Full Simulation SUSY Studies: Jet-Based Signatures

ATLAS SUSY Working Group

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Jet Based SUSY Signatures

- SUSY events are expected to be a copious source of high p_T jets generated through cascade decays of heavy squarks and gluinos.
- Techniques for measuring masses of strongly interacting sparticles often involve use of edges in kinematic variables (invariant masses, stranverse mass etc.) derived from combinations of jets and leptons → good jet energy resolution and linearity essential.
- 100k fully simulated SUSY events used both to assess measurement precisions (for SUSY) and performance of reconstruction algorithms (algorithm development and calibration).

Technical Details

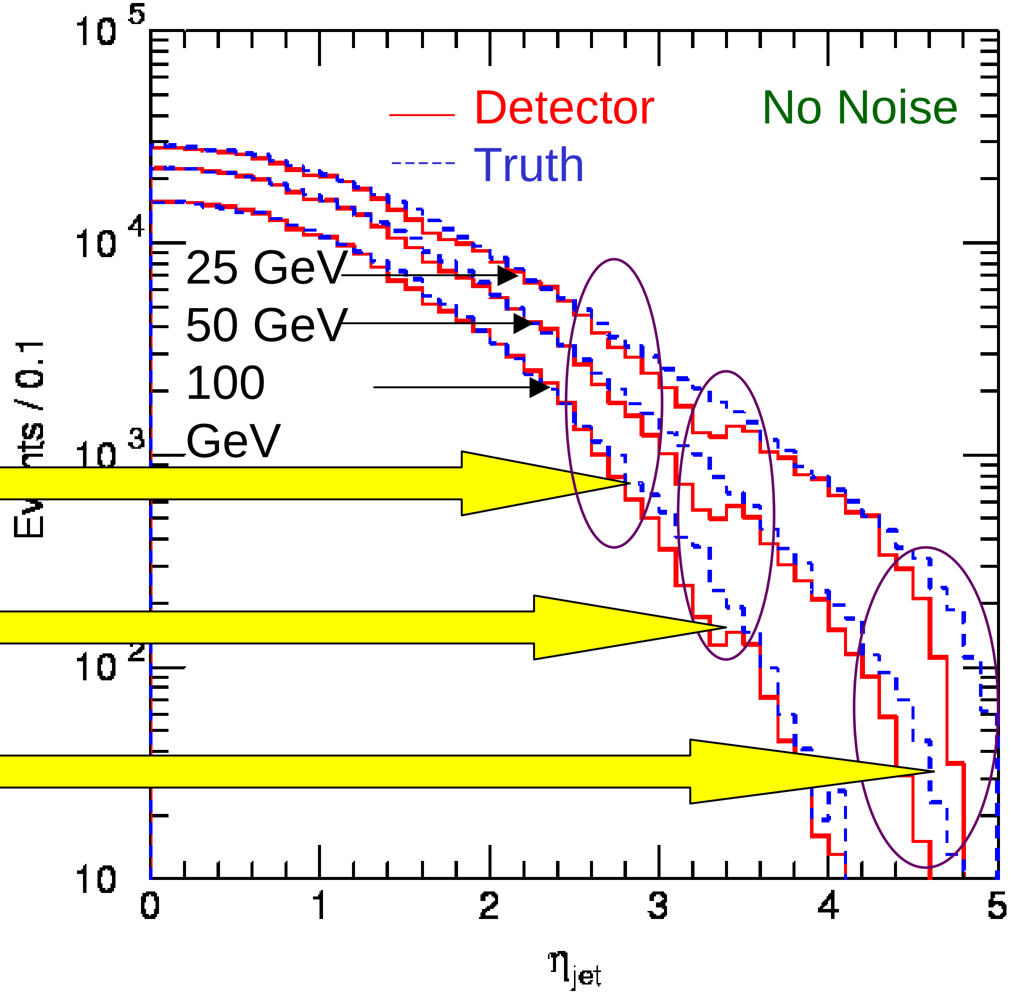
- Event generation with Isajet 7.64 coupled to Herwig 6.400.
- Simulation with 'standard' DC1 3.2.1 release (+ muon redigitisation), reconstruction with 6.0.3.
- Two noise scenarios:
  - without electronic noise;
  - with electronic noise and with noise cut turned on.
- Studies performed using both K_T and Cone jet-finding algorithms.
- B-tagging performed at CBNT level using fortran algorithm from b Working Group.
- Further details on Thursday in Jet/E_T^{miss} Working Group session (Gupta/Costanzo talks).

Jet Algorithms (6.0.3)

- JetRec seeded Fixed Cone algorithm ($\Delta R = 0.4$) used for most studies.
- JetRec K_T algorithm also used.
- Jets corrected in CombinedJetRec using H1 style cell weighting technique: low E_T cells corrected to Hadronic scale (low E-density), high E_T cells left at EM scale.
- Correction also for low p_T ID tracks looping out of cone in magnetic field.
- Many plots compare measured detector jet E_T with equivalent MC truth jet → truth jet with smallest ΔR.

Jet Algorithm Performance

- Simplest test → distribution of Truth and Detector jets as function of η.
- Some problems evident:
  - Poorer performance for |η|>2.5;
  - Loss of Detector jets in Barrel-Endcap transition;
  - Shower leakage at large η .
- Needs work …

