Introduction to hadronic collisions: theoretical concepts and practical tools for the LHC

Lecture 5

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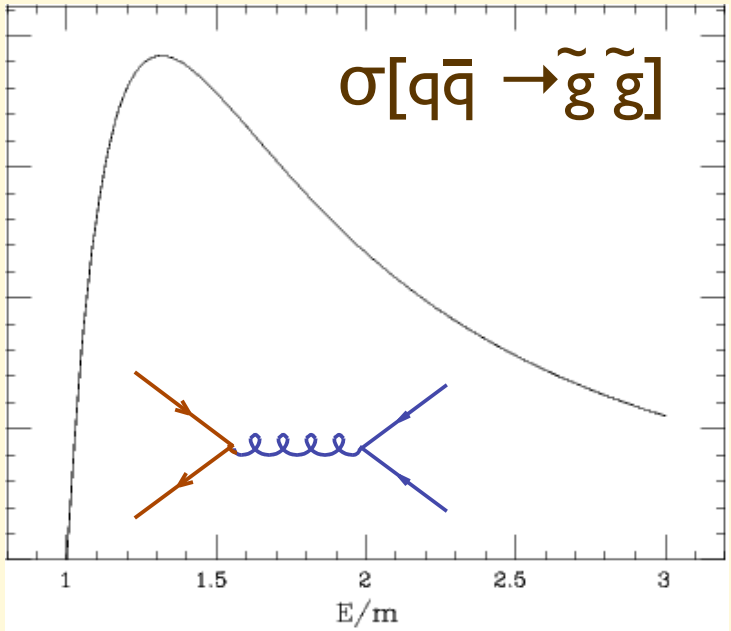
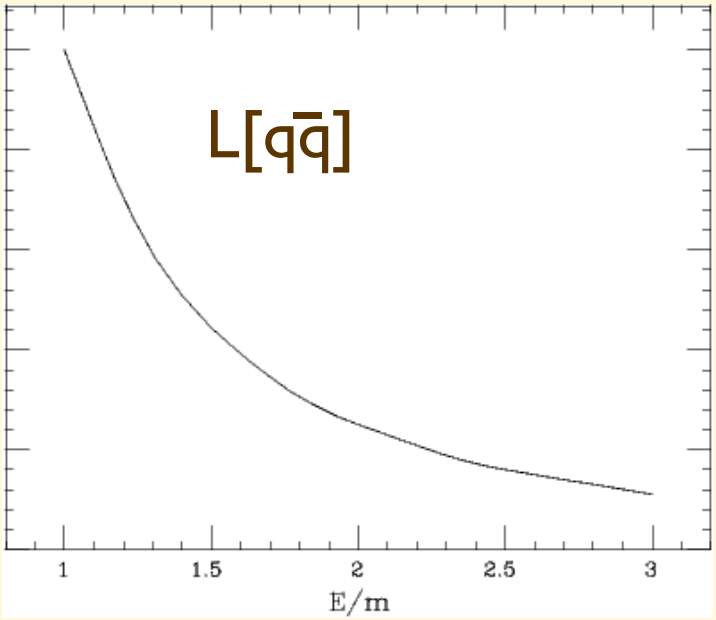
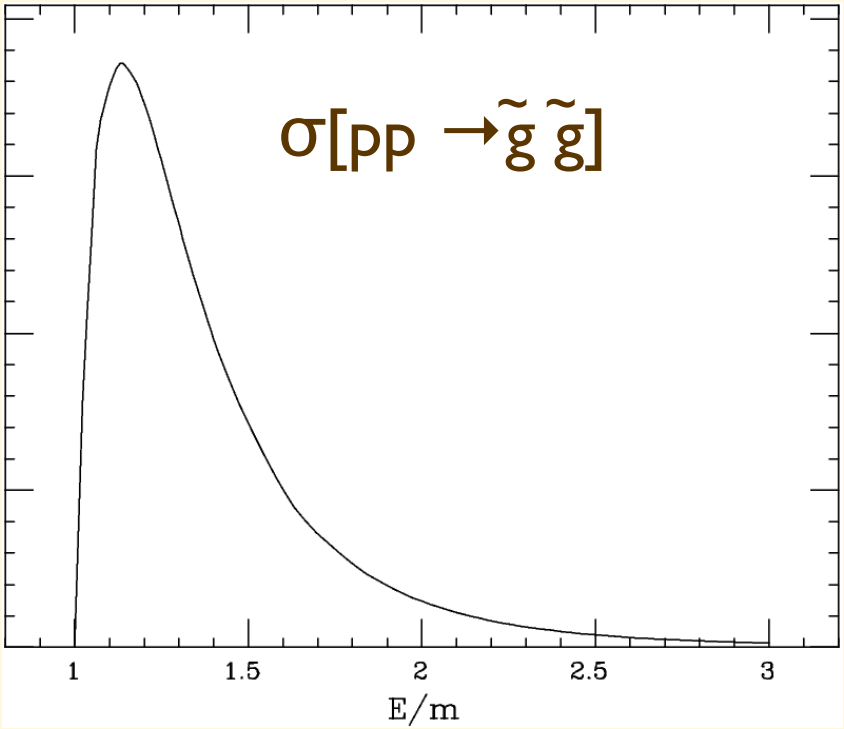
Ex: Gluino pair production

