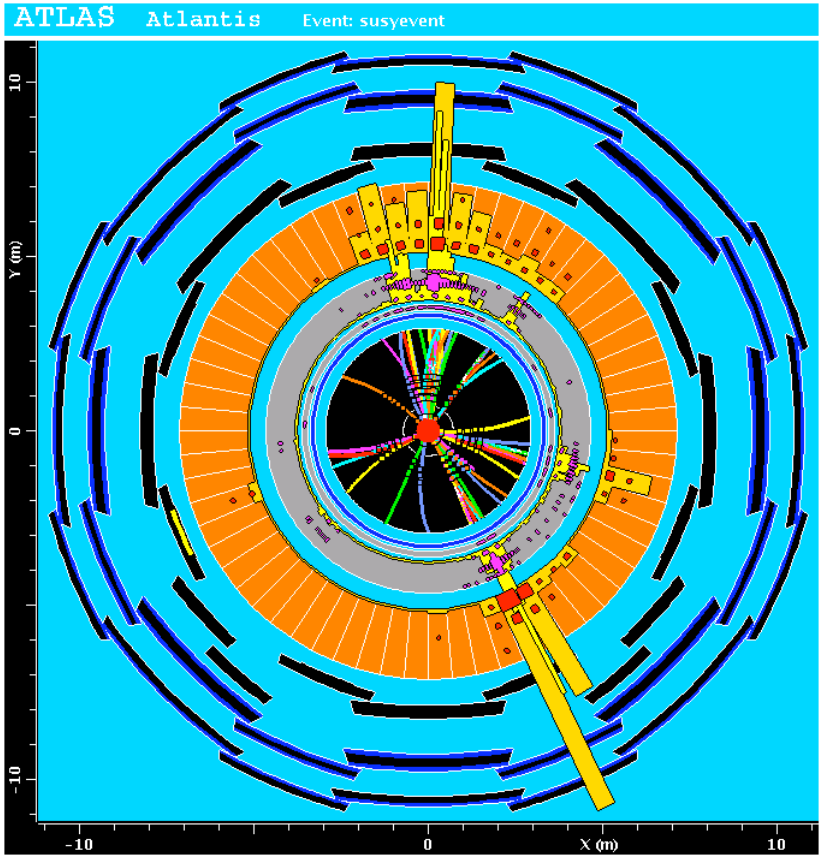
Standard Model Background for SUSY Search @LHC (ME and mE_T) -Topics related to Tevatron business-

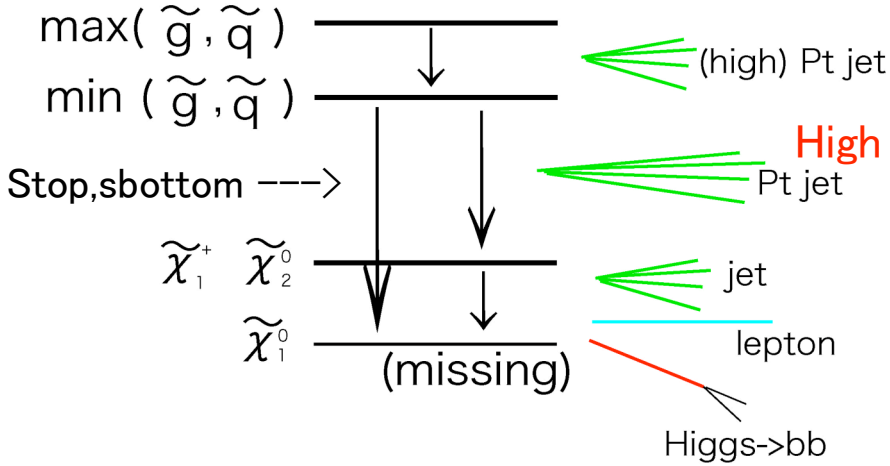
[0] Event topologies of SUSY signal
[1] Background estimation using the Matrix Element
[2] Signal estimation using the Matrix Element
[3] Topology-dependence of mE_T
[4] Conclusion

S.Asai and T.Sasaki (Univ. of Tokyo)

[0] Events topology of SUSY @ LHC (Gravity- mediation + R-parity)



Gluino/squark are produced copiously,
"Cascade decay" follows after.



Event topologies of SUSY are:

$$\not{E}_T + \begin{matrix}\textbf{High } \mathbf{P_T} \\ \textbf{multi-jets}\end{matrix} + \begin{matrix}\text{leptons} \\ \text{b-jets} \\ \tau\text{-jets}\end{matrix}$$

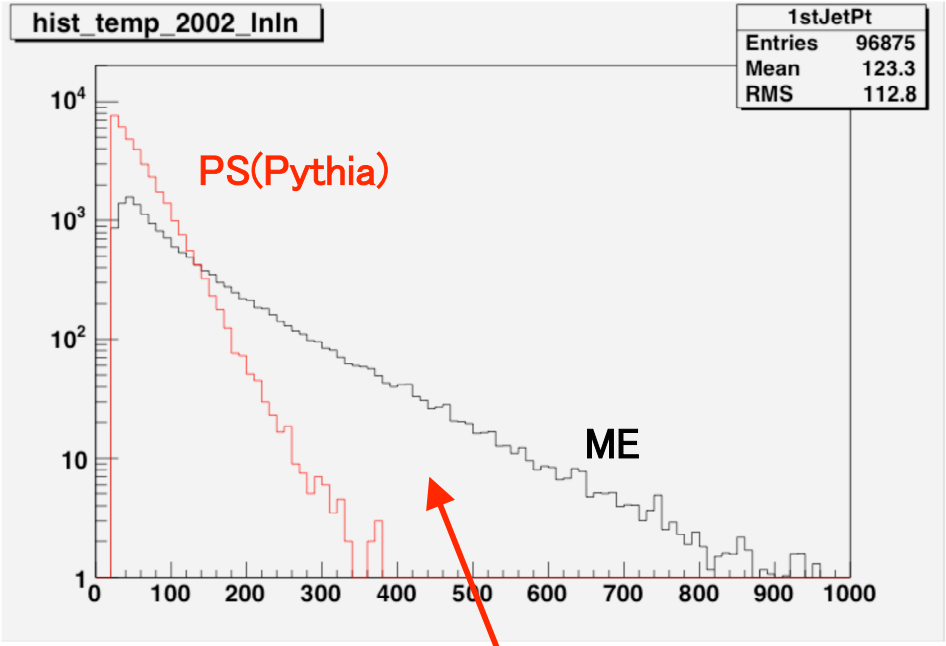
Basically the same, but the event topologies are more complicated than Tevatron due to Cascade decays:

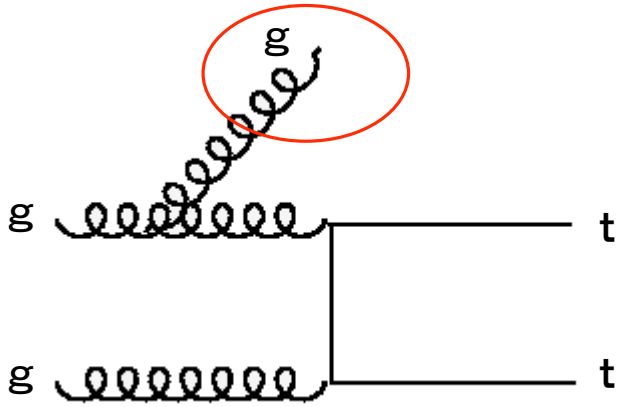
(1) E_T^{miss} should be controlled in multi-jets topology (N>=4).

