



南京大學
NANJING UNIVERSITY

Search for New Physics at Colliders
2026-04-19

Long-lived Particles and Dark Showers at the LHC

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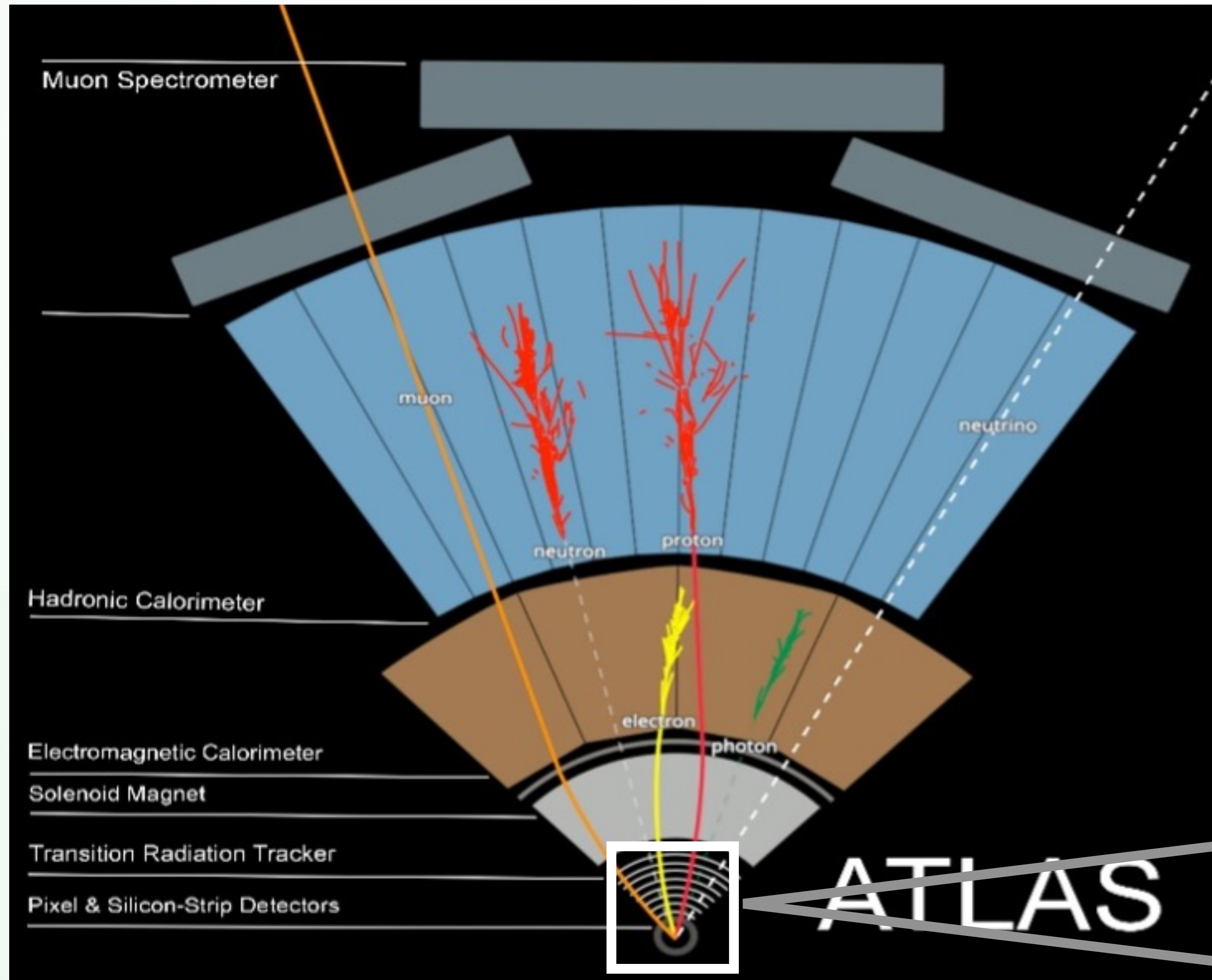


Contact info: liubx28@mail.sysu.edu.cn

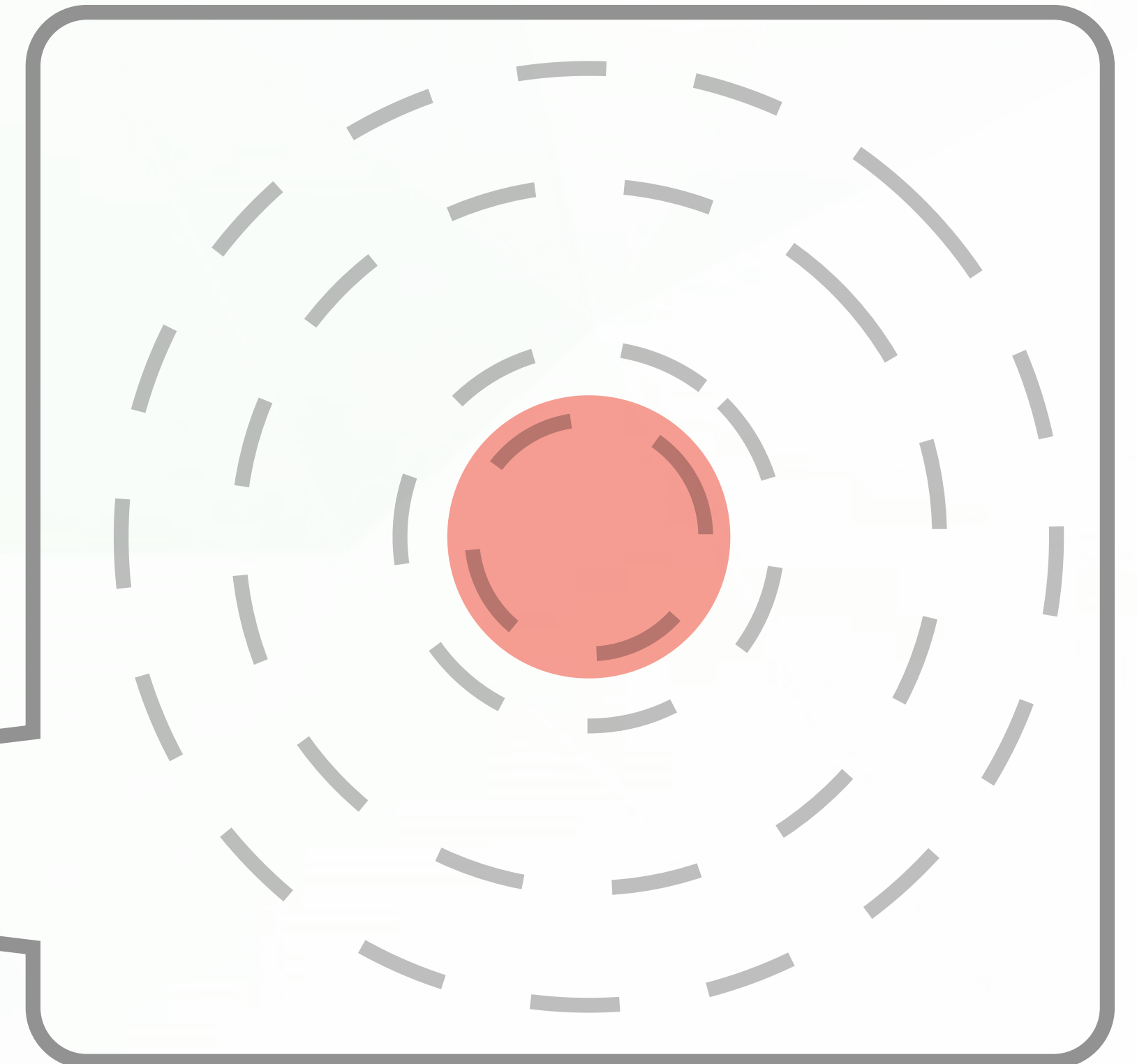


**The LHC experiments
can only reconstruct
prompt physics objects**

Prompt Region



- The **prompt region** is very small compared to the entire detector volume!



Prompt Region

Hidden sector scalar decays to stable particle **near the collision point**

Displaced Region

Hidden sector scalar decays to stable particle **displaced from the collision point**

Detector Stable Region

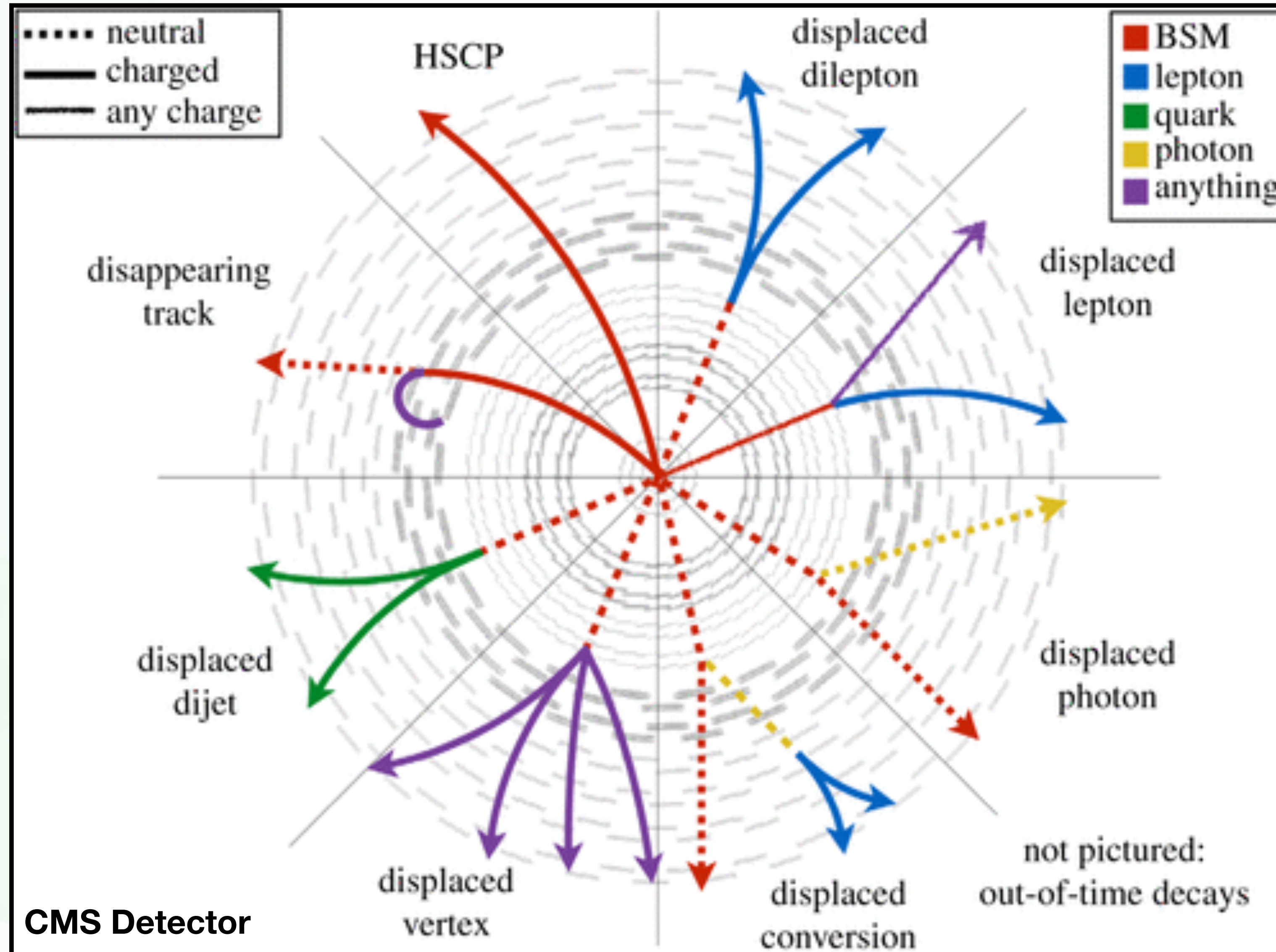
Hidden sector scalar decays to **neutrinos/dark matter candidates**

10^{-4}

10^3

scalar $c\tau$ [m]

Long-lived Particle Search

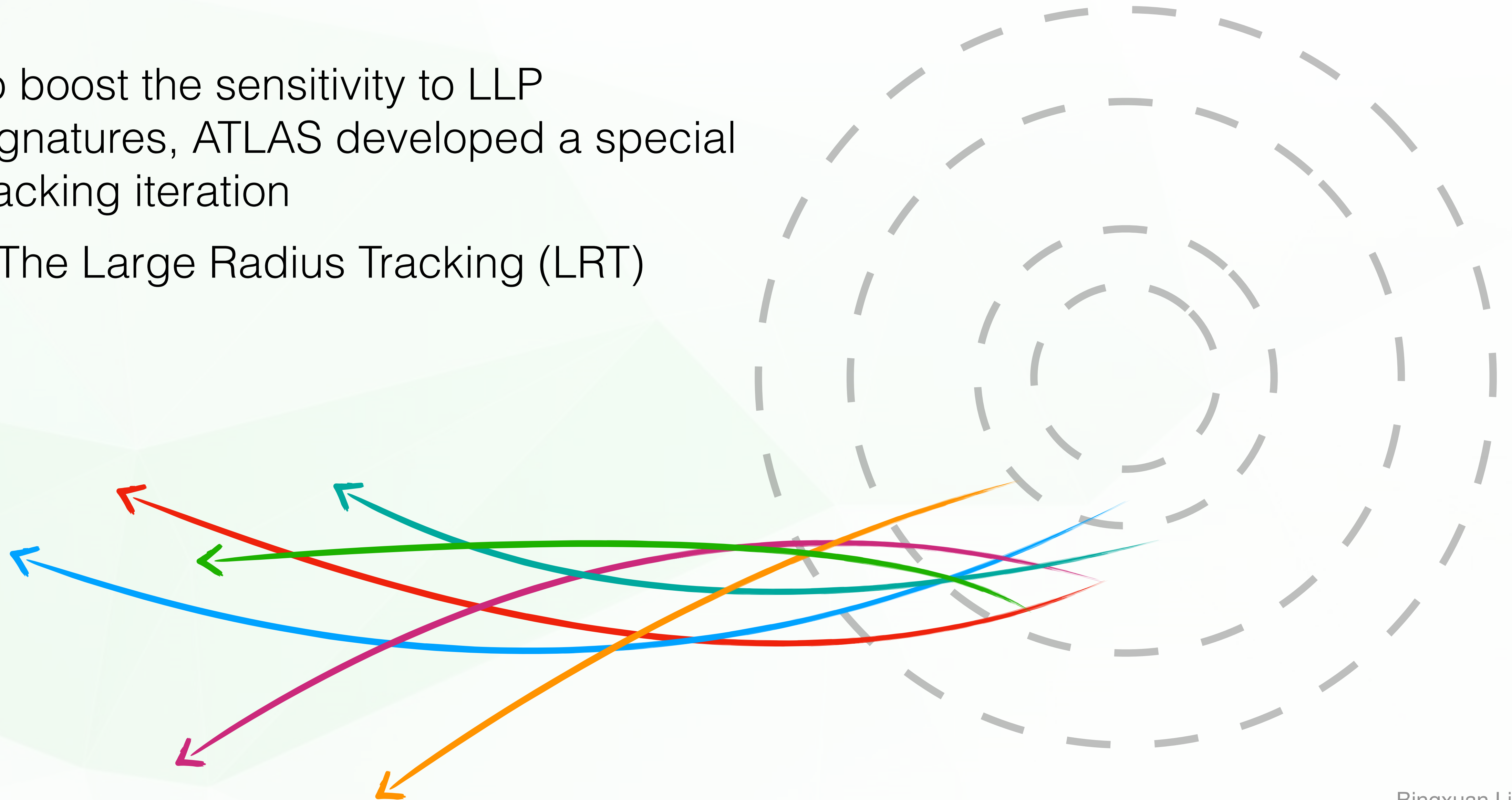


- In fact, we have a very broad LLP search program
- This summary wheel was made more than a decade ago
- Nowadays it is even more comprehensive
- But let me focus on the inner detector today

