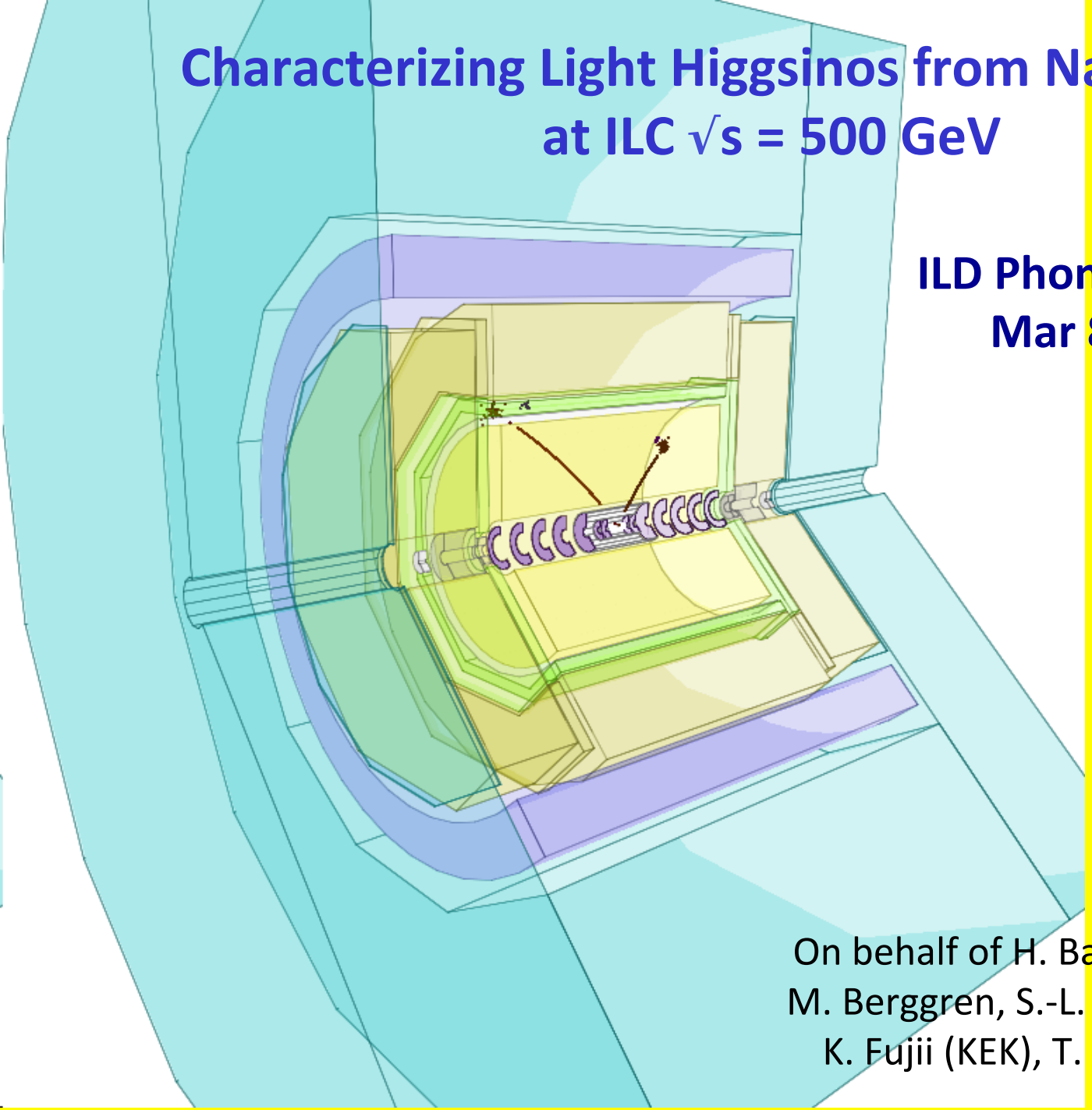
Characterizing Light Higgsinos from Natural SUSY at ILC $\sqrt{s}$ = 500 GeV



ILD Phone Meeting
Mar 8, 2017

Jacqueline Yan (KEK)
On behalf of H. Baer (Univ of Oklahoma),
M. Berggren, S.-L. Lehtinen, J. List (DESY),
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Outline

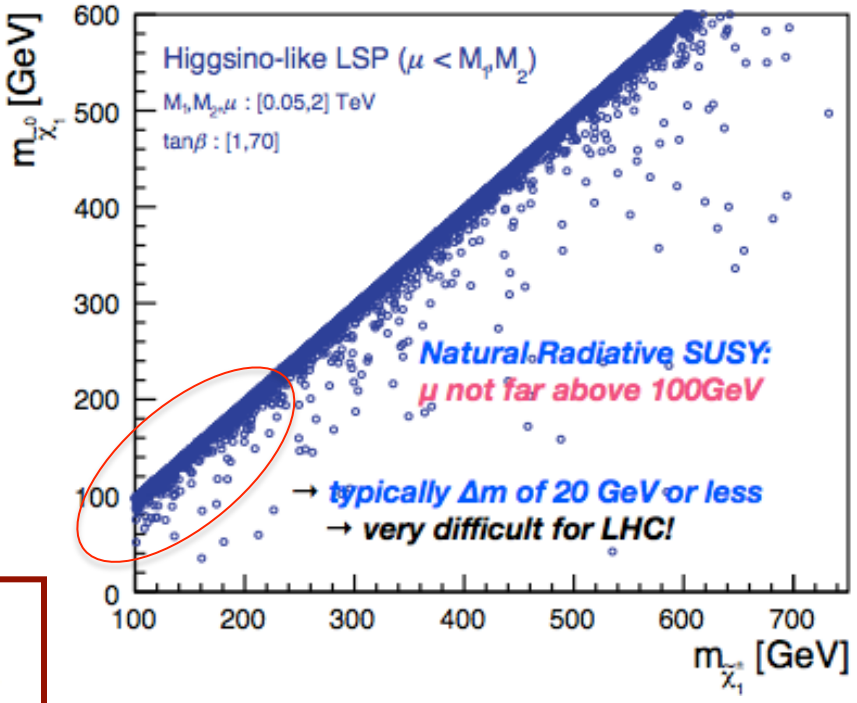
- Motivation of study
- Analysis method
- Updated results
- Goals and Plans

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)

Goal of Light Higgsino Study

This study

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, tanβ

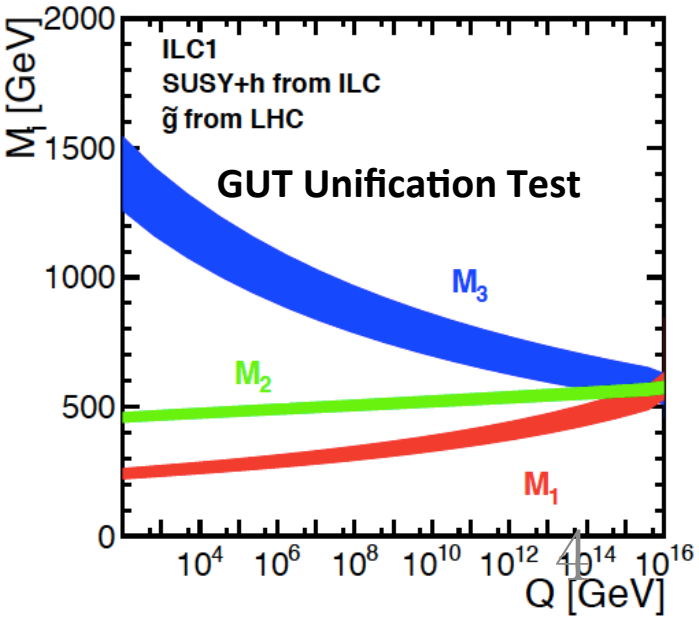
Why?

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

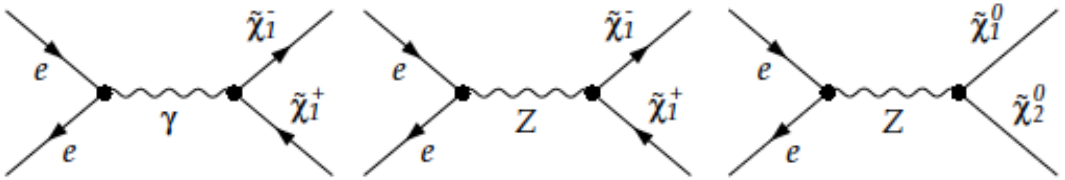
How?

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

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



Benchmarks in this Study



√s = 500 GeV, full ILD detector simulation

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 complies with naturalness** (no need for ISR tag)

Benchmarks with smaller ΔM are drawing attention ,
as ILC1 is (almost) excluded by LHC

- ILC1 (and some ILC2) results shown at LCWS2016 and https://arxiv.org/pdf/1702.05333.pdf
- Recently, Progress made in ILC2 and Mirage Mediation (nGMM1) (ΔM as small as 4.5 GeV)

More detailed status on another page

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
$\Delta M(N_2,N_1)$	**21.3**	**9.7**
$M(\chi_2^0)$ [GeV]	124.0	157.8
$\Delta M(C_1,N_1)$	**14.6**	**10.2**

Defined at GUT scale ,
Defined at weak scale Observables

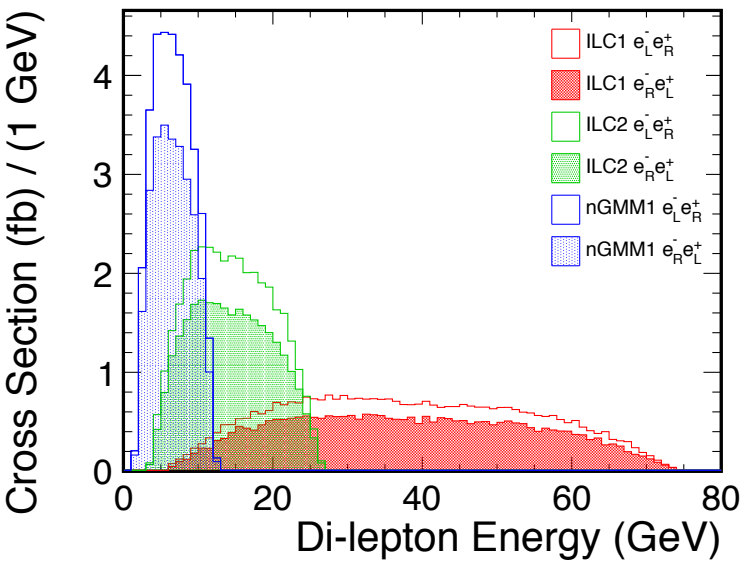
analyzing more challenging benchmarks with smaller ΔM

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

Higgsino mass precisions ＜～1% (H20) should be achievable

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)

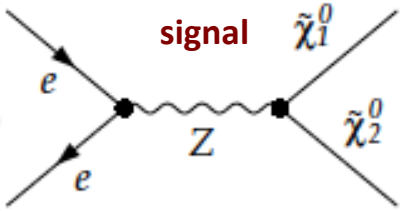
Process (Pe-,Pe+)	ILC1	ILC2	nGMM1
C1C1 (-1,+1)	1799.9	1530.5	1520.6
C1C1 (+1,-1)	334.5	307.2	309.5
N1N2 (-1,+1)	490.9	458.9	463.5
N1N2 (+1,-1)	378.5	353.8	357.3

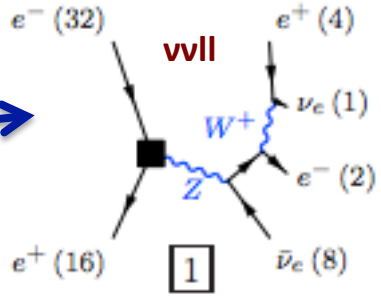
Event Selection

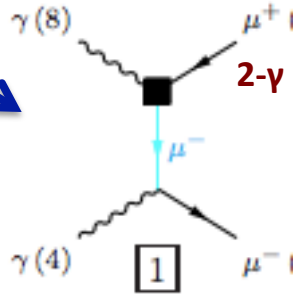
Neutralino mixed production with leptonic decay

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

- 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





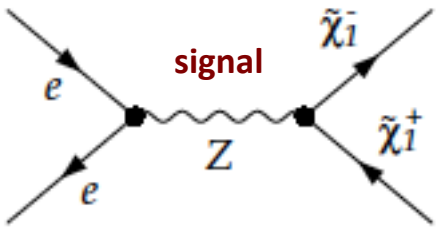


Chargino pair production with semileptonic decay

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

- 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)

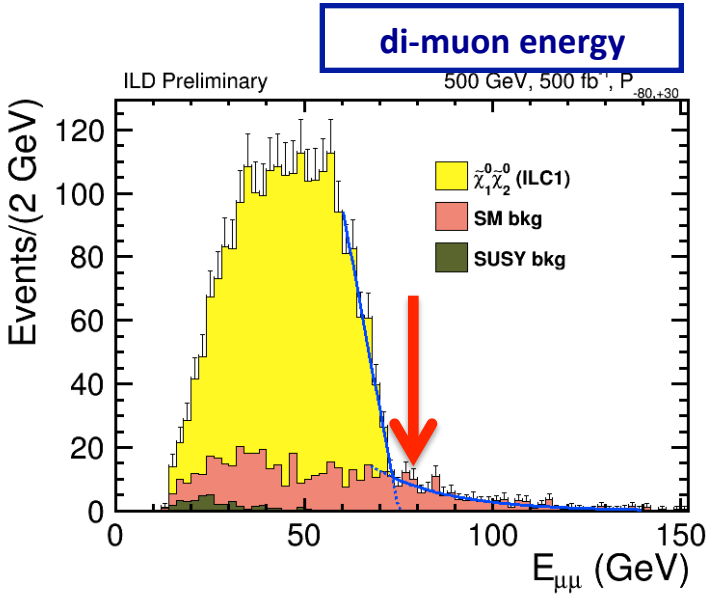


Extraction of Higgsino Mass and Cross Section

Mass:

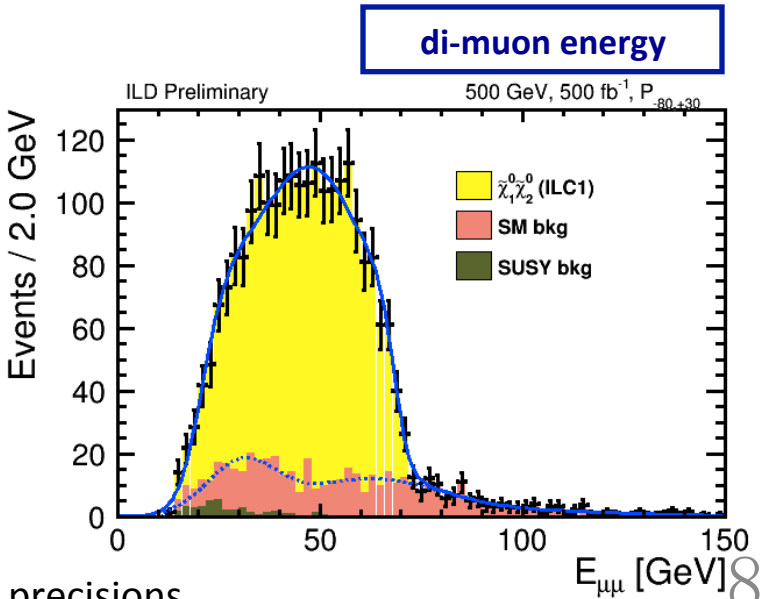
- Kinematic edges of dilepton/dijet energy and invariant mass are functions of $\sqrt{s}$ and Higgsino masses
- **Extract kinematic edges by a fit to distributions ➔ calculate masses**

