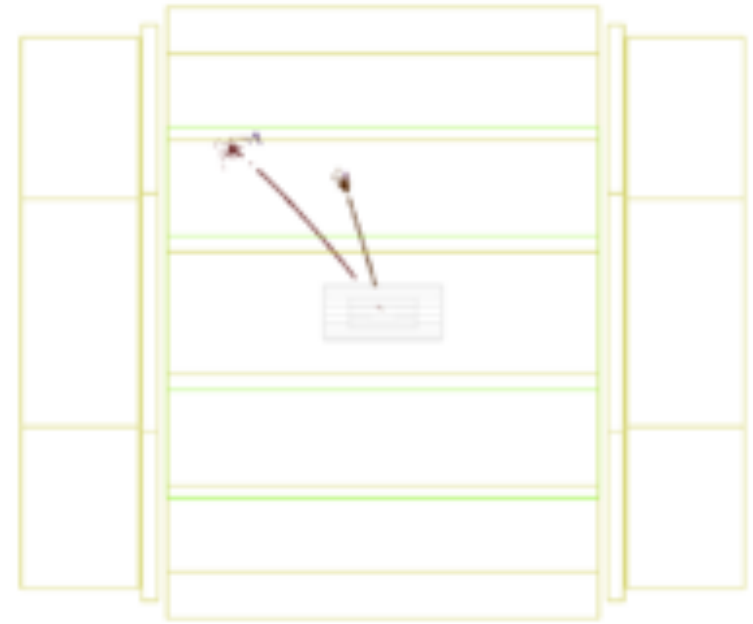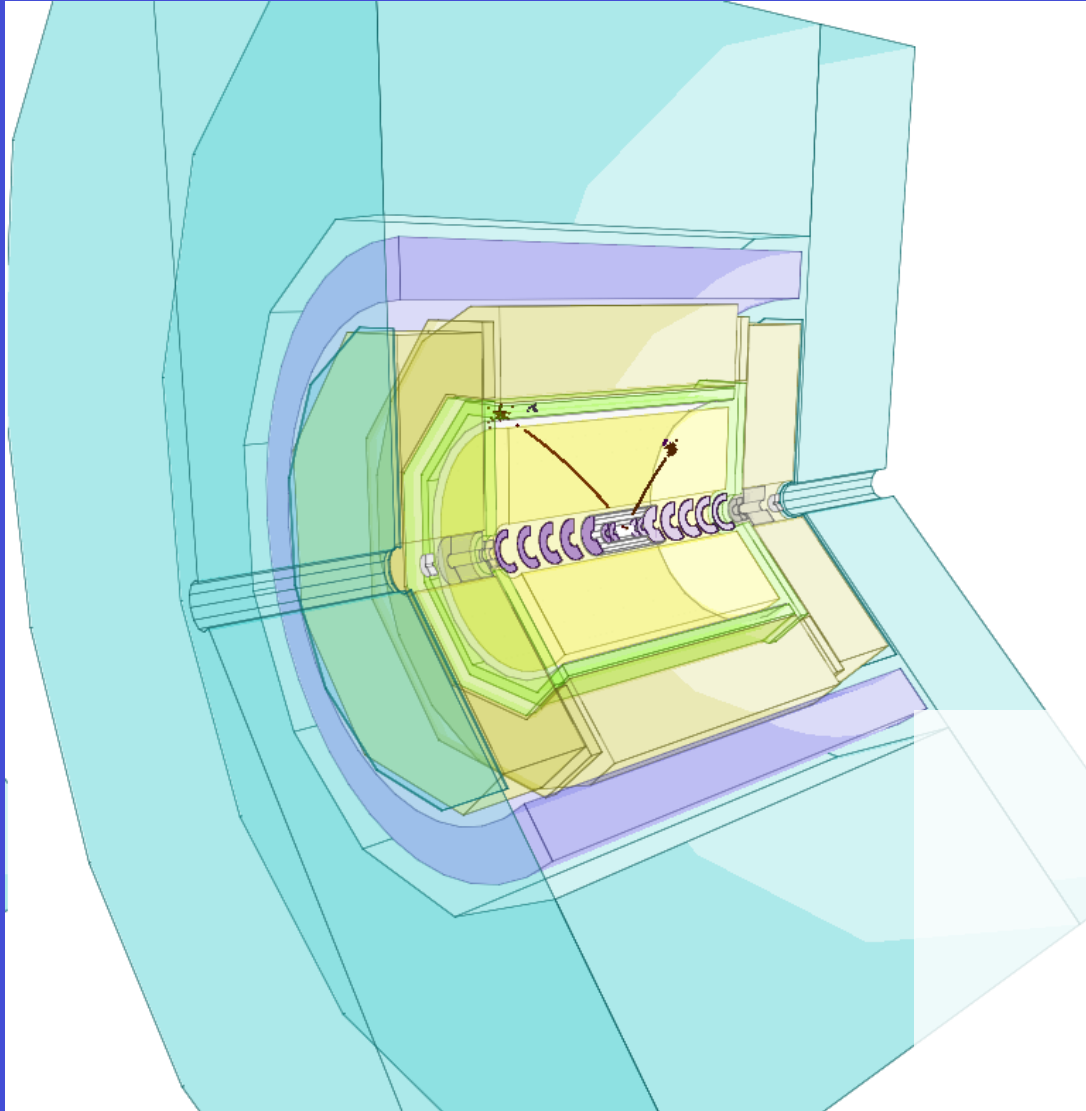# Characterizing Light Higgsinos from Natural SUSY at ILC √s = 500 GeV

Jacqueline Yan (KEK)
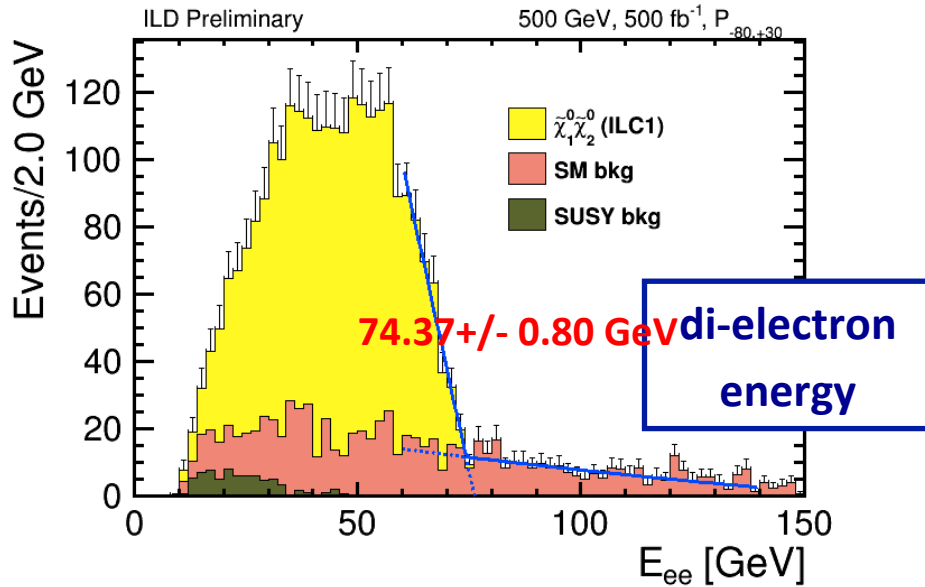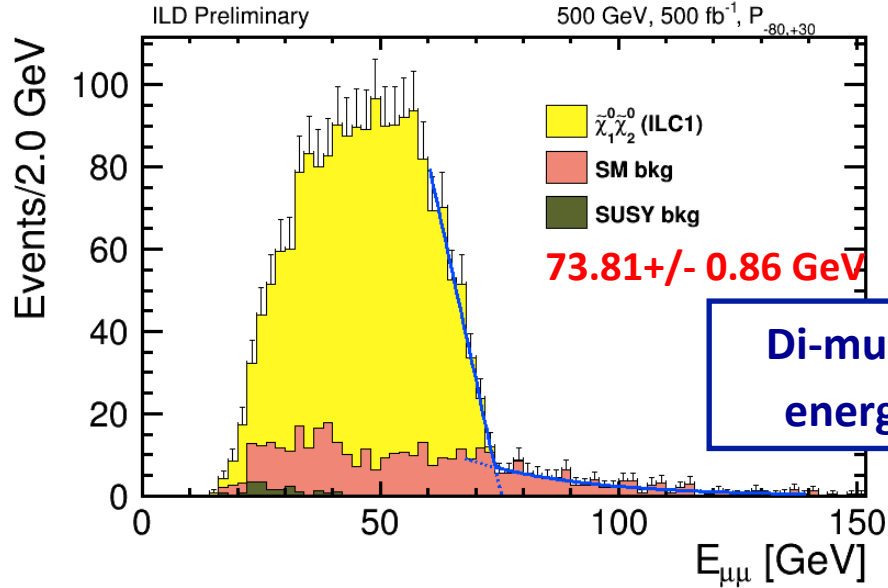
Friday Meeting

