

2010 Highlights from the CMS Experiment

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on behalf of the CMS Collaboration

New Physics!

Mass Generation Problem: what is the origin of the SM elementary particle masses? Higgs Boson? Other Mechanism?

Dark-Matter Problem: $\sim 25\%$ of the universe consists of invisible matter. SUSY? ...?

Extra Dimensions: Are there more than three space dimensions? If yes, they give rise to new heavy particles, microscopic black holes, ...!

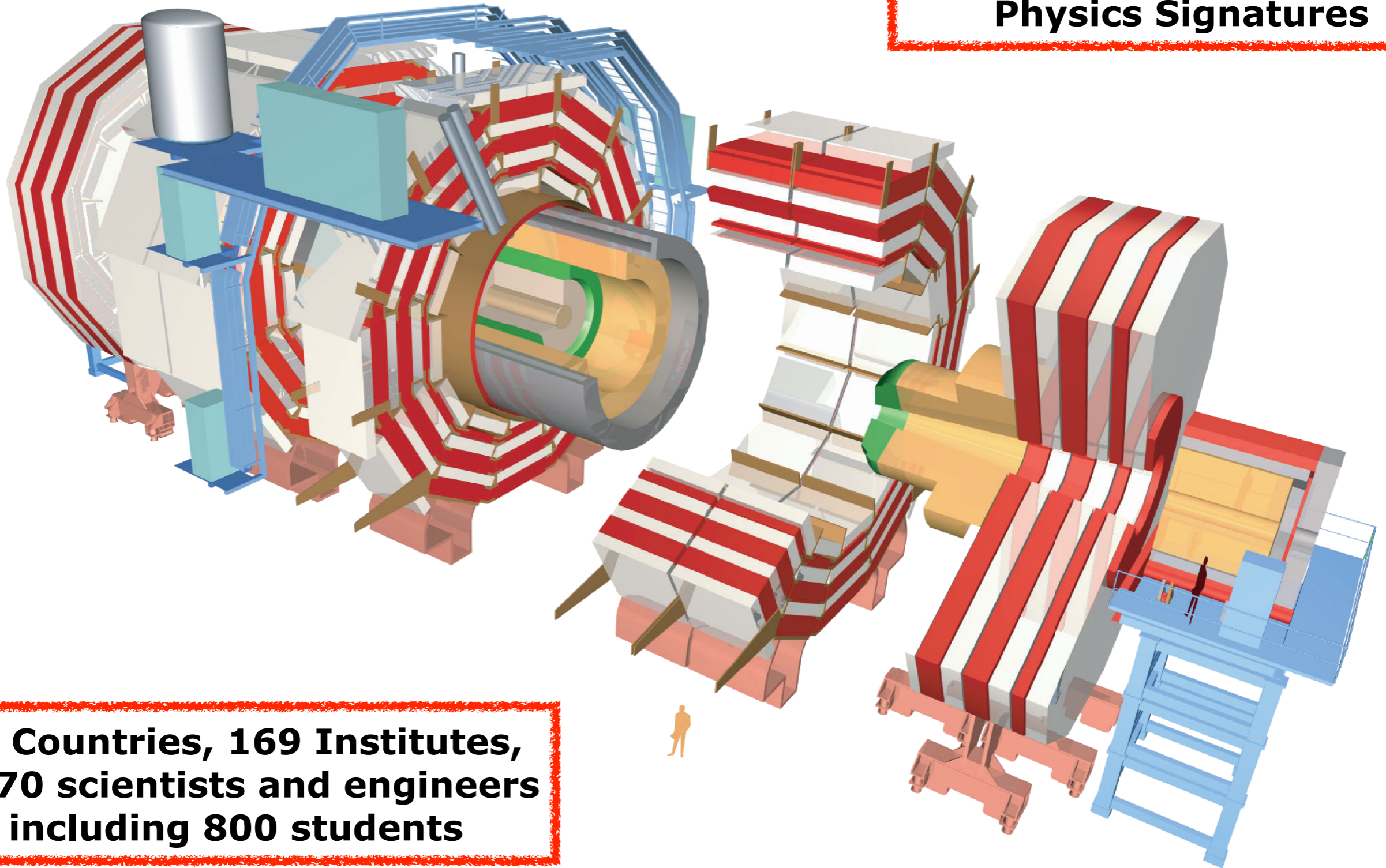
The CMS Detector

Standard Model Physics
Searches for New Physics
First Heavy Ion Results
Prospects for 2011

