SUSY Mass Resolution Studies Progress Report

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Outline

- The Colorado SUSY group
- SUSY parameter points and masses
- Simulation tools
- Endpoint method studies
- Determining masses by minimizing χ^2
- Current status and future work

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SUSY FastMC Studies at CU Boulder

Many undergraduates contribute to SUSY and calorimetry studies at CU.

Those that have contributed to this presentation include:

Chris Geraci	Paul Steinbrecher	Elliot Smith
Maria Gulda	Kyle Miller	Jack Gill

`http://hep-www.colorado.edu/SUSY`

`http://hep-www.colorado.edu/~nlc`

SUSY FastMC Studies at CU Boulder

Our task:

- Attempt reconstruction of SUSY masses using fast MC detector simulation

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Our task:

- Attempt reconstruction of SUSY masses using fast MC detector simulation
- Determine whether measurements are attainable
- Determine whether changes in detector or accelerator design might help with measurements

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The SUSY Parameter points

Nine separate parameter points chosen for studies: SPS1-9

- 6 mSUGRA parameter points
- 2 GMSB points
- 1 AMSB point

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We have focused on SPS1 and several other mSUGRA points

The SUSY Parameter points

	mSUGRA					
	SPS1	SPS2	SPS3	SPS4	SPS5	SPS6
M_0	100	1450	90	400	150	150
$M_{1/2}$	250	300	400	300	300	300
A_0	-100	0	0	0	-1000	0
$tan(\beta)$	10	10	10	50	5	10
μ	352.39	124.77	508.59	377.03	639.80	393.09

	GMSB			AMSB
	SPS7	SPS8		SPS9
Λ	$40,000$	$100,000$	M_0	400
M_{mes}	$80,000$	$200,000$	$M_{3/2}$	60000
N_5	3	1		
$tan(\beta)$	15	15	$tan(\beta)$	10
μ	300.03	398.31	μ	869.90

The SUSY Masses

	minimal SUGRA						GMSB		AMSB
	SPS1	SPS2	SPS3	SPS4	SPS5	SPS6	SPS7	SPS8	SPS9
$\widetilde{\chi}_1^0$	96.05	79.54	160.55	118.66	119.51	117.50	161.65	137.19	175.51
$\widetilde{\chi}_2^0$	176.82	135.34	296.95	218.14	226.33	215.54	260.06	252.33	549.03
$\widetilde{\chi}_3^0$	358.81	140.84	512.87	383.91	642.83	398.70	306.26	404.00	874.37
$\widetilde{\chi}_4^0$	377.81	269.45	529.57	401.08	652.95	418.06	379.94	426.28	875.97
$\widetilde{\chi}_1^+$	176.38	104.03	296.85	218.06	226.33	215.20	256.33	252.03	175.67
$\widetilde{\chi}_2^+$	378.23	269.03	529.51	402.28	652.68	418.19	379.45	426.47	877.22
h^0	113.97	115.71	116.95	115.39	119.79	114.71	113.57	114.83	114.83
H^0	394.15	1444.10	573.03	404.63	694.03	457.84	378.37	515.01	912.56
A^0	393.63	1442.95	572.42	404.43	693.86	457.26	377.89	514.49	911.74
H^+	401.77	1446.18	578.30	416.28	698.49	464.40	386.70	521.17	915.83
$\widetilde{\nu}_e$	186.00	1454.17	275.99	441.22	244.52	243.25	249.06	347.61	309.71
$\widetilde{e}_R^-$	142.97	1451.69	178.33	416.54	191.45	191.30	127.43	175.87	303.01
$\widetilde{e}_L^-$	202.14	1456.33	287.11	448.40	256.30	255.81	261.47	356.61	319.66
$\widetilde{\tau}_1^-$	133.22	1439.46	170.59	267.61	180.67	184.34	120.45	169.42	271.28
$\widetilde{\tau}_2^-$	206.13	1450.38	289.22	414.91	257.86	258.31	263.40	357.59	322.54
$\widetilde{t}_1$	379.11	1003.88	623.83	530.58	220.74	474.12	779.09	957.65	1005.17
$\widetilde{t}_2$	574.71	1307.41	819.54	695.88	644.65	659.73	863.00	1058.68	1128.80
$\widetilde{b}_1$	491.91	1296.56	757.50	606.86	535.86	589.80	822.17	1021.90	1112.07
$\widetilde{b}_2$	524.59	1520.09	791.35	706.45	622.99	623.42	843.35	1048.26	1232.88
$\widetilde{u_R}$	520.45	1530.08	791.78	715.10	624.49	621.87	830.54	1033.16	1227.35
$\widetilde{u_L}$	537.25	1532.70	816.57	730.24	641.82	638.97	859.66	1080.25	1218.09
$\widetilde{g}$	595.19	784.37	914.26	721.03	710.31	708.58	926.04	820.50	1275.18

