

Searches for Supersymmetry in All-Hadronic Final States with CMS

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on behalf of the CMS collaboration

EPS-HEP 2011, Grenoble, July 23th



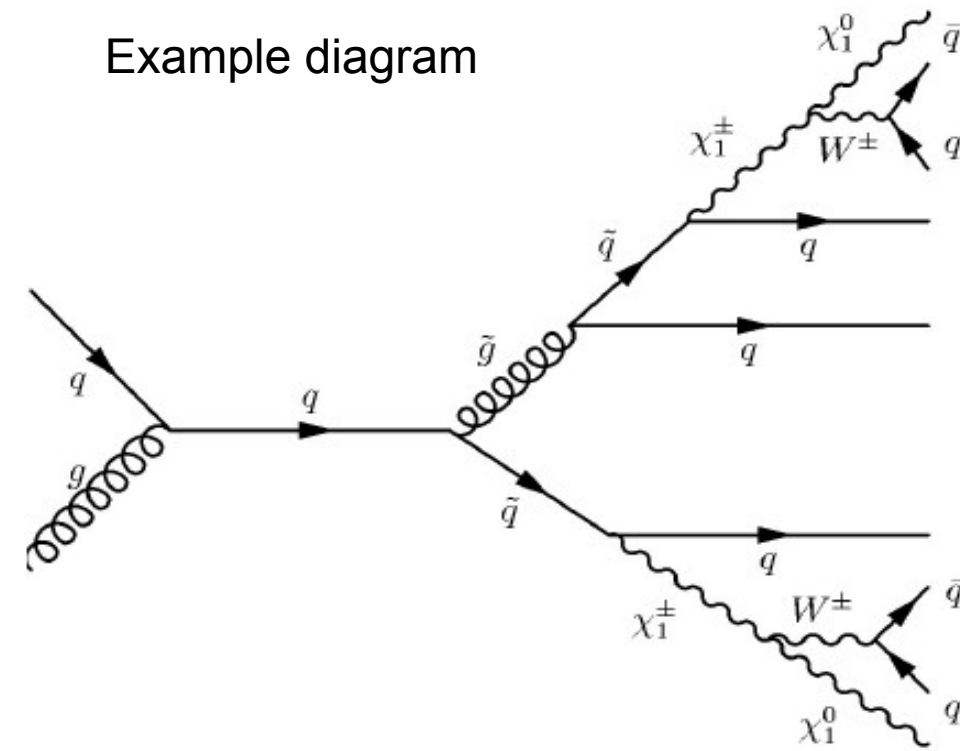
GEFÖRDERT VOM



Bundesministerium
für Bildung
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SUSY cross section is dominated by squark and gluino pair/associated production

Example diagram



- R-parity conservation
 - pair/associated SUSY production
 - Stable LSP
 - Cascade decay of primary produced SUSY particles
 - **missing E_T** ,
 - many jets,
 - possibly leptons
- (dedicated analyses & talk).

Data-driven estimation of all relevant Standard Model backgrounds in addition to MC simulation:

- Jets + Missing Transverse Energy, 36 pb^{-1} :
Inclusive, least model-dependent
- “Razor”, 36 pb^{-1} :
Variables related to SUSY mass-scale using hemisphere algorithm
- α_T Search, 1.1 fb^{-1} :
Effective suppression of QCD-multijet production
- Results & Sensitivity: using up to 1.1 fb^{-1} of integrated luminosity

Emphasis on

- data-driven background modeling,
- inclusive selection.

$$H_T = \sum_i^{\text{jets}} |\vec{p}_{T,i}|$$

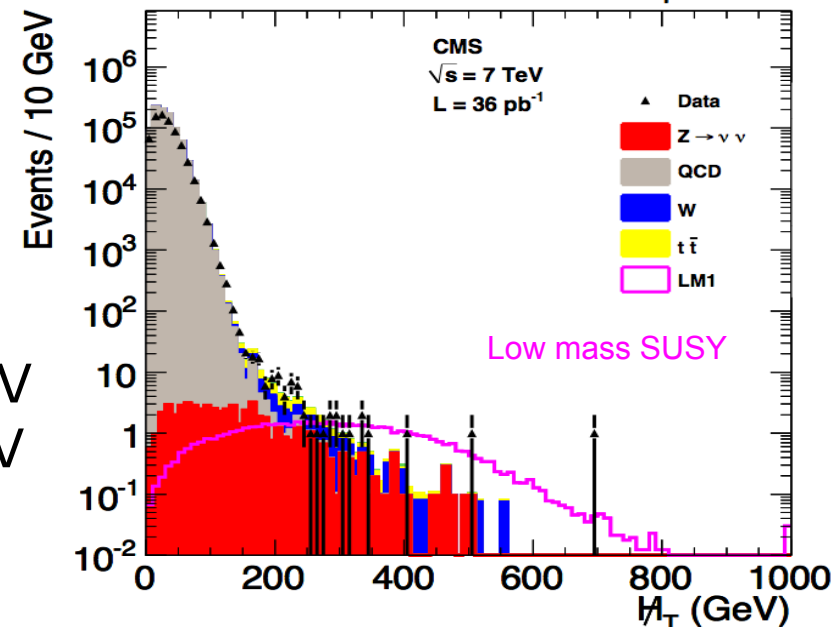
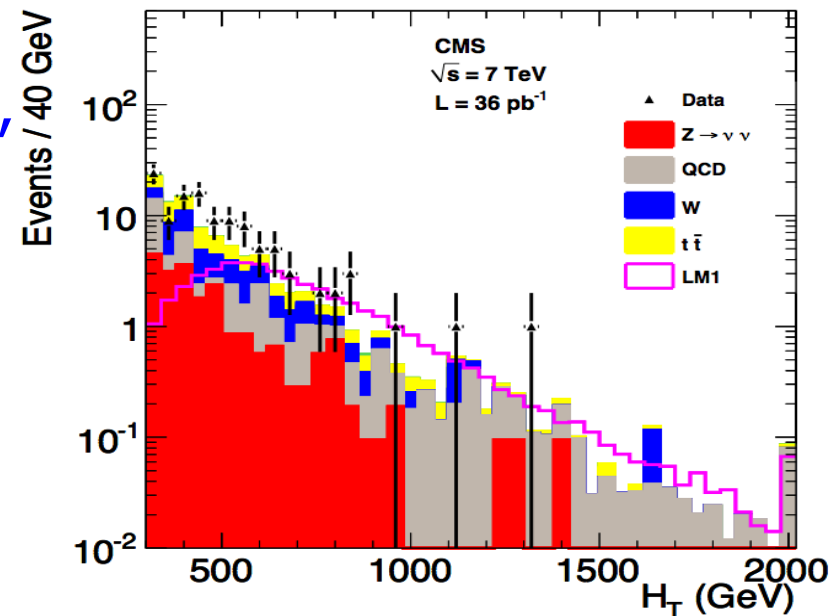
$$\cancel{H}_T = - \left| \sum_i^{\text{jets}} \vec{p}_{T,i} \right|$$

(Missing) Transverse Hadronic Energy

Search selections:

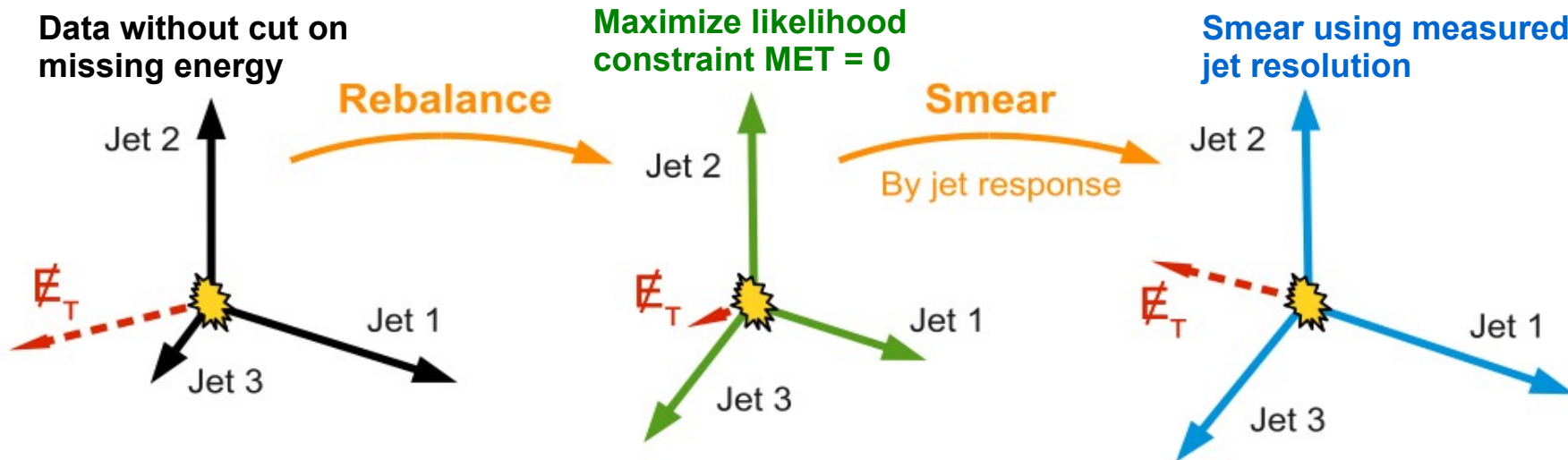
- ≥ 3 jets $p_T > 50$ GeV,
- Jets not colinear with MHT
- $MHT > 250$ GeV **Or** • $MHT > 150$ GeV
- $HT > 300$ GeV • $HT > 500$ GeV

