

C O D E X - b

a transverse detector
for long-lived
particles at
the LHC

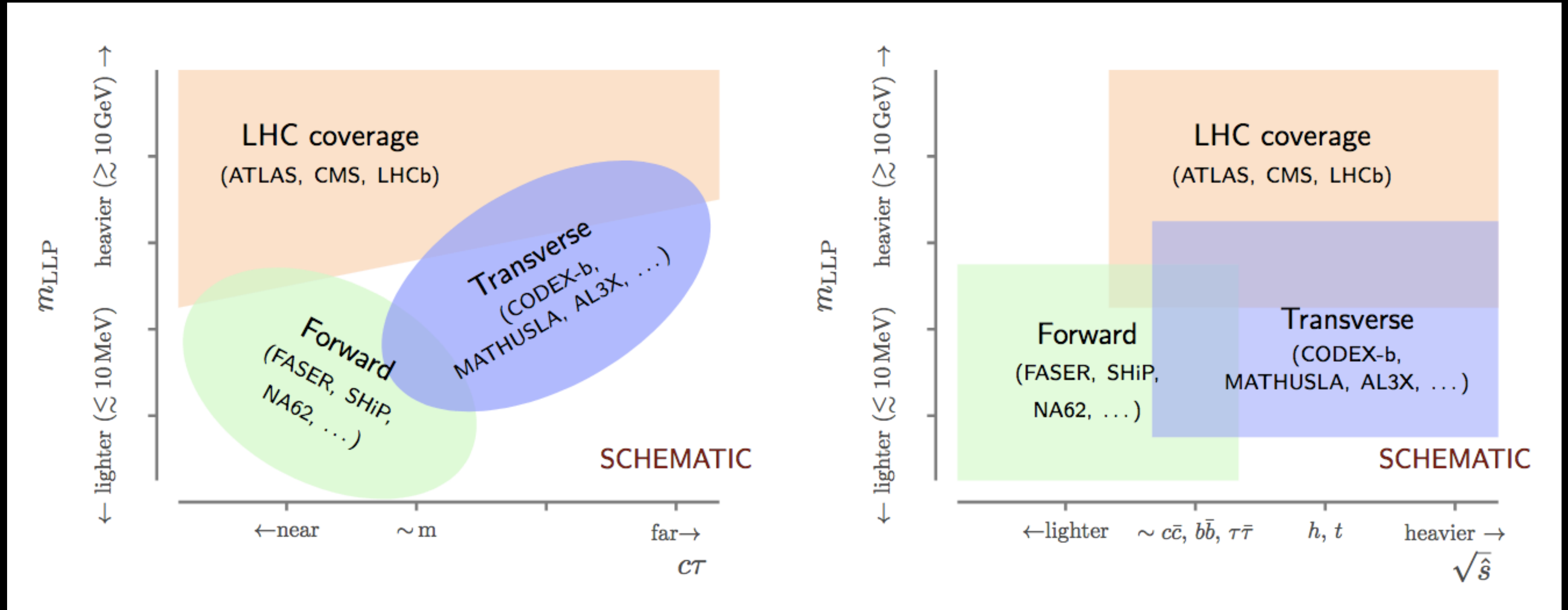
James Beacham

Duke University

3 March 2021

Physics Beyond Colliders
Annual Workshop

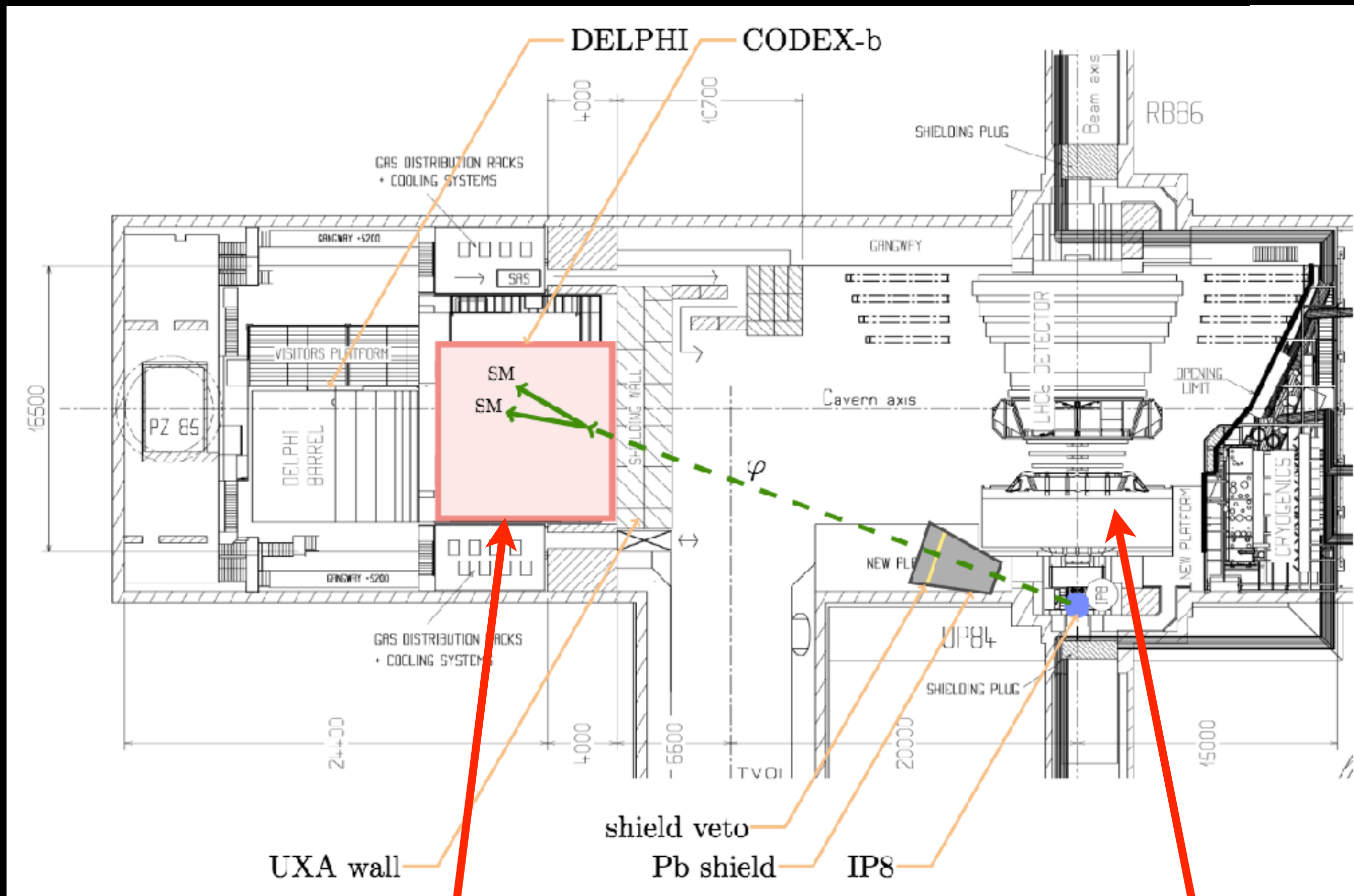
Extending the reach of the LHC to LLPs



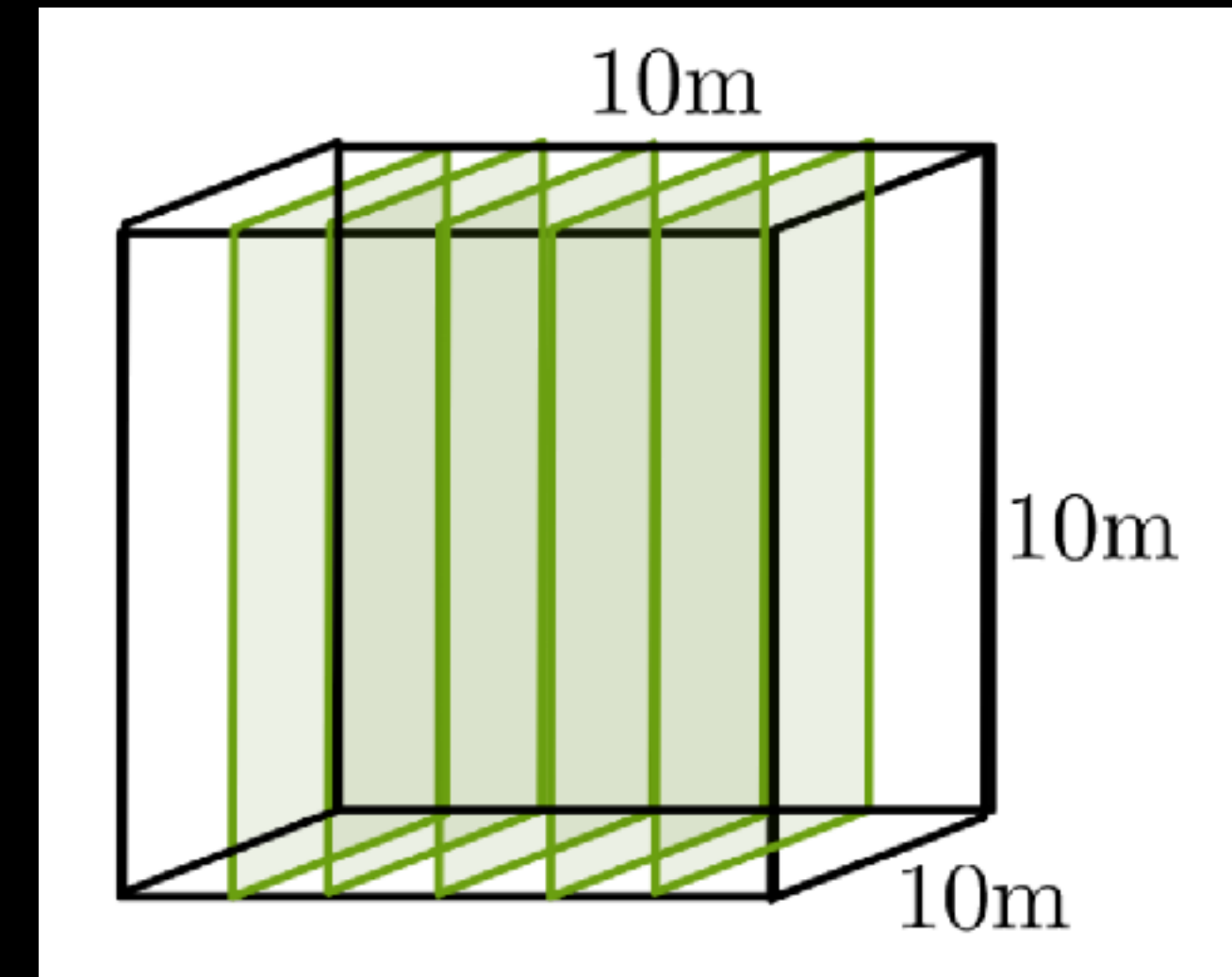
A transverse LLP detector is imperative

CODEX-b: A transverse LLP detector for the HL-LHC

Expression of interest, Nov. 2019:
[1911.00481](#)



Nutshell:
Neutral LLPs
produced inside
LHCb decay to
charged
particles ~25m
away inside
CODEX-b



CODEX-b

LHCb

Compact Detector for
Exotics at LHCb

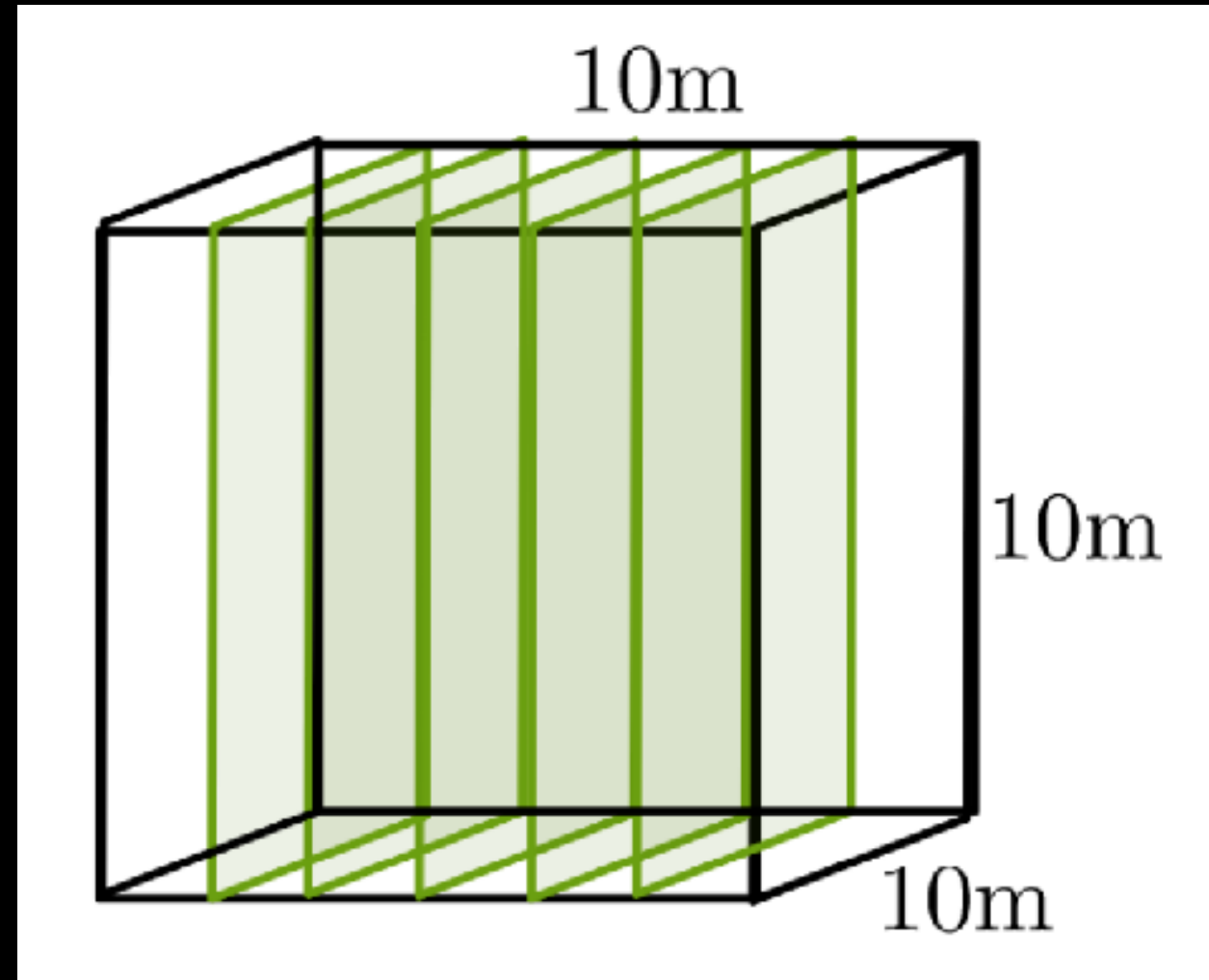
Straightforward detector design (more later)

Accessible, zero-background location with
necessary services in the DELPHI/UxA cavern
(near LHCb)

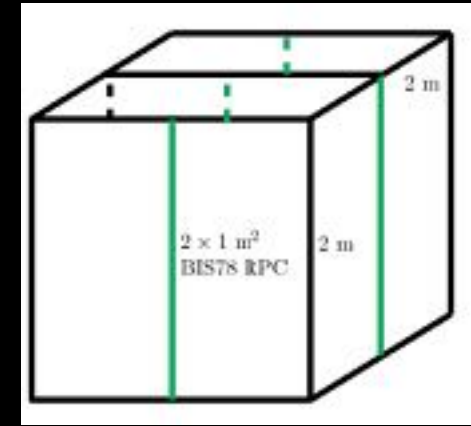
Integration with LHCb trigger-less readout

