Cosmological Connection of SUSY Models at the LHC

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Discovery Time...

We are about to enter into an era of major discovery

Dark Matter: we need new particles to explain the content of the universe

Standard Model: we need new physics

Supersymmetry solves both problems!

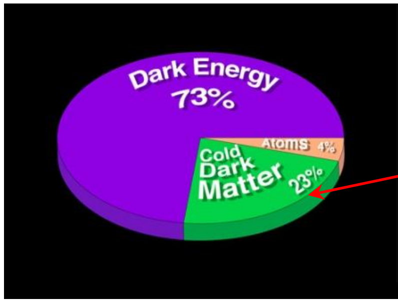
The super-partners are distributed around 100 GeV to a few TeV

LHC: directly probes TeV scale

Future results from PLANCK, direct and indirect detections, rare decays etc. experiments in tandem with the LHC will confirm a model

This talk: Can we establish SUSY models at the LHC?
How accurately we can calculate dark matter density?

SUSY at the LHC

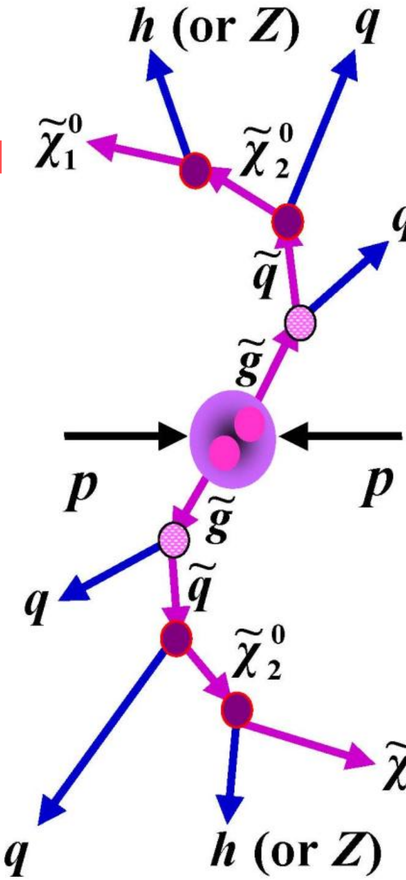


DM

(or l^+l^-, $\tau+\tau-$)

High P_T jet

[mass difference is large]



The p_T of jets and leptons depend on the sparticle masses which are given by models

Colored particles are produced and they decay finally into the weakly interacting stable particle

DM

R-parity conserving

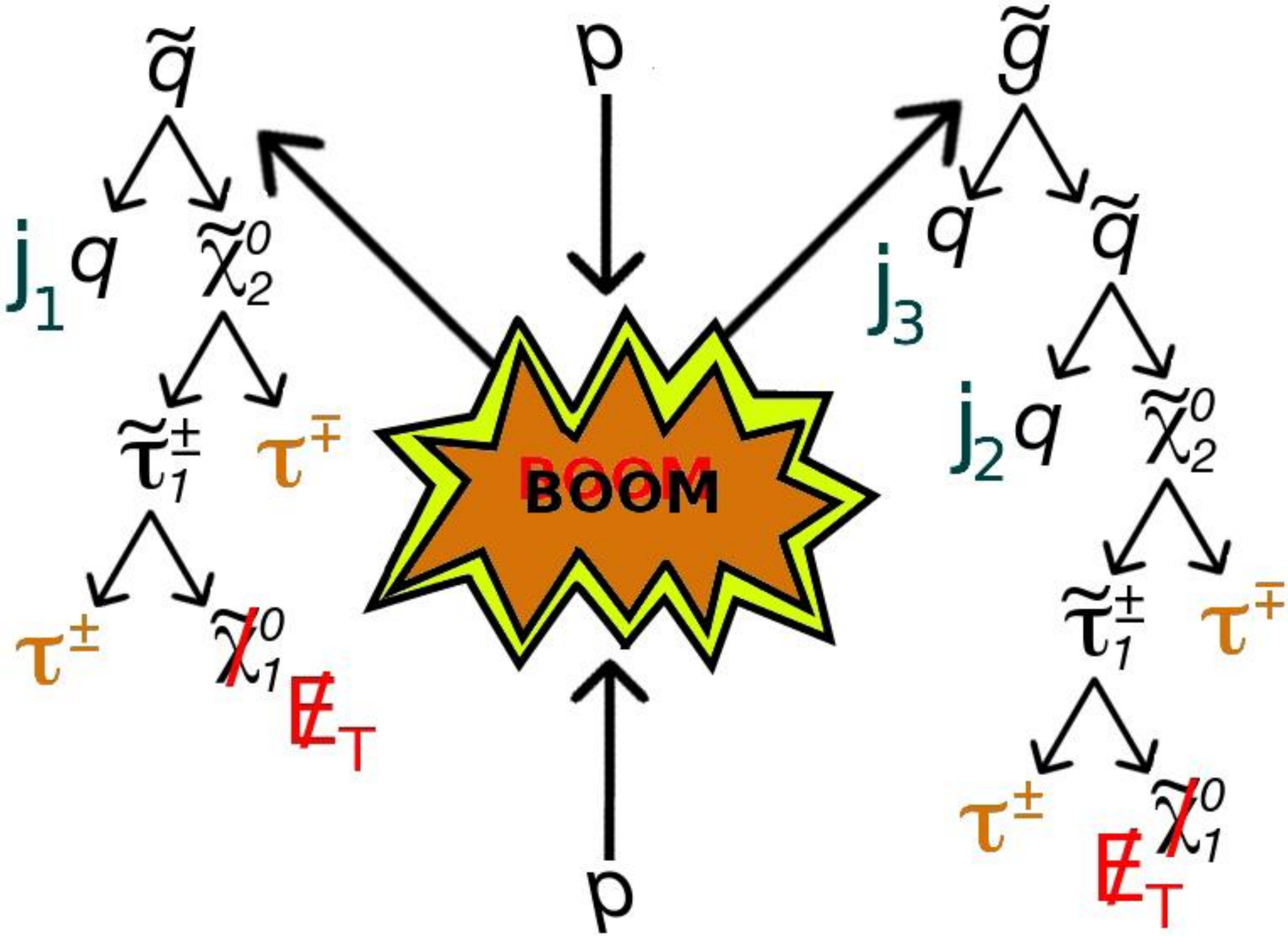
High P_T jet

(or l^+l^-, $\tau+\tau-$)

The signal :

jets + leptons+ t's +W's+Z's+H's + missing E_T

SUSY at the LHC: Dilemma...