(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

Recent Activities (more detailed status)

（1）comparisons between ILCSoft versions

（2）**Optimize signal selection and cuts**

- to **improve significance**
- To **converge to a common set of analysis method** which **works for both overlay and non-overlay** AND hopefully for all benchmarks
- Today will show **preliminary results for neutralino channels with "Marlin reconstruction carried out using the validated v01-16-02"**
- Demonstrated that there are no significant differenced in results no matter using which ILCSoft version (DBD tracking used)

（3）Production of additional aa2f and ae/ea3f bkg SGV samples (Mikael)

Considering legitimate precuts to use in production

These should be mostly gone at the end, but need to confirm (not included in plots shown today)

- We are working on a paper which includes results on all 3 benchmarks, and also SUSY parameter extraction and theory

Optimization in signal selection and Pt cut

<Goal> **Converge to a set which can give good significance for both "with" and "without" overlay, and works for all scenarios of ΔM**

Change#1: definition of "# of charged tracks",

OLD: no Pt requirement : this led to under-estimation of bkg (which has overlay)

NEW: **require Pt>2 GeV**

Change#2: isolated lepton selection and removal of extra Pt cuts
in order to recover signal efficiency for case of "overlay in signal sample"

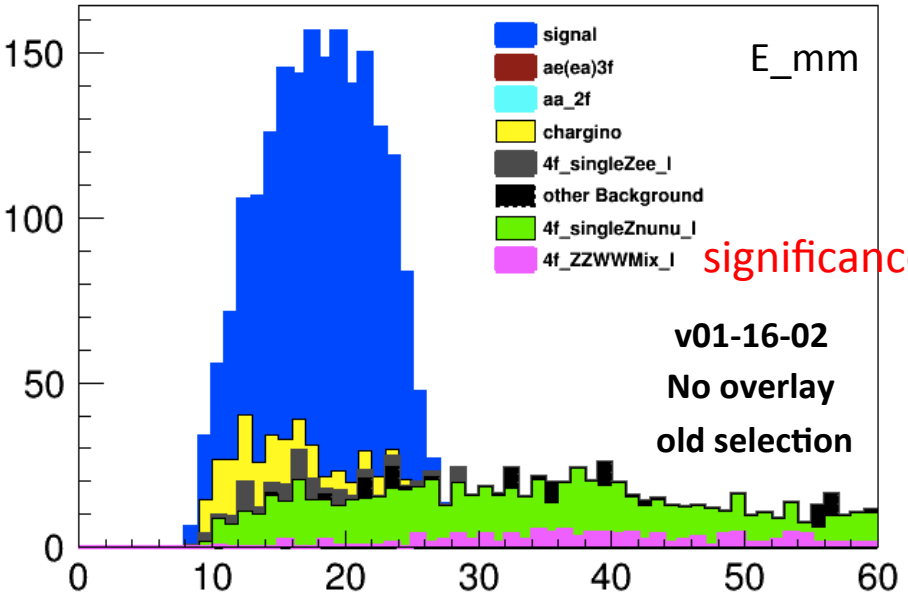
OLD: Leptons chosen without Pt requirement
ILC2: Pt cut 4 GeV/2 GeV for mm/ee , Mirage: Pt cut 2.2 GeV for mm and ee

NEW: only choose from leptons with Pt>2GeV (in lepton selection processor)
Remove Pt cut from following analysis cuts

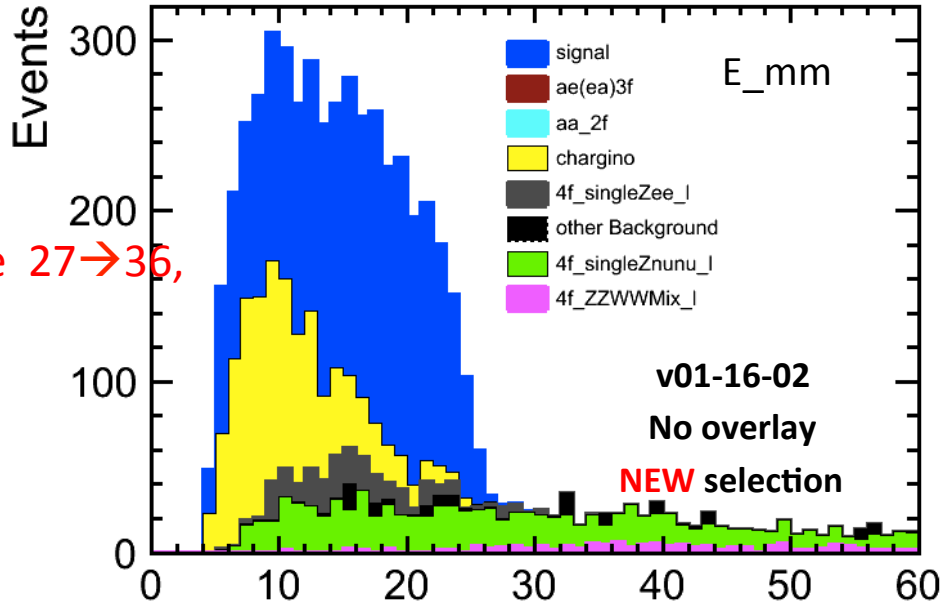
In the next page, comparisons will be shown for Change#2

ILC2 : N1N2 left pol, without overlay

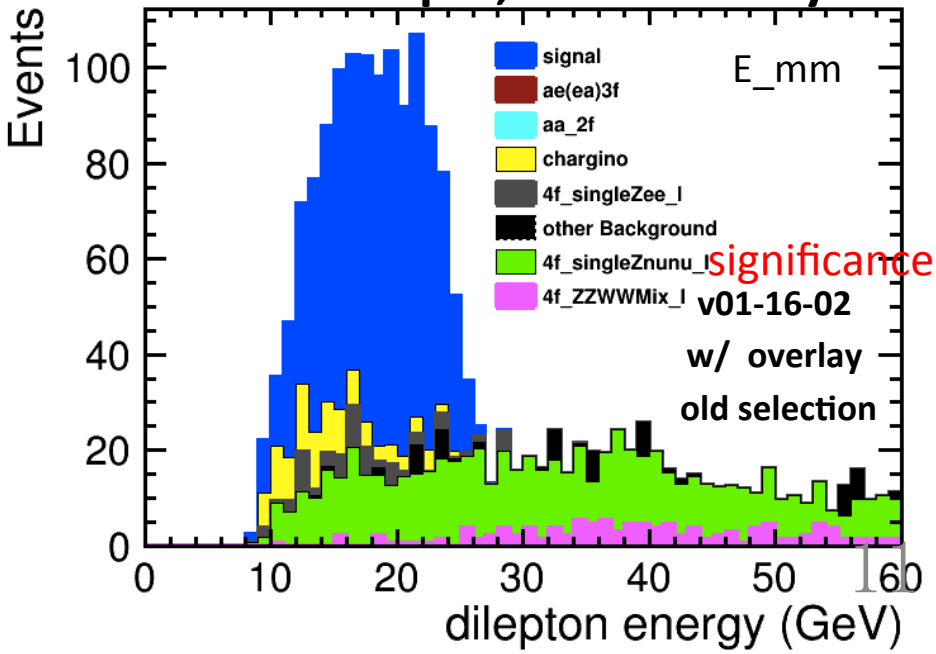
similar improvement in other channels of ILC2 and Mirage



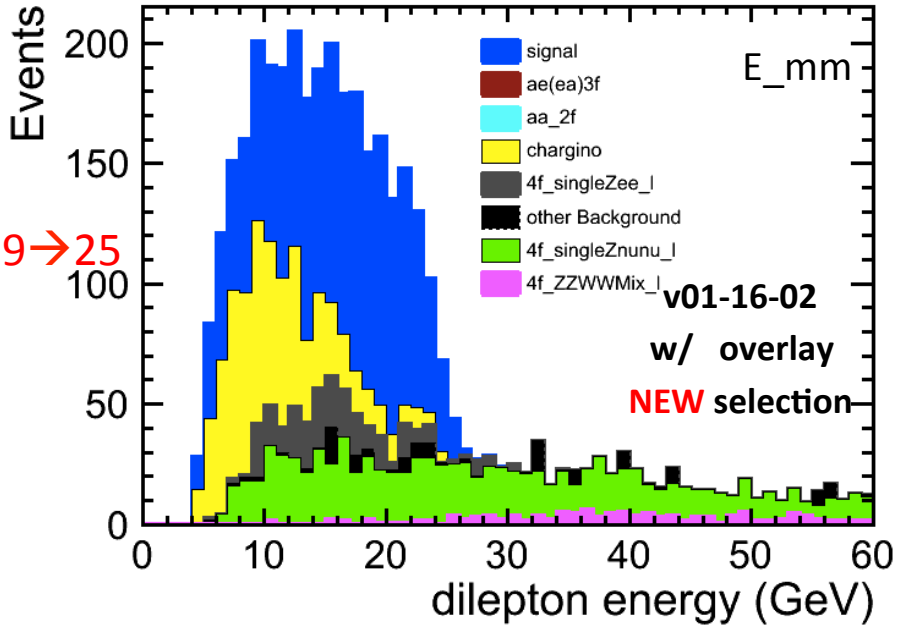
significance 27→36,



ILC2 : N1N2 left pol, with overlay



significance 19→25

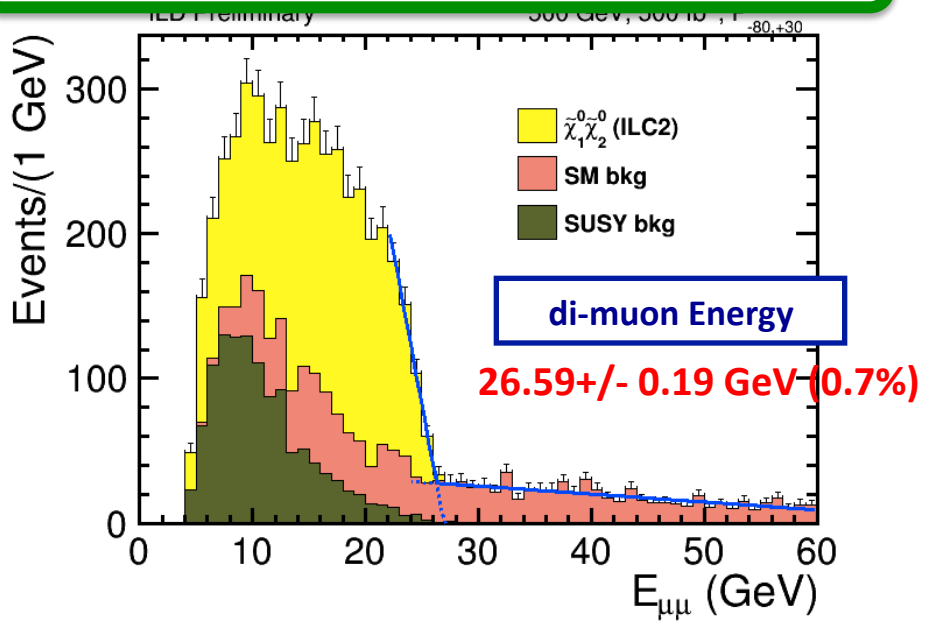


Neutralino mixed production with leptonic decay

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

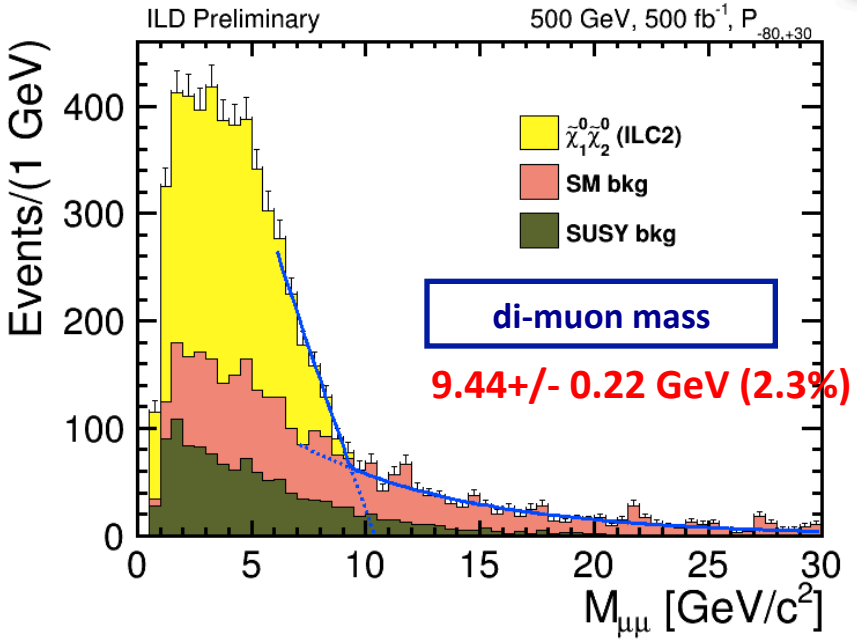
ILC2 @500fb-1 v01-16-02

Without overlay



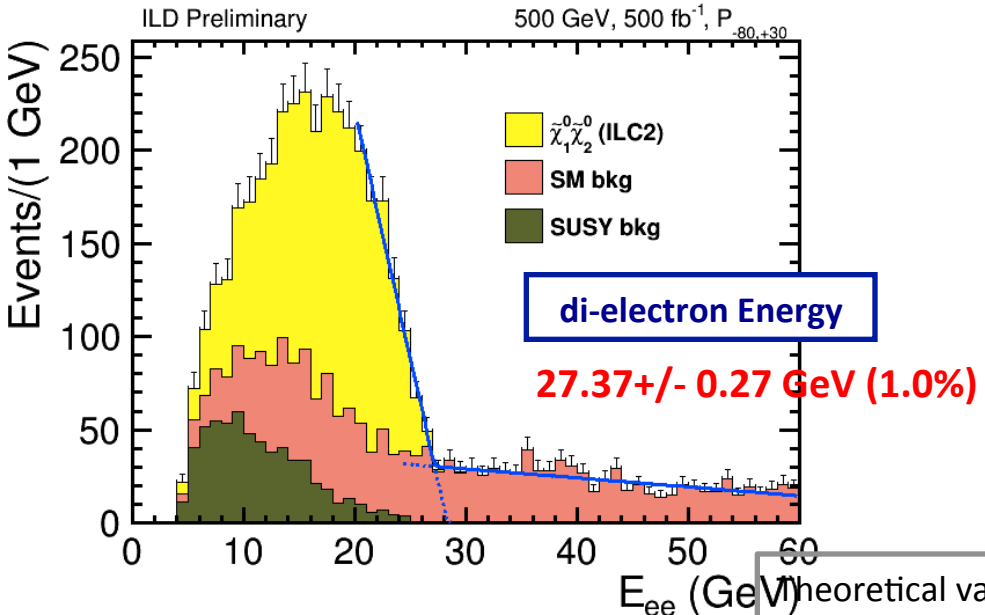
di-muon Energy

26.59+/- 0.19 GeV (0.7%)



