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Update on the status of the **milliQan Experiment**



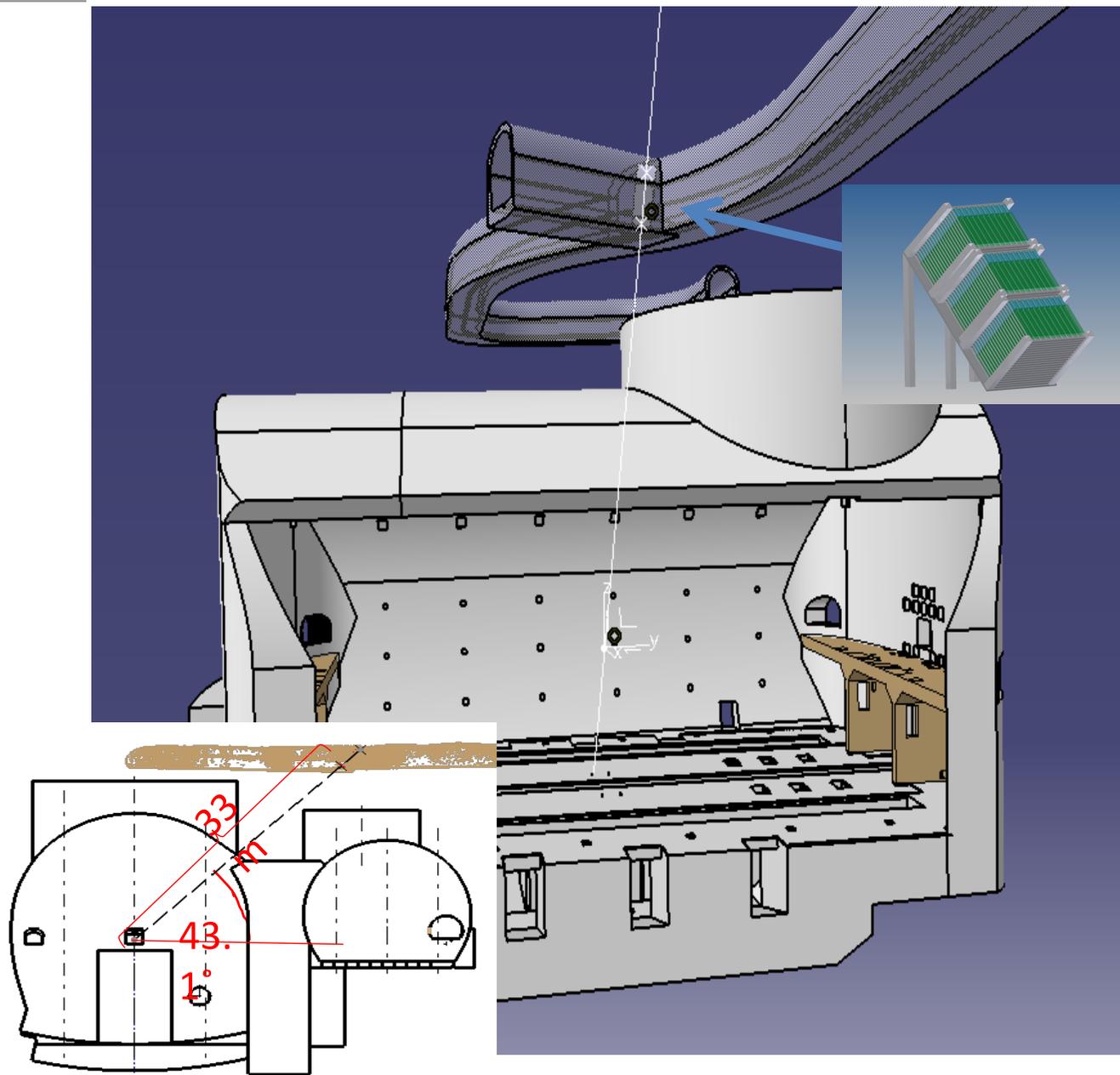
Long Lived Particle Workshop (CERN)
May 18, 2018

Christopher S. Hill
The Ohio State University
(milliQan co-spokesperson)



1 slide intro/reminder of milliQan experiment

- Add a detector sensitive to hidden sectors via milli-charged particles produced in CMS collisions
 - *With Q down to $\sim 10^{-3}e$, dE/dx is 10^{-6} MIP \rightarrow need long active area to see signal, $\mathcal{O}(1)$ PE.*
- Install ~ 1 m x 1 m x 3 m scintillator array, pointing back to IP, in well shielded area of LHC Point 5
 - *PX56 observation and drainage “gallery” (aka tunnel)*
 - *With triple coincidence, random background is controlled*