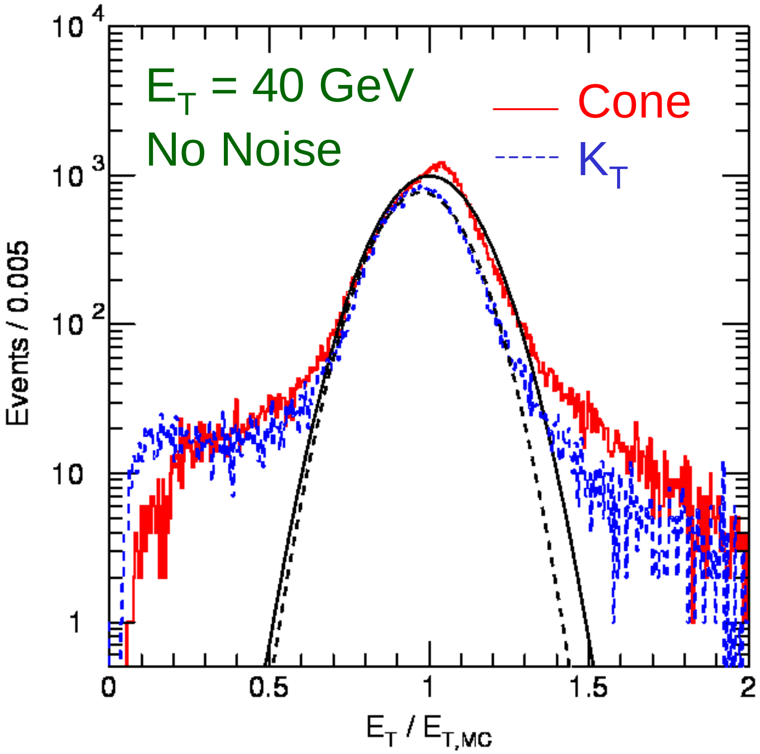


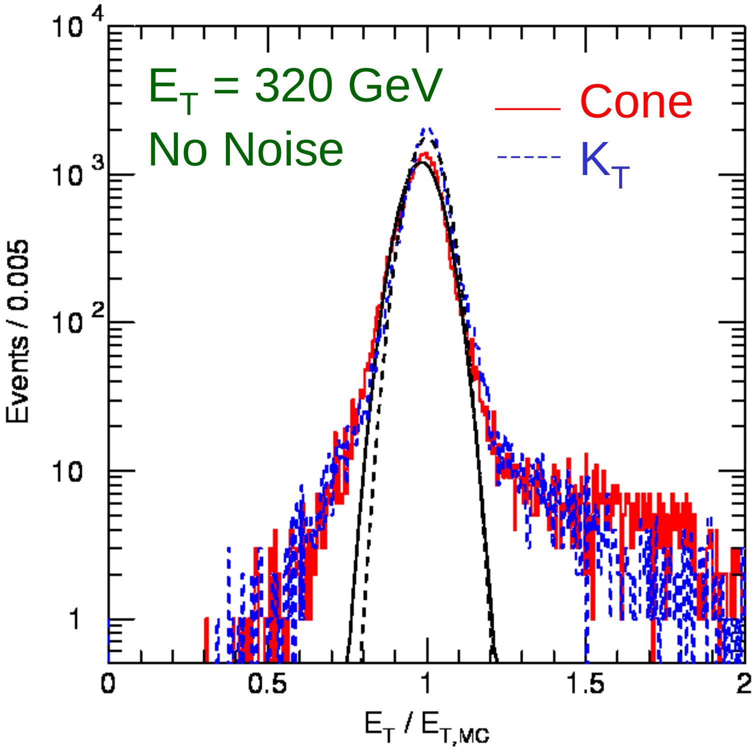
Jet Algorithm Performance

- η dependent fudge factor applied to jets in $|\eta| < 2$:

$$F=(1+0.03|\eta|-0.04|\eta|^2)^{-1}$$

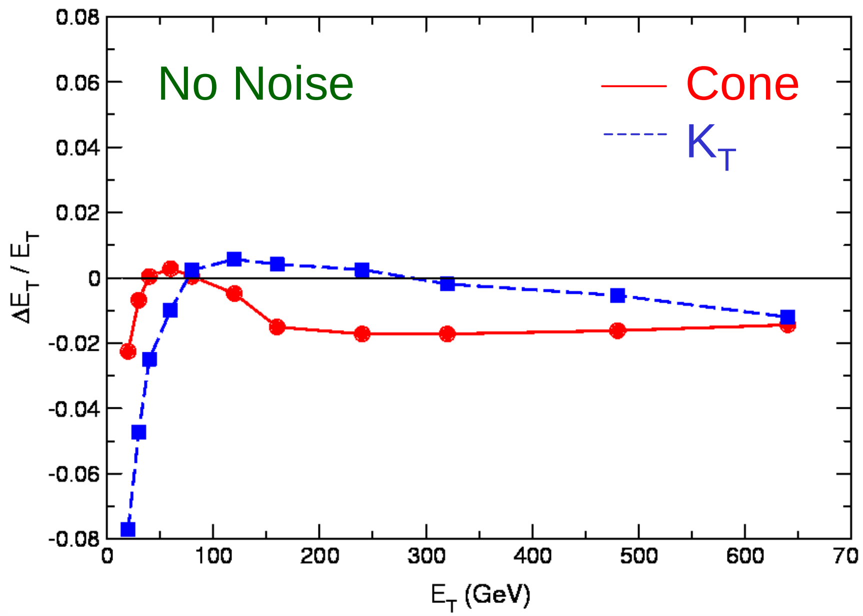
- Non-Gaussian tails remain however.

