Debriefing: ATLAS SVJ Result

Deepak Kar
University of Witwatersrand (South Africa)

MITP Dark Showers Workshop (Online)
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But, first the briefing!

Physics Briefing

Tags:
LHCP 2023,
new physics,
dark matter,
physics results

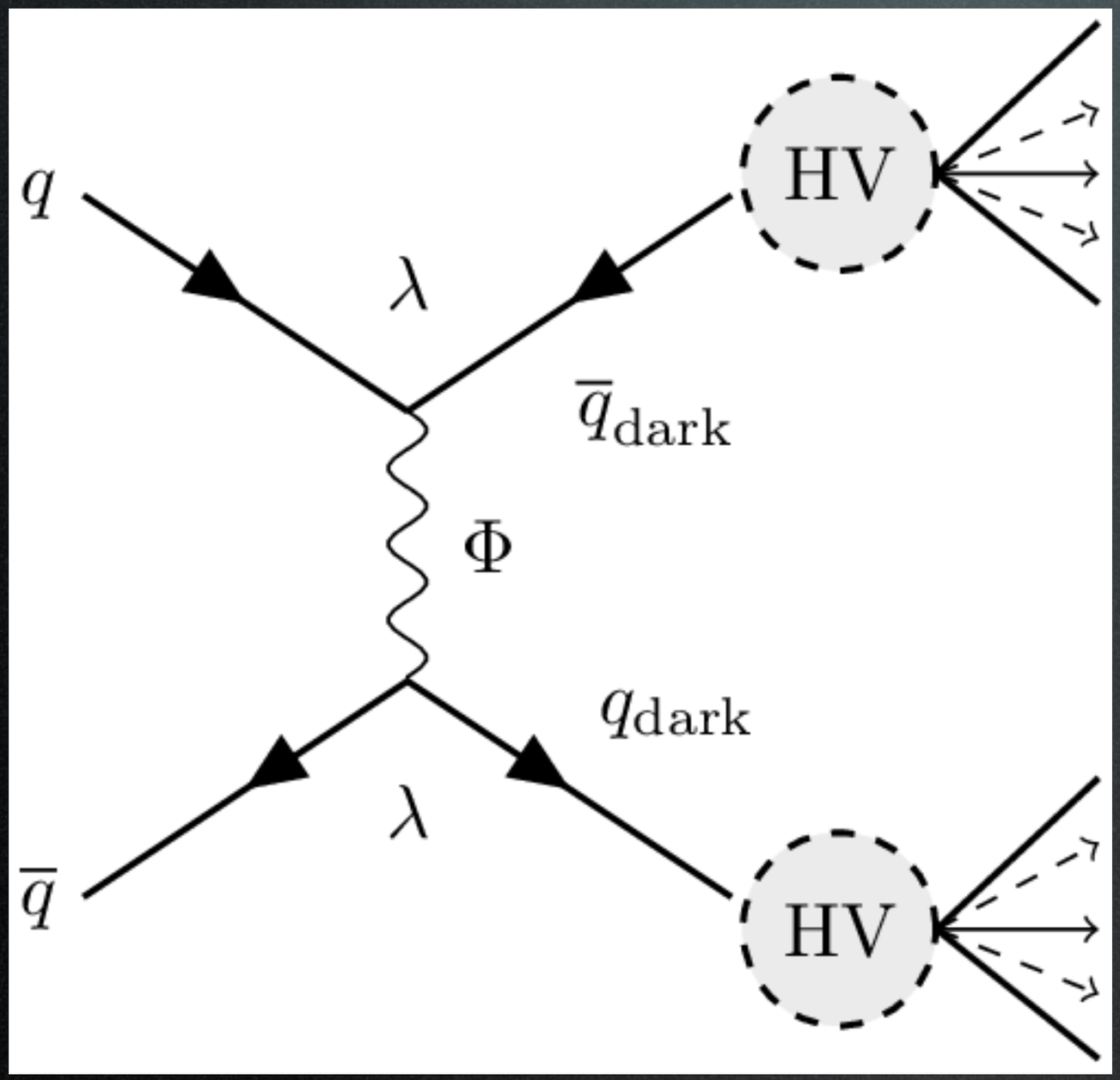
Not a jet all the way: is dark matter hiding in plain sight?

26 May 2023 | By ATLAS Collaboration

What happens if dark-matter particles are produced inside a jet of Standard-Model particles? This leads to a novel detector signature known as semi-visible jets! The ATLAS Collaboration has come up with the first search for semi-visible jets, looking for them in a general production mode where two protons interact by exchanging an intermediate particle, which is then converted into two jets.

The elusive nature of dark matter remains one of the biggest mysteries in particle physics. Most of the searches have so far looked for events where a “weakly interacting” dark-matter particle is produced alongside a known Standard-Model particle. Since the dark-matter particle cannot be seen by the ATLAS detector, researchers look for an imbalance of transverse momentum (or “missing energy”). However, some theoretical models predict a “strongly interacting” dark sector, with dark quarks and gluons as replicas of Standard-Model quarks and gluons. Semi-visible jets would arise when dark quarks decay partially to Standard-Model quarks and partially to stable dark hadrons (the “invisible fraction”). Since they are produced in pairs, typically along with additional Standard-Model jets, the missing energy arises when all the jets are not fully balanced. The direction of the missing energy is often aligned with one of the semi-visible jets, as can be seen in the event display above.

What We Searched for?

