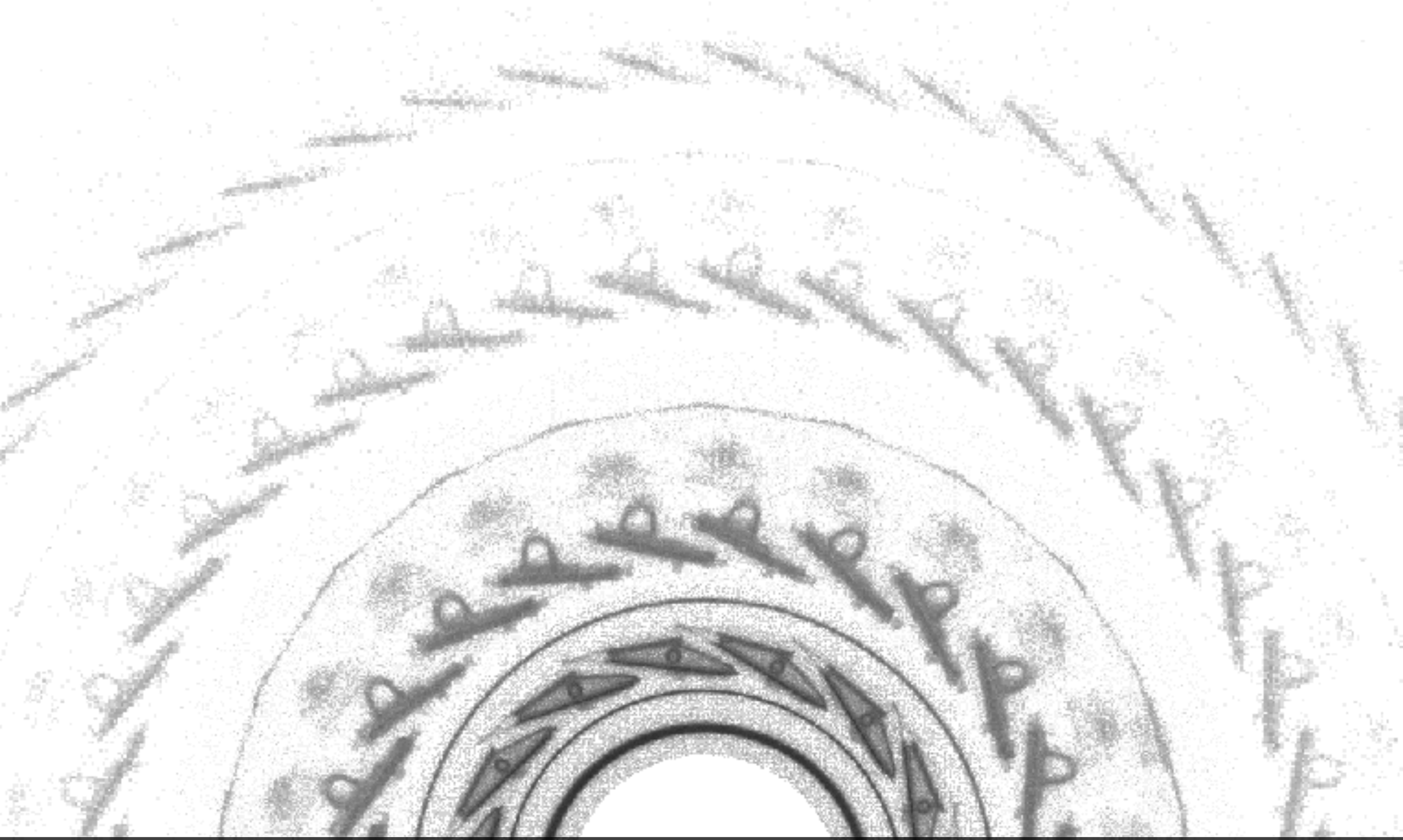


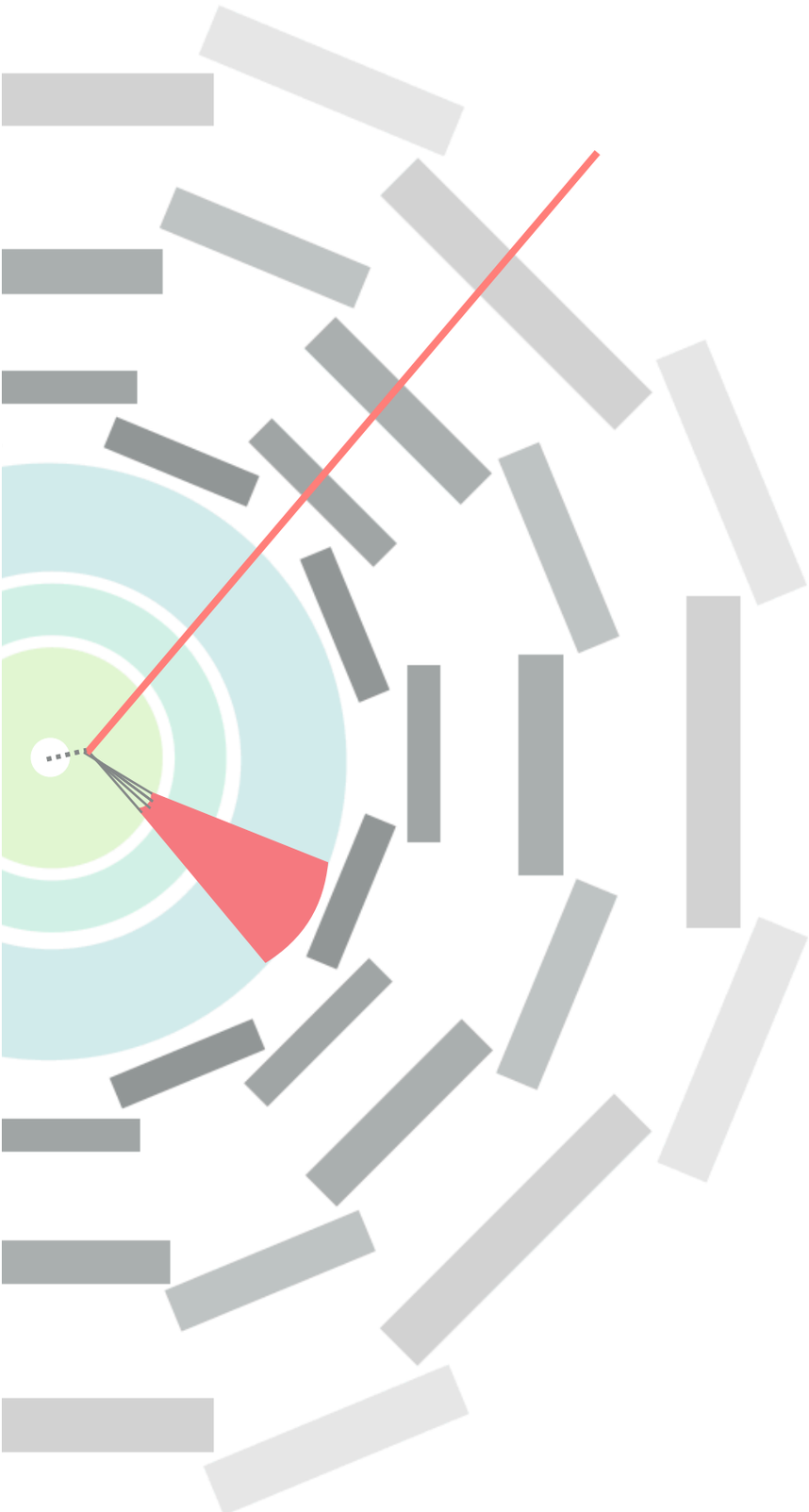
Search for Supersymmetry in events with a displaced vertex and a muon

Karri Folan DiPetrillo, on behalf of the ATLAS Collaboration

7th LHC LLP Workshop

26 May 2020

Introduction/Overview



Motivation

Semi-leptonic LLP decays

R-parity Violating Supersymmetry

The Analysis

SUSY-2018-33, 136 fb^{-1}

Muon Spectrometer only / E_T^{miss} trigger

Non-standard reconstruction

Inner Detector Displaced Vertex + Muon

This talk

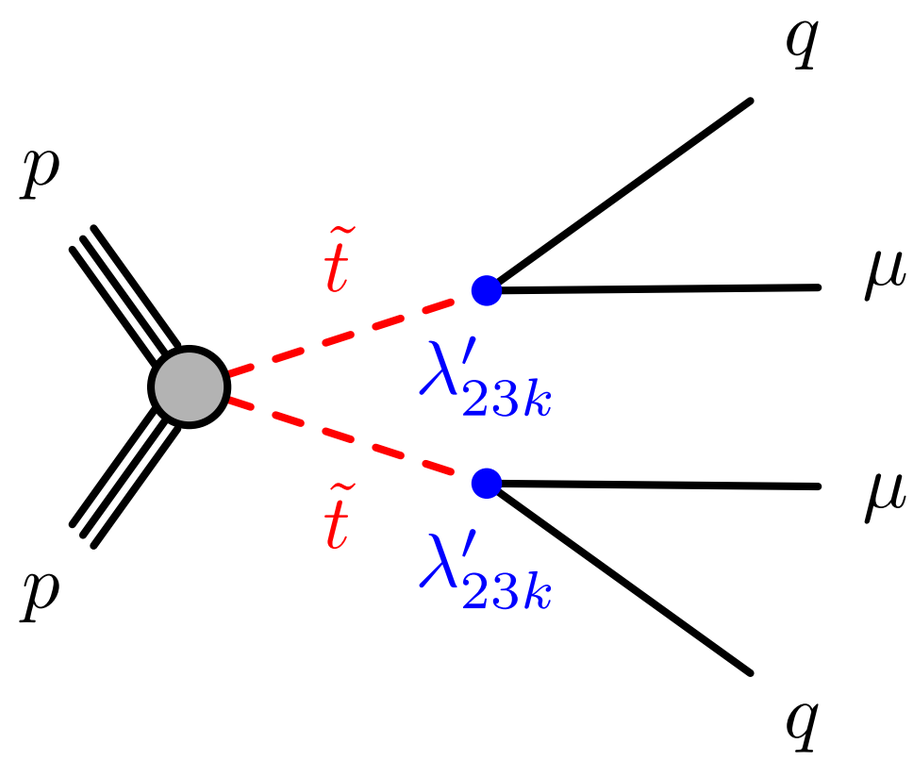
Overview of the analysis

Personal take on where we could improve

Motivation

R-parity violating Supersymmetry (SUSY)

small λ' couplings result in a long-lived lightest SUSY particle, undergoes semi-leptonic decay



Most interested in lifetimes $\tau \approx \mathcal{O}$(ps) - $\mathcal{O}$(10 ns)

