Exploration of b-philic SVJ and new discriminating observables

Deepak Kar with Sukanya Sinha, Wandile Nzuza, Nishita Desai

CERN, May 2024

Exploration of b-philic SVJ and ~~new discriminating observables~~

Deepak Kar with Sukanya Sinha, Wandile Nzuza, Nishita Desai

CERN, May 2024

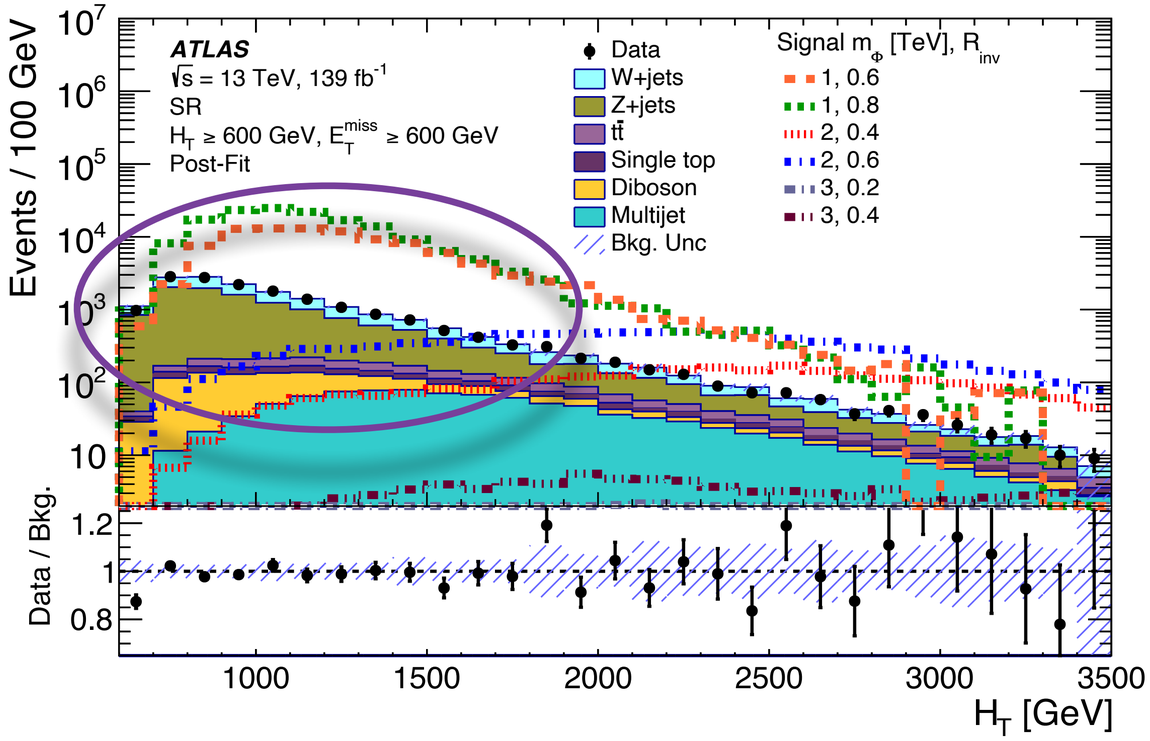
Exploration of b-philic SVJ and studies on SVJ generation

Deepak Kar with Sukanya Sinha, Wandile Nzuza, Nishita Desai

CERN, May 2024

Part 1: SVJ with heavy flavour

ATLAS Published Result:



- Experimentally: can we reduce our dominant background in the most signal-rich region?
- Theoretically: well motivated, helicity flipping suppression can force the dark ρ to go to $b\bar{b}$.
- The advantage: the SVJ candidate can be better identified by the presence of b-hadrons.

Current Constraints?

