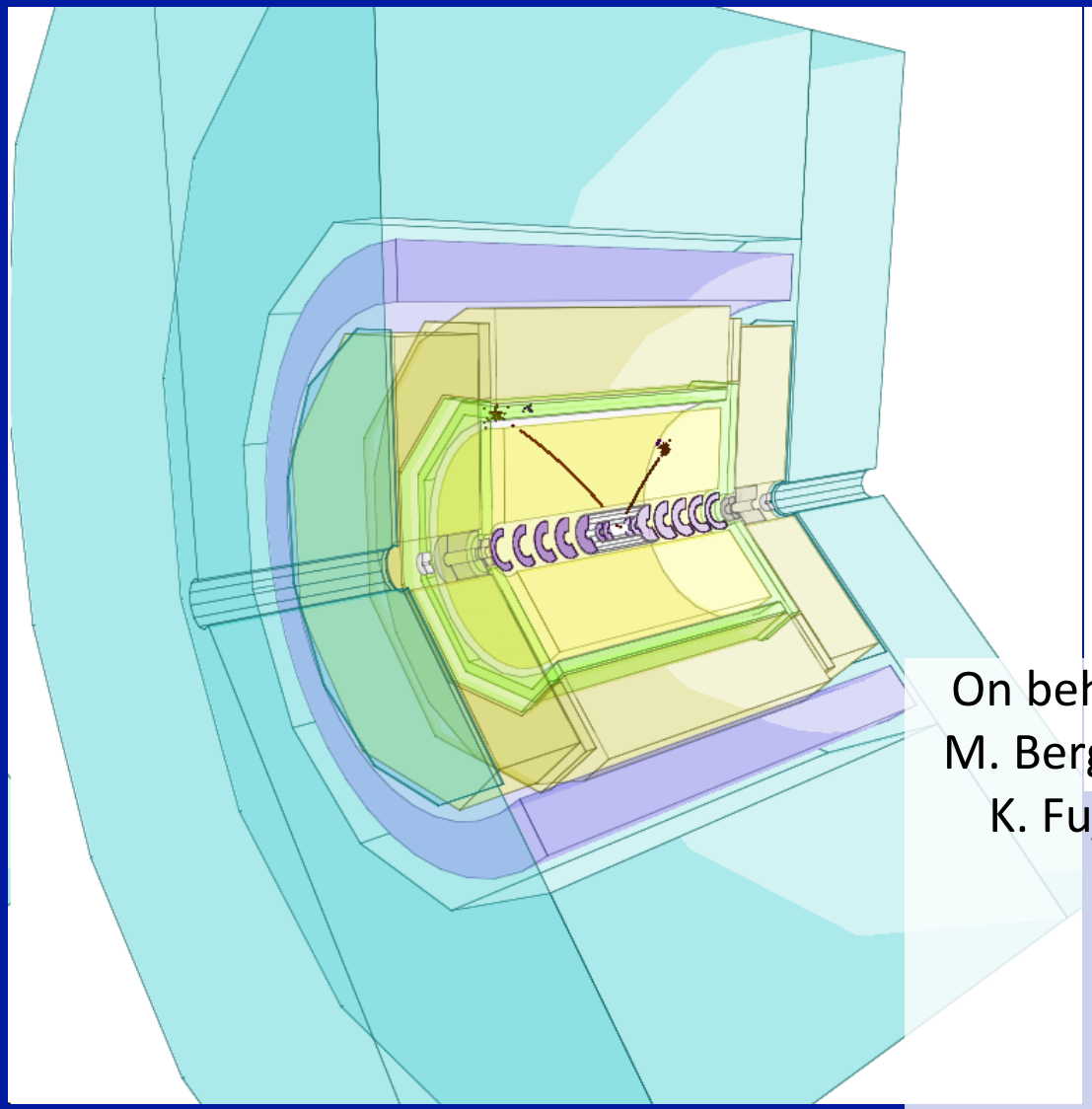
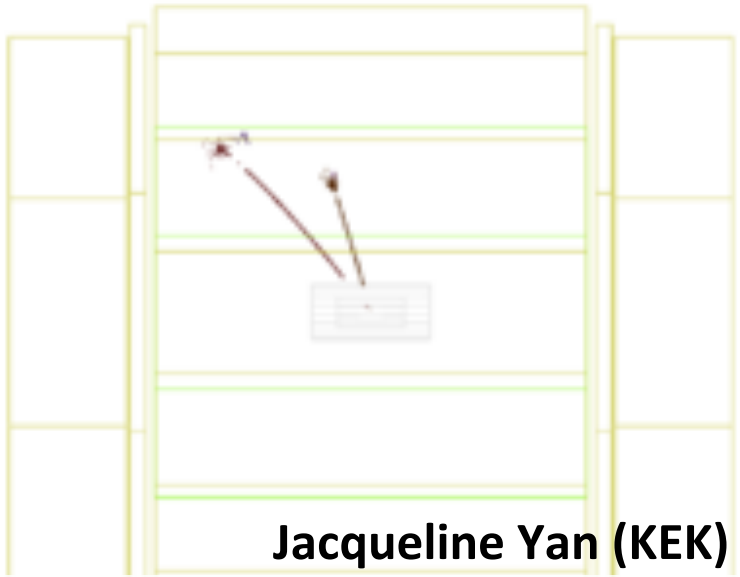
Characterizing Light Higgsinos from Natural SUSY at ILC $\sqrt{s}$ = 500 GeV





Jacqueline Yan (KEK)

On behalf of H. Baer (Univ of Oklahoma), M. Berggren, S.-L. Lehtinen, J. List (DESY), K. Fujii (KEK), T. Tanabe (Univ of Tokyo)

ILD Software and Analysis Meeting

July 13, 2016

Outline

- Current status of bkg samples
- Preliminary results for extraction of Higgsino mass and cross section
- Goals and plans

Status of 4f and 2f bkg

- Received production of major 4f bkg samples with large statistics from Miyamoto-san over last two weeks
- Checked already that they are consistent with last DBD production
- Bkg distribution is much smoother now

- spikes in lower energy region due to aa2f and ae3f bkg
- conducting pre-selection studies (including modification of processor) before requesting SGV production to Mikael