- long-lived particle decays result in Inner Detector displaced vertices
- also complementary to prompt searches

one of several ATLAS searches designed to cover long-lived RPV signatures

DV+muon Analysis Strategy

In general

use stop → μ + jet as a benchmark

but remain open minded to other signals

eg. LLP → μ + 2 jets, cascade decays, lighter masses etc

We know from previous versions of the analysis

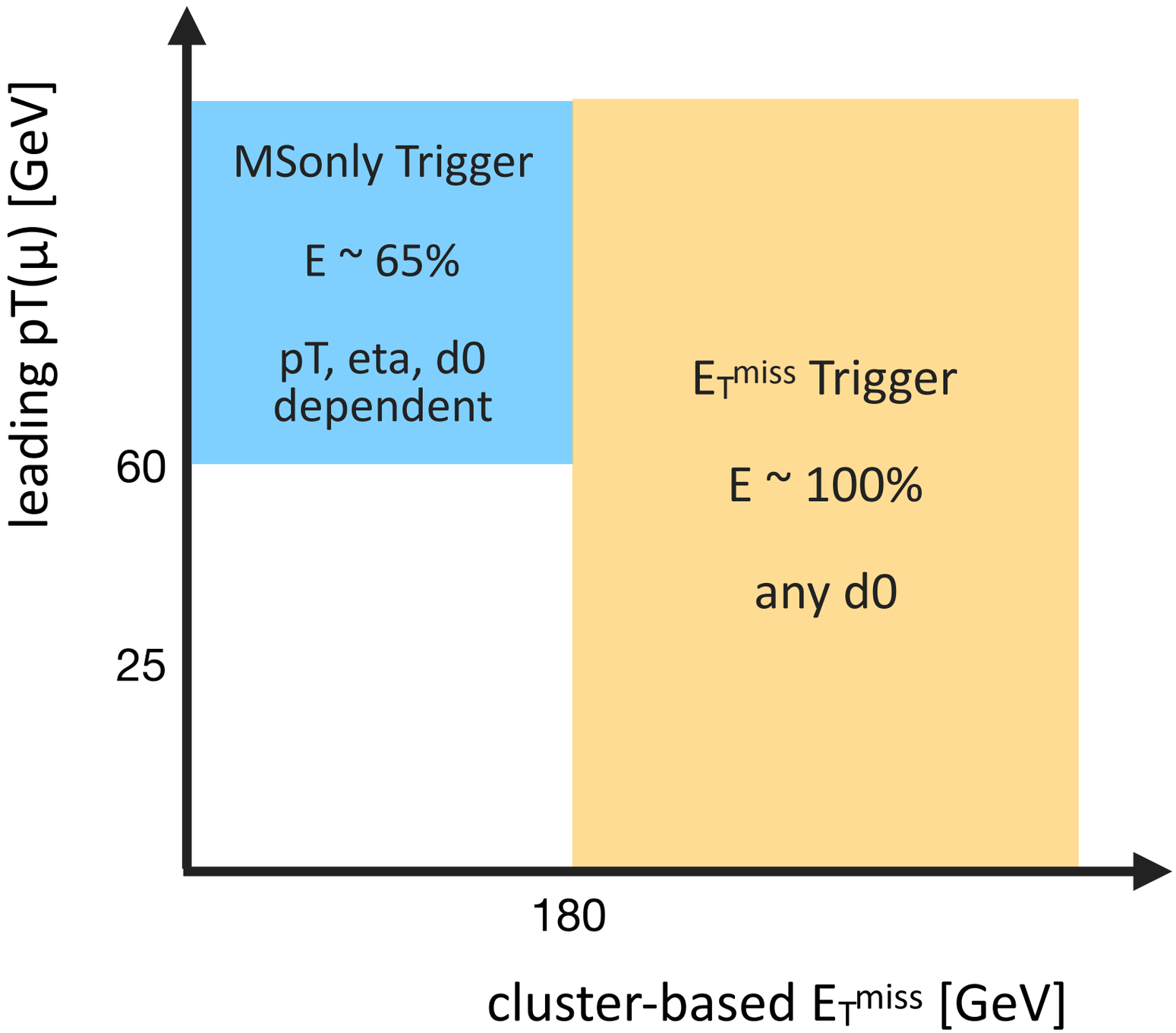
we can have ~0 expected background

and retain excellent signal efficiency

Define two levels of selection for vertices and muons

1. pre-selection - loose, lets us study backgrounds
2. full selection - tight, strong background rejection

Trigger Strategy



Used two ways to trigger on displaced muons

MSonly trigger

new: E_T^{miss} trigger

Orthogonal SRs

different backgrounds

eg. cosmics v. fake muons

Lesson: E_T^{miss} trigger has

better signal efficiency

lower backgrounds

Non-standard Reconstruction

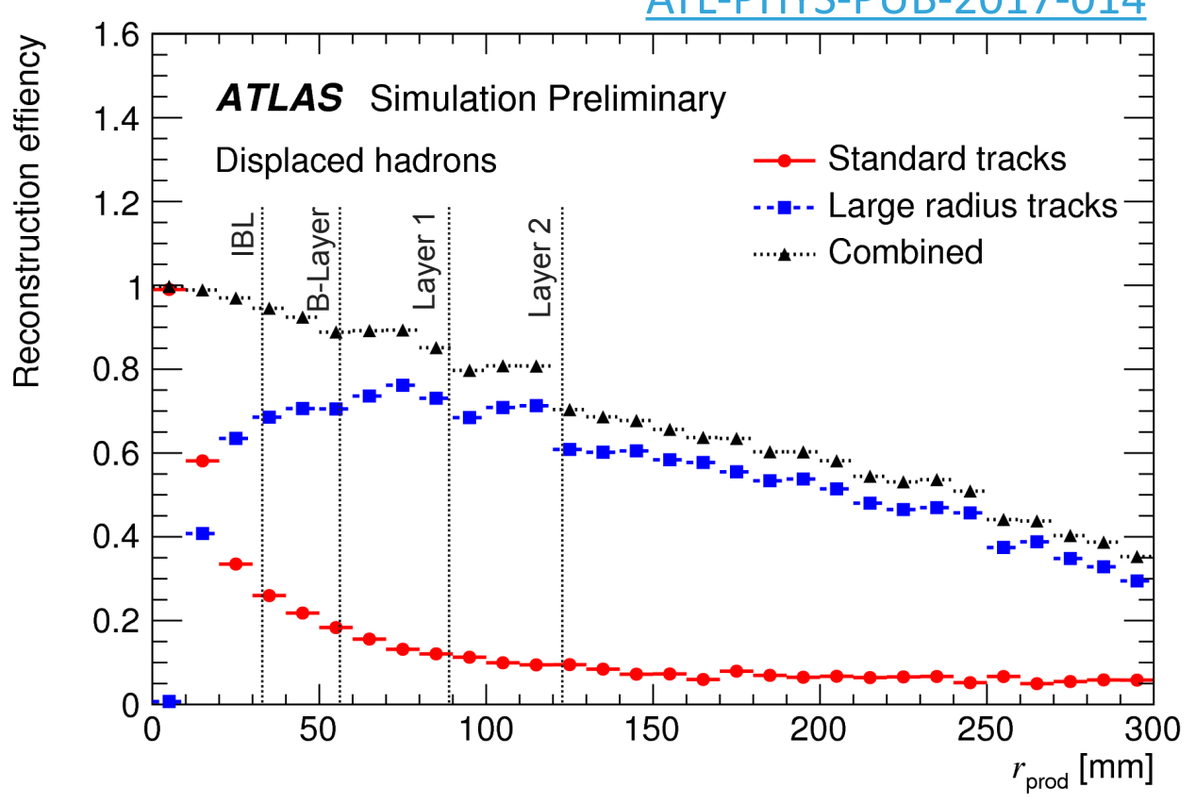
Inner Detector Tracking

standard ATLAS tracking requires |d0| < 10 mm
large radius tracking is an additional pass of tracking with loosened impact parameter and hit requirements

