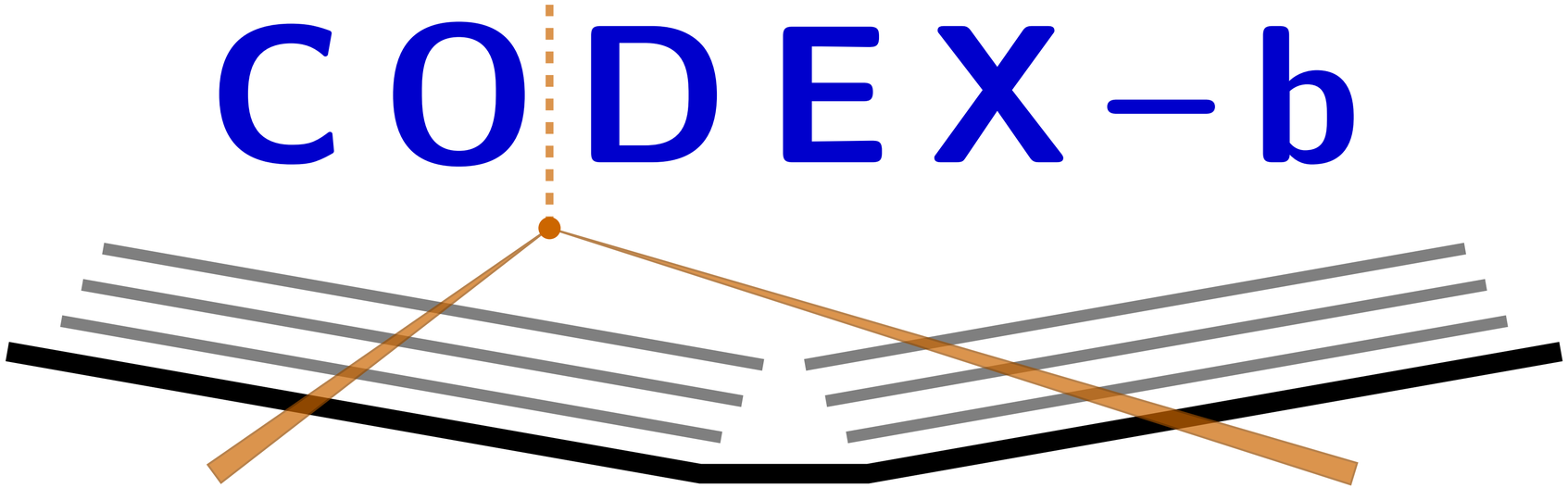
Compact Detector for Exotics at LHCb



Vladimir V Gligorov

On behalf of the CODEX-b collaboration

EPS-HEP 2025, Marseille, 09-07-2025

Why long lived particle searches?

Long lifetimes arise from a hierarchy of scales or a small coupling*

Three mechanisms:

- Off-shell decay
- Small splitting (phase space)
- Small coupling

Lessons from the SM:

- generic if there is more than one scale
- Often 3 body decays
- Weak theory prior on lifetime

(e.g. proton decay!)

