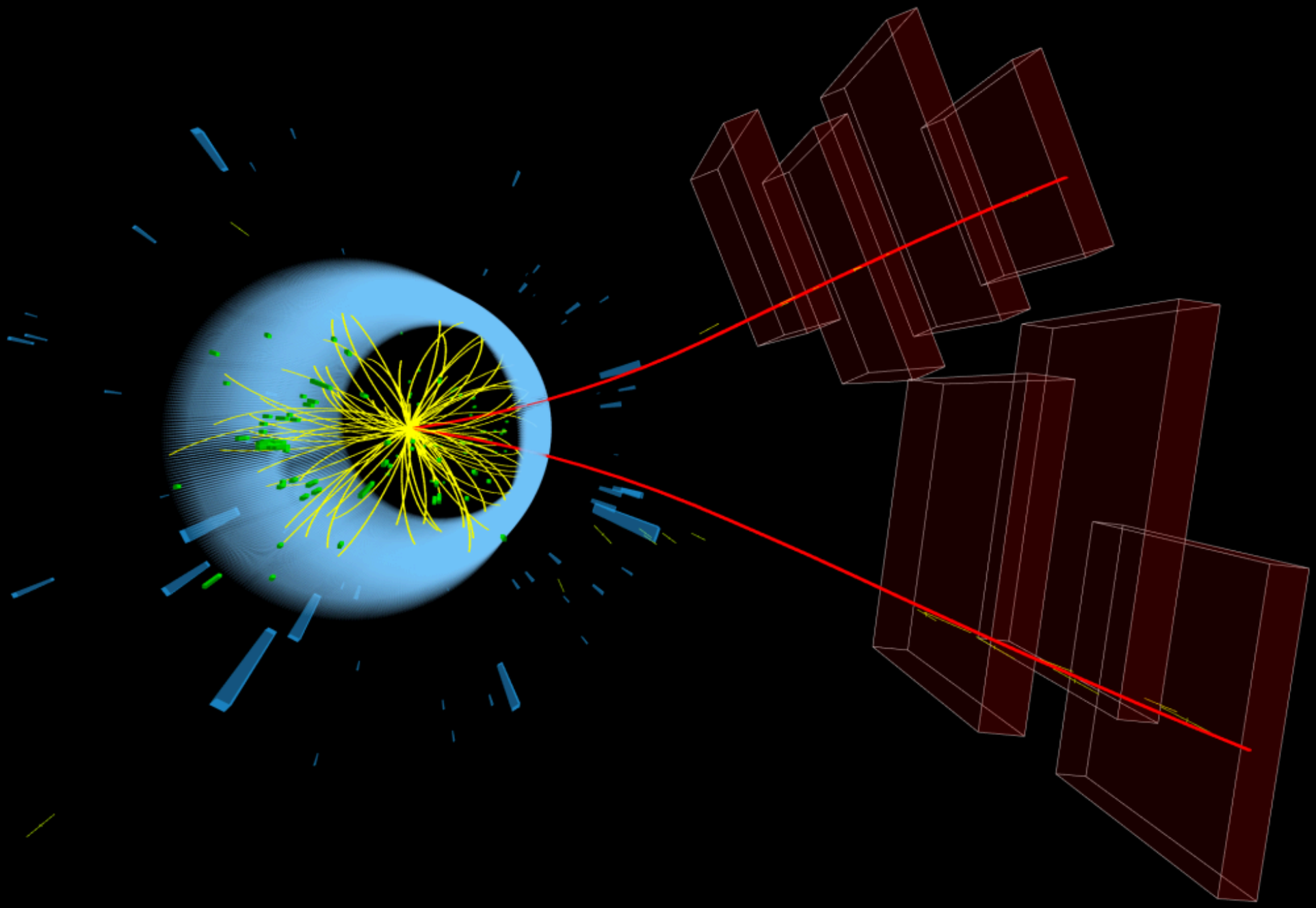
Displaced vertices with the CMS track trigger

