Search for SUSY in jets+MET final state (13 TeV)

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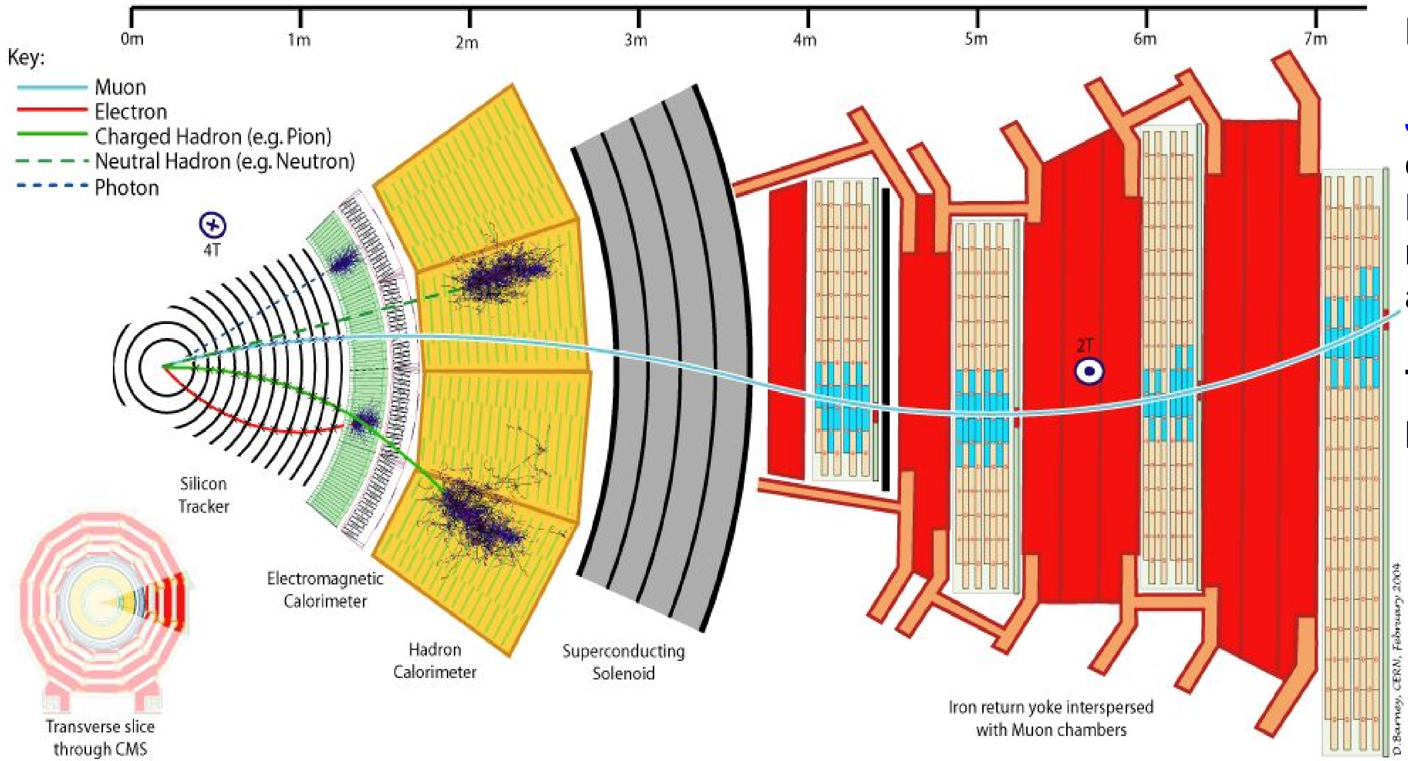
CMS detector



For jets +MET search :

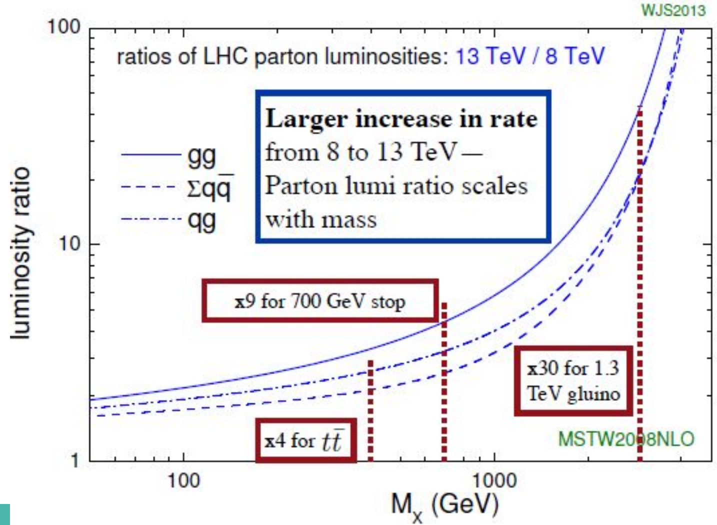
Jets : deposit major part of energy in calorimeter
MET: is calculated from all reconstructed particles in an event

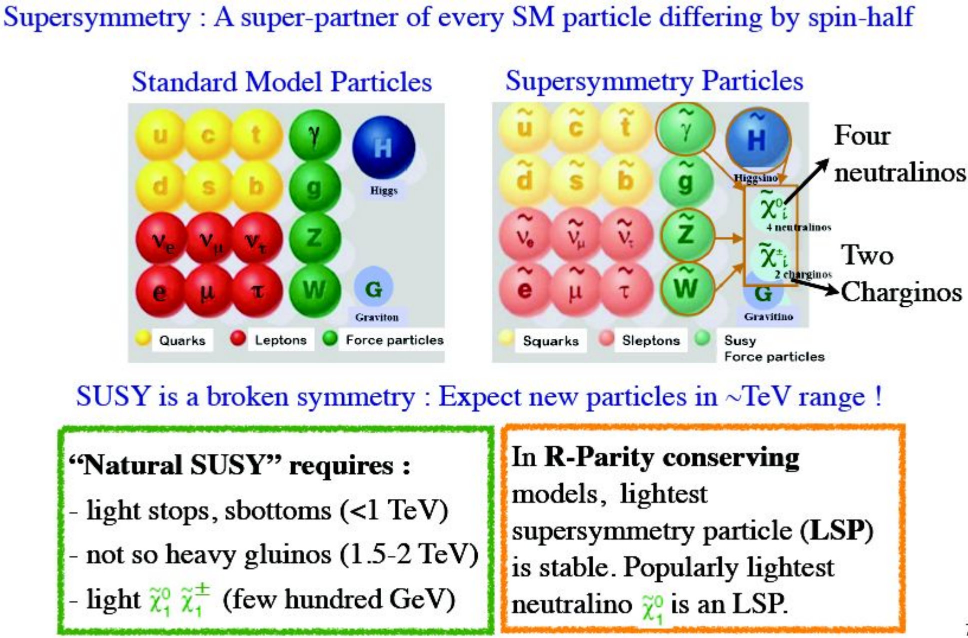
…………………………………

Tracker: helps to reduce pile-up from jets

Introduction (8TeV to 13 Tev)