Signal acceptance 20-30%

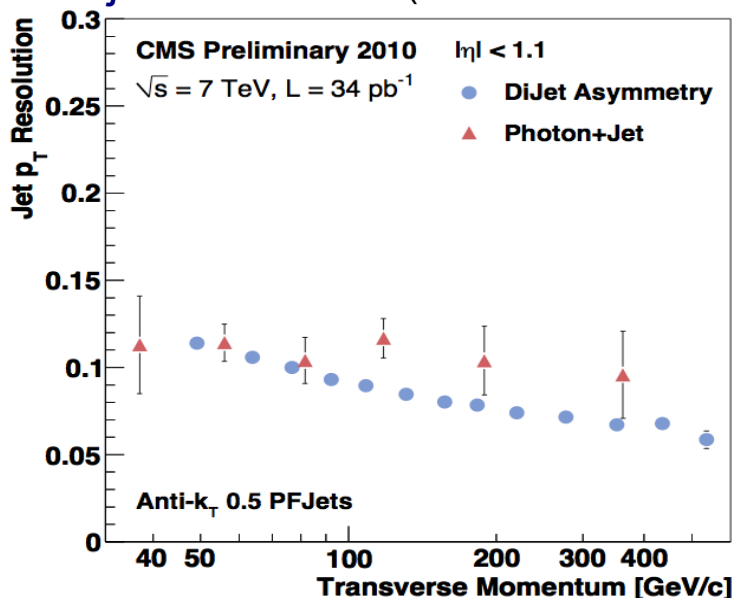


QCD estimation from data

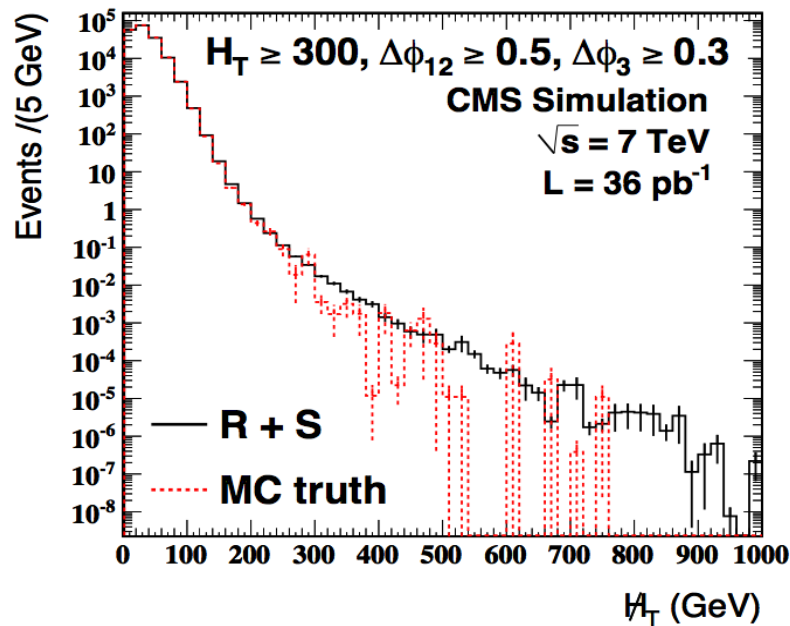
Submitted to JHEP, arXiv:1106.4503



Gaussian jet resolution: (CMS JME-10-014)

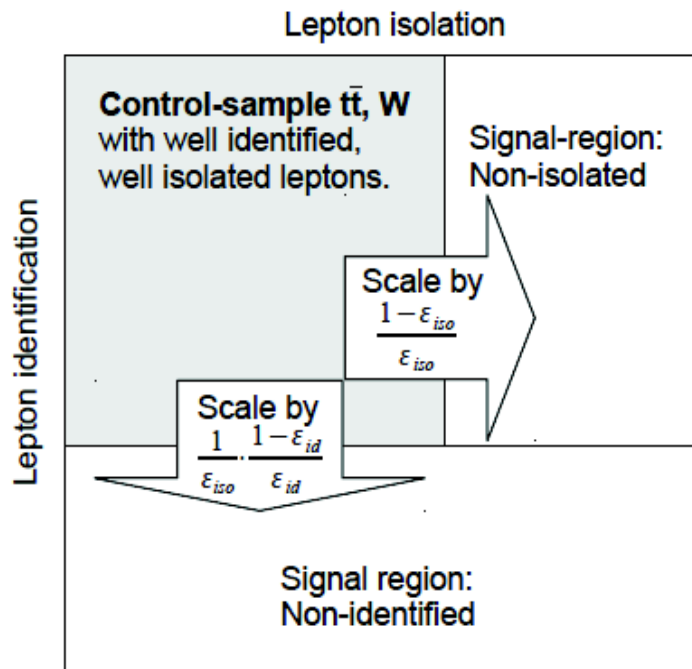


Closure: Method works better than 40%:

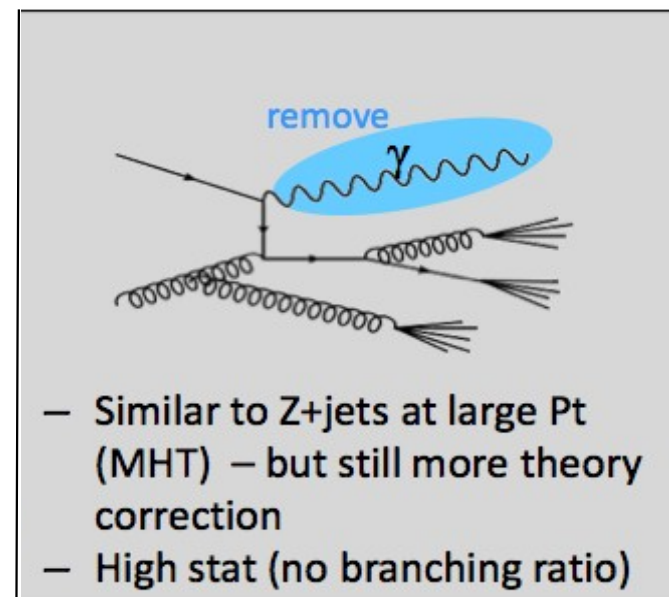


W / tt background:

Lepton lost due to isolation or identification



Z \rightarrow $\nu\nu$ from γ -jets data:



Calculation γ / Z ratio:

Z. Bern et al., arXiv:1106.1423

Lepton is a hadronically decaying tau:

Isolated muon control sample from data

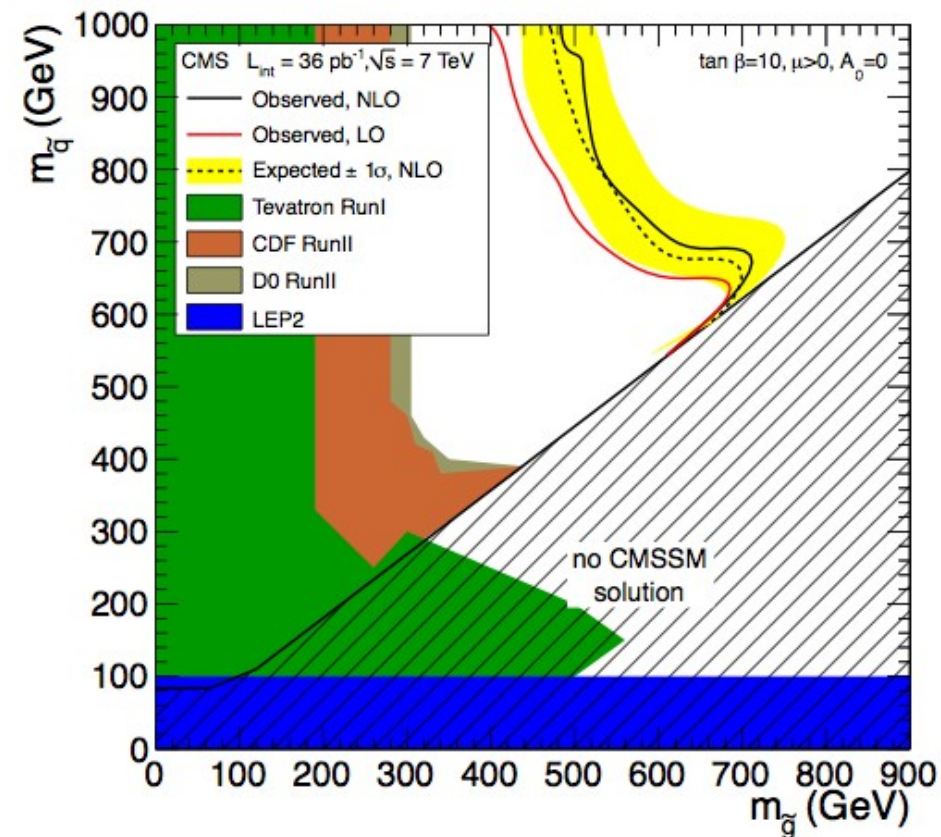
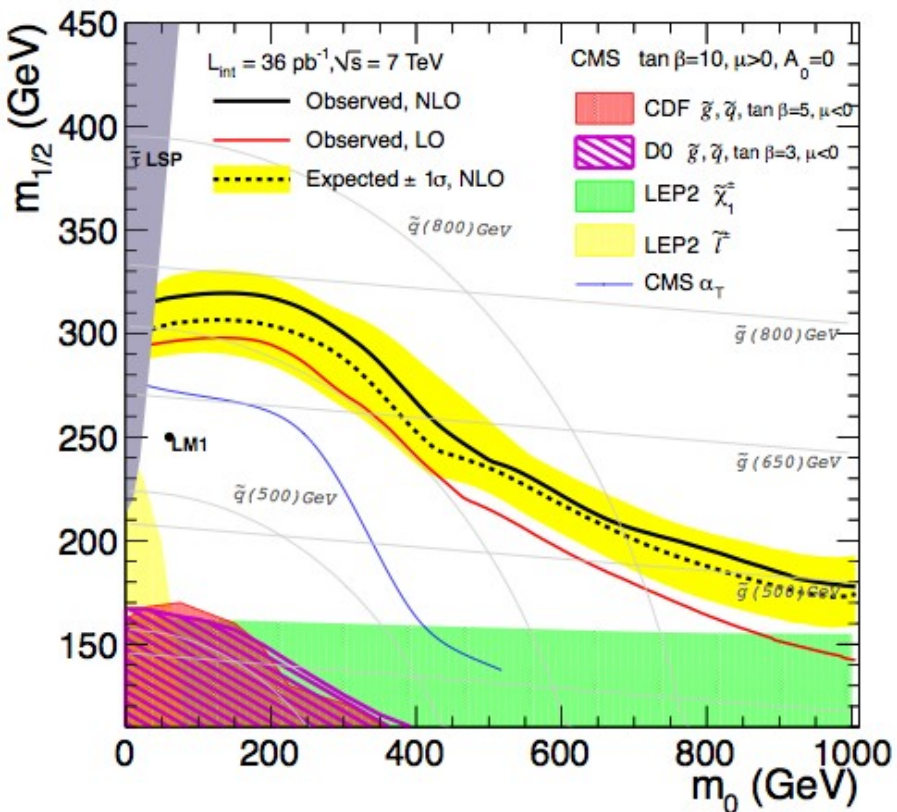
Replace muon by hadronic tau response from MC

Event yields:

	Expected	Observed
MHT > 250 GeV	18.8 ± 3.5	15

	Expected	Observed
HT > 500 GeV	43.8 ± 9.2	40

Interpretation in the CMSSM plane:



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The "Razor" Search

Hemisphere algorithm to cluster events into an effective di-jet system

Submitted to JHEP, arXiv:1107.1279

Define:

$$M_{\Delta} = \frac{M_{\tilde{q}}^2 - M_{\chi^0}^2}{M_{\tilde{q}}}$$

As a measure for the mass-scale, estimator:

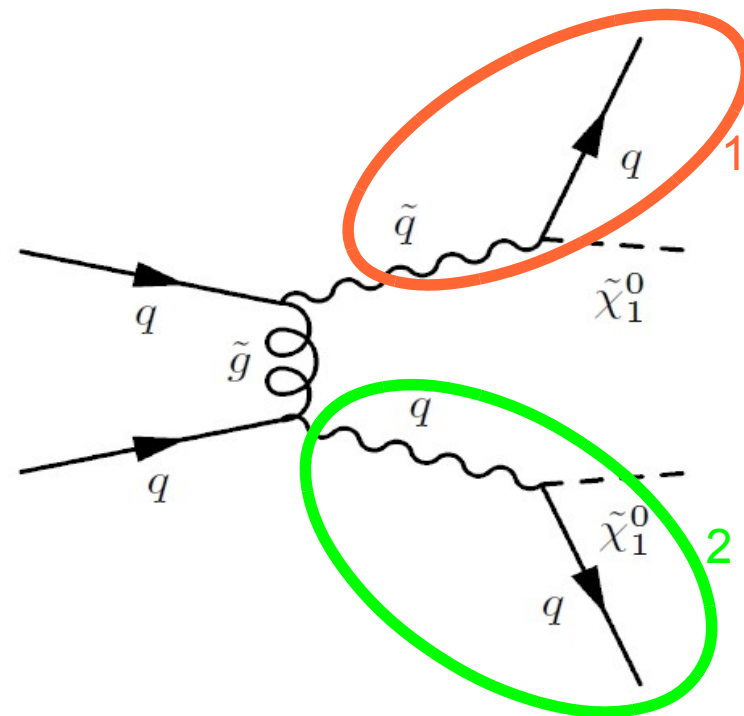
$$M_R = 2 \sqrt{\frac{(E_1 \cdot p_{z,2} - E_2 \cdot p_{z,1})^2}{(p_{z,1} - p_{z,2})^2 - (E_1 - E_2)^2}}$$

$$M_T^R = \sqrt{\frac{\cancel{E}_T(p_{T,1} + p_{T,2}) - \vec{\cancel{E}}_T(\vec{p}_{T,1} + \vec{p}_{T,2})}{2}}$$

and the dimensionless ratio

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

C. Rogan, arXiv:1006.2727



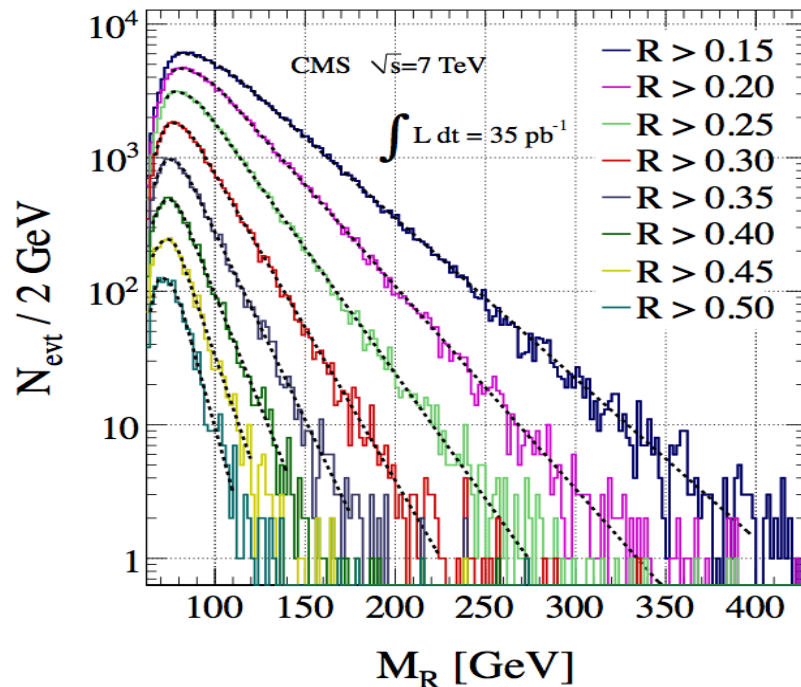
For the QCD background

$$M_R = \sqrt{\hat{s}}$$

is falls like a power law

The "Razor" Search

Submitted to JHEP, arXiv:1107.1279

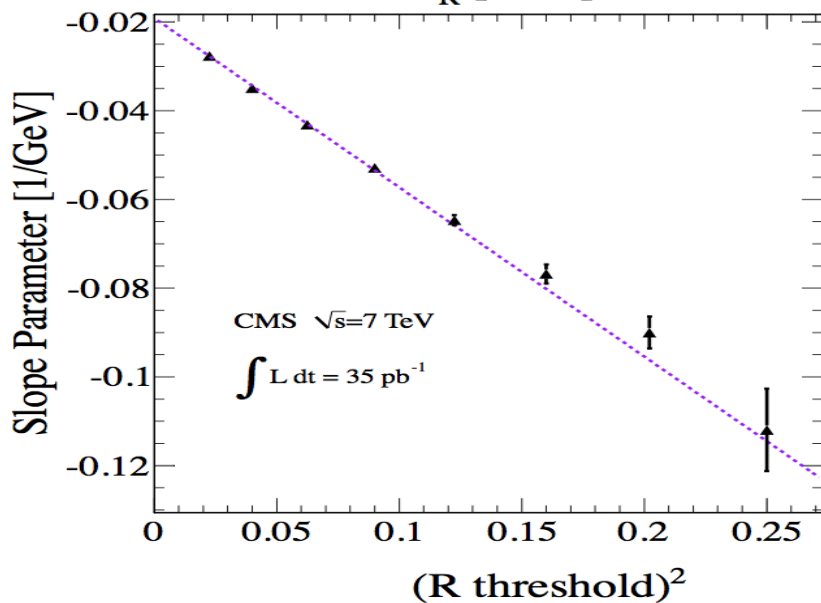


QCD-data:

- M_R falls exponentially
- Slope depends linearly on R^2

QCD prediction:

- Extrapolate to signal-region
 $M_R > 500 \text{ GeV}, R > 0.5$

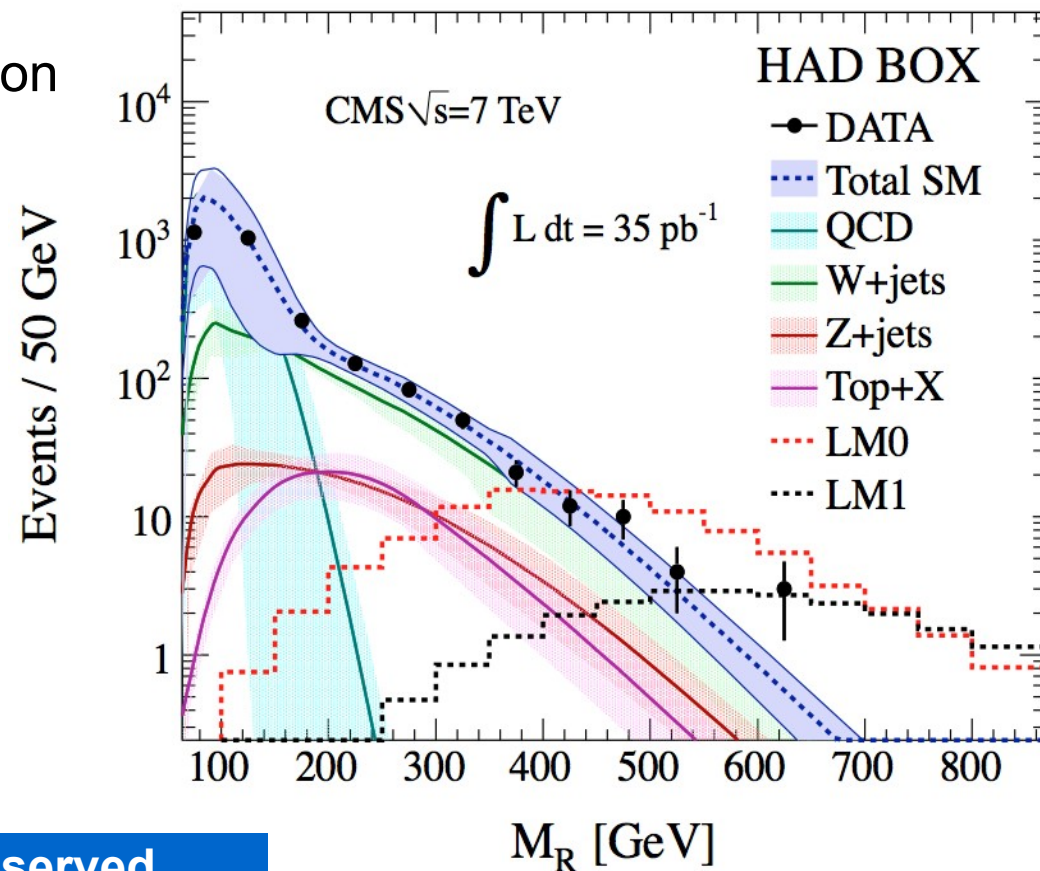


Background modeling:

- Classify events as hadronic, muon or electron,
- Use shapes from lepton boxes
- Use QCD shape from di-jet data
- Fit in $80 < M_R < 400$ GeV
- Extrapolate to high M_R

Event selection

- ≥ 2 jets with $p_T > 30$ GeV
- $\Delta\Phi(\text{hemispheres}) < 2.8$
- $R > 0.5$, $M_R > 500$ GeV

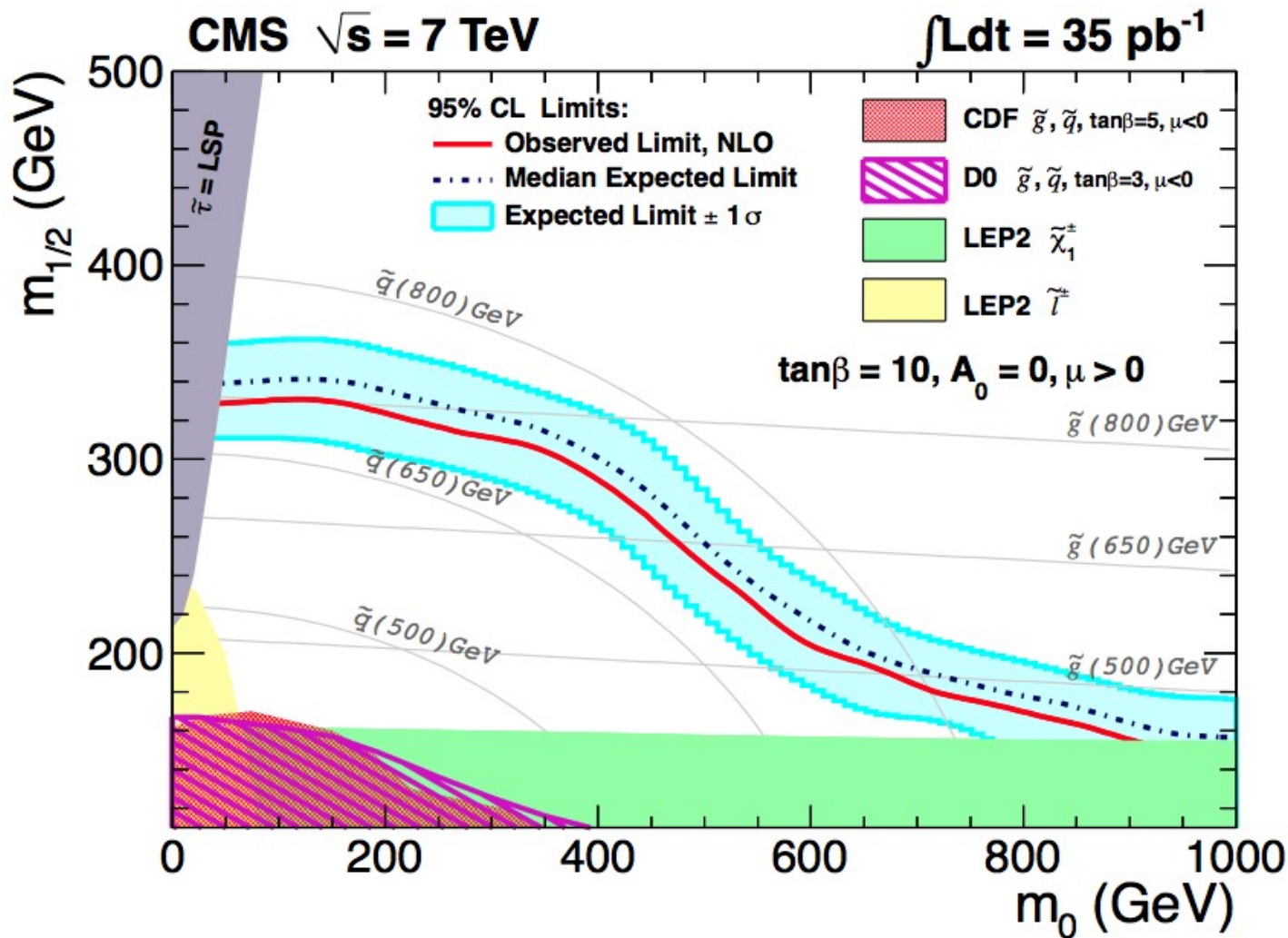


	Expected	Observed
MR > 500 GeV	5.5 ± 1.4	7

The "Razor" Search

Results interpreted in the CMSSM plane

Submitted to JHEP, arXiv:1107.1279



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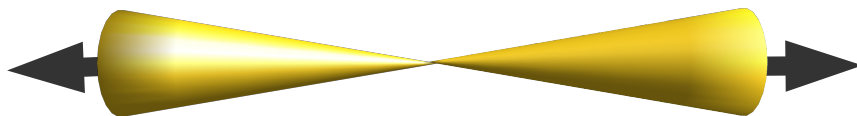
The α_T search

Recombine jets to two pseudo-jets, suppress QCD by α_T :

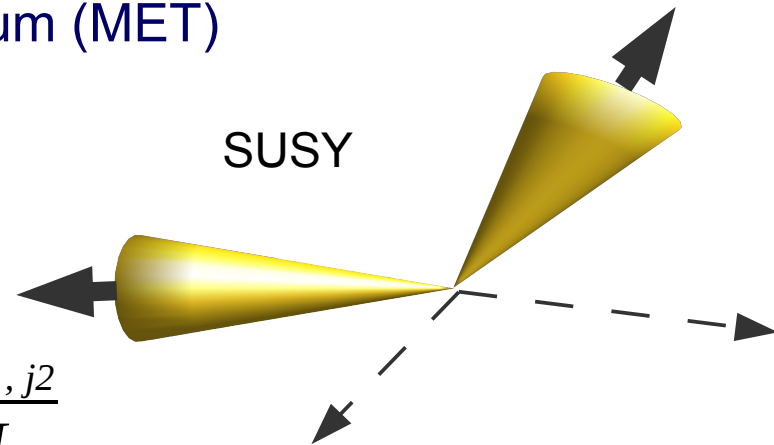
- α_T uses jet momenta and angles
- no direct use of missing transverse momentum (MET)

