Search for Dark Matter with Semi-Visible Jets:

Initial studies

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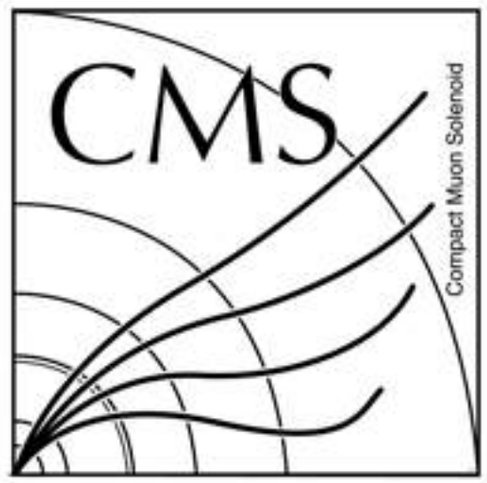
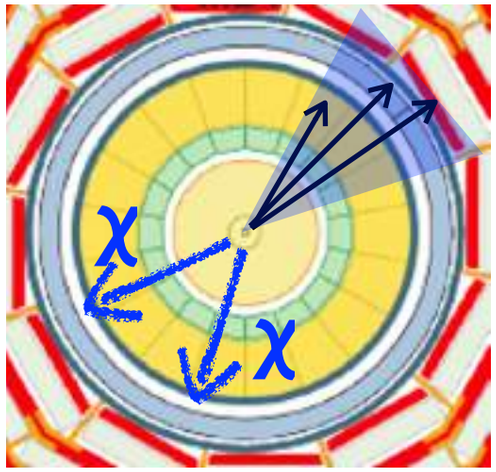


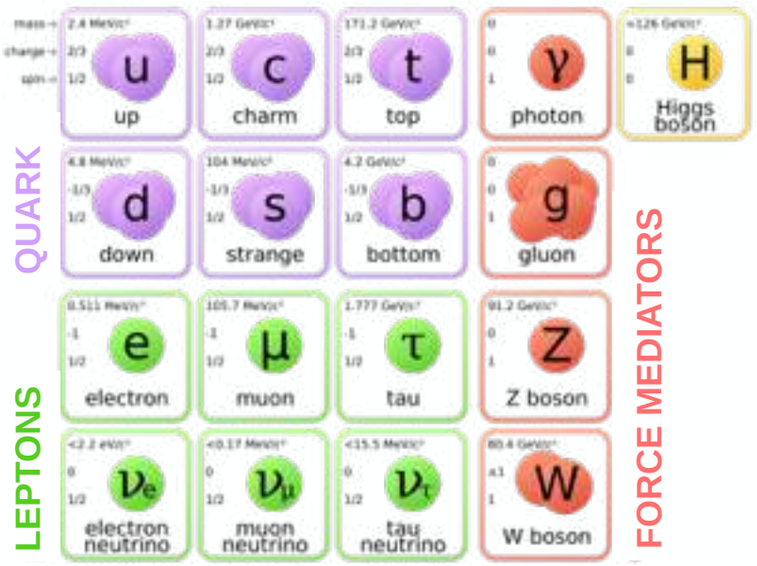
Reminder of the analysis idea

Phys.Rev.Lett. 115 (2015) no.17, 171804

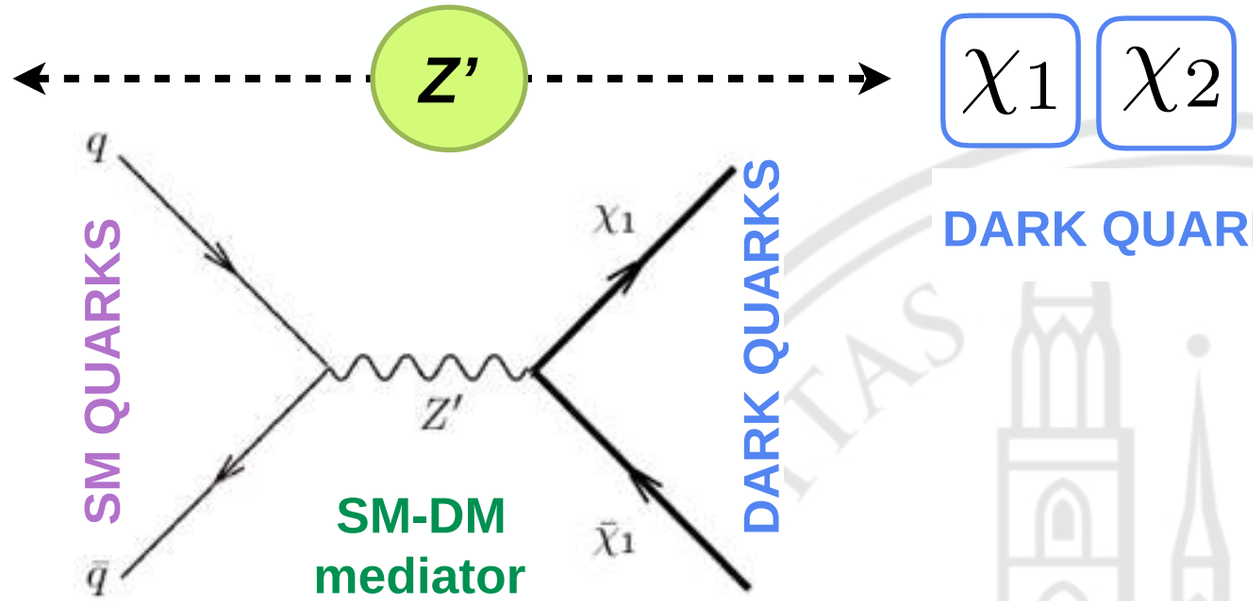
- at LHC we assume that the **DM candidate is neutral and stable**
  - search strategy with signatures with MET + jets and/or leptons
- relaxing the assumption that the dark sector is weakly coupled, a **new family of signals** emerge



Standard Model sector



Dark sector



A new hypothetical dark sector can be considered:

- 2 dark “quarks” interacting via a new fundamental force
- connected to SM particles through a heavy, leptophobic gauge boson Z’