Extraction of Higgsino Mass

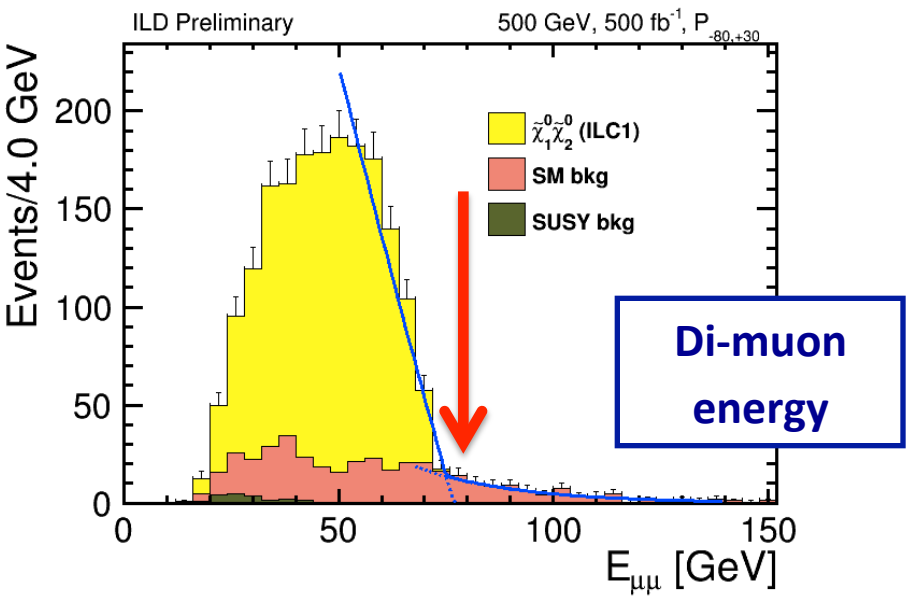
[work in progress]

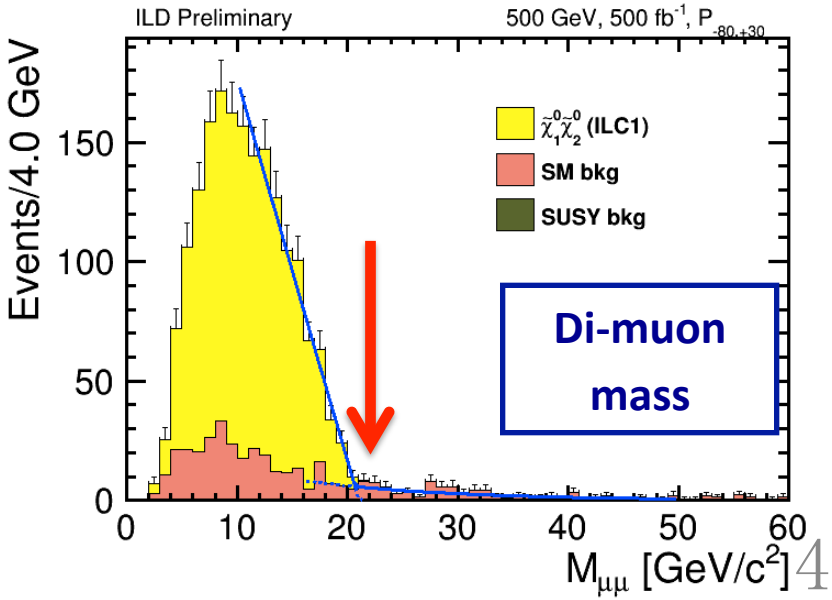
Neutralino mixed production with leptonic decay

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

- The position of the kinematic edges of the dilepton energy (E_{ll}) and invariant mass (M_{ll}) are functions of CM energy and the two neutralino masses.
- The maximum values $E_{ll,max}$ and $M_{ll,max}$ are extracted by a fit to obtain the neutralino masses after correcting for detector/reconstruction effects`

Similar for case of chargino pair production (ll → jj)





Cuts have been designed so as not to destroy upper edge

- Use toy MC (generated from MC data fit) to evaluate statistical uncertainty
- Making progress in kinematic edge extraction

Edge extraction precision ~1 %

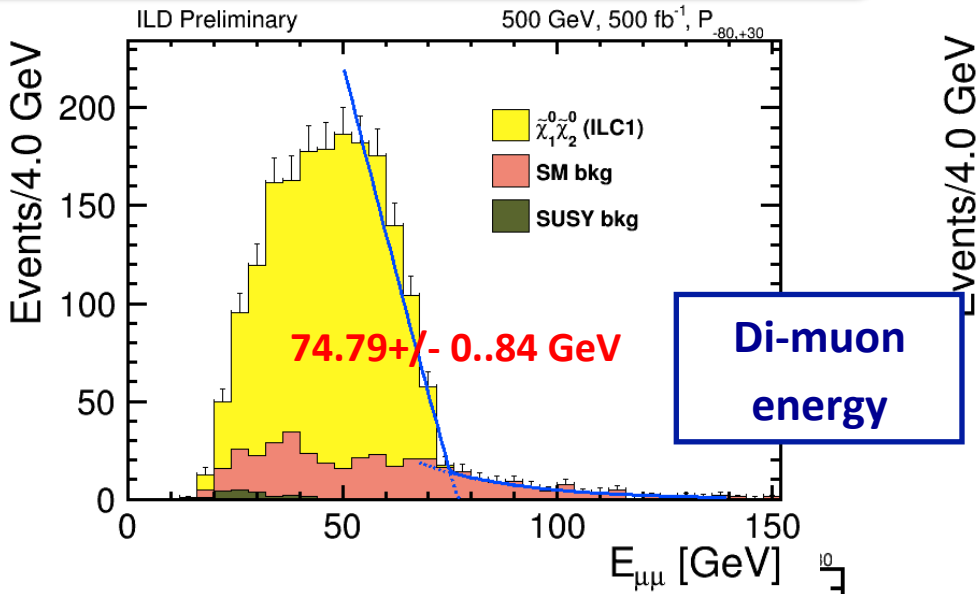
Neutralino mixed production with leptonic decay

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

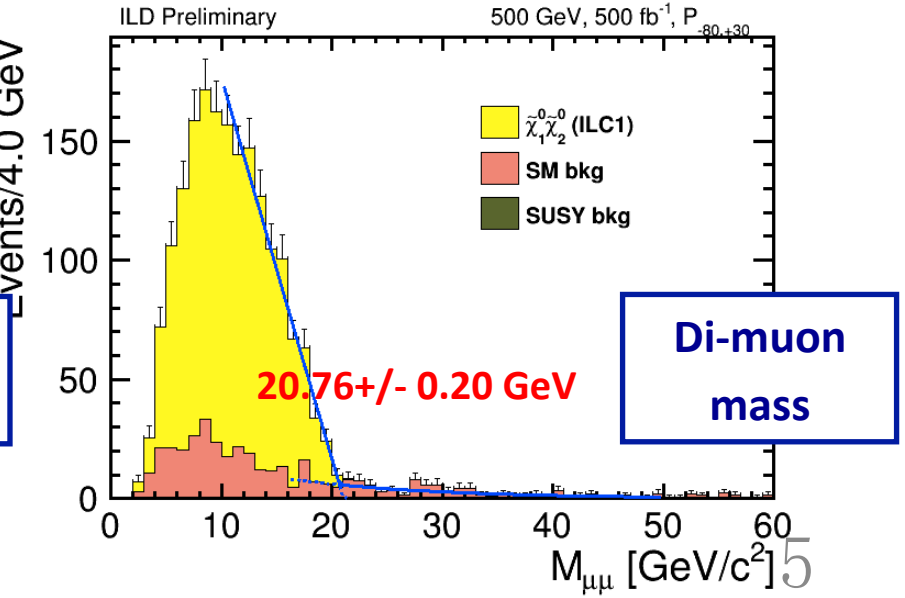
Polarization (Pe-,Pe+) = (-0.8, +0.3)

