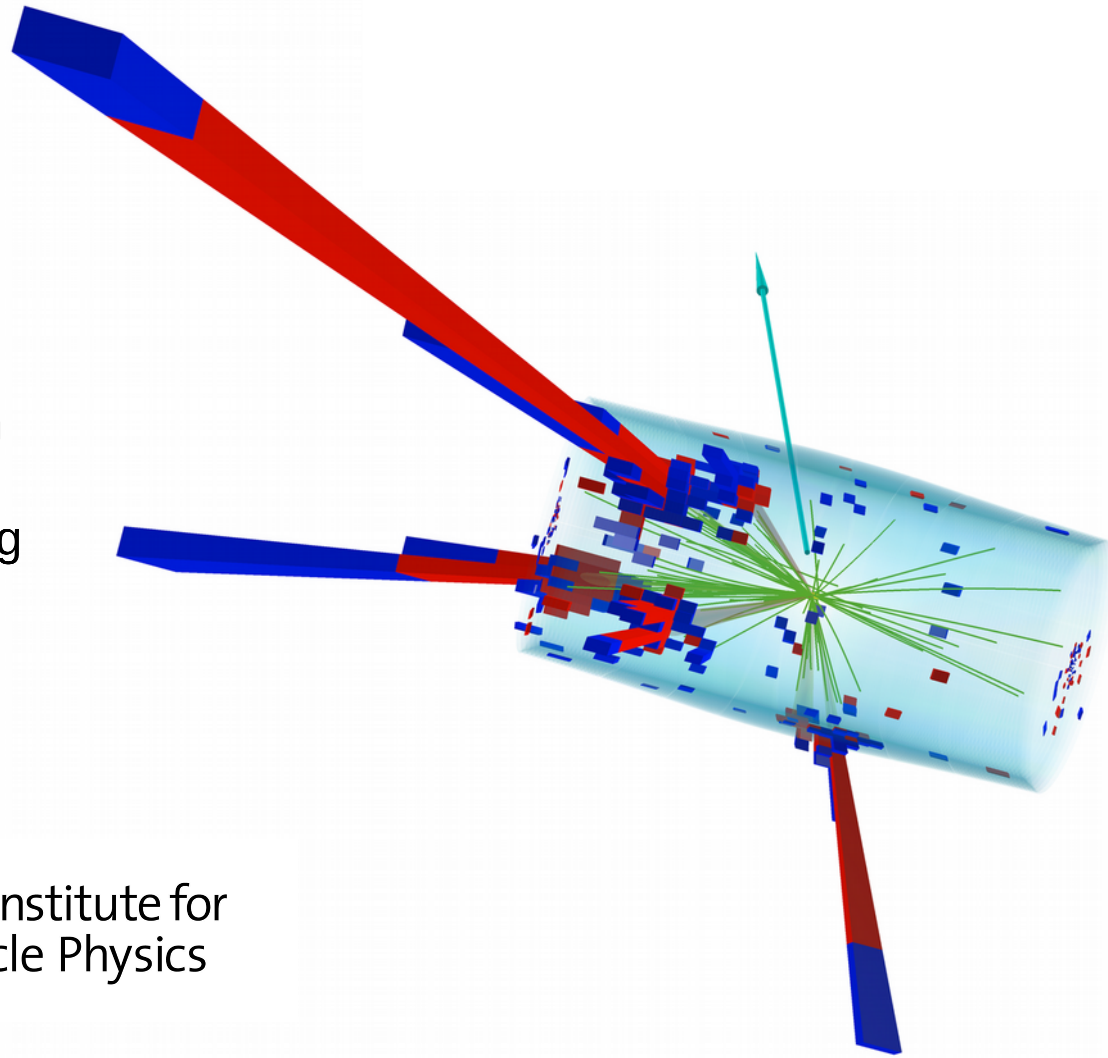
Searches for SUSY via strong production in fully hadronic final states at CMS



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for the CMS collaboration

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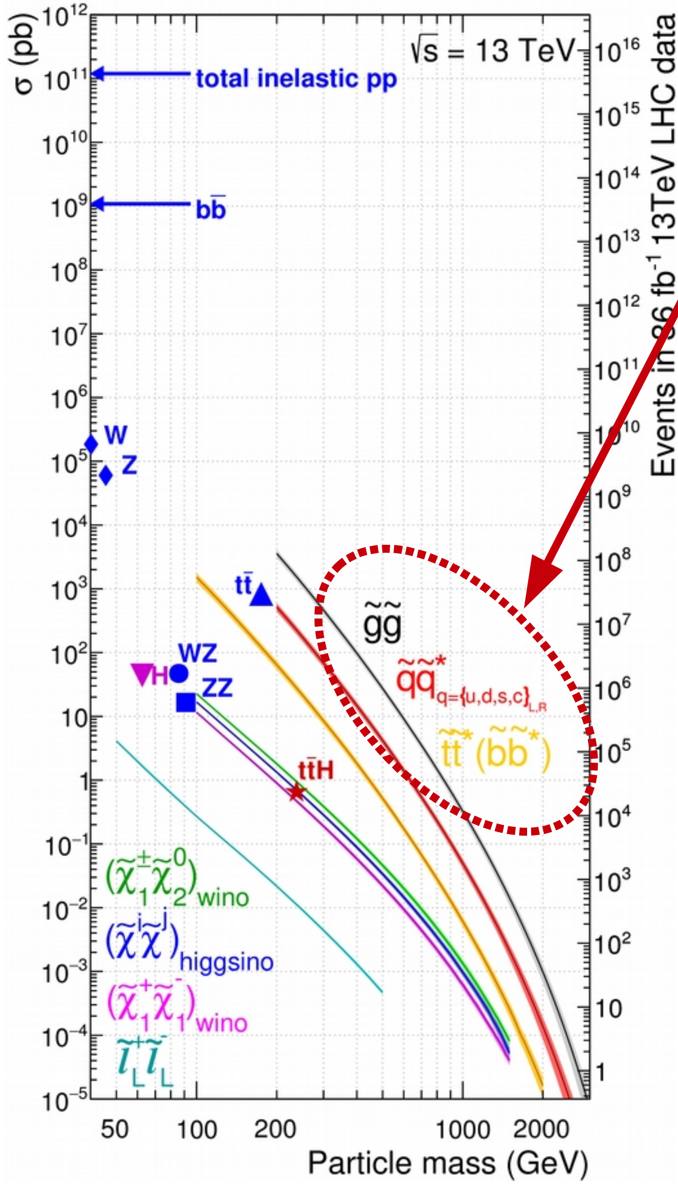
Genève, 25 August 2017