Reminder of the analysis idea

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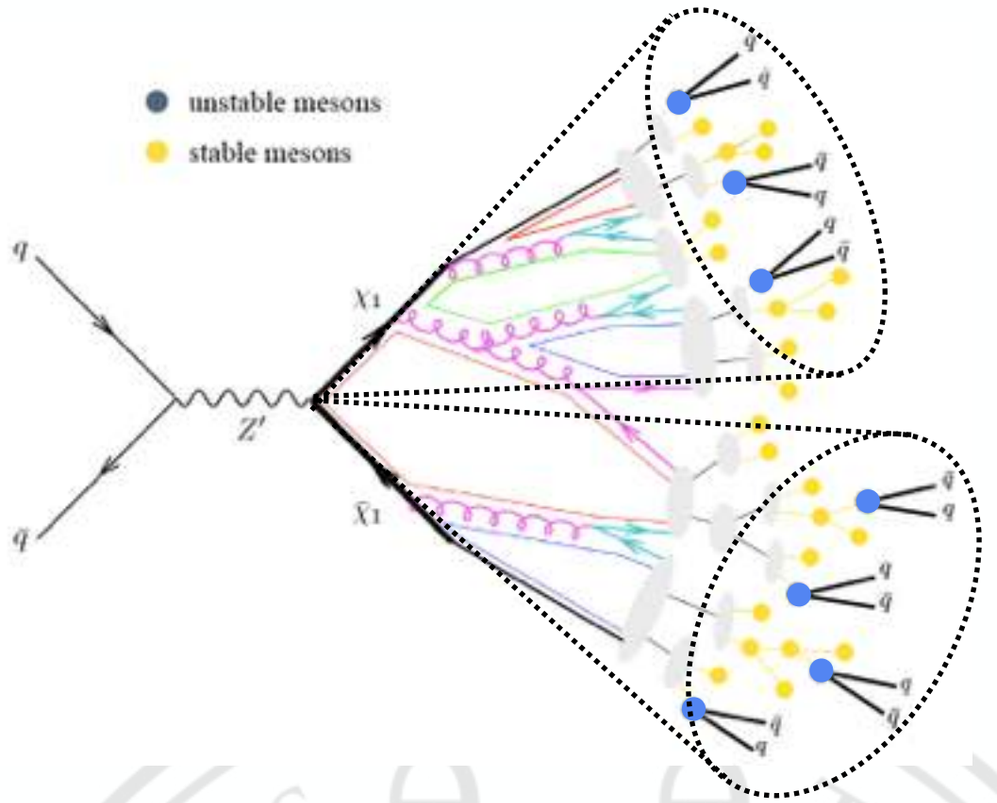
Signature:

- DM mesons and baryons produced in QCD-like jet
  - unstable dark particles can decay back to the "visible" sector
- DM particles would appear as **semi-visible jets**
  - a fraction of the energy is visible
  - signature: **multijet + MET**



Signal characterization:

- production of dark particles leading to an energy imbalance
  - **large missing energy (MET)**
- invisible particles produced within the jets
  - **small Δϕ(jet, MET)**
- invariant mass of the semi-visible jets pairs peaks around the mediator mass

Generating the signal samples

- I built an initial basic repository with some shell scripts used to do the private MC production, from GEN-SIM to MINIAODSIM
  - https://github.com/grauco/SVJ_production
- The scripts are thought to be run on the Tier3 machine of our institute, so they should be modified to order to use them on lxplus

- The generation is done using Pythia only:
  - we have modified the emptyFragment to include some dedicated Pythia settings discussed with the theorists
  - it would be important to translate the production in MG+Pythia, in order to have LHe informations stored (see: pdf, q2, etc, for the future)

Adjusting and processing the signal MINIAOD samples

- In addition to the standard generation flow, we have added some modifications to include HV particles (for instance while pruning the genParticles) and to have them invisible (see https://github.com/grauco/SVJ_production/blob/master/set_config.sh)

- Once the signal MINIAOD samples are ready, we are using two frameworks to process them:
  1. The B2G Analyzer to produced the ntuples
     - https://github.com/cmsb2g/B2GAnaFW/tree/v8.0.x_v2.4
  2. Our internal frameworks to finally produce the trees
     - https://github.com/grauco/ttDM

Selection

We implemented some basic requirements, following the selection described in the phenomenological paper:

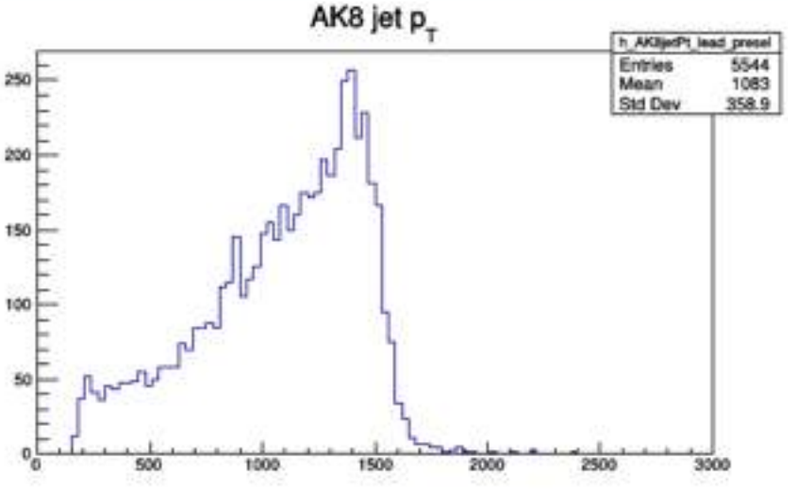
- **at least two AK8* jets**
- **AK8 jets with p^T > 200 GeV and |η|<2.5**
- **MET > 100 GeV**
- **$|\eta_{jet0}-\eta_{jet1}|$ < 1.1**, removes t-channel QCD
- **MET/M_T > 0.15**, which effectively acts as a MET requirement; cutting on the dimensionless ratio avoids sculpting the M_T distribution.
- **min (Δφ(MET, jet0), Δφ(MET, jet1))<1.**, suppressing electroweak background

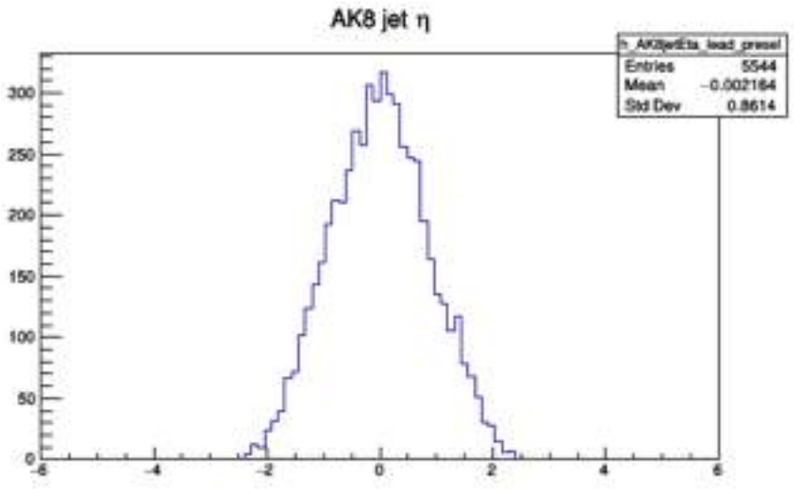
In the following slides some "N-1" plots are presented for the main variables, at reconstruction level.