small coupling

$$\Gamma \sim y^2 \left(\frac{m}{M}\right)^n m$$

hierarchy of scales

Set by symmetry structure,

typically n ≥ 4

* could either be a hierarchy or loop suppression

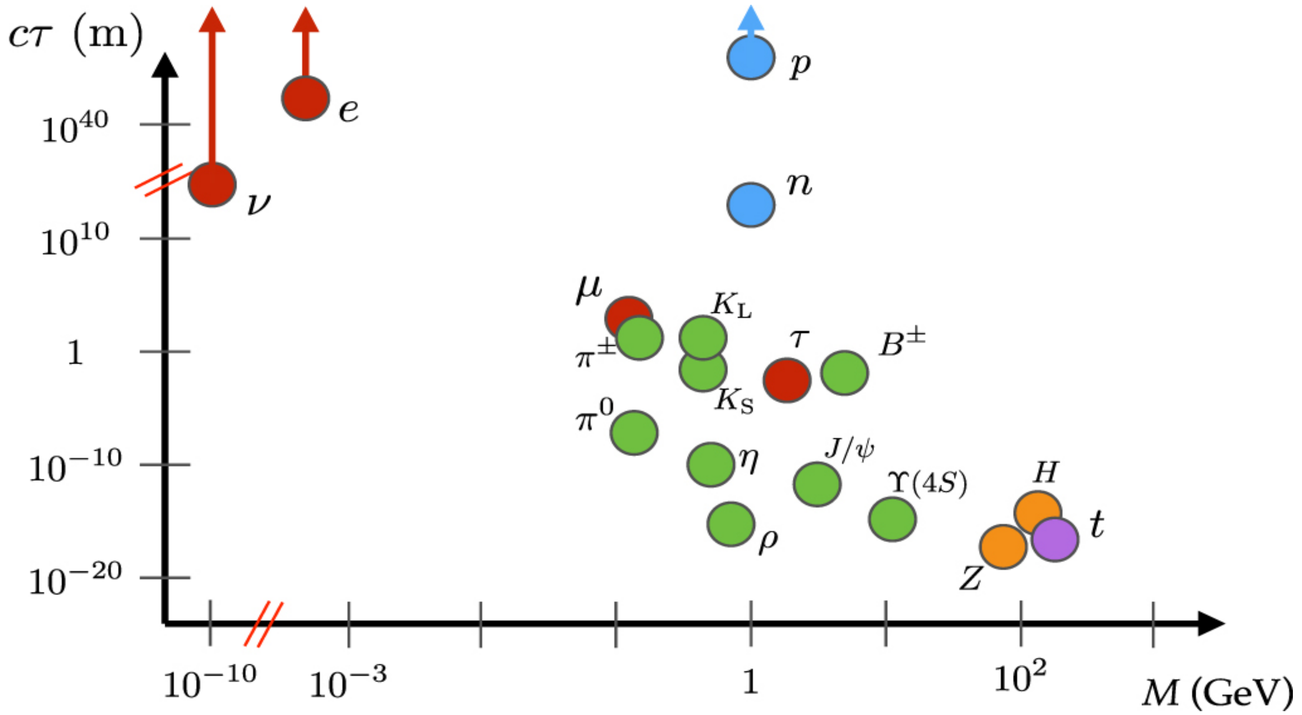
LLP mass vs lifetime vs production

broken sym
weak mixing/ marginal operator
technically natural

$m \ll M$, typically $n \geq 4$
loop factors

$$\Gamma \sim \varepsilon^2 \left(\frac{m}{M}\right)^n \mathrm{PS}$$

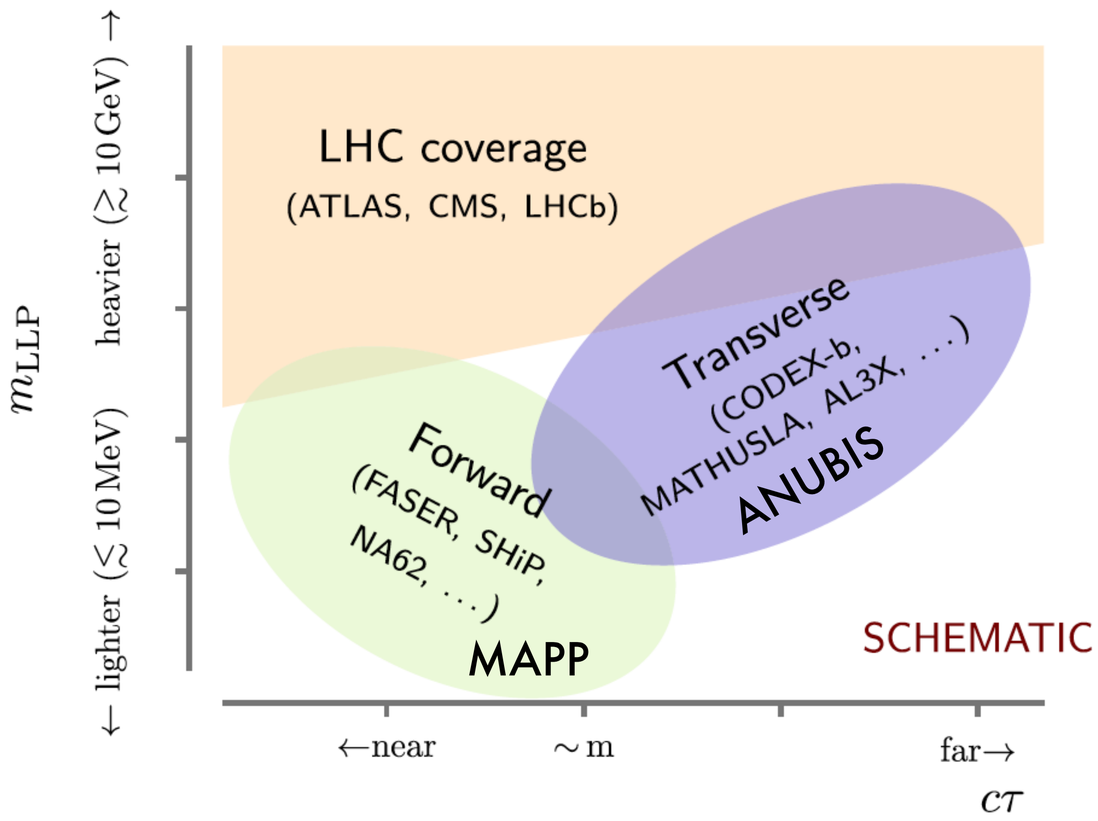
squeezed spectra
approx sym
multibody decays

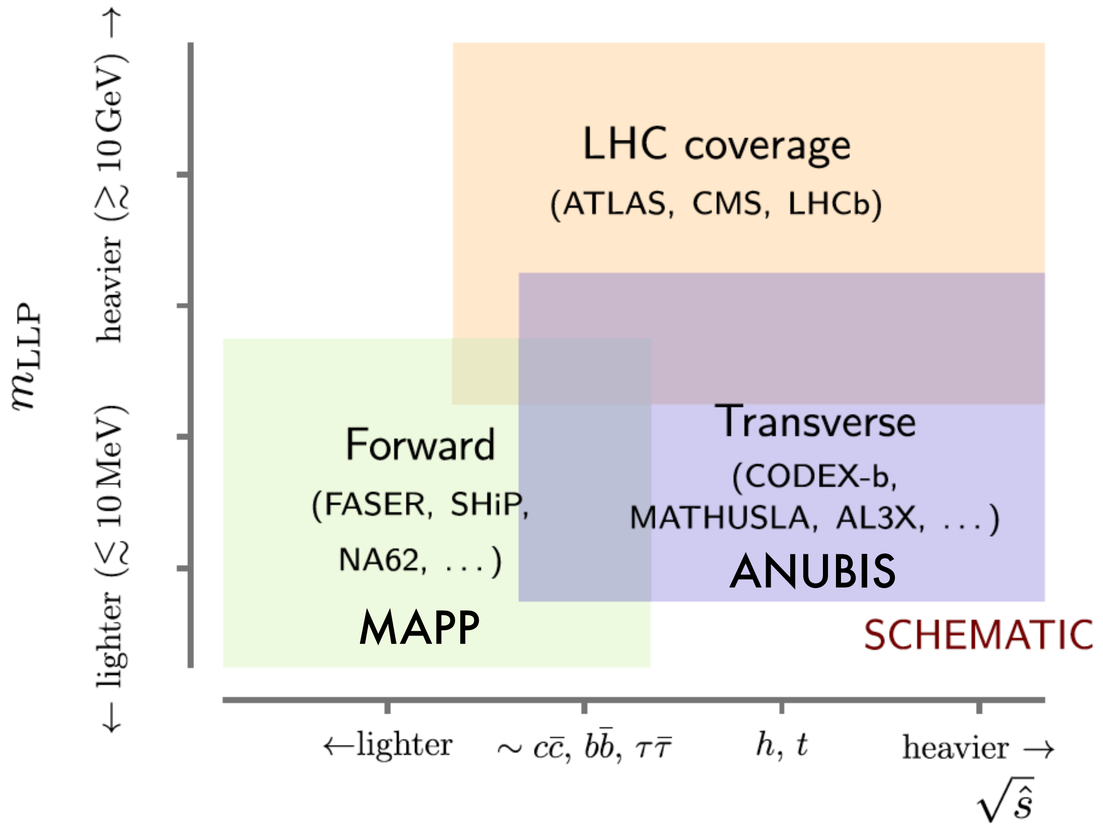


The bigger the mass, the smaller the required coupling to get a long lifetime

Production & decay heavily depend on the LLP and the portal used to access it.