Figure credit: J. Antonelli

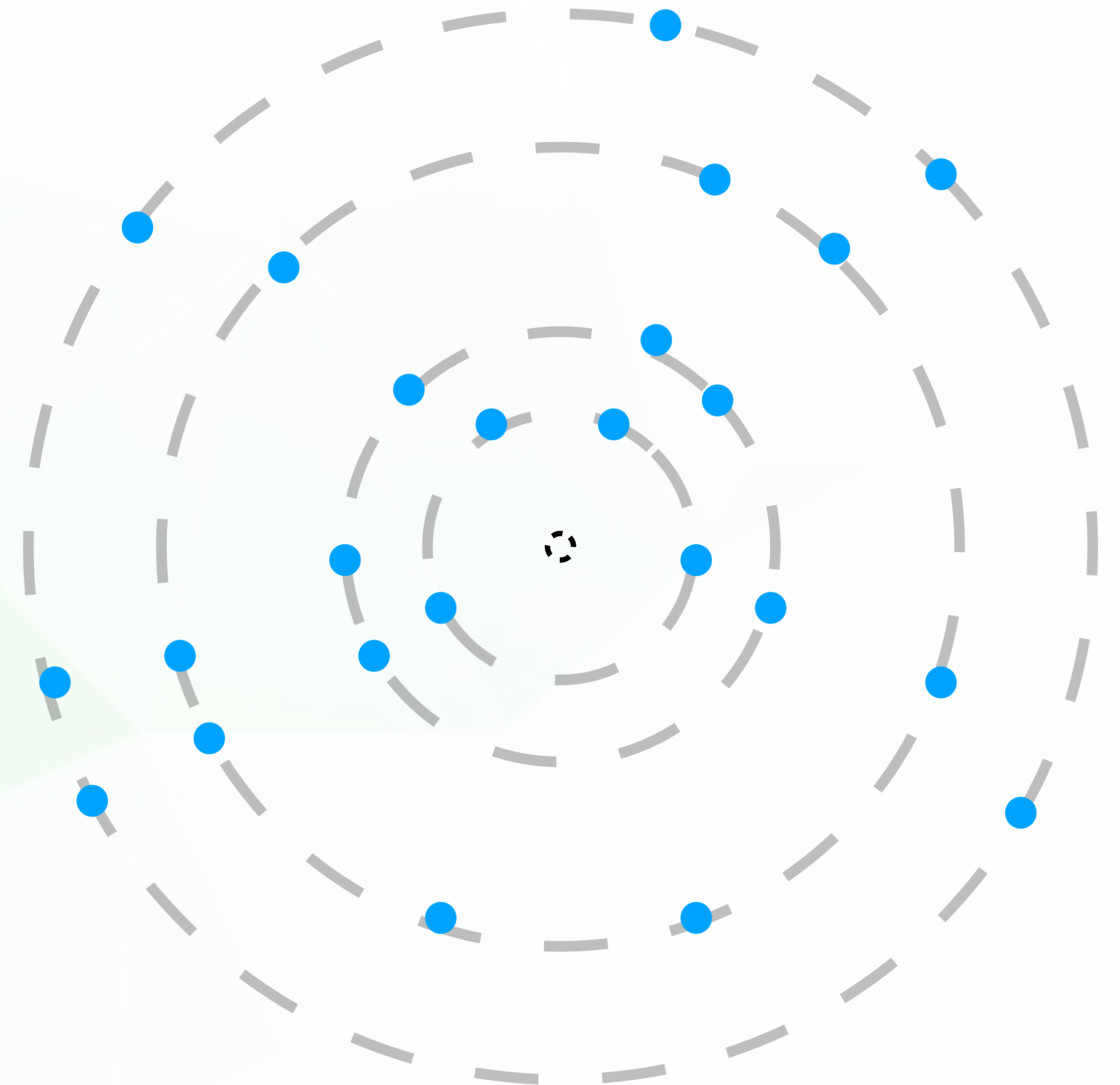
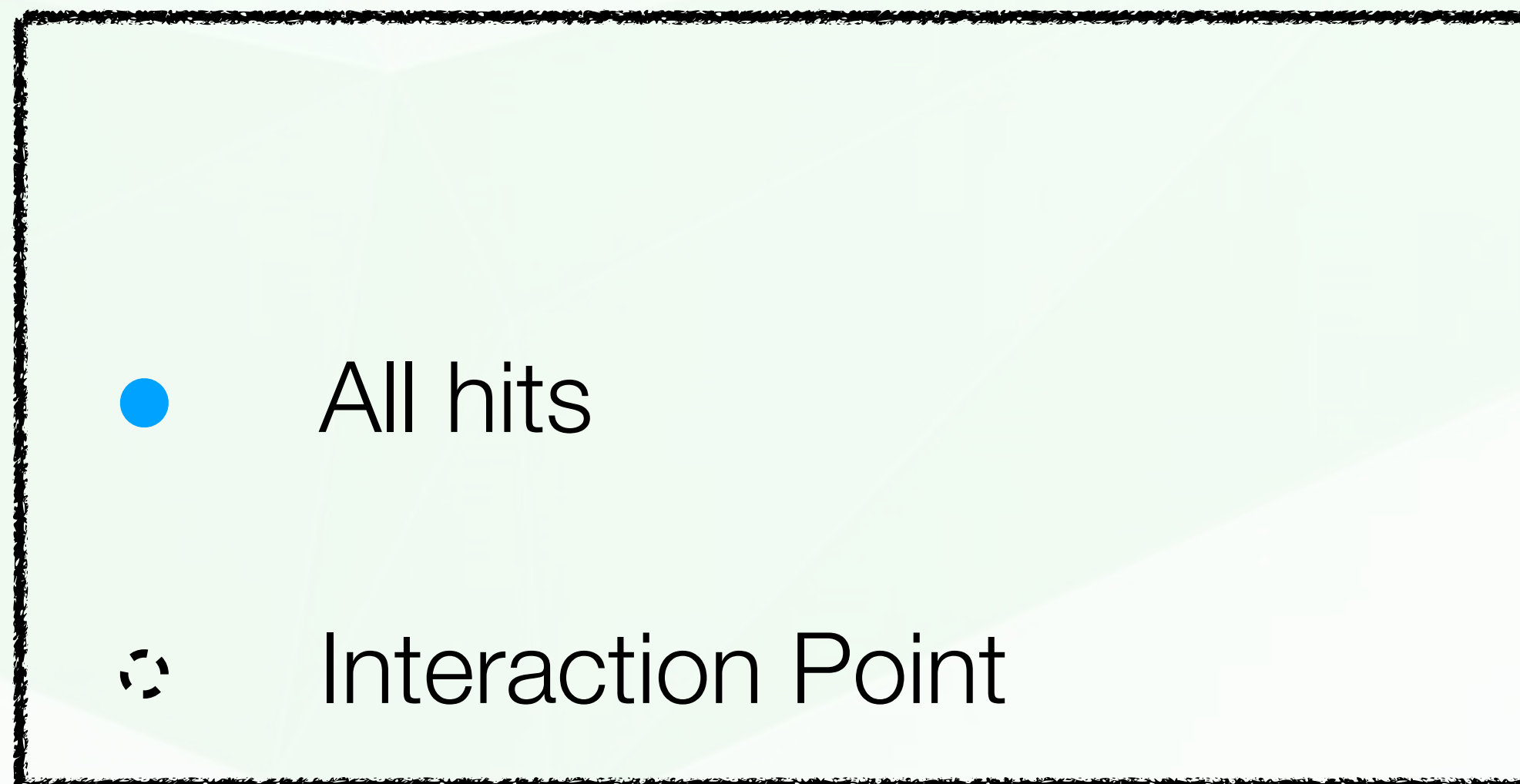
Large Radius Tracking

- To boost the sensitivity to LLP signatures, ATLAS developed a special tracking iteration
 - The Large Radius Tracking (LRT)



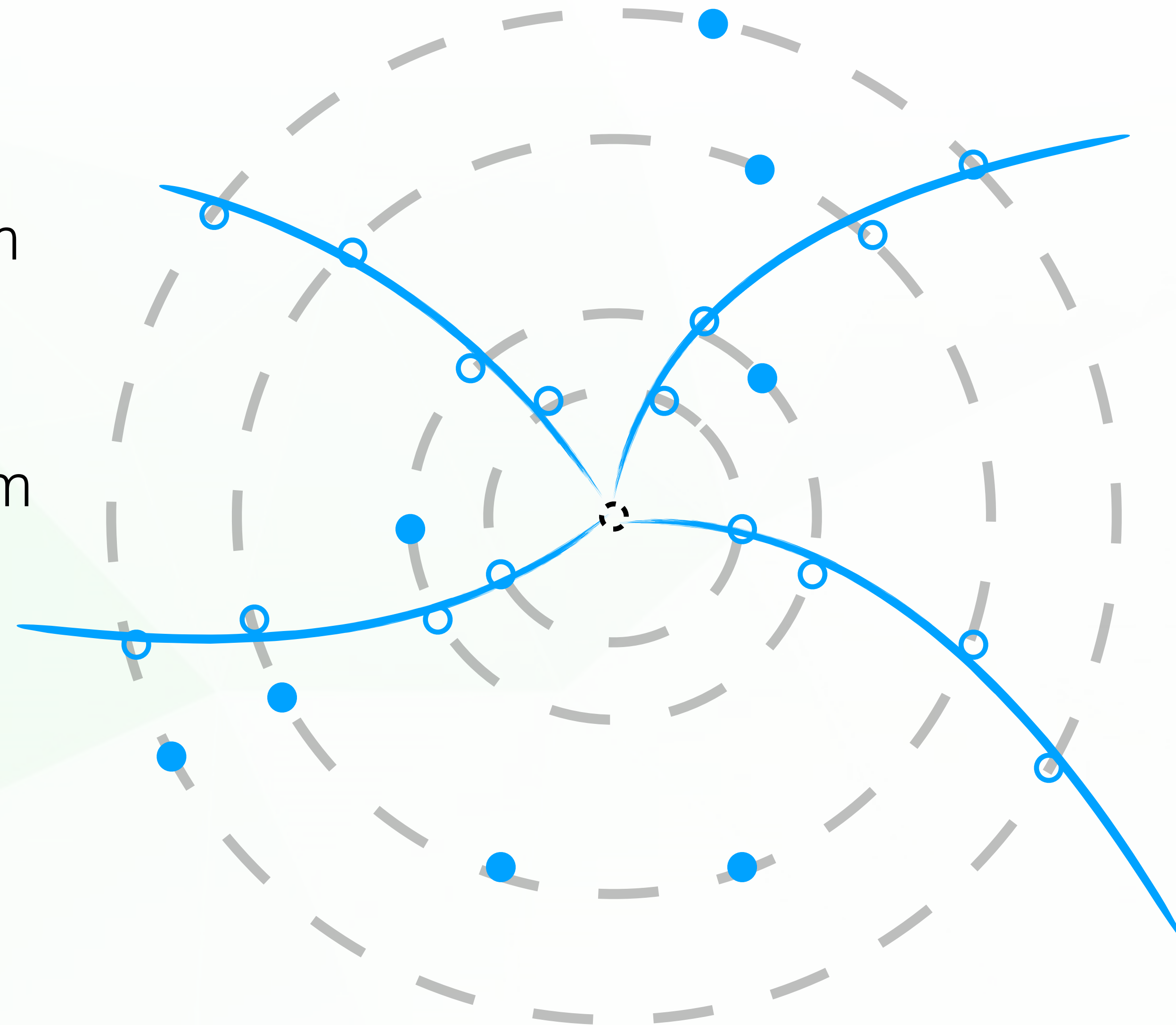
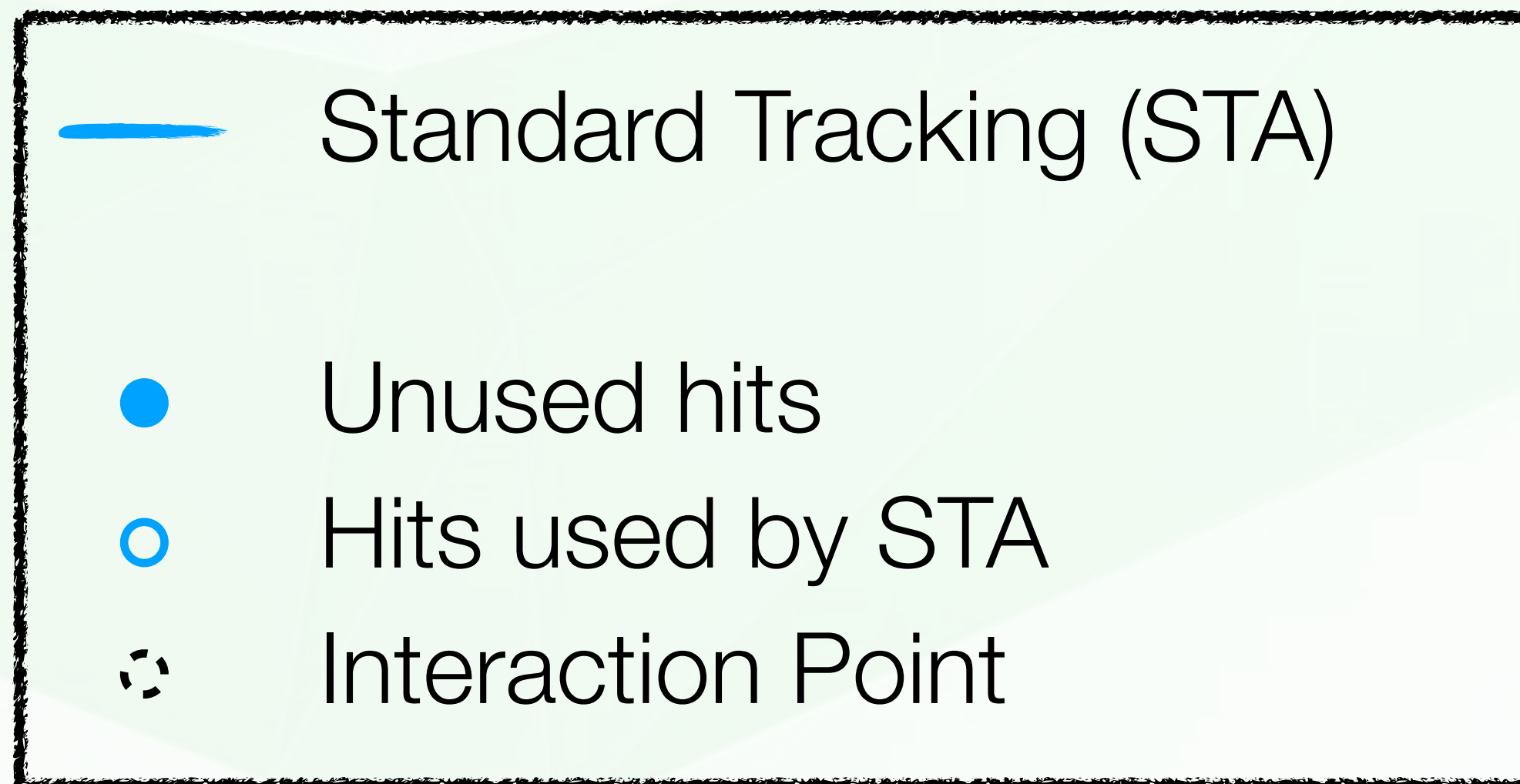
Large Radius Tracking

