Sterile neutrinos at the high-luminosity LHC

work with Juan Carlos Helo and Martin Hirsch

arXiv: 1803.02212

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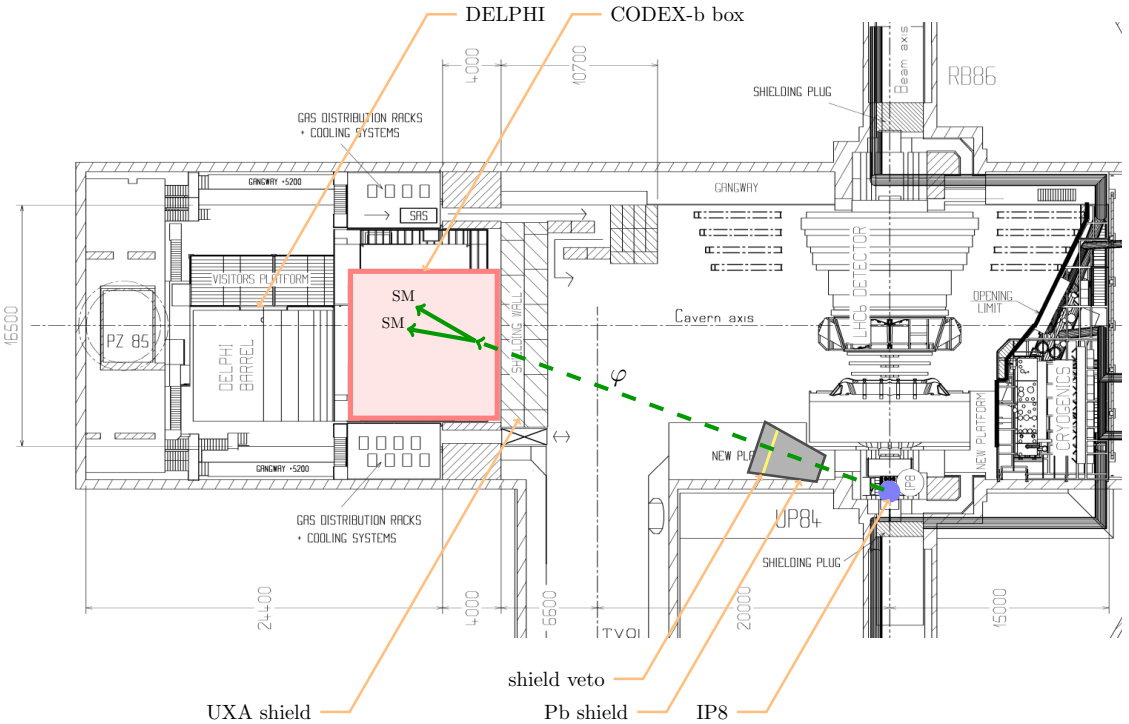
Motivation

- Light long-lived particles (LLLPs) appear in many extensions of the standard model (SM) including sterile neutrinos.
- It is expected that the LHC will deliver up to $3000/fb$ of luminosity over the next $15 - 20$ years
- No promptly decaying new particles found (yet) at the LHC
- New proposals to search for LLLPs: CODEX-b, FASER and MATHUSLA, all based on the idea to exploit LHC's large luminosity

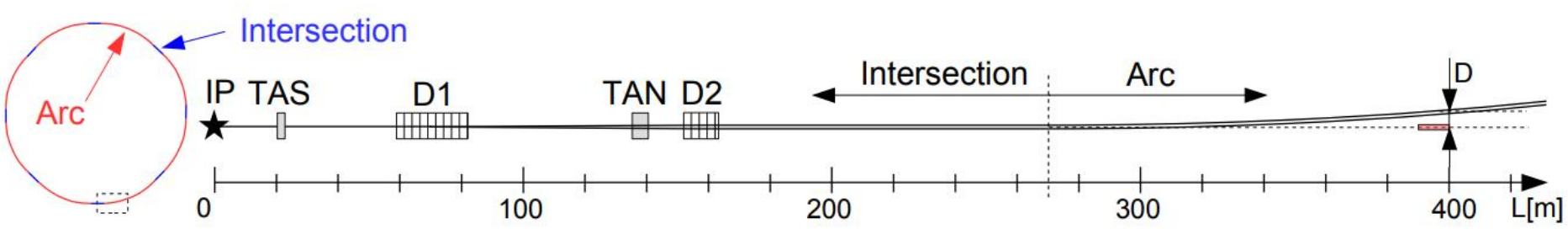
Detectors: CODEX-b



CODEX-b, a Compact Detector for Exotics at LHCb: $10m \times 10m \times 10m$ [arXiv : 1708.09395]

