Summary of physics based detector optimization studies

'08 9/12 Y. Takubo (Tohoku U.)

Introduction

Purpose of this talk

• The physics optimization group has continued the discussion and hard-work for the ILD optimization.

• Some results for the benchmark processes are already obtained.

In this talk, the conclusions are discussed, based on the physics studies at the optimization meeting, so far.

- This slide is mainly prepared with results presented at the optimization meeting before Cambridge meeting.

  (← Sorry, if your new results are not included.)

Physics benchmarks

Physics benchmark processes

- ZH branching ratio : Edinburgh and Bristol group, Wenbiao, Satoru, Yan
  - Br(H→cc) (@ 250GeV)
- Top analysis : Katsumasa, Andreas
  - σ, A_{FB}, ΔM_{top} (@ 500GeV)

Study is still ongoing.
→ We cannot derive any conclusion, yet.

- ZH-recoil mass : Li, Kazuto
  - $\Delta\sigma(ZH)$, ΔM_H (@ 250GeV)
- SUSY-jet mode : Jenny, Taikan, Daniela
  - $\Delta\sigma(\chi^+\chi^-, \chi_2^0\chi_2^0)$, ΔM_χ (@ 500GeV)
- Z*→ττ : Taikan
  - σ, A_{FB}, Pol(τ) (@ 500GeV)

We have some results.
→ **Discussion is done based on these analysis.**

Detector geometries

We perform the optimization studies with 6 geometries:

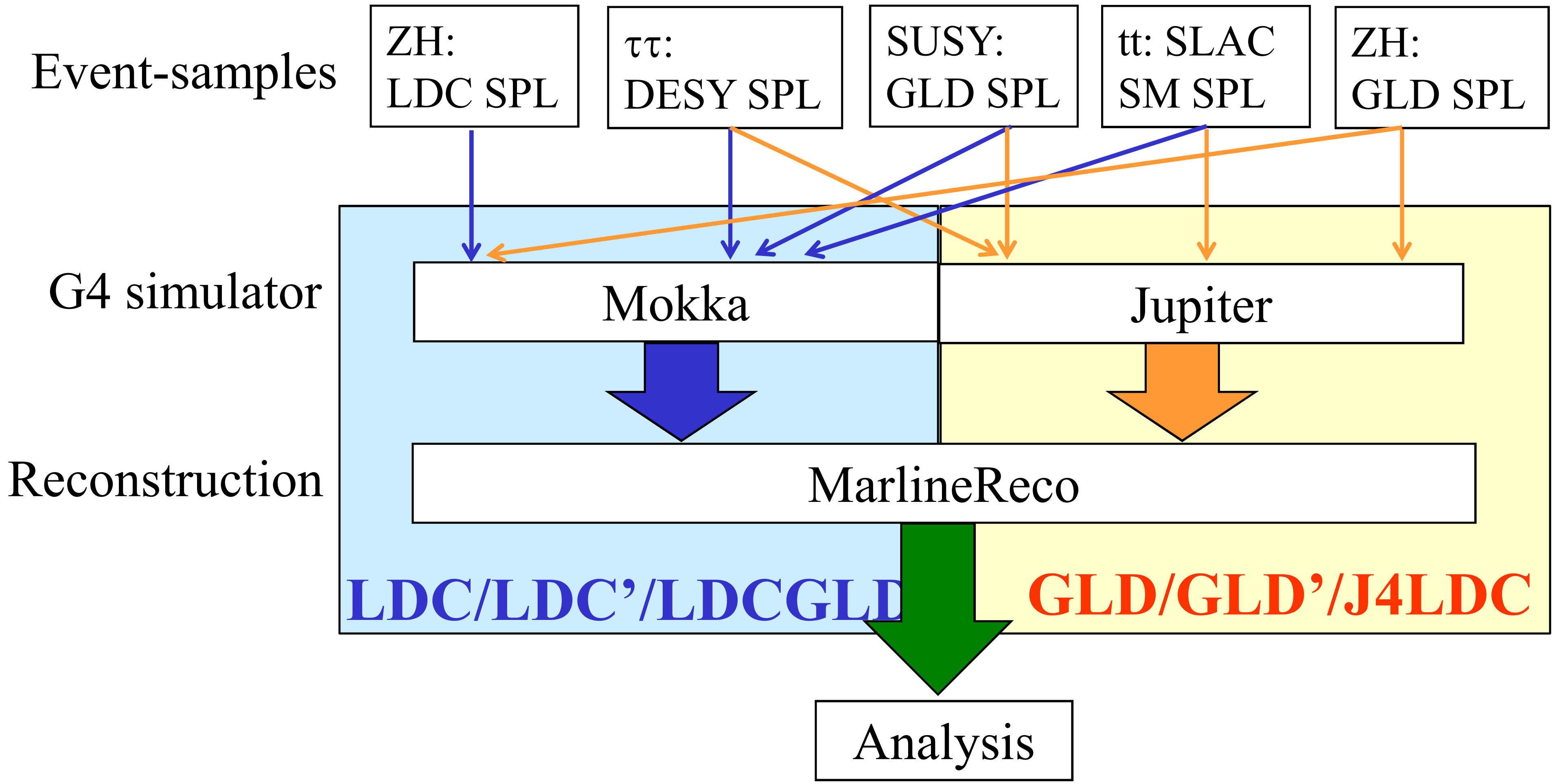
- LDC/LDC'/LDCGLD : Prepared in Mokka
- GLD/GLD'/J4LDC : Prepared in Jutpiter

