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Early searches for supersymmetry at the LHC in the all-hadronic channel

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Introduction

How do we look for supersymmetry at the LHC?

- *What are the challenges of the all-hadronic channel?*

How can we guard against mismeasurement?

- *Can we use kinematics to constrain fake missing E_T?*

How do we account for Standard Model backgrounds?

- *What data-driven tools exist to estimate real missing E_T?*

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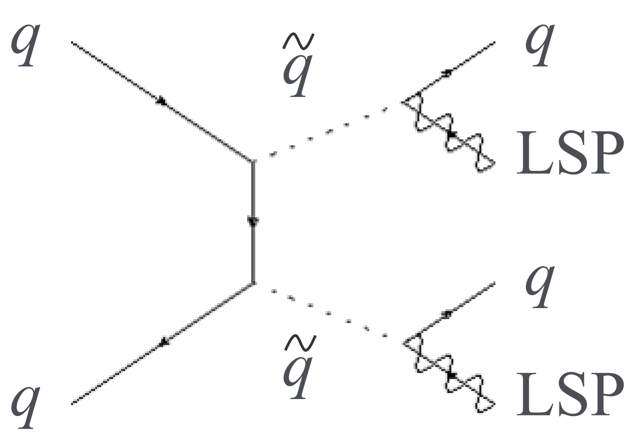
Supersymmetry at the LHC

Supersymmetry is an extension to the Standard Model (SM) that predicts massive, undetectable superpartners to SM particles.

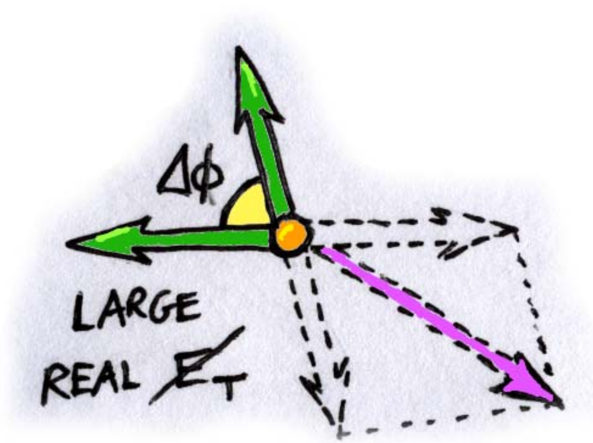
These may be produced in LHC proton-proton collisions.

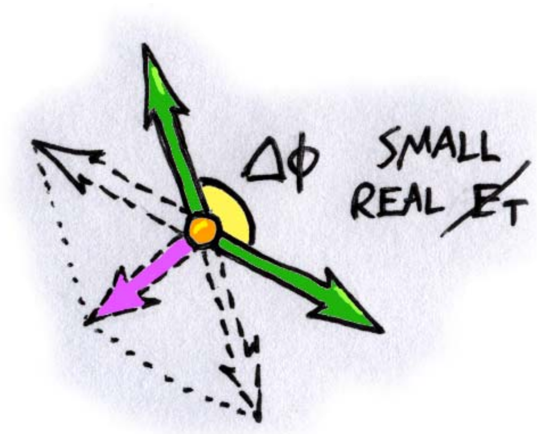
Typical experimental signature:

- *Large missing transverse energy plus final state objects.*



+ *similar*





The all-hadronic channel

We consider events with only jets in the final state:

- *"Jet": clustered energy deposits in the calorimeters from the hadronisation of partons.*
- *Tracking information may also be used for identification and/or correction of measured jet energy.*

Advantage: no isolated leptons, which can indicate SM processes with *real* missing E_T (typically featuring $W \to l\nu$)

- *Still leaves $Z \to \nu\nu$, $W \to \tau\nu$ (the τ decaying hadronically)*

Disadvantage: Large QCD background. Statistically unlikely detector mismeasurements, that produce *fake* missing E_T, start to overwhelm any non-SM signal.