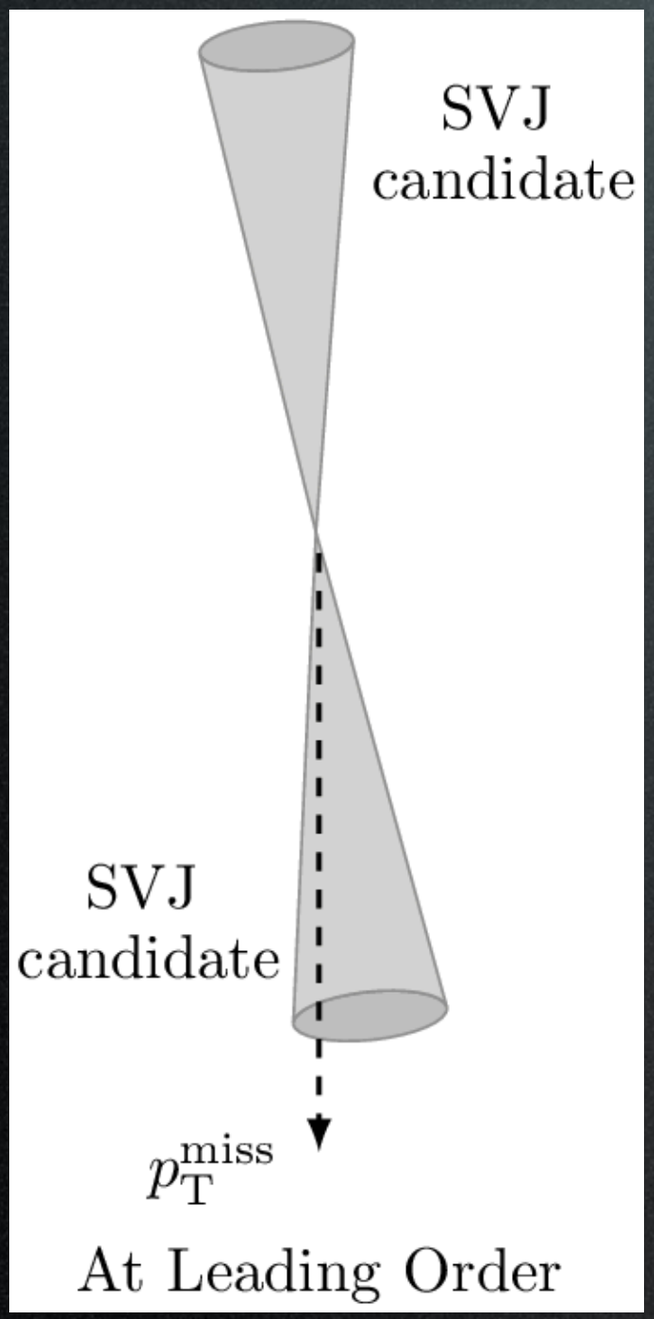


SVJ in t-channel production mode

Signal simulation Making use of Pythia8 HV module

arXiv:2305.18037

The topology and the challenges for SVJ

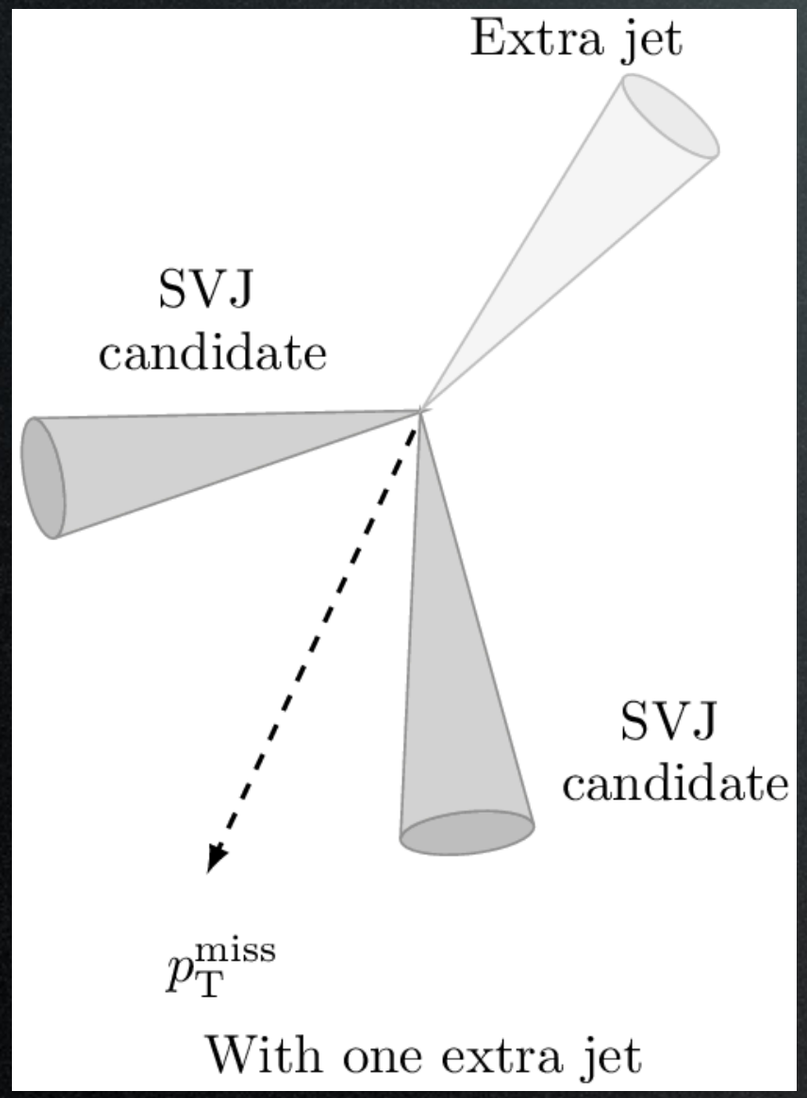


Same fraction
of dark hadrons
In each jet

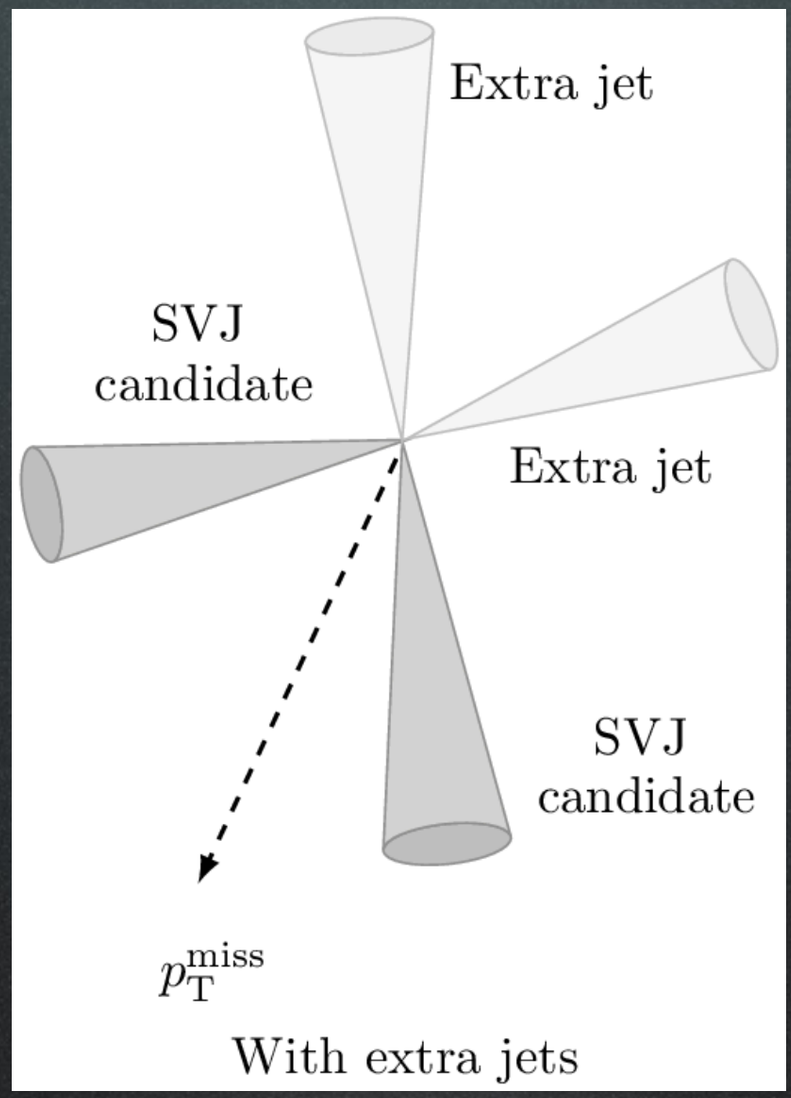
Why any **MET**?

arXiv:2305.18037

The topology and the challenges



With one extra jet



With extra jets

A real event will look like this!

