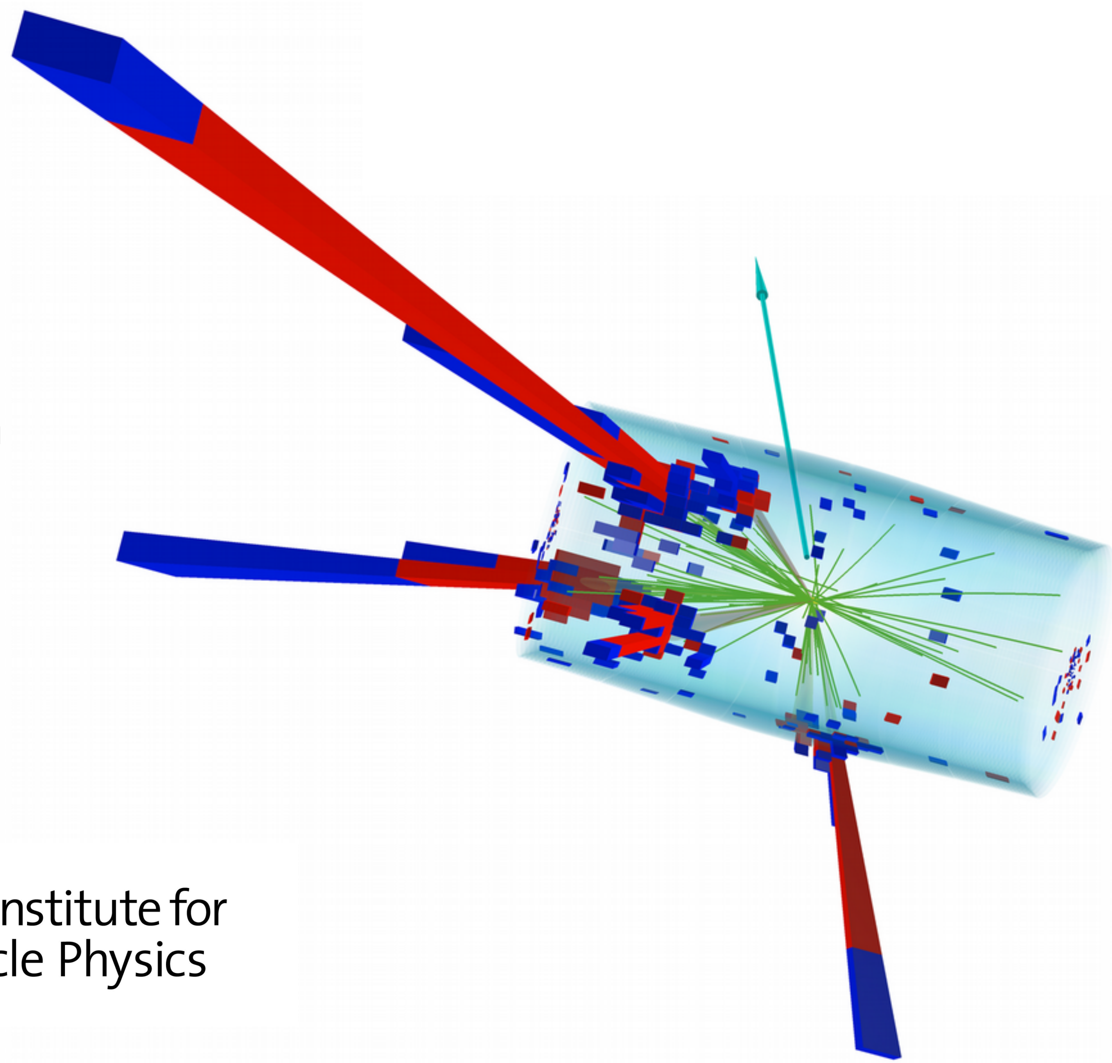
Searches for SUSY via strong production in fully hadronic final states at CMS



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ETH Zürich

for the CMS collaboration

EPS-HEP, Venice
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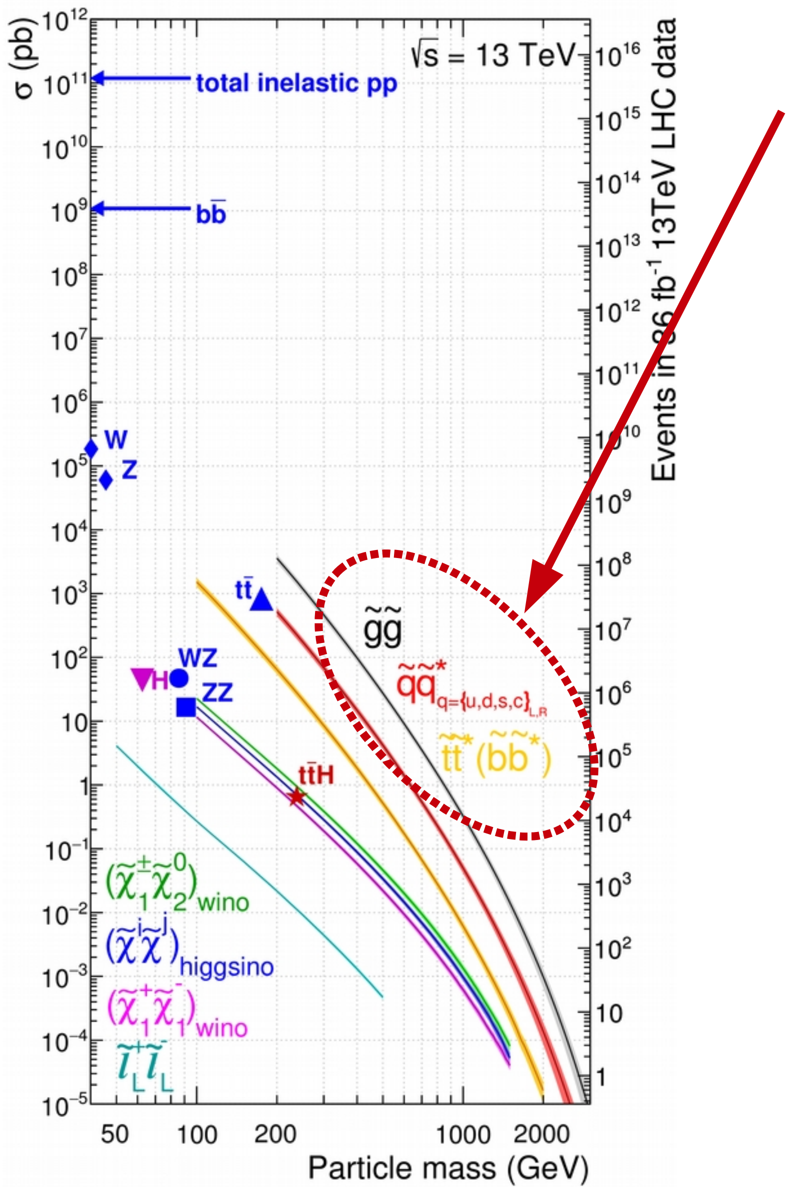
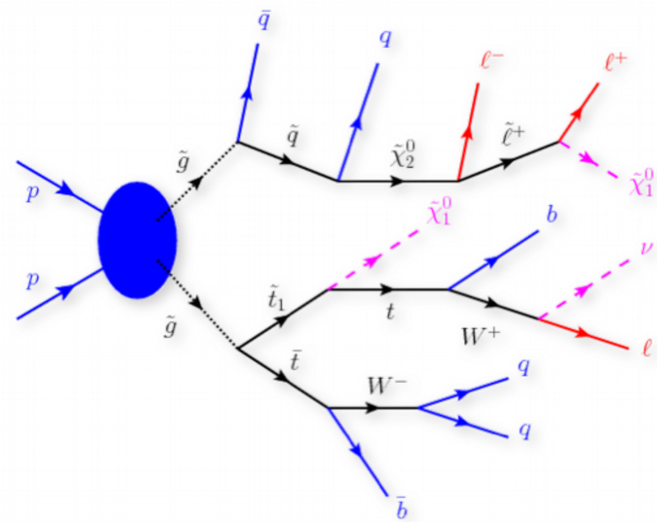
ETH Institute for Particle Physics

