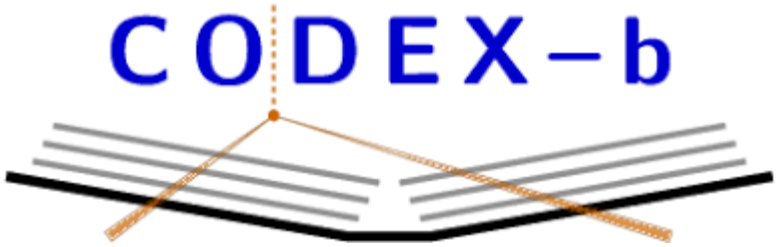
CODEX-b: concept and current status

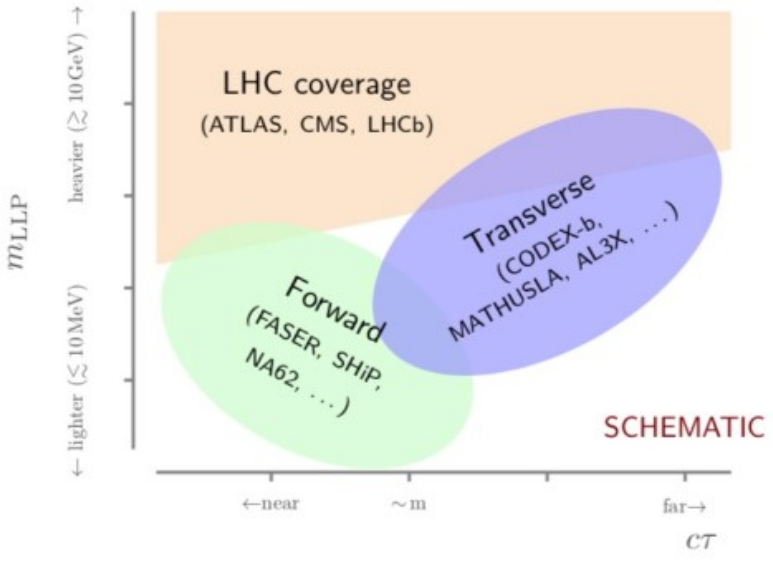
Louis Henry, on behalf of the CODEX-b collaboration
LLPX, virtual 09/11/2021

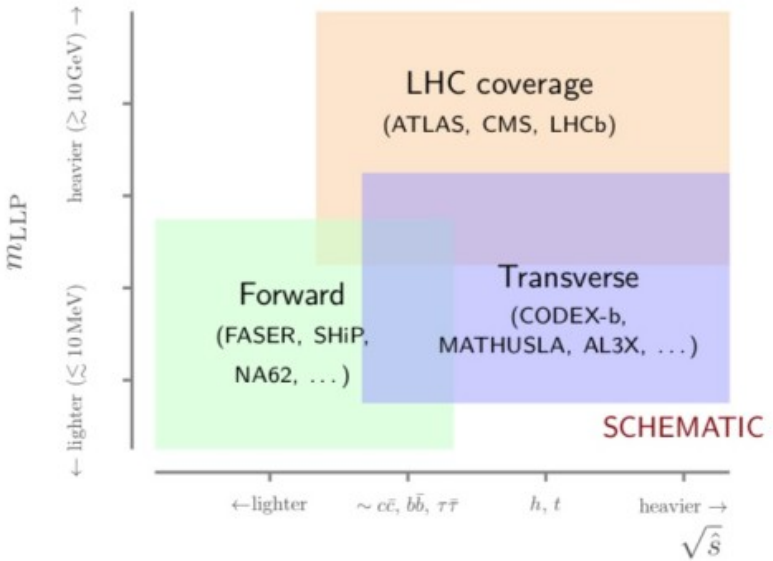


LLP: LHC context

- During last few years, push in the LHC community to look for LLPs.
  - Experiments, triggers designed around ~ prompt NP.
  - The LHC could be producing mounds of them that we would not detect/trigger on them.
  - Lots of ideas: J. Phys. G: Nucl. Part. Phys. 47 090501 (2020), 2110.14675
- Working at an interaction point of the LHC offers unique opportunity to access NP produced in high centre-of-mass energy collisions.
  - Recent paper on opportunities at LHC, modifying triggers: 2110.14675.

