

Search for millicharged particles with the milliQan experiment using Run 3 data

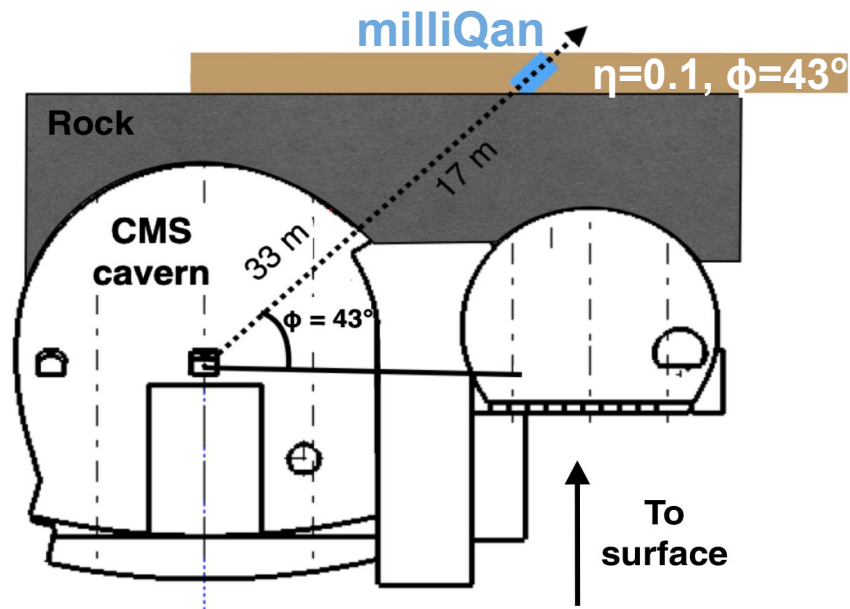
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US LUA Annual Meeting
17 December 2024



The what? (and where?)

- MilliQan experiment searches for millicharged particles at the LHC
- It is housed in an drainage gallery above the CMS experiment, shielded by most of the beam backgrounds by 17m of rock
- Muon flux from cosmics is 100 times smaller than the surface





The why?

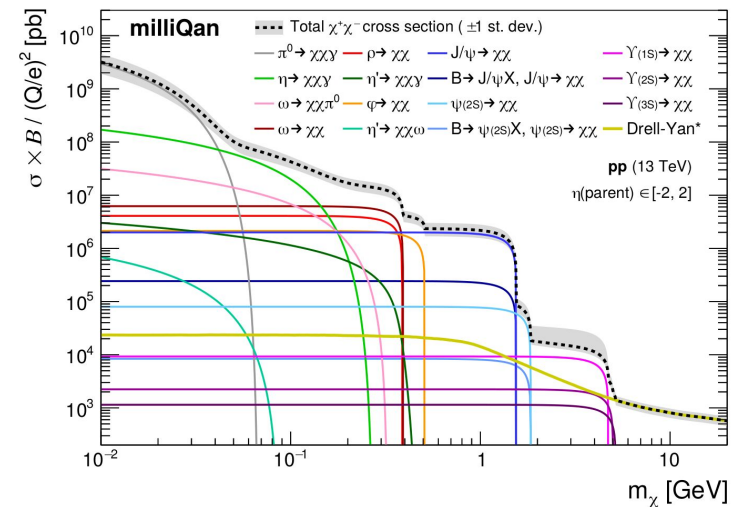
- Charge quantization in the Standard Model is not well understood
- LHC can provide access to hidden sector particles
- Hidden sector provides rich phenomenology including stable dark matter candidates

Consider dark sector containing U(1) abelian gauge field, A' , interacting with SM hypercharge B through kinetic mixing

$$\mathcal{L} = \mathcal{L}_{SM} - \frac{1}{4} A'_{\mu\nu} A'^{\mu\nu} + i\bar{\psi} (\not{\partial} + ie'A' - i\kappa e'\not{B} + iM_{mCP}) \psi$$

Results in a Dirac fermion with mass M_{mCP} and electric charge $ke'\cos\theta_W$

small \Rightarrow milli-charged particles (mCPs)