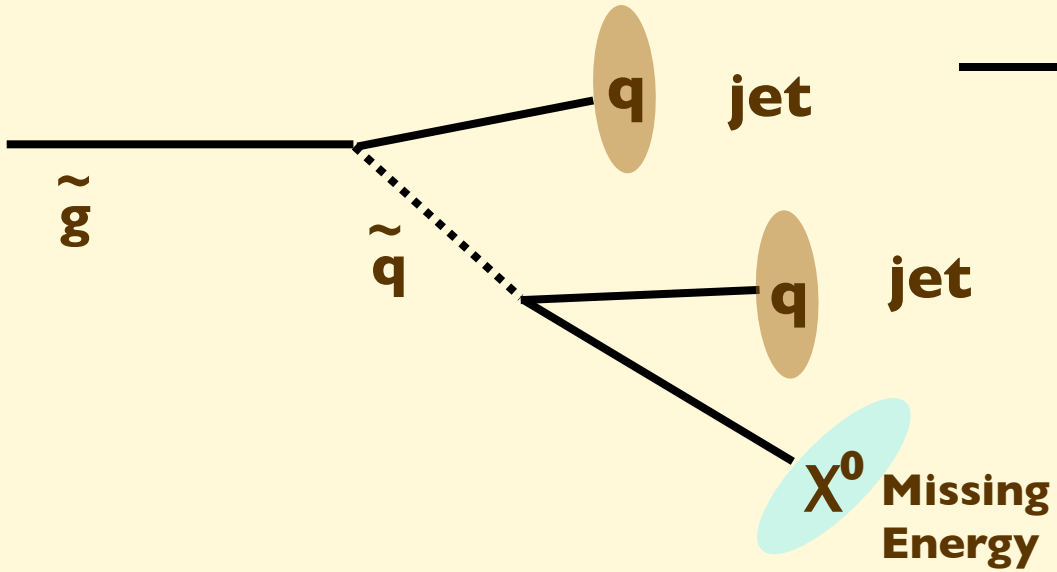


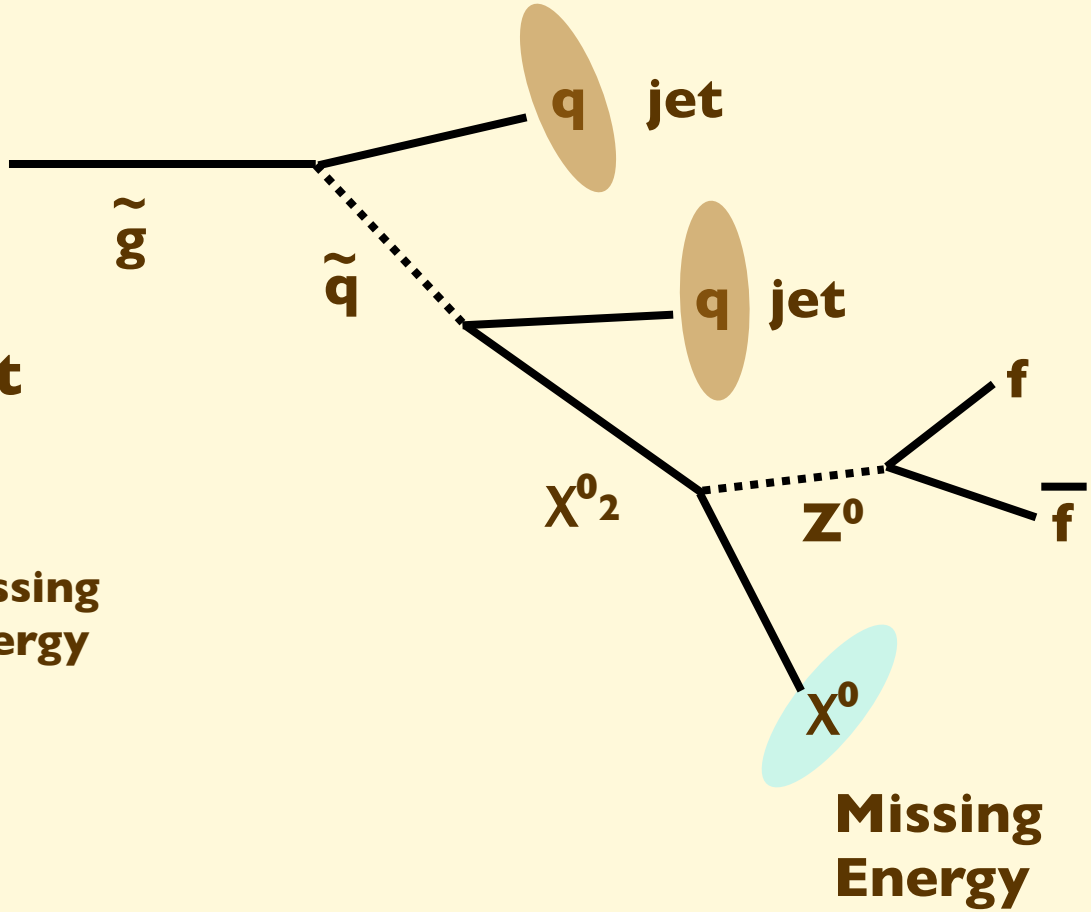


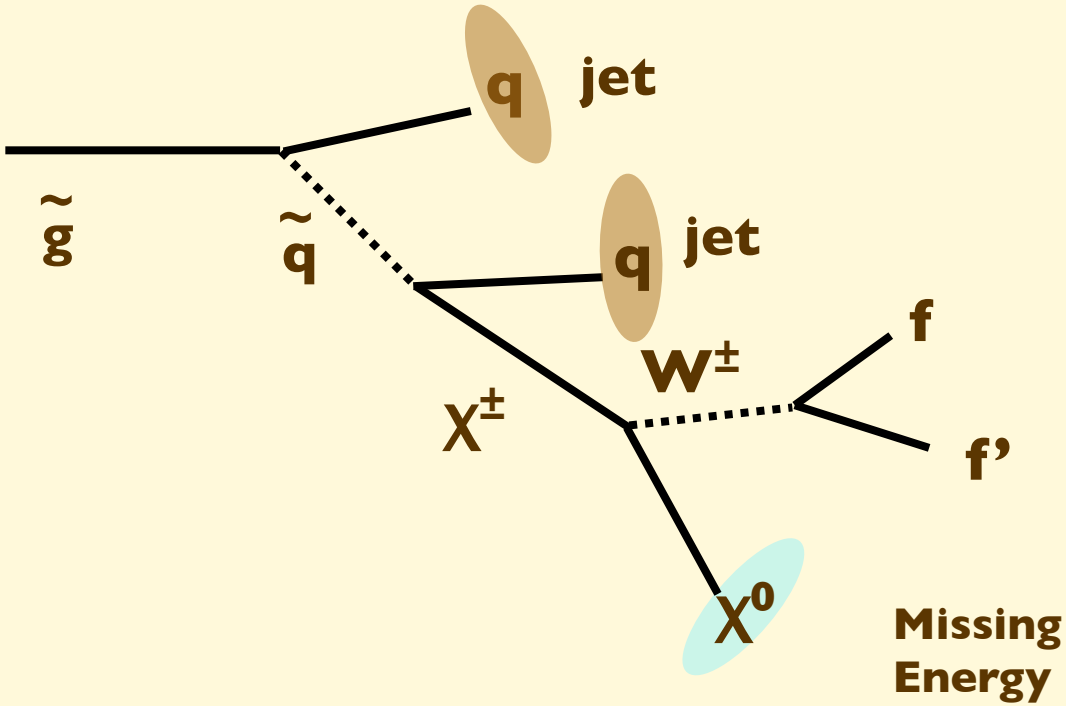


⇒ slow gluinos, β~0.5

Gluino final states





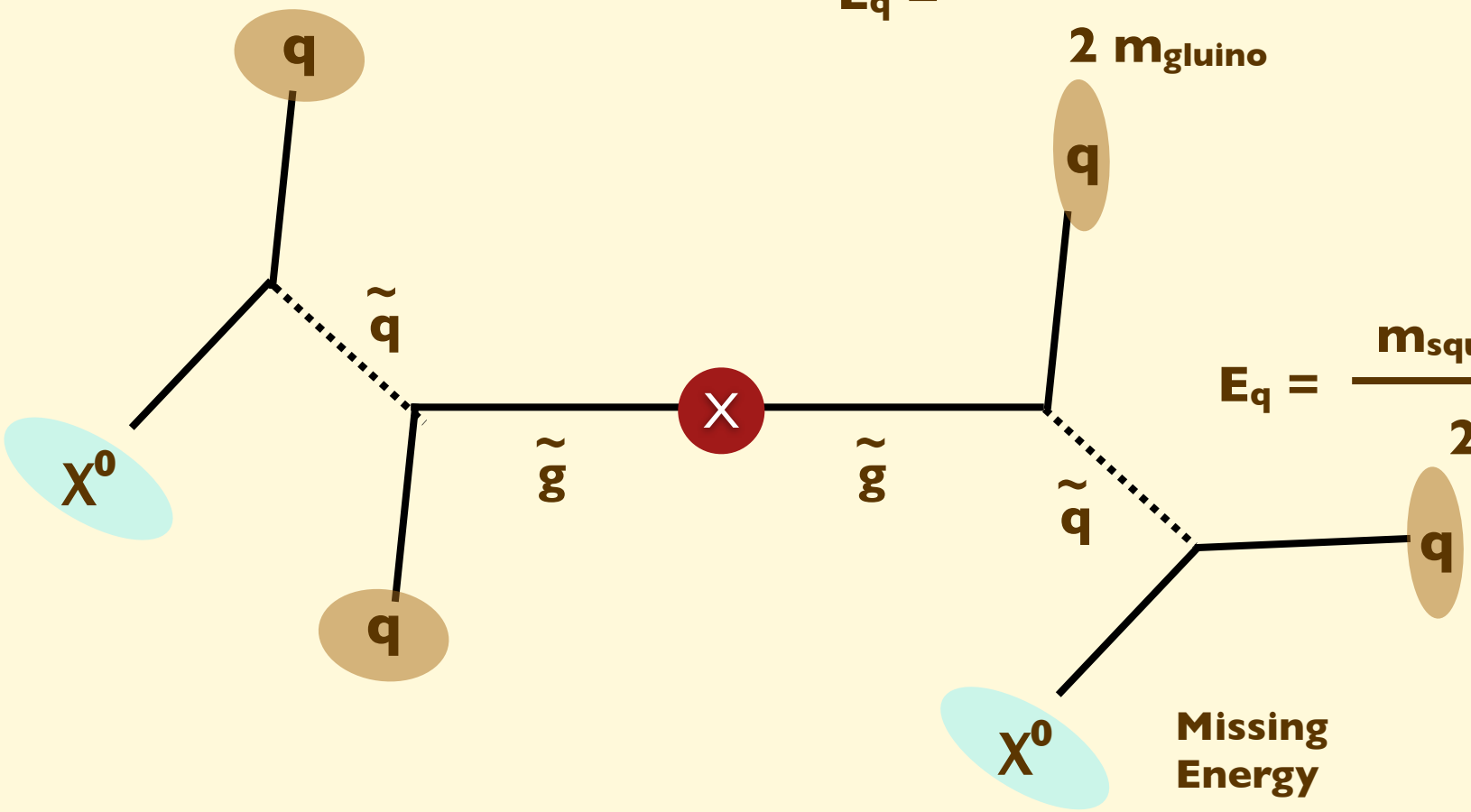


$\tilde{g} \rightarrow$ ≥2 jet + MET + ≥0 $\ell^\pm$

$\tilde{g}\,\tilde{g} \rightarrow$ 4 jet + MET

$$E_q = \frac{m_{gluino}^2 - m_{squark}^2}{2\, m_{gluino}}$$

$$E_q = \frac{m_{squark}^2 - m_{\chi}^2}{2\, m_{squark}}$$



Widely-spaced jets, no significant hierarchy in transverse energies and missing E_T

Typical analysis cuts (ATLAS):

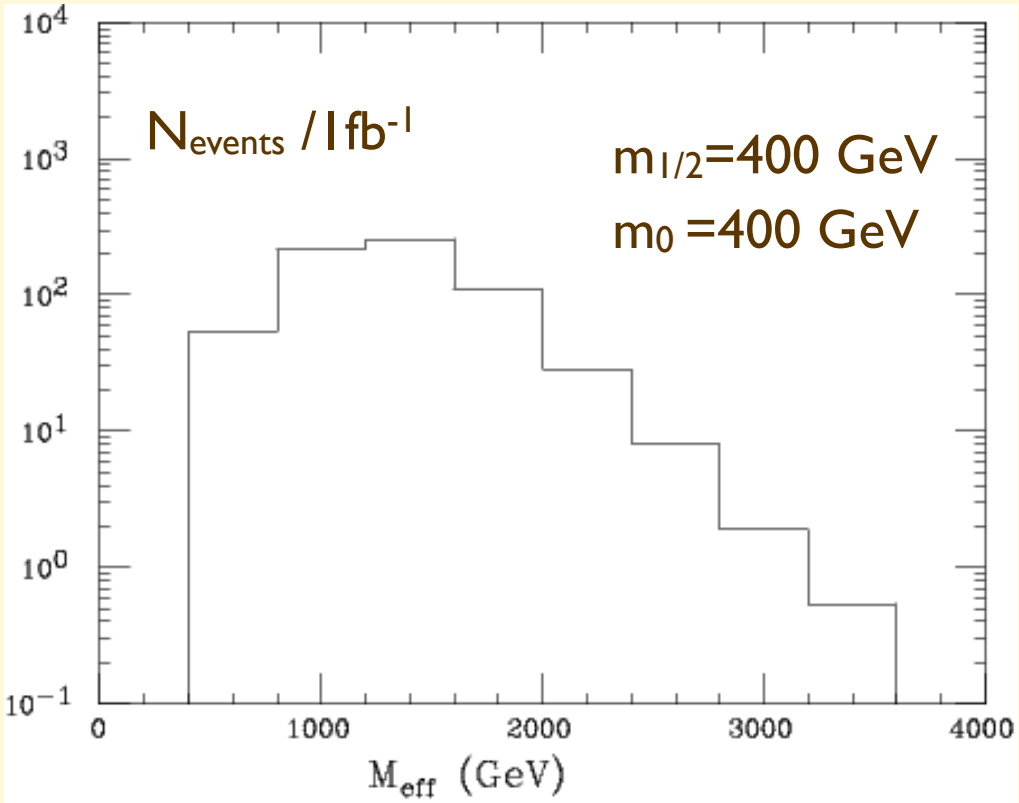
≥4jets, E_T>50 GeV leading jet E_T>100 GeV

no lepton with E_T>20 GeV

MissET> max(100, 0.2 M_{eff})

