ETH Institute for Particle Physics

SUSY searches in Jets + MET at CMS

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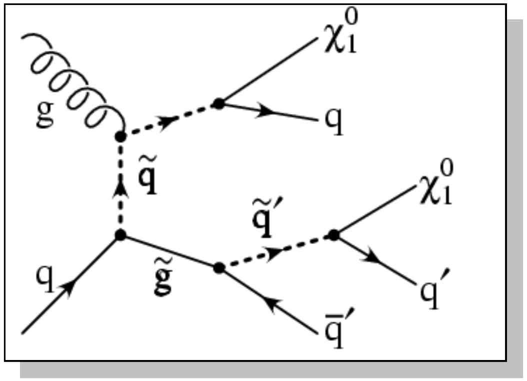
Outline

- What are we looking for?
  - → Signal topology
  - → SM Backgrounds
  - → Detector backgrounds
- Searches at CMS
  - → Variables
  - → Analyses strategies
- Interpretation of the results
- Outlook

SUSY in Jets+MET

This talk presents searches which were thought having SUSY in mind:

- High rate of gluino, squark production

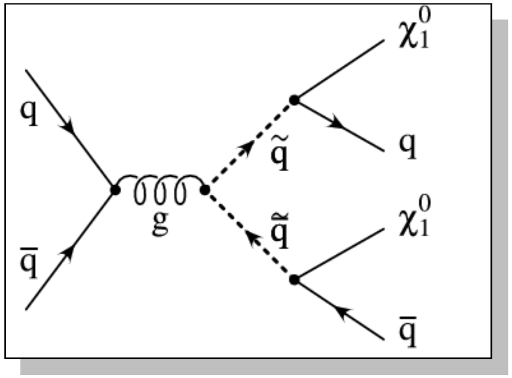


This is translated into the topology:

- Final states with jets, invisible energy due to LSP (ME_T)

These searches are sensitive to processes which:

- Are strongly produced
- Have a massive, weakly interactive, stable colorless particle



If a model does not predict hadronically rich events, with invisible energy

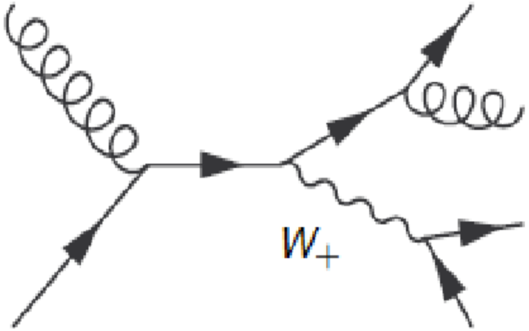
- This is the wrong place to look at ;)

SM in Jets+MET

Standard Model processes can be divided in **two broad categories**:

"Reducible":

- QCD:
  - ✗ Huge cross section, potential jet fluctuations create *fake* ME_T
  - ✓ Generally, reduced to negligible amount with topological cuts
- W+Jets, Top:
  - ✗ They have genuine ME_T
  - ✓ But also a lepton → *lepton veto*



"Irreducible":

- Z(vv)+Jets:
  - ✗ Same topology, real ME_T
  - ✓ Cannot be reduced (at least efficiently), must be estimated

Analysis strategies (in a nutshell):

First Step: define a variable which reduces QCD multijet contribution to manageable/negligible contribution.

Second Step: define a set of cuts which reduce all the possible backgrounds

- Leptons? B-jets?
- Each cut has an acceptance and an efficiency (e.g. electron reconstruction)
  - Estimate "what remains", example: select a control sample (e.g. 1e for W+j), and correct it with acceptance, cut/reconstruction efficiencies

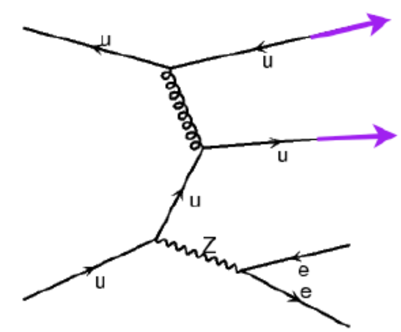
Third Step: define a method for estimating the irreducible background

- Example: a related physics process, well measurable and possibly with low signal contamination
- This defines again a control sample, to be corrected by theoretical ratios, etc...

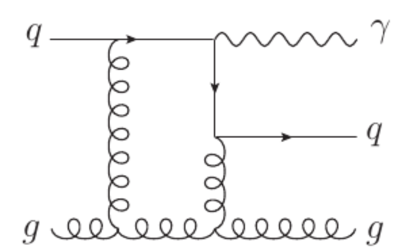
Control Sample: example

Z(νν)+jets control samples:

- **Z(ll)+jets:**
  - ✓ **Pro:** same process (just different Br), virtually free from signal (no ME_T, mass window)
  - ✗ **Con:** statistics



- **W(lν)+jets:**
  - ✓ **Pro:** really similar process process, higher statistics
  - ✗ **Con:** contamination from signal, Top



- **γ+jets:**
  - ✓ **Pro:** high statistics, virtually free from signal (ME_T~0)
  - ✗ **Con:** massless, different couplings → higher th. uncertainties

Detector subtleties in Jets+MET

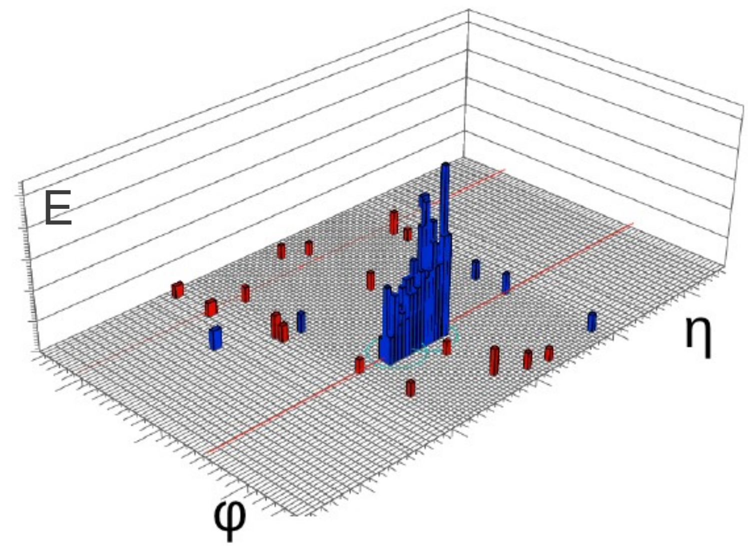
Detectors are not perfect... and momentum imbalance is a quite sensitive quantity

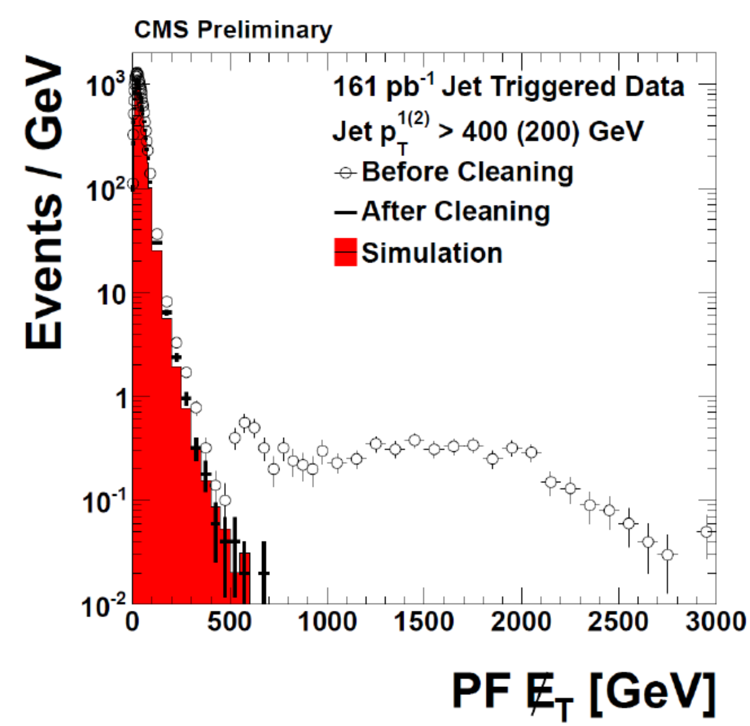
Possible sources of "fake ME_T":

- Electronic noise in the Hadronic Calorimeter
- Anomalous ECAL hits (particle directly hits the electronics)
- Cosmic rays (muons)
- Beam halo: muons produced by the proton beams interacting with the pipe
- Low-quality jets (clustered detector noise)
- Detector dead regions (not recorded energy)

Event-by-event quality filters developed since the beginning of data taking.

Also, multiple interactions ("Pile-Up") can create some issues





Search variables

Different search variables, exploiting kinematic properties:

- **MH_T:** "Classical" approach
- **α_T:** Very strong QCD rejection
- **M_{T2}:** Self-protection against QCD, spectra information
- **M_R, R^2 (*Razor*):** Strong QCD rejection, approximation of masses differences

Different analysis strategies:

- "Simple" cut and count (M_{T2})
- "Multibinned" analysis (MH_T and α_T)
- Shape analysis (Razor)

Four different analyses, different approaches:

- Complementarity
- Redundancy
- Like ATLAS and CMS

MHT (1.1/fb): definition

Multibinned analysis based on:

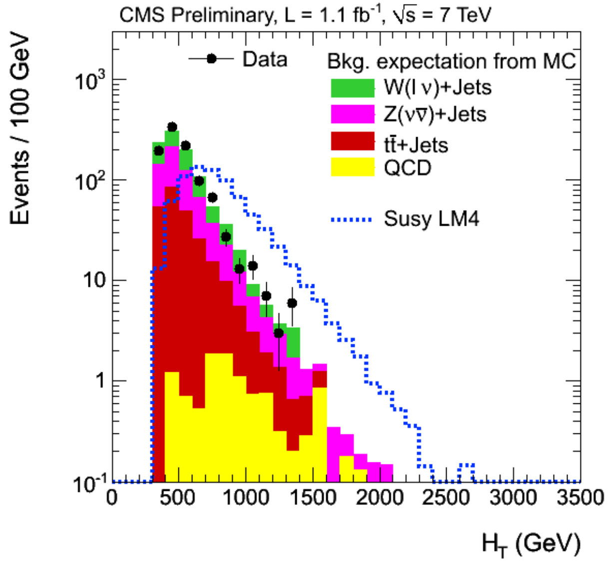
- **H_T**: scalar sum of jets p_T>50 GeV, |η|<2.5
- **MH_T**: vector sum of jets p_T>30 GeV, |η|<5

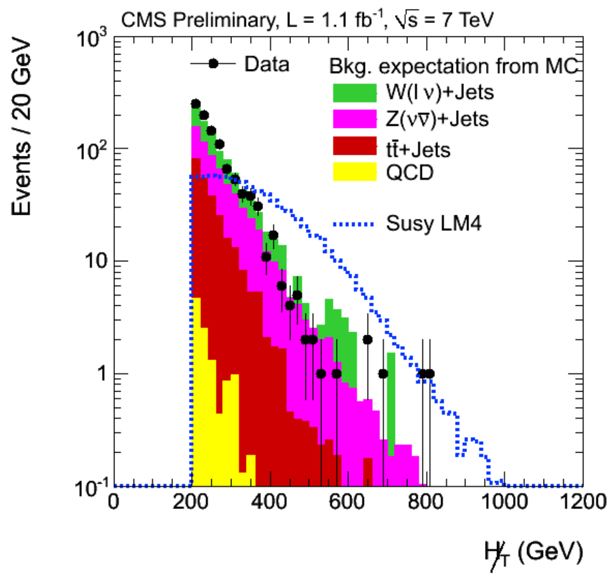
Event Selection:

- N^{jets}(pT>50 GeV, |η|<2.5)>=3
- H_T>350 GeV, MH_T>200 GeV → reduces QCD
- $\Delta\varphi(jet_N, MH_T) > 0.5$ (n=1,2) && $\Delta\varphi(jet_3, MH_T) > 0.3$ →protects against MH_T due to jet mismeasurement
- Veto on isolated electrons/muons (loose cuts), pT>10 GeV, |η|<2.5 (2.4) for electrons (muons) → reduces W+jets, Top

Search Regions:

- *Medium H_T/MH_T*: H_T>500 GeV, MH_T > 350 GeV
- *High H_T*: H_T > 800 GeV, MH_T > 200 GeV
- *High MH_T*: H_T>800 GeV, MH_T > 500 GeV





MHT (1.1/fb): backgrounds

QCD Multijets: *Rebalance and Smearing method*

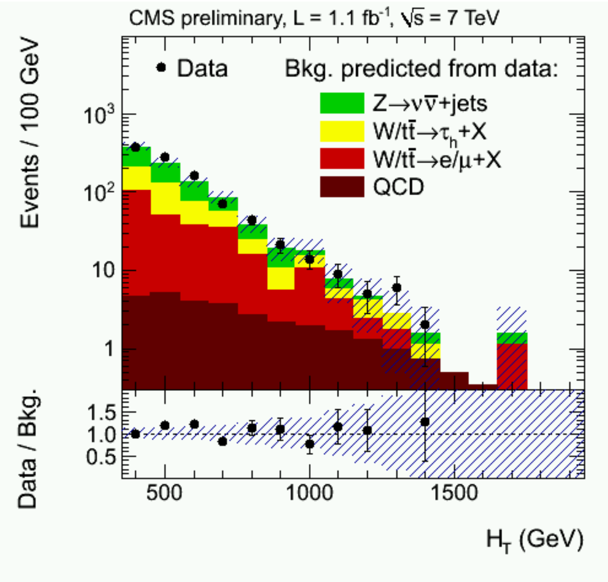
- Rebalance: get momentum imbalance reweighting jets in data
- Smear: apply jet response function to jets (tail included)

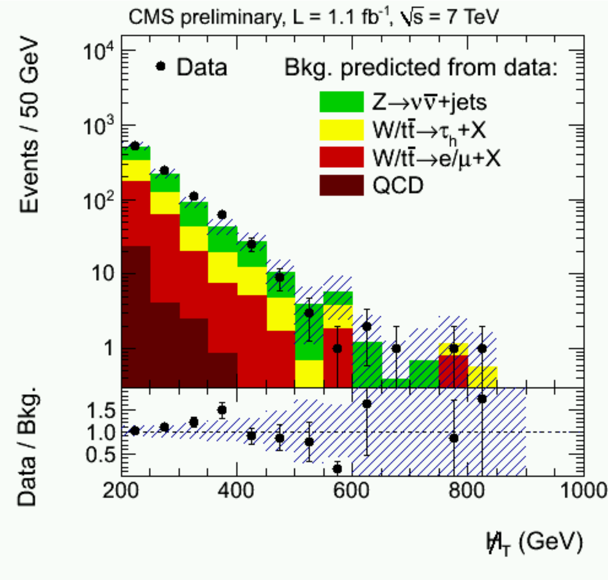
Z(*vv*)+jets:

- Using γ+jets events as control sample
- Z(*ll*)+jets used as cross check

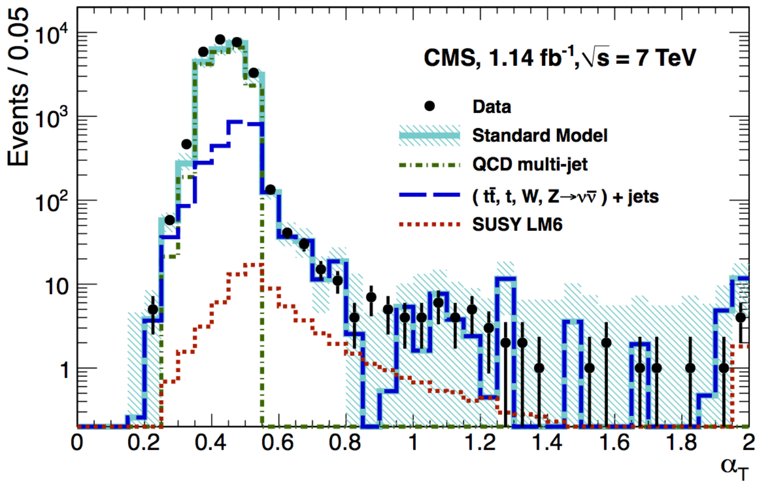
W+jets, Top:

- *Lost Lepton* technique: 1(e/μ) control sample with m_T<100 GeV, corrected by acceptance, reco/ID/iso efficiencies.
- *Tau template*: 1(μ) control sample, where the μ is substituted with a response function for τ^{had}





α_T (1.1/fb): definition



α_T variable is designed to separate events with low MET or mismeasurement from genuine events.