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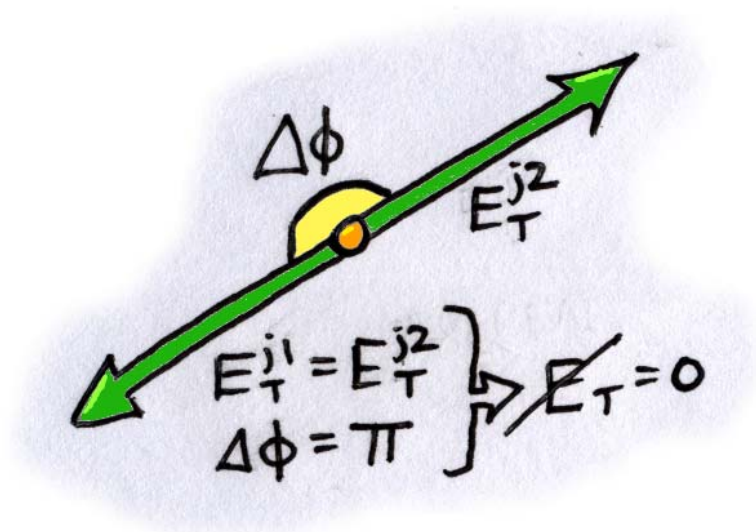
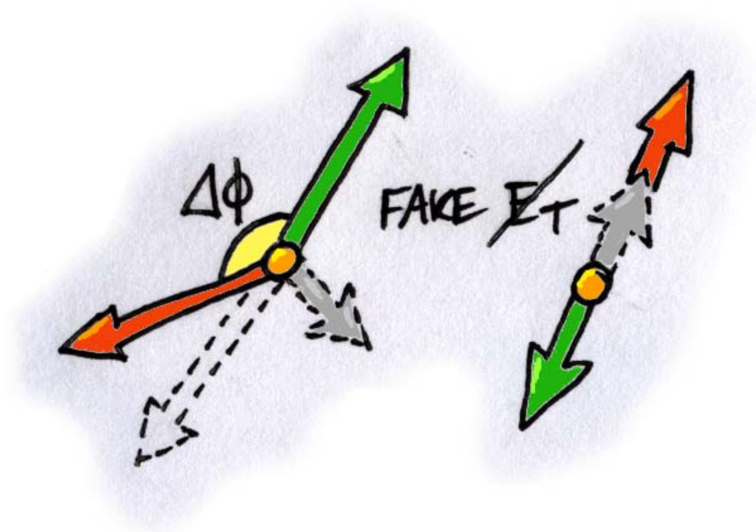
Allowing for mismeasurement

QCD-like events will generally conserve transverse momentum.





Mismeasurement leads to the observation of “fake” missing E_T. The search described here takes the following approach:

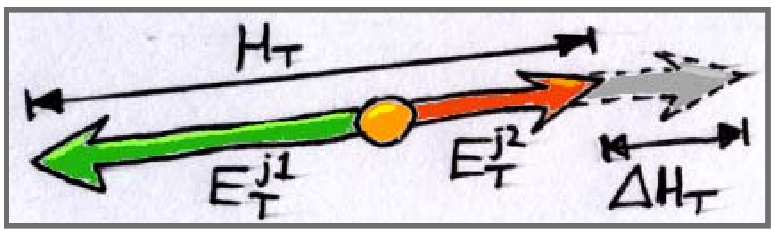
- Use only “trusted” physics objects as input to the missing E_T calculations, ignoring unclustered energy and events with “anomalies”.
- Use event observables that compensate for object mismeasurements.