(2) High Pt multi-jets are important to estimate SM background contributions and SUSY reconstruction.

These are important for SUSY search @ LHC and Pre-studies @ Tevatron play important role.

[1] Background estimation using Matrix Elements
-- Problem in Parton Shower --





Additional jet is emitted
with Parton shower

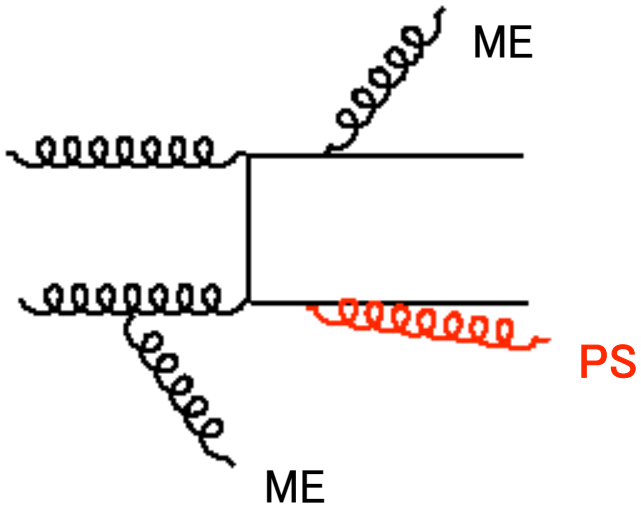
Parton Shower is the good model in the collinear region,
(since all LL are summed up)

but PS has some problem in the high P_T region.

Hard jet is not emitted in Parton Shower. (It is famous problem.)

-> High P_T jets should be estimated with the Matrix Element.

ME-PS Matching



(1) High P_T (>40GeV) partons are generated with ALPGEN(V1.33). About 260M unweighted events are produced.

(2) Collinear and soft regions are covered with Parton Shower Pythia(6.2). Pt ordering is applied.

(3) ME-PS matching is performed to remove double counts:

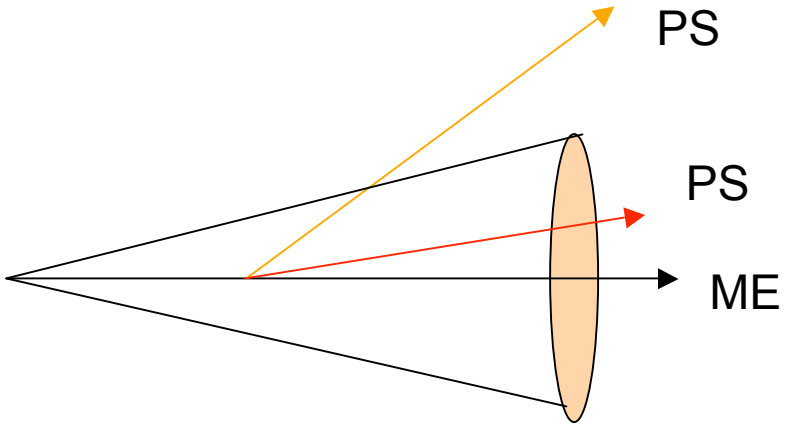
No-Shower branching probability is given by pQCD: Sudakov factor Δ:

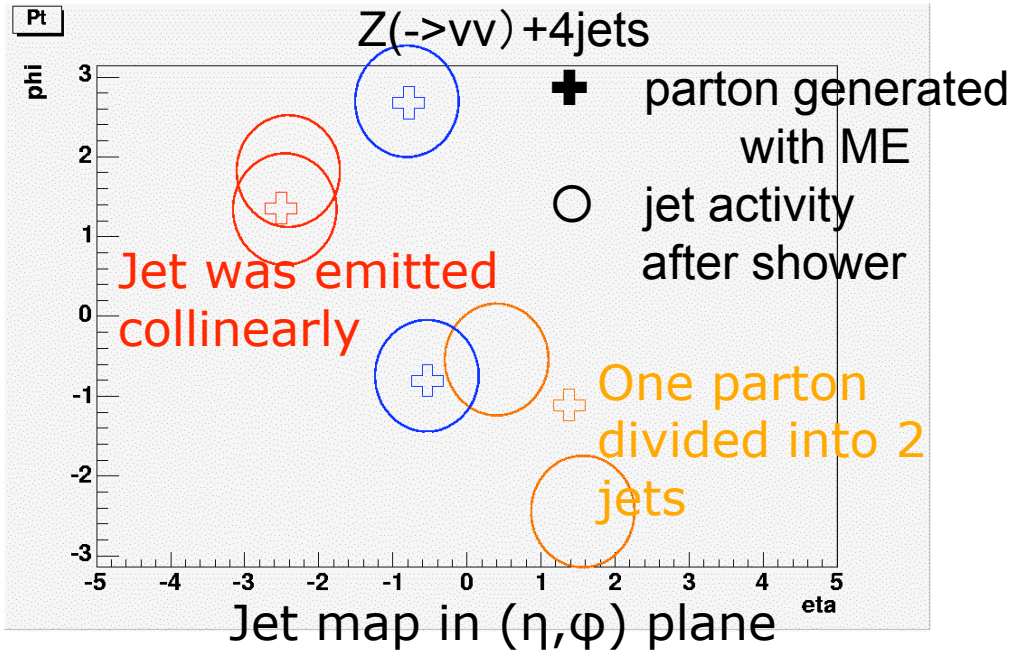
Two major methods exist:

(A) CKKW: Events is reweight with Sudakov factor (product of Δ for all line)

(B) MLM: veto is applied after shower evolution <--- Fast We use this method.

