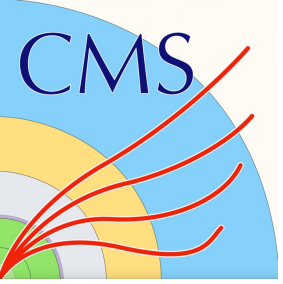


THE OHIO STATE UNIVERSITY

LHC Run 3 milliQan detector

Matthew Joyce (The Ohio State University)

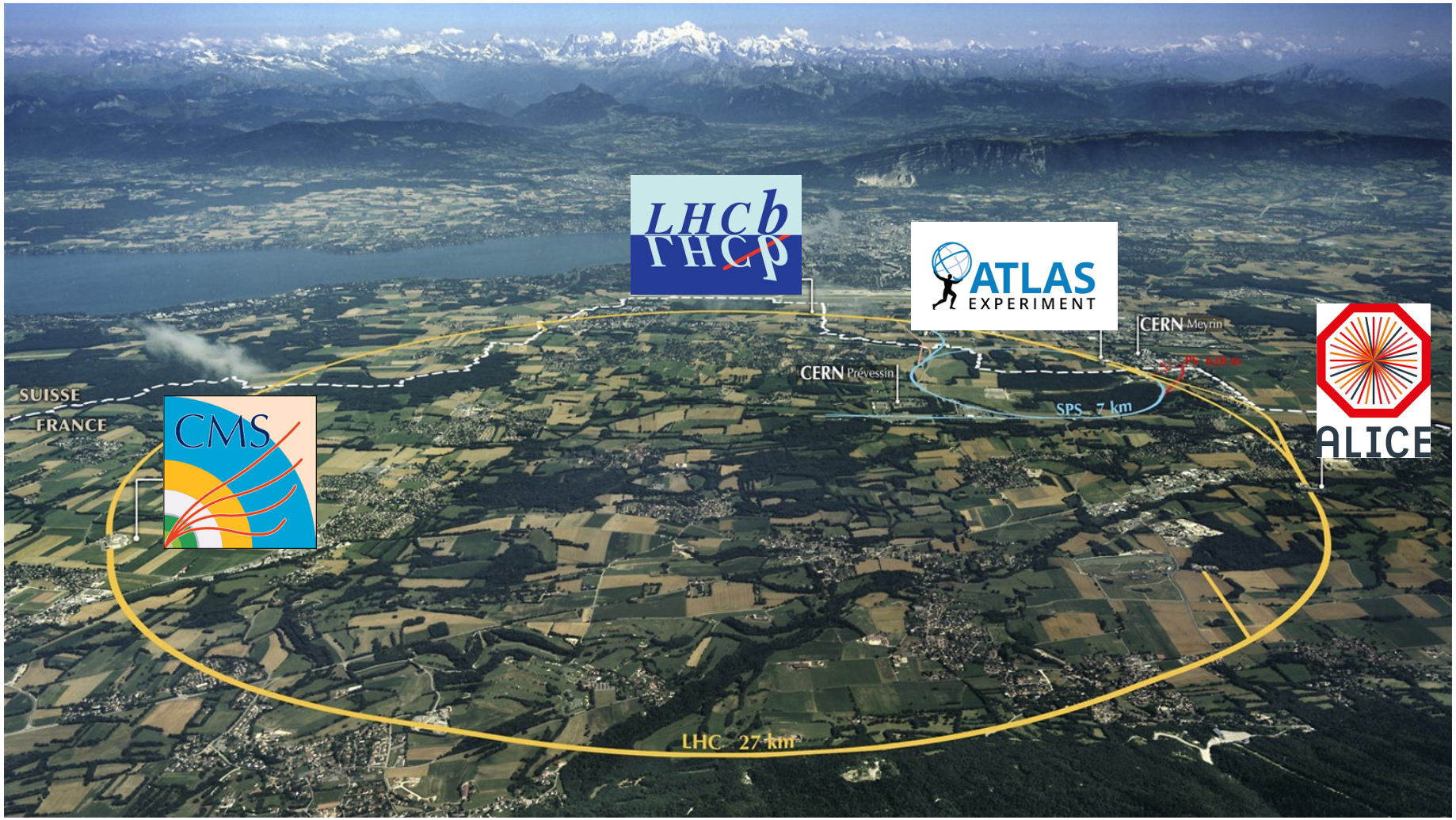
On behalf of the milliQan collaboration

DPF-Pheno 2024

May 13, 2024

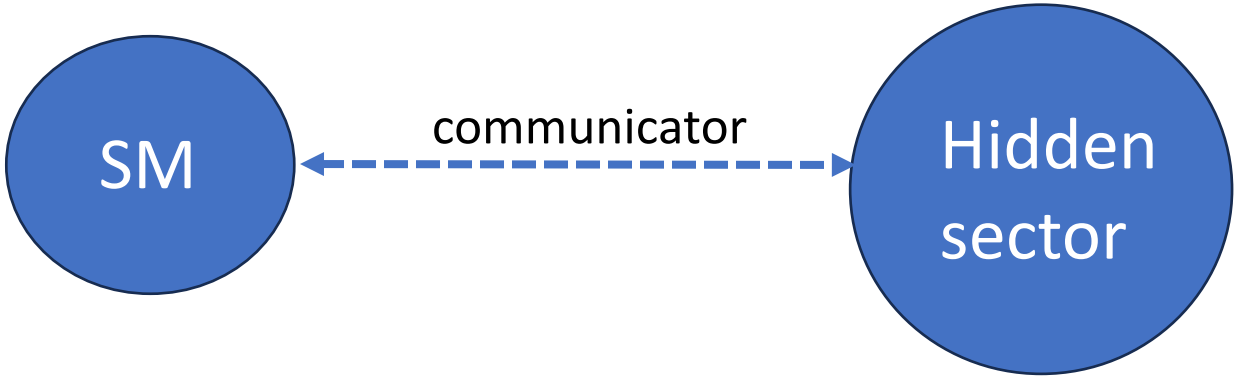
Large Hadron Collider (LHC)

- No sign of new physics seen at the LHC (yet)
- Where could it be hiding?



