The Night before the LHC

The accelerator is aligned with care,
in hopes beams soon would be there

.

Mihoko M. Nojiri
(KEK & IPMU)

a famous poem

The Night before Christmas

'Twas the night before Christmas,
when all through the house
Not a creature was stirring, not even a mouse;

The stockings were hung by the chimney with care,
In hopes that St. Nicholas soon would be there;

by Clement Clarke Moore

Not quite “full scale“ this year but

- I gave a talk in SUSY 2006, when it was scheduled in 2007.

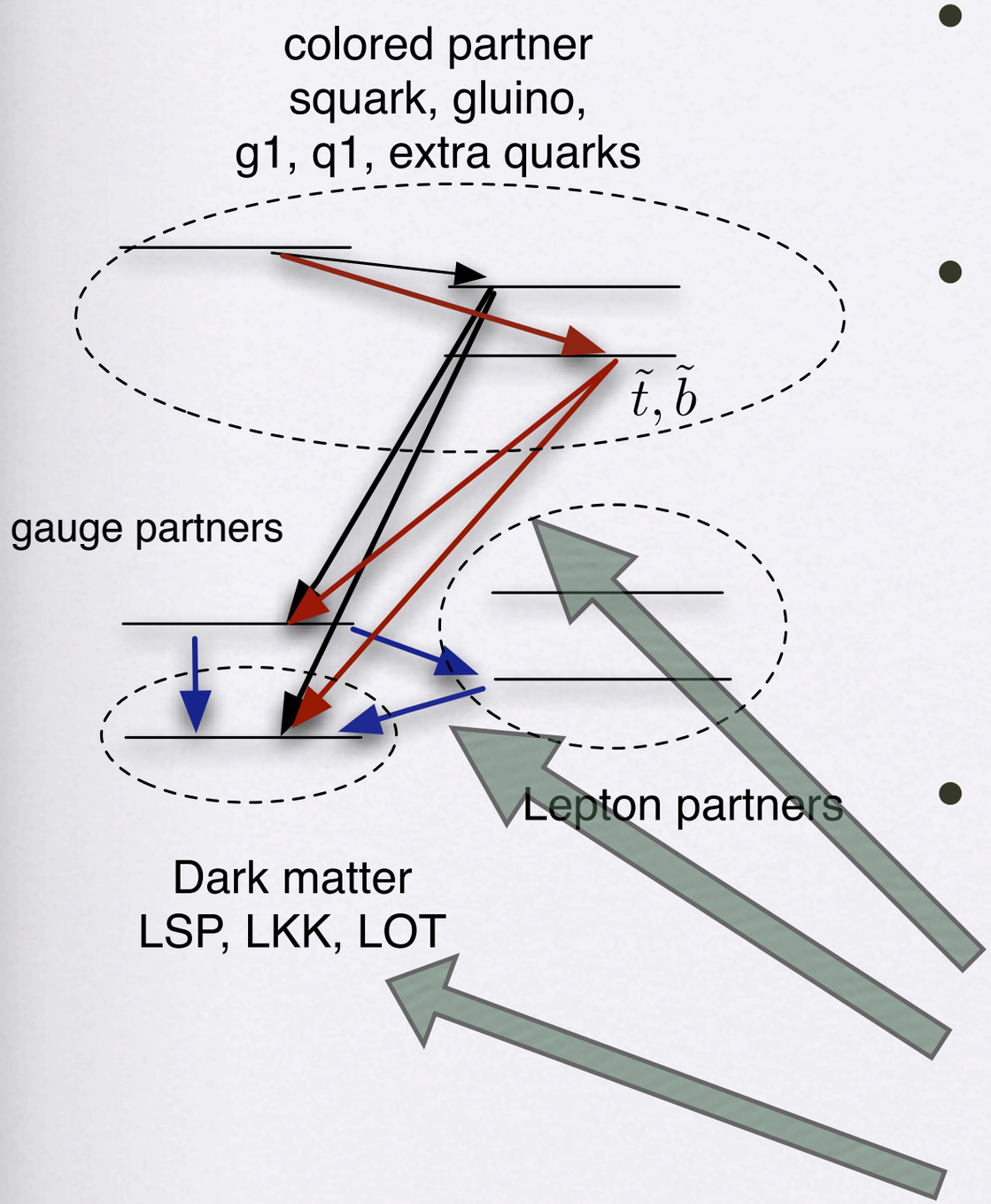
- Though, it is not quite in 14TeV, LHC may be starting this year. 10 TeV by Oct? Good year?? GLAST also launched on June 11, 2008, and working so far.

- Theorists all hopes something new, “the gift”, and you must have your special plans for “the night before the LHC” (the item may vary from CMSSM minimum to unparticle, though.) Real people(Ex and Acc) are working like hell... quenches, crygentic systems,....

- Most likely the era of “freedom of model building” (SUSY, e-dim, black holes, branes....) will over. There will be more data, more constraints, more handle

- but when? and how?

I have shown this slide so many times



- **"SUSY signature"** "Models with new colored particles decaying into a stable neutral particle--LSP"
- "New physics" are migrated into SUSY category.
  - Universal extra dimension lightest of first level KK is stable. .
  - Little Higgs model with T parity. T parity in the model, T odd sector has stable particle (AH)
- Signal: assume mass difference is large

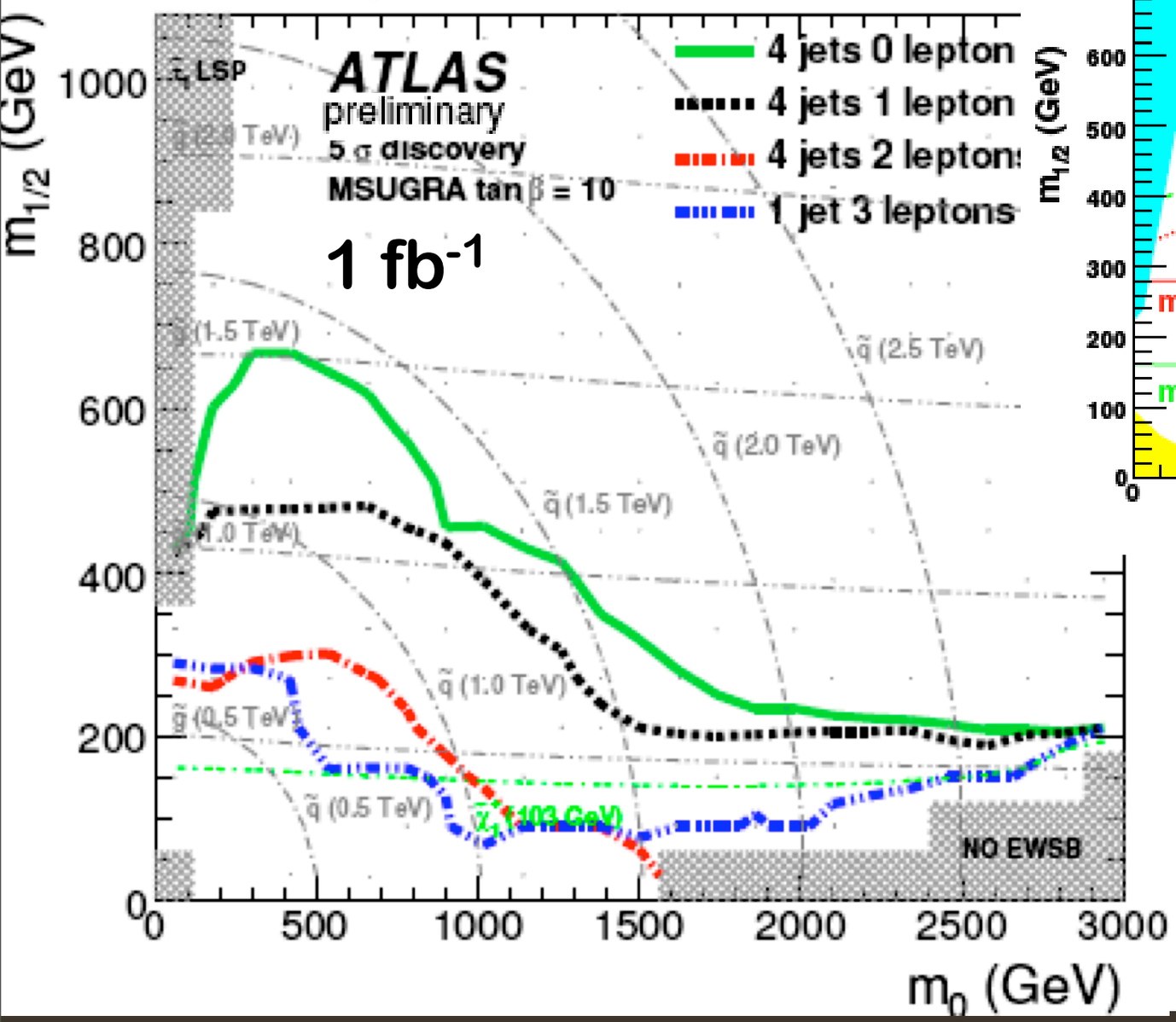
  High P_T jets (p_{T1}>100GeV, $p_{T2,3,4}$>50GeV)

  p_{Tl}>20GeV, S_T>0.2

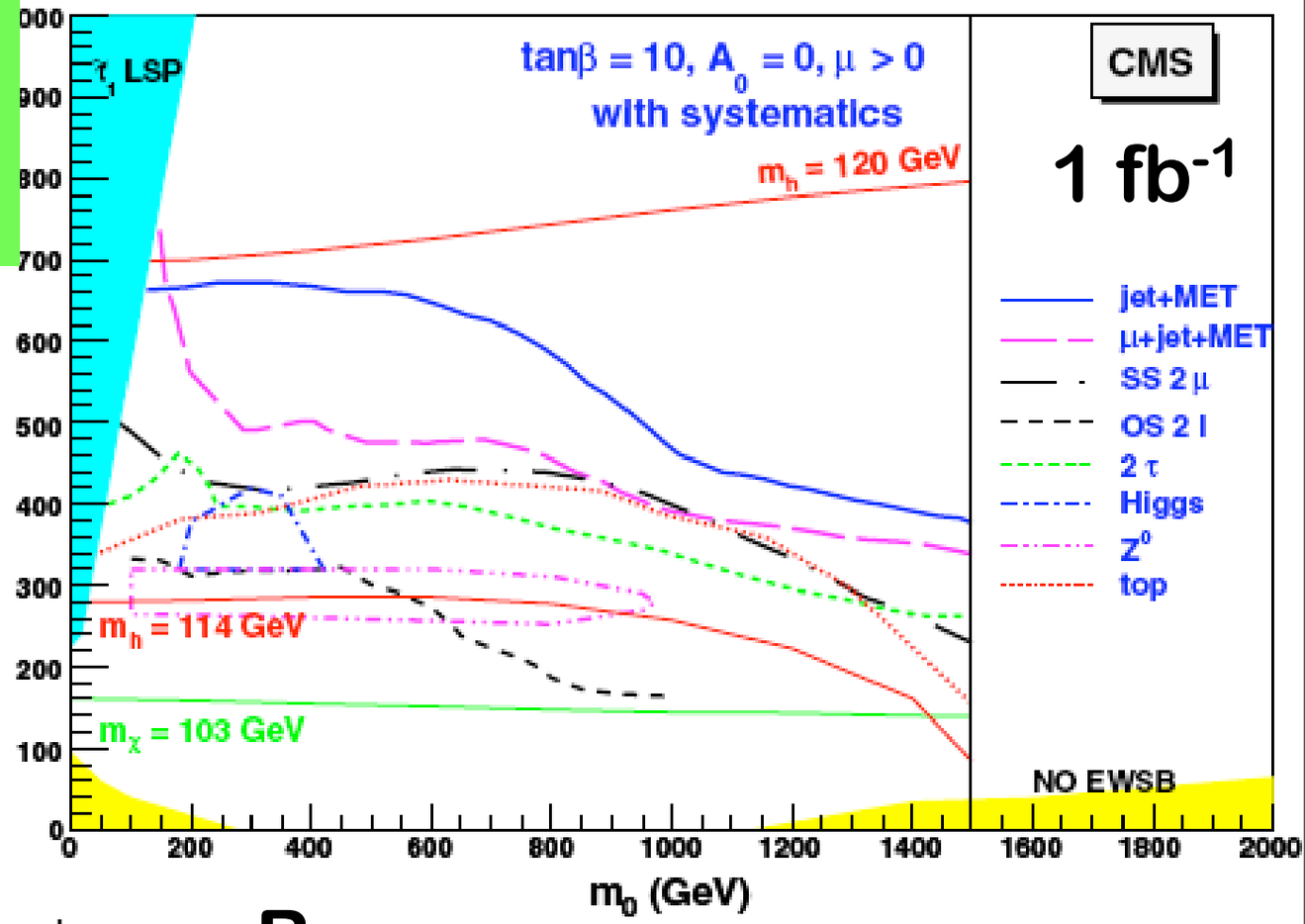
  E_{Tmiss}> max(100GeV, 0.2M_{eff})

mSUGRA reach at ATLAS & CMS (1 fb^{-1})

