CODEX-b: status and plans

COmpact Detector for EXotics at LHCb

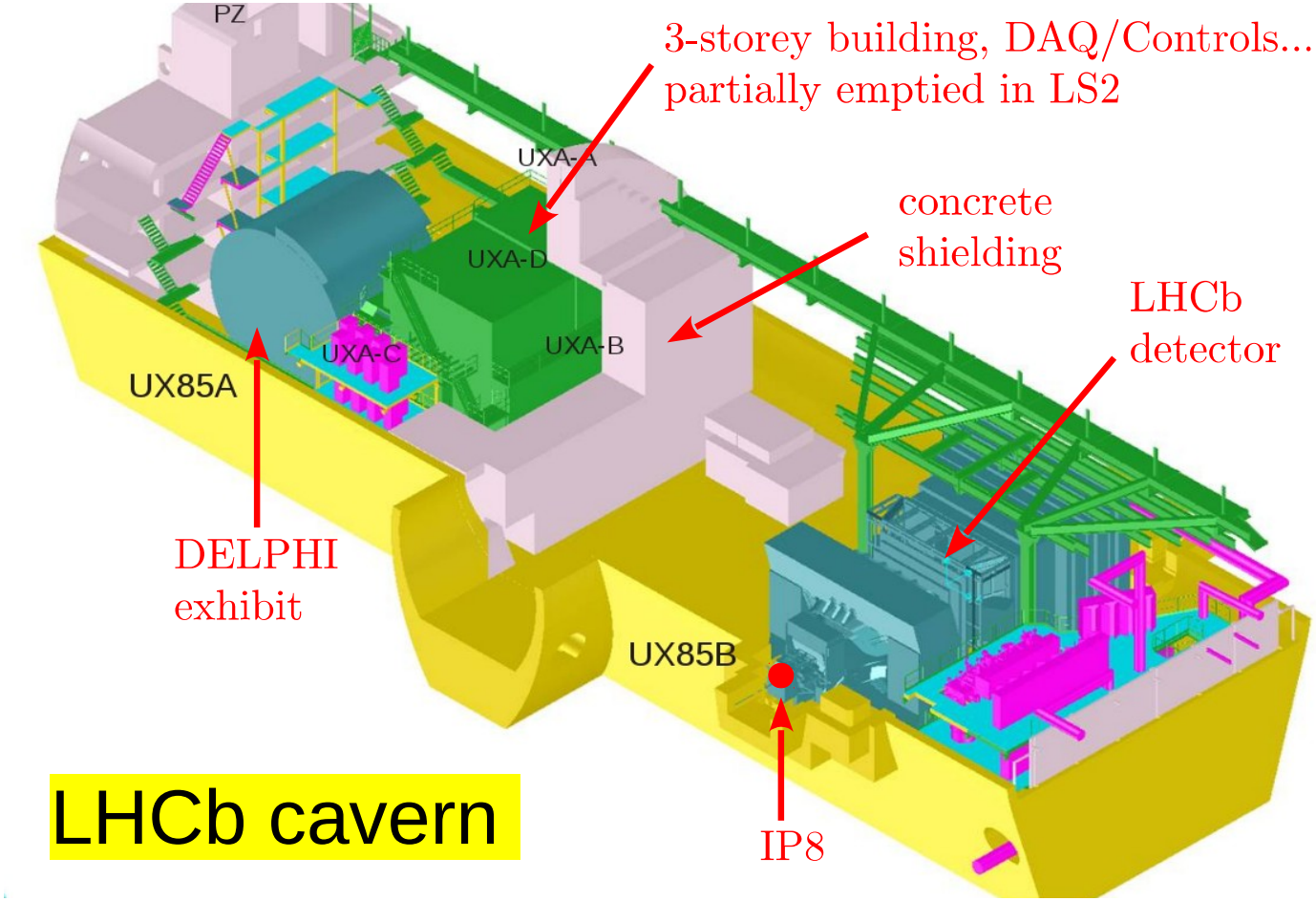
[1708.09395]

