Impact of Tracker Design on Higgs/SUSY Measurement

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Physics Goals

- ➔ To determine the Higgs mass precision, cross section using Higgsstrahlung signal ($e^+e^- \to ZH \to e^+e^- X$) based on the ILC500 beam setup and nominal detectors LDMAR01 & SDMAR01.

- ➔ To evaluate the impact of charged tracking performance on Higgs/SUSY mass, BR(H→CC) measurement.

- ➔ To estimate the effect of ISR, beamstrahlung and beam energy spread on Higgs/SUSY mass measurement.

Worldwide Study of the Physics and Detectors for Future Linear e+ e- Colliders

Monte Carlo Generator & Simulation

* MC Generator: Pandora V2.2, Pythia V3.1, with latest patches

  NEW - Using ILC500 beam setup, beam energy spread is 0.11%

  polarization of electron is - 85%, no polarization for positron

* Analysis Platform: Java Analysis Studio V2.2.5

* Detectors: LDMAR01(LD), SDMAR01(SD)

* Fast Monte Carlo Simulation

* $e^+e^- \to ZH \to e^+e^- X$, M_H = 120, 140, 160 GeV, L = 500 fb^{-1}

* $e^+e^- \to \tilde{\mu}_R^+ \tilde{\mu}_R^- \to \mu^+ \tilde{\chi}_1^0 \mu^- \tilde{\chi}_1^0$, L = 50 fb^{-1}, $P(e^-)$ = 80%, $P(e^+)$ = 0

  three mass pairs with high, medium and low mass difference

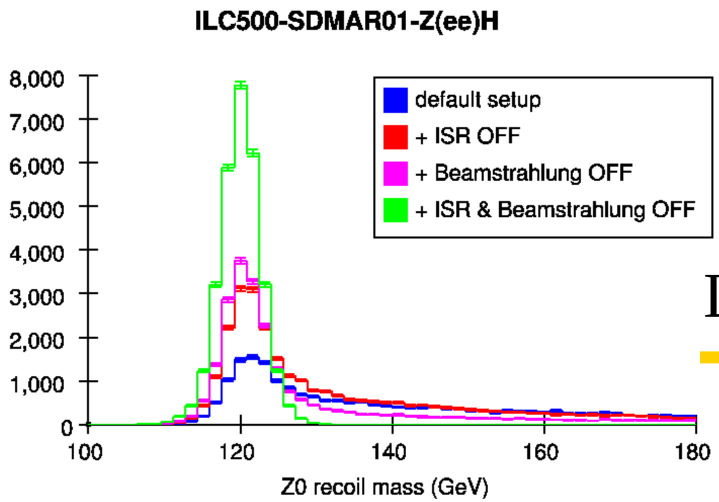
Selection cuts for Higgsstrahlung Signal

* Selection cuts for Higgsstrahlung signal (see backup slides)
  1). Energy of lepton from charged track: E(lepton) > 10 GeV
  2). Polar angle of lepton: $|\cos(\theta)| < 0.9$
  3). No. of leptons satisfy 1) and 2): N(lepton) >=2
  4). Invariant mass of lepton pairs: $|M_{ll} - M_{Z^0}| < 5$ GeV
  5). Polar angle of Z0: $|\cos(\theta_{Z^0})| < 0.6$ (to suppress ZZ)
  6). Angle between lepton pairs: $\cos(\theta_{ll}) > -0.7$ (to suppress WW)
  7). Energy of the most energetic photon: E(photon)<100 GeV (to suppress Zγ)

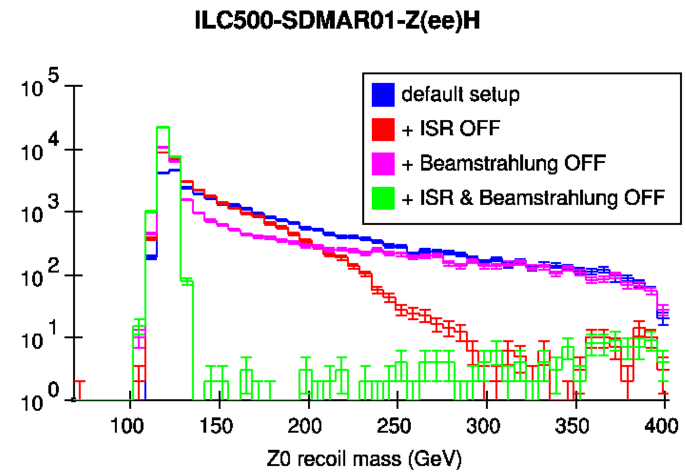
➔ Cross sections and selection efficiencies

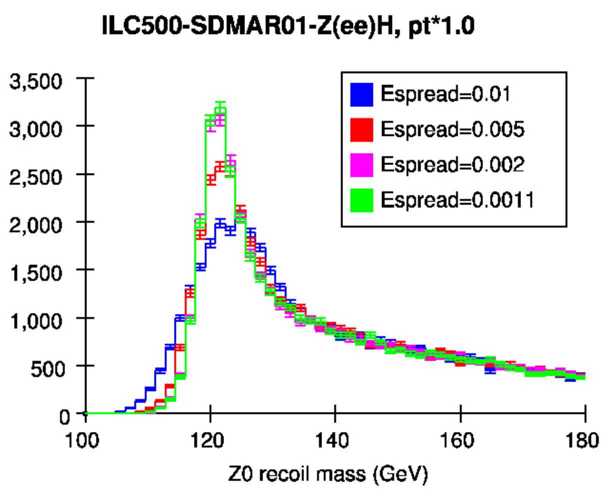
M_H (GeV)	Cross Section (fb)	LD-Eff. (%)	SD-Eff. (%)	Events (500 fb^{-1})
120	2.34 +/- 0.015	55.28	55.28	647
140	2.15 +/- 0.022	56.37	56.37	606
160	2.01 +/- 0.032	56.64	56.67	569
ZZ BKGD	475.0 +/- 3.4	1.011	1.011	2401

Effect of ISR, Beamstrahlung & Beamspread



Log scale





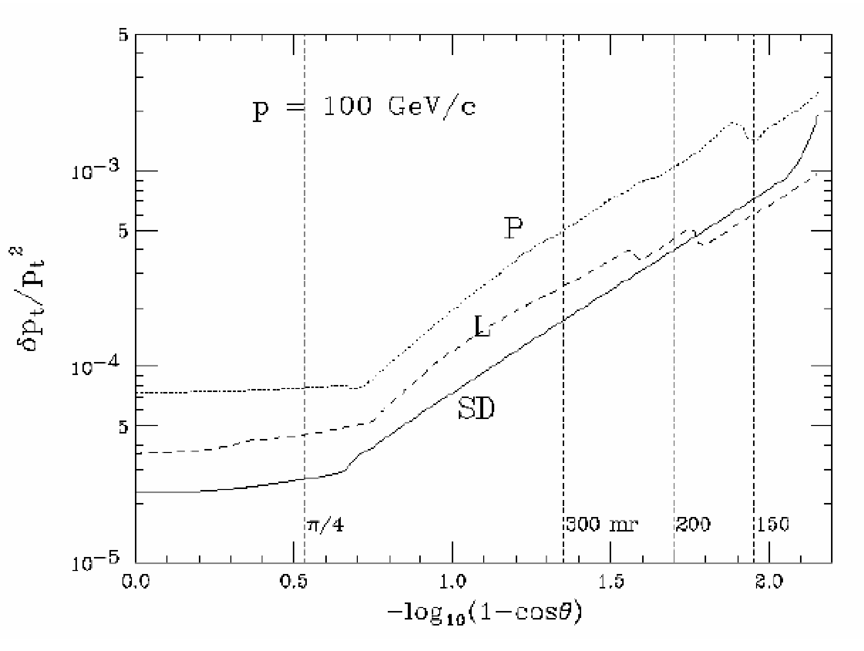
➔ ISR and Beamstrahlung broaden the Z0 recoil mass and make long tail

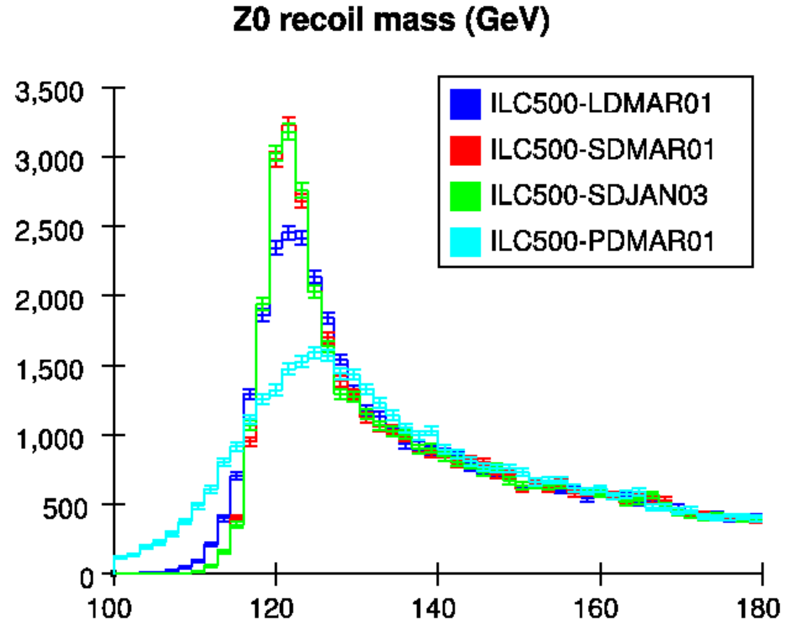
➔ But better performance is obtained by decreasing beam energy spread down to ~ 0.2%.

Z0 Recoil Mass for Baseline Detectors

➔Silicon detector works the best for charged track momentum resolution and Z0 recoil mass among baseline detectors.