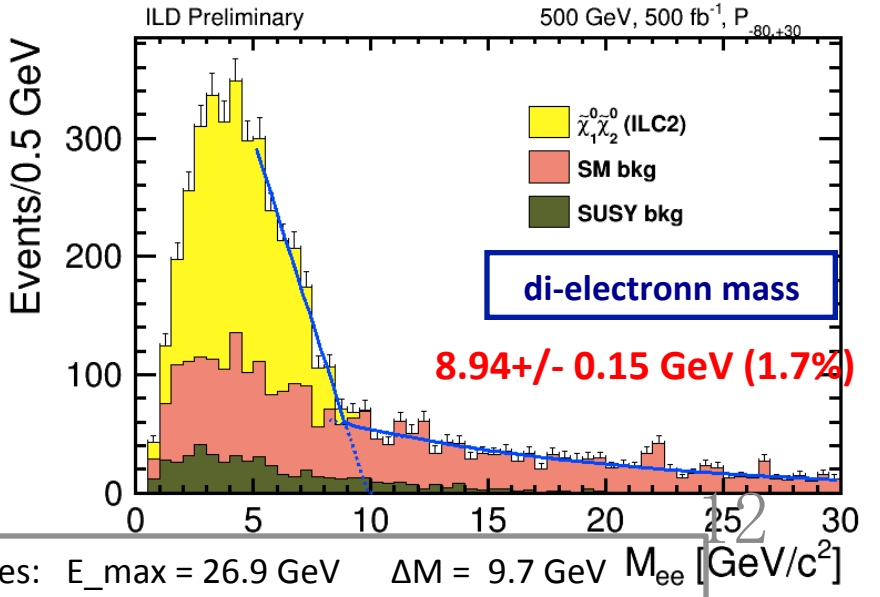
di-muon mass

9.44+/- 0.22 GeV (2.3%)



di-electron Energy

27.37+/- 0.27 GeV (1.0%)



di-electronn mass

8.94+/- 0.15 GeV (1.7%)

Theoretical values: E_max = 26.9 GeV ΔM = 9.7 GeV

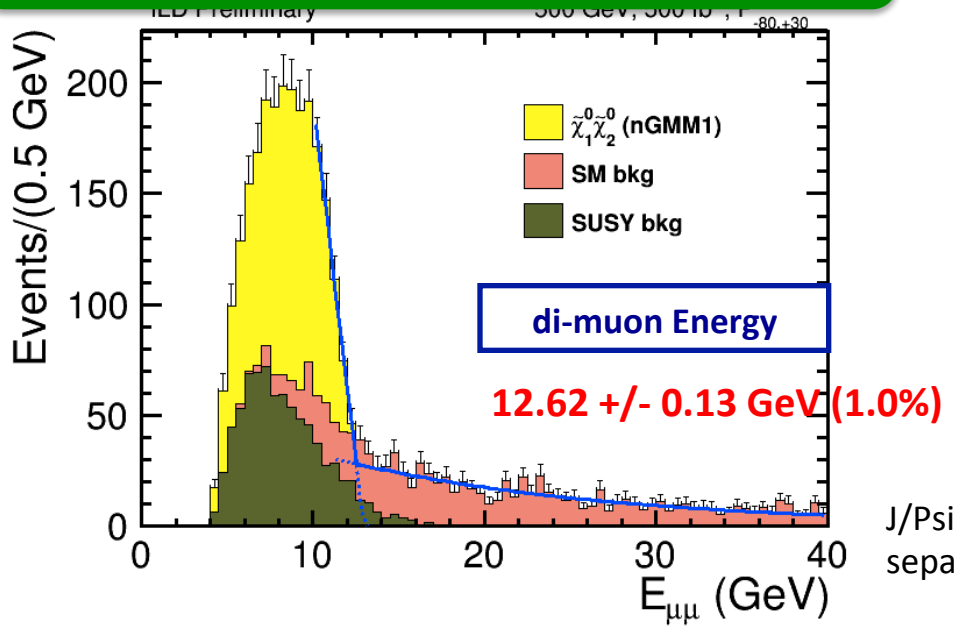
Neutralino mixed production with leptonic decay

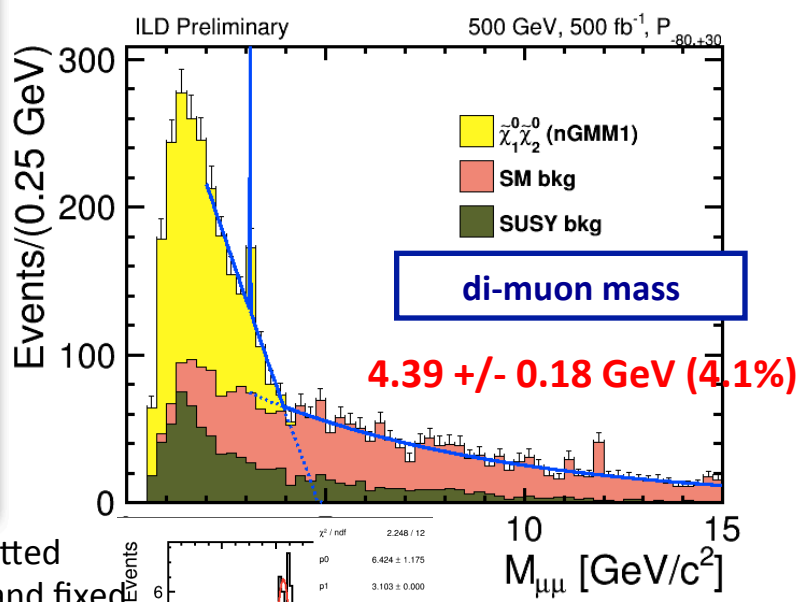
$$e^+e^- \to \tilde{\chi}_1^0 \tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \tilde{\chi}_1^0 \ell^+ \ell^-$$

Mirage Mediation @500fb-1

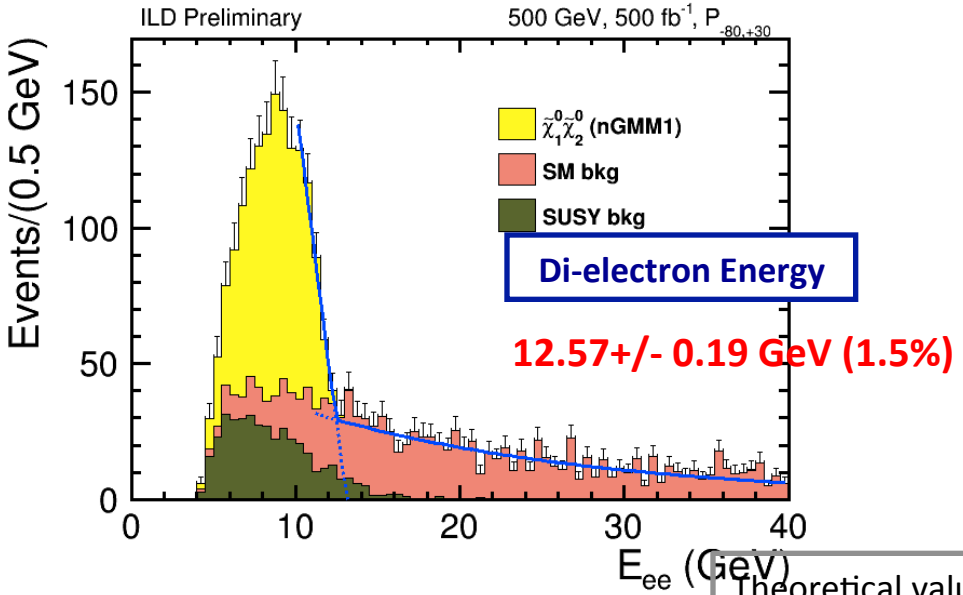
v01-16-02

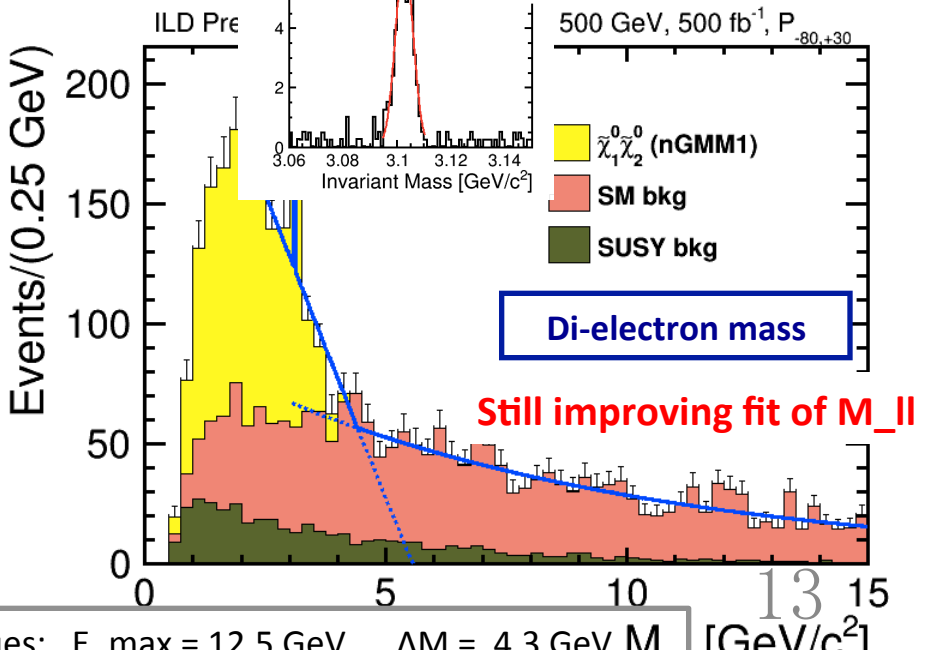
Without overlay





J/Psi peak fitted separately and fixed





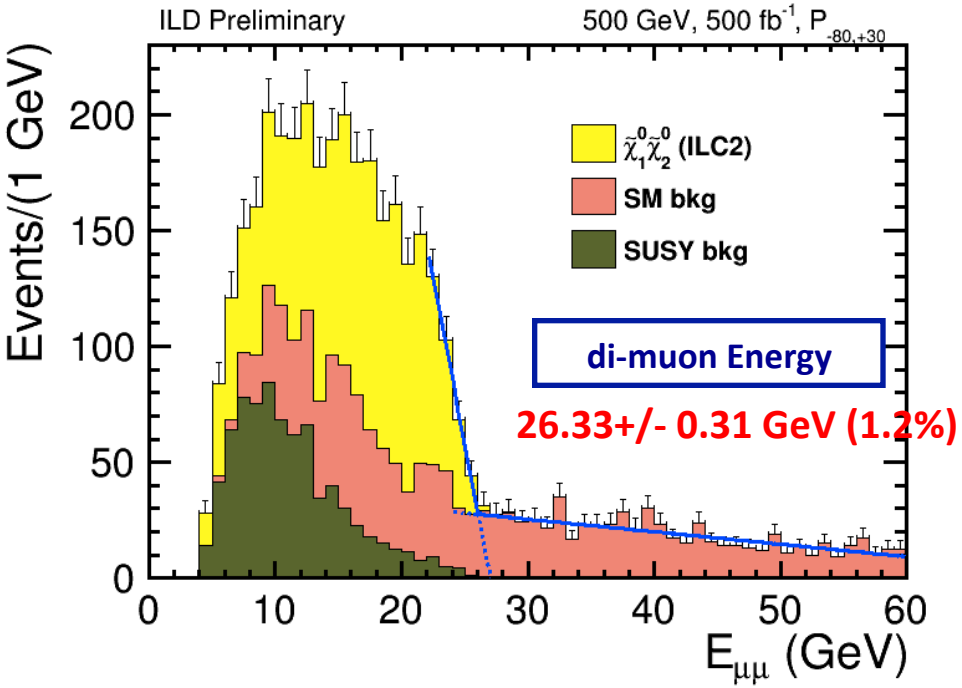
Theoretical values: E_max = 12.5 GeV ΔM = 4.3 GeV

Neutralino mixed production with leptonic decay

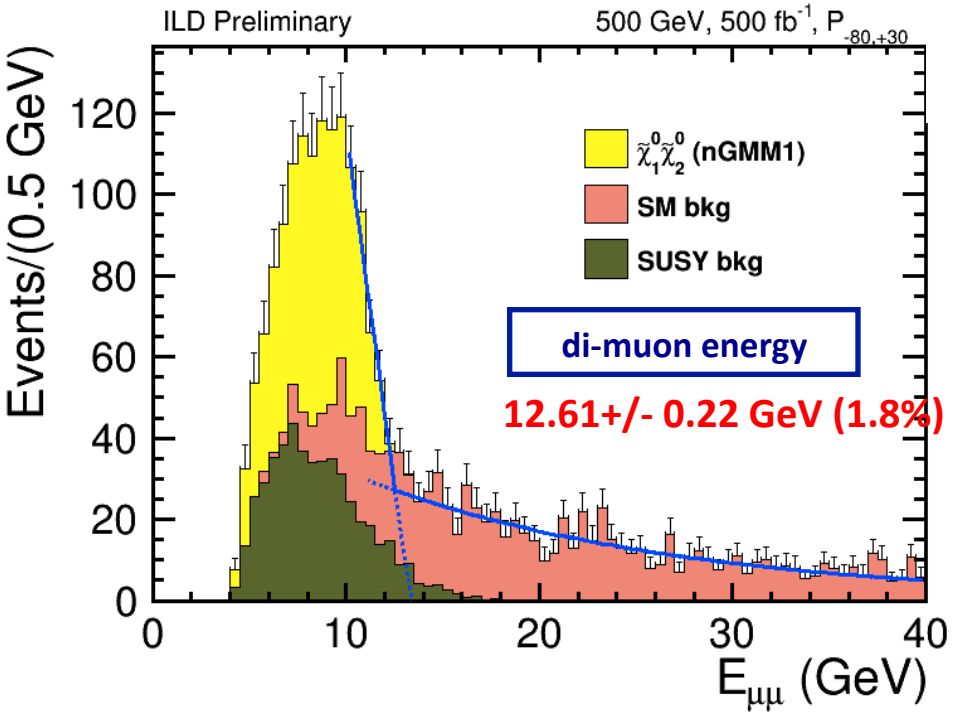
$$e^+e^- \to \tilde{\chi}_1^0 \tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \tilde{\chi}_1^0 \ell^+ \ell^-$$

With current analysis methods, <u>able to deal with case of overlay in signal,</u> even for Mirage benchmark