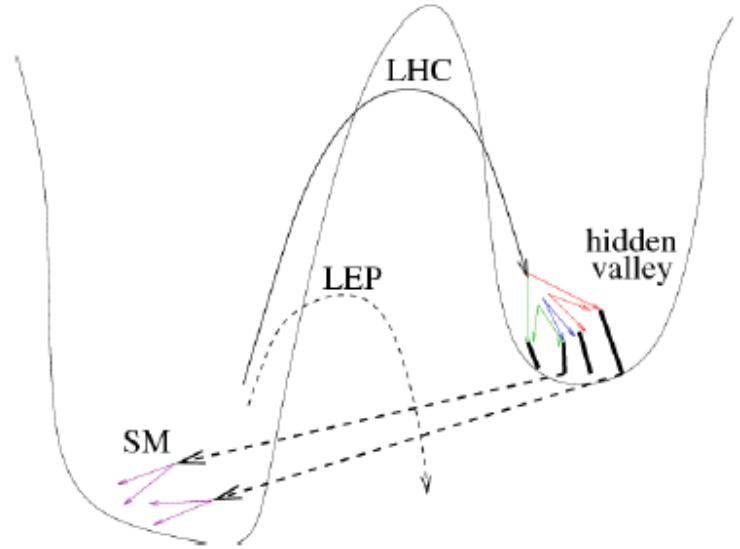
Hidden sector

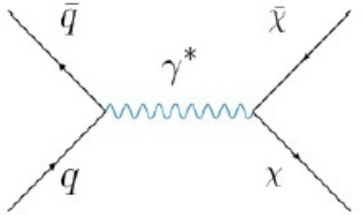
- Basic structure of hidden sector models:



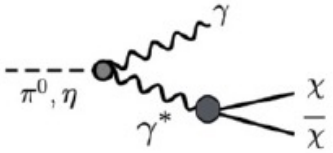
- Kinetic mixing between dark photon and SM photon provides portal to hidden sector
- The new particle(s) under ”dark EM” get small SM charge $Q = \epsilon e$ -> millicharged particles (MCP)