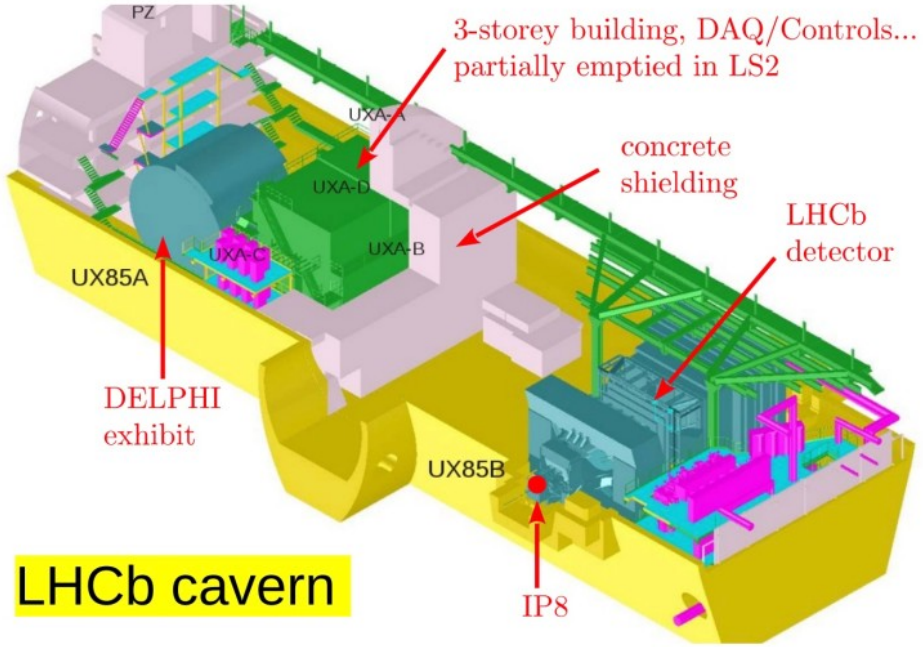
- CODEX-b belongs to the 'transverse' family, specialising in a specific angular coverage.

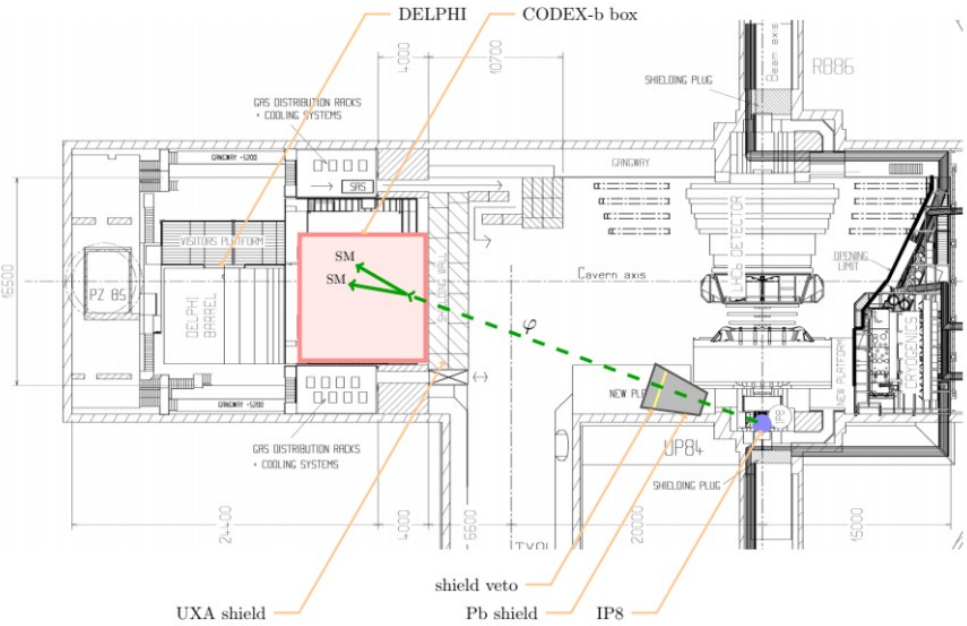




An answer: CODEX-b

- CODEX-b: COmpact Detector for EXotics at LHCb
  - Expression of interest: 1911.00481.
- Cheap, off-axis (transverse) tracker behind a huge shield and a long distance away from LHCb, in preexisting cavern.
- Trade-off between size and distance.
- Would be located either in the former D1 room or at the current location of DELPHI.
  - Possible some servers are still in the room, possibilities studied.

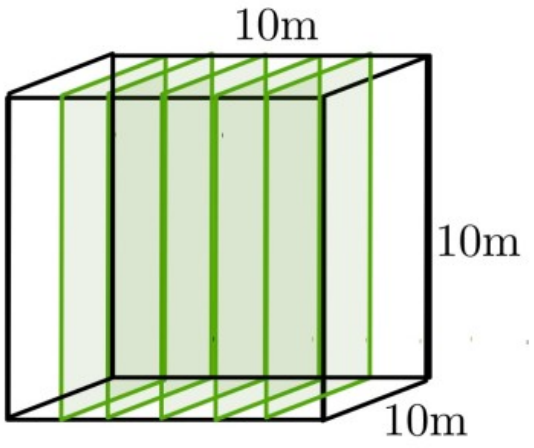




Base layout of the detector

- CODEX-b is far from the primary vertex → even a reduced angular acceptance corresponds to a large area.
- Need cheap, efficient and fast detection.
- Why fast?
  - Interplay with LHCb is easier.
- Answer: Resistive Plate Chambers (RPC's) – fast, precise, cheap for large area. 6 RPC layers at 4 cm intervals on each box face with 1 cm granularity.
  - Additional 5 layers inside (improve vertex resolution and tracking efficiency);
  - 50-100 ps timing from RPC's foreseen for mass reconstruction