→ Physics performance was compared between different geometries.

	Mokka			Jupiter		
	LDC	LDC'	LDCGLD	J4LDC	GLD'	GLD
• B (T)	: 4.0	3.5	3.0	4.0	3.5	3.0
• TPC drift region Rmin (cm)	: 37.1	37.1	37.1	34.0	43.5	43.7
• ECAL Rmin (cm)	: 160.5	182.5	202	160	185	210
• ECAL total thickness (cm)	: 17.2	17.2	17.2	19.8	19.8	19.8
• HCAL total thickness (cm)	: 127.2	127.2	127.2	96	109	120
• TPC Z half length (cm)	: 218.6	224.8	250	206	225	250
• Endcap CAL Z (cm)	: 230	255	270	220	245	280

Analysis procedure

- Most event-samples are generated by both Mokka and Jupiter.
- MarlineReco is used for all physics analysis.



ZH recoil mass

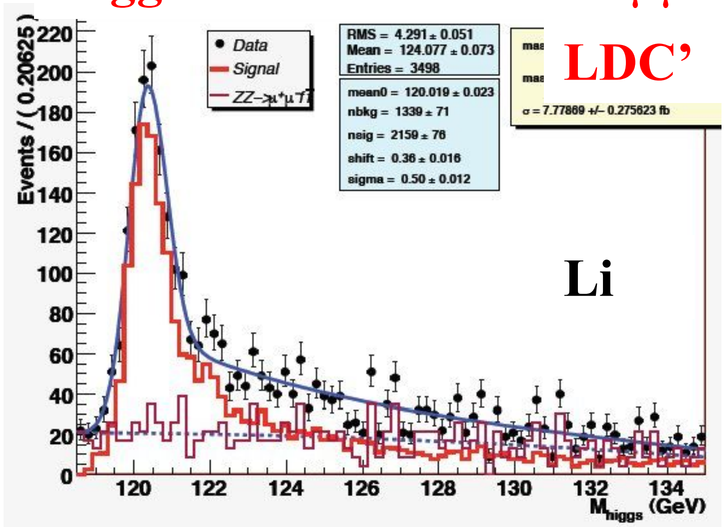
Reconstruction of ZH-recoil mass

$\Delta\sigma(ZH)$ and ΔM_H are obtained from the recoil mass distribution for $500 fb^{-1}$.

- Decay of SM-Higgs is assumed.
- Fitting function of the recoil-mass: .

$$f(x) = N \begin{cases} e^{-\frac{(x-x_0)^2}{2\sigma^2}} & : \quad \frac{x-x_0}{\sigma} \le k \\ \beta e^{-\frac{(x-x_0)^2}{2\sigma^2}} + (1-\beta) e^{-(x-x_0)\frac{k}{\sigma}} e^{\frac{k^2}{2}} & : \quad \frac{x-x_0}{\sigma} > k \end{cases}$$

Higgs recoil mass for Z→μμ



Z → μμ

	ΔM_{recoil}	$\Delta\sigma(ZH)$
• LDCGLD	: 29MeV	: 0.32fb
• LDC'	: 23MeV	: 0.28fb
• LDC	: 23MeV	: 0.27fb