M_{eff} = MET + $\sum_{i=1,..,4} E_T^i$

Transverse sphericity > 0.2



SM Backgrounds

Missing energy ⇒ νs ⇒ W/Z production

"Irreducible": individual events cannot be distinguished from the signal

Z+4jets, Z→ νν

"Reducible": individual events feature properties which distinguish them from the signal, but these can only be exploited with limited efficiency

W+3jets, W→ τν, τ→hadrons (jet)

τ jet has low multiplicity, and originates from a displaced vertex, because of τs lifetime

W+4jets, W→ e/μ ν, lepton undetected

e/μ can be detected, but cannot be vetoed with 100% efficiency, else the signal would be killed as well (e /μ may come from π conversions or decays)

tt → W+jets, with W→ leptons as above

In addition to the above, top decays have b's, but these cannot be detected and vetoed with 100% efficiency

“Instrumental”: individual events resemble the signal because of instrumental “effects” (namely instrumental deficiencies)

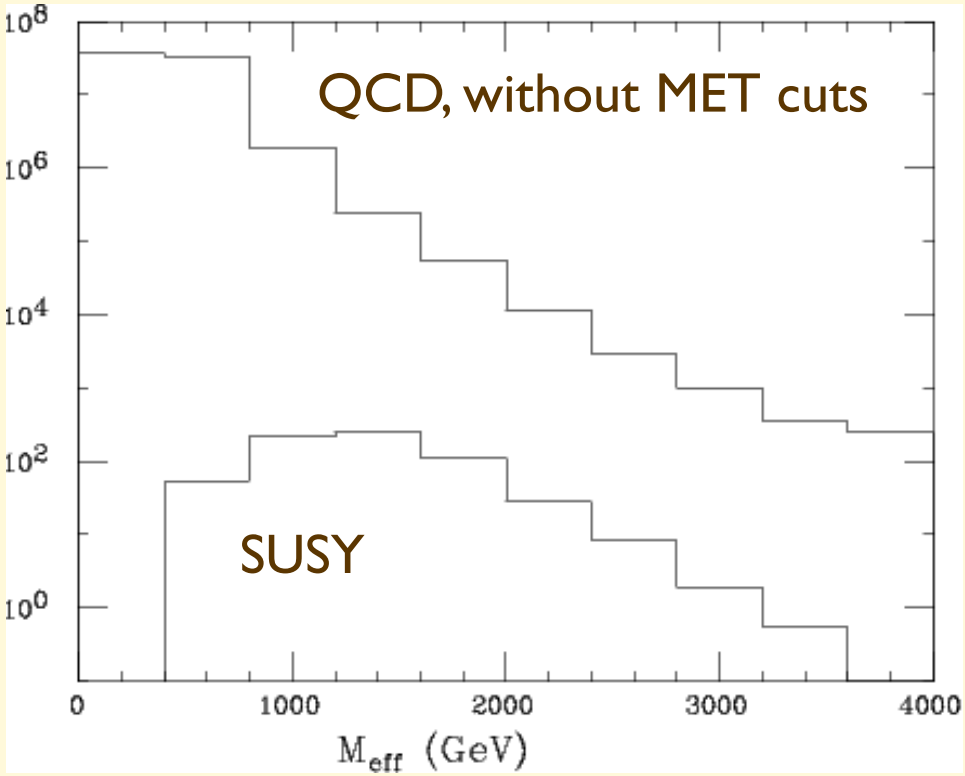
Multijets

The missing ET may originate from several sources:

Mismeasurement of the energy of individual jets

Incomplete coverage in rapidity (forward jets undetected)

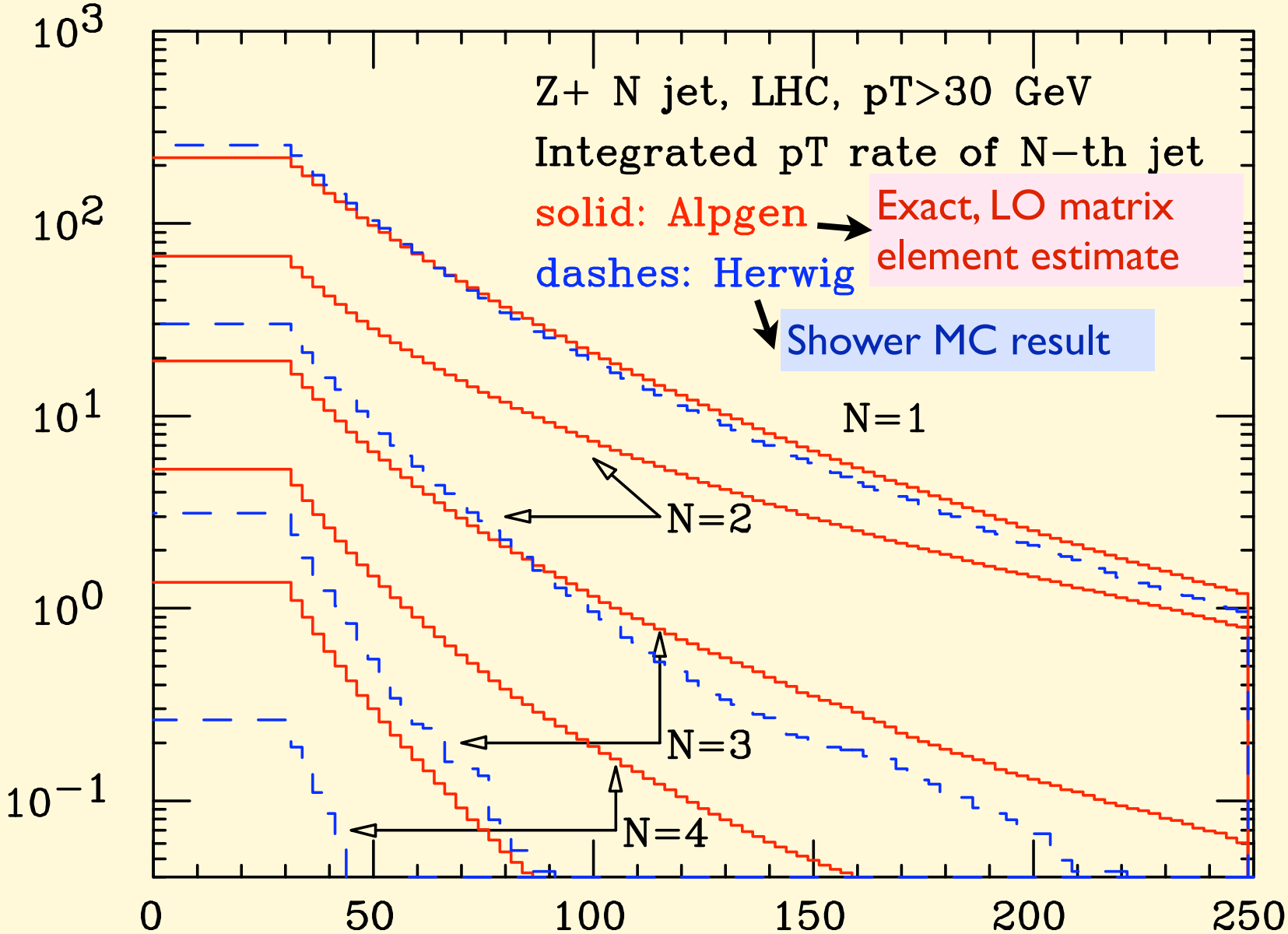
Accidental extra deposits of energy (cosmic rays on time, beam backgrounds, , electronic noise, etc.etc.etc.)



