Dark Matter search using Semi-Visible jets

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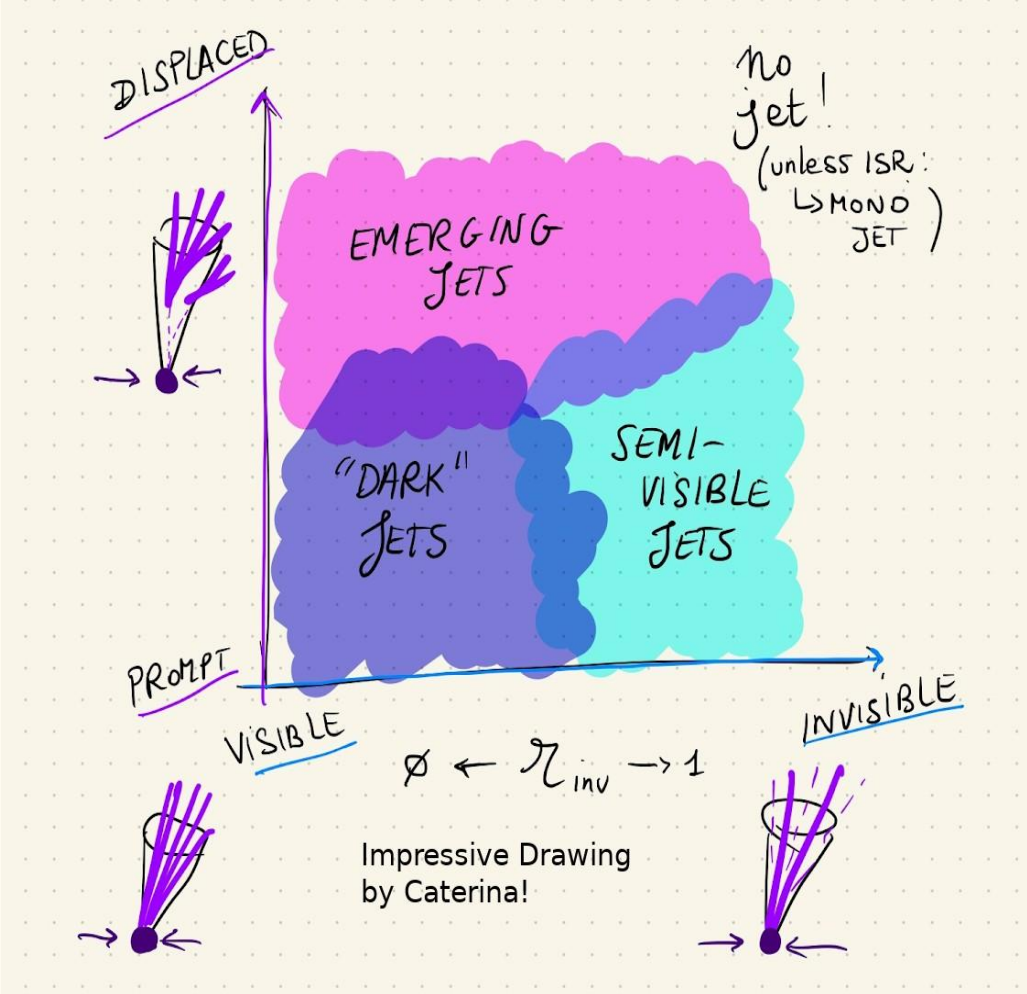
INTRODUCTION

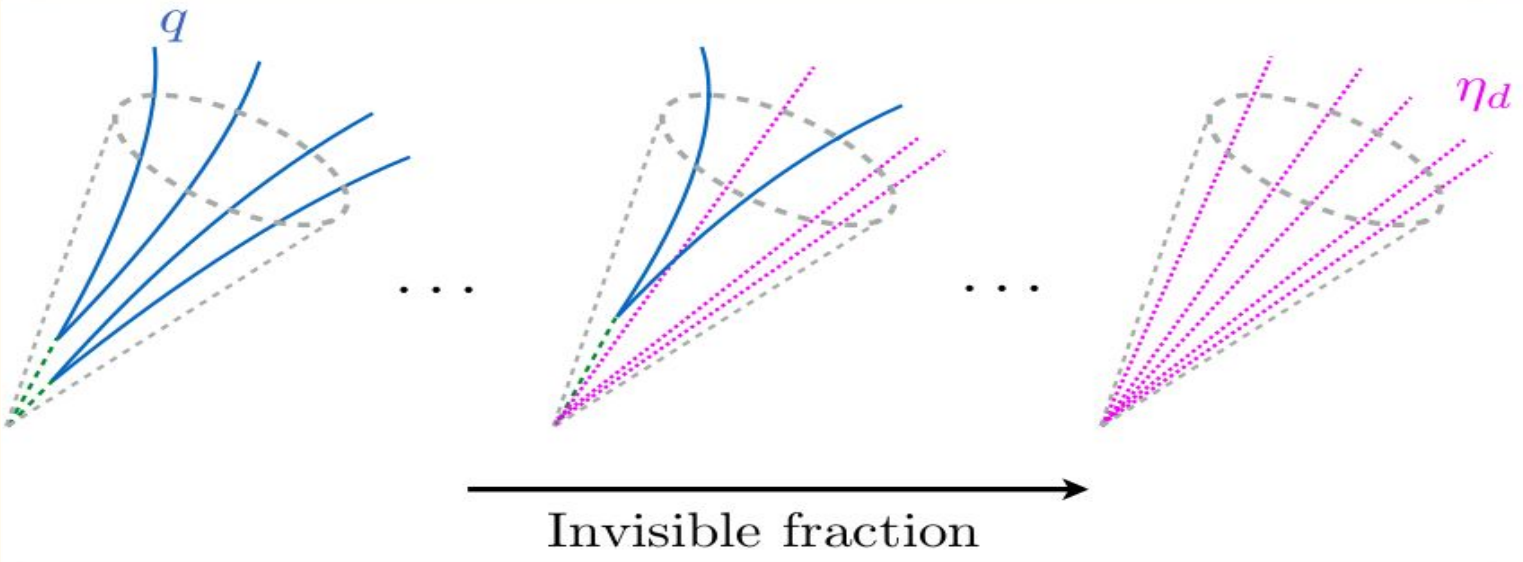
Introduction

Dark jets & semi-visible jets: two new search ideas

- We haven't found new physics ... **yet!**
- We look at two unusual topologies & hidden phase space corners
  - Signature based search, using benchmark model
- Dark hadrons decay promptly in a QCD-like fashion partially back to visible sector (semi-visible jets "SVJ")
  - Showering mostly using Pythia hidden valley module



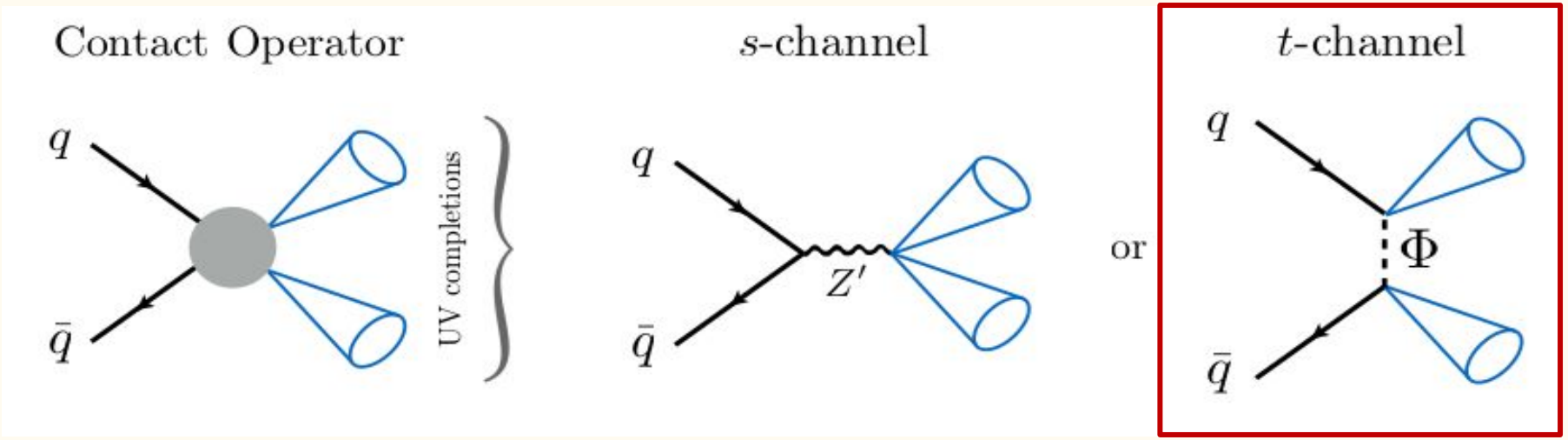
Semi - visible jets production



Based on the Paper:

LHC Searches for Dark Sector Showers

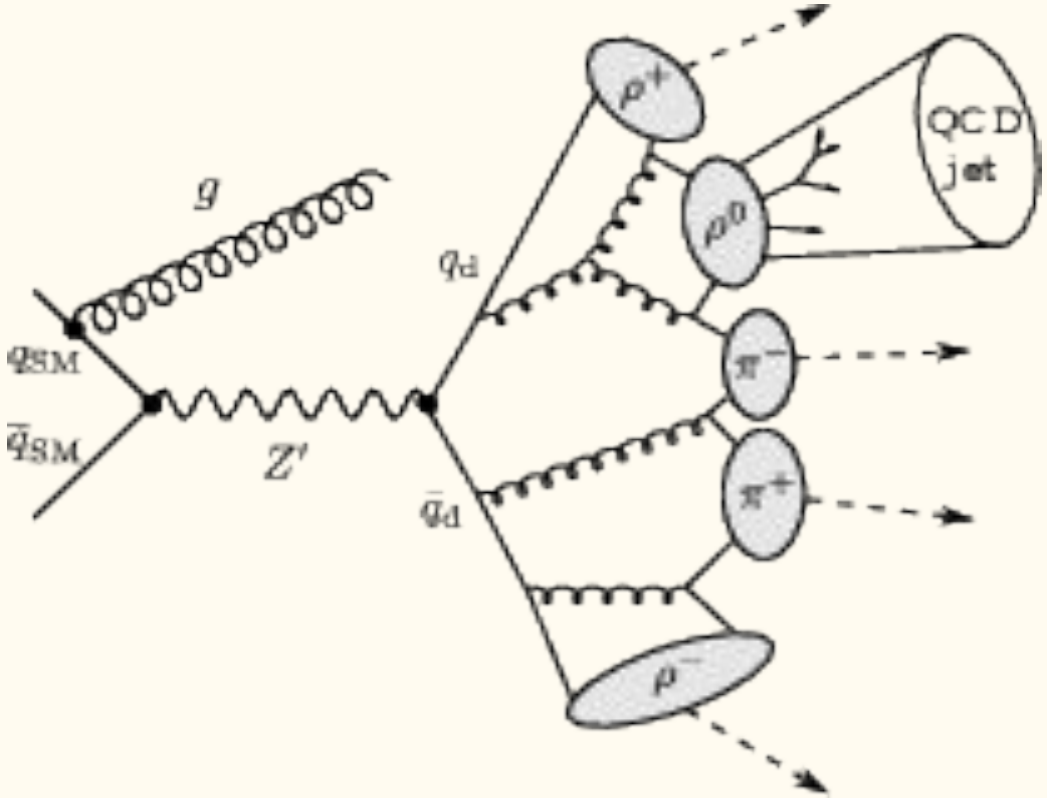
Tim Cohen et al [arXiv: 1707.05326]



Semi-visible jets - idea

Two different dark quark flavours

- Combine to form π^+, π^-, π^0, and ρ^+, ρ^-, ρ^0
- Only ρ^0 is unstable and (promptly) decays to SM quarks
- Other mesons are (collider-)stable → invisible



Model Parameters:

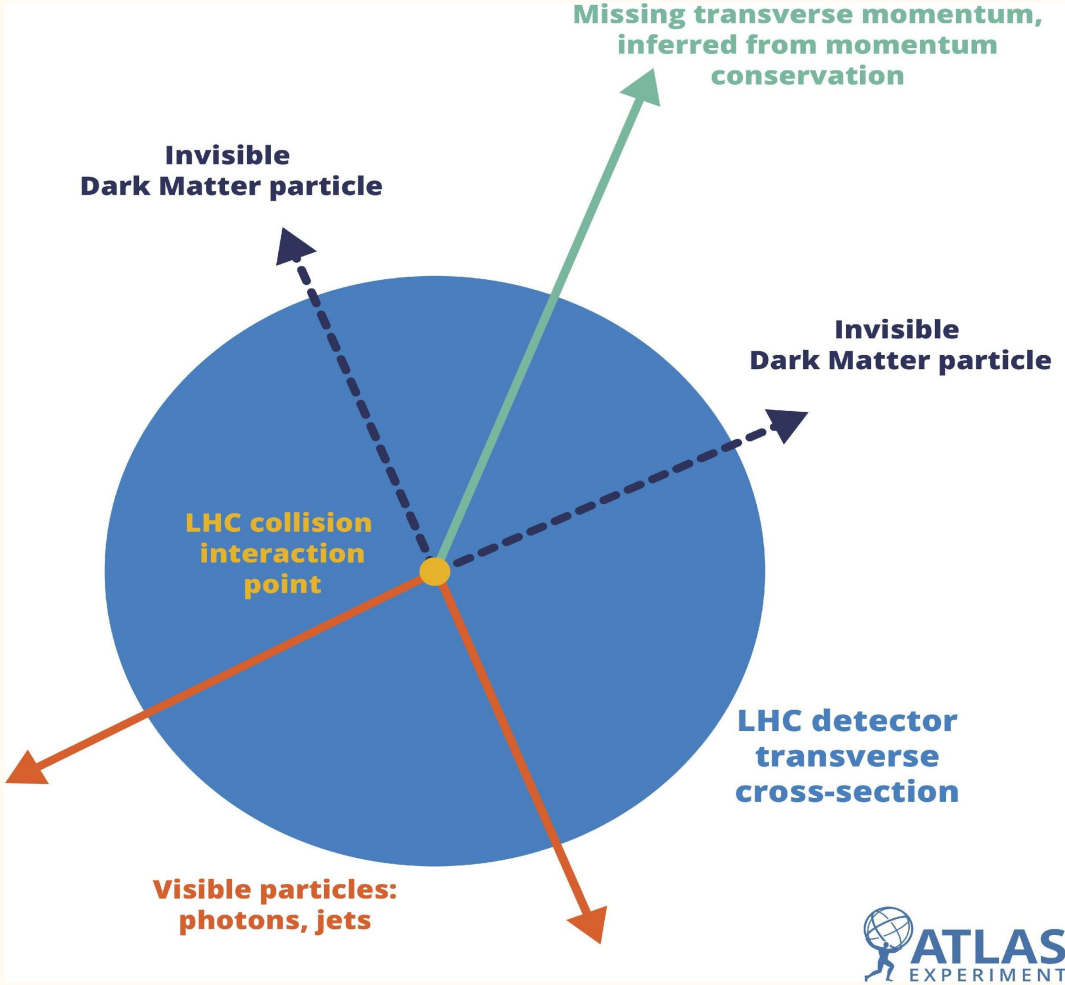
1. M_ϕ = Mass of Scalar Bi - fundamental (mediator)
2. M_d = Mass of dark hadrons
3. r_{inv} = no. of stable dark hadrons/ no. of hadrons

Continued...

