Searches for SUSY in All-Hadronic Events with Exclusive Jets

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on behalf of the CMS collaboration

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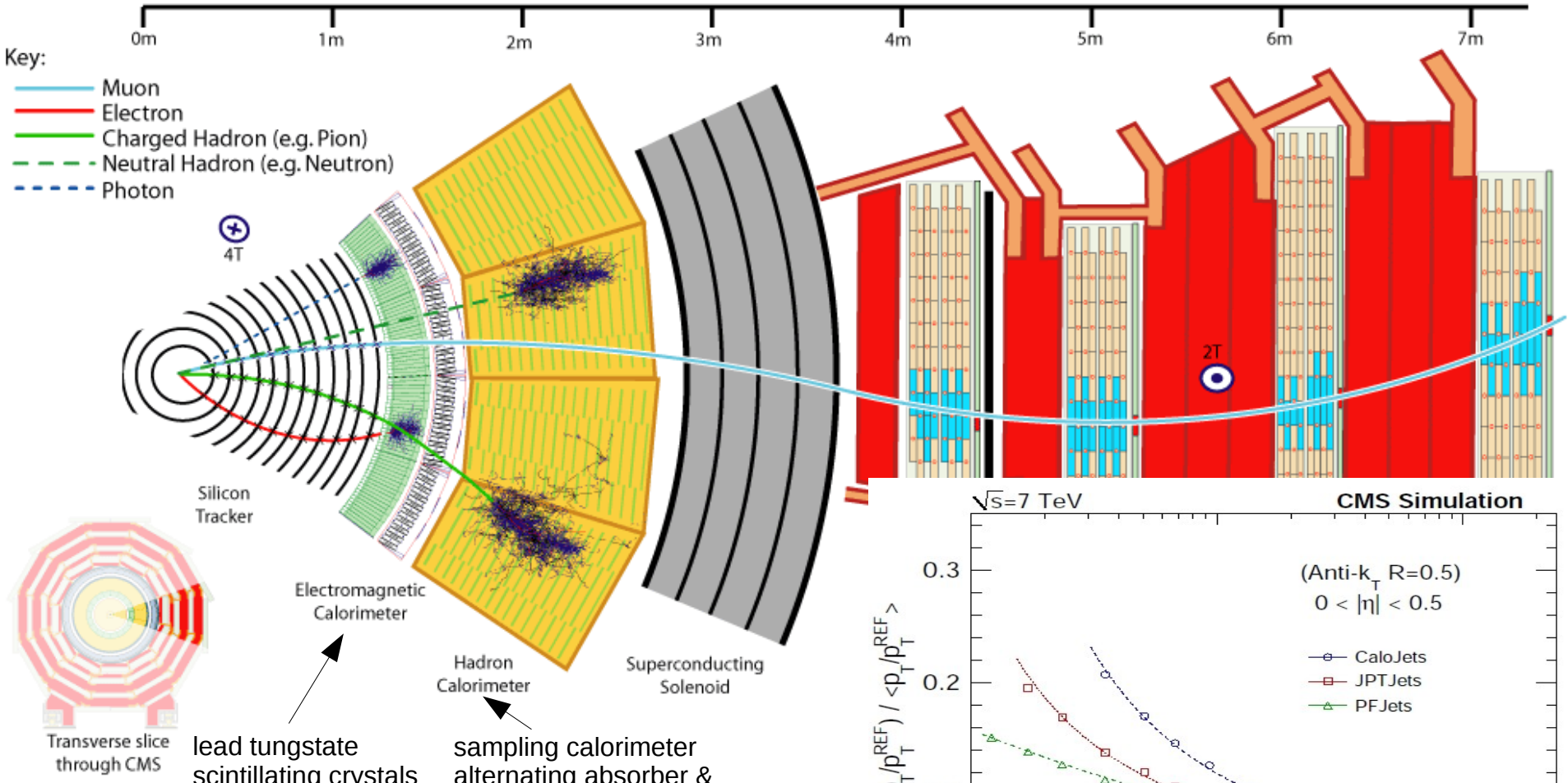
Overview

Searches for SUSY in Exclusive Jet Final States:

- Introduction: SUSY in all-hadronic final states
- α_T definition: di-jets and multi-jet final states
- Validation: the α_T variable in the 7 TeV data
- Background: estimation from data using eta-uniformity

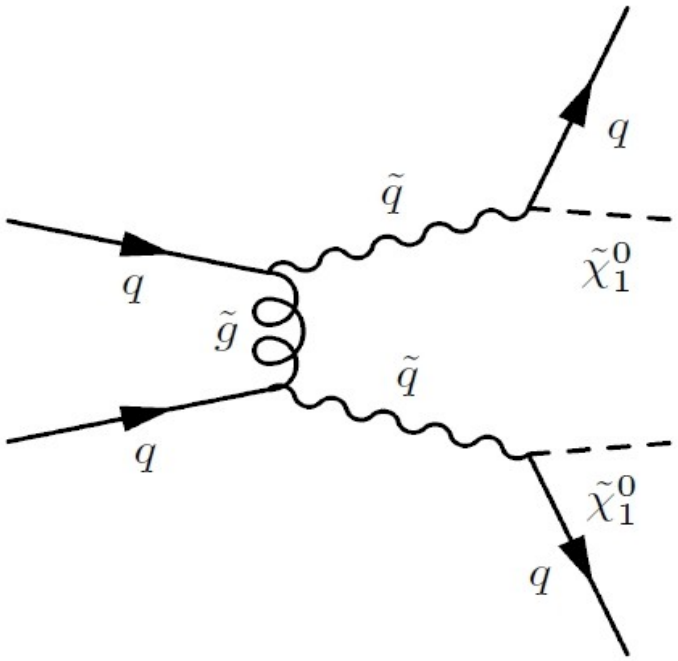
The CMS detector



calorimeter-jet resolution: $\frac{\sigma_{p_T}}{p_T} \approx \frac{100\,\%}{\sqrt{p_T}}$

Introduction

SUSY topology:
(example)

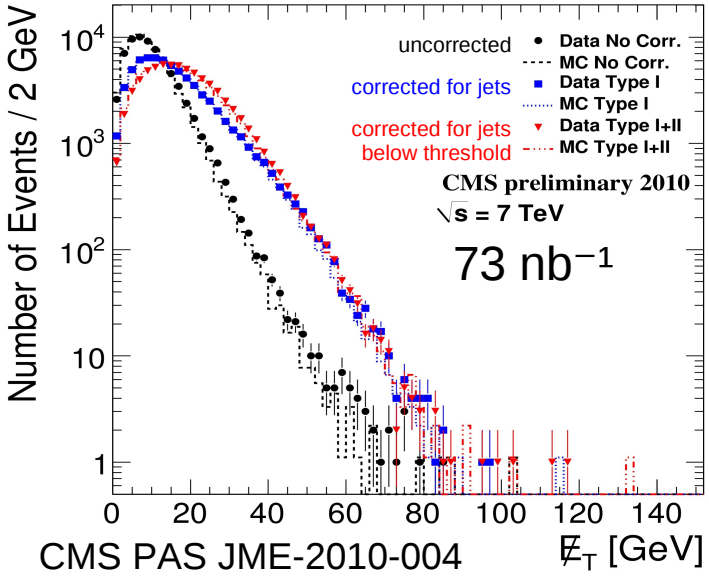


- Pair production of SUSY sParticles,
  e.g. $\tilde{q}\,\tilde{q}$, requires $m(\tilde{q})<m(\tilde{g})$
- Assumed R-parity conservation leads to 2 jets + MET
- Squark and neutralino mass-measurements in this channel possible with high luminosity
- In general, longer cascades with more than one jet (+MET)

Analysis requirements: At least two jets.