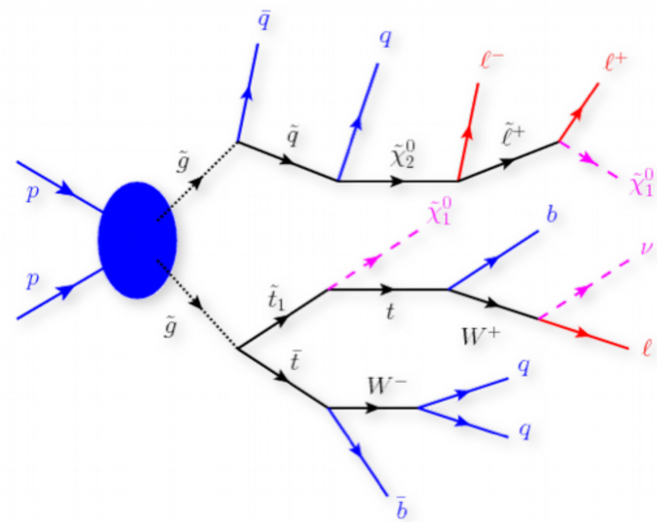
ETH Institute for Particle Physics

Why fully hadronic?



Largest cross section for **strong production, gluinos & squarks,** of SUSY

Largest branching ratio to jets



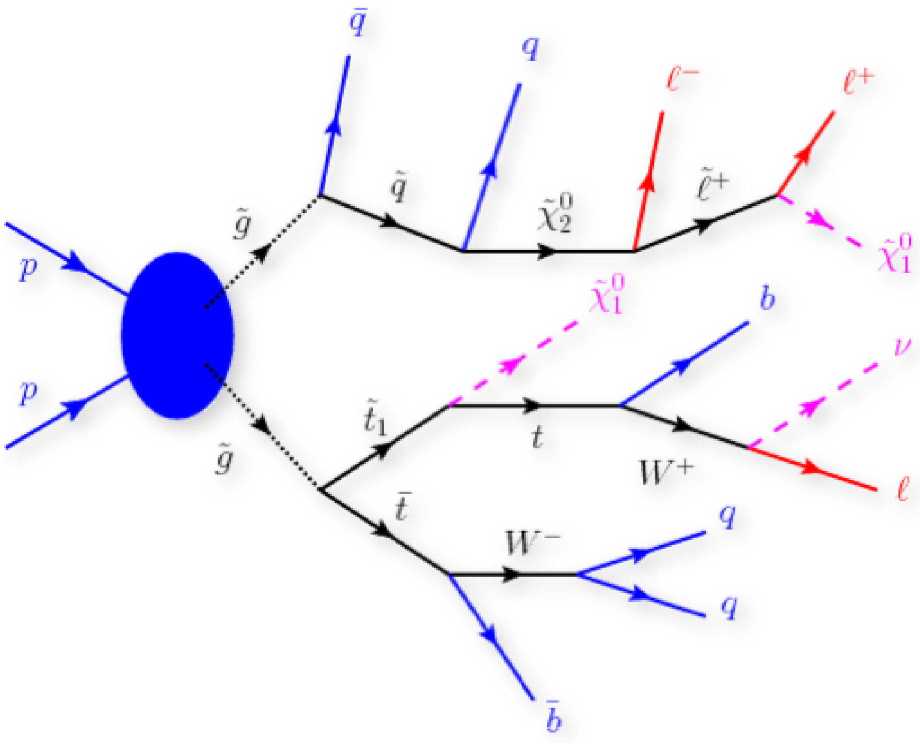
Fully hadronic searches of strongly produced SUSY

→ **discovery channel at energy frontier**

Characteristics of a SUSY event

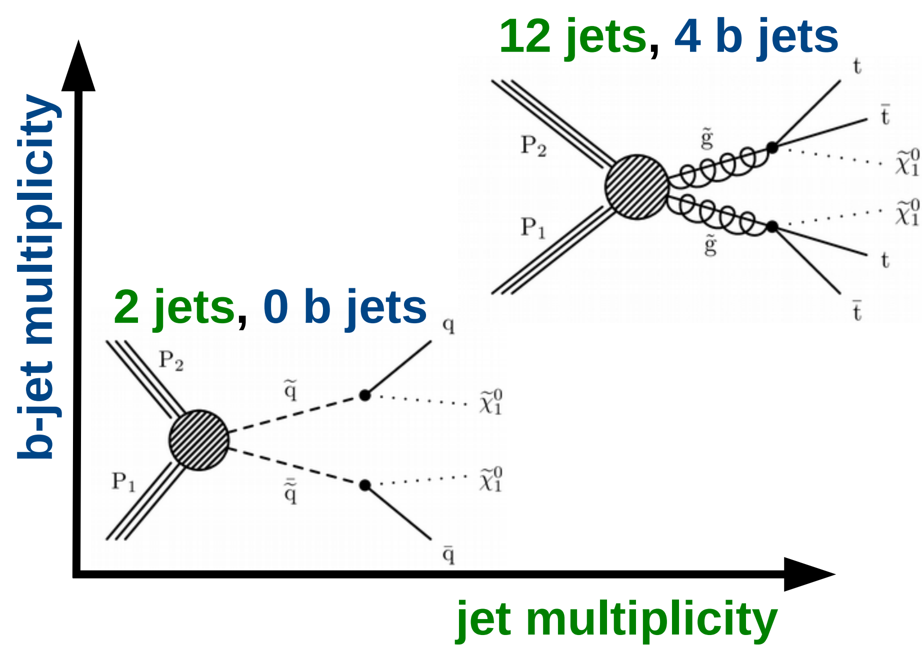
Assuming **R parity** to be **conserved**:

- SUSY particle produced in **pairs**
- Large missing transverse energy (ME_T) from **2** undetected neutralinos
- Many jets
- A lot of hadronic activity



Strategy for fully hadronic inclusive searches

- Lepton veto
- Sensitivity to very different signals through binning in **jet** & **b-jet** multiplicity
- Binning in $\mathbf{H_T}$ for **energy scale** sensitivity
- Discovery variable $\mathbf{M_{T2}}$:

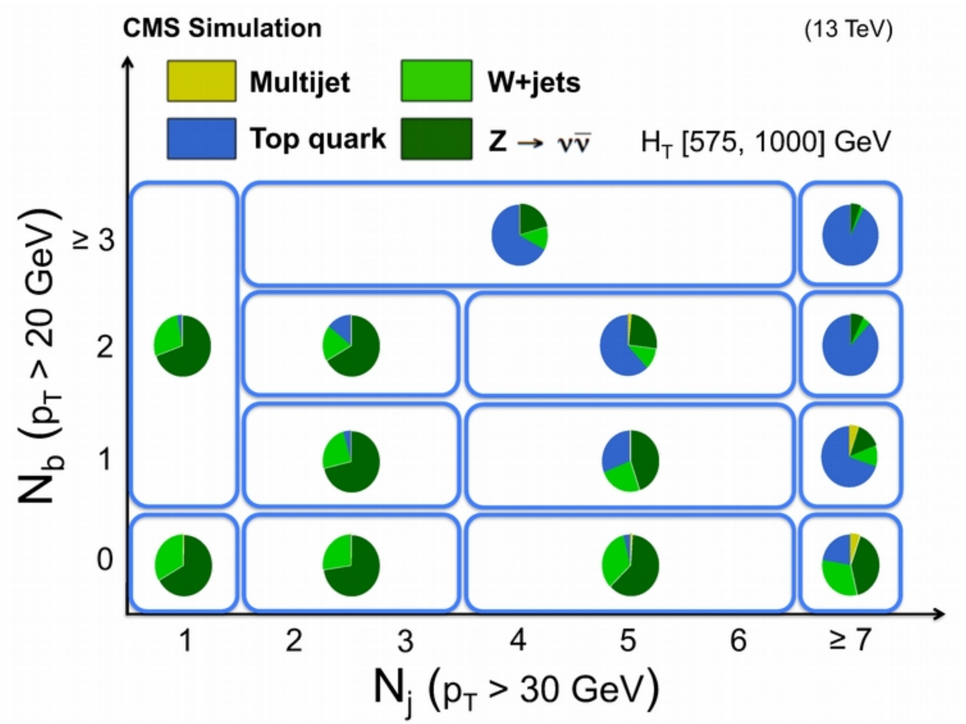


$$\mathrm{H}_T = \sum_{jets} |\vec{p_T}|$$

$$\mathrm{M}_{T2}(m_c) = \min_{\vec{p}_T^{c(1)} + \vec{p}_T^{c(2)} = \vec{p}_T^{miss}} [\max(M_T^{(1)}, M_T^{(2)})]$$

Main backgrounds

- **QCD multi-jet:**
  - Mis-measurement of a jet leads to imbalanced event → **instrumental ME_T**
- **W-jets & ttbar (Lost lepton):**
  - **ME_T from neutrino** from leptonic W decay
  - Charged lepton not caught by lepton veto
- **$Z_{\nu\nu}$+jets:**
  - **ME_T from the two neutrinos**

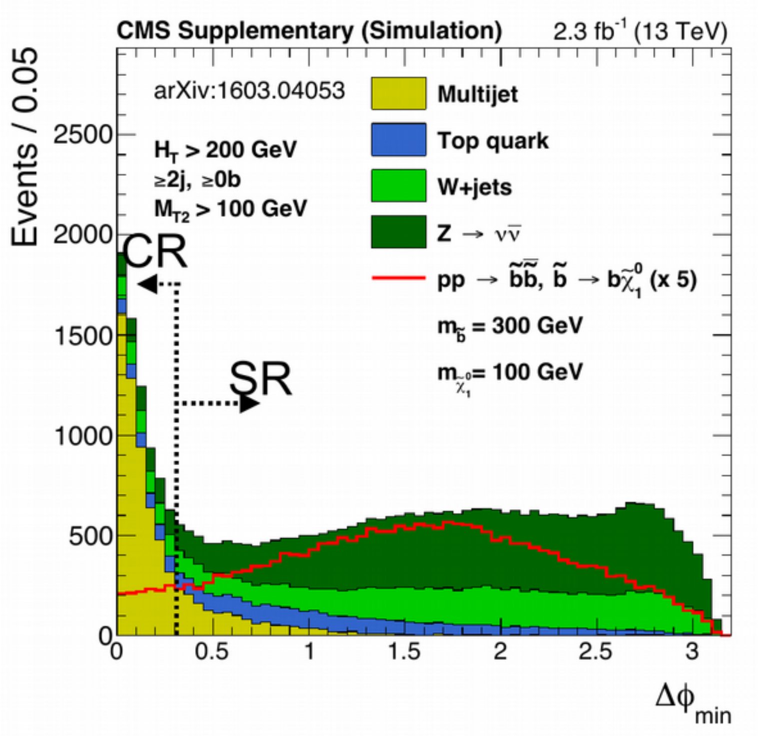


QCD background estimate via ΔΦ

- Invert $\Delta\varphi(ME_T$, jets) cut

$$r_\phi = \frac{N(\Delta\phi_{min}(jets, E_T^{miss}) > 0.3)}{N(\Delta\phi_{min}(jets, E_T^{miss}) < 0.3)}$$