Biplab Dey

for the CODEX-b WG

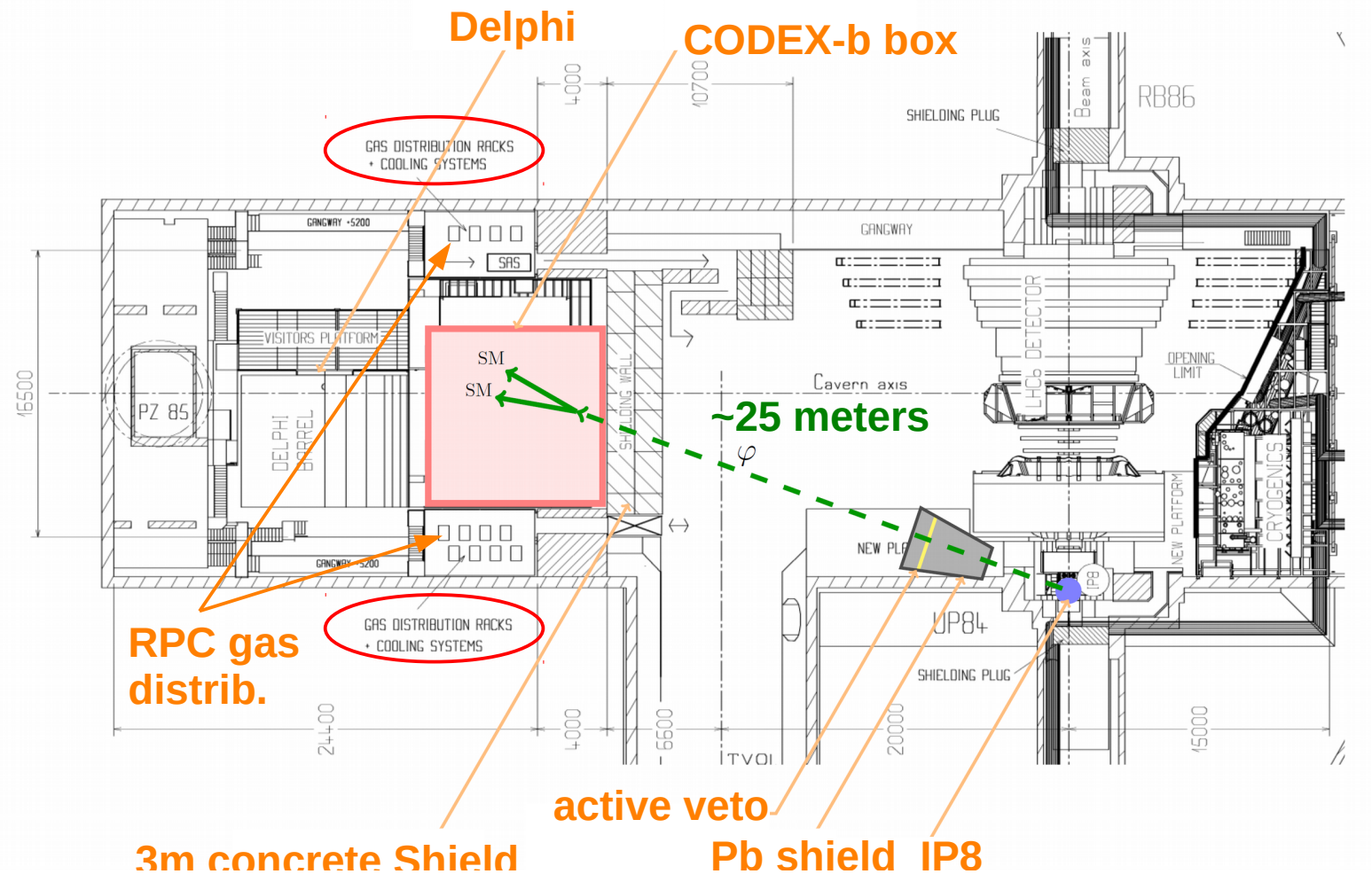
LLP workshop, 29th May 2019, CERN

Reminder: the CODEX-b proposal at Point 8



- DAQ racks in UXA-D move to surface for Run 3. Space available.
- Shielded, underground, $10 \times 10 \times 10$ m box, around 25 m from IP.
- Instrument with RPC tracking layers $\Rightarrow$ CODEX-b

LHCb cavern: another view



- If DELPHI is removed, access to even 20 × 10 × 10 m box.
- Angular acceptance ∼ 1%.