Introduction of the variable α, α_T

Traditional SUSY searches require large MET and search for an excess over the SM in the tail



→ requires extraordinary good understanding of detector and SM-background

→ previous talk by C. Rogan

Alternative analysis not based on MET:

- Dimension-less variable $\alpha_T = \frac{p_{T2}}{M_T}$
- characterizes momentum balance in the event
- allows to suppress multi-jet QCD background

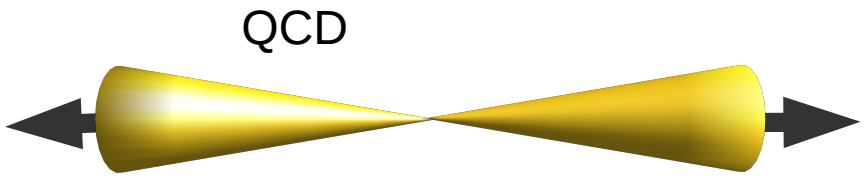
based on L. Randall, D. Tucker-Smith, PRL **101** 221803 (2008).

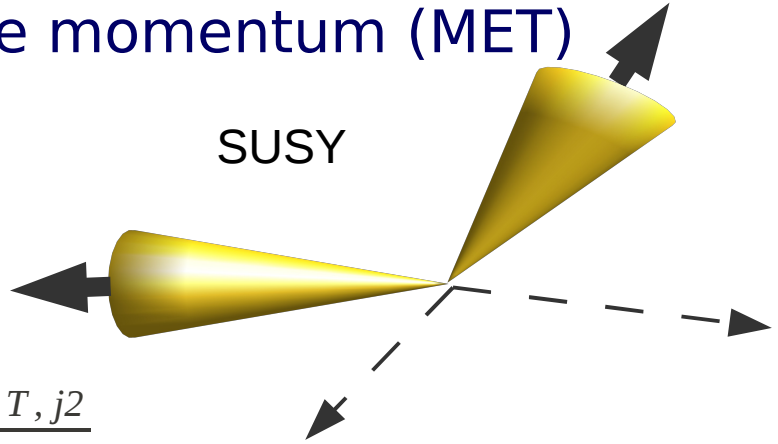
→ CMS follows both strategies

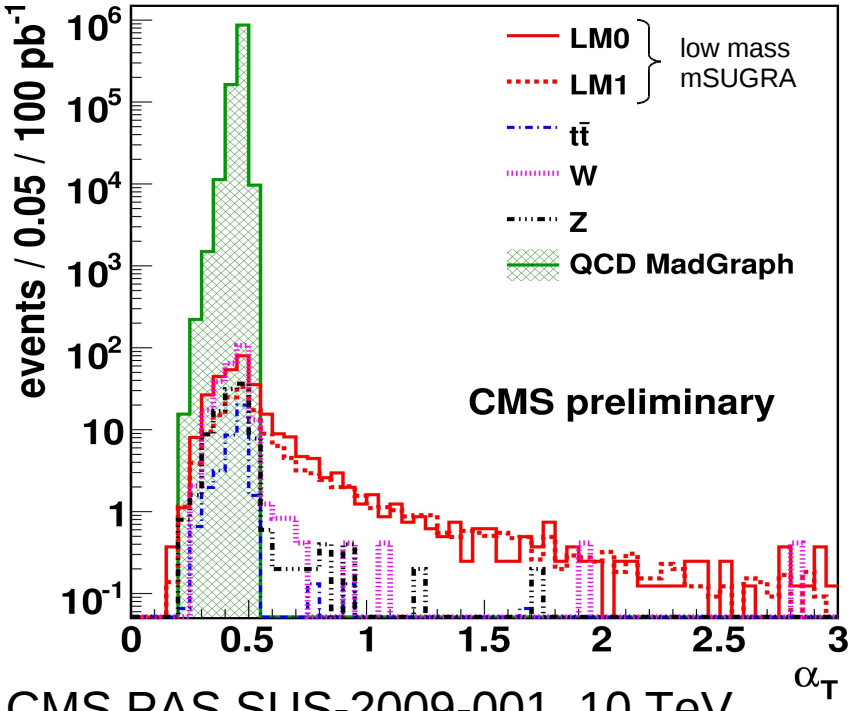
Suppressing QCD with α_T

Exclusive di-jet final state:

α_T takes into account the jet momenta and angles, it makes no use of missing transverse momentum (MET)







CMS PAS SUS-2009-001, 10 TeV

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

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

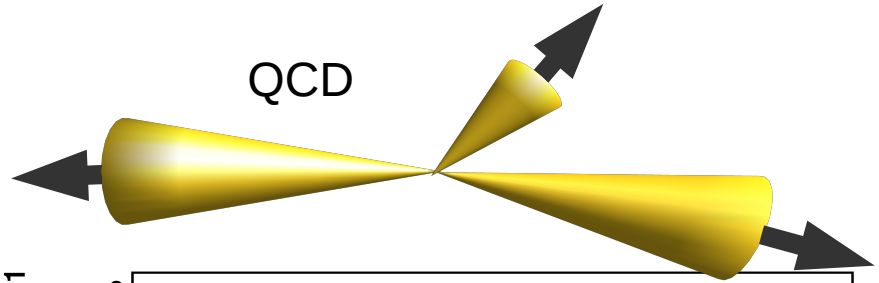
$$\rightarrow \alpha_T = \sqrt{\frac{p_{T,j2} / p_{T,j1}}{2(1 - \cos\Delta\phi)}}$$

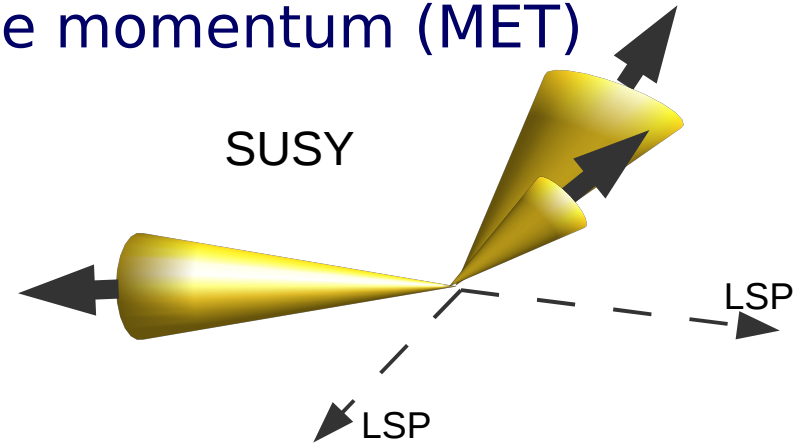
In QCD: $\alpha_T \leq 0.5$ since $p_{T,j2}$ is by definition the lower momentum jet.
Exception: A third jet is completely lost.