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Simulation Tools

Event Generation:

- ISAJET - SUSY and Standard Model background
- HERWIG - $e^+e^- \rightarrow e^+e^-\gamma^*\gamma^*$
- WHIZARD - multiple parton final state events

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Analysis

- ROOT

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Endpoint Method Overview

$$e^+e^- \rightarrow X\bar{X}$$

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$$E(X) = 250GeV$$

$$E(Z) = \gamma(E_{Z,cm} + \beta P_{Z,cm} cos(\theta))$$

Energy of visible (particle Z) follows a uniform distribution between an E_{max} and E_{min}.

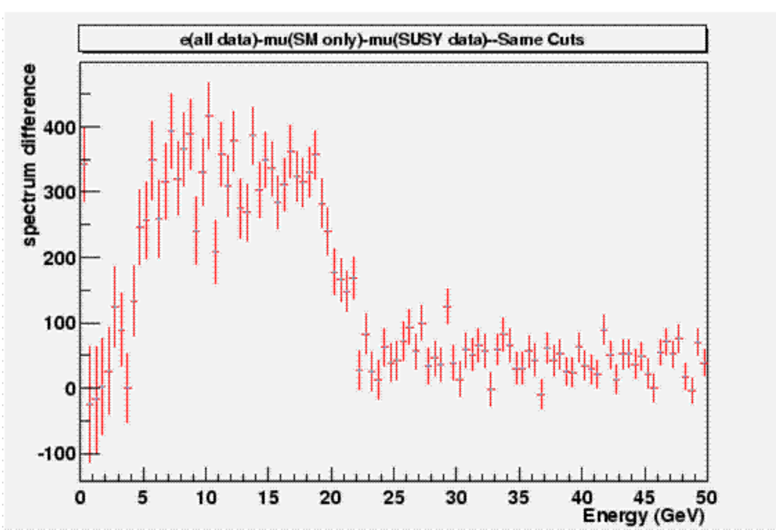
Endpoint method - Example: SPS1 $\widetilde{\nu}_e\overline{\widetilde{\nu}}_e$

$$e^+e^- \to \widetilde{\nu}_e\overline{\widetilde{\nu}}_e$$

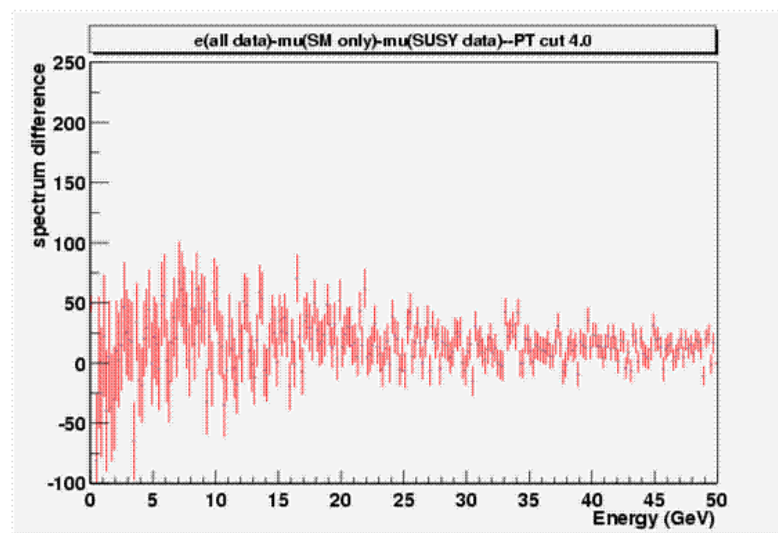
$$\widetilde{\nu}_e \to \widetilde{\chi}_1^0\nu(87.9\%)$$

