RECONSTRUCTING
UNCONVENTIONAL OBJECTS

TOVA HOLMES
PITT PACC WORKSHOP: LHC PHYSICS FOR RUN 3
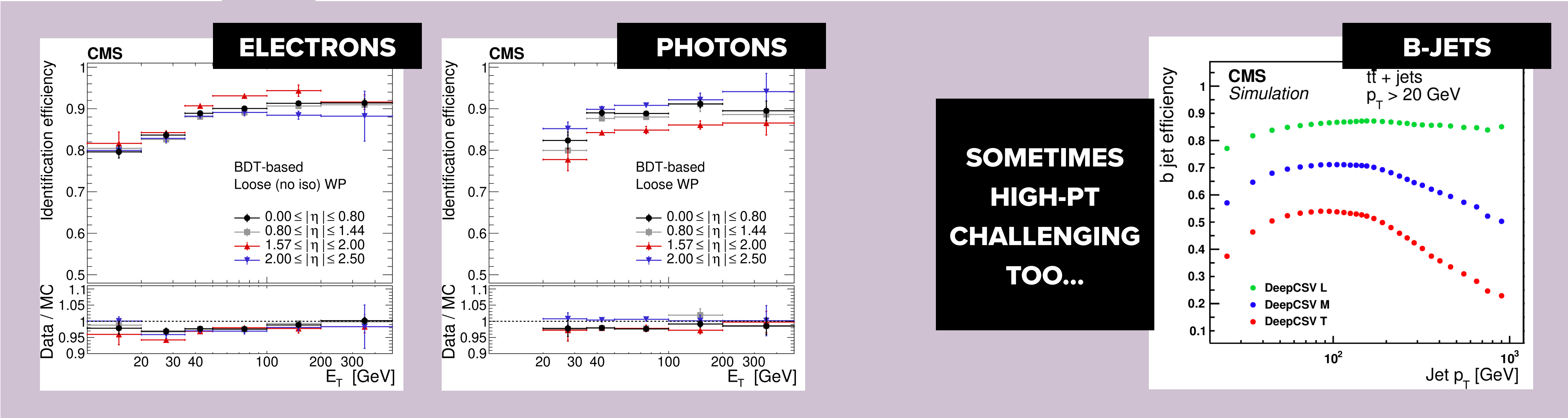APRIL 7-9, 2021

RECONSTRUCTION CLASSIC

- **Most reliable reconstruction for objects that are**

HIGH-PT

PROMPT

LOCALIZED

RECONSTRUCTION CLASSIC

- **Most reliable reconstruction for objects that are**
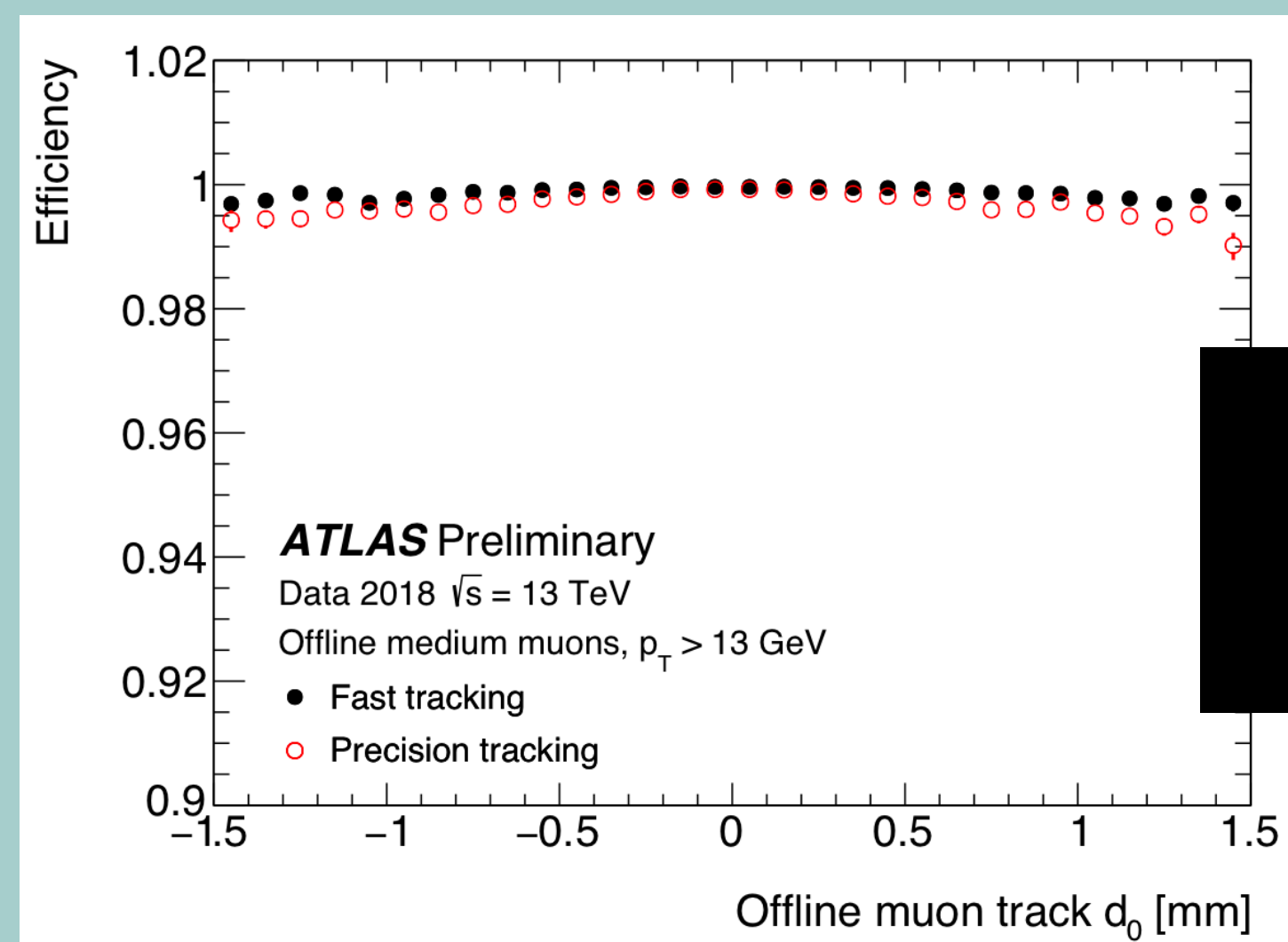
HIGH-PT **PROMPT** **LOCALIZED**

ELECTRONS

PHOTONS

SOMETIMES HIGH-PT CHALLENGING TOO...

B-JETS

RECONSTRUCTION CLASSIC

- **Most reliable reconstruction for objects that are**

HIGH-PT

PROMPT

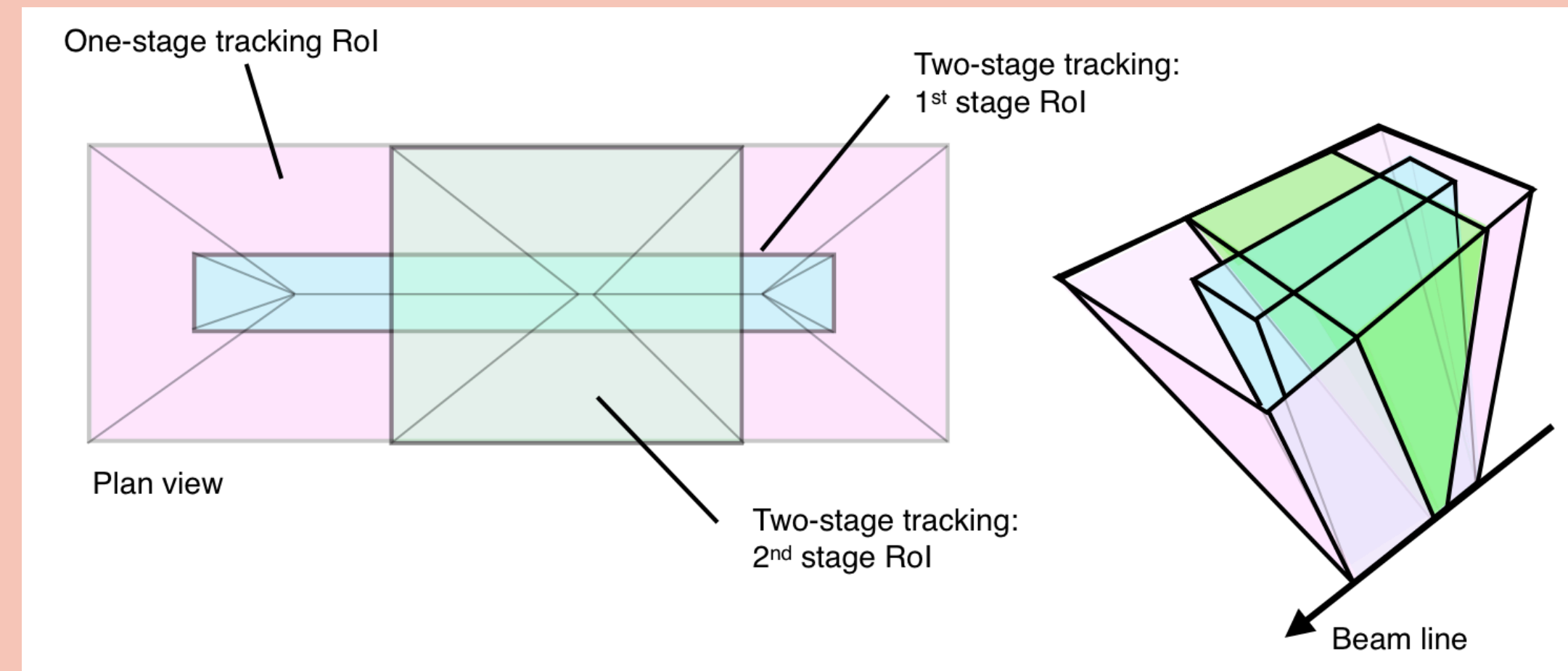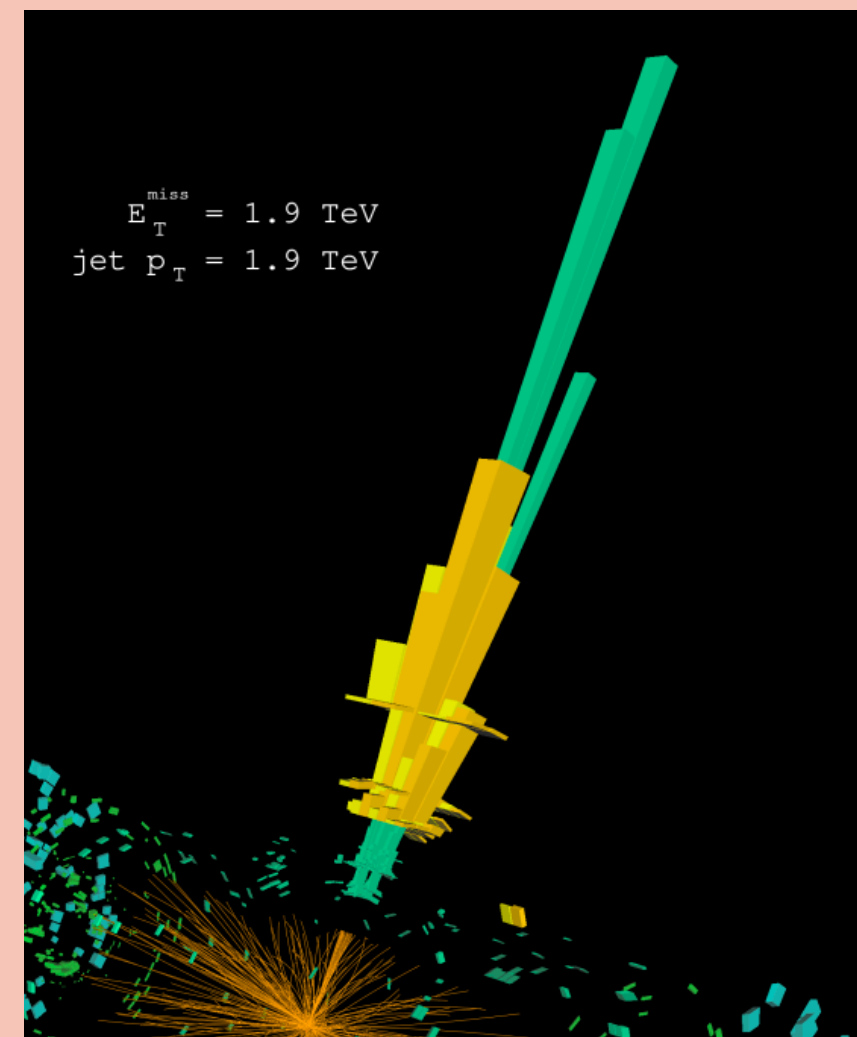**LOCALIZED**

LOOKS GOOD, BUT CHECK THE AXES

ATLAS Preliminary
Data 2018 $\sqrt{s}$ = 13 TeV
Offline medium muons, p_T > 13 GeV
● Fast tracking
○ Precision tracking

Efficiency

Offline muon track d_0 [mm]