Compact size and *modest cost* with ability to
extend

CODEx-b latest



CODEx-b is an HL-LHC detector



CODEx- β is a scaled-down demonstrator for Run 3

Priority is finalising CODEx- β design and plans

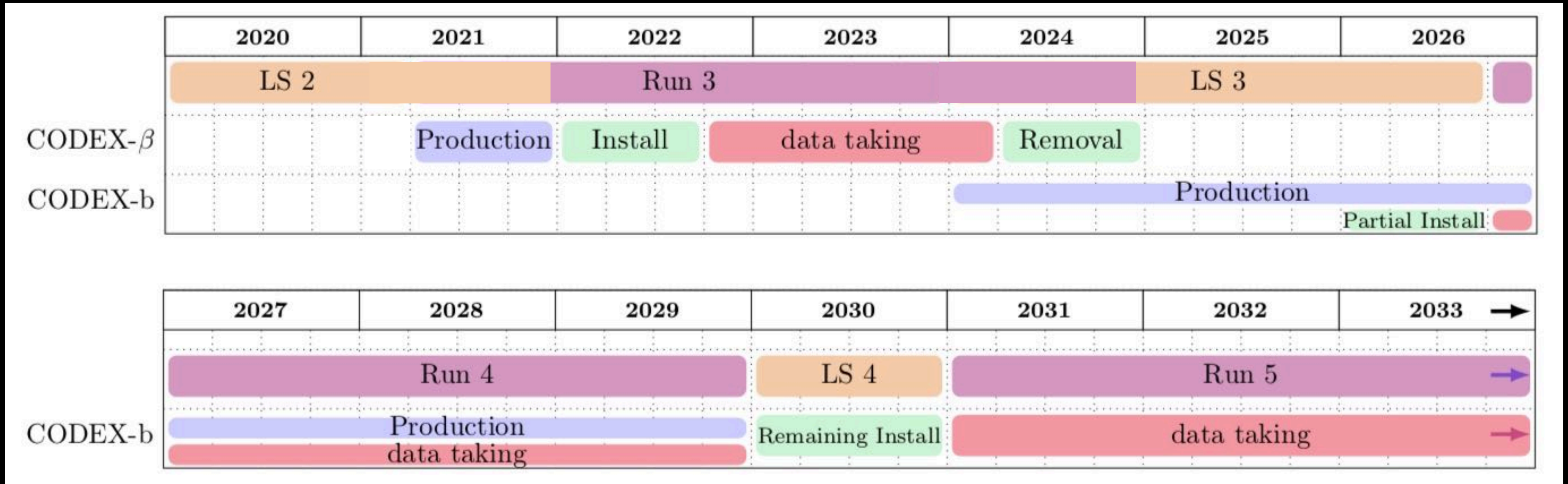
Technical drawings underway

Experience with CODEx- β will inform refinements of full CODEx-b design

The collaboration is expanding!

J.A. Evans	X. Cid Vidal
D. Robinson	P. Ilten
H. Ramani	R. Gonzalez Suarez
M. Papucci	H. Schindler
T. Gorordo	S. Knapen
G. Pasztor	S. Farry
A. De Roeck	F. Polci
R. Dumps	J. Williams
N. Watson	B. Nachman
M. Sokoloff	C. Vazquez Sierra
R. Vari	J. Alimena
G. Aielli	M. Borsato
M. Charles	J. Beacham
O. Le Dortz	B. Dey
E. Ben Haim	J. Glover
V. Coco	P. Swallow
D. Northacker	S. Lopez Solino
V. Gligorov	

CODEX-b projected timeline

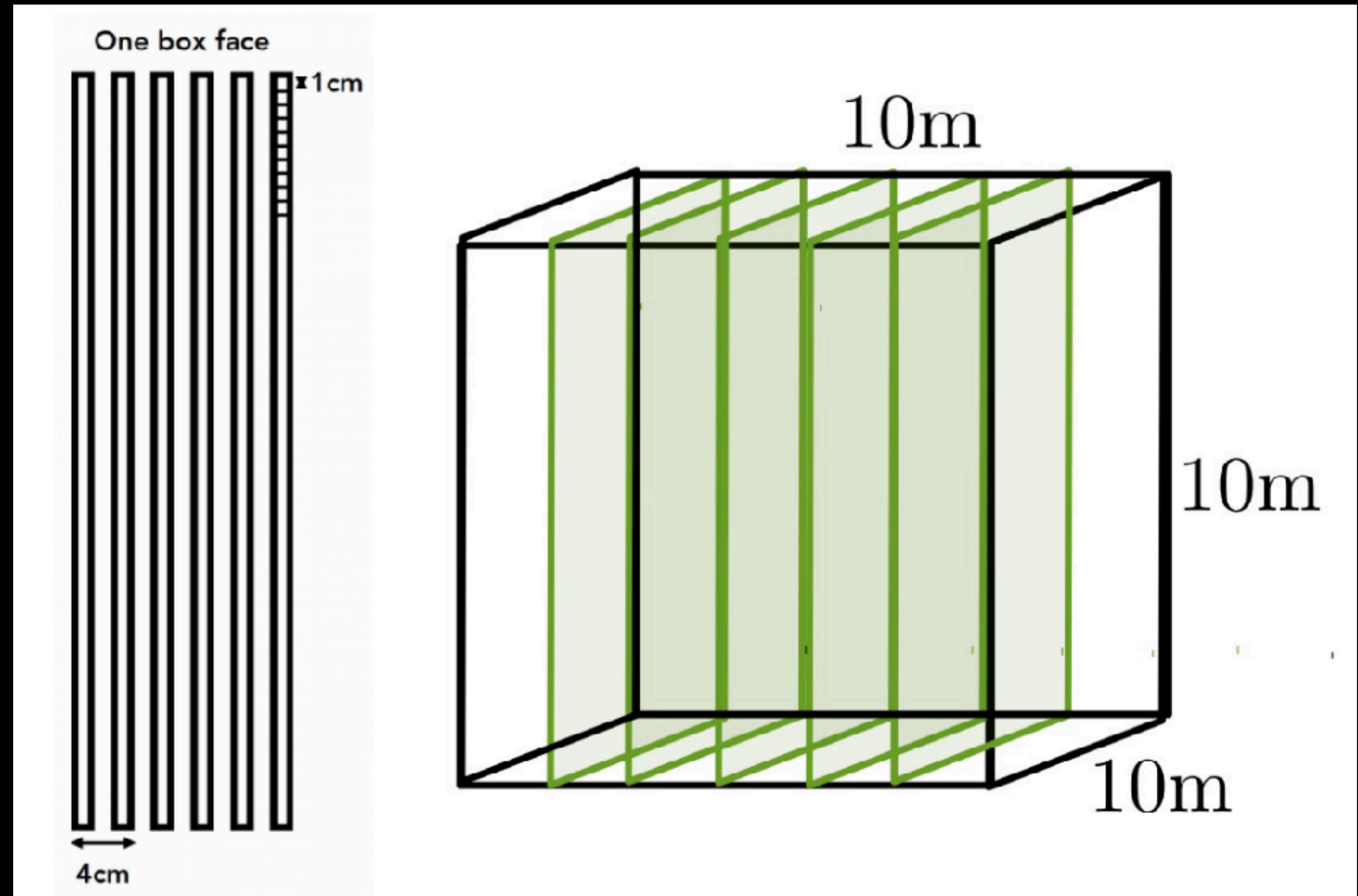


NB: Timeline currently being fine-tuned; CODEX- β timeline still tentative; shift everything to the right a bit for CODEX-b (e.g., additional design time)

CODEx-b baseline design

High physics potential at relatively low cost (<€10M) and with a straightforward, achievable design

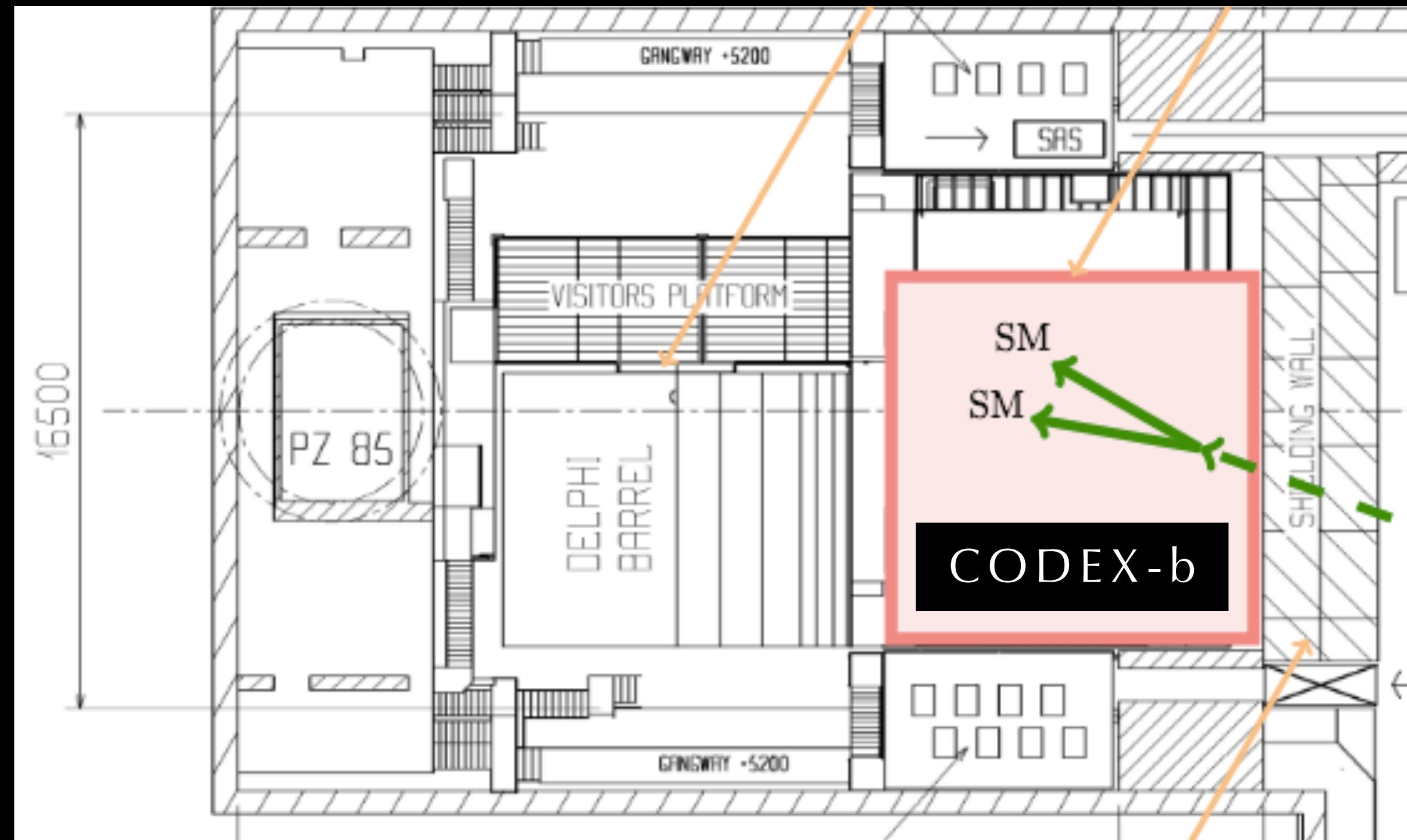
- 10x10x10 m³ box, with 1% angular acceptance
- Resistive plate chambers (RPCs), the same kind to be used for the Phase 2 upgrade of the ATLAS muon system
- RPCs are fast, precise, and cheap for such a large area
- 6 RPC layers at 4 cm intervals on each box face with 1 cm granularity
- Additionally 5 layers inside, to improve vertex resolution and tracking efficiency
- 50-100 ps timing expected from RPCs, for mass reconstruction