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**

Four fully hadronic searches at CMS

H_T^{miss}	**SUS-16-033** arxiv1704.07781	35.9 fb^{-1}	Focus on these latest results in this talk
M_{T2}	**SUS-16-036** arxiv1705.04650	35.9 fb^{-1}	
Razor	**SUS-16-016**	12.9 fb^{-1}	
α_T	**SUS-15-004**	2.3 fb^{-1}	

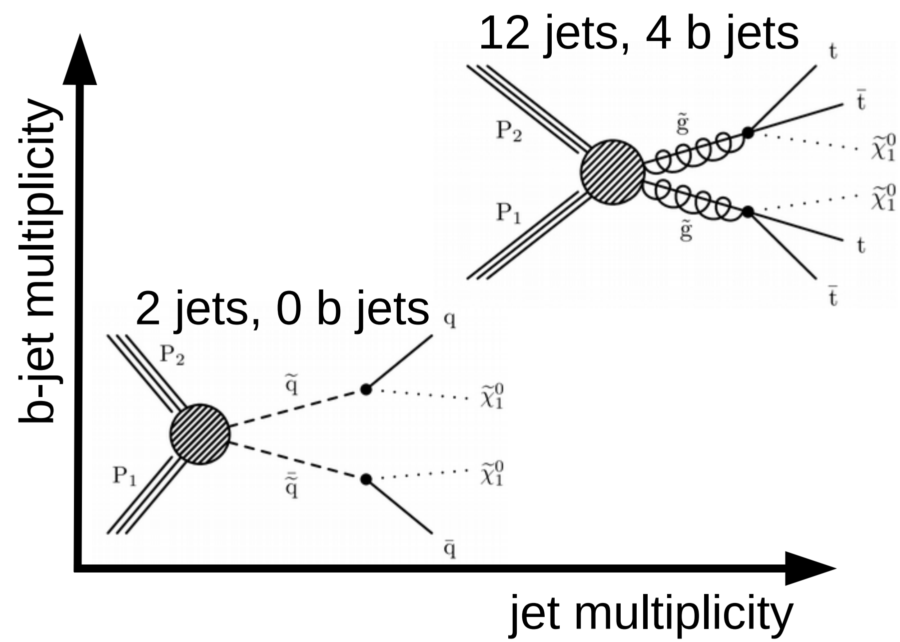
Plus many other SUSY searches at CMS that will be presented:

- 1+ lepton (C. Schomakers)
- 3rd gen. squark production (I. Suarez)
- EW produced SUSY (M. Liu)
- Compressed and cascades with Higgs (C. Heidegger)
- Final states with photons (M. Weinberg)

Strategy for fully hadronic inclusive searches

- Lepton veto
- Large ME_T from neutralinos
- Many jets
- A lot of hadronic activity

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



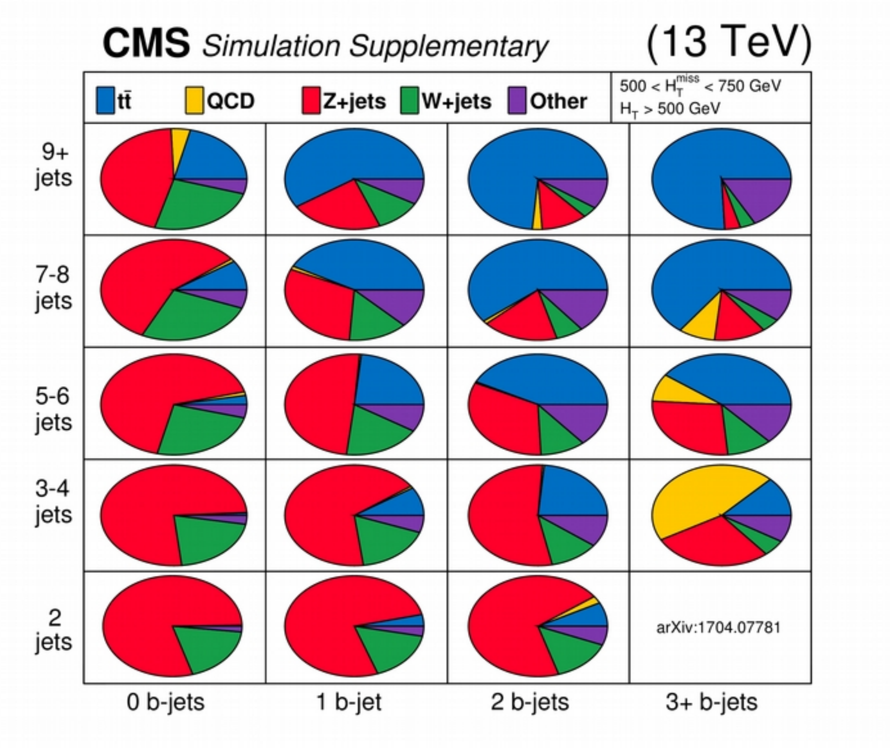
$$\mathrm{H}_T = \sum_{jets} |\vec{p_T}|$$

