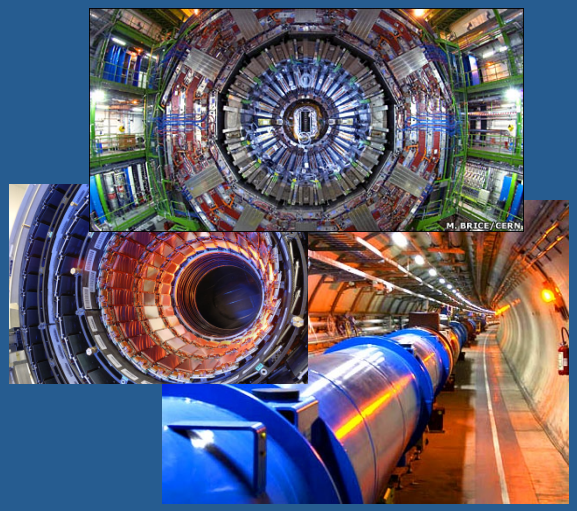
Status of the CMS Experiment



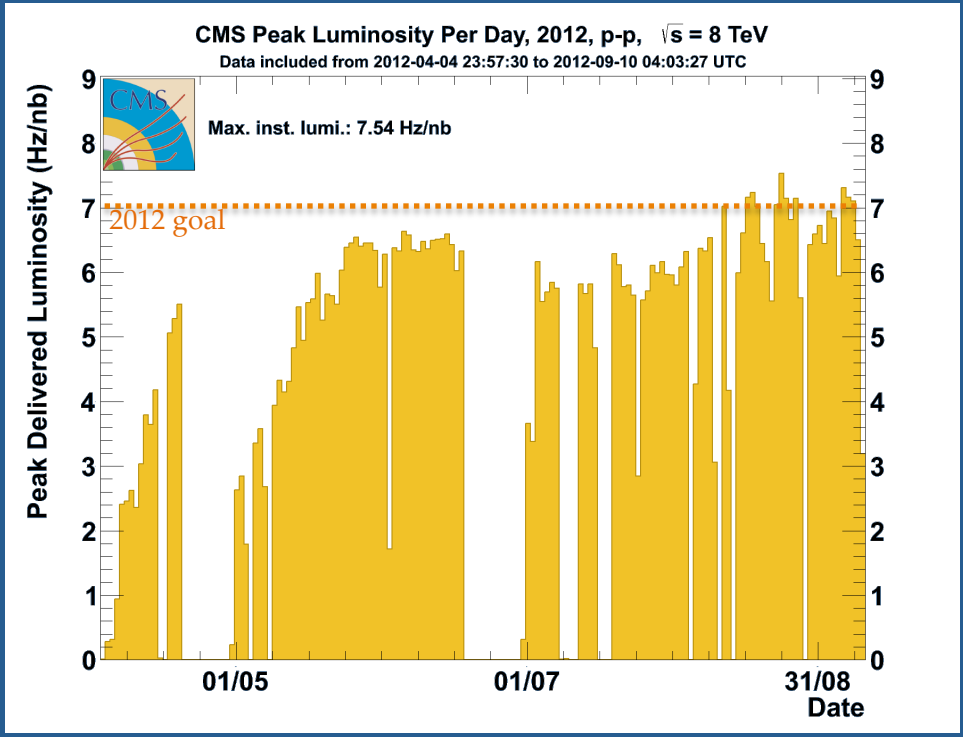
Chris Neu
University of Virginia

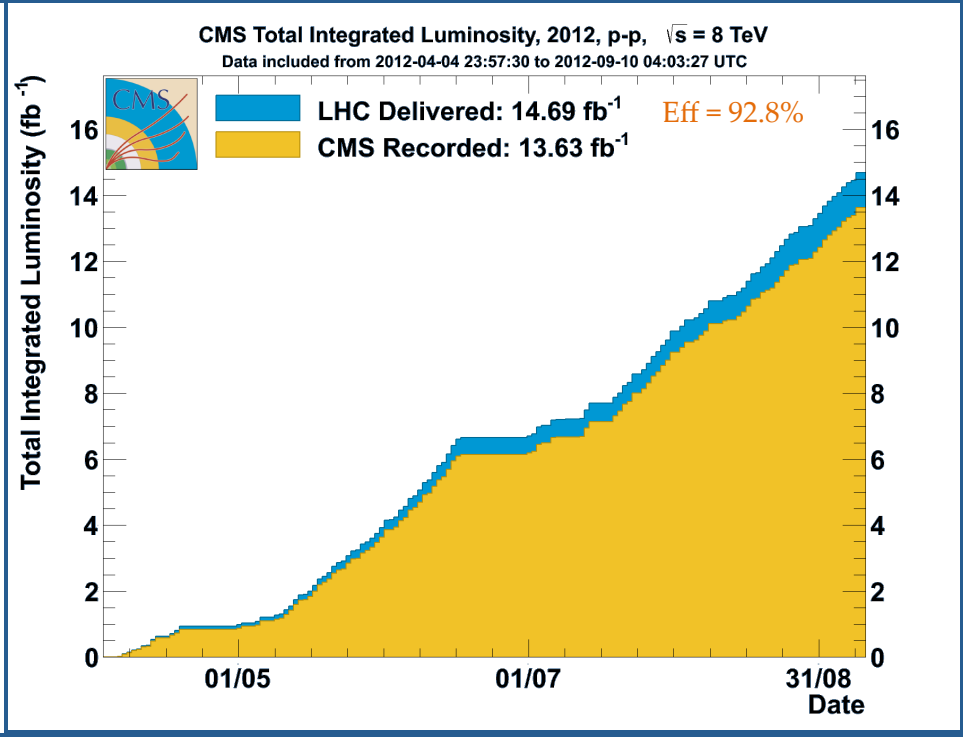
On behalf of the CMS Collaboration

TOP2012:
5th International Workshop
on Top Quark Physics

Winchester, Hampshire, UK
17 September 2012

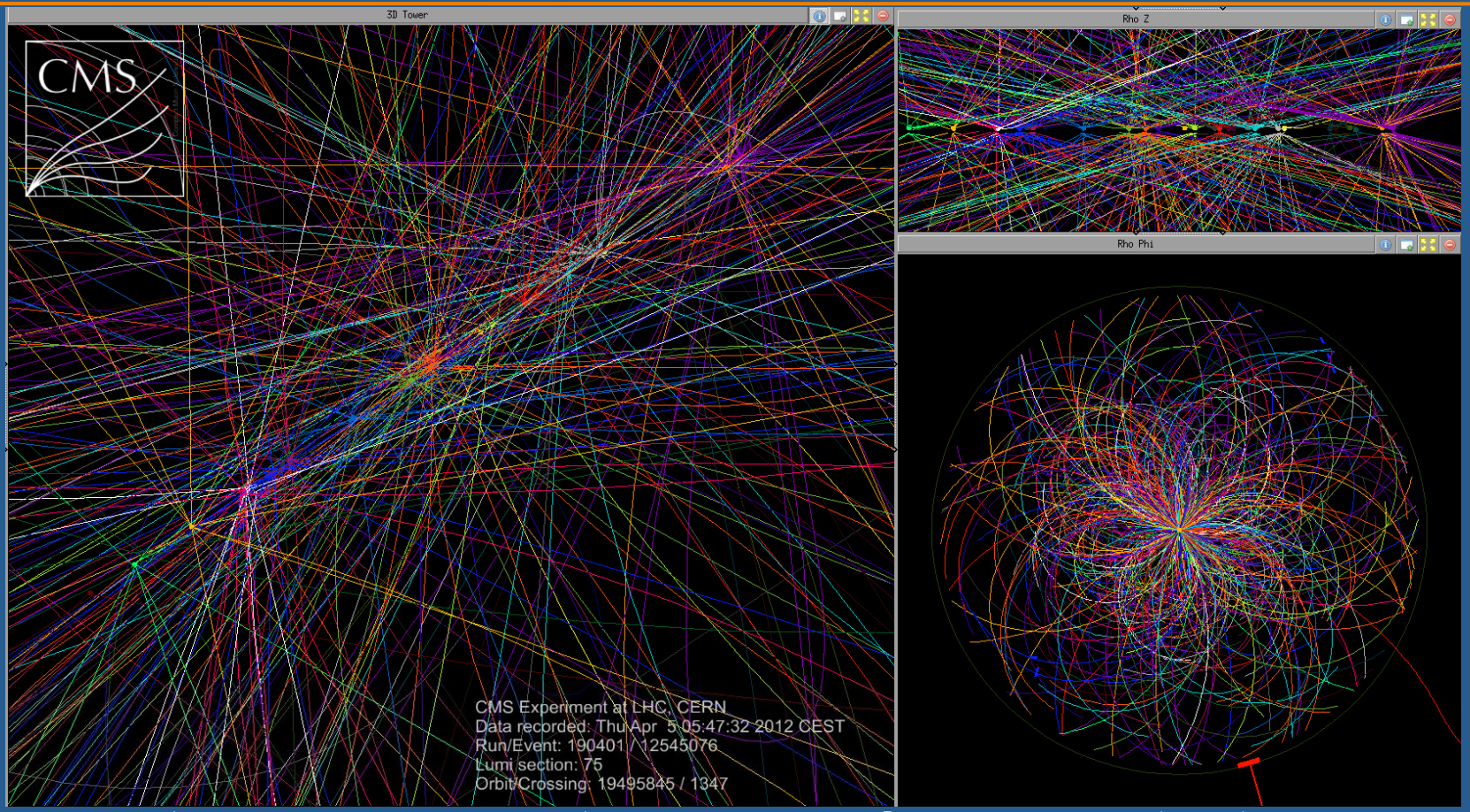
The Status of CMS Starts with the LHC…





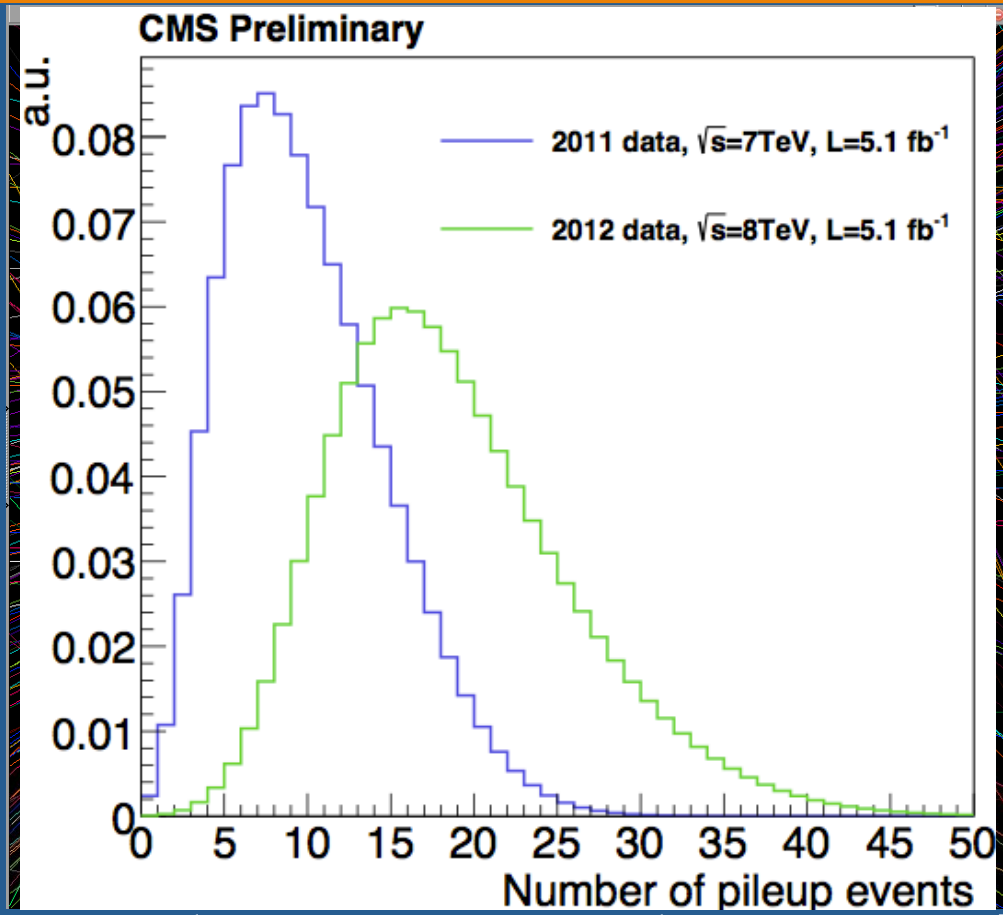
- Incredible performance of LHC in 2012:
  - Instantaneous luminosity goal of 7E33/cm^{2}s achieved in August
  - LHC running stably and integrated luminosity steadily increasing
    - Current average: 1/fb per week
    - Nine more weeks in 2012-13 p-p run → ~22/fb in total 8 TeV data sample