ILC2 v01-16-02 **With overlay**



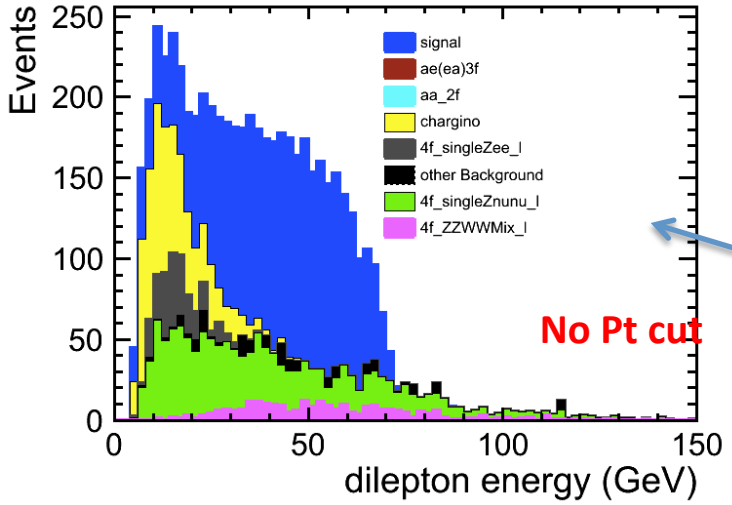
Mirage v01-16-02 **With overlay**



Please compare with "no-overlay" results in top left plots on pages 12 and 13

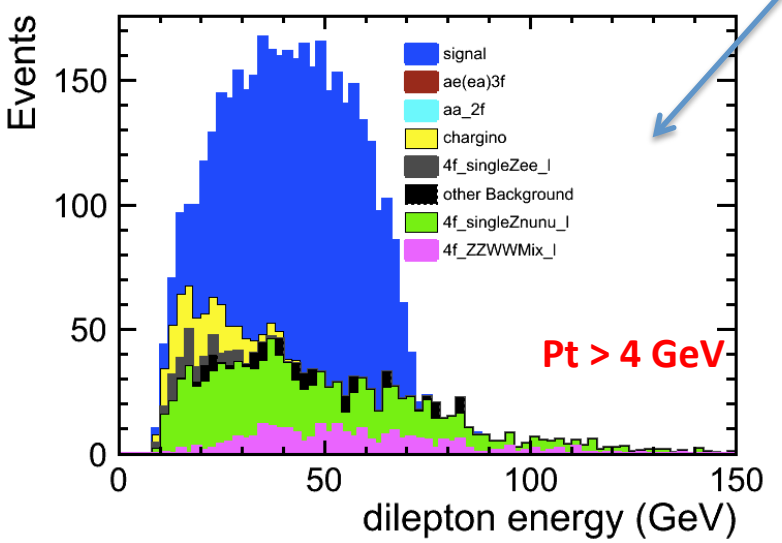
Pt cut or not ?

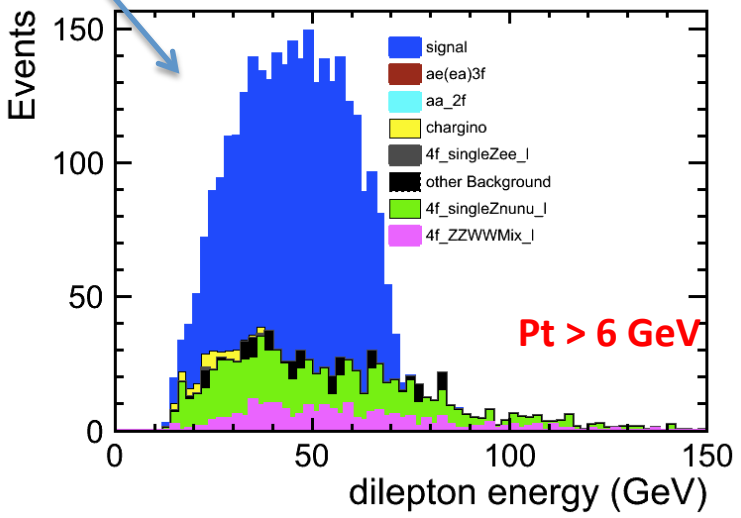
- have one set of cuts for “discovery” (loose cuts, no Pt cut) which applies to all benchmarks
- **Then a tighter set of cuts for “precision measurement” optimized for each benchmark**
- **Different cuts for kinematic edge extraction and cross section measurement**



ILC1, N1N2, no overlay

di-muon energy





Summary

- **made progress in analysis of benchmarks with smaller ΔM**
- **Optimized analysis methods for neutralino analysis with works well for both "overlay" and "no-overlay"** in signal samples, and for all three benchmarks

  ➔ **improvement in significance**

- Currently obtainable statistical precisions for (no overlay): **Assuming H20**

  Mass : < ～ 0.5% (ILC1, ILC2) <～1.5% (nGMM1)

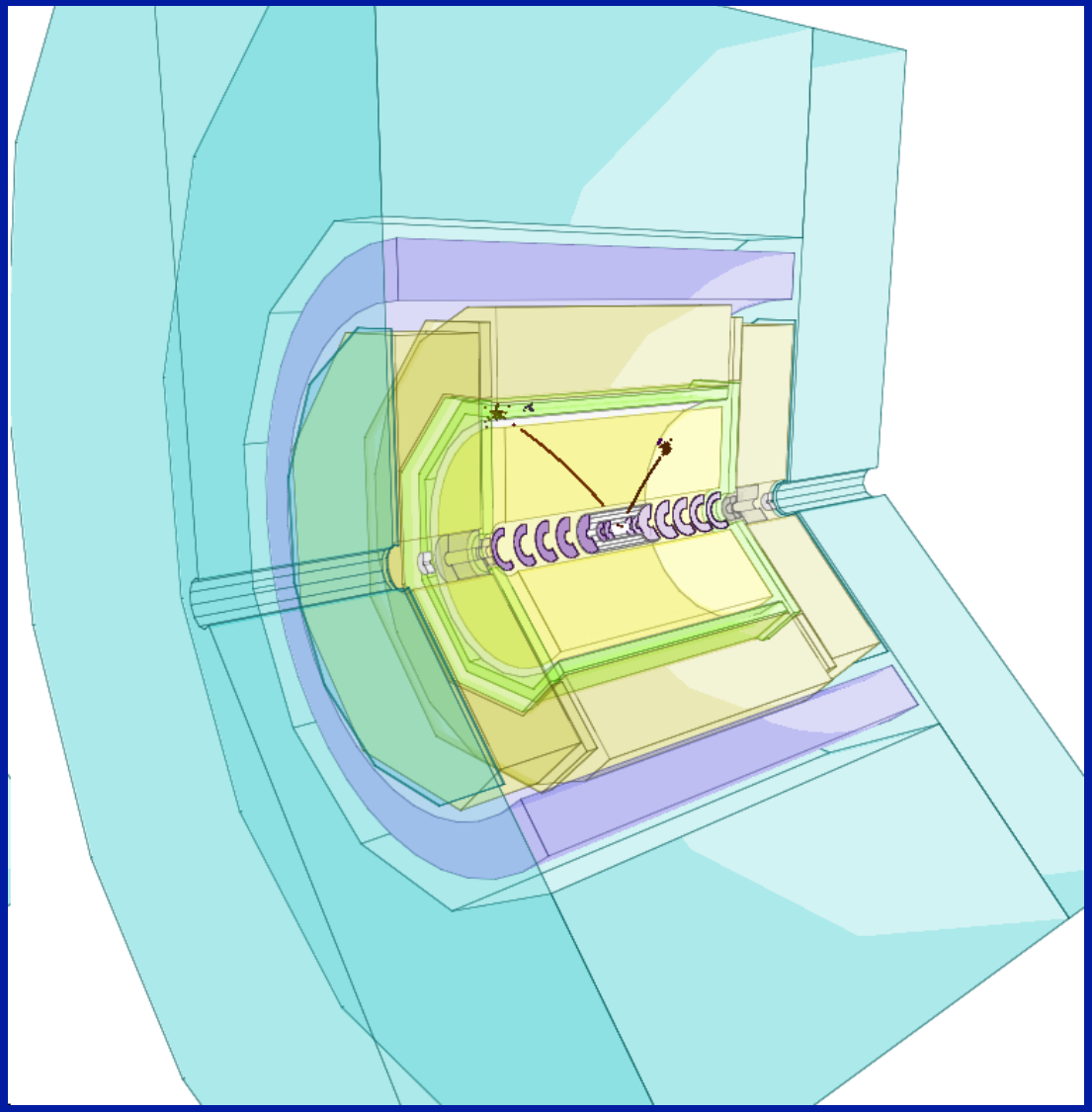
  Cross section : 1−2% (ILC1, ILC2)

- Showed no difference in final results regardless of ILCSoft version (results today shown using v01-16-02, which is validated and consistent with SM bkg)

Plans

- re-optimize analysis methods for chargino analysis, also to accommodate all scenarios
- Implement SGV samples when ready → reconfirm they are removed by current cuts
- Work on paper
- Consider contribution from Higgsino analysis to staging scenario (next talk)

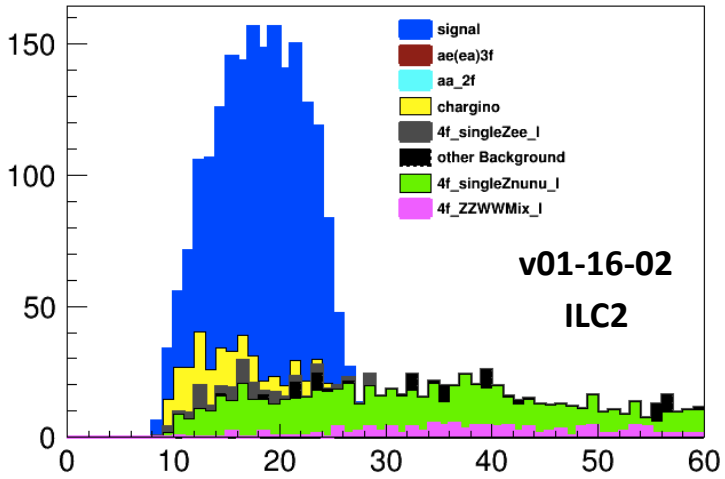
Backup

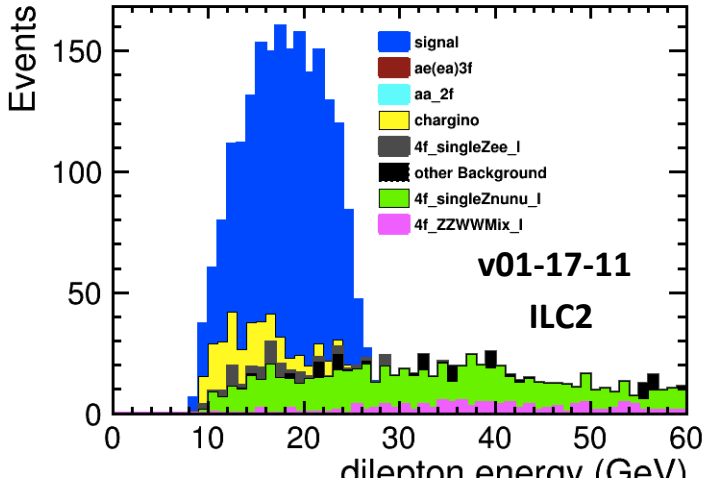


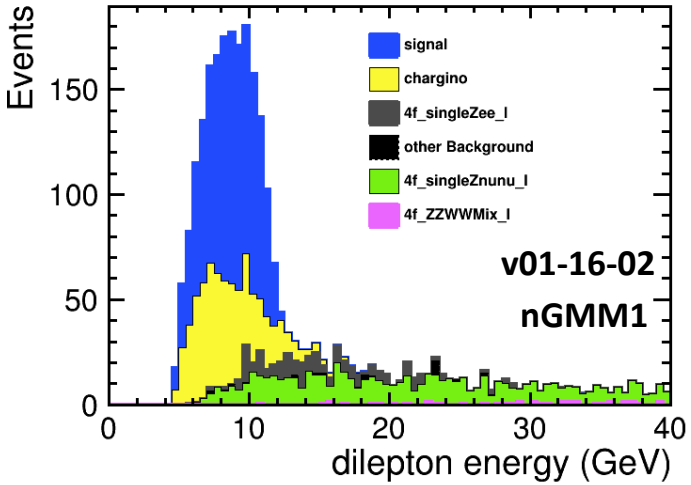
Version comparison

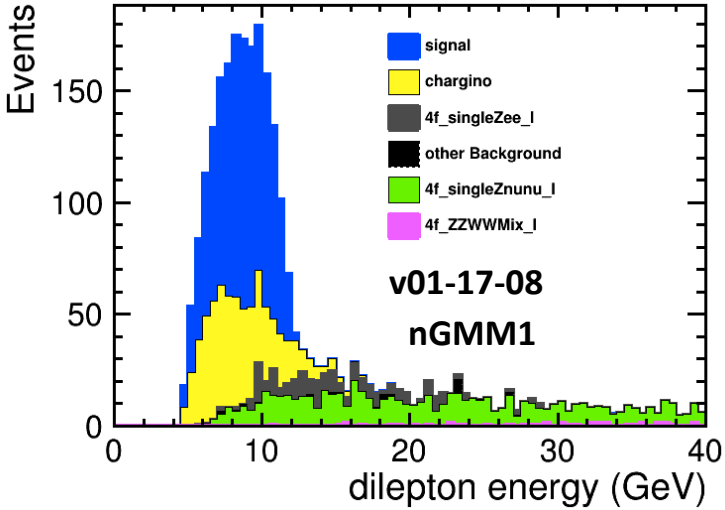
- **final analysis results based on "Marlin reco using the validated v01-16-02" shows no significant difference from other versions, for both ILC2 and Mirage**
- Working with software experts to cross check between versions