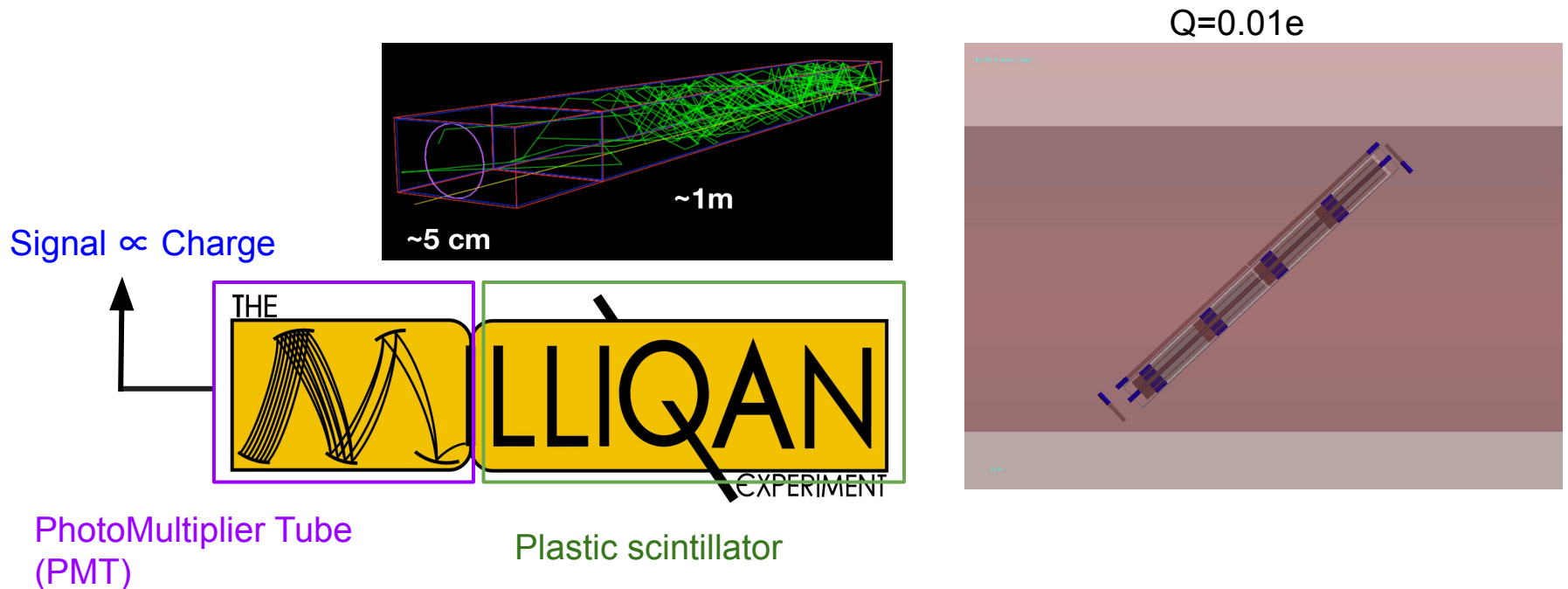


Any process that produces electrons at the LHC can produce mCPs!



The how?

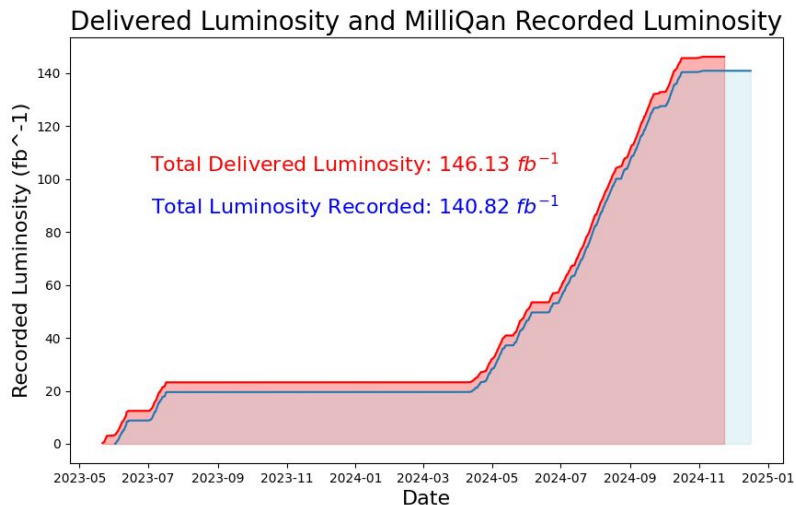
- Charged particle passing through the plastic scintillator ($5 \times 5 \times 60 \text{ cm}^3$) produces light which is amplified and collected by a PhotoMultiplier Tube (PMT)
- Extremely sensitive detector capable of detecting single photo electrons deposited by mCPs and also saturating signal from muons