The Compact Muon Solenoid Detector

Total weight 14000 t
Overall diameter 15 m
Overall length 28.7 m

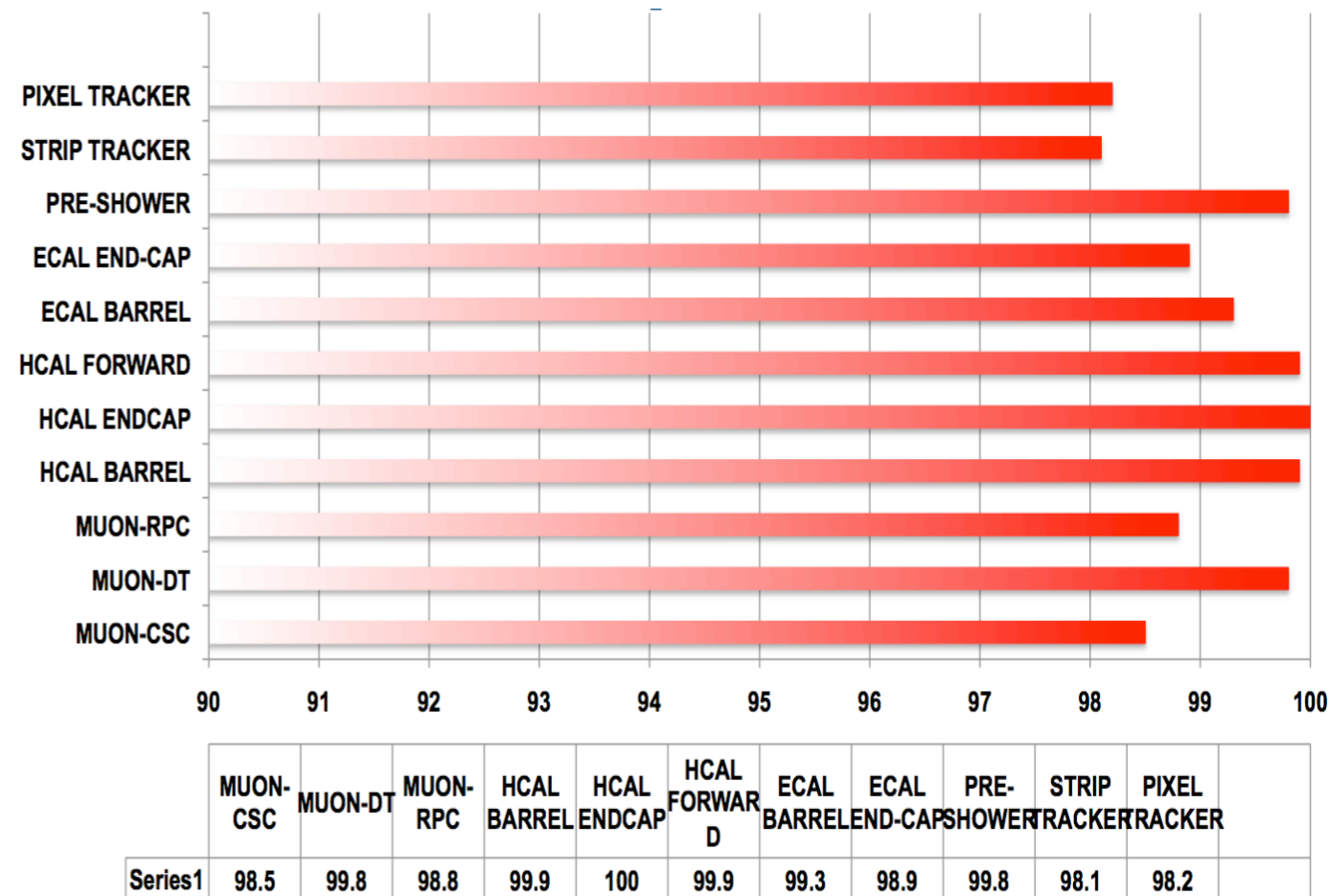
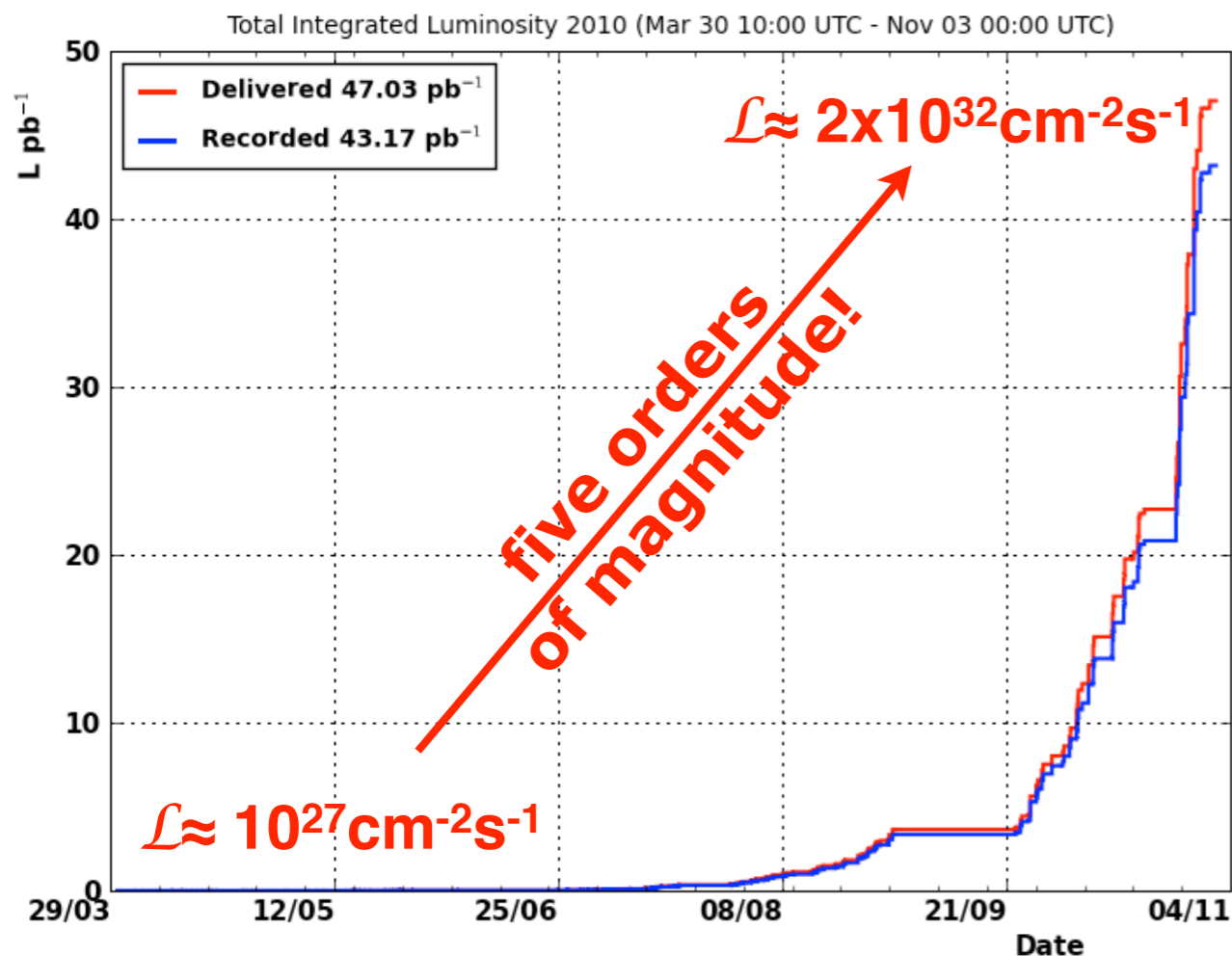
**General-Purpose Detector
Suited for Large Variety of
Physics Signatures**



**39 Countries, 169 Institutes,
3170 scientists and engineers
including 800 students**

LHC & CMS pp Operations 2010

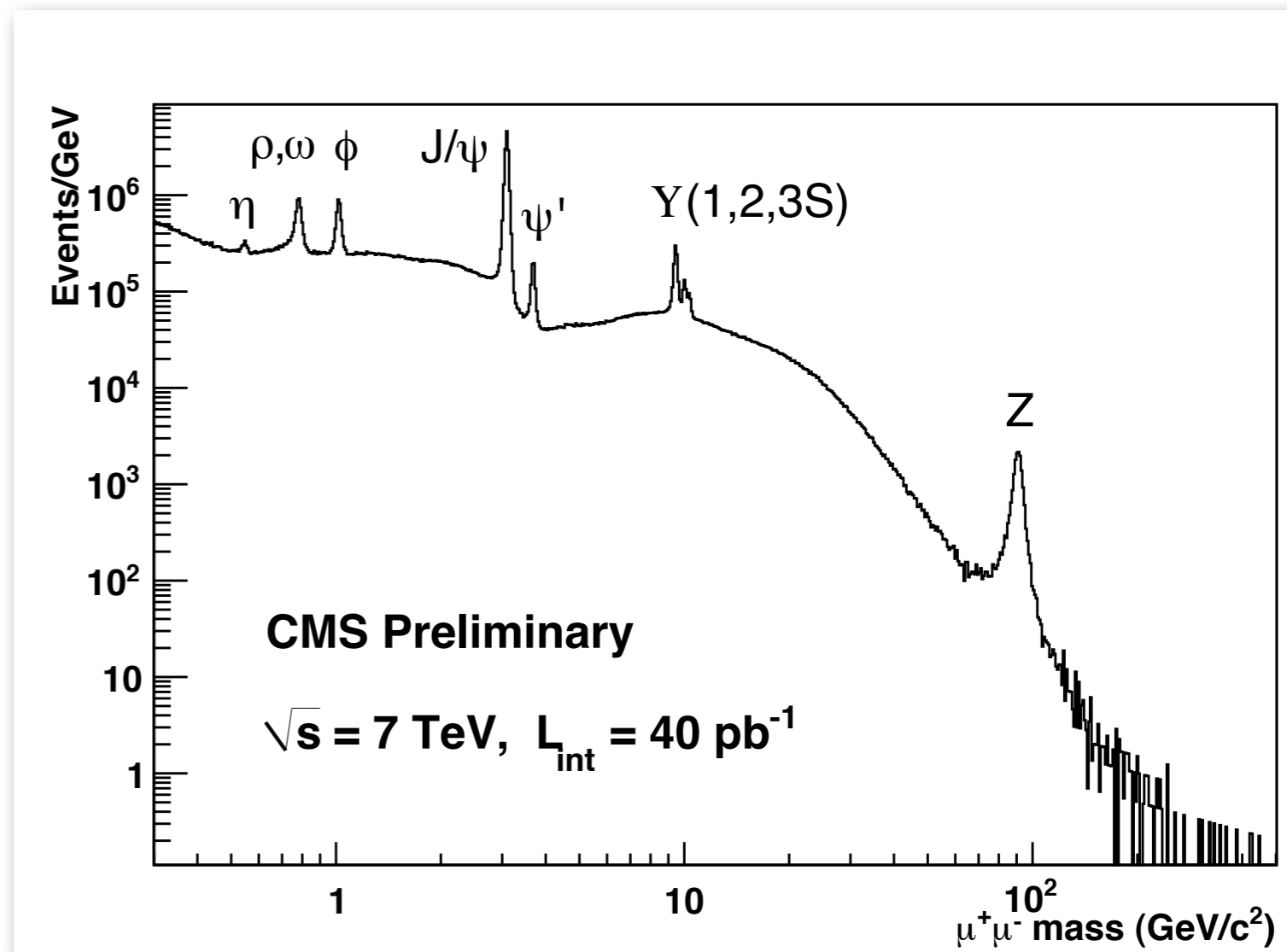
- ➔ $\sim 47 \text{ pb}^{-1}$ delivered by LHC and $\sim 43 \text{ pb}^{-1}$ collected by CMS ($\epsilon \approx 92\%$)
- ➔ Average fraction of operational channels per CMS sub-system $> 99\%$
- ➔ Good performance, handled increase of more than **5 orders of magnitude** in instantaneous luminosity over 7 months!



