MAPP-2:
The Search for Long-Lived Neutral Particles at the HL-LHC

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ABSTRACT

The second **MoEDAL Apparatus for Penetrating Particles (MAPP-2)** is proposed for deployment at the High-Luminosity LHC (HL-LHC), **comprising a large instrumented tunnel decay volume** adjacent to IP8 **with a volume of 1200 m³**. The detector utilizes large-area scintillator panels with *x*–*y* wavelength-shifting fibres read out by silicon photomultipliers arranged in a "Russian Doll" configuration to measure the **displaced vertices of long-lived particles** (LLPs) emanating from IP8. The detector incorporates a radiator layer to also allow the registration of photons in the final state. The sensitivity of MAPP-2 is complementary to other planned LLP detectors and the existing LHC general-purpose detectors. **We present a few physics benchmarks to illustrate this sensitivity**. The initial plans for deploying the MAPP-2 detector at the HL-LHC were **endorsed by the LHCC**. An LoI to be submitted to the LHCC is under preparation.

The MoEDAL-MAPP Facility

The proposed **location** for MAPP-2 is the **LHC's UGC1** gallery adjacent to IP8. An overview of the MoEDAL-MAPP facility is provided in Fig. 1.

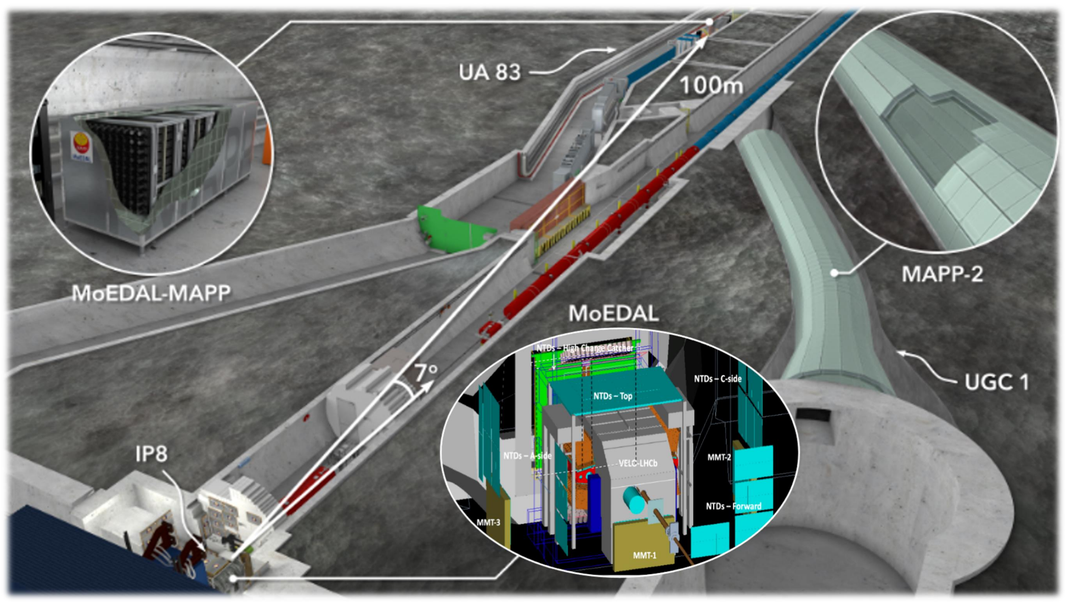

Fig. 1. A schematic of the MoEDAL-MAPP arena located at the LHC's IP8, featuring the locations of the MoEDAL (IP8), MAPP-1 (UA83), and future MAPP-2 (UGC1) detectors.

The MAPP-2 Detector

The **MAPP-2 detector** is currently in the **research and development phase**. The currently proposed design employs **three nested layers of scintillator planes** read out by **fast wavelength-shifting (WLS) fibres** attached to **SIPMs**. With all fibers instrumented, the **position resolution** is **≥ 1 cm** in *X* and *Y*. A **lead radiator layer** is also included to allow the **registration of photons** in the final state.

