https://arxiv.org/abs/1810.03636

Leveraging the ALICE/L3 cavern for long-lived exotics

BERKELEY LAB

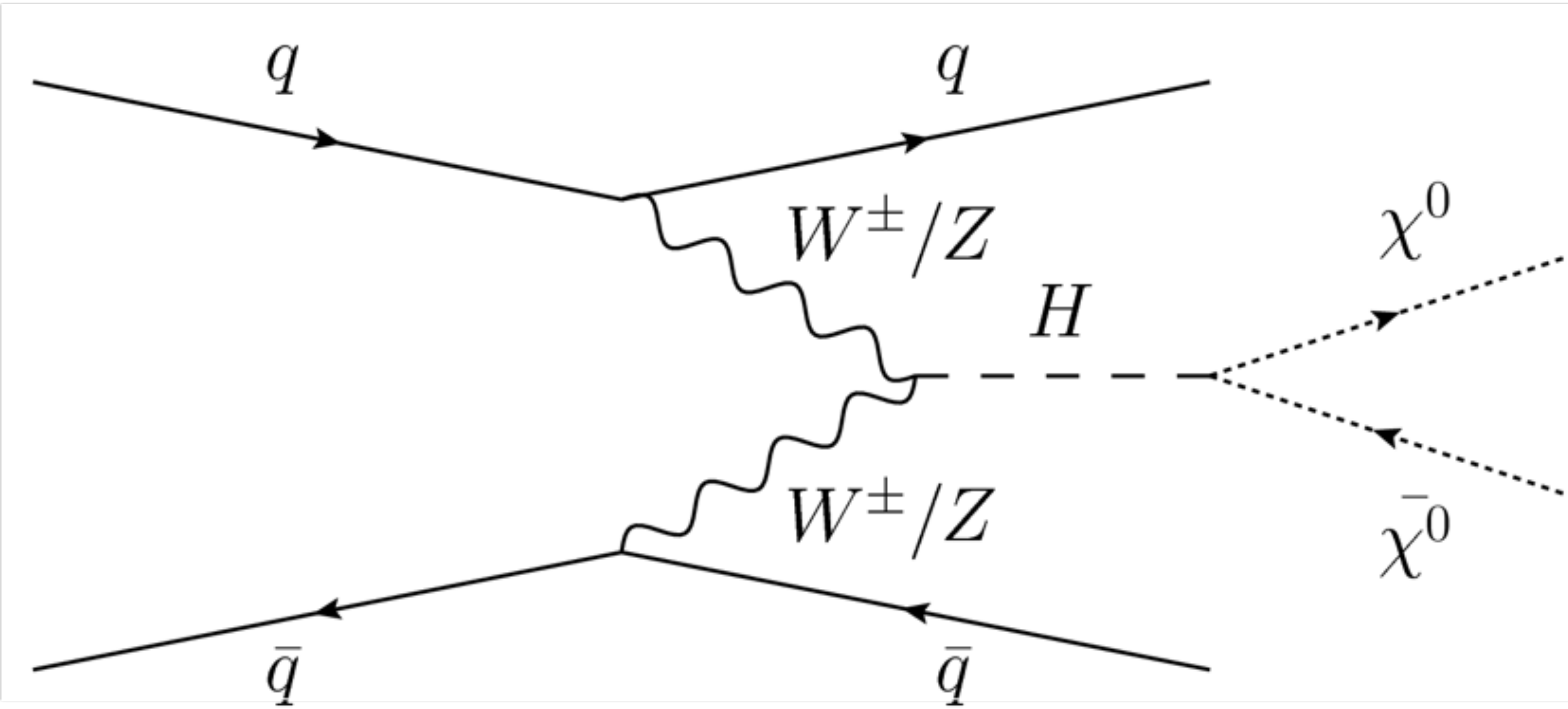
BERKELEY EXPERIMENTAL PARTICLE PHYSICS

Benjamin Nachman

in collaboration with Vava Gligorov, Simon Knapen, Michele Papucci, and Dean Robinson

Fourth workshop of the LHC LLP Community, Oct. 2018

Motivation



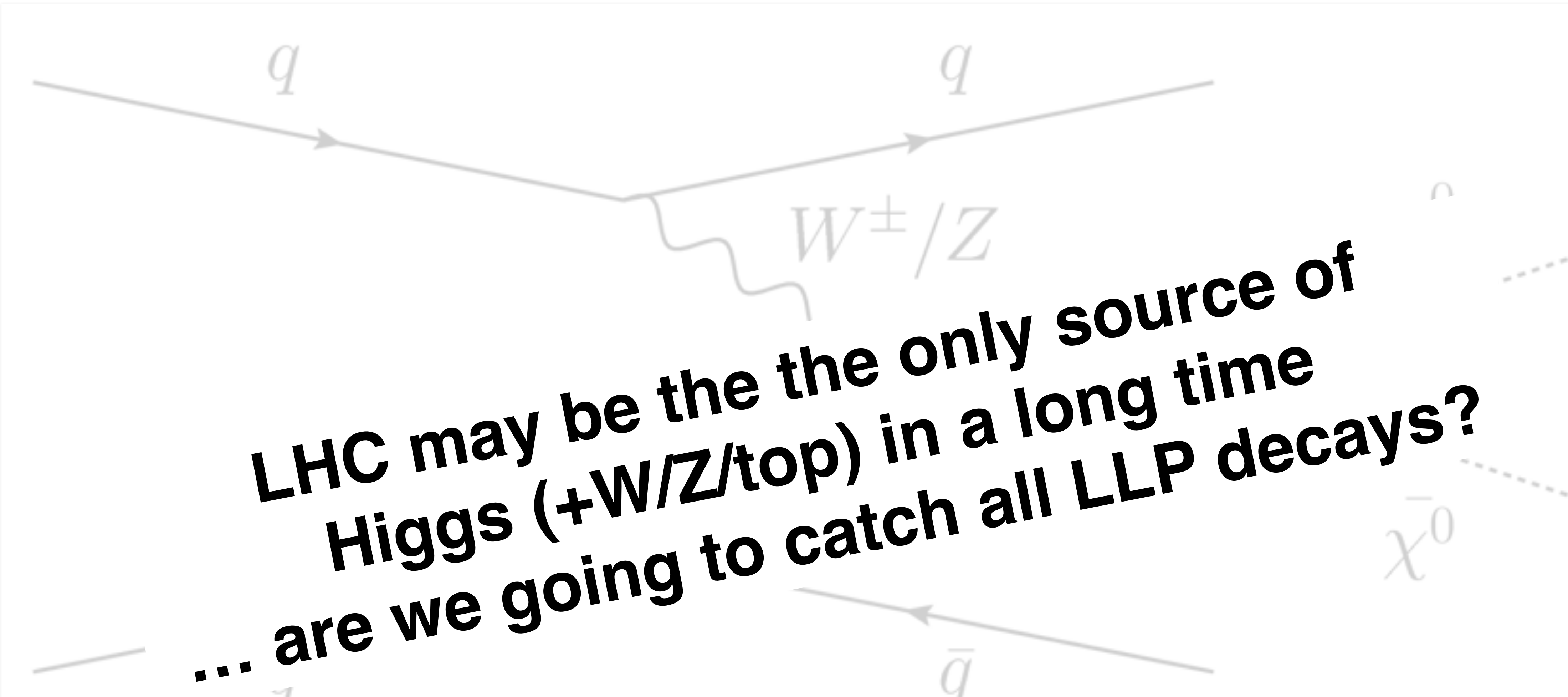
Higgs → MET

The Higgs could be the portal to Dark Matter.