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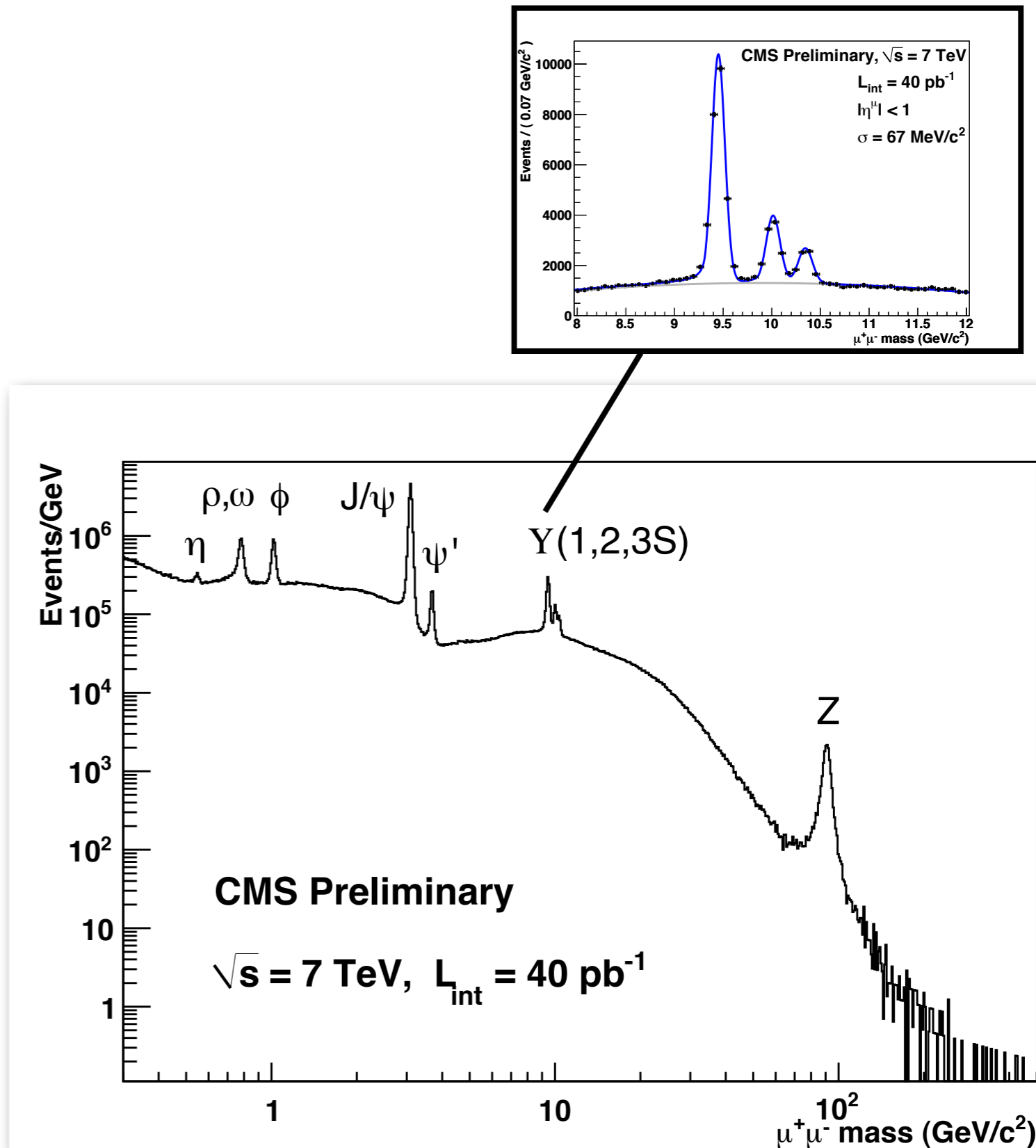
Di-Electron and Di-Muon Spectra

