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Updates and plans for NA64 - Joint BSM/FPC meeting 12.03.2025

Paolo Crivelli, ETH Zurich, Institute for Particle Physics and Astrophysics on behalf of NA64 collaboration

$(L_\mu - L_\tau)\,Z'$ model

X.-G. He, G. C. Joshi, H. Lew, and R. R. Volkas, Phys. Rev. D 44, 2118 (1991).
R. Foot, X. G. He, H. Lew, and R. R. Volkas, Phys. Rev. D 50, 4571 (1994).

SM extension: $SU(3)_c \otimes SU(2)_L \otimes U(1)_Y \otimes U(1)_{L_\mu - L_\tau}$

Lagrangian: $\mathcal{L} \supset -\frac{1}{4} F'_{\alpha\beta} F^{\alpha\beta\prime} + \frac{m_{Z'}^2}{2} Z'_\alpha Z^{\alpha\prime} - g_{Z'} Z'_\alpha J^\alpha_{\mu-\tau},$ where $g_{Z'} = \epsilon_{Z'} e$

$J^\alpha_{\mu-\tau}$ is the $U(1)_{L_\mu - L_\tau}$ leptonic current, $J^\alpha_{\mu-\tau} = (\bar{\mu}\gamma^\alpha \mu - \bar{\tau}\gamma^\alpha \tau + \bar{\nu}_\mu \gamma^\alpha P_L \nu_\mu - \bar{\nu}_\tau \gamma^\alpha P_L \nu_\tau)$

Decay rate $\Gamma(Z' \to \bar{\nu}\nu) = \frac{\alpha_{Z'} m_{Z'}}{3},$ with $\alpha_{Z'} = g_{Z'}^2/(4\pi)$

At $m_{Z'} > 2m_\mu$ the visible decays to SM leptons, $Z' \to \bar{\mu}\mu$, open.

Extension of $(L_\mu - L_\tau)\, Z'$ model to include LDM

$\mathcal{L} \supseteq -g_\chi Z'_\alpha J^\alpha_\chi$, with J^α_χ being a DS current reading

W. Altmannshofer, S. Gori, S. Profumo, and F. S. Queiroz, J. High Energy Phys. 12 (2016) 106.

$$J^\alpha_\chi = g_\chi \begin{cases} i\chi^* \partial^\alpha \chi + \text{H.c.}, & \text{complex scalar} \\ 1/2 \bar{\chi}\gamma^\alpha\gamma^5\chi, & \text{Majorana} \\ i\bar{\chi}_1\gamma^\alpha\chi_2, & \text{pseudo-Dirac} \\ \bar{\chi}\gamma^\alpha\chi, & \text{Dirac} \end{cases}$$

relic density is set by

$\bar{\chi}\chi(\to Z^{(*)\prime} \to)\bar{f}f,\ f = \mu,\ \tau,\ \nu,$

$$\langle\sigma v\rangle \propto (g_\chi g_{Z'})^2 m_\chi^2 / m_{Z'}^4 = y m_\chi^{-2} \text{ for Dirac DM.} \quad y = (g_\chi g_{Z'})^2 \left(\frac{m_\chi}{m_{Z'}}\right)^4.$$

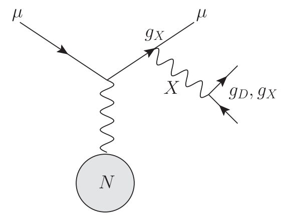
$m_{Z'} > 2m_\chi$, coupling $g_\chi > g_{Z'}$,

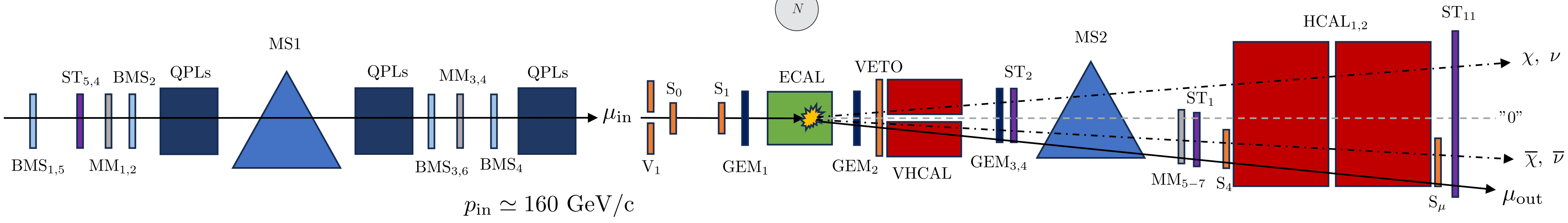
$\alpha_D = g_\chi^2/(4\pi)$

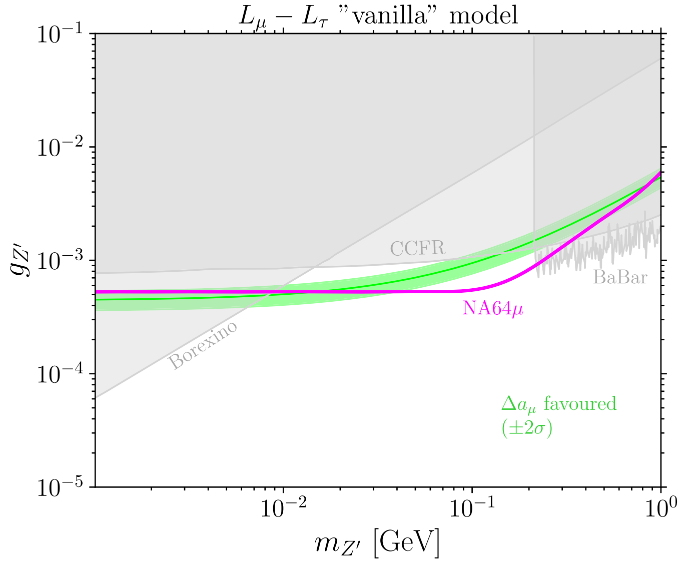
$$\Gamma(Z' \to \bar{\chi}\chi) = \frac{\alpha_D m_{Z'}}{3}\left(1 + \frac{2m_\chi^2}{m_{Z'}^2}\right)\sqrt{1 - \frac{4m_\chi^2}{m_{Z'}^2}},$$