- The LRT uses unused hits after the standard tracking (STA)
 - Ensure orthogonality
- Optimised for charged particles from LLP decays
 - $|d_0|$ max: 5 mm (STA) to 300 mm
 - $|z_0|$ max: 200 mm (STA) to 500 mm



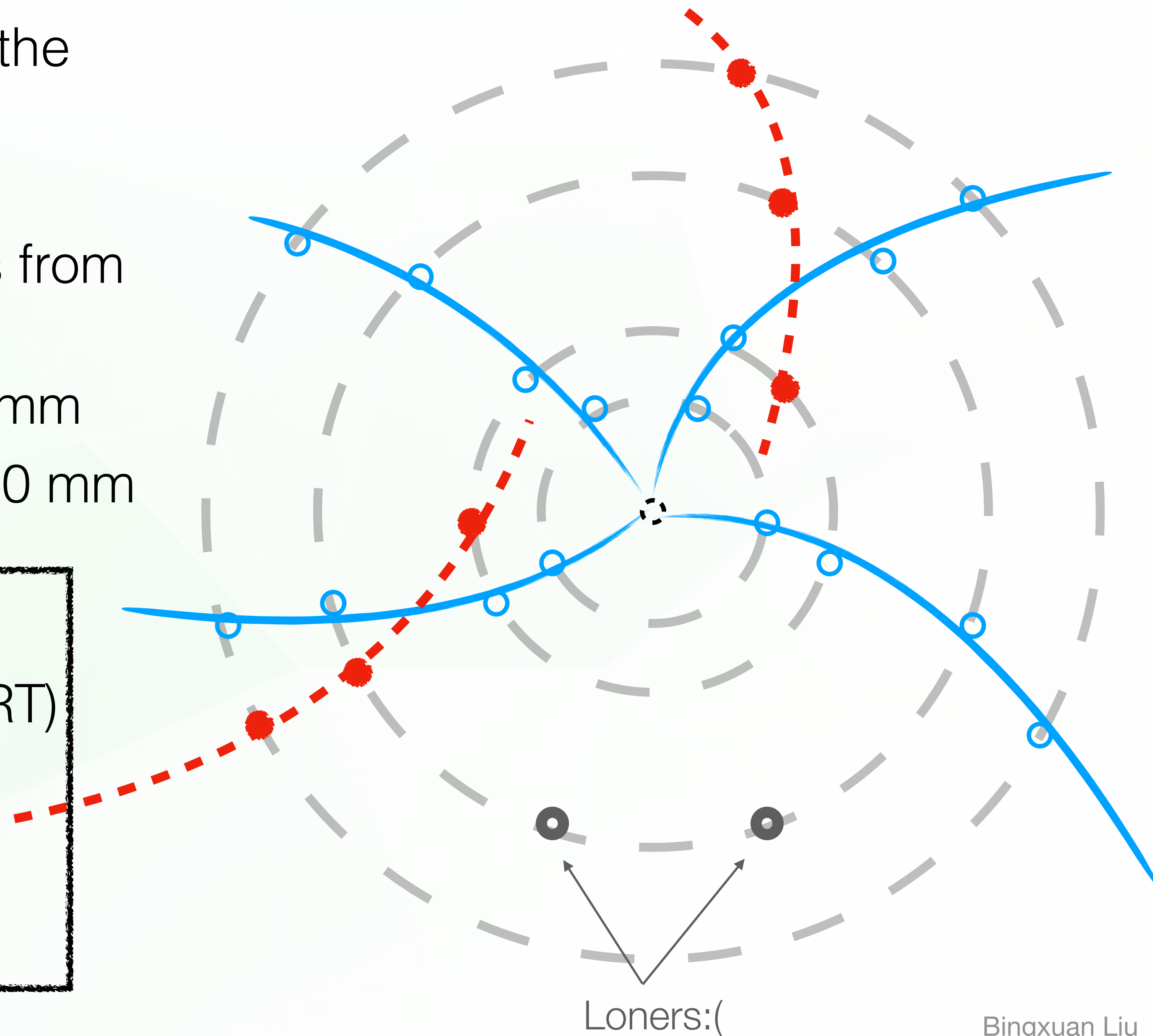
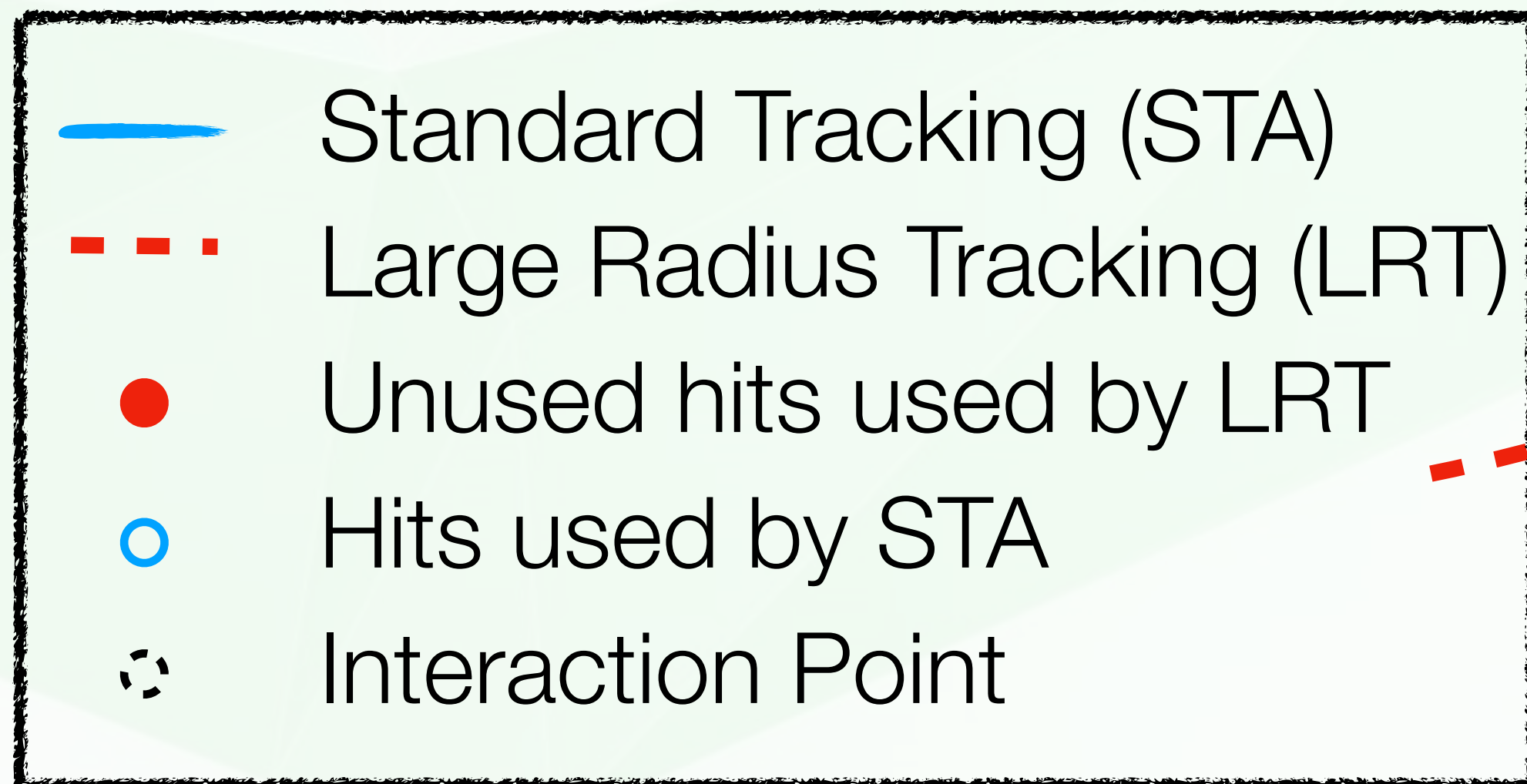
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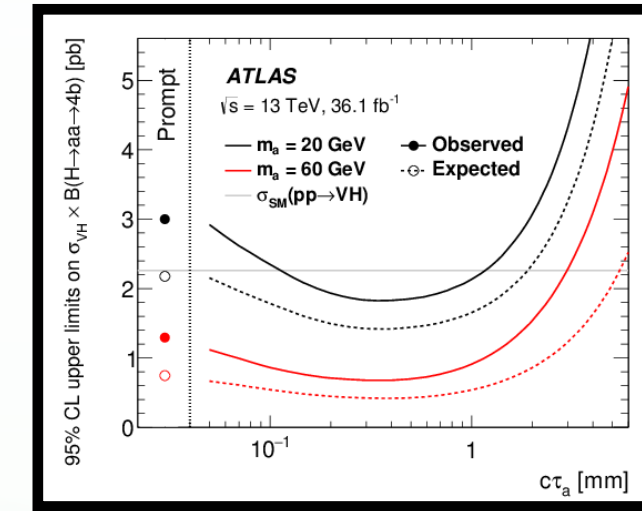
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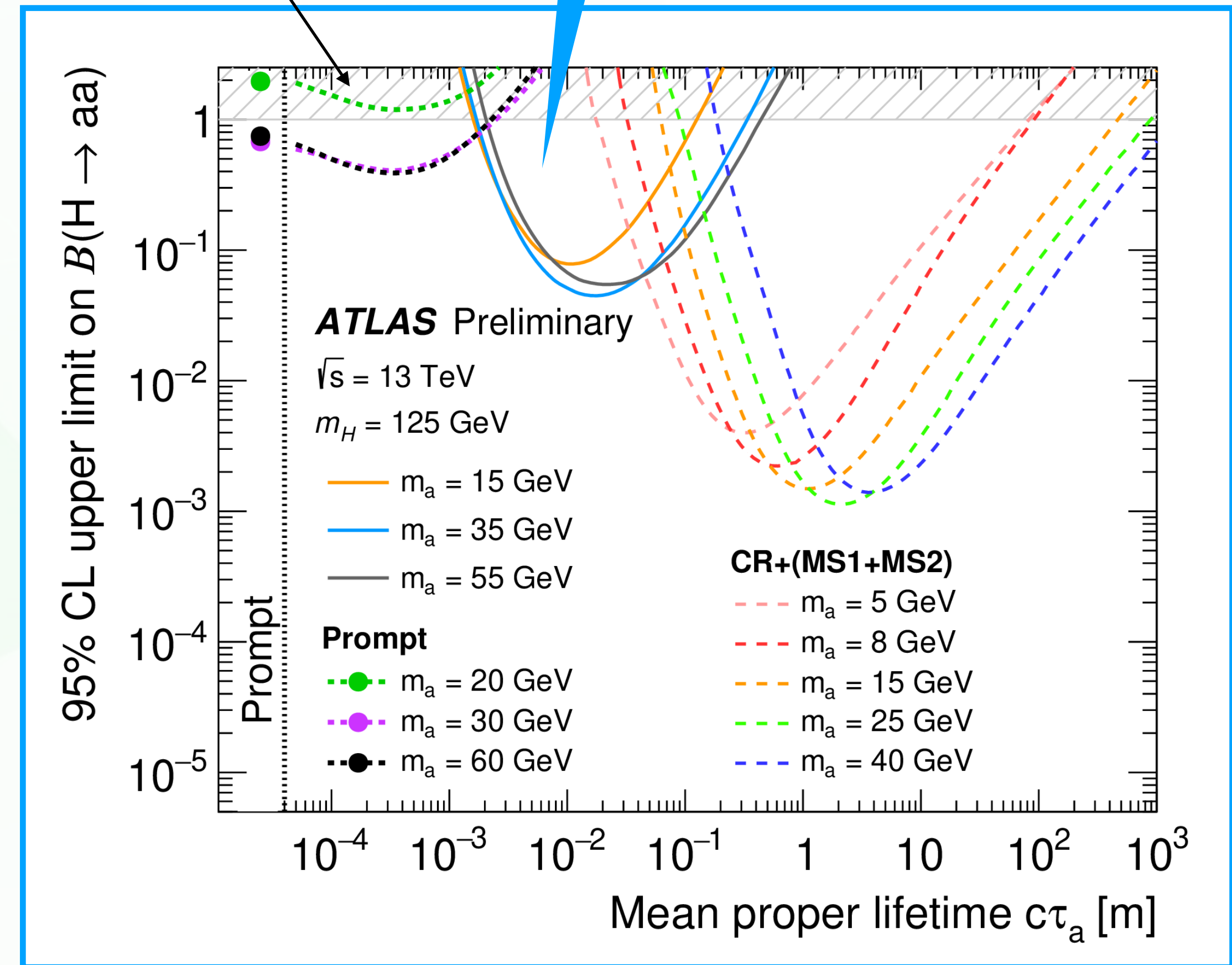


VH4b Dedicated LLP Search

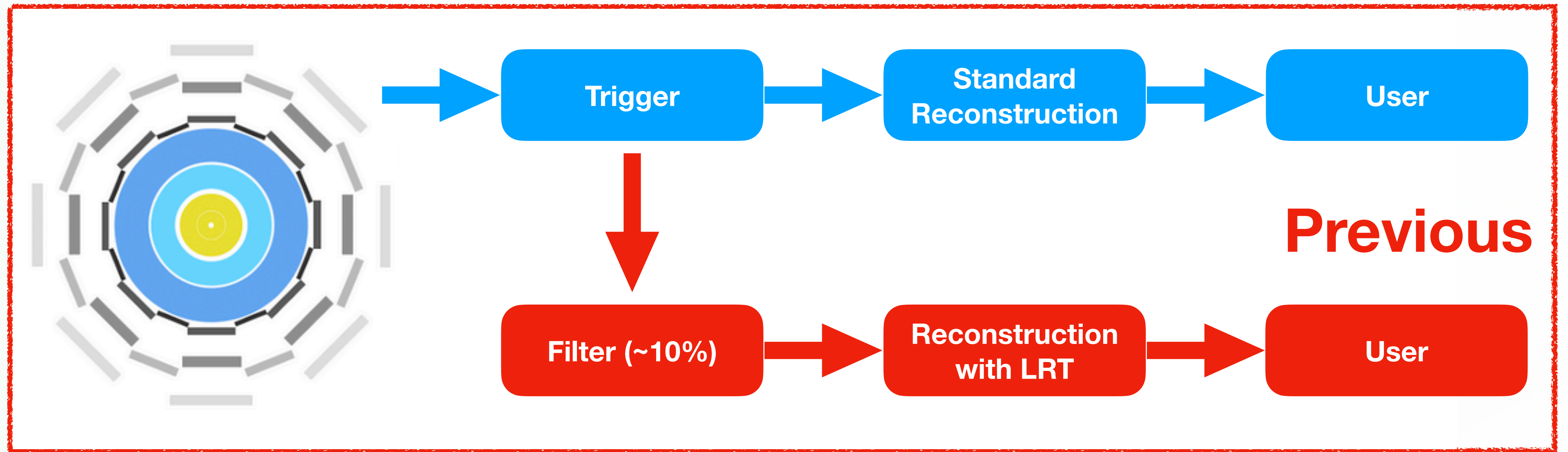
- Searching for $VH(\rightarrow aa \rightarrow 4b)$ where the light scalar a has an intermediate lifetime
- With LRT, we were able to reconstruct those displaced vertices from long-lived a decays
- We instantly appreciate the power of dedicated reconstruction algorithms



Gap filled!