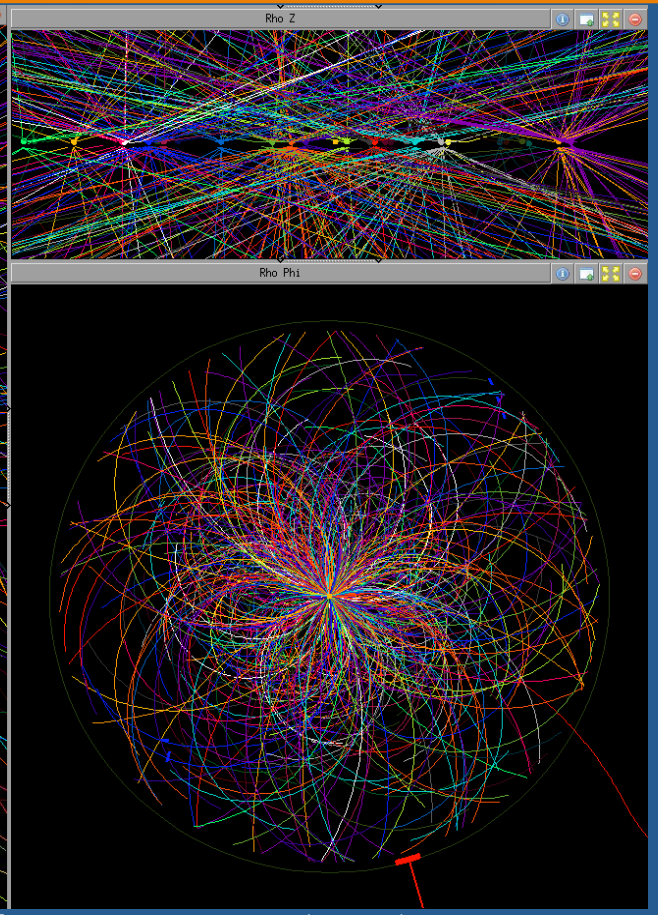
LHC Performance Poses Challenges



- High instantaneous luminosity → increased pileup
- Example: ~16 primary vertices
  - Complicated environment – but actually quite common
  - Observed events with up to *78 reconstructed vertices*

LHC Performance Poses Challenges





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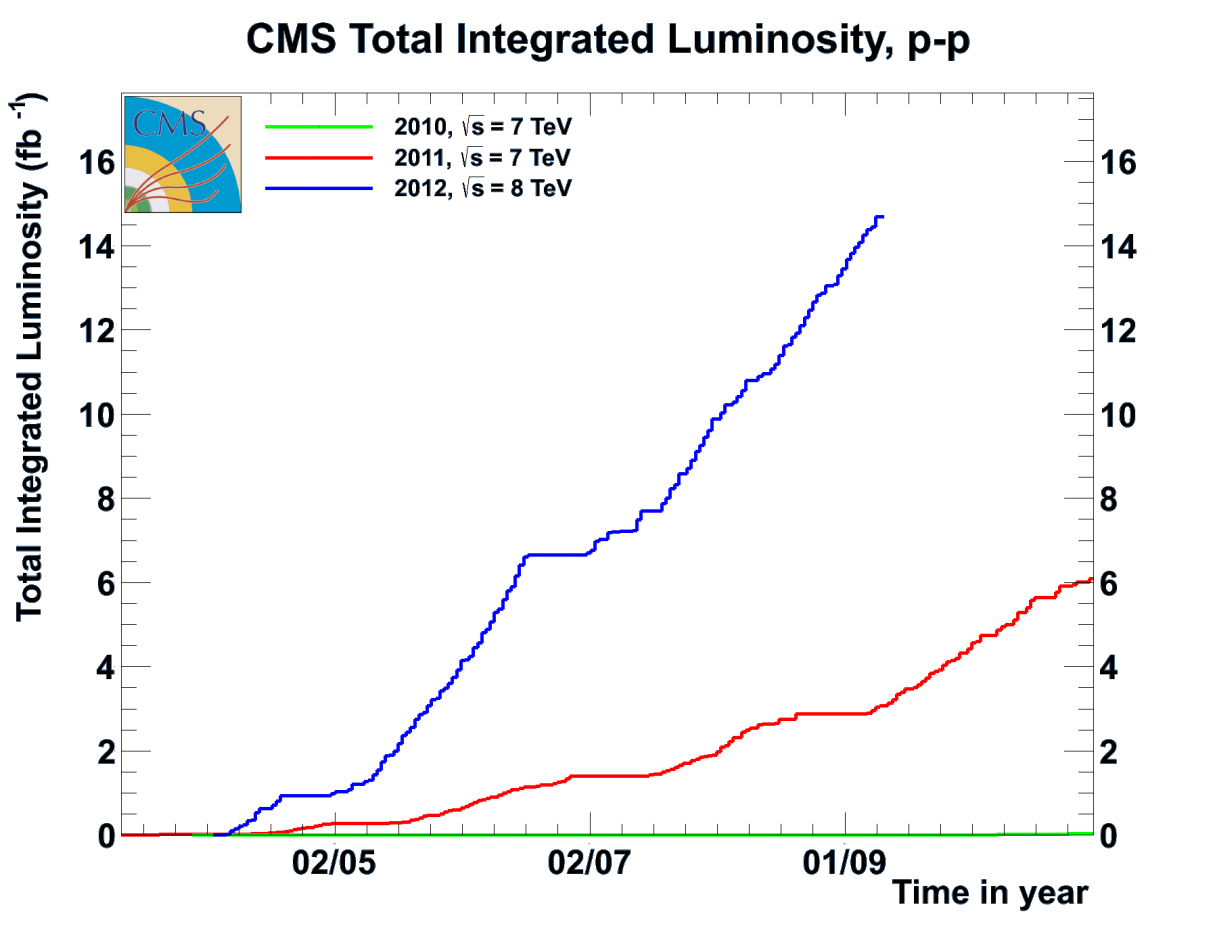
The Cumulative CMS Data Sample and Top

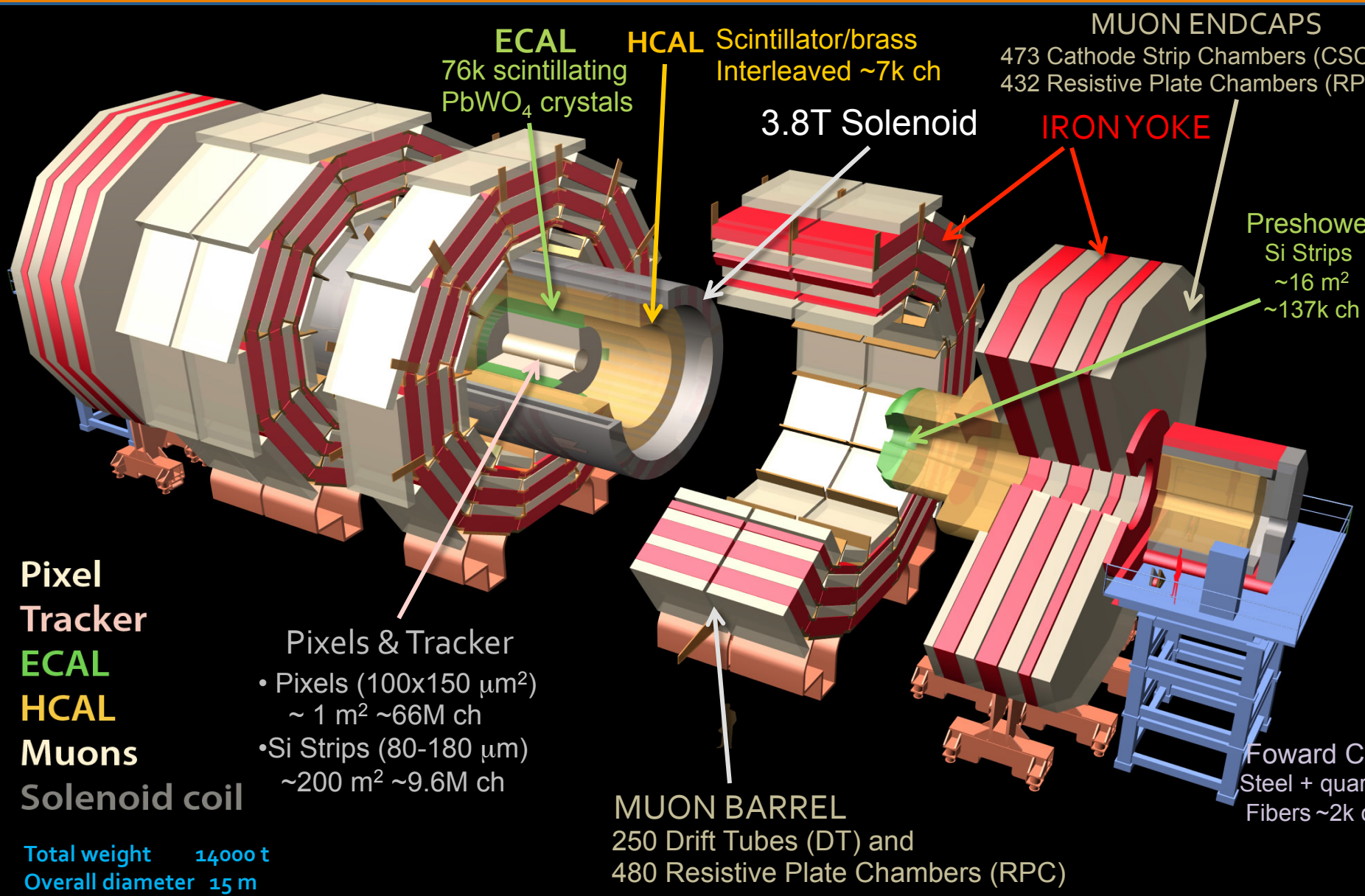


Experiment, Era	Ttbar Yield
CDF, D0 (1.96 TeV, 10/fb)	71k
CMS, ATLAS (7 TeV, 5/fb)	825k
CMS, ATLAS (8 TeV, 5/fb)	1.2M