If N^{jets}>2, jets are merged into 2 *pseudojets* (minimizing the ΔE_T between them)

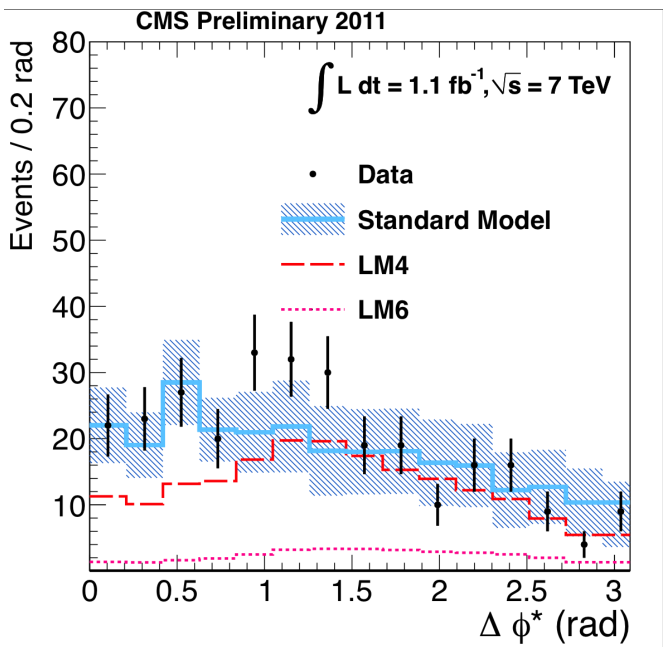
$$\alpha_T = \frac{1}{2}\frac{H_T - \Delta H_T}{\sqrt{H_T^2 - (MHT)^2}}. \qquad H_T = \sum_{\text{jets } j} p_{Tj}$$

$$\Delta H_T = p_{T\text{pseudojet 1}} - p_{T\text{pseudojet 2}}$$

Multibin approach in H_T, with 8 bins: 275-325, 325-375, then in 100 GeV steps till 875-∞

Event Selection:

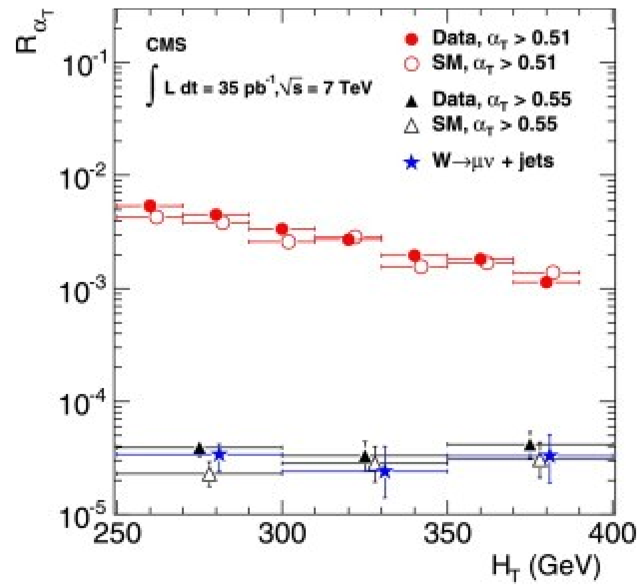
- H_T>275 GeV (with H_T/MH_T cross trigger)
- $p_T^{j1,j2}$>100 GeV, |η|<2.5
- MH_T/ME_T<1.25 (soft jets protection)
- Δφ* : angular separation between the jet nearest to MH_T and MH_T recomputed removing that jet. Veto if Δφ*<0.5 and the jet is near a problematic ECAL channel
- α_T>0.55 (QCD rejection)
- Veto on isolated e/μ p_T>10 GeV



α_T (1.1/fb): backgrounds

QCD multijet:

- Checked if any significant contribution with: $R_{\alpha_T} = \frac{\alpha_T > 0.55}{\alpha_T < 0.55}$



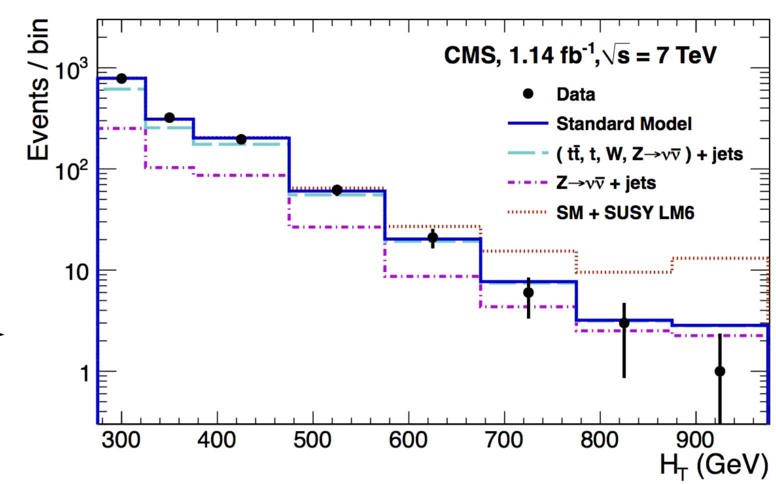
Z(*νν*)+jets:

- Using γ+jets events as control sample
- Cross check predicting events in 1μ sample

W+jets, Top in e/μ channels

- *Lost Lepton* technique: 1(μ) control sample, scaled by MC^{HAD}/MC^{μ}

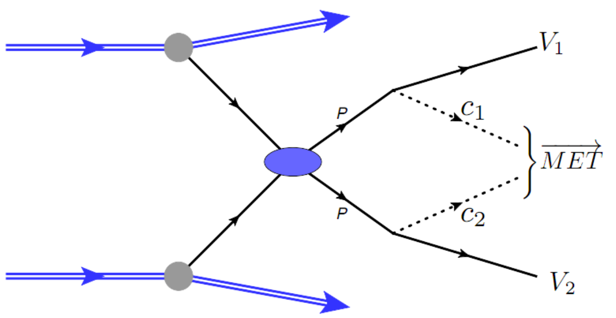
Furthermore, the control samples are used as constrains for SM hypothesis test using a Maximum Likelihood technique



M_{T2} (1.1/fb): definition

M_{T2} (or *stransverse mass*) is an extension of M_T in case of 2 decay chain with "missing particles":

$$M_{T2}(m_c) = \min_{p_T^{c(1)}+p_T^{c(2)}=p_T^{miss}} \left[\max\left(m_T^{(1)}, m_T^{(2)}\right)\right]$$



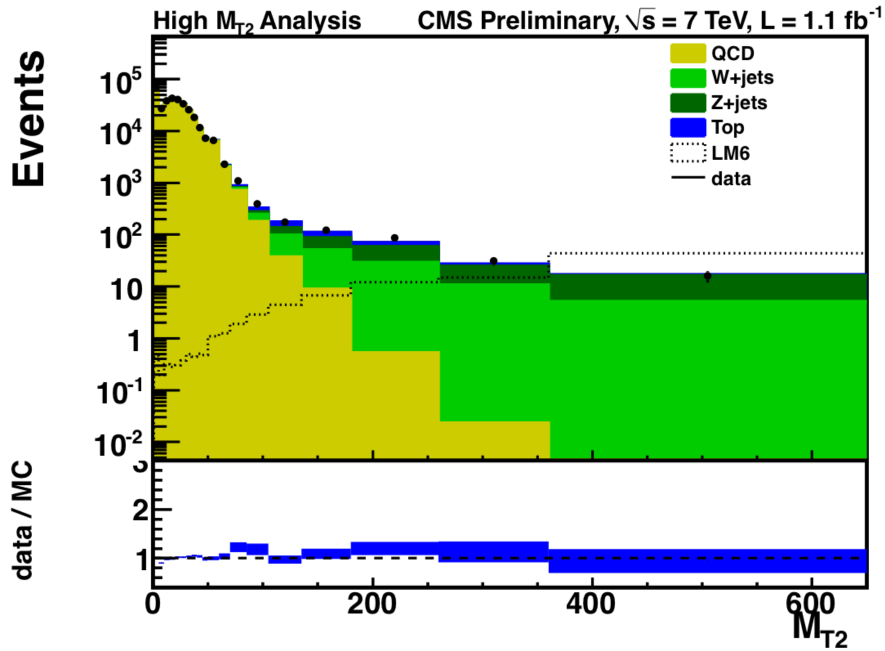
If m_c is known, the endpoint corresponds to m_p

Multijet events are divided into 2 *pseudojets* with hemisphere algorithm

Simplified formula in case of no ISR, zero masses:

$$M_{T2}^2 = 2p_T^{(1)}p_T^{(2)}(1+\cos\phi_{1,2})$$

- M_{T2}~ 0 for back-to-back systems (even with mismeasurement)
- M_{T2}< ME_T for asymmetric, nearly back-to-back mismeasured pseudojets
- M_{T2}~ ME_T for symmetric systems
- QCD is pushed to low M_{T2} values



M_{T2}(1.1/fb): definition

Analysis strategy: simple cut&count, M_{T2} spectrum divided in 3 regions:

- QCD dominated: M_{T2}< 80 GeV
- SM dominated: 200 < M_{T2}< 400 GeV
- Signal: M_{T2}> 400 GeV

Event selection:

- N^{jets}>2, H_T>600 GeV, ME_T> 30
- $P_T^{jet1,2}$> 100 GeV, |η|<2.4
- $|MH_T - ME_T|$ < 70 GeV (cut on upstream transverse momentum)
- minΔφ(jet, ME_T) > 0.3 (protection against mismeasured jets)
- Veto on e/μ p_T>10 GeV

Backgrounds:

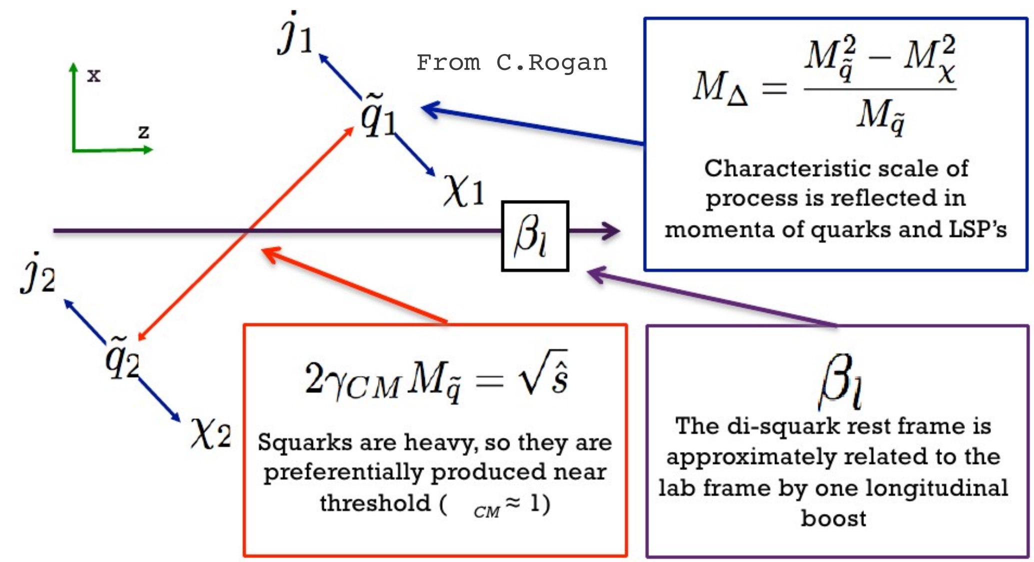
QCD multijets: factorization method based on functional form, fitted in QCD dominated region (contribution negligible)

SM Backgrounds: estimated in SM region, extrapolated to Signal region:

- Z(νν)+j: from W(μν) sample, with b-tag veto
- W+j, Top in e/μ channels: Lost Lepton on e/μ control samples
- W+j, Top in τ^{had} channel: MC based

Razor (4.4/fb): definition

Razor variables approximate boosted frames with a razor frame, where visible energies are written as a scale invariant under longitudinal boosts.



Razor boost: $\beta_L^R \equiv \frac{p_z^{j_1} + p_z^{j_2}}{E_{j_1} + E_{j_2}}$

Scale: $M_R \equiv \sqrt{(E_{j_1} + E_{j_2})^2 - (p_z^{j_1} + p_z^{j_2})^2}$

A transverse observable M_T^R is also defined, whose maximum value peaks at M_Δ:

$$M_T^R \equiv \sqrt{\frac{E_T^{miss}(p_T^{j1} + p_T^{j2}) - \vec{E}_T^{miss} \cdot (\vec{p}_T^{\,j1} + \vec{p}_T^{\,j2})}{2}}$$

The ratio of these two quantities gives a dimensionless discriminant, the *Razor R:*

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

Objects are merged in 2 *pseudojets*, with hemisphere algorithm

Razor (4.4/fb): Phenomenology

Signal is expected to have heavy scale M_Δ, SM not

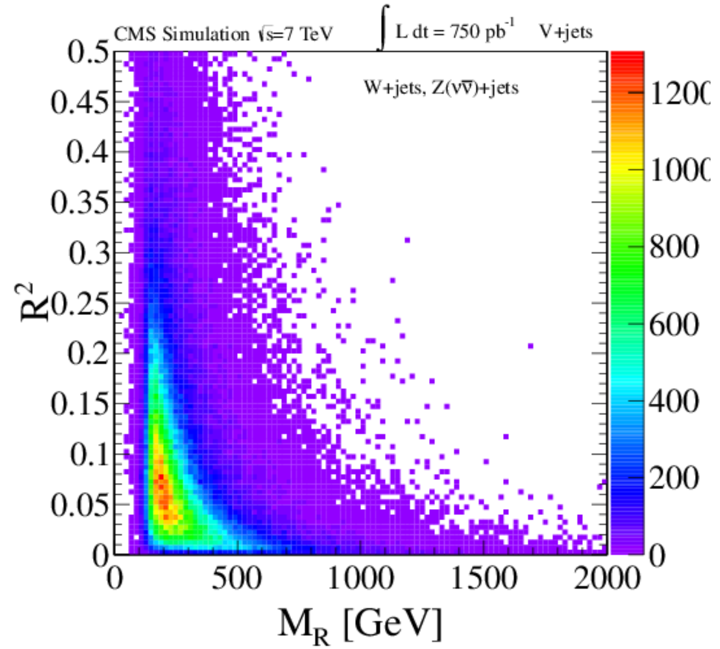
- Peak over steeply falling spectrum

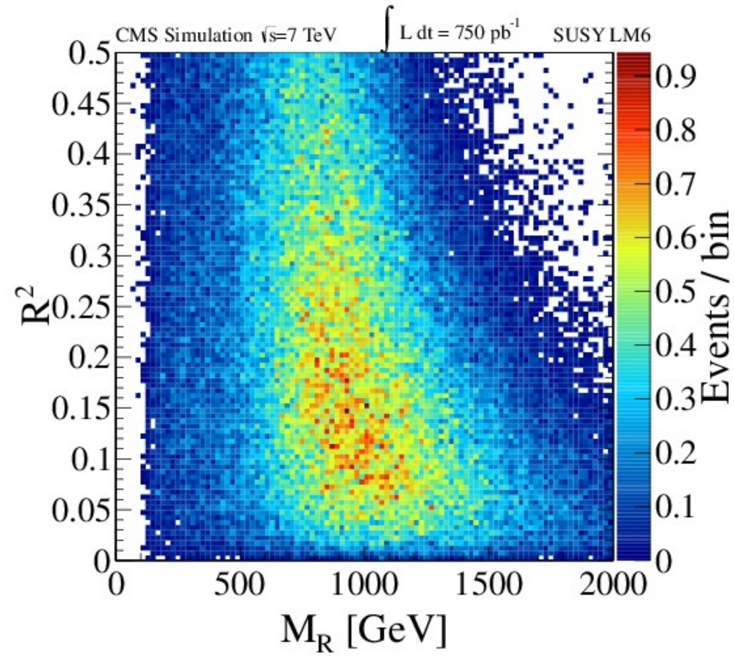
For signal *R* has a maximum value of 1, and <R>~0.5

- QCD peaks ~0

Analysis strategy:

- On most of the R^2-M_R plane, these variables have simple exponential behavior
- 2D functional forms are extracted in a set of hierarchical data samples *(boxes)*: ELE-MU, MU-MU, ELE-ELE, MU, ELE, HAD
- R^2-M_R shape parameters are extracted in SM dominated fit regions