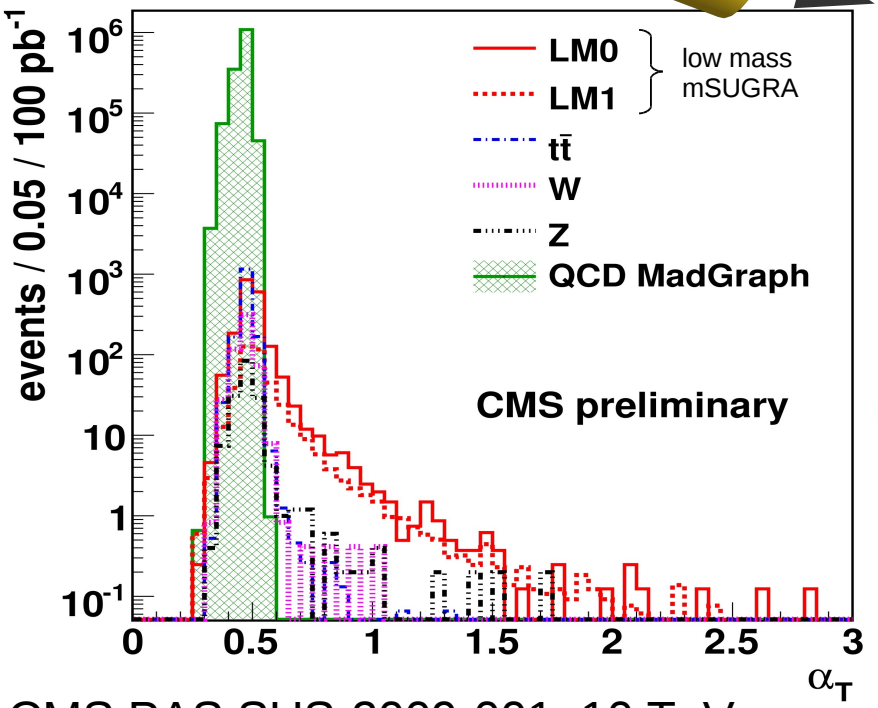
Suppressing QCD with α_T

Exclusive n-jet, n≥3 final state:

α_T takes into account the jet momenta and angles, it makes no use of missing transverse momentum (MET)







CMS PAS SUS-2009-001, 10 TeV

$$H_T = \sum_{\text{jets } j} p_{Tj}\,, \quad \text{MHT} \equiv |\sum_{\text{jets } j} -\vec{p}_{Tj}|$$

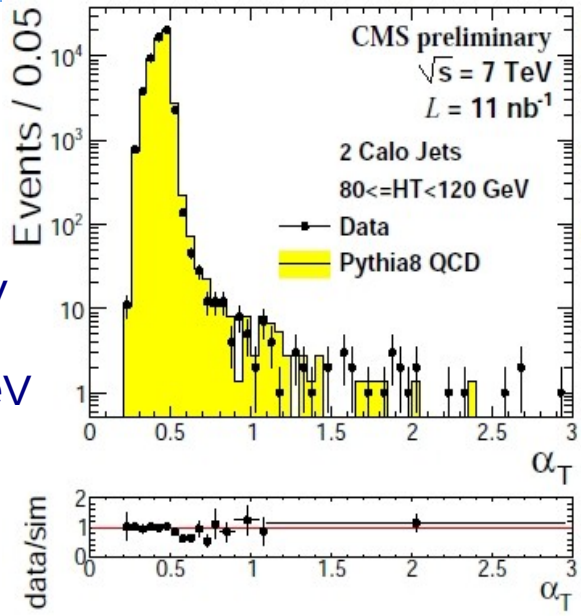
$$\Delta H_T = p_{T\text{pseudojet 1}} - p_{T\text{pseudojet 2}}$$

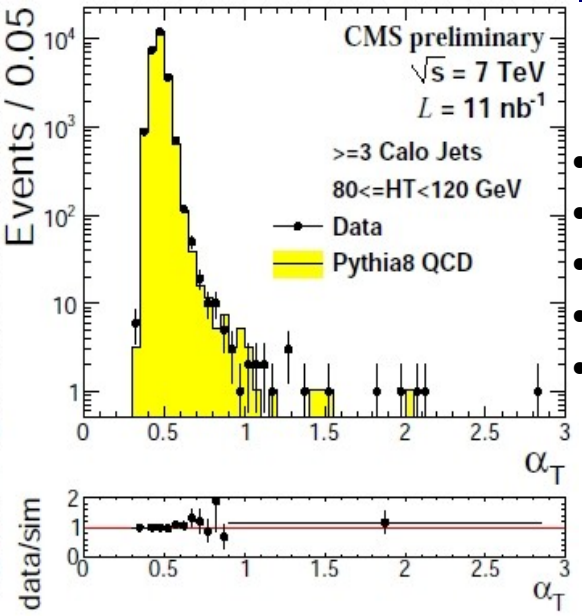
$$\alpha_T = \frac{1}{2}\frac{H_T - \Delta H_T}{M_T} \quad \rightarrow \quad \alpha_T = \frac{1}{2}\frac{H_T - \Delta H_T}{\sqrt{H_T^2 - (MHT)^2}}$$

The two pseudo-jets are formed such, that ΔHT is minimal.
α_T < 0.55 still holds for multi-jet QCD events

Validation of α_T in data (CaloJets)