High-Resolution
Electron & Muon
Reconstruction over
full kinematic range

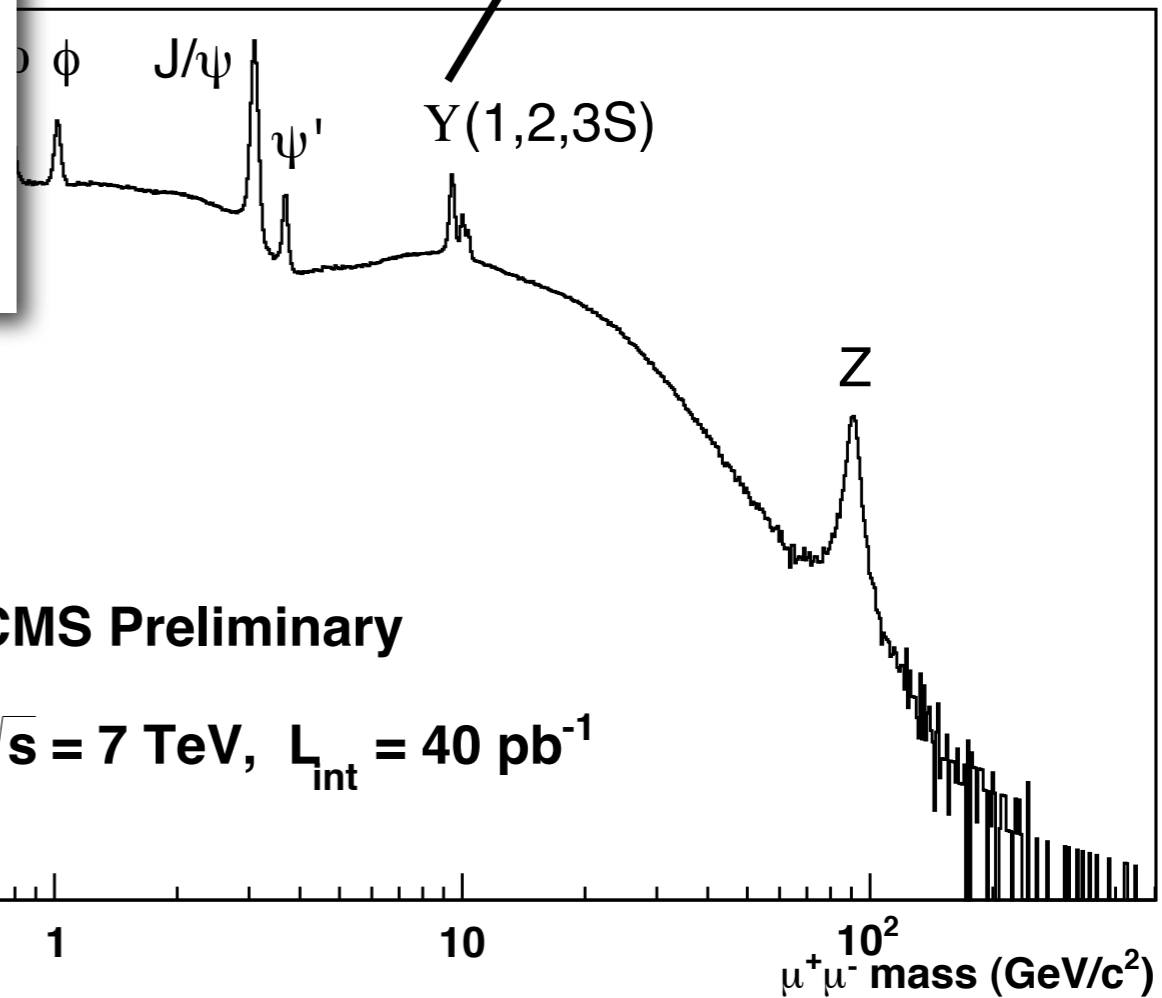
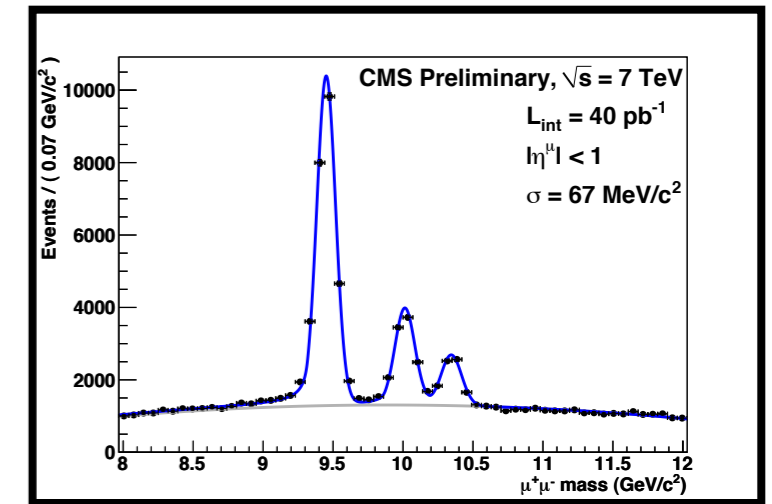
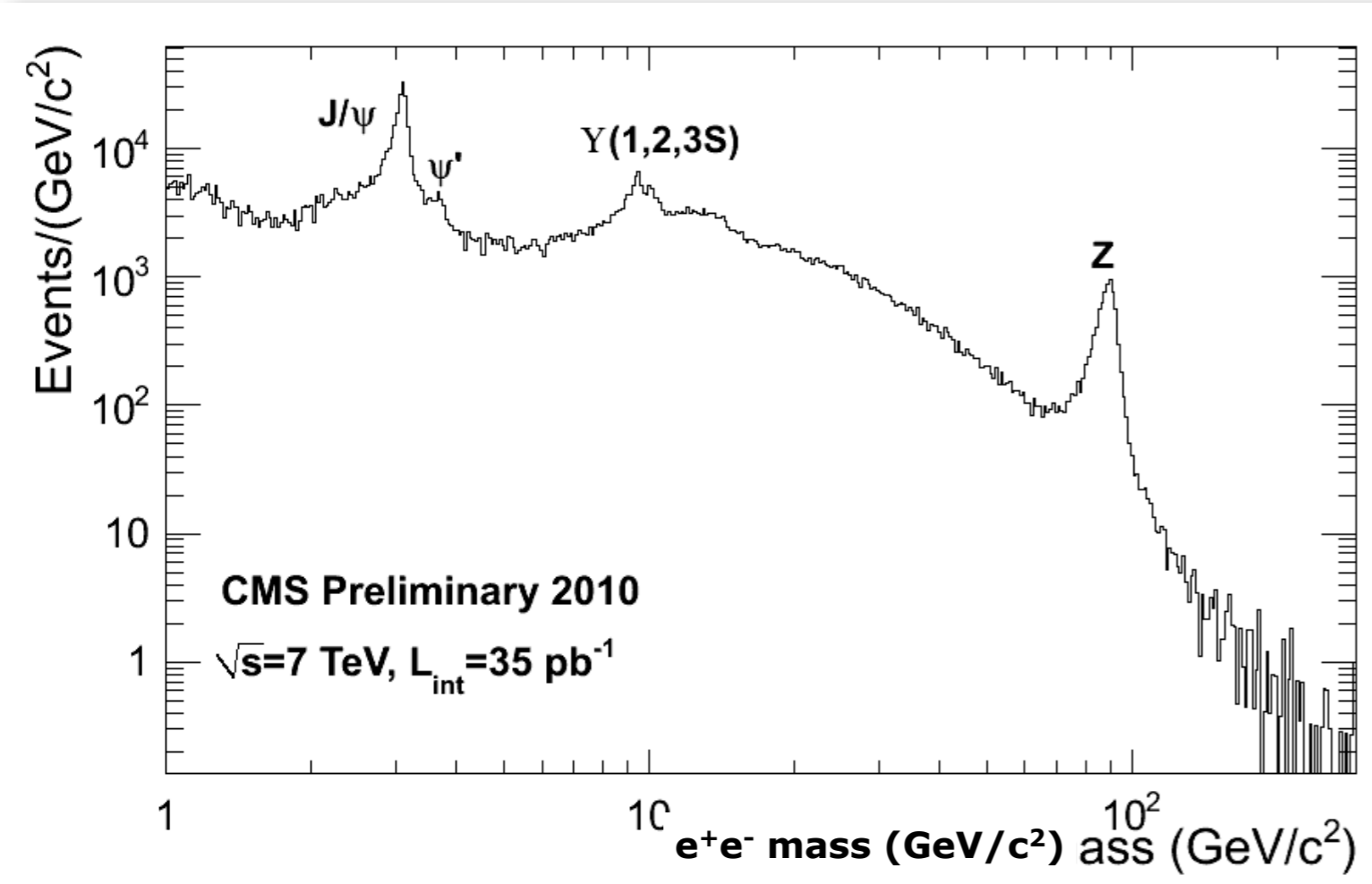


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High-Resolution
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full kinematic range