CMS PAS SUS-2011-003

QCD



SUSY



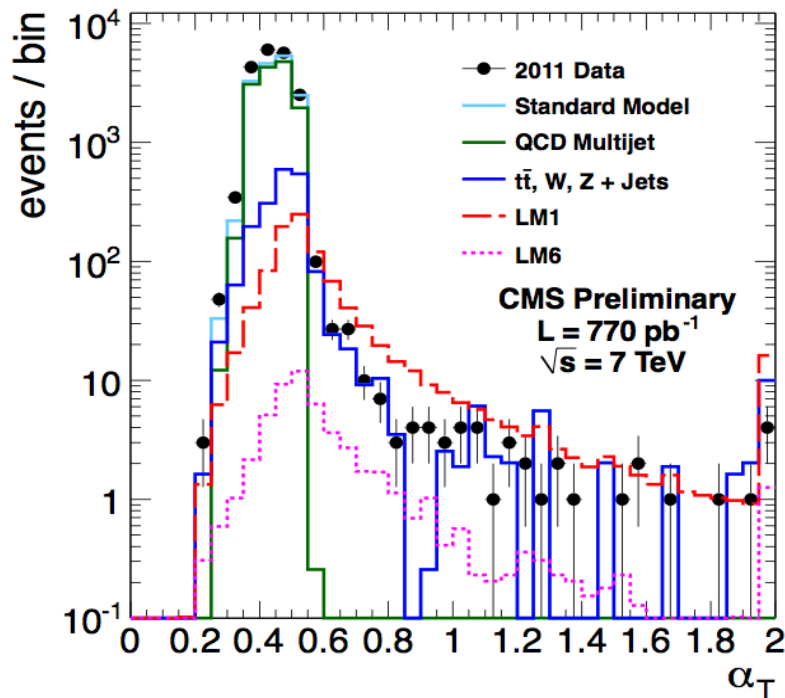
$$\alpha_T = \frac{p_{T,j2}}{M_T}$$

$$M_T = \sqrt{2p_{T,j1} p_{T,j2} (1 - \cos(\Delta\phi))}$$

$$\rightarrow \alpha_T = \sqrt{\frac{p_{T,j2}/p_{T,j1}}{2(1 - \cos \Delta\phi)}}$$

In QCD: $\alpha_T \leq 0.5$ since $p_{T,j2}$ is by definition the lower momentum jet.

Exception: A third jet is completely lost.

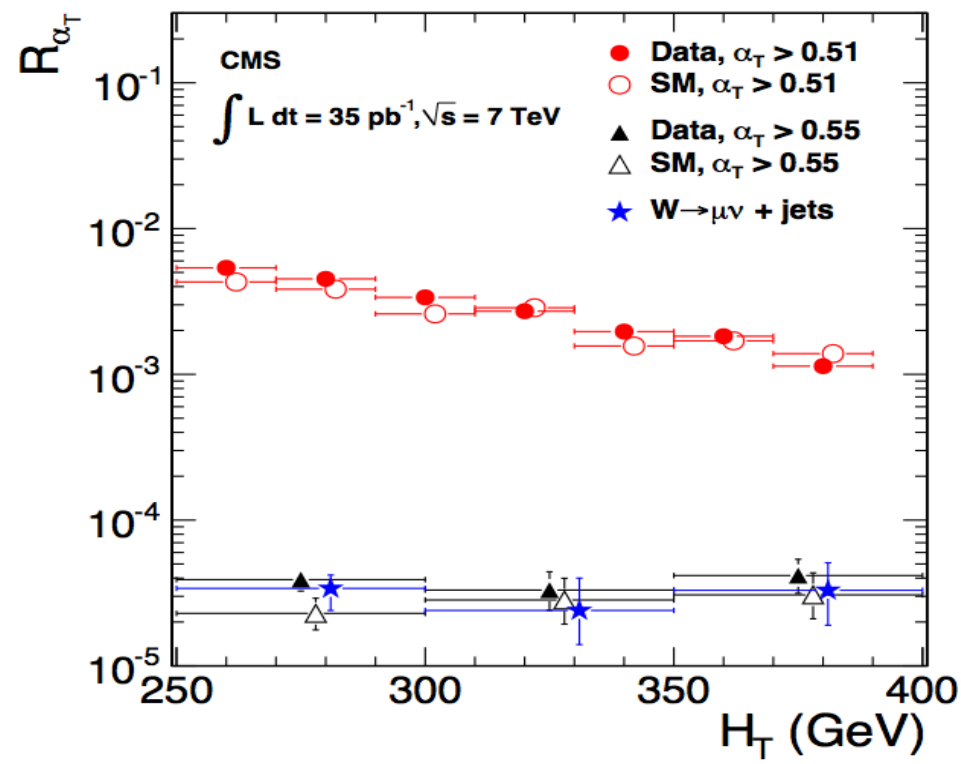
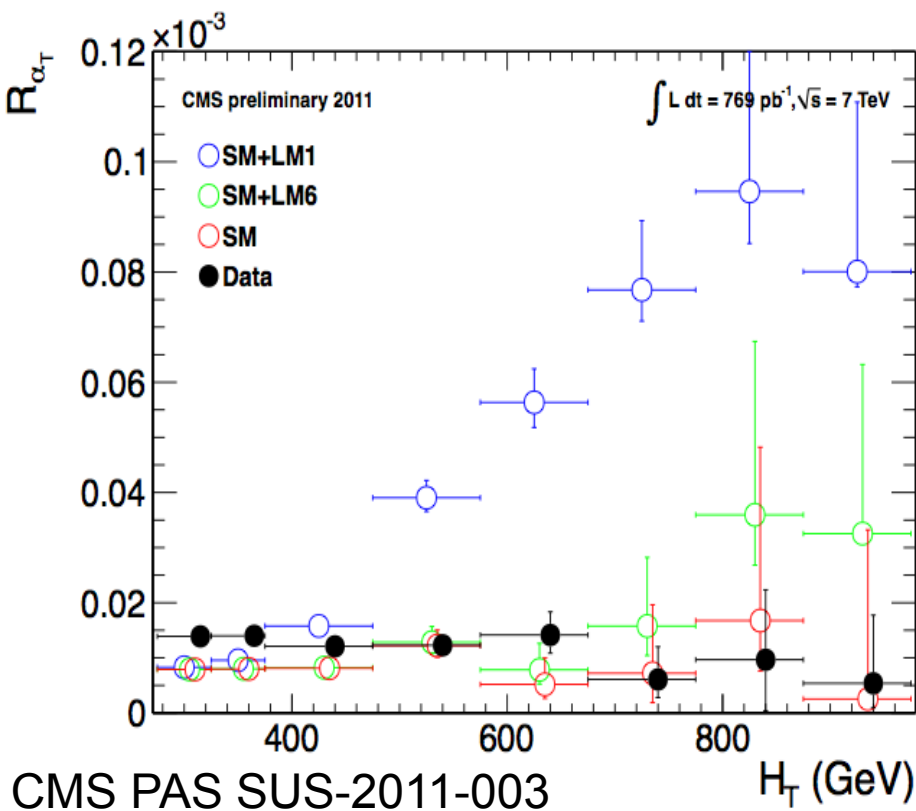


The α_T search

$$R_{\alpha_T} = \frac{\alpha_T > 0.55}{\alpha_T < 0.55}$$

EWK: real MET \leftrightarrow constant R_{α_T}

QCD: MET from jet-resolution \leftrightarrow R_{α_T} Falling with HT since jet resolution improves with pT