$r_{inv} \rightarrow 0$ [dark hadrons decay entirely to visible states]

$r_{inv} \rightarrow 1$ [none of the dark hadrons decay back to the SM (on collider timescales)]

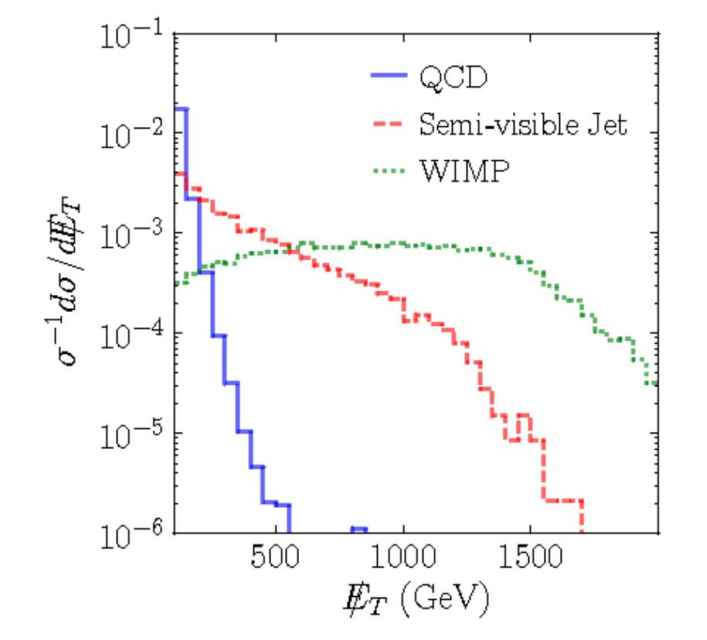
Characteristic mass scale for the dark hadrons, $\mathbf{M_d}$, and the dark strong coupling, $\boldsymbol{\alpha_d}$ affect the number of dark hadrons produced during dark shower → impacts jet multiplicity.

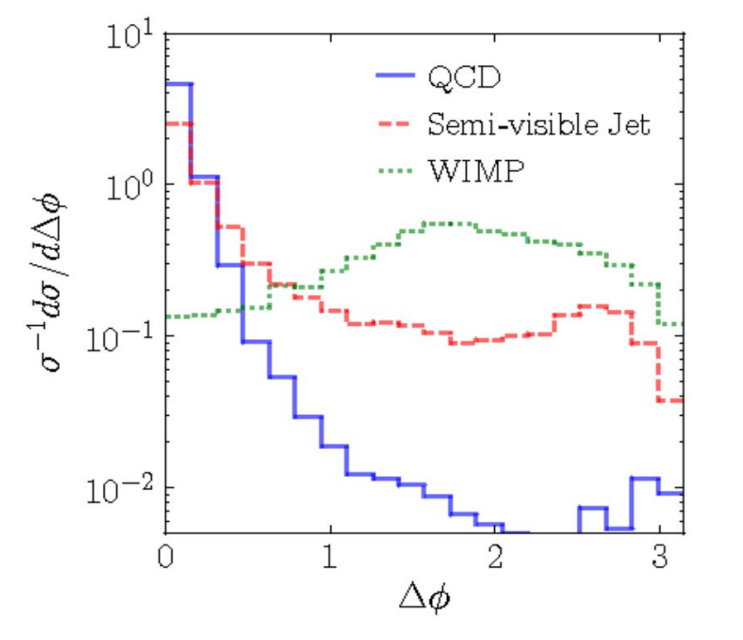


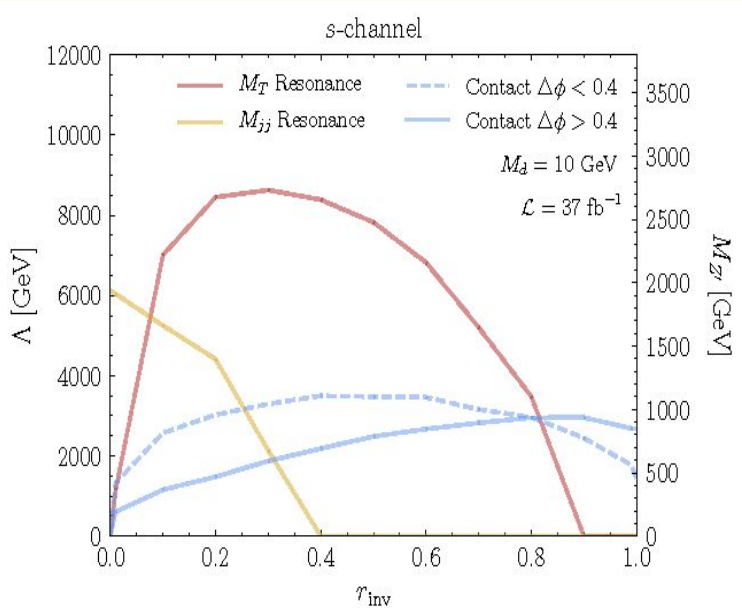
- Signature of semi-visible jets = jets with aligned p_T^{miss} !
- Typical (mono-jet) searches are insensitive, because they require p_T^{miss} to be far away from jets

Semi-visible jets - channels and search strategy

- *t*-channel first looked at for analysis kick-off
  - Strategy: Cut on p_T^{miss} and $\Delta\varphi$ (p_T^{miss}, closest jet), then count
- *s*-channel studies started
  - Strategy: Look for bump in m_{jj} ($r_{\text{inv}} \approx 0$) or transverse jet mass m_T ($r_{\text{inv}} > 0.1$)







Plots from Tim Cohen et al

Particle Level Studies with standalone samples

Signal:

- Madgraph+Pythia8 using UFO provided by authors (using hidden valley module to simulate dark shower) (https://github.com/smsharma/SemivisibleJets)

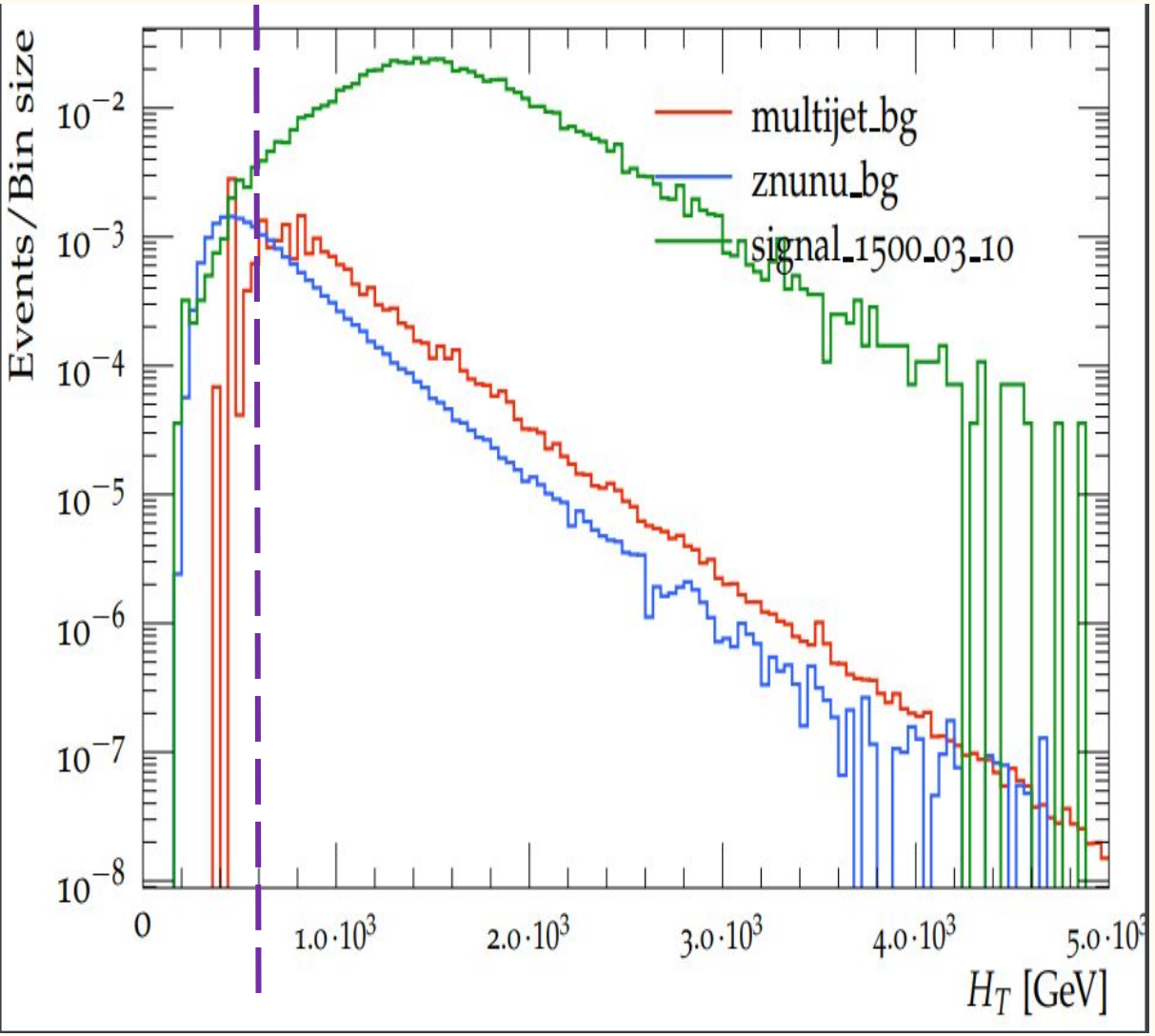
Background:

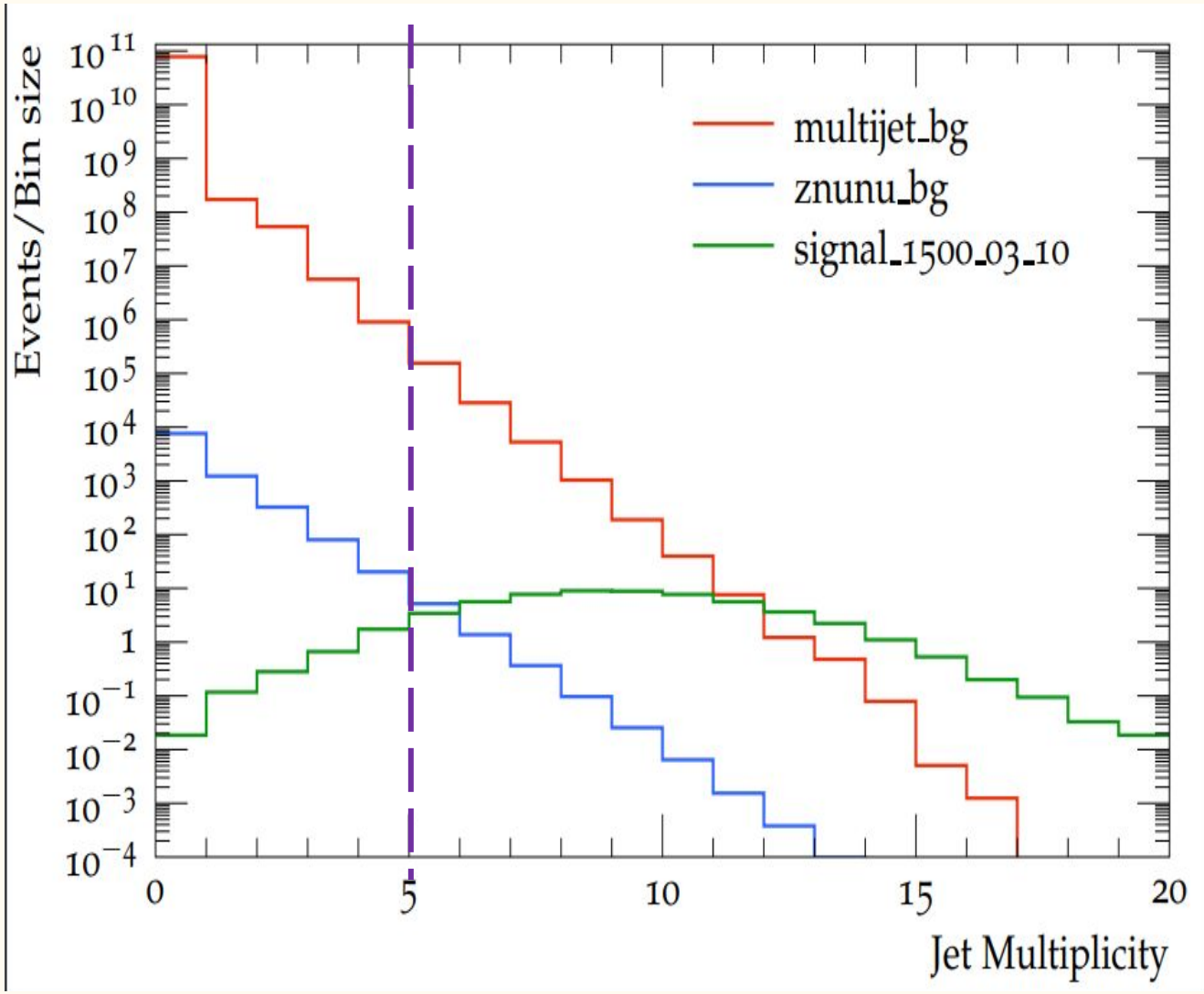
- Znunu: MadGraph+Pythia8 sample
- Multijets: Pythia8 multijet sample

Observables being considered for particle level studies (performed with Rivet analysis toolkit):

- Jet multiplicity
- Missing transverse Energy (MET)
- $\Delta\phi$ (Angle between the closest jet and the MET)
- H_T (Scalar sum of jet p_T)