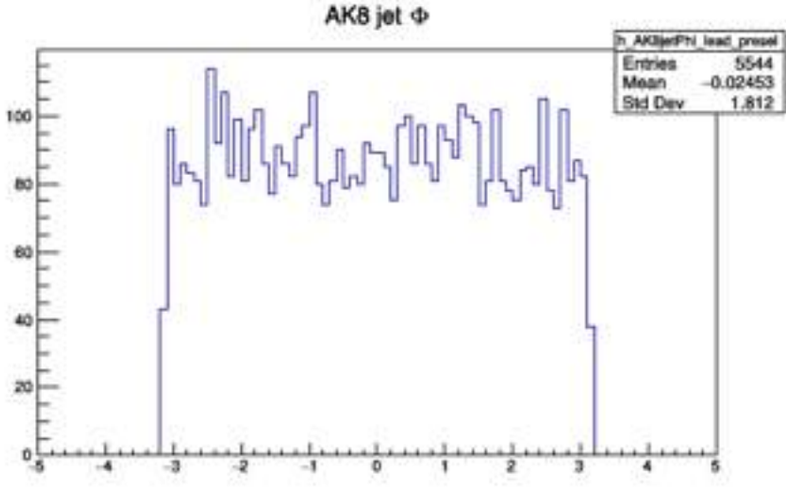
**in the pheno paper a cone radius of 1.1 is used, to mimic ATLAS strategy*