Physics reach: global snapshot

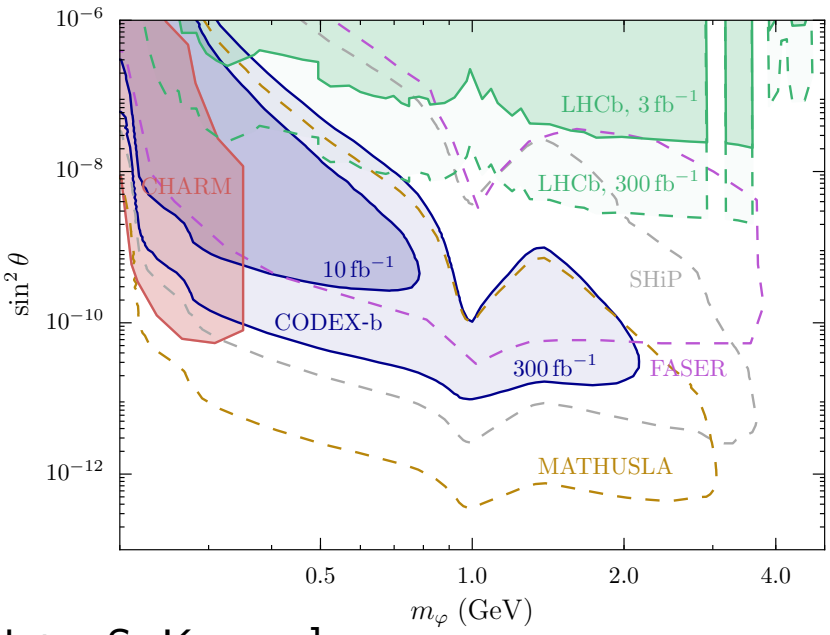
- CODEX-b: complementary with other proposals with competitive reach/$ in all four portals
  - Scalar portal → Dark Higgs/scalars
  - Neutrino portal → Heavy Neutral Leptons
  - Pseudoscalar portal → Axion-like particles
  - Vector portal → Dark photon
- Some snapshots...

  (see Gaia F.'s epic ESPP slides as well)

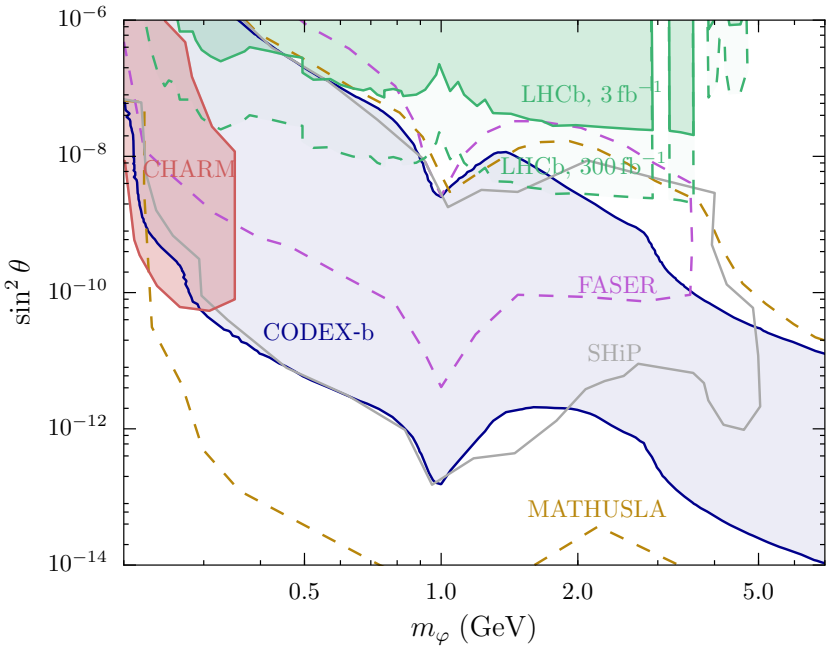
Higgs-scalar mixing

- Minimal extension of Higgs sector: $\mathcal{L} \sim \mu\varphi HH^\dagger + \frac{\lambda}{2}\varphi^2 HH^\dagger$
- Scalar singlet w/ Higgs-φ mixing angle $\theta \ll 1$. $c\tau \propto 1/\theta^2$
- Run1 LHCb has searched in $B \to K^{(*)}\varphi(\to \mu^+\mu^-)$. CODEX-b nicely complement in the longer lifetime regime. *Tag with LHCb events.*
- Many more modes if $\lambda \neq 0$. (eg. Higgs$\to \varphi\varphi$). Unique coverage