- No magnetic field, no calorimetry, no Cherenkov
  - Possible to reconstruct mass from geometry, showcased in Phys. Rev. D 97, 015023 (2018).
- Coincidence with rest of the event at LHCb being studied



Physic motivation and reach

- Considering the distance from the interaction point and the transverse position, aiming at a certain mass/lifetime range and at decaying NP produced through heavy intermediate state (e.g. Higgs).

- Many studies reported in 1911.00481.

- Right: sensitivity contours of diverse experiments.
- Note the shape difference with respect to LHCb → complementarity.
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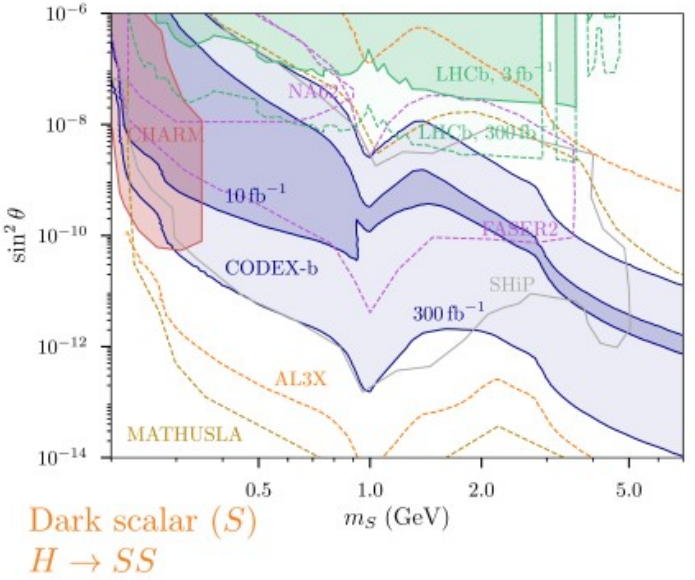


- Below: summary of accessible states from 1911.00481

Vector (A')	$hA'A'$	$F'F$
$F'F$	Fig. 7	no reach

Scalar (S)	$SH^\dagger H$	$S^2H^\dagger H$
$SH^\dagger H$	Fig. 9a	Fig. 9b

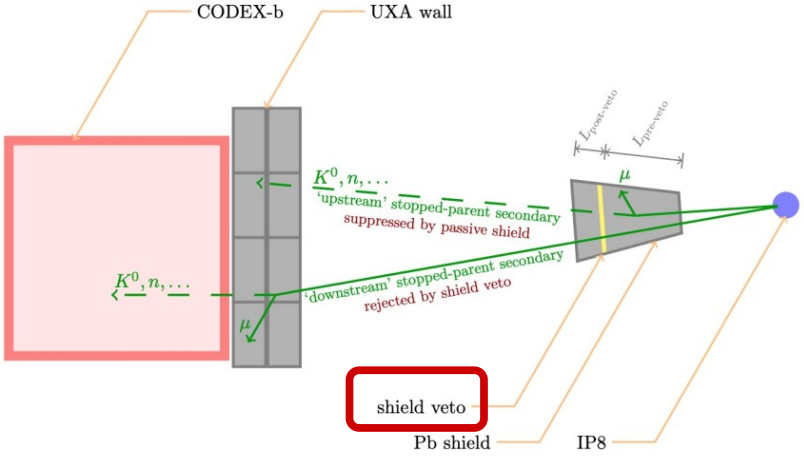
HNL (N)	$\tilde{H}\bar{L}N$
$\tilde{H}\bar{L}N$	Fig. 14

ALP (a)	$\partial_\mu a\bar{q}\gamma^\mu\gamma^5 q$	$a\tilde{G}G$	$a\tilde{F}F$	$a(W\tilde{W}-B\tilde{B})$
	Fig. 11	Fig. 12	pending	pending

Production portal
Decay portal
UV operator

How to achieve 0 background ?

- First answer: let's put a huge shield!
  - 32λ of concrete (7λ)+Pb,W (25λ).
  - Stops the 10^{14} neutrons & K_L / 300 fb^{-1}.
  - But also gives more chances to muons to interact deep into the shield and shower: **stopped-parent secondaries**.