* LDMAR01 and SDMAR01 are selected for Higgs Study

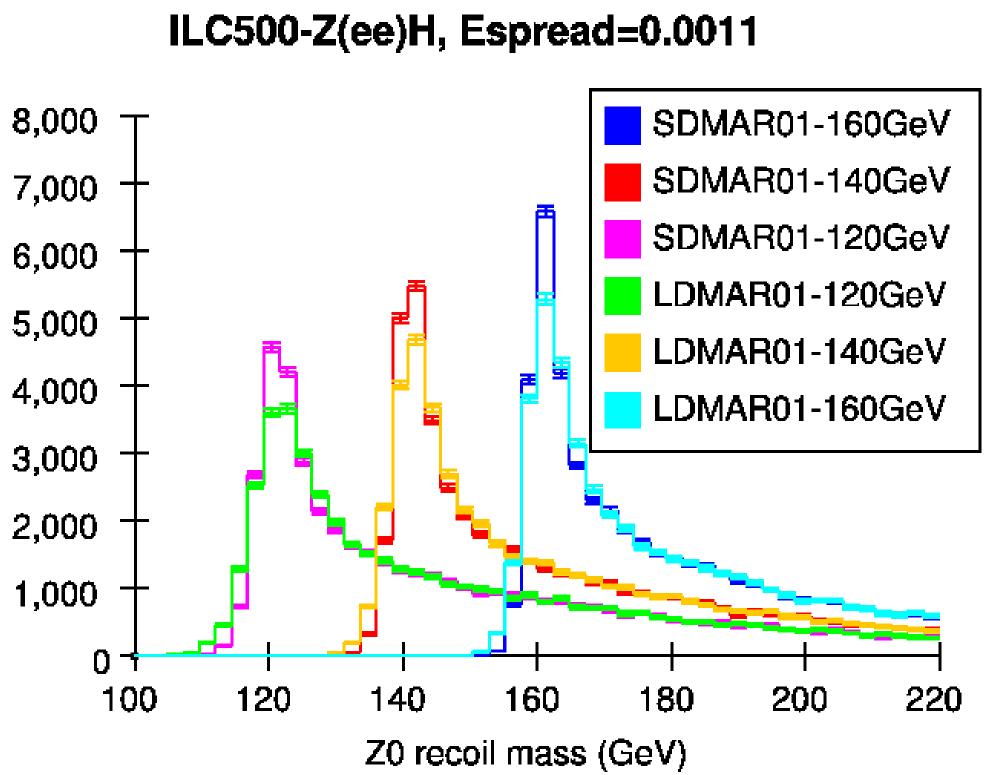




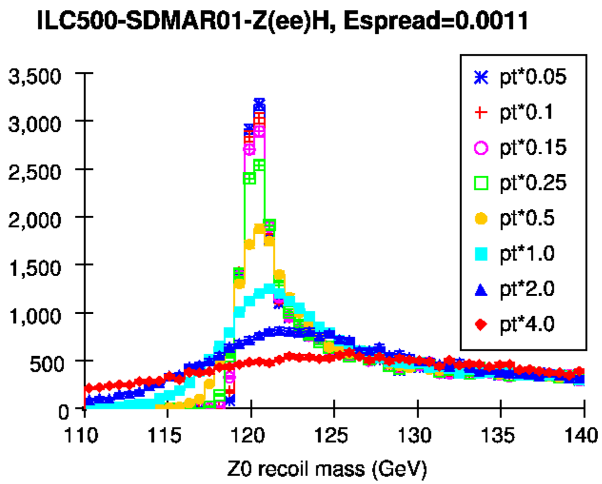
Z0 Recoil Mass Spectrum

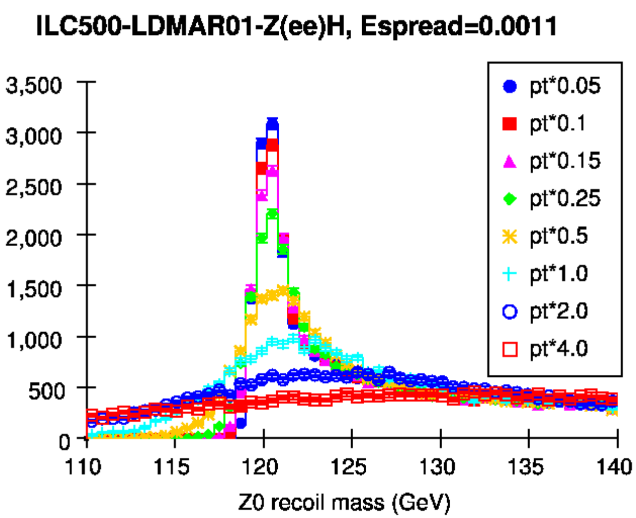
➔ SD has better performance than LD for Z0 recoil mass.

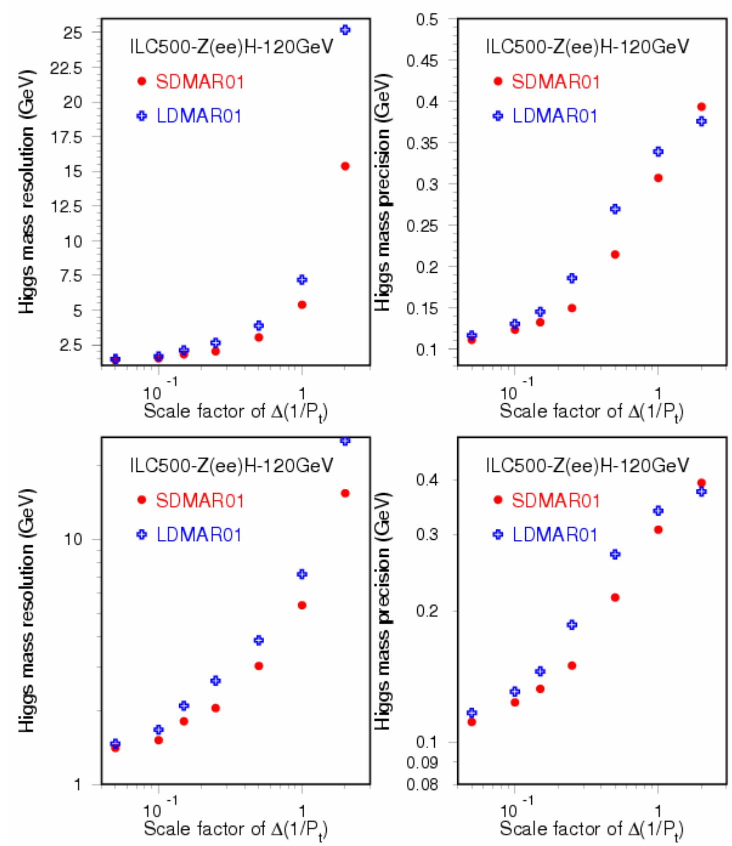
* 100K signal events are generated for each Higgs mass point (120, 140 and 160 GeV). The plot shows the signal events kept after selection. No normalization are made for the plot.



