Latest CODEX-b Developments

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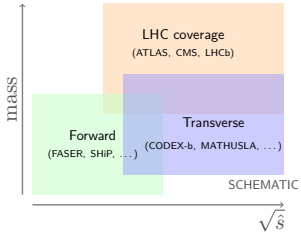
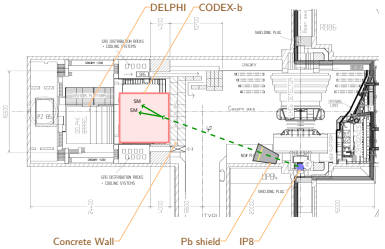
CODEX-b concept

- Theoretically well-motivated $\lesssim \mathcal{O}(10\text{GeV})$ Long-lived Particles (LLPs) can be produced predominantly at high $\sqrt{\hat{s}}$ (eg Higgs decays)
- Motivates shielded displaced LLP detector transverse to a LHC interaction point

Physics paradigm:



Detector paradigm:



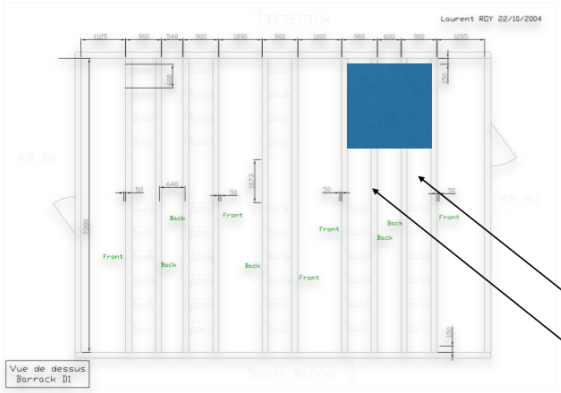
COmpact Detector for EXotics at LHCb

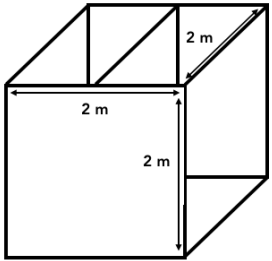
[Original proposal: 1708.09395] [Expression of Interest: 1911.00481] [Snowmass: 2203.07316]

CODEX-β Demonstrator Update

Demonstrator detector

To be installed in the old LHCb HLT server room; $2 \times 2 \times 2\,\mathrm{m}^3$ cube of RPC triplets





FALSE FLOOR

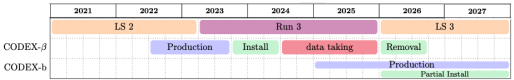
LOADBEARING RAILS

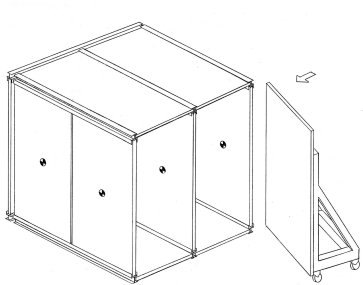
Main Goals

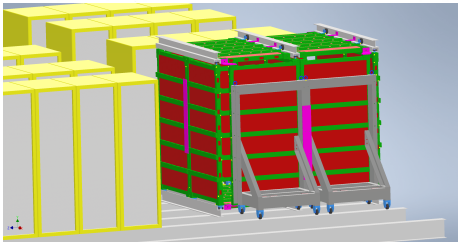
- Enable data-driven background measurements to validate the preliminary background simulations
- Demonstrate the seamless integration of the detector with the LHCb readout
- Demonstrate the suitability of RPC technology for tracking
- Demonstrate the ability to reconstruct known SM backgrounds from expected decays inside detector
- Demonstrate the suitability of the mechanical support structure and its scalability to the full CODEX-b detector

Milestone achievements

- Demonstrator location secured
- Funding to build RPC chambers secured
- Mechanical design done
- Everything in place to integrate with LHCb DAQ
- Plan to produce modules 2nd half this year, then install
- CERN-based team secured to commission demonstrator





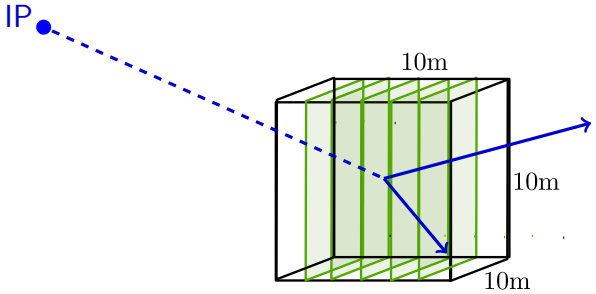


CODEX-b Geometry Optimization

(Funded by LBL LDRD)

Baseline Design

Our proof-of-concept analyses used a simple regular cubic design with inner + hermetic surface tracking layers:



- Demonstrated $\mathcal{O}(1)$ LLP vertex reconstruction efficiencies (subject to hit resolution and momentum thresholds)
- Used 400 $2 \times 2\,\mathrm{m}^2$ RPC triplet panels $\Rightarrow$ $4800\,\mathrm{m}^2$ of RPC

The tracking layer surface area is the main driver of costs and installation time.