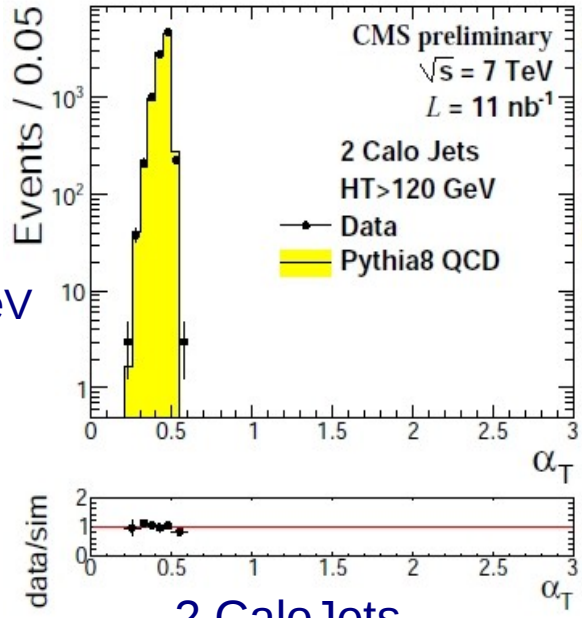
80 GeV < HT < 120 GeV

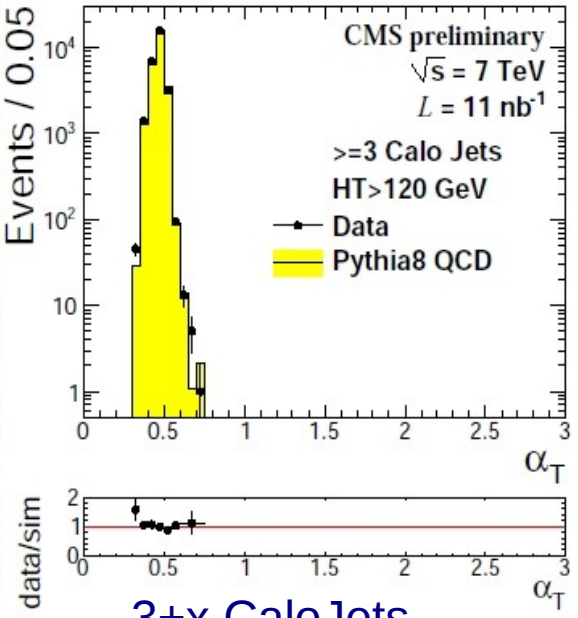




- Trigger: jet 15 GeV (uncor)
- leading jet pT > 40 GeV (corr)
- other jets pT > 20 GeV (corr)
- all jets |η| < 3
- jet ID cuts

120 GeV < HT





$\int L \simeq 11\ nb^{-1}$

Very good agreement within statistical uncertainties!

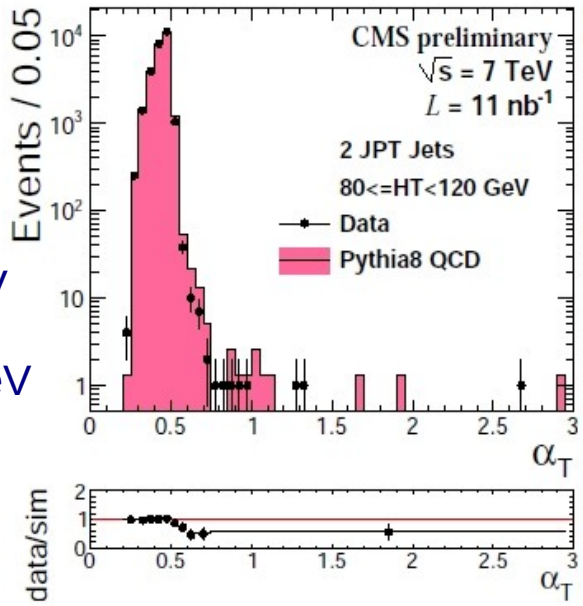
2 CaloJets

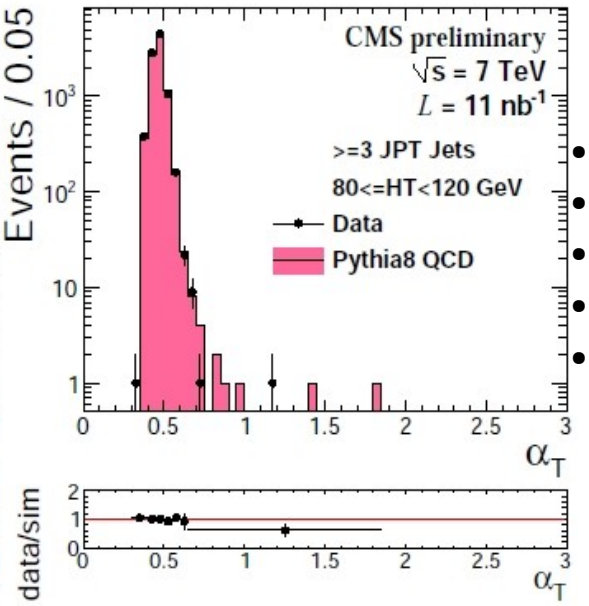
3+x CaloJets

CMS PAS SUS-2010-001

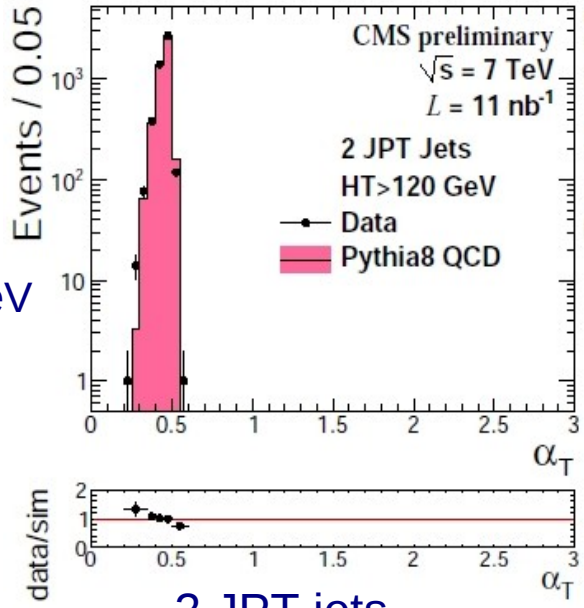
Validation of α_T in data (Jet-plus-Track)

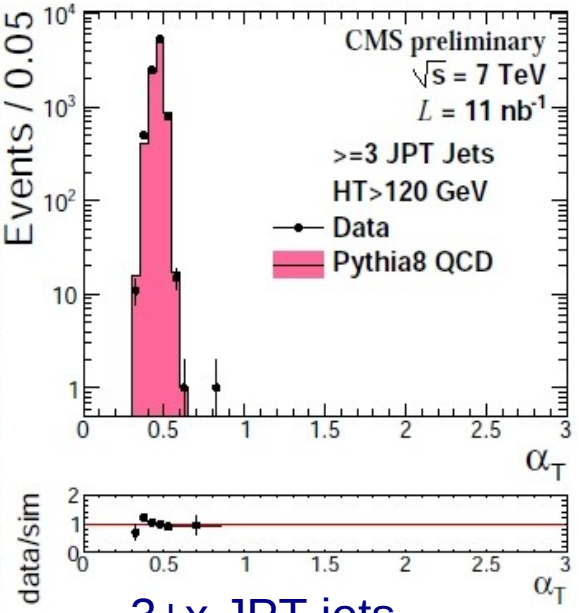
80 GeV < HT < 120 GeV





120 GeV < HT





2 JPT jets

3+x JPT jets

- Trigger: jet 15 GeV (uncor)
- leading jet pT > 40 GeV (corr)
- other jets pT > 20 GeV (corr)
- all jets |η| < 3
- jet ID cuts

$\int L \simeq 11\ nb^{-1}$

Very good agreement within statistical uncertainties!