Impact of Track Momentum Resolution



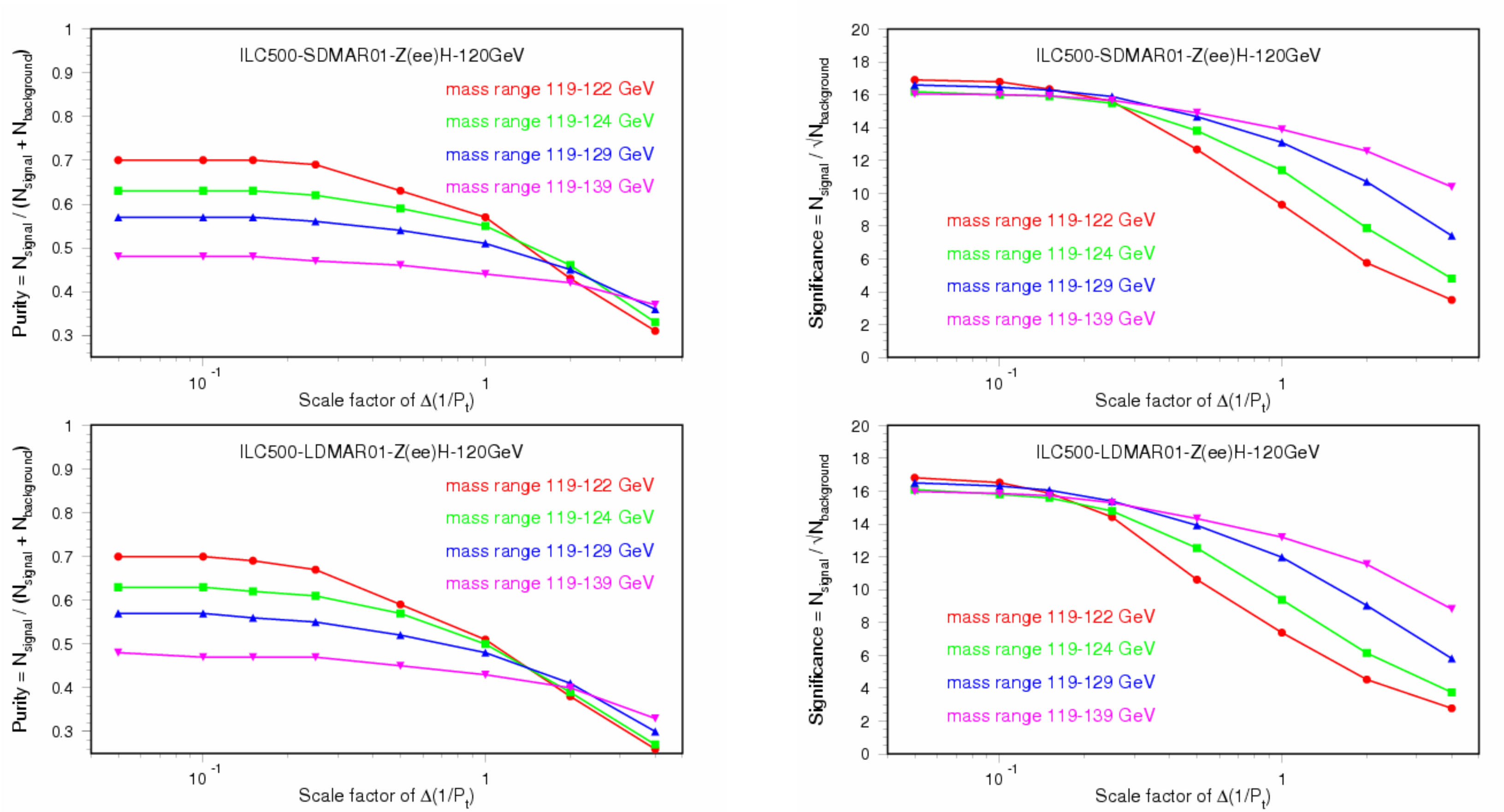




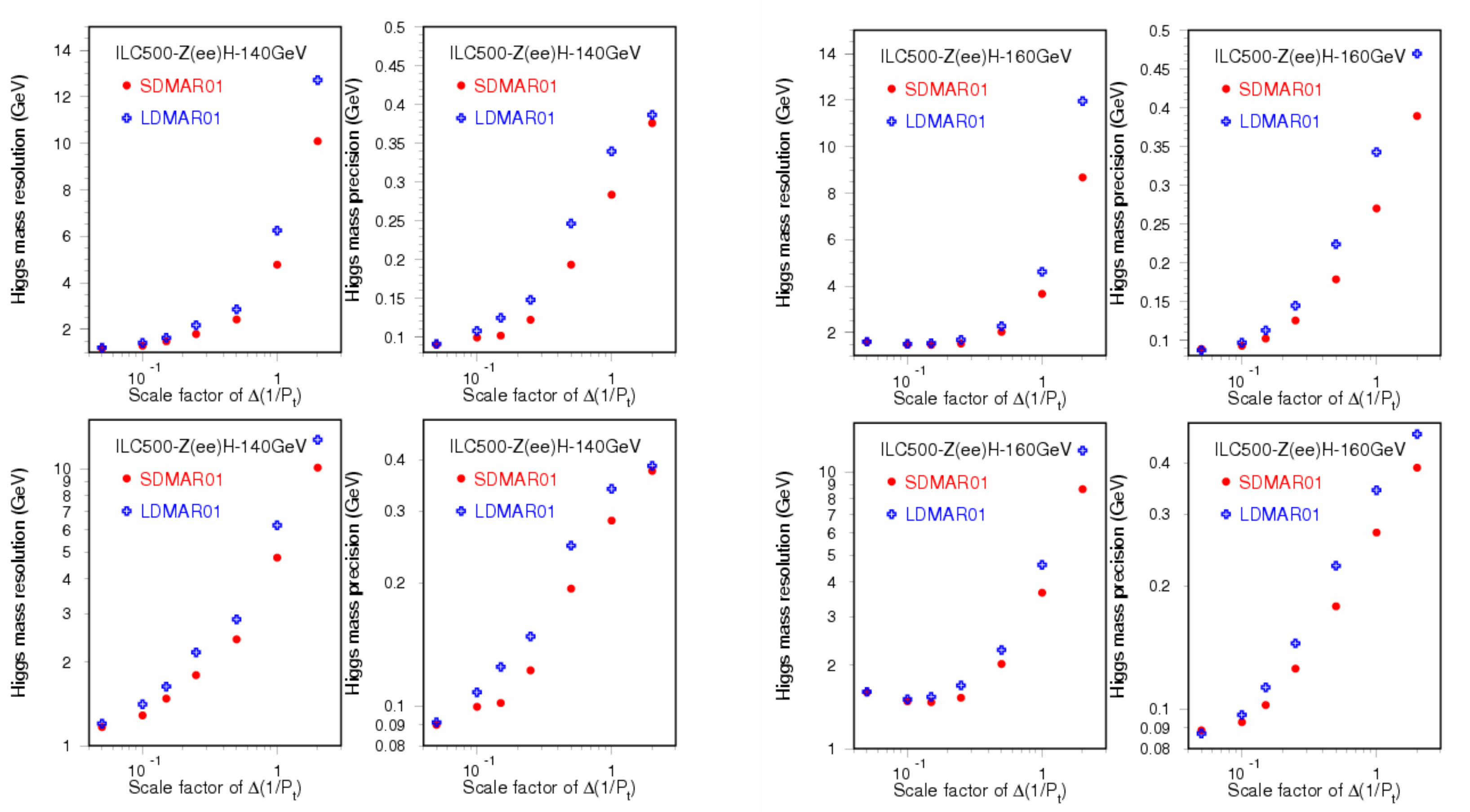
➔ Higgs mass resolution & precision are continuously improving by rescaling the factor of track resolution down to ~ 0.1.

Purity & Significance

➔The purity and significance of Higgsstrahlung signal are saturated when the re-scale factor of track momentum resolution down to ~ 0.2.



Higgs Mass Resolution and Precision



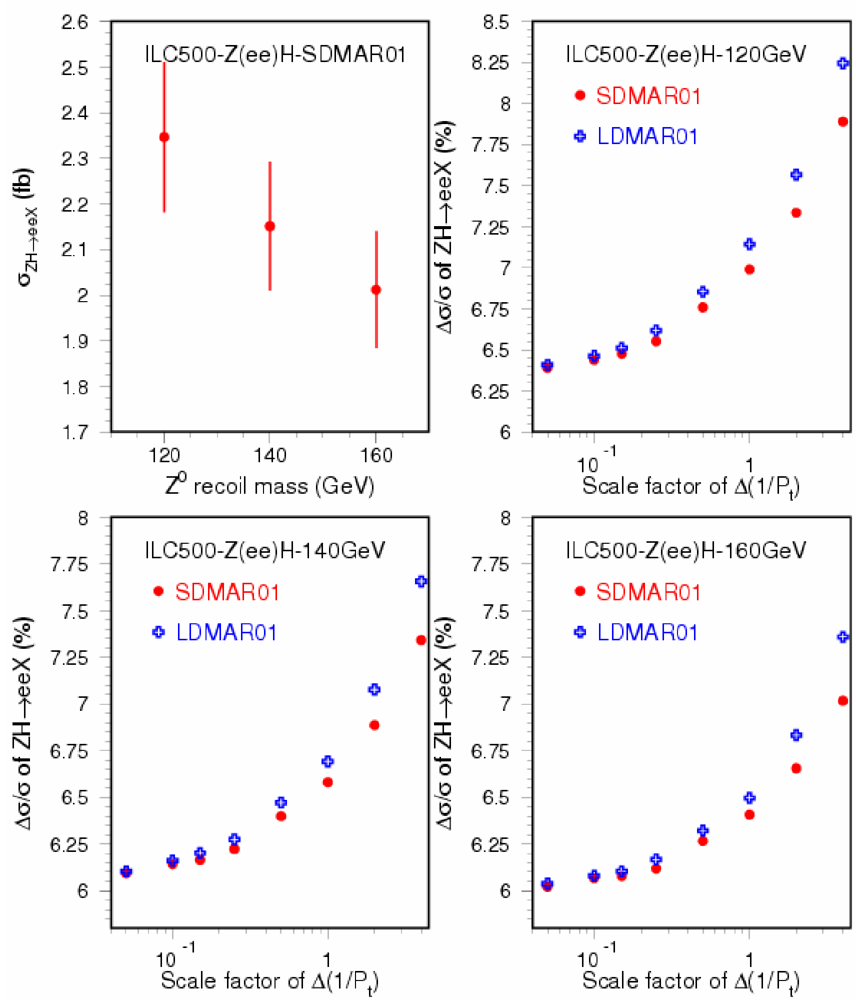
SD: $(\sigma M_{H,}, \Delta M_{H})$ =(5.4, 0.31) - 120; (4.8, 0.28) - 140; (3.7, 0.27) - 160 GeV

LD: $(\sigma M_{H}, \Delta M_{H})$= (7.2, 0.34) - 120; (6.2, 0.34) - 140; (4.6, 0.34) - 160 GeV

