CODEX-b: status and plans

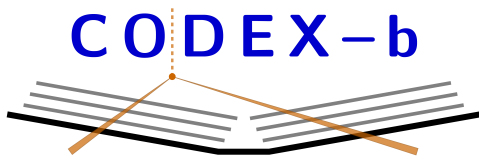
COmpact Detector for EXotics at LHCb

[1708.09395, 1901.09966(PBC BSM WG), 1909.xxxxx (EoI)]

Biplab Dey

+ Vava Gligorov, Simon Knapen, Michele Papucci, Dean Robinson

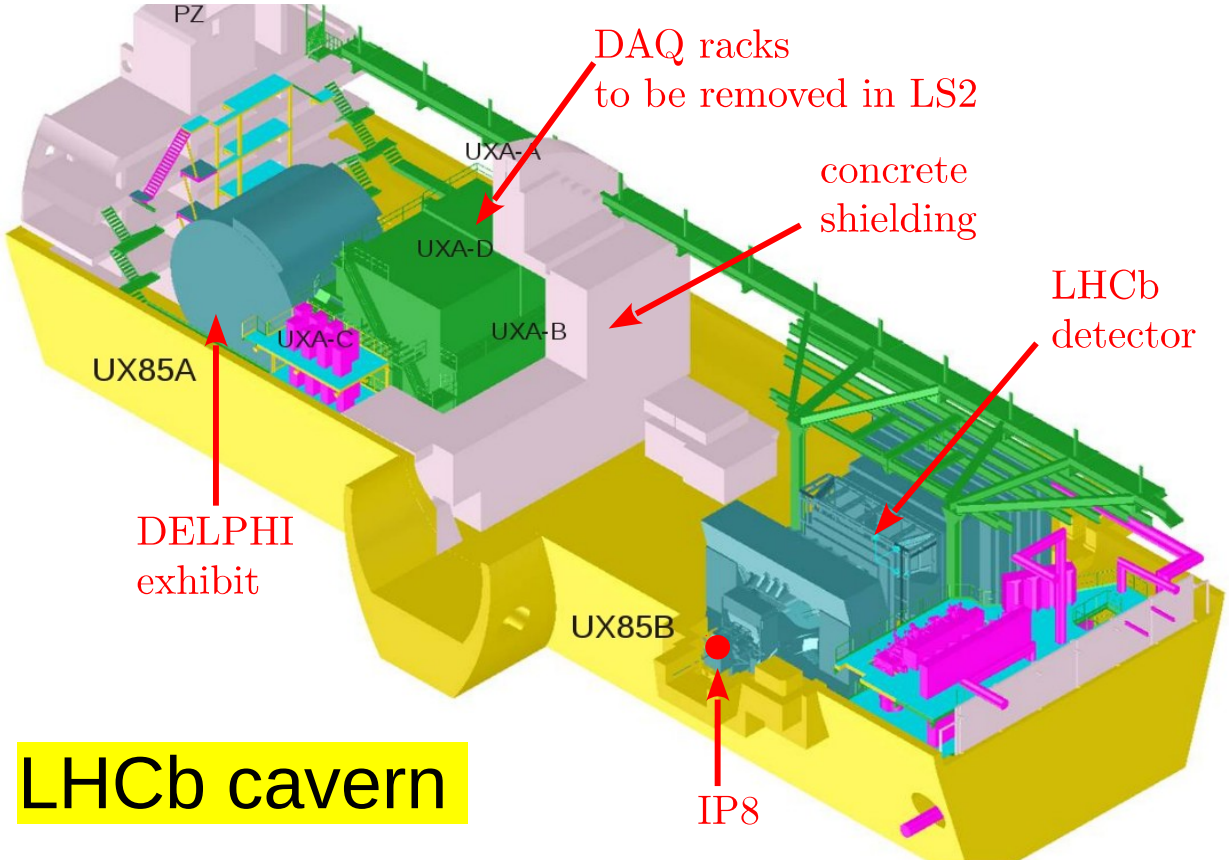
(for the CODEX-b WG)



EPS-HEP, 12^{th} July 2019, Ghent

Outline

CODEX-b proposal in LHCb cavern

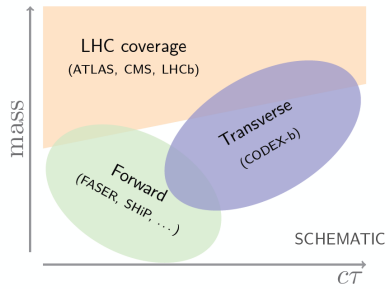


- DAQ racks in UXA-D1 move to surface in LS2. One floor available by end-2019.
- Entire UXA-D can *potentially* be available.
- Instrument with tracking layers $\Rightarrow$ CODEX-b

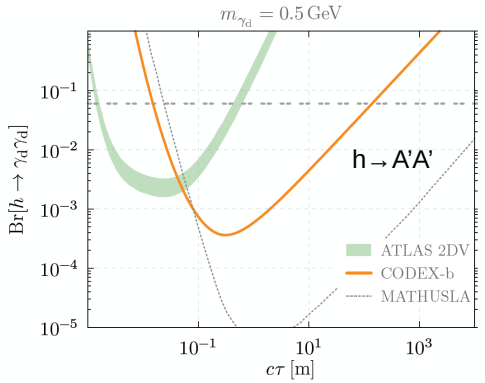
- Shielded, underground, $10 \times 10 \times 10$ m^3 vol, ~ 30 m from IP8.
- Unique feature: possibility to tag w/ LHCb events (more later).

Complementarity : dark photon example

- Mass, coupling and $\sqrt{\hat{s}}$: large $c\tau$ (v. weakly coupled) particles tend to be produced via intermediate heavy states (large $\sqrt{\hat{s}}$)

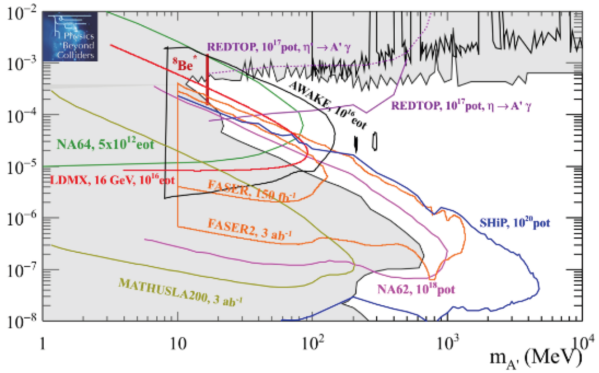


e.g. Exotic Higgs decays

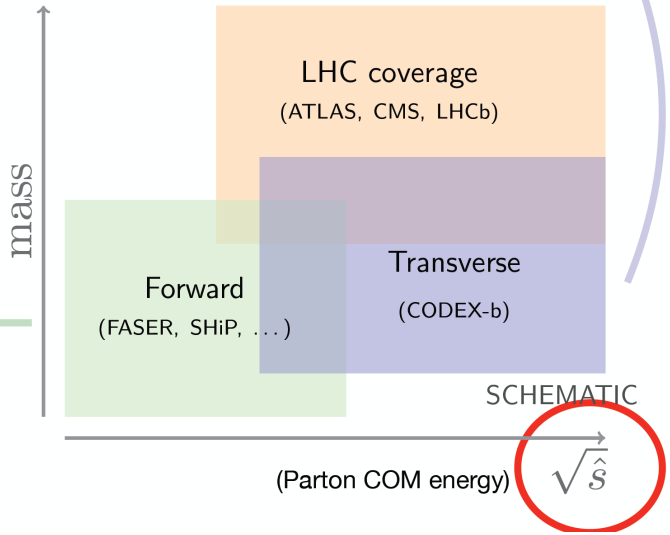


e.g. Dark photon (π^0, η^0 decays)

