# NA64 experiment:
Search for hidden sectors at the CERN SPS

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NA64 is a fixed target experiment combining the active beam dump technique with missing energy measurements to search for invisible decays of a massive A' dark boson produced in the reaction eZ—> eZA' of electrons scattering off a Pb nuclei as possible candidate for dark matter.
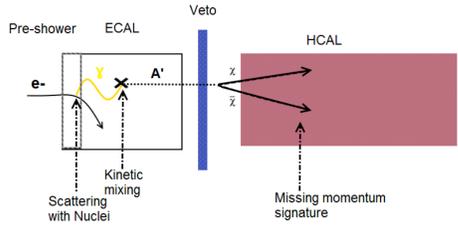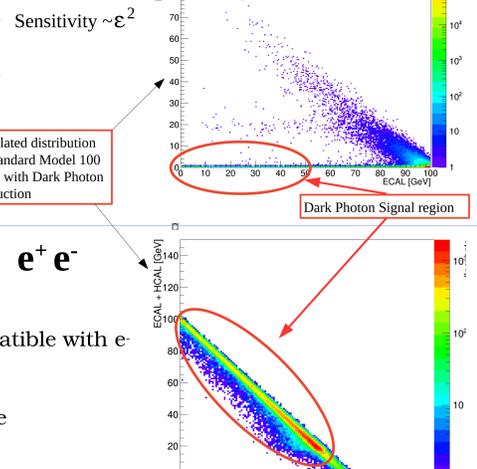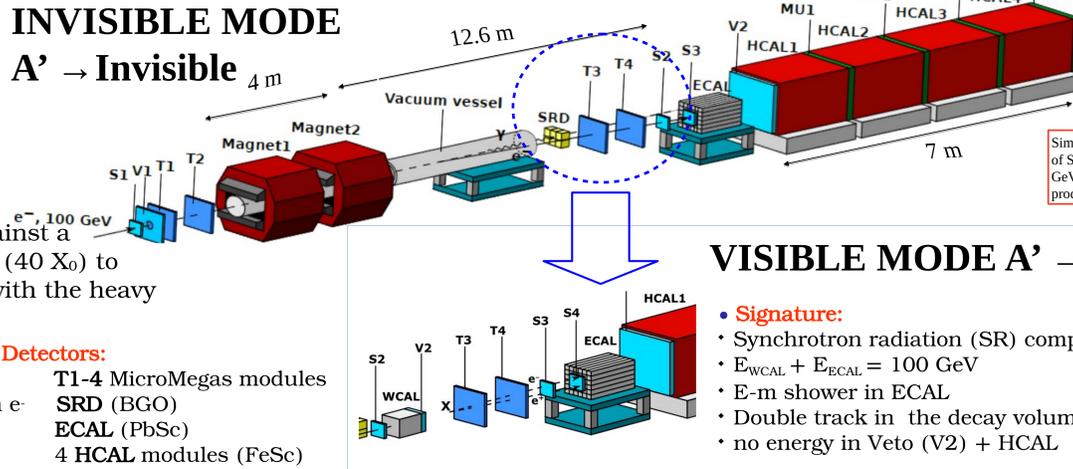
INVISIBLE MODE
A' → Invisible

A 100 GeV electron beam is dumped against a sandwich of lead and scintillators ECAL (40 X_0) to produce massive A' through scattering with the heavy nuclei.

- Signature:
  - Reconstructed 100 GeV momentum
  - Synchrotron radiation (SR) compatible with e-
  - < 50 GeV energy deposit in ECAL
  - no energy in Veto (V2) + HCAL

Detectors:
- T1-4 MicroMegas modules
- SRD (BGO)
- ECAL (PbSc)
- 4 HCAL modules (FeSc)

Sensitivity ~ε^2

Simulated distribution of Standard Model 100 GeV with Dark Photon production

Dark Photon Signal region

VISIBLE MODE A' → $e^+ e^-$

- Signature:
  - Synchrotron radiation (SR) compatible with e-
  - $E_{WCAL} + E_{ECAL} = 100$ GeV
  - E-m shower in ECAL
 - Double track in the decay volume
  - no energy in Veto (V2) + HCAL

Electron tagging with synchrotron radiation

- Synchrotron radiation Power's:
$$P = \frac{q^2 c}{6\pi R^2}\frac{E^4}{(Mc^2)^4} \qquad P \propto E^4 \qquad P \propto M^{-4}$$

- Two arrays of four BGO crystals used as detector, first two crystal used to measure SR and last two to measure backscattering.
- Events with high-energy ionization from incoming hadrons rejected by requiring coincidence between the two SR BGO.
- Suppression factor of ~10^{-5} reached for hadrons with an efficiency of ~95% for e-

E. Depeor et al. NIM A 866 (2017) 196
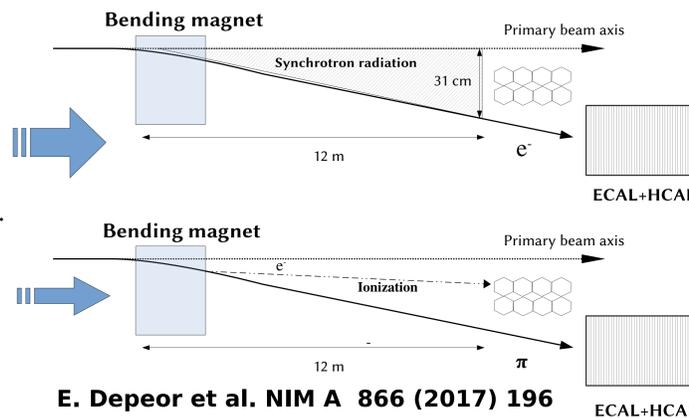
Comparison with MC simulation
- Excellent agreement reached between data and MC.
- Coincidence in signal between the two BGO crystals improves by two orders of magnitude the suppression factor for hadrons with light impact on the efficiency for e-.
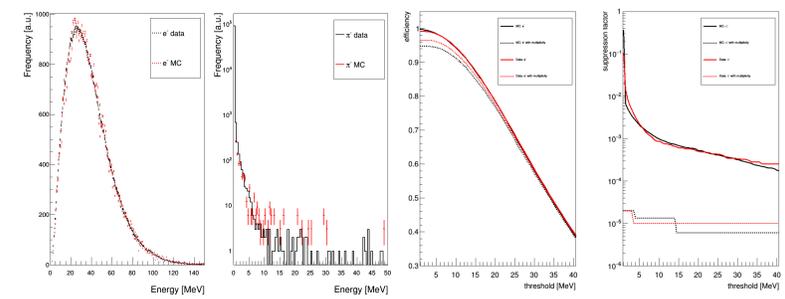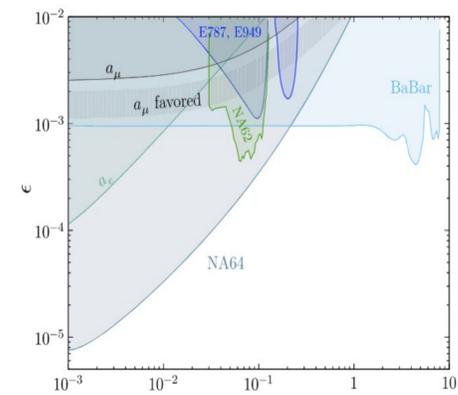
INVISIBLE MODE RESULTS

(E_{ECAL} ; E_{HCAL}) plane with ~3.0 x 10^{11} eot.

Area I —> QED dimuon production, $e^-Z —> e^-Z\gamma$; $\gamma —> \mu^+\mu^-$ of muon pair photo-production characterised by the energy ~ 10 GeV deposited by the dimuon pair in the HCAL.

Area II —> SM events from the hadron electro-production in the target which satisfy the energy conservation
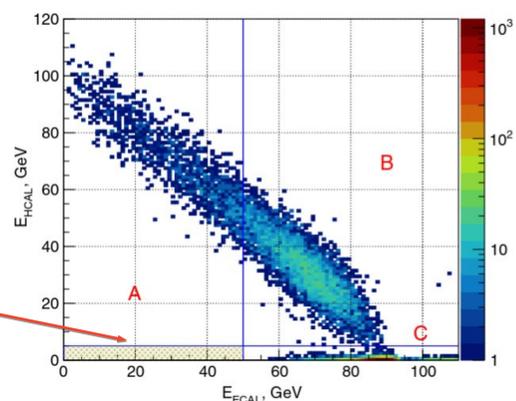$E_{ECAL} + E_{HCAL} \simeq 100$ GeV

Distribution of events after applying all selection criteria shows no events in signal region

The side bands A and C are used for the background estimate inside the signal box.

Signal region

→ Phys. Rev. Lett. 118, 011802 (2017)
→ Phys. Rev. D 97, 072002 (2018)
→ Phys. Rev. Lett. 123, 121801(2019)

The NA64 90% C.L. exclusion region in the ($m_{A'}$; ε) plane.
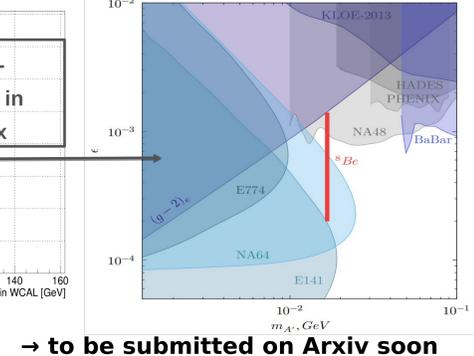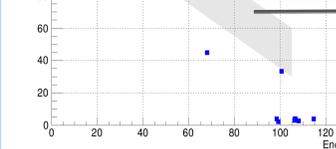
VISIBLE MODE RESULTS

- Motivations:
  - Beryllium anomaly detected by Atomki could be explained by protophobic gauge boson detectable in NA64 which would explain anomalous $(g-2)_\mu$ as well.

→ A. J. Krasznahorkay et al. Phys. Rev. Lett.116, 042501 (2015)

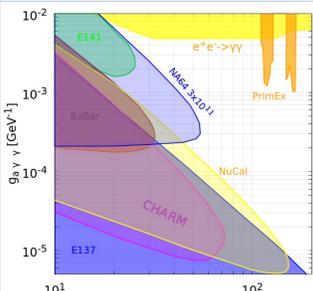→ J. L. Feng et al. Phys. Rev. D95, 035017 (2017)
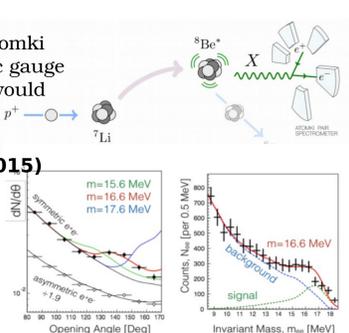
New 2018 data!

No signal-like event in signal box

Neutral events

→ to be submitted on Arxiv soon

New ALP search recasting invisible mode data!

Produced via Primankoff production:

$$e^-Z —> e^-Z\gamma;$$
$$\gamma Z —> a Z$$

Signature:
- ECAL < 50 GeV
- No activity in the VETO
- No activity in first HCAL module
- Energy deposition in last two HCAL is > 10 GeV

- If some energy is recorded in the last two HCAL
  ==> ALPS decay inside HCAL
- No energy in HCAL
  ==> ALPS decay outside setup

Outlook

→ Approved physic program after LS2:
- Invisible mode : Accumulate ~ 5×10^{12} EOTS to cover light thermal dark matter parameter space justified by relic density
- visible mode: Increase coverage of parameter space with focus on ^{8}Be anomaly
- New measurement using Muon beam NA64$_\mu$! $\mu Z \to \mu Z + Z_\mu(\to$ invisible) Complementary for dark matter scenario and $(g-2)_\mu$ anomaly. Test beam in 2022

→ Future options being investigated:
- $K_L \to$ mirror K_L oscillations — S.N. Gninenko and N.V. Krasnikov; Phys. Rev. D92 (2015) 034009; arXiv:1503.01595 [hep-ph]
- π^0, h,h', K_S,$K_L \to$ invisible — S.N. Gninenko; Phys. Rev. D91 (2015) 015004; arXiv:1409.2288 [hep-ph]
- A' → $+ e^- + e^+$ — Gopolang Mohlabeng; Phys. Rev. D99 (2019) 115001; arXiv:1902.05075 [hep-ph]
- $a \to \gamma + \gamma$, $a \to e^- + e^+$ (ALP search) — NA64 collaboration; CERN-SPSC-2018-015 / SPSC-SR-231

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