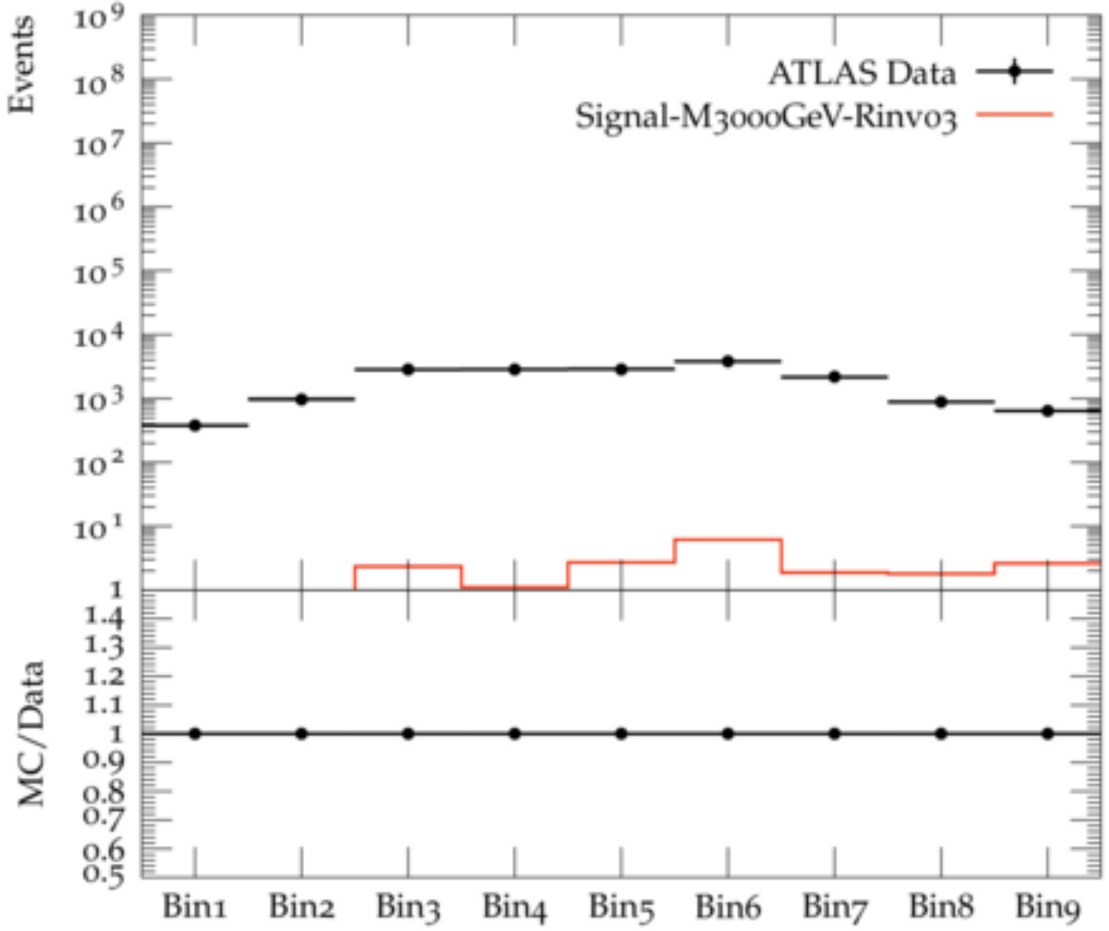
- ATLAS t-channel SVJ: *Phys. Lett. B 848 (2024) 138324*
- ATLAS Hbb+DM: *JHEP 11 (2021) 209*
- SUSY with MET and 3 or more b-jets: *Eur. Phys. J. C 83 (2023) 561*

  Also Deborah Pinna's talk from yesterday…

Current Constraints?

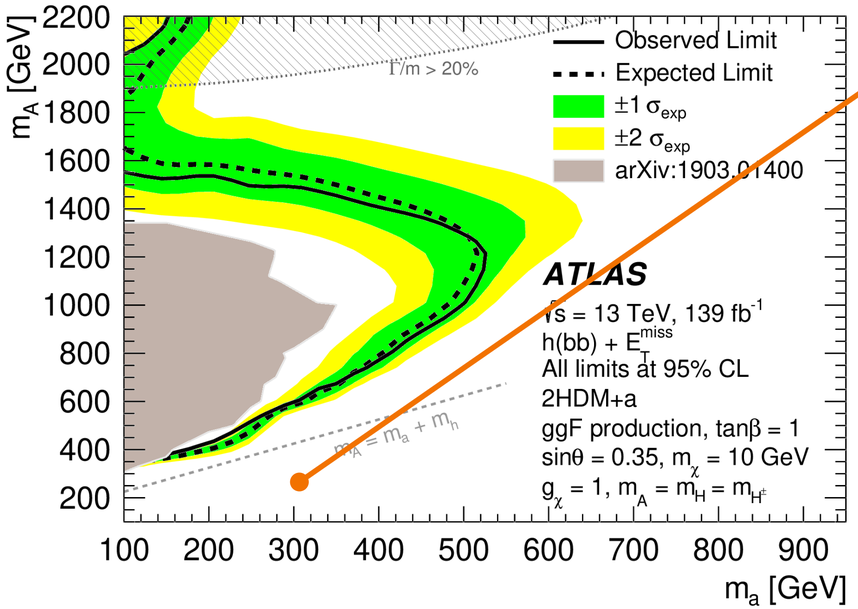
- ATLAS t-channel SVJ: *Phys. Lett. B 848 (2024) 138324*

Lower cross-section,
SR requirement of less than two b-jets



Current Constraints?