8/26/2016

Outline

Update on edge and cross section extraction

- Finished analysis for chargino

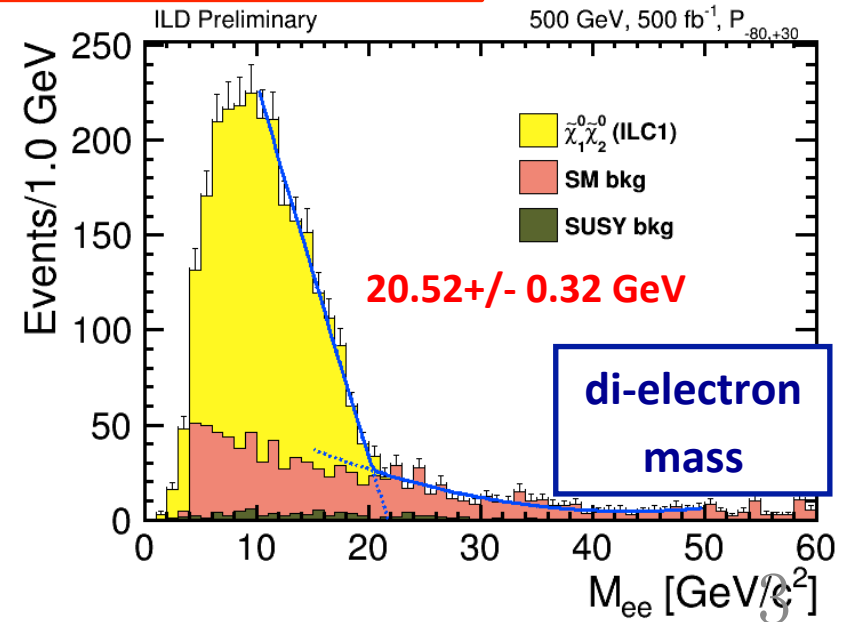- Now kinematic edge and cross section precisions are extracted for all channels , both left and right polarization

Neutralino mixed production with leptonic decay

$$e^+ e^- \to \widetilde{\chi}_1^0 \widetilde{\chi}_2^0 \to \widetilde{\chi}_1^0 \widetilde{\chi}_1^0 \ell^+ \ell^-$$

Polarization (Pe-,Pe+) = (-0.8, +0.3)

preliminary

73.81+/- 0.86 GeV

Di-muon energy

20.76+/- 0.20 GeV

Di-muon mass

Edge precision ∼ 1 %

74.37+/- 0.80 GeV **di-electron energy**
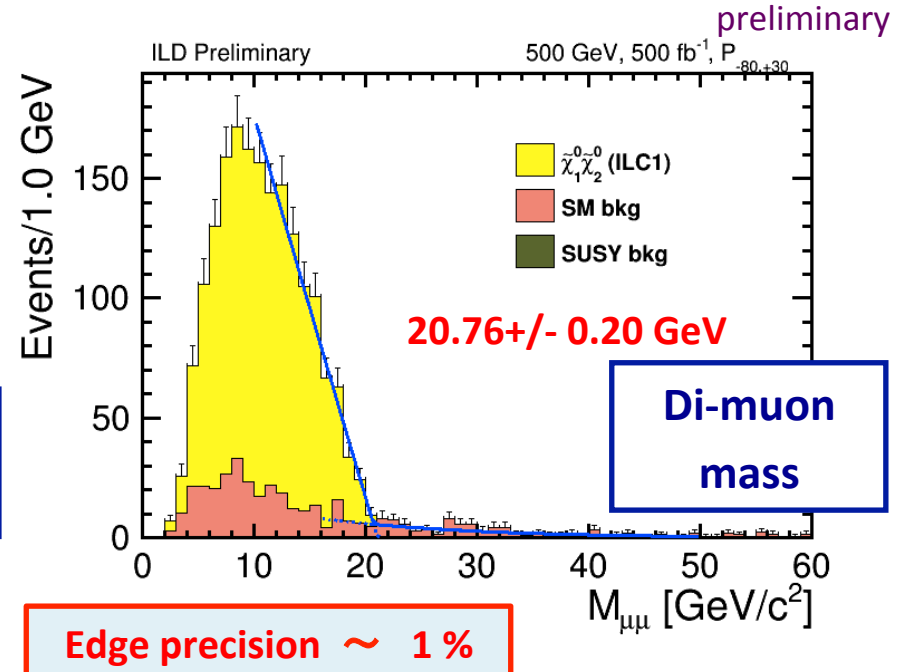
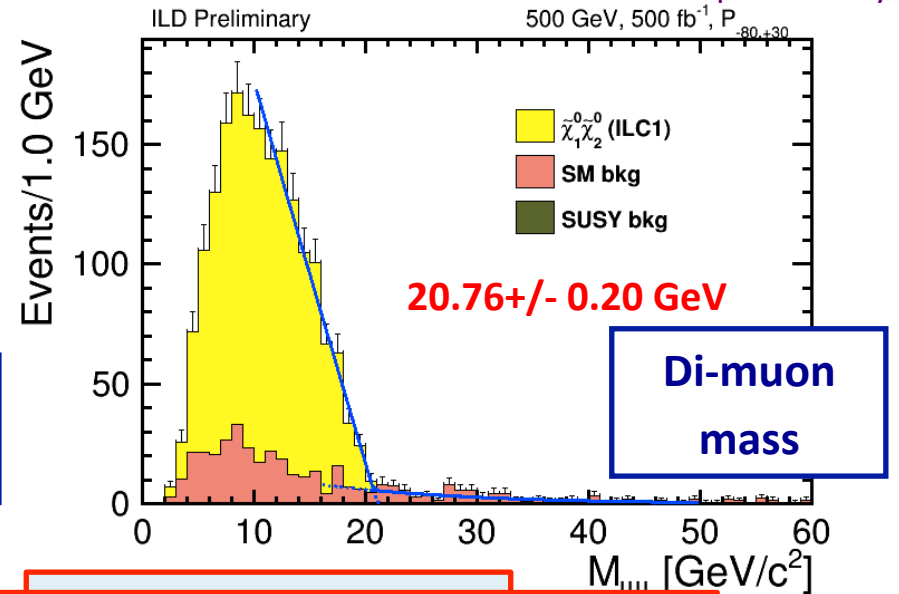**20.52+/- 0.32 GeV**

di-electron mass

Neutralino mixed production with leptonic decay

$$e^+e^- \rightarrow \widetilde{\chi}_1^0 \widetilde{\chi}_2^0 \rightarrow \widetilde{\chi}_1^0 \widetilde{\chi}_1^0 \ell^+ \ell^-$$

Polarization (Pe-,Pe+) = (-0.8, +0.3)