SUSY at the LHC

Final states → Model Parameters
→ Calculate dark matter density

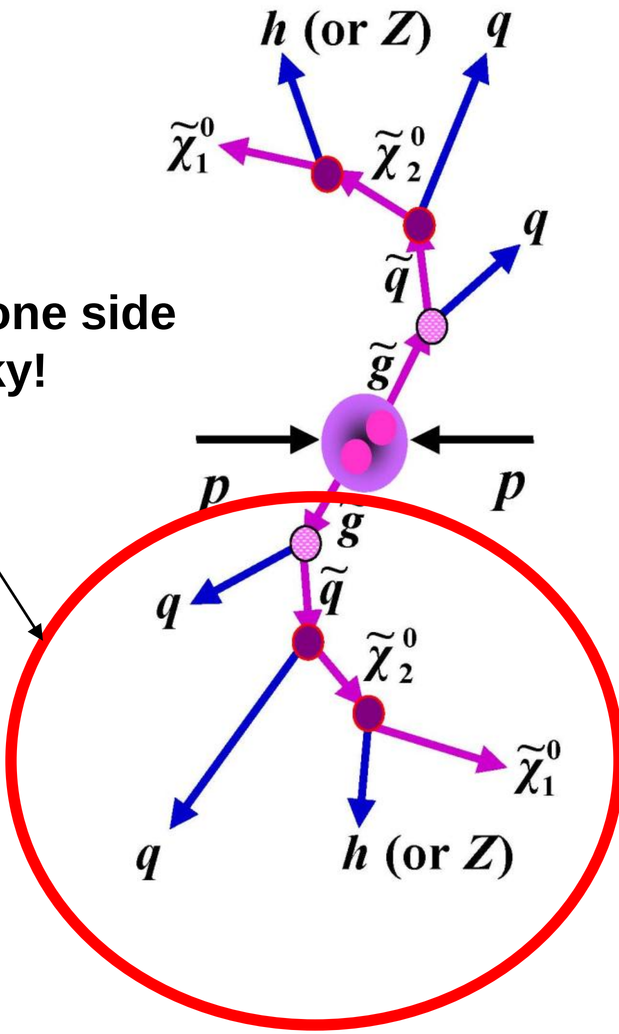
Reconstruct sparticle masses, e.g.,

$$\tilde{Q} \rightarrow q + l + \tilde{\chi}_1^0$$

$$\tilde{\boldsymbol{L}} \rightarrow \boldsymbol{l} + \tilde{\boldsymbol{\chi}}_1^0$$

$$\tilde{\chi}_{2,3,4}^0 \rightarrow Z, h, \bar{l}l + \tilde{\chi}_1^0 \quad \text{etc.}$$

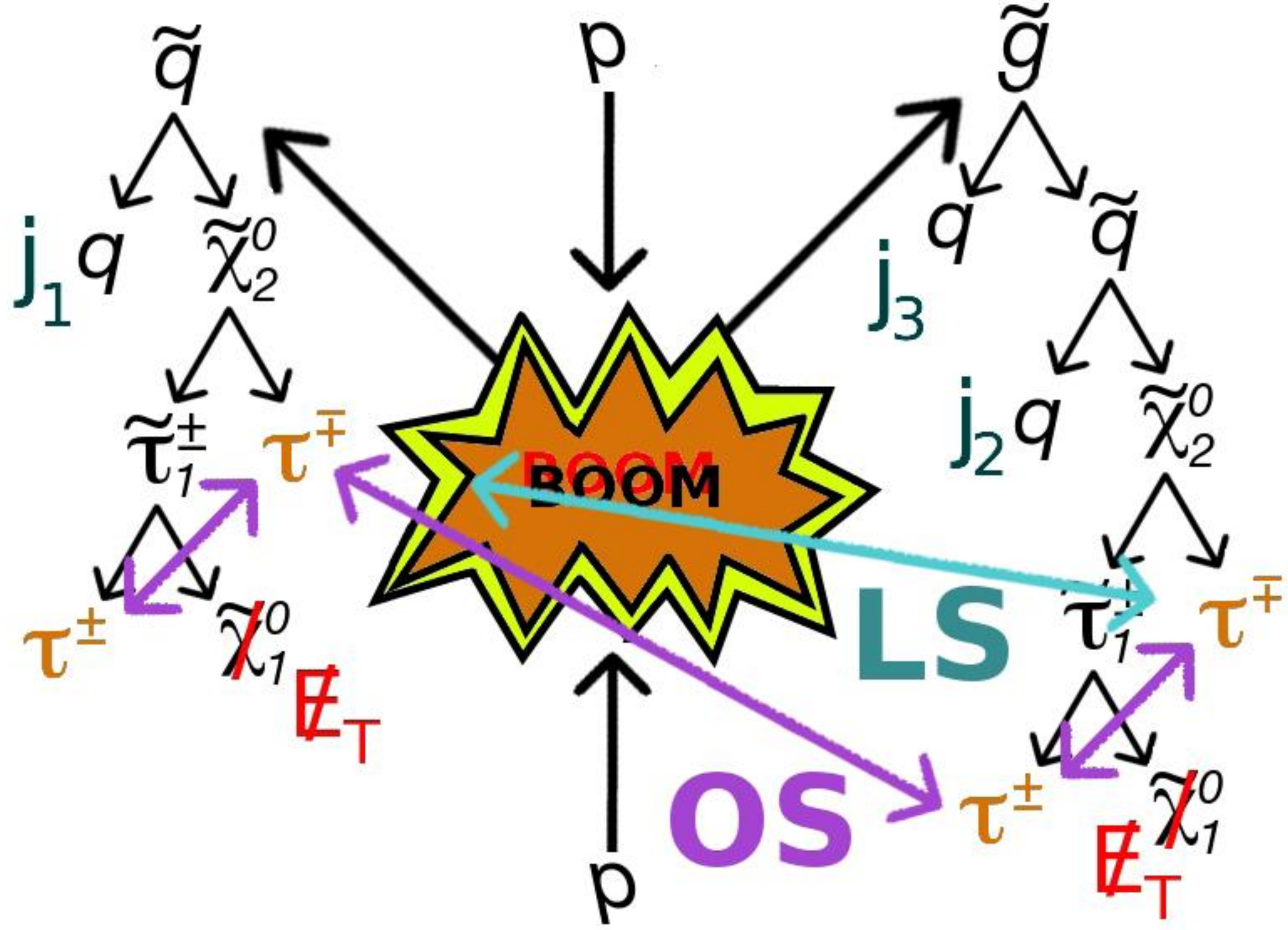
Identifying one side is very tricky!