If a Hidden Valley (+ friends), Higgs could be bridge to BSM.

Higgs → MET/displaced

Motivation



LHC may be the the only source of Higgs (+W/Z/top) in a long time

… are we going to catch all LLP decays?

Higgs → MET

The Higgs could be the portal to Dark Matter.

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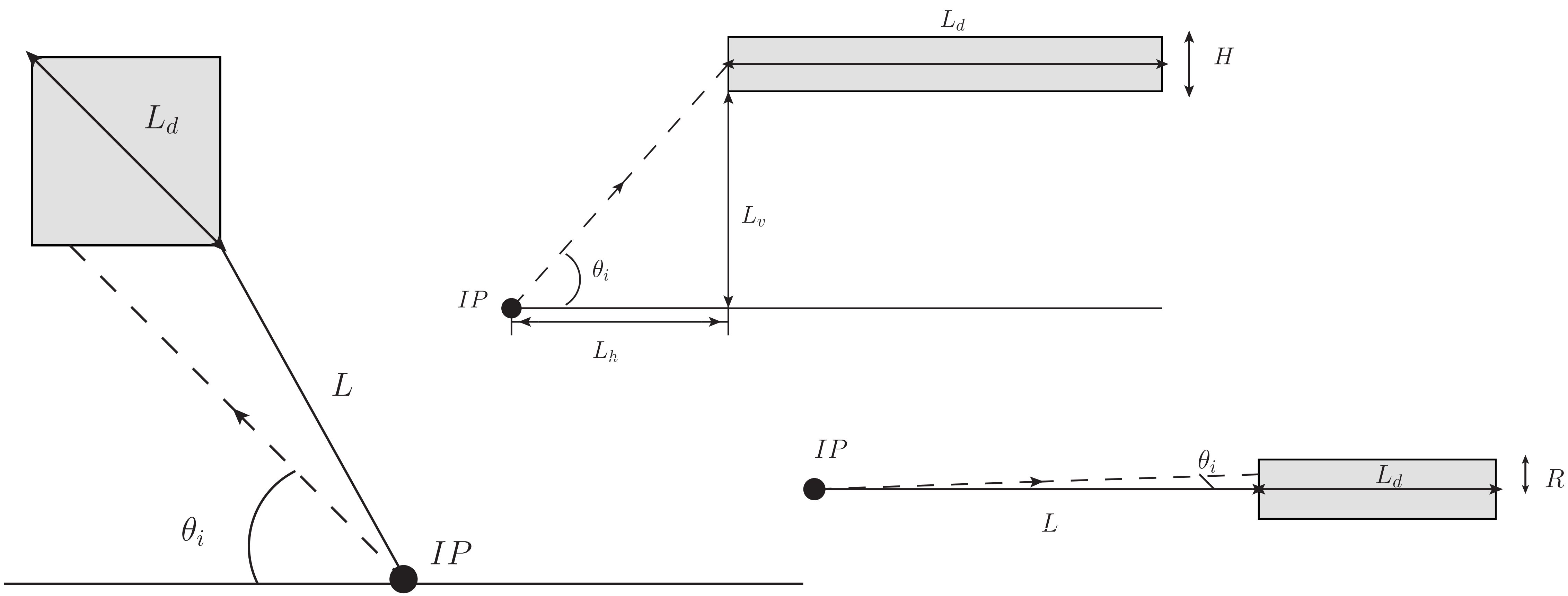
Higgs → MET/displaced

Motivation Part II

There is a landscape of ideas for new detectors.



Have we thought of all the (at least somewhat) sensible ideas?

nice pictures are from D. Dercks et al., 1810.03617

New idea: Get closer to the IP?

In the long lifetime limit,

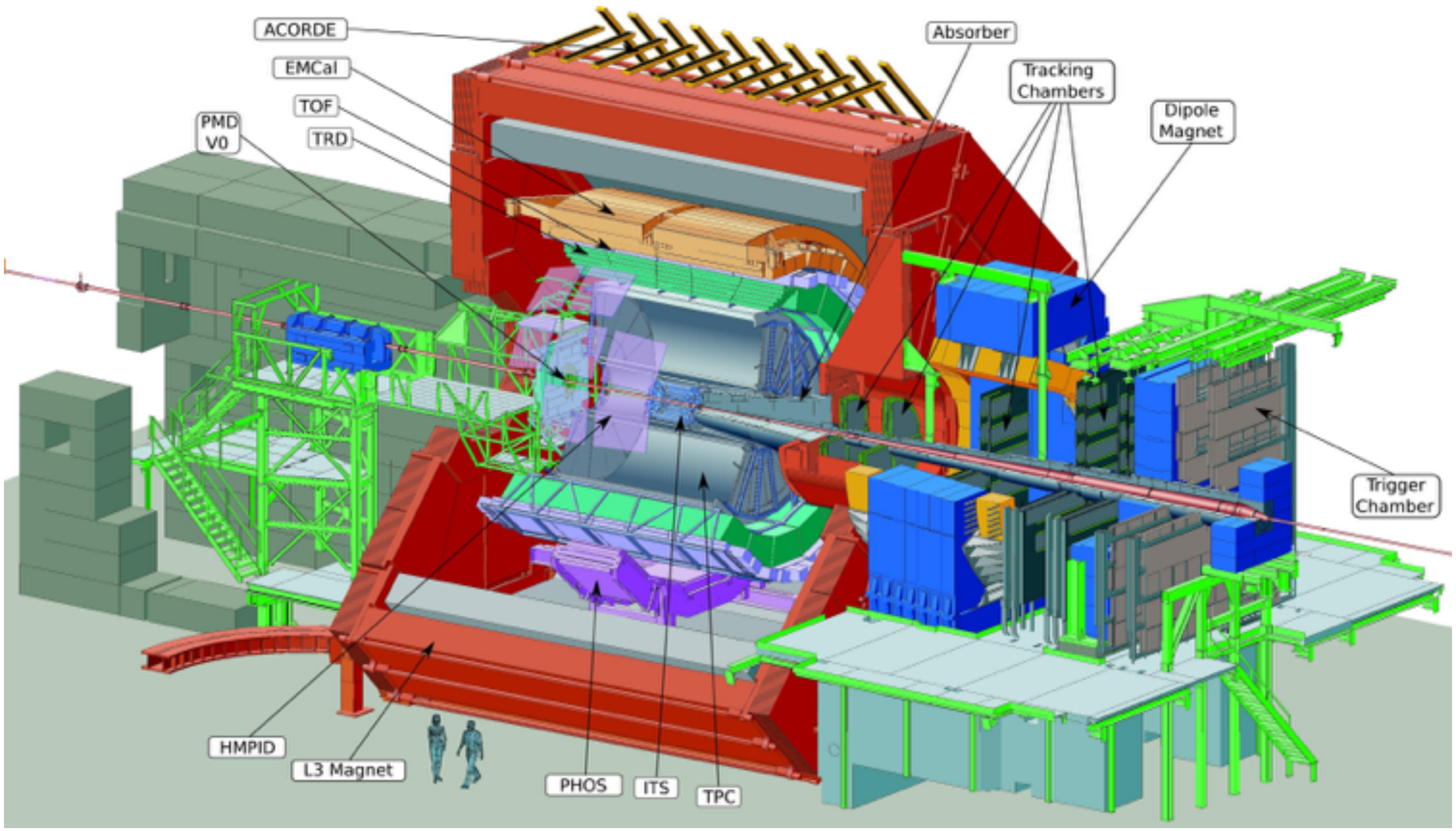
$$\epsilon_{\text{fid}} \simeq \underbrace{\frac{\Delta\phi}{2\pi}\int_{\eta_0}^{\eta_1}}_{\text{geometry}} d\eta\, d\gamma\, \overbrace{f(\eta,\gamma)\frac{\ell}{\beta\gamma c\tau}}^{\text{physics}}$$

