New physics reconstruction with ISR

KEK & IPMU

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for CERN SM-BSM

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Plan of the talk

- Introduction: nasty ISR in SUSY process.
- Solution (simplified)
- Solution (general case)
- Measuring ISR, physics and on going works.

Initial and final state radiations are important part of hadron collider physics

- Especially, when we produce heavy particle, typical p_T of quark and gluon from initial state parton is sqrt(Q^2). It is neither 'soft' nor too 'colinear'.
- The ISR jets are often serious background for sparticle mass reconstruction. In this talk I provide a solution to the problem.
- I am showing "SUSY production+ up to 1-jets" generated by MadGraph/Madevent + PYTHIA, with k_T-MLM matching, so that I can track on hardest QCD emission.
- I also provide some comparison with PS-MC result(PYTHIA/HERIWG fortran) . Detector simulation is AcerDet with my personal modification .....Jet reconstruction algorithm is Cambridge-Aahen (Fastjet) .

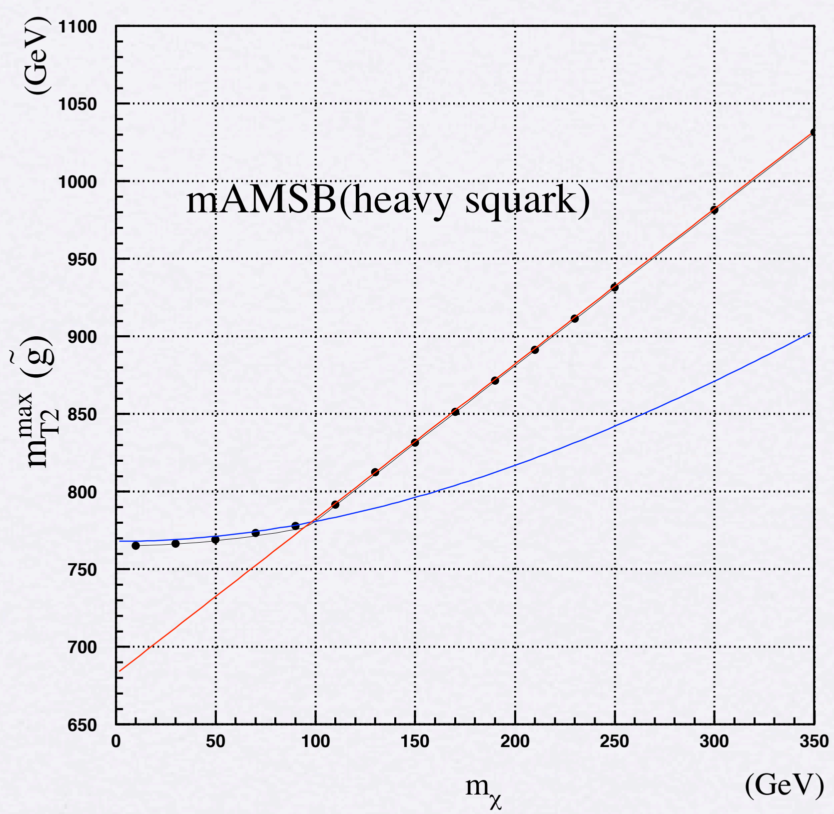
Basic ingredient:MT2

- Kinematical variable useful for the processes with large missing momentum. MT2 is defined as

$$m_{T2}(\mathbf{p}_T^{vis(1)}, m_{vis}^{(1)}, \mathbf{p}_T^{vis(2)}, m_{vis}^{(2)}, m_\chi) \equiv \min_{\{\mathbf{p}_T^{\chi(1)}+\mathbf{p}_T^{\chi(2)}=-\mathbf{p}_T^{vis(1)}-\mathbf{p}_T^{vis(2)}\}} \left[\max\{m_T^{(1)}, m_T^{(2)}\}\right],$$

- end point is gluino mass and it has kink at LSP mass for the process

$$pp \to \tilde{g}\tilde{g}$$
$$\tilde{g} \to \tilde{q}^* q \to q\bar{q}\tilde{\chi}_1^0$$



Cho et al

- There are huge number of math works regarding to the end point. But Here I focus on application to the real processes. Most serious problem is " How to define pvis"

- Normally people takes heighest pT objects hoping purely QCD activity is manageable.

2009年8月12日水曜日

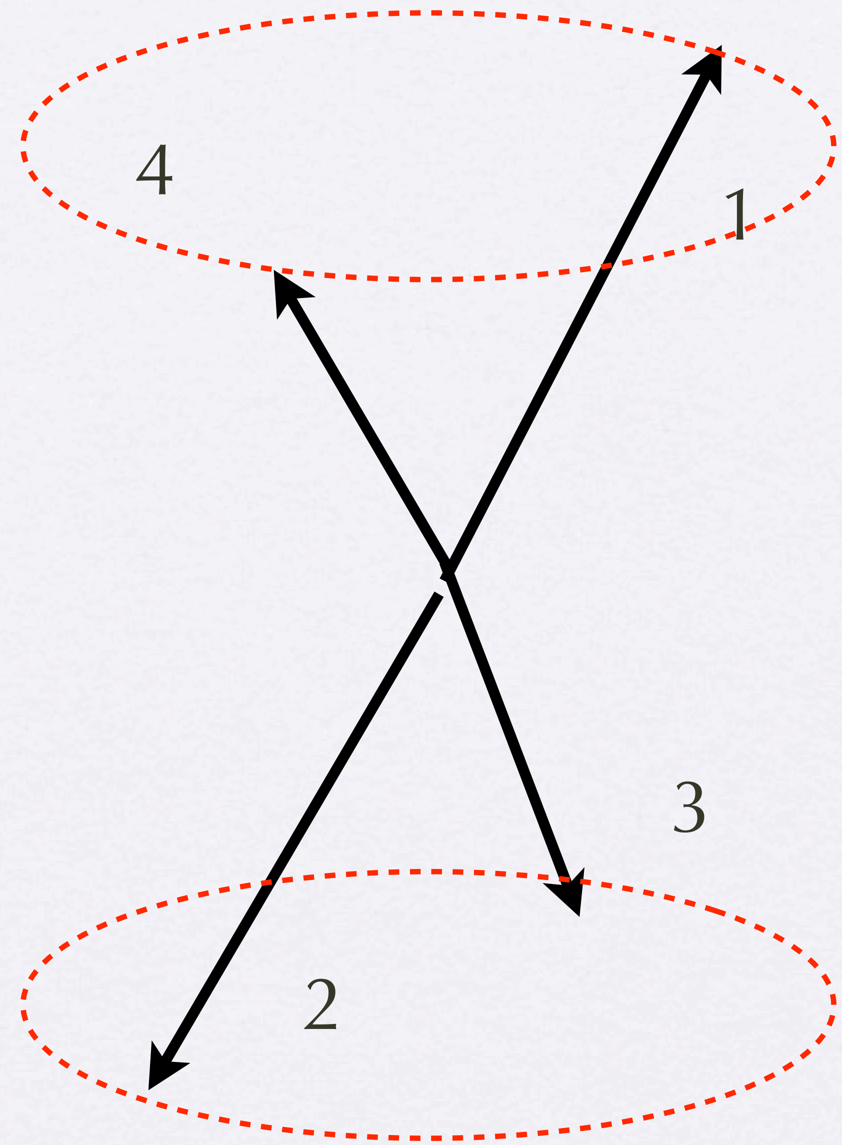
reconstruction step

- Simplified Example: M_{T2} mass reconstruction for pp-> 2 gluino-> 4j +2 LSP (in acutual life the branch is small. I will go though full decay later.)

- Reconstruction steps: 1)Take 2 highest pT jets j_1 and j_2

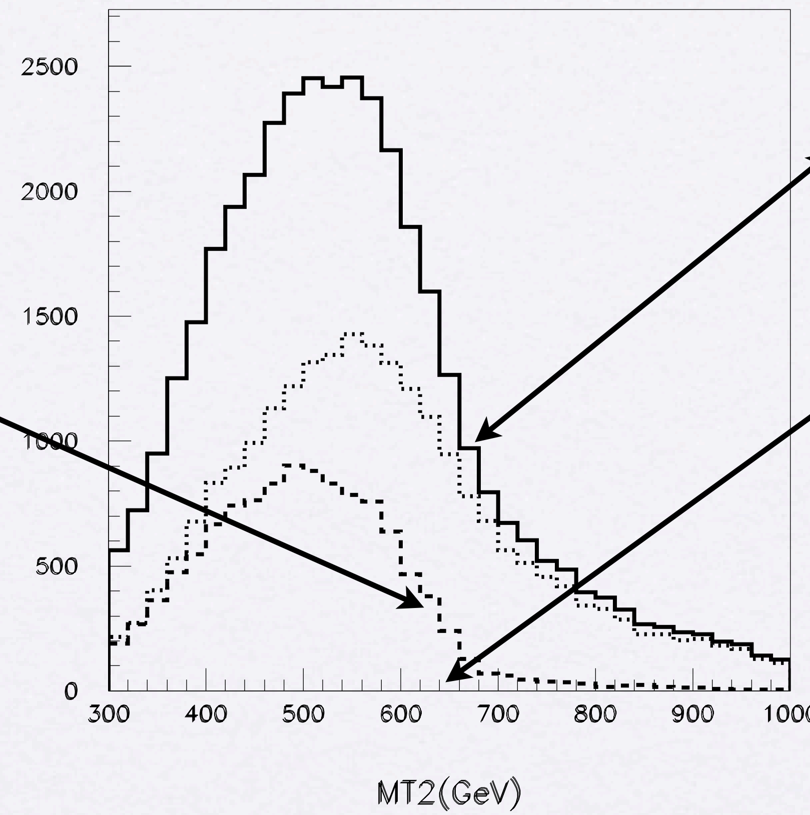
- 2) associate j_3 and j_4 to one for each

- 3)take combination of jets that gives smaller m_{T2}.



- Now this is it. (jet level)   glgl + (up to one jet)

Events without resolved Initial radiation(ISR) after matching: “exclusive”