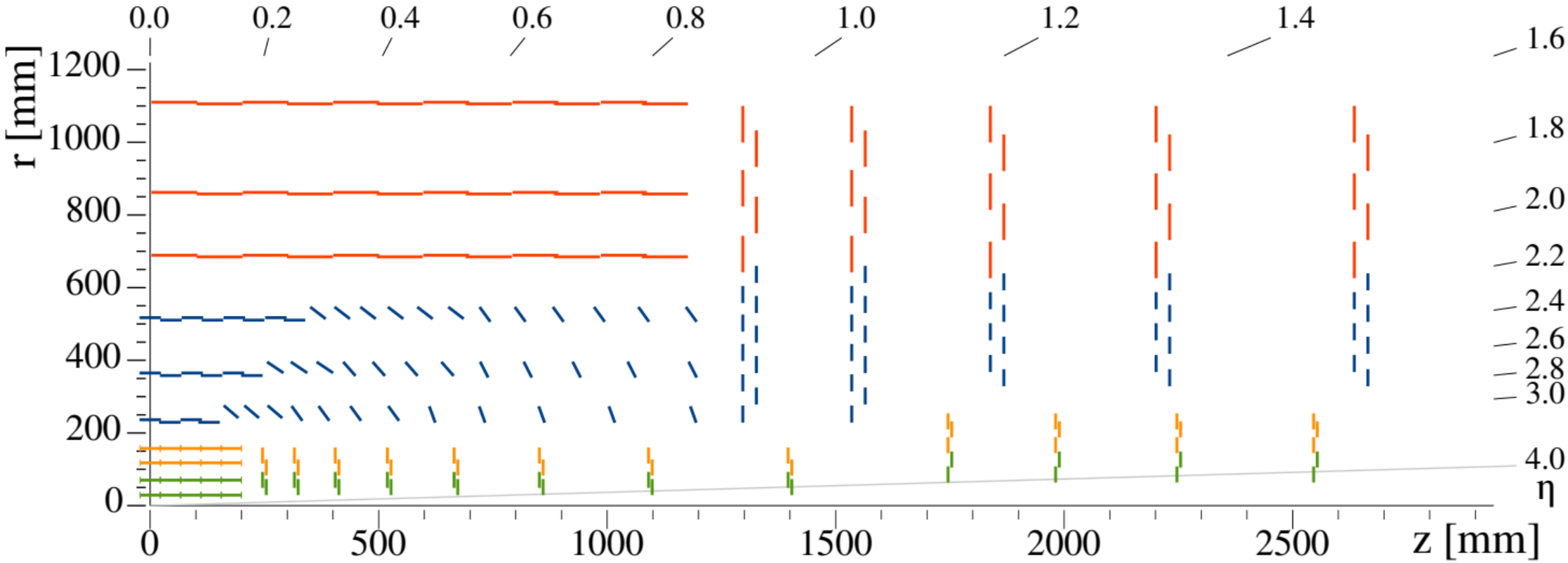


Simon Knapen

With Yuri Gershtein, Jared Evans and Diego Redigolo

CMS Level 1 track trigger

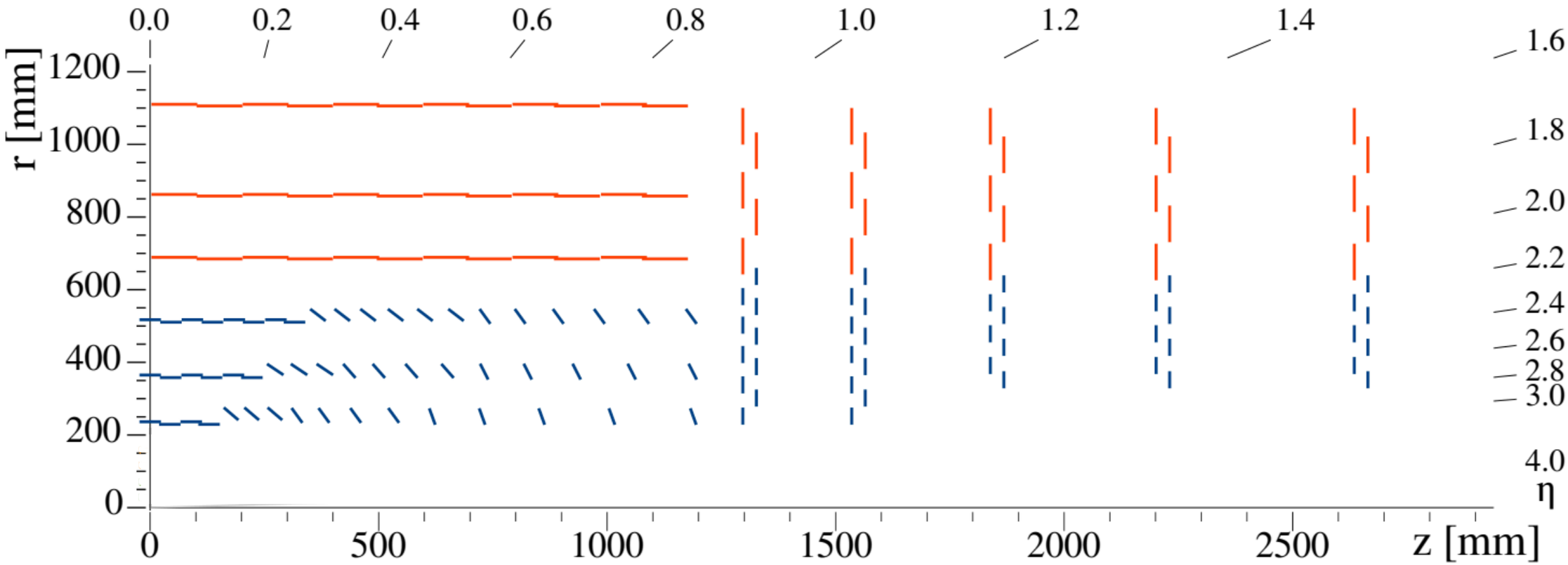
Phase II tracker layout



CMS-TDR-014

CMS Level 1 track trigger

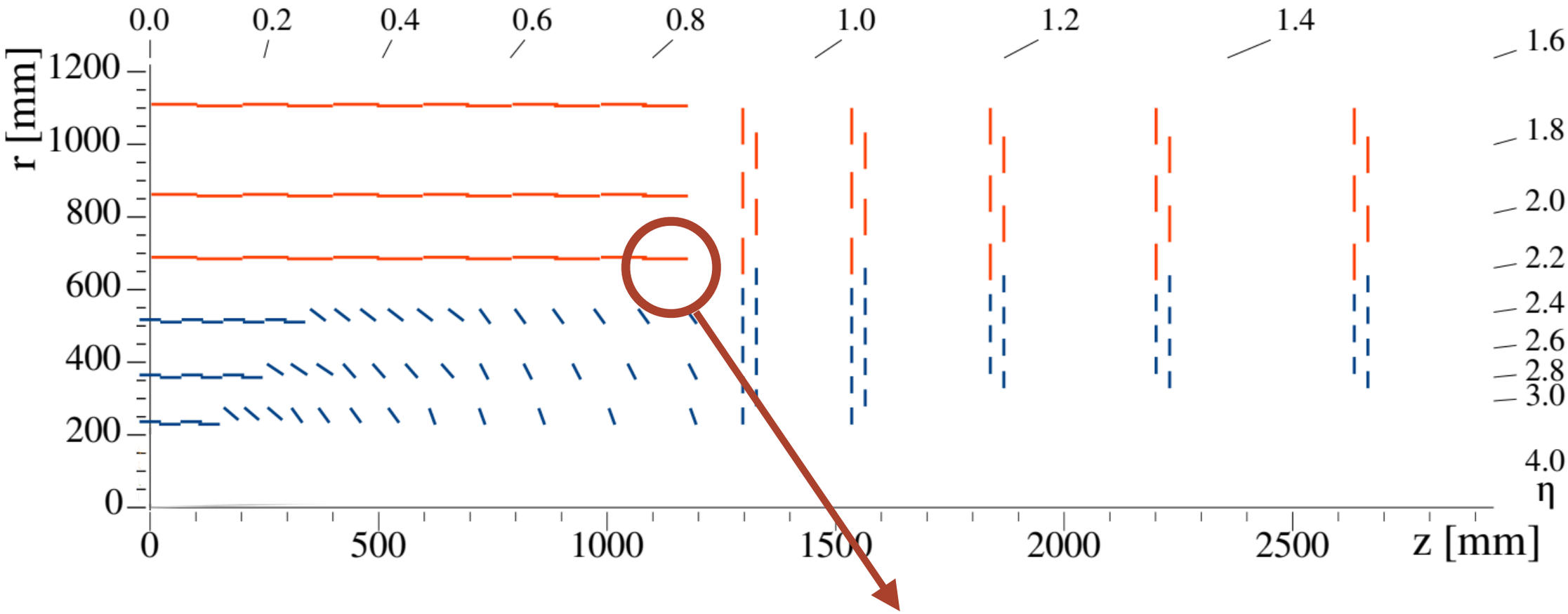
Phase II tracker layout



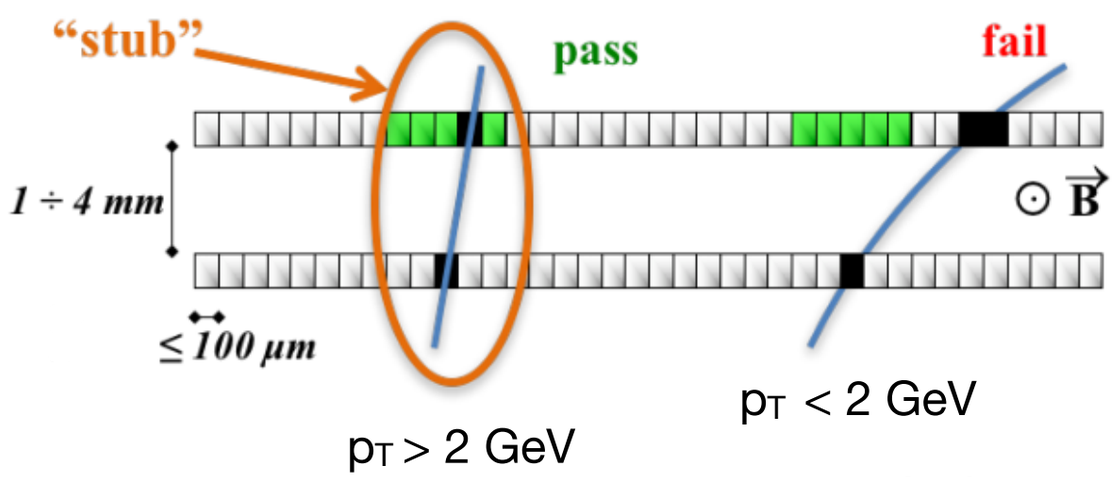
CMS-TDR-014

CMS Level 1 track trigger

Phase II tracker layout



Each module independently measures the p_T of the stubs



Only stubs with $p_T > 2$ GeV are used in track reconstruction

CMS-TDR-014

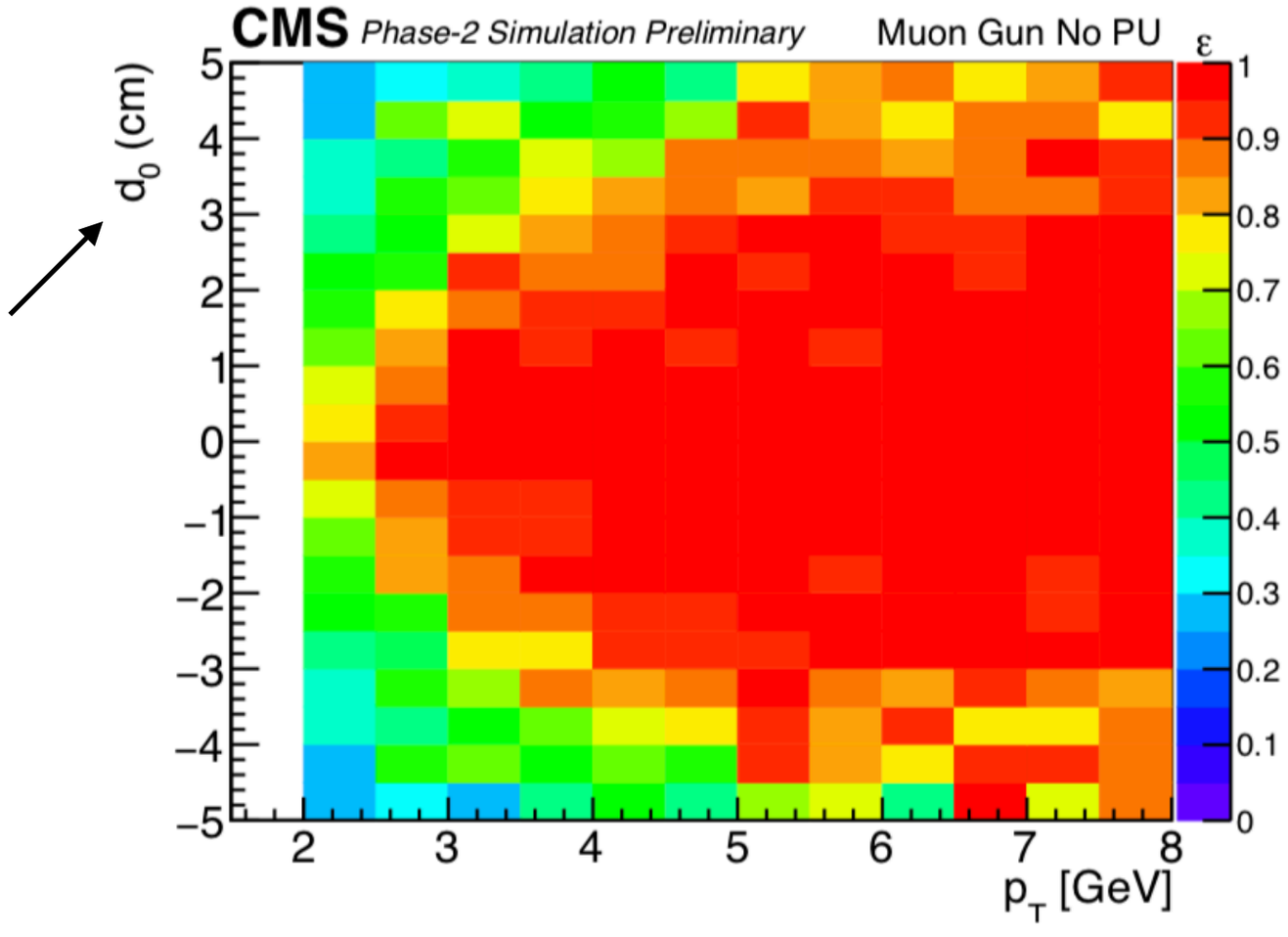
Displaced tracks

Key point: For moderate displacements, stubs are still reconstructed

↓

In principle, track trigger could find displaced tracks*

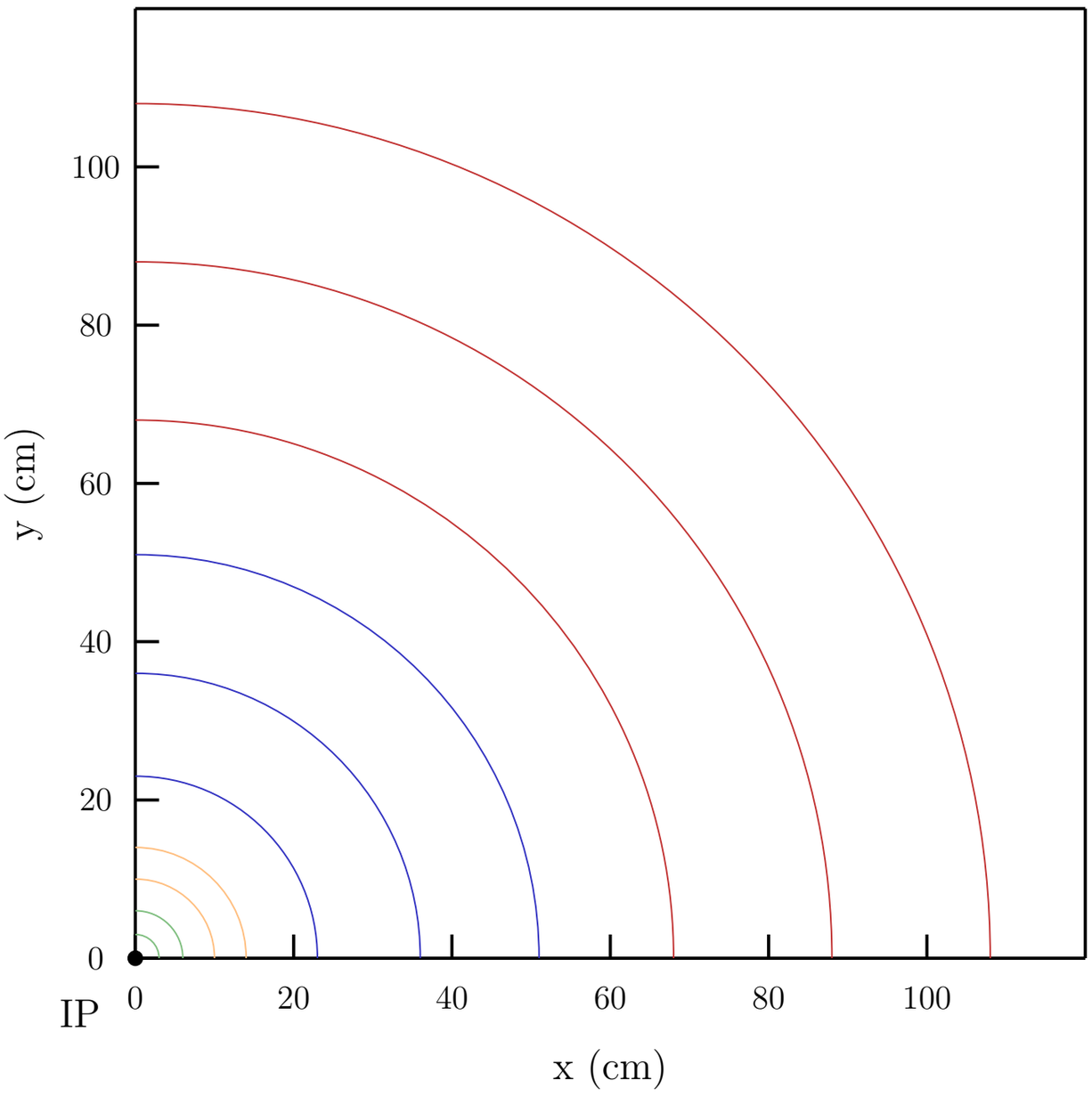
Impact parameter in the transverse plane



Y. Gershtein: arXiv 1705.04321
CMS PAS FTR-18-018

* but additional resources likely needed

Toy detector simulation



Procedure:

1. Propagate track
   (including multiple scattering)

Y. Gershtein: arXiv 1705.04321
Y. Gershtein, SK: arXiv 1907.00007

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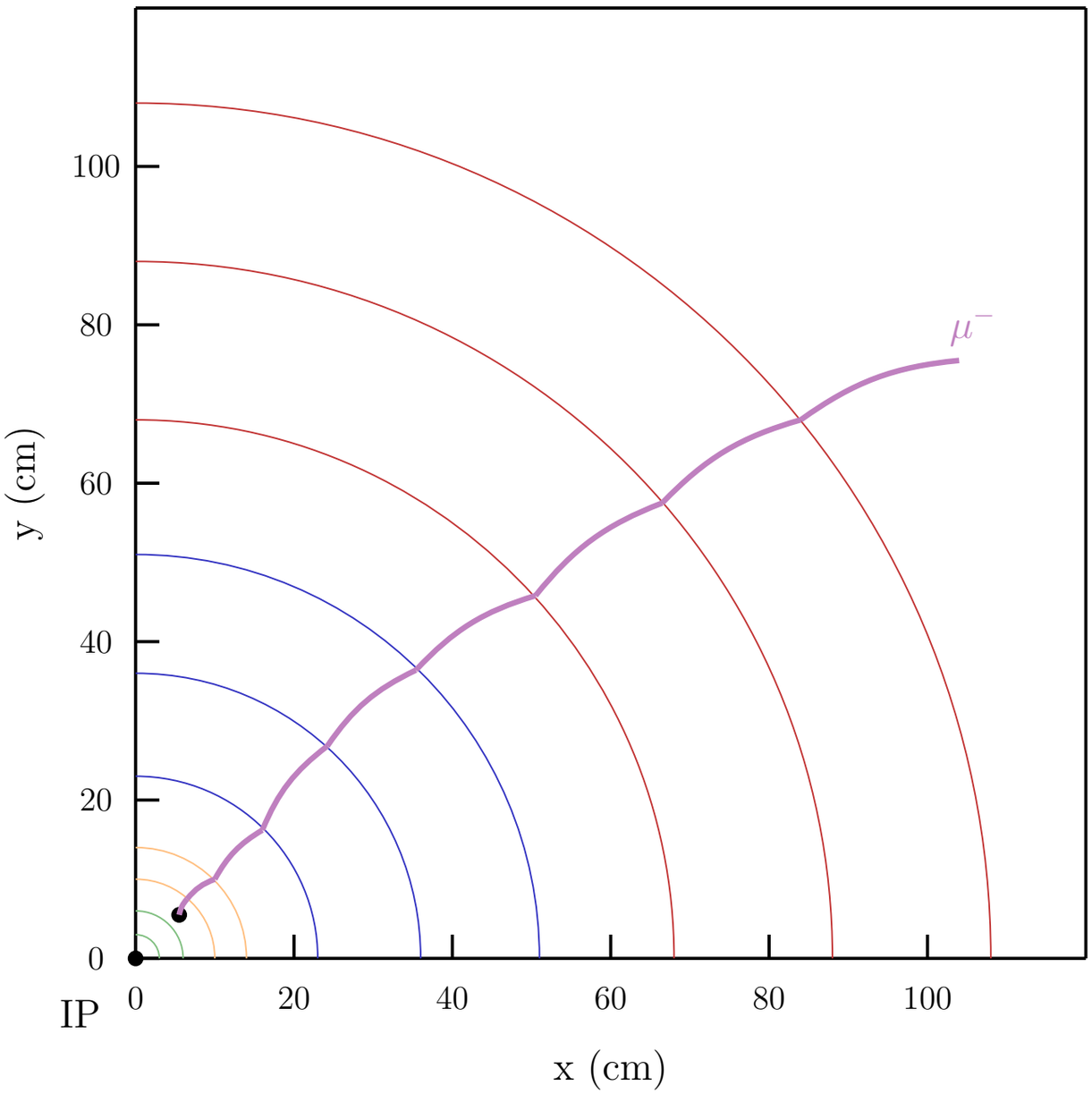

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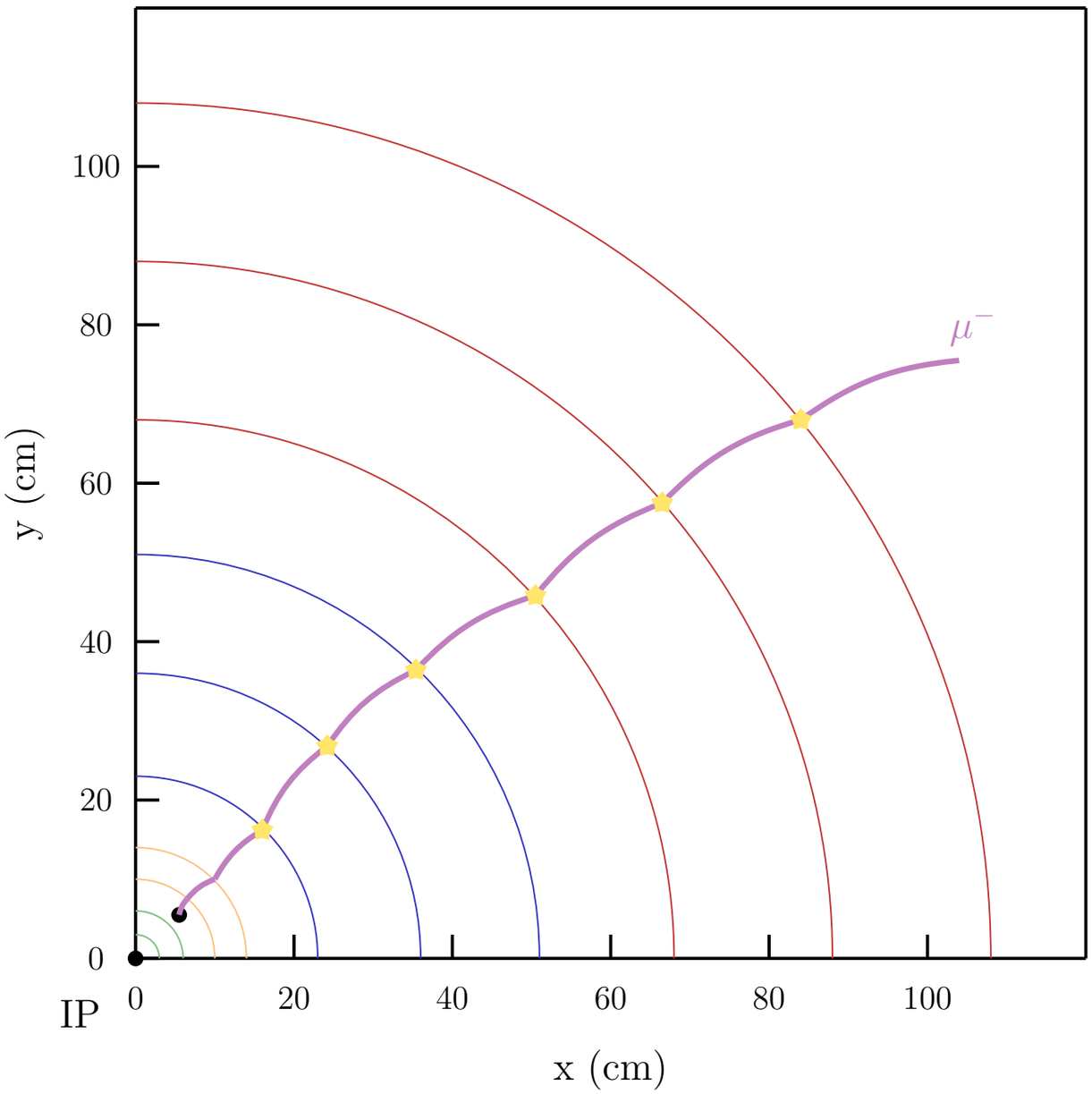
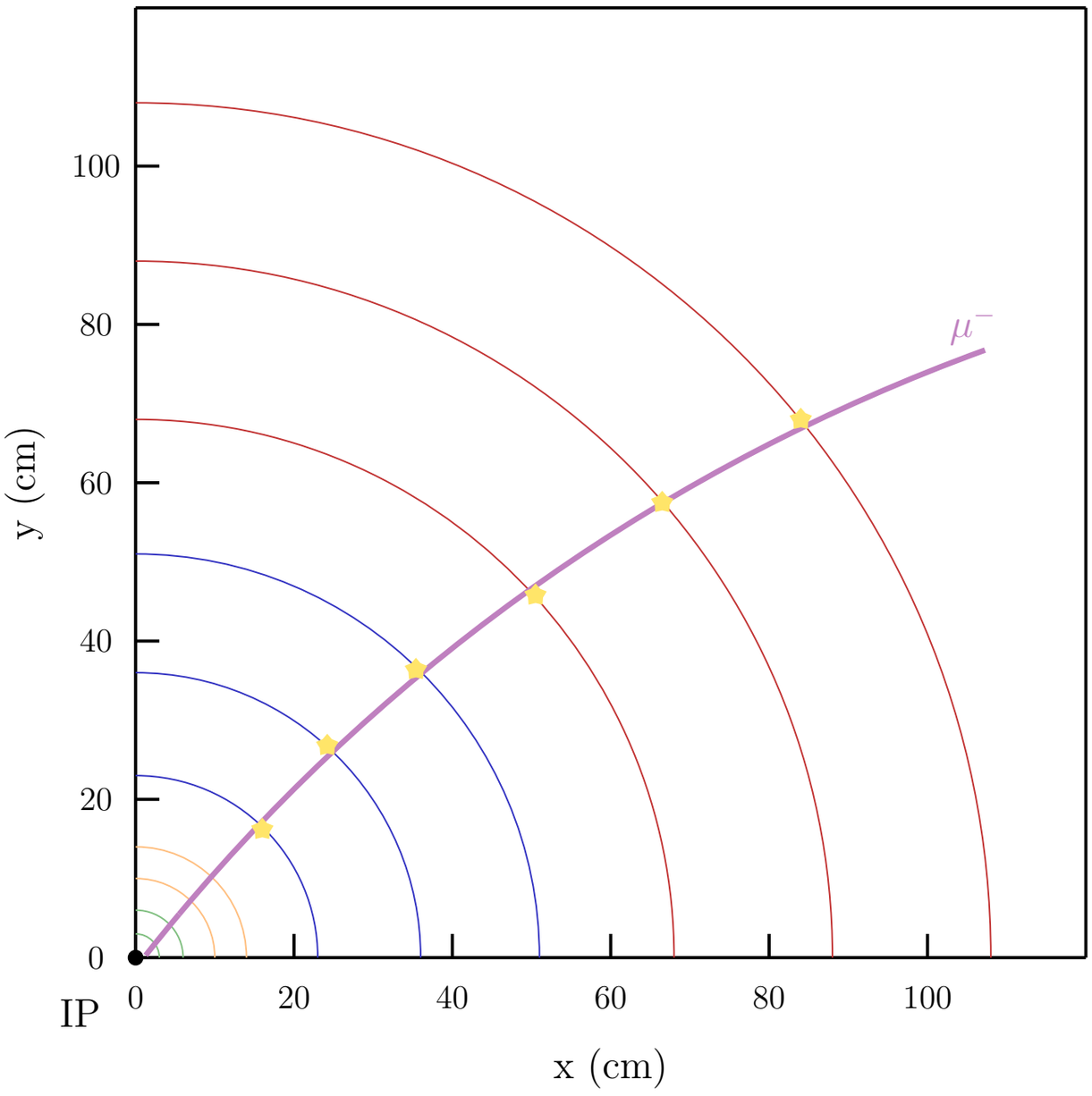


Procedure:

1. Propagate track
   (including multiple scattering)
2. Find the stubs
   (smearing for resolution)

Y. Gershtein: arXiv 1705.04321
Y. Gershtein, SK: arXiv 1907.00007

Toy detector simulation

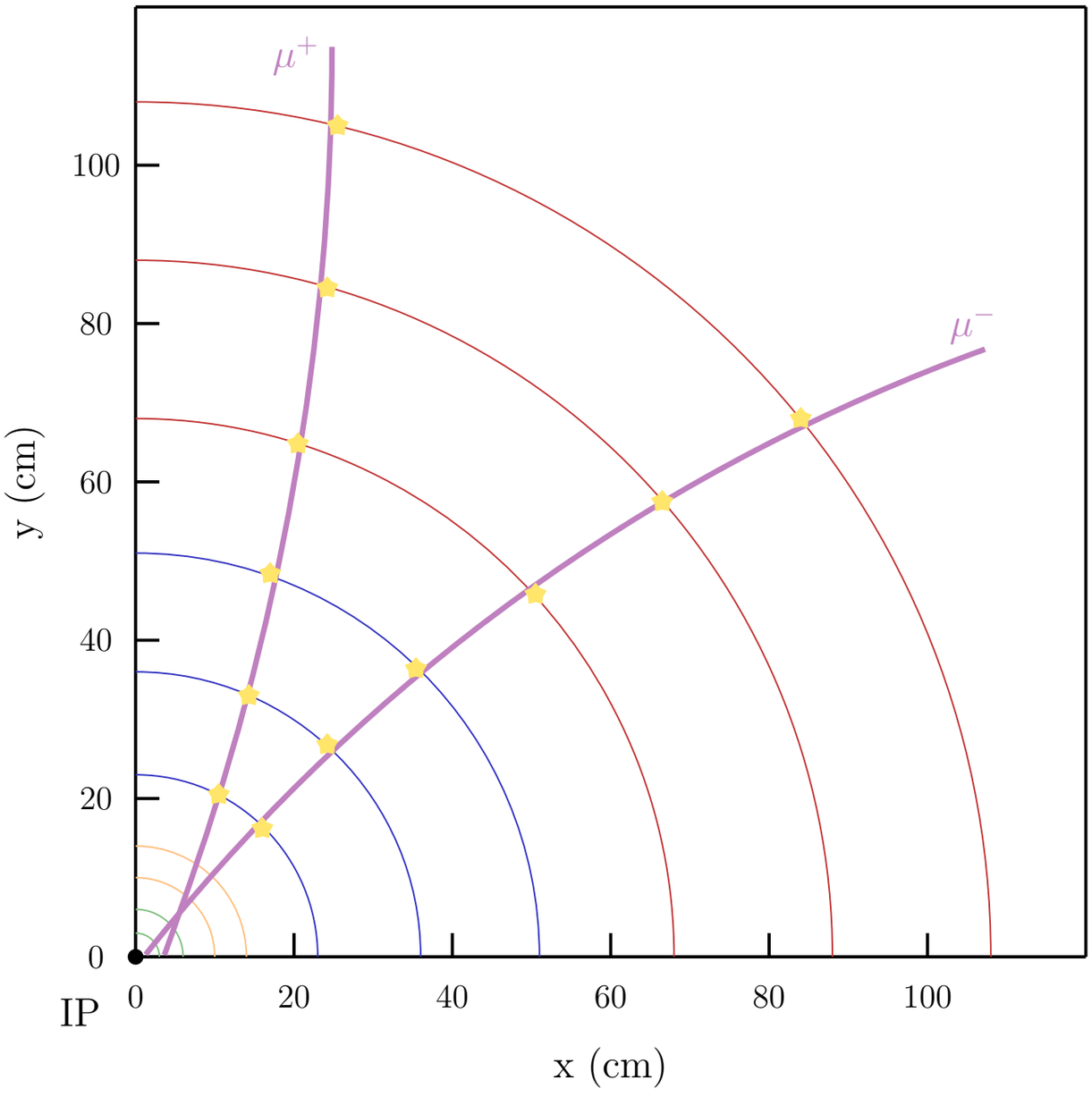


Procedure:

1. Propagate track
   (including multiple scattering)
2. Find the stubs
   (smearing for resolution)
3. Fit a helix to the stubs
   (require at least 5 stubs)

Y. Gershtein: arXiv 1705.04321
Y. Gershtein, SK: arXiv 1907.00007

Toy detector simulation



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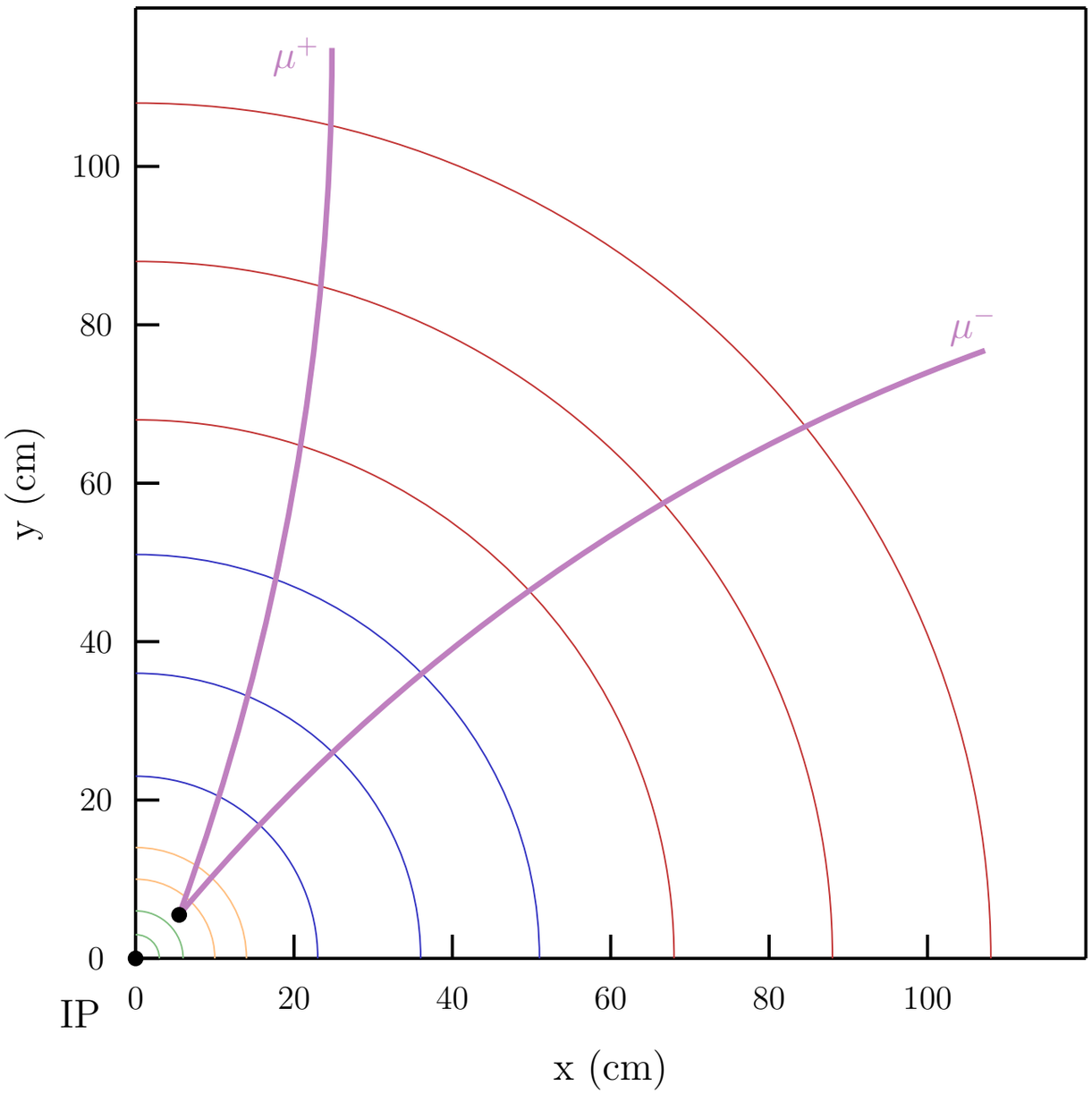


Procedure:

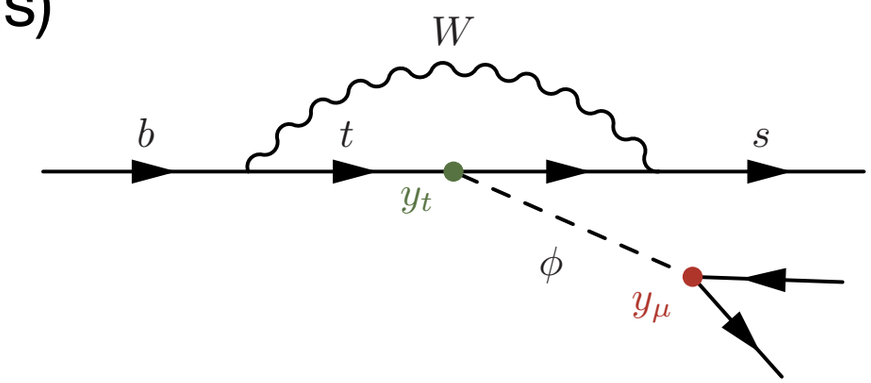
1. Propagate track
   (including multiple scattering)
2. Find the stubs
   (smearing for resolution)
3. Fit a helix to the stubs
   (require at least 5 stubs)
4. Reconstruct a vertex

Y. Gershtein: arXiv 1705.04321
Y. Gershtein, SK: arXiv 1907.00007

Signal & Background

Signal: displaced dimuon resonance (dark Higgs)

$$B \to X_s \phi$$
$$\hookrightarrow \mu\mu$$



Y. Gershtein, SK: arXiv 1907.00007

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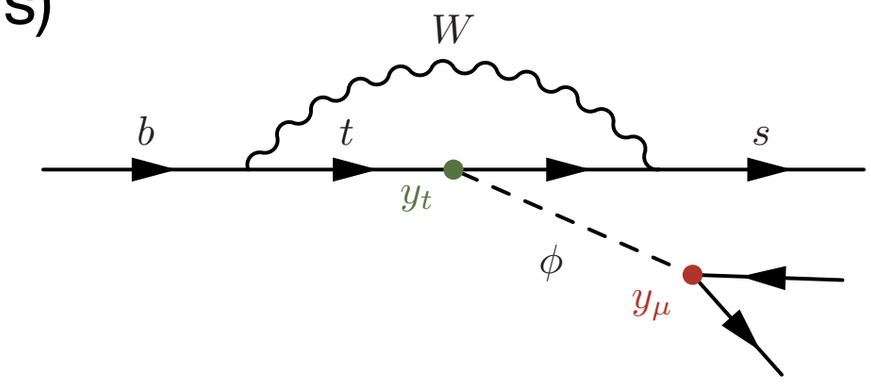


Backgrounds:

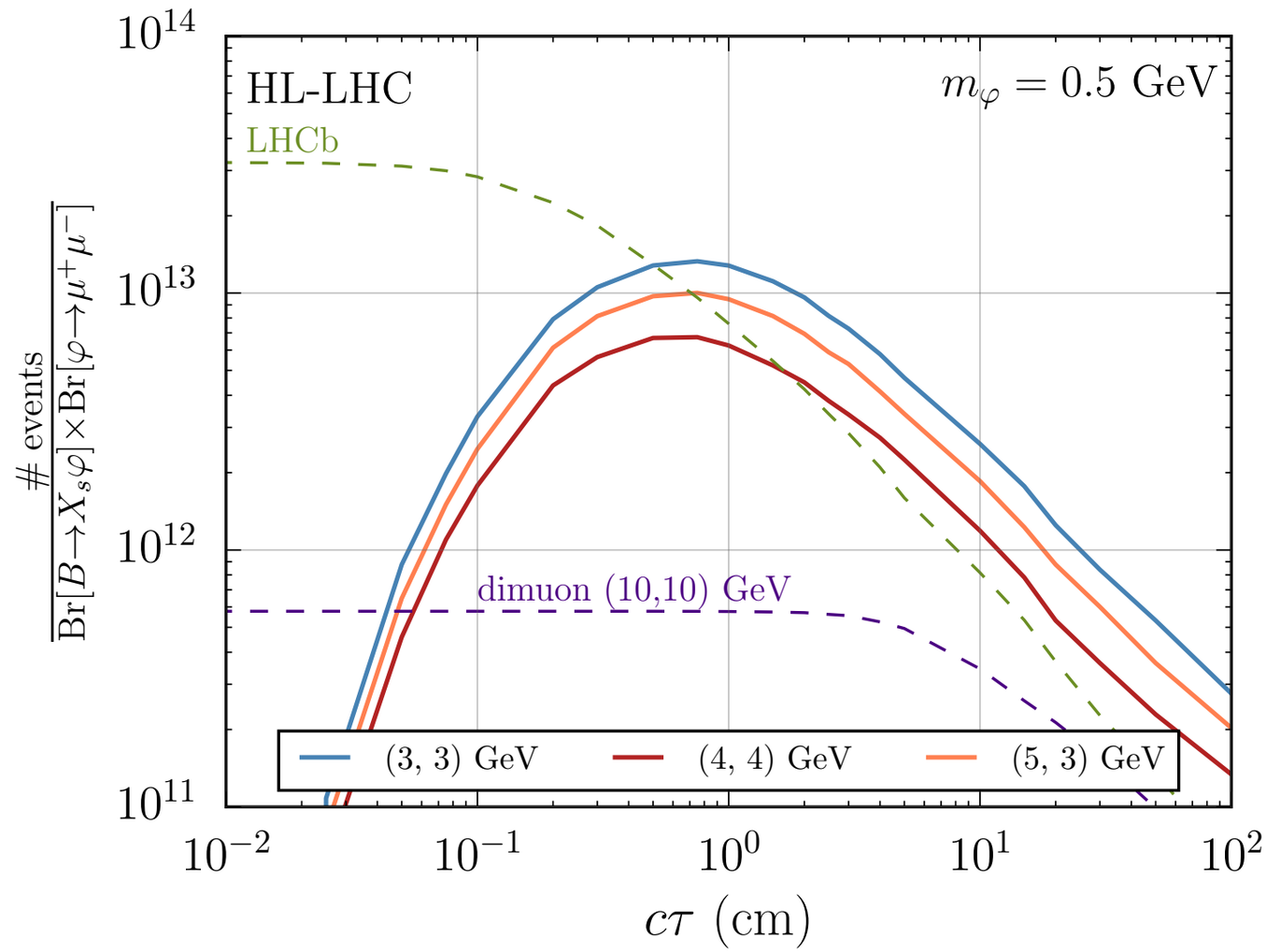
- Fake vertices → Vertex quality, pointing & muon matching
- Kaons $(K_S \to \pi^+\pi^-)$ → Muon matching
- B-mesons → Cut vertex radial distance (R_T>1.5 cm)

Goal: suppress background factor of 10^{-4} with minimal cuts on signal

Y. Gershtein, SK: arXiv 1907.00007

Trigger yield

Total yields for our (Level-1) trigger strategy, for different pT thresholds



Competitive with LHCb, much better than a (generous) normal dimuon trigger

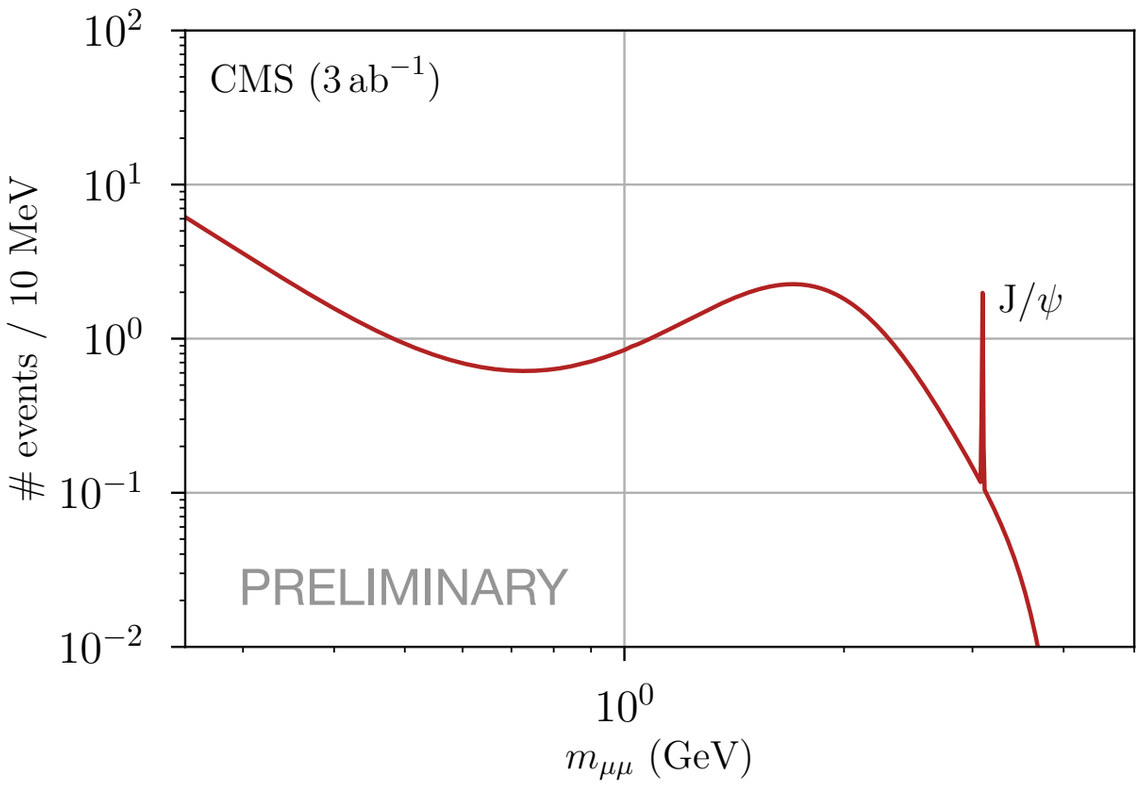
Y. Gershtein, SK: arXiv 1907.00007

Offline analysis

Main background from B-meson decays

<u>For example:</u>

$$B^+ \to \mu^+ \nu_\mu D^0 X$$
$$\hookrightarrow \mu^- \bar{\nu}_\mu K^+$$



Can be reduced to O(1) levels with:

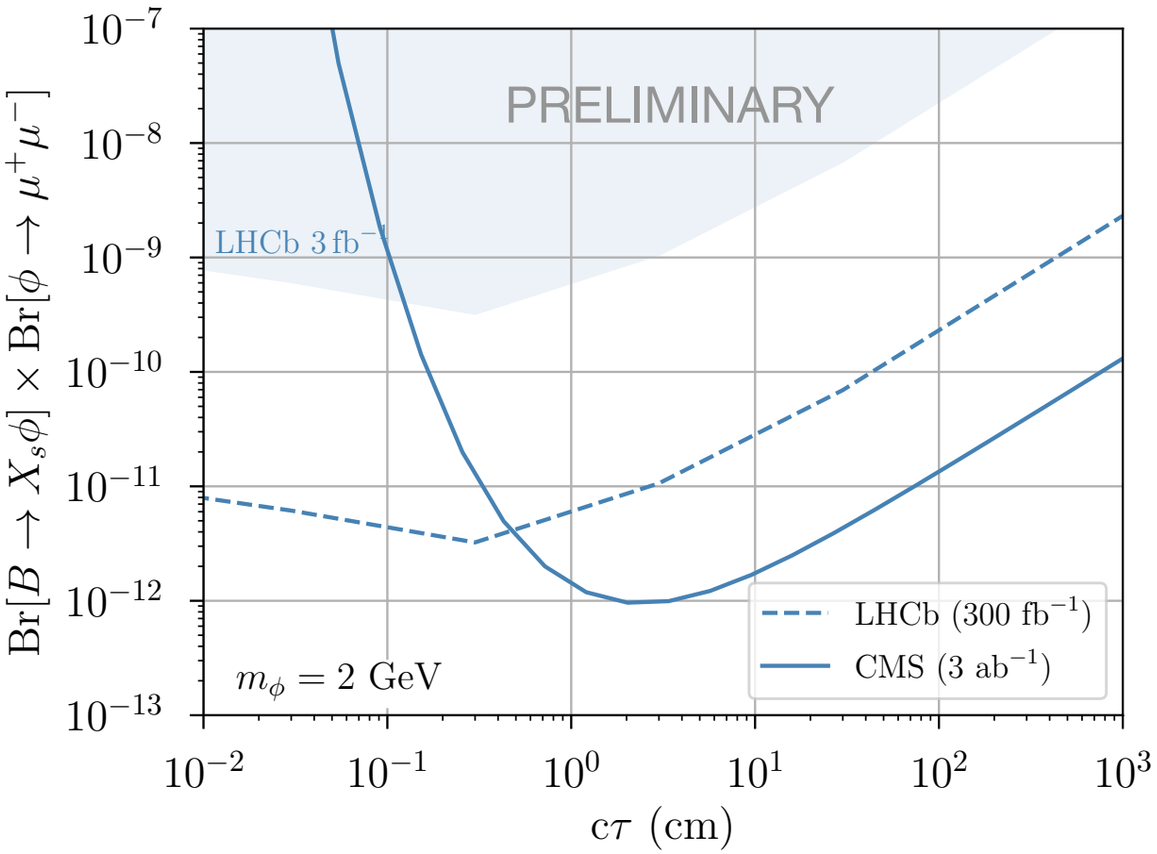
- Cuts on vertex displacement (> 5 cm)
- Isolation cuts
- Minimal p_T cuts

J. Evans, SK: in preparation

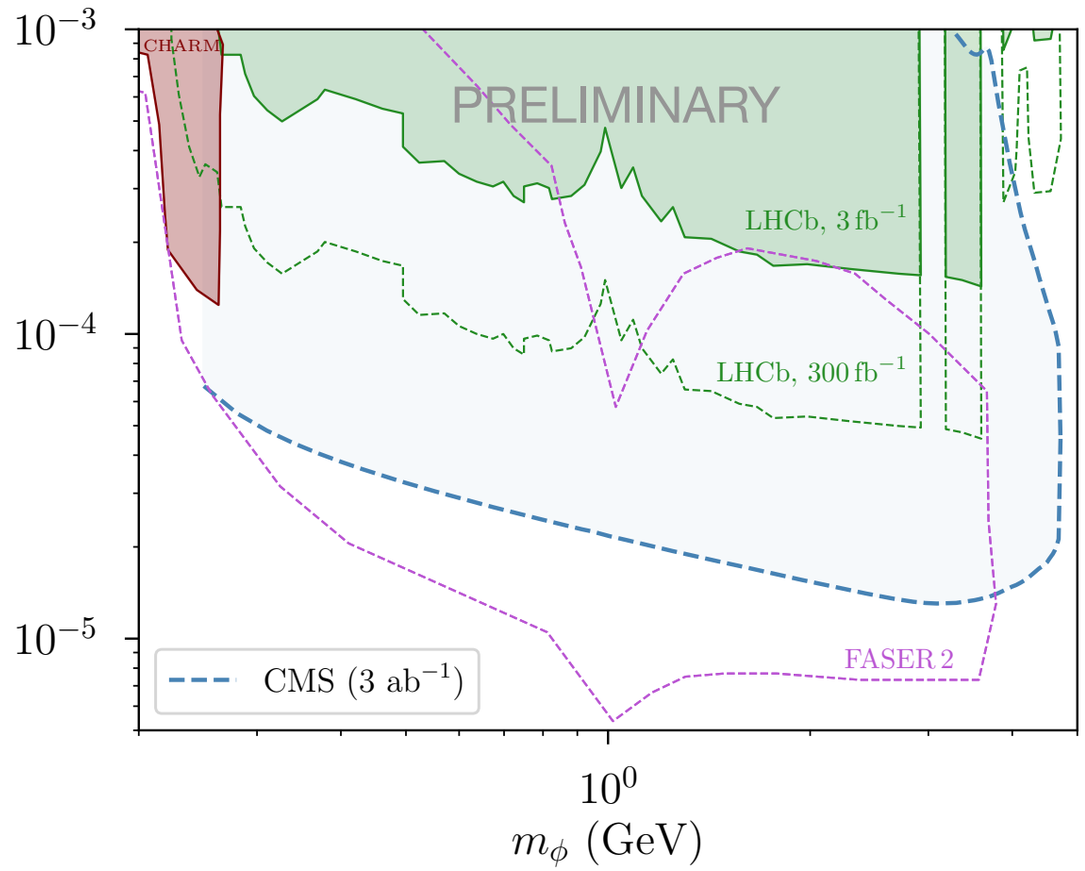
Offline analysis

Reach:

Model independent



dark Higgs



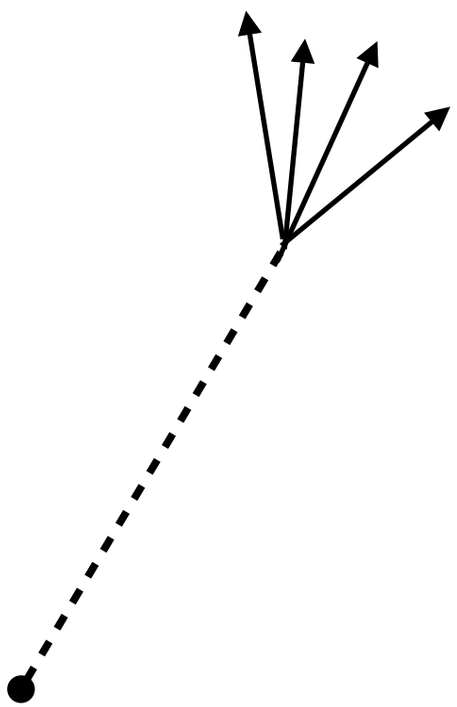
CMS reach is optimistic, since “junk” backgrounds are not modeled

LHCb reach rescaled from current limits, assuming backgrounds remain negligible.

J. Evans, SK: in preparation

Generalizations

Multi-track DV



Axion-like particles
Exotic Higgs decays

Y. Gershtein, SK, D. Redigolo: in progress

Selection

- 4 reconstructed tracks (pT > 2 GeV)
- Good quality vertex
- R_T > 3 cm

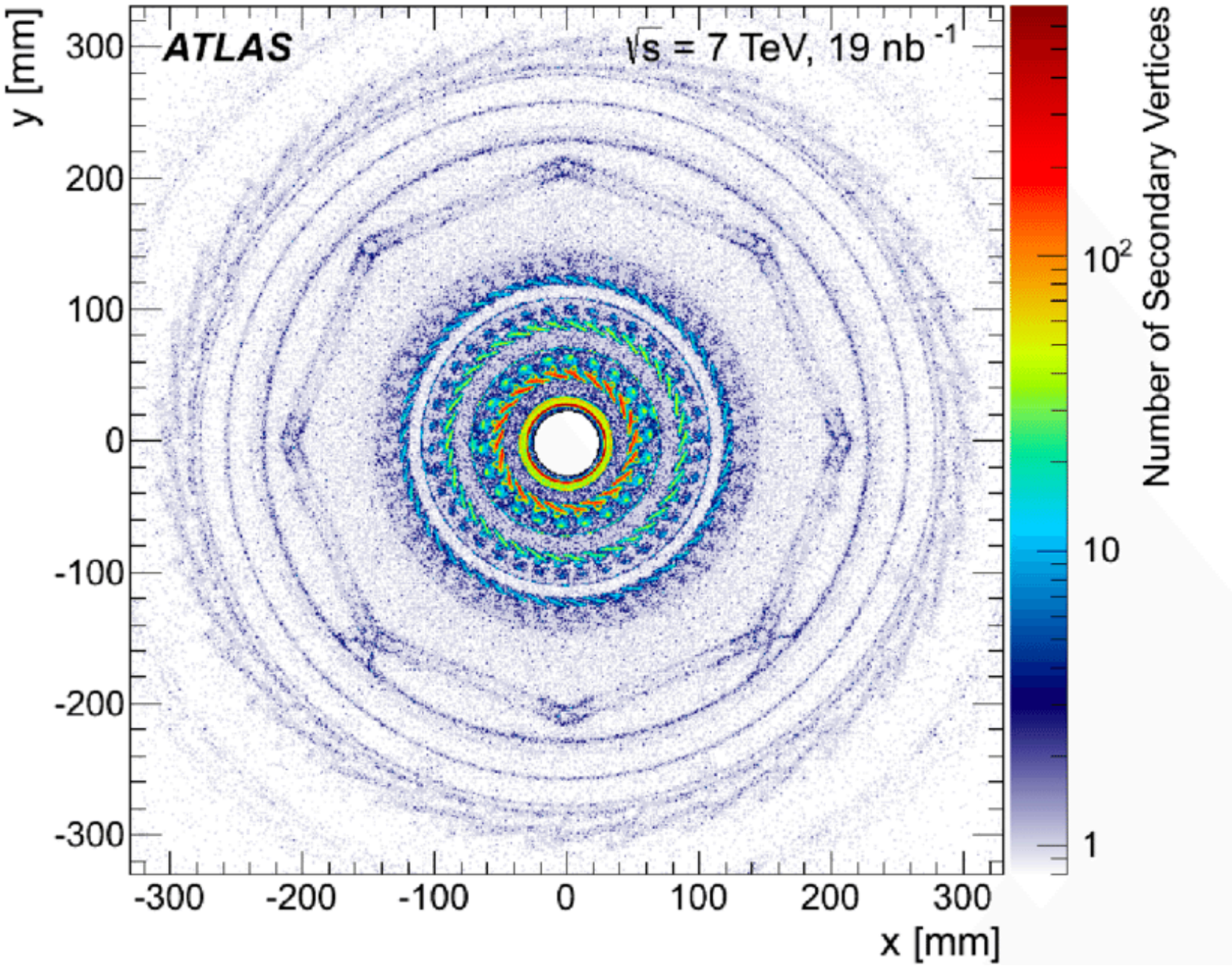
Backgrounds

- Fake vertices → ≥ 4 tracks
- B-mesons → cut on L_{xy}
- Material interactions → ??

(Could be a long shot, in terms of latency)

Material interactions

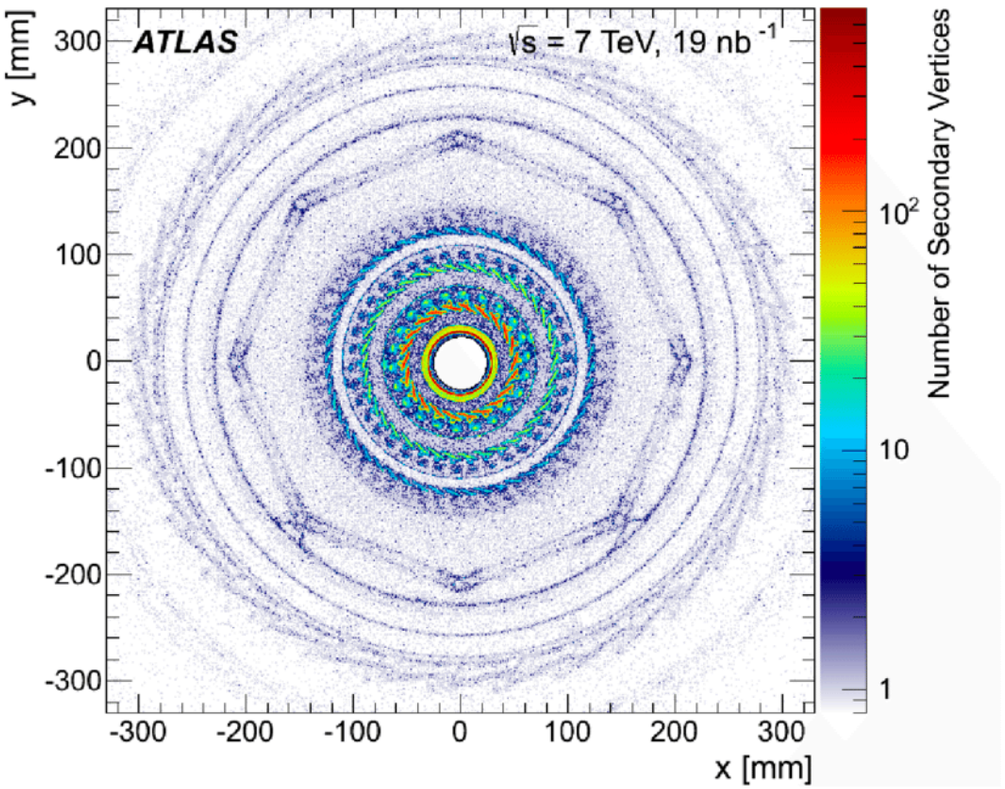
HUGE amount secondaries in detector material

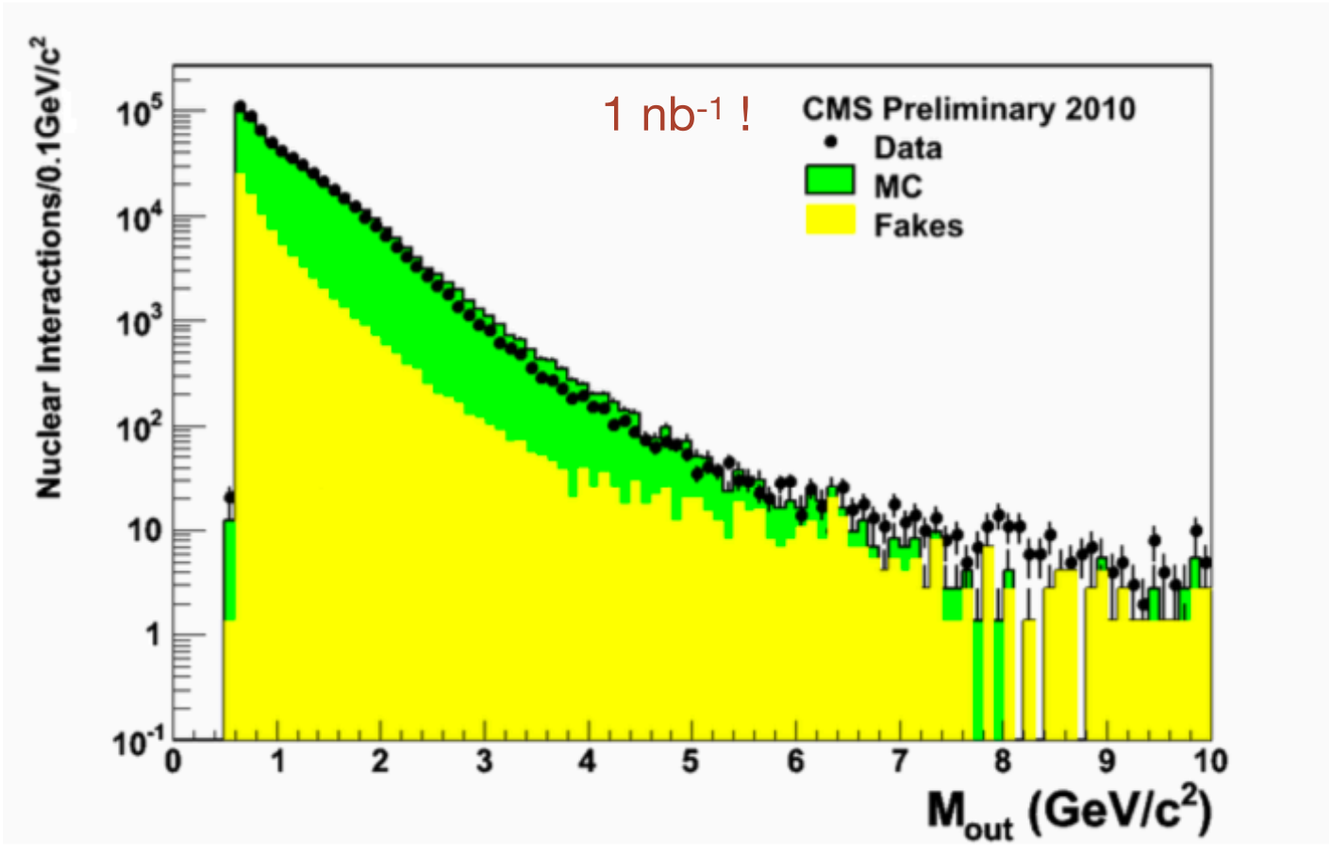


Must verify that this does not swamps the trigger bandwidth!