Want a big geometric volume and to have rapidity coverage where there is plenty of (boost-integrated) signal.

Also, would be great to have high energy (to produce H, etc.), lots of data, and wouldn't it be nice to have PID?

New idea: LLPs with IP2

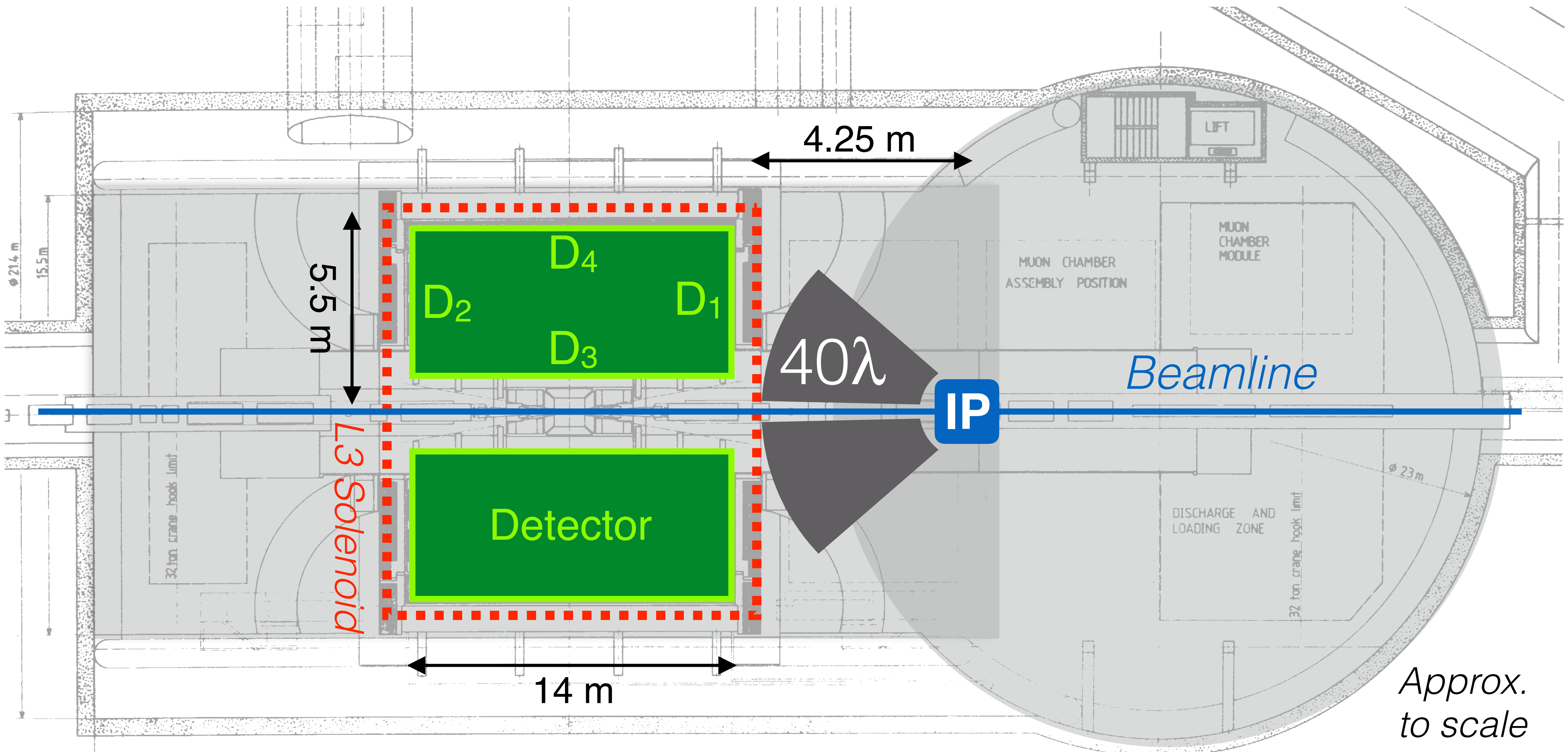
There is no official physics program in the ALICE/L3 cavern (IP2) during Run 5.



…however, there is a great magnet & a TPC waiting for LLPs !

A Laboratory for Long-Lived eXotics

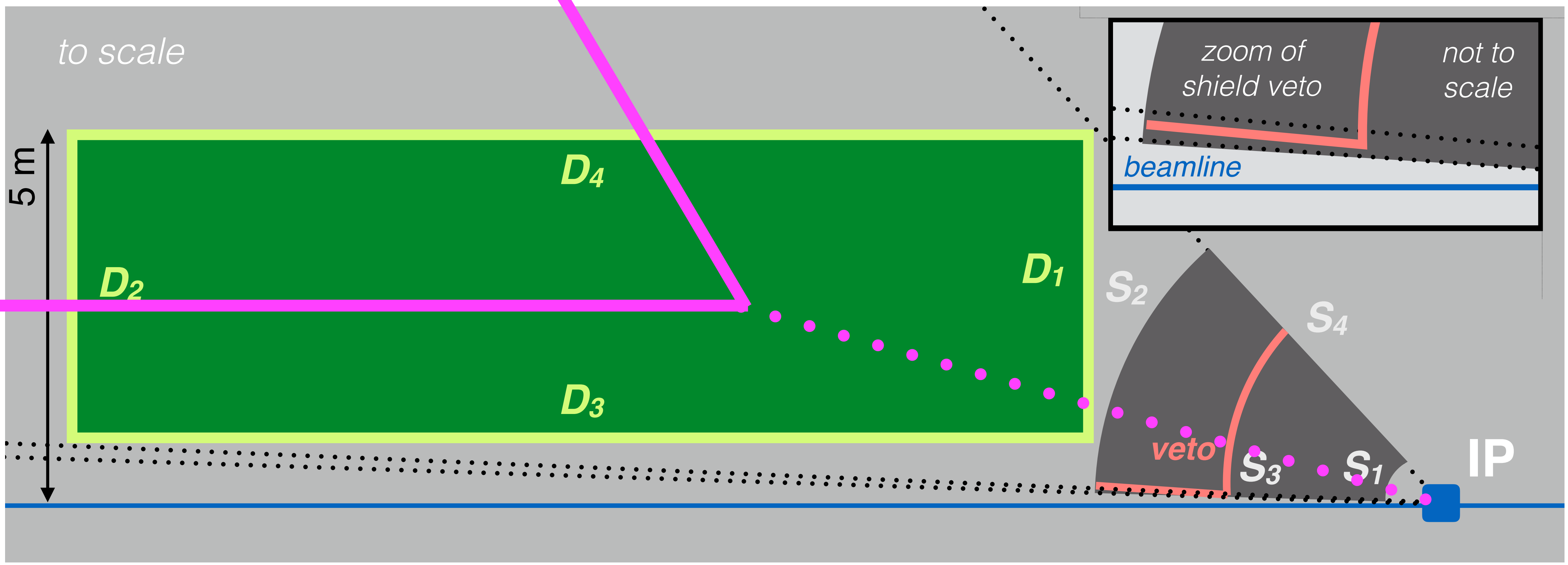
(called "AL3X" and pronounced "Alex")