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

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

Main backgrounds

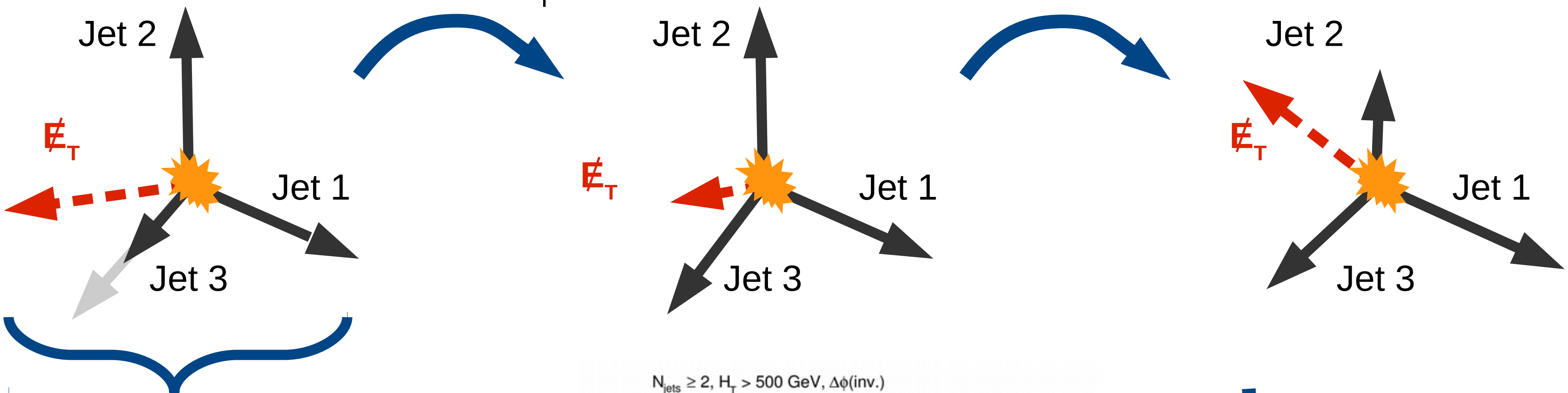
- **QCD multi-jet:**
  - Mis-measurement of a jet leads to imbalanced event → **instrumental ME_T**
- **W-jets & ttbar (Lost lepton):**
  - **ME_T from neutrino** from leptonic W decay
  - Charged lepton not caught by lepton veto because of acceptance, reconstruction or isolation
- **$Z_{\nu\nu}$+jets:**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



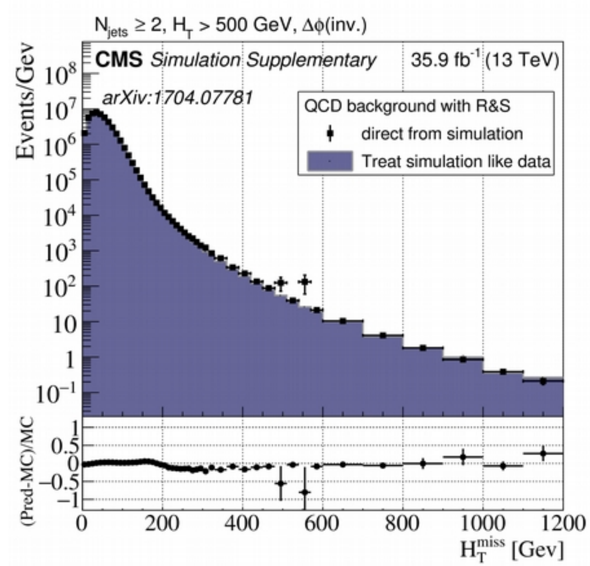
QCD Estimate: Rebalance and Smear

Rebalance jets to true hard scatter event with $ME_T \approx 0$

Smear jets according to response

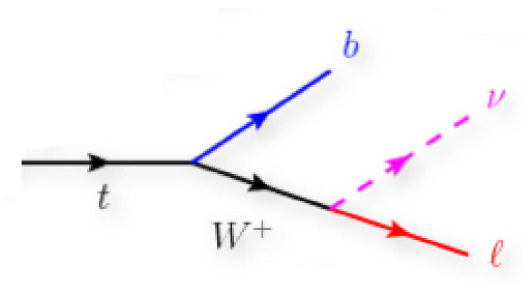


QCD multi-jet events have no intrinsic ME_T, only **instrumental ME_T** due to detector response that depends on η & p_T of jets