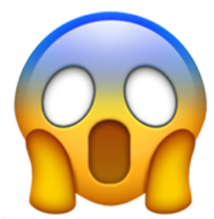
Material interactions

HUGE amount secondaries in detector material





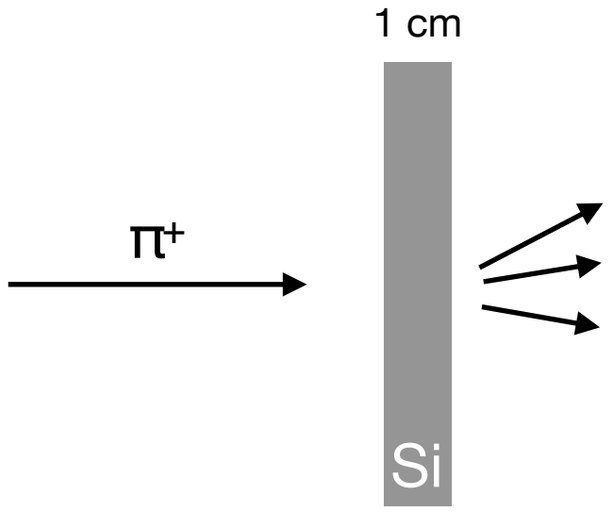
- 5% of all pions with p_T>5 GeV create secondary vertex
- ~ 30 MHz rate in HL LHC conditions

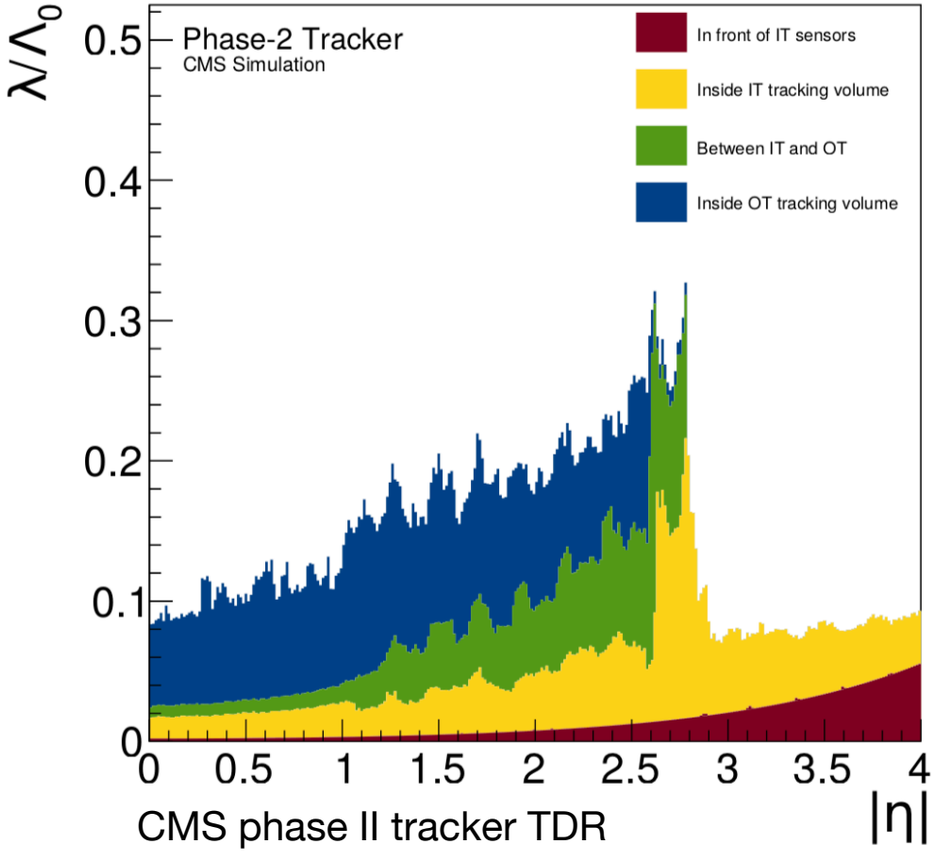


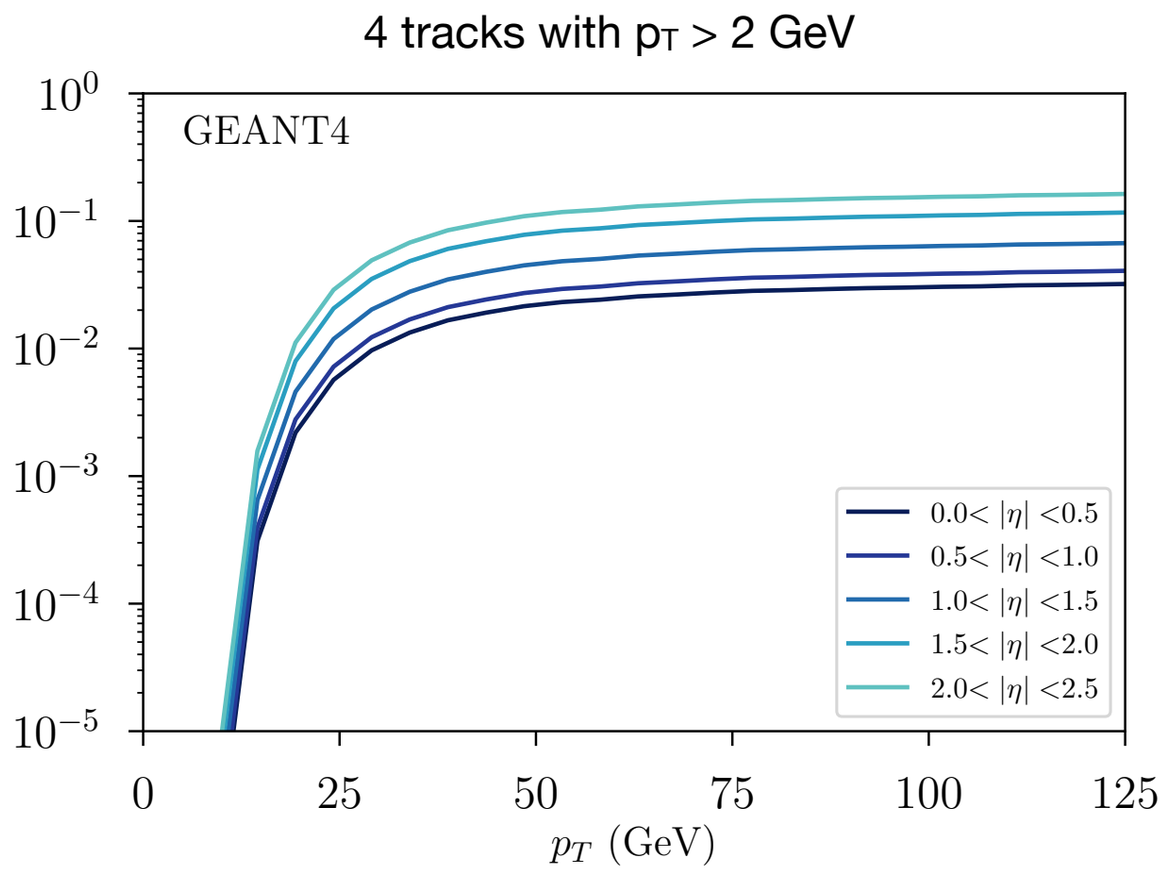
Must verify that this does not swamps the trigger bandwidth!

Material interactions

Pion gun in GEANT4



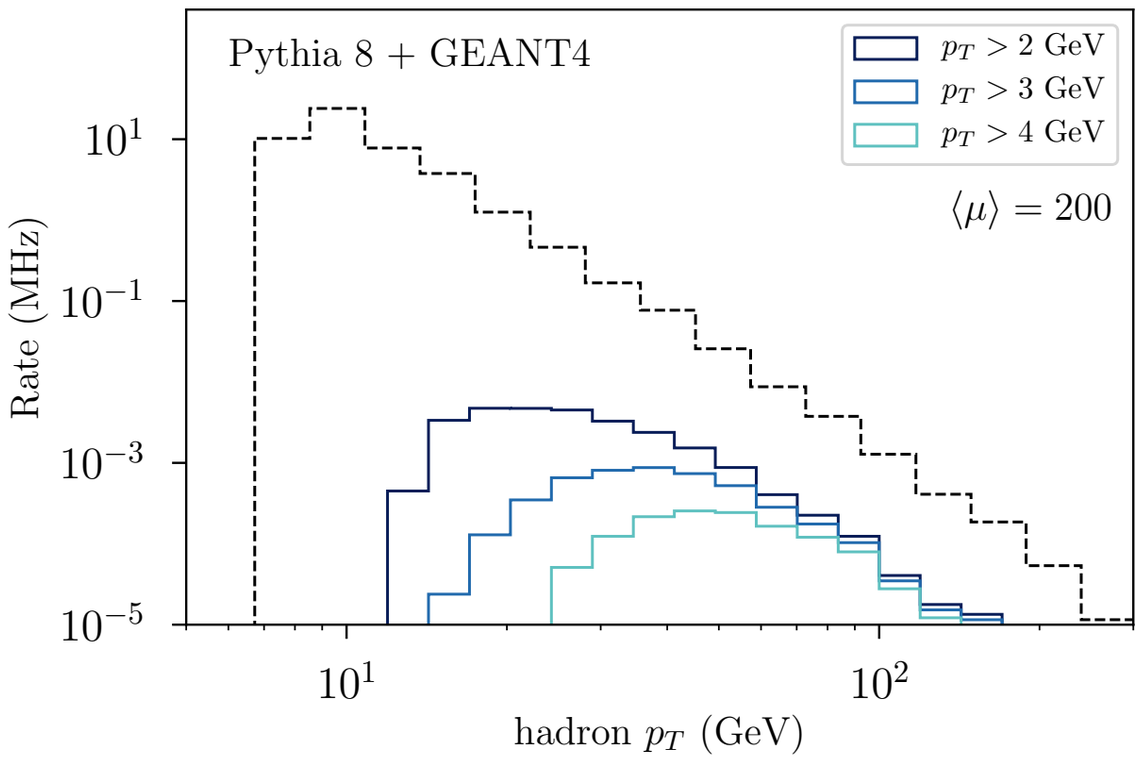




Y. Gershtein, SK, D. Redigolo: in progress

Material interactions

Fold in particle production rate



Rate can be brought to ~ kHz

Conservative assumptions:

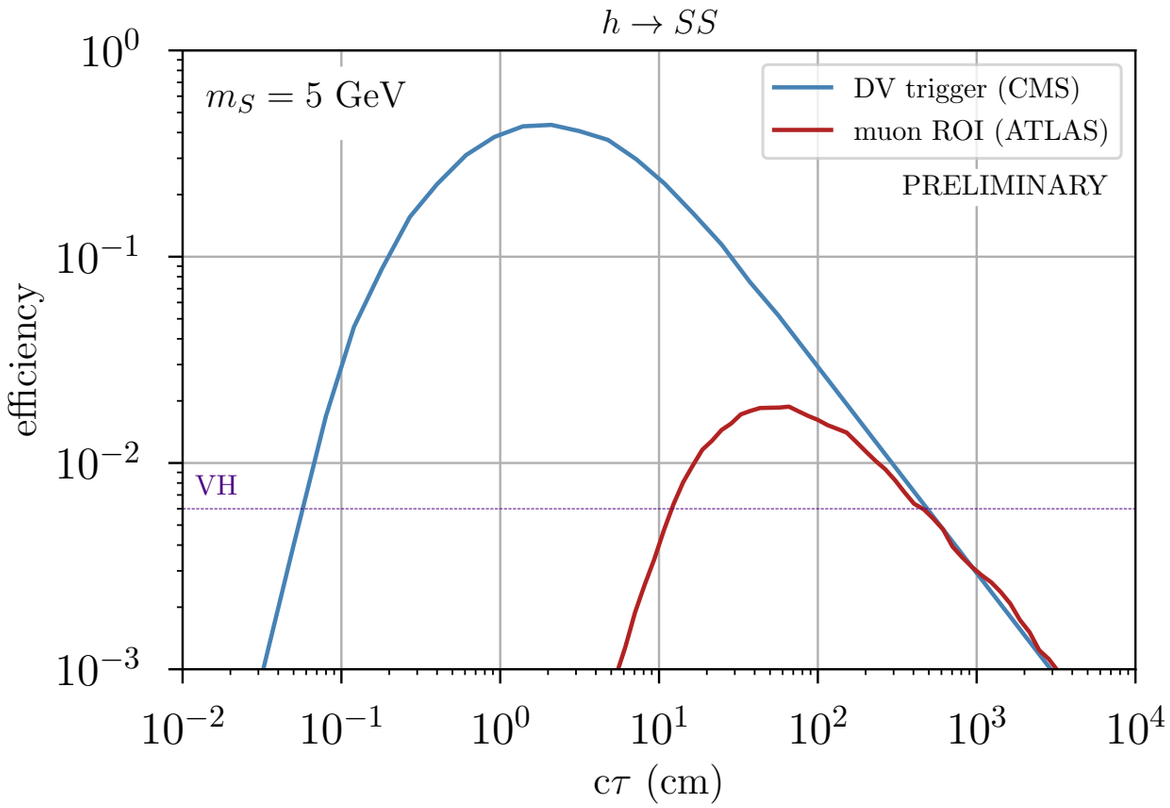
- Assumed 100% reco efficiency for tracks, *regardless of origin*
- No material veto attempted
- No isolation imposed

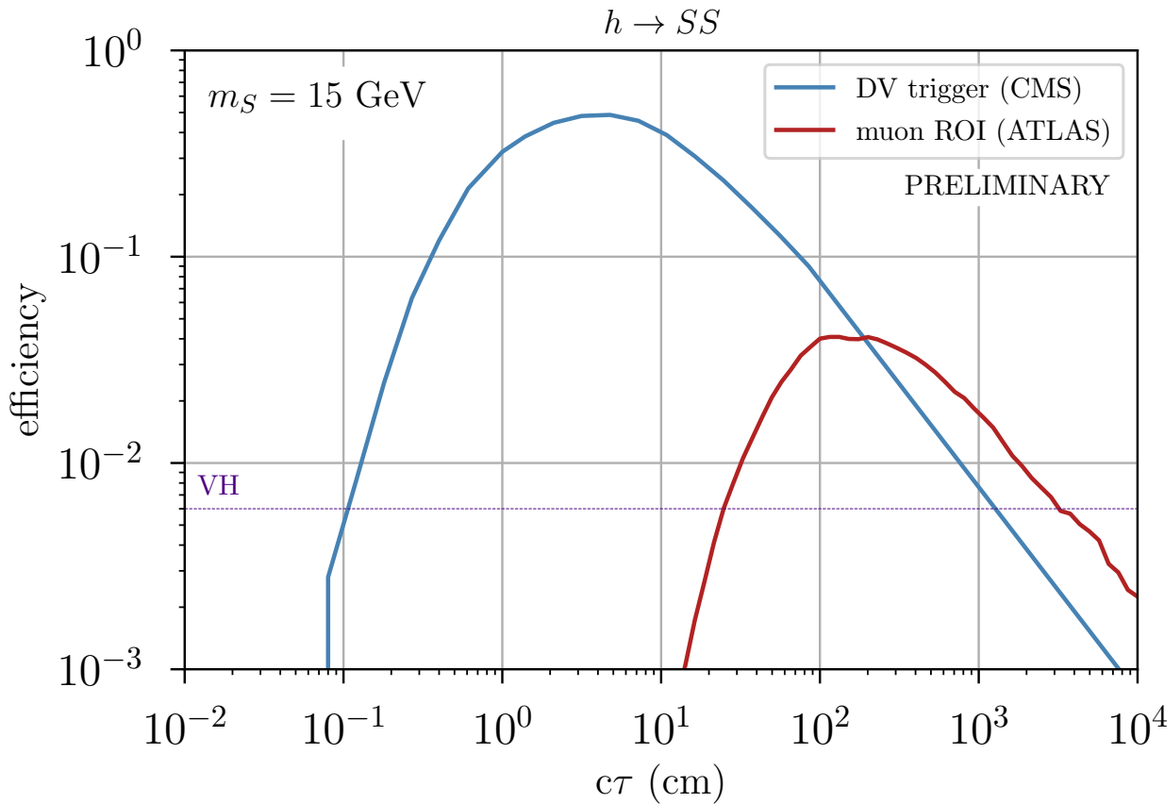
Y. Gershtein, SK, D. Redigolo: in progress

Results

Example: $h \to SS$

$\hookrightarrow$ hadrons





Qualitative gain in sensitivity appears possible

Y. Gershtein, SK, D. Redigolo: in progress
ATLAS muon ROI trigger: arXiv 1811.07370

Conclusions

The CMS track trigger is very cool

It could in principle yield qualitative improvements for LLPs

Great challenges to overcome, but our experimental friends are very clever.