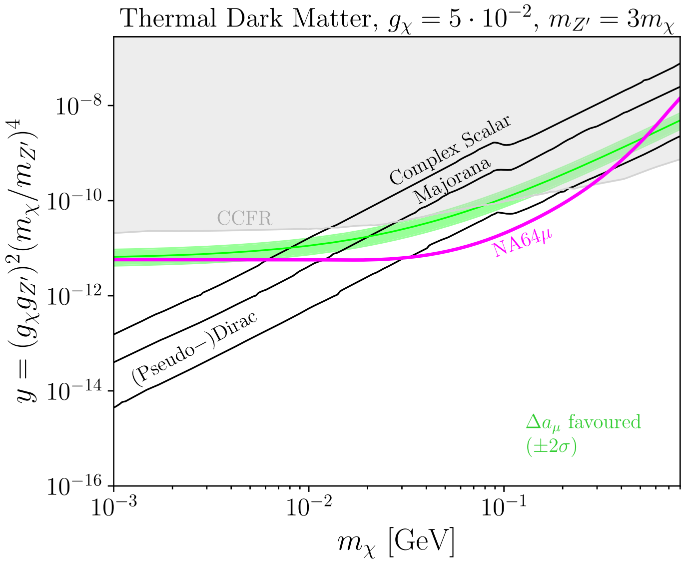
Current $(L_\mu - L_\tau)\, Z'$ NA64 results

NA64, PRL 132, 211803 (2024)
NA64, PRD 110, 112015 (2024)

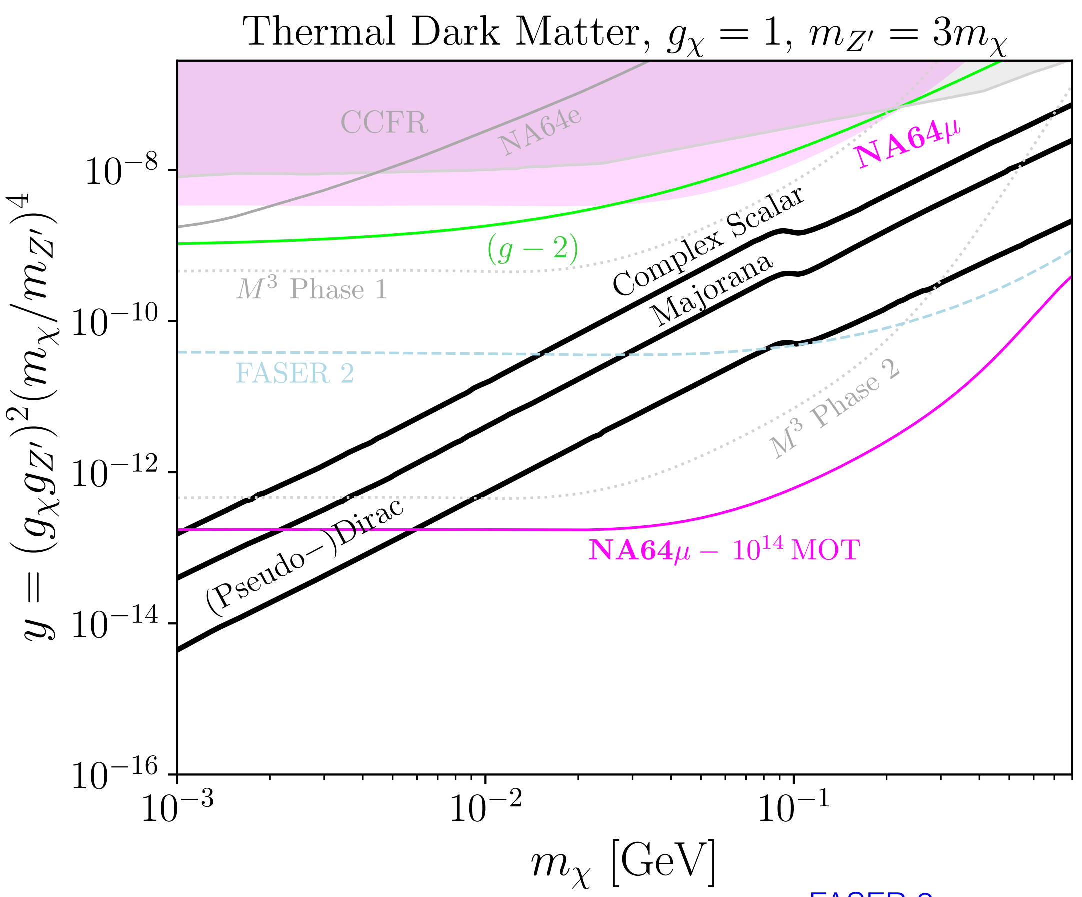








Prospects and proposed plot



Plot adapted from
NA64, PRD 110, 112015 (2024)

M3:
Y. Kahn, G. Krnjaic, N. Tran, A. Whitbeck
https://link.springer.com/article/10.1007/JHEP09(2018)153

FASER 2:
A. Ariga, R. Balkin, I. Galon, E. Kajomovitz and Y. Soreq
https://doi.org/10.1103/PhysRevD.109.035003