Events with resolved Inital state radiation: “inclusive

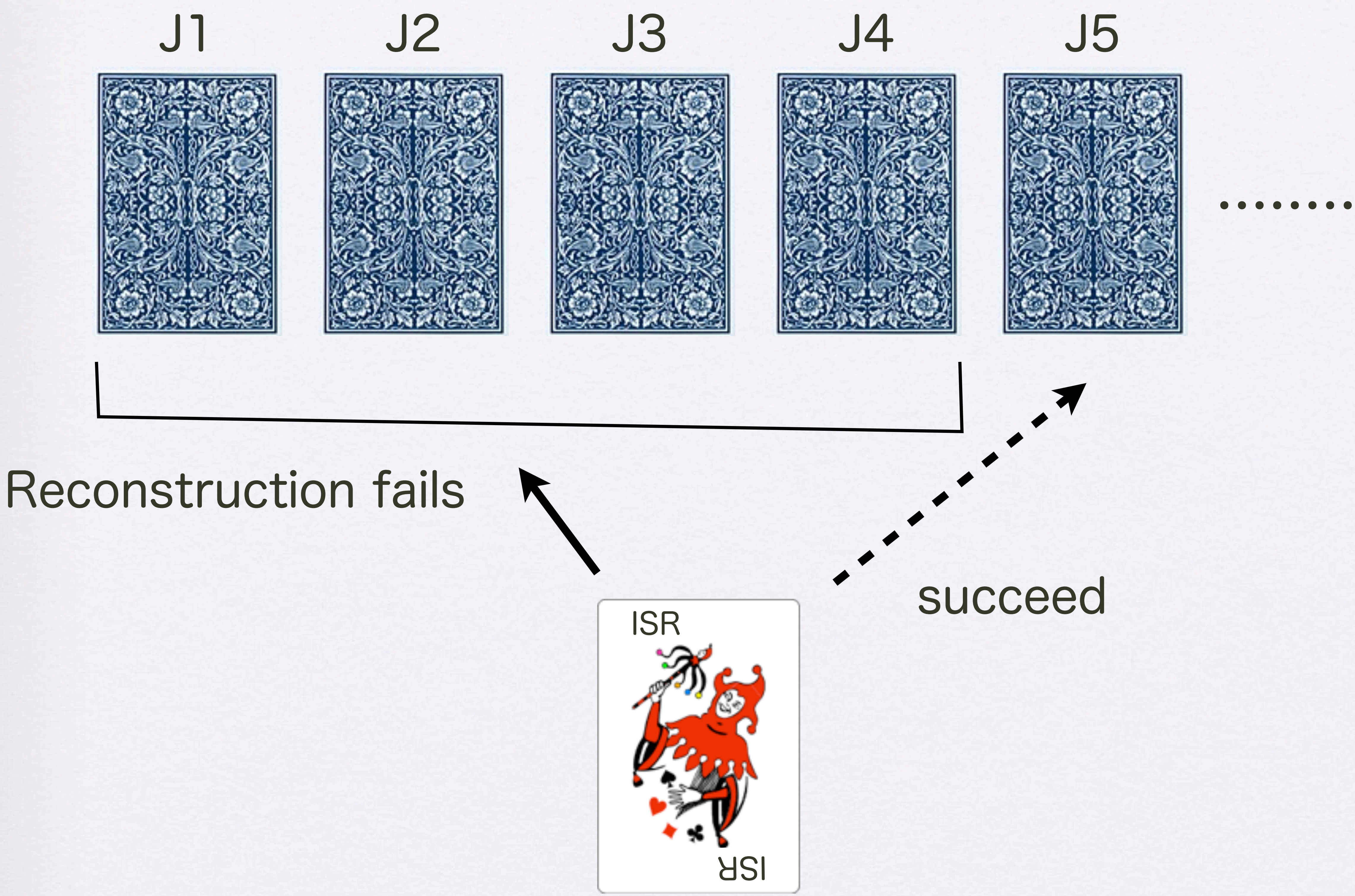
input gluino mass 690GeV

total cross section 3pb
50000 events, no SUSY cut
η cut=3

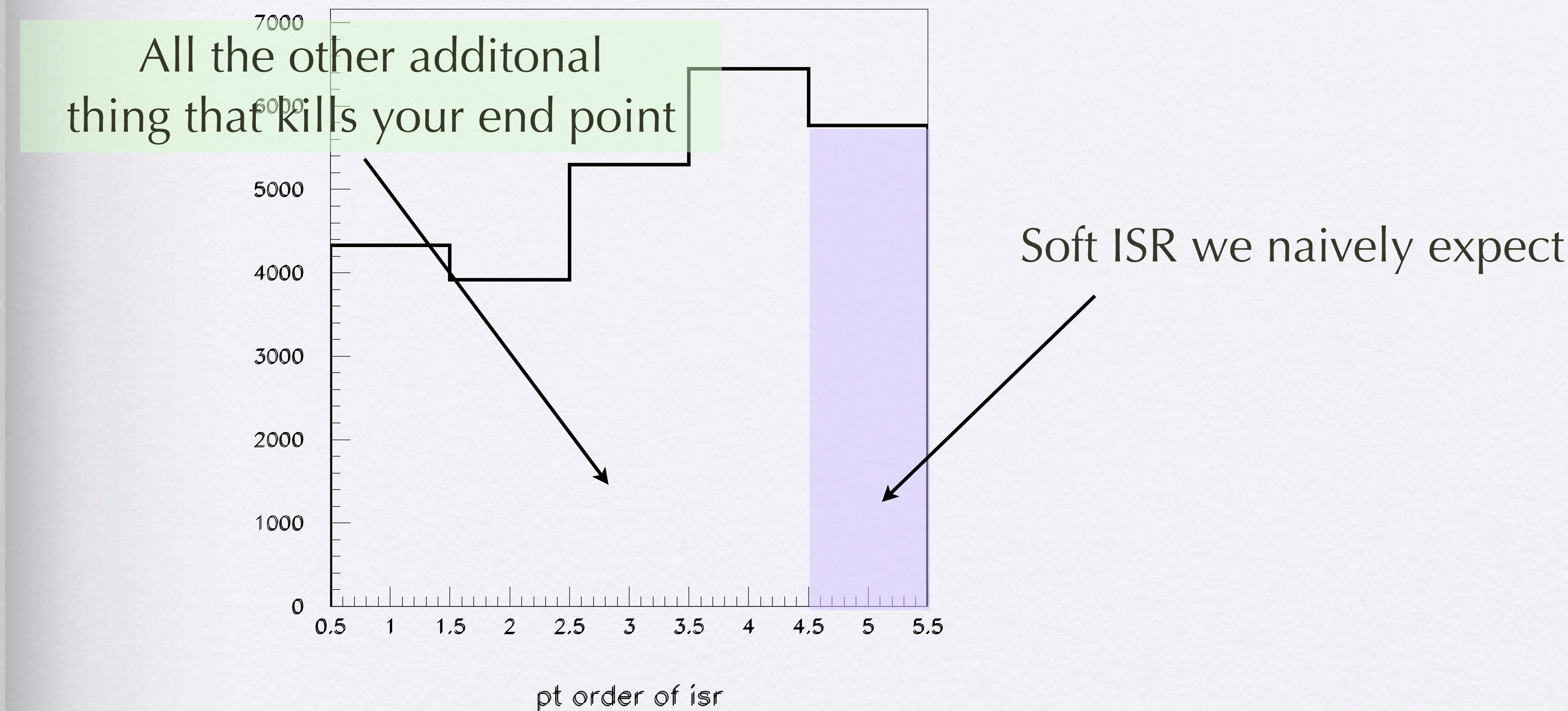
Inclusive/exclusive =1.4 for gluino pair
0.8 for squark pair

ISR is specially bad for gluino production

arXive:0905.1201


J1
J2
J3
J4
J5
Reconstruction fails
succeed
ISR
ISR

P_T order of the additional jet



- Hard and high PT additional jet is actually dominant part of the production cross section.

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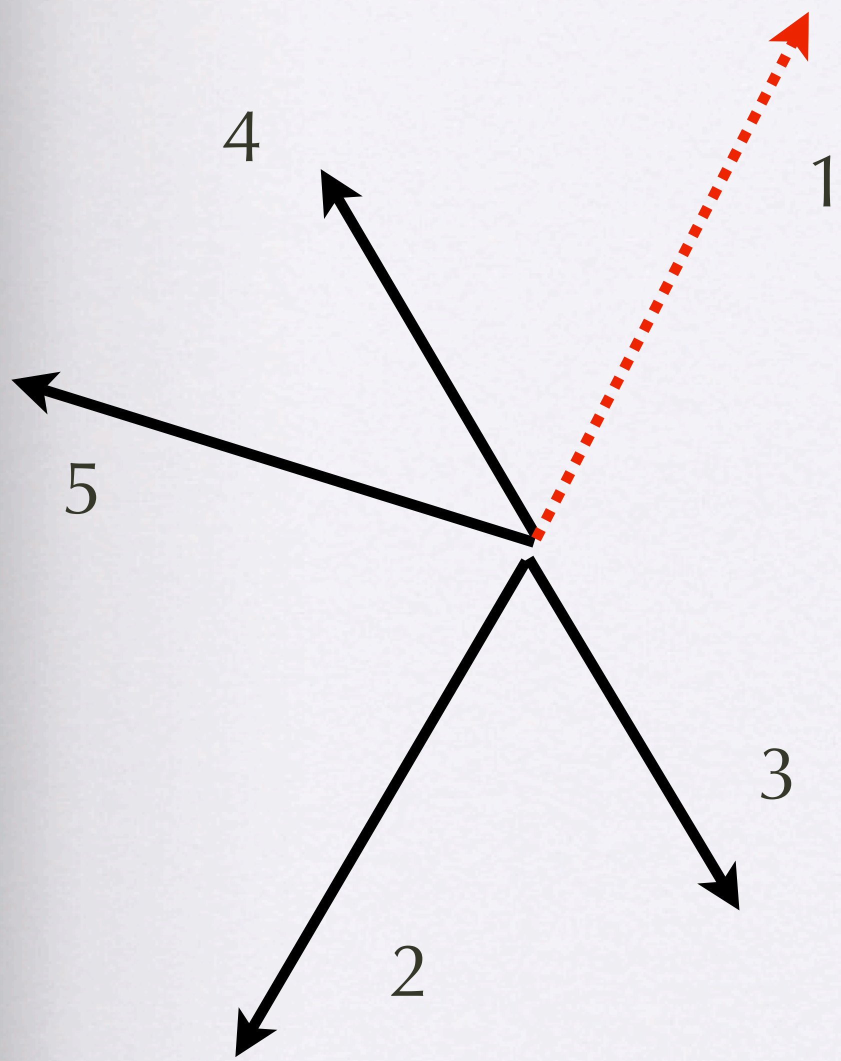
II. How to get around (conceptional change)

- We are working on "5 jet system" rather than "4 jet system". More than half events have additional jets!



Proposing new step for mass reconstruction

1) take the 5 highest p_T jet ("five" is enough because "hard emission" is perturbative)

2) remove one of the jet i, and calculate "$M_{T2}(i)$"

3) take minimum of $M_{T2}(i)$

$$M_{T2}^{min} = \min M_{T2}(i) = M_{T2}(i_{min})$$

i_{min} may be true ISR!

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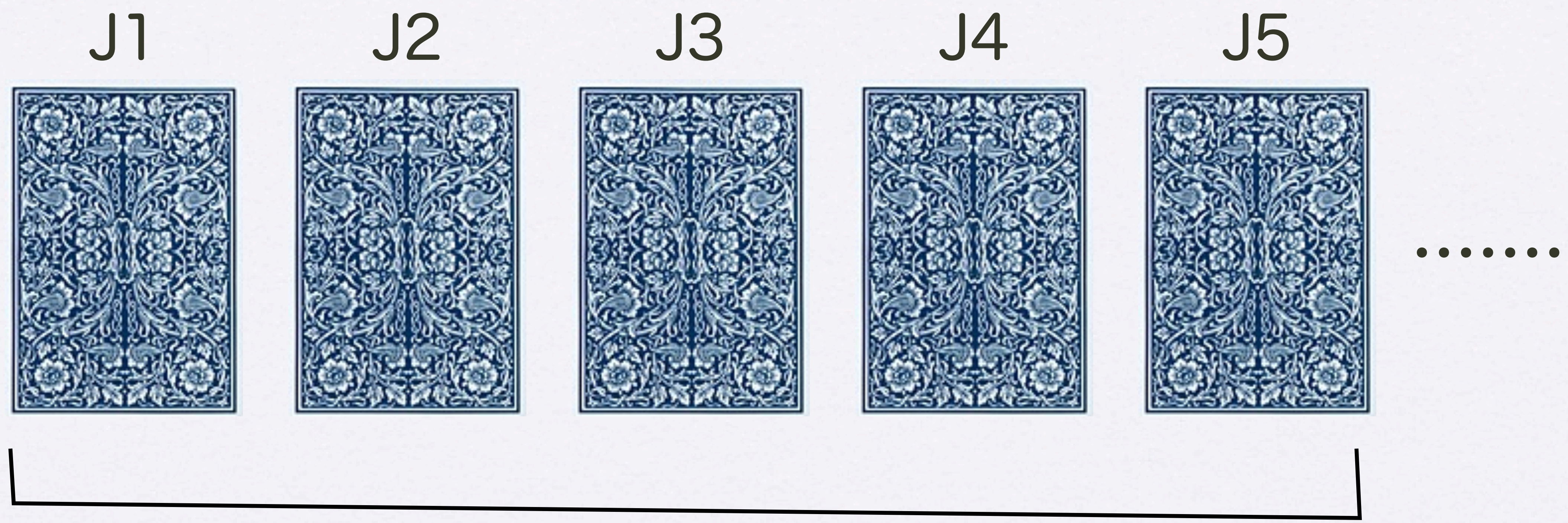
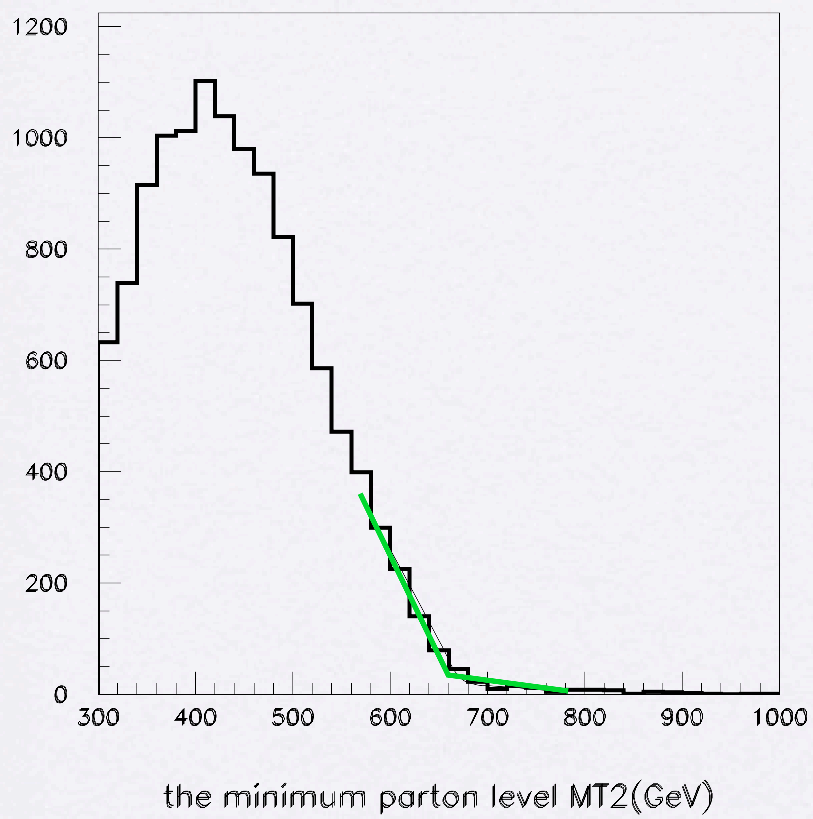


