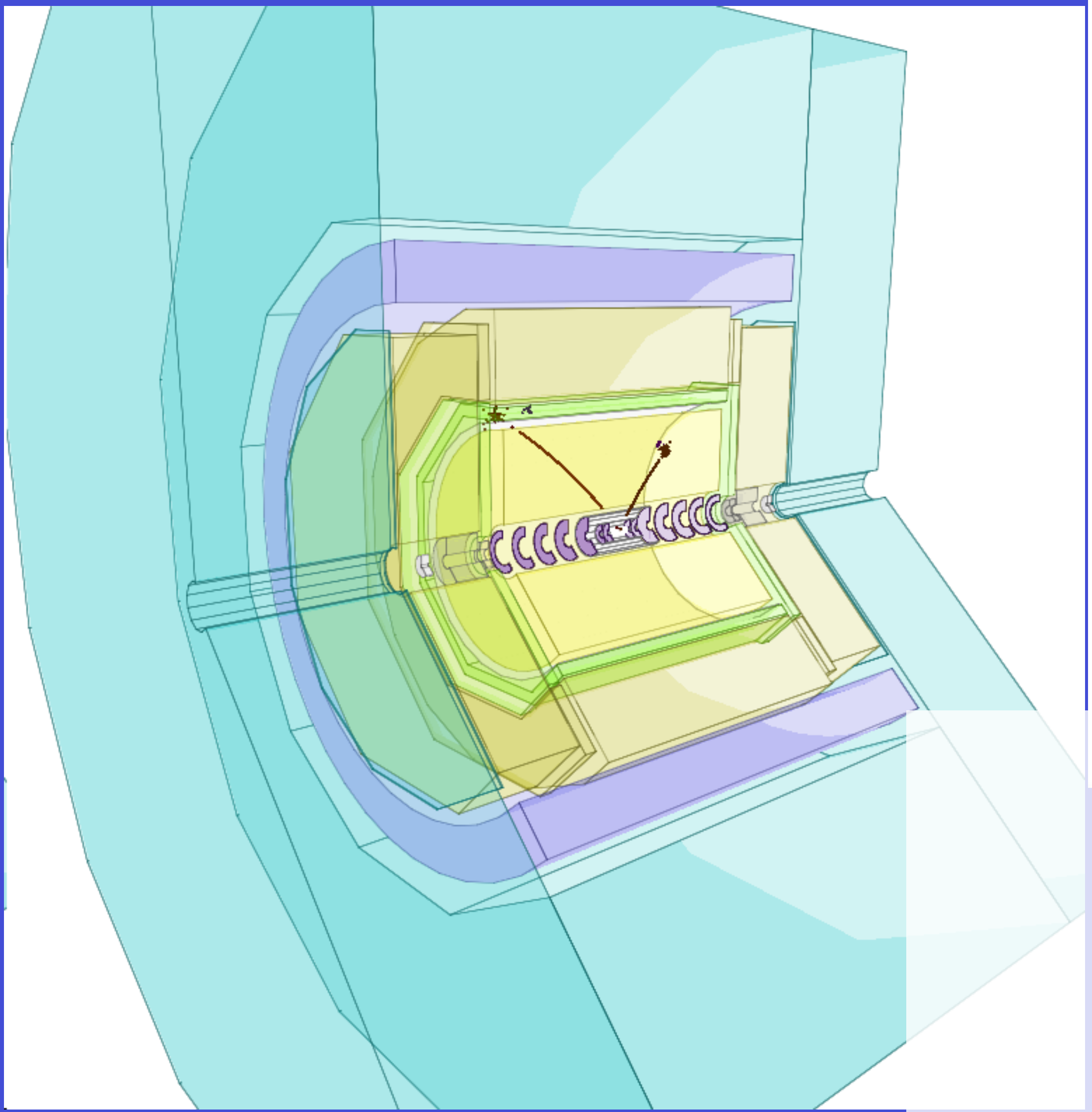
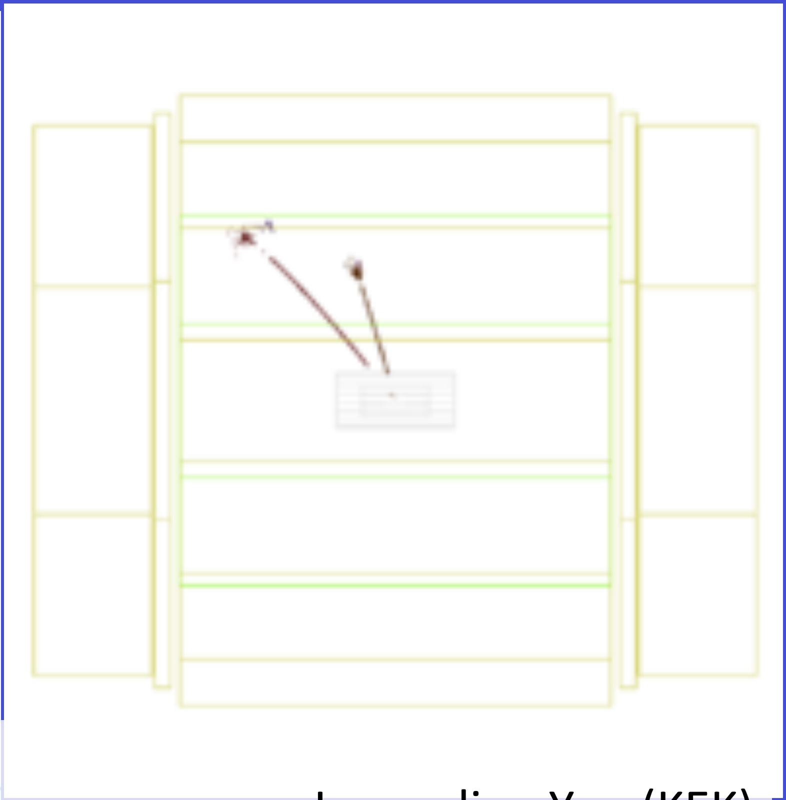
Characterizing Light Higgsinos from Natural SUSY at ILC $\sqrt{s}$ = 500 GeV





Jacqueline Yan (KEK)

The 48th General Meeting

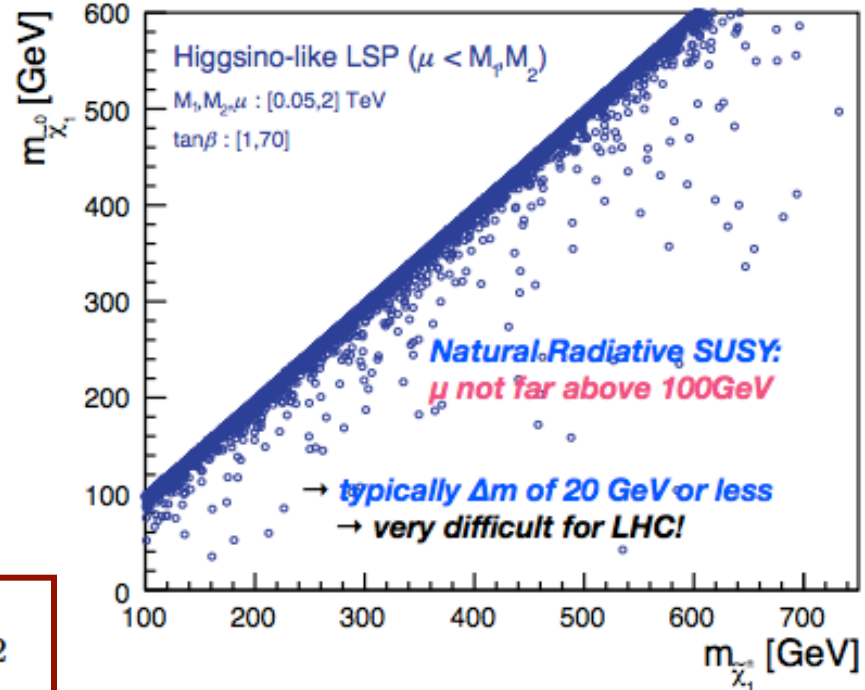
of the ILC Physics Subgroup

9/10/2016

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]

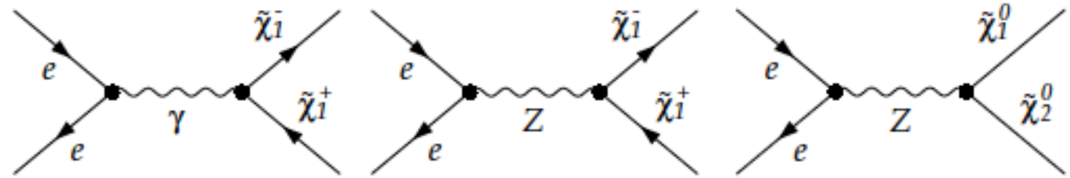
$$\frac{M_Z^2}{2} = \frac{m_{H_d}^2 + \Sigma_d^d - (m_{H_u}^2 + \Sigma_u^u)\tan^2\beta}{\tan^2\beta - 1} - \mu^2$$

- 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)

Benchmarks in this Study



RNS model (Radiatively-driven natural SUSY)

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

- **ΔM about 10-20 GeV complies with naturalness** (ISR tag not needed)

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

Currently studying ILC1 benchmark

(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

BR($\chi_1^+ \rightarrow \chi_1^0 qq'$)	67%
BR($\chi_1^+ \rightarrow \chi_1^0 l\nu$) (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%

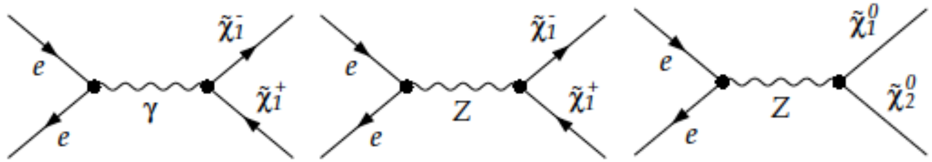
NUHM2 model parameters [arXiv:1404.7510]

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

Higgs precision measurements useful for parameter determination

Defined at GUT scale
Defined at weak scale
Observables

Goal of Light Higgsino Study



This study

Demonstrate measurement precision of Higgsino masses and production cross sections

- **Study dependence of cross section on beam polarization**
  → Determine mixing ratio
  Higgsino vs. Bino vs. Wino

Masses and cross sections as input →

Determine SUSY parameters
e.g. **M_1, M_2, μ, tanβ**

S.-L. Lehtinen et al

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

How?
- **Global χ^2 fit of to observables**

Study input parameters and required precision for parameter extraction; interplay with Higgs precision measurements

Existing studies

(1) "Tackling light higgsinos at the ILC", M. Berggren et al. [arXiv:1307.3566]
- √s= 500 GeV, ΔM ∼1 GeV → use ISR tag, , Based on full ILD simulation

(2) "Physics at a Higgsino Factory", H. Baer et al. [arXiv:1404.7510]
- √s= 250 (340) GeV for ILC1 (ILC2), ΔM = 10-20 GeV, detector effects based on resolution formula

Ongoing studies

Light Higgsinos with ΔM= 10 – 20 GeV , J. Yan, T. Tanabe et al

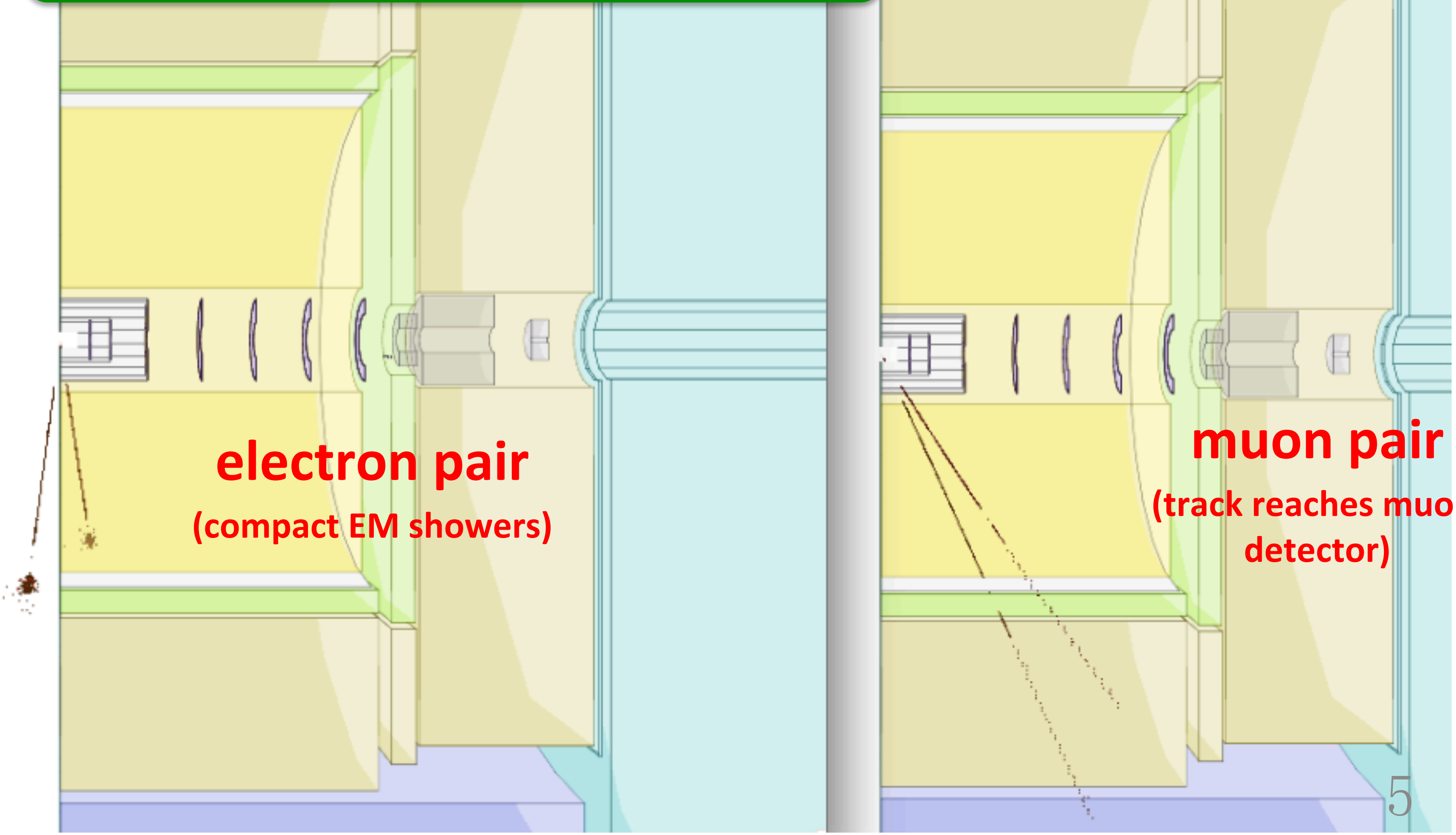
√s= 500 GeV, ΔM ∼10-20 GeV , Based on full ILD simulation