Will come back to these soon

Move IP, add absorber, increase lumi.
See what comes out the back!

A Laboratory for Long-Lived eXotics



Will come back to these soon

Move IP, add absorber, increase lumi.
See what comes out the back!

Zero background near IP

Assuming we can set up the detector,
there are at least three challenges:

(i) Detector Trigger Rate

Using a TPC, need trigger rate to be O(1-10) kHz

(ii) Shield Veto Rate

This reduces our effective lumi, better be < O(1) MHz

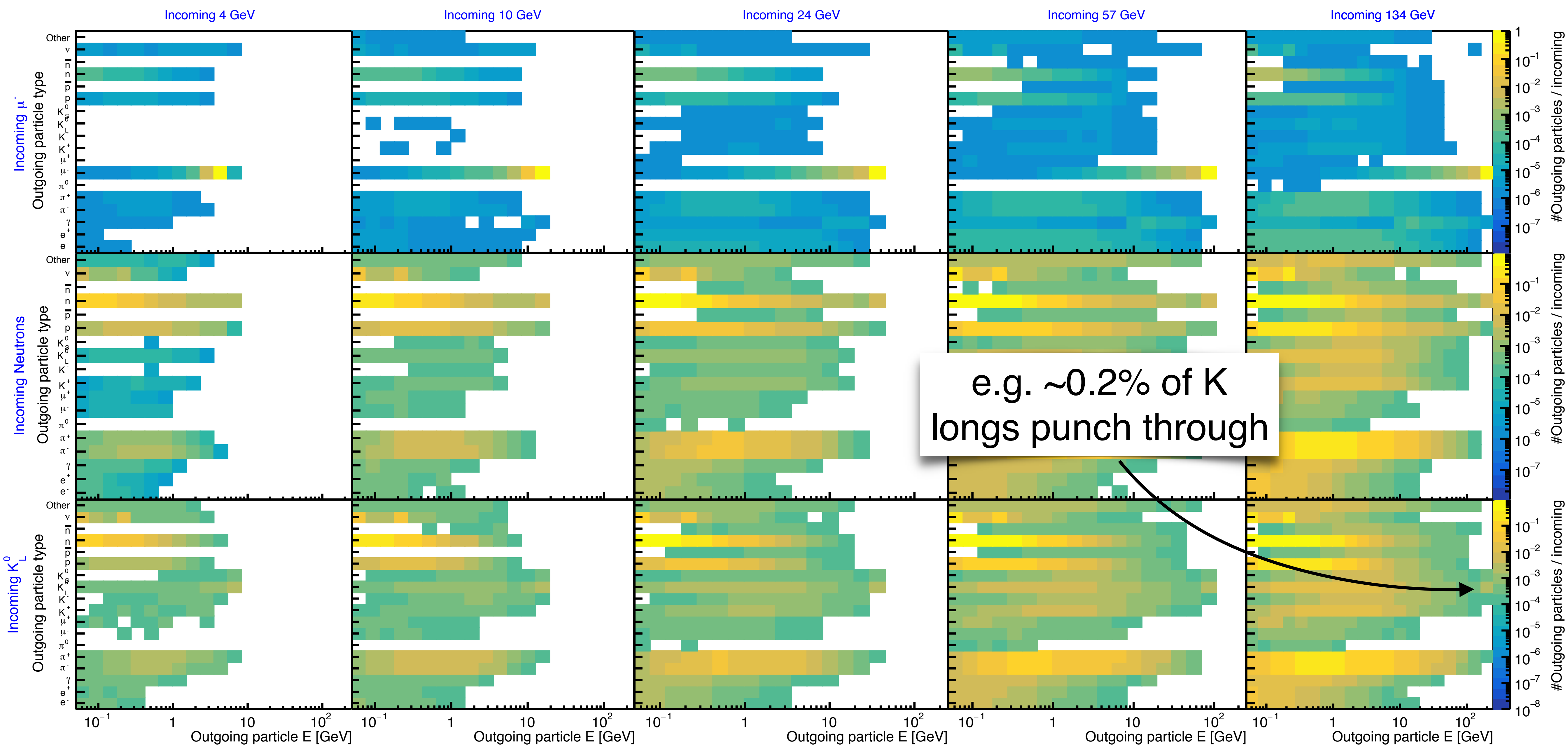
(iii) Potentially ‘irreducible’ background rate

Ideally we won’t rely much on reco to veto backgrounds
(though we have a B-field and a great detector)