Note) these were before recent optimization of selection methods

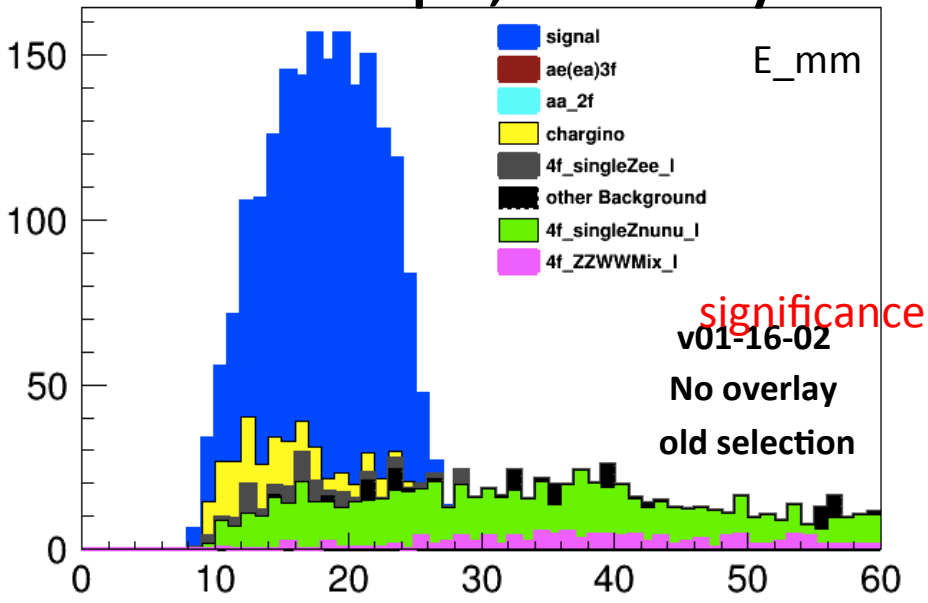




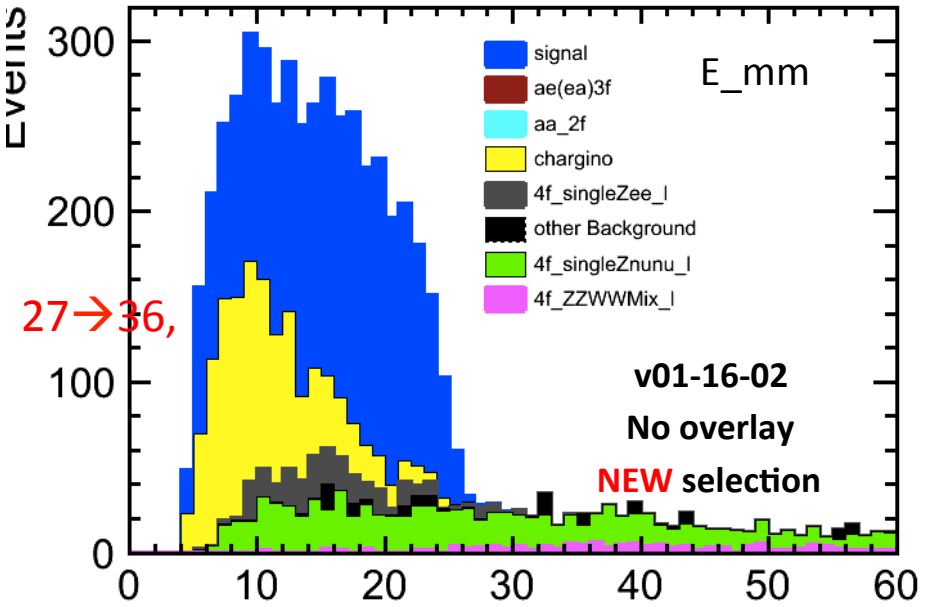




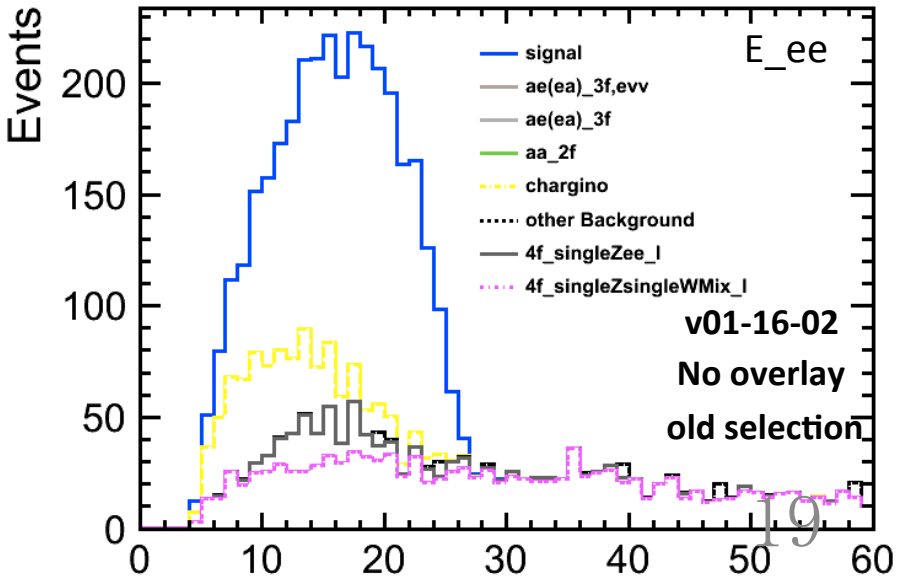
ILC2 : N1N2 left pol, no overlay

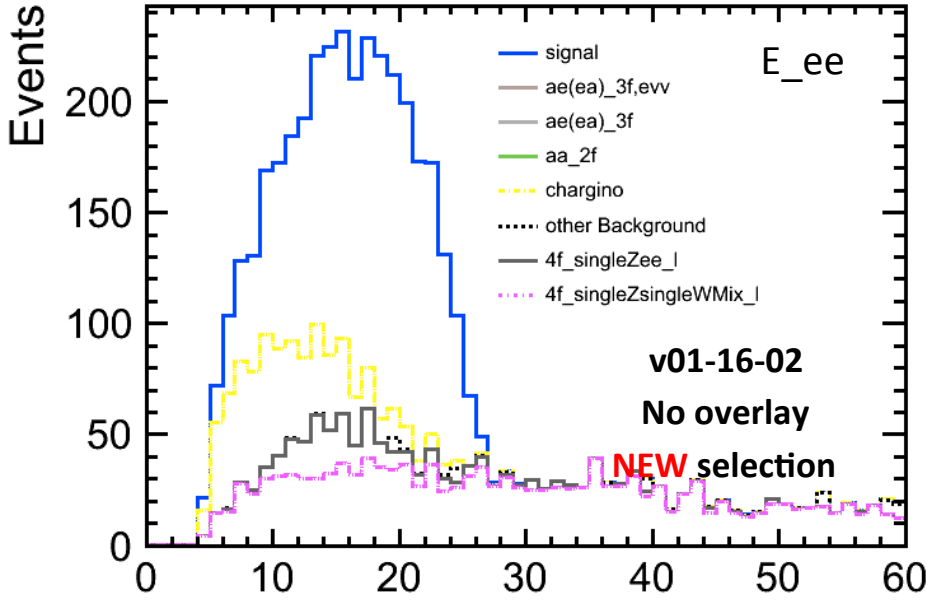


significance 27→36,

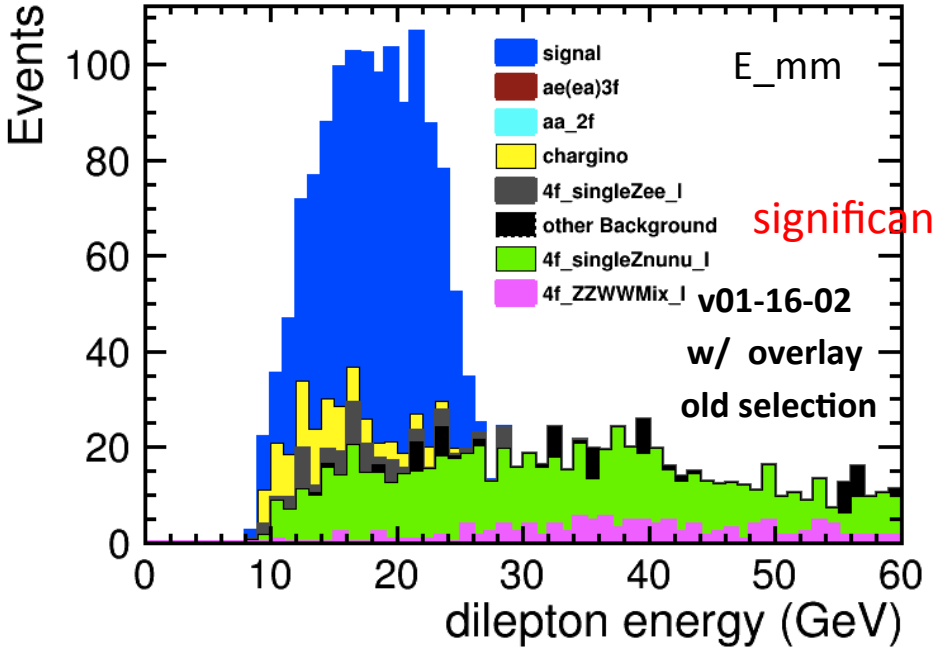


Remaining SUSY bkg : 25% is real 2 muons, ～1/2 is semileptonic W* decay (1 fake)

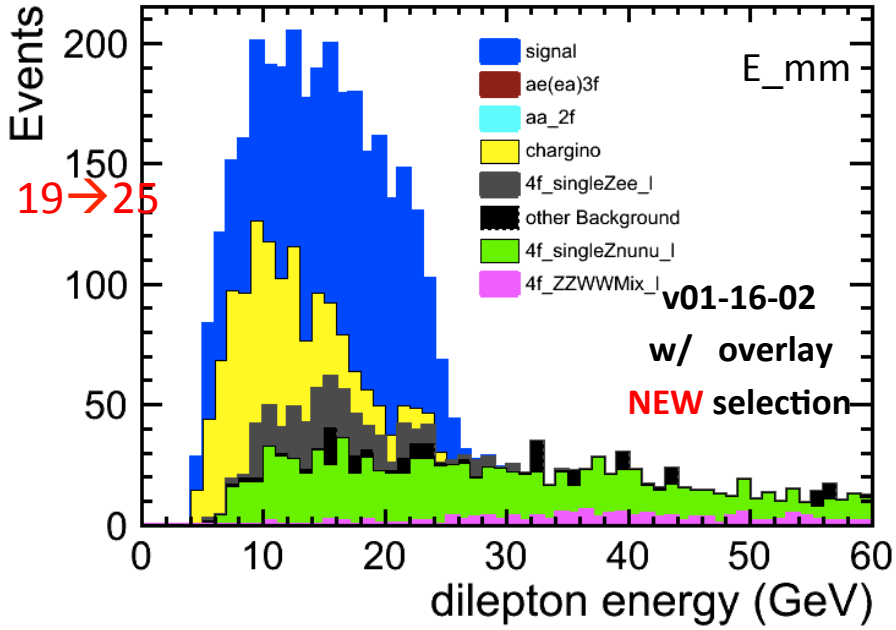




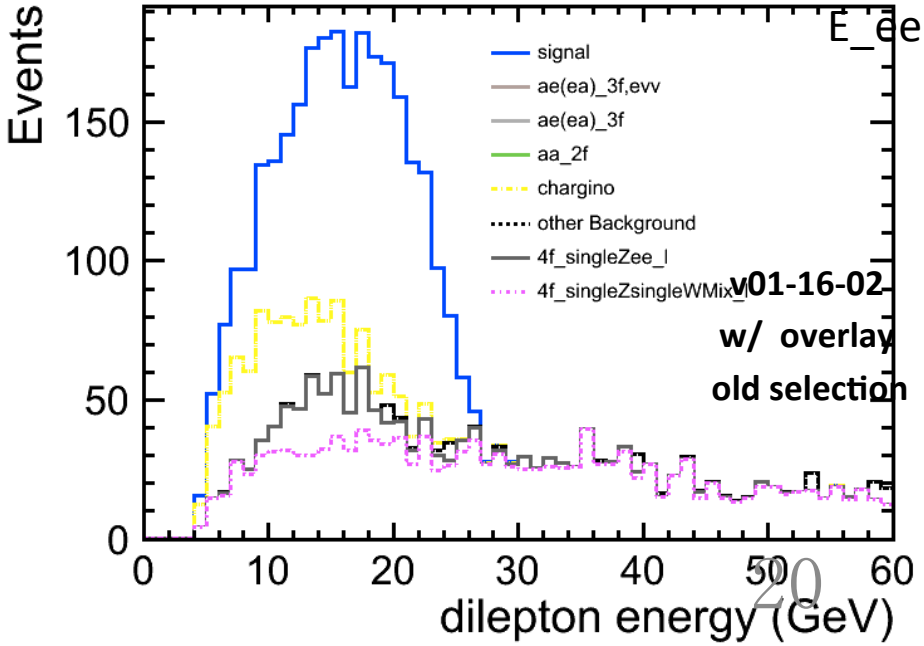
ILC2 : N1N2 left pol, with overlay

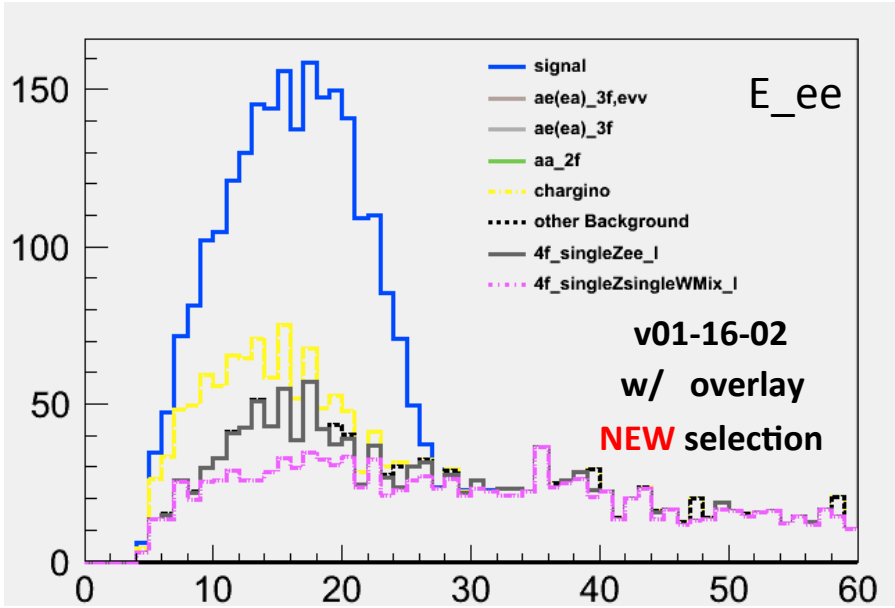


significance 19→25

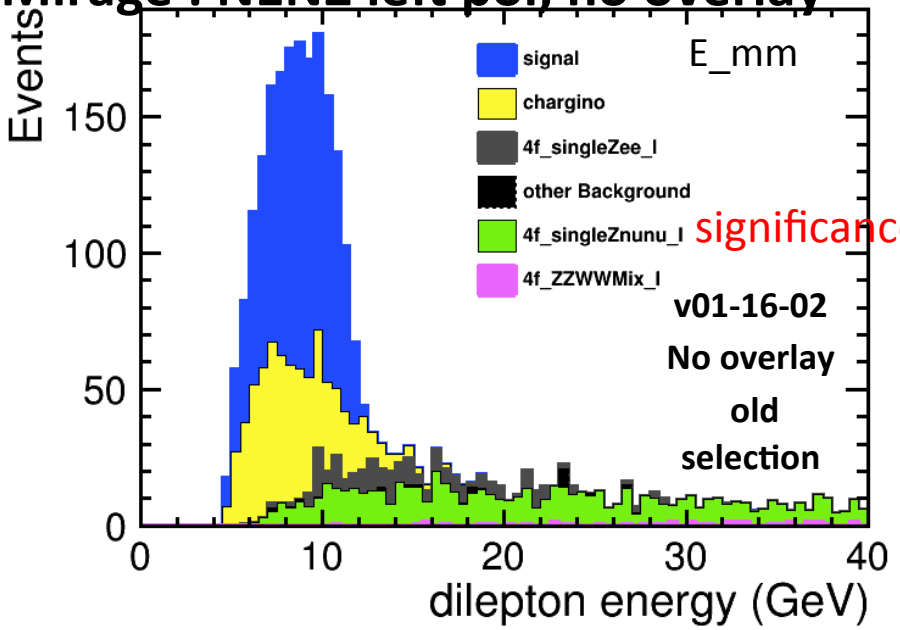


Remaining SUSY bkg : 25% is real 2 muons, ～1/2 is semileptonic W* decay (1 fake)