[JHEP11\(2021\)229](#)



- BUT! It was not ideal.
- The original LRT has a very high fake rate which explodes the computing time and disk storage
- Only ~10% of the data can be processed, and it requires tedious technical work to actually use it in the analysis

Large Radius Tracking Run 3 Version

Tighten selections at various stages of the track reconstruction compared to Run 2 version

Generic ATLAS
Tracking Iteration

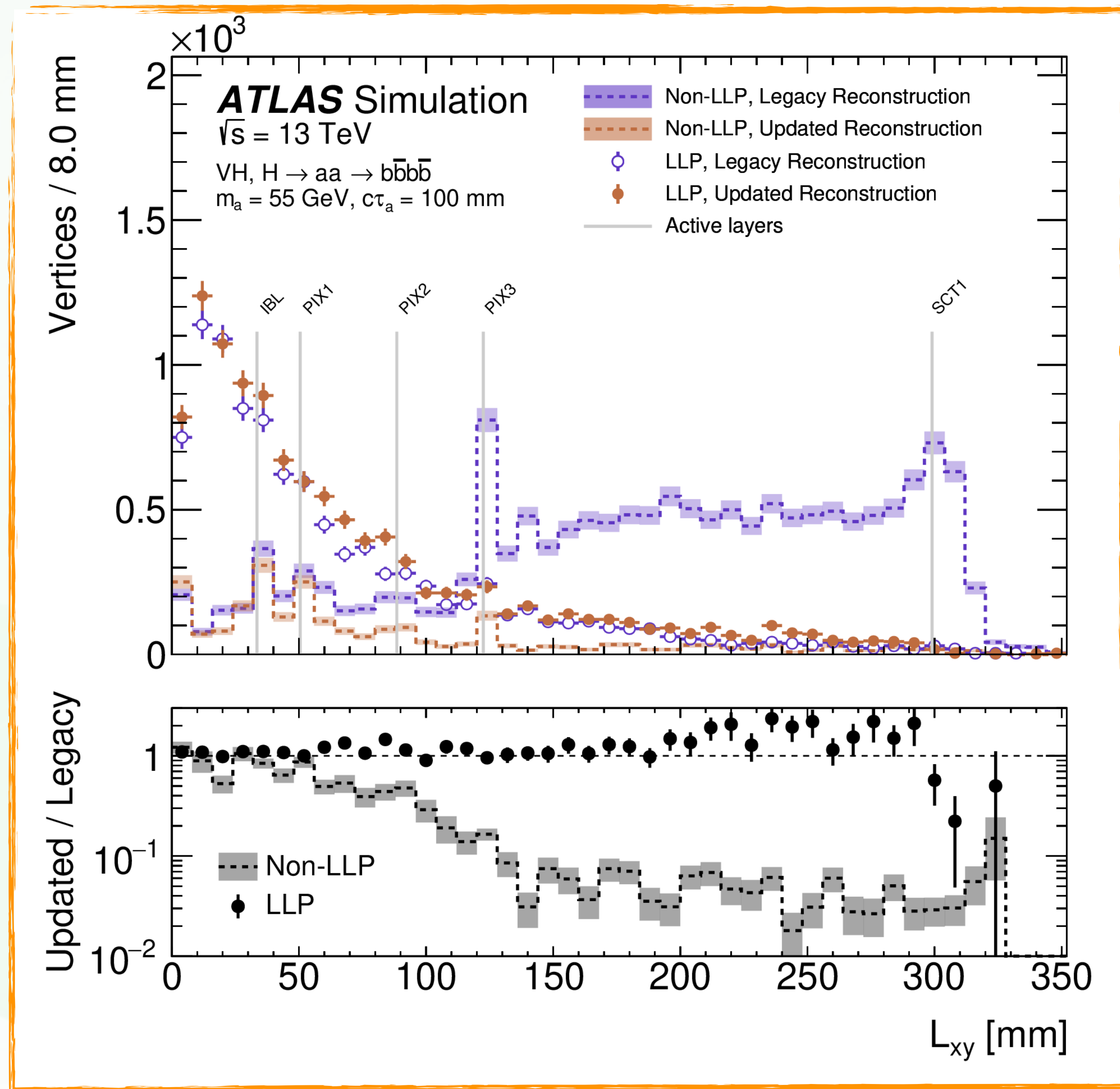


Only SCT seeds are used instead of SCT || Pixel

Prioritize confirmed seeds:
A seed (1-2-3) is confirmed by another (1-2-4)

Change seeds ranking to prioritize signal like tracks

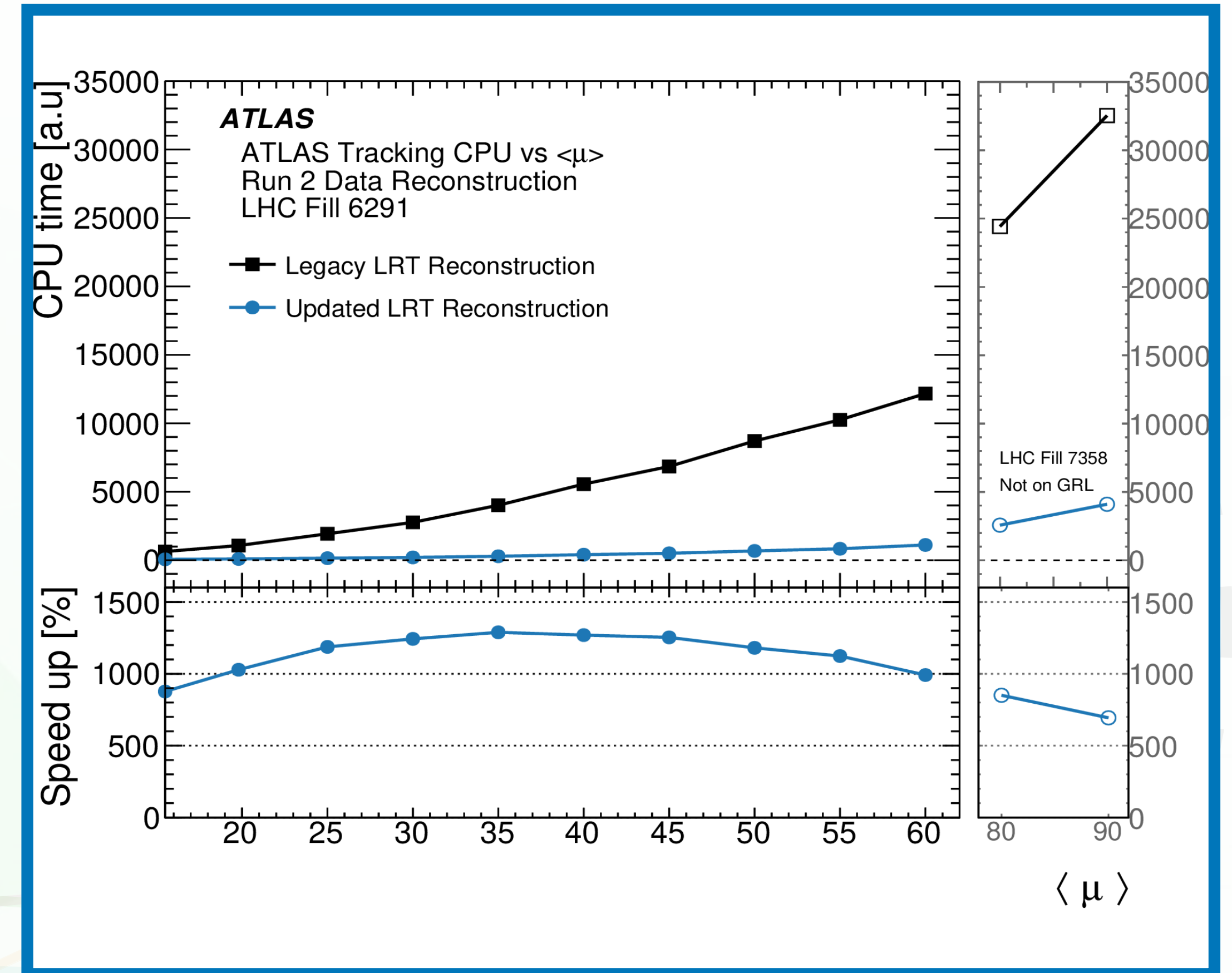
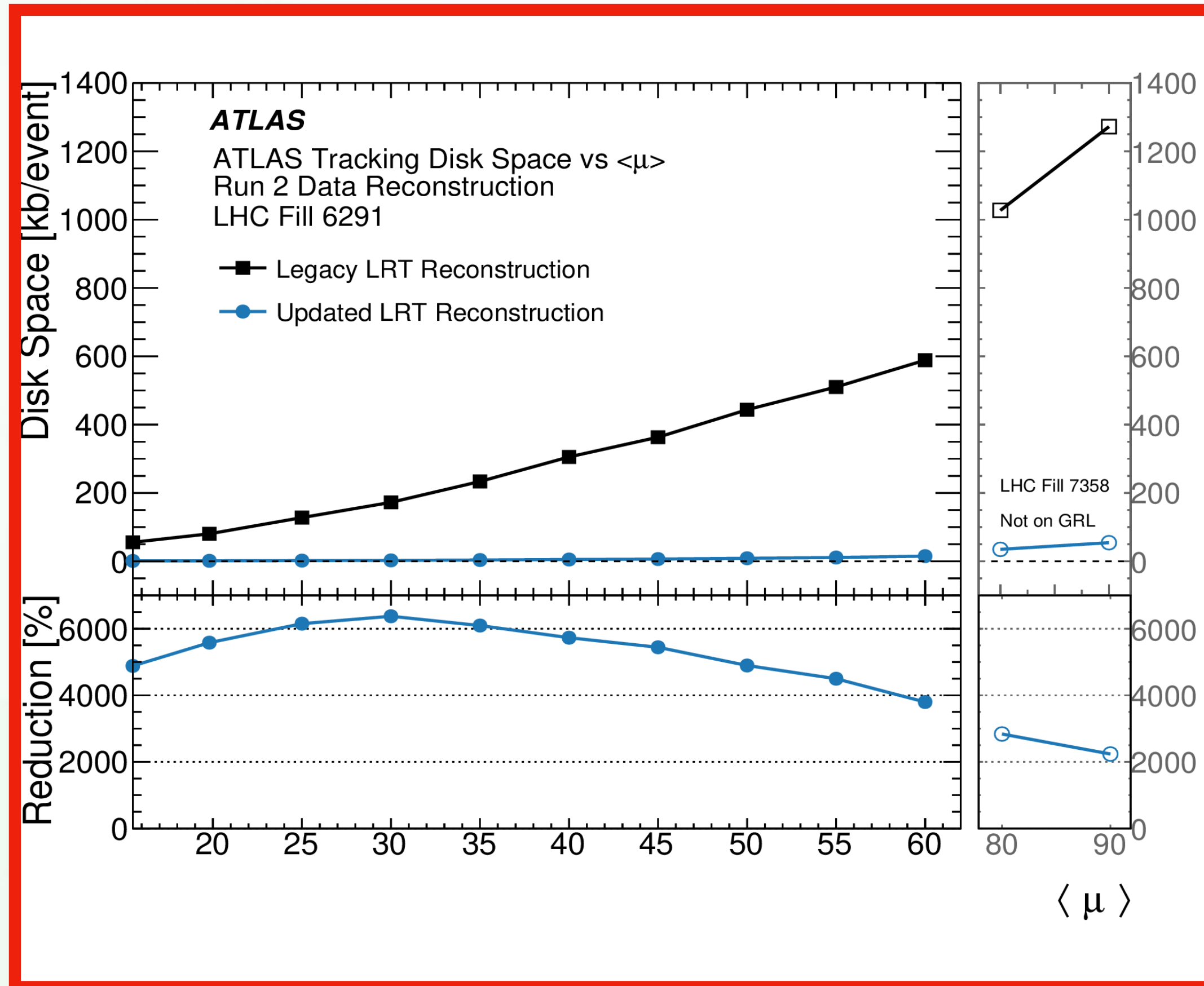
Optimized to reduce the fake rate



- Managed to reduce the fake rate dramatically while retaining the signal efficiency
- It leads to a greatly improved displaced vertex reconstruction performance

~10X fewer fake vertices!!!

Large Radius Tracking Run 3 Version Eur.Phys.J.C83(2023)1081



- A few magnitudes deduction of disk usage (**>40 times smaller**) and CPU time (**~10 times lower**) compared to the legacy LRT algorithm.

LLP Search Paradigm Shift

- LRT is now turned on by default from now on
 - LRT tracks are **available in every reconstructed event**
- The ATLAS LLPs search program will embrace a paradigm shift

shift

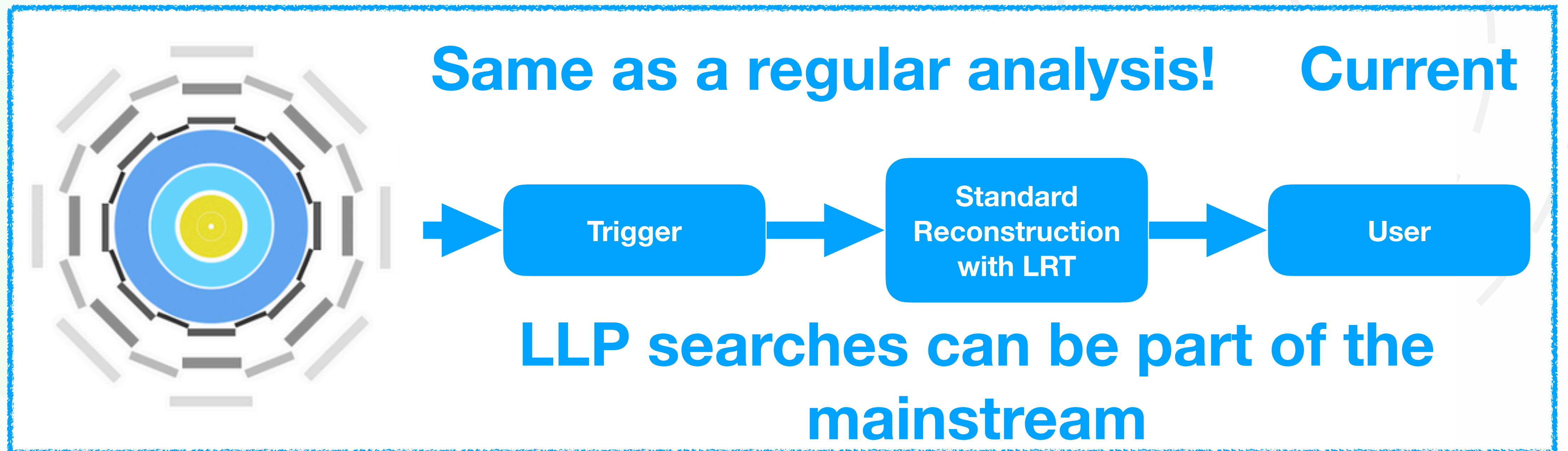
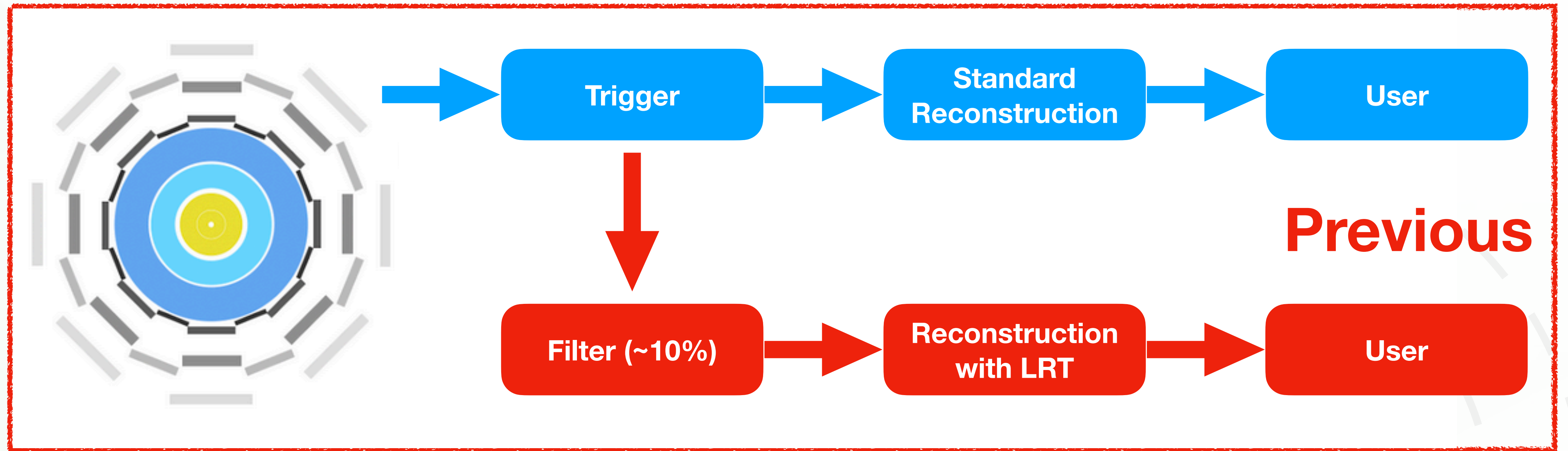
shift