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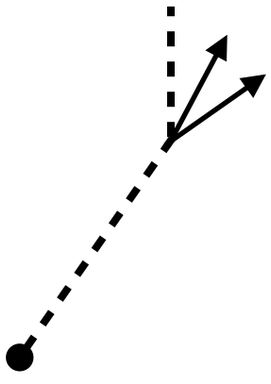
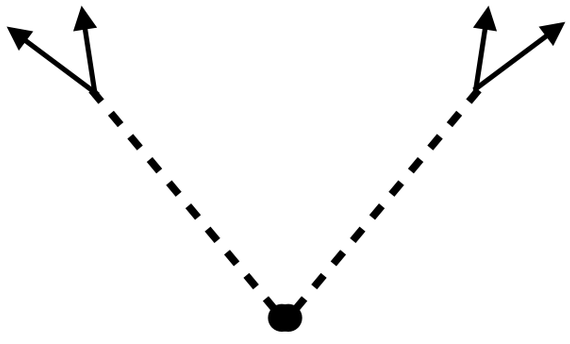
Other things to study

DV + MET



Double DV



Your favorite model

What can ATLAS do?

Happy to collaborate!

Shameless advertising

Physics Beyond Colliders meets theory: informal discussions about PBC selected topics

8-10 June 2020
CERN
Europe/Zurich timezone

Search...

- Overview
- Registration
- Timetable
- Contribution List
- Participant List
- Videoconference Rooms

With FIPS 2020 being postponed to the Fall of 2020, this virtual workshop aims to host a few talks and informal discussions related to searches for feebly interacting light particles. The scope is primarily on accelerator-based probes of hidden sectors, with a mix of theory and experiment.

The workshop will be fully virtual and consist out of 3 sessions of each 2 hours, taking place from 4pm to 6pm CERN time on the 3 days of the workshop. The timing is chosen to maximize the workshop's accessibility to as many time zones as possible. Talks are by invitation only.

If the status of the COVID crisis permits this, a conference room will be provided for CERN-based physicists to attend the talks. No in-person visits to CERN for the purpose of this workshop can be accommodated.

Starts 8 Jun 2020, 16:00
Ends 10 Jun 2020, 18:00
Europe/Zurich

CERN
Virtual only

Simon Knapen
Diego Redigolo
Gaia Lanfranchi

There are no materials yet.

https://indico.cern.ch/event/910753/overview

Back-up

A simple example

Dark Higgs:

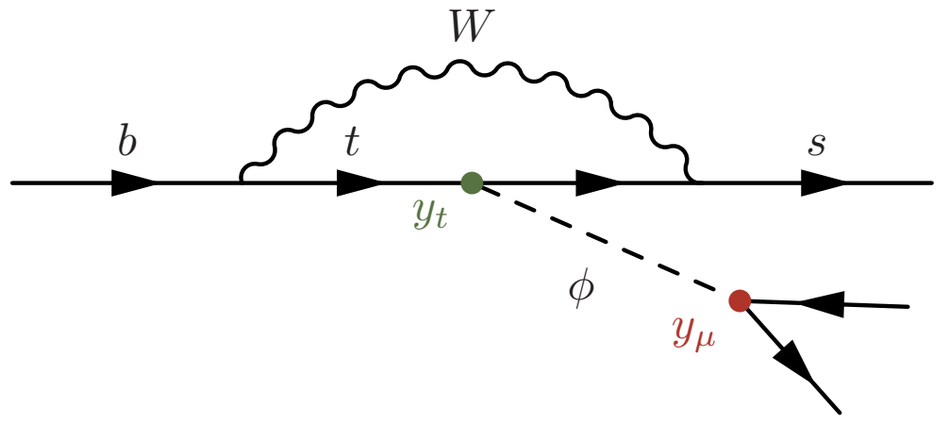
(Most minimal extension of the Standard Model)

$$\mu\,\phi H^\dagger H \quad \rightarrow \quad s_\theta y_f \phi \bar{f} f \qquad (s_\theta \ll 1)$$

<u>Production:</u> (for $m_\phi < m_B - m_K$)

$$\mathrm{Br}[B \to X_s \phi] \approx 6\, s_\theta^2\, (1 - m_\phi^2/m_B^2)^2$$

R. S. Willey and H. L. Yu (1982)
R. Chivukula and A. V. Manohar (1988)
B. Grinstein, L. J. Hall, and L. Randal (1988)



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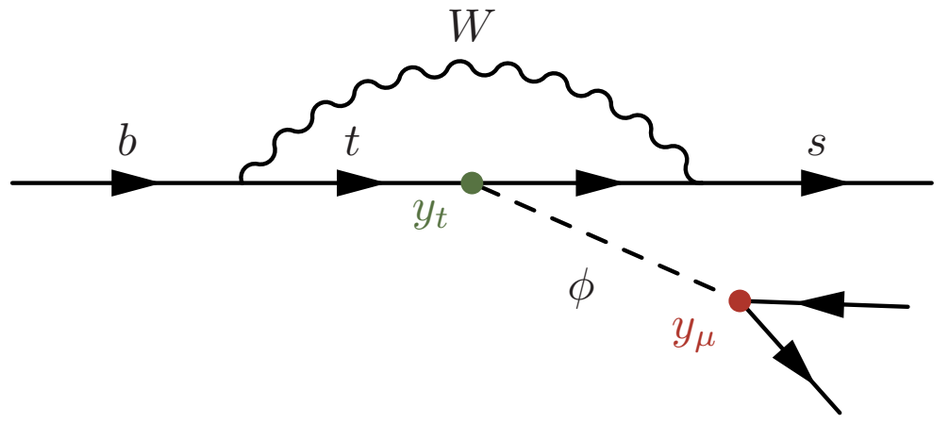
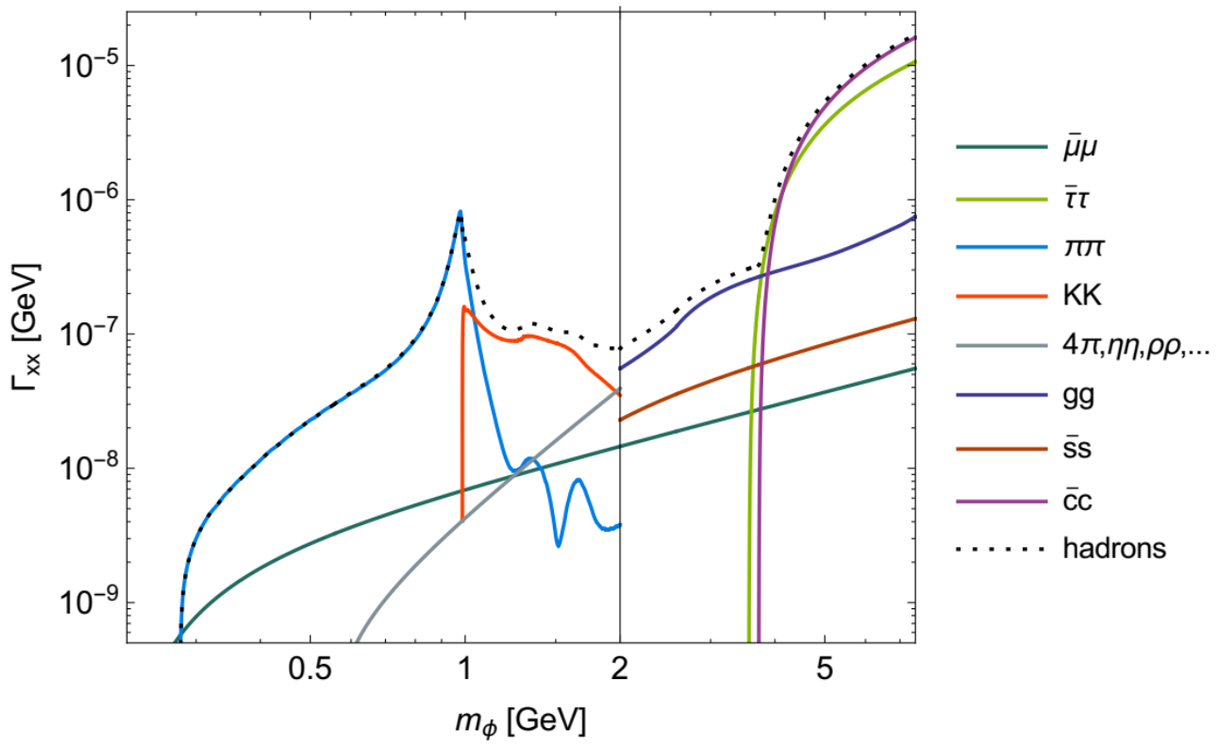


<u>Decay</u>:

Complicated…

… but long-lived



M. Winkler: arXiv 1809.01876

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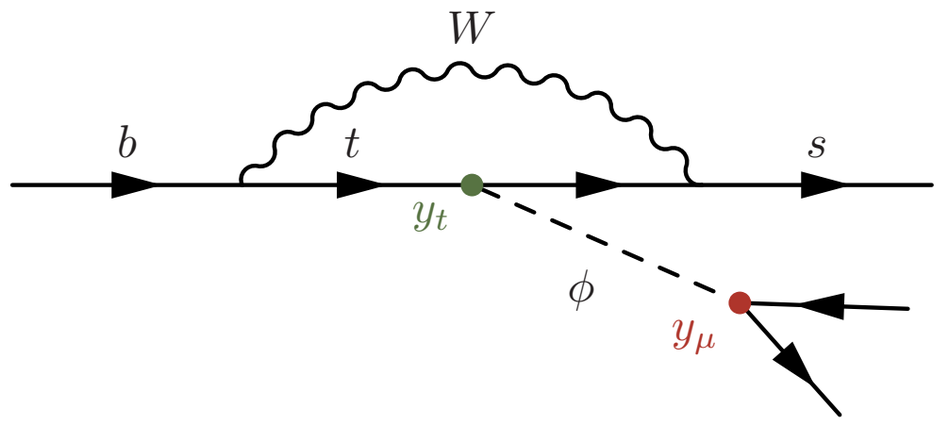

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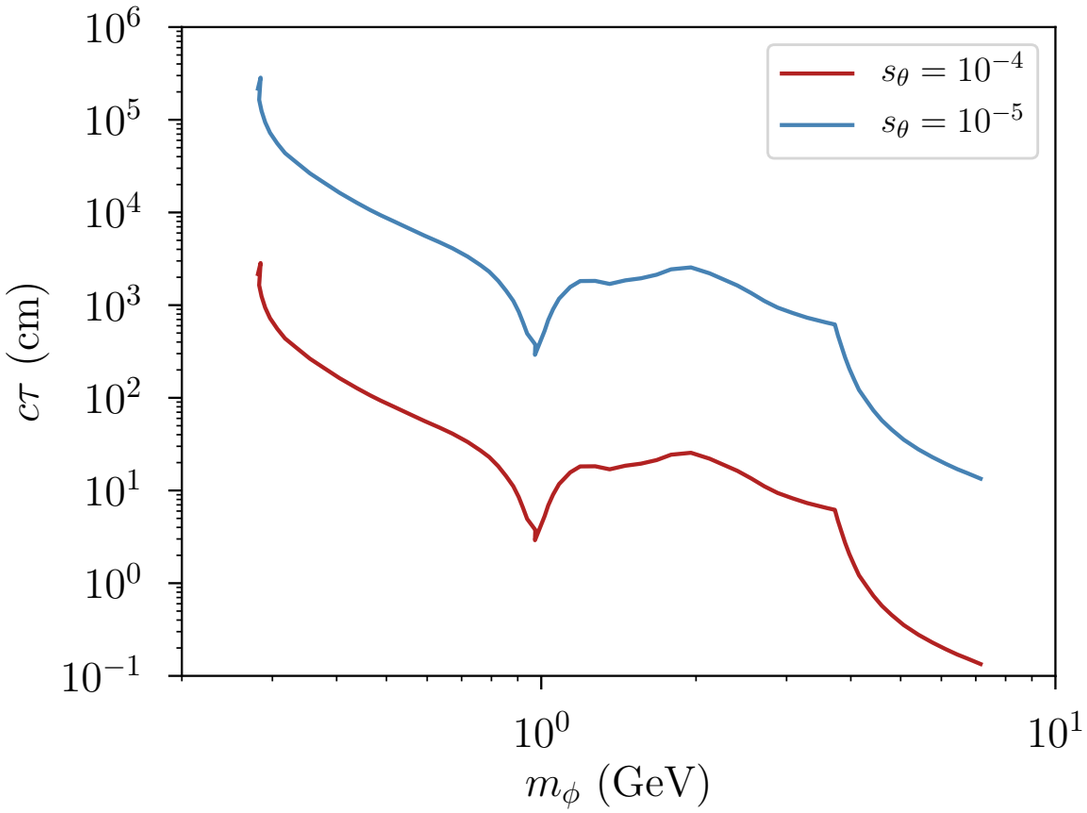
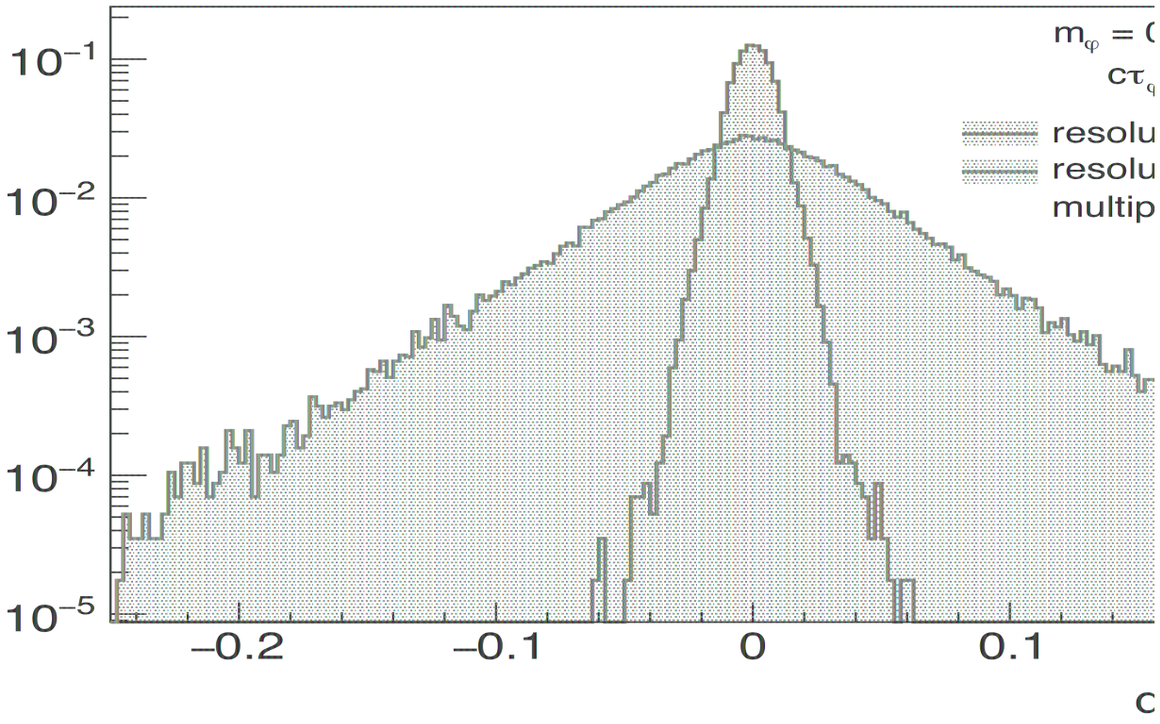
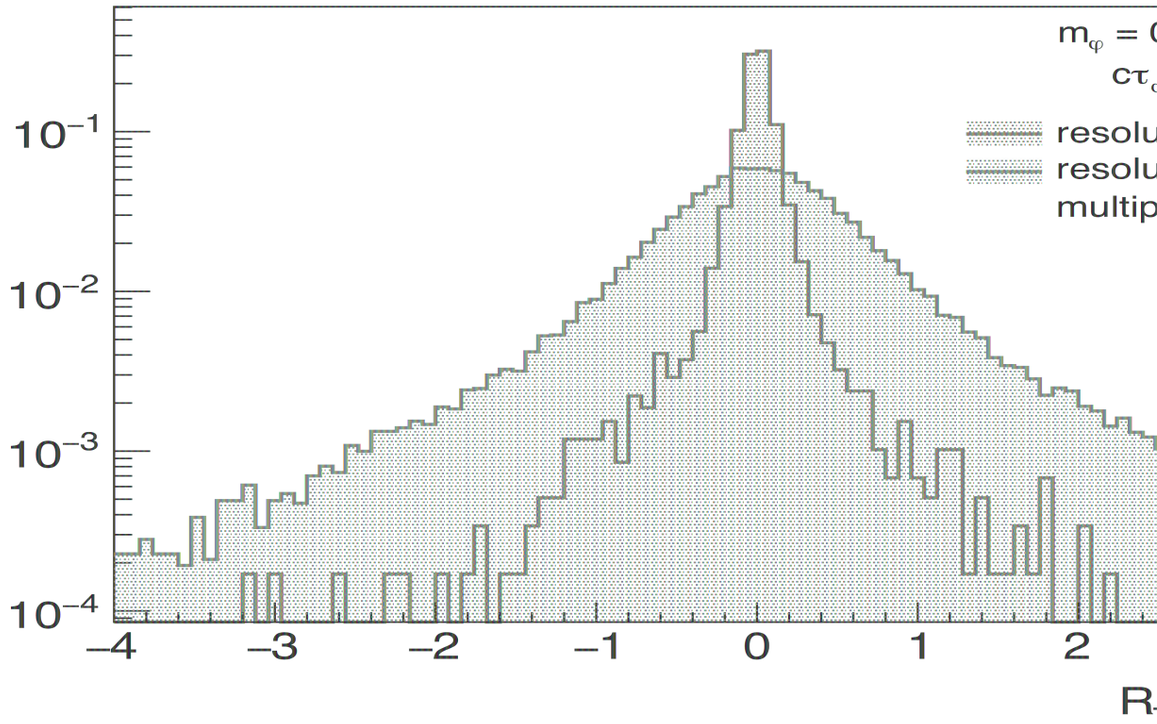