1909.xxxxx (EoI)
(in preparation)



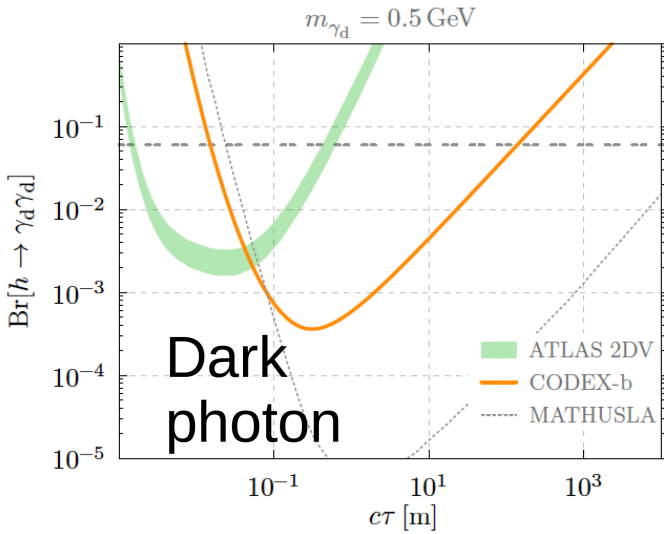
[courtesy: S. Knapen]

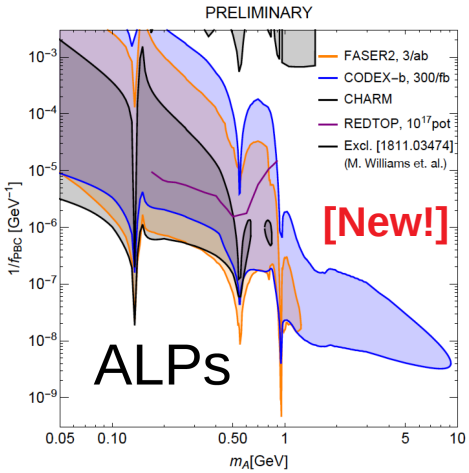


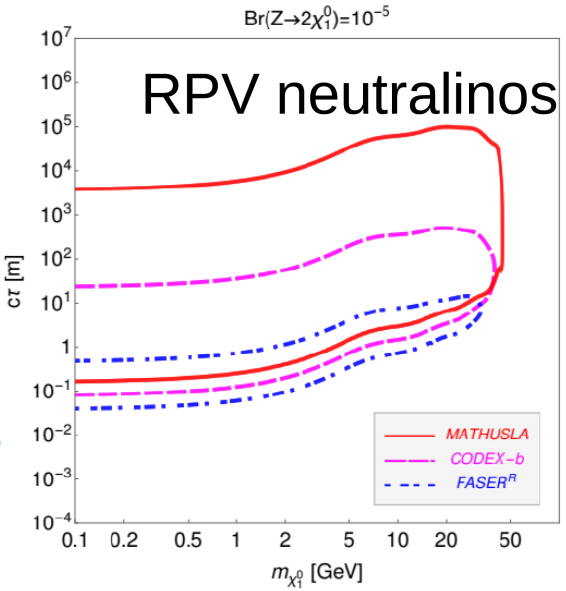
- Low mass/$c\tau$ dark photons at LHCb: see C. Sierra's morning talk.

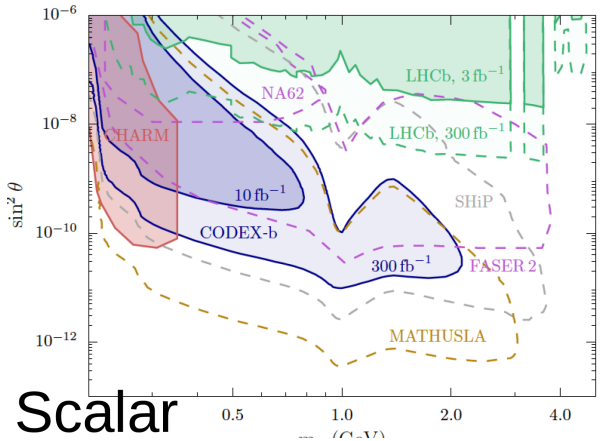
CODEX-b: WIDE PHYSICS REACH [1901.09966(PBC BSM WG)]

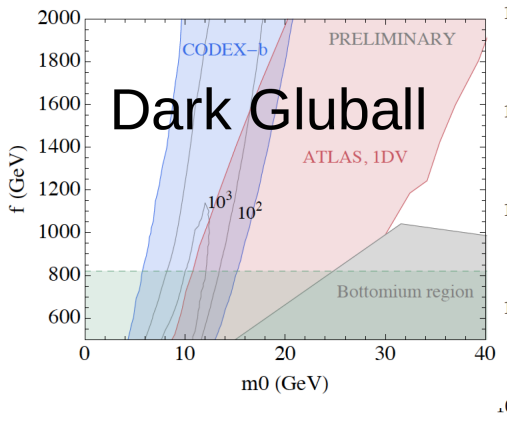
- Part of the PBC BSM WG. Featured in several Granada ES talks.