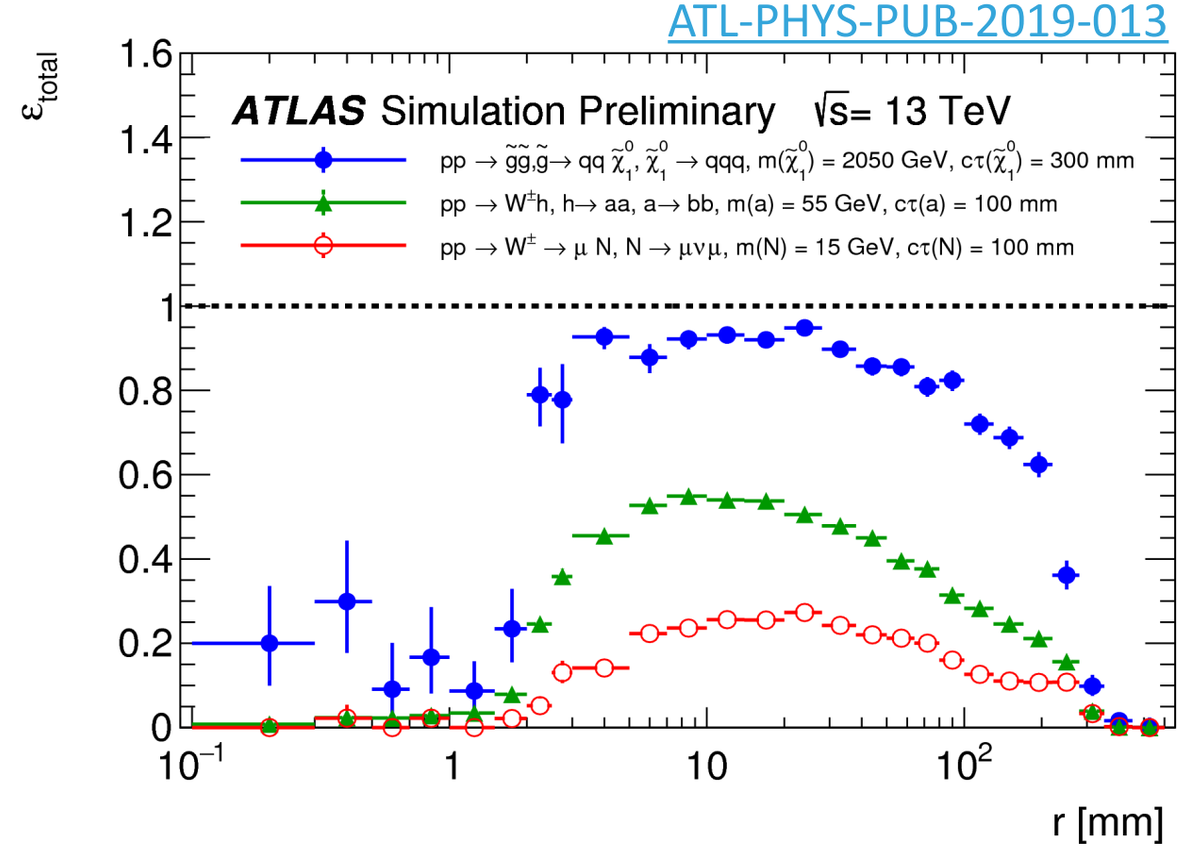
Secondary Vertexing

forms vertices using tracks with pT > 1 GeV and |d0| > 2 mm

ATL-PHYS-PUB-2017-014



ATL-PHYS-PUB-2019-013



Muon Selection

Pre-selection: Transverse impact parameter, |d0|>2 mm

E_T^{miss} trigger selection: pT > 25 GeV, |eta|<2.5

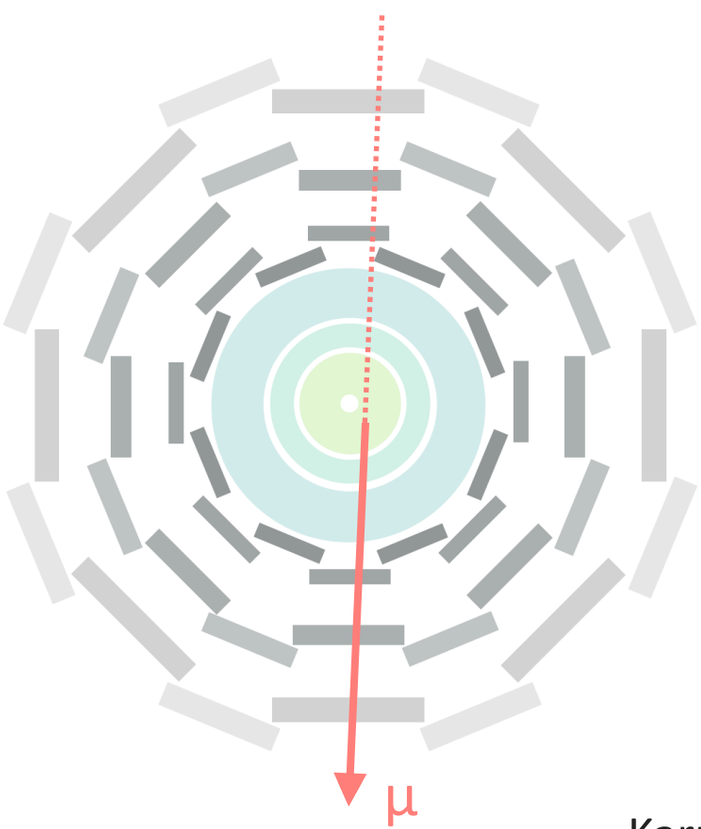
Muon trigger selection: pT > 62 GeV, |eta|<1.05

Full selection: dedicated vetoes to reject muons from backgrounds

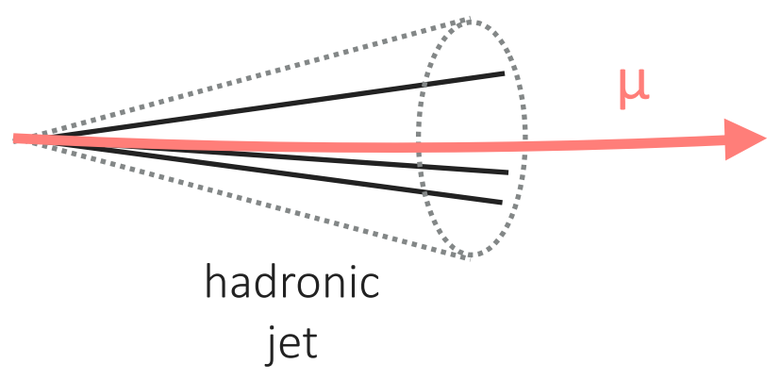
cosmics, heavy flavor decays and algorithm fakes

also used to form control regions for background estimation

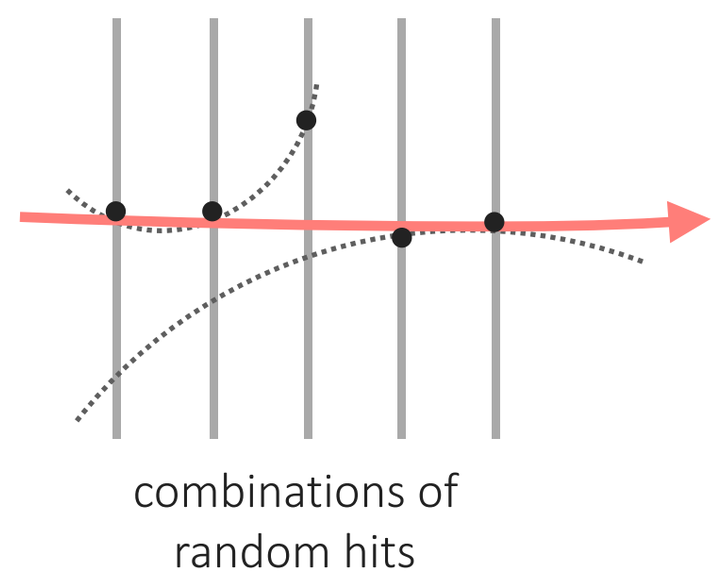
Cosmics



Heavy Flavor Decays



Algorithm Fakes



Displaced Vertex Pre-selection

Fiducial volume

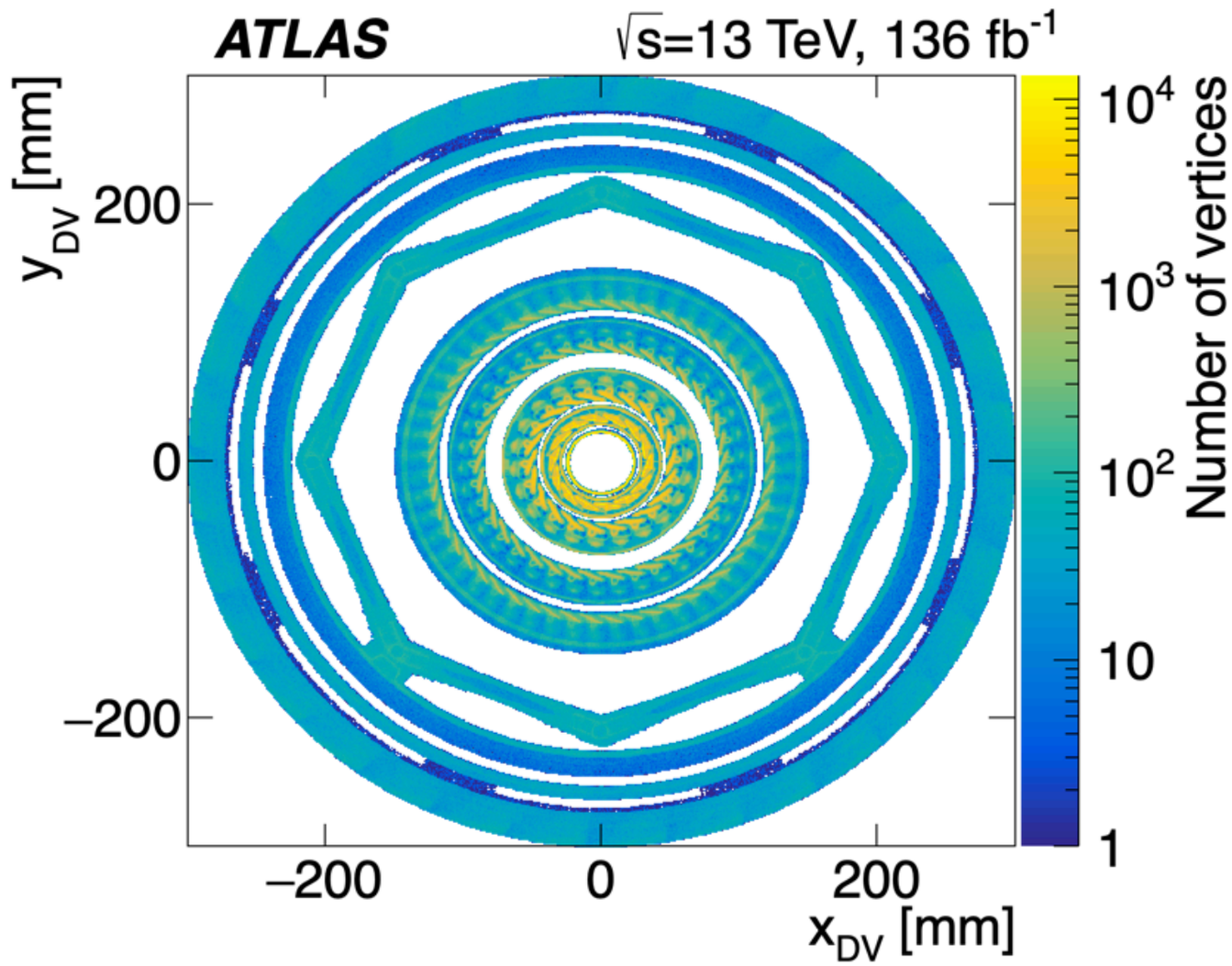
Rxy < 300 mm and |Z|<300 mm ensures displaced tracks can be reconstructed by strip detector