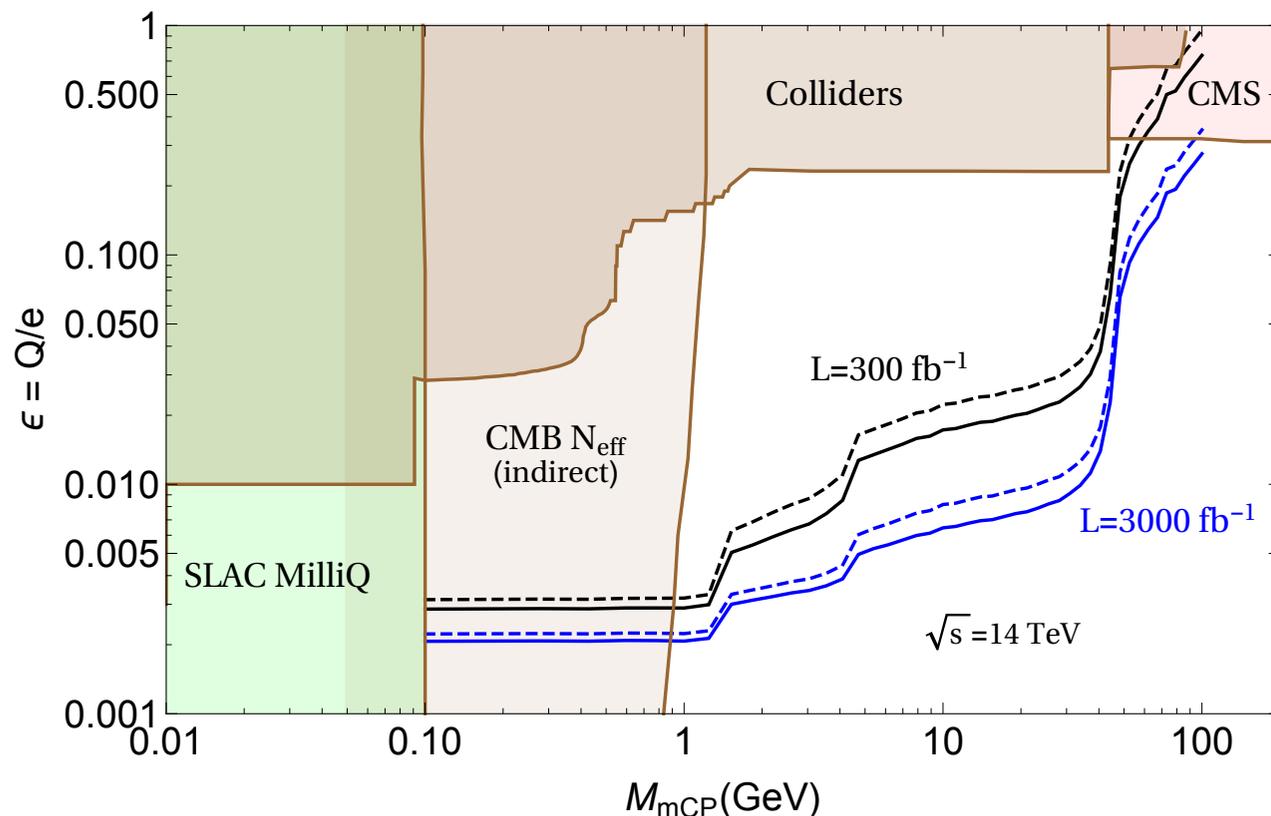


Expected Sensitivity of milliQan

- milliQan will **greatly extend the parameter space explored for particles with small charge and masses above 100 MeV.**

- *Calculations+simulations indicate that with 300 fb^{-1} sensitivity to a particle with charge $\mathcal{O}(10^{-3}) e$ can be achieved for masses of $\mathcal{O}(1) \text{ GeV}$, and charge $\mathcal{O}(10^{-2}) e$ for masses of $\mathcal{O}(10) \text{ GeV}$.*

- *Reach improves with $3000 \text{ fb}^{-1} \text{ HL-LHC}$*



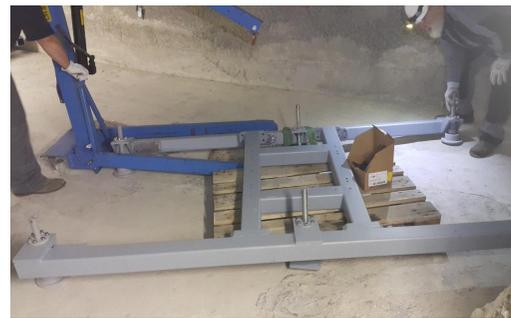
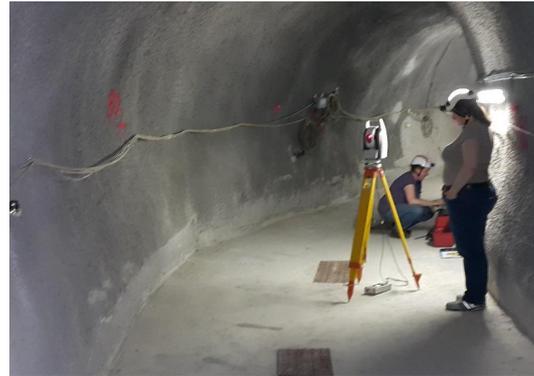
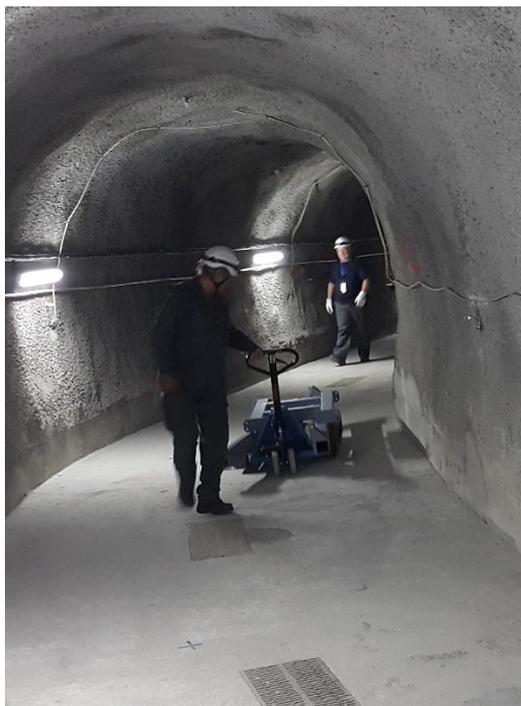
A Letter of Intent to Install a Milli-charged Particle Detector at LHC P5