How do these signals look in the detector? (1)

√s =500 GeV

Neutralino mixed production with leptonic decay

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

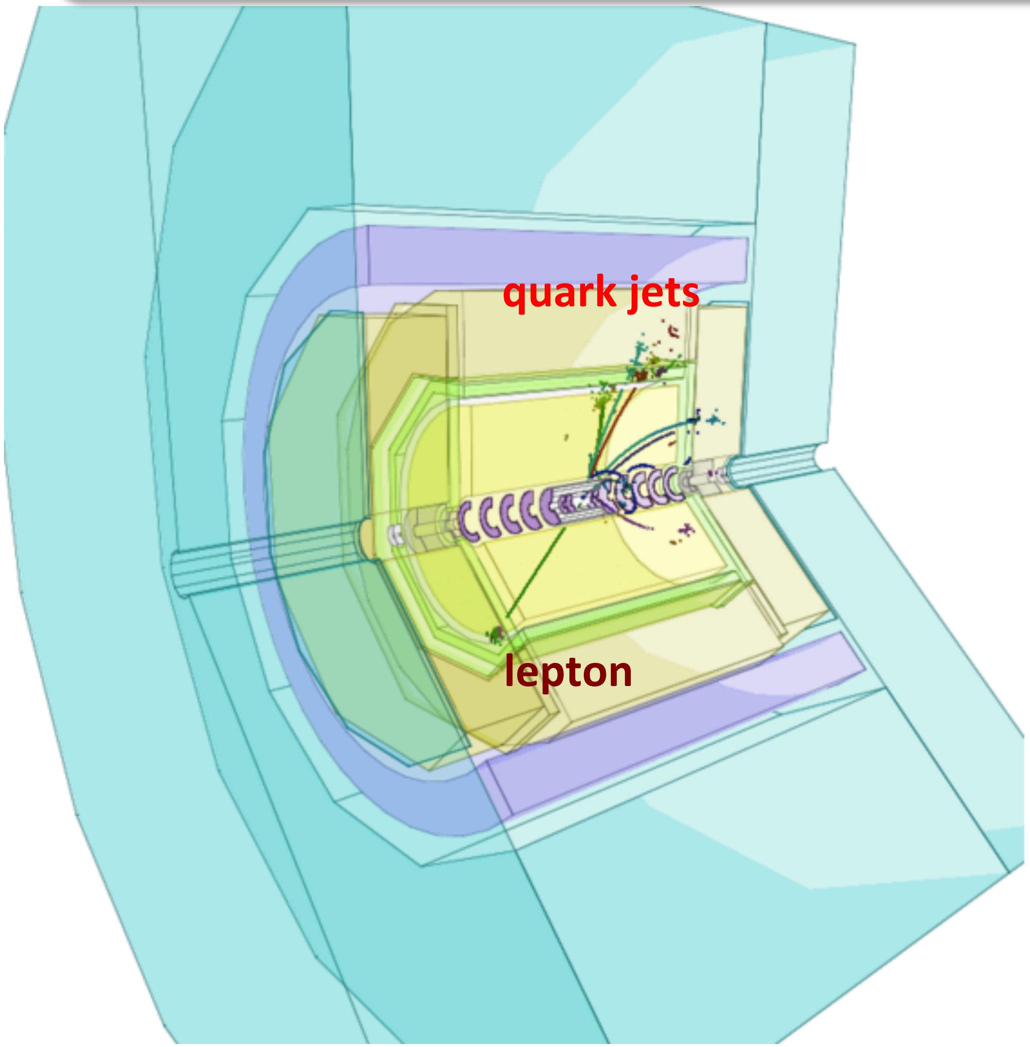


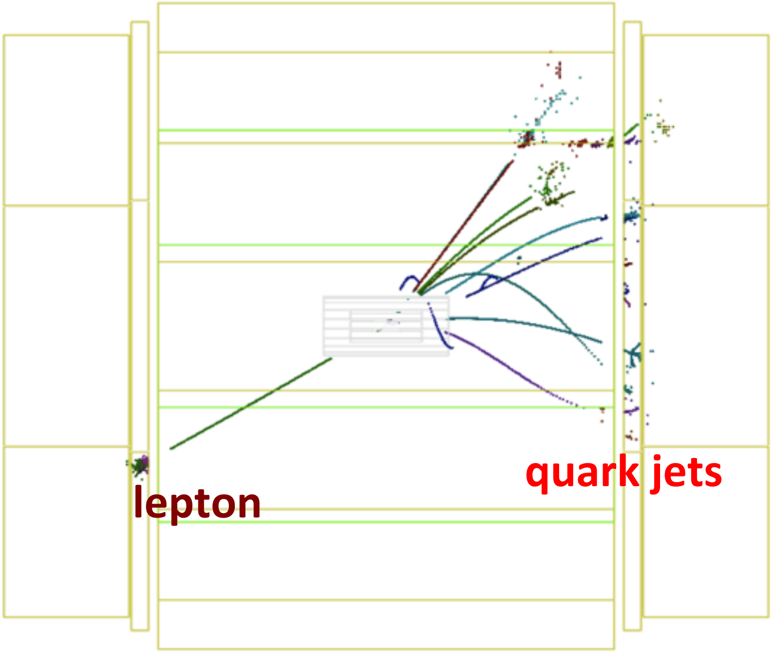
How do these signals look in the detector? (2)

√s =500 GeV

Chargino pair production with semileptonic decay

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



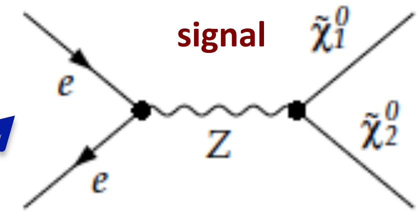


Event Selection

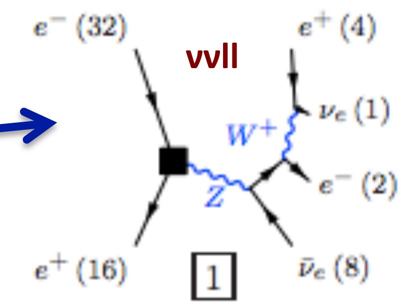
Neutralino mixed production with leptonic decay

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

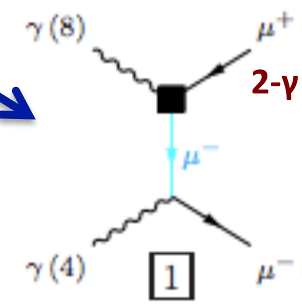
- Reconstruct **two leptons (ee or μμ) which originate from Z^* emission in decay of χ_2^0 to χ_1^0**



- Major residual bkg. are 4f processes accompanied by large missing energy (vvll)



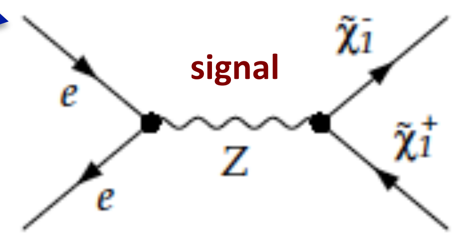
- 2-γ processes are removed by BeamCal veto, cuts on lepton track p_T, and coplanarity



Chargino pair production with semileptonic decay

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

- 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.

Extraction of Higgsino Mass

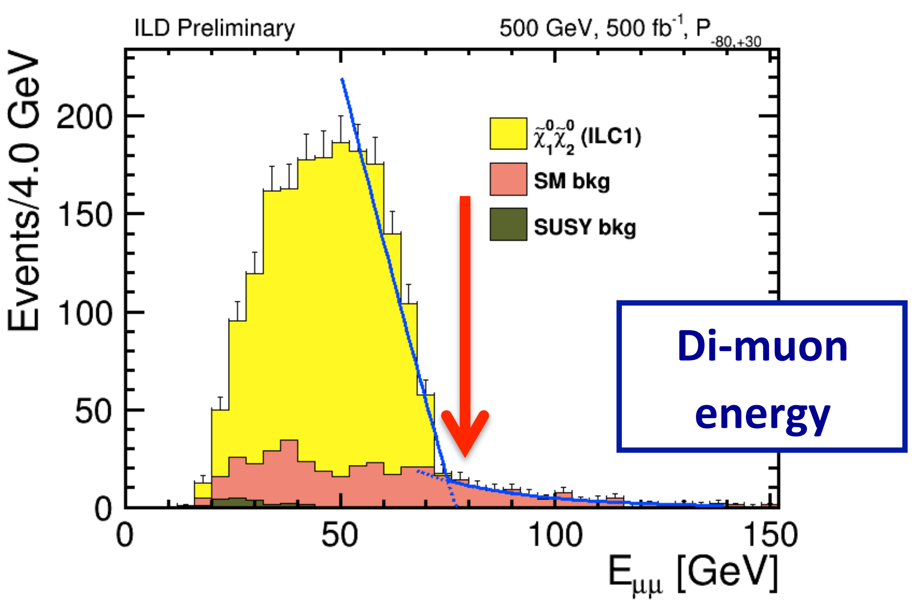
Neutralino mixed production with leptonic decay

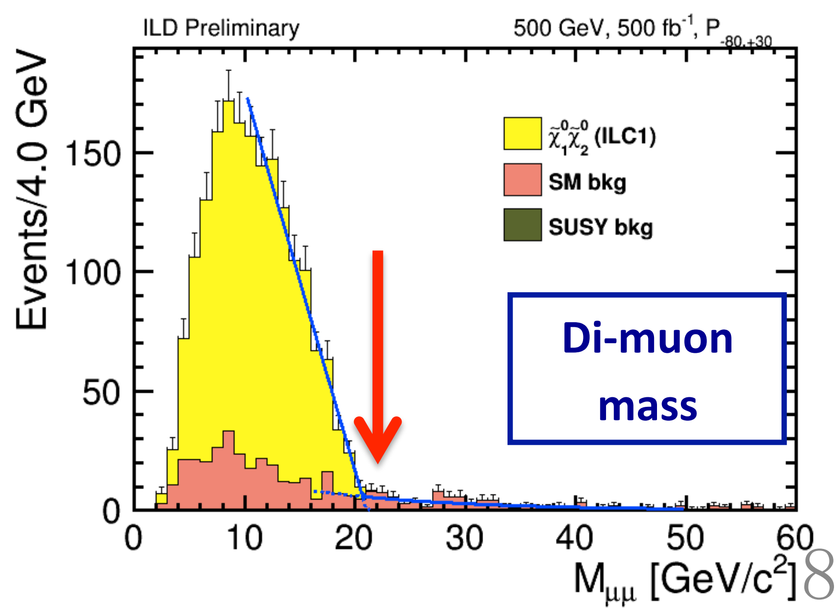
$$e^+e^- \to \tilde{\chi}_1^0 \tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \tilde{\chi}_1^0 \ell^+ \ell^-$$