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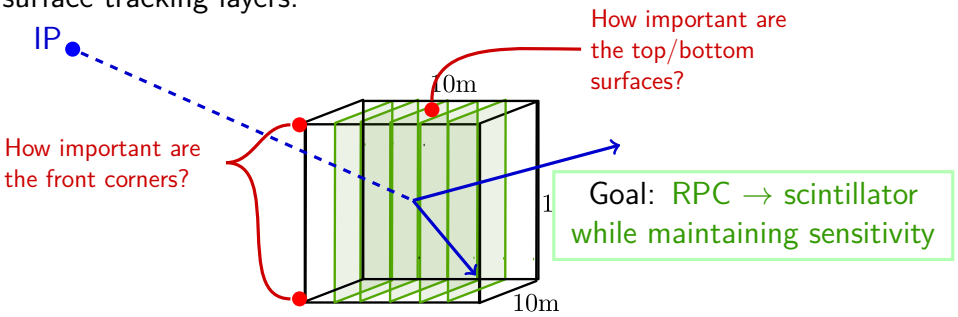

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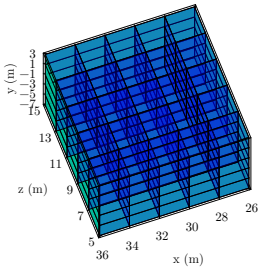
Challenge

Optimize detector shape and tracking layers for best sensitivity:

- Probe many different portals; many detection signatures, kinematics; select representative portals over the theory and phenomenological space
- Model response of different configurations to different theoretical scenarios with newly developed adaptive simulation framework



Consider more possible panel locations/orientations

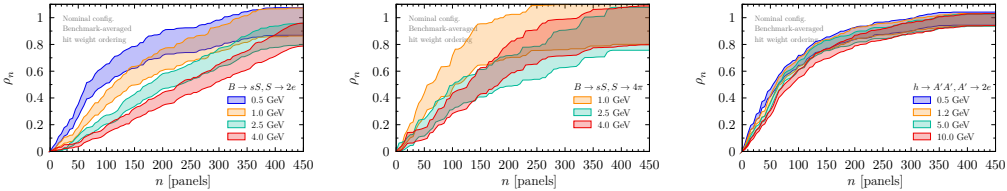
Require for track reconstruction:

- 6 hits per track
- 2cm separation
- $p > 600\,\text{MeV}$

Finite element is $2 \times 2\,\text{m}^2$ RPC triplet

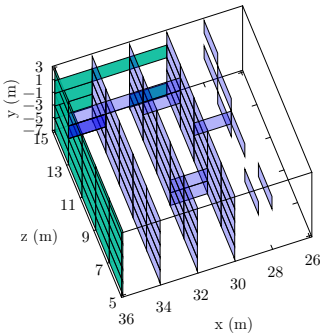
Naive Optimization Estimator

Order by naive hit weight density on each panel. Compute relative vertex reconstruction efficiencies as a function of number of panels

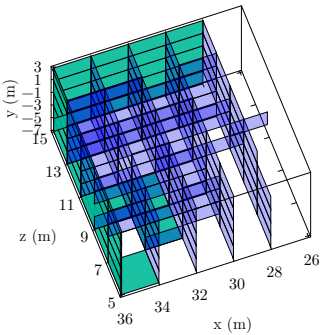


- Weighting by hits $\Leftrightarrow$ weighting panels closer to decay vertex. Leads to good vertex reconstruction
- High negative curvature $\Rightarrow$ most 'work' done by relatively few panels
- Estimator does well for all Higgs benchmarks, and some B benchmarks!
- Can nominally reduce RPC coverage by about $30 - 50\%$ for some portals (replace with cheaper scintillator for soft BG control)

Configurations



150 panels: rel. eff. $\sim 40 - 80\%$

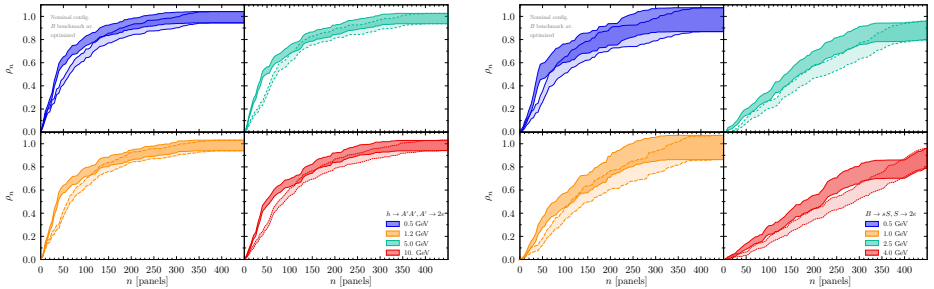


250 panels: rel. eff. $\sim 50 - 90\%$

For this estimator, external panels on 'back' and 'downstream' faces, plus internal panels along x transverse direction are favored. Similar to baseline configuration.

Systematic Optimization

Can implement a more systematic 'branch and bound' optimization method



Naive (fast) estimator does comparably well!

Outlook

- CODEX-b can attain good sensitivity over the space of LLP scenarios while reducing the required amount of tracking layers by an $\mathcal{O}(1)$ factor
- We have an efficient optimization estimator of best partial configurations, plus full optimization pipeline, as needed
- Can rapidly update results for variations in configuration.

Thanks

More updates: @CodexExperiment

Extras:

Scenarios

Study 11 benchmarks, that well-represent the typical different kinematic configurations for different LLP portals

Portal/Model	Production		Finite hit resolution	Track momentum threshold	Acoplanar topology	Masses	Analogous simplified model
	single	multiple	(opening angle)	(soft tracks)	(missing energy)	[GeV]	
$h \to A'A'$ $[A' \to 2e]$	—	✓	✓	—	—	0.5, 1.2, 5, 10	ALP
$b \to sS$ $[S \to 2e]$	✓	—	—	✓	—	0.5, 1, 2.5, 4	ALP
$b \to sS$ $[S \to 4\pi]$	✓	—	—	✓	✓	1, 2.5, 4	ALP, HNL

TABLE I: The three benchmark production and decay portals and their topologies and typical sensitivity-limiting features, along with the selected mass points for each portal, for a total of elevent benchmark models. Also indicated are other simplified models—variations of axion-like particles (ALP) and heavy neutral leptons (HNL)—with analogous features.