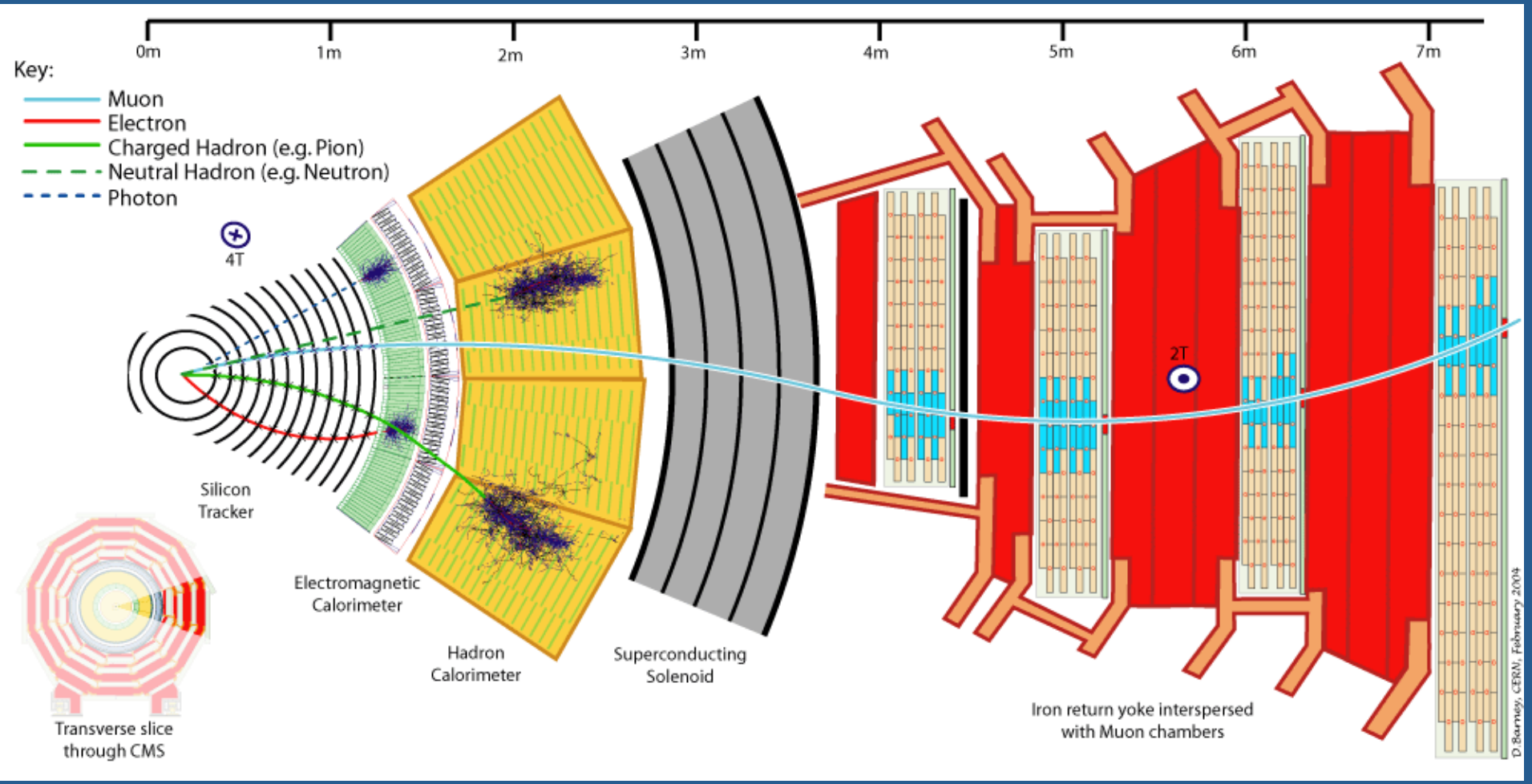
Large LHC data samples = large samples for top-quark studies.

Complementarity of LHC and Tevatron programs

The CMS Detector

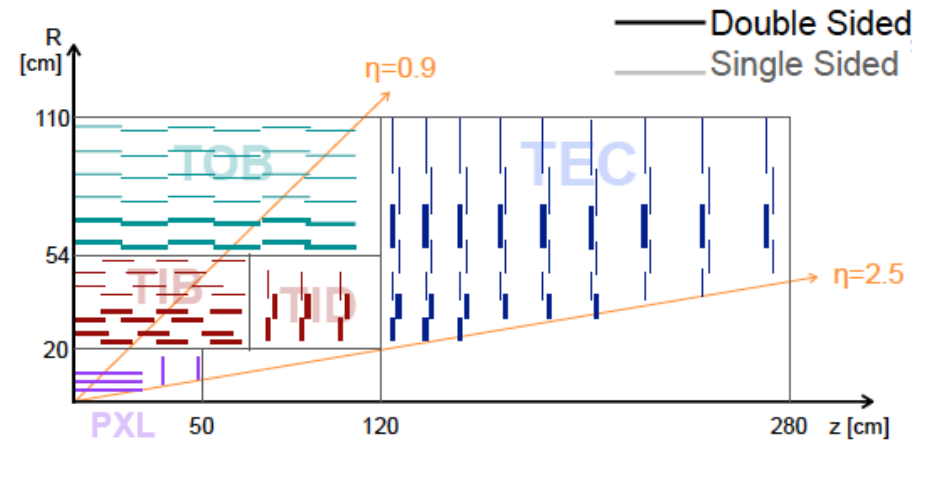


Particle Detection and Subsystems



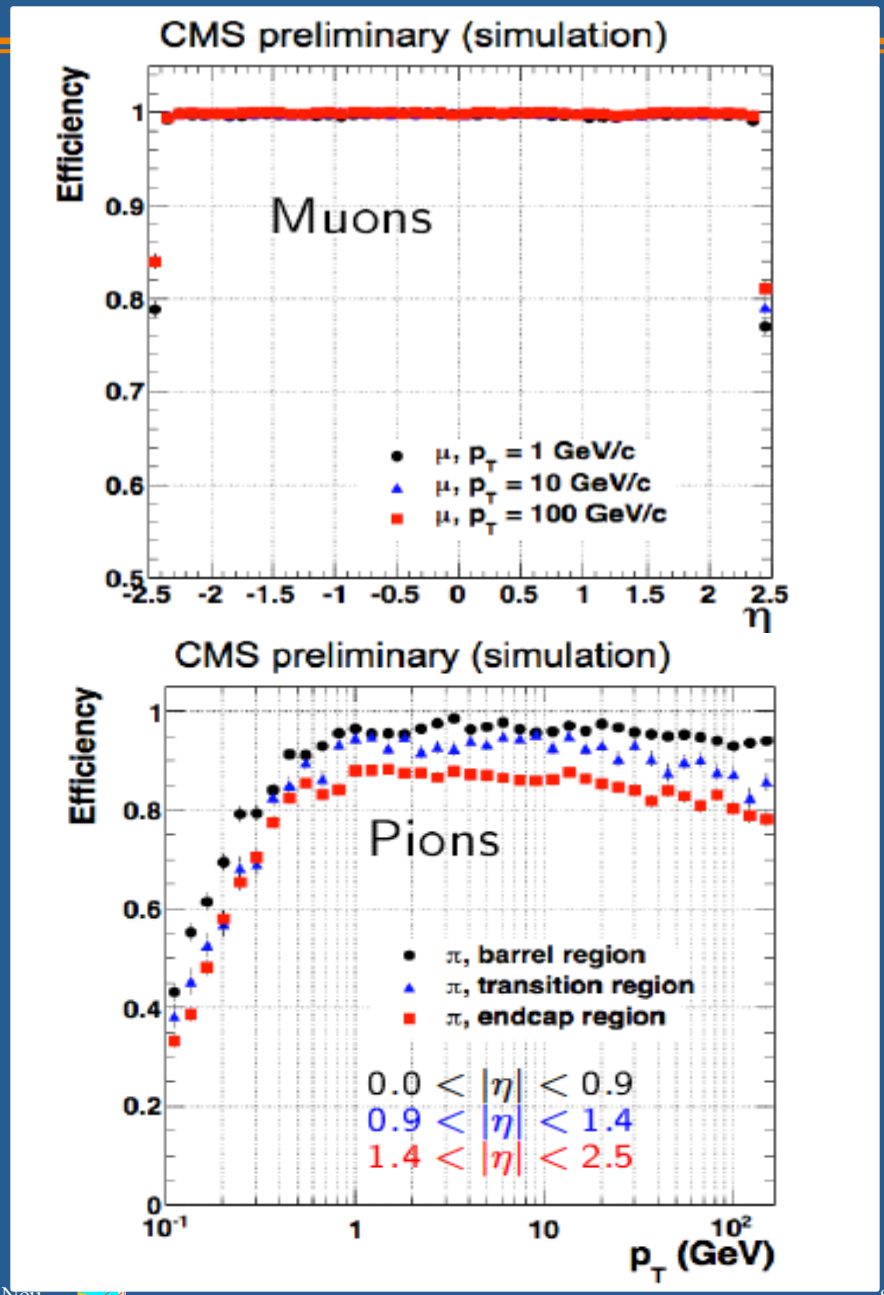
Detecting the top-quark signature utilizes nearly every CMS subsystem

Charged Particle Tracking



- Pixels: 1.1 m^2 total area,
  - 66M channels, 97% working
  - Sensor size: 100 μm x ~ 150 μm
  - Hit resolution:

    11.2 μm (trans.), 26.8 μm (long.)
- Strips: 198 m^2 total area
  - 9.6M channels, 97.5% working
  - Strip pitch: 85-205 μm
  - Hit resolution: 16 - 40 μm



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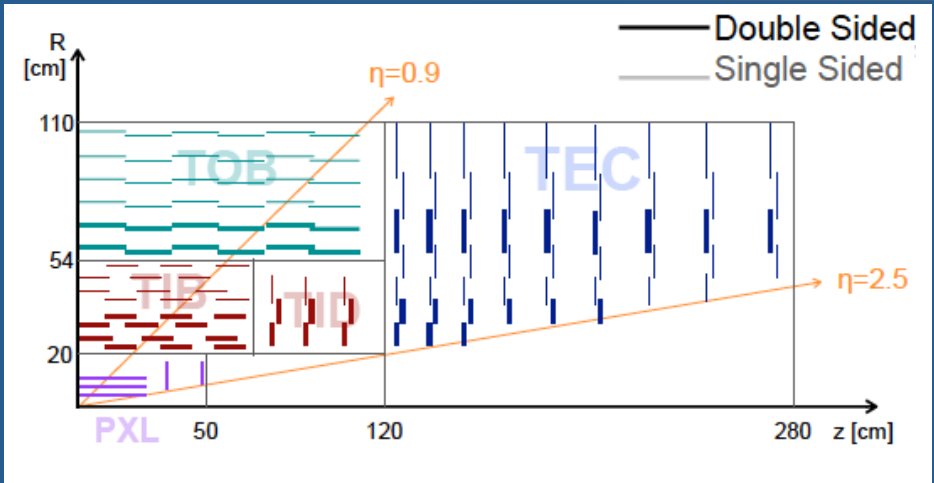