The α_T observable

Dijets: Randall (2008) proposed $\alpha = E^{j2}{}_{\mathrm{T}} / \mathrm{M(dijet)}$. We use $\alpha_T = E^{j2}{}_T / M_T(\mathrm{dijet})$:

Denominator: $$M_T = \sqrt{2E_T^{j1}E_T^{j2}\left(1-\cos\Delta\phi\right)} = \sqrt{H_T^2 - \mathbf{p}_T^2}$$

Numerator: $$E_T^{j2} = \tfrac{1}{2}\left(H_T - \Delta H_T\right)$$



$$H_T = E_T^{j1} + E_T^{j2}$$

$$\Delta H_T = E_T^{j1} - E_T^{j2}$$

Conserved event, perfect measurement $\Rightarrow \alpha_T$ = 1/2

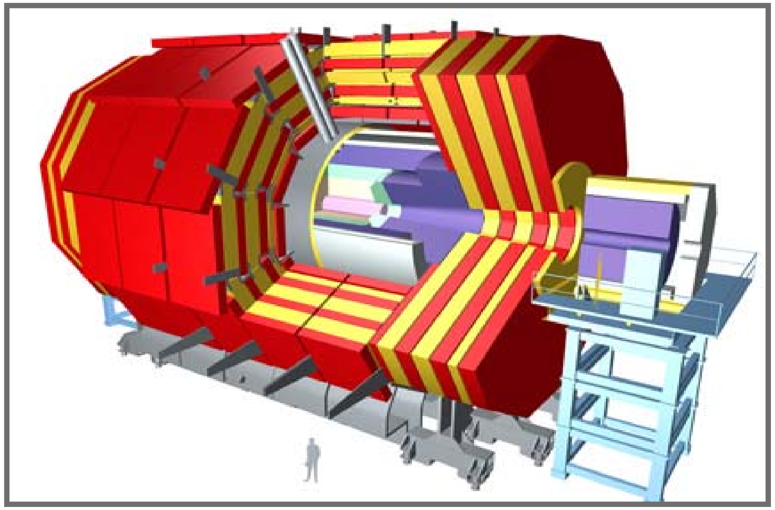
Real missing E_T: Small denom. $\Rightarrow$ large α_T

Mismeasurement: Small num. $\Rightarrow$ small α_T

Extension to n-jets: Generalise ΔH_T

$$\alpha_{T(N)} = \frac{1}{2}\frac{H_T - \min.\left(\Delta H_T\right)}{\sqrt{H_T^2 - \mathbf{p}_T^2}}$$

The CMS experiment



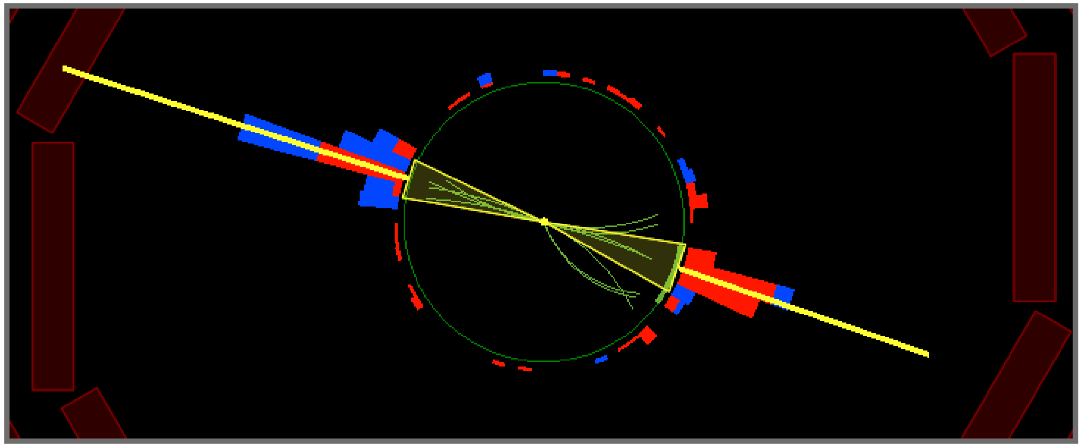
Solenoid: 3.8 T magnetic field.