CODEX-b: Possible extensions / improvements

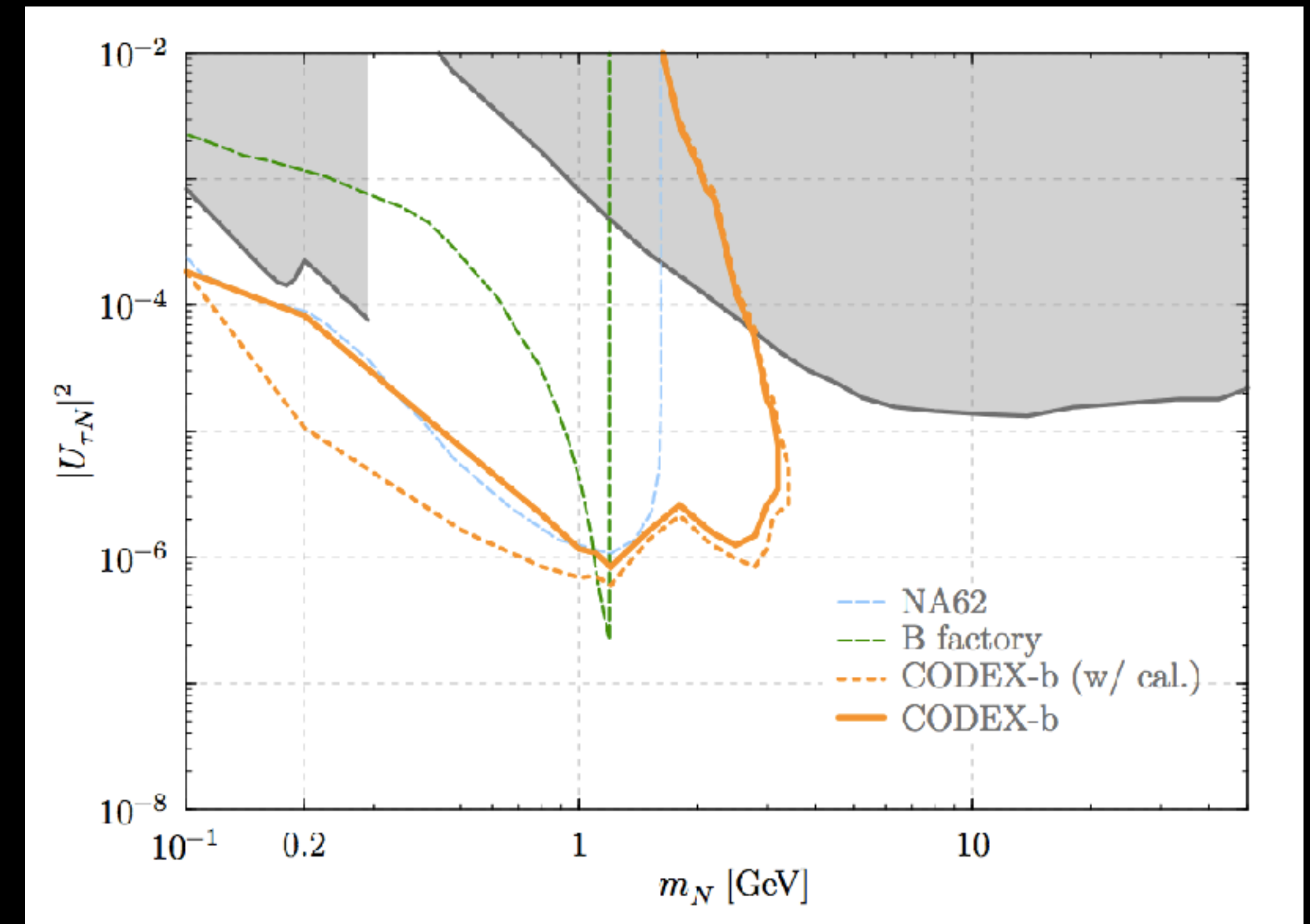
DELPHI is still present in cavern

- If removed, could either shift CODEX-b back a bit or could enable a 20x10x10 m³ box



Calorimetry

- Provides several important capabilities, such as PID and expansion to invisible final states, neutral hadrons, photons, etc.