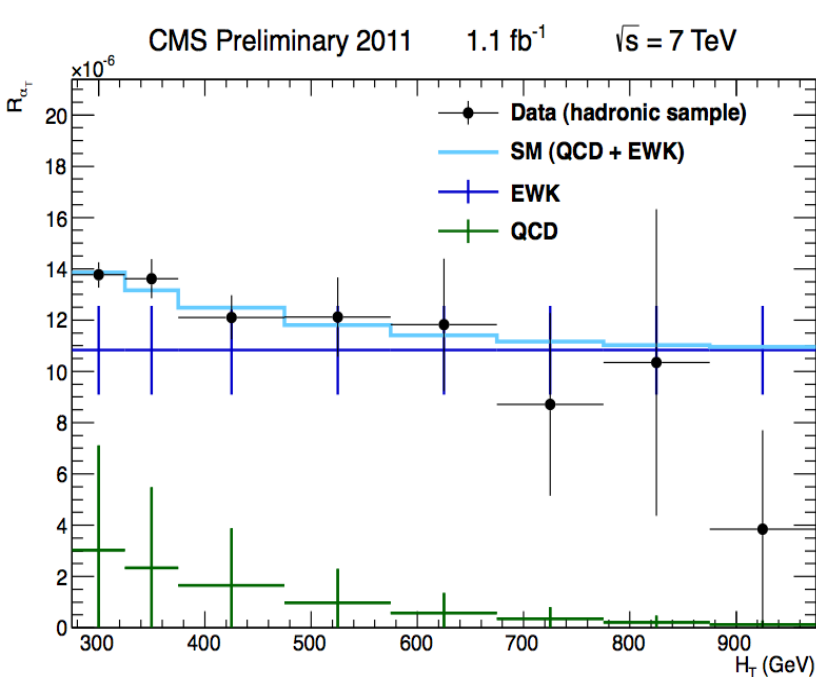


The α_T search

CMS PAS SUS-2011-003

Results: Expected and observed event yields

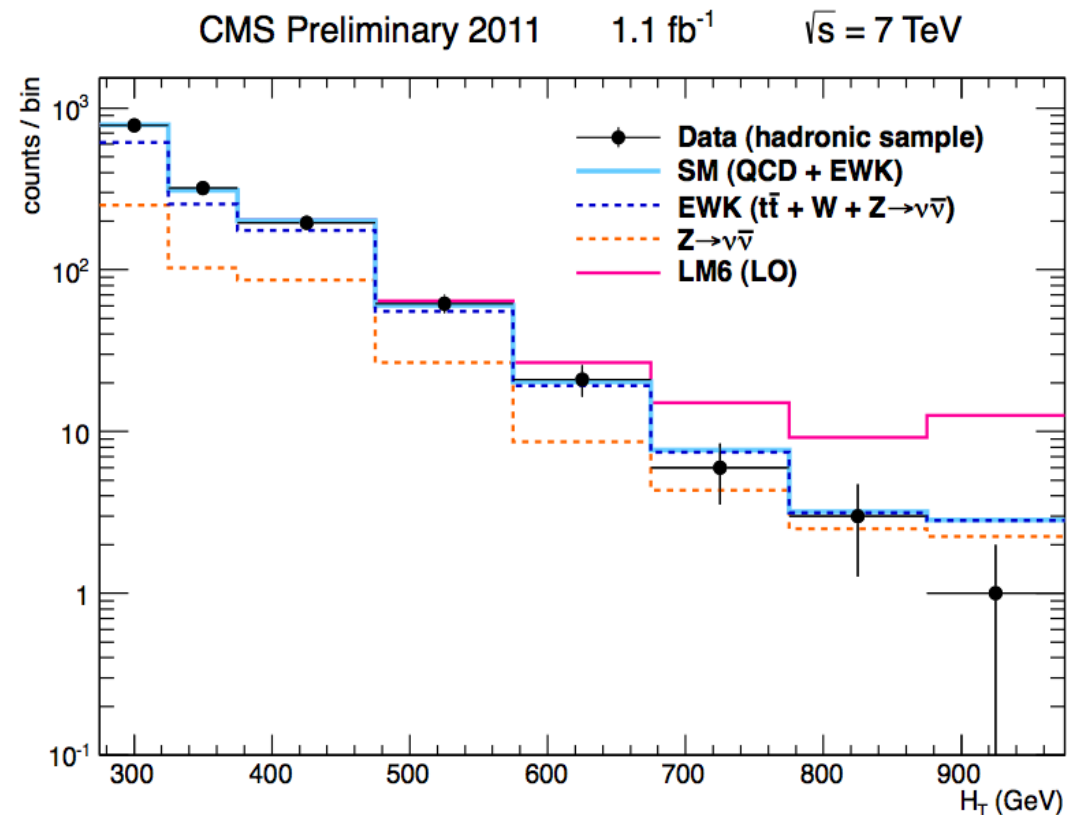
- No excess observed in the data
- Calculated limits using the exclusive HT-bins as separate channels with correlated uncertainties



QCD: modeled by exponential

EWK: data-driven estimation:

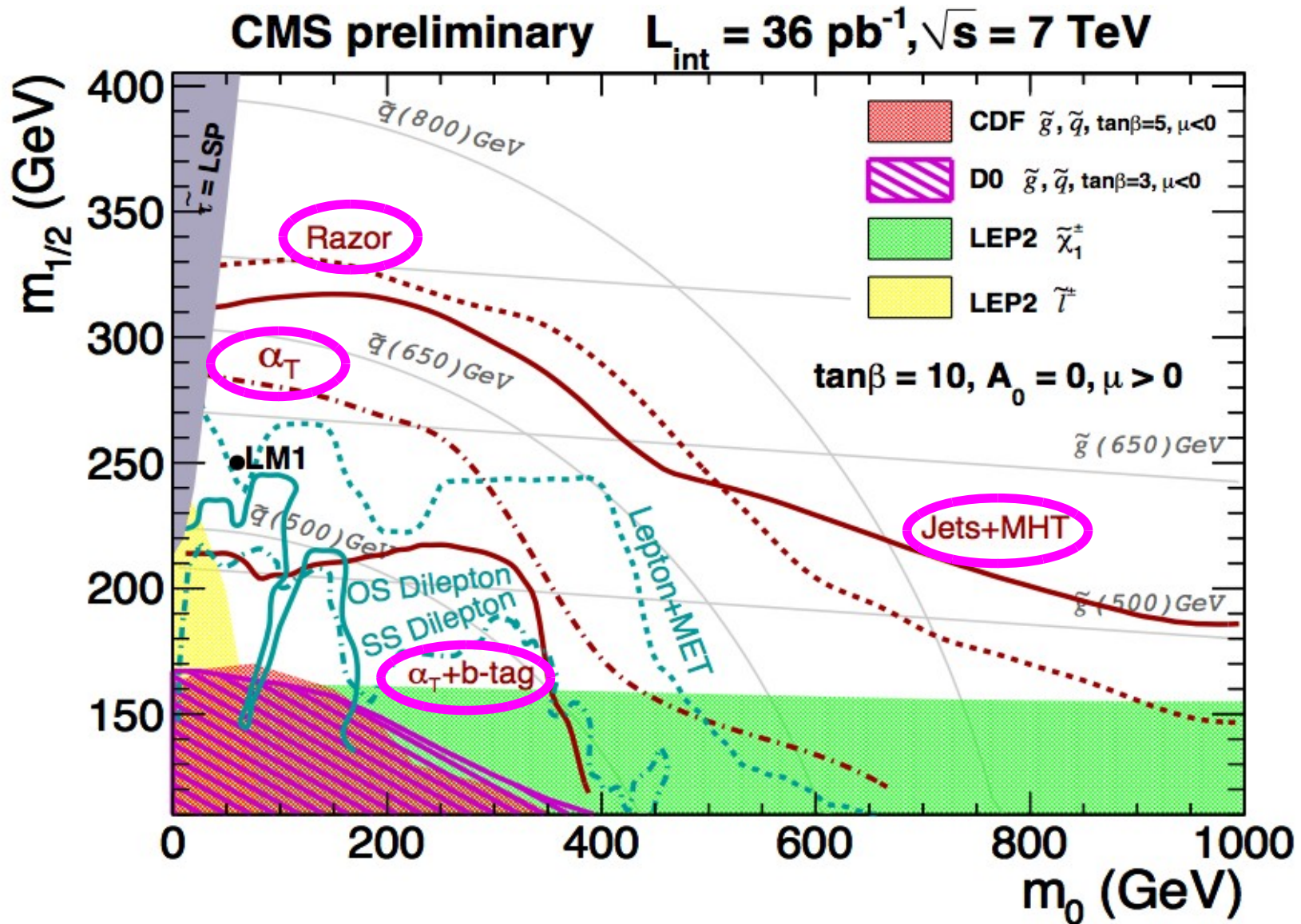
$t\bar{t}/W$ from isolated muon sample, $Z \rightarrow \nu\bar{\nu}$ from γ +jets