preliminary

ILD Preliminary 500 GeV, 500 fb⁻¹, P₋₈₀,₊₃₀

73.81+/- 0.86 GeV

Di-muon energy

ILD Preliminary 500 GeV, 500 fb⁻¹, P₋₈₀,₊₃₀

20.76+/- 0.20 GeV

Di-muon mass

Theoretical values: E_max = 74.9 GeV   ΔM = 21.3 GeV

74.37+/- 0.80 GeV

di-electron energy

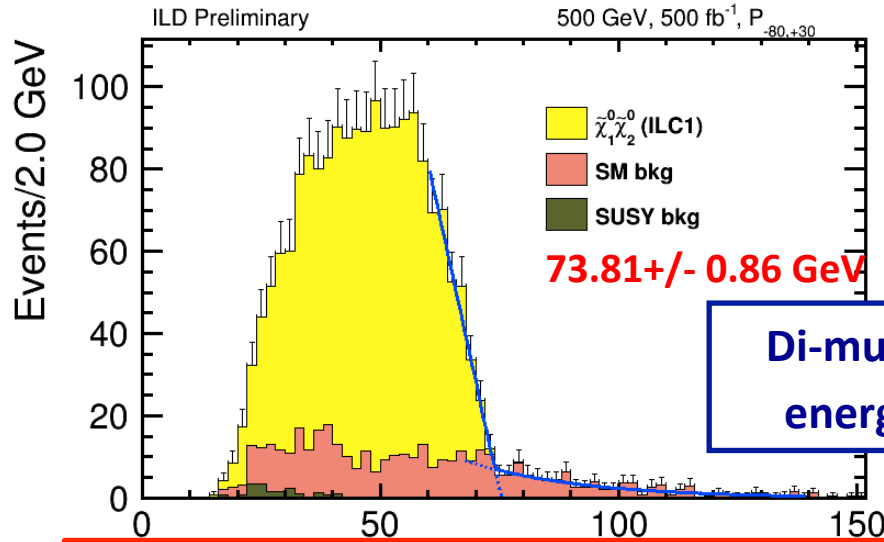20.52+/- 0.32 GeV

di-electron mass

4

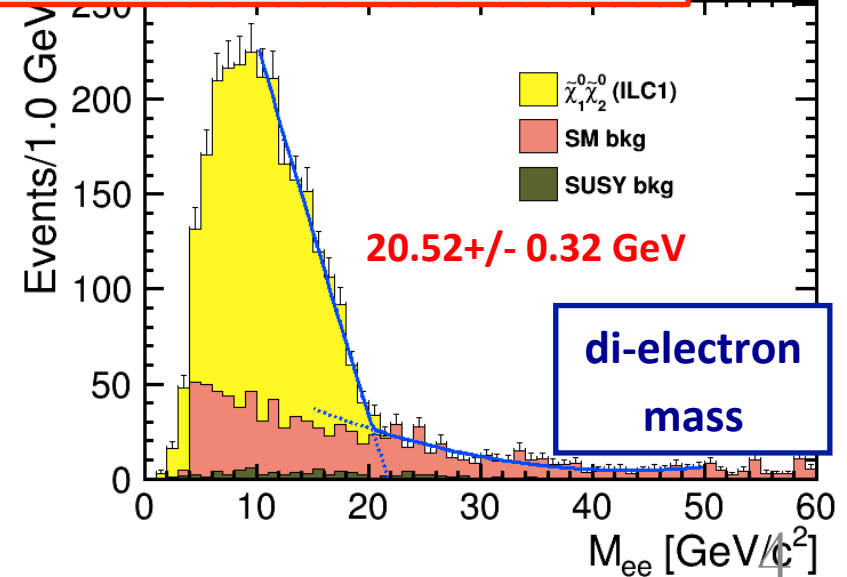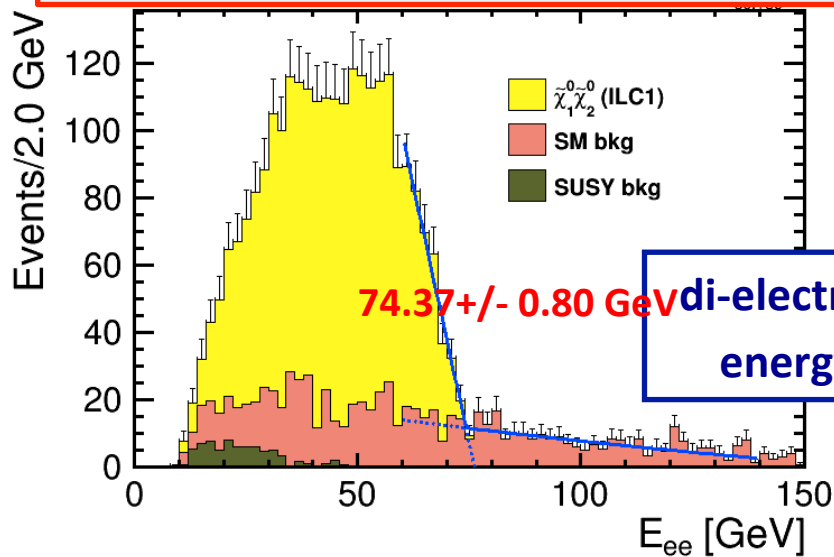**Neutralino mixed production with leptonic decay**

$$e^+ e^- \to \widetilde{\chi}_1^0 \widetilde{\chi}_2^0 \to \widetilde{\chi}_1^0 \widetilde{\chi}_1^0 \ell^+ \ell^-$$

Polarization (Pe-,Pe+) = (-0.8, +0.3)

preliminary

MN1 = 102.3 GeV
MN2 = 123.0 GeV

73.81+/- 0.86 GeV

Di-muon energy

20.76+/- 0.20 GeV

Di-muon mass

Theoretical values: MN1 = 102.7 GeV   MN2 = 124.0 GeV

MN1 = 100.3 GeV
MN2 = 120.8 GeV

74.37+/- 0.80 GeV

di-electron energy
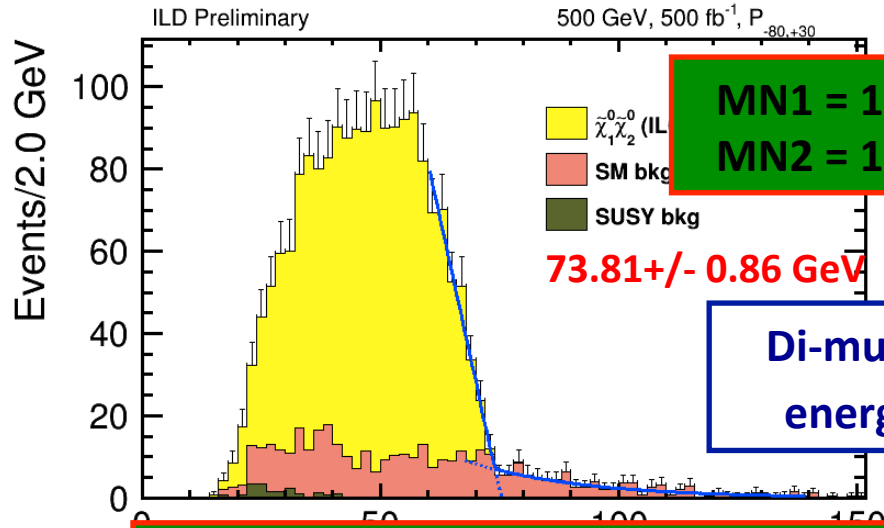
20.52+/- 0.32 GeV

di-electron mass

5

Neutralino mixed production with leptonic decay

$$e^+ e^- \rightarrow \widetilde{\chi}_1^0 \, \widetilde{\chi}_2^0 \rightarrow \widetilde{\chi}_1^0 \widetilde{\chi}_1^0 \ell^+ \ell^-$$

Polarization (Pe-,Pe+) = (+0.8, -0.3)

Much less bkg
Precision slightly better (?)

preliminary

ILD Preliminary — 500 GeV, 500 fb^{-1}, P$_{+80,-30}$

$\widetilde{\chi}_1^0 \widetilde{\chi}_2^0$ (ILC1)
SM bkg
SUSY bkg

73.77+/- 0.84 GeV

Di-muon energy

E$_{\mu\mu}$ [G

Events/2.0 GeV

20.93+/- 0.22 GeV

Di-muon mass

M$_{\mu\mu}$ [GeV/c^2]

Events/1.0 GeV

Edge precision < ~ 1 %

73.45+/- 0.61 GeV

di-electron energy

E$_{ee}$ [GeV]

Events/2.0 GeV

20.89+/- 0.19 GeV

di-electron mass

M$_{ee}$ [GeV/c^2]

