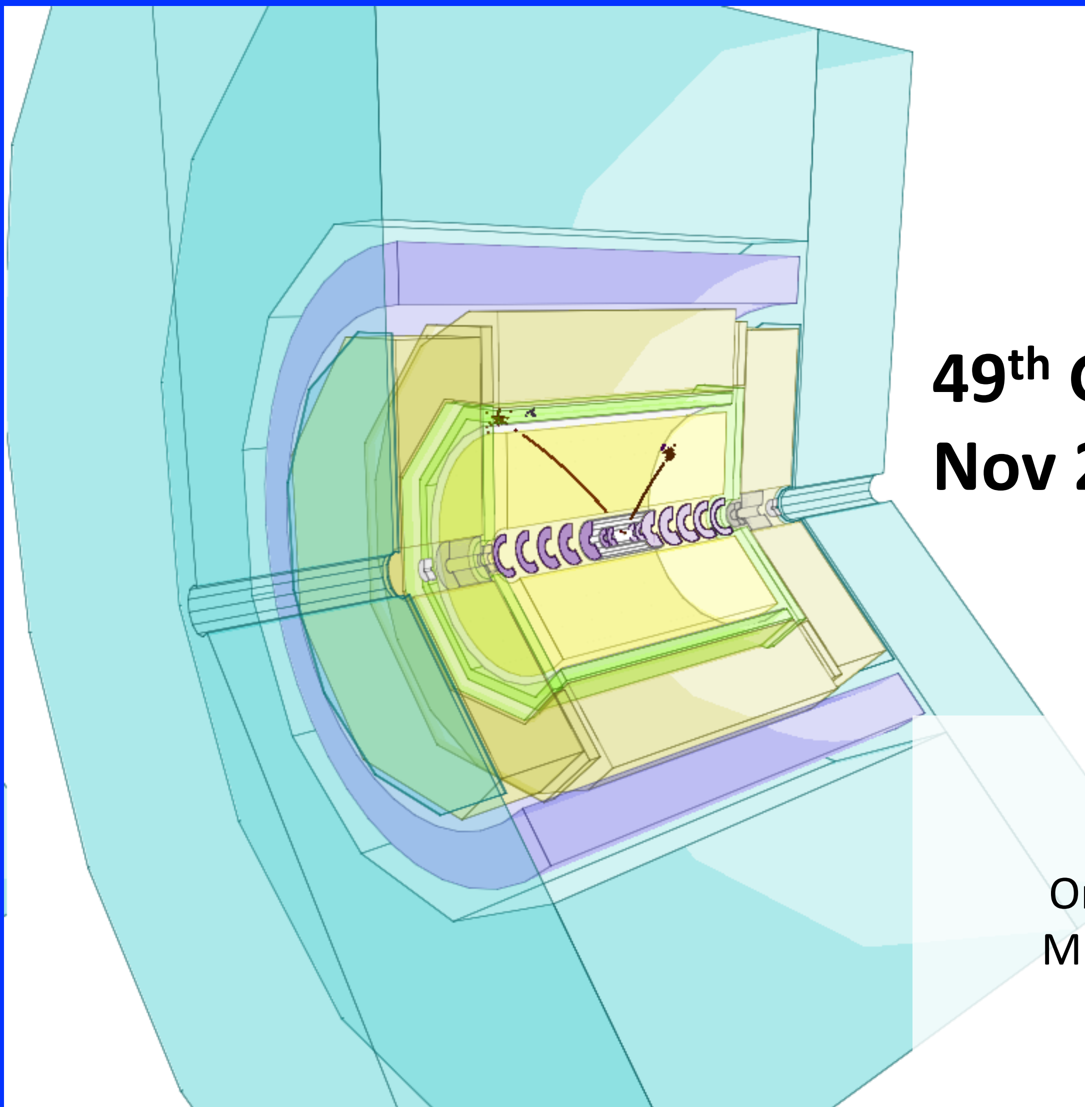
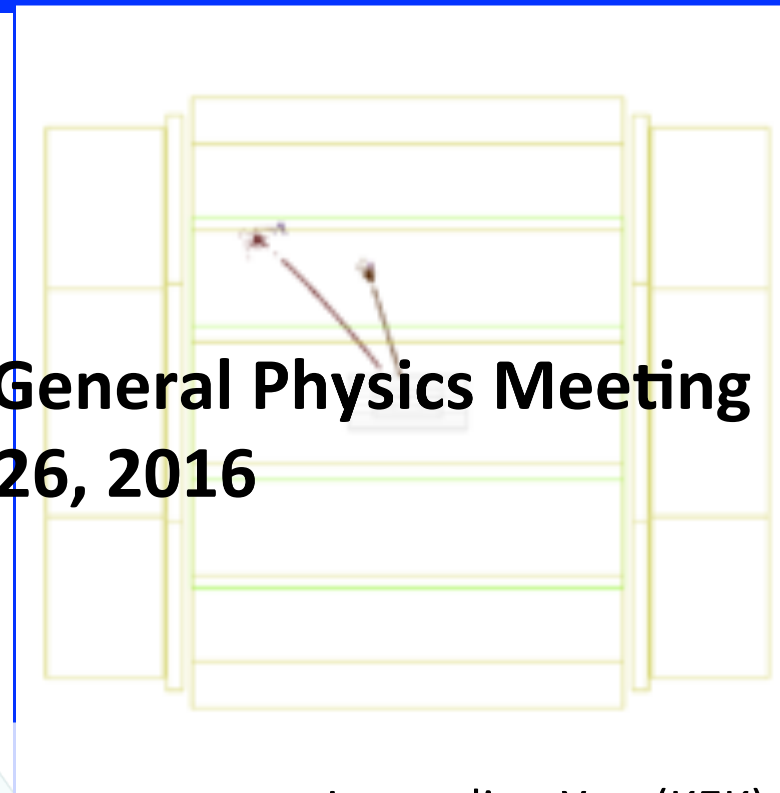
Characterizing Light Higgsinos from Natural SUSY at ILC $\sqrt{s}$ = 500 GeV





49th General Physics Meeting
Nov 26, 2016

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)

Goal of Light Higgsino Study

J. Yan, T. Tanabe, K. Fujii et al

Demonstrate measurement precision of Higgsino masses and production cross sections

Serve as a basis for future discussions of ILC run scenario in the case of new particles being discovered

Results of masses and cross sections (= "observables") as input

S.-L. Lehtinen (DESY) et al

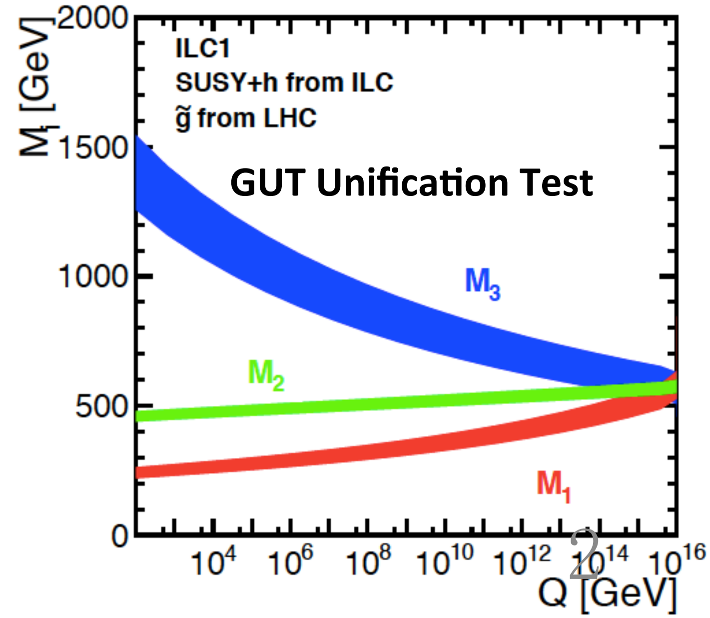
determine SUSY parameters

e.g. M_1, M_2, μ, $\tan\beta$

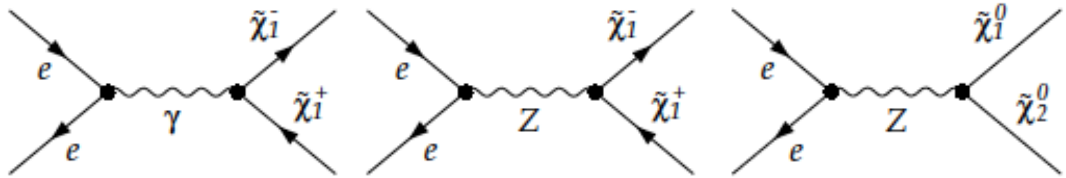
Why?
- To get info about unobserved sparticles
- To test GUT-scale models

How?
- Global χ^2 fit of to observables

Study required input parameters and precisions;
interplay with Higgs precision measurements



Benchmarks in this Study



RNS model (Radiatively-driven natural SUSY)

- **4 light Higgsinos:** $\widetilde{\chi}_1^0$ (LSP) $\widetilde{\chi}_2^0$ $\widetilde{\chi}_1^+$ $\widetilde{\chi}_1^-$

- **ΔM approximately complies with naturalness** (ISR tag not needed)

This study: **√s = 500 GeV**
Full detector simulation

process	σ_{ILC1}	σ_{ILC2}
$e^+e^- \to \widetilde{\chi}_1^+\widetilde{\chi}_1^-$,left	1800.8	1530.5
$e^+e^- \to \widetilde{\chi}_1^+\widetilde{\chi}_1^-$,right	334.8	307.2
$e^+e^- \to \widetilde{\chi}_1^0\widetilde{\chi}_2^0$,left	491.4	458.9
$e^+e^- \to \widetilde{\chi}_1^0\widetilde{\chi}_2^0$,right	379.8	353.8

BR	ILC1	ILC2
$BR(\widetilde{\chi}_1^+ \to \widetilde{\chi}_1^0 qq)$	67%	67%
$BR(\widetilde{\chi}_1^+ \to \widetilde{\chi}_1^0 l\nu)$	22%	22%
$BR(\widetilde{\chi}_2^0 \to \widetilde{\chi}_1^0 qq)$	58%	63%
$BR(\widetilde{\chi}_2^0 \to \widetilde{\chi}_1^0 l\nu)$	7.4%	8.0%

NUHM2 model parameters [arXiv:1404.7510]

Benchmark	ILC1	ILC2
M_0 [GeV]	7025	5000
$M_{1/2}$ [GeV]	568.3	1200
A_0 [GeV]	-10427	-8000
tanβ	10	15
μ [GeV]	115	150
M_A [GeV]	1000	1000
$M(\chi_1^0)$ [GeV]	102.7	148.1
$M(\chi_1^\pm)$ [GeV]	117.3	158.3
$M(\chi_2^0)$ [GeV]	124.0	157.8
$M(\chi_3^0)$ [GeV]	267.0	538.8

ΔM : 15-20 GeV **ΔM～ 10 GeV**

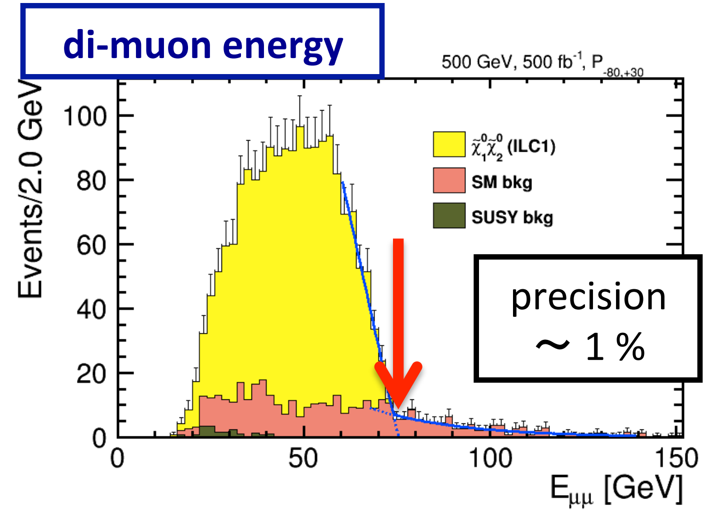
Defined at GUT scale ,
Defined at weak scale **Observables**

Extraction of Higgsino Mass and Cross Section

Mass:

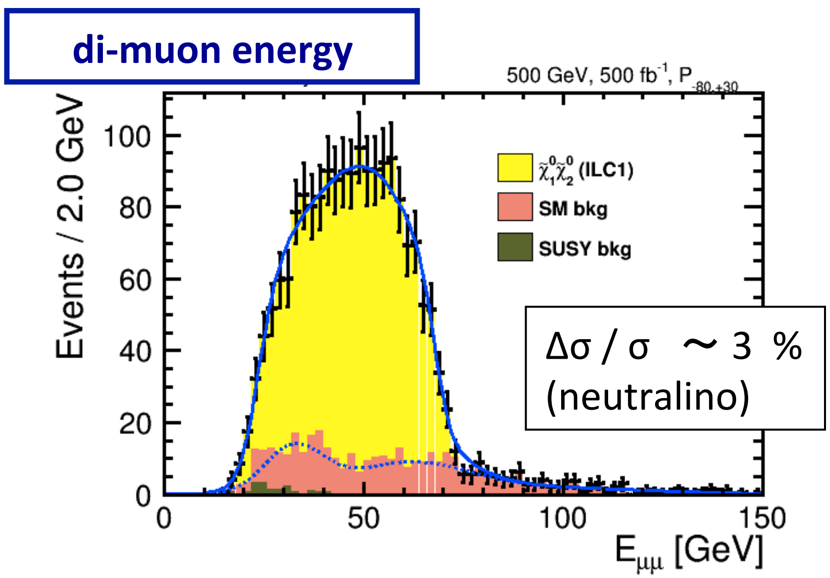
- Kinematic edges of dilepton/dijet energy and invariant mass are functions of $\sqrt{s}$ and Higgsino masses
- **Extract kinematic edges by a fit to distributions ➔ calculate masses**

(requires correction for detector resolution)



Cross section:

Count number of events under dilepton / dijet energy



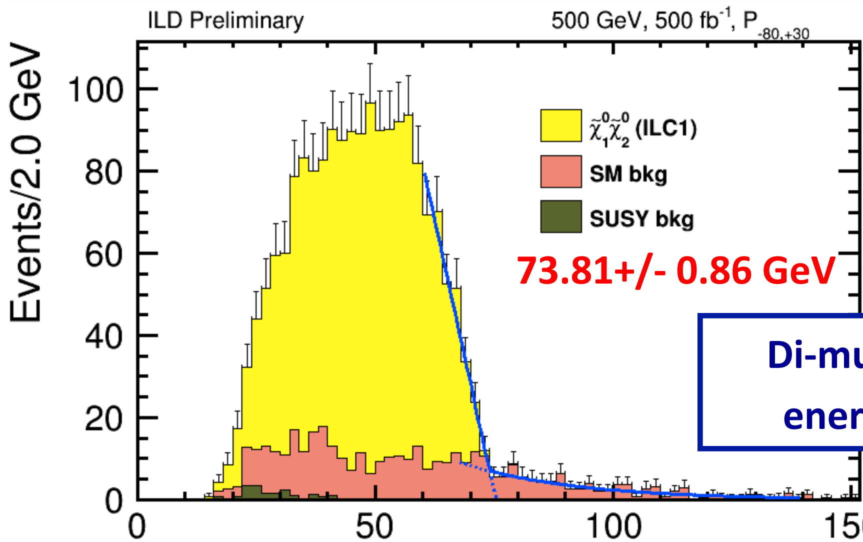
- Use Toy Monte Carlo to obtain mass and cross section precisions

Neutralino mixed production with leptonic decay

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

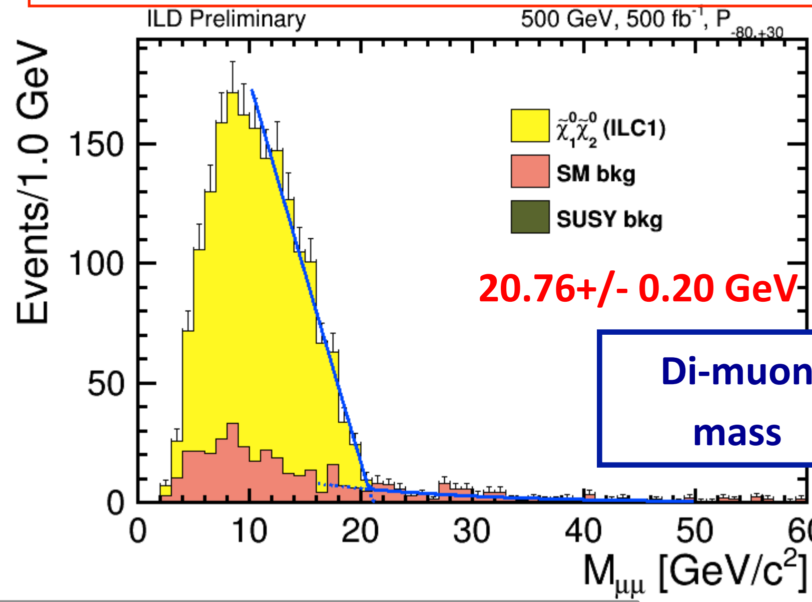
Left Polarization **(Pe-,Pe+) = (-0.8, +0.3)**

Edge precisions ∼1 %, assuming 500 fb^-1



73.81+/- 0.86 GeV

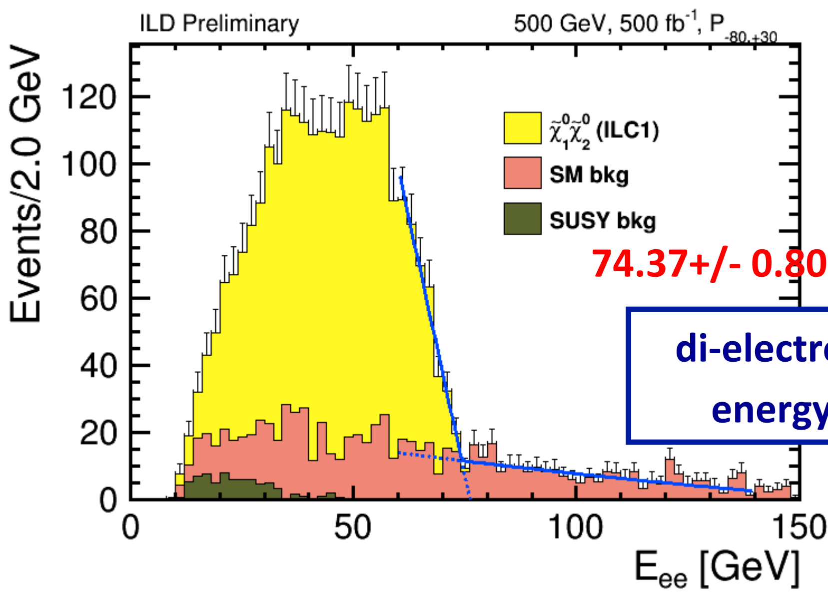
Di-muon energy



20.76+/- 0.20 GeV

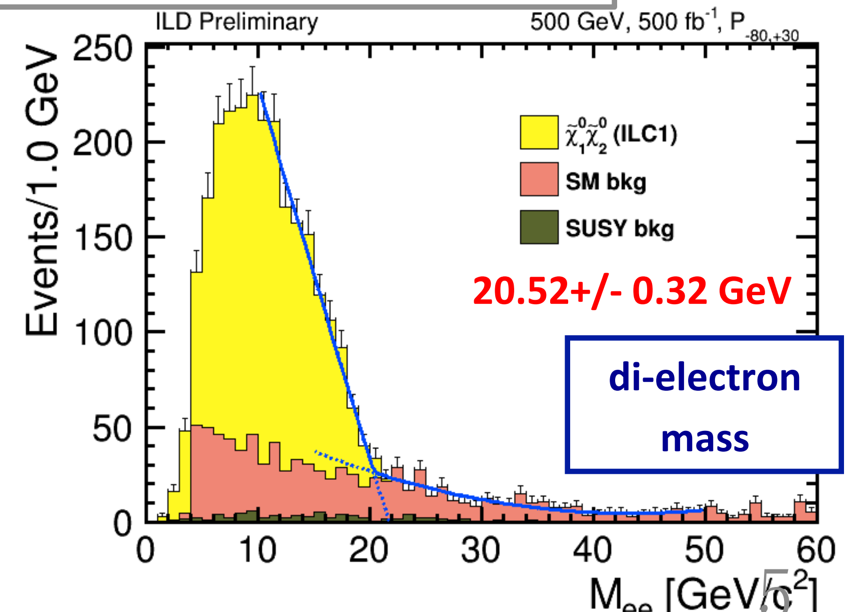
Di-muon mass

Theoretical values: E_max = 74.93 GeV ΔM = 21.28 GeV



74.37+/- 0.80 GeV

di-electron energy



20.52+/- 0.32 GeV

di-electron mass

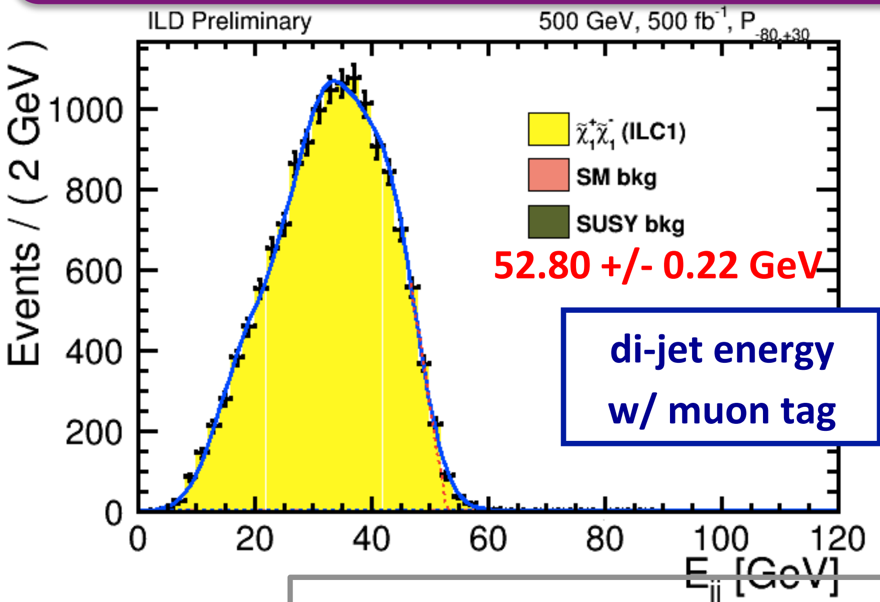
Chargino pair production with semileptonic decay