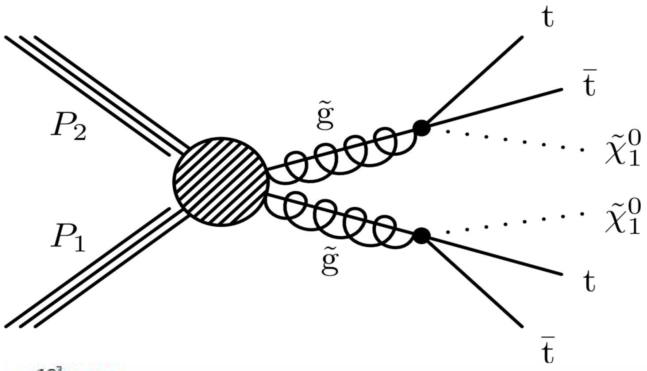
- 20 fb^{-1} of 8TeV Data but no sign of SUSY (R parity Conserving)
- But we did discover something , a light higgs of mass ~ 125 GeV
- Naturalness puts some SUSY particles at TeV scale accessible at LHC
- 13 TeV parton luminocity gives a σ boost at high masses

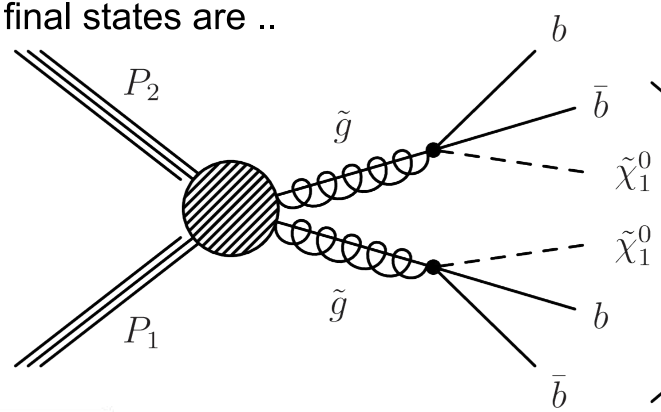


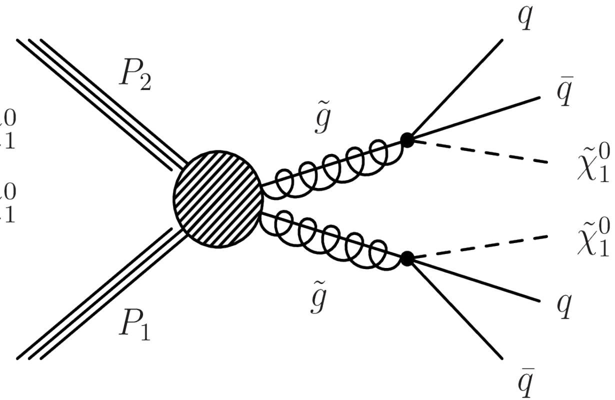


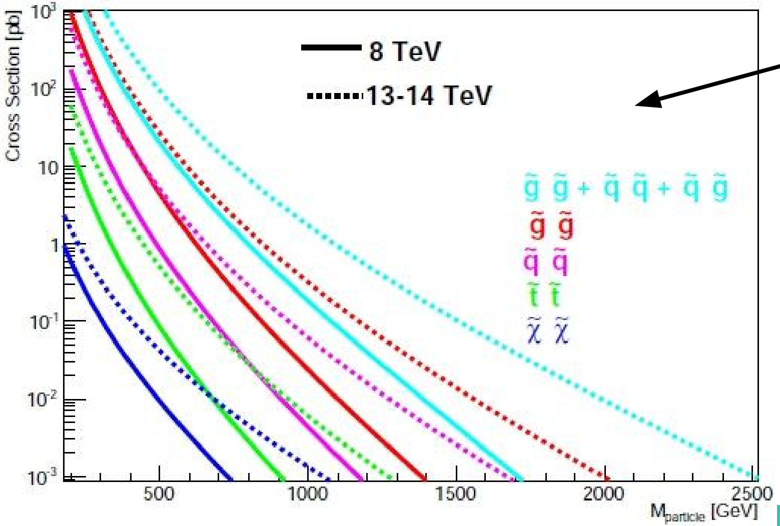
SUSY scenarios

Some gluino pair production final states are ..