Austin Ball,¹ Jim Brooke,² Claudio Campagnari,³ Albert De Roeck,¹ Brian Francis,⁴ Martin Gastal,¹ Frank Golf,³ Joel Goldstein,² Andy Haas,⁵ Christopher S. Hill,⁴ Eder Izaguirre,⁶ Benjamin Kaplan,⁵ Gabriel Magill,^{7,6} Bennett Marsh,³ David Miller,⁸ Theo Prins,¹ Harry Shakeshaft,¹ David Stuart,³ Max Swiatlowski,⁸ and Itay Yavin^{7,6}

Mechanical Structure Deployed in TS1 of 2017



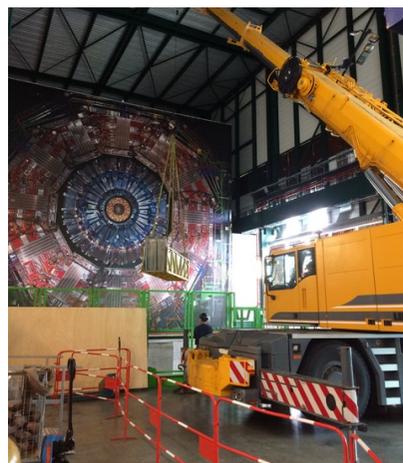
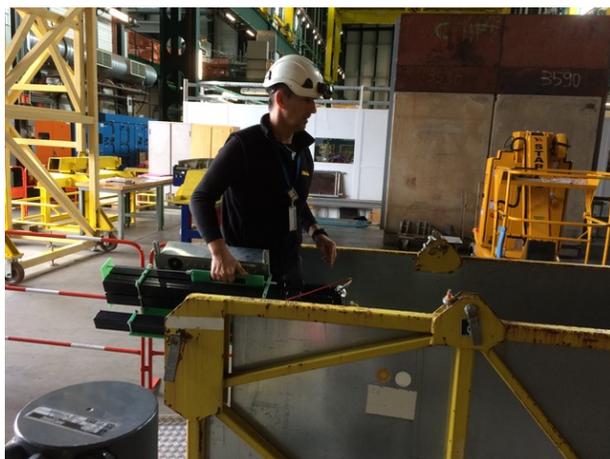
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- Supports weight of “final” milliQan
- Rotates out of position to allow passage



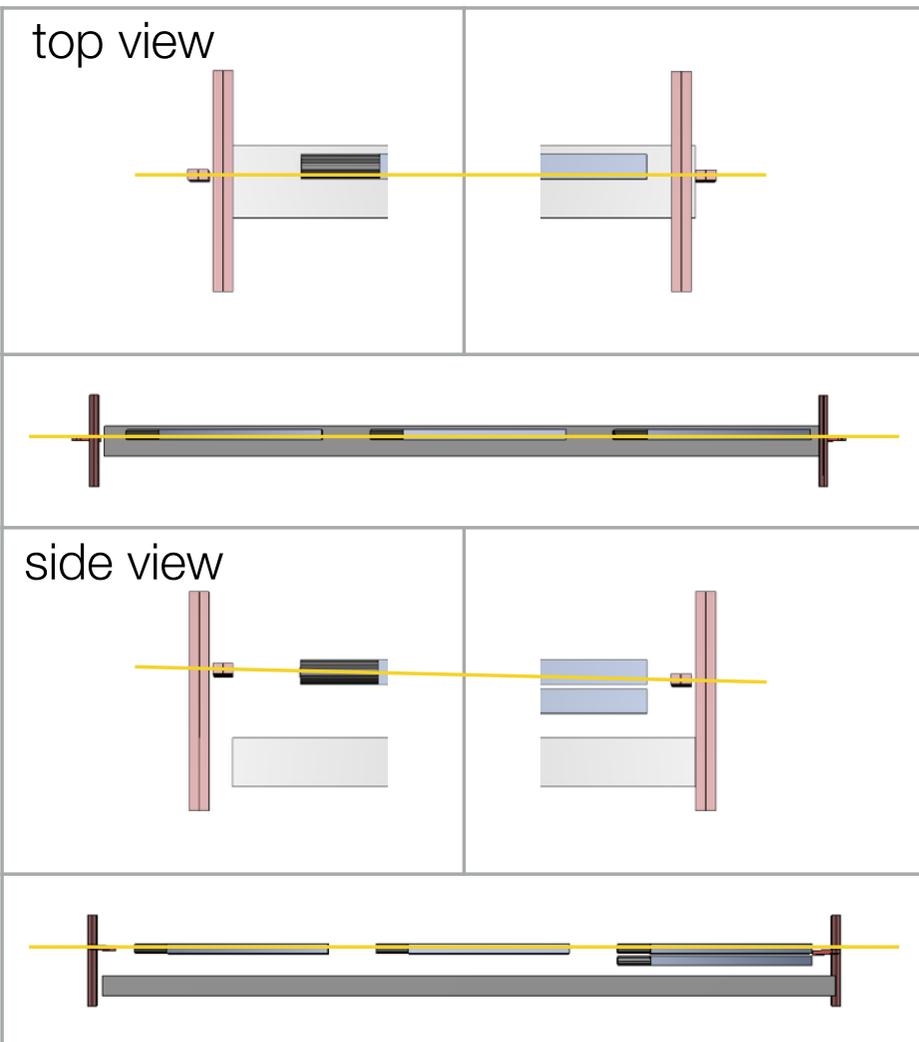
Demonstrator Installed in TS2 of 2017



- 12 scintillator bars installed (1% full milliQan) + 2 hodoscope packs on either end

