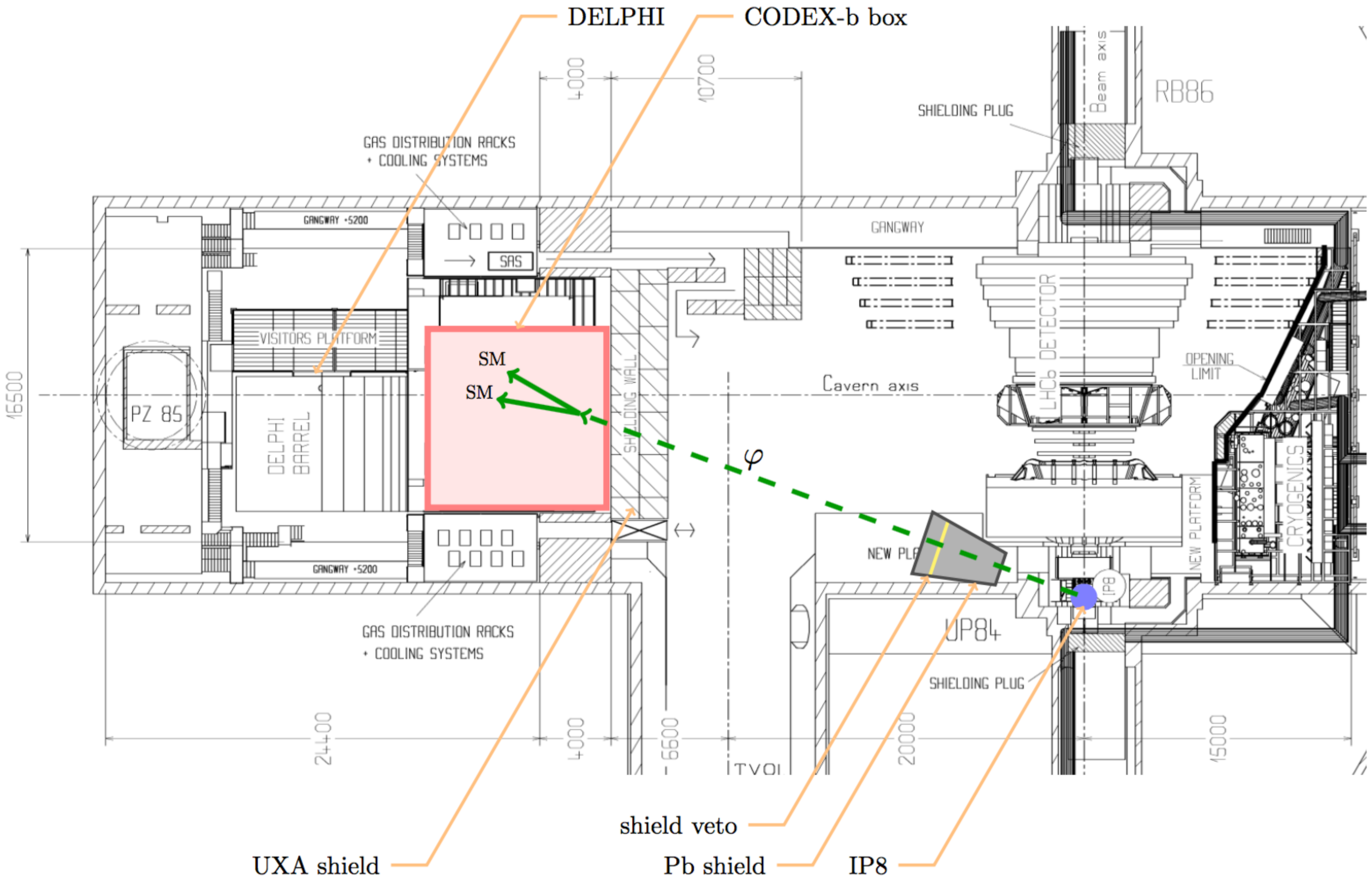
DAQ and triggering for CODEX-b



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HSF/LLP session on trigger & reco sw