Performance

Track impact parameter in transverse plane



Vertex distance in transverse plane



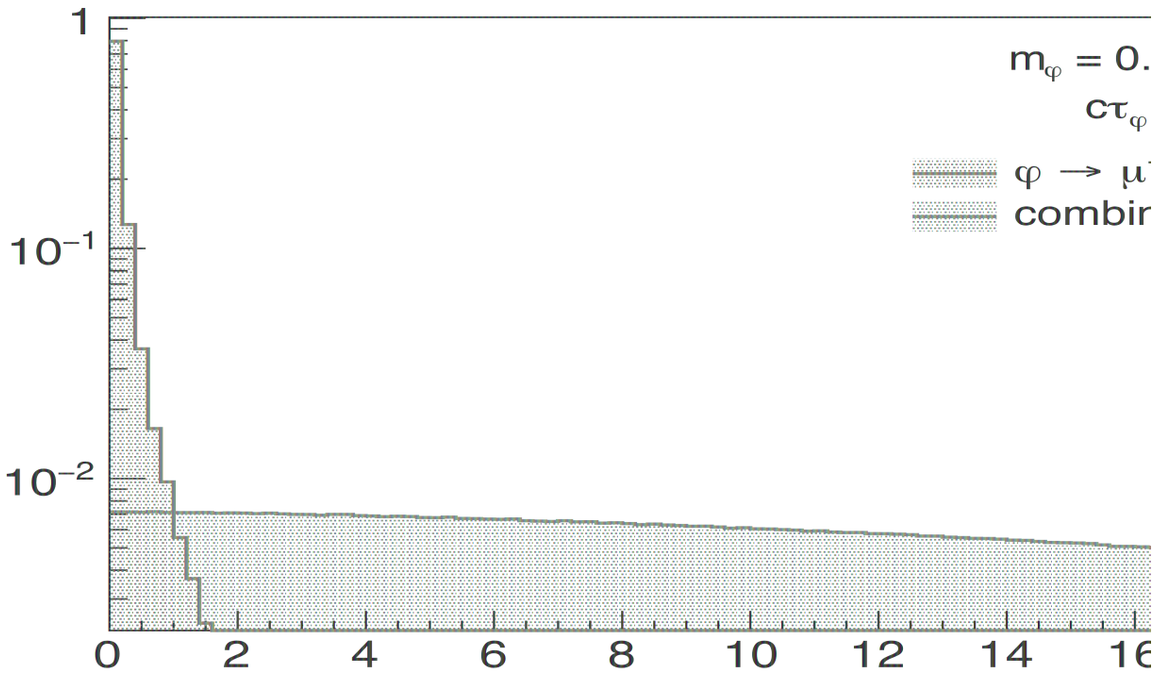
Fairly good resolution on d_0, resolution on vertex location is poor as expected.

Y. Gershtein, SK: arXiv 1907.00007

Fighting fakes

Assume 30 fake tracks per event → 225 fake “vertices” per event!

Distance between tracks in z-direction



$\Delta_z < 1.0\ \mathrm{cm}$

↓

~ 10^{-2} suppression

Y. Gershtein, SK: arXiv 1907.00007

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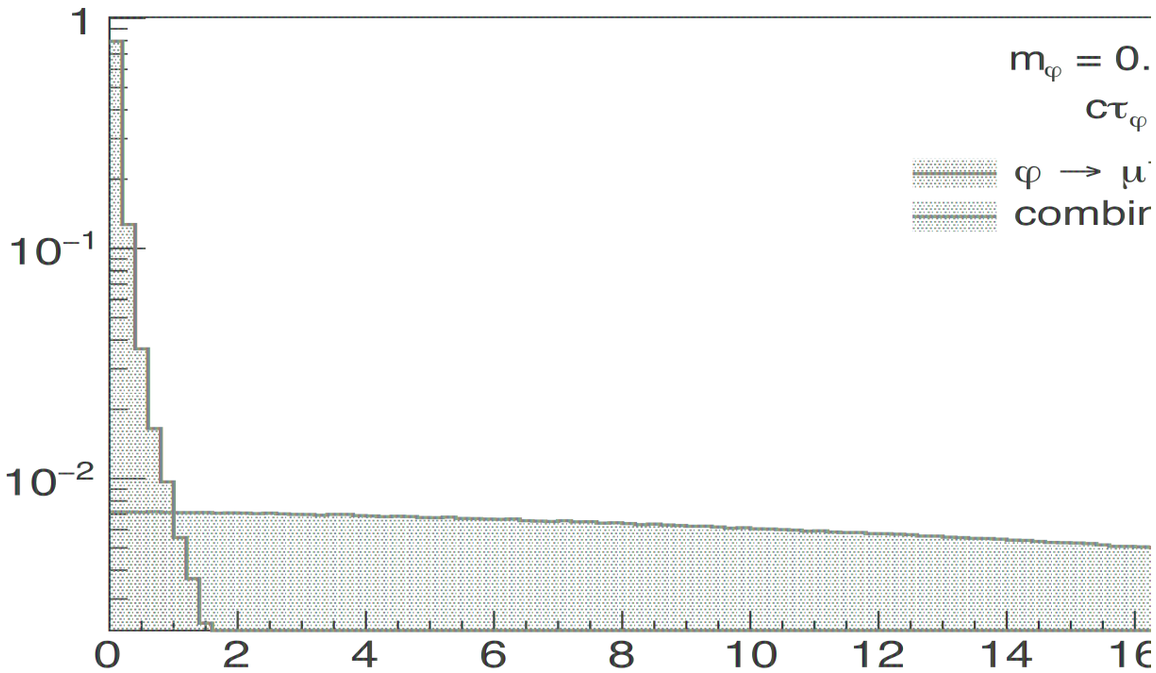
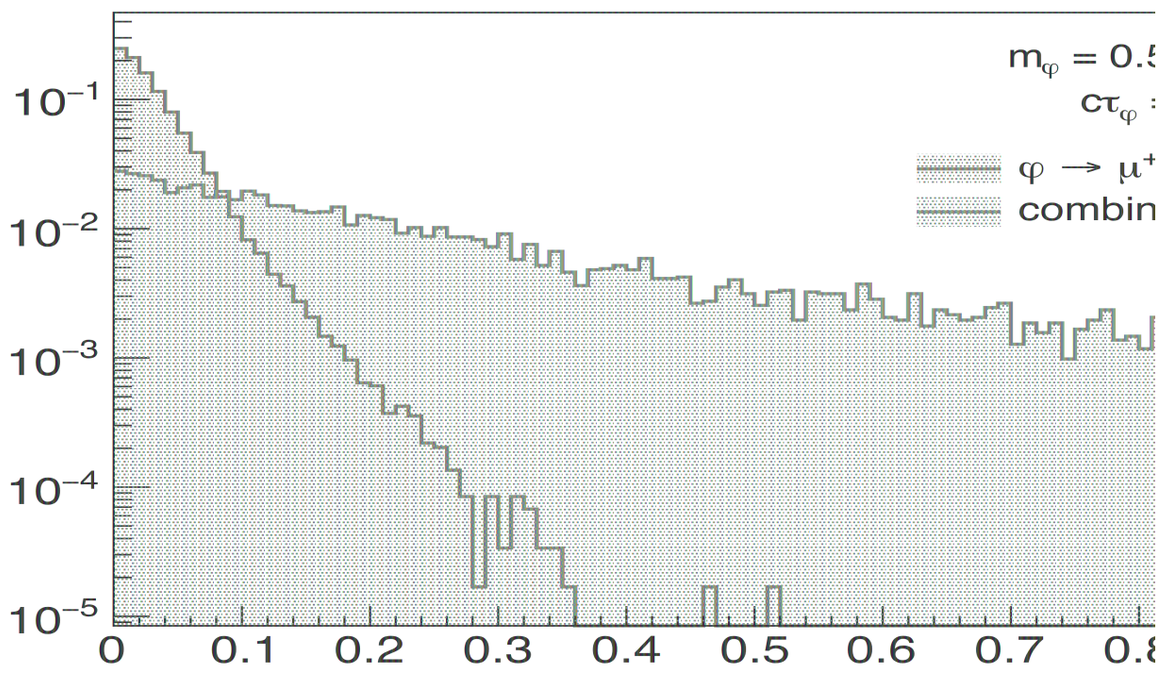