We may not be able to solve for masses of all the sparticles from a model

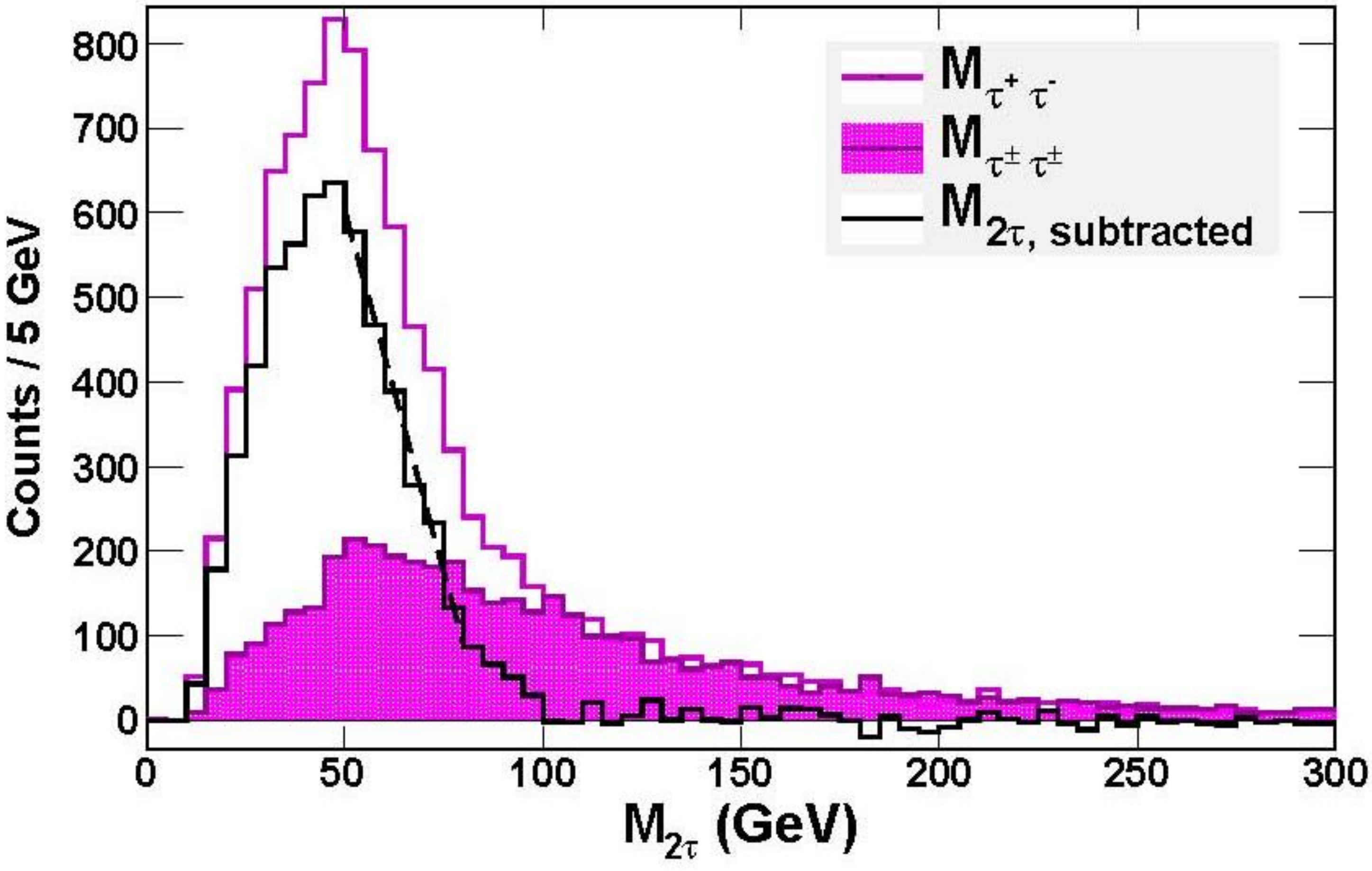
Solving for the MSSM : Very difficult

SUSY at the LHC: Dilemma…



SUSY at the LHC Dilemma…

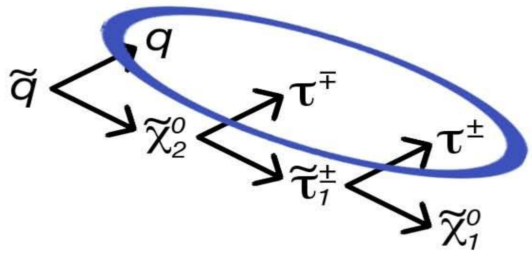
OS-LS Subtraction



Extracting One side: $j\tau\tau$: BEST

- **OS-LS selection of ditaus selects $\tilde{\chi}_2^0$, but if we need to reconstruct the entire side**

- **We use the following subtraction scheme : BEST**



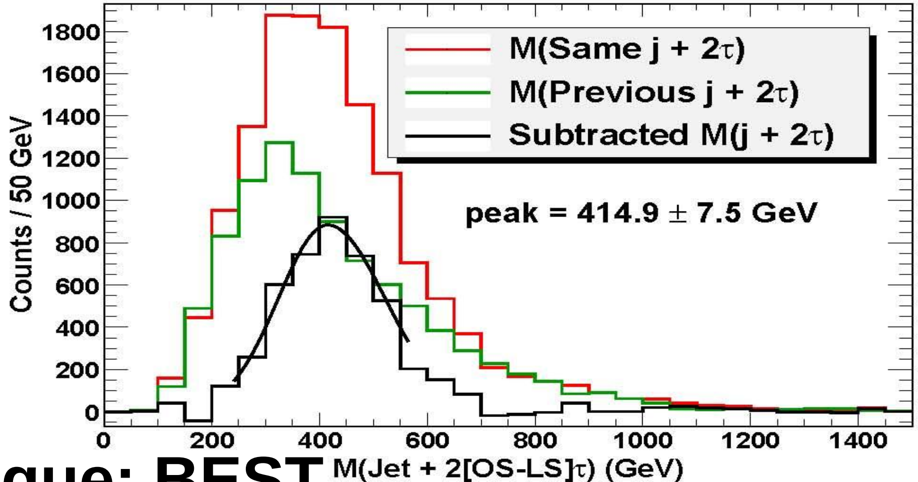
The OS-LS τ pair has momentum related to the momentum of this Same Event Jet.

