New Method for Mass Measurement using Integral Charge Asymmetry at LHC

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Outline

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Working with A Charge Asymmetric Collider

- The LHC is a charge asymmetric machine, unlike most other HE particle colliders
- For charged final states ($FS^{\pm}$), we define the integral charge asymmetry (ICA) as

$$A_C = \frac{N(FS^+) - N(FS^-)}{N(FS^+) + N(FS^-)} \quad (1)$$

- For a given inclusive process produced at the:
  - LHC in $p + p$ collisions: $A_C \geq 0$
  - TEVATRON in $p + \bar{p}$ collisions: $A_C \approx 0$

The Simplest Applicable Process

- To illustrate this discussion let's pick the $W^{\pm} \to \ell^{\pm}\nu + X$ process
- We obviously chose a leptonic decay mode $(\ell^{\pm} = e^{\pm} \;/\; \mu^{\pm})$ because:
  - S/B for this process in online and offline event selection
  - the hard isolated lepton enables to measure the sign of the produced $W^{\pm}$
- The considered event toplogy is: $1\ell^{\pm} + \not{E}_T + X$
- Therefore our actual observable is:

$$A_C = \frac{N(\ell^+) - N(\ell^-)}{N(\ell^+) + N(\ell^-)} \quad (2)$$

Relation between $A_C(W^\pm \to \ell^\pm \nu + X)$ and the proton structure

- The ICA originates solely from the production mechanisms
- More quantitatively, let's look at the main flavour contribution to A_C:

$$A_C \approx \frac{u(x_{1,2}, M_W^2)\bar{d}(x_{2,1}, M_W^2) - \bar{u}(x_{1,2}, M_W^2)d(x_{2,1}, M_W^2)}{u(x_{1,2}, M_W^2)\bar{d}(x_{2,1}, M_W^2) + \bar{u}(x_{1,2}, M_W^2)d(x_{2,1}, M_W^2)} \quad (3)$$

  other flavour contributions are CKM suppressed ($\frac{|V_{cs}|^2}{|V_{ud}|^2}, \frac{|V_{us}|^2}{|V_{ud}|^2}, \frac{|V_{cd}|^2}{|V_{ud}|^2}, \ldots$)
- Producing $W^\pm$ implies:
  - $Q^2 \approx M_{W^\pm}$ and $x_{1,2} = \frac{M_{W^\pm}}{\sqrt{s}} \cdot e^{\pm y_W}$
    i.e at $\sqrt{s} = 7$TeV: $|y_W| \leq 4.3 \Rightarrow x \in [1.7 \times 10^{-4}, 1.]$
- And, in this range of x's, yields a positive $A_C(W^\pm \to \ell^\pm \nu + X)$
- The key and new (wrt other usage of asymmetries) idea is to correlate A_C to a mass scale
- How?
  - by varying Q $\Rightarrow$ a DGLAP evolution of the PDFs $\Rightarrow$ an evolution of A_C
  - a calibrated measurement of A_C constitutes an indirect measurement of $M_{W^\pm}$

A SM Test Bench Process

Parton Level Setup in MCFM v5.8

- Calculate separately $\sigma^\pm = \sigma(p + p \to W^\pm \to \ell^\pm \nu)$ at $\sqrt{s} = 7$ TeV
- $A_C^{Theory} = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-}$
- LO Matrix Elements (ME): $W^\pm + 0Lp$ & $W^\pm + 1Lp$ (Lp: light partons, i.e. u/d/s/g)
- QCD Scales: $\mu_R = \mu_F = \mu_0 = \sqrt{M^2(W^\pm) + p_T^2(W^\pm)}$
- LO PDFs: MRST2007lomod (default), CTEQ6L1, and MSTW2008lo68cl
- Vary $M_{W^\pm}$: 20.1, 40.2, 80.4, 160.8, 321.6, 643.2, 1286.4 GeV