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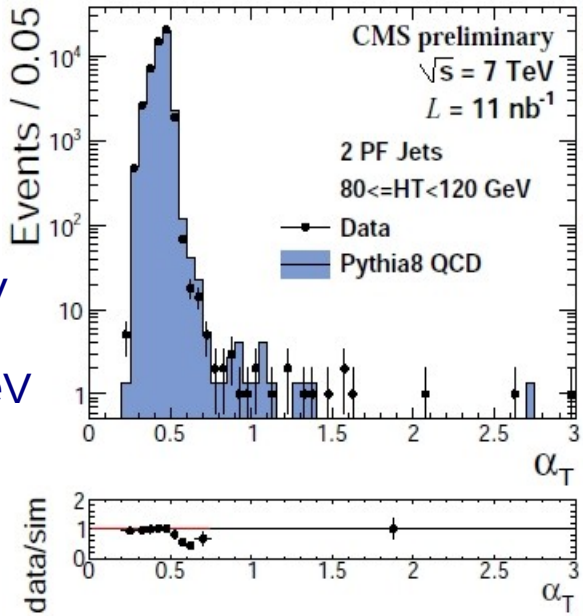
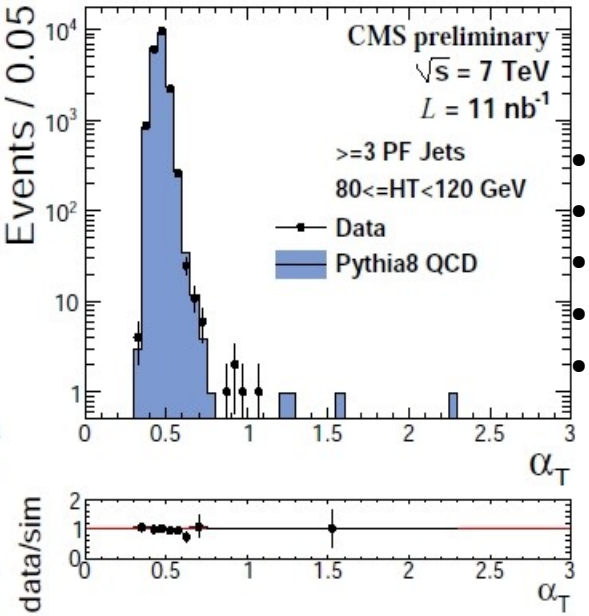
Validation of α_T in data (Particle Flow)

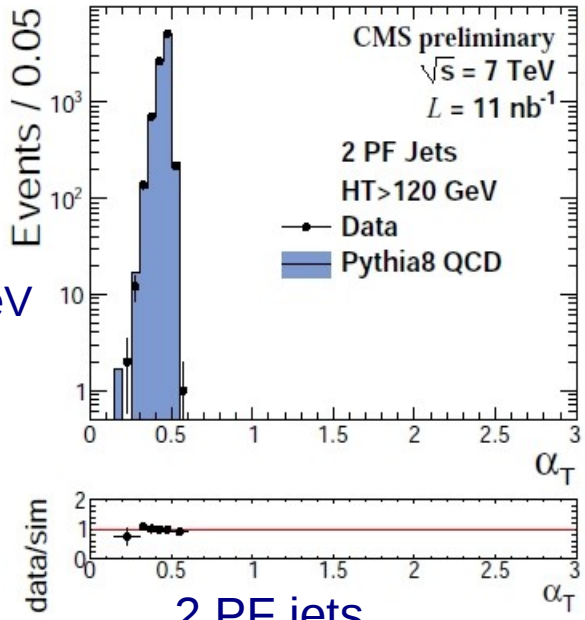
80 GeV < HT < 120 GeV

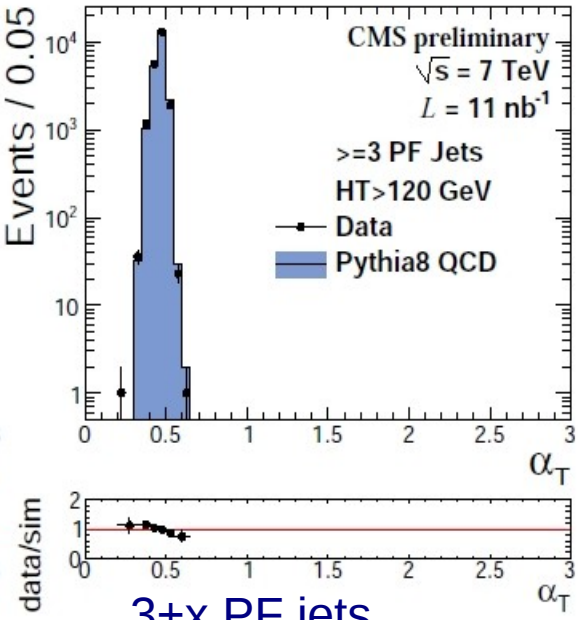




- Trigger: jet 15 GeV (uncor)
- leading jet pT > 40 GeV (corr)
- other jets pT > 20 GeV (corr)
- all jets |η| < 3
- jet ID cuts

120 GeV < HT





$\int L \simeq 11\ nb^{-1}$

Very good agreement within statistical uncertainties!