Events/1.0 GeV

6

Neutralino mixed production with leptonic decay

$$e^+ e^- \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 \ell^+ \ell^-$$
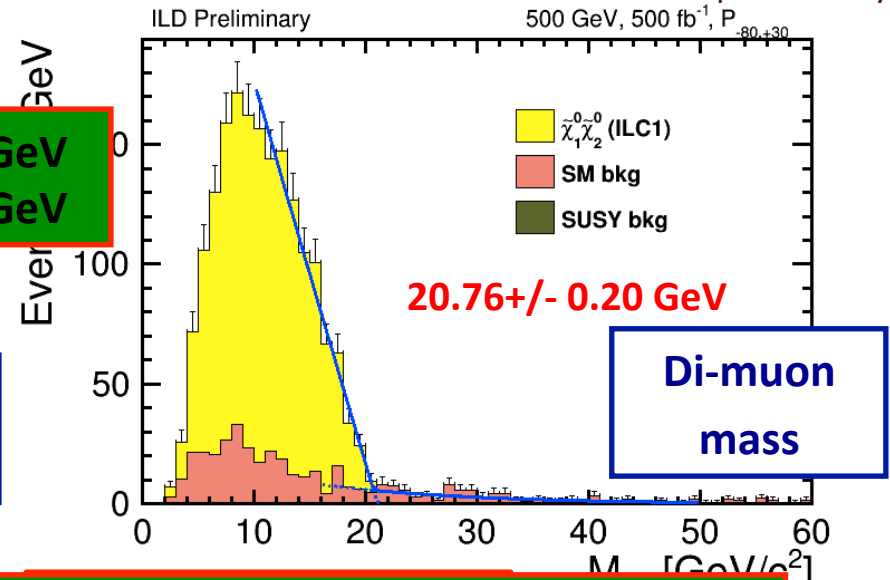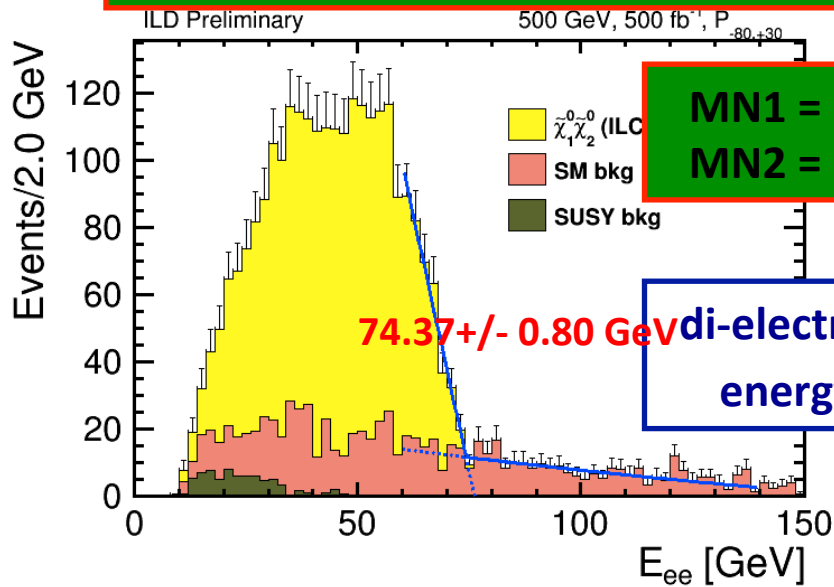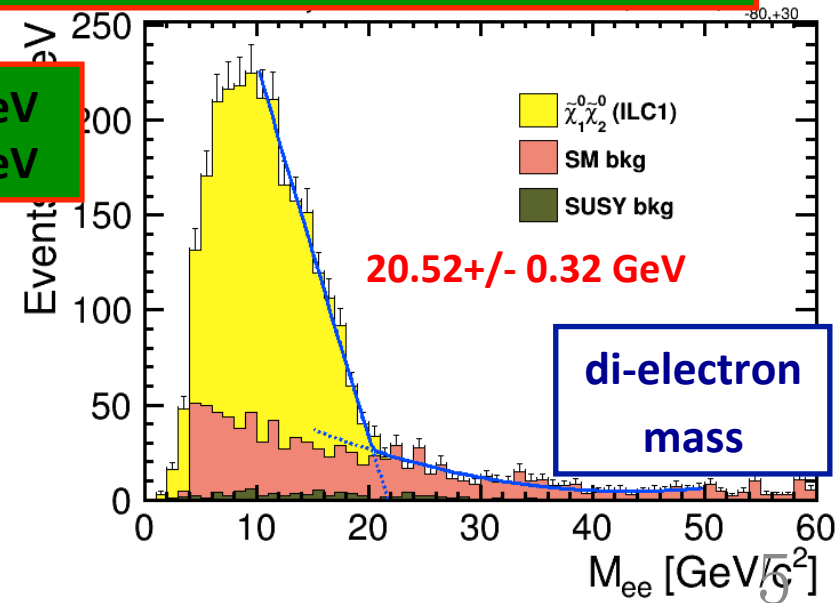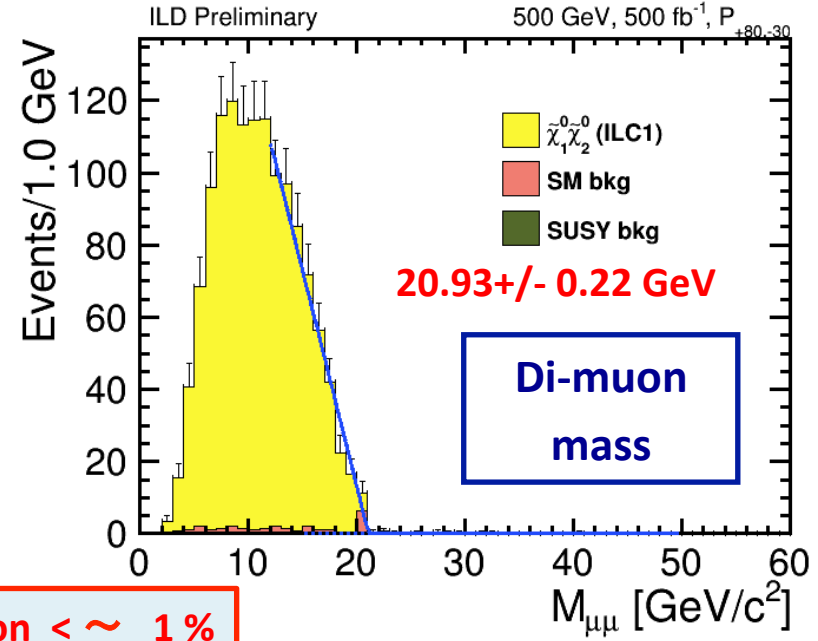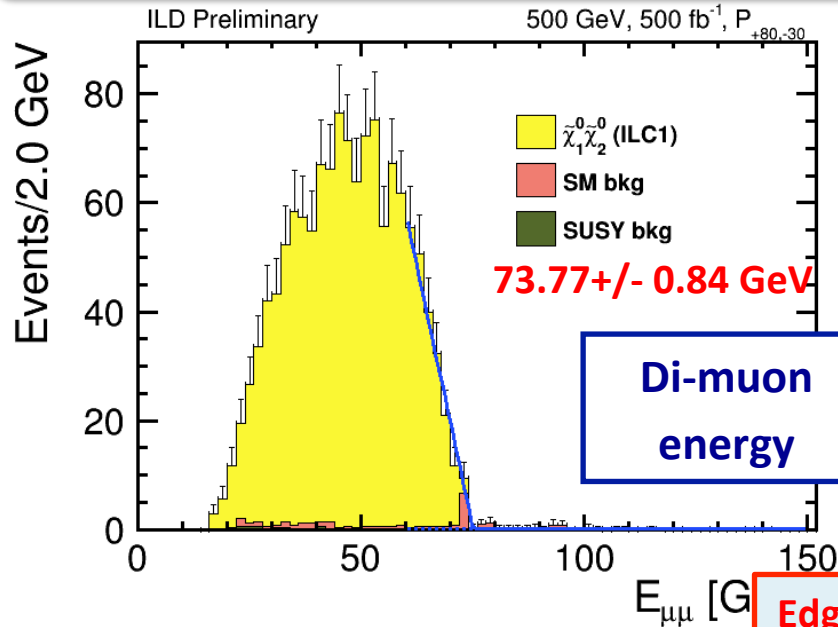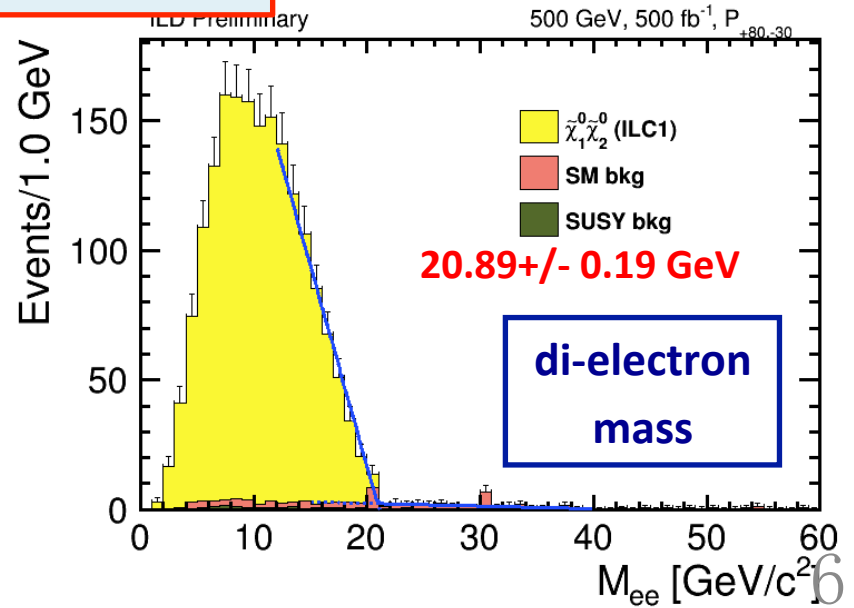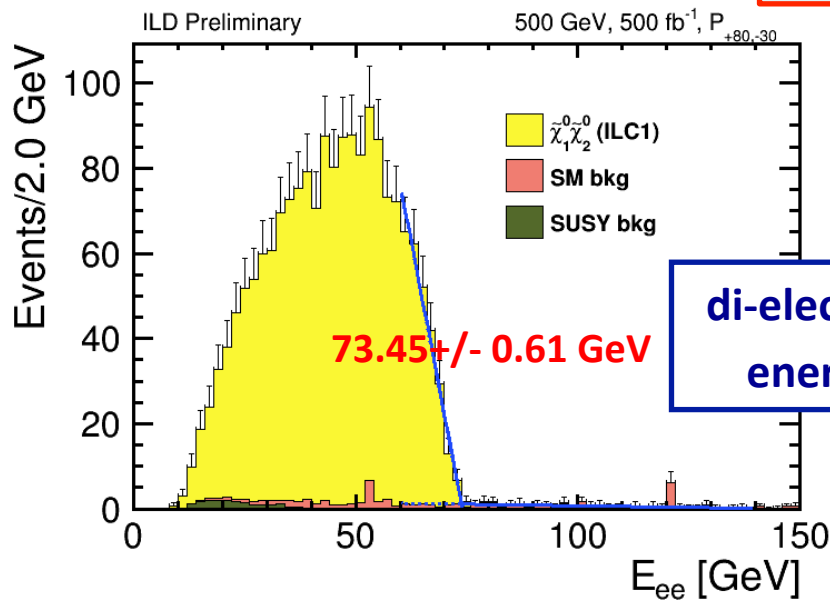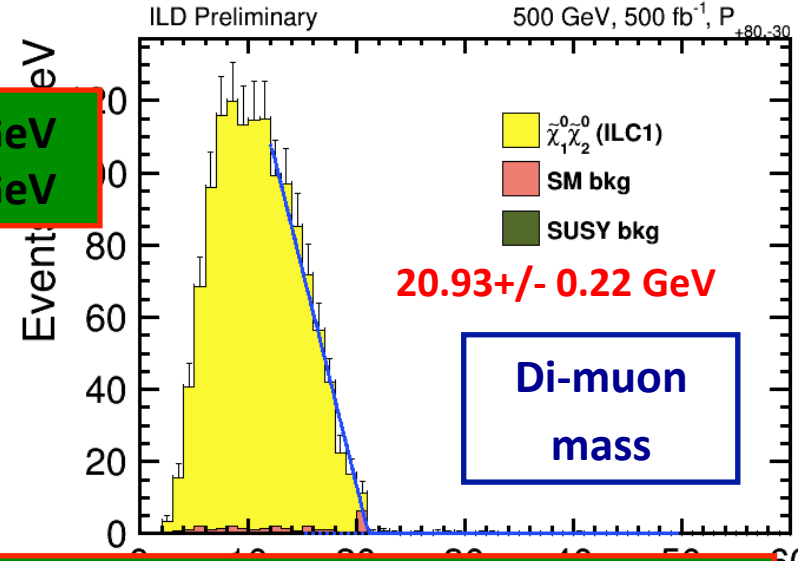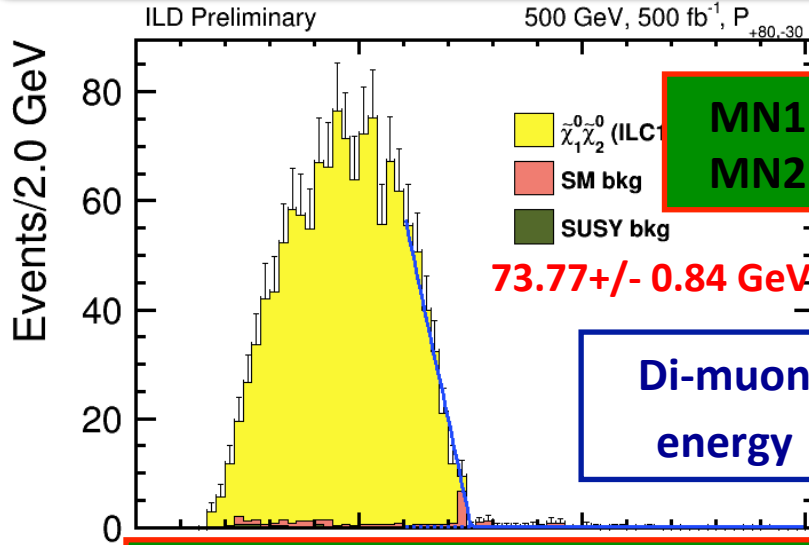
Polarization (Pe-,Pe+) = (+0.8, -0.3)
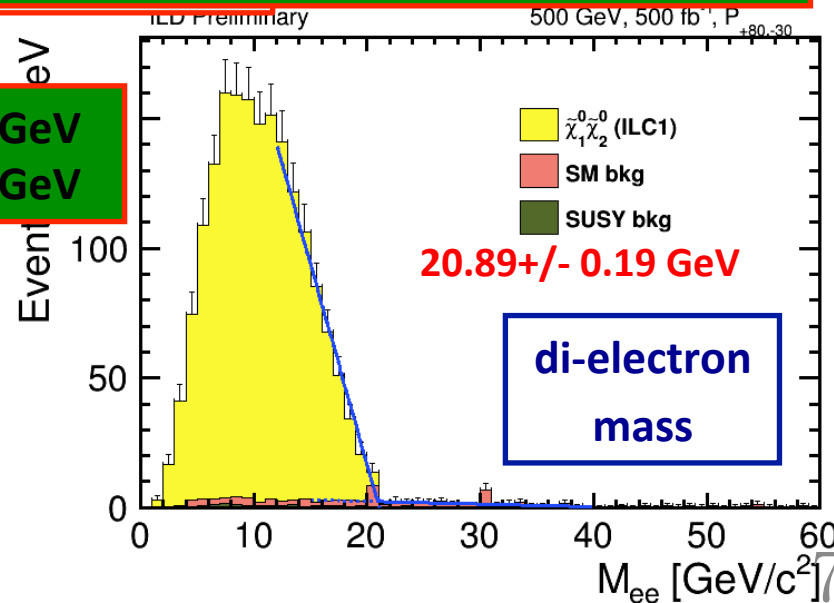
Much less bkg
Precision slightly better (?)

