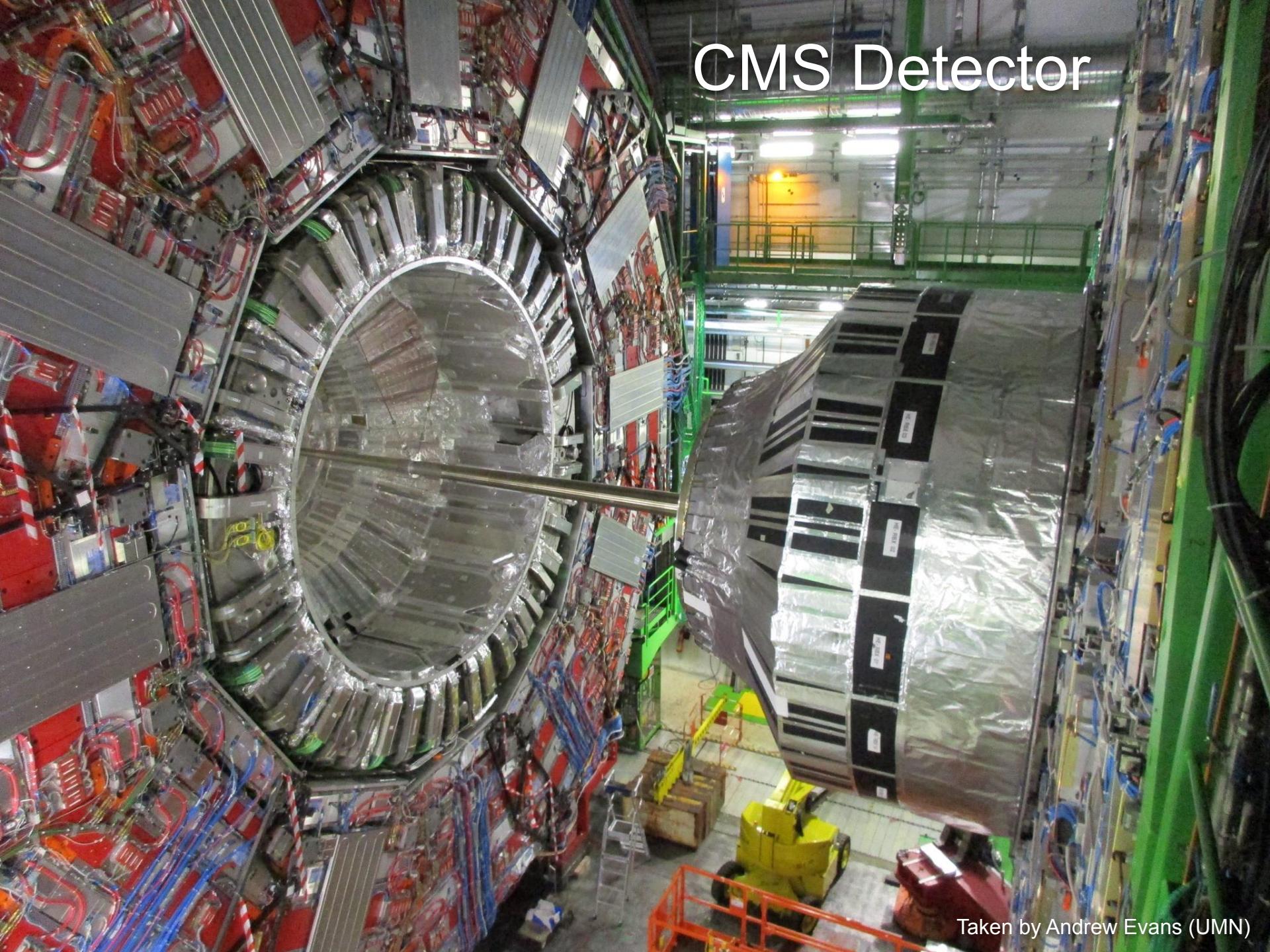


CMS and the LHC

Josh Hiltbrand, Tom Eichlersmith



CMS Detector



Taken by Andrew Evans (UMN)

CMS DETECTOR

Total weight : 14,000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T

STEEL RETURN YOKE

12,500 tonnes

SILICON TRACKERS

Pixel ($100 \times 150 \mu\text{m}$) $\sim 1\text{m}^2$ $\sim 66\text{M}$ channels
Microstrips ($80 \times 180 \mu\text{m}$) $\sim 200\text{m}^2$ $\sim 9.6\text{M}$ channels

SUPERCONDUCTING SOLENOID

Niobium titanium coil carrying $\sim 18,000\text{A}$

MUON CHAMBERS

Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 540 Cathode Strip, 576 Resistive Plate Chambers

PRESHOWER

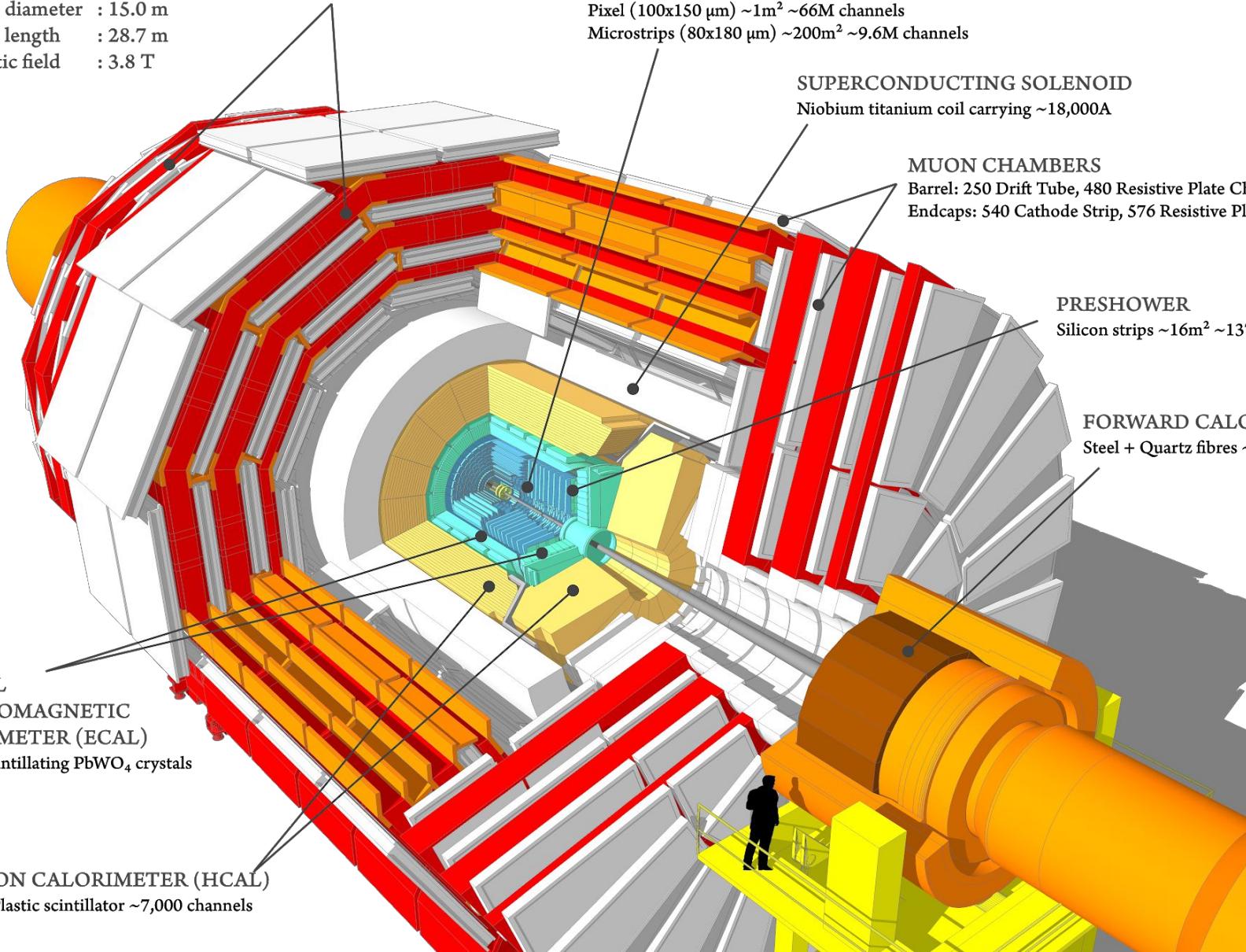
Silicon strips $\sim 16\text{m}^2$ $\sim 137,000$ channels

FORWARD CALORIMETER

Steel + Quartz fibres $\sim 2,000$ Channels

CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
 $\sim 76,000$ scintillating PbWO_4 crystals