Zurek, Strassler

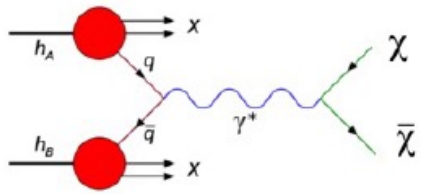




Meson decays

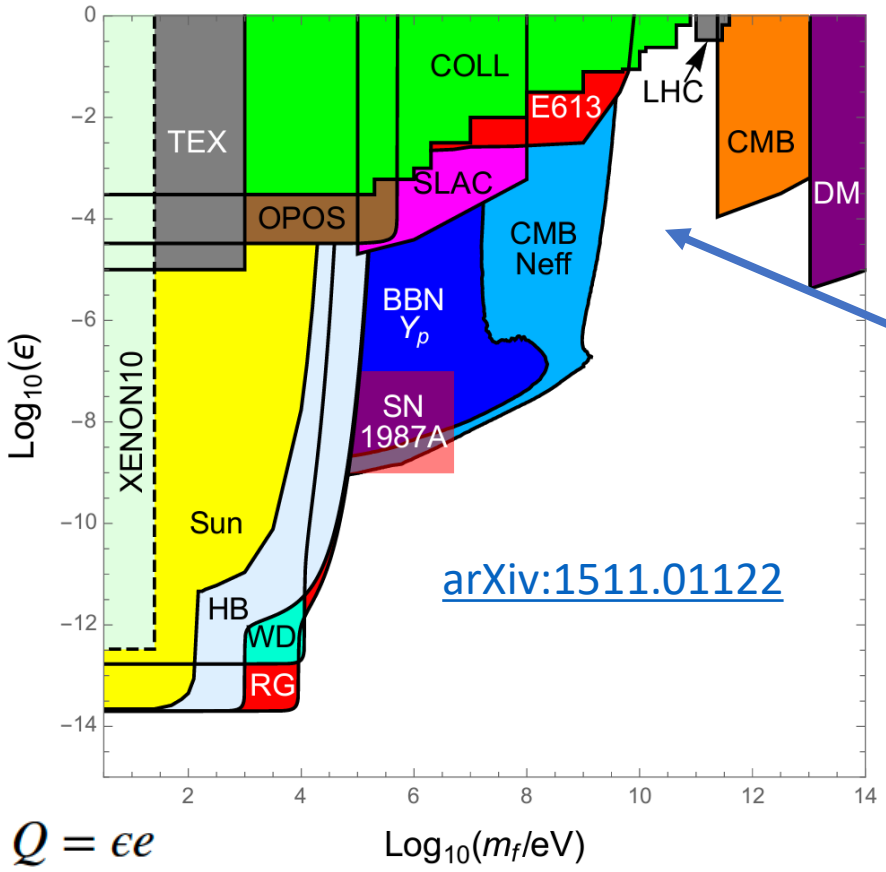


Dalitz decays



Drell-Yan

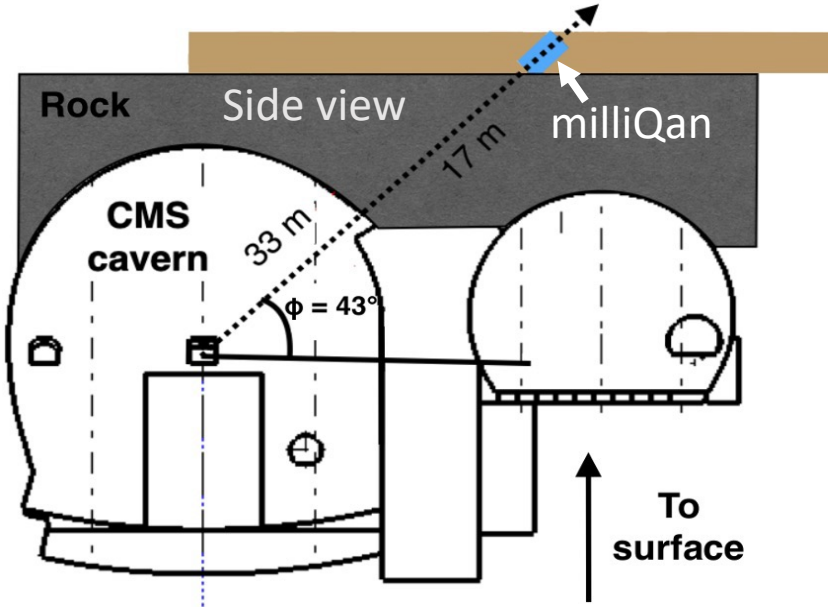
Searching for MCPs at the LHC

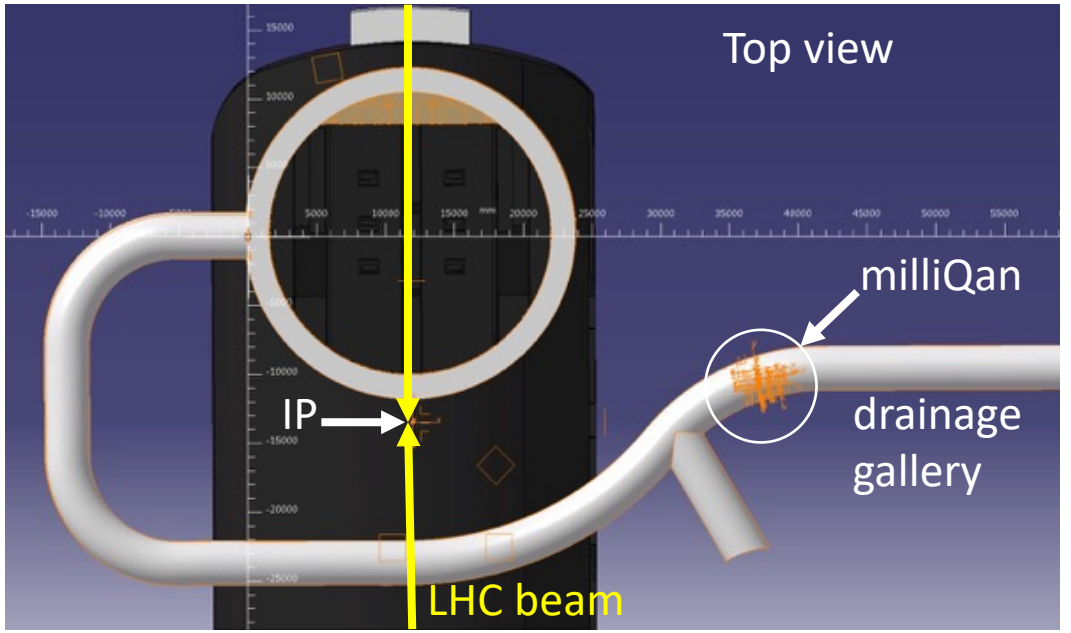


- General purpose LHC detectors not great for this since dE/dx ~ Q^2
- Gap in coverage for ~ GeV, low-charged particles
- Target with milliQan
- Basic requirements:
  - Suppress other collision products
  - Detect very small ionization from MCPs
  - Distinguish between shower/cosmic backgrounds and things coming from IP