	$L_{min}(m)$	$L_{max}(m)$	ϕ	η	$\mathcal{L}(fb^{-1})$
CODEX-b	25	35	0.4	[0.2, 0.6]	300

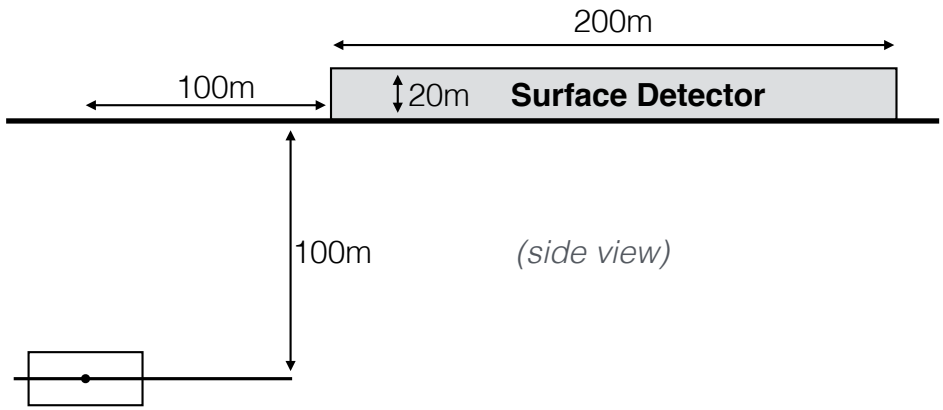
Detectors: FASER



FASER: ForwArd Search ExpeRiment, a cylindrical detector in very forward direction along beam axis [arXiv : 1708.09389, 1710.09387]

	$L_{min}(m)$	$L_{max}(m)$	ϕ	η	$\mathcal{L}(fb^{-1})$	r(m)
FASER^R	390	400	2π	$[6.68,+\infty]$	3000	1

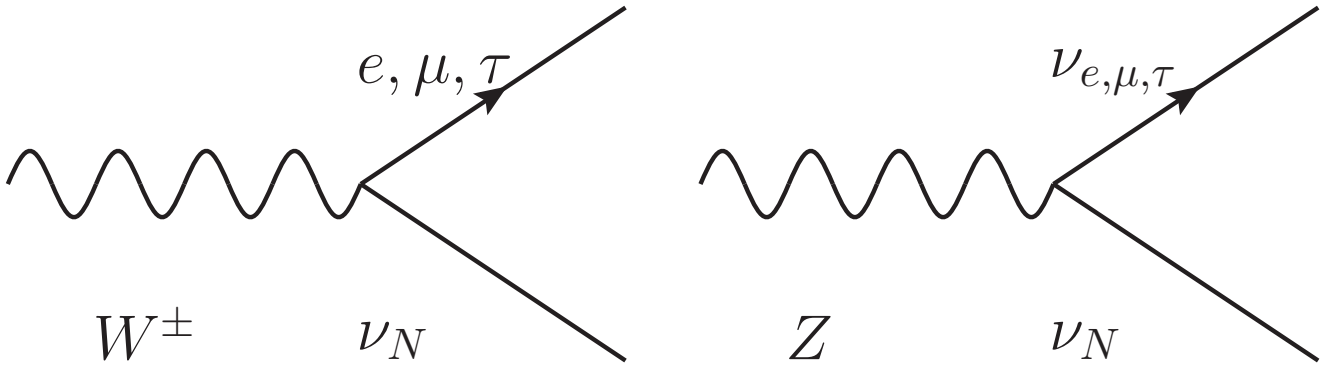
Detectors: MATHUSLA



MATHUSLA: [arXiv : 1606.06298]
MAssive Timing Hodoscope for Ultra Stable neutraL pArticles:
surface detector above the ATLAS IP: $200m \times 200m \times 20m$

	$L_{min}(m)$	$L_{max}(m)$	ϕ	η	$\mathcal{L}(fb^{-1})$
MATHUSLA	141 & 269	170 & 323	$\pi/2$	[0.88, 1.65]	3000