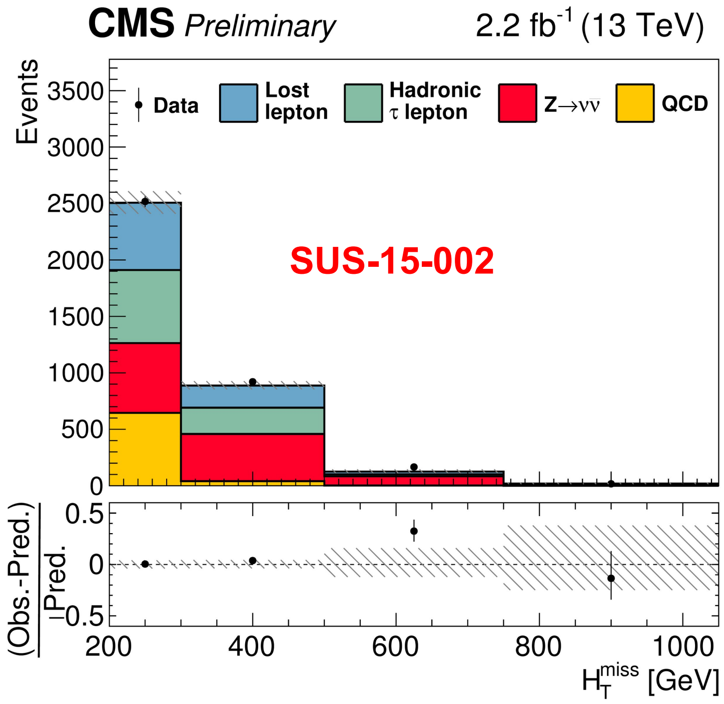


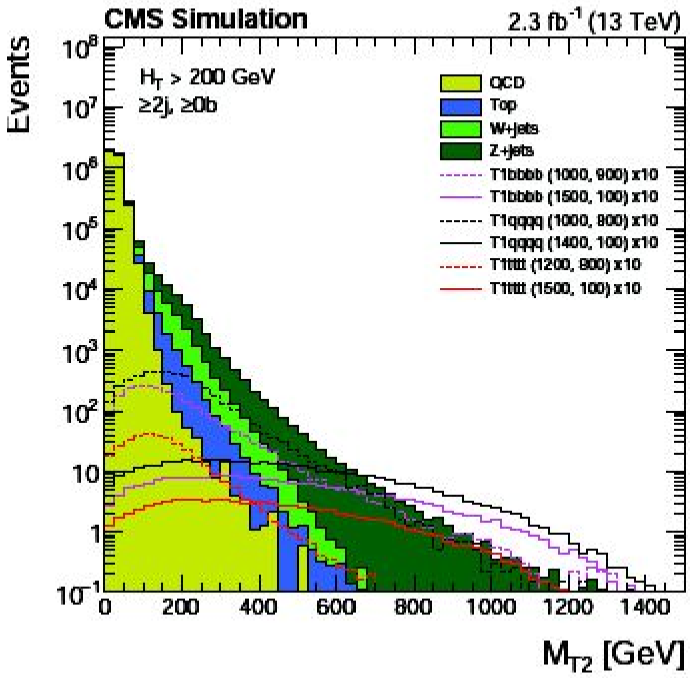


arXiv:1411.1427

- **Inclusive searches designed to cover a broad range of scenarios for strongly produced SUSY**
- **Significant increase in gluino pair production cross section from 8TeV to 13 TeV: ~50x for 1.5 gluinos.**
- **Expect to extend sensitivity of with a few fb-1 of data.**

Search Variable H_T^{miss} ,M_{T2}





SUS-15-003

$$H_T^{miss} = \left| -\sum^{\text{All jets}} p_T^{jets} \right|$$

$$M_{T2}(m_X) = \min_{\vec{p}_T^{X(1)} + \vec{p}_T^{X(2)} = \vec{p}_T^{miss}} \left[\max\left(M_T^{(1)}, M_T^{(2)} \right) \right]$$

Search variable α_T and Razor

$$\alpha_T = \frac{E_T{}^{j_2}}{M_T}$$

$$M_T = \sqrt{\left(\sum_{i=1}^{2} E_T{}^{j_i}\right)^2 - \left(\sum_{i=1}^{2} p_x^{j_i}\right)^2 - \left(\sum_{i=1}^{2} p_y^{j_i}\right)^2}$$

E^{j2}_T is the transverse energy of less energetic jet 2
M_T is transverse mass of dijet system
SUS-15-005

Razor Variables:
For dijet system

$$M_R \equiv \sqrt{(|\vec{p}_{j_1}| + |\vec{p}_{j_2}|)^2 - (p_z^{j_1} + p_z^{j_2})^2}$$

$$M_T^R \equiv \sqrt{\frac{E_T^{miss}(p_T^{j_1} + p_T^{j_2}) - \vec{E}_T^{miss} \cdot (\vec{p}_T^{j_1} + \vec{p}_T^{j_2})}{2}}$$

$$R \equiv \frac{M_T^R}{M_R}$$

SUS-15-004

SM backgrounds

Dominant backgrounds are

- **Top/W +jets background**

- **Lepton is not identified**
- **In W(τν)+jets ,when τ decays to hadronic final states**

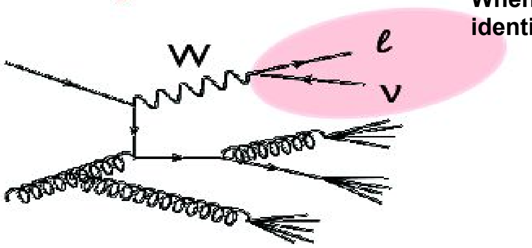
- **Z(νν)+jets is an irreducible background**
- **This process has the same final state as the signal**

- **QCD enters the search region because**

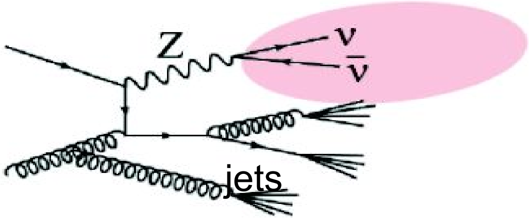
It can give rise to fake MET in the event through extreme tails of jet resolution

- **In QCD events there is no real MET**
- **When jet energy is mismeasured , it gives rise to Fake MET**

When this e is not identified



MET



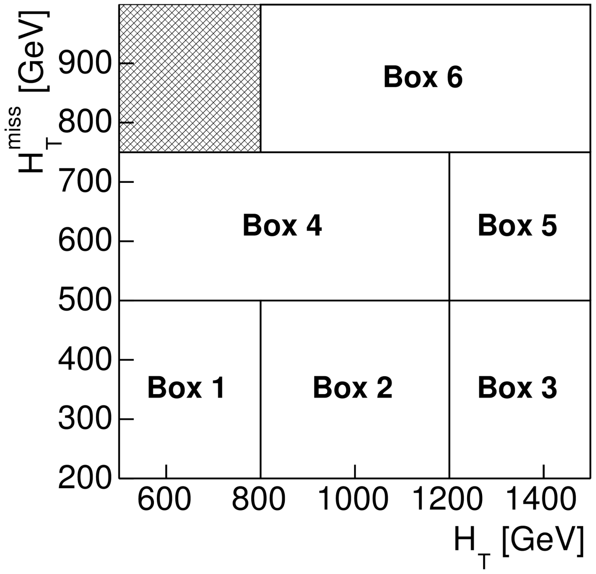
This process has exactly same final states as the signal