AK8 jets kinematics

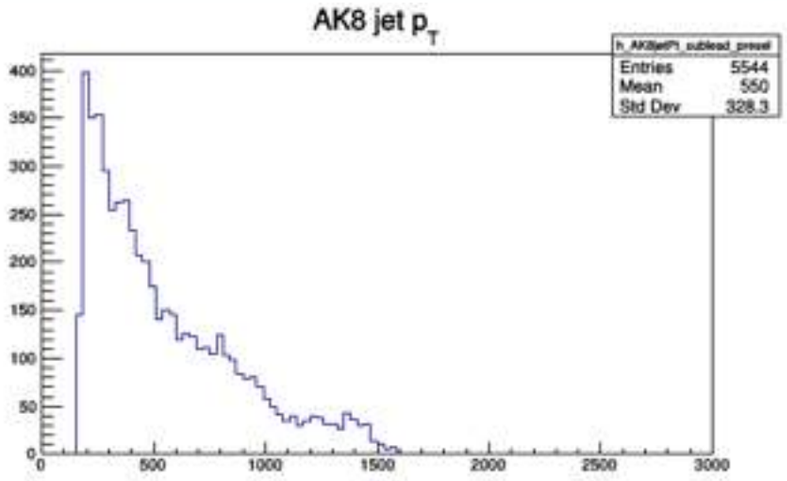
leading jet

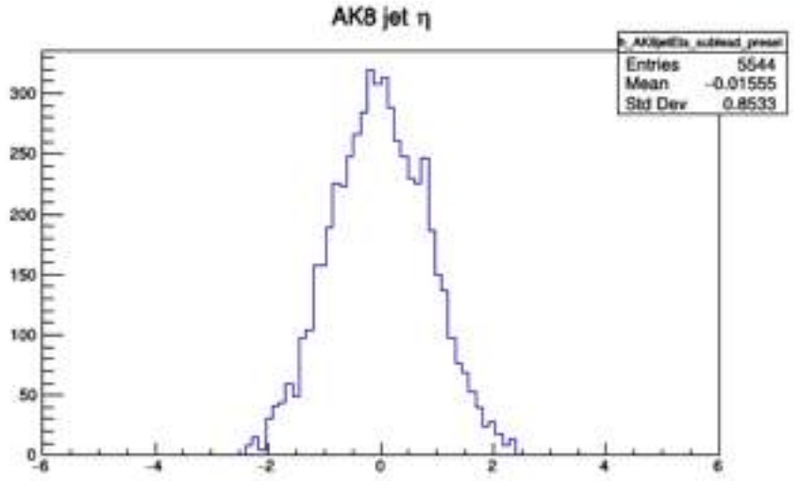


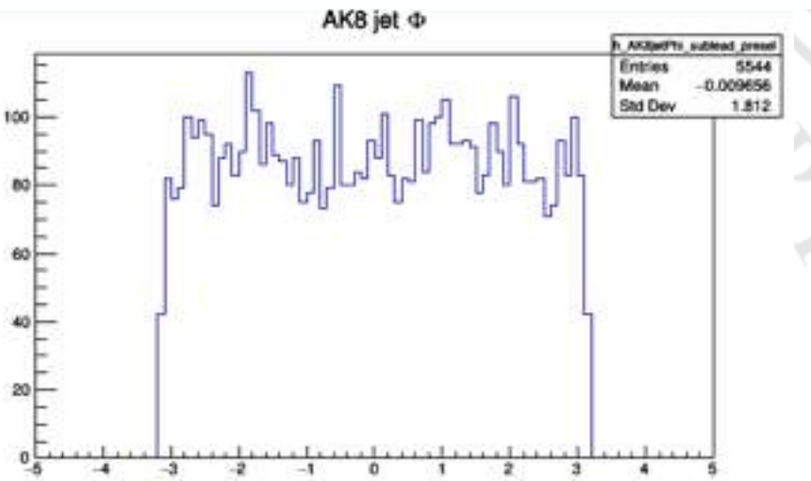




sub-leading jet



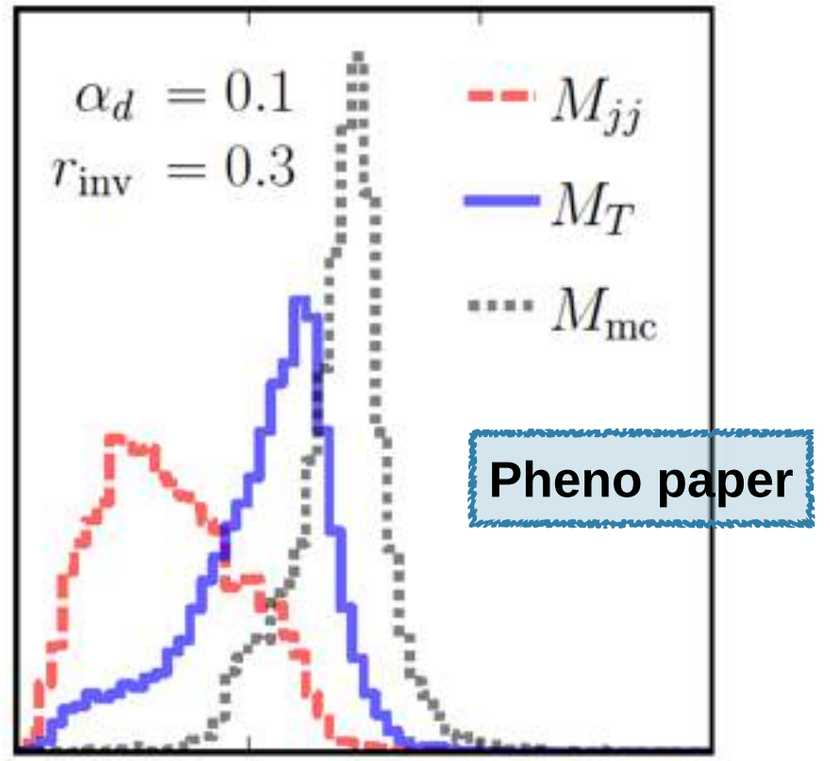




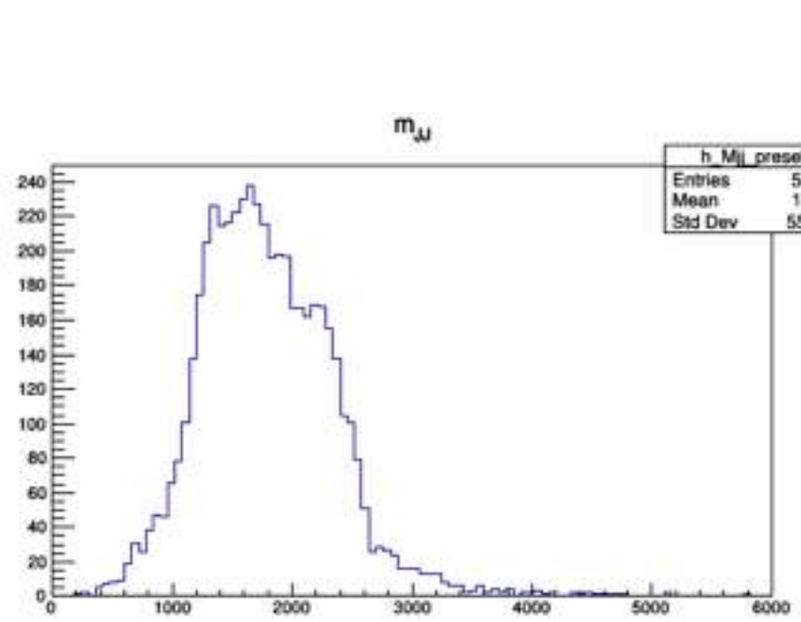
Masses

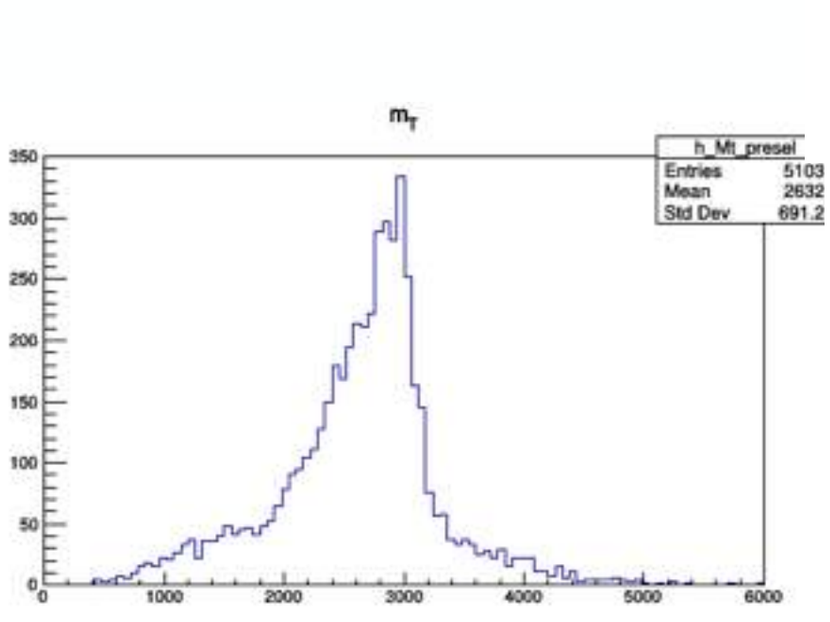
- **M_{jj}**: invariant mass of the two leading jet