- ATLAS Hbb+DM: JHEP 11 (2021) 209



Selection	Benchmark signal ATLAS yield	Benchmark signal our yield	Data yield	SVJ-b signal yield
2 b-tagged SR				
$150 \leq E_{\mathrm{T}}^{\mathrm{miss}} < 200$ GeV	60	110	14259	39
$200 \leq E_{\mathrm{T}}^{\mathrm{miss}} < 350$ GeV	70	100	13724	59
$350 \leq E_{\mathrm{T}}^{\mathrm{miss}} < 500$ GeV	3.6	6	799	0.28
3 b-tagged SR				
$150 \leq E_{\mathrm{T}}^{\mathrm{miss}} < 200$ GeV	5.3	9	408	0.5
$200 \leq E_{\mathrm{T}}^{\mathrm{miss}} < 350$ GeV	18	7	658	1.8
$350 \leq E_{\mathrm{T}}^{\mathrm{miss}} < 500$ GeV	2.9	0.5	42	0.2

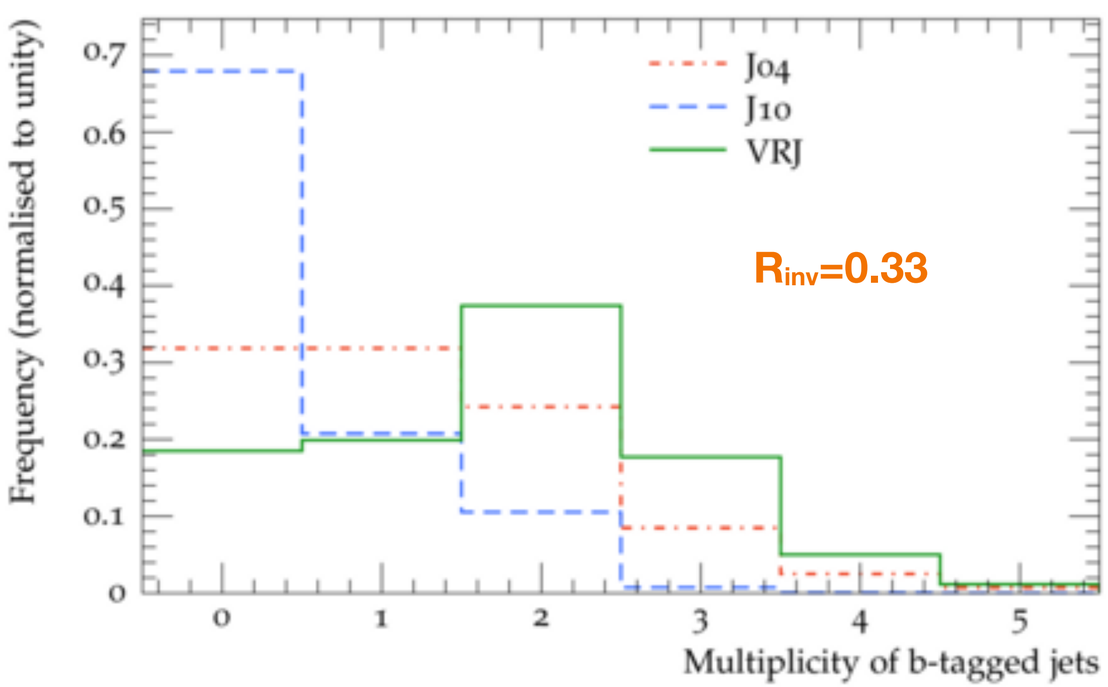
Current Constraints?