Sources of Theoretical Uncertainties

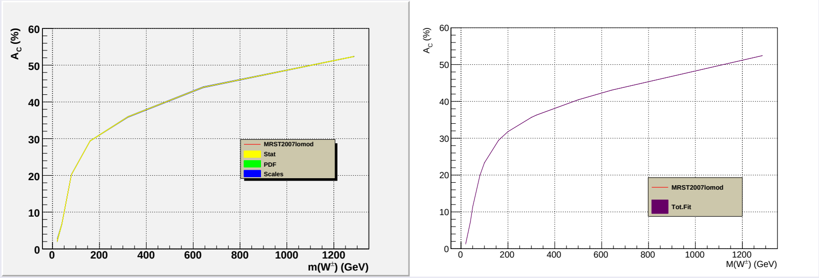
- Statistical: $\delta_{Stat} A_C = \frac{2\sqrt{(\sigma^- \cdot \delta\sigma^+_{Stat})^2 + (\sigma^+ \cdot \delta\sigma^-_{Stat})^2}}{(\sigma^+ + \sigma^-)^2}$
- PDF: $\begin{cases} \delta\sigma^{Up}_{PDF} = \sqrt{\sum_{i=1}^N [Max(\sigma_i^+ - \sigma_0, \sigma_i^- - \sigma_0, 0)]^2} \\ \delta\sigma^{Down}_{PDF} = \sqrt{\sum_{i=1}^N [Max(\sigma_0 - \sigma_i^+, \sigma_0 - \sigma_i^-, 0)]^2} \end{cases}$
- QCD Scales: $\delta\sigma^{Up}_{Scale} = \sigma(\mu_0/2) - \sigma(\mu_0)$ and $\delta\sigma^{\mathrm{Down}}_{\mathrm{Scale}} = \sigma(2\mu_0) - \sigma(\mu_0)$
- Total: $\delta\sigma^{Up/Down}_{Total} = \sqrt{(\delta\sigma^{Up/Down}_{PDF})^2 + (\delta\sigma^{Up/Down}_{Scale})^2 + (\delta\sigma_{Stat})^2}$

$A_C(W^{\pm} \to e^{\pm}\nu_e)$ for MRST2007lomod (1/2)

$M_{W^{\pm}}$ (GeV)	A_C (%)	$\delta_{Stat} A_C$ (%)	$\delta_{Scale} A_C$ (%)	$\delta_{PDF} A_C$ (%)	$\delta_{Total} A_C$ (%)
20.1	2.20	± 0.24	$+0.47$ / $+0.10$	0.00	$+0.52$ / -0.26
40.2	6.77	± 0.12	$+0.02$ / -0.11	0.00	$+0.12$ / -0.16
<u>80.4</u>	20.18	± 0.06	$+0.05$ / -0.03	0.00	$+0.08$ / -0.07
160.8	29.39	± 0.05	$+0.00$ / $+0.03$	0.00	$+0.05$ / -0.06
321.6	35.92	± 0.05	-0.11 / $+0.10$	0.00	$+0.11$ / -0.11
643.2	43.99	± 0.05	-0.14 / $+0.13$	0.00	$+0.15$ / -0.14
1286.4	52.36	± 0.06	$+0.03$ / -0.02	0.00	$+0.07$ / -0.07

Table : MRST2007lomod A_C table with the breakdown of the different sources of theoretical uncertainty.

$A_C(W^\pm \to e^\pm \nu_e)$ for MRST2007lomod (2/2)



- Fits functional form: $A_C[M_{W^\pm}] = \sum_{i=0}^{N} A_i \times [Log[Log[M_{W^\pm}]]]^i$, inspired by the analytical solution of DGLAP equations
- Fit replaces discrete sampling of $A_C[M_{W^\pm}]$ and $\delta A_C[M_{W^\pm}]$ accounts for the correlation between the fit parameters