- **M_T**: transverse mass, $M_T^2 = M_{jj}^2 + 2\left(\sqrt{M_{jj}^2 + p_{T\,jj}^2}\,E_T - \vec{p}_{T\,jj}\cdot\vec{E}_T\right)$
- **M_{MC}**: M_{MC} is the reconstructed $M_{Z'}$ computed from all the reclustered jets and truth-level dark-matter four-vectors

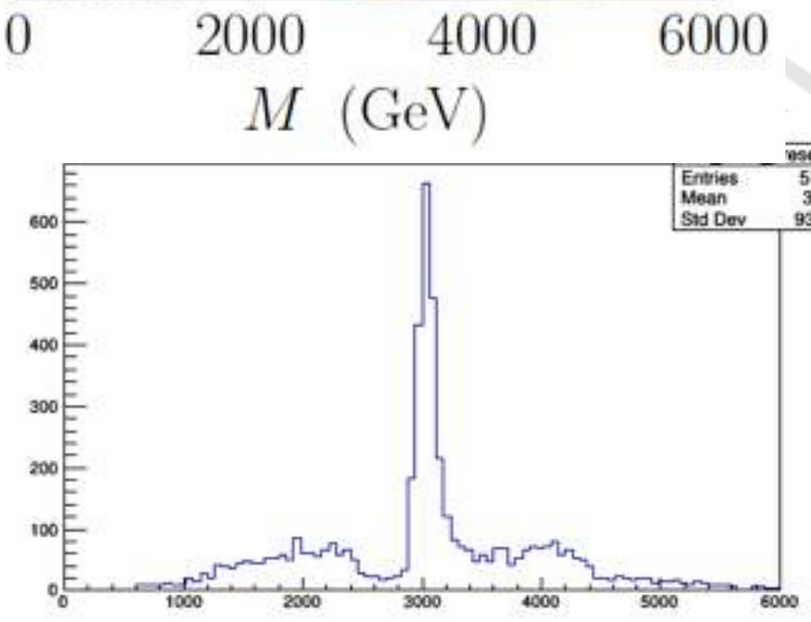
- These masses should respect the ordering
  $M_{jj} < M_T < M_{MC}$



