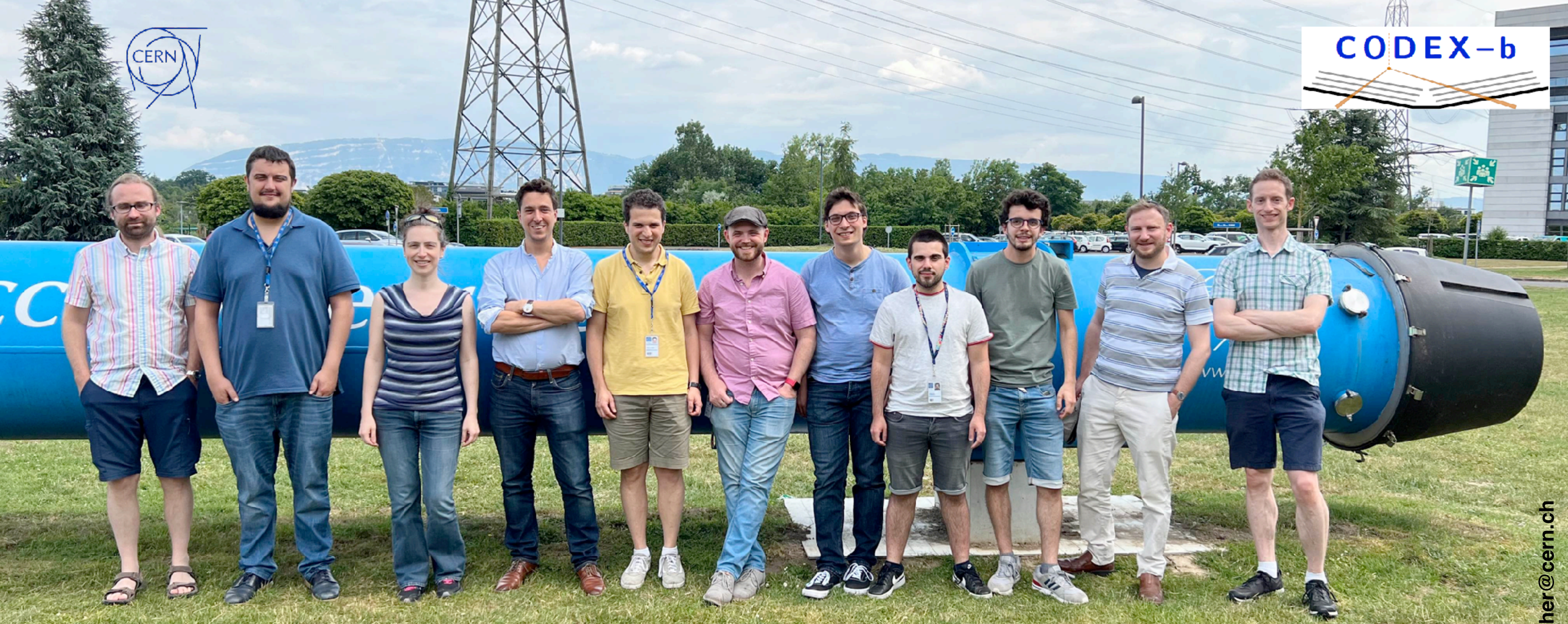


# Status of the CODEX-b(eta) experiment

**Titus Mombächer (CERN)**
on behalf of the CODEX-b collaboration

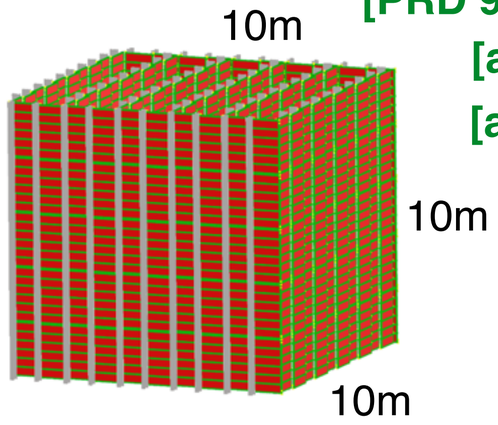
**PBC workshop**

25.03.2024

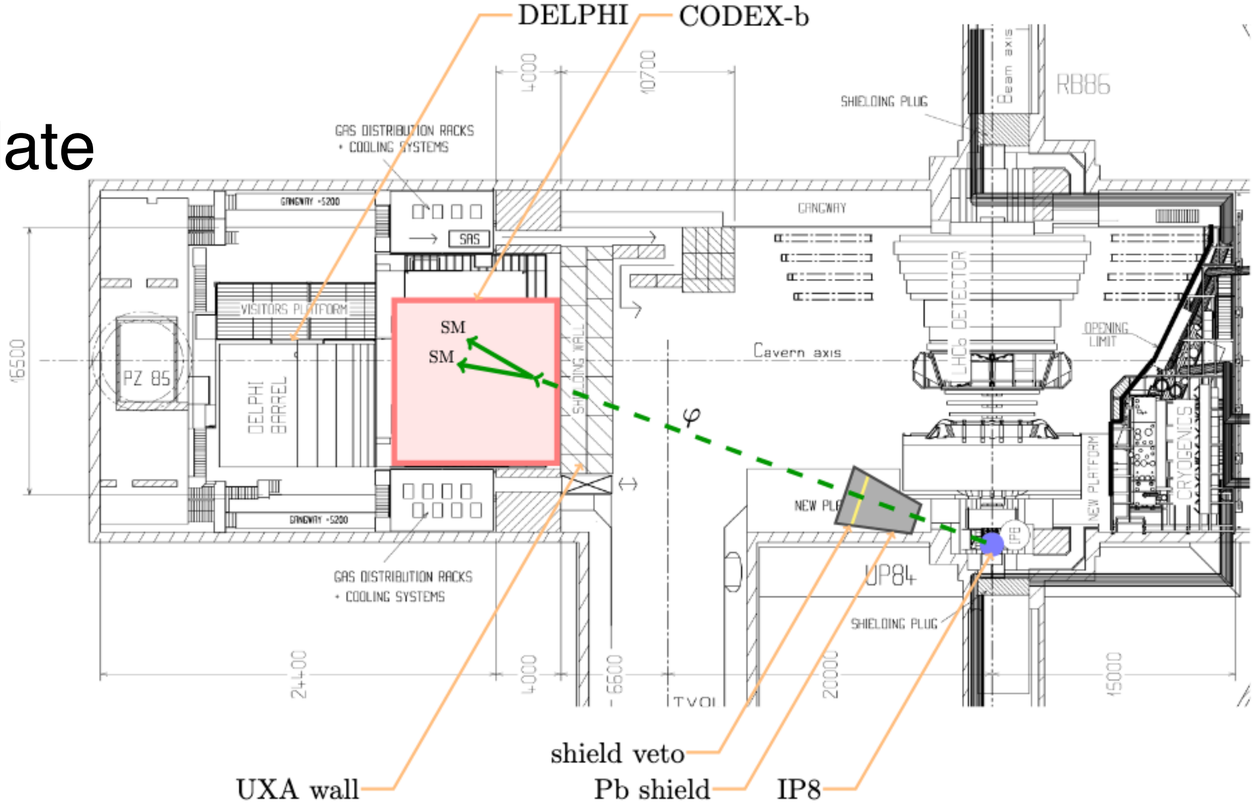
titus.mombacher@cern.ch

# **CO**mpact **D**etector for **EX**otics at LHC**b**

[PRD 97, 015023 (2018)]
[arXiv:1911.00481]
[arXiv:2203.07316]