Displacement

Rxy > 4 mm

Material veto

to reject hadronic interactions

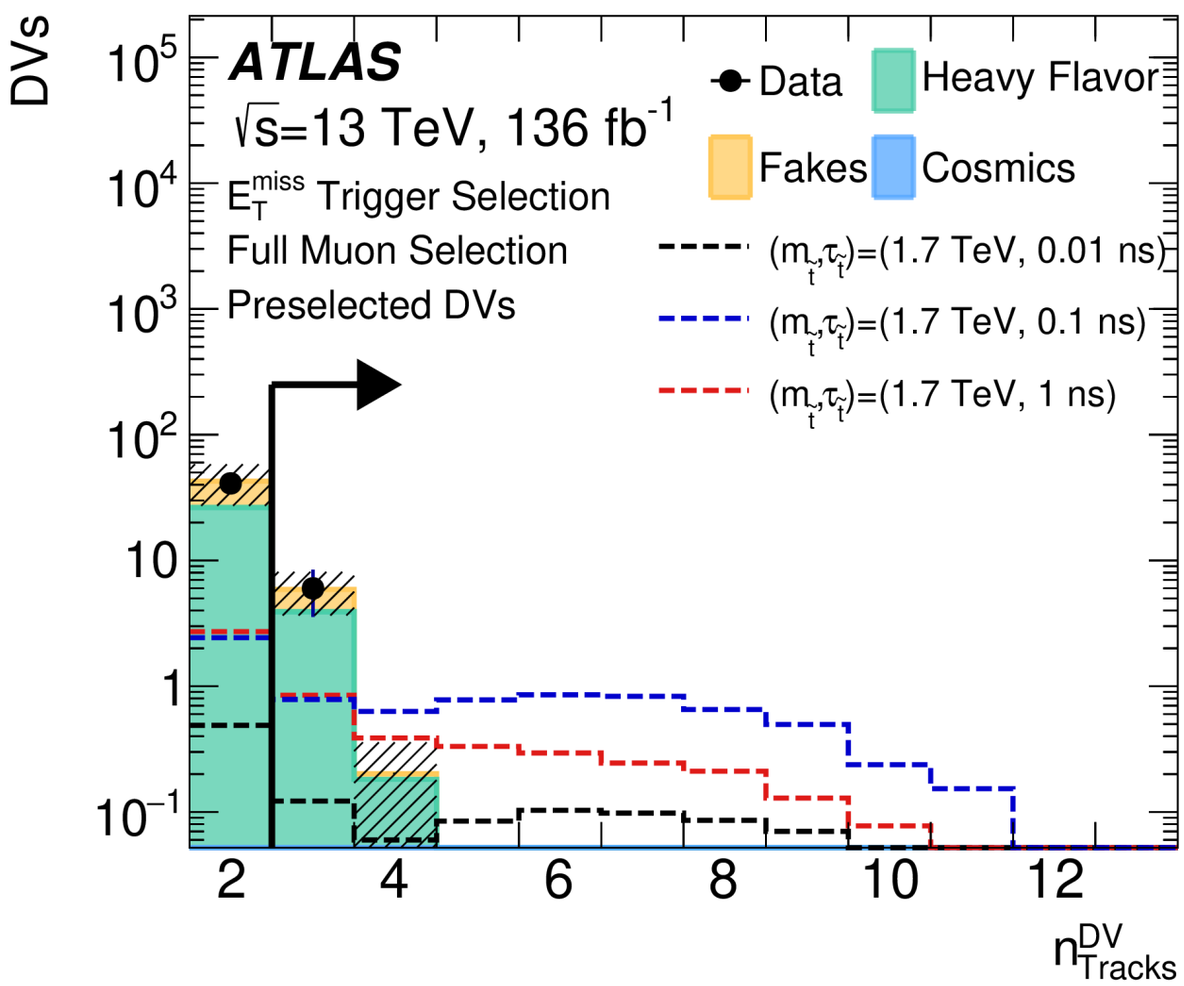


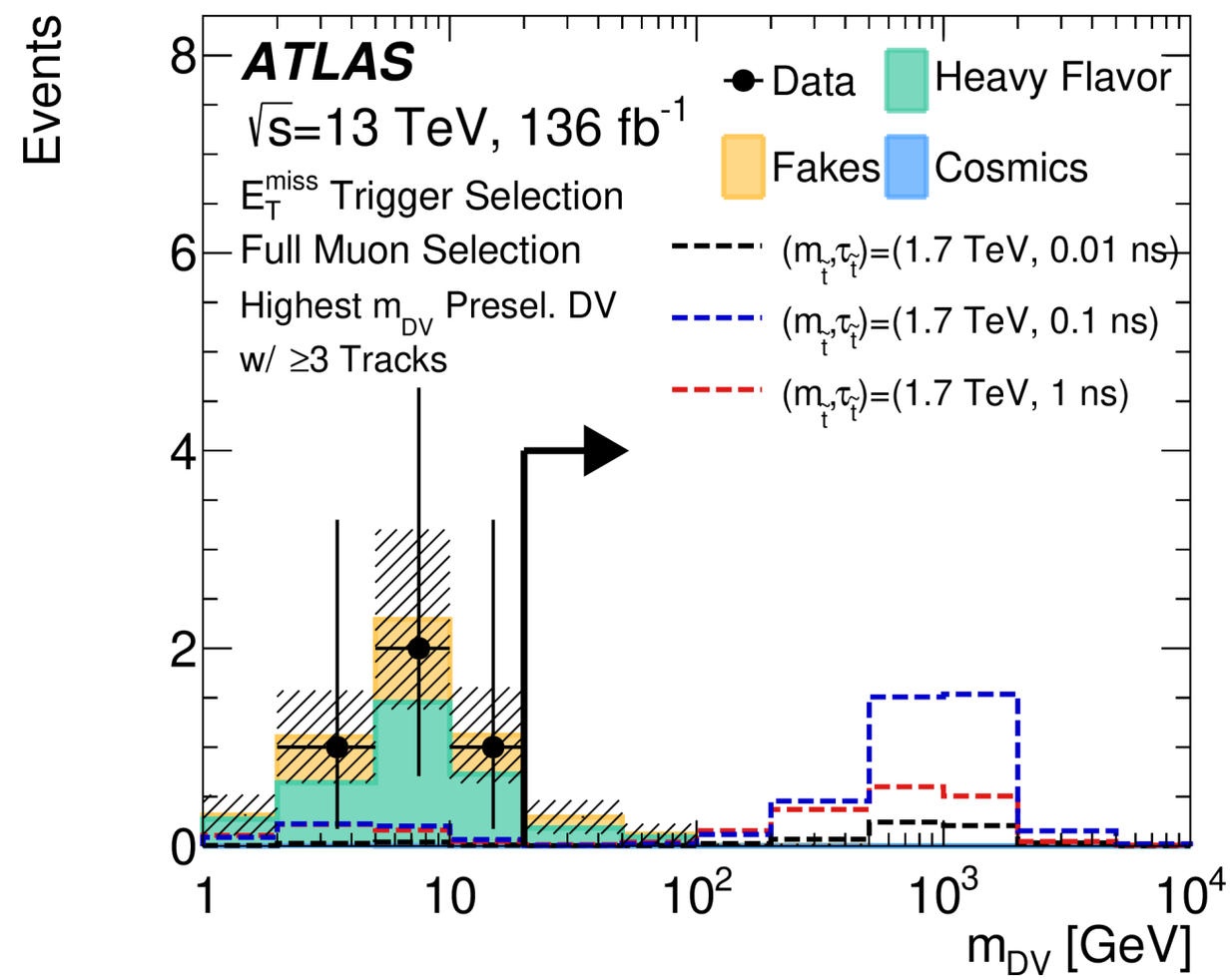
Common to ATLAS SUSY DV analyses

Displaced Vertex Final Selection

At least 3 tracks and mass > 20 GeV

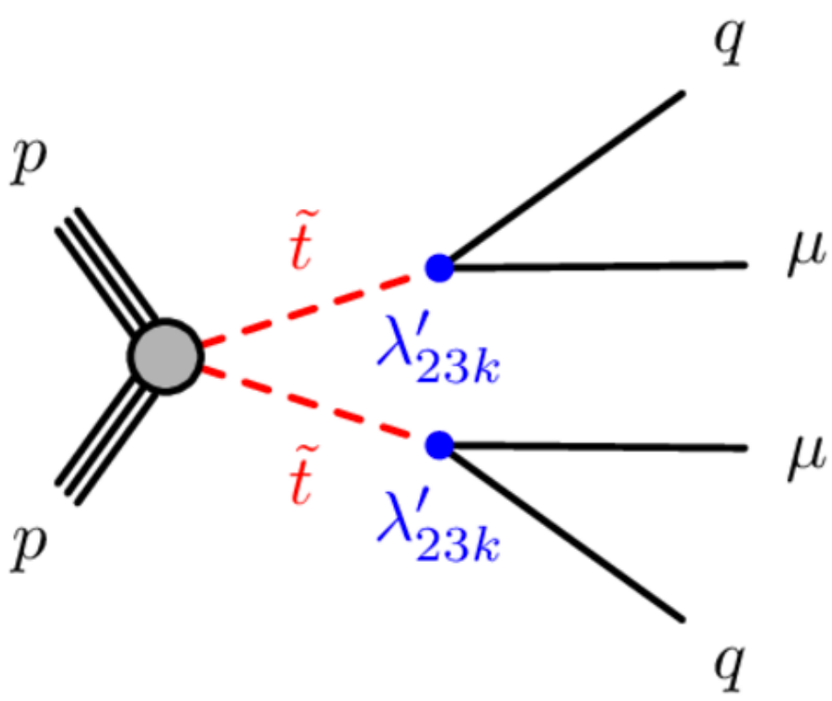
designed to reject random track crossings

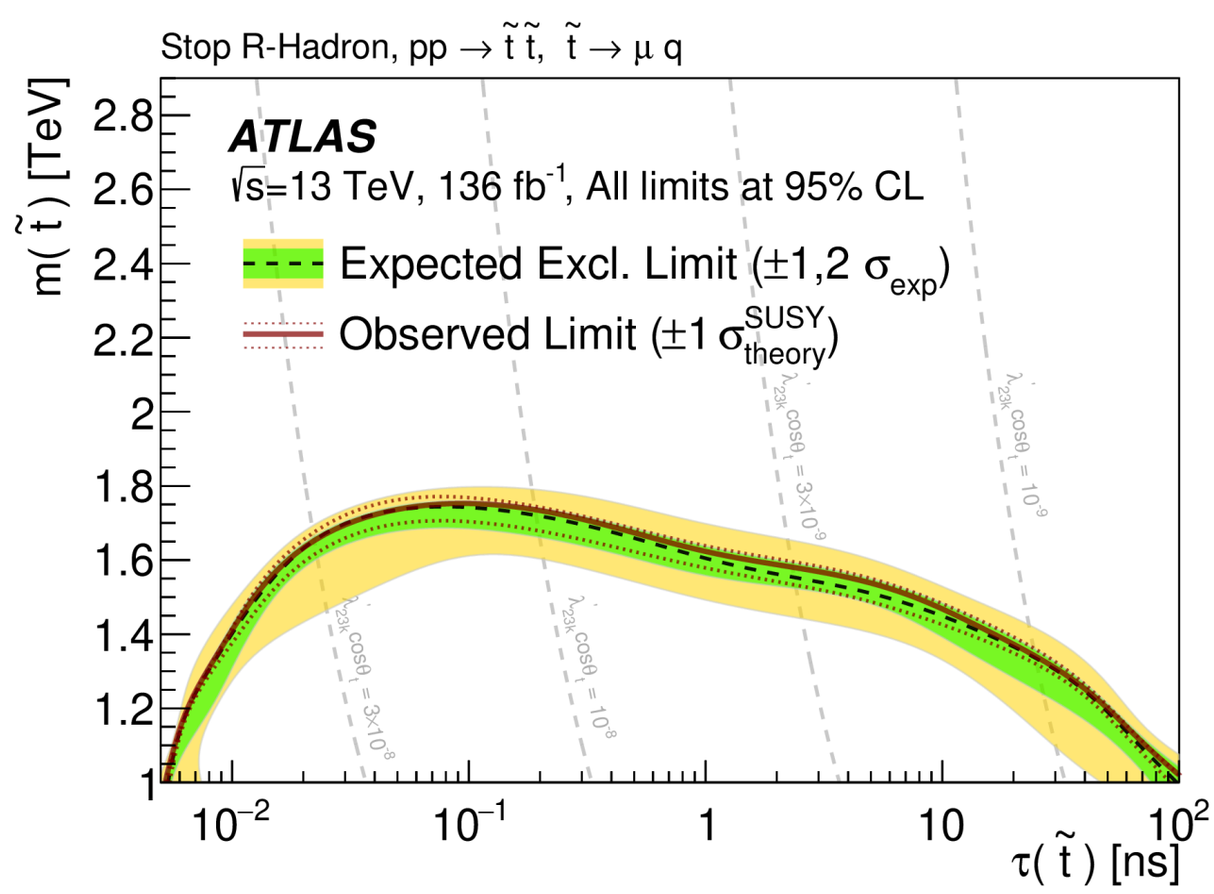




Results

Signal Region	Expected	Observed
E_T^{miss} trigger	0.43 ± 0.16 (stat.) ± 0.16 (syst.)	0
Muon trigger	1.88 ± 0.20 (stat.) ± 0.28 (syst.)	1