$A_C(W^\pm \to e^\pm \nu_e)$ for CTEQ6L1 & MSTW2008lo68cl

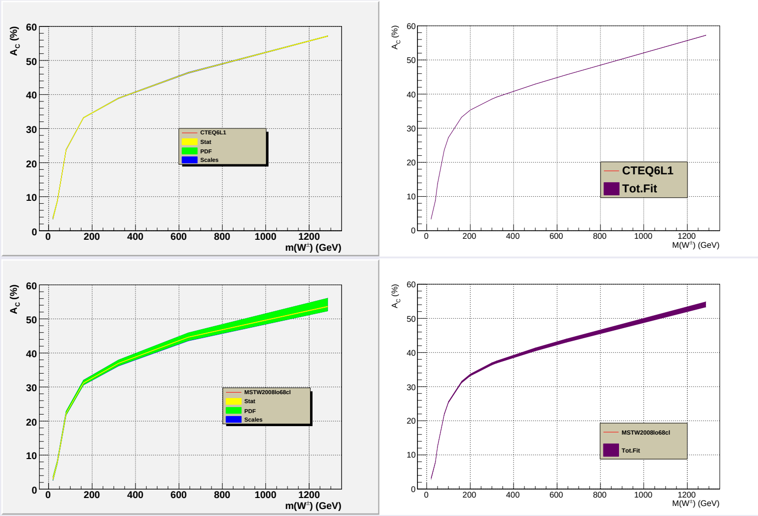


Figure : Theoretical A_C template curves: CTEQ6L1 (upper row) & MSTW2008lo68cl (lower row)

Event Selection: Electron Channel

- Generator:
  Herwig++ v2.5.0
- Detector Fast Simulation:
  Delphes v1.9
- Collider Hypotheses:
  - $\sqrt{s} = 7$ TeV
  - L=1 fb^{-1}
- $p_T(e^\pm) > 25$ GeV
- $|\eta(e^\pm)| < 1.37$ or
  $1.53 < |\eta(e^\pm)| < 2.4$
- Isolation:
  Tracker & Calorimeter
- $\not{E}_T > 25$ GeV
- $M_T > 40$ GeV

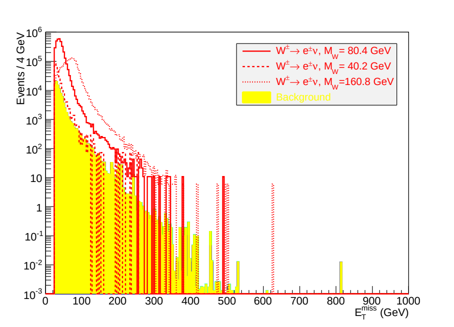


Figure : $\not{E}_T$ distribution for the $W^\pm \to e^\pm \nu_e$ analysis

Event Yields & Expected ICA

Process	ϵ (%)	N_{exp} (k evts)	$A_C \pm \delta A_C^{Stat}$ (%)
Signal: $W^\pm \to e^\pm \nu_e$			
$M_{W^\pm} = 40.2$ GeV	0.81 ± 0.01	290.367	9.66 ± 1.57
$M_{W^\pm} = 60.3$ GeV	13.69 ± 0.05	2561.508	11.2 ± 0.38
$M_{W^\pm} = \underline{80.4}$ GeV	29.59 ± 0.04	3343.195	16.70 ± 0.18
$M_{W^\pm} = 100.5$ GeV	39.19 ± 0.07	2926.093	20.77 ± 0.22
$M_{W^\pm} = 120.6$ GeV	44.84 ± 0.07	2357.557	23.1 ± 0.21
$M_{W^\pm} = 140.7$ GeV	48.66 ± 0.07	1899.820	25.29 ± 0.20
$M_{W^\pm} = 160.8$ GeV	51.28 ± 0.07	1527.360	26.8 ± 0.19
$M_{W^\pm} = 201.0$ GeV	54.54 ± 0.07	1.032	29.26 ± 0.18
Background	-	91.614 ± 1.706	10.07 ± 0.15
$W^\pm \to \mu^\pm \nu_\mu / \tau^\pm \nu_\tau / q\bar{q}\prime$	0.211 ± 0.003	71.350	12.92 ± 1.25
$t\bar{t}$	5.76 ± 0.02	6.600	1.00 ± 0.37
$t + b, \ t + q(+b)$	3.59 ± 0.01	1.926	28.97 ± 0.35
$W + W, \ W + \gamma^*/Z, \ \gamma^*/Z + \gamma^*/Z$	2.94 ± 0.01	2.331	10.65 ± 0.35
$\gamma + \gamma, \ \gamma + jets, \ \gamma + W^\pm, \ \gamma + Z$	0.201 ± 0.001	0.759	17.25 ± 0.53
γ^*/Z	0.535 ± 0.001	5.746	4.43 ± 0.23
QCD HF	$(0.44 \pm 0.17) \times 10^{-4}$	1.347	14.29 ± 37.41
QCD LF	$(0.87 \pm 0.33) \times 10^{-4}$	1.555	71.43 ± 26.45

