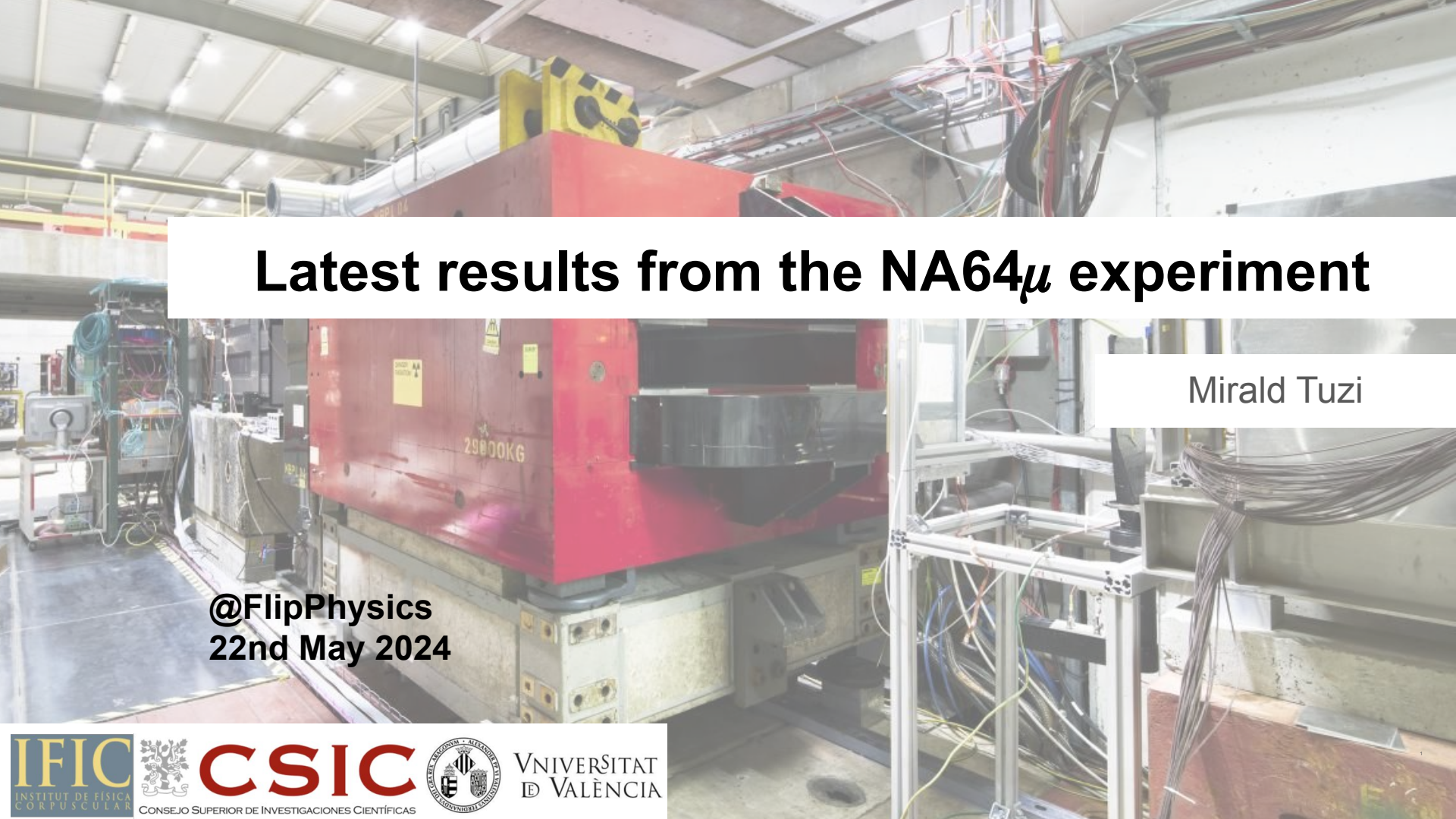

Latest results from the NA64μ experiment

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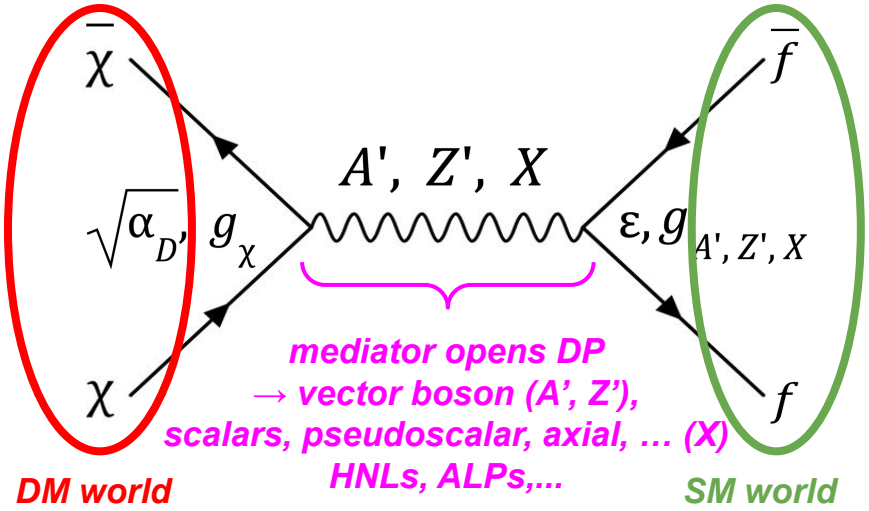
Motivation: Dark sectors (DS) to explain dark matter

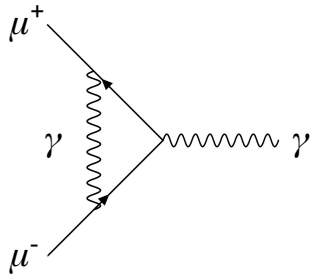
- Aside from gravity, an **additional** force between dark matter (DM) and visible particles (standard model, SM) may exist
- **Mediator of force**: particles at sub-GeV mass scale, which could decay into dark matter
- Interact **feebly** with SM particles through various mechanisms (dark portals, DP)



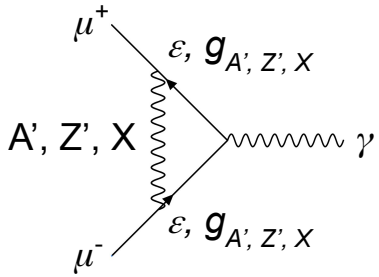
Motivation: Dark sectors (DS) to explain dark matter