The when?

- Four layers of 4x4 scintillators to provide clean signature of mCPs going in a straight line
 - Near-zero background coming from PMT dark rate, muons and cosmic showers
- Side, front and back panels veto backgrounds
- Constructed in 2023, has collected 141 fb⁻¹ data during Run 3

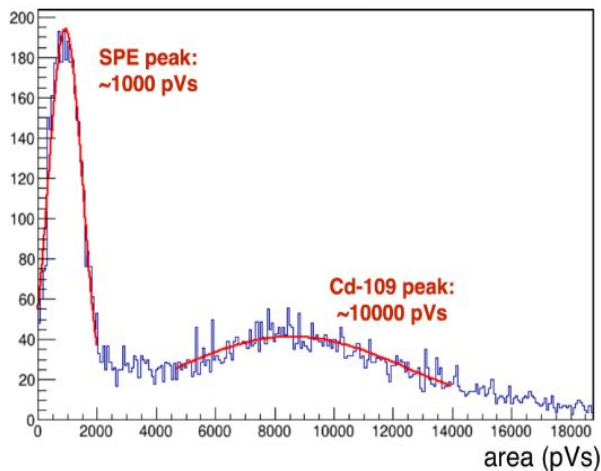




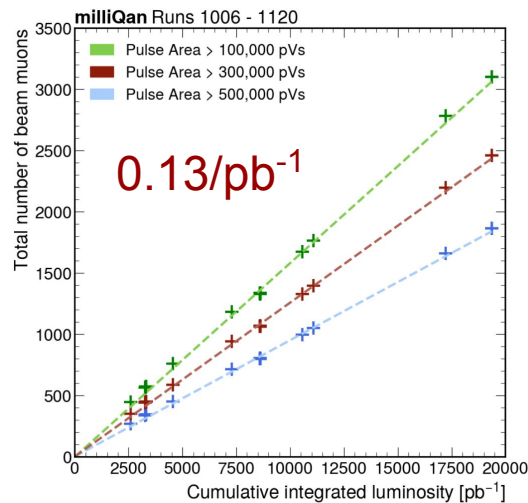
Detector performance

- Signal would be single photo electrons in a straight line with close timing ($\Delta t < 15\text{ns}$)
- **Beam muons** provide an excellent handle to calibrate detector response, alignment and validate simulation
- **Cosmic muons** set used to perform timing calibrations

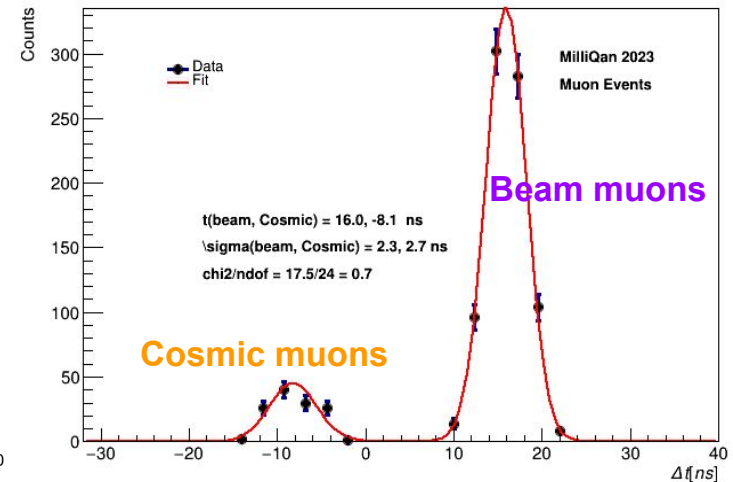
Scintillator and PMTs response calibrated using Cd109 source



