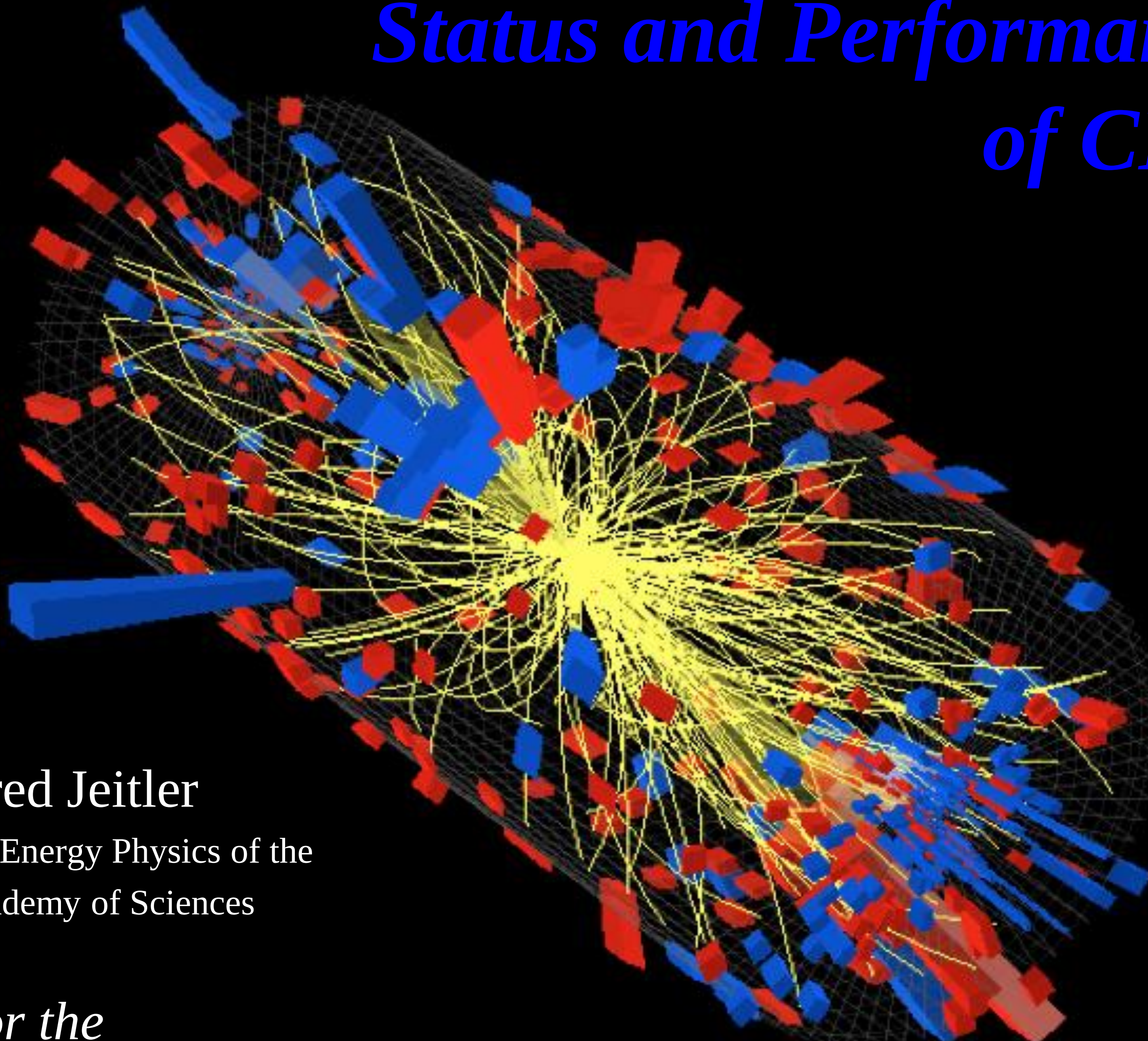
Status and Performance of CMS



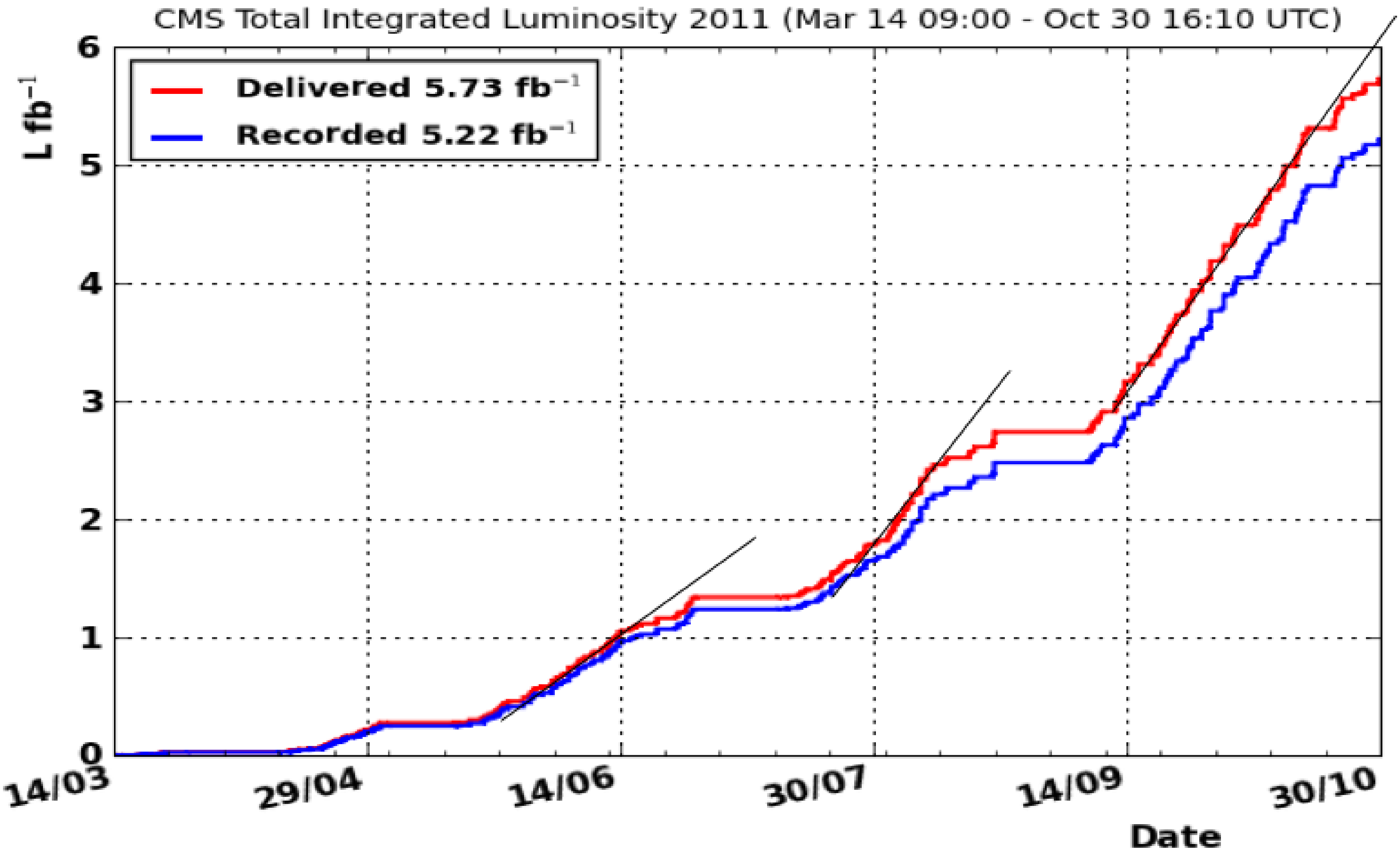
Manfred Jeitler

Institute of High Energy Physics of the Austrian Academy of Sciences

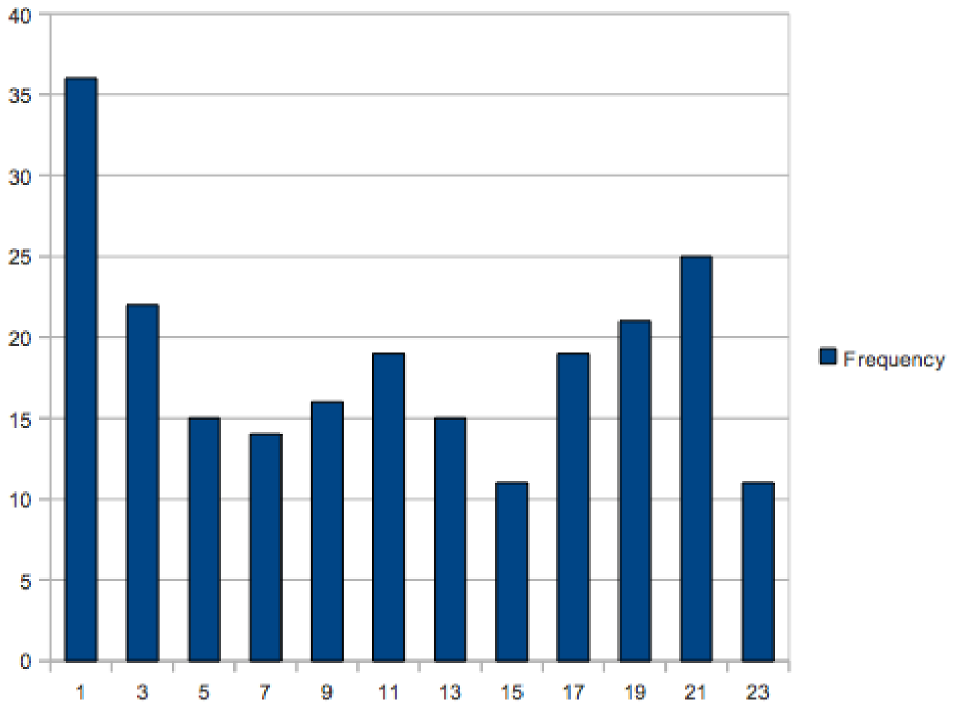
for the

CMS collaboration

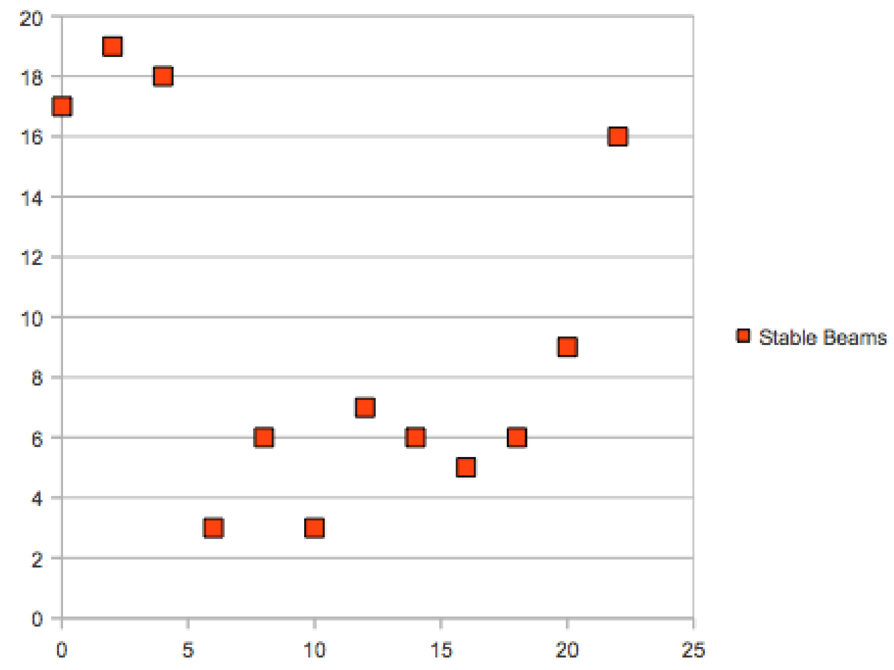
integrated luminosity



2011



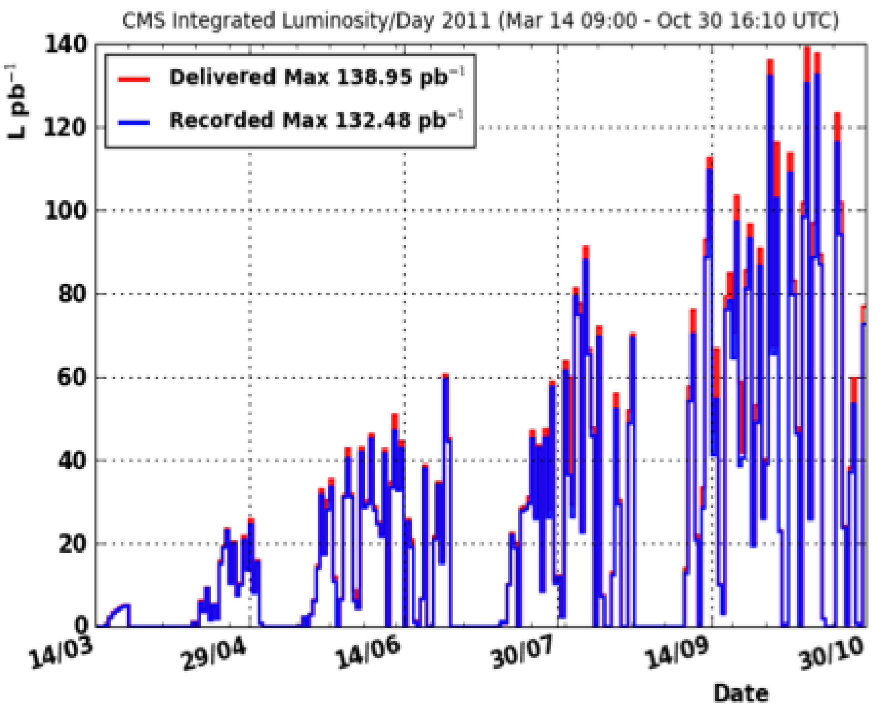
2010



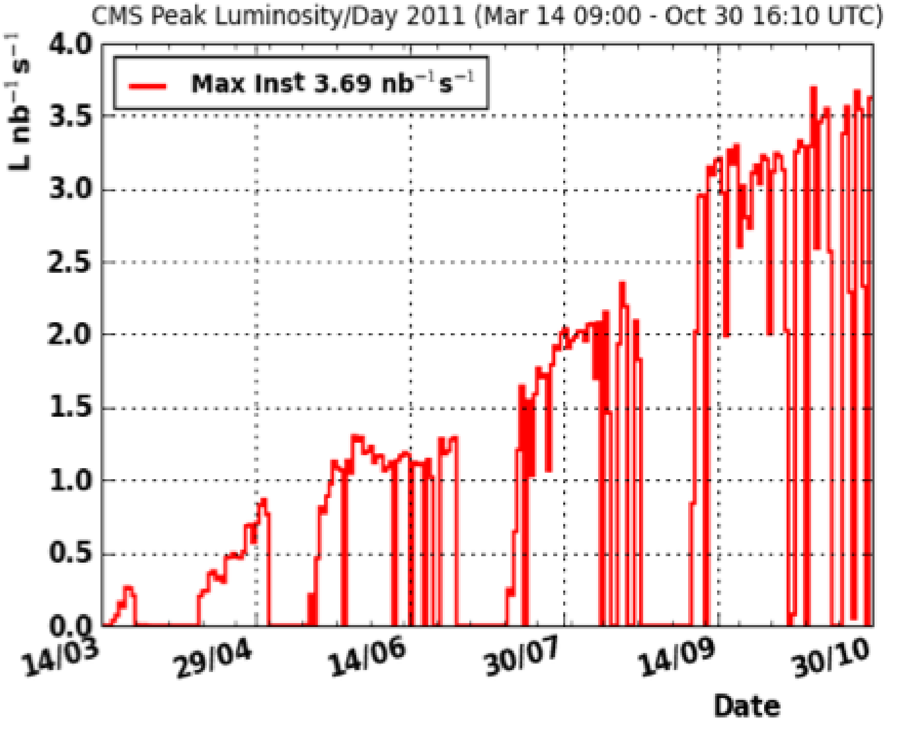
Start time of stable beams more uniformly distributed in 2011