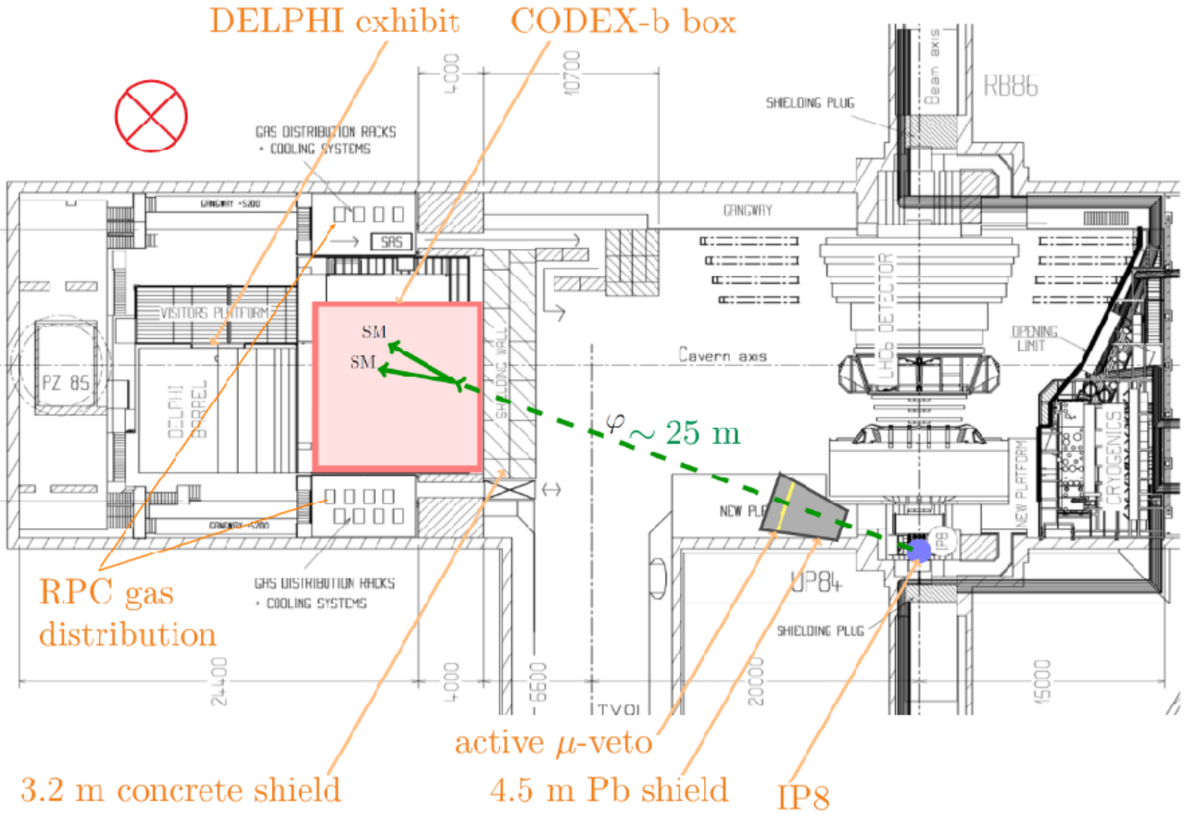


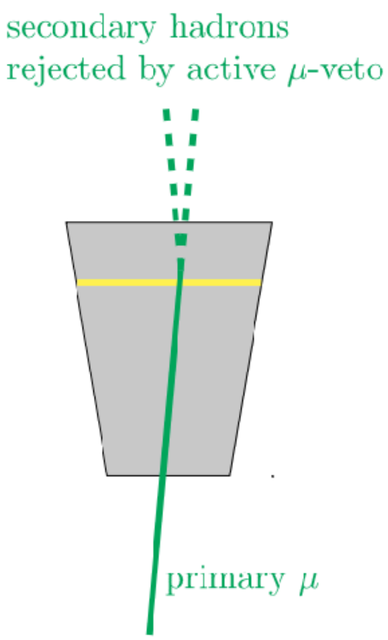

- Medium-scale transverse LLP detector
  - Proposed ~25m from IP8
  - From Run 4
- Cube instrumented with Resistive Plate Chambers (RPC)
  - Well known technology (ATLAS Upgrade system)
  - Medium size - low cost
- Zero background experiment
  - Shield + 3.2m concrete wall crucial
- Can integrate into LHCb trigger



# Backgrounds

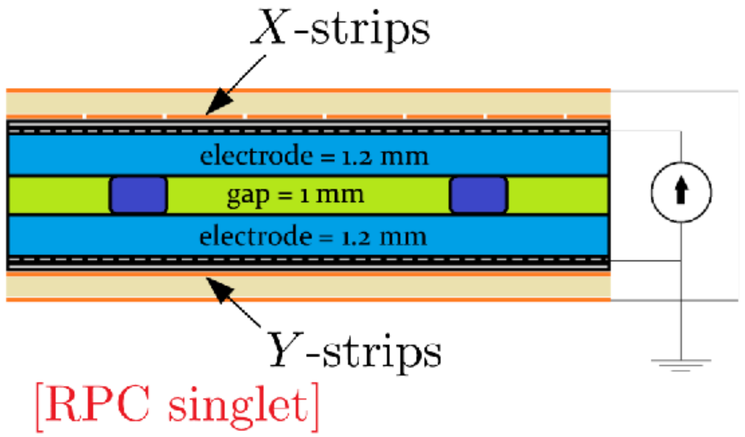
- Muons (primary/secondary)
- Neutrons, Kaons produced in passive shielding from Muons
- Decay in detector or produce particles from scattering
- ~$25\lambda$ shield (conservative) with active veto to veto primary muons
- Expect to go down to $\lesssim 1$ background over $300\,\text{fb}^{-1}$



