First dark photon results @ LHCb

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HPS Meeting
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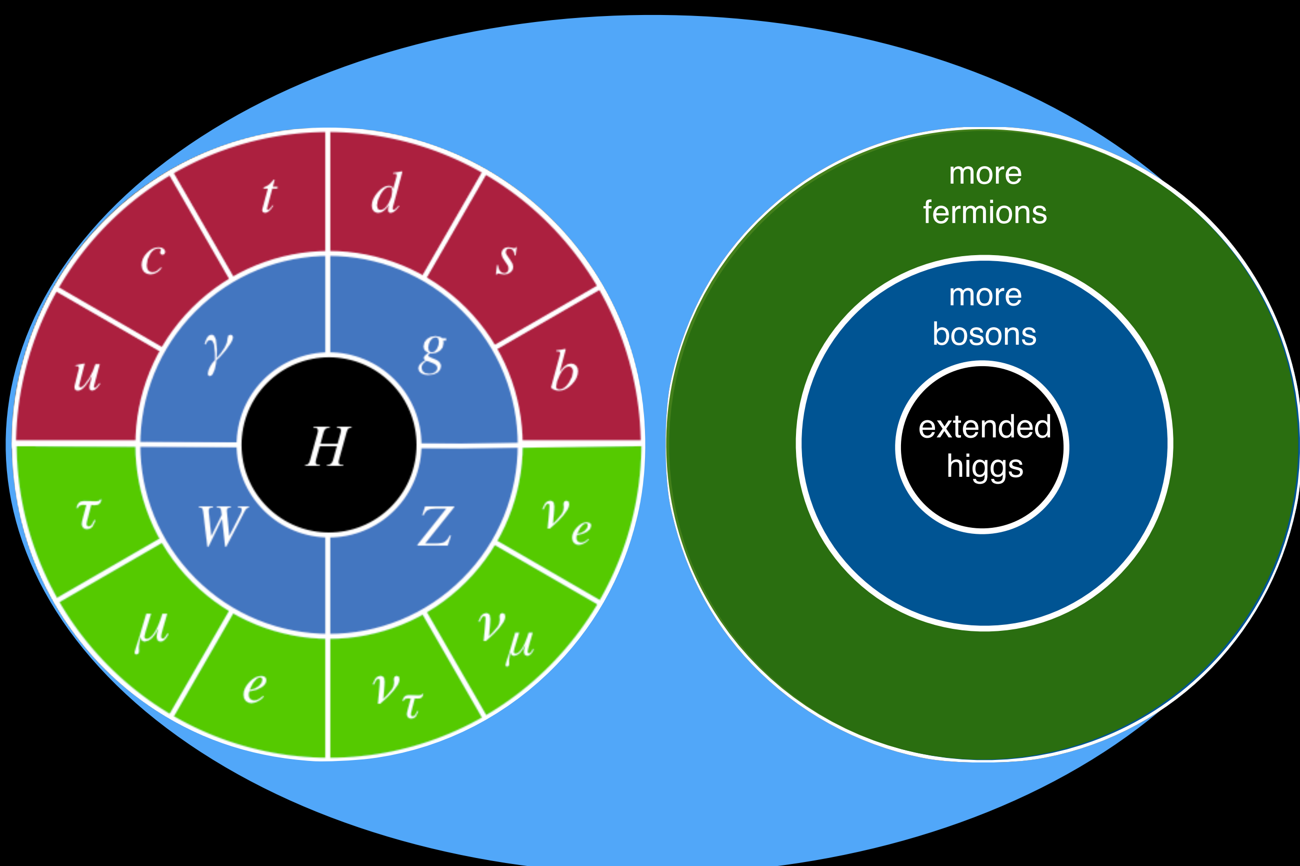
The Large Hadron Collider
LHCb
70 institutes
16 countries
700 physicists
400 papers

Dark Matter Paradigms

(apologies to axions)

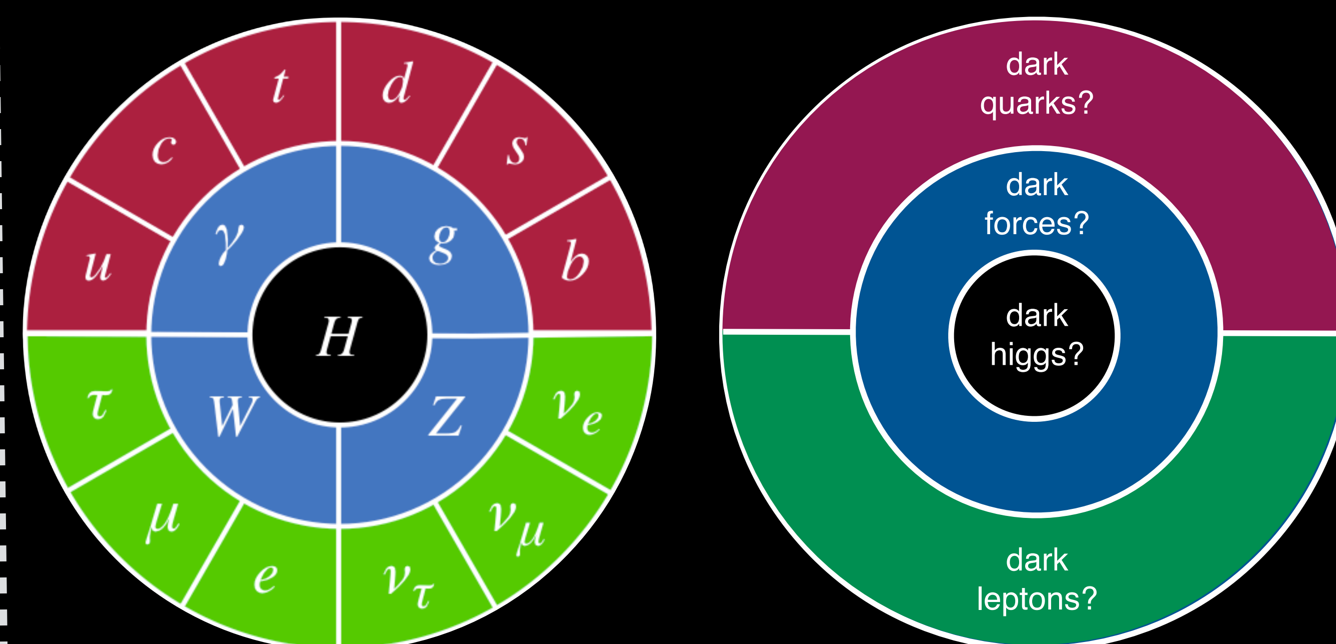
WIMP



SM and DM particles are part of a larger unified theory at the TeV scale.

LHCb searches for indirect evidence of this via quantum effects (flavor physics) — but that's another talk.

Hidden Sector(s)



No direct SM-DM connections.

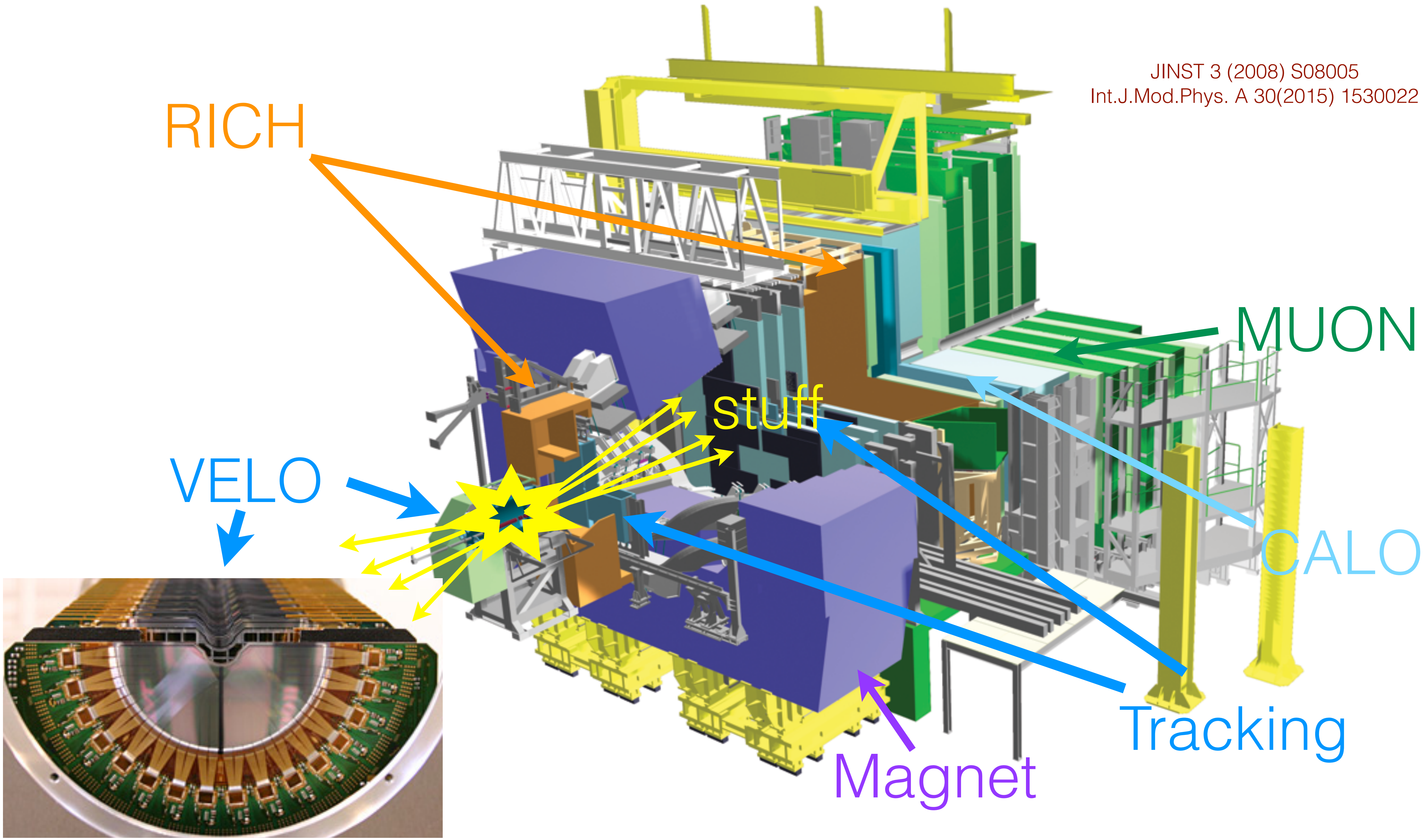
LHCb searches for this directly, and has world-leading sensitivity in certain regimes. (This talk is only A'.)

LHCb Detector

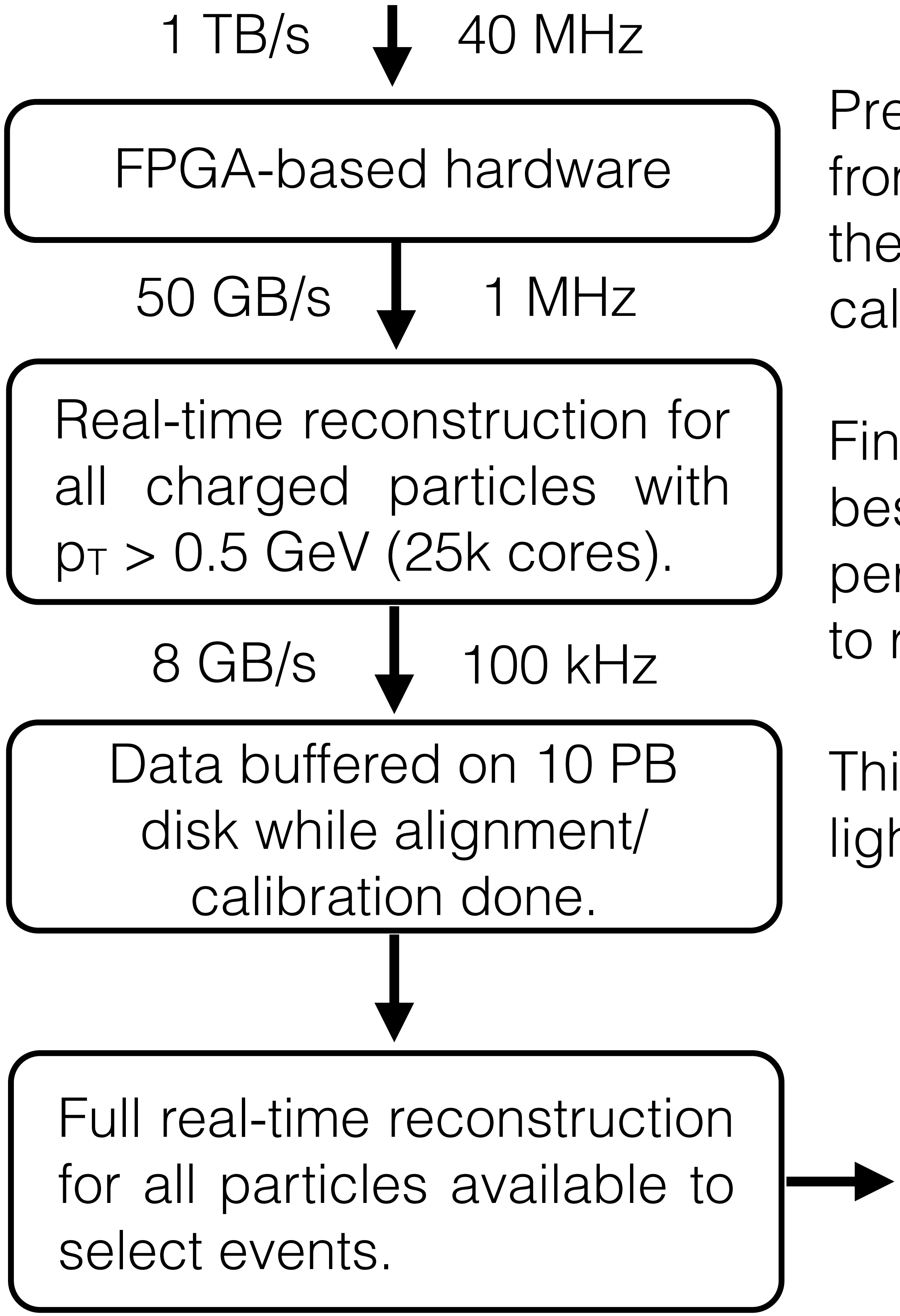
LHCb is a forward Spectrometer ($2 < \eta < 5$)

(roughly 1-15°)

JINST 3 (2008) S08005
Int.J.Mod.Phys. A 30(2015) 1530022



Real-Time Processing (Run 2)



Precision measurements benefit greatly from using the final/best reconstruction in the online event selection—need real-time calibration!

Final event selection done with access to best-quality data, removing the need (but perhaps not the desire) to retain the ability to re-reconstruct the data offline.

This approach provides huge benefits to light BSM searches as well.

Heavy use of machine learning algorithms.

V.Gligorov, MW, JINST 8 (2012) P02013.

5 PB/year (mix of full events & ones where only high-level info kept)

Real-Time Processing (Run 3)

5 TB/s | 40 MHz

Real-time reconstruction for all charged particles with $p_T > 0.5$ GeV.

↓

Data buffered on disk while alignment/calibration done.

↓

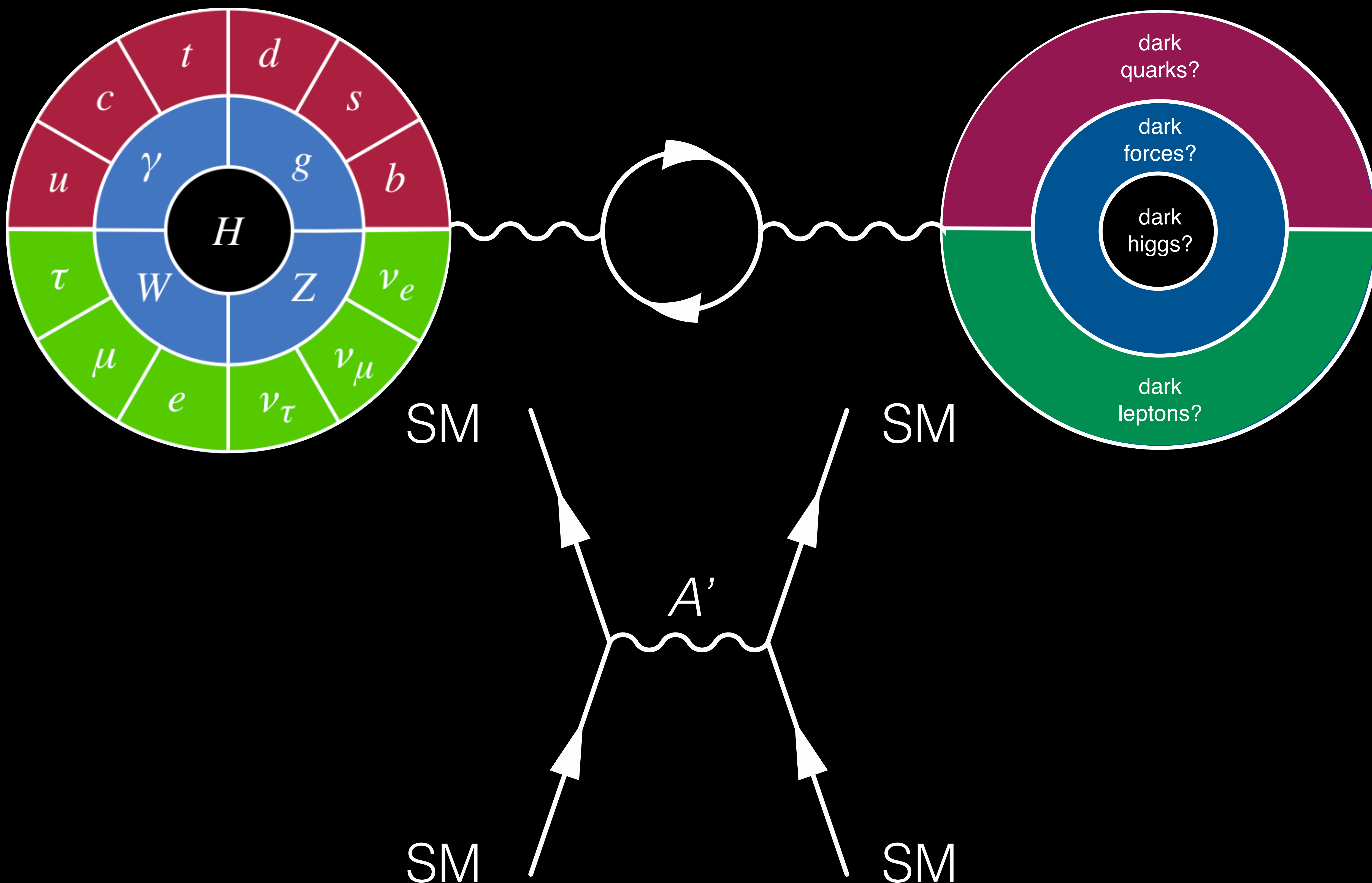
Full real-time reconstruction for all particles available to select events.

→ 20 PB/year (mostly only high-level info kept, few RAW events to be stored)

Need for a hardware stage is being removed for Run 3, while simultaneously increasing the luminosity by a factor of 5.

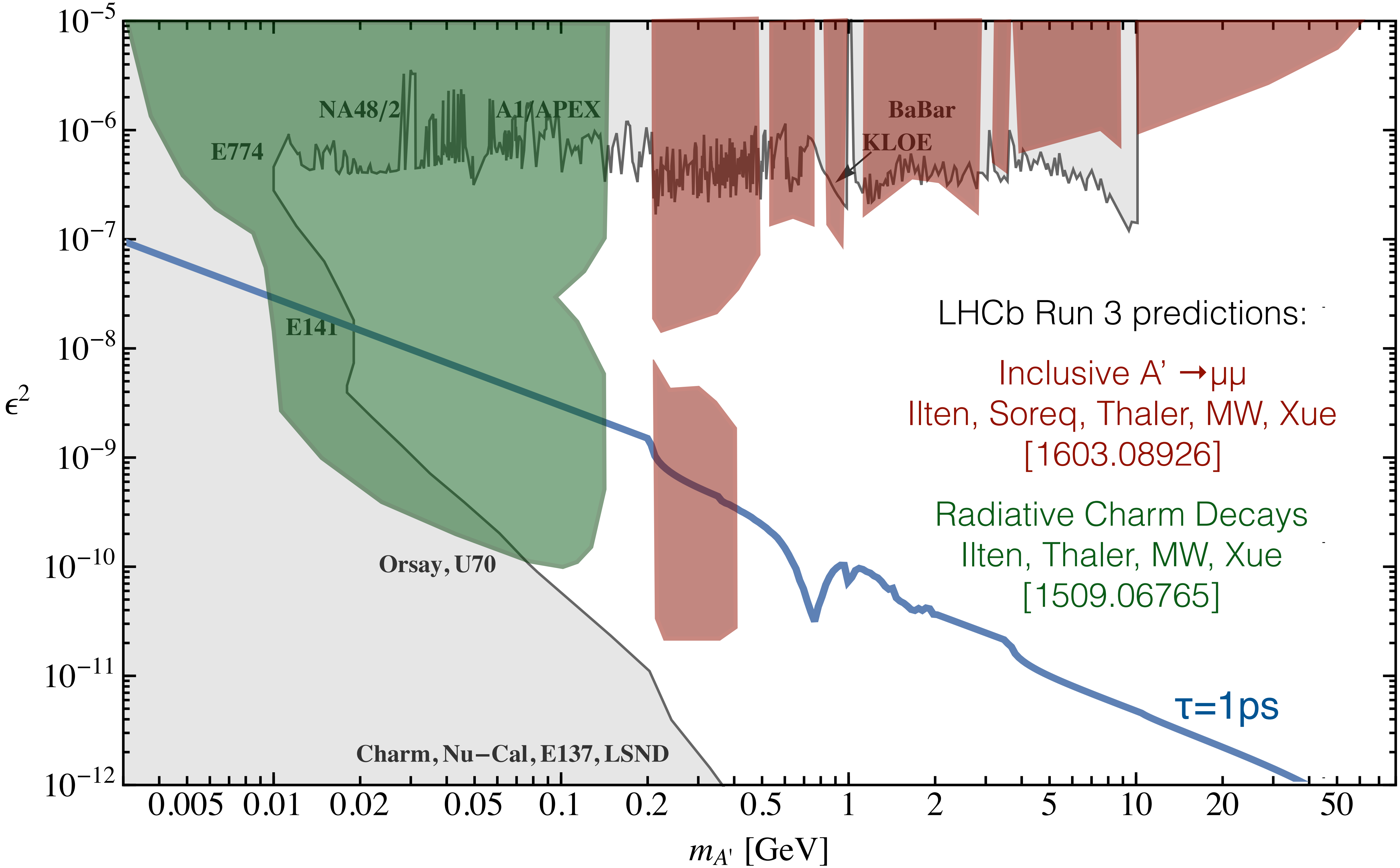
Huge potential gains for low-mass physics, including dark photons.

Dark Photons



Visible A' Decays

Leverage LHCb's world-leading τ resolution and planned move to a triggerless readout.

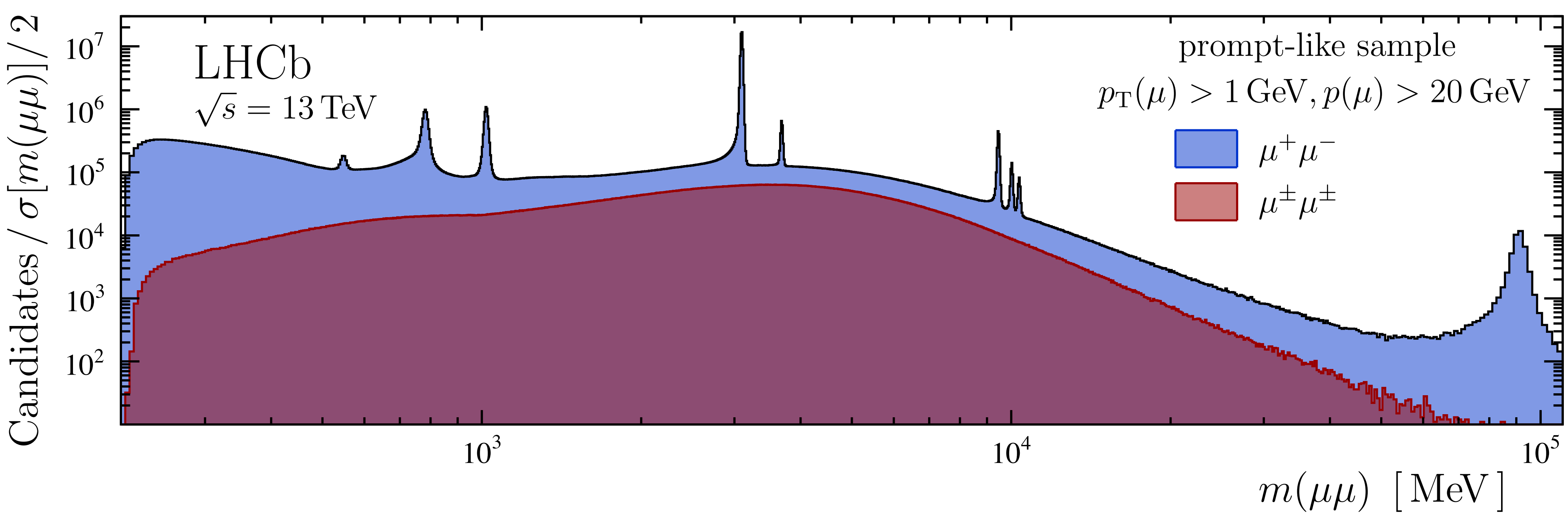


Prompt A'

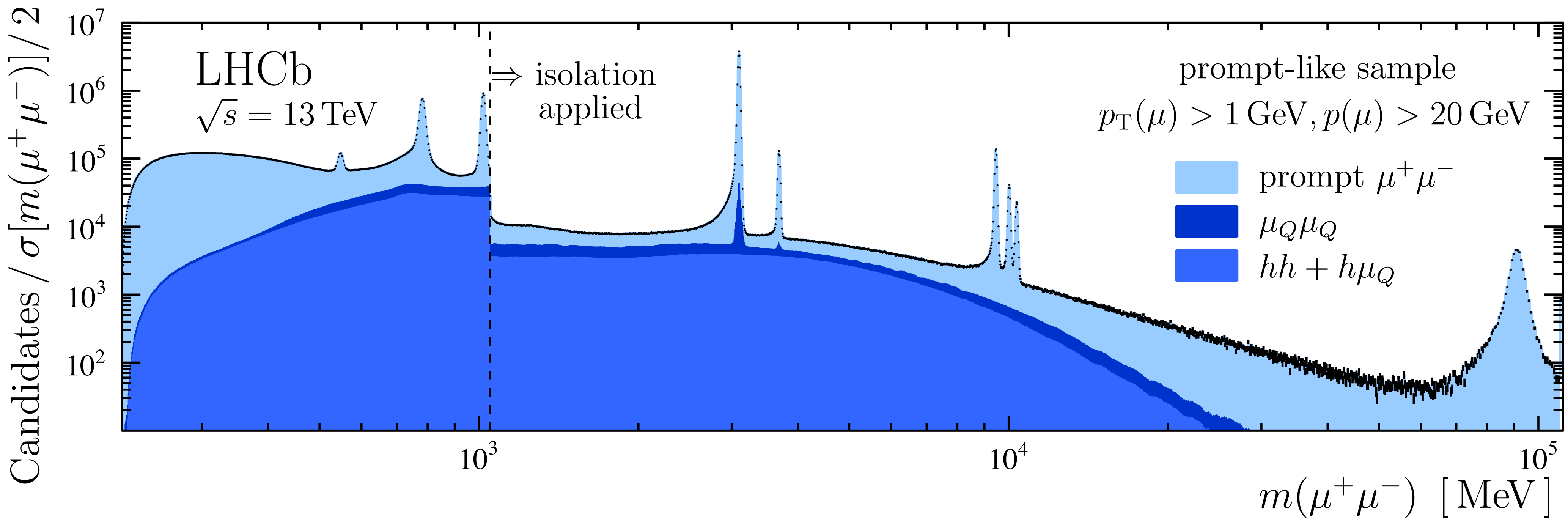
LHCb-PAPER-2017-038
1710.02867

Major hurdles: suppressing misidentified (non-muon) backgrounds and reducing the event size enough to record the prompt dimuon sample. Accomplished these by moving to real-time calibration in Run 2.

trigger output



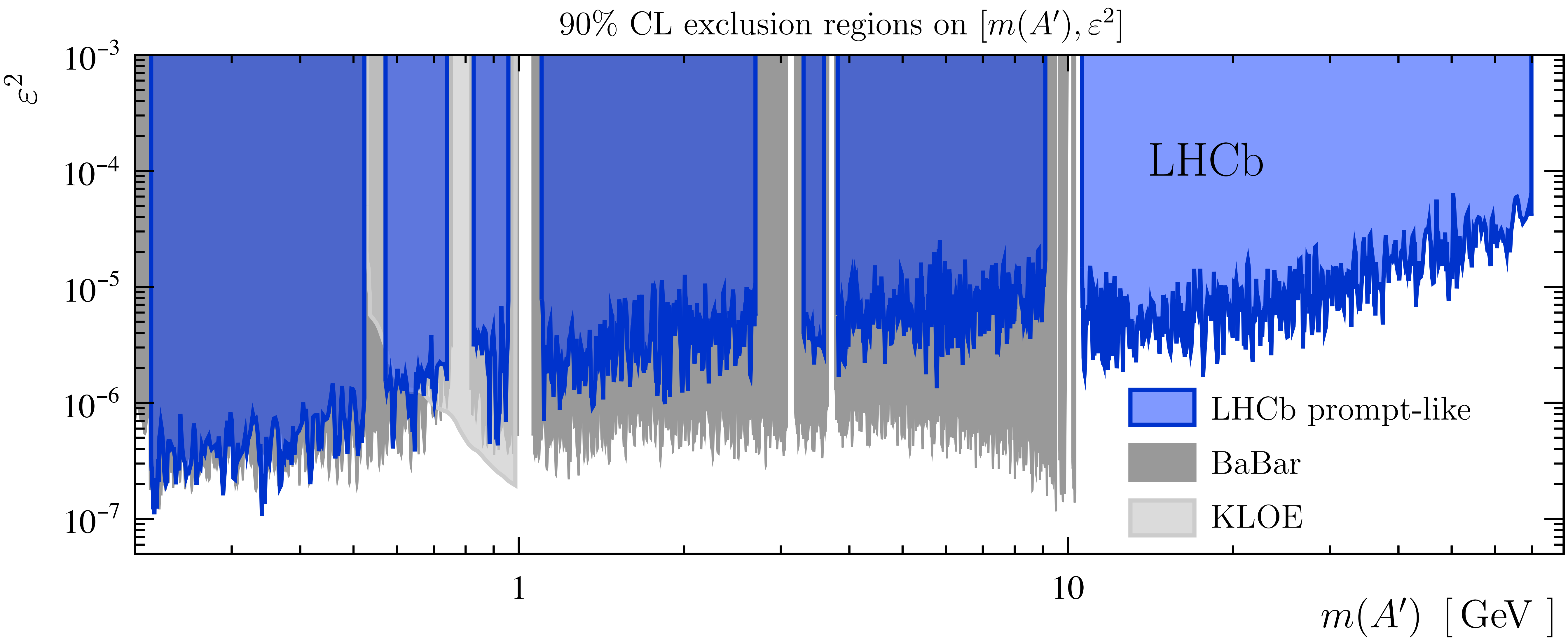
final prompt A' sample (isolation applied above 1.1 GeV, backgrounds determined)



Prompt A'

LHCb-PAPER-2017-038
1710.02867

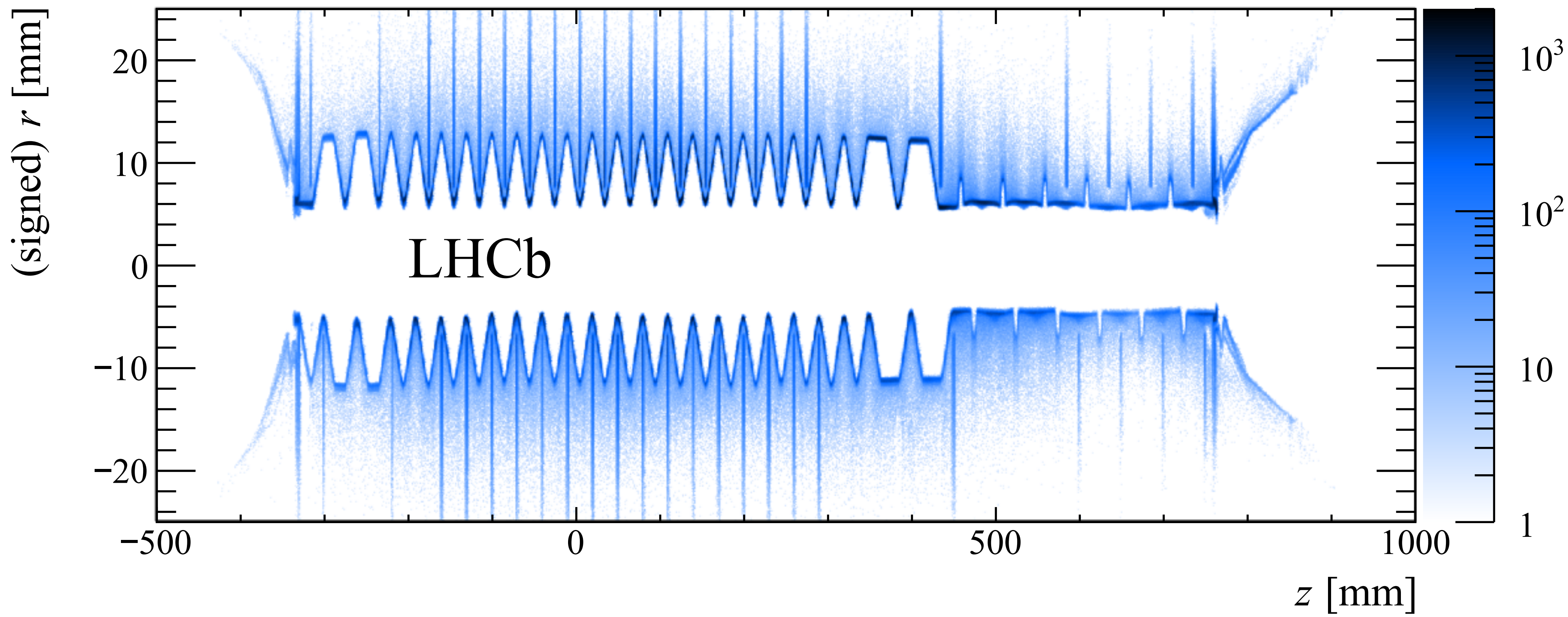
Even though the 2016 data sample is 10x smaller than the expected one in Run 3 — and the current trigger is only 1-2% efficient at low masses — we still roughly equal BaBar as the best limits. Above 10 GeV, these are the most stringent limits. (N.b., these results are consistent with our predictions after accounting for hardware trigger & luminosity.)

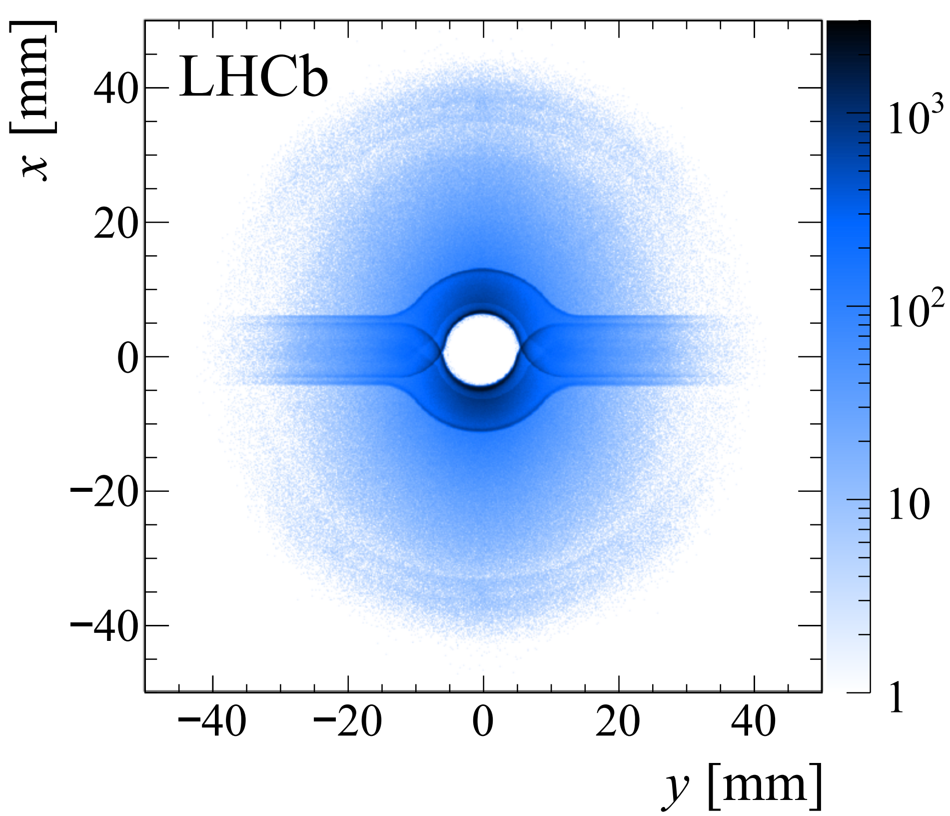


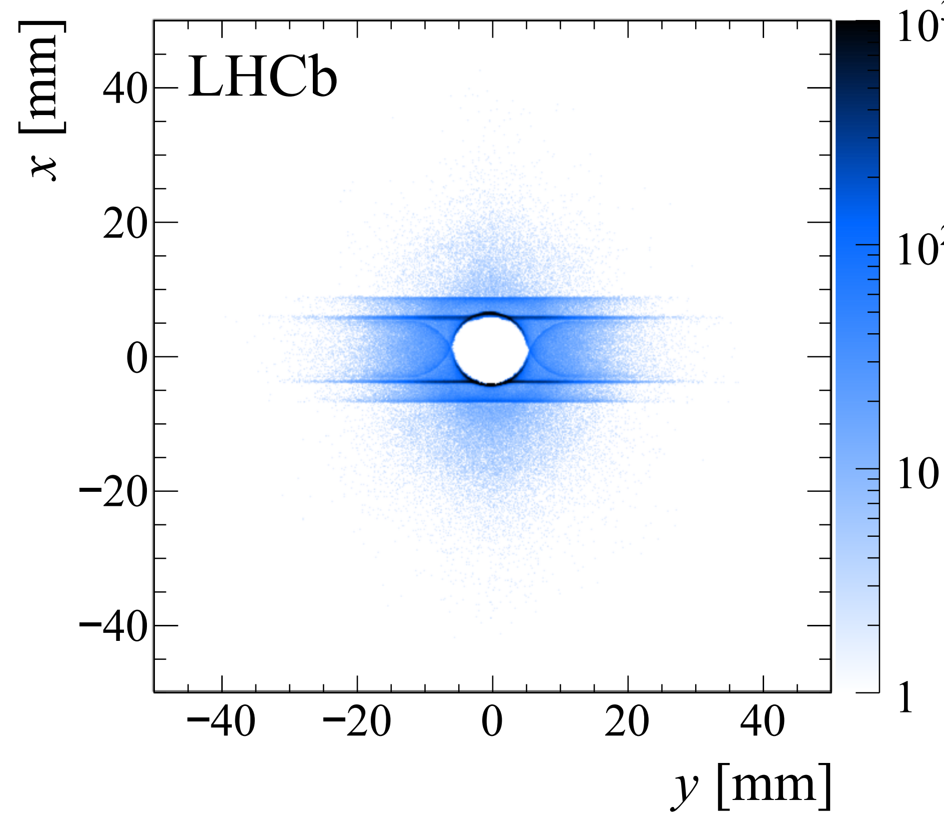
N.b., the bump hunt follows MW, 1705.03587. This is a completely generic method that I show produces valid CIs (and limits) with minimal effort/input from the analysts.

Long-Lived A’

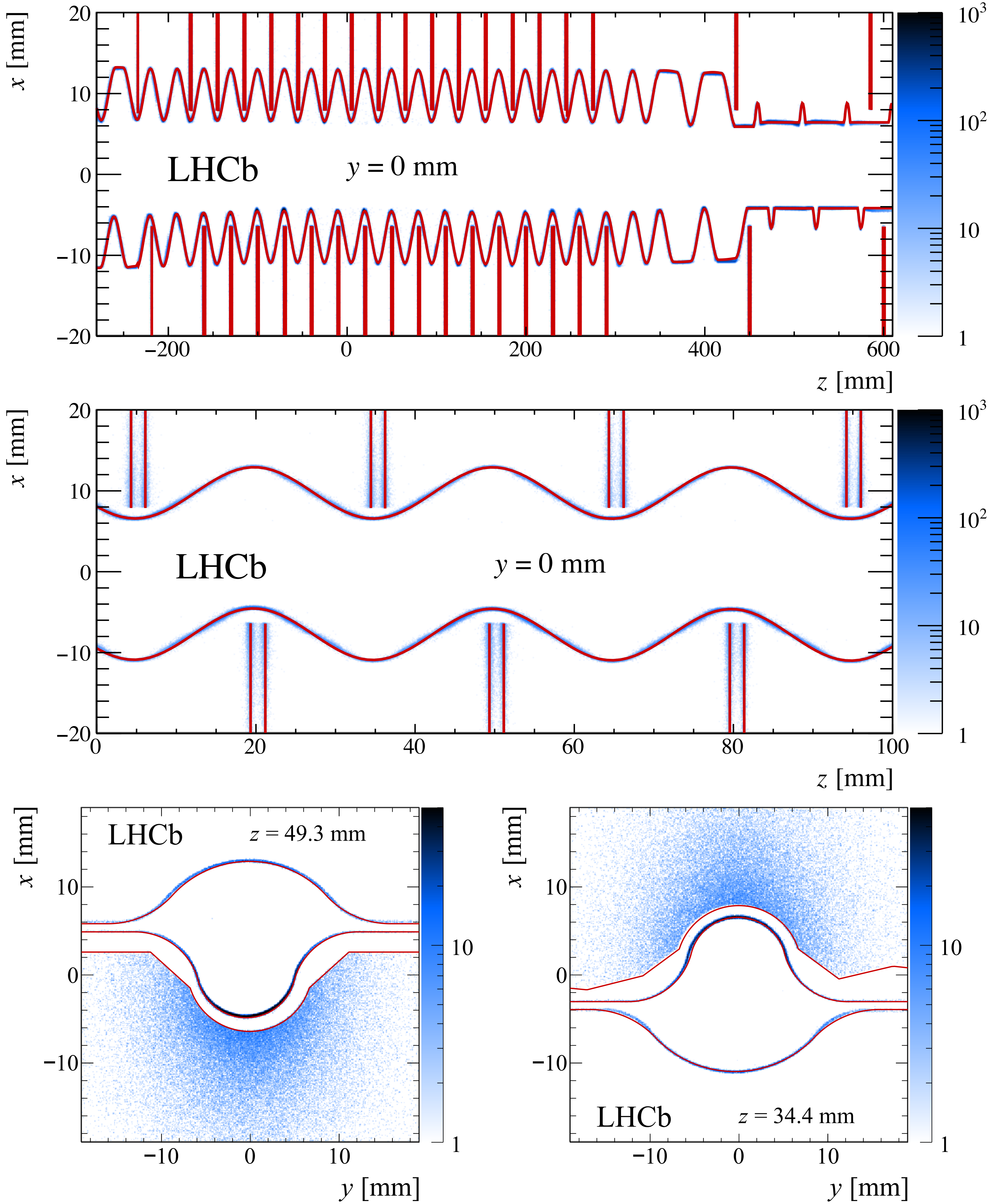
Major hurdle: building a high-precision map of the VELO material to enable vetoing ALL photon conversions. (Of course, this was easy using simulation for the predictions!)





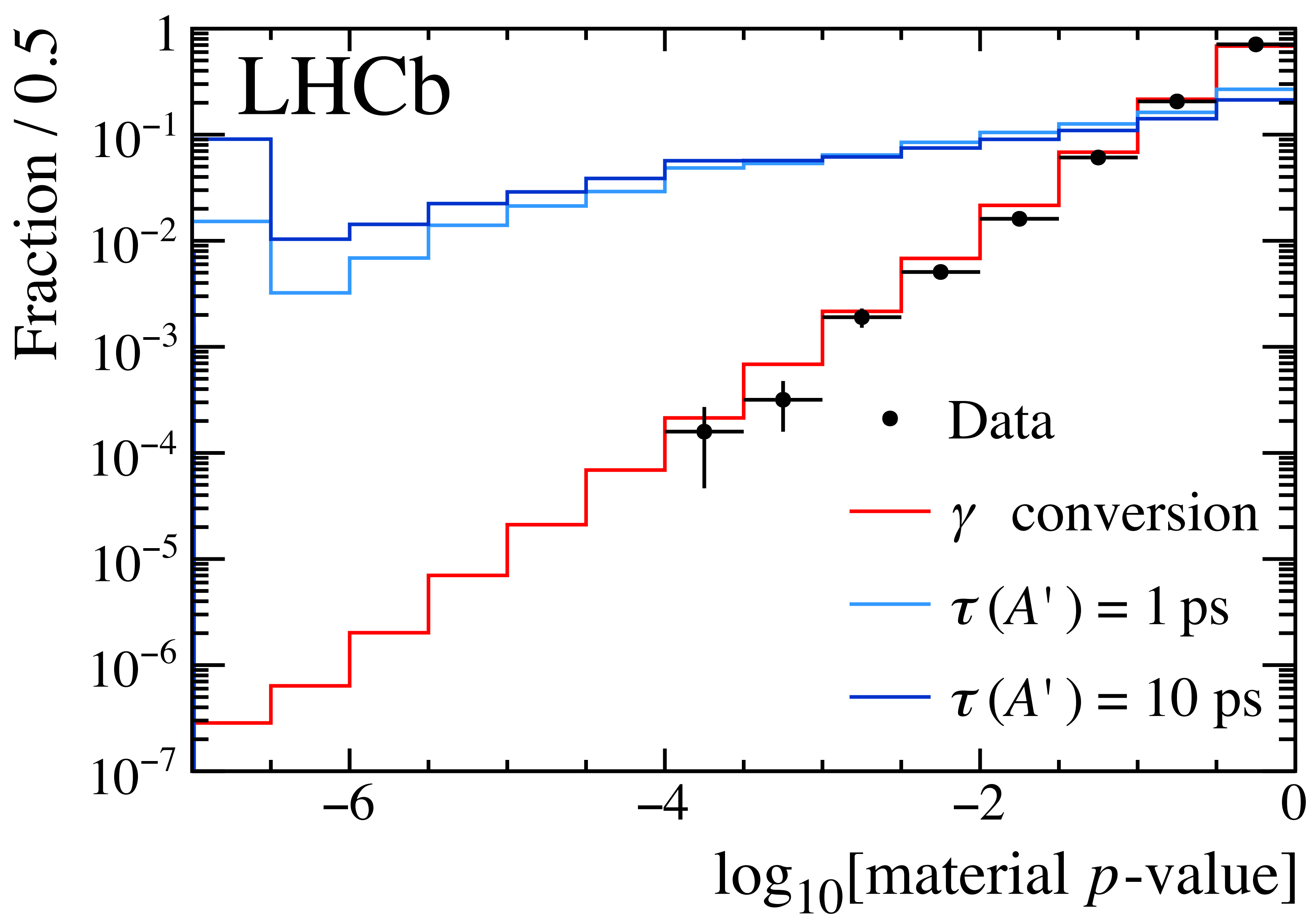


D. Dosset, P. Ilten, T. Latham, C. Wallace, MW (to appear very soon).



Long-Lived A'

Developed a data-driven method to determine the p-value for the from-material hypothesis for any vertex. Conversion-dominated data region found to be consistent with only conversions (expect < 10 A' signal event in this region for any mass, lifetime).



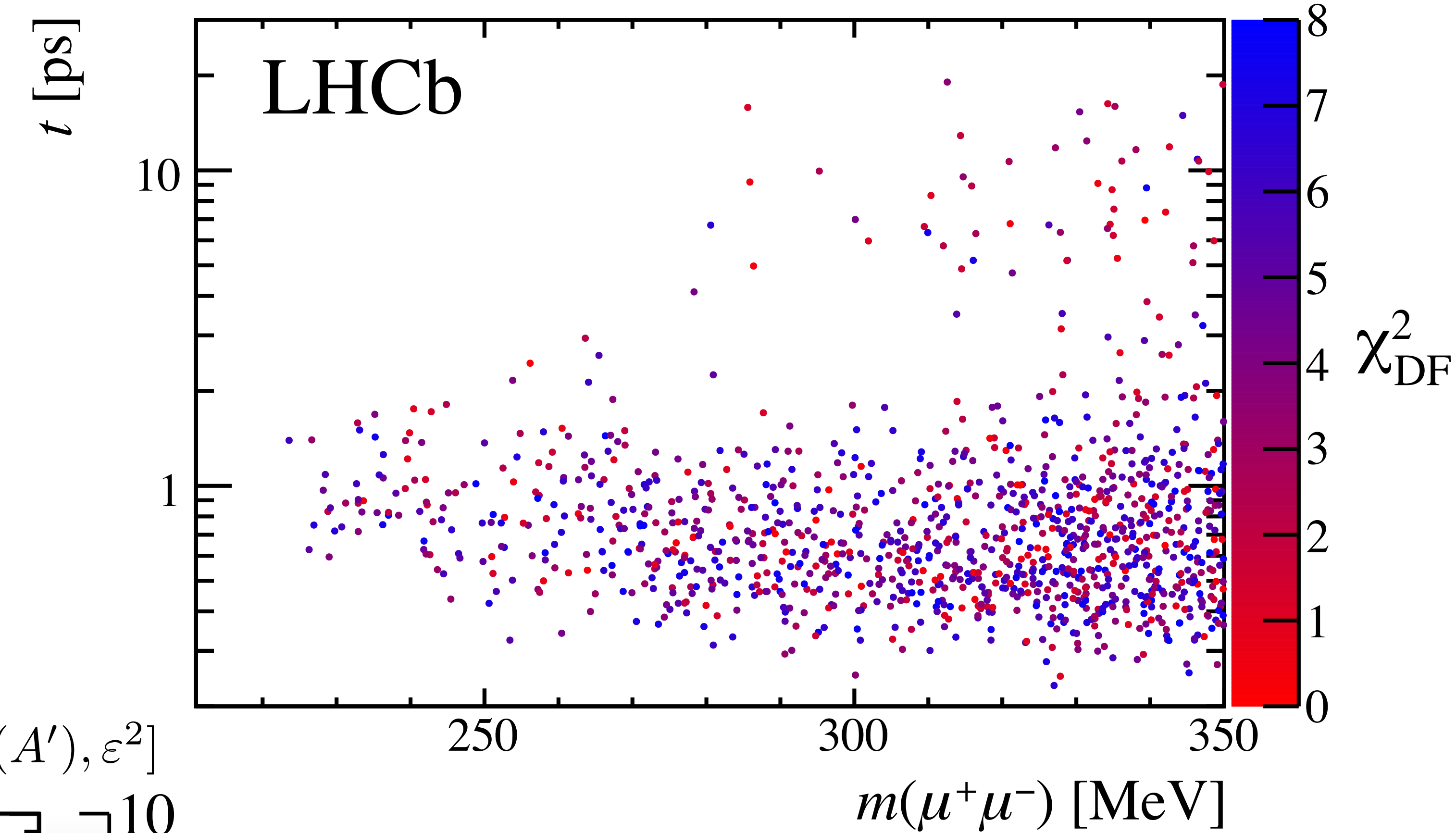
Good separation between conversions and signal — but much better performance expected in the Run 3 VELO (for several reasons).

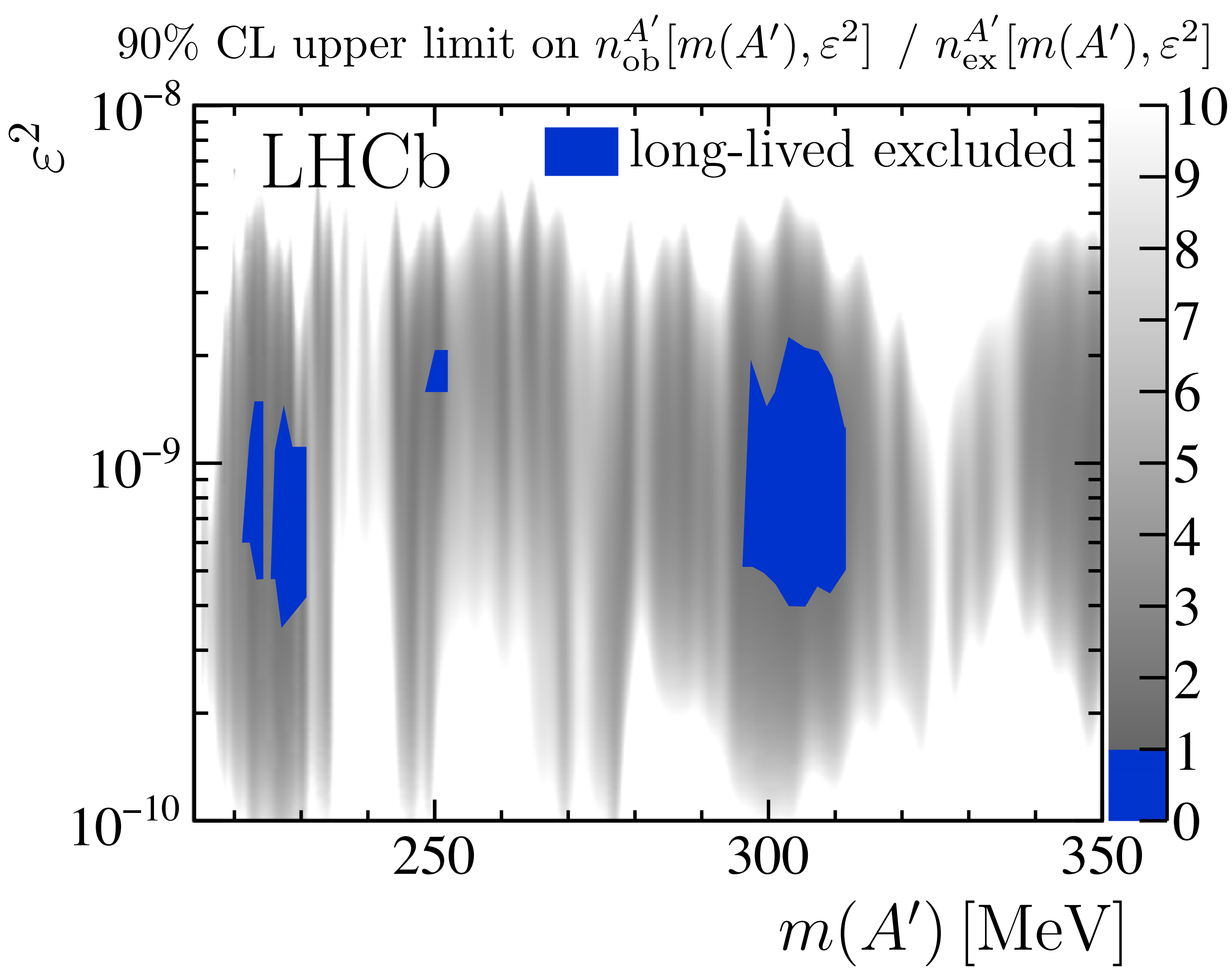
LHCb-PAPER-2017-038
1710.02867

Long-Lived A'

Long-lived sample ~conversion free!

After applying the material veto, the sample is ~conversion free, with some remaining backgrounds from heavy-flavor at short lifetimes, and the low-mass tail of KS-to-pipi double misID at large lifetimes and masses.





Achieve first sensitivity using a displaced-vertex signature by performing 3-D fits in the bump hunt.