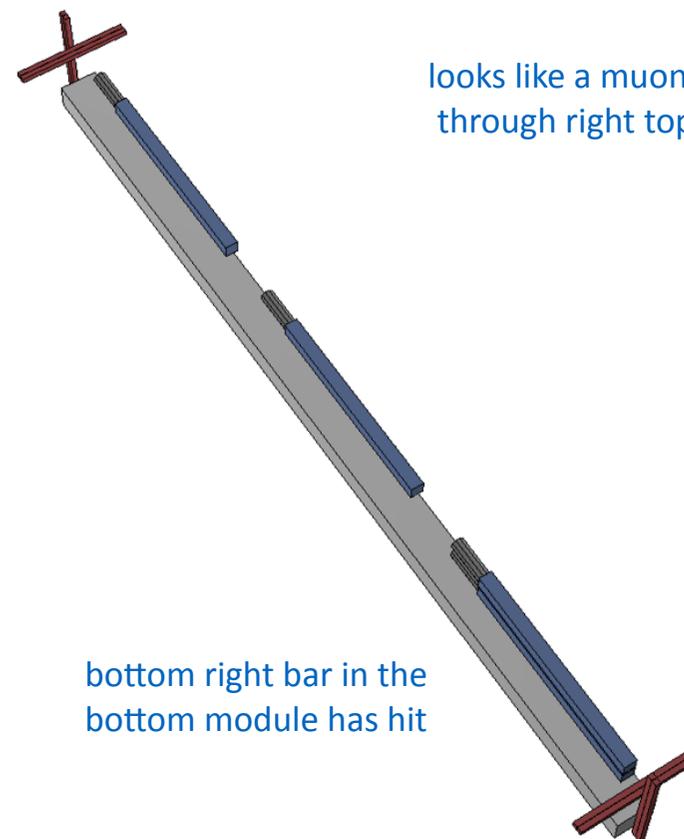


Event Display from Demonstrator



20170925_071105

looks like a muon going
through right top MBs

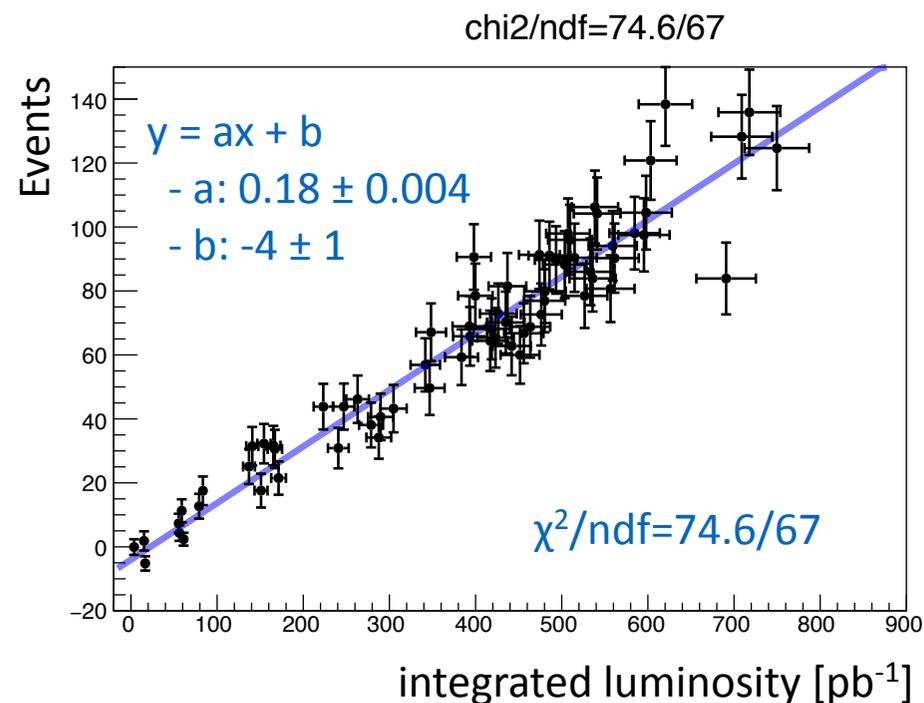


bottom right bar in the
bottom module has hit



Analysis of Data from Demonstrator

- Confirmed alignment to IP
 - *Seeing muons from CMS at expected rate*
- Backgrounds
 - *two correlated hits + random*
 - *cosmics + random*
 - *radiation + random*
- To understand this better, tag comics events using more scintillator