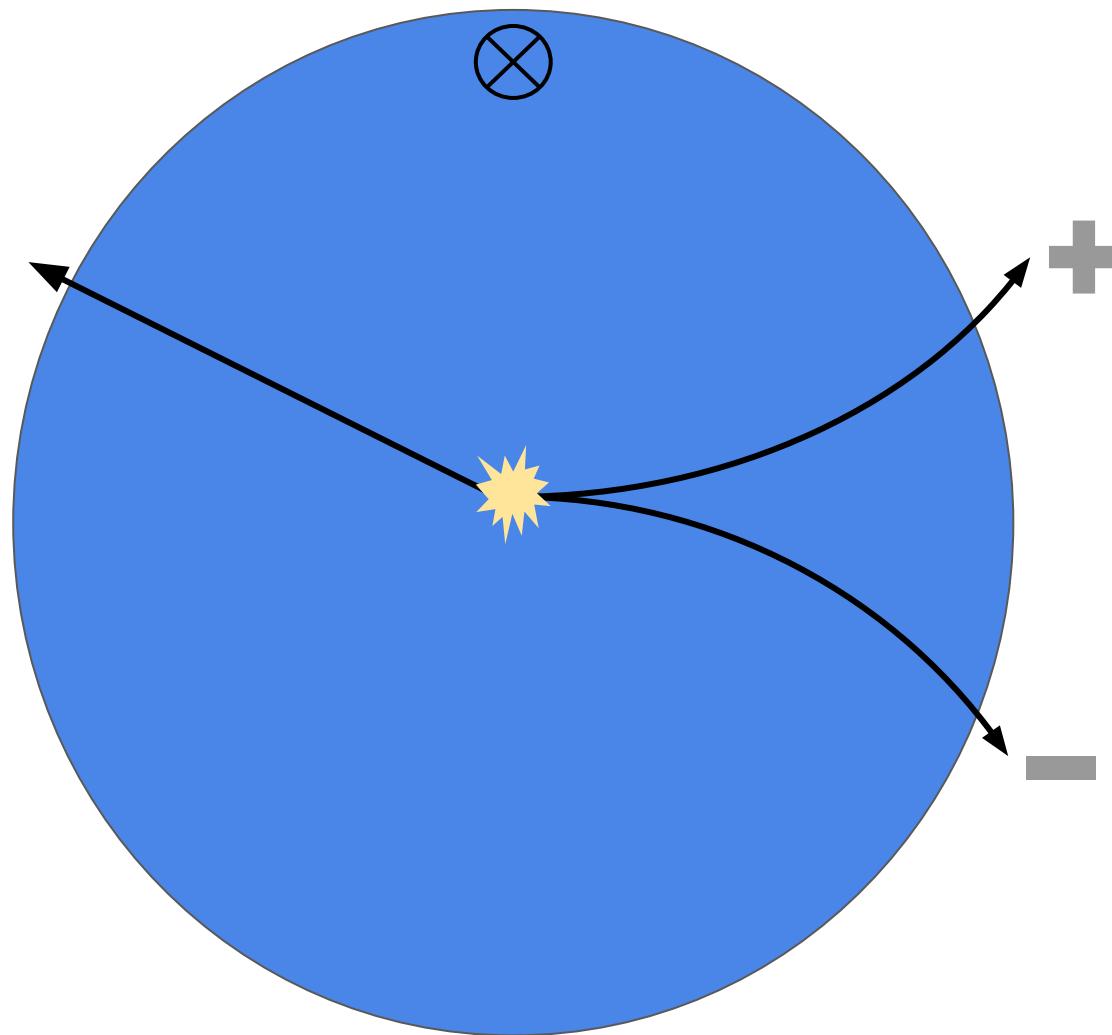
HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator $\sim 7,000$ channels