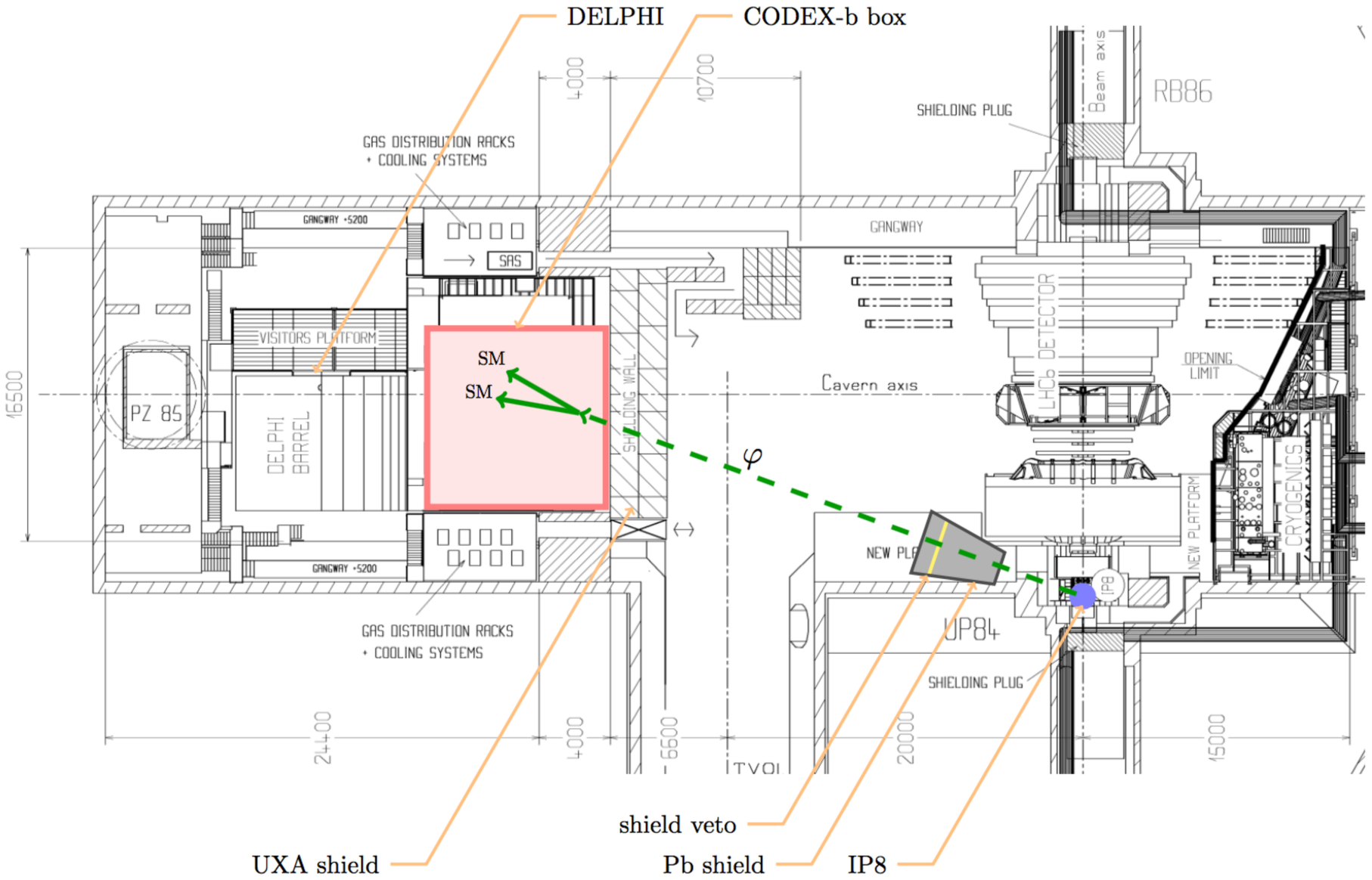
Coverage of transverse experiments



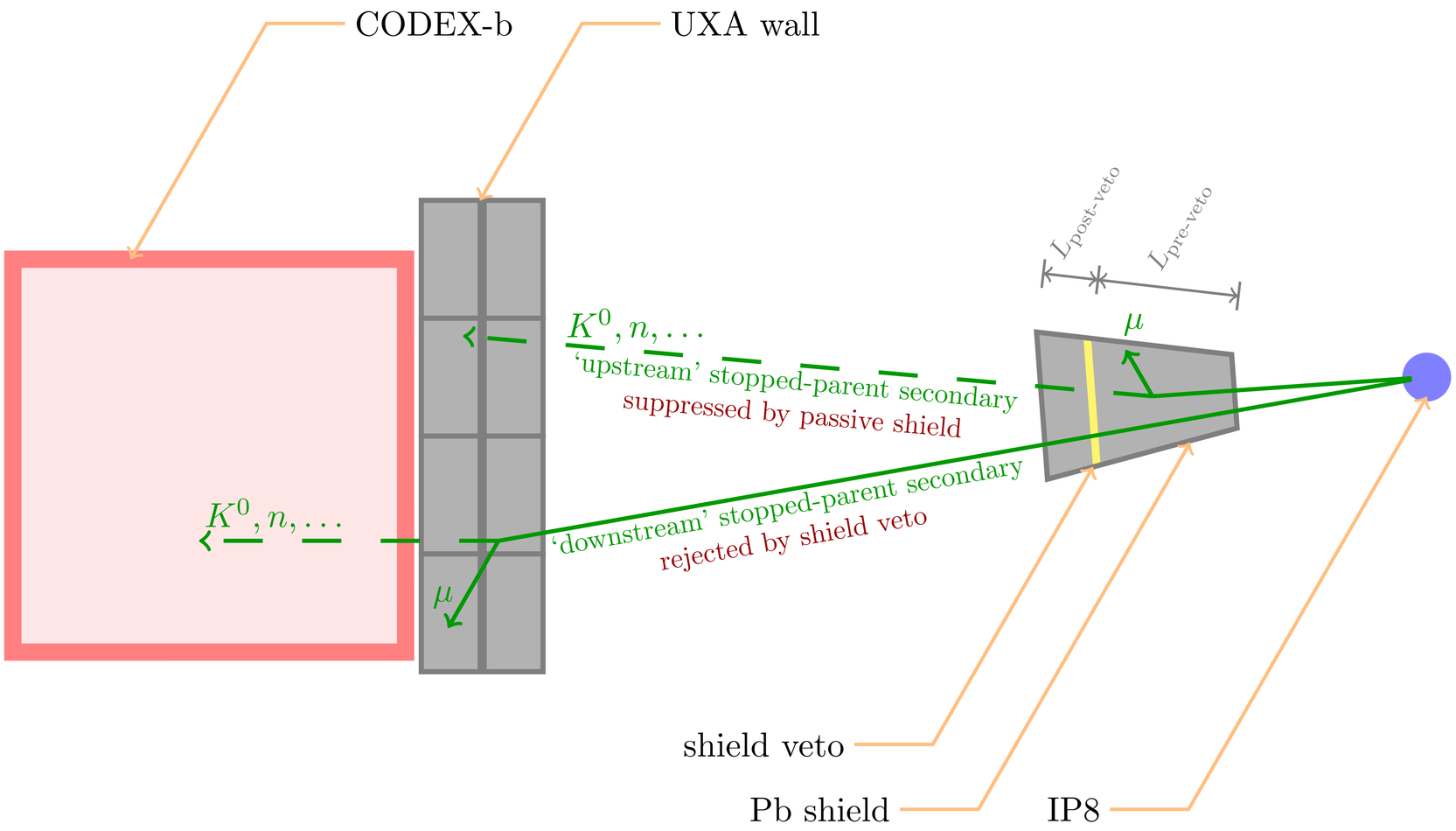


No single "golden" experiment — need complementary capabilities!