Room for improvement

We did a great job with DV+muon

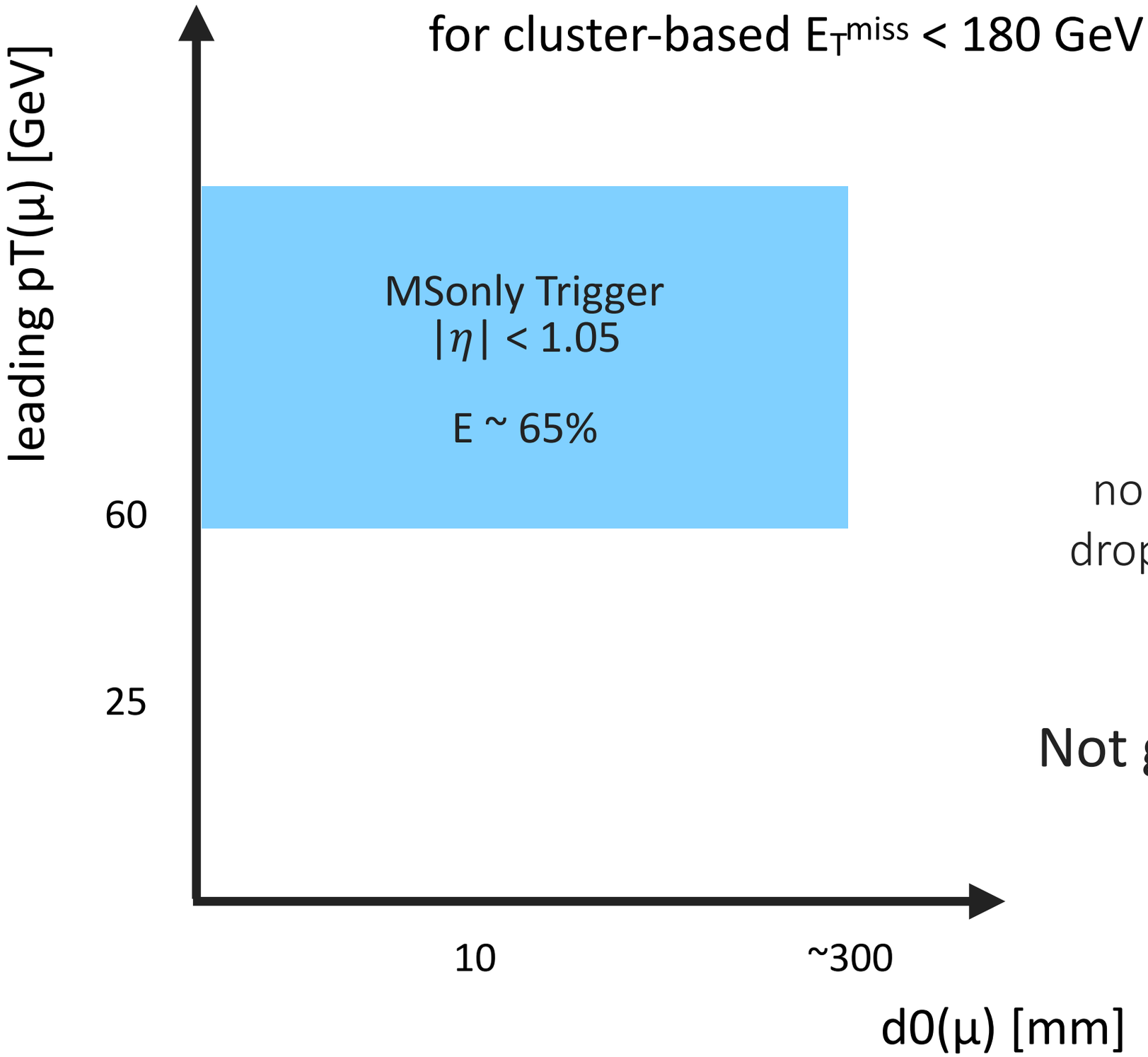
probed interesting phase space, and made
many interesting improvements w.r.t Run 1 version

If only we had more time,
or more analyzers..

Three areas where we can do better

Trigger strategy
Additional signal region(s) for smaller lifetimes
Improved vertex efficiency at larger displacement

Trigger Improvements



Current Status

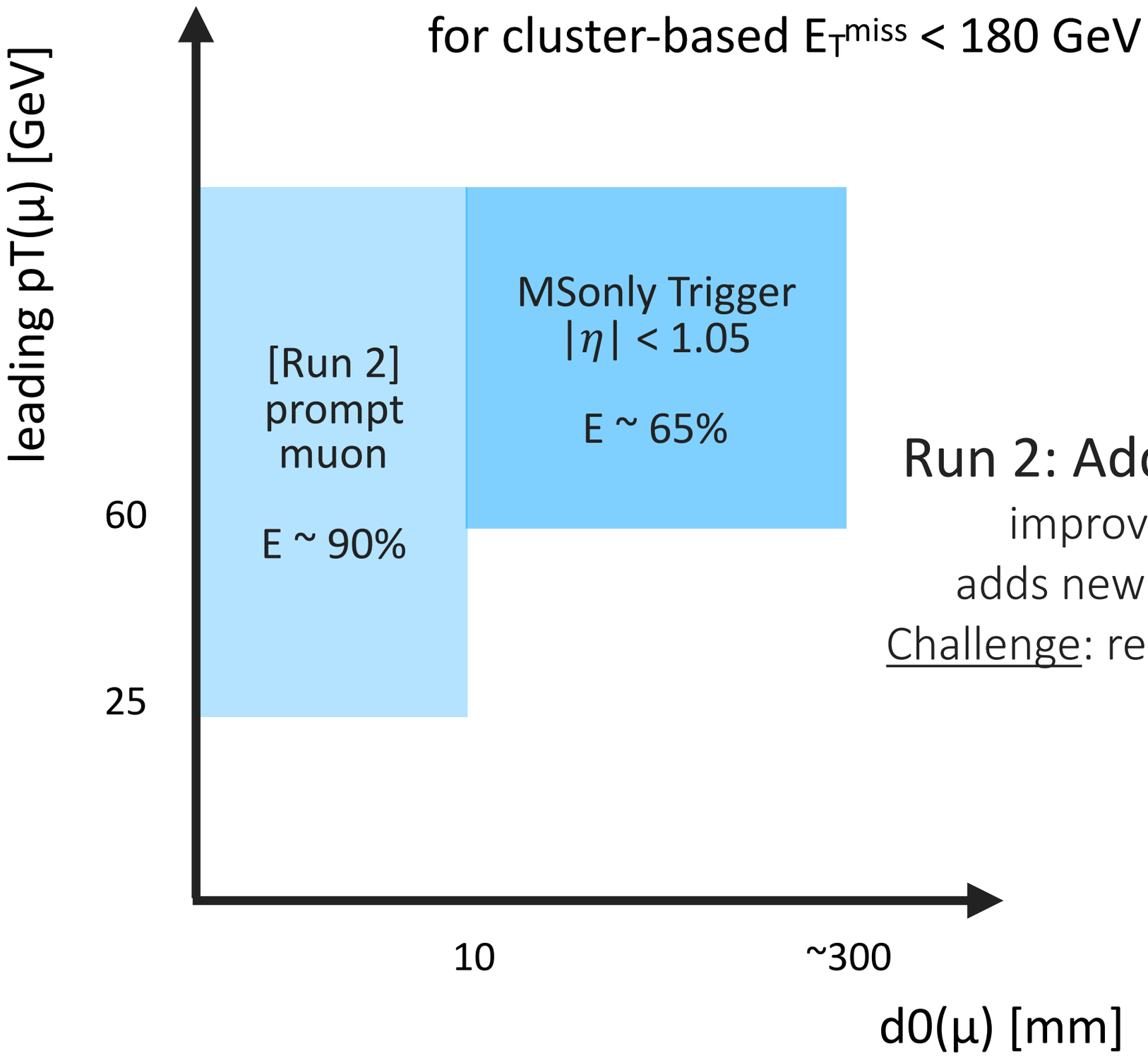
high pT threshold

no endcaps (high rates)

drop off in Efficiency v. d0

Not great for light LLPs!

Trigger Improvements



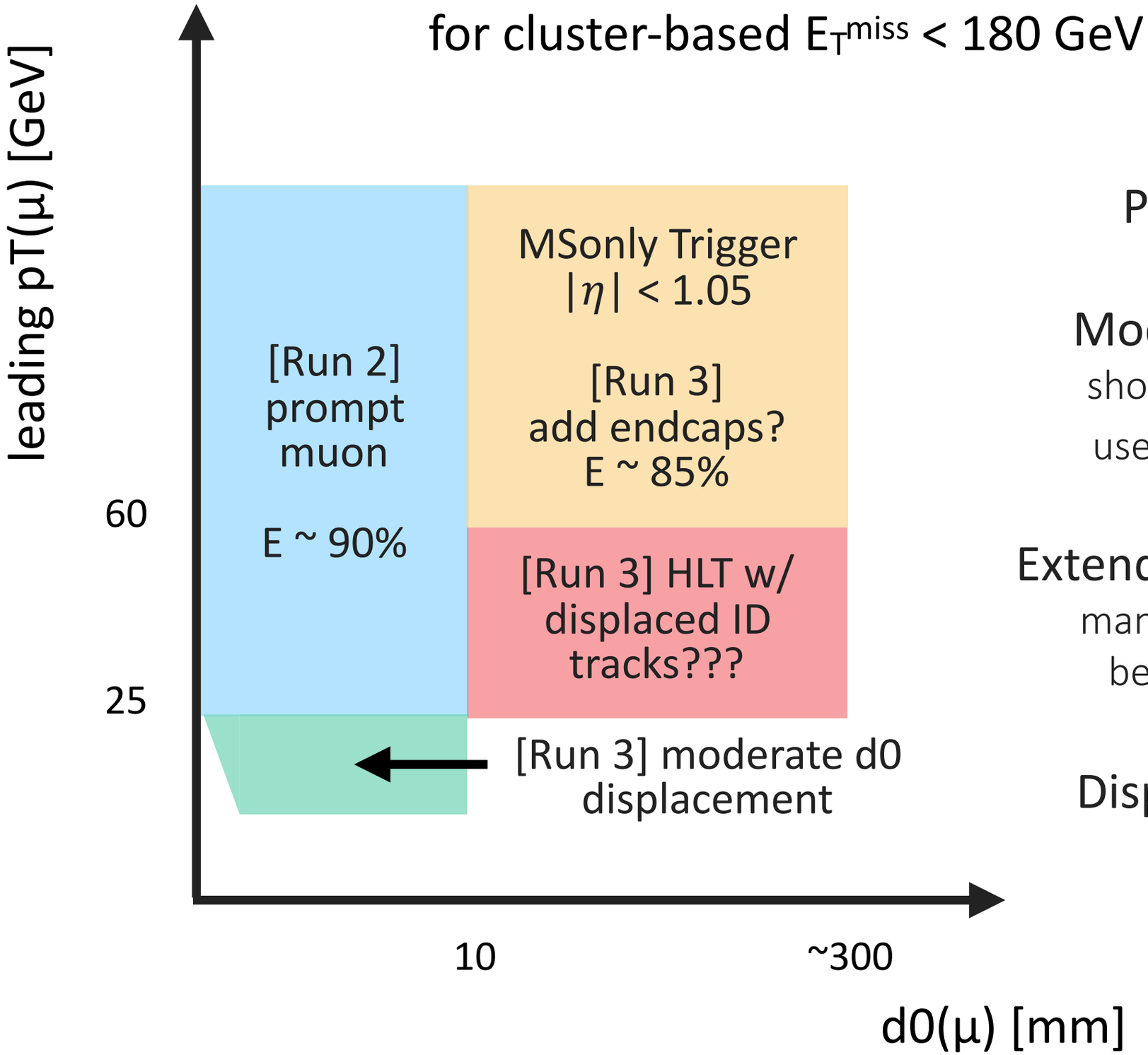
Run 2: Add prompt muon trigger

improves AxE for pT > 60 GeV

adds new phase space: lighter LLPs

Challenge: requires different data stream!