Z → ee

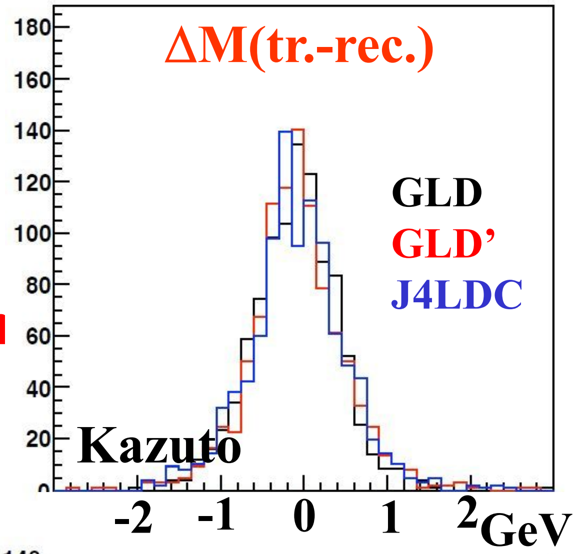
	ΔM_{recoil}	$\Delta\sigma(ZH)$
• LDCGLD	: 51MeV	: 0.52fb
• LDC'	: 47MeV	: 0.49fb
• LDC	: 47MeV	: 0.52fb

- **The difference between detector geometry is small.**
- LDC/LDC' has slightly better performance than GLD.

← Due to better momentum resolution?

Resolution of ZH-recoil mass

The influence of the tracking performance on the ZH-recoil mass was investigated with ZH→μμH.

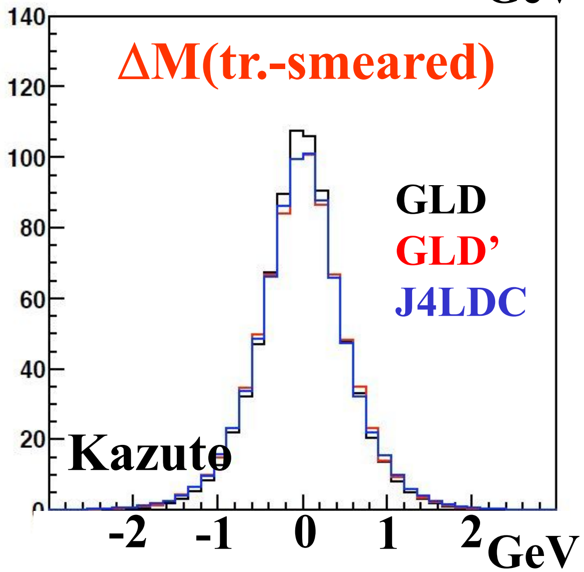


σ_M(tr.-rec.) ($\cos\theta_{lepton}$ <0.6)

- GLD : 0.44GeV
- GLD' : 0.43GeV
- J4LDC : 0.45GeV

The recoil-mass resolution was the same level.

The true momentum was smeared with tracking performance.



σ_M(tr.-smeared) ($\cos\theta_{lepton}$ <0.6)

- GLD : 0.43GeV
- GLD' : 0.46GeV
- J4LDC : 0.44GeV

σ_M(tr.-smeared) was consistent with σ_M(tr.-rec.).

→ **The tracking performance determines the recoil-mass resolution.**

τ analysis

Forward-backward asymmetry

Tau selection cuts

- 1 positive & 1 negative jets
- Opening angle > 170deg.
- $|\cos\theta| < 0.9$
- Visible energy > 40GeV
- Ntrack <= 6
- Veto of 2 e and μ

Tau selection efficiency

- GLD : 22.9%
- GLD' : 22.8%
- J4LDC : 22.7%
- LDC' : 22.7%

No significant difference

- Acc(Bhabha) : 0.4ppm for GLD'
- Acc($\gamma\gamma \rightarrow \tau\tau$) : 0.0 for true-MC study

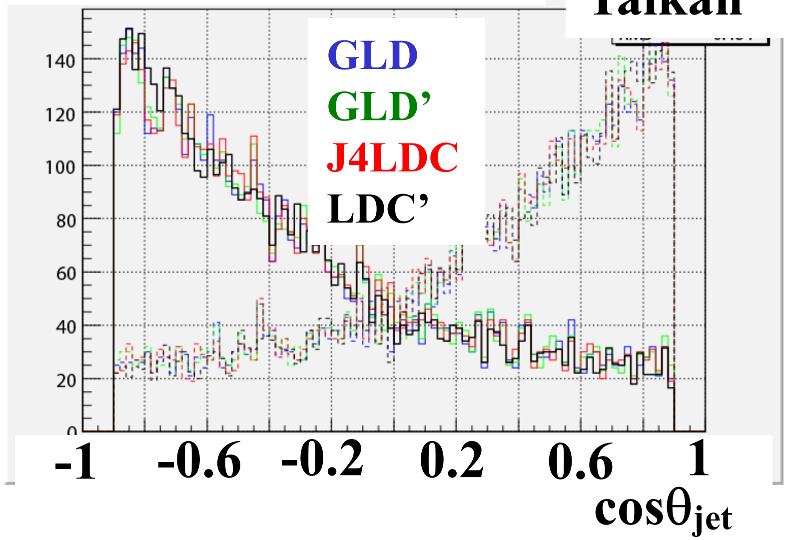
A_{FB} for $80fb^{-1}$ ($A_F = (N_F - N_B)/(N_F+N_B)$)