The CODEX-b experiment

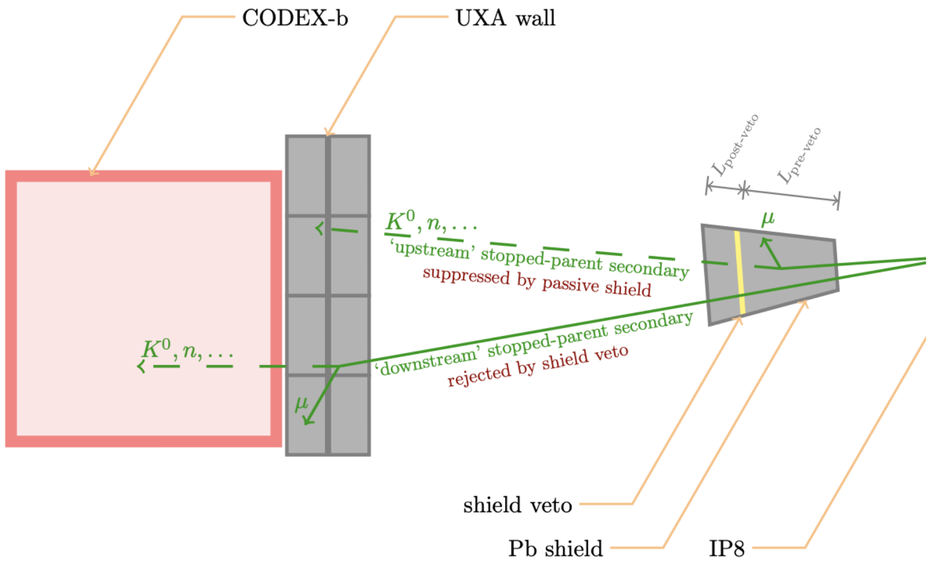


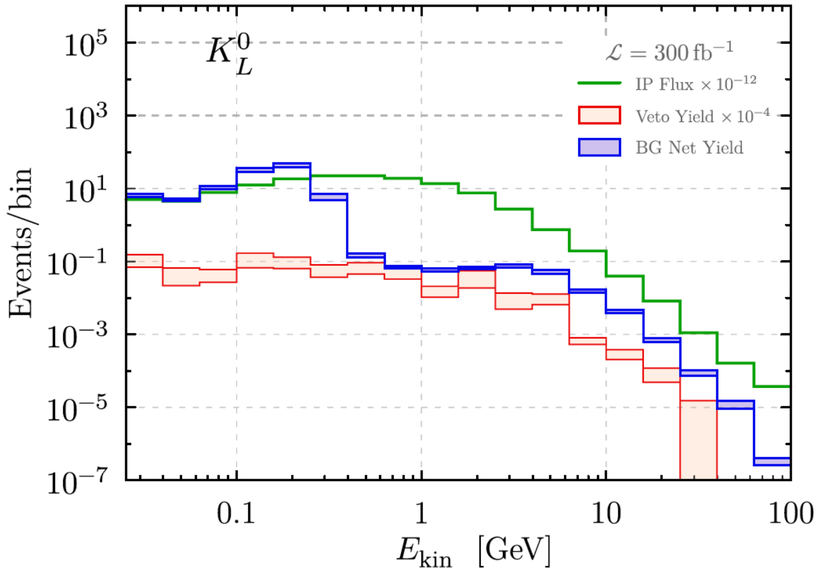
Minimal shield & veto design



First part of the shield attenuates muon & neutral hadron backgrounds which could enter the detector volume and scatter or decay within it. A thin active veto layer eliminates secondary production of backgrounds within the shield itself.

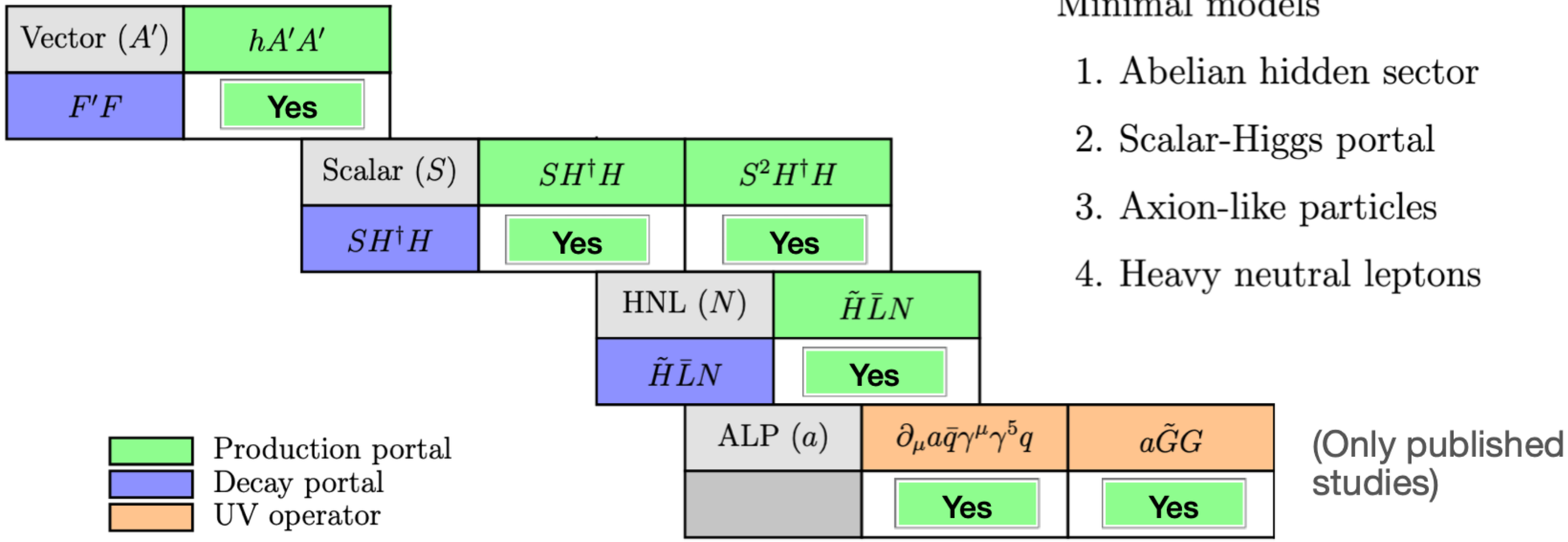
CODEX-b backgrounds





- Main background sources: Flux of n and μ from IP and recombination of K_L on UXA wall.
- Shielding: 20λ (Pb), 5λ (veto) and 7λ (UXA wall).
- Particle fluxes reduced to $\leq 1 \rightarrow$ simulation verified with measurements in situ.
- CODEX-β demonstrator to validate background estimations.

CODEX-b physics reach



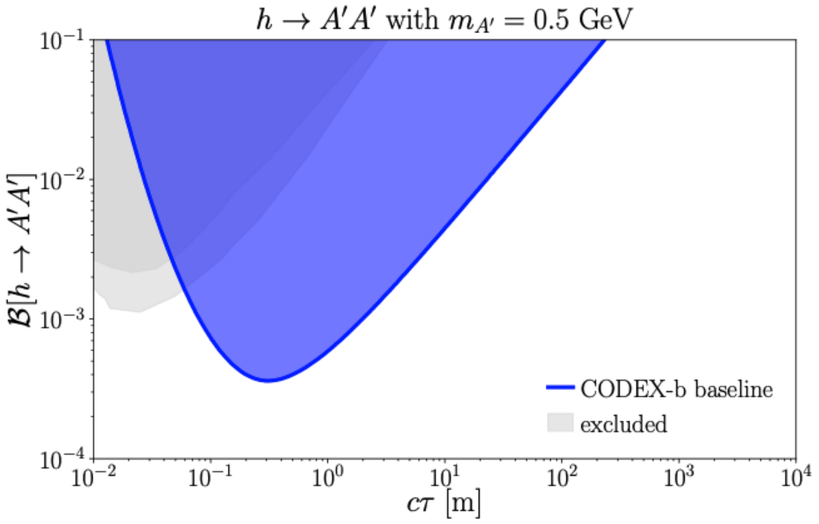
Minimal models

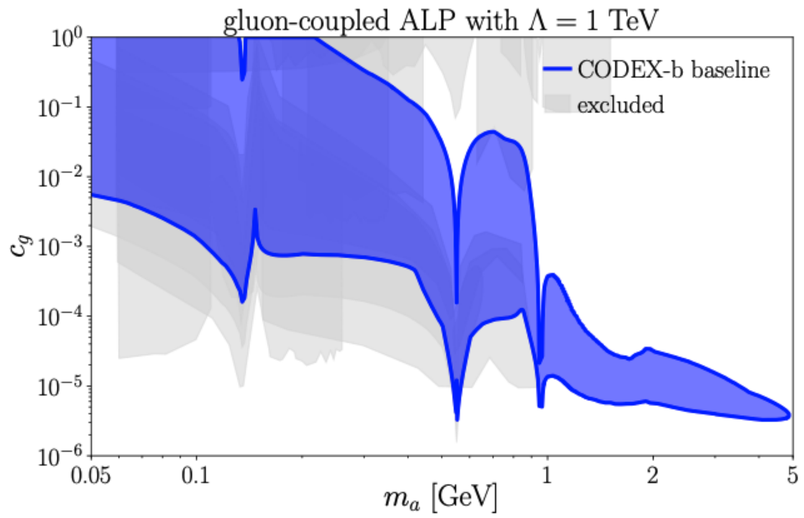
1. Abelian hidden sector
2. Scalar-Higgs portal
3. Axion-like particles
4. Heavy neutral leptons