Trigger Improvements



Possibilities in Run 3…

Moderate d0, low pT muons
should be able to do this already,
useful for slightly displaced $\tau \rightarrow \mu$

Extend MSonly trigger to endcaps
managed in 2018 for pT > 80 GeV,
better with New Small Wheel?

Displaced ID tracks at HLT??

Target smaller lifetimes

New SRs needed

with additional selections you can go closer to pp-interaction point

Option 1:

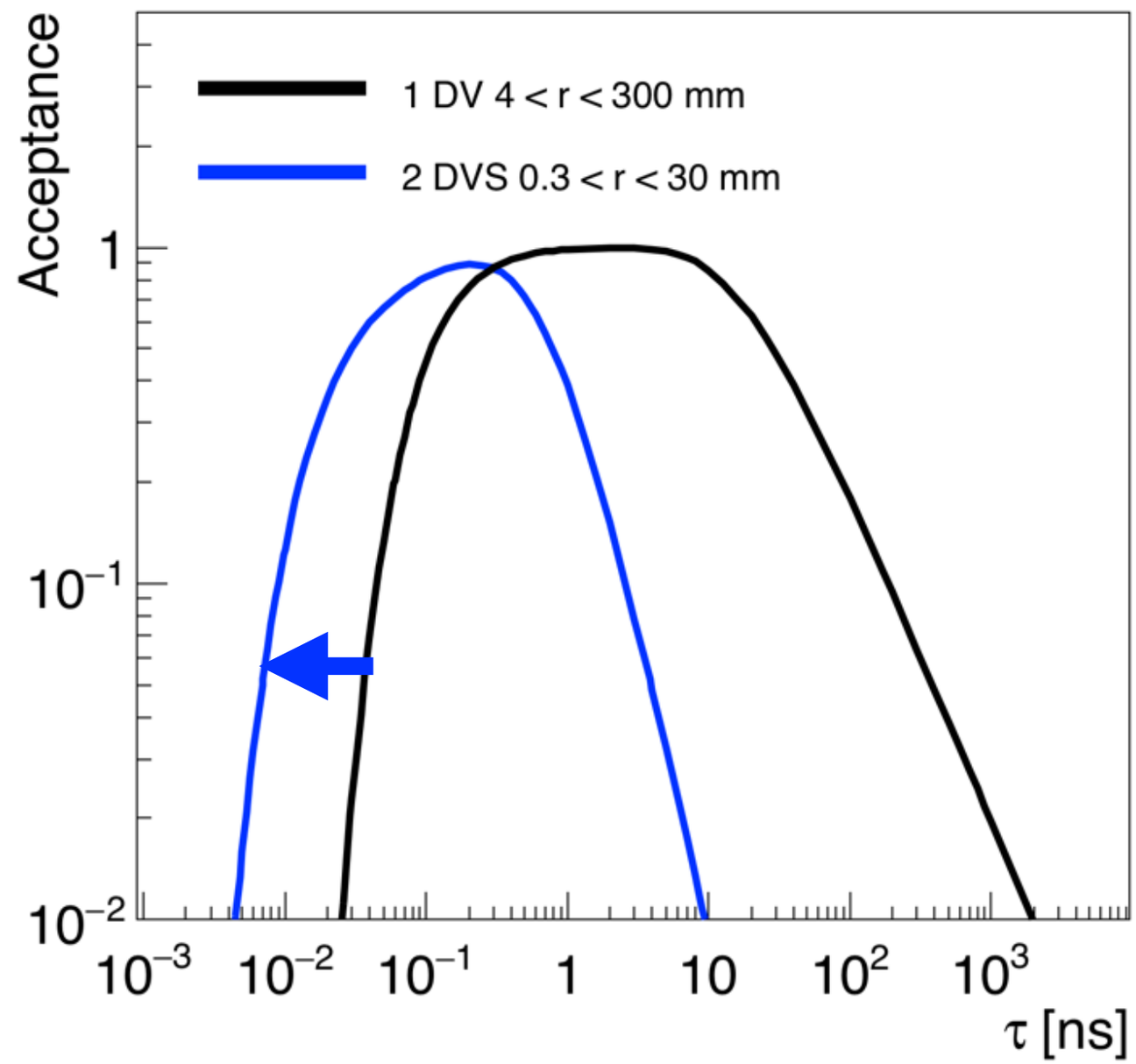
add a **2 DV Signal Region**

<u>challenge</u>: rethink vertex reconstruction

Option 2:

Use standard prompt triggers, require multiple slightly displaced muons and/or jets

may not even need vertexing



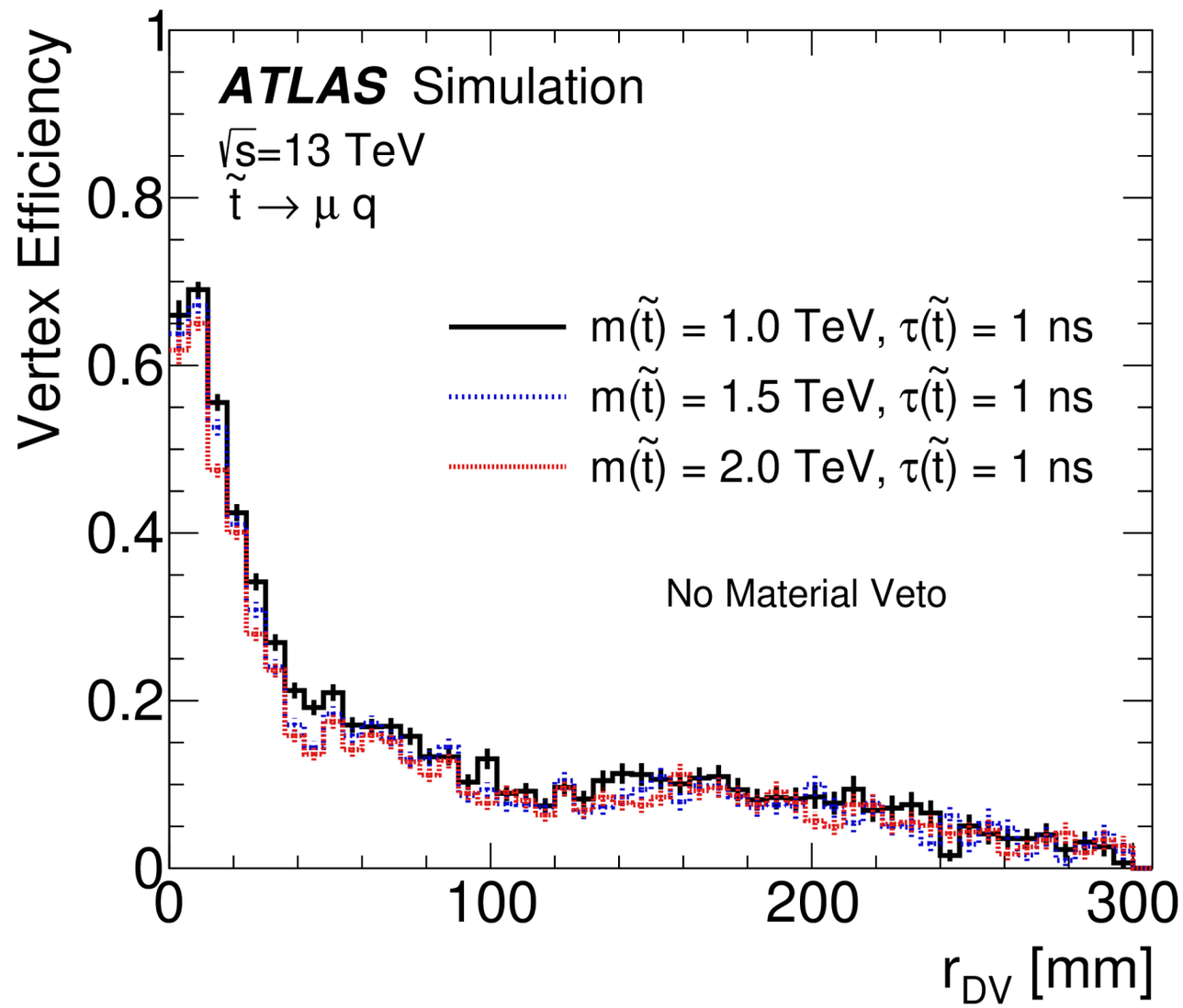
Improve efficiency for longer lifetimes

Could we do better?

part of the challenge is reduced tracking efficiency at large radii

but we also know there are reconstructed tracks NOT included in displaced vertices