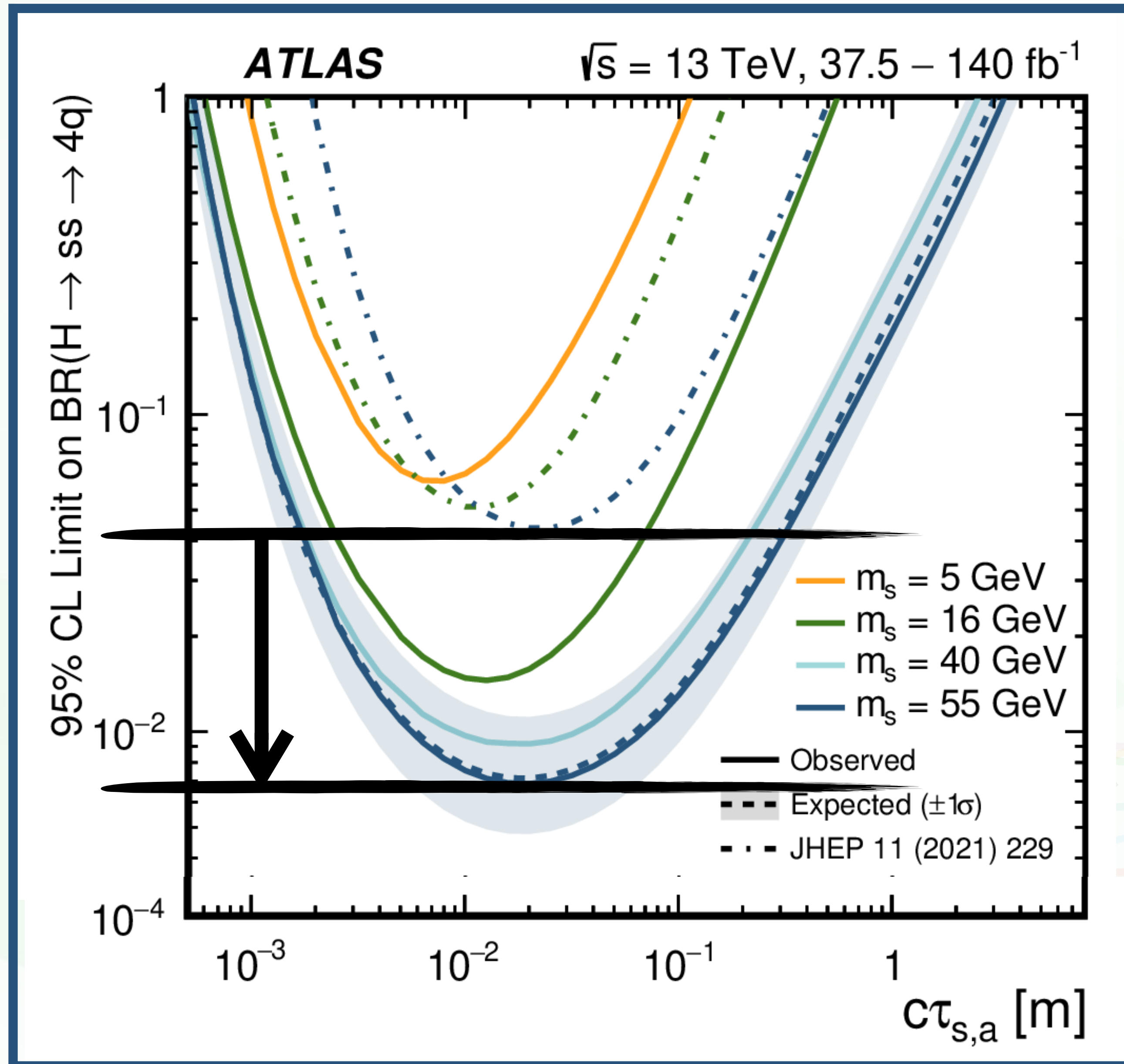
shift

shift

shift

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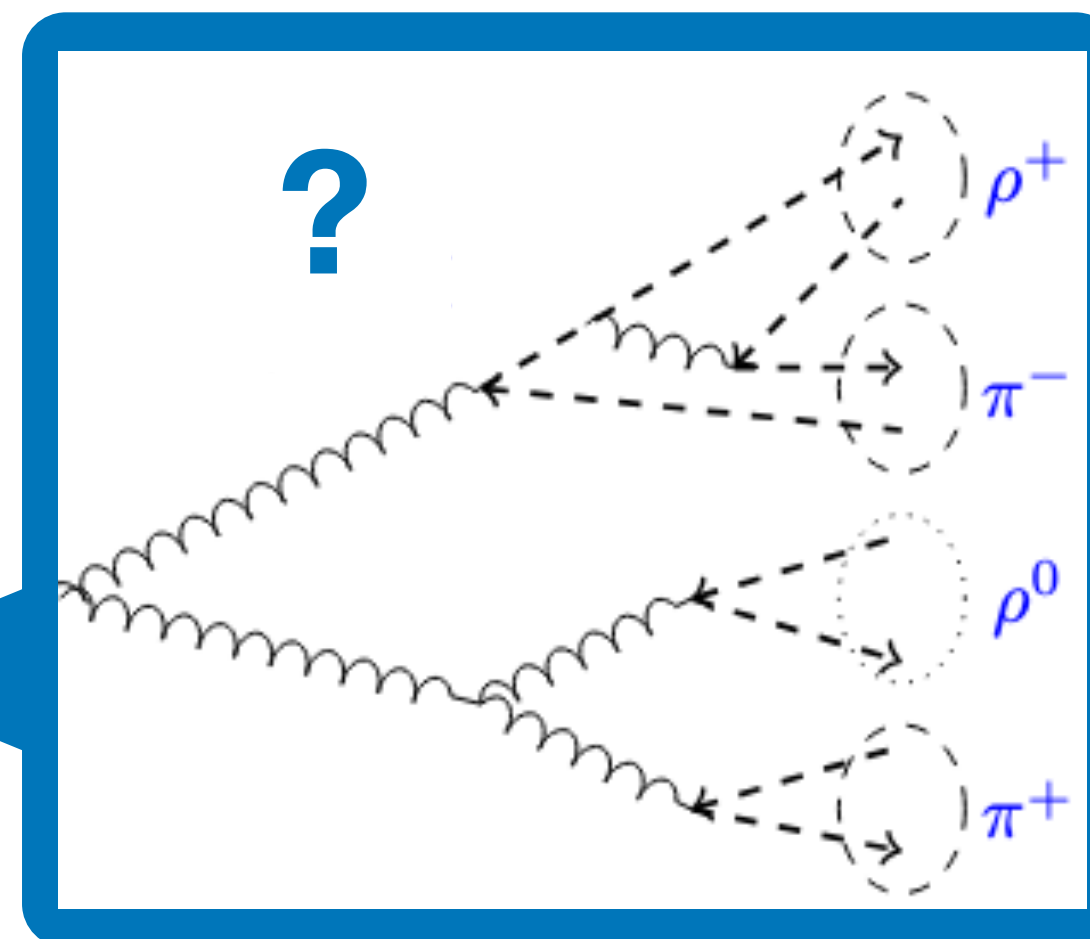
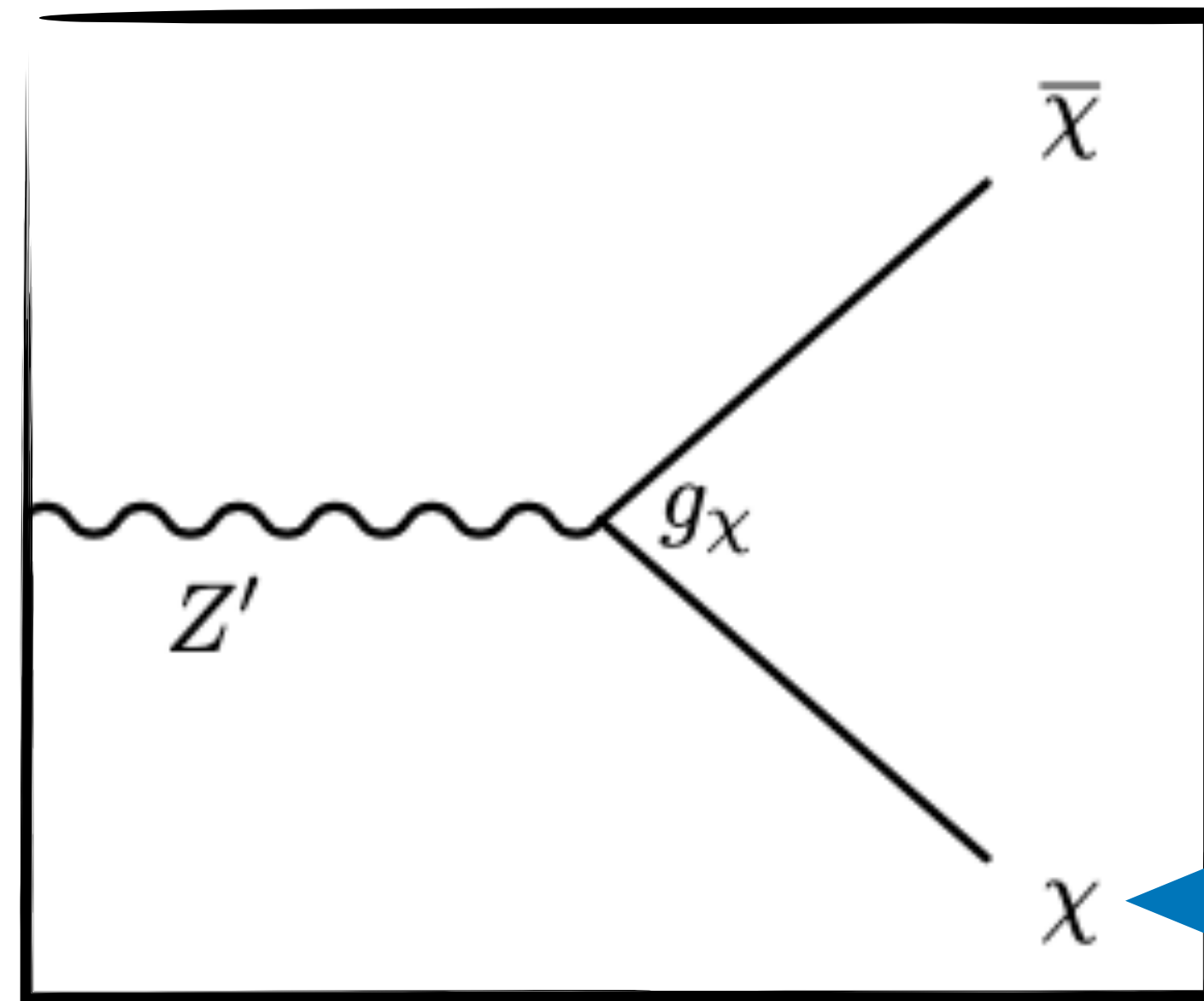
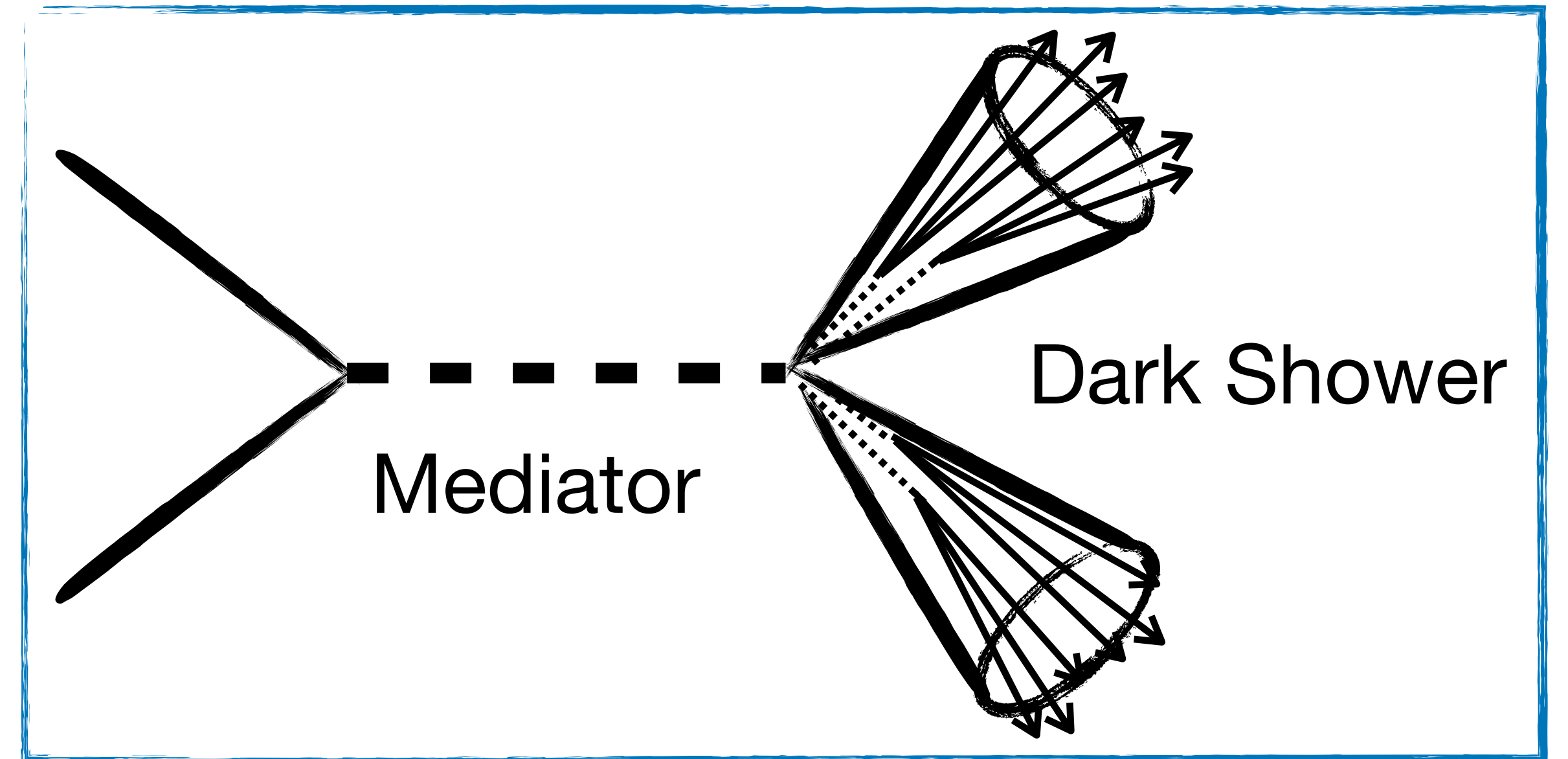




