Search for Supersymmetry at CMS in all hadronic final states

Division of Particles and Fields 2011 : Brown University, RI, USA

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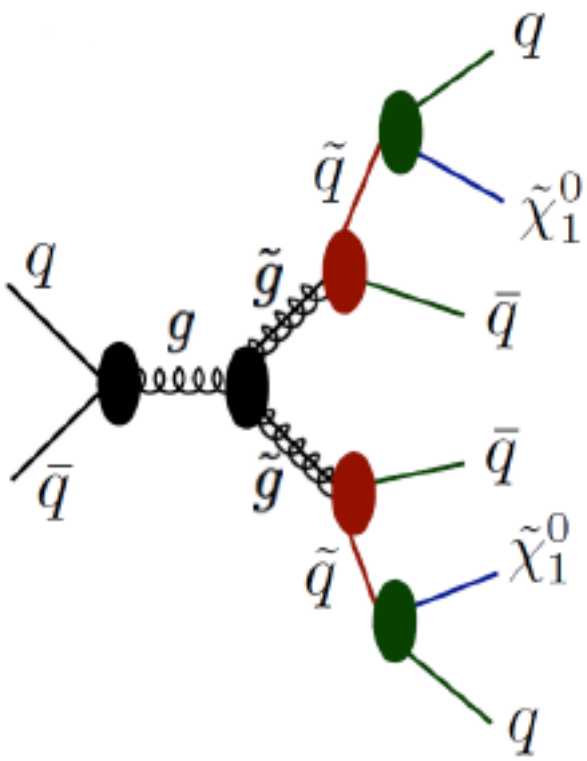
Motivation



- Consider R-Parity conserving SUSY
- Strongly interacting *sparticles* dominate
- Cascade decay of squarks/ gluinos $\longrightarrow$ stable LSP($\tilde{\chi}_1^0$)
- Leads to signature of missing transverse energy (MET) and Jets

Hadronic SUSY searches at CMS

- Although large signal cross-section for hadronic searches –have to deal with large Standard Model backgrounds
  - Perform several independent analyses
  - Data-Driven background estimation essential for all methods

- Jets + MET inclusive search – inclusive search – relies on precise determination of all SM backgrounds with robust data-driven techniques (2010, 36pb^{-1}) – updates forthcoming
- Razor: uses kinematic variables to characterise SUSY pair-production (2010, 36pb^{-1}) – updates forthcoming
- α_T method: Reduces QCD background substantially (2011, 1.1fb^{-1})

arxiv:1106.4503 – Submitted to JHEP

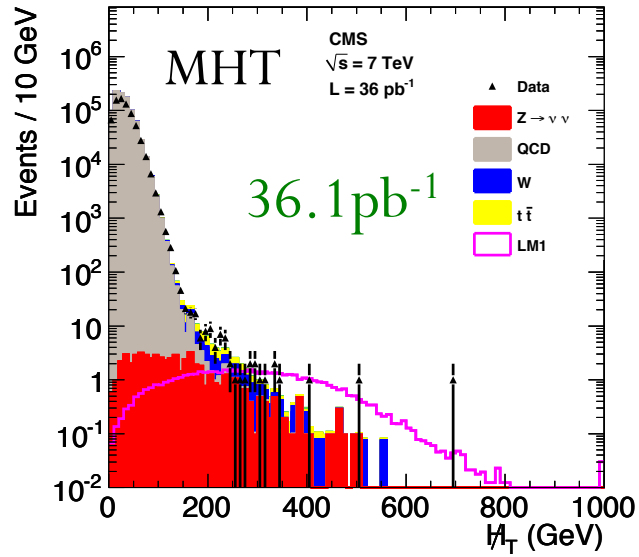
Jets + MET: Overview

- Sensitive variables

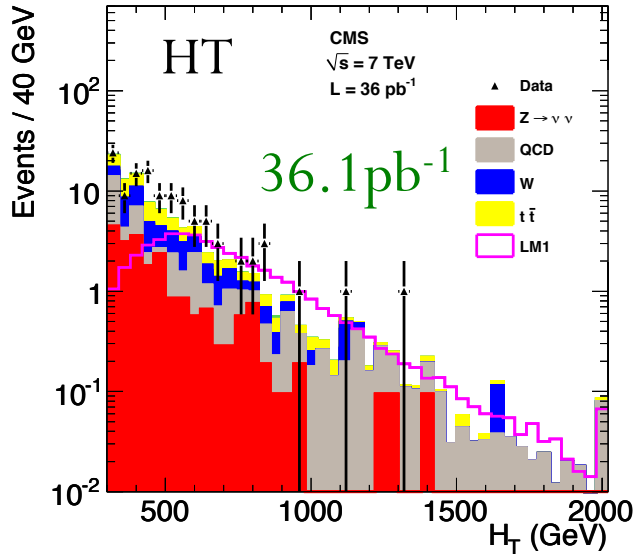
$$H_T = \sum_i^{jets} \left| \vec{p}_{T,i} \right|$$

$$\not{H}_T = \left| -\sum_i^{jets} \vec{p}_{T,i} \right|$$

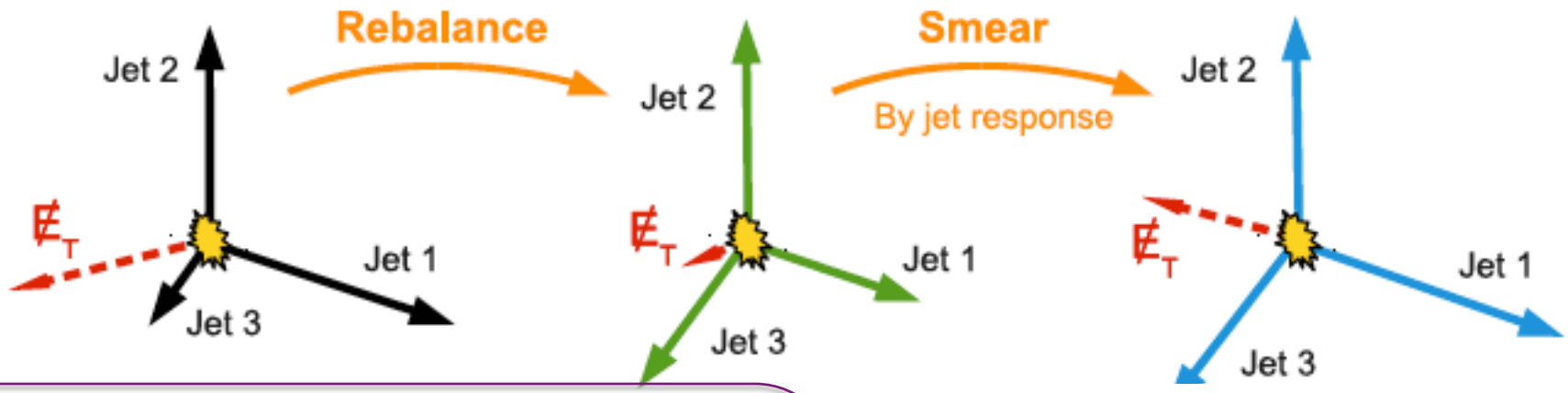
(Missing) Transverse Hadronic Energy (MHT/HT)