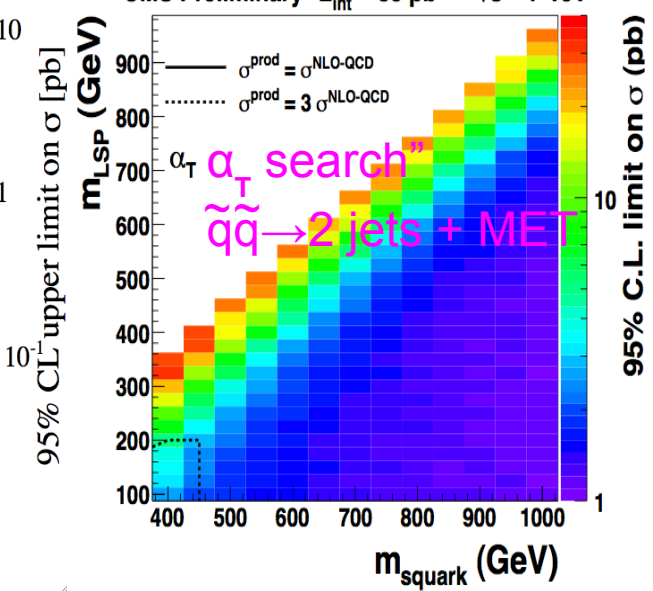
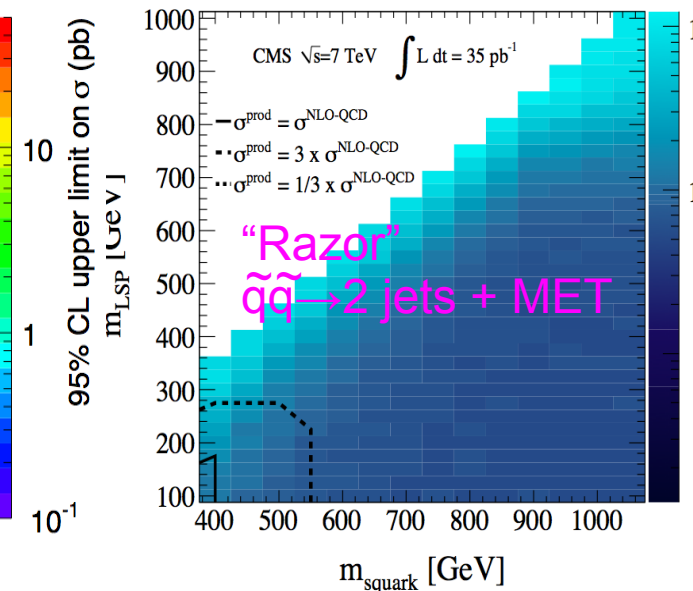
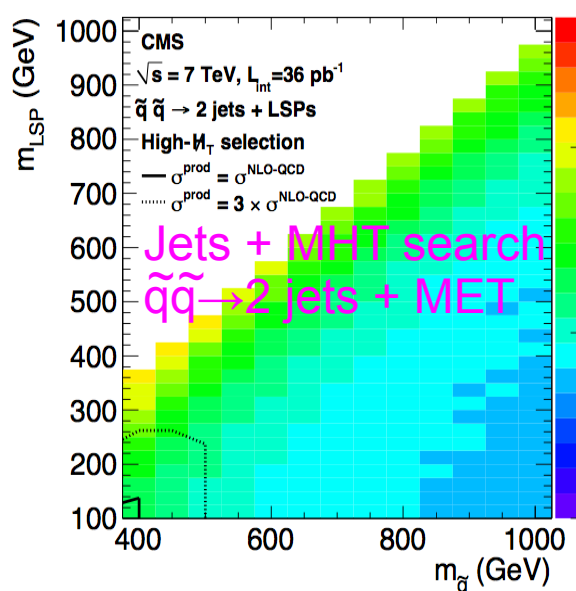
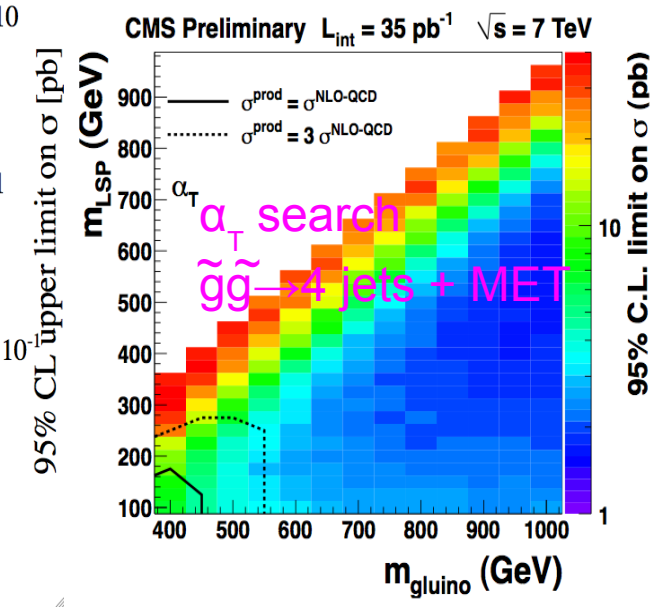
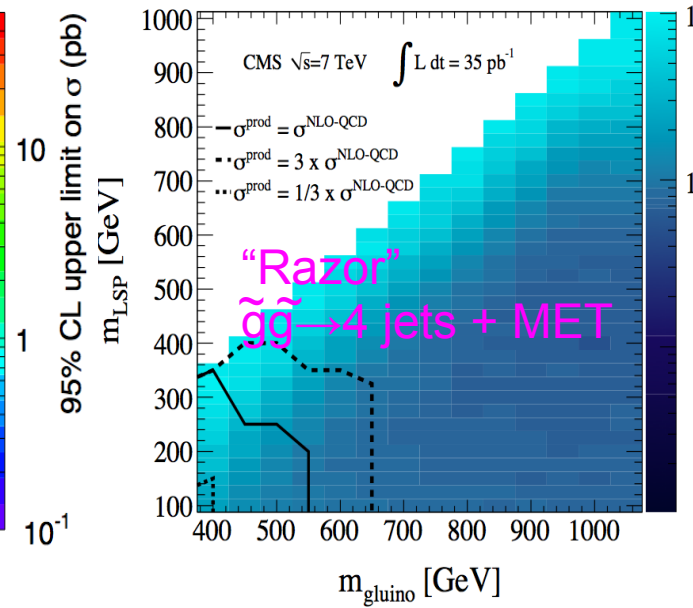
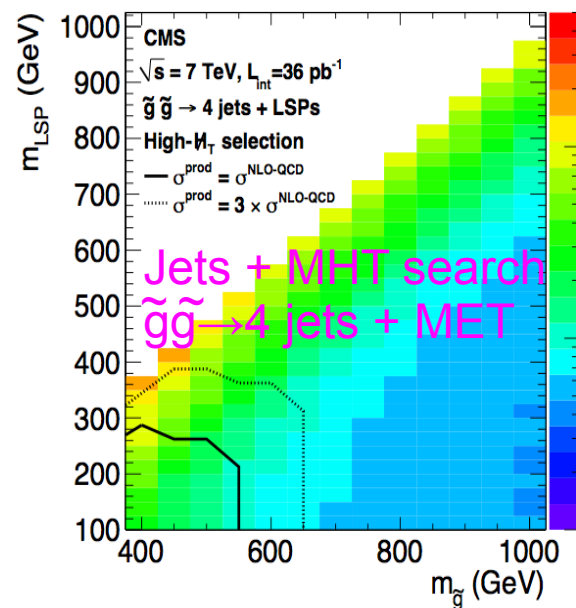
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Results: 36 pb^{-1} Integrated Luminosity

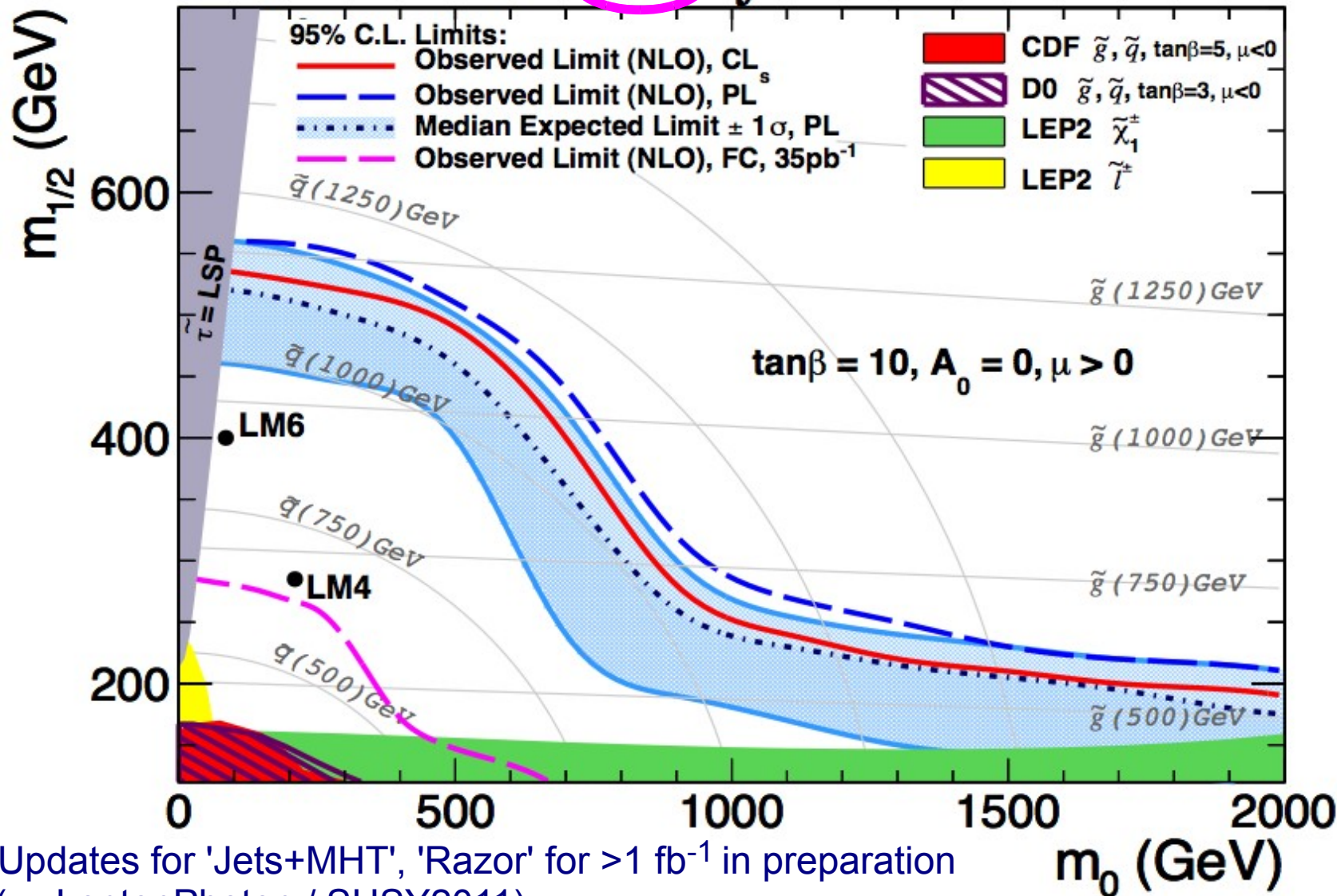


Results: Cross section limits for simplified models



Results: 1.1 fb⁻¹ Integrated Luminosity

CMS preliminary α_T $\int \mathcal{L} dt = 1.1 \text{ fb}^{-1}$ $\sqrt{s} = 7 \text{ TeV}$