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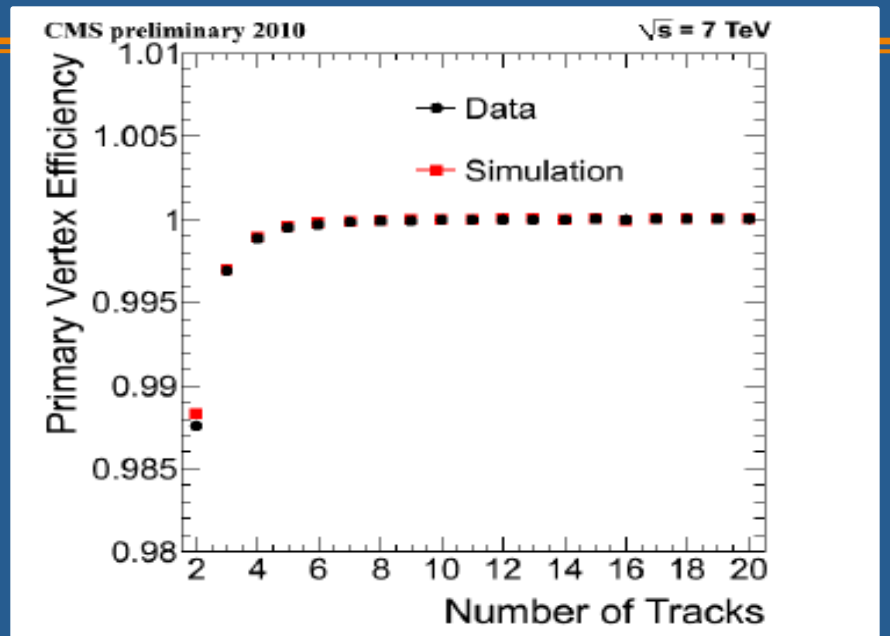
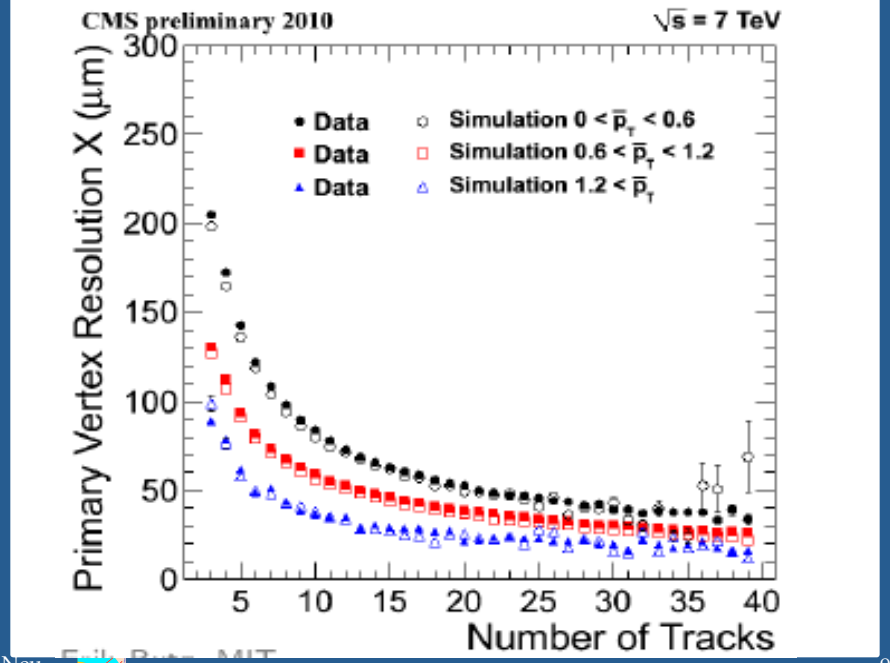
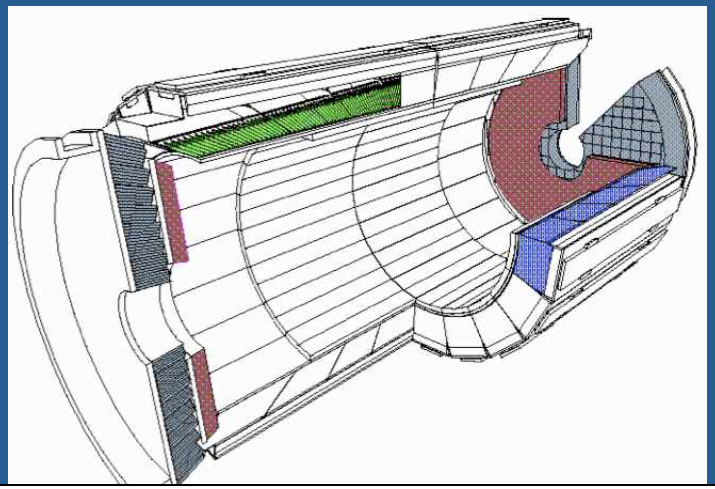
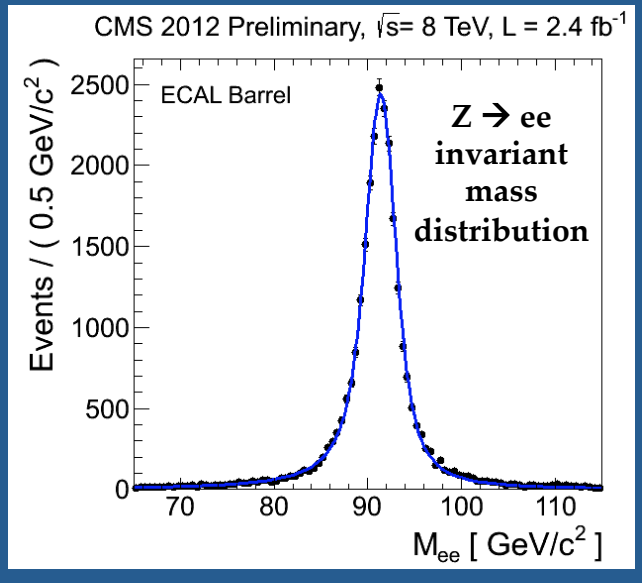




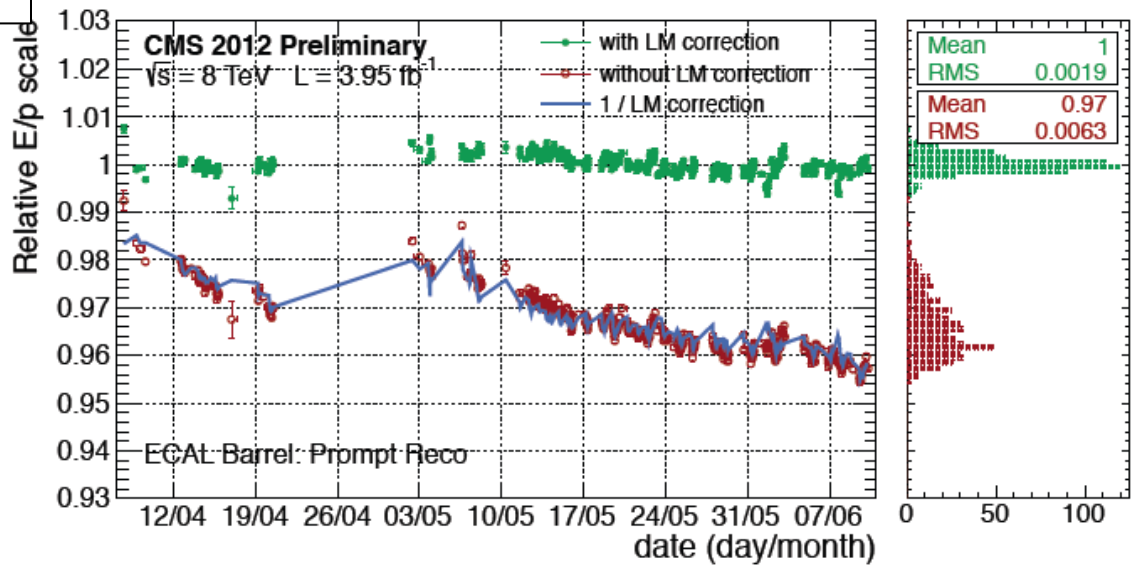
ECAL



$$\frac{\sigma(E)}{E} = \frac{2.8\%}{\sqrt{E(\mathrm{GeV})}} \oplus \frac{0.128}{E(\mathrm{GeV})} \oplus 0.3\%$$



- ECAL: ~76k $PbWO_4$ crystals ~$26X_0$ deep
  - Barrel: $|\eta| < 1.479$
  - Endcap: $1.479 < |\eta| < 3.0$
- Preshower: 20cm thick Si/Pb layers
  - $1.653 < |\eta| < 2.6$

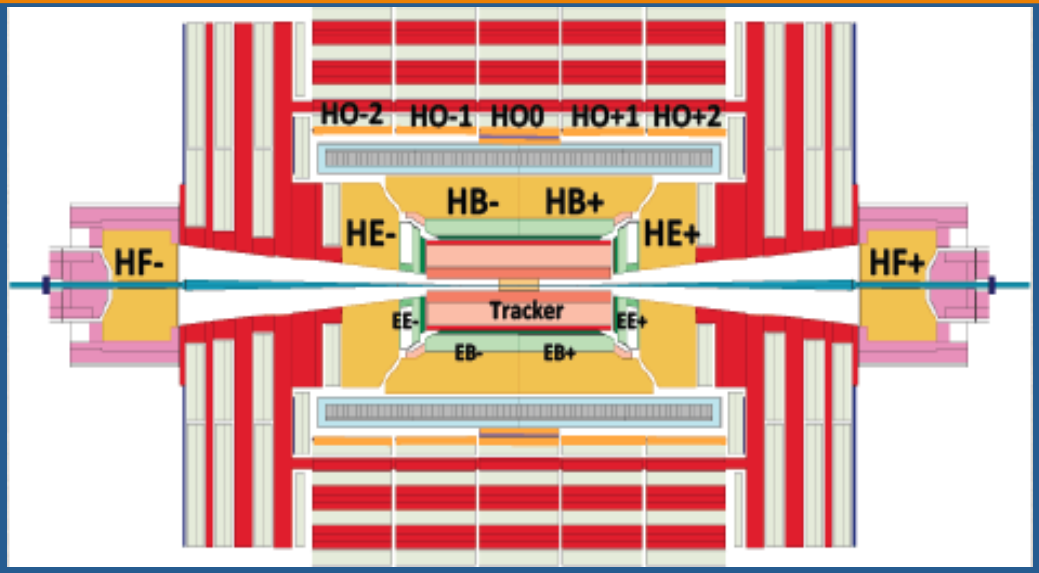


HCAL

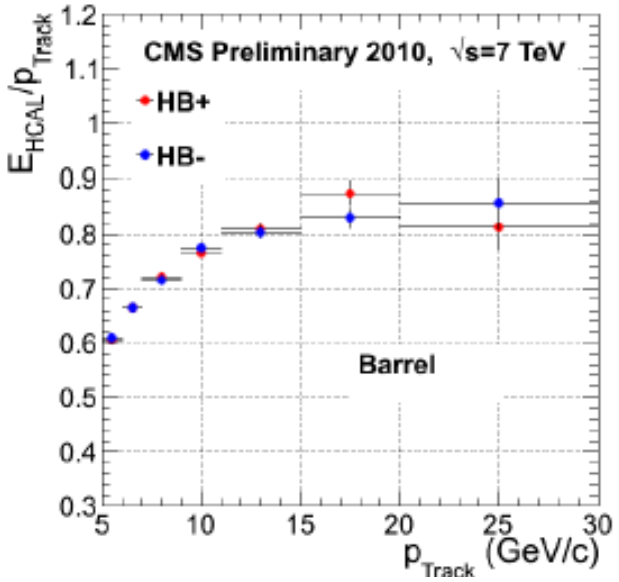
- Mostly brass/scintillator hermetic sampling calorimeter
- Jet energy resolution:

  $dE/E \sim 120\%/\sqrt{E} + 6.9\%$
- Jet angular resolution:

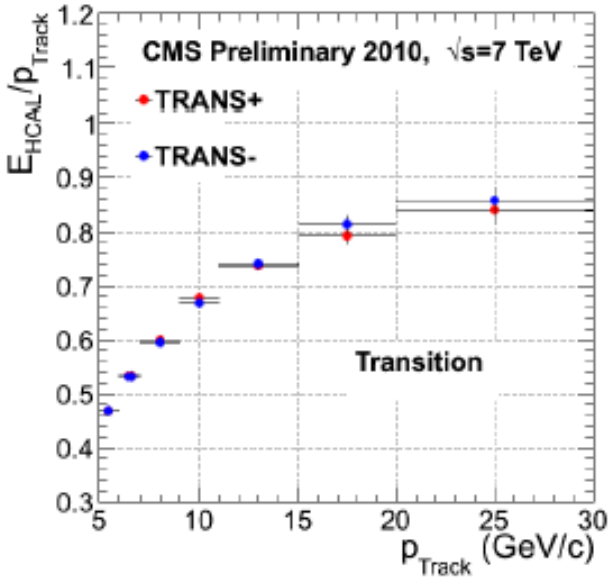
  20 mrad in φ, 30 mrad in θ



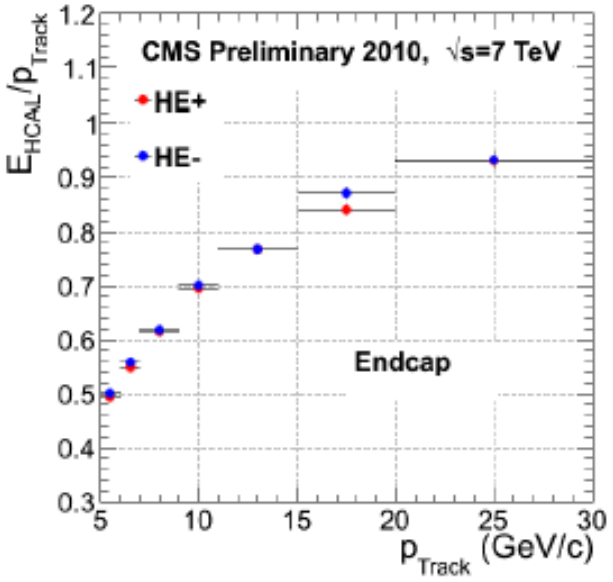
Mean response for pT>5 GeV tracks:



$|\eta| < 1.1$



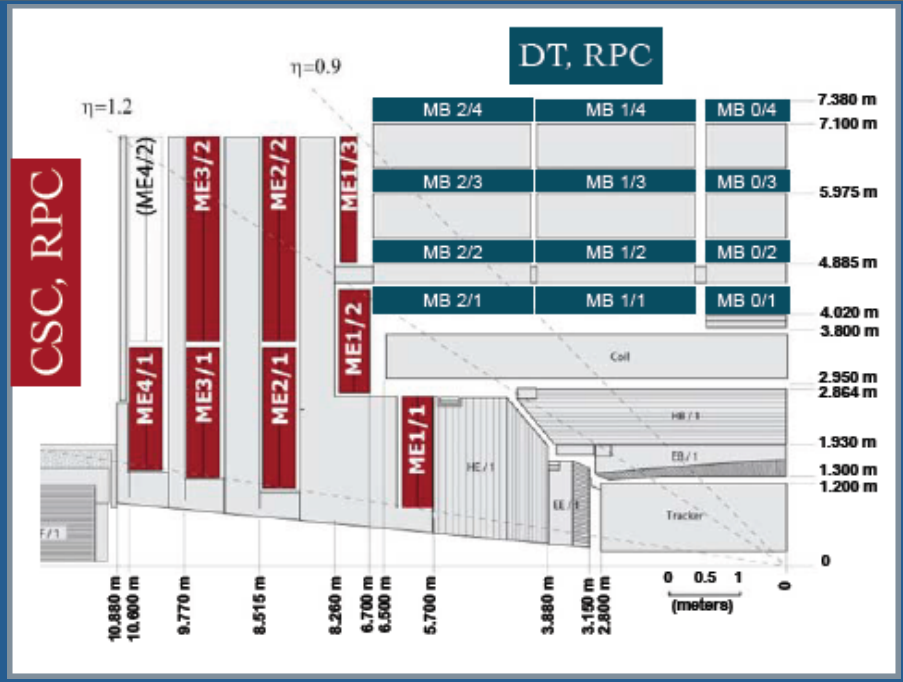
$1.1 < |\eta| < 1.7$



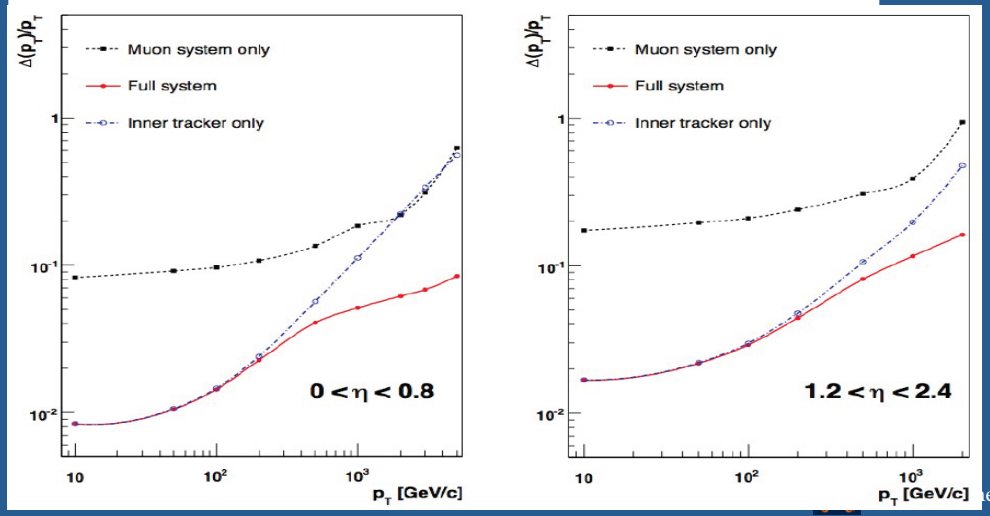
$1.7 < |\eta| < 2.2$

Muons

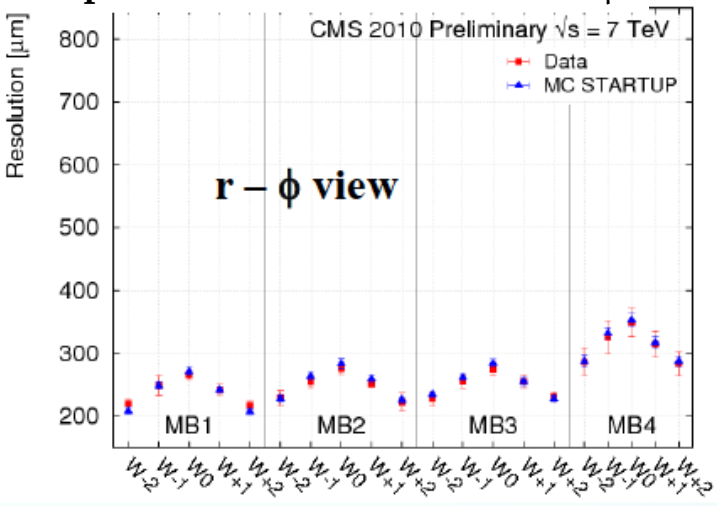
- Drift Tubes: $|\eta| < 1.2$
  - 4 tracking stations measure trajectory in **r-ϕ** and **r-z**
- Resistive Plate Chambers: $|\eta| < 1.6$
  - 6 layers in barrel; 3 layers in endcap
  - Provide fast timing information
- Cathode Strip Chambers: $0.8 > |\eta| < 2.4$
  - 3-4 tracking stations
- Shielding: 10-20 λI → low punch-through



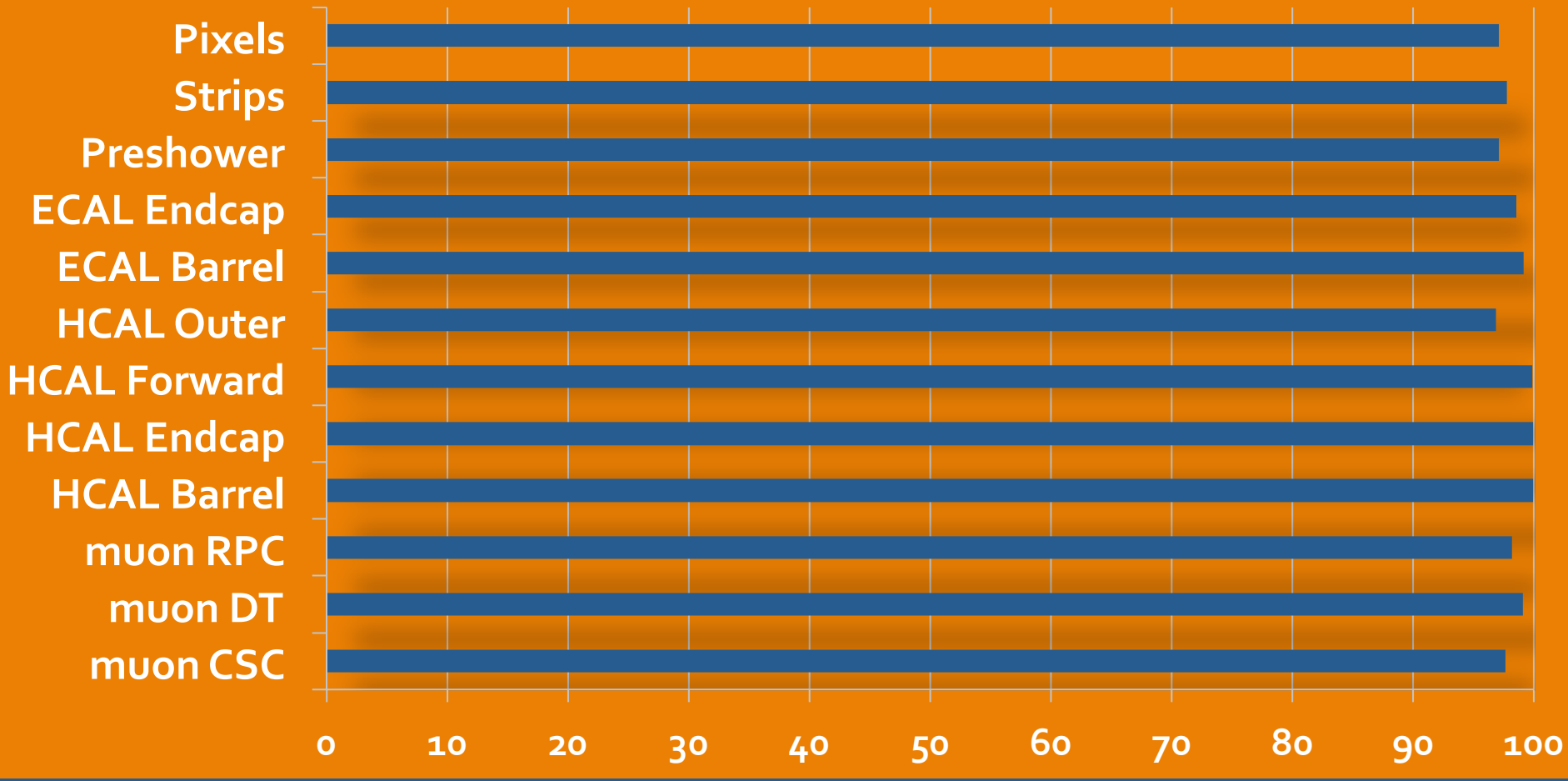
Muon pT resolution for combined measurement