preliminary

MN1 = 103.1 GeV
MN2 = 124.0 GeV

73.77+/- 0.84 GeV

Di-muon energy

20.93+/- 0.22 GeV

Di-muon mass

Theoretical values: MN1 = 102.7 GeV   MN2 = 124.0 GeV

MN1 = 103.4 GeV
MN2 = 124.3 GeV

73.45+/- 0.61 GeV

di-electron energy

20.89+/- 0.19 GeV

di-electron mass

7

Chargino pair production with semileptonic decay

$$e^+ e^- \rightarrow \widetilde{\chi}_1^+ \widetilde{\chi}_1^- \rightarrow \widetilde{\chi}_1^0 \widetilde{\chi}_1^0 q q' \ell \nu$$
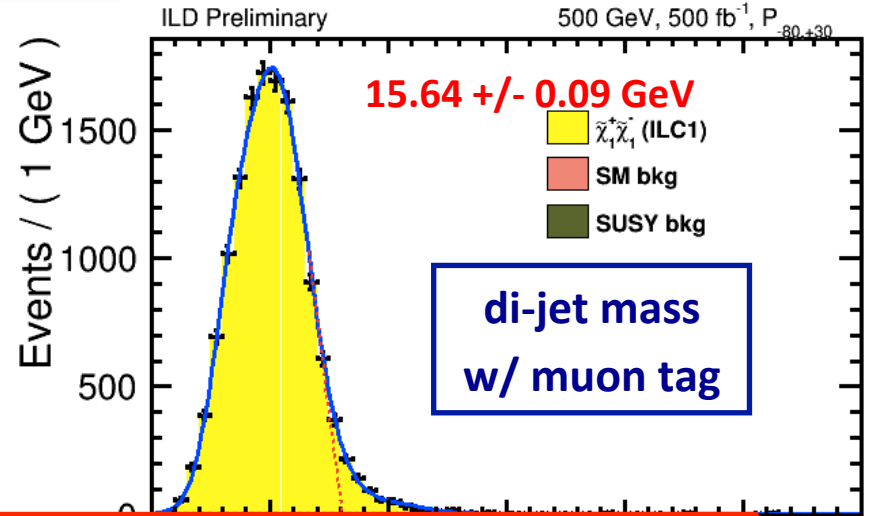
Polarization (Pe-,Pe+) = (-0.8, +0.3)
SM and SUSY backgrounds almost fully eliminated