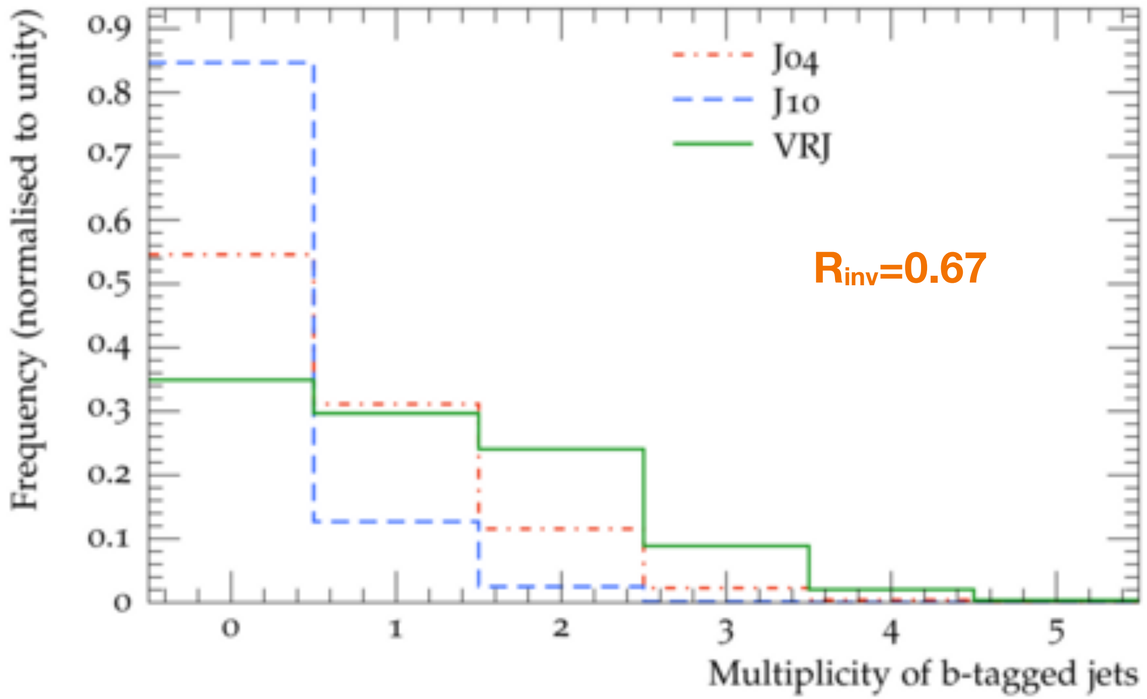
Selection	Benchmark signal ATLAS yield	Benchmark signal our yield	Data yield	SVJ-b signal yield
SR-B	10.13	7	7	0
SR-M	28.30	18	18	0
SR-C	34.71	32	32	0

- SUSY with MET and 3 or more b-jets: *Eur. Phys. J. C 83 (2023) 561*

There may be other/newer analyses though … but also signal modelling is far from settled

What jets to use?





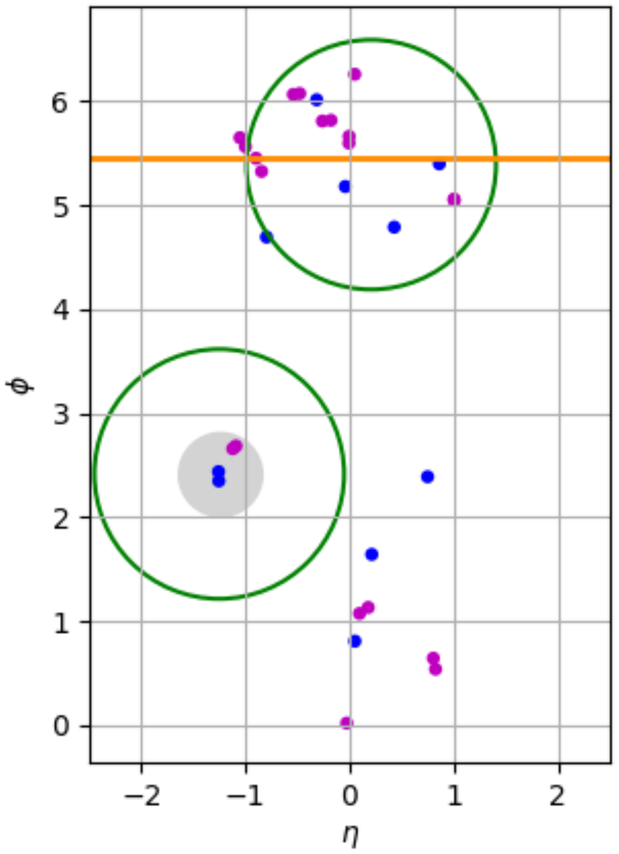
Jet multiplicity: indicative of signal selection efficiency