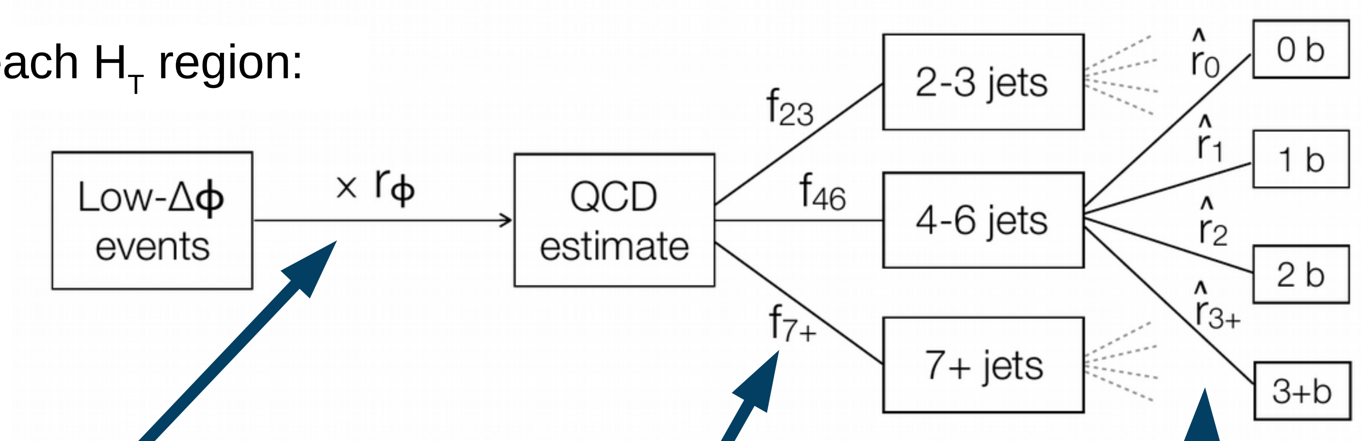
- Fit r_φ at low M_{T2} & extrapolate to signal region inclusively in each H_T region
  →Then split among N_j/N_b with data based transfer factors

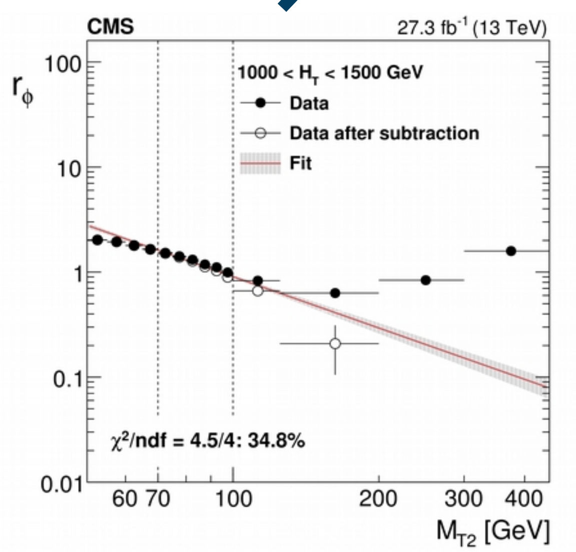


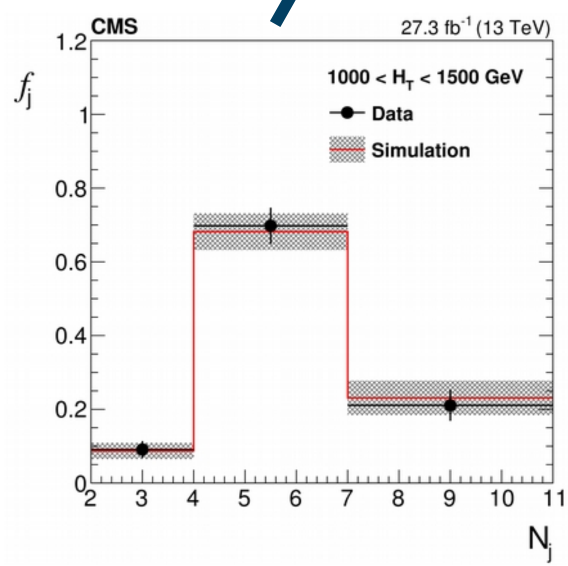
$$N_{QCD}^{SR} = N^{CR}(H_T, M_{T2}) \cdot r_\phi(M_{T2}) \cdot f_j(H_T) \cdot r_b(N_j)$$

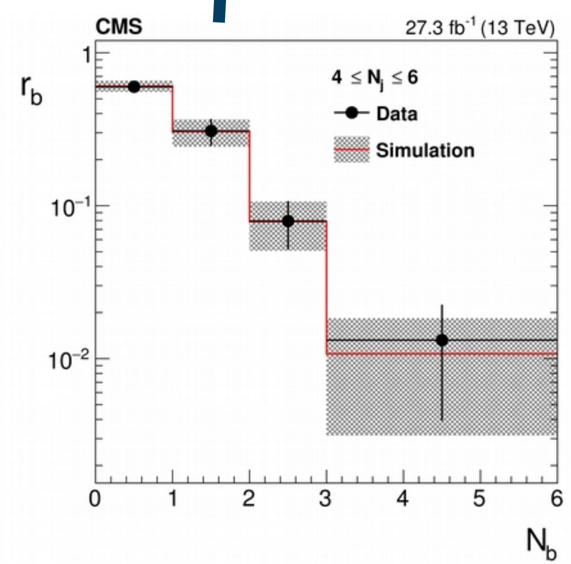
QCD estimate: transfer factors

In each H_T region:

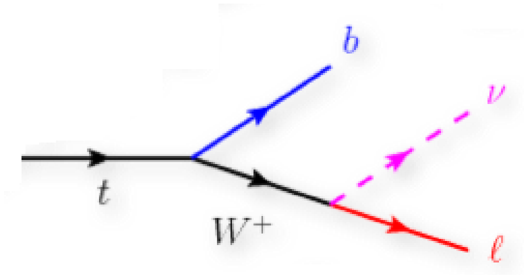




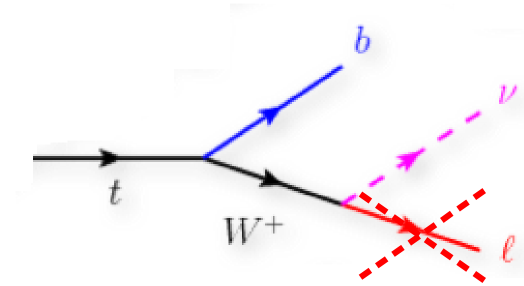




Lost Lepton estimate

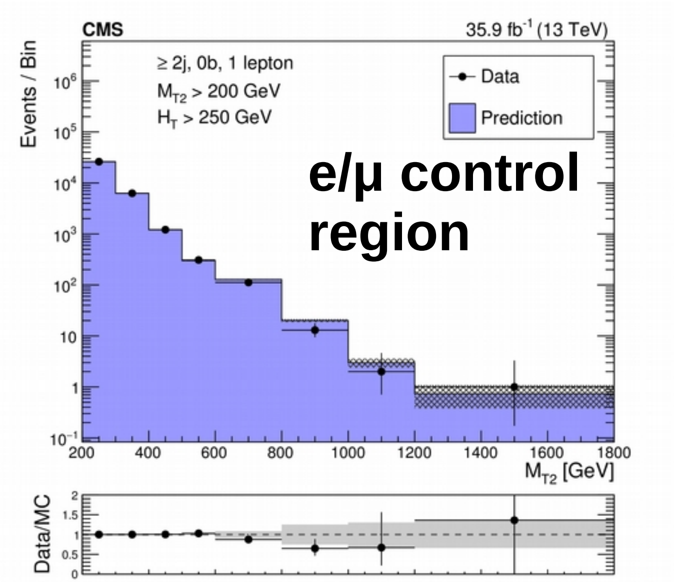


Probability from MC to lose it



Single lepton (e/μ) control region

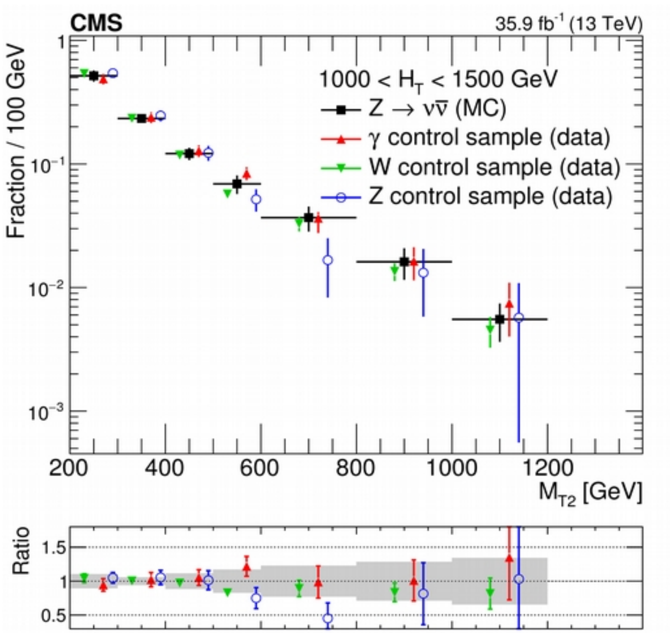
0 lepton signal region

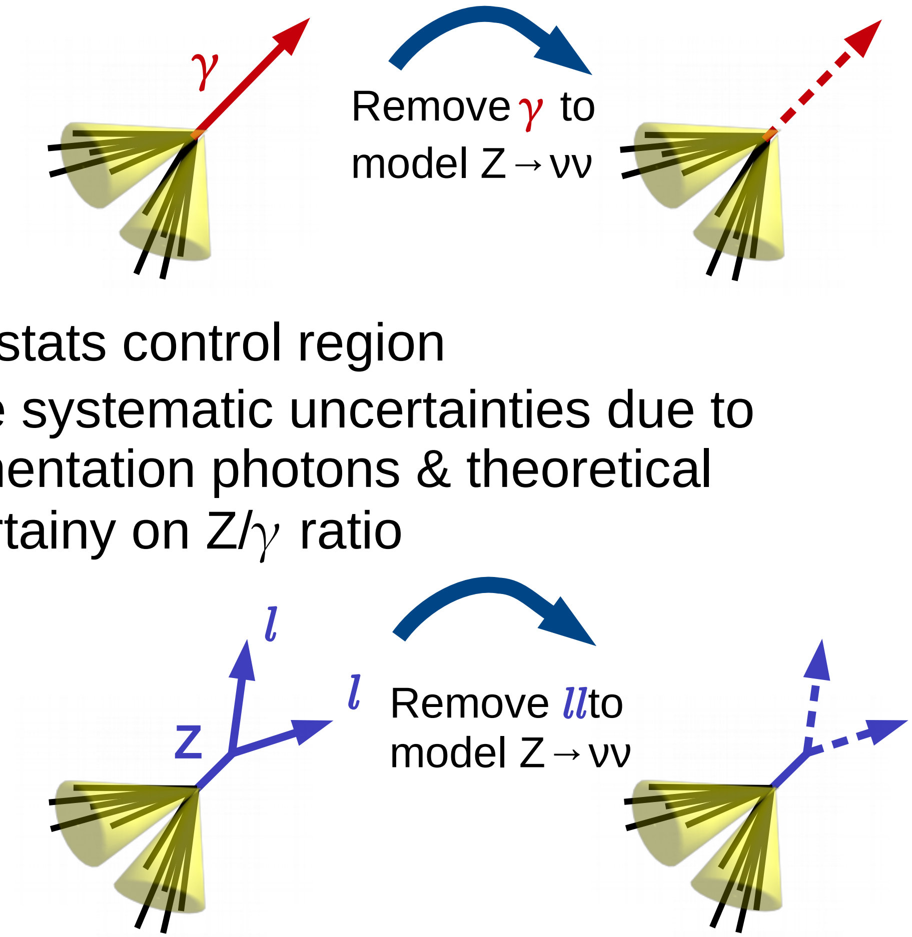


- Charged lepton not seen because of
  - Acceptance of detector
  - Reconstruction/ID
  - Non-isolation