- GLD : 46.6±0.6 %
- GLD' : 46.7±0.6 %
- J4LDC : 46.7±0.6 %
- LDC' : 46.8±0.6 %

There is no difference between detector geometries.

Distribution of $\cos\theta_{jet}$

Taikan



Selection efficiency of A_{pol} (1)

$\tau \rightarrow \pi\nu$ and $\tau \rightarrow \rho\nu$ were used for polarization measurement.

$\tau^{\pm} \rightarrow \pi^{\pm}\nu$ selection

	Efficiency	Purity
• GLD	: 21.3%	85.7%
• GLD'	: 21.4%	83.6%
• J4LDC	: 21.4%	80.8%
• LDC'	: 21.2%	88.5%

↑ Better for larger geometry

↓ Better for larger geometry and fine ECAL granularity

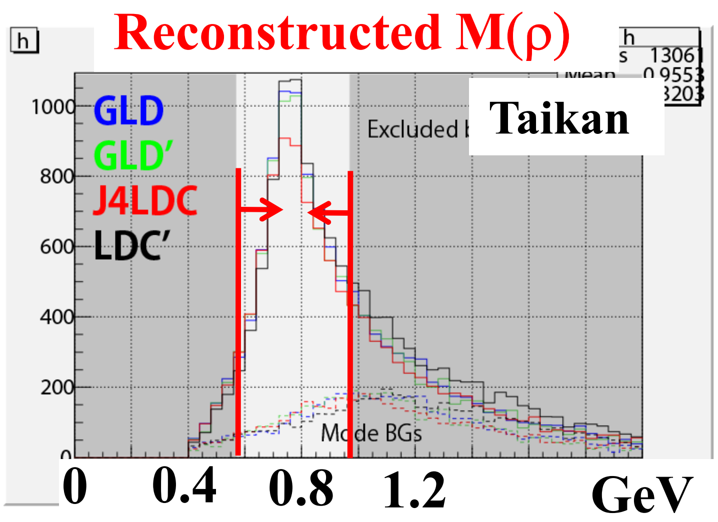
- Efficiency: No significant difference
- Purity: J4LDC has the worst performance.
  - Due to the worse γ-separation from ρ

→ Large geometry and fine ECAL granularity have advantage for $\tau \rightarrow \pi\nu$ selection.

Selection efficiency of A_{pol} (2)

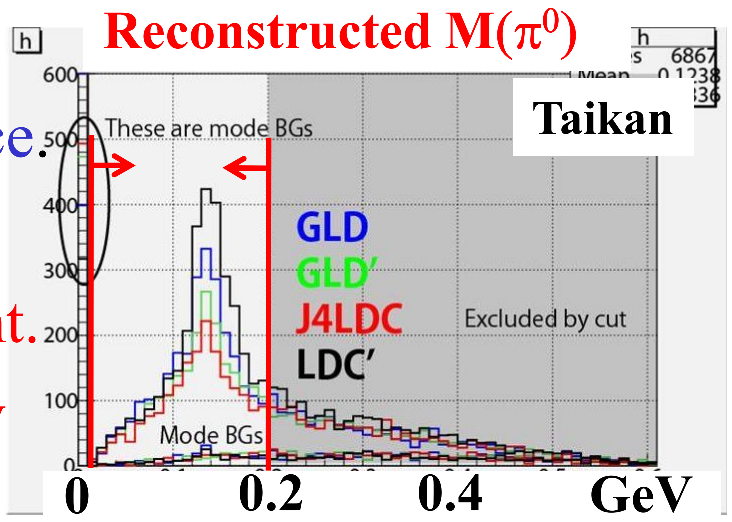
$\tau^{\pm} \rightarrow \rho^{\pm}\nu$ ($\rho^{\pm} \rightarrow \pi^{\pm}\pi^{0}$) selection

	Efficiency	Purity
• GLD	: 5.3% ↑ better	92.3%
• GLD'	: 4.3%	90.3%
• J4LDC	: 3.7%	90.5%
• LDC'	: 6.4% ↓ better	93.9%



- Purity: Not so much difference
- Efficiency: J4LDC has the worst performance.
  - Due to worse π^0 and ρ reconstruction
  - ← Cluster separation at ECAL is important.