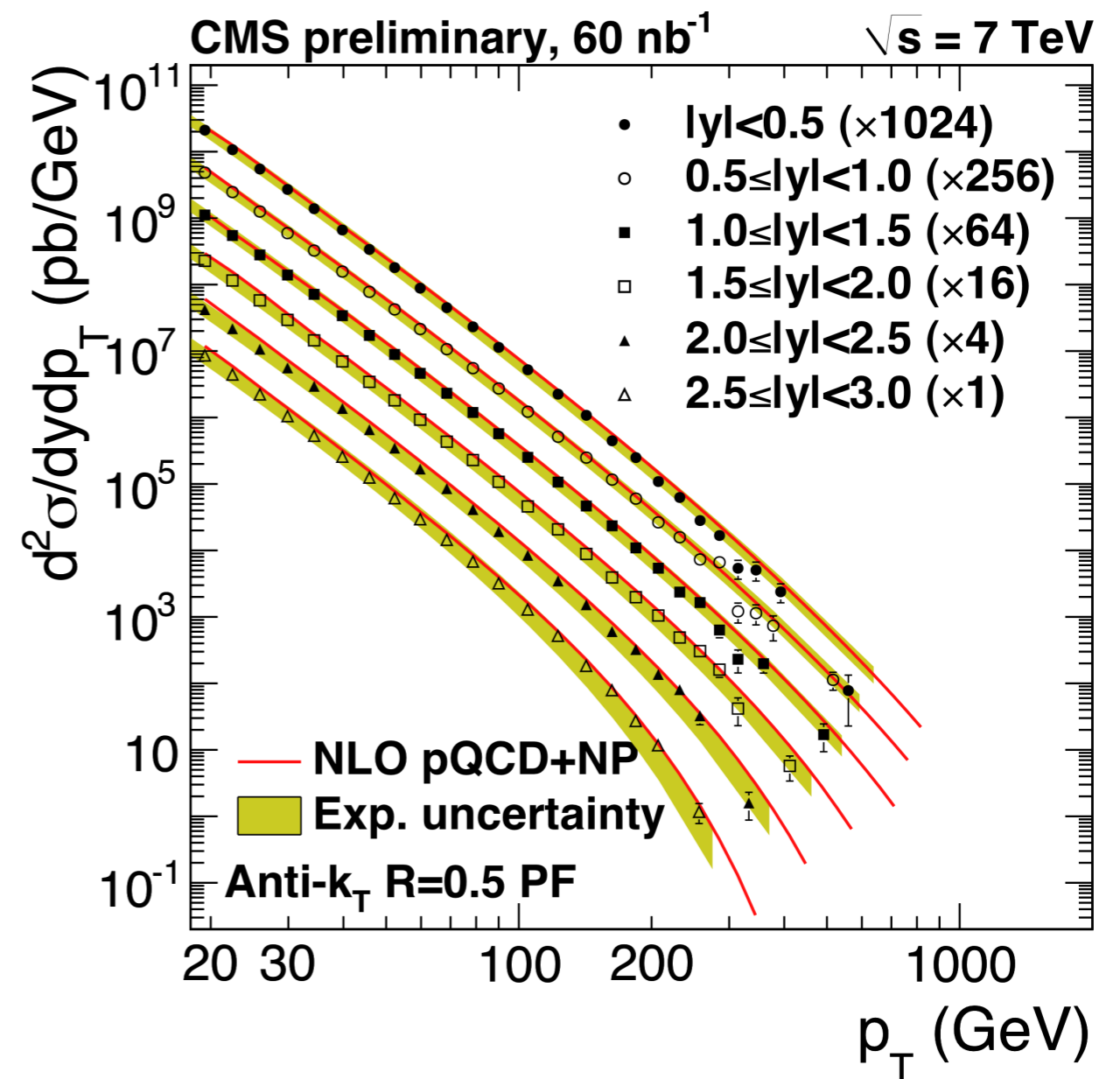
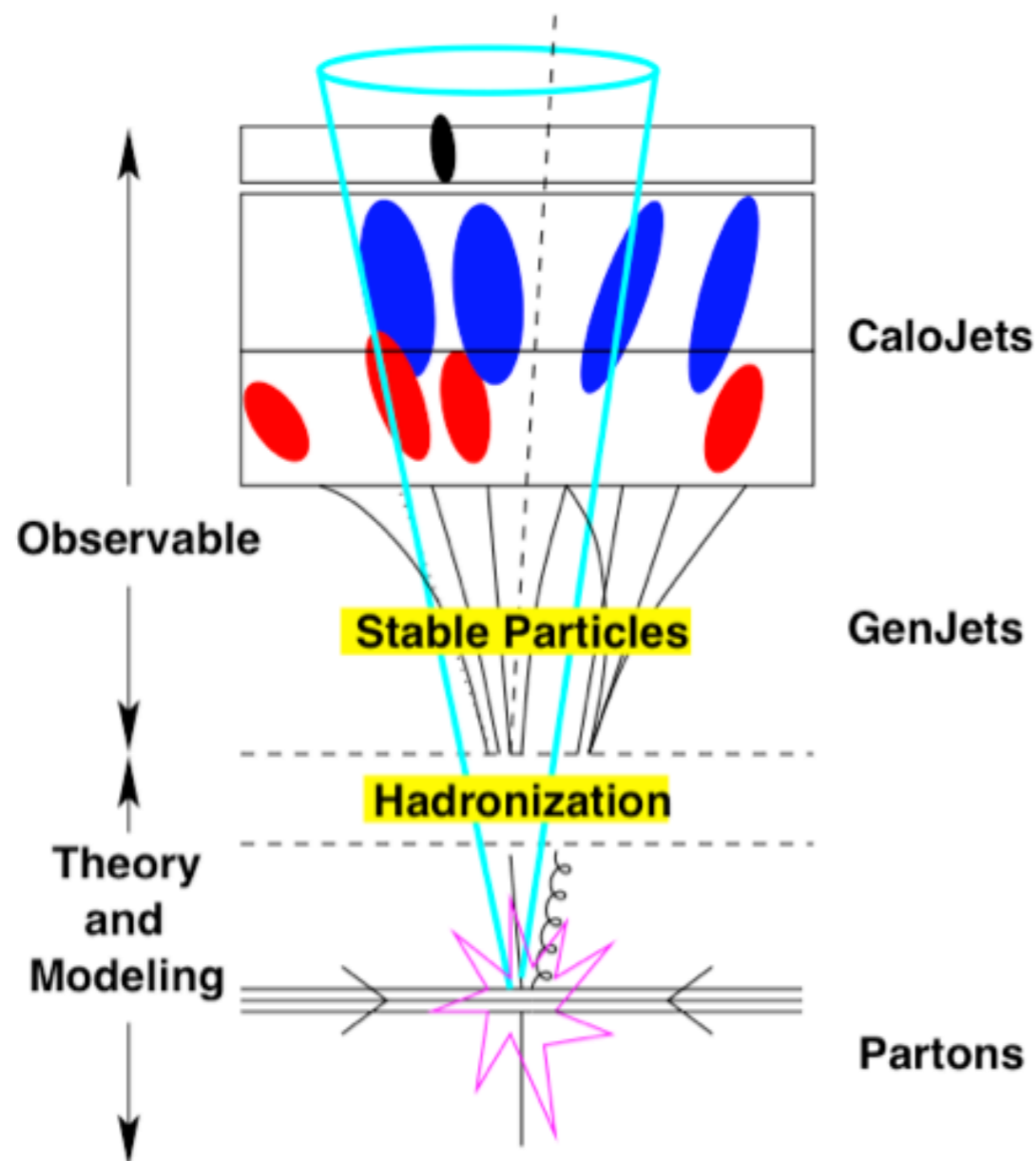
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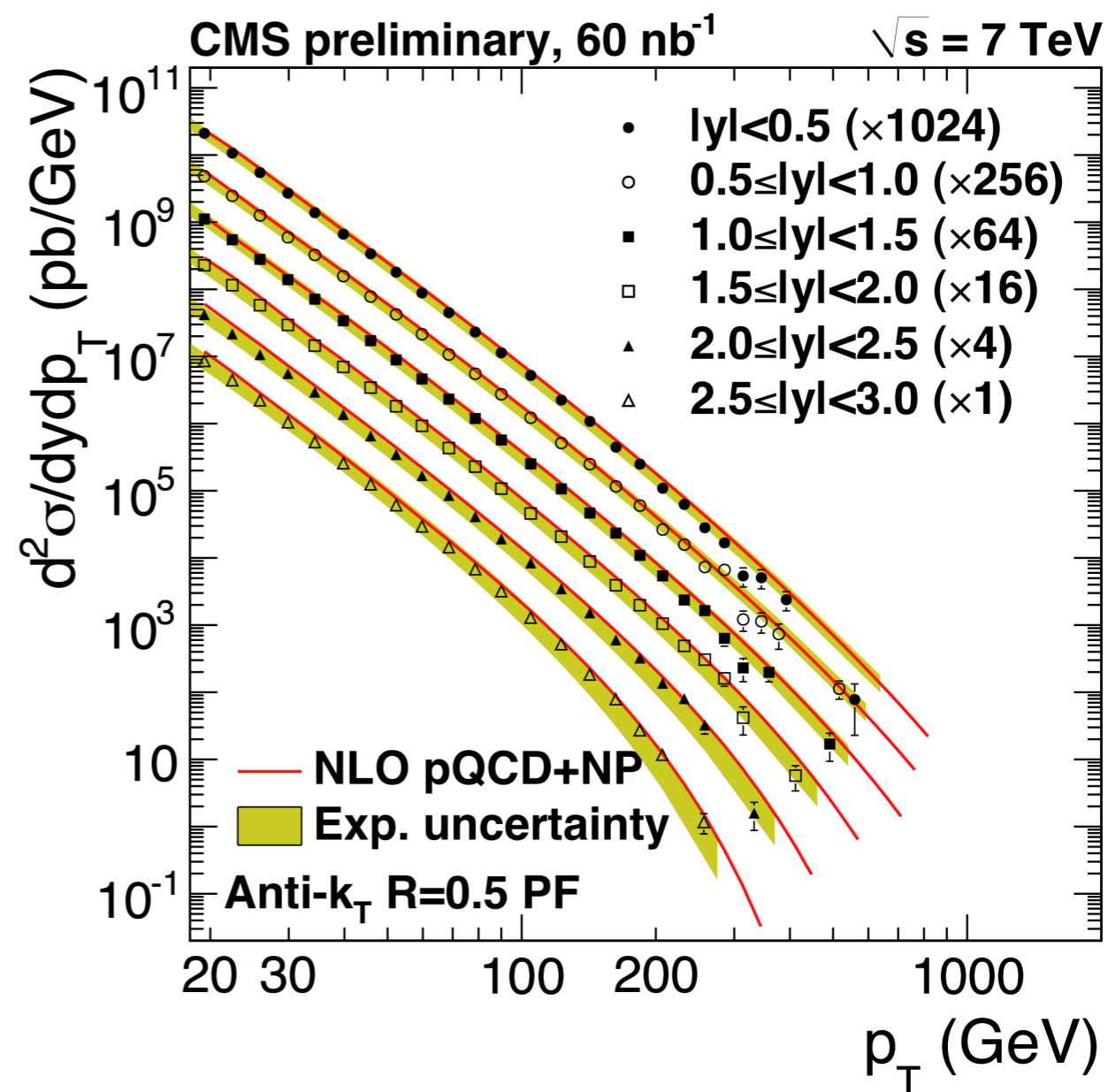
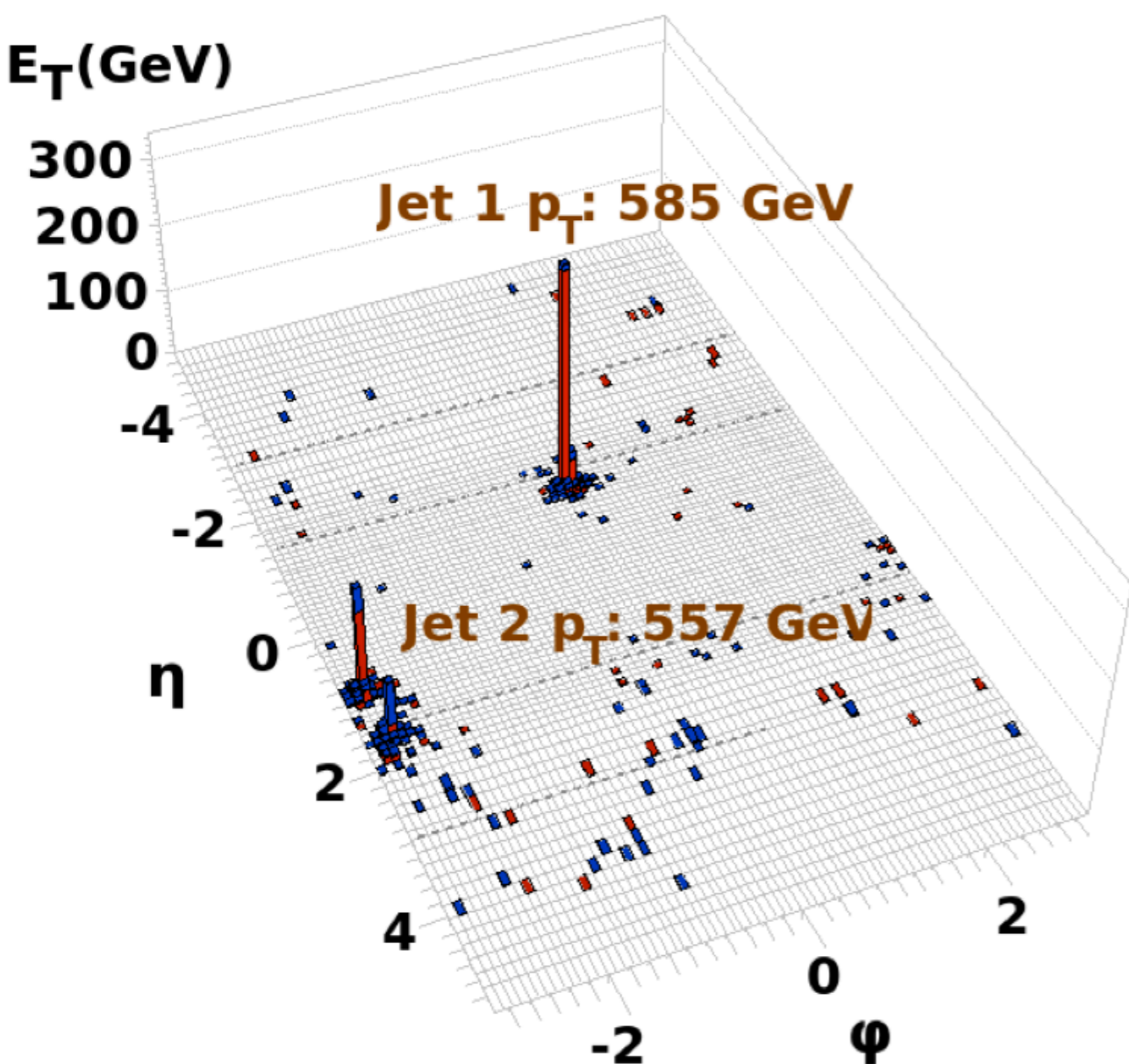
Inclusive Jet Production