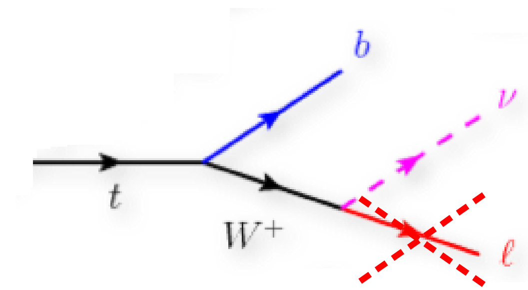


Good agreement with out of the box simulation

Lost Lepton estimate

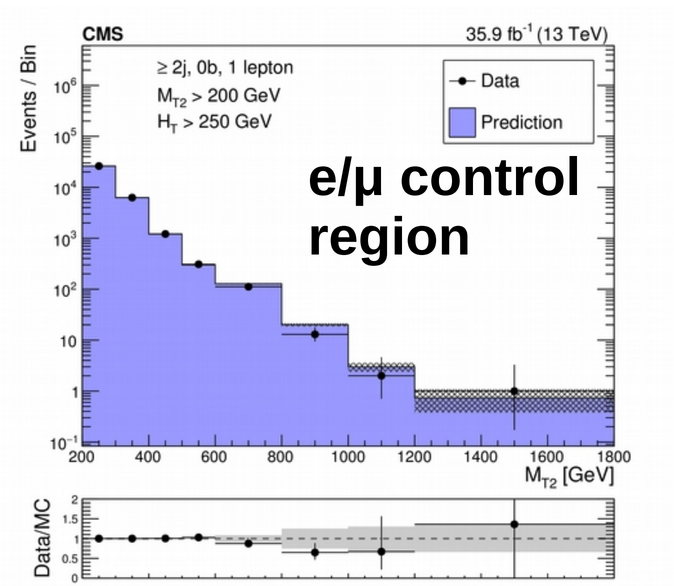


Probability from MC to lose it



Single lepton (e/μ) control region

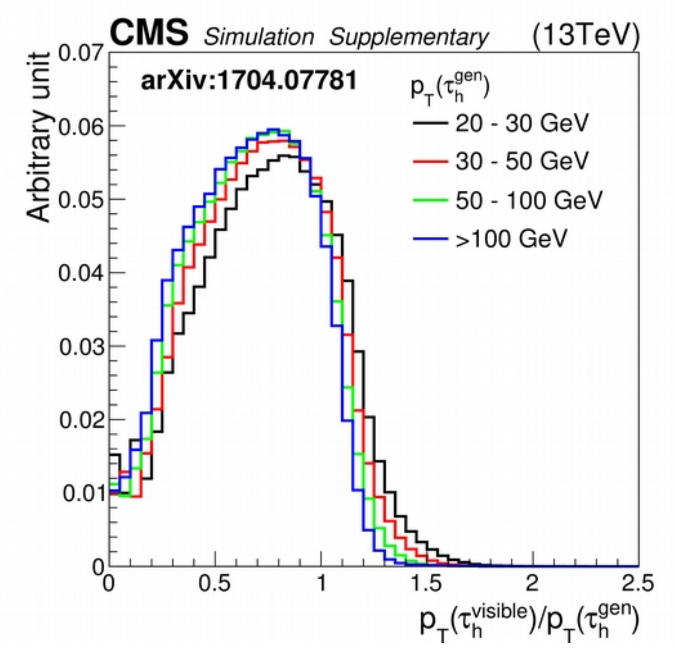
0 lepton signal region

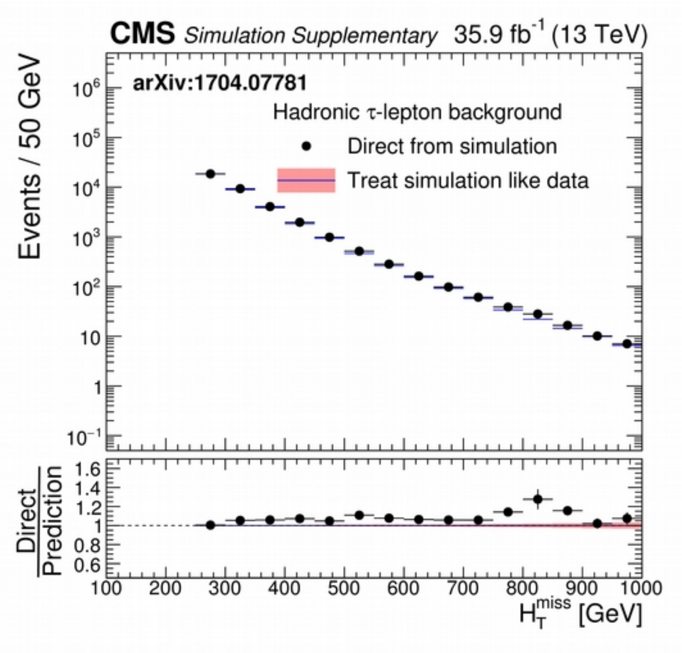


- Charged lepton not seen because of
  - Acceptance of detector
  - Reconstruction/ID
  - Non-isolation
- **Suppress with efficient lepton veto**

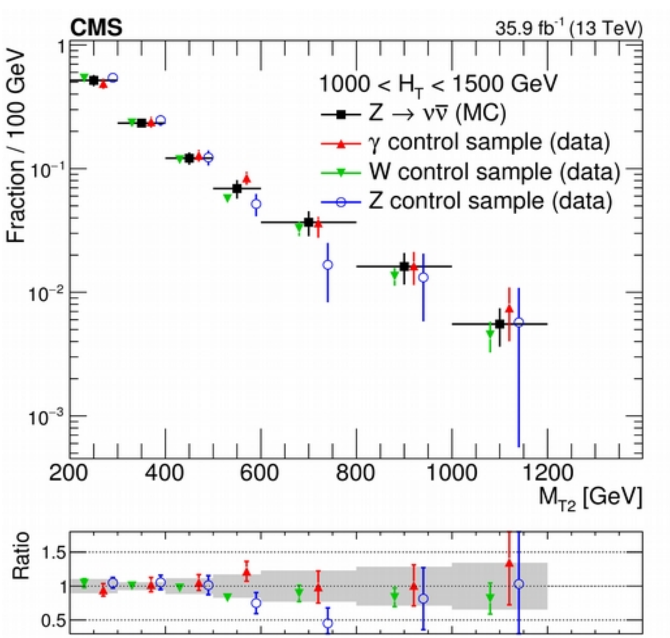
Special estimate of hadronic Tau decays for H_T^{miss} analysis

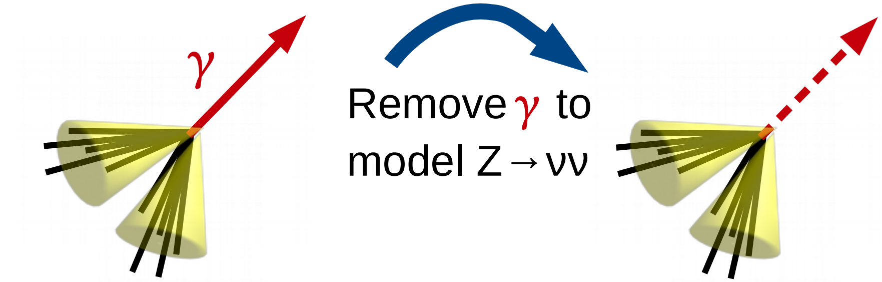
- Single μ control region in data
- Smear μ p_T with τ_h response function
- Recompute event kinematics