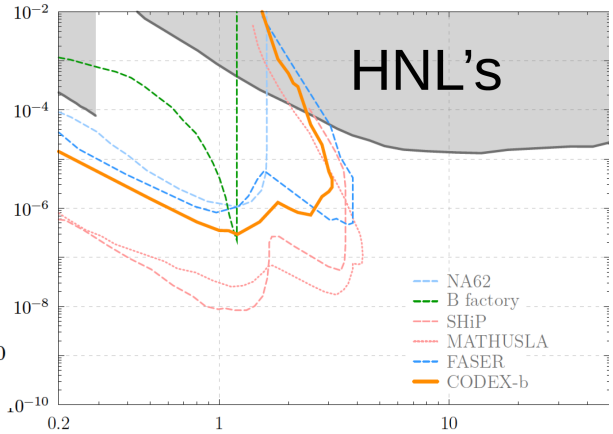










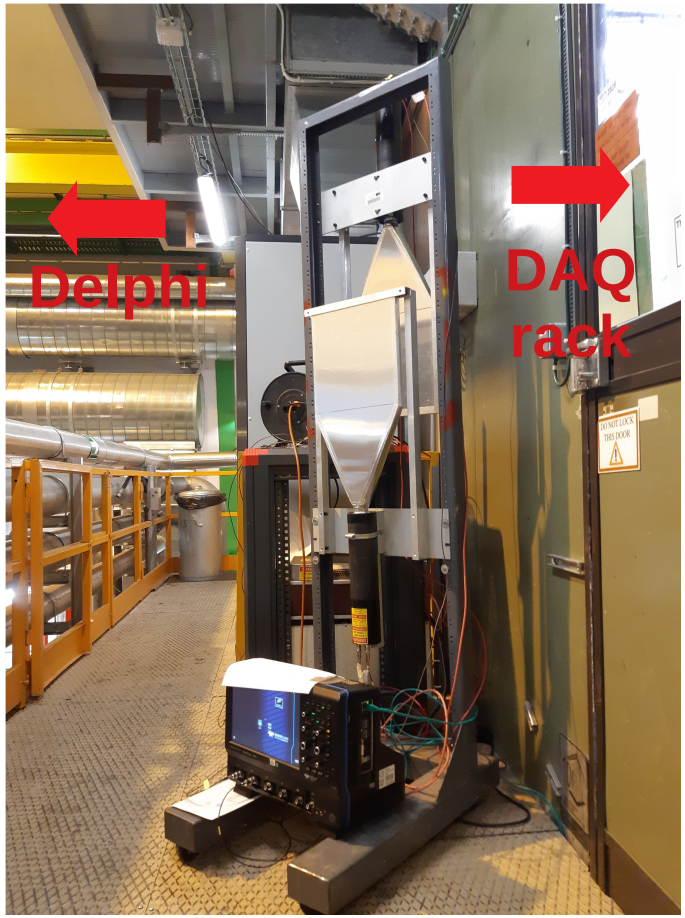


Outline

Background measurement in LHCb cavern

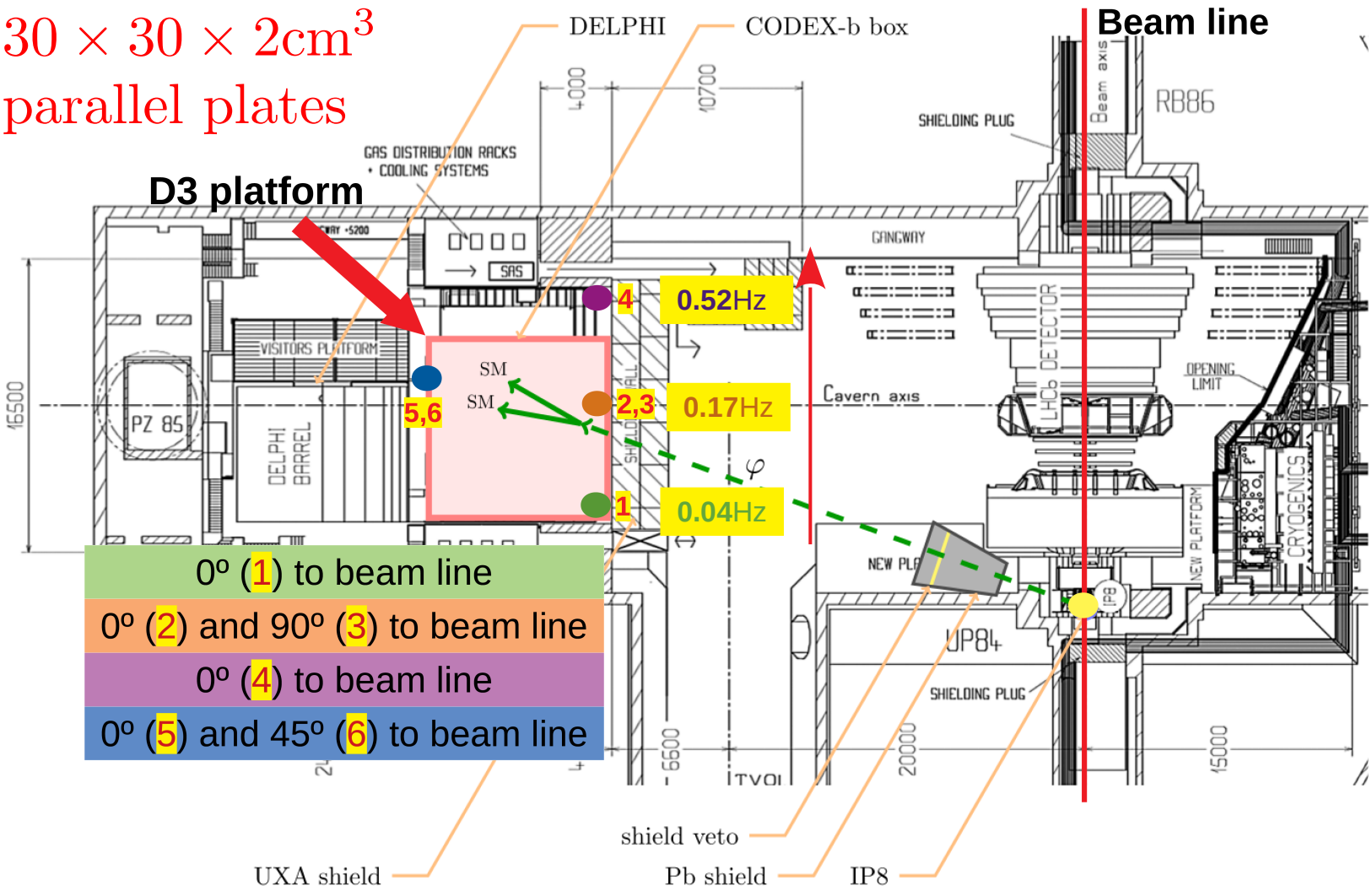
- Understanding background rates critical for reach studies.
- Summer student in 2018 to measure charged flux at different points behind the LHCb shielding wall (UXA85) [CERN-STUDENTS-Note-2018-213].