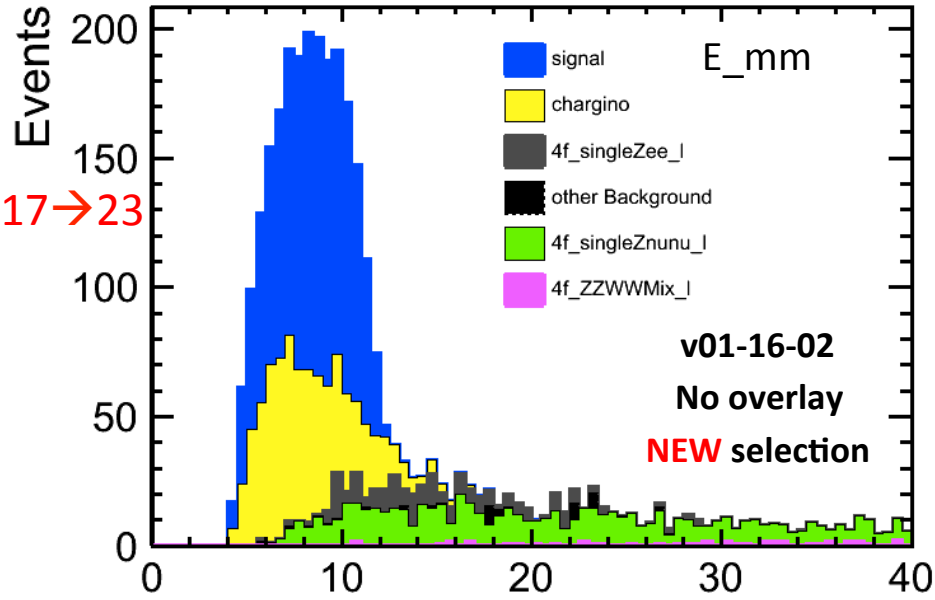


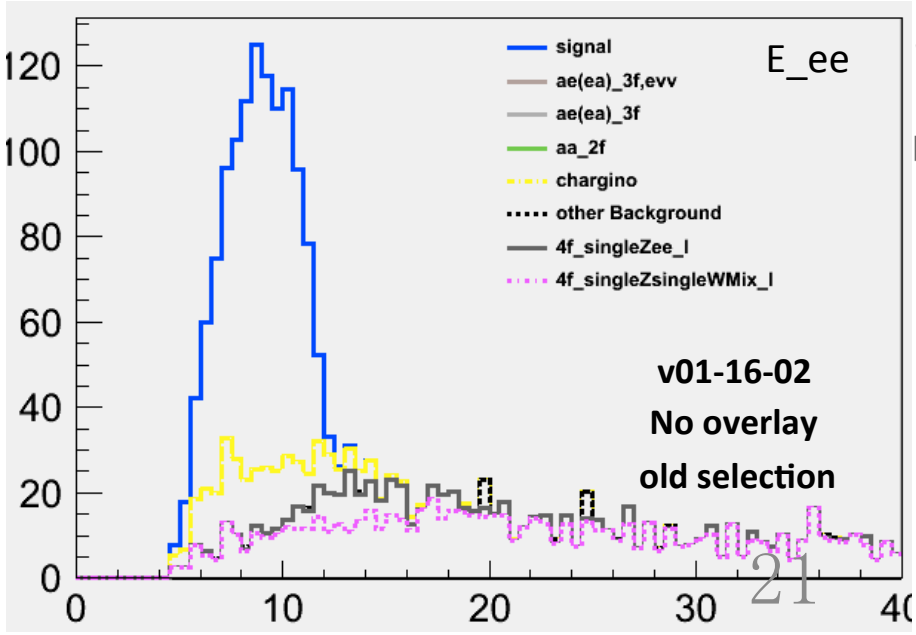


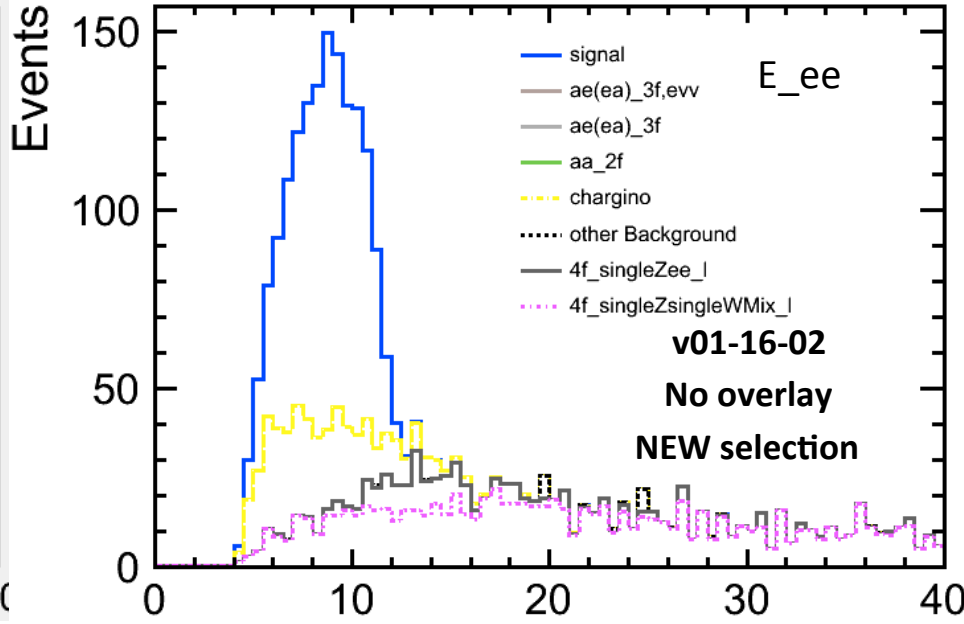
Mirage : N1N2 left pol, no overlay



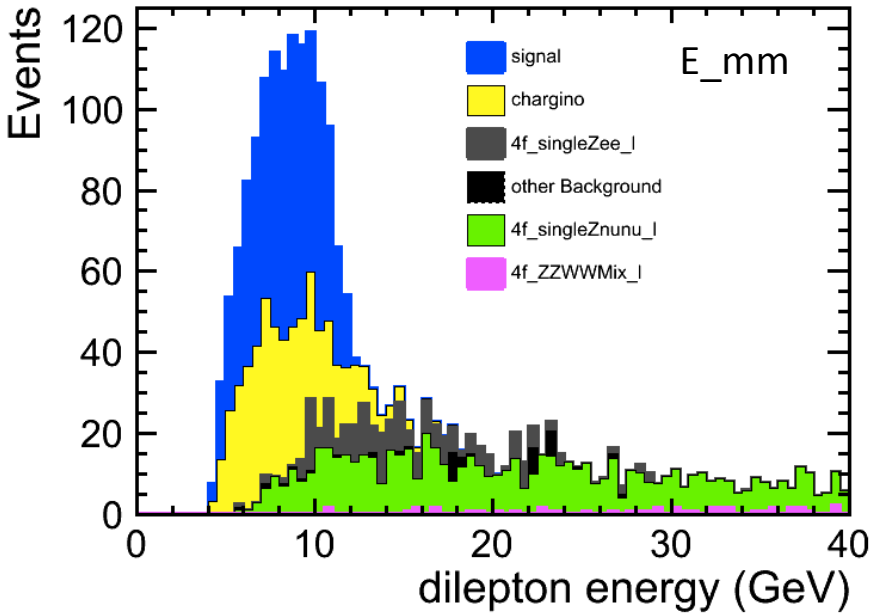
significance 17→23

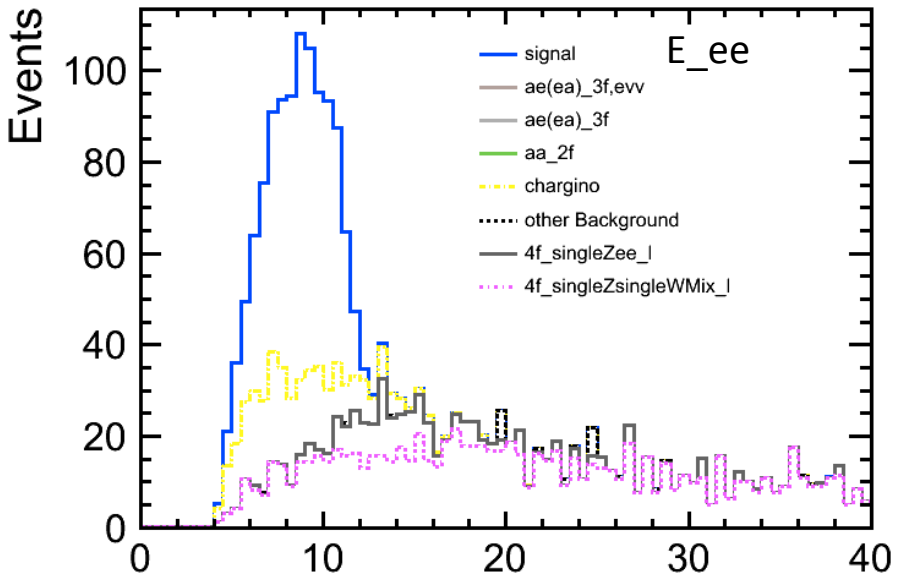




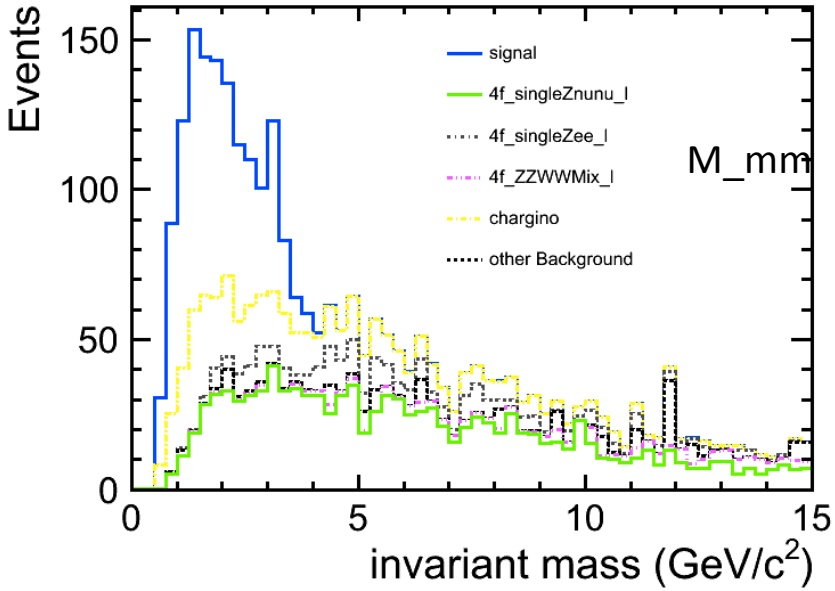


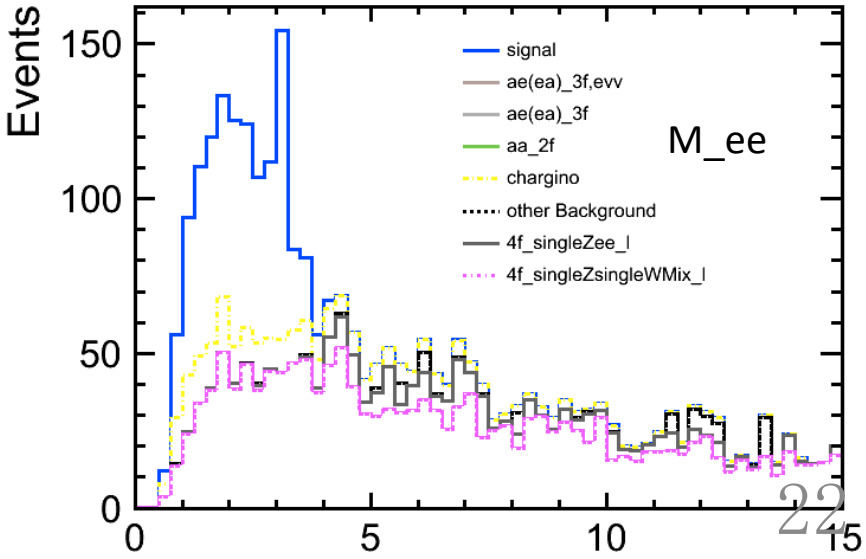
Mirage : N1N2 left pol, with overlay, all NEW selection, v01-16-02



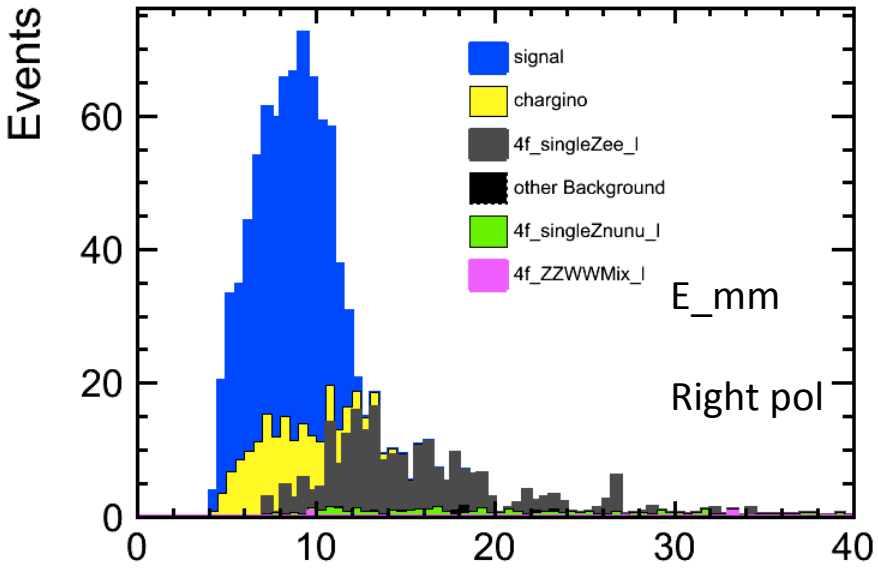


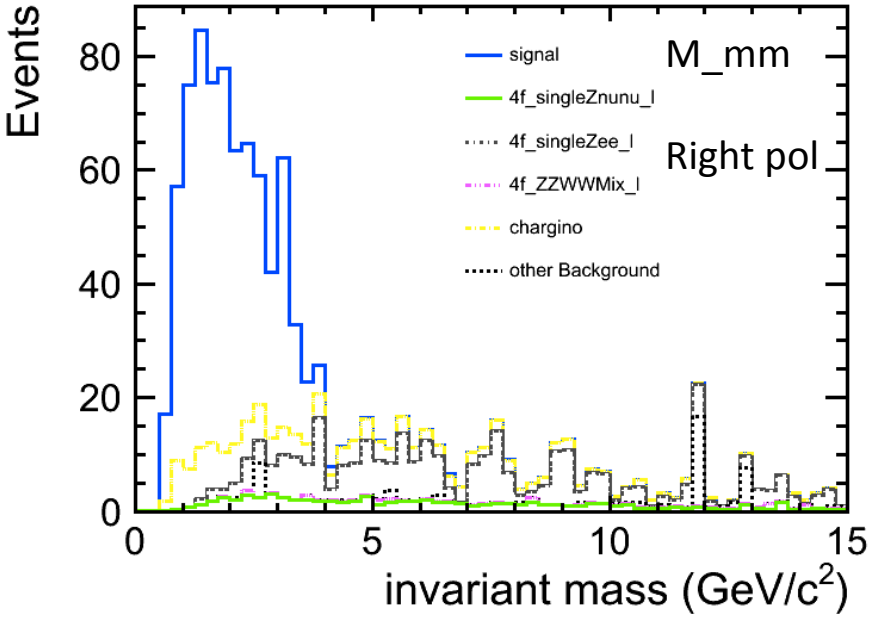
Concerned about SUSY bkg covering higher kinematic edge