Try all 5 jets and
take minimum so that
end point is clean.

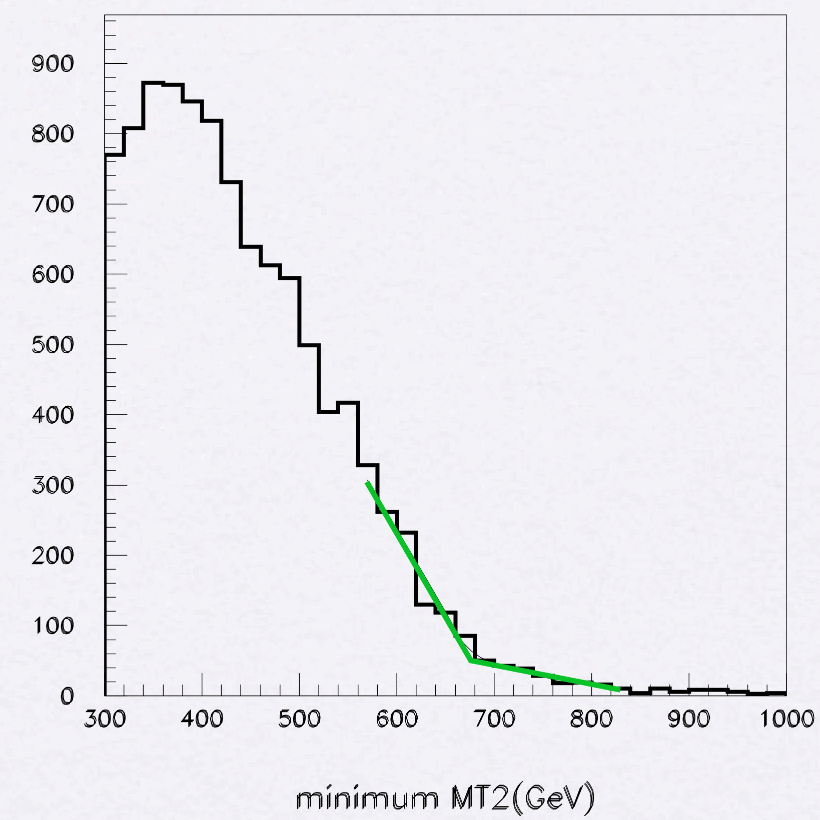
The End point

parton level distribution



673.9 +/- 2.5 GeV

jet level



675.4 +/- 6.4 (imin. ge.3)
672.7+/- 3.5 (for all)

- We recover end point.

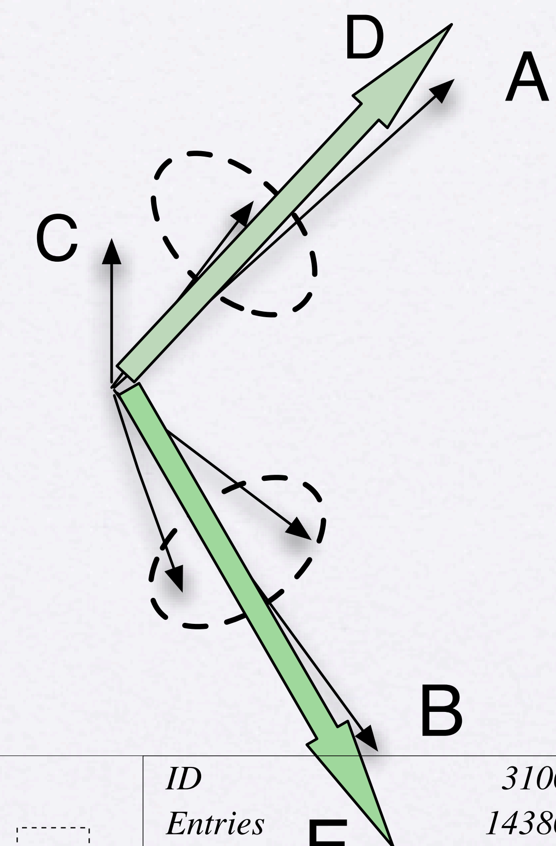
arXive:0905.1201

III. Is this practical?

- In general, squarks and gluinos are co-produced, even if squark is heavier than gluino.
- In general gluino decays into complicated final state. requiring 5jet kills all events.
- Define the method that works for more general case-- m(squark)>> m(gluino) but MSSM decays

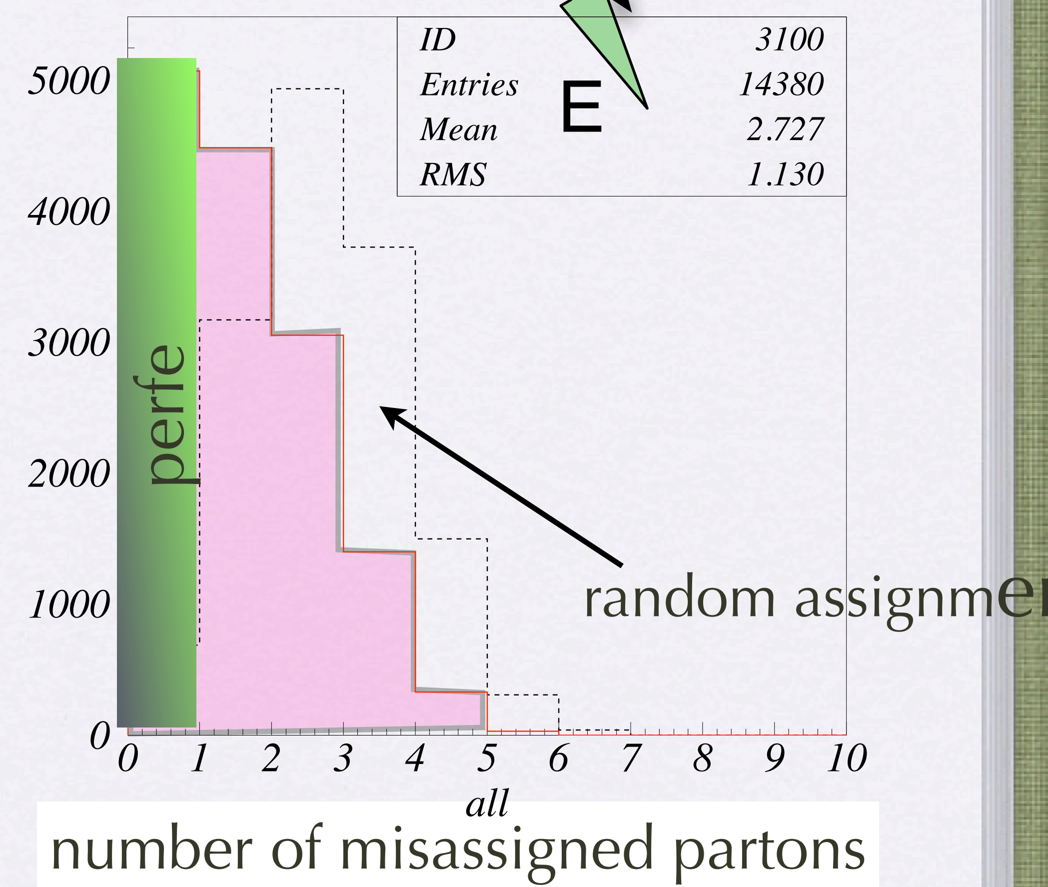
hemisphere method and inclusive m_{T2}

MMN, Shimizu, Kawagoe, Okada



- define M_{T2} variable without specifying initial state. (work for complicated decay chains)
- take two leading jets (A, B) , associate the other jets (C) into either A or B using Lund distance measure. Take Hemisphere momentum,the sum of jet momenta in the same group(D, and E) , as visible object.
- "decay products of a sparticle ~ a hemisphere" with reasonable probability. (~30% is perfect) mis-assignment tend to give smaller m_{T2}. [end point clean]

from Nojiri ,Shimizu, Takeuchi ,Sakurai (JHEP 0810:100,2008)



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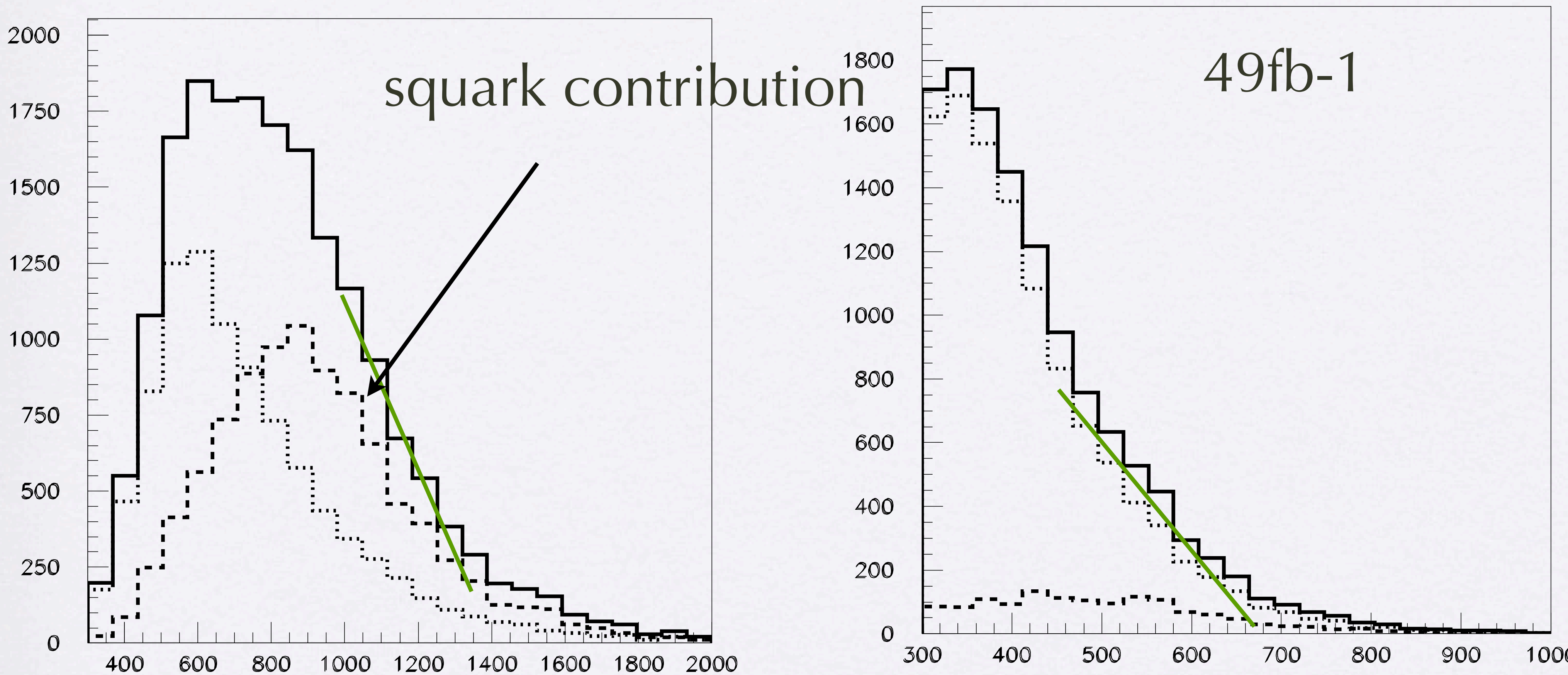
M_{T2}, M_{T2}(sub), M_{T2}(min)