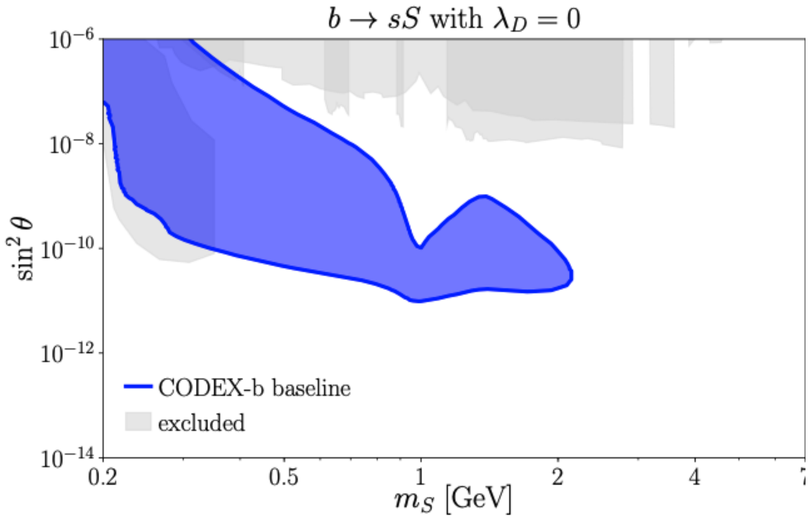
(Only published studies)

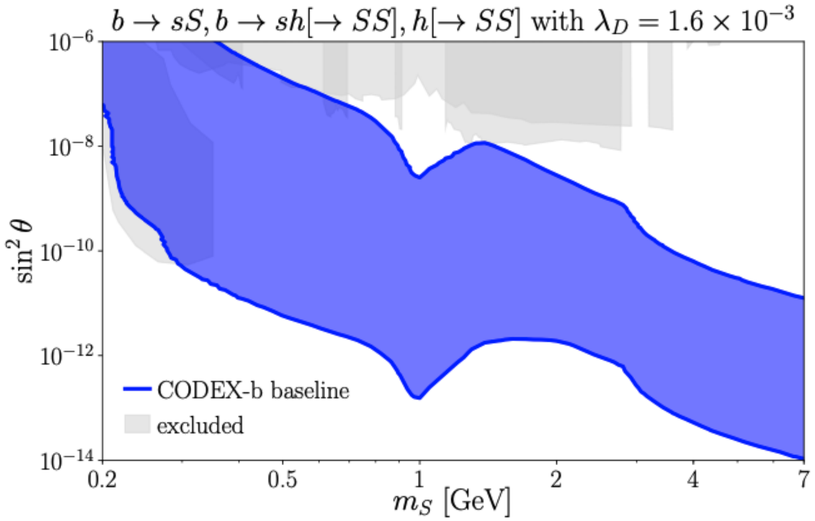
ESPPU:[https://indi.to/vcSMb]