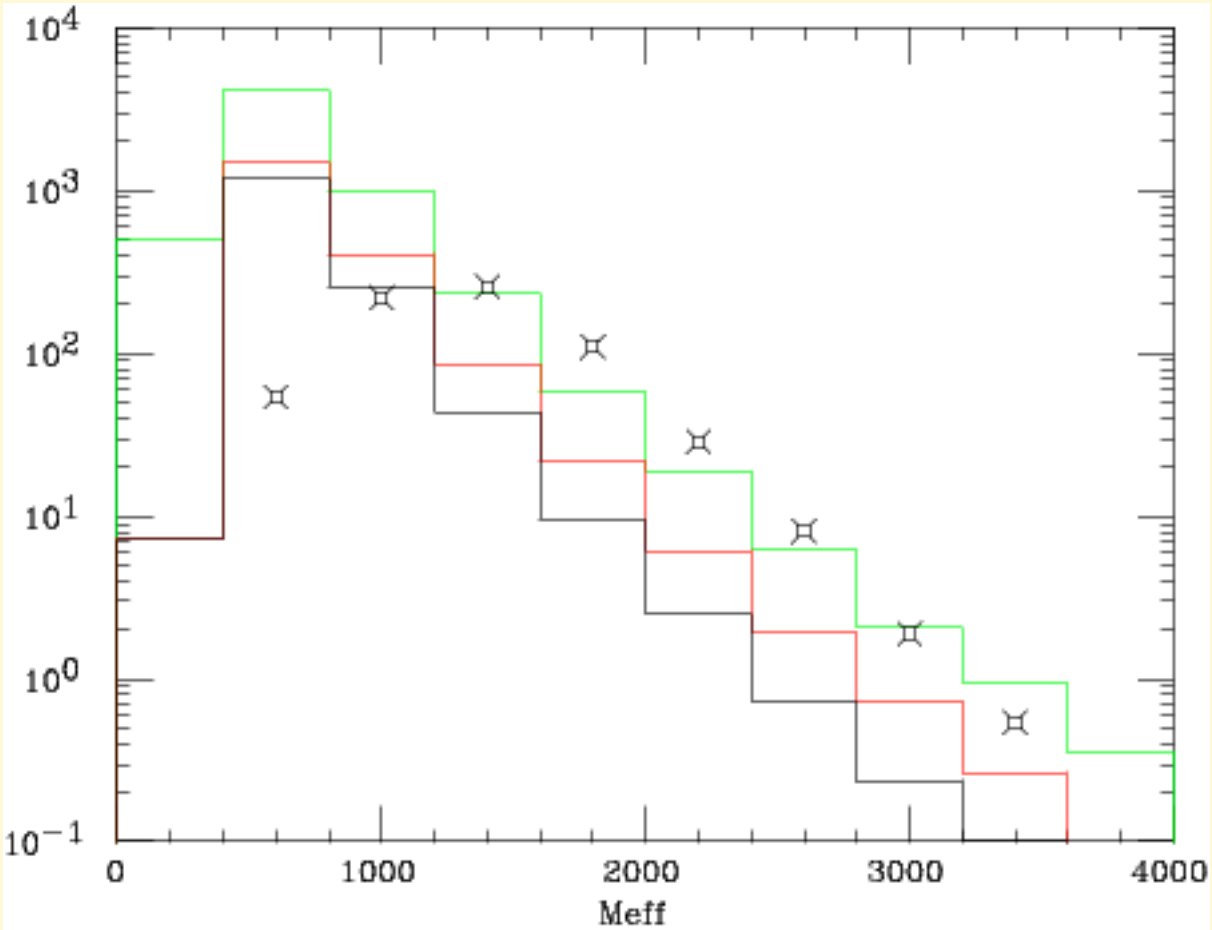
It is sufficient that these effects leave a permille fraction of the QCD rate for the signal to be washed away!

Z(→νν) + jets

1. Shower MC vs Matrix element results



Z(→νν) + jets



Jet cuts only

+ MET cut

+ ST cut

SUSY

Normalizing the bg rate using data ...

Use Z->ee + multijets, apply same cuts as MET analysis but replace MET with ET(e^+e^-)

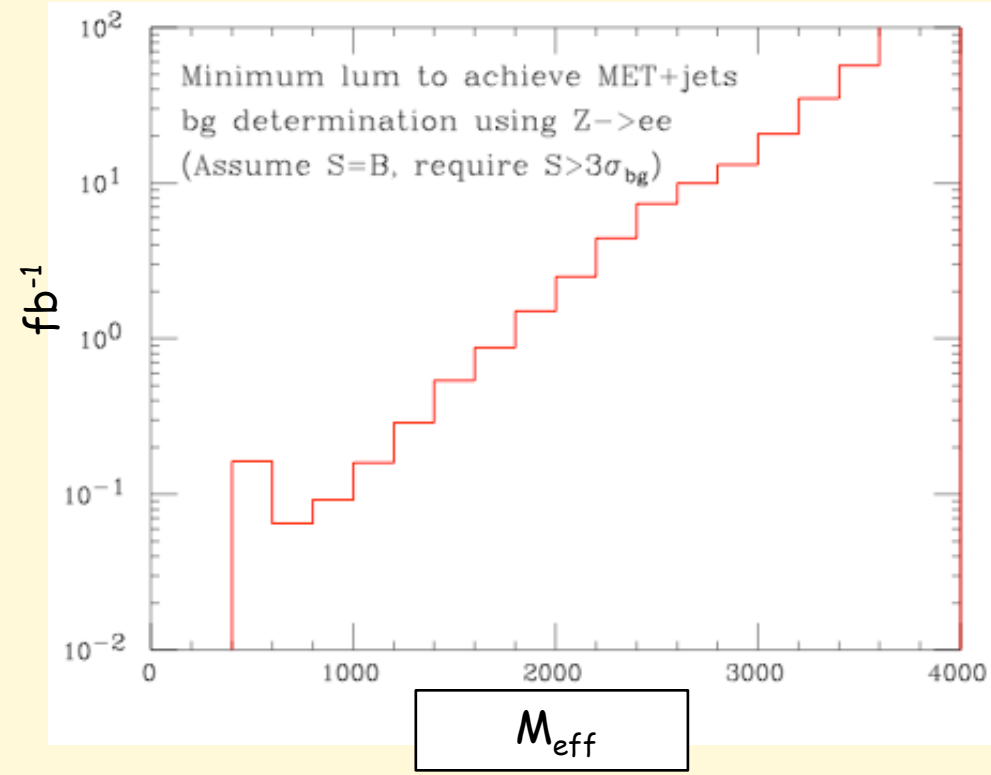
Extract $Z \rightarrow \nu\nu$ bg using, bin-by-bin:
$(Z \rightarrow \nu\nu) = (Z \rightarrow ee)\ B(Z \rightarrow \nu\nu)/B(Z \rightarrow ee)$

Assume that the SUSY signal is of the same size as the bg, and evaluate the luminosity required to determine the Z->nunu bg with an accuracy such that:

$$N_{susy} > 3 \text{ sigma}$$

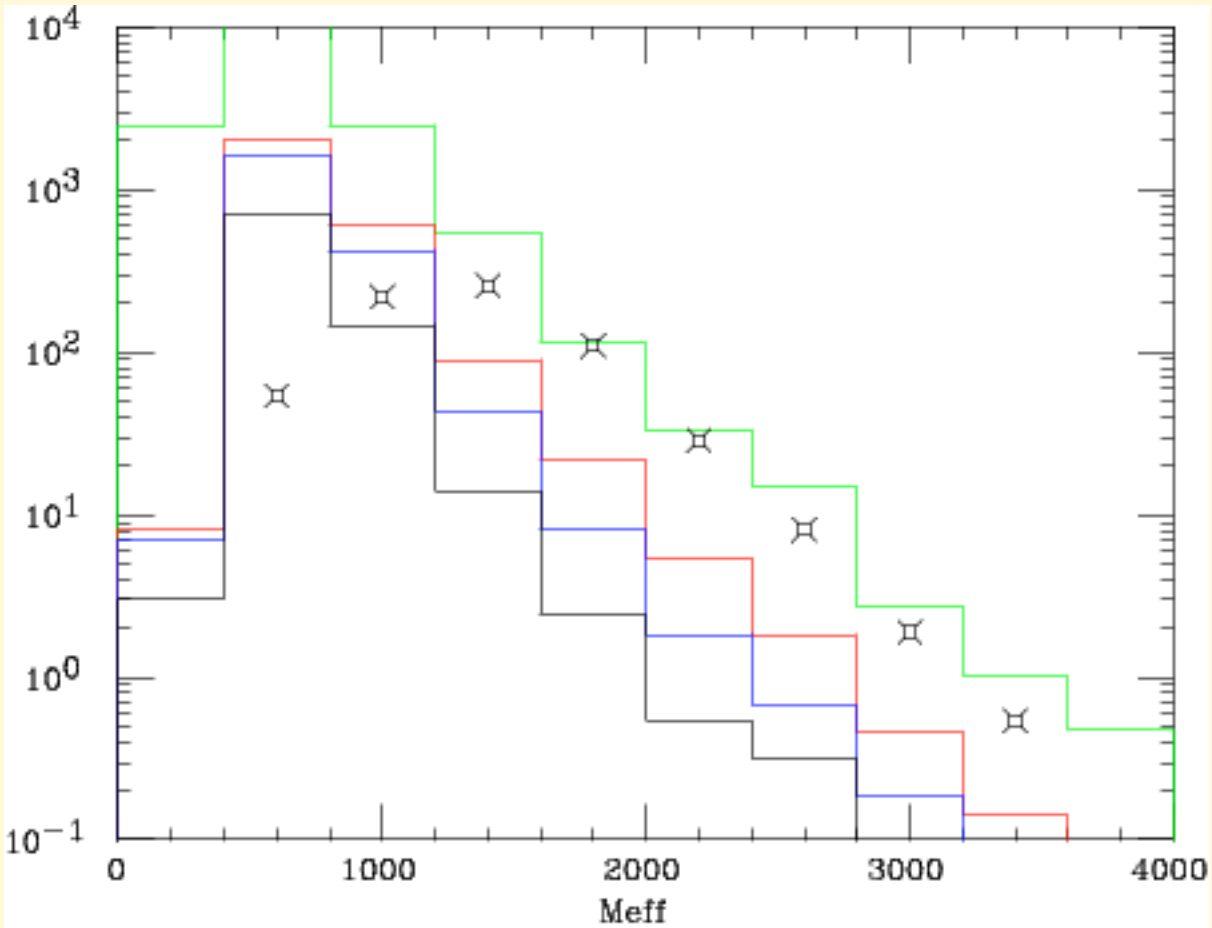
where

$$\text{sigma} = \text{sqrt}[\ N(Z \rightarrow ee)\ ] * B(Z \rightarrow \nu\nu)/B(Z \rightarrow ee)$$



=> several hundred pb^{-1} are required. They are sufficient if we believe in the MC shape (and only need to fix the overall normalization). Much ore is needed if we want to keep the search completely MC independent