Searching for MCPs at the LHC

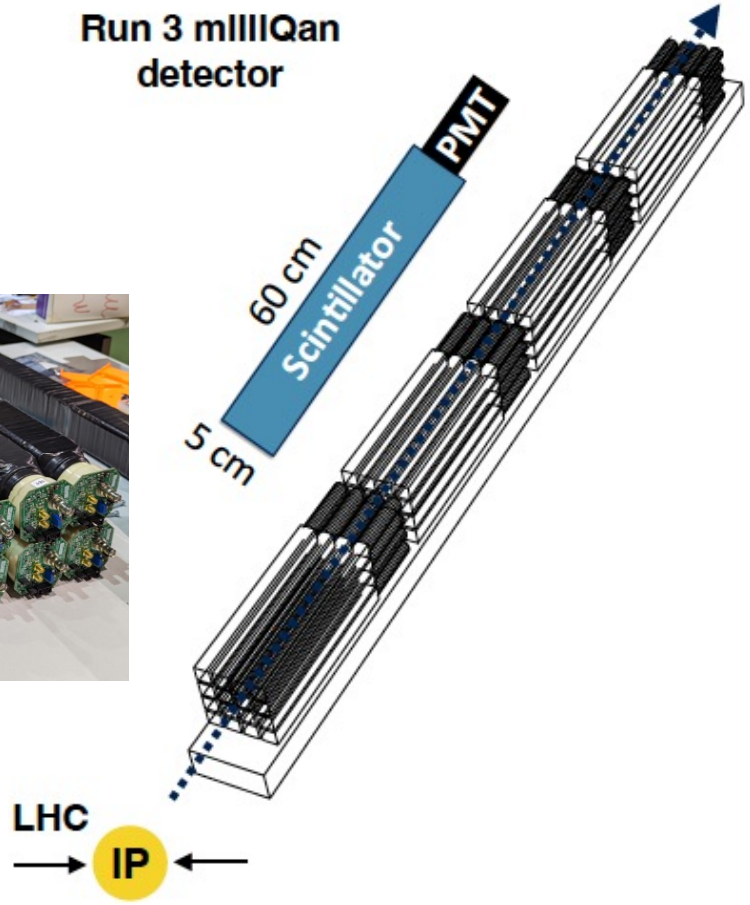
- Installed at CMS site in existing ‘drainage gallery’
  - 33 m from CMS IP
  - 17 m of rock suppress beam particles
  - Angled toward CMS interaction point