Large regions of parameter space are nearly accessible in this sample. (Results are better than our predictions here.)

N.b., have a plan to greatly reduce the backgrounds in next update.

A' Results

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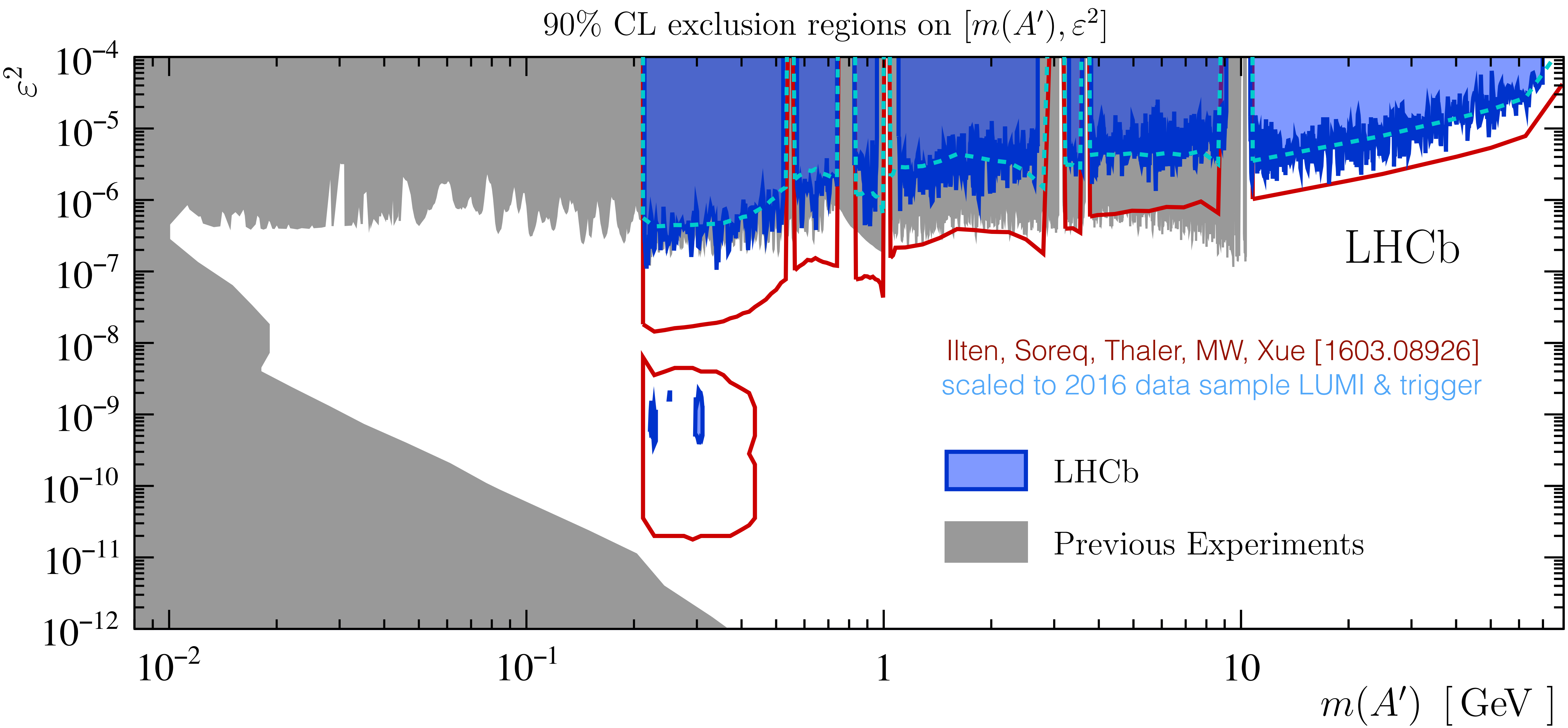
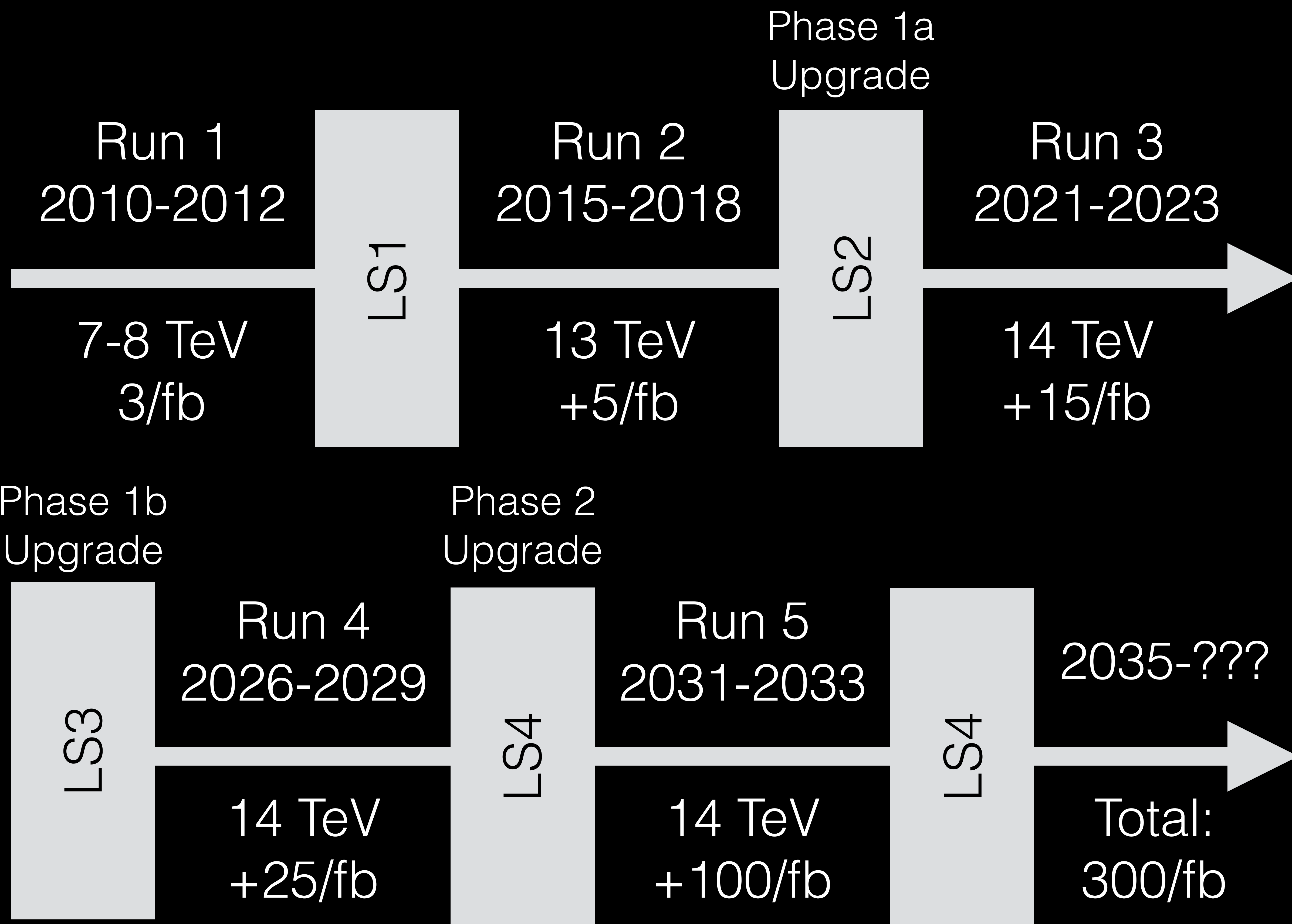
1710.02867

The 2016 dimuon results are consistent with (better than) our predictions for prompt (long-lived) dark photons. We implemented huge improvements in the 2017 triggers for low masses (~2.5 gain for prompt, 4x looser IP cuts for displaced), so plan quick turn around on 2017 dimuon search — then onto electrons.



Best guess: the Run 3 dimuon predictions are quite good, assuming that the Run 3 detector performs as expected.

Long Term Plans



Summary

LHCb is now officially a dark-photon experiment with unique sensitivity that is expected to improve greatly in the (near and far) future.