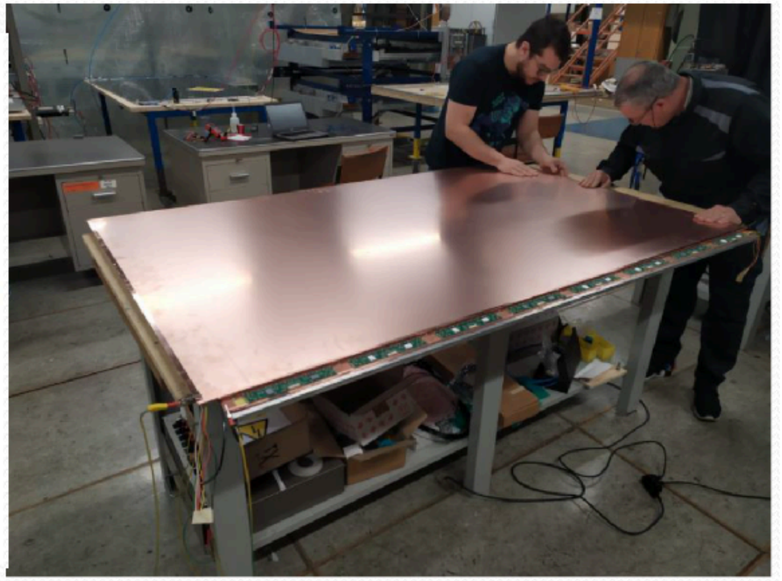



# Detector technology

- RPC's designed for Upgrade 1 of ATLAS Muon system „BIS78“
- Triplet of RPC’s, $\mathcal{O}(1\,\text{mm})$ spatial resolution in X-Y; timing resolution $\mathcal{O}(100\,\text{ps})$
- Cost-effective for large-area tracker like CODEX-b
- Well established procedures from ATLAS productions



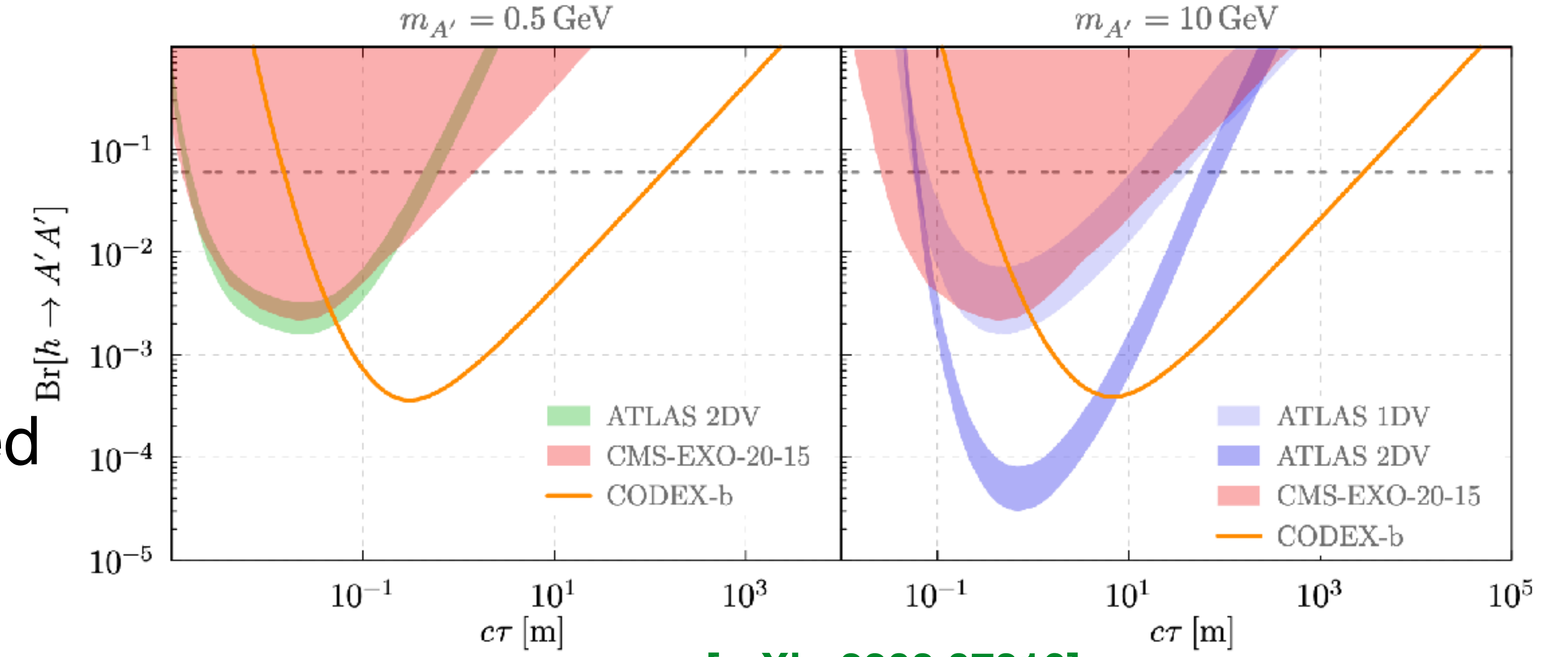
[RPC singlet]



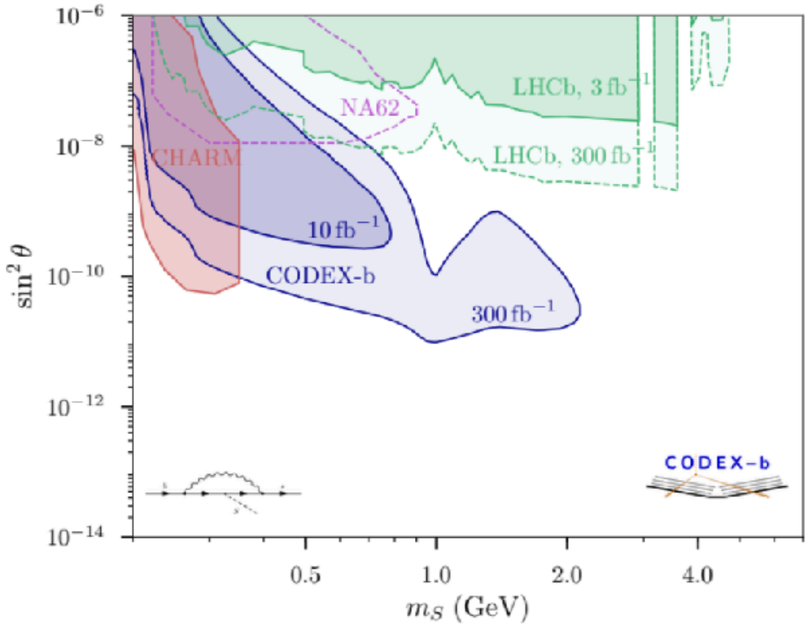
# Physics reach

- Many UV complete and minimal benchmarks studied
- Two representative examples:
  - $h \to A'A' \to 2e2e$
  - $b \to sS \to s\ell\ell$
- Unique reach from CODEX-b wrt existing experiments
- Find many more scenarios in the EoI