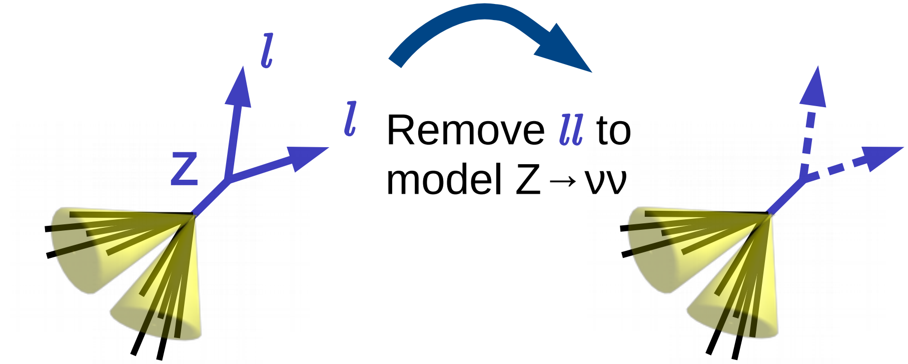
Z→νν Estimate





γ+jets

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

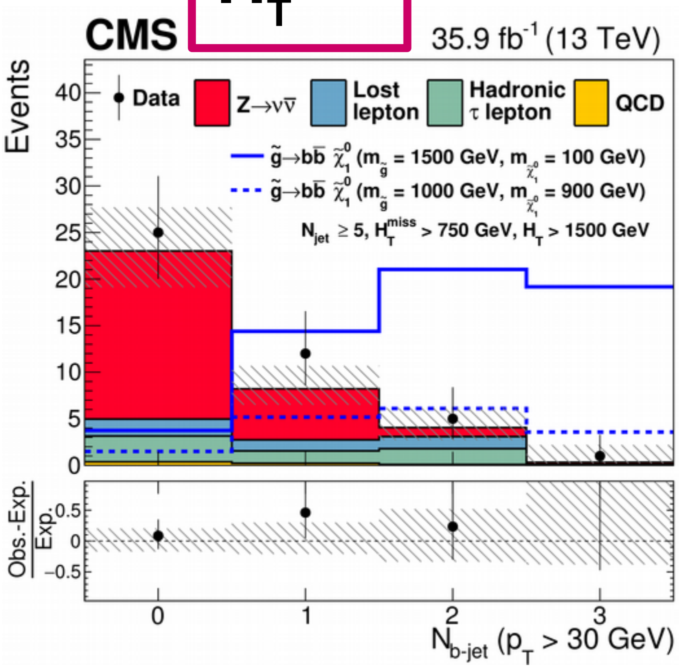


Z→ll

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

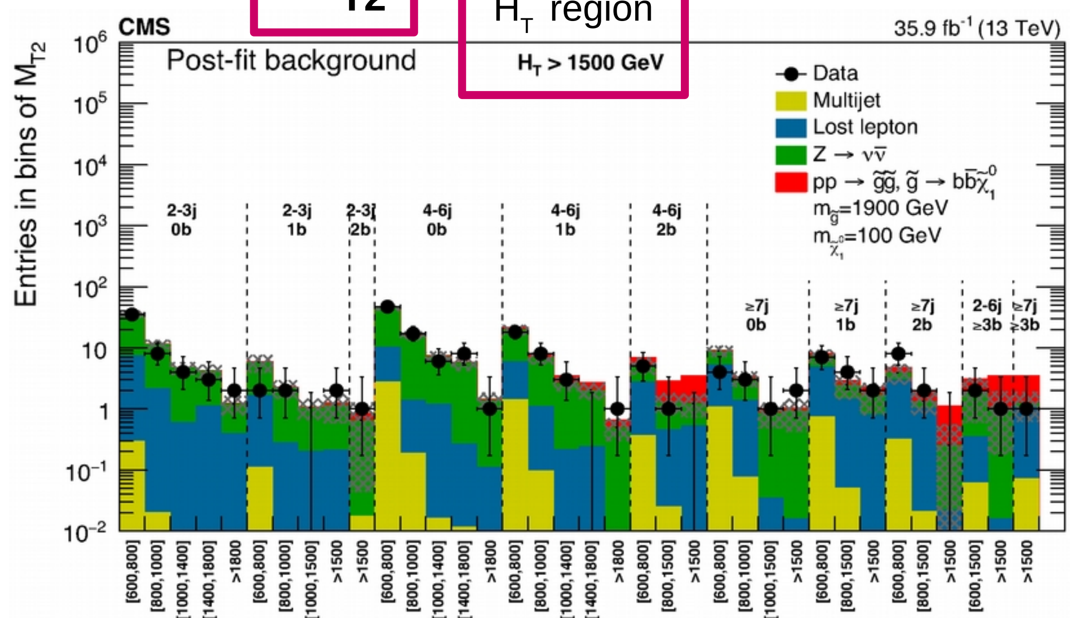
Selected results

H_T^{miss}



M_{T2}

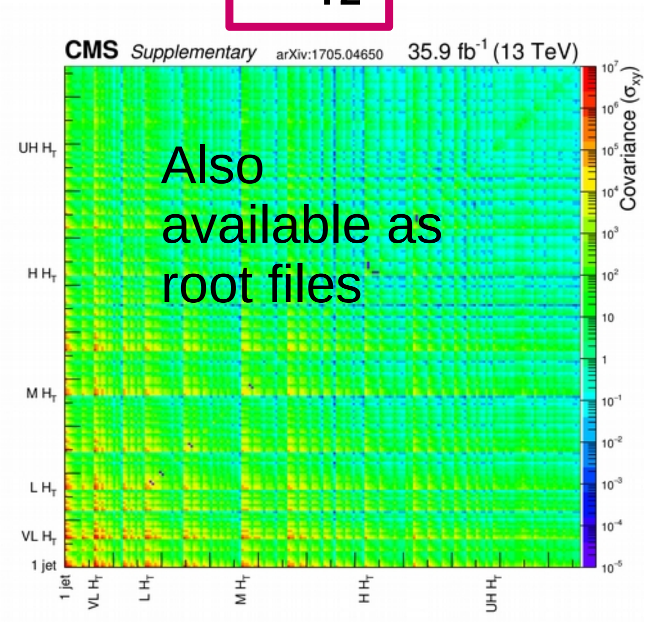
Highest H_T region



Good agreement with the standard model

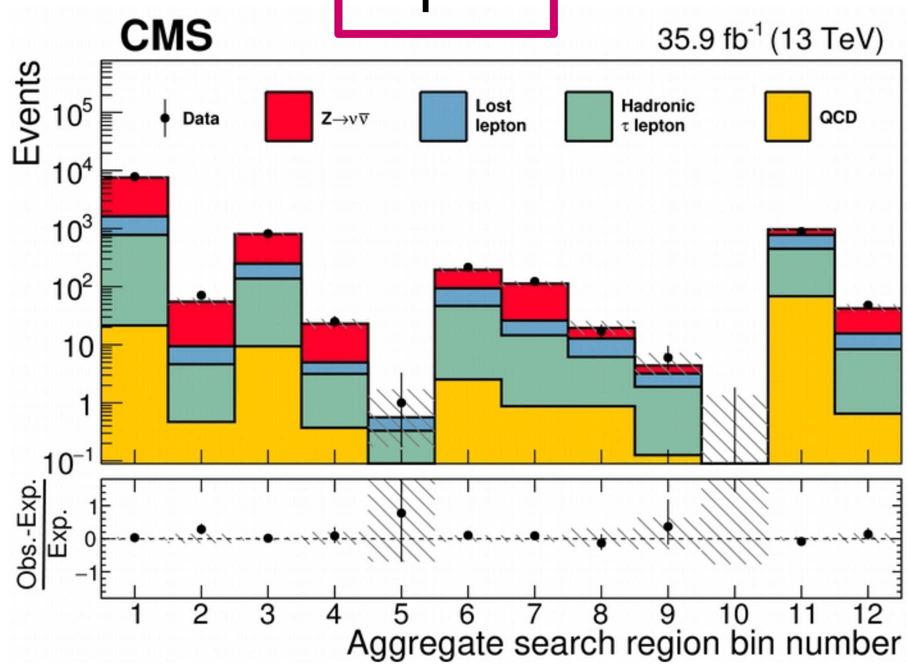
Aggregate signal regions & covariance matrix for easier reinterpretation

