A Search for Light Dark Matter at the CERN SPS: Multiplexed XY Resistive Micromegas Tracker for NA64

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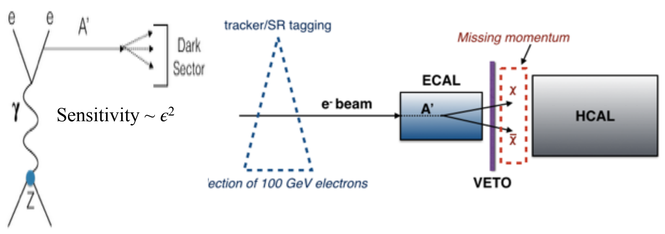
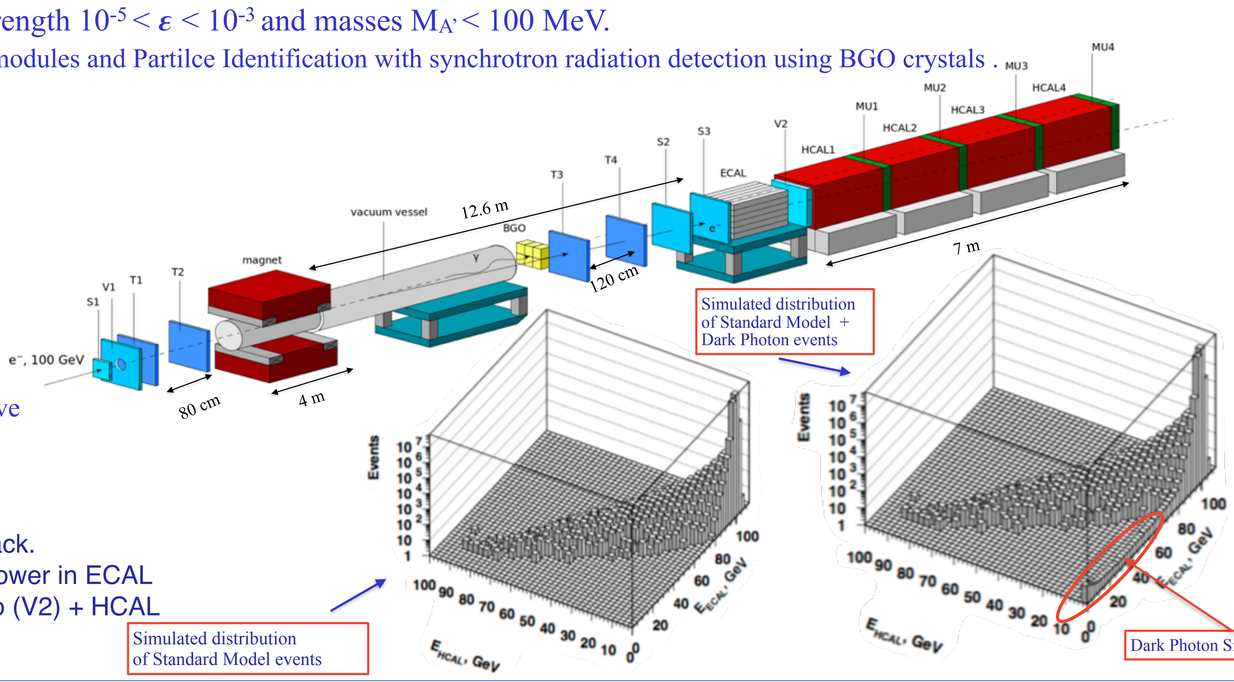
NA64 is a fixed target experiment combining the active beam dump technique with missing energy measurement searching for invisible decays of massive A' produced in the reaction eZ—> eZA' of electrons scattering off a nuclei (A,Z), with a mixing strength $10^{-5} < \varepsilon < 10^{-3}$ and masses $M_{A'} < 100$ MeV.

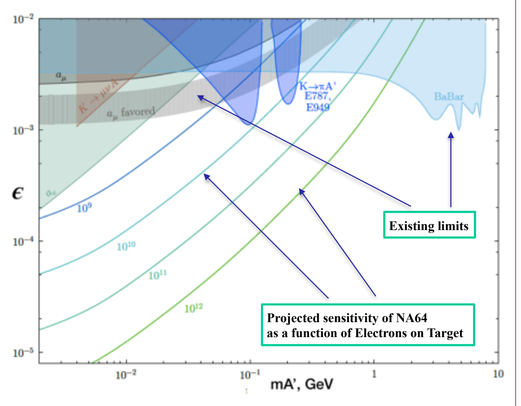
Our Group's Responsibility: Particle Tracking with Micromegas modules and Partilce Identification with synchrotron radiation detection using BGO crystals .



For NA64 a beam of 100 GeV electrons will be dumped against an ECAL, a sandwich of lead and scintillators (34 X_0), to produce massive A' through scattering with the heavy nuclei.

- 3 main requirements:
  - clean mono-energetic electron beam of 100 GeV
  - e^- tagging with MM tracker (T 1-4) and SR (BGO)
  - 4π fully hermetic ECAL + HCAL
- Signature:
  - in: 100 GeV e^- track.
  - < 50 GeV EM shower in ECAL
  - no energy in Veto (V2) + HCAL

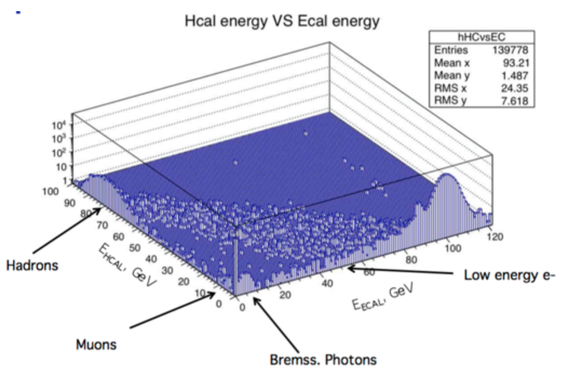


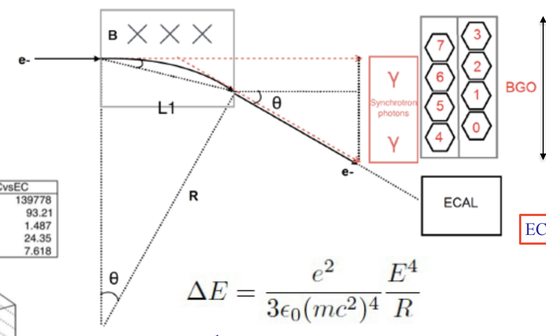


With 10^{10} accumulated events (possible to accumulate 5×10^{10} electrons in a month's run time) NA64 may completely exclude the still favoured parameter space by $(g-2)_\mu$.

October' 2015 1st test beam (2 weeks) —> Synchrotron tagging with BGO crystals

NA64 Preliminary data
B-field off

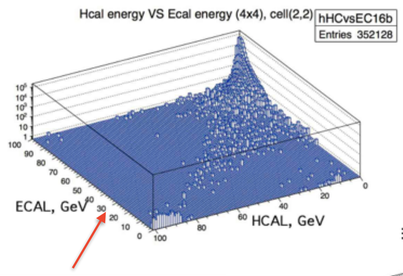




$$\Delta E = \frac{e^2}{3\epsilon_0 (mc^2)^4} \frac{E^4}{R}$$

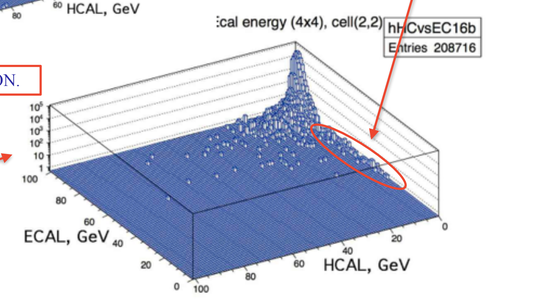
$\Delta E \propto m^{-4}$

Hadron and muon suppression
Level of beam impurity $\lesssim 10^{-2}$



ECAL vs HCAL energy with B-field ON.

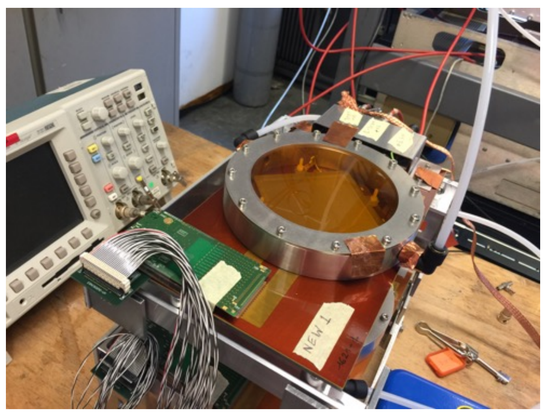
Low Energy Tail to be rejected by tracking

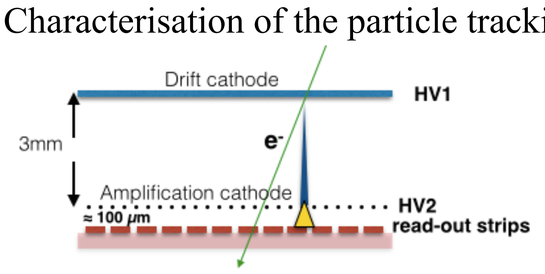


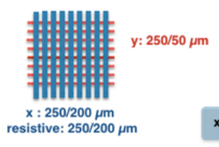
ECAL vs HCAL energy after synchrotron tagging.

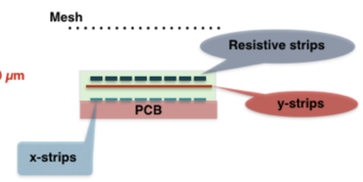
Beam Purity for Light Dark Matter Search in Beam Dump Experiment
D. Banerjee, P. Crivelli, and A. Rubbia (Zurich, ETH)
Adv. High Energy Phys. 2015 (2015) 105730 (http://www.hindawi.com/journals/ahep/2015/105730/)

July' 2016 2nd beam (2 weeks) —> Characterisation of the particle tracking with optimised MM modules

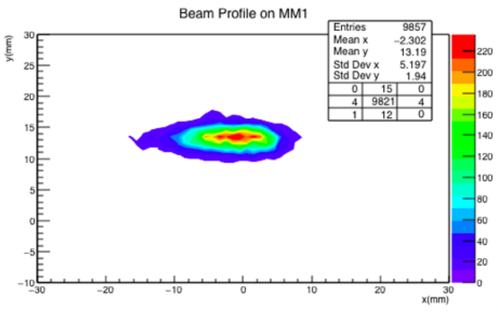








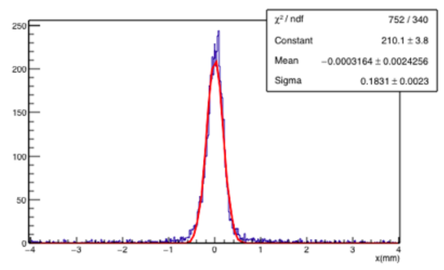
Efficiency ~ 98.6 %
Improved from ~ 50% as calculated in October' 2015 beam time.
Reason for inefficiency was smaller inner width between Y strips which restricted reasonable signal induction to the X strips from the Resistive layer.



—> Micromegas detectors are two stage parallel plate avalanche chambers.
—> Narrow amplification gap ~ 128 μm
—> Wider drift gap ~ 3 mm.
—> Charged particle drift towards the micro-mesh under an E-field of 0.6 kV/cm (HV1).
—> Produces avalanche of secondary electrons under high amplification field ~ 50 kV/cm (HV2).

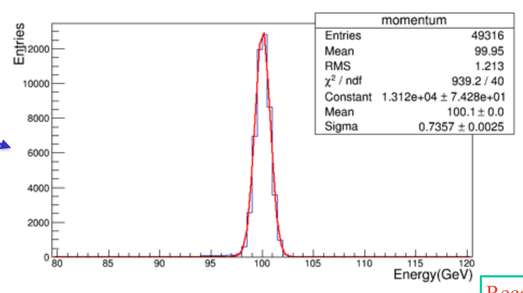
8cm x 8cm Multiplexed Resistive XY Micromegas modules of 250 μm strip pitch used for tracking.
Modules multiplexed by a factor 5. *"S. Procureur et al NIM A 729 (2013) 888-894"*
Clustering algorithm and readout software written and tested for readout with APV chip and integrated with the COMPASS DAQ used for NA64.
One APV with 128 readout channels used to read 640 strips per detector.

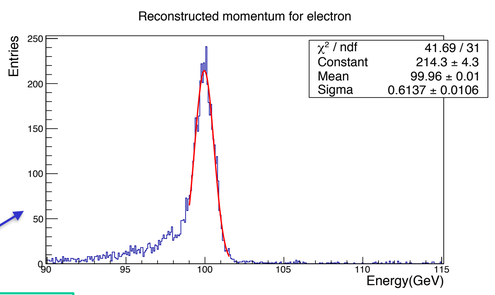
Spatial Resolution ~ $\sigma/\sqrt{2} = 0.180/\sqrt{2} = 127$ μm for each co-ordinate.



Micromegas modules used for tracking the incoming particle under a magnetic field ~ 1.9 T for a 4 m magnet. Tracking was tested with simulation and with data during the July' 2016 beam run.

Reconstructed momentum for 100 GeV beam from Geant4 simulation.
Momentum resolution ~ 0.7 GeV





Reconstructed momentum for 100 GeV beam from data.
Momentum resolution ~ 0.6 GeV

Momentum Reconstruction from data matches well with Simulation.
Analysis ongoing to use tracking information in the July' 2016 data for background rejection.

Outlook

Approved physics programme:

- A 4 week beam time for October' 2016 already approved. Physics data taking planned for this beam run.
- Goal is to exclude the still favoured parameter space by $(g-2)_\mu$.

- Future options being investigated:
  - A' —> e^+e^- channel *S.N. Gninenko et al;* **IEEE Trans.Nucl.Sc. 62 (2015) 3283; arXiv:1503.05687[physics.ins-det]**
  - μZ —> μZ + Z_μ(—> νν, μμ), *S.N. Gninenko et al;* **Phys. Rev. D91 (2015) 095015; arXiV:1412.1400 [hep-ph]**
  - K_L (K_S) —> invisible, *S.N. Gninenko and N.V. Krasnikov;* **Phys. Rev. D92 (2015) 034009; arXiv:1503.01595 [hep-ph]**
  - π —> invisible foreseen. *S.N. Gninenko;* **Phys. Rev. D91 (2015) 015004; arXiv:1409.2288 [hep-ph]**

Timeline for NA64: December '2013 "Proposal for an Experiment to Search for Light Dark Matter at the SPS" was submitted to CERN (*arXiV:1312.3309 [hep-ex]*). April' 2014 P348 was discussed at the 113th Meeting of the SPSC and a test run of two weeks recommended for estimation of background and performance study of the detectors. At the January' 2015 SPSC meeting a beam time period of two weeks (October' 2015) was approved for P348. March' 2016 P348 experiment was approved as an SPS experiment with the reference number NA64 and beam run periods approved for July' 2016 and October' 2016..

Ideal educational platform for high energy particle physics, since 2014: 1 PhD (ongoing), 2 master and 2 semester thesis, 1 "Matura" work (ongoing).

FNSNF ETH zürich

ETH Institute for Particle Physics

https://na64.web.cern.ch
http://www.rubbia-group.ethz.ch