W(→lν) +4 jets



Jet cuts only

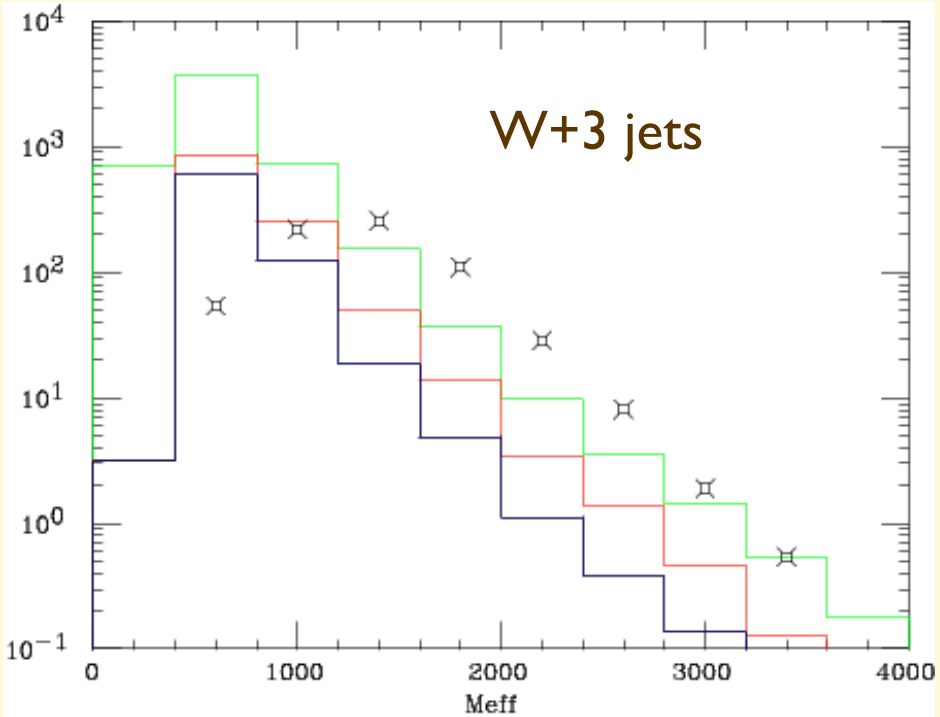
+ MET cut

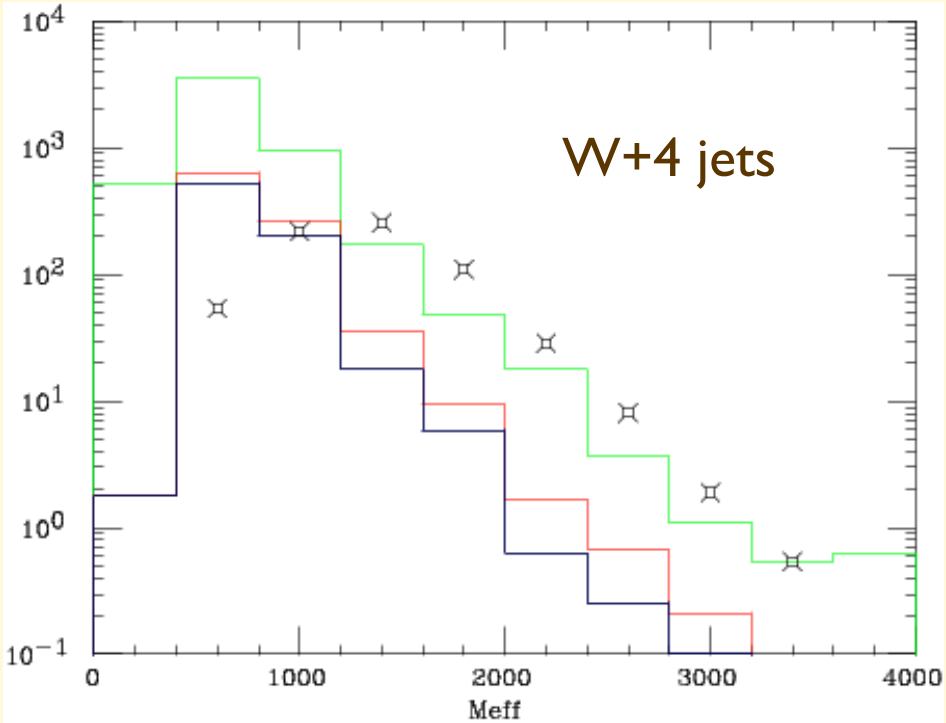
+ ST cut

+ pt_{lept}<20

SUSY

W(→tau-jet ν) + jets





Jet cuts only

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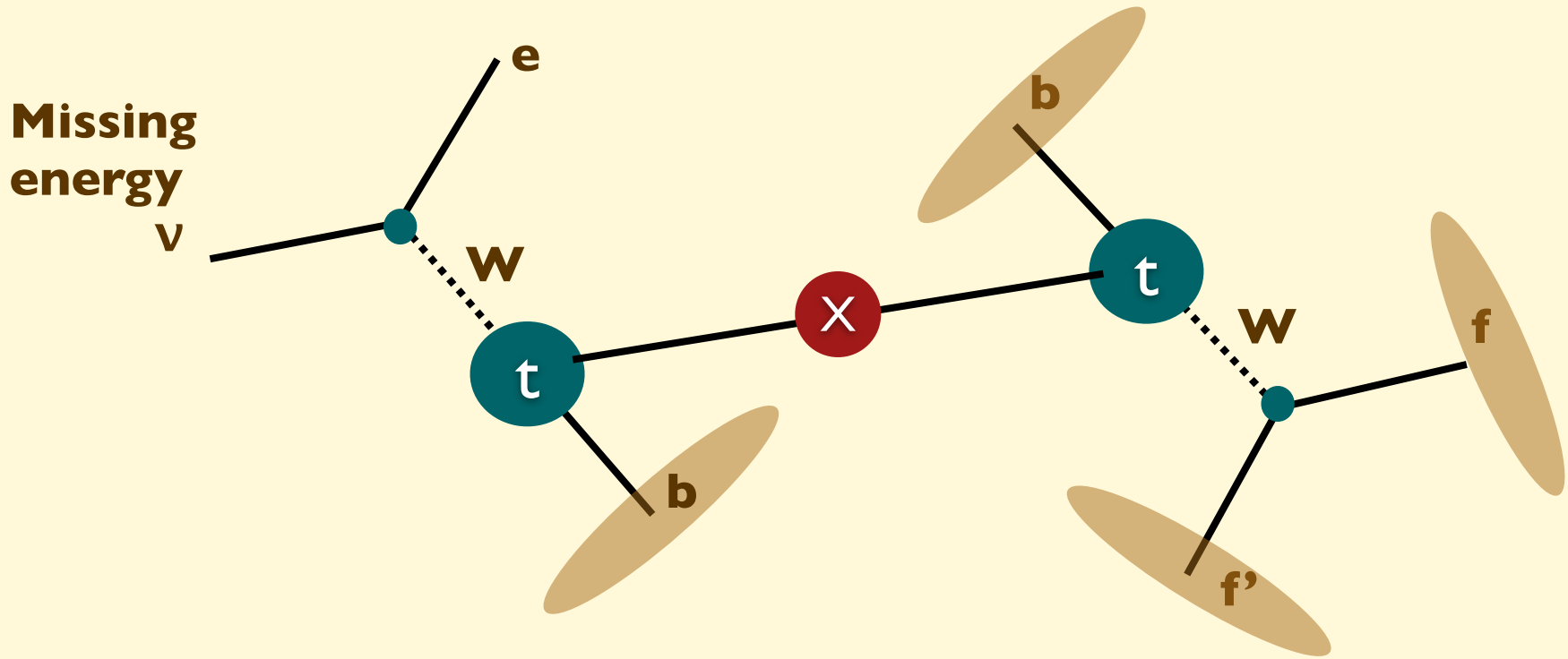
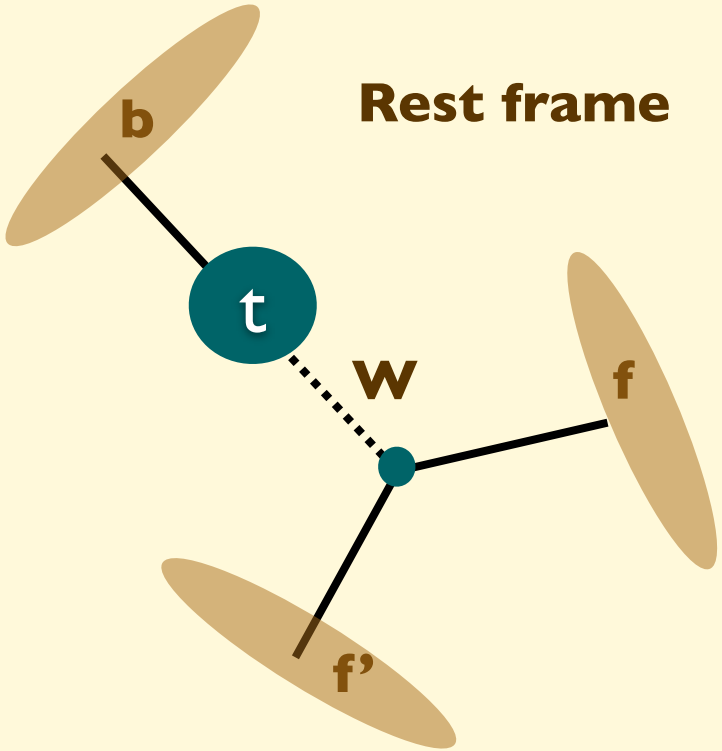
SUSY