statistical precision 1.0 – 1.5 %

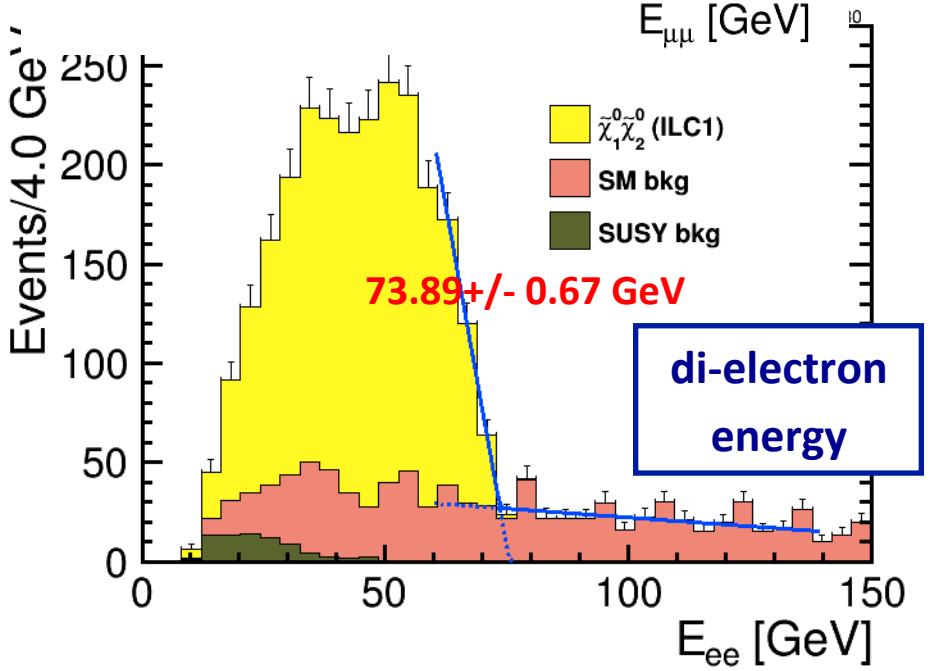
preliminary



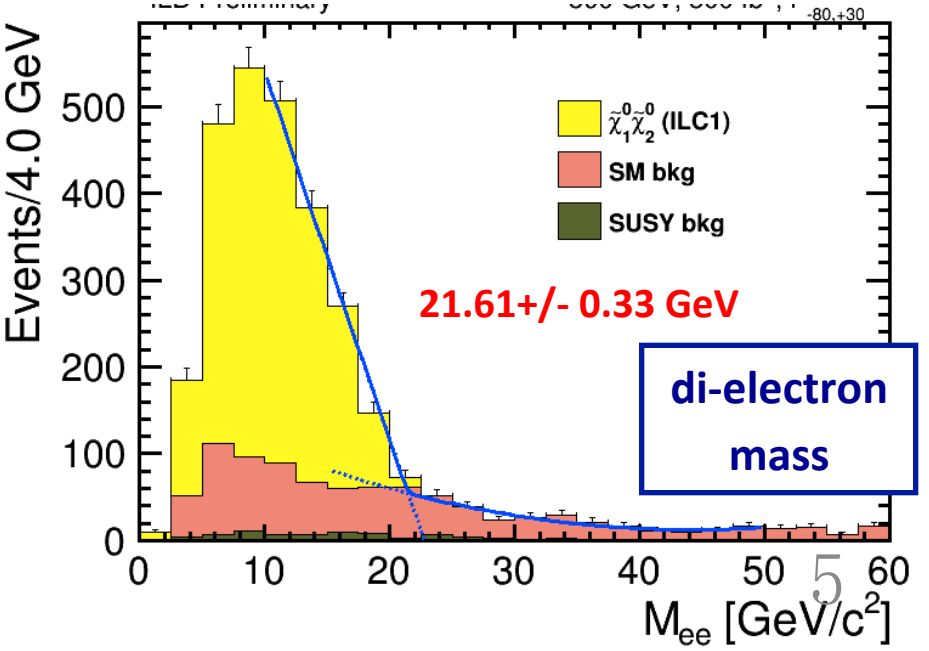
Di-muon energy



Di-muon mass



di-electron energy



di-electron mass

Neutralino mixed production with leptonic decay

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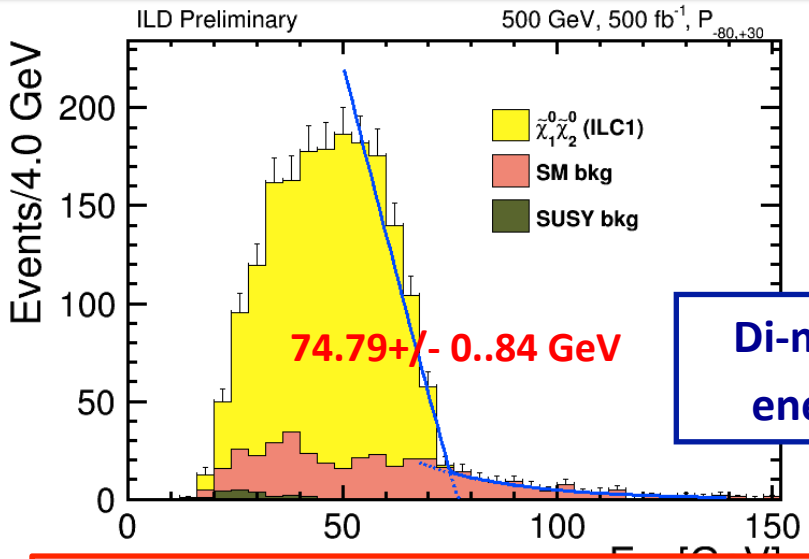
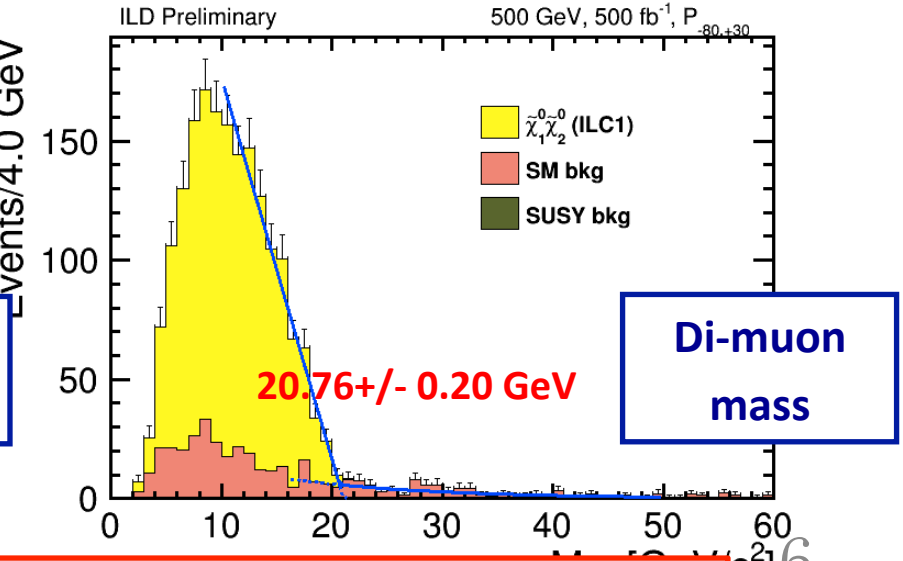
preliminary

