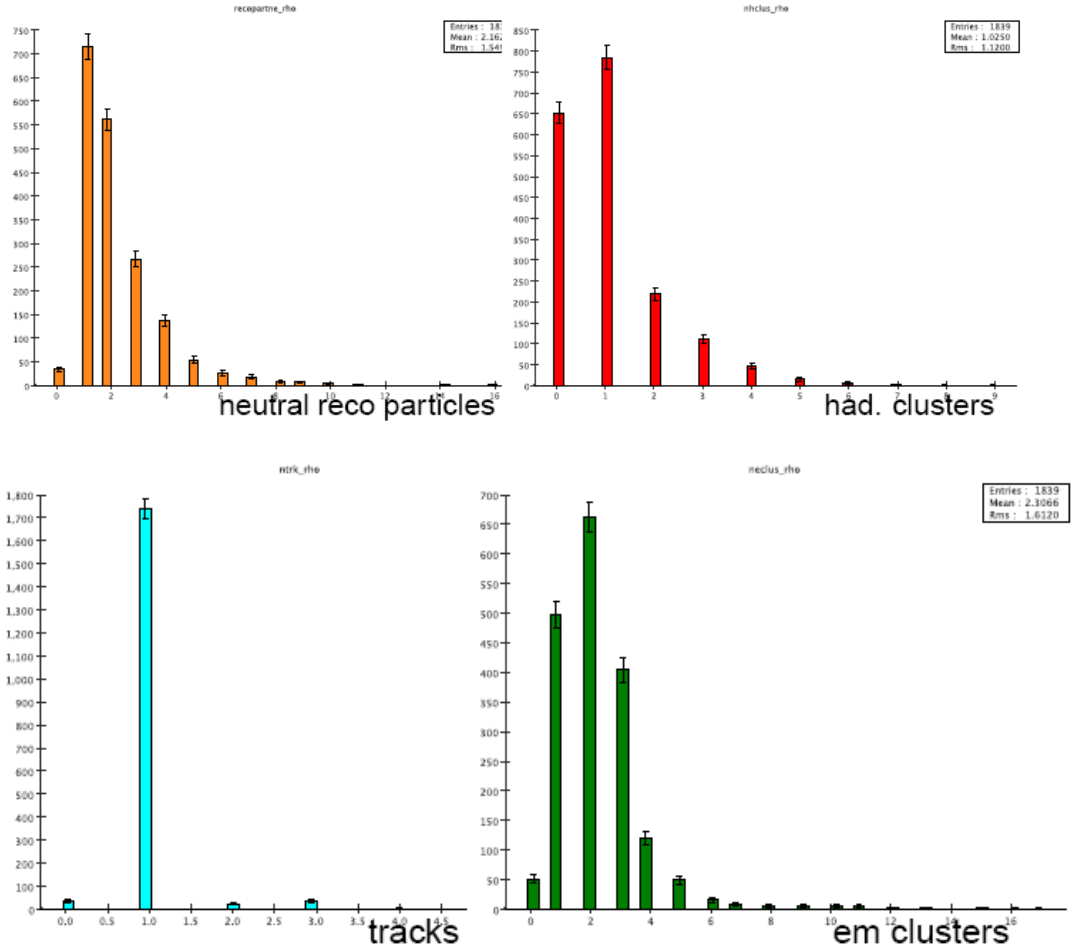
- Tau benchmarking analysis addresses LoI requirement
- Challenges detector performance regarding
  - Calorimetry and tracking for nearby tracks
  - π^0 reconstruction
  - Efficiency and purity
- Observables are cross-section, A_{FB}, tau polarization
- Analysis is somewhat late relative to other benchmarking analyses
  - But beginning to make real progress

Additional slides

Example: selected $\tau \rightarrow \rho\nu$ events

For τ reconstruction

- Study neutral particles and charged tracks, EM and HAD clusters
- Also investigate cluster shapes, depth of starting point



Subhendu, Jan. 27, 2009 benchmarking mtg