M_{T2}



Also available as root files

H_T^{miss}

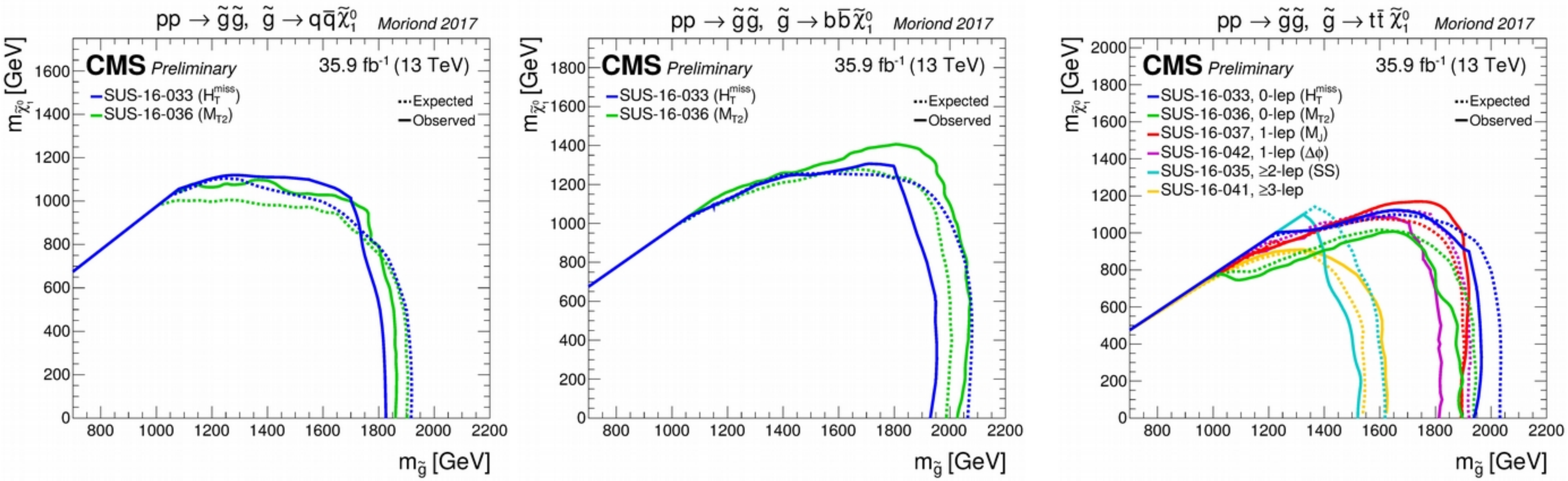


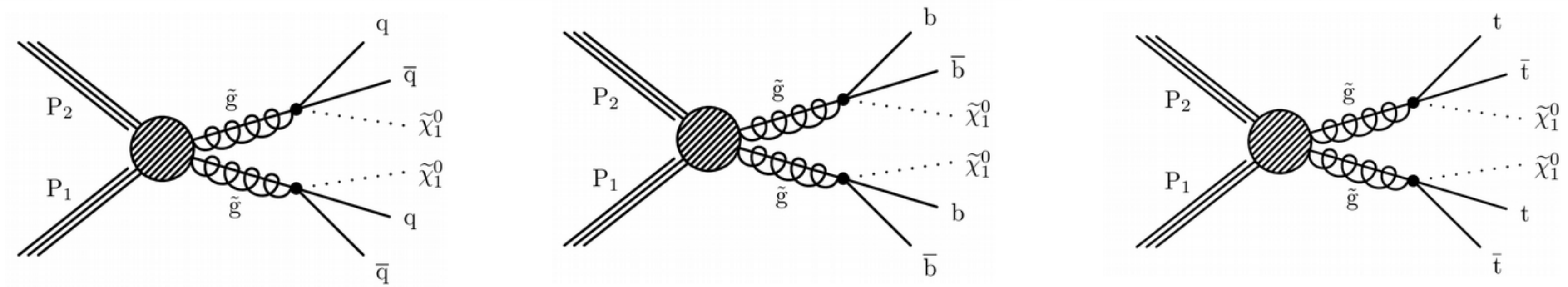
M_{T2} @12.9 fb-1

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

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

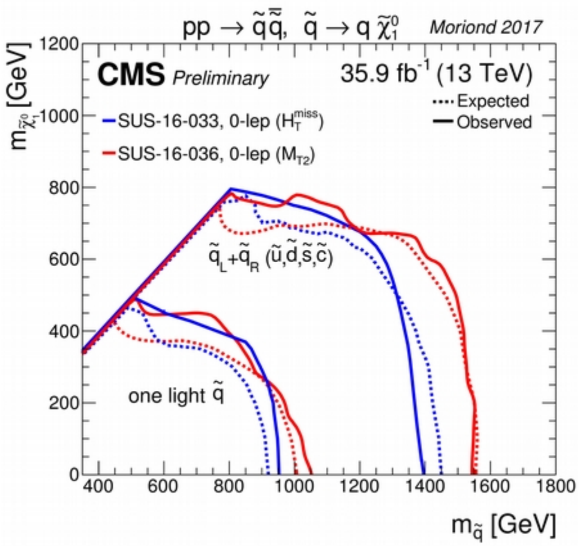
Exclusion Limits – Gluino production