Measured Jet Production rate in good agreement within experimental and theoretical uncertainties



Inclusive Jet Production

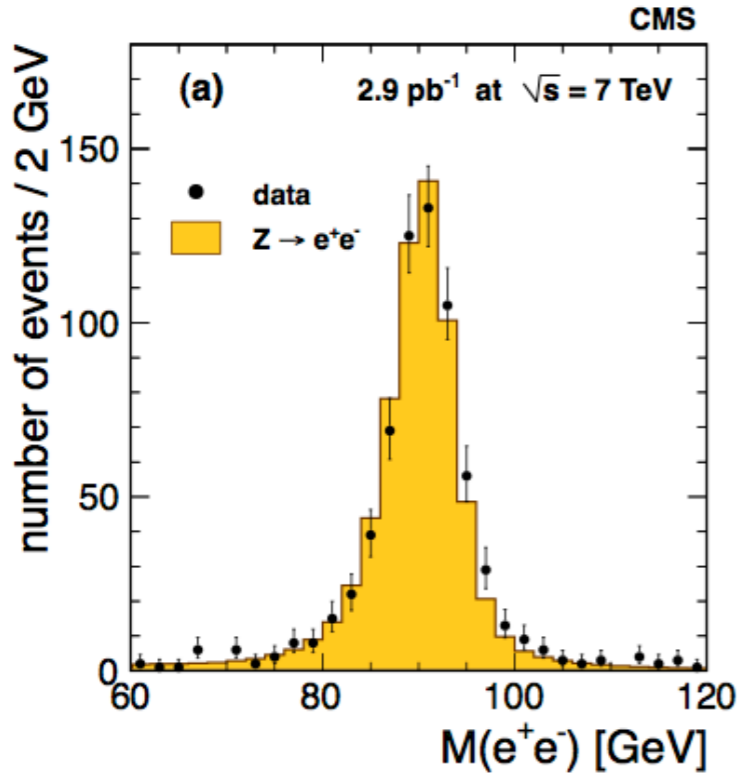
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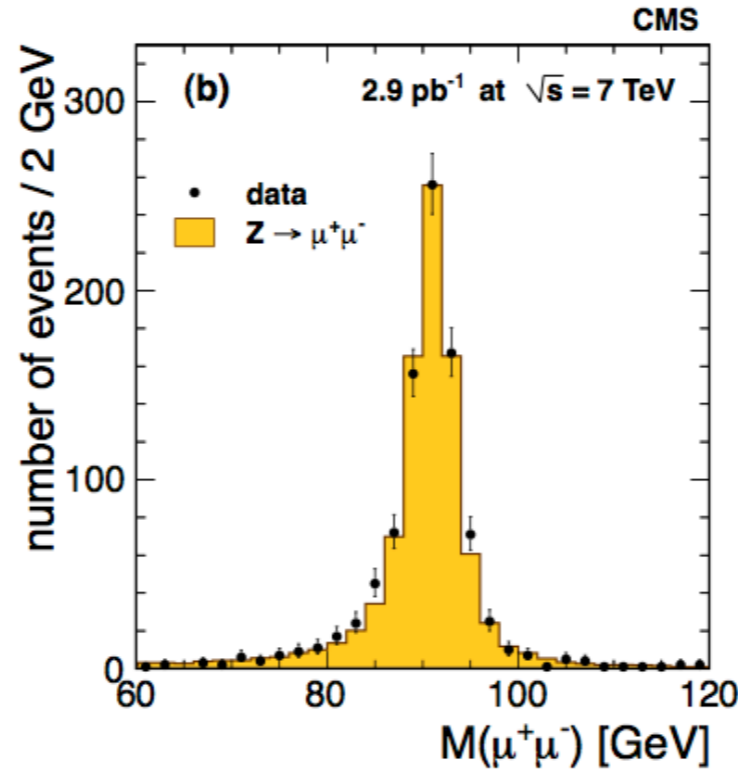
W & Z Boson Production