I think we can do better



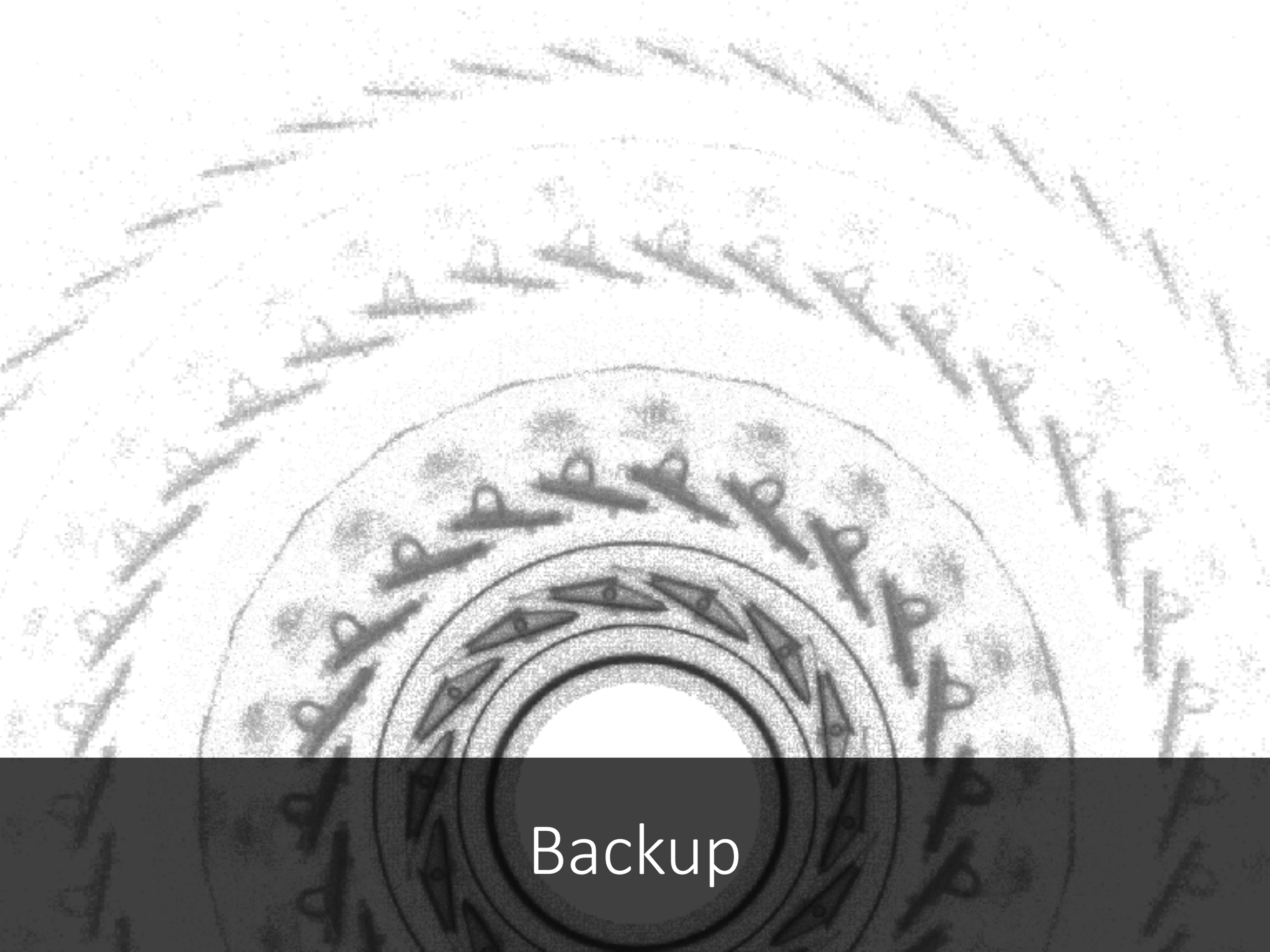
Conclusions

Presented overview of ATLAS DV+muon analysis

first ATLAS LLP analysis with full Run 2 dataset
common displaced vertex strategy within ATLAS SUSY
new trigger strategy and muon selection with respect to Run 1

Also shared some ideas for where we can improve

improvements to trigger strategy
new signal regions to target smaller lifetimes
and reconstruction efficiency for larger displacements



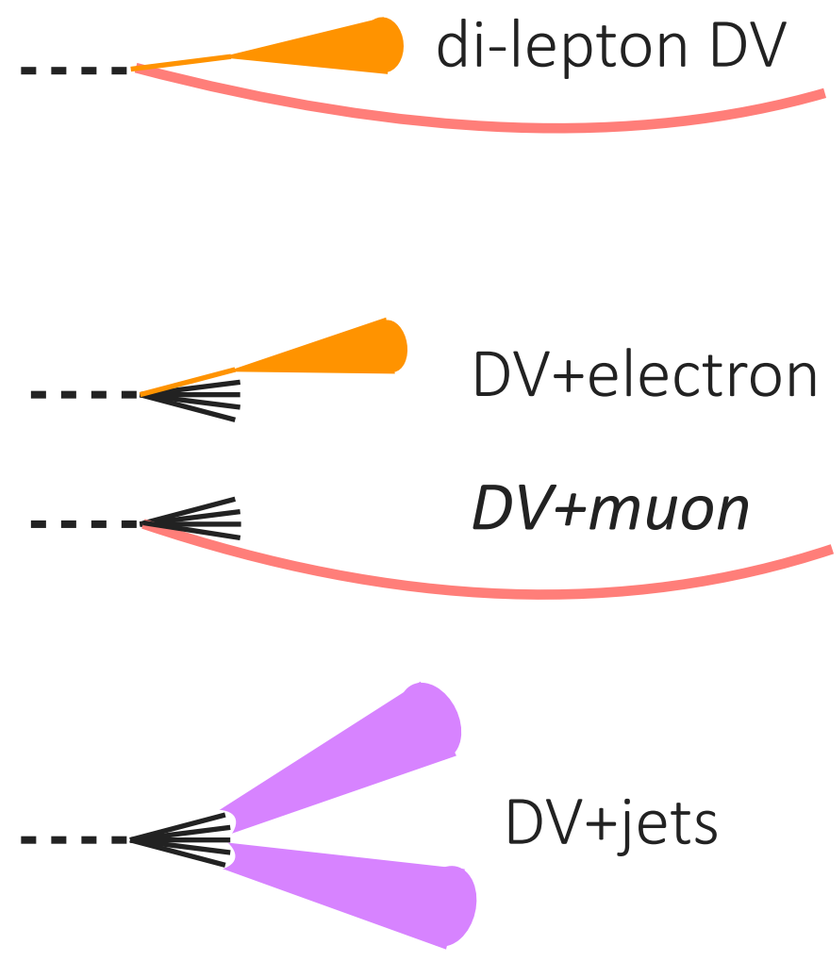
Backup

Motivation: R-parity violating supersymmetry

ATLAS has several analyses looking for displaced vertices

DV+muon uniquely sensitive to λ'_{2jk}

Coupling	Physics Signature	Example Detector Signature
λ_{ijk}	leptonic LLP decays ee,μμ,μe,…	di-lepton DV
λ'_{1jk}	semi-leptonic LLP decays lq,lqq	DV+electron
λ'_{2jk}		***DV+muon***
λ''_{ijk}	hadronic LLP decays qq,qqq	DV+jets