Pheno paper



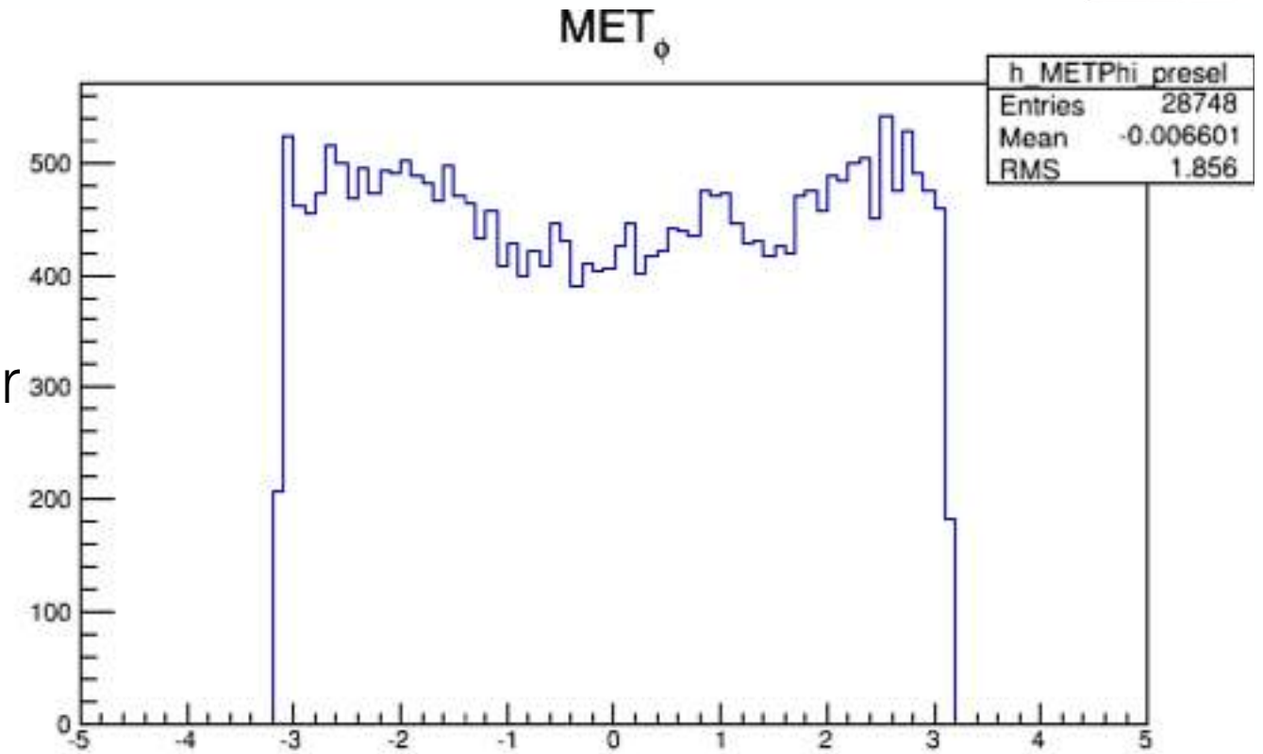


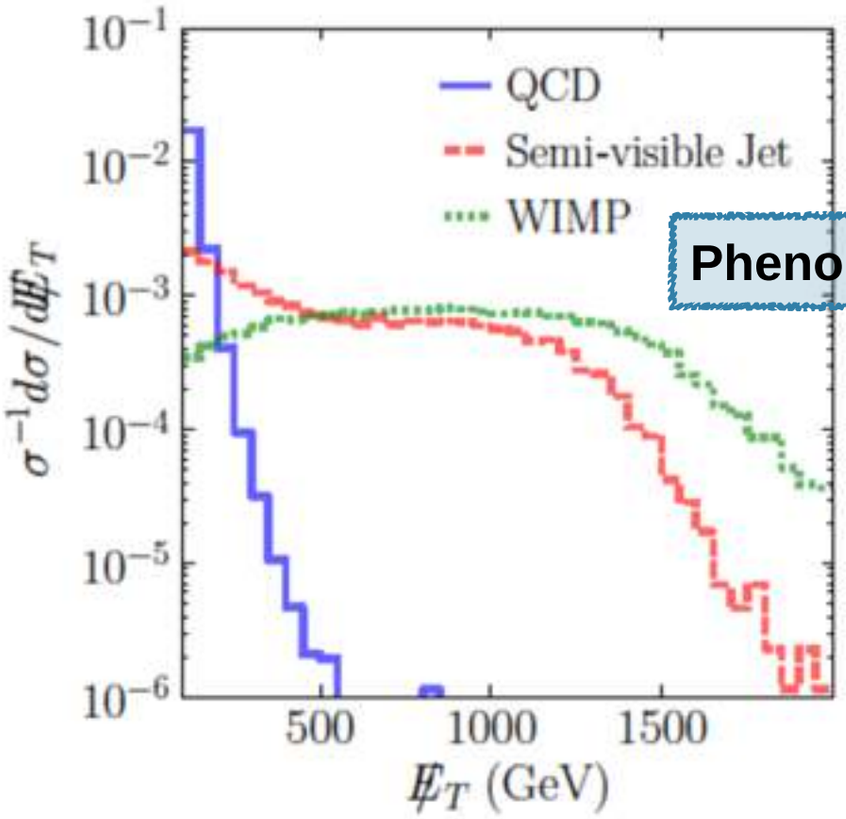


Similar shapes wrt the phenopaper, still some peaks to be understood

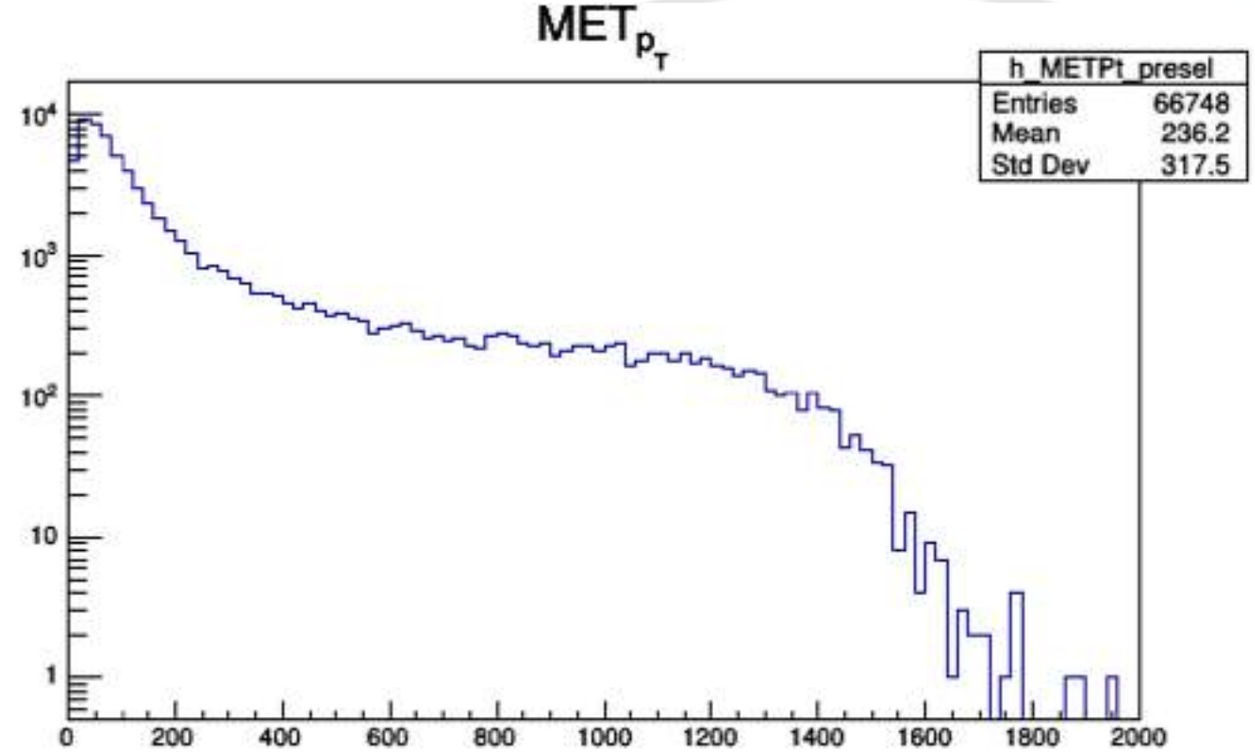
MET

- MET ϕ and p^T
- Comparing the plots for the magnitude, similar shapes are obtained, with a higher tail for high values of MET wrt QCD