$\lambda = 0$:



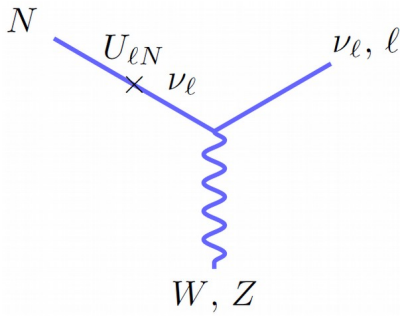
$\lambda = 1.6 \times 10^{-3}$:



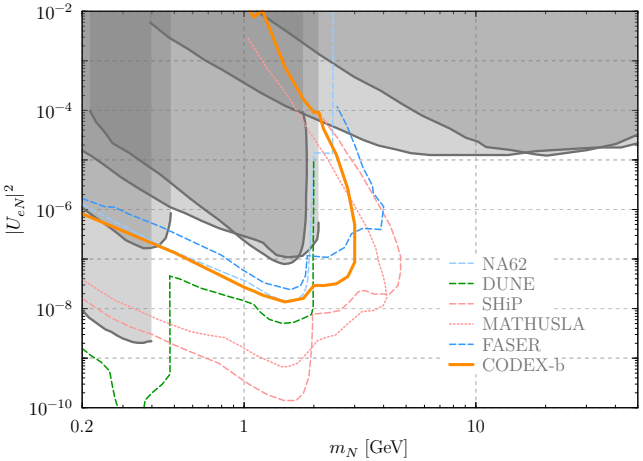
[plots: S. Knapen]

Heavy Neutral Leptons (HNLs)

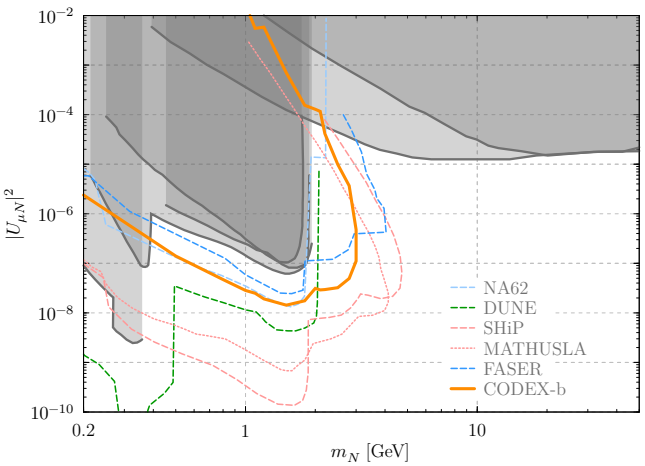
- Neutrinos oscillate and therefore have masses $\Rightarrow$ not in SM.
- RH Majorana HNL mass terms: $\mathcal{L} \sim YN(H \cdot L) + \overline{N}MN$
- $m_{\rm Dirac} \sim Y\langle v\rangle_H \ll M_N$. Active-sterile mixing angle: $U \sim \frac{m_{\rm Dirac}}{M_N} \ll 1$. $m_\nu \sim U^2 M_N \sim 0$
- Production/decay similar to neutrinos folded with $U_{\ell N}$
- Single HNL coupling either to $e/\mu/\tau$:



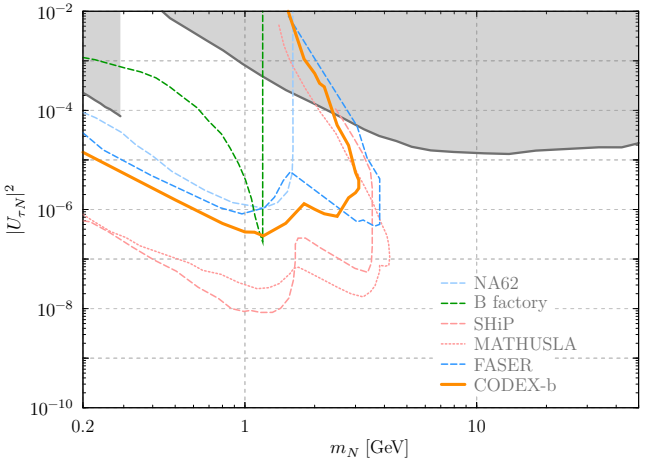
e:



μ:



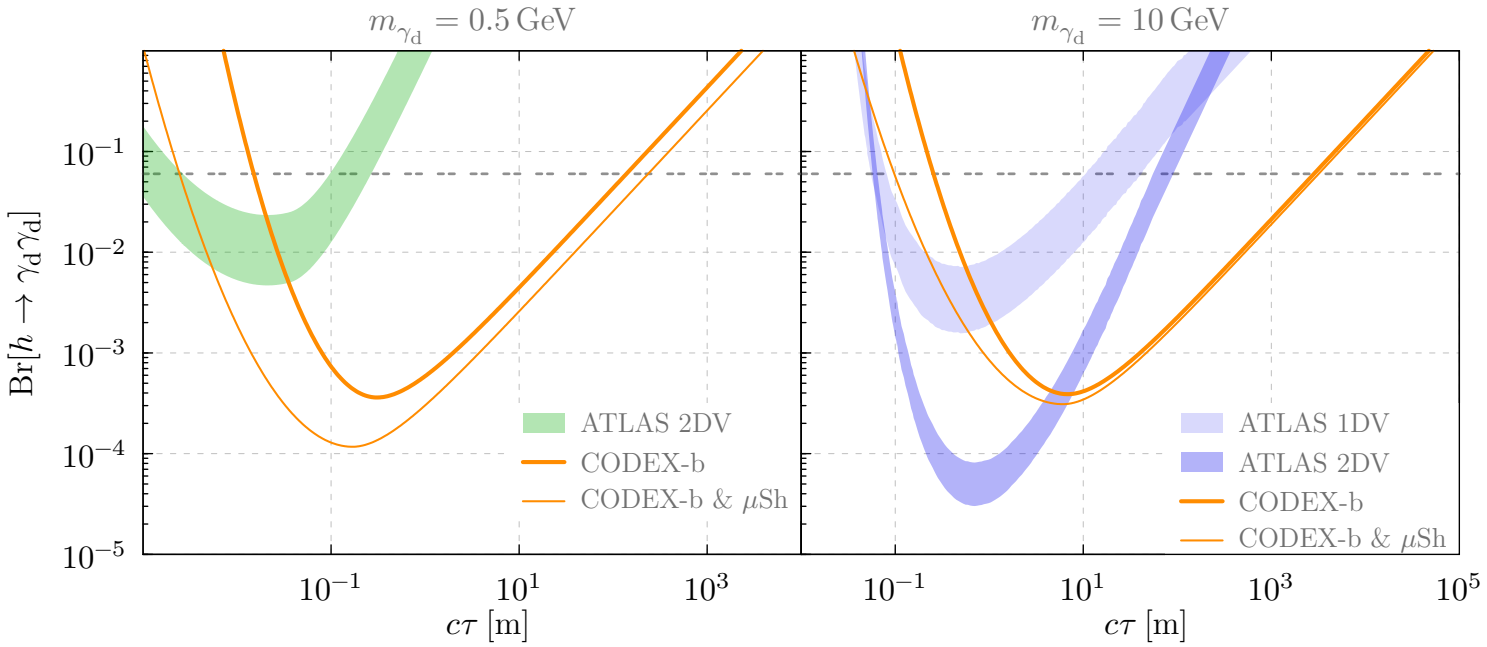
τ:



[plots: D. Robinson]

Dark photons via exotic Higgs decays

- A'-γ mixing + coupling to Higgs: $\mathcal{L} \supset \epsilon F'_{\mu\nu} B^{\mu\nu} + y h F'_{\mu\nu} F'^{\mu\nu}$
- Short $c\tau$ region: D^* decays + inclusive $A' \to \mu^+\mu^-$ at LHCb.
- Longer lifetimes: CODEX-b does better than ATLAS disp. dijet searches (proj. to HL-LHC)