- Inclusive MT2: use hemisphere momenta as visible object of MT2 → squark mass
- subsystem MT2: dis-regard some activity and calculate inclusive MT2 for the rest. (useful when squark is much heavier than gluino
- MT2 min= min MT2(i): MT2(i) is the subsystem MT2 with the i-th jet removed. for practical purpose, i≦.5

How it looks like (non-forced decay)

- n(pT>300GeV) ≧1 for M_{T2} and 0 for M_{T2min}



M_{T2} distribution
(in slightly modified definition)

M_{T2} min

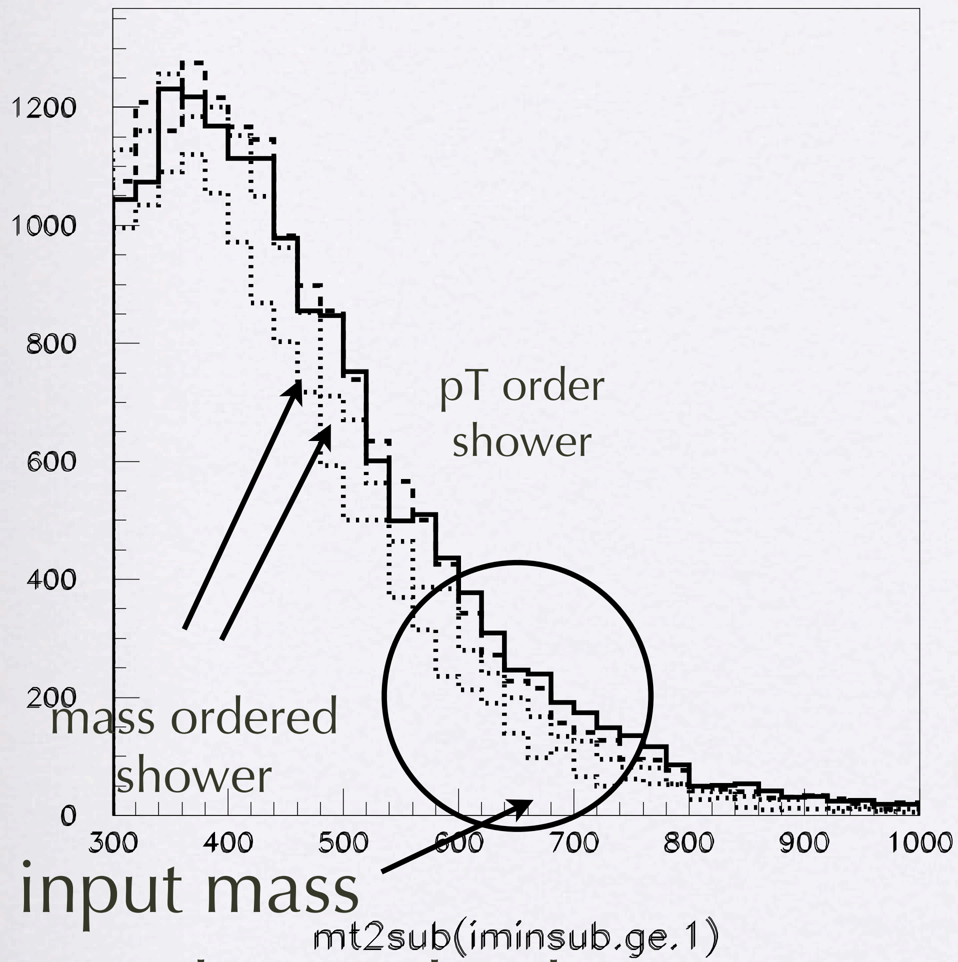
m(squark) ~1420GeV m(gluino)~690 GeV
integrated luminosity L=49fb^{-1}

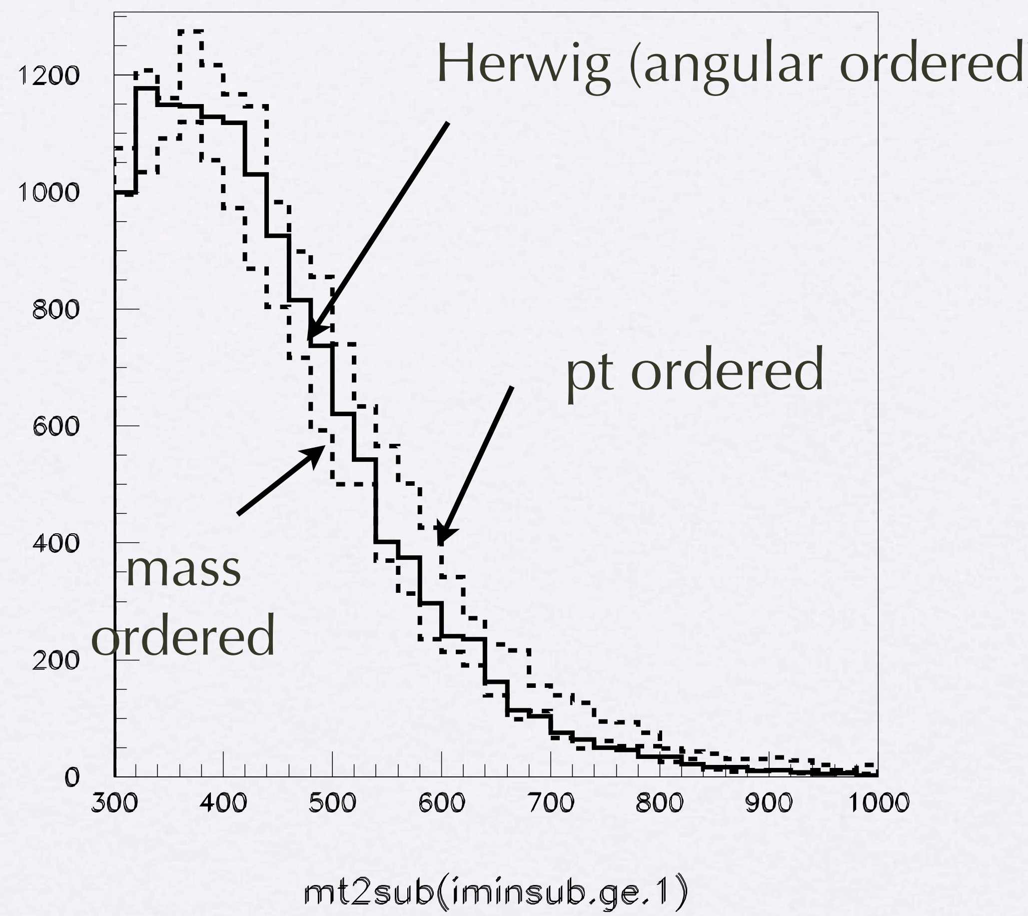
Alwall, Nojiri Hiramatsu in preparation

Shower dependence
(gluino production only : forced decay)

gl gl vs glgl + up to one j glgl production

for the jets with pT> 50 GeV |eta|<2.5 SUSY cut Preliminary





The results shows

☆inclusive analysis maybe sensitive to PS is pT cut for the jet is low.

☆ The results are more stable after adding gluino glulino +jet contribution

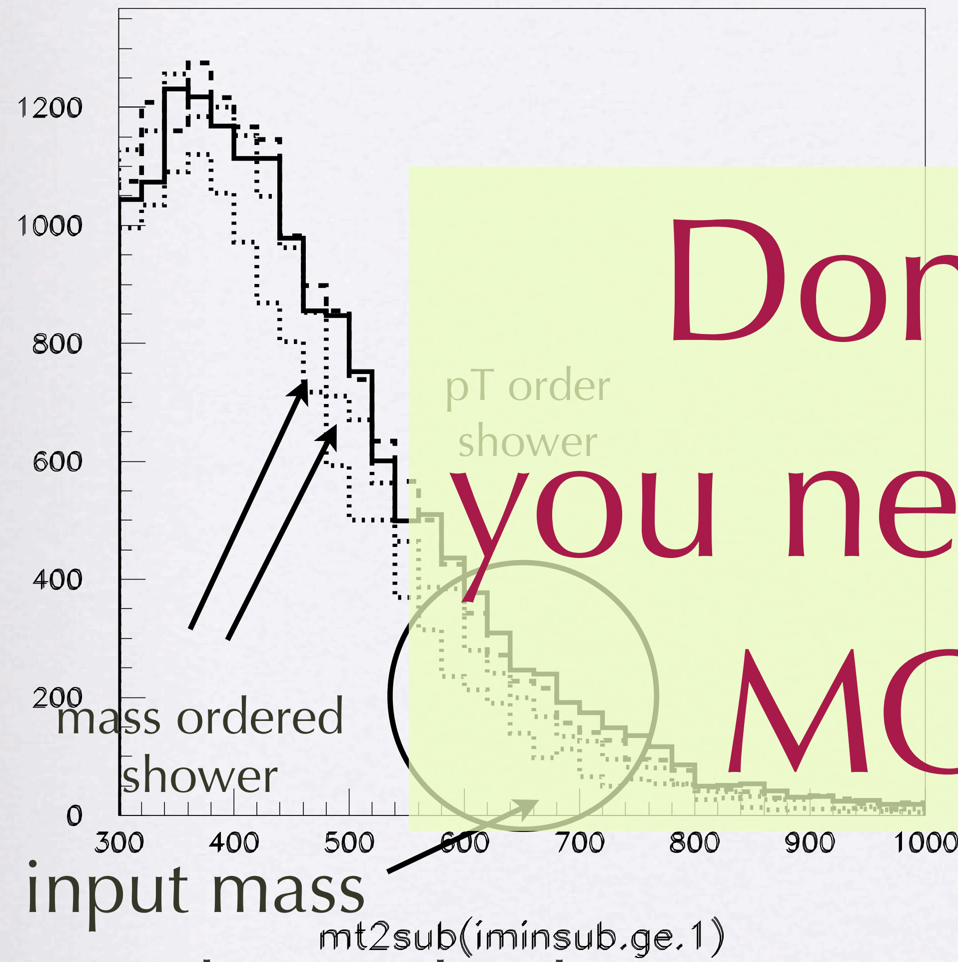
Shower dependence
(gluino production only : forced decay)