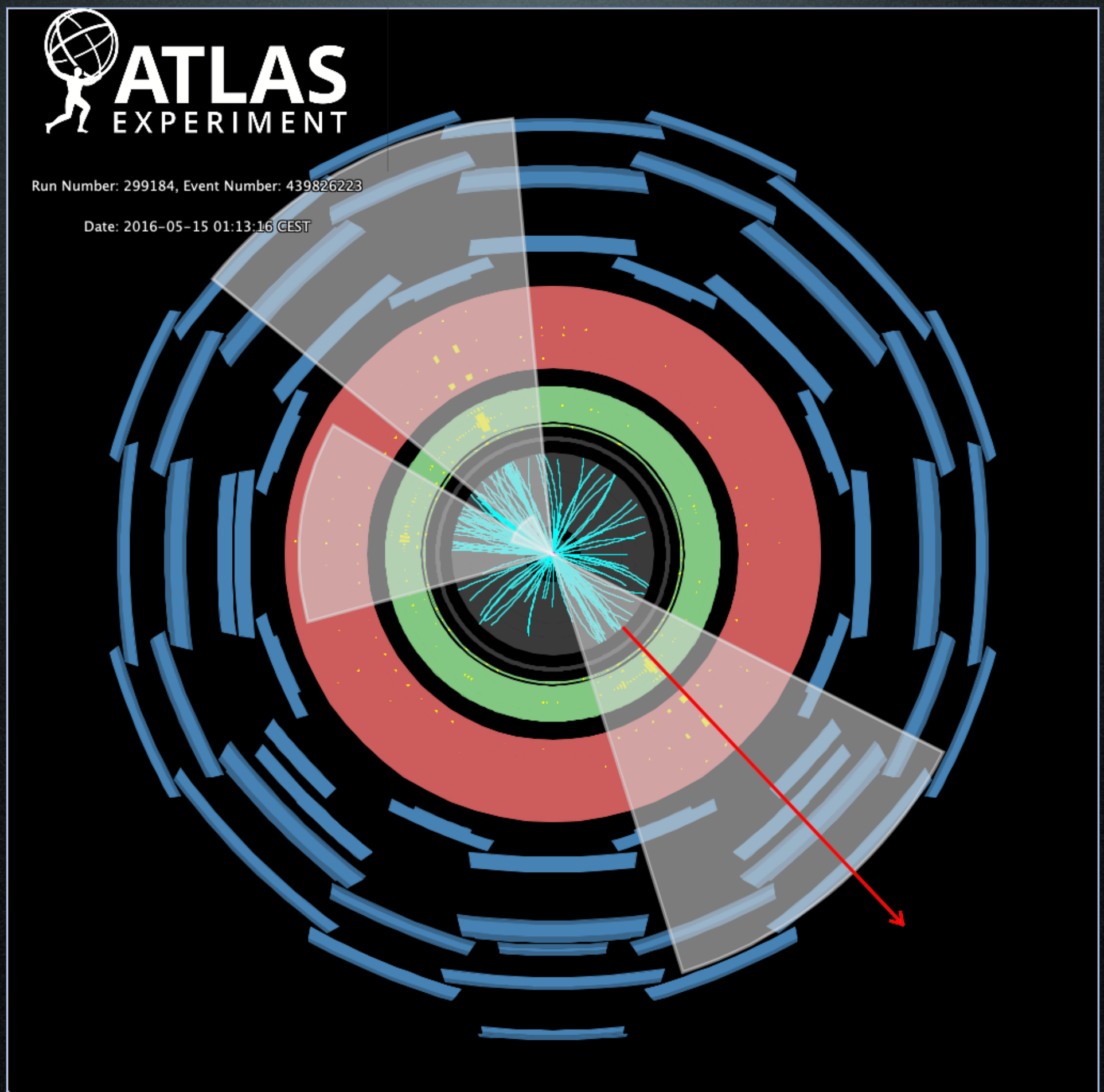
Quantum fluctuations, and boost by extra jets

Therefore MET

ATLAS EXPERIMENT

Run Number: 299184, Event Number: 439826223

Date: 2016-05-15 01:13:16 CEST



Signal Samples: into the Hidden Valley

- Simplest possible implementation to give a search-able experimental signature.

- Single dark QCD flavour, one loop running of dark QCD coupling, confinement scale of 6.5 GeV, coupling between dark and SM sector taken to be unity.