DT spatial resolution: ~250um in r-ϕ



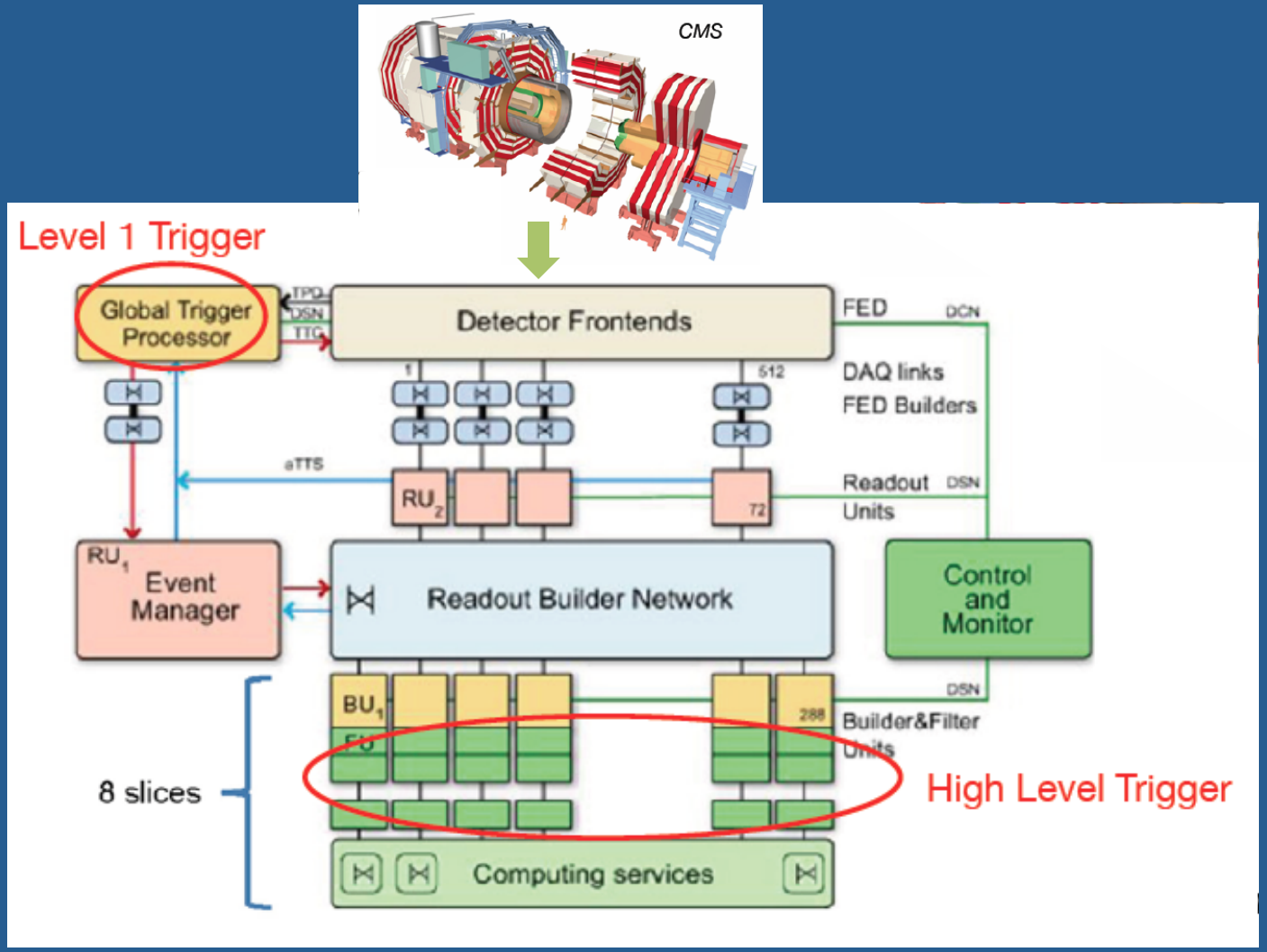
Particle Detection and Subsystems



Pixel Tracker	Strip Tracker	Pre shower	ECAL Barrel	ECAL Endcaps	HCAL Barrel	HCAL Endcaps	HCAL Frwrd	HCAL Outer	Muon DT	Muon CSC	Muon RPC
97.1%	97.75%	97.1%	99.16%	98.54%	99.92%	99.96%	99.88%	96.88%	99.1 %	97.67 %	98.2%

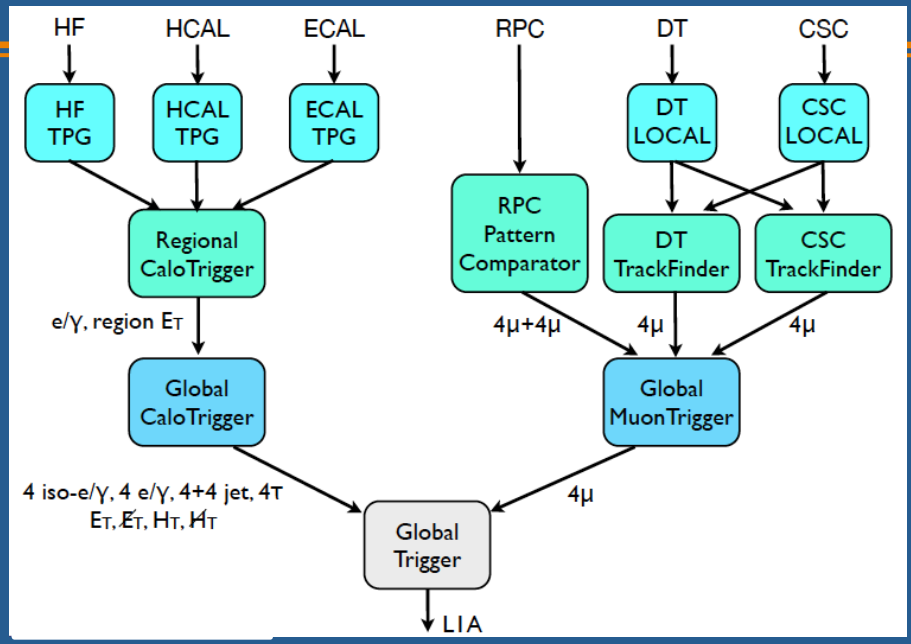
Trigger Overview

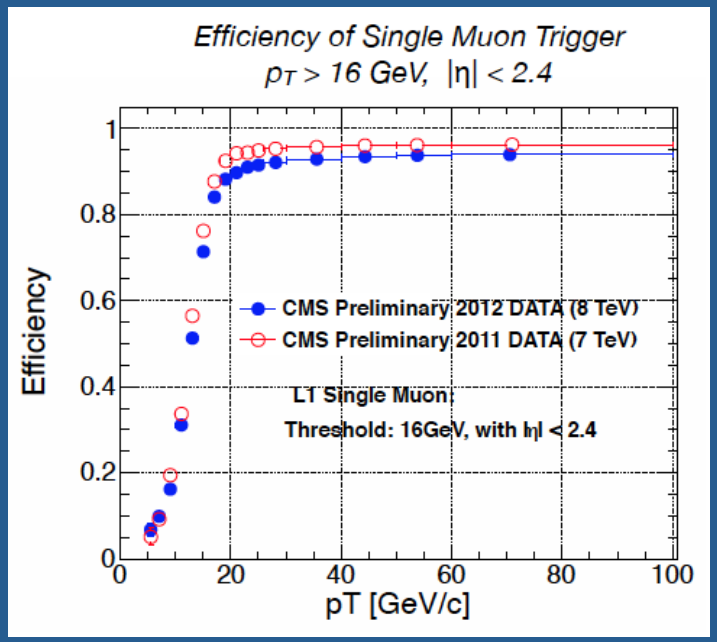
- Two-level trigger system

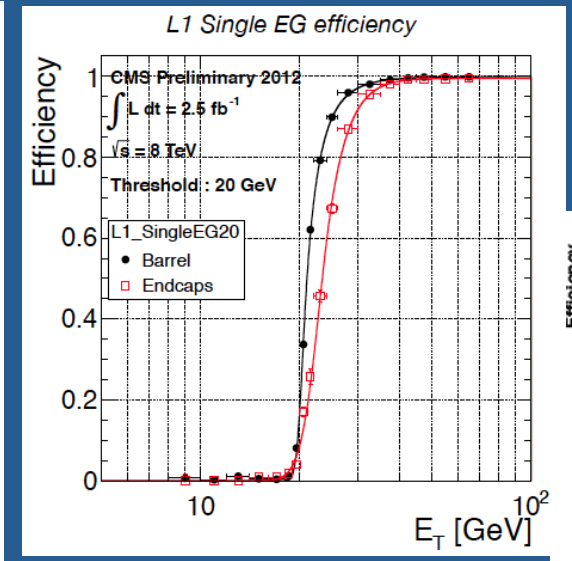


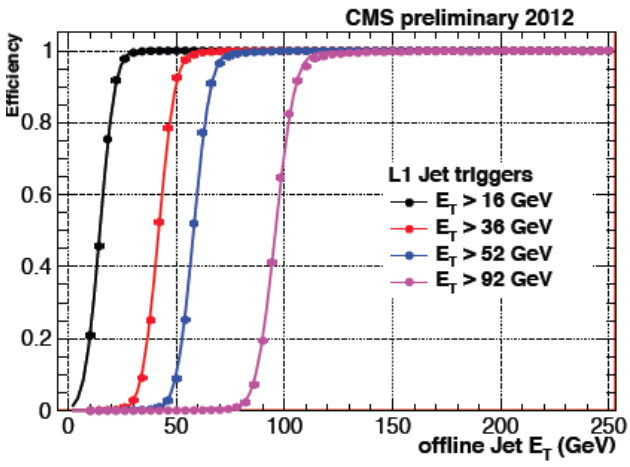
The L1 Trigger

- L1: 40Mhz → 100kHz
  - implemented in dedicated hardware
  - inputs from calorimetry and muon systems
  - deadtime ~3%