$$\widetilde{\nu}_e \to \widetilde{\chi}_1^+e^-(8.9\%)$$

left polarization



right polarization



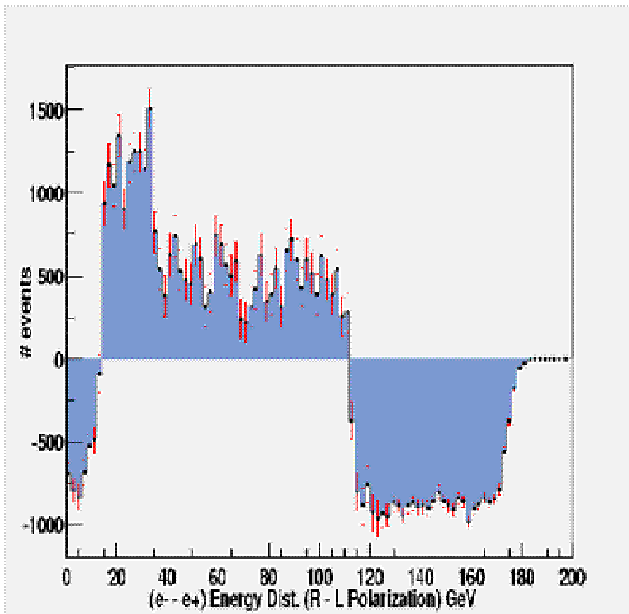
Endpoint method - SPS1 $\widetilde{\nu}_e \overline{\widetilde{\nu}}_e$ - Results

	E_{low}	E_{high}
No Brems	4.11 ± 0.04	21.10 ± 0.09
Brems	4.22 ± 0.08	20.40 ± 0.12

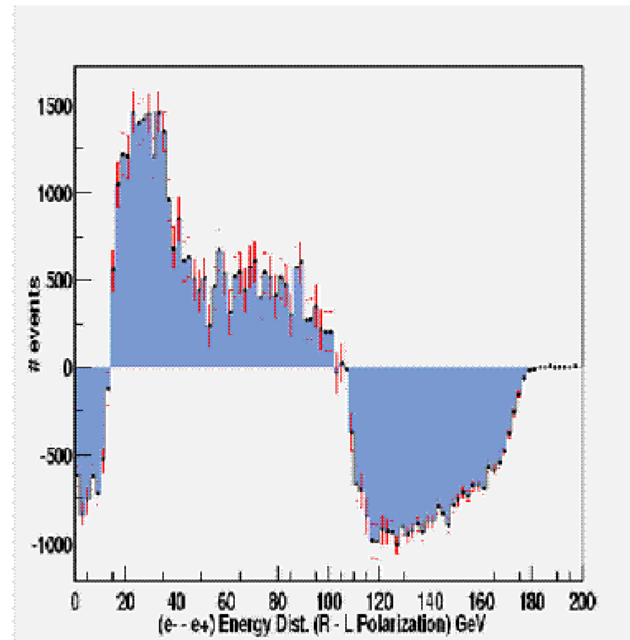
	$M_{\widetilde{\nu}_e}$	$M_{\widetilde{\chi}_1^0}$
Input	186.00	176.38
No Brems	184.7 ± 0.7	175.1 ± 0.7
Brems	188.4 ± 0.7	178.9 ± 0.7

ndpoint method and Beam/Bremsstrahlun

No Bremsstrahlung



With Bremsstrahlung



Bremsstrahlung and beamstrahlung destroy the energy endpoints. However, the energy distribution is still highly dependent upon the particle masses.