$A_C(S)$ after Background Subtraction

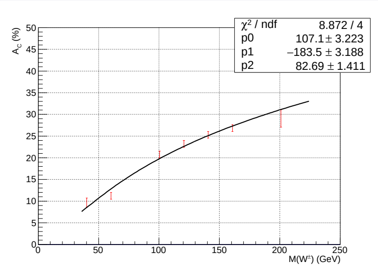
- In presence of B, the measured A_C is that of S+B, not just of S
- $A_C^{Exp}(S+B) = \frac{A_C^{Exp}(S)+\alpha^{Exp}\cdot A_C^{Exp}(B)}{1+\alpha^{Exp}}$, where $\alpha^{Exp} = \frac{N_B^{Exp}}{N_S^{Exp}}$
- Invert the relation to get the *"background subtraction equation"*:

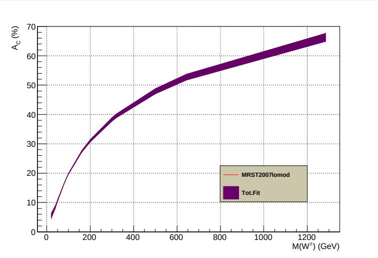
$$A_C^{Exp}(S) = (1+\alpha^{Exp})\cdot A_C^{Exp}(S+B) - \alpha^{Exp}\cdot A_C^{Exp}(B) \quad (4)$$

ICA Experimental Systematic Uncertainties

- Strategy:
  - instead of trying to derive unreliable systematics using Delphes,
  - we use systematics quoted in analyses of real data
  - $\delta_{Syst} A_C(W^{\pm} \to e^{\pm}\nu_e/\mu^{\pm}\nu_{\mu}) = 1.0\ /\ 0.4\%$ [arXiv:1206.2598 / arXiv:1312.6283 [hep-ex]]
  - $\delta_{Syst} \frac{\sigma(pp\to W^{\pm}\to\ell^{\pm}\nu_{\ell})}{\sigma(pp\to\gamma^*/Z\to\ell^{\pm}\ell^{\mp})} = 1.0\%$ [arXiv:1107.4789 [hep-ex]]
- Gaussian smearings of $N_S^{\pm}$ and $N_B^{\pm}$ propagated into the subtraction equation
- Enable to calculate both $A_C^{Meas}(S)$ and $\delta A_C^{Meas}(S)$ account for the correlations between $A_C(S+B)$, $A_C(B)$, and α
- Build reconstruted $A_C^{Meas}(S) \pm \delta A_C^{Meas}(S)$ mass templates
- Fit these templates with polynomials of Log(Log) and include the correlations between the fit parameters into $\delta A_C^{Meas.Fit}(S)$

Experimental Template Curve for the Electron Channel





$$A_C^{Meas}(W^{\pm} \to e^{\pm} + \nu_e) = -107.1 - 183.5 \times Log(Log(M_{W^{\pm}})) + 82.69 \times Log(Log(M_{W^{\pm}}))^2 \quad (5)$$

- This template curve encodes the 2 types of experimental biases:
  - the event selection
  - the remaining background

Extracting $M_{W^\pm}$ in the Electron and Muon Channels

- Analogous analysis performed to the muon channel
- Measured ICA of both channels are translated into indirect $M_{W^\pm}$ measurements:

$$A_C^{Meas}(S) = (16.70 \pm 0.35)\% \Rightarrow M^{Meas}(W^\pm \to e^\pm \nu_e) = 81.08^{+2.06}_{-2.02}\ \mathrm{GeV} \quad (6)$$

$$A_C^{Meas}(S) = (17.52 \pm 0.18)\% \Rightarrow M^{Meas}(W^\pm \to \mu^\pm \nu_\mu) = 80.83^{+0.82}_{-0.82}\ \mathrm{GeV} \quad (7)$$

- Combine using weighted mean & RMS:

$$M^{Comb.Meas.}(W^\pm) = 80.86 \pm 0.54\ (\mathrm{Exp.Comb.})\ \mathrm{GeV} \quad (8)$$

- Theory uncertainties for this given mass ($\pm$0.24 GeV) obtained by looking-up the theoretical template curve
- Sum in quadrature experimental & theory uncertainties

$$M_{W^\pm} = 80.86^{+0.59}_{-0.59}\ (\mathrm{Tot.\ MRST2007lomod})\ \ \mathrm{GeV} \quad (9)$$