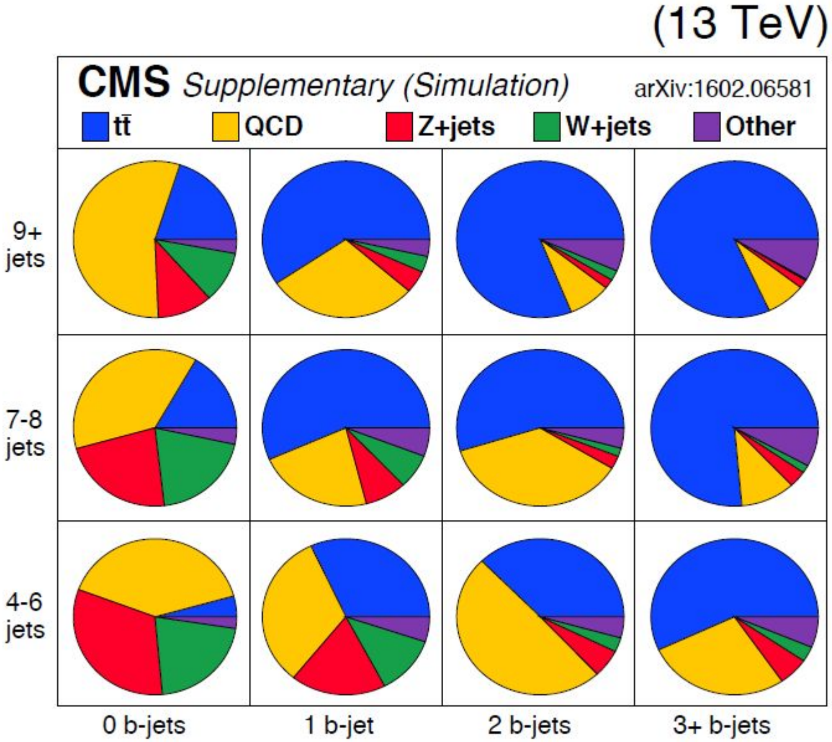
I will use MHT(**SUS-15-002)** analysis as an example to discuss about search region phase space and background estimation methods (. . .in next slides)

SUS-15-002(H_T^{miss})search bins

- **6 bins in HT/MHT**
- **3 bins in N_{jet}**
- **4 bins in $N_{b\text{-}jet}$**

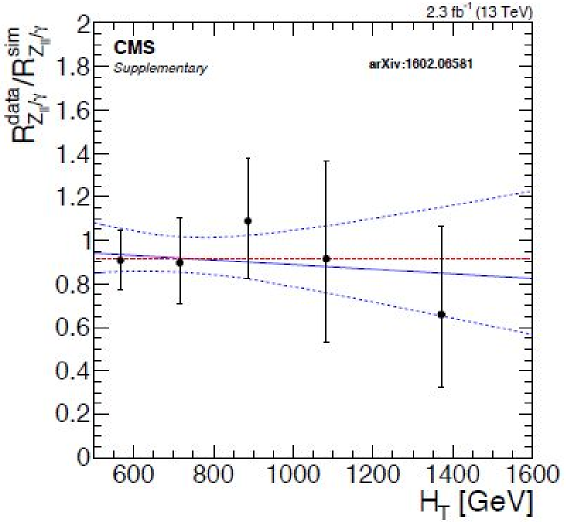
Total number of search bins = 6x3x4 =72





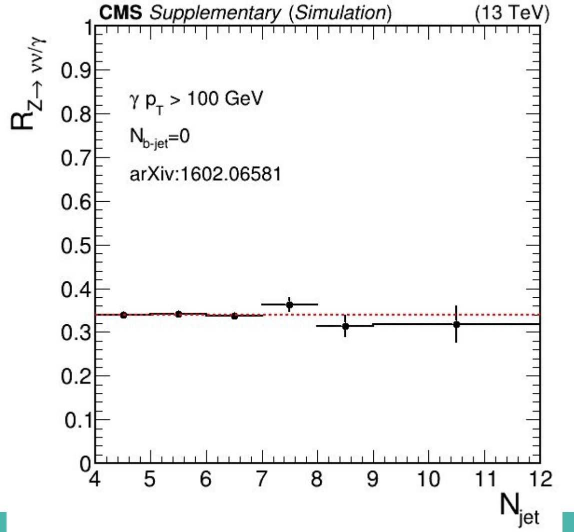
Z to neutrinos background

- A straightforward method is to use Z (→ e+e- or μ+μ-) +Jets events as the topology of events is identical if one ignores leptons in the event
- But this process have few events in the control region
- γ + Jets control region has more events but also more systematic uncertainties
- A combination of both control region makes bkg estimation more effective



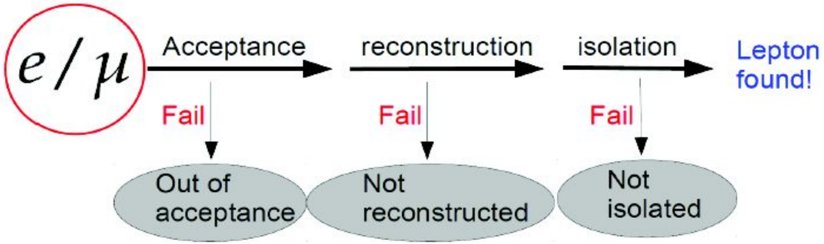
$$N_{\gamma\text{+Jets}} \times \boxed{\text{Correct for } \gamma \text{ identification, QCD contamination}} \times \frac{\sigma(Z\text{+Jets})}{\sigma(\gamma\text{+Jets})} = N_{Z(\nu\nu)\text{+Jets}}$$

