CMS Open Data

Status and plans

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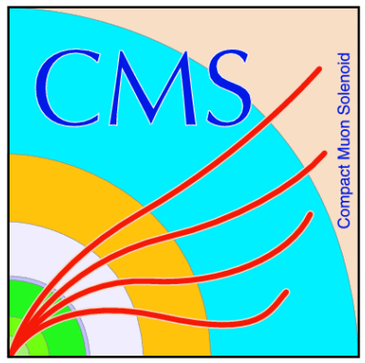
on behalf of the CMS Collaboration

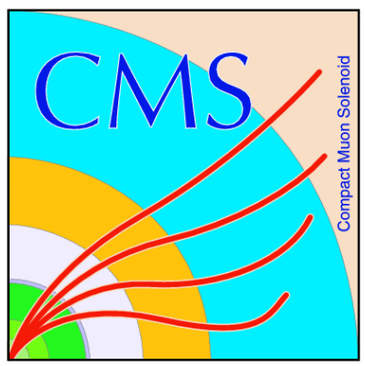
(Re)interpreting the results of new physics searches at the LHC
Imperial College, London
2nd April 2019

What is CMS Open Data about



- **Provide a setup** to do whatever a CMS member did, could have done or could still do with the CMS data, without any formal constraint for non-CMS members
- (Approximately) **reproduce** the **results**, or **produce** new ones
- Modify whatever you want to modify
- Compare to your favourite hypothesis
- Drawbacks:
  - can only be done on already released data sets
  - will probably need a similar **effort** as if a CMS person or group would have done it