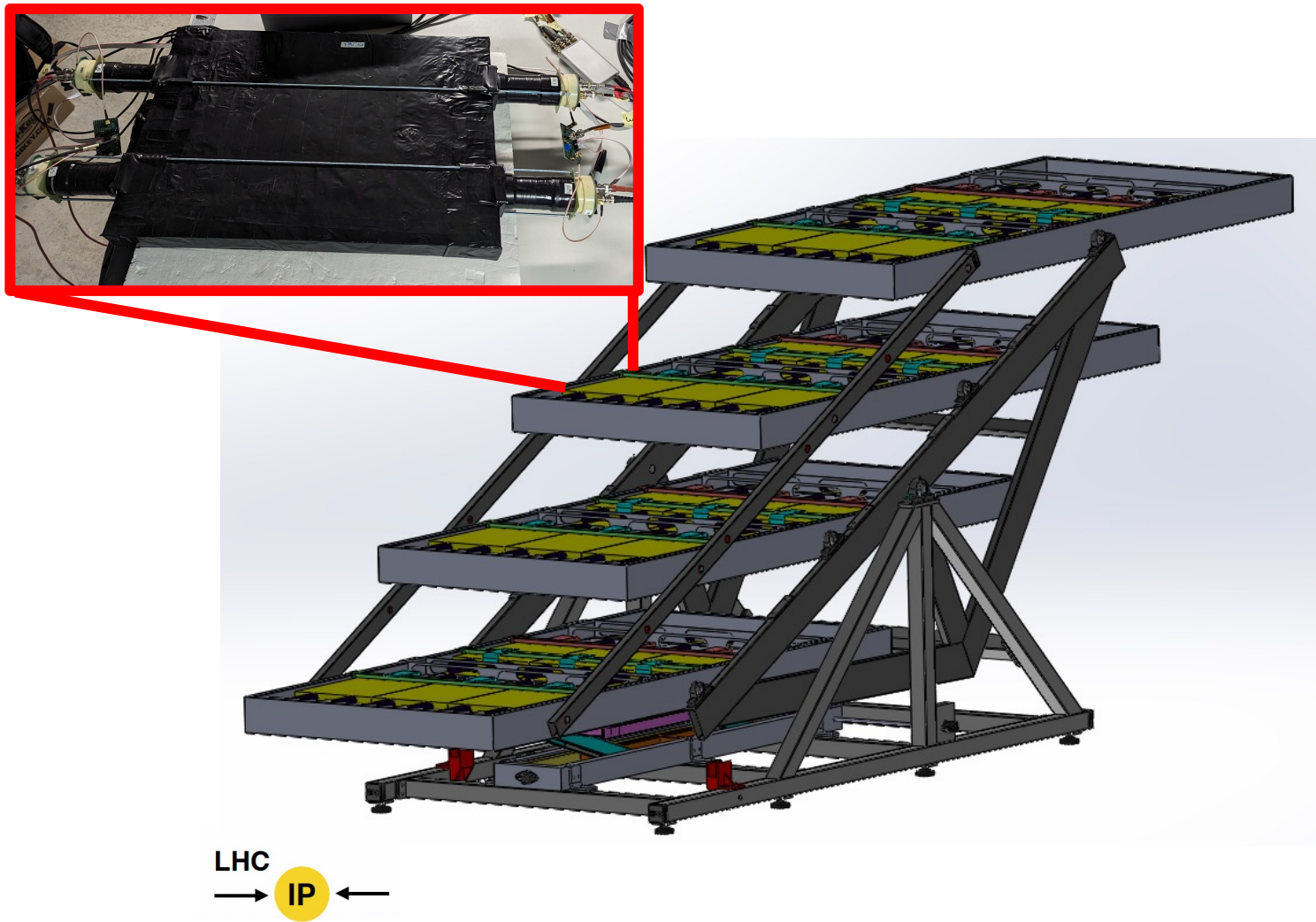
milliQan Run 3 bar detector

- Basic design:
  - Array of 64 60 x 5 x 5 cm scintillator bars + PMTs arranged in 4 layers, pointed at IP used to detect small ionization from MCPs
- Signal:
  - Expect an MCP produced at IP to produce a few scintillation photons detected in multiple layers
- Backgrounds:
  - Cosmic background:
    - Activates multiple bars within same layer
    - Can reject by multilayer signal requirement
  - Dark counts:
    - Small signals in individual bars
    - Can reject by multilayer signal requirement
  - Beam muons:
    - Large number of scintillation photons detected in multiple layers
    - Can identify using signal strength



milliQan slab detector

- Bar detector sensitivity above ~ 1.4 GeV limited by angular acceptance
- Second detector using four layers of twelve 40 x 60 x 5 cm slabs + PMTs
- Surface area equivalent to ~ **1100** 5 x 5 cm bars
- Significantly improves acceptance for Q > ~0.01e

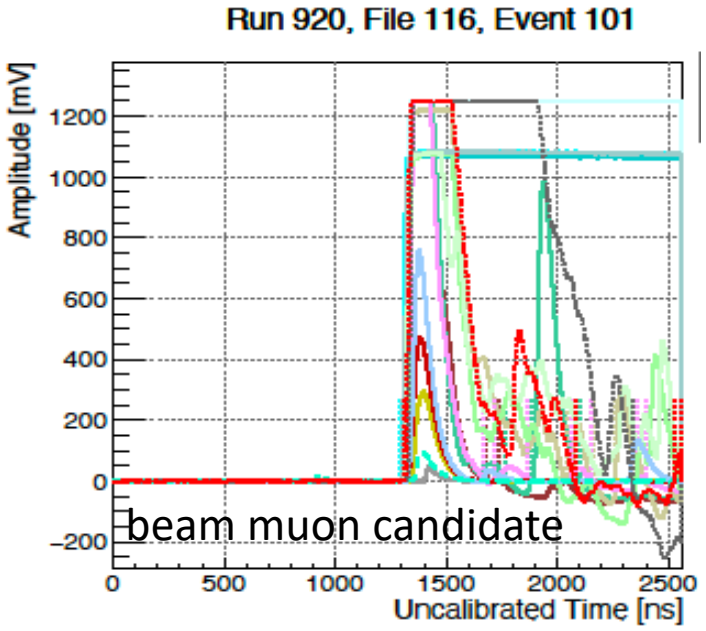


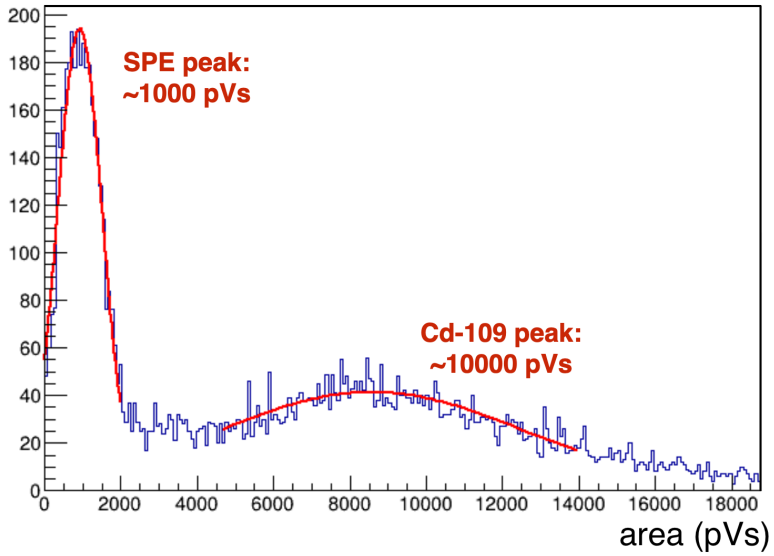
Slab detector status

- All slabs tested and ready for installation
- First layer and DAQ system installed
- Installation of remaining layers happening now!
- Plan to be fully installed and collecting physics data by end of June!