- 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.
- $E_{ll,max}$ and $M_{ll,max}$ are extracted by a fit to obtain the neutralino masses

  need correction 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

Outline of Today’s Talk

- Motivation

- Analysis Methods

- Current results

  Now have a full set of preliminary results for all channels

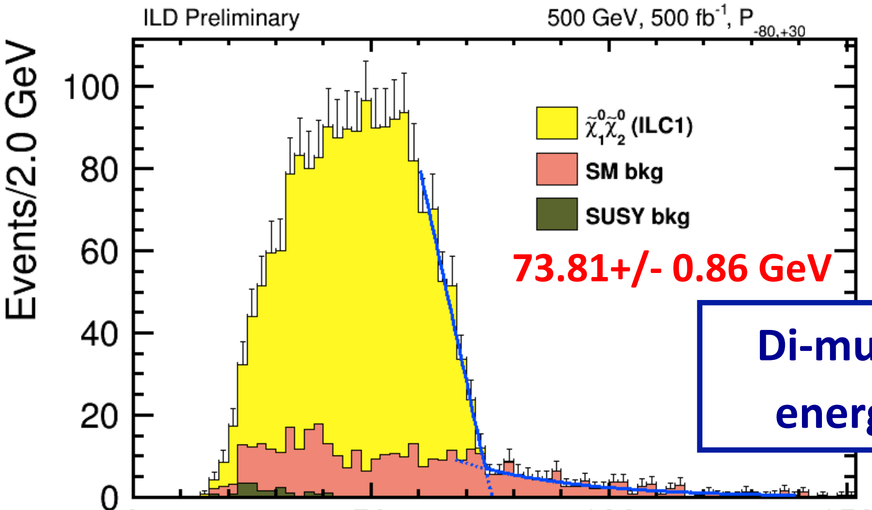
- Conclusion and Plans

Neutralino mixed production with leptonic decay

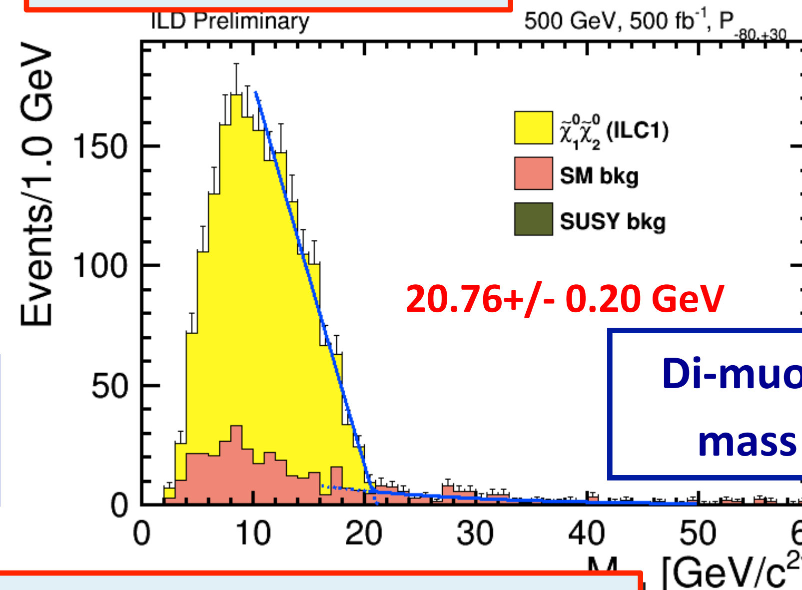
$$e^+e^- \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 \ell^+ \ell^-$$

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

Edge precision ～ 1 %

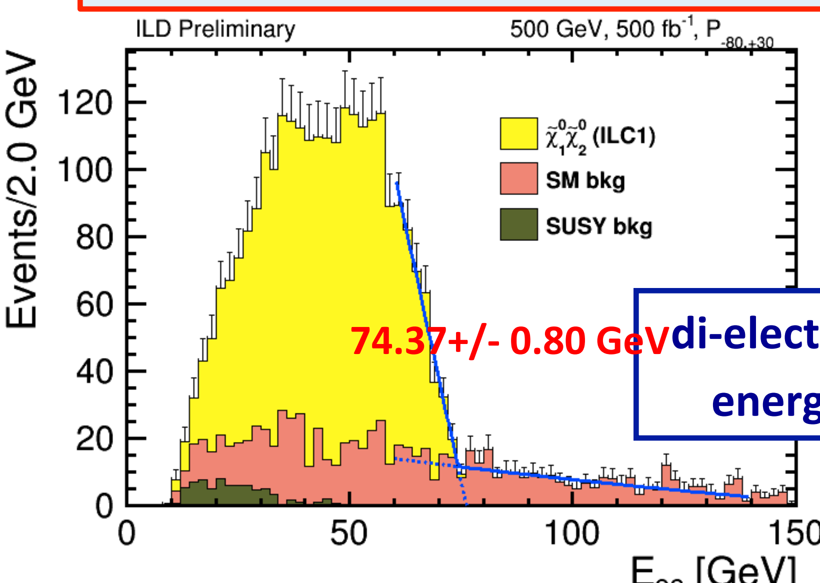


Di-muon energy

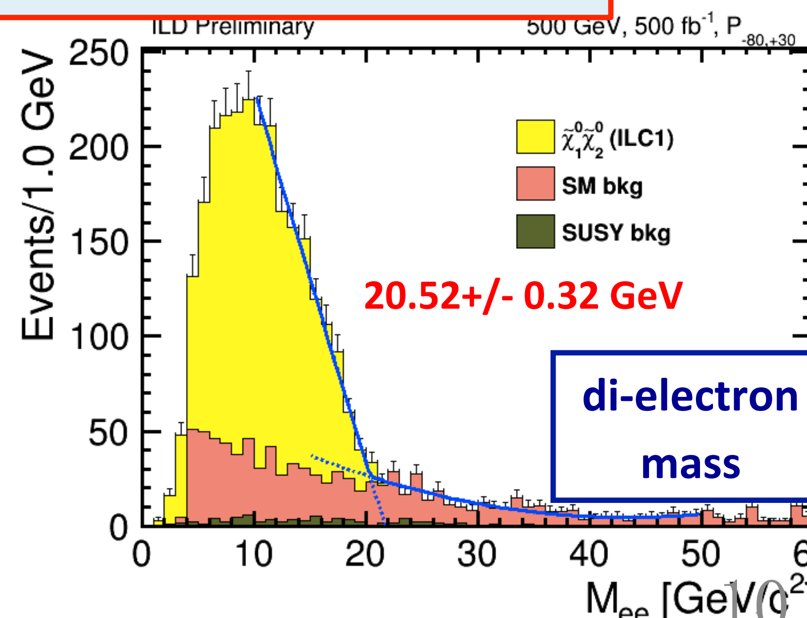


Di-muon mass

Theoretical values: E_max = 74.9 GeV ΔM = 21.3 GeV



di-electron energy



di-electron mass

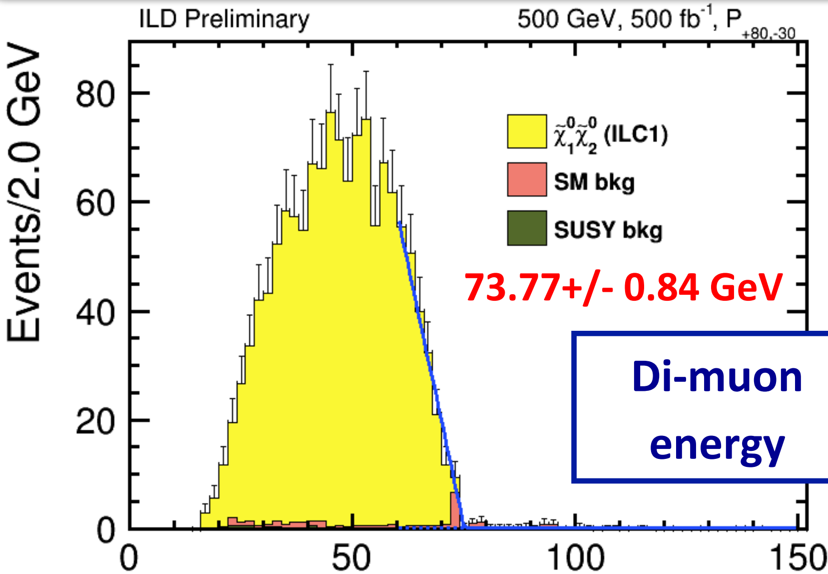
Neutralino mixed production with leptonic decay

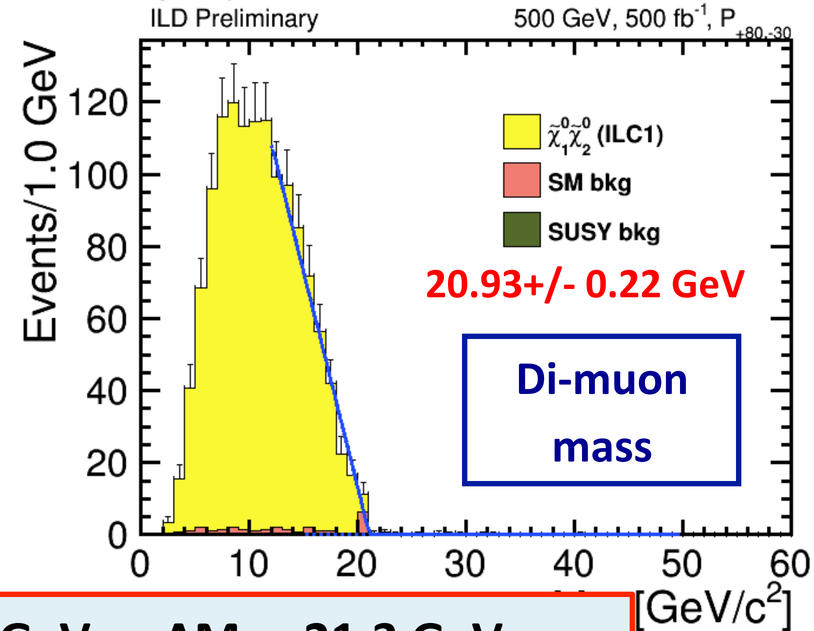
$$e^+e^- \rightarrow \tilde{\chi}_1^0\,\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0\ell^+\ell^-$$

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

Much less bkg
Precision slightly better

Edge precision < ~ 1 %





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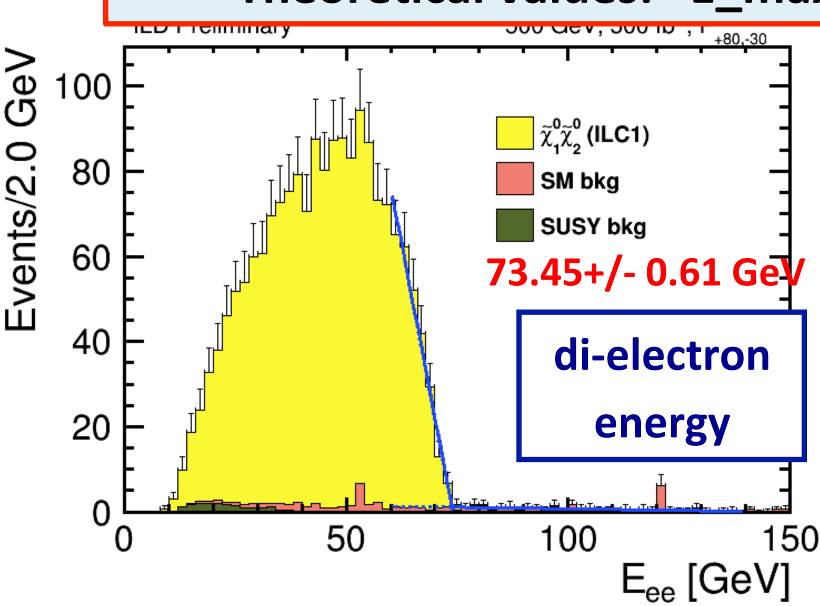
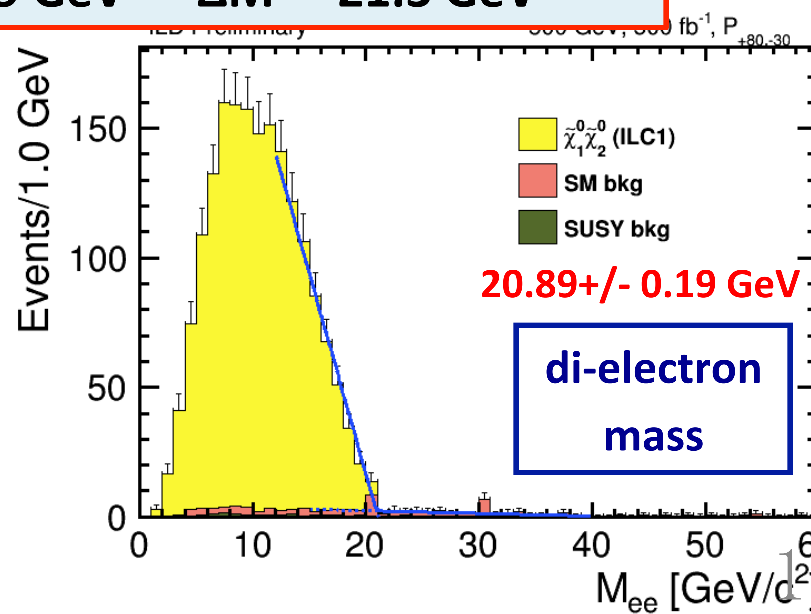