ME-PS matching (MLM: Mangano method)





- Jet, after shower evolution, should be matched to the parton generated with ME except for the soft and collinear regions.
- For example, Z+4jets sample is shown in (η,φ) plane
  Blue jets are perfect matching to the partons.
  Soft jet was emitted collinearly, but collinear jet is acceptable.
  One parton divided into 2 jets (outside ME cone 0.7)
  -> Such event should be covered by 5jet ME.
  -> this event is discarded (Veto) Veto probability is corresponding to Sudakov factor

Event selection

[1] Showered and MLM-matched samples are fed into FAST simulation of ATLAS detec.
Single Gaussian smearing is applied for jet and mE$_T$ measurements.(we should update)

[2] Standard SUSY selections are applied

(A) 0 lepton mode

- Missing E$_T$ > 100GeV
- At least 1 jet :P$_T$>100GeV
- At least 4 jets :P$_T$>50GeV
- Transverse Sphericity >0.2

(B) 1 lepton mode

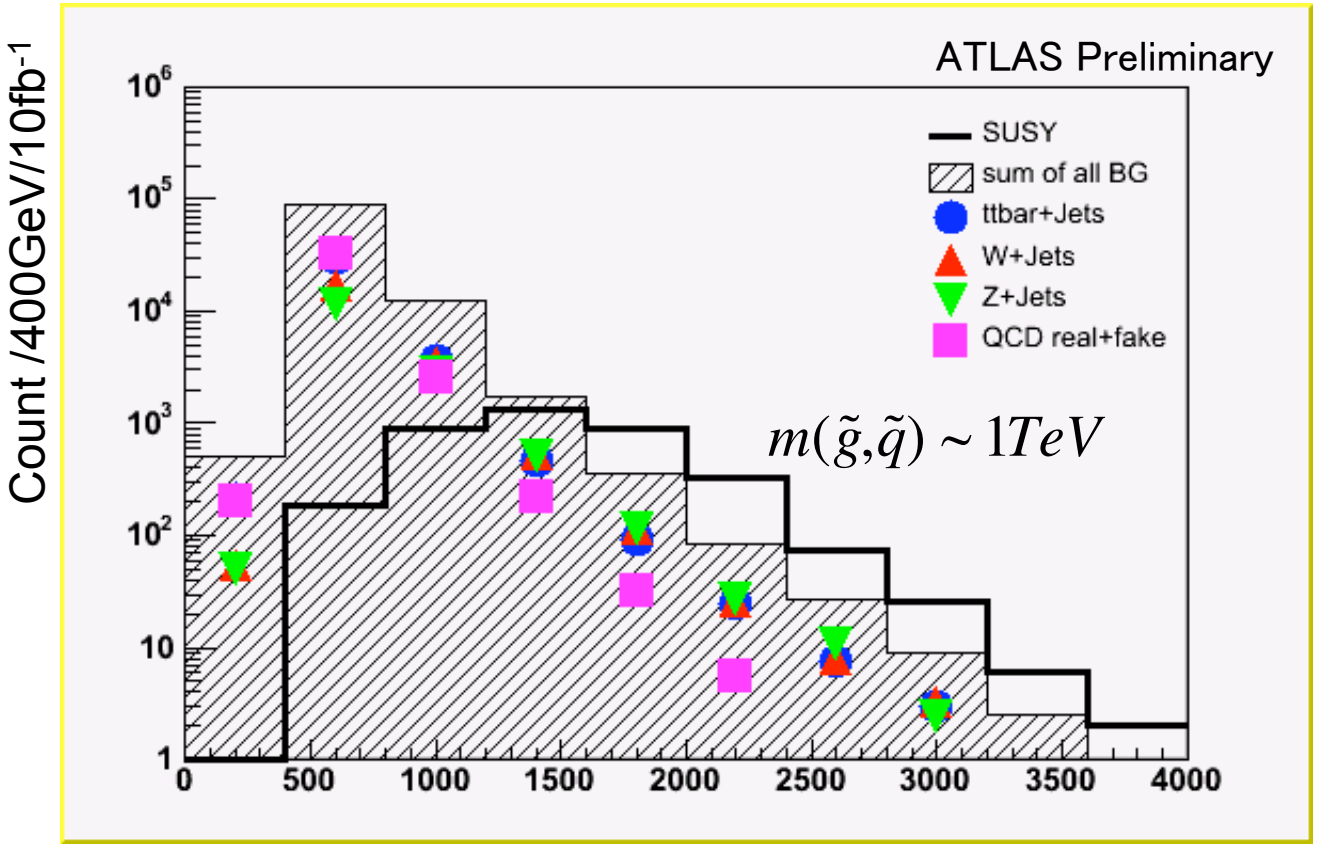
- Missing E$_T$ > 100GeV
- At least 1 jet :P$_T$>100GeV
- At least 4 jets :P$_T$>50GeV
- Transverse Sphericity >0.2
- 1 lepton (e, μ : P$_T$ >10GeV)
- Transverse mass between lepton and missing E$_T$ >100GeV

essence of selection

High P$_T$ multijets(N>=4)
Large missing E$_T$
with/without Iso. lepton

- We need optimization of these selections depending on SUSY mass scale in order to improve S/N and make plot of discovery potential.
  Not yet finished: (It is Homework until the final Note)

Result (1)　No lepton mode

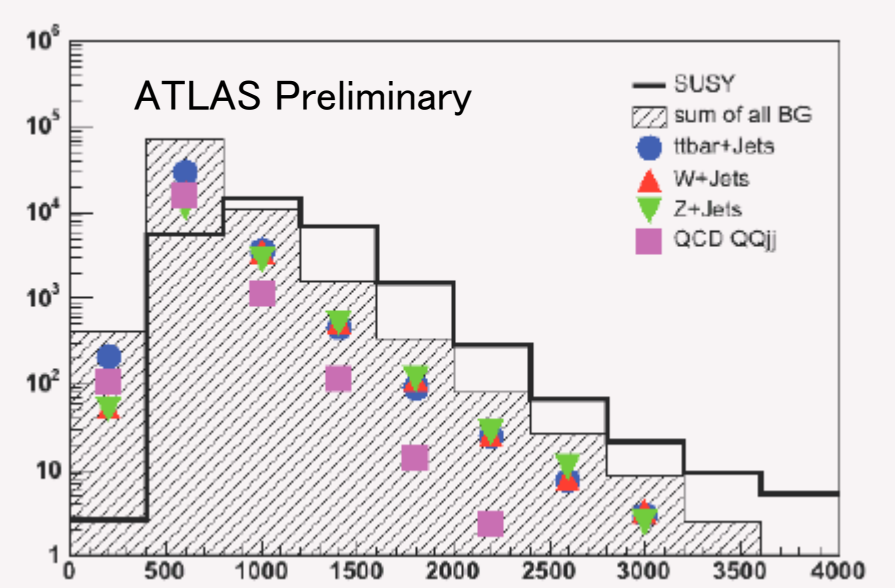


Effective Mass(GeV) = mE_T + ΣP_T(4jets)

(1) Background increases **by factor 2–4** than the PS prediction depending on $M_{eff.}$
(2) Slope becomes more gentle, and **similar to the signal** **<-- important Point**
(3) All BG contributions are the same order.　Not easy to understand BG using real data.
　　-> see Next Page.