- D3 platform behind shield wall, during Run II
- $30 \times 30\text{cm}^2$ plastic scintillators from Herschel det. in LHCb
- Very successful campaign: $\sim$ 50K triggers in 17 days
- Validate simulation employing these measurements



Four measurement positions on D3 platform

$30 \times 30 \times 2\text{cm}^3$ parallel plates

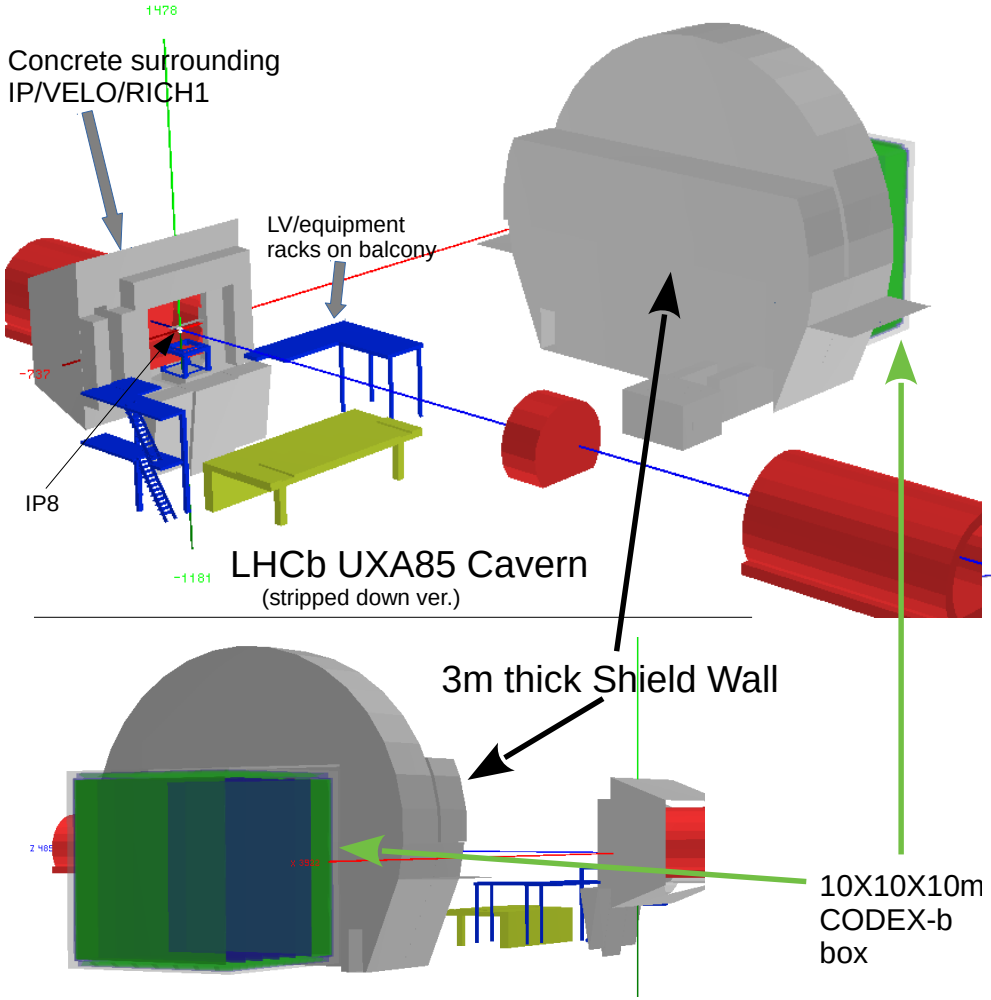


- Rate increases from upstream (pos. 1) to downstream (pos. 4) end.

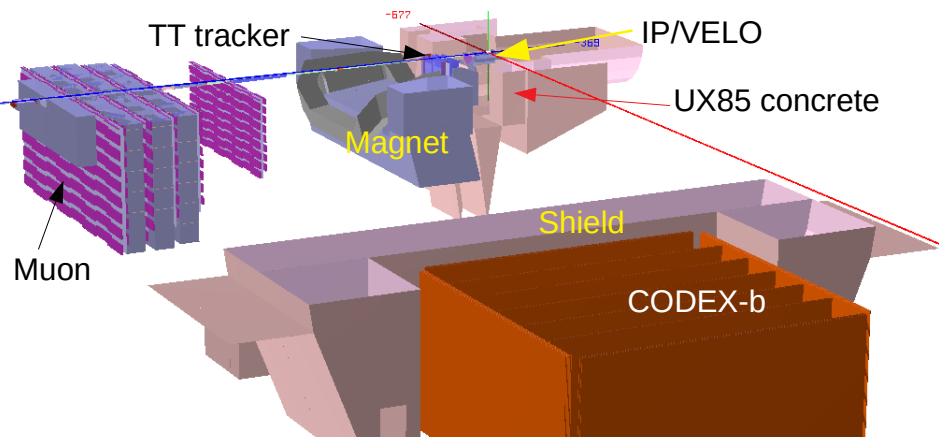
Outline

Geometry elements in LHCb simulation

- Bkgd. simulation this far away from the detector is non-trivial.

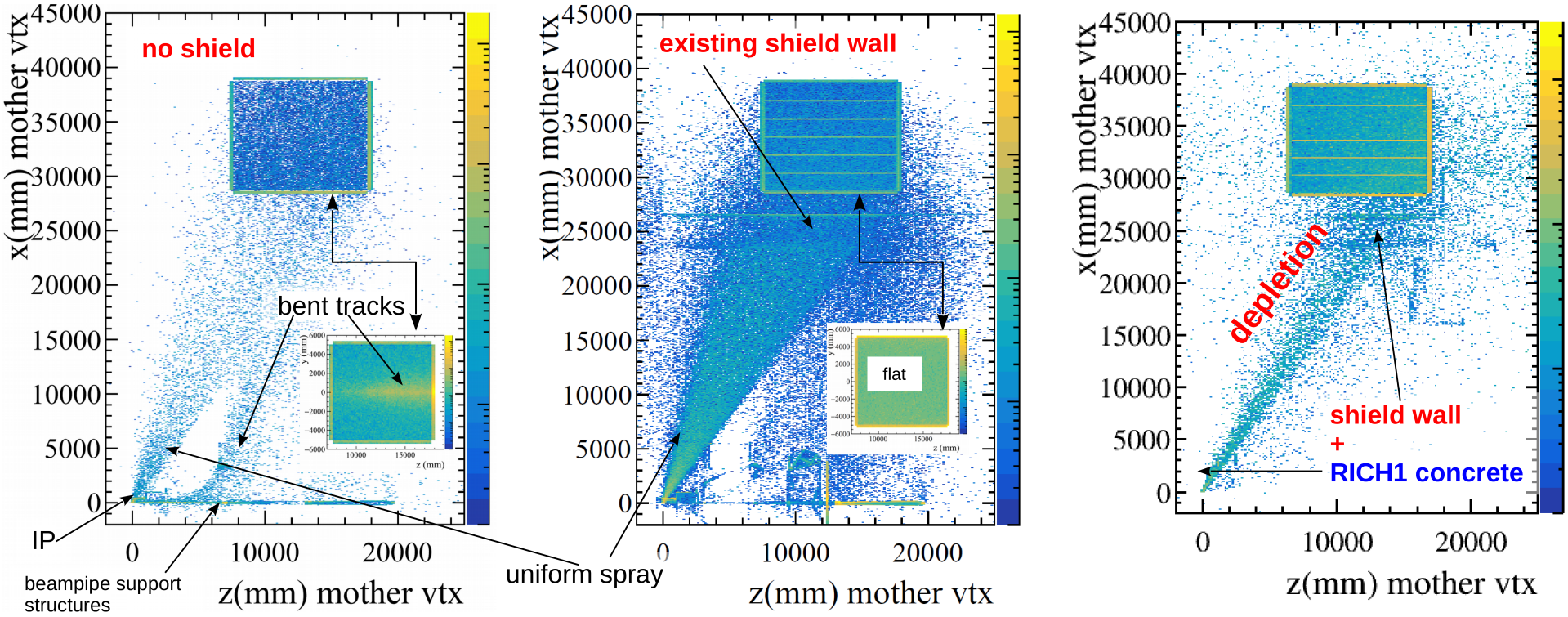


- Concrete: shield wall + additional cavern shielding.
- LHCb: magnet, VELO, RICH1, TT