Simulations

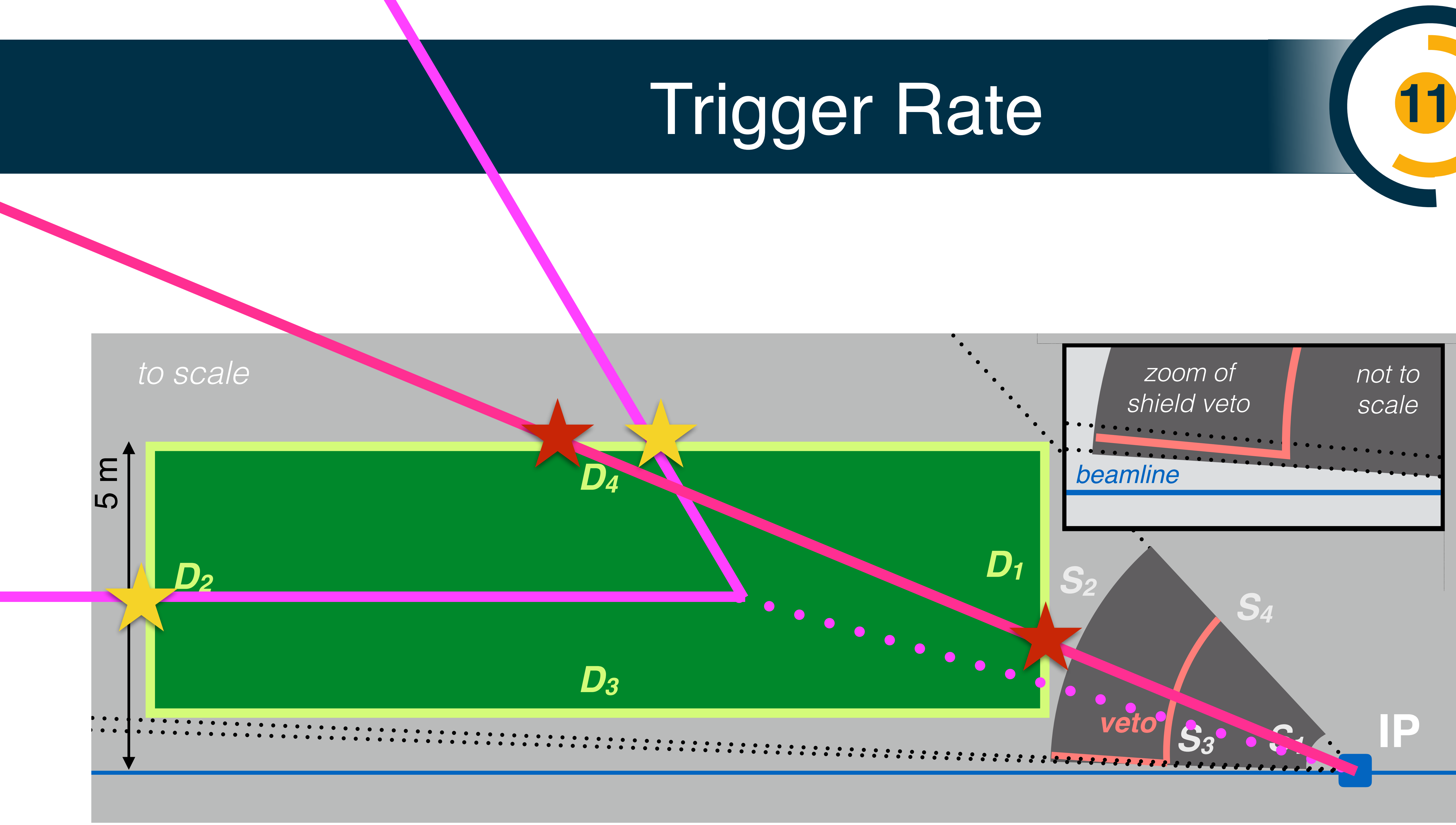
We ran extensive Geant4 simulations of particles entering the absorber.

Higher energy



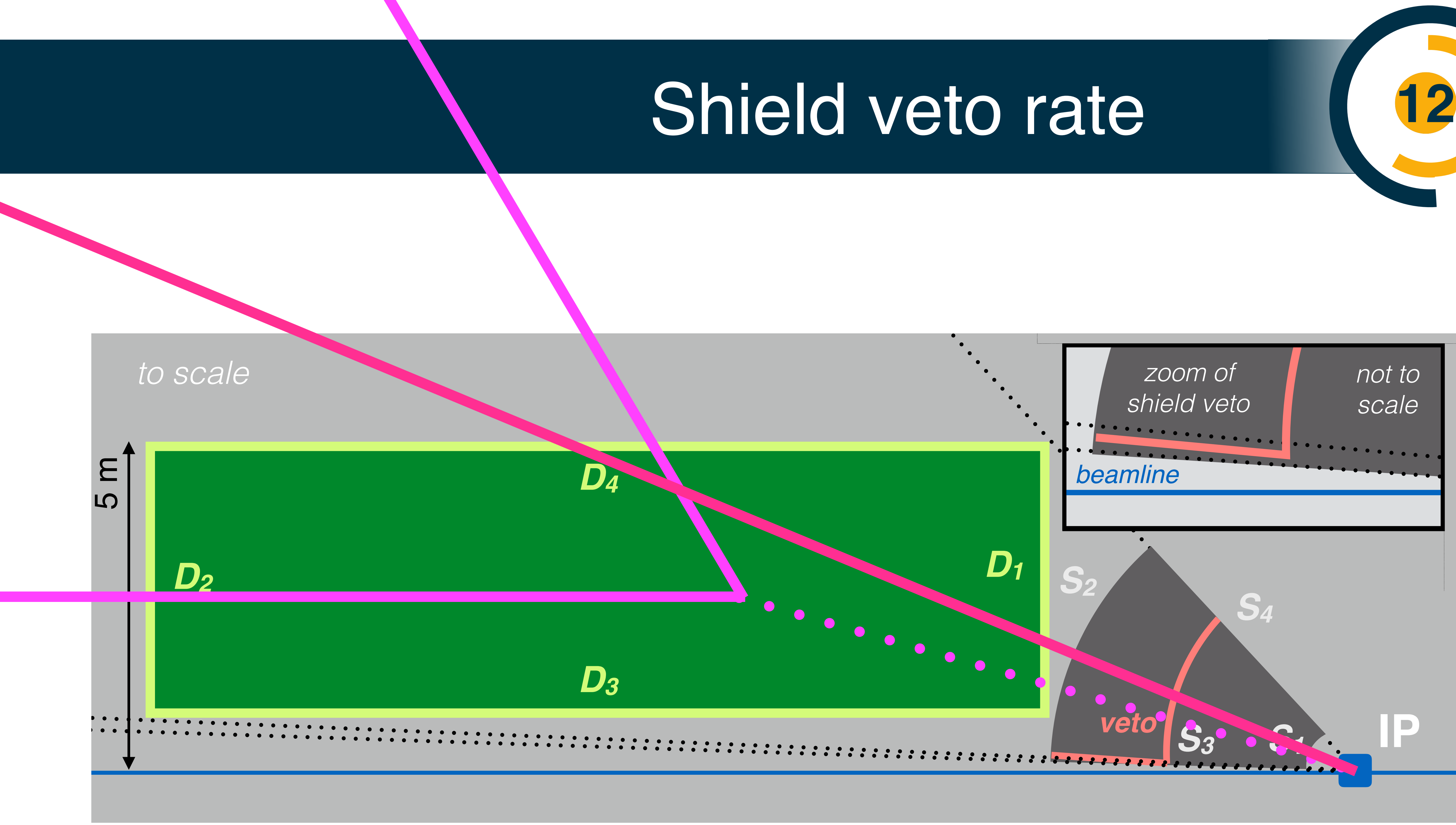
(this is just a sample - many particles / energies not shown)

Trigger Rate



Can use coincidences in the trigger (light green) to mitigate the large rate from prompt and shield-initiated muons.