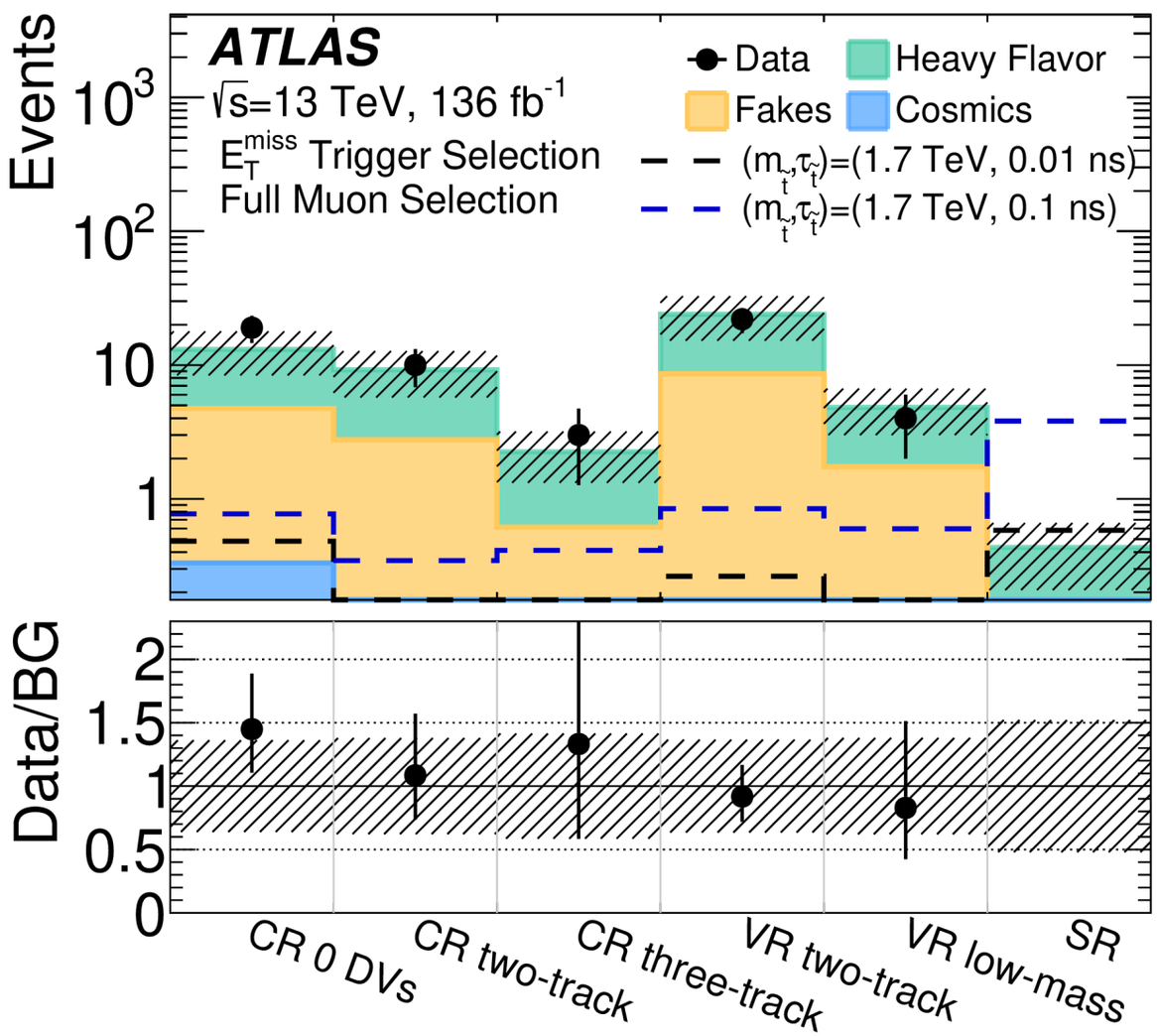


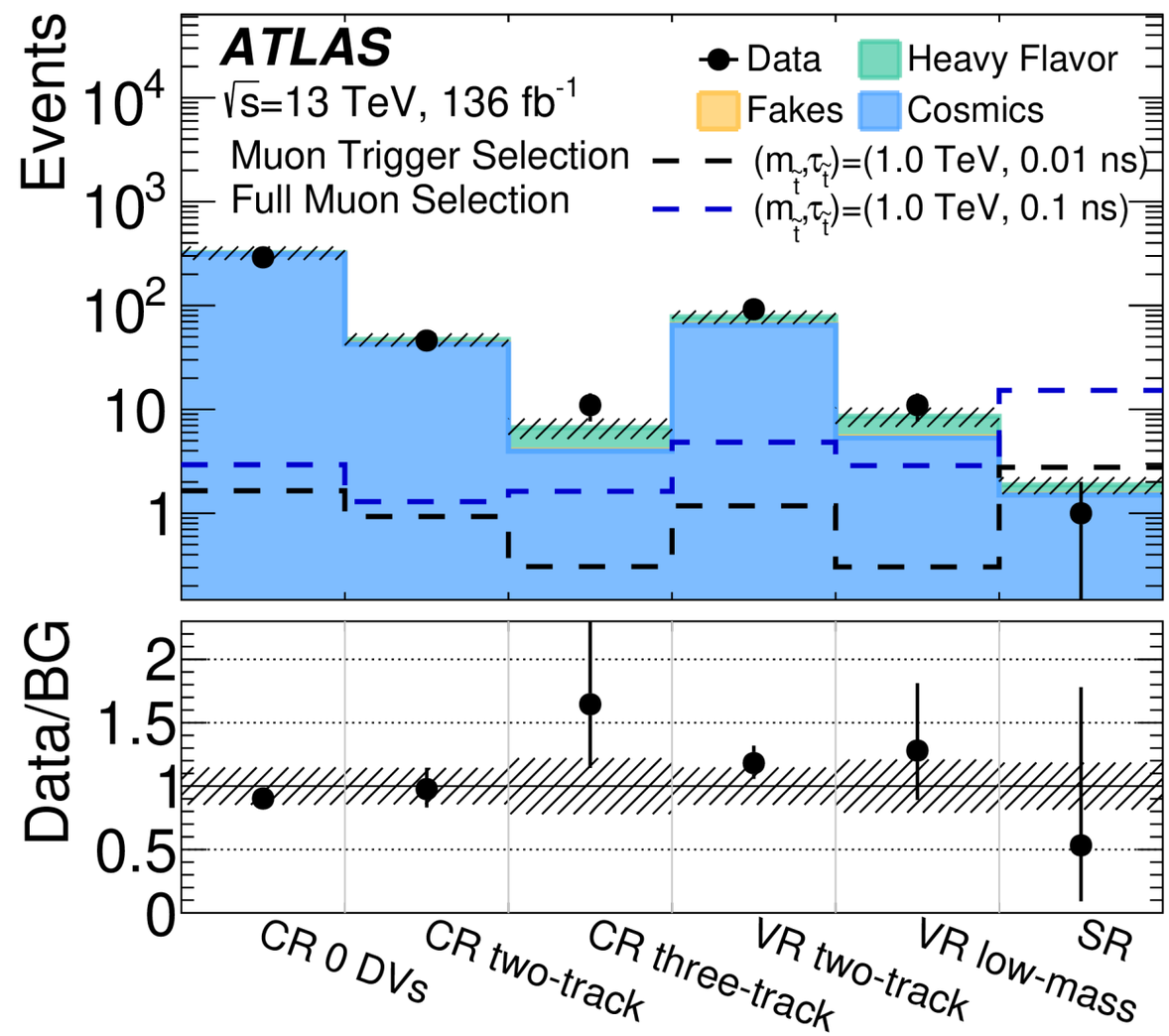
Background estimation

$$N_{SRevents} = TF \times N_{CRevents}$$

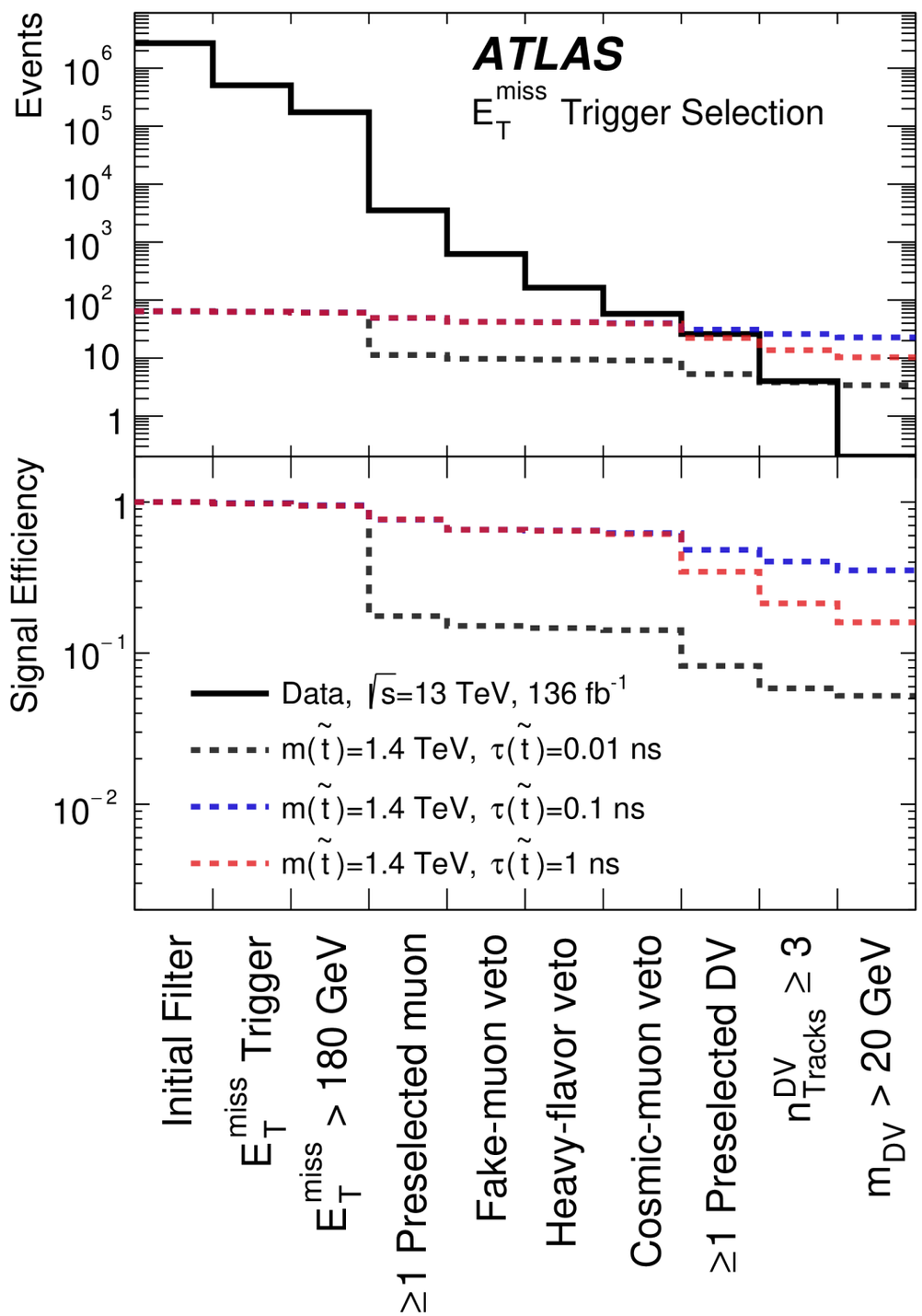
Invert muon vetos one by one - obtain $N_{CRevents}$ for each muon background

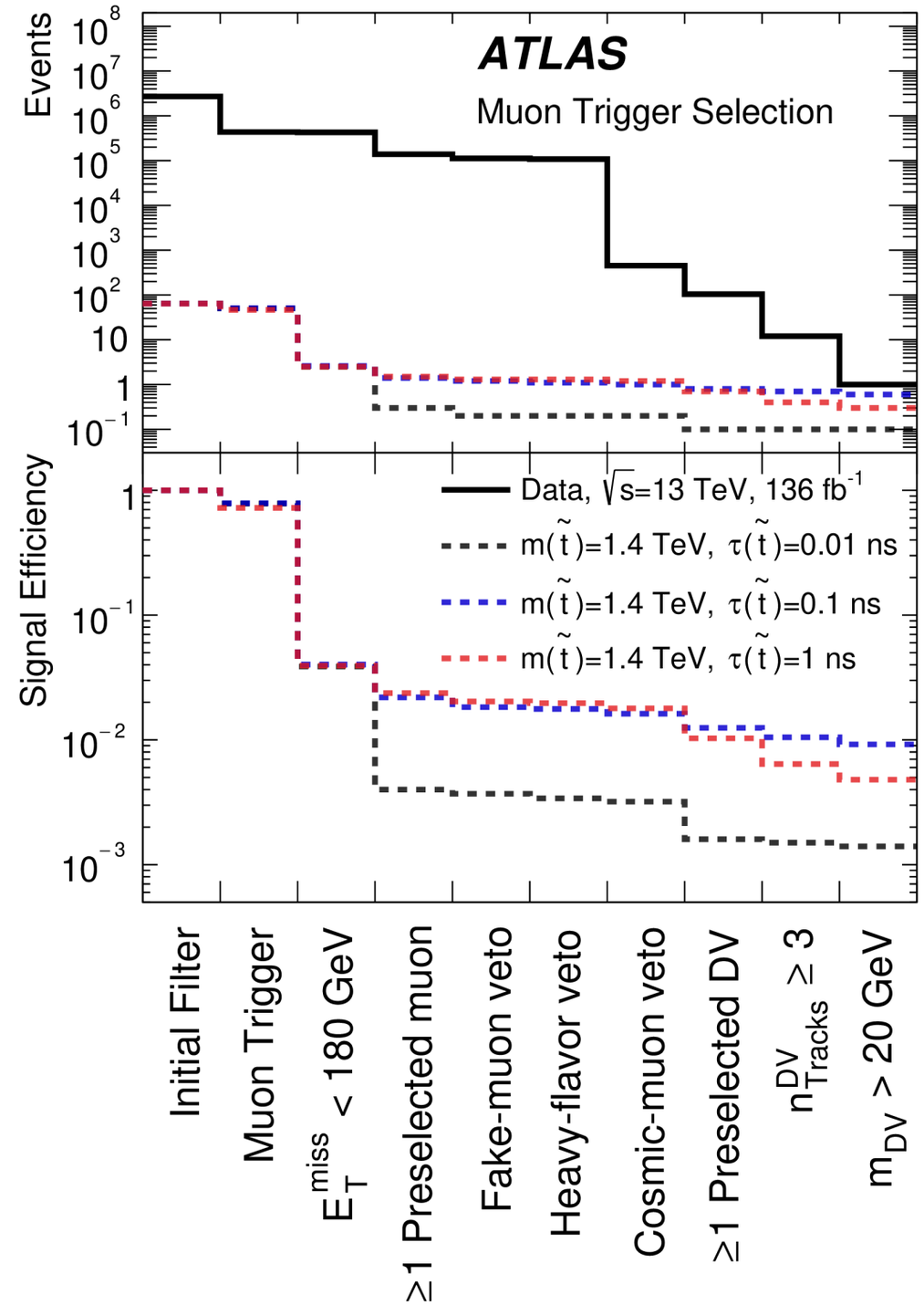
transfer factors measured in events with no preselected DVs





Selection Efficiency





Reinterpretation material

Parametrized efficiencies provided as Aux material