- >= 3 jets, pT >50 GeV
- Jets not collinear with MHT vector (QCD suppression)
  (LM – low mass SUSY test point)
- Define 2 search regions:
  - HT >300 GeV, MHT>250 GeV
  - HT > 500 GeV, MHT >150 GeV



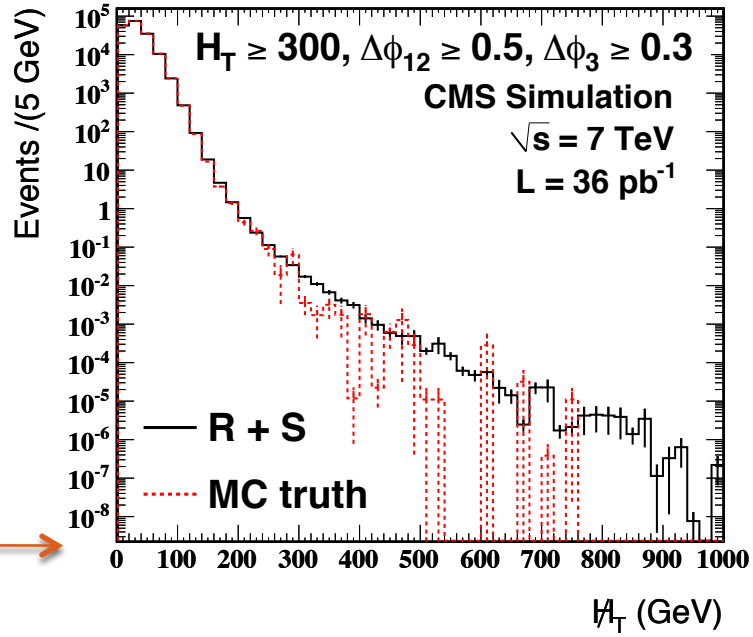
Jets + MET : QCD prediction



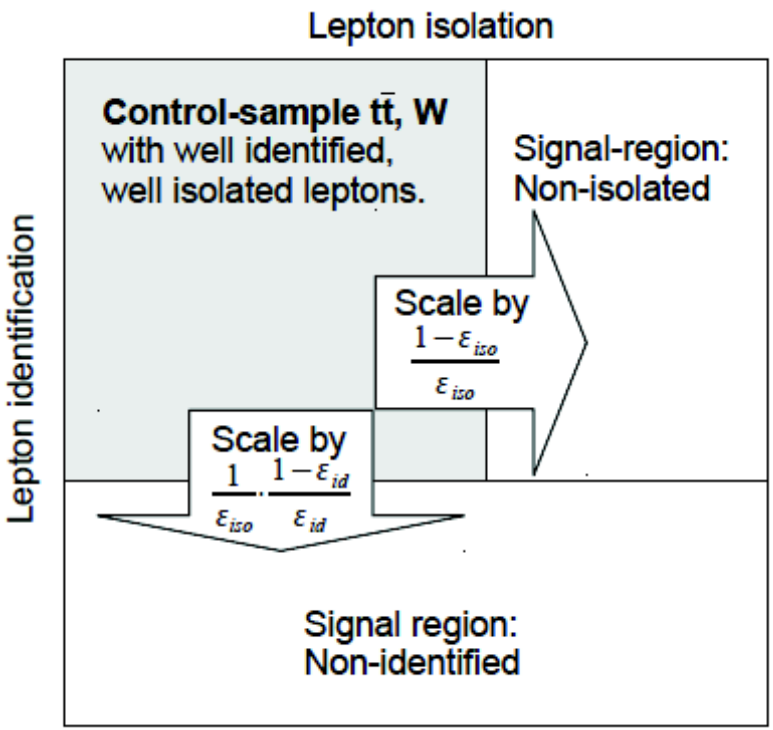
1) REBALANCE the data events using jet pT resolutions by maximizing likelihood subject to constraint MHT = 0

2) SMEAR rebalanced jets with resolution functions – obtained from photon+jet and dijet events

CLOSES WELL

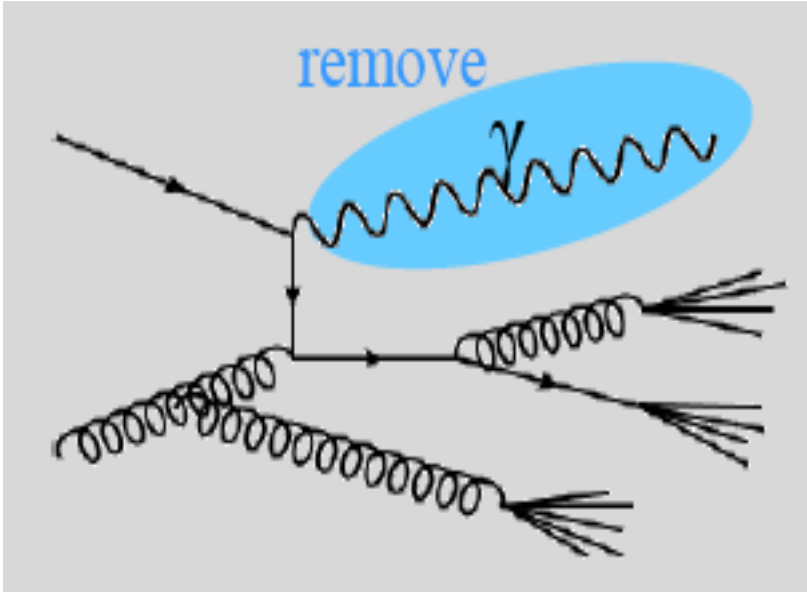


Jets + MET: W/tt and Z background



"lost-lepton" method – leptons enter our background by either being not isolated, not reconstructed or out of acceptance