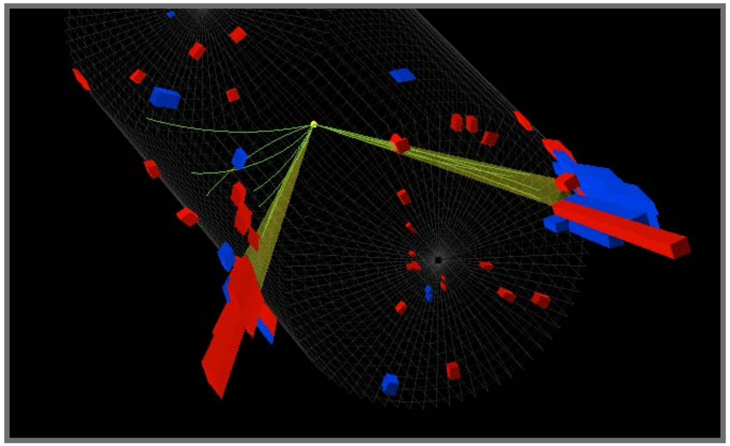
Energy measurements:

- Electromagnetic calorimeter (ECAL);
- Hadronic calorimeter (HCAL).

Tracking: All-silicon tracker.

Muon chambers outside solenoid.





Event selection

Triggers:

- High-Level Trigger (HLT) Single 110 GeV jet.

Pre-selection:

- Jet requirements (also defines event jet multiplicity, N):
  - » At least two jets with $p_T > 50$ GeV, $|\eta| < 3.0$, EM fraction < 0.9;
  - » Leading jet $p_T > 100$ GeV, $|\eta| < 2.0$;
  - » Second jet $p_T > 100$ GeV;
- Lepton veto: Reject events with isolated e or μ, $p_T > 10$ GeV;
- Photon veto: Reject events with isolated γ, $p_T > 25$ GeV;
- "Bad" jet veto: Reject events with $p_T > 50$ GeV jets that fail $|\eta|$, EM fraction requirements.

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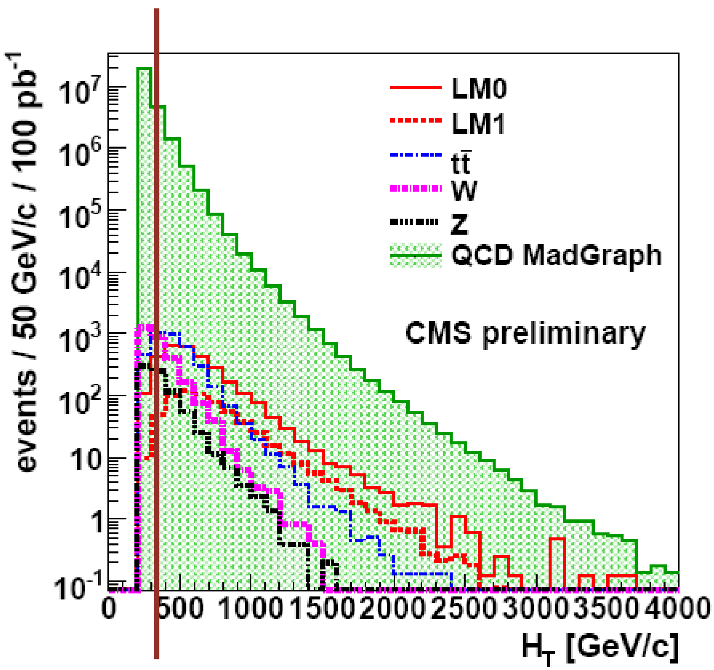
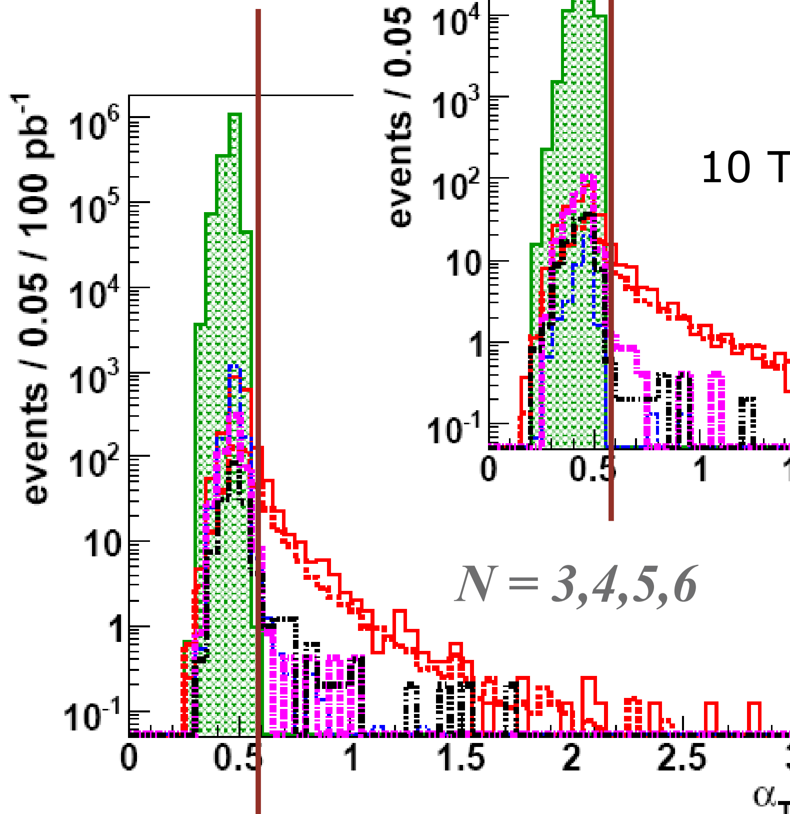
Applying the kinematic cuts