Existing cavern shielding elements

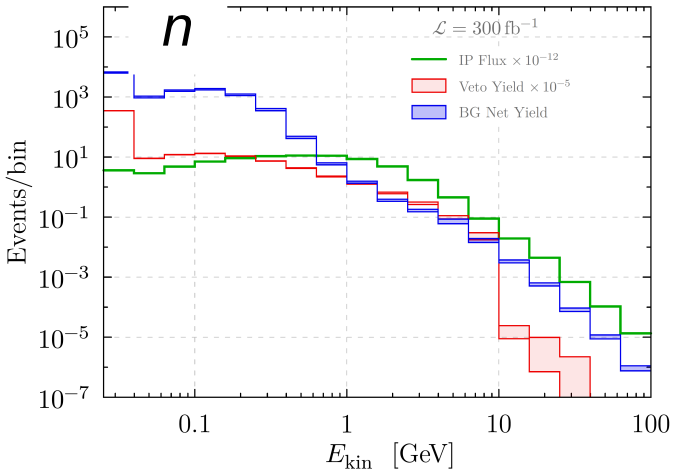
- Ongoing studies: understand existing shielding elements in cavern.
- *Preliminary* studies on secondary decay vertices (MC truth):

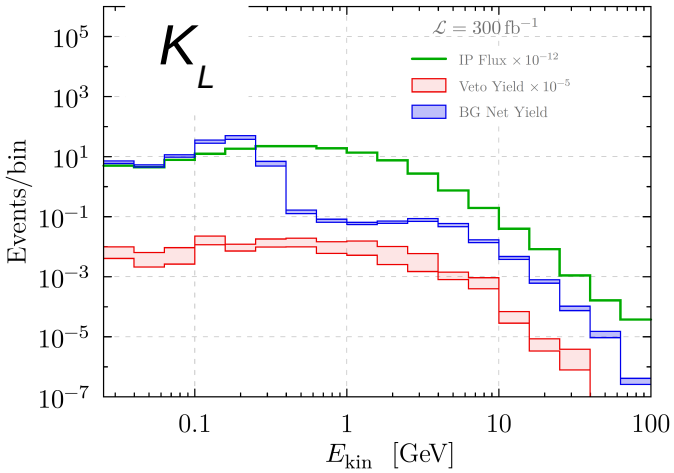


- Concrete wall around RICH1 "qualitatively" explains the depletion of hits in upstream region, seen in the BG measurements

Another background estimate study

- LBNL group updated study with improvements in the high energy tail, neutrino, geometry, neutral-muon correlations.



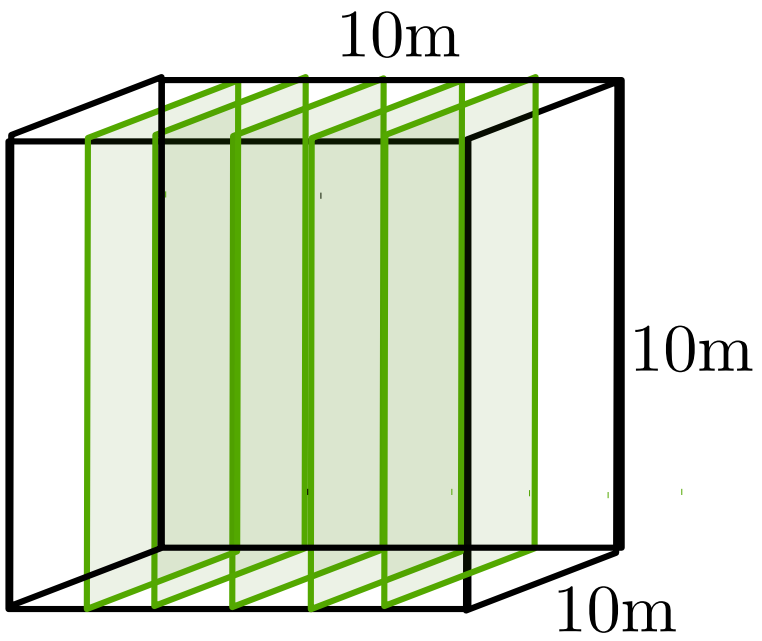


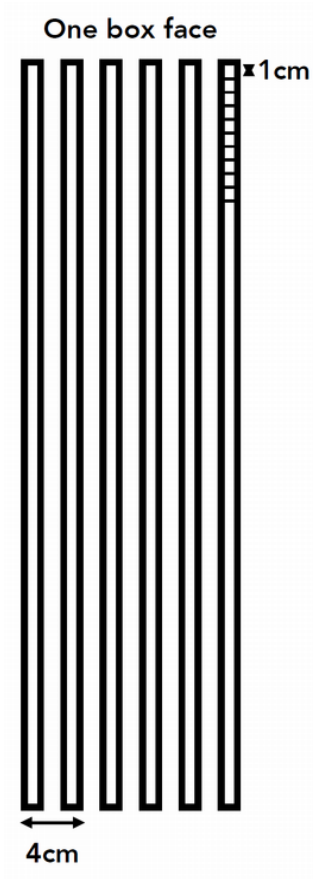
1909.xxxxx (EoI), in preparation:

BG species	Particle yields: Net ($E_{\mathrm{kin}}^{\mathrm{neutral}} > 0.6\,\mathrm{GeV}$)	Particle yields: Shield Veto	Eff. yield
γ	0.12 ± 0.02	$(8.79 \pm 0.81) \times 10^4$	–
n	8.05 ± 0.65	$(4.59 \pm 0.19) \times 10^5$	$\lesssim 1$
$\bar{n}$ (no cut)	$(3.24 \pm 0.72) \times 10^{-3}$	83.60 ± 67.30	$\ll 1$
K_L^0	0.35 ± 0.04	$(3.25 \pm 1.60) \times 10^3$	$\lesssim 0.1$
K_S^0	$(5.26 \pm 1.14) \times 10^{-3}$	$(2.45 \pm 1.74) \times 10^2$	$\ll 1$
$\nu + \bar{\nu}$	$(2.32 \pm 0.00) \times 10^{13}$	$(2.96 \pm 0.07) \times 10^6$	$\lesssim 0.1$
$p^{\pm}$	$(1.29 \pm 0.25) \times 10^2$	$(1.62 \pm 0.06) \times 10^6$	–
$e^{\pm}$	$(3.47 \pm 0.18) \times 10^2$	$(2.08 \pm 0.01) \times 10^7$	–
π^+	10.90 ± 1.05	$(5.73 \pm 0.34) \times 10^5$	–
π^-	9.91 ± 0.92	$(5.37 \pm 0.33) \times 10^5$	–
K^+	0.60 ± 0.23	$(7.15 \pm 2.84) \times 10^3$	–
K^-	0.15 ± 0.08	$(2.43 \pm 1.68) \times 10^3$	–
μ^+	$(9.40 \pm 0.01) \times 10^4$	$(9.40 \pm 0.01) \times 10^9$	–
μ^-	$(7.28 \pm 0.01) \times 10^4$	$(7.28 \pm 0.01) \times 10^9$	–

Outline

Towards signal track reconstruction...