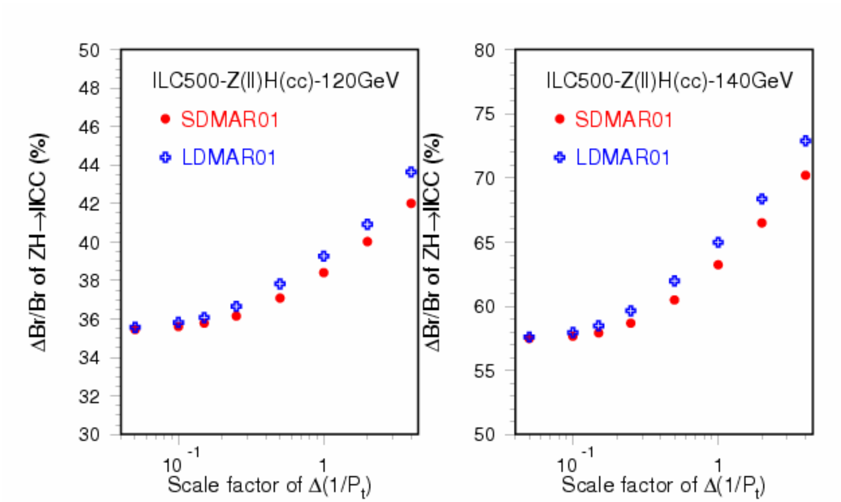
Cross Section of ZH → e^+e^- X

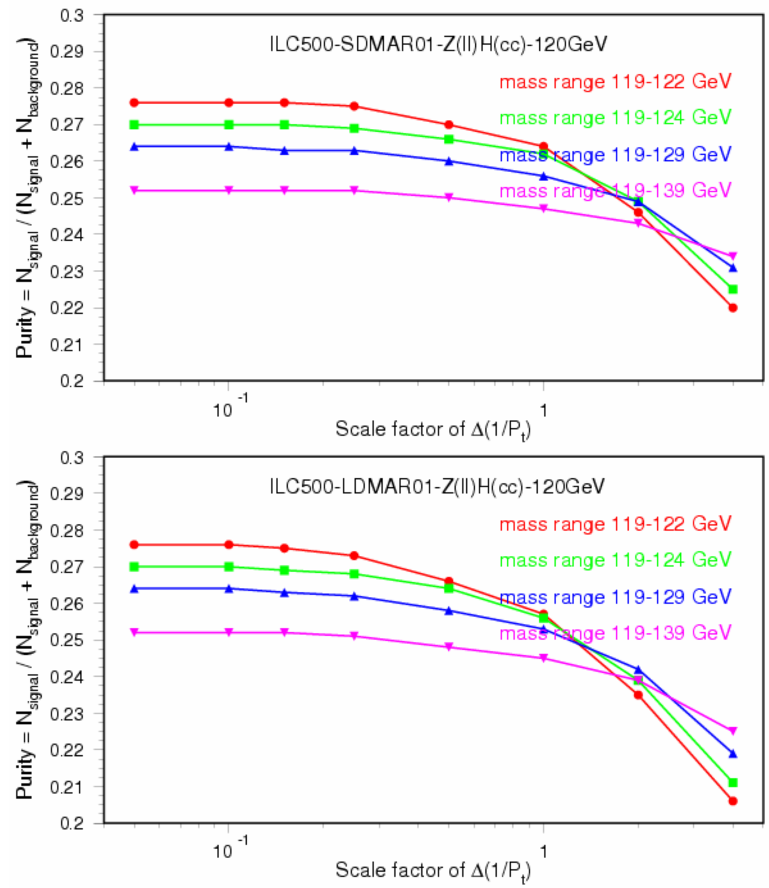
➔ Relative Error Δσ/σ
- ~ 7.0 % (120 GeV Higgs)
- ~ 6.6 % (140 GeV Higgs)
- ~ 6.4 % (160 GeV Higgs)

➔ Insensitive to charged track momentum resolution, only has ~10% improvement if one improves track momentum resolution by factor of ~4.



Branching Ratio of H → CC





- * C-tagging Eff = 50% (assuming)
  Eff of B quark = 4.4%
  Eff of UDS quark = 0.5%
- * Br (H→CC) =
  2.8% (120GeV), 1.4% (140GeV)

→ ΔBr/Br ~ 39% (120GeV), 64% (140GeV) **for Z→l+l-, 1000 fb^{-1}**

→ ΔBr (H→CC) is insensitive to track momentum resolution.

SUSY Mass Measurement

- Smuon and Neutralino masses can be determined by measuring endpoints of muon energy spectra.
- Mass error mainly comes from relative errors of E_{min} & E_{max}.

$$M^2_{\tilde{\mu}^\pm_R} = E^2_{cm} \bullet \frac{E_{min} \times E_{max}}{(E_{min}+E_{max})^2}$$

$$M^2_{\tilde{\chi}^0_1} = M^2_{\tilde{\mu}^\pm_R} \bullet \{1 - 2\frac{E_{min}+E_{max}}{E_{cm}}\}$$

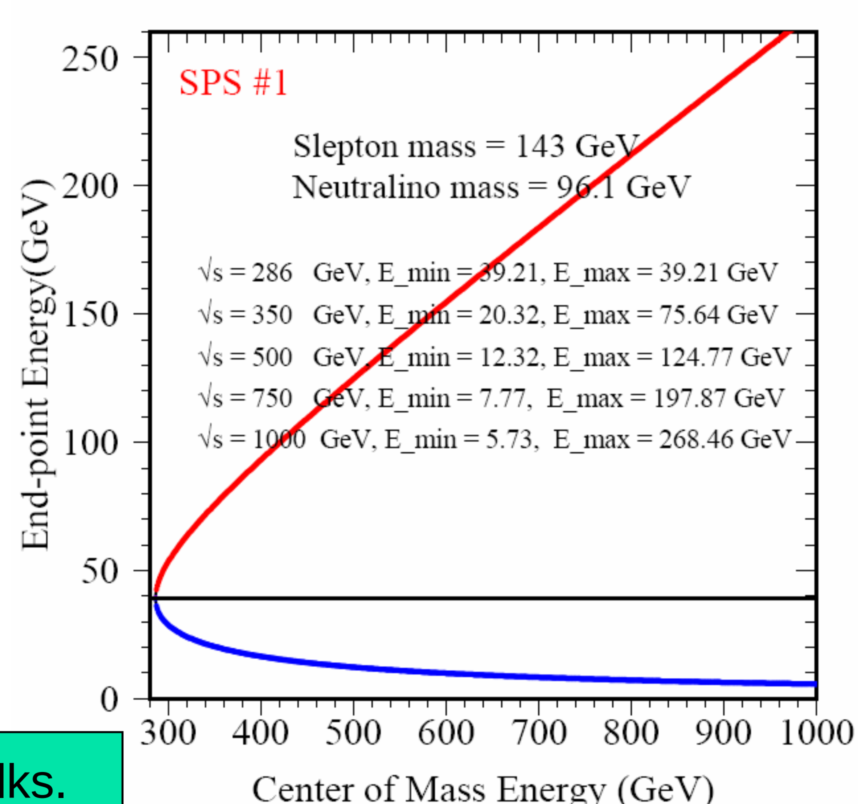
$$\frac{\Delta M_{\tilde{\mu}^\pm_R}}{M_{\tilde{\mu}^\pm_R}} = A \bullet \sqrt{[\frac{\Delta E_{min}}{E_{min}}]^2 + [\frac{\Delta E_{max}}{E_{max}}]^2}$$

$$\frac{\Delta M_{\tilde{\chi}^0_1}}{M_{\tilde{\chi}^0_1}} = \frac{M^2_{\tilde{\mu}^\pm_R}}{M^2_{\tilde{\chi}^0_1}} \bullet \sqrt{(\frac{C}{E_{min}} - \frac{1}{E_{cm}})^2 \Delta E^2_{min} + (\frac{-C}{E_{max}} - \frac{1}{E_{cm}})^2 \Delta E^2_{max}}$$

where,

$$A = \frac{E_{max}-E_{min}}{2(E_{max}+E_{min})}, \quad B = \frac{E_{max}+E_{min}}{E_{cm}}, \quad C = A(1-2B)$$

Mis-typed in previous talks.



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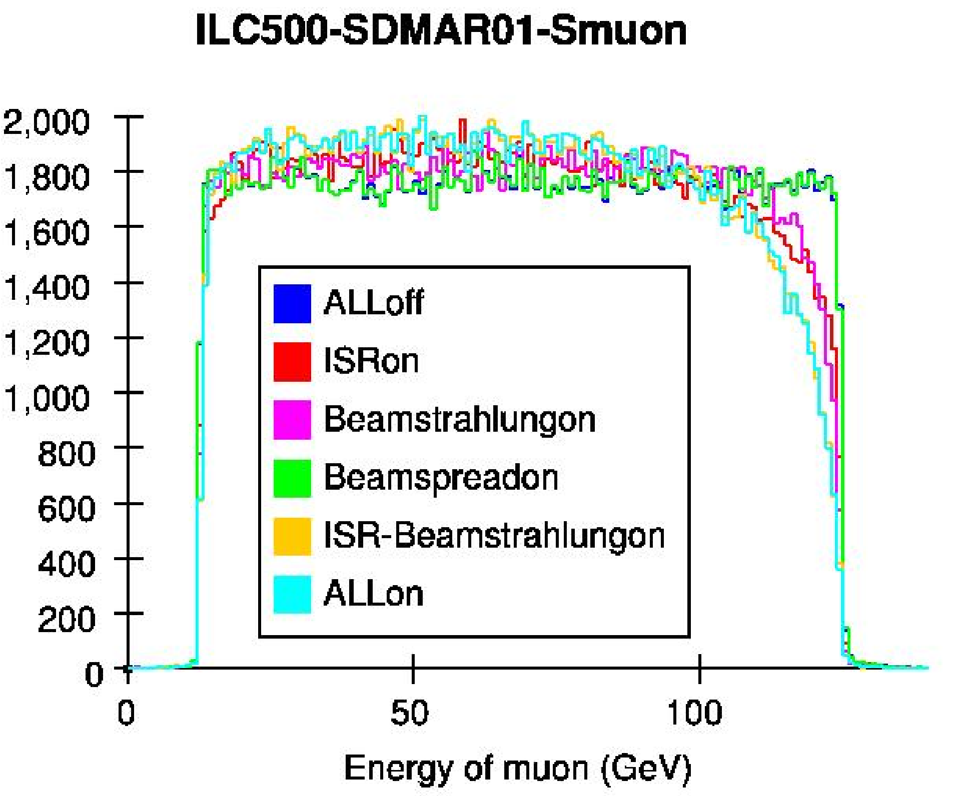
ILC Beam Effect – SPS#1

➔ ISR and Beamstrahlung distort the endpoints of muon energy spectrum significantly(~40%).

➔ Beam energy spread has little effect (~3%).