In principle, we can say lots using first 1fb -1. understand of background is the key.



contours (incl. systematics)



- **Beware:**
  - **Different significance definitions!**
  - **CMS: syst. uncertainties estimated for 10 fb^{-1} (except 0-lepton: 1 fb^{-1})**

new direction since last year "m_{T2}"

- M_{T2} uses missing E_T as the constraint on possible LSP momenta to get the parent sparticle mass info . It has been known as useful quantity for years(Barr, Lester, Stephens hep-ph/0304226)

- The M_{T2} is the function of a test LSP mass. Cho et al(arXiv: 0709.0288) realized that the MT2(m_{test}) has kink at the true LSP mass if the decay final state is 3 body. Many applications in lepton channel, gauge mediation(sorry I do not write all references here.....)

- "Inclusive MT2" can be used in more general context to determine "the highest sparticle mass". (MMN et al arXiv: 0802.2412)The use for early stage model discrimination is discussed by Hubisz et al (arXiv:0805.2398)

- It is also useful to guess m(squark) and m(gluino) simultaneously (Nojiri,Sakurai, Shimizu, and Takeuchi to appear.)

NEW!

classic m_{T2} (Barr, Lester,Stephens)

MT2 can be defined when there are two visible objects and the missing momentum of a event as follows

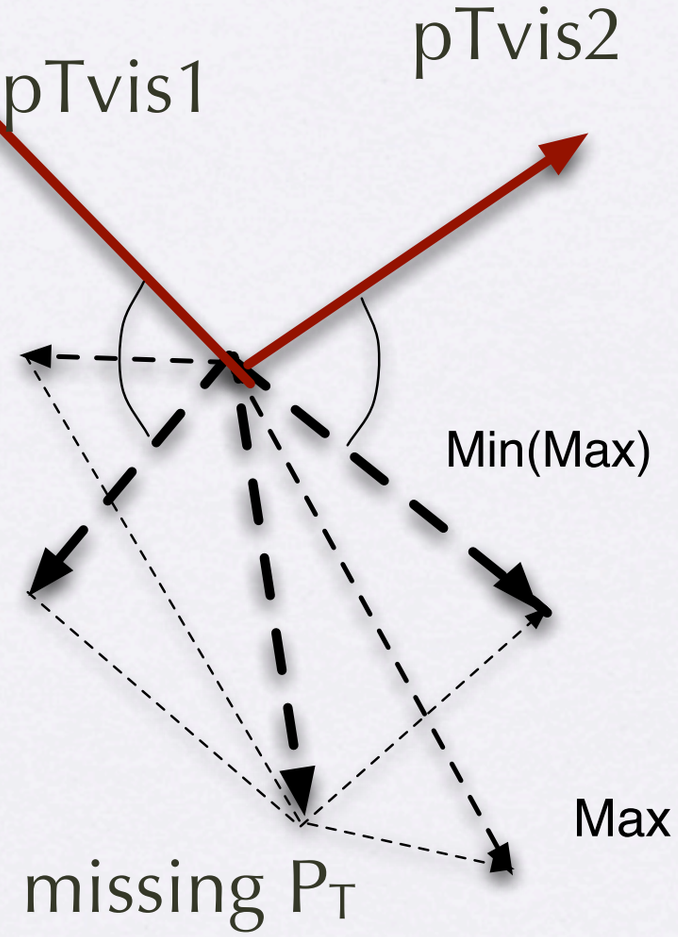
$$m_{T2}(\mathbf{p}_T^{vis(1)}, m_{vis}^{(1)}, \mathbf{p}_T^{vis(2)}, m_{vis}^{(2)}, m_\chi) \equiv \min_{\{\mathbf{p}_T^{\chi(1)}+\mathbf{p}_T^{\chi(2)}=-\mathbf{p}_T^{vis(1)}-\mathbf{p}_T^{vis(2)}\}} \left[\max\{m_T^{(1)}, m_T^{(2)}\}\right]$$

- I always decided to skip this awfully complicated definition in my SUSY talks .

- motivated by hadron collider transverse mass analysis, expand it for two missing massive particles (LSP).

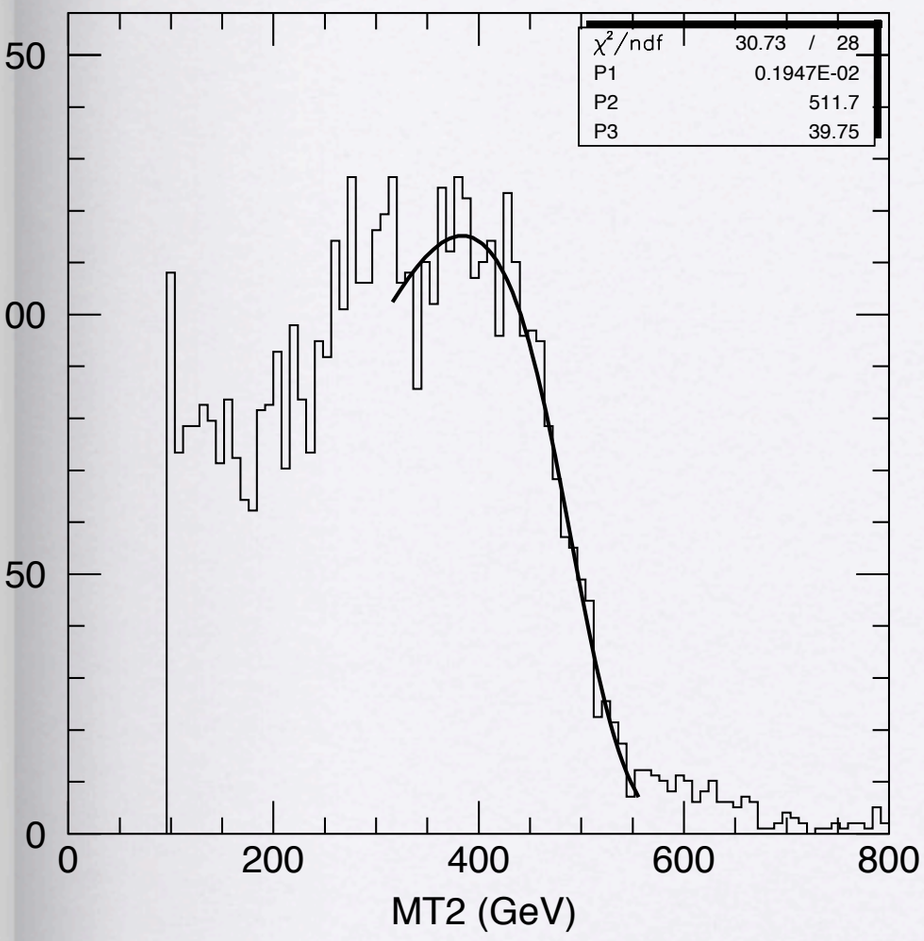
- a set of true LSP momenta can be trial LSP momenta, so min(max(M_{T1},M_{T2})) is bounded above by the parent sparticle masses of the events.

- Amazingly, it works. (see next slide.)



from LHC/LC(2004) and recent ATLAS study

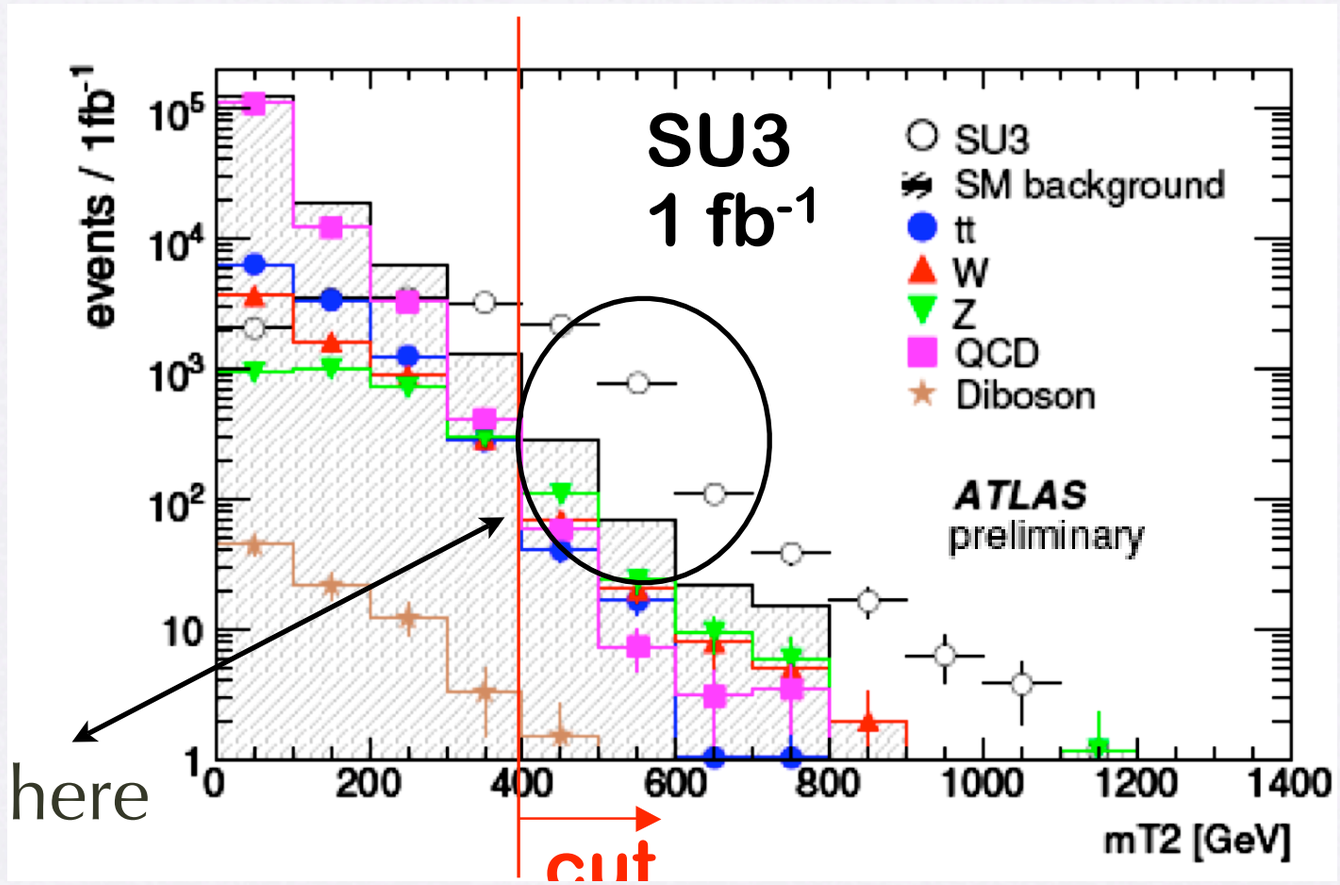
$$pp \to \tilde{q}_R \tilde{q}_R \to 2j\tilde{\chi}_1^0\tilde{\chi}_1^0$$



need high cuts
such as $p_T(jet_{1,2})$>200GeV

squark mass from very sharp
mT2 end point.