Measured Rate: $0.18/\text{pb}^{-1}$

Expected Rate from Simulation:
 $0.22/\text{pb}^{-1}$

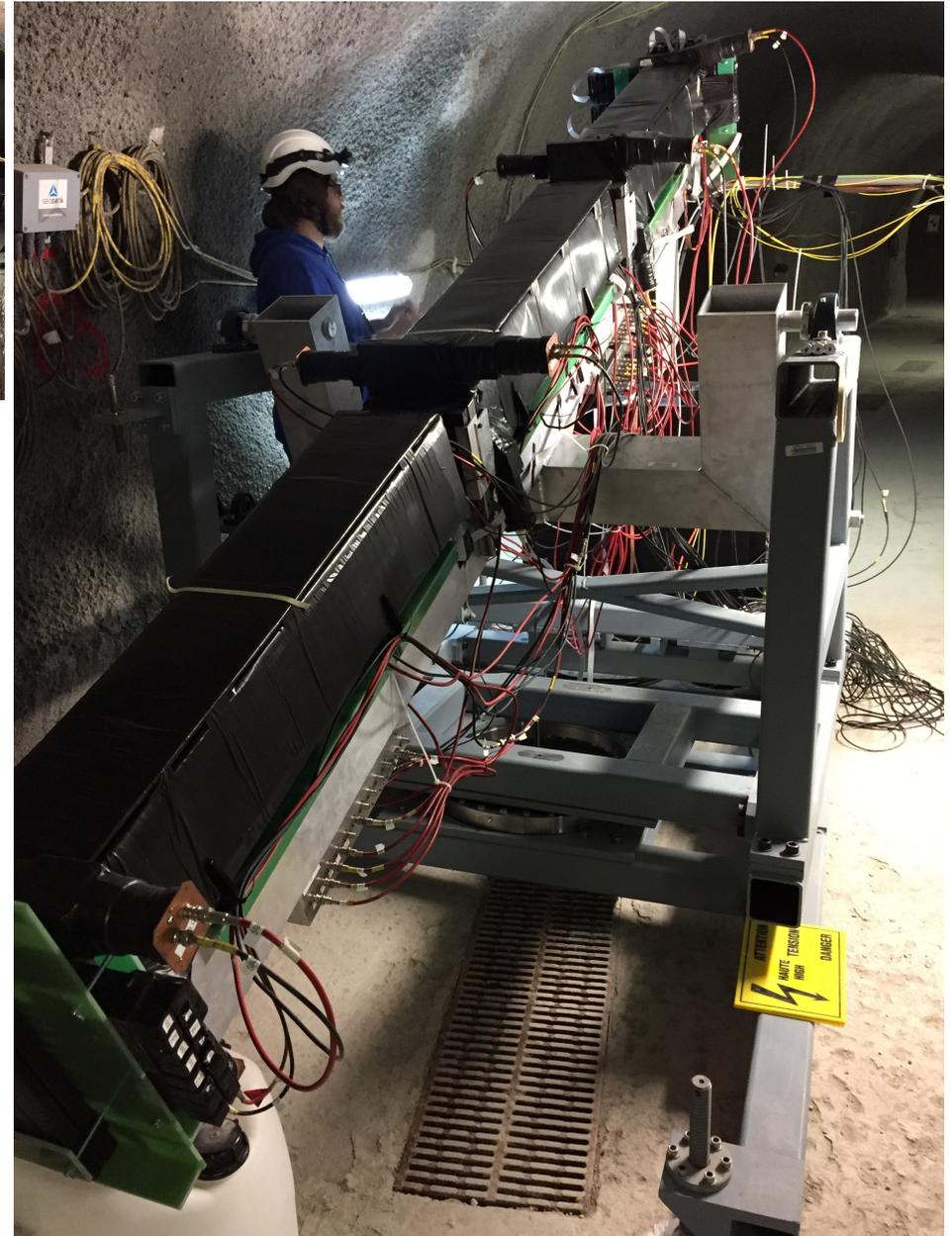
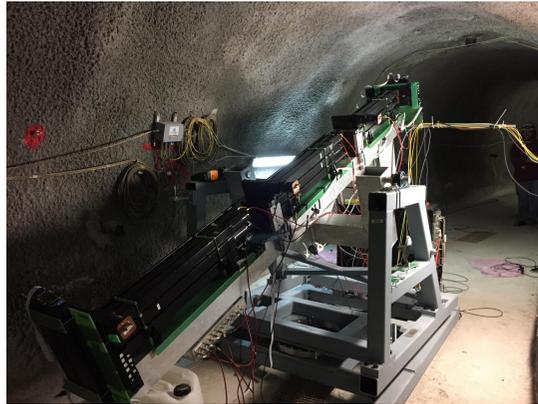