Additional motivation: $(g\text{-}2)_\mu$ anomaly

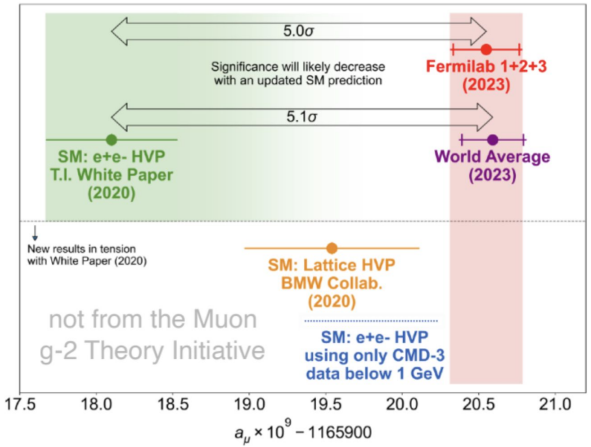
→ *we can check it "for free"*



standard model



possible DS extension

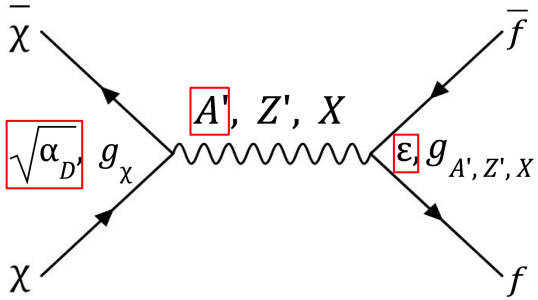


B. Li, Proceedings of Science (HQL 2023) 009
DOI: http://doi.org/10.22323/1.462.0009

DS in the NA64 experiment

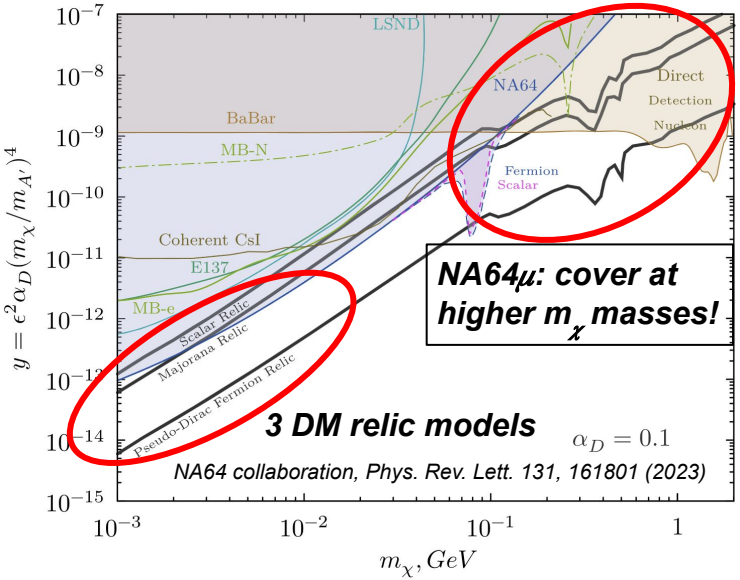
NA64: a ***fixed target*** experiment at the CERN SPS, probing light dark matter (LDM) candidates using **electron** (e^-), **positron** (e^+) and **muon** (μ) beams