integrated and instantaneous luminosity

CMS integrated luminosity / day



CMS peak luminosity for each day

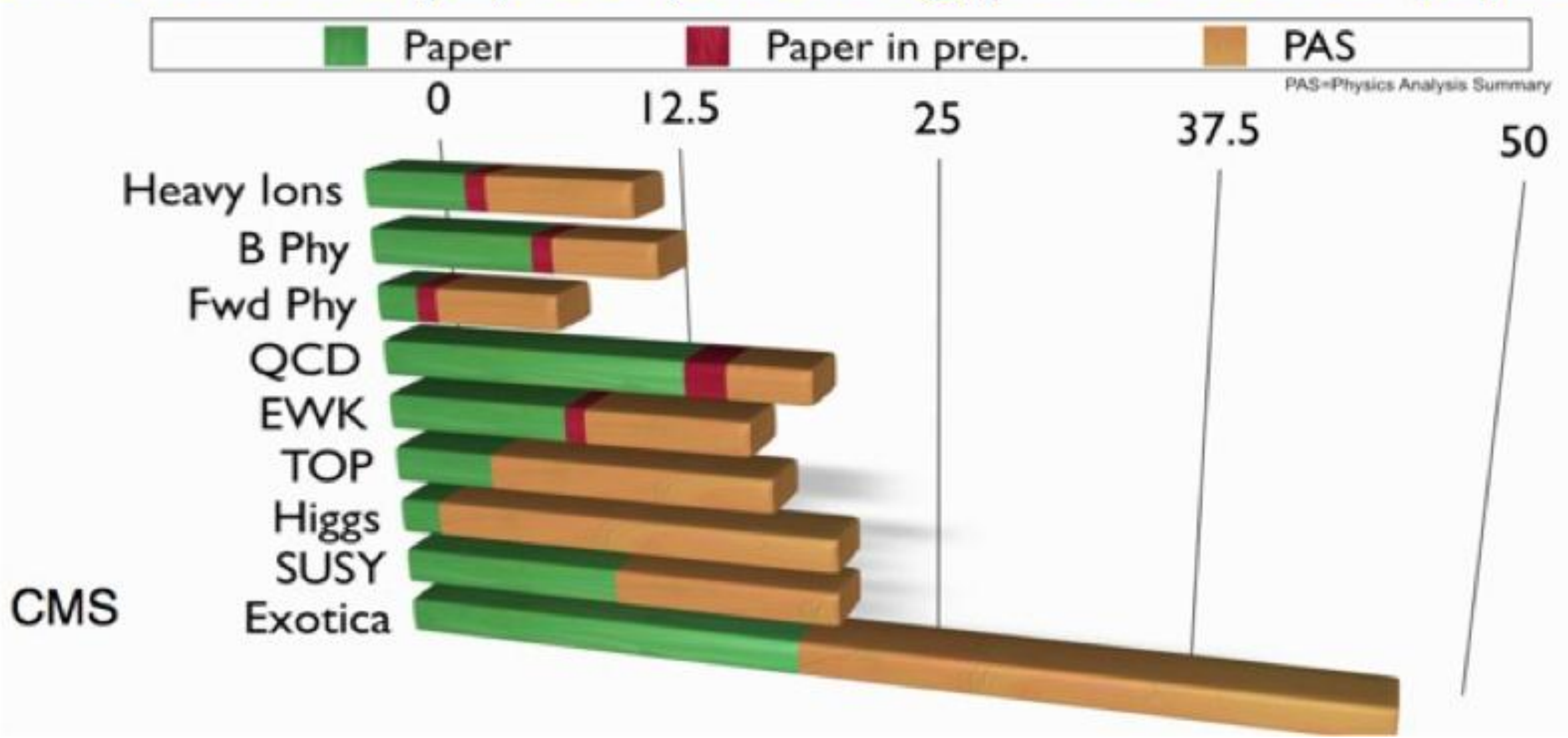


integrated luminosity

- ATLAS and CMS have each accumulated more than 5 fm^{-1}
- for 2012, we expect about 15 fm^{-1} per experiment
  - ATLAS and CMS
- end fo 2012: expect a world total of 30 fm^{-1} @ $\sqrt{s} = 7$ TeV
  - or maybe slightly higher energy

CMS publications

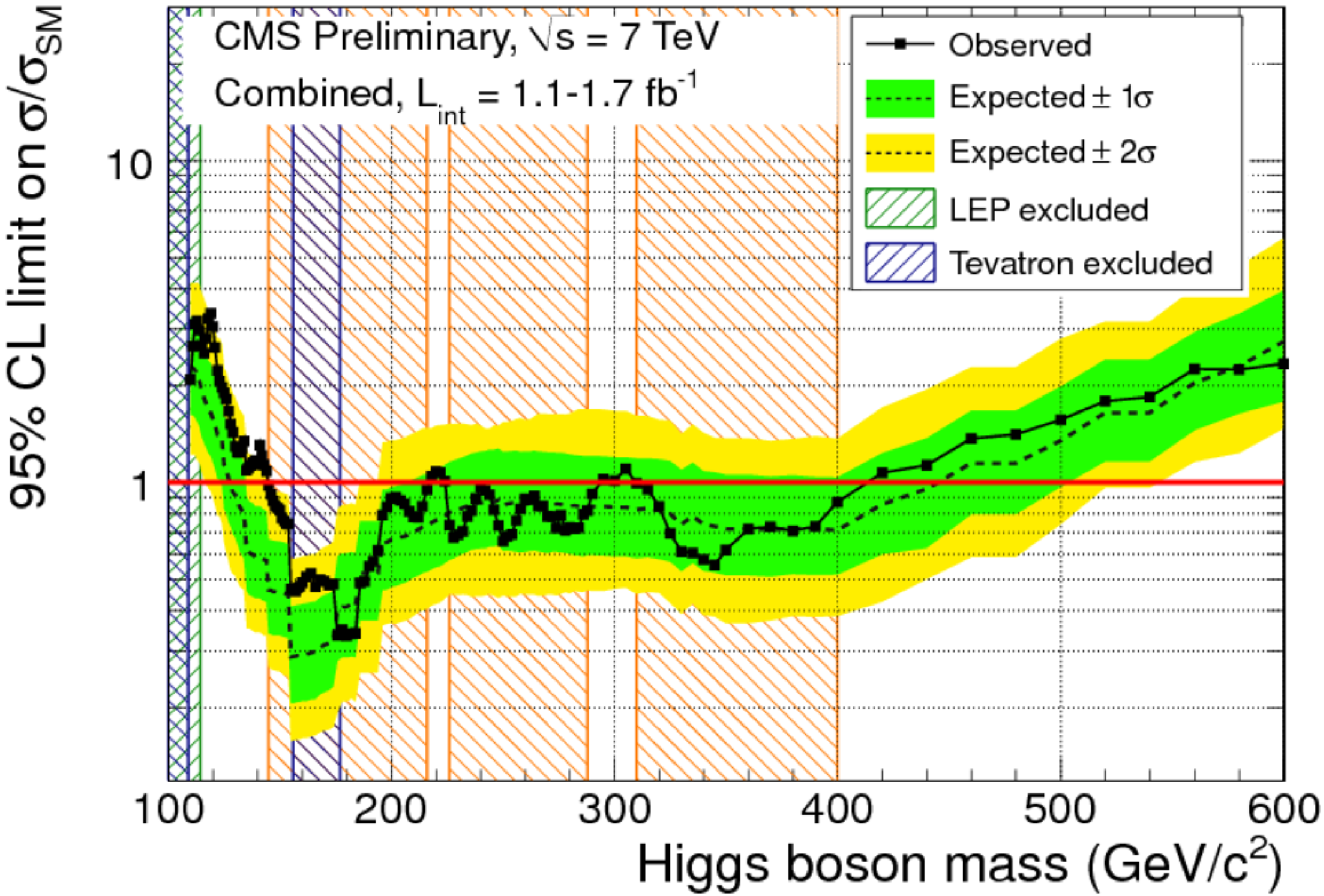
More than 100 papers (including performance papers)



where is the new physics?

- so far, no Higgs, no SUSY (☹ ?)
- by the end of 2012, with an integrated luminosity of 30 fm^{-1} (15 fm^{-1} per experiment), Standard-Model Higgs should be discovered, or excluded over wide range
  - in time before the planned LHC shutdown in 2013-2014 (for energy upgrade to $\sqrt{s}$ = 14 TeV)
- for SUSY, constraints are not so tight
  - SUSY may just not be "minimal" or completely "light"
  - but this is not a requirement
  - it is only so in the most simple model

Higgs exclusion plot



what if H *?*

- if LHC does not find the Higgs → harder to sell LHC to funding agencies (or to the public) ... but:

- I have heard theoretical physicists say:
  "I *believe* they will find the Higgs at LHC ... but I would rather *wish* they didn't!"
  - implying that this way, we would go beyond the Standard Model in our understanding

- exclusion of Standard-Model Higgs mechanism would be a very important discovery!
  - we have to explain this also to the public!

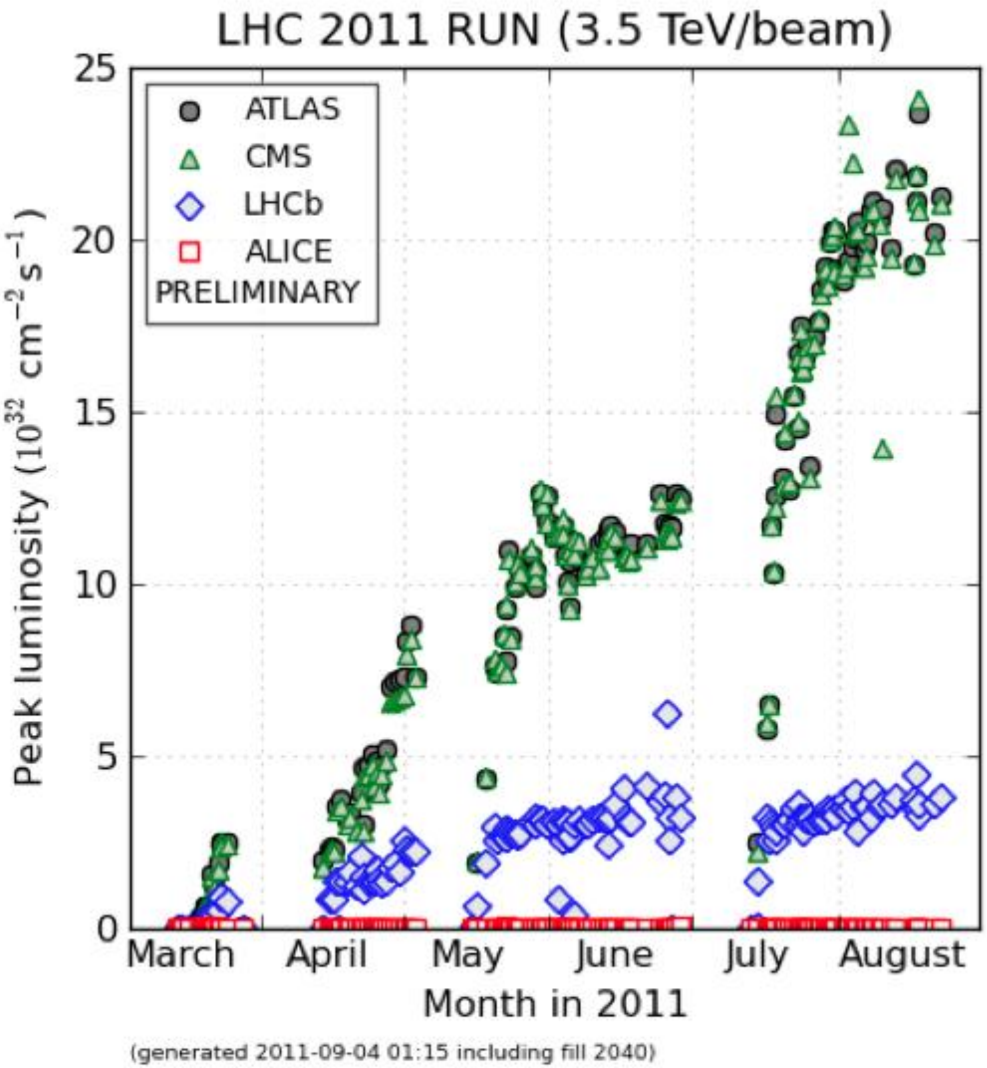
precision !

- we all think of potential discoveries but ...
- 2011 has brought us a lot of “standard” physics
  - from Electroweak to QCD and Top physics
- insurance for understanding our detector response
  - but also:
- possible deviation in precision measurements might give us hints of new and unexpected physics !