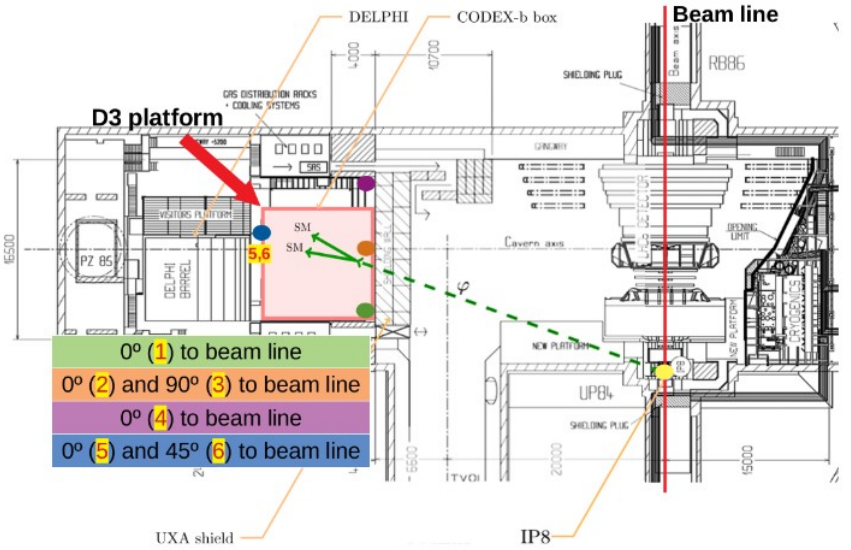
- To achieve truly 0 background, need to use an active shield:
  - Deep enough that the rejection rate is much smaller than the event rate
  - Not too close to Codex-b, or else the muon will have been stopped already.
- Nominal shield in so-called '20+5λ', in total 12λ from Codex-B.

BG species	Particle yields			Net yield
	Net ($E_{\text{kin}}^{\text{neutral}} > 0.4\,\text{GeV}$)	Shield veto rejection (total)	Shield veto rejection (±/0 correlation)	
γ	0.54 ± 0.12	$(8.06 \pm 0.60) \times 10^4$	$(2.62 \pm 1.03) \times 10^3$	–
n	58.10 ± 4.63	$(4.59 \pm 0.15) \times 10^5$	$(3.44 \pm 0.51) \times 10^4$	–
n ($> 0.8\,\text{GeV}$)	2.78 ± 0.25	$(1.03 \pm 0.06) \times 10^5$	$(7.45 \pm 1.92) \times 10^3$	$\lesssim 1$
$\bar{n}$ (no cut)	$(3.24 \pm 0.72) \times 10^{-3}$	34.40 ± 25.80	$(7.12 \pm 2.19) \times 10^{-2}$	$\ll 1$
K_L^0	0.49 ± 0.05	$(1.94 \pm 0.74) \times 10^3$	54.40 ± 19.20	$\lesssim 0.1$
K_S^0	$(6.33 \pm 1.39) \times 10^{-3}$	93.90 ± 45.80	0.74 ± 0.19	$\ll 1$
$\nu + \bar{\nu}$	$(5.69 \pm 0.00) \times 10^{13}$	$(7.35 \pm 0.12) \times 10^6$	$(7.31 \pm 0.11) \times 10^6$	–
μ^+	$(1.04 \pm 0.00) \times 10^6$	$(1.04 \pm 0.00) \times 10^{10}$	$(1.04 \pm 0.00) \times 10^{10}$	–
μ^-	$(8.07 \pm 0.01) \times 10^5$	$(8.07 \pm 0.01) \times 10^9$	$(8.07 \pm 0.01) \times 10^9$	–

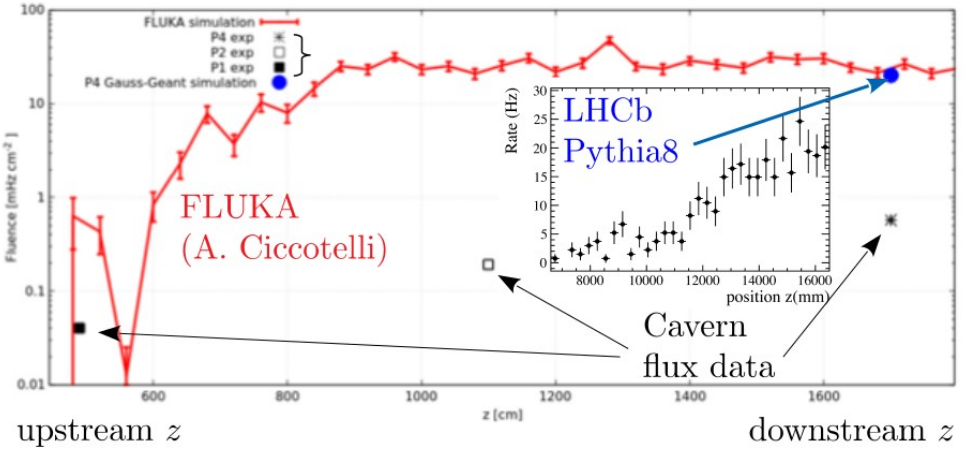
How to trust our simulation though?