- Repeat the whole procedure for CTEQ6L1 & MSTW2008lo68cl:

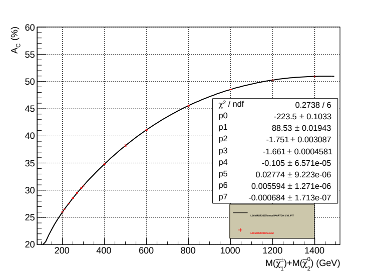
$$M_{W^\pm} = 80.14^{+0.60}_{-0.60}\ (\mathrm{Tot.\ CTEQ6L1})\ \ \mathrm{GeV} \quad (10)$$

$$M_{W^\pm} = 81.36^{+1.48}_{-1.44}\ (\mathrm{Tot.\ MSTW2008lo68cl})\ \ \mathrm{GeV} \quad (11)$$

A SUSY Physics Case

Parton Level Setup using Resummino v1.0.0

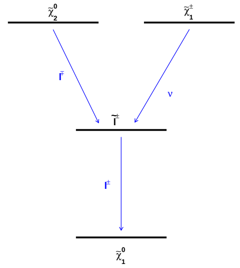
- Calculate separately at $\sqrt{s} = 8$ TeV:
  - $\sigma^+ = \sigma(p + p \to \tilde{\chi}_1^+ + \tilde{\chi}_2^0)$
  - $\sigma^- = \sigma(p + p \to \tilde{\chi}_1^- + \tilde{\chi}_2^0)$
- $A_C^{Theory} = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-}$
- LO MEs & LO PDFs: MRST2007lomod (default), CTEQ6L1, and MSTW2008lo68cl
- QCD Scales: $\mu_R = \mu_F = \mu_0 = M_{\tilde{\chi}_1^{\pm}} + M_{\tilde{\chi}_2^0}$
- Vary: $M_{\tilde{\chi}_1^{\pm}} = M_{\tilde{\chi}_2^0} =$ 100, 105, 115, 125, 135, 145, 150, 200, 250, 300, 400, 500, 600, 700 GeV



- $A_C[M_{\tilde{\chi}_1^{\pm}} + M_{\tilde{\chi}_2^0}] = \sum_{i=0}^{N} A_i \times [Log[Log[M_{\tilde{\chi}_1^{\pm}} + M_{\tilde{\chi}_2^0}]]]^i$

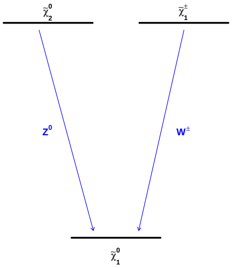
Different SUSY Scenarios (1/2)

- S1 Signal:
  - Lightest SUSY particles: $\tilde{\chi}_1^\pm$, $\tilde{\chi}_{1,2}^0$, $\tilde{\ell}^\pm$
  - $M_{\tilde{\chi}_1^\pm} = M_{\tilde{\chi}_2^0}$
  - $BR(\tilde{\chi}_1^\pm \to \tilde{\ell}^\pm(\to \ell^\pm \tilde{\chi}_1^0) + \nu) = 100\%$
  - $BR(\tilde{\chi}_2^0 \to \tilde{\ell}^\pm(\to \ell^\pm \tilde{\chi}_1^0) + \ell^\mp) = 100\%$
  - Vary: $M_{\tilde{\chi}_2^0} \in [100, 700]$ GeV by steps of100 GeV
  - Set: $M_{\tilde{\chi}_1^0} = M_{\tilde{\chi}_2^0}/2$ and $M_{\tilde{\ell}^\pm} = [M_{\tilde{\chi}_2^0} + M_{\tilde{\chi}_1^\pm}]/2$



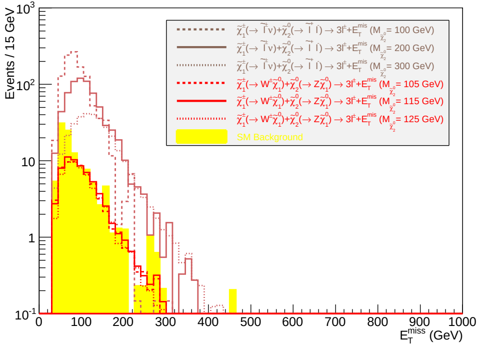
Different SUSY Scenarios (2/2)