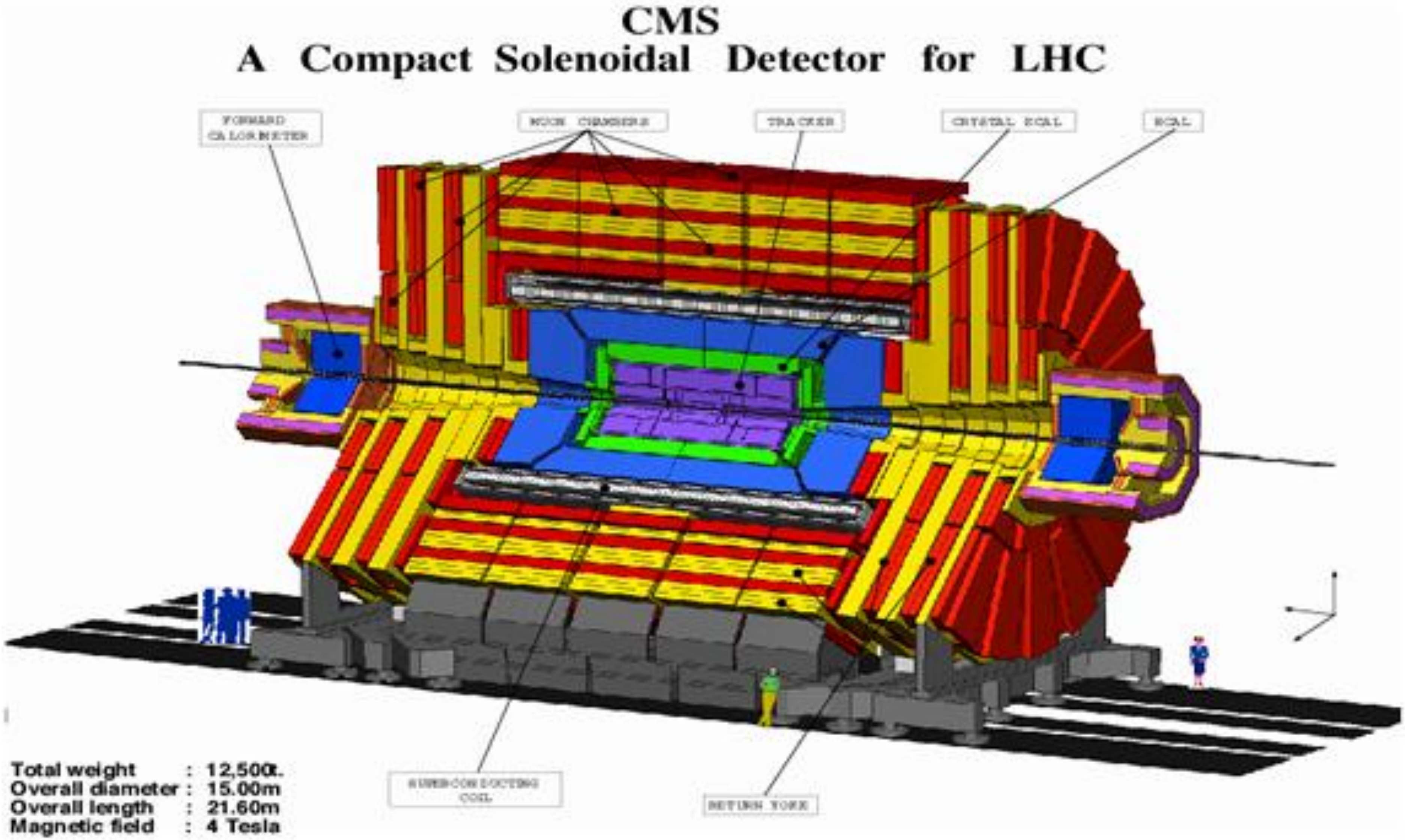
B-physics

B-physics

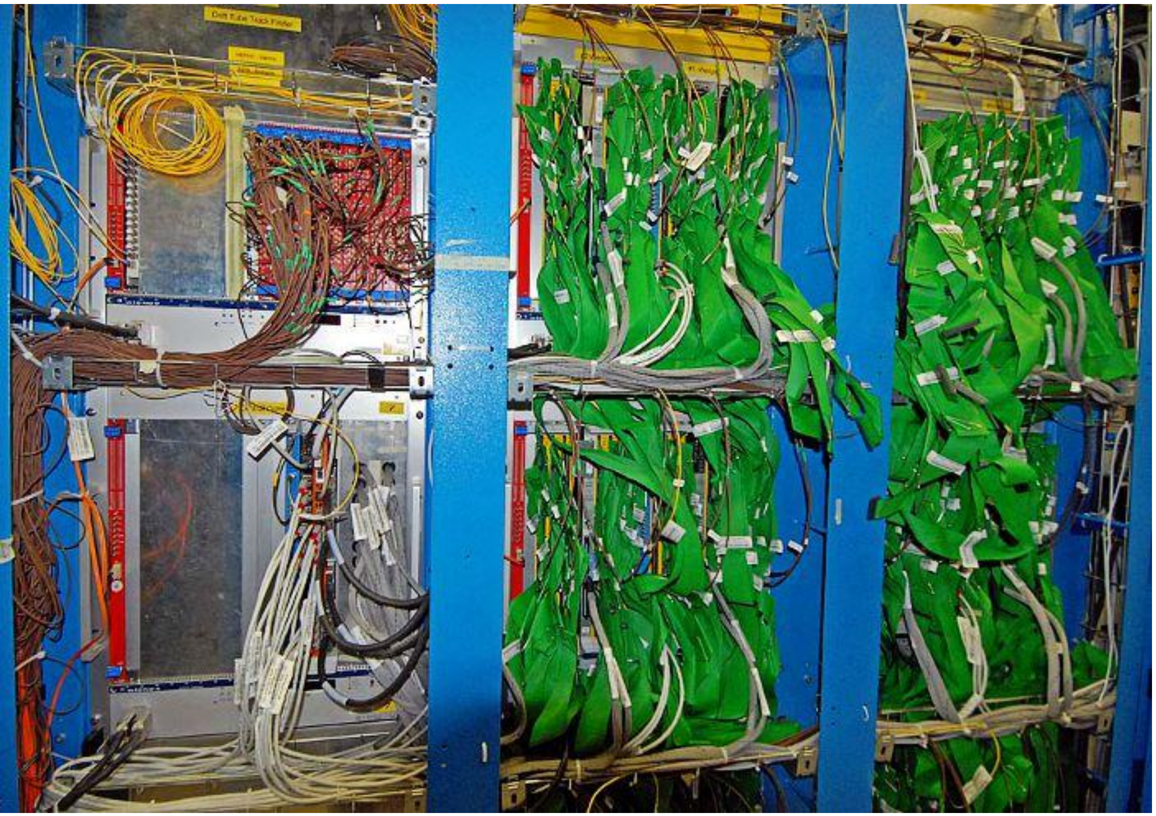
- for B-physics, LHCb has big advantage: low-energy hadron trigger
  - much better for hadronic decay modes
- advantage of CMS: higher luminosity
  - may be competitive when using muon triggers
  - triggering on two muons



The Compact ***MUON*** *Solenoid*



Level-1 muon trigger



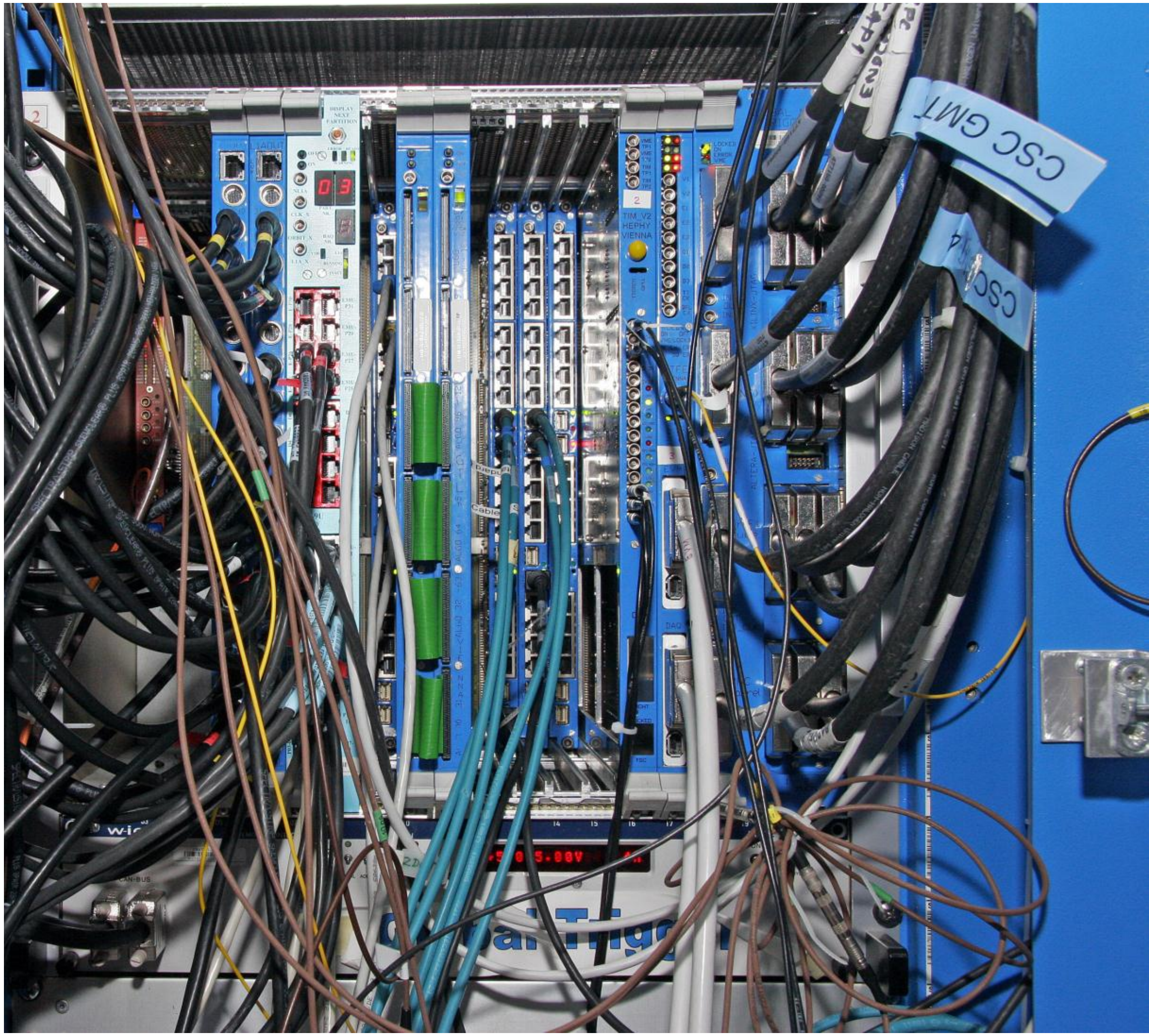
Drift Tube
Track Finder

Level-1 muon trigger

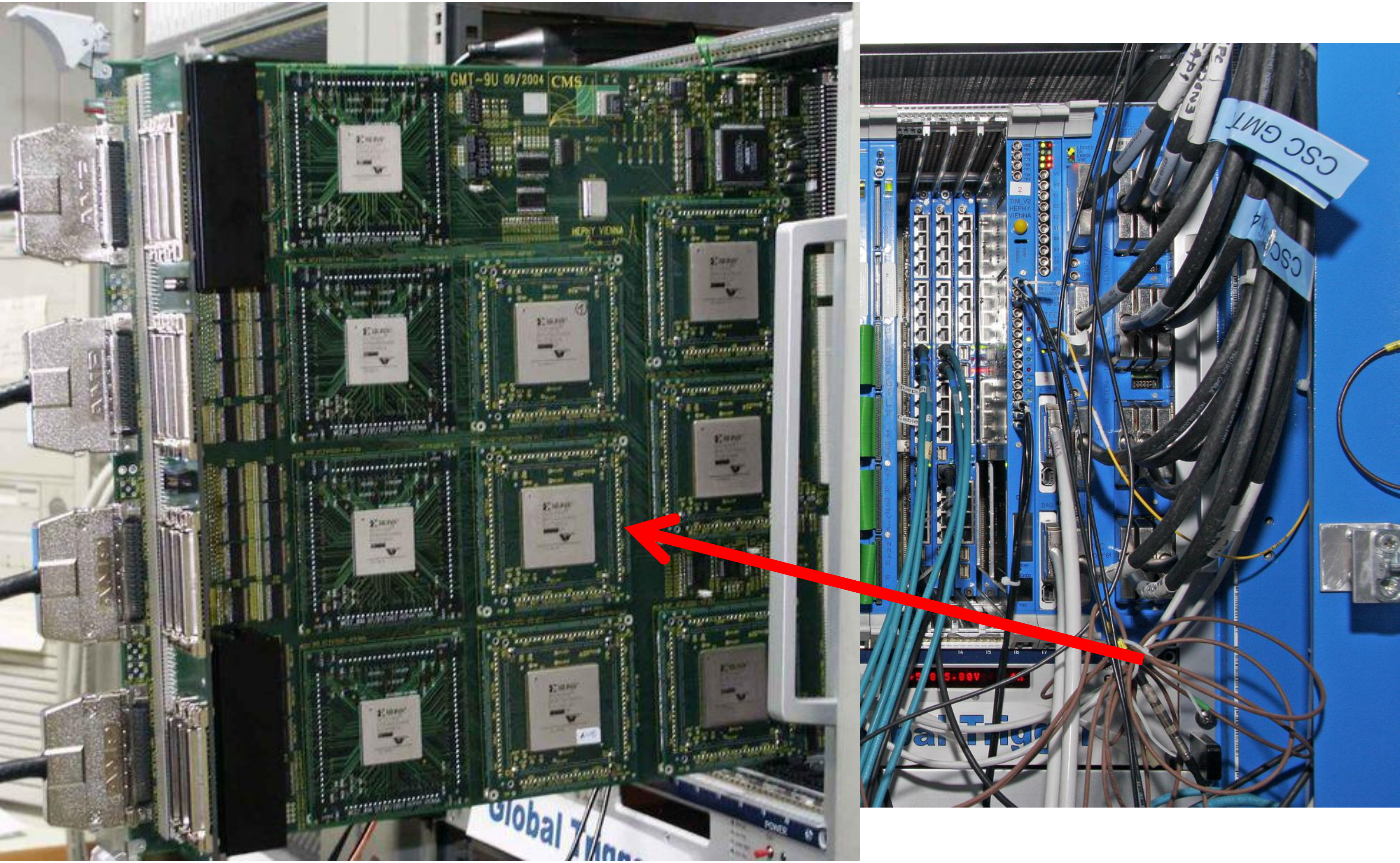
Global Trigger

and

Global Muon Trigger

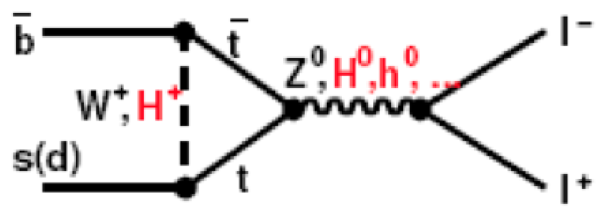


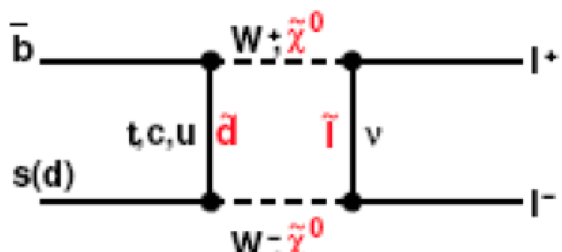
Level-1 muon trigger



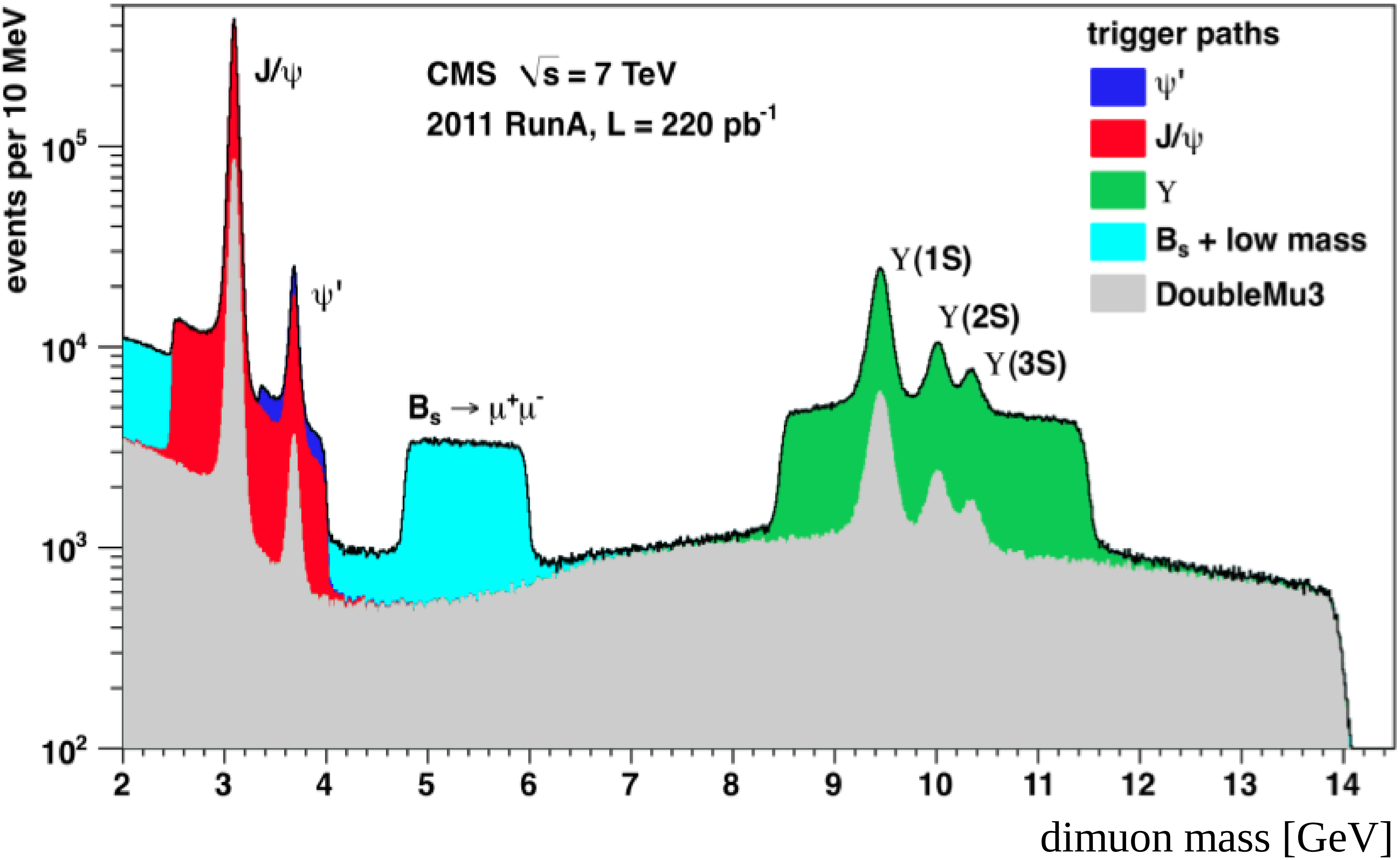
B-physics: $B_s \rightarrow \mu\mu$

- rare decay $B_s \rightarrow \mu\mu$
- Standard Model Branching Ratio: **3.4×10^{-9}**
  - for $B_d \rightarrow \mu\mu$: **$\sim 1 \times 10^{-10}$**
- very sensitive to enhancement due to new physics