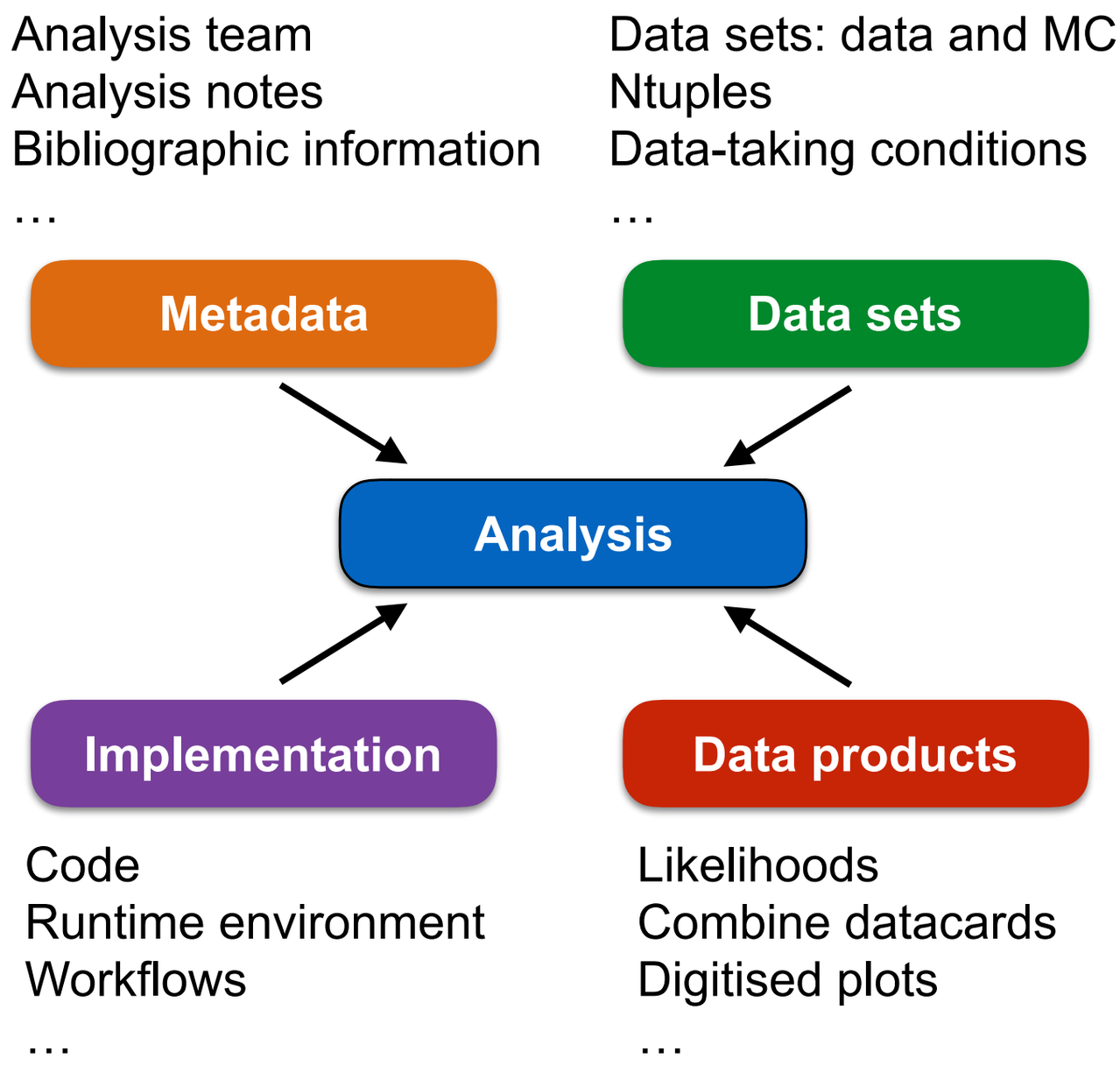
What is CMS Open Data NOT about



- Not a tool to browse existing published CMS results
  - use e.g. INSPIRE-HEP, arXiv, …
- Not a tool to (re)interpret published results by comparing with theory
  - use e.g. HEPData, Rivet, …
- Not a toolbox to recast published results into a different form
  - use recasting tools (see preceding and later contributions)
  - maybe in the future…?