- **Suppress with efficient lepton veto**

$Z\rightarrow\nu\nu$ Estimate





γ+jets

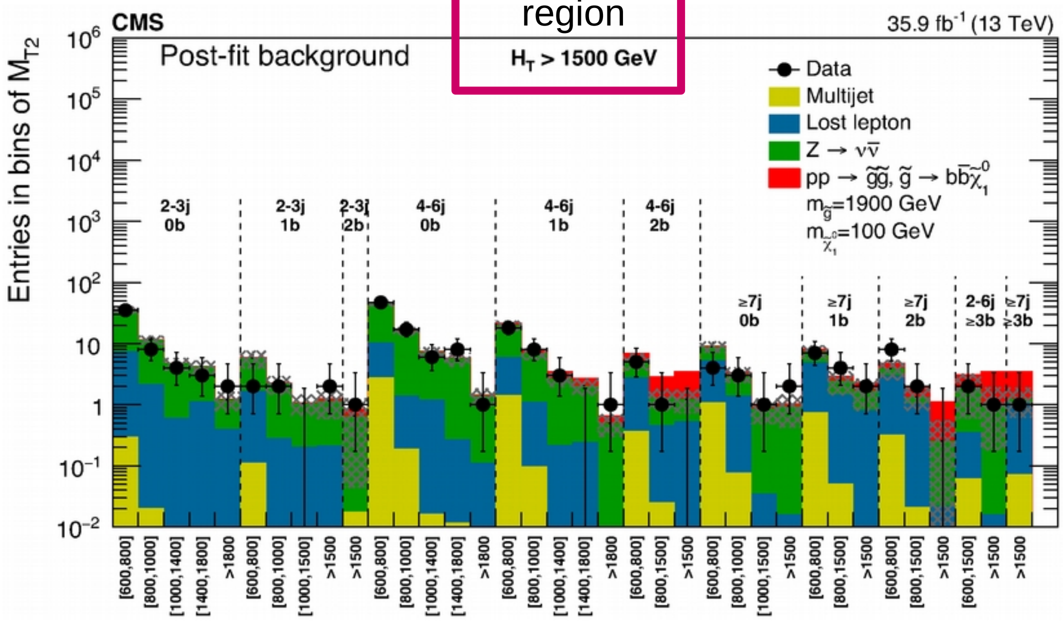
- High stats control region
- Large systematic uncertainties due to fragmentation photons & theoretical uncertainy on Z/γ ratio

$Z\rightarrow ll$

- Lower stats, now possible with 40 fb^{-1}
- Lower uncertainties (same process)
- Account for purity due to Top from **eμ data control region**