preliminary

di-jet energy w/ muon tag

52.80 +/- 0.22 GeV

Legend:
- $\widetilde{\chi}_1^+\widetilde{\chi}_1^-$ (ILC1)
- SM bkg
- SUSY bkg

ILD Preliminary — 500 GeV, 500 fb^{-1}, P$_{-80,+30}$

15.64 +/- 0.09 GeV

di-jet mass w/ muon tag

Legend:
- $\widetilde{\chi}_1^+\widetilde{\chi}_1^-$ (ILC1)
- SM bkg
- SUSY bkg

Theoretical values: E_max = 56.4 GeV   ΔM = 15.1 GeV

ILD Preliminary — 500 GeV, 500 fb^{-1}, P$_{-80,+30}$

53.15 +/- 0.24 GeV

di-jet energy w/ electron tag

Legend:
- $\widetilde{\chi}_1^+\widetilde{\chi}_1^-$ (ILC1)
- SM bkg
- SUSY bkg

E_{jj} [GeV]

ILD Preliminary — 500 GeV, 500 fb^{-1}, P$_{-80,+30}$

17.41 +/- 0.15 GeV

di-jet mass w/ electron tag

Legend:
- $\widetilde{\chi}_1^+\widetilde{\chi}_1^-$ (ILC1)
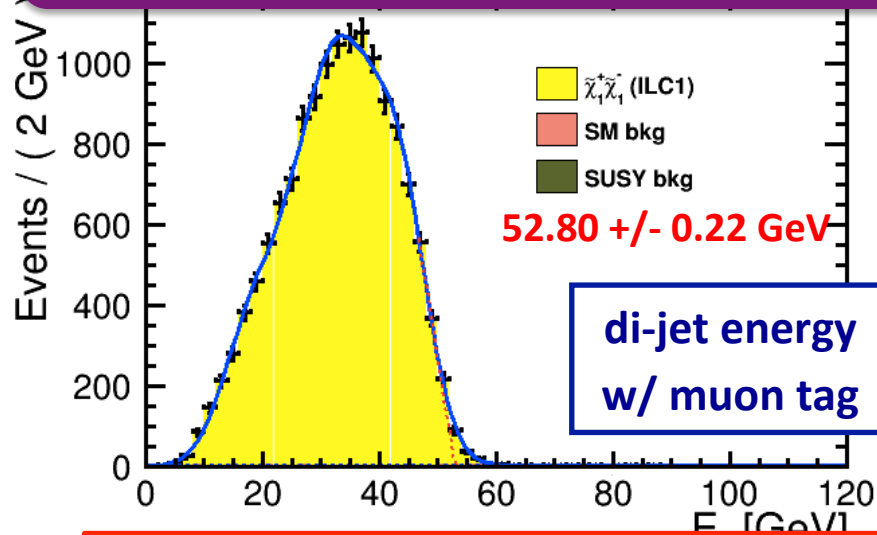- SM bkg
- SUSY bkg

M_{jj} (GeV/c^2)