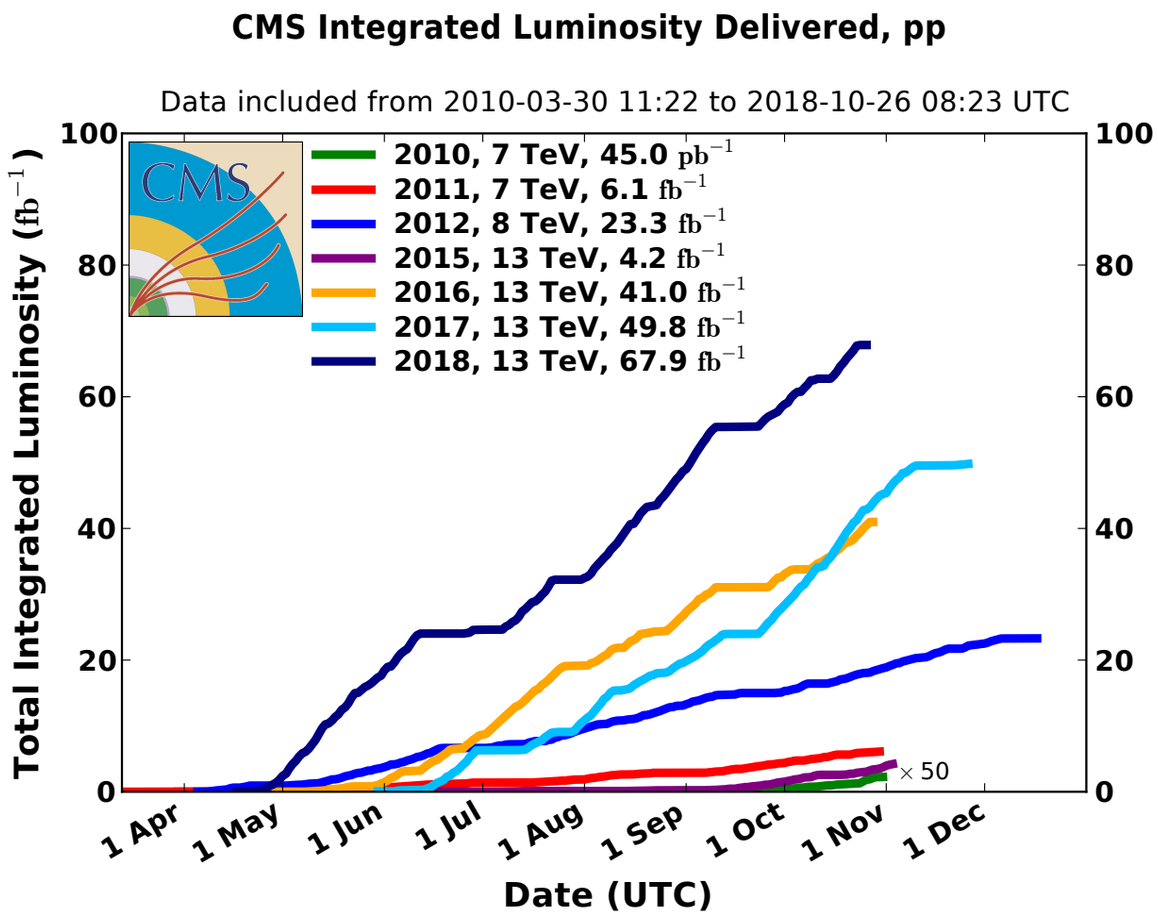
The vision

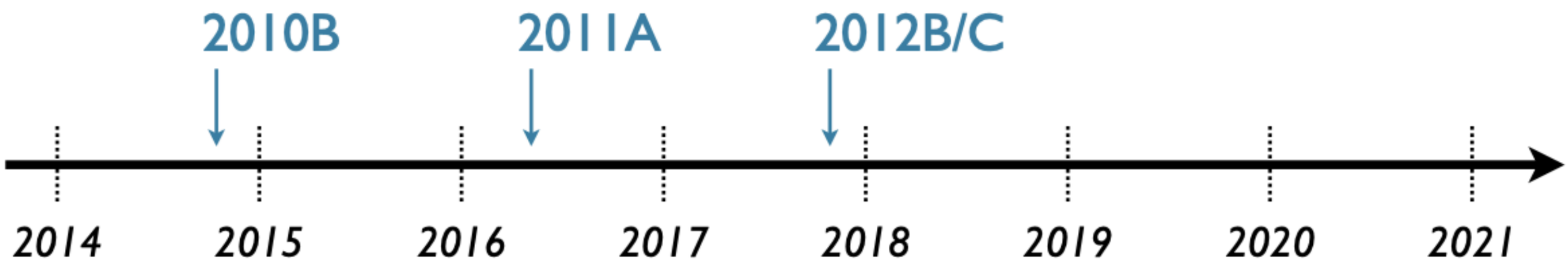
- **Preserve data and knowledge**
- **Open sharing** — data and knowledge more likely to survive if constantly used
- Make data available to school **pupils** and **researchers alike** — allow them e.g. to reconstruct the Higgs discovery
- Mine data to test new theories and provide crucial references



CMS Open Data

- **CMS publishes 50% of its collision data** three years after data taking
  - practically, ~five years after data taking
  - policy updated in 2018 (compare to other LHC experiments)
  - open data are released under the Creative Commons CC0 waiver
- **Up to 100% within ten years**
- Currently available:
  - 2010: 32 pb^{-1}
  - 2011: 2.3 fb^{-1},
  - 2012: 11.6 fb^{-1}





Information on Open Data

CERN Open Data Portal: http://opendata.cern.ch/about/CMS

CMS (DPHEP) **Open Data levels**:

- Level 1: Open access publication and additional numerical data
  - INSPIRE
- Level 2: Simplified data for Outreach and Education
  - Open Data - Education
- Level 3: Reconstructed data and the software to analyse them
  - Open Data - Research
- Level 4: Raw data, and the software to reconstruct and analyse them

higher computational effort

Challenges

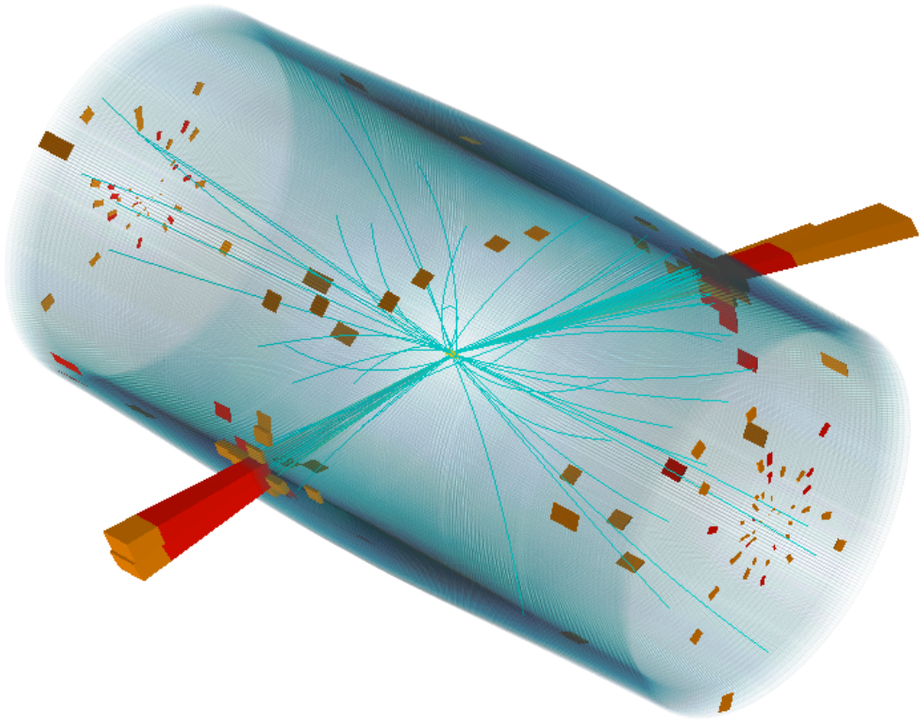
https://www.lojic.org/explore-local-data-through-lojics-new-online-metadata-search

- Need to preserve knowledge
- **immediate metadata**:
  - beam conditions, event and run numbers, provenance information (software versions, reconstruction chains)
- **context metadata**:
  - select correct objects, document them
  - apply further corrections, document them
  - information available at time of analysis, but often not preserved
- Need to collect all information and release it together with the data

Example why preserving a full CMS analysis is difficult

- Take e.g. a “simple” dijet analysis
- Select two jets and calculate dijet invariant mass
- **Jets are complicated**
  - need to be calibrated, need to preserve exact version of jet energy corrections
  - correct energy resolution according to measured differences in data and simulation
  - noise rejection cuts
  - pileup rejection strategies
  - trigger efficiencies
  - …
- **Inputs are from different groups** of people within the collaboration
- Preserve data sets and **exact versions** of reconstruction algorithms used
  - we re-reconstruct our data several times
  - older versions cannot be preserved (but the corresponding software), only latest-greatest versions are kept