good signal background ratio,but
QCD background maybe important



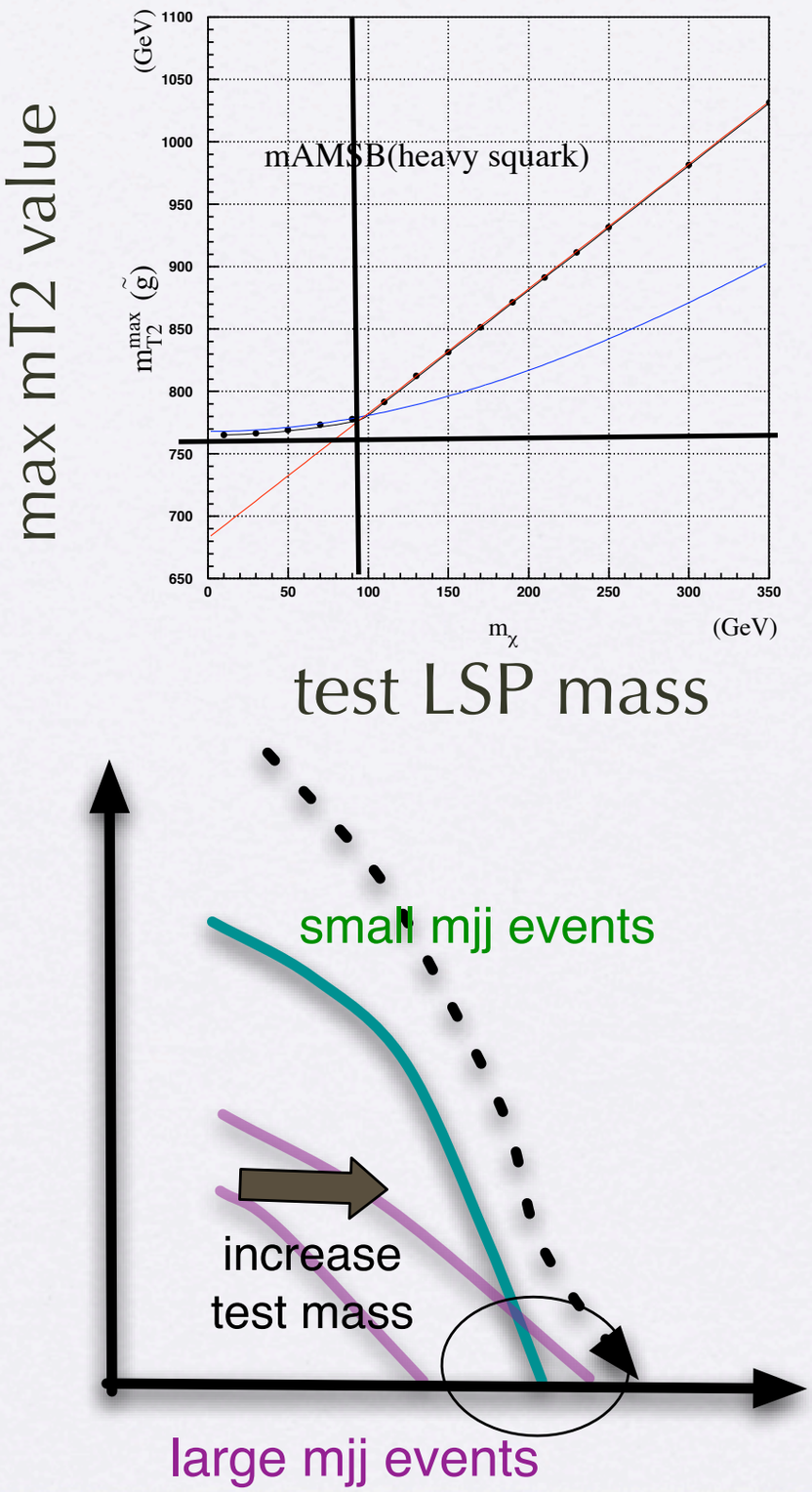
Largest S/N here

second example LSP mass and M_{T2}

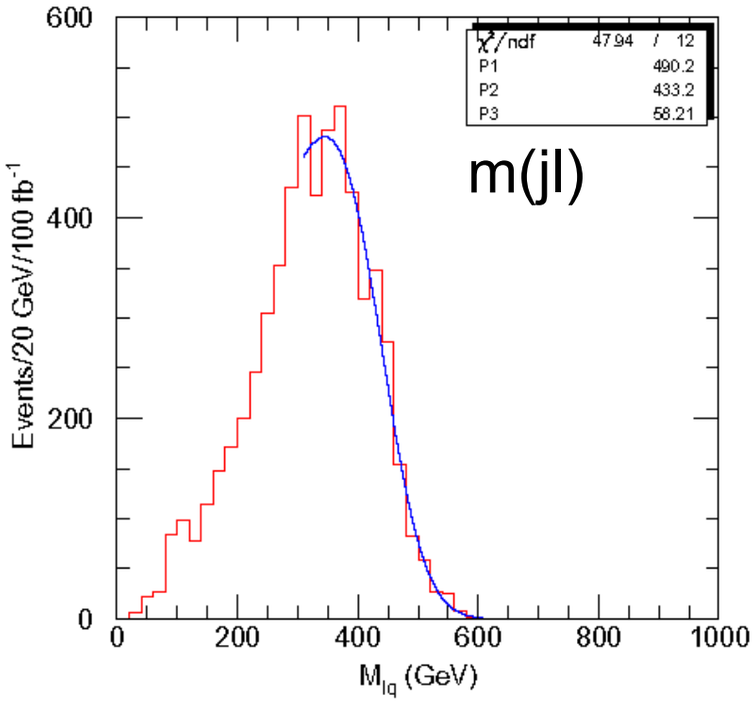
Cho Choi Kim Park
arXiv:00711.4526 arXiv:0709.0288

$$pp \to \tilde{g}\tilde{g} \to 4j\tilde{\chi}_1^0\tilde{\chi}_1^0$$

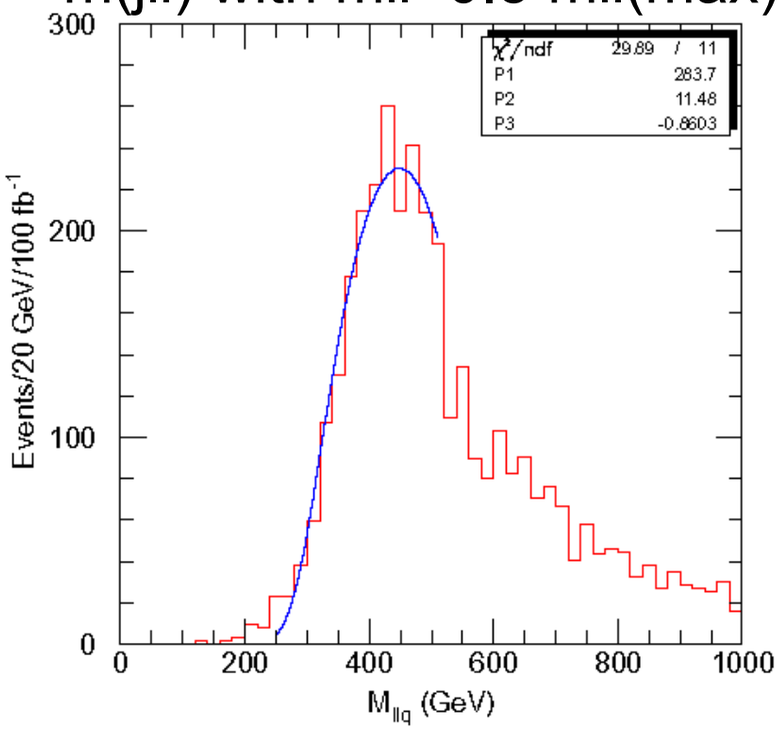
- Kink at mtest=mLSP. LSP mass from jets +missing Et channel.
- The end point events different for mtest<mLSP and mtest> mLSP.
- The relation is not sensitive to initial state radiation, sparticles boosts.
- Many systematics. Jet momentum, fitting function dependence--especialy near the kink.

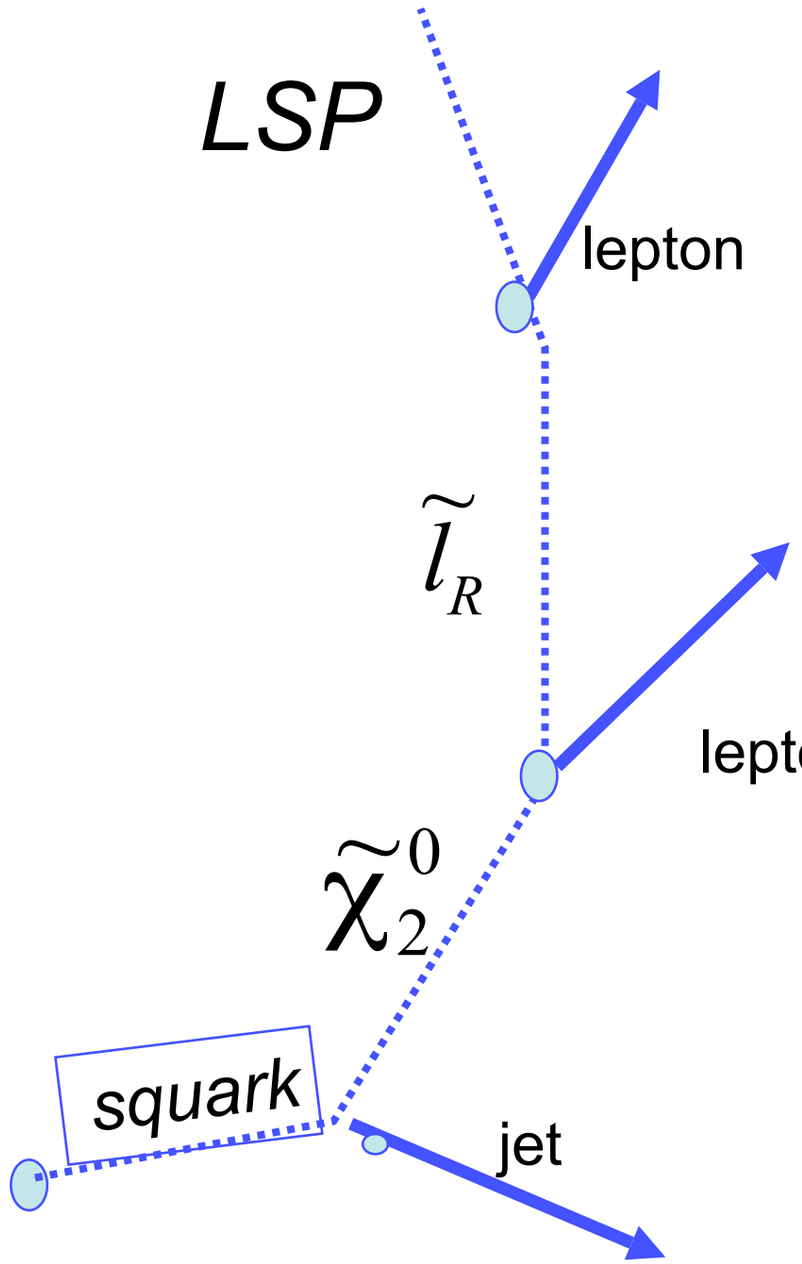


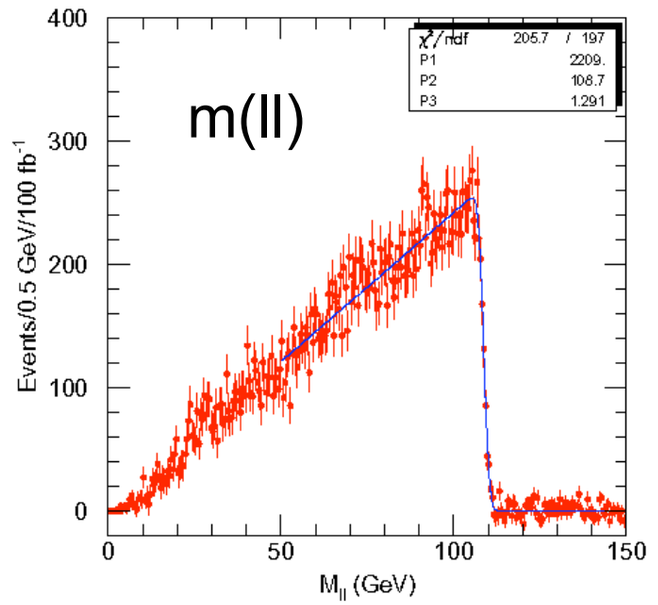
LSP mass determination from mll chananel
Br(sq-> chi02-> sl-> LPS) =0.3 x 0.1