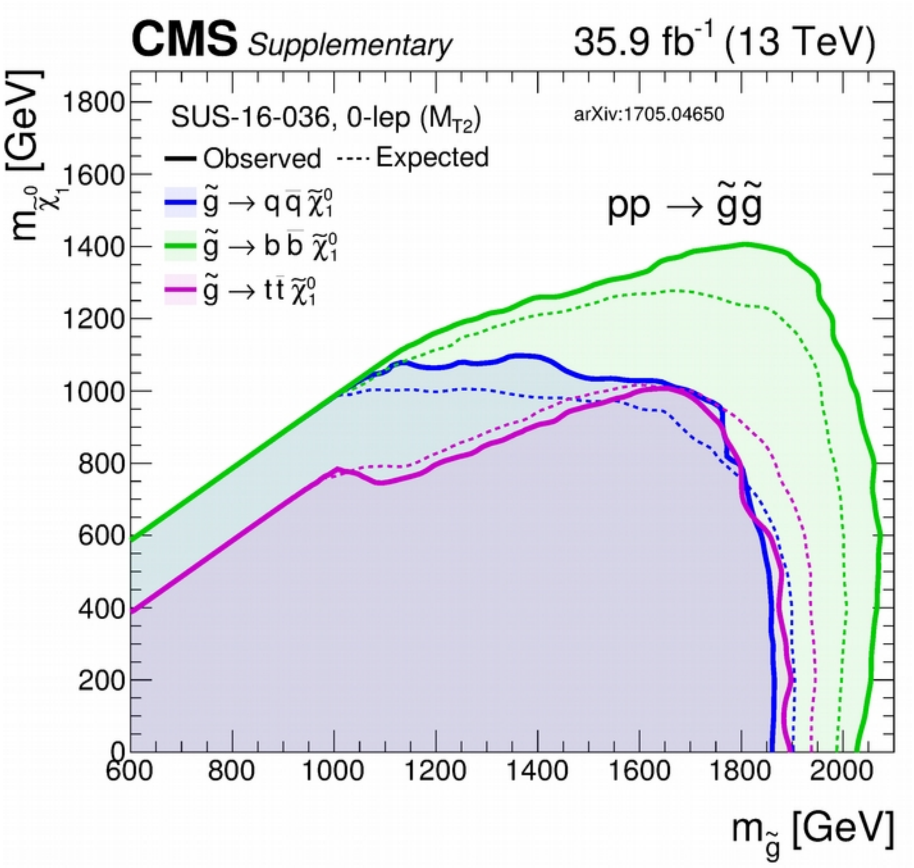
Selected results

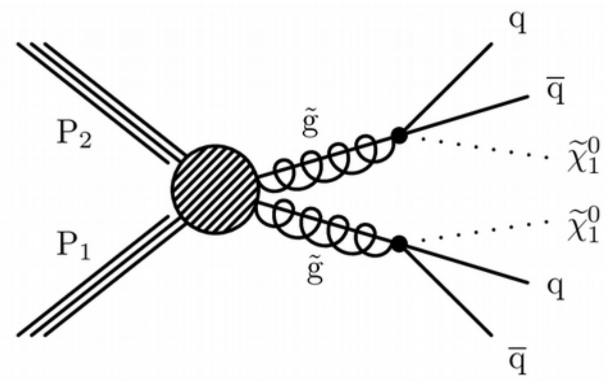
Highest H_T region



Good agreement with the standard model

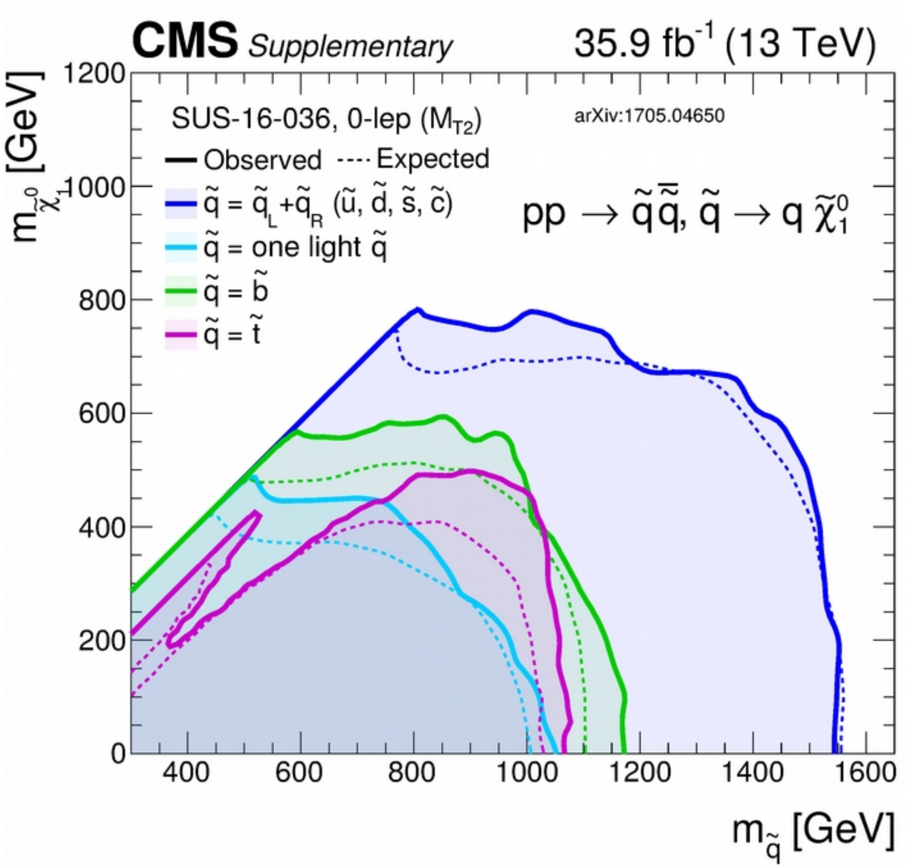
Exclusion Limits – Gluino production

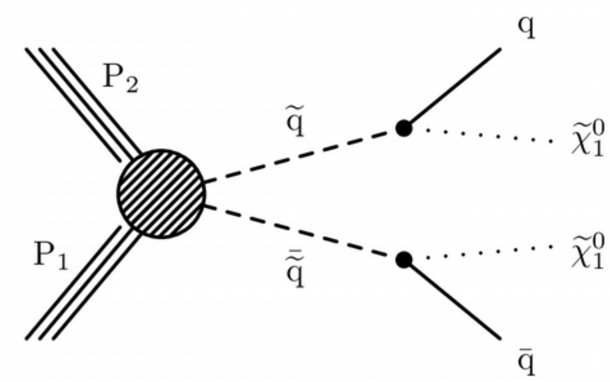




Extended reach up to about 2 TeV along gluino mass

Exclusion Limits – Direct squark production





Extended reach by to about 1TeV along squark mass

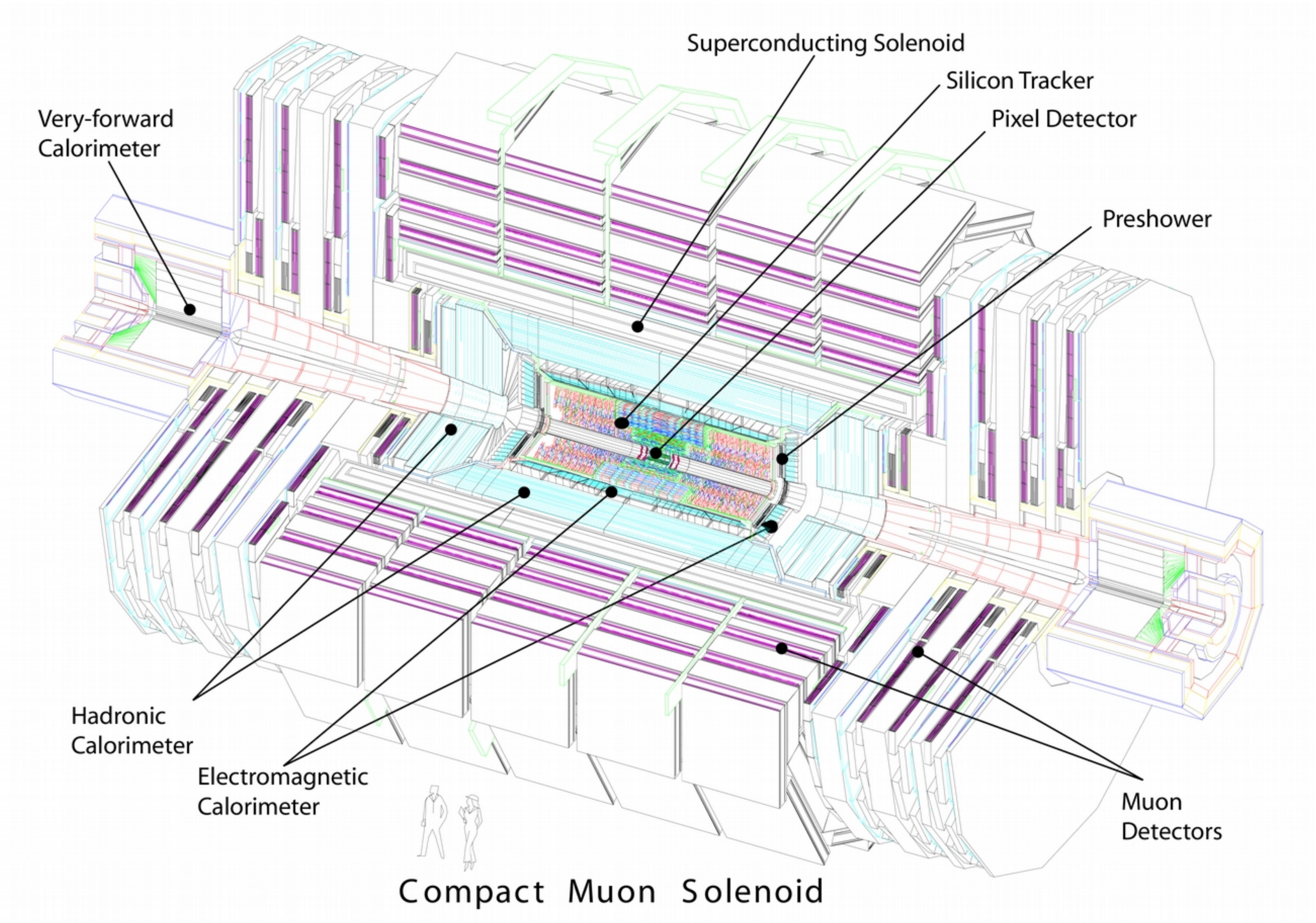
Conclusions

- Showed results of a fully hadronic search for SUSY with the M_{T2} variable with 35.9 fb^{-1} collected by the CMS detector
- Probed the direct squark and gluino production at the energy frontier
- No significant excess over background predictions:
  → Exclude masses of up to about 2 TeV for gluinos and 1 TeV for squarks