CODEX-b physics reach



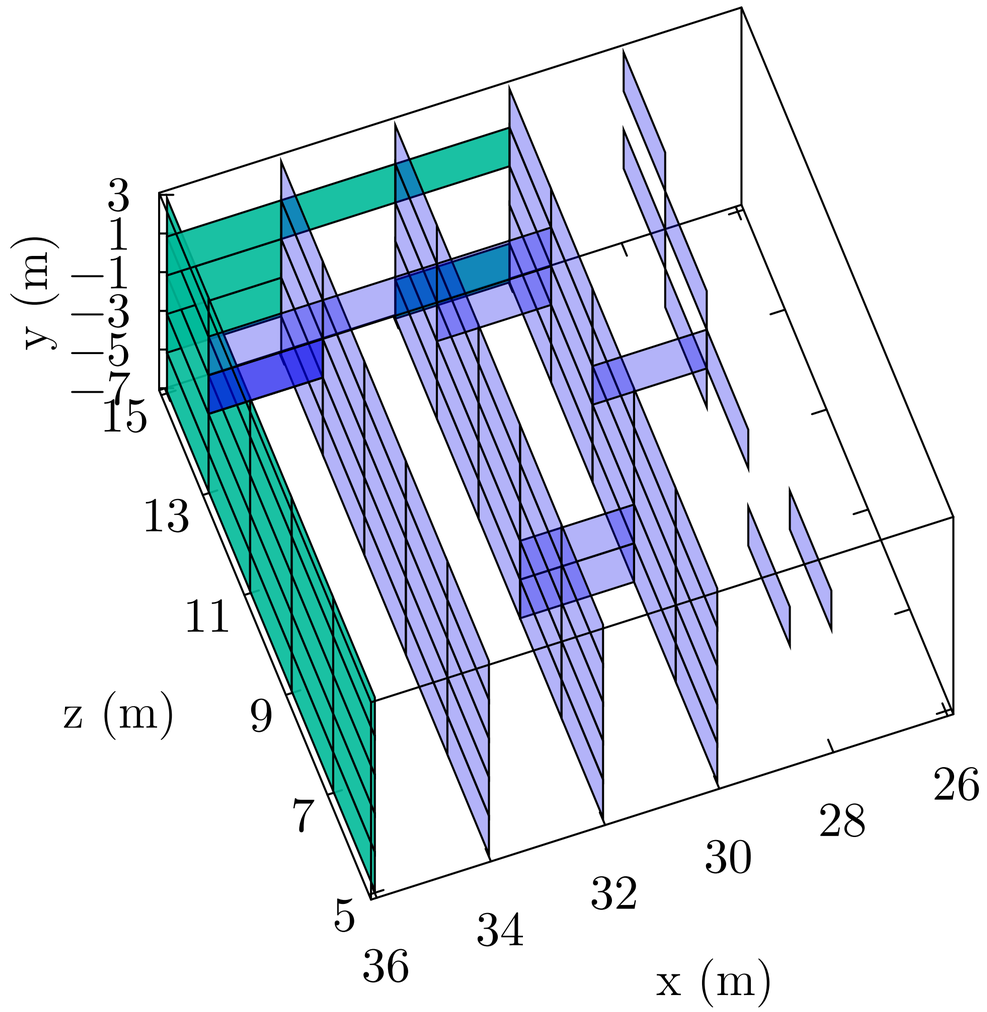


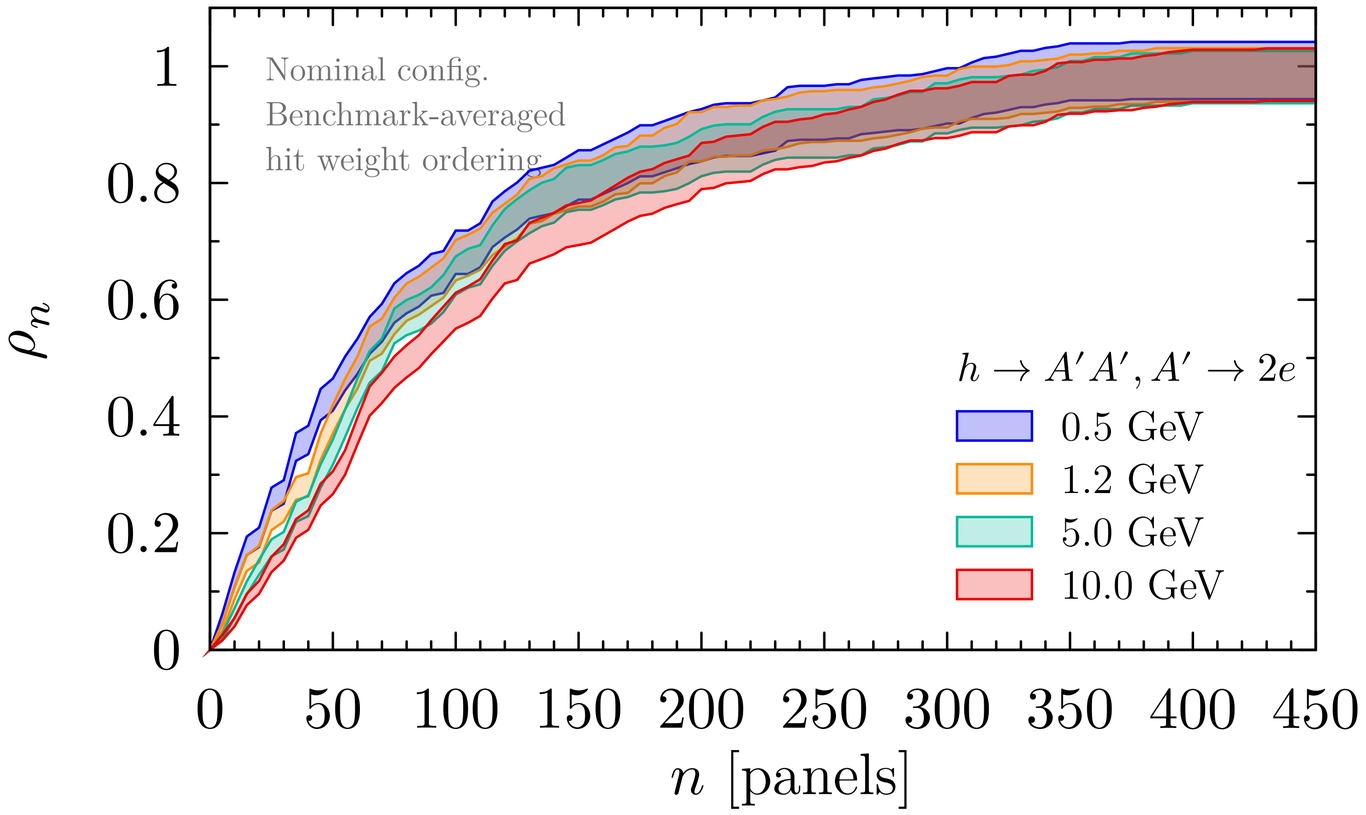




Optimized geometry

Road ahead for CODEX-b
Snowmass 2021 LOI
https://inspirehep.net/literature/2051244





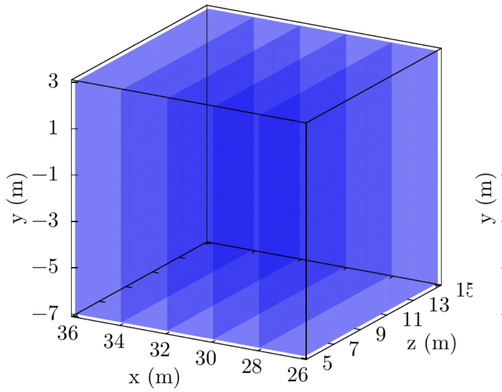
We can optimize the layout reducing cost by ~x2 maintaining most sensitivity for many benchmarks

Optimized geometry

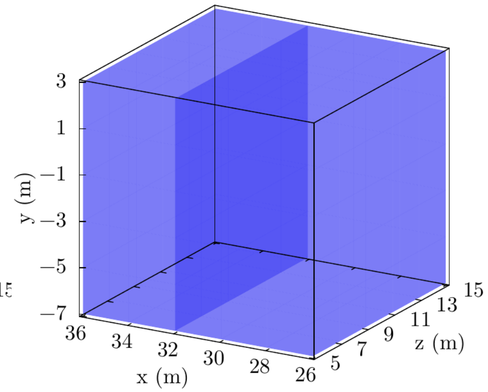
Figure 4: Efficiency relative to nominal configuration ($c\tau$-averaged).

m_{LLP} [GeV]	scenario 1	2	3
$h \to A'A', A' \to 2e$			
0.5	0.81(3)	0.56(2)	0.80(3)
1.2	0.81(3)	0.55(2)	0.72(3)
5.0	0.86(4)	0.58(3)	0.71(3)
10.0	0.88(4)	0.55(3)	0.75(4)
$b \to sS', S' \to 2e$			
0.5	0.94(11)	0.61(8)	0.77(9)
1.0	0.94(11)	0.55(7)	0.74(9)
2.5	0.85(10)	0.33(5)	0.53(7)
4.0	0.81(11)	0.22(4)	0.42(6)

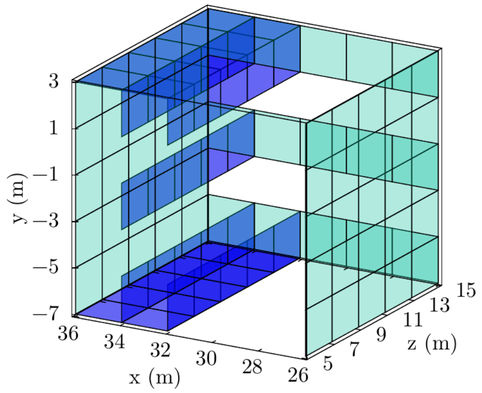
- Link to the ESPPU update: https://arxiv.org/pdf/2505.05952