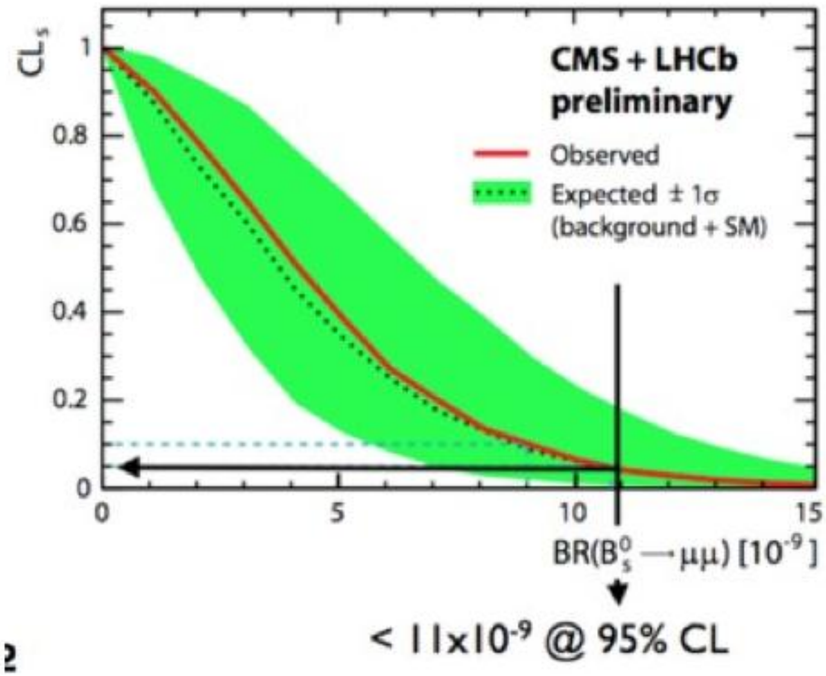




di-muon events



$B_s \to \mu\mu$ results

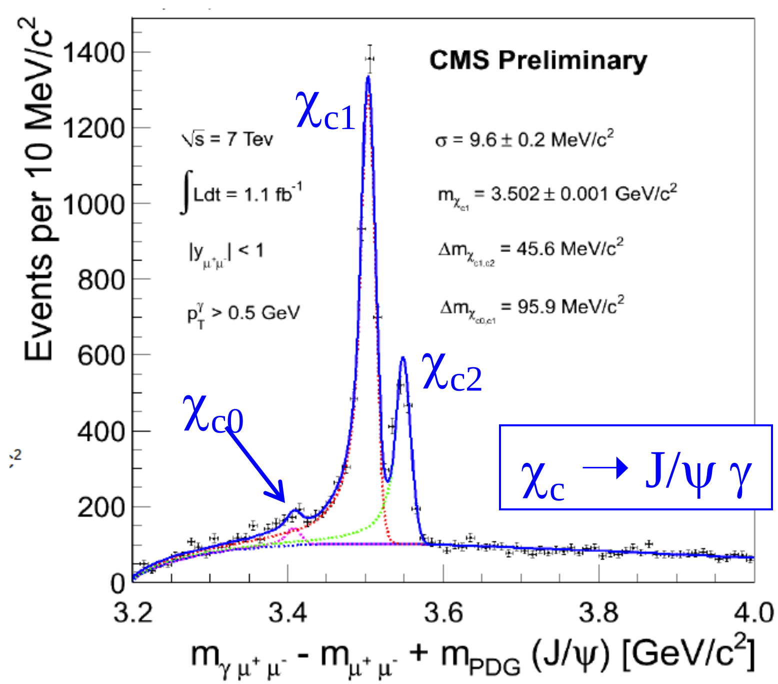


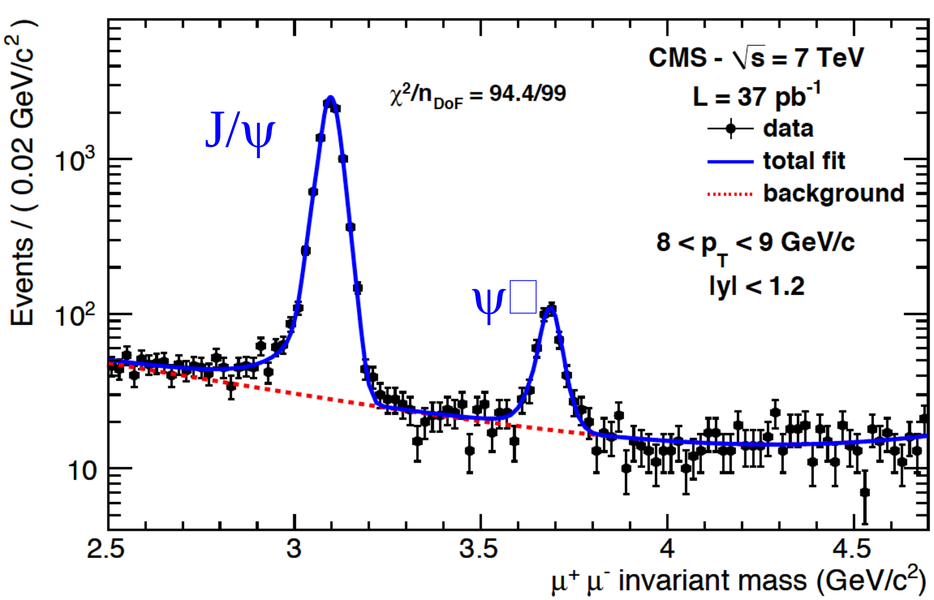
Channel	Expected (95% CL)	Observed (95% CL)	LHCb (95% CL)	Comb. (95% CL)
$B_s \to \mu\mu$	1.8×10^{-8}	1.9×10^{-8}	1.5×10^{-8}	1.1×10^{-8}
$B_d \to \mu\mu$	4.8×10^{-9}	4.6×10^{-9}	5.2×10^{-9}	

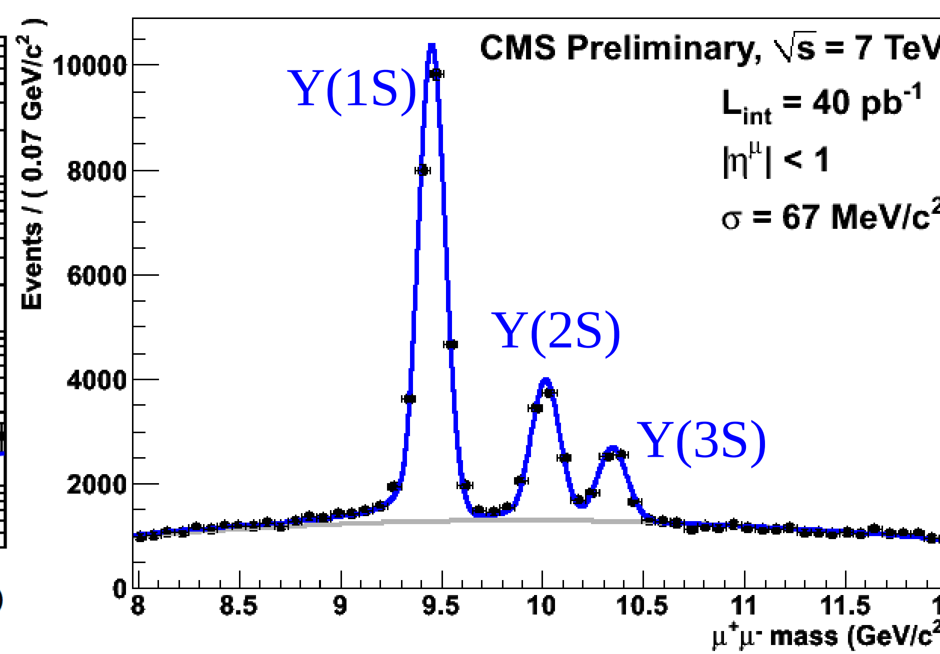
Quarkonia

Quarkonium production

- Good dimuon mass resolution (resolve Upsilon states)
- Photon conversion (crucial for χ_c and χ_b studies)
- High-efficiency, low-rate triggers; low p_T thresholds
- (Secondary) vertexing to separate the $B \to J/\psi\, X$ and $B \to \psi'\, X$ non-prompt contributions

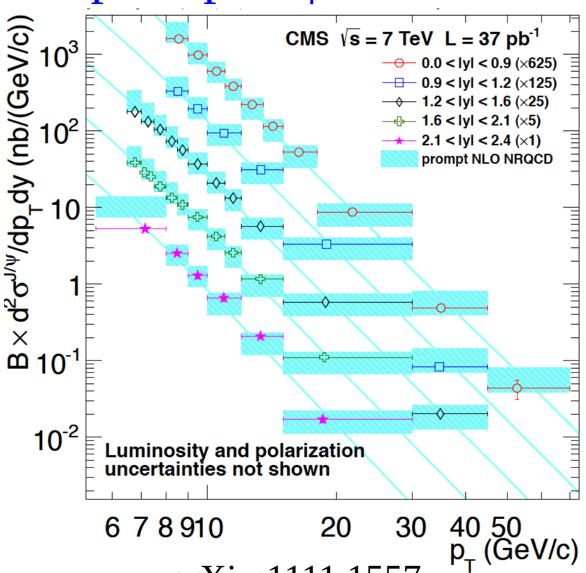






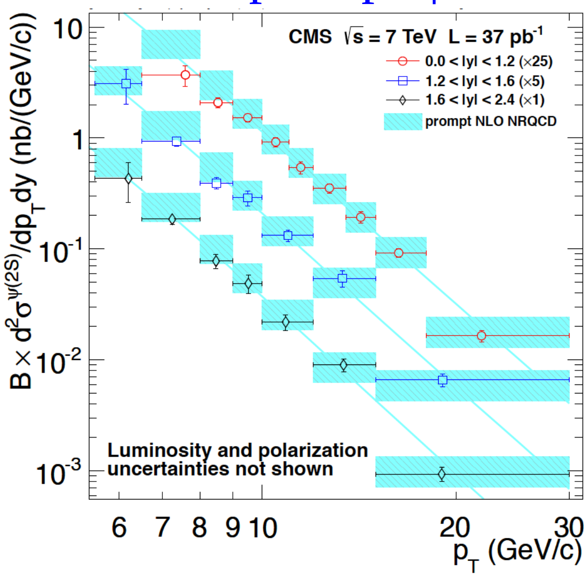
p_T differential cross section in rapidity bins

prompt J/ψ



arXiv:1111.1557

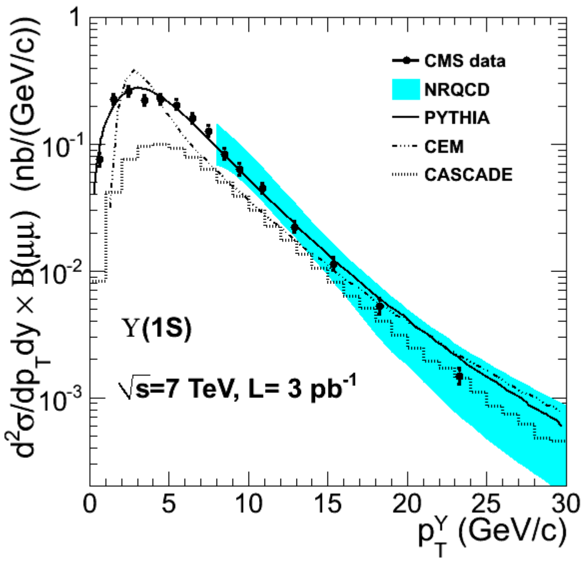
prompt ψ□

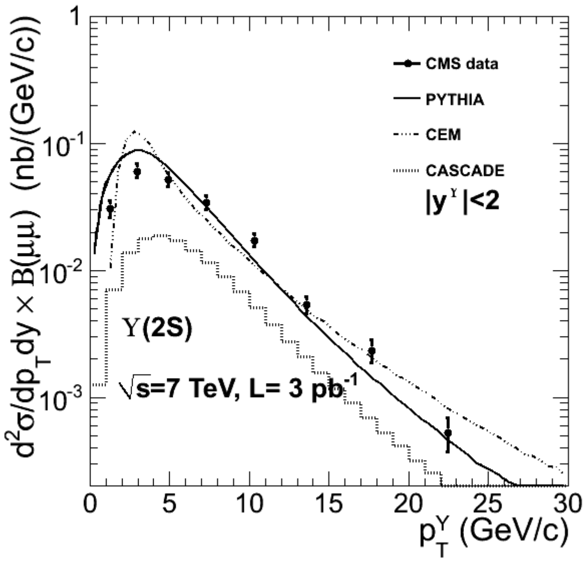


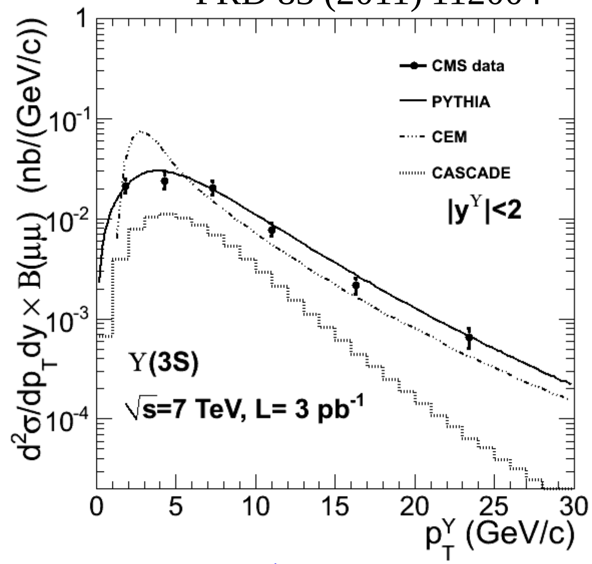
- S states measured with 2010 data
- B → psi component subtracted
- In agreement with NLO NRQCD

- P-wave states under study
- Polarization measurement ongoing
- Exotic qqbar states under scrutiny