→ Large geometry and fine ECAL granularity have advantage for $\tau \rightarrow \rho\nu$ selection.

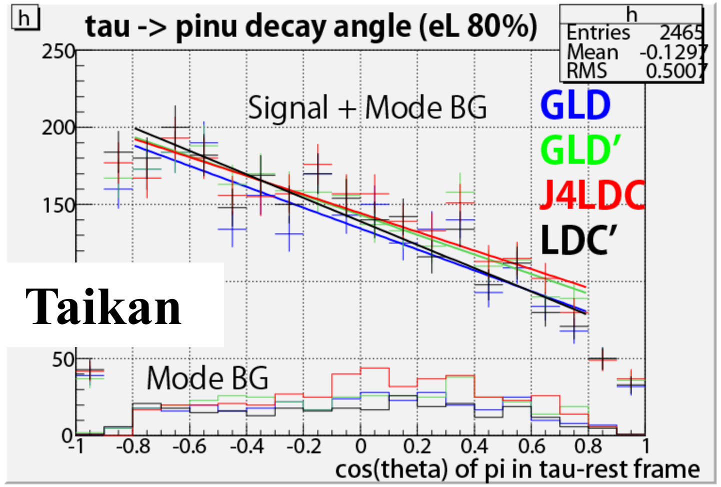


Measurement accuracy of A_{pol}

$A_{pol}(\tau^{\pm} \rightarrow \pi^{\pm}\nu)$ for eL:80%

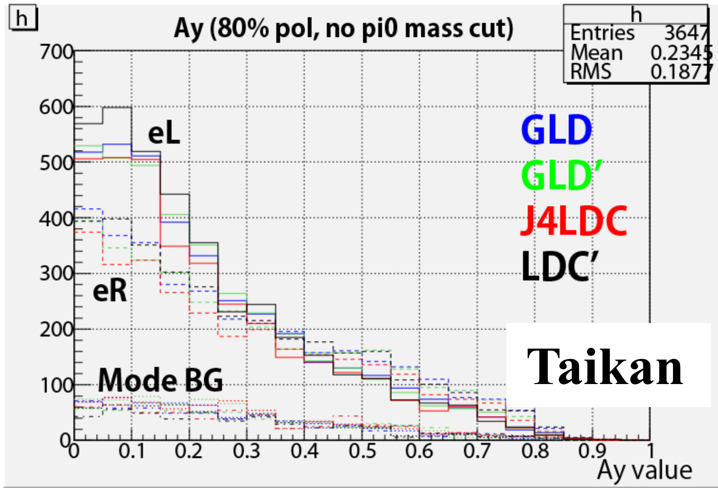
	A_{pol}	A_{pol} shift by B.G.
• GLD	: 54.9±4.7%	-4.5%
• GLD'	: 52.1±4.6%	-7.7%
• J4LDC	: 52.2±4.7%	-10.3%
• LDC'	: 58.0±4.5%	-3.3%

A_{pol} shift is large for J4LDC by worse purity.



$A_{pol}(\tau^{\pm} \rightarrow \rho^{\pm}\nu)$ for eL:80%

	A_{pol}	A_{pol} shift by B.G.
• GLD	: 34.5±4.3%	-1.7%
• GLD'	: 42.6±7.4%	-1.1%
• J4LDC	: 36.3±8.2%	-0.8%
• LDC'	: 36.8±6.1%	-1.0%



A_{pol} accuracy in J4LDC is the worst due to worse selection efficiency.

SUSY analysis

Chargino/Neutralino selection

ZZ/WW separation is important for Chargeno/Neutralino selection.

Chargino selection

	Chargino	Neutralino
• GLD	: 13.7%	1.3%
• GLD'	: 13.5%	1.4%
• J4LDC	: 13.6%	1.4%

(Acc(SM 4jet) : 0.00% for LDC')