Signal Background Comparison





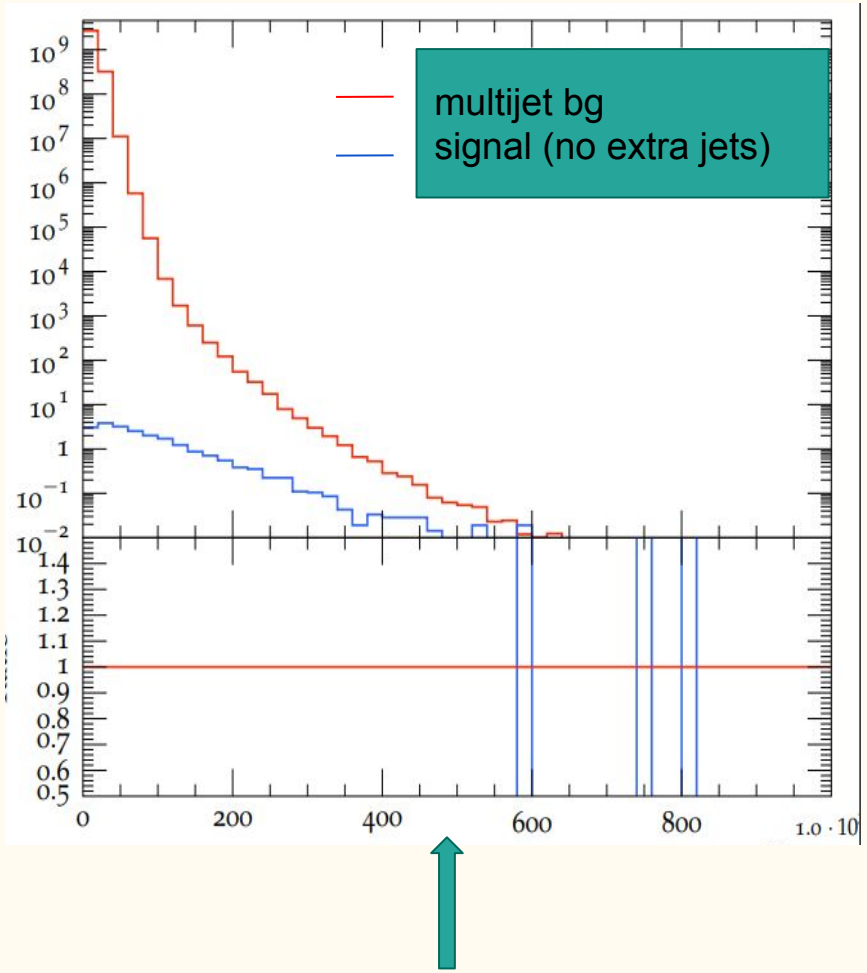
H_T Plot

Dashed line denotes cut H_T > 600 GeV

Jet multiplicity plot

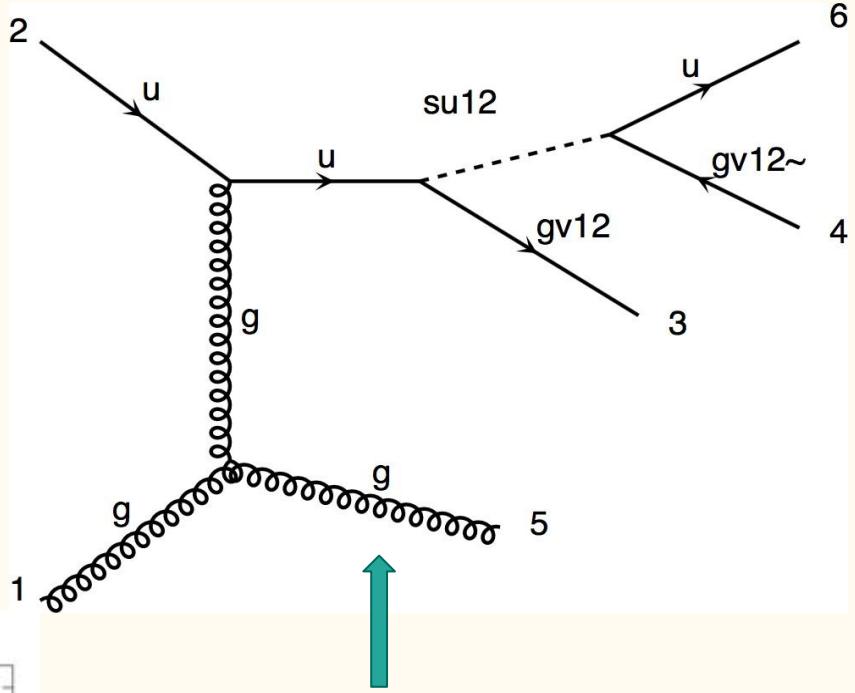
Dashed line denotes jet multiplicity > 5

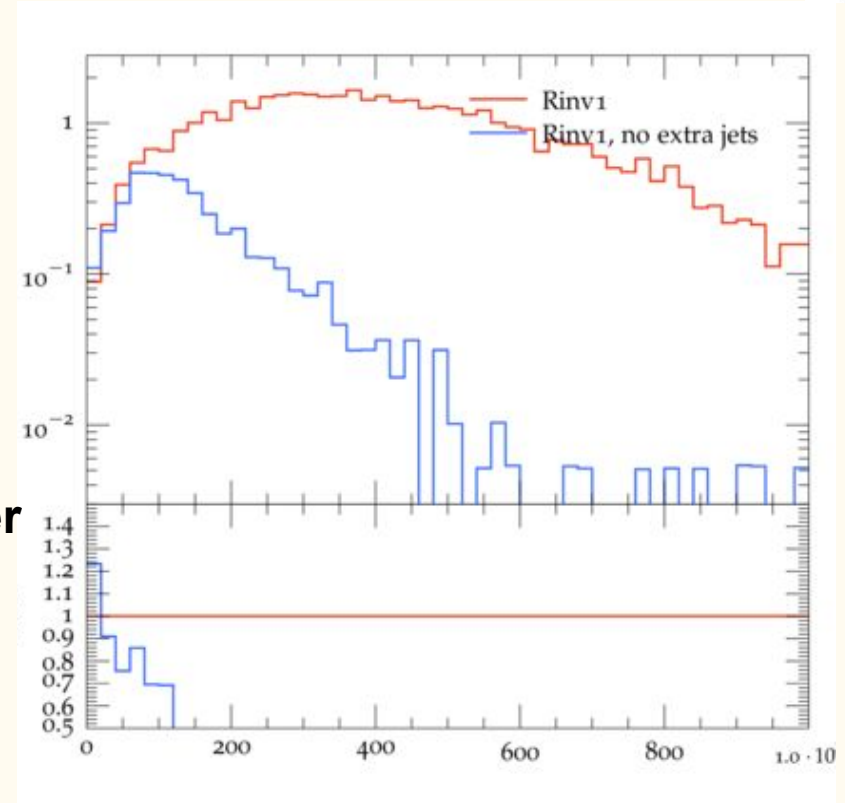
- **Why we need two extra jets?**



Particle level MET plots for 2 scenarios:

1. signal (no extra jets) vs multijet background
3. r_{inv} = 1 (with and without extra jets)