gl gl vs glgl + up to one j

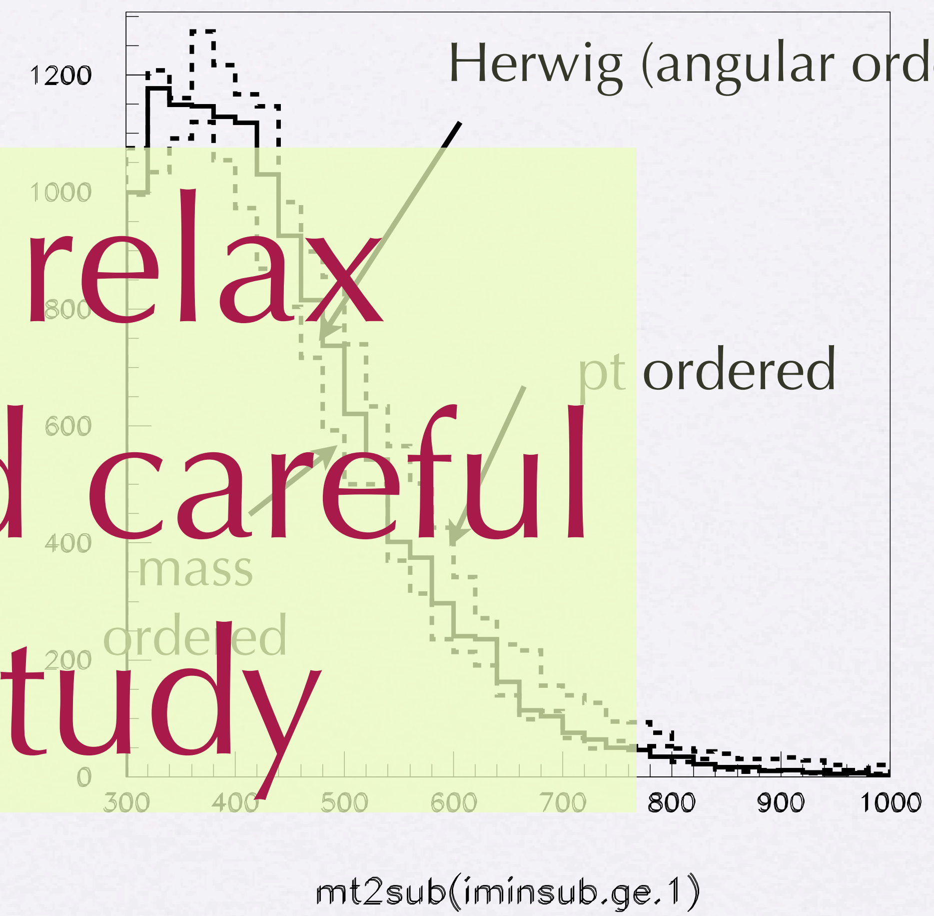
glgl production

for the jets with pT> 50 GeV |eta|<2.5 SUSY cut

Preliminary



input mass



Don't relax you need careful MC study

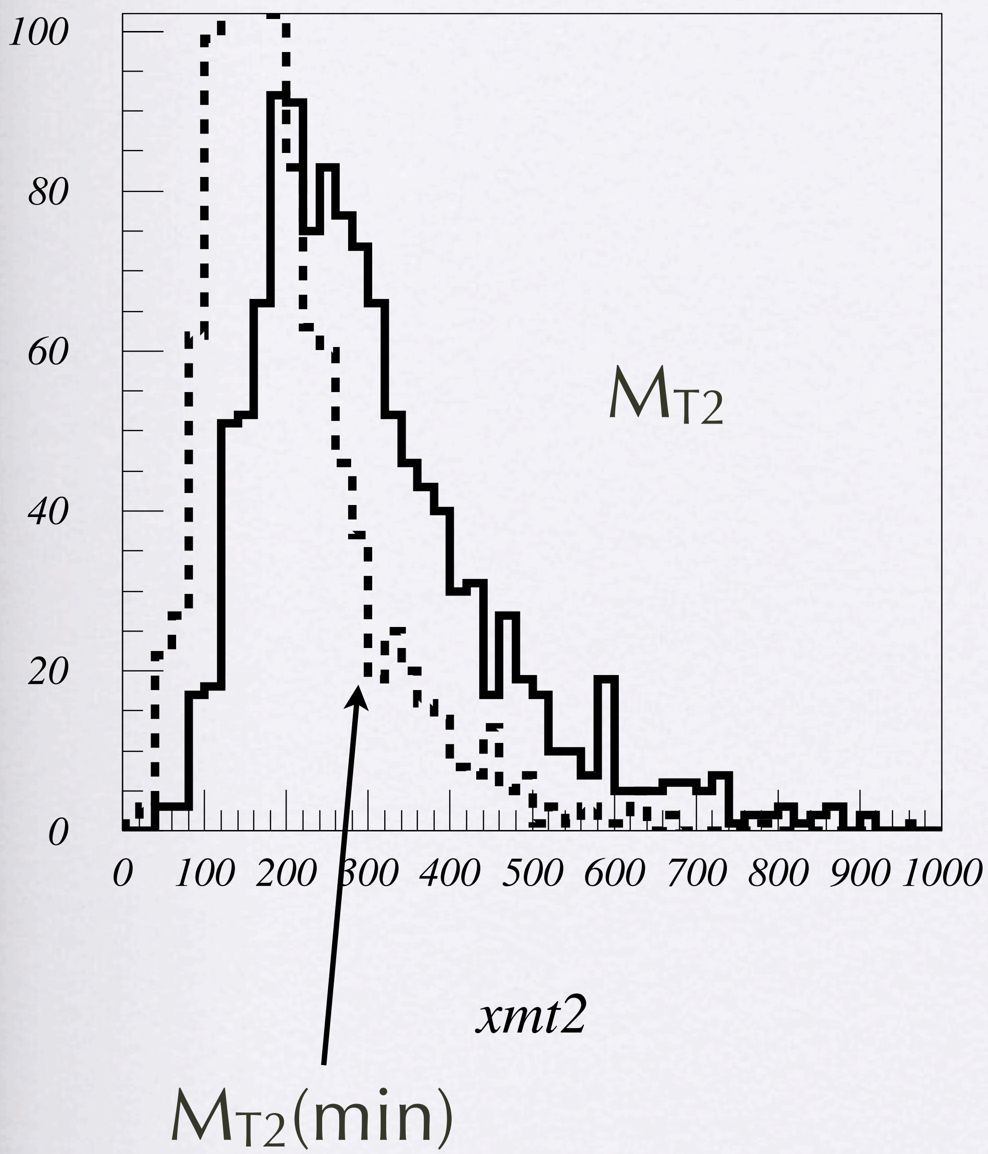
The results shows

☆inclusive analysis maybe sensitive to PS is pT cut for the jet is low.

☆ The results are more stable after adding gluino glulino +jet contribution

Background

tt+ up to 2 jet distribution
with standard SUSY cut
(ALPGEN+HERWIG)



- ttbar+jets , W+jets, Z+jets (leptonic decay) for SUSY
- cut: M_{eff}> 500 GeV, p_{1T}> 100 GeV, p_{2T}, p_{3T}, p_{4T} > 50 GeV, E_{Tmiss}> 0.2x Meff
- natural mT2 end point must be less than mt, but smearing,additional jets......
- removing a jet reduce the background in large MT2 region significantly but it does not completely kill the background

Takeuchi, Nojiri ... in preparations

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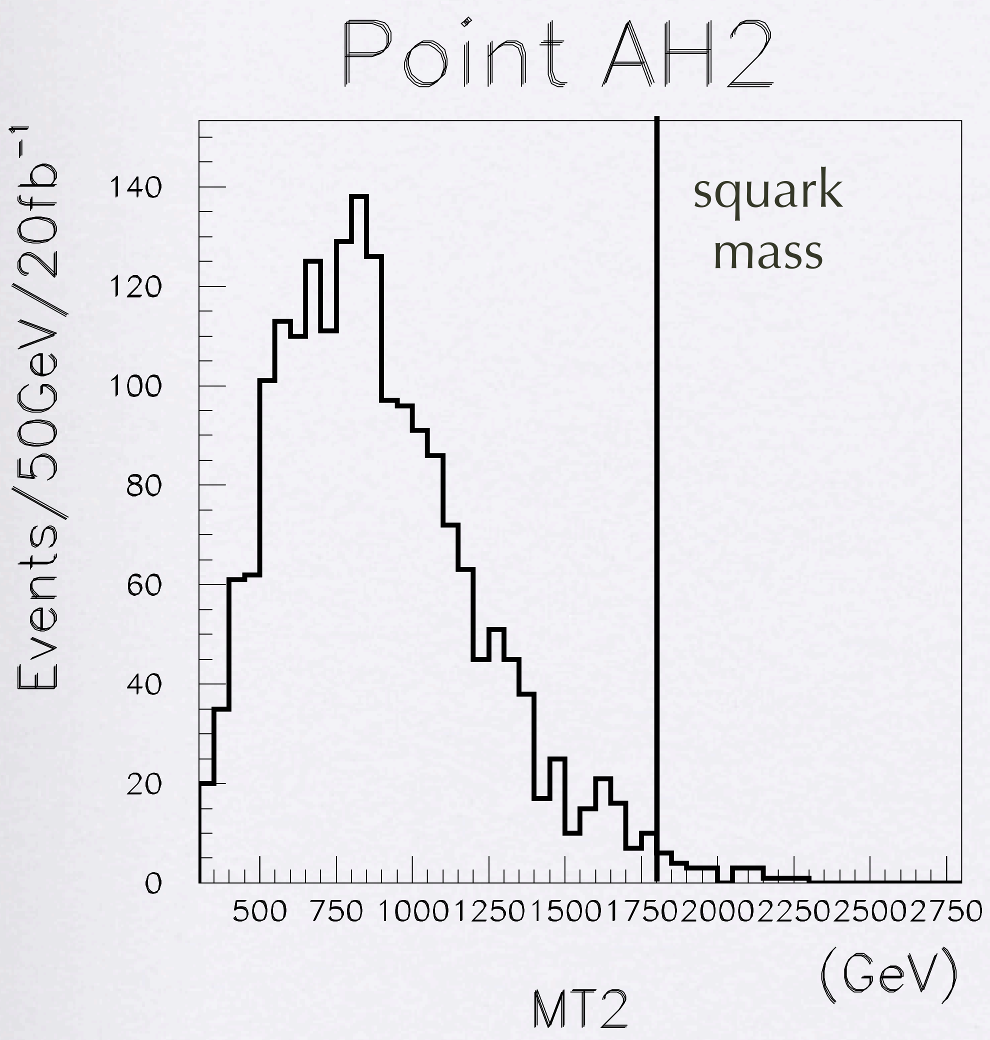
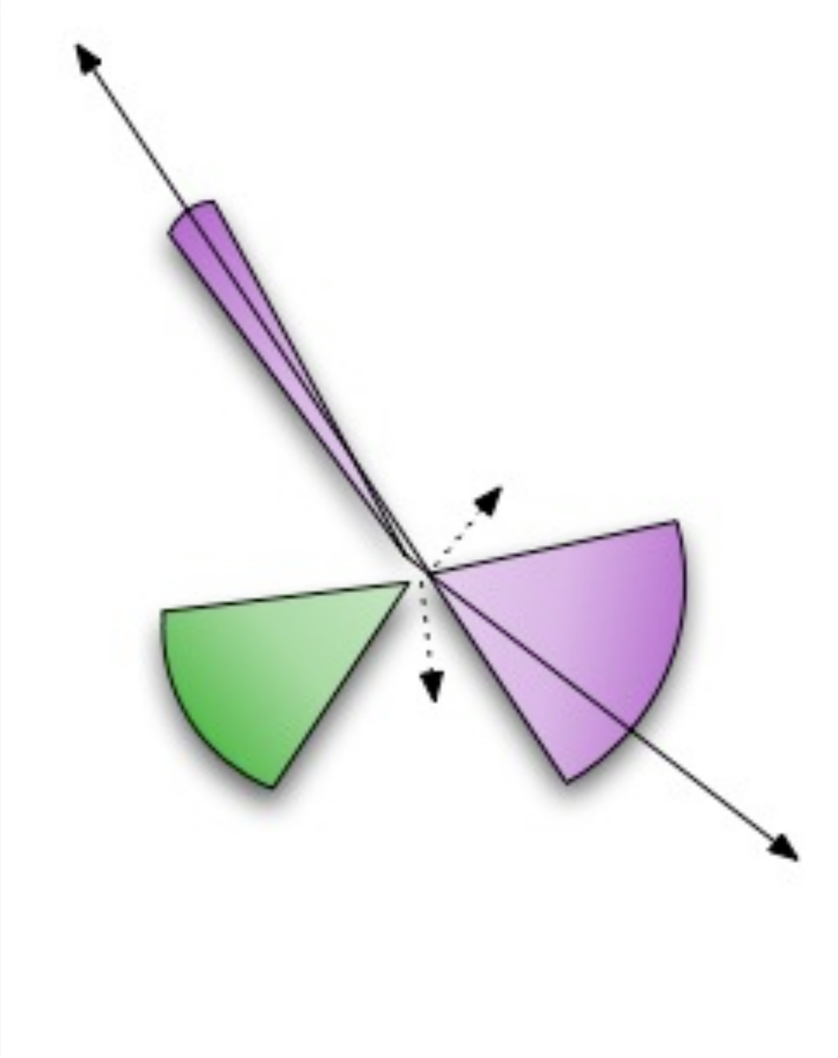
Really heavy squark case