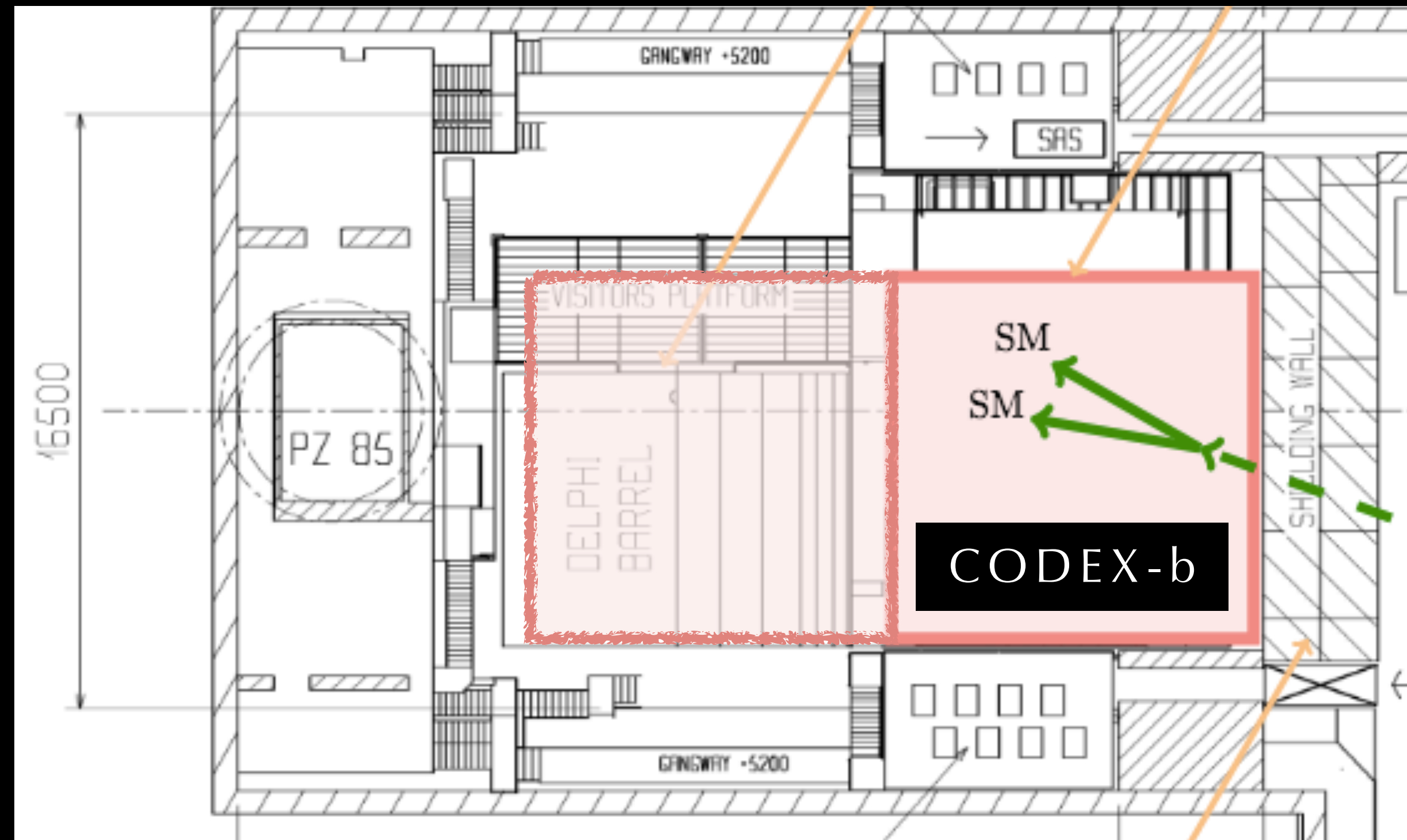


Dirac HNL for $U_{\tau N} \gg U_{eN}, U_{\mu N}$, for $N \rightarrow \nu \pi^0$

CODEX-b: Possible extensions / improvements

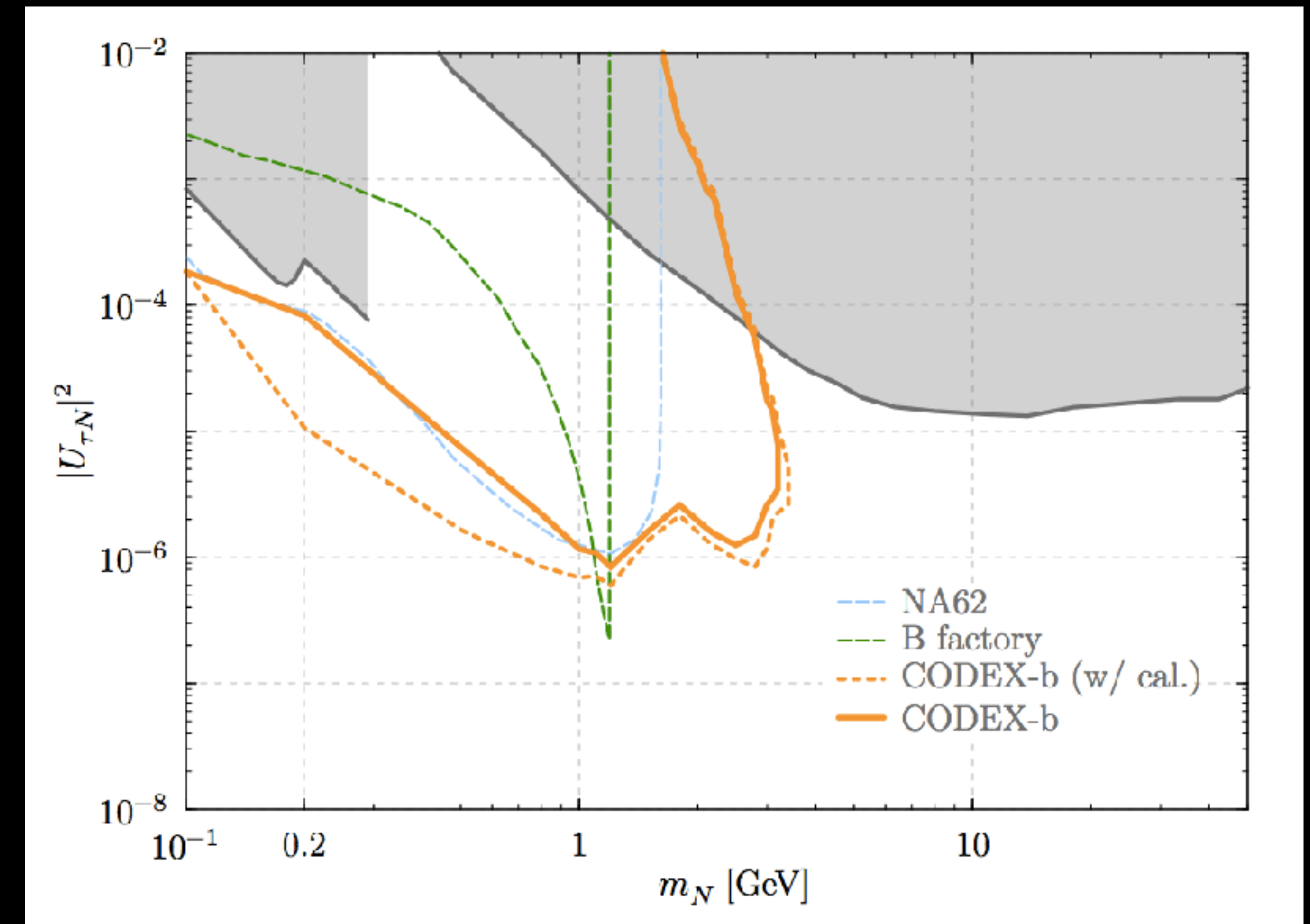
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CODEx-b projected physics reach

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

Abelian hidden sector : $F_{\mu\nu}F'^{\mu\nu}, hA'_\mu A'^\mu$

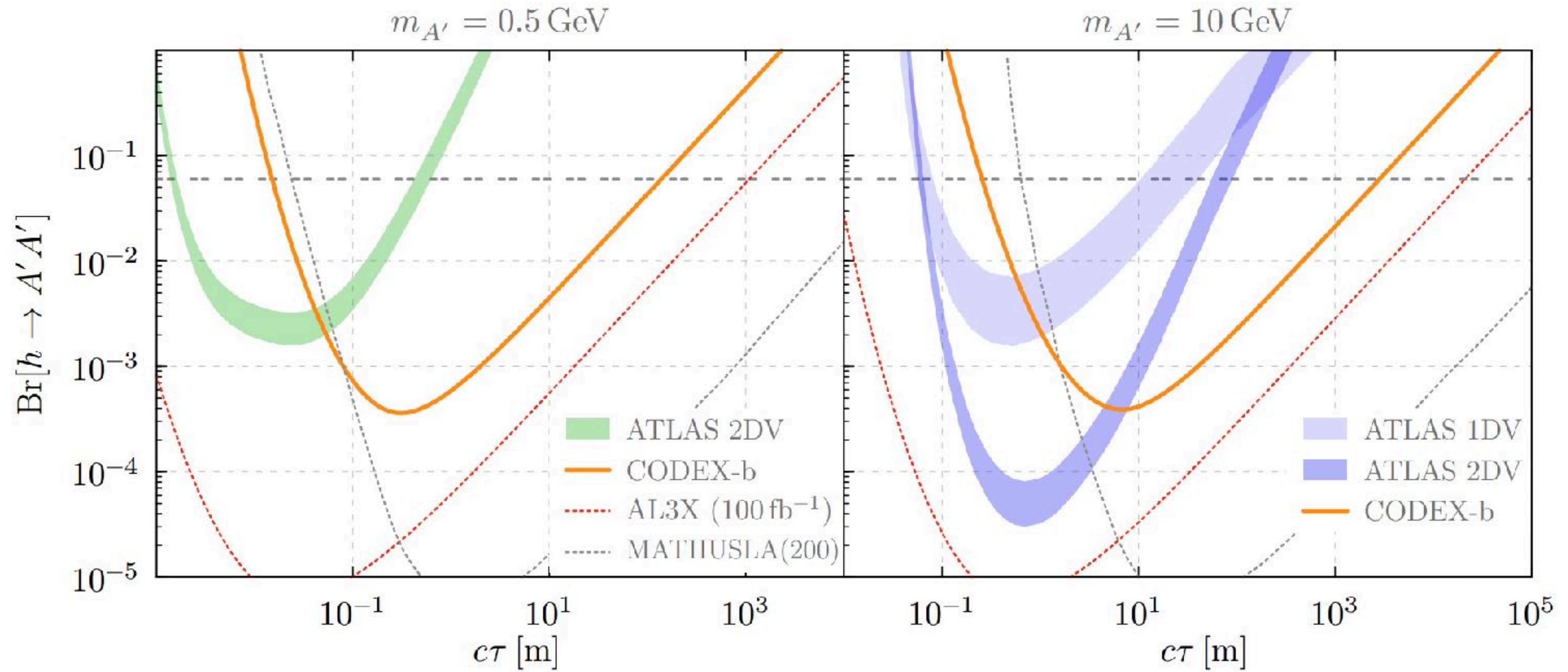
Scalar-Higgs portal : $S^2H^\dagger H, SH^\dagger H$