Z Boson

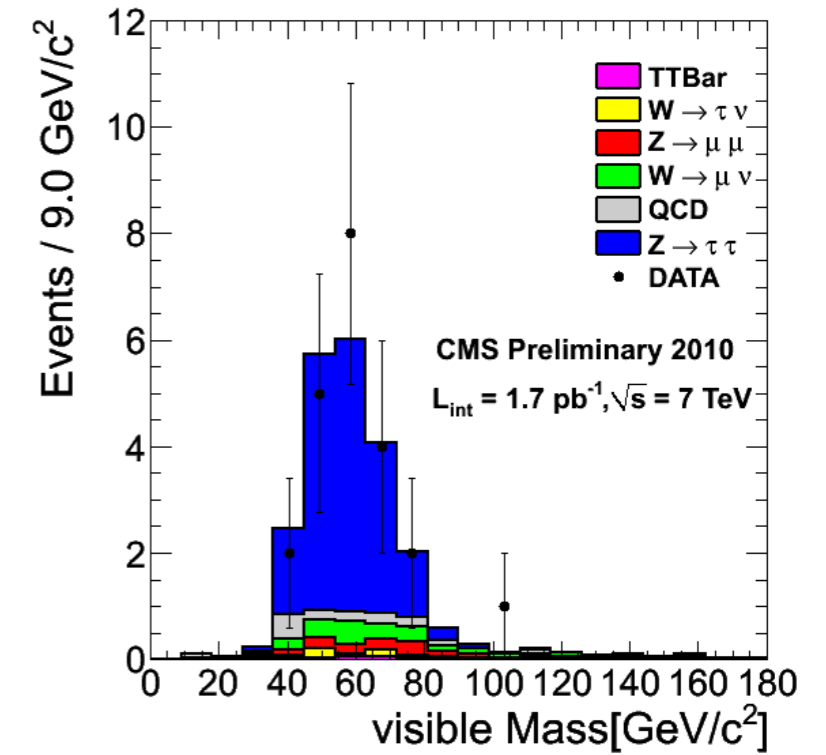
electron(s)



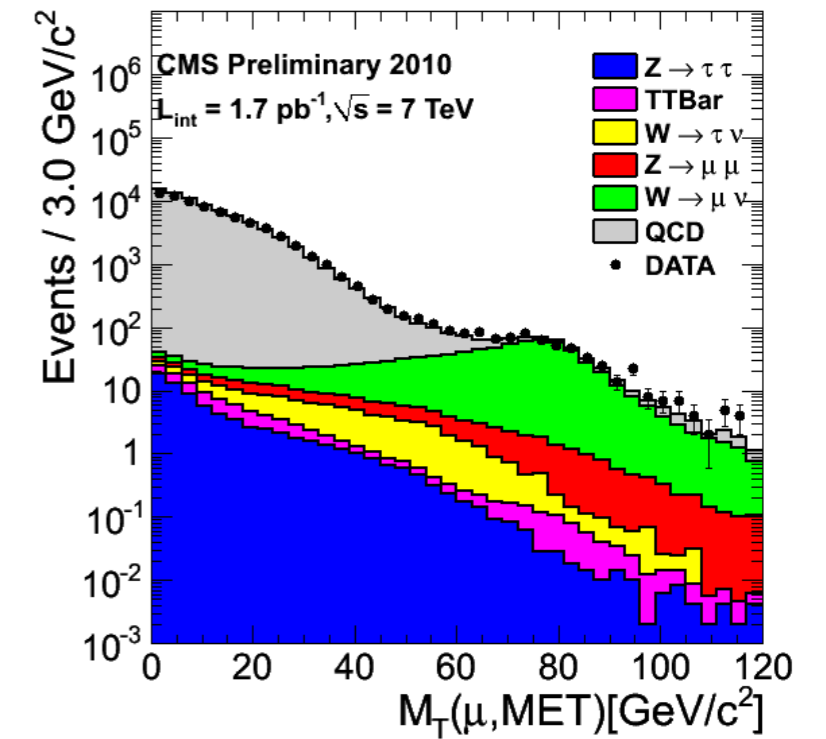
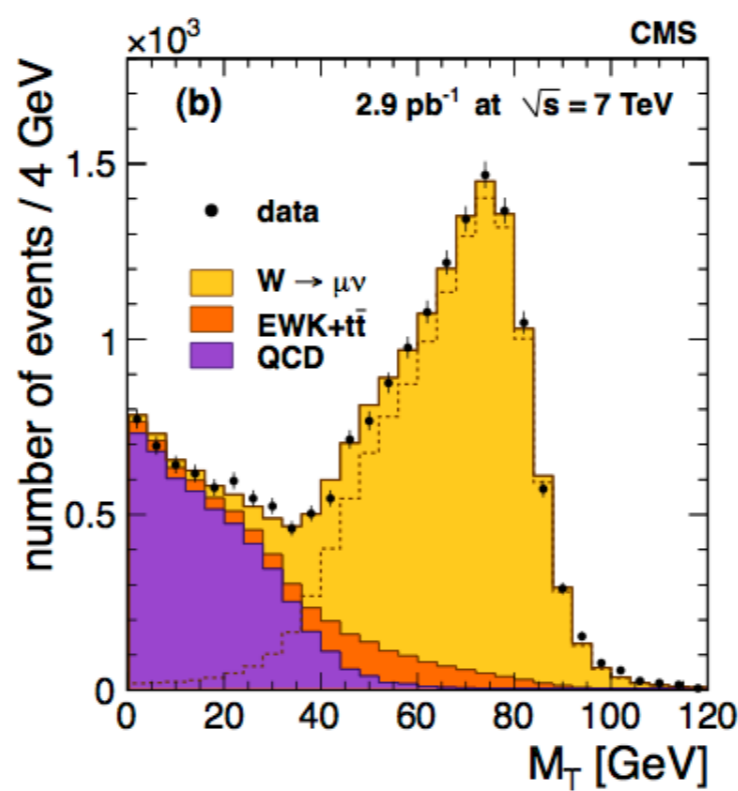
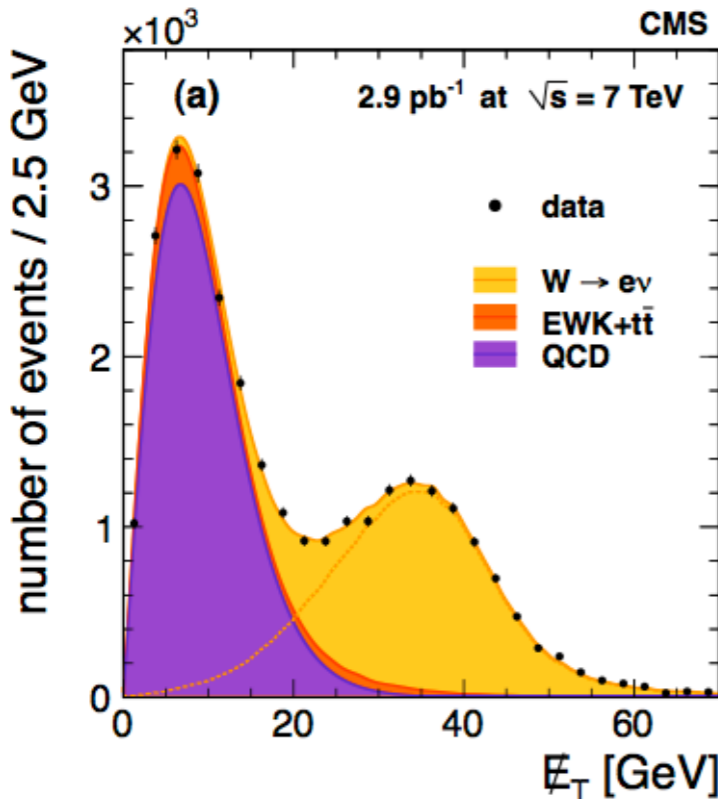
muon(s)