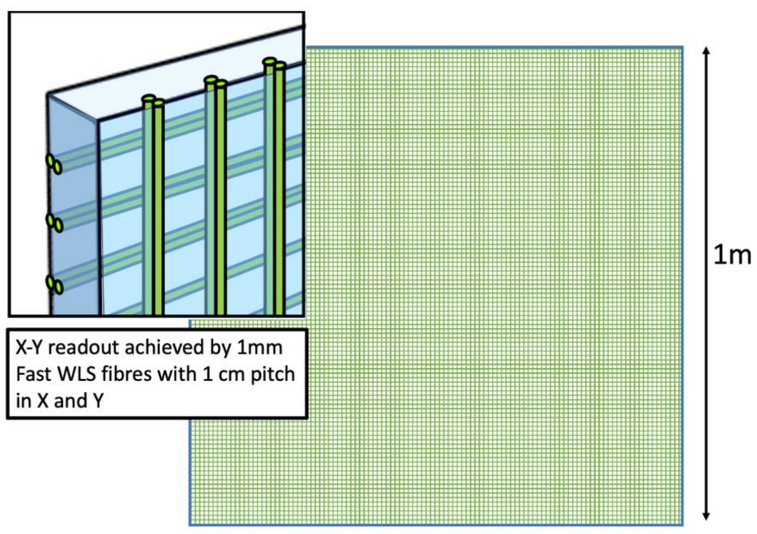

Fig. 2. An illustration of the scintillator tiles comprising the MAPP-2 detector.

BASIC MAPP-2 Tile – Position determination to better than 1 cm in X and Y

Dark Higgs at MAPP-2

We consider a model benchmark scenario involving **light CP-even SM gauge-singlet dark scalars** produced through the **minimal Higgs-portal scenario**. The corresponding Lagrangian can be written as

$$\mathcal{L} = \mathcal{L}_{\text{Kin}} + \mathcal{L}_{\text{DS}} + \mu_S^2 S^2 - \frac{\lambda_S}{4} S^4 + \mu^2 |H|^2 - \lambda |H|^4 - \epsilon_h S^2 |H|^2$$

The **last term** is the **Higgs portal quartic scalar interaction**. Proceeding with **electroweak symmetry breaking**, this term generates **Yukawa-like couplings** between the dark Higgs and the SM fermions,

$$\mathcal{L}_{\text{eff}} = -m_{\phi_h}^2 \phi_h^2 - \sin\theta \frac{m_f}{v} \phi_h f \bar{f} - \lambda v h \phi_h \phi_h$$

To illustrate MAPP's sensitivity, we simulated a common benchmark scenario involving **rare $B \to X_s \phi_h$ decays**. As a proxy, we use **Pythia 8** to generate *B* meson samples **decaying** inclusively to **dark scalars** and subsequently **to muons** via $B \to K\left(\phi_h \to \mu^+\mu^-\right)$.