PRD 83 (2011) 112004

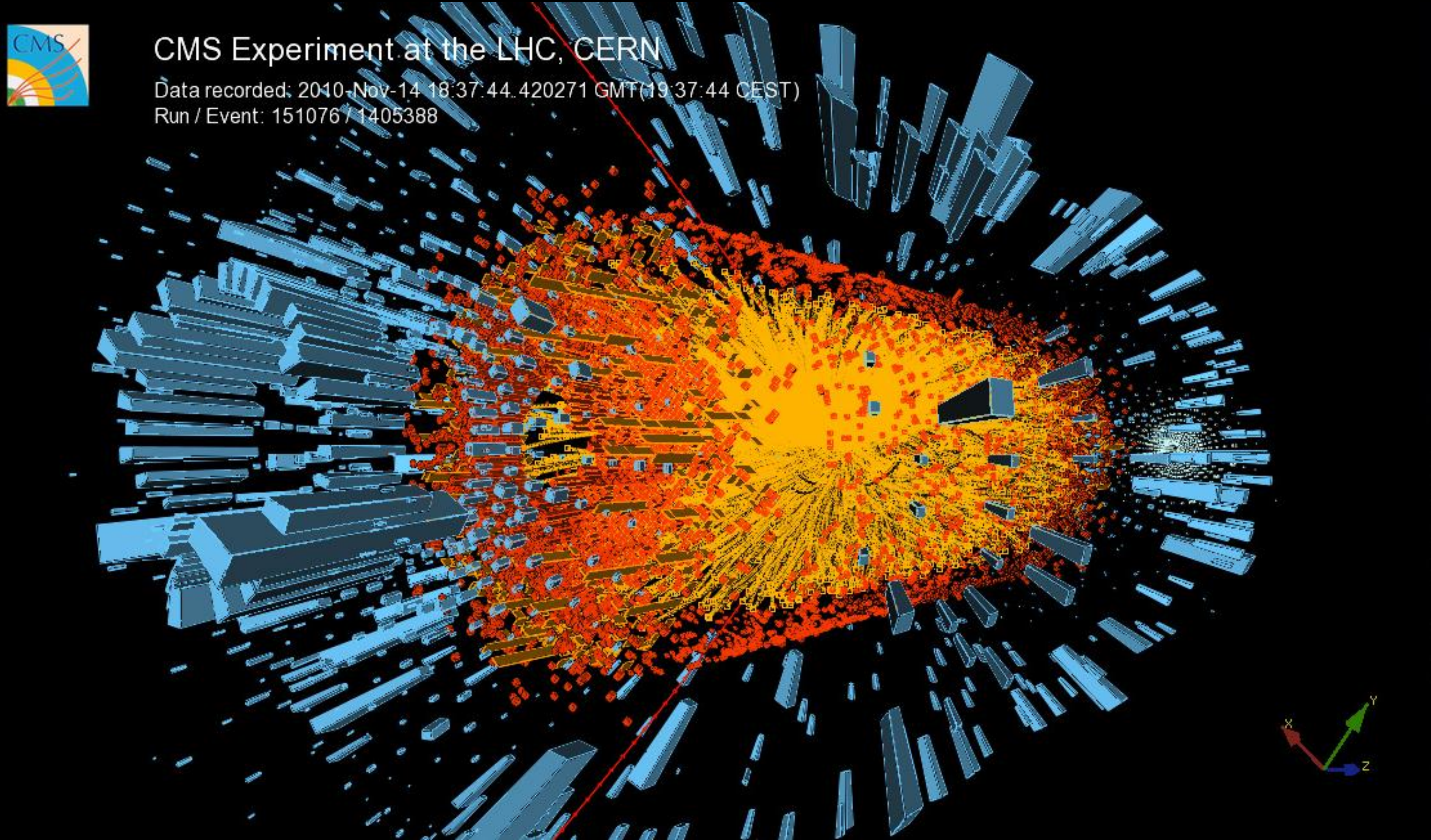




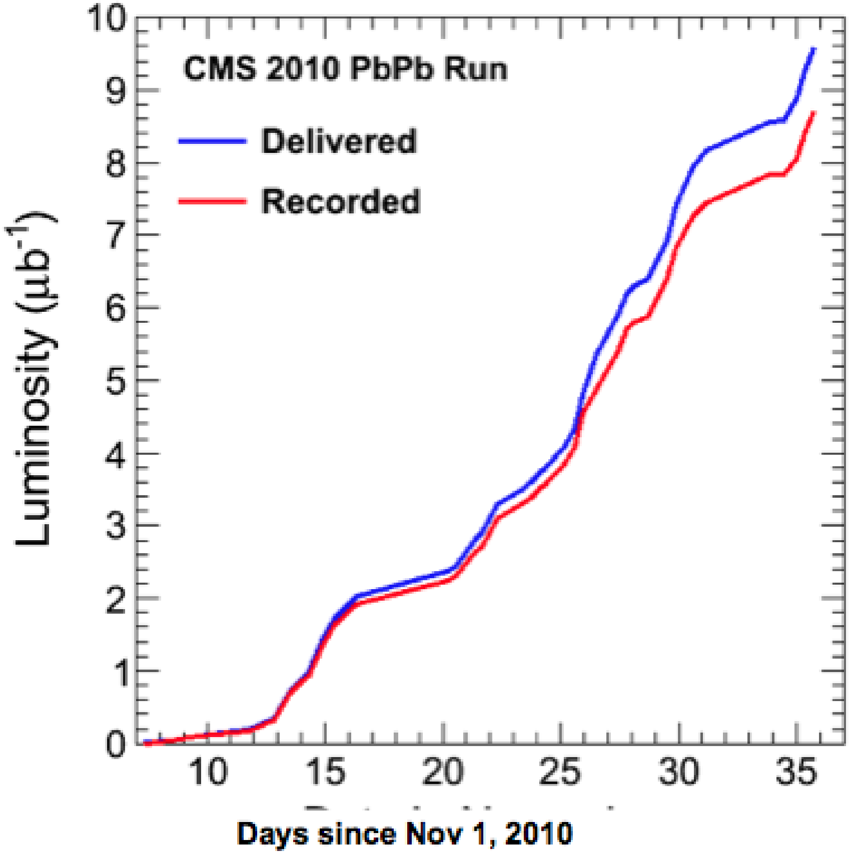


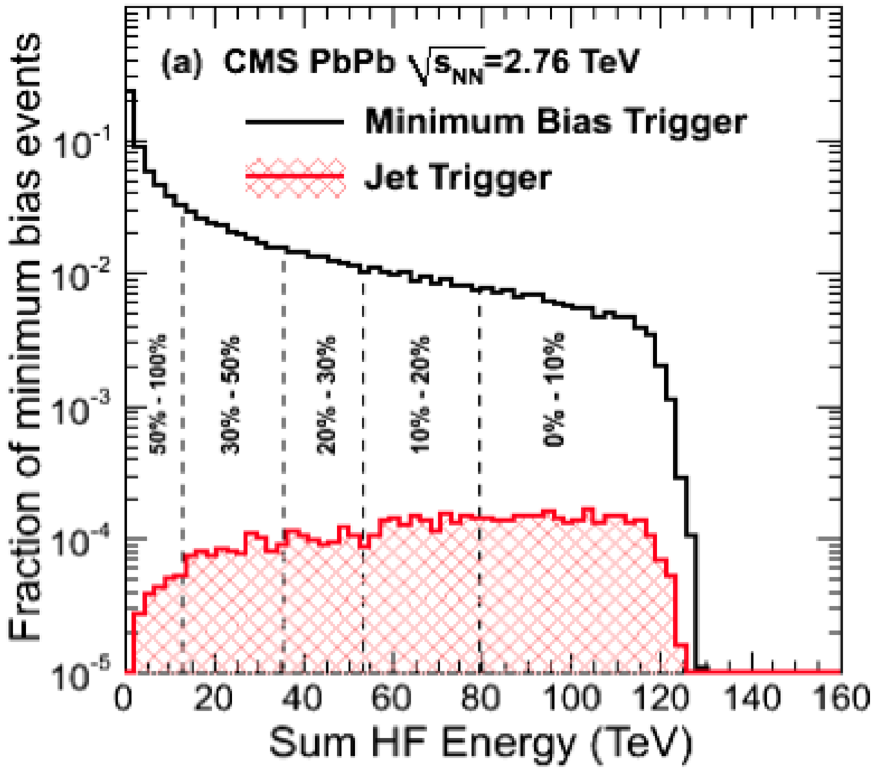
Heavy-Ion physics

- now starting 2011 heavy-ion run
- interesting results from 2010 data
- expect up to 10 times more data from 2011 run



Heavy-Ion @ CMS in 2010





Recorded luminosity PbPb 8.7 μb^{-1}

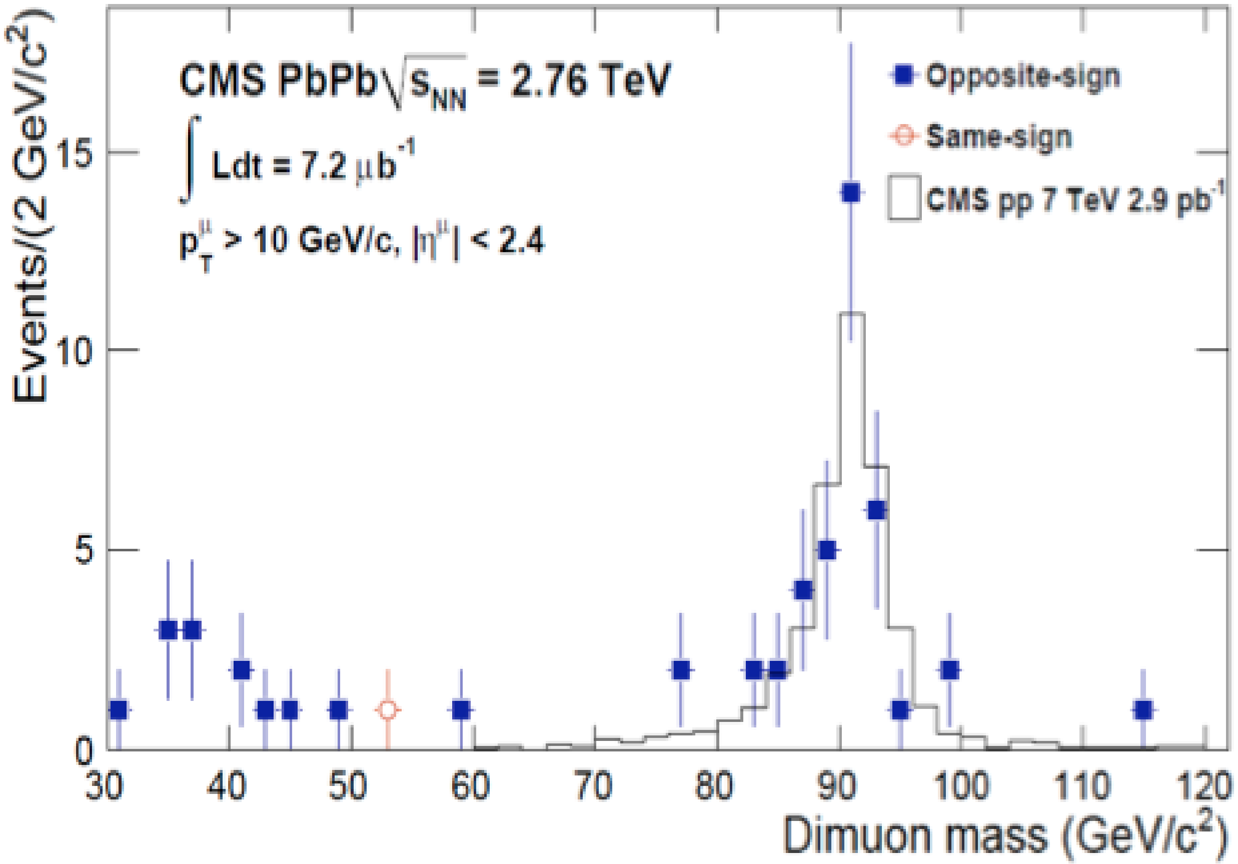
Recorded luminosity pp@2.76 TeV 241 nb^{-1}

Total PbPb data volume ~0.89 PetaByte

Triggering on minimum bias, jets, muons and photons

- ALL rare probes written to tape
- ~half of minimum bias written

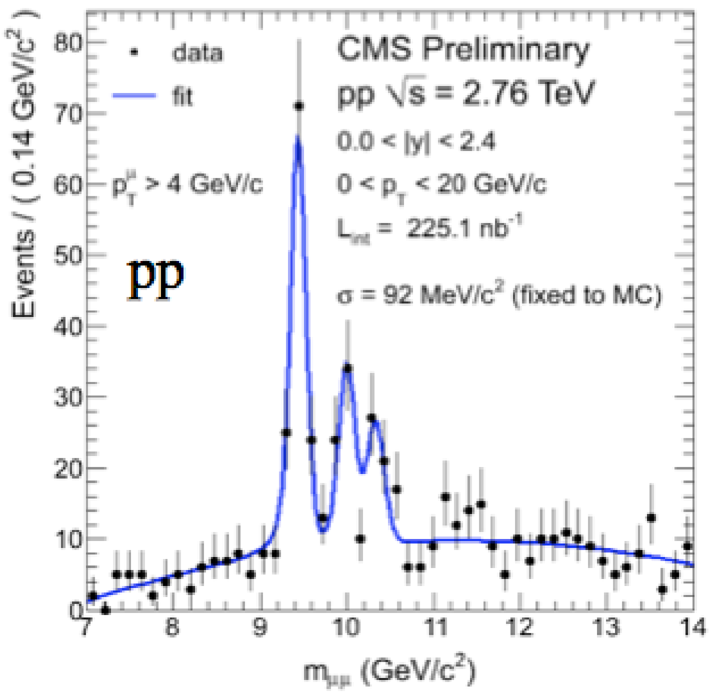
Heavy Ions: Z → μ μ

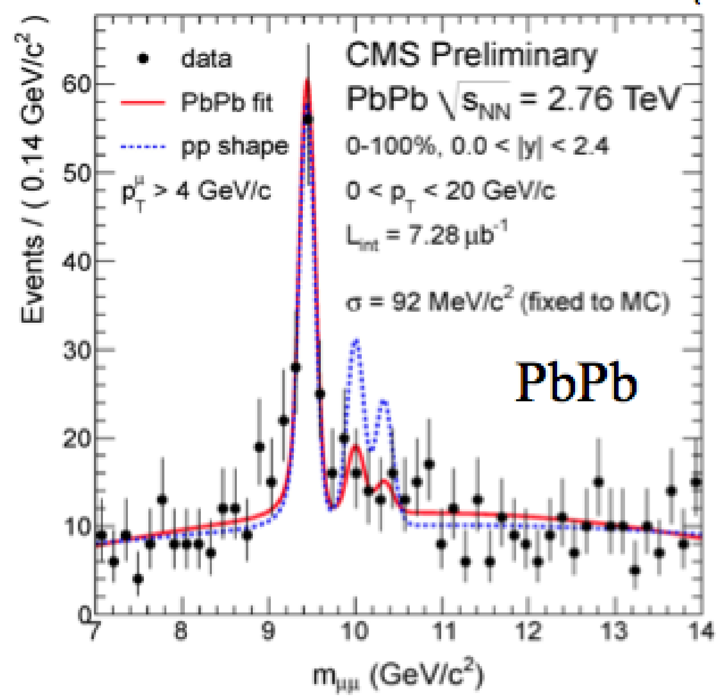


- clean Z signals from opposite-sign di-muon
- no modification is found with respect to the pp reference

Heavy Ions: excited-Upsilon suppression

PRL 107 (2011) 052302





$$\Upsilon(2S+3S)/\Upsilon(1S)\Big|_{pp} = 0.78^{+0.16}_{-0.14} \pm 0.02 \qquad \Upsilon(2S+3S)/\Upsilon(1S)\Big|_{PbPb} = 0.24^{+0.13}_{-0.12} \pm 0.02$$

$$\frac{\Upsilon(2S+3S)/\Upsilon(1S)\Big|_{PbPb}}{\Upsilon(2S+3S)/\Upsilon(1S)\Big|_{pp}} = 0.31^{+0.19}_{-0.15} \pm 0.03$$

- Excited states Υ(2S,3S) relative to Υ(1S) are suppressed
- Probability to obtain measured value, or lower, if the real double ratio is unity, has been calculated to be less than 1%

Heavy-Ion running

- run in different regime than for protons

- protons: Level-1 trigger rate up to 100 kHz
  - no problem reaching design value!
  - High-Level Trigger output rate: a few hundred Hz

- heavy-ion running: limit Level-1 trigger rate to a few kHz
  - much bigger events
  - at Level-1 Accept, CMS reads out the whole detector!
    - differently from ATLAS

Forward physics

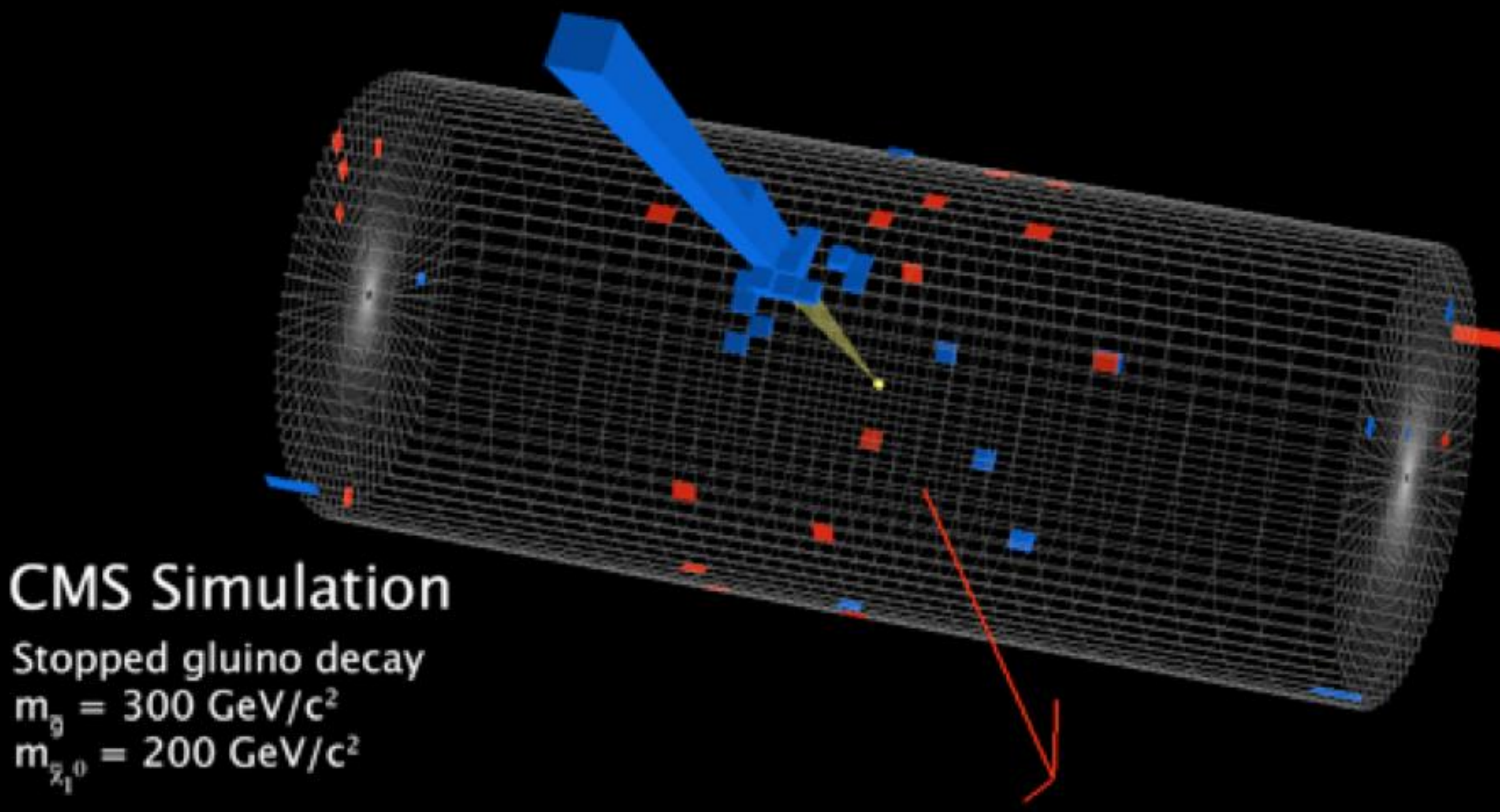
- diffractive measurements need rapidity gap
  - no pile-up
- special low-pileup runs? or
- special low-pileup bunches?
  - both mean loss to high-intensity physics