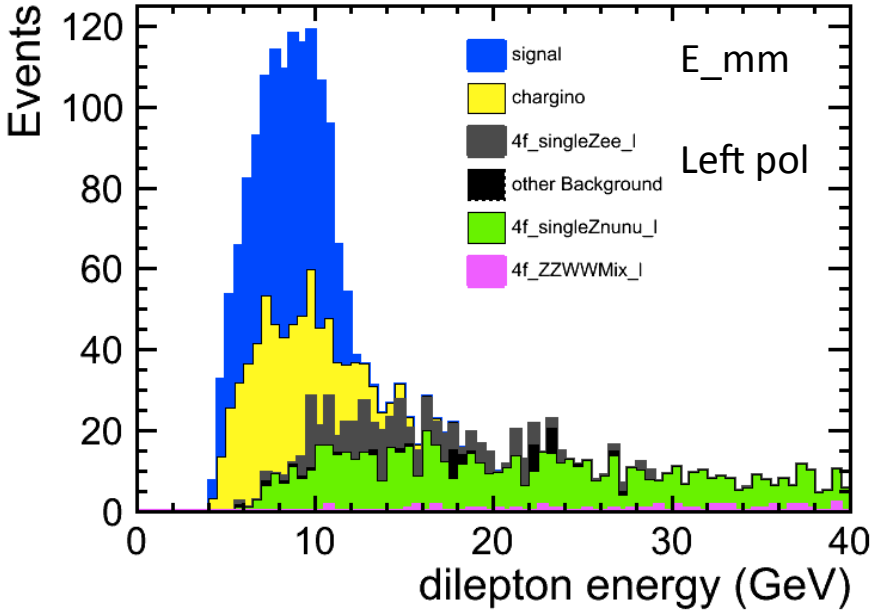


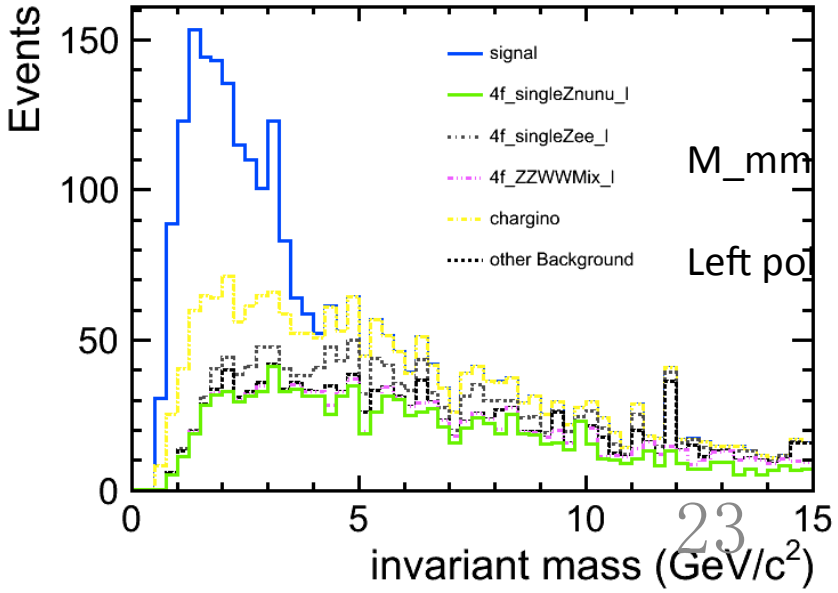


Mirage , v01-16-02, left vs right polarization, with overlay









ILC2 : N1N2 left pol, mumu, v01-16-02, without overlay

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	10606.7	13232.1	8648.64	2.6771e+06	906.095	56.3452	264326	3.00127e+06	280.839	0	
Generated	:	949500	2.3467e+06	5.61762e+06	1.2138e+06	704600	7.17376e+07	1.35308e+06	23700	2.28257e+07	1.06772e+08	621651	621651	
Expected	:	3.38654e+06	9.81253e+06	5.30337e+06	6.61606e+06	4.32432e+06	1.33855e+09	453047	28172.6	1.32163e+08	1.50063e+09	140420	140420	3.62469
Cut0	:	2.1489e+06	6.05387e+06	2.4287e+06	4.10309e+06	1.65708e+06	1.84338e+09	296466	18954.9	4.85045e+07	1.90859e+09	48076	48076	1.10044
Cut1	:	872915	311142	820202	169098	4264.27	8.71643e+08	68710.8	547.694	2.19281e+07	8.95818e+08	7627.59	7627.59	0.254845
Cut2	:	818207	272828	569569	129857	4031.56	5.41897e+06	68379.8	511.262	965354	8.2477e+06	7591.78	7591.78	2.64227
Cut3	:	369927	241.018	179191	1345.36	18.8684	3.32465e+06	3465.45	347.968	524259	4.40345e+06	1658	1658	0.789961
Cut4	:	232166	105.16	111691	538.307	18.8684	2.14952e+06	3443.84	280.311	289298	2.78707e+06	1655.89	1655.89	0.991584
Cut5	:	17810.3	71.8268	17619.2	77.7113	6.28948	24449.2	166.866	81.9278	67640.5	127924	1479.32	1479.32	4.11234
Cut6	:	13003.5	0.376323	6571.65	6.2839	0	19882.9	166.261	79.9611	20471.5	60182.5	1477.82	1477.82	5.9514
Cut7	:	19.3098	0	2794.12	6.2839	0	99.0678	166.242	76.0278	349.268	3510.32	1477.82	1477.82	20.9244
Cut8	:	0	0	2689.72	6.2839	0	33.6364	164.901	76.0278	121.364	3091.93	1467.8	1467.8	21.7369
Cut9	:	0	0	1855.57	6.2839	0	33.6364	164.901	71.1278	121.364	2252.88	1467.8	1467.8	24.0634
Cut10	:	0	0	1108.76	6.2839	0	0	160.233	4.59414	113.864	1393.74	1467.8	1467.8	27.439

OLD

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	10606.7	13232.1	8648.64	2.6771e+06	906.095	56.3452	264326	3.00127e+06	280.839	0	
Generated	:	949500	2.3467e+06	5.61762e+06	1.2138e+06	704600	7.17376e+07	1.35308e+06	23700	2.28257e+07	1.06772e+08	621651	621651	
Expected	:	3.38654e+06	9.81253e+06	5.30337e+06	6.61606e+06	4.32432e+06	1.33855e+09	453047	28172.6	1.32163e+08	1.50063e+09	140420	140420	3.62469
Cut0	:	1.29367e+06	45126.9	1.03327e+06	221551	21827.4	1.84338e+09	24407.4	18954.9	4.85045e+07	1.89454e+09	6975.92	6975.92	0.160269
Cut1	:	395811	1740.08	356379	2971.73	37.7369	8.71643e+08	10365.3	547.694	2.19281e+07	8.94339e+08	3678.14	3678.14	0.122992
Cut2	:	371639	1573.79	205294	2302.2	31.4474	5.41897e+06	10307.1	511.262	965354	6.97598e+06	3660.29	3660.29	1.38548
Cut3	:	371639	1573.79	205277	2302.2	31.4474	5.14303e+06	10307.1	425.549	812985	6.54757e+06	3660.29	3660.29	1.43006
Cut4	:	233036	1307.24	126152	1106.26	25.1579	3.3524e+06	10036.3	332.807	444619	4.16902e+06	3571.7	3571.7	1.74852
Cut5	:	18005.7	727.838	22792.7	270.429	0	55580.2	1209.14	97.3437	107027	205711	2832.68	2832.68	6.20297
Cut6	:	13168.9	7.04288	8241.34	12.95	0	45983.6	1206.39	95.377	40596.9	109312	2828.67	2828.67	8.44695
Cut7	:	45.4324	0	3554.18	6.2839	0	325.235	1206.39	91.4437	895.641	6124.61	2828.67	2828.67	29.8945
Cut8	:	26.1226	0	3291.32	6.2839	0	148.562	1185.75	91.4437	320.37	5069.85	2798.68	2798.68	31.5505
Cut9	:	26.1226	0	2446.21	6.2839	0	148.562	1185.75	86.5437	320.37	4219.85	2798.68	2798.68	33.4065
Cut10	:	19.686	0	1688.58	6.2839	0	114.925	1180.2	20.0101	312.87	3342.55	2798.68	2798.68	35.7129

NEW

ILC2 : N1N2 left pol, mumu, v01-16-02, with overlay

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	10606.7	13232.1	8648.64	2.6771e+06	906.095	56.3452	264326	3.00127e+06	280.839	0	
Generated	949500	2.3467e+06	5.61762e+06	1.2138e+06	704600	7.17376e+07	1.29296e+06	23700	2.28257e+07	1.06712e+08	606651	606651	
Expected	3.38654e+06	9.81253e+06	5.30337e+06	6.61606e+06	4.32432e+06	1.33855e+09	453047	28172.6	1.32163e+08	1.50063e+09	140420	140420	3.62469
Cut0	2.1489e+06	6.05387e+06	2.4287e+06	4.10309e+06	1.65708e+06	1.84338e+09	343002	18954.9	4.85045e+07	1.90864e+09	71699.4	71699.4	1.64114
Cut1	872915	311142	820202	169098	4264.27	8.71643e+08	84084.7	547.694	2.19281e+07	8.95833e+08	11970.1	11970.1	0.399926
Cut2	818207	272828	569569	129857	4031.56	5.41897e+06	83043.1	511.262	965354	8.26237e+06	11818.4	11818.4	4.10861
Cut3	369927	241.018	179191	1345.36	18.8684	3.32465e+06	3057.33	347.968	524259	4.40304e+06	1118.72	1118.72	0.533076
Cut4	232166	105.16	111691	538.307	18.8684	2.14952e+06	3031.76	280.311	289298	2.78665e+06	1115.57	1115.57	0.668141
Cut5	17810.3	71.8268	17619.2	77.7113	6.28948	24449.2	128.377	81.9278	67640.5	127885	964.621	964.621	2.68729
Cut6	13003.5	0.376323	6571.65	6.2839	0	19882.9	114.302	79.9611	20471.5	60130.5	906.236	906.236	3.66814
Cut7	19.3098	0	2794.12	6.2839	0	99.0678	114.283	76.0278	349.268	3458.36	906.236	906.236	13.7173
Cut8	0	0	2689.72	6.2839	0	33.6364	112.866	76.0278	121.364	3039.9	897.303	897.303	14.3003
Cut9	0	0	1855.57	6.2839	0	33.6364	112.866	71.1278	121.364	2200.85	897.303	897.303	16.1208
Cut10	0	0	1108.76	6.2839	0	0	108.814	4.59414	113.864	1342.32	897.303	897.303	18.9606

OLD

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	10606.7	13232.1	8648.64	2.6771e+06	906.095	56.3452	264326	3.00127e+06	280.839	0	
Generated	949500	2.3467e+06	5.61762e+06	1.2138e+06	704600	7.17376e+07	1.23373e+06	23700	2.28257e+07	1.06653e+08	606651	606651	
Expected	3.38654e+06	9.81253e+06	5.30337e+06	6.61606e+06	4.32432e+06	1.33855e+09	453047	28172.6	1.32163e+08	1.50063e+09	140420	140420	3.62469
Cut0	1.29367e+06	45126.9	1.03327e+06	221551	21827.4	1.84338e+09	22943.4	18954.9	4.85045e+07	1.89454e+09	5562.63	5562.63	0.127799
Cut1	395811	1740.08	356379	2971.73	37.7369	8.71643e+08	8959.02	547.694	2.19281e+07	8.94338e+08	2538.61	2538.61	0.0848878
Cut2	371639	1573.79	205294	2302.2	31.4474	5.41897e+06	8854.95	511.262	965354	6.97453e+06	2513.37	2513.37	0.951527
Cut3	371639	1573.79	205277	2302.2	31.4474	5.14303e+06	8854.95	425.549	812985	6.54611e+06	2513.37	2513.37	0.982158
Cut4	233036	1307.24	126152	1106.26	25.1579	3.3524e+06	8568.12	332.807	444619	4.16755e+06	2432.83	2432.83	1.19136
Cut5	18005.7	727.838	22792.7	270.429	0	55580.2	871.998	97.3437	107027	205373	1802.56	1802.56	3.96022
Cut6	13168.9	7.04288	8241.34	12.95	0	45983.6	796.549	95.377	40596.9	108903	1691.01	1691.01	5.08489
Cut7	45.4324	0	3554.18	6.2839	0	325.235	796.549	91.4437	895.641	5714.77	1690.69	1690.69	19.6466
Cut8	26.1226	0	3291.32	6.2839	0	148.562	772.859	91.4437	320.37	4656.96	1667.75	1667.75	20.9706
Cut9	26.1226	0	2446.21	6.2839	0	148.562	772.859	86.5437	320.37	3806.95	1667.75	1667.75	22.5398
Cut10	19.686	0	1688.58	6.2839	0	114.925	768.04	20.0101	312.87	2930.39	1667.75	1667.75	24.5946

NEW

Mirage N1N2 mumu

(Pe-,Pe+) = (-0.8, +0.3）　v01-16-02, no overlay

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	10606.7	13232.1	8648.64	2.6771e+06	900.36	56.3452	264326	3.00126e+06	283.641	0	
Generated	949500	2.3467e+06	5.61762e+06	1.2138e+06	704600	7.17376e+07	1.88845e+06	23700	2.28257e+07	1.07308e+08	1.03862e+06	1.03862e+06	
Expected	3.38654e+06	9.81253e+06	5.30337e+06	6.61606e+06	4.32432e+06	1.33855e+09	450180	28172.6	1.32163e+08	1.50063e+09	141820	141820	3.66084
Cut0	2.1489e+06	6.05387e+06	2.4287e+06	4.10309e+06	1.65708e+06	1.84338e+09	281065	18954.9	4.69615e+07	1.90703e+09	36775.5	36775.5	0.842122
Cut1	872915	311142	820202	169098	4264.27	8.71643e+08	50441	547.694	2.19275e+07	8.95799e+08	1965.22	1965.22	0.0656605
Cut2	818207	272828	569569	129857	4031.56	5.41897e+06	50233.9	511.262	965327	8.22953e+06	1959.74	1959.74	0.683062
Cut3	372355	1630.03	204796	2643.83	44.0264	5.07894e+06	7965.33	410.151	786935	6.45571e+06	1216.32	1216.32	0.478667
Cut4	232984	1245.73	125360	1182.14	44.0264	3.31454e+06	7878.03	317.408	430759	4.11431e+06	1216.32	1216.32	0.599562
Cut5	17985.8	677.516	22513.6	289.695	6.28948	52309	701.38	82.9262	104065	198631	1186.05	1186.05	2.6533
Cut6	13135.2	7.04288	8137.53	12.95	0	43259.2	700.72	80.9595	39224.2	104558	1185.79	1185.79	3.64654
Cut7	26.1226	0	3493.98	6.2839	0	243.946	700.72	77.0262	820.137	5368.21	1185.79	1185.79	14.6472
Cut8	6.81283	0	3243.83	6.2839	0	114.925	683.599	77.0262	278.367	4410.85	1172.63	1172.63	15.6932
Cut9	6.81283	0	2398.73	6.2839	0	114.925	683.599	72.1262	278.367	3560.84	1172.63	1172.63	17.044
Cut10	6.4366	0	1160.52	6.2839	0	33.6364	639.092	1.7128	200.505	2048.19	1172.63	1172.63	20.6623