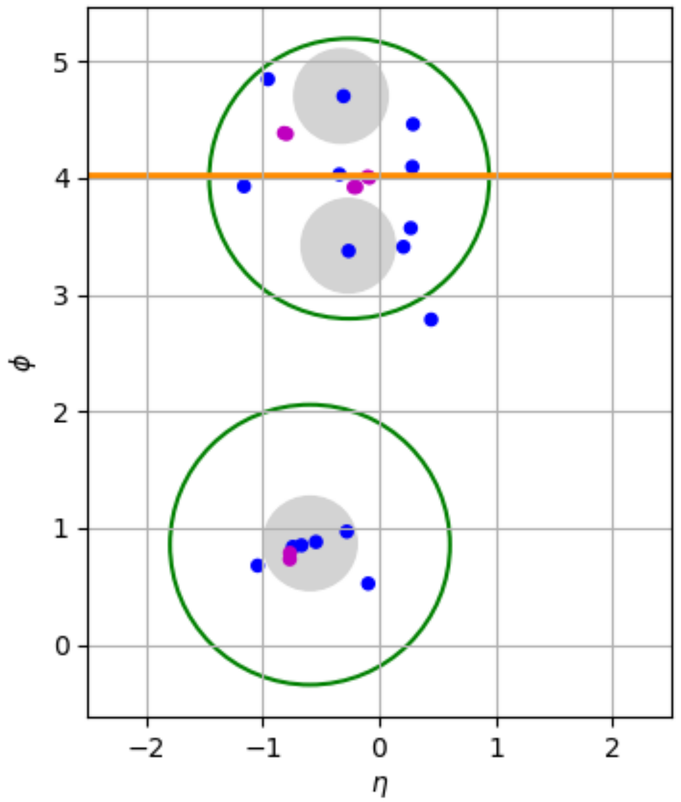
An Aside: VR jets

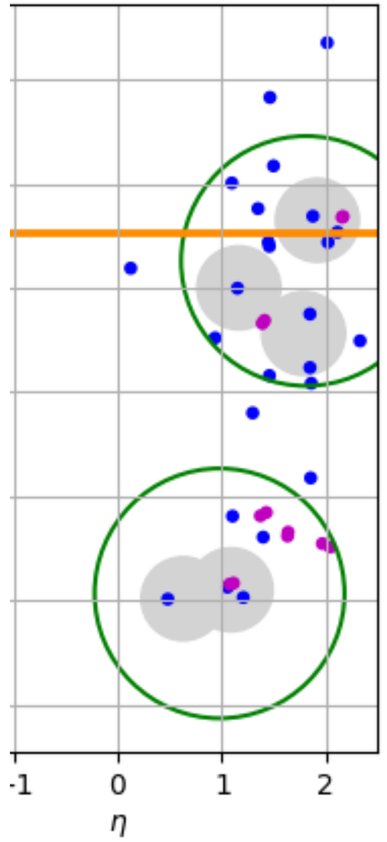
- SVJs typically have larger spread, with *holes* in them.
- Large radius jets typically have a high p_T threshold, which misses a lot of signal
- **V**ariable **R**adius jets can have an expanded radius based on a mass-like parameter rho over p_T of the jet.
- Conservatively, we used Antik$_T$4 jets as inputs.

	Selection Efficiency in %	
Selection	Signal R_{inv}= 0.33	Signal R_{inv}= 0.67
J04	33	12
J10	11	3
VRJ	60	35