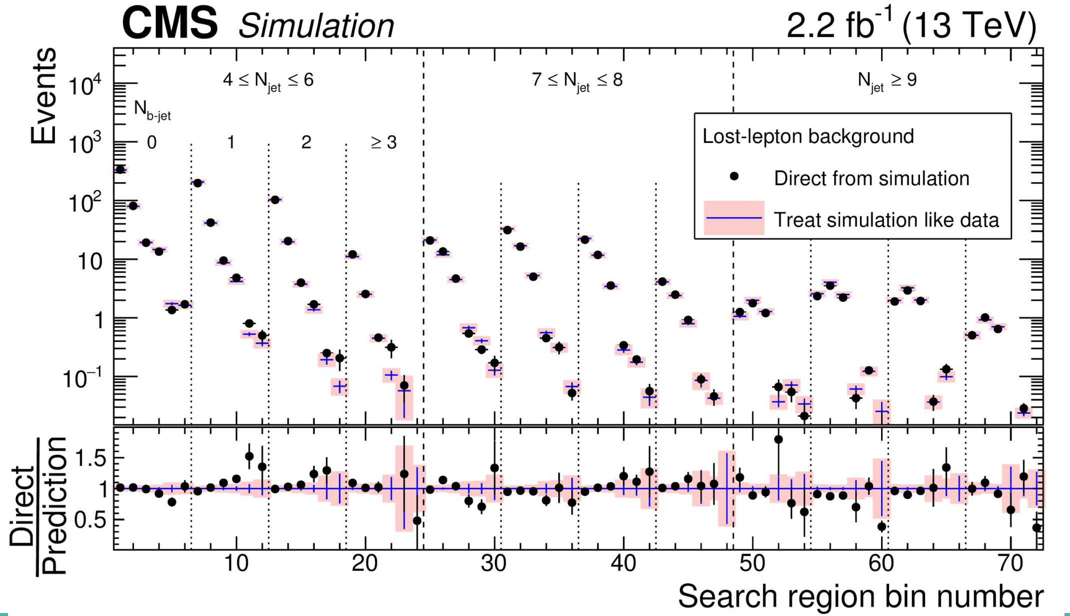
Estimated Z(vv)+jets events in data



W/Top +jets bkg (lost lepton),data driven

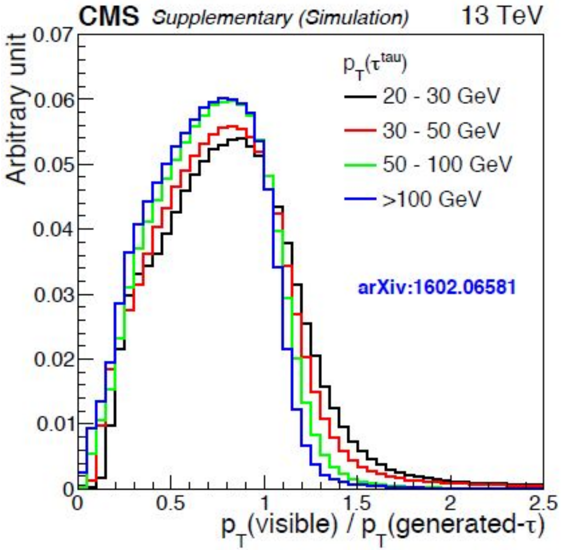
- Enters the signal region when the lepton fails the lepton veto
- Use MC information to know the probability($\in_{eff}$) of happening this
- Take single μ/e control sample of from data
- Use lepton $\in_{eff}$ to trace back no of leptons that failed the

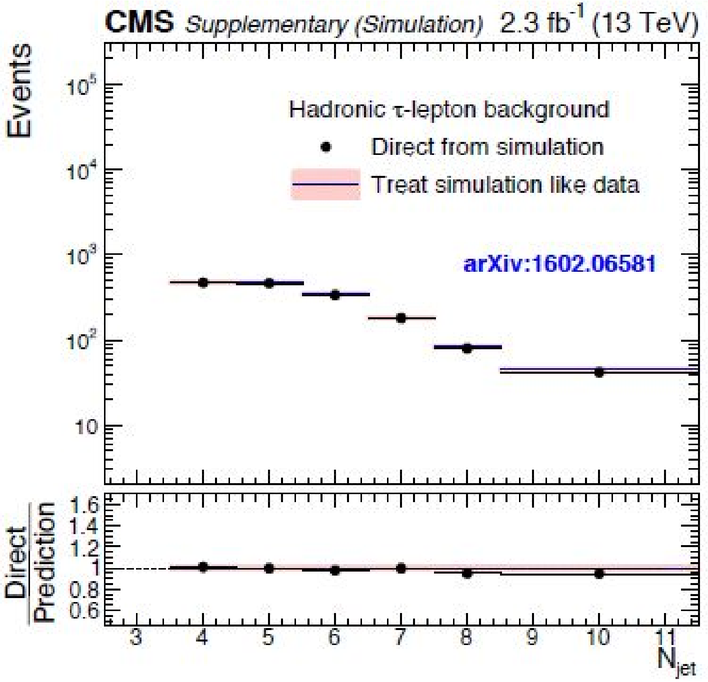




W+jets/top - hadronic tau background

- Results from hadronic decay of tau

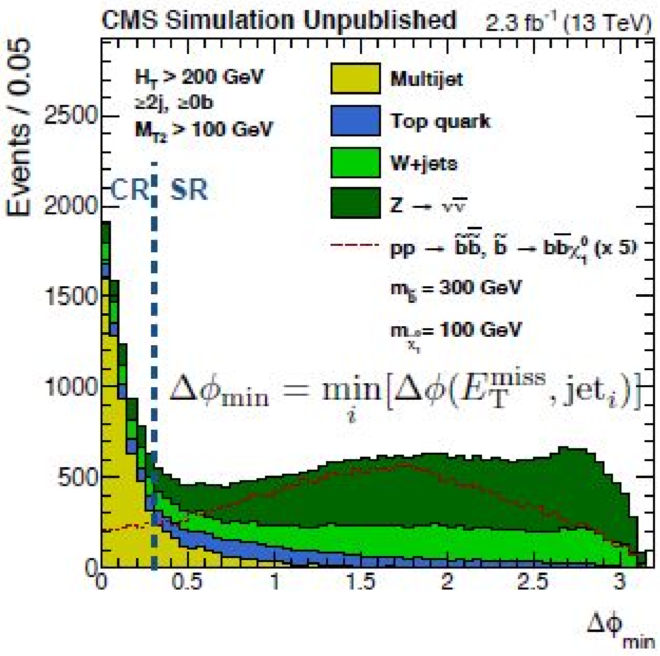




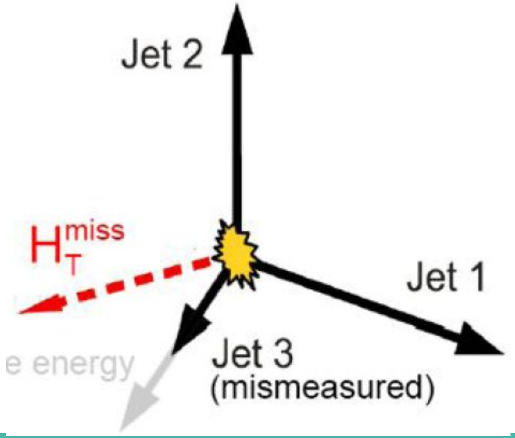
- Get single muon control sample from data
- Smear with hadronic tau template
- Gives the estimated number of had τ events

QCD multijet background

- QCD events do not have real missing energy but jet energy can be mismeasured
  - This results fake MET region
- This fake MET tends to be aligned with jet
- We reject 90% of background events with minimal effect on signal using cuts on low Δϕ