HLTTrackingPublicResults

RECONSTRUCTION CLASSIC

■ **Most reliable reconstruction for objects that are**

HIGH-PT

PROMPT

LOCALIZED

E_T^{miss} = 1.9 TeV
jet p_T = 1.9 TeV

One-stage tracking RoI

Two-stage tracking:
1st stage RoI

Plan view

Two-stage tracking:
2nd stage RoI
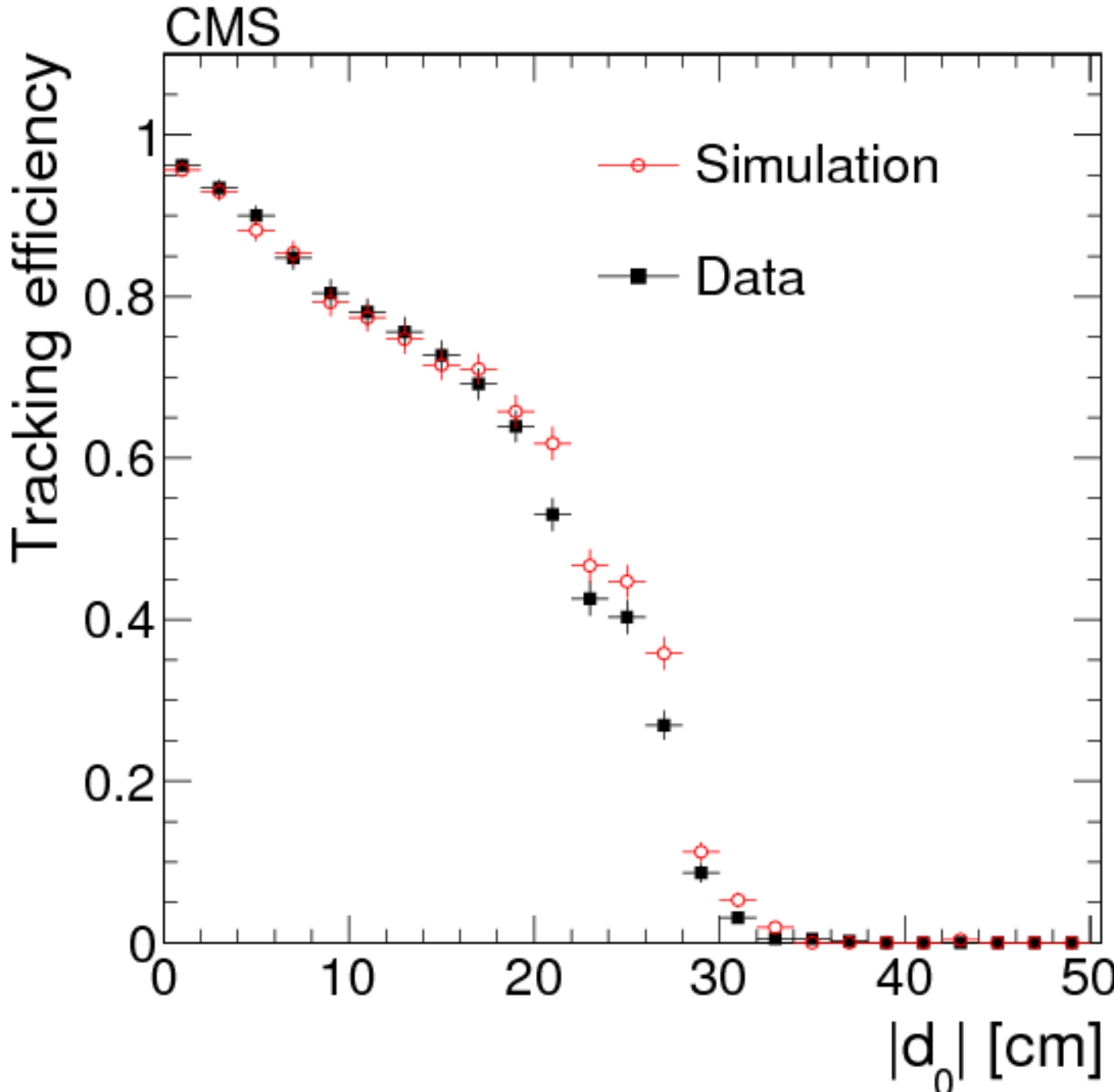
Beam line

RECONSTRUCTION CLASSIC

HIGH-PT
PROMPT
LOCALIZED

- **But just because it's challenging to move outside these regions doesn't mean we haven't done it!**
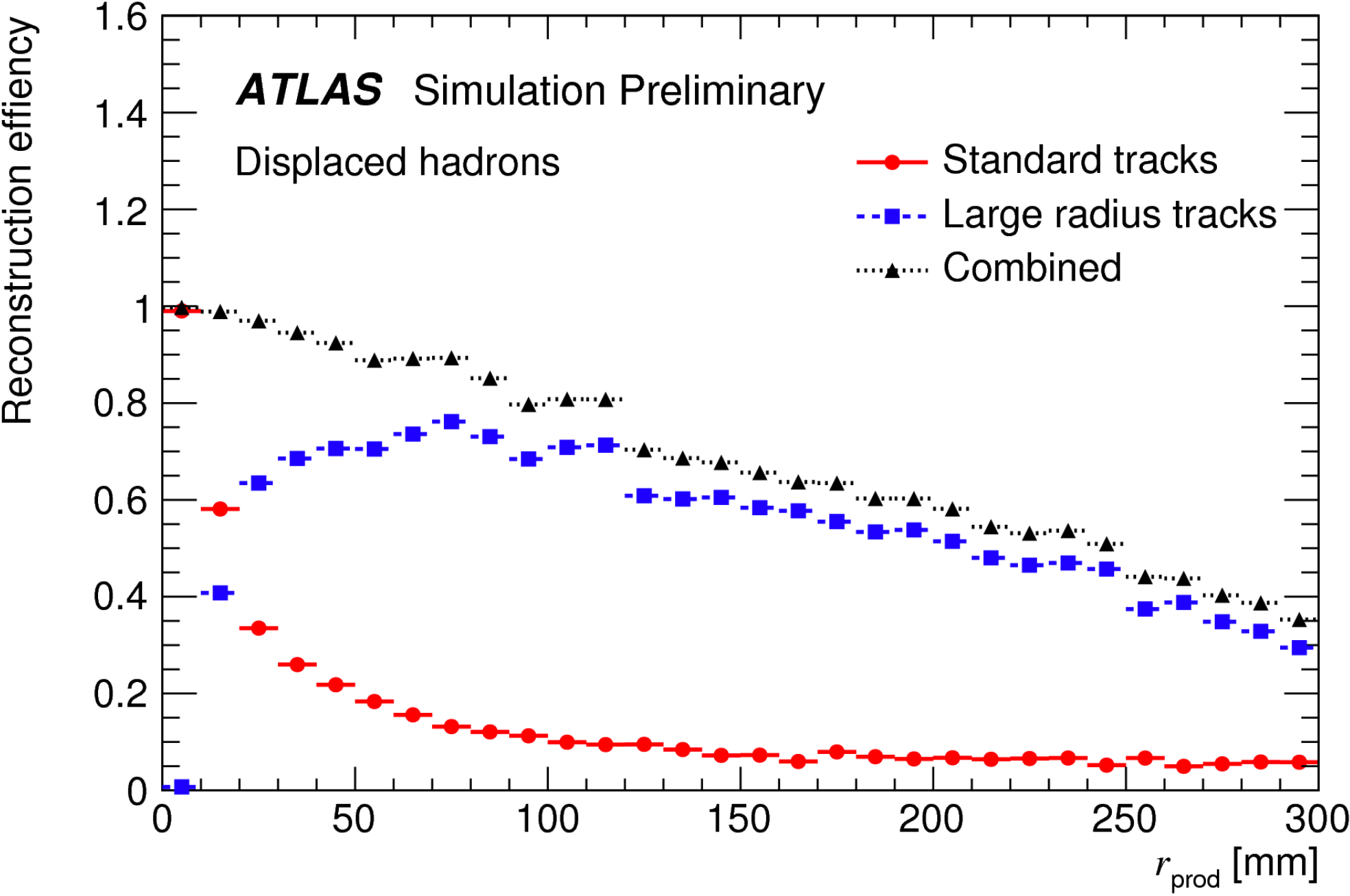
RECONSTRUCTION FEATS SO FAR
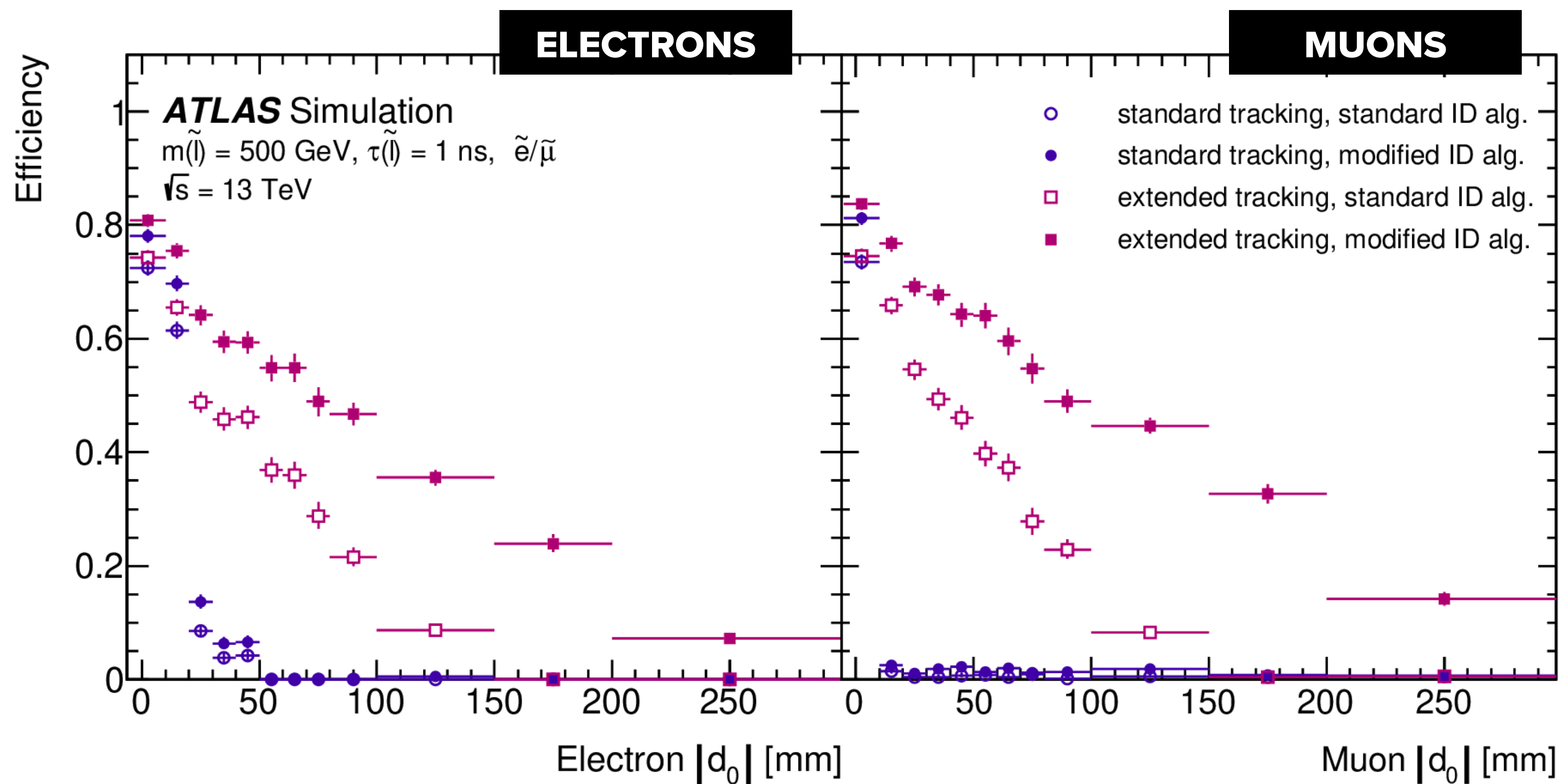## (A VERY INCOMPLETE SAMPLING)

DISPLACED TRACKING

CMS-EXO-11-101

ATL-PHYS-PUB-2017-014

RECONSTRUCTION FEATS SO FAR
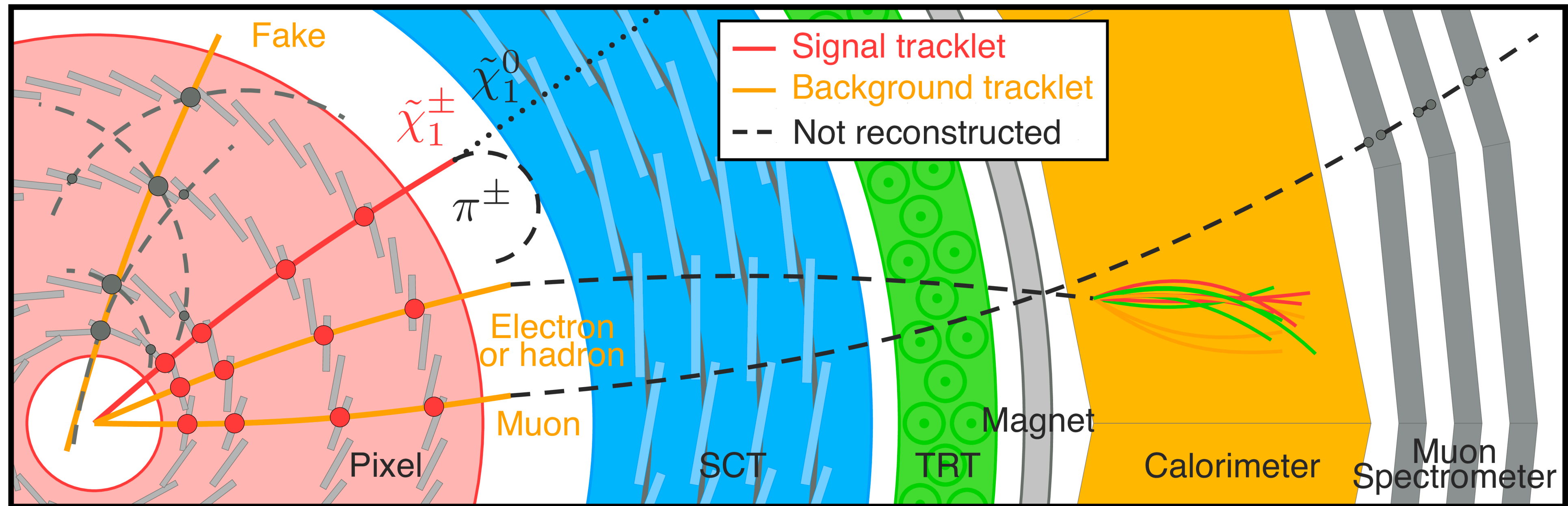## (A VERY INCOMPLETE SAMPLING)