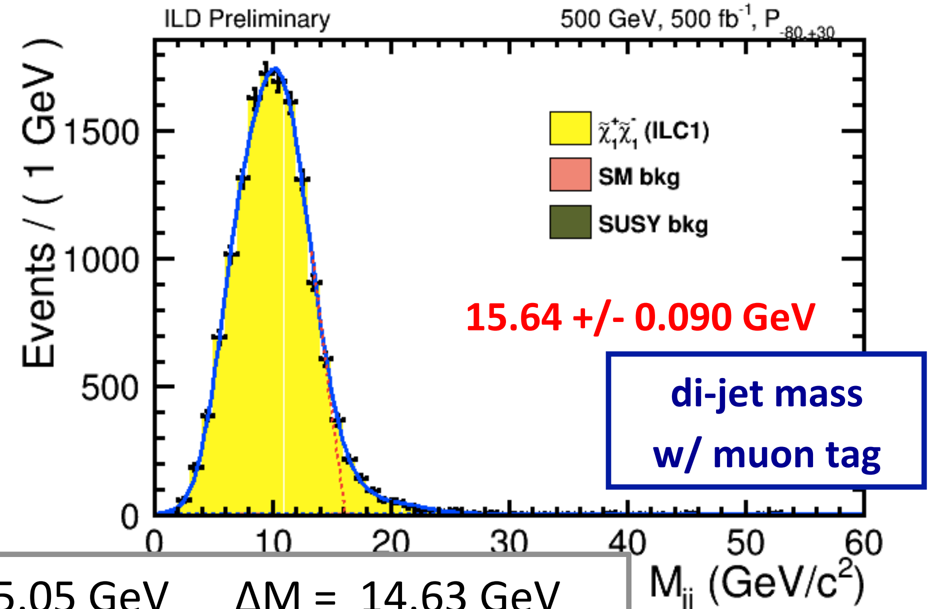
$$e^+e^- \rightarrow \tilde{\chi}_1^+ \tilde{\chi}_1^- \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 q q' \ell \nu$$

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

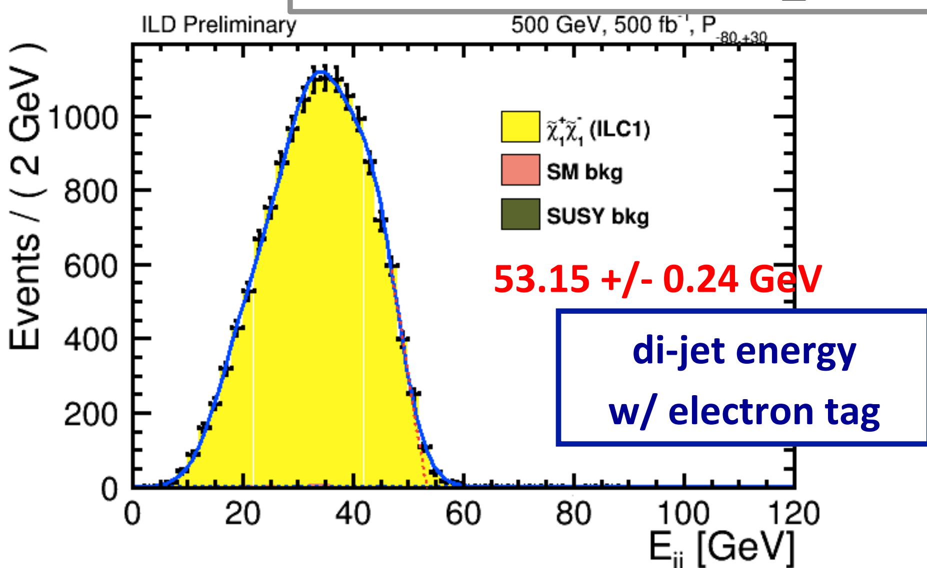
Edge precisions ~0.5 %, assuming 500 fb^-1

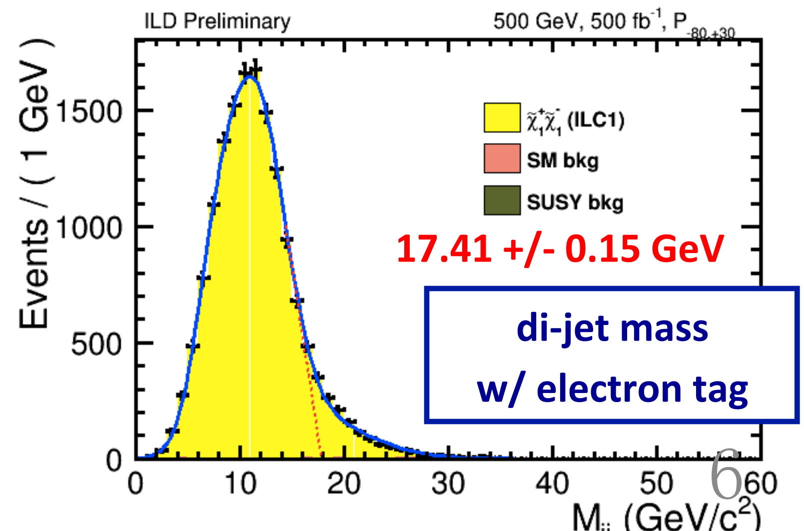
Almost all bkg rejected





Theoretical values: E_max = 55.05 GeV ΔM = 14.63 GeV

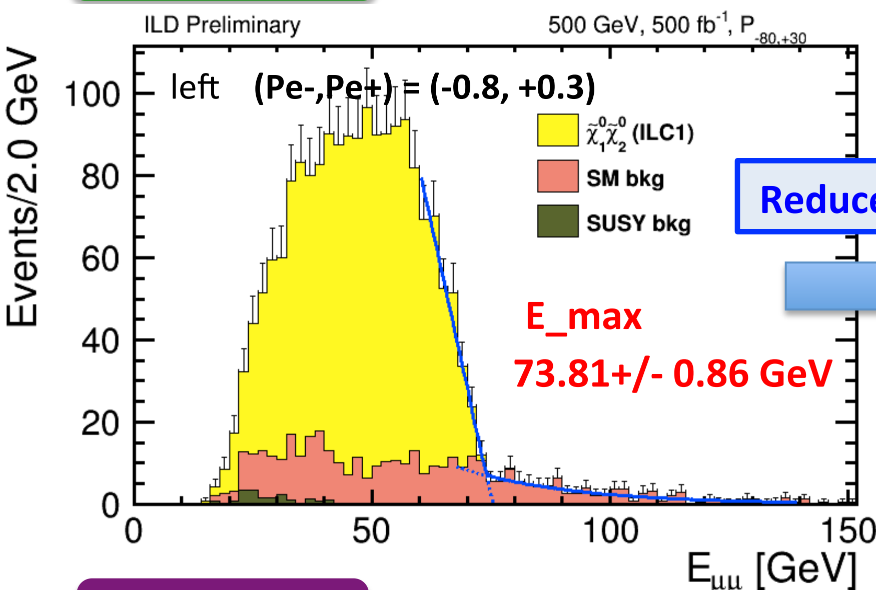




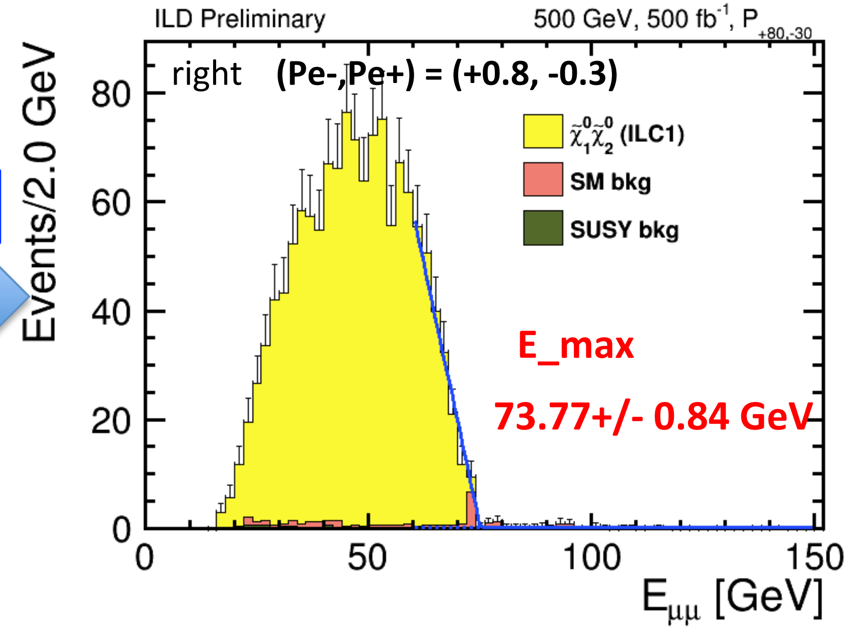
Left polarization vs right polarization

L=500 fb-1

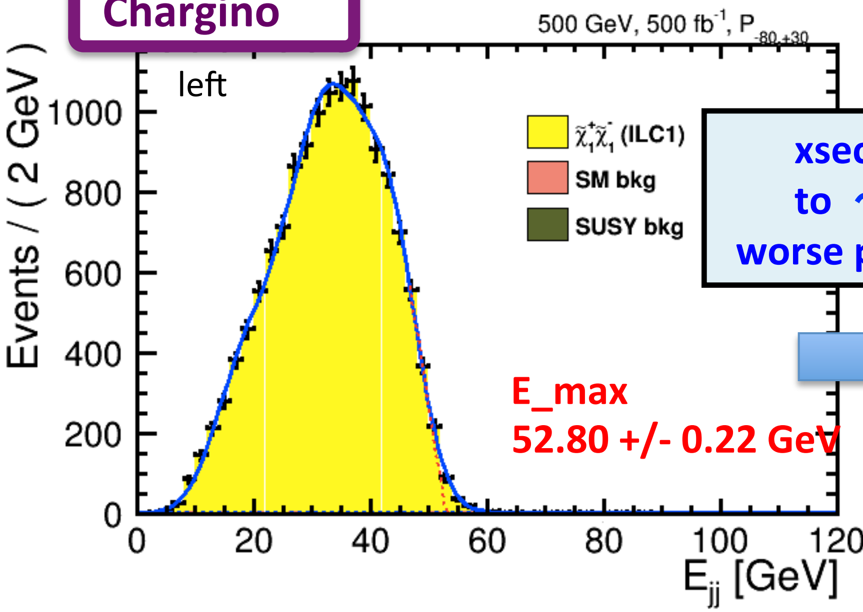
Neutralino



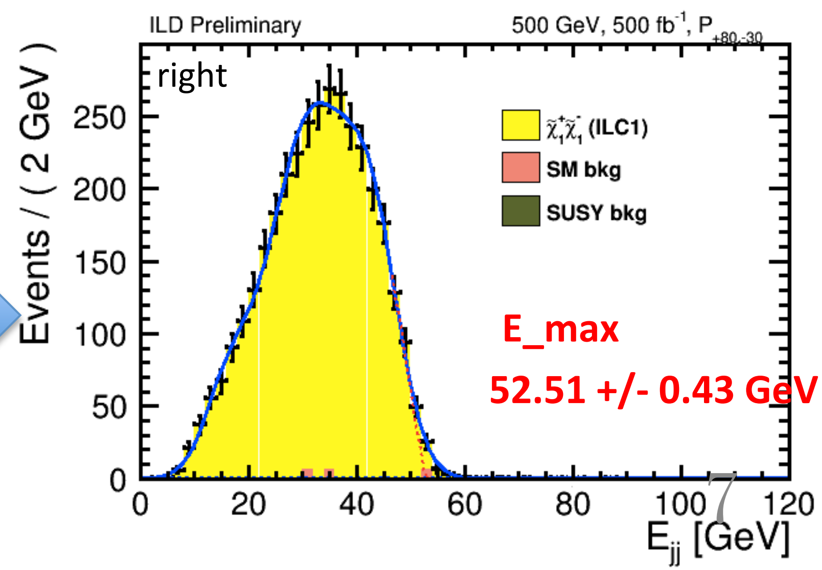
Reduced BKG



Chargino



xsec falls to ～1/5 worse precision



Higgsino Mass Precisions (combined)

apply χ^2 fit to "observables" (kinematic edges)

(Ell_max, Ejj_max, Mll_max, Mjj_max are functions of Higgsino masses)

Neutralino

4 channels (mm, ee, left, right)

N1N2	MN1	ΔMN1/MN1	MN2	ΔMN2/MN2
	102.54	0.758%	123.36	0.688%
H20		0.424%		0.385%

Scale results to H20

For each polarization:

- Default : 500 fb-[1]
- H20: 1600 fb^{-1}

Chargino

4 channels (m tag, e tag, left, right)

C1C1	MN1	ΔMN1/MN1	MC1	ΔMC1/MC1
	116.60	0.447%	132.79	0.435%
H20		0.250%		0.243%

8 channels (m, e, left, right, N1N2, C1C1)

ALL	MN1	ΔMN1/MN1	MN2	ΔMN2/MN2	MC1	ΔMC1/MC1
	110.56	0.405%	130.90	0.372%	126.09	0.396%
H20		0.226%		0.208%		0.221%

Theoretic values: MN1 = 102.70 GeV MN2 = 123.98 GeV, MC1 = 117.33 GeV

MN1: χ^0_1 mass MN2: χ^0_2 mass MC1: $\chi^\pm_1$ mass

- **<u>combined statistical mass precision ～ 0.2% （H20)</u>**
- Dominated by precision of chargino channel (higher cross section)

- Neutralino results consistent with theoretic values
- Chargino results deviated due to jet energy resolution

H20		0.424%		0.385%

- H20: 1600 fb^{-1}

Chargino

4 channels (m tag, e tag, left, right)

C1C1	MN1	ΔMN1/MN1	MC1	ΔMC1/MC1
	116.60	0.447%	132.79	0.435%
H20		0.250%		0.243%

ALL

8 channels (m, e, left, right, N1N2, C1C1)

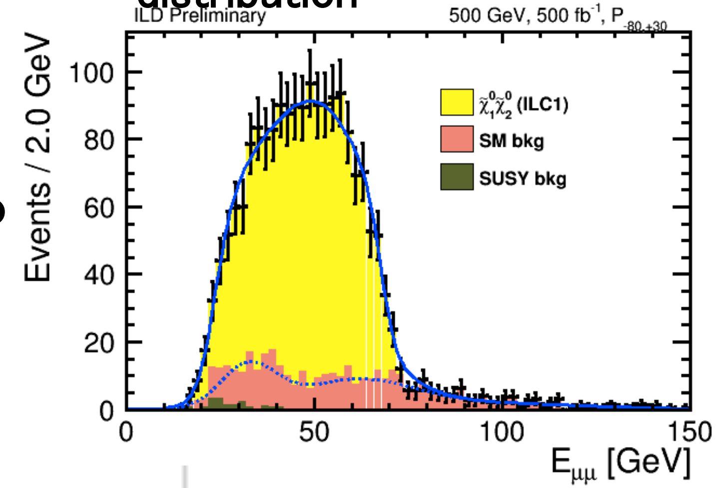
	MN1	ΔMN1/MN1	MN2	ΔMN2/MN2	MC1	ΔMC1/MC1
	110.56	0.405%	130.90	0.372%	126.09	0.396%
H20		0.226%		0.208%		0.221%

Theoretic values: MN1 = 102.70 GeV MN2 = 123.98 GeV, MC1 = 117.33 GeV

MN1: χ^0_1 mass MN2: χ^0_2 mass MC1: $\chi^\pm_1$ mass

Cross section precisions

Count # of events under distribution



- Neutralino (N1N2): 1 –1.5% (H20)

  right polarization has better precision due to suppressed BKG

- Chargino (C1C1) : 0.3–0.7% (H20)

  scales with size of cross section

N1N2	$\Delta\sigma/\sigma$	C1C1	$\Delta\sigma/\sigma$
left, mumu	3.49%	left, mu-tag	0.85%
left, ee	3.17%	left, e-tag	0.83%
combined	2.35%	combined	0.59%
H20	1.31%	H20	0.33%
N1N2	$\Delta\sigma/\sigma$	C1C1	$\Delta\sigma/\sigma$
right mumu	2.80%	right mu-tag	1.75%
right ee	2.41%	right e-tag	1.71%
combined	1.83%	combined	1.22%
H20	1.02%	H20	0.68%

Also analyzing more challenging benchmarks with smaller ΔM

➔ compare precision of SUSY parameter extraction

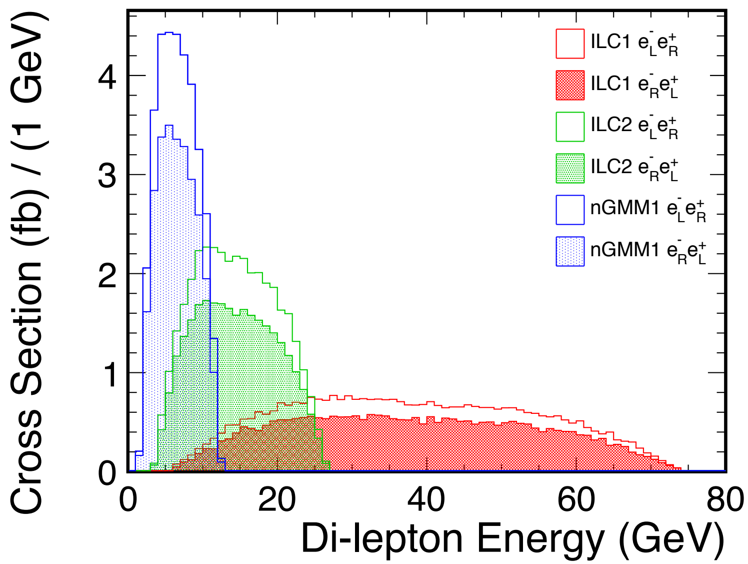
- **Currently working on ILC2**

Despite reduced visible energy, doable without large change in analysis strategies

- **Will show ILC1 & ILC2 results at LCWS2016**

Masses [GeV] from LHA files:

	ILC1	ILC2	nGMM1
M(N1)	102.7	148.1	151.4
M(N2)	124.0	157.8	155.8
ΔM(N2,N1)	**21.3**	**9.7**	**4.4**
M(C1)	117.3	158.3	158.7
ΔM(C1,N1)	**14.6**	**10.2**	**7.3**



Cross sections [fb] for $\sqrt{s}$=500 GeV with TDR beam parameters ,
Event Generator: WHIZARD v1.95, DBD setup)

Process (Pe-,Pe+)	ILC1	ILC2	nGMM1
C1C1 (-1,+1)	1799.9	1530.5	1520.6
C1C1 (+1,-1)	334.5	307.2	309.5
N1N2 (-1,+1)	490.9	458.9	463.5
N1N2 (+1,-1)	378.5	353.8	357.3

Neutralino mixed production with leptonic decay

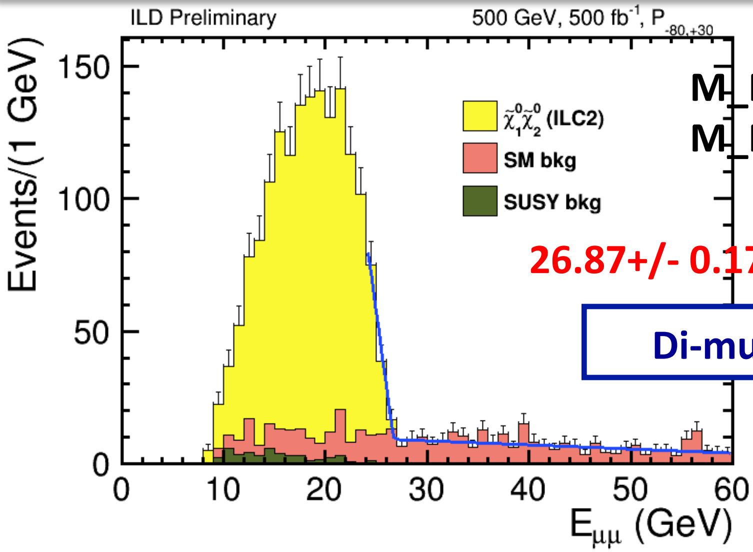
$$e^+e^- \rightarrow \widetilde{\chi}_1^0 \widetilde{\chi}_2^0 \rightarrow \widetilde{\chi}_1^0 \widetilde{\chi}_1^0 \ell^+ \ell^-$$

ILC2, μμ

Pt cut and Muon ID criteria loosened
Other selection same as ILC1

L=500 fb-1

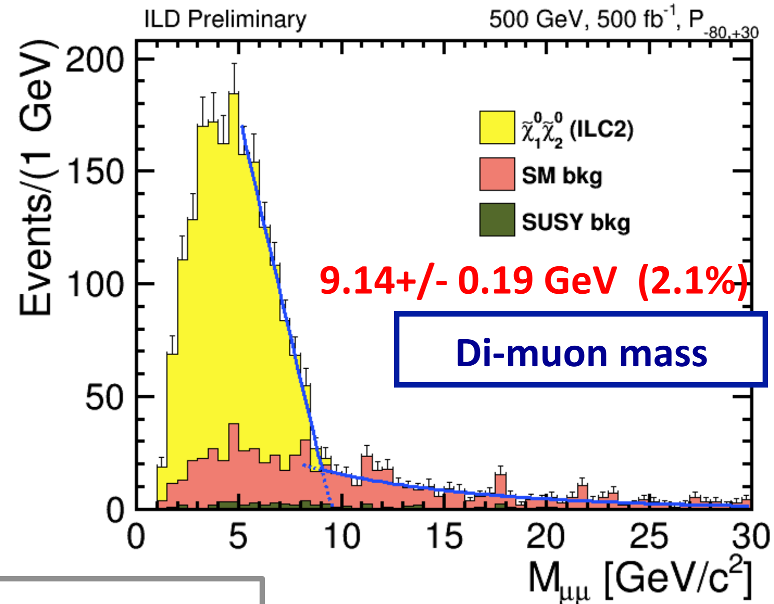
(Pe-,Pe+) = (-0.8, +0.3)



M_N2: 150.09 GeV
M_N1: 140.97 GeV

26.87+/- 0.17 GeV (0.6%)

Di-muon energy

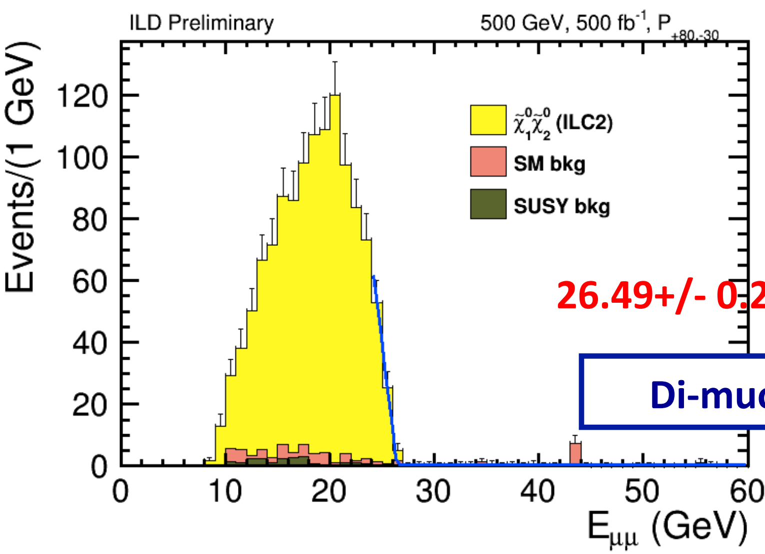


9.14+/- 0.19 GeV (2.1%)

Di-muon mass

Theoretical values: E_max = 26.85 GeV ΔM = 9.7 GeV
M_N2: 157.8 GeV M_N1: 148.1 GeV

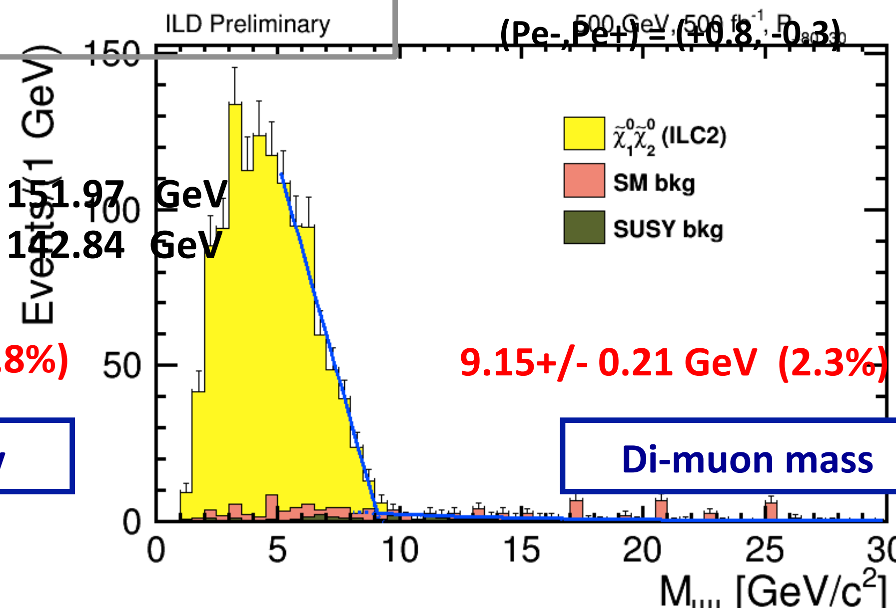
(Pe-,Pe+) = (+0.8, -0.3)



M_N2: 151.97 GeV
M_N1: 142.84 GeV

26.49+/- 0.22 GeV (0.8%)

Di-muon energy



9.15+/- 0.21 GeV (2.3%)

Di-muon mass

Neutralino mixed production with leptonic decay

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

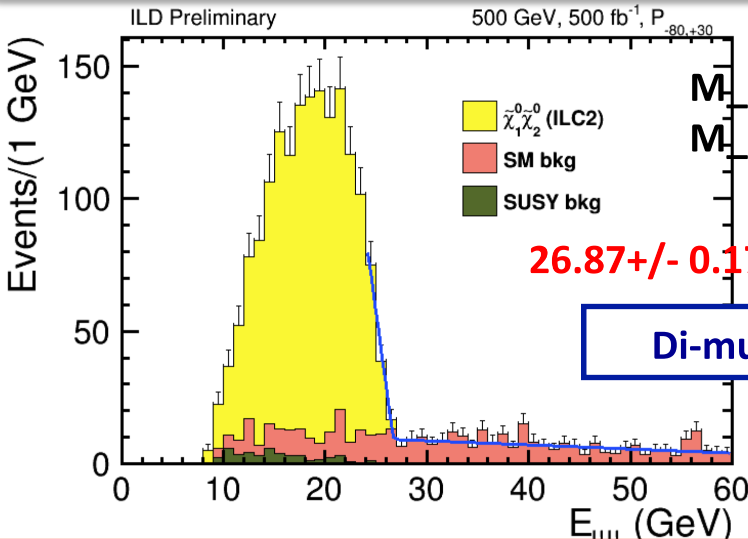
ILC2, μμ

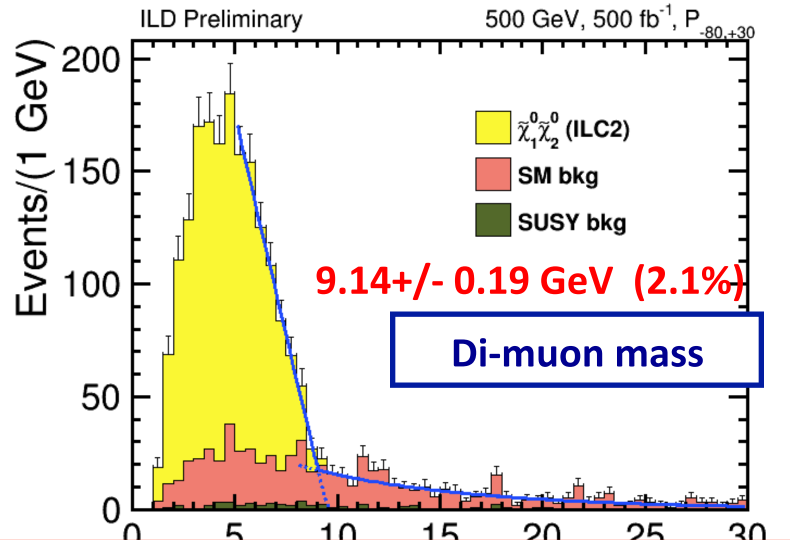
Pt cut and Muon ID criteria loosened
Other selection same as ILC1

L=500 fb-1

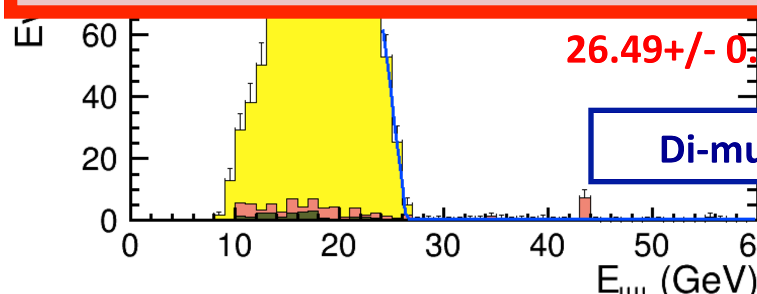
(Pe-,Pe+) = (-0.8, +0.3)

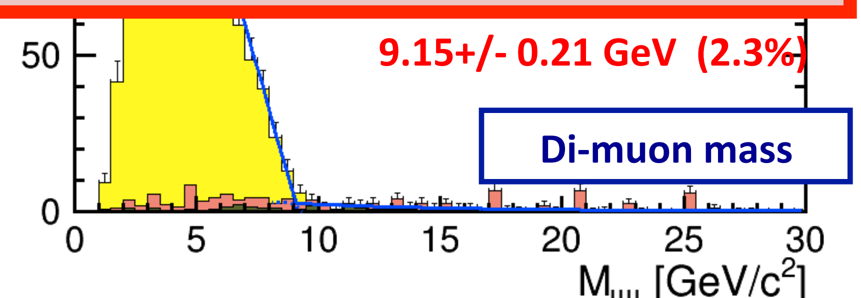
M_N2: 150.09 GeV
M_N1: 140.97 GeV





- After loosened μ selection criteria (ratio of E_calorimeter over P_tot), μ statistics increased ➔ now precision of E_$\mu\mu$ is slightly better for ILC2 (may also benefit from steeper slope of signal distribution)
- Plan to optimize μ selection for ILC1 as well, after LCWS2016

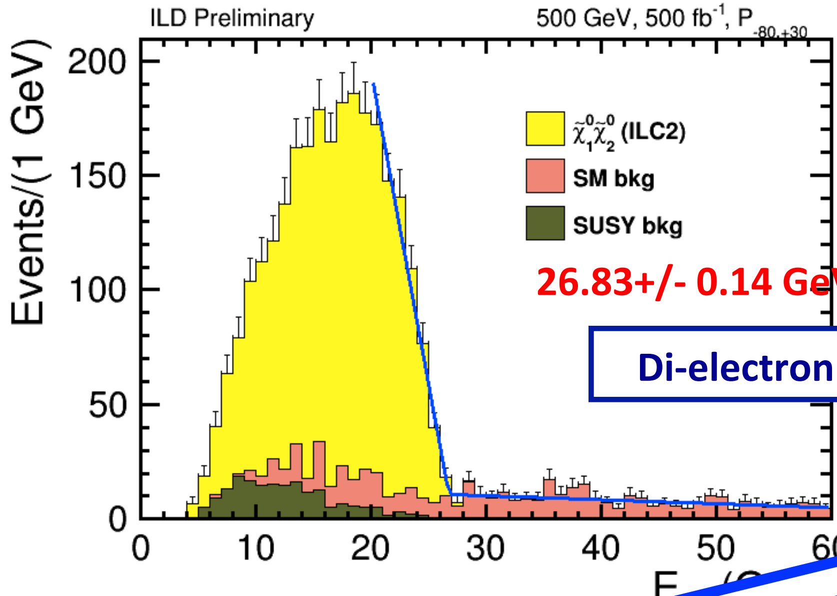




Neutralino mixed production with leptonic decay

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

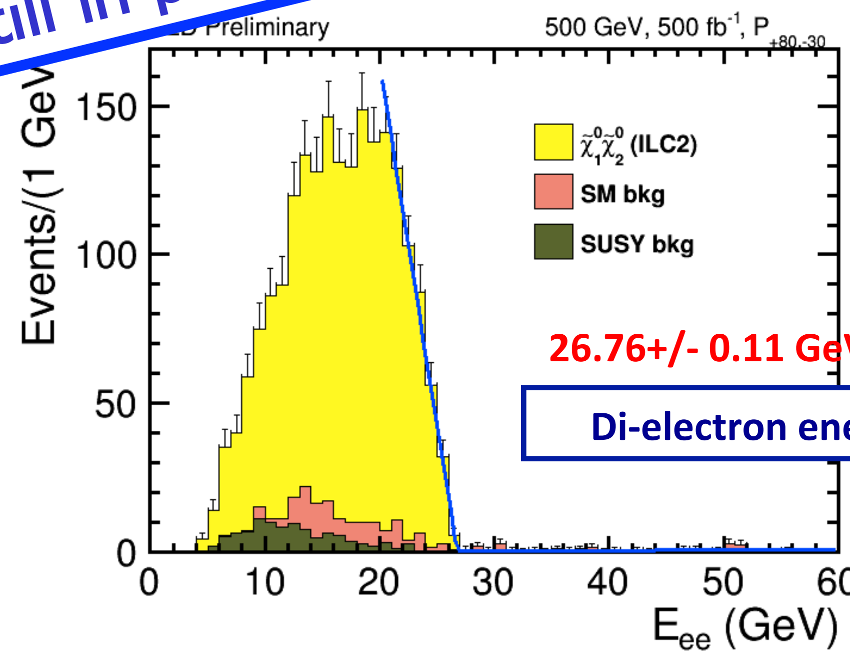
ILC2, ee



26.83+/- 0.14 GeV (0.5%)

Di-electron energy

Electron channels still in progress （checking）



26.76+/- 0.11 GeV (0.4%)

Di-electron energy

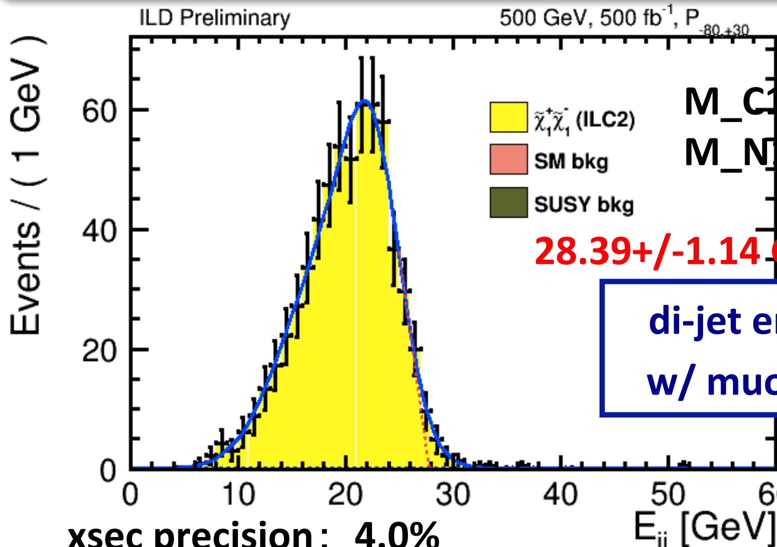
Chargino pair production with semileptonic decay

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

ILC2 μ-tag

All ILC1 cuts applied, with exception of
- Pt_mis cut loosened from 10 → 7 GeV
- Muon ID criteria loosened

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

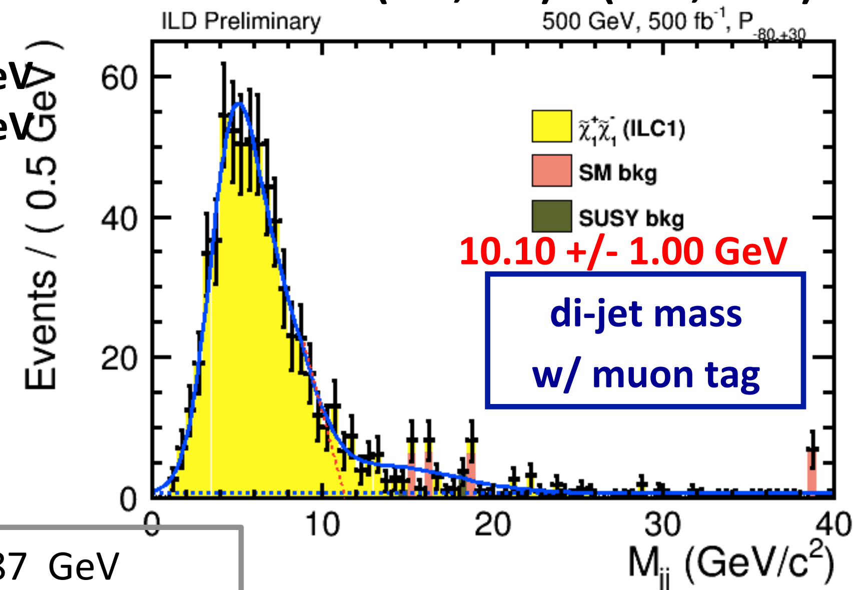


M_C1: 153.83 GeV
M_N1: 143.73 GeV

28.39+/-1.14 GeV (4.0%)

di-jet energy w/ muon tag

xsec precision : 4.0%

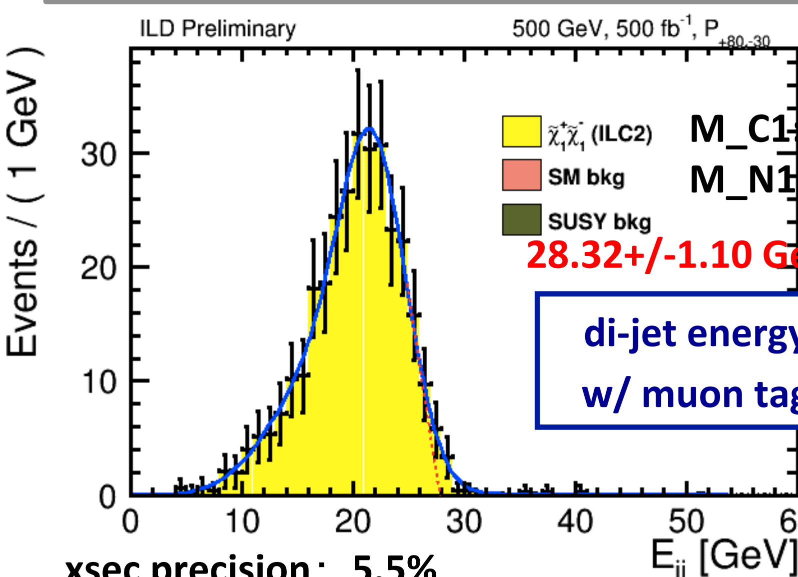


10.10 +/- 1.00 GeV

di-jet mass w/ muon tag

Theoretical values: E_max = 27.66 GeV , ΔM = 9.87 GeV
M_C1: 158.3 GeV, M_N1: 148.1 GeV