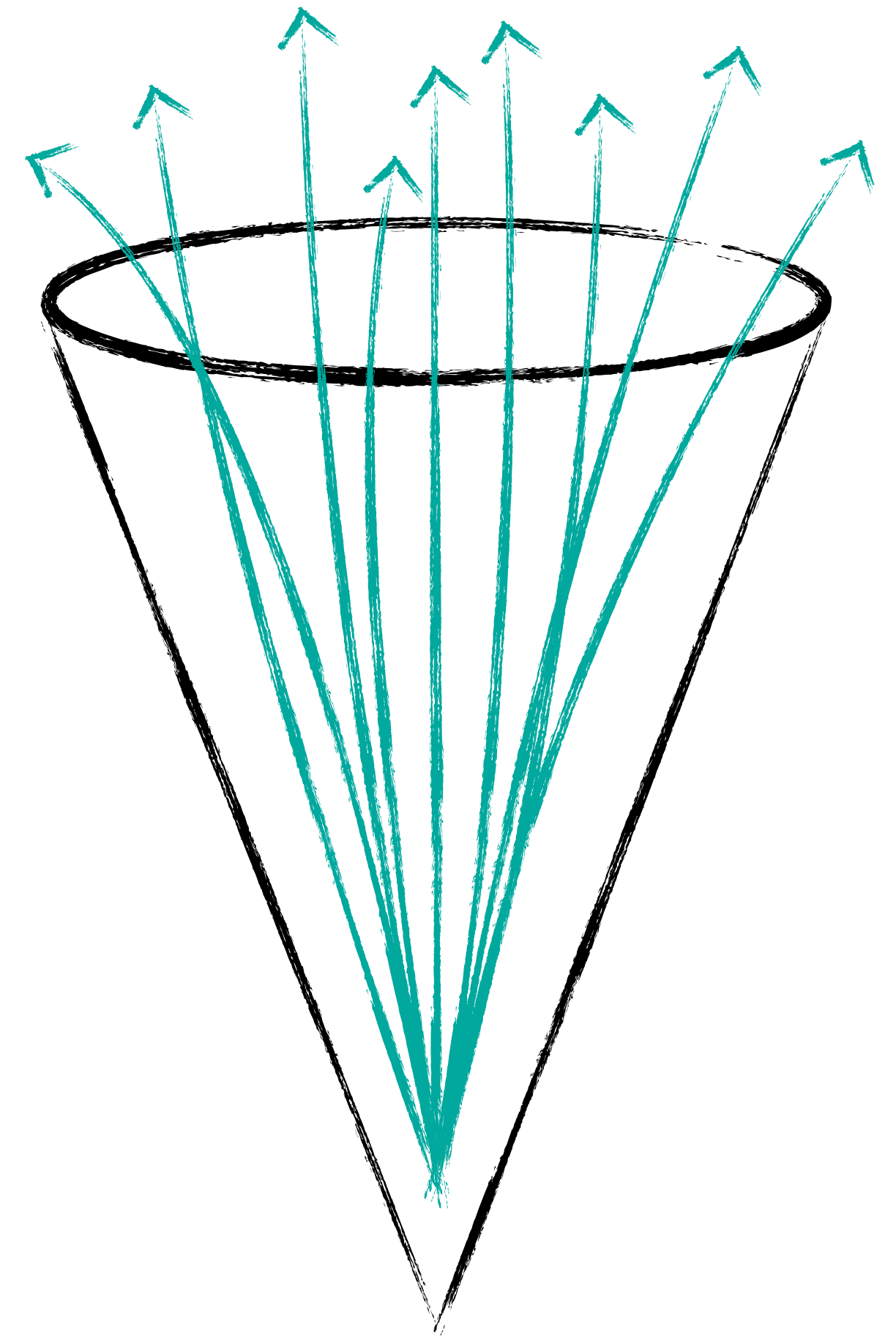
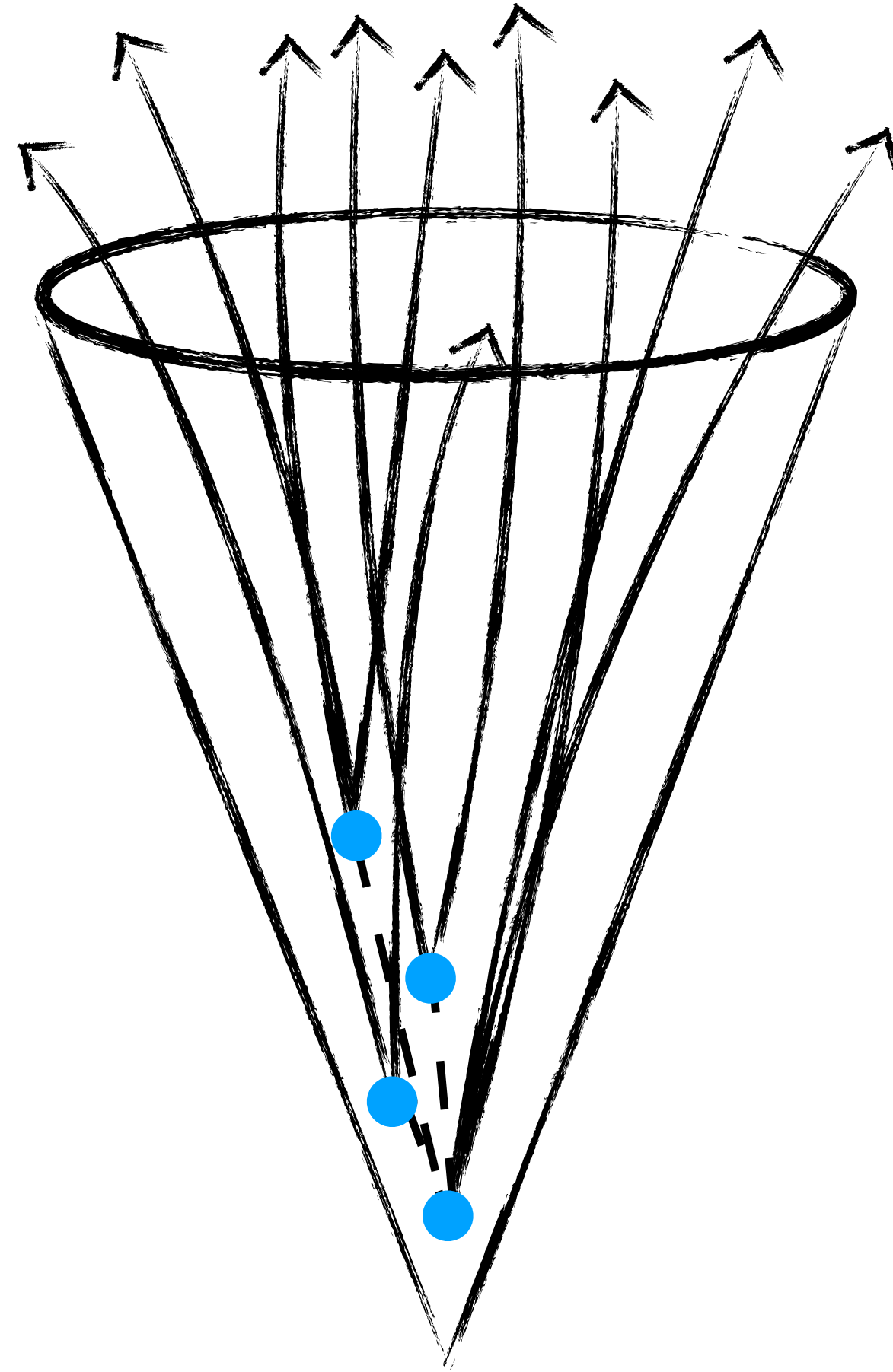
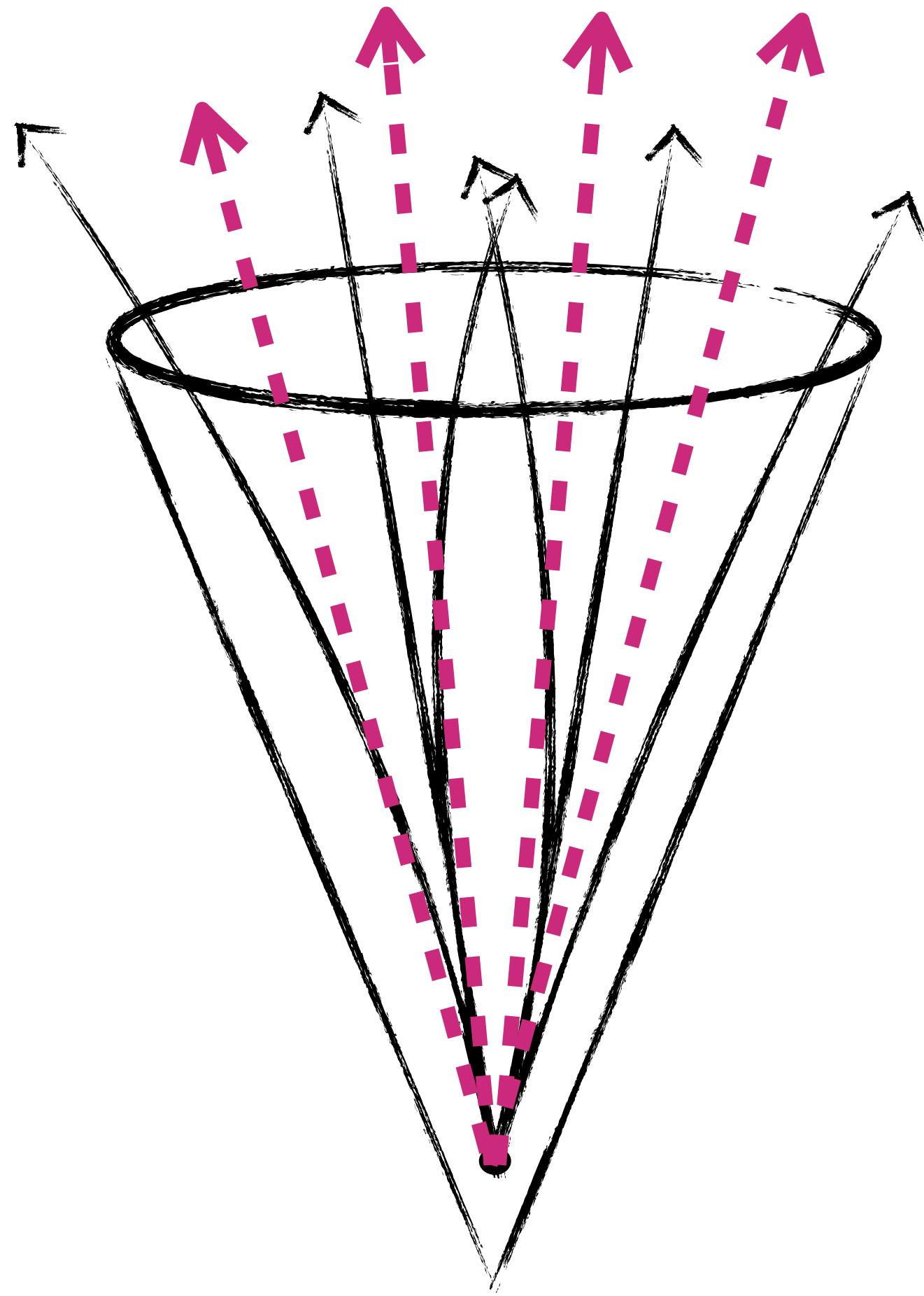
- The new LRT is applied to the same Higgs to DVs searches but:
 - More production channels are included thanks to the much simplified analysis process
 - **10-40 times improvements on the same dataset!**
 - **PRL Editor's Choice**

Jets are normal

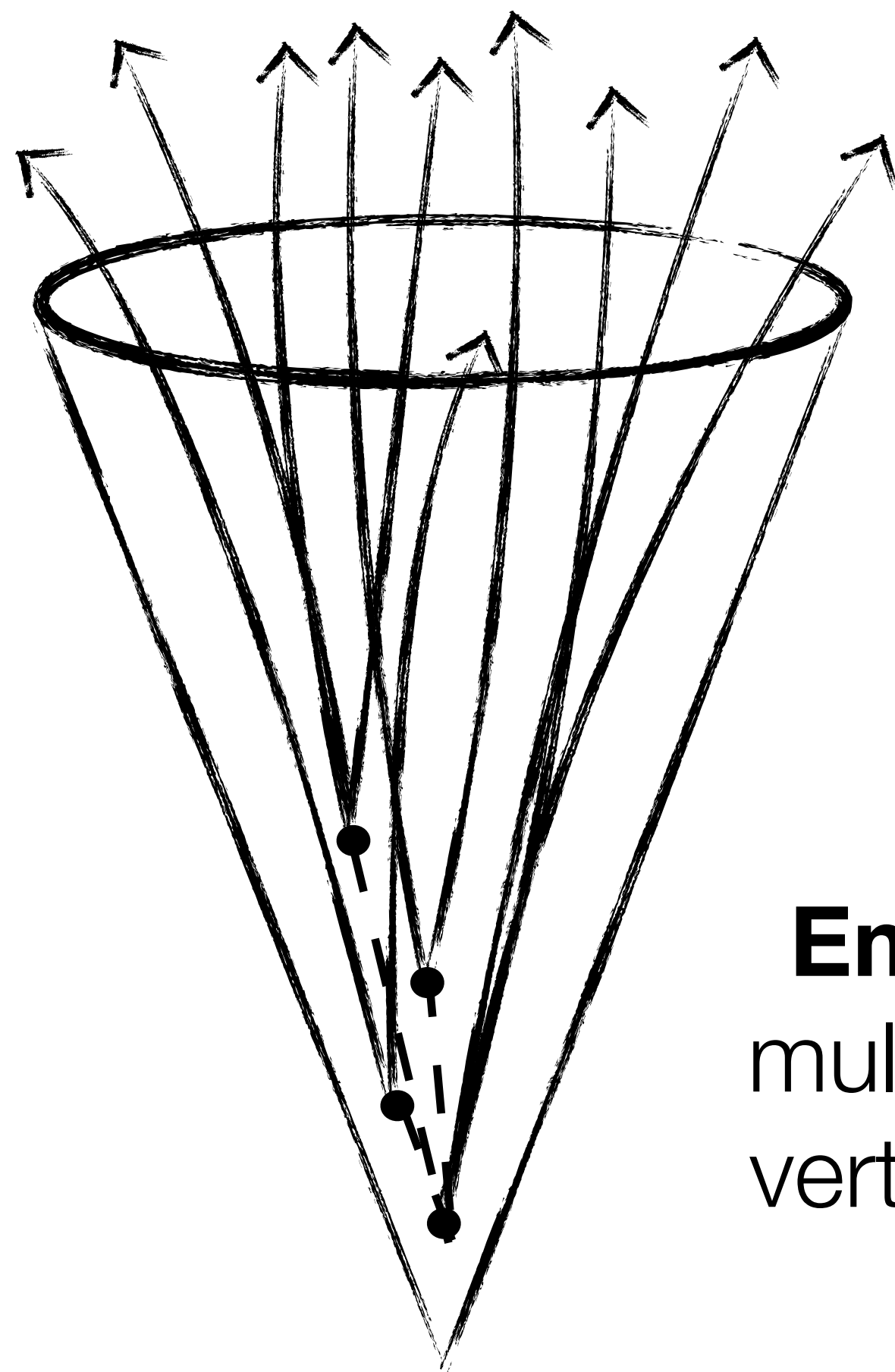
Dark shower is intriguing!
Confining force $SU(N)$
analogous to QCD