- TOTEM : forward detector near CMS
- so far completely independent of CMS
  - issue: long latency from “Roman pots” (far from CMS)
- now integration is underway
  - common triggers
  - later possibly also common readout

Heavy Stable Charged Particles (HSCP)
aka "stopped gluinos"

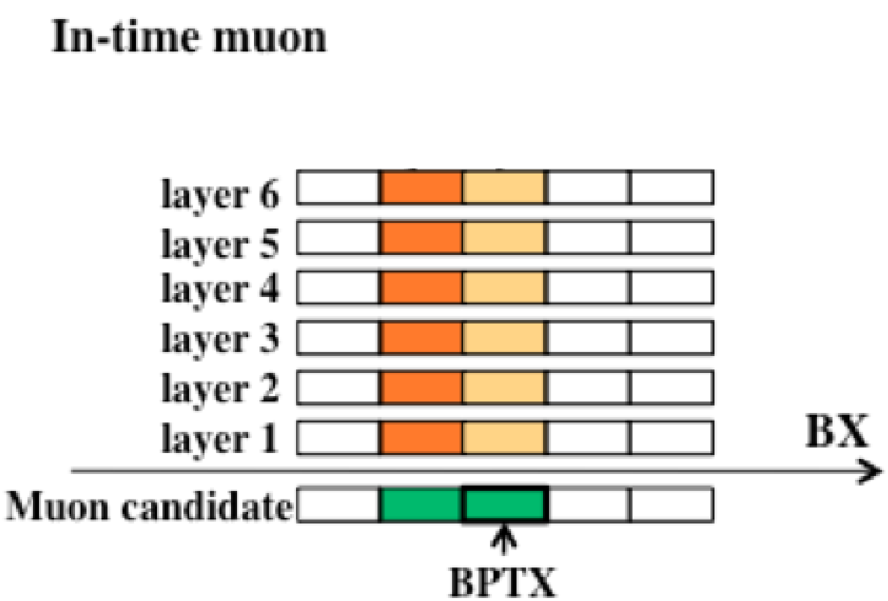
- some models predict meta-stable (long-lived) particles
  - produced in proton-proton collision
  - decay in later "time slice"
  - LHC "time slice" = 25 ns
- when getting Level-1 trigger, CMS reads out the "trigger" time slice
  - some subdetectors read out a few bunch crossings before and after
  - but not all subdetectors: tracker reads out only "central" bunch crossing
- get muon trigger from HSCP decay and look back in time: how was it created?
  - which prompt tracks appeared in tracker at creation time?
  - if the prompt information did not result in a Level-1 trigger

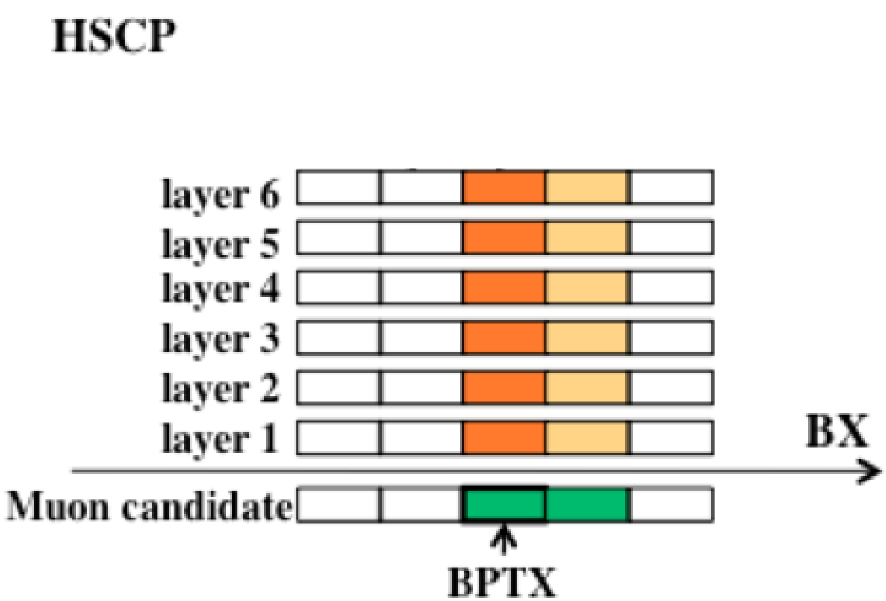
stopped gluino



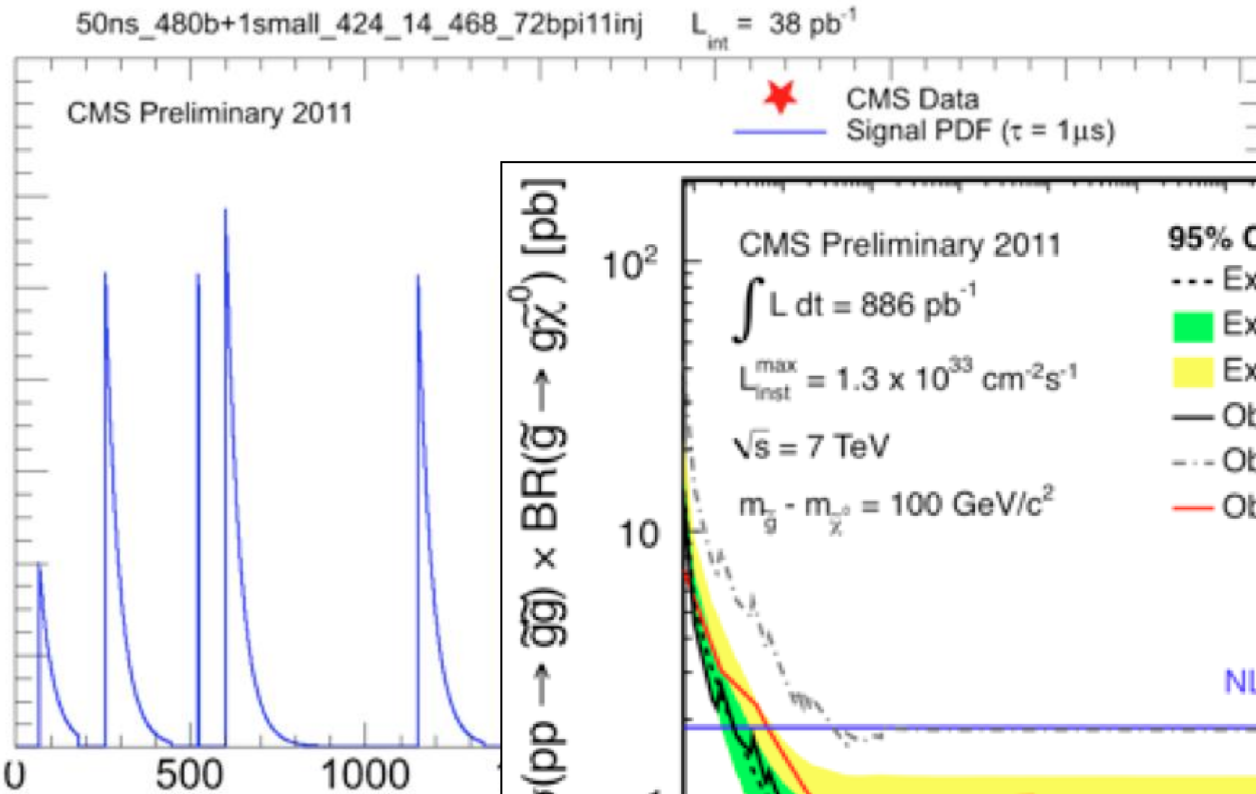
HSCP trigger

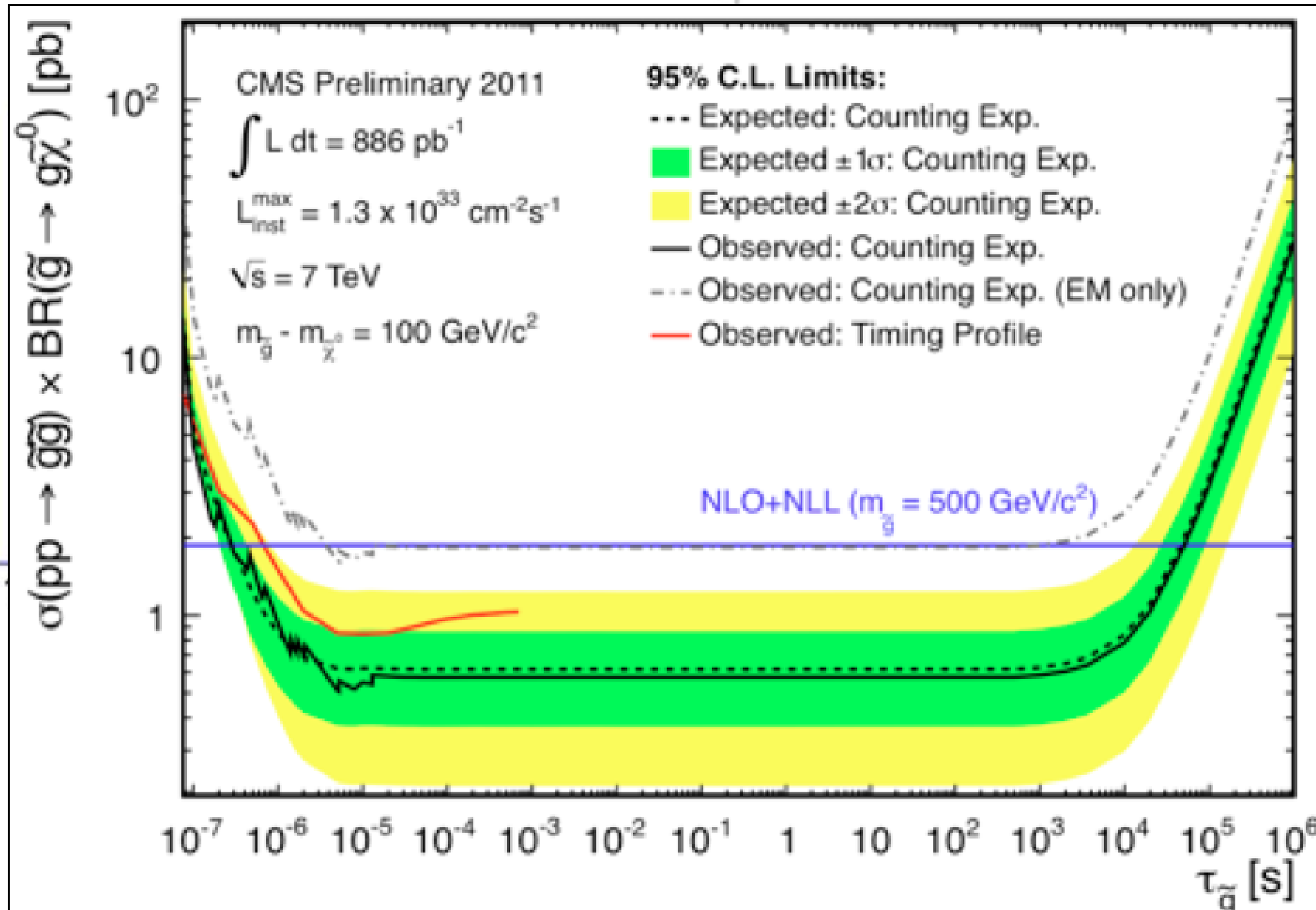
- RPC muon chambers trigger twice
  - once 1 BX early, once in time
- time slices before a beam crossing are disabled
  - at 50 ns bunch spacing
- second trigger in a row is suppressed by “trigger rules”
- → always trigger where we want to read out the tracker
  - in time for “normal” events, 1 BX early for “HSCP” events