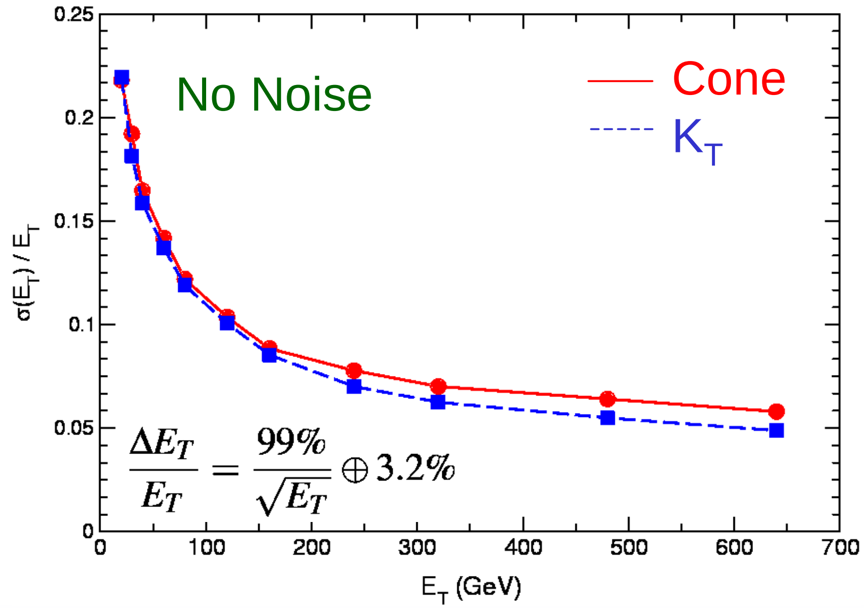




Jet Algorithm Performance

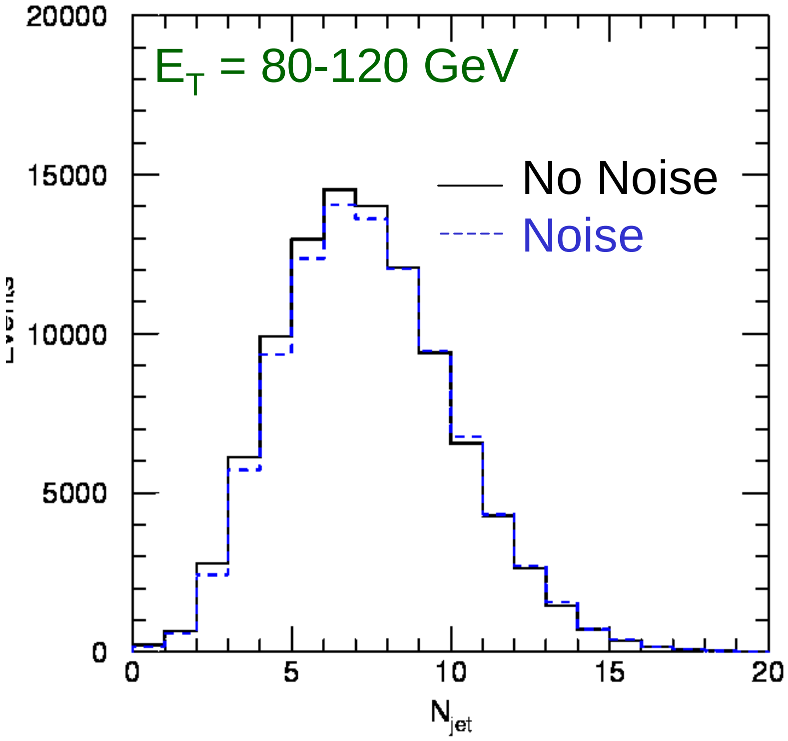
- Gaussian equivalent energy resolution (68%) calculated from width of window containing 90% of jets.
- Jet energy scale from mean inside window.
- In absence of noise better linearity from Cone at low E_T, but better resolution from K_T.

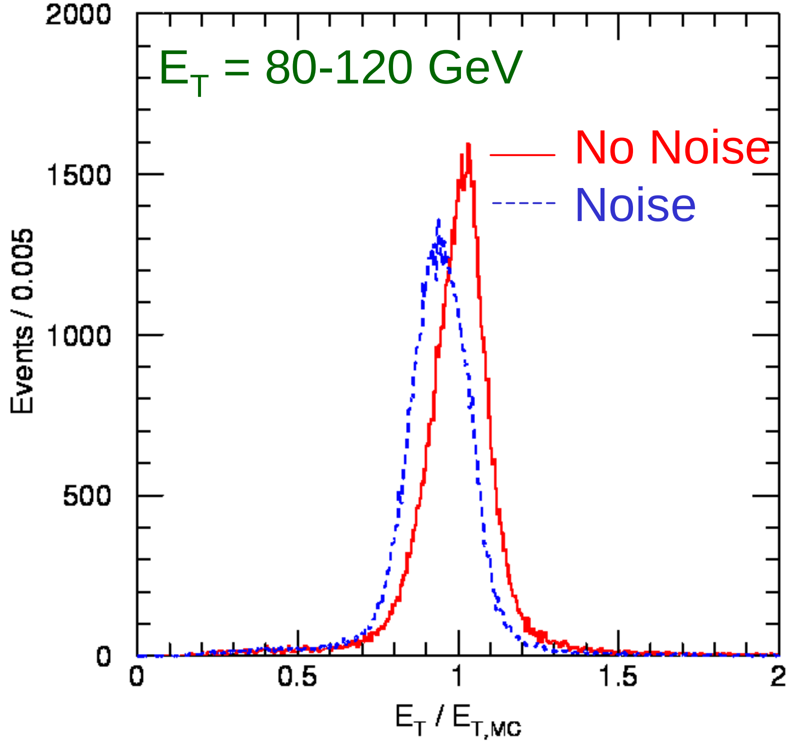




Jet Algorithm Performance

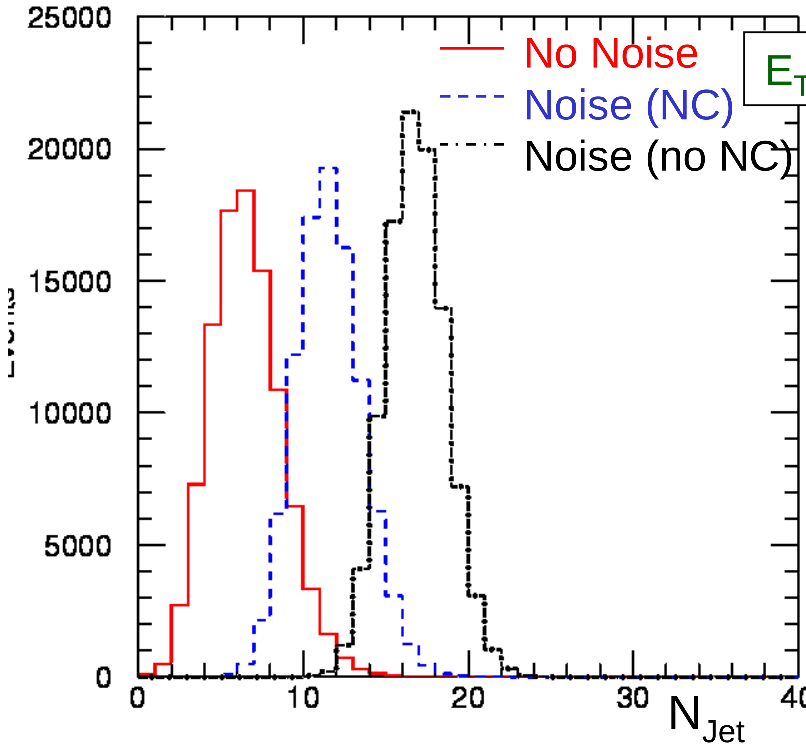
- With noise and 2σ noise cut Cone performance degraded but not dramatically so.
- Unsurprising given H1 calibration in absence of noise.
- Re-calibration needed.