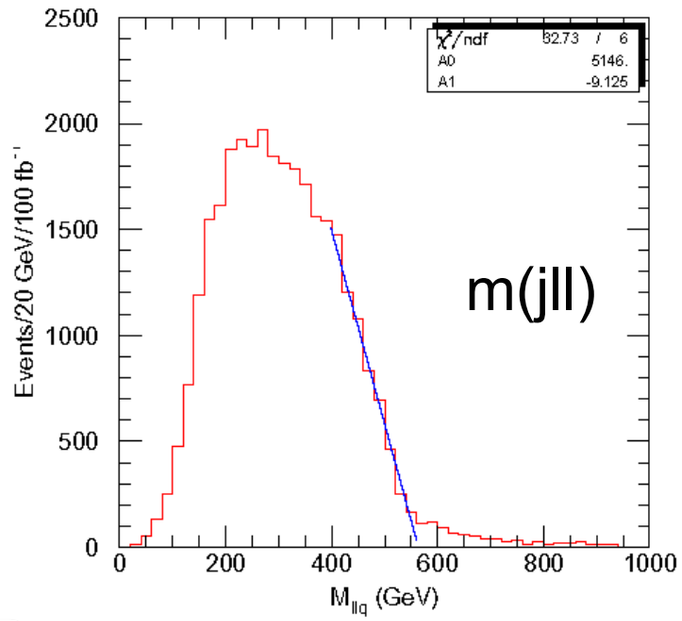


m(jll) with mll>0.5 mll(max)





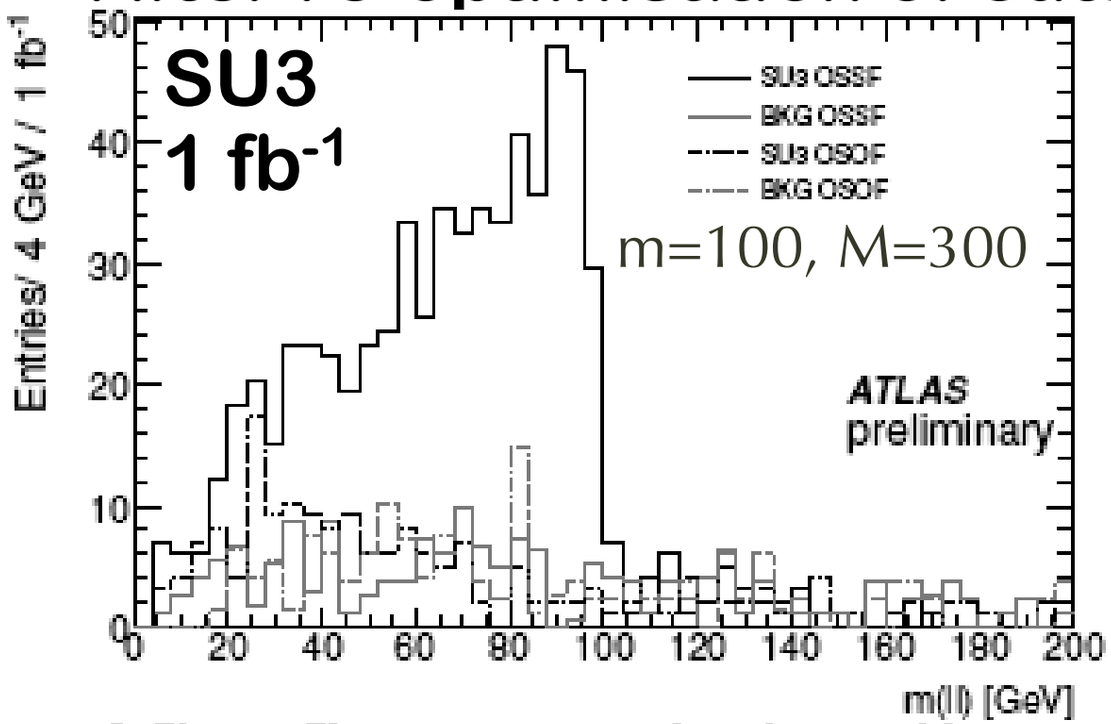


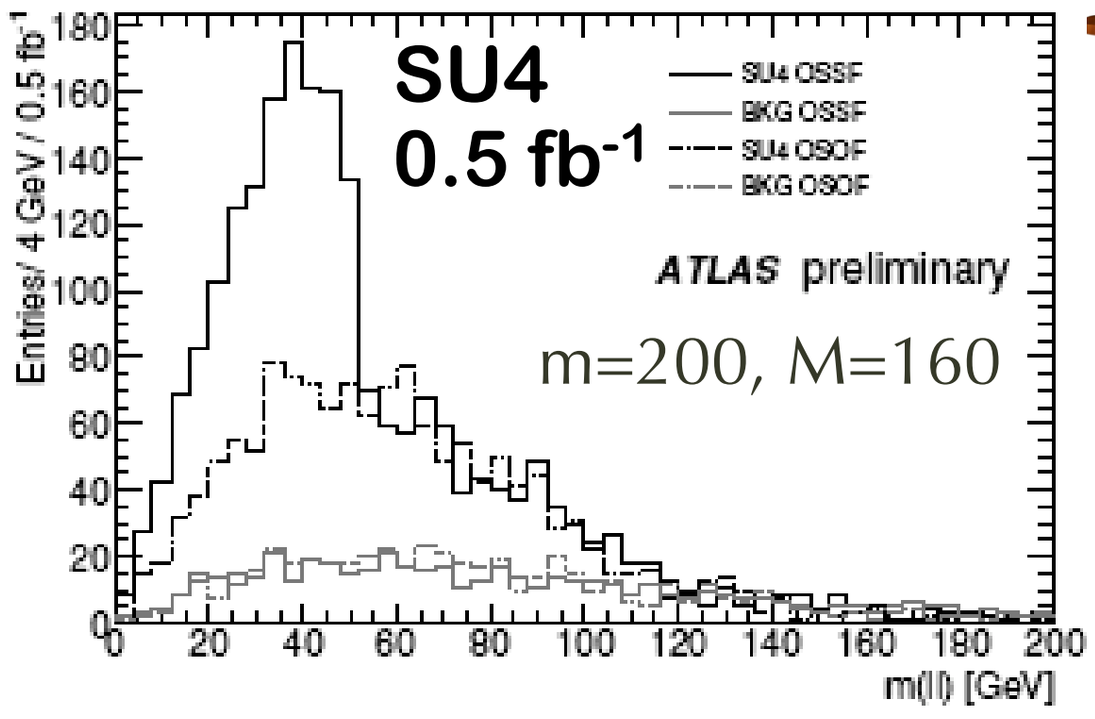


from ATLAS TDR

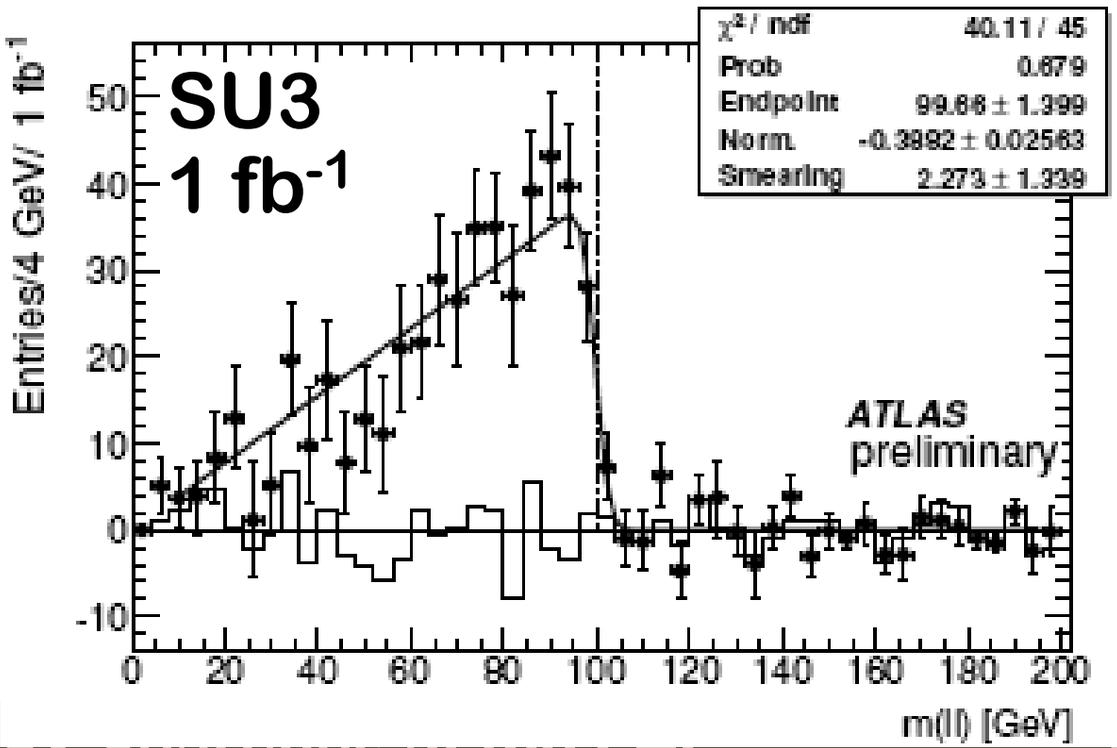
Early SUSY measurements with 1 fb^{-1} (if M_{SUSY} < 1 TeV)