We collect all $2\tau+$ Jet pairs: get related pairs plus random pairs.

Using Jets from Previous Events: get only random pairs.

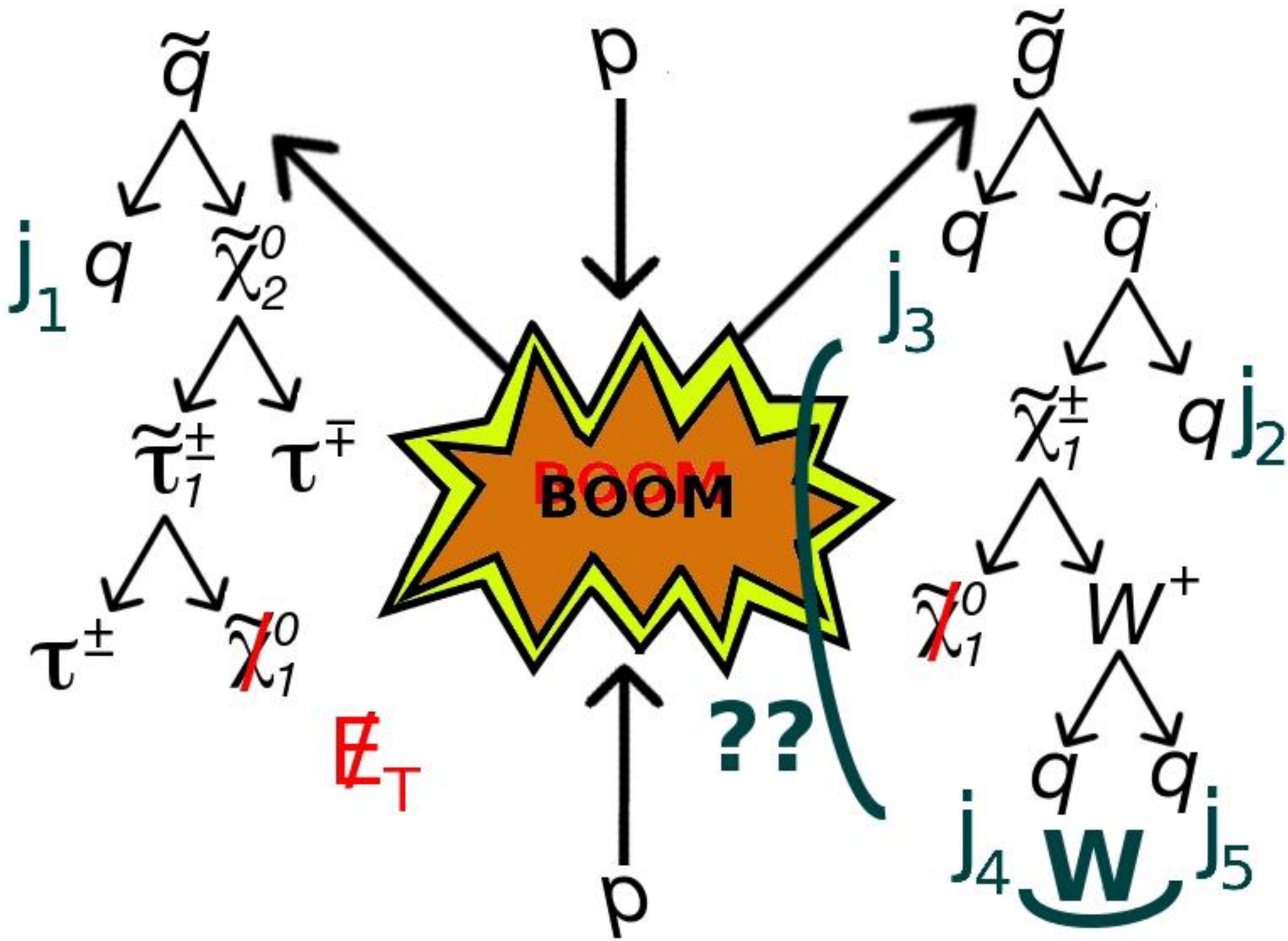
Normalize and perform the Same Jet - Previous Jet subtraction:

- Random pairs will cancel.
- Only the related pairs remain.