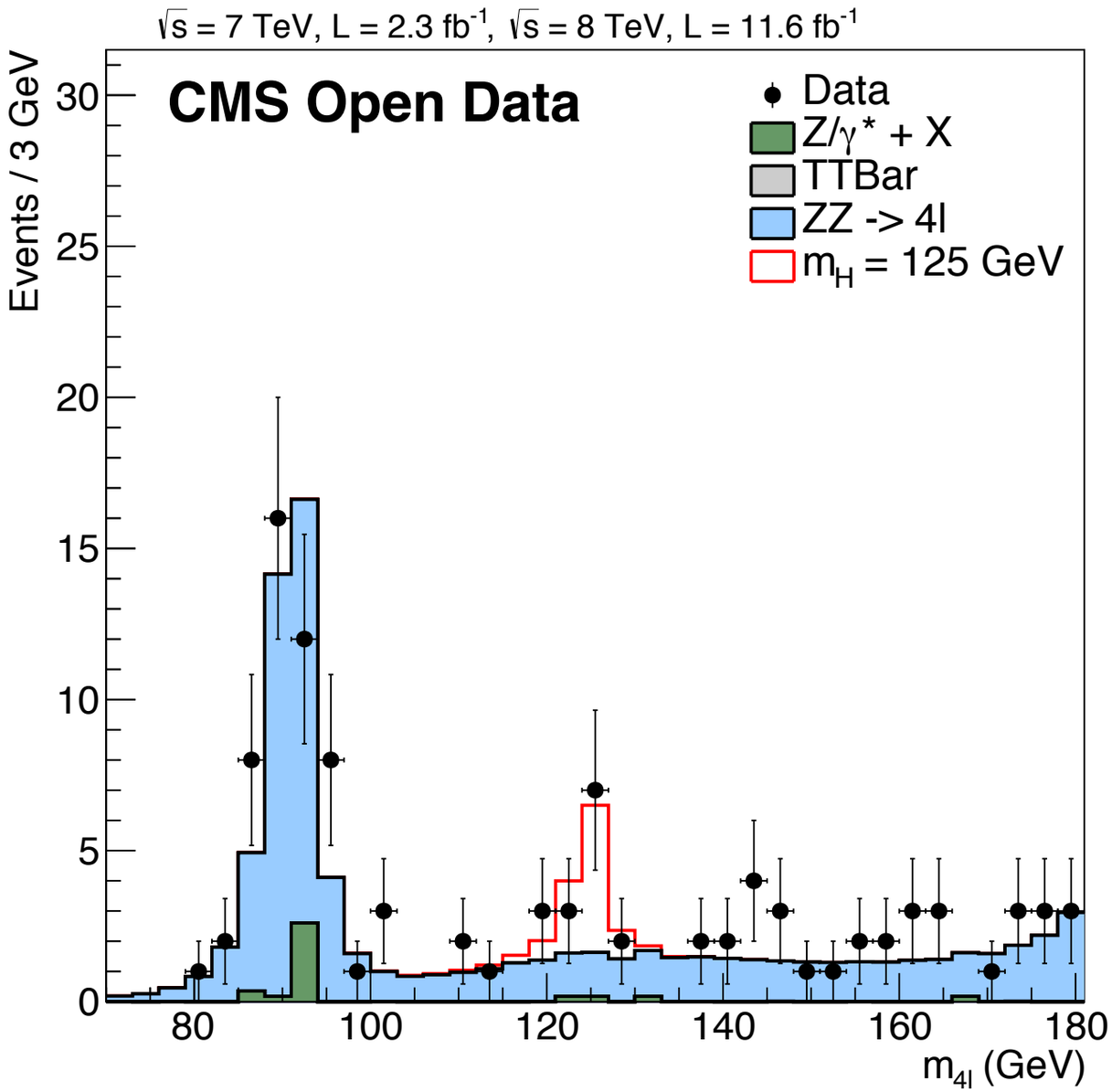
+ conditions of each subdetector
+ selection of “good runs”
+ luminosity
+ …