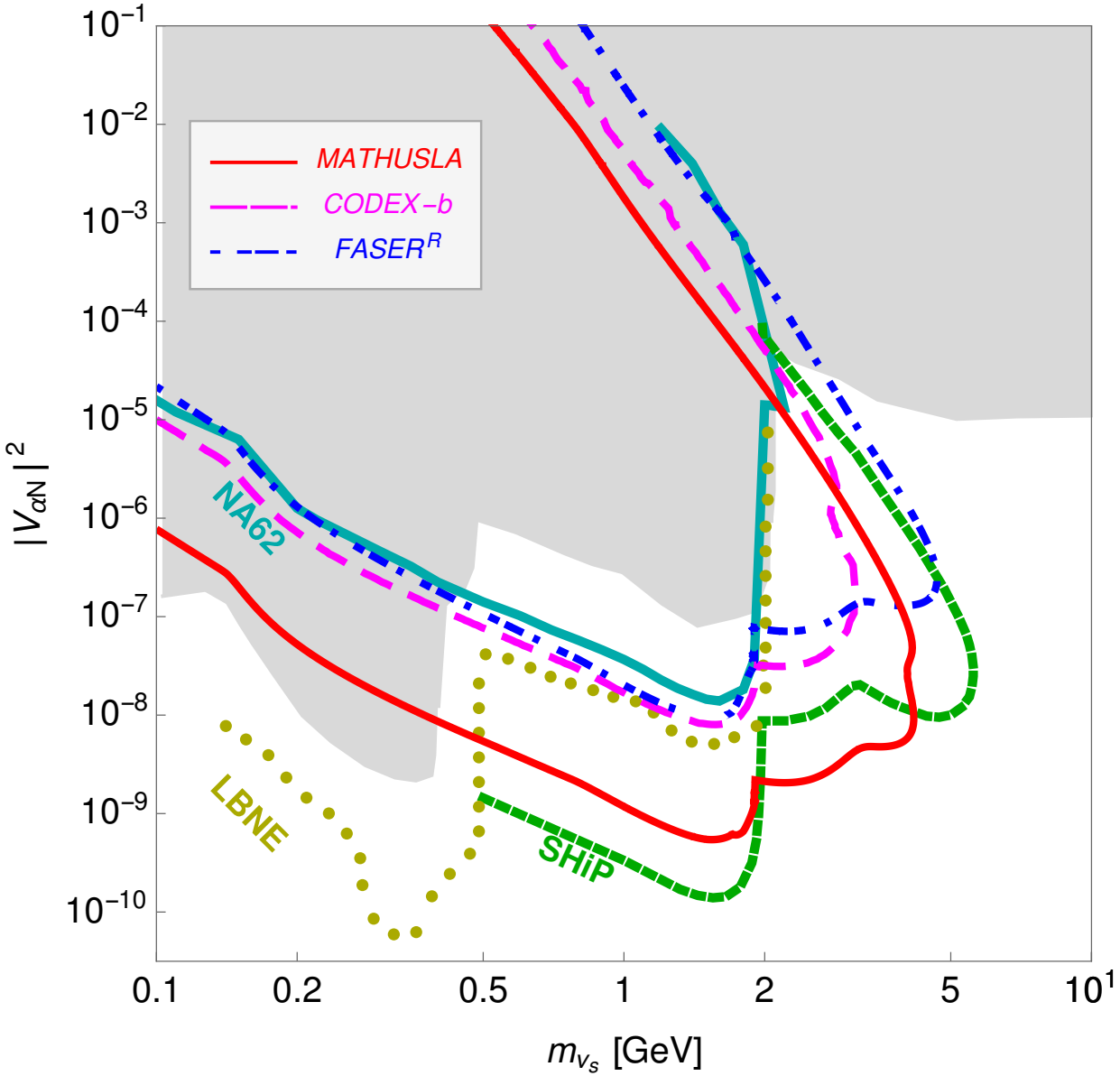
Type-I Seesaw Model



$$\mathcal{L} = \frac{g}{\sqrt{2}} V_{\alpha N_j}\, \bar{l}_\alpha \gamma^\mu P_L \nu_{S_j} W^-_{L\mu} + \frac{g}{2\cos\theta_W} \sum_{\alpha,i,j} V^L_{\alpha i} V^*_{\alpha N_j} \overline{\nu_{S_j}} \gamma^\mu P_L \nu_i Z_\mu$$

- V: mixing matrix between active and sterile neutrinos
- $|V_{\alpha N_j}|^2$ controls **both** production **and** decay of sterile neutrinos
- For simplicity, only one of $|V_{eN}|$ and $|V_{\mu N}|$ assumed as non-zero
- Production channels: D- and B-mesons, W-, Z- and Higgs bosons

Numerical Results: sterile neutrinos



Conclusion

- LHC(LHCb) up to 3000(300)/fb luminosity by 2035. Great discovery potential for LLLPs
- New proposed detectors: CODEX-b, FASER and MATHUSLA
- Example model: sterile neutrino
  - FASER^R and CODEX-b show very similar sensitivities,
  - MATHUSLA is more sensitive than both FASER^R and CODEX-b, even competitive with the fixed target experiment SHiP.
- MATHUSLA shows the best sensitivity but has the largest instrumented volume. FASER setups considered so far are quite small, and hence interesting to study.

Thank You!