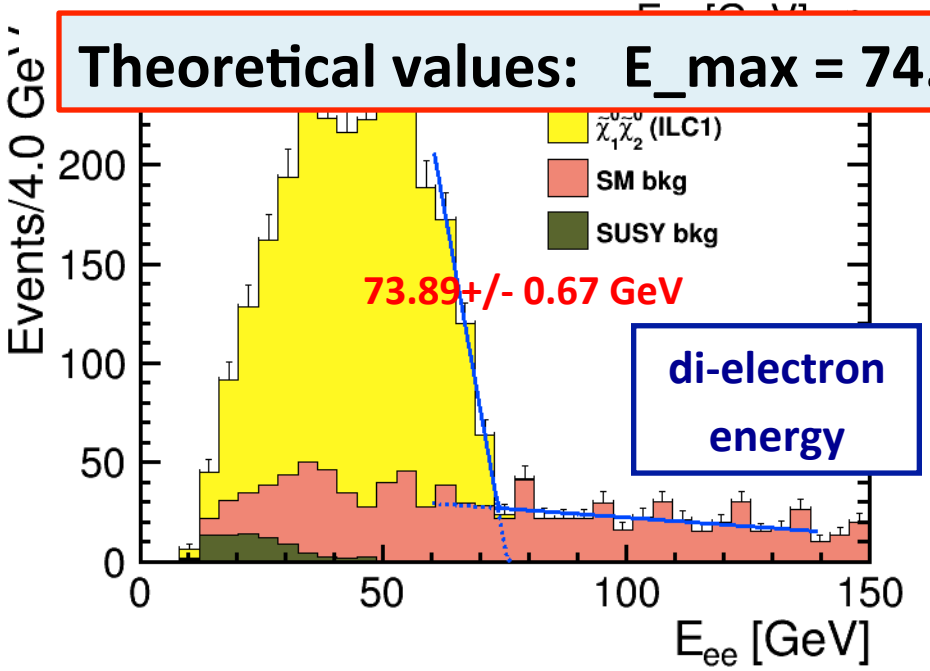


Di-muon energy

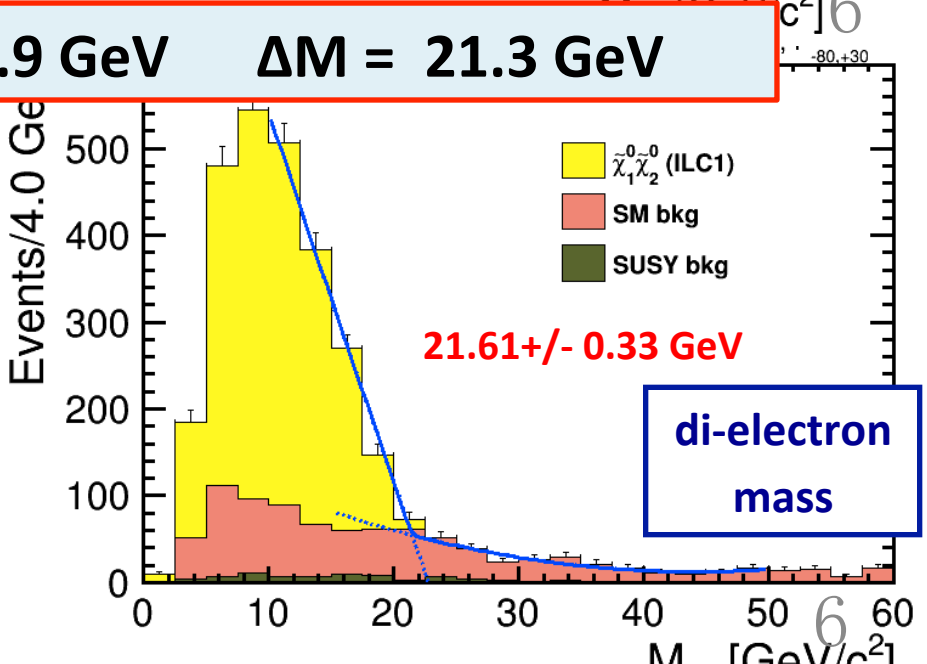


Di-muon mass

Theoretical values: E_max = 74.9 GeV ΔM = 21.3 GeV



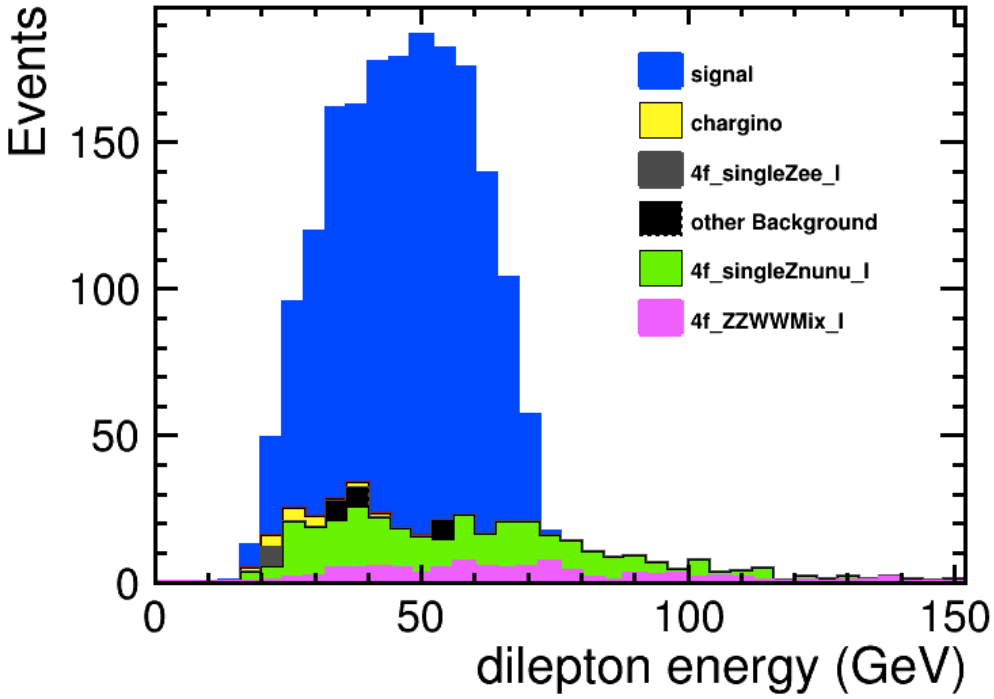
di-electron energy



di-electron mass

Di-muon energy

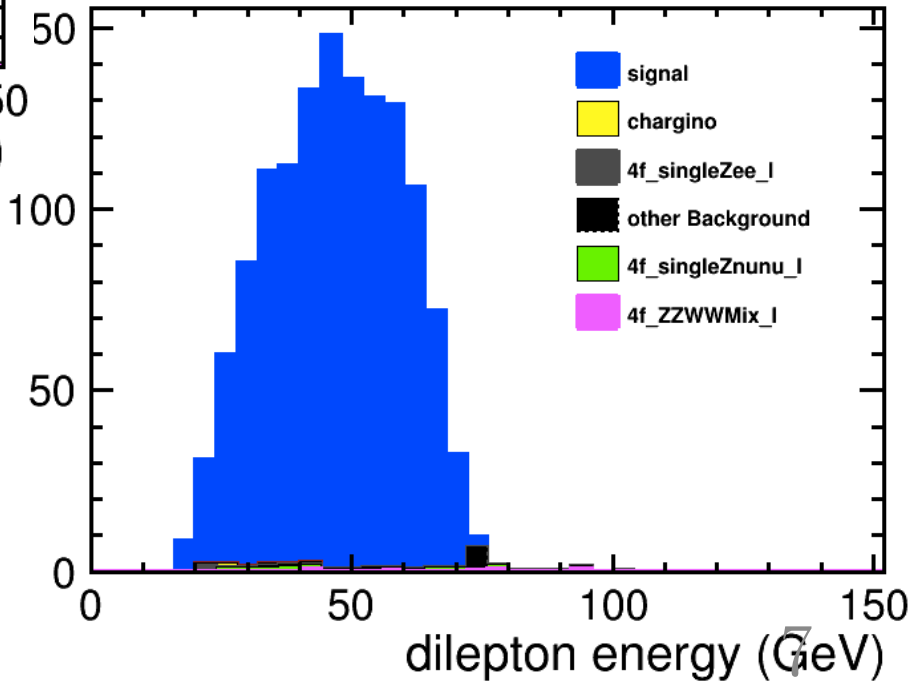
(Pe-,Pe+) = (-0.8, +0.3)



Background is greatly suppressed for right-hand polarization