Rich phenomenology
depending on the dark
confinement scale, mass
hierarchy and decay
branching ratios



Dark showers are characterized with **dark matter candidates**, **displaced vertices** and **high decay multiplicity**

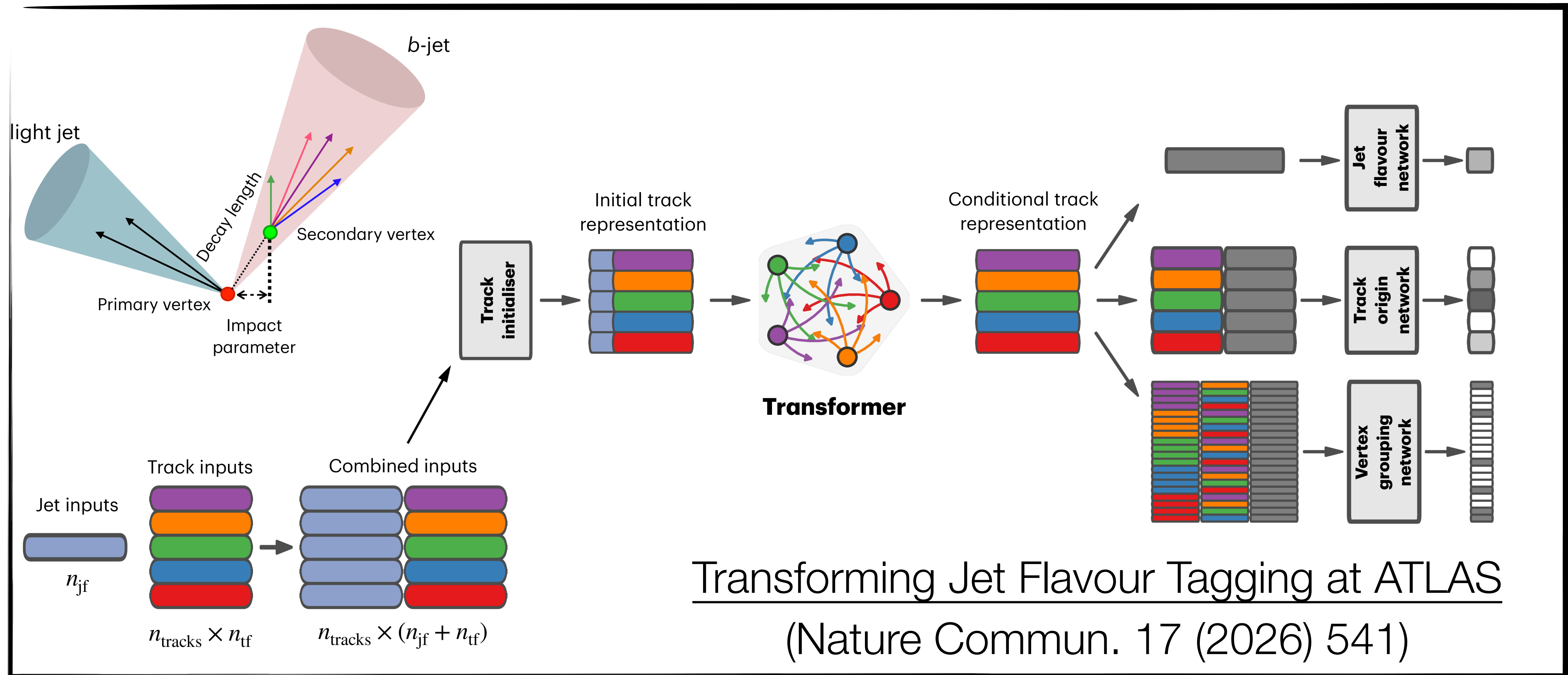


Emerging jets:
multiple displaced
vertices in the jets

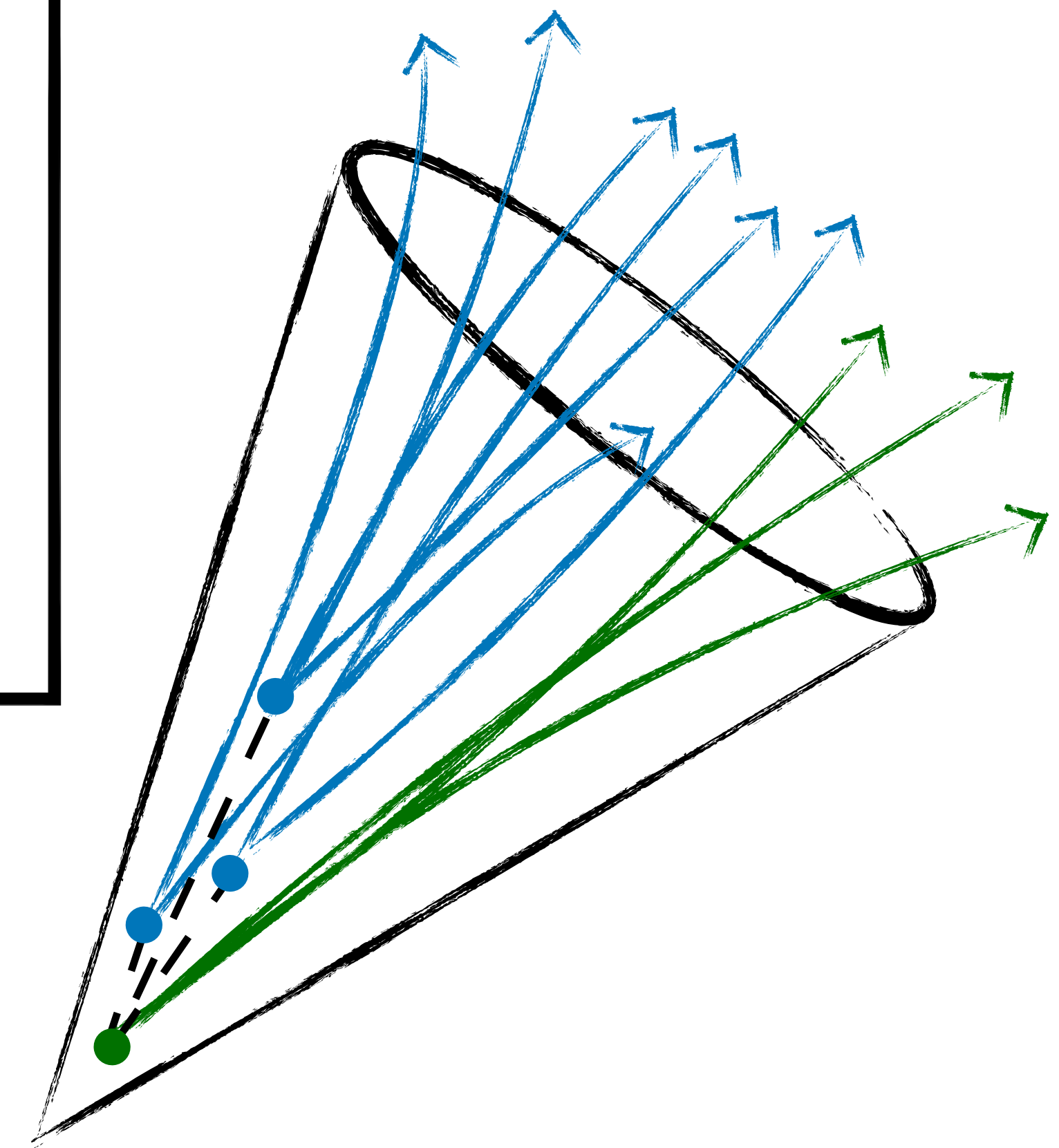
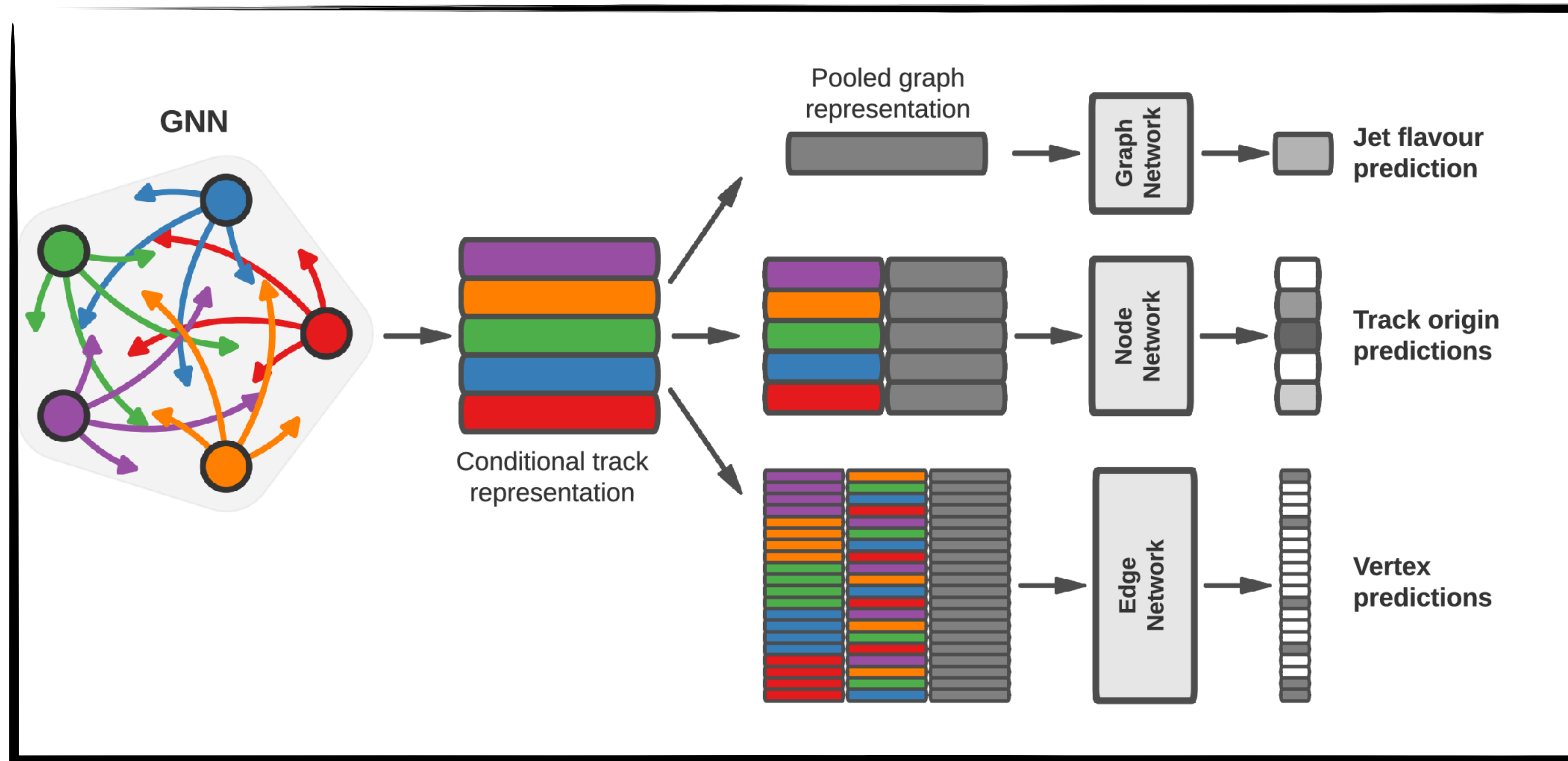
JHEP 05 (2015) 059

