The MilliQan experiment

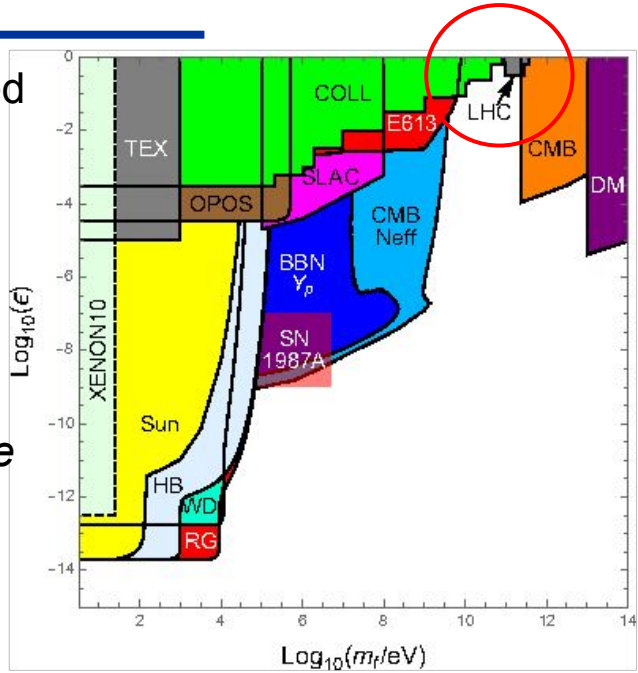
Presentation and status

Steven Lowette and David Vannerom, November 15th, 2023

The physics

Quantization of the electromagnetic charge remains unexplained

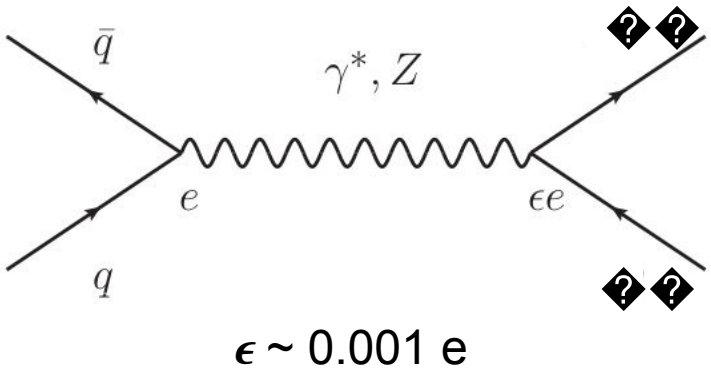
Search for low-/milli-charged particles (mCPs) with charge ϵ x e and mass m_f



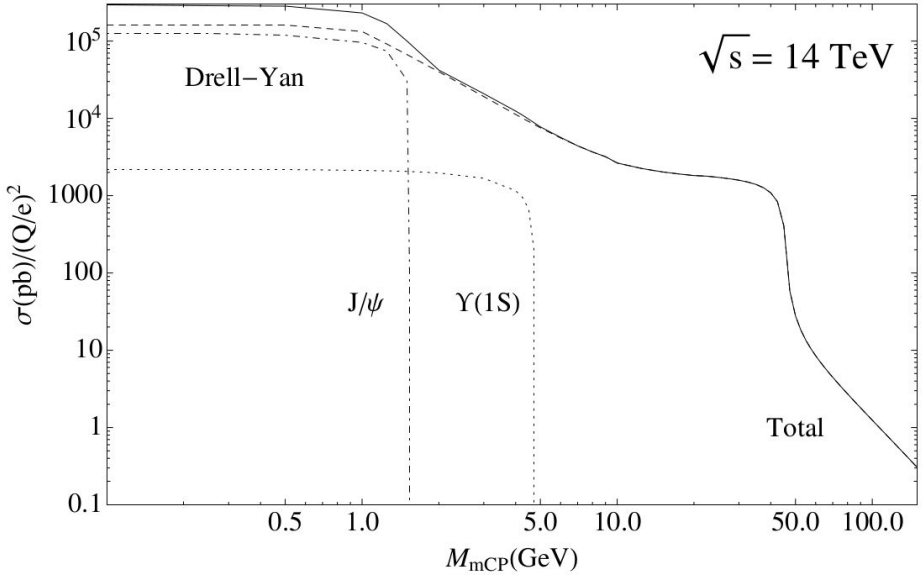
The LHC is a great place to explore the high mass region

A generic model

Drell-Yan production of a new fermion χ effectively charged under Standard Model hypercharge:



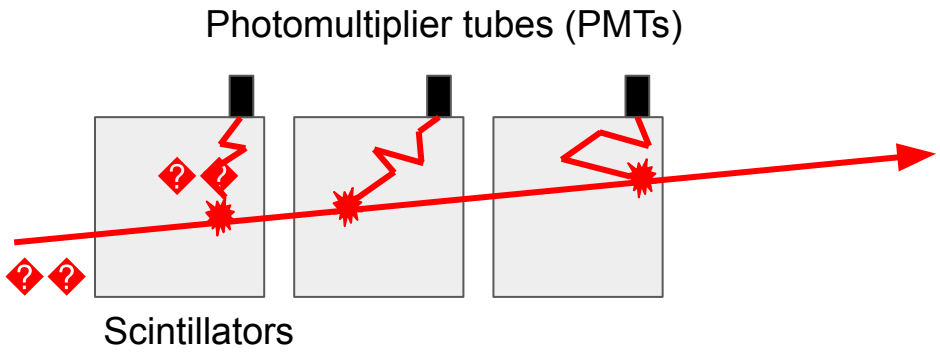
ϵ ~ 0.001 e



Any process with two leptons in the final state can partake in mCPs production.

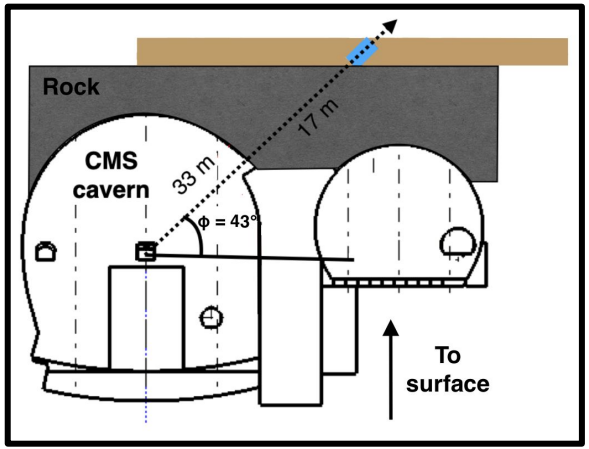
The detection principle

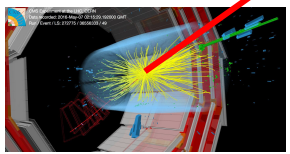
Searching for coincident **low-photon-count** events in a series of scintillators:

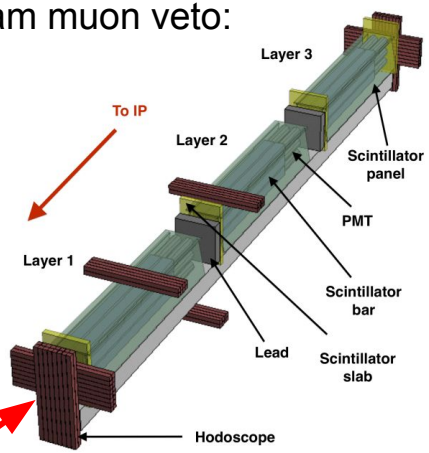


LHC Run-2 detector (2018)

3 x 2 bars (cross-section) x 3 layers with panels and slabs for cosmic and beam muon veto:



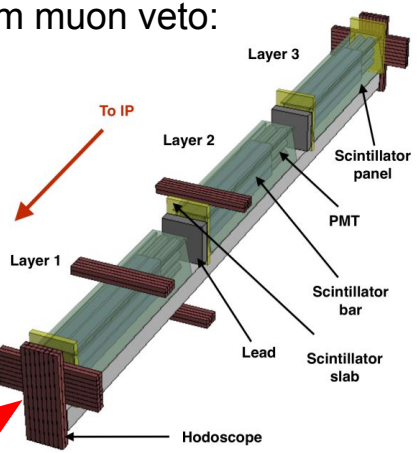


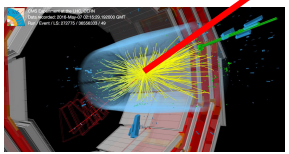


LHC Run-2 detector (2018)

3 x 2 bars (cross-section) x 3 layers with panels and slabs for cosmic and beam muon veto:

	Selection	Data Beam-on $t = 1106$ h	Data Beam-off $t = 1042$ h	Signal $m_\chi = 0.05$ GeV $Q/e = 0.007$	Signal $m_\chi = 1.0$ GeV $Q/e = 0.02$	Signal $m_\chi = 3.0$ GeV $Q/e = 0.1$
Common	≥ 1 hit per layer	2 003 170	1 939 900	136.4	34.2	5.7
Selections	Exactly 1 hit per layer	714 991	698 349	123.1	31.0	5.0
	Panel veto	647 936	632 494	122.5	30.8	4.9
	First pulse is max	418 711	409 296	114.3	30.6	4.8
	Veto early pulses	301 979	295 040	113.9	30.6	4.8
	max n_{pe} / min $n_{\mathrm{pe}} < 10$	154 203	150 949	104.2	29.6	4.7
	$\Delta t_{\mathrm{max}} < 15$ ns	5 284	5 161	72.8	28.4	4.4
	Slab muon veto	5 224	5 153	72.8	28.4	4.4
	Straight path	350	361	68.4	28.1	4.2
	$\mathrm{N_{slab}} = 0$	332	339	64.8	16.9	0.0
	$\mathrm{N_{slab}} \geq 1$	18	22	3.6	11.2	4.2
SR 1	$\mathrm{N_{slab}} = 0$ & min $n_{\mathrm{pe}} \in [2, 20]$	129	131	47.4	0.4	0.0
SR 2	$\mathrm{N_{slab}} = 0$ & min $n_{\mathrm{pe}} > 20$	52	45	0.0	16.5	0.0
SR 3	$\mathrm{N_{slab}} = 1$ & min $n_{\mathrm{pe}} \in [5, 30]$	8	9	1.1	0.5	0.0
SR 4	$\mathrm{N_{slab}} = 1$ & min $n_{\mathrm{pe}} > 30$	4	4	0.0	8.7	0.0
SR 5	$\mathrm{N_{slab}} \geq 2$	1	1	0.0	2.0	4.2



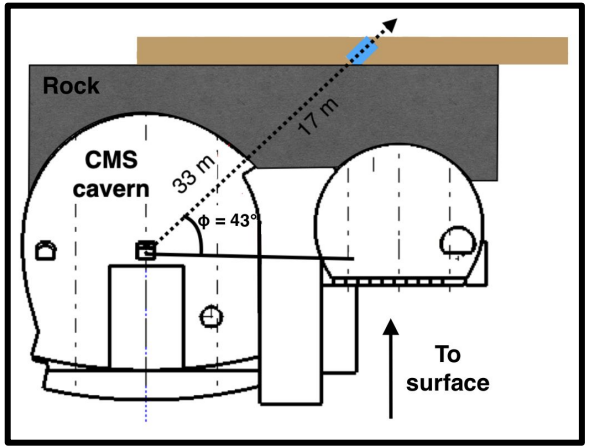


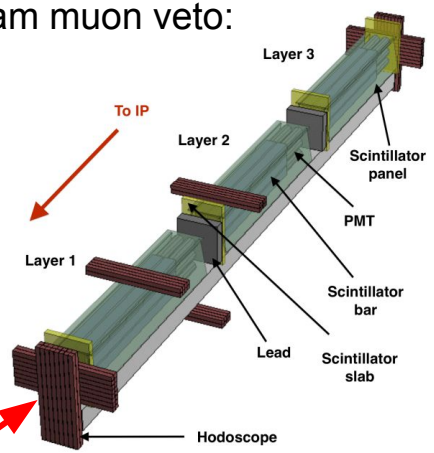
LHC Run-2 detector (2018)

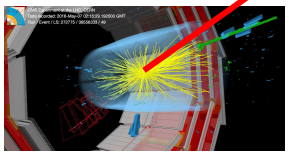
3 x 2 bars (cross-section) x 3 layers with panels and slabs for cosmic and beam muon veto:

3 papers:

- 1410.6816
- 2005.06518
- 2104.07151

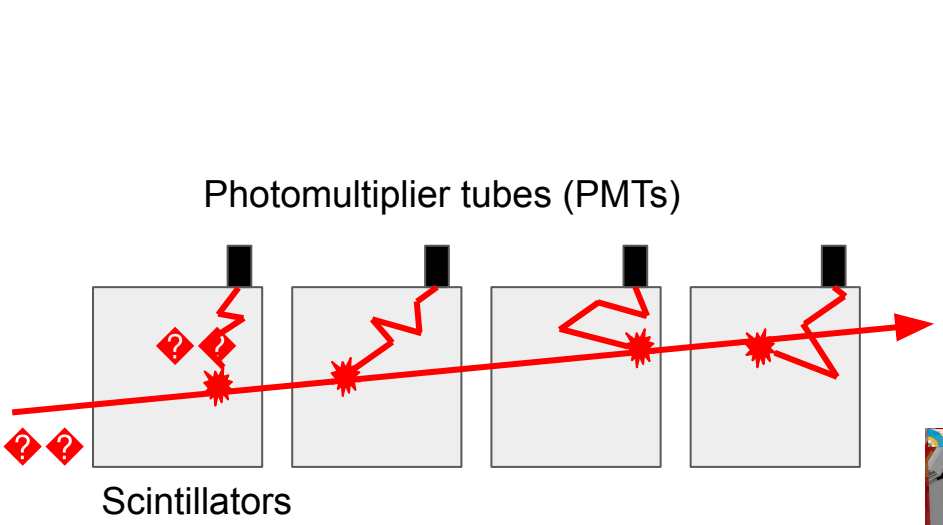


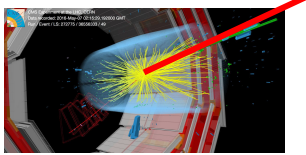


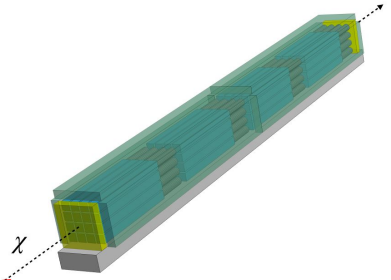


LHC Run-3 detector (2022-...)

4 x 4 bars (cross-section) x 4 layers with panels and slabs for cosmic and beam muon veto



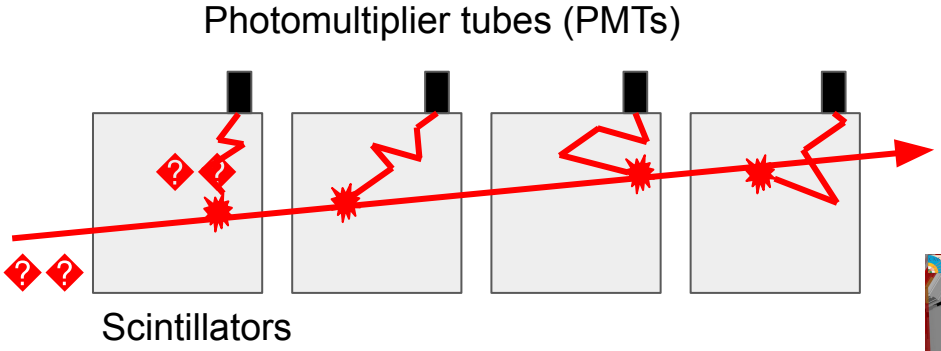


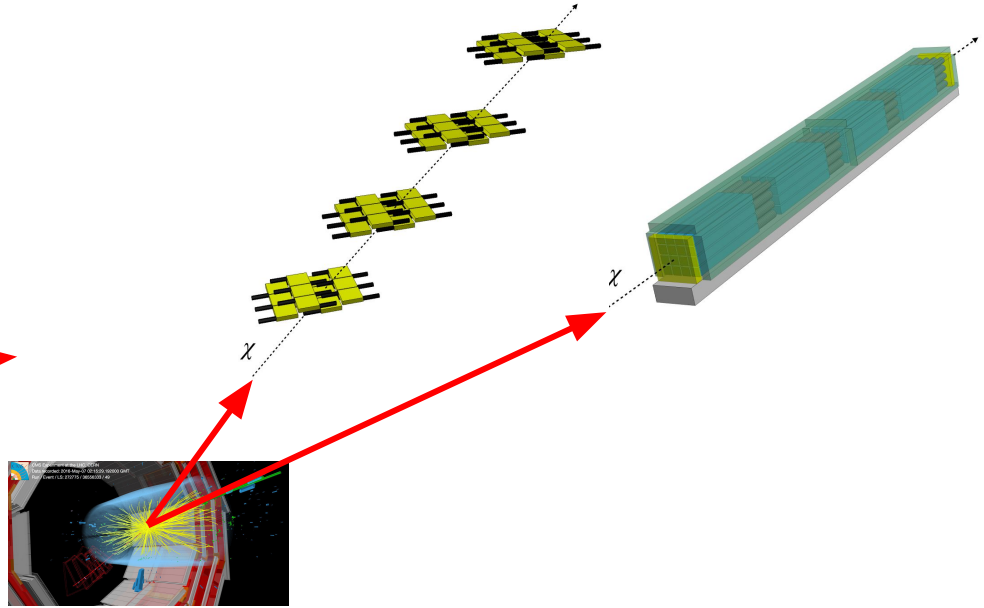


LHC Run-3 detector (2022-...)

4 x 4 bars (cross-section) x 4 layers with panels and slabs for cosmic and beam muon veto

+ **Slab detector!**

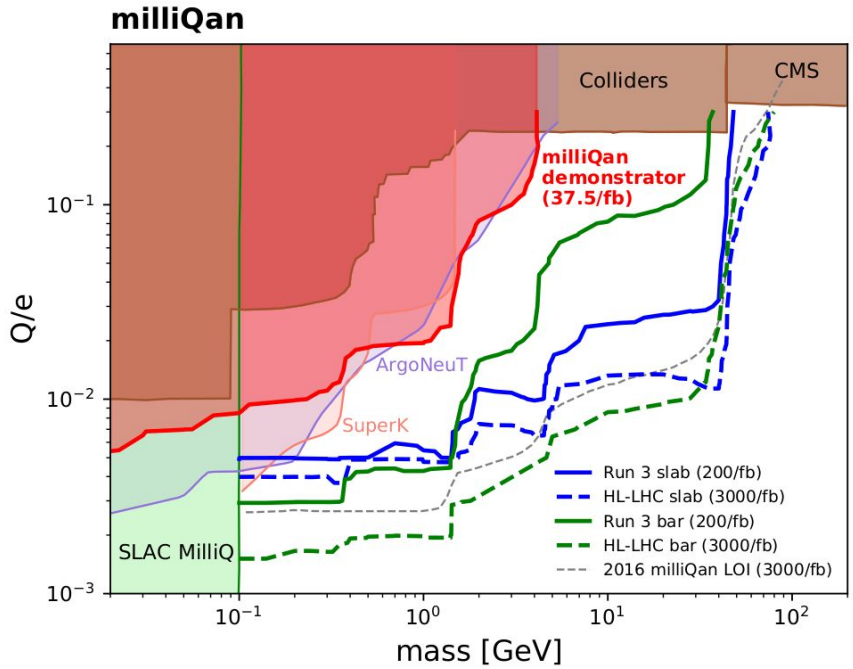




Current status

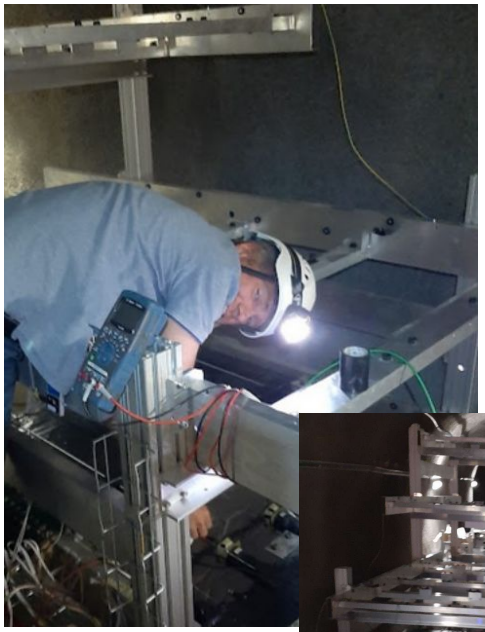
Run-2 detector demonstrated how such a “simple” design can allow for exploration of mCP existence:

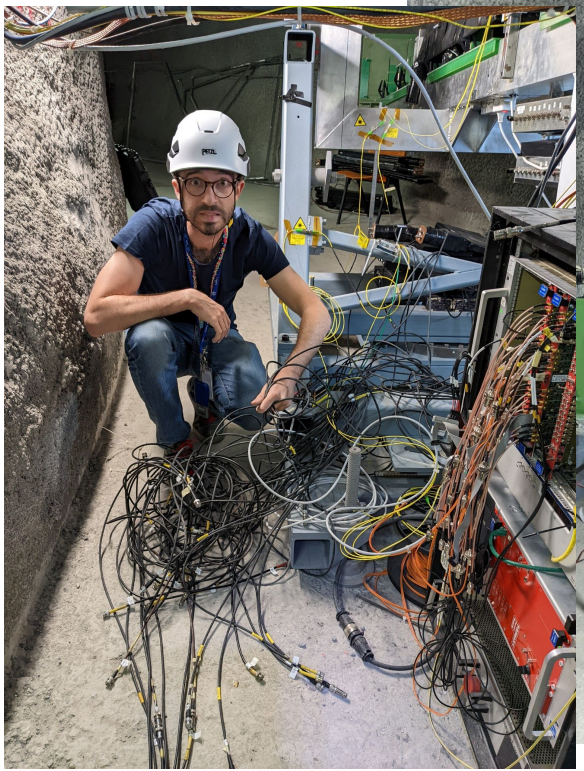
Run-3 design expands and improves on it.



IIHE @ MilliQan

Run-3 detector assembly and commissioning





IIHE @ MilliQan

We are involved in:

- Run-3 detector assembly and commissioning
- Data analysis:
  - Run-3 nominal search for mCPs
  - Explore mCP production in meson decay from cosmic ray showers (upgoing mCPs in MilliQan). Submitted a project with ULB (Juanan).

Stay tuned!