Shield veto rate



Placement of veto chosen to reduce its rate (move back) but stop most charged-particle initiated showers (move forward)

The remainder

BG species	Full shield (S_1–S_2) shield veto rate	Full shield (S_1–S_2) BG flux/pp	Evade shield BG flux/pp	Net BG flux/pp into detector (no cuts)	BG rate per $100\,\text{fb}^{-1}$
$n+\bar{n}$ ($>3\,\text{GeV}$)	—	$4. \times 10^{-16}$	—	$3. \times 10^{-6}$	$\lesssim 0.2$
$p+\bar{p}$	$2. \times 10^{-6}$	$1. \times 10^{-14}$	—	$5. \times 10^{-7}$	—
μ	0.006	$3. \times 10^{-11}$	0.007	0.01	—
e	$5. \times 10^{-7}$	$3. \times 10^{-15}$	—	$3. \times 10^{-7}$	—
K_L^0	—	$1. \times 10^{-15}$	—	$6. \times 10^{-8}$	$\lesssim 1$
K_S^0	—	$4. \times 10^{-16}$	—	$3. \times 10^{-8}$	$\ll 1$
γ	—	$1. \times 10^{-15}$	—	$1. \times 10^{-7}$	—
$\pi^\pm$	$2. \times 10^{-6}$	$5. \times 10^{-15}$	—	$4. \times 10^{-7}$	—
$K^\pm$	$2. \times 10^{-7}$	$9. \times 10^{-16}$	—	$8. \times 10^{-8}$	—
$\nu+\bar{\nu}$ ($>3\,\text{GeV}$)	—	0.01	$3. \times 10^{-4}$	0.2	$\lesssim 10$

for neutrons and neutrinos, very conservative since we don't simulate the reaction product kinematics

Background already ~0 without exploiting the tracker!

(we leave reco for future studies)

Setting up AL3X

from earlier…

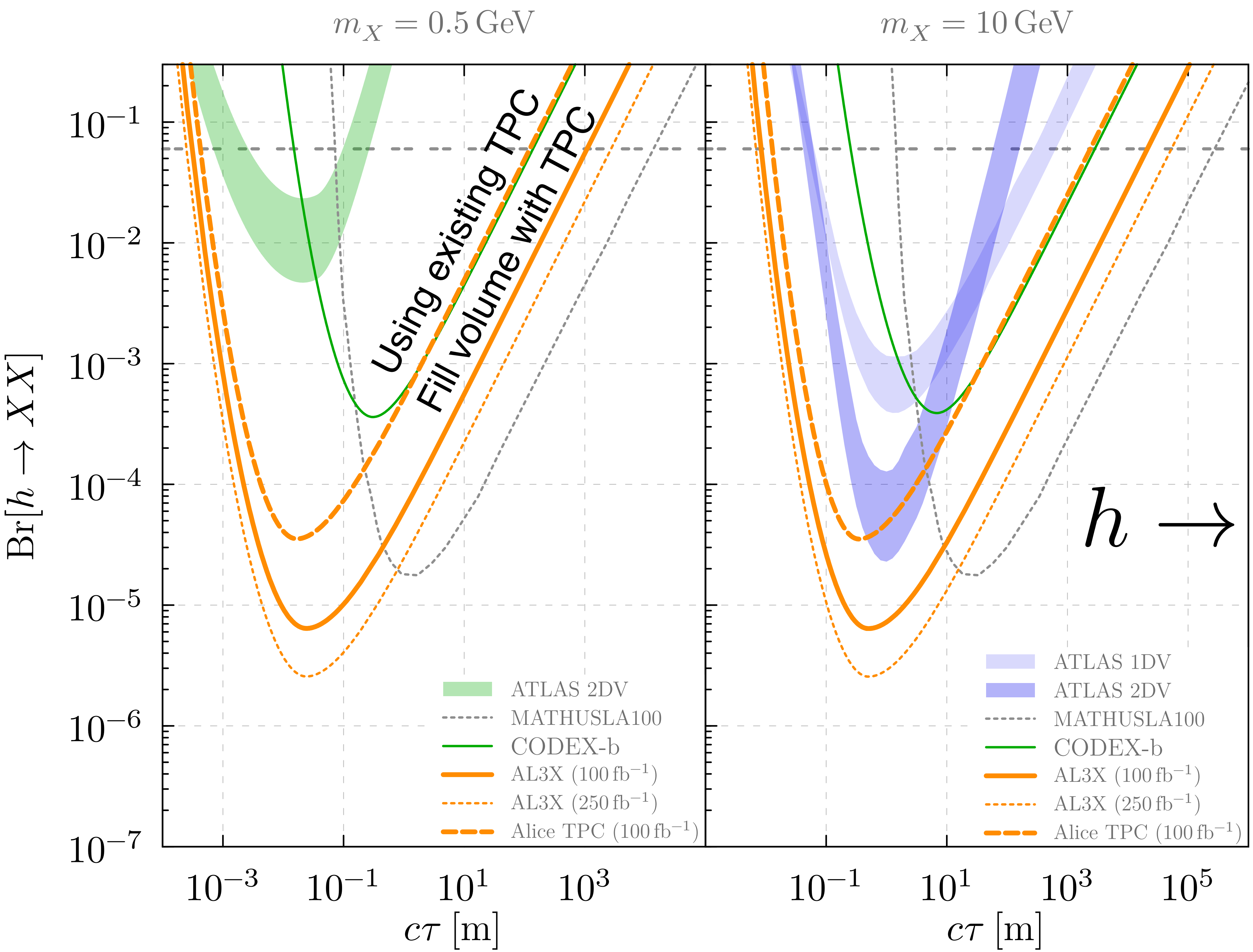
Move IP, add absorber, increase lumi.
See what comes out the back!

Has to be moved in multiples of 12.5 ns x *c*. In principle, moving 11.25 m is possible, though would require adjusting magnets.

Our simplest model would require a lot of W. However, it is easy to save money with a Pb/Steel/W hybrid (and using the 1m of solid Fe door on the L3 magnet)

In terms of total lumi., we would need a tiny fraction of ATLAS and CMS. Bigger challenge is beam stability and modifying IP2 optics. We suspect this would be the biggest driver in cost / effort.