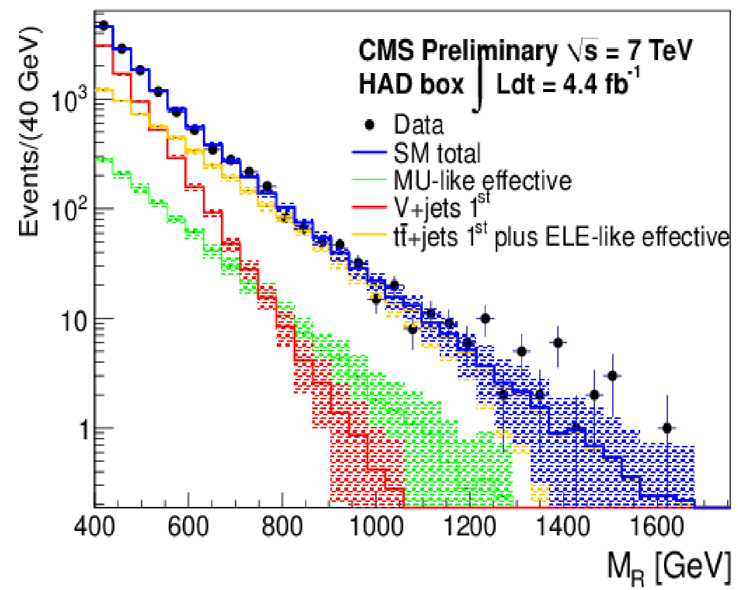




Razor (4.4/fb): Backgrounds

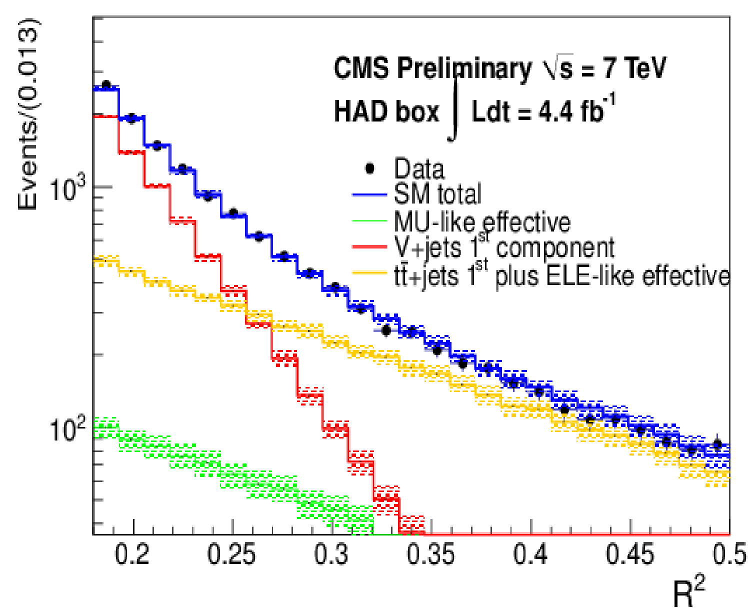
Functional form for M_R for SM is a double exponential:

- Second component dominates high M_R, independent on the box → associated with large ISR



Event selections:

- Triggers:
  - Hadronic: >1 jet p_T>56 GeV, moderate/tight cuts on R/M_R
  - Muon: >0 muon p_T>10 GeV, |η|<2.5, loose cuts on R/M_R
  - Electron: >0 electron p_T>10 GeV, |η|<2.1, loose cuts on R/M_R
- Razor cuts:
  - Leptonic boxes: M_R>300 GeV, 0.11< R^2 < 0.5
  - Hadronic boxes: M_R>400 GeV, 0.18< R^2 < 0.5



Exclusion Limits

Commonalities:

- Use of hybrid frequentist CL_s estimator
- Common tools developed in the CMS community
- Signal contamination taken into account

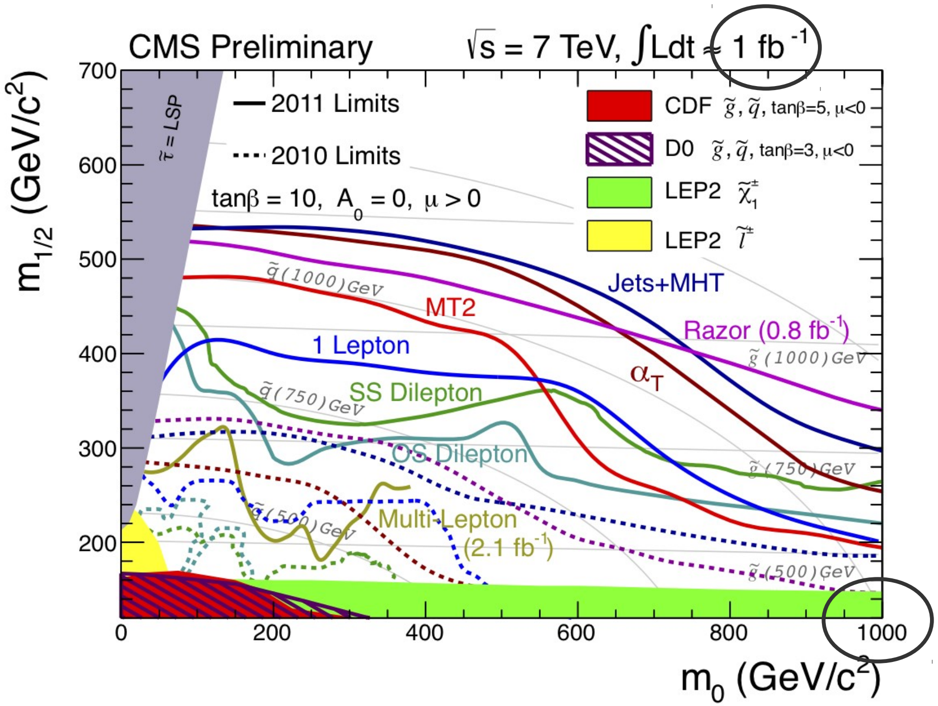
Technicalities for mSugra scans:

- For “Summer11” analyses:
  - NLO Prospino cross-sections
  - CTEQ6 pdf/scale uncertainties
- For “Winter 2012” analyses:
  - NLO+NLLO cross sections
  - CTEQ6+MSTW pdf / scale uncertainties

Technologies:

- $\mathbf{M_{T2}}$: single bin
- $\mathbf{MH_T}$: each bin is a statistical channel, best limit taken
- $\boldsymbol{\alpha_T}$: Maximum Likelihood SM background+Signal
- **Razor**: all the boxes considered through Maximum Likelihood

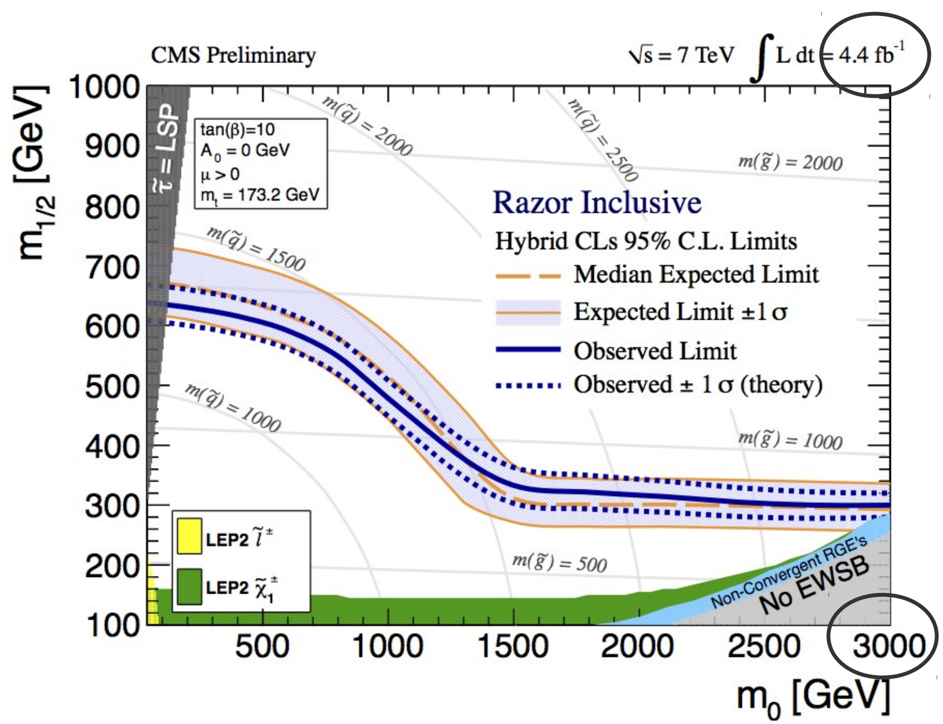
Exclusion Limits



Caveat: *M_{T2} limit is a combination of "M_{T2}" (low m_0) and "$M_{T2}b$" (high m_0)*

Msugra/CMSSM:

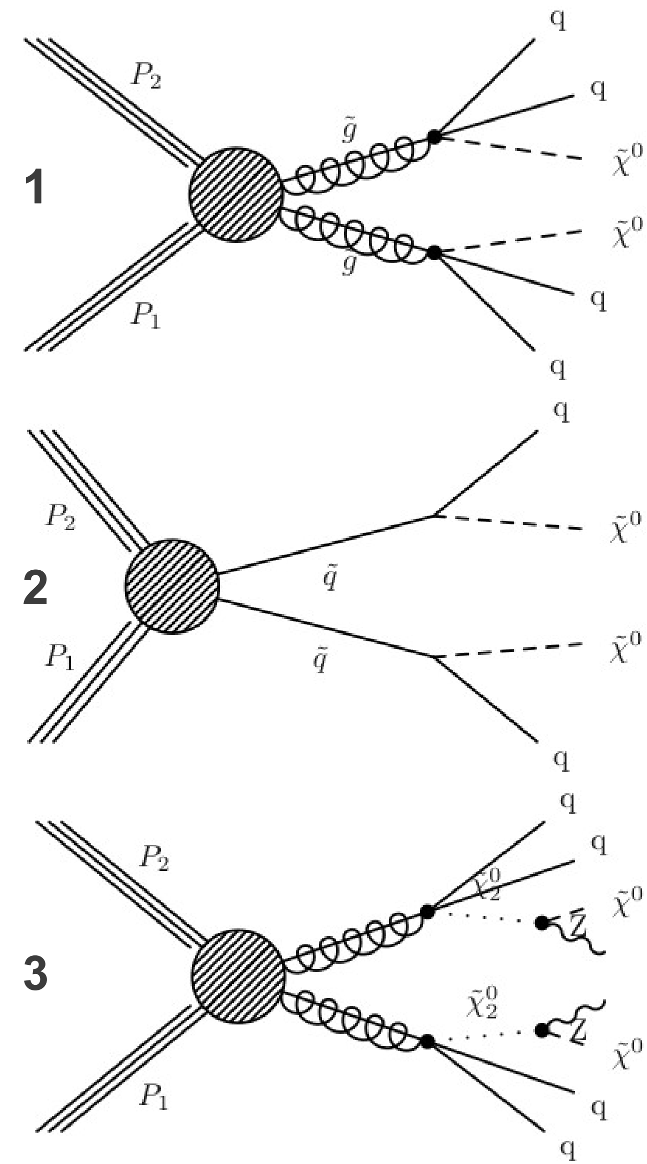
- tanβ=10
- A_0=0
- μ>0



Topology based limits

Interpretation in given also in the language of Simplified Models
Three topologies considered (only MH_T and α_T):

1) $\tilde{g}\tilde{g}$ production, with $\tilde{g} \to qq\chi_0$
2) $\tilde{q}\tilde{q}$ production, with $\tilde{q} \to q\chi_0$
3) $\tilde{g}\tilde{g}$ production, with $\tilde{g} \to qqZ\chi_0$



Cross sections have been computed with PROSPINO in decoupling regime, and branching ratios = 1

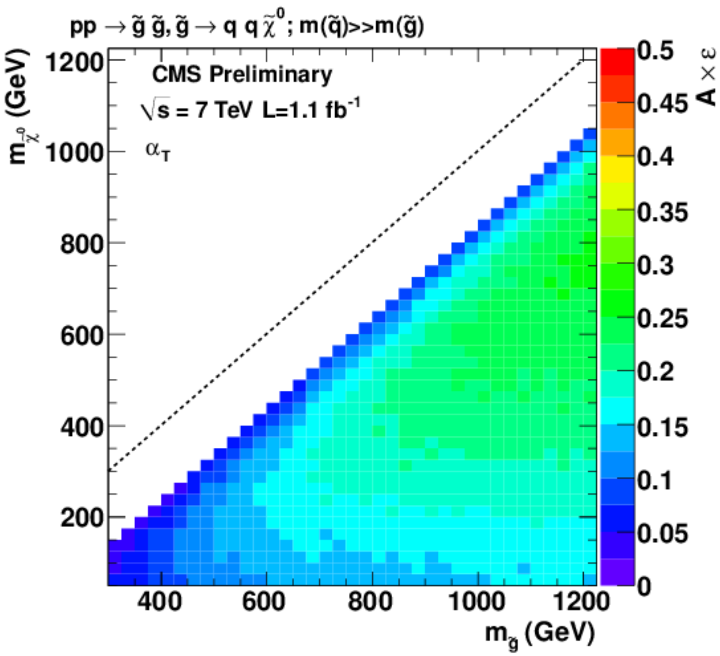
Different mass splittings explored

Language is SUSY, but not constrained to it

Three exclusion lines reported:

- Nominal
- With 1/3 – 3 times the cross section

α_T "simplified"



Higher efficiency for higher $\tilde{q},\tilde{g}$ mass

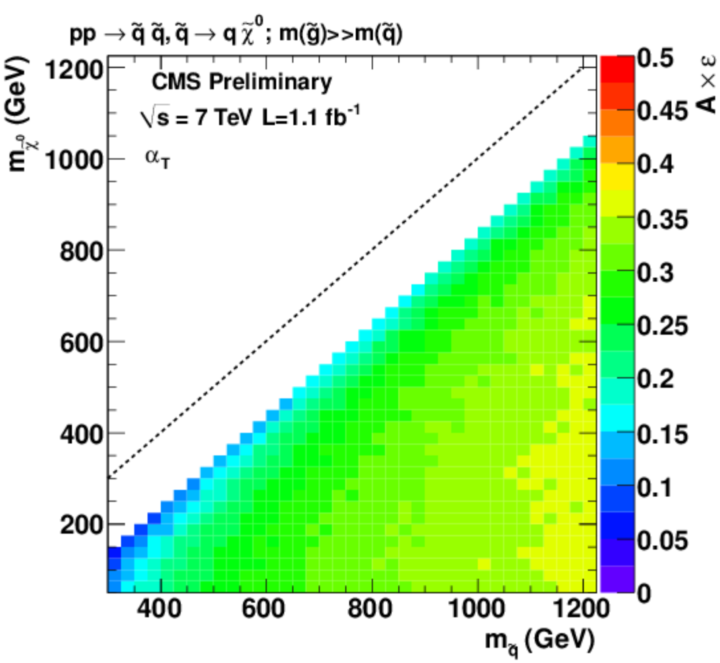
- Higher jet p_T

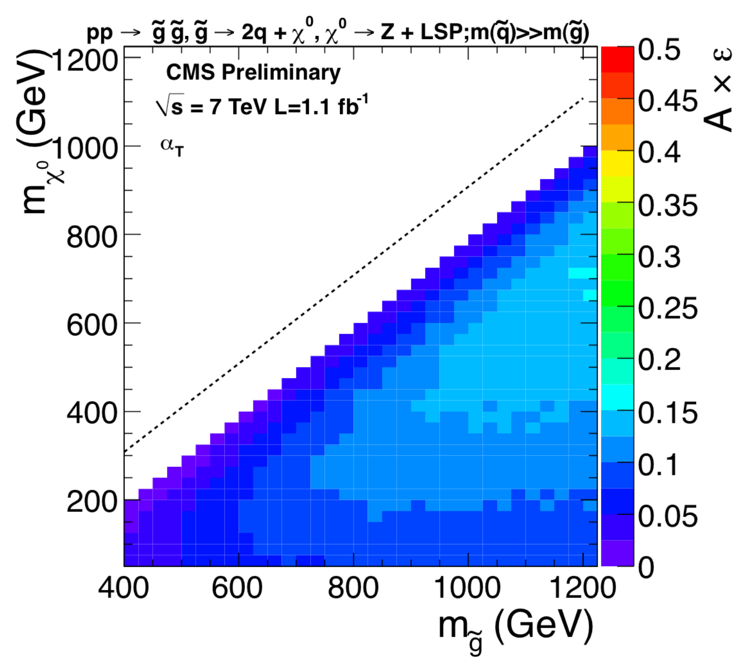
Lower efficiency for higher jet multiplicity