[arXiv:1911.00481]




[arXiv:2203.07316]

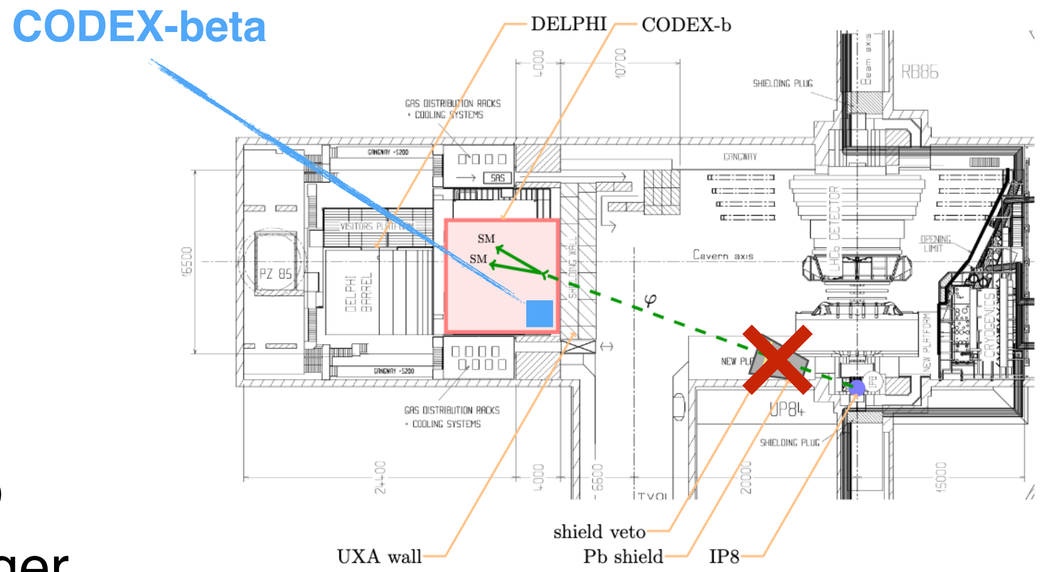


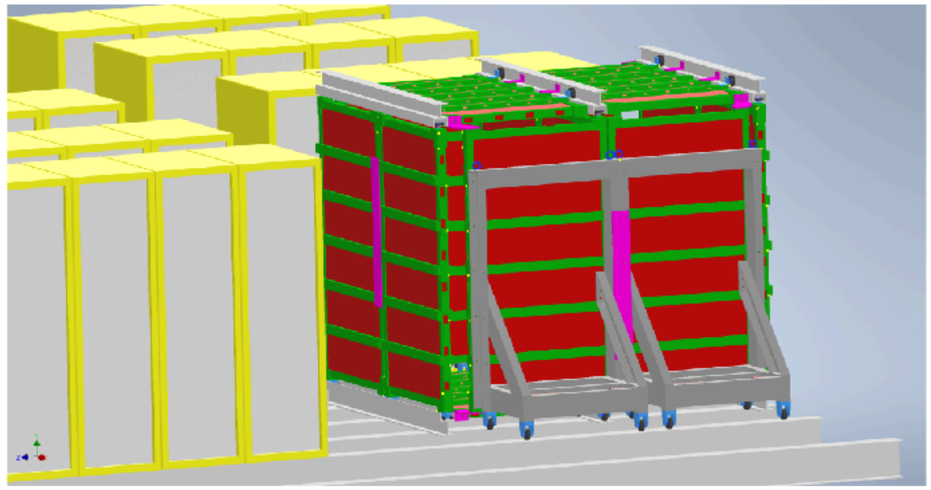
# The CODEX-b collaboration

- 53 Authors
- 22 Institutes
- 13 countries
- And growing!
- Last year had our first collaboration week!

# CODEX-beta - a demonstrator

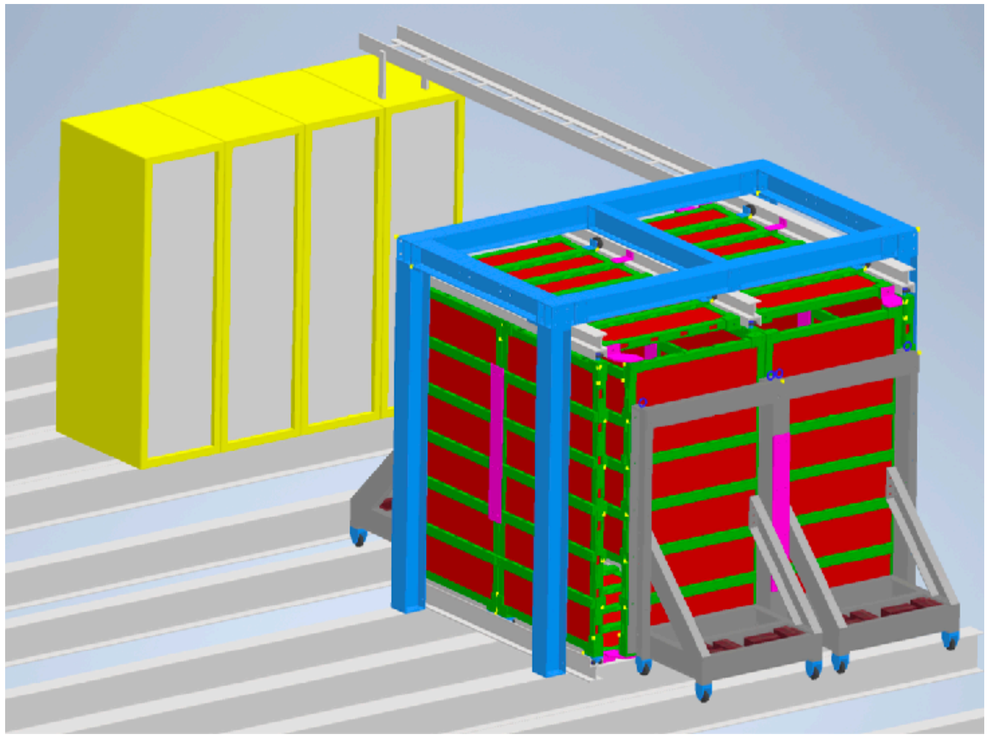
- Small $(2 \times 2 \times 2)\,\mathrm{m}^3$ detector to demonstrate core principles:
  - Demonstrate the ability to reconstruct SM backgrounds and validate simulation
  - Guarantee zero-background, optimise active veto
  - Demonstrate seamless integration into LHCb trigger
  - Demonstrate RPC as suitable baseline tracking technology for CODEX-b
  - Demonstrate suitability of mechanical support for RPC's and scalability for CODEX-b
- Build expertise within collaboration