(a) 500 RPCs

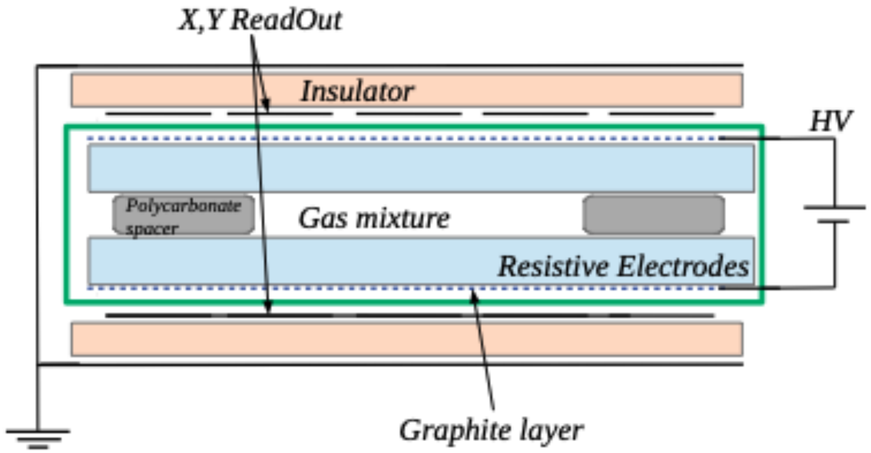


(b) 350 RPCs



(c) 350 RPCs

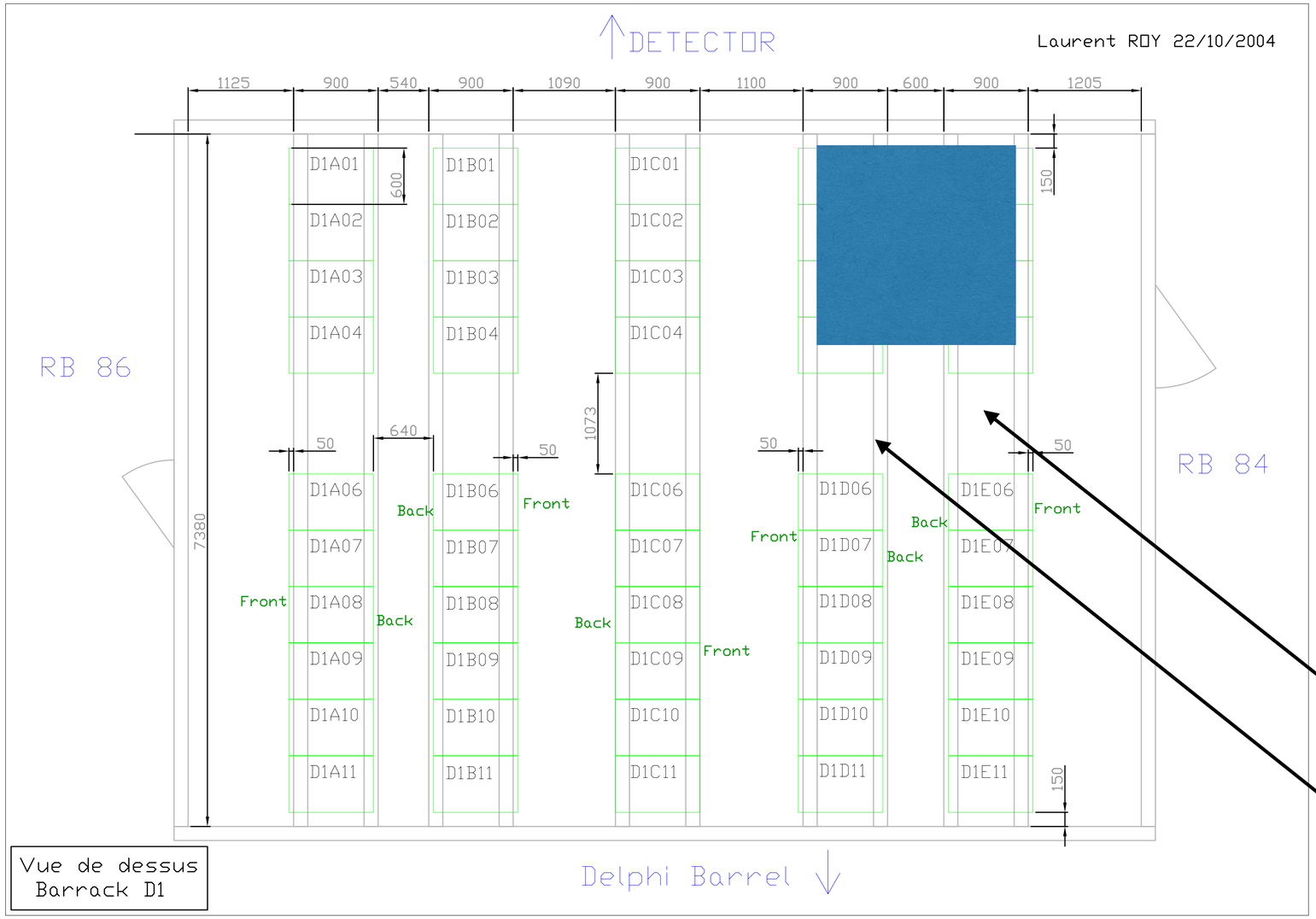
Baseline detector technology

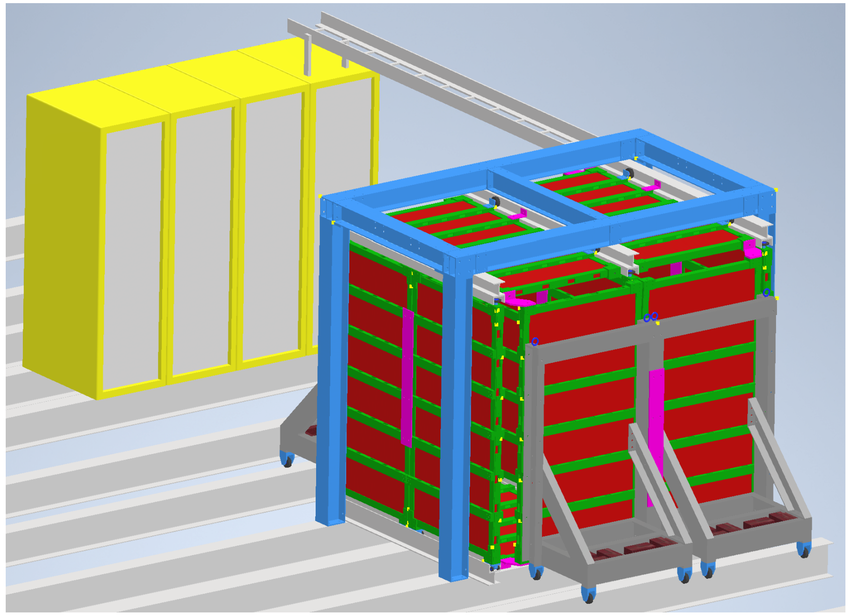


- ATLAS BIS-78 technology (3 independent detectors per chamber):
  - 5mm of spatial resolution.
  - 300ps of timming resolution.
  - 10 $\mathrm{kHz/cm^2}$.
- Detection through electron avalanche.

- Triplets $\rightarrow$ 3 RPCs working on coincidence mode.
- Assembly from zero with ATLAS expertise:
  - Glueing strip pannels and resistoring.
  - Front-End electronics installation.
  - Faraday cage development.
  - Gas and electric lines prepared.