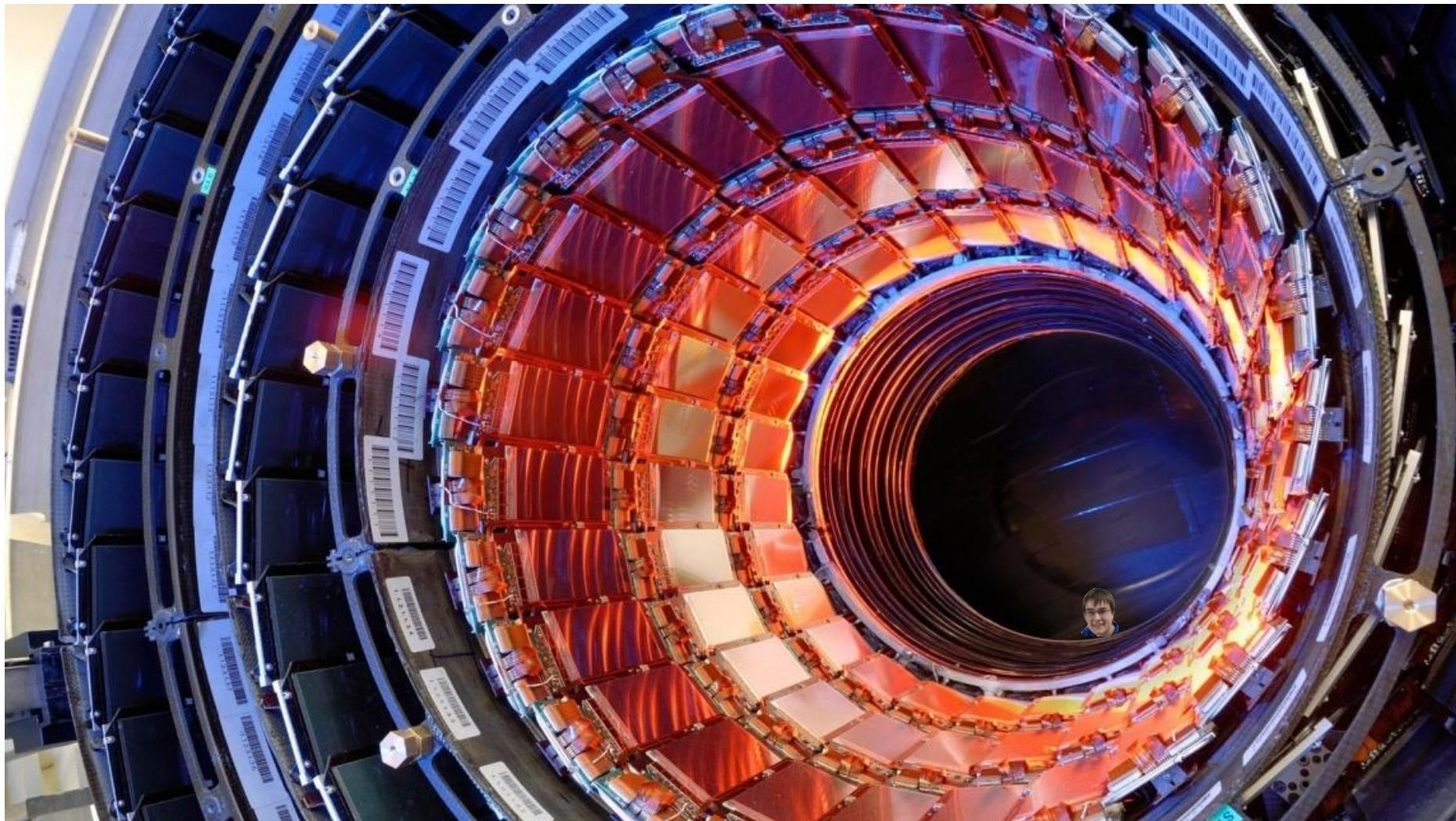
Solenoid Magnet



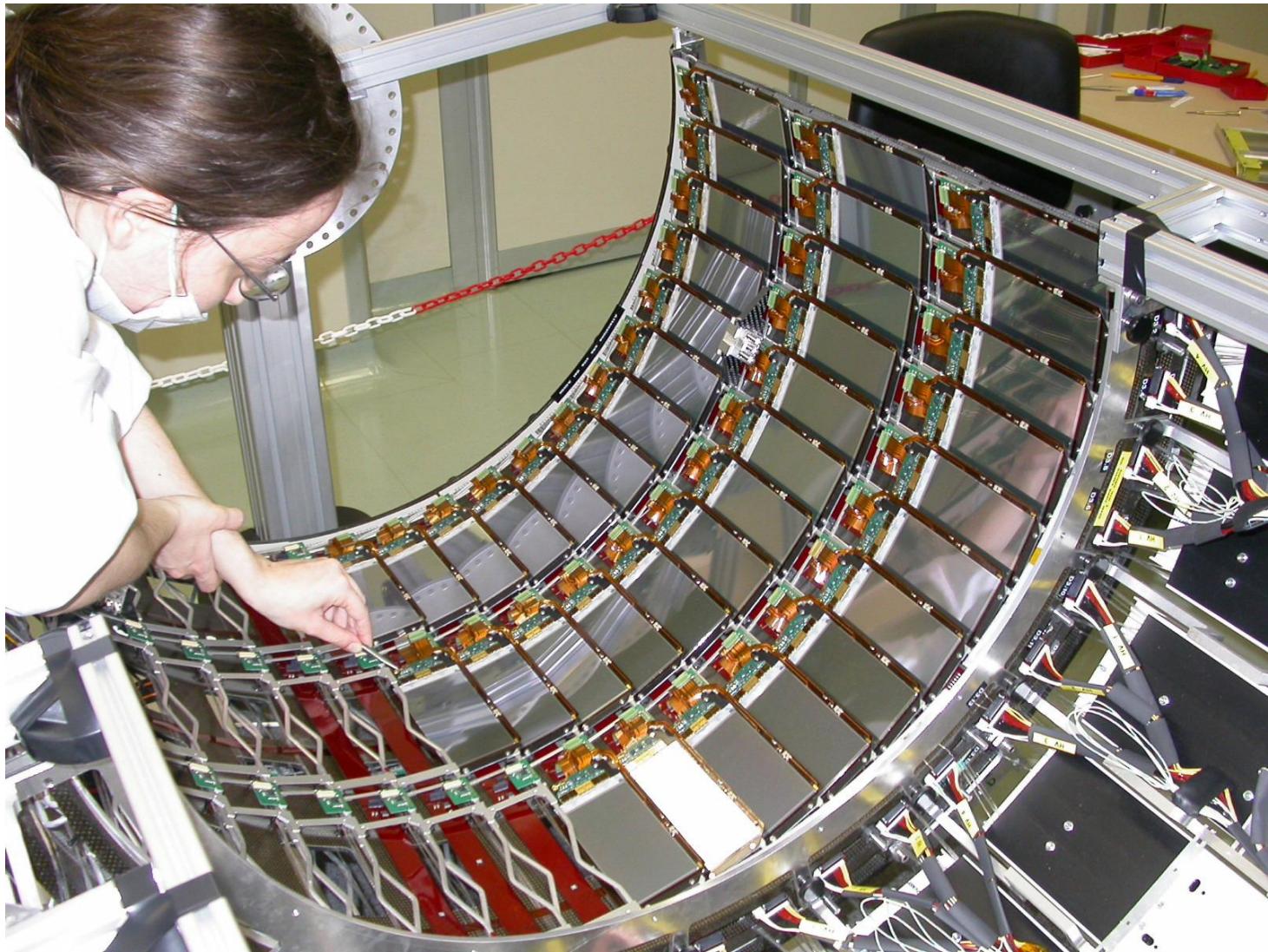
Particles in a Magnetic Field



Tracker

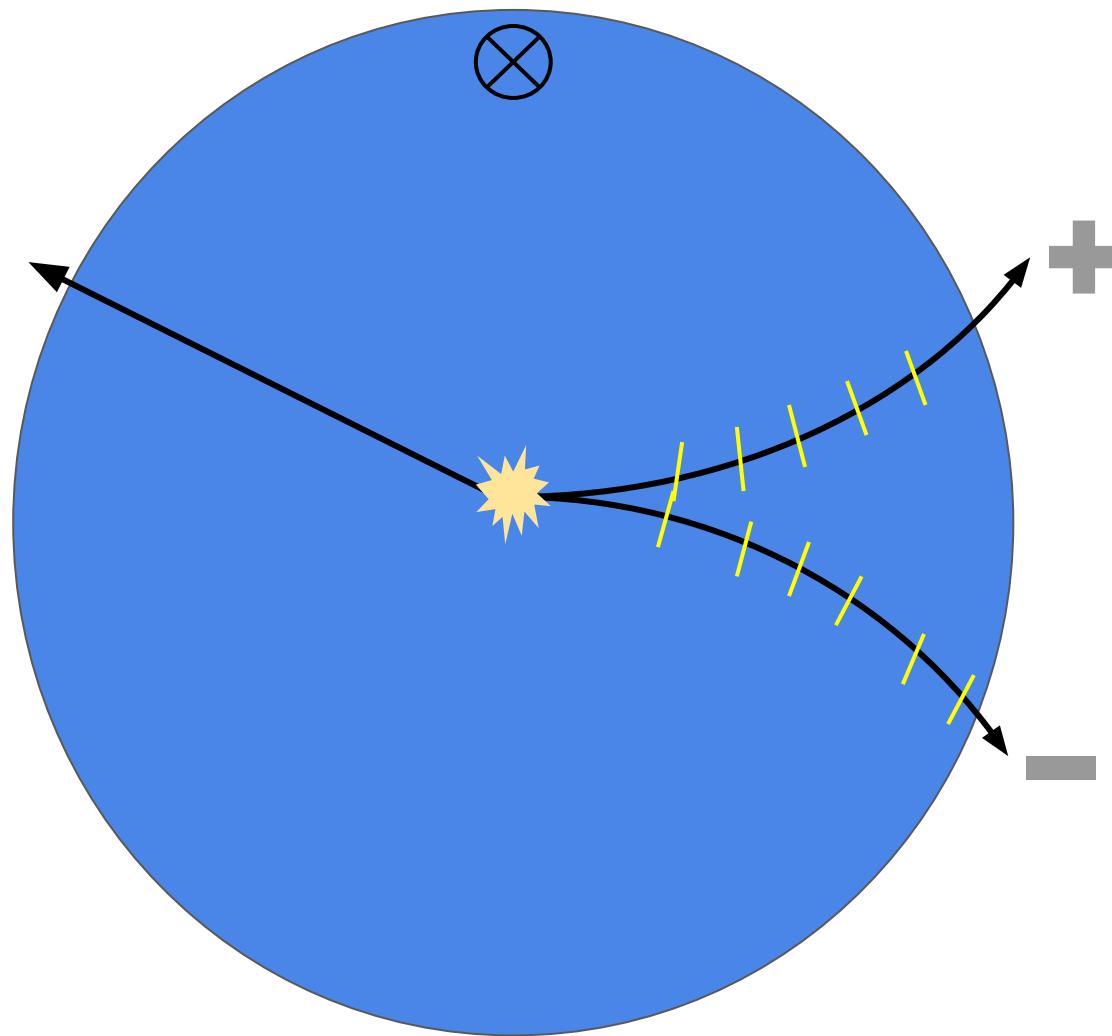


CMS: <http://cms.cern/detector/identifying-tracks>

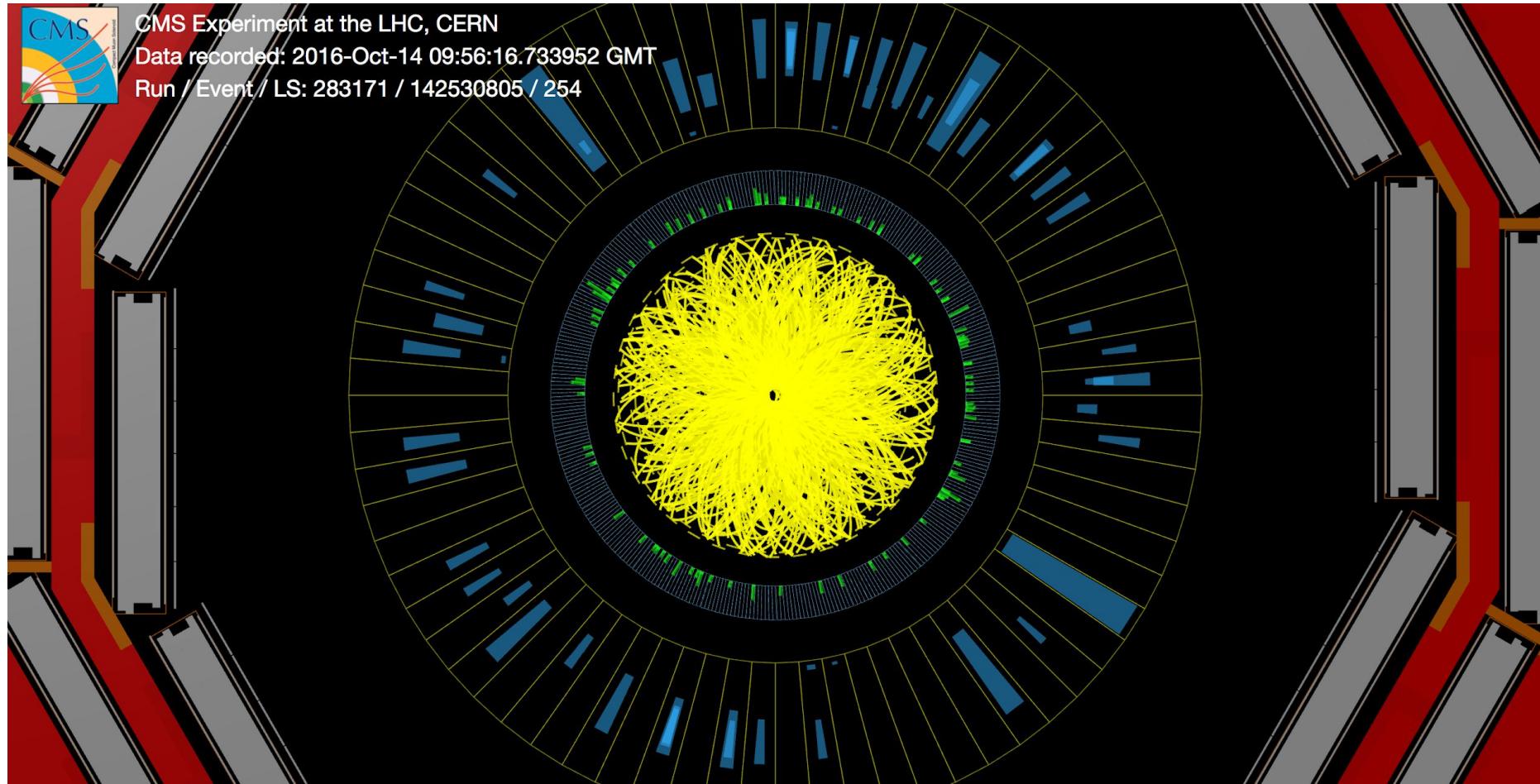


CERN: <http://cds.cern.ch/record/1431467>