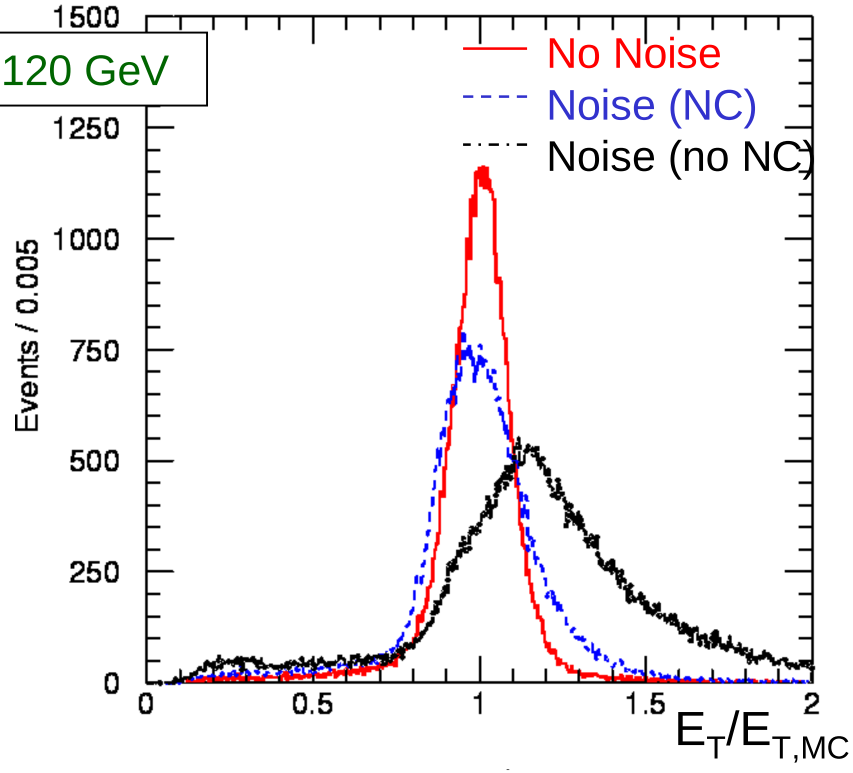


Jet Algorithm Performance

- With noise K_T performance degraded still further, especially in absence of noise cut.
- Caused by protojet E_T>0 cut and large (effective ΔR=1.0) K_T tower acceptance cone → bias in favour of +ve energies.