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”

… into the hidden valley!

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

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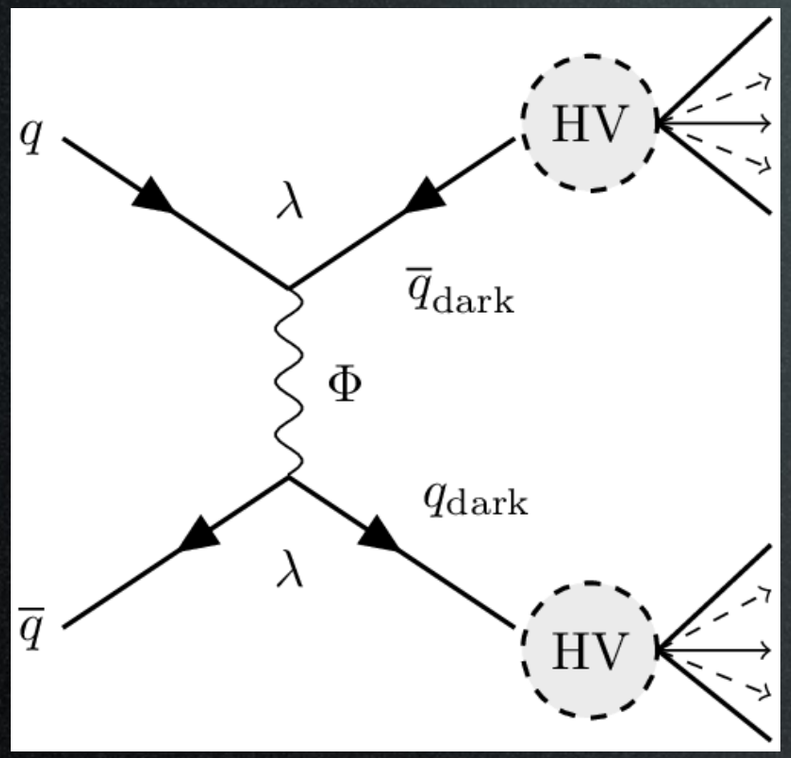
SVJ Search



Results in jets interpersed with dark hadrons, with missing transverse momentum direction aligned with one of the SVJs in leading order. Not so for events with extra jets and large boost.

Events with two central jets, MET trigger, leading jet p_T > 250 GeV, H_T > 600 GeV, MET 600 > GeV, jet closest to MET with $\Delta\Phi$<2

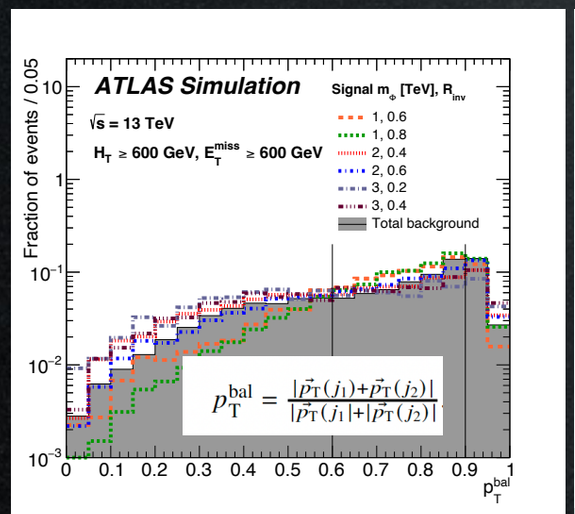
Define: SR (muon veto), and three CRs, 1L, 1L1B, 2L (with muons and b-tagged jets)

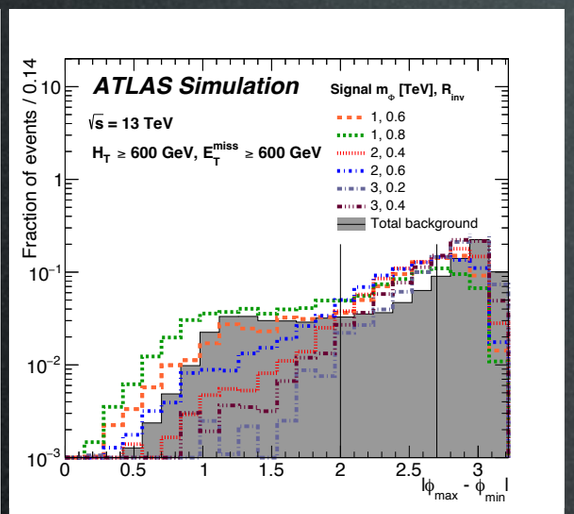
Usually signs of detector noise, so discarded in analyses

arXiv:2305.18037

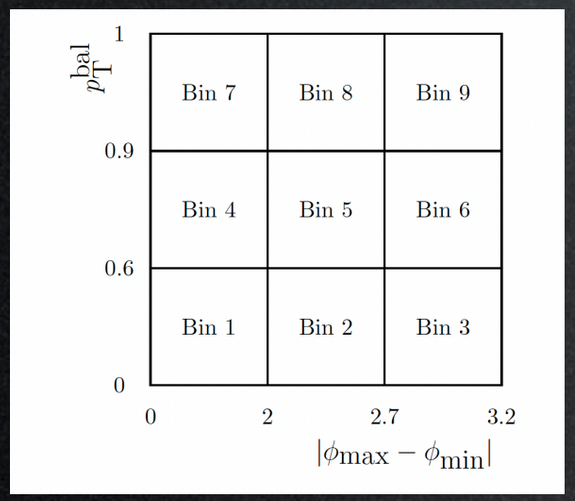
Background Estimate

Two sensitive observables:

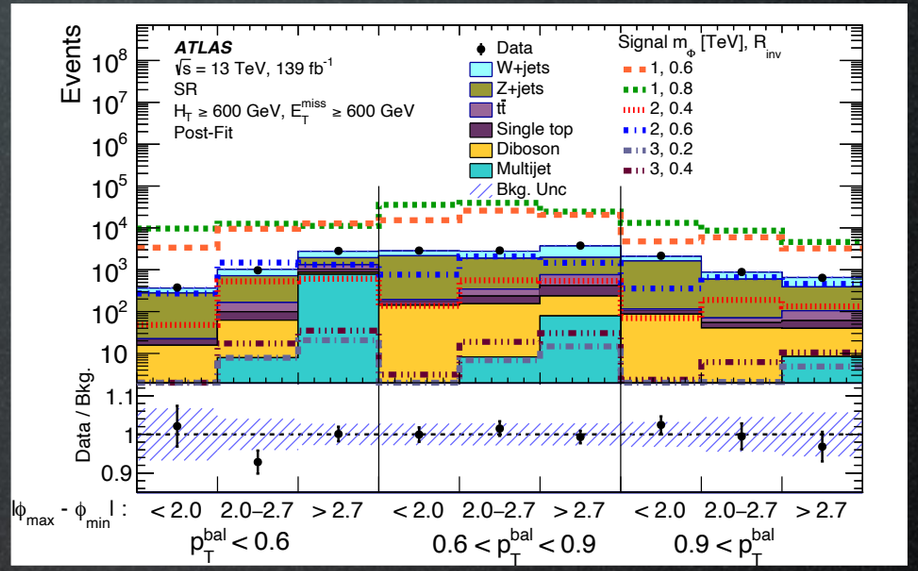




Used to Form a 9-bin grid, with yields in each bin treated as observables:



Partially data-driven method, simultaneously fit SR and three CRs to obtain scale factors for each bg process:



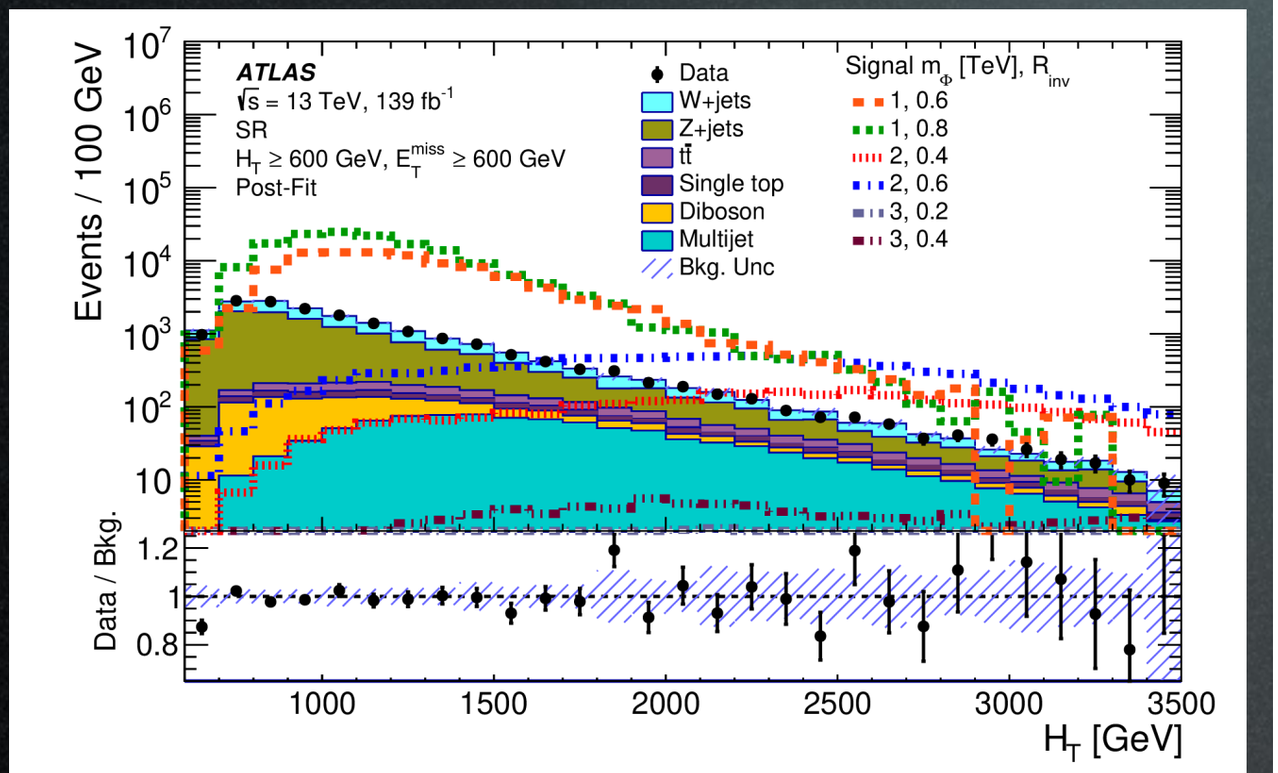
Process	k^{SF}
Z+jets	1.18 ± 0.05
W+jets	1.09 ± 0.04
Top processes	0.64 ± 0.04
Multijet	1.10 ± 0.04