Particles in a Magnetic Field

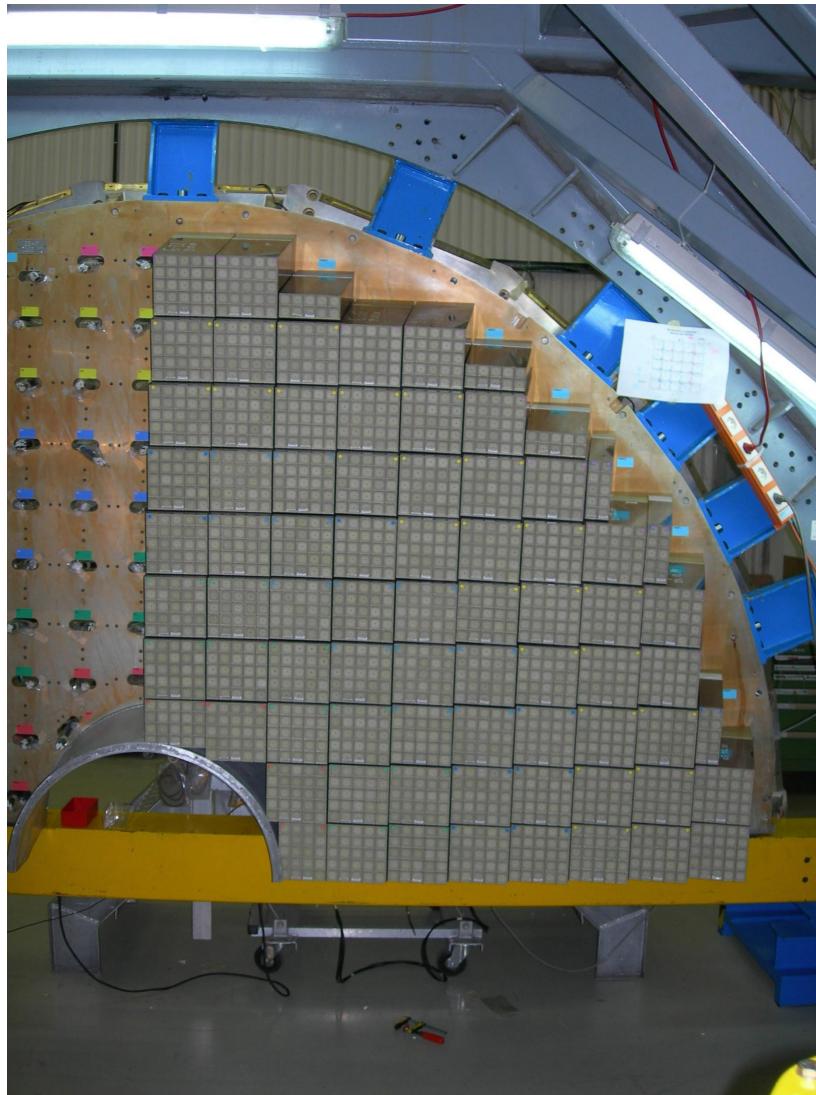


Quickly gets out of hand...



CERN: <http://cds.cern.ch/record/2231915>

Electromagnetic CALorimeter (ECAL)



CERN:
<http://cds.cern.ch/record/1431479>

Hadronic CALorimeter (HCAL)





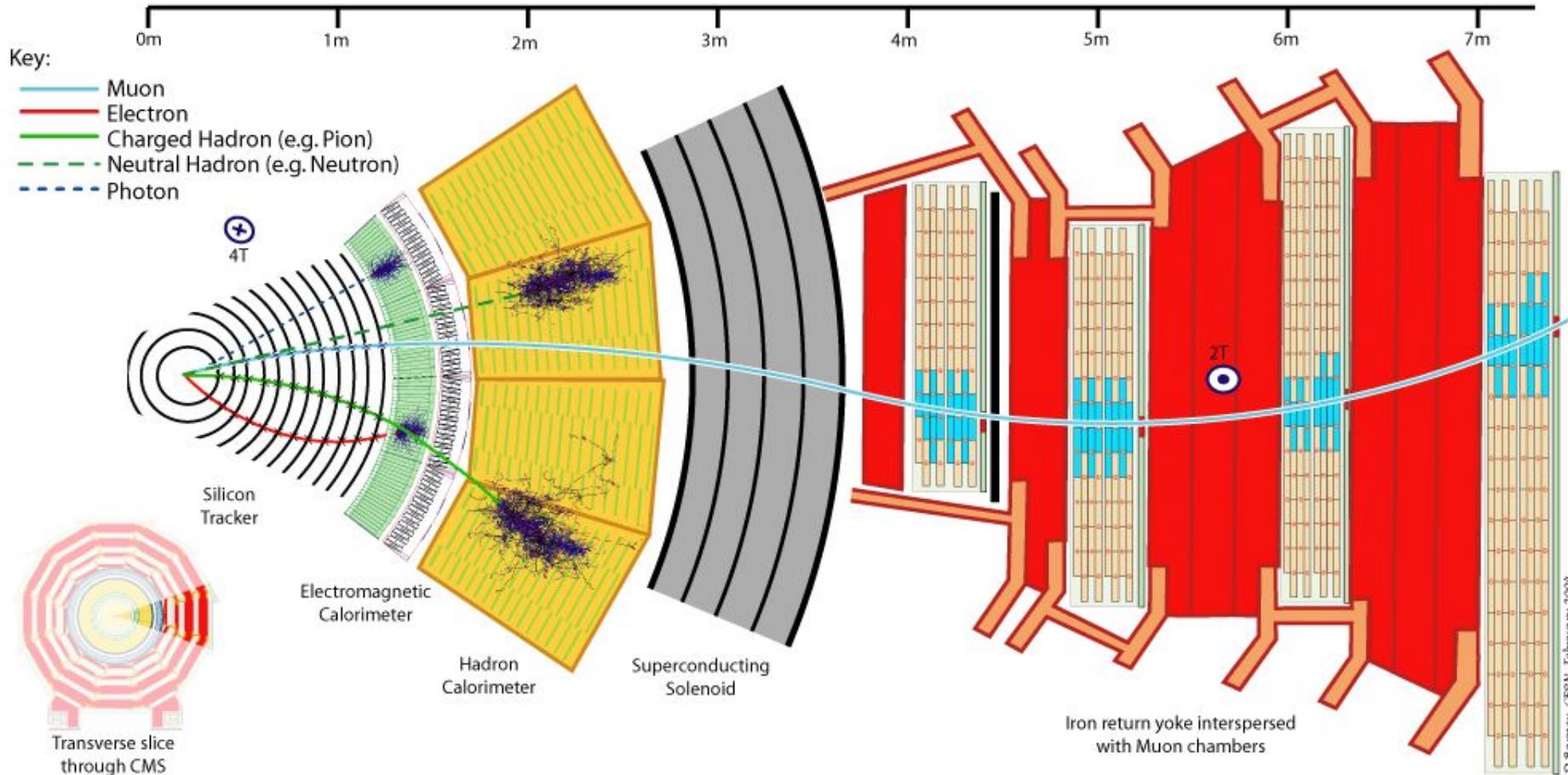
CERN: <http://cds.cern.ch/record/1431485>