2 PF jets

3+x PF jets

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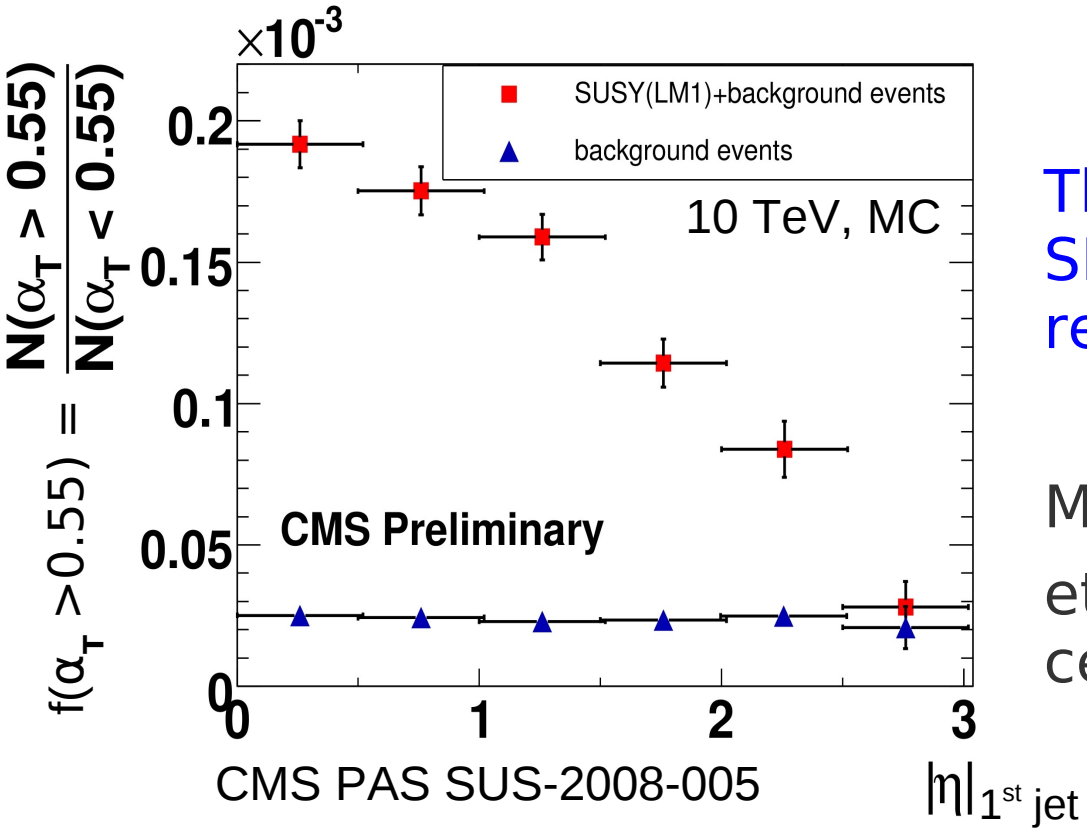
Background prediction using the eta-uniformity

- SUSY events tend to be more central compared to the SM-background (QCD multi-jet, $t\bar{t}$, $Z\rightarrow\nu\bar{\nu}$)
- The fraction of SM-events surviving the α_T >0.55 cut compared to the rejected is uncorrelated to η of the leading jet



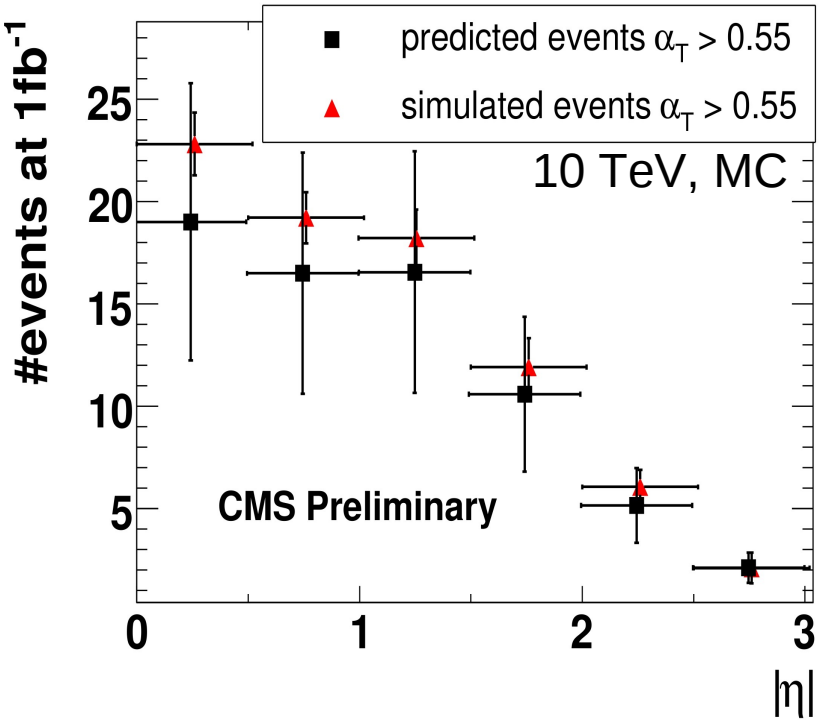
This allows to factorize the SM-background in the signal region:

Measure f(α_T>0.55) at high eta and extrapolate to the central region.

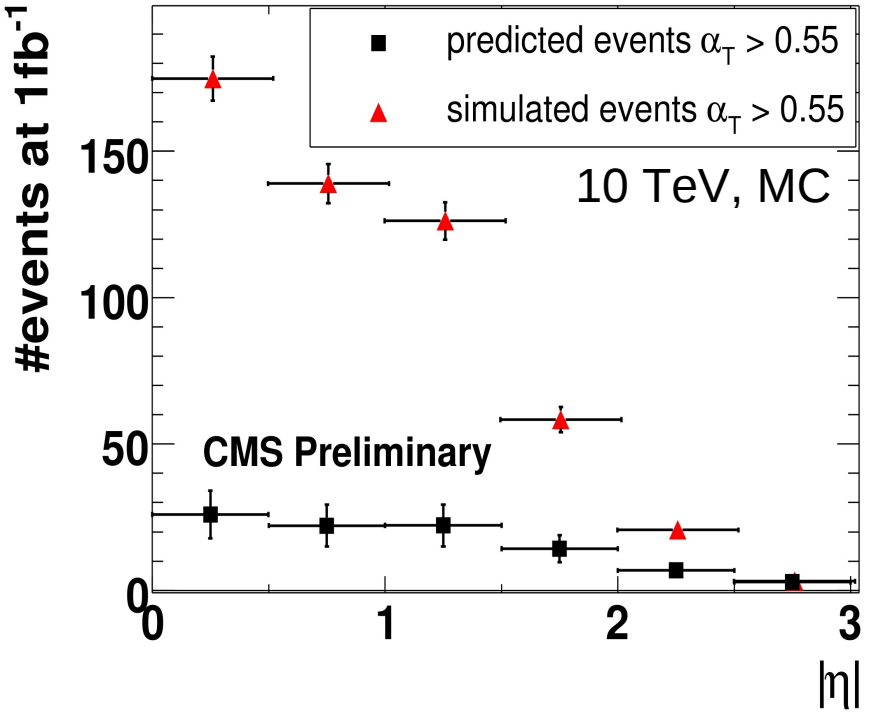
Background prediction using the eta-uniformity

Closure test: Comparing estimation with MC simulation.