- α_T was initially designed for 2-jets systems

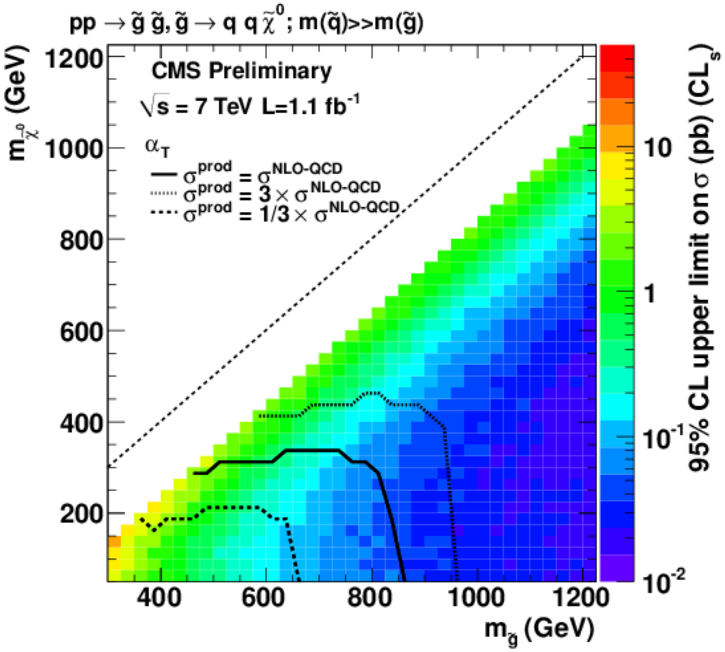
α_T less efficient when the visible energy increases

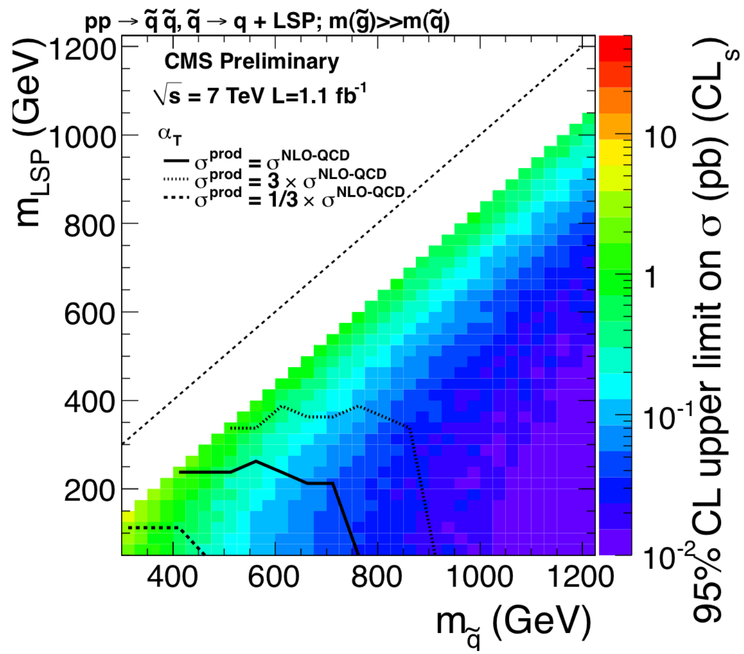
- It better explores regions where MH_T~H_T

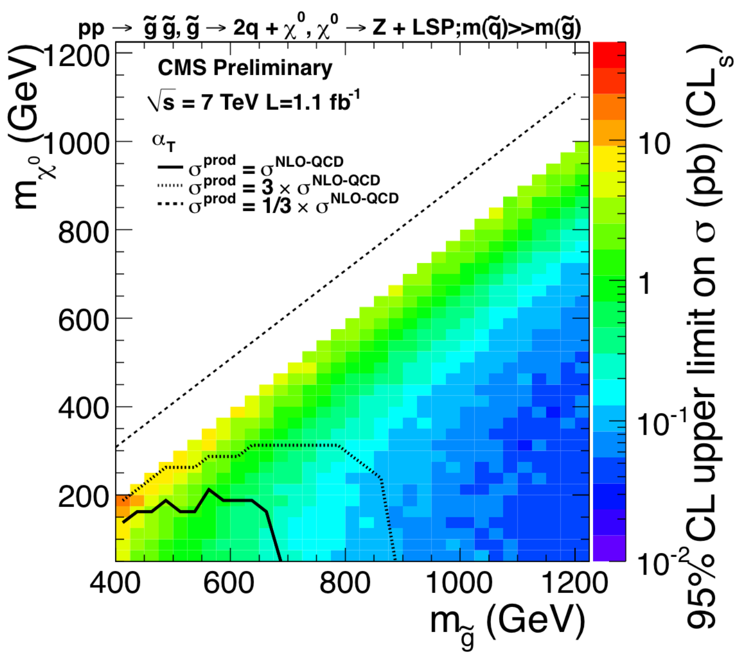




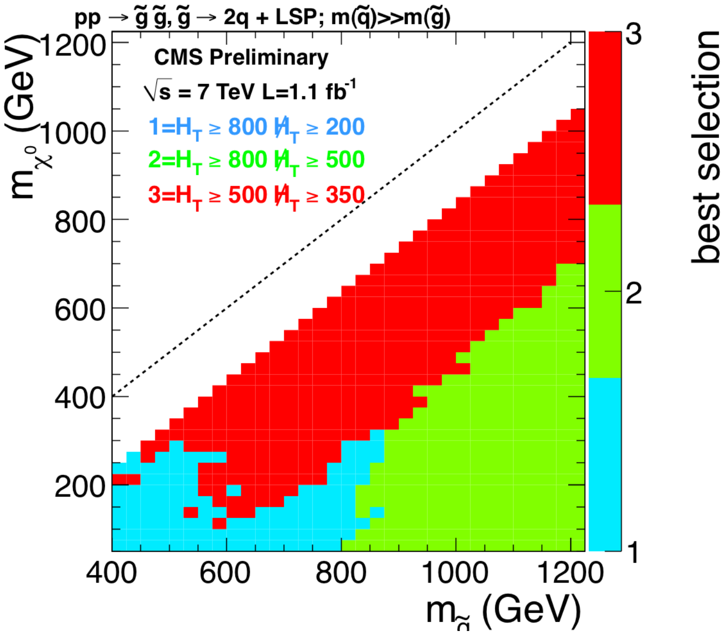
α_T "simplified"







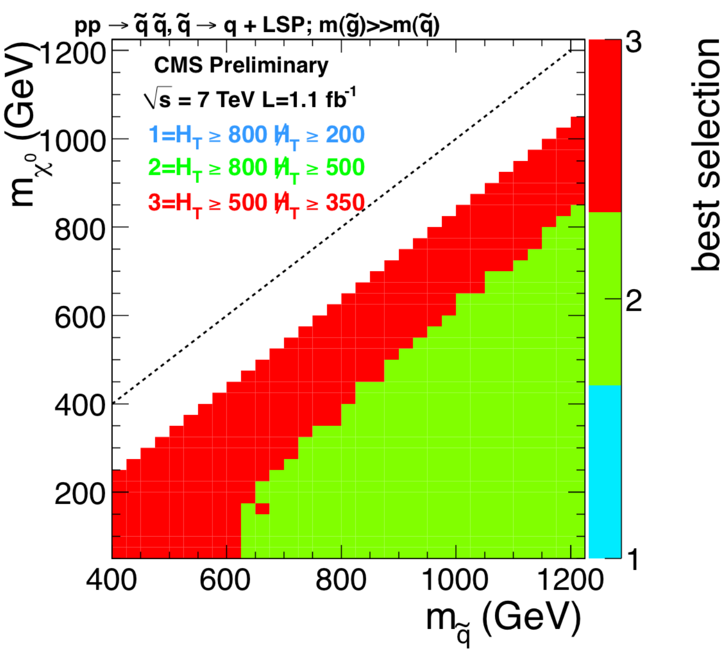
MH_T "simplified"

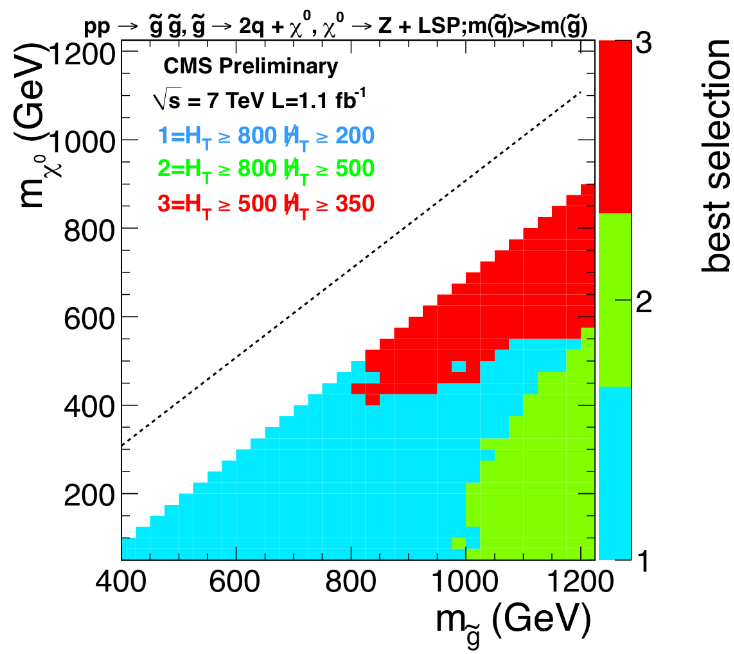


Medium selection (3) better performs in small mass splitting scenario

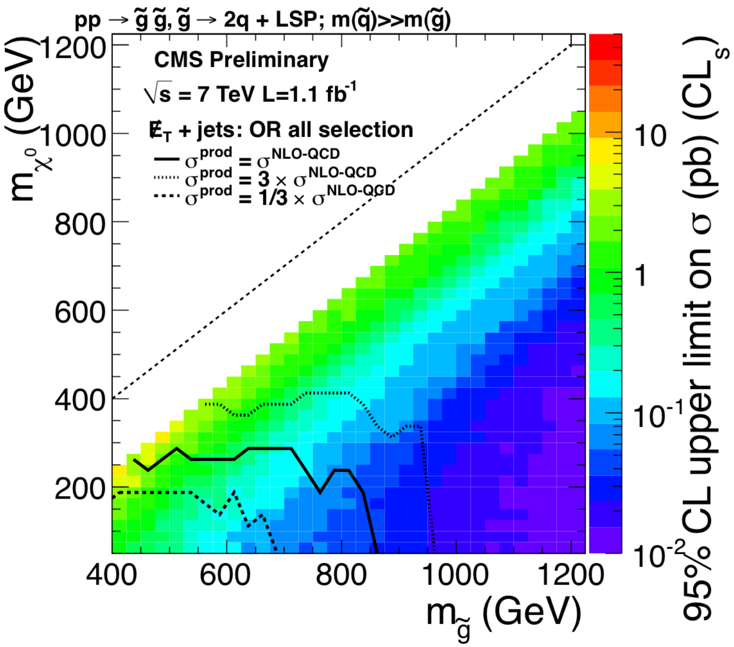
High MH_T selection (2) dominates for large mass splittings

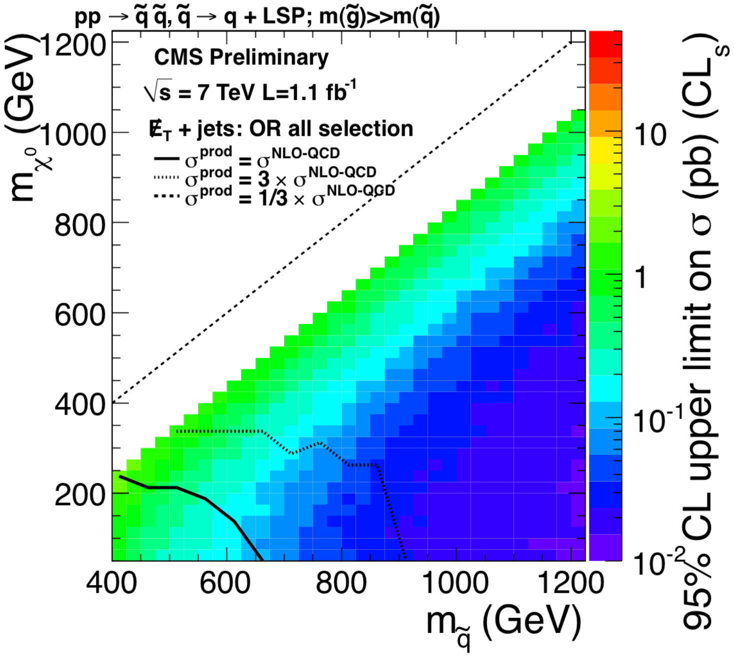
High H_T selection (1) is preferred in case of longer cascades (and lot of visible energy)

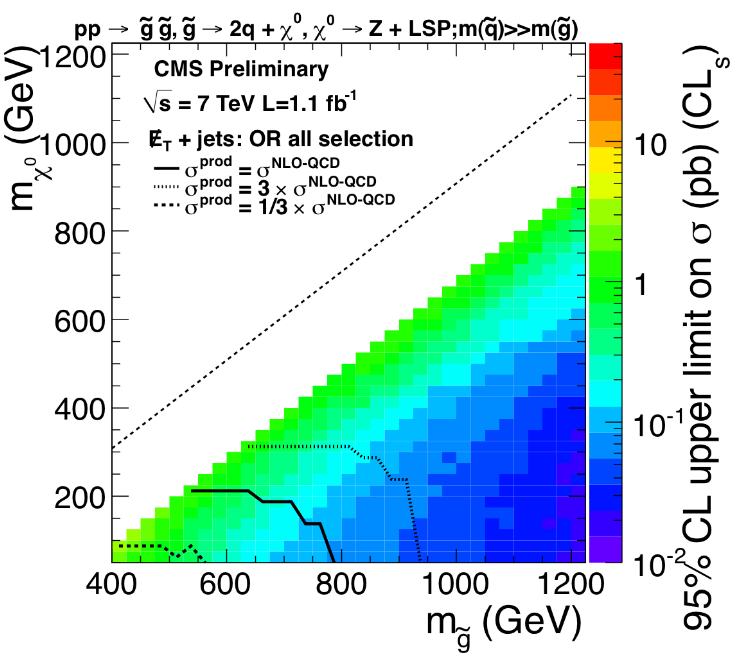




Topology based limits







Outlook

Updates to full 2011 dataset are ongoing for MH_T, α_T , M_{T2}, with improvements wrt 1.1/fb analyses

Sensitivity to large region of the phase space, compatible results with 4 different methodologies

- No excess seen...