DISPLACED LEPTONS

SUSY-2018-14

RECONSTRUCTION FEATS SO FAR
(A VERY INCOMPLETE SAMPLING)

DISAPPEARING TRACKS

ATLAS-CONF-2021-015   EXO-19-010

RECONSTRUCTION FEATS SO FAR
(A VERY INCOMPLETE SAMPLING)

2016: 36.2 fb^{-1} (13 TeV)

CMS

- Data
- Cosmic ray muon simulation
- $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_2^0$, $\tilde{\chi}_2^0 \rightarrow \mu^+\mu^-\tilde{\chi}^0$
  ($m_{\tilde{g}} = 1000$ GeV, $m_{\tilde{\chi}_2^0} = 625$ GeV, $m_{\tilde{\chi}^0} = 250$ GeV)
- MCHAMP $\rightarrow \mu^\pm\mu^\pm$ ($|Q| = 2e$, $m_{MCHAMP} = 600$ GeV)

Fraction of Entries / 5.0 ns

Δt_{DT} [ns]

ATLAS EXPERIMENT

Run 306147
Event 16519
2016-08-11 21:51:33 CEST

COSMIC RECONSTRUCTION

COLLISION RECONSTRUCTION

Jet (R=0.4)
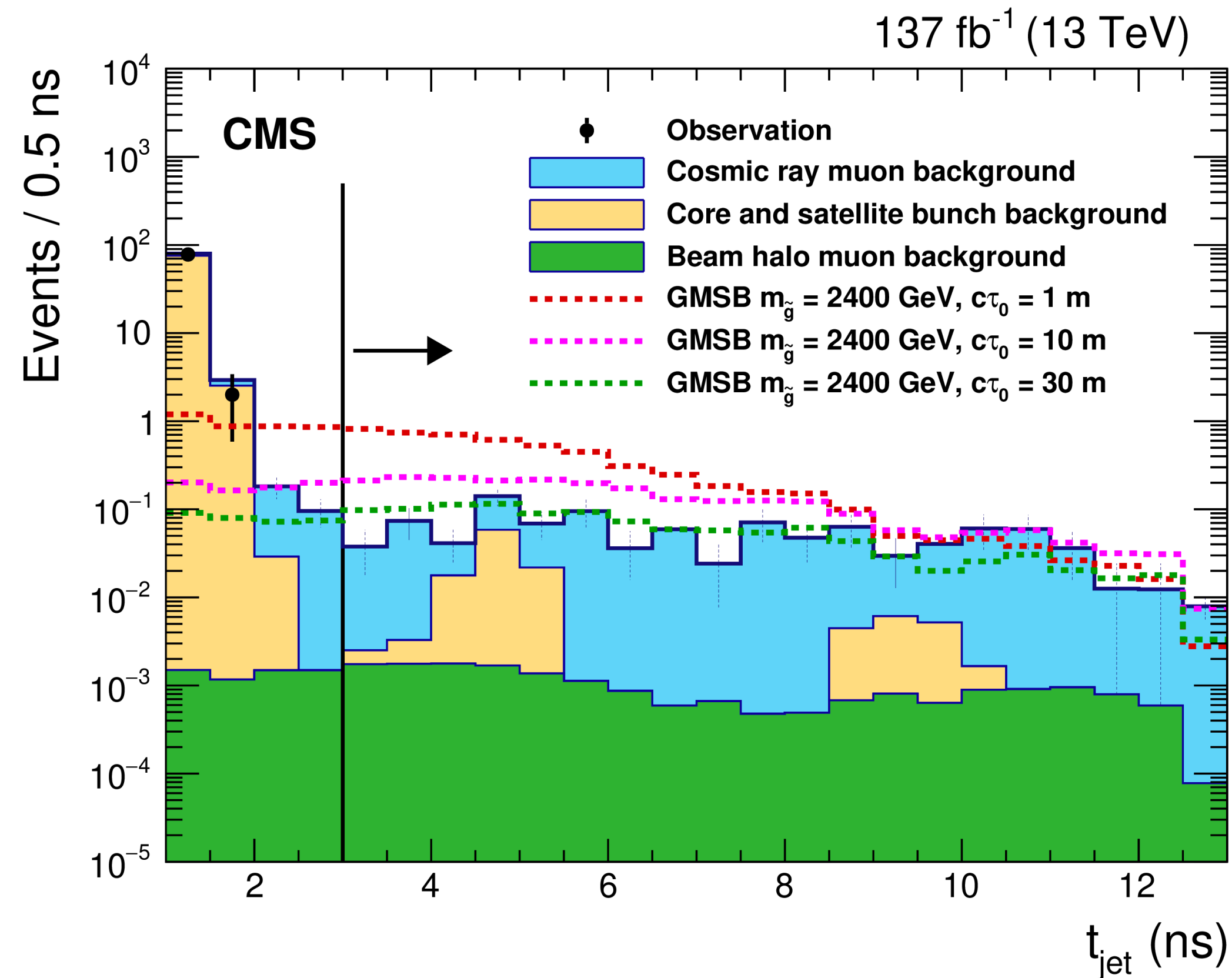
α

Muon Segments

η

ϕ
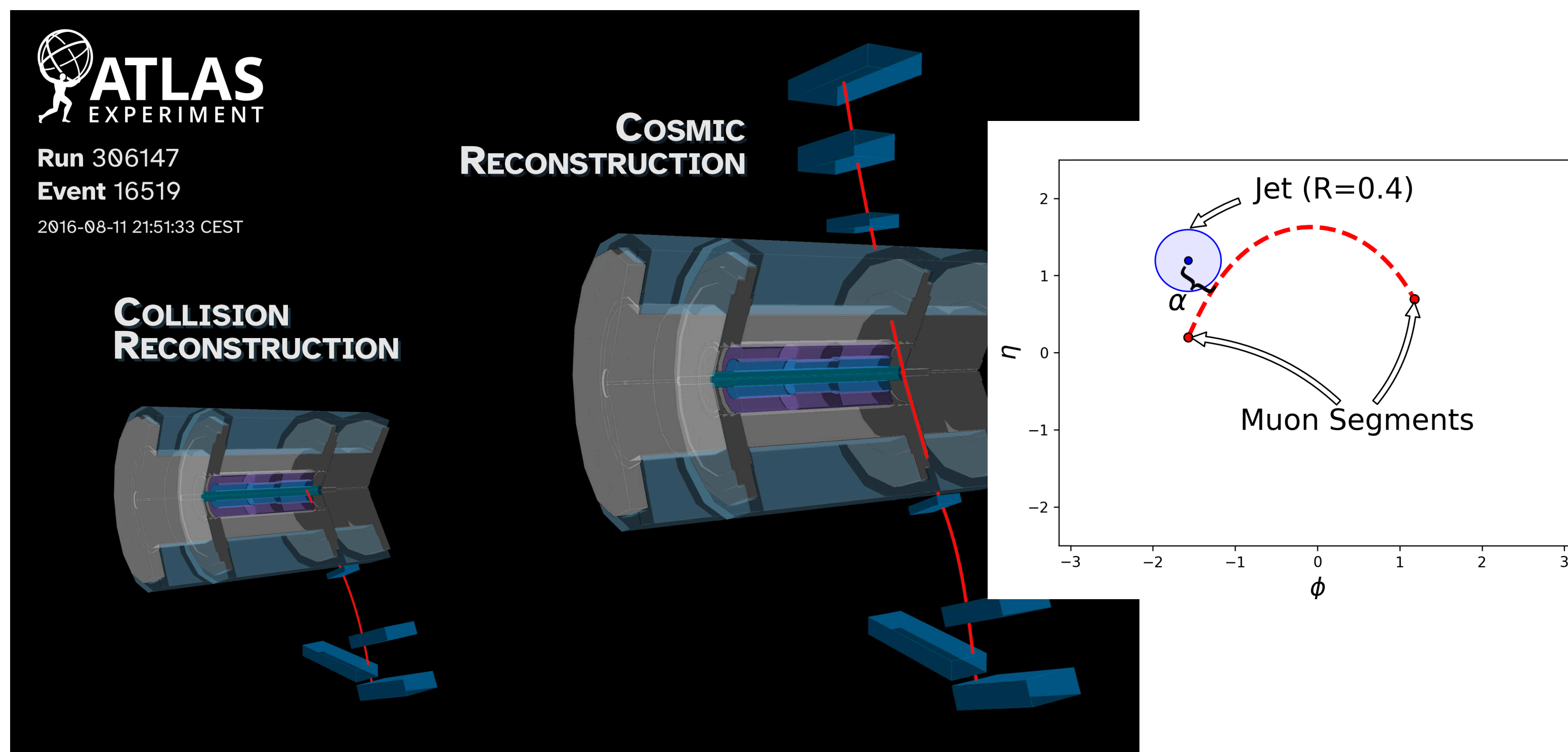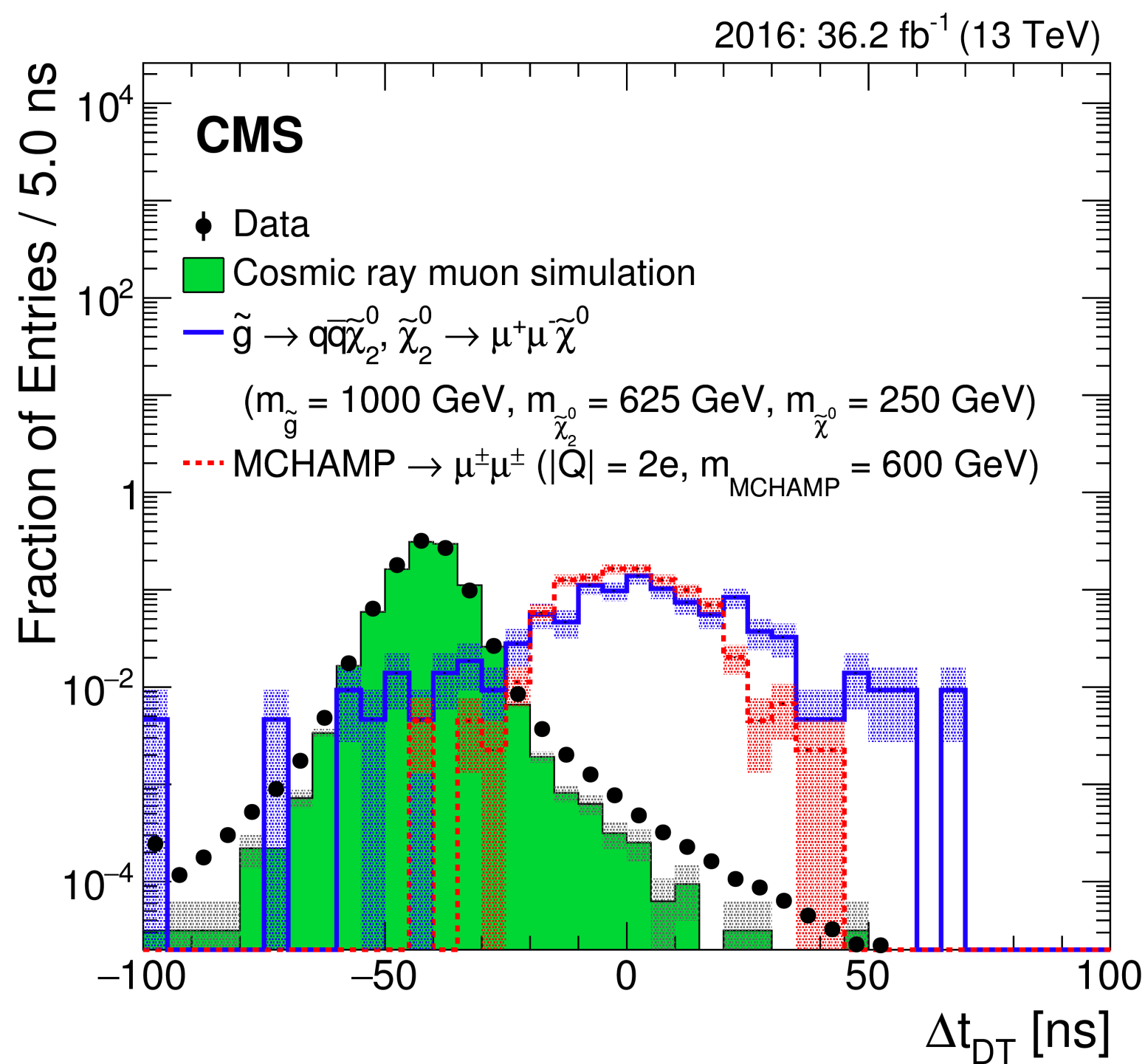
CMS-EXO-16-004