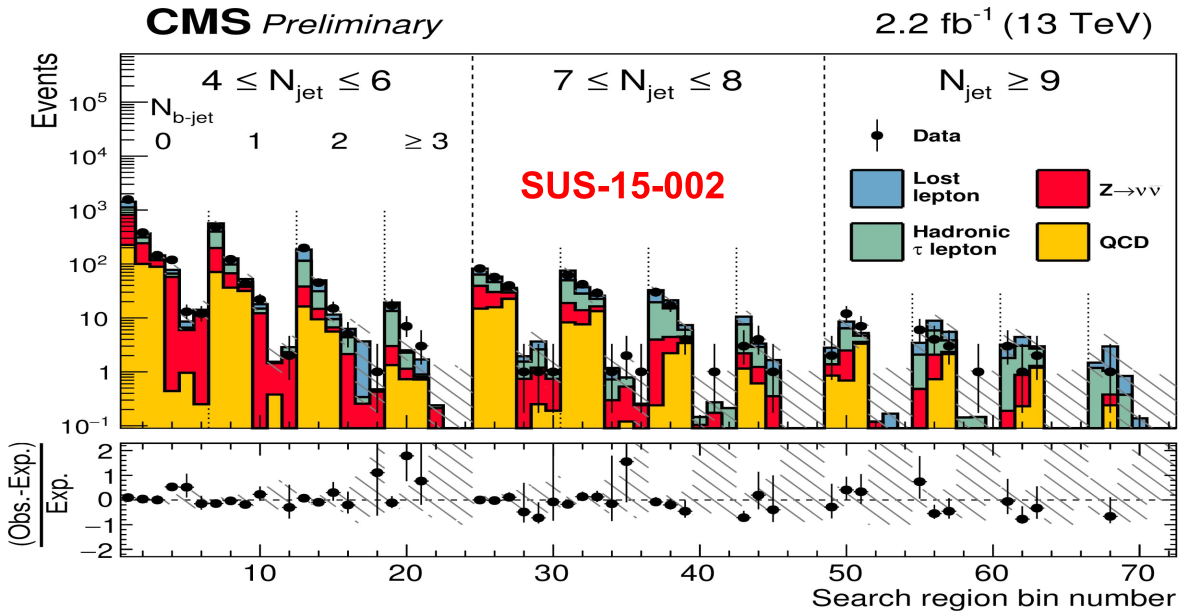


$\Delta\phi(H_T^{miss}$, ith jet) = Angle between H_T^{miss} and ith jet



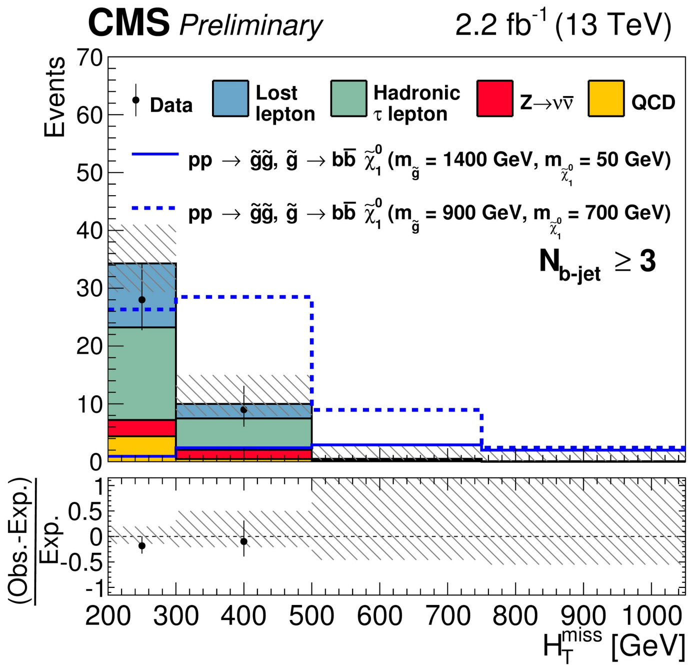
Low **Δϕ = QCD control region**
High **Δϕ = signal region**
Use **high/low** ration to go from control region to signal region