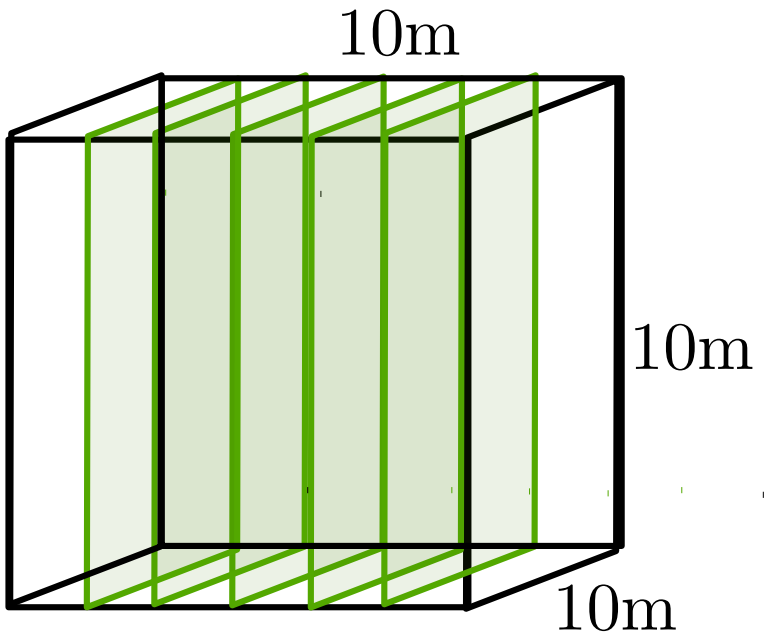


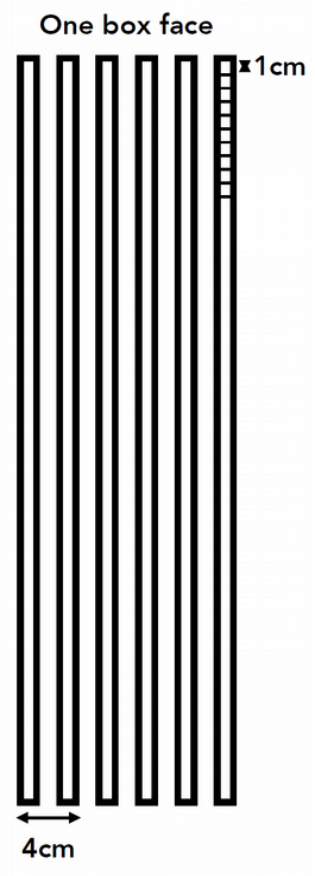
[plots: S. Knapen]

ALPS/Dark glueballs: placeholder

More reach plots coming soon, in preparation for EOI...

Reminder: baseline tracking geometry





- 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

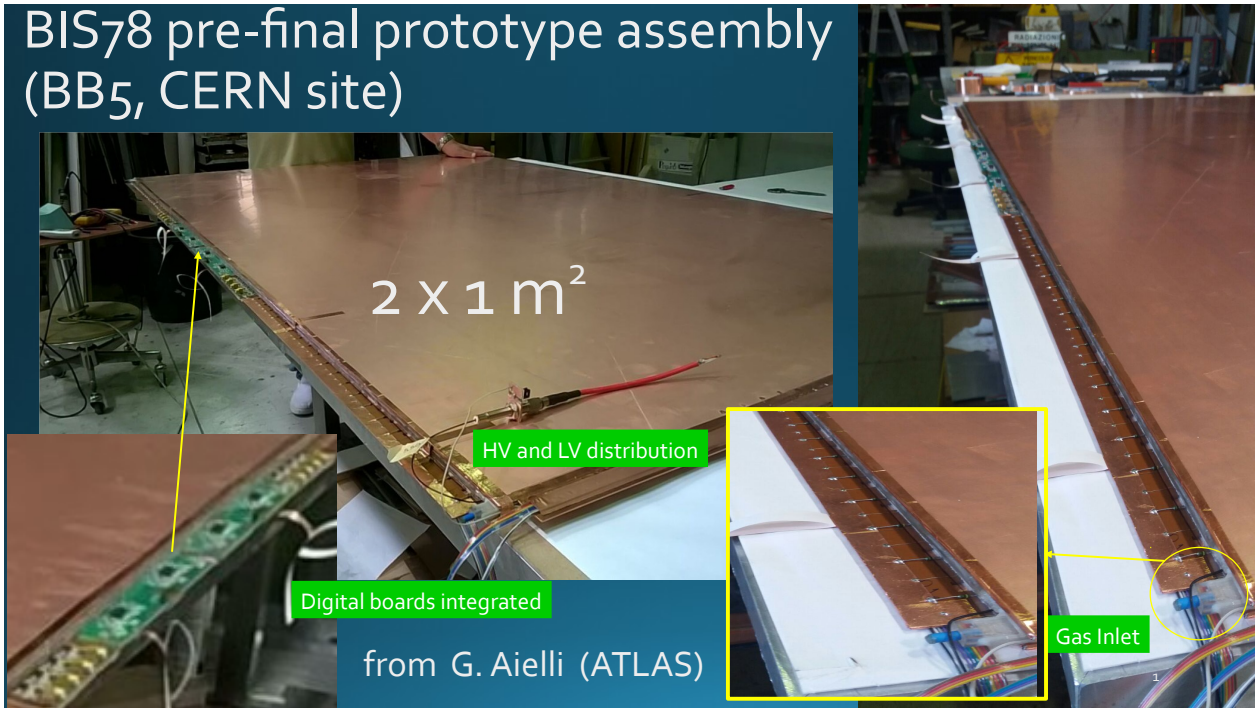
- 5 equally spaced triplets along the depth to minimize distance between reconstructed vertex and 1st measurement. $\epsilon_{\text{tracking}} \sim \mathcal{O}(1)$.
- 50-100 ps timing from RPC's foreseen for mass reconstruction