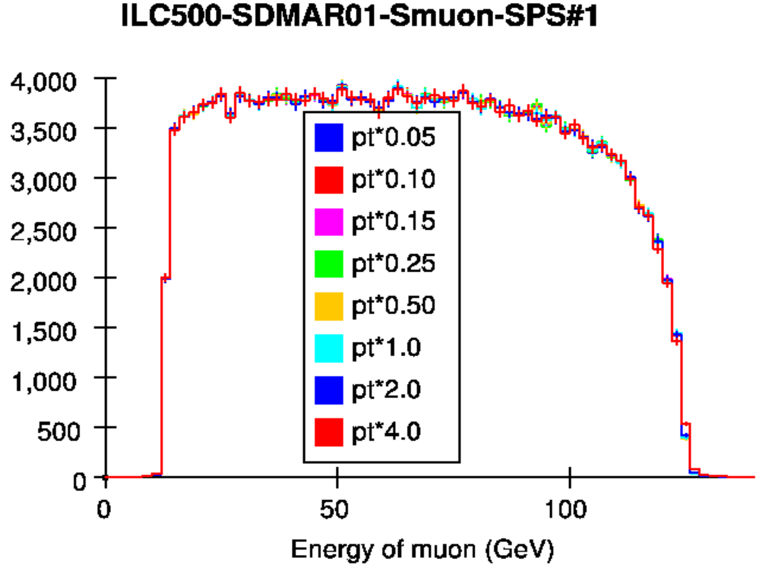
L = 50fb^{-1} 20% random background	Smuon mass error (relative)	Neutralino mass error (relative)
ALL OFF	260 MeV (0.182%)	167 MeV (0.174%)
Beam energy spread(0.11%) ON	266 MeV (0.186%)	172 MeV (0.179%)
ALL ON	420 MeV (0.294%)	294 MeV (0.306%)

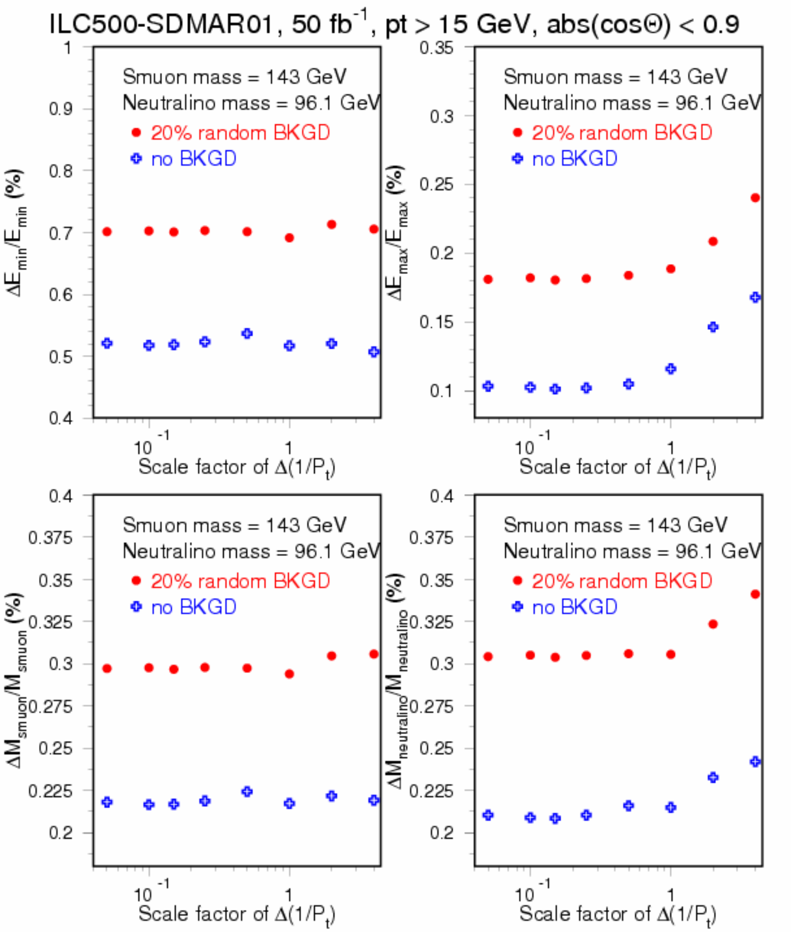


SPS#1, High Mass Difference (ΔM=47 GeV)

➔No apparent improvement on Susy mass precision by improving track resolution.
➔Smuon mass error is dominant by relative error of the low energy endpoint E_{min}.

➔Susy mass precision is affected by background contamination. The mass errors degraded ~30% when 20% random background(20% of N_{signal}) presented.





Medium and Low Mass Difference

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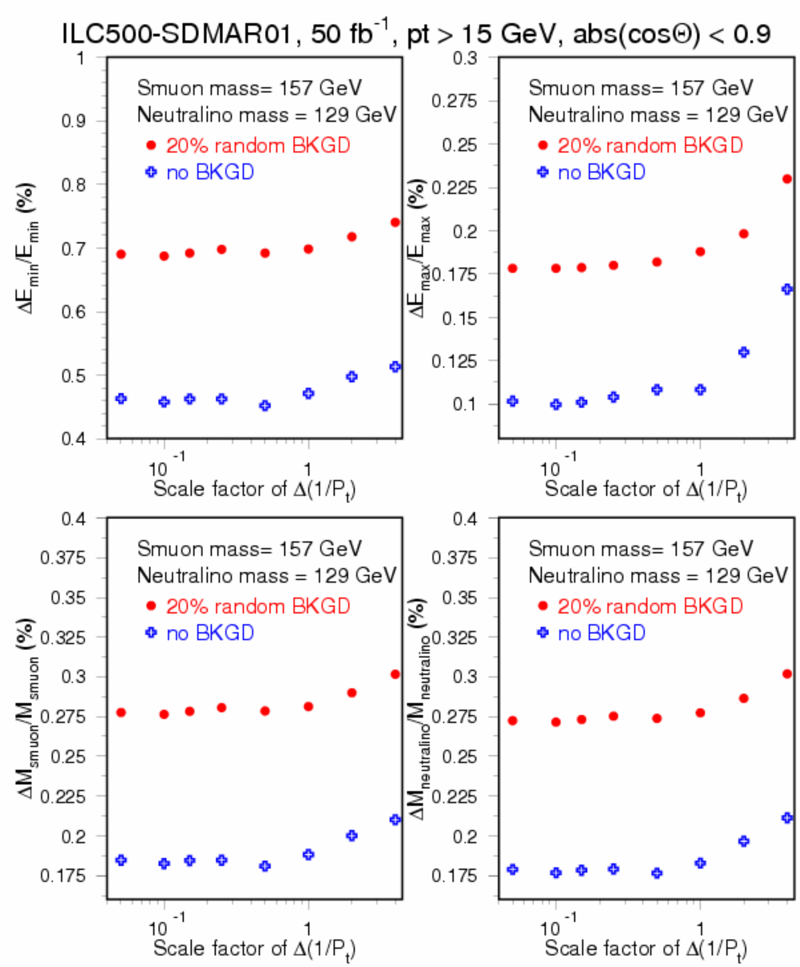
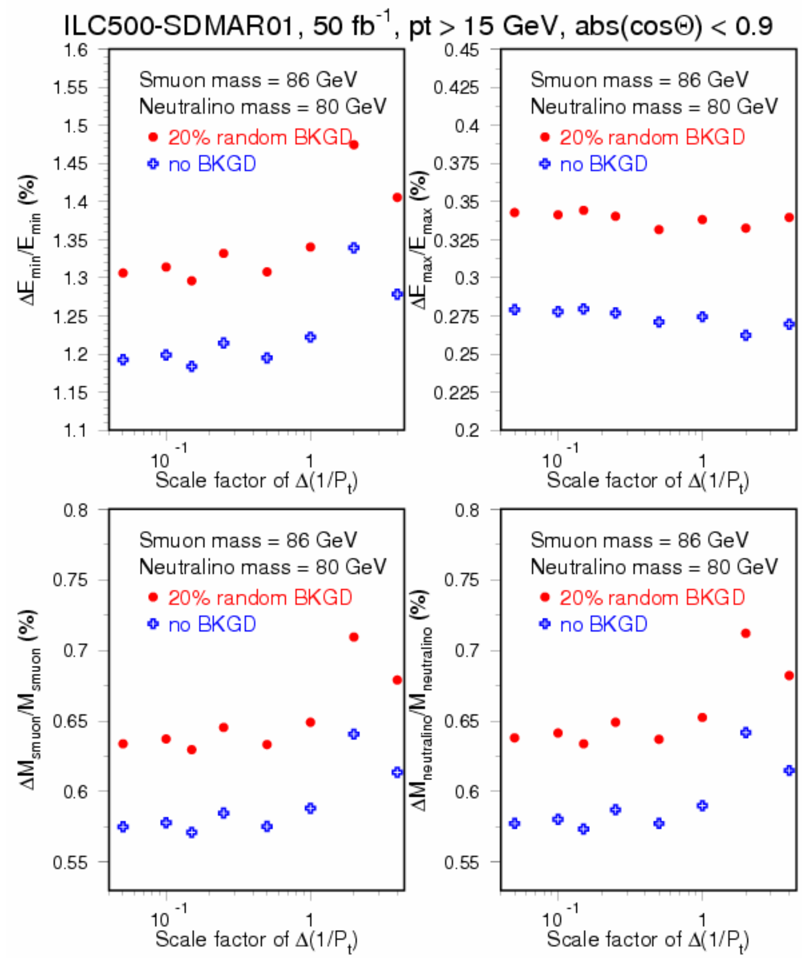
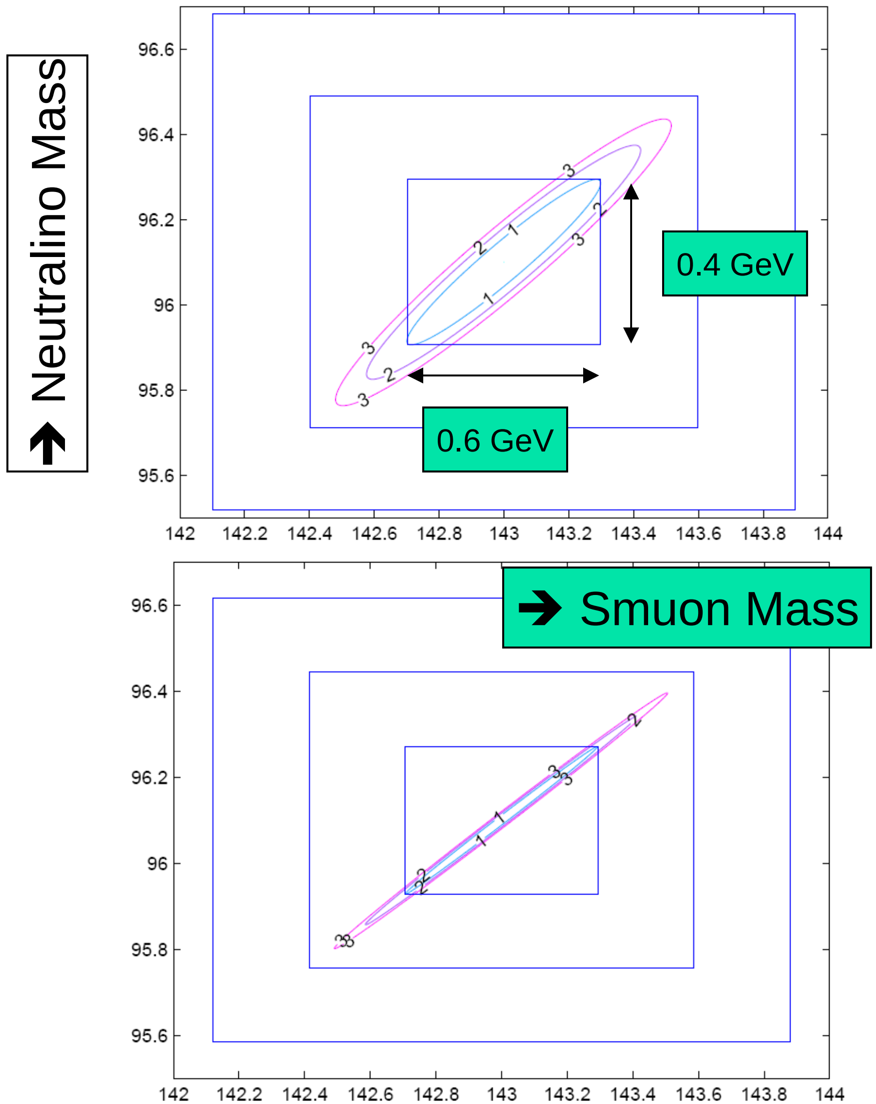
ΔM = 28 GeV