Challenges ahead:

- Very high jet multiplicity region (e.g. high $m_{1/2}$)
- Low ME_T regions (compressed spectra)
- Always improving background prediction
    - At some point, SM rare processes will kick in
    - Reduce possible signal kick-in in control regions

References

Detector noise: CERN-CMS-DP-2010-025 (HCAL), CERN-CMS-DP-2011-010 and arXiv:1106.5048v1 (ME_T)

γ+jets for Z(νν)+ jets: Bern et al. arXiv:1106.1423v2

MH_T: CMS PAS SUS-11-004

$Alpha_T$: 10.1016/j.physletb.2011.03.021, CMS PAS SUS-11-003, Phys. Rev. Lett. 101, 221803 (original th. paper)

M_{T2}: CMS PAS SUS-11-005, Phys. Rev. D 80, 074007 (MT2 as discovery variable)

Razor: CMS PAS SUS-12-005, arXiv:1006.272 (original th. Paper), “Razor for Searches at the LHC” C.Rogan talk at LPC Topic of the Week

Simplified Models: arXiv:1105.2838v1

CMS public SUSY results: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

NLO QCD SUSY corrections: Beenakker, H"opker, Spira, Zerwas arXiv:hep-ph/9610490v1

Compressed Spectra: LeCompte, Martin et Al. arXiv:1111.6897

Backup

Details on Detector noise

Event cleaning:

- Beam scraping removal (fraction of high-quality tracks in the event was required to be greater than 25%, for events with at least ten charged-particle tracks)
- $Sum(p_T^{tracks})/H_T > 0.1$
- ≥ 1 primary vertex
- Beam halo events removal using CSC detector information [1]
- HBHE noise removal using pulse shape and topological information
- Event charge fraction (Track sum pT / HT > 0.1)

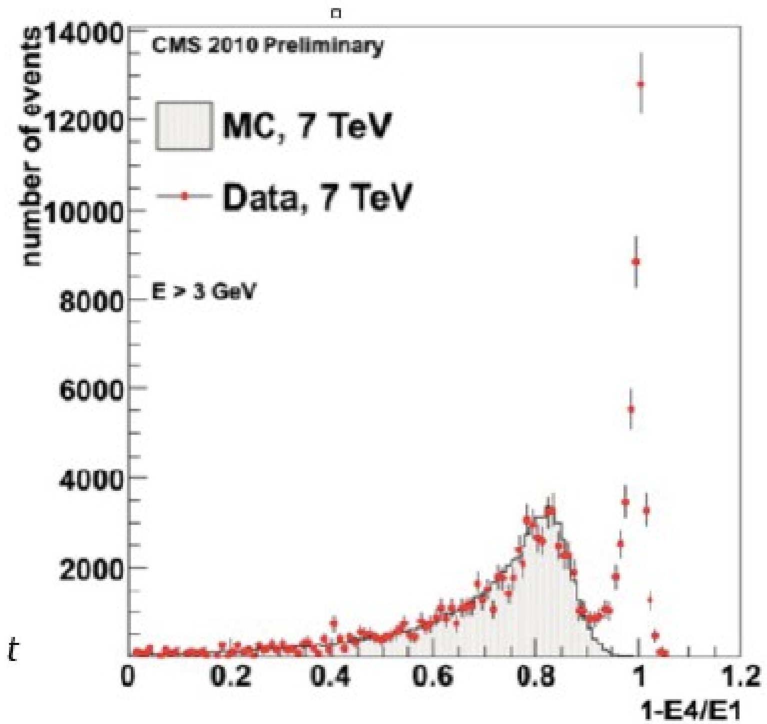
Jet cleaning (99-99.9% efficient):

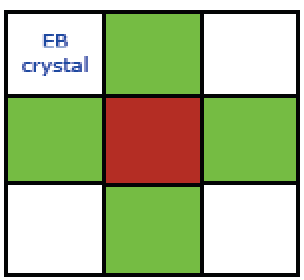
- PF Jets: NHF<0.99, NEM<0.99, NConstituents>1
  - For eta >2.4: CHF>0, Charged Multiplicity>1, CEF<0.99
- Calo Jets: Number hits 90% Energy>1, HBHE>0.01, fHPD<0.98

ECAL noise

In a small fraction of events, anomalous energy deposits in ECAL with:

- Distinct pulse shape
- Different timing
- Single crystal
- Only in the barrel



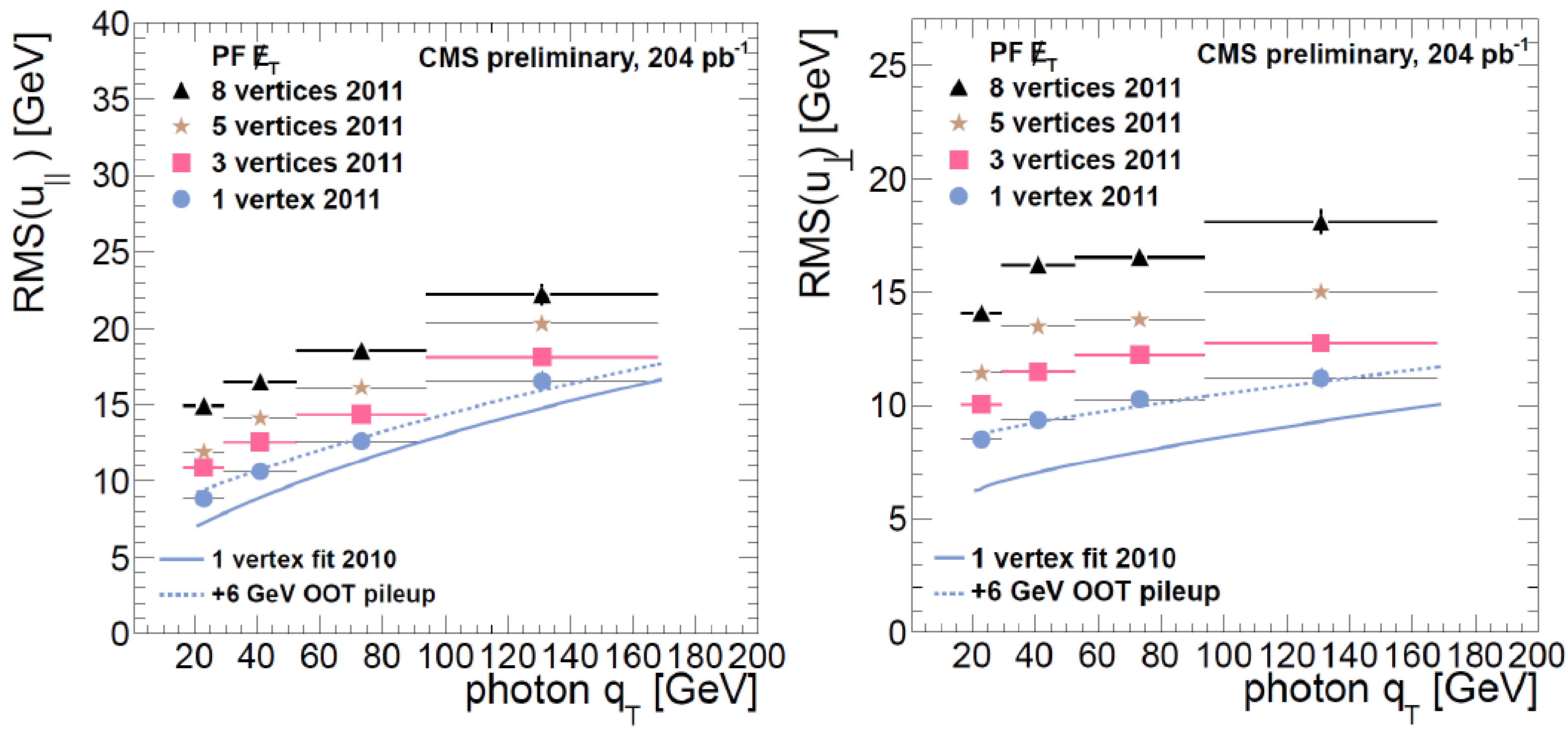


Identified as highly ionizing particles hitting the APD (in the endcap different electronics)

Identified by:

- Ratio between energy in single crystal and 4 neighbours crystals (E4/E1)
- Pulse shapes

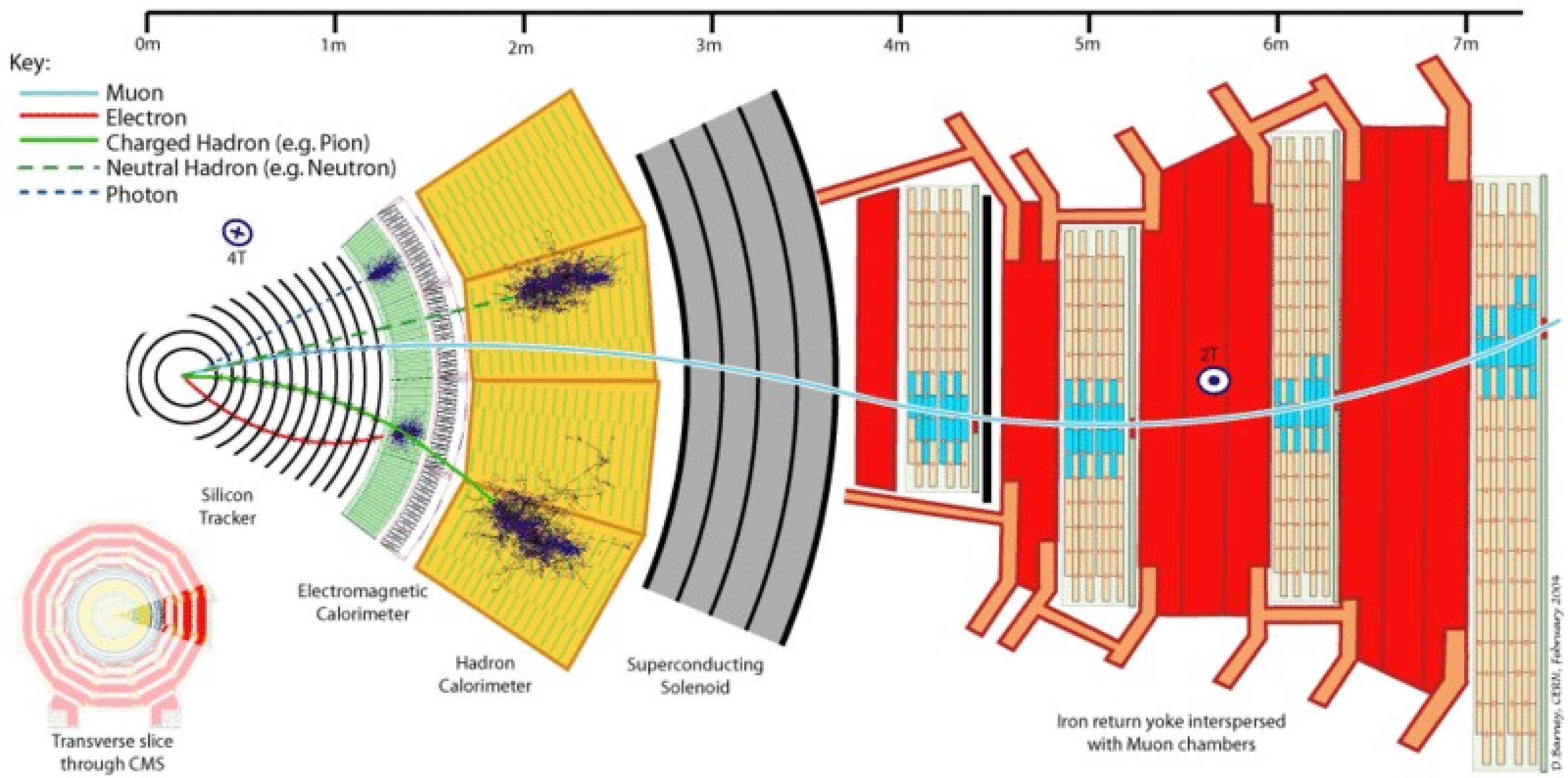
MET in Photon+Jet Events



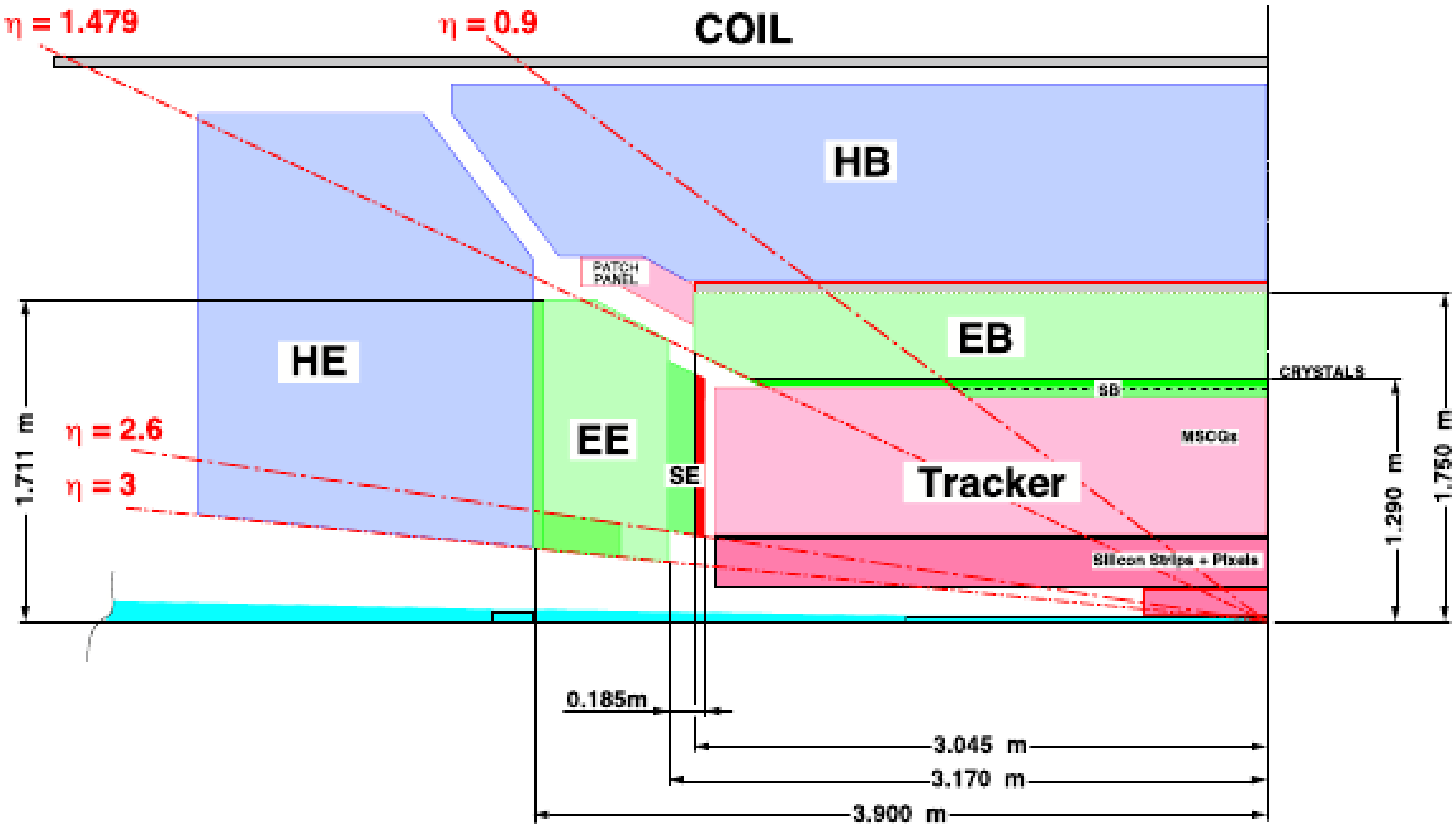
- The resolution degrades with increasing # of verticies as expected
- Even at 1 vertex, the resolution is degraded in 2011 by ~6 GeV in quadrature compared to the 2010 due to out-of-time pileup
- Work in progress to mitigate the pileup effects in MET reconstruction and to understand the slight worsening of MET resolution in 2011

July, 2011 7

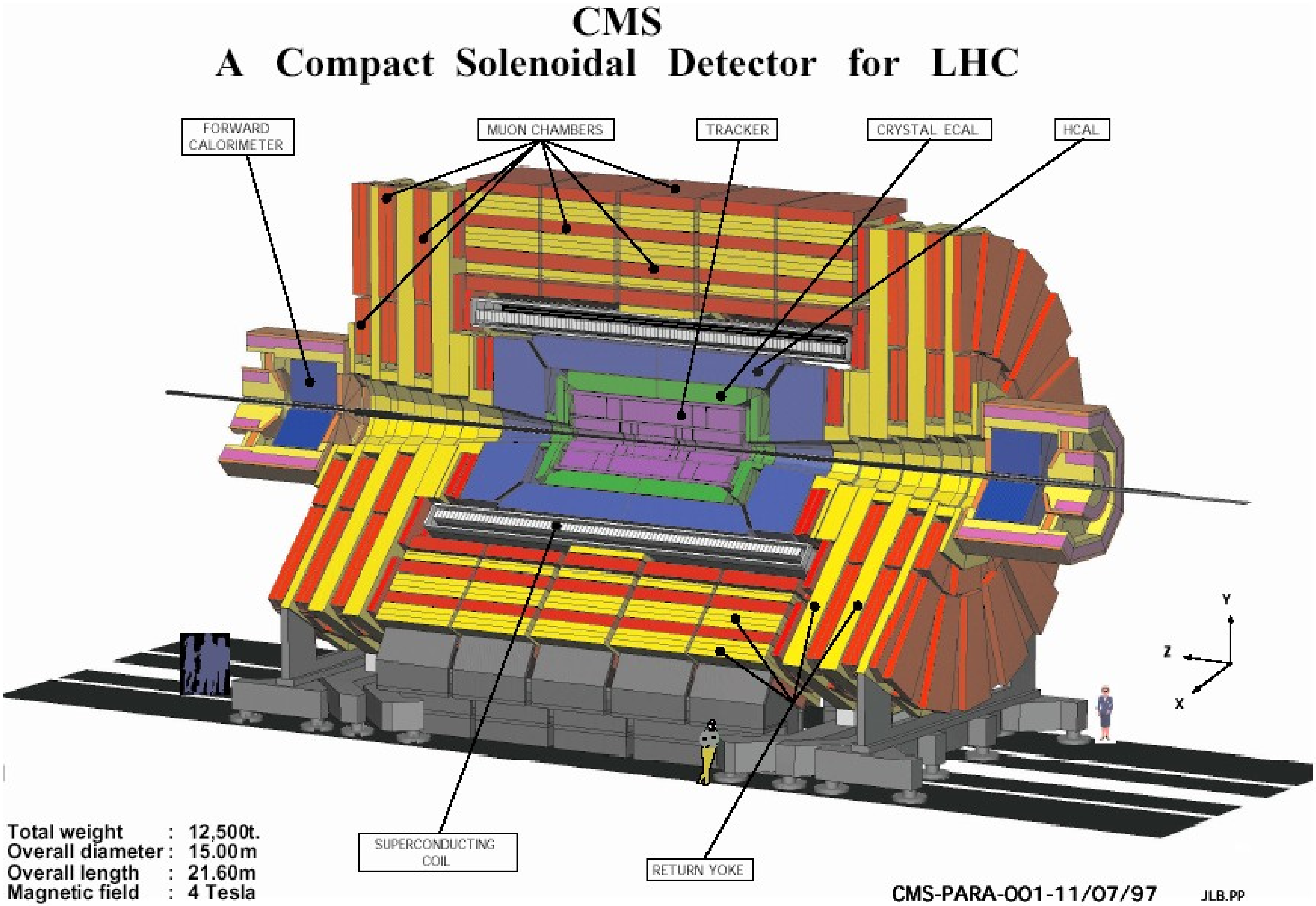
CMS – Slice


0m
1m
2m
3m
4m
5m
6m
7m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon
4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
Transverse slice through CMS
D.Barney, CERN, February 2004