Di-muon energy

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



We will study the difference in statistical precisions of edge and cross sections

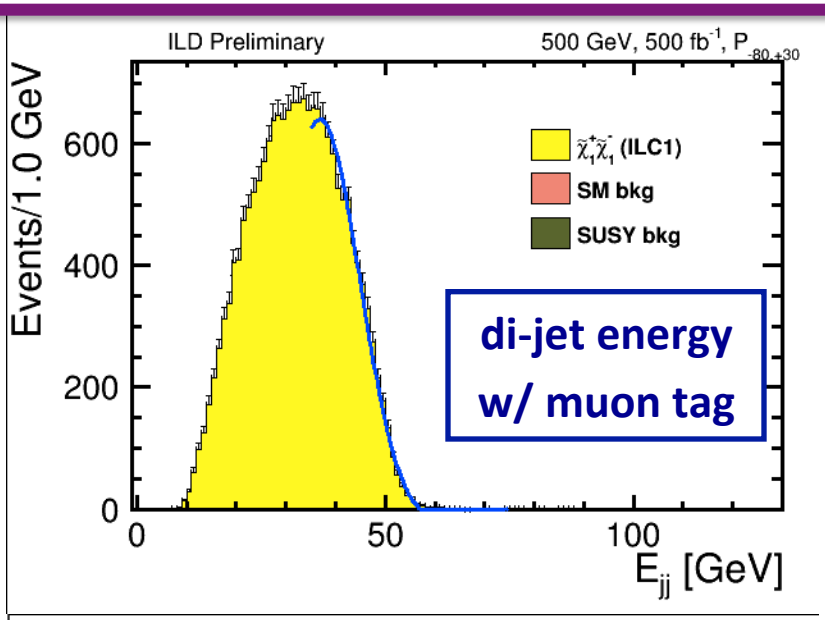
Chargino pair production with semileptonic decay

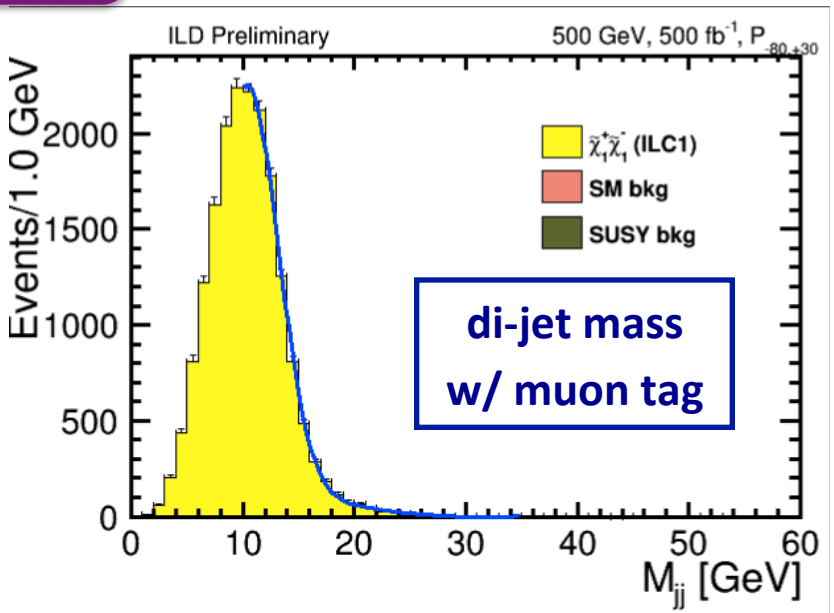
$$e^+e^- \to \tilde{\chi}_1^+ \tilde{\chi}_1^- \to \tilde{\chi}_1^0 \tilde{\chi}_1^0 qq' \ell\nu$$