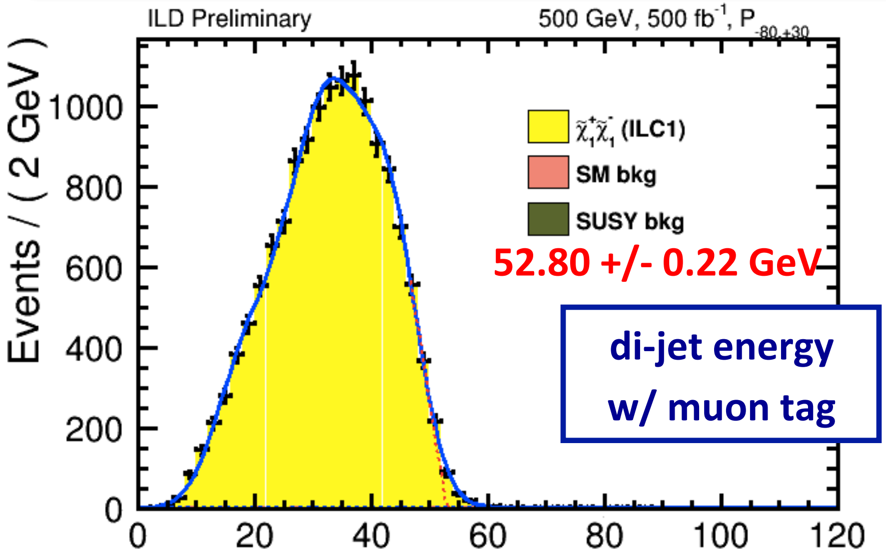


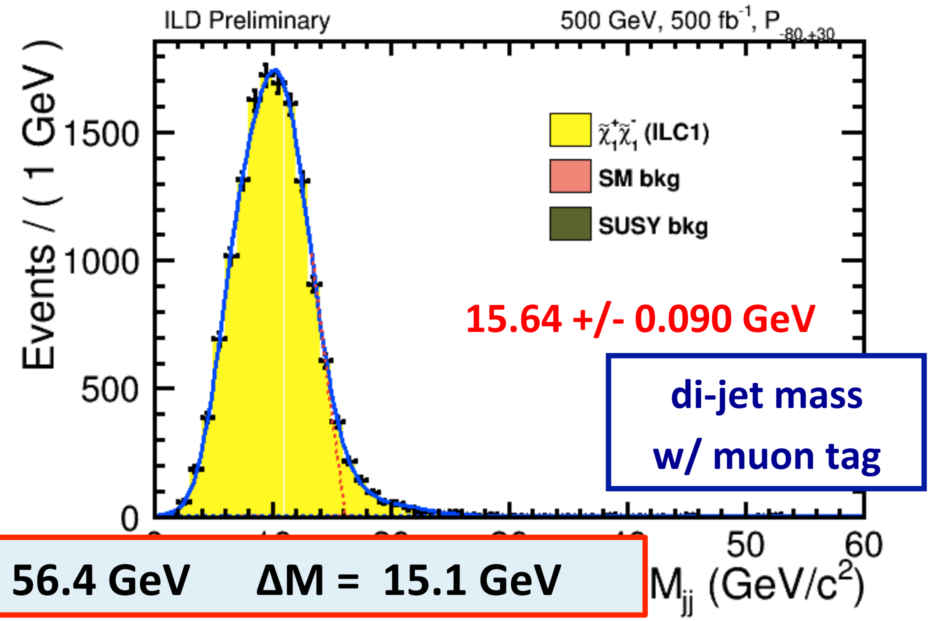
Chargino pair production with semileptonic decay

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

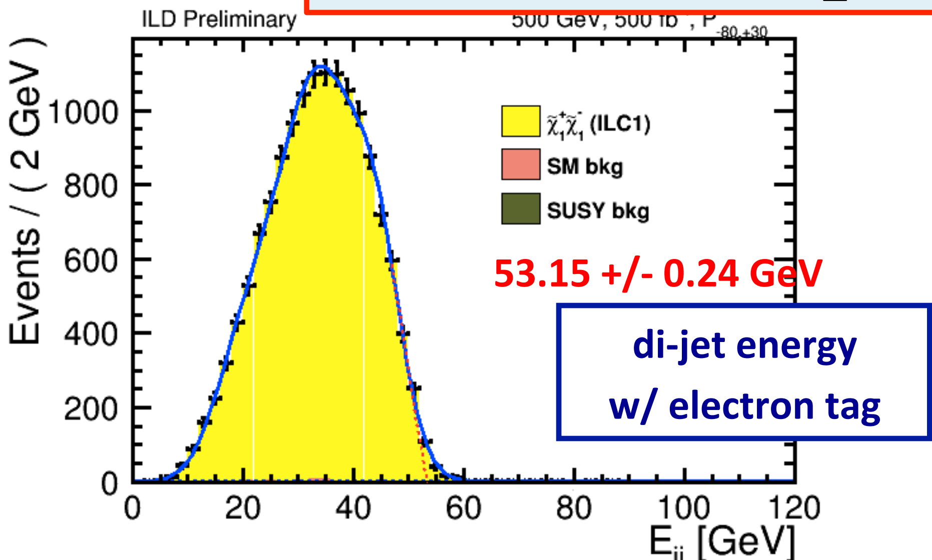
Left Polarization **(Pe-,Pe+) = (-0.8, +0.3)**

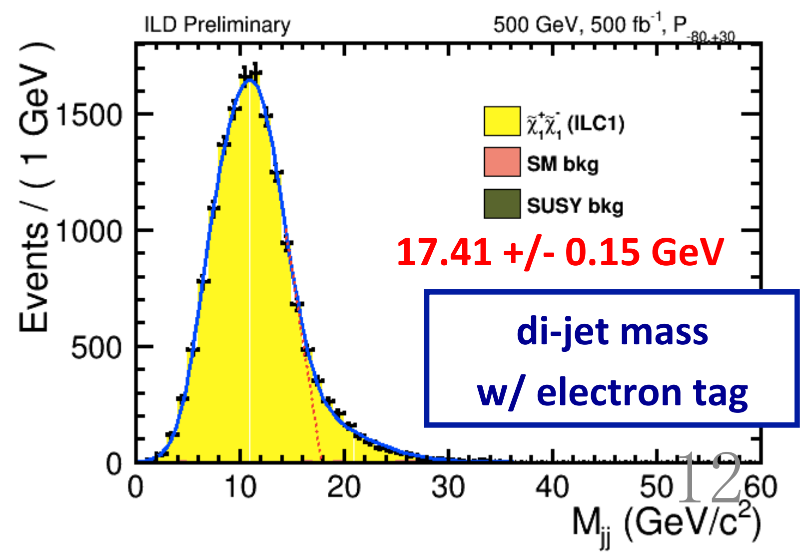
Almost all bkg rejected





Theoretical values: E_max = 56.4 GeV ΔM = 15.1 GeV



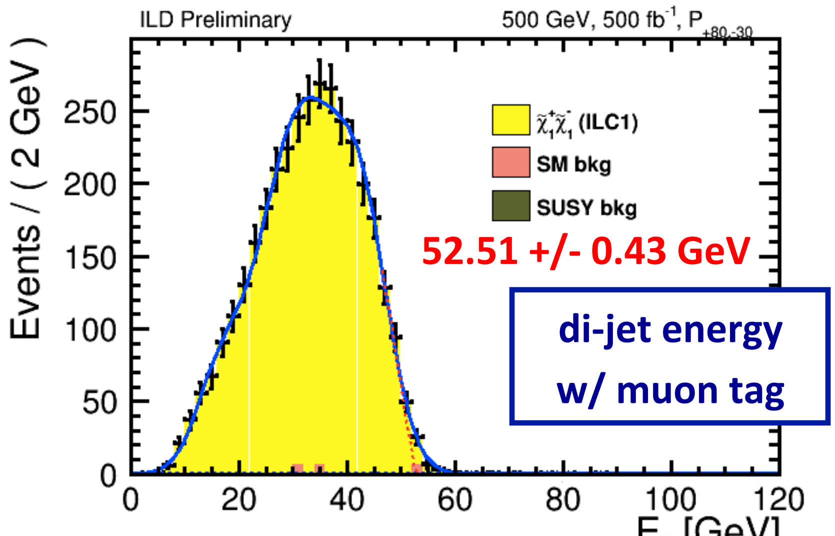


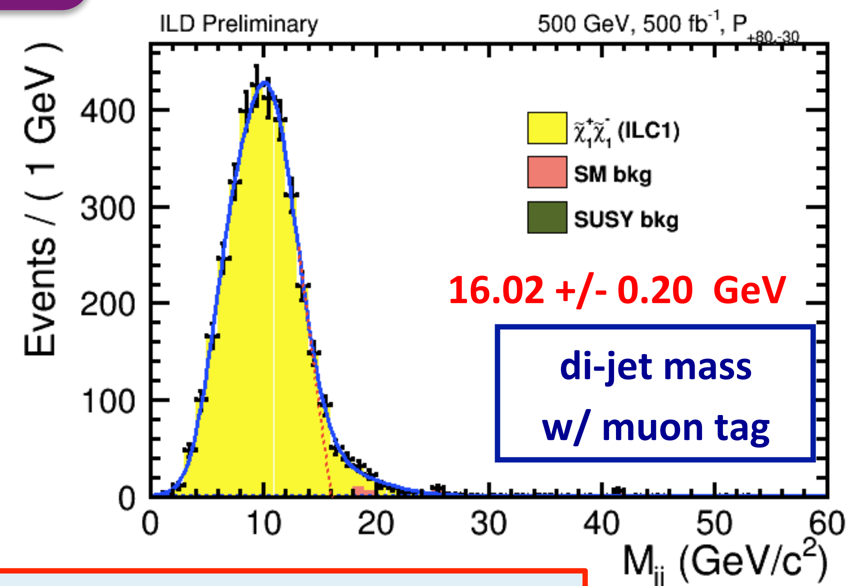
Chargino pair production with semileptonic decay

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

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

Cross section ~ 1/5 of left polarization





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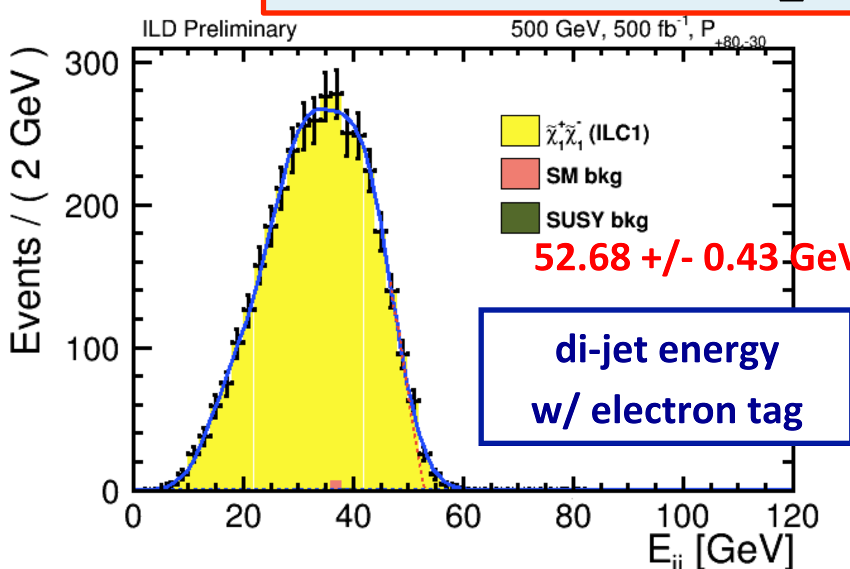
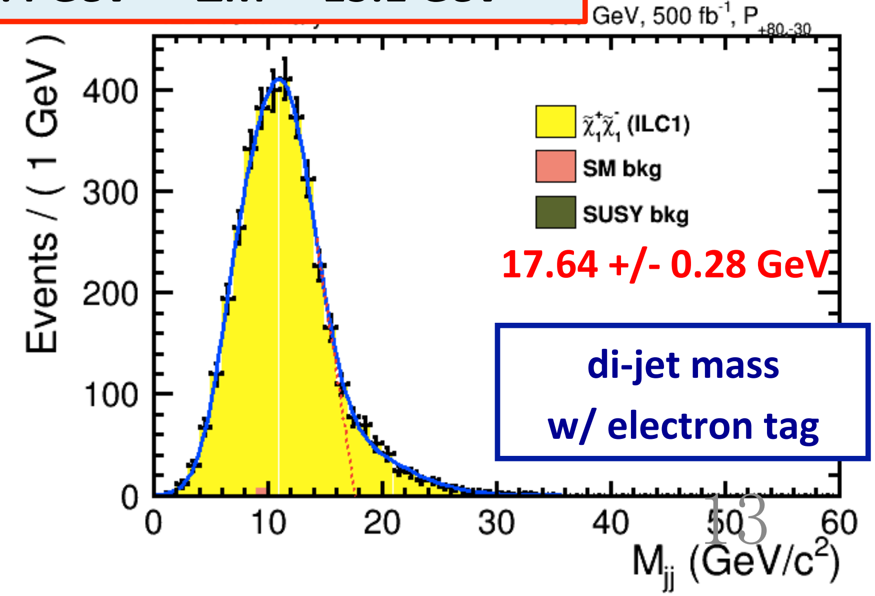
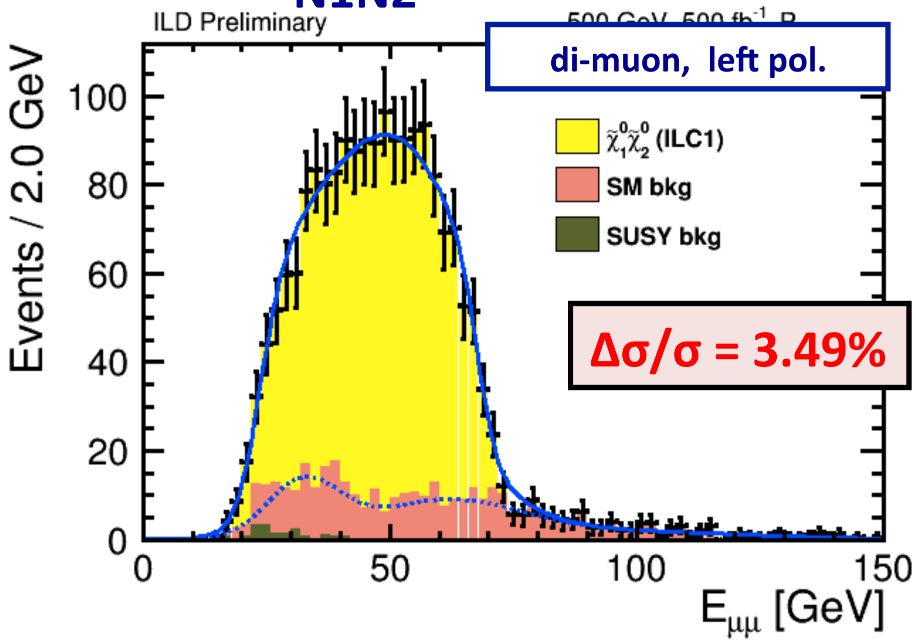