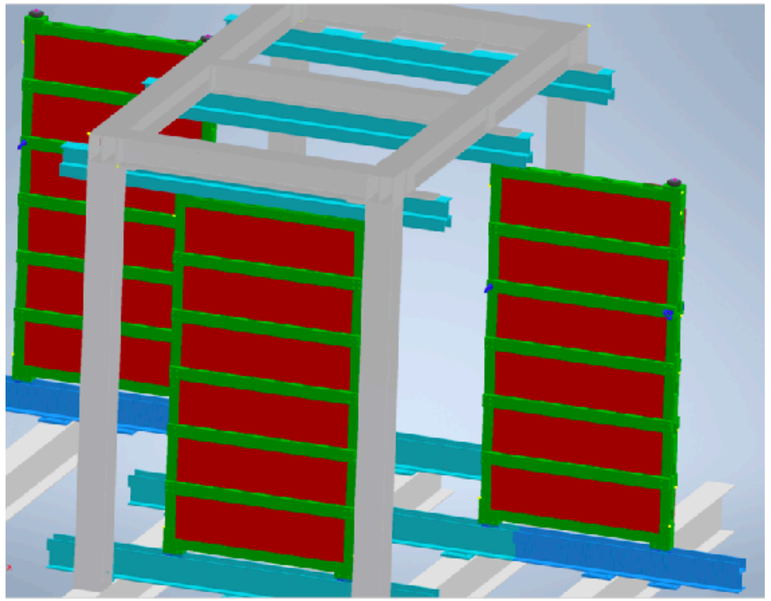


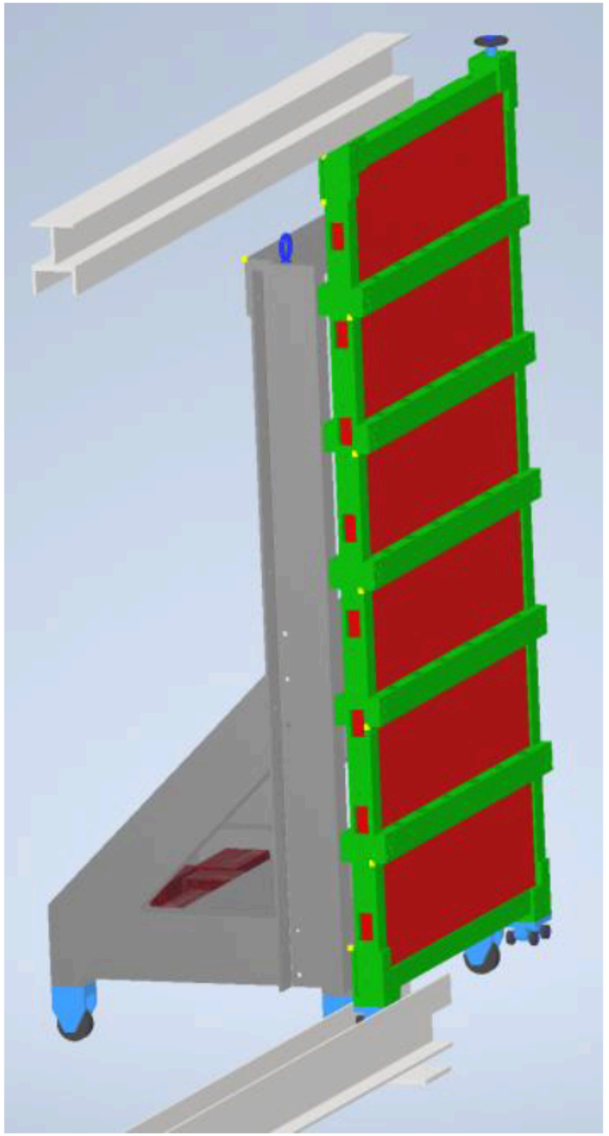



# CODEX-beta design

- 2 RPC triplets per face, one central layer: 42 RPC’s
- Tight space constraints, chambers rolled in with carts







# CODEX-beta overall status

- **Official status: time-limited R&D project within LHCb**
  - Thanks to LHCb colleagues for fruitful discussions!
  - Installation plan to be published in the next months
- RPC production more than half way
- Frames for triplets producing in full swing
- Finalising outer structure and steps for installation in LHCb cavern
- Simulation and reconstruction efforts advancing

**CODEX-$\beta$ Installation Plan**

The CODEX-b team

(Dated: February 2024)

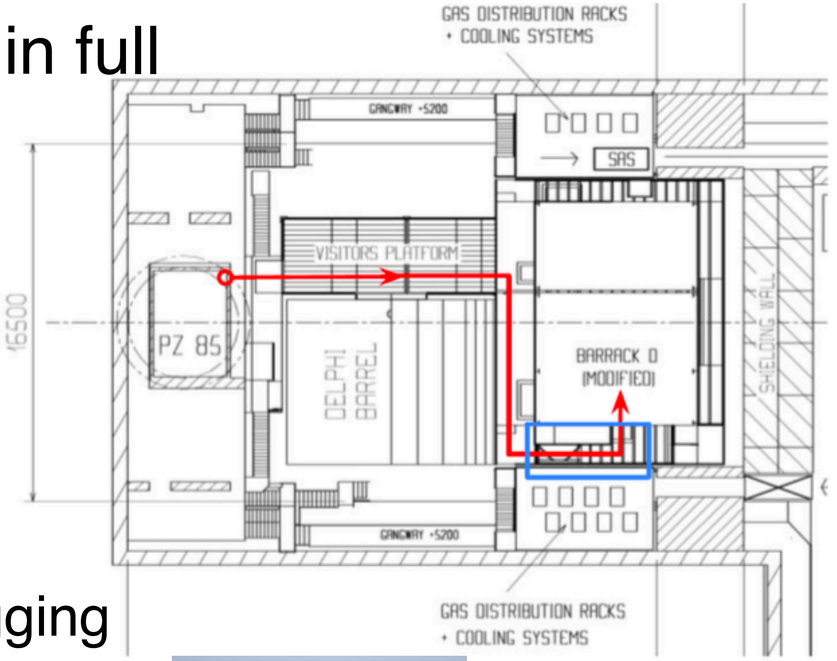
67p document iterated with LHCb

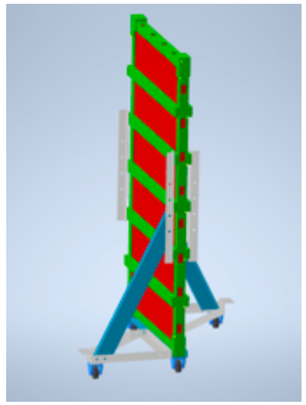
# RPC construction

- Singlet and triplet assembly @CERN in several steps
  - Glue strip panels to backplanes
  - Apply ~100 resistors to connect to ground
  - Attach readout cards
  - Close 2 planes around one gas gap
  - Insert 3 singlets into one frame
- Test at each step of the assembly
  - Test all resistors and connections
  - Noise tests
  - Triplet together for coincidence test and efficiency test with Muons
- **22/42 RPC's already assembled!**