ΔM = 6 GeV



New Results about SUSY Masses



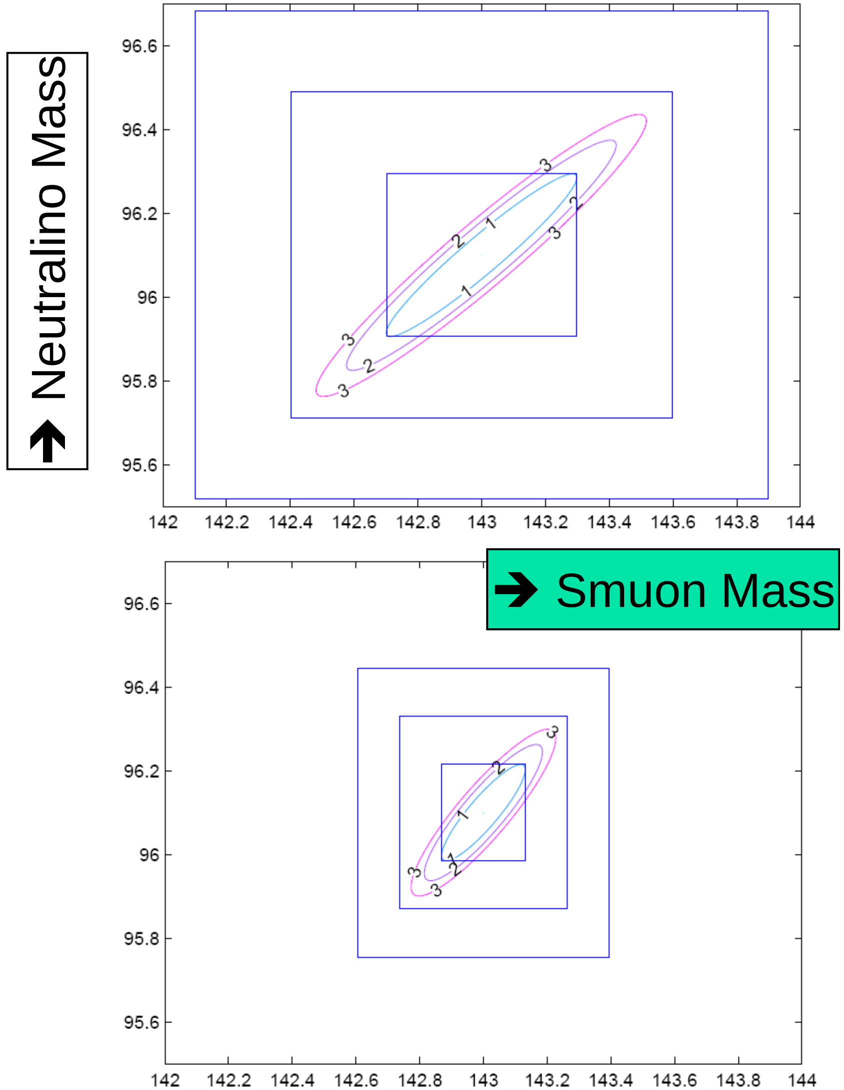
Ecm = 500 GeV
Mneu = 96.1 Gev
Msmuon = 143 GeV
dEmin/Emin = 5.0E-3
dEmax/Emax = 1.0E-3

→dMneu ~ 0.2 GeV
→dMsmuon ~ 0.3 GeV

Ecm = 500 GeV
Mneu = 96.1 Gev
Msmuon = 143 GeV
dEmin/Emin =5.0E-3
dEmax/Emax=2.0E-4

→dMneu ~ 0.2 GeV
→dMsmuon ~ 0.3 GeV

New Results about SUSY Masses



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➔dMneu ~ 0.2 GeV
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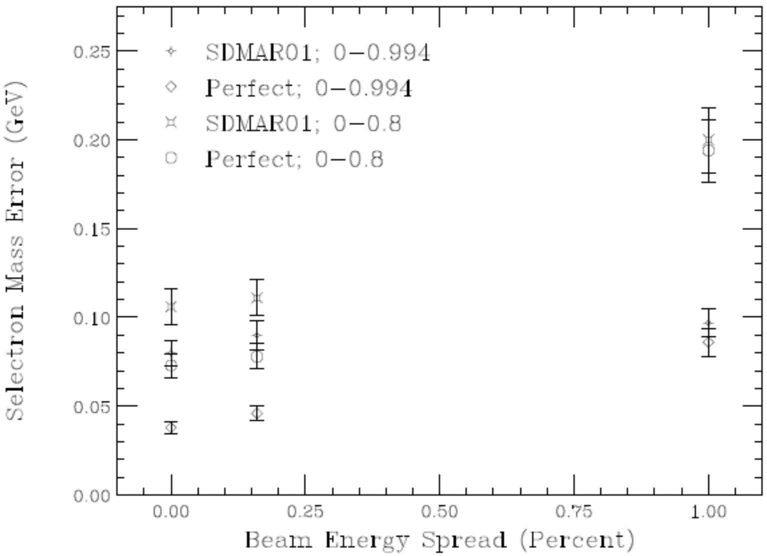
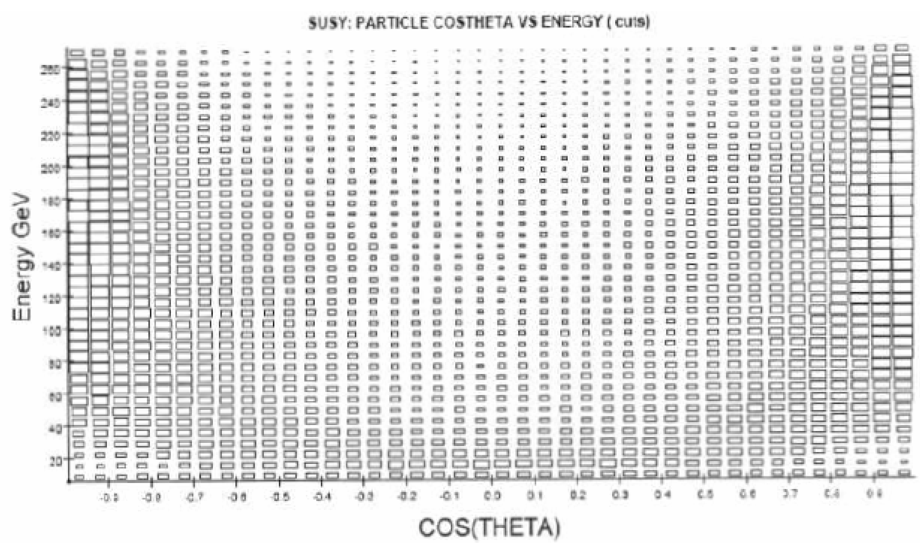
Ecm = 500 GeV
Mneu = 96.1 Gev
Msmuon = 143 GeV
dEmin/Emin =2.0E-3
dEmax/Emax=1.0E-3

➔dMneu ~ 0.1 GeV
➔dMsmuon ~ 0.15 GeV

Results from Bruce Schumm’s Group

- Ecm=1000 GeV, Mneu=95 GeV, Mselectron=143.1 GeV, the lightest neutralino mass is assumed to be known precisely.
- For large beam energy spread(1%), the sensitivity to selectron mass has little dependence on the detector resolution.
- For the expected beam energy spread(0.16%), substantial improvement in selectron mass can be achieved by improving the detector resolution, particularly in the forward region.
- Ref: hep-ex/0507053, “Selectron Mass Reconstruction and the Resolution of the Linear Collider Detector”, by Bruce Schumm et.al..





Summary and Conclusions

- ➔ The conclusions are based on ILC500, SD & LD, Higgsstrahlung and Smuon pair signal, fast Monte Carlo simulation results.
- ➔ ISR and Beamstrahlung have significant impact on Higgs/SUSY measurement.
- ➔ Beam energy spread ≤ 0.2% has little effect on Higgs/SUSY masses.
- ➔ Track momentum resolution affect Higgs mass significantly with better track performance yielding better Higgs mass resolution & precision until the re-scale factor of track momentum resolution down to ~ 0.2.
- ➔ Track momentum resolution has little effect on the cross section of Higgsstrahlung signal, branching ratio of H ➔ CC and SUSY masses.