Heavy neutral leptons : HLN

Axion-like particles: $\partial^\mu a \bar{\psi} \gamma_\mu \gamma_5 \psi, aW_{\mu\nu}\tilde{W}^{\mu\nu}, aB_{\mu\nu}\tilde{B}^{\mu\nu}, aG_{\mu\nu}\tilde{G}^{\mu\nu}$

CODEx-b provides major extensions to reach of currently-running LHC detectors at a modest cost

CODEx-b projected physics reach

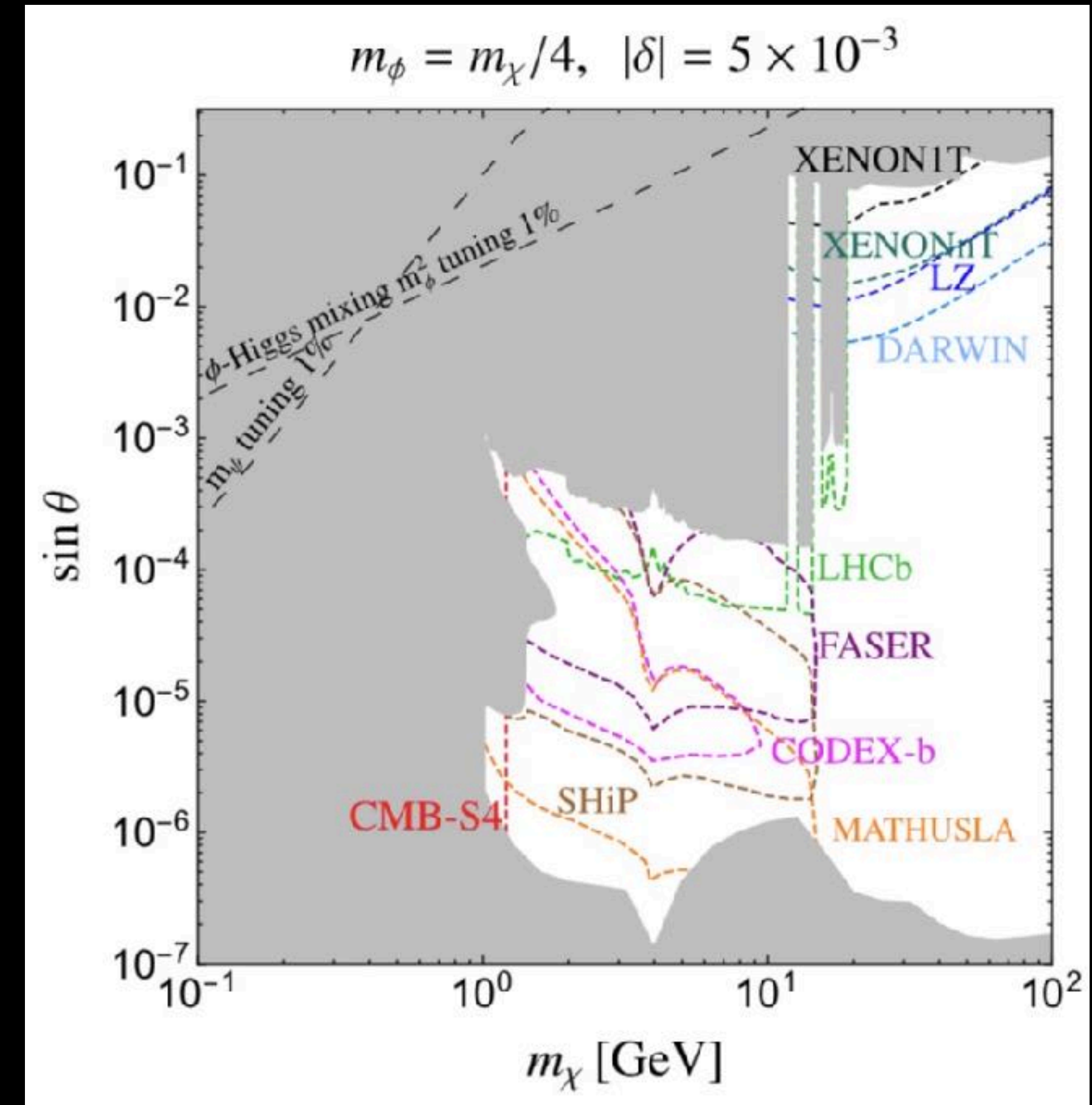
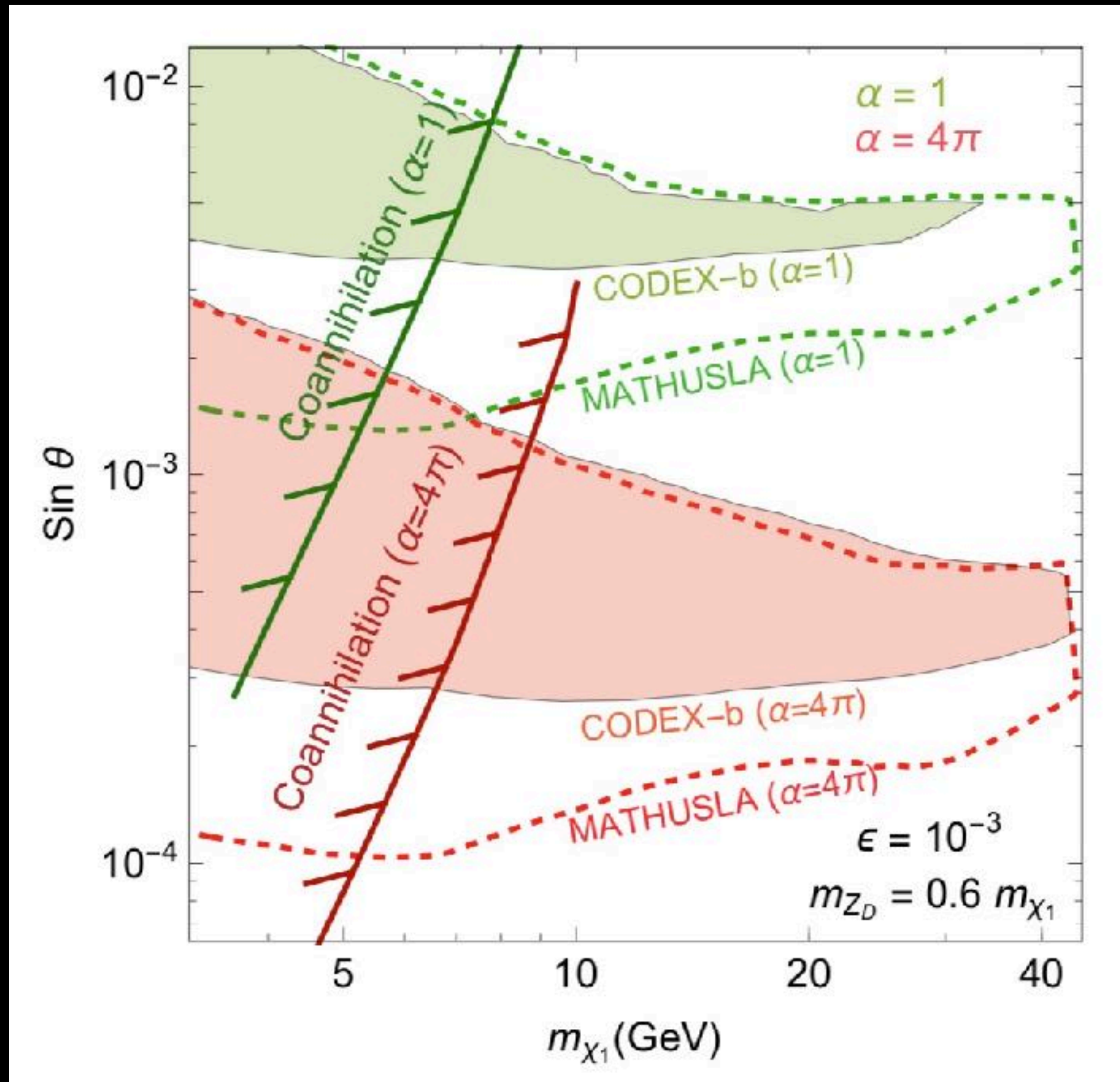