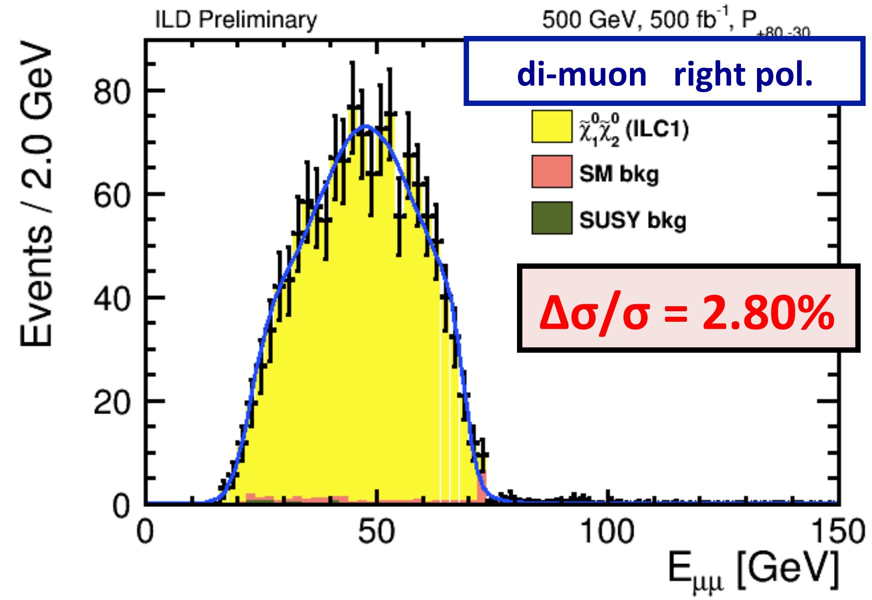


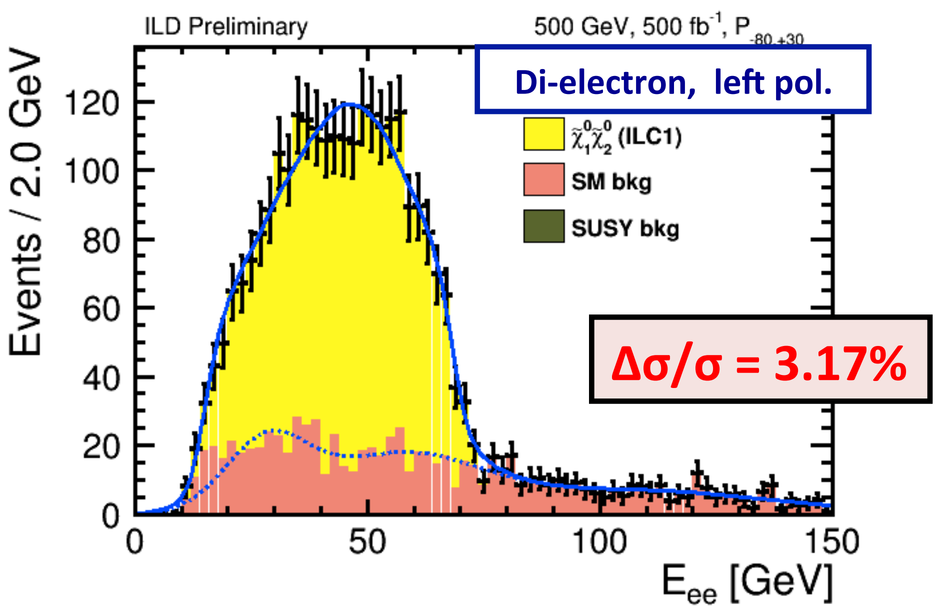
Extraction of Cross Section

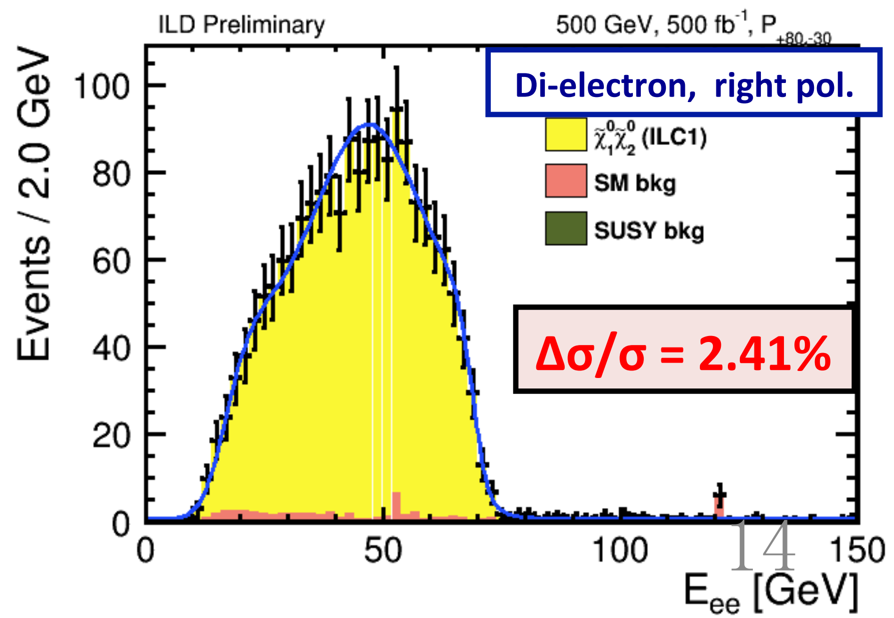
N1N2

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



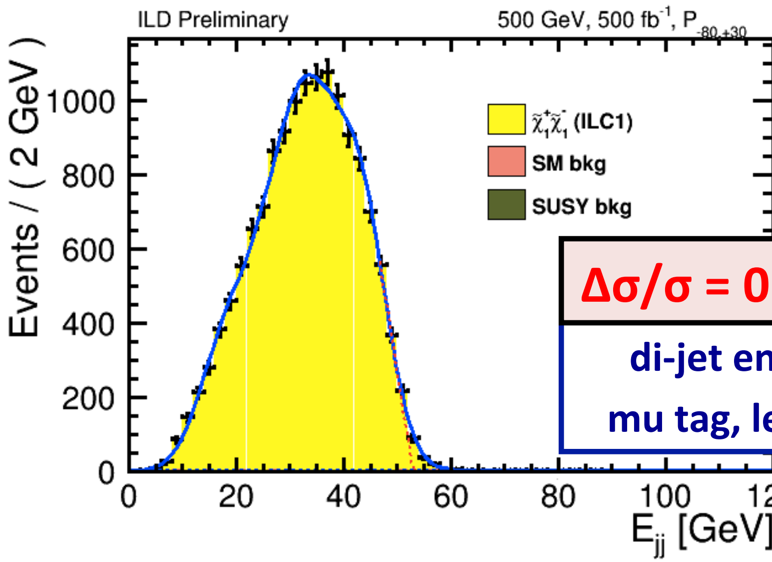






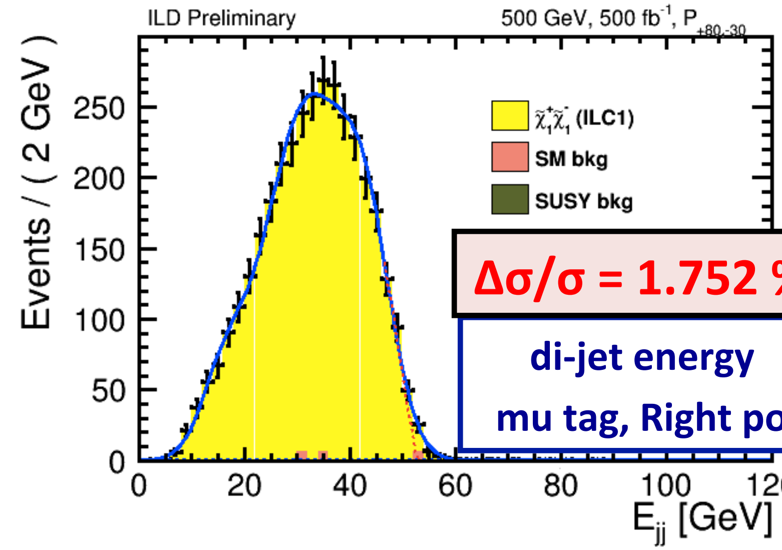
Extraction of Cross Section C1C1

- Left pol has x2 better precision
- dependent on statistics



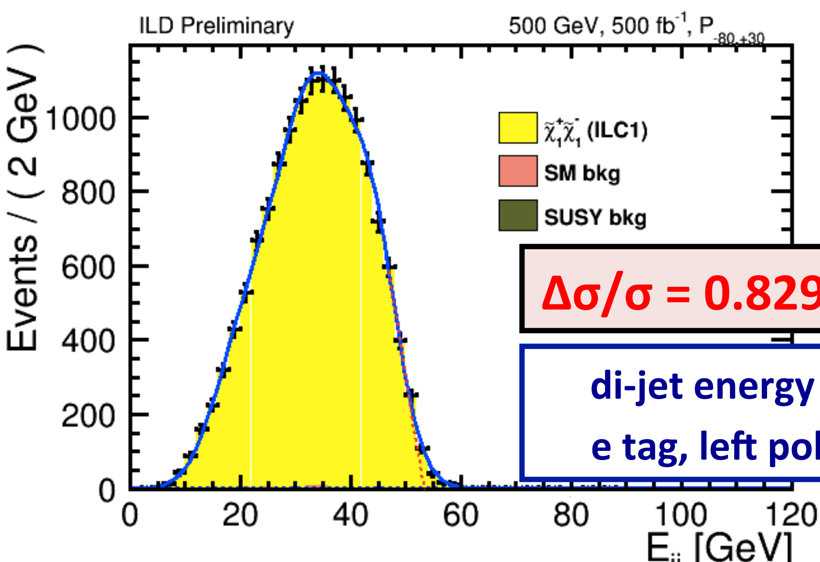
Δσ/σ = 0.851 %

di-jet energy
mu tag, left pol



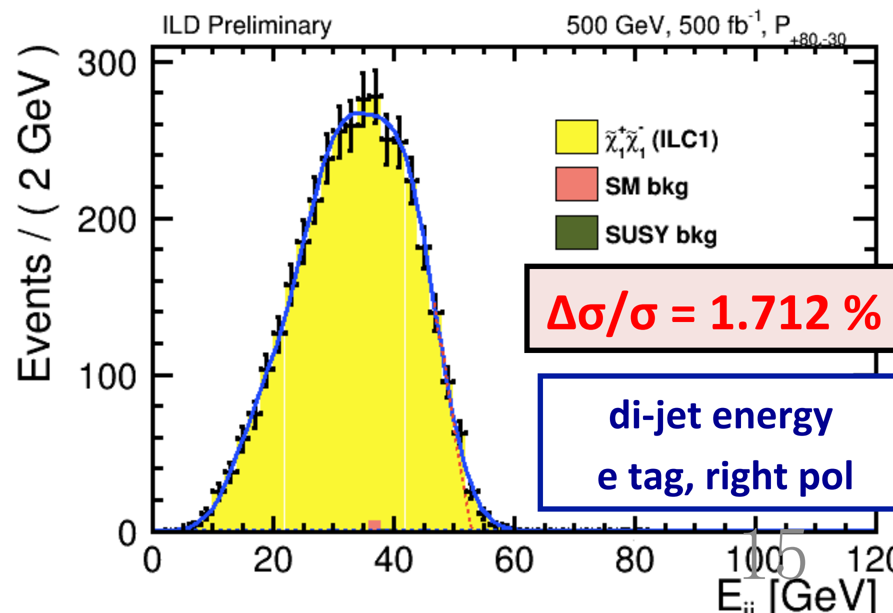
Δσ/σ = 1.752 %

di-jet energy
mu tag, Right pol



Δσ/σ = 0.829 %

di-jet energy
e tag, left pol



Δσ/σ = 1.712 %

di-jet energy
e tag, right pol

Summary of Mass Precisions

Edge precision propagated to mass precision

N1N2:

- **edge precision ～1 % , mass precision about 1 – 2%**
- **Left polarization ee has worse precision :**

  high bkg w.r.t right pol + wider distribution than mumu

C1C1: mass precision is better for left polarization by a factor of 2 (statistics)

N1N2

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%**

Theoretical values: MN1 = 102.7 GeV MN2 = 124.0 GeV, MC1 = 117.8 GeV

C1C1

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%**

Summary of Mass Precisions (Combined Results)