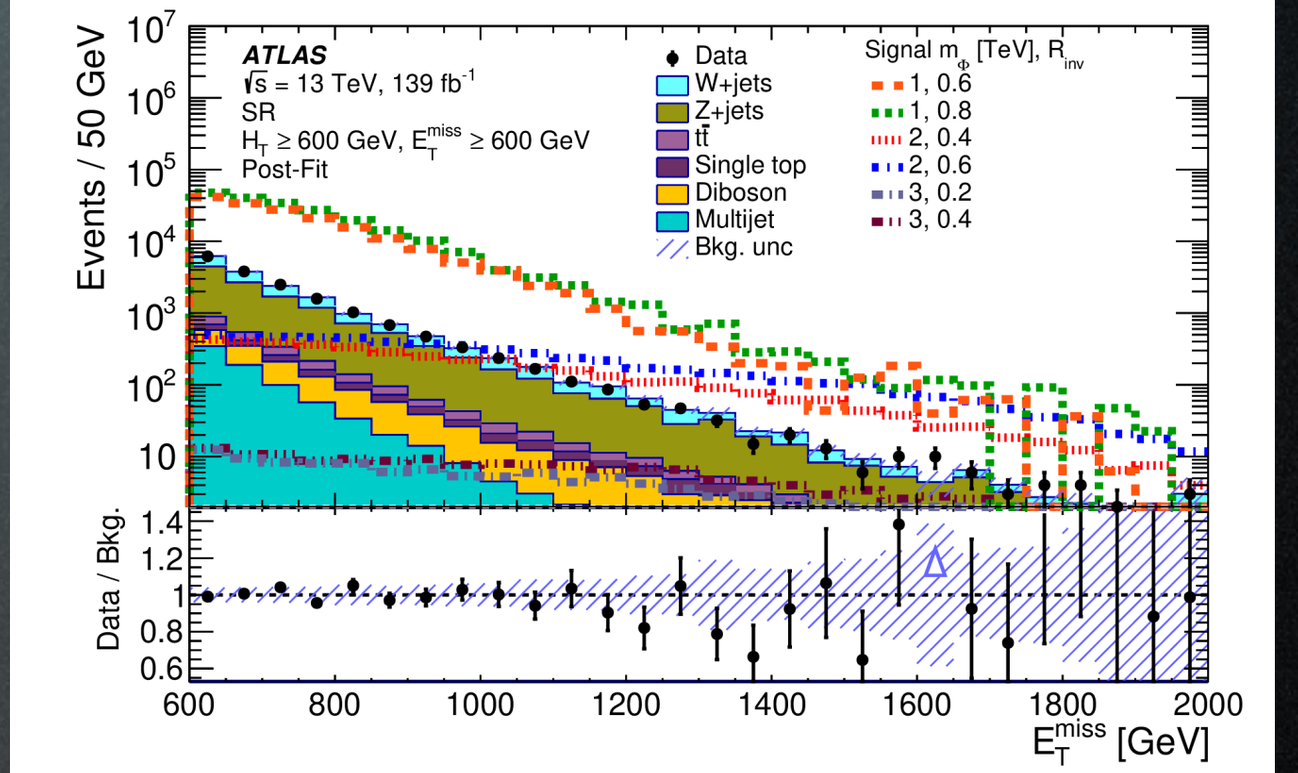
Absence of signal, good postfit agreement :(

Multijet reweighed in using a dedicated VR given by MET within 250 to 300 GeV, then fitted