Bar detector status

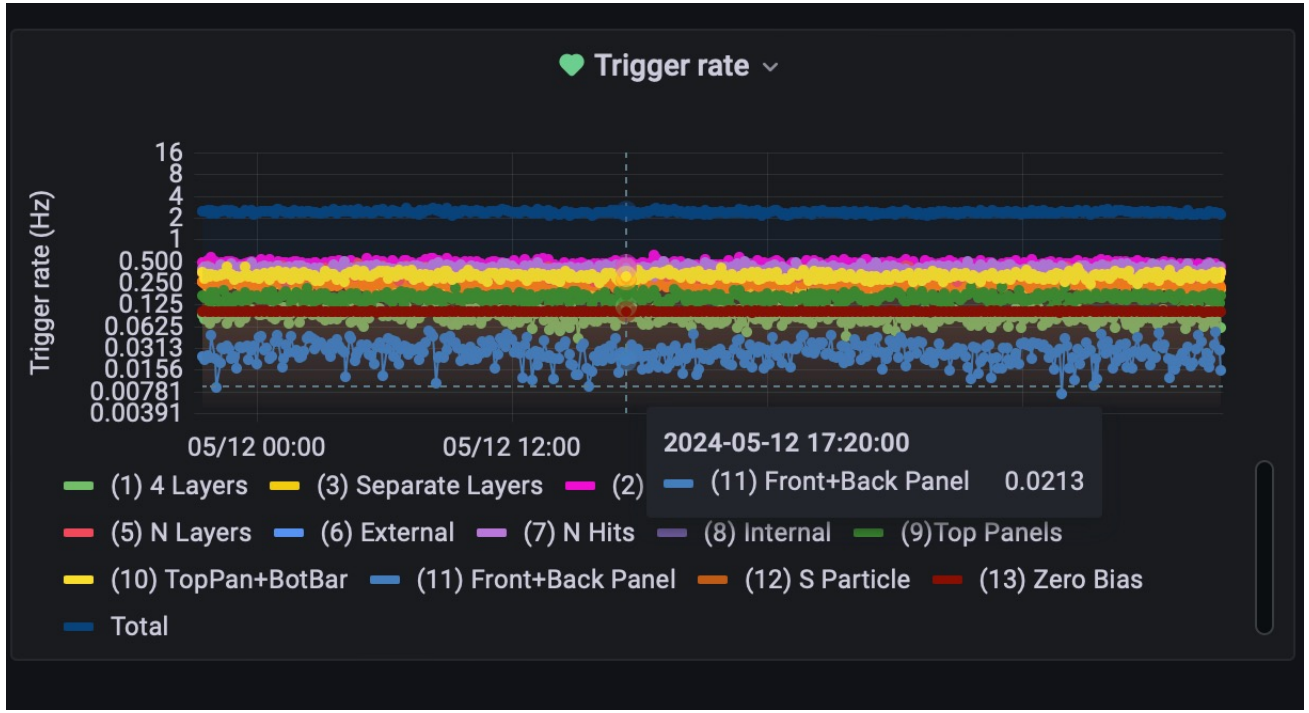
- Construction and source calibration completed last year
- Studies using beam and cosmic muon backgrounds ongoing