Top final states



Top final states

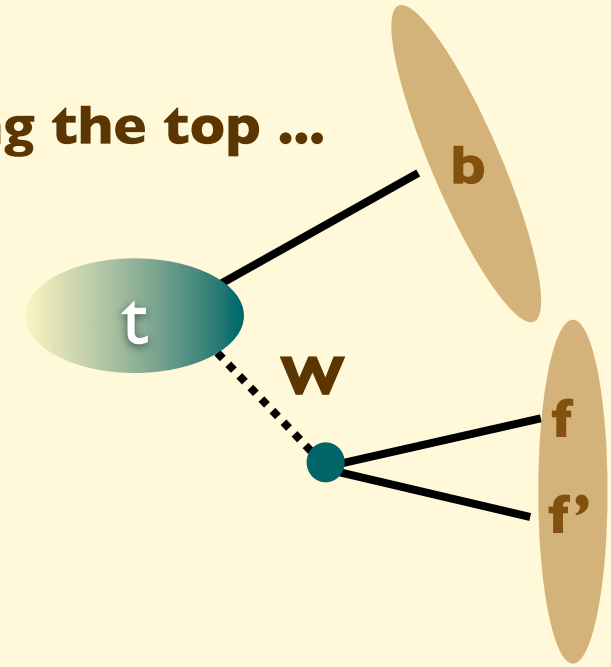


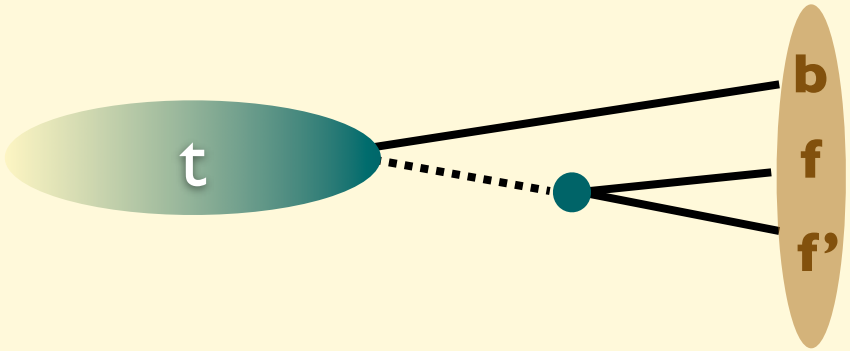
Rest frame

$$p_b = \frac{m_{top}^2 - m_W^2}{2\, m_{top}}$$

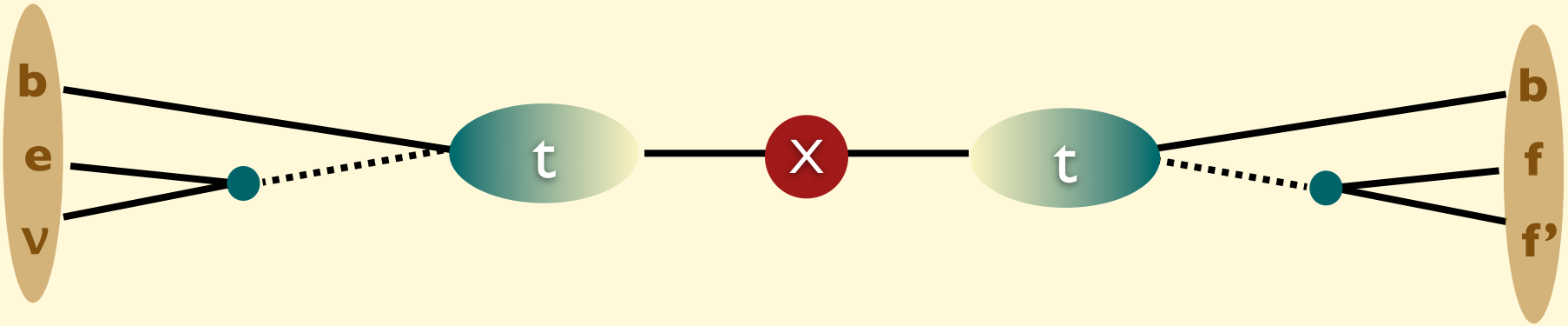
$$p_f^{max} = \frac{m_W}{2} \; \frac{m_{top}^2 + m_W^2}{2\, m_{top}\, m_W}$$

Boosting the top ...



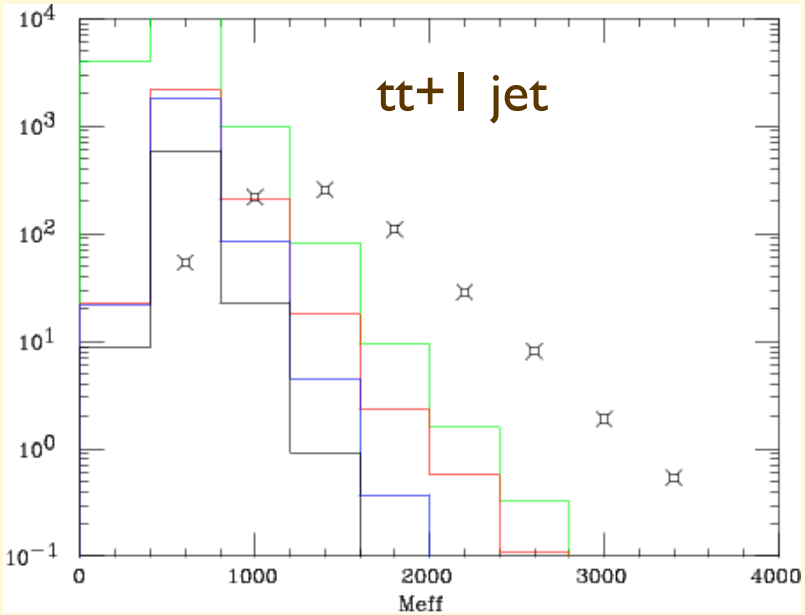


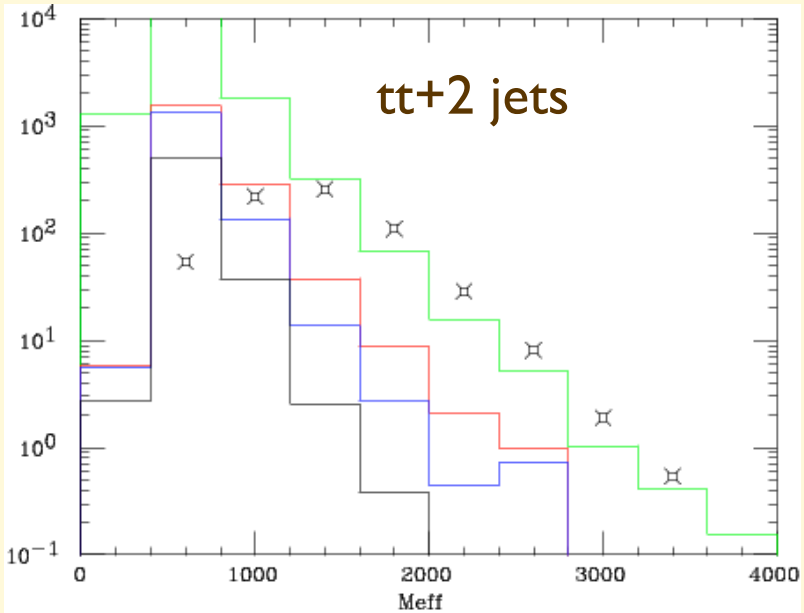
Top final states

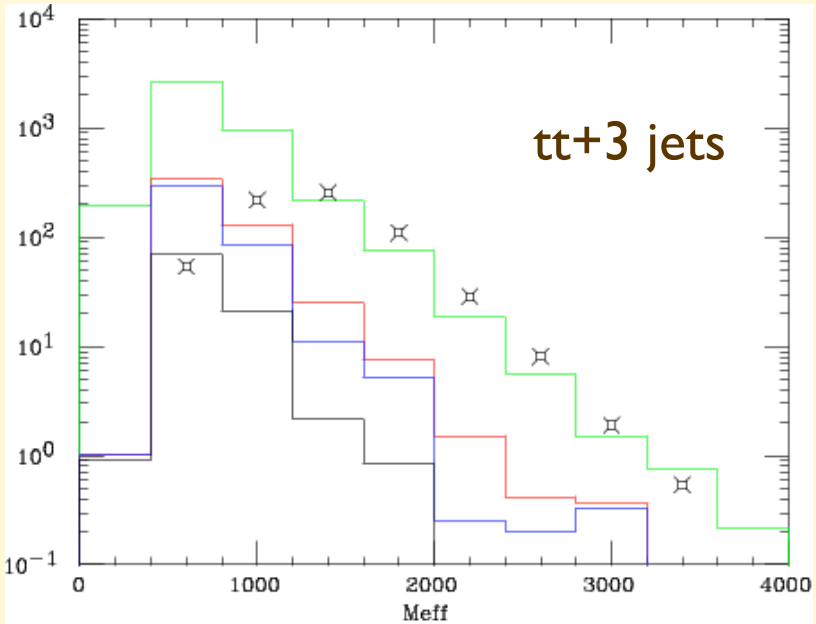


Large Meff leads to highly collimated final states

Sphericity and multi-jet cuts very effective against the leading-order t-tbar contribution!