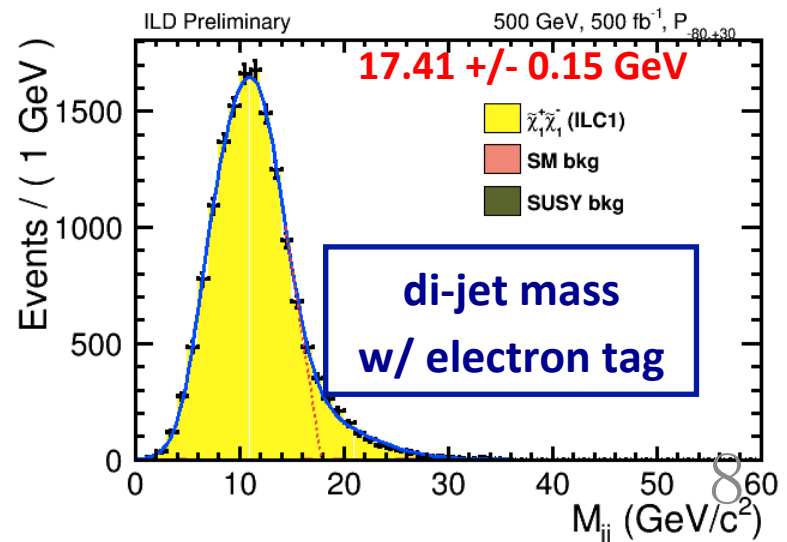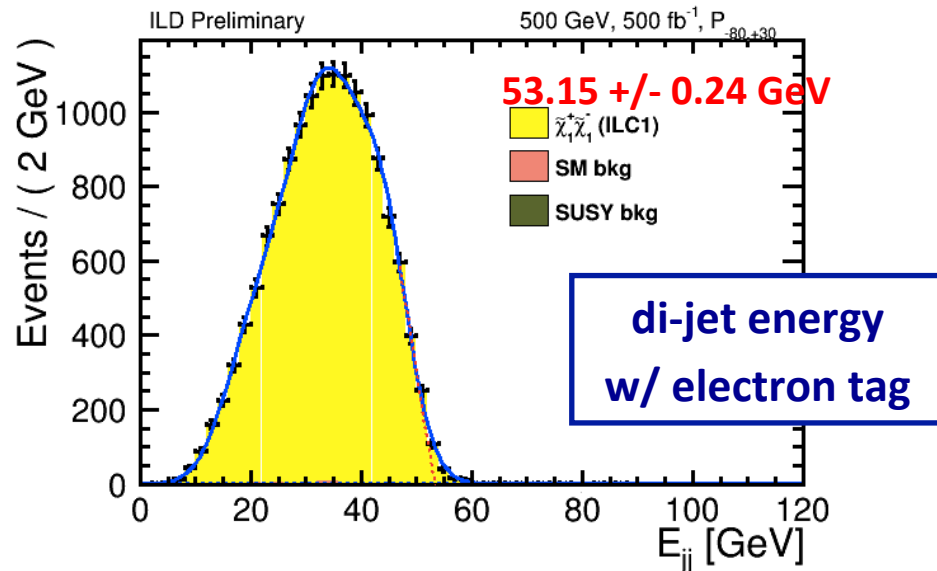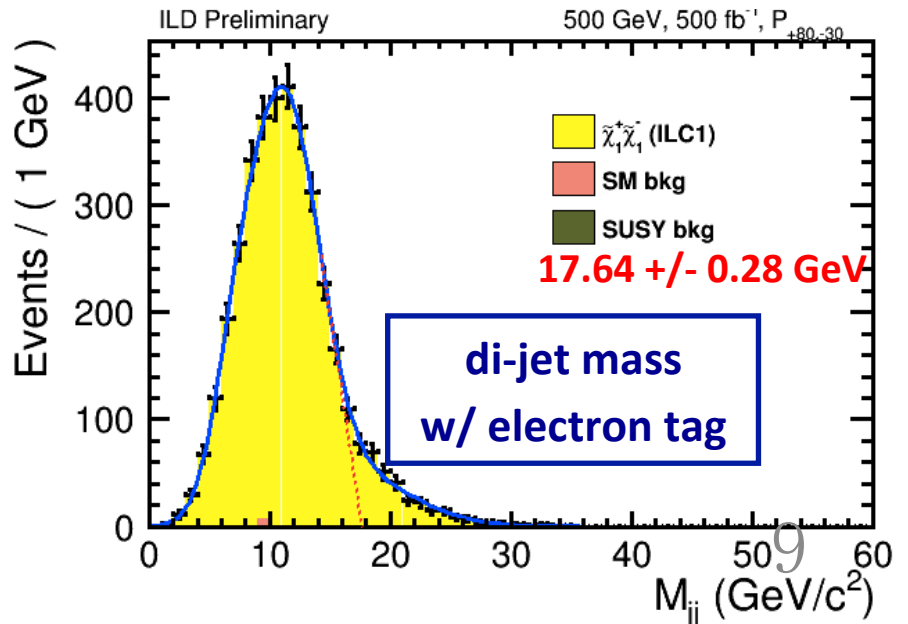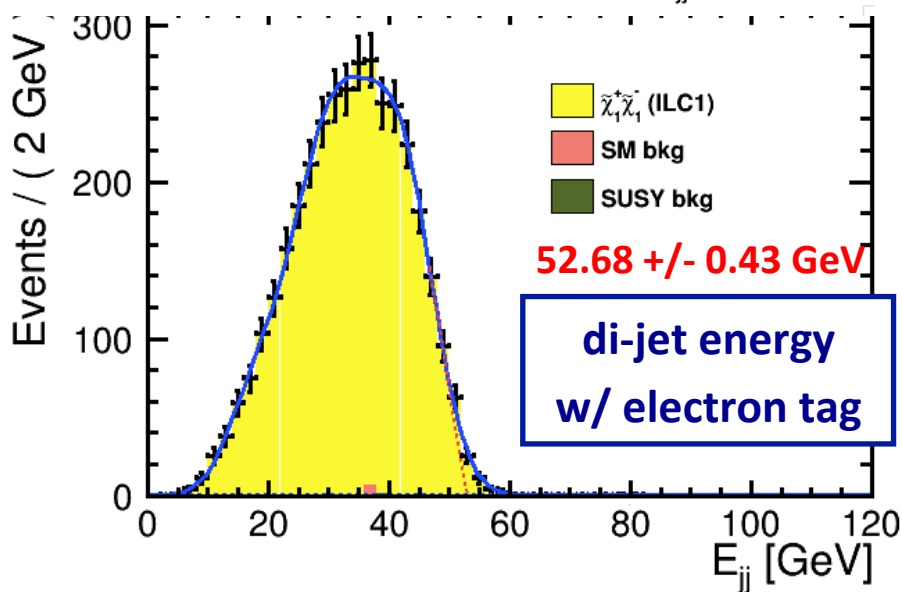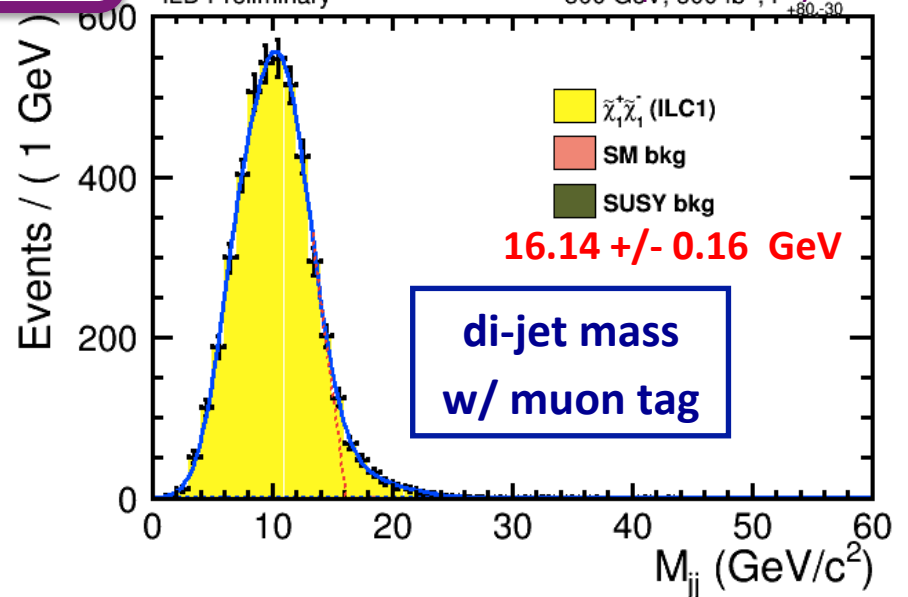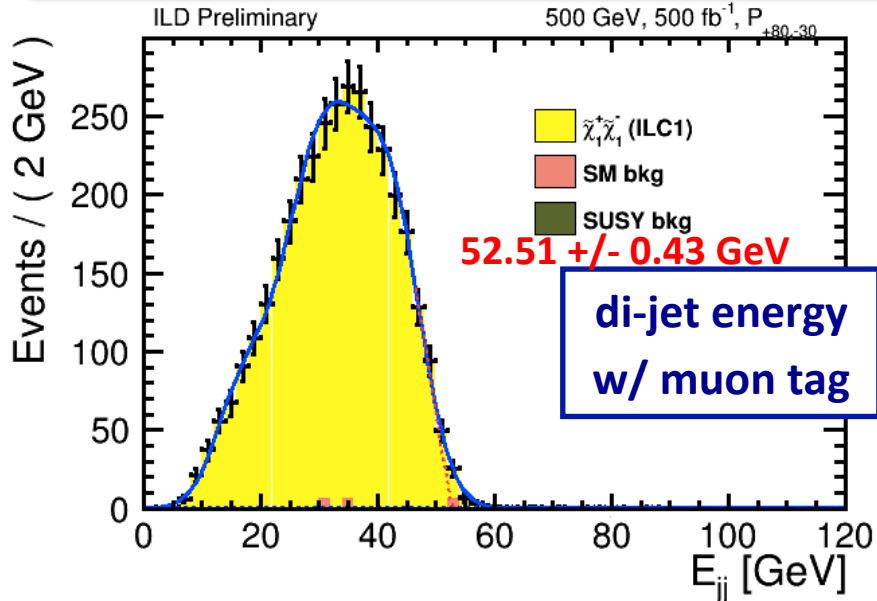**Chargino pair production with semileptonic decay**

$$e^+ e^- \rightarrow \widetilde{\chi}_1^+ \widetilde{\chi}_1^- \rightarrow \widetilde{\chi}_1^0 \widetilde{\chi}_1^0 q q' \ell \nu$$