example: A' model (dark photon)



$$\langle \sigma v(\bar{\chi}\chi(\rightarrow A' *\rightarrow)\, \bar{f}f)\rangle \propto \alpha_D \varepsilon^2 \frac{m_\chi^2}{m_{A'}^4} = y/m_\chi^2$$

(annihilation rate)

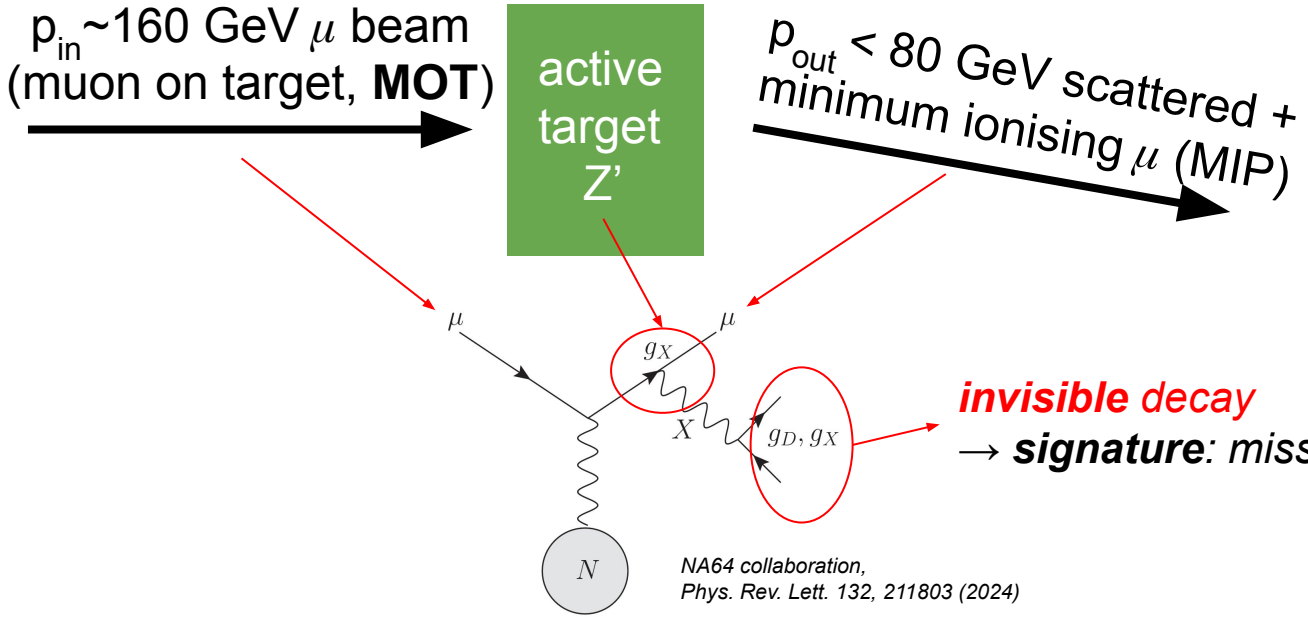


This talk: LDM searches with **muons** – the ***NA64μ experiment***
→ Benchmark model: L_μ-L_τ Z' – only couples to μ,τ families

$$\langle \sigma v(\bar{\chi}\chi(\rightarrow Z' *\rightarrow)\, \bar{f}f)\rangle \propto \left(g_\chi g_{Z'}\right)^2 \frac{m_\chi^2}{m_{Z'}^4} = y/m_\chi^2$$