Jet cuts only

+ MET cut

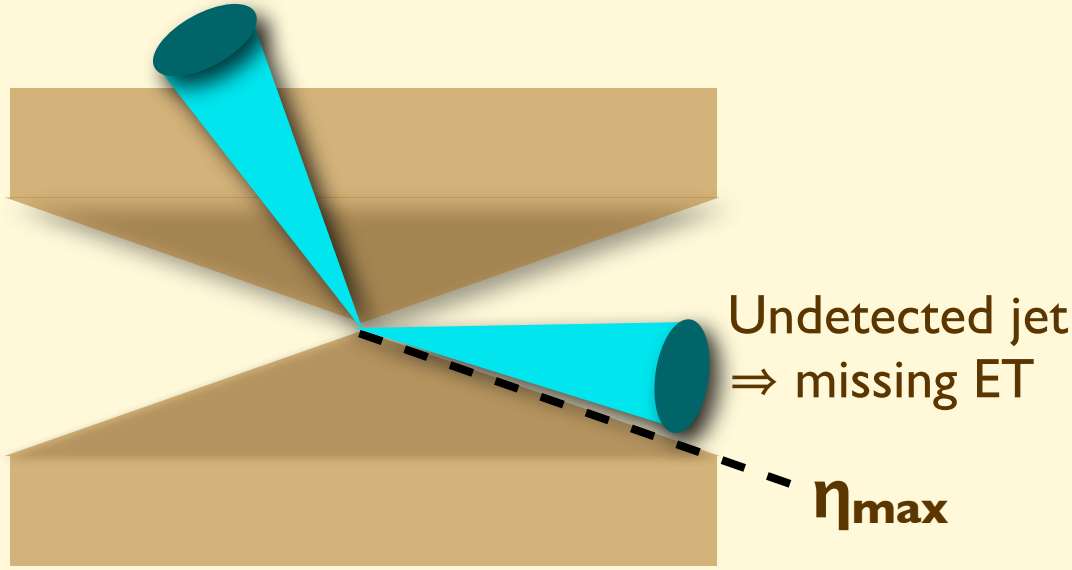
+ ST cut

+ pt_{lept}<20

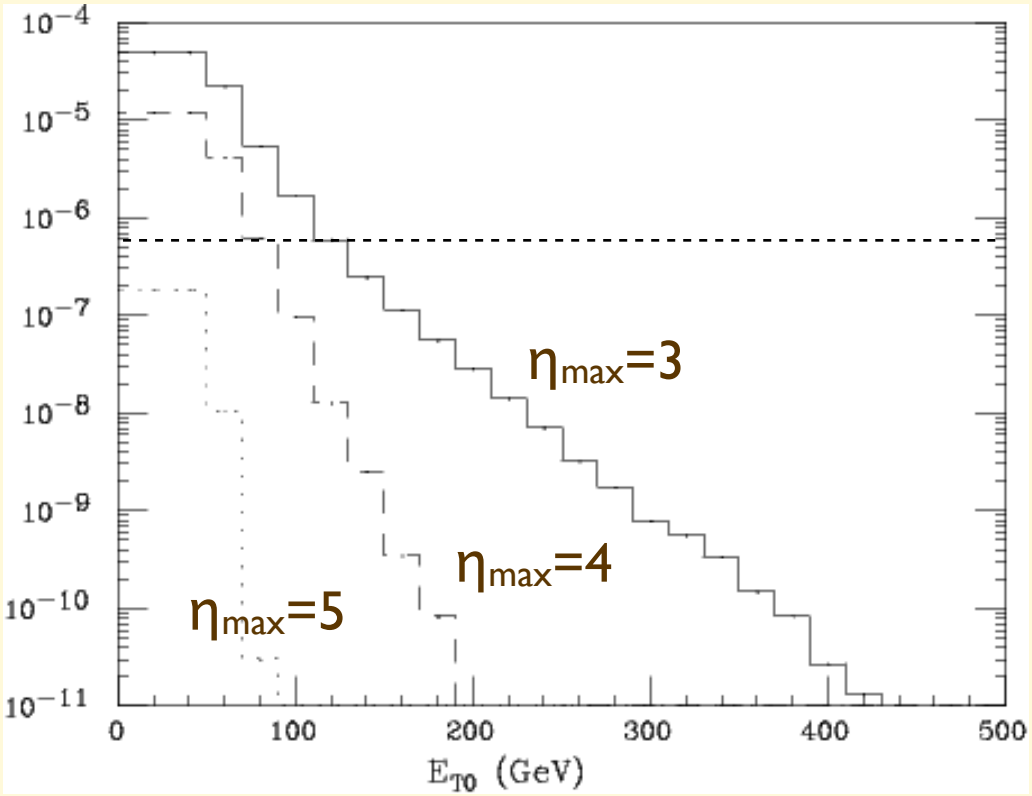
SUSY

All jet multiplicities contribute at approximately the same level!!

Instrumental sources of missET: incomplete calorimeter η coverage



σ(jet-jet with MET> E_{To}) / $\sigma(pp \rightarrow X)$

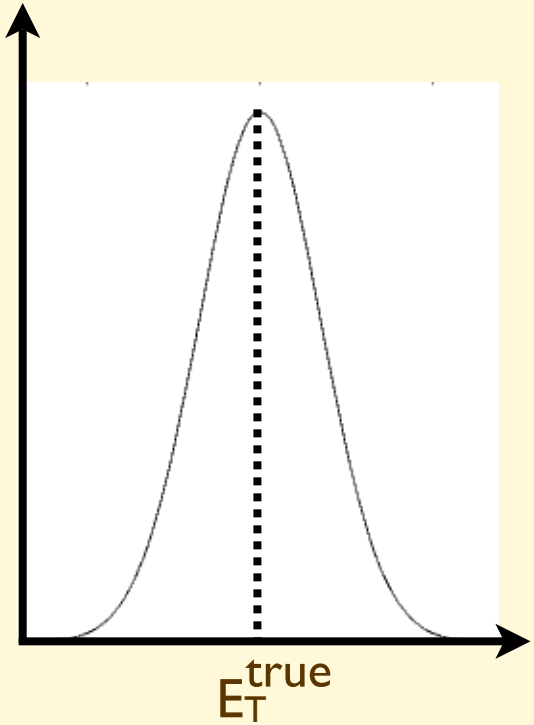


cfr:
$\sigma(W \rightarrow l\nu)/\sigma(pp \rightarrow X) \approx 6 \times 10^{-7}$

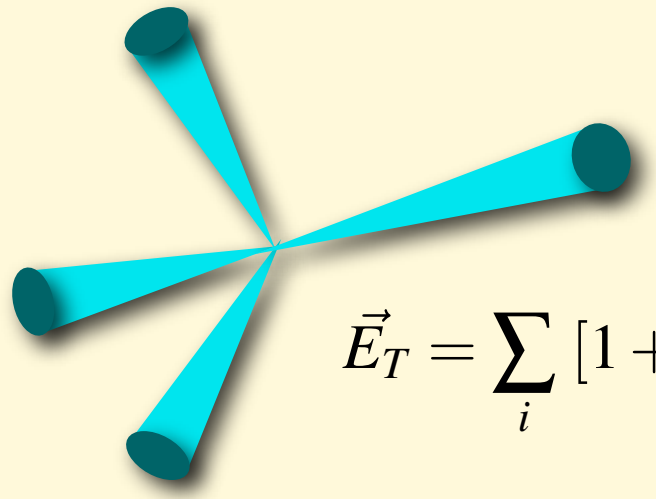
NB:
At $L=10^{34}$ cm^{-2} s^{-1},
$\langle N(\text{pp collisions}) \rangle \approx 20$

⇒ probability 20x larger

Instrumental sources of missET: jet energy resolution



$$\mathrm{Prob}[p_T] \propto \exp - \frac{(p_T - p_T^{\mathrm{true}})^2}{\sigma^2} \qquad \sigma = C\sqrt{E_T^{\mathrm{true}}/\mathrm{GeV}}, \quad C = O(1)$$