- Previous results obtained through extensive - and conservative – simulation campaign.

- Measurement campaign performed in Run 2, documented in 1912.03846.



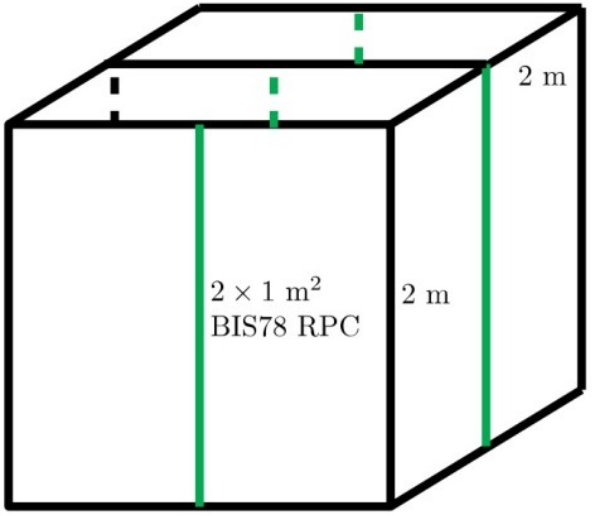
- Rates show that ambient noise can be neglected.
- Simulation overestimates by an order of magnitude the noise rates.
- Recently performed second simulation studies with FLUKA: agrees with Geant4+Pythia8.

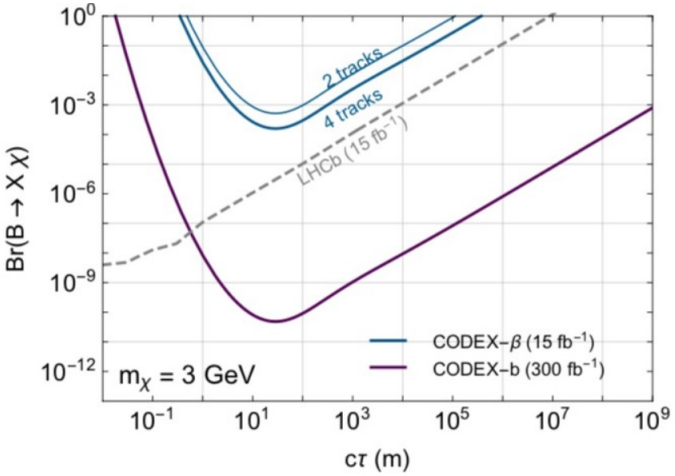


FLUKA agrees with Geant4, current MC estimate maintained

Testing the concept: CODEX-β

- CODEX-b is an HL-LHC detector, but we must do a lot in the meantime.
- Testing technology, background rates, reconstruction can be achieved by installing a smaller version: CODEX-β.
- 6 detector faces + 1 inner station:
  - 14 BIS7 RPCs triplet chambers. Enough space already in D1 area of the cavern once DAQ racks shifted out.
  - 2×2×2 m^3 demonstrator for Run 3 (1/25 of full detector).
- No active veto, so expect ~10^7 K_L decays in demonstrator.
  - Useful to validate the reconstruction algorithms designed for the full detector.
- First try to include CODEX-b in the LHCb online system.