Scale control sample according to efficiencies measured in data



Z and Gamma similar characteristics at high pT

Remove photon pT to mimic MET

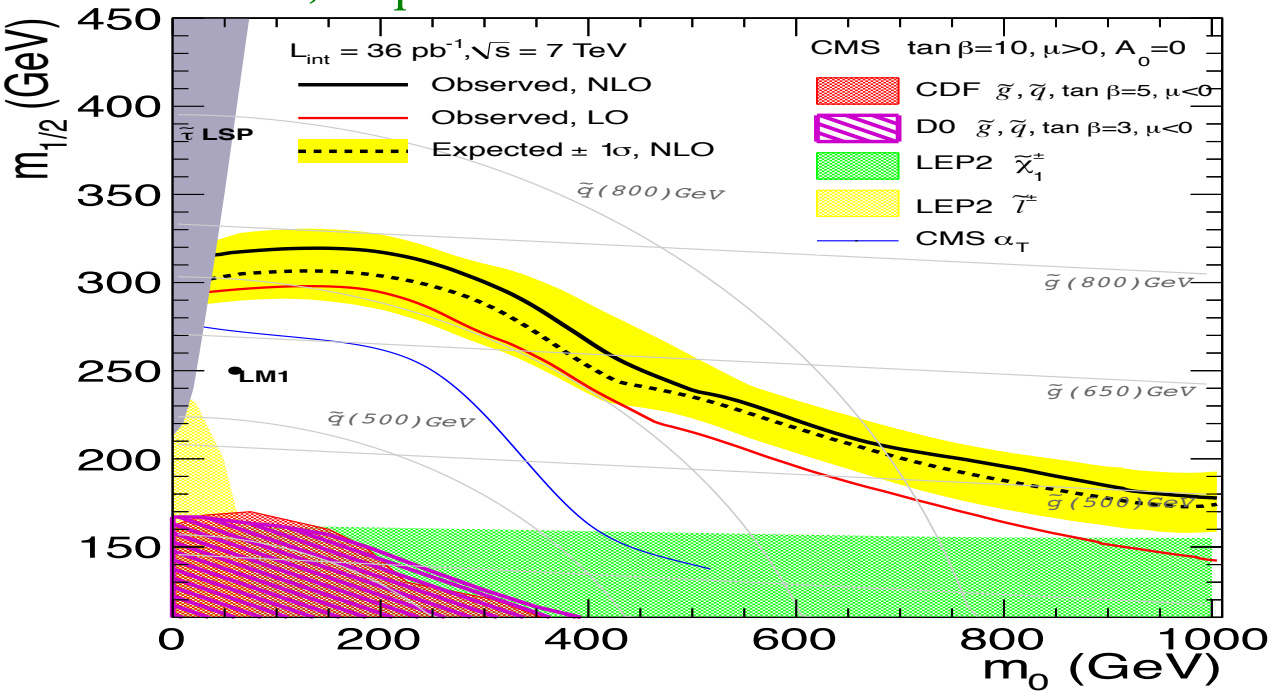
Select photon control sample

Apply corrections for efficiency, purity (i.e.number of background photons), and ratio of event yields

Jets + MET: Results/Interpretation

	Expected SM background	Observed
MHT >250 GeV	18.8±3.5	15
HT > 500 GeV	43.8±9.2	40

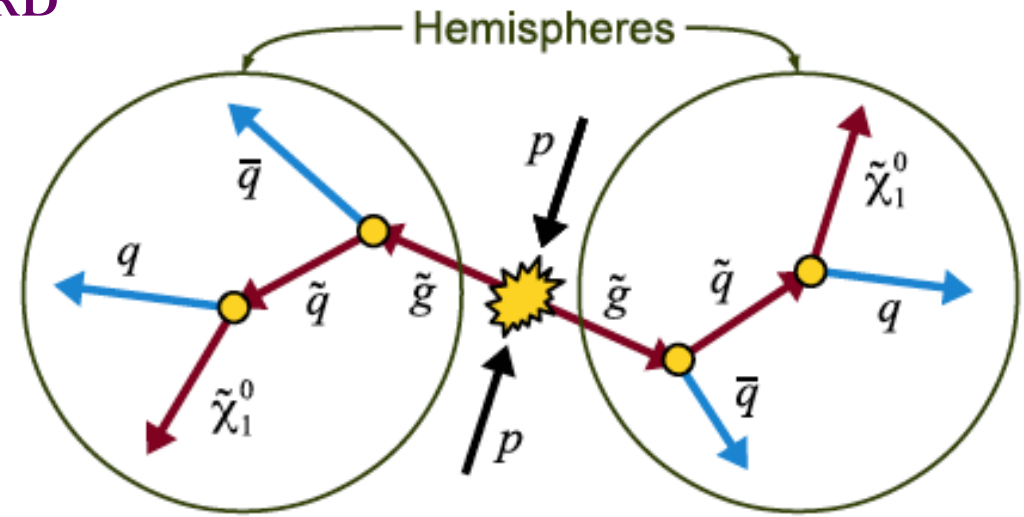
2010, 36pb^{-1} **arxiv:1106.4503 – Submitted to JHEP**



Razor search: Overview

arxiv:1107.1279 – Submitted to PRD

- Cluster events into two hemispheres
- Define new variables:



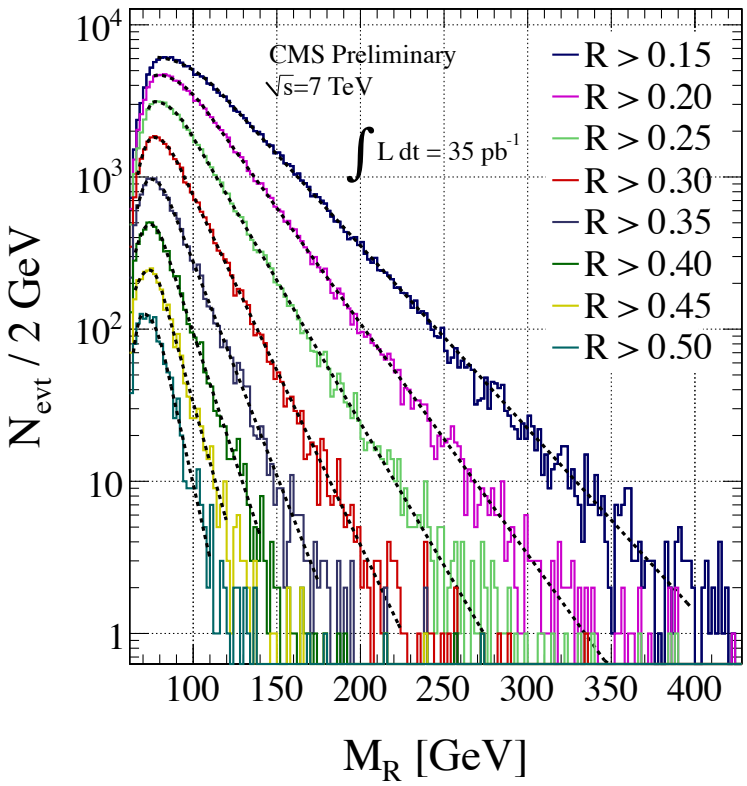
$$M_R = 2\sqrt{\frac{(E_1 \cdot p_{z,2} - E_2 \cdot p_{z,1})^2}{(p_{z,1} - p_{z,2})^2 - (E_1 - E_2)^2}}$$

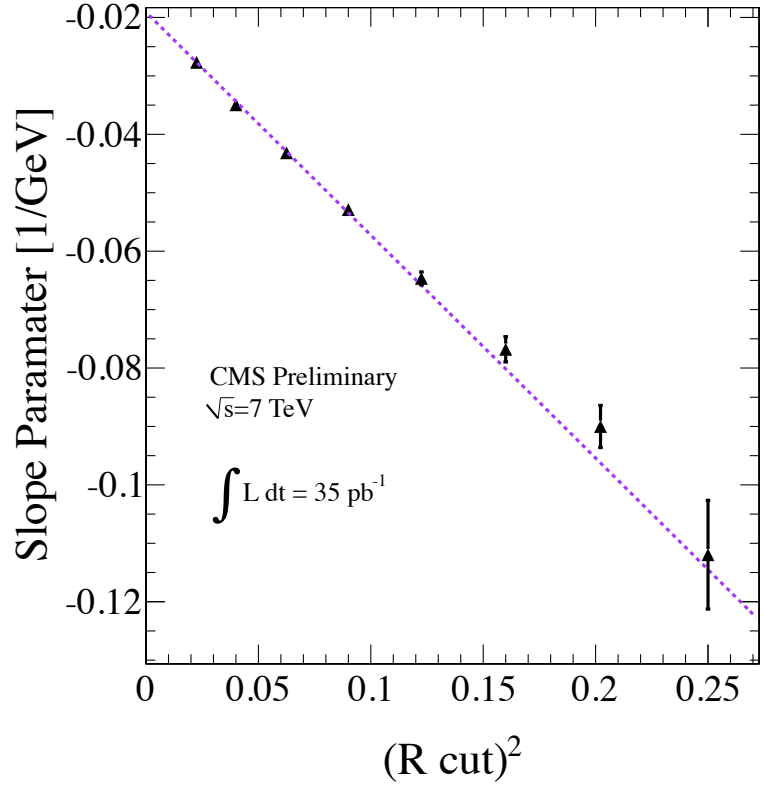
$$M_T^R = \sqrt{\frac{\not{E}_T(p_{T,1} + p_{T,2}) - \vec{\not{E}}_T(\vec{p}_{T,1} + \vec{p}_{T,2})}{2}}$$