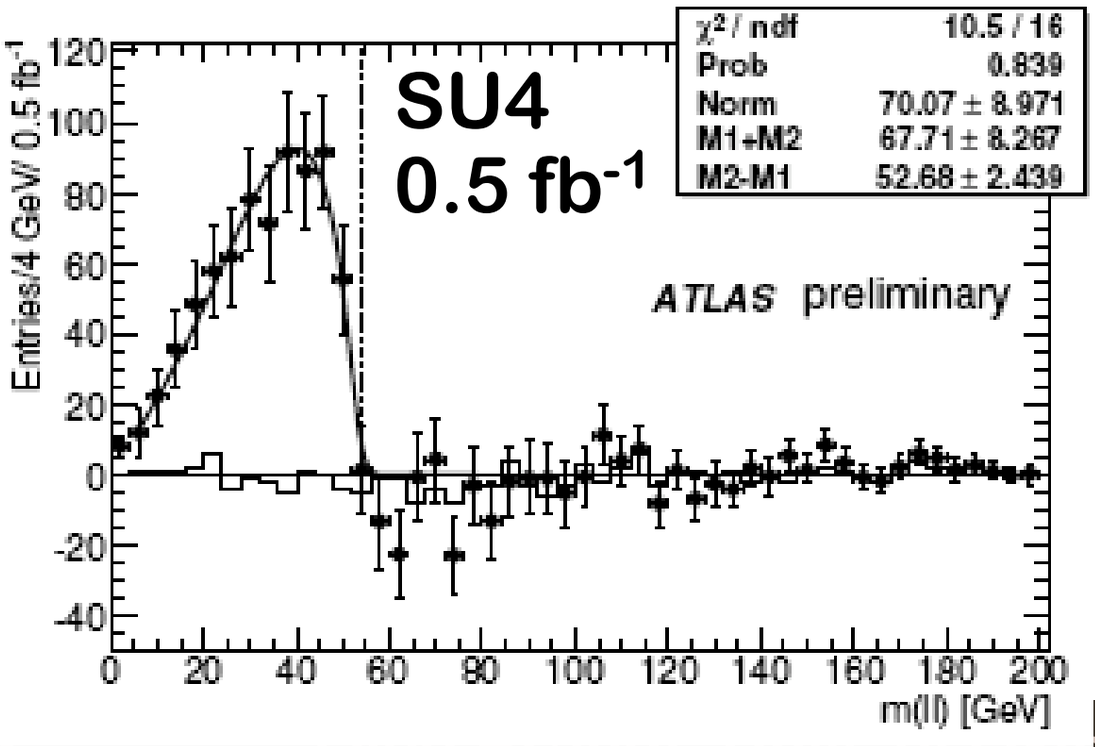
- **After re-optimisation of cuts:**





- **After flavour substraction:**





MMN
SUSY06

summary of SPS 1a

from LHC/LC study

particle	mass	error(low)	error(high)	
gluino	595	16.3	8.0	bbll
squark(L)	540	21.2	8	
squark(R)	520	17.7	11.8	M_{T2} 10GeV sys
$\tilde{\chi}_4^0$	378	14.6	5.1	
$\tilde{\chi}_2^0$	177	13.4	4.7	
$\tilde{\chi}_1^0$	96	13.2	4.7	

Good results but only for light slepton ,
low mass SUSY and high luminosity

- Most of mass error is LSP mass error. Mass differences are known rather precisely
- Access to 3 neutralino mass, information on 3 of (M1,M2,μ, tanβ)
- selectron and smuon mass error is about same to that of N02
- stau mass also can be measured from tau tau end point. many fake tau background. Need more study, but don't be nervous.

hemisphere method and inclusive m_{T2}

MMN, Shimizu, Kawagoe, Okada

- define M_{T2} variable without specifying initial state. (work for complicated decay chains)

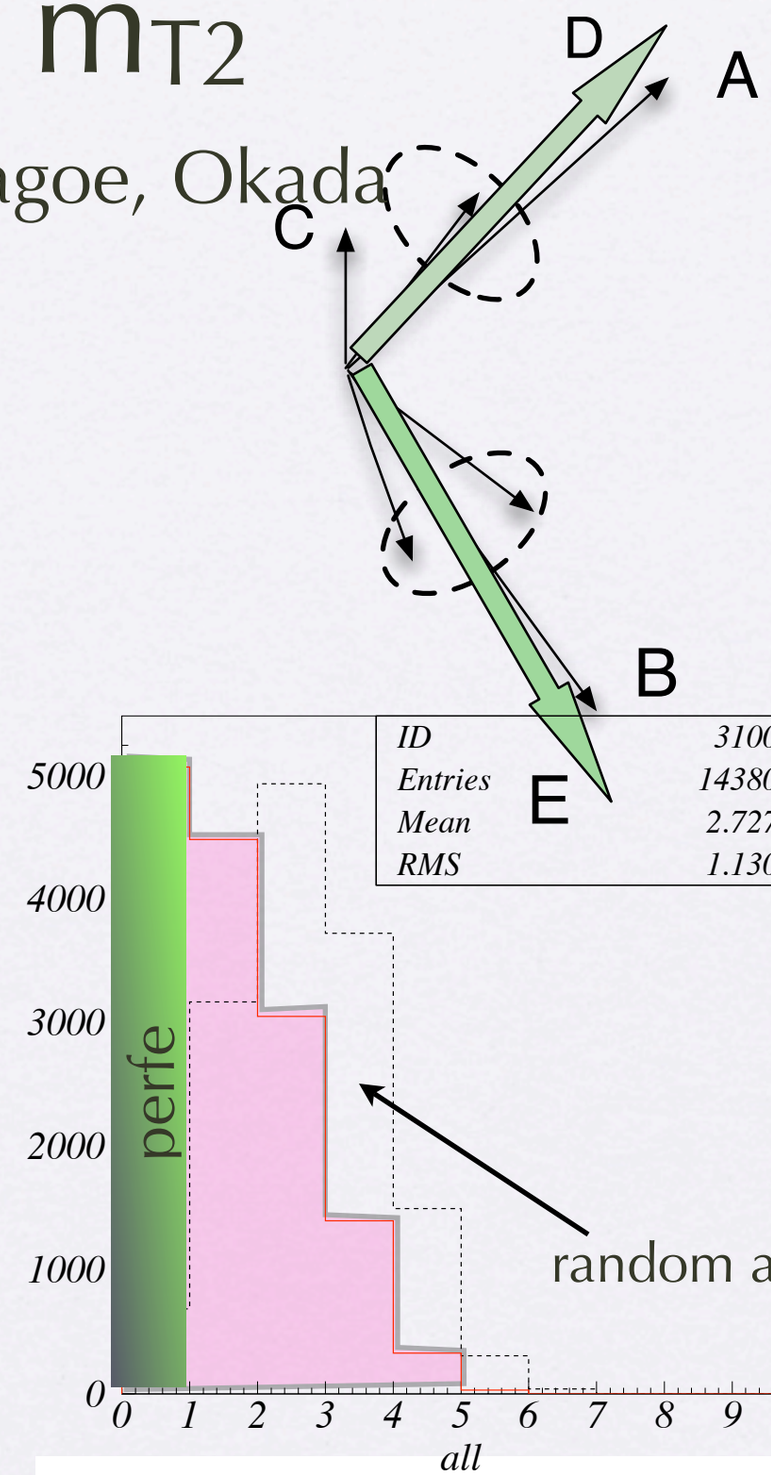
- take two leading jets (A, B) , associate the other jets (C) into either A or B using Lund distance measure. Take Hemisphere momentum,the sum of jet momenta in the same group(D, and E) , as visible object.

- "decay products of a sparticle ⇄ a hemisphere" with reasonable probability. (~30% is perfect) mis-assignment tend to give small m_{T2}.

- **Other approach** MTGEN(Lester and Bar 0708.1028)

try all particle combination and minimize.