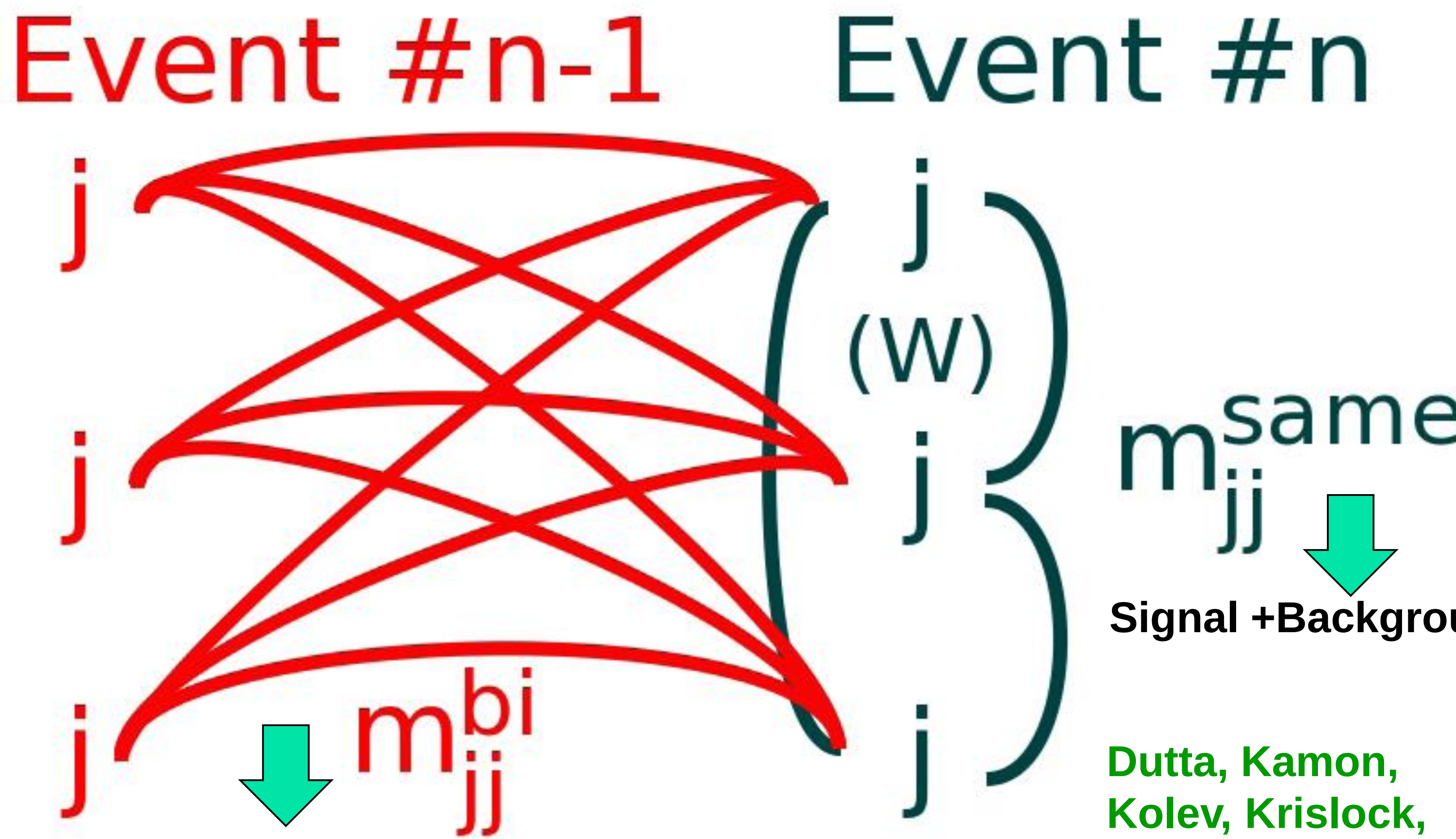


Bi Event Subtraction technique: BEST

BEST and SUSY Dilemma…



BEST



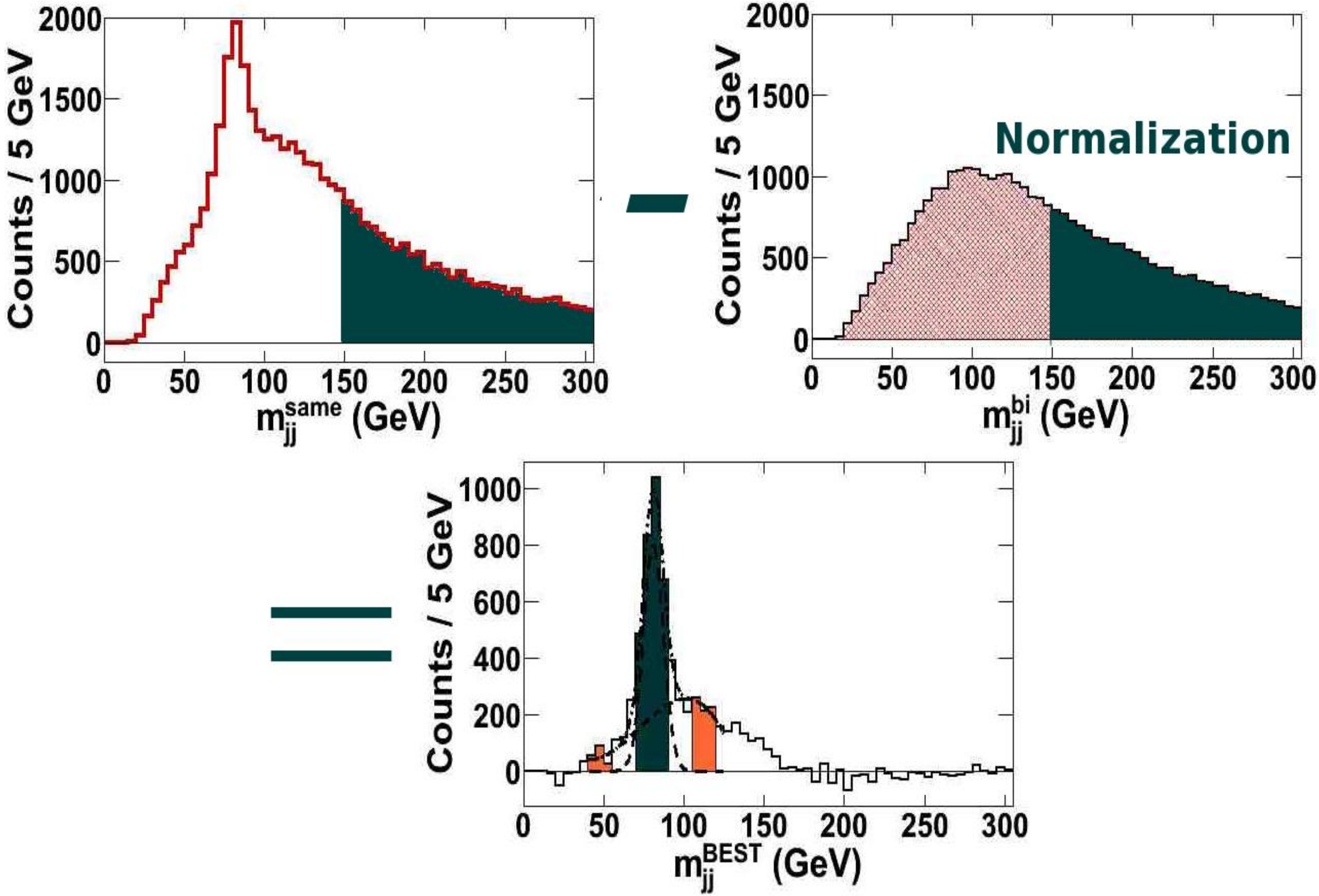
Signal +Background

Background

Dutta, Kamon, Kolev, Krislock,

arXiv:1104.2508 [hep-ph] PLB'11

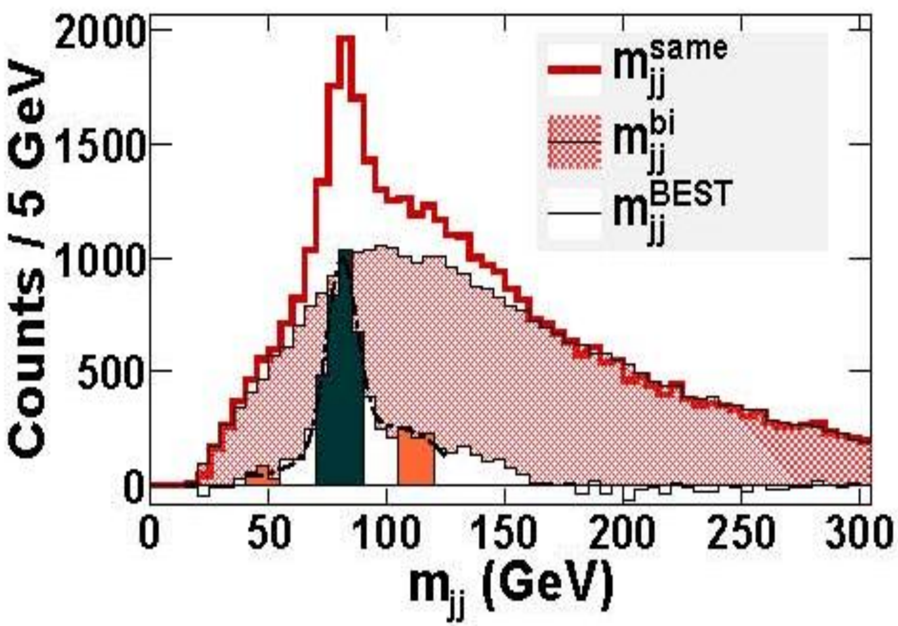