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European Research Council
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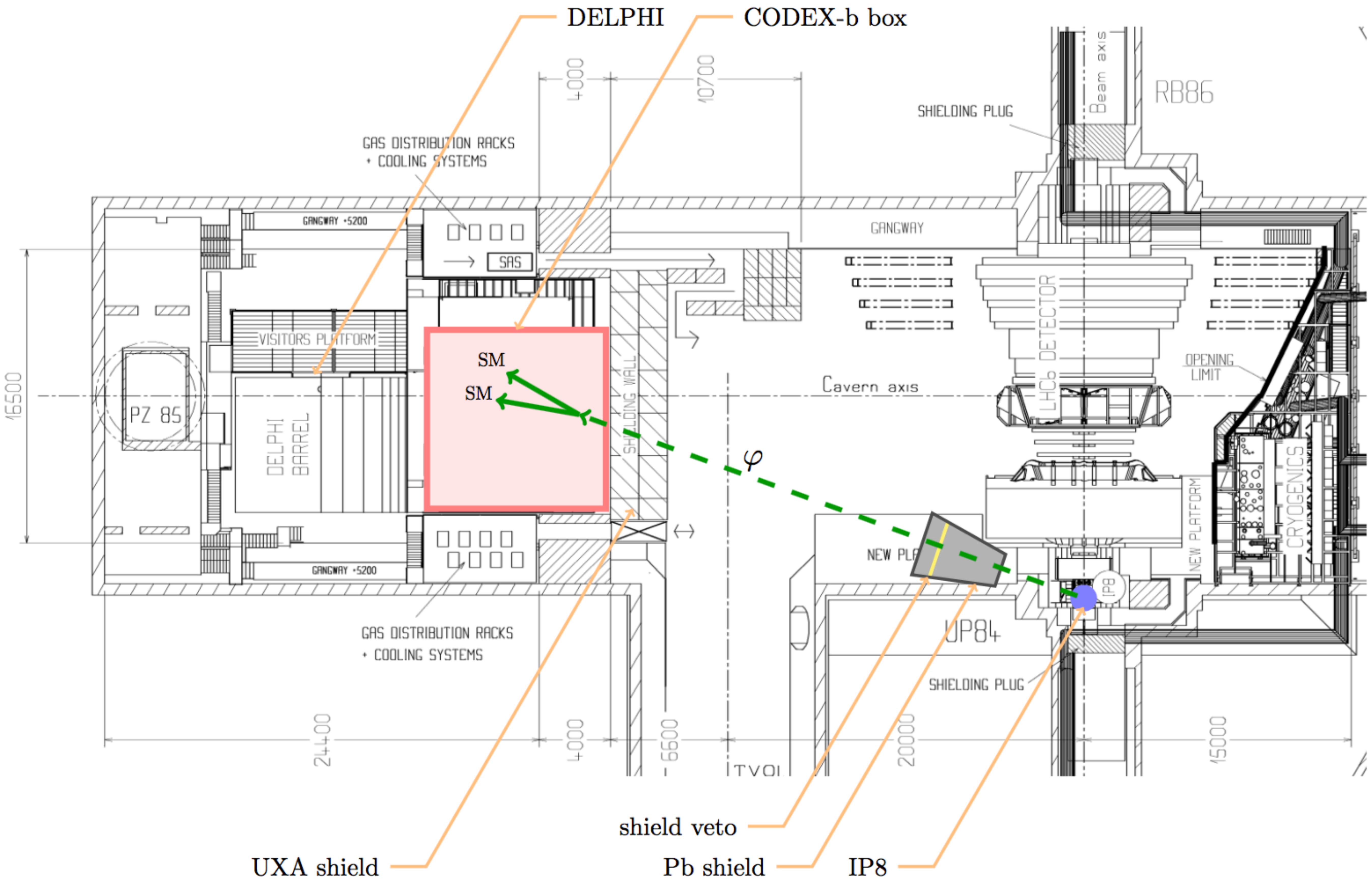
Objective is full integration with LHCb



LHCb Run 3 Trigger Diagram

30 MHz inelastic event rate (full rate event building)

Software High Level Trigger

Full event reconstruction, inclusive and exclusive kinematic/geometric selections