from Nojiri ,Shimizu, Takeuchi ,Sakurai in preparation

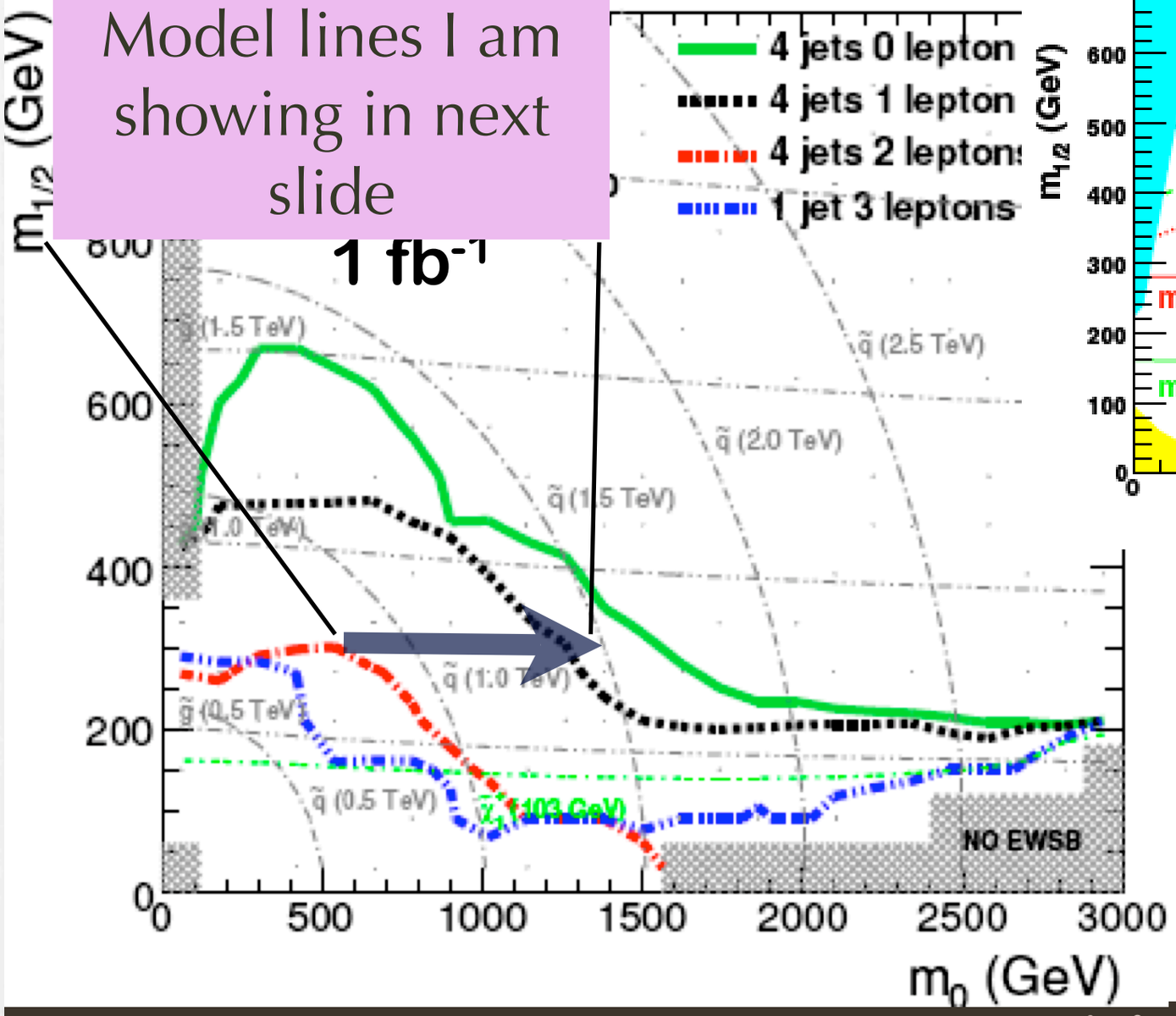


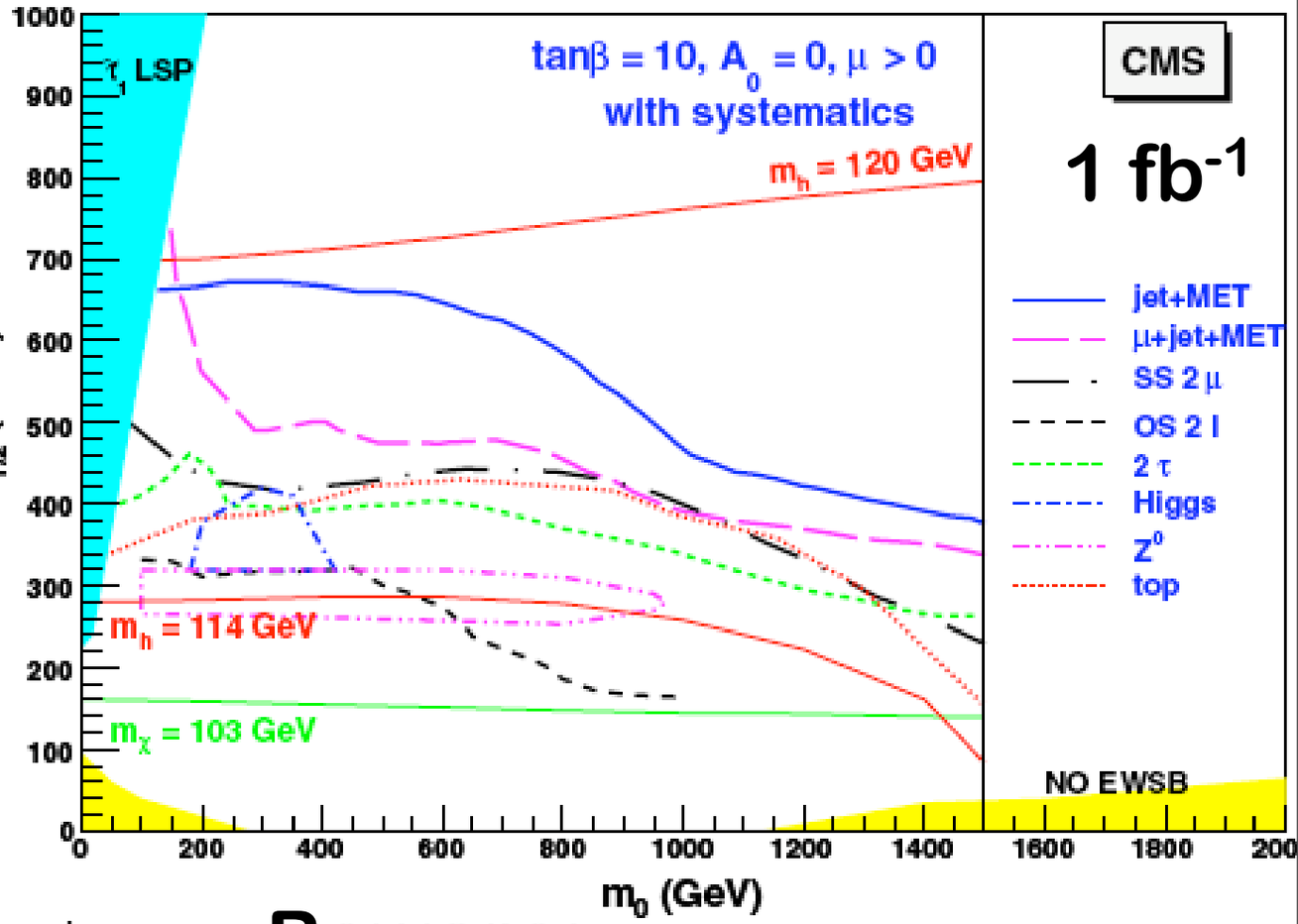
What happens if we apply "the inclusive MT2" to SUGRA like points (but turning mu paramter so that Ωh2~0.1)

$A_0 = 0$, $\mu > 0$, $\tan\beta = 10$, 36 contours (incl. systematics)

- **Assumed uncertainties (ATLAS):**
  - **QCD: 50%**
  - **tt, V+j: 20%**

Model lines I am showing in next slide





- **Beware:**
  - **Different significance definitions!**
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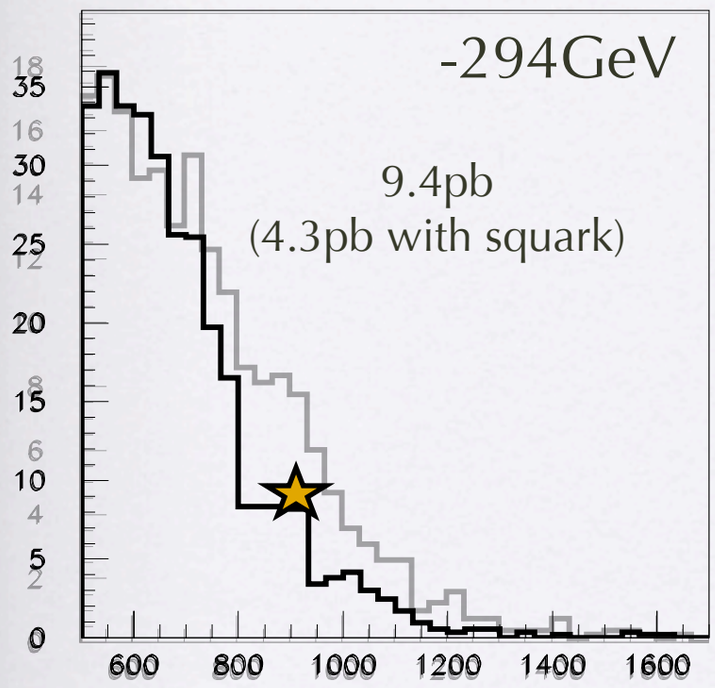
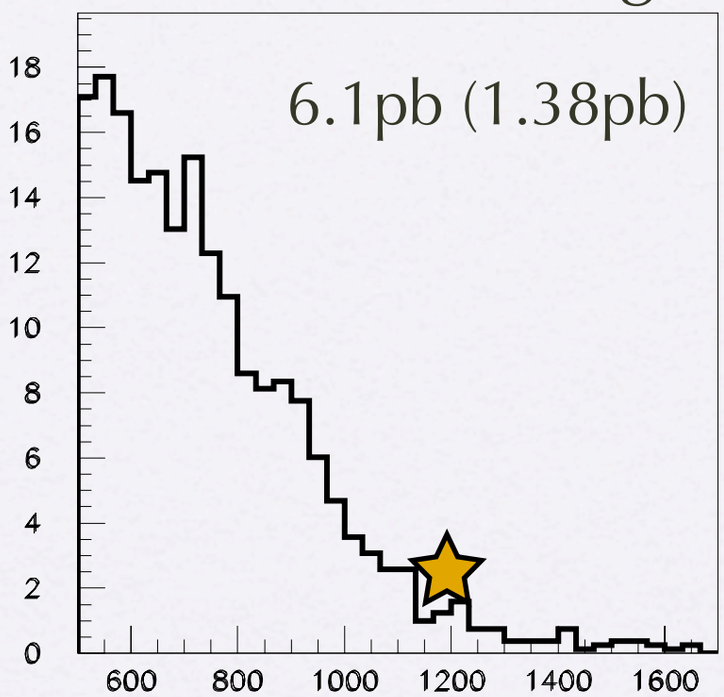
tracing squark mass

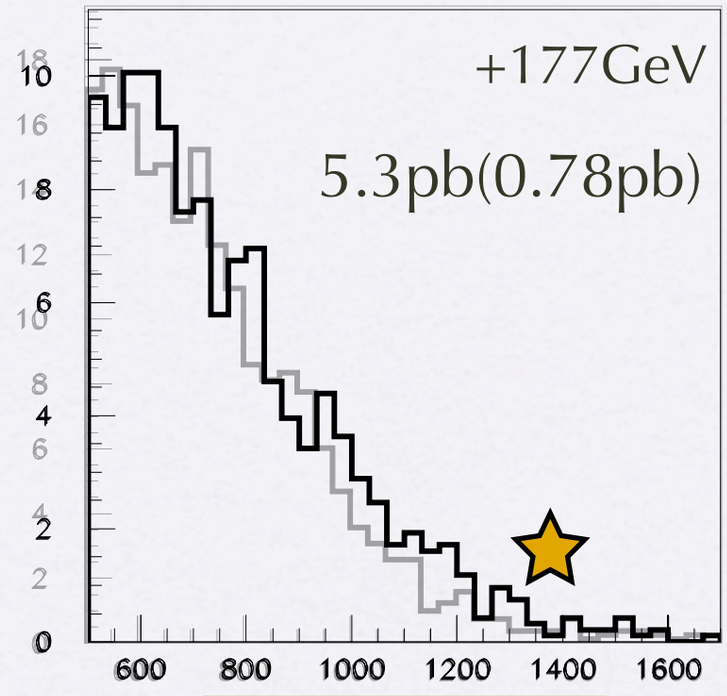
number of events/1 fb (50000events generated and scaled)



msq=881GeV
mgl=745

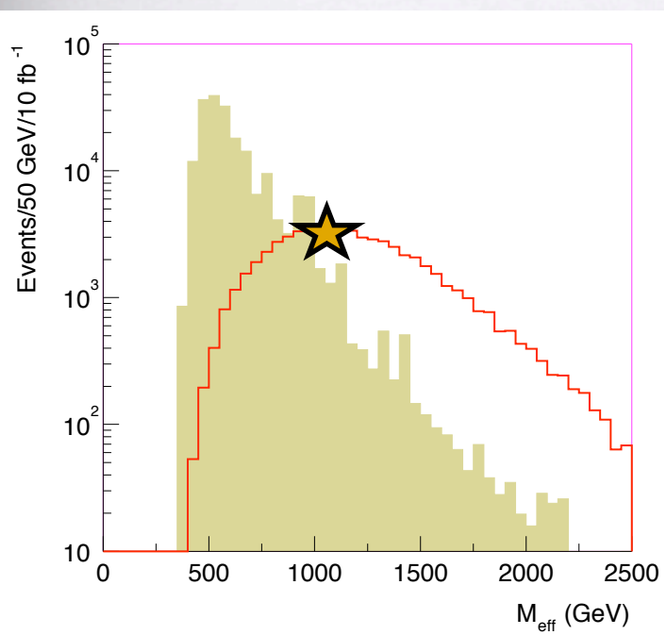


msq=1175GeV
mgl=773



msq=1342GeV
mgl=795

Isasusy+herwig+AcerDet



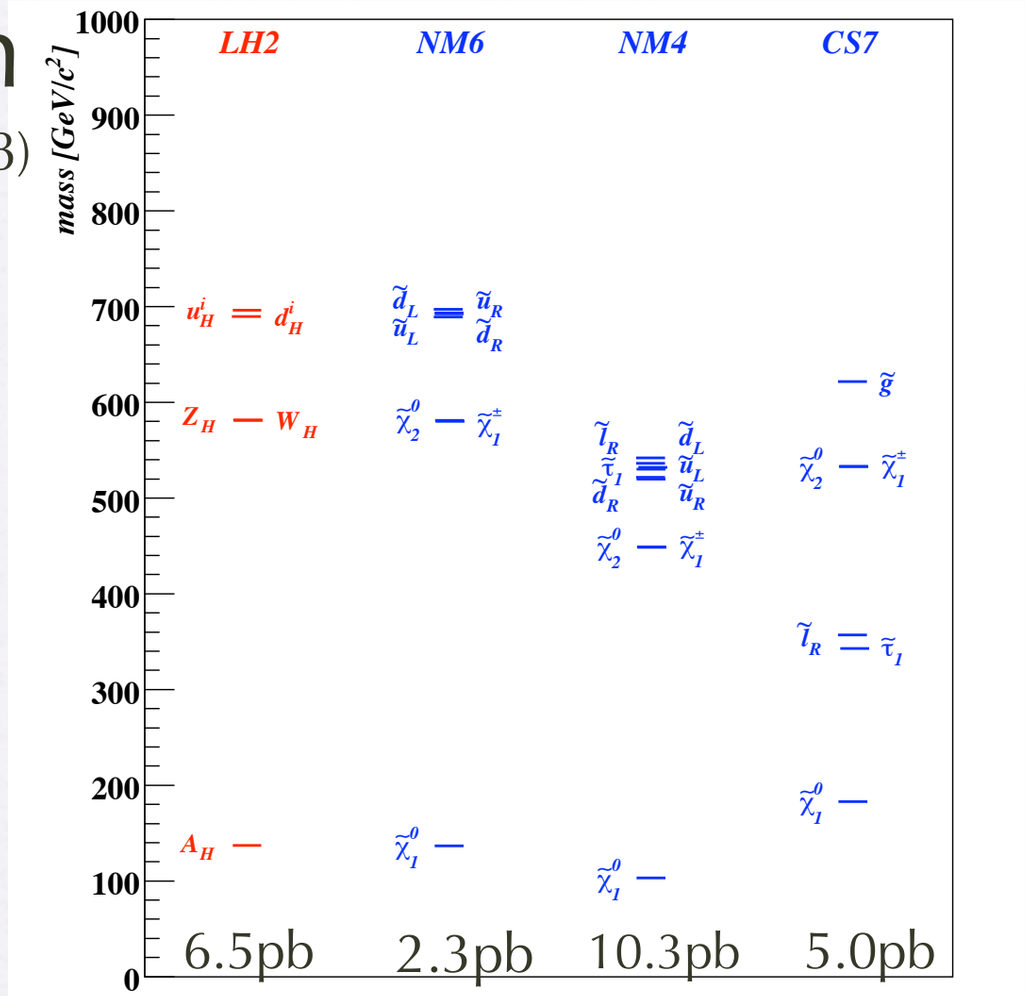
Maybe inclusive M_{T2} is better than M_{eff} because BG is small in the region sensitive to the mass.
note: M_{eff} peak position is average gl/sq mass, but the region may be affected by background.