The signature at NA64μ

Missing momentum technique

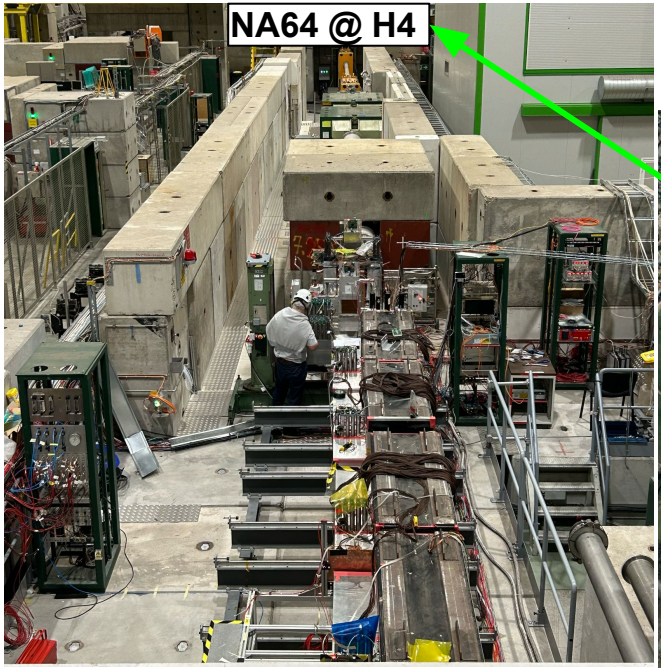


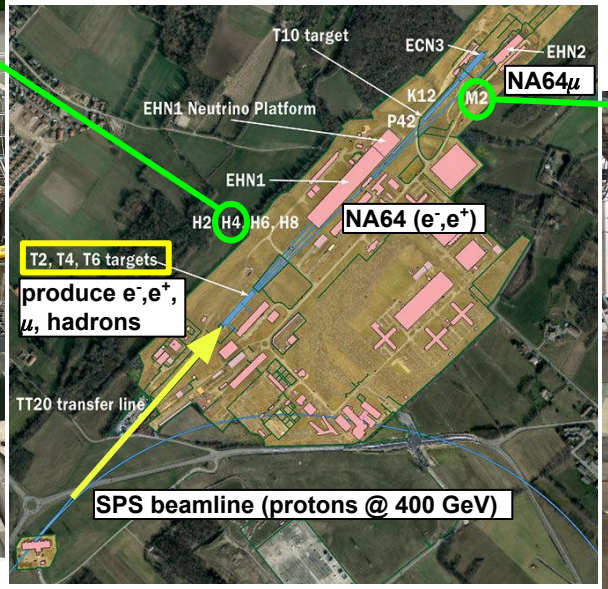
***invisible** decay*
→ ***signature**: missing momentum*

NA64 collaboration,
Phys. Rev. Lett. 132, 211803 (2024)

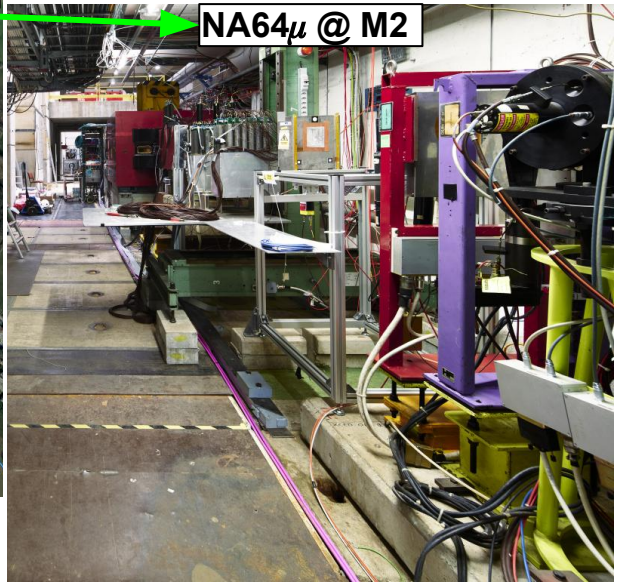
Why "active" target? It is an *electromagnetic calorimeter* (ECAL) → It can also measure deposited energy

NA64 @ CERN SPS

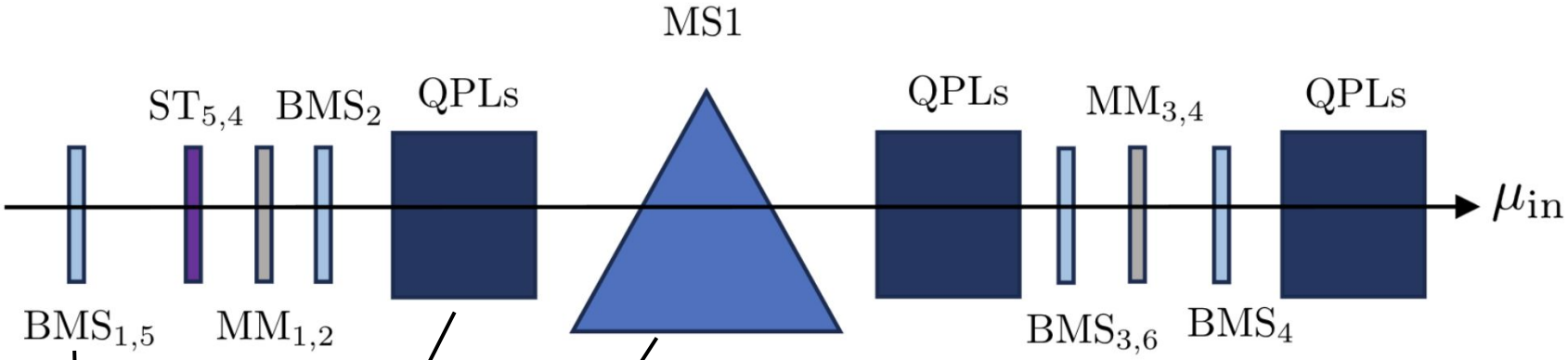




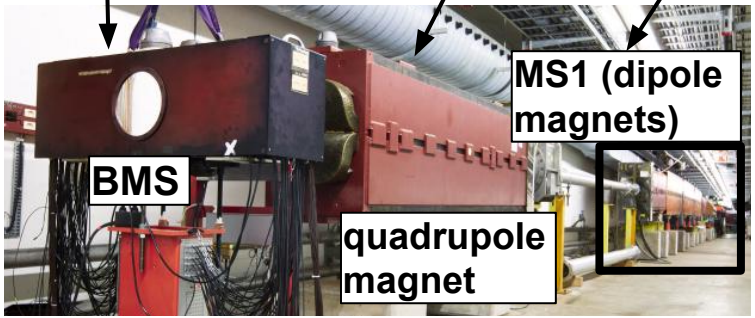
CERN Prévessin site (North Area)



The NA64μ setup: M2 beamline



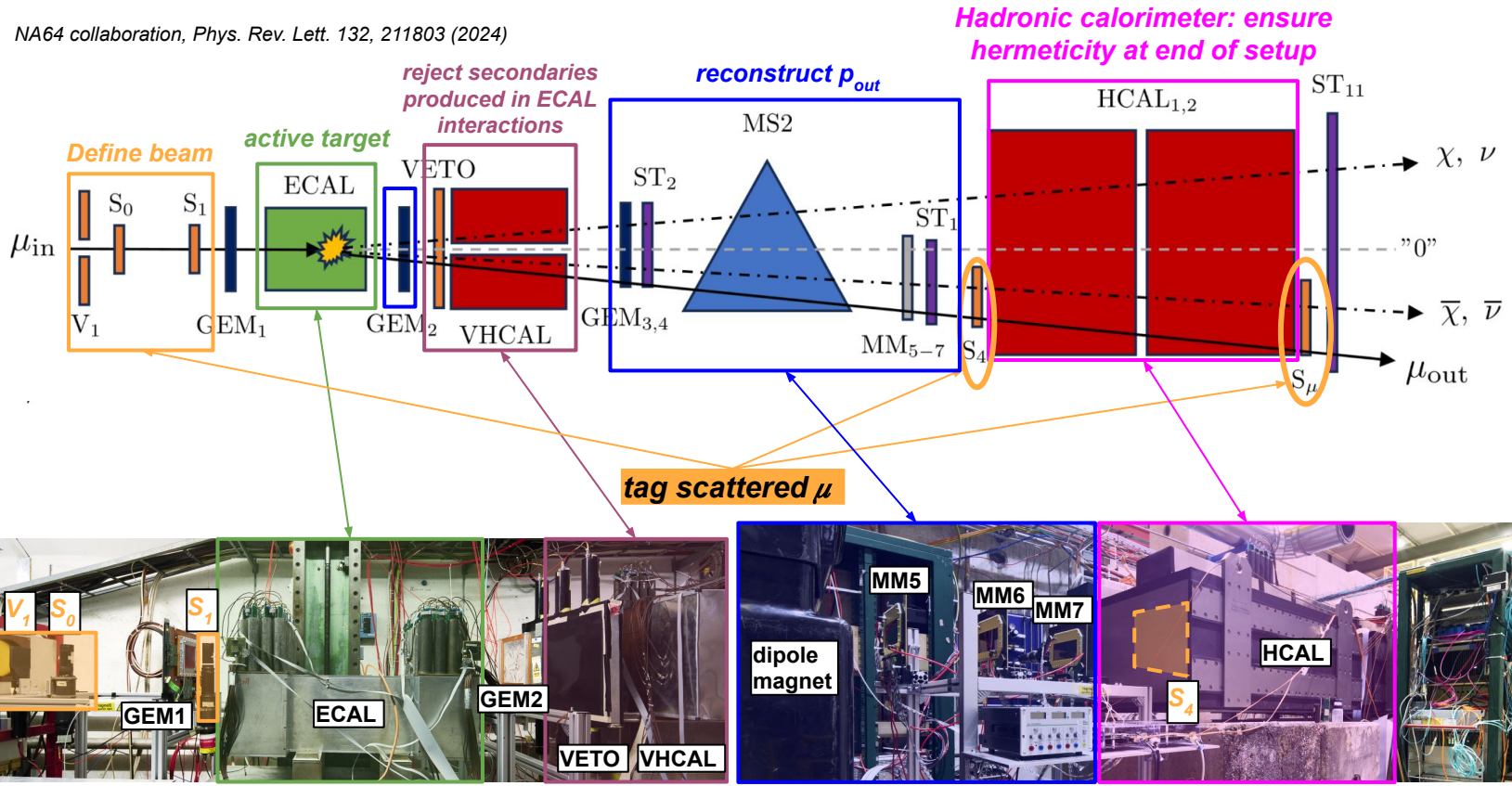
NA64 collaboration, Phys. Rev. Lett. 132, 211803 (2024)



measure incoming momentum @ 160 GeV

The NA64μ setup: main part

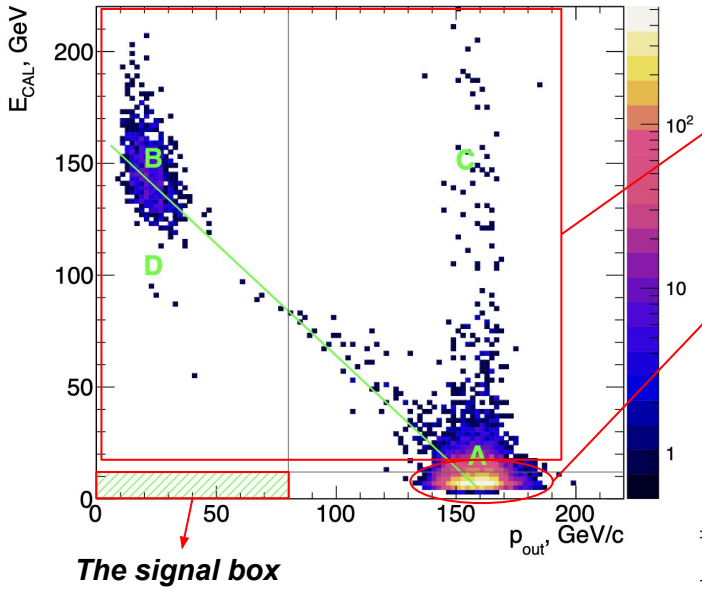
NA64 collaboration, Phys. Rev. Lett. 132, 211803 (2024)



Results 2022: Hermeticity of setup

Hermeticity: Is the total initial momentum fully contained within the setup?
→ Crucial for a missing momentum and energy experiment!

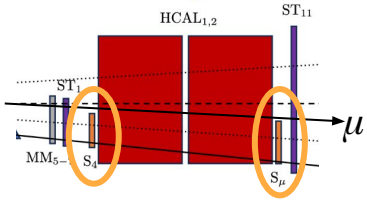
NA64 collaboration, Phys. Rev. Lett. 132, 211803 (2024)



The signal box

Muons with non-MIP deposits in ECAL, HCAL, VETO or VHCAL

Unscattered muons. Can pass trigger if electrons are knocked out of material nearby S_4 and S_μ

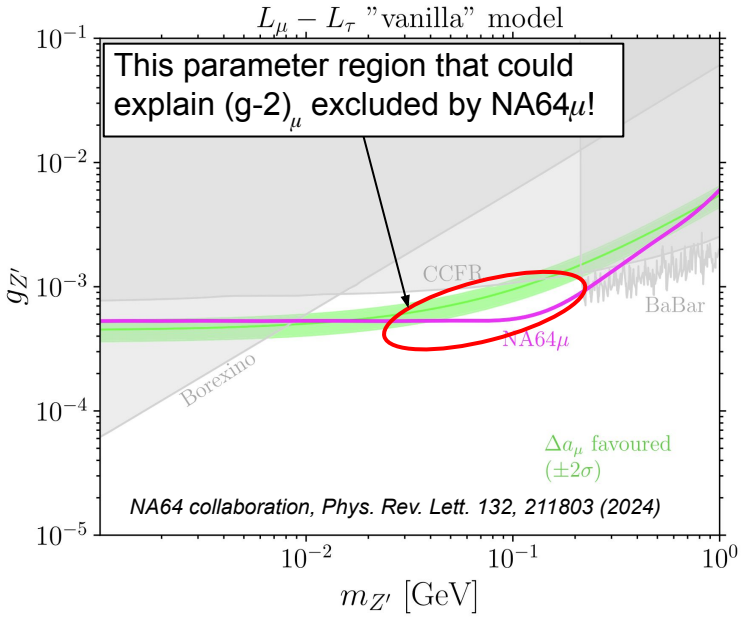


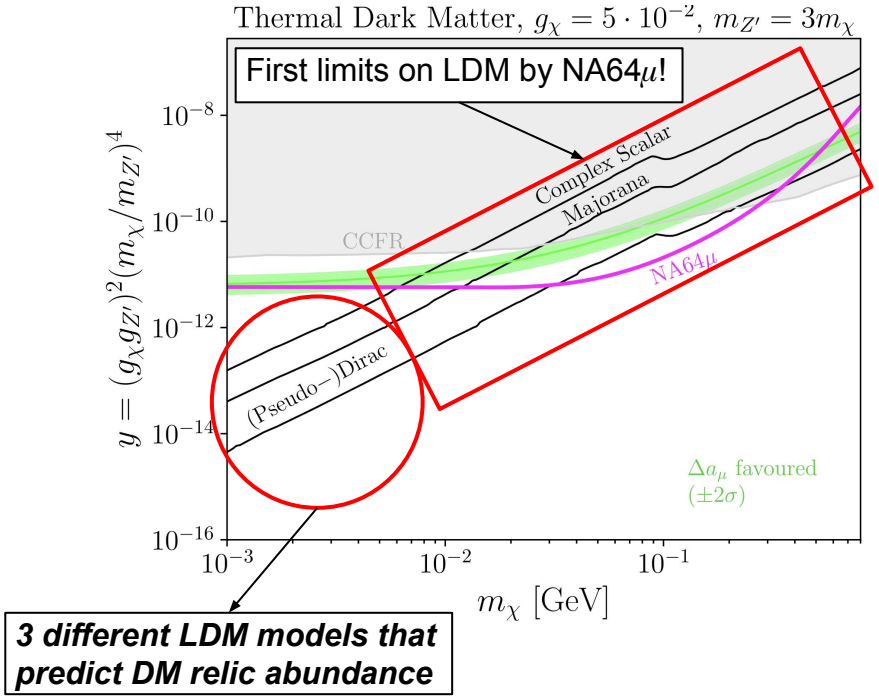
μ @ 160 GeV

Background source	Background, n_b
(I) Momentum mis-reconstruction	0.05 ± 0.03
(II) $K \to \mu + \nu$, ... in-flight decays	0.010 ± 0.001
(III) Calorimeter non-hermeticity	< 0.01
Total n_b (conservatively)	0.07 ± 0.03

No signal in 1.98x10^{10} MOT observed

Results 2022: First exclusion limits





3 different LDM models that predict DM relic abundance

Data 2023: More statistics with less background

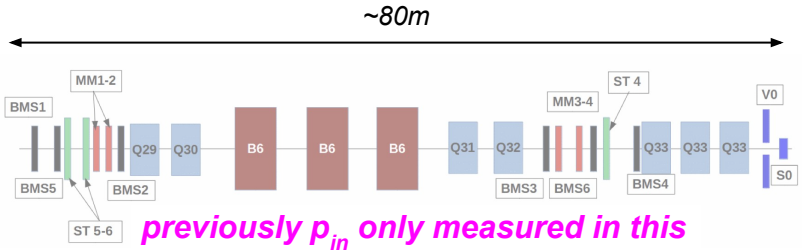
Background source	Background, n_b
(I) Momentum mis-reconstruction	0.05 ± 0.03
(II) $K \to \mu + \nu$, ... in-flight decays	0.010 ± 0.001
(III) Calorimeter non-hermeticity	< 0.01
Total n_b (conservatively)	0.07 ± 0.03

Collected ~1.5x10^{11} MOT @1-2e6 μ/s
→ ~2-3x higher intensity compared to 2022
(In 2022: ~2x10^{10} MOT @~6e5 μ/s)

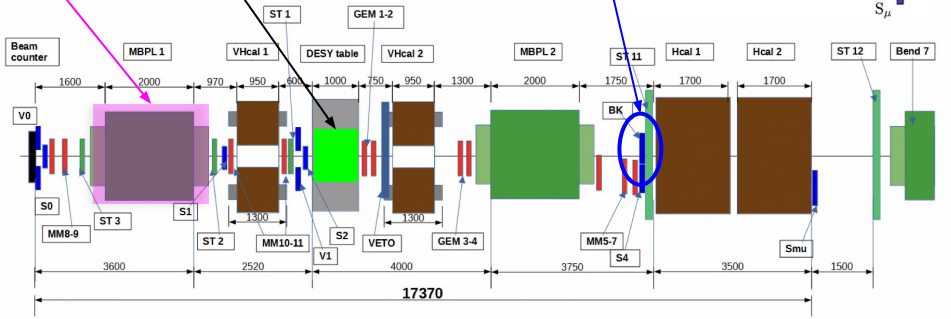
measure p_{in} right before target

target

Additional veto (to better reject unscattered μ)



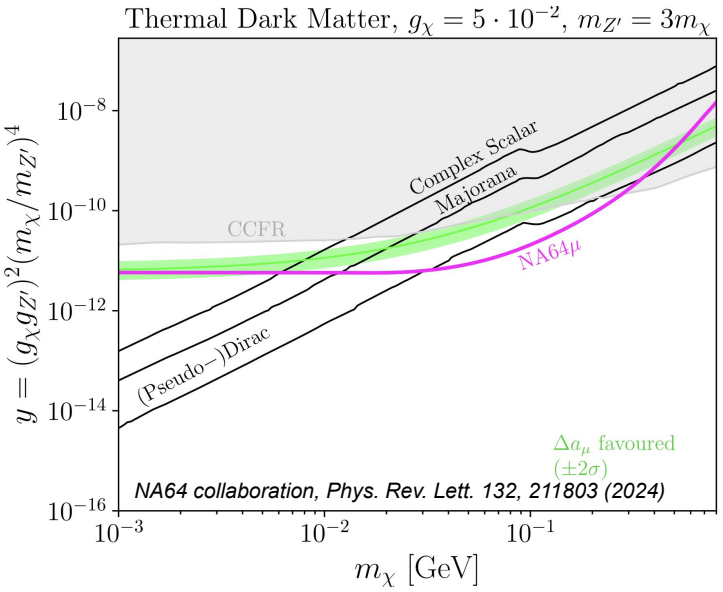
previously p_{in} only measured in this region (~80m tracking region)



Analysis ongoing! Preliminary results look promising…

Summary and Outlook: 2024 run and beyond LS3

- Demonstrated **feasibility** of missing momentum technique in DS searches with a high-intensity muon beam
- **First exclusion limits** reported for the Z' and χ parameter space



Forthcoming work

- **2024**: Take additional 1.5x10^{11} MOT to fully cover (g-2)$_\mu$ parameter space, and complement NA64 LDM searches in the high mass region
- **Beyond CERN Long Shutdown 3 (LS3)**: Prepare the experiment to run at intensities beyond 1e6 μ/s, collecting ~2x10^{13} MOT
- Explore other interesting physics channels (lepton flavour changing processes, axion like particles, …)

Thanks for your attention!

Acknowledgements

The NA64 collaboration, in particular Laura Molina Bueno, Henri Sieber and Paolo Crivelli

The NA64 collaboration in front of the M2 beamline experimental hall, where the NA64μ experiment is located

PID2021-123955NA-100