6 bars on top of MQ bars in parallel
3-4 bars perpendicular to MQ bars

Demonstrator Upgraded during 2017-18 YETS



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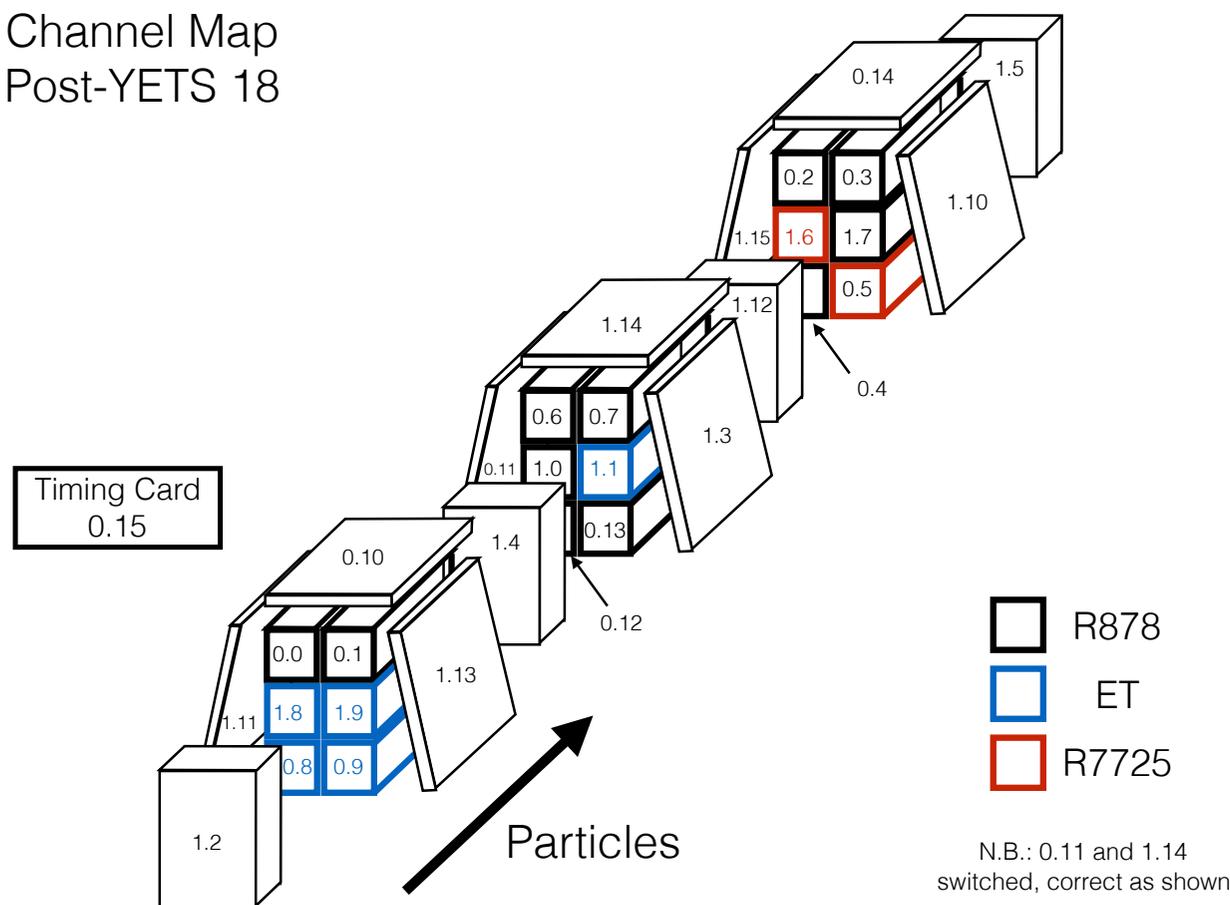
- Added additional set of milliQan bars in vertical dimension to aid with cosmic identification
- Added thin sheets on scintillator on top and side to aid in cosmic veto
- Added scintillator slabs between between bars to help understand longitudinal “showers”
- Added some environmental sensors to help understand environment
- Added more hodoscope packs to aid in “tracking”



Demonstrator Upgraded during 2017-18 YETS

- Now have 18 milliQan bars
- 9 thin scintillator veto sheets
- 4 scintillator slabs between bars
- Expanded hodoscope
- Timing information from CMS
- 4 magnetic field sensors
- Temperature & humidity sensors
- Fire protection system

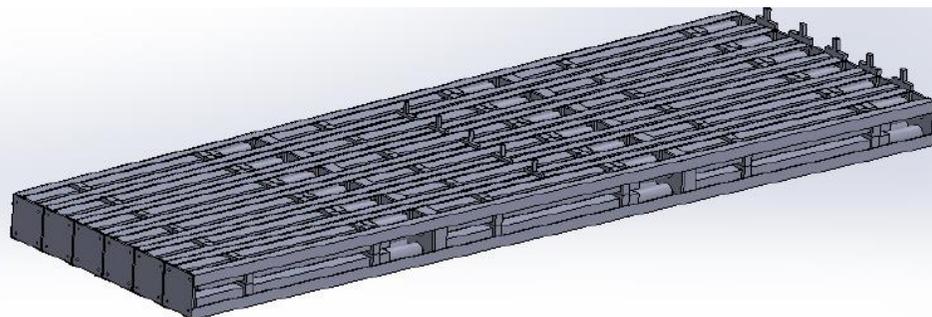
Channel Map
Post-YETS 18



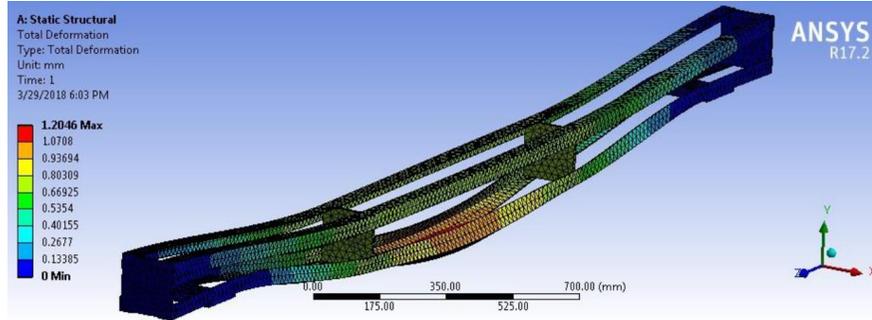
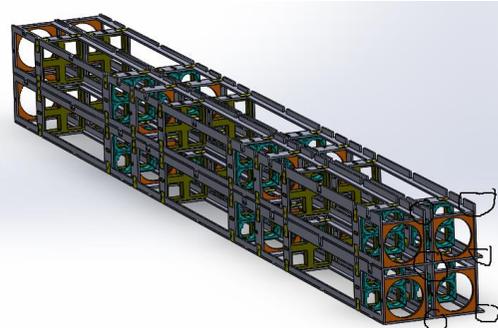
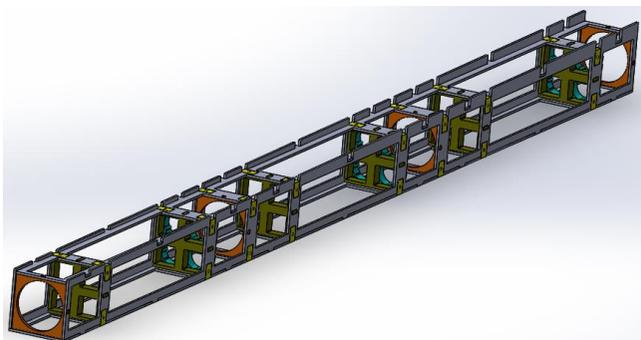
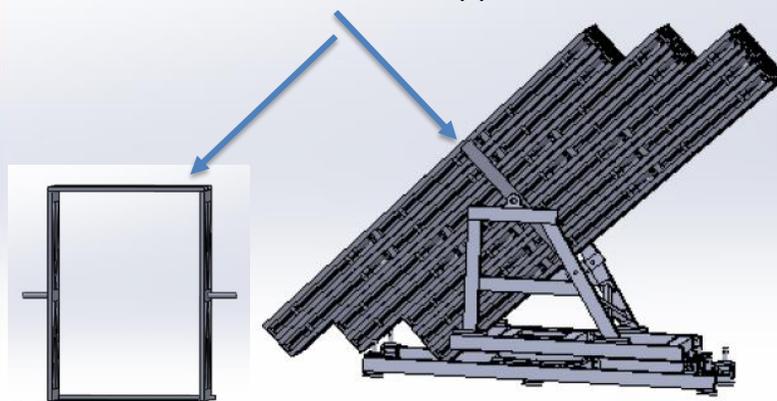