Beam muon flux measured in data agrees well with the simulation



Timing calibration using beam muons and downward going cosms

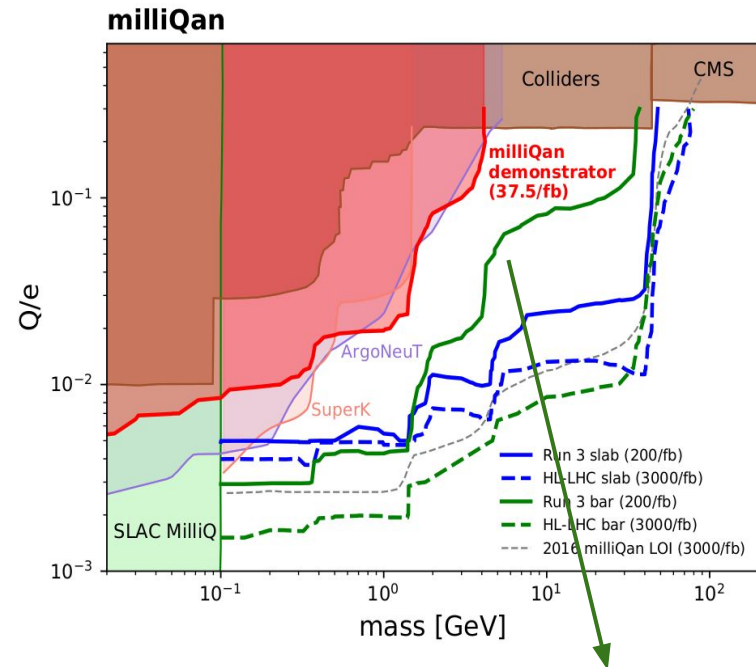




The search

- Signal signature:
 - Hits in four layers in a row
 - Timing of hits within 15ns
- Using beam-off data to estimate the dark rate and other backgrounds
 - Near-zero backgrounds seen in Signal region
- Currently finalizing background estimation and systematics

Confident to place world leading limits on m_{CP} mass and charge using Run 3 data

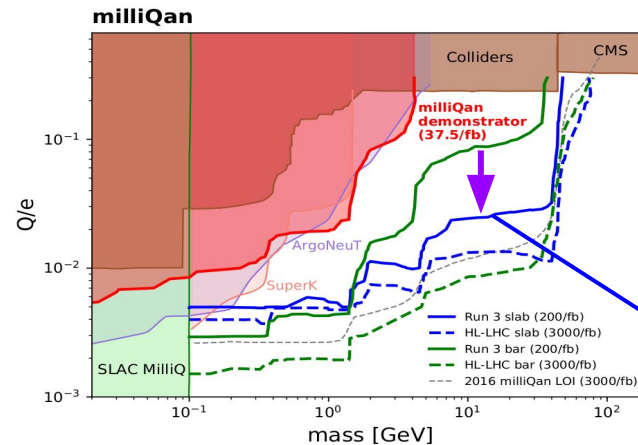


Run 3 bar detector
Great sensitivity at low mass and charge



Slab detector

- Four layers of 3x4 array of 40x60x5 cm³ **slabs**
- **Improved sensitivity** for mCPs with masses above 1.4 GeV due to increased acceptance
- Recently finished construction - Detector commissioning ongoing!
- With its higher acceptance, slab detector is sensitive to other signals like [sexaquark](#) and [fractionally charged particles from atmosphere](#) (through the earth!)