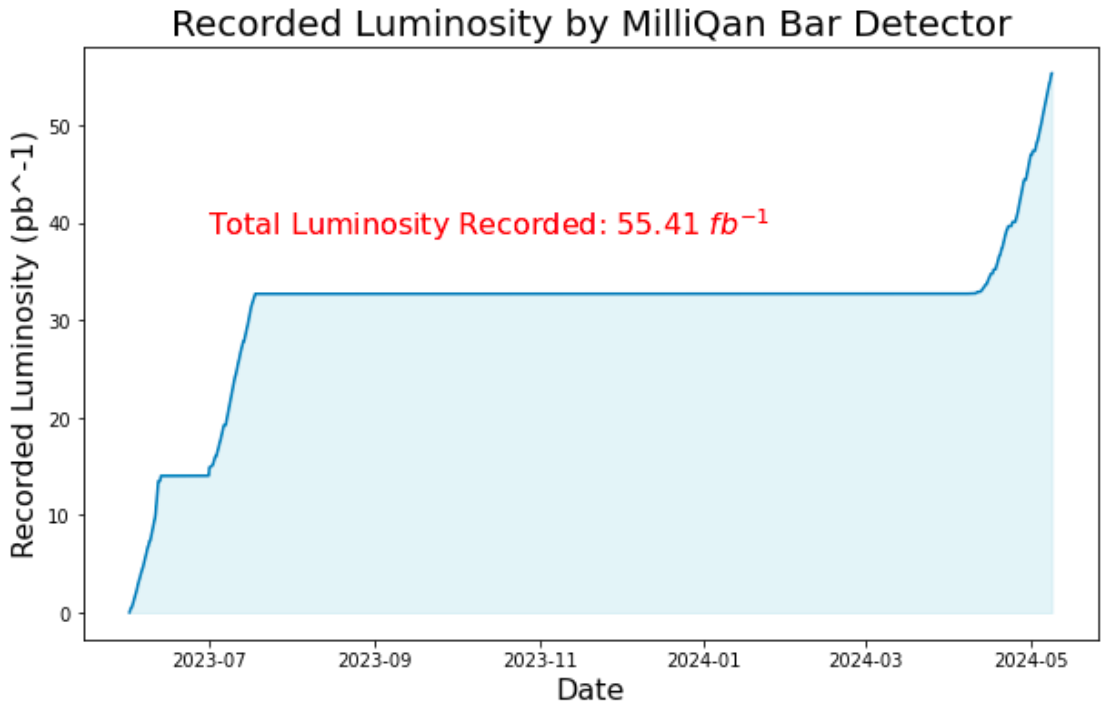




Bar detector status

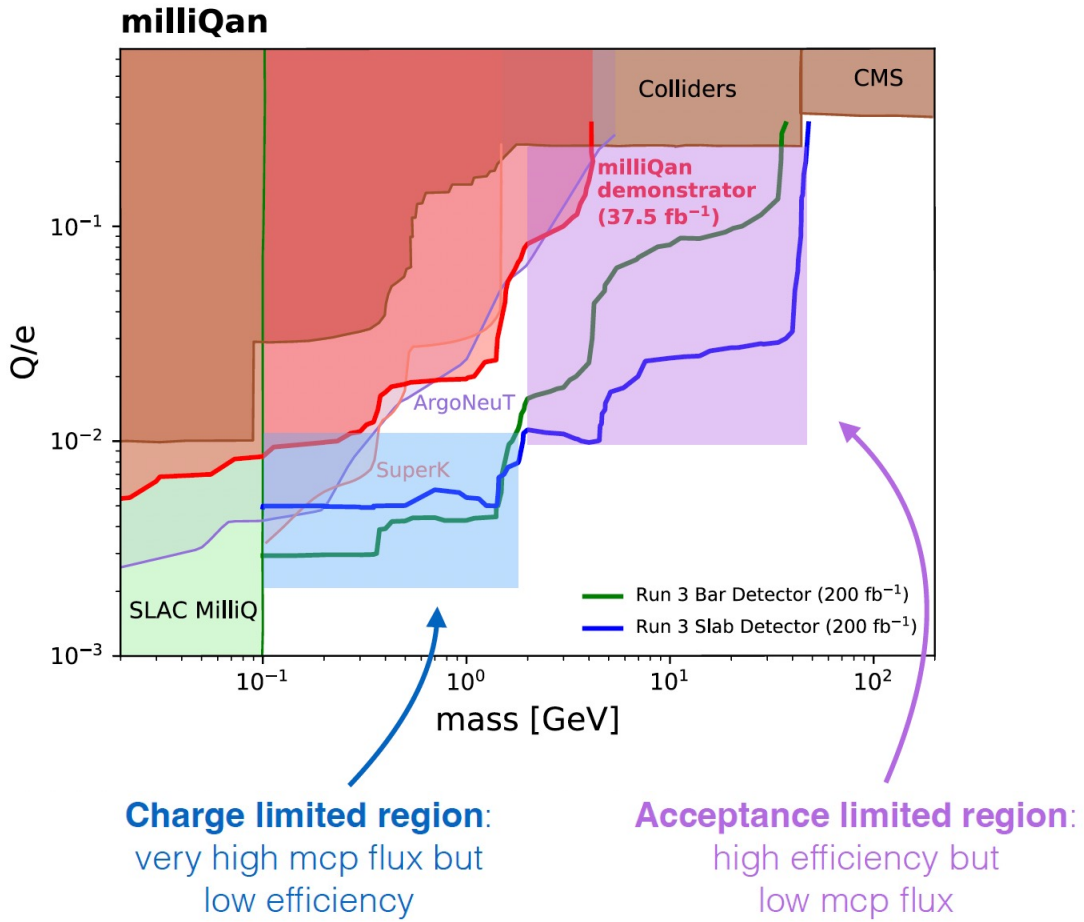
- Currently taking physics data since June 2023!
- Web based monitoring and remote to help with remote shifting
- Collected ~55 fb^{-1} of collision data so far from LHC Run 3 and still running!