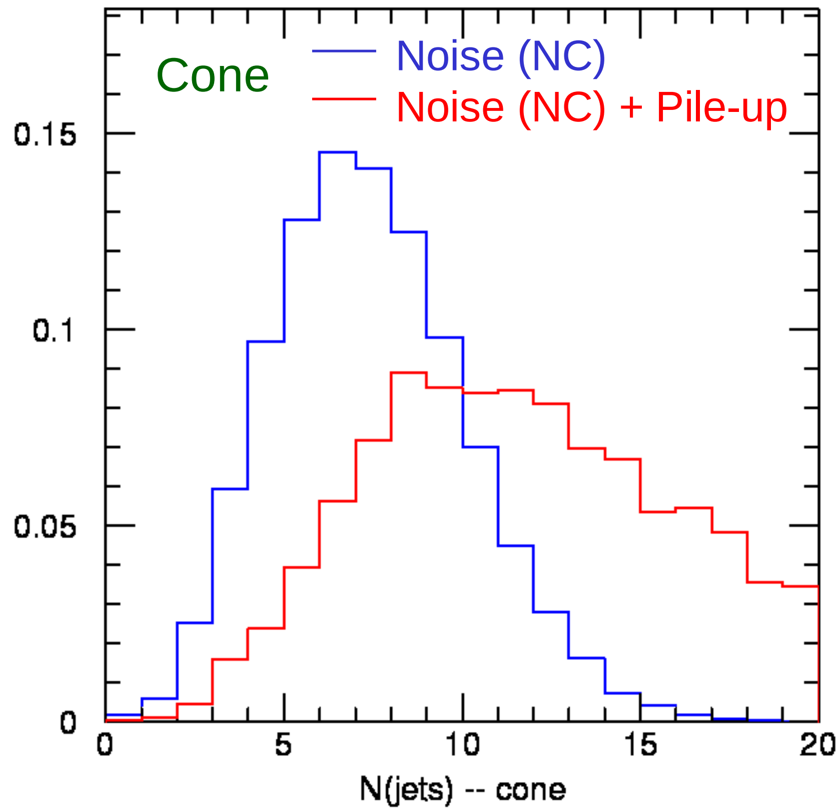


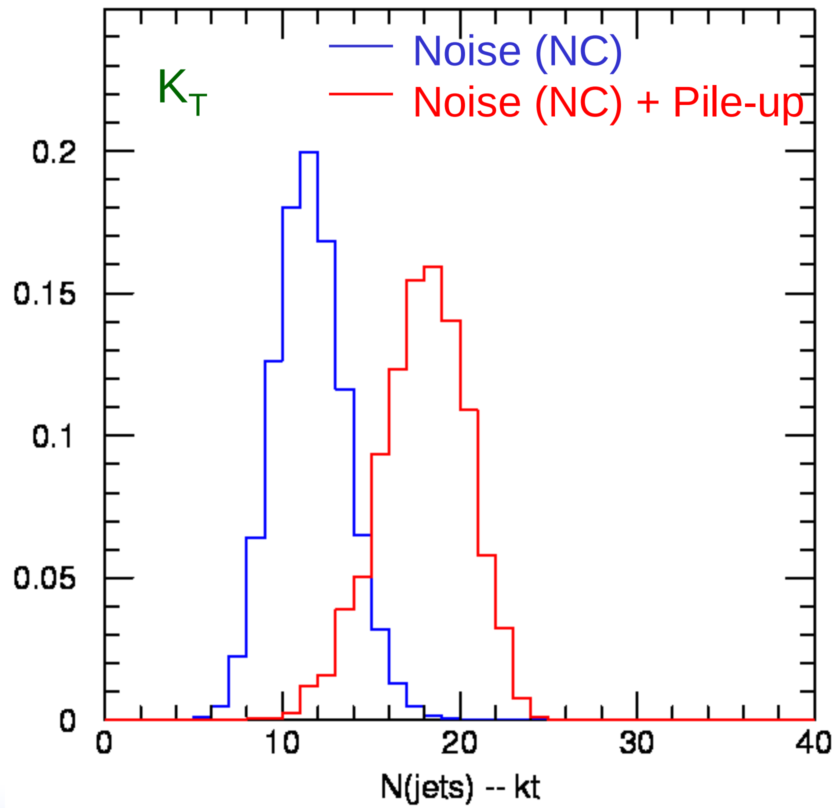
E_T = 80-120 GeV



Jet Algorithm Performance

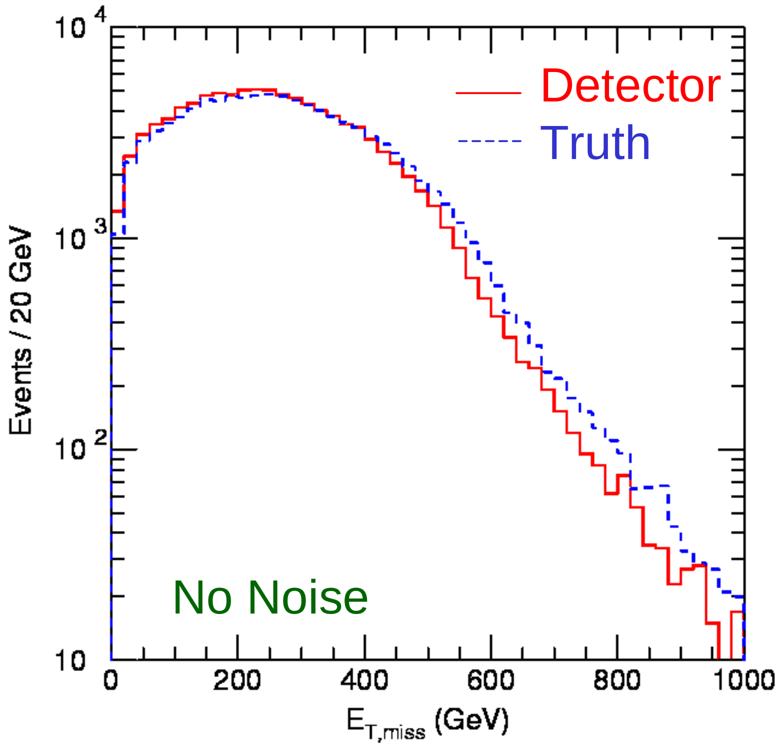
- With pile-up, noise and noise cut more jets found as expected.
- Again bigger shift for K_T.

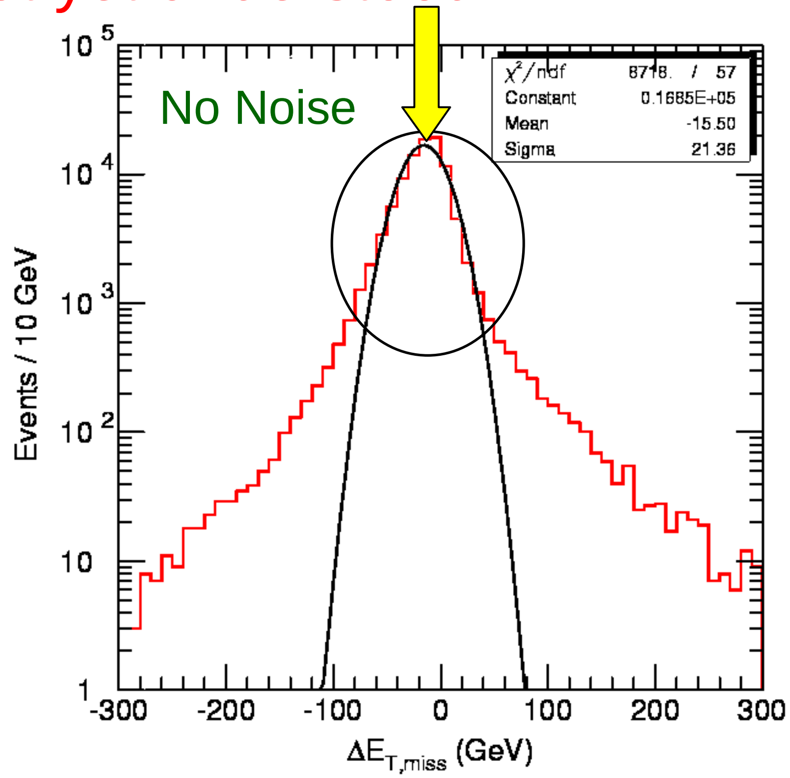




Missing E_T Performance

- Reconstructed using MissingET package with H1 style cell weighting (as in CombinedJetRec).
- Truth E_T^{miss} from vector sum of p_T of ν and $\tilde{\chi}^0_1$.
- Systematic shift ~ 15 GeV not yet understood.