- calculate MT2 from two hemisphere(making mt2 min) + highest PT jet
- Plot M_{T2min}=min[MT2(p_{hemi1}+j_1,p_{hemi2}),MT2(p_{hemi1},p_{hemi2}+j_1)]

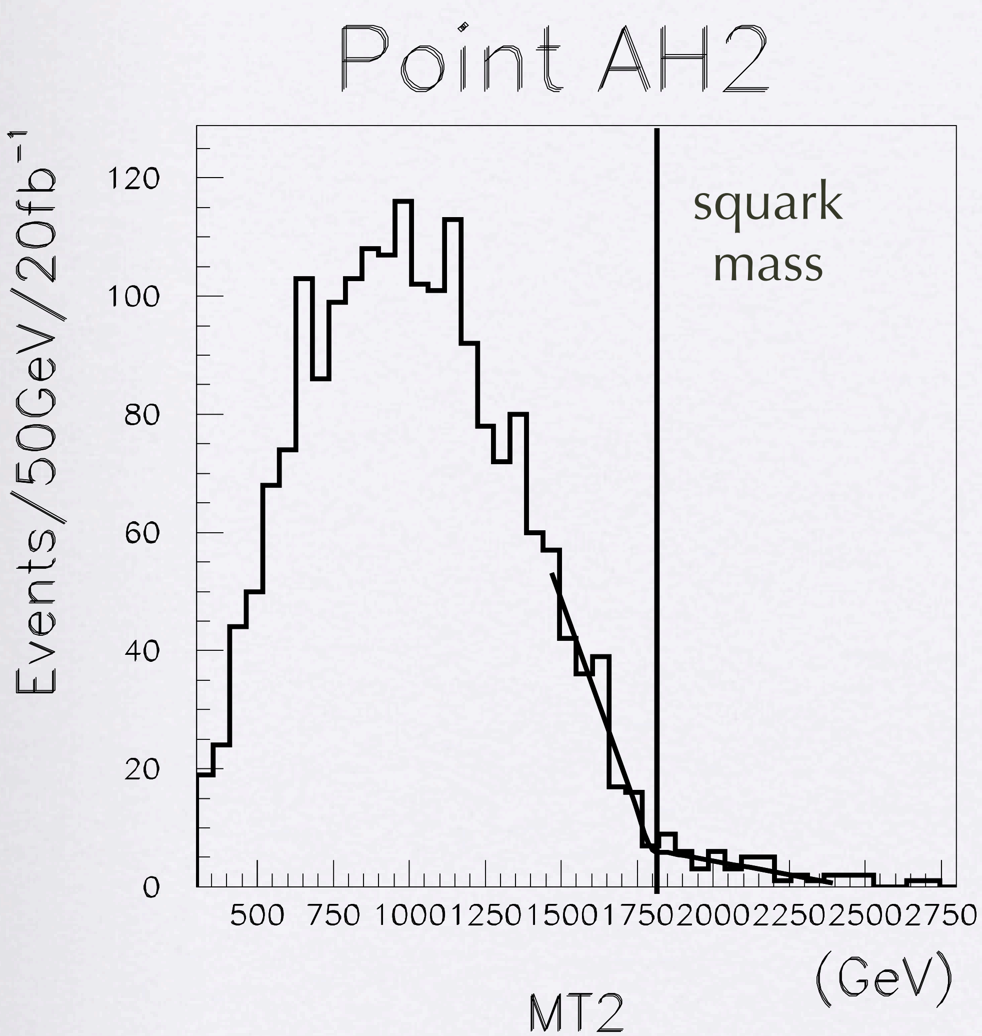


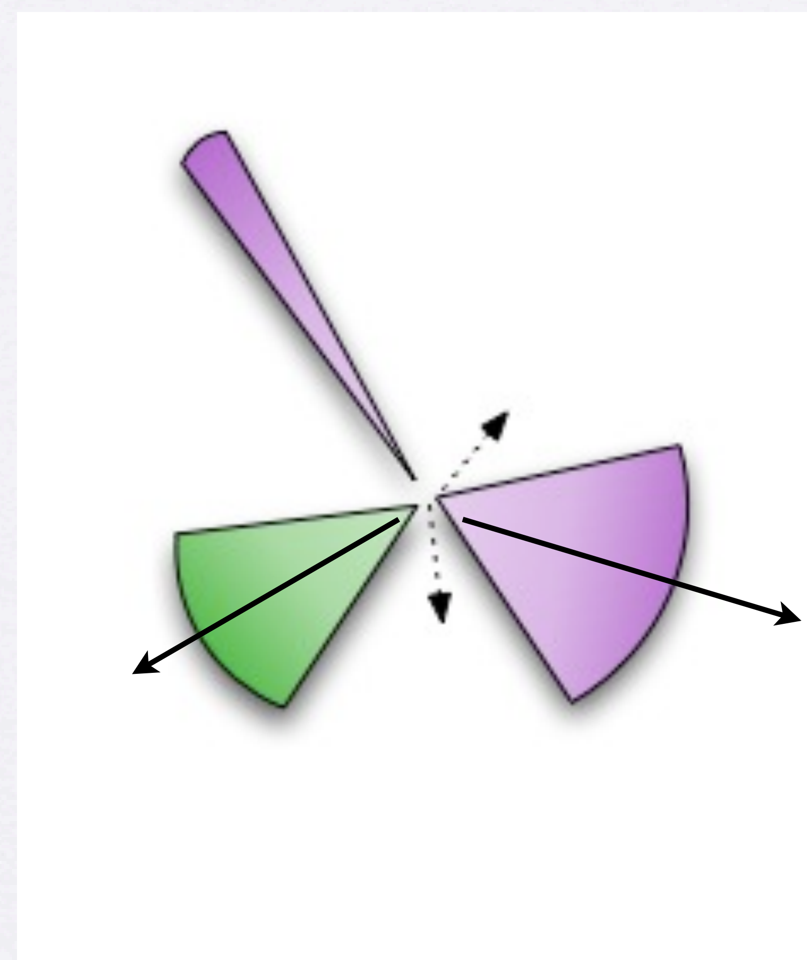


Sakurai, Nojiri arXiv:0907.4234

Really heavy squark case

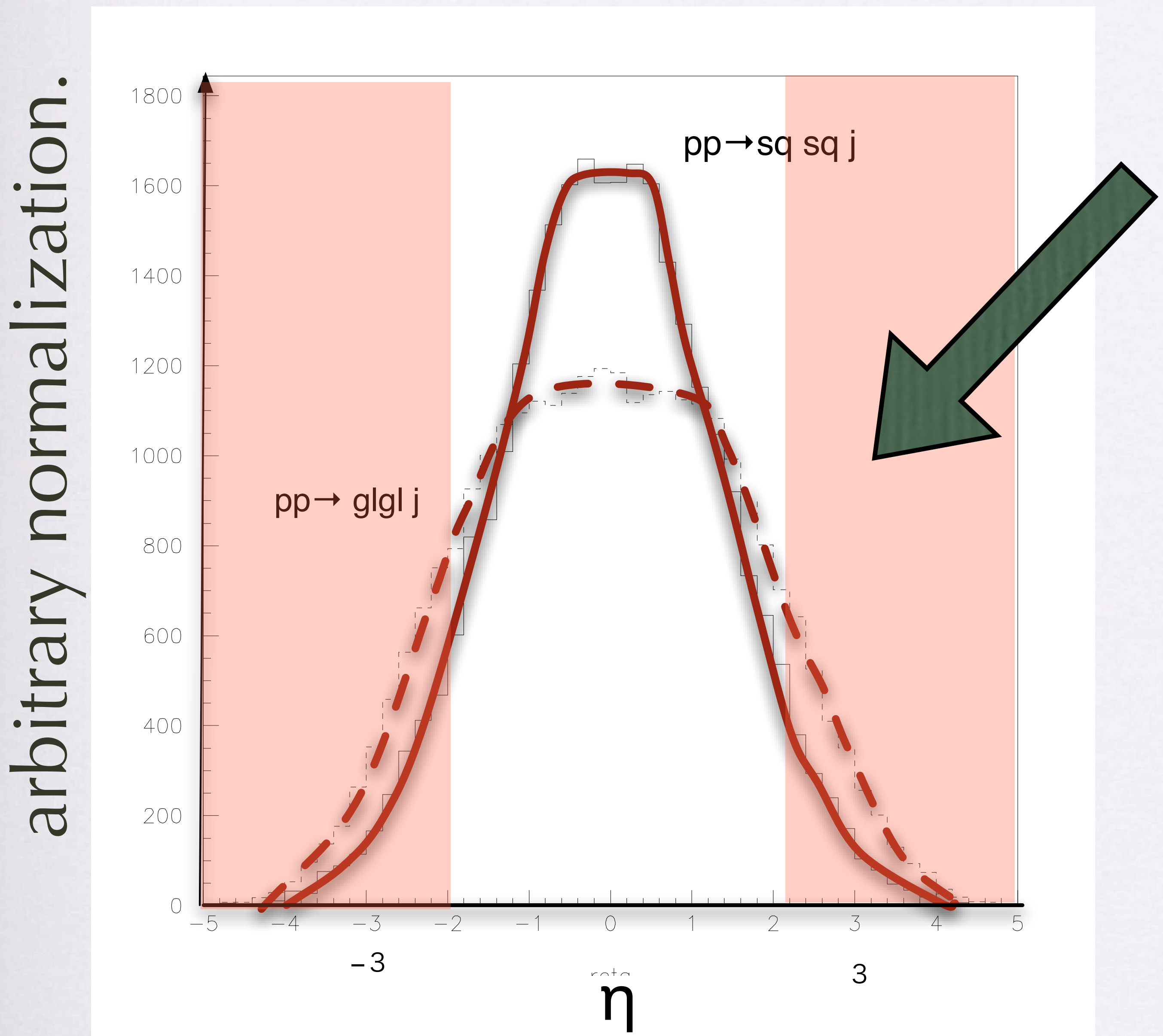
- calculate MT2 from two hemisphere(making mt2 min) + highest PT jet
- Plot M_{T2min}=min[MT2($p_{hemi1}+j_1, p_{hemi2}$),MT2($p_{hemi1}, p_{hemi2}+j_1$)]