Hardware proposals

- Discussions with experts within and outside LHCb earlier this year.
- Electronics must be easily integrable within the upgrade LHCb R/O.
- Re-use of current LHCb muon (MWPC) M1 station chambers considered.
- RPC technology+expertise from ATLAS Muon Upgrade as baseline.
- LHCb online experts confirm ATLAS RPC board that talks to FELIX (ATLAS Upgrade R/O), can talk to the LHCb TELL40 board (LHCb Upgrade R/O) $\Rightarrow$ critical!

RPC's from ATLAS Muon Upgrade

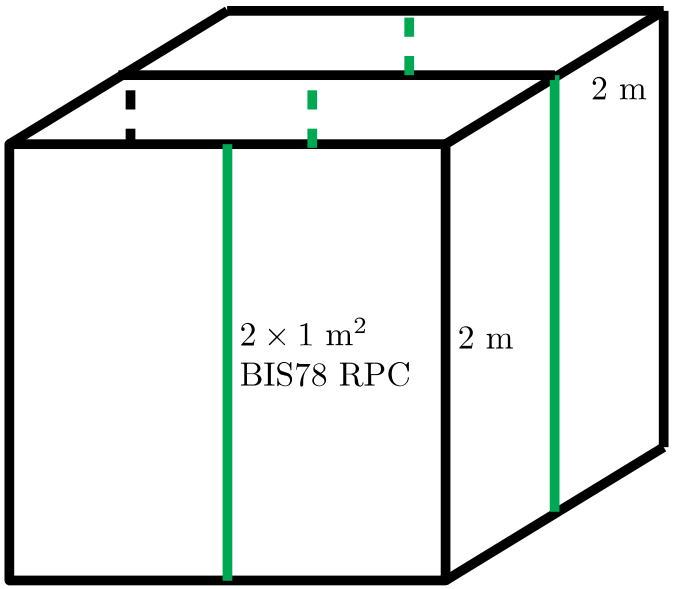
- BIS78 Phase I (LS2) new RPC's: 1mm gas gap, 1.2mm bakelite electrodes, 25 mm strips ($\sigma \sim 1$ cm w/ charge-centroid analysis)
- Environment-friendly gas, 6.5kV w/ new FE, $\sigma_t \sim 0.4\,\mathrm{ns}$/singlet,



- R&D on BI Phase II RPC's for HL-LHC based on BIS78
- 20mm strips, $3 \times 0.5\mathrm{m}^2$ pads
- Perfect timing for CODEX-b in LS3!

Demonstrator for Run 3

- Our USP: tag CODEX-b event with LHCb activity.



- $2 \times 2 \times 2$ m^3 demonstrator for Run 3 $\Rightarrow$ 1/25 of full detector
- 6 faces + 1 inner station $\Rightarrow$ 14 BIS78 triplet chambers.
- Enough space already in D1 area of the cavern once DAQ racks shifted out before EOY.