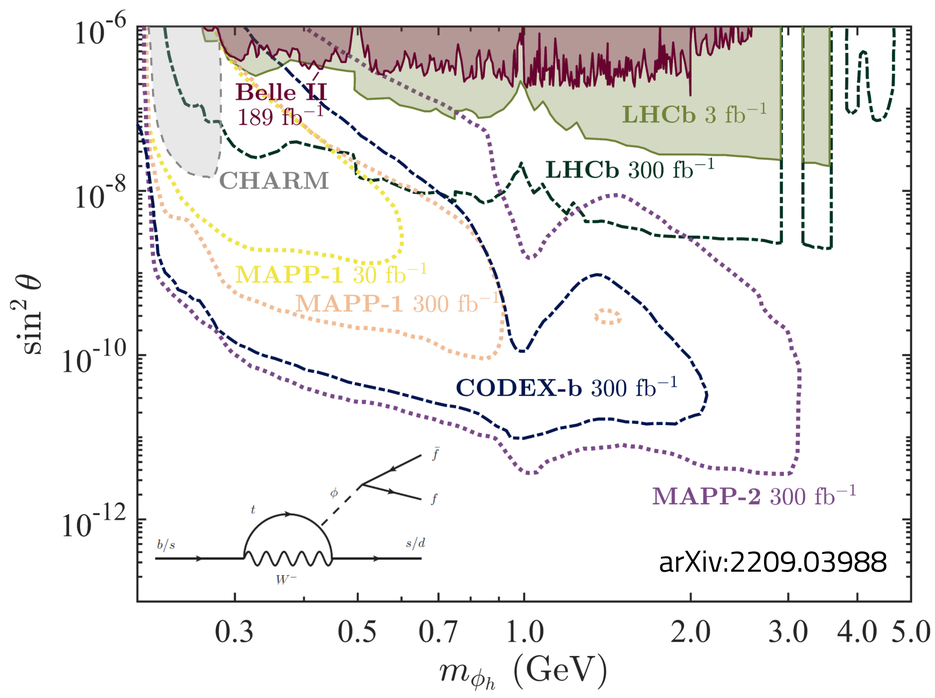

Fig. 3. Background-free projected sensitivities of MAPP-1 and MAPP-2 to long-lived dark Higgs bosons at the 95% confidence level.

Sterile Neutrinos at MAPP-2

As a **second benchmark scenario** to demonstrate the sensitivity of MAPP-2, we present results for **sterile neutrinos in the *B* – *L* model**. **Pair production of right-handed neutrinos *N*** from either a *B* – *L* gauge boson ***Z′*** or the SM ***Z*** boson was considered.

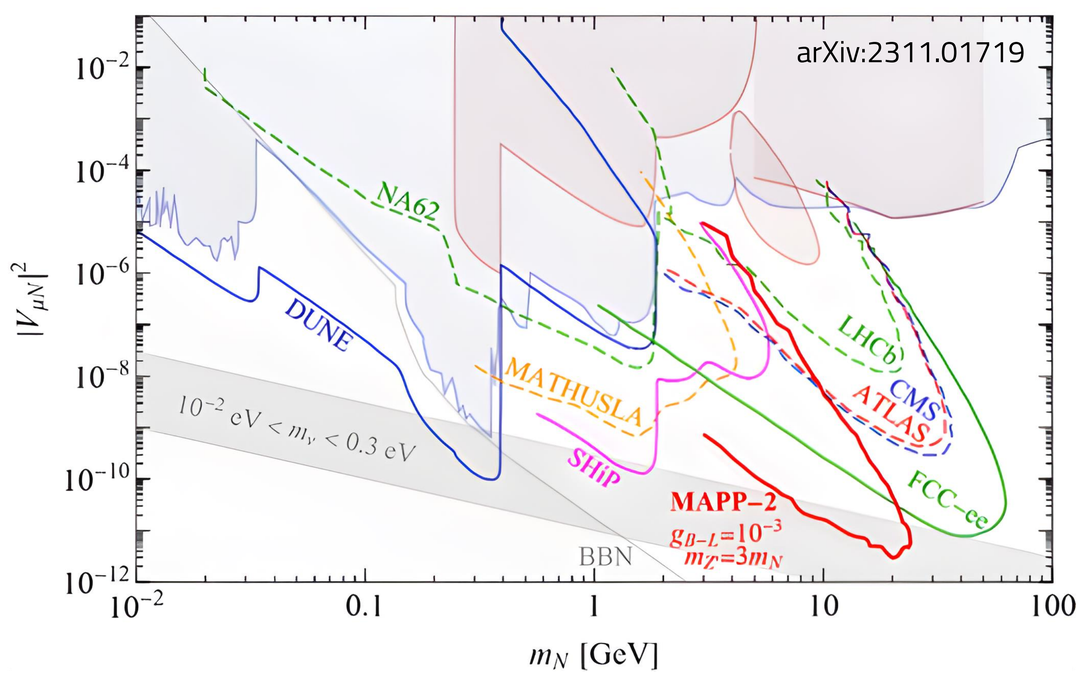

Fig. 4. Projected sensitivities of MAPP-2 (background-free) and other proposed experiments on the active–sterile neutrino mixing strength as a function of the sterile neutrino mass at the 95% confidence level.

Acknowledgments

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