- ➔ Ref: physics/0506198,"Impact of Tracker Design on Higgs and Slepton Measurememt", Hai-Jun Yang, Keith Riles.

Future Plan

- Michigan group will assist with SiD …… resolutions, and reconstruction, but with priority given to ongoing tracker alignment R&D with frequency scanned interferometry.
- Application of advanced data mining technique, boosted decision trees (BDT), for ILC physics analysis to improve the performance. Michigan group pioneered the application of BDT in HEP data analysis, we successfully applied BDT for MiniBooNE data analysis and ATLAS Di-Boson analysis. The performance of BDT is better than ANN based on our studies. We would like to collaborate with other groups on this issue if you are interested in and/or have MC samples on hand for application.

* Hai-Jun Yang, Byron P. Roe, Ji Zhu, "*Studies of boosted decision trees for MiniBooNE particle identification*", Nucl. Instrum. & Meth. A 555 (2005) 370-385, physics/0508045

* Byron P. Roe, Hai-Jun Yang,Ji Zhu, Yong Liu, Ion Stancu, Gordon McGregor, "*Boosted decision trees as an alternative to artificial neural networks for particle identification*", Nucl. Instrum. & Meth. A 543 (2005) 577-584, physics/0408124

BACKUP SLIDES

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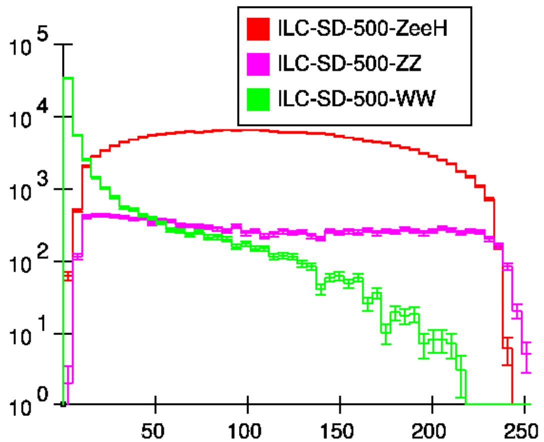
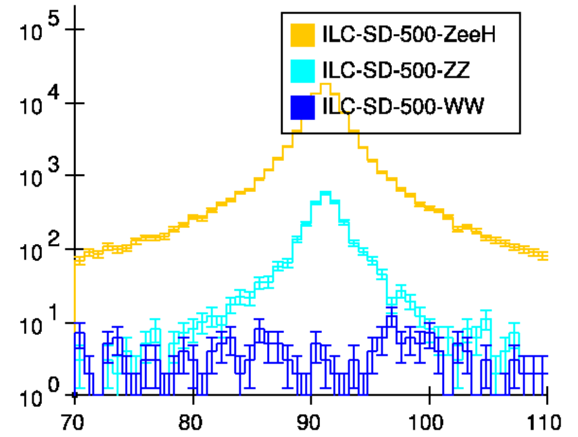
Some Useful Variables for Higgs Selection

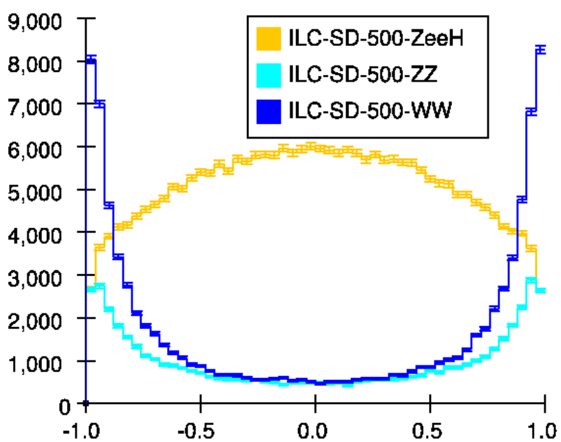
Energy of electron (GeV)



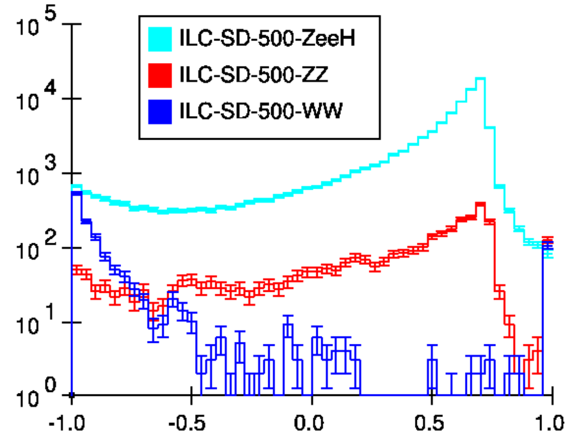
Z0 mass (GeV)



cos (polar angle of lepton)

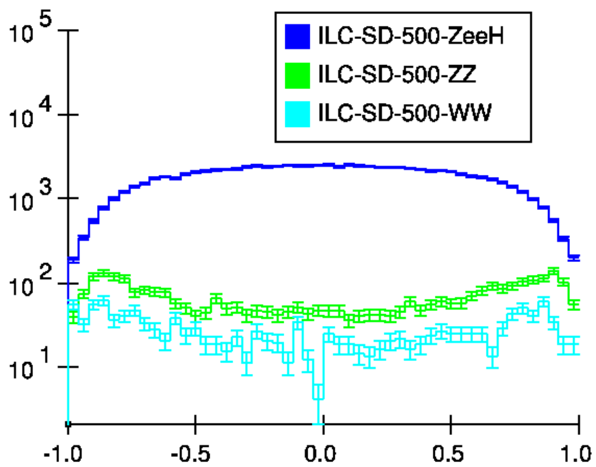


cos(angle between two leptons)

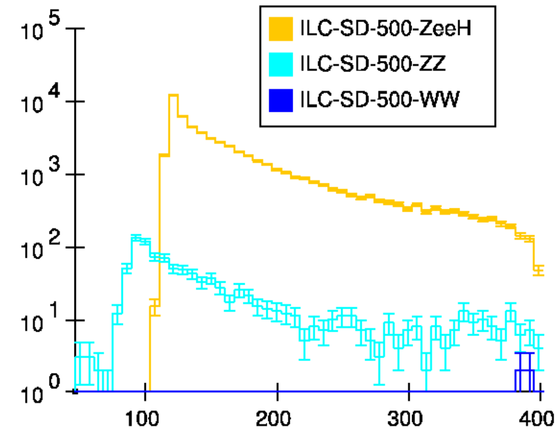


Some Useful Variables for Higgs Selection

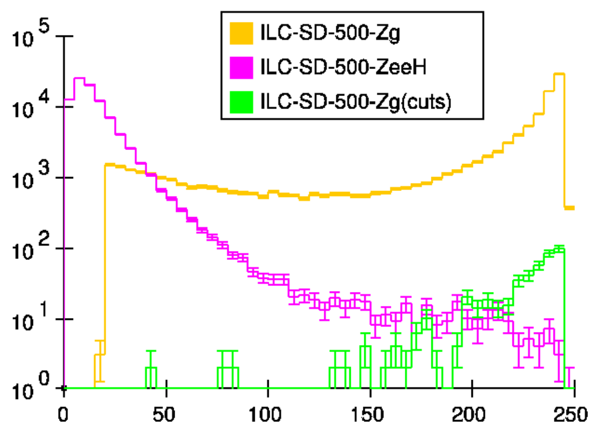
cos(polar angle of Z)



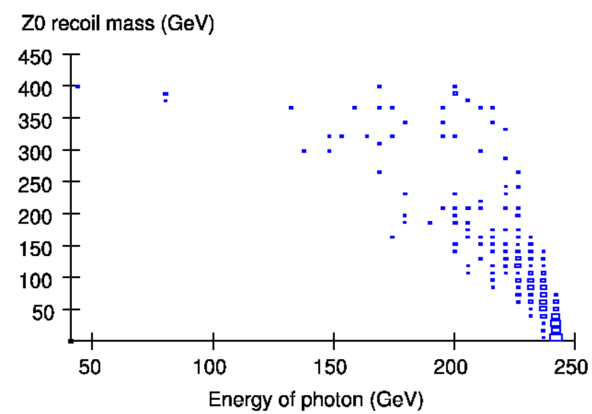
after cuts: Z0 recoil mass (GeV)



Energy of Photon (GeV)