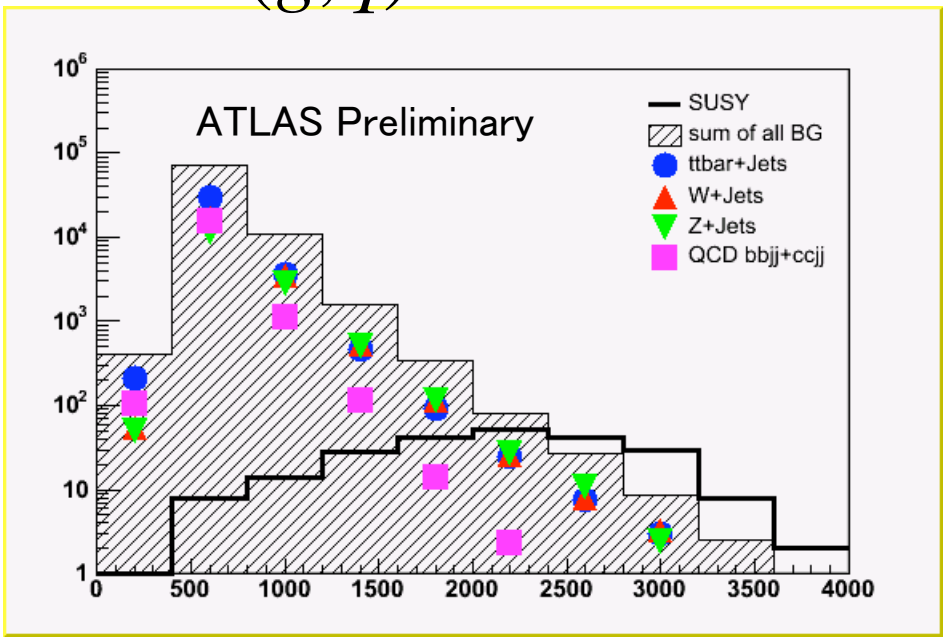
Result (2)　No lepton mode for the other mass

$m(\tilde{g},\tilde{q}) \sim 700GeV$



M_{eff}(GeV)

$m(\tilde{g},\tilde{q}) \sim 1.5TeV$



M_{eff}(GeV)

Distribution of the signal is very similar to background distributions. (700GeV case)
Small excess can be seen only M_{Eff}>3TeV　(1.5TeV Case)

How to understand these BG contributions　with “real data”?

We will use “LO generator” even in 2007 for such multijets process,　so there is no prediction of the absolute value of the cross-section. We should　normalize the predictions with the real data.

Extrapolate from small mE_T to high mE_T(Signal dominate) is necessary.

Many processes contribute to background.　-> should separate each contribution.

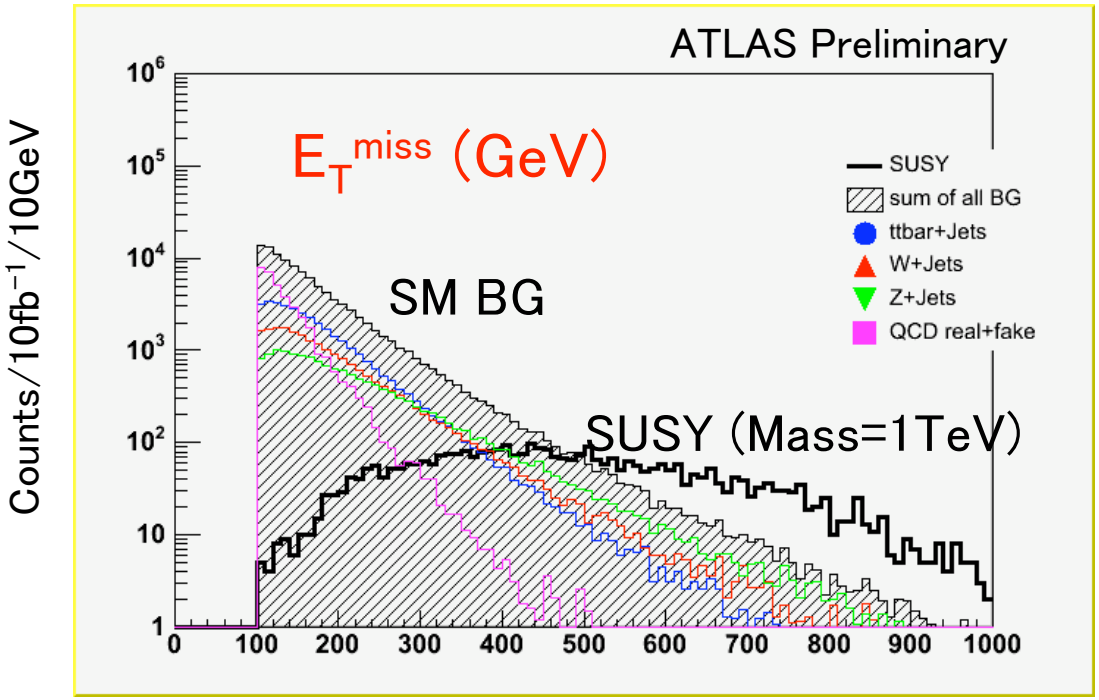
M_{eff} is discomposed into E_T^{miss} and P_T of jets