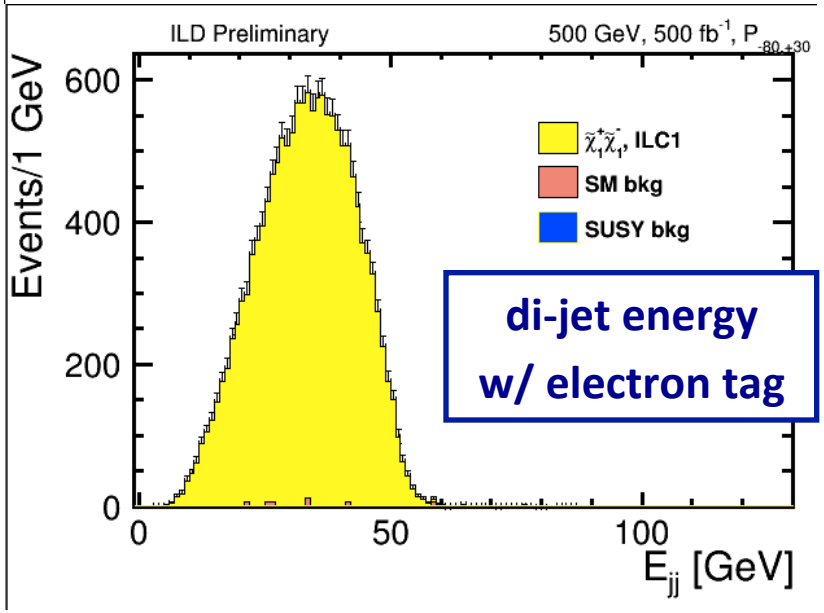
Polarization (Pe-,Pe+) = (-0.8, +0.3)

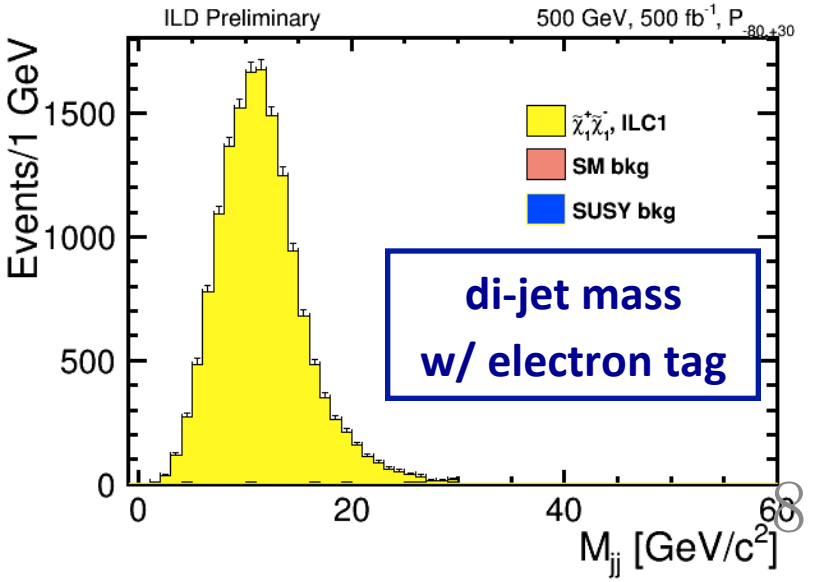
SM and SUSY backgrounds almost fully eliminated

preliminary









Extraction of Cross Section [work in progress]

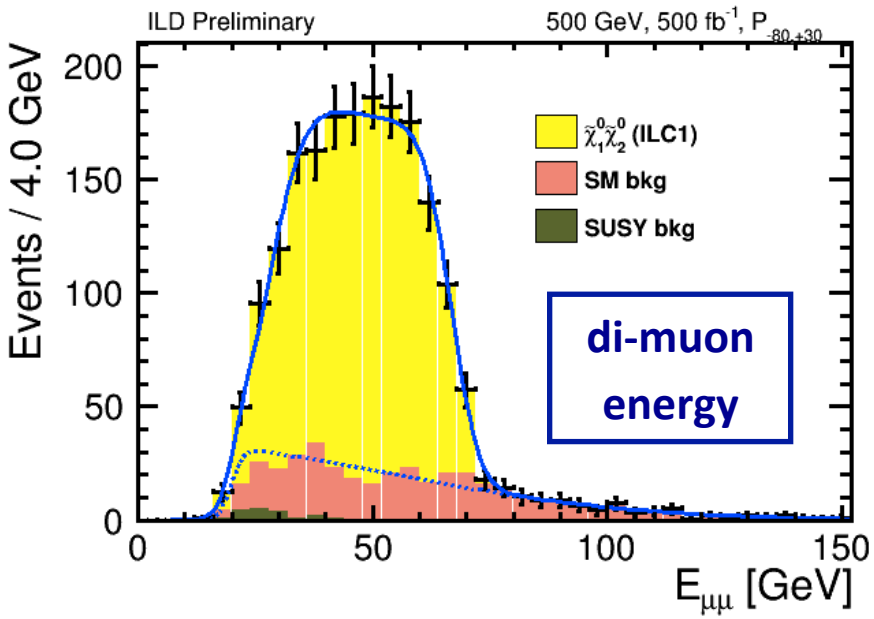
Strategy: Fit overall shape to estimate total number of signal events

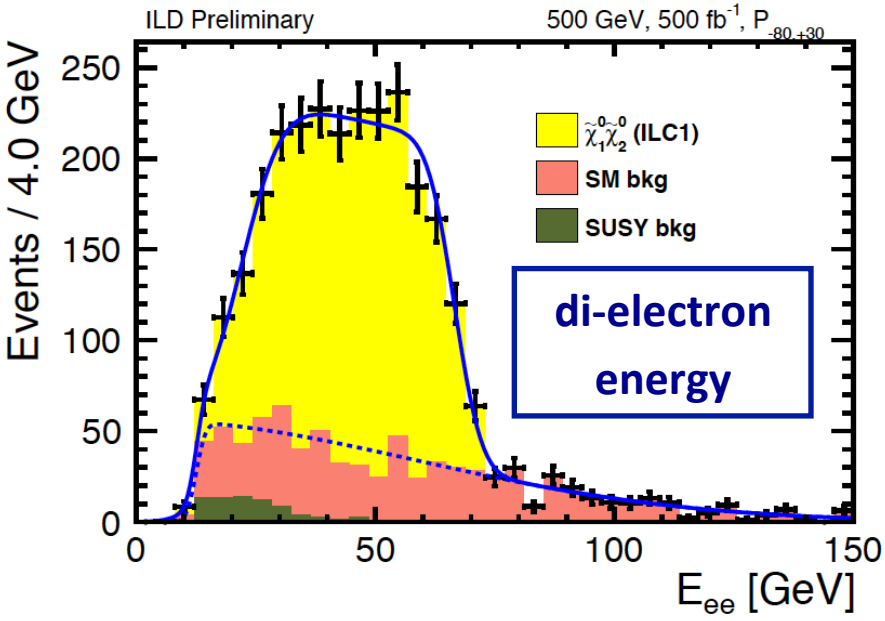
Neutralino mixed production with leptonic decay