# Frame construction and preparation of installation steps

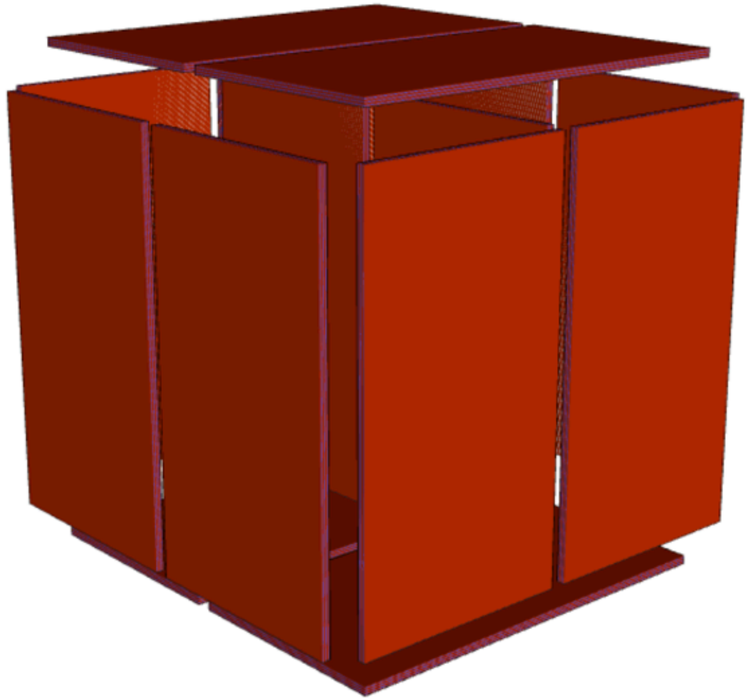
- Mechanical frame production in full swing in Cincinnati
  - First prototype worked quite well
  - 3 refined frames produced
  - **4/14 frames @CERN**
- Finalising the plans for the concrete installation in D1
  - Manoeuvring plans with CERN rigging experts
  - Gas system being set up by CERN gas group in summer



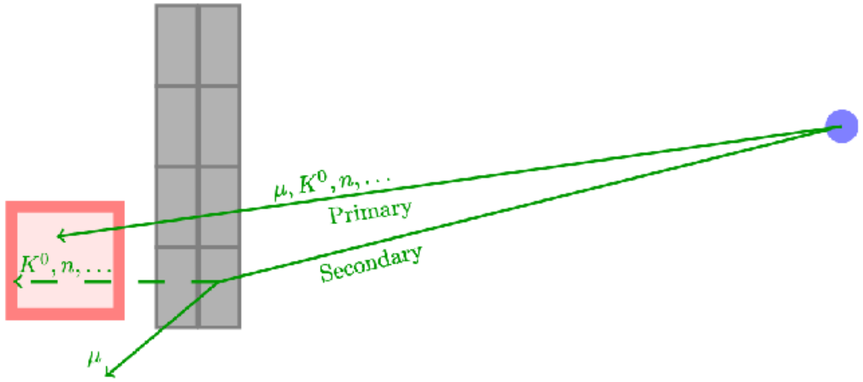
# DAQ, Software and simulation

- Aim: integrate into/trigger LHCb event
  - RPC ATLAS design - need to reformat signal to LHCb DAQ
  - Discussing with candidates for DAQ development
  - Clear path for writing “CODEX-beta” trigger
  - Mitigation: run CODEX for background validation without LHCb
- Reconstruction
  - Expected hit rate even without shield <100 Hz (compared to 30MHz main LHC experiments) - simplifies DAQ situation and allows playground for tracking algorithms
  - No magnetic field - simple straight line fits and vertexing
- Simulation
  - Geometry description ready
  - Working on description of cavern and digitisation of hits

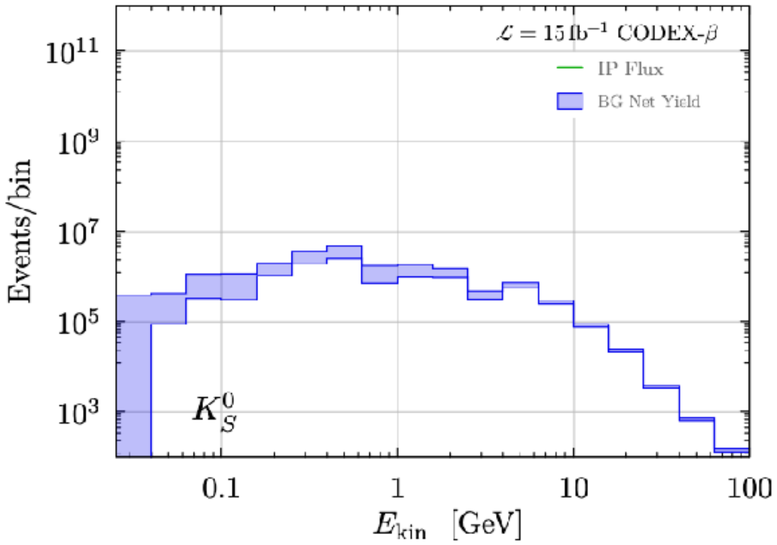


# Towards measurements with CODEX-beta

- Crucial to understand and properly simulate background
- Measure fluxes and compare to simulation
  - Exploit decay vertex distribution and opening angles to test energy spectrum, acceptance and path length effects
  - Calibrate background simulation
  - Optimisation of shielding design
- Closure test with $K^0_S$ lifetime:
  - Many boosted $K^0_S$ produced in UXA wall
  - Fit $K^0_S$ lifetime from vertex and opening angle distribution of $K^0_S \to \pi^+\pi^-$
- Also some New Physics searches possible
  - Publication with updated realistic prospects for CODEX-beta analyses in progress