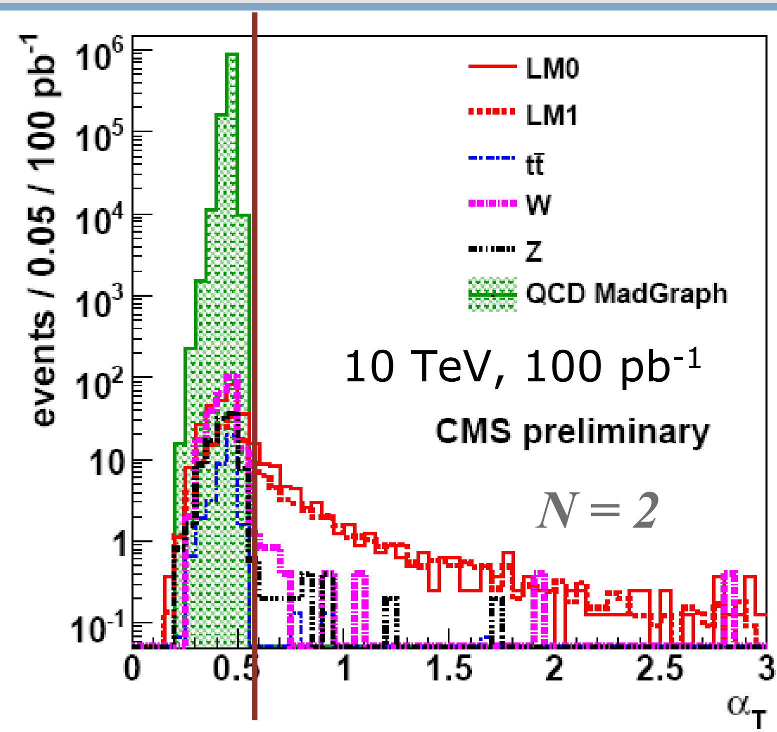
Additional cut made on $H_T > 350$ GeV

Final cut made on $\alpha_T > 0.55$



H_T of events passing selection

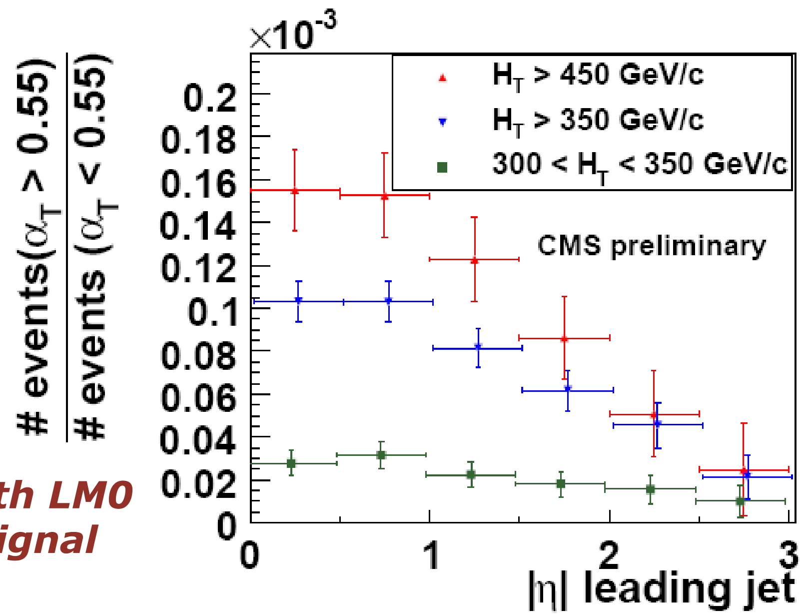




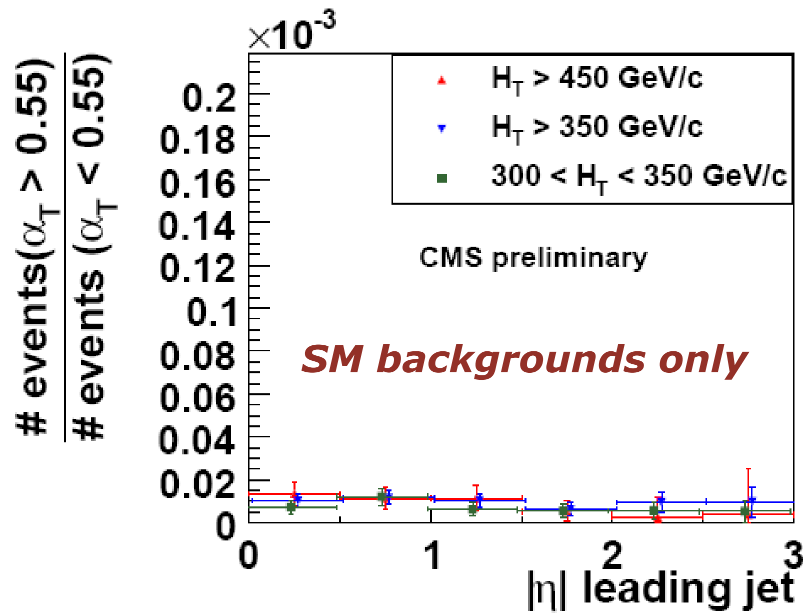
QCD is heavily suppressed

Estimating SM contributions

1) Treat the backgrounds as one, exploiting non-SM signal centrality.



With LM0 signal



2) Estimate individual SM background contributions, e.g.

<u>$Z \rightarrow \nu\nu$ + jets</u>
$Z \rightarrow \mu\mu$ is statistics limited;
use W+jets, γ+jets.

<u>tt + jet(s), W + jet(s), etc.</u>
Replace $W \rightarrow \mu\nu$ with
$W \rightarrow \tau\nu$ in data using τ template.

Conclusions

We can look for SUSY in the all-hadronic channel:

- *Signature: Large missing E_T + final state jets.*

Non-SUSY backgrounds can be controlled with kinematics:

- *Mismeasured QCD events are the dominant SM background;*
- *Compensating observables, e.g. α_T, can suppress these.*

Tools exist for estimating real missing E_T SM backgrounds.

Thanks for listening – any questions?