Higgs to dark photons

CODEx-b projected physics reach

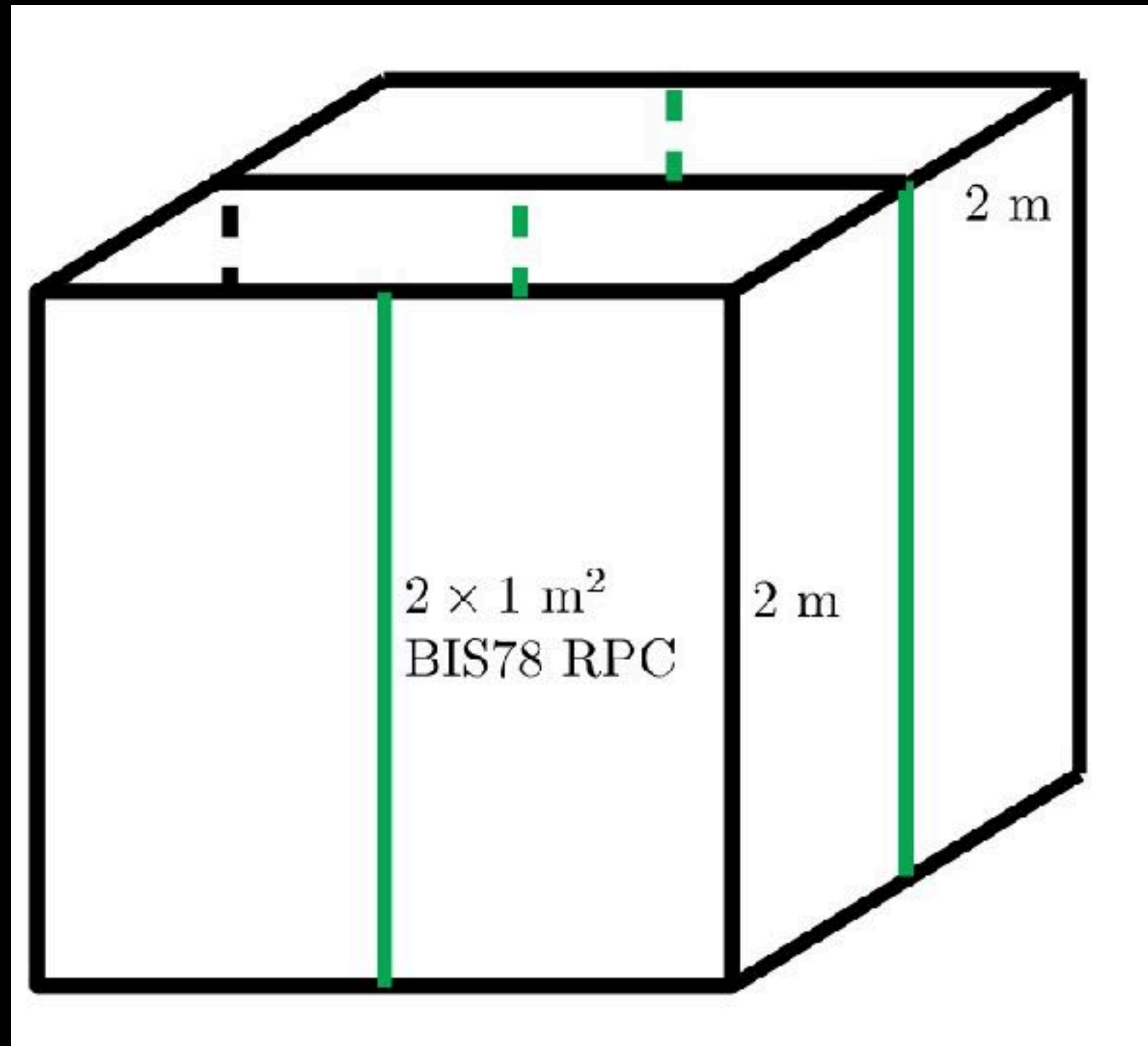
Coscattering dark matter

Coannihilation dark matter



MATHUSLA200, 3/ab
CODEx-b, 300/fb

C O D E X - β



Expected hardware
cost of ~€150K
for CODEX- β

- C O D E X - β is a 2x2x2 m³ demonstrator for Run 3
- 6 detector faces + 1 inner station: 14 RPC triplet chambers
 - Space exists already in the cavern for CODEX- β , provided some DAQ racks can be shifted

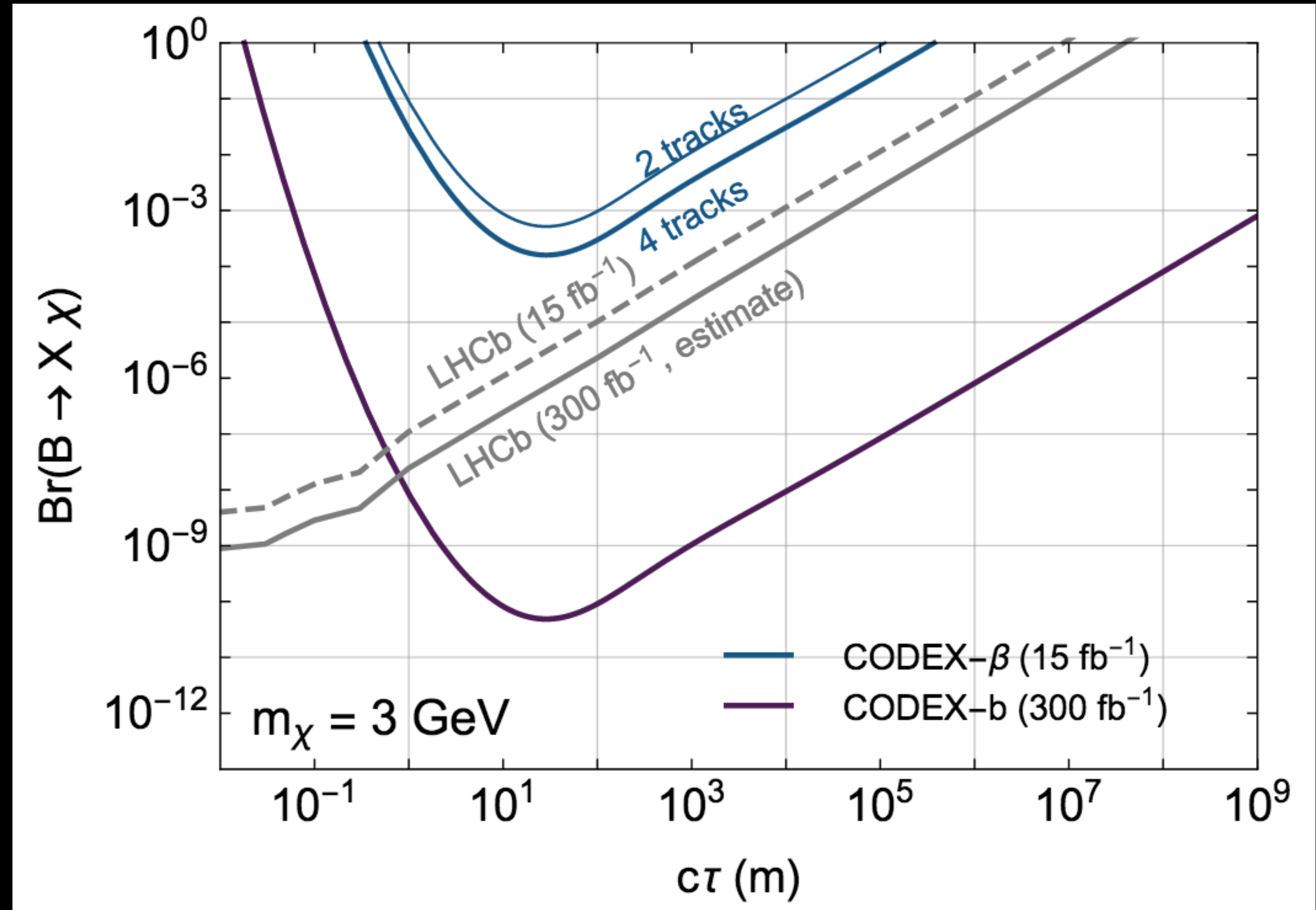
C O D E X - β goals:

- 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
- Detect and reconstruct a reasonable rate of neutral particles decaying inside the hermetic detector volume
- Show that CODEX-b can be integrated into the LHCb DAQ and demonstrate an ability to trigger LHCb to retain an event that looks interesting in CODEX-b

C O D E X - β

Can even do some proof-of-concept physics with CODEX- β

Funding efforts underway, with very positive response from LHCb management



Conclusions...