Dimensionless Ratio

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

Razor search: QCD background



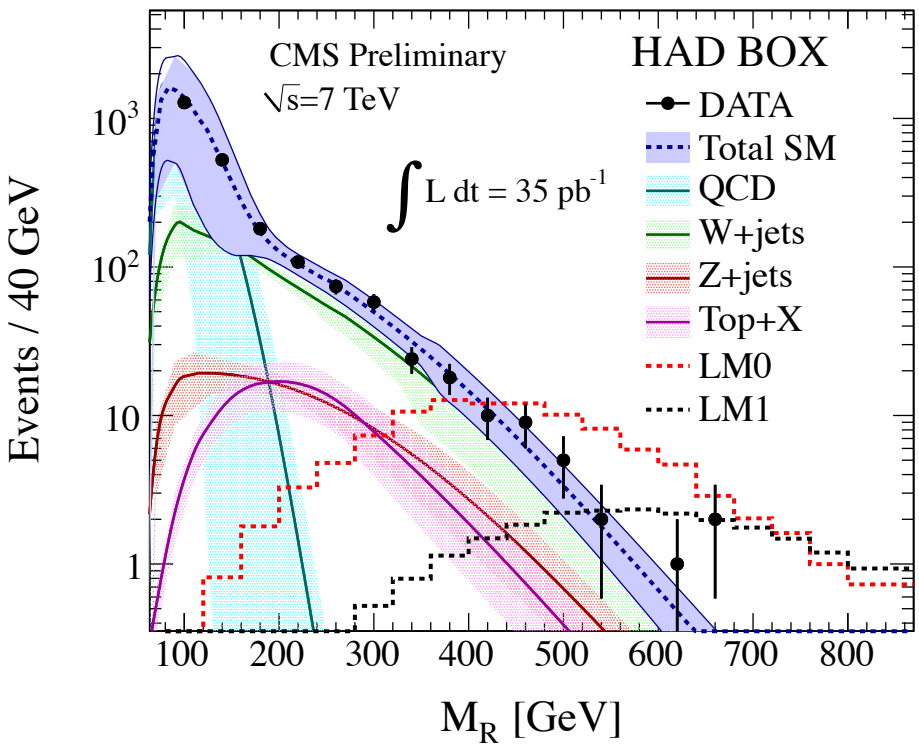


- M_R falls exponentially for QCD
- Slope depends linearly on R^2

Extrapolate to search region, $M_R > 500$ GeV, $R > 0.5$

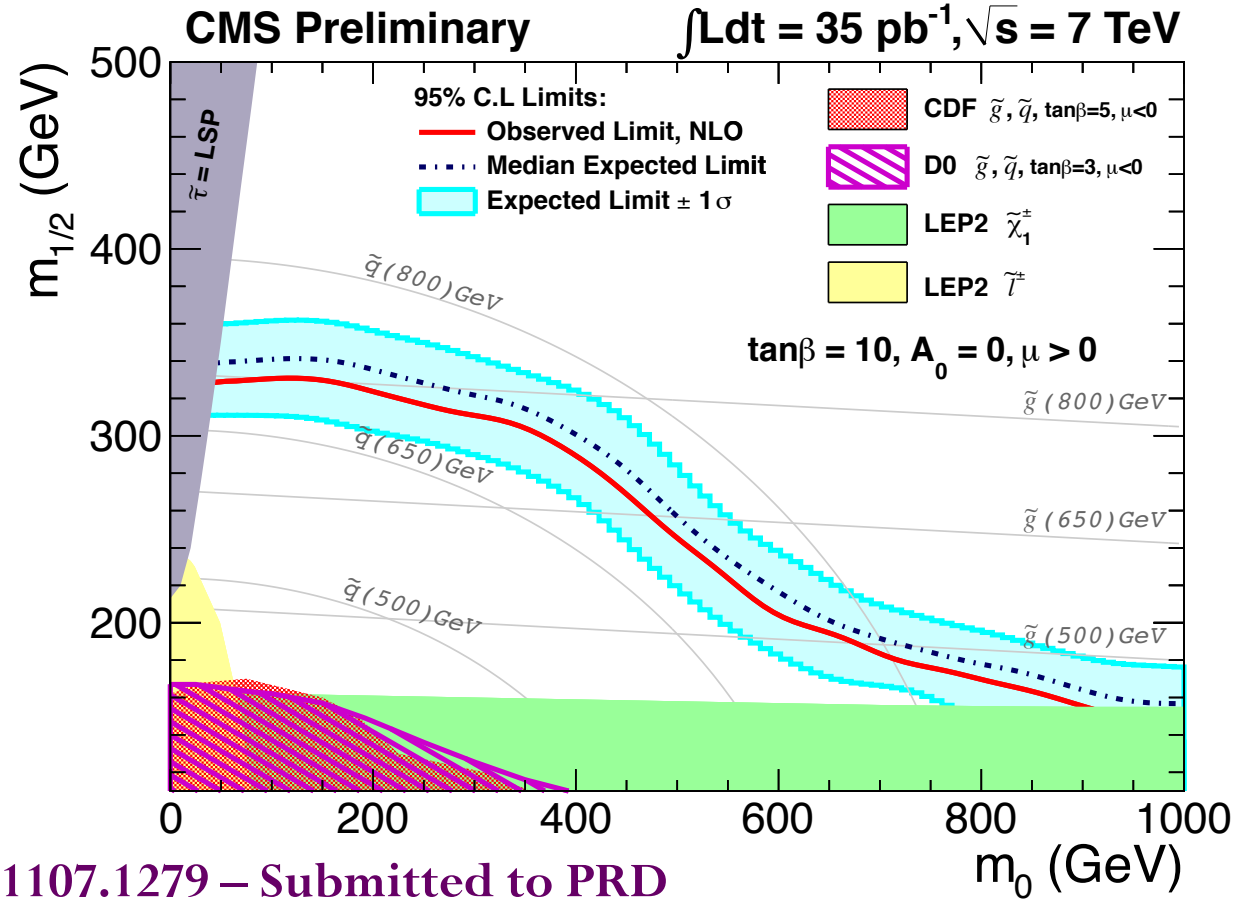
Razor search : background modeling

- Three independent control "boxes" for electrons, muons, hadrons
- Identify control regions which are dominated by W(lv) and another dominated by non-QCD
- Use shapes and normalisations from lepton boxes to estimate background in the hadronic box
- Having detemined R and MR shape and normalisations in control regions – the SM yields are then extrapolated into the signal region, large-R, high-MR