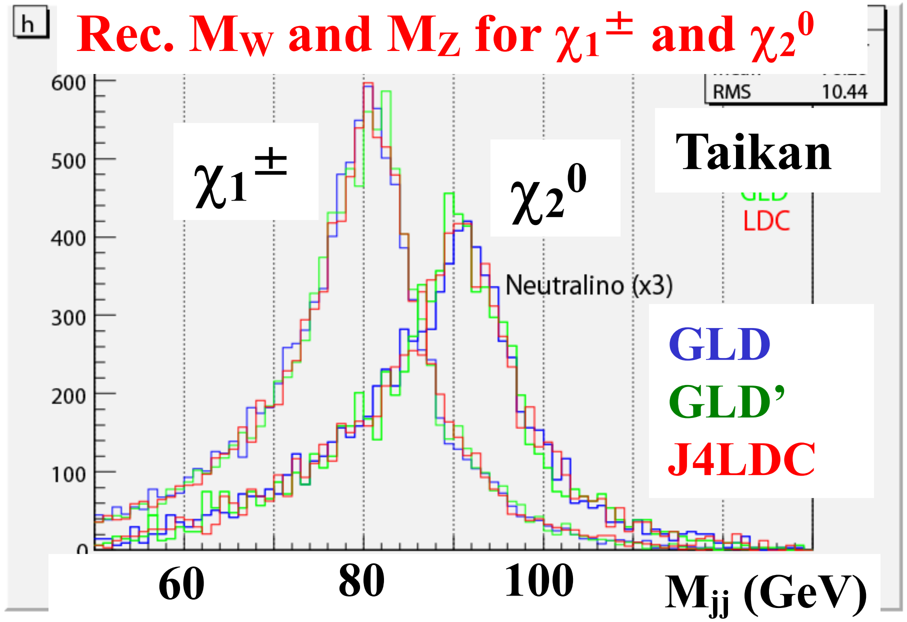
Neutralino selection

	Chargino	Neutralino
• GLD	: 0.3%	16.4%
• GLD'	: 0.3%	17.1%
• J4LDC	: 0.3%	16.9%

(Acc(SM 4jet) : 0.01% for LDC')

No difference was observed in chargino/neutralino selection.

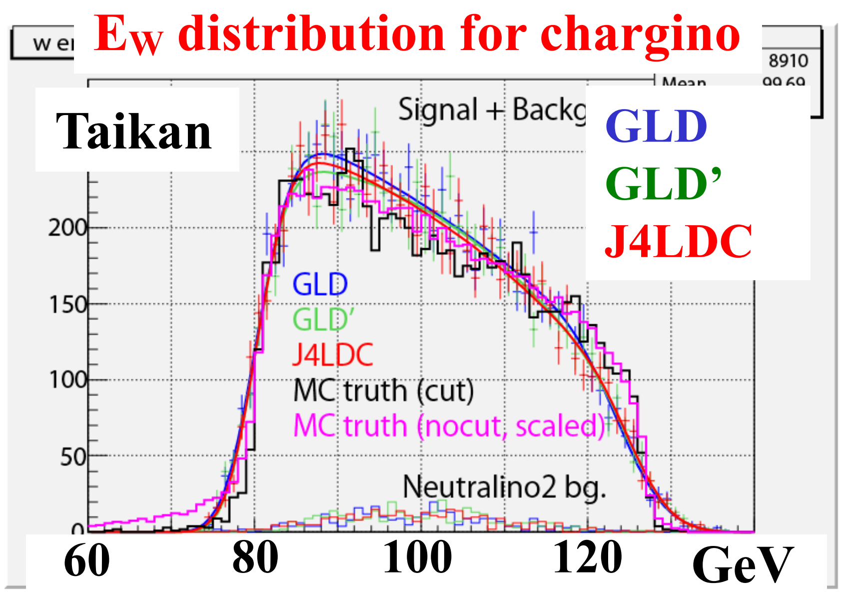
→ The energy resolution is the same level for 4-jets at E_{jet}~50GeV.



SUSY mass measurement (1)

Mass of Chargino/LSP was obtained by fitting the E_W distributions.

• Fitting: (center) the 3rd polynomial & (edge) conv. of linear func. and gaussian



Chargino/LSP

	Chargino	LSP (χ_1^0)
• Input	: 210.21	117.36
• GLD	: 215.4±1.15	121.6±0.72
• GLD'	: 216.3±1.55	120.8±0.89
• J4LDC	: 215.0±1.20	120.4±0.76

• Chargino/LSP mass can be derived within the statistical error.

• The difference of the measurement accuracy cannot be discussed.