Can only approximate with reasonable computational effort

What's possible with CMS Open Data

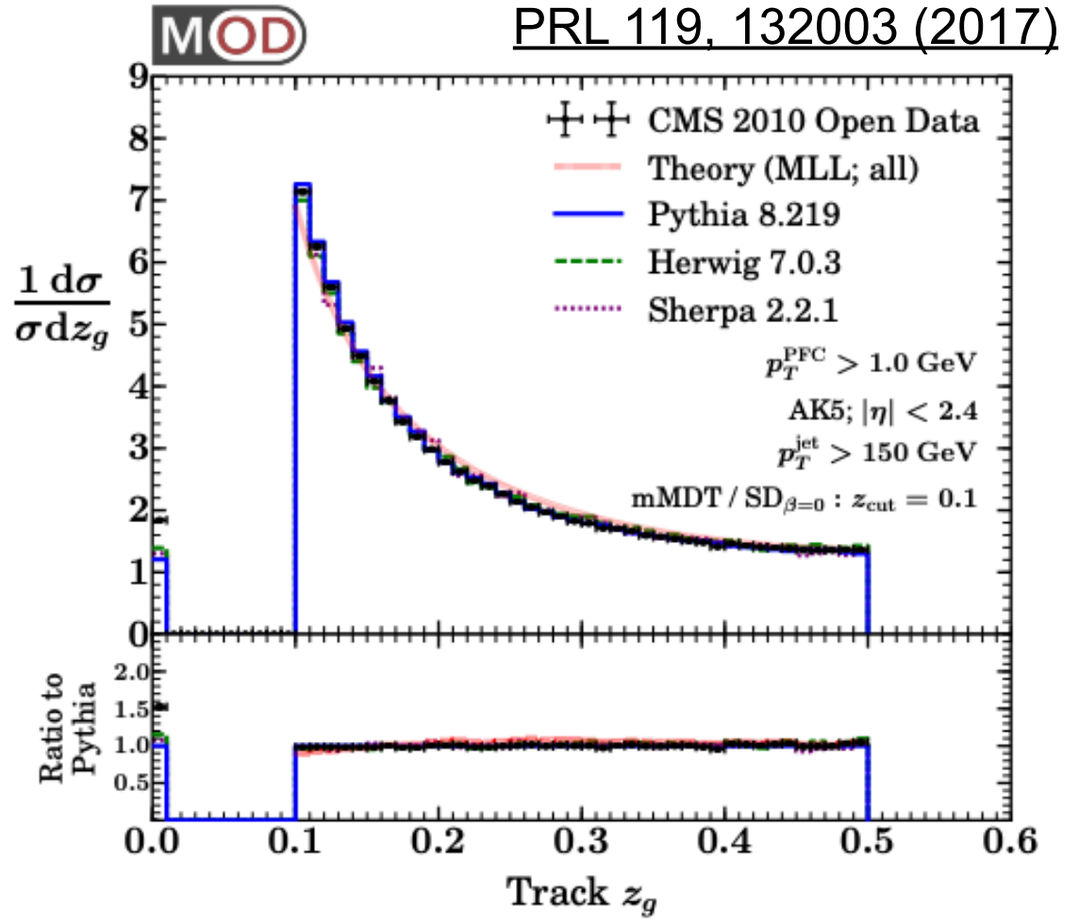
- You can **rediscover the Higgs** boson
  - see e.g. http://opendata.cern.ch/record/5500
- Different levels of computational complexity available
  - from reproducing the plot from pre-processed files
  - to processing ~80 TB of CMS AOD files in CMSSW
- Perform a full-fledged physics analysis!