SUSY-2018-15

RECONSTRUCTION FEATS SO FAR
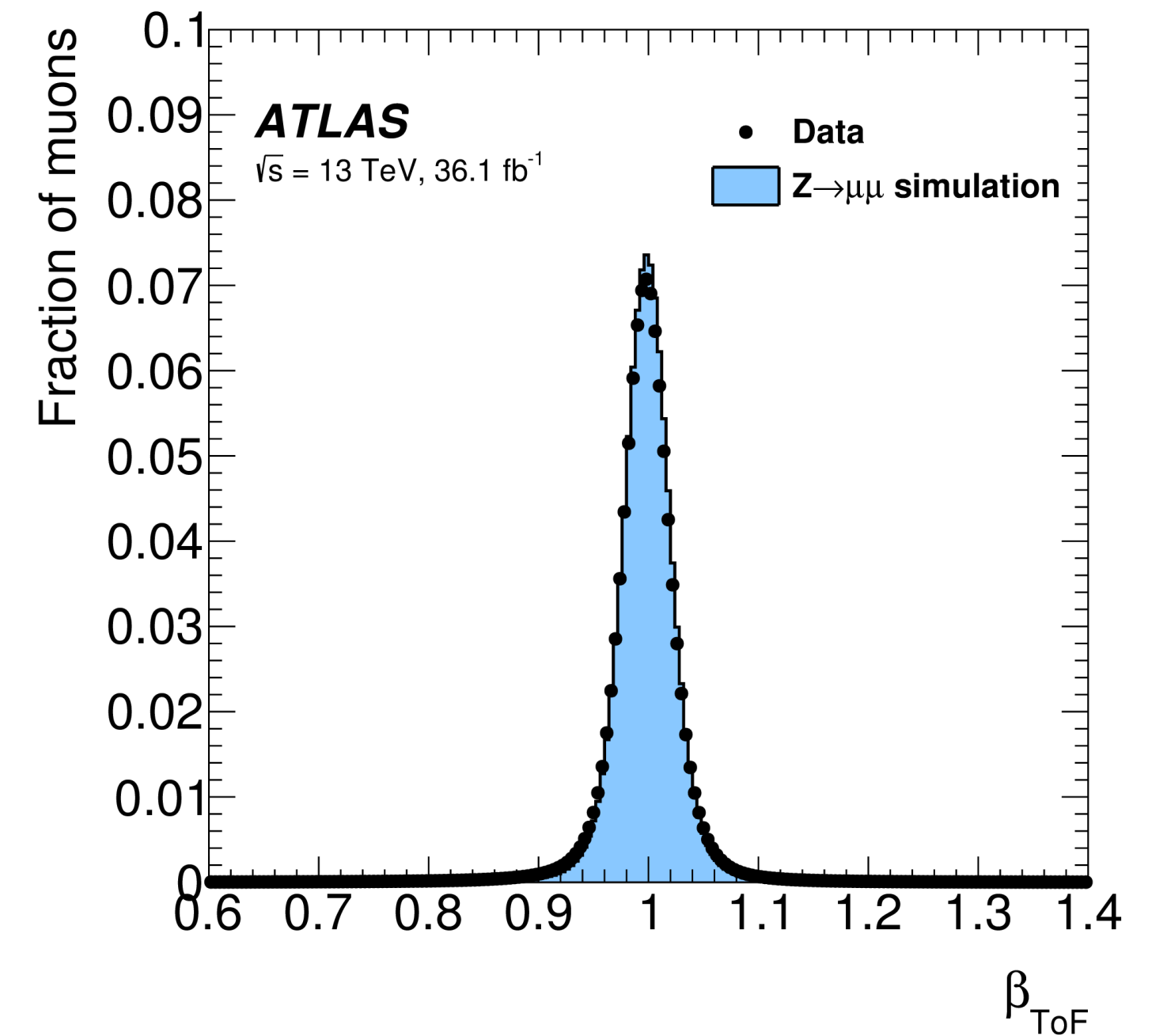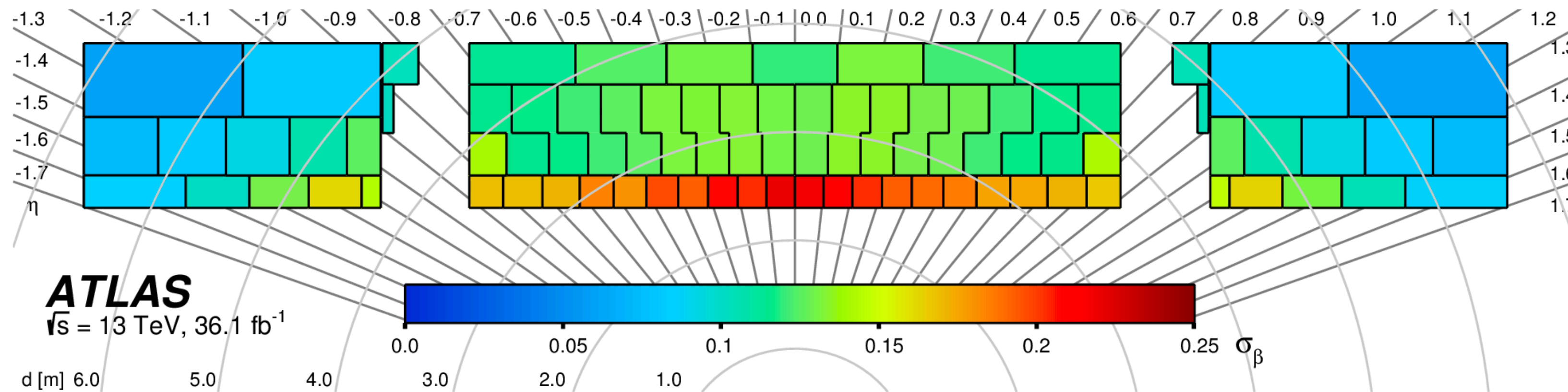## (A VERY INCOMPLETE SAMPLING)

USING TIMING

EXO-19-001

RECONSTRUCTION FEATS SO FAR
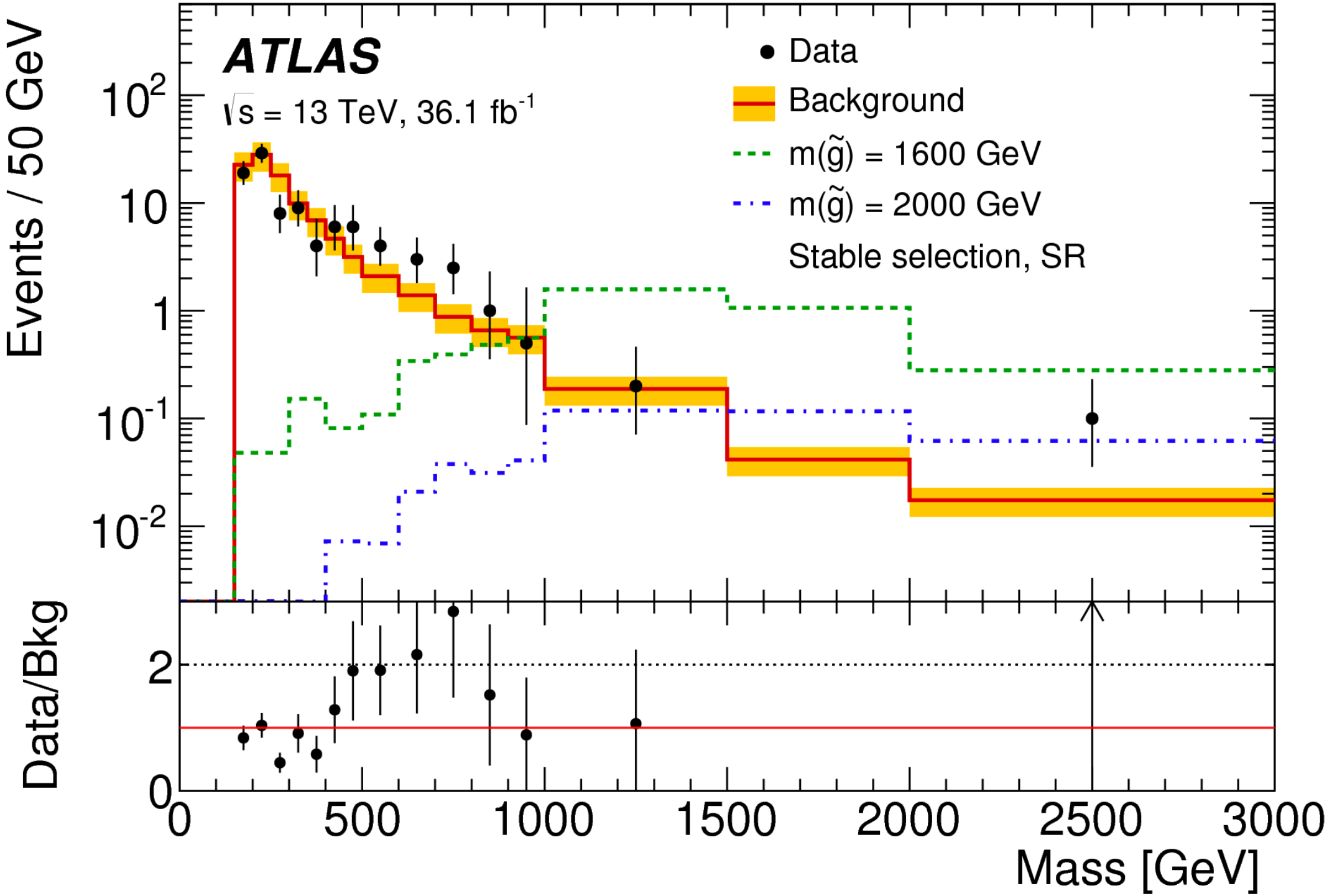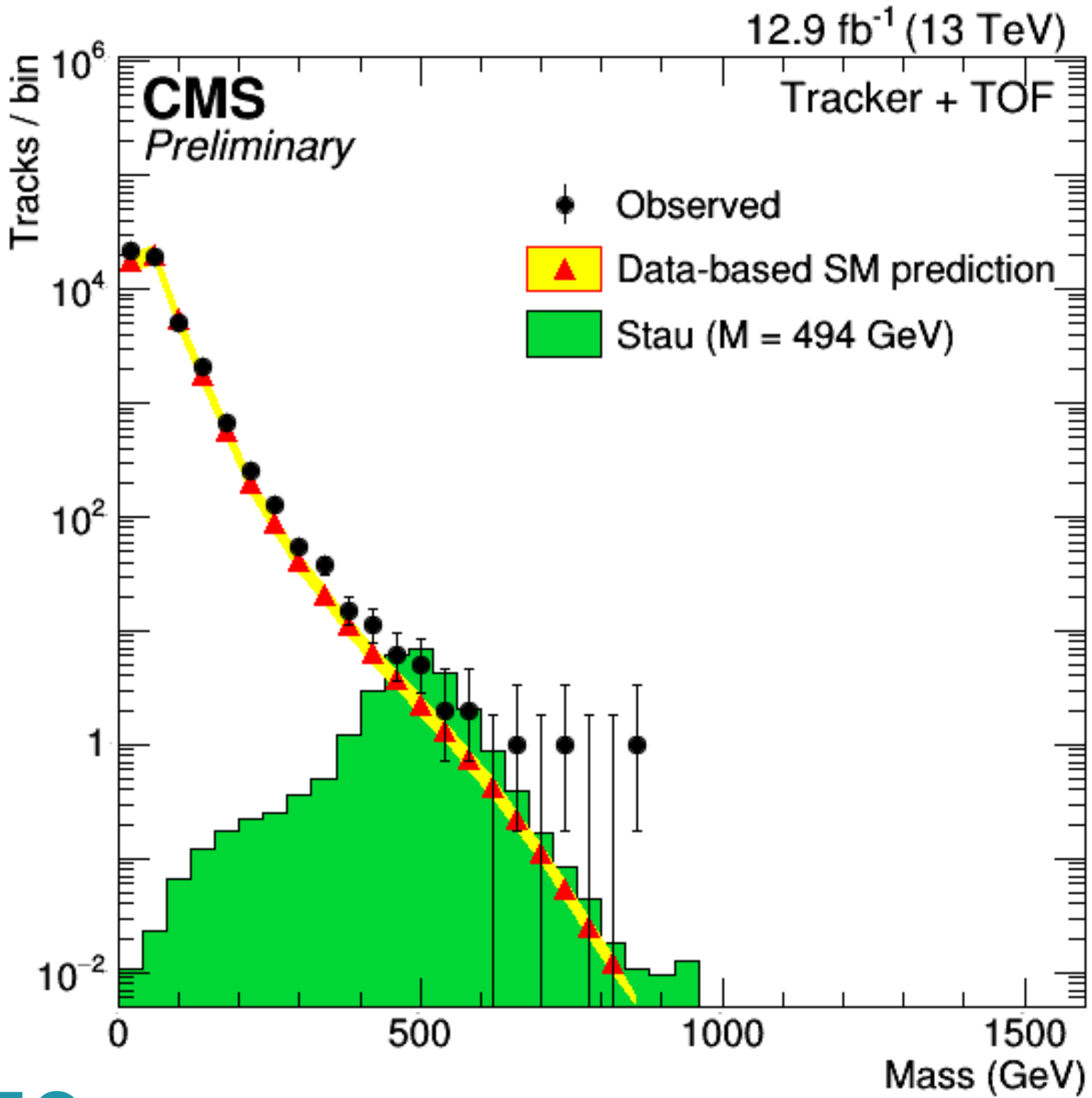## (A VERY INCOMPLETE SAMPLING)