Muon Chambers

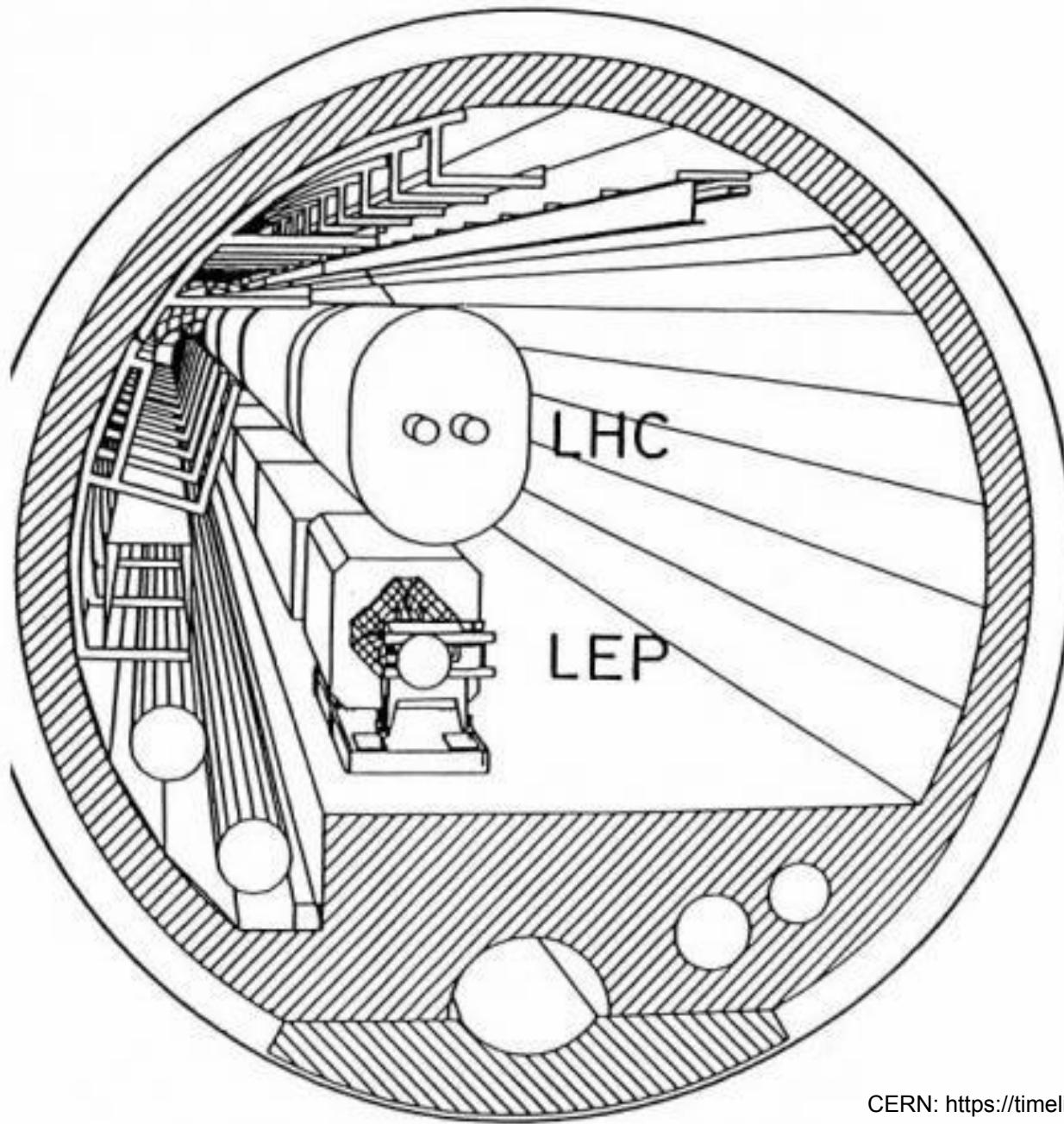


CERN: <http://cds.cern.ch/record/2016899?ln=en>

All Together



Timeline



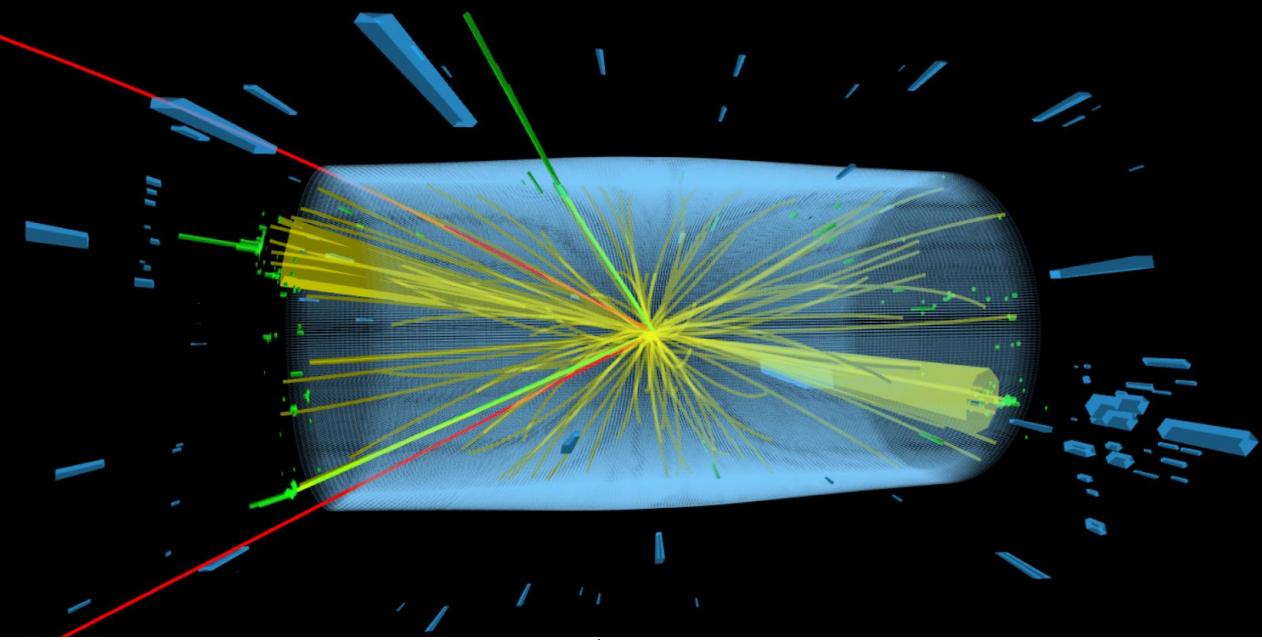


CMS Experiment at the LHC, CERN

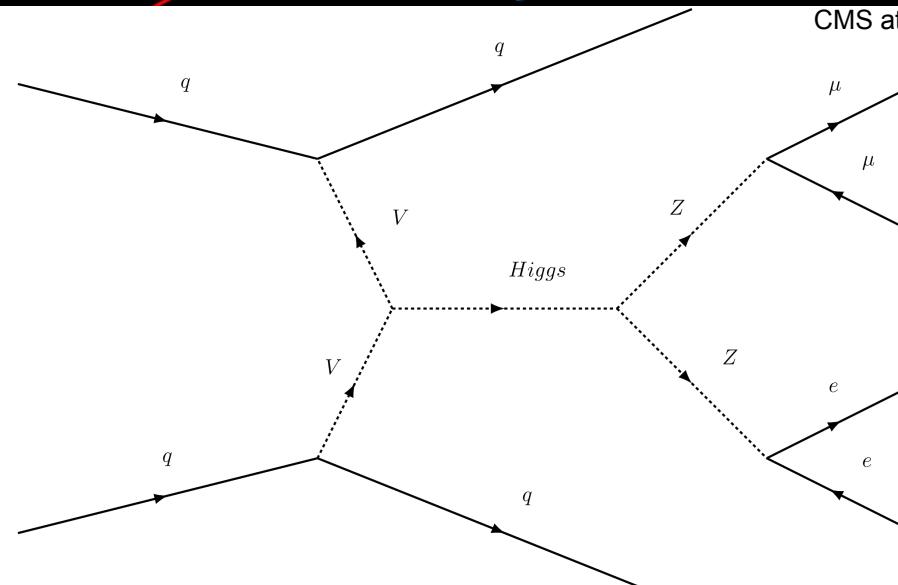
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Run / Event / LS: 276525 / 2665335317 / 1561