Documentation: **SUS-16-036** arxiv1705.04650

BACK UP

The CMS detector

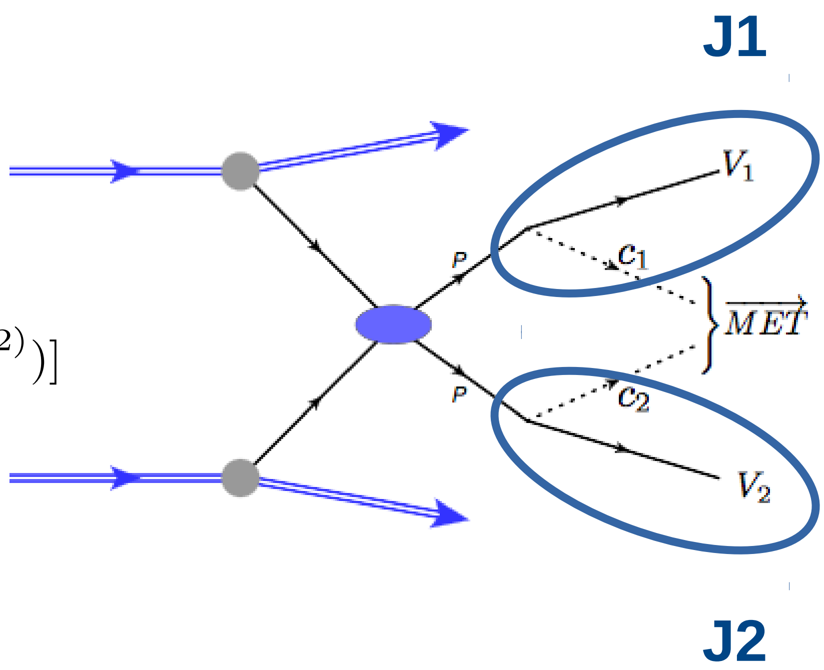


The M_{T2} Variable

- M_{T2} is a generalized ME_T like variable for decays with 2 unobserved particles

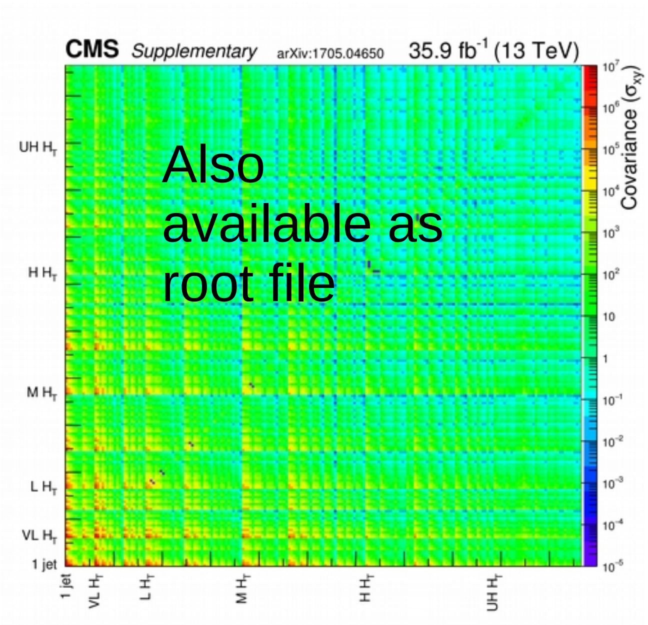
$$M_{T2}(m_c) = \min_{\vec{p}_T^{\,c(1)} + \vec{p}_T^{\,c(2)} = \vec{p}_T^{\,miss}} \left[\max(M_T^{(1)}, M_T^{(2)})\right]$$

- Split visible part of event into 2 hemispheres (pseudojets) for calculation of M_{T2}



Approximative formula:
$(M_{T2})^2 \sim p_T(J1) \cdot p_T(J2) \cdot (1+\cos\varphi_{12})$

Aggregate signal regions & covariance matrix for easier reinterpretation



Region	N_j	H_T [GeV]	M_{T2} [GeV]	Prediction	Data	N_{95}^{obs}
2j loose	≥ 2	>1000	>1200	38.9 ± 11.2	42	26.6–27.8
2j tight	≥ 2	>1500	>1400	2.9 ± 1.3	4	6.5–6.7
4j loose	≥ 4	>1000	>1000	19.4 ± 5.8	21	15.8–16.4
4j tight	≥ 4	>1500	>1400	2.1 ± 0.9	2	4.4–4.6
7j loose	≥ 7	>1000	>600	$23.5^{+5.9}_{-5.6}$	27	18.0–18.7
7j tight	≥ 7	>1500	>800	$3.1^{+1.7}_{-1.4}$	5	7.6–7.9

Signal **12.9 fb^{-1}**	Expected limit [fb] (full analysis)	Expected limit [fb] (best aggregated region)
$pp \to \tilde{g}\tilde{g}, \tilde{g} \to b\bar{b}\tilde{\chi}_1^0$ ($m_{\tilde{g}} = 1700\,GeV$, $m_{\tilde{\chi}_1^0} = 0\,GeV$)	1.80	3.84
$pp \to \tilde{g}\tilde{g}, \tilde{g} \to b\bar{b}\tilde{\chi}_1^0$ ($m_{\tilde{g}} = 1000\,GeV$, $m_{\tilde{\chi}_1^0} = 950\,GeV$)	234	498

Full analysis give significantly better limits than the **best aggregate region**

Exclusion Limits – Direct stop production