- **Combined statistical mass precision better than 0.4%**
- **Now we juts need to calibrate for systematical shift !**

Chi square fit of 4 variables (Ell_max, Ejj_max, Mll_max, Mjj_max)

polarization		ΔMN1/MN1	ΔMN2/MN2	ΔMC1/MC1
left	mu	0.602%	0.548%	0.580%
left	e	0.772%	0.730%	0.765%
right	mu	1.053%	0.950%	1.027%
right	e	1.019%	0.930%	1.018%
combined		**0.398%**	**0.366%**	**0.389%**
H20		**0.223%**	**0.205%**	**0.218%**

Default : 500 fb-1 for each polarization
H20: 1600 fb-1 for each polarization

Summary of Cross Section Precisions

- **For N1N2: right polarization benefits from low bkg**
- **For C1C1, no bkg anyhow, so left polarization is better due to higher statistics (cross section is larger by a factor of 4-5)**

N1N2	$\Delta\sigma/\sigma$
left, mumu	3.49%
left, ee	3.17%
right mumu	2.80%
right ee	2.41%

C1C1	$\Delta\sigma/\sigma$
left, mu-tag	0.85%
left, e-tag	0.83%
right mu-tag	1.75%
right e-tag	1.71%

Summary

Precision measurement of light Higgsinos with small ΔM (10-20 GeV)

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

This study: Full ILD detector simulation

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

- Analysis of **neutralino mixed production ($\chi_1^0 \chi_2^0$)** and **chargino pair production ($\chi_1^+ \chi_1^-$)**
- Data selection yields good S/B ratio ; almost no background for chargino
- **Fit kinematic edges to extract Higgsino masses**
- **Fit to overall distribution to extract production cross sections**

Obtained preliminary results for some channels

- **Edge precision ～1 %**
- **Combined mass precision ～ 0.4% → scaled to H20 ～ 0.2%**
- **xsec precision : neutralino: 3.5% (left), 2.8% (right) , chargino: 0.8% (left) 1.7% (right)**
- **results obtained in this study become input to SUSY parameter determination**

To extract other SUSY parameters, test GUT-scale physics and SUSY-breaking mechanism

[S.-L. Lehtinen, in progress]

Plan for Analysis

Top priority is to converge current results

- Statistic precision obtained using current toy MC
- calibration of systematic shift (detector and jet energy resolution)

  conduct calibration using Higgsino samples with different masses

  several points in a M(NLSP) – ΔM plane, Intervals of ～ 2 GeV

  Plan to start simulating samples in mid of September

- **Analysis including gamma gamma over-lay bkg**

- **Analysis at other CM energies and polarizations:**

  Enable more precise gaugino mass determination

  Threshold scan for precise Higgsino mass extraction

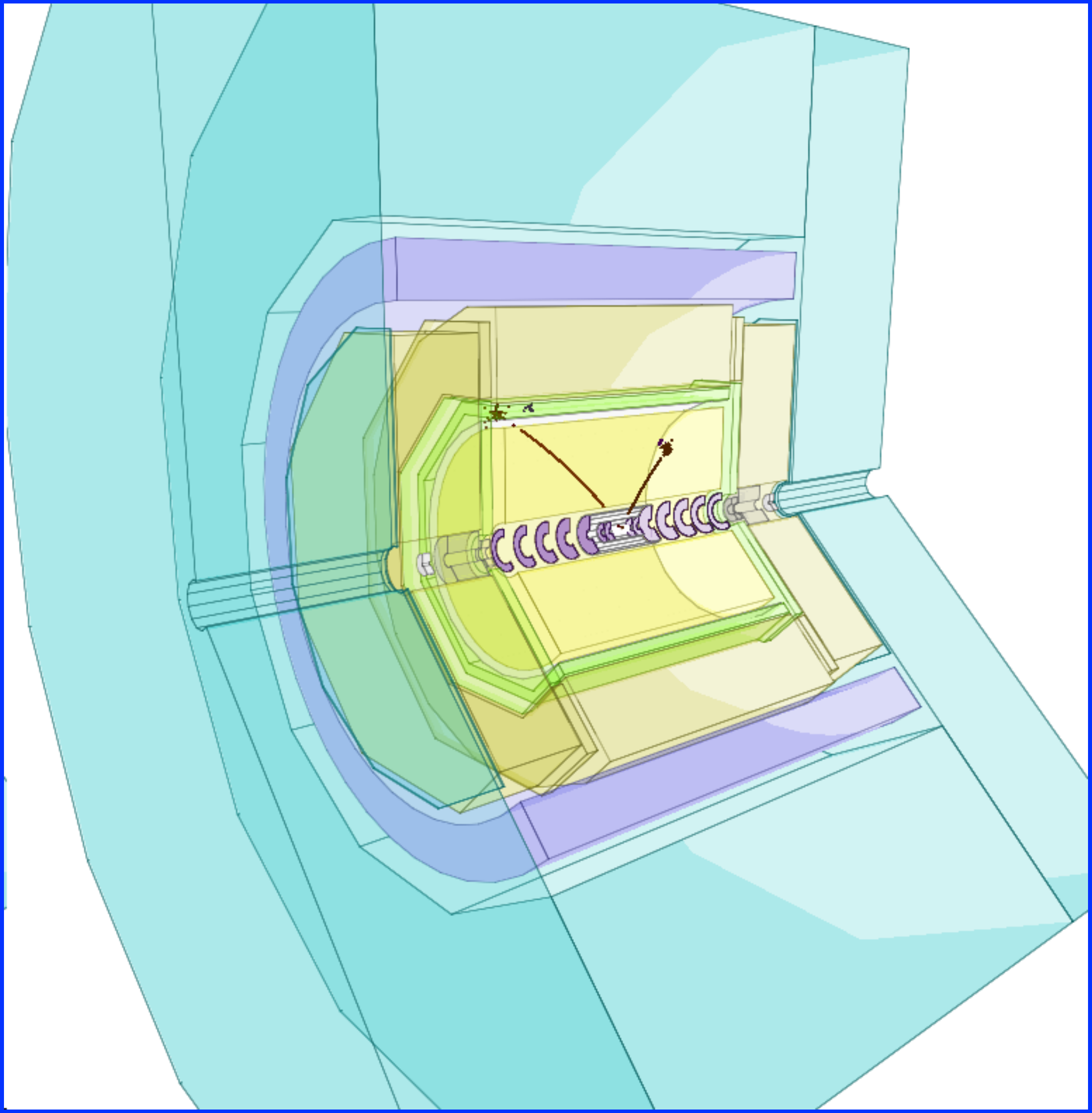
Plans for publication and document

- Follow up document to ICFA letter

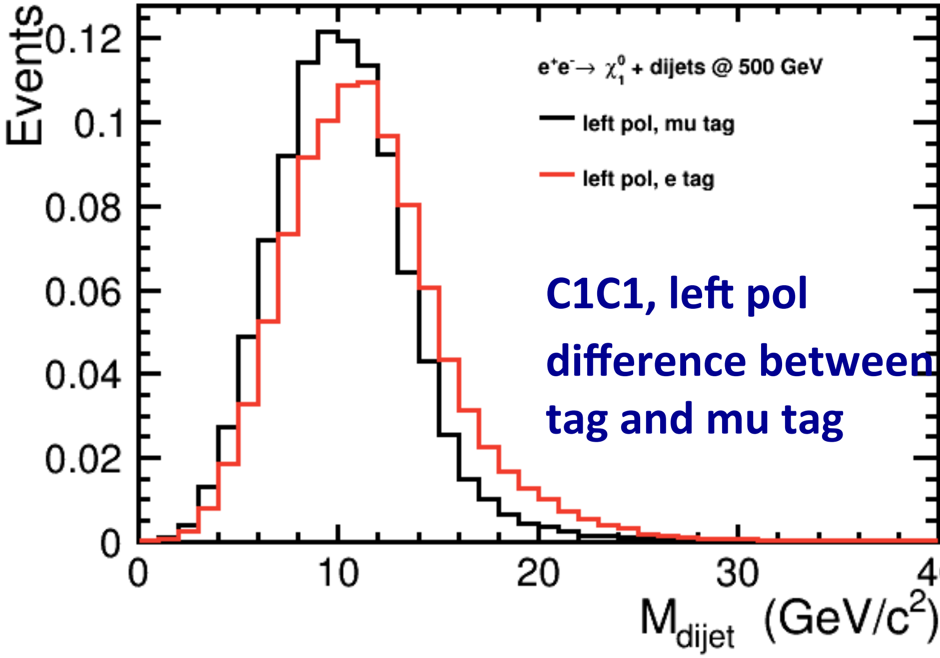
  (section on new particle discovery: 1st draft～end of September)

- publication

Thank you for listening

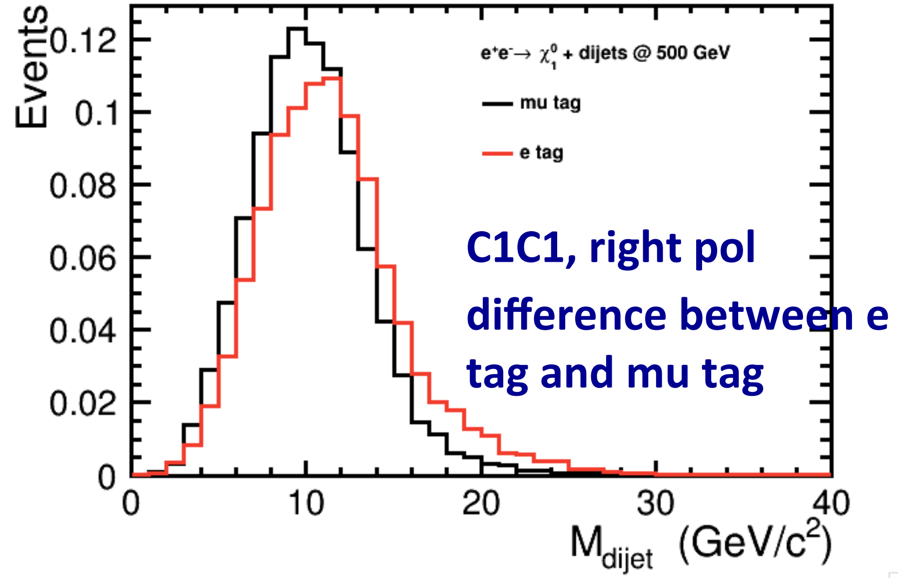


Additional Material



C1C1, left pol

difference between e tag and mu tag

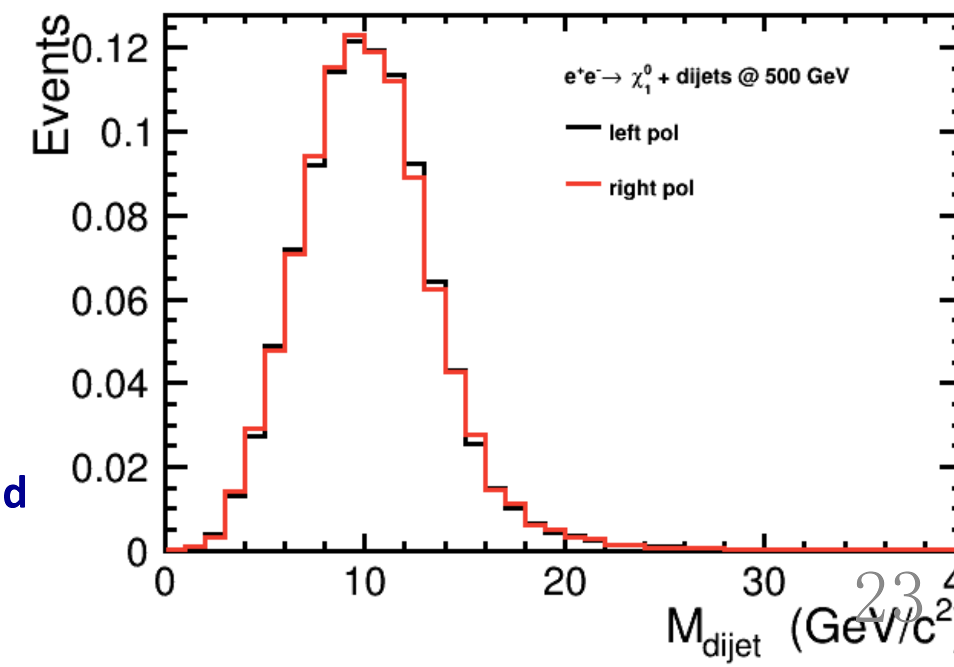


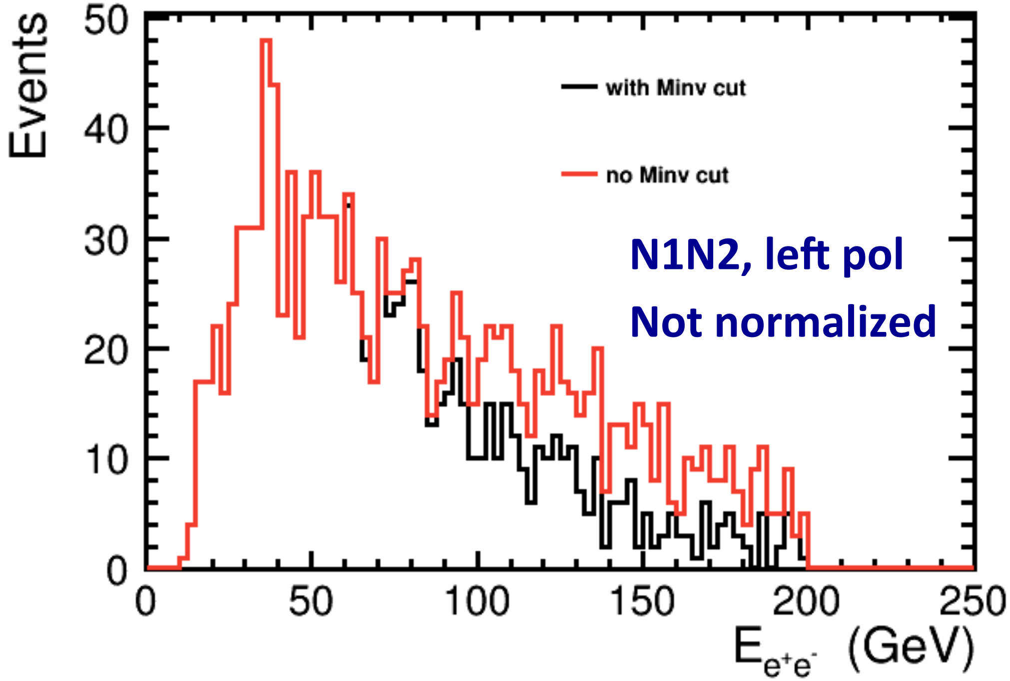
C1C1, right pol

difference between e tag and mu tag

C1C1 left:

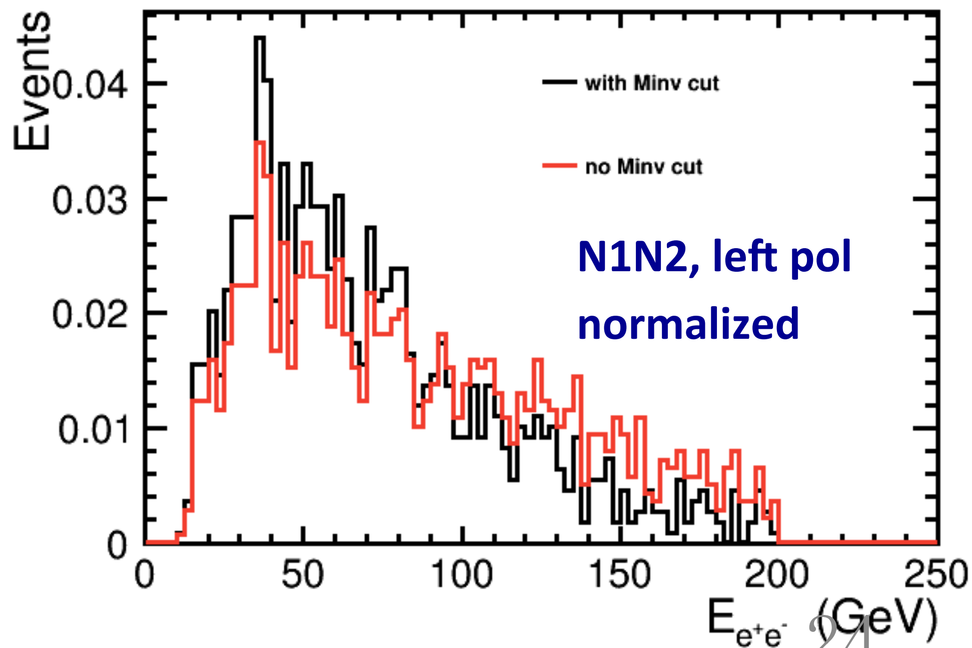
no difference between left and right polarization

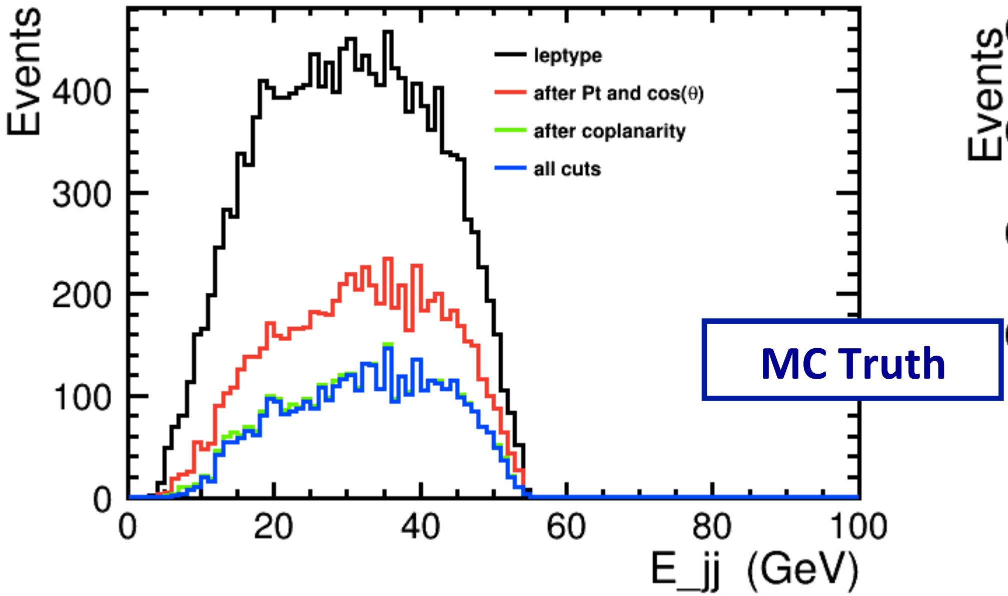


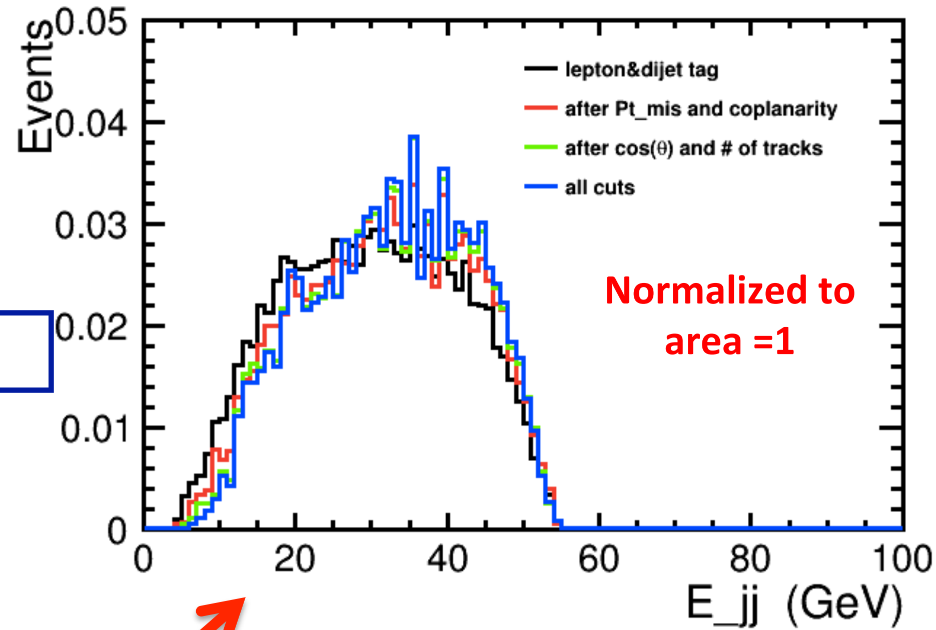


4f_szeorsw_l_lr bkg

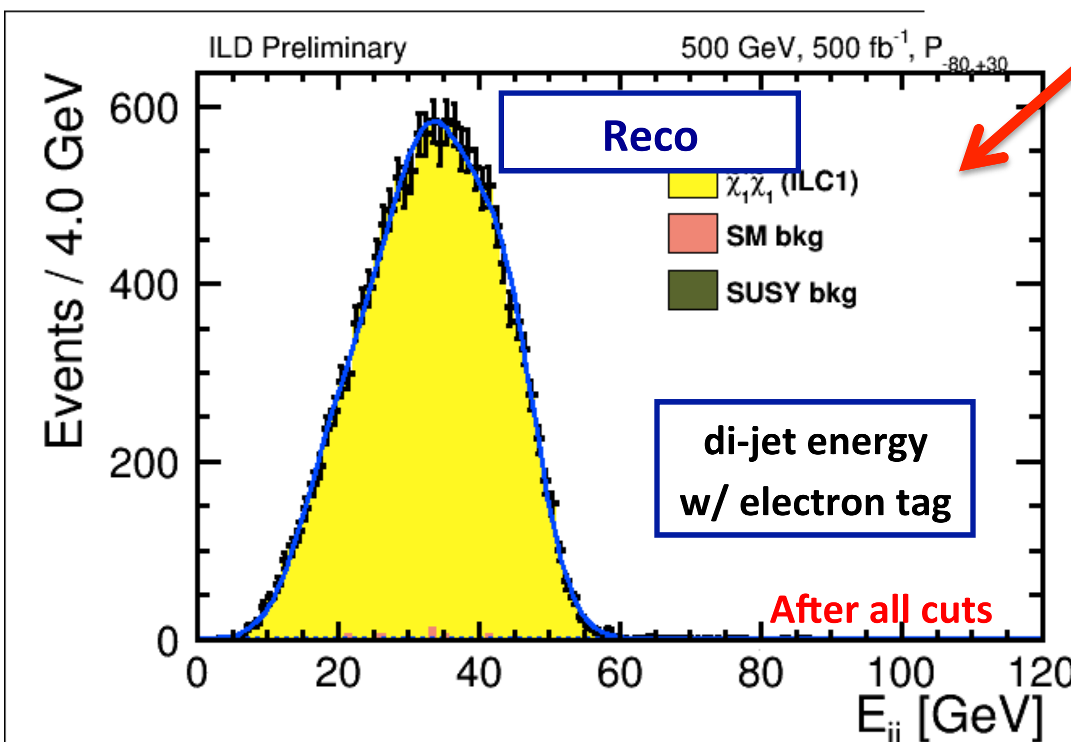
Flatter bkg (without Minv cut) has better precision







Looks SAME



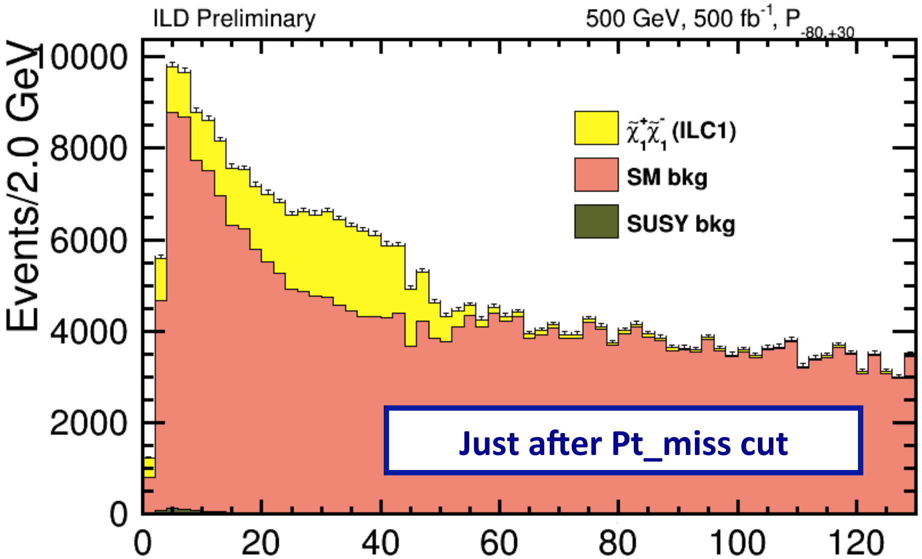
Change in distribution of Di-jet energy with respect to cuts (SIGNAL)