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

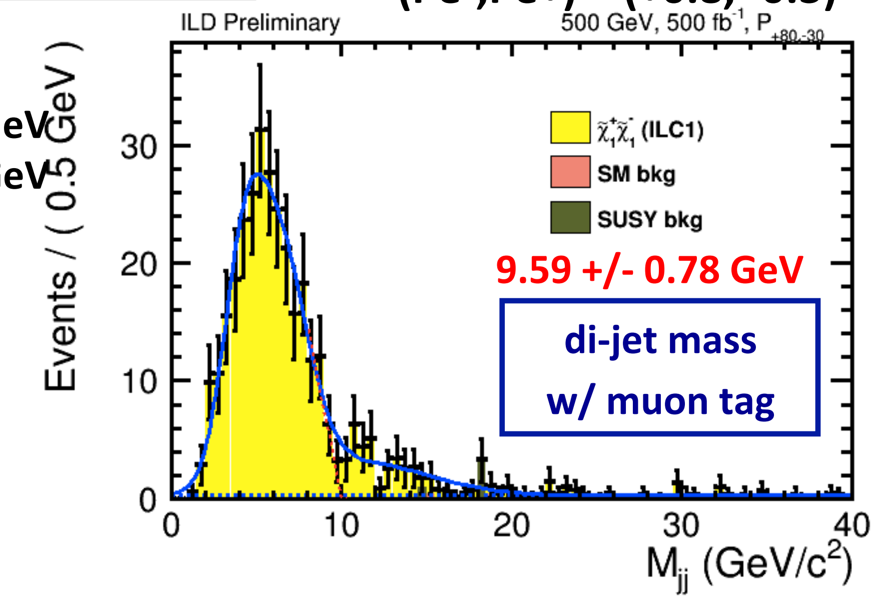


M_C1: 147.94 GeV
M_N1: 138.35 GeV

28.32+/-1.10 GeV (3.9%)

di-jet energy w/ muon tag

xsec precision : 5.5%



9.59 +/- 0.78 GeV

di-jet mass w/ muon tag

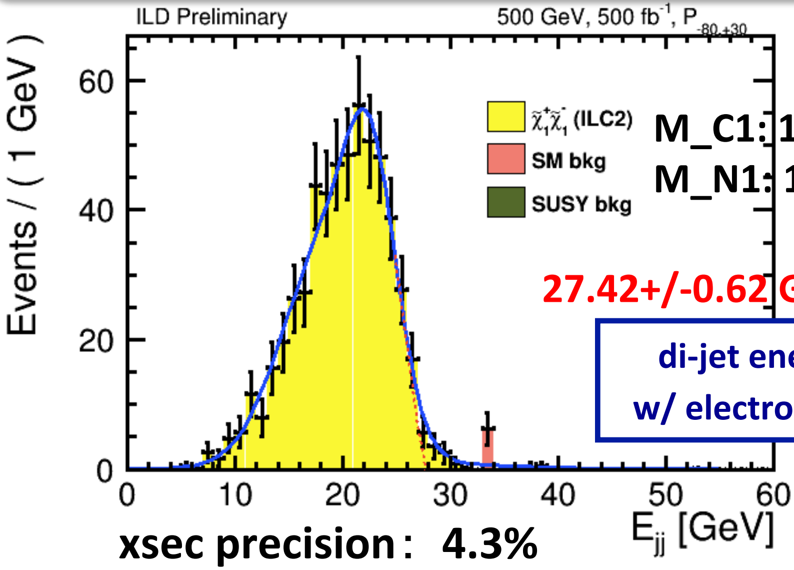
Chargino pair production with semileptonic decay

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

ILC2 e-tag

All ILC1 cuts applied, with exception of
- Pt_mis cut loosened from 10 → 7 GeV
- Muon ID criteria loosened

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

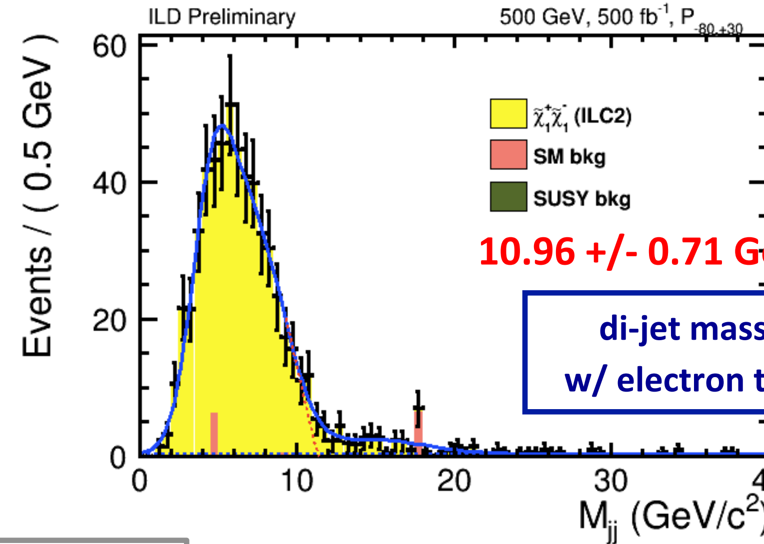


M_C1: 168.19 GeV
M_N1: 157.23 GeV

27.42+/-0.62 GeV (2.2 %)

di-jet energy w/ electron tag

xsec precision : 4.3%

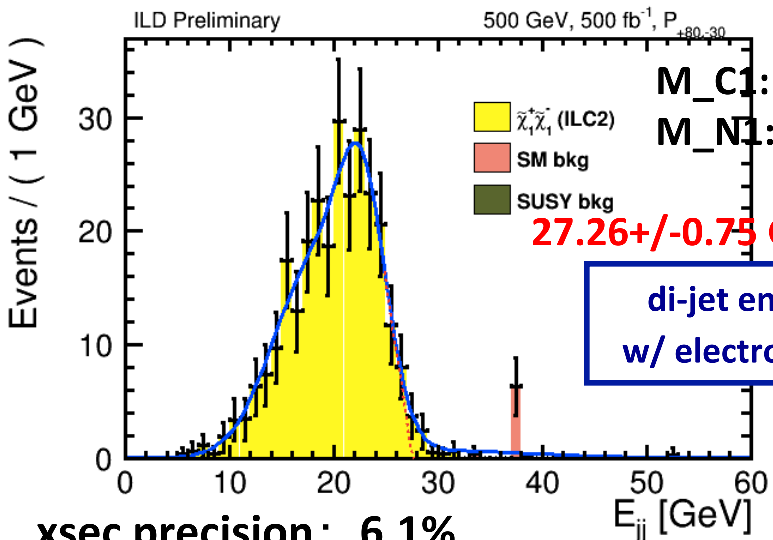


10.96 +/- 0.71 GeV

di-jet mass w/ electron tag

Theoretical values: E_max = 27.66 GeV , ΔM = 9.87 GeV
M_C1: 158.3 GeV, M_N1: 148.1 GeV

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

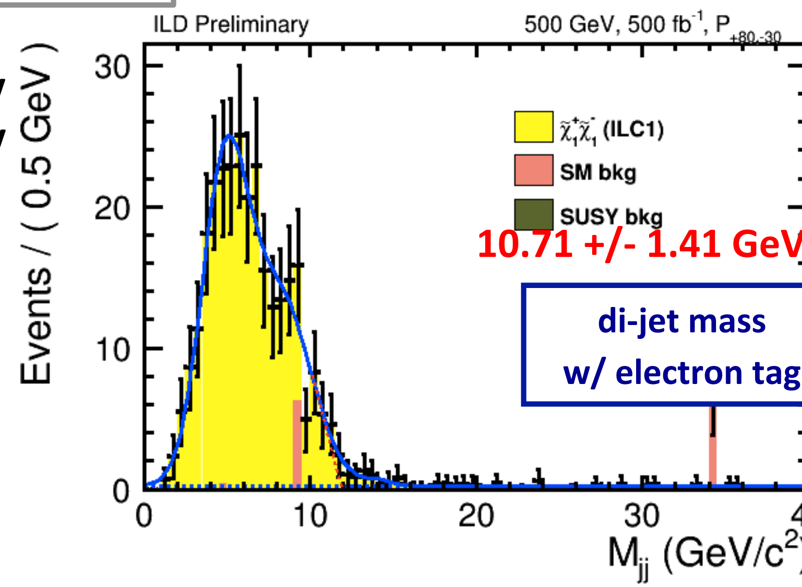


M_C1: 166.10 GeV
M_N1: 155.39 GeV

27.26+/-0.75 GeV (2.8 %)

di-jet energy w/ electron tag

xsec precision : 6.1%



10.71 +/- 1.41 GeV

di-jet mass w/ electron tag

Chargino pair production with semileptonic decay

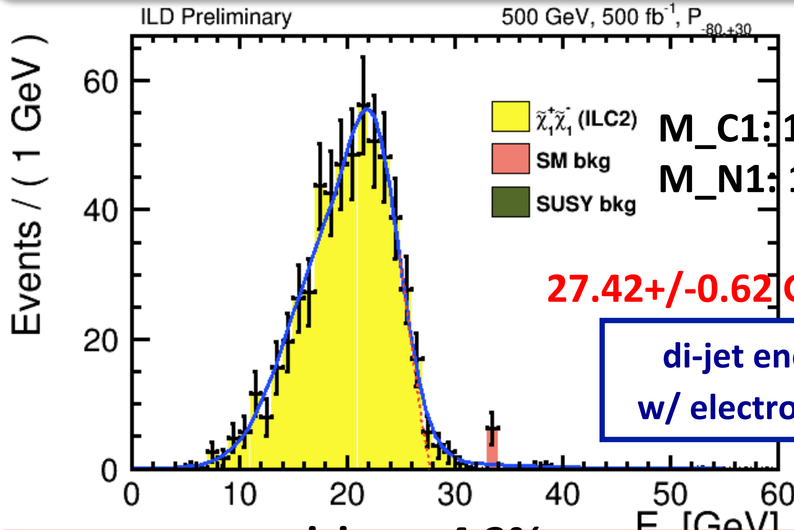
$$e^+e^- \to \widetilde{\chi}_1^+ \widetilde{\chi}_1^- \to \widetilde{\chi}_1^0 \widetilde{\chi}_1^0 qq'\ell\nu$$

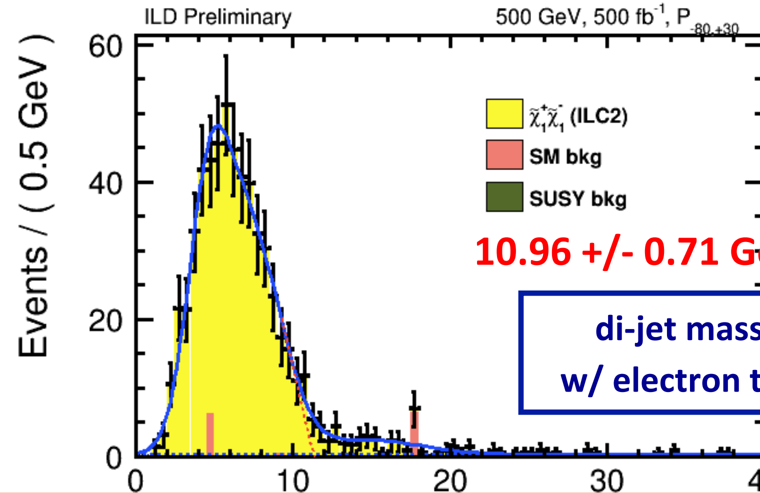
ILC2 e-tag

All ILC1 cuts applied, with exception of
- Pt_mis cut loosened from 10 → 7 GeV
- Muon ID criteria loosened

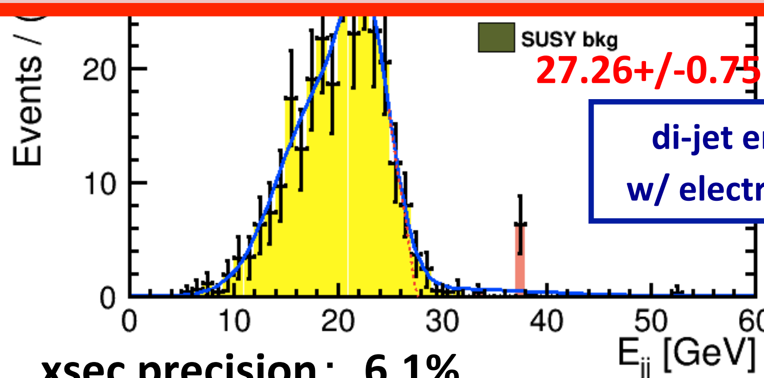
(Pe-,Pe+) = (-0.8, +0.3)

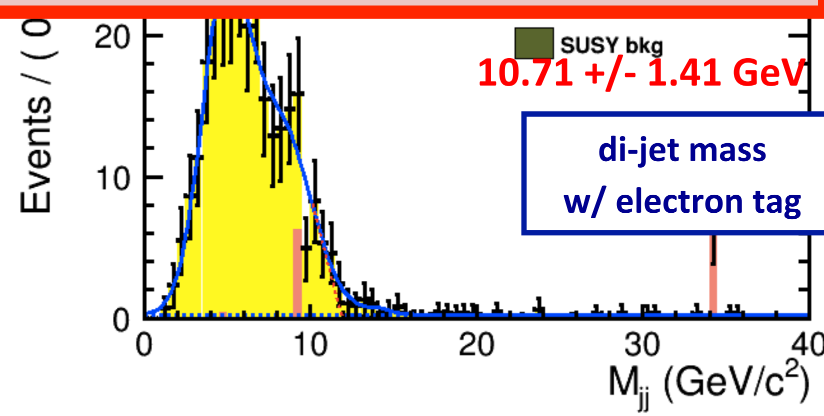
M_C1: 168.19 GeV
M_N1: 157.23 GeV





Will think of how to improve statistics for the measurement of these soft particles（in terms of lepton selection method, loosening of cuts, etc···)





xsec precision： 6.1%

Summary for Light Higgsino Study

Precision measurement of light Higgsinos with small ΔM (< 20 GeV)

- Motivated by both experiment (complementary to LHC) and theory (naturalness)

This analysis: **neutralino mixed production ($\chi_1^0 \chi_2^0$)** and **chargino pair production ($\chi_1^+ \chi_1^-$)**

Full ILD detector simulation, L=500 fb-1 at √s = 500 GeV, (Pe-, Pe+) = (-0.8,+0.3), (+0.8, -0.3)

- Fit kinematic edges to extract Higgsino masses
- Fit to overall distribution to extract production cross sections

Obtained statistical precisions for ALL channels of ILC1

- **Assuming H20 : Mass : ~ 0.2% , Cross section : neutralino: 1–1.5% , chargino: 0.3 –0.7%**

results obtained in this study become input to SUSY parameter determination

test GUT-scale physics and SUSY-breaking mechanism

full H20 run, three $\sqrt{s}$

S.-L. Lehtinen (DESY) et al

$$\Delta M_1 = 1.5\%$$
$$\Delta M_2 = 1.0\%$$
$$\Delta M_3 = 11.6\%$$
$$\Delta \mu = 0.1\%$$
$$\Delta \tan\beta = 2.5\%$$

All channels analyzed for ILC2 as well , *some channels still undergoing confirmation*

- Selection methods adjusted to accommodate softer leptons/jets
- Higgsino mass and xsec precisions should not be much worse than ILC1
- Optimization for ILC2 give hints on how to improve ILC1

Plans

Until LCWS

- **Nov 25 at KEK: " ILC Detector Meeting"**
- **Nov 26 at KEK: "ILC General Physics Meeting"** ➔ **present results**
- **Nov 30: present LCWS results to ILD** (phone meeting) ➔ **present results**

At LCWS: show current stage of ILC1 results and most of ILC2 results

After LCWS

- study effect of **jet energy resolution**

  Possible improvement from identifying and removing ISR photons from jets
- **Improve lepton tagging efficiency**
- assess a gap in di-electron invariant mass in SM bkg due to generator cuts

  maybe need to generate major electron channel bkg with generator cut of $0.5 < M_{ee} < 4$ GeV

