A kinematics-based approach to fake MET background rejection in LHC dark matter searches.

Rob Bainbridge[1] Oliver Buchmüller[1] Henning Flächer[2]
Jad Marrouche[1] Tanja Rommerskirchen[3]
Markus Stoye[1] Alex Tapper[1] Tom Whyntie[1]

[1]Imperial College London, UK

[2]CERN

[3]Universität of Zürich

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   - Results
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The role of $\not{E}_T$ in dark matter searches

In hadron collider events, the missing transverse energy of the event, $\not{E}_T$, is used to infer the presence of missing matter (e.g. LSPs). There are two major sources of $\not{E}_T$ that contribute to "dark matter" backgrounds:

Real $\not{E}_T$

- Arises from SM processes involving neutrinos.
- Irreducable: must be estimated using MC or (preferably) data-driven methods.

Fake $\not{E}_T$

- Detector-based (mismeasurement, noise) and external (beam halo, cosmics). Will require a thorough understanding of our detector.
- Can we use event kinematics to protect "on-the-fly"?

Dijet Searches for Supersymmetry at CMS

Randall and Tucker-Smith [Randall 2008]

Proposed a search based on the kinematic properties of the dijet system only, using $\Delta\phi(j1, j2)$, mT2 [Lester 1999], and

$$\alpha = \frac{E_T^{j2}}{M^{j1,j2}} \quad (1)$$

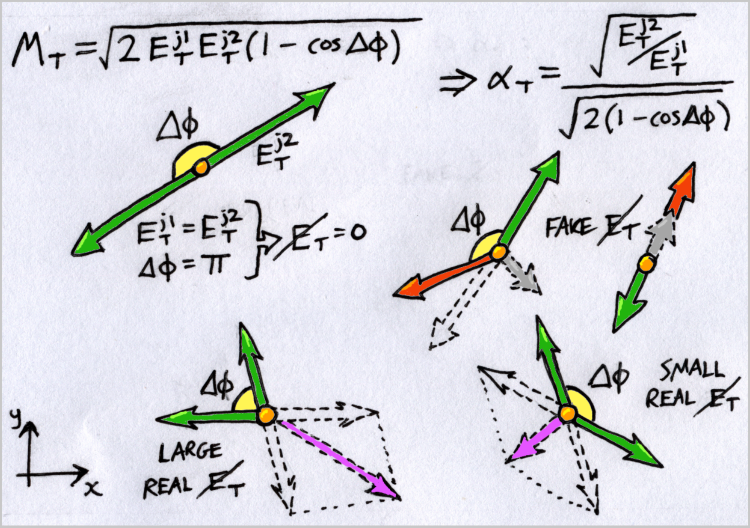
CMS Dijet Search [CMS PAS SUS-08-005]

Developed the approach, using instead the more effective

$$\alpha_T = \frac{E_T^{j2}}{M_T{}^{j1,j2}} \quad (2)$$

where M_T is the transverse mass of the dijet system.

The dijet search illustrated



α_T in terms of generic variables - I

Ideally, we would like to consider events with *n*-jets.
The first step: generalise the components of α_T for *n* objects.

The denominator

This is straightforward to define in terms of the "Tevatron variables" H_T and $\not{H}_T = -\mathbf{h}_T = -\sum \mathbf{p}_{T(i)}$:

$$M_{T(N)} = \sqrt{(\sum E_{T(i)})^2 + (\sum \mathbf{p}_{T(i)})^2} \quad (3)$$

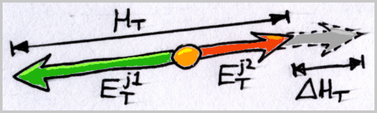
$$= \sqrt{{H_T}^2 + {\not{H}_T}^2} \quad (4)$$

Note that the E_T of the objects are added before squaring. This has implications when combining objects together...

α_T in terms of generic variables - II

The numerator

Consider a mismeasured QCD dijet event:



For the dijet system, we define

$$H_T = E_T^{j1} + E_T^{j2} \text{ and } \Delta H_T = E_T^{j1} - E_T^{j2} \quad (5)$$

and notice that

$$E_T^{j2} = \frac{1}{2}(H_T - \Delta H_T) \quad (6)$$

So α_T incorporates a "handle" on the dijet mismeasurement.

α_T in terms of generic variables - III

Putting it all together...

$$\alpha_T = \frac{1}{2}\frac{H_T - \Delta H_T}{\sqrt{{H_T}^2 - {\not{H}_T}^2}} \tag{7}$$

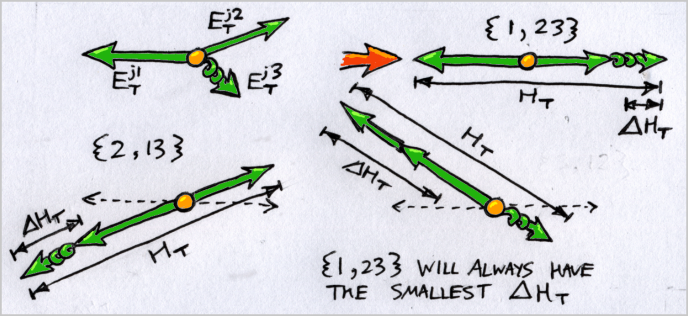
$$= \frac{1}{2}\frac{1 - \frac{\Delta H_T}{H_T}}{\sqrt{1 - \frac{{\not{H}_T}^2}{{H_T}^2}}} \tag{8}$$

- For a perfectly measured event with no real $\not{E}_T$, $\alpha_T = 0.5$.
- Real $\not{E}_T$ decreases the denominator, pushing α_T beyond 0.5.
- Any E_T imbalance (i.e. mismeasurement) in the dijet system is naturally protected against in the numerator.