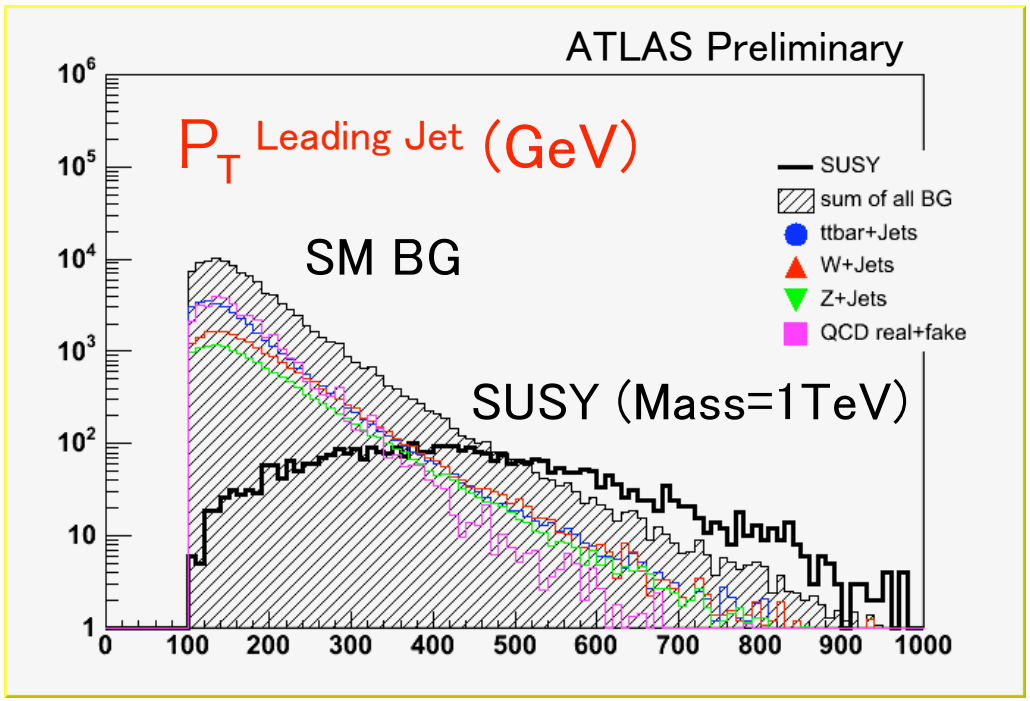
In the region of E_t^{miss}>800GeV clear excess can be observed.

-> E_T^{miss} is vital for SUSY search.
Extrapolate from small mE_T (BG region) to large mE_T(signal region):
It is very important to estimate these slops:
slop depends on
- process (tt < W < Z)
- choice of scales (μ_R Q_{PS})
- PDF

-> Detail studies at Tevatron play important role
-> Examine MLM and CKKW with real data
---> Next page

High P_T jets are also emitted in the background process.
(no good separation)



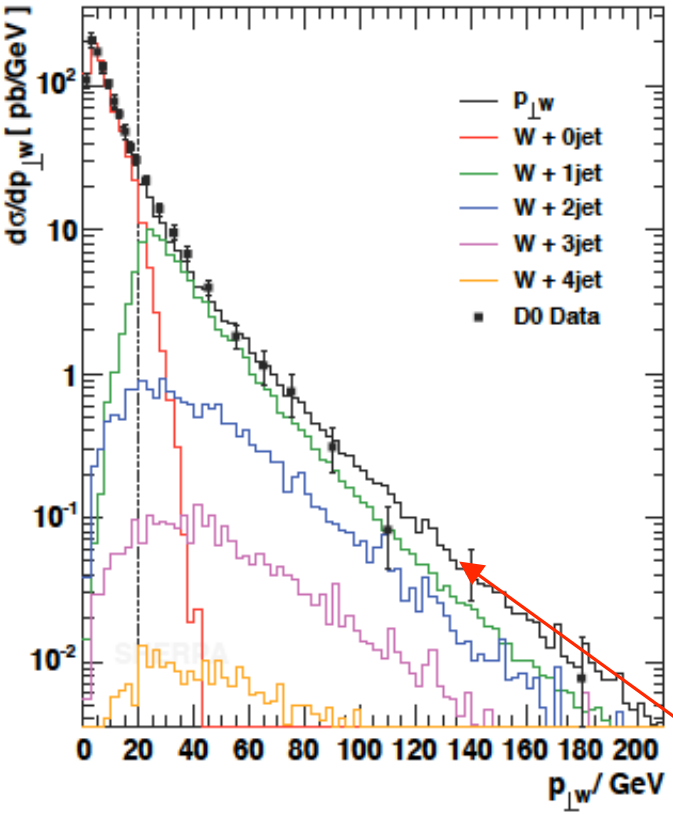


These figures show P_T_W and Njet distributions using Run I data

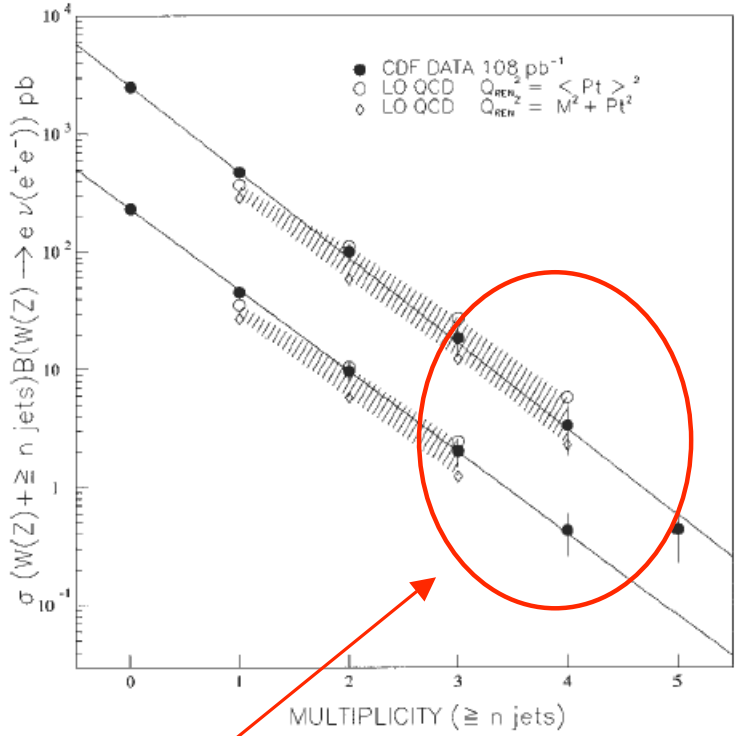
Krauss et al

Phys. Rev. D 63, 072003 (2001)

Pt distribution of W



Jet Multiplicity distribution of W/Z + Njets



Interesting regions: Slop depends on Njets and there are still large uncertain in the scale choice in the high multiplicity region.