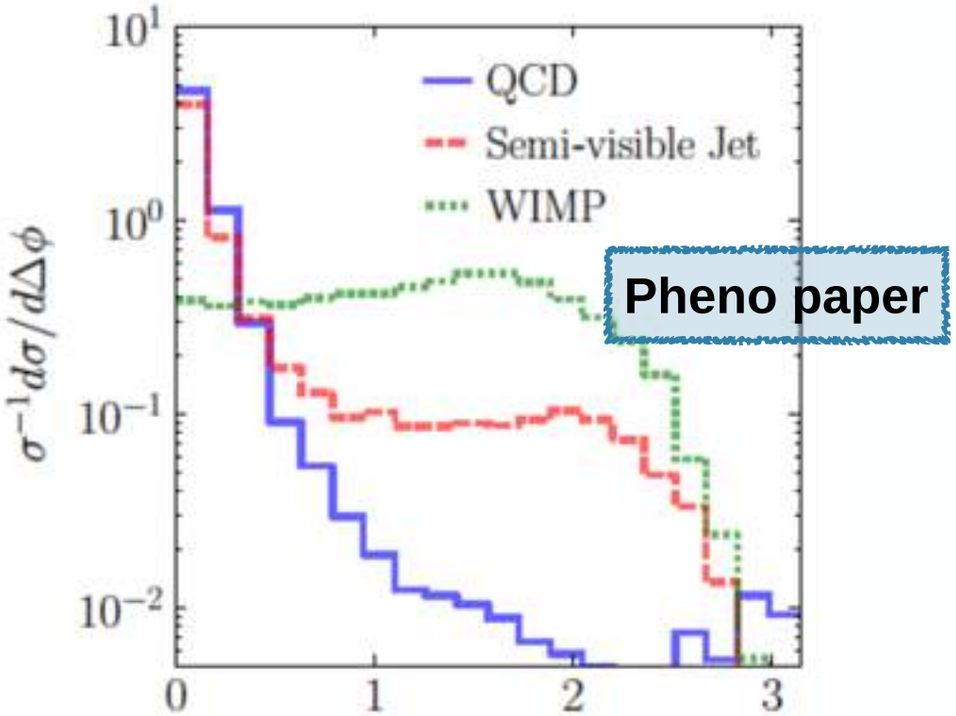
Pheno paper



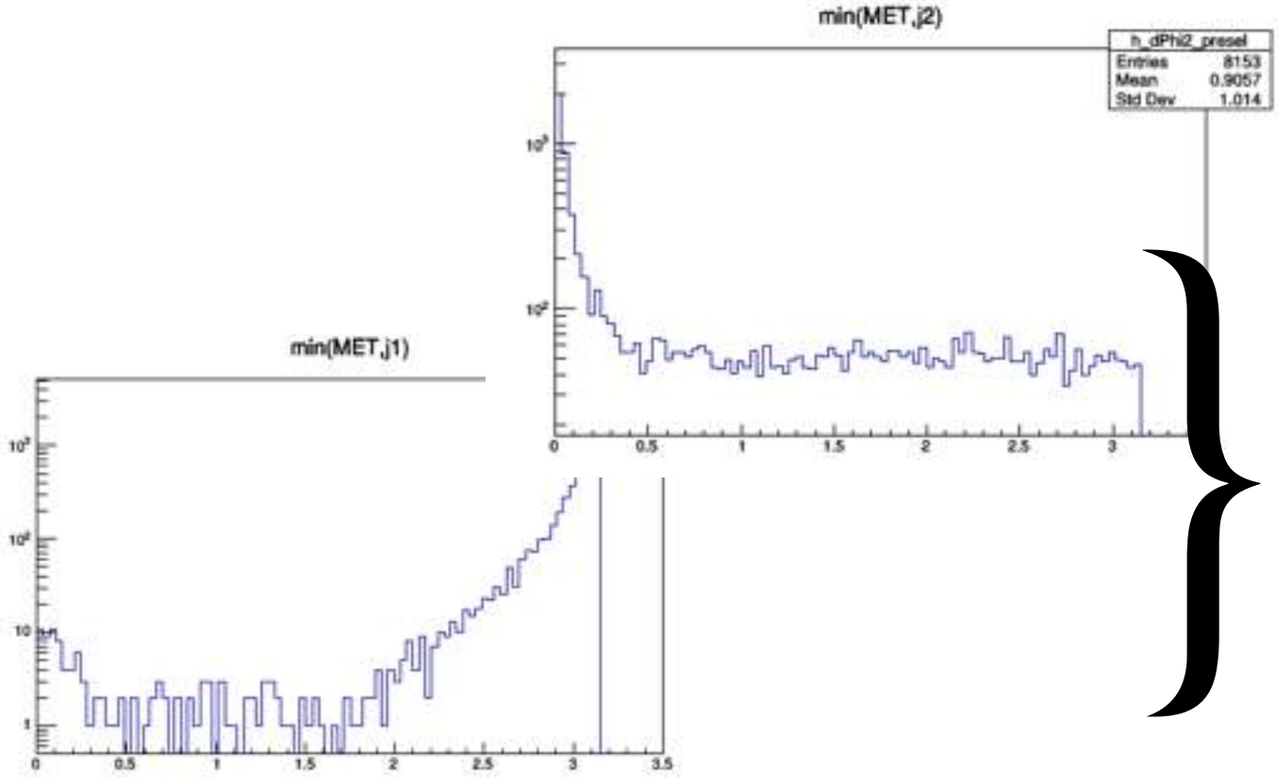
Δϕ

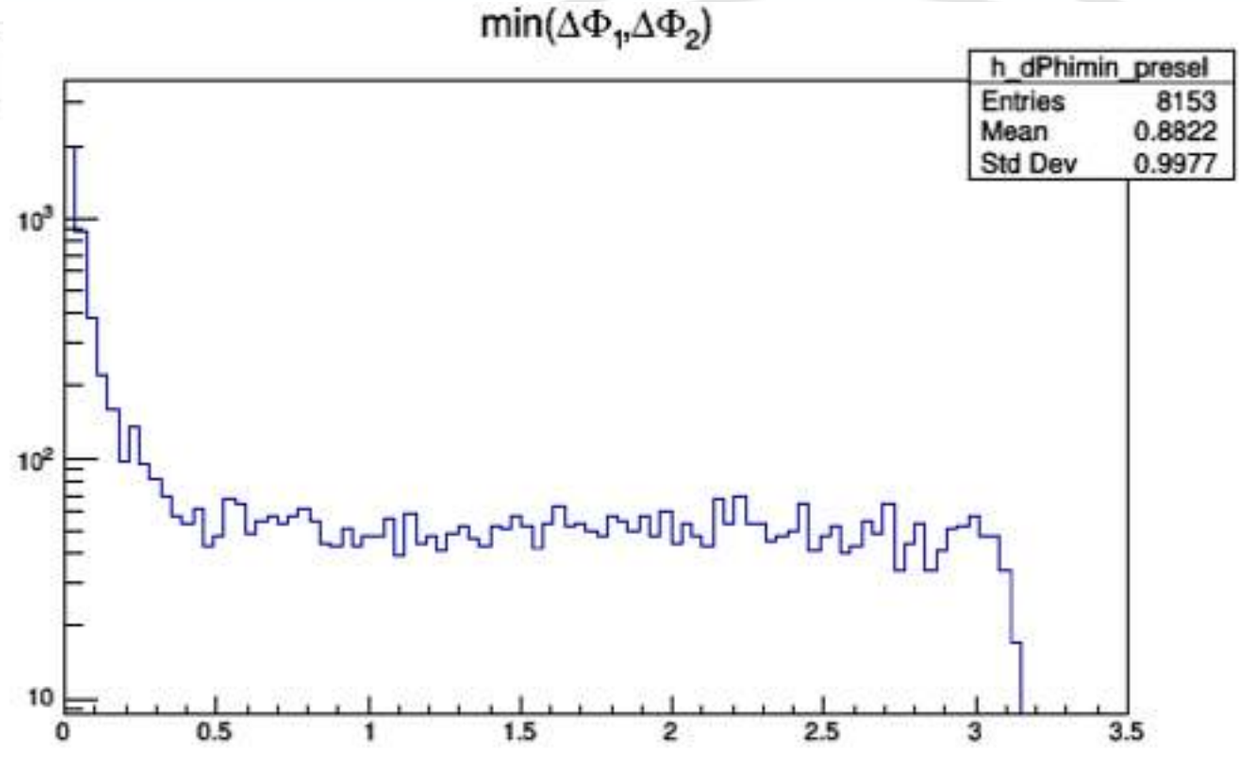
- Δϕ separation between the MET and the two leading jets
- The minimum Δϕ is taken as discriminant value
- Plots at “N-1 selection” level
- Similar trend observed wrt pheno paper

➡ Next step is to check also Δϕ, Δη and ΔR between the two leading AK8.