Other approach MTGEN(Lester and Bar 0708.1028)
try all particle combination and minimize.

early stage discrimination

(Hubisz,Lykken,Pierini,Spiropulu arXiv:0805.2398)

- MT2 is more sensitive to the SUSY mass scale itself.
- LH model: quark partner (spin 1) large cross section
- Corresponding SUSY(cross section with same order) has lighter mass. inclusive MT2 becomes very good measure to separate them.
- using shape rather than end point. “misusing”? need more understanding of the shape.



Little Higgs

SUSY models

LH2	NM4		CS7	
LH2				
100	r(mT2-500)	4.9σ	r(mT2-500)	6.7σ
	r(Meff1400)	3.0σ	r(MET420)	6.5σ
	r(M1400)	2.7σ	r(4j)(3j)	4.0σ
1000	r(mT2-500)	14.1σ	r(mT2-500)	18.9σ
	r(mT2-300) [TriJet]	11.0σ	r(MET420)	16.7σ
	r(mT2-400) [DiJjet]	7.9σ	r(mT2-500) [TriJet]	8.8σ
	r(Meff1400)	7.2σ	r(4j)(3j) [DiJet]	7.3σ
	r(M1400)	6.6σ	r(mT2-300) [DiJet]	6.7σ
NM4				

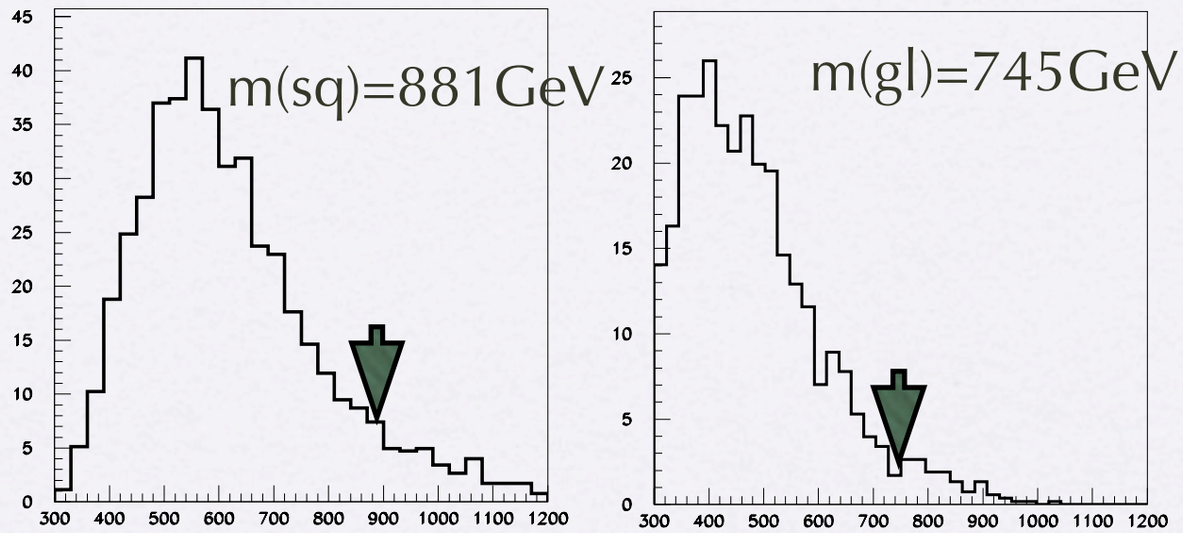
$100pb^{-1}$ may not be realistic

“1 jet subtracted mT2” (NEW!)

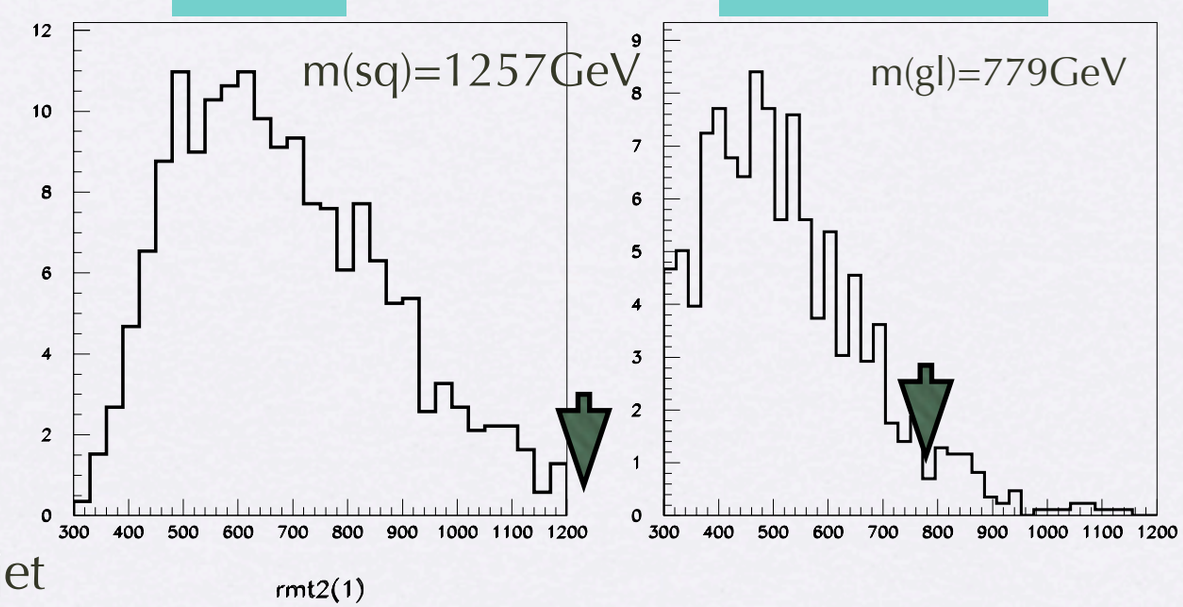
- gluino-squark co-production is dominant part of SUSY production cross section.
- Squark either decay into gluino/ or neutralino/chargino. High pT jets are expected.
- So, remove the highest pt jet from the jet system, calculate M_{T2} for the rest, it gives us gluino mass if m(squark)>m(gluino)
- Determine both gluino and squark masses

Nojiri, Sakurai, Shimizu, Takeuchi in preparetion

model f(9.5pb)



MT2 MT2(sub)



require only one jet with P_T> 300 GeV

model c(5.8pb)

E_{Tmiss} constraint and mass determination

MMN, Polesello, Tovey arXiv 0712.2718
similar by Cheng et al 0802.4290

- We have seen that missing Et constraint has independent LPS information.
- How about if we apply this to 4 lepton channel very well known channel

$\tilde{q}_L \to \tilde{\chi}_2^0 q \to \tilde{l}_R l q \to \tilde{\chi}_1^0 l l q.$ for both side

$$p_x(\alpha_1) + p_x(\alpha_2) = E_x^{miss},$$
$$p_y(\alpha_1) + p_y(\alpha_2) = E_y^{miss},$$

+10 event wise constraint for 8 unknowns (LSP momentum)

$$(p(a_1) + p(b_1) + p(c_1) + p(\alpha_1))^2 = (p(a_2) + p(b_2) + p(c_2) + p(\alpha_2))^2 = m_\delta^2,$$
$$(p(a_1) + p(b_1) + p(\alpha_1))^2 = (p(a_2) + p(b_2) + p(\alpha_2))^2 = m_\gamma^2,$$
$$(p(a_1) + p(\alpha_1))^2 = (p(a_2) + p(\alpha_2))^2 = m_\beta^2,$$
$$(p(\alpha_1))^2 = (p(\alpha_2))^2 = m_\alpha^2.$$

with 4 end point info

State	Input	End-Point Fit		Hybrid Method, E_T^{miss}		Hybrid Method, no E_T^{miss}	
		Mean	Error	Mean	Error	Mean	Error
$\tilde{\chi}_1^0$	96.05	96.5	8.0	95.8(92.2)	5.3(5.5)	97.7(96.9)	7.6(8.0)
$\tilde{l}_R$	142.97	143.3	7.9	142.2(138.7)	5.4(5.6)	144.5(143.8)	7.8(8.1)
$\tilde{\chi}_2^0$	176.81	177.2	7.7	176.4(172.8)	5.3(5.4)	178.4(177.6)	7.6(7.9)
$\tilde{q}_L$	537.2–543.0	540.4	12.6	540.7(534.8)	8.5(8.7)	542.9(541.4)	12.2(12.7)

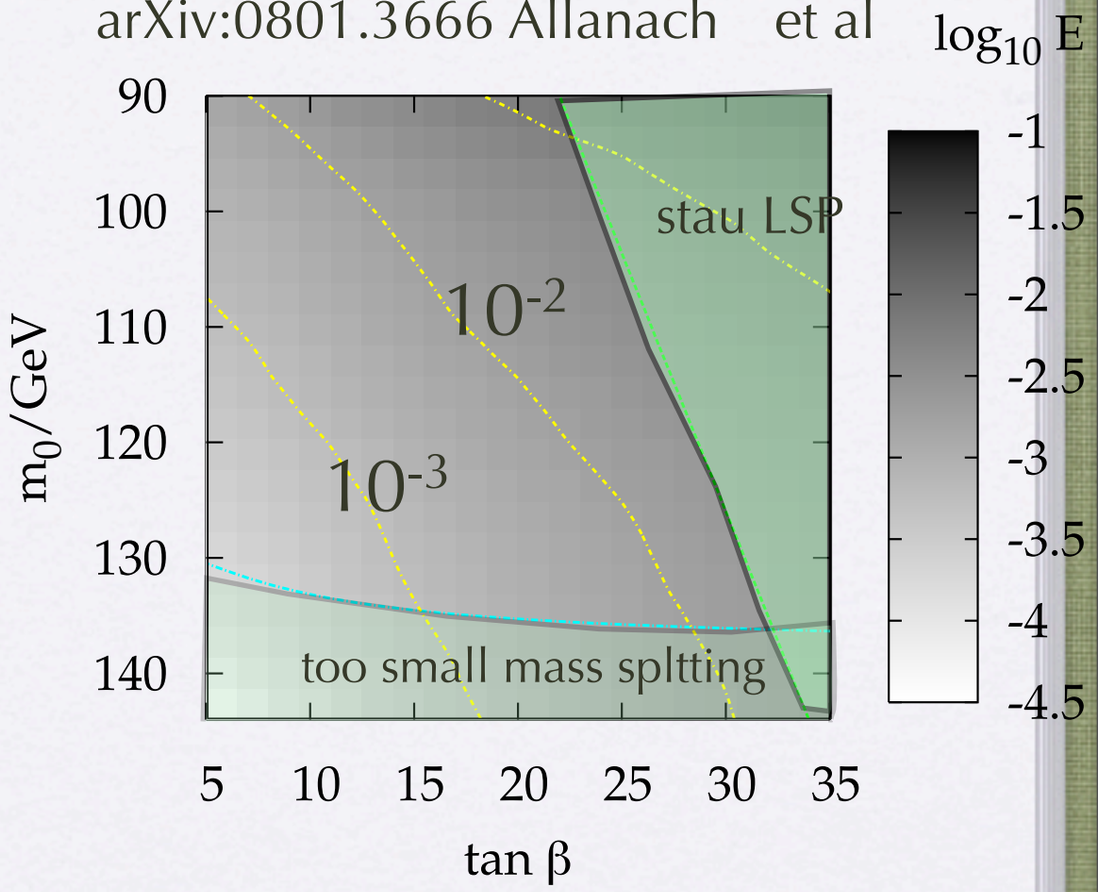
my other favorite “toys”
these days...
(now I can stop anytime)

Flavor and LHC --2 lepton end points and LFV

- If there is LFV, the mass splitting appears in mass eigenvalues as well. claimed end point error is O (0.1 GeV) (for sps1A)

- The error for mass splitting can be 10^{-4} level? (Allanach arXiv0801.3666) Remember that e and μ show different response to the detector.

arXiv:0801.3666 Allanach et al



near SPS1a, 30fb^{-1}

- Models: Wide valarety of models MSSM+ν, gauge meditation + SUGRA (for example Feng et al, horizontal symmetry, arXive0712.0674).