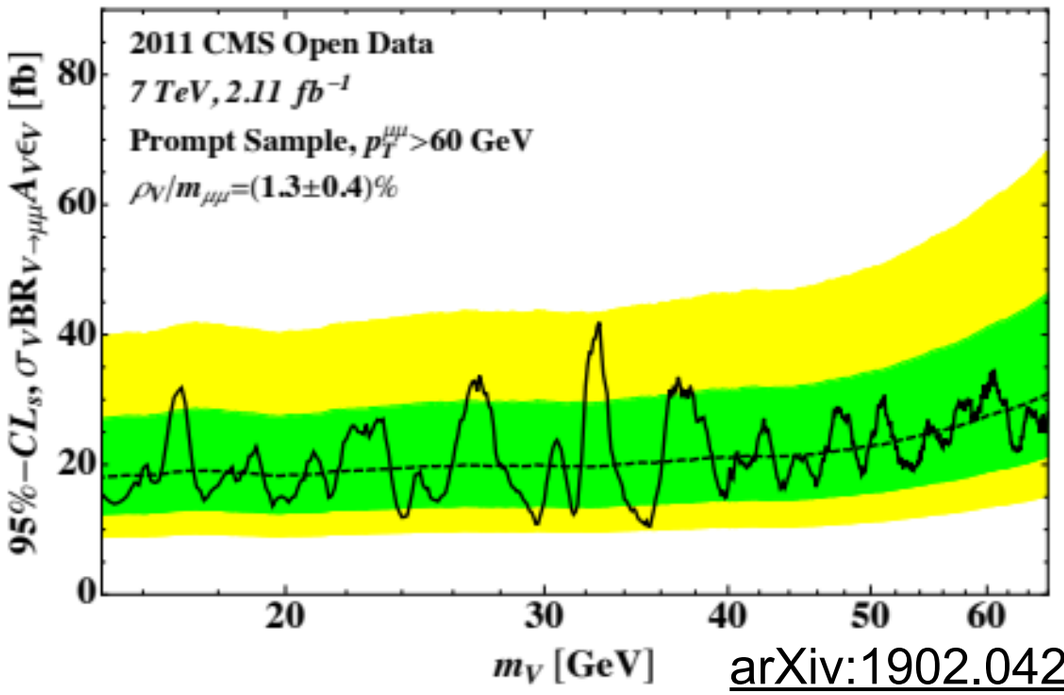


Use of CMS Open Data

- CMS Open Data have been used for physics publications!
  - see e.g. PRL 119, 132003 (2017)
  - and arXiv:1902.04222
- And also for physics education
  - see e.g. Particle Physics Playground, masterclasses, …
- Reaction to use of CMS Open Data within CMS are **uniquely positive**
- We are aware that there are groups that have started to study the CMS Open Data, but have given up because of difficulties
- Rather difficult to analyse the data without **CMS-knowledge**/expertise in **experimental HEP data analysis**
  - planning a **workshop aimed at theorists**

PRL 119, 132003 (2017)





arXiv:1902.04222

Feedback from use of CMS Open Data

- See Phys. Rev. D 96, 074003 (2017) and response at workshop in October 2017 + arXiv:1902.04222
- **Scattered information**: trying to improve Open Data web interface (with CERN scientific information service)
- **Lack of validation examples**: added several more examples, continuously adding more
- **Information overload**: working on simplifying the data formats
- **Presence of superfluous data**: adding documentation on how to filter data sets more efficiently
- **Corrections documented in publications not directly applicable**: see previous slides
- **Provenance information not always complete**: available for most analyses
- …