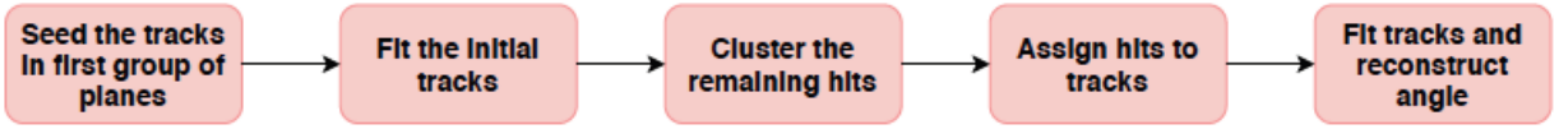


- Resistive Plate Chambers (RPC's) – fast, precise, cheap for large area
- 6 RPC layers at 4 cm intervals on each box face with 1 cm granularity

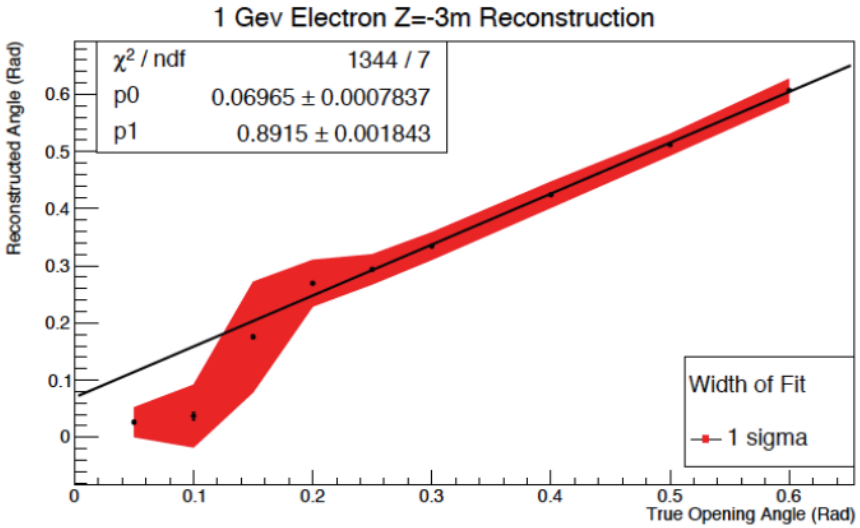
- 5 equally spaced triplets along the depth to minimize distance between reconstructed vertex and 1st measurement. $\epsilon_{\text{tracking}} \sim \mathcal{O}(1)$.
- $\mathcal{O}(100)$ ps (R&D) timing from RPC's for mass reconstruction

Track reconstruction

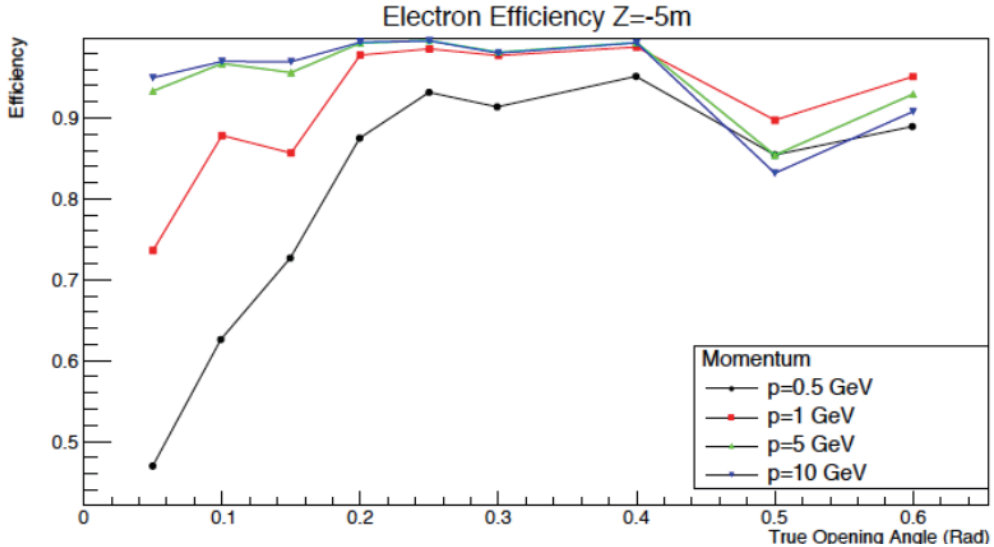
- Preliminary tracking in place for nominal geometry:



Angle reconstruction:



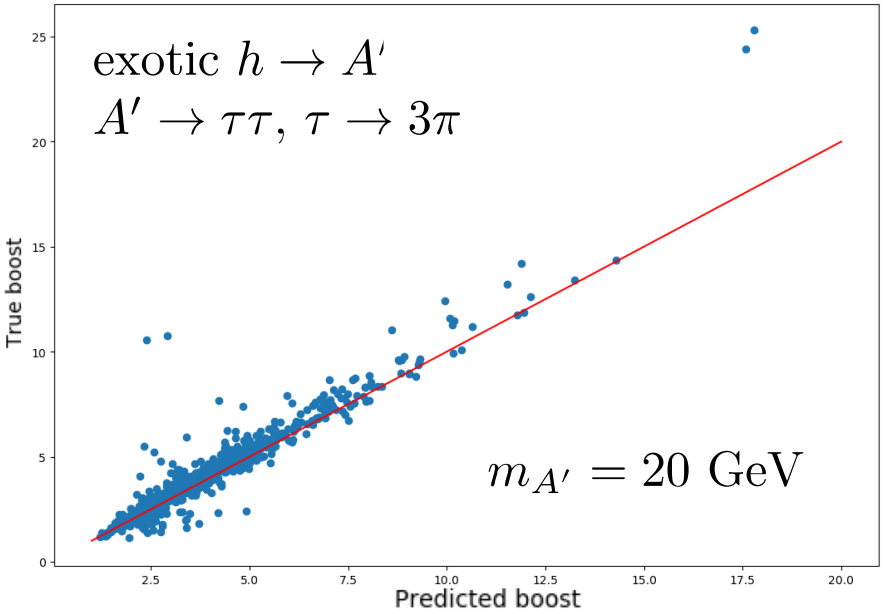
Reconstruction efficiency:



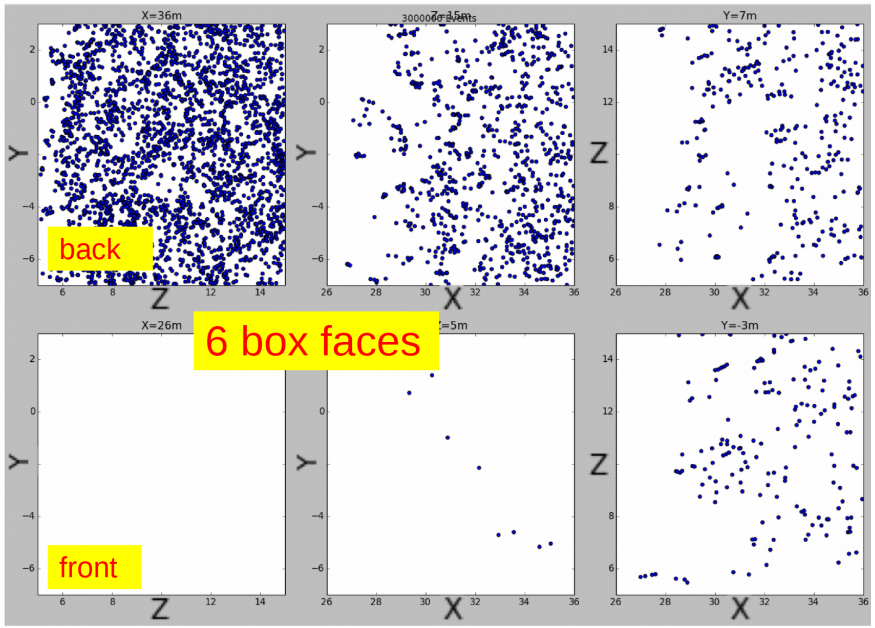
Boost reconstruction

- Boost determination important for sensitivity to the LLP mass
- Studies ongoing on both 2-body $A' \to \mu\mu$ and more complicated multi-body $A' \to \tau\tau$, with $\tau \to 3\pi$ topology.

- Neural net from topological variables to reconstruct boost.



- Optimize geometry from # hits in different RPC planes.



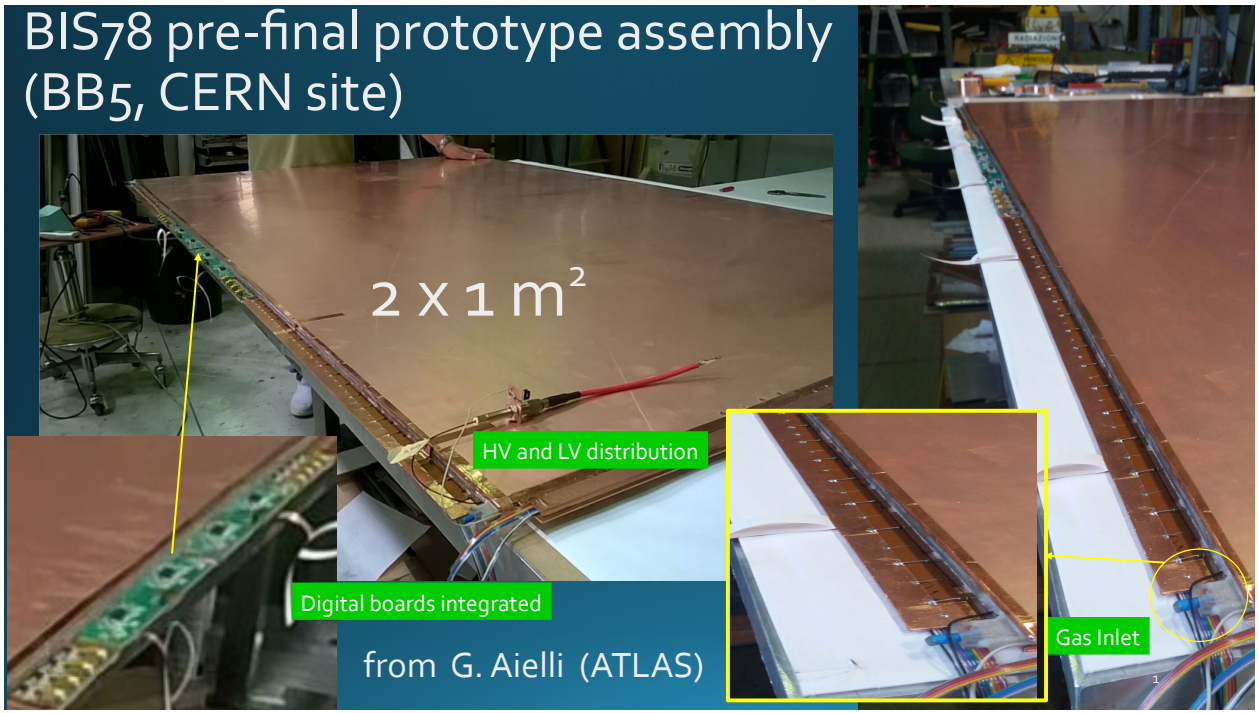
Tagging CODEX-b events with LHCb activity

- CODEX-b is around 30 m (100 ns) from LHCb IP8: 4 LHC bunch crossings
- Tagging CODEX-b with LHCb activity could be very interesting.
- Studies ongoing with $h \to A'A'$, $A' \to \mu\mu$, with one A' each in LHCb/CODEX-b acceptance.
- Associated jets (in LHCb) studies from exotic Higgs production.
- Also $b \to X_s\chi$ and $b \to X_c\mu N$ where the SM particles are detected inside LHCb

Outline

RPC's from ATLAS Muon Upgrade

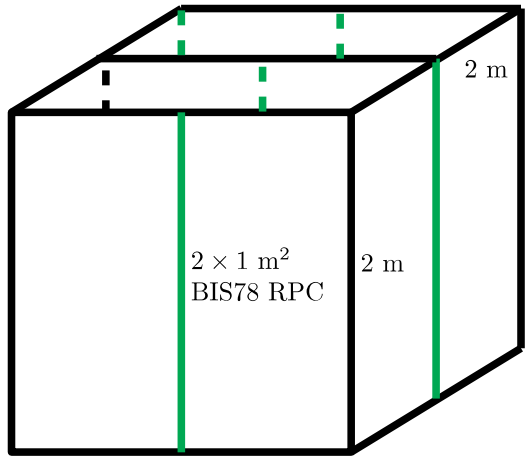
- RPC technology+expertise from ATLAS Muon Upgrade as baseline
- ATLAS Phase I (BIS78) upgrade for the demonstrator: 1mm gas gap, 1.2mm bakelite electrodes, 25 mm strips ($\sigma \sim 1$ mm w/ charge-centroid analysis)



- ATLAS Phase II Upgrade (BI) RPC's for full CODEX-b.
- 20mm strips, faster integrated FE.