USING TIMING

RECONSTRUCTION FEATS SO FAR
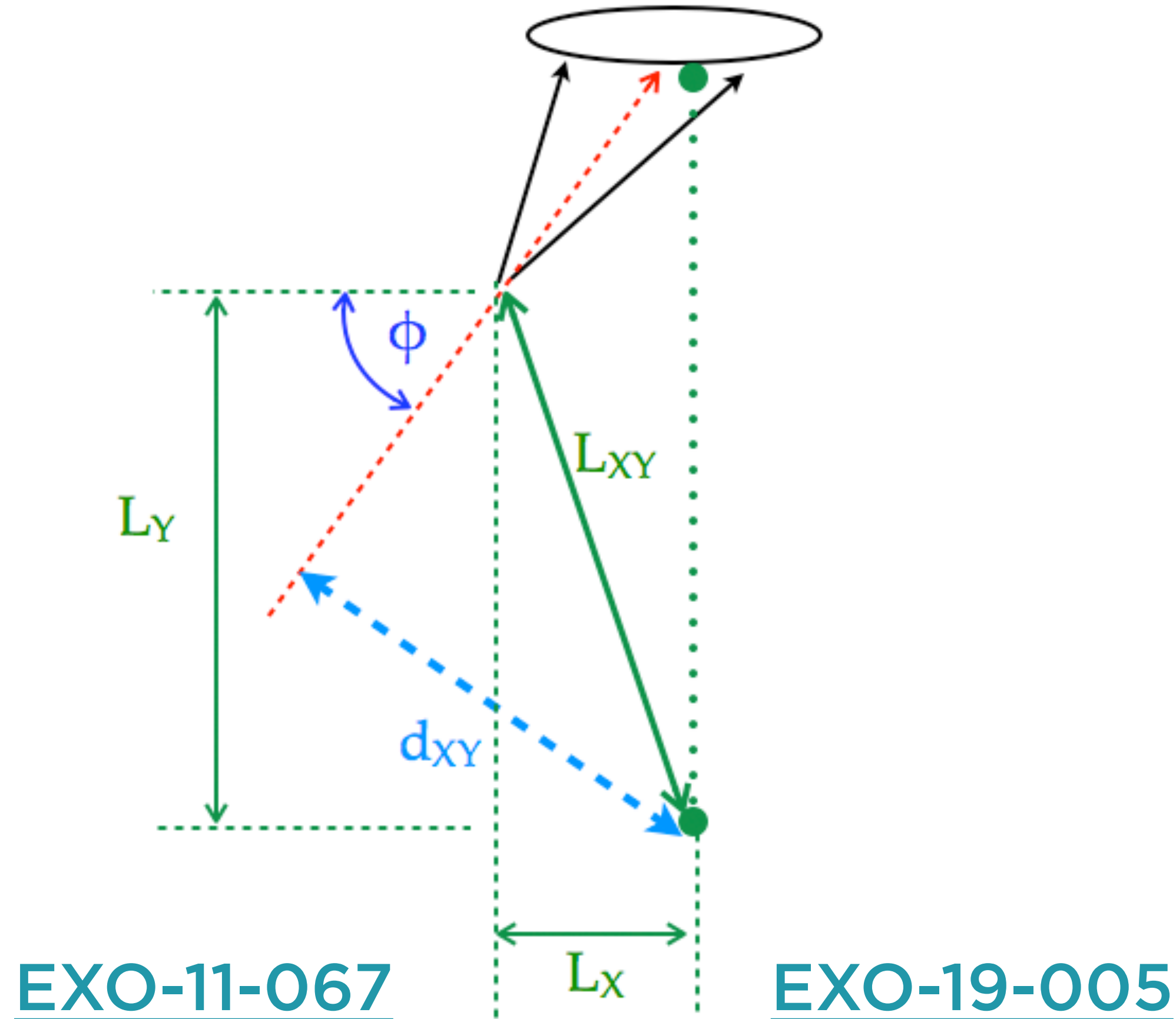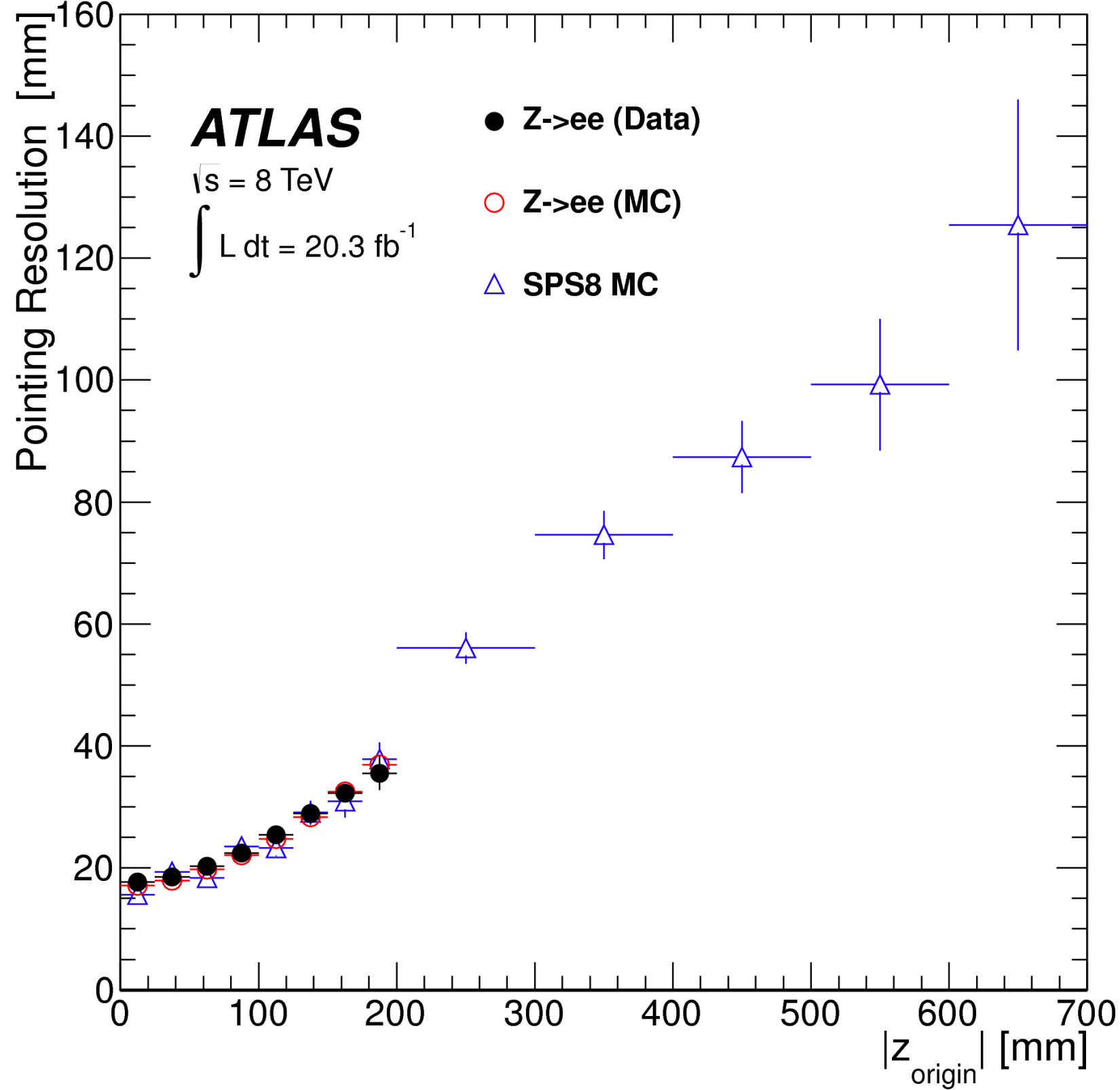## (A VERY INCOMPLETE SAMPLING)

TRACKER DIRECT DETECTION

EXO-16-036

SUSY-2016-31

RECONSTRUCTION FEATS SO FAR
(A VERY INCOMPLETE SAMPLING)

NON-POINTING PHOTONS

SUSY-2013-17

EXO-11-067   EXO-19-005

NEW DIRECTIONS

- **So far focus has (mostly) been on LLP signatures**
  - Taking advantage of displacement and delay measurements
    - Sometimes very anomalous signatures, e.g. disappearing track,
  - Often relatively high-pT
  - Light leptons, not so much taus
  - Calo signals that can be approximated as jets/photons
- **These constraints partially come from our past trigger capabilities — time to re-think them for Run 3**
  - Can use high-pT photon triggers to find displaced electrons, but no equivalent for displaced hadronic taus
  - Now is the time to rethink what is possible for reconstruction, and figure out if we can find a way to collect that data

NEW DIRECTIONS (AN EVEN LESS COMPLETE SAMPLING)

- **How do we look for more complex displaced objects, e.g. taus?**

  - GMSB stau scenarios are very well motivated, but have very weak limits from the LHC

  - First LHC exclusion in the lifetime regime where you'd target displaced taus came out this year