Data vs SM backgrounds

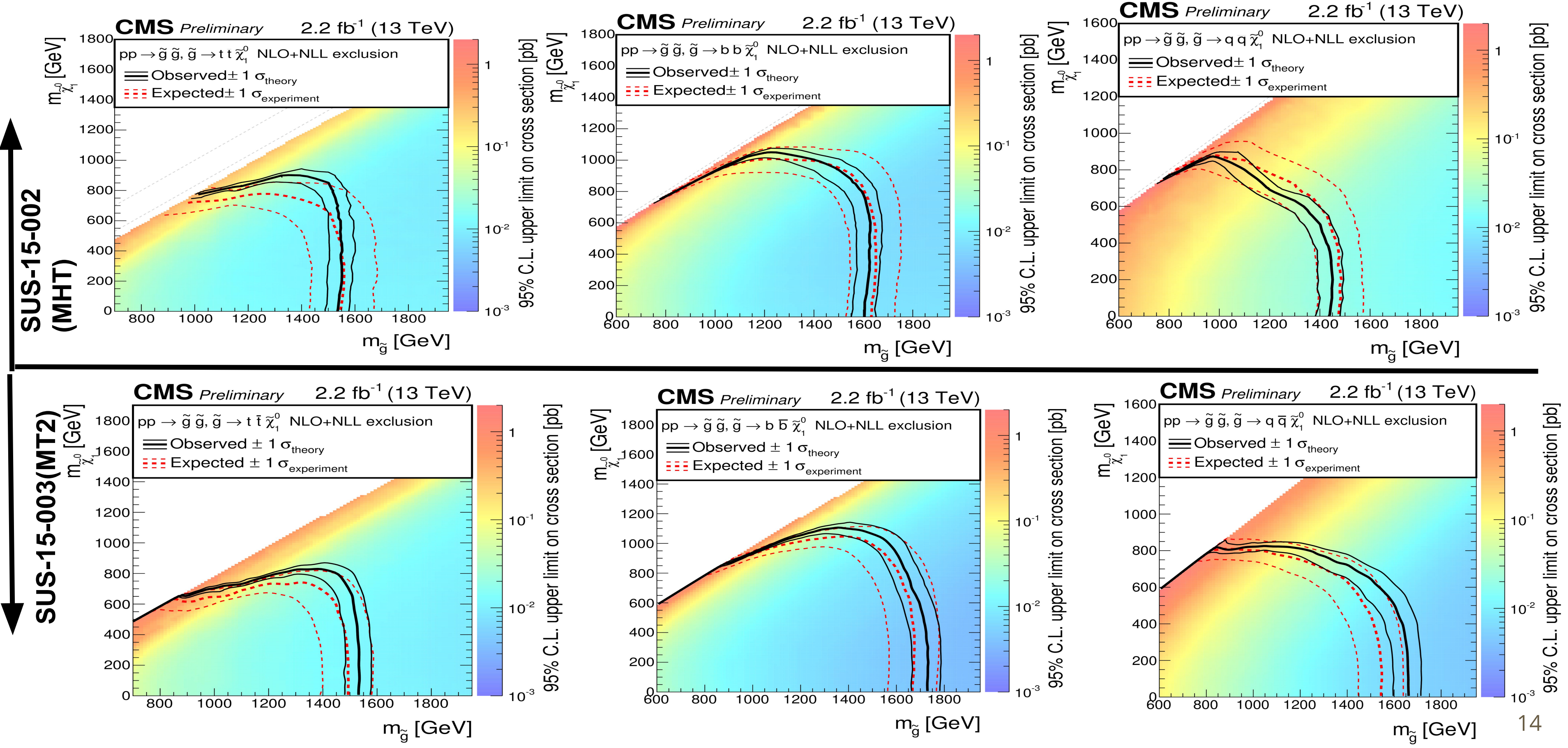


- No broad excess consistent with signal expectation
- Data agrees

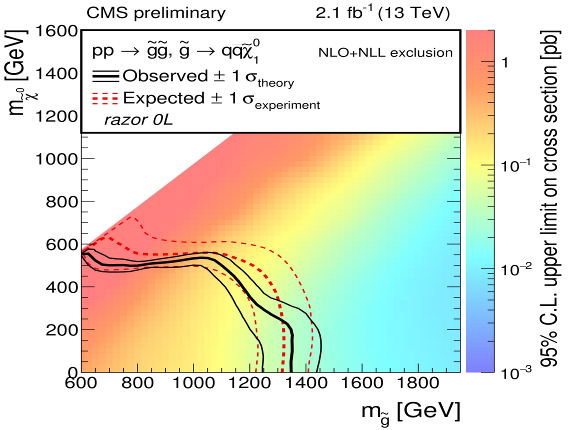
with SM background expectation

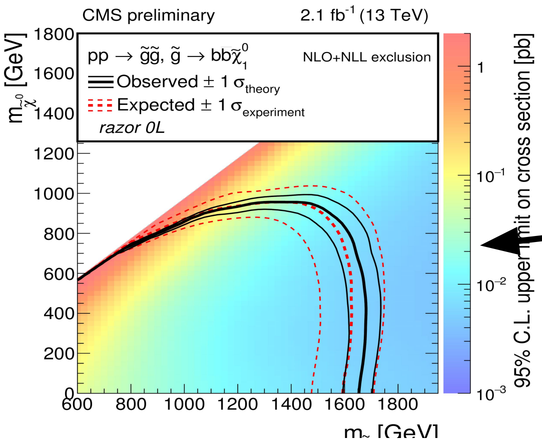


Interpretation: Gluino pair production

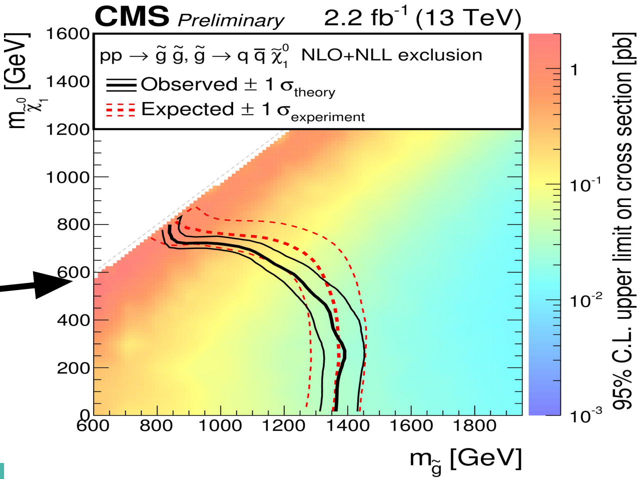


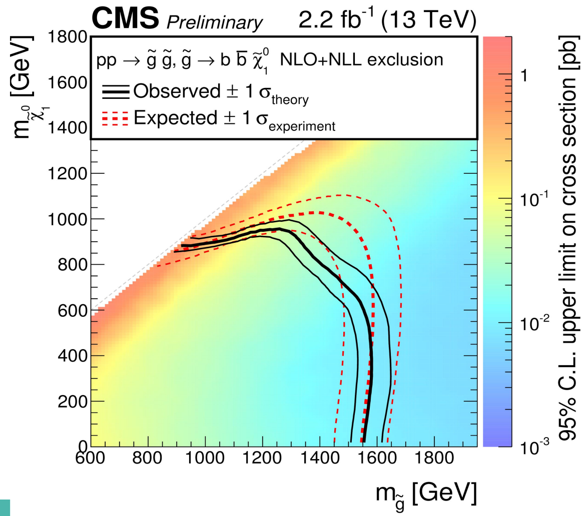
Interpretation : Gluino pair production





RaZOR : **SUS-15-004**





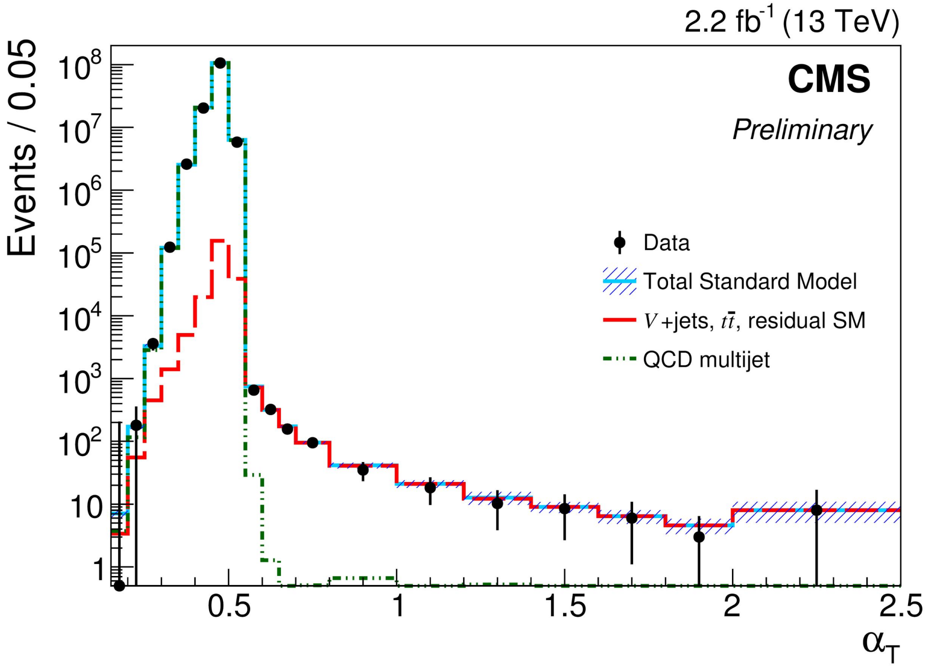
α_T : **SUS-15-005**

Conclusion

- **Results from a variety of analyses to search for supersymmetric partners in 2.3 fb^{-1} of 13 TeV data in CMS experiment**
- **The gluinos of mass up to 1.6 TeV excluded for low LSP masses**
- **The exclusion limits are improved as much as 150-200 GeV compared to the 8 TeV limits**