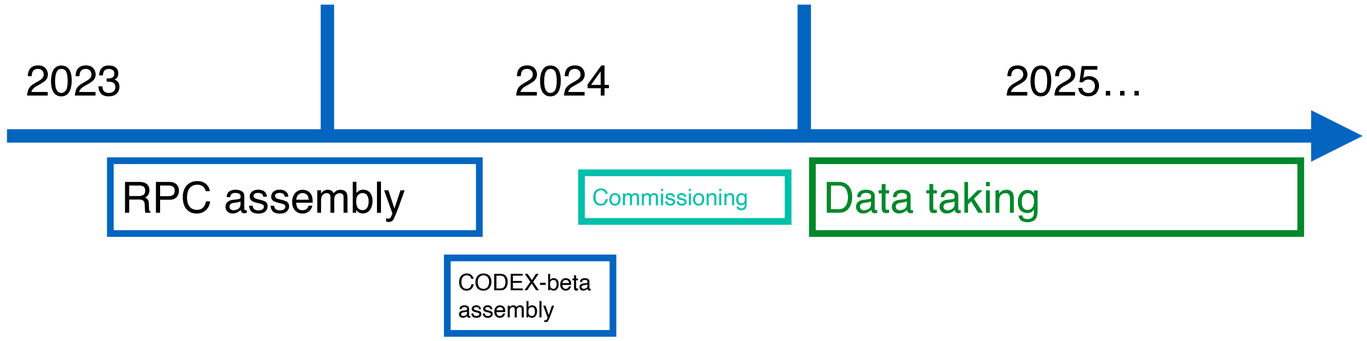



GEANT4-based simulation

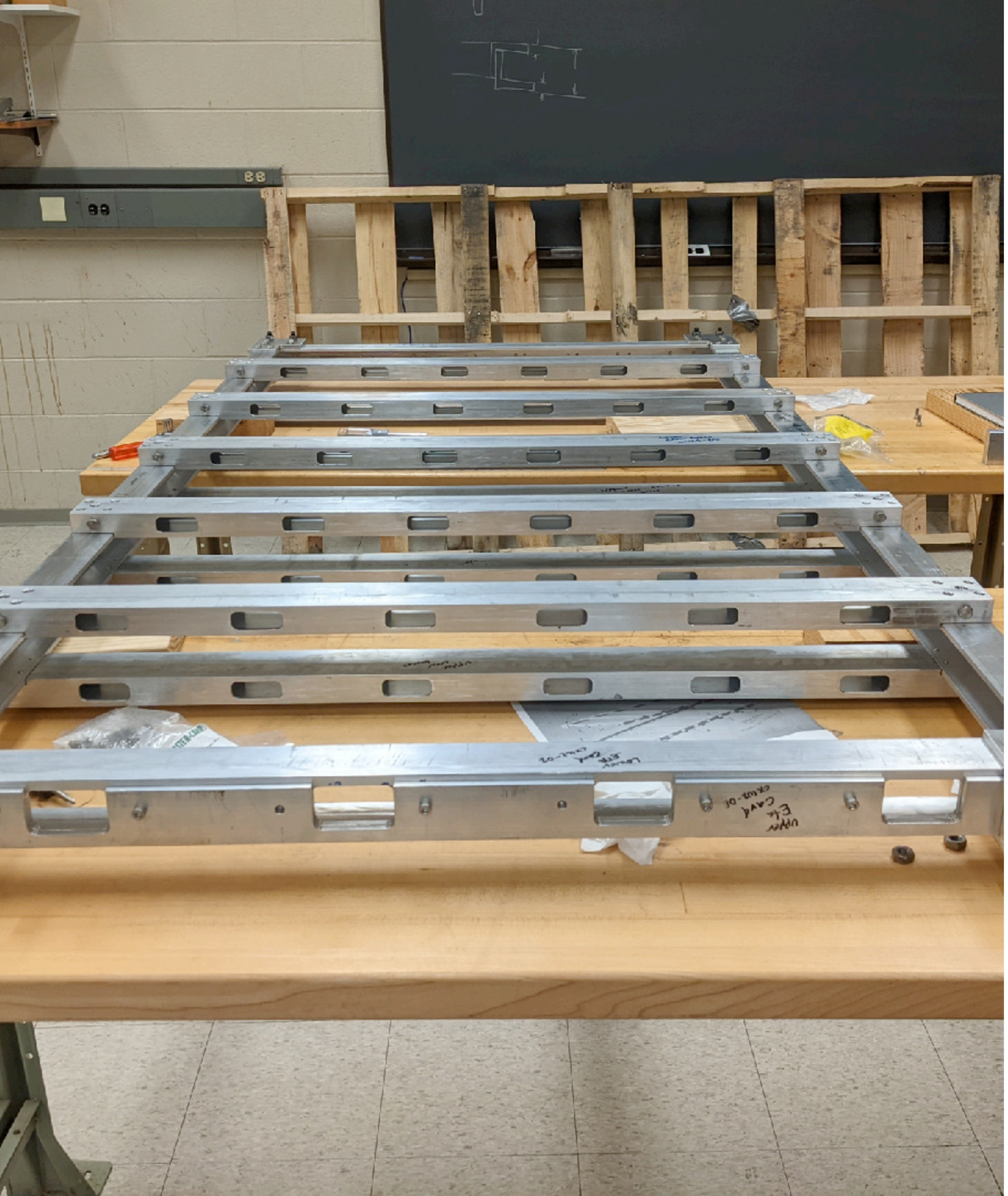


# Summary

- CODEX-b will offer excellent physics reach for small cost (total ~10M€)
- CODEX-beta for Run 3 **approved by LHCb** as time-limited R&D project
- Construction progressing steadily
  - RPC production half way
  - Now concentrating on finalising installation steps
  - Advancing DAQ, reconstruction and simulation activities
  - Support from LHCb, ATLAS, ANUBIS, CMS colleagues
- Aim to start commissioning this year to take data in 2025