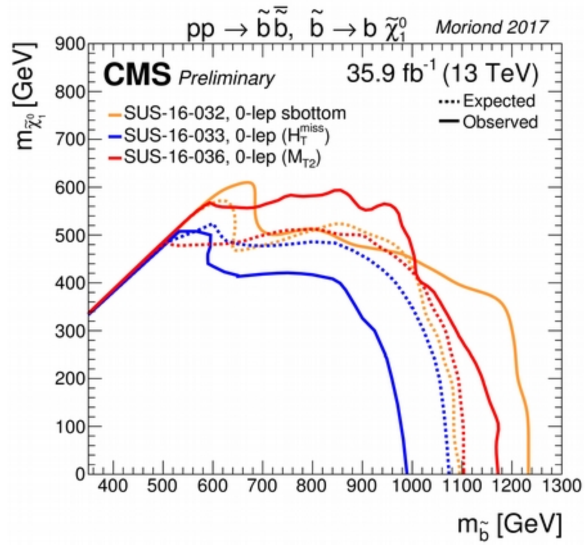


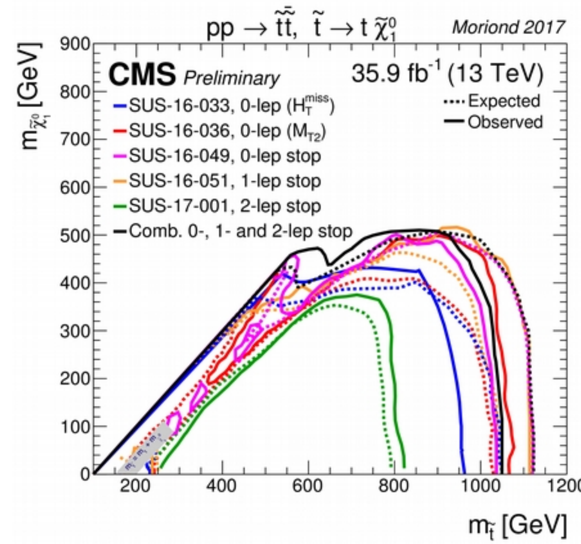


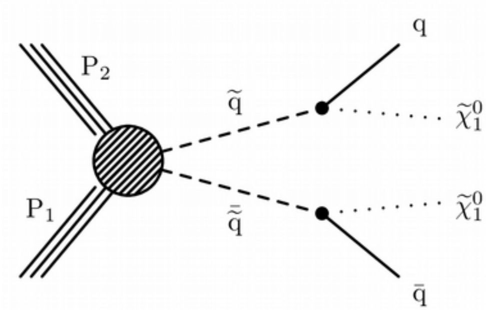
- Similar reach for both analyses
- Hadronic analyses have similar reach as leptonic channels
- Extended reach up to about 2 TeV along gluino mass

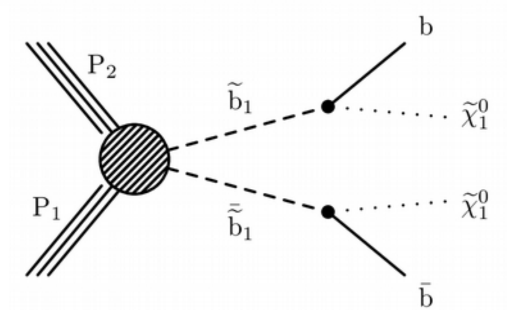
Exclusion Limits – Direct squark production