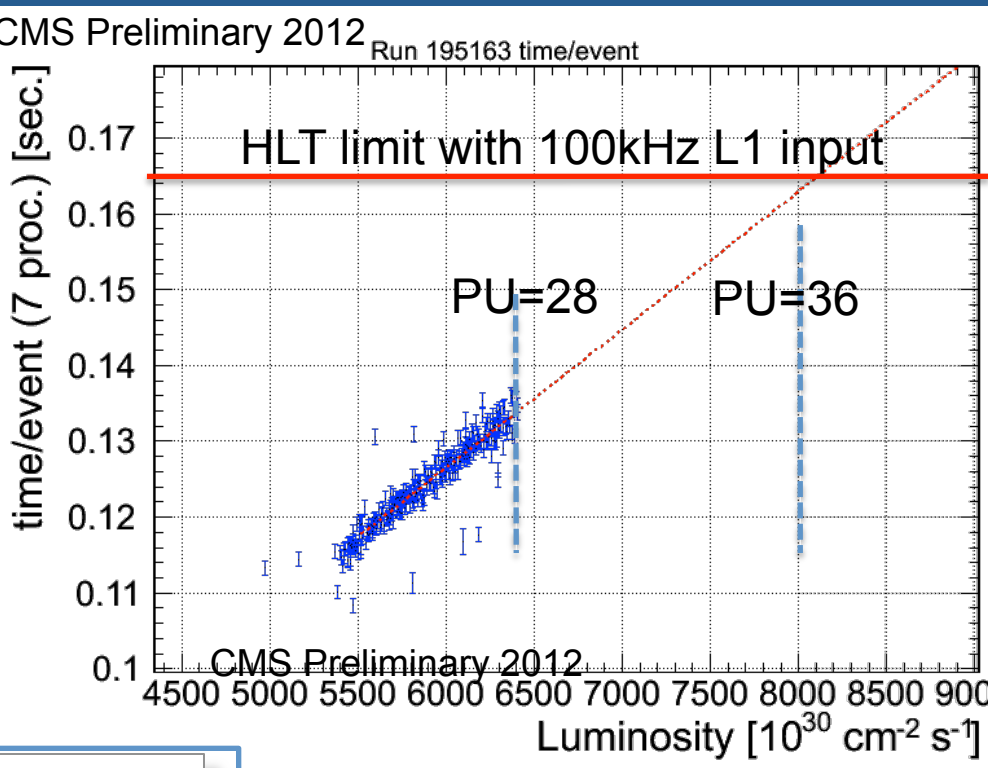


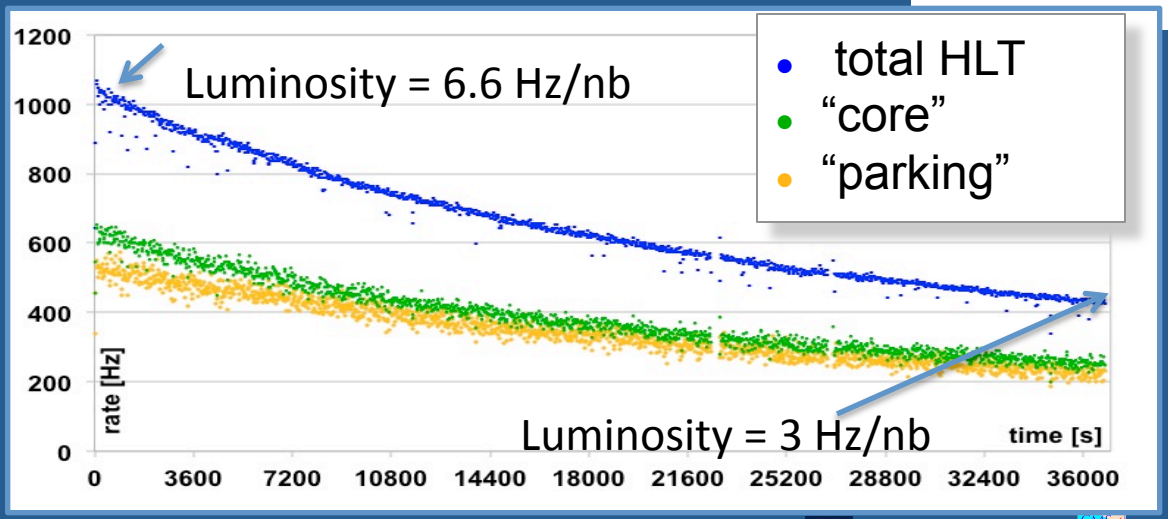


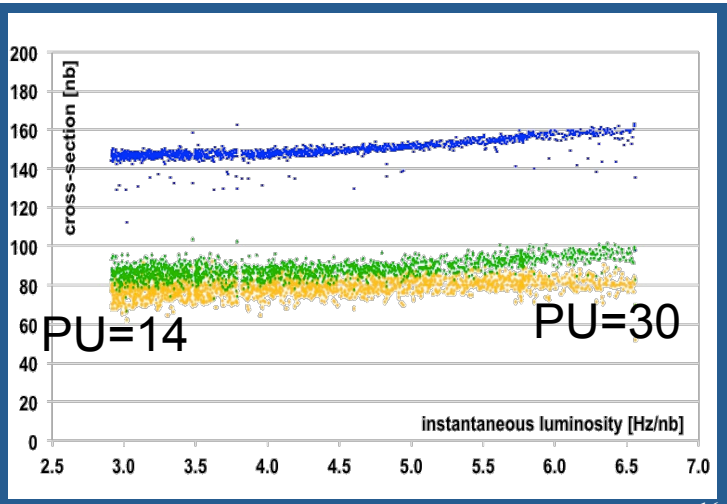


High-Level Trigger

- Implemented in dedicated processing farm
  - 13k CPUs, 20k event-processors (hyperthreading)
- Data from all detectors available
- Trigger object similar to offline object used in analysis
- 100kHz input 160ms to run 400 algs (compare to 3s/evt in offline reco)







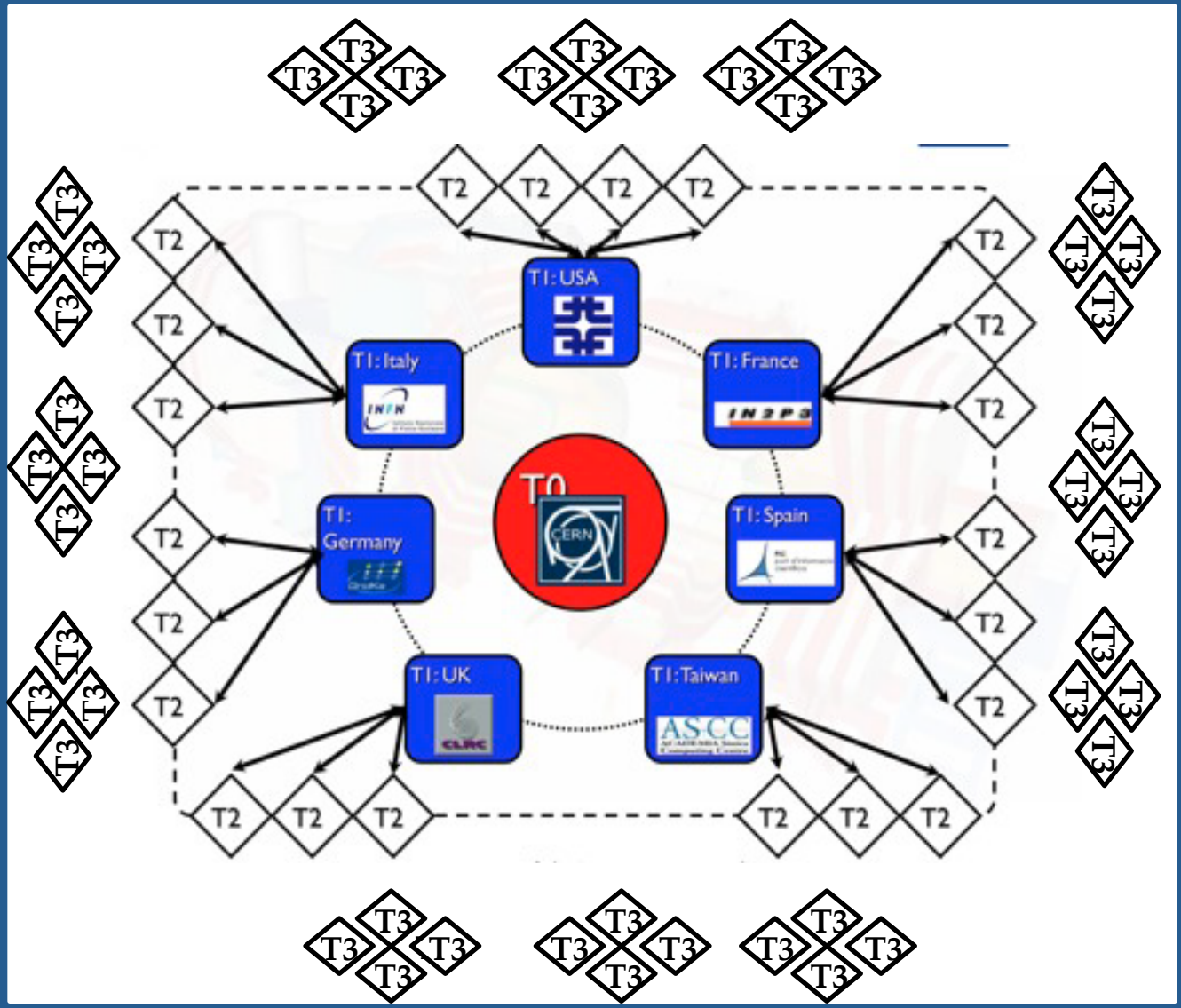
Triggers for Top-Quark Physics

- Take advantage of all objects in top quark signature to maximize acceptance: leptons, jets, MET
- L1 Triggers: Single/Double μ, e/γ, Quad Jet
- HLT Triggers:
  - Single e, μ
  - Double lepton
  - e/μ/τ + jets (+MET) (Different numbers of jets)
  - Multijet triggers (4-6 jets)
- As luminosity increases, make adjustments to control rates:
  - Increase thresholds
  - Improve ID/iso
  - Combine more objects

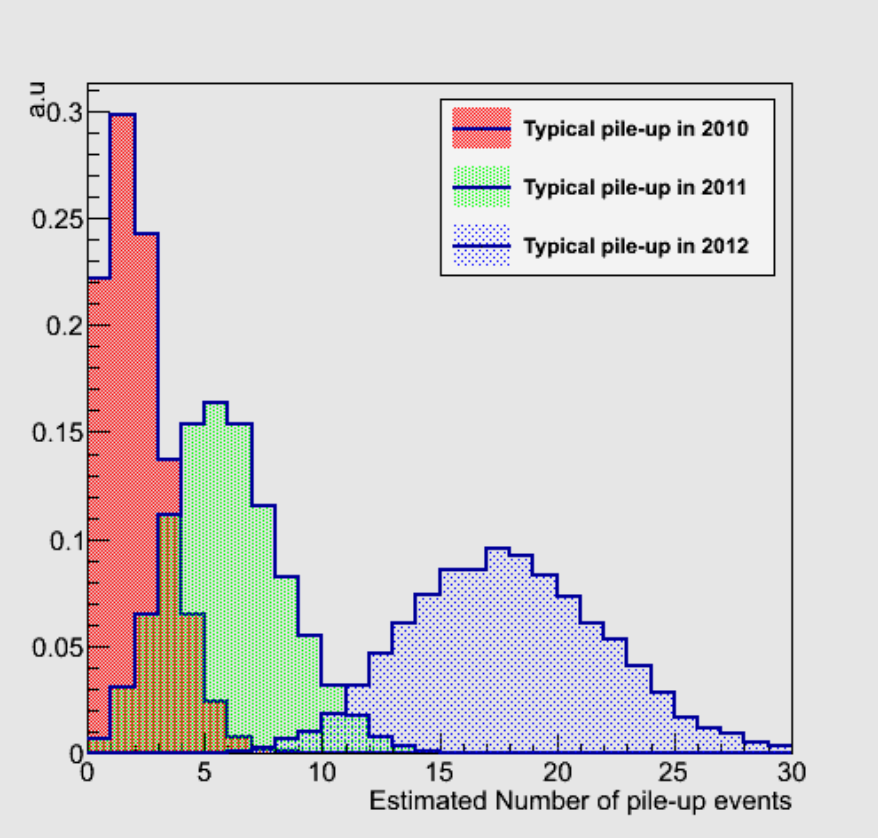
Handling all the Data

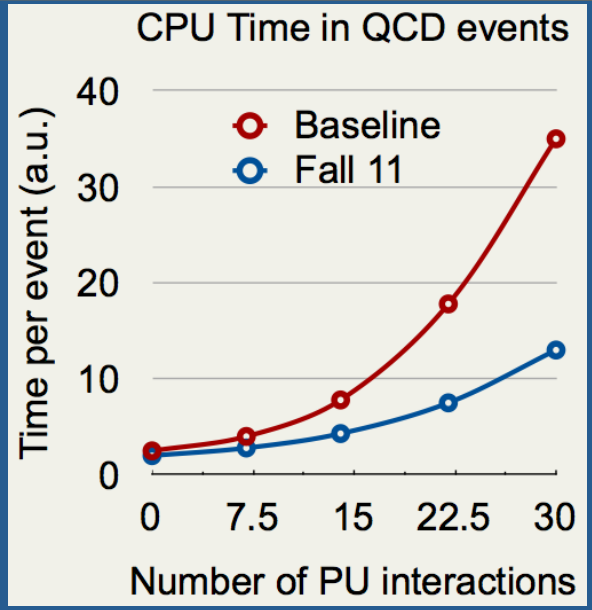
- Tier 0:
  - Prompt reco, calibrations, copy of RAW and first RECO data
- Tier 1:
  - Distribute RECO/ AOD, re-reco, gen/storage of SIM
- Tier 2:
  - Simulation, user data access/ analysis
- Tier 3: user analysis

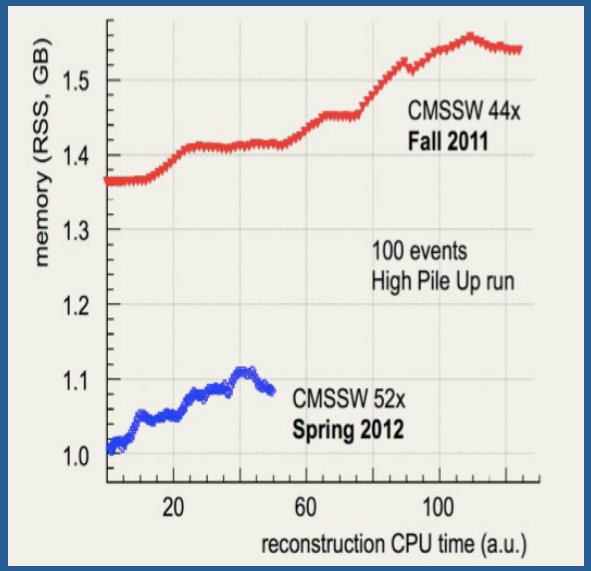
Tiered structure:



Processing the Data



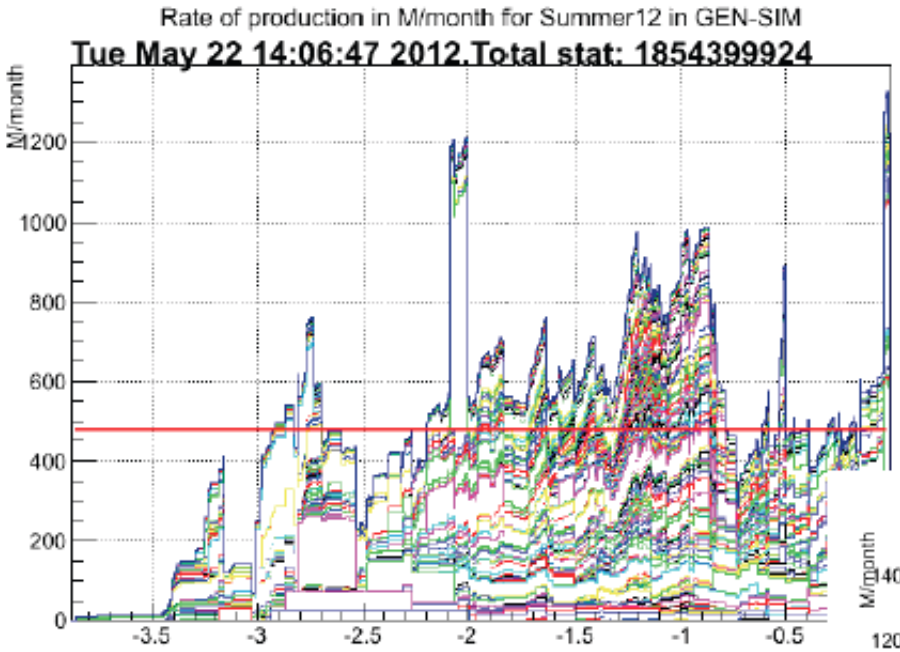




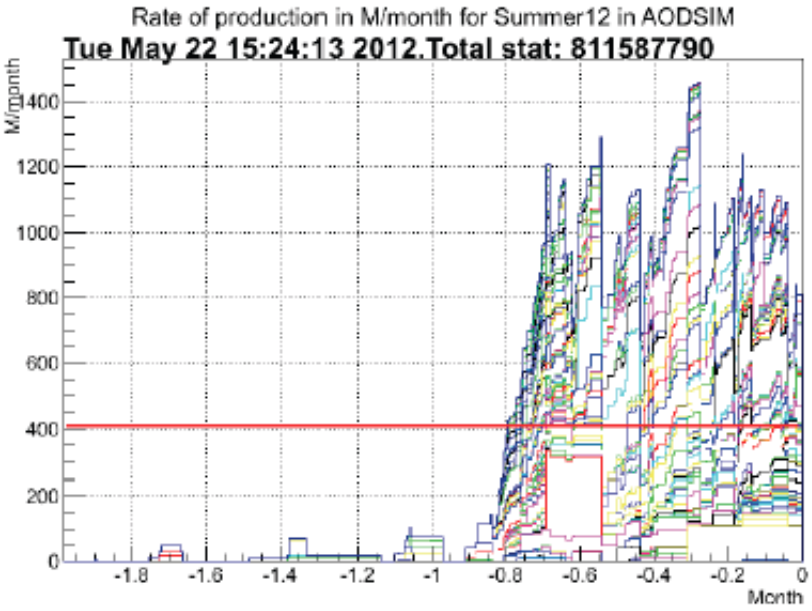
- Big increase in pileup necessitates streamlining of algorithms

Processing the Simulated Samples

MC Production Speed

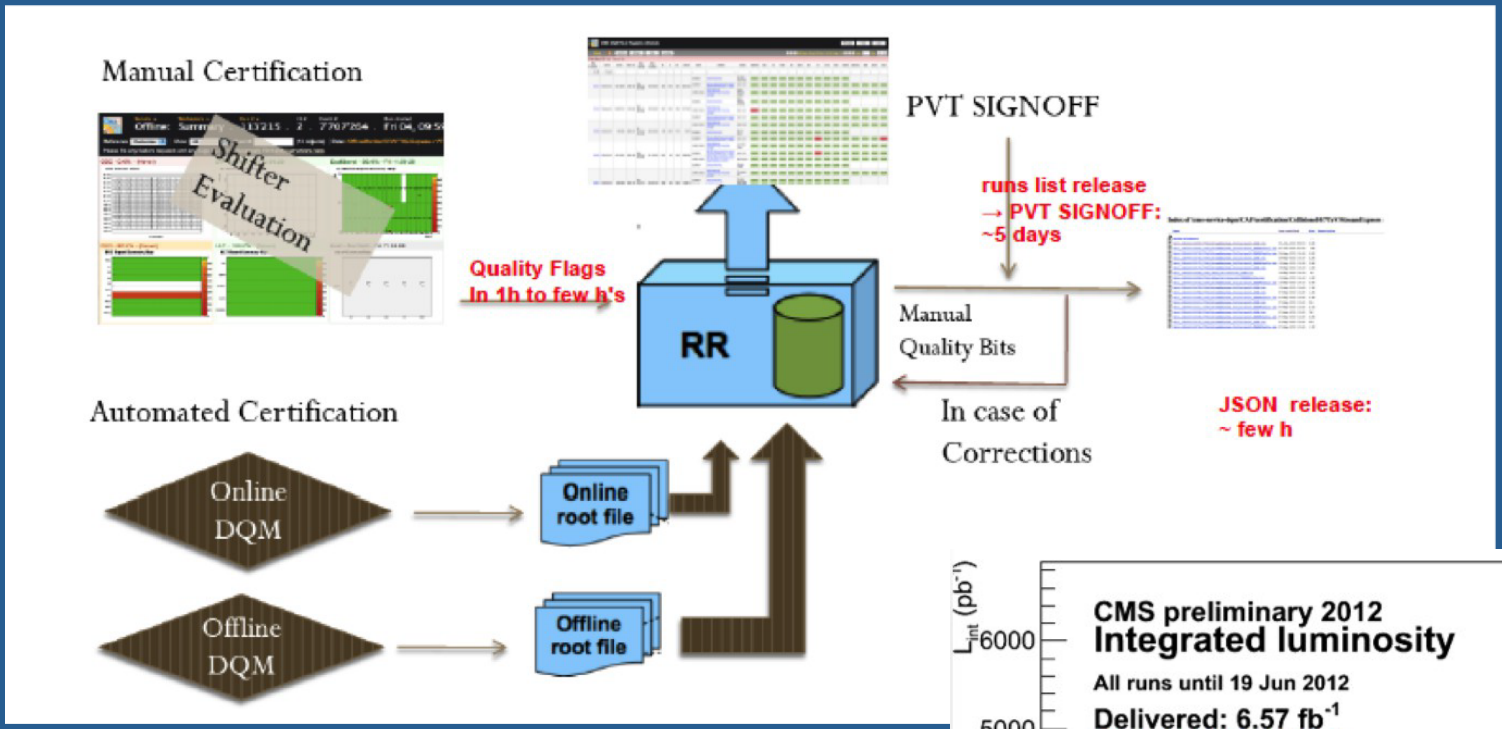


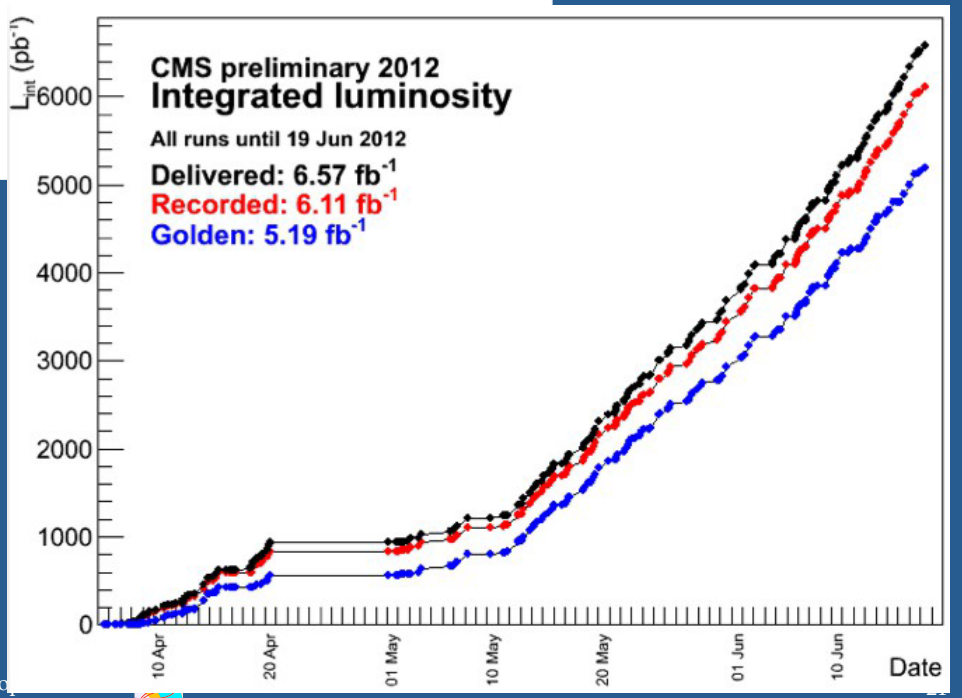
- Gen-Sim is primarily done at Tier-2s
  - Reaching close to 500M events a month



- Digi-Reco is mostly Tier-1s
  - More than 1B events a month
  - A more challenging IO and reco problem with extra pile-up

Data Certification

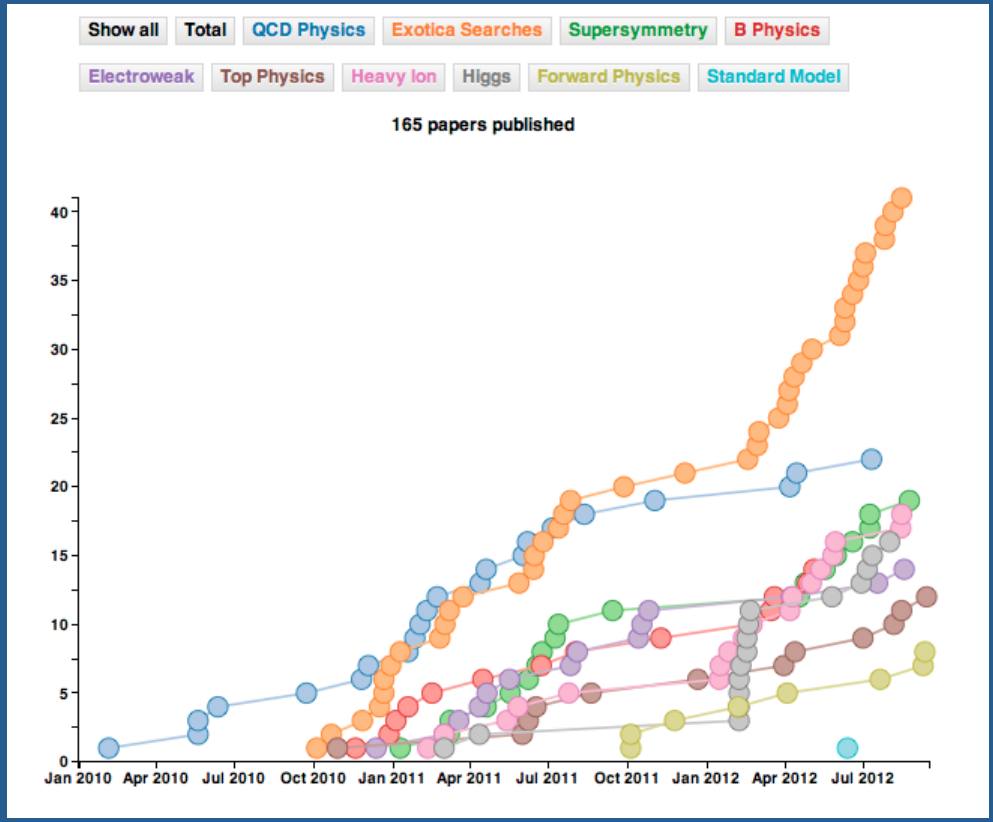




- Data certification strategy allows rapid incorporation of new data in analyses – as little as one week!

Summary and Outlook

- CMS is matching the excellent performance of the LHC
- Detector subsystems fully operational and at/better than design performance
- Trigger coping with demands of high pileup
- Computing model successfully keeping up with data and simulation demands



Collected data sample allows study of the fundamental world at an unprecedented level.