These studies are very interesting output from Tevatron for SUSY search@ LHC

Result(3) Result of One Lepton mode

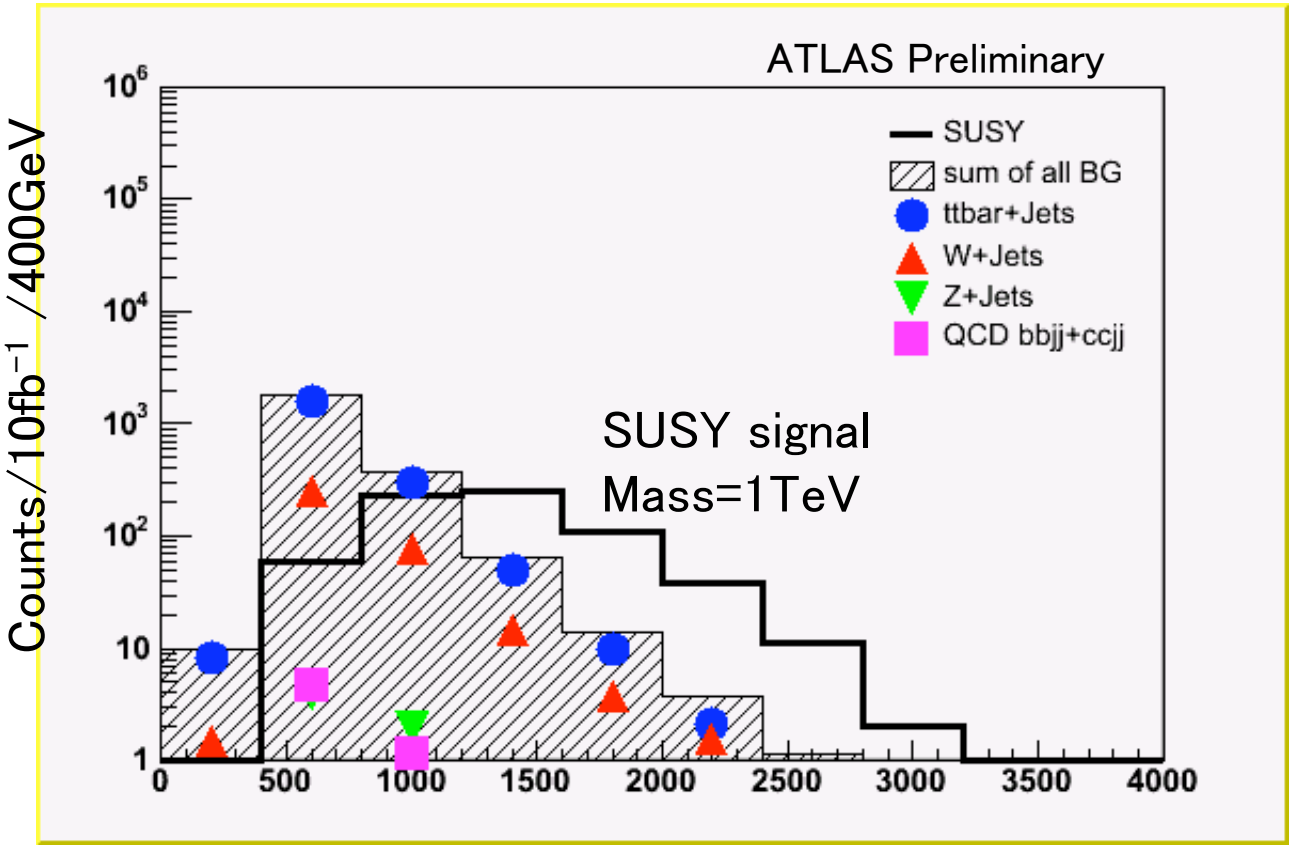
Signal is reduced to 20–40% of no lepton mode,
Backgrounds are suppressed by factor about 20–30

QCD multijet and Z+Njets are suppressed significantly
S/B is better than
no lepton mode,

(1) One lepton mode gives clean discovery.

(2) Top is dominant background. Top is more controllable and predictable.
Only one dominant BG
–> easy to extrapolate form low mE_T to high mE_T region:
Good point for us.

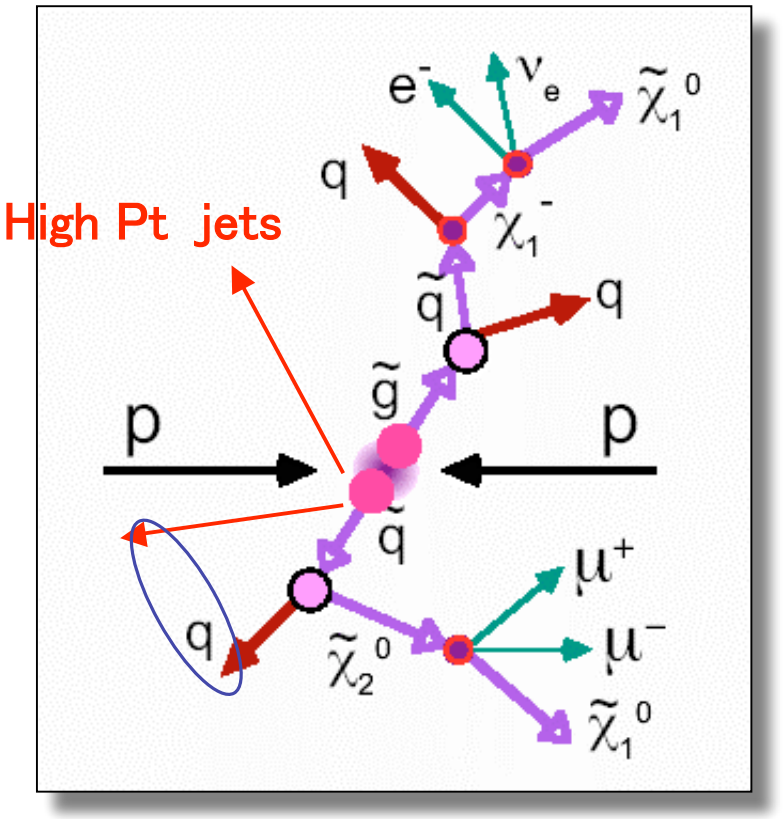
Two dominant
BG processes
(1) tt+Njets
(2) W+Njets

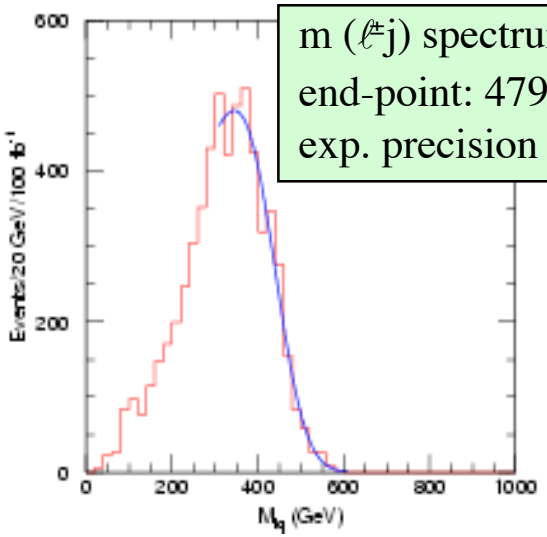


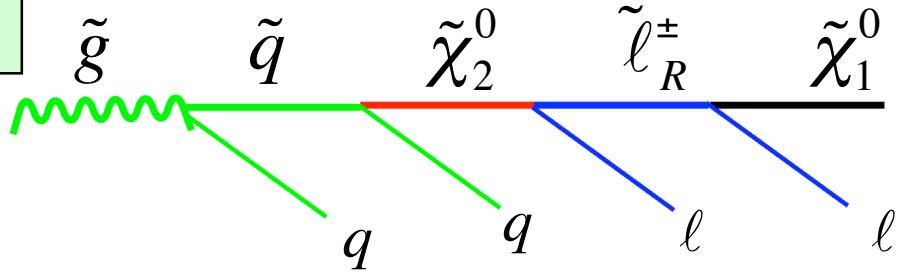
[2] High Pt jets coming from QCD ISR also affect on the reconstruction of SUSY decay chain.