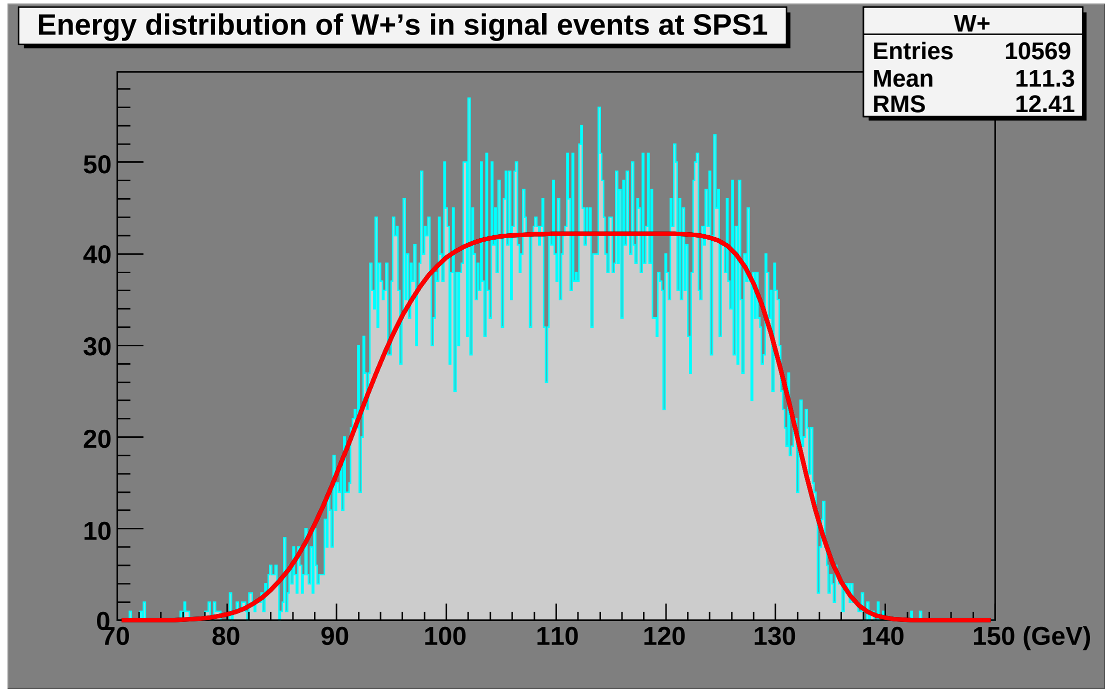
Endpoint method - $\widetilde{\chi}_1^{\pm} \to W^{\pm}\widetilde{\chi}_1^0$