Mechanical Supports for Modules

- ▶ The layer
- ▶ The steps



The "cage" holds the layers together and attaches them to the support structure

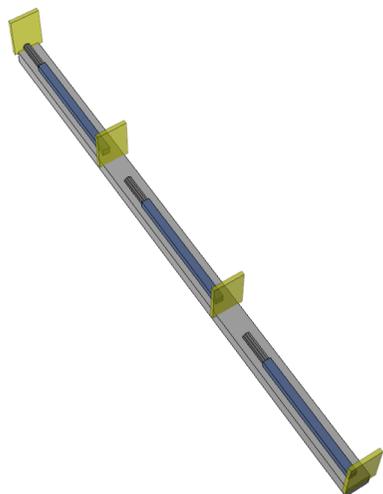




Data from Upgraded Demonstrator

- Have been taking data since end of YETS

Run 816, file 117, event 3472



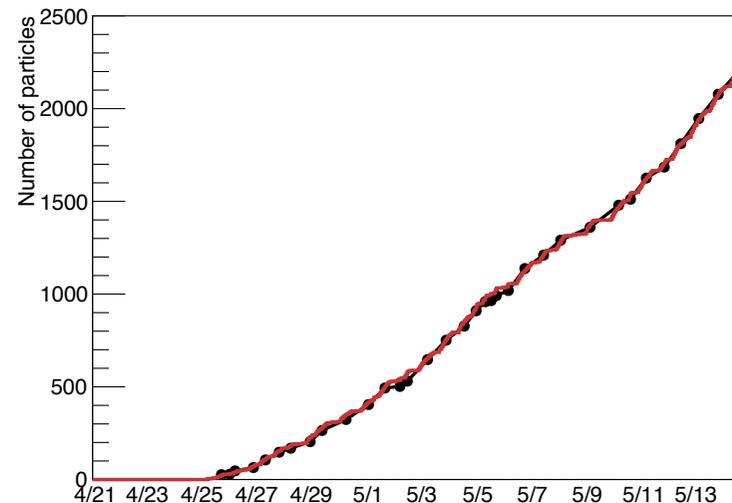
view from top



view from side



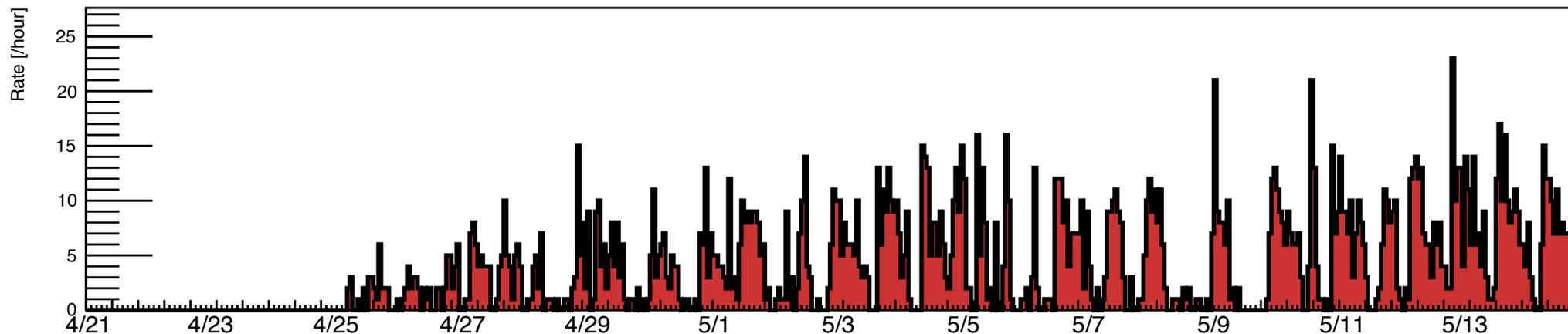
Number of through-going particles



Red = cumulative version of the plot below

Black = CMS luminosity from http://lpc-afs.web.cern.ch/lpc-afs/LHC/2018/luminosity_data_pp.txt