Example Events

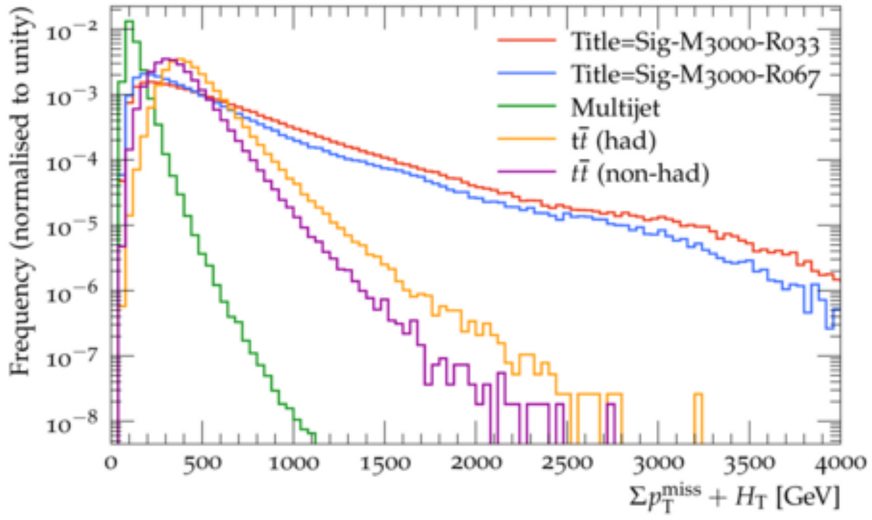


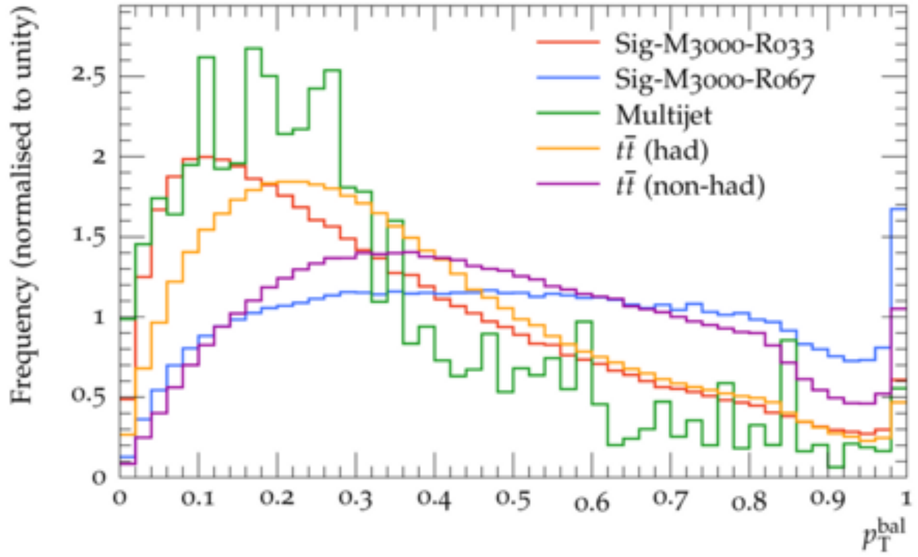


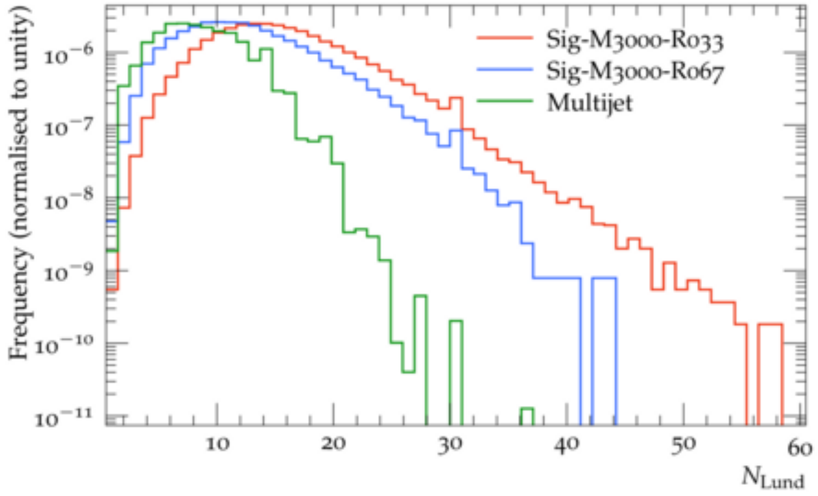


Shows the advantage of using VR jets

Some Promising Observables







No golden bullet, but MET is a very detector level observable …

Part 2: SVJ Generation Models

- Only one we have so far: Pythia8 HV, and the model parameters are still being discussed.
- Many parameters, with non-trivial impact on the produced signature or interpretation of result.
- Herwig7 HV model is under active development ;-)
- Question: can we have a simplified topology generator, while not doing something *obviously wrong*

Sabine Hossenfelder 
@skdh

That's basically what it is. The "dark sector" or "hidden sector" is a name for increasingly contrived and complex collections of particles (and their interactions) which physicists have invented and that no one has ever seen.

> 
> **Benjamin Titus** @Benny_Switch · Feb 14
> Replying to @WKCosmo
> Please tell me what “Dark Sector” means. I thought I was well read enough, but I’ve been seeing this phrase thrown around and all I get from it is “additional Dark things that may or may not be there”

Will Kinney 
@WKCosmo

There's a very good reason why the default assumption is that dark matter consists of a single type of particle: Dark matter must be stable, and only the lightest particle in a mass hierarchy is stable. For example, the only stable baryon in the Standard Model is the proton.