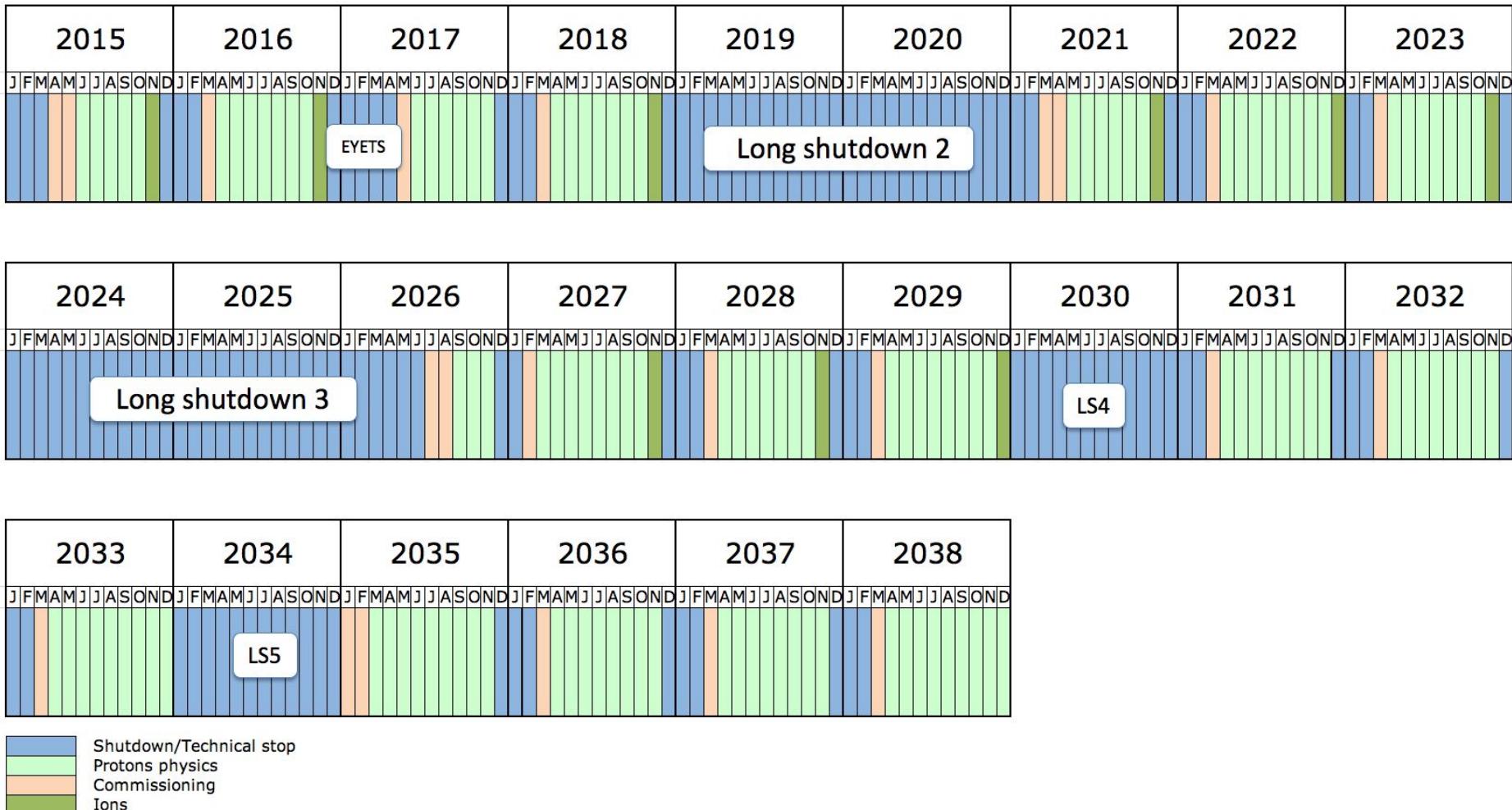
Higgs Discovery



CMS at CERN: <http://cds.cern.ch/record/1459462>



Long Term Schedule

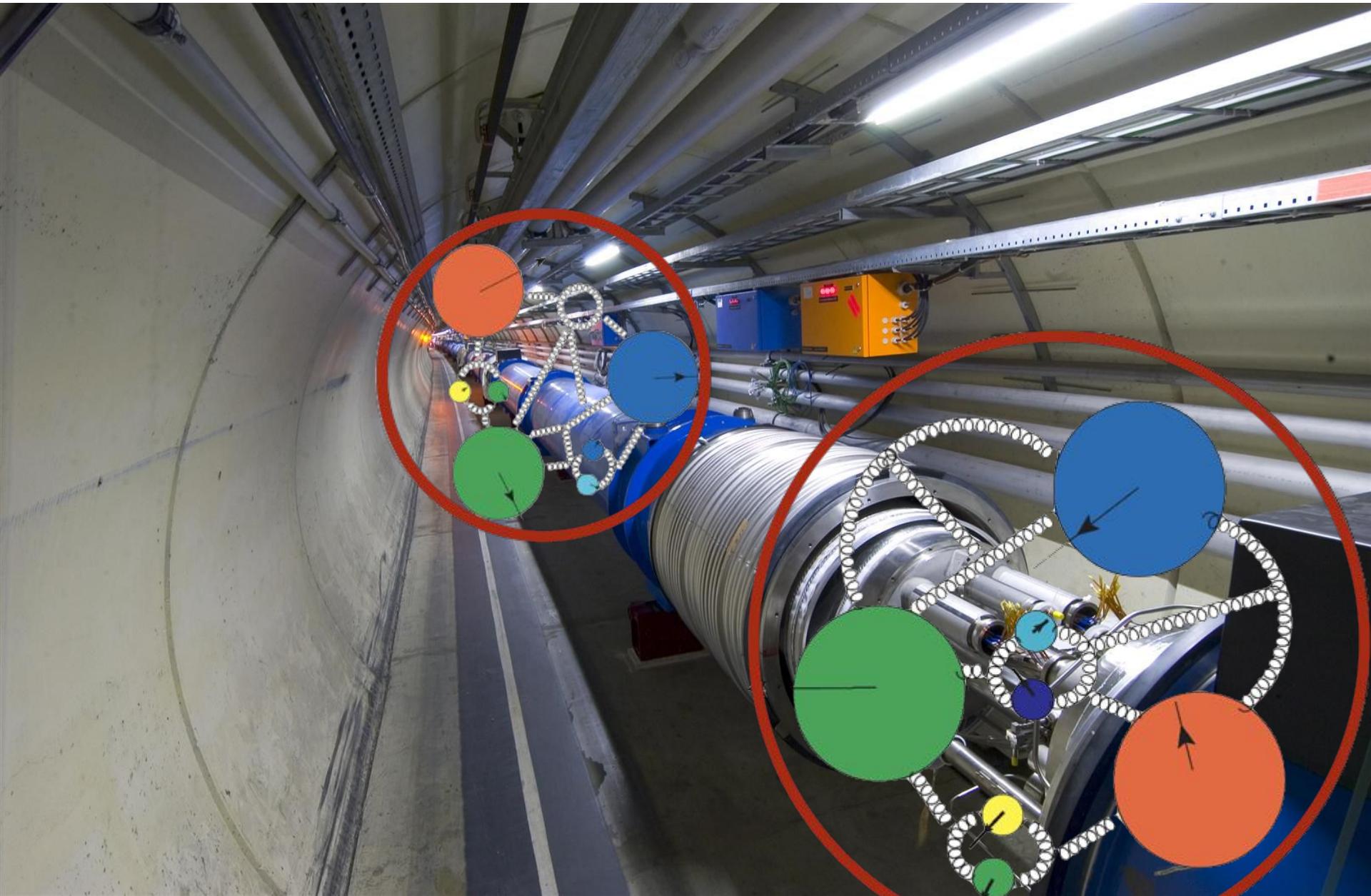


CERN: <https://lhcb-commissioning.web.cern.ch/lhc-commissioning/schedule/HL-LHC-plots.htm>

Long Shutdown 1 ⇒ Higher Energy



Proton Bags

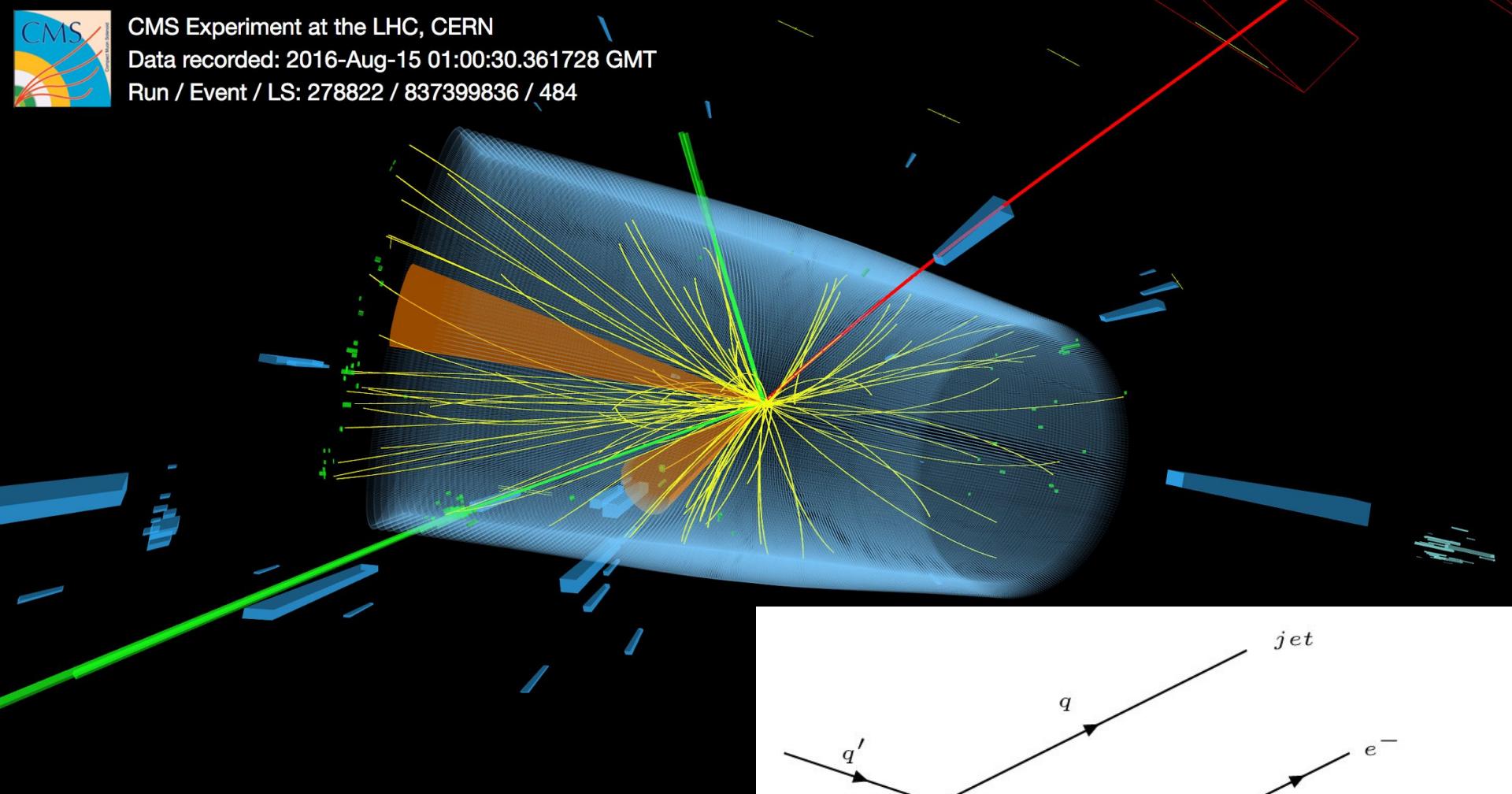




CMS Experiment at the LHC, CERN

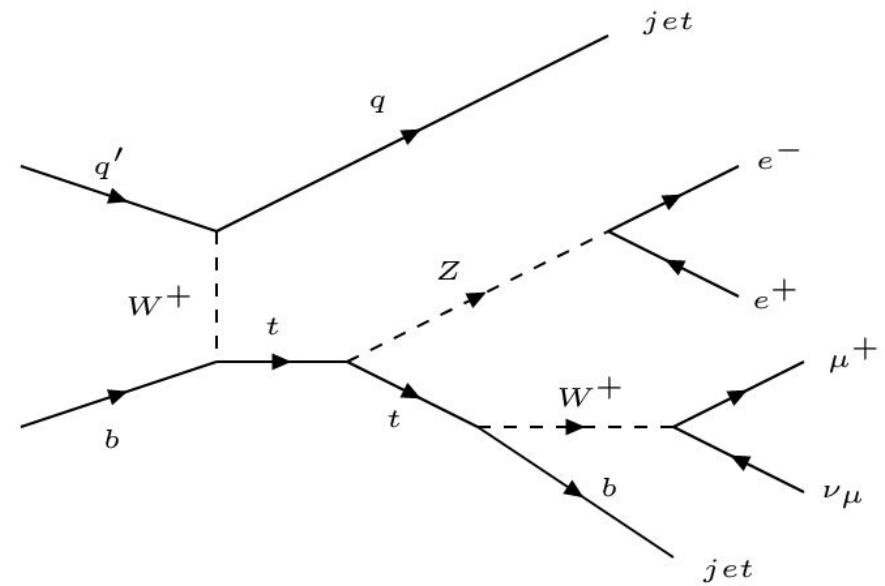
Data recorded: 2016-Aug-15 01:00:30.361728 GMT