  - Only looking at leptonic decays of taus, so much less sensitive to staus than selectrons and smuons
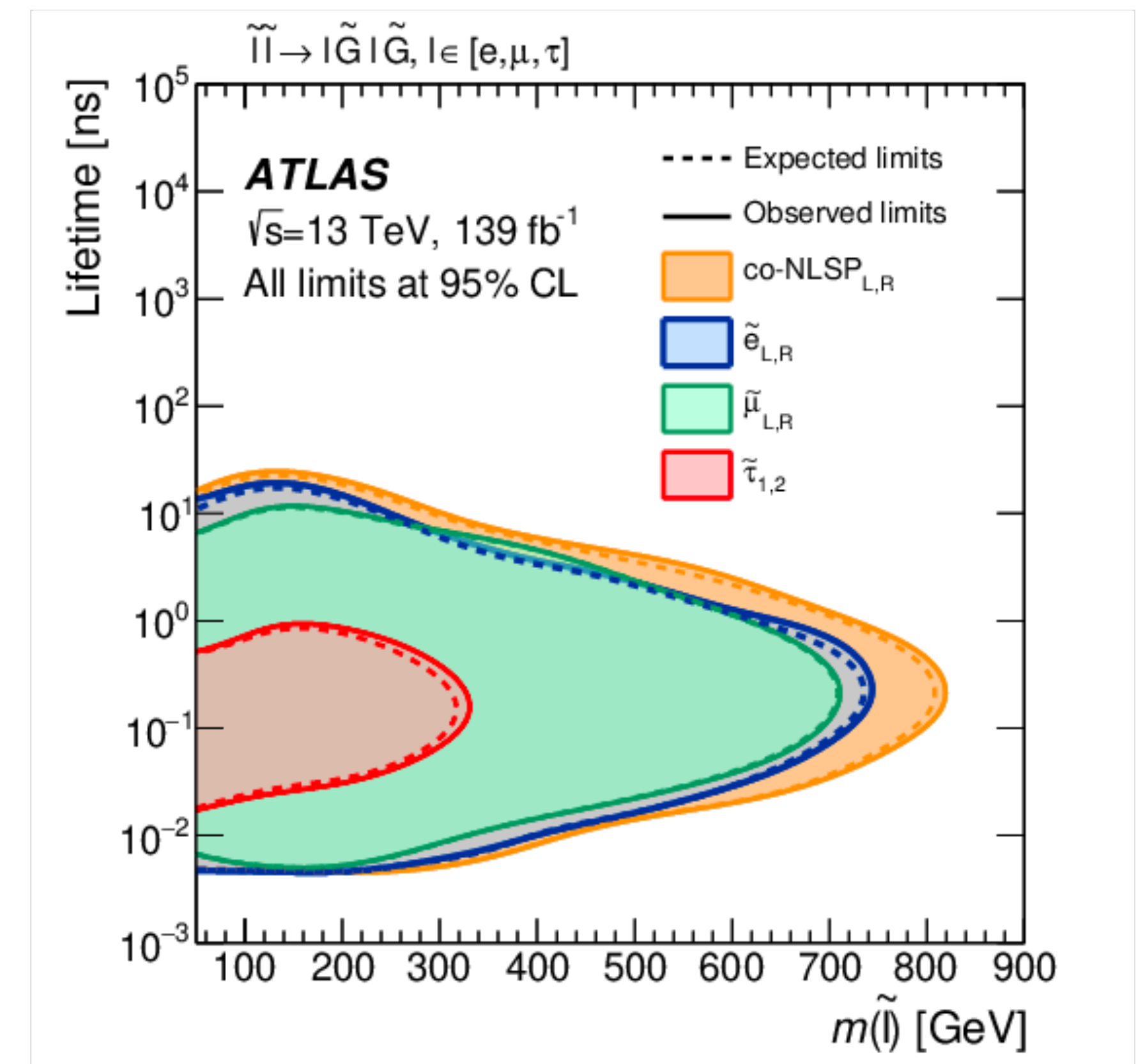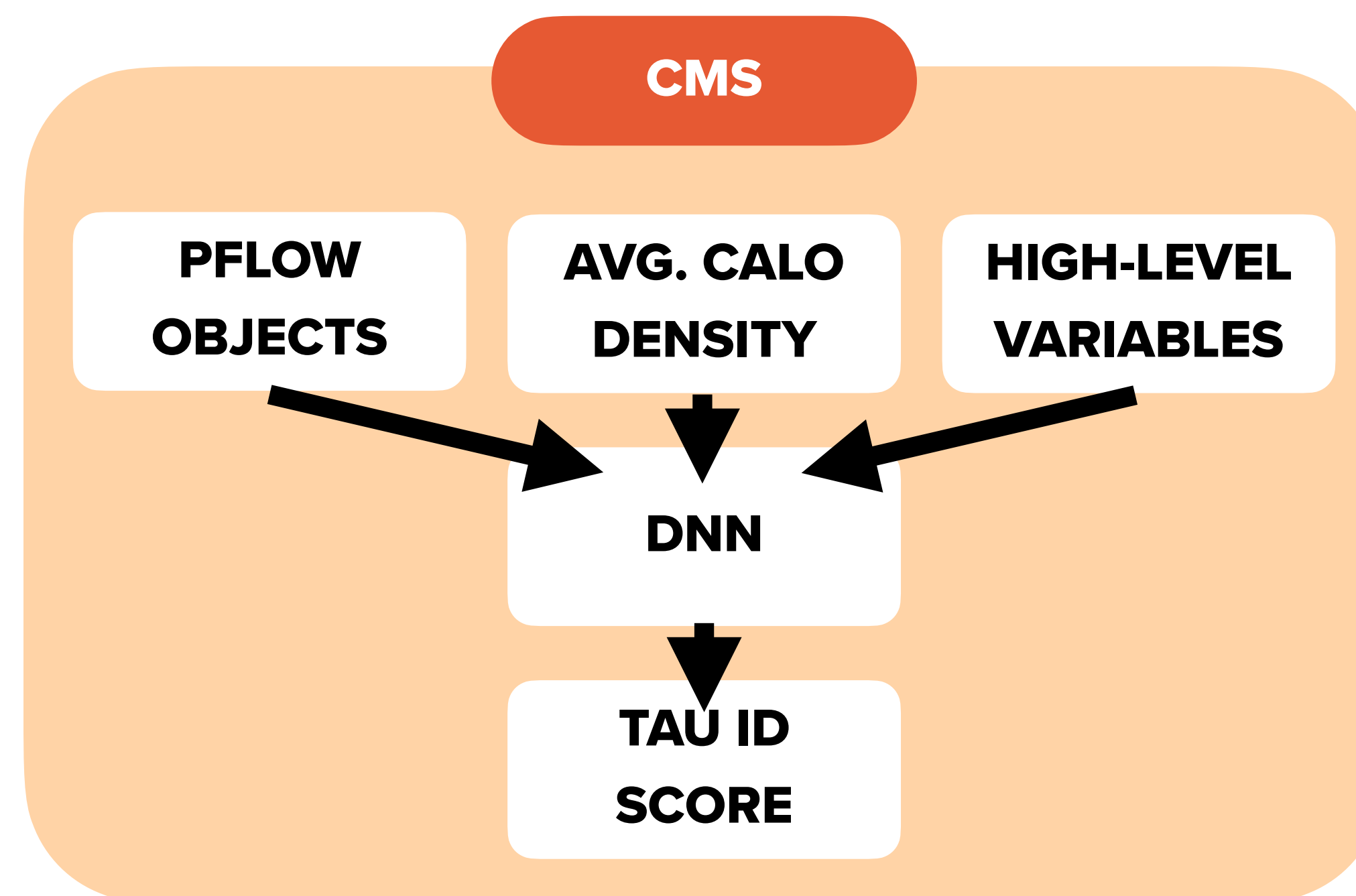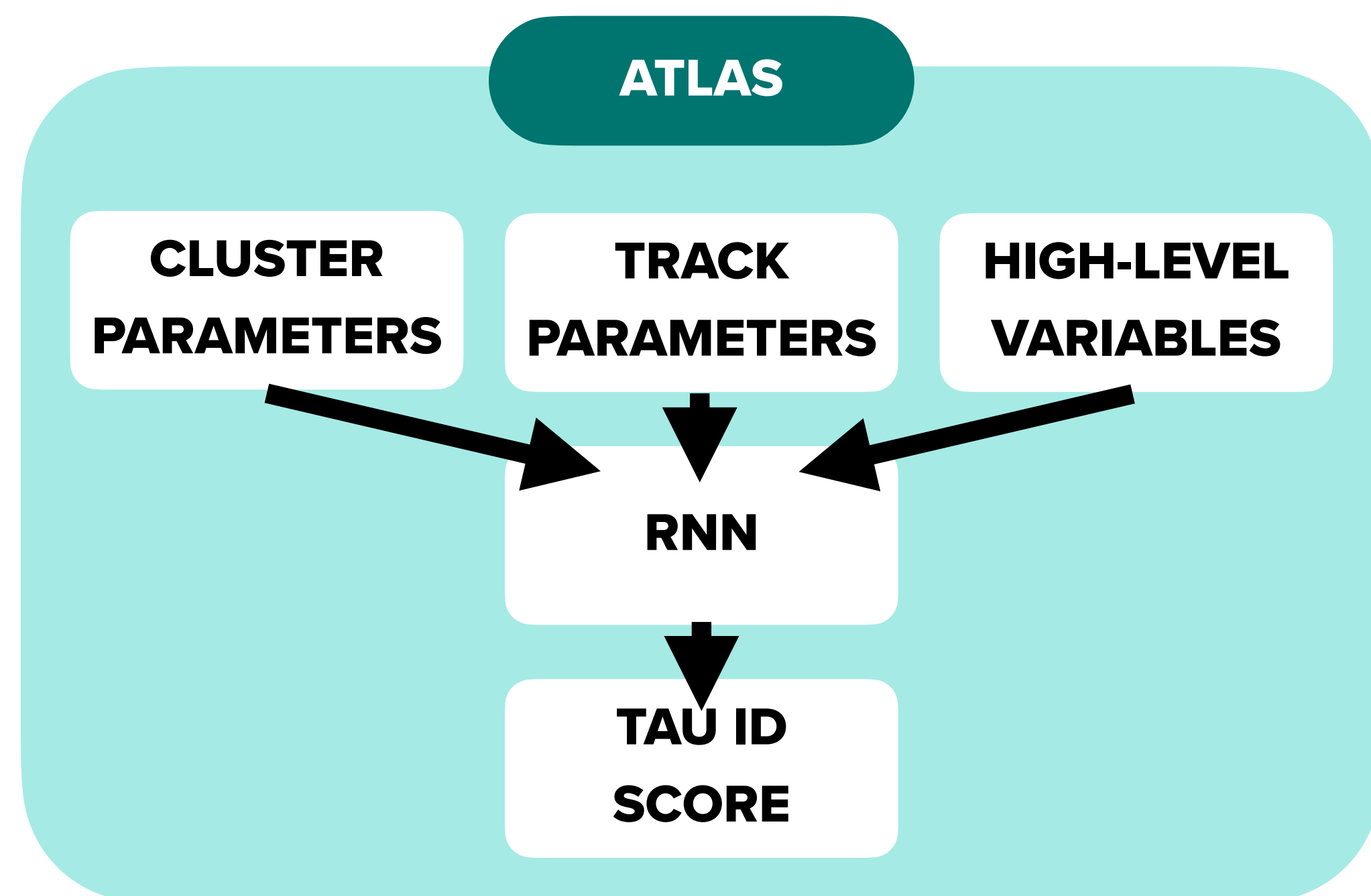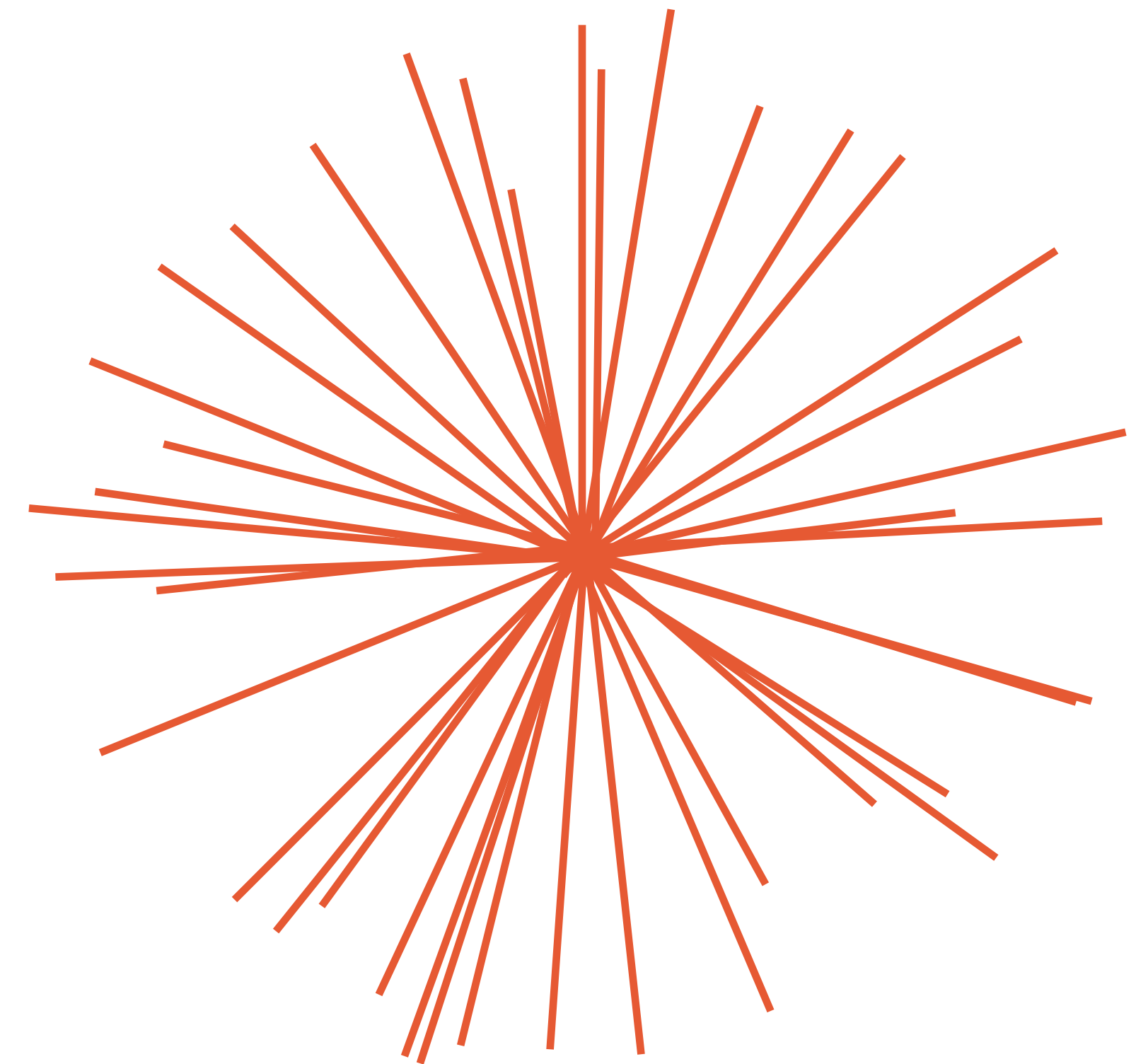
NEW DIRECTIONS (AN EVEN LESS COMPLETE SAMPLING)

■ **How do we look for more complex displaced objects, e.g. taus?**

   – Both experiments now using neural networks for tau ID

ATL-PHYS-PUB-2019-033   DP2019_033

NEW DIRECTIONS (AN EVEN LESS COMPLETE SAMPLING)

- **But moving beyond LLPs — what about diffuse objects?**

  - Dark sectors with large 't Hooft couplings → diffuse jets (SUEPs)