We select high Pt jet as this quark,then make kinematic distributions and obtain mass-information from edge.

If contamination of high Pt jet from the QCD increases, and purification
of this quark becomes worse.
Kinematic distribution becomes unclear
due to wrong combination.
(This was already mentioned in the previous TeV4LHC and waiting for ME generator for SUSY)



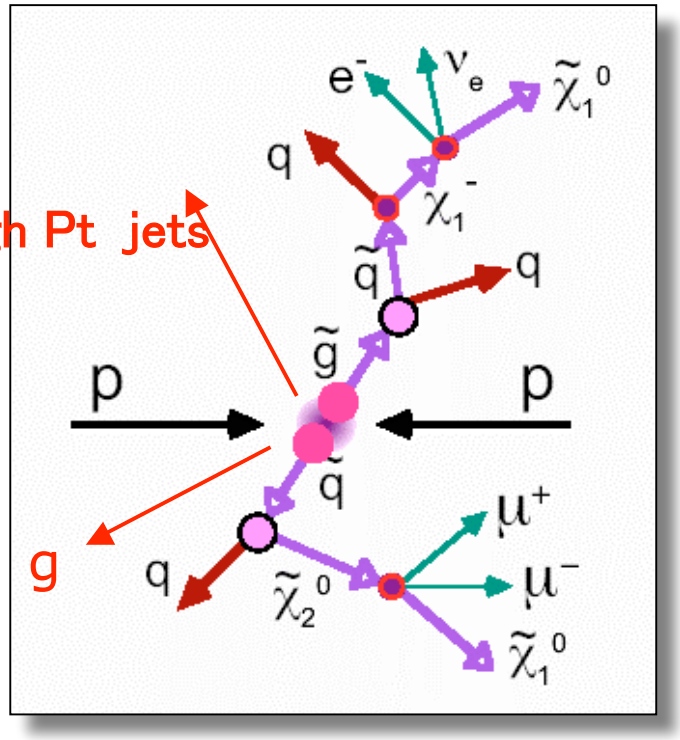


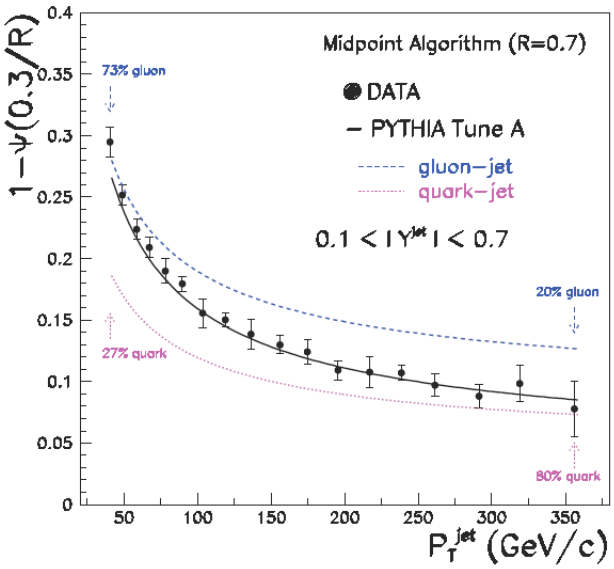


Additional jets in SUSY signal should be estimated with ME as the same as BG.
-> MadSUSY is ready now.

Just start production and check with my student(H.Nomoto)
We will estimate these effects of wrong combinations.
(Home work [2] for final note)

Interesting suggestion (S.Padhi (Wisconsin))
Jet shape is also useful even in proton Collider (CDF Phy. Rev. D71 (2005) 112002)





<- Jet sharpness is different:
Jet originated from QCD is mainly gluon,
can we enhance quark from SUSY decay using this sharpness?

[3] Fake missing E_T

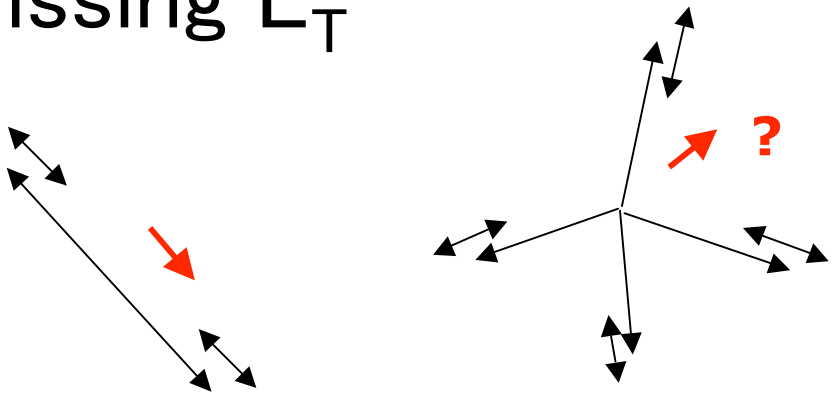
Missing E_T is mainly produced with
ν /neutralino and vital for SUSY search.

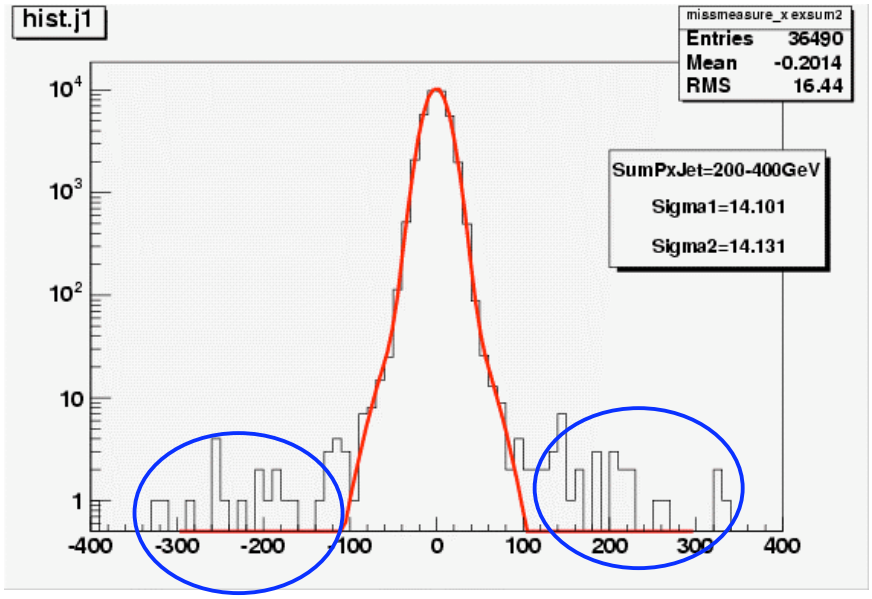
Missing E_T is also produced with
the limited energy resolution of
Hadronic jet: call as "fake mE_T"

Non-Gaussian distribution of jet energy
measurements makes non-Gaussian
tail in missing E_T distribution .
-> This long tail is dangerous source of BG,
Since QCD multijet has huge cross-section.