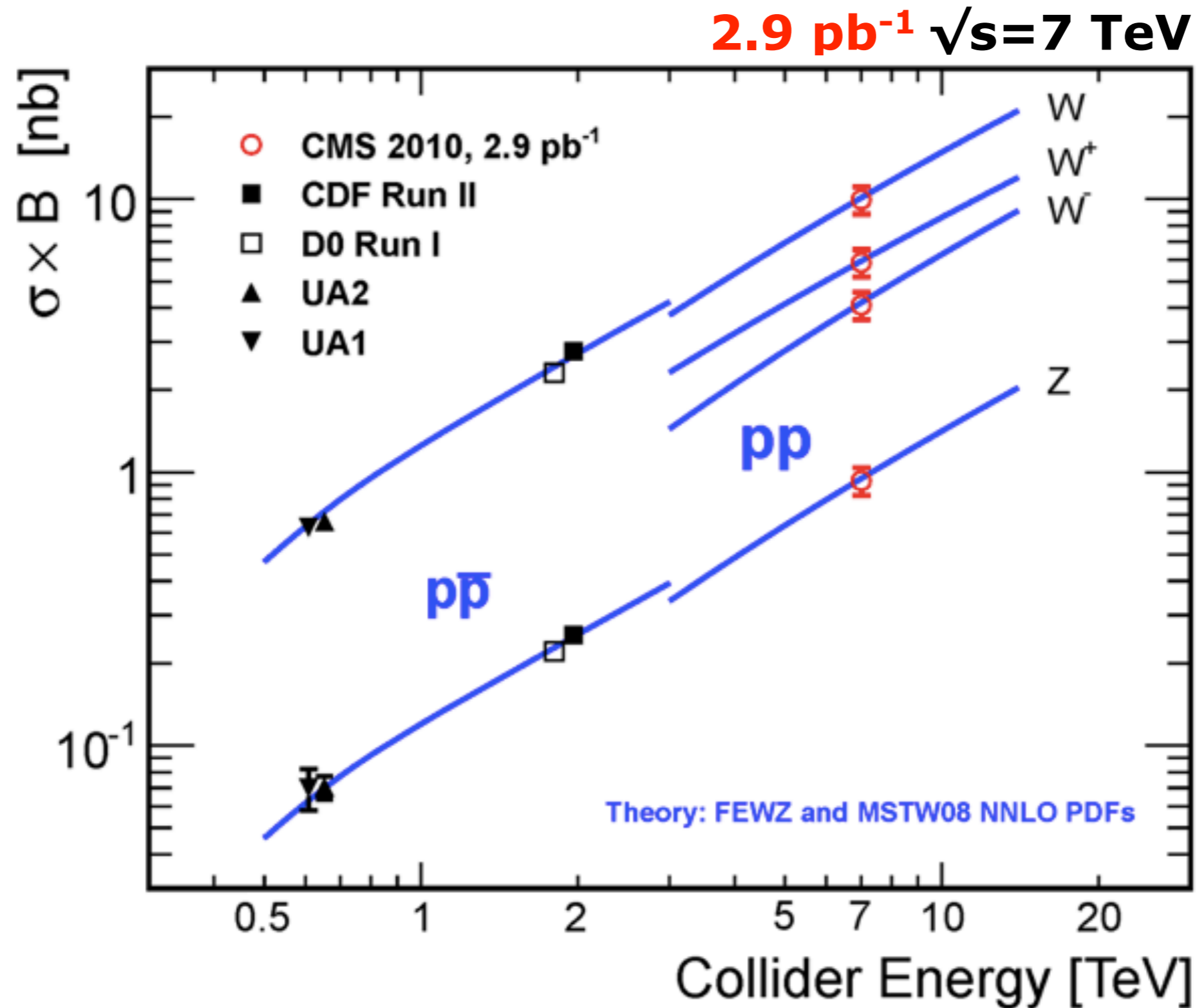
tau(s)



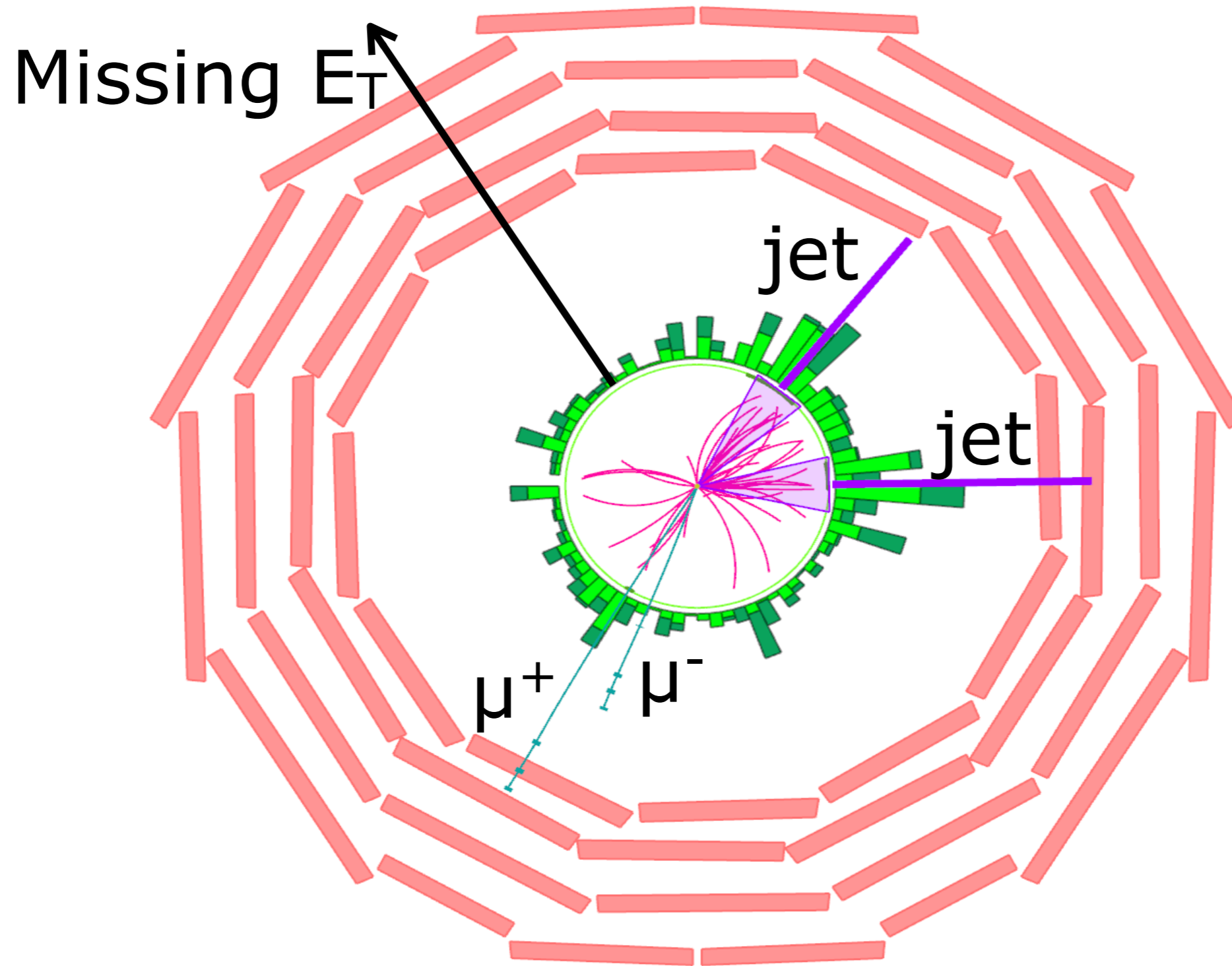
W Boson



W & Z Boson Production: Results



Top Pair Production



Top Di-Muon Candidate Event