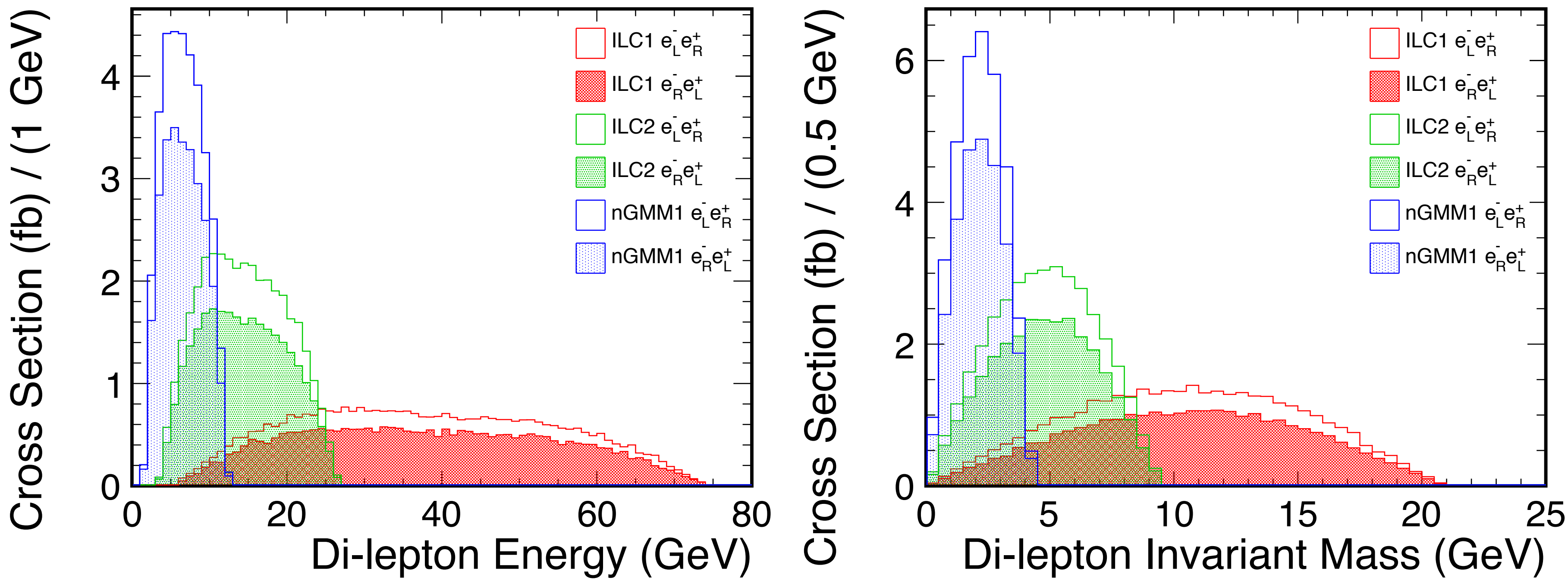
- begin **simulation and analysis for Mirage4_74_2 benchmark**
- continue working on **Higgsino paper which includes all three benchmarks :**

  theory, analysis, and SUSY parameter extraction_

Additional Material

WHIZARD-level distributions

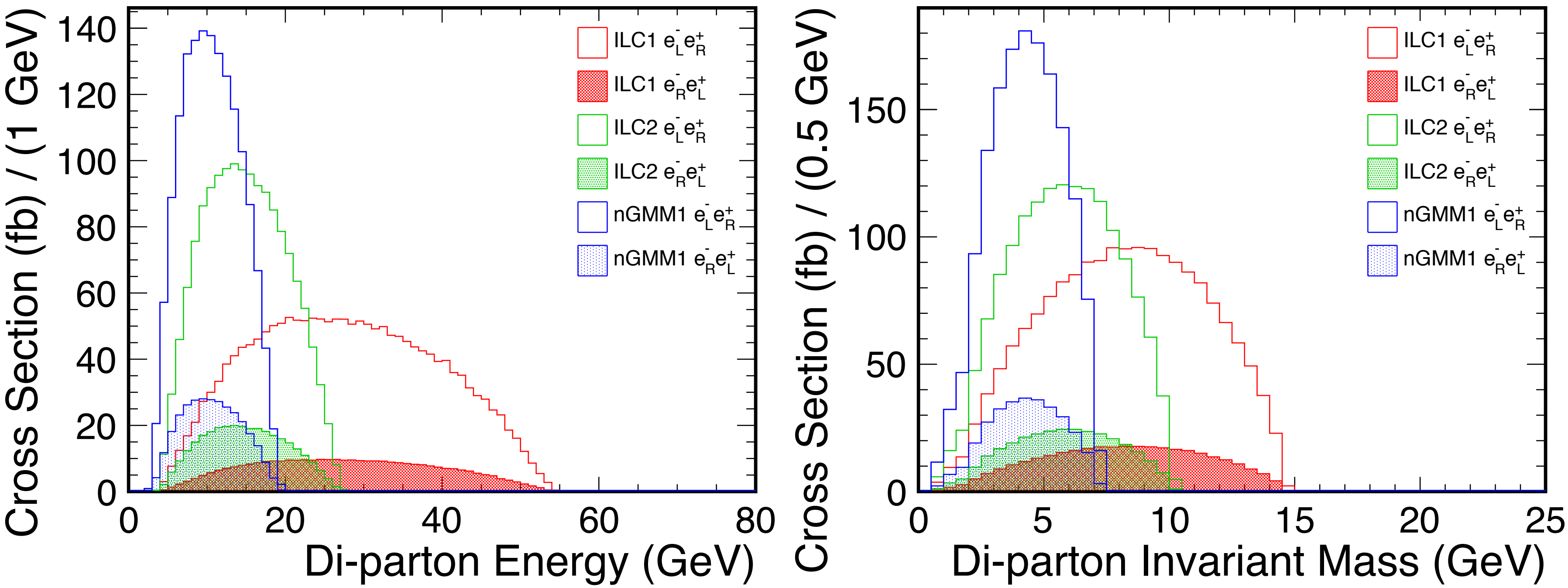
$$e^+e^- \to \tilde{\chi}_1^0\tilde{\chi}_2^0, \quad \tilde{\chi}_2^0 \to \tilde{\chi}_1^0\ell^+\ell^-$$



	ILC1	ILC2	nGMM1
ΔM(N2,N1)	21.3	9.7	4.4

WHIZARD-level distributions

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

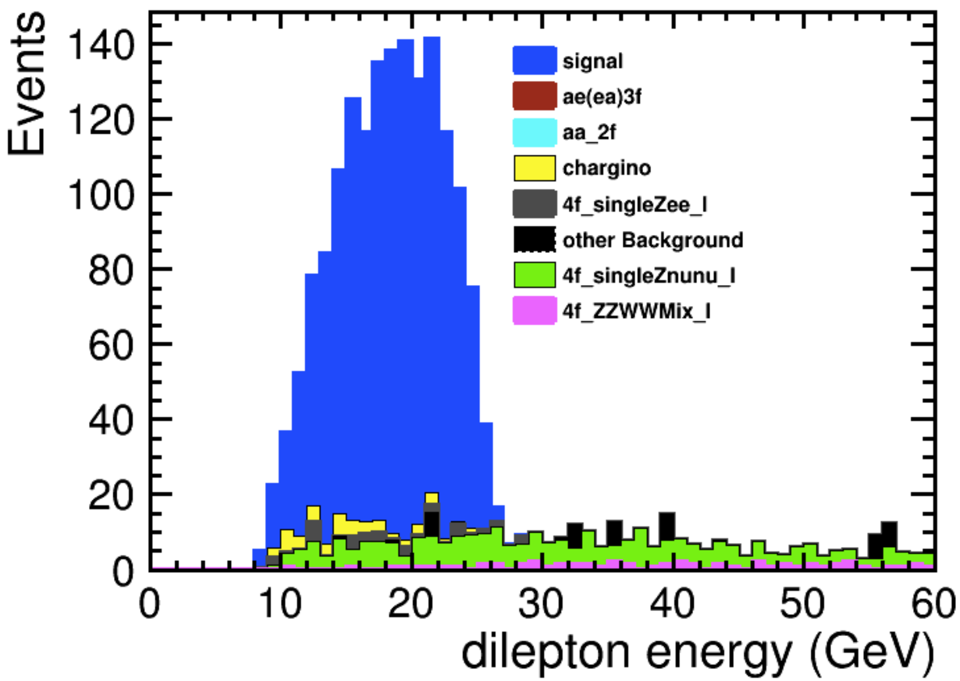


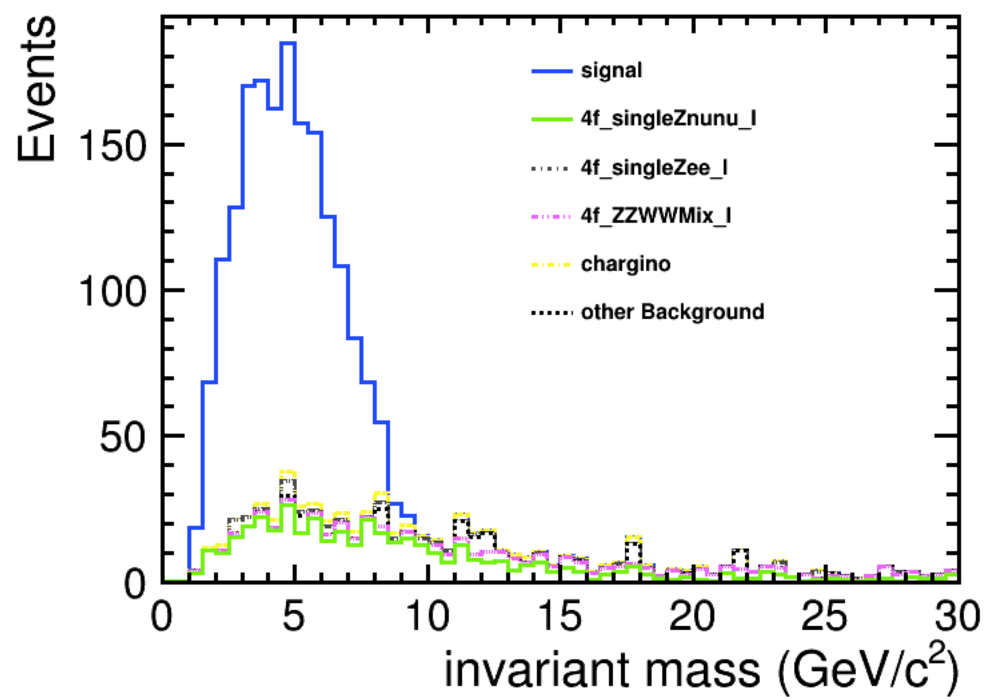
	ILC1	ILC2	nGMM1
ΔM(C1,N1)	14.6	10.2	7.3

Xsec fits for ILC2 N1N2

Neutralino mixed production with leptonic decay

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





Efficiency and signal yield

	yield(ILC2)	yield(ILC1)	lepton eff(ILC2	lepton eff (ILC1)
N1N2				
muon,left	2159	1515	63.58	45.44
muon,right	1150	1276		
elec,left	2159	1990	77.29%	79.38%
elec, right	1756	1736		
C1C1				
muon,left	610	14173	84.17%	54.48%
muon,right	313	3466		
elec,left	556	14437	56.16%	51.03%
elec, right	270	3526		

N1N2 efficiency definition:
Muon (similar for electron)
Top: hAnl>GetEntries("leptype==13&&nZmm==2")
Bottom: hGen->GetEntries("nZmm==2")

C1C1 efficiency definition:
Muon (similar for electron)
Top: hTr->GetEntries("nWqq==2&&nWmm==1&&abs(PDG)==13&&TagbestlepM==1&&abs(PDGOrig)==1000024")
Bottom: hTr->GetEntries("nWqq==2&&nWmm==1&&abs(PDG)==13&&abs(PDGOrig)==1000024")

Cuts for ILC2 N1N2

- **lepton type (μμ or ee)** : the two leptonic channels of N1N2 analysis
- **nTrack = 2 :** number of charged tracks
- **no hit in BeamCal :** veto γγ2f BG
- **Pt_lep1,2 > 4 GeV and |cosθlep1,2| < 0.95:**
- **Coplanarity < 1.0 rad :** angle between leptons in x-y plane
- **Evis – Eγmax < 40 GeV :** visible energy (very small for signal)
- **Emis > 300 GeV :** missing energy (very large for signal)
- **|cosθmissing| < 0.98 :** θ of missing energy events
- **|cosθZ| < 0.98 :** Z* production angle
- **Pt_dl < 80 GeV :** transverse momentum of dilepton
- **Minv<20 GeV :** dilepton invariant mass: determines ΔM

last of all observe distributions of Minv and dilepton energy (E_dl)

Kinematic edge is a function of Higgsino mass and ΔM

Cuts for ILC1 N1N2

- **lepton type (μμ or ee)** : the two leptonic channels of N1N2 analysis
- **nTrack = 2 :** number of charged tracks
- **no hit in BeamCal :** veto γγ2f BG
- **Pt_lep1,2 > 6 GeV and |cosθlep1,2| < 0.95:**
- **Coplanarity < 1.0 rad :** angle between leptons in x-y plane
- **Evis – Eγmax < 40 GeV :** visible energy (very small for signal)
- **Emis > 300 GeV :** missing energy (very large for signal)
- **|cosθmissing| < 0.98 :** θ of missing energy events
- **|cosθZ| < 0.98 :** Z* production angle
- **Pt_dl < 80 GeV :** transverse momentum of dilepton
- **Minv<50 GeV :** dilepton invariant mass: determines ΔM

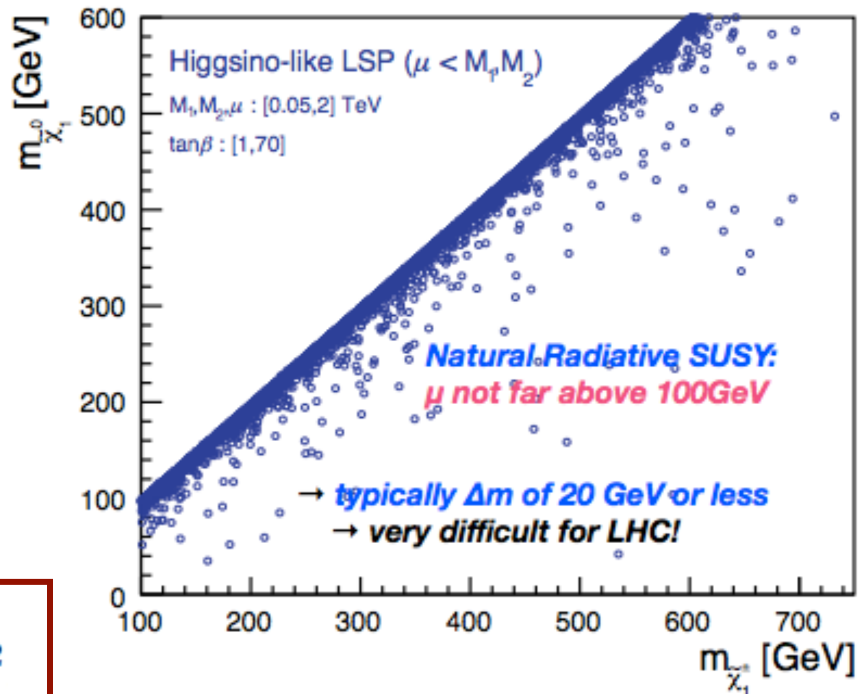
last of all observe distributions of Minv and dilepton energy (E_dl)

Kinematic edge is a function of Higgsino mass and ΔM

Motivation for Searching Light Higgsinos with Small ΔM

❖ **From experimental point of view:**

- LHC already excluded large regions with large ΔM = M(NLSP) – M(LSP)
- Remaining region with compressed spectrum
  very small visible energy release,
  near impossible to probe at LHC
  ➔ **ILC is essential**



❖ **From theoretical point of view:**

Compressed Higgsino spectra related to naturalness [e.g. arXiv:1212.2655, arXiv:1404.7510]

$$\frac{M_Z^2}{2} = \frac{m_{H_d}^2 + \Sigma_d^d - (m_{H_u}^2 + \Sigma_u^u)\tan^2\beta}{\tan^2\beta - 1} - \mu^2$$

- To maintain **small electroweak fine tuning ΔEW (<∼3%)**, all contributions on right-hand-side should be comparable to M(Z) ➔ requires **μ ∼ 100–300 GeV**

  top and bottom squarks in the few TeV regime, gluino mass 2−4 TeV,
  1st, 2nd generation squarks and sleptons in the 5−30 TeV regime

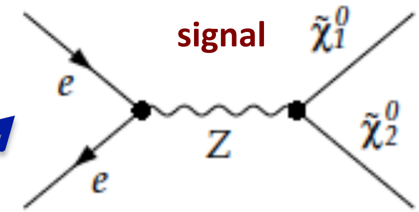
- μ feeds mass to both SM (W, Z, h) and SUSY particles (Higgsinos)
- Higgsino masses not too far from masses of W, Z, h (∼100 GeV)

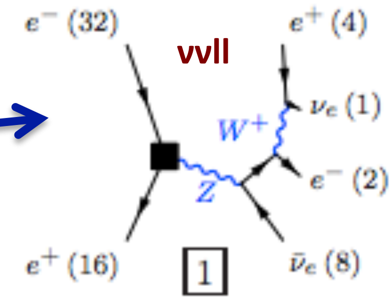
Event Selection

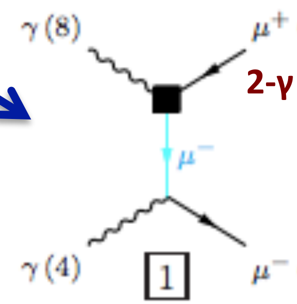
Neutralino mixed production with leptonic decay

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

- 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 (ννll)
- 2-γ processes are removed by BeamCal veto, cuts on lepton track p_T, and coplanarity



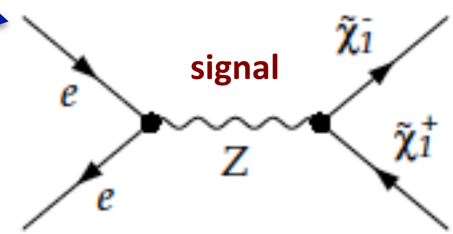




Chargino pair production with semileptonic decay

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

- 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.



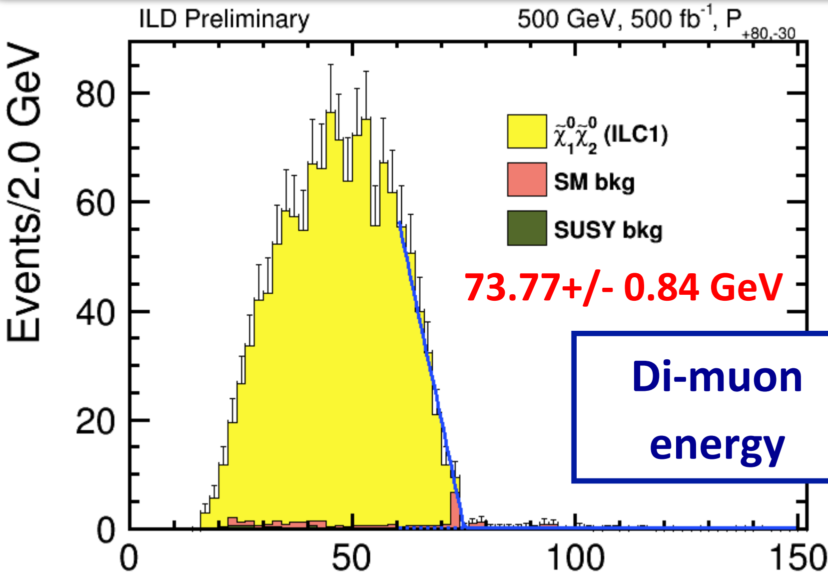
Neutralino mixed production with leptonic decay

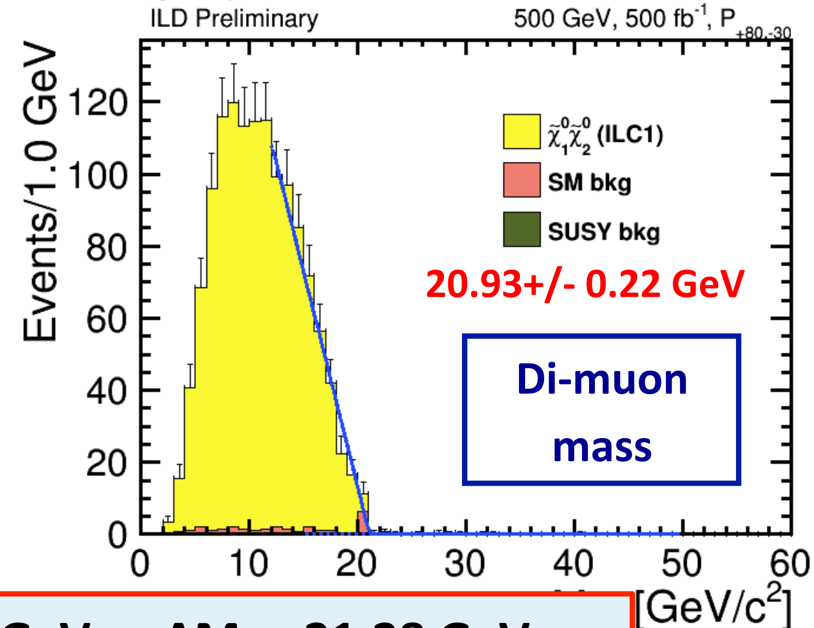
$$e^+e^- \rightarrow \tilde{\chi}_1^0\,\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0\ell^+\ell^-$$