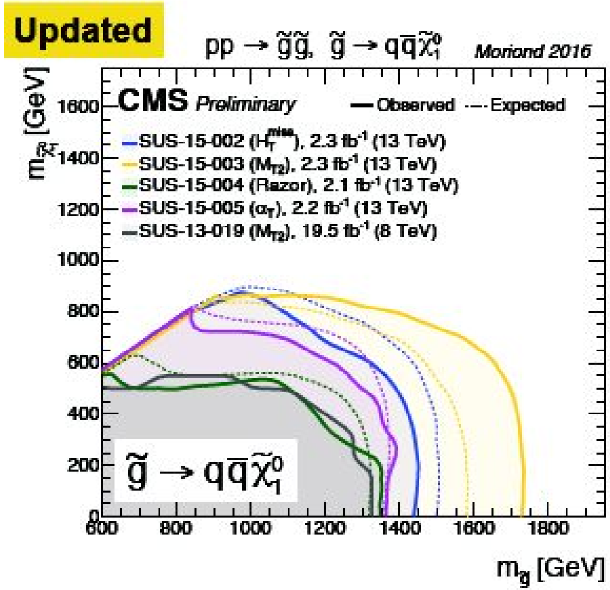
Back-up slides

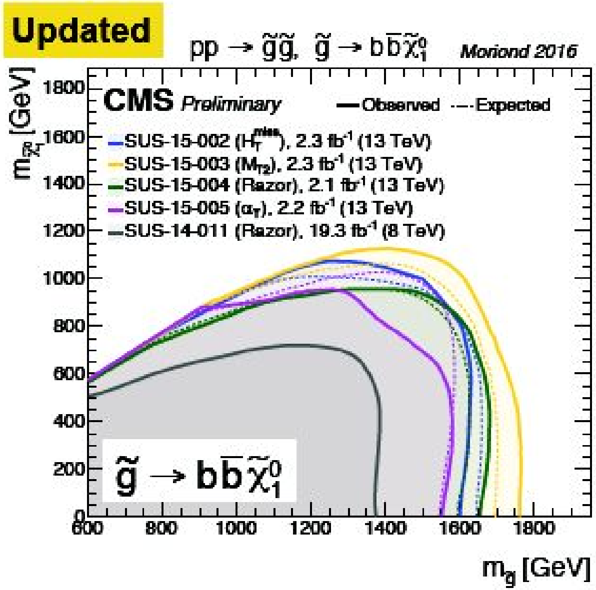
α_T

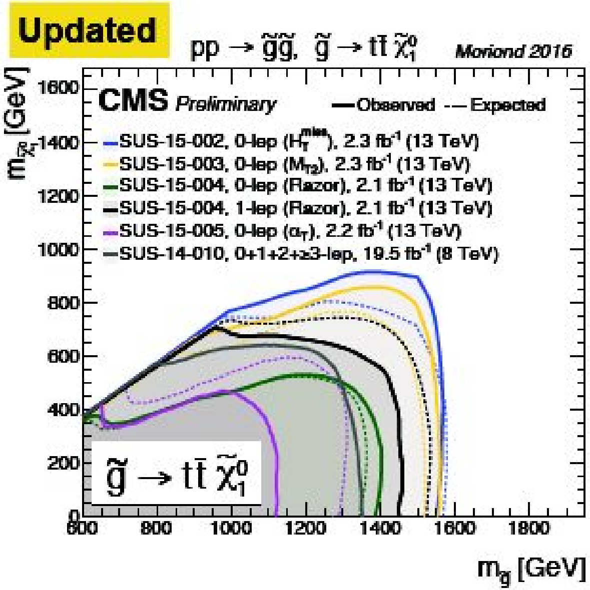


2.2 fb-1 (13 TeV)
CMS
Preliminary
Data
Total Standard Model
V+jets, $t\bar{t}$, residual SM
QCD multijet
Events / 0.05
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10
1
0.5
1
1.5
2
2.5
α_T

Interpretation : gluino pair production







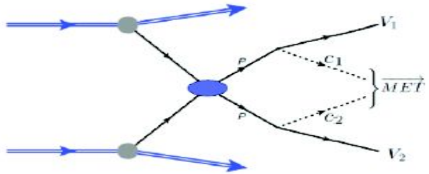
All hadronic search variables and SM backgrounds

$H_T = \sum_{i=jets} |p_T^{jets}|$ =scalar sum of p_T of all jets

N_{jet} = Number of jets in the event

$N_{b\text{-}jet}$ = Number of b-jets in the event

Analysis designed search variables

All jets → $H_T^{miss} = \mid -\sum \vec{p}_T^{\,jets} \mid$ Missing Transverse Hadronic energy **SUS-15-002**	For dijet events $\alpha_T = \frac{E_T^{j_2}}{M_T}$ E^{j2}_T is the transverse energy of less energetic jet 2 M_T is transverse mass of dijet system **SUS-15-005**
$M_{T2}(m_X) = \min_{\vec{p}_T^{X(1)}+\vec{p}_T^{X(2)}=\vec{p}_T^{miss}} \left[\max\left(M_T^{(1)}, M_T^{(2)}\right)\right]$  **SUS-15-003**	$M_R \equiv \sqrt{(\lvert\vec{p}_{j_1}\rvert + \lvert\vec{p}_{j_2}\rvert)^2 - (p_z^{j_1} + p_z^{j_2})^2}$ $M_T^R \equiv \sqrt{\frac{E_T^{miss}(p_T^{j_1} + p_T^{j_2}) - \vec{E}_T^{miss}\cdot(\vec{p}_T^{j_1} + \vec{p}_T^{j_2})}{2}}$ $R \equiv \frac{M_T^R}{M_R}$ **SUS-15-004**