Standard Model background only
(QCD multijet, $t\bar{t}$, $Z\rightarrow\nu\bar{\nu}$)



Standard Model + Low mass SUSY
(SUSY LM1, QCD multijet, $t\bar{t}$, $Z\rightarrow\nu\bar{\nu}$)



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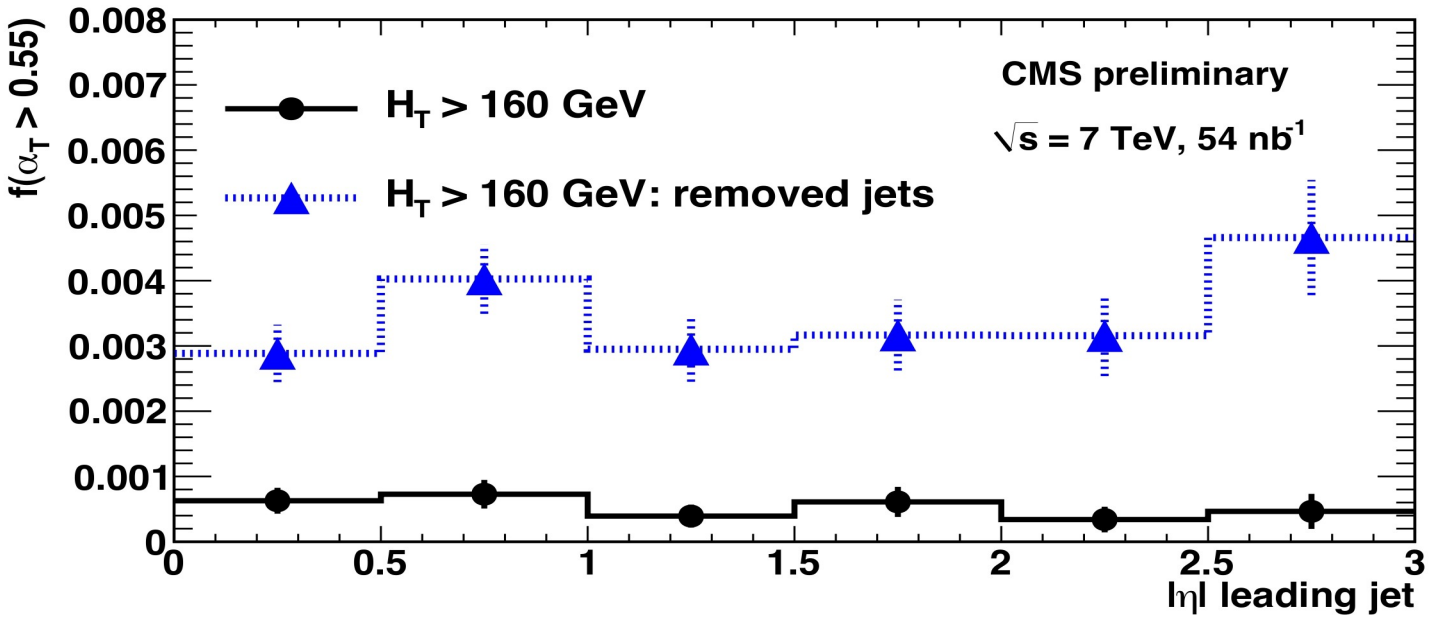
Validating eta uniformity of f(α_T>0.55) in data

Even if randomly jets are removed (ID inefficiencies) the eta-uniformity of the fraction of QCD events that fail the α_T >0.55 cut is preserved



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

CMS PAS SUS-2010-001

Analysis requires HT>350 GeV, but for the background-factorization, events with low HT could be used:

→ higher statistics, especially in region α_T >0.55, since the steepness of falloff of α_T depends on HT.

→ however, the failure-fraction f(α_T >0.55) of QCD events must be a decreasing function of HT, so that the low HT control sample gives an upper bound on the background prediction

Validate HT dependence in data

Fraction of QCD events failing the α_T veto

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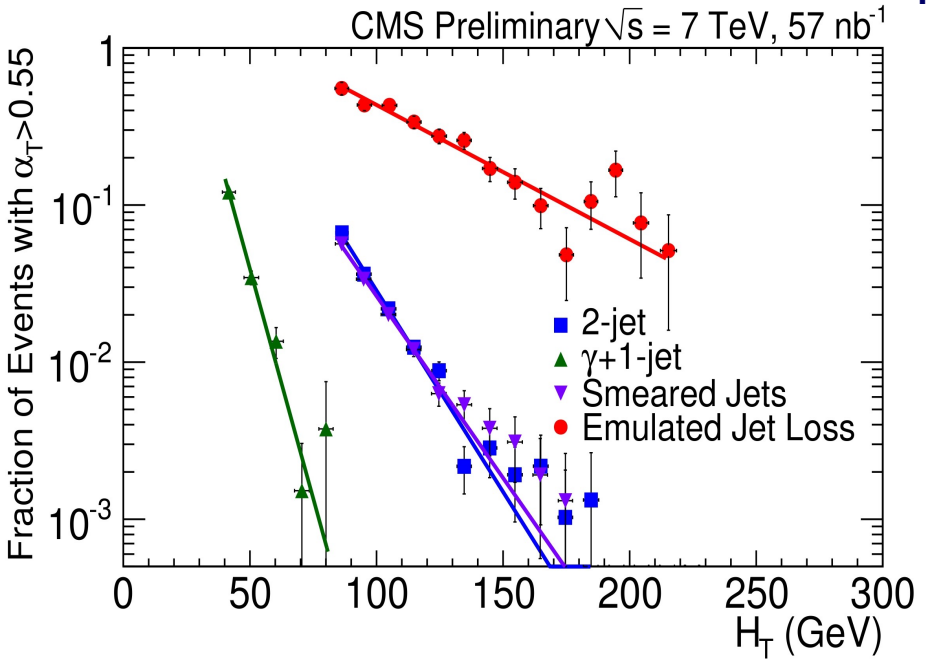
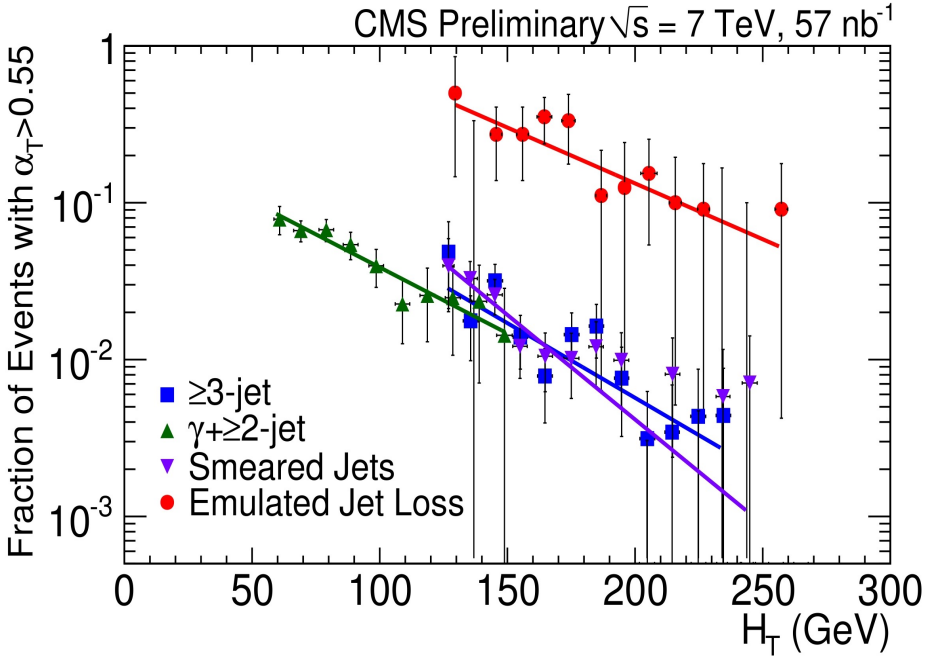