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

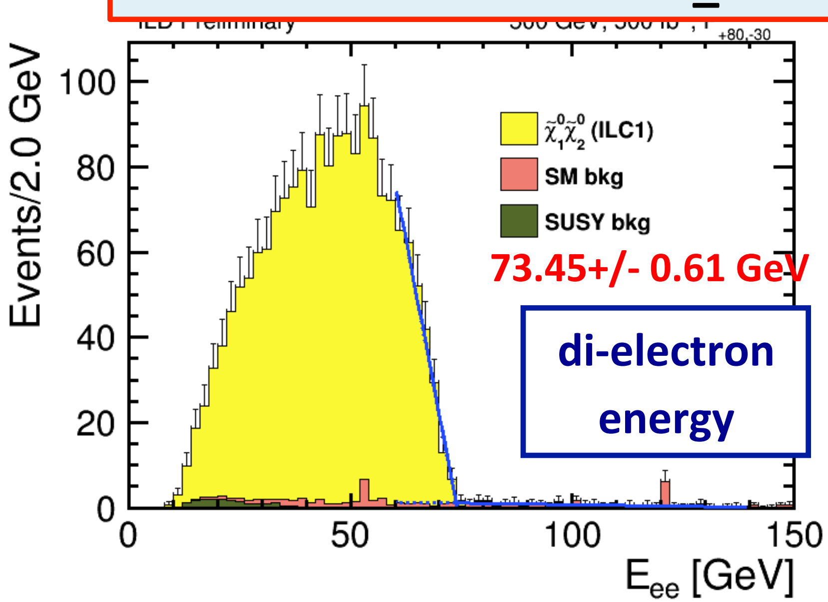
Much less bkg
Precision slightly better

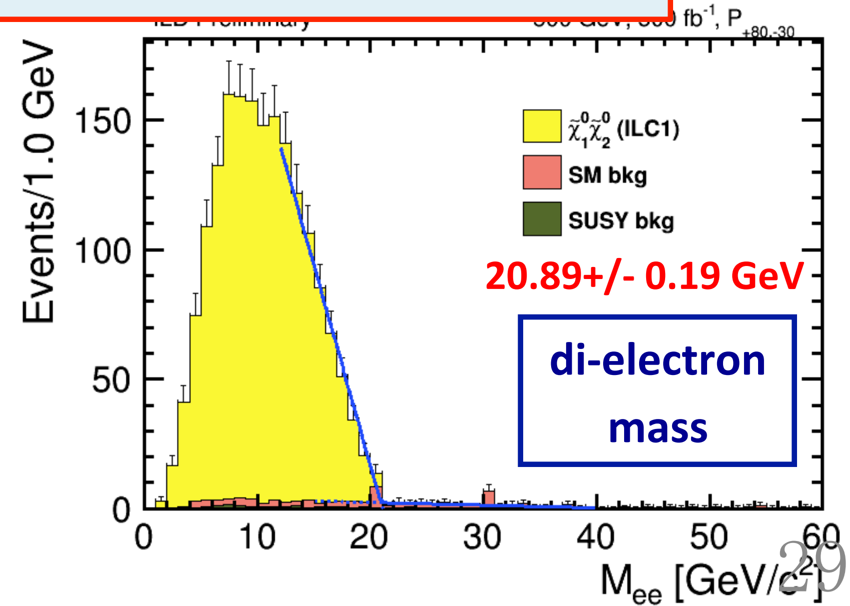
Edge precision < ~ 1 %





Theoretical values: E_max = 74.93 GeV ΔM = 21.28 GeV



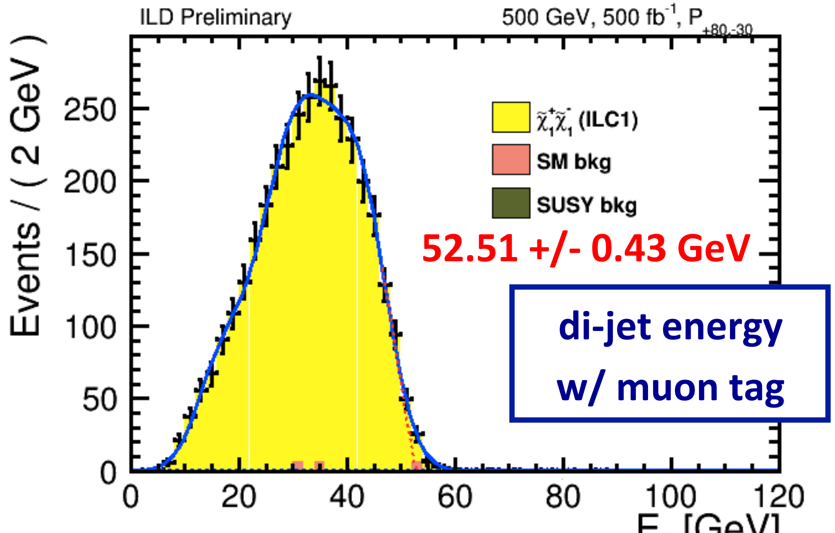


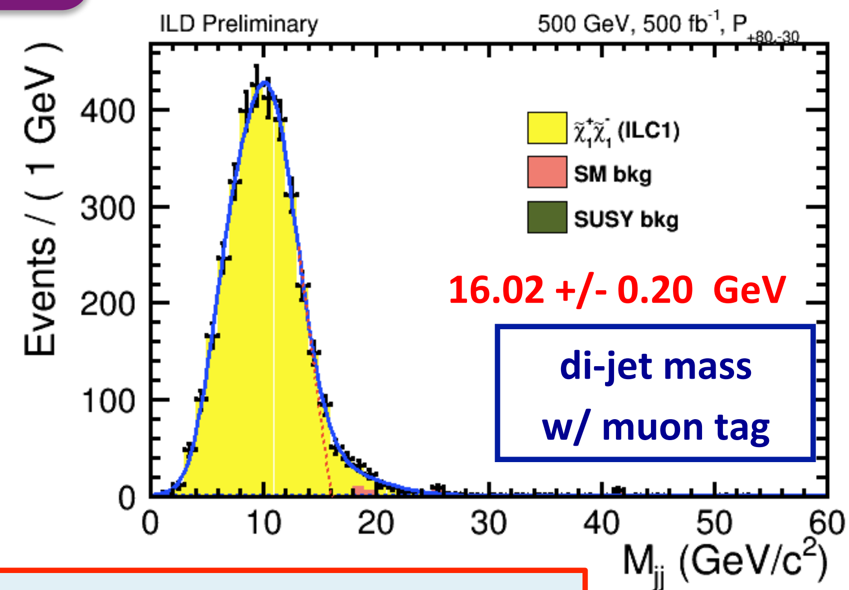
Chargino pair production with semileptonic decay

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

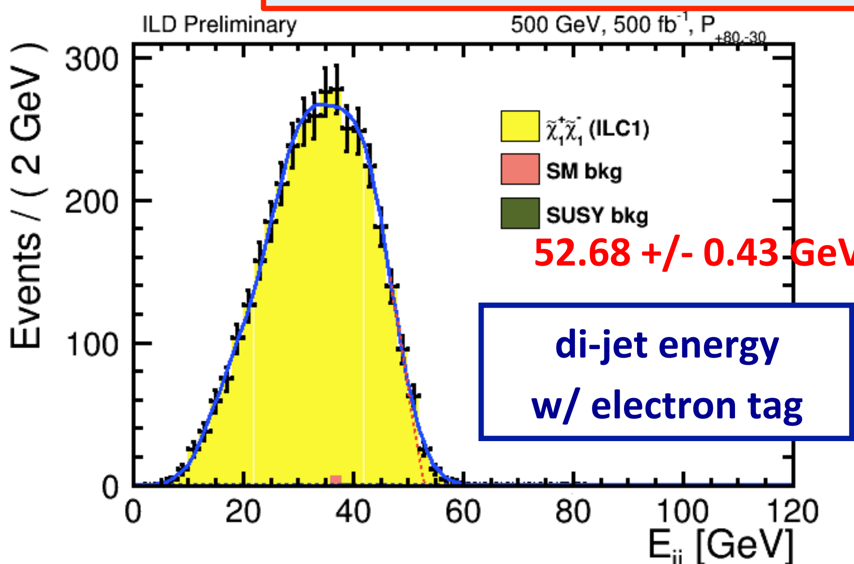
right Polarization (Pe-,Pe+) = (+0.8, -0.3)

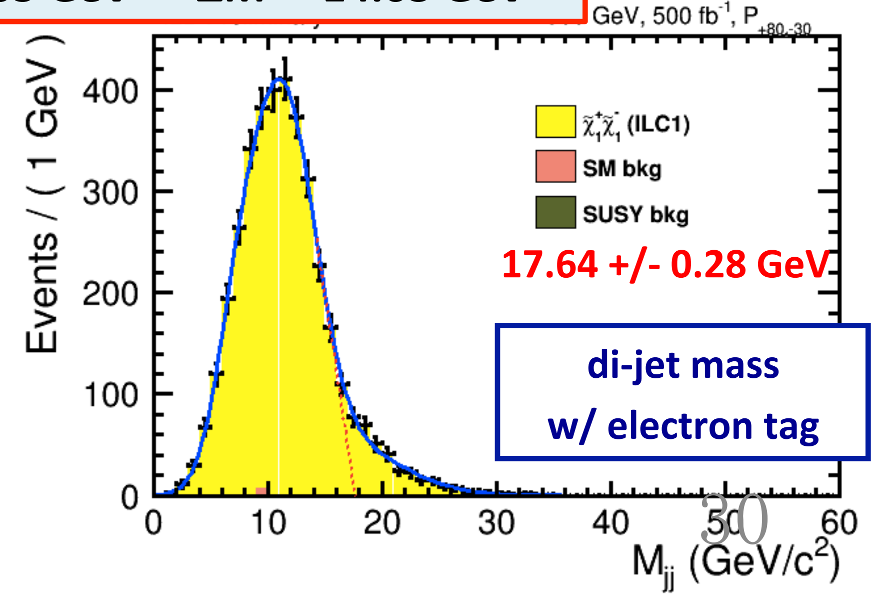
Cross section ~ 1/5 of left polarization





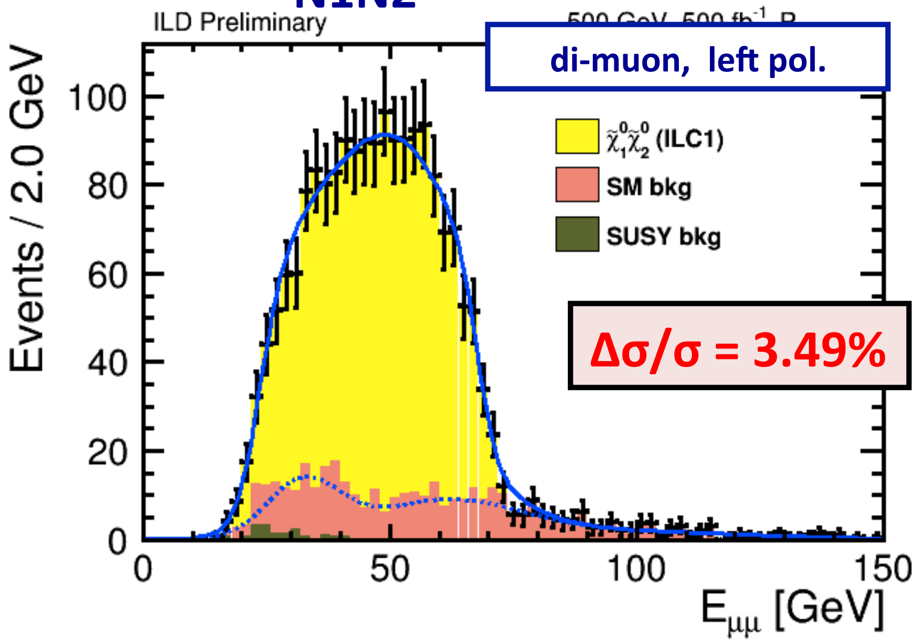
Theoretical values: E_max = 55.05 GeV ΔM = 14.63 GeV

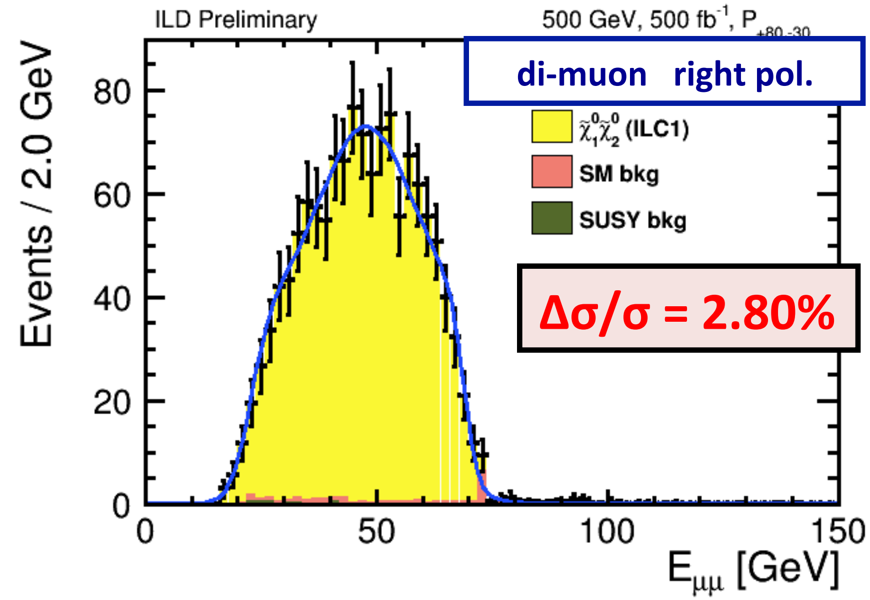


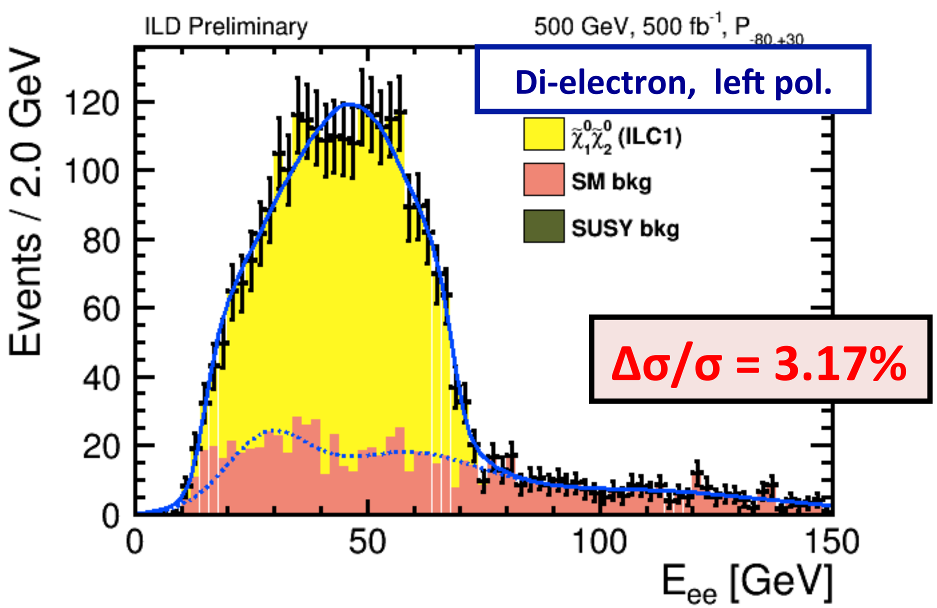


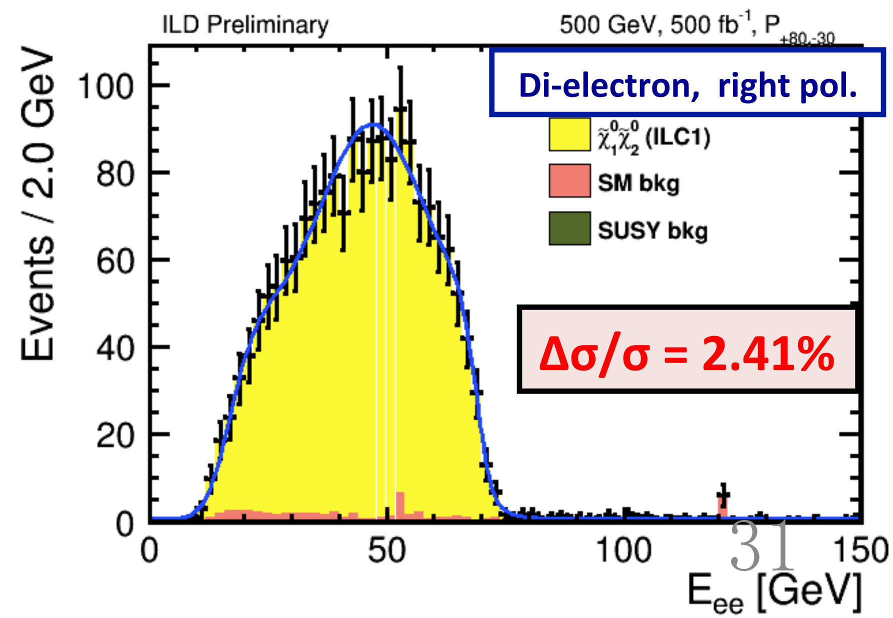
Extraction of Cross Section
N1N2

Uncertainty of right pol is about 3 / 4 of left pol dependent on statistics (evaluated using Toy MC)