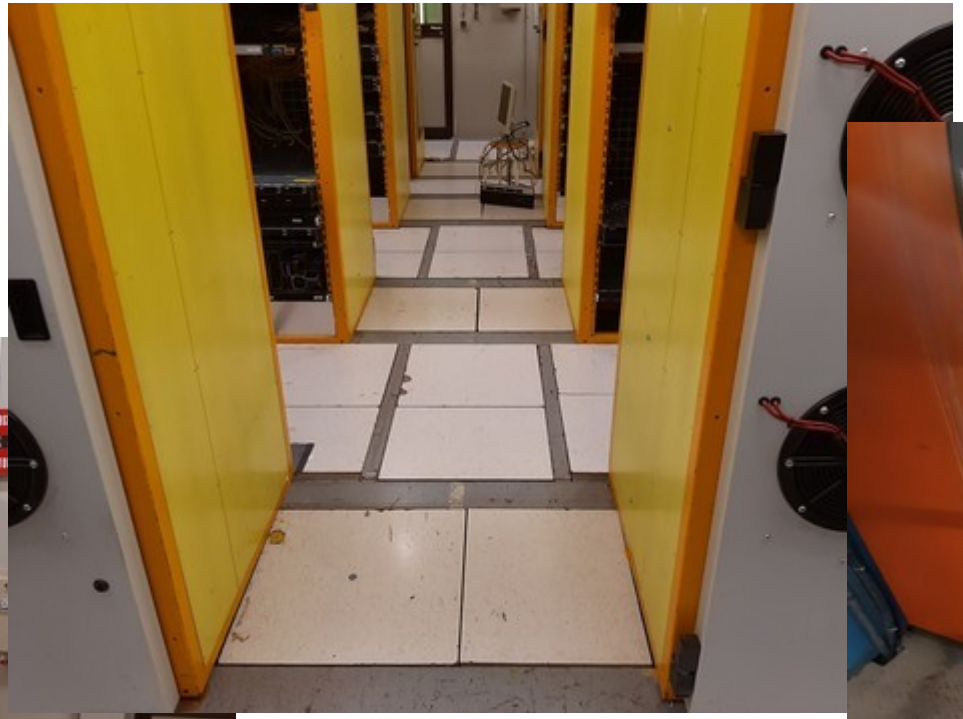


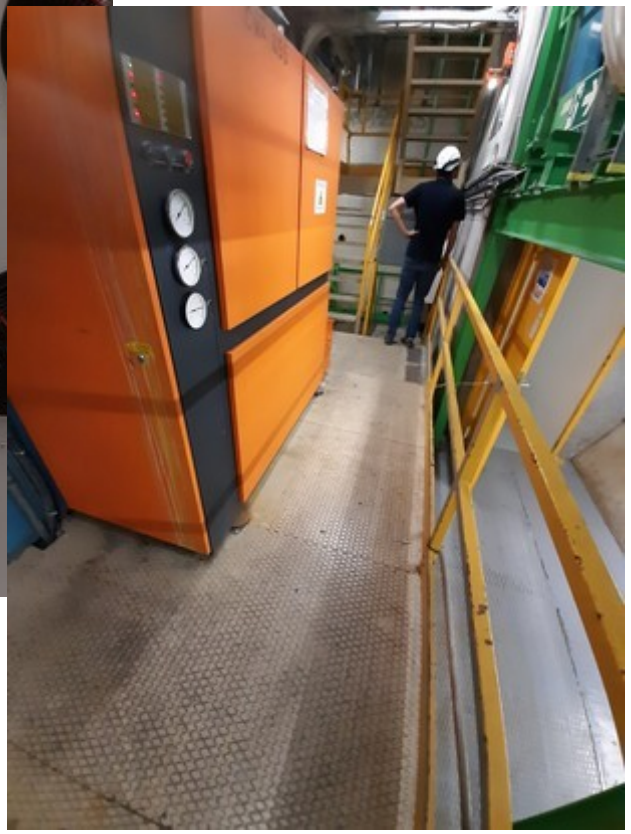


- Physics reach limited to 2/4-body.
  - e.g. multibaryonic decays from hidden valley.

From blueprints to cavern: exploration of the room

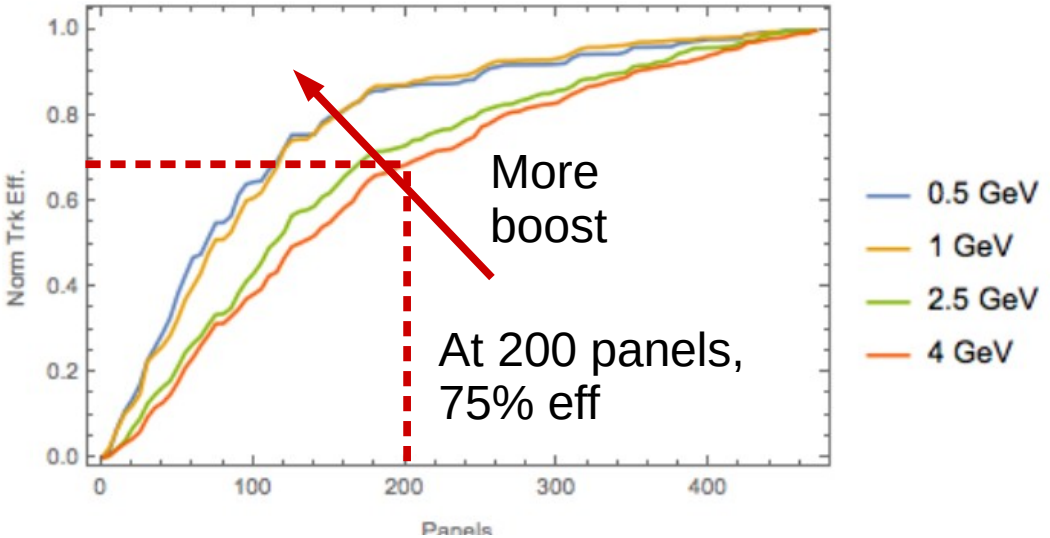
- This summer, we went to IP8 to take measurements, understand how to install the detector.
- Moved forward discussions about how to bring CODEX-β inside, where to get the power from, where exactly to put the detector.
- Mock-up being built out of plywood to make sure panels fit.