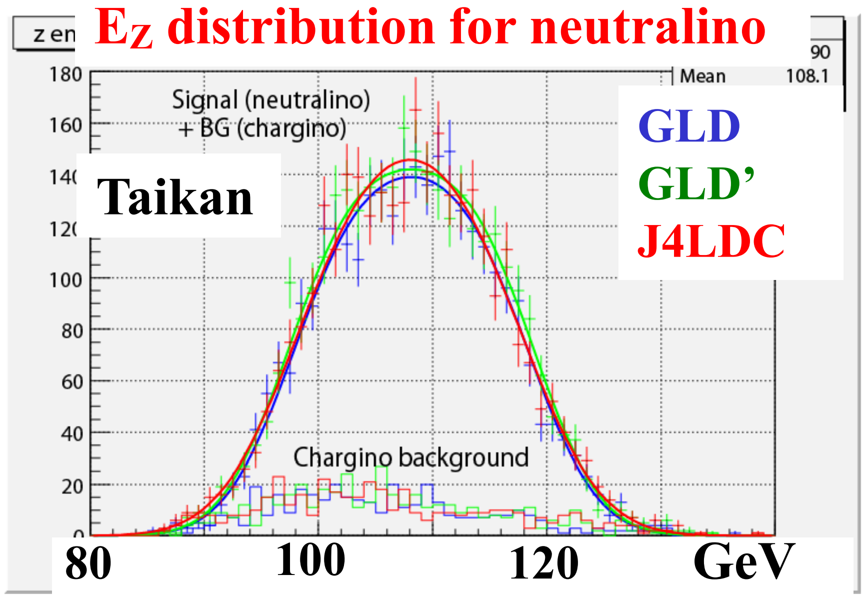
  ➢ The fitting function should be improved.

• **In E_W-distribution, significant difference is not found.**

SUSY mass measurement (2)

Mass of Neutralino/LSP was obtained by fitting the E_Z distributions.

- Fitting: erf(left) & erfc(right)



Neutralino/LSP

	Neutralino	LSP (χ_1^0)
• Input	: 210.67	117.36
• GLD	: 214.6±0.49	120.6±0.31
• GLD'	: 214.9±0.44	120.6±0.29
• J4LDC	: 214.4±0.51	120.7±0.31

- Chargino/LSP mass can be derived within the statistical error.
- **Difference of the measurement accuracy is not significant.**

Conclusion from physics studies

- ZH-recoil mass
  - ZH-mass reconstruction : **Not large difference**
  - The recoil-mass resolution is determined by tracking performance.
- Tau analysis
  - A_{FB} : **No significant difference**
  - A_{pol} : Large geometry and fine ECAL granularity have advantage.
    - ✓ The cluster separation at ECAL is important for selection of $\tau \rightarrow \pi\nu$ and $\tau \rightarrow \rho\nu$.
- SUSY analysis
  - SUSY selection efficiency : **No significant difference**
  - → The energy resolution is the same level for 4-jets at E_{jet}~50GeV.
  - SUSY mass : **No significant difference**

Homework & To be discussed

- Comparison between LDC' and GLD'.

  ← We do not understand the difference and consistency between LDC' and GLD' by physics study.

  - Should all physics benchmarks be compared?: ZH-recoil, ZH-jet mode, top-pair, SUSY

- What detector model will be used for LOI?

  - All the detector parameters will not be fixed at this meeting.
  - We should consider how and who determine the remaining parameters.

Backup

Benchmark processes

	$\sqrt{s}$ (GeV)	Observable	Comments
ZH → eeX	250	σ, m_H	m_H=120GeV, test materials and γ_{ID}
ZH → $\mu\mu$X	250	σ, m_H	m_H=120GeV, test $\Delta P/P$
ZH, H→cc, Z→$\nu\nu$	250	Br(H→cc)	Test heavy flavor tagging and anti-tagging of light quarks and gluon
ZH, H→cc, Z→qq	250	Br(H→cc)	Same as in multi-jet event
Z* → $\tau\tau$	500	σ, A_{FB}, Pol(τ)	Test π^0 rec. and τ rec. aspects of PFA
tt, t→bW, W→qq'	500	σ, A_{FB}, m_{top}	Test b-tag. and PFA in multi-jet events. m_{top}=175GeV
$\chi^+ \chi^-$, $\chi_2^0 \chi_2^0$	500	σ, m_χ	Pint 5 of Table 1 of BP report. W/Z separation by PFA.