CMS – Inner part



CMS – Overall

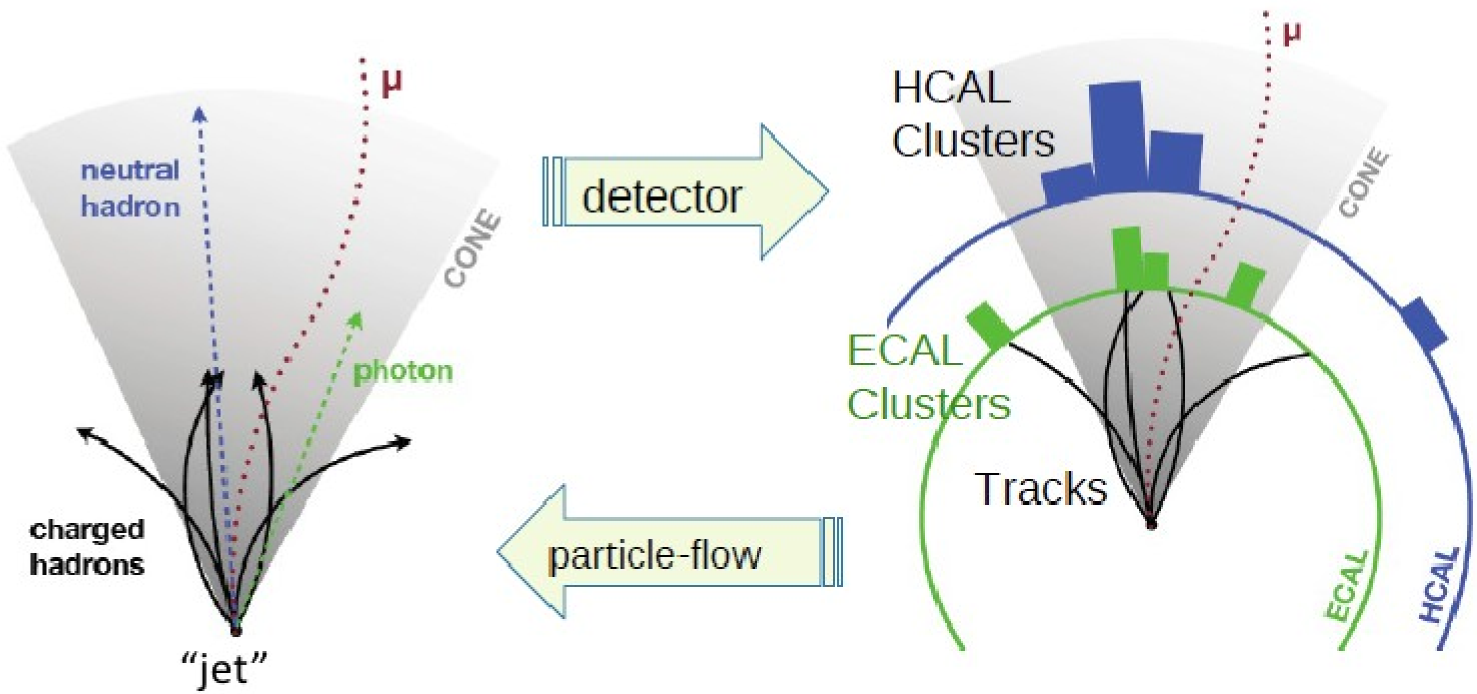


CMS
A Compact Solenoidal Detector for LHC
FORWARD CALORIMETER
MUON CHAMBERS
TRACKER
CRYSTAL ECAL
HCAL
SUPERCONDUCTING COIL
RETURN YOKE
Y
Z
X
Total weight : 12,500t.
Overall diameter : 15.00m
Overall length : 21.60m
Magnetic field : 4 Tesla
CMS-PARA-001-11/07/97
JLB.PP

Particle Flow

A different approach in reconstruction:

- Information from different subdetectors is used to identify *candidates*
- Higher level objects (jets, electrons...) are built up from these candidates
- Corrections are *candidate based*



Hemispheres

Same idea, slightly different measures for grouping jets:

- *Razor:* minimal squared masses of both hemispheres

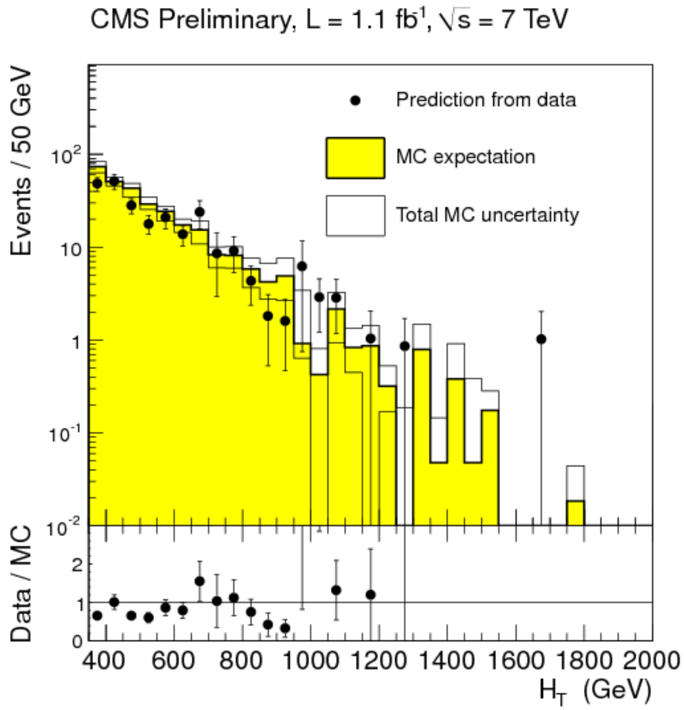
$$m_{ik}^2 + m_j^2 \leq m_i^2 + m_{jk}^2 \longrightarrow (E_i - p_i \cos\theta_{ik}) \leq (E_j - p_j \cos\theta_{jk})$$

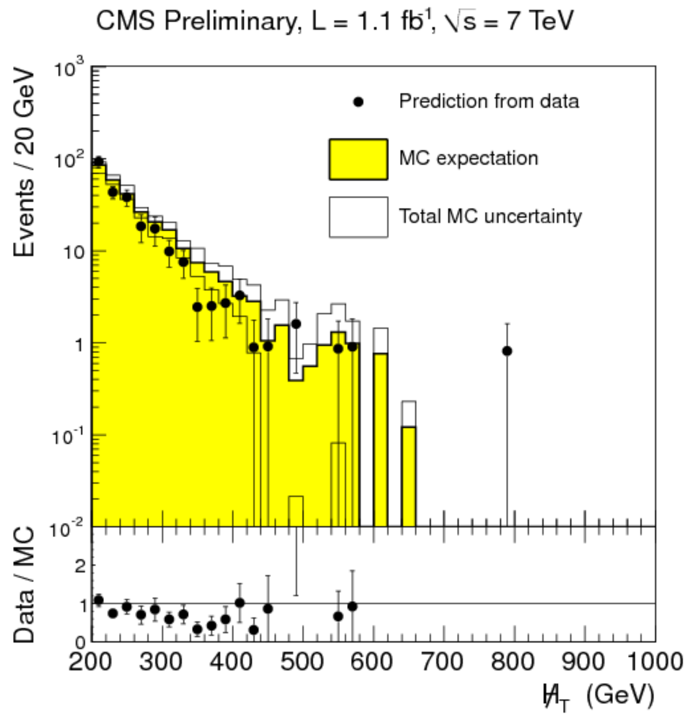
- M_{T2}: minimal Lund distance: $(E_i - p_i cos\theta_{ik})\frac{E_i}{(E_i + E_k)^2}$

- α_T: ΔH_T balance (minimal ΔE_T between the two jets)

MH_T material

Lost Lepton Prediction

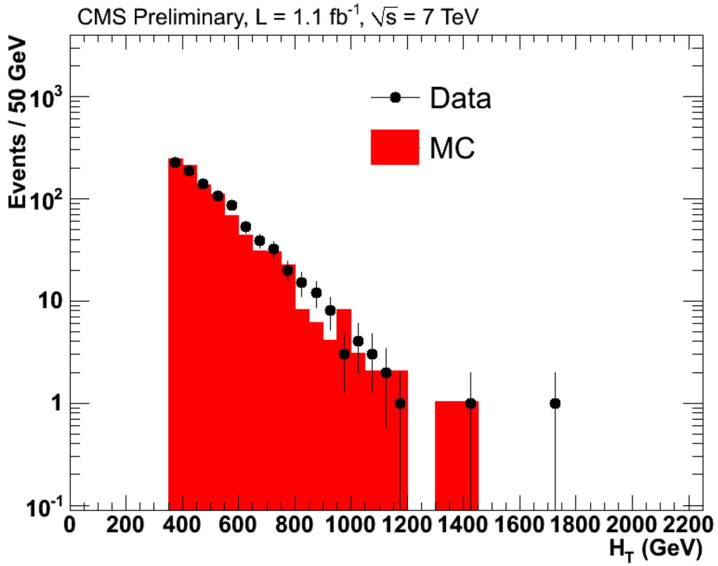


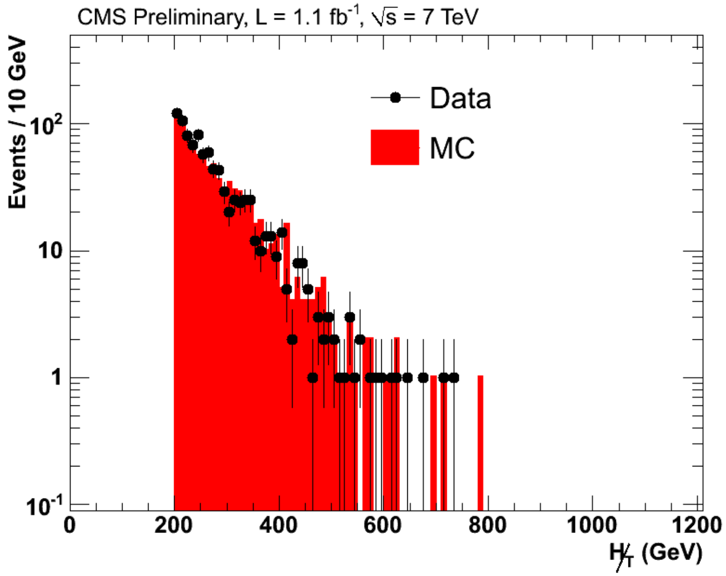


	Baseline (H_T >350 GeV) ($\not{H}_T$ >200 GeV)	Medium (H_T >500 GeV) ($\not{H}_T$ >350 GeV)	High H_T (H_T >800 GeV) ($\not{H}_T$ >200 GeV)	High $\not{H}_T$ (H_T >800 GeV) ($\not{H}_T$ >500 GeV)
$Z \to \nu\bar{\nu}$ from γ+jets	$376 \pm 12 \pm 79$	$42.6 \pm 4.4 \pm 8.9$	$24.9 \pm 3.5 \pm 5.2$	$2.4 \pm 1.1 \pm 0.5$
$t\bar{t}/W \to e, \mu$+X	$244 \pm 20^{+30}_{-31}$	$12.7 \pm 3.3 \pm 1.5$	$22.5 \pm 6.7^{+3.0}_{-3.1}$	$0.8 \pm 0.8 \pm 0.1$
$t\bar{t}/W \to \tau_h$+X	$263 \pm 8 \pm 7$	$17 \pm 2 \pm 0.7$	$18 \pm 2 \pm 0.5$	$0.73 \pm 0.73 \pm 0.04$
QCD	$31 \pm 35^{+17}_{-6}$	$1.3 \pm 1.3^{+0.6}_{-0.4}$	$13.5 \pm 4.1^{+7.3}_{-4.3}$	$0.09 \pm 0.31^{+0.05}_{-0.04}$
Total background	928 ± 103	73.9 ± 11.9	79.4 ± 12.2	4.6 ± 1.5
Observed in data	986	78	70	3