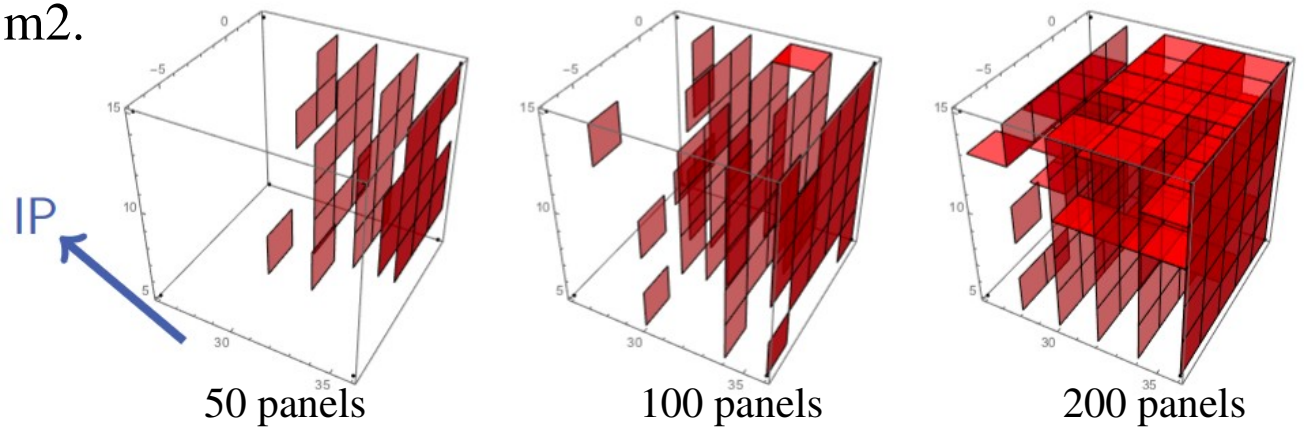


Progress on the detector design

- Manufacturing of the RPCs will start soon.
  - Adapt ATLAS RPCs to our needs. Currently BIS7 Phase I, adapt ATLAS RPCs into our own mechanical supports (R&D starting).
- CODEX-b full potential unlocked in symbiosis with LHCb → need for DAQ to be integrated in LHCb.
  - CODEX-b takes its know-how and electronics from ATLAS muon chambers.
  - Now checked and approved that these boards can talk to LHCb's TELL40 boards.