$\Delta_z < 1.0$ cm

↓

~ 10^{-2} suppression

Impact parameter of mother



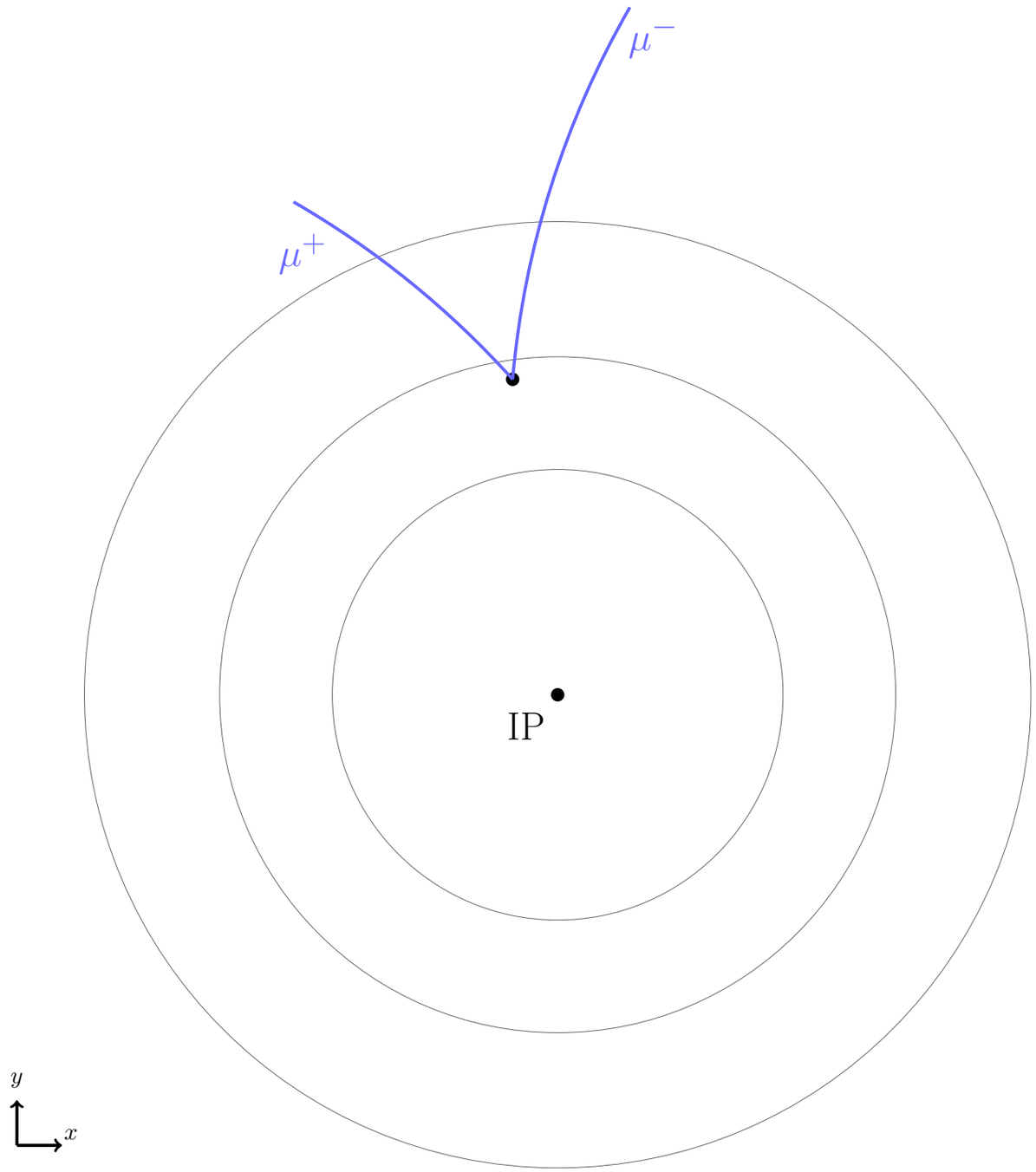
$d_T < 0.1$ cm

↓

~ 10^{-2} suppression

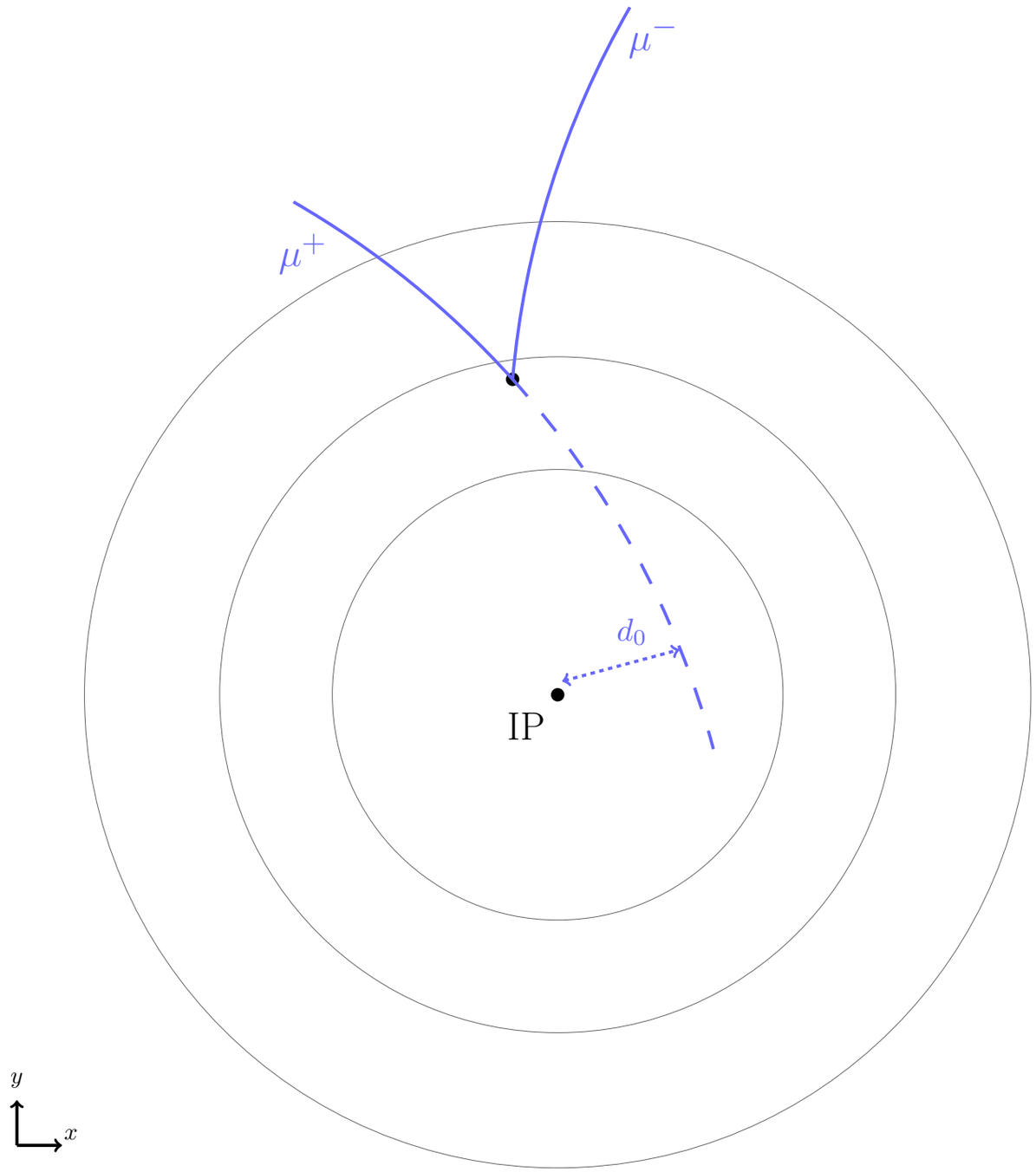
Y. Gershtein, SK: arXiv 1907.00007

Some notation



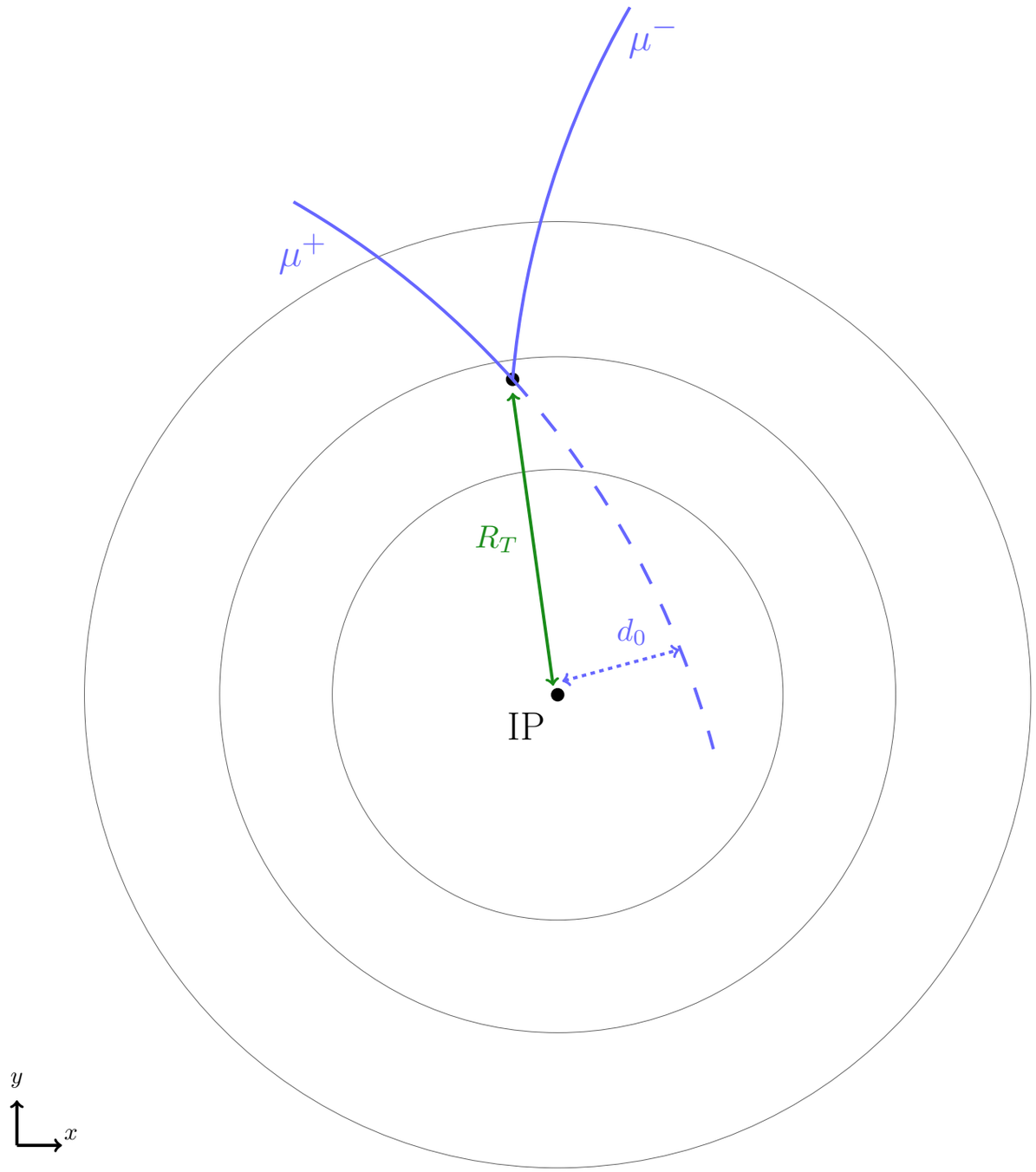
Y. Gershtein, SK: arXiv 1907.00007

Some notation



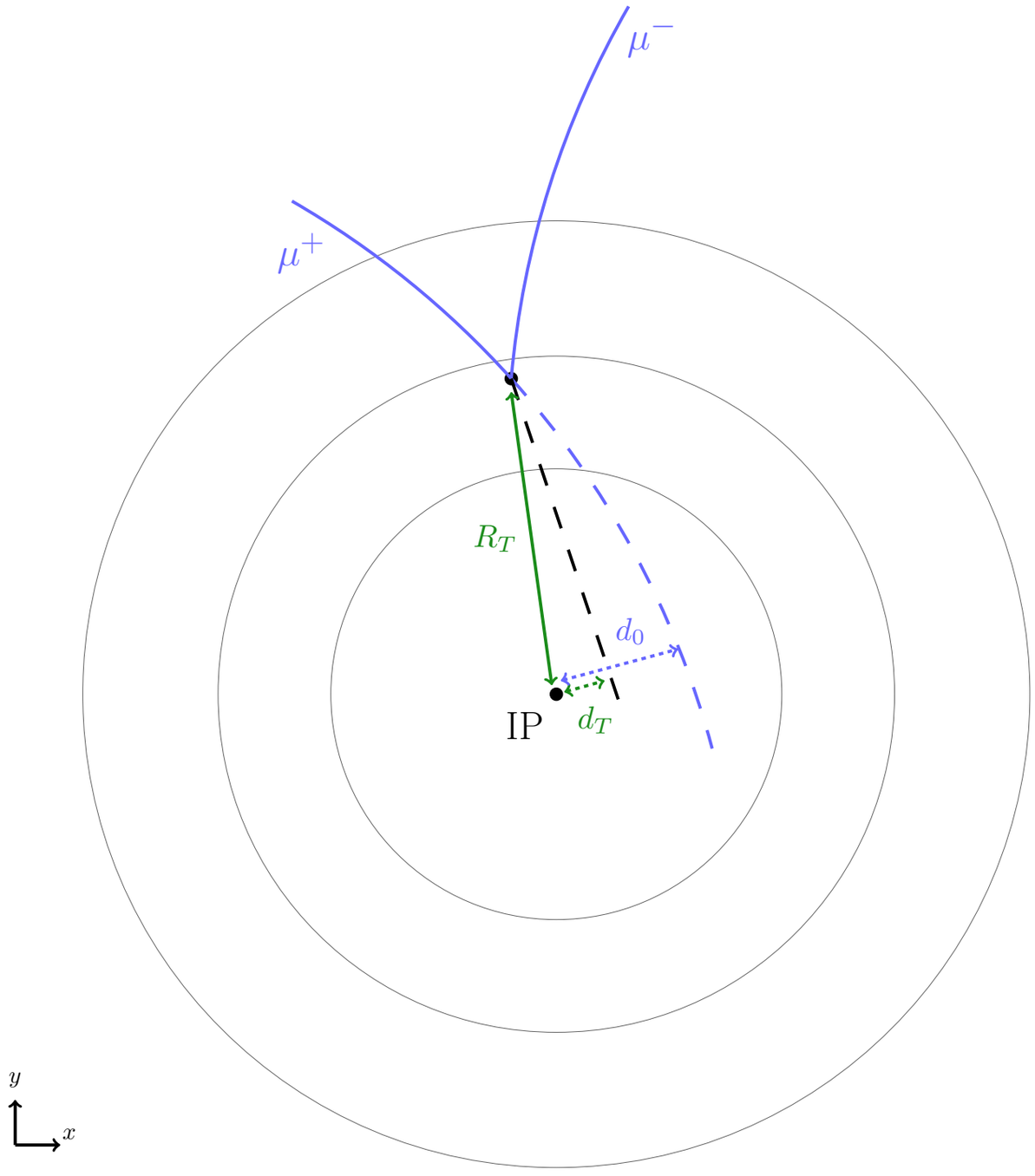
Y. Gershtein, SK: arXiv 1907.00007

Some notation



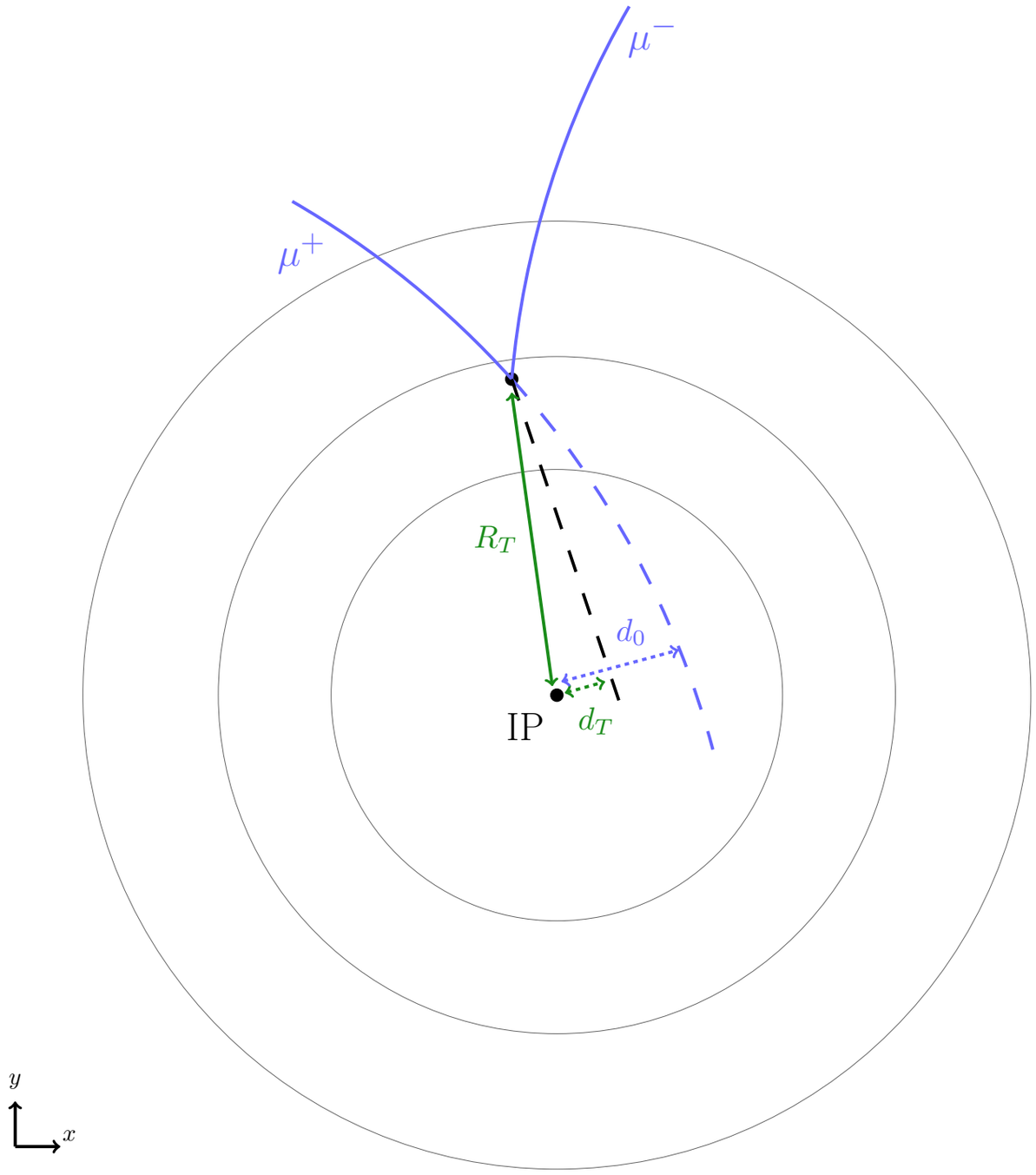
Y. Gershtein, SK: arXiv 1907.00007

Some notation

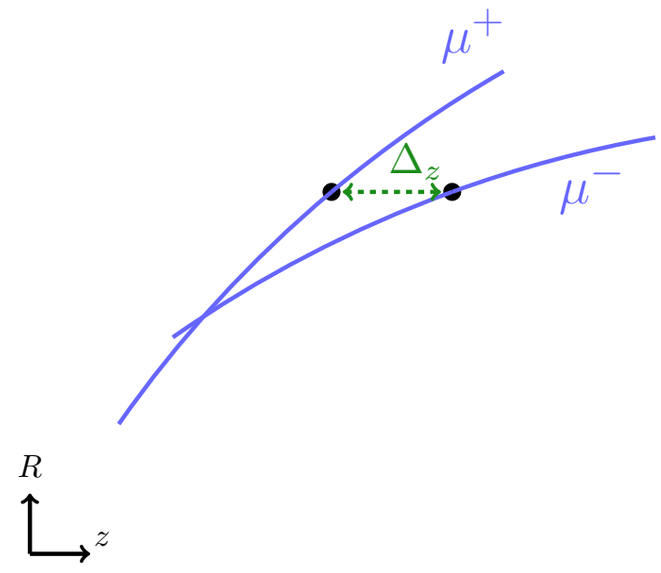


Y. Gershtein, SK: arXiv 1907.00007

Some notation



Vertex is never perfect:
Δ_z measures vertex quality



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Background rates

Target: backgrounds ≲ 1kHz

Rates, *before* demanding matching with muon system:

minimum p_T selection	fakes (kHz)	K_S (kHz)
(3, 3) GeV	1000	800
(4, 4) GeV	600	240
(5, 3) GeV	840	200

Rate in ~ 1 kHz regime if the muon fake rate ≲ 5% per track

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$R_T > 1.5$ cm and $d_0 > 0.1$ cm reduce true muons from B-meson decays < 1 kHz

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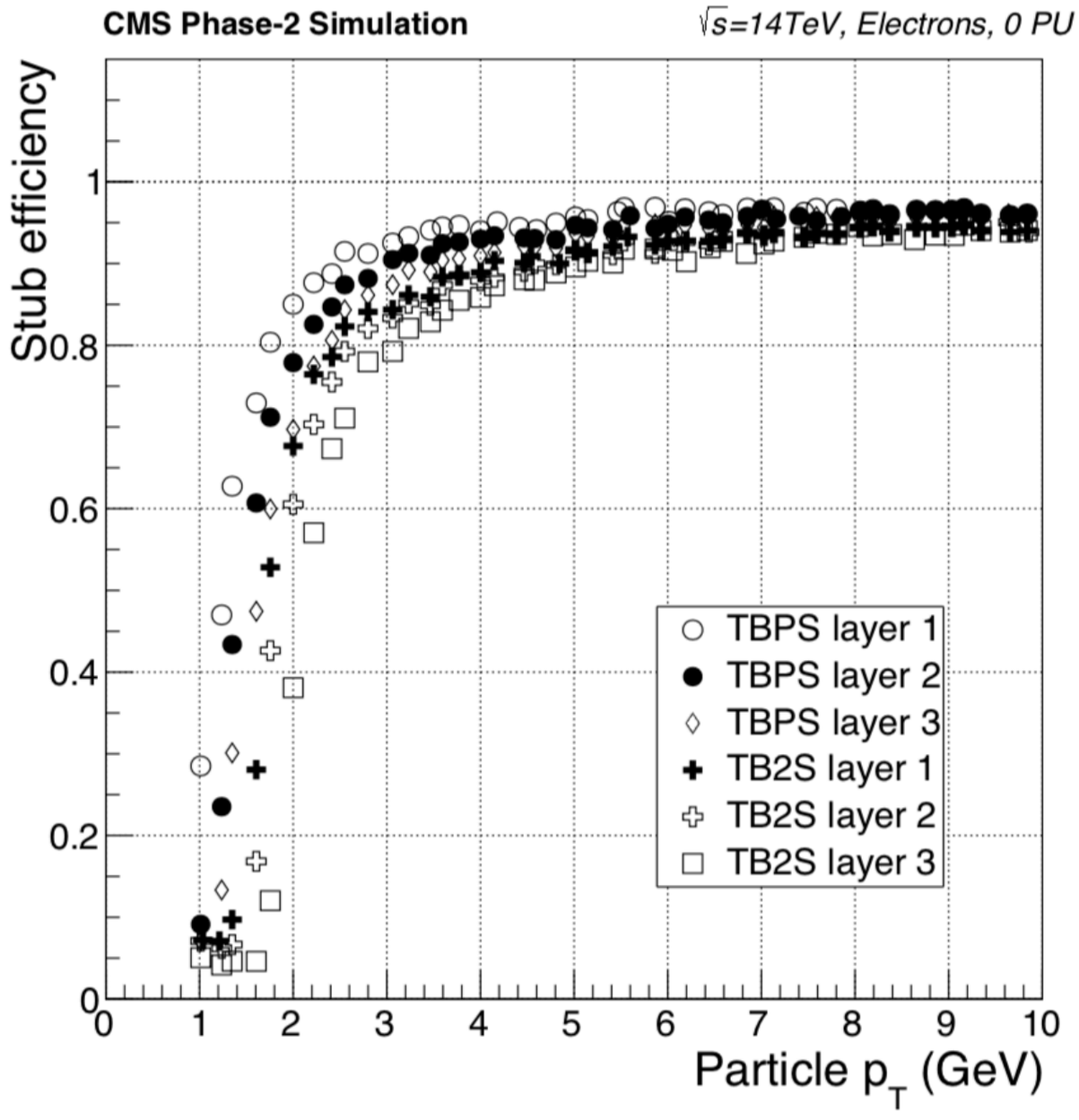
Stub reconstruction efficiency



CMS phase II tracker TDR