-> Fake missing Et tends to point
jet direction if jet multiplicity is small.
So we can remove the non-Gaussian tail,
direction of the mE_T is required not to point to jet.
This is useful @ Tevatron.

For multi-jet events
direction of the fake mE_T is smeared.
This is Big difference between LHC and Tevatron.
Not easy to remove fake missing Et for multijet
topologies, and
Non-Gaussian is new source of background @ LHC





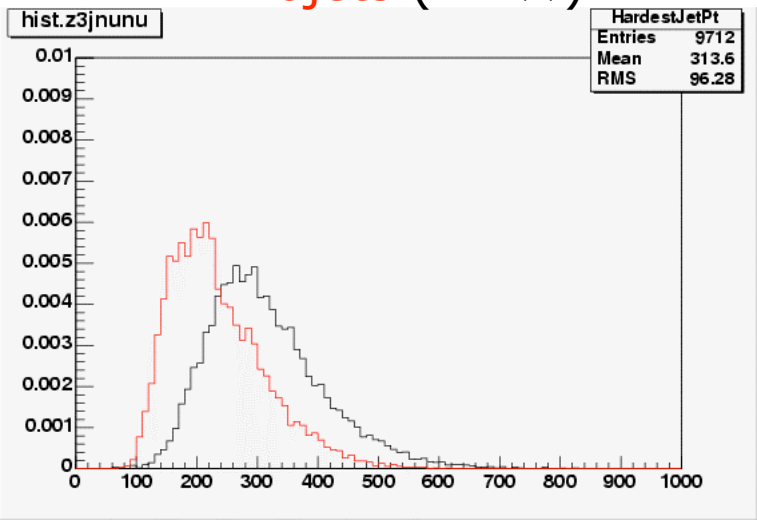
Non-Gaussian Tail

Measured Ex - Neutrino Ex

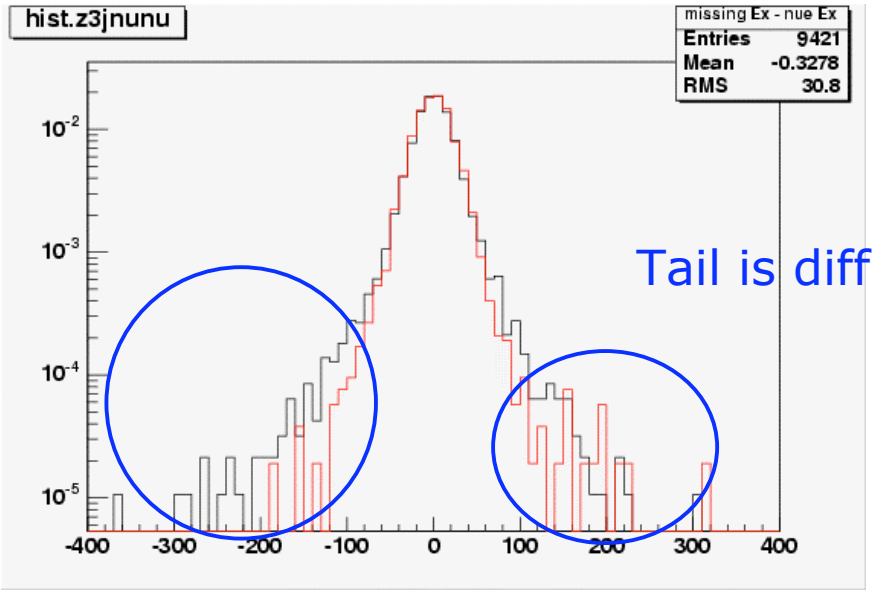
Topology dependence

So we need more careful study on missing E_T.
3 jet- and 6 jet- samples are produced with ALPGEN. (ΣE_T of both topologies are generated to be the same in order to obtain the same resolution.)

Z+3jets (Z→νν)
Z+6jets (Z→νν)



P_T of leading Jet



Tail is different

Fake missing Ex(GeV)

6jet-sample is more spherical than 3jet-sample :
Energitic jet appears in 3jet-sample:

Non Gaussian tail is observed(? Still checking)
Tail in 3jet-sample is larger than 6jet.
Resolution of 6-jet is worse than 3jets
Tail structure looks like to depend on the topology. -> Study @ Tevatron is interesting.

Conclusion

[1] Backgrounds for SUSY search are estimated with the Matrix Element information.

(1) The background increases by factor 2-4

(2) Shape of Background becomes similar to signal.

-> BG estimation using real data is essential. We need to understand slop of distributions.

(3) W/Z+Njets studies @ Tevatorn give good information for us.

(4) QCD multijet contributions are the same order of the other background processes: need more careful treatment.

-> Missing E_T is vital business.

[2] QCD high Pt jets are also important in SUSY signal (MadSUSY)

[3] Missing E_T: the resolution and tail are very important.

Non-Gaussian tail is observed in " fake missing E_T distribution".

Topology dependence is also observed.

Generated background processes

There are 4 dominant background processes.

Generated process	Jet multiplicity	Event Num unweighted	Corr. L(fb^{-1})
tt(→bbl ν l ν) + Njets	N= 0 – 3	7 M	60
tt(→bbl ν qq) + Njets	N= 0 – 3	25 M	60
W(→l ν) + Njets	N= 2 – 6	30 M	20
Z(→ ν ν) + Njets	N= 2 – 6	20 M	40
Z(→ τ τ) + Njets	N= 2 – 6	15 M	70
QCD QQ+Njets (Q=b,c semileptonic decay)	N= 2	100 M	20
QCD mlutijets (light flavor)	N= 4	60 M	10

Real Missing E_T

Fake missing

Except for QCD multijets, there is "real missing E_T" due to neutrino.
QCD multijets with "fake missing E_T" becomes background.
QCD samples are still exclusive. The others samples are inclusive samples.
Contribution of QCD will increase if inclusive samples are used. (producing now)