Zg -after cuts



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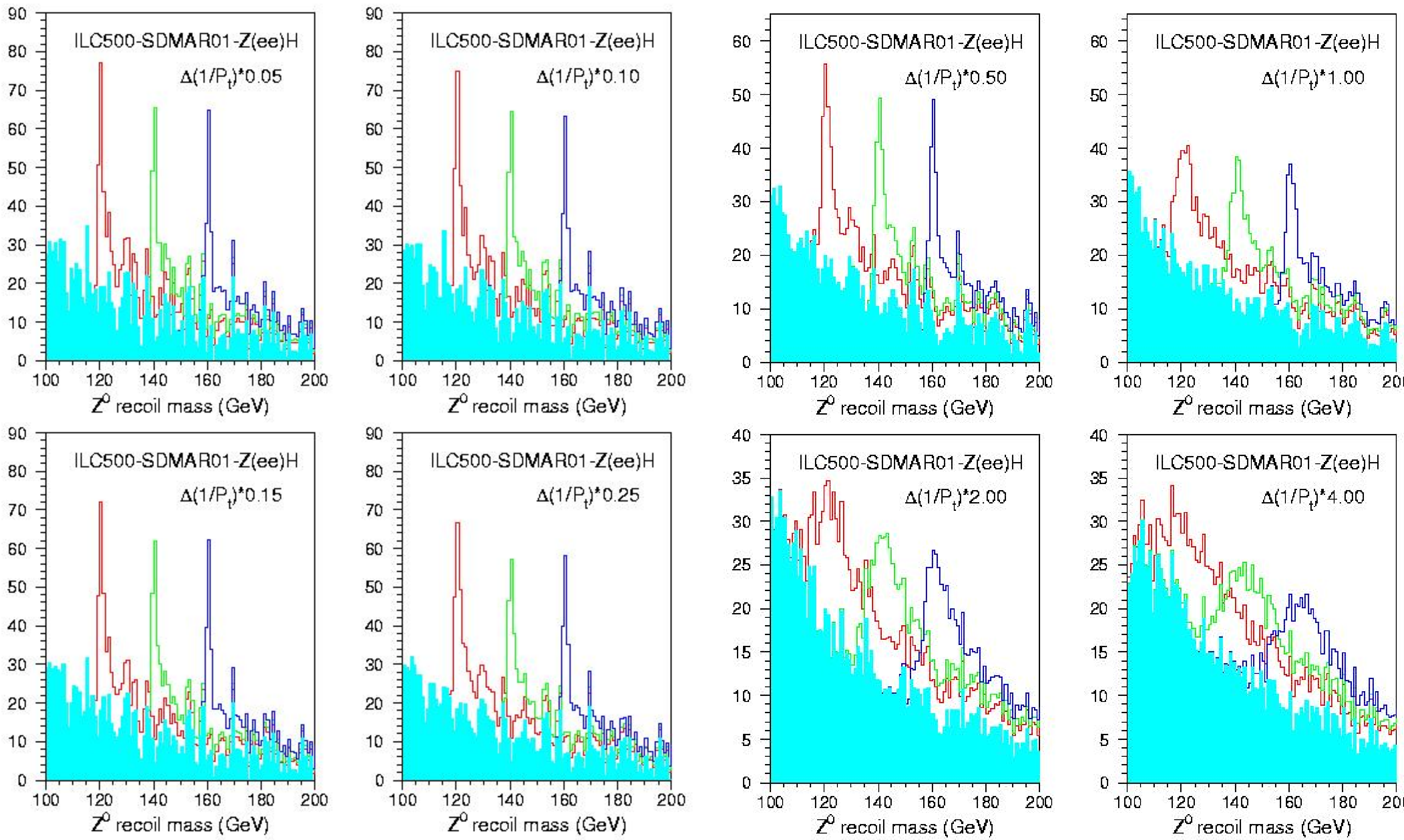
Z0 Recoil Mass (with ZZ bkgd, $500fb^{-1}$)



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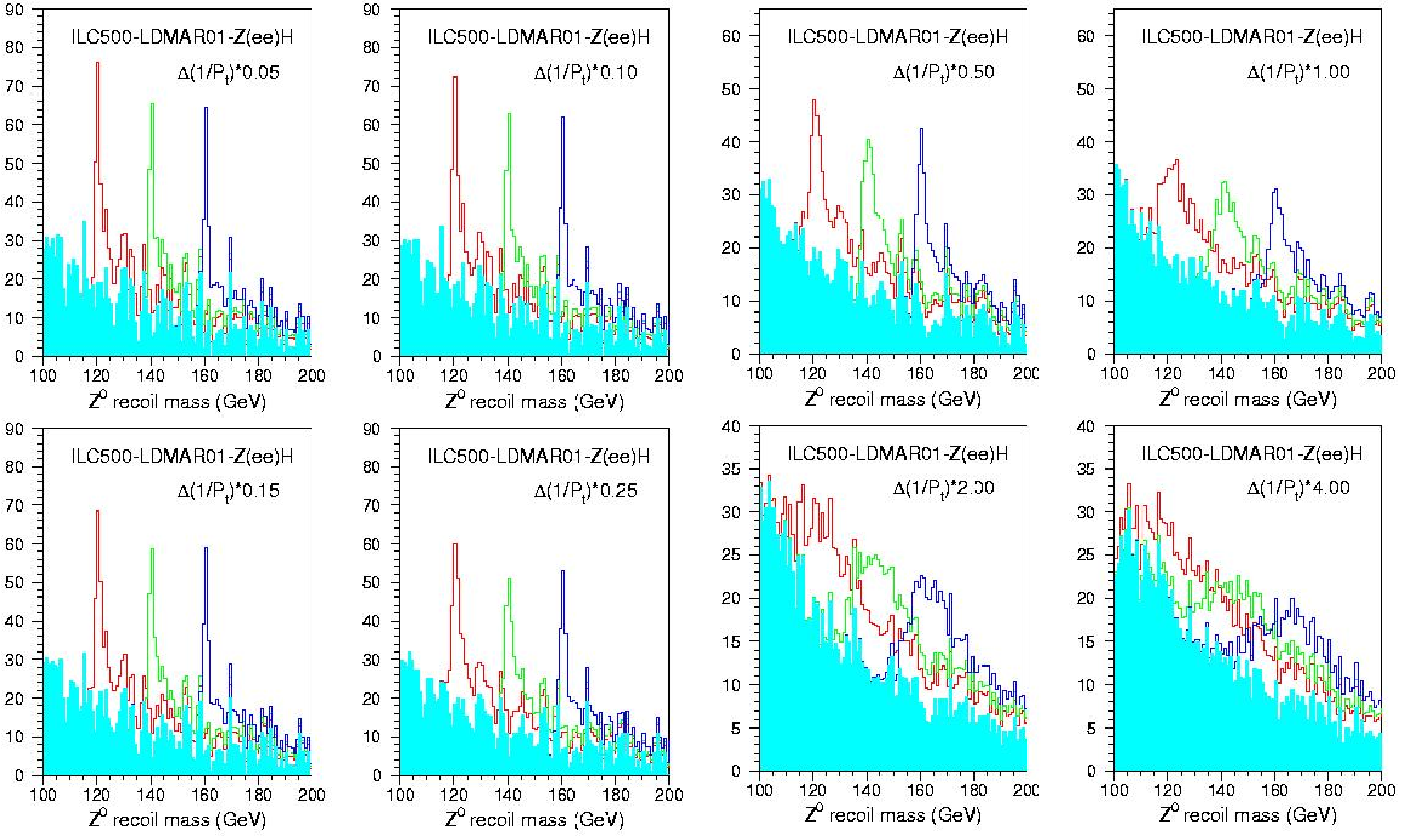
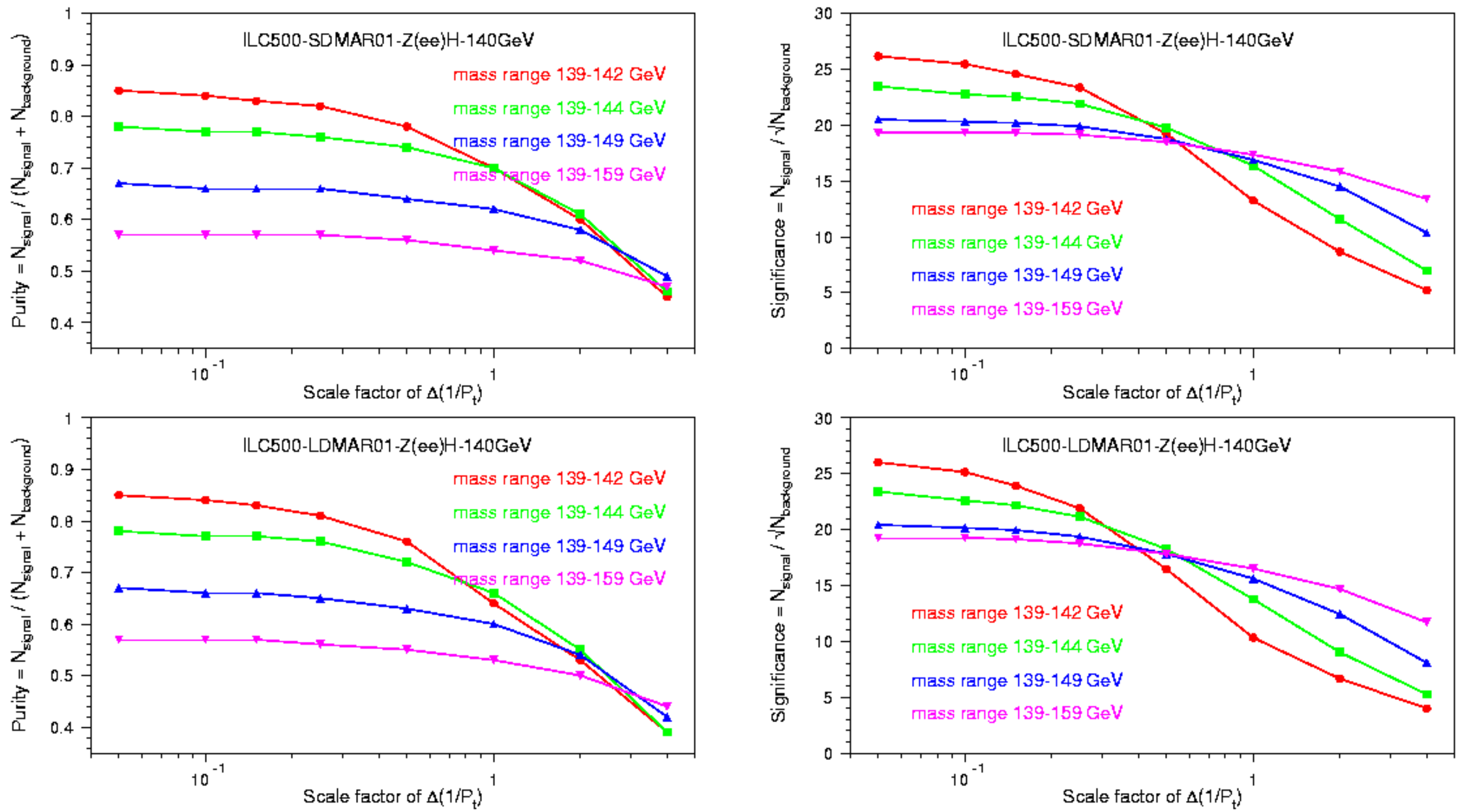


Purity and Significance – M_H = 140 GeV



Purity and Significance – M_H = 160 GeV