Run / Event / LS: 278822 / 837399836 / 484



CERN: <http://cds.cern.ch/record/2649553>

Top Quark Production



Long Shutdown 2 ⇒ Higher Luminosity



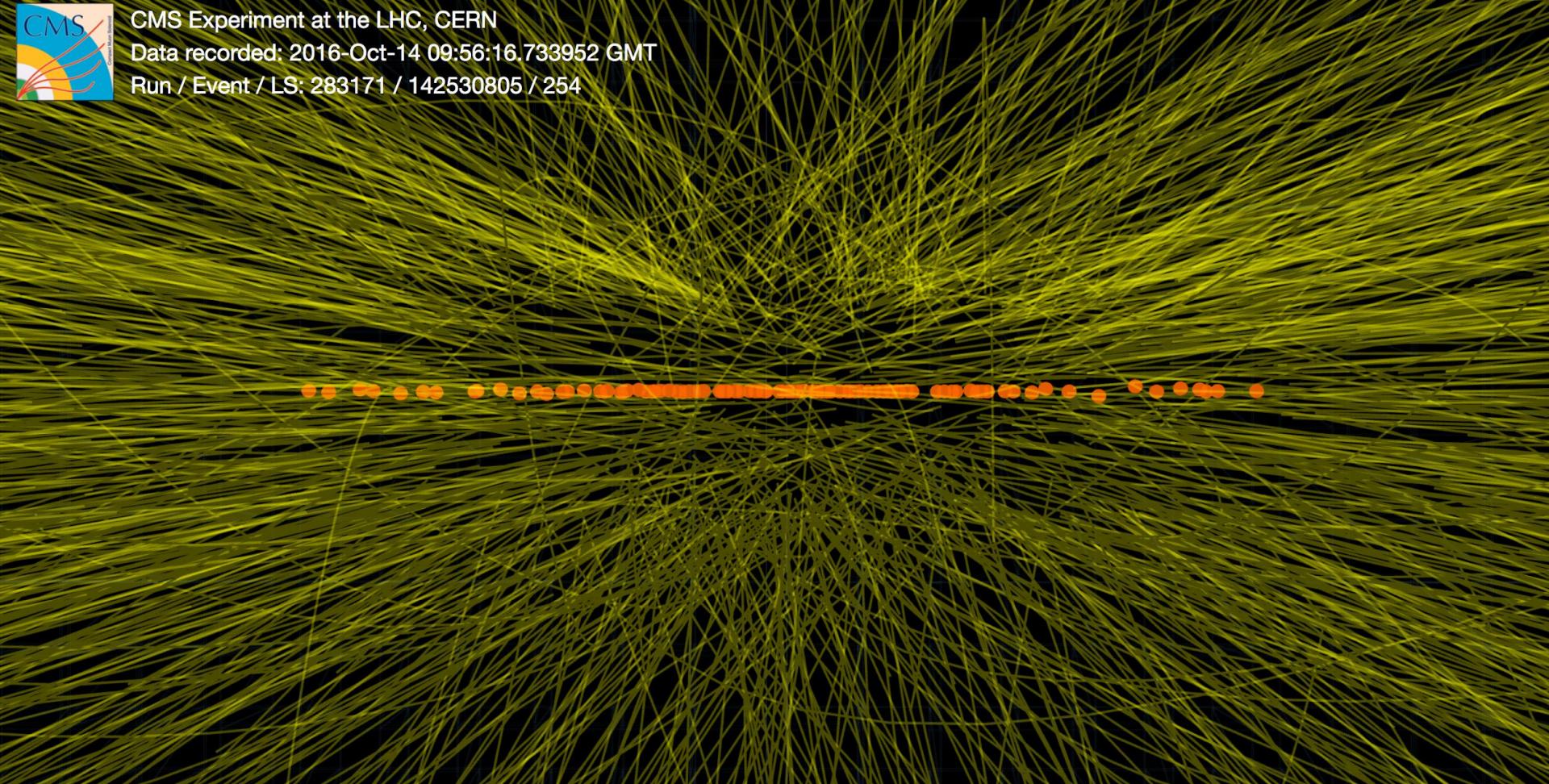
CERN: <http://cds.cern.ch/record/2672153>



CMS Experiment at the LHC, CERN

Data recorded: 2016-Oct-14 09:56:16.733952 GMT

Run / Event / LS: 283171 / 142530805 / 254



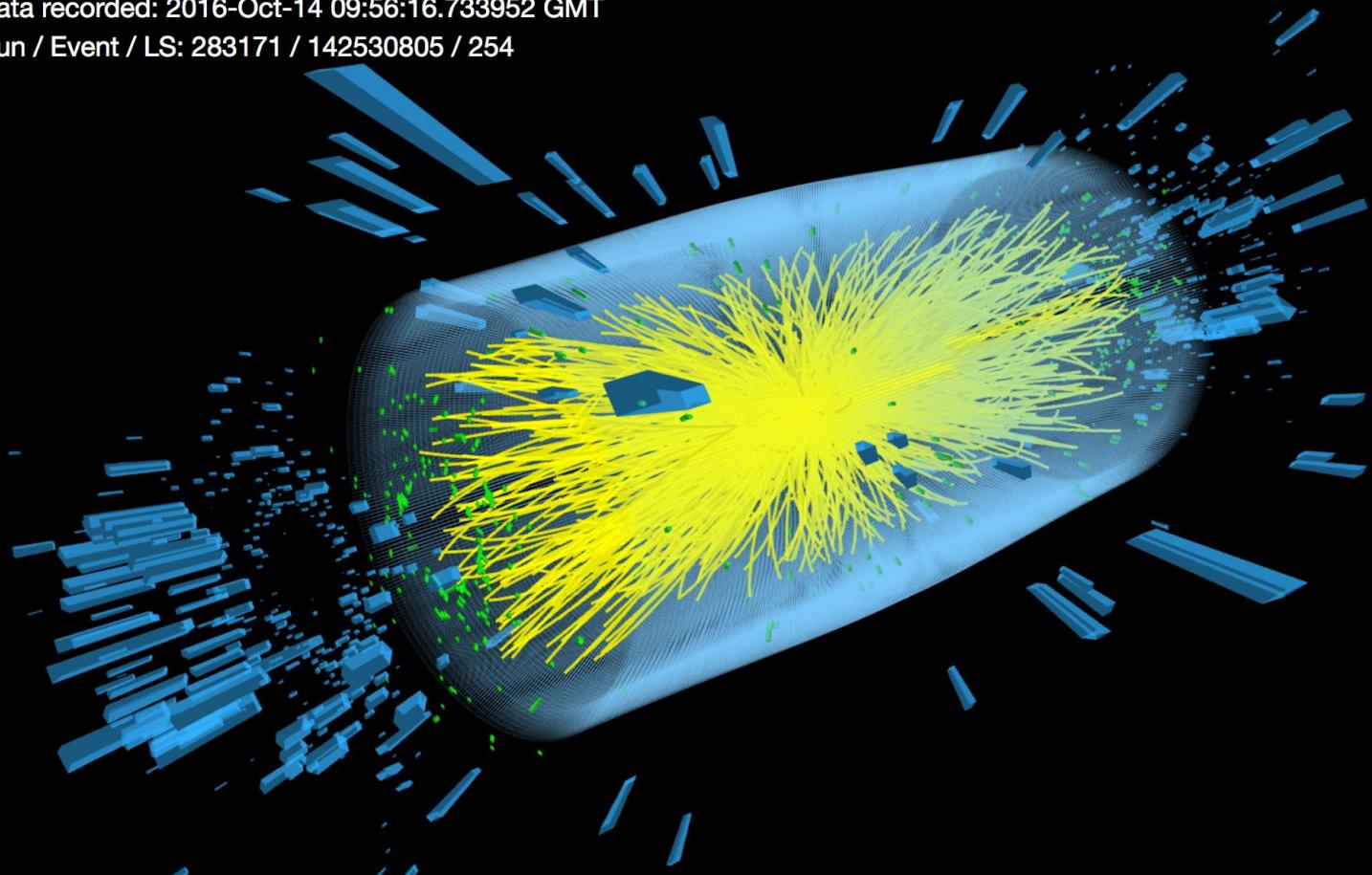
CERN: <http://cds.cern.ch/record/2231915>