stopped gluinos

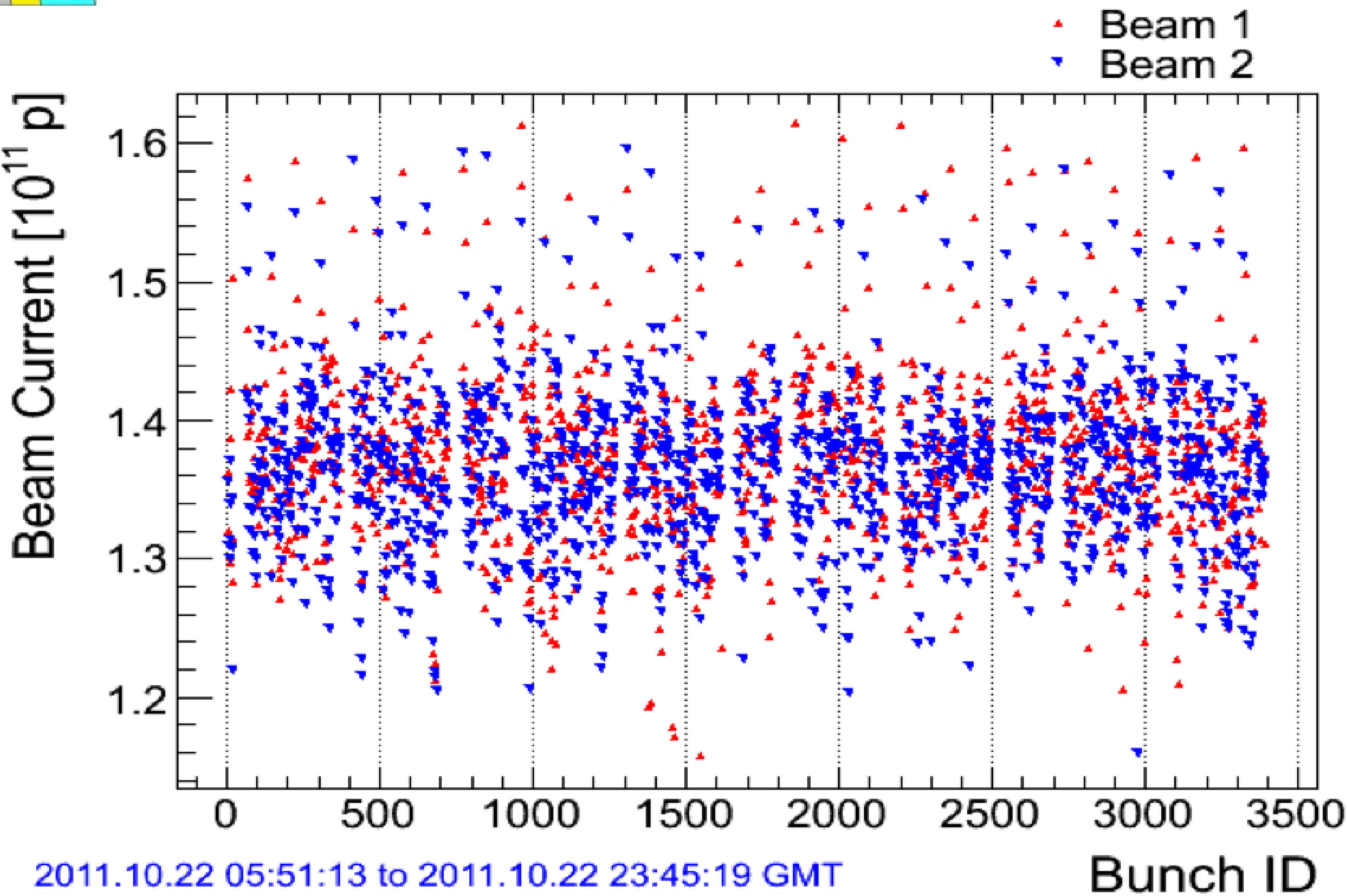




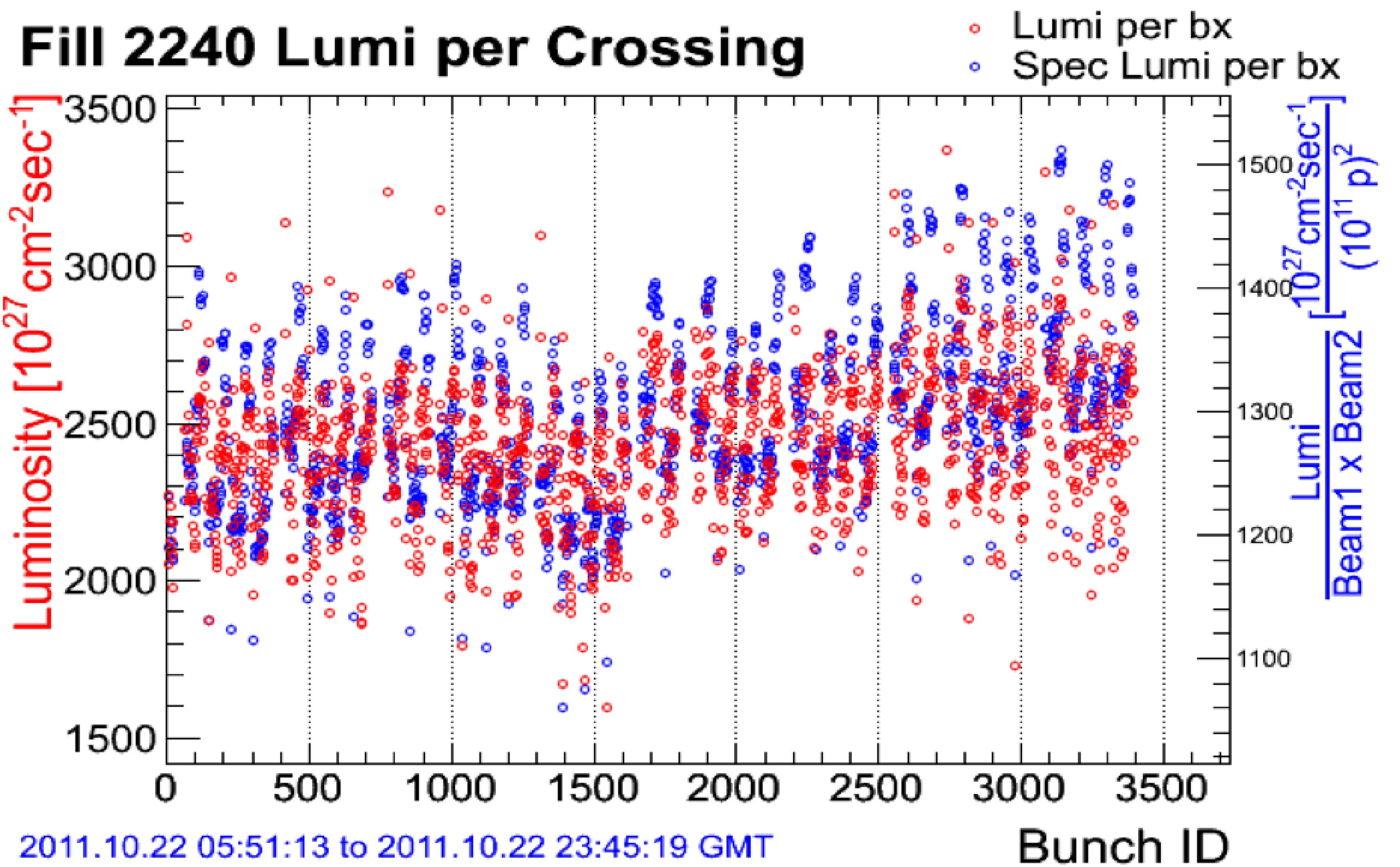
luminosity measurements

- accurate determination of luminosity is essential for precision measurements
- discrepancy between ATLAS and CMS has been seen
- base method in CMS: zero-counting
  - get luminosity from probability, that a “tower” of the Hadronic Forward calorimeter (HF) sees zero hits
  - becomes difficult at high pile-up → look for alternative methods
- Pixel cluster counting
  - good correlation between luminosity and number of Pixel clusters
  - Pixel detector has low occupancy
  - use prescaled zero-bias trigger (only beam crossing required) for representative subsample of bunch crossings

luminosity measurements

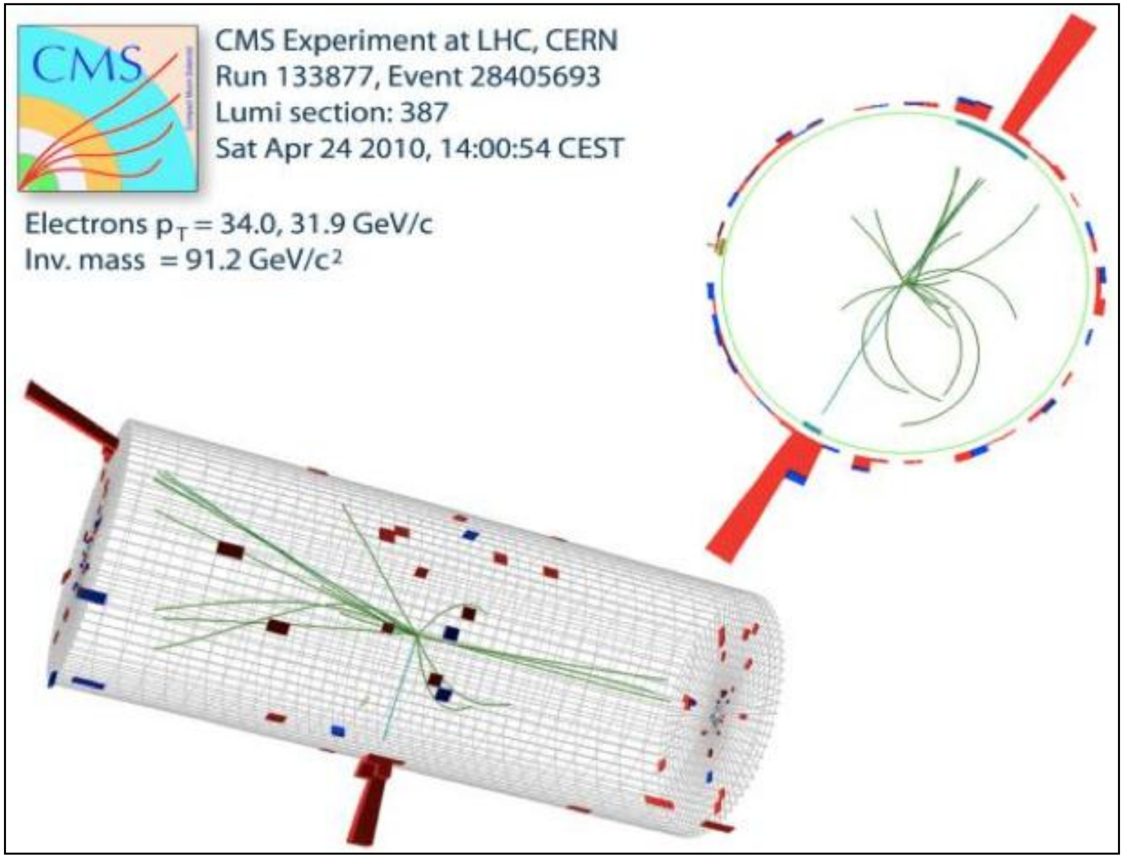


luminosity measurements



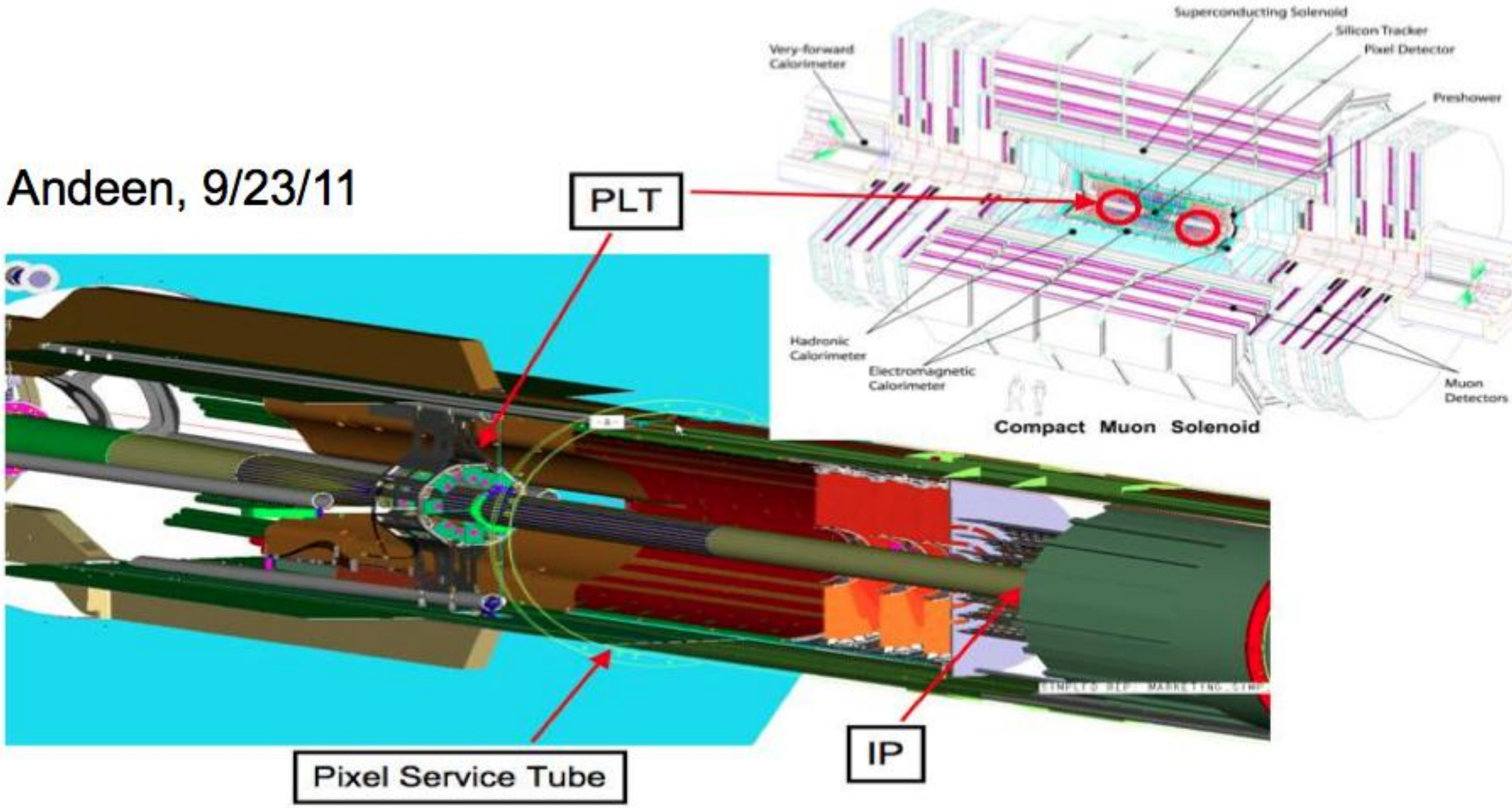
luminosity measurements

- W, Z decays as "standard candles"
  - invert cross section measurement
- cross sections have been accurately measured
- high production rates
  - frequent measurements possible



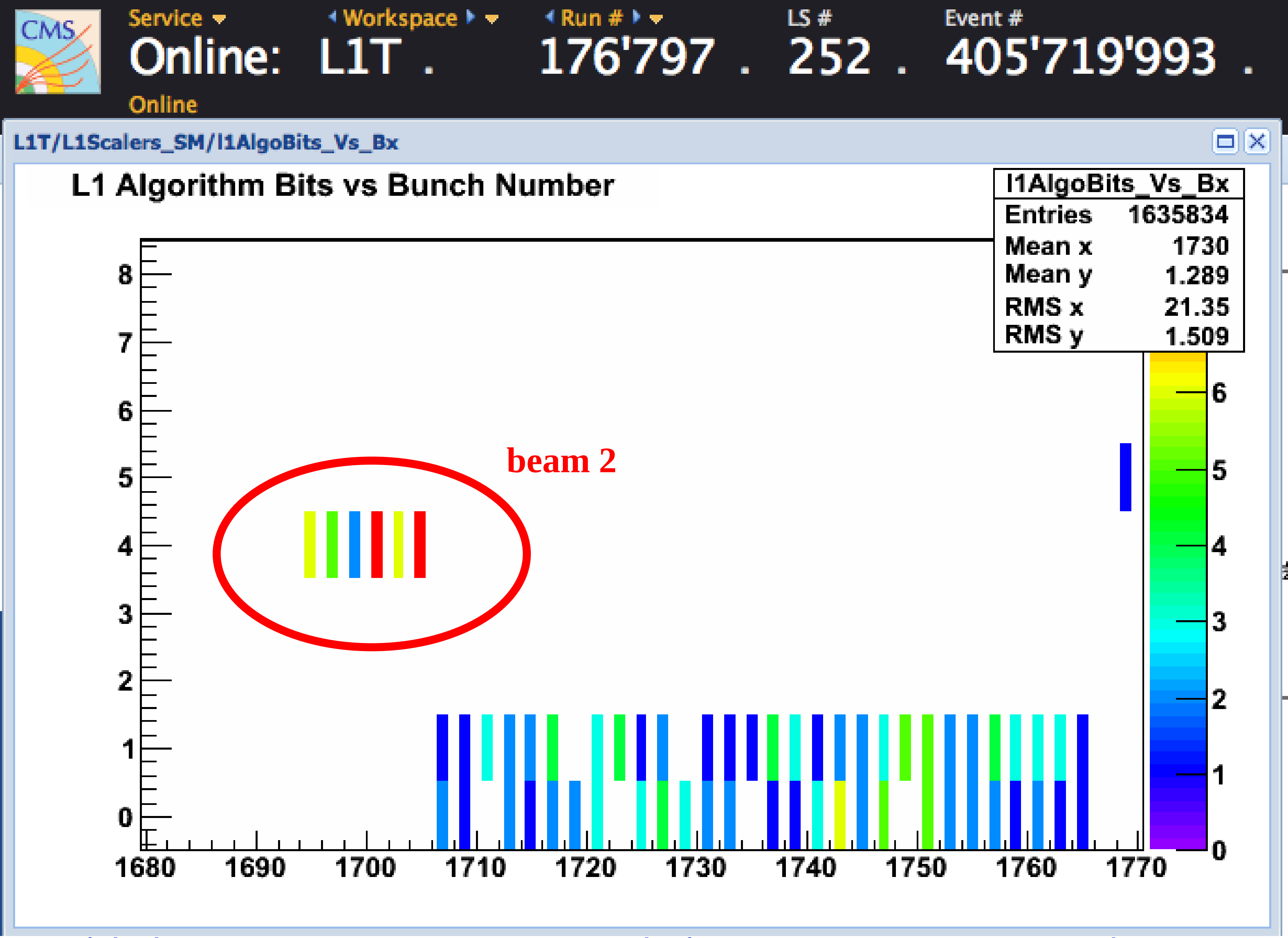
luminosity measurements

- Pixel Luminosity Telescope (PLT)
  - dedicated diamond detectors in Pixel system
  - 1.75 meters from interaction point, both sides
  - Measure number of 3-fold coincidences in each bunch crossing



beam background studies

- beam gas is an important factor for background
- monitor and measure by using "unpaired" bunches
  - some bunches collide in ALICE or LHCb but not in ATLAS / CMS
- after a high-luminosity "bunch train": high induced activity with decay time of several time slices (*"albedo"*)
- have to use unpaired bunches *before* a bunch train (not *after*)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L1 Algorithm Bits vs Bunch Number
l1AlgoBits_Vs_Bx
Entries 1635834
Mean x 1730
Mean y 1.289
RMS x 21.35
RMS y 1.509
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1770