Buffer events to disk, perform online detector calibration and alignment

Add offline precision particle identification and track quality information to selections

Output full event information for inclusive triggers, trigger candidates and related primary vertices for exclusive triggers

10 GB/s to storage

CODEX-b is a similar distance to the IP as LHCb's muon spectrometer
From Run 3 onwards LHCb will operate a triggerless full detector readout @ 30 MHz
Therefore go for the simplest solution: integrate CODEX-b "as another subdetector"

Consequences

Integrating CODEX-b as a subdetector* enormously simplifies the work to be done on the software and/or trigger

1. Reuse LHCb software, not only the Gaudi framework but also the reconstruction and physics event model. A particle in CODEX-b is just like a particle in another part of LHCb.
2. From the CODEX-b side have to provide algorithms which decode the front-end output into a format readable by the LHCb framework, and of course an algorithm to reconstruct tracks inside CODEX-b.
3. Can transparently "trigger" on activity in CODEX-b or a combination of CODEX-b and LHCb activity. Same for activity in the shield veto.
4. For events selected as interesting by CODEX-b, the LHCb fragment of the event comes for free for future analysis.

*For the technical implementation not organisation, collaboration structure, etc.

Estimated trigger rates

CODEX-b is designed to be a 0 background experiment

The preliminary estimates from the original CODEX-b paper have been roughly validated using 2018 data taken in UX85A and will be verified further using the CODEX-β demonstrator.

Once the active shield is installed particle rates inside CODEX-b are expected to be below 1 Hz.

Therefore baseline assumption is to keep any events with tracks in CODEX-b for offline analysis. Preliminary tracking studies look good, first proper implementation for CODEX-β in 2022.

After 300 fb^{-1} (roughly $3 \cdot 10^7$ s of datataking)

BG species	Particle yields: irreducible by shield veto	Particle yields: reducible by shield veto	Baseline Cuts
$n + \bar{n}$	7	$5 \cdot 10^4$	$E_{\text{kin}} > 1\,\text{GeV}$
K_L^0	0.2	870	$E_{\text{kin}} > 0.5\,\text{GeV}$
$\pi^\pm + K^\pm$	0.5	$3 \cdot 10^4$	$E_{\text{kin}} > 0.5\,\text{GeV}$
$\nu + \bar{\nu}$	0.5	$2 \cdot 10^6$	$E > 0.5\,\text{GeV}$

CODEX-β

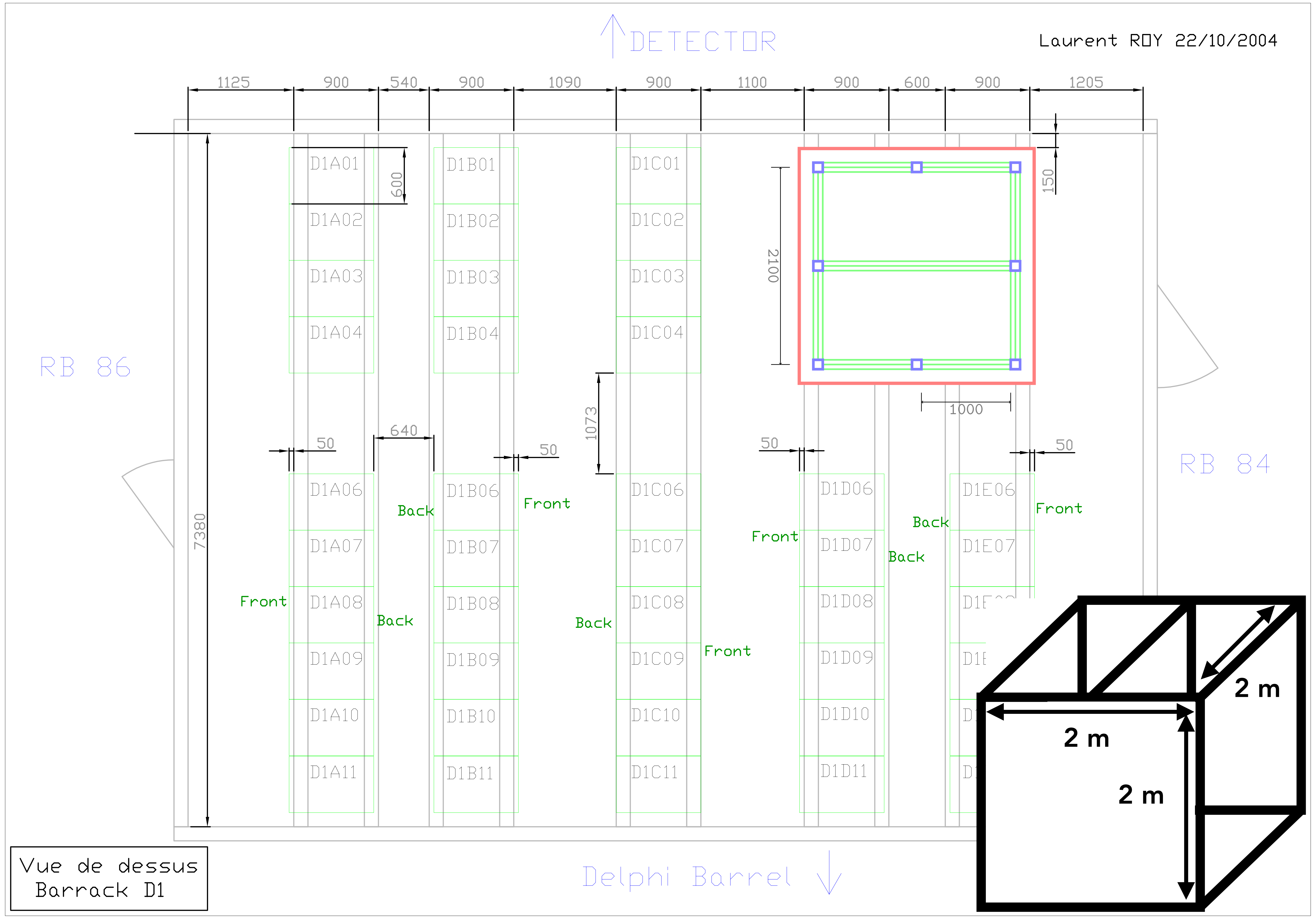
8 m³ demonstrator based on RPCs for the ATLAS Muon system upgrade

Send data via GBT link to same backend FPGA readout board as the rest of LHCb.

Data formats & integration in the LHCb simulation are WIP (a preliminary simulation exists).

Unlike CODEX-b no shield, so expect higher particle rates. But volume is 1% of full CODEX-b and instantaneous luminosity is 10% of that assumed for LHCb U2, which will largely compensate.

Therefore expect that the same trigger strategy outlined for the full detector will also work for the demonstrator.



Scaling from CODEX-β to CODEX-b

CODEX-β will be read out by a single FPGA card (cost O(5) kUSD)

We probably will not use the full capacity of this card, but this is something we will learn as we go along with CODEX-β. May be able to perform the track reconstruction directly in the readout card if there is spare capacity.

The data volume scales with detector surface area and number of RPC layers in each detector side. CODEX-β has 3 layers per side, for CODEX-b may go up to 6 (optimisation ongoing).

CODEX-b would also have additional internal stations, again the optimisation of this is ongoing.

So for the full CODEX-b could expect O(50) current generation readout FPGA boards to suffice. Not a very significant contribution to the overall detector cost, in particular if we can do the reconstruction on the readout boards. DAQ design for LHCb Upgrade 2 is still under discussion, but no reason why CODEX-b shouldn't be able to follow whatever LHCb decides to do.

Conclusion

The CODEX-b design minimizes the reconstruction and triggering challenges ahead.

Straightforward integration with LHCb DAQ&HLT brings physics benefits — LHCb tags the signal. Studies ongoing to quantify benefits in e.g. Higgs associated production.

The reuse of LHCb software and its quality assurance framework enormously reduces the workload.

Expect to learn lessons about all the fine print associated to these statements with CODEX-β and iterate from there.