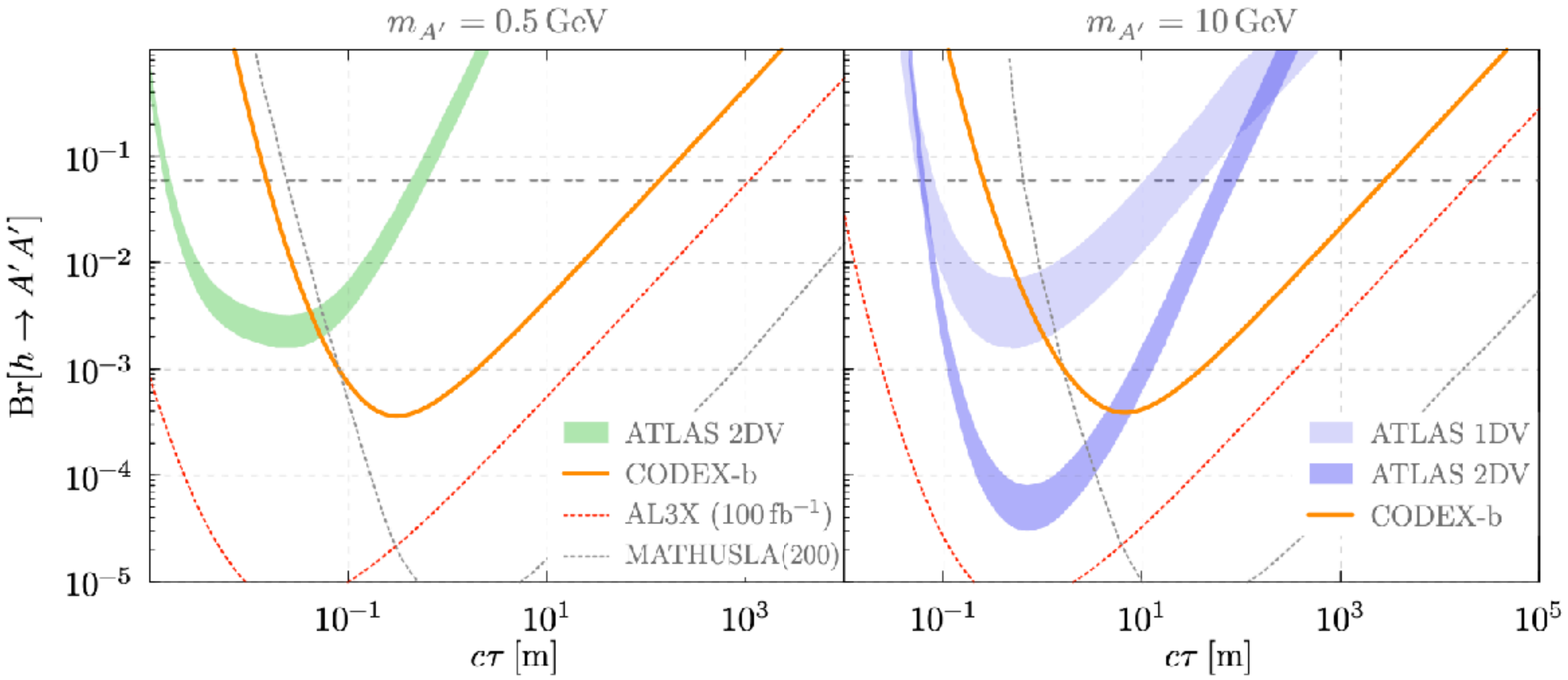

**Collaborators welcome!**

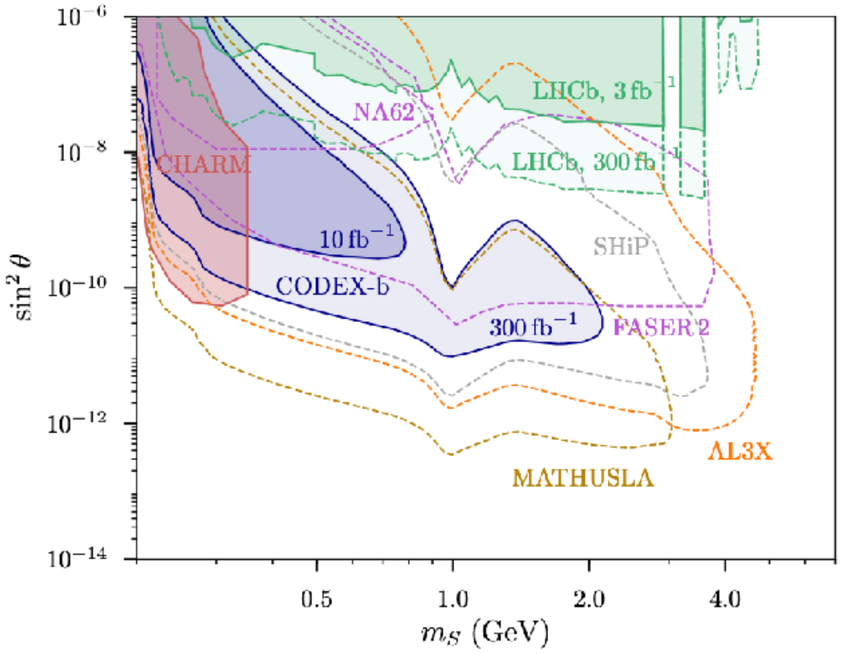


# Backup

[arXiv:1911.00481]

# Comparison to other proposals



[arXiv:1911.00481]

# Backgrounds with nominal scenario

| BG species | Particle yields | | | Net yield |
|---|---|---|---|---|
| | Net ($E_{\text{kin}}^{\text{neutral}} > 0.4\,\text{GeV}$) | Shield veto rejection (total) | Shield veto rejection ($\pm/0$ correlation) | |
| $\gamma$ | $0.54 \pm 0.12$ | $(8.06 \pm 0.60) \times 10^4$ | $(2.62 \pm 1.03) \times 10^3$ | – |
| $n$ | $58.10 \pm 4.63$ | $(4.59 \pm 0.15) \times 10^5$ | $(3.44 \pm 0.51) \times 10^4$ | |
| $n$ ($> 0.8\,\text{GeV}$) | $2.78 \pm 0.25$ | $(1.03 \pm 0.06) \times 10^5$ | $(7.45 \pm 1.92) \times 10^3$ | $\lesssim 1$ |
| $\bar{n}$ (no cut) | $(3.24 \pm 0.72) \times 10^{-3}$ | $34.40 \pm 25.80$ | $(7.12 \pm 2.19) \times 10^{-2}$ | $\ll 1$ |
| $K_L^0$ | $0.49 \pm 0.05$ | $(1.94 \pm 0.74) \times 10^3$ | $54.40 \pm 19.20$ | $\lesssim 0.1$ |
| $K_S^0$ | $(6.33 \pm 1.39) \times 10^{-3}$ | $93.90 \pm 45.80$ | $0.74 \pm 0.19$ | $\ll 1$ |
| $\nu + \bar{\nu}$ | $(5.69 \pm 0.00) \times 10^{13}$ | $(7.35 \pm 0.12) \times 10^6$ | $(7.31 \pm 0.11) \times 10^6$ | |
| $p^{\pm}$ | $(2.07 \pm 0.26) \times 10^2$ | $(9.24 \pm 0.36) \times 10^5$ | $(9.24 \pm 0.36) \times 10^5$ | – |
| $e^{\pm}$ | $(4.53 \pm 0.02) \times 10^3$ | $(4.38 \pm 0.02) \times 10^7$ | $(4.38 \pm 0.02) \times 10^7$ | – |
| $\pi^+$ | $34.70 \pm 2.27$ | $(2.96 \pm 0.20) \times 10^5$ | $(2.96 \pm 0.20) \times 10^5$ | – |
| $\pi^-$ | $31.40 \pm 2.12$ | $(2.68 \pm 0.19) \times 10^5$ | $(2.68 \pm 0.19) \times 10^5$ | – |
| $K^+$ | $0.83 \pm 0.30$ | $(3.08 \pm 1.24) \times 10^3$ | $(3.08 \pm 1.24) \times 10^3$ | – |
| $K^-$ | $0.23 \pm 0.12$ | $(1.12 \pm 0.63) \times 10^3$ | $(1.12 \pm 0.63) \times 10^3$ | – |
| $\mu^+$ | $(1.04 \pm 0.00) \times 10^6$ | $(1.04 \pm 0.00) \times 10^{10}$ | $(1.04 \pm 0.00) \times 10^{10}$ | – |
| $\mu^-$ | $(8.07 \pm 0.01) \times 10^5$ | $(8.07 \pm 0.01) \times 10^9$ | $(8.07 \pm 0.01) \times 10^9$ | – |

Nothing remains