2:36 AM · Feb 15, 2023 · **72.4K** Views

33 Retweets **17** Quote Tweets **411** Likes

SVJ Generation Models

- Only one we have so far: Pythia8 HV, and the model parameters are still being discussed.
- Many parameters, with non-trivial impact on the produced signature or interpretation of result.
- Herwig7 HV model is under active development ;-)
- Question: can we have a simplified topology generator, while not doing something *obviously wrong*

Developed by Nishita Desai, details shown in (online) MITP Youngstars Dark Shower workshop last year (https://indico.mitp.uni-mainz.de/event/377/)

The idea:

Let dark quarks split into stable and unstable dark hadrons by Rinv fraction:

- The unstable dark hadron decays back to SM quarks -> SM hadrons.
- The stable dark hadrons are the invisible components.

The splitting is determined by: Average Number of Dark hadrons (N_{avg}) and energy distribution by:

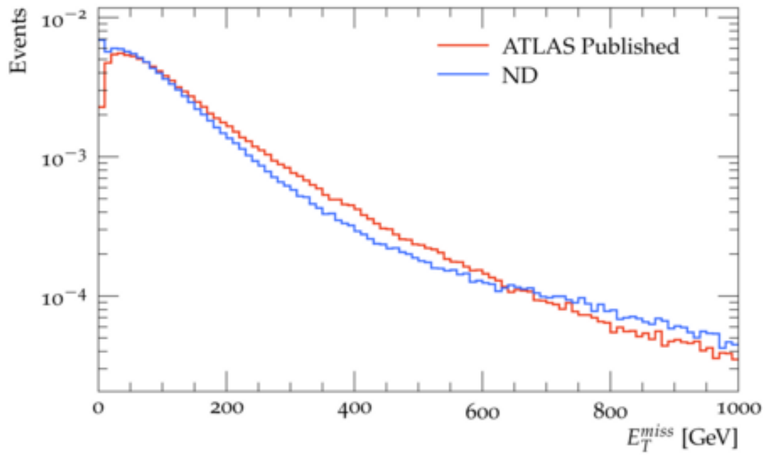
$$f(r) = \frac{1 - a^{2r}}{1 - a^{2r_{\max}}}$$

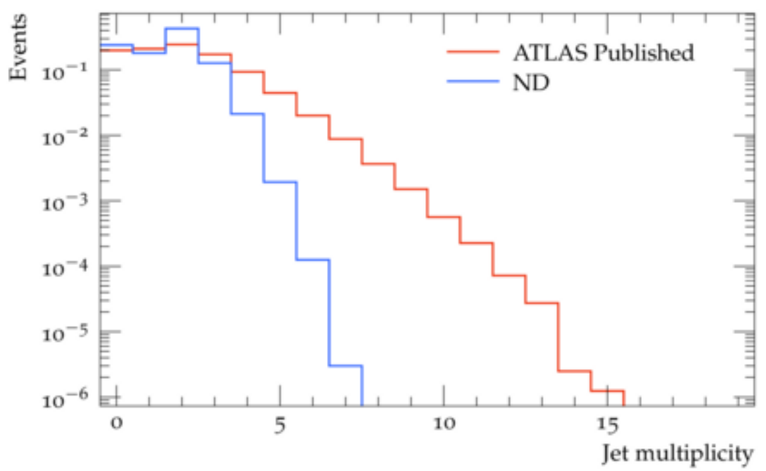
Less Free Parameters!

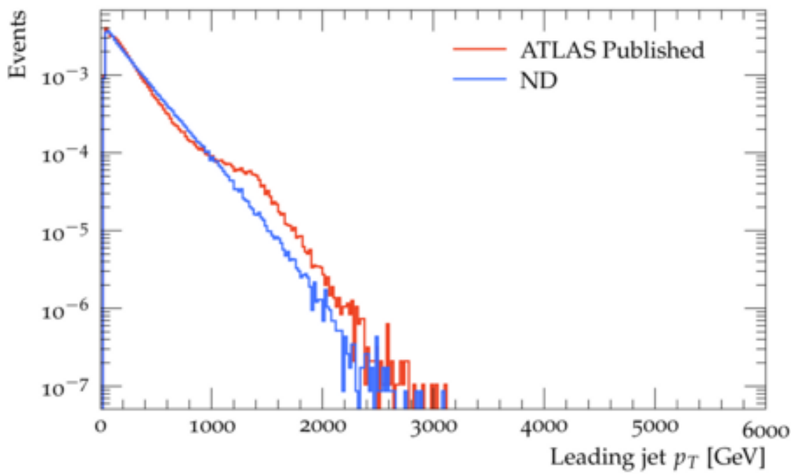
Exact number of hadrons in each event will be different so splitting in each event will be different. It depends on number of hadrons (which is in turn set by N_{avg} value)