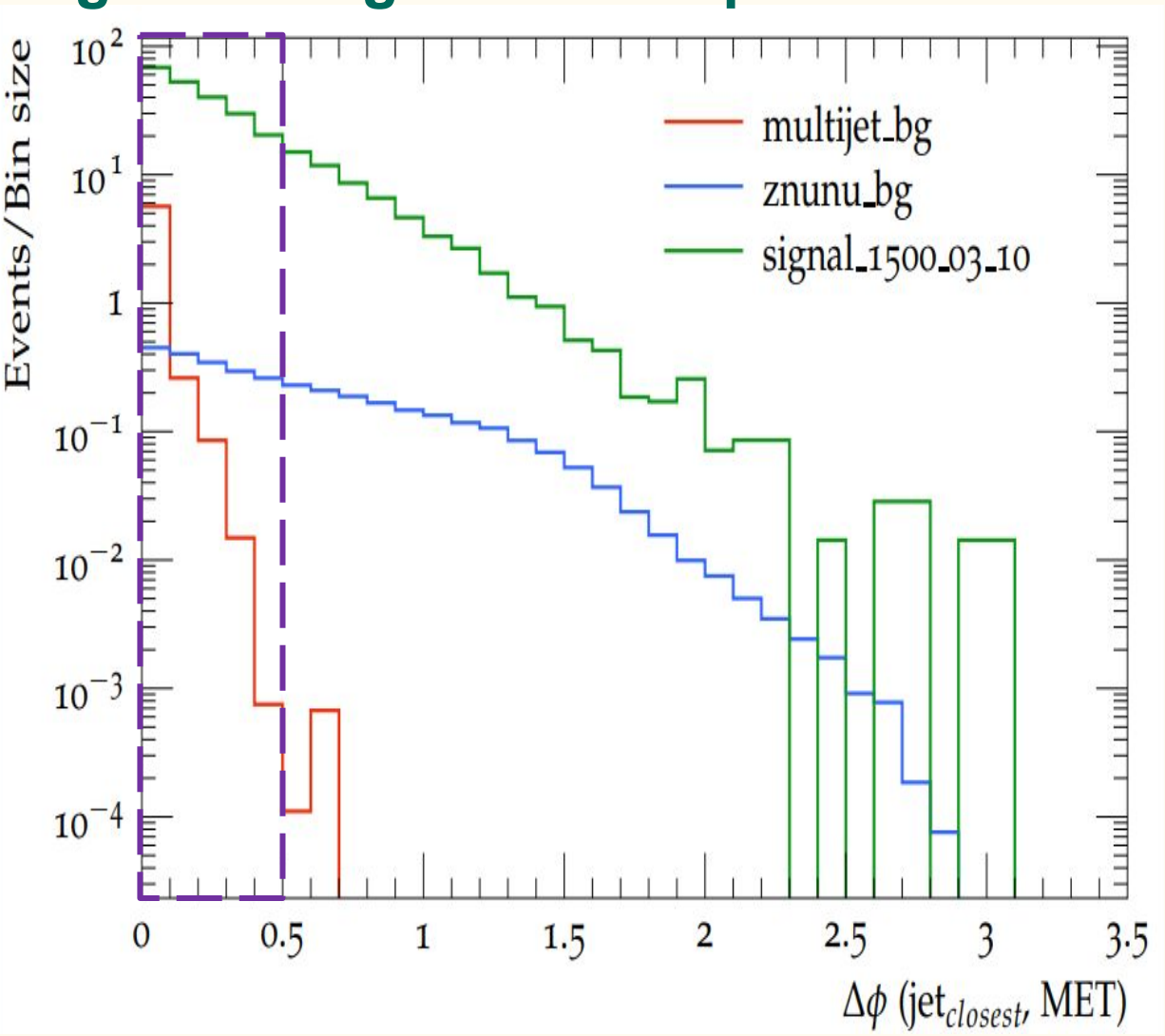


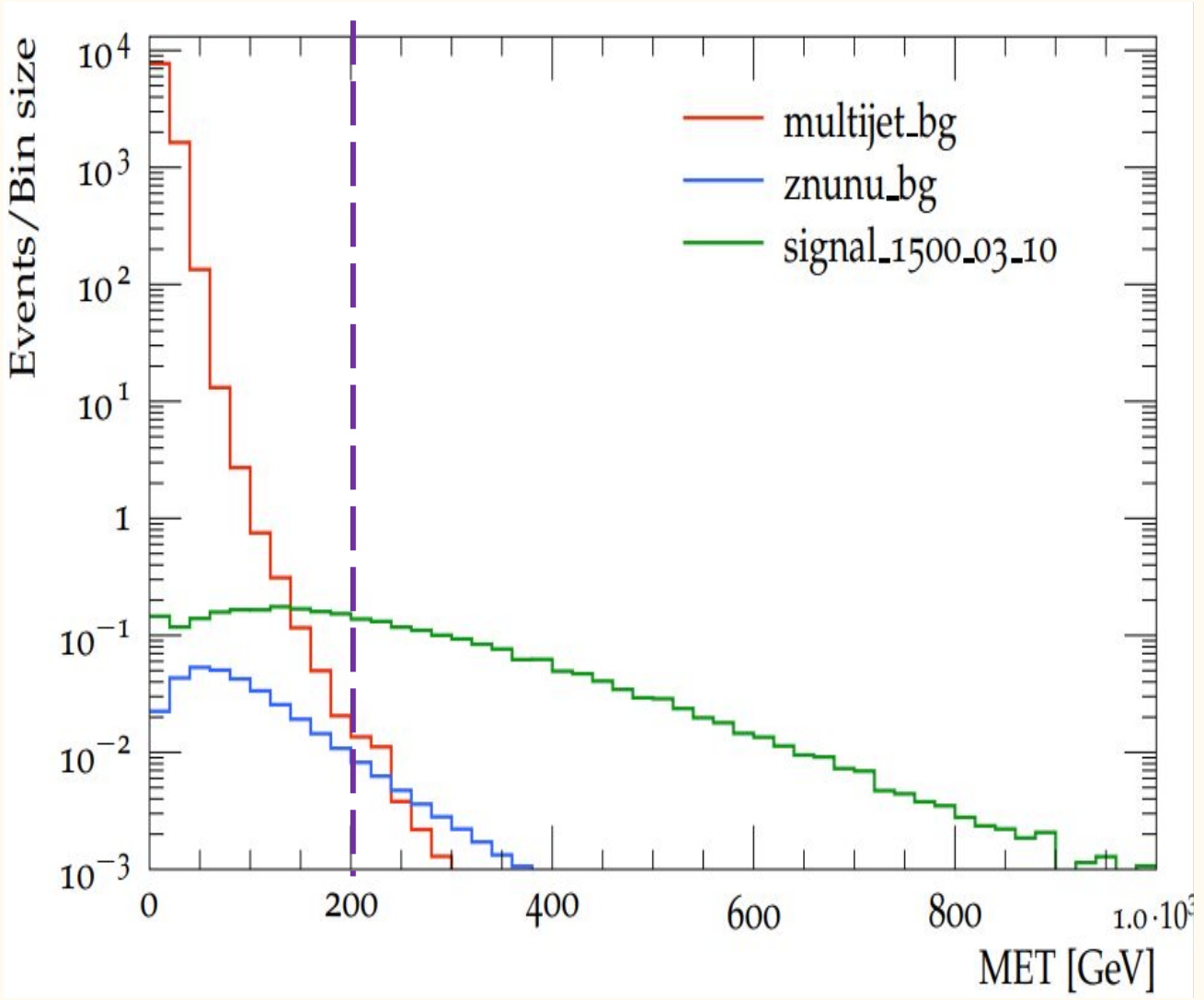
2 extra jets required to obtain a proper signal which is visible over the QCD background, unlike the no extra jet case (fig above).

Extra jet multiplicity is due to twisted s-channel diagram contributions even when generating t-channel.

XS also increases on adding the 2 jets, which makes the search more powerful.

Signal Background Comparison





$\Delta\phi$ plot

Purple dashed box highlights $\Delta\phi < 0.5$ region

MET plot

Dashed line denotes MET > 200GeV
Adding this cut helps to reduce the background contribution

Studies with Detector level samples (ongoing)

Signal:

Madgraph + Pythia 8 with r_{inv} = 0.4, 0.6 and M_D = 10 GeV, M_{phi} = 1500 GeV

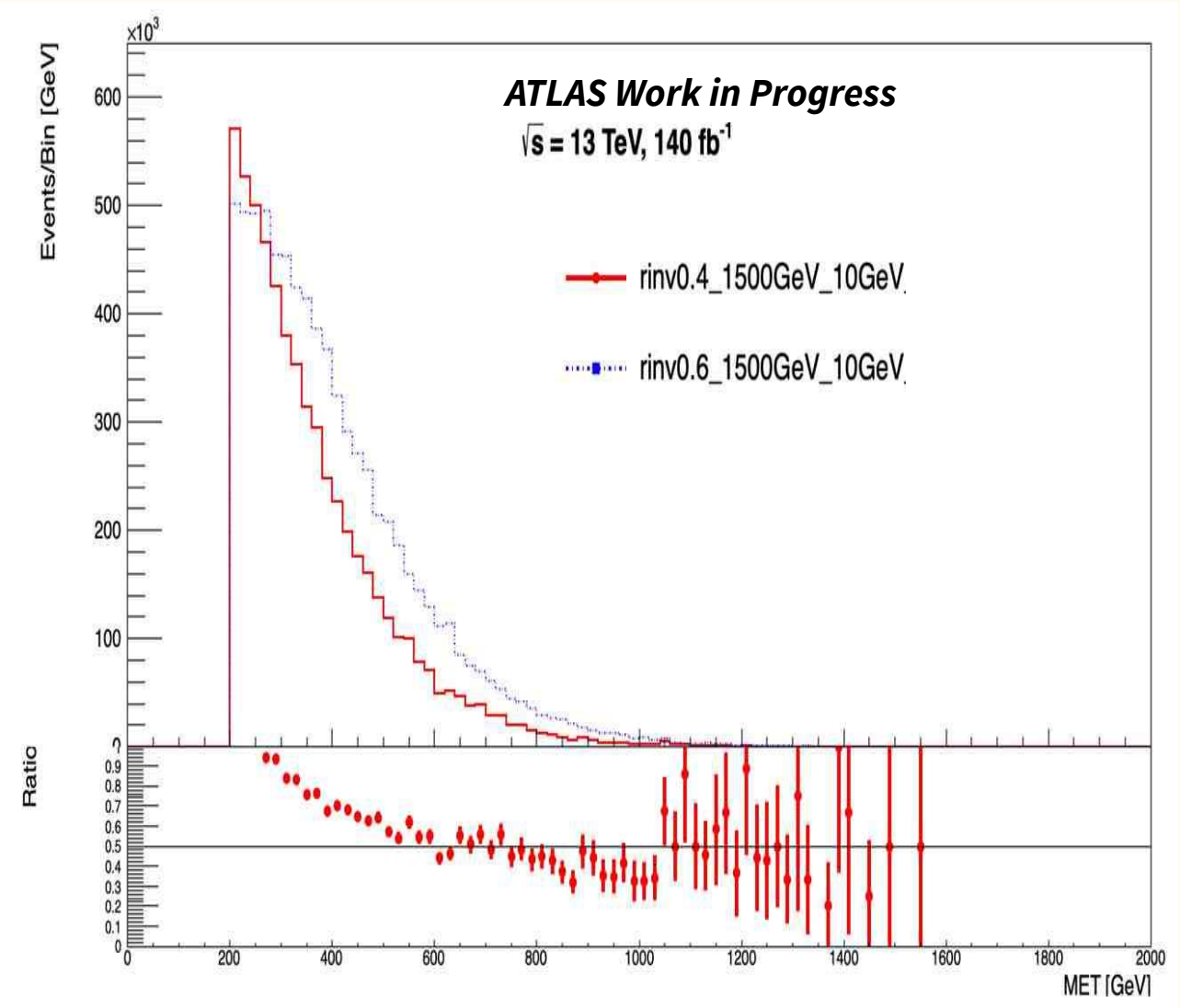
Dominant background:

- Z ν ν + jets
- W + jets
- Multijet
- ttbar

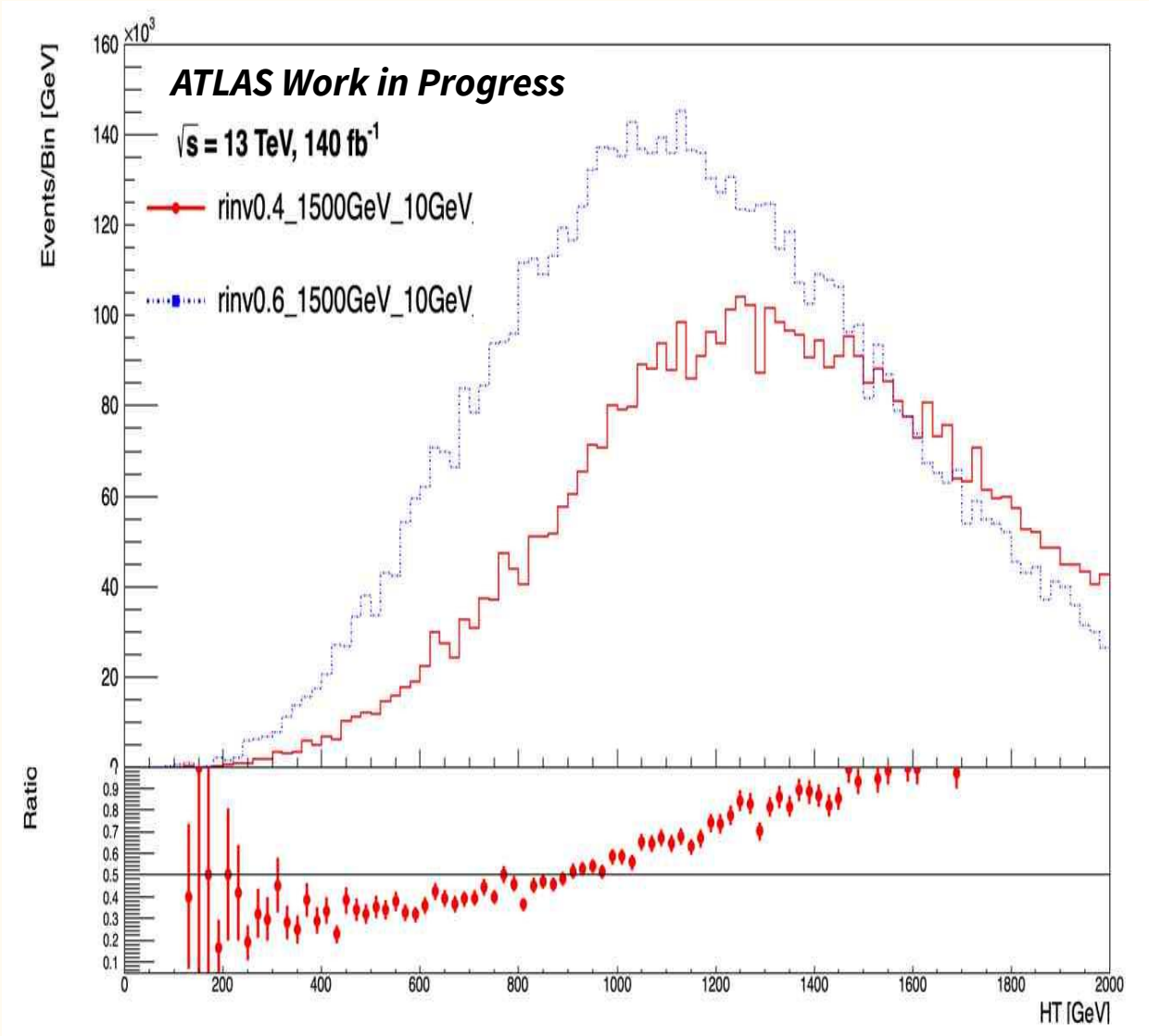
Event selections being considered for performance and optimization studies:

1. Looking at events with MET trigger
2. Minimum MET > 200 GeV
3. No leptons

First look at Detector level samples



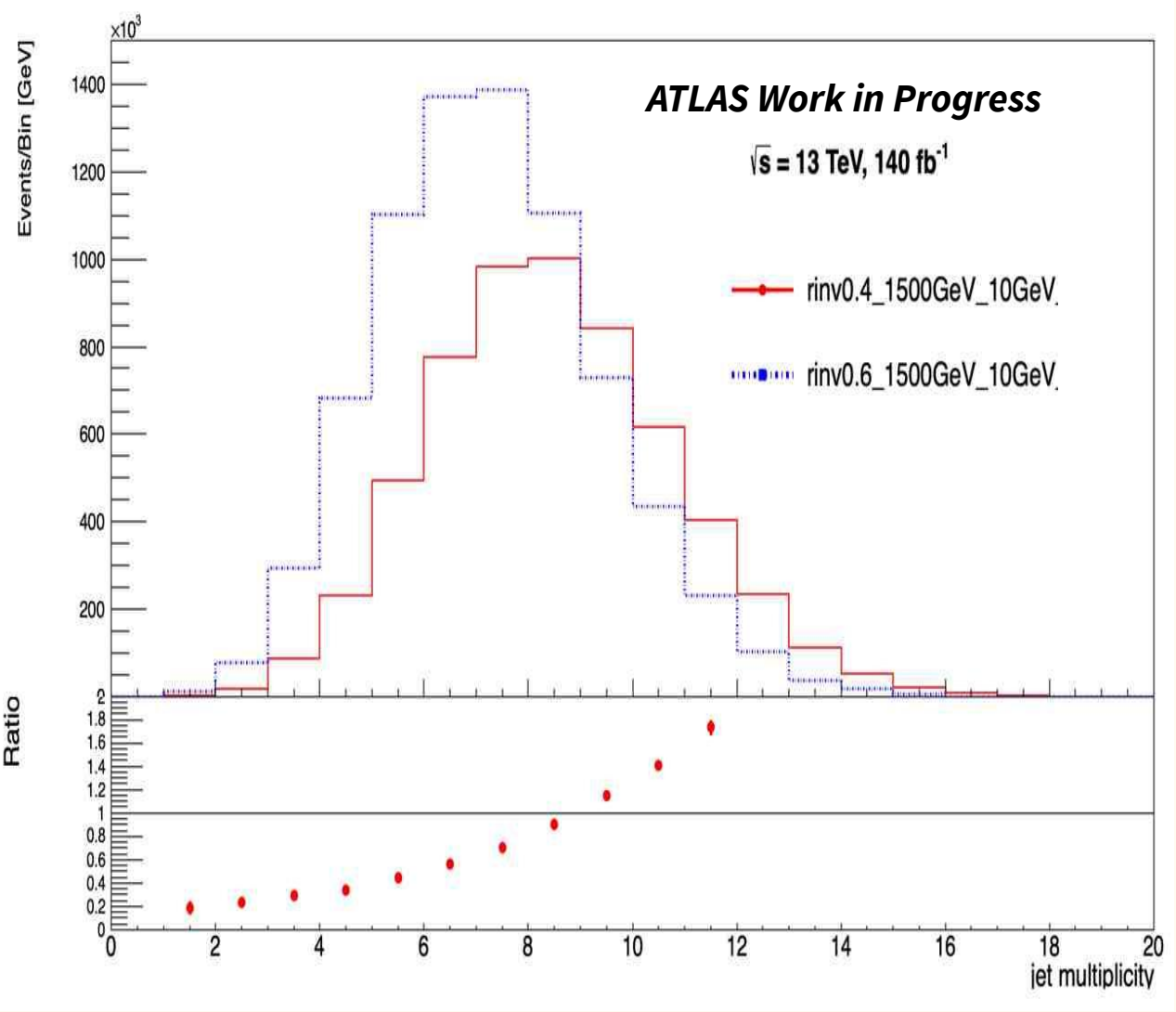
MET plot

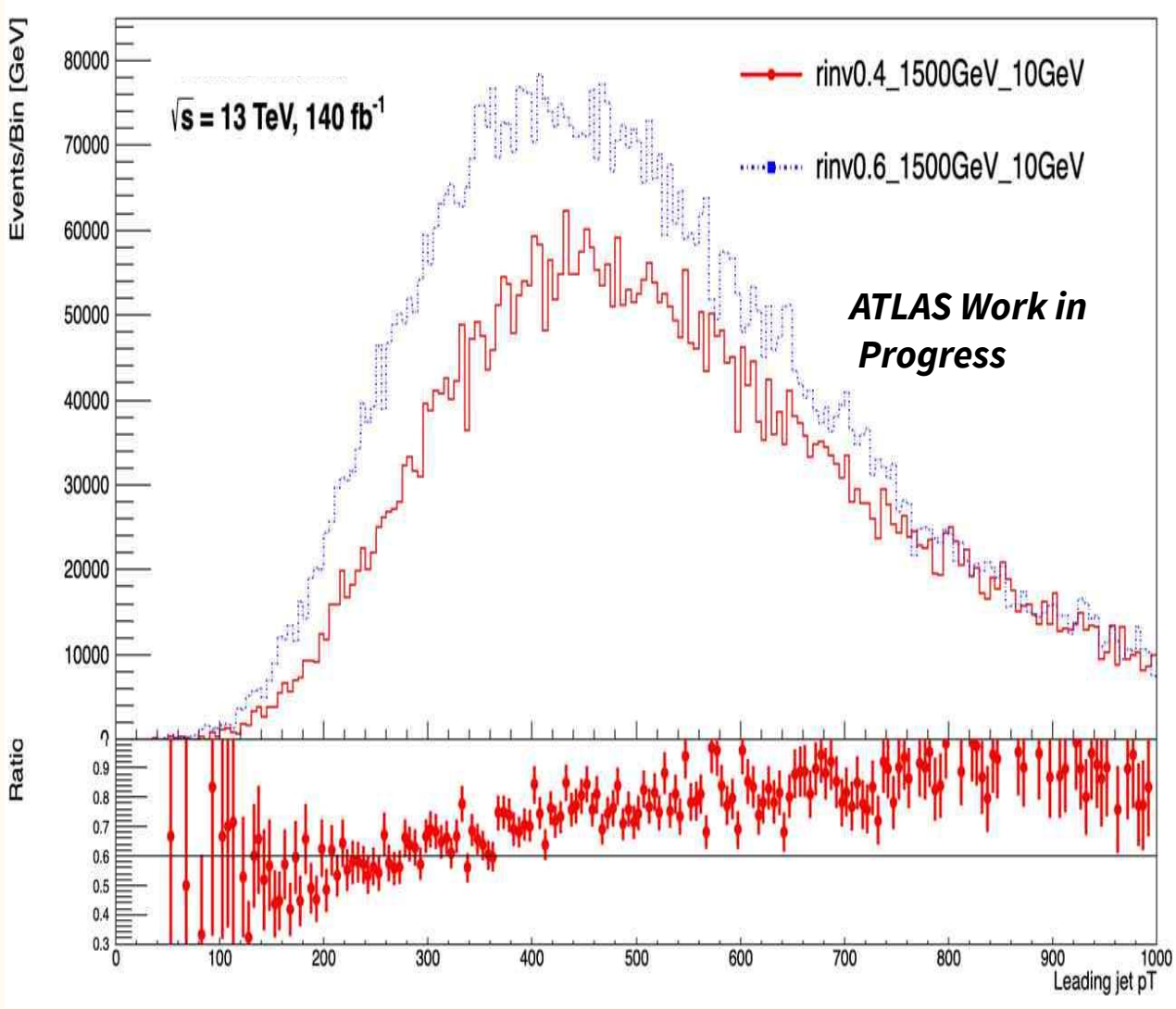


H_T Plot

A minimum criteria of missing transverse momentum > 200 GeV is necessary to study semi visible jets over QCD jets, and H_T indicates that events have a lot of energetic jets.

First look at Detector level samples





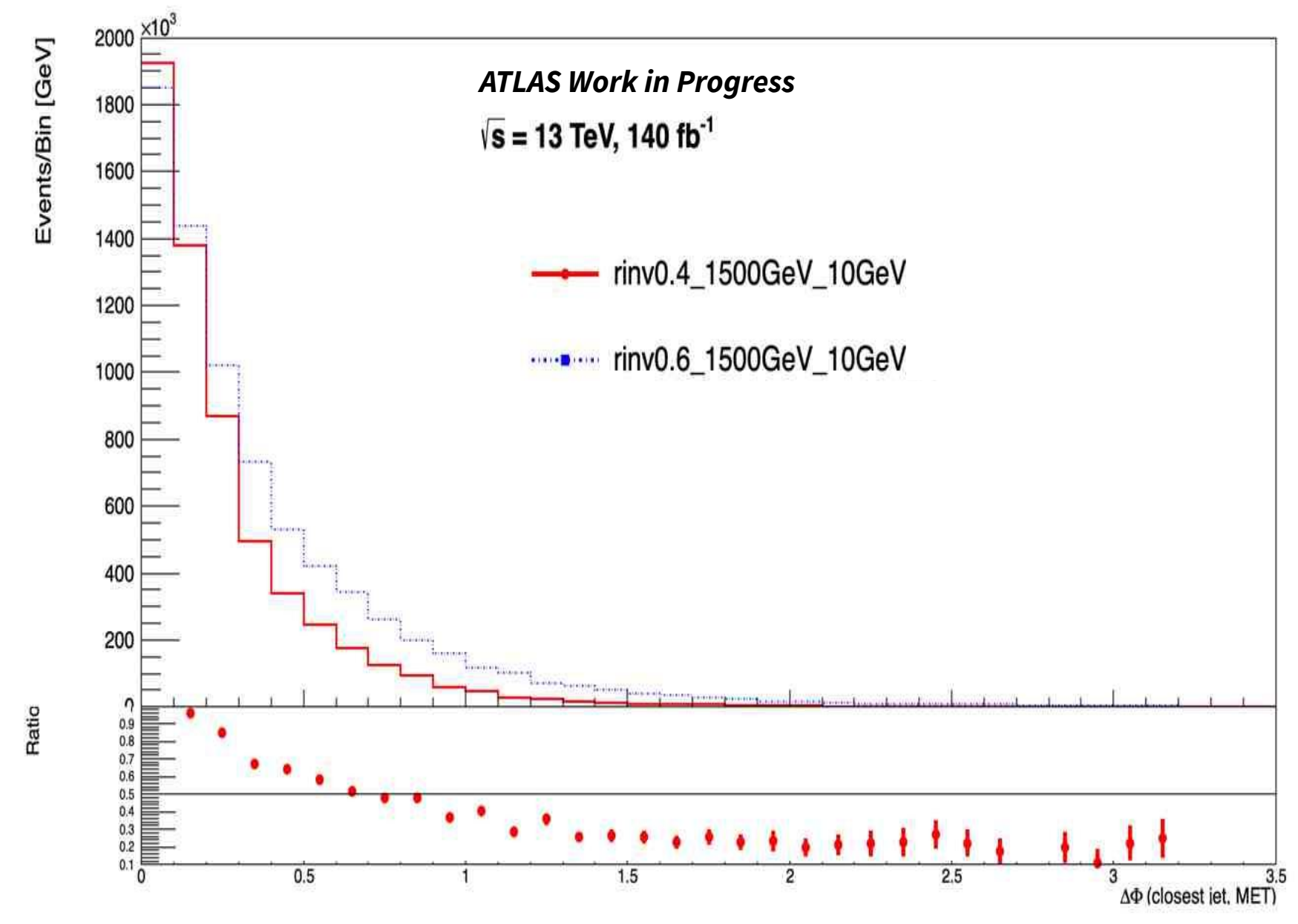
Jet Multiplicity Plot

High jet multiplicity as seen before!

Leading jet pT plot

Leading jet is very energetic.

First look at Detector level samples



Δϕ plot

Overall trend matches with particle level studies!

Most no.of events in Δϕ < 0.5 (i.e. MET is mostly close to the jet)

Next Steps

- First look at semi-visible jets in ATLAS! No experimental public result yet.
- We think the semi-visible “additions” to DMSimp (model in MadGraph) make it radiate significantly more. Want to understand Semi Visible Jets radiation model with DMSimp.
- Need to decide control region for cut and count approach.
- Jets with MET along it are usually discarded, and hence some performance study maybe necessary to explore this unique topology.
- Investigate jet substructure variables → may help discriminate SVJ from quark/gluon jets.