What BEST Looks Like…

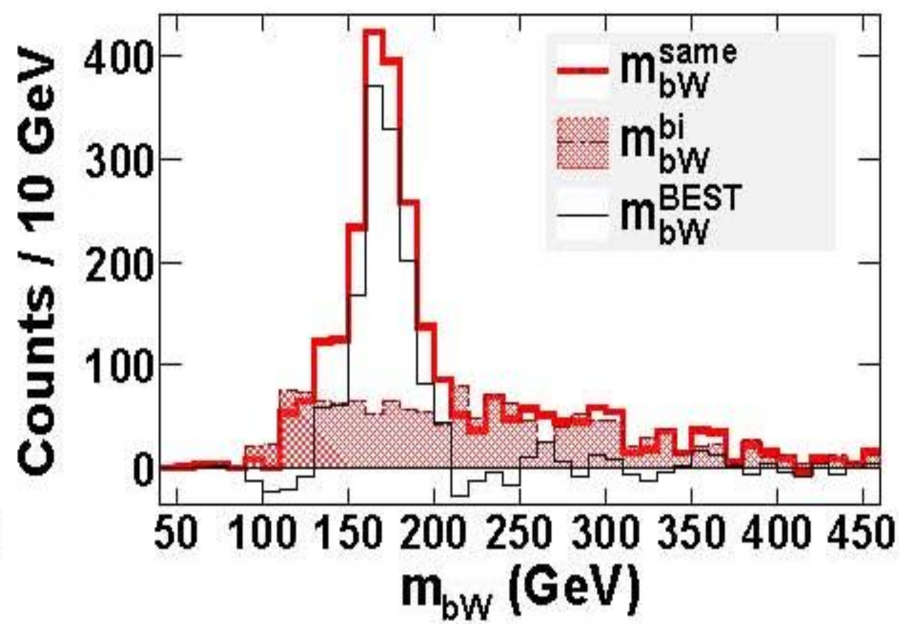


Top reconstruction : BEST

Even with backgrounds, BEST triumphs.

- 7 TeV collision energy @ LHC, 2 fb^{-1}.
- ALPGEN - $t\bar{t}$ signal and W+jets background
- PYTHIA - shower
- PGS - detector