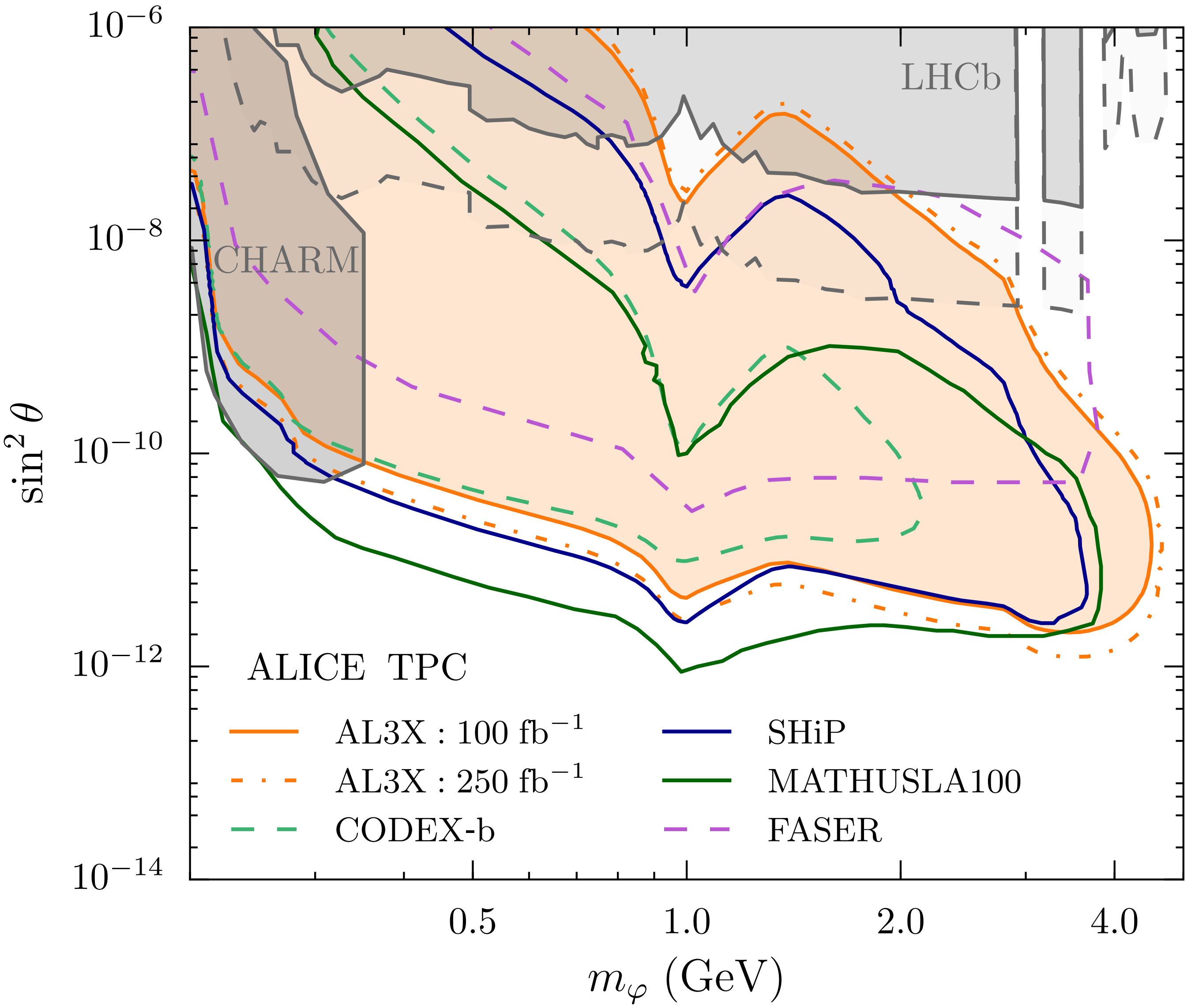
AL3X Sensitivity: Higgs



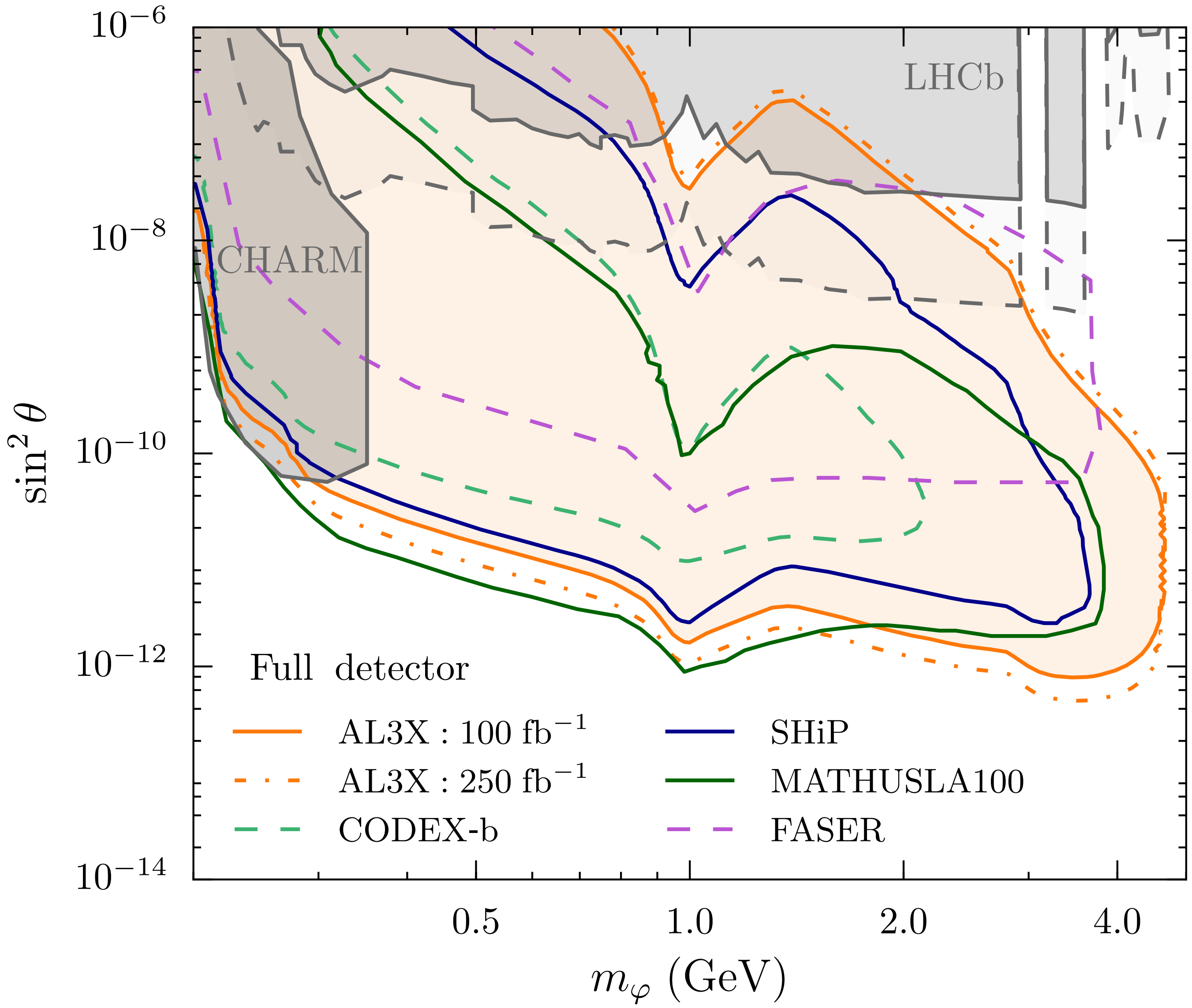
$$h \to XX$$

AL3X Sensitivity: B-decays

Using existing TPC



Fill space with TPC



Also some sensitivity to dark photons (not shown - see paper for details)

AL3X team

V. Gligorov	LHCb
S. Knapen	Theory
B. Nachman	ATLAS
M. Papucci	Theory
D. Robinson	Theory

We are just getting started and welcome new ideas and collaborators!