arXiv:2305.18037

Results

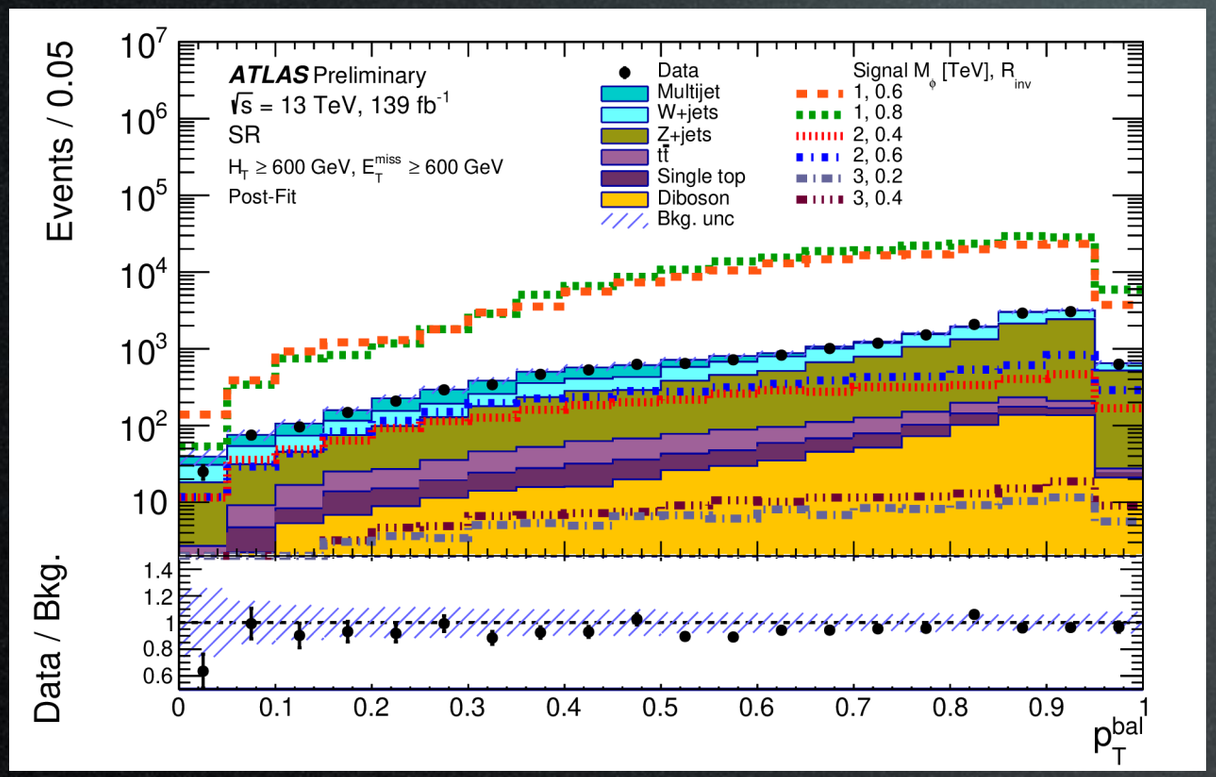


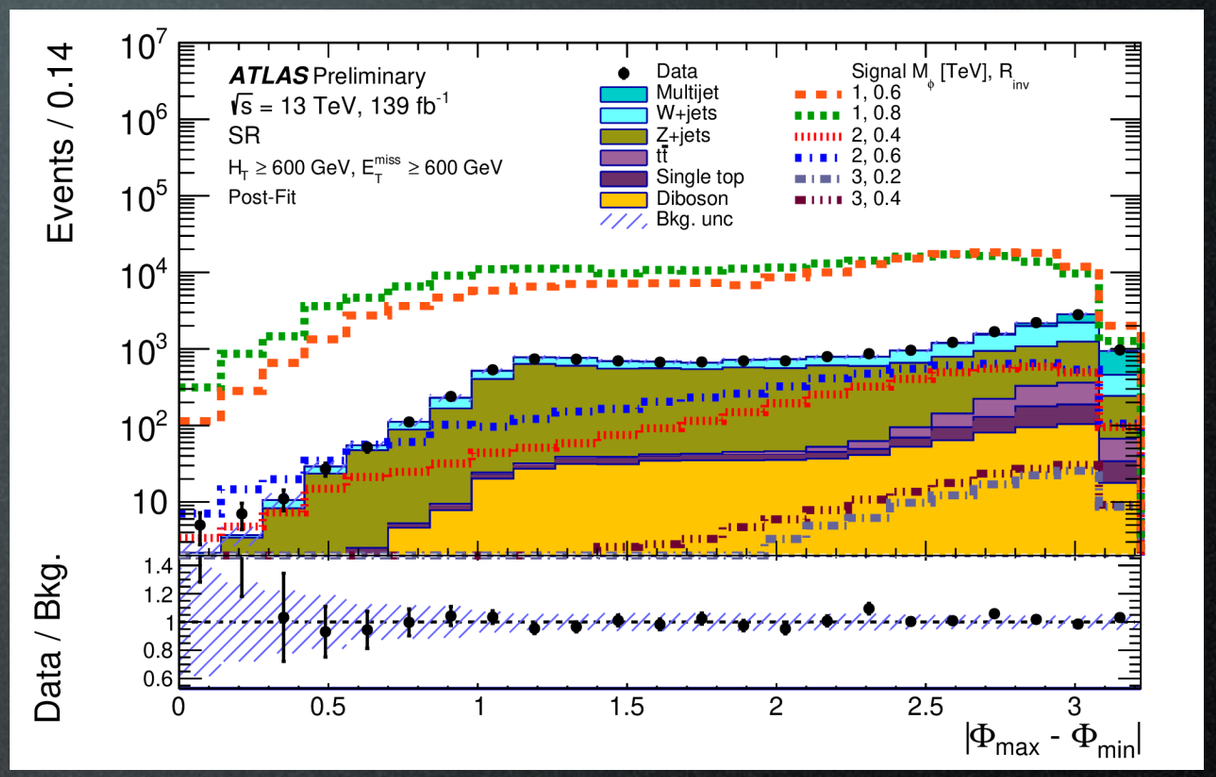


Excellent agreement between data and background prediction: H_T and MET

arXiv:2305.18037

Results



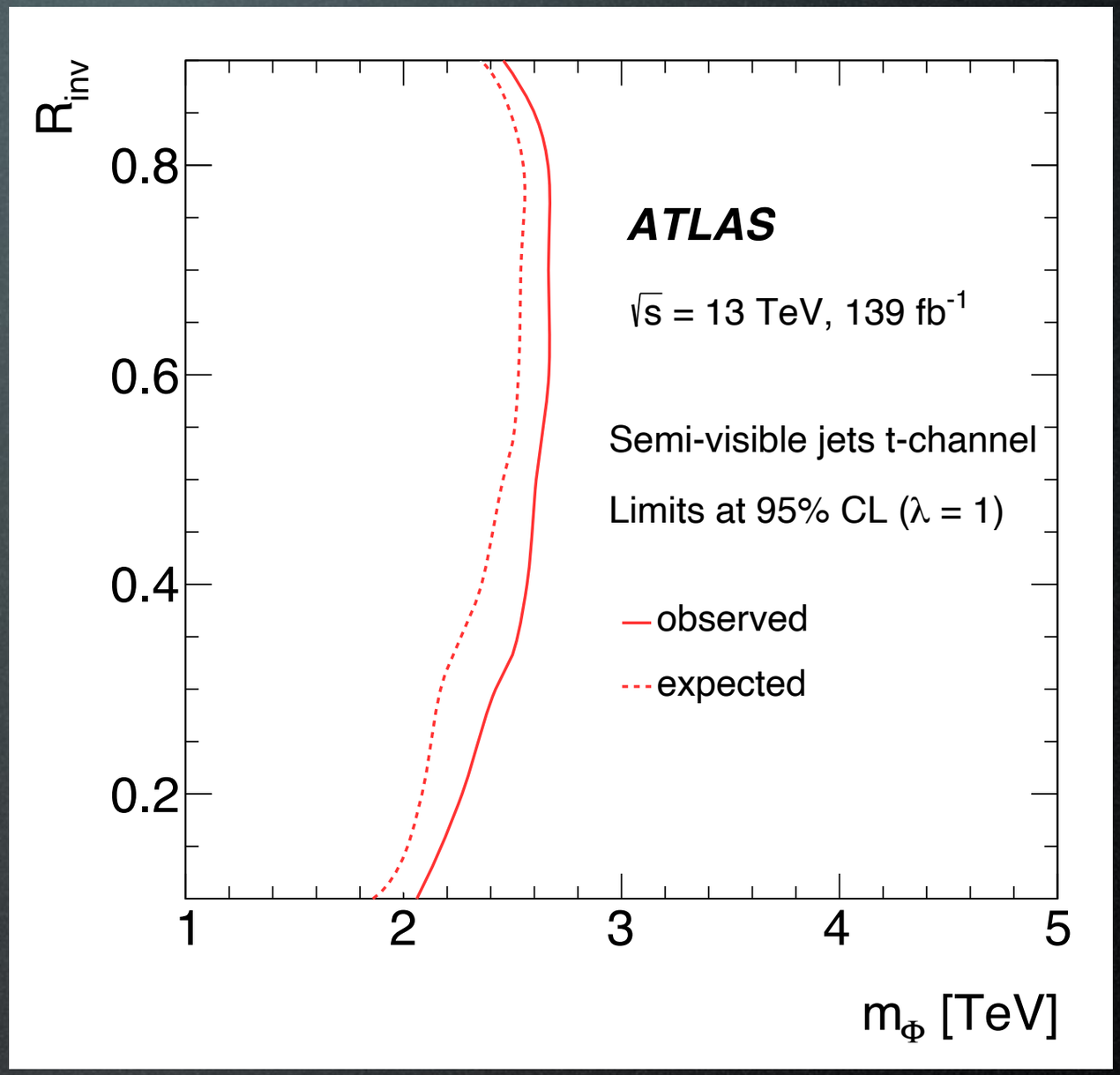


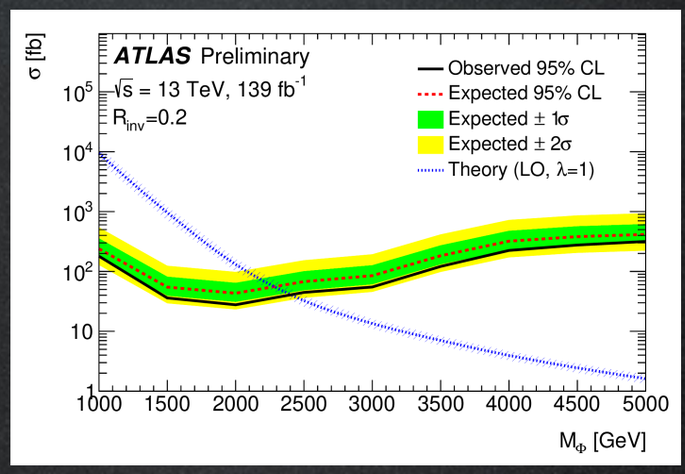
Excellent agreement between data and background prediction: $P_T^{balance}$ and max-min ϕ