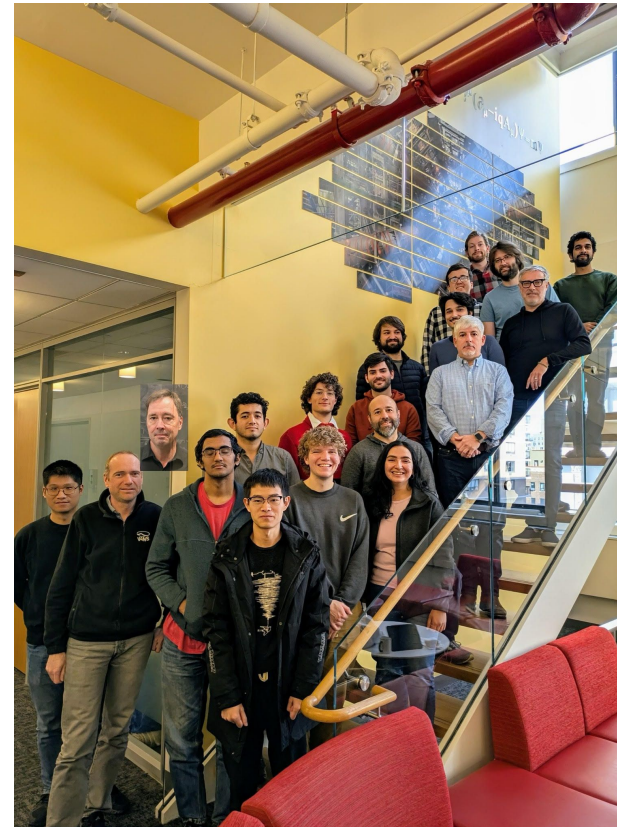


Run 3 slab detector
Improved sensitivity at high mass



Summary

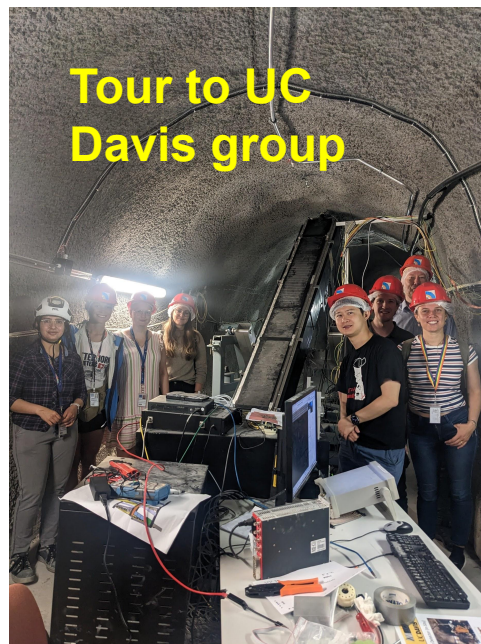
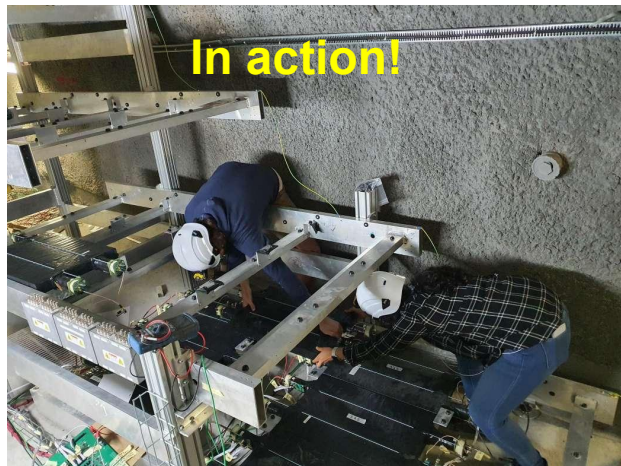
- *MilliQan provides a highly sensitive model-independent probe for mCPs*
- Run 3 physics program is robust and diverse with sensitivity to other long-lived particles
 - First results targeting Moriond 2025!
- True demonstration of the power of low-budget AGILE experiment on the physics reach!
 - Aligned with [P5](#) interests
 - Lot of opportunities for early-career scientists and students to contribute
- Sister experiments like [FORMOSA](#) and [SubMET](#) use similar technology and provide complementary sensitivity



7th milliQan workshop, NYU, December, 2024



Bonus pictures!



Message me if you are interested in the milliQan tour!