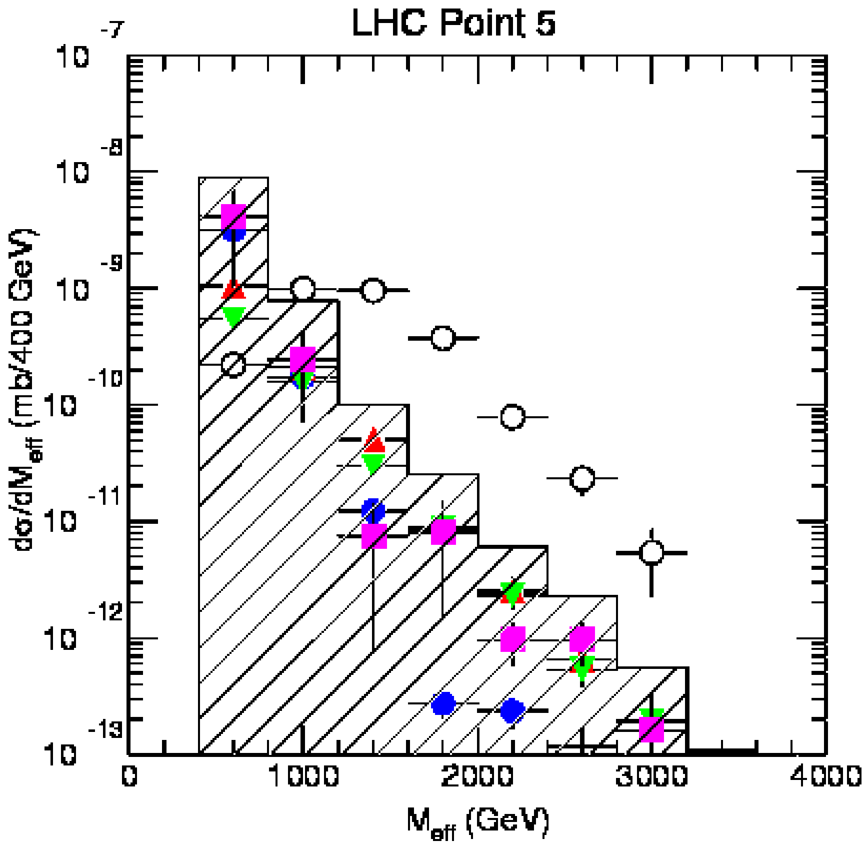


SUSY Mass Scale

- First measured SUSY parameter likely to be mass scale:
  - Defined as weighted mean of masses of initial sparticles.
- Calculate distribution of 'effective mass' variable defined as scalar sum of masses of all jets (or four hardest) and E_T^{miss}:

$$M_{eff}=\Sigma p_T^i + E_T^{miss}.$$

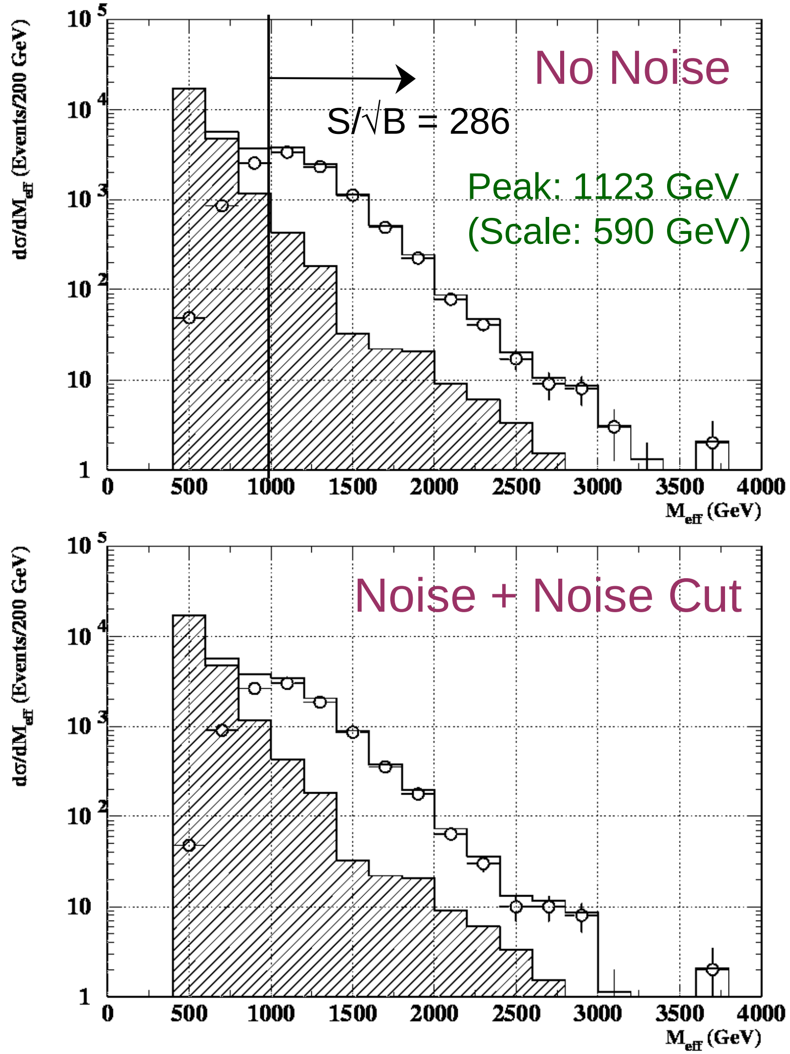
- Distribution peaked at ~ twice SUSY mass scale for signal events.
- Significant excess at large M_{eff}.



Jets + E_T^{miss} + 0 leptons

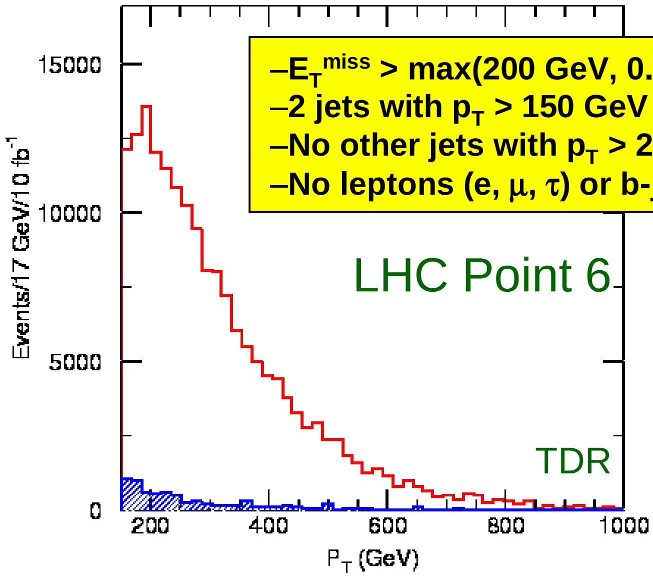
SUSY Mass Scale

- Repeated using full simulation sample.
- Backgrounds from fast simulation (atlfast-fortran).
- Cuts used to reduce SM backgrounds (QCD, Z+jet, W+jet, ttbar):
  - At least 4 jets with $p_T > 50$ GeV
  - At least 2 jets with $p_T > 100$ GeV
  - ETmiss > max(100 GeV, $0.25\Sigma|p_T^{j(i)}|$)
  - Transverse sphericity $S_T > 0.2$
  - No muons or isolated electrons

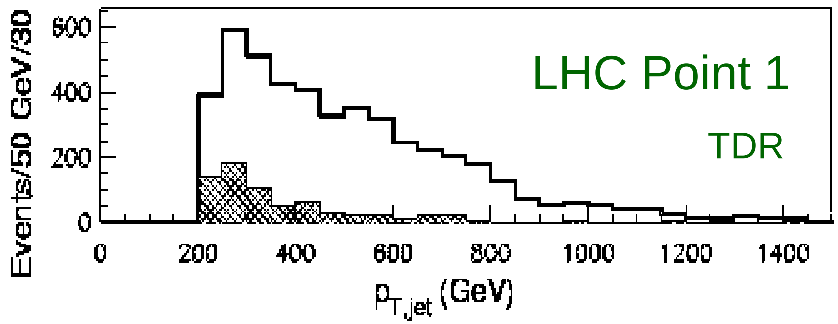


$\tilde{q}_R$ Mass Measurement

- At chosen point $\tilde{q}_R \rightarrow q\tilde{\chi}^0_1$ with BR > 99%.
- Measurements of $\tilde{q}_R$ mass for input to mSUGRA parameter fits therefore difficult.
- In TDR distribution of jet p_T in dijet + E_T^{miss} events used (similar to effective mass).
- Hard cuts used to reject QCD, ttbar, Z+jet background.
- Cuts harder still at LHC Point 1 where cross-section smaller.