Moving forward

- Seek feedback from ALICE / community (you!)
- Study impact of reco. with possibility to reduce absorber
- Optimize absorber configuration to minimize cost

AL3X in Context

	Higgs decay	B-meson decay	π,η-decay (dark photon)	Progress	Cost
FASER		✔	✔	Collaboration formed	$
CODEX-b	✔	✔		sub-collaboration formed	$
SeaQuest			✔	experiment exists	$
AL3X	✔	✔	✔	Proof of concept	$$
MATHUSLA	✔	✔		Letter of intent	$$
SHiP		✔	✔	Technical design report	$$$

MOEDAL: monopoles, already running

MiliQan: milicharged particles, phase 1 detector in place

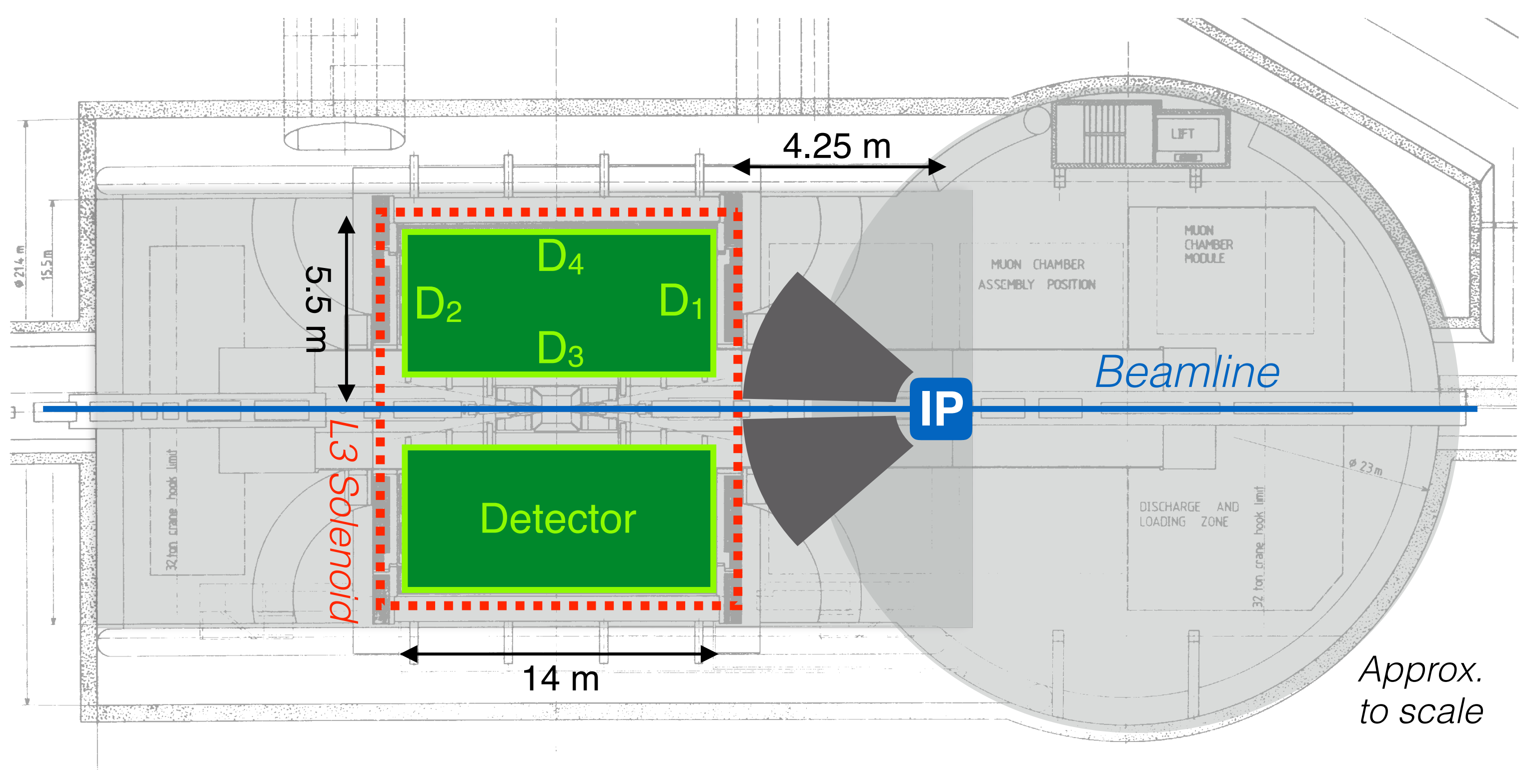
slide stolen from Simon Knapen

Conclusions and Outlook

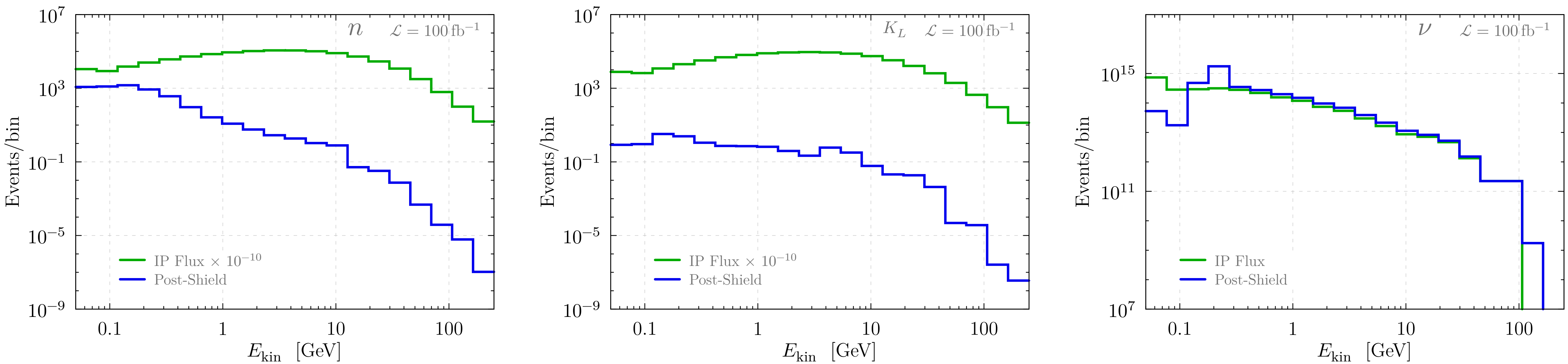
We have proposed a new idea to build a dedicated LLP detector at one of the IPs.

IP2 in Run 5 may be a good match and would allow for an extensive physics program due excellent tracking capabilities.

Happy to hear your feedback!



Questions?



n
ℒ = 100 fb⁻¹
IP Flux × 10⁻¹⁰
Post-Shield
Events/bin
E_kin [GeV]
K_L
ℒ = 100 fb⁻¹
IP Flux × 10⁻¹⁰
Post-Shield
Events/bin
E_kin [GeV]
ν
ℒ = 100 fb⁻¹
IP Flux
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