An exponential decrease of $f(\alpha_T > 0.55)$ in dependence of H_T is observed:

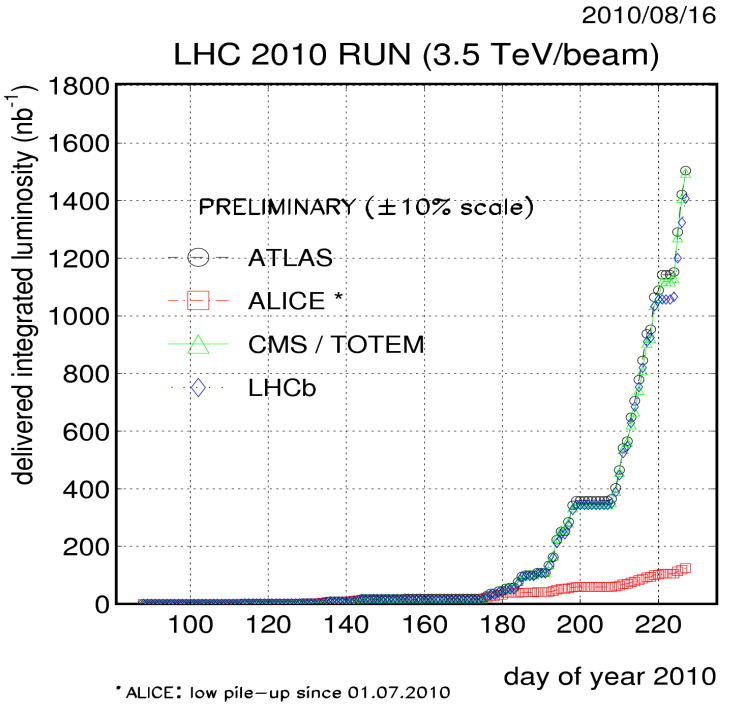
- The jet spectrum itself is exponential
- The jet-loss probability (which leads to $\alpha_T > 0.55$) decreases with pT
- perturbation of α_T by a lost jet of given pT decreases with H_T

→ Decrease of the failure fraction f as a function of H_T allows to obtain a strong upper limit on the background, from a lower H_T (and therefore high statistic) control sample

Conclusion

- α_T is a powerful variable to suppress QCD multi-jet background to all-hadronic SUSY
- α_T behavior in data up to HT<200 GeV is as expected
- Failure fraction f(α_T>0.55) uniform in η, even when additional jet-failures are induced
- Background can be estimated and validated using data

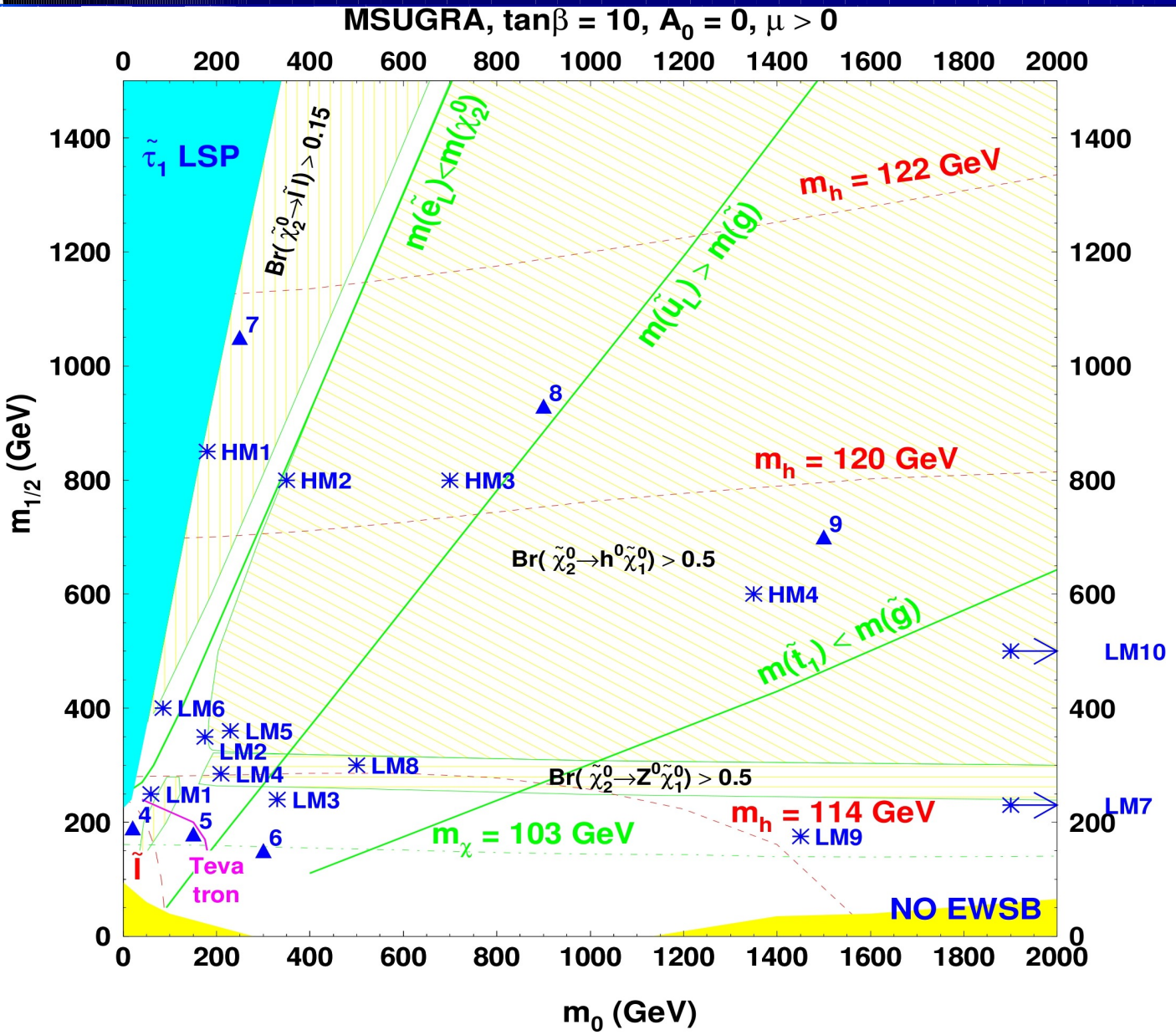
Sensitivity to new physics beyond the Standard Model (and Tevatron) already with few 10 pb^{-1} expected.



http://lpc.web.cern.ch/lpc/lumiplots.htm

Backup

CMS mSUGRA benchmark points



CMS Physics TDR, Volume II: CERN-LHCC-2006-021, 25 June 2006