Razor search: Results

	Expected SM background	Observed
MR >500 GeV, R > 0.5	5.5±1.4	7



2010, 35pb^{-1}

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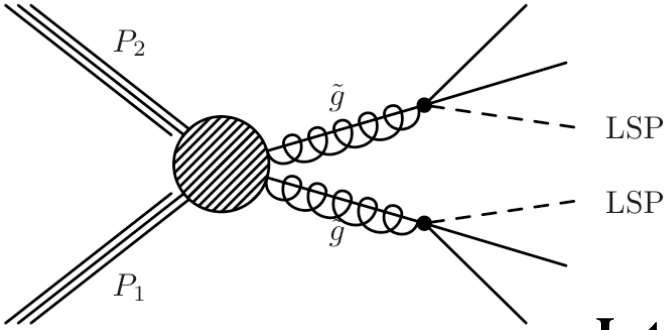
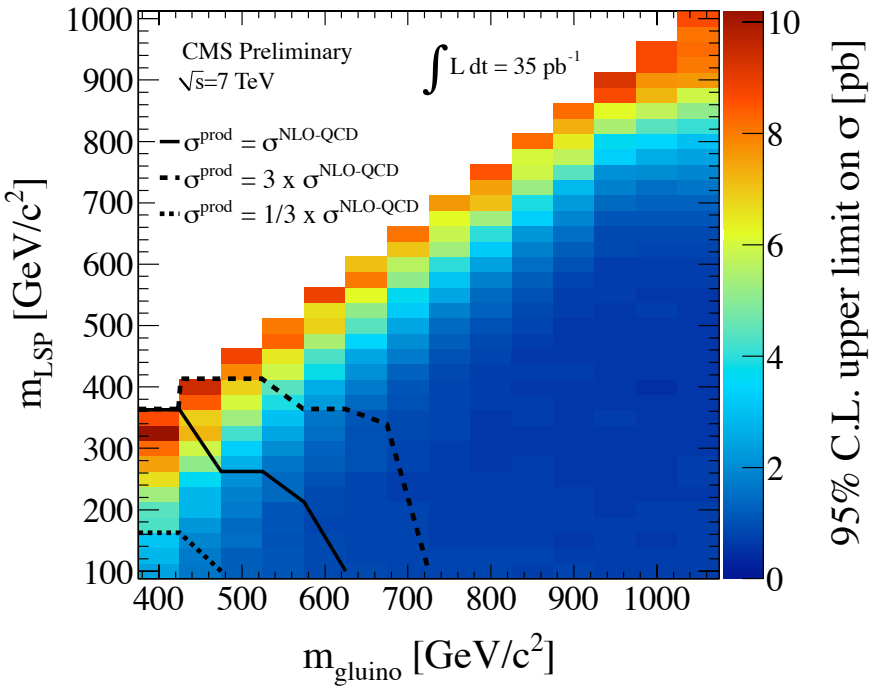
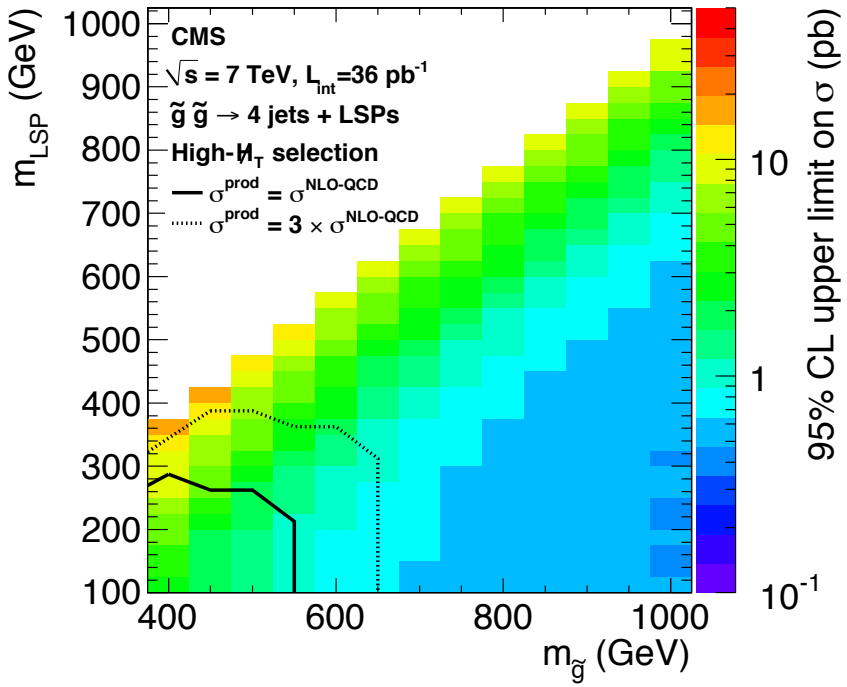
Simplified models 2010, 35pb^{-1}



RaZor

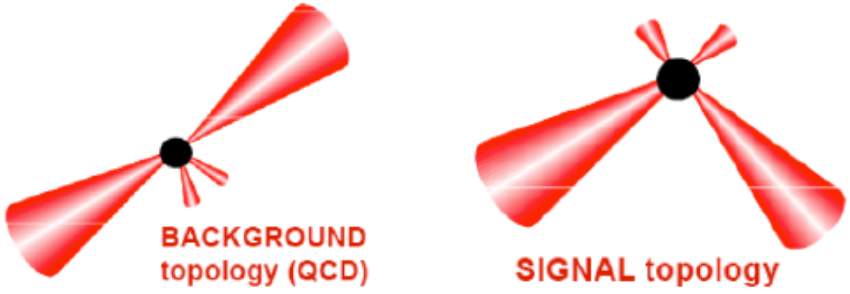
Jets + MET inclusive

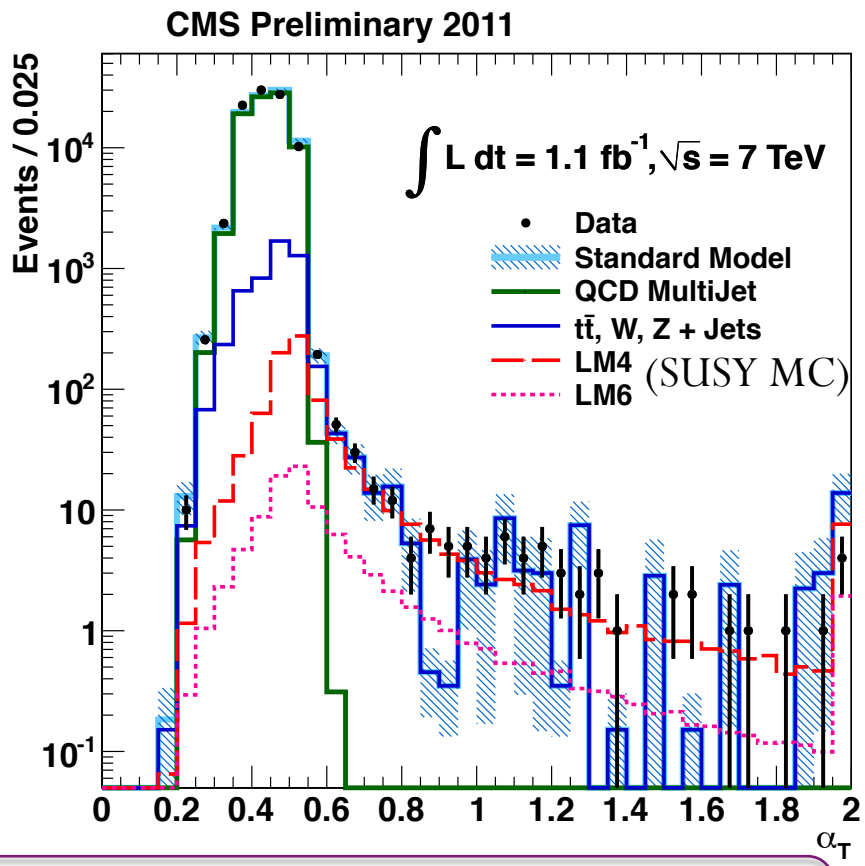




α_T method: Overview

CMS : PAS-SUS-11-003





- Effective QCD reduction by using kinematic variable:

$$\alpha_T = \sqrt{\frac{p_{T,j_2} / p_{T,j_1}}{2(1-\cos\Delta\phi)}}$$

QCD : $\cos\Delta\Phi \approx -1$, $\alpha_T \leq 0.5$

Processes with genuine Missing Transverse Energy: $\alpha_T > 0.5$

α_T method: Background estimation

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

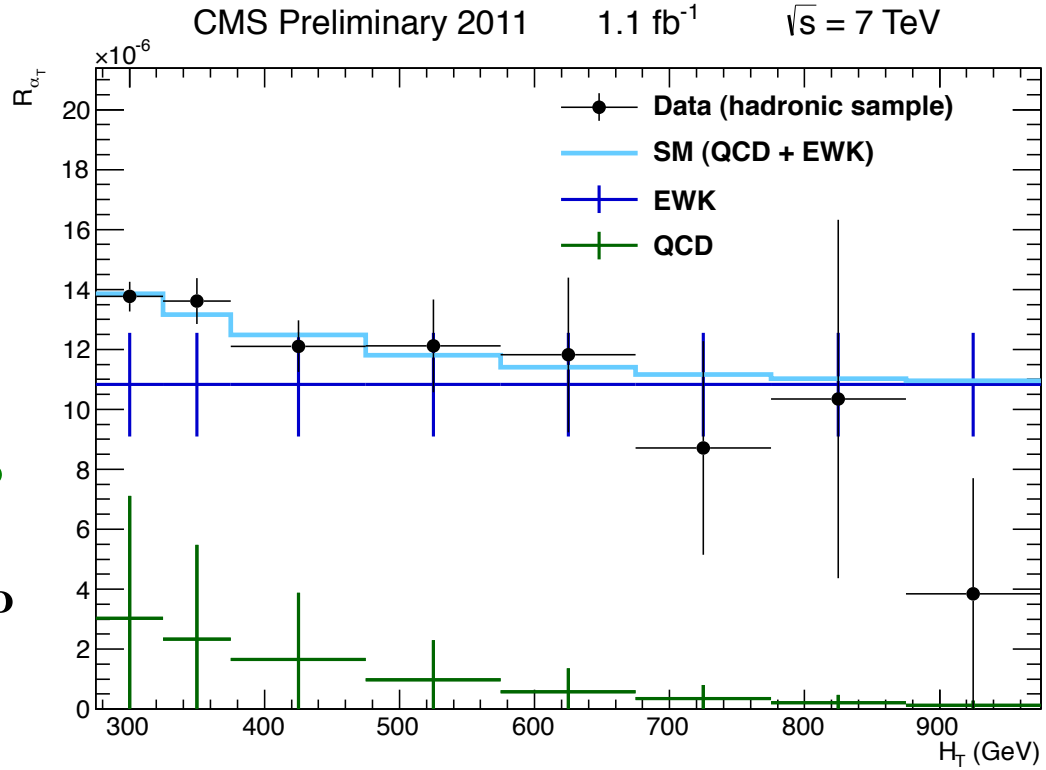
Electroweak backgrounds – real MET – flat $R_{\alpha T}$