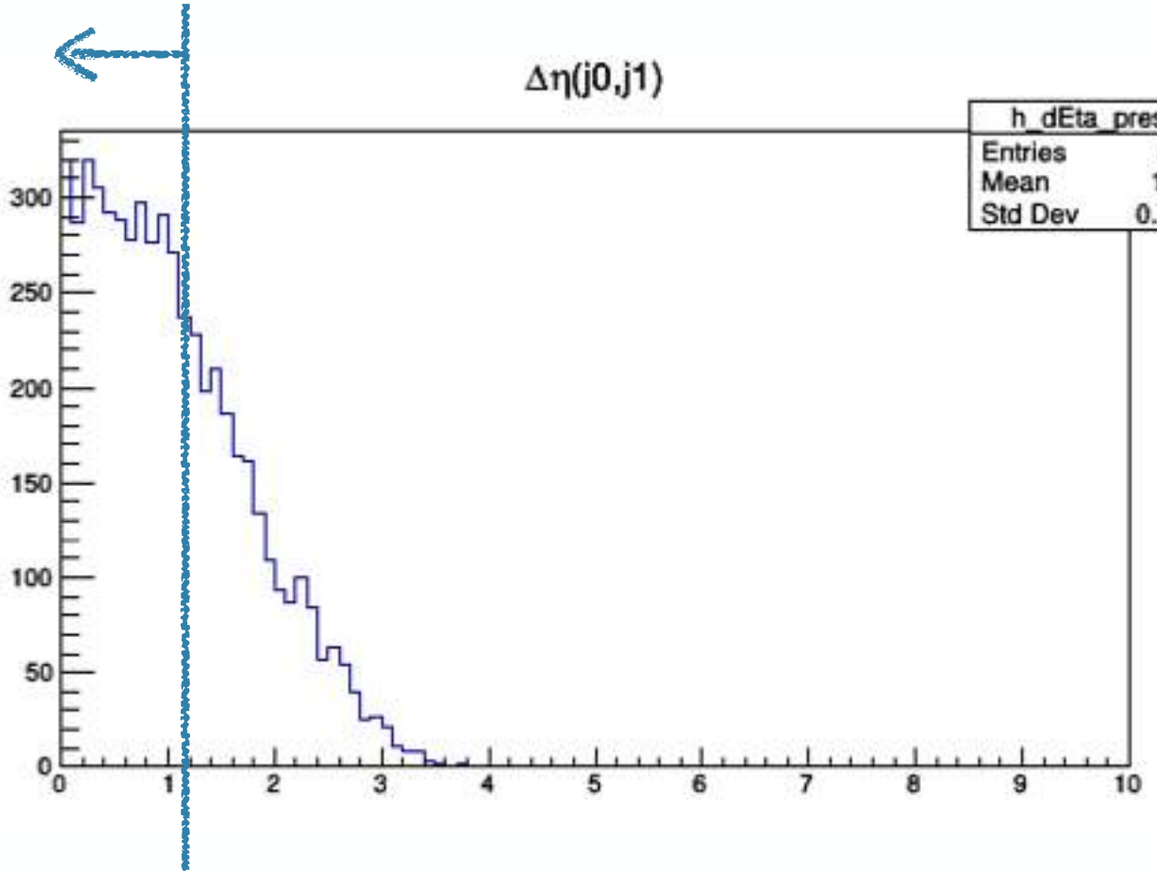
Pheno paper

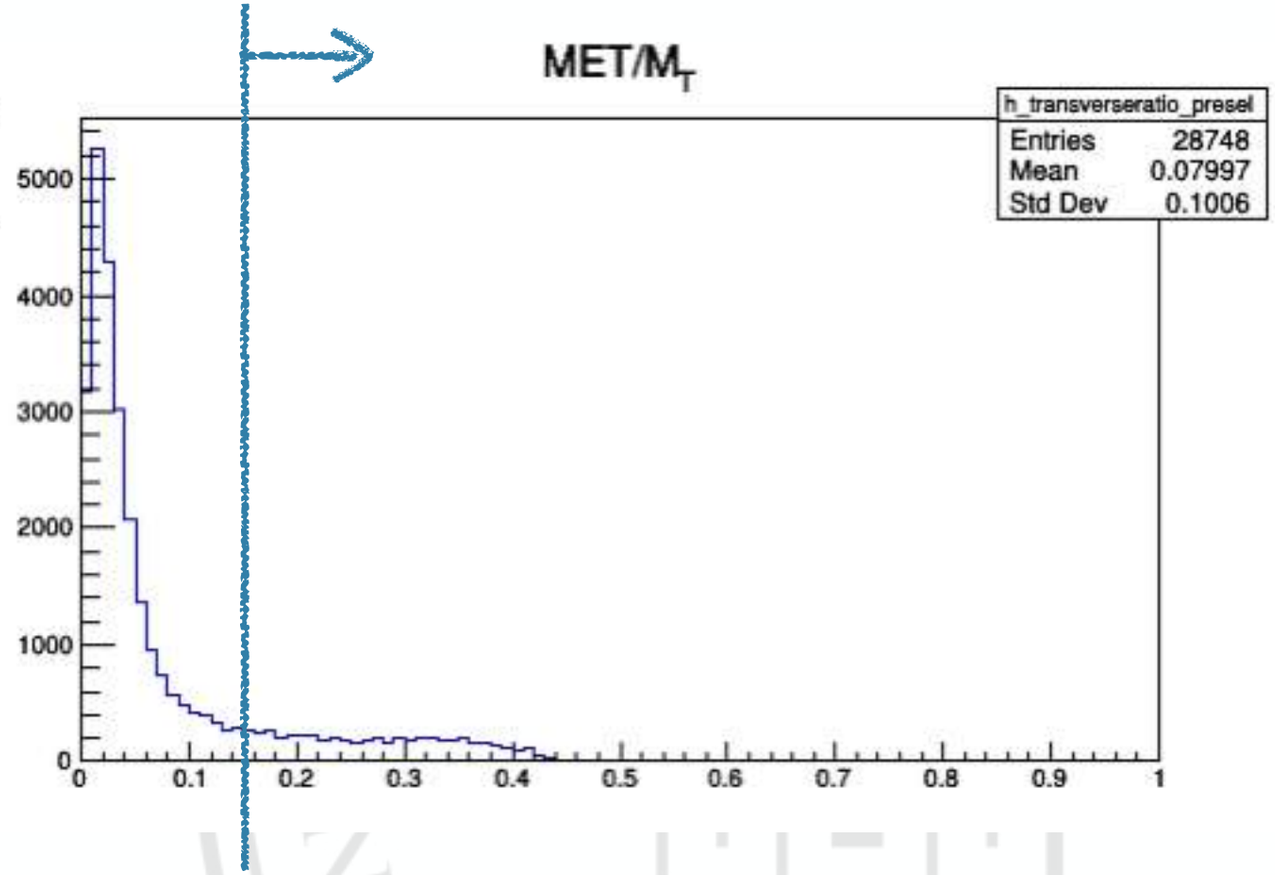




Additional variables

- Additional variables are suggested in the phenomenological paper
- We present here the “N-1” plots for two of the other variables proposed:
  - the ratio MET/M_T
  - the pseudorapidity separation between the two leading jets





To do and future steps

- Translate the signal sample generation in MadGraph + Pythia
- Study trigger strategy
- Investigate new variables, along with a deeper study of the signal topology and signature
  - Angular distributions between the two jets?
  - How is the energy of the jet distributed?
  - Etc.