A transverse LLP detector is imperative to extend and fully actualize the LHC's research program

CODEx-b is an elegant proposal that provides strong physics-reach-per-euro

CODEx-b location exists and is accessible and serviceable, with a clear path for construction and installation

Plans underway for construction of CODEx- β demonstrator

New collaborators are always welcome

CODEx-b expression of
interest, Nov. 2019:
[1911.00481](#)

... and LLP Community reminder

Experimental particle physics, post-Higgs, is cartography

This means looking everywhere and preparing for discovery

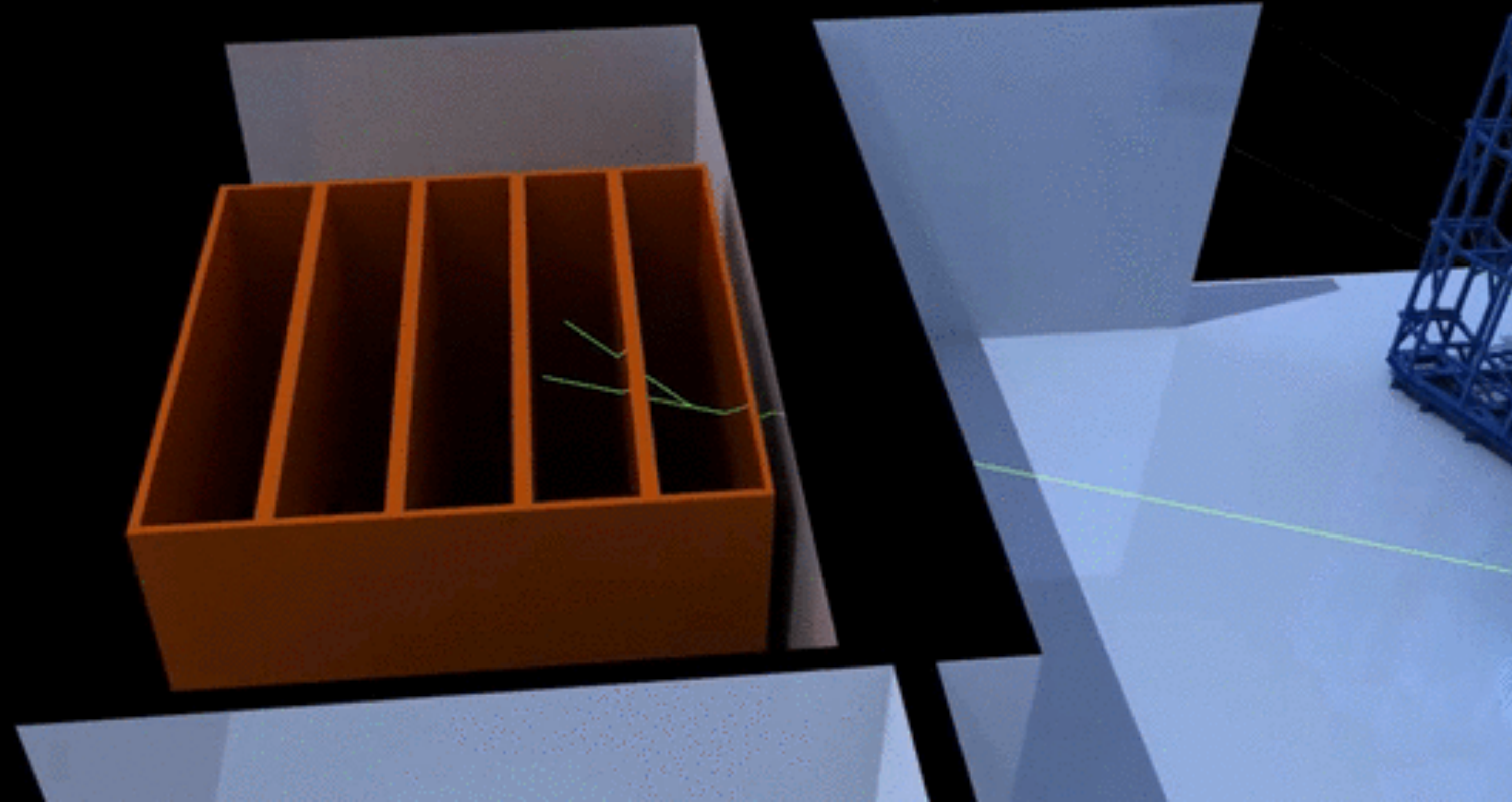
LLP signals will need independent corroboration

Finally, the low-mass/soft final states with rather long lifetimes are challenging for all three experiments. These signatures can be covered partially by NA62 [388] operating in beam dump mode, or by SHiP [389], or by dedicated LHC experiments like CODEX-b [104] (see section 5.3.5), FASER [105] (see section 5.3.6), or MATHUSLA [103] (see section 5.3.4). Each of these dedicated experiments is sensitive to different LLP lifetimes, masses, and production modes based on their position and orientation and thus each can be considered a necessary component of a comprehensive, coordinated search program for very long-lived particles at the LHC.

LLP Community white paper, page 109

J.Phys.G 47 (2020) 9, 090501

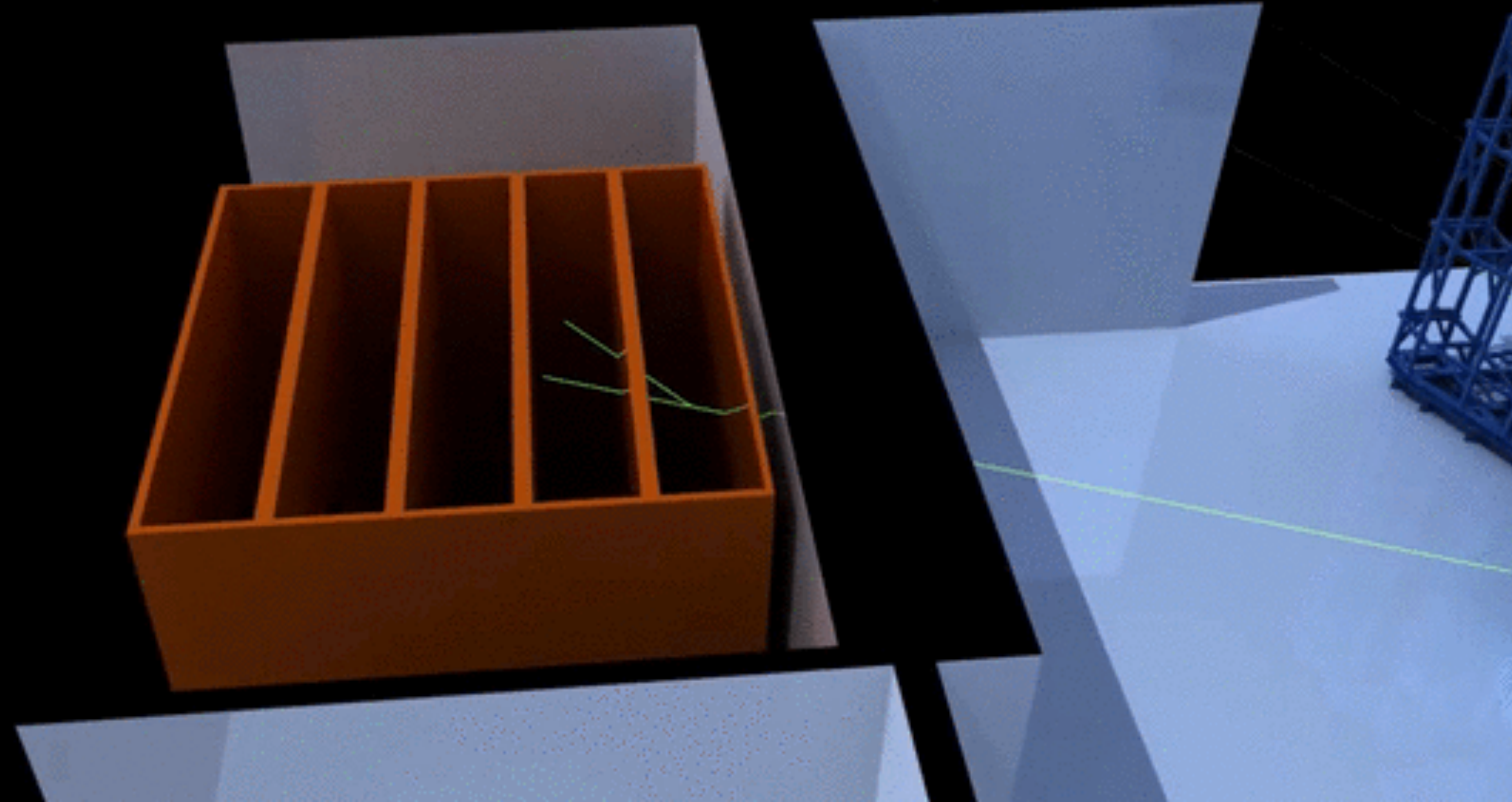
CODEx-b outreach video — brand new!



youtu.be/V4Y7H_H2IKM

END

CODEx-b outreach video — brand new!



youtu.be/V4Y7H_H2IKM

END

Reserve slides

Shielding