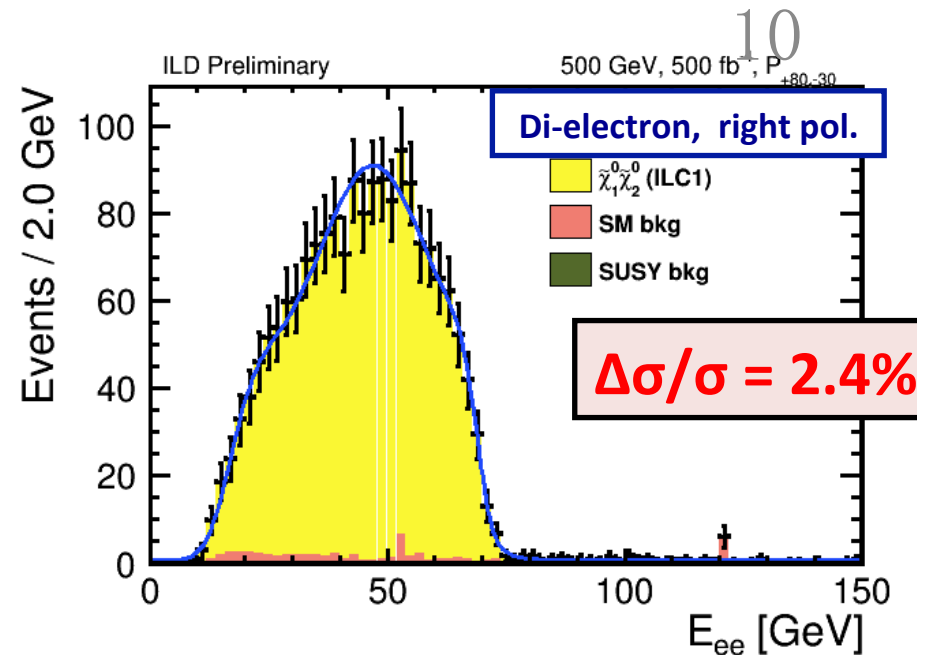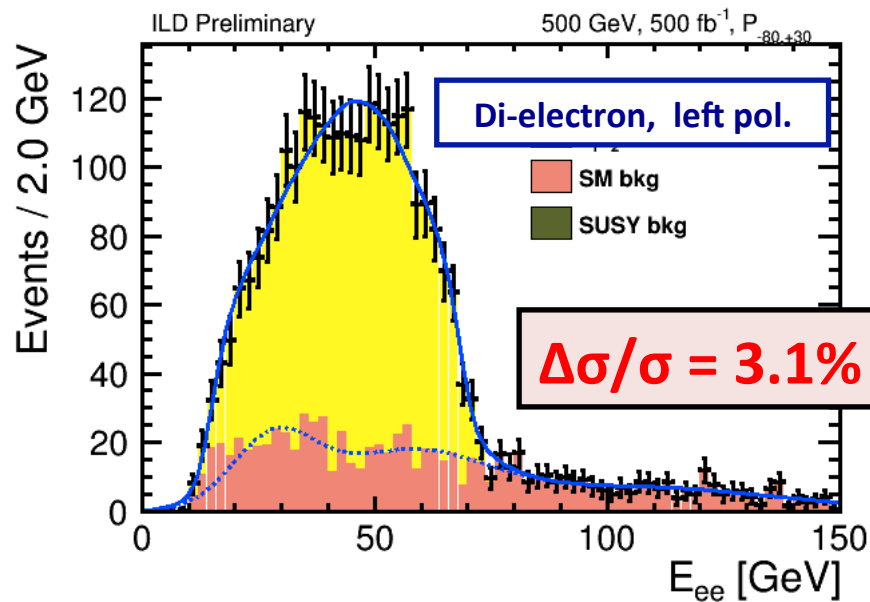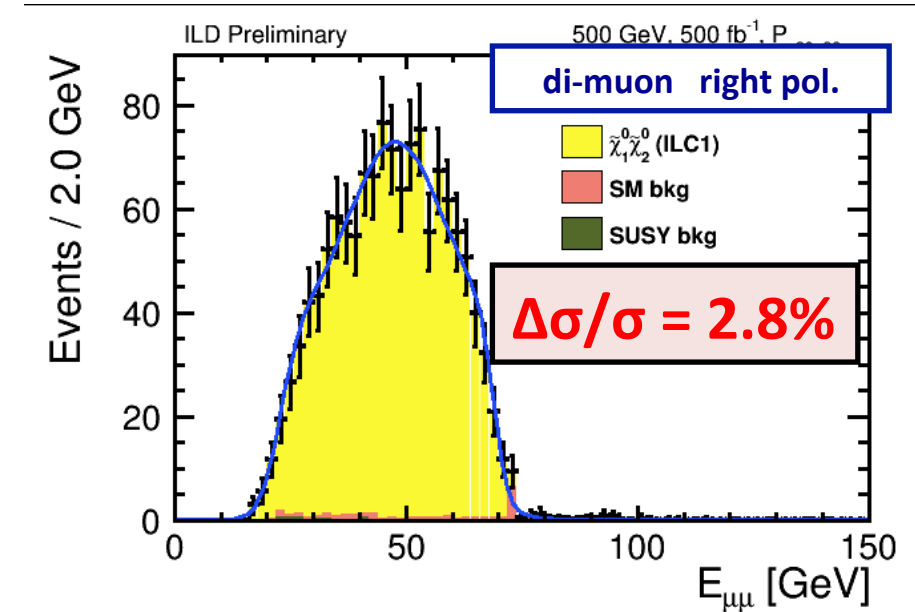**Polarization (Pe-,Pe+) = (+0.8, -0.3)**

SM and SUSY backgrounds almost fully eliminated

52.51 +/- 0.43 GeV

di-jet energy w/ muon tag

16.14 +/- 0.16 GeV

di-jet mass w/ muon tag

52.68 +/- 0.43 GeV

di-jet energy w/ electron tag

17.64 +/- 0.28 GeV

di-jet mass w/ electron tag

Extraction of Cross Section

Uncertainty of right pol is about ¾ of left pol (evaluated using Toy MC)

Extraction of Cross Section

Polarization (Pe-,Pe+) = (-0.8, +0.3)

**Left pol.
Δσ/σ = 0.8 %**

**di-jet energy
w/ muon tag**

**Right pol
Δσ/σ = 1.7 %**

- **Left pol has x2 better precision**
- **similar to edge precision**

**di-jet energy
w/ muon tag**

Error Propagation (see calculations attached separately)

- **Neutralino edge precision 〜1 %**

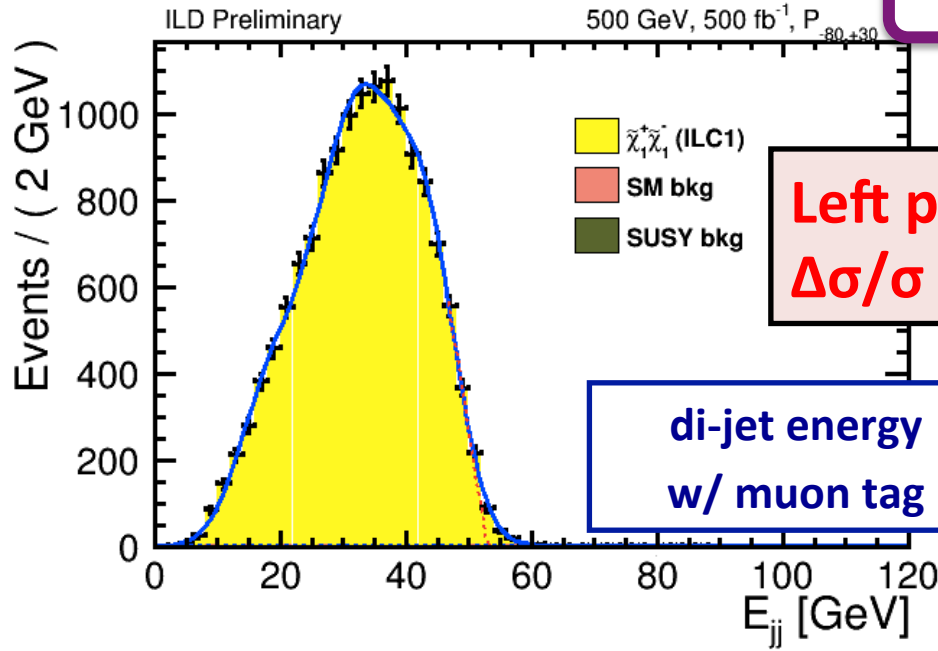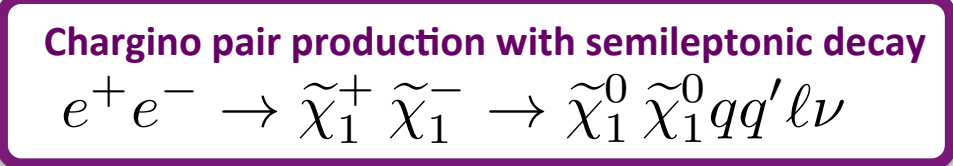- **neutralino mass uncertainty 1.5 – 2%**

- **Chargino edge precision〜 0.5 (left pol)**

- **Chargino mass uncertainty 〜0.5%**

	edge（Ejj）	edge（Mjj）	xsec
left, mu-tag	0.41%	0.58%	0.85%
left, e-tag	0.45%	0.88%	0.83%
right mu-tag	0.82%	0.99%	1.75%
right e-tag	0.82%	1.60%	1.71%

		calculated	calculate	observed	observed	observed	observed	calculated	calculated	calculated	calculated
		M1	M2	delta_M	Δdelta_M	Emax	Δ Emax	ΔM1	ΔM1/M1	ΔM2	ΔM2/M2
N1N2	mm	102.255	123.015	20.76	0.2	73.81	0.86	1.7697	1.73%	1.7583	1.43%
left	ee	100.296	120.811	20.5156	0.324223	74.3688	0.798674	2.1711	2.16%	2.1468	1.78%
N1N2	mm	103.058	123.988	20.93	0.22	73.77	0.84	1.8189	1.76%	1.8056	1.46%
right	ee	103.409	124.299	20.89	0.19	73.45	0.61	1.4406	1.39%	1.4280	1.15%

Summary and Plans

Obtained complete set of preliminary results for all channels : edge and xsec

Calculated Higgsino mass precisions

- Observed differences between channels (polarizations, lepton flavor, etc....)
- ➔ need to comprehend differences

- Plan to calibrate deviation between extracted and theoretic edge values
- Simulate Higgsino samples with different masses
- Plan to do so in beginning – mid of September
- At the same time as simulate samples for study of gamma gamma overlay blg

- Discuss with collaborators about plan for publication

(option 1) Converge analysis of current benchmark to a paper

(option 2) include study on another benchmark (other CM energies and polarizations)

Additional Material