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

$$\widetilde{\chi}_1^{\pm} \to \widetilde{\chi}_1^0 W^{\pm}$$

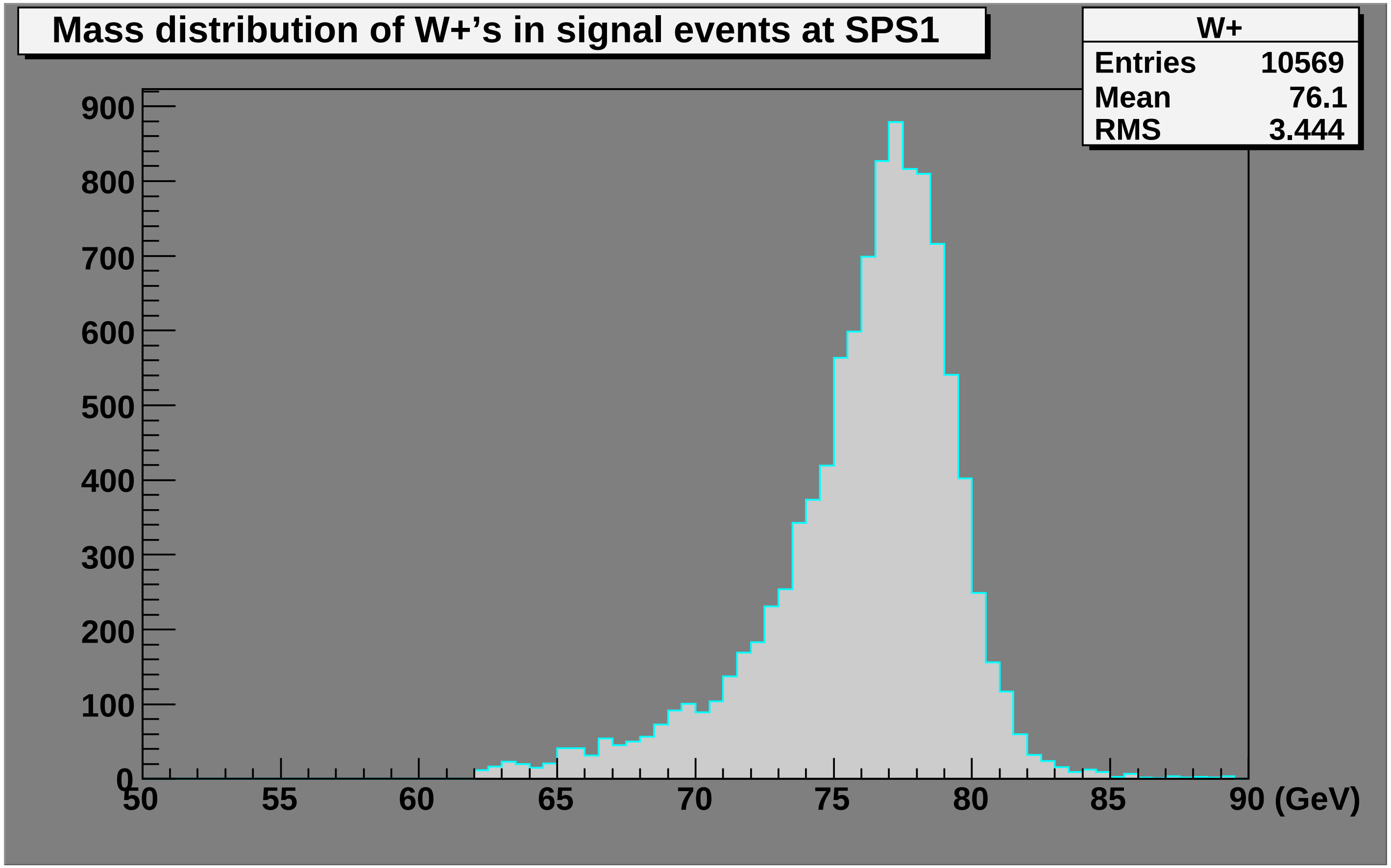
$$W^{\pm} \to \ell^{\pm}\nu_\ell$$

$$W^{\mp} \to q\bar{q}'$$



	Reconstructed Mass	MC Mass
$\widetilde{\chi}_1^0$	101.0 ± 0.3 (statistical)	95.185
$\widetilde{\chi}_1^{\pm}$	186.8 ± 0.5 (statistical)	180.374

Endpoint method - $\widetilde{\chi}_1^\pm \rightarrow W^\pm \widetilde{\chi}_1^0$



Bias in W mass reconstruction affects reconstruction of gaugino mass

Endpoint Method - Conclusions

- 2-body decays provide a distinct signal for SUSY searches
- The endpoint method can be used to make a rough first calculation of the mass
- Brems-/beamstrahlung make precision measurements impossible
- Precision measurements are impossible in the best case when the visible particle is a W or Z

SUSY signals are distinct enough to yield precision mass measurements

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Measuring Masses by χ^2 Analysis

- Use ISAJET to create one year of SUSY, SM data
- Determine cuts to isolate signal
- Compare energy distribution to distribution using different input masses
  - Each variation uses 10 years of data in order to minimize uncertainty in histogram bin size
- Best mass for 1-year data set corresponds to minimum χ^2
- Uncertainty is the change in mass which causes a change of 1 in χ^2

χ^2 Analysis - SPS6 $\widetilde{\nu}_e\overline{\widetilde{\nu}}_e$

$$e^+e^- \to \widetilde{\nu}_e\overline{\widetilde{\nu}}_e$$

$$\widetilde{\nu}_e \to \widetilde{\chi}_1^0\nu_e; \overline{\widetilde{\nu}}_e \to \widetilde{\chi}_1^- e^+$$

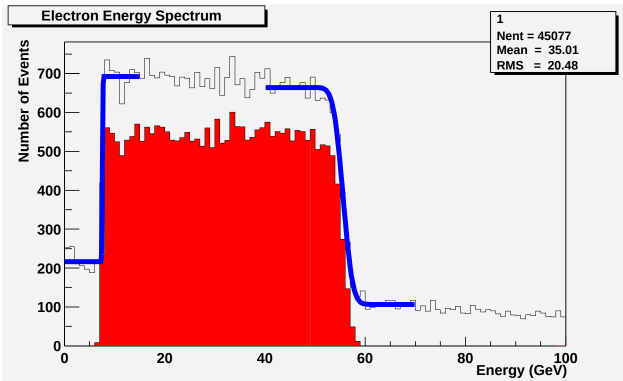
$$\widetilde{\chi}_1^- \to \widetilde{\chi}_1^0 W^- \to hadrons$$

Cuts:

- number of particles
- reconstructed W mass
- energy of W

χ^2 Analysis - SPS6 $\widetilde{\nu}_e\overline{\widetilde{\nu}}_e$

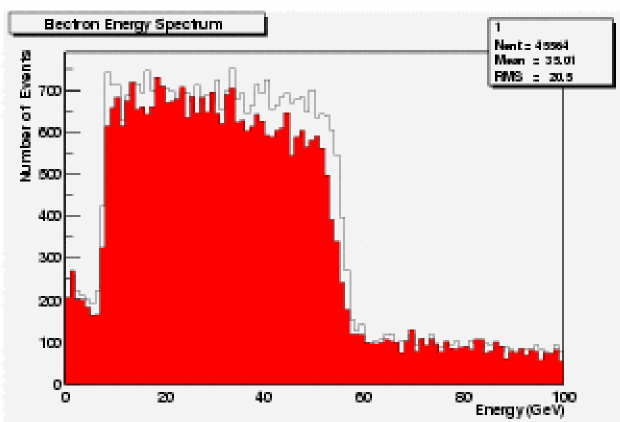
No Bremstrahlung



	Recon Mass	MC Mass
$\widetilde{\nu}_e$	243.6 ± 0.5	243.85
$\widetilde{\chi}_1^{\pm}$	222.1 ± 0.5	222.38

red = signal

With Bremstrahlung

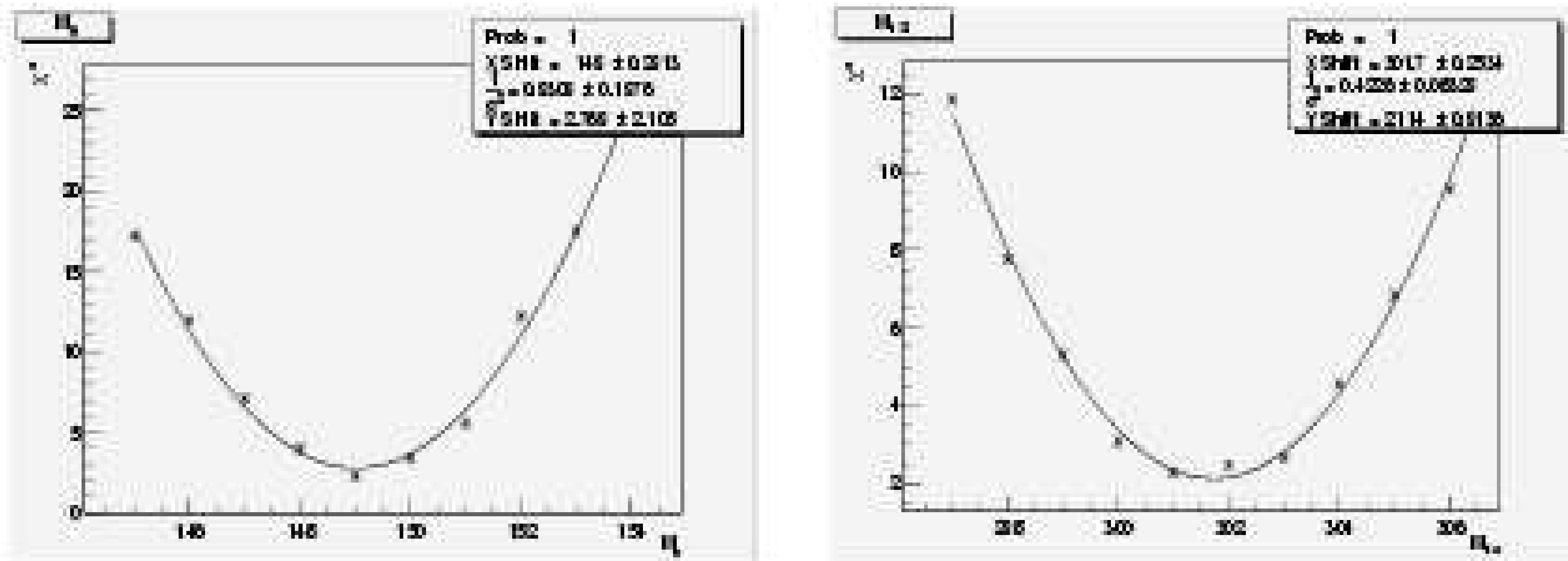


	Recon Mass	MC Mass
$\widetilde{\nu}_e$	248.9 ± 0.8	243.85
$\widetilde{\chi}_1^{\pm}$	227.4 ± 0.4	222.38

red = bremstrahlung

χ^2 Analysis - SPS6 $\widetilde{\nu}_e\overline{\widetilde{\nu}}_e$

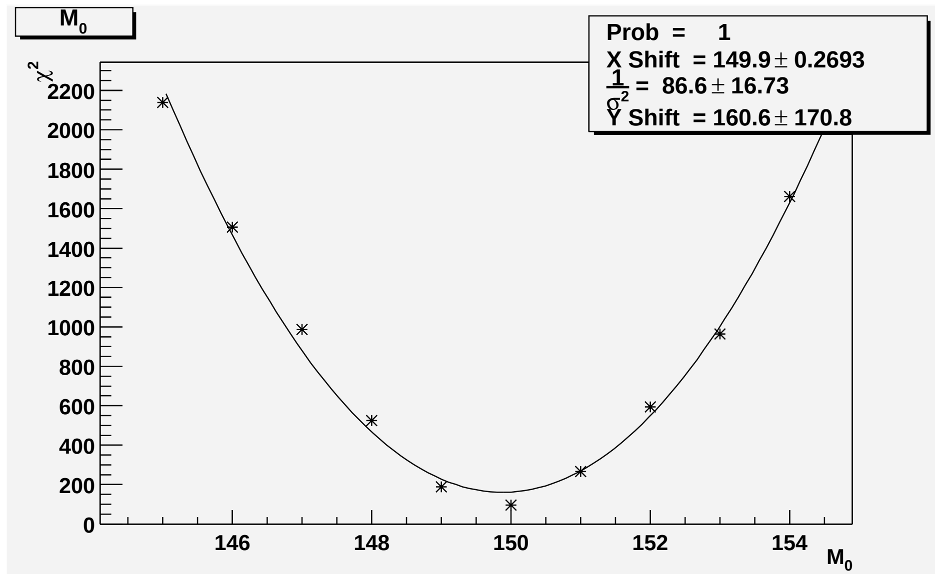
- χ^2 of the distribution varies as a function of M_0 and $M_{1/2}$



	Recon Mass	MC Mass
$\widetilde{\nu}_e$	243.6 ± 0.1	243.85
$\widetilde{\chi}_1^{\pm}$	222.4 ± 0.3	222.38

χ^2 Analysis - SPS6 $\widetilde{\nu}_e \overline{\widetilde{\nu}}_e$

- Similar analysis as at SPS6:



	Recon Mass	MC Mass
$\widetilde{\nu}_e$	244.8 ± 0.1	245.9

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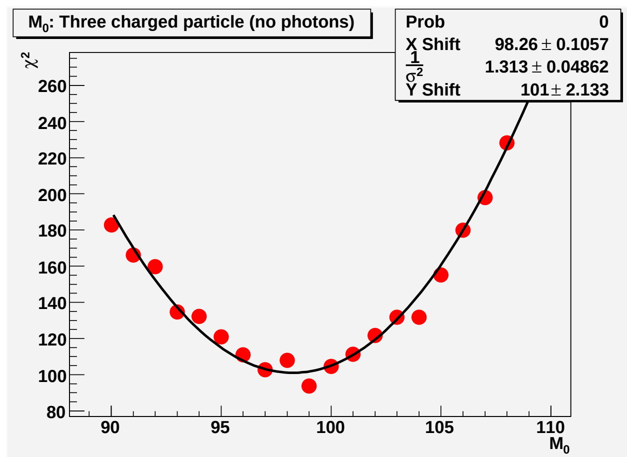
Current Status and Future Work

- Signal analysis is an ongoing process



Three-prong taus produce energy distributions that may yield successful mass determination.

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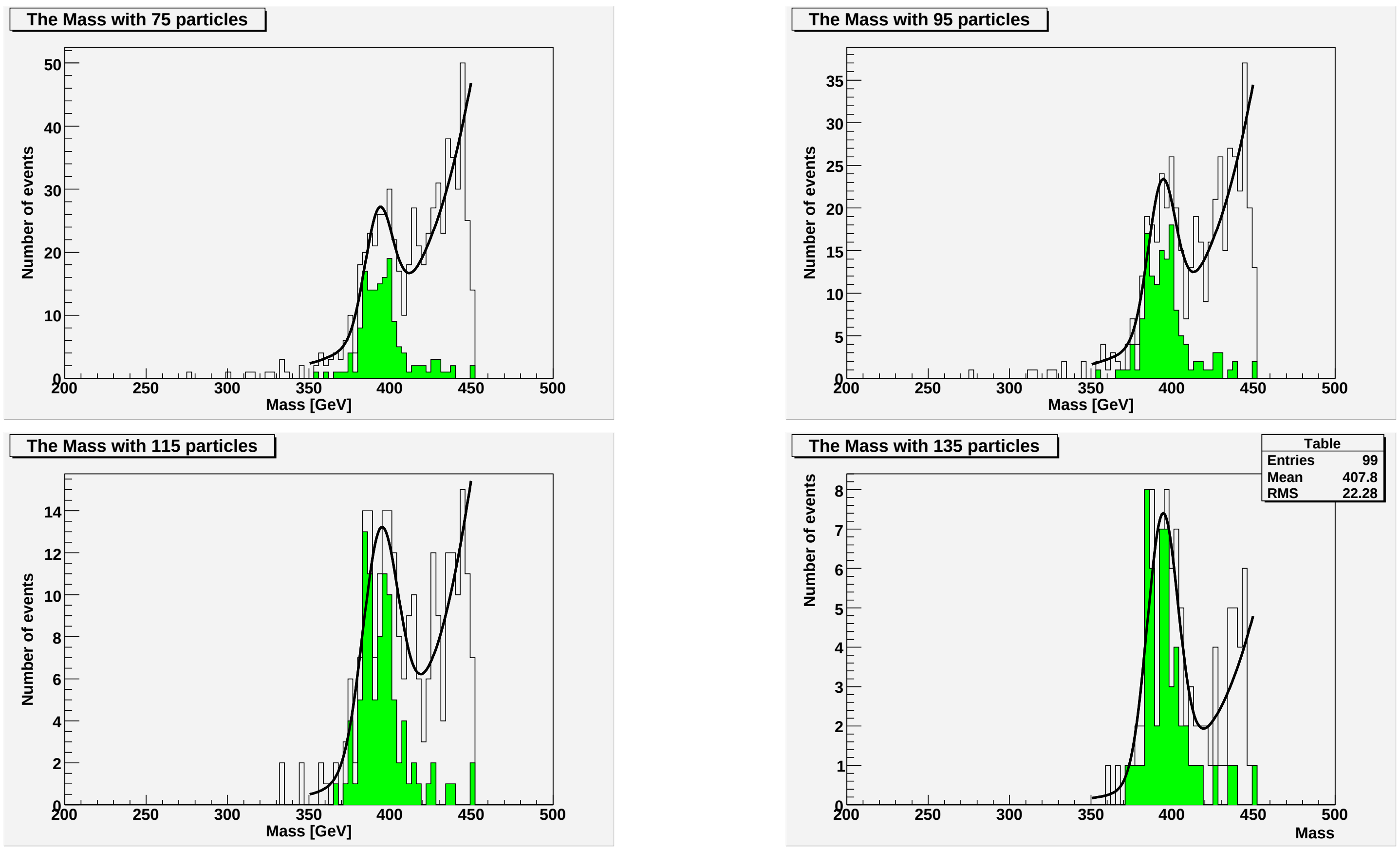

$H+ \rightarrow t\bar{b}$ at 1TeV produces a significant mass peak.

Snowmass Mountain, CO - 14092’