Expected sensitivity

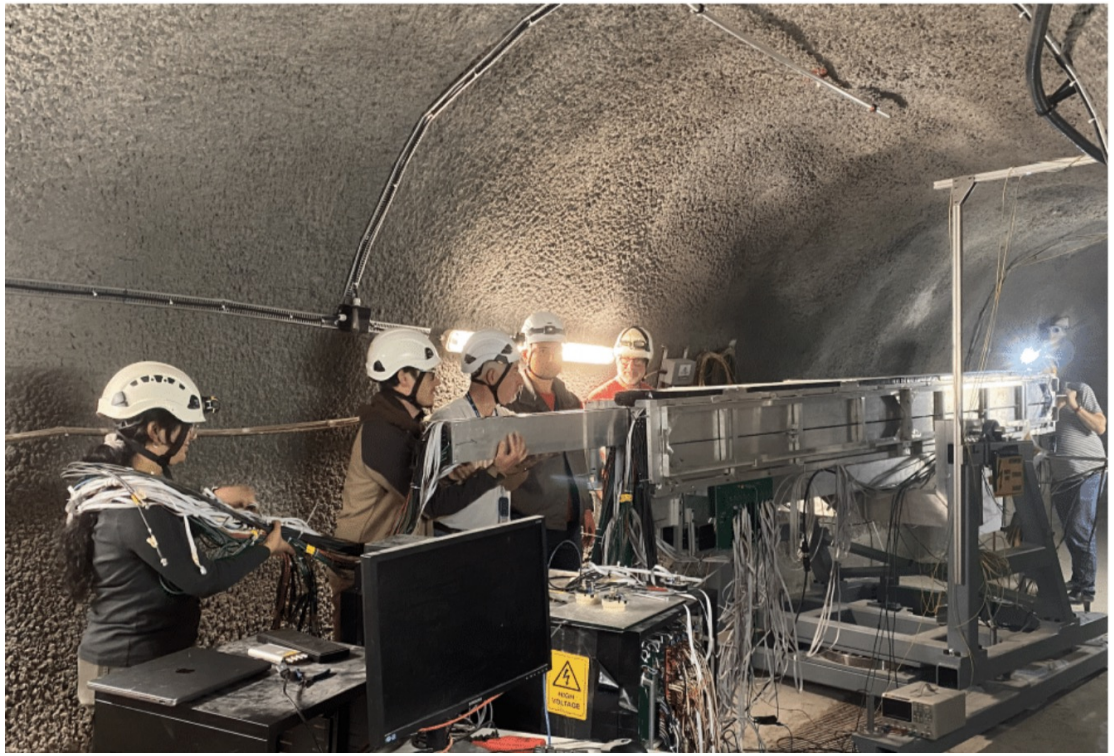
- Bar detector -> targets charge limited region
- Slab detector -> targets acceptance limited region
- Expected combined sensitivity:
  - Charges ~0.001-0.1 e
  - Masses ~0.1-45 GeV
- Projections published in:
  - [PhysRevD.104.032002]



Summary

- The Run 3 milliQan bar detector running and collecting physics data with first analysis results expected later this year
- Slab detector installation in progress and expect physics data-taking later this year
- Both provide excellent sensitivity to millicharged particles

Collaboration meeting (Dec 2023)



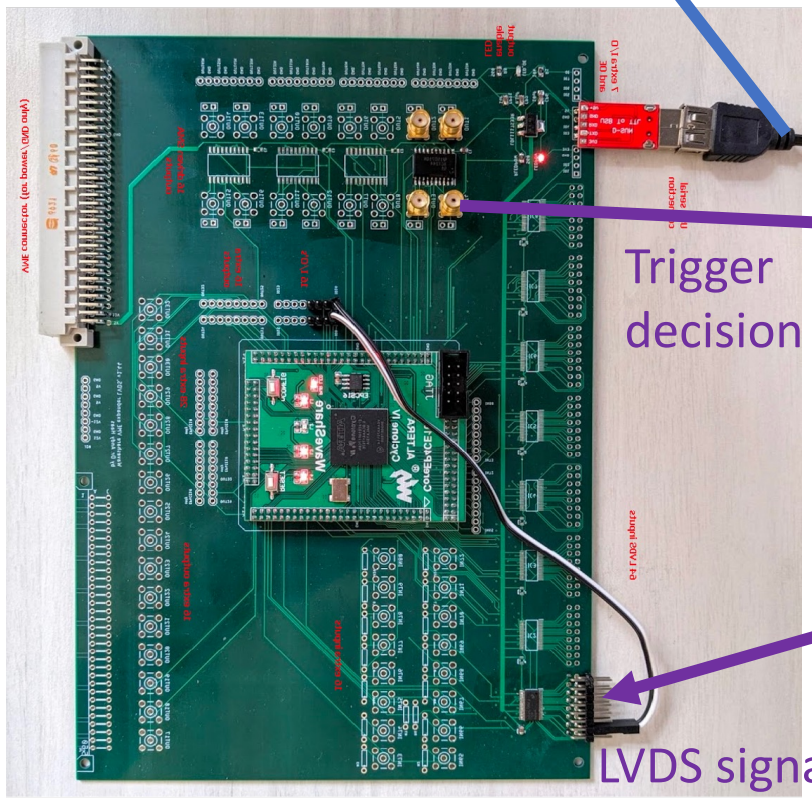
The milliQan collaboration

Backup

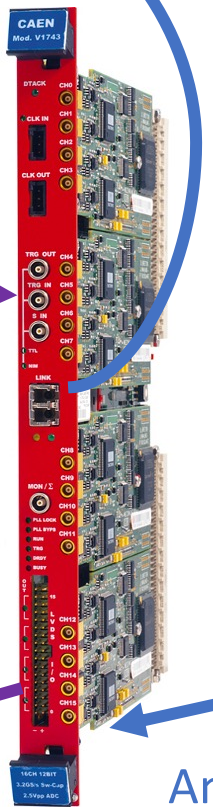
milliQan DAQ

Digitized pulses

Trigger info



Trigger decision



LVDS signals for trigger decision

Amplified PMT pulses

=

+

- High SPE efficiency -> PMT output amplified with customized base (~100 ns pulse length)
- Reconstruct complete pulse information -> 16 channel CAEN V1743 digitizer with ~GHz sampling frequency over ~μs window
- Flexible trigger decisions -> Customized trigger board equipped with Altera Cyclone IV FPGA

Production at LHC