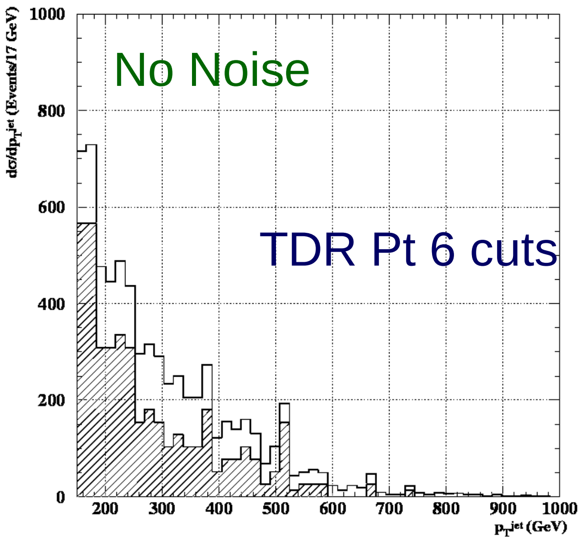
–E_T^{miss} > max(200 GeV, 0.2M_{eff})
–2 jets with p_T > 150 GeV
–No other jets with p_T > 25 GeV
–No leptons (e, μ, τ) or b-jets

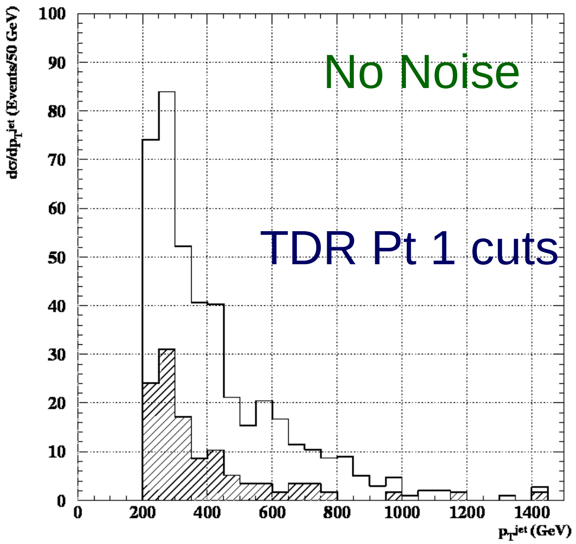


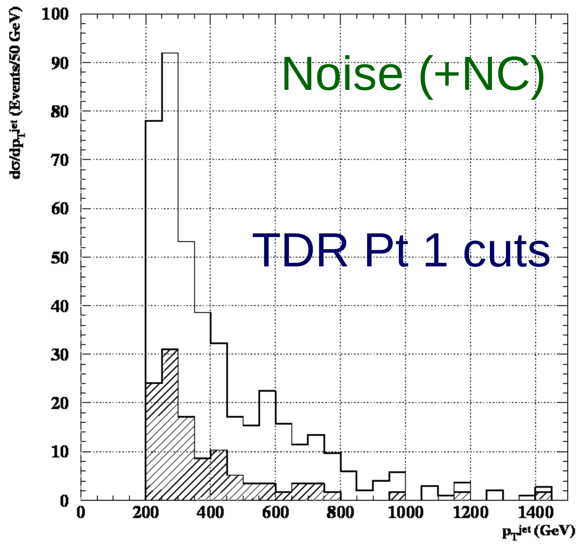
–E_T^{miss} > 400 GeV
–2 jets with p_T > 200 GeV, |η|<2
– ΔR(j1,j2) > 1
–$p_T^{j1}+p_T^{j2}$ > 500 GeV
–No other jets with p_T > 15 GeV
–No leptons (e, μ, τ)

$\tilde{q}_R$ Mass Measurement

- Repeated with full simulation sample.
- Backgrounds from TDR (atlfast-fortran).
- Point 6 (loose) cuts insufficient (σ_{susy} ~ factor 10 lower).
- Point 1 (hard) cuts much better.
- Little sensitivity to noise (with noise cut).