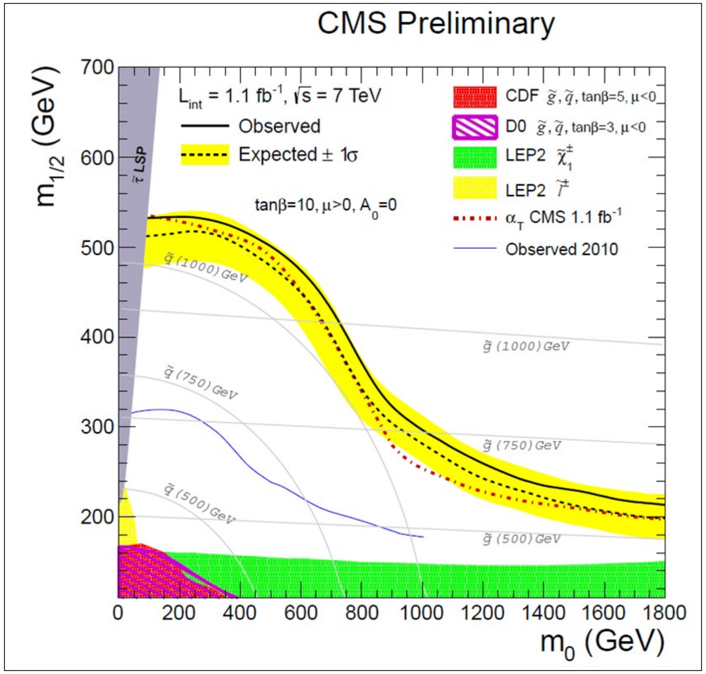
MH_T material

Photon control sample



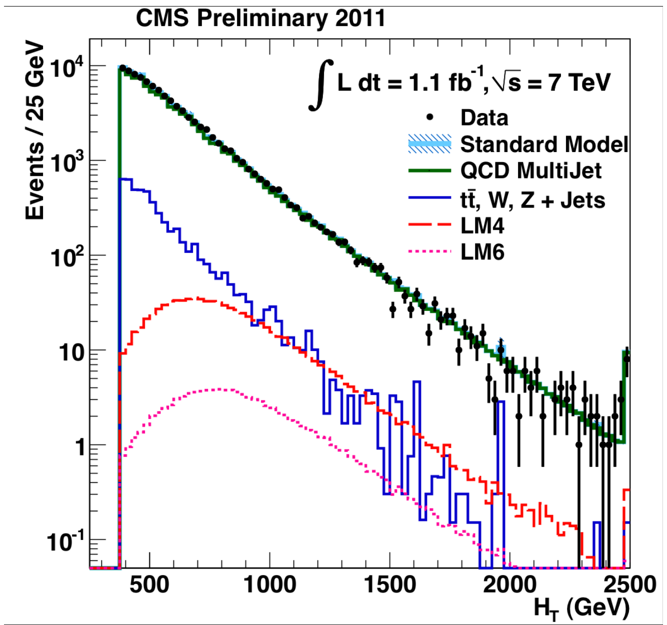


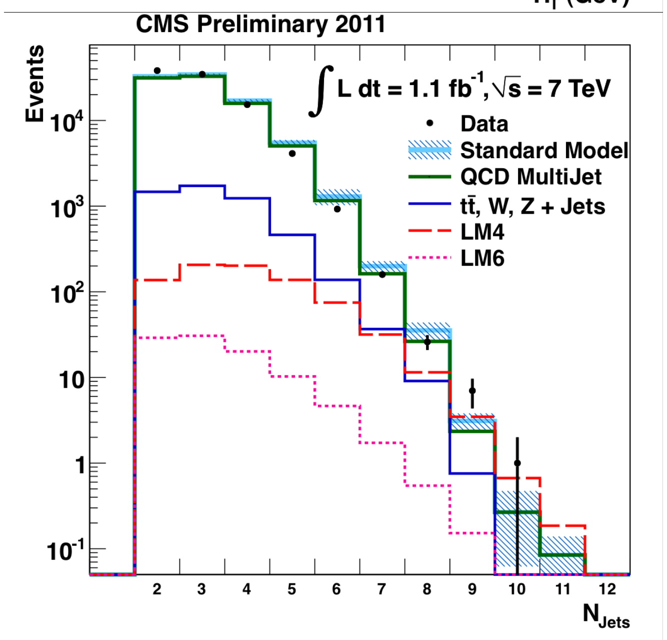
mSugra exclusion

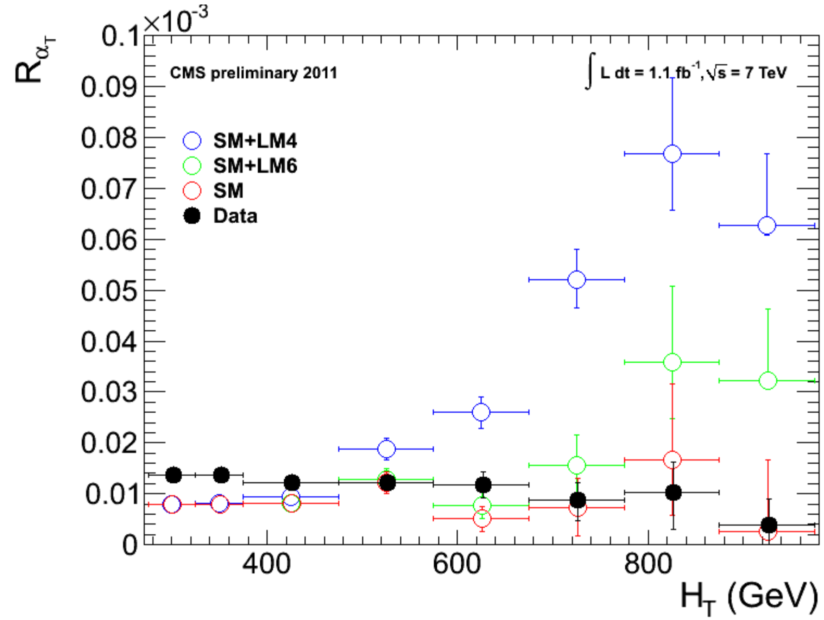


α_T material

Control plots for $H_T \geq 375$ GeV and $MH_T > 100$ GeV, before α_T cuts







$$\alpha_{\rm T} = \frac{E_{\rm T}^{\rm jet_2}}{M_{\rm T}} = \frac{E_{\rm T}^{\rm jet_2}}{\sqrt{\left(\sum_{i=1}^{2} E_{\rm T}^{{\rm jet}_i}\right)^2 - \left(\sum_{i=1}^{2} p_x^{{\rm jet}_i}\right)^2 - \left(\sum_{i=1}^{2} p_y^{{\rm jet}_i}\right)^2}}$$

$$\alpha_T = \frac{1}{2} \cdot \frac{H_T - \Delta H_T}{\sqrt{H_T^2 - (MHT)^2}}.$$

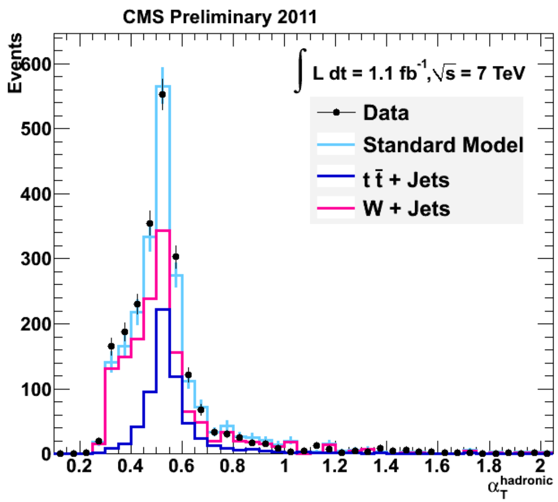
$$H_T = \sum_{\text{jets } j} p_{Tj}$$

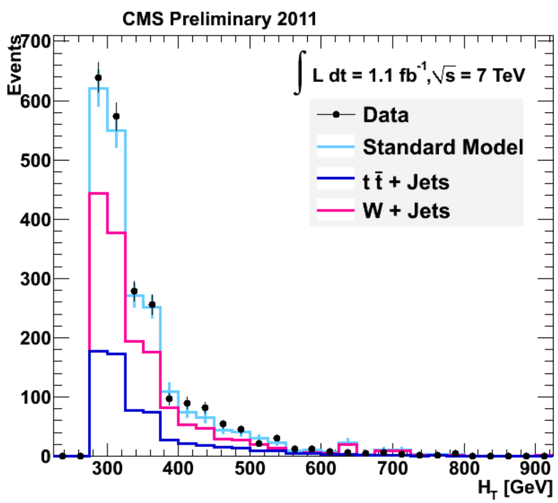
$$\Delta H_T = p_{T\text{pseudojet 1}} - p_{T\text{pseudojet 2}}$$

α_T material

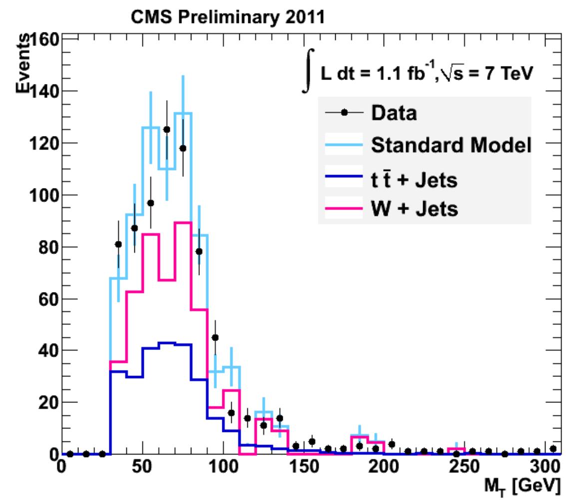
Muon control plots for $H_T \geq 375$ GeV and $MH_T > 100$ GeV

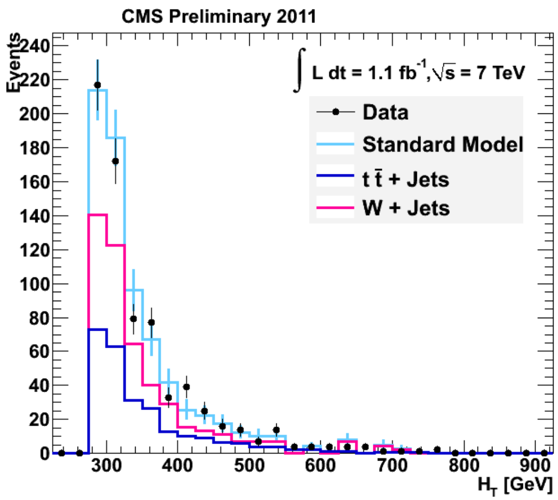
Before α_T cuts





After α_T cuts



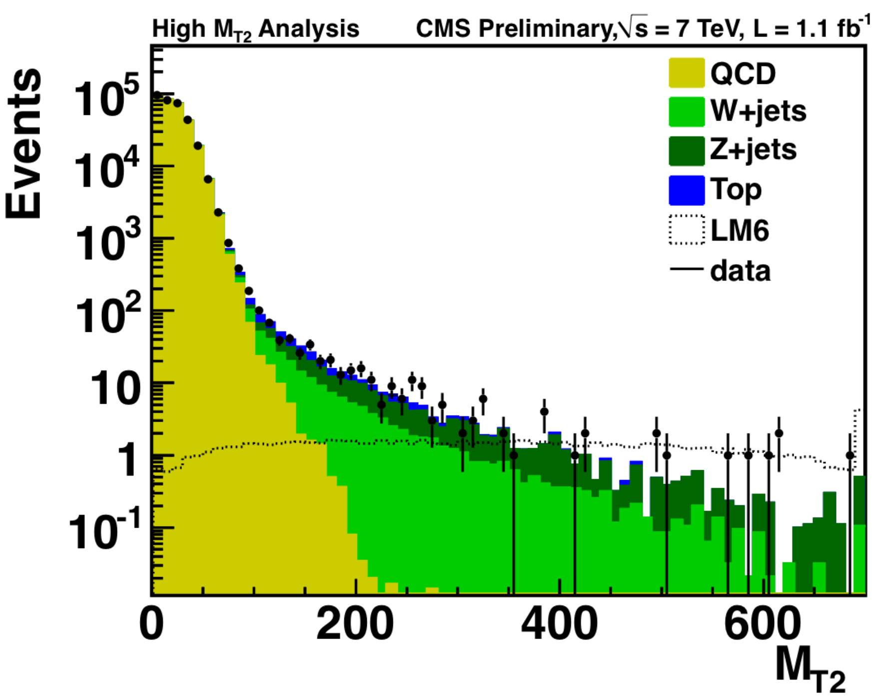


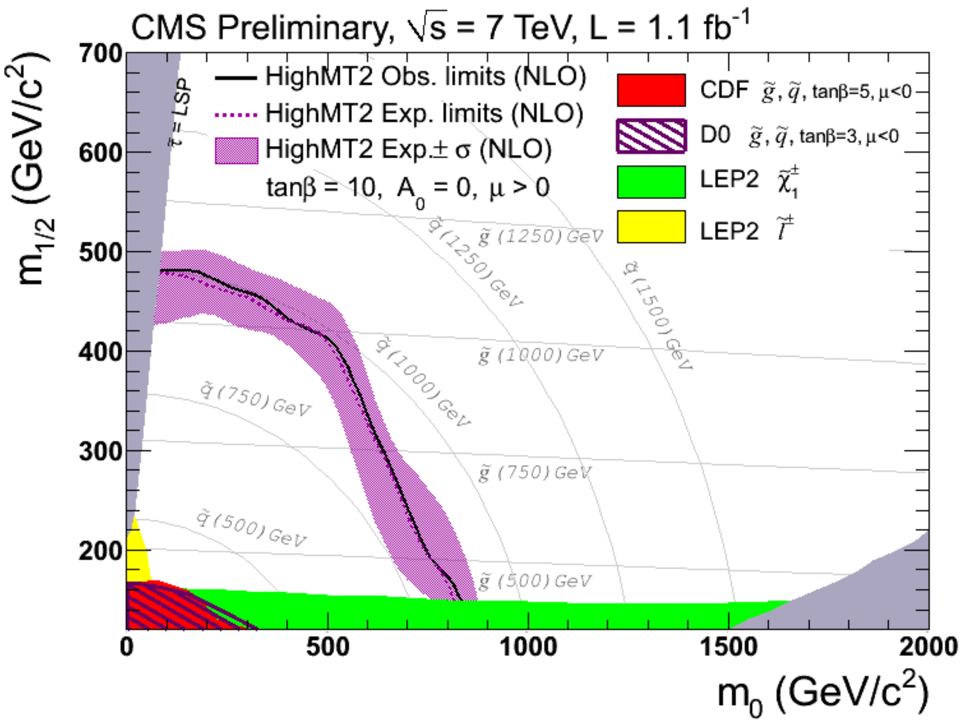
α_T material

H_T Bin (GeV)	275–325	325–375	375–475	475–575
W + $t\bar{t}$ background	363.7	152.2	88.9	28.8
$Z \to \nu\bar{\nu}$ background	251.4	103.1	86.4	26.6
QCD background	172.4	55.1	26.9	5.0
Total Background	787.4	310.4	202.1	60.4
Data	782	321	196	62
H_T Bin (GeV)	575–675	675–775	775–875	875–∞
W + $t\bar{t}$ background	10.6	3.1	0.6	0.6
$Z \to \nu\bar{\nu}$ background	8.7	4.3	2.5	2.2
QCD background	1.0	0.2	0.1	0.0
Total Background	20.3	7.7	3.2	2.9
Data	21	6	3	1

MT2 material (?)

$$Bkgd(M_{T2} \geq 400\text{GeV}) = 12.6 \pm 1.3 \pm 3.5 \text{ events}$$





Boxes definition

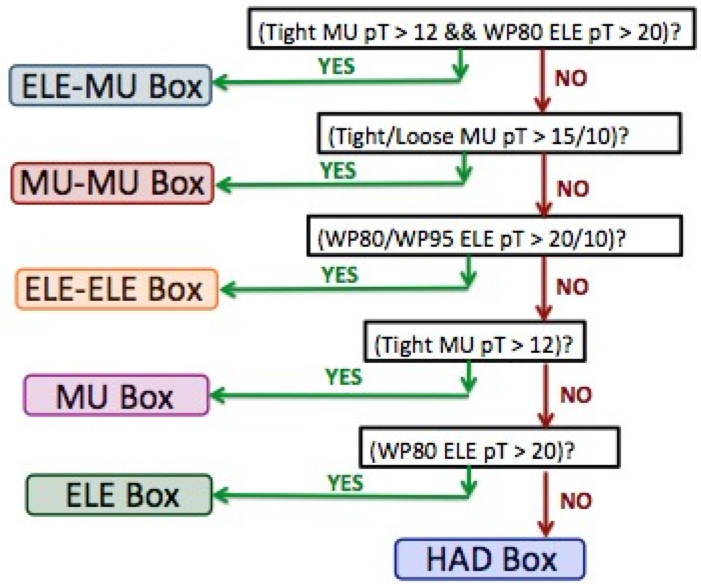


Figure 1: Flow diagram of box classification logic. The box selection proceeds according to a box hierarchy in order to ensure complete orthogonality of box selections and to resolve ambiguities when an event satisfies more than one box's selection criteria.

Razor material

QCD control box

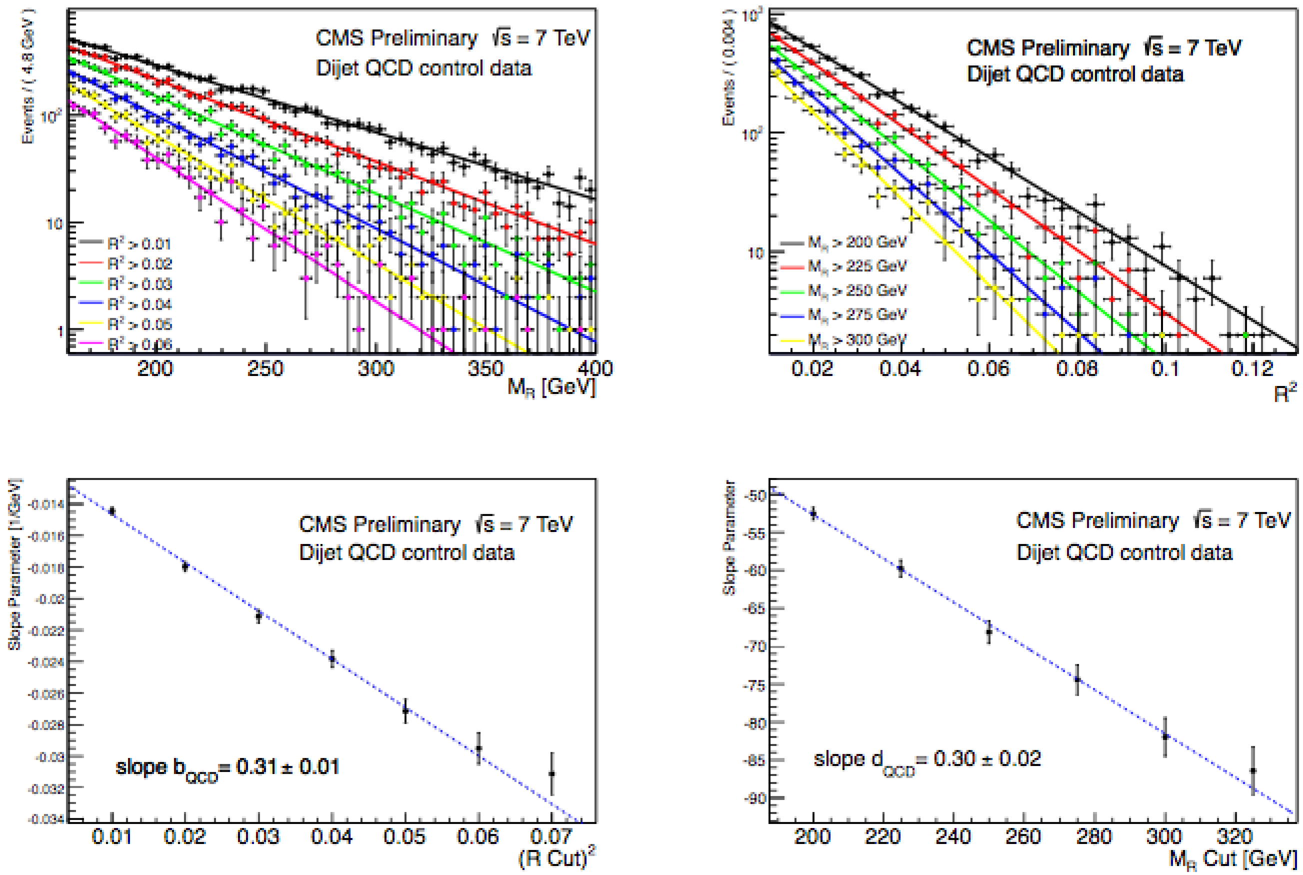


Figure 3: (Top left) M_R distributions for different values of the R^2 threshold for events in data selected in the QCD control box. (Top right) R^2 distributions for different values of the M_R threshold for events in data selected in the QCD control box. (Bottom left) The exponential slope S from fits to the M_R distribution, as a function of the square of the R^2 threshold for data events in the QCD control box. (Bottom right) The coefficient in the exponent S from fits to the R^2 distribution, as a function of the square of the M_R threshold for data events in the QCD control box.