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

Δσ / σ = 3 - 5 %

preliminary





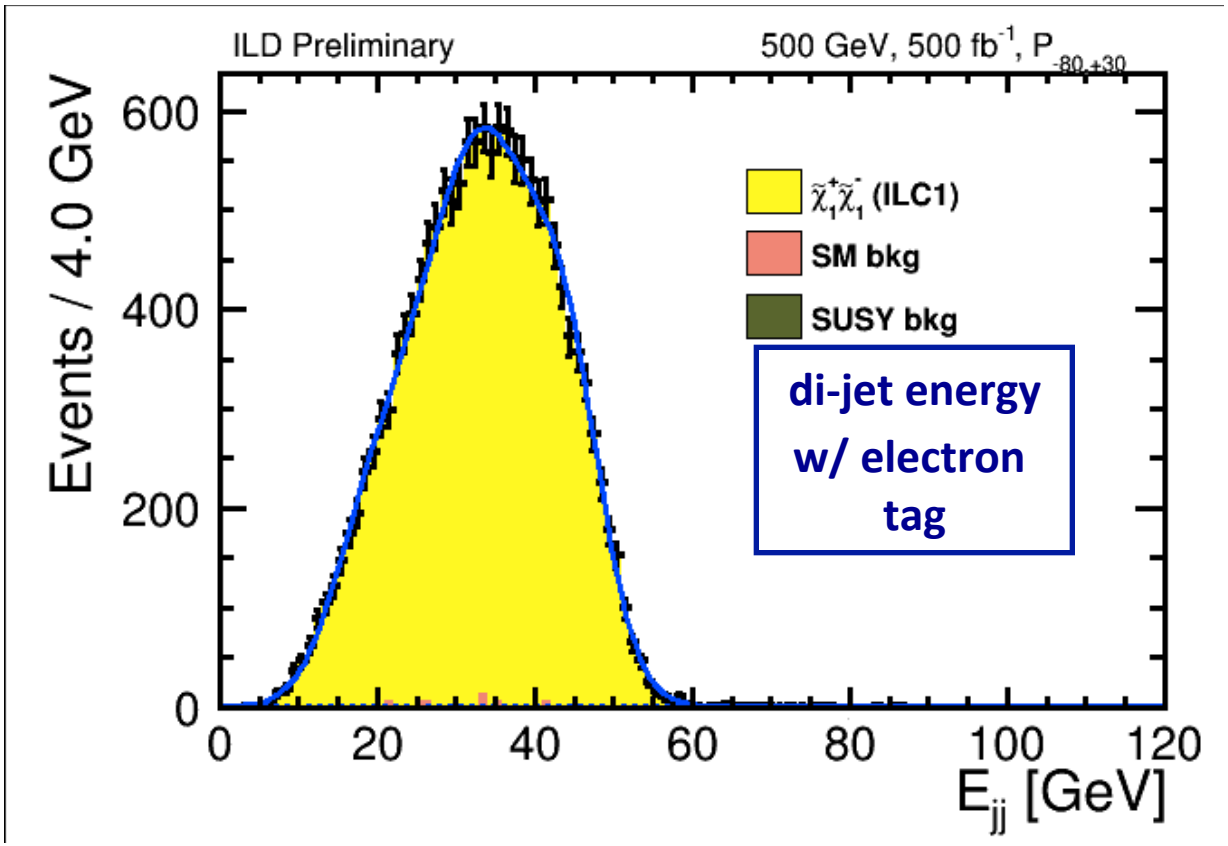
The results of Higgsino mass and cross section become input to the parameter fit to extract SUSY parameters (e.g. Wino and Bino masses, tanβ, etc.)

Extraction of Cross Section [work in progress]

Chargino pair production with semileptonic decay

$$e^+e^- \to \tilde{\chi}_1^+ \tilde{\chi}_1^- \to \tilde{\chi}_1^0 \tilde{\chi}_1^0 qq'\ell\nu$$

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



Δσ / σ = 0.8 %

Fit with triple Gaussian

Other channels have similar shapes in the case of chargino

Summary and Plans

Obtained preliminary results for some channels, presented at ILD Meeting (7/13)

- **For neutralino: Edge precision 1.0 -1.5% , Cross section precision 3-5%**
- **Edge values generally consistent with theoretical values within uncertainty range**

- **For chargino : Cross section precision : 0.8%**
- **Still working on edge extraction : difficulties involving jet energy resolution**
- **Will probably use steepest slope method**

- **Need to observe change in signal distribution due to cuts by comparing with generator truth**

- **Need to implement gamma gamma overlay bkg**
- **Other CM energies and polarizations: precise mass determination, input necessary for theoretical studies, etc…**

Additional Material

Extraction of Higgsino Mass

[work in progress]

Neutralino mixed production with leptonic decay

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

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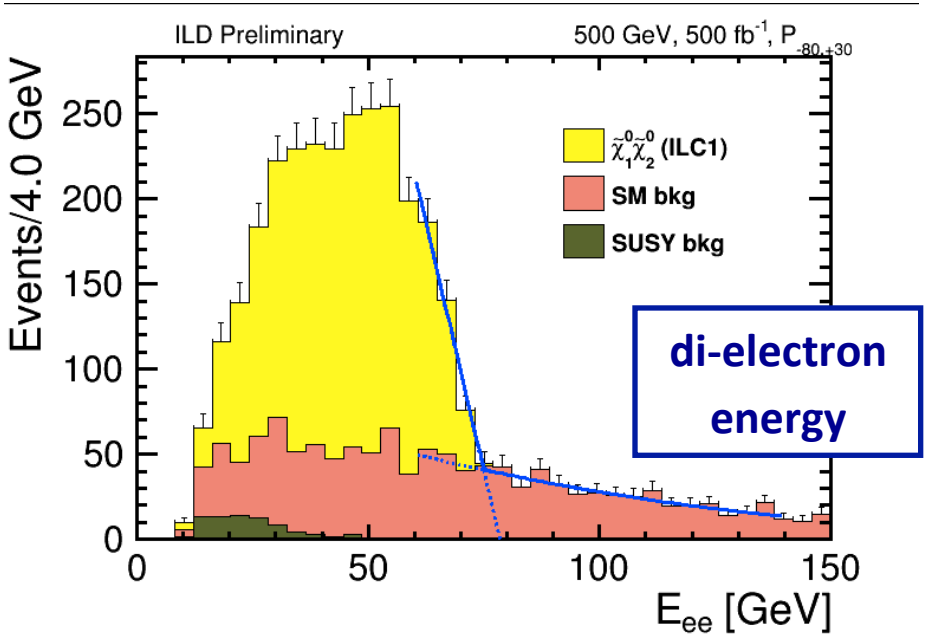
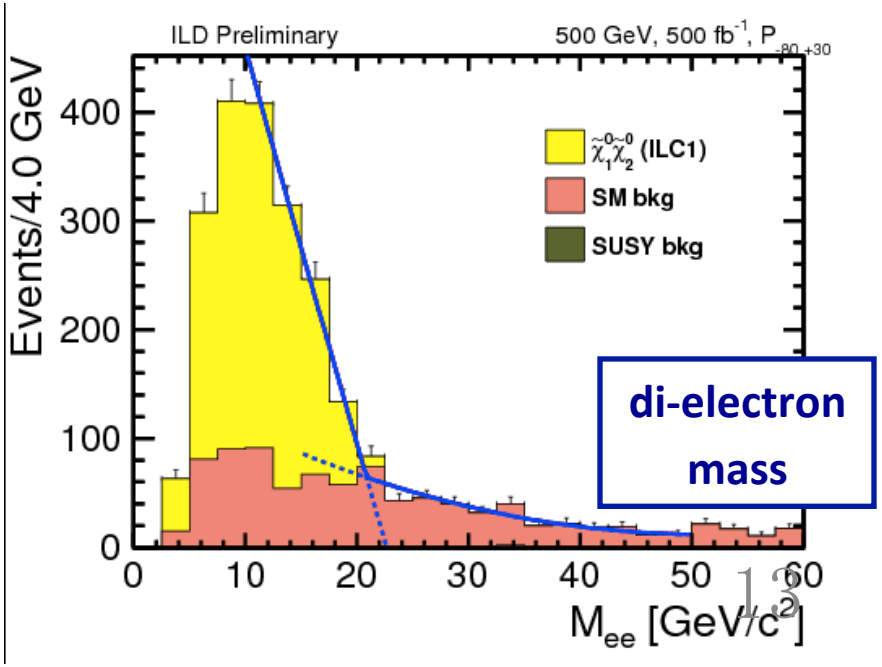
Similar for case of chargino pair production (ll → jj)