- S2 Signal:
  - Lightest SUSY particles: $\tilde{\chi}_1^\pm$, $\tilde{\chi}_{1,2}^0$
  - $M_{\tilde{\chi}_1^\pm} = M_{\tilde{\chi}_2^0}$
  - $BR(\tilde{\chi}_1^\pm \to \tilde{\ell}^\pm(\to \ell^\pm \tilde{\chi}_1^0) + \nu) = 100\%$
  - $BR(\tilde{\chi}_2^0 \to \tilde{\ell}^\pm(\to \ell^\pm \tilde{\chi}_1^0) + \ell^\mp) = 100\%$
  - Set: $M_{\tilde{\chi}_1^0} = M_{\tilde{\chi}_2^0}/2$
  - Case S2a: W and Z decay off-shell, $M_{\tilde{\chi}_2^0} = 100$ GeV and $M_{\tilde{\chi}_1^0} = 50$ GeV
  - Case S2b: W and Z decay on-shell, $M_{\tilde{\chi}_2^0} \in [200, 700]$ GeV by steps of 100 GeV, also $M_{\tilde{\chi}_2^0} \in [105, 145]$ GeV by steps of 10 GeV with $M_{\tilde{\chi}_1^0} = 13.8$ GeV, plus $[M_{\tilde{\chi}_2^0}, M_{\tilde{\chi}_1^0}] =$ [150,50] GeV and [250,125] GeV



Event Selection for $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to 3\ell^{\pm} + \not{E}_T$ analysis

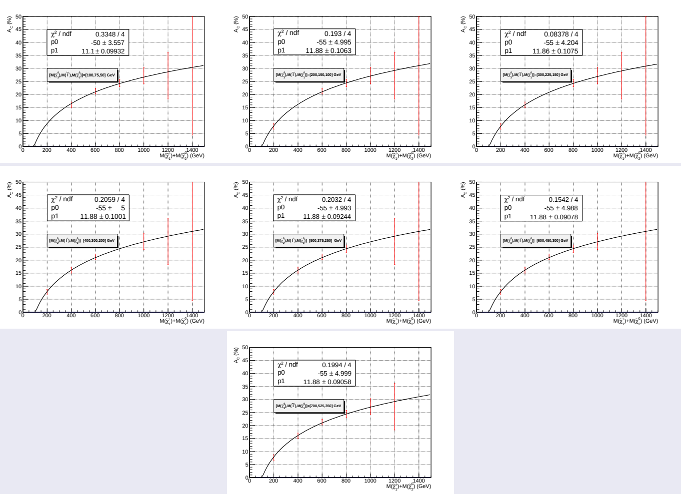
- Generators: Herwig++, Alpgen & Pythia8
- Fast Sim.: Delphes
- Collider Hypotheses:
  - $\sqrt{s} = 8$ TeV, L=20 fb^{-1}
- Electron Candidates:
  $|\eta(e^{\pm})| < 1.37$ or
  $1.53 < |\eta(e^{\pm})| < 2.47$
  $p_T(e^{\pm}) > 10$ GeV
- Muon Candidates:
  $|\eta(\mu^{\pm})| < 2.4$
  $p_T(\mu^{\pm}) > 10$ GeV
- $p_T(\ell^{\pm}_{1,2,3}) > 20, 10, 10$ GeV
- Isolation:
  Tracker & Calorimeter
- $\not{E}_T > 35$ GeV
- $M_{T2} > 75$ GeV