CMS Experiment at the LHC, CERN

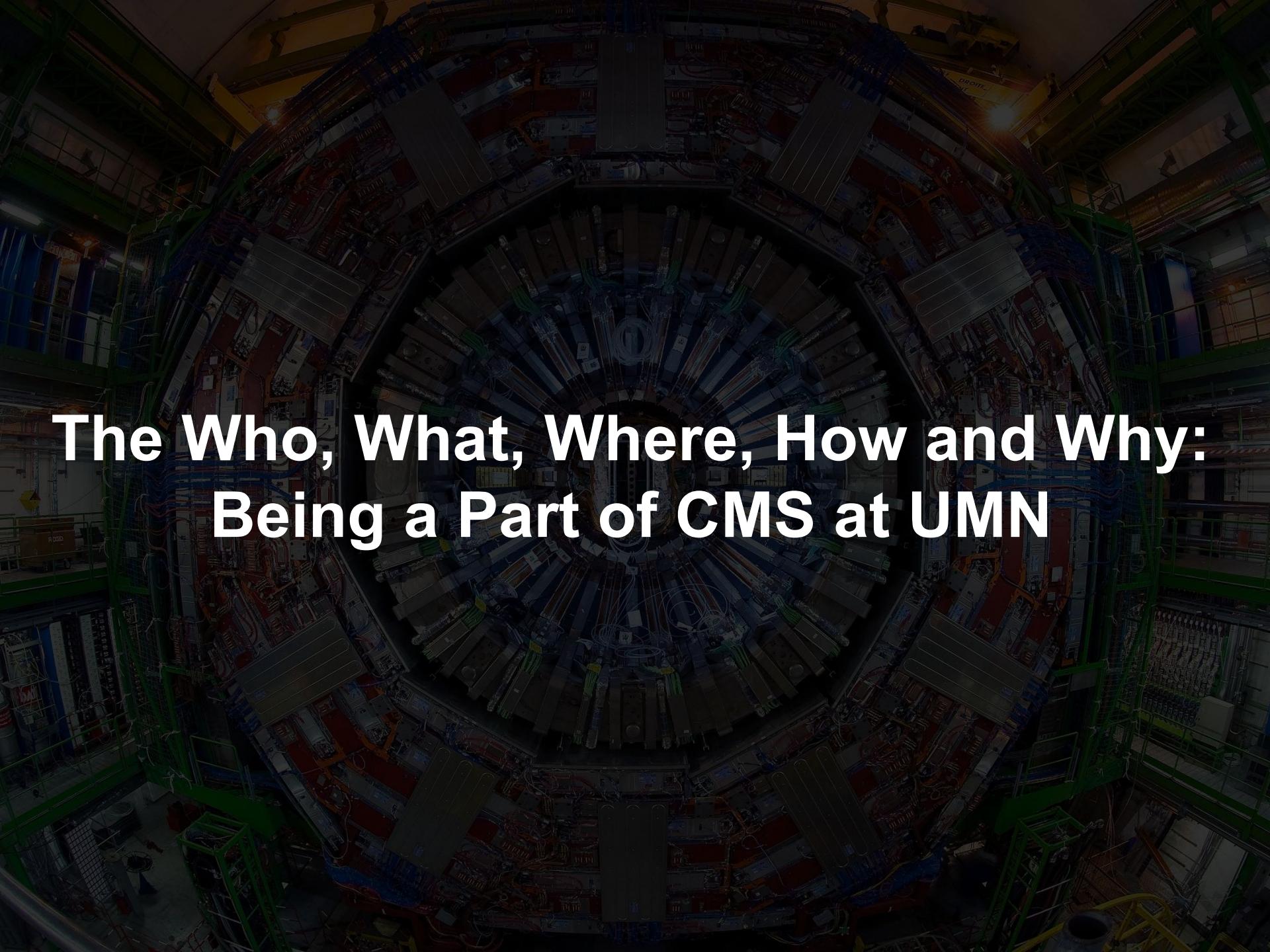
Data recorded: 2016-Oct-14 09:56:16.733952 GMT

Run / Event / LS: 283171 / 142530805 / 254



CERN: <http://cds.cern.ch/record/2231915>

Questions?



The Who, What, Where, How and Why: Being a Part of CMS at UMN

Why Are We Here?

J. Hiltbrand

- Fascinated by understanding fundamental building blocks of universe
- In undergrad, cultivated an interest in programming as well
- Like Tom, working in HEP looked to be a compelling combination of math, physics and also computer programming

T. Eichlersmith

- Enjoyed analytical thinking and programming
- Thought Particle Physics was a fascinating blend of mathematics and physics

How Do (Did) We Get Here?

J. Hiltbrand

- Waconia, MN
- B.S. in physics at University of Minnesota Duluth
 - REU here, summer 2014
- REU made non-trivial impression to come to UMN for grad school

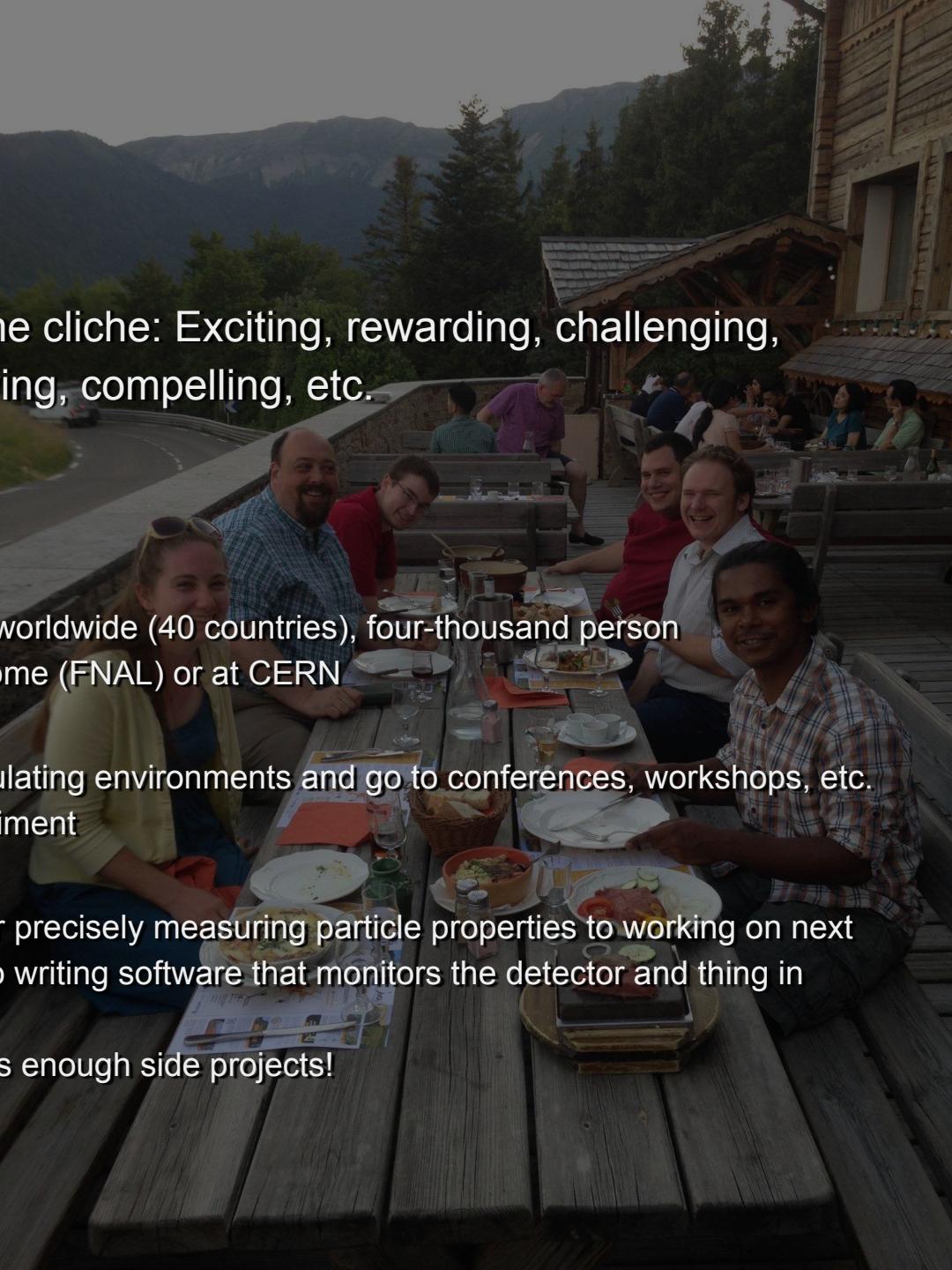
T. Eichlersmith

- Richfield, MN
- Hamline University
 - REU at CERN through University of Michigan
- University of Minnesota

What Is It Like Here?

Feelings are multi-faceted, some cliche: Exciting, rewarding, challenging, enlightening, sometimes annoying, compelling, etc.

- Diversity of people
 - Ability to work with people from a worldwide (40 countries), four-thousand person collaboration, whether closer to home (FNAL) or at CERN
- Diversity of locations
 - Opportunity to work in highly-stimulating environments and go to conferences, workshops, etc. to discuss all aspects of the experiment
- Diversity of work
 - From searching for new physics or precisely measuring particle properties to working on next generation of detector hardware to writing software that monitors the detector and thing in between
 - Hard to get stuck in a rut if one has enough side projects!



Where Do We Go From Here?

Ph.D. students in our CMS group at MN have shown a “diversity” of career paths upon completing their degree

- Some are in academia
 - HEP
 - S. Cooper (2012) - UA Assistant Research Scientist based at CERN
 - J. Pastika (2014) - Baylor postdoc based at FNAL
 - Non-HEP
 - K. Klapoetke (2014) - Mathematics instructor at Normandale
- Many have found themselves outside physics
 - J. Haupt (2011) - Data science at Bind On-Demand Health Insurance
 - A. Gude (2015) - Data science at Intuit
 - N. Tambe E (2015) - Software engineer at CommScope
 - J. Turkewitz (2016) - Data science at Microsoft
 - S. Kalafut (2017) - Research scientist at 3M
- Even both!
 - P. Dudero (2011) - Postdoc at Texas Tech, now software engineer at General Dynamics

Questions for Us?

What are current high school students' concerns when considering going into physics / pursuing graduate school?

What are high school physics teachers' concerns in preparing students to degree in physics (HEP or not)?

How can high school students prepare now for pursuing a Ph.D. in HEP?