Assumption alert: assumes the event *should* be evenly split!

Trijet events

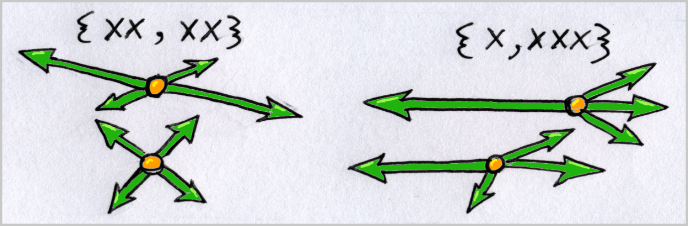
The question is, how do we define ΔH_T for n object systems?



- Choosing the combination with the smallest ΔH_T picks out the most "balanced" configuration by construction.
- We add the E_T of each object so that M_T is the same for every combination.
- $\alpha_T = 1/3$ for an "equilateral" event - an exercise for the reader.

Tetrajet events

For the the three jet case, the most balanced combination is always $\{1, 23\}$, resulting in $\alpha_T = E_T{}^{j1}/M_T$. This is not the case for $n \geq 4$:

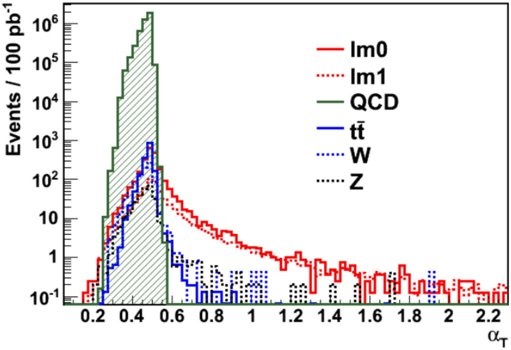


α_T for n-objects

$$\alpha_T = \frac{1}{2} \frac{H_T - \min.\Delta H_T}{\sqrt{H_T{}^2 - \not{H}_T{}^2}} \quad (9)$$

Results for 2-6 jet events (inclusive)

Unofficial CMS plot - for your eyes only.



"Standard" n-jet preselection, with $H_T > 350\,\mathrm{GeV}$, $2-6$ jets inclusive. Sharp edge for QCD (fake $\not\!\!E_T$), "leakage" from real $\not\!\!E_T$ - as you'd expect.

Some caveats

Beware of model/parameter space

- Masses of NLSP/LSP may affect usefulness of such observables.
- Long-chain cascades lead to small MHT/HT ratios.

"Catastrophic mismeasurements"

- α_T effective when one jet is mismeasured - but not two.
- Studies underway...

α_T should complement calometric $\sum E_T$ and $\not{E}_T$-based searches

- By design, we do not use full detector information...
- We need to further understand the limitations of the primary object approach.

Conclusions

- We present a complementary technique for $\not{E}_T$-based searches for dark matter at the LHC.
- α_T is an observable designed to reject fake $\not{E}_T$ backgrounds (e.g. QCD) based on kinematics and simple physical assumptions.
- We have extended α_T from a dijet-only to an inclusive *n*-jet topology search, which may make SUSY discoveries possible with a few $100\mathrm{pb}^{-1}$ of data.
- It is not a "magic bullet" - terms and conditions apply!

Thank you for listening

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Phys. Lett. B **463** 99 (1999)

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Current limits from the Tevatron (D0) Dijet Searches

- 2.1 fb^{-1} integrated luminosity at $\sqrt{s} = 1.96\,\mathrm{GeV}$.
- Nothing seen so far!
- 95 % C.L. lower limits of 379 GeV and 308 GeV set on the squark and gluino masses respectively.
- Regime probed: $\tan\beta = 3$, $A_0 = 0$, and $\mu < 0$.

Whole detector or "primary objects"?

Observables like α_T are a departure from traditional methods.

Whole detector - Calometric $\sum E_T$ and $\not{E}_T$

- Takes into account everything observed - more accurate.
- Will take time to understand.

"Primary object" approach

Characterise the event in terms of the physics objects present.

- Objects must pass quality cuts, e.g. E_T, p_T, isolation, etc.
- Then calculate event observables using these objects.
- Introduces a new source of fake $\not{E}_T$ - "Resolution".
- Objects must the "cross-cleaned" to avoid double counting.