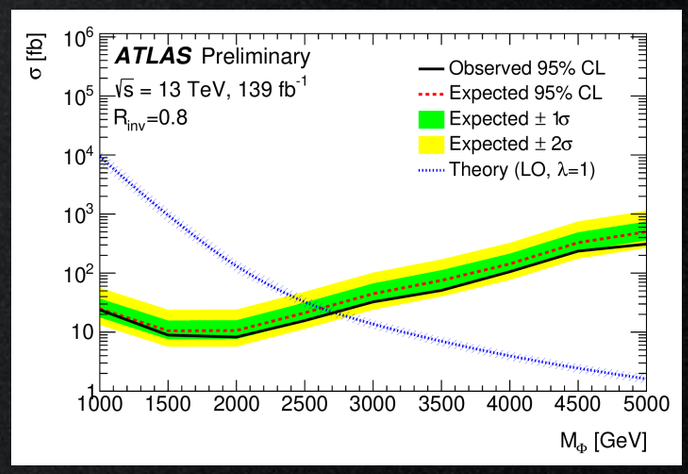
arXiv:2305.18037

Results

- Excellent agreement between data and background prediction.
- Limits on mediator mass separately for each R_{inv}
- Data yield in SR, proxy for model independent limit with this SR selections: 17388







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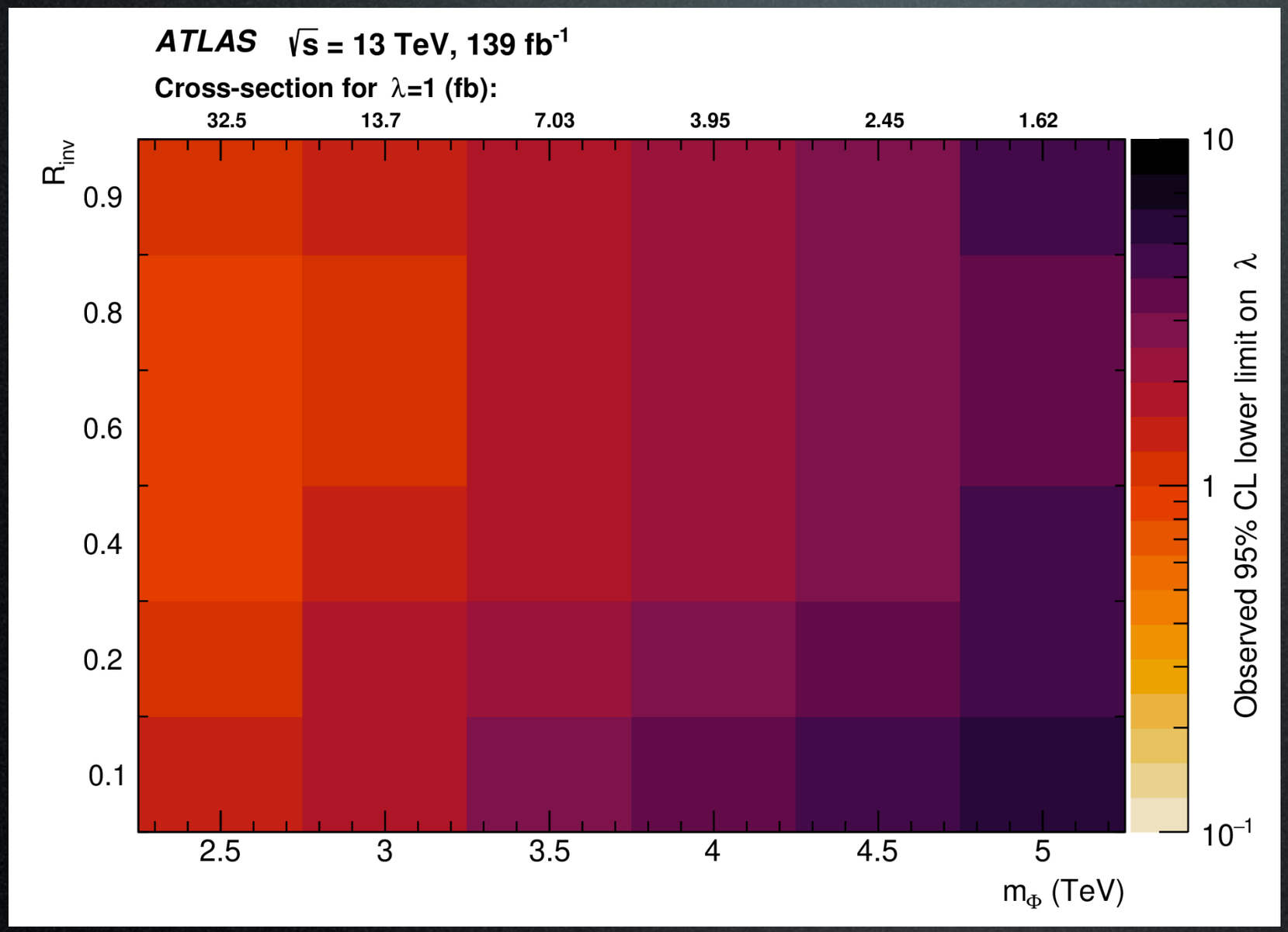
Results



For mediator mass of 2.5 TeV or higher can also express the limits in terms of the q-q_d-ϕ vertex coupling strength λ, with the XS scaling as λ^4

Summary

- Novel signatures are fun!
- Perhaps we need more a bottom up/ signature driven approach than a top down/model driven approach?
- Unless we search for them, can't really rule them out, can we?

Discussion points For the WS highlighted!