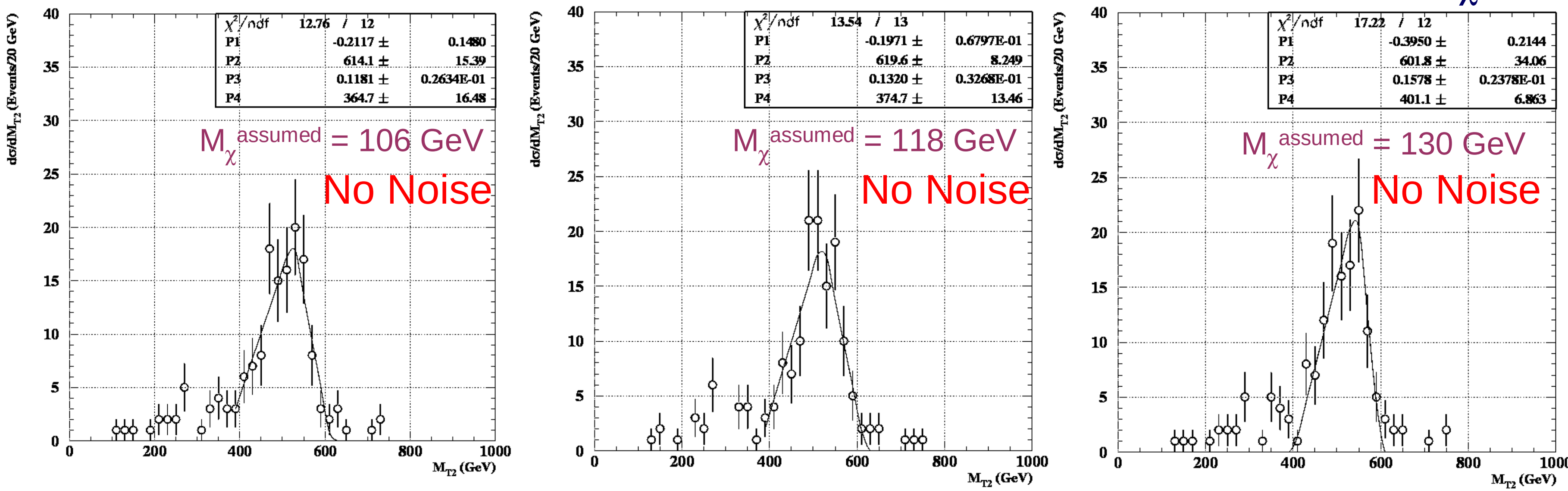
$\tilde{q}_R$ Mass Measurement

- Alternative approach is to use the 'stransverse mass' m_{T2} for events containing two invisible final state particles, defined by:

$$m_{T2}^2 = \min_{q_T^{\chi(1)}+q_T^{\chi(2)}=E_T^{miss}} [\max\{m_T^2(p_T^{j(1)},q_T^{\chi(1)};m_\chi),m_T^2(p_T^{j(2)},q_T^{\chi(2)};m_\chi)\}]$$

where m_T is the transverse mass (Lester *et al.*).

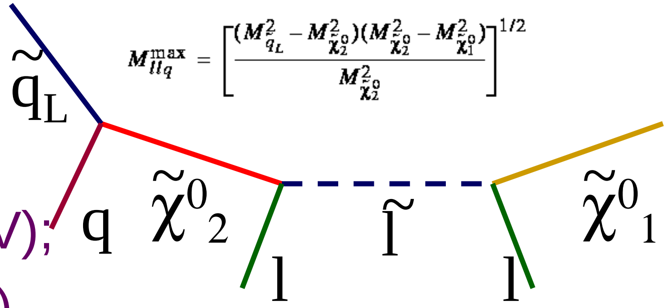
- Gives sharp edge at mass of $\tilde{q}_R$ given assumed value of m_χ.

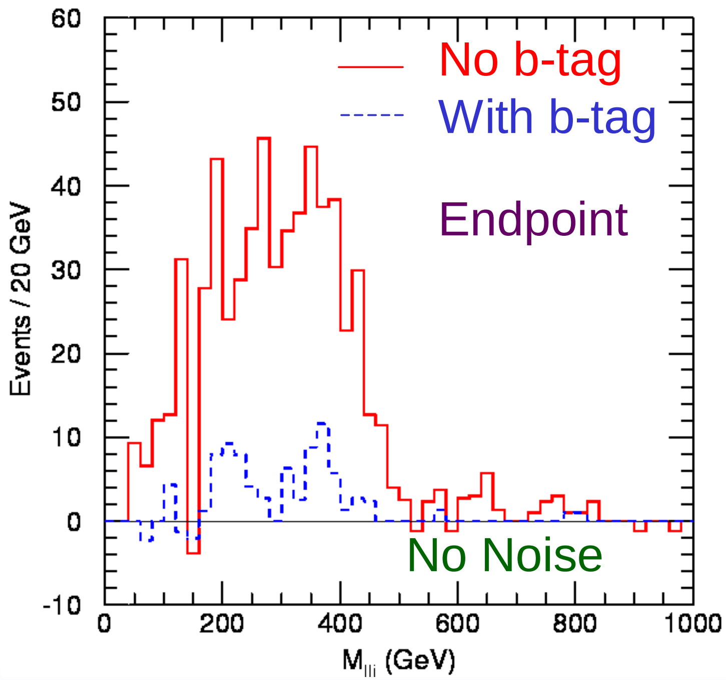


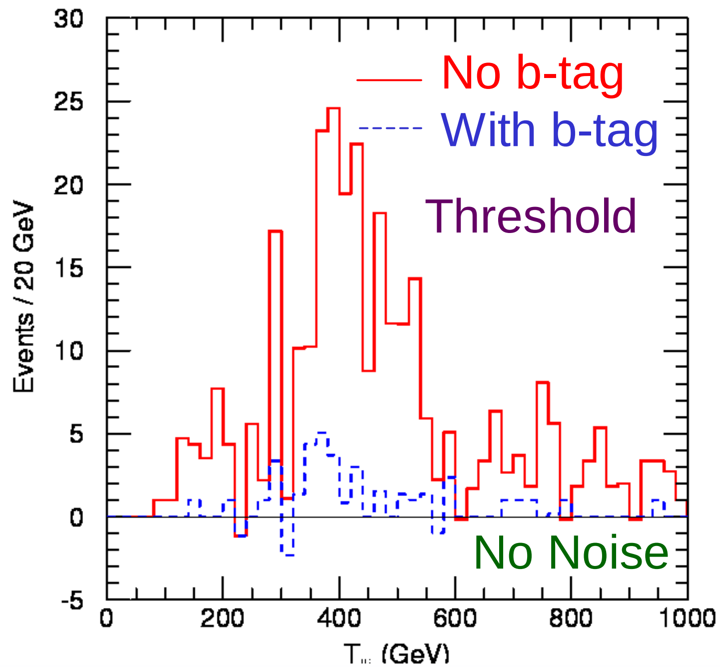
Edge expected ~ 611 GeV → overall error estimated to be ~ 5% (pessimistic)

llj Endpoint and Threshold

- Follows on from dilepton endpoint measurements (Davide)
- Main source of $\tilde{\chi}^0_2$ is $\tilde{q}_L \rightarrow \tilde{\chi}^0_2 q$.
- Assume 2 hardest jets from $\tilde{q}_L$ decays:
  - Smaller M(llj) value < $\tilde{q}_L$ endpoint (501 GeV);
  - Larger M(llj) value > $\tilde{q}_L$ threshold (249 GeV).







Conclusions

- Jet reconstruction making progress
  - More studies and optimisation needed now for realistic noise and pile-up scenarios.
- Missing ET reconstruction working well but still needs to be fully understood.
- Full simulation supports fast sim results reported in TDR.
- Looking forward to the first 5146 pb^{-1} of data !