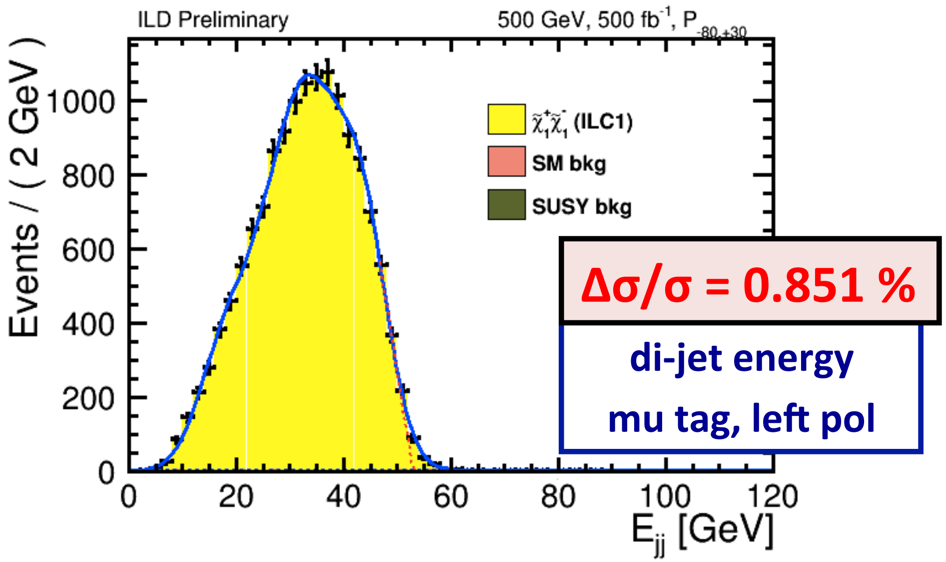


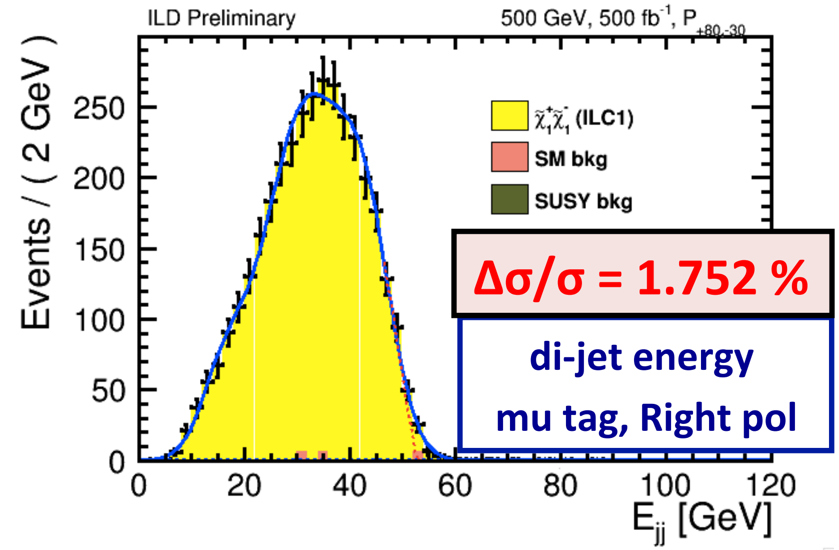


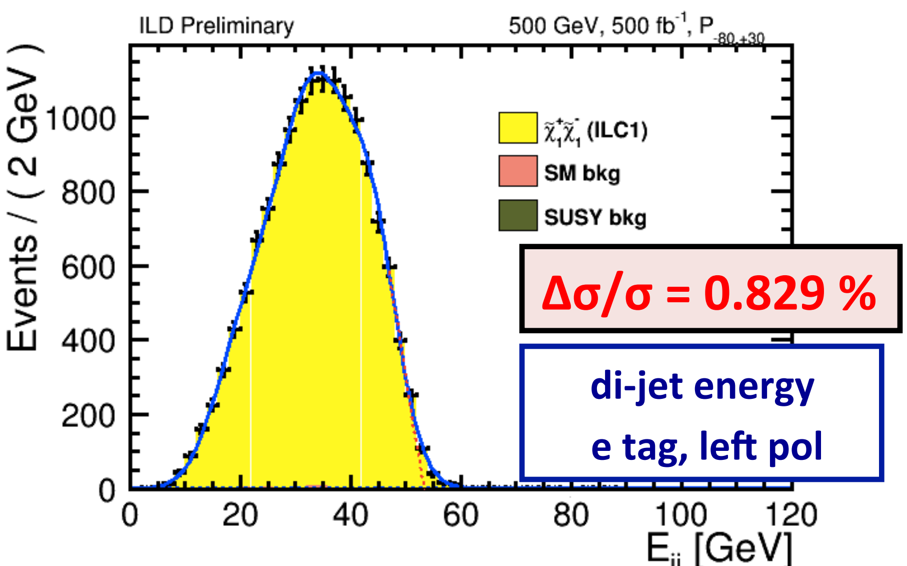


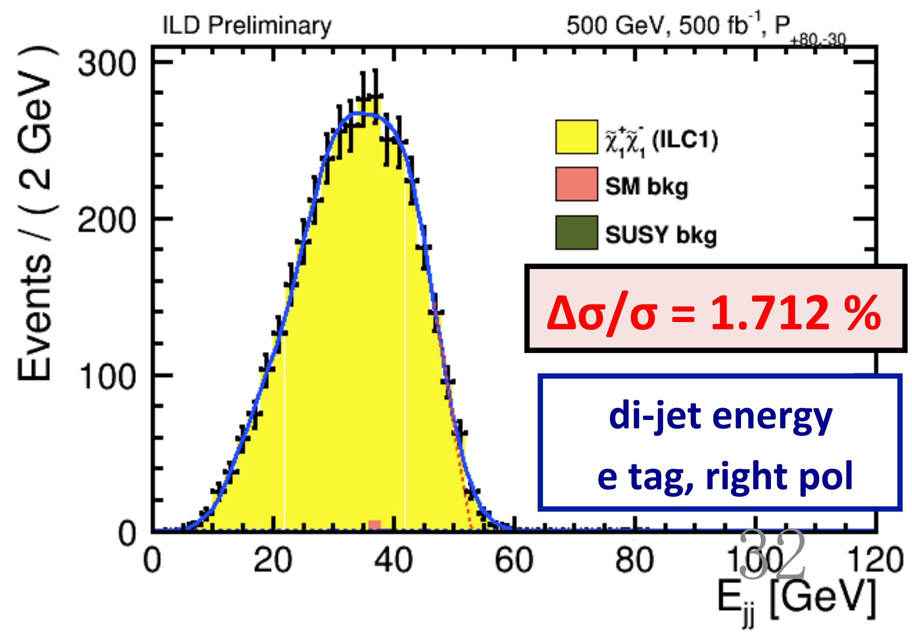
Extraction of Cross Section C1C1

- Left pol has x2 better precision
- dependent on statistics



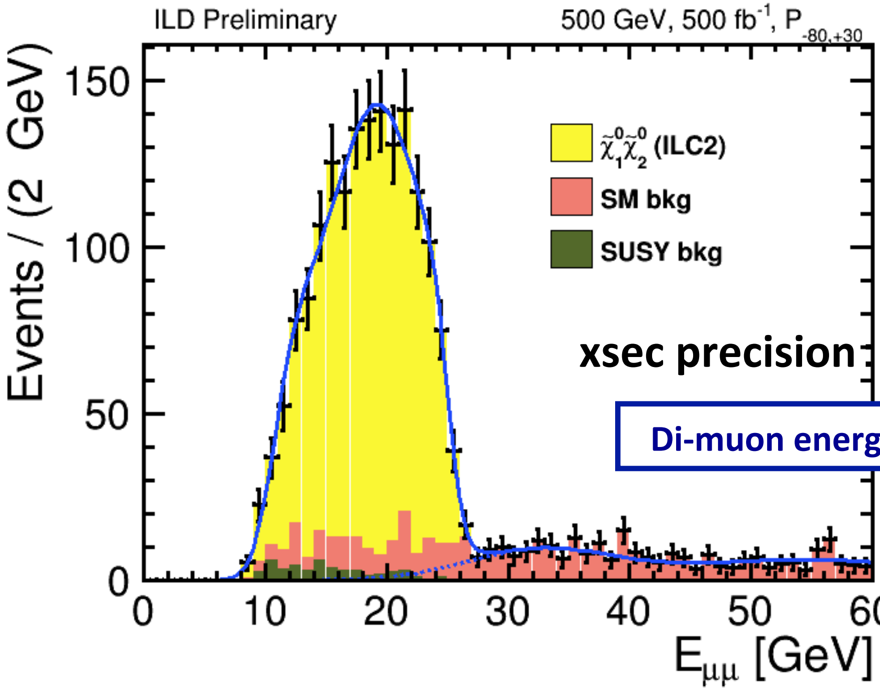






Xsec fits for ILC2 N1N2

ILC2: (Pe-,Pe+) = (-0.8, +0.3)



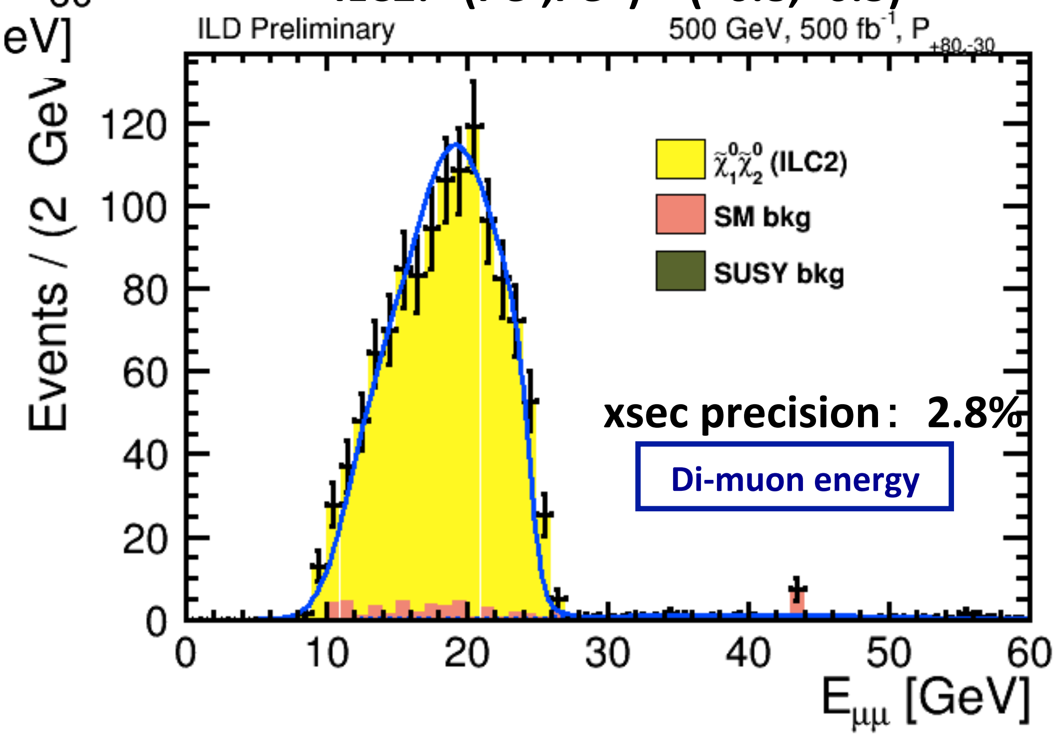
xsec precision : 2.7%

Di-muon energy

Neutralino mixed production with leptonic decay

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

ILC2: (Pe-,Pe+) = (+0.8, -0.3)



xsec precision : 2.8%

Di-muon energy

ILC2 Cut Table: N1N2 left polarization, mumu

Cut10 : 945.386 36.1696 2159.05 38.75
Polarization: (e-,e+) = (-0.8,+0.3)

Reduction Table

Process	2f_l	2f_h	4f_l	4f_sl	4f_h	aa_2f	Ch	aa_4f	ae3f	BG	Signal	Signf	
Cross Section	6773.07	19625.1	10566.2	13232.1	8648.64	2.6771e+06	906.095	26.0064	261580	2.99845e+06	280.839	0	
Generated	949500	2.3467e+06	5.58174e+06	1.2138e+06	704600	7.17376e+07	1.35308e+06	8300	2.26291e+07	1.06524e+08	622651	622651	
Expected	3.38654e+06	9.81253e+06	5.28308e+06	6.61606e+06	4.32432e+06	1.33855e+09	453047	13003.2	1.3079e+08	1.49923e+09	140420	140420	3.62639
Cut0	2.1489e+06	6.05387e+06	2.42023e+06	4.22121e+06	3.19932e+06	1.845e+09	131918	0	4.83904e+07	1.91156e+09	50331.3	50331.3	1.15117
Cut1	369688	117.74	199206	211.807	0	9.34249e+08	2966.99	0	1.15692e+07	9.46391e+08	4663.82	4663.82	0.151602
Cut2	338190	79.246	130429	148.07	0	5.11411e+06	2950.05	0	553509	6.13941e+06	4633.7	4633.7	1.86939
Cut3	331497	0	119800	78.4665	0	5.04102e+06	1678.23	0	541496	6.03557e+06	3077.96	3077.96	1.25254
Cut4	126906	0	64248.8	12.5796	0	2.99956e+06	1617.35	0	283772	3.47612e+06	2988.86	2988.86	1.6024
Cut5	4416.64	0	10725.2	12.5796	0	47962.8	186.86	0	64277.9	127582	2184.45	2184.45	6.06403
Cut6	678.292	0	5960.91	0	0	37247.9	186.842	0	20496.5	64570.5	2182.38	2182.38	8.44688
Cut7	31.2224	0	2313.23	0	0	320.312	186.842	0	245.5	3097.11	2182.38	2182.38	30.0355
Cut8	13.7132	0	2209.25	0	0	21.8171	181.678	0	80.5	2506.96	2159.05	2159.05	31.6075
Cut9	13.7132	0	1224.07	0	0	21.8171	181.678	0	80.5	1521.78	2159.05	2159.05	35.5869
Cut10	6.28661	0	674.558	0	0	4.91819	179.124	0	80.5	945.386	2159.05	2159.05	38.75

ILC2 Cut Table: N1N2 right polarization, mumu

Cut10 : 227.708 161.488 1150.5 30.9906

Polarization: (e-,e+) = (+0.8,-0.3)

Reduction Table

Process	2f_l	2f_h	4f_l	4f_sl	4f_h	aa_2f	Ch	aa_4f	ae3f	BG	Signal	Signf	
Cross Section	5960.13	11663.4	7482.28	2943.64	741.331	2.6771e+06	233.28	26.0064	254270	2.96042e+06	223.035	0	
Generated	949500	2.3467e+06	5.58174e+06	1.2138e+06	704600	7.17376e+07	1.35308e+06	8300	2.26291e+07	1.06524e+08	622651	622651	
Expected	2.98006e+06	5.83168e+06	3.74114e+06	1.47182e+06	370665	1.33855e+09	116640	13003.2	1.27135e+08	1.48021e+09	111517	111517	2.89844
Cut0	1.90282e+06	3.36716e+06	1.71042e+06	935367	275567	1.845e+09	68230.8	0	4.81962e+07	1.90145e+09	40214.2	40214.2	0.922213
Cut1	155831	731.52	152570	481.142	0	8.71657e+08	2212.32	0	2.19218e+07	8.93891e+08	5157.25	5157.25	0.172494
Cut2	147362	588.141	67418.6	161.676	0	5.41902e+06	2198.83	0	962865	6.59961e+06	5125.45	5125.45	1.99436
Cut3	139500	12.5799	36595.1	13.2896	0	3.32467e+06	571.971	0	522469	4.02383e+06	1303.49	1303.49	0.649705
Cut4	98183	12.5799	21306.4	6.24784	0	2.14954e+06	564.997	0	286895	2.5565e+06	1300.3	1300.3	0.813039
Cut5	4821.3	6.28997	5094.61	6.24784	0	24449.2	23.3857	0	67420.9	101822	1163.47	1163.47	3.62549
Cut6	4118.03	6.28997	1031.78	0	0	19882.9	23.0801	0	20482.2	45544.3	1163.37	1163.37	5.383
Cut7	0.770192	0	200.774	0	0	99.0678	23.0801	0	410.06	733.752	1163.37	1163.37	26.7098
Cut8	0	0	155.016	0	0	33.6364	22.1379	0	142.529	353.32	1150.5	1150.5	29.6681
Cut9	0	0	108.715	0	0	33.6364	22.1379	0	142.529	307.019	1150.5	1150.5	30.1357
Cut10	0	0	75.9479	0	0	0	21.7311	0	130.029	227.708	1150.5	1150.5	30.9906

ILC1 Cut Table: N1N2 left polarization, mumu

Polarization: (e-,e+) = (-0.8,+0.3)

Reduction Table

Process	2f_l	2f_h	4f_l	4f_sl	4f_h	aa_2f	Ch	aa_4f	ae3f	BG	Signal	Signf	
Cross Section	6773.07	19625.1	10566.2	13232.1	8648.64	2.6771e+06	1065.17	26.0064	261580	2.99861e+06	300.791	0	
Generated	949500	2.3467e+06	5.58174e+06	1.2138e+06	704600	7.17376e+07	2.33207e+06	8300	2.26291e+07	1.07503e+08	1.0963e+06	1.0963e+06	
Expected	3.38654e+06	9.81253e+06	5.28308e+06	6.61606e+06	4.32432e+06	1.33855e+09	532585	13003.2	1.3079e+08	1.49931e+09	150395	150395	3.8839
Cut0	1.84022e+06	62768.8	1.46378e+06	1.98579e+06	430258	1.845e+09	6227.38	0	4.83904e+07	1.89918e+09	16478.1	16478.1	0.378114
Cut1	185899	0.376323	89936.7	12.9538	0	8.71657e+08	2425.99	0	2.19281e+07	8.93864e+08	2121.19	2121.19	0.0709487
Cut2	176420	0.376323	62927.4	12.9538	0	5.41902e+06	2410.6	0	965354	6.62614e+06	2105.07	2105.07	0.817649
Cut3	175961	0.376323	54146.6	12.9538	0	1.35498e+06	1985.79	0	295459	1.88255e+06	1804.44	1804.44	1.3145
Cut4	120835	0.376323	32485.6	0.373803	0	895478	1950	0	167734	1.21848e+06	1749.98	1749.98	1.5842
Cut5	5708.39	0.376323	3408.47	0.373803	0	3496.68	21.7669	0	33867	46503.1	1530.26	1530.26	6.98221
Cut6	4935.45	0.376323	1656.45	0	0	2188.4	21.7669	0	4743.09	13545.5	1527.48	1527.48	12.4416
Cut7	6.4366	0	795.253	0	0	33.6364	20.6055	0	23	878.932	1520.51	1520.51	31.0408
Cut8	0	0	785.559	0	0	33.6364	19.4559	0	9.00002	847.652	1515.69	1515.69	31.1779
Cut9	0	0	500.845	0	0	33.6364	19.4559	0	9.00002	562.937	1515.69	1515.69	33.2447
Cut10	0	0	374.054	0	0	33.6364	19.4559	0	9.00002	436.147	1515.69	1515.69	34.3075

ILC2 Cut Table: N1N2 left polarization, ee

Cut10 : 945.386 36.1696 2159.05 38.75

Polarization: (e-,e+) = (-0.8,+0.3)

Reduction Table

Process	2f_l	2f_h	4f_l	4f_sl	4f_h	aa_2f	Ch	aa_4f	ae3f	BG	Signal	Signf	
Cross Section :	6773.07	19625.1	10566.2	13232.1	8648.64	2.6771e+06	906.095	26.0064	261580	2.99845e+06	280.839	0	
Generated :	949500	2.3467e+06	5.58174e+06	1.2138e+06	704600	7.17376e+07	1.35308e+06	8300	2.26291e+07	1.06524e+08	622651	622651	
Expected :	3.38654e+06	9.81253e+06	5.28308e+06	6.61606e+06	4.32432e+06	1.33855e+09	453047	13003.2	1.3079e+08	1.49923e+09	140420	140420	3.62639
Cut0 :	2.1489e+06	6.05387e+06	2.42023e+06	4.22121e+06	3.19932e+06	1.845e+09	131918	0	4.83904e+07	1.91156e+09	50331.3	50331.3	1.15117
Cut1 :	369688	117.74	199206	211.807	0	9.34249e+08	2966.99	0	1.15692e+07	9.46391e+08	4663.82	4663.82	0.151602
Cut2 :	338190	79.246	130429	148.07	0	5.11411e+06	2950.05	0	553509	6.13941e+06	4633.7	4633.7	1.86939
Cut3 :	331497	0	119800	78.4665	0	5.04102e+06	1678.23	0	541496	6.03557e+06	3077.96	3077.96	1.25254
Cut4 :	126906	0	64248.8	12.5796	0	2.99956e+06	1617.35	0	283772	3.47612e+06	2988.86	2988.86	1.6024
Cut5 :	4416.64	0	10725.2	12.5796	0	47962.8	186.86	0	64277.9	127582	2184.45	2184.45	6.06403
Cut6 :	678.292	0	5960.91	0	0	37247.9	186.842	0	20496.5	64570.5	2182.38	2182.38	8.44688
Cut7 :	31.2224	0	2313.23	0	0	320.312	186.842	0	245.5	3097.11	2182.38	2182.38	30.0355
Cut8 :	13.7132	0	2209.25	0	0	21.8171	181.678	0	80.5	2506.96	2159.05	2159.05	31.6075
Cut9 :	13.7132	0	1224.07	0	0	21.8171	181.678	0	80.5	1521.78	2159.05	2159.05	35.5869
Cut10 :	6.28661	0	674.558	0	0	4.91819	179.124	0	80.5	945.386	2159.05	2159.05	38.75

ILC2 Cut Table: N1N2 right polarization, ee

Cut10 : 347.065 29.6525 1766.12 38.4195

Polarization: (e-,e+) = (+0.8,-0.3)

Reduction Table

Process	2f_l	2f_h	4f_l	4f_sl	4f_h	aa_2f	Ch	aa_4f	ae3f	BG	Signal	Signf	
Cross Section :	5960.13	11663.4	7482.28	2943.64	741.331	2.6771e+06	233.28	26.0064	254270	2.96042e+06	223.035	0	
Generated :	949500	2.3467e+06	5.58174e+06	1.2138e+06	704600	7.17376e+07	1.35308e+06	8300	2.26291e+07	1.06524e+08	622651	622651	
Expected :	2.98006e+06	5.83168e+06	3.74114e+06	1.47182e+06	370665	1.33855e+09	116640	13003.2	1.27135e+08	1.48021e+09	111517	111517	2.89844
Cut0 :	1.90282e+06	3.36716e+06	1.71042e+06	935367	275567	1.845e+09	68230.8	0	4.81962e+07	1.90145e+09	40214.2	40214.2	0.922213
Cut1 :	348952	82.2538	136959	254.47	0	9.34249e+08	1537.28	0	1.15507e+07	9.46288e+08	3726.21	3726.21	0.121131
Cut2 :	318859	67.4158	68865.8	158.293	0	5.11411e+06	1528.65	0	553112	6.0567e+06	3701.47	3701.47	1.50357
Cut3 :	312250	0	60446	41.4731	0	5.04102e+06	876.676	0	541542	5.95617e+06	2488.21	2488.21	1.01933
Cut4 :	117226	0	28217	0.752627	0	2.99956e+06	851.716	0	284195	3.43005e+06	2419.18	2419.18	1.30576
Cut5 :	4331.67	0	6379.33	0.752627	0	47962.8	103.15	0	64222	123000	1786.5	1786.5	5.05731
Cut6 :	681.173	0	1788.44	0	0	37247.9	102.845	0	20533.5	60353.9	1783.83	1783.83	7.15608
Cut7 :	35.4134	0	407.908	0	0	320.312	102.845	0	324.5	1190.98	1783.83	1783.83	32.7057
Cut8 :	6.27674	0	313.128	0	0	21.8171	101.013	0	89.5	531.735	1766.12	1766.12	36.8434
Cut9 :	6.27674	0	217.76	0	0	21.8171	101.013	0	89.5	436.367	1766.12	1766.12	37.6326
Cut10 :	0.376122	0	151.715	0	0	4.91819	100.556	0	89.5	347.065	1766.12	1766.12	38.4195

ILC1 Cut Table: N1N2 left polarization, ee

Cut10 : 930.921 35.0004 1998.89 36.9291

Polarization: (e-,e+) = (-0.8,+0.3)