  - Evade searches because energy is not localized; can look like soft pile-up

  - Can be targeted with high track multiplicity and spherical nature of the decay

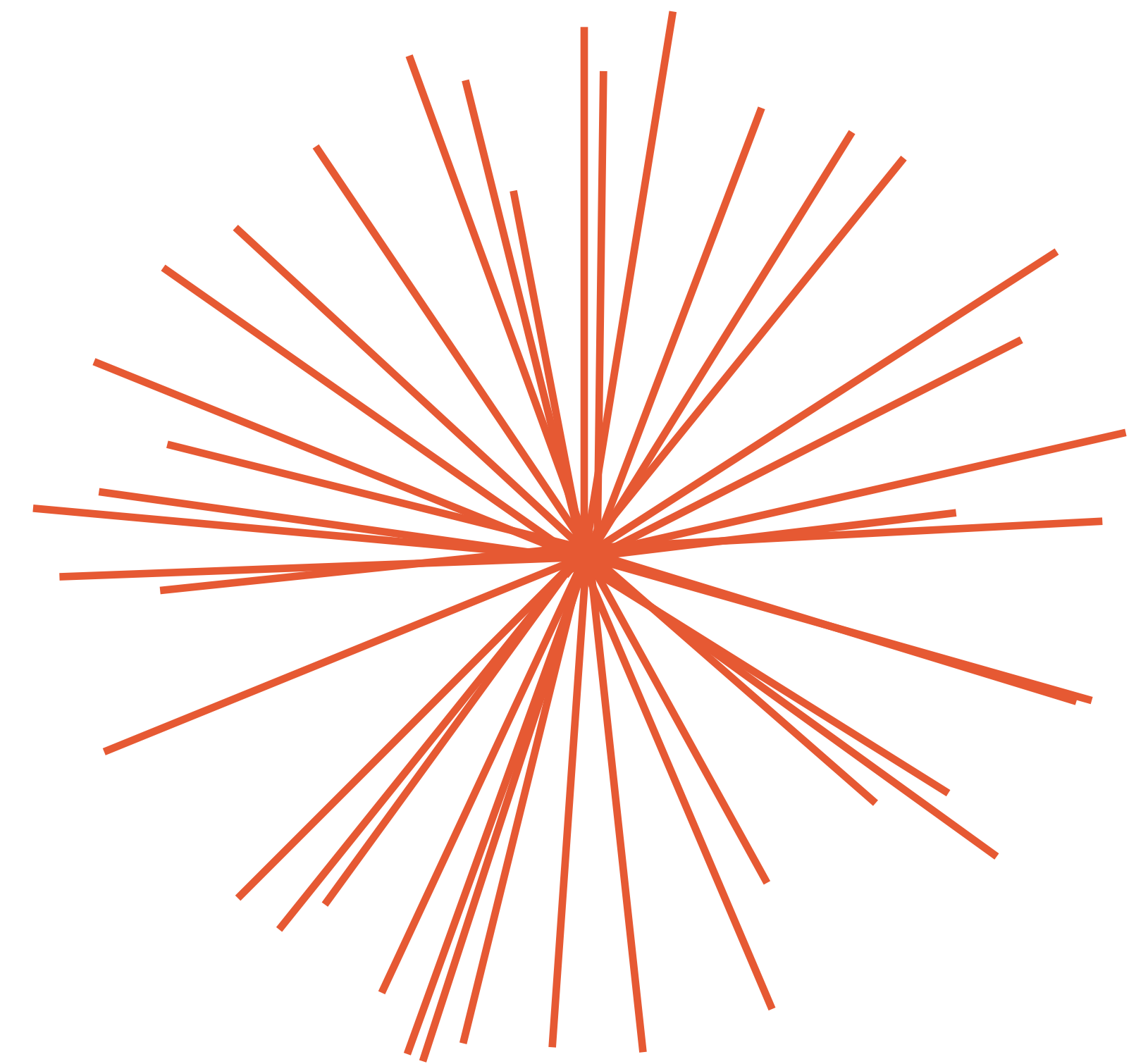   - Much historical and recent work to characterize these event shapes

Cesarotti, Reece, Strassler

Knapen, Pagan Griso, Papucci, Robinson

NEW DIRECTIONS (AN EVEN LESS COMPLETE SAMPLING)
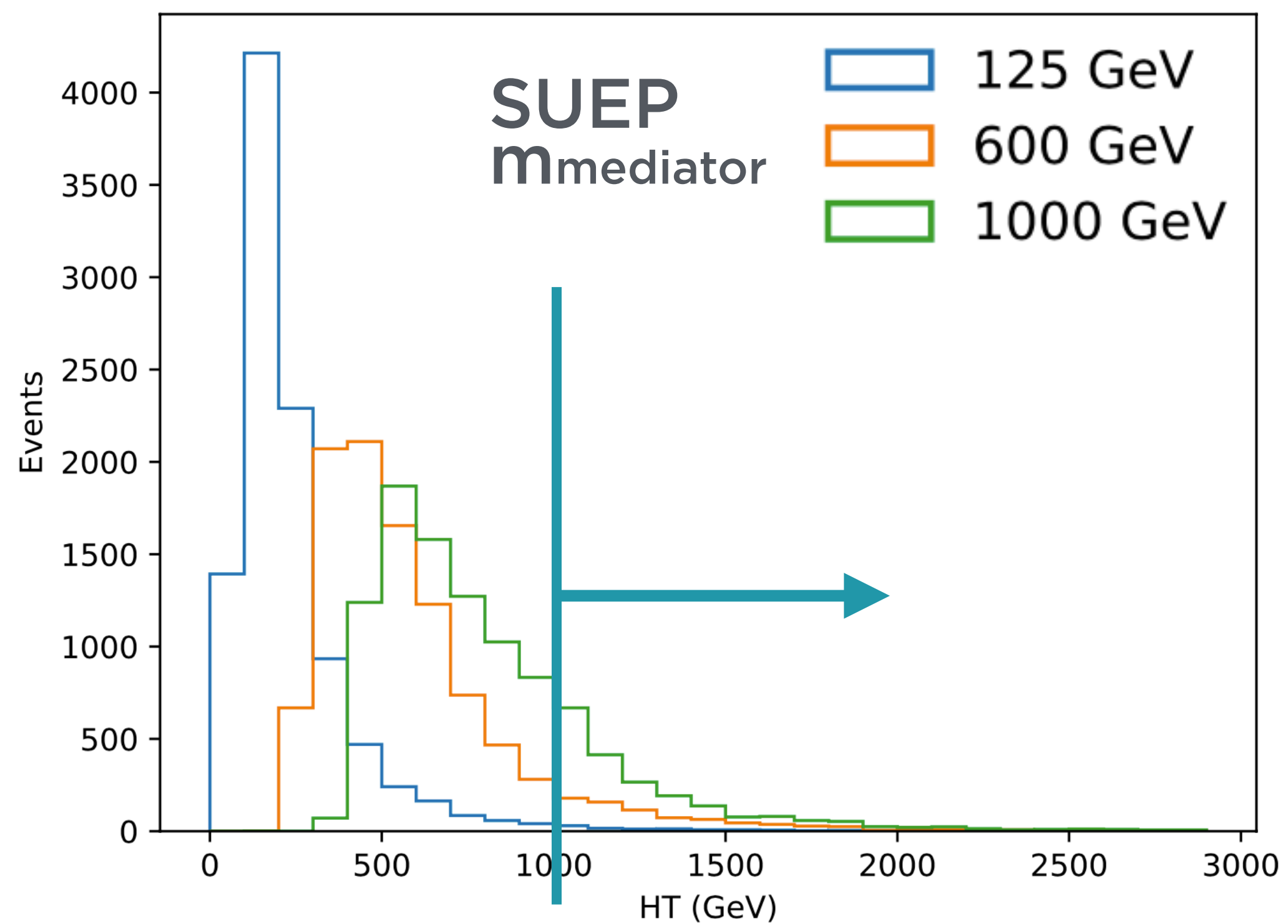
In practice, not this simple:
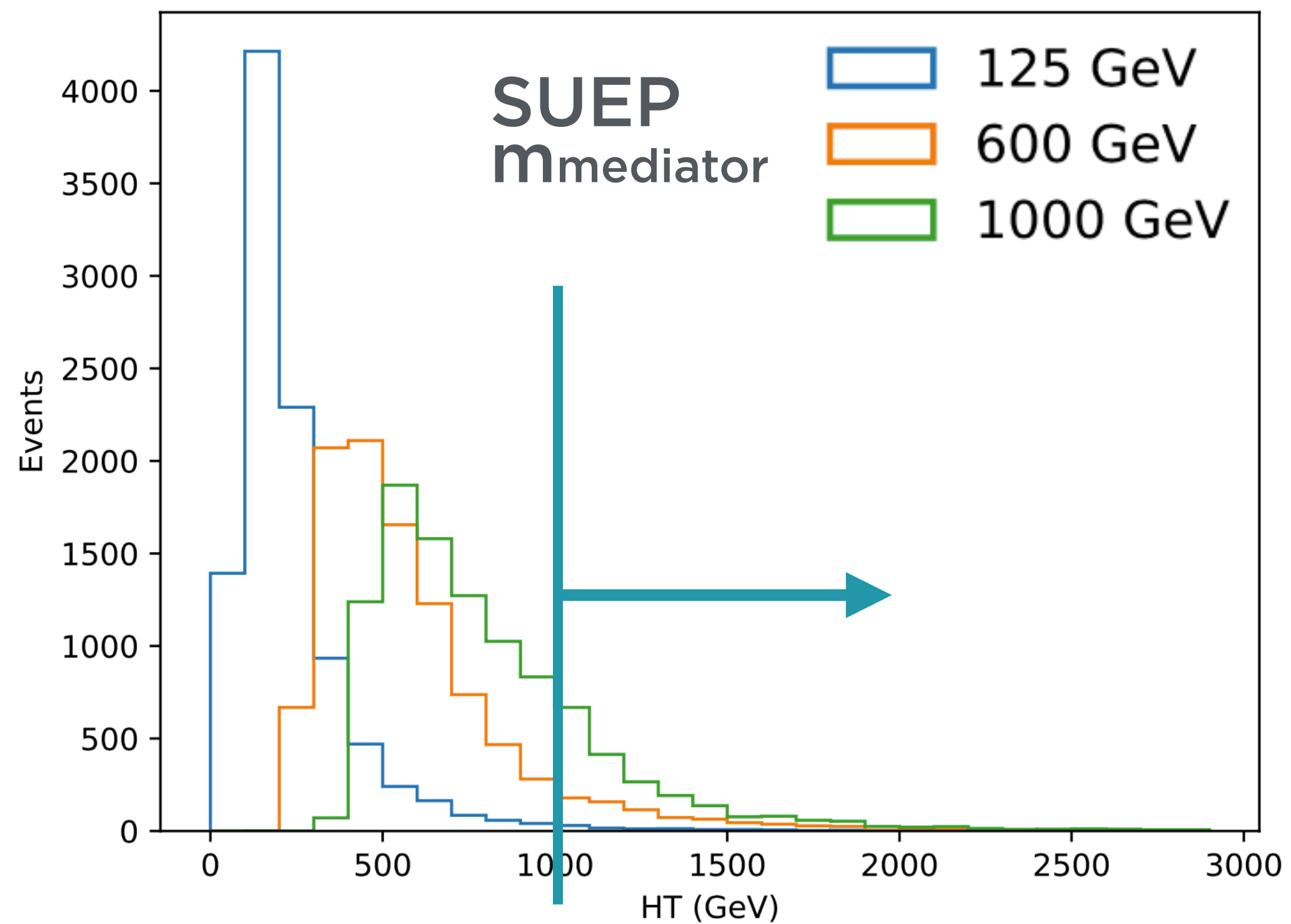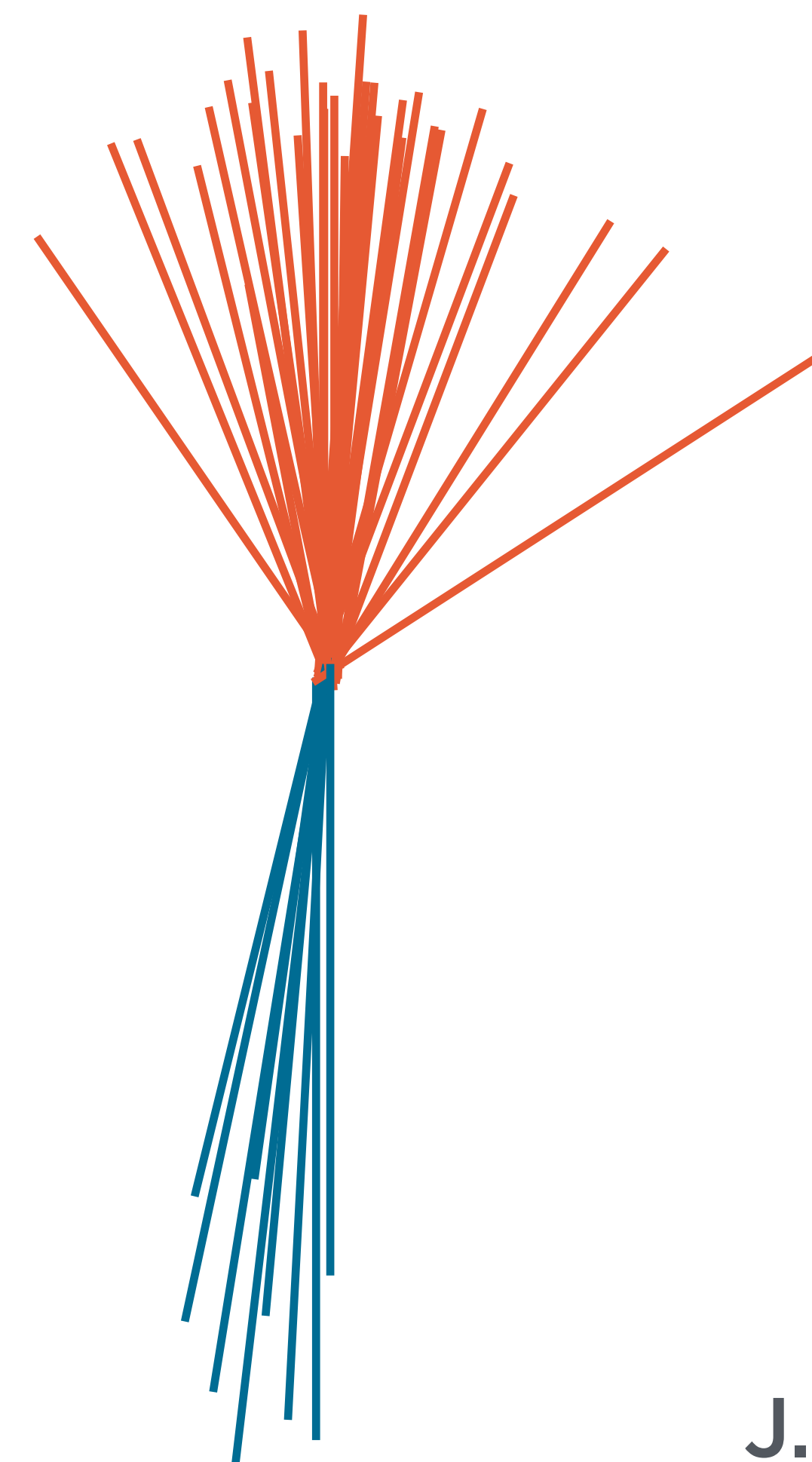