Mu control box

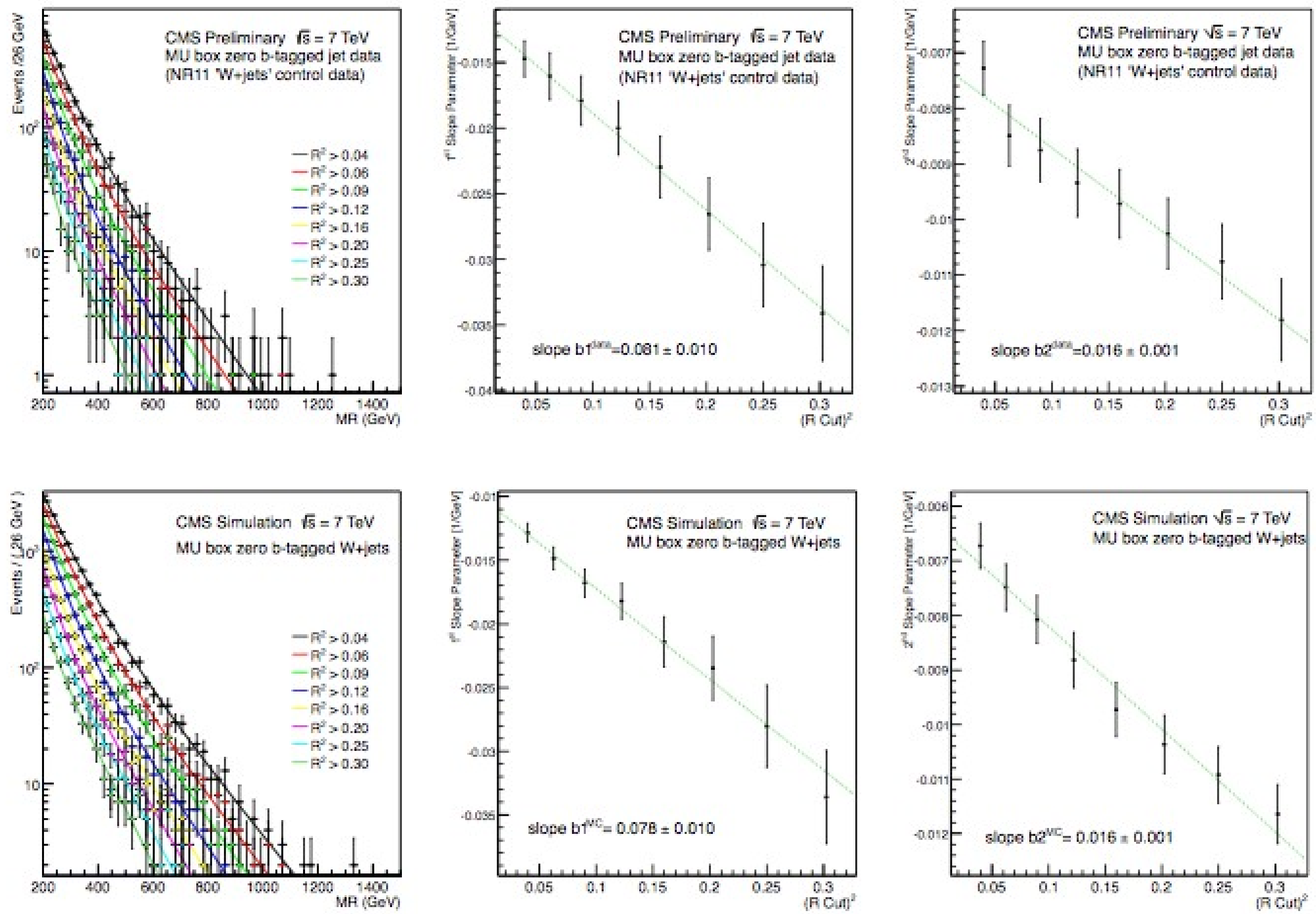
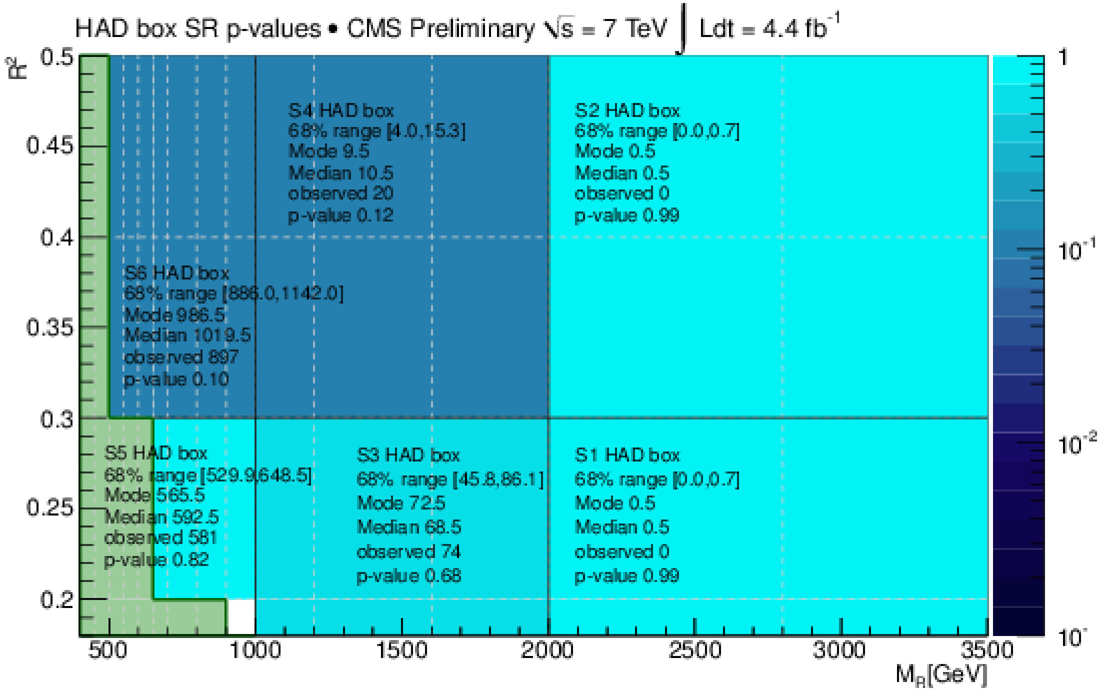


Figure 4: (Top left) M_R distributions for different values of the R^2 threshold for events in data selected in the MU box with the requirement of 0 b-tagged jets. The dotted lines show two independent exponential components fit to the the M_R distribution, (top center) value of the first exponential slope S from fits to the M_R distribution, as a function of the R^2 threshold (top right) value of the second exponential slope S from fits to the M_R distribution, as a function of the R^2 threshold. (Bottom) The corresponding in simulated W+jets events.

Razor material



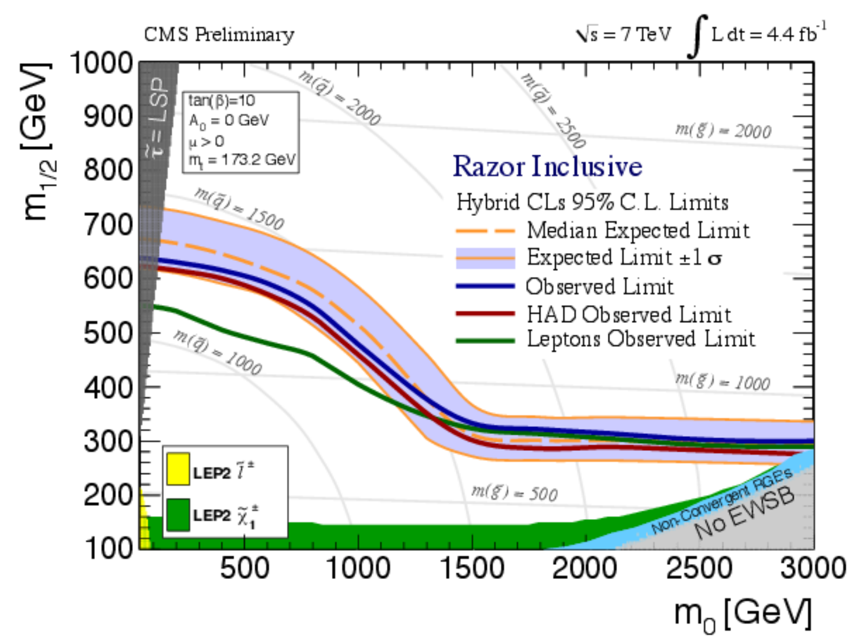


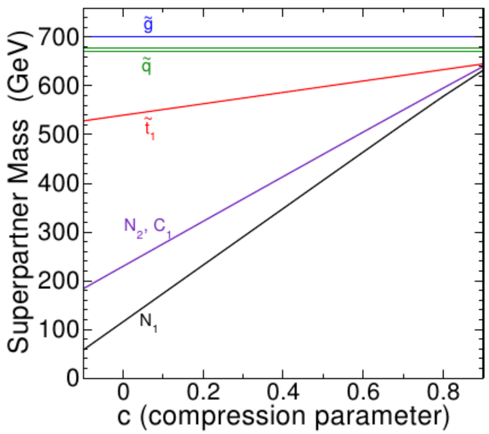
Figure 12: Observed (solid blue curve) and median expected (dot-dashed curve) 95% CL limits in the $(m_0, m_{1/2})$ CMSSM plane with $\tan\beta = 10$, $A_0 = 0$, $\mathrm{sgn}(\mu) = +1$ from the razor analysis. The ± one standard deviation equivalent variations in the uncertainties are shown as a band around the median expected limit. Shown separately the observed HAD-only (solid crimson) and leptonic-only (solid green) 95% CL limits.

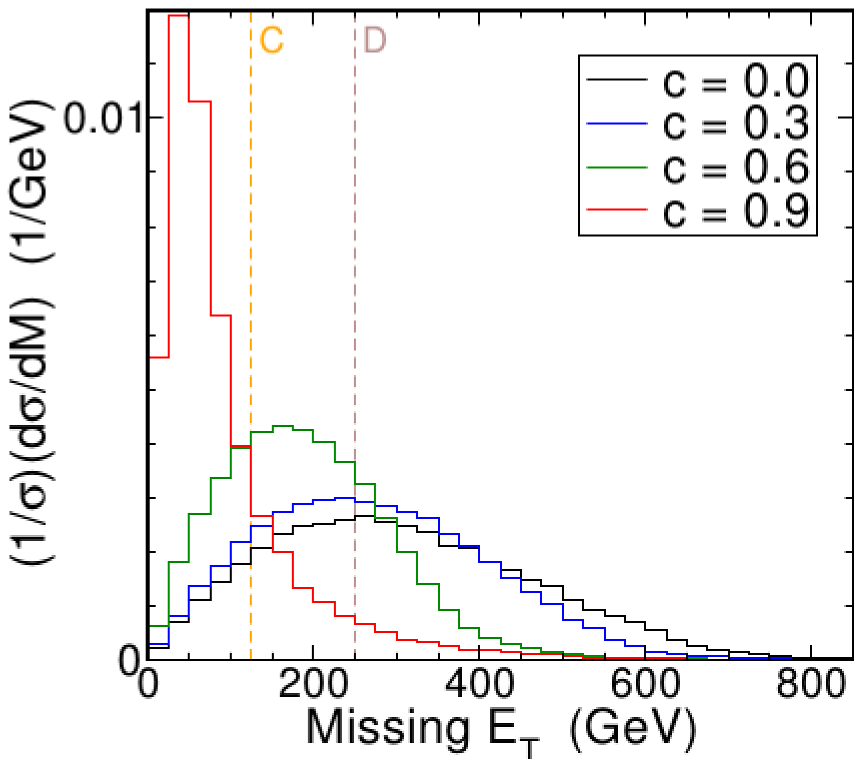
Compressed spectra

What if BSM is characterized by low ME_T, reduced H_T, smaller cross-sections?

This can happen if:

- $\Delta M(\tilde{g}$, LSP) is small
- ΔM(NLSP, LSP) is small (effect on cascades)
- Direct production of light stops/sbottoms (not covered here)





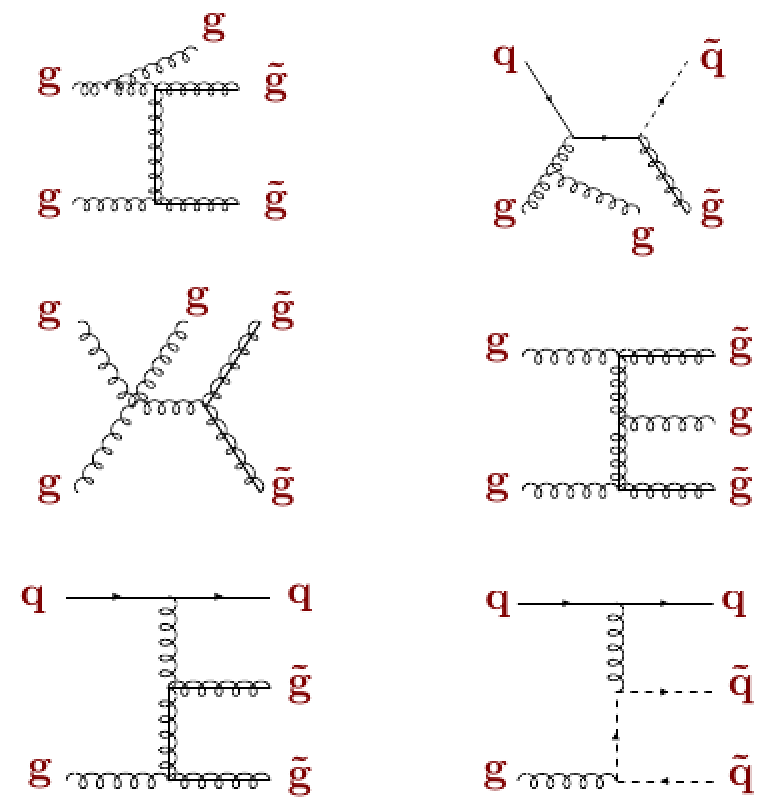
Is Jets+MET blind?

- Topological variables can help
- Searches have already left the “excess in tail-only” model
- Improvements in cuts, technologies
- At some point, it's matter of:
  - Statistics
  - Precision of SM background estimates

ISR: issue or advantage?

NLO ISR *(hard ISR)* emission in SUSY processes can help maximizing ME_T and H_T $\rightarrow$ signal can be enhanced

- How much do we know ISR?
- How well is it modeled in simulations?
  - ➔ Necessity to move e.g. to MadGraph for signal samples
- Can we “tag” it?



W. Beenaker, R. Hopker, M. Spira, P. Zerwas, hep-ph/9610490

2011 SMS limits