Reduction Table

Process	2f_l	2f_h	4f_l	4f_sl	4f_h	aa_2f	Ch	aa_4f	ae3f	BG	Signal	Signf	
Cross Section	6773.07	19625.1	10566.2	13232.1	8648.64	2.6771e+06	1065.17	26.0064	261580	2.99861e+06	300.791	0	
Generated	949500	2.3467e+06	5.58174e+06	1.2138e+06	704600	7.17376e+07	2.33207e+06	8300	2.26291e+07	1.07503e+08	1.0963e+06	1.0963e+06	
Expected	3.38654e+06	9.81253e+06	5.28308e+06	6.61606e+06	4.32432e+06	1.33855e+09	532585	13003.2	1.3079e+08	1.49931e+09	150395	150395	3.8839
Cut0	1.84022e+06	62768.8	1.46378e+06	1.98579e+06	430258	1.845e+09	6227.38	0	4.83904e+07	1.89918e+09	16478.1	16478.1	0.378114
Cut1	370709	7.90279	202605	232.557	0	9.34249e+08	3491.12	0	1.15692e+07	9.46396e+08	3829.66	3829.66	0.124487
Cut2	339108	7.15014	131982	161.026	0	5.11411e+06	3468.38	0	553509	6.14234e+06	3796.34	3796.34	1.53131
Cut3	326820	0	109309	53.7053	0	4.05147e+06	3056.24	0	446325	4.93703e+06	2721.13	2721.13	1.22432
Cut4	124943	0	58984.8	6.28981	0	2.54505e+06	2950.29	0	242702	2.97463e+06	2611.06	2611.06	1.51325
Cut5	3756.07	0	9005.42	6.28981	0	29306.4	82.7328	0	54031.4	96188.3	2020.56	2020.56	6.44759
Cut6	495.138	0	5388.26	0	0	22010.1	82.4337	0	15209	43184.9	2017.23	2017.23	9.48802
Cut7	9.70654	0	2064.4	0	0	208.738	77.8352	0	133	2493.68	2007.8	2007.8	29.9256
Cut8	1.13998	0	2021.29	0	0	16.8989	75.2367	0	27.5	2142.06	1999.13	1999.13	31.0655
Cut9	1.13998	0	1050.45	0	0	16.8989	75.2367	0	27.5	1171.23	1998.89	1998.89	35.5019
Cut10	0	0	811.285	0	0	16.8989	75.2367	0	27.5	930.921	1998.89	1998.89	36.9291

ILC2 Cut Table: C1C1 left polarization, mu tag

Polarization: (e-,e+) = (-0.8,+0.3)

Reduction Table

Process	2f_l	2f_h	4f_l	4f_sl	4f_h	aa_2f	N1N2	aa_4f	ae3f	BG	Signal	Signf	
Cross Section :	6773.07	19625.1	10566.2	13232.1	8648.64	2.6771e+06	280.839	26.0064	261580	2.99783e+06	906.095	0	
Generated :	949500	2.3467e+06	5.58174e+06	1.2138e+06	704600	7.17376e+07	622651	8300	2.26291e+07	1.05794e+08	1.35308e+06	1.35308e+06	
Expected :	3.38654e+06	9.81253e+06	5.28308e+06	6.61606e+06	4.32432e+06	1.33855e+09	140420	13003.2	1.3079e+08	1.49891e+09	453047	453047	11.7001
Cut0 :	2.97791e+06	8.92902e+06	3.0183e+06	6.29276e+06	4.18404e+06	1.34285e+09	0	0	1.23824e+08	1.49208e+09	183479	183479	4.74967
Cut1 :	215888	810057	2.19699e+06	440342	219030	1.18992e+06	0	0	860560	5.93279e+06	14217.9	14217.9	5.83025
Cut2 :	144855	232428	2.19234e+06	418755	62421.7	587577	0	0	639364	4.27774e+06	9309.7	9309.7	4.49631
Cut3 :	19467.9	18229.3	2.08897e+06	69424.5	253.387	116934	0	0	131973	2.44525e+06	3728.56	3728.56	2.38259
Cut4 :	276.316	312.952	2.04942e+06	46427.5	0	760.468	0	0	2331.05	2.09952e+06	1075.35	1075.35	0.741958
Cut5 :	142.317	107.041	2.04899e+06	34910.3	0	195.135	0	0	536.501	2.08488e+06	659.507	659.507	0.456677
Cut6 :	60.1868	9.30082	2.04838e+06	62.8483	0	163.127	0	0	57	2.04874e+06	658.22	658.22	0.459789
Cut7 :	14.0019	0.376323	2.04823e+06	12.5737	0	4.20718	0	0	0	2.04826e+06	657.357	657.357	0.459239
Cut8 :	13.2494	0	2.04823e+06	6.2839	0	4.20718	0	0	0	2.04826e+06	656.934	656.934	0.458944
Cut9 :	13.2494	0	2.04823e+06	6.2839	0	4.20718	0	0	0	2.04826e+06	656.909	656.909	0.458354

```
if (iZDecayMode == 13) {  //Zmumu mode
  cut1  = "leptype==13&&nLeps1==1&&nBCAL==0";
  cut2 = "Ptmis>7";  // "jet_pt1>2 && jet_pt2>5";//&&Ptmis>10";
  cut3 = "jet_cop<1.0";
  cut4 = "abs(jet_costheta1)<0.95&&abs(jet_costheta2)<0.95&&nTrack2>1&&(jet_nTrack-nTrack2)>1";
  //    cut4 = "abs(jet_costheta1)<0.95&&abs(jet_costheta2)<0.95&&jet_pt1>1 && jet_pt2>1&&nTrack2>1&&(jet_nTrack-nTrack2)>1";
  cut5  = "cosJJlep<0.2&&cosJlep2<0";
  cut6  = "(Evis-Ephotonmax)<60" ;//Evis<40,17
  cut7  = "Emis>400" ;
  cut8 =  "abs(cosmis)<0.98";
  cut9 = "ptjj<50";
  //abs(jet_coll) < 0.98&&ptjj<50";
  //&&(Elep1+Elep2)>35";
  cut10 = "jj_mass < 15";//130
  //cut10 = "jj_e < 230";
```

ILC2 Cut Table: C1C1 right polarization, mu tag

Polarization: (e-,e+) = (+0.8,-0.3)

Reduction Table

Process	2f_l	2f_h	4f_l	4f_sl	4f_h	aa_2f	N1N2	aa_4f	ae3f	BG	Signal	Signf	
Cross Section :	5960.13	11663.4	7482.28	2943.64	741.331	2.6771e+06	223.035	26.0064	254270	2.96041e+06	233.28	0	
Generated :	949500	2.3467e+06	5.58174e+06	1.2138e+06	704600	7.17376e+07	622651	8300	2.26291e+07	1.05794e+08	1.35308e+06	1.35308e+06	
Expected :	2.98006e+06	5.83168e+06	3.74114e+06	1.47182e+06	370665	1.33855e+09	111517	13003.2	1.27135e+08	1.4802e+09	116640	116640	3.03158
Cut0 :	2.63307e+06	5.20654e+06	1.77488e+06	1.37424e+06	358554	1.34285e+09	0	0	1.70482e+08	1.52468e+09	94891.2	94891.2	2.43009
Cut1 :	176641	533942	1.68588e+06	70585.4	18470.4	1.18992e+06	0	0	1.29565e+06	4.97109e+06	7376.6	7376.6	3.30604
Cut2 :	116679	149108	1.68477e+06	59829.7	5680	587577	0	0	963034	3.56668e+06	4840.02	4840.02	2.56107
Cut3 :	15284.8	12303.1	1.67218e+06	11734	46.316	116934	0	0	205874	2.03436e+06	1911.44	1911.44	1.3395
Cut4 :	223.302	307.027	1.66781e+06	5614.12	0	760.468	0	0	970.673	1.67568e+06	529.063	529.063	0.408642
Cut5 :	127.565	112.951	1.66772e+06	3147.78	0	195.135	0	0	233.5	1.67154e+06	329.683	329.683	0.254974
Cut6 :	41.1958	50.6961	1.66765e+06	30.4428	0	163.127	0	0	93	1.66803e+06	329.301	329.301	0.254946
Cut7 :	19.6352	6.28997	1.66763e+06	0.752273	0	4.20718	0	0	0	1.66767e+06	328.945	328.945	0.254698
Cut8 :	7.05852	0	1.66763e+06	0.37596	0	4.20718	0	0	0	1.66765e+06	328.92	328.92	0.25468
Cut9 :	7.05852	0	1.66763e+06	0.37596	0	4.20718	0	0	0	1.66765e+06	328.869	328.869	0.254641
Cut10 :	0	0	1.66763e+06	0	0	0.999997	0	0	0	1.66764e+06	311.082	311.082	0.240871

```
if (iZDecayMode == 13) {  //Zmumu mode
  cut1  = "leptype==13&&nLeps1==1&&nBCAL==0";
  cut2 = "Ptmis>7";  // "jet_pt1>2 && jet_pt2>5";//&&Ptmis>10";
  cut3 = "jet_cop<1.0";
  cut4 = "abs(jet_costheta1)<0.95&&abs(jet_costheta2)<0.95&&nTrack2>1&&(jet_nTrack-nTrack2)>1";
  //    cut4 = "abs(jet_costheta1)<0.95&&abs(jet_costheta2)<0.95&&jet_pt1>1 && jet_pt2>1&&nTrack2>1&&(jet_nTrack-nTrack2)>1";
  cut5  = "cosJJlep<0.2&&cosJlep2<0";
  cut6  = "(Evis-Ephotonmax)<60" ;//Evis<40,17
  cut7  = "Emis>400" ;
  cut8 =  "abs(cosmis)<0.98";
  cut9 = "ptjj<50";
  //abs(jet_coll) < 0.98&&ptjj<50";
  //&&(Elep1+Elep2)>35";
  cut10 = "jj_mass < 15";//130
  //cut10 = "jj_e < 230";
```

ILC2 Cut Table: C1C1 left polarization, e tag

```
Cut10 :      2.04823e+06      1685.15       556.602       0.388863
Polarization: (e-,e+) = (-0.8,+0.3)
```

Reduction Table

Process	:	2f_l	2f_h	4f_l	4f_sl	4f_h	aa_2f	N1N2	aa_4f	ae3f	BG	Signal	Signf	
Cross Section	:	6773.07	19625.1	10566.2	13232.1	8648.64	2.6771e+06	280.839	26.0064	261580	2.99783e+06	906.095	0	
Generated	:	949500	2.3467e+06	5.58174e+06	1.2138e+06	704600	7.17376e+07	622651	8300	2.26291e+07	1.05794e+08	1.35308e+06	1.35308e+06	
Expected	:	3.38654e+06	9.81253e+06	5.28308e+06	6.61606e+06	4.32432e+06	1.33855e+09	140420	13003.2	1.3079e+08	1.49891e+09	453047	453047	11.7001
Cut0	:	2.97791e+06	8.92902e+06	3.0183e+06	6.29276e+06	4.18404e+06	1.34285e+09	0	0	1.23824e+08	1.49208e+09	183479	183479	4.74967
Cut1	:	265865	230025	2.18272e+06	270277	65378	4.69081e+06	0	0	6.68666e+06	1.43917e+07	8298.58	8298.58	2.18686
Cut2	:	160005	96429.9	2.18134e+06	257536	29874.4	2.96822e+06	0	0	5.74779e+06	1.14412e+07	6558.75	6558.75	1.93848
Cut3	:	24943.3	5657.27	2.06899e+06	46334.9	100.966	693575	0	0	1.80149e+06	4.6411e+06	3108.73	3108.73	1.44254
Cut4	:	382.466	194.352	2.04875e+06	32554.3	0	68667.2	0	0	312067	2.46262e+06	771.343	771.343	0.491452
Cut5	:	335.994	97.7404	2.04847e+06	27340.6	0	50124.8	0	0	265287	2.39165e+06	579.83	579.83	0.374886
Cut6	:	27.3275	6.29023	2.0483e+06	21.1283	0	21643.2	0	0	11707.3	2.0817e+06	579.408	579.408	0.401527
Cut7	:	7.18905	0	2.04823e+06	6.28981	0	0	0	0	0	2.04824e+06	578.967	578.967	0.404484
Cut8	:	7.18905	0	2.04823e+06	0	0	0	0	0	0	2.04823e+06	578.948	578.948	0.404472
Cut9	:	7.18905	0	2.04823e+06	0	0	0	0	0	0	2.04823e+06	578.948	578.948	0.404472

```
if (iZDecayMode == 13) {  //Zmumu mode
  cut1  = "leptype==13&&nLeps1==1&&nBCAL==0";
  cut2 = "Ptmis>7";  // "jet_pt1>2 && jet_pt2>5";//&&Ptmis>10";
  cut3 = "jet_cop<1.0";
  cut4 = "abs(jet_costheta1)<0.95&&abs(jet_costheta2)<0.95&&nTrack2>1&&(jet_nTrack-nTrack2)>1";
  //    cut4 = "abs(jet_costheta1)<0.95&&abs(jet_costheta2)<0.95&&jet_pt1>1 && jet_pt2>1&&nTrack2>1&&(jet_nTrack-nTrack2)>1";
  cut5  = "cosJJlep<0.2&&cosJlep2<0";
  cut6  = "(Evis-Ephotonmax)<60" ;//Evis<40,17
  cut7  = "Emis>400" ;
  cut8 =  "abs(cosmis)<0.98";
  cut9 = "ptjj<50";
  //abs(jet_coll) < 0.98&&ptjj<50";
  //&&(Elep1+Elep2)>35";
  cut10 = "jj_mass < 15";//130
  //cut10 = "jj_e < 230";
```

ILC2 Cut Table: C1C1 right polarization, e tag

Polarization: (e-,e+) = (+0.8,-0.3)

Reduction Table

Process		2f_l	2f_h	4f_l	4f_sl	4f_h	aa_2f	N1N2	aa_4f	ae3f	BG	Signal	Signf	
Cross Section	:	5960.13	11663.4	7482.28	2943.64	741.331	2.6771e+06	223.035	26.0064	254270	2.96041e+06	233.28	0	
Generated	:	949500	2.3467e+06	5.58174e+06	1.2138e+06	704600	7.17376e+07	622651	8300	2.26291e+07	1.05794e+08	1.35308e+06	1.35308e+06	
Expected	:	2.98006e+06	5.83168e+06	3.74114e+06	1.47182e+06	370665	1.33855e+09	111517	13003.2	1.27135e+08	1.4802e+09	116640	116640	3.03158
Cut0	:	2.63307e+06	5.20654e+06	1.77488e+06	1.37424e+06	358554	1.34285e+09	0	0	1.70482e+08	1.52468e+09	94891.2	94891.2	2.43009
Cut1	:	243855	151696	1.68048e+06	53021.3	5527.38	4.69081e+06	0	0	8.56541e+06	1.53908e+07	4265.16	4265.16	1.08704
Cut2	:	142563	62978.7	1.68024e+06	43662.7	2700.96	2.96822e+06	0	0	7.49421e+06	1.23946e+07	3351.61	3351.61	0.951872
Cut3	:	22746.5	4149.08	1.66998e+06	9044.84	12.2397	693575	0	0	2.33334e+06	4.73285e+06	1597.22	1597.22	0.73406
Cut4	:	312.69	105.64	1.66771e+06	3634.58	0	68667.2	0	0	206941	1.94737e+06	382.664	382.664	0.274189
Cut5	:	265.245	62.2548	1.66766e+06	2575.44	0	50124.8	0	0	189651	1.91034e+06	286.24	286.24	0.207082
Cut6	:	32.9641	0.376339	1.66765e+06	25.516	0	21643.2	0	0	13499.6	1.70285e+06	286.214	286.214	0.219314
Cut7	:	12.9618	0	1.66763e+06	0.376313	0	0	0	0	0	1.66765e+06	285.883	285.883	0.22136
Cut8	:	12.9618	0	1.66763e+06	0	0	0	0	0	0	1.66765e+06	285.578	285.578	0.221124
Cut9	:	12.9618	0	1.66763e+06	0	0	0	0	0	0	1.66765e+06	285.578	285.578	0.221124

```
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  //abs(jet_coll) < 0.98&&ptjj<50";
  //&&(Elep1+Elep2)>35";
  cut10 = "jj_mass < 15";//130
  //cut10 = "jj_e < 230";
```

ILC1 Cut Table: C1C1 left polarization, mu-tag

Polarization: (e-,e+) = (-0.8,+0.3)

Reduction Table

Process	2f_l	2f_h	4f_l	4f_sl	4f_h	aa_2f	N1N2	aa_4f	ae3f	BG	Signal	Signf	
Cross Section :	6773.07	19625.1	10566.2	13232.1	8648.64	2.6771e+06	300.791	26.0064	261580	2.99785e+06	1065.17	0	
Generated :	949500	2.3467e+06	2.84884e+06	1.9401e+06	704600	7.17376e+07	1.0963e+06	8300	2.26291e+07	1.04261e+08	2.33207e+06	2.33207e+06	
Expected :	3.38654e+06	9.81253e+06	5.28308e+06	6.61606e+06	4.32432e+06	1.33855e+09	150395	13003.2	1.3079e+08	1.49892e+09	532585	532585	13.7538
Cut0 :	2.5406e+06	0	3.21083e+06	1.6053e+06	1463	1.34285e+09	6448.59	0	1.23824e+08	1.47404e+09	139638	139638	3.63688
Cut1 :	166279	0	2.05938e+06	12369.8	121.502	1.18992e+06	1135.45	0	860560	4.28976e+06	57982.8	57982.8	27.8078
Cut2 :	116859	0	2.03424e+06	6042.91	32.1319	465397	964.755	0	519208	3.14274e+06	38240.3	38240.3	21.4408
Cut3 :	24514.9	0	1.82201e+06	838.307	0	83683.4	530.5	0	109325	2.04091e+06	26085.4	26085.4	18.1438
Cut4 :	507.2	0	1.75586e+06	541.814	0	554.622	22.288	0	2234.05	1.75972e+06	14611.8	14611.8	10.9695
Cut5 :	345.949	0	1.75524e+06	514.594	0	131.168	0	0	511.501	1.75674e+06	14307.6	14307.6	10.7511
Cut6 :	152.933	0	1.75387e+06	6.28999	0	100.16	0	0	41	1.75417e+06	14295.4	14295.4	10.7497
Cut7 :	20.8147	0	1.75325e+06	0	0	3.20718	0	0	0	1.75327e+06	14230.5	14230.5	10.7039
Cut8 :	20.8147	0	1.75325e+06	0	0	3.20718	0	0	0	1.75327e+06	14229.6	14229.6	10.7032
Cut9 :	20.8147	0	1.75325e+06	0	0	3.20718	0	0	0	1.75327e+06	14180.9	14180.9	10.6667

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Cu
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```
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   //&&(Elep1+Elep2)>35";
   cut10 = "jj_mass < 15";//130
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```

Mass Precisions (individual channels)

√s = 500 GeV

L = 500 fb^{-1}

Convert precisions of kinematic edges to those of Higgsino masses

MN1: χ^0_1 mass MN2: χ^0_2 mass MC1: $\chi^\pm_1$ mass

Neutralino: 1 – 2%

polarization		MN1	MN2	ΔMN1	ΔMN1/MN1	ΔMN2	ΔMN2/MN2
left	mm	102.26	123.02	1.77	**1.7%**	1.76	**1.4%**
left	ee	100.30	120.81	2.17	**2.2%**	2.15	**1.8%**
right	mm	103.06	123.99	1.82	**1.8%**	1.81	**1.5%**
right	ee	103.41	124.30	1.44	**1.4%**	1.43	**1.1%**

Chargino: left pol is better than 1%

～ 2 times better than right pol

polarzation		MN1	MC1	ΔMN1	ΔMN1/MN1	ΔMC1	ΔMC1/MC1
left	mu tag	113.50	129.14	0.82	**0.7%**	0.82	**0.6%**
left	e tag	122.96	140.37	1.19	**1.0%**	1.18	**0.8%**
right	mu tag	116.42	132.44	1.76	**1.5%**	1.75	**1.3%**
right	e tag	125.34	142.98	2.20	**1.8%**	2.18	**1.5%**

Theoretic values MN1 = 102.70 GeV MN2 = 123.98 GeV, MC1 = 117.33 GeV

Chargino Search