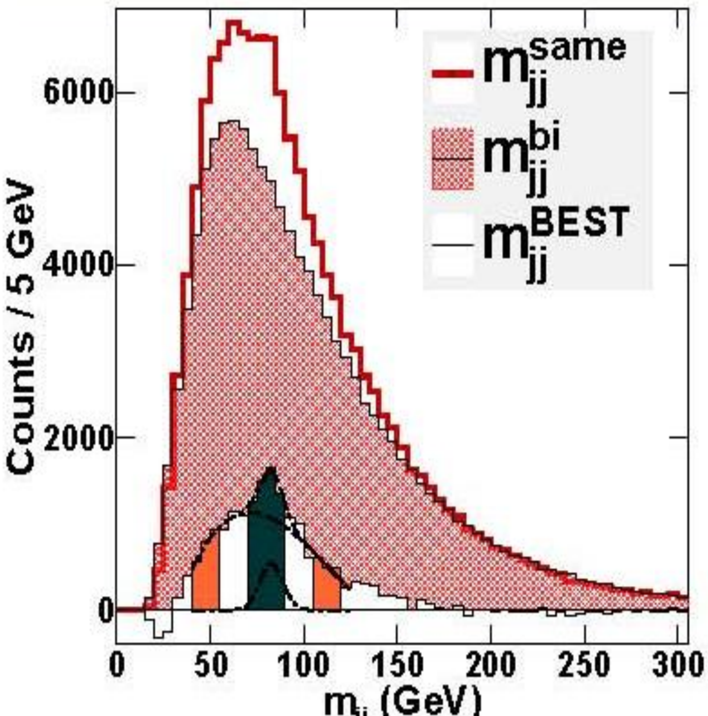
$m_W = 81.11 \pm 0.32$ GeV

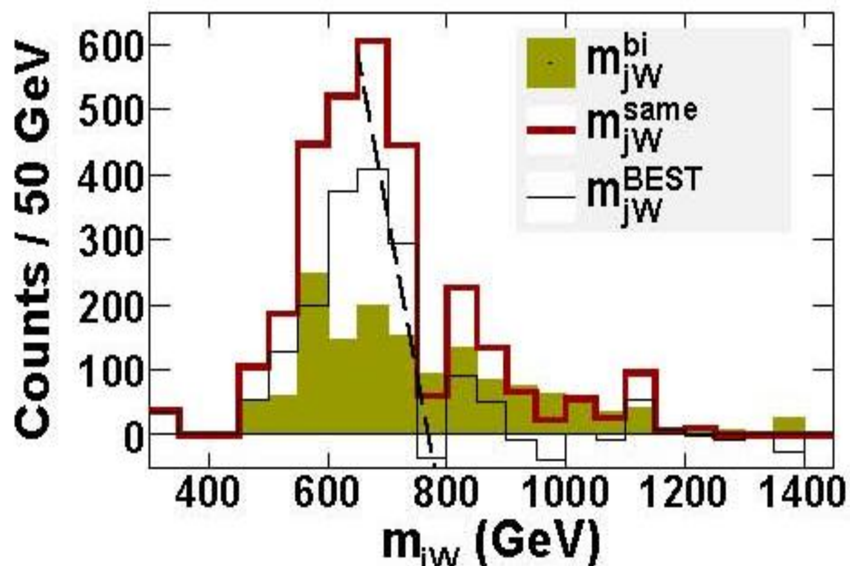
$m_t = 170.5 \pm 1.5$ GeV

End Point Techniques with BEST

Even with backgrounds on top of SUSY, BEST triumphs.

- 14 TeV collision energy @ LHC, 100 fb^{-1}.
- nuSUGRA: $m_0 = 360$ GeV, $m_{1/2} = 500$ GeV, $\tan\beta = 40$, $A_0 = 0$, and $m_H = 732$ GeV.
- SM: $t\bar{t}$, W+Jets, and Z+Jets.





$m_{jW}^{\max} = 769 \pm 18$ GeV

Significance improves 5 times with BEST

Determining mSUGRA Parameters

✓Solved by inverting the following functions:

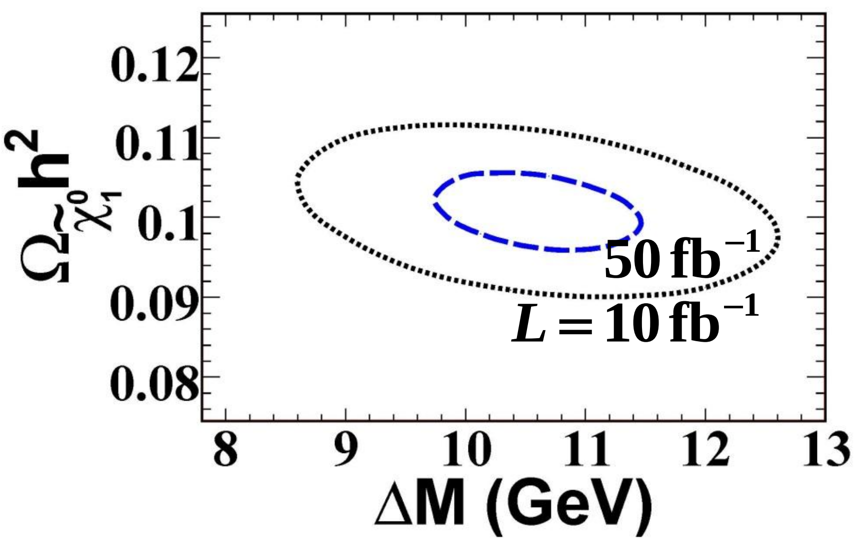
$$M^{\text{peak}}_{j\tau\tau} = X_1(m_{1/2}, m_0)$$
$$M^{\text{peak}}_{\tau\tau} = X_2(m_{1/2}, m_0, \tan\beta, A_0)$$
$$M^{\text{peak}}_{\text{eff}} = X_3(m_{1/2}, m_0)$$
$$M^{(b)\,\text{peak}}_{\text{eff}} = X_4(m_{1/2}, m_0, \tan\beta, A_0)$$

$\xrightarrow{10\ \text{fb}^{-1}}$

$$\left\{\begin{aligned} m_0 &= 210 \pm 5 \\ m_{1/2} &= 350 \pm 4 \\ A_0 &= 0 \pm 16 \\ \tan\beta &= 40 \pm 1 \end{aligned}\right.$$

$$\Omega_{\tilde{\chi}_1^0} h^2 = Z(m_0, m_{1/2} \tan\beta, A_0)$$

Arnowitt, Dutta, Gurrola, Kamon, Krislock and Toback'PRL, 08



$$\delta\Omega_{\tilde{\chi}_1^0} h^2 / \Omega_{\tilde{\chi}_1^0} h^2 = 6.2\%\ (30\ \text{fb}^{-1})$$
$$= 4.1\%\ (70\ \text{fb}^{-1})$$