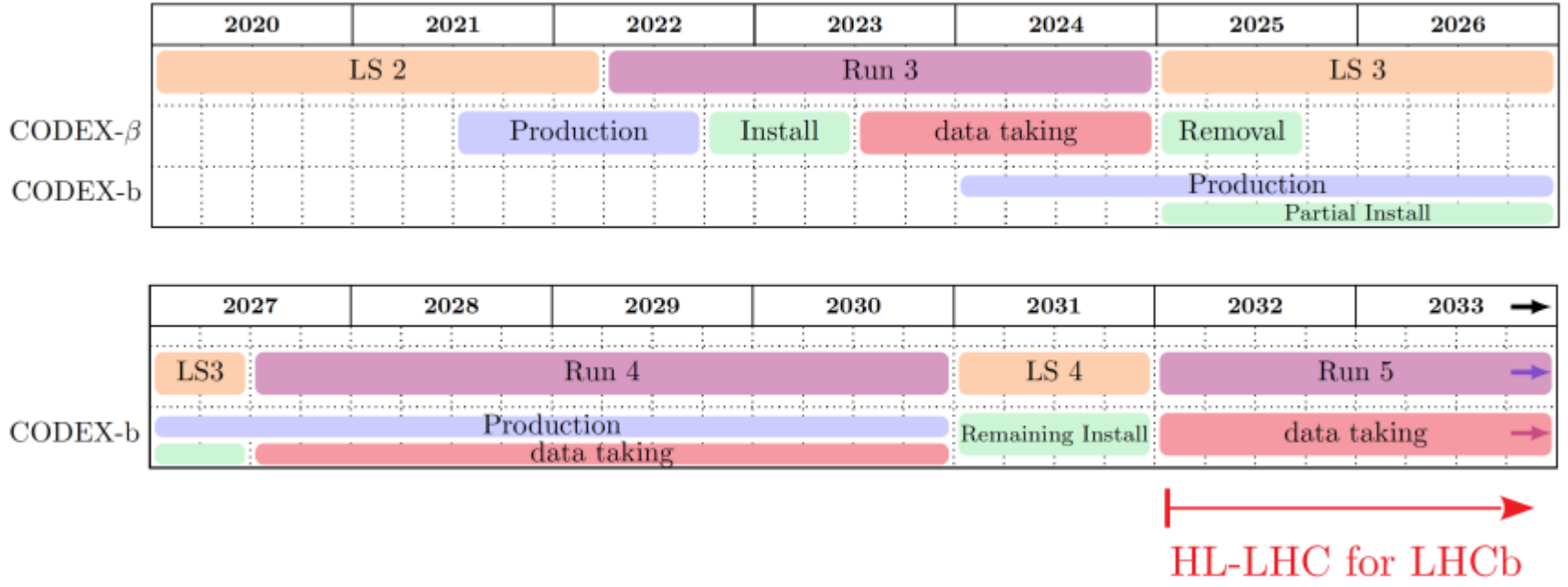


- Newer module and detector designs, also considering fewer RPCs, going from 6000 m2 to 3000 m2.

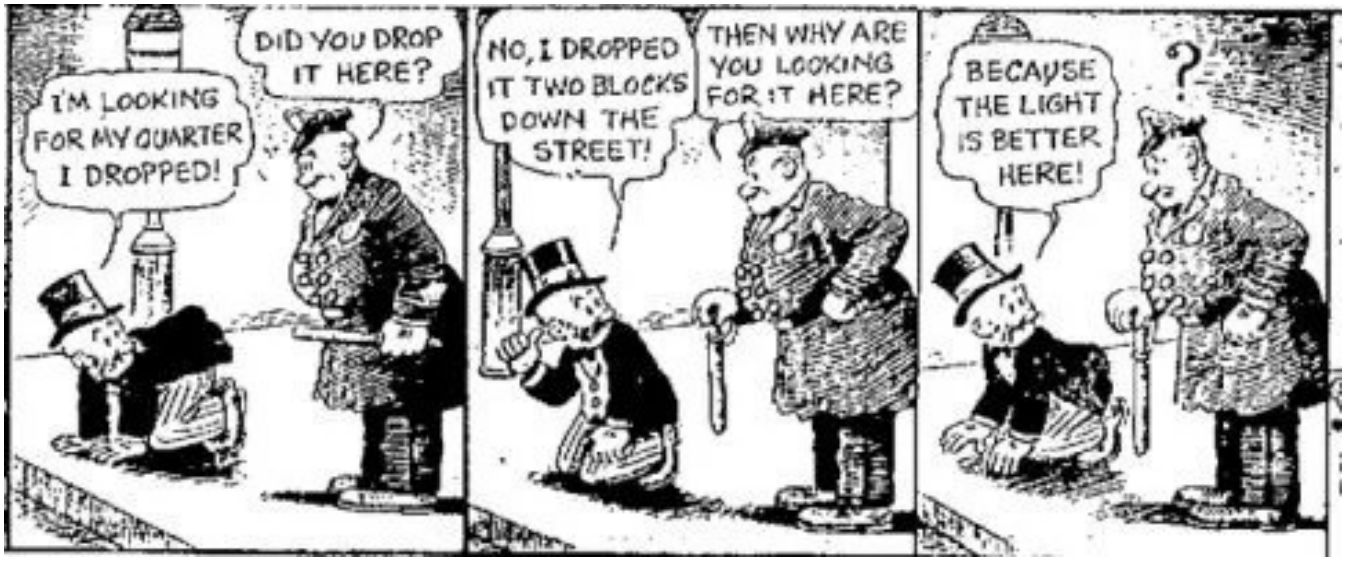


News and conclusion

- Explorations of the CODEX-β room have been conducted, plans to install the detector being set.
- Collaboration is **expanding** rapidly, getting more organised with dedicated working groups
- Budget is being finalised for CODEX-β (~200k CHF): essential for future plans for CODEX-b (O(10M CHF)).
- Working on a detailed installation plan to communicate to the LHCb safety experts, and then the installation team → objective end of 2021.



Thank you!


I'M LOOKING FOR MY QUARTER I DROPPED!
DID YOU DROP IT HERE?
NO, I DROPPED IT TWO BLOCKS DOWN THE STREET!
THEN WHY ARE YOU LOOKING FOR IT HERE?
BECAUSE THE LIGHT IS BETTER HERE!
?

Machine-induced backgrounds

- Additional RadMon unit to be placed in CODEX-β area for Run 3 to monitor hadron backgrounds (thanks to Giuseppe Lerner).
- In discussion with LHCb lumi group as well as CERN radiation group to include CODEX-b area for Run 3 beam condition MIB studies.