**Jets with (a lot)
LLPs inside!!**

Transformer-based Flavour Tagger

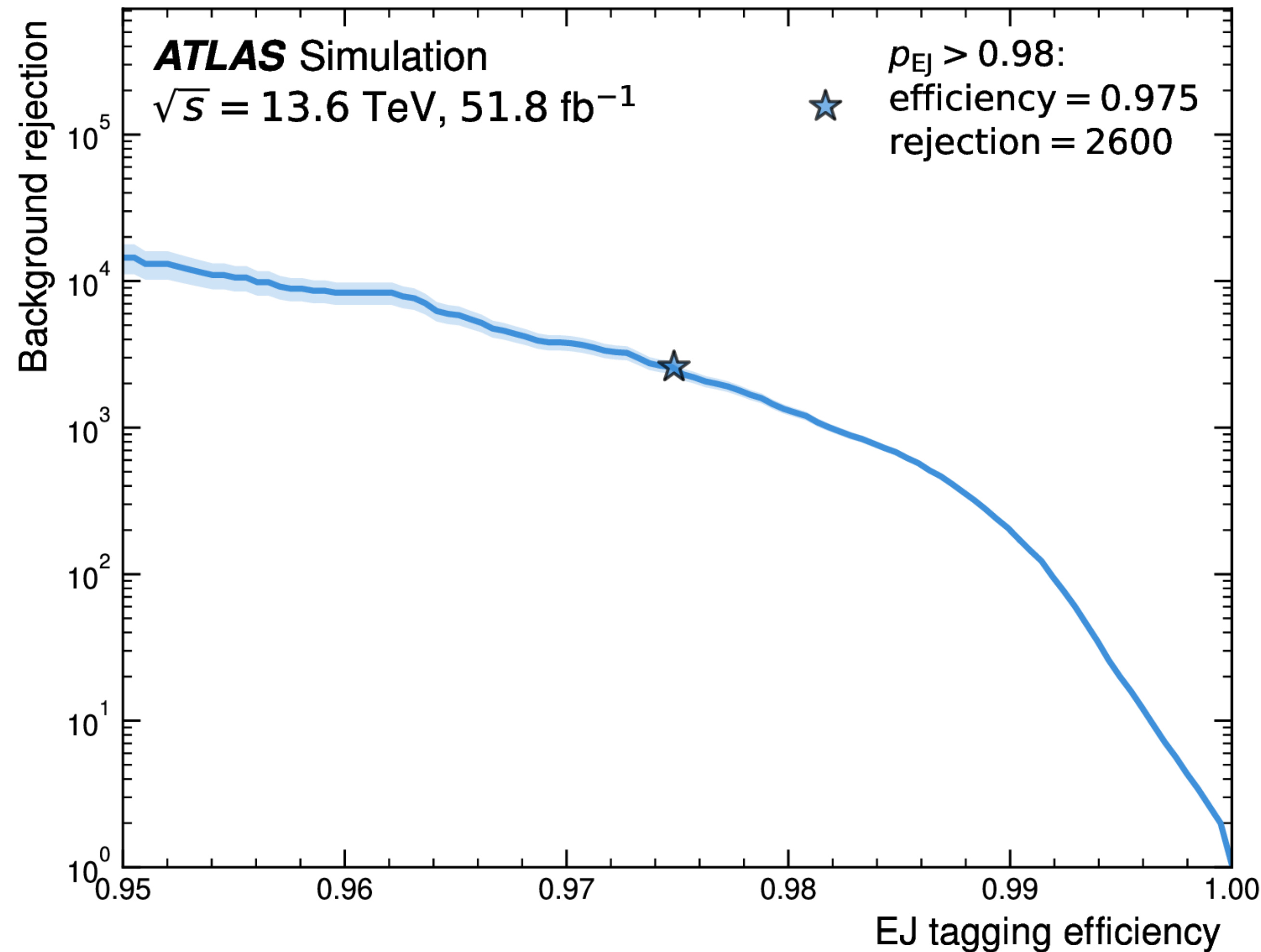


Emerging Jets: GN2 Variation



Remapping the physic domain knowledge:
displaced, prompt and fake

Emerging Jets: GN2 Variation

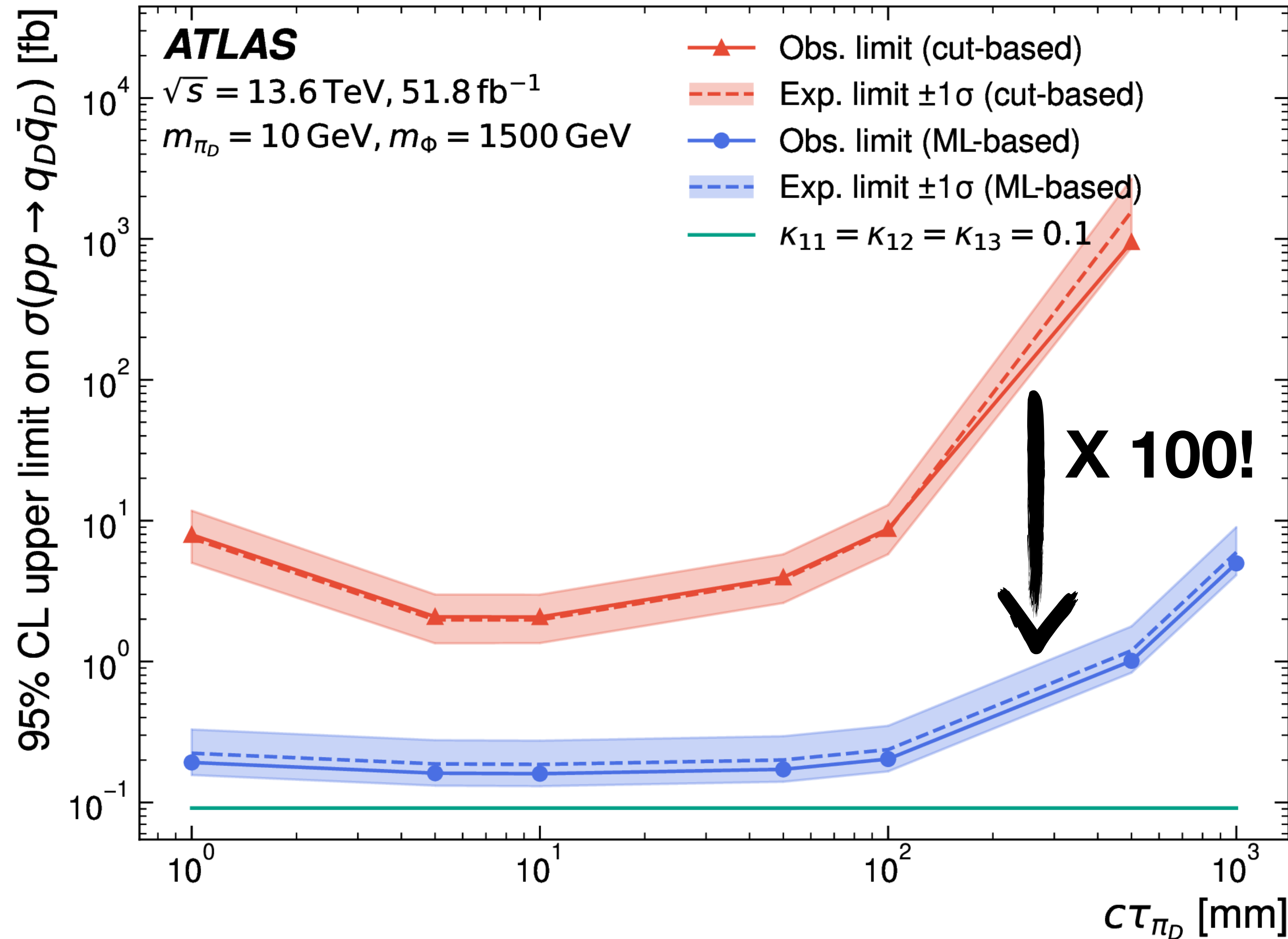


GN2 variation works amazingly well!

97.5% efficiency for a 1/2600 fake rate

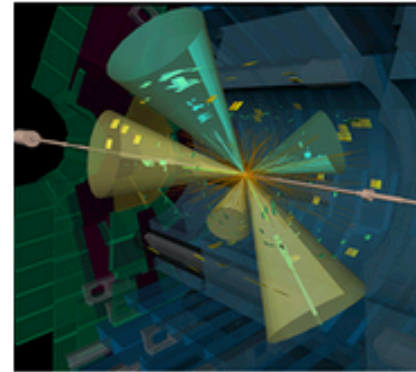
It proves that physics inspired constraints are powerful and portable!

Emerging Jets: GN2 Variation



The GN2 EMJ variation achieves sensitivities that are almost two orders of magnitude higher compared to traditional cut-based approaches!!

**We can reconstruct
displaced tracks, and we
can tag those weird jets**



EDITORS' SUGGESTION

Search for Light Long-Lived Particles in pp Collisions at $\sqrt{s} = 13$ TeV Using Displaced Vertices in the ATLAS Inner Detector

G. Aad *et al.* (ATLAS Collaboration)

Phys. Rev. Lett. **133**, 161803 (2024) - Published 17 October, 2024

A search for long-lived particles at the LHC with a new scheme for reconstructing particle-tracks with significantly displaced vertices results in an order-of-magnitude improvement in constraints.

PRL 133 (2024) 161803

Progress In **series**

About R



RESEARCH HIGHLIGHT

ATLAS narrows the hunt for dark matter

28 Jan 2026 [Lorna Brigham](#)

A new search for emerging jets at CERN has ruled out key dark sector scenarios

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Transforming jet flavour tagging at ATLAS

[The ATLAS Collaboration](#)

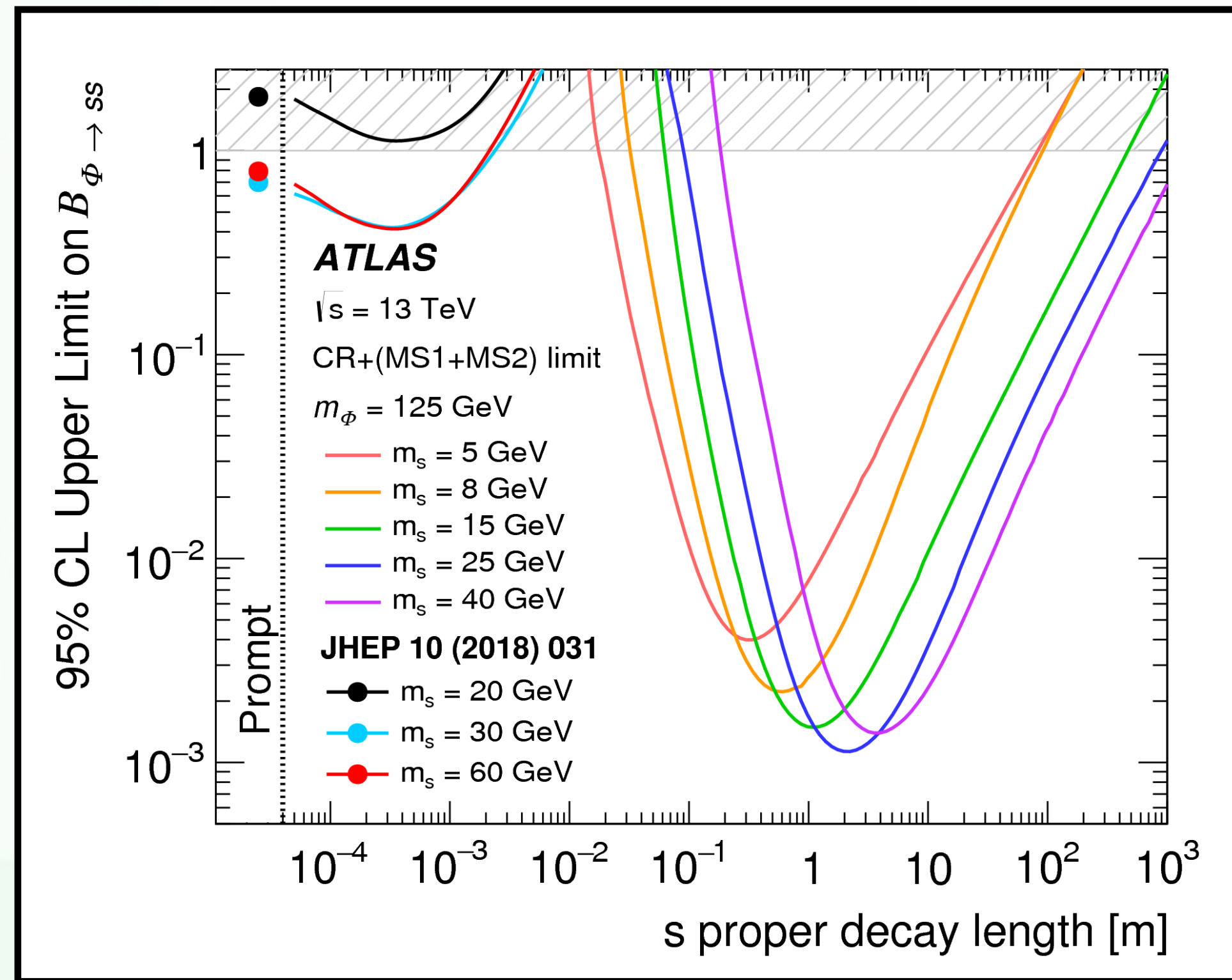
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Nature Commun. 17 (2026) 541

Rep. Prog. Phys. 88 (2025) 097801

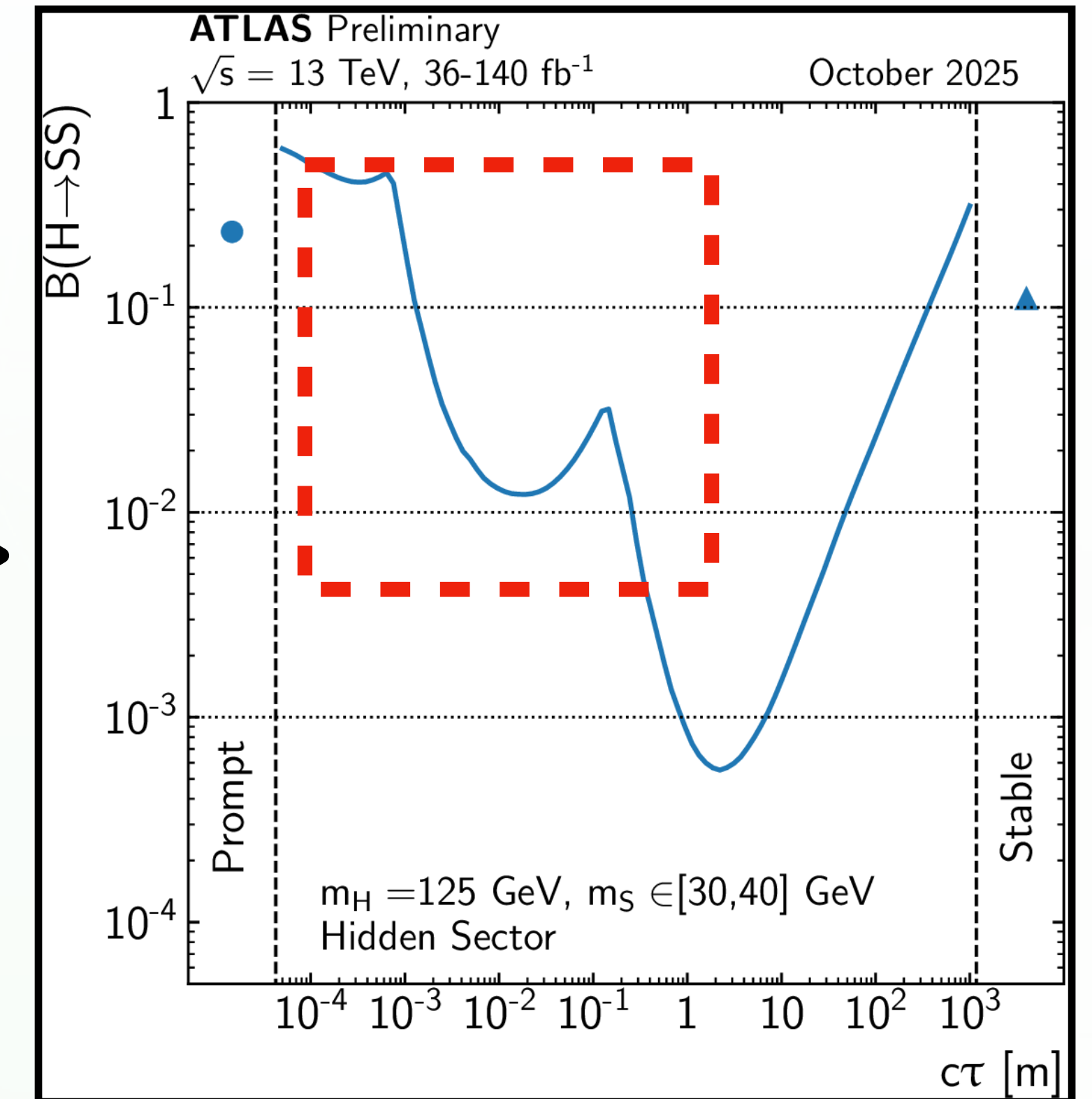
2018



7 Years



2025



2018: [JHEP \(2018\) 31:](#)

2021: [JHEP11\(2021\)229:](#)

2023: [Eur.Phys.J.C83\(2023\)1081:](#) New LRT development

2024: [PRL 133 \(2024\) 161803:](#)

Explore b -tagging on LLPs

Higgs to DV search using old LRT

Higgs to DV search using new LRT

Also 7 years:

2019

Conceiving
Idea

2022

ATLAS
Prototype

2024

Full
Calibration

2026

Publication

Performance work takes a long time



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Thank You!