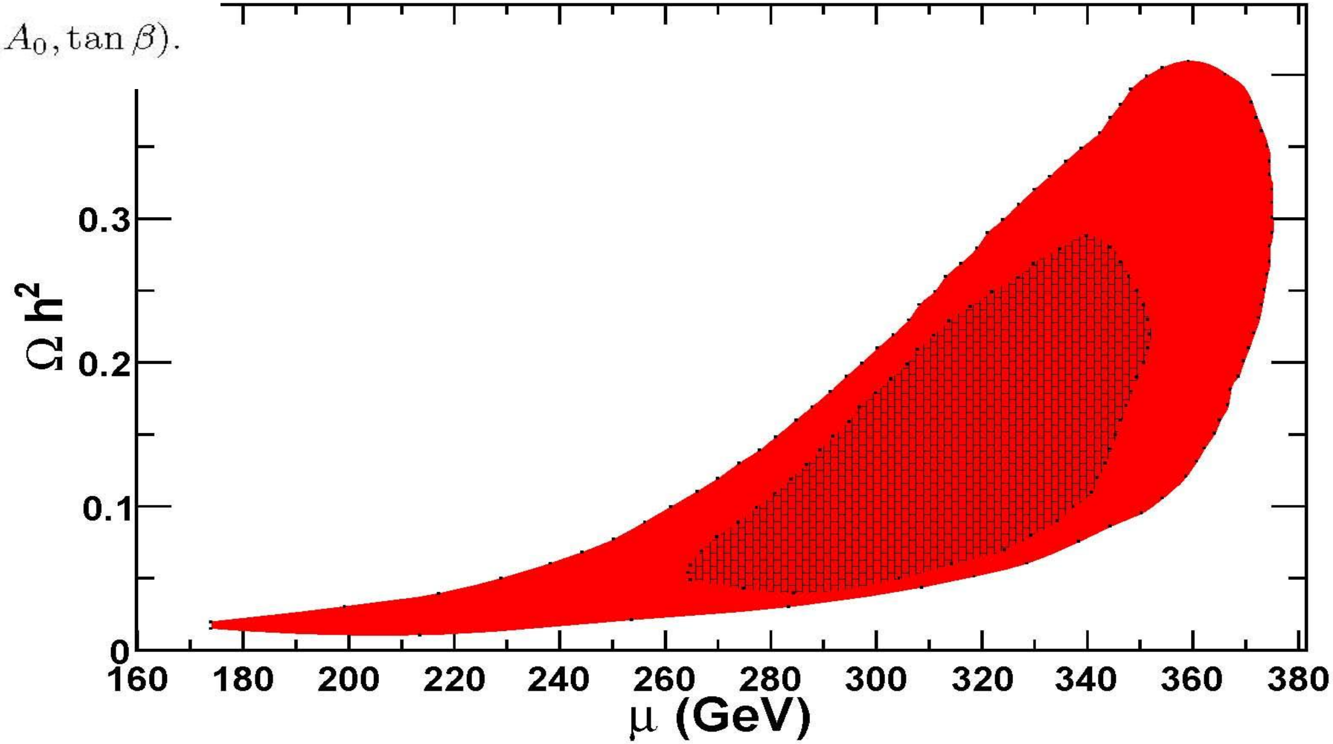
$$\delta\sigma_{\tilde{\chi}_1^0 - p} / \sigma_{\tilde{\chi}_1^0 - p} \approx 7\%\ (30\ \text{fb}^{-1})$$

NUSUGRA: Relic Density

Non Universal SUGRA Model: $m_{Hu}^2 = m_0^2(1+\delta_u^2), m_{Hd}^2 = m_0^2(1+\delta_d^2),$

- $M_{\rm eff}^{\rm peak} = f_1(m_{1/2});$
- $M_{\rm eff}^{(b,\ {\rm no}\ W)\ {\rm peak}} = f_2(m_{1/2});$
- $M_{jW}^{\rm end} = f_3(m_{1/2}, m_H);$
- $M_{j\tau\tau}^{\rm peak} = f_4(m_{1/2}, m_H, m_0);$
- $M_{\tau\tau}^{\rm end} = f_5(m_{1/2}, m_H, m_0, A_0);$
- $M_{j\tau}^{\rm end} = f_6(m_{1/2}, m_H, m_0, A_0, \tan\beta).$

$\mathcal{L}$ (fb^{-1})	$m_{1/2}$ (GeV)	m_H (GeV)	m_0 (GeV)	A_0 (GeV)	$\tan\beta$	μ (GeV)	$\Omega_{\tilde{\chi}_1^0}h^2$
1000	500 ± 3	727 ± 10	366 ± 26	3 ± 34	39.5 ± 3.8	321 ± 25	$0.094^{+0.107}_{-0.038}$
100	500 ± 9	727 ± 13	367 ± 57	0 ± 73	39.5 ± 4.6	331 ± 48	$0.088^{+0.168}_{-0.072}$
Syst.	± 10	± 15	± 56	± 66	± 4.5	± 48	$^{+0.175}_{-0.072}$



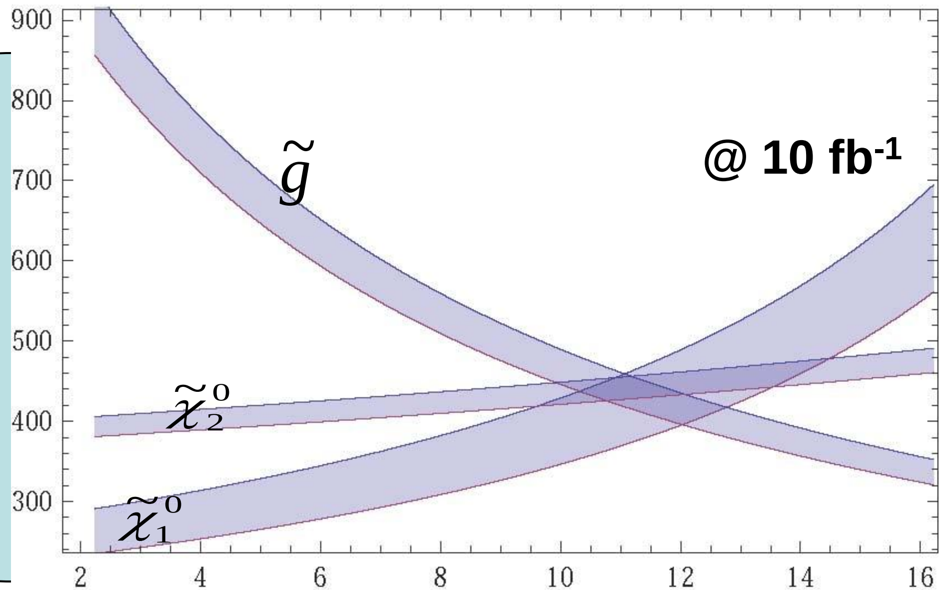
Dutta, Kamon, Kolev, Krislock, Oh, **PRD '10**

Mirage Mediation

- **We have moduli mediation plus anomaly mediation**

- **Using observables like: M_{eff}, $M_{\tau\tau}$, P_t, $M_{j\tau\tau}$, it is possible to reconstruct the gaugino masses to check the gaugino unification scale**

Input from the experimental measurements



Values of the masses at the GUT scale

Dutta, Kamon, Sinha, Wang, to appear

Conclusion

- Signature contains missing energy (R parity conserving) many jets and leptons : **Discovering SUSY should not be a problem!**

- Once SUSY is discovered, attempts will be made to measure the sparticle masses (highly non trivial!), establish the model and make connection between particle physics and cosmology

- Different cosmologically motivated regions of the SUGRA models have distinct signatures.
- Use the signatures and BEST to construct a decision tree
- It is possible to determine model parameters and the relic density based on the LHC measurements

- non-universal model parameters (Higgs non-universality)----Can be determined

- Mirage mediation models? ----Can be determined