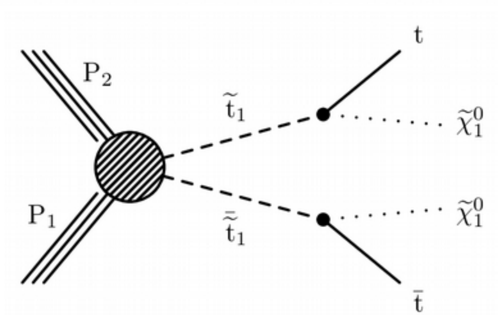












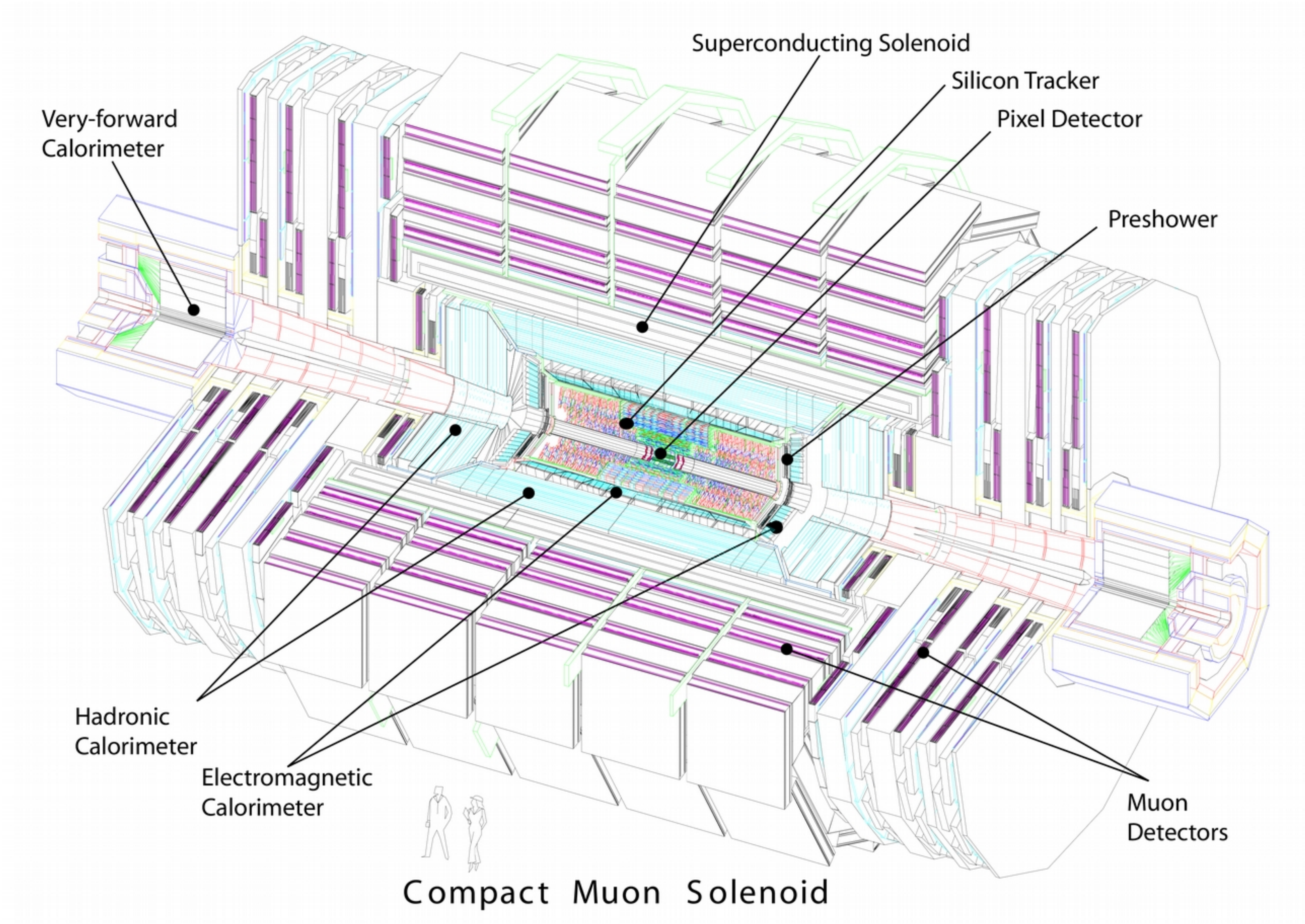
- Similar reach for both analyses
- Have similar reach as leptonic channels for stop production
- Extended reach by to about 1TeV along squark mass

Conclusions

- Showed results of 2 fully hadronic inclusive searches for SUSY 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 with two independent approaches

BACK UP

The CMS detector

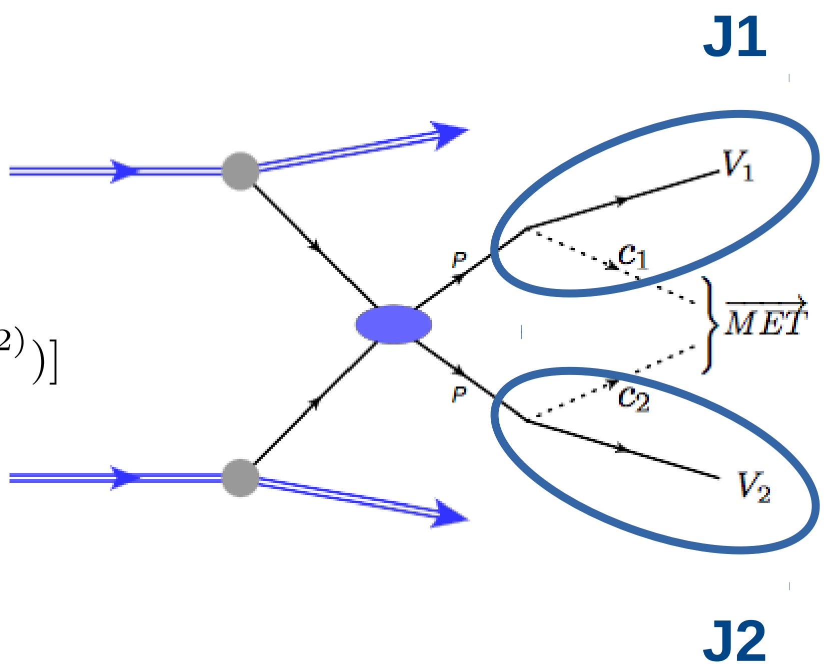


The M_{T2} Variable

- 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}



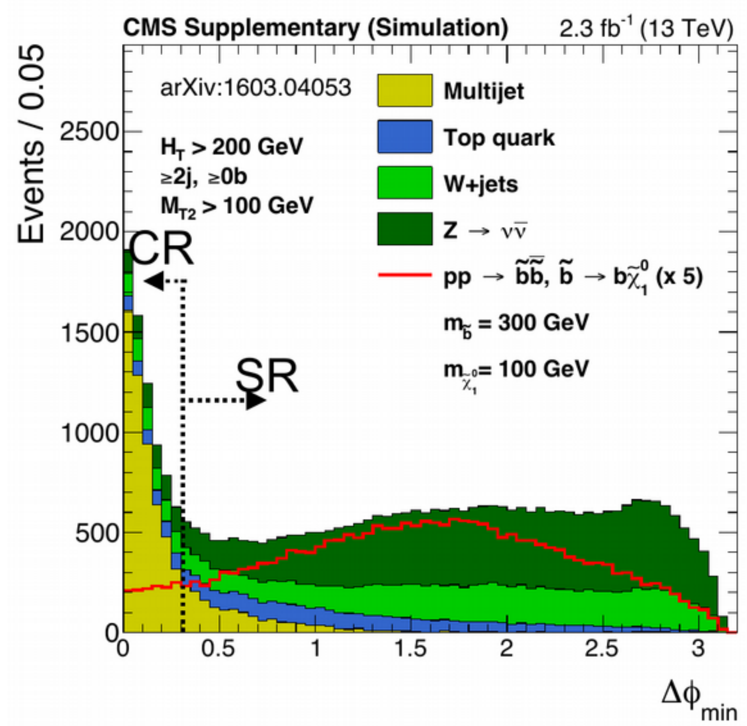
Approximative formula:
$(M_{T2})^2 \sim p_T(J1) \cdot p_T(J2) \cdot (1+\cos\varphi_{12})$

QCD background estimate via delta Phi

- Invert $\Delta\varphi(ME_T, \text{jets})$ 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_{CR} coming from signal triggers



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

In each H_T region: