CODEX-β: opening the book for CODEX-b

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7TH LLP WORKSHOP

Expression of Interest

arXiv:1911.00481 [hep-ex]

Expression of Interest for the CODEX-b Detector

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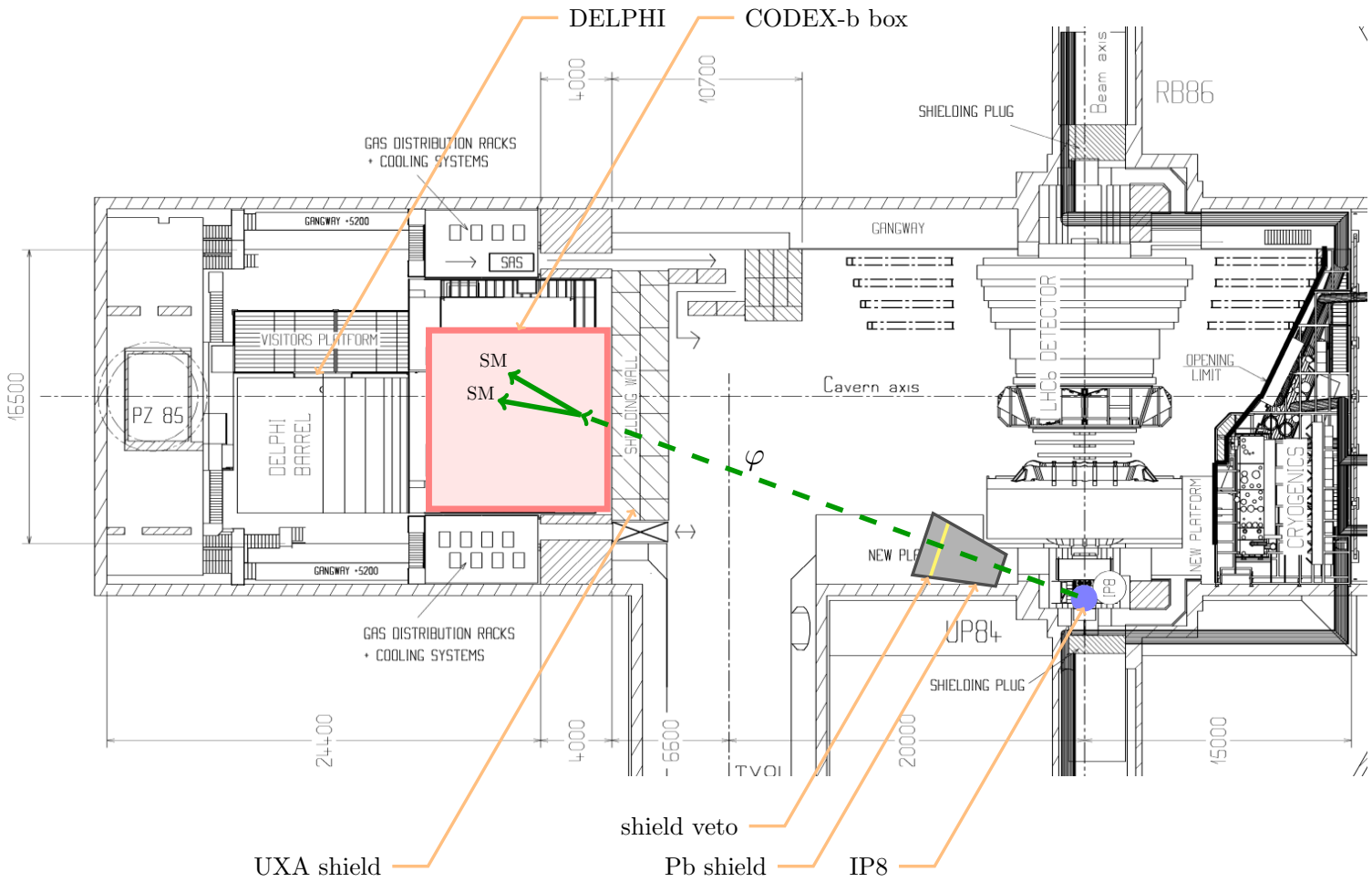
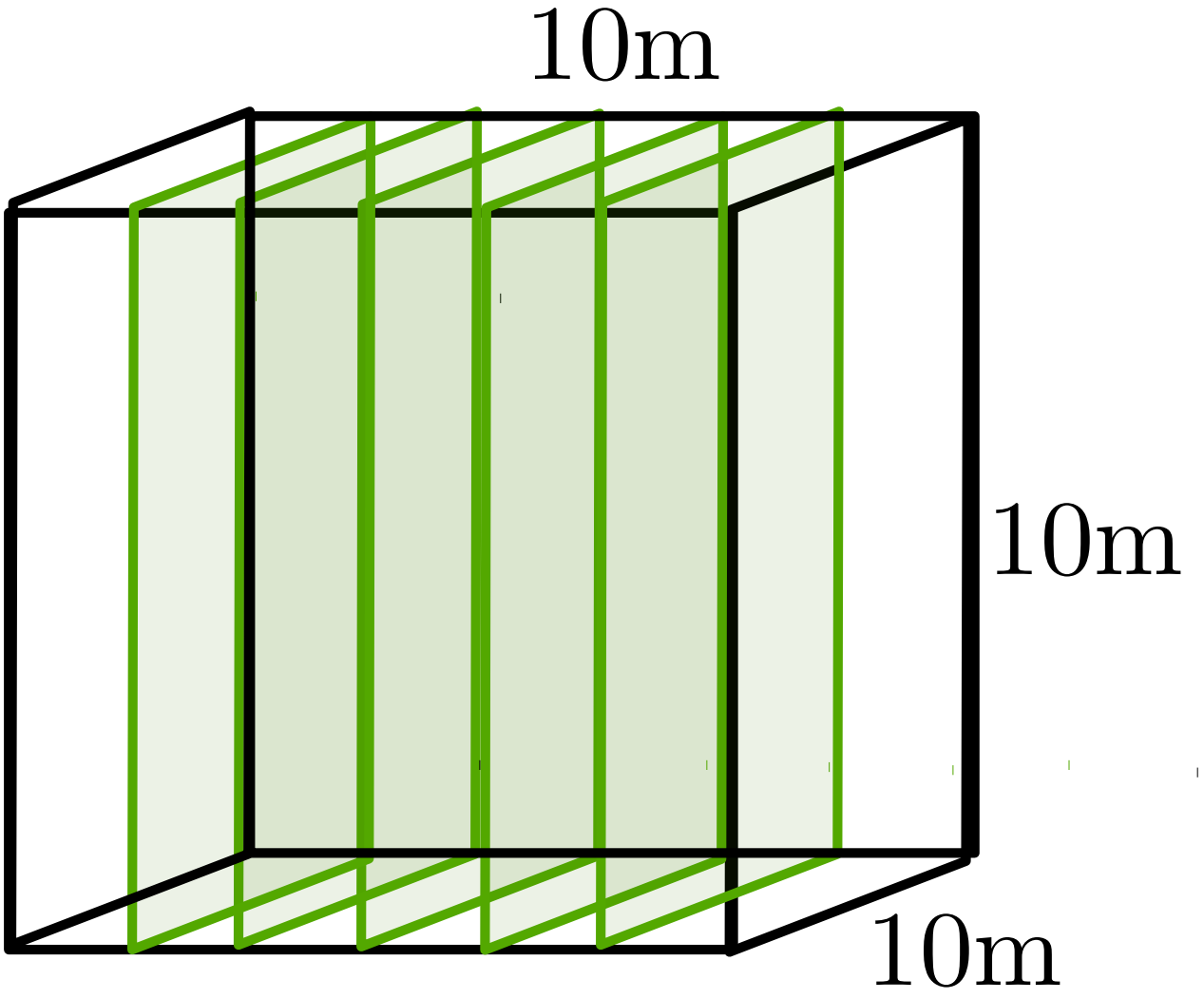
- A **Co**mpact **D**etector for **Ex**otics at LHC**b**
- letter of interest released last November, arXiv:1911.00481 [hep-ex]
- letter of intent submitted
- collaboration growing: 28 contributors and 16 institutes

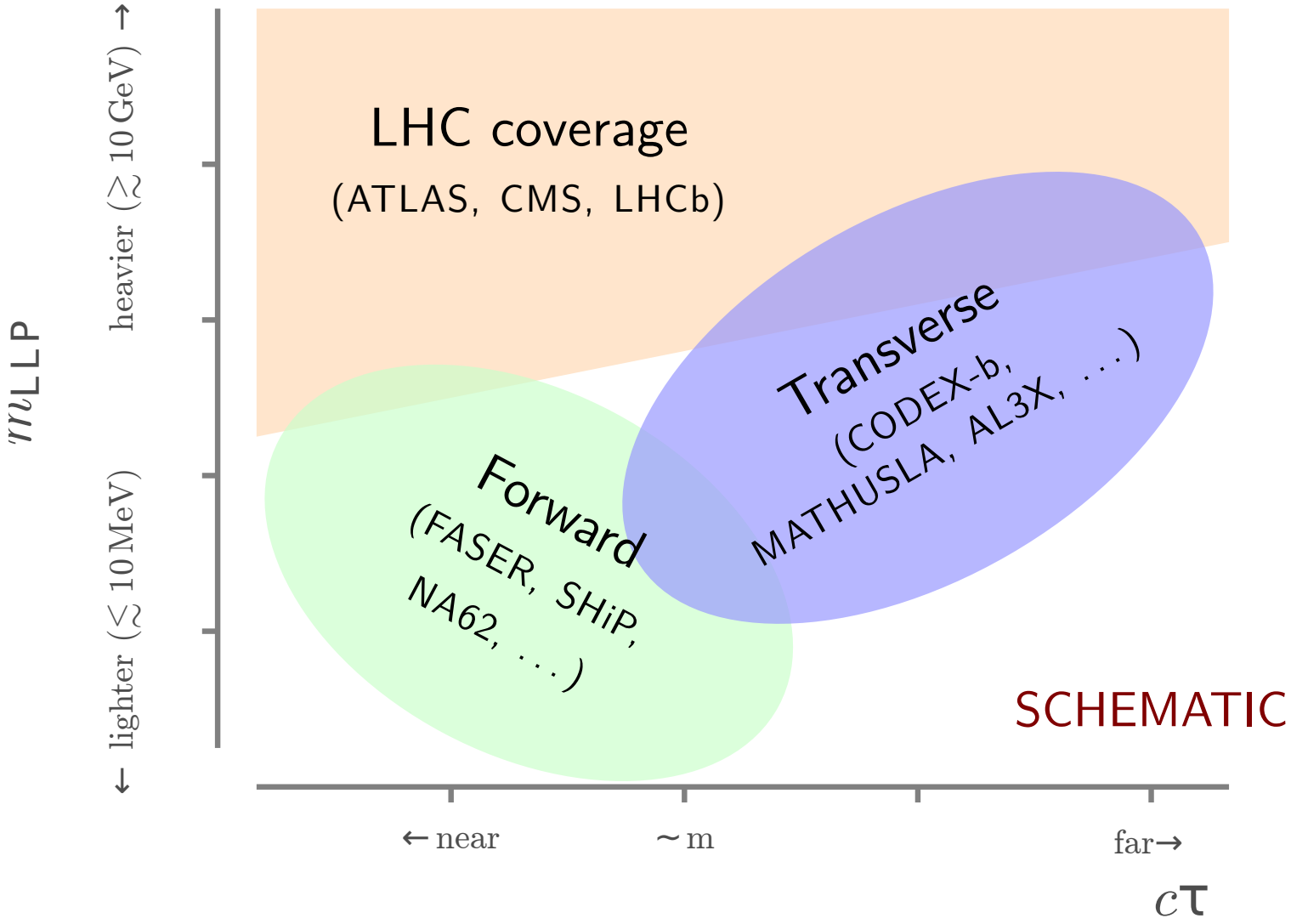
CODEX-b in a Nutshell



Zooming In



A Picture is Worth . . .



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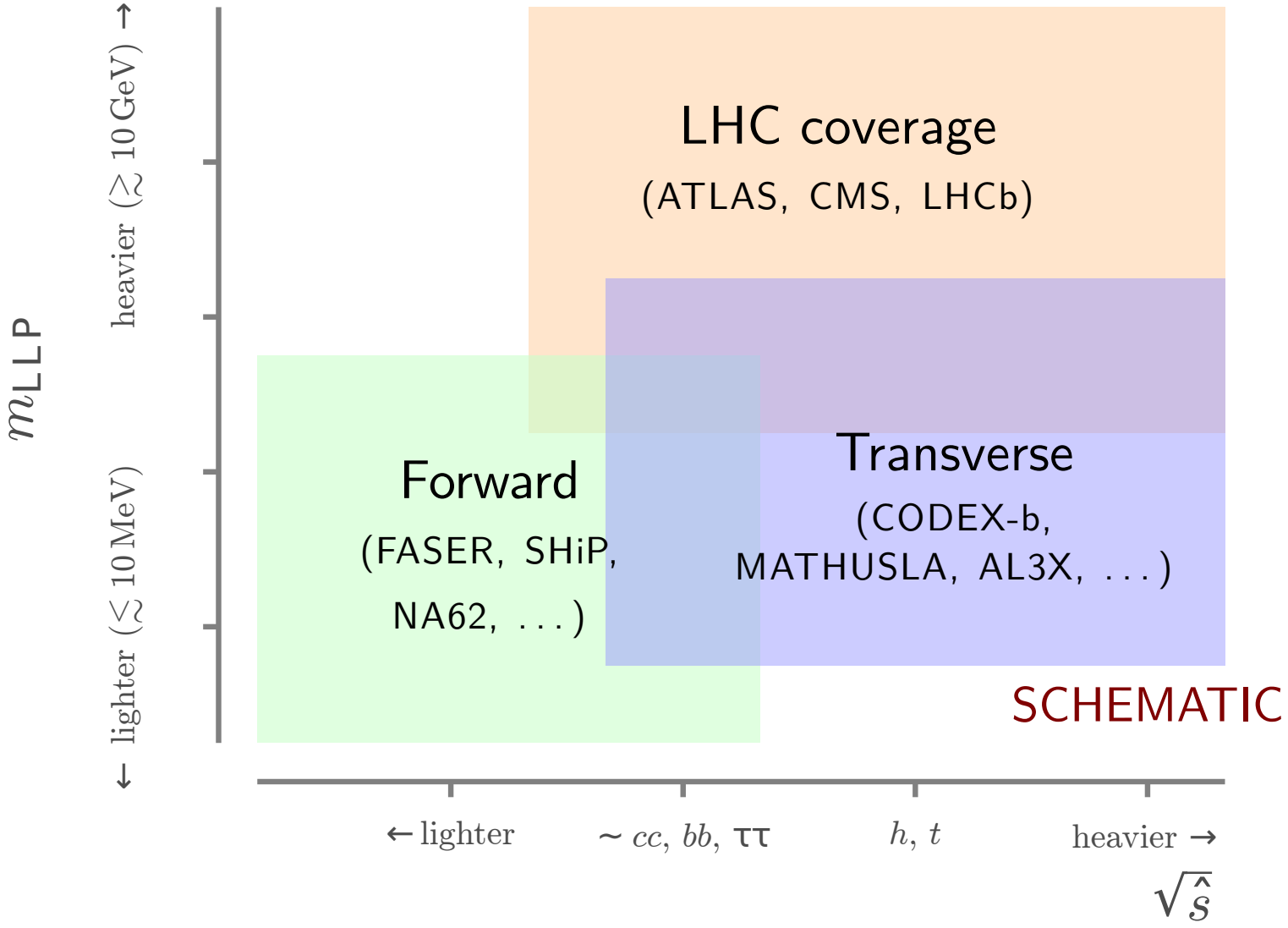
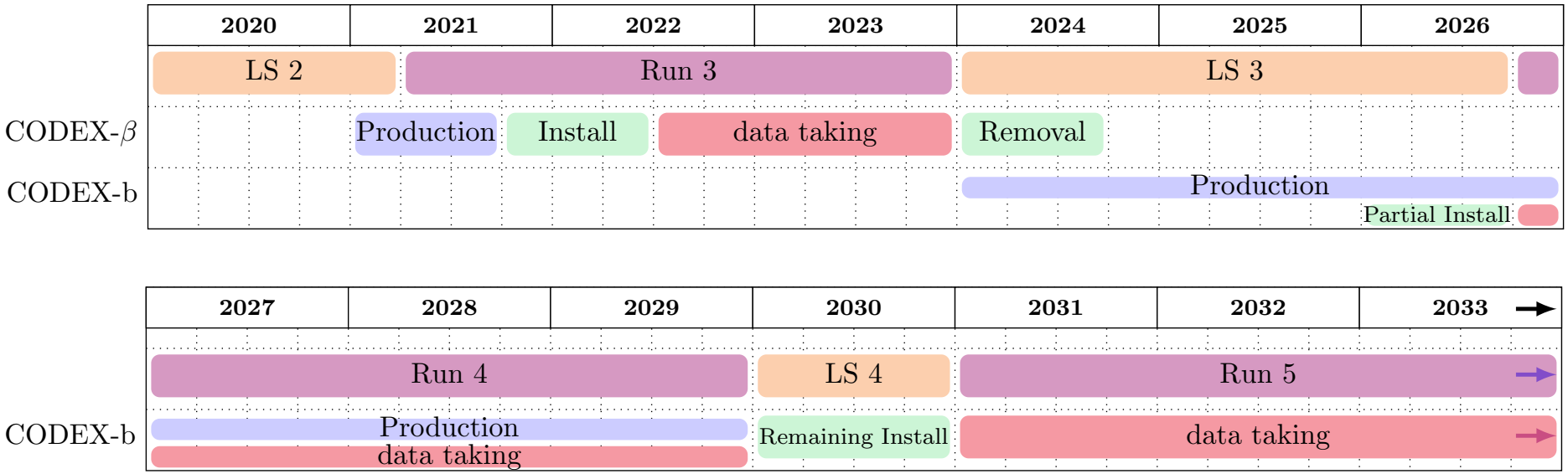


Why CODEX-b?

1. we need a transverse detector at the LHC
2. probes a wide range of LLP models; complementary or competitive with existing/proposed detectors
3. accessible zero background location with necessary services, DELPHI/UXA cavern
4. integration with LHCb trigger-less readout
5. compact size and modest cost with ability to extend

Timing is Key (pre COVID-19)



- significant progress has been made
- priority is finalising CODEX-β design and plans
- Birmingham (James Glover) working on technical drawings
- more detailed design informed from CODEX-β

Reach

Model Overview

Vector (A')	$hA'A'$	$F'F$
$F'F$	yes	no reach

Scalar (S)	$SH^\dagger H$	$S^2H^\dagger H$
$SH^\dagger H$	yes	yes

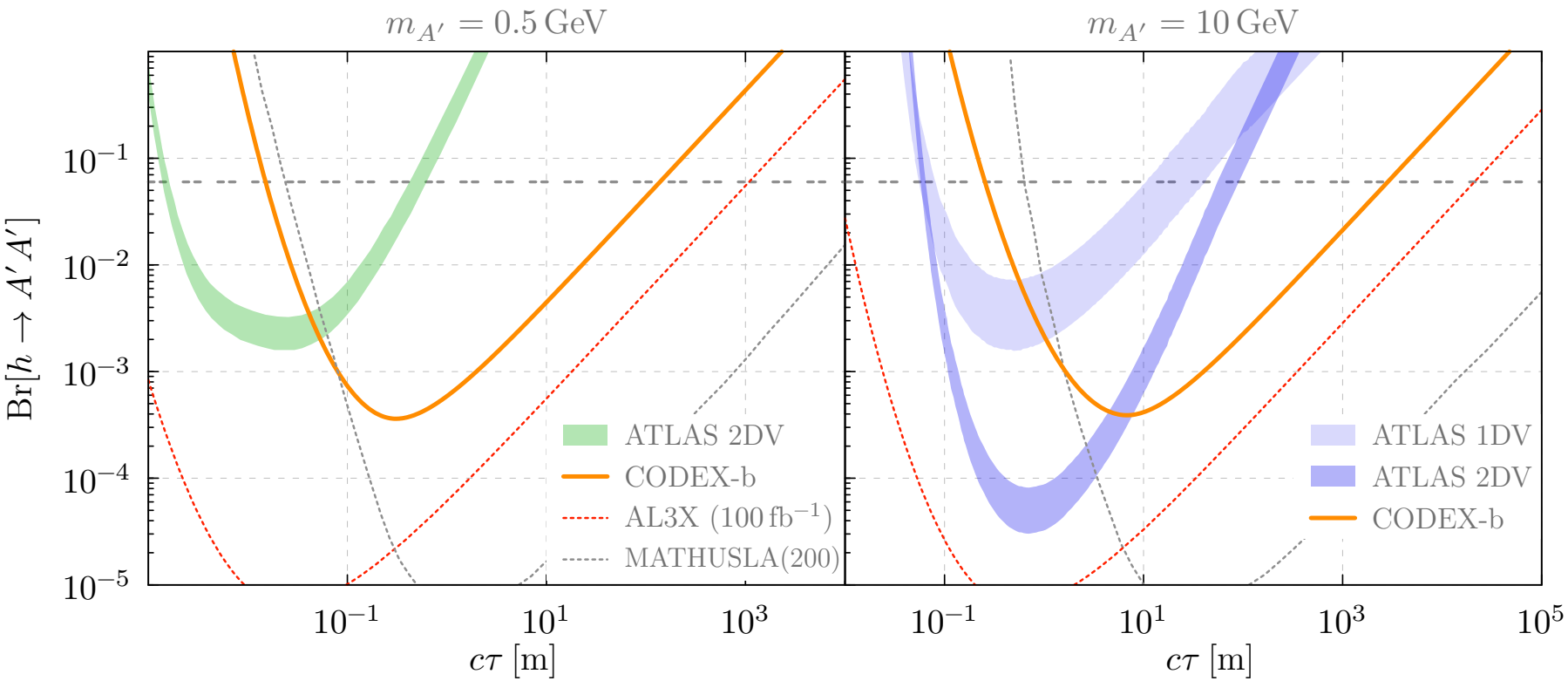
HNL (N)	HLN
HLN	yes

ALP (a)	$\partial_\mu a\bar{q}\gamma^\mu\gamma^5 q$	$a\tilde{G}G$	$a\tilde{F}F$	$a(W\tilde{W}-B\tilde{B})$
	yes	yes	pending	pending

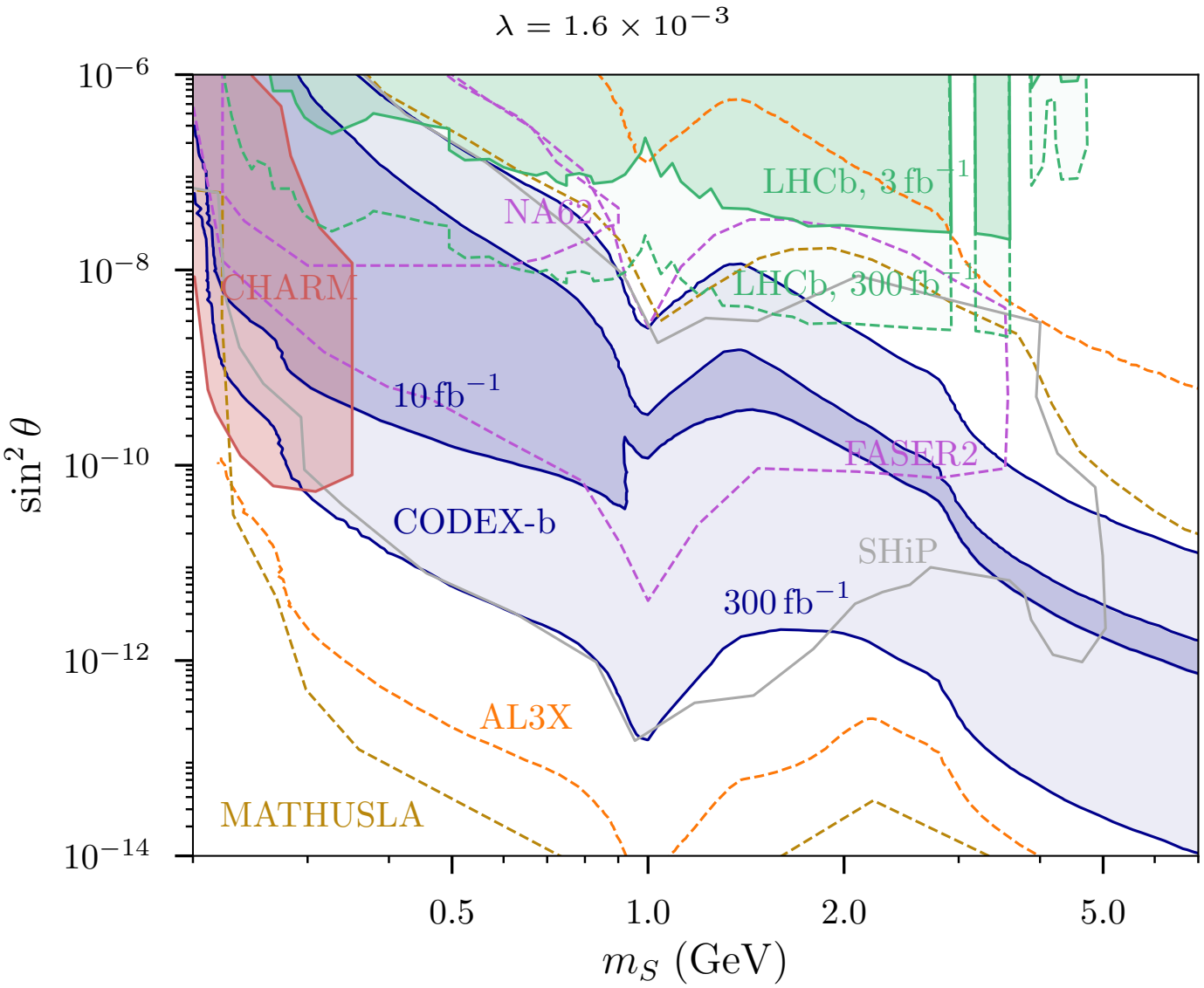
- Production portal
- Decay portal
- UV operator

Dark Photon

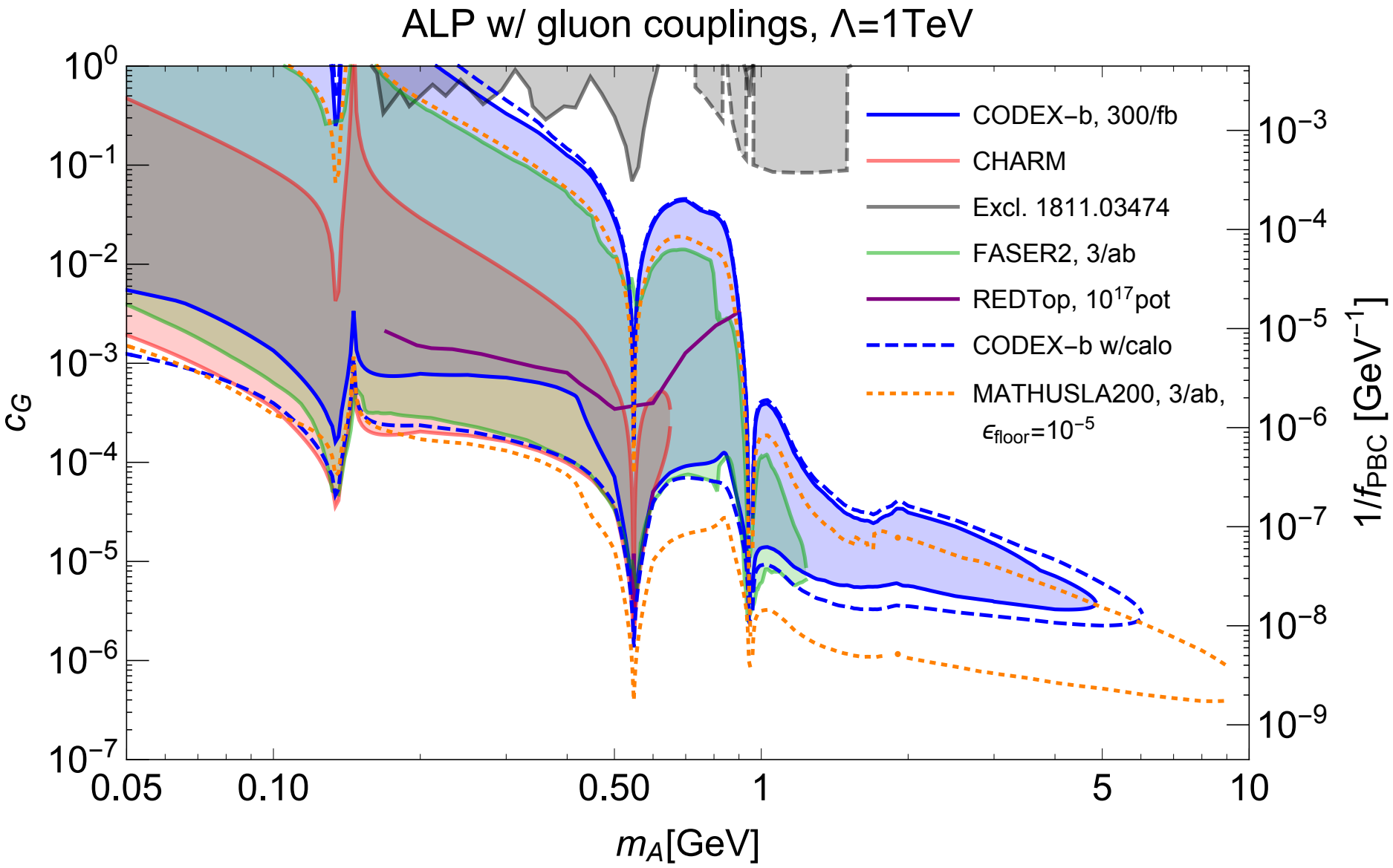
- no sensitivity to inclusive production from EM currents
- sensitive to production from $H \to A'A'$ decays



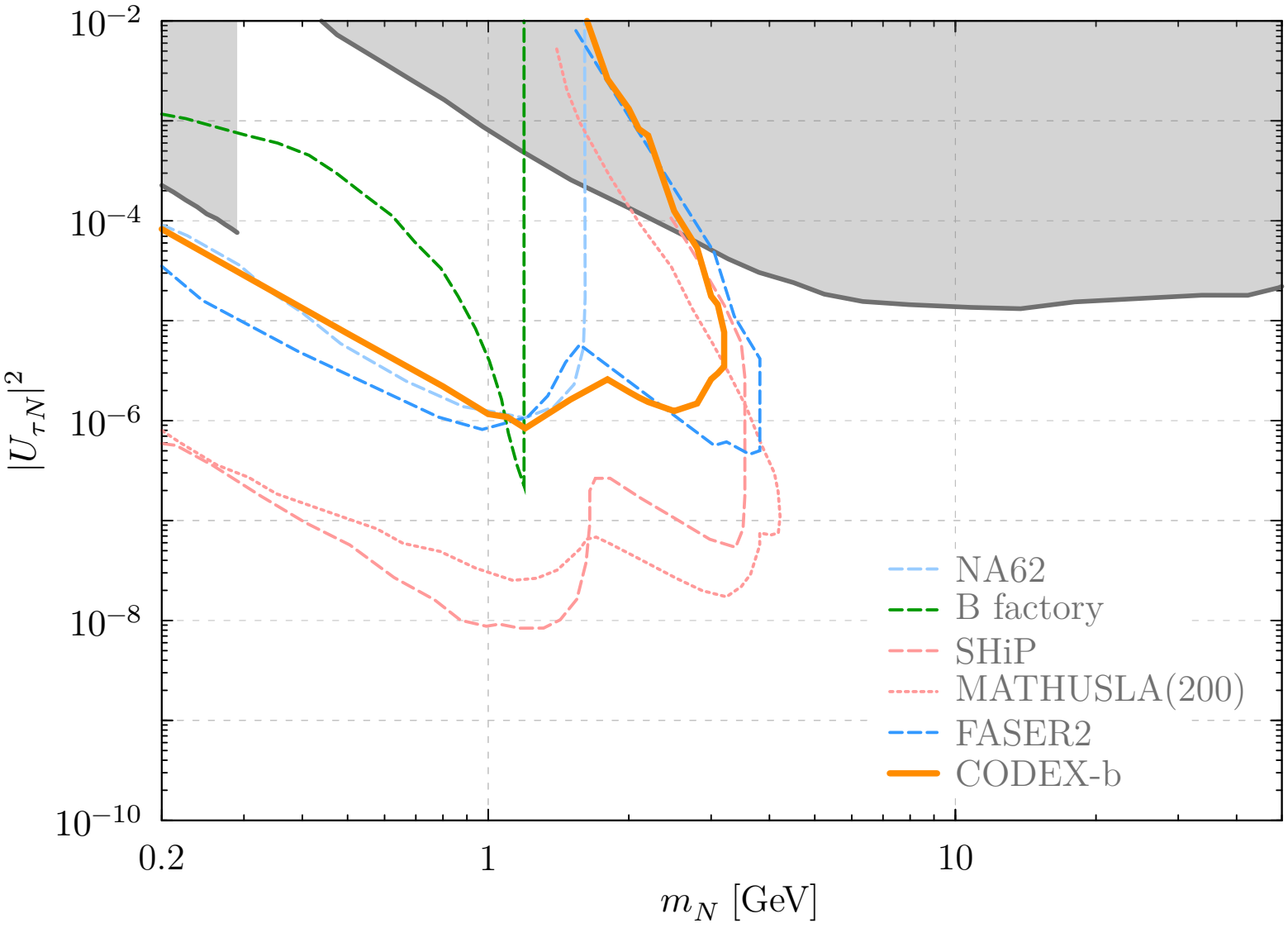
Higgs Portal



Gluon Coupled ALPs

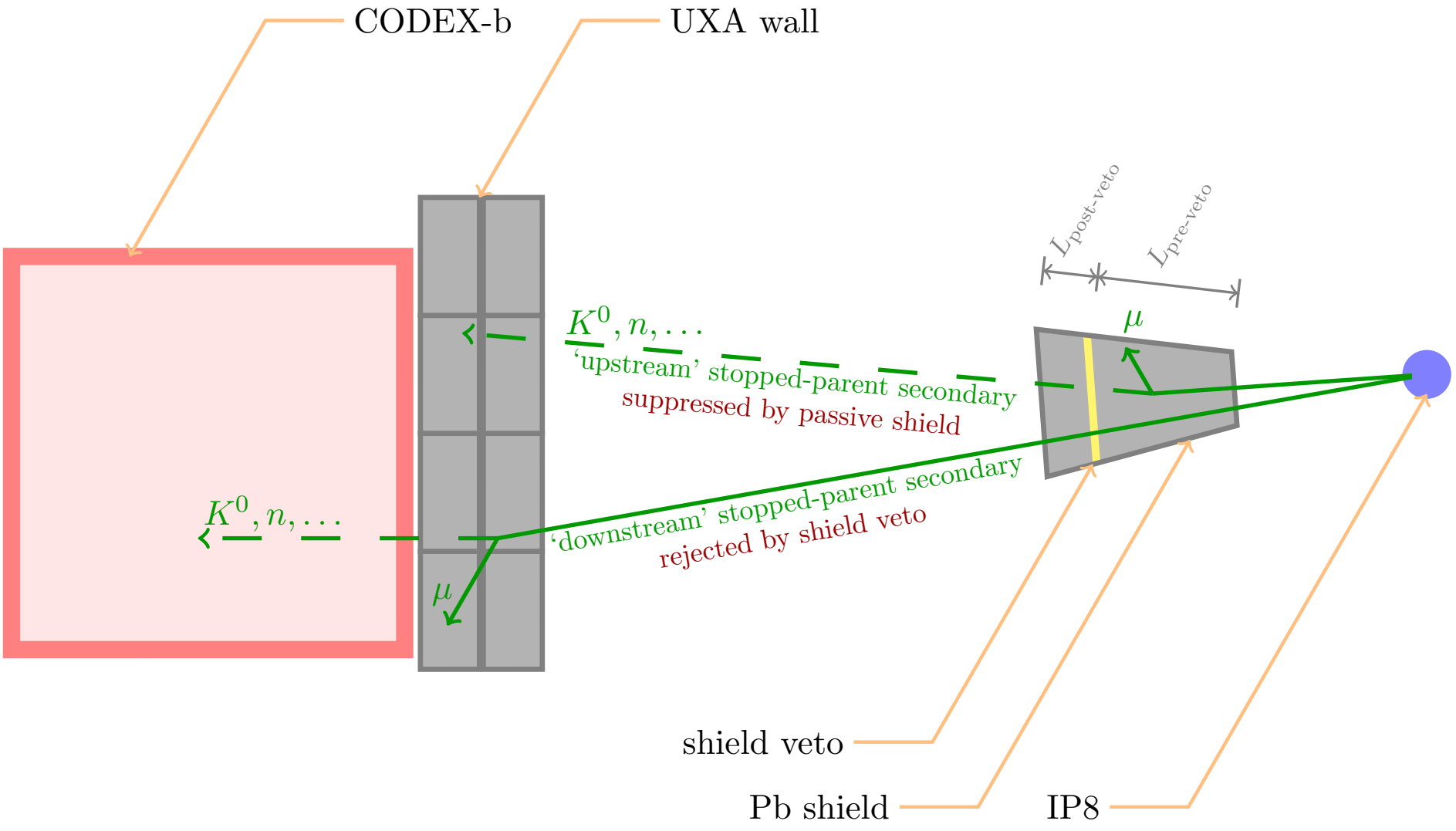


Heavy Neutral Leptons

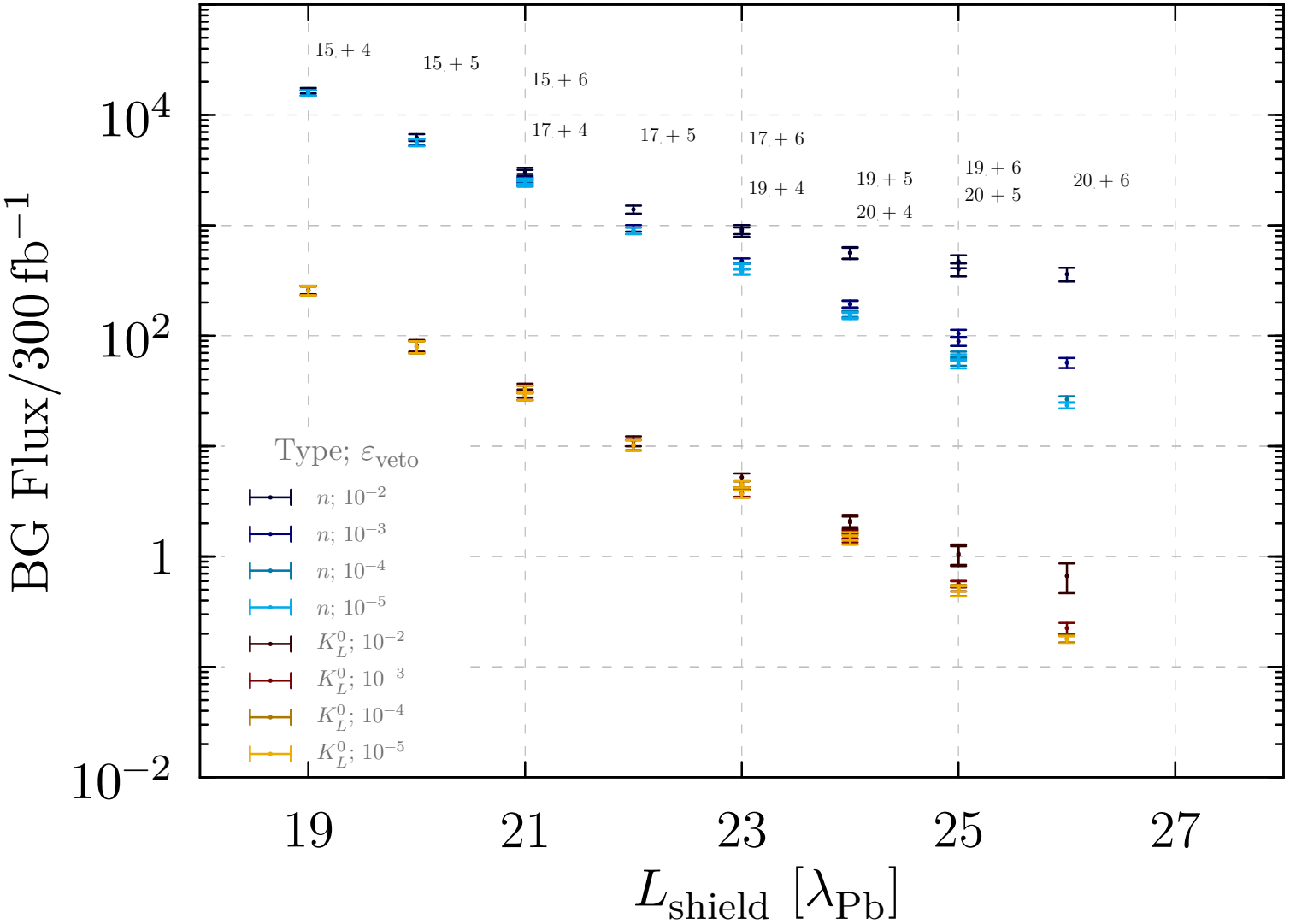


Building CODEX-b

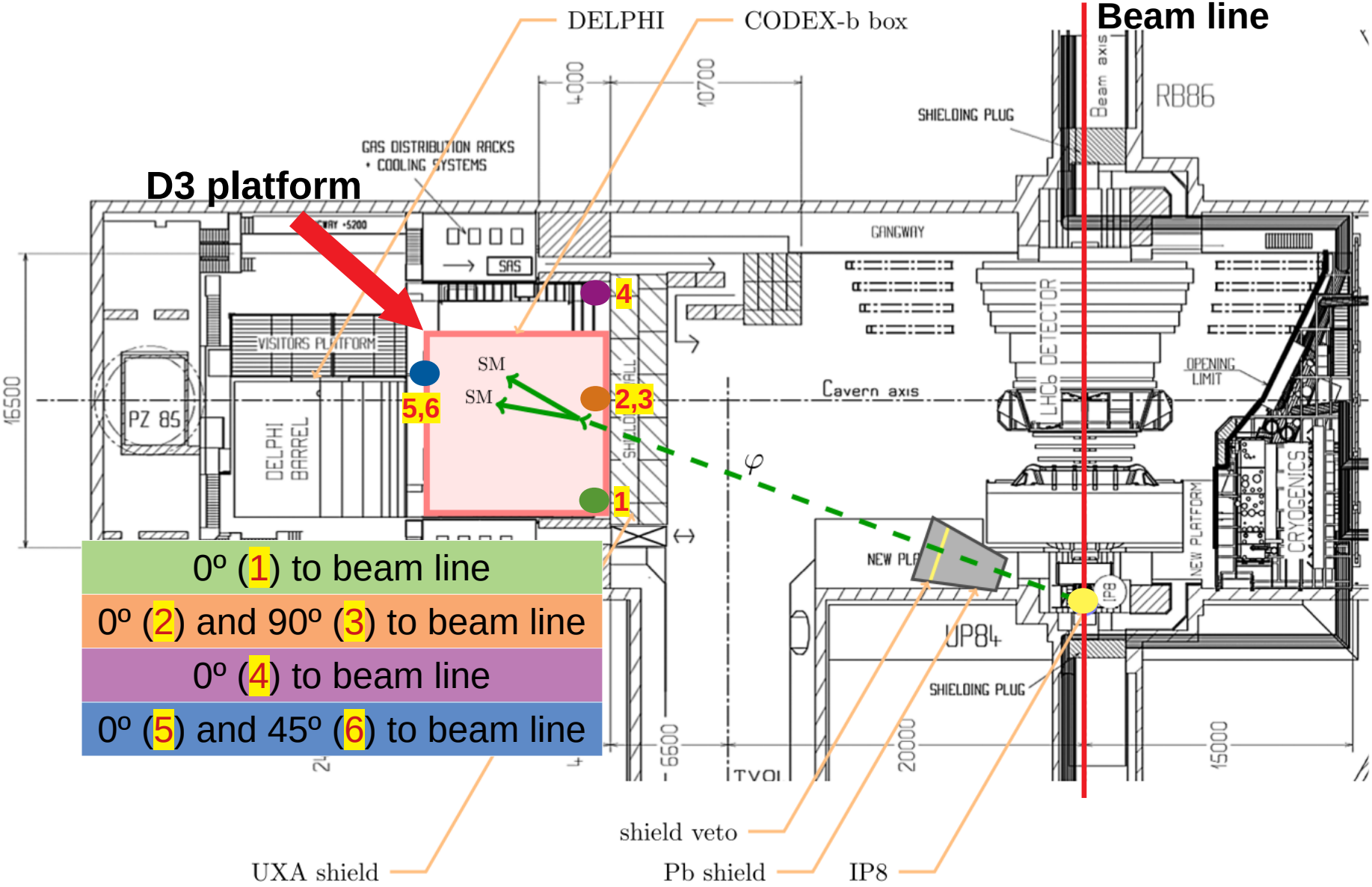
Shielding


CODEX-b
UXA wall
$L_{\text{post-veto}}$
$L_{\text{pre-veto}}$
$K^0, n, \ldots$
'upstream' stopped-parent secondary
suppressed by passive shield
μ
$K^0, n, \ldots$
'downstream' stopped-parent secondary
rejected by shield veto
μ
shield veto
Pb shield
IP8

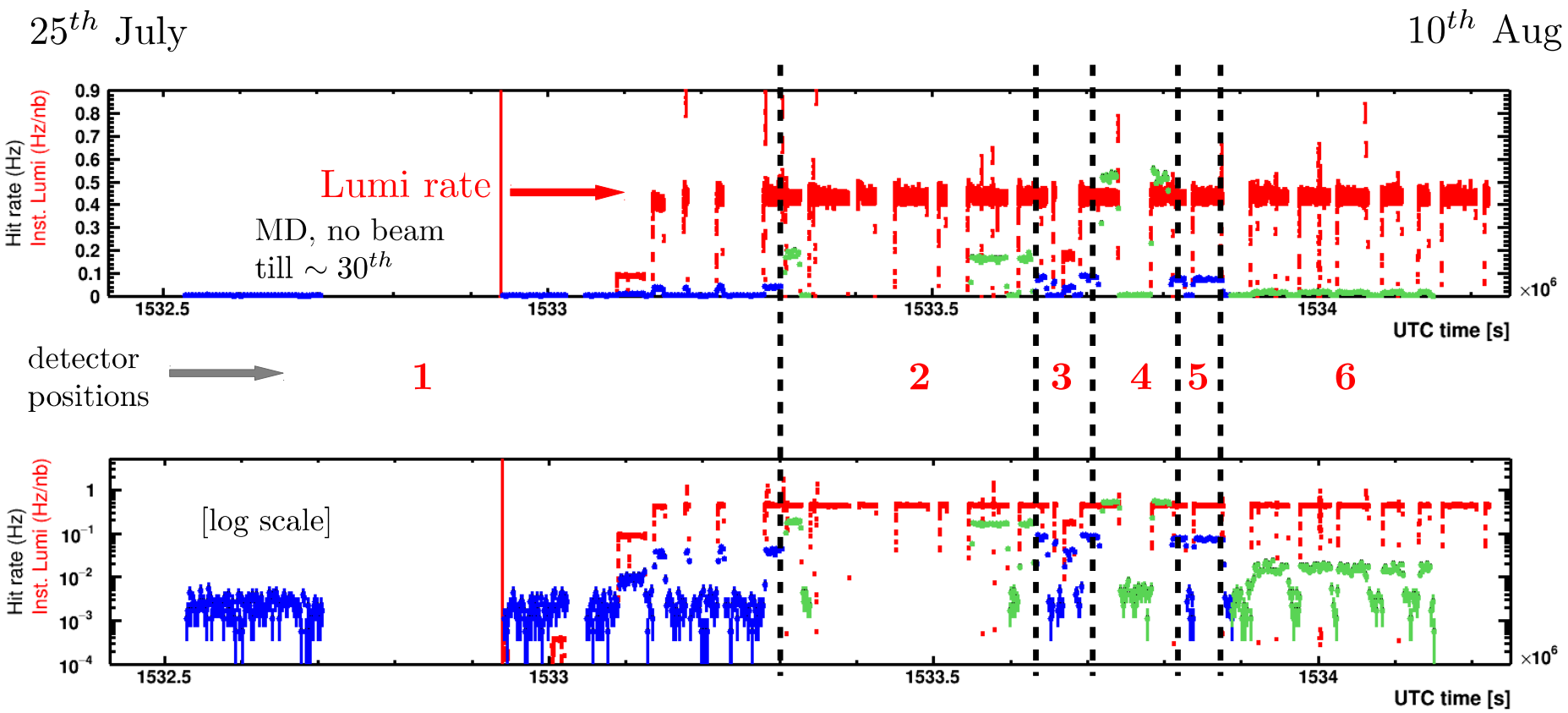
Background Simulation



Background Measurement



Background Measurement



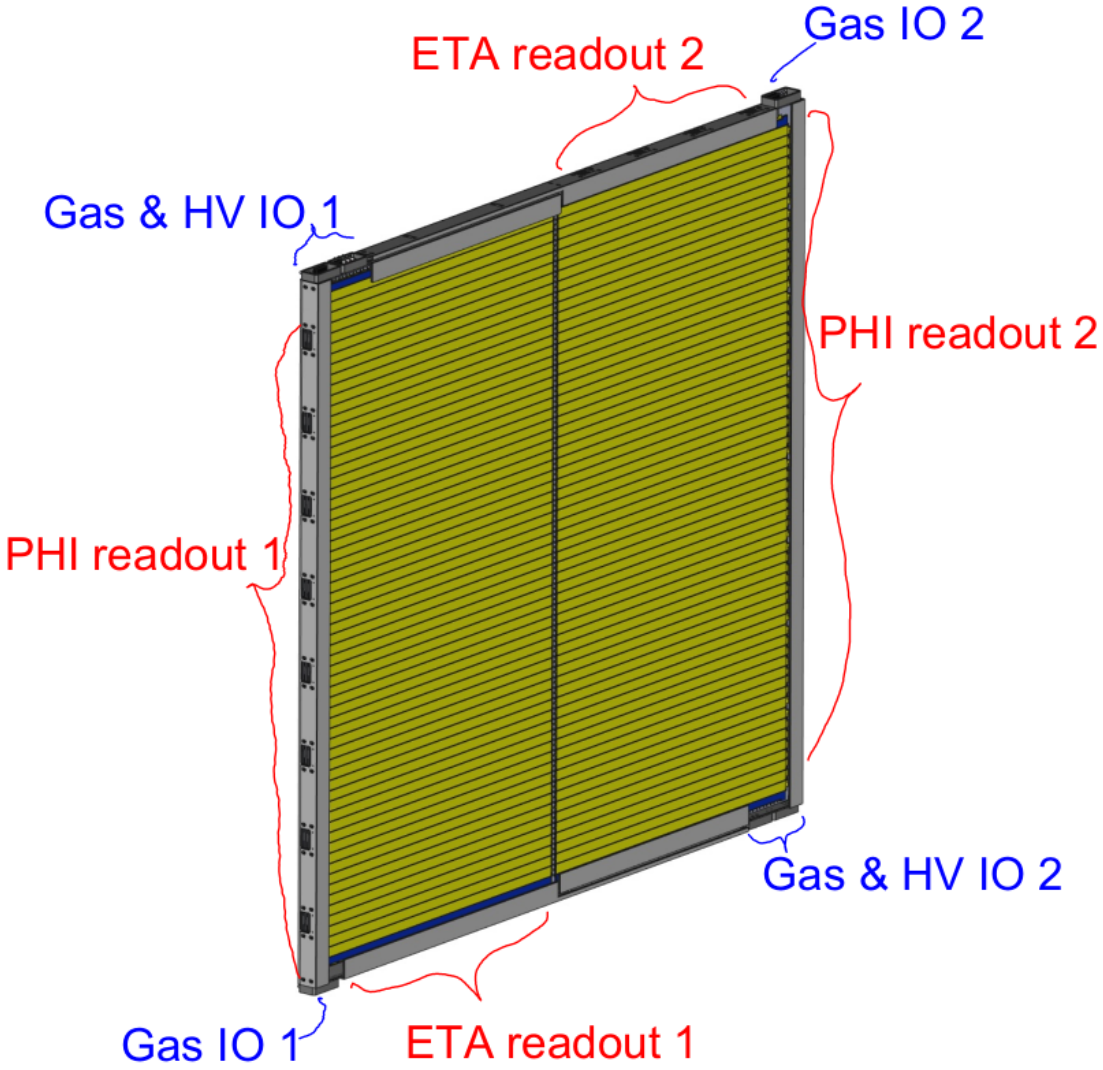
- 0.2 Hz hit rate at point 2 indicates GEANT4 prediction of 10 Hz is conservative

CODEX-β

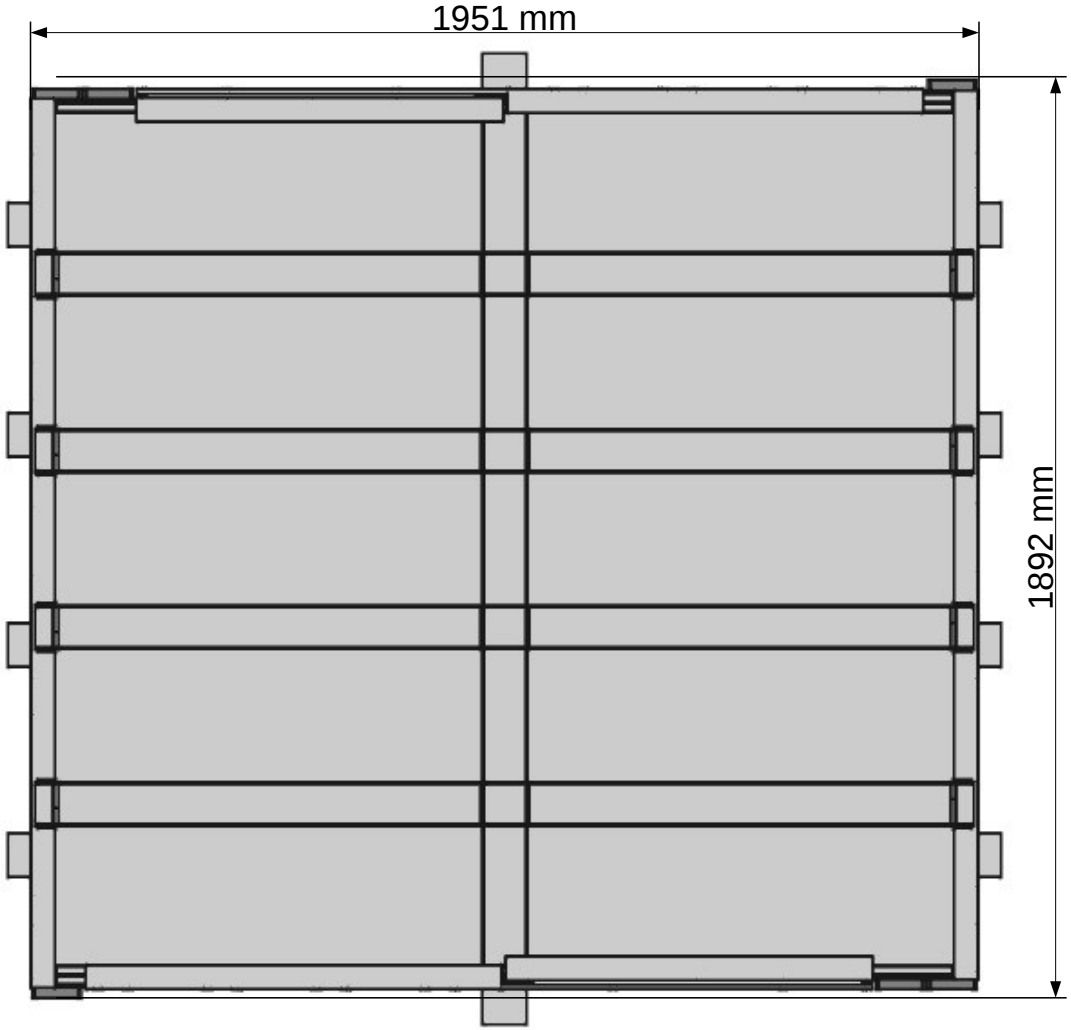
- $2 \times 2 \times 2$ m^3 with central layer, each layer with triplet of RPCs
- each layer made of 2×1 m^2 RPC block, 42 such layers
- expected hardware cost of 150k EUR

1. *Demonstrate the ability to detect and reconstruct charged particles which penetrate into the DELPHI cavern as well as the decay products of neutral particles decaying within the DELPHI cavern.*
2. *Detect and reconstruct a reasonable rate of neutral particles decaying inside the hermetic detector volume.*
3. *Show that CODEX-b can be integrated into the LHCb DAQ and demonstrate an ability to give a trigger to LHCb to retain an event that looks interesting in CODEX-b.*

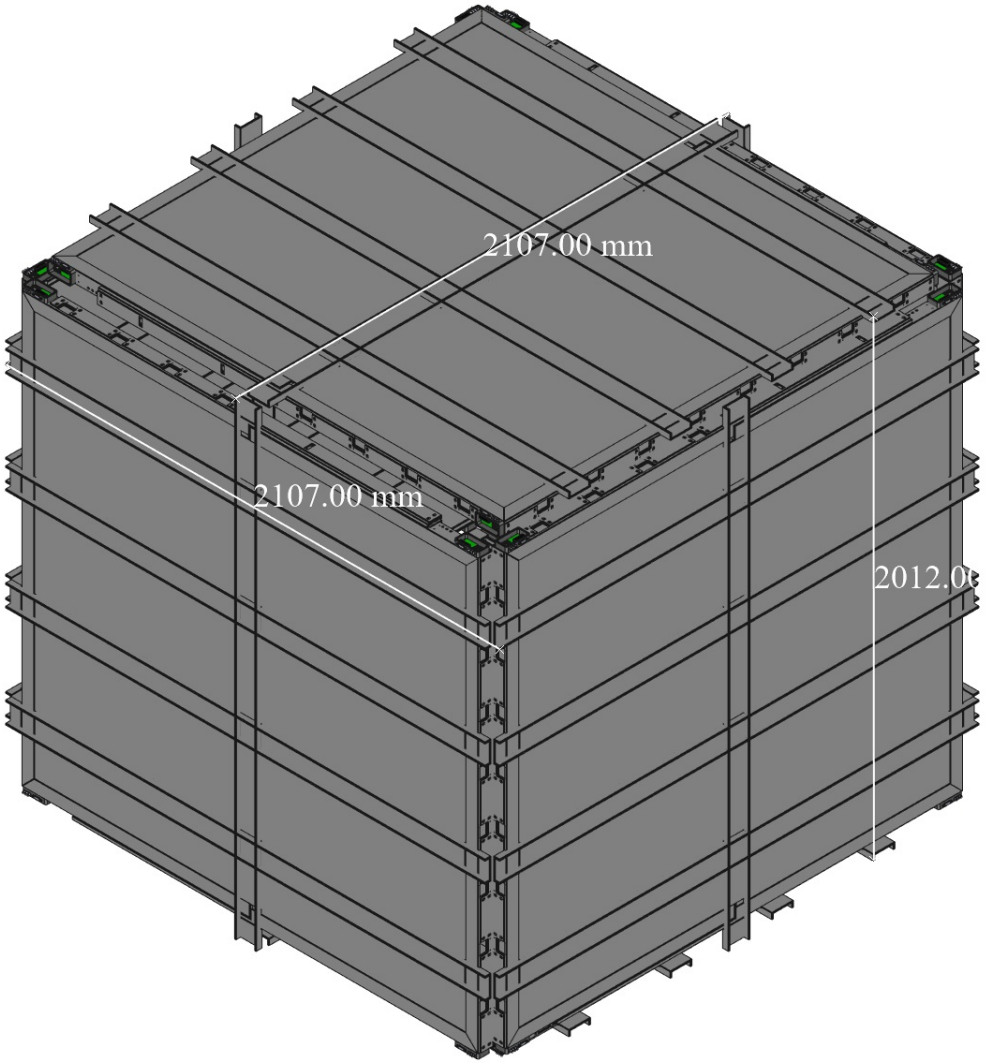
Triplet Support



Outside Support



Full Structure



Outlook

Some Thoughts

- forward/beam-dump experiments give us light LLPs with medium/long lifetimes and low $\sqrt{\hat{s}}$
- LHC detectors give us heavy LLPs with long lifetimes
- transverse detectors give us light LLPs with long lifetimes and high $\sqrt{\hat{s}}$
- *we need a transverse detector at LHC*

- CODEX-b covers does not have world-leading reach ...
- covers significant portions of parameter space
- low cost in comparison to other proposals

- clear path forward for building CODEX-b
- first steps taken, CODEX-β plans underway

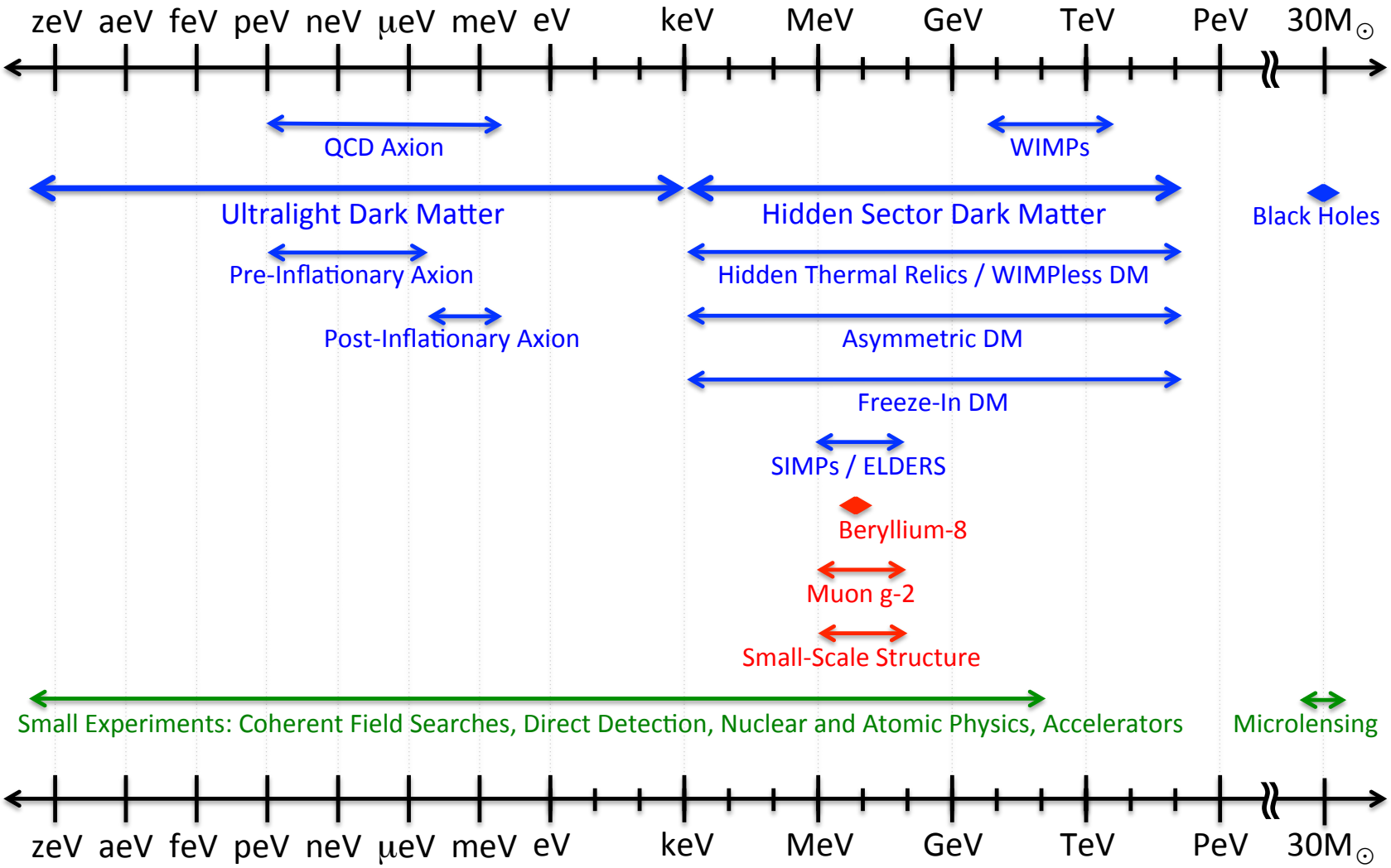
Looking for new collaborators!

Backups

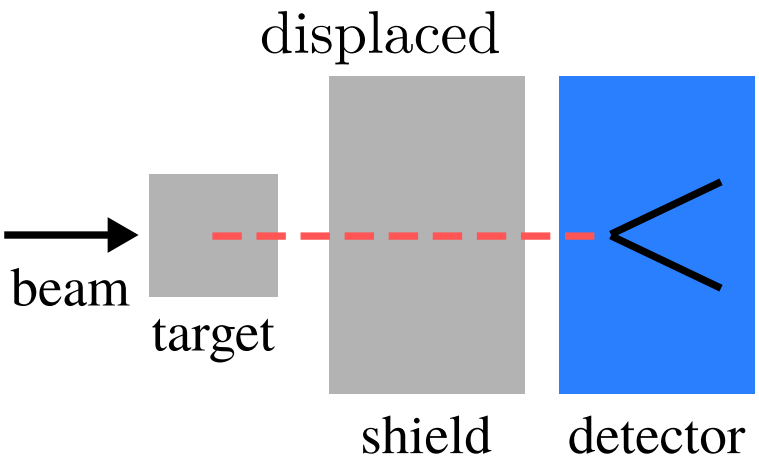
Widening the Net

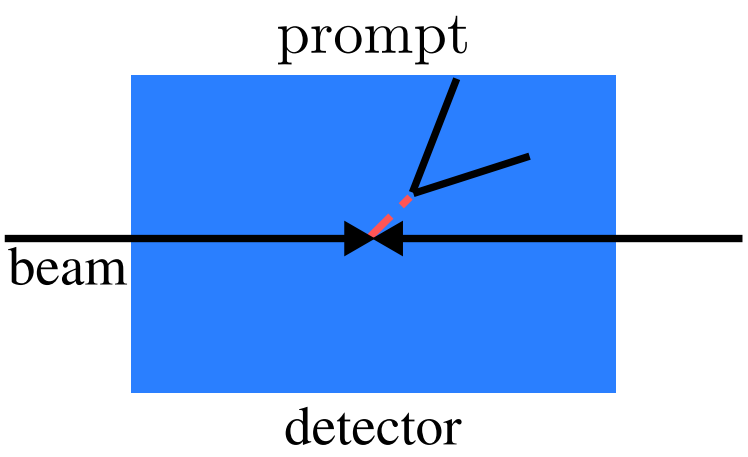
arXiv:1707.04591 [hep-ph]

Dark Sector Candidates, Anomalies, and Search Techniques



Simultaneous Searches





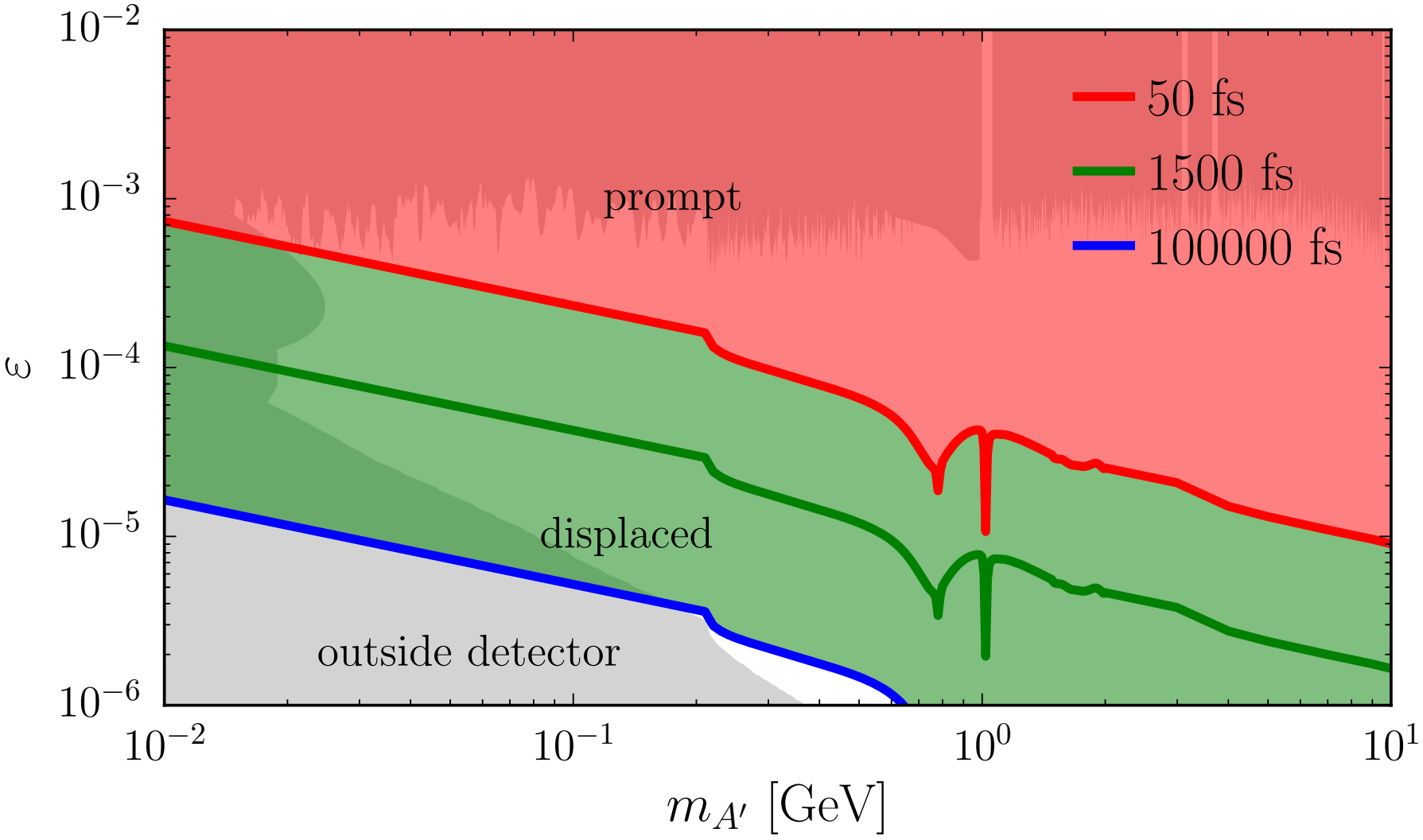
- sensitive to long lifetimes
- EM background free
- difficult to normalise

- sensitive to shorter lifetimes
- bump hunt on large EM background
- normalised from sidebands

- do both simultaneously for best of both worlds

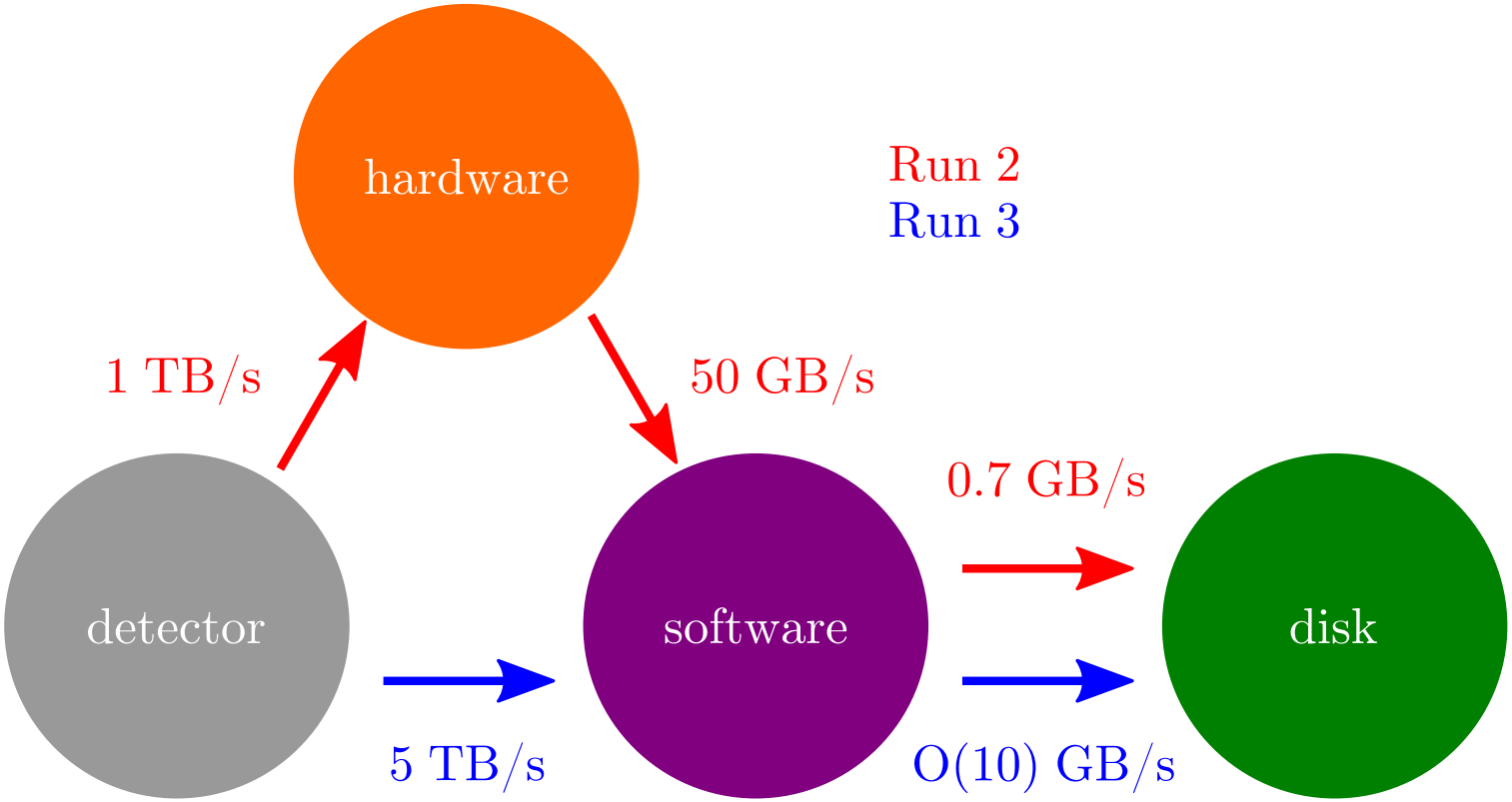
Parameter Space

JHEP 06 (2018)



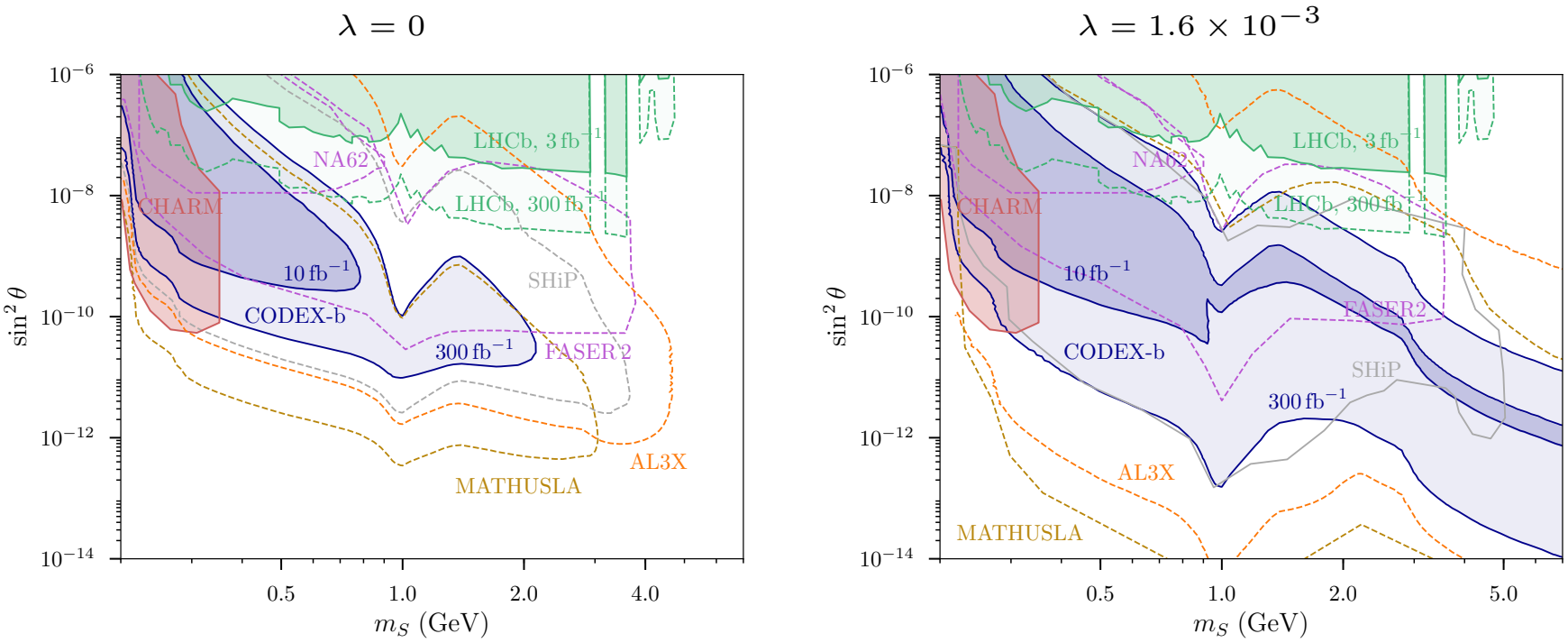
LHCb Trigger

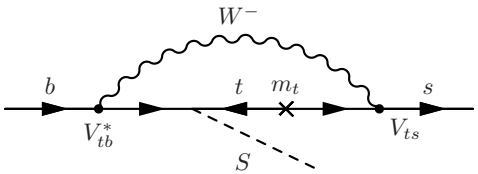
LHCb, JINST 8 (2013)

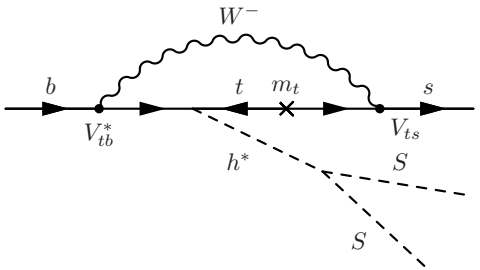


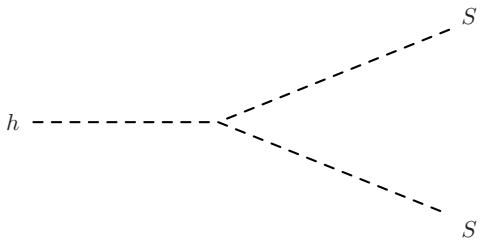
- real-time calibration and full event reconstruction in Run 2
- inclusive dimuon from threshold and jet triggers in Run 2
- full detector readout in Run 3

Higgs Portal

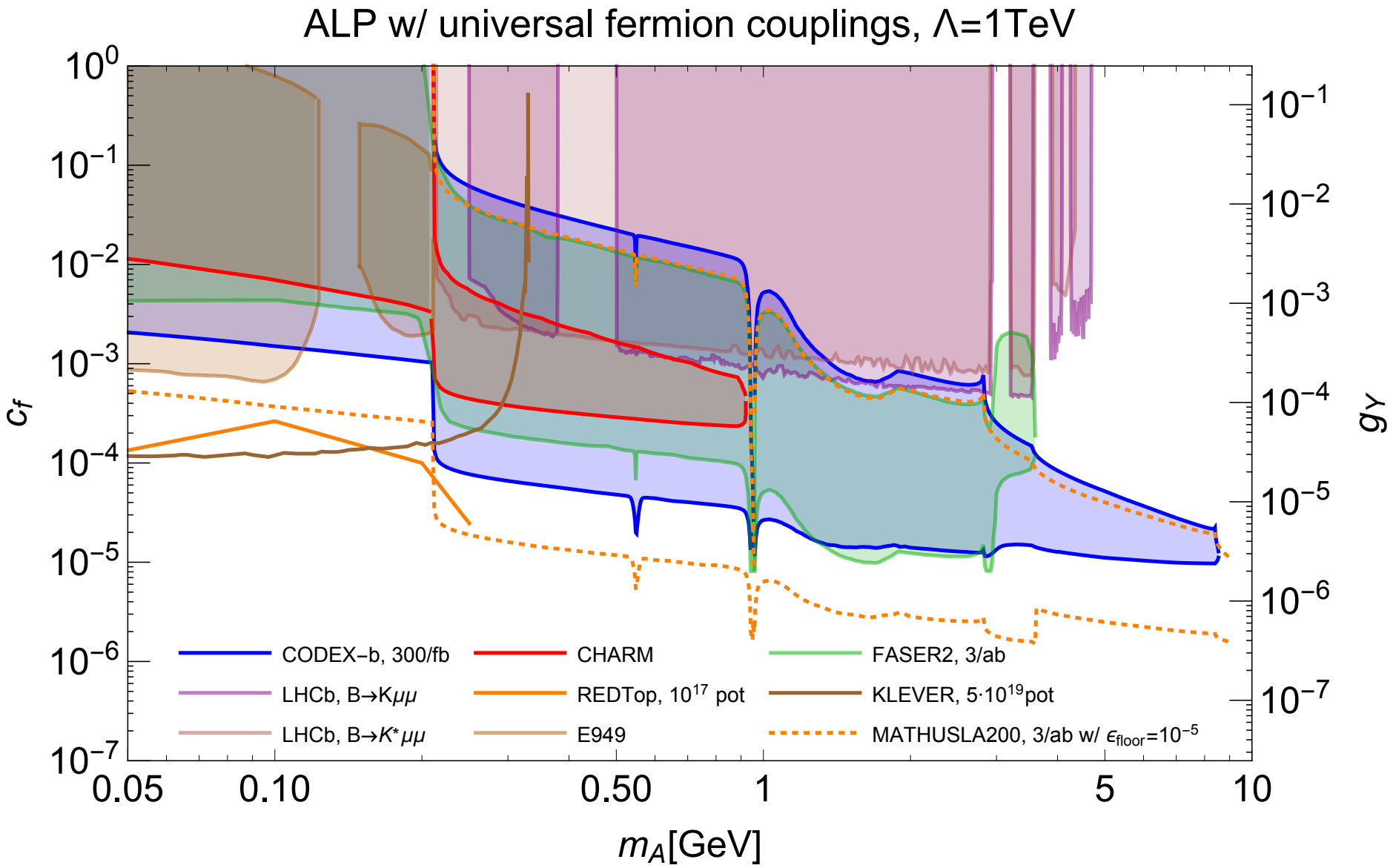




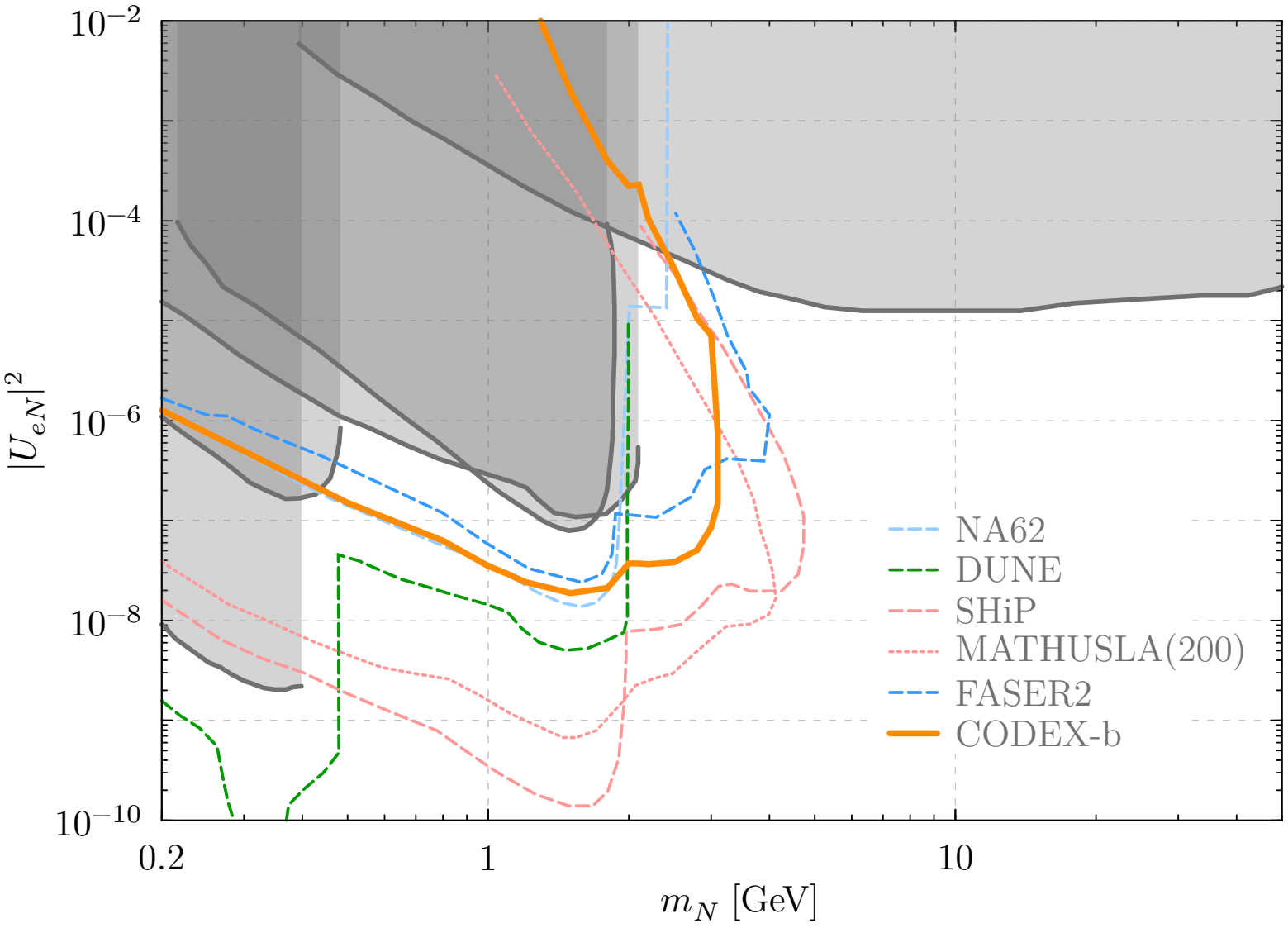




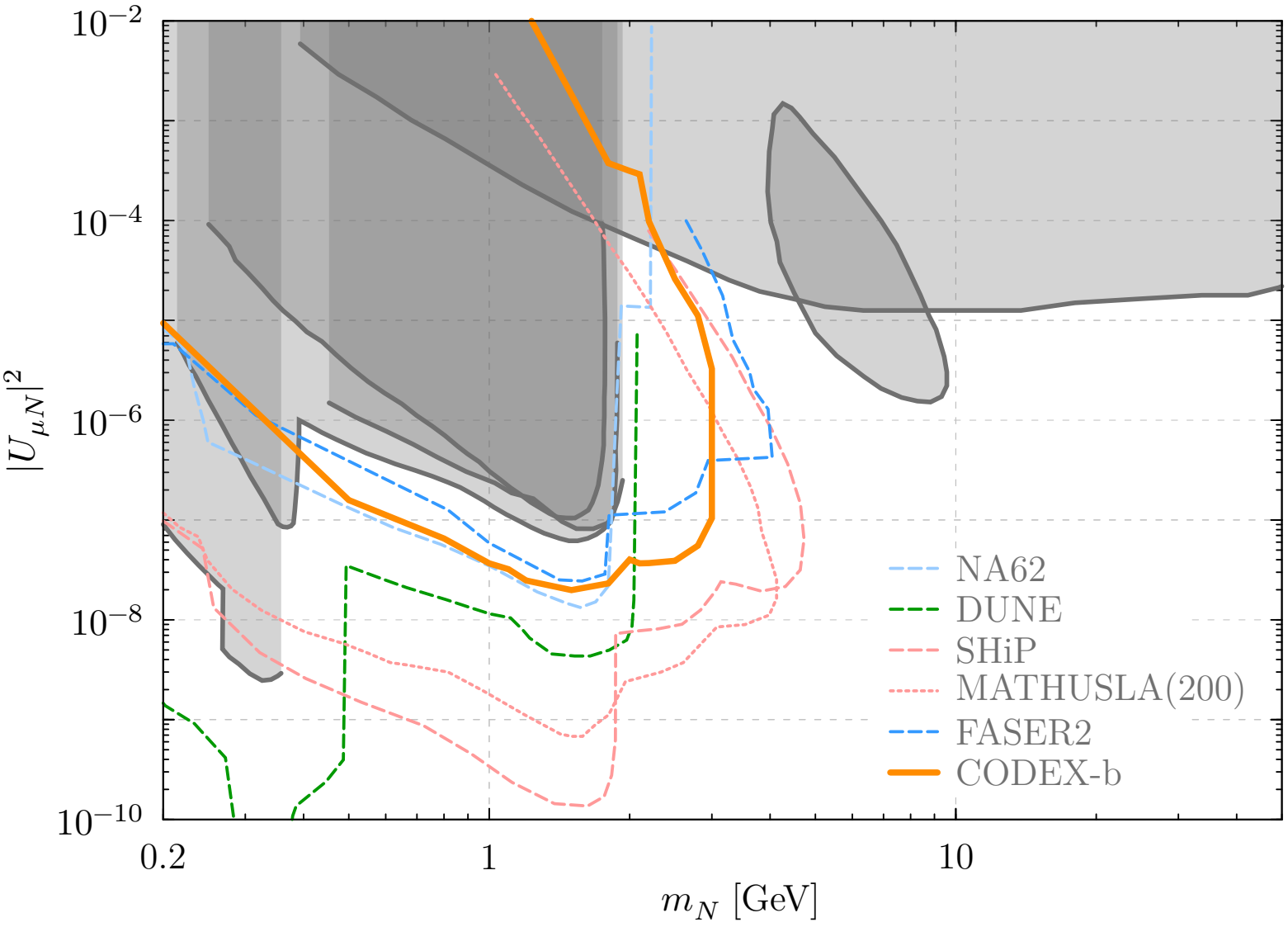
Fermion Coupled ALPs



Heavy Neutral Leptons



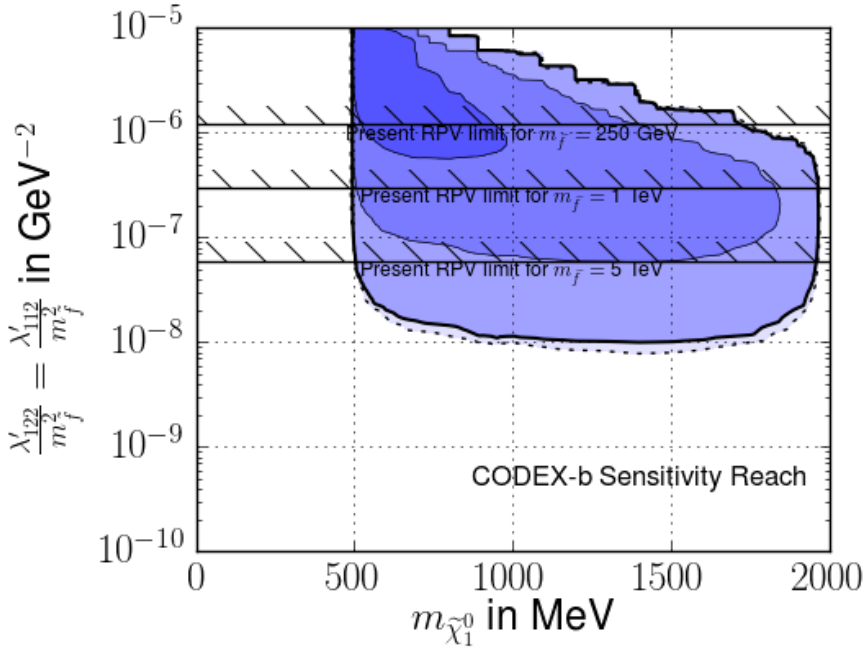
Heavy Neutral Leptons

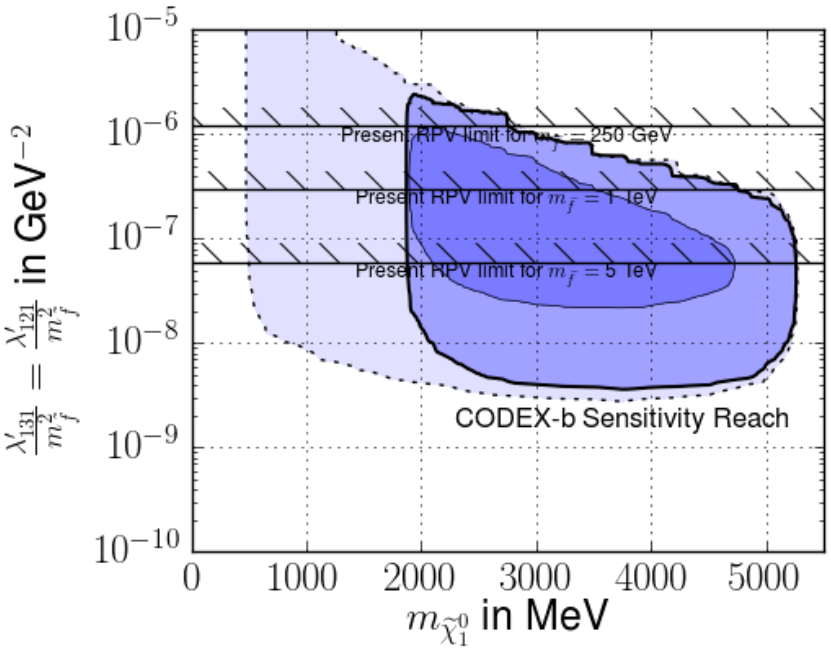


R-parity Violating Supersymmetry

- study from Dercks, Vries, Dreiner, and Wang in PRD 99 055039 (2019)