QCD – mismeasured jets, jet resolution increases with pT – ratio falls

Data – ratio consistent with no QCD

Use data-driven techniques to estimate W, top, from W → *lν*

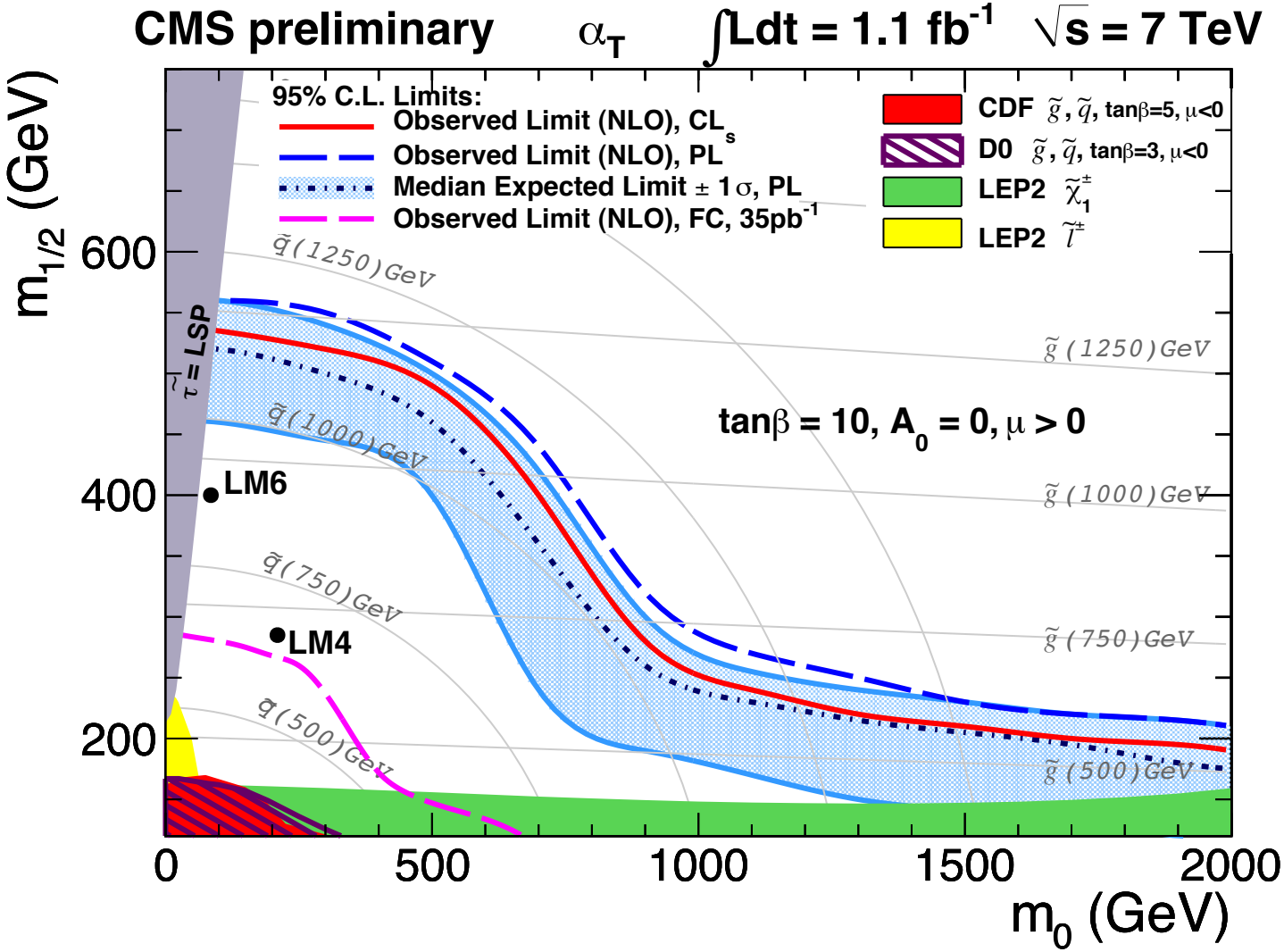
Z background from Gamma +Jets



Shape analysis is performed over the entire HT > 275 GeV region to estimate SM background

α_T method: Results 2011

CMS : PAS-SUS-11-003



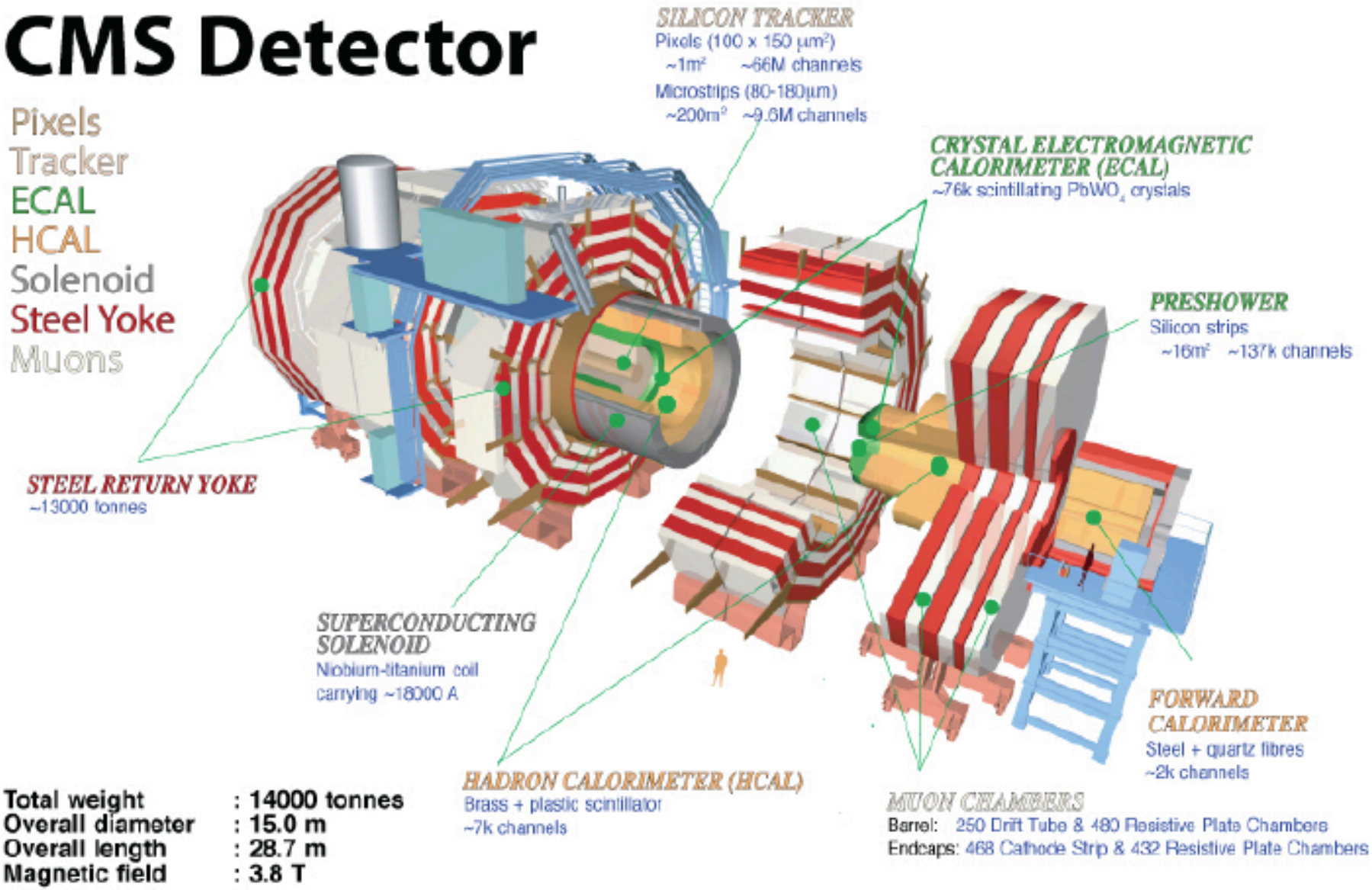
Conclusions

- No evidence for SUSY in the hadronic channel yet, up to 1.1fb^{-1} has been analysed and presented here today
- Are able to place limits in the SUSY parameter space
- CMS has several analyses in hadronic SUSY which use independent **Data-Driven background estimation techniques** – we do not rely on Simulation – makes for robust results

CMS is well prepared for discoveries….

BACK UP

CMS


CMS Detector
Pixels
Tracker
ECAL
HCAL
Solenoid
Steel Yoke
Muons
SILICON TRACKER
Pixels (100 x 150 μm²)
~1m² ~66M channels
Microstrips (80-180μm)
~200m² ~9.6M channels
CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76k scintillating PbWO4 crystals
PRESHOWER
Silicon strips
~16m² ~137k channels
STEEL RETURN YOKE
~13000 tonnes
SUPERCONDUCTING SOLENOID
Niobium-titanium coil
carrying ~18000 A
FORWARD CALORIMETER
Steel + quartz fibres
~2k channels
HADRON CALORIMETER (HCAL)
Brass + plastic scintillator
~7k channels
MUON CHAMBERS
Barrel: 250 Drift Tube & 480 Resistive Plate Chambers
Endcaps: 468 Cathode Strip & 432 Resistive Plate Chambers
Total weight : 14000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T