*plot shows track-based HT

J. Nelson

NEW DIRECTIONS (AN EVEN LESS COMPLETE SAMPLING)
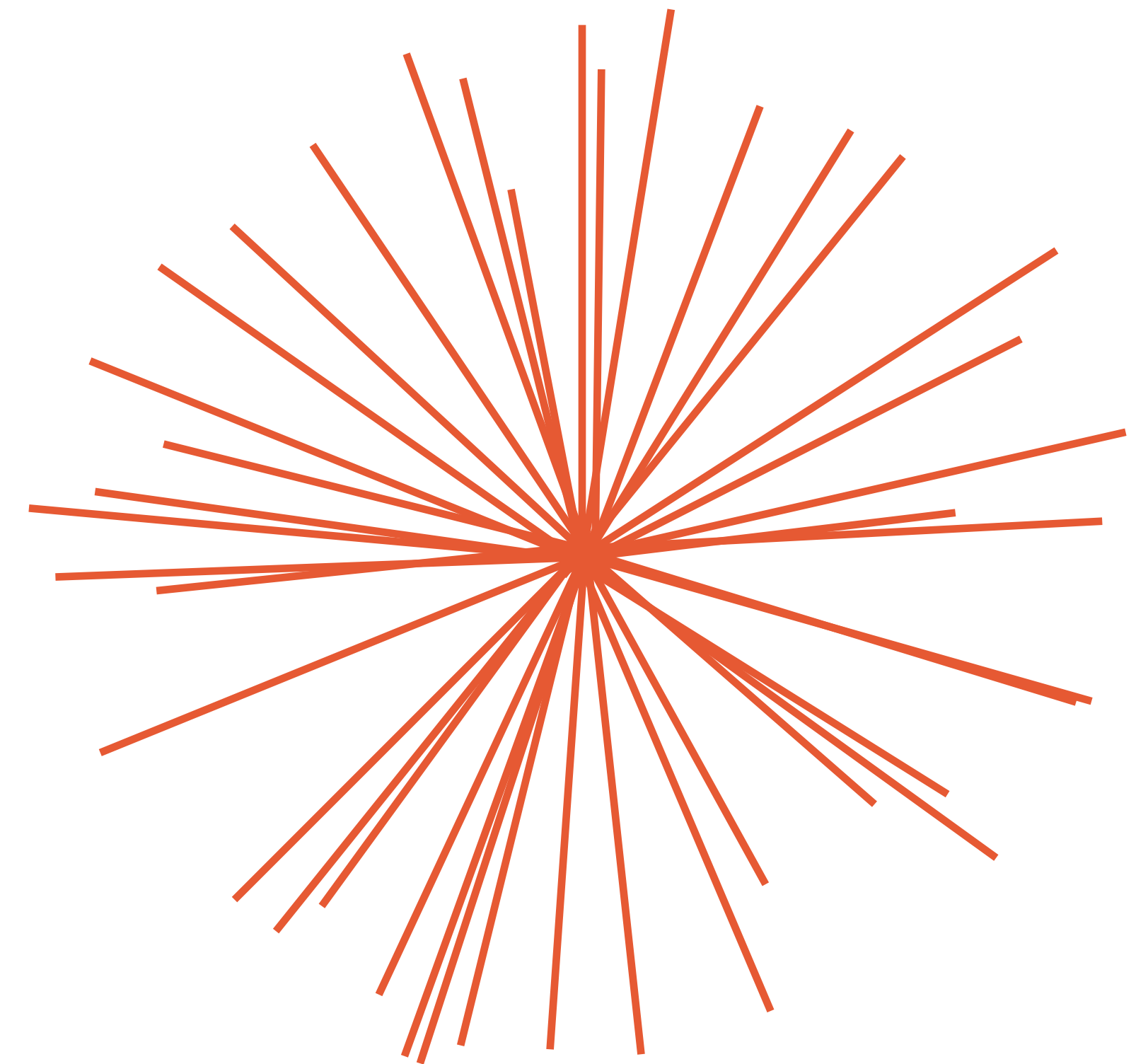
- **In practice, not this simple:**

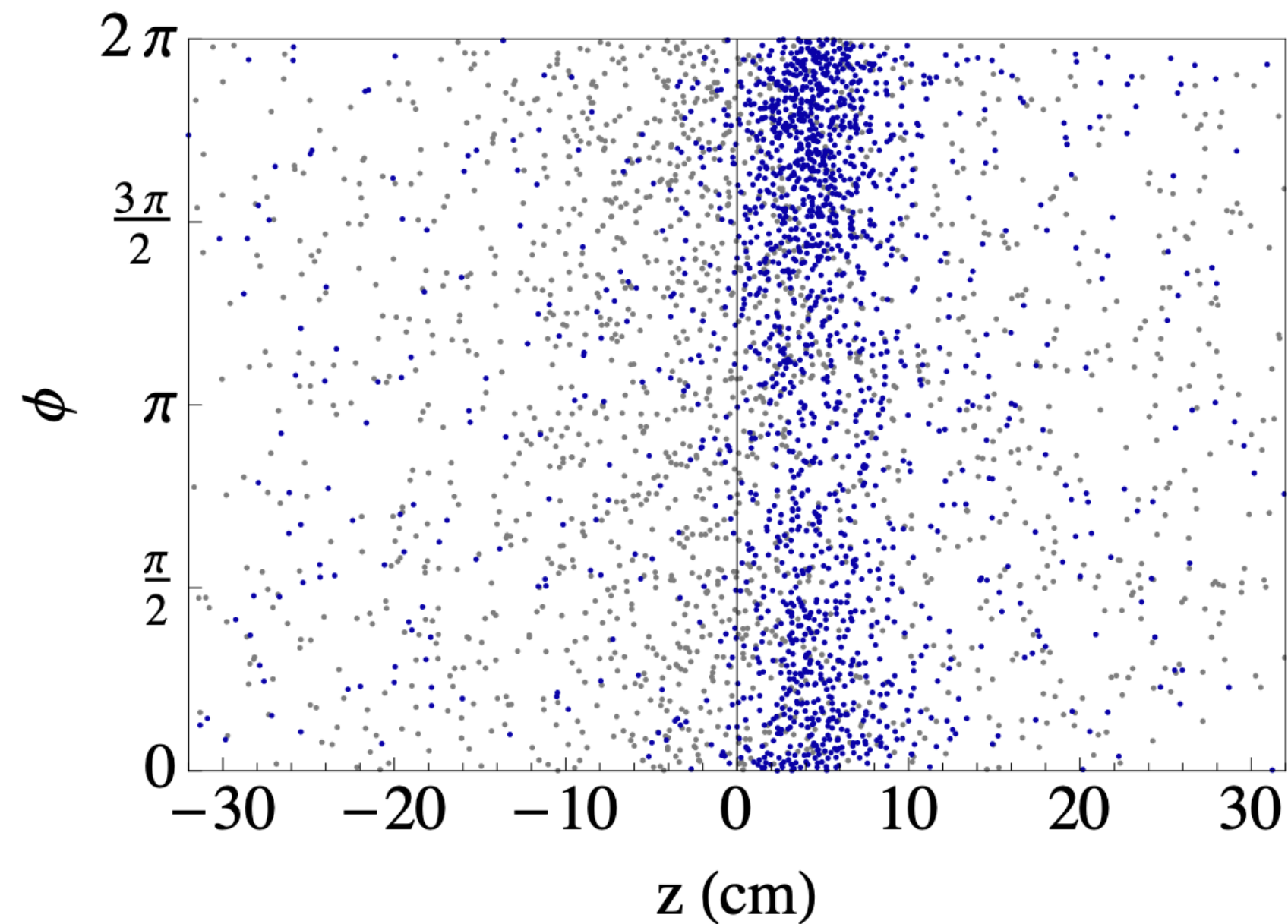*plot shows track-based HT

J. Nelson

NEW DIRECTIONS (AN EVEN LESS COMPLETE SAMPLING)

- **Want to get around this? Need a trigger...**
  - Of course a lot of interest in SUEPs was kicked off by a paper describing one way to do that

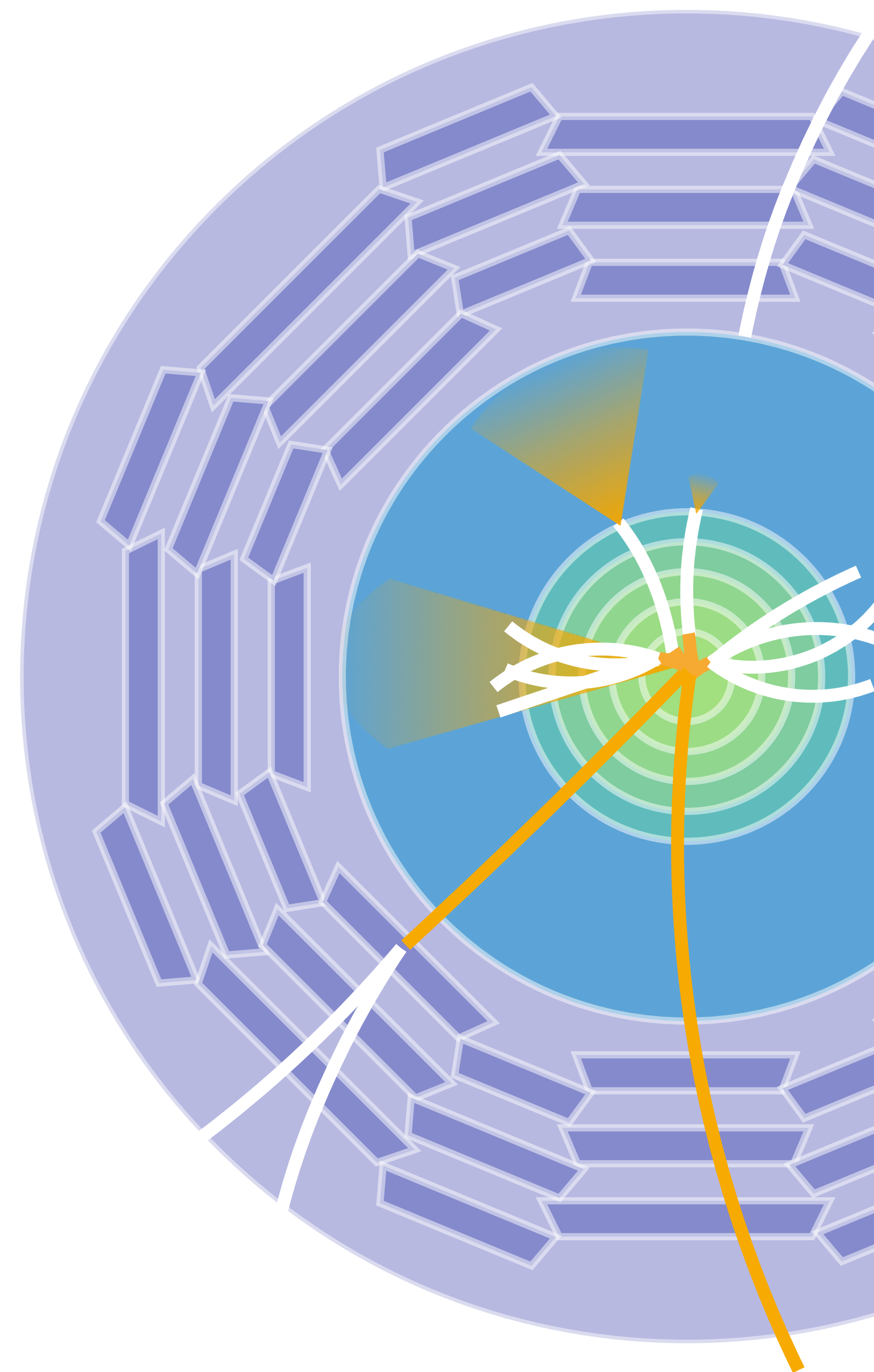**Knapen, Pagan Griso, Papucci, Robinson**

NEW DIRECTIONS

- **And much much more…**
  - How to improve displaced tracking, and include it in the trigger?
  - How to target even shorter disappearing tracks?
  - How to deal with dark showers with a variety of lifetimes?
  - How to use machine learning to identify complex unconventional signatures?
- **All in conjunction with improvement to the trigger which will allow us to collect this data**
  - more on that from Juliette, up next!

THANK YOU!