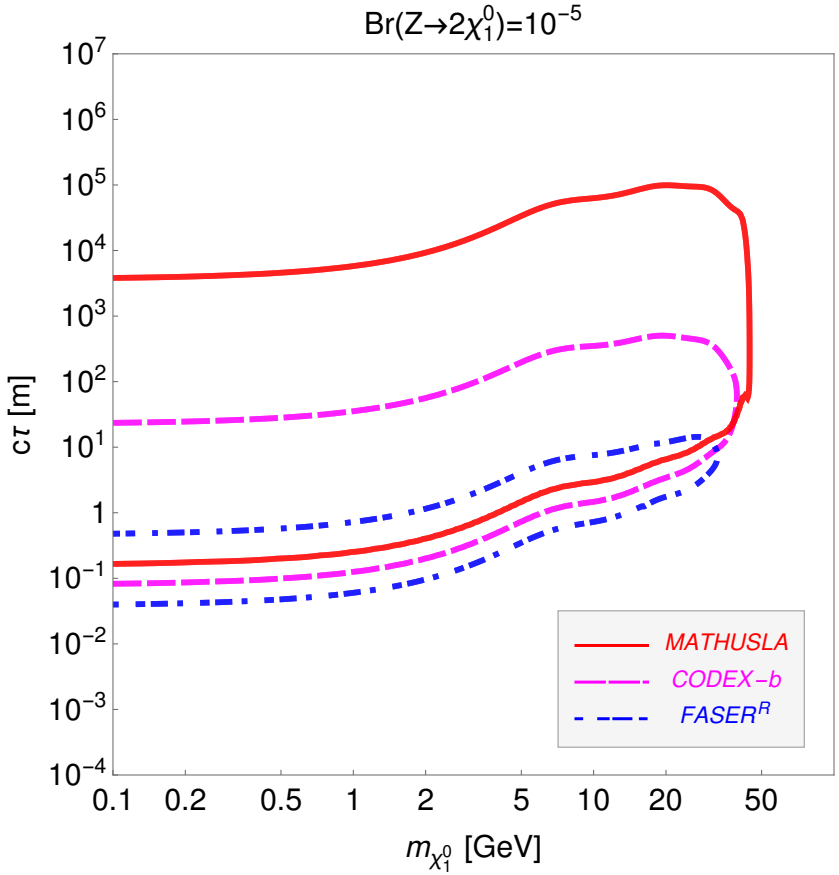
benchmark	coupling	production	decay products
1	$\lambda'_{122},\ \lambda'_{112}$	$D_s^{\pm} \to \tilde{\chi}_1^0 + e^{\pm}$	$\eta, \eta', \phi, K^{0,\pm} + \nu_e,\ e^{\mp}$
4	$\lambda'_{131},\ \lambda'_{121}$	$B^{0,\pm} \to \tilde{\chi}_1^0 + X^{0,\pm}$	$D^{\pm}, D^{*\pm} + e^{\mp}$

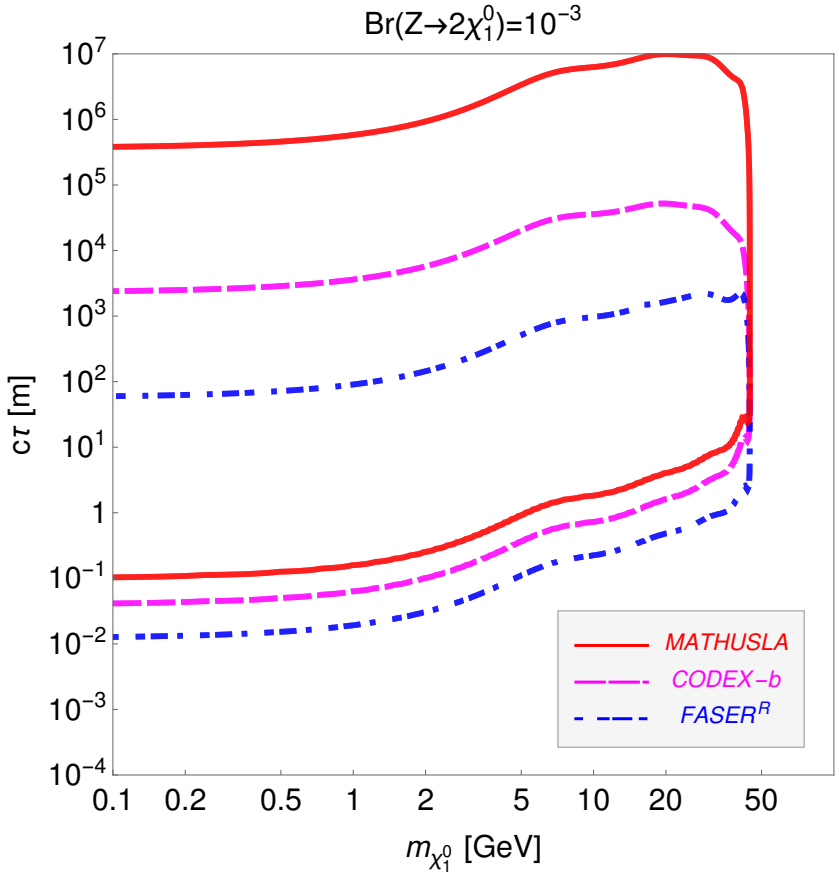




R-parity Violating Supersymmetry

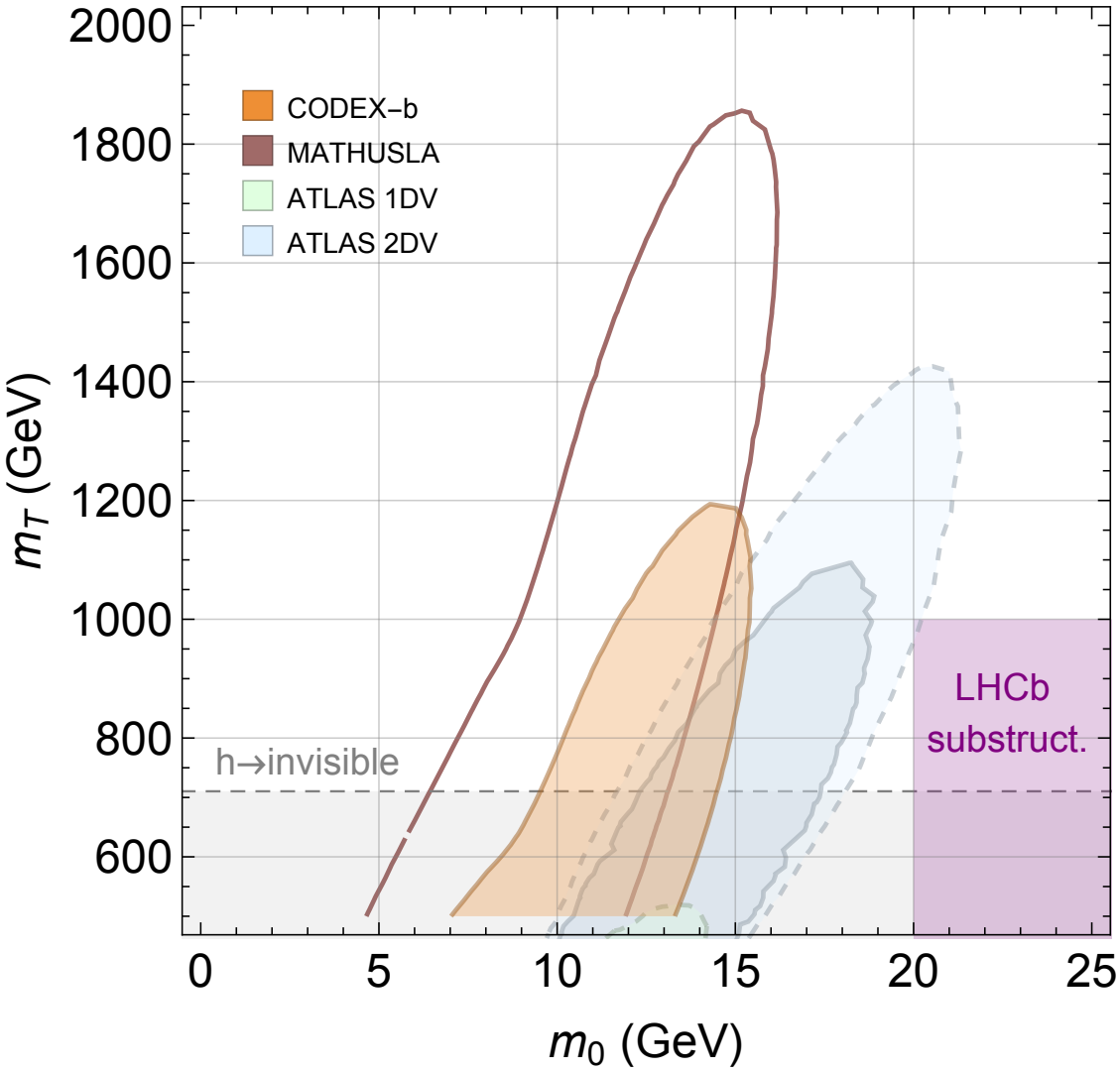
- study from Helo, Hirsch, and Wang in JHEP 07 056 (2018)





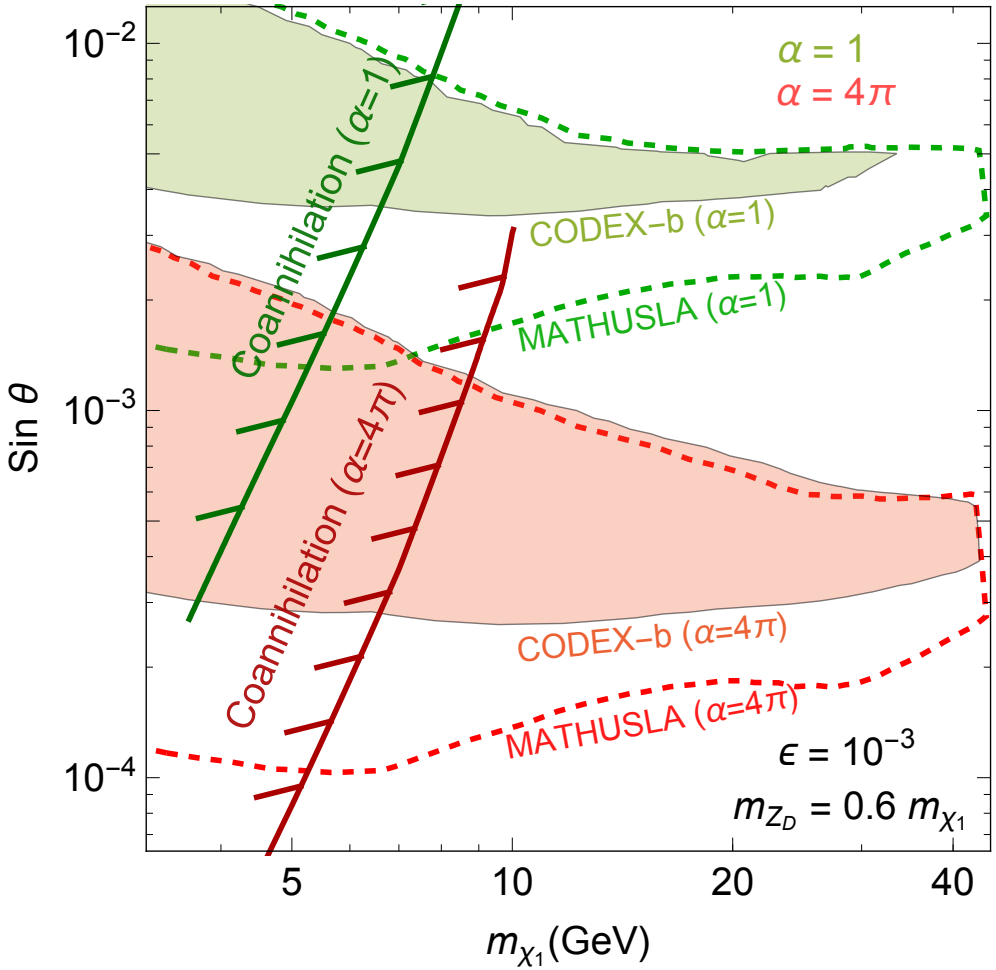
Neutral Naturalness

- consider fraternal twin Higgs model and search for glueball



Dark Matter Models

- a number of models considered including inelastic, co-scattering, co-annihilation, *etc.*



Backgrounds

- 10^{14} neutrons and K_L^0 per 300 fb^{-1}
- this requires 32λ of shielding
- 7λ from UXA wall, 25λ from lead shield
- expect $\approx 10^9$ muons per 300 fb^{-1} which can produce secondaries
- 10^3 K_L^0 per 300 fb^{-1} pass through the shield
- need active layer in shield for vetoing
- update of previous studies with detailed GEANT4 study