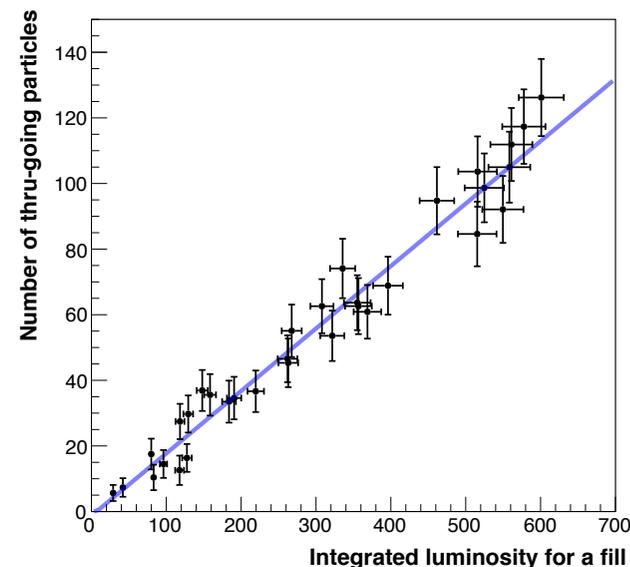
Number of through-going particles



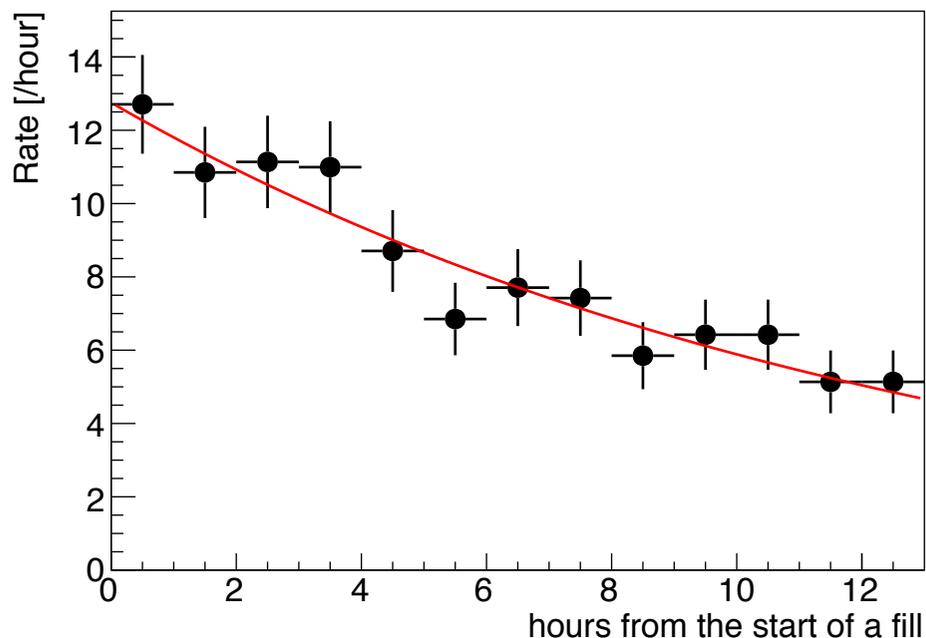


Data from Upgraded Demonstrator (cont.)

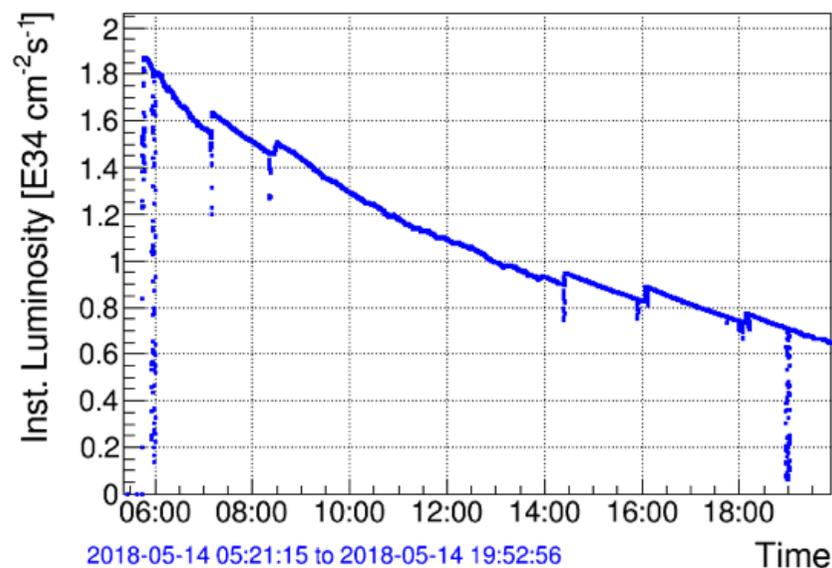
- Have confirmed muon rate observed in 2017
- Observe luminosity structure within a fill
 - *Measured time constant of 13 ± 2 h*
 - *Consistent with beam lifetime of fill of 14 h*
- Study of *in situ* background with additional handles provided by upgrades is ongoing



Number of events with at least one hit in each end



Fill 6681 Instantaneous Luminosity





Timeline & Next Steps

- Plan is to **have experiment ready for physics before Run 3 (2020)**
 - *Construction/Installation during LS2*
 - *Take data for Runs 3,4,5, ...*
- Have already **installed 1/100th scale demonstrator in tunnel** that has been **taking data since September 2017**
 - *Opportunity to make in situ background measurements with beam before Run 3*
 - *Have already learned a lot from this data about operating environment*
- Engineering/mechanics **at an advanced stage**
 - *Final support structure already in place, module designs becoming mature*
- On track to **meet schedule (if funded)**
 - *M&S ~\$1M*