Cuts have been designed so as not to destroy upper edge

- Use toy MC (generated from MC data fit) to evaluate statistical uncertainty
- Making progress in kinematic edge extraction

Edge extraction precision ～1 %

ILC1

Cross sections (pure beam polarizations)
√s=500 GeV with TDR beam parameters

(Pe-, Pe+)	(-1.0,+1.0)	(+1.0,-1.0)
$\sigma(\chi_1^+\chi_1^-)$ [fb]	1800	335
$\sigma(\chi_1^0\chi_2^0)$ [fb]	491	379
$\sigma(\chi_2^0\chi_3^0)$ [fb]	11.0	8.42
$\sigma(\chi_1^0\chi_1^0)$ [fb]	2.03	1.56
$\sigma(\chi_2^0\chi_2^0)$ [fb]	0.53	0.41
$\sigma(\chi_1^0\chi_3^0)$ [fb]	0.28	0.20

Branching ratios

BR($\chi_1^+ \rightarrow \chi_1^0$ qq')	67%
BR($\chi_1^+ \rightarrow \chi_1^0$ lν) (l=e,μ)	22%
BR($\chi_2^0 \rightarrow \chi_1^0$ qq')	58%
BR($\chi_2^0 \rightarrow \chi_1^0$ ll) (l=e,μ)	7.4%

Cut table N1N2 , μμ (Pe-, Pe+) = (-80,+30)

	sig	bkg	4f_l	aa_2f	ae_3f	SUSY bkg
xsec	300.8	3.00E6	10566.2	2.68E6	261580	1065.2
N_gen	150395	1.50E9	5.28E6	1.34E9	1.31E8	532585
Lep_type nTrack=2	1974	9.1E8	444255	8.9E8	2.2E7	2426
BCAL veto	1950	6.0E6	149871	5.5E6	965354	2411
Pt_lep,1,2	1675	2.0E6	105721	1.4E6	295459	1986
cosθ_lep	1624	1.3E6	56001	910330	167734	1950
coplanarity	1407	48366	5272	3509	33067	22
Evis	1404	14325	2465	2248	4743	22
Emis, cosθmis	1393	1063	929	34	9	19
cosZ, Pt_ll, Minv	1393	545	429	34	9	19

Cut table C1C1 , μtag (Pe-, Pe+) = (-80,+30)

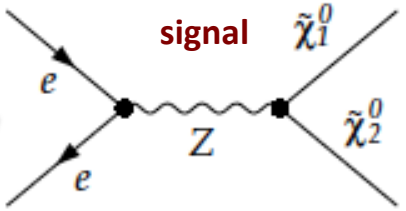
	sig	bkg	4f_l	aa_2f	ae_3f	SUSY bkg
Xsec [fb]	1065.2	3.00E6	10566.2	2.68E6	261580	300.8
N_gen	532585	1.50E9	5.28E6	1.34E9	1.31E8	150395
nLep=1 BCAL veto	57983	1.5E9	443296	1.2E6	860530	1135
Ptmis	38240	2.7E6	377010	465397	519308	964
Jet_coplanarity	26085	1.5E6	86399	83683	109325	531
Jet_cosθ nTrack (per jet) > 1	14612	305870	3066	555	2234	22
cosθjet-lep Evis	14308	3753	791	100	41	0
Emis, cosθmis	14231	83	57	3	0	0
Pt_jj, M_jj	14173	51	31	3	0	0

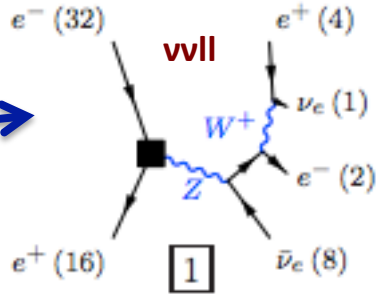
Event Selection

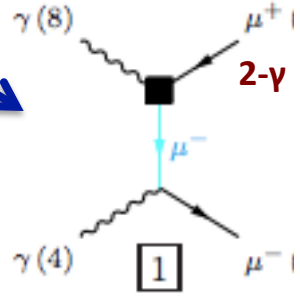
Neutralino mixed production with leptonic decay

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

- Reconstruct **two leptons (ee or μμ) which originate from Z* emission in decay of χ_2^0 to χ_1^0**
- Major residual bkg. are 4f processes accompanied by large missing energy (vvll)
- 2-γ processes are removed by BeamCal veto, cuts on lepton track p_T, and coplanarity







Chargino pair production with semileptonic decay

$$e^+e^- \to \tilde{\chi}_1^+\,\tilde{\chi}_1^- \to \tilde{\chi}_1^0\,\tilde{\chi}_1^0 qq'\ell\nu$$

- Reconstruct **two jets which originate from W* emission in decay of $\chi_1^\pm$ to χ_1^0**
- Use lepton (e or μ) from the other chargino as tag
- BeamCal veto, cuts on missing p_T, # of tracks, # of leptons, and coplanarity remove almost all bkg.

(signal significance > 100)