The CODEX-β demonstrator





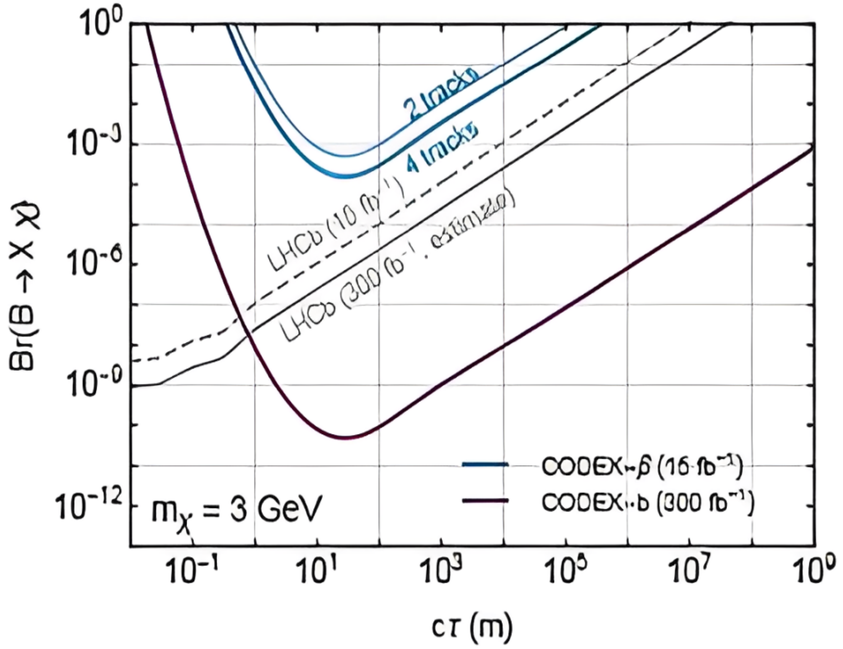
FALSE FLOOR

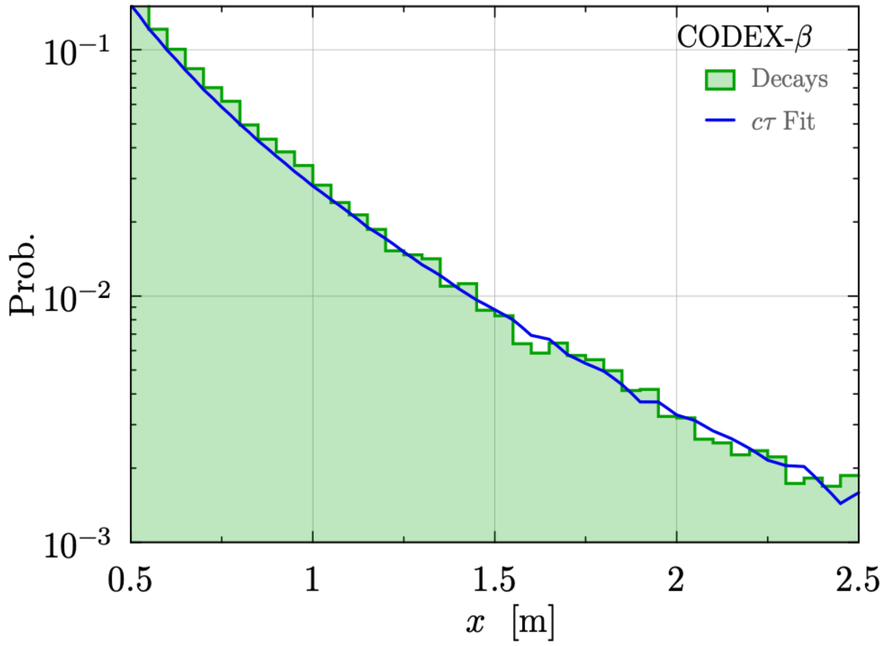
LOADBEARING RAILS

Installed in the old LHCb HLT server room, 2x2x2 metre cube

Physics with CODEX-β

- Distribution of background components in D1 barracks.
- Relatively high sensitivity to multitrack hadronic LLP decays.
- K_S^0 lifetime measurement.





Status of CODEX-β

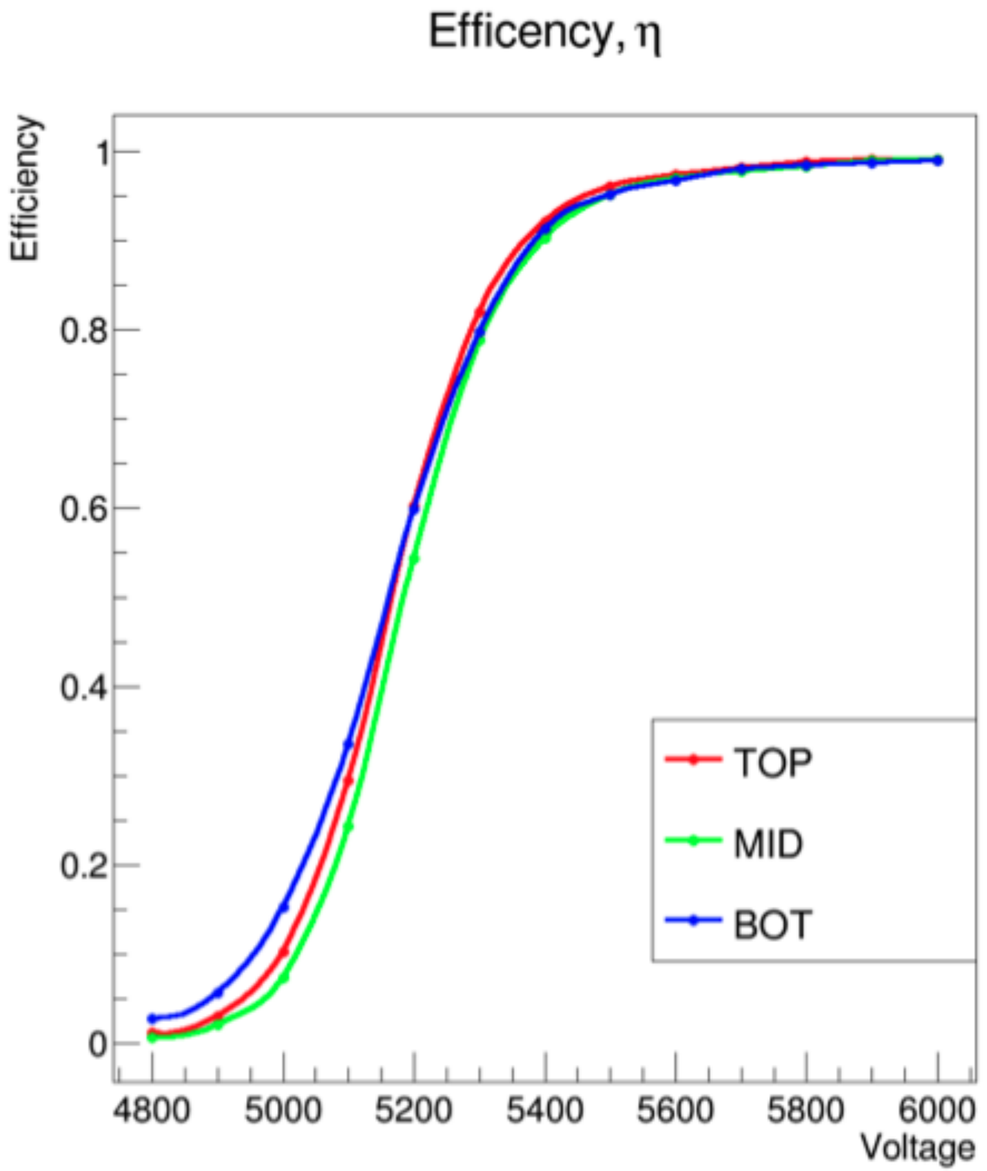
The support superstructure has been fully assembled at D1 barracks. Full connection to electrical services (HV and LV) and Gas recirculator is established.

RPC tests with muons succesfull, comprising:

- Noise rates.
  - False triggers.
  - Hit correlations.
  - Efficiency curves

No gas leaks after full assembly.

Now validating RPC performance in situ.



Road ahead for CODEX-β & conclusion

- Fully develop Sim/Reco framework.
- Demonstrate integration with LHCb.
- Slow control framework being developed.
- Data Collection and Transmission (DCT) modules will be in hand in August.

Aim to record >1fb-1 of data during Run 3!

The CODEX-b collaboration advances towards first data
Proposals for the "big" detector are advancing well

Backups