planning for 2012: bunch-filling scheme

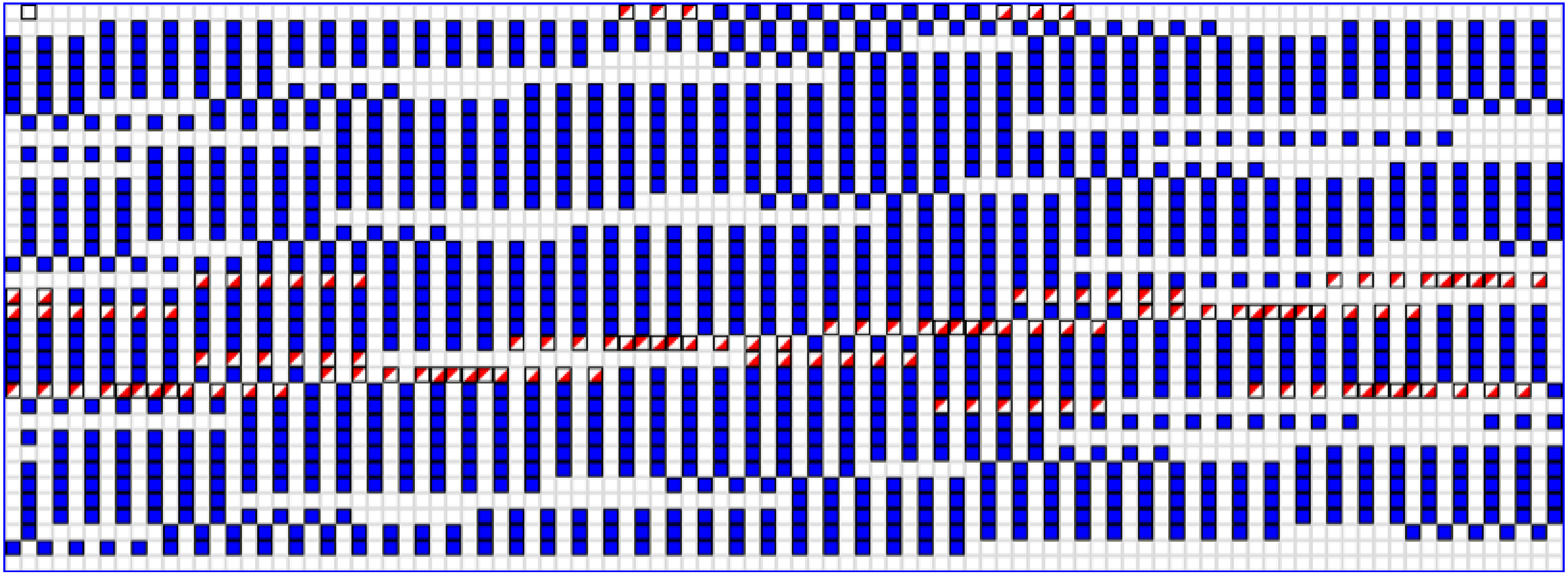
- original LHC plan: a bunch every 25 ns
  - for proton running (spacing for heavy ions is wider)
  - 40 MHz, except for gaps due to accelerator design
  - experiments layed out for this
- so far, LHC has been running at 50 ns bunch spacing
  - easier for the accelerator
  - makes some things easier for experiments, too
- at same total luminosity, luminosity per bunch and therefore pileup is lower at 25 ns
  - easier to disentangle events, better for analysis

LHC bunch-filling scheme

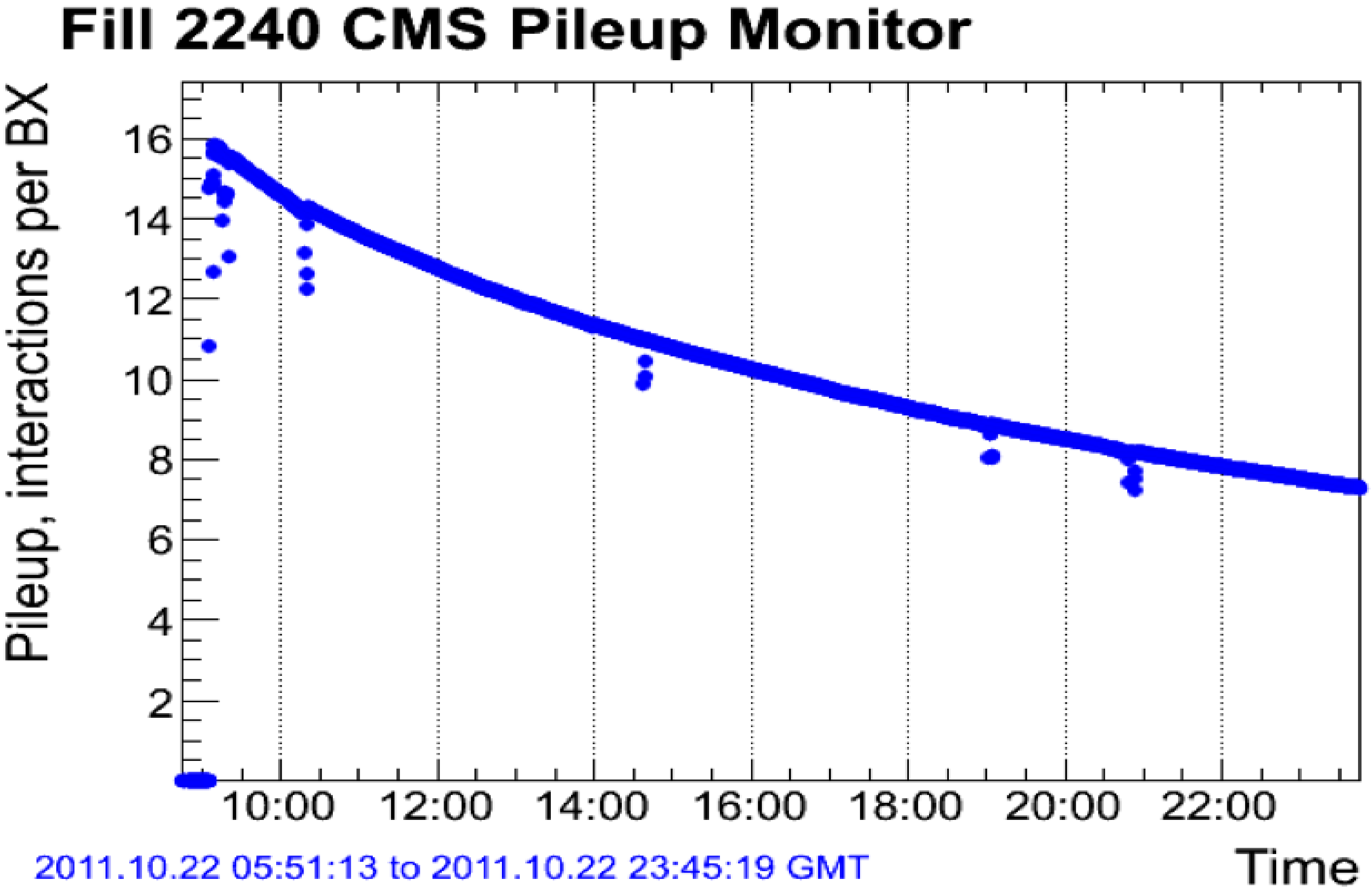
LHC orbit with 3564 "bunch crossings"
(colliding bunches in CMS: blue; single bunches in CMS: red/white):

Fill 2129 Bunch Pattern at CMS *1317 luminosity bunch pairs – $\times 10^{27} cm^{-2} sec^{-1}$*

BX 0 → 98



average number of interactions per bunch crossing



planning for 2012: LHC energy

- in 2010 and 2011, LHC has been running at a beam energy of 3.5 TeV
  - 7 TeV collision energy ($\sqrt{s}$ = 7 TeV)
- after shutdown in 2013-2014, design beam energy of 7 TeV will be reached
  - $\sqrt{s}$ = 14 TeV
- for 2012, discussion to possibly increase beam energy to 4 TeV, i.e. $\sqrt{s}$ = 8 TeV
  - would be beneficial for the CMS experiment (if luminosity is the same)
  - higher production cross sections, in particular for heavy objects
  - e.g, gg-produced, 2.5 TeV mass SUSY particle: cross section should increse more than 3 times if ($\sqrt{s}$ = 7 TeV) → ($\sqrt{s}$ = 8 TeV)

the future: CMS upgrade plans

- why upgrade?
- radiation damage to inner detectors (Pixels, Si Strips)
  - replacement planned from the beginning
- obsolescence
  - long preparation times for big experiments
  - newer electronics will improve reliability and performance
- higher rates and increased pileup call for better detector resolution
- must not jeopardize performance of detector during data taking!

the future: CMS upgrade plans

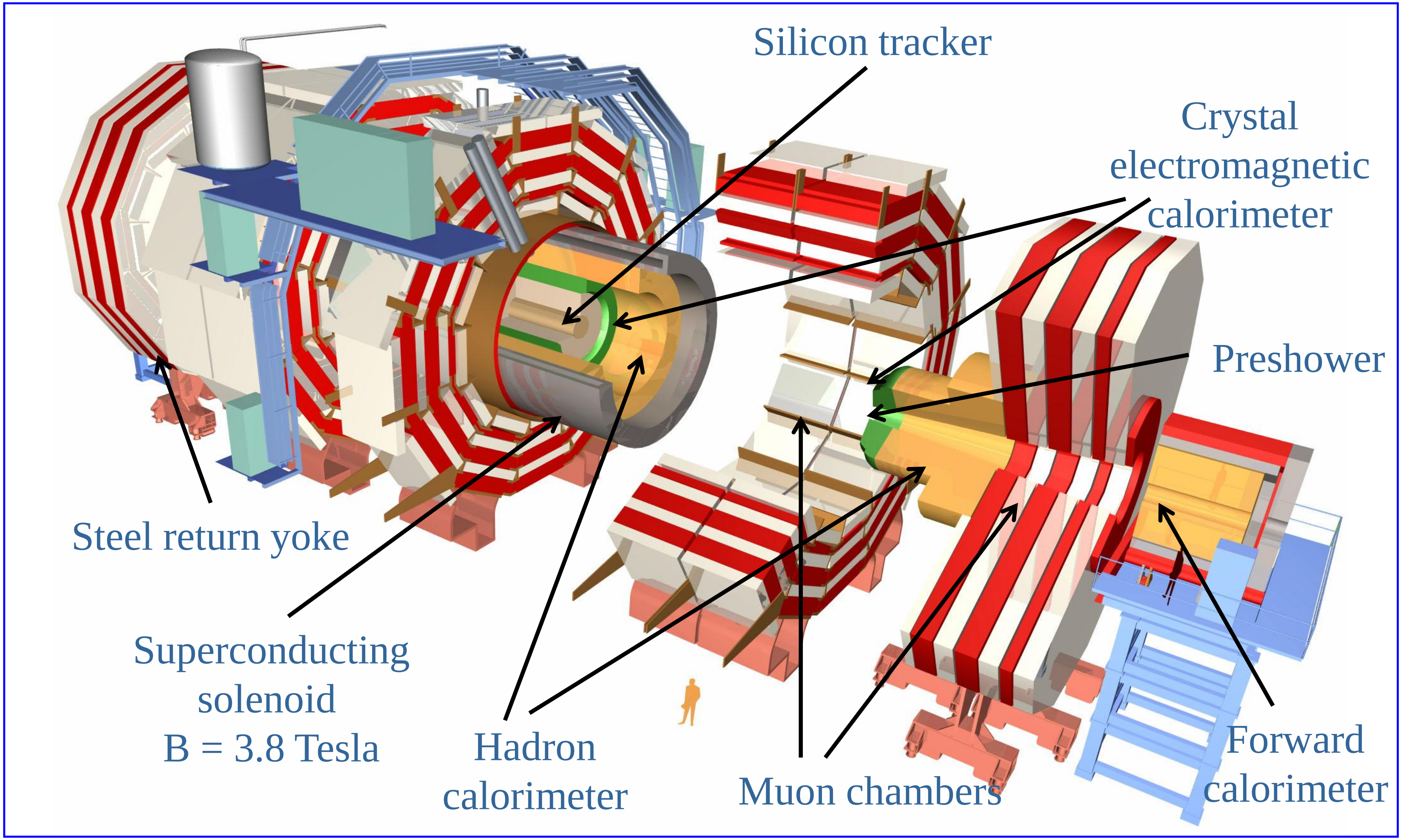
- 2013-2014 first "long shutdown"
- upgrade part of trigger electronics
  - will not be completely ready in 2015
  - but prepare systems and let the run in parallel
- 2015-2017 data taking @ ($\sqrt{s}$ = 14 TeV)
  - switch from old to new systems during Christmas break
- 2018 starting second "long shutdown"
  - inner detector upgrade
- schedule will change over time – stay tuned!

THANK YOU

СПАСИБО

BACKUP

Compact Muon Solenoid



the "ridge" in Pb-Pb collisions: paper

JHEP

Published for SISSA by Springer

Received: *May 12, 2011*
Accepted: *July 7, 2011*
Published: *July 18, 2011*

Long-range and short-range dihadron angular correlations in central PbPb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV

the "ridge" in Pb-Pb collisions

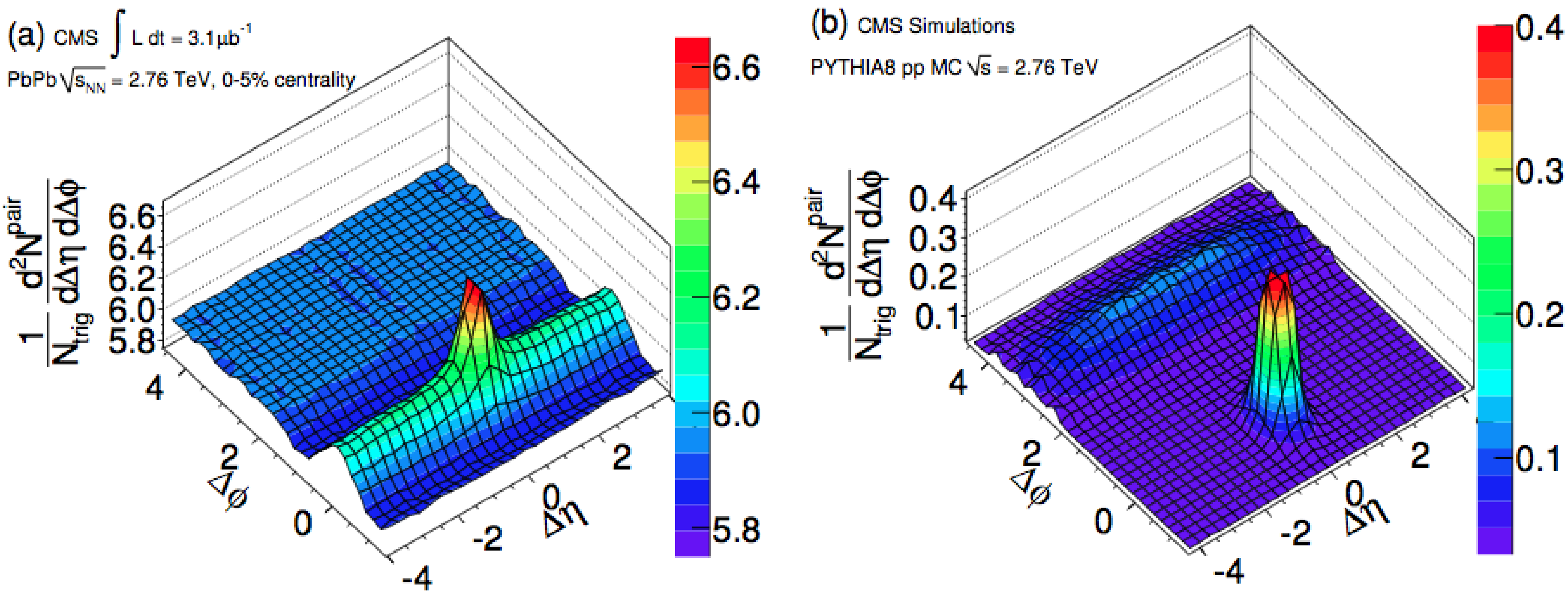


Figure 1. Two-dimensional (2-D) per-trigger-particle associated yield of charged hadrons as a function of $|\Delta\eta|$ and $|\Delta\phi|$ for $4 < p_T^{trig} < 6$ GeV/c and $2 < p_T^{assoc} < 4$ GeV/c from (a) 0-5% most central PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, and (b) PYTHIA8 pp MC simulation at $\sqrt{s} = 2.76$ TeV.

Muon trigger