Expected and Measured ICA

Process	$\alpha^{Exp} \pm \delta\alpha^{Stat}$	Z_N (σ)	$A_C^{Exp} \pm \delta A_C^{Stat}$ (%)	$A_C^{Meas.} \pm \delta A_C^{Meas.}$ (%)
S1 Signal $[M_{\tilde{\chi}_2^0}, M_{\tilde{\ell}^{\pm}}, M_{\tilde{\chi}_1^0}]$ GeV				
[100, 75, 50]	$(9.98 \pm 0.26) \times 10^{-2}$	31.70	7.70 ± 0.27	7.70 ± 0.83
[200, 150, 100]	$(15.58 \pm 0.36) \times 10^{-2}$	23.86	16.06 ± 0.20	16.06 ± 0.85
[300, 225, 150]	$(34.28 \pm 0.79) \times 10^{-2}$	13.79	21.30 ± 0.17	21.30 ± 0.96
[400, 300, 200]	$(96.89 \pm 2.22) \times 10^{-2}$	6.04	24.40 ± 0.18	24.40 ± 1.29
[500, 375, 250]	$(288.49 \pm 6.61) \times 10^{-2}$	2.25	27.21 ± 0.16	27.21 ± 1.75
[600, 450, 300]	$(869.13 \pm 19.89) \times 10^{-2}$	0.74	27.20 ± 0.14	27.20 ± 1.97
[700, 525, 350]	$(2417.44 \pm 55.45) \times 10^{-2}$	0.23	29.06 ± 0.15	29.06 ± 2.02
S2 Signal $[M_{\tilde{\chi}_2^0}, M_{\tilde{\chi}_1^0}]$ GeV				
[100, 50]	$(78.221 \pm 6989.644) \times 10^{1}$	-0.06	7.62 ± 0.38	7.62 ± 0.88
[105, 13.8]	$(177.34 \pm 4.21) \times 10^{-2}$	3.55	7.84 ± 0.23	7.85 ± 1.58
[115, 13.8]	$(167.29 \pm 3.91) \times 10^{-2}$	3.74	7.73 ± 0.21	7.73 ± 1.55
[125, 13.8]	$(190.49 \pm 4.44) \times 10^{-2}$	3.32	9.34 ± 0.21	9.34 ± 1.60
[135, 13.8]	$(199.69 \pm 4.61) \times 10^{-2}$	3.18	10.43 ± 0.17	10.43 ± 1.62
[145, 13.8]	$(223.26 \pm 5.16) \times 10^{-2}$	2.87	11.50 ± 0.19	11.50 ± 1.67
[150, 50]	$(382.23 \pm 8.90) \times 10^{-2}$	1.71	12.06 ± 0.19	12.06 ± 1.85
[200, 100]	$(1023.46 \pm 23.44) \times 10^{-2}$	0.62	16.66 ± 0.20	16.66 ± 2.00
[250, 125]	$(1405.78 \pm 32.29) \times 10^{-2}$	0.44	18.28 ± 0.18	18.28 ± 2.01
[300, 150]	$(2164.23 \pm 49.59) \times 10^{-2}$	0.26	20.98 ± 0.18	20.98 ± 2.02
[400, 200]	$(6083.89 \pm 138.89) \times 10^{-2}$	0.05	24.11 ± 0.17	24.11 ± 2.03
[500, 250]	$(18.881 \pm 0.431) \times 10^{-5}$	-0.03	27.51 ± 0.16	27.51 ± 2.03
[600, 300]	$(57.637 \pm 1.316) \times 10^{-5}$	-0.06	27.25 ± 0.18	27.25 ± 2.03
[700, 350]	$(182.517 \pm 4.167) \times 10^{-5}$	-0.07	27.91 ± 0.17	27.91 ± 2.03

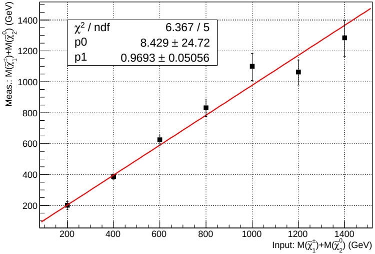
Experimental Template Curves for S1 Signal

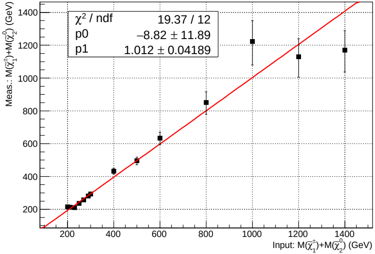


Indirect Determination of $M_{\tilde{\chi}_1^\pm} + M_{\tilde{\chi}_2^0}$ (Exp. Uncert.)