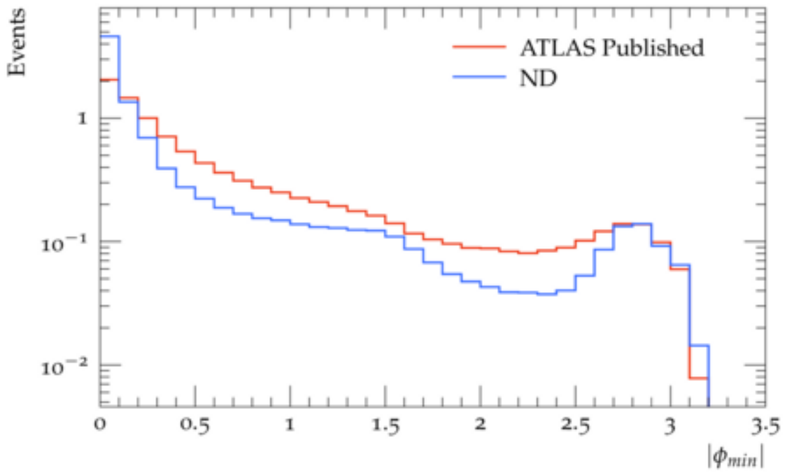
How does this look (work in progress)?

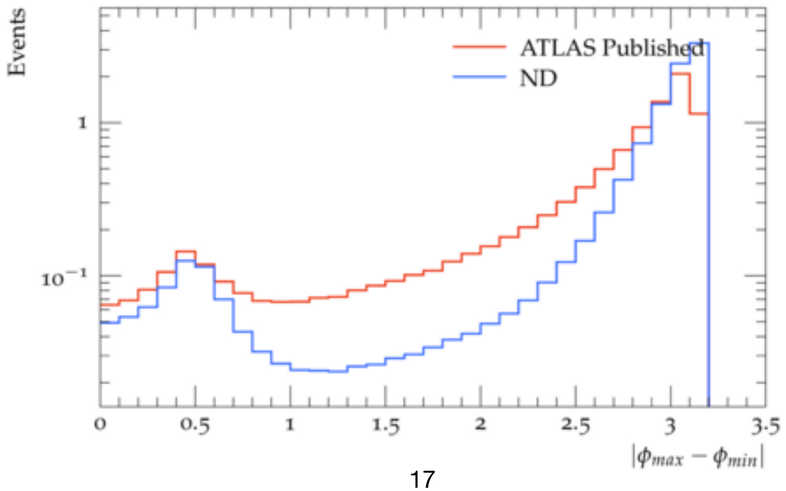
… with a specific parameter choice, fairly insensitive to reasonable variations

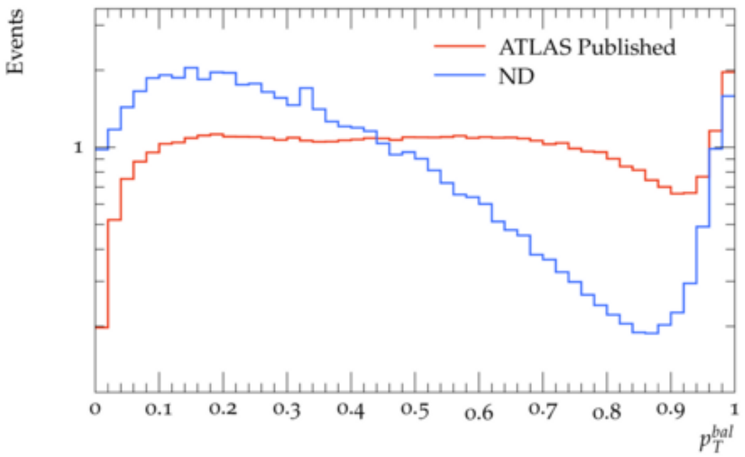












Not a Summary

… rather looking forward!

- Experiments want a simple (but not unphysical) way to generate unexplored signatures.
- Choices to be made: hard process (UFO for t-channel, mediator for s-channel, glueballs?), HV setup, simplified models …
- How to map an unmeasurable output R_{inv} to an input R_{inv}? For a single dark flavour, this is straightforward (ATLAS t-channel result) but for dark flavour of two (CMS s-channel result), rather complicated decay chain in an effort to conserve this. Again, can we simplify this, which will help in other SVJ-like signatures as well.
- Observables: stay tuned ;-)

A week back…