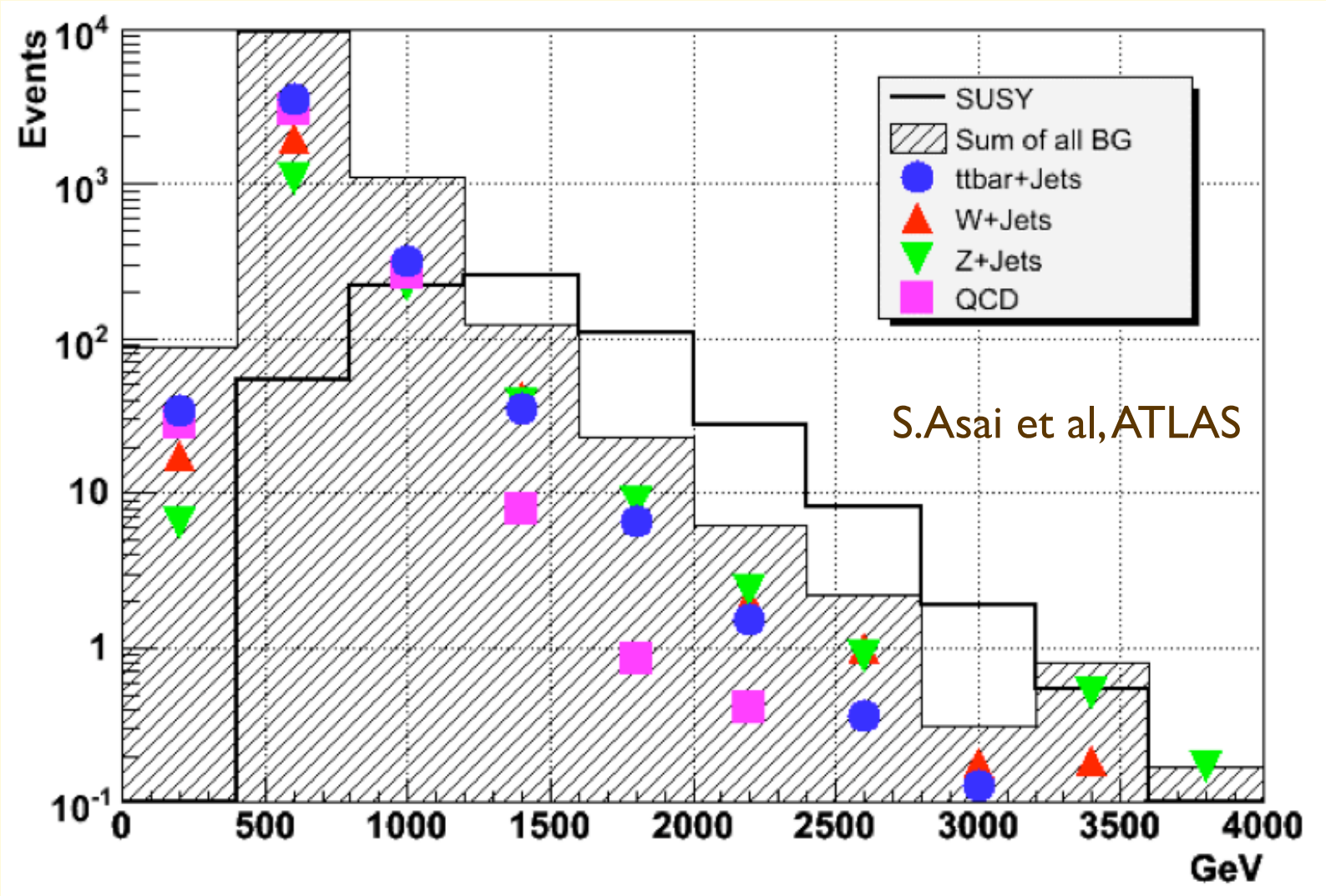


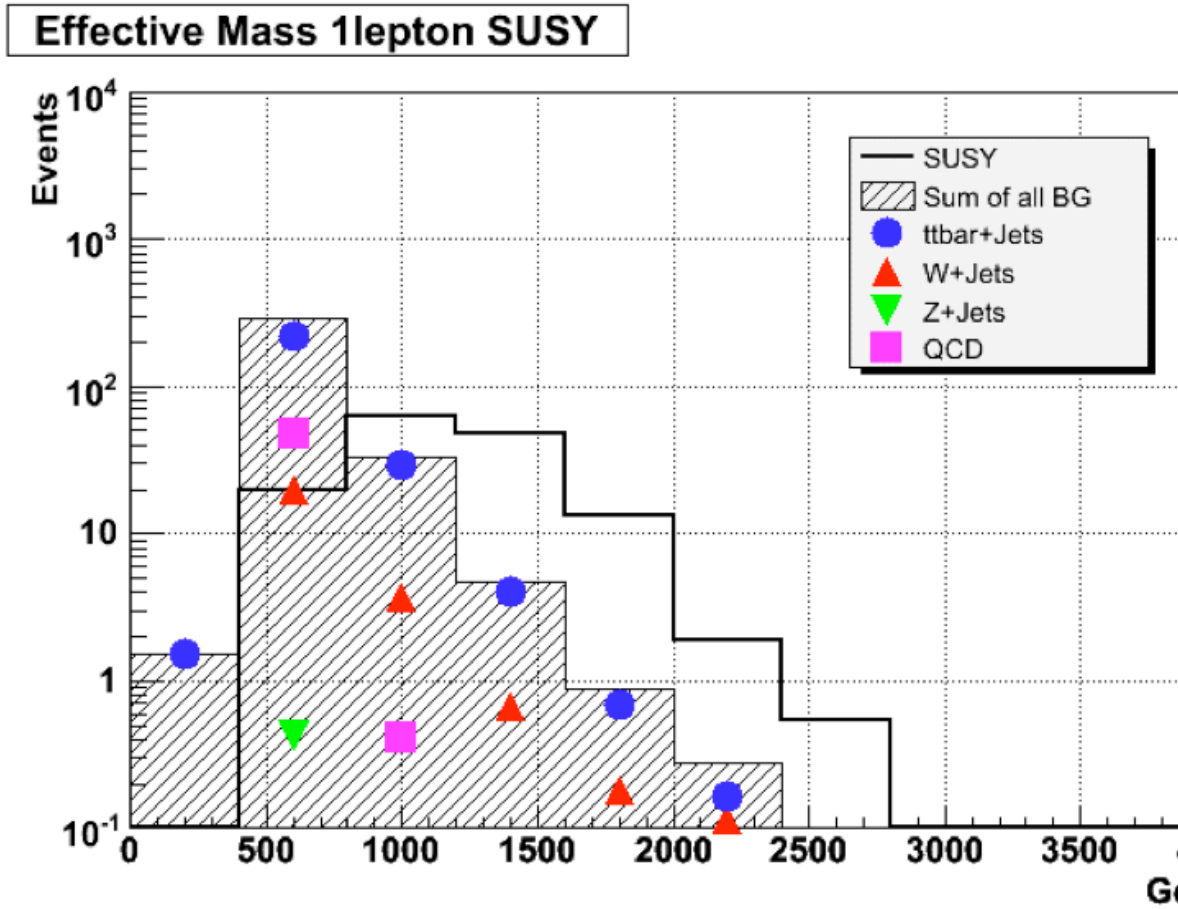
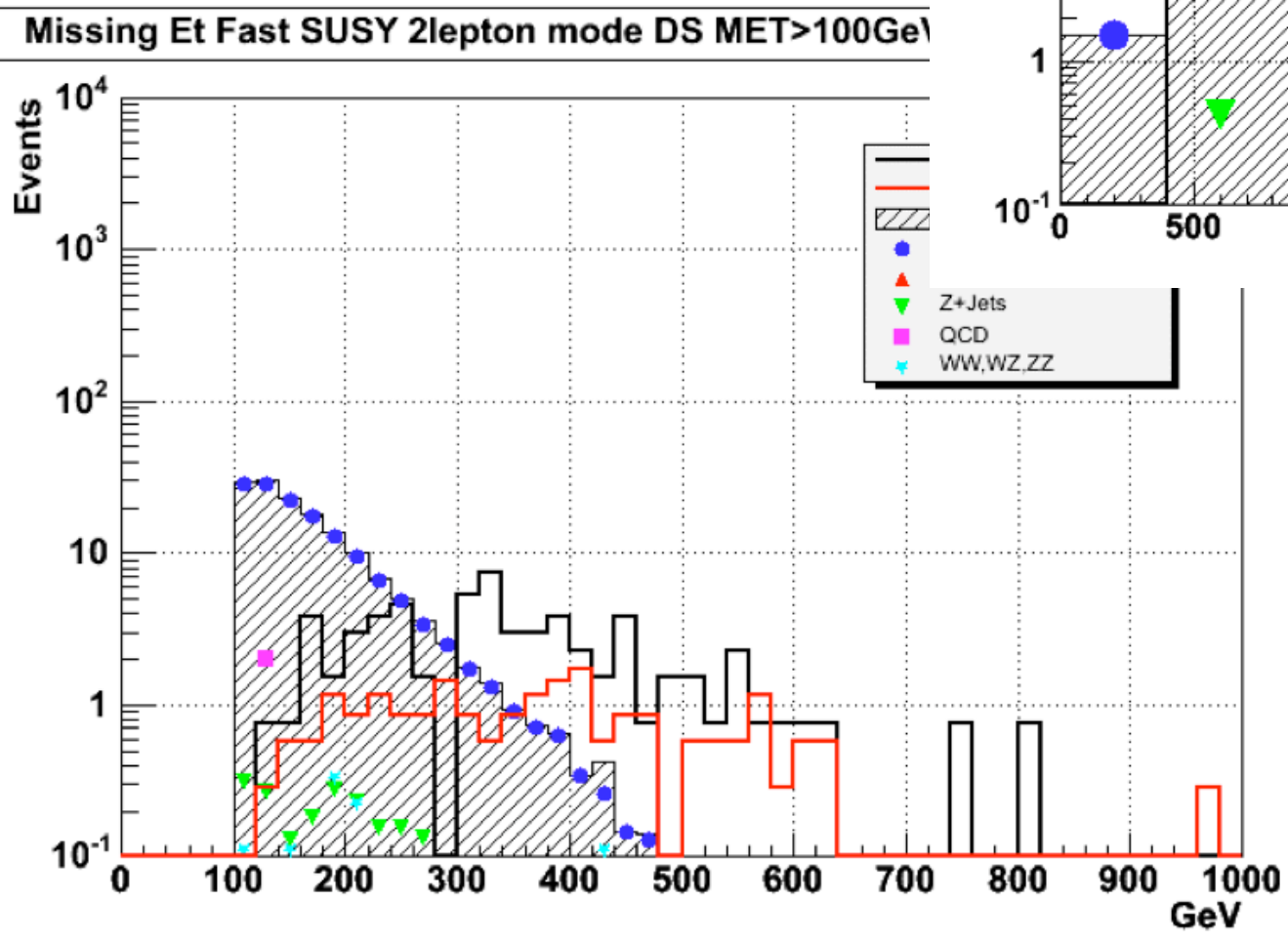
$$\vec{E}_T = \sum_i [1 + \delta_i]\, \vec{p}_{T,i}^{\,\mathrm{true}} = \sum_i \delta_i\, \vec{p}_{T,i}^{\,\mathrm{true}}$$

$$\langle |\vec{E}_T|^2 \rangle = \sum_{i,j} \langle \delta_i \delta_j \rangle \vec{p}_{T,i} \cdot \vec{p}_{T,j} \qquad \langle \delta_i \delta_j \rangle = \frac{C^2}{p_{T,i}} \delta_{ij}$$

$$\langle \mathrm{MET} \rangle = C \sqrt{\sum_i p_{T,i}}$$

Overall result, after the complete detector simulation, etc....



Adding leptons ...

S.Asai et al, ATLAS