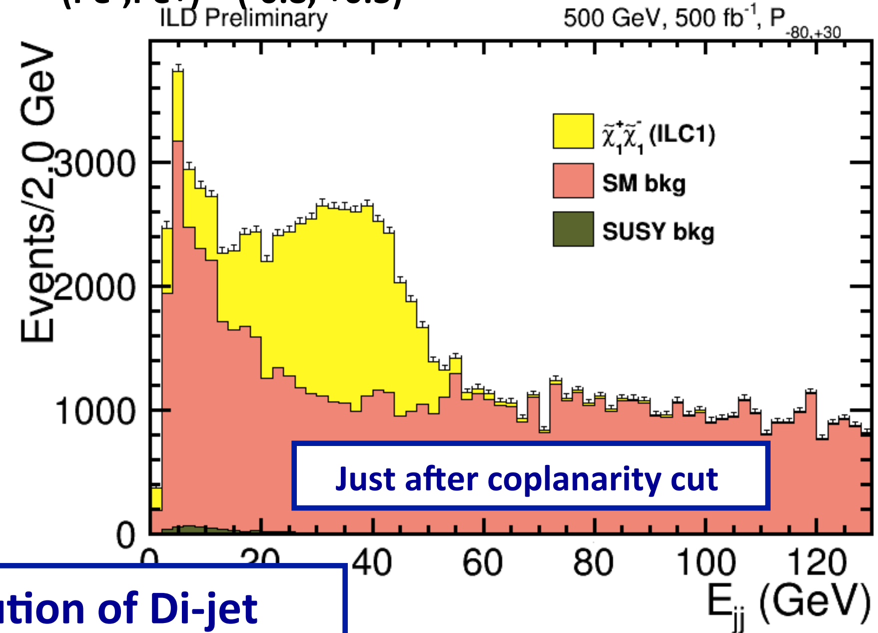
Cuts applied on Reconstructed variables

Chargino pair production with semileptonic decay

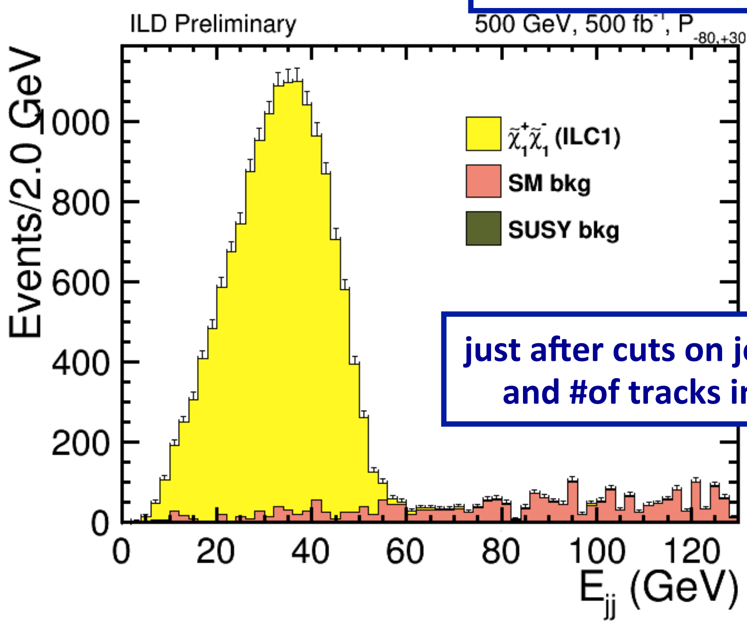
$$e^+e^- \rightarrow \tilde{\chi}_1^+ \tilde{\chi}_1^- \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 q q' \ell \nu$$

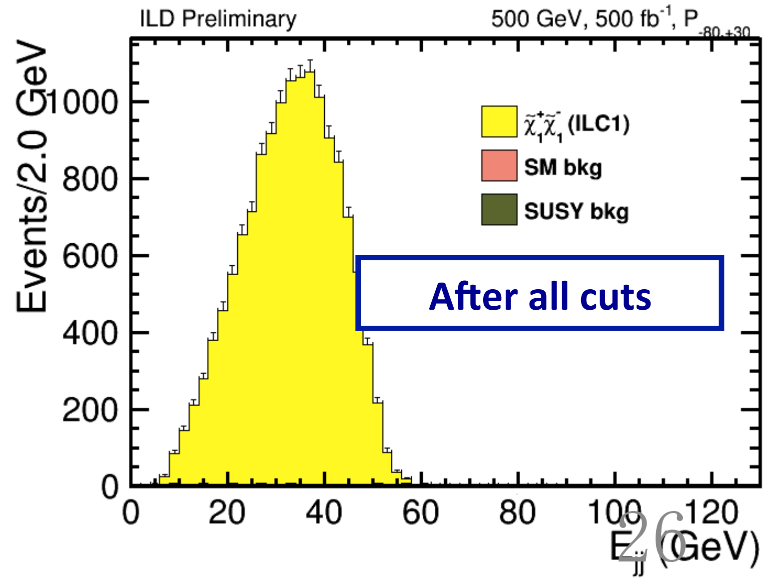
(Pe-,Pe+) = (-0.8, +0.3)





Change in distribution of Di-jet energy with respect to cuts (BKG)





Cuts for 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

Cuts for C1C1

- lepton type (μ or e tag) and # of lepton =1
- Pt_mis > 10 GeV
- Jet Coplanarity < 1.0 rad
- |cosθjet1,2| < 0.95:
- nTrack(in jet) >1 :
- no hit in BeamCal :
- cosθjet1-lep < 0.2, cosθjet2-lep < 0 angle between jets and leptons
- Evis – Eγmax < 60 GeV :
- Emis > 400 GeV :
- |cosθmissing| < 0.98 :
- |cosθZ| < 0.98 :
- Pt_jj < 50 GeV :
- Minv<30 GeV :

last of all observe distributions of Minv and dijet energy (Ejj)

Kinematic edge is a function of Higgsino mass and ΔM

Fits of NUHM2 Parameters

[S.-L. Lehtinen]

ILC2

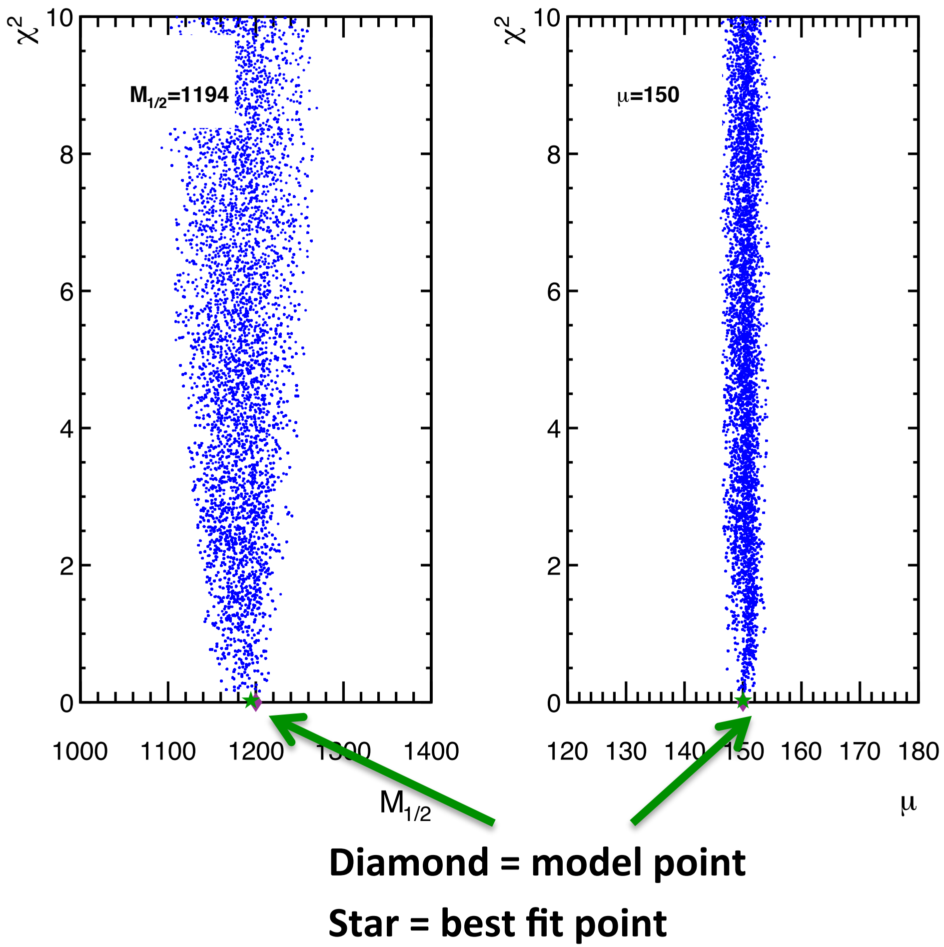
All 6 parameters are simultaneously varied. Initial values are set to be near the model values.

Each blue point corresponds to a set of parameter values. The χ^2 value is computed for each point.

Using the χ_1^0, χ_2^0, $\chi_1^\pm$ masses and production cross sections, $\mathbf{M_{1/2}}$ can be determined.

Adding Higgs mass and BR as measured at the ILC fixes μ and possibly constrains other parameters

In addition, if χ_3^0 can be observed in $\chi_2^0\chi_3^0$, tanβ can be constrained as well. (ILC1)



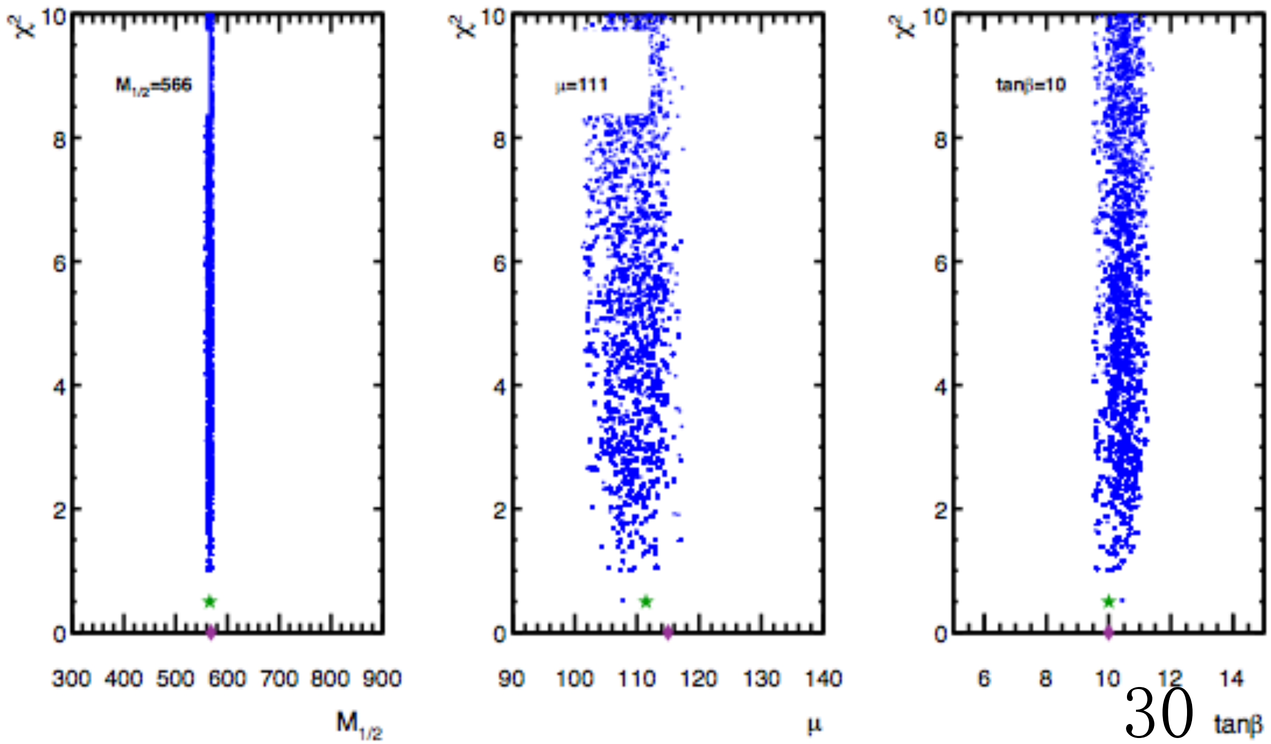
Outlook

- **Test gaugino mass unification by fitting weak scale parameters M_1 and M_2**

[S.-L. Lehtinen]

parameter	scale	ILC1
m_0	GUT	7025
$m_{1/2}$	GUT	568.3
A_0	GUT	−10426.6
$\tan\beta$	weak	10
μ	weak	115
m_A	weak	1000

- tanβ constrained if we add χ_3^0 mass and $\chi_1^0\chi_3^0$ production cross section



ILC1

Cross sections (pure beam polarizations)
$\sqrt{s}$=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%
$BR(\chi_1^+ \rightarrow \chi_1^0 l\nu)$ ($l=e,\mu$)	22%
$BR(\chi_2^0 \rightarrow \chi_1^0 qq')$	58%
$BR(\chi_2^0 \rightarrow \chi_1^0 ll)$ ($l=e,\mu$)	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 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
Cut10	14.0019	0	1.75324e+06	0	0	3.20718	0	0	0	1.75325e+06	14173	14173	10.6608

Cut Table: C1C1 left 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 :	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 :	440593	0	2.18564e+06	1.41835e+06	1303.09	4.69081e+06	2280.9	0	6.68666e+06	1.54256e+07	72311.8	72311.8	18.3684
Cut2 :	183455	0	2.11847e+06	1.29514e+06	363.816	2.01091e+06	1892.27	0	4.70162e+06	1.03118e+07	47855.5	47855.5	14.8682
Cut3 :	32097.7	0	1.81125e+06	254878	6.65116	448367	1198.9	0	1.50445e+06	4.05224e+06	26589.9	26589.9	13.1659
Cut4 :	1312.43	0	1.75645e+06	193270	0	51091.1	109.868	0	270643	2.27288e+06	15180.8	15180.8	10.036
Cut5 :	1194.81	0	1.7549e+06	158984	0	37688.8	15.579	0	228069	2.18085e+06	14591.6	14591.6	9.84785
Cut6 :	132.869	0	1.75377e+06	187.228	0	16862.3	13.8184	0	7410.43	1.77837e+06	14582.2	14582.2	10.8903
Cut7 :	0.376225	0	1.75326e+06	0	0	0	11.3776	0	0	1.75327e+06	14507	14507	10.911
Cut8 :	0.376225	0	1.75326e+06	0	0	0	11.3776	0	0	1.75327e+06	14506.4	14506.4	10.9106
Cut9 :	0.376225	0	1.75326e+06	0	0	0	11.1108	0	0	1.75327e+06	14455.1	14455.1	10.8721
Cut10 :	0.376225	0	1.75324e+06	0	0	0	11.1108	0	0	1.75325e+06	14437	14437	10.8586