Sakurai, Nojiri arXiv:0907.4234

IV. SUSY initial state radiation depends on production process.



24% of the events
for gluino pair production

14% for squark pair production

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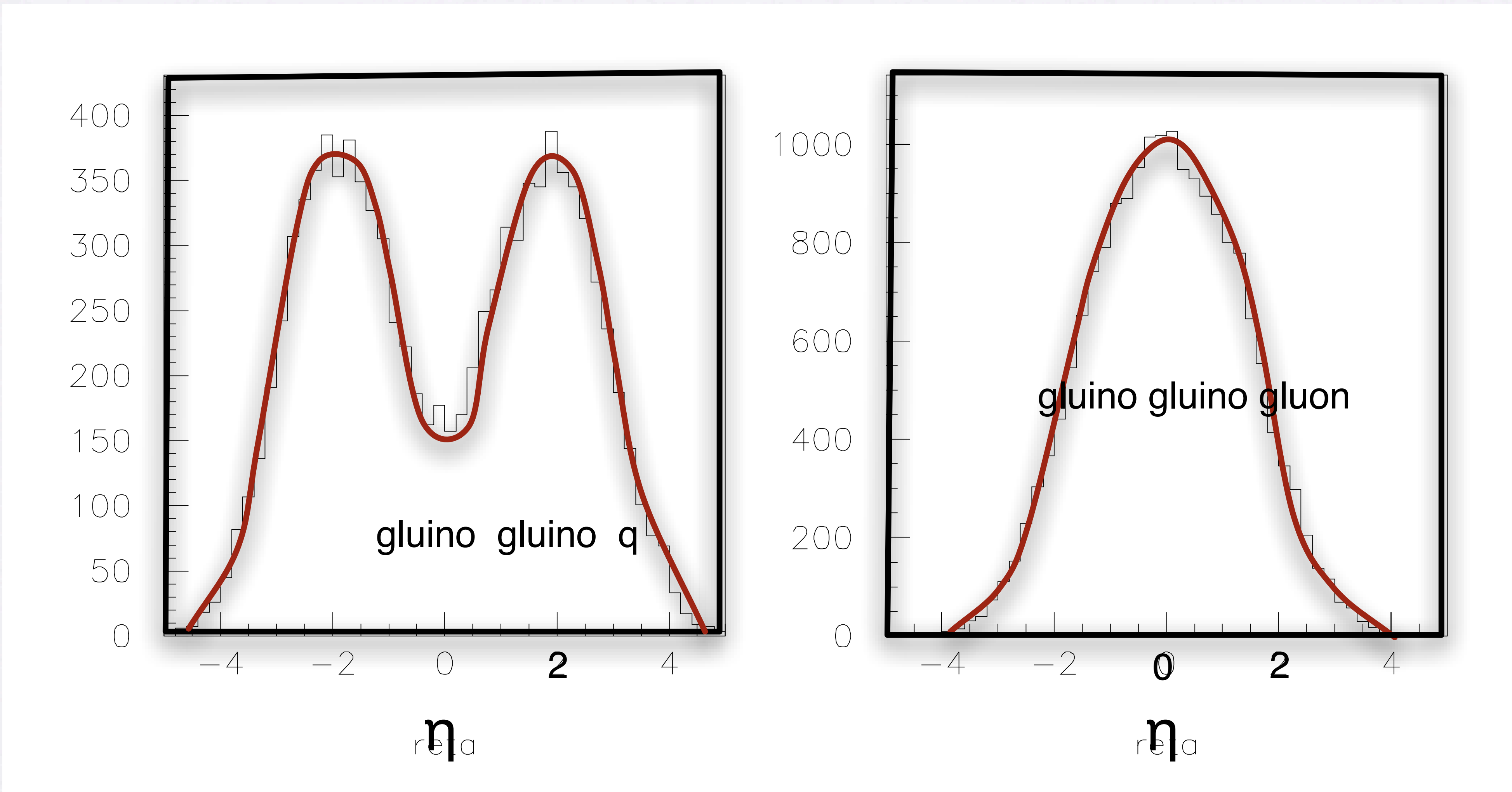
hard forward jets come from q (hard) →q g branch



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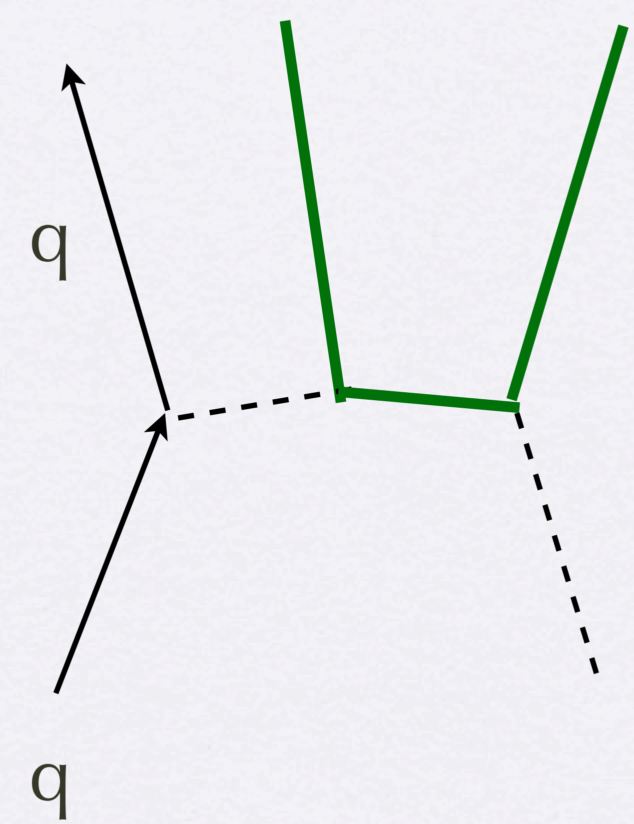
Why so many additional jets

- 4 coulor octet particles in the final state (dominant process g g→ gluino gluino) many radiations..

$$P_{qq} \propto \frac{1+z^2}{1-z}$$

- + 1 jet
  - gluon gluon → gluon gluino gluino (low energy)
  - qg → q squark gluino
    (high energy and high luminosity, and quark takes most of energy at the branching.)



Why do we want to see it

- If the dominant production process of X comes from direct q-X(squark) -Y(gluino) coupling, you should not see a hard quark in the forward region. The initial state quark rather goes to the hard process.

- If the production process is dominantly from g-X-X(gluino),   a hard quark may go in the forward direction.

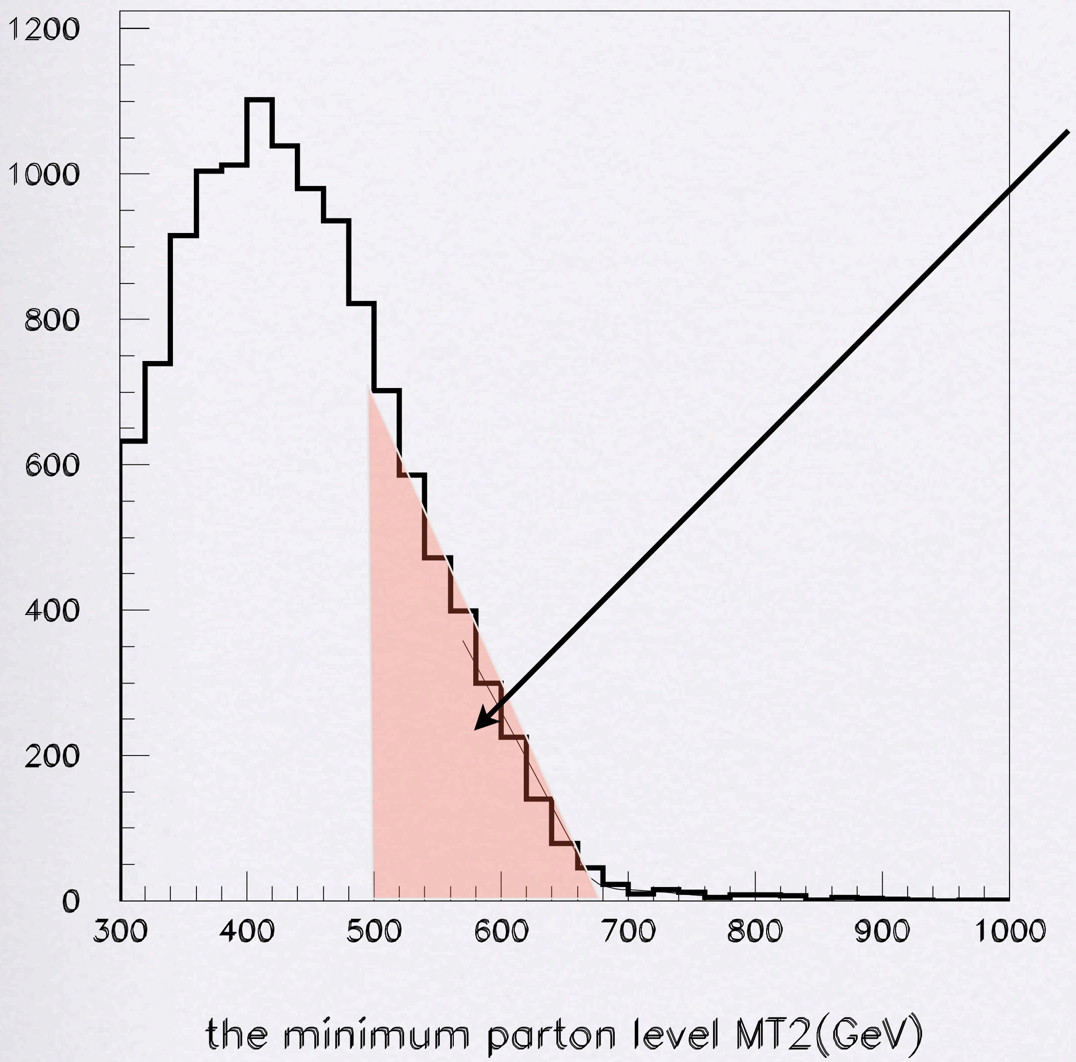
  - quark-squark-gluino coupling is not effective for gluino gluino production because you have to pick up- anti-quark in that case)

- "Decay independent" discrimination of the production process

η distribution of ISR jet near the MT2 end point

- A “removed jet” has higher probability to be ISR near the end point of MT2min

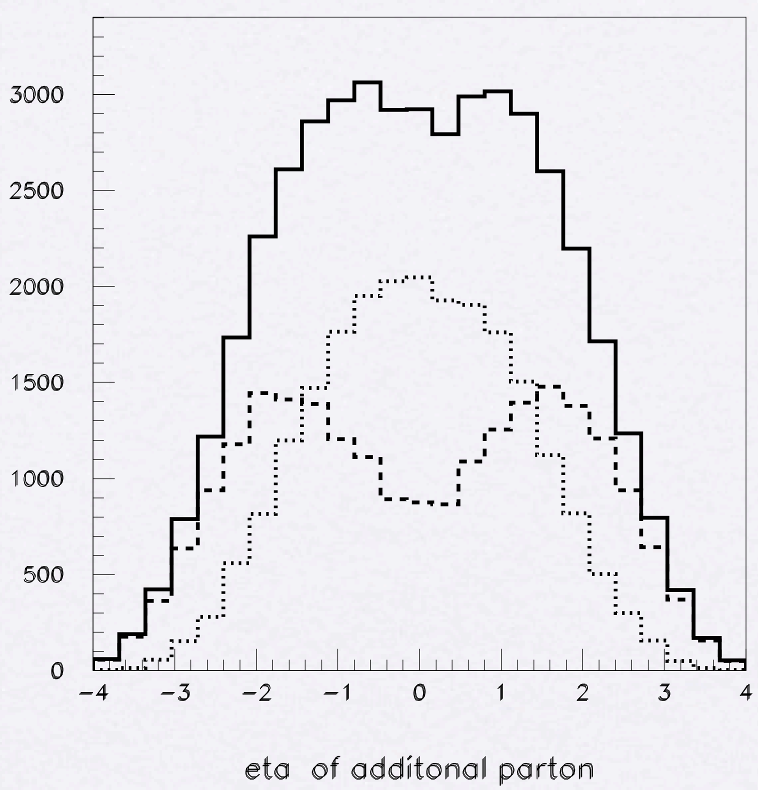
- parton level study shows....



45% (of inclusive sampele) correct!