$\int$ Ldt = 250fb^{-1}@250GeV, 500fb^{-1}@500GeV

Target of measurement accuracy

TABLE II: Benchmark reactions for the evaluation of ILC detectors

	Process and Final states	Energy (TeV)	Observables	Target Accuracy
Higgs	$ee \to Z^0h^0 \to \ell^+\ell^- X$	0.35	M_{recoil}, σ_{Zh}, BR_{bb}	$\delta\sigma_{Zh} = 2.5\%$, $\delta BR_{bb} = 1\%$
	$ee \to Z^0h^0$, $h^0 \to b\bar{b}/c\bar{c}/\tau\tau$	0.35	Jet flavour , jet $(E, \vec{p})$	δM_h=40 MeV, $\delta(\sigma_{Zh} \times BR)$=1%/7%/5%
	$ee \to Z^0h^0, h^0 \to WW^*$	0.35	M_Z, M_W, σ_{qqWW^*}	$\delta(\sigma_{Zh} \times BR_{WW^*})$=5%
	$ee \to Z^0h^0/h^0\nu\bar{\nu}$, $h^0 \to \gamma\gamma$	1.0	$M_{\gamma\gamma}$	$\delta(\sigma_{Zh} \times BR_{\gamma\gamma})$=5%
	$ee \to Z^0h^0/h^0\nu\bar{\nu}$, $h^0 \to \mu^+\mu^-$	1.0	$M_{\mu\mu}$	5σ Evidence for $M_h = 120$ GeV
	$ee \to Z^0h^0, h^0 \to invisible$	0.35	σ_{qqE}	5σ Evidence for $BR_{invisible}$=2.5%
	$ee \to h^0\nu\bar{\nu}$	0.5	$\sigma_{bb\nu\nu}$, M_{bb}	$\delta(\sigma_{\nu\nu h} \times BR_{bb}) = 1\%$
	$ee \to t\bar{t}h^0$	1.0	σ_{tth}	δg_{tth}=5%
	$ee \to Z^0h^0h^0$, $h^0h^0\nu\bar{\nu}$	0.5/1.0	σ_{Zhh}, $\sigma_{\nu\nu hh}$, M_{hh}	δg_{hhh}=20/10%
-CDM	$ee \to \tilde{\tau}_1^+\tilde{\tau}_1^-$, $\tilde{\chi}_1^+\tilde{\chi}_1^-$ (Point 3)	0.5		$\delta M_{\tilde{\tau}_1}$=1 GeV, $\delta M_{\tilde{\chi}_1^0}$=500 MeV,
	$ee \to \tilde{\chi}_2^0\tilde{\chi}_3^0$, $\tilde{\chi}_1^+\tilde{\chi}_1^-$ (Point 2)	0.5	M_{jj} in $jj\not{E}$, $M_{\ell\ell}$ in $jj\ell\ell\not{E}$	$\delta\sigma_{\tilde{\chi}_2\tilde{\chi}_3} = 4\%$, $\delta(M_{\tilde{\chi}_2^0} - M_{\tilde{\chi}_1^0})$= 500 MeV
	$ee \to \tilde{\chi}_1^+\tilde{\chi}_1^-/\tilde{\chi}_i^0\tilde{\chi}_j^0$ (Point 5)	0.5/1.0	$ZZ\not{E}$, $WW\not{E}$	$\delta\sigma_{\tilde{\chi}\tilde{\chi}}$=10%, $\delta(M_{\tilde{\chi}_3^0} - M_{\tilde{\chi}_1^0})$ =2 GeV
	$ee \to H^0A^0 \to b\bar{b}b\bar{b}$ (Point 4)	1.0	Mass constrained M_{bb}	δM_A=1 GeV
Precision SM	$ee \to t\bar{t} \to 6\ jets$	1.0		5σ Sensitivity for $(g-2)_t/2 \le 10^{-3}$
	$ee \to f\bar{f}$ $(f = e, \mu, \tau; b, c)$	1.0	$\sigma_{f\bar{f}}$, A_{FB}, A_{LR}	5σ Sensitivity to $M_{Z_{LR}} = 7$ TeV

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Detector geometries

		GLD	GLD’	J4LDC	LDC’
ECAL Rmin	cm	210	185	160	182.5
B	T	3	3.5	4	3.5
ECAL # layers		33	33	33	20/9
ECAL Rad. Length	X0	28.4	28.4	28.4	22.87
HCAL # Layers		46	42	37	48
Int. Length(Total)	λ	6.79	6.29	5.67	6.86
HCAL Rmax		361.7	325.0	285.7	335.9
Cryostat Rin		375	330	300	335.9

ECAL(Jupiter): W(3mm) + Scinti.(2mm) + Gap(1mm), 12-sided no-gap
(Mokka):W(2.1mm/4.2mm)+Si(0.32mm), Gap(0.5mm), 8-sided, with-gap

HCAL(Jupiter): Fe(20mm)+Scinti.(5mm)+Gap(1mm), 12-sided, no-gap
(Mokka): Fe(20mm)+Scinti.(5mm)+Gap(1.5mm), 8(in)/8(out)-sided, no-gap