OLD

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	10606.7	13232.1	8648.64	2.6771e+06	900.36	56.3452	264326	3.00126e+06	283.641	0	
Generated	949500	2.3467e+06	5.61762e+06	1.2138e+06	704600	7.17376e+07	1.88845e+06	23700	2.28257e+07	1.07308e+08	1.03862e+06	1.03862e+06	
Expected	3.38654e+06	9.81253e+06	5.30337e+06	6.61606e+06	4.32432e+06	1.33855e+09	450180	28172.6	1.32163e+08	1.50063e+09	141820	141820	3.66084
Cut0	1.29367e+06	45126.9	1.03327e+06	221551	21827.4	1.84338e+09	18676.3	18954.9	4.69615e+07	1.89299e+09	2612.27	2612.27	0.0600403
Cut1	395811	1740.08	356379	2971.73	37.7369	8.71643e+08	9152.4	547.694	2.19275e+07	8.94337e+08	1464.66	1464.66	0.0489763
Cut2	371639	1573.79	205294	2302.2	31.4474	5.41897e+06	9108.22	511.262	965327	6.97475e+06	1460.49	1460.49	0.552955
Cut3	371639	1573.79	205277	2302.2	31.4474	5.14303e+06	9108.22	425.549	812972	6.54635e+06	1460.49	1460.49	0.570757
Cut4	233036	1307.24	126152	1106.26	25.1579	3.3524e+06	8982.53	332.807	444606	4.16795e+06	1460.24	1460.24	0.715134
Cut5	18005.7	727.838	22792.7	270.429	0	55580.2	856.179	97.3437	107027	205358	1418.31	1418.31	3.11903
Cut6	13168.9	7.04288	8241.34	12.95	0	45983.6	855.189	95.377	40596.9	108961	1417.78	1417.78	4.26742
Cut7	45.4324	0	3554.18	6.2839	0	325.235	855.189	91.4437	895.641	5773.41	1417.78	1417.78	16.7189
Cut8	26.1226	0	3291.32	6.2839	0	148.562	834.503	91.4437	320.37	4718.6	1398.69	1398.69	17.883
Cut9	26.1226	0	2446.21	6.2839	0	148.562	834.503	86.5437	320.37	3868.6	1398.69	1398.69	19.272
Cut10	19.3098	0	1206.72	6.2839	0	67.2729	786.057	1.7128	242.508	2329.87	1398.69	1398.69	22.906

NEW

Mirage N1N2 ee **(Pe-,Pe+) = (-0.8, +0.3) v01-16-02, no overlay**

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	10606.7	13232.1	8648.64	2.6771e+06	900.36	56.3452	264326	3.00126e+06	283.641	0	
Generated	949500	2.3467e+06	5.61762e+06	1.2138e+06	704600	7.17376e+07	1.88845e+06	23700	2.28257e+07	1.07308e+08	1.03862e+06	1.03862e+06	
Expected	3.38654e+06	9.81253e+06	5.30337e+06	6.61606e+06	4.32432e+06	1.33855e+09	450180	28172.6	1.32163e+08	1.50063e+09	141820	141820	3.66084
Cut0	2.1489e+06	6.05387e+06	2.4287e+06	4.10309e+06	1.65708e+06	1.84338e+09	281065	18954.9	4.69615e+07	1.90703e+09	36775.5	36775.5	0.842122
Cut1	837842	22165.1	448702	16845.6	257.869	9.34245e+08	7962.29	481.607	1.16822e+07	9.47262e+08	1165.3	1165.3	0.037862
Cut2	769091	19574.6	321584	13667.5	226.421	5.11408e+06	7926.43	449.083	648303	6.8949e+06	1161.6	1161.6	0.44234
Cut3	649229	142.901	254206	2096.49	0	5.02413e+06	3176.32	374.381	630666	6.56402e+06	937.369	937.369	0.365843
Cut4	256862	97.7404	141417	461.465	0	2.99381e+06	3133.69	306.434	339548	3.73564e+06	937.332	937.332	0.484905
Cut5	9610.54	84.7836	24459.7	88.3783	0	47028	253.424	68.8196	67473.9	149067	883.207	883.207	2.28081
Cut6	1271.14	0	13258.6	1.13975	0	36479.3	252.456	61.5888	23913.9	75238.2	882.918	882.918	3.20013
Cut7	70.2166	0	5136.2	0	0	315.394	252.456	56.5879	1613.5	7444.35	882.918	882.918	9.6754
Cut8	22.2798	0	4940.82	0	0	21.8171	245.997	55.1565	1448.5	6734.57	869.676	869.676	9.97308
Cut9	22.2798	0	2985.11	0	0	21.8171	245.997	52.4399	593.5	3921.15	869.676	869.676	12.5647
Cut10	7.42659	0	1182.54	0	0	0	223.309	0.721667	129	1543	869.387	869.387	17.7007

OLD

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	10606.7	13232.1	8648.64	2.6771e+06	900.36	56.3452	264326	3.00126e+06	283.641	0	
Generated	949500	2.3467e+06	5.61762e+06	1.2138e+06	704600	7.17376e+07	1.88845e+06	23700	2.28257e+07	1.07308e+08	1.03862e+06	1.03862e+06	
Expected	3.38654e+06	9.81253e+06	5.30337e+06	6.61606e+06	4.32432e+06	1.33855e+09	450180	28172.6	1.32163e+08	1.50063e+09	141820	141820	3.66084
Cut0	1.29367e+06	45126.9	1.03327e+06	221551	21827.4	1.84338e+09	18676.3	18954.9	4.69615e+07	1.89299e+09	2612.27	2612.27	0.0600403
Cut1	789017	376.123	435727	3464.43	0	9.34245e+08	4344.39	481.607	1.16822e+07	9.47161e+08	1119.24	1119.24	0.0363672
Cut2	719472	329.457	297281	3003.87	0	5.11408e+06	4327.49	449.083	648303	6.78725e+06	1115.53	1115.53	0.428155
Cut3	719472	329.457	297278	3003.87	0	5.04099e+06	4327.49	379.549	635337	6.70112e+06	1115.53	1115.53	0.430897
Cut4	290410	316.5	169634	844.94	0	2.99956e+06	4266.78	310.646	341021	3.80636e+06	1114.72	1114.72	0.571277
Cut5	11641.7	232.846	30045.1	198.7	0	47962.8	434.955	68.8196	67884.9	158470	1030.9	1030.9	2.58127
Cut6	1490.76	0	15682.9	1.13975	0	37247.9	433.986	61.5888	24094.4	79012.7	1030.61	1030.61	3.64276
Cut7	75.5875	0	6043.04	0	0	320.312	433.986	56.5879	1640.5	8570.01	1030.61	1030.61	10.5183
Cut8	22.2798	0	5794.71	0	0	21.8171	424.293	55.1565	1475.5	7793.76	1014.52	1014.52	10.8097
Cut9	22.2798	0	3534.67	0	0	21.8171	424.293	52.4399	611.5	4667	1014.52	1014.52	13.4594
Cut10	7.42659	0	1426.72	0	0	0	398.018	0.721667	138	1970.89	1013.98	1013.98	18.5595

NEW

Mirage N1N2 mumu

(Pe-,Pe+) = (-0.8, +0.3）　v01-16-02, with overlay

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	10606.7	13232.1	8648.64	2.6771e+06	900.36	56.3452	264326	3.00126e+06	283.641	0	
Generated	:	949500	2.3467e+06	5.61762e+06	1.2138e+06	704600	7.17376e+07	1.88845e+06	23700	2.28257e+07	1.07308e+08	1.03862e+06	1.03862e+06	
Expected	:	3.38654e+06	9.81253e+06	5.30337e+06	6.61606e+06	4.32432e+06	1.33855e+09	450180	28172.6	1.32163e+08	1.50063e+09	141820	141820	3.66084
Cut0	:	1.29367e+06	45126.9	1.03327e+06	221551	21827.4	1.84338e+09	17731	18954.9	4.69615e+07	1.89299e+09	1902.37	1902.37	0.043724
Cut1	:	395811	1740.08	356379	2971.73	37.7369	8.71643e+08	7998.67	547.694	2.19275e+07	8.94336e+08	889.433	889.433	0.0297415
Cut2	:	371639	1573.79	205294	2302.2	31.4474	5.41897e+06	7913.16	511.262	965327	6.97356e+06	880.119	880.119	0.333263
Cut3	:	371639	1573.79	205277	2302.2	31.4474	5.14303e+06	7913.16	425.549	812972	6.54516e+06	880.119	880.119	0.343995
Cut4	:	233036	1307.24	126152	1106.26	25.1579	3.3524e+06	7702.66	332.807	444606	4.16667e+06	845.487	845.487	0.41416
Cut5	:	18005.7	727.838	22792.7	270.429	0	55580.2	596.234	97.3437	107027	205098	783.103	783.103	1.72588
Cut6	:	13168.9	7.04288	8241.34	12.95	0	45983.6	546.489	95.377	40596.9	108653	753.882	753.882	2.2792
Cut7	:	45.4324	0	3554.18	6.2839	0	325.235	546.489	91.4437	895.641	5464.71	753.882	753.882	9.55999
Cut8	:	26.1226	0	3291.32	6.2839	0	148.562	525.176	91.4437	320.37	4409.27	729.242	729.242	10.1731
Cut9	:	26.1226	0	2446.21	6.2839	0	148.562	525.176	86.5437	320.37	3559.27	729.242	729.242	11.1357
Cut10	:	19.3098	0	1206.72	6.2839	0	67.2729	488.008	1.7128	242.508	2031.82	728.991	728.991	13.8741

Mirage N1N2 ee

(Pe-,Pe+) = (-0.8, +0.3）　v01-16-02, with overlay

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	10606.7	13232.1	8648.64	2.6771e+06	900.36	56.3452	264326	3.00126e+06	283.641	0	
Generated	949500	2.3467e+06	5.61762e+06	1.2138e+06	704600	7.17376e+07	1.88845e+06	23700	2.28257e+07	1.07308e+08	1.03862e+06	1.03862e+06	
Expected	3.38654e+06	9.81253e+06	5.30337e+06	6.61606e+06	4.32432e+06	1.33855e+09	450180	28172.6	1.32163e+08	1.50063e+09	141820	141820	3.66084
Cut0	1.29367e+06	45126.9	1.03327e+06	221551	21827.4	1.84338e+09	17731	18954.9	4.69615e+07	1.89299e+09	1902.37	1902.37	0.043724
Cut1	789017	376.123	435727	3464.43	0	9.34245e+08	3830.21	481.607	1.16822e+07	9.4716e+08	844.246	844.246	0.027432
Cut2	719472	329.457	297281	3003.87	0	5.11408e+06	3789.82	449.083	648303	6.78671e+06	837.053	837.053	0.32129
Cut3	719472	329.457	297278	3003.87	0	5.04099e+06	3789.82	379.549	635337	6.70058e+06	837.053	837.053	0.323348
Cut4	290410	316.5	169634	844.94	0	2.99956e+06	3731.7	310.646	341021	3.80583e+06	835.447	835.447	0.4282
Cut5	11641.7	232.846	30045.1	198.7	0	47962.8	348.767	68.8196	67884.9	158384	763.247	763.247	1.91322
Cut6	1490.76	0	15682.9	1.13975	0	37247.9	312.687	61.5888	24094.4	78891.4	711.582	711.582	2.52209
Cut7	75.5875	0	6043.04	0	0	320.312	312.687	56.5879	1640.5	8448.71	711.582	711.582	7.43482
Cut8	22.2798	0	5794.71	0	0	21.8171	300.727	55.1565	1475.5	7670.19	681.319	681.319	7.45535
Cut9	22.2798	0	3534.67	0	0	21.8171	300.408	52.4399	611.5	4543.12	681.319	681.319	9.42607
Cut10	7.42659	0	1426.72	0	0	0	279.348	0.721667	138	1852.22	680.767	680.767	13.5264

ILC2 : N1N2 left pol, mumu, v01-16-02

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	10606.7	13232.1	8648.64	2.6771e+06	906.095	56.3452	264326	3.00127e+06	280.839	0	
Generated	949500	2.3467e+06	5.61762e+06	1.2138e+06	704600	7.17376e+07	1.35308e+06	23700	2.28257e+07	1.06772e+08	621651	621651	
Expected	3.38654e+06	9.81253e+06	5.30337e+06	6.61606e+06	4.32432e+06	1.33855e+09	453047	28172.6	1.32163e+08	1.50063e+09	140420	140420	3.62469
Cut0	2.1489e+06	6.05387e+06	2.4287e+06	4.10309e+06	1.65708e+06	1.84338e+09	296466	18954.9	4.85045e+07	1.90859e+09	48076	48076	1.10044
Cut1	872915	311142	820202	169098	4264.27	8.71643e+08	68710.8	547.694	2.19281e+07	8.95818e+08	7627.59	7627.59	0.254845
Cut2	818207	272828	569569	129857	4031.56	5.41897e+06	68379.8	511.262	965354	8.2477e+06	7591.78	7591.78	2.64227
Cut3	369927	241.018	179191	1345.36	18.8684	3.32465e+06	3465.45	347.968	524259	4.40345e+06	1658	1658	0.789961
Cut4	232166	105.16	111691	538.307	18.8684	2.14952e+06	3443.84	280.311	289298	2.78707e+06	1655.89	1655.89	0.991584
Cut5	17810.3	71.8268	17619.2	77.7113	6.28948	24449.2	166.866	81.9278	67640.5	127924	1479.32	1479.32	4.11234
Cut6	13003.5	0.376323	6571.65	6.2839	0	19882.9	166.261	79.9611	20471.5	60182.5	1477.82	1477.82	5.9514
Cut7	19.3098	0	2794.12	6.2839	0	99.0678	166.242	76.0278	349.268	3510.32	1477.82	1477.82	20.9244
Cut8	0	0	2689.72	6.2839	0	33.6364	164.901	76.0278	121.364	3091.93	1467.8	1467.8	21.7369
Cut9	0	0	1855.57	6.2839	0	33.6364	164.901	71.1278	121.364	2252.88	1467.8	1467.8	24.0634
Cut10	0	0	1108.76	6.2839	0	0	160.233	4.59414	113.864	1393.74	1467.8	1467.8	27.439

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 > 2 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