# Large Hadron Collider experiment zeroes in on magnetic monopoles

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The MoEDAL detector. Credit: CERN

The late physicist Joseph Polchinski once said the existence of magnetic monopoles is "one of the safest bets that one can make about physics not yet seen." In its quest for these particles, which have a magnetic charge and are predicted by several theories that extend the Standard Model, the MoEDAL collaboration at the Large Hadron Collider (LHC) has not yet proven Polchinski right, but its latest findings mark a significant stride forward.

The results, reported in two papers posted on the *arXiv* preprint server, considerably narrow the search window for these hypothetical particles.

At the LHC, pairs of magnetic monopoles could be produced in interactions between protons or heavy ions. In collisions between protons, they could be formed from a single virtual photon (the Drell–Yan mechanism) or the fusion of two virtual photons (the photon-fusion mechanism). Pairs of magnetic monopoles could also be produced from the vacuum in the enormous magnetic fields created in near-miss heavy-ion collisions, through a process called the Schwinger mechanism.

Since it started taking data in 2012, MoEDAL has achieved several firsts, including conducting the first searches at the LHC for magnetic monopoles produced via the photon-fusion mechanism and through the Schwinger mechanism.

In the first of its latest studies, the MoEDAL collaboration sought monopoles and high-electric-charge objects (HECOs) produced via the Drell–Yan and photon-fusion mechanisms. The search was based on proton–proton collision data collected during Run 2 of the LHC, using the full MoEDAL detector for the first time.

The full detector comprises two main systems sensitive to magnetic monopoles, HECOs and other highly ionizing hypothetical particles. The first can permanently register the tracks of magnetic monopoles and HECOs, with no background signals from Standard Model particles. These tracks are measured using optical scanning microscopes at INFN Bologna.

The second system consists of roughly a ton of trapping volumes designed to capture magnetic monopoles. These trapping volumes—which make MoEDAL the only collider experiment in the world that can definitively and directly identify the magnetic charge of magnetic monopoles—are scanned at ETH Zurich using a special type of magnetometer called a SQUID to look for any trapped monopoles they may contain.

In their latest scanning of the trapping volumes, the MoEDAL team found no magnetic monopoles or HECOs, but it set bounds on the mass and production rate of these particles for different values of particle spin, an intrinsic form of angular momentum.

For magnetic monopoles, the mass bounds were set for magnetic charges from 1 to 10 times the fundamental unit of magnetic charge, the Dirac charge (gD), and the existence of monopoles with masses as high as about 3.9 trillion electronvolts (TeV) was excluded.

For HECOs, the mass limits were established for electric charges from 5e to 350e, where e is the electron charge, and the existence of HECOs with masses ranging up to 3.4 TeV was ruled out.

"MoEDAL's search reach for both monopoles and HECOs allows the collaboration to survey a huge swathe of the theoretical 'discovery space' for these hypothetical particles," says MoEDAL spokesperson James Pinfold.

In its second latest study, the MoEDAL team concentrated on the search for monopoles produced via the Schwinger mechanism in heavy-ion collision data taken during Run 1 of the LHC. In a unique endeavor, it scanned a decommissioned section of the CMS experiment beam pipe, instead of the MoEDAL detector's trapping volumes, in search of trapped monopoles.

Once again, the team found no monopoles, but it set the strongest-to-date mass limits on Schwinger monopoles with a charge between 2gD and 45gD, ruling out the existence of monopoles with masses of up to 80 GeV.

"The vital importance of the Schwinger mechanism is that the production of composite monopoles is not suppressed compared to that of elementary ones, as is the case with the Drell–Yan and photon-fusion processes," explains Pinfold. "Thus, if monopoles are composite particles, this and our previous Schwinger-monopole search may have been the first-ever chances to observe them."

The MoEDAL detector will soon be joined by the MoEDAL Apparatus for Penetrating Particles, MAPP for short, which will allow the experiment to cast an even broader net in the search for new particles.

**More information:** Search for Highly-Ionizing Particles in pp Collisions During LHC Run-2 Using the Full MoEDAL Detector, *arXiv* (2023). DOI: 10.48550/arxiv.2311.06509

B. Acharya et al, MoEDAL search in the CMS beam pipe for magnetic monopoles produced via the Schwinger effect, *arXiv* (2024). DOI: 10.48550/arxiv.2402.15682

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