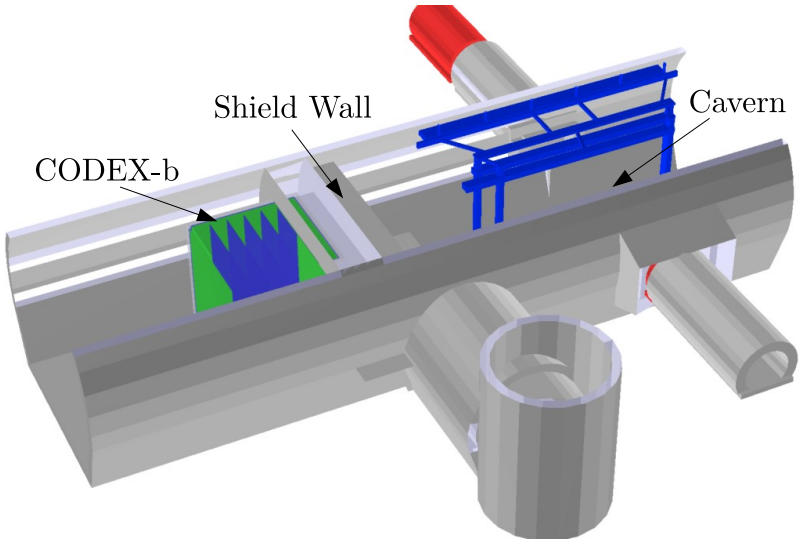
- Main goal: reconstruct K_L^0's in the volume from IP8 during 2021-23.

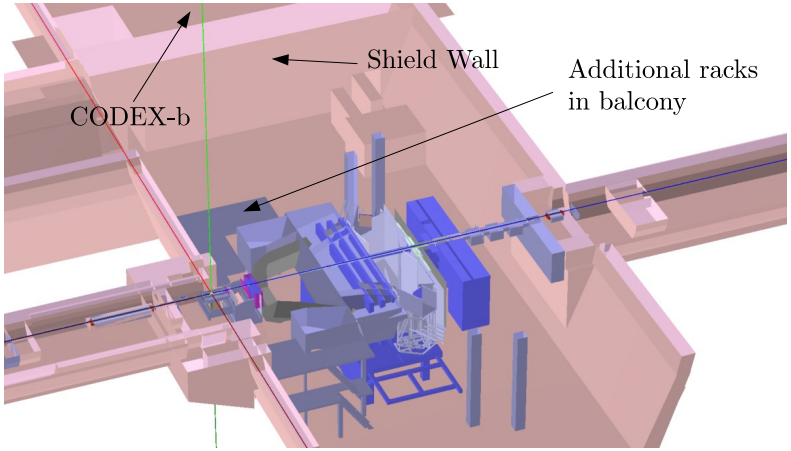
Managerial issues for demonstrator

- CODEX-b mini-workshop in March'19 at CERN.
- LHCb management recommended for an EOI targeting LHCb week in September'19.
- Part of LHCb U2 physics case [1808.08865]
- ATLAS RPC group needs formal "blessing" from ATLAS management.
- Ongoing discussions with LPHNE engineers/technicians for mechanics and chamber construction.
- Overall cost for demonstrator expected around sub-200K Euro.

Word on simulation/tracking activities

- We're a zero-background experiment. Scattering/shielding from cavern infrastructure is important.
- CODEX-b volume is outside LHCb acceptance, not fully realistic in current simulation.





- Data-driven validation of background levels + tracking studies ongoing (not for today).

Summary and looking ahead

- Slow but steady progress on several fronts – hardware, simulation, theory.
- We've a concrete plan for baseline hardware using ATLAS Upgrade RPC's
- Focusing on installing demonstrator by end-2021 – collect data over Run3.
- Working towards an EOI in Fall'19 for review within LHCb.

List of collaborators

- Theorists: D. Robinson, S. Knapen, M. Papucci, H. Ramani, J. Evans
- LHCb: J. Lee (CERN summer student), V. Gligorov, R. Le Gac, S. Stone, V. Vagnoni, M. Sokoloff, P. Ilten, M. Williams, M. Witek, V. Tisserand, E. B. Haim, O. A. De Aguiar Francisco, B. Dey, V. Coco, R. Dumps, X. Vidal, H. Schindler
- Helpful discussions with computing/sim/detector experts: M. Frank, G. Corti, B. Couturier, D. Muller, G. Aielli and R. Cardarelli(ATLAS RPC), A. Cardini, M. Palutan, N. Neufeld, R. Lindner, and others
- Very much open to the LLP community to join us!