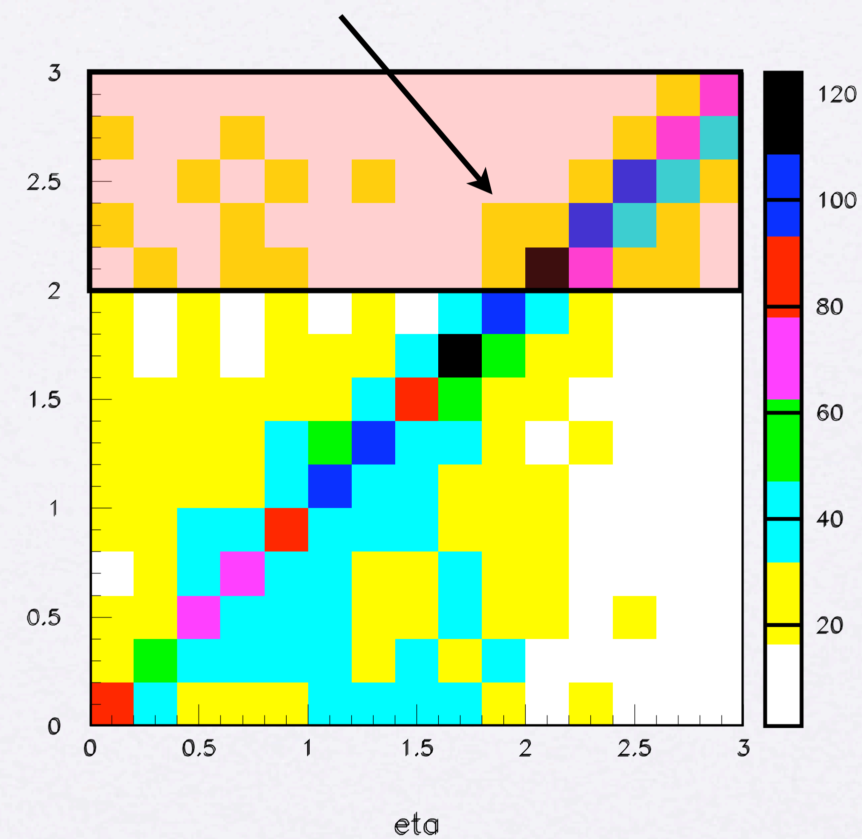
if it is not correct,
the true one should live between M_{T2}^{min} and M_{T2}^{max}

ISR parton distribution



parton level distribution of
ISR jets for pt> 100GeV

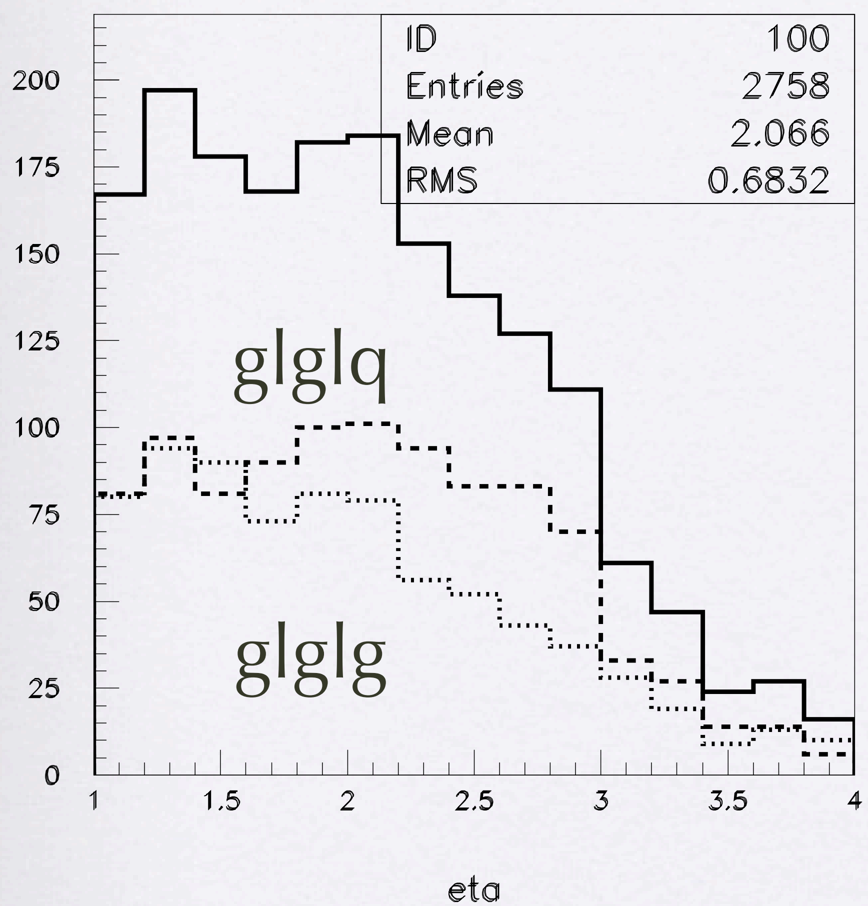
Here it is 65% correct

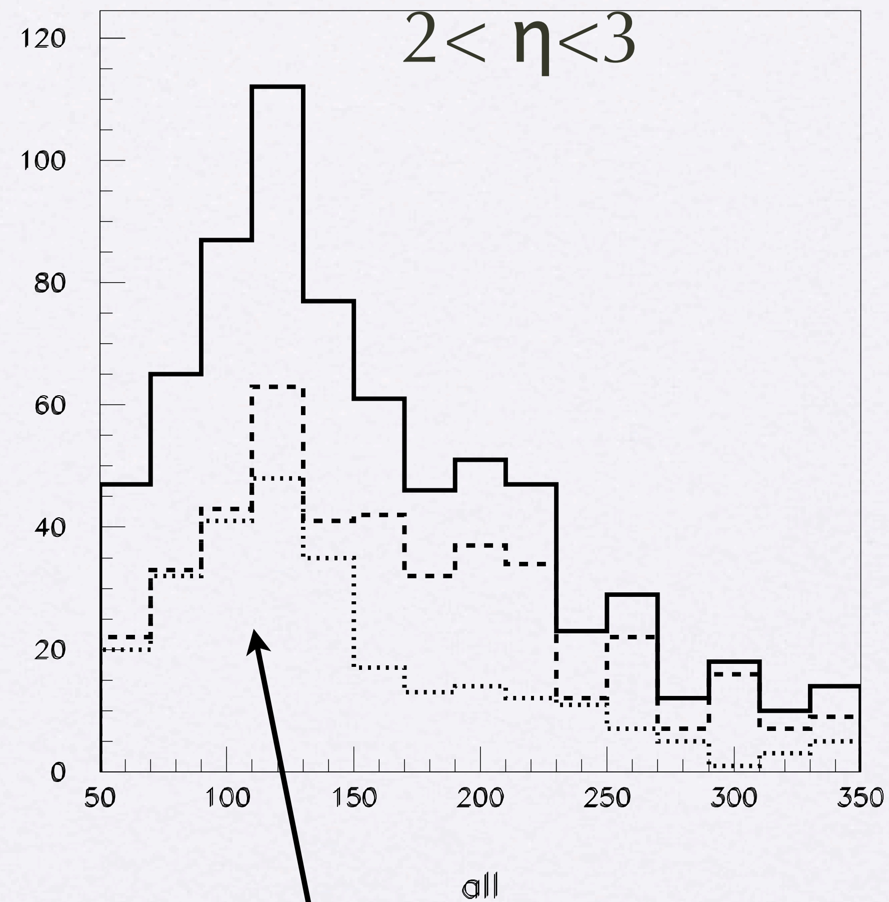


ISR candidate jet
vs ISR parton

ArXiv:0905.1201

η and pT distribution





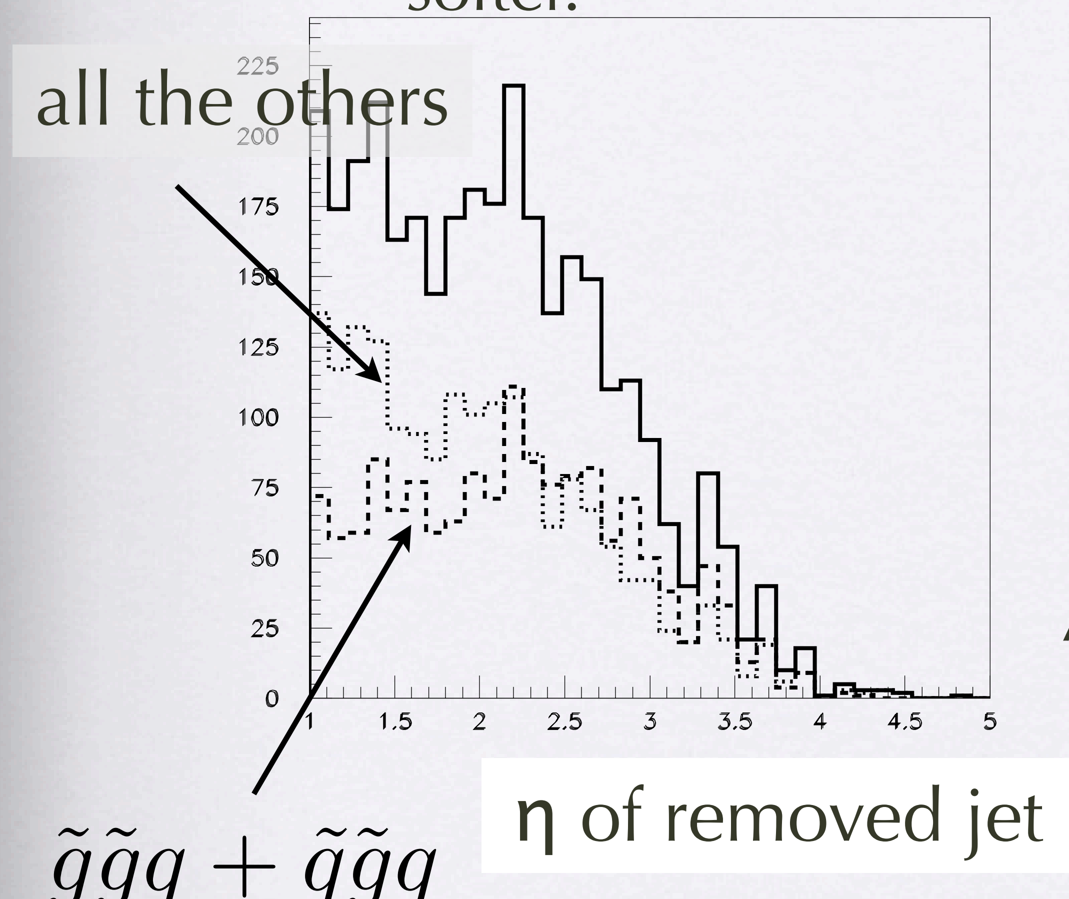
- quark contributes high PT forward jet.

Energy bin	q	g	all
150 GeV$p_T > 90$ GeV	147	124	276
250 GeV$> p_T > 150$ GeV	157	87	228
450 GeV$> p_T > 250$ GeV	71	24	96

Alwall Hiramatsu Nojiri in preparation

ISR jet for mixed production and non-forced decay

- non-force decay -> sparticle decays all possible decay channel. more jets in the final state.
- but ISR parton (in Madgraph matched gluino gluino+ jet sample) leads j_i, i<6, because jets from final decay chains are softer.



- cut 450 GeV<M_{T2}min(5jet) <700GeV+ standard SUSY cuts. (upper bound must be set by inclusive mt2 end point.

Alwall , Hiramatsu, Nojiri in preparation

Summary

- gluino production should come with a hard ISR. (dominant process is not "LO" process).
- ISR can be removed under the assumption that the ISR exists.
- PS dependence reduced with additional jet.
- Model independent determination of the interaction of heavy colored particle.
    - forward jet→ particle with no u (d) numbers. gluino pair production, top partner pair production
    - no forward jet → direct coupling to u and d dominate production. s-up, s-down, KK up, KKdown quark, quark partner in little Higgs model.