CODEX-b demonstrator for Run III

- $2 \times 2 \times 2\text{m}^3$ box: 1/25 of the full detector
- Install in D1 during 2021 for data taking during Run III.
- Uses 14 ATLAS BIS78 triplet chambers.



  - ATLAS BI type R/O: will deploy preliminary version of TDC integrated in the FPGA. Time resolution $\sim 800/\sqrt{12} \sim 230$ ps.
  - Main goals: detect K_L^0's and proof of concept for R/O integration with LHCb.
  - Fruitful discussion with LHCb management in March'19. Received list of materials to prepare $\Rightarrow$ EoI targeting Sep'19 LHCb week.

Outline

Summary and outlook

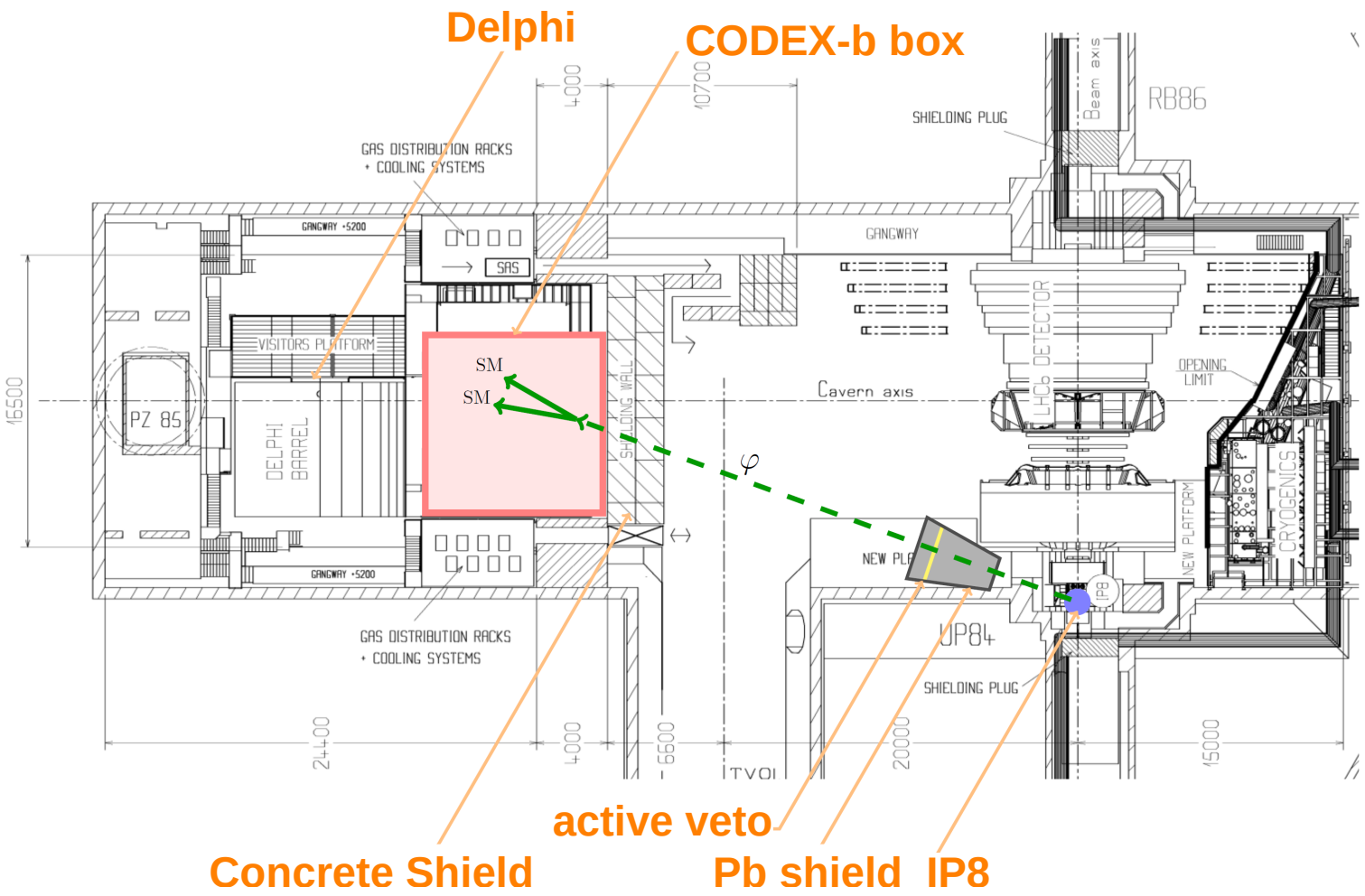
- CODEX-b: wide physics reach, complementary with other experiments/proposals. Relatively inexpensive.
- Progress in understanding 2018 BG measurements, via simulation as well as CODEX-b BG simulation ongoing.
- Boost-reco/tracking performance on-track or better than in proof-of-concept paper.
- Concrete proposal to install a $2 \times 2 \times 2\text{m}^3$ demonstrator using ATLAS Phase I Upgrade RPC's in end 2021.
- Preparing an EoI for submission to LHCb management.

List of contributors/collaborators

- Theory: J. Evans, S. Knapen, M. Papucci, H. Ramani, D. Robinson
- Experiment: G. Aielli, R. Carderelli, V. Coco, B. Dey, R. Dumps, O. A. De Aguiar Francisco, G. Gibbons, V. Gligorov, E. B. Haim, P. Ilten, J. Lee, B. Nachman, R. Quessard, H. Schindler, M. Sokholoff, S. Stone, V. Tisserand, V. Vagnoni, R. Vari, X. Cid Vidal, N. Watson, M. Williams, M. Witek
- LHCb expertise and help: M. Frank, G. Corti, B. Couturier, D. Mueller, N. Neufeld, R. Lindner and others
- New collaborators are most welcome

Backup slides

CODEX-b: another view



- If DELPHI is removed, access to even $20 \times 10 \times 10$ m box.
- Angular acceptance $\sim 1\%$.

Infrastructure support requests to LHCb

- Infrastructure: space, power, gas. Gas racks close to D1.
- Online: LHC clock (BXID) and LHCb tagging information
- Backend readout has two possibilities:
  - BE close to FE in D1 and standalone CODEX-b R/O sent to surface. Bring LHC clock to D1.
  - Data sent from D1 to UX85B (LHCb side) to be integrated into the LHCb stream.
- From ATLAS RPC group: BIS78 R/O has an FPGA-based DCT board that collects data from the FE's.
- The DCT board hosts one lpGBTx chip that should communicate with an LHCb PCIe40 board via bi-dir. GBT links.