- Possibility to improve μ→e γ bounds (PSI, MEG)

Any discovery of non-universality at LHC would be exciting!

Stop sector (something I really want to see.)

The top-bottom edge

Polessello in Focus week (07) in IPMU

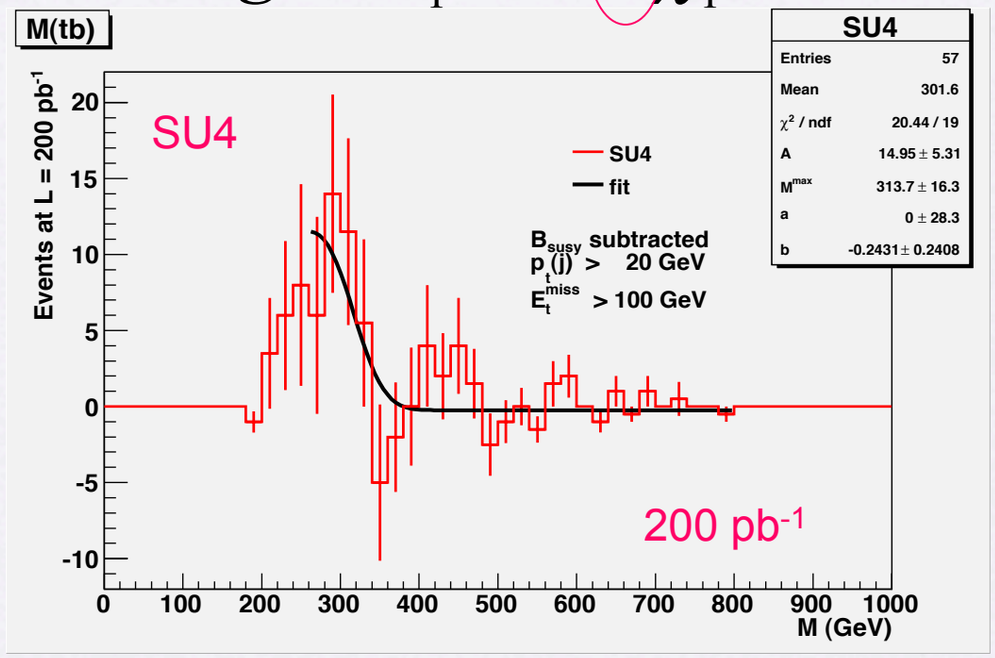
Work on Point SU4: BR($\tilde{g} \to \tilde{t}_1 t$)=42%, $\sigma(\tilde{g}\tilde{g} + \tilde{g}\tilde{q}) \sim 165$ pb

Study decay chain $\tilde{g} \to \tilde{t}_1 t \to tb\tilde{\chi}_1^{\pm}$

Channel previously studied by Hisano, Kawagoe, Nojiri in fast sim

Reconstruct fully hadronic top, and subtract jjb combinatorial using sidebands

$$\tilde{g} \to \tilde{t}_1 t \to tb\tilde{\chi}_1^{\pm}$$



Full simulation

$M(tb)$

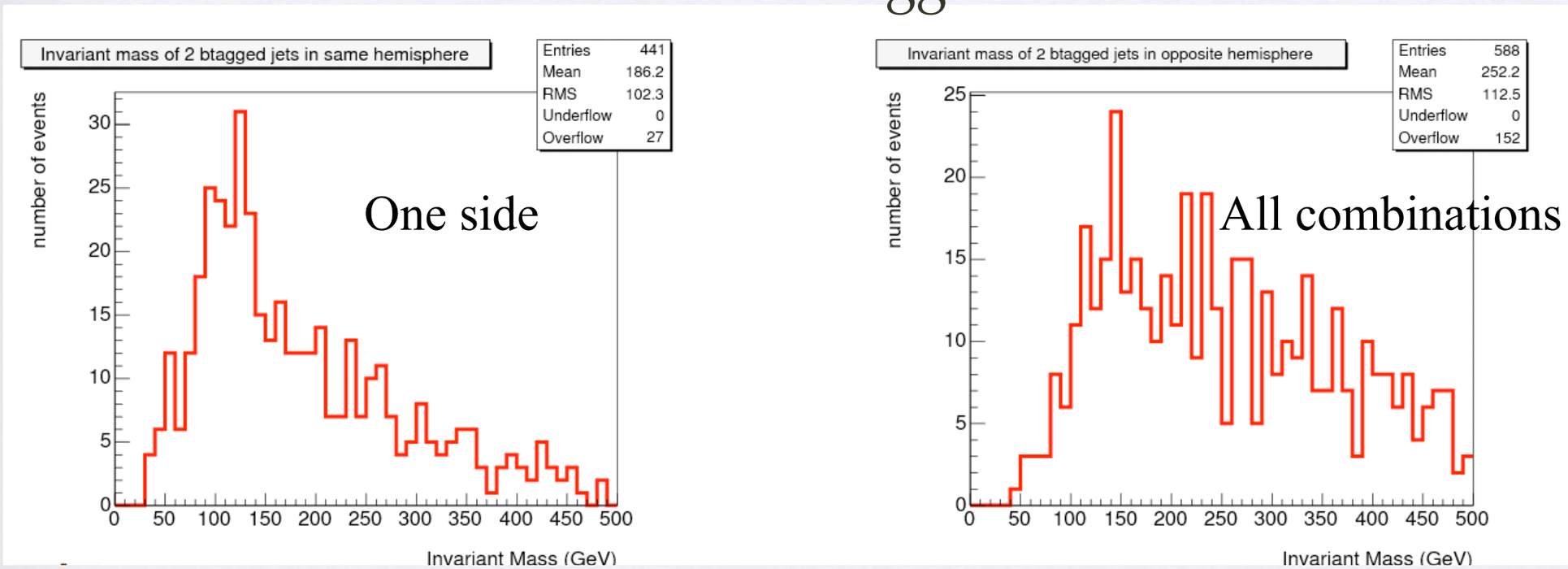
For this very low mass point, edge in principle visible with very little statistics

In practice need really good understanding of detector to attack this channel

jet reconstructions in SUSY events

- In some class of SUSY model, colored particles are heavy, therefore W, Z, H, top from their decays is relativistic.
- The decay products go colinear. typically find in small ΔR
- For example jet paris in a hemisphere-> less combinatrial background.

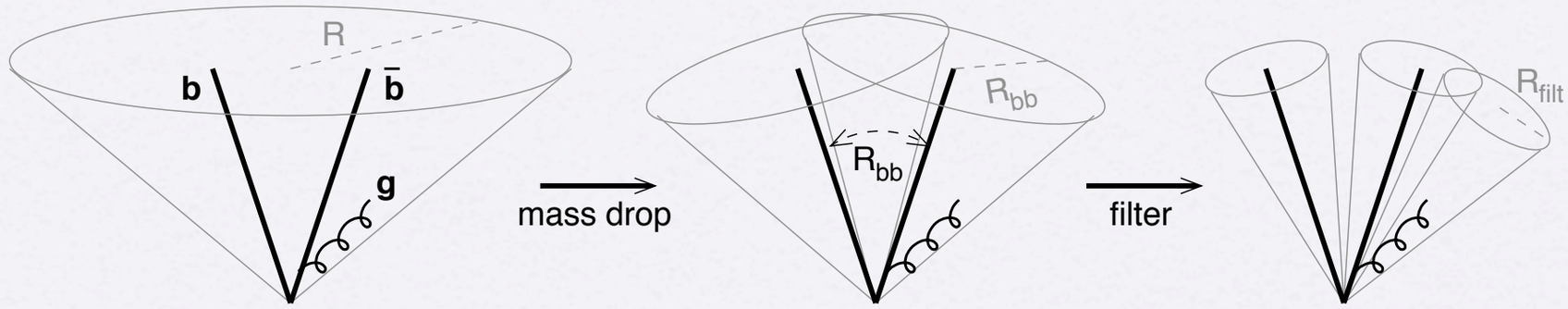
CMS Higgs search in SUSY events



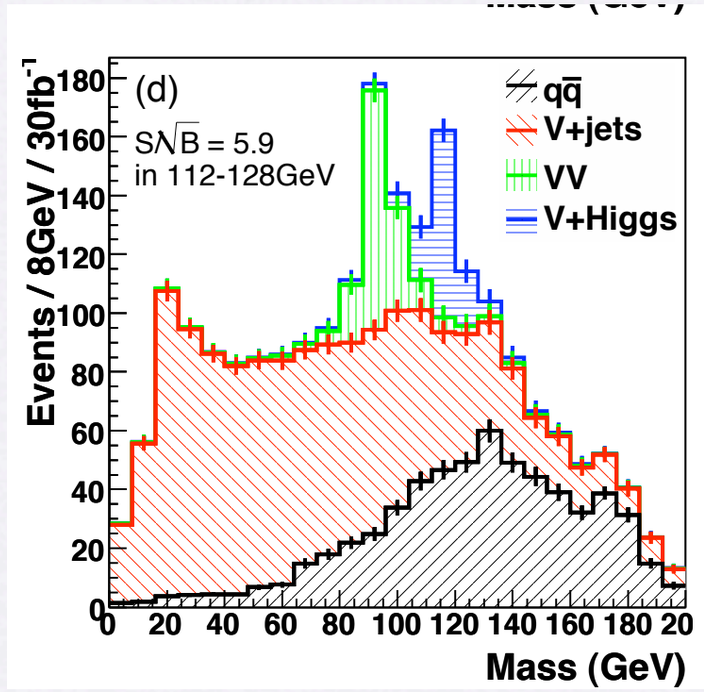
jet substructure

Butterworth, Ellis, Raklev hep-ph/0702150.
Butterworth, Davison, Rubin, Salam, 0802.2470

ex: pp→WH, ZH



- Trying to improve mass resolutions
- 1)take somewhat large R~1.2 select massive jet 2) look for the scale with significant mass drop + symmetric jet. (reject QCD). 3) select additional jets further to find hard activity but kill underlying events.
- Revival of "nearly dead" WH->b bbar??
- application in extra dim(High PT top Kaplan et al arXiv:09) , 0806.0848 SUSY?
- What is "the algorithm" to sort out jets to parent massive particle??



OK, good luck for all of you

- A Proverb:

  “There’s no such thing as bad weather, only the wrong clothes”

  →Of course LHC is not perfect place, but you can find clear-cuts...think more

- strategy is changing.. we need to work on what the nature takes.

- Hope many experimental plenary talks next year.