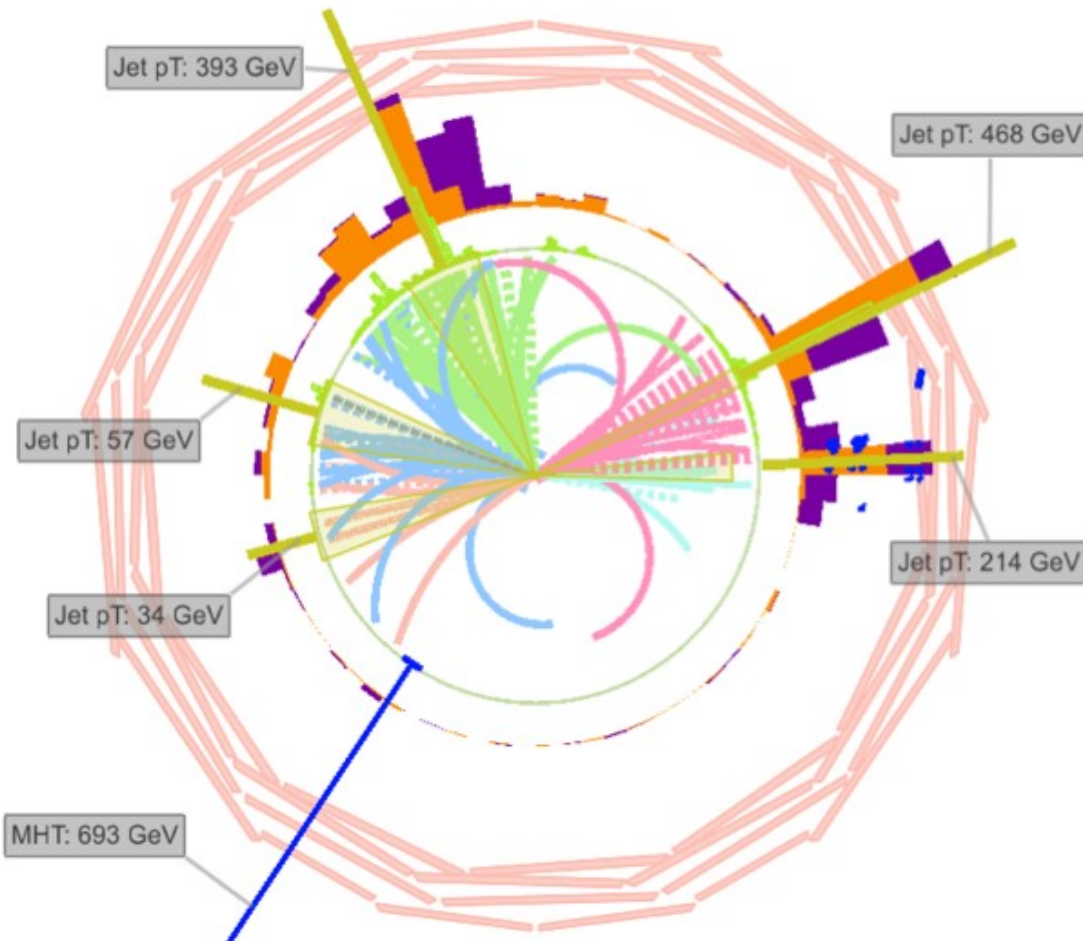


- Updates for 'Jets+MHT', 'Razor' for $>1 \text{ fb}^{-1}$ in preparation (\rightarrow LeptonPhoton / SUSY2011)

A candidate event...



CMS Experiment at LHC, CERN
 Data recorded: Tue Oct 26 07:13:54 2010 CEST
 Run/Event: 148953 / 70626194
 Lumi section: 49



MHT = 693 GeV
 HT = 1132 GeV
 $M_{\text{eff}} = MHT + HT = 1.83 \text{ TeV}$
 No b-tagged jet
 No isolated lepton
 Incompatible with W or top mass
 ...compatible with $Z \rightarrow \nu\nu$

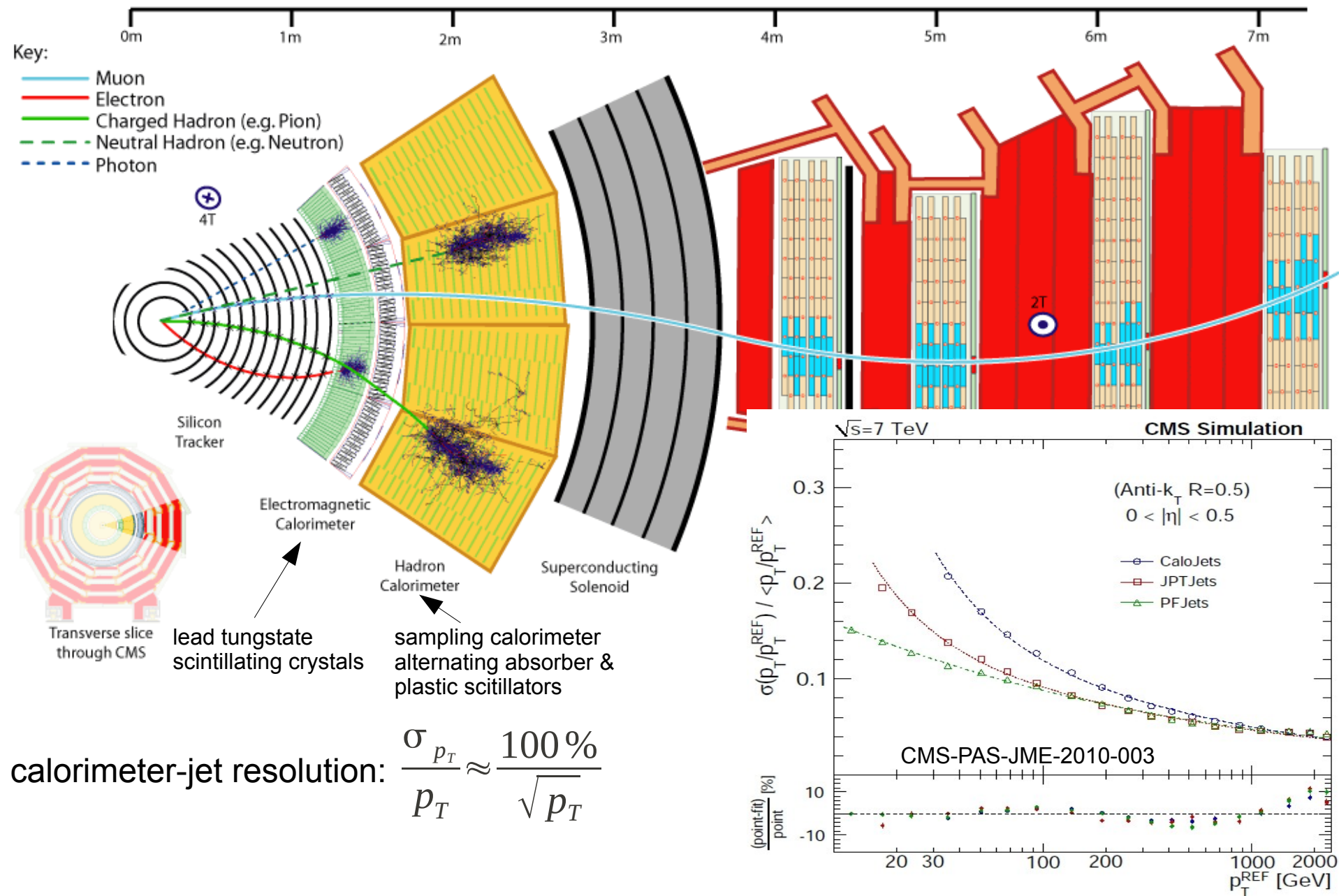
Conclusion

- No sign for Supersymmetry in the hadronic channel observed in up to 1.1 fb^{-1} at CMS, yet.
- The results constrain the SUSY parameter space, e.g. exclude squark masses $\lesssim 1.1 \text{ TeV}$ in CMSSM $\tan\beta=10$, $\mu>0$, $A_0=0$
- Several complementary analyses in place
- The Standard Model background is measured directly from the data, reducing the uncertainties from simulation and theory
- CMS is prepared for discoveries!



Backup

The CMS detector



CMS mSUGRA benchmark points