Bottom line: **simplify/facilitate use of Open Data**

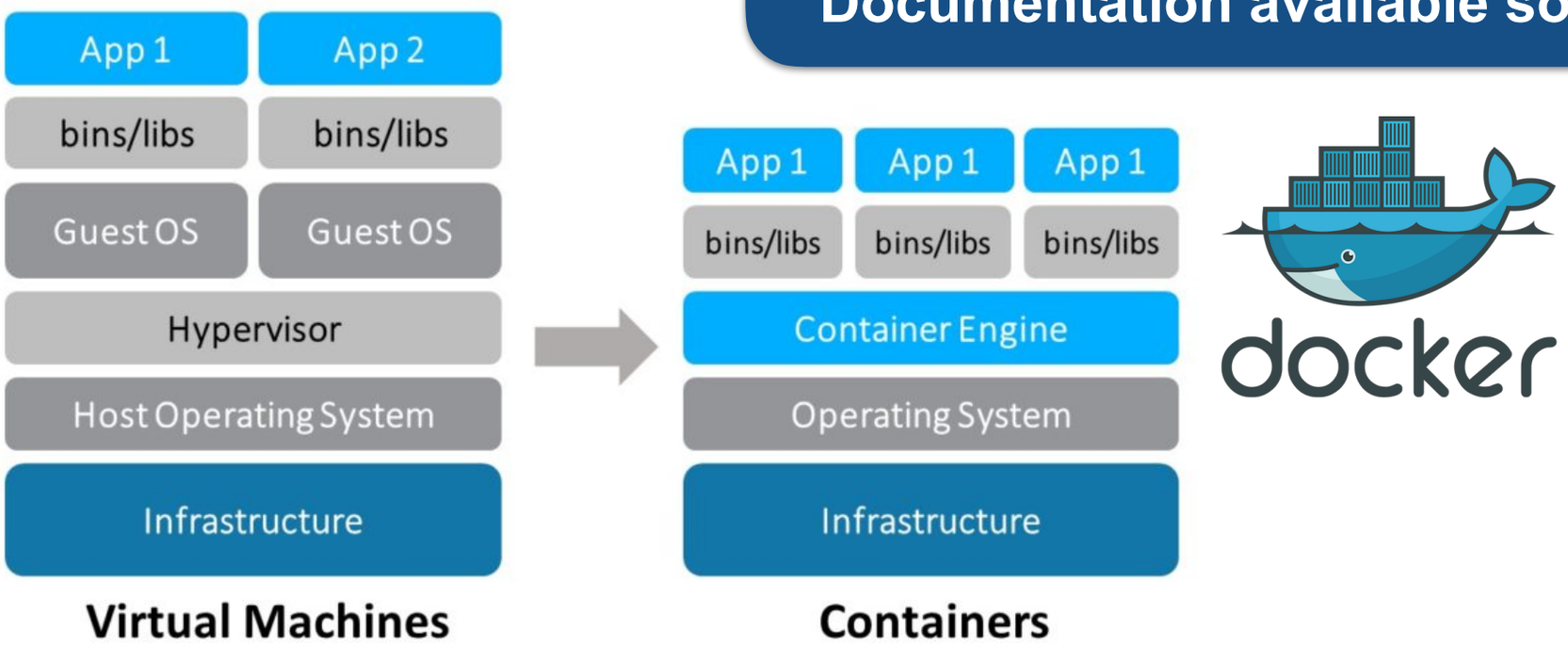
Simplify data formats

- Most of CMS open data users do not necessarily want to **learn CMSSW**
- "Get rid of CMSSW" as soon as possible
- ➜ Developing Physics Object Extractor code
- Improving documentation and tools to get scientific results from experimental data
  - Luminosity calculation
  - Experimental methods (tag & probe, MVA…)
  - MC generation
  - Improving/expanding trigger analysis examples
  - …
- Moving towards object-level formats: AOD ➜ MiniAOD/NanoAOD
  - examples will be provided

Software containers vs. virtual machines

- Previously provided on virtual machines with CMSSW installation
  - …and will continue to do so
- **New**: Docker software **containers**
  - allow to preserve full analysis
- Can run these containers on HPC-platforms
  - e.g. using Kubernetes **orchestration**
- Currently working on defining **workflows** (e.g. within **CERN REANA project**)
  - run physics analysis steps

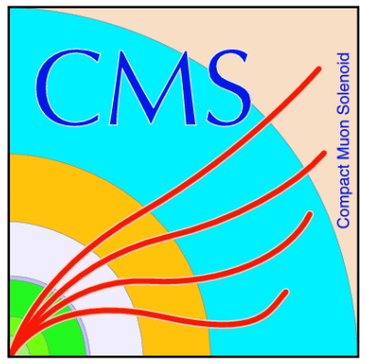
Documentation available soon!



Upcoming data releases

- Provide examples and data sets for use in **machine learning**
  - including their production workflows
- New documentation for **MC production**
  - enable production of custom MC for anyone with the required resources
- Publish **rest of 2010 collision data** and additional 2010 simulation
  - also improved metadata for all 2010 data
- Provide further **2012 simulation samples**
- Improved provenance information and new search functionalities for MC, ”on demand” MC
- First **CASTOR data** (with corresponding metadata and instructions)
- … and more to come later

Summary



- CMS is **leading the LHC Open Data effort**
- We are trying to facilitate the use of CMS Open Data
  - improved documentation and software tools + containers
  - simplified data formats
  - planning on organising a workshop aimed at theorists
- Release of new data imminent
- Please let us know if you have any feedback!


CERN