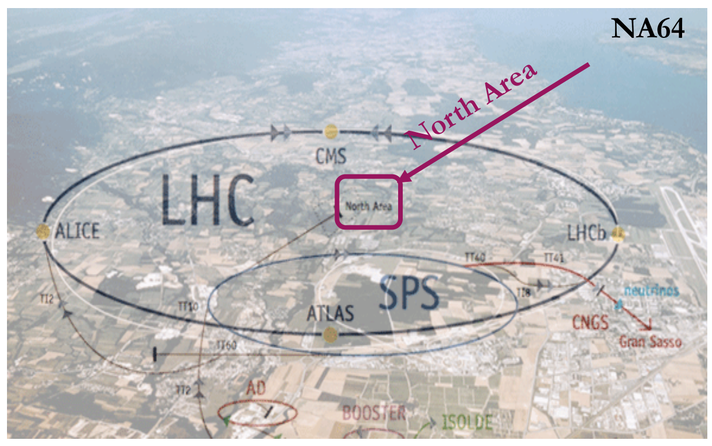
Search for new physics in ρ^0 decays in the NA64 experiment

S. Gertsenberger, A. Ivanov, A. Zhevlakov
Joint Institute for Nuclear Research

introduction

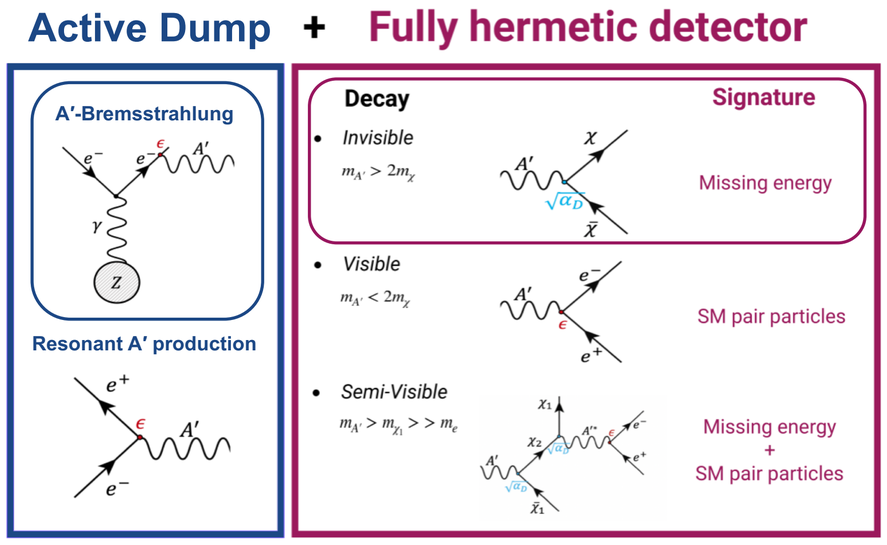
The primary goal of the NA64 is searching for a vector mediator between dark and our matter. The NA64e, one of the subprograms, looks for a dark photon A'. In NA64μ is considered another type of vector mediators Z′ or Z_μ, which predominantly interact with the second and third generations of leptons.
Missing energy/momentum experiments are sensitive to any process in which a beam electron transfers most of its energy to invisible particles, leading to a missing energy signal with no accompanying penetrating particles.



NA64e (since 2015)
100 GeV e-beam
Search for vector-mediated LDM
The NA64 Collab., arXiV:1312.3309

NA64μ (since 2021)
160 GeV μ-beam
Z' as a solution to the (g-2)μ and complementary LDM searches
D. Banerjee et al. (The NA64 Collab.), CERN-SPSC2019-002/SPSC-P-359

NA64h (test run 2025)
50 GeV π-beam
Search for hadrophilic DS
Y. M. Andreev et al. [NA64] arXiv:2406.01990



B. Banto Oberhauser DOI 10.22323/1.481.0015

Fig.1. Sketch of the production and detection of A' at NA64

vector meson search motivation

The exclusive photoproduction of vector mesons, $\gamma N \rightarrow V N$ ($V = \rho, \omega, \varphi$), can be an important source of real missing energy/momentum signals.

Dark matter production through A' Bremsstrahlung leads to an observed final state consisting solely of a much lower energy (and transversely deflected) recoil electron, with the rest of the energy carried by the produced DM particles, which pass through the detector without interacting.

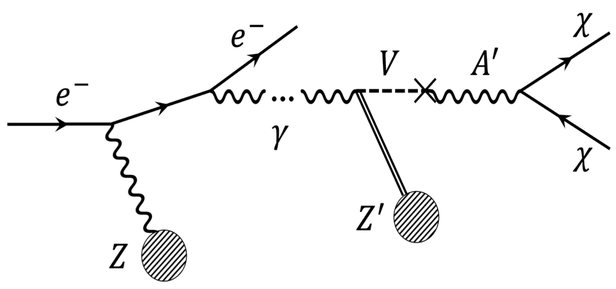
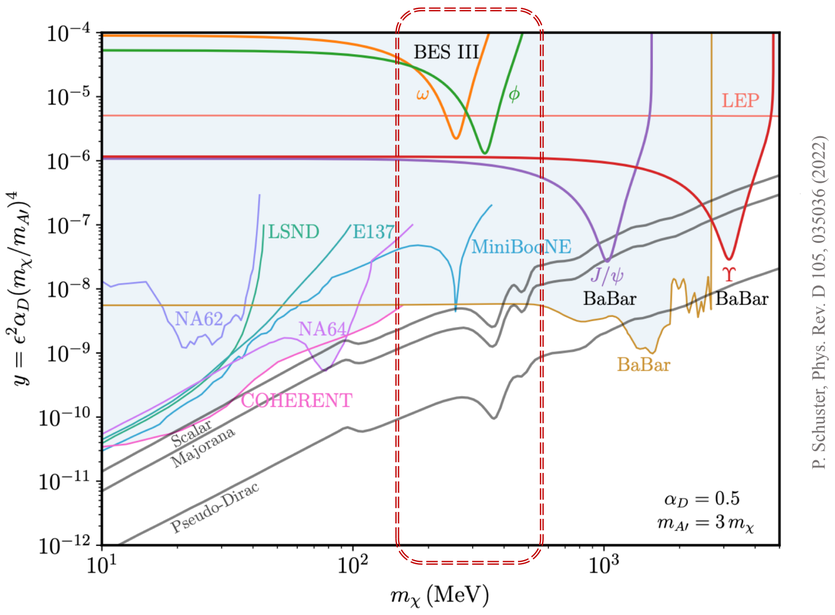


Fig.2. A hard photon is produced in the ECAL, and converts to a vector meson V in an exclusive photoproduction process in the calorimeter.

New additional channel for A' searches

Invisible decays of the light mesons ω and φ have been searched at BESIII experiment. There is no existing experimental bound for $\rho^0 \rightarrow DM$ process.

The investigation for ρ - meson decay allows to explore the dashed rectangle area (fig.3) and set a limit on these parameters space which are universal parameters for comparing different experiments and types of DM



P. Schuster, Phys. Rev. D 105, 035036 (2022)

Fig.3. Constraints on the dark photon model and existing constraints from current bounds on invisible vector meson decays

simulation of ρ^0 production at NA64

The simulation of the process of ρ - meson production was carried out using the Geant4 software package. Based on the results of the simulation of 10^8 events, about 12.8×10^3 ρ - meson were produced (fig. 4). For the further analysis it is necessary $E_{\rho^0} > 40$ GeV.
With statistics of total electrons on target $N_e = 2.6 \times 10^{12}$ accumulated since 2015, 9.47×10^6 ρ - mesons are expected.

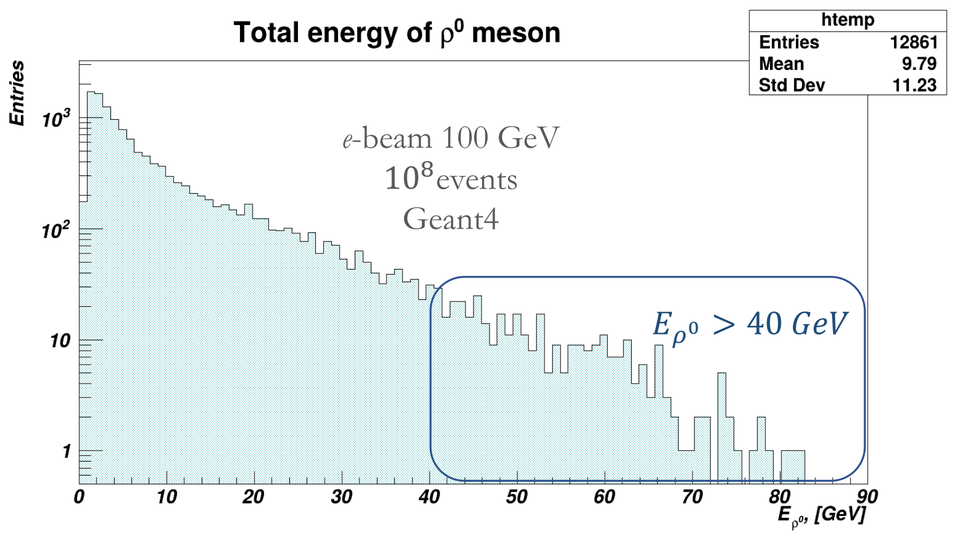


Fig.4. The total energy distribution of ρ^0 mesons produced in 100 millions events of a 100 GeV electron beam

Geant4 hadronic models do not include detailed simulations of exclusive photoproduction processes and describes only the process of incoherent photoproduction. Constraints on the decays of ρ - meson are represented in fig.5 for the the process of incoherent photoproduction for the current NA64 statistics, preliminary statistics for 2026, and future statistics to be collected during RUN 4.

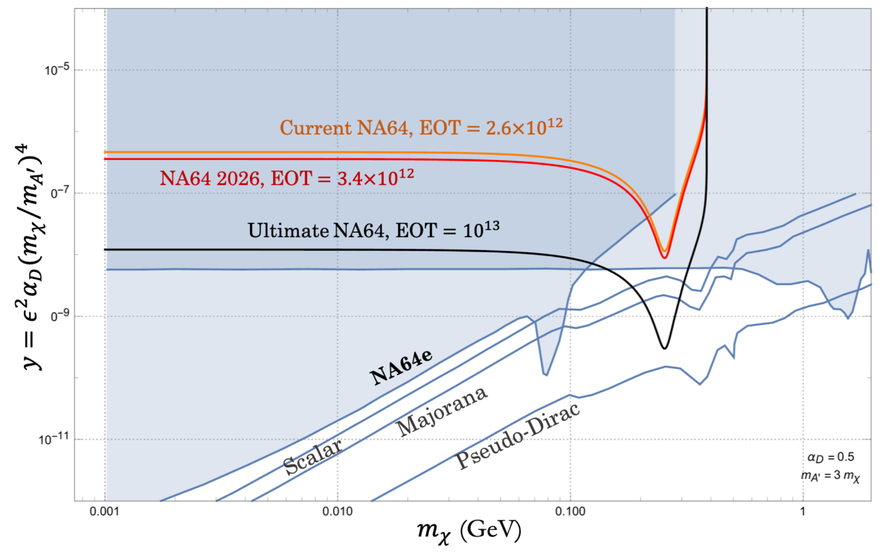


Fig.5. Constraints on the decays of invisible ρ^0 mesons calculated for $E_{\rho^0} > 40\ GeV$. The filled area represents the existing experimental bounds for the dark photon models

summary and plans

With statistics of total electrons on target $N_e = 2.6 \times 10^{12}$ collected since 2015, 9.47×10^6 incoherent ρ - mesons are expected.
Geant4 does not include the exclusive photoproduction processes. For a full assessment of the yield of ρ - mesons in the experiment, it is also necessary to take into account the process of coherent photoproduction on nuclei. Additional generators are capable of covering this task. This will also increase the peak size, which appears inconclusive for incoherent processes. A coherent process will be added to the simulation. The full implementation of the search for the invisible ρ^0 decay will continue.