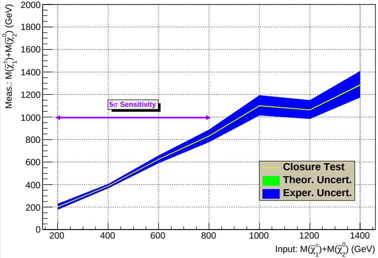
Input $M_{\tilde{\chi}_1^\pm} + M_{\tilde{\chi}_2^0}$ (GeV)	$A_C^{Meas.Fit} \pm \delta A_C^{Meas.Fit}$ (%)	Meas. $M_{\tilde{\chi}_1^\pm} + M_{\tilde{\chi}_2^0}$ (GeV)
S1 Signal		
200.	7.70 ± 1.62	$201.79^{+26.30}_{-22.78}$
400.	16.06 ± 0.52	$386.63^{+17.42}_{-16.56}$
600.	21.30 ± 0.56	$624.12^{+33.36}_{-31.43}$
800.	24.40 ± 0.67	$831.24^{+55.66}_{-51.70}$
1000.	27.21 ± 0.80	$1100.14^{+91.85}_{-83.85}$
1200.	27.20 ± 0.78	$1063.52^{+84.32}_{-77.32}$
1400.	29.06 ± 0.89	$1285.12^{+121.49}_{-109.70}$
S2 Signal		
200.	7.62 ± 0.74	$214.89^{+12.08}_{-11.33}$
210.	7.85 ± 0.60	$212.28^{+9.83}_{-9.32}$
230.	7.73 ± 0.60	$210.37^{+9.81}_{-9.30}$
250.	9.34 ± 0.53	$236.25^{+10.02}_{-9.54}$
270.	10.43 ± 0.50	$257.54^{+10.34}_{-9.85}$
290.	11.50 ± 0.47	$280.68^{+10.83}_{-10.34}$
300.	12.06 ± 0.46	$293.53^{+11.19}_{-10.71}$
400.	16.66 ± 0.49	$432.55^{+18.63}_{-17.73}$
500.	18.28 ± 0.54	$495.50^{+24.10}_{-22.79}$
600.	20.98 ± 0.66	$633.64^{+39.45}_{-36.79}$
800.	24.11 ± 0.83	$850.74^{+71.20}_{-64.95}$
1000.	27.51 ± 1.07	$1222.74^{+143.06}_{-126.20}$

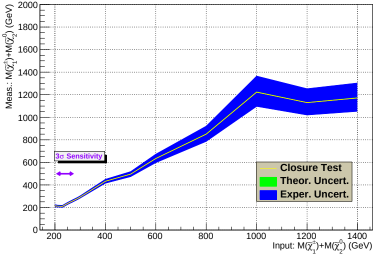
Closure Tests w/ Expt. Uncert.: S1 Signal (LHS), S2 Signals (RHS)





Final Plots w/ Full Uncert.: S1 Signal (LHS), S2 Signal (RHS)





Conclusions (1/2)

New Method

- Designed for charged-current production processes at LHC
- Independent of the final state kinematics
- Model Independent
  - Does not depend on BSM couplings
  - Only depends on proton PDF
- Especially well-suited when many final state particles escape detection

Accuracy of Indirect Measurements

-	$W^{\pm}$	S1 Signal		S2 Signal	
-	$M_{W^{\pm}}$ =80.4 GeV	5σ: [200-800] GeV	[1.0-1.4] TeV	3σ: [210-270] GeV	[0.29-1.4] TeV
$\frac{\delta M^{Fit}_{FS^{\pm}}}{M^{Fit}_{FS^{\pm}}}$ (%)	**1.8**	**1.3-6.7**	**8-9**	**4.0-4.6**	**4-12**
$\frac{\mid M^{Fit}_{FS^{\pm}} - M^{True}_{FS^{\pm}} \mid}{M^{True}_{FS^{\pm}}}$ (%)	**1.8**	**0.9-3.9**	**8.2-11.4**	**0.2-0.9**	**3.2-16.4**
$\frac{\mid M^{Fit}_{FS^{\pm}} - M^{True}_{FS^{\pm}} \mid}{\delta M^{Fit}_{FS^{\pm}}}$ (σ)	**1.0**	**0.1-0.6**	**0.9-1.6**	**0.2-1.2**	**0.6-1.7**

- Note: W results include δ_{PDF}, SUSY results don't

Conclusions (2/2)

Linearity & Bias

- This indirect mass measurement technique
  - does not need any linearity corrections
  - does not need any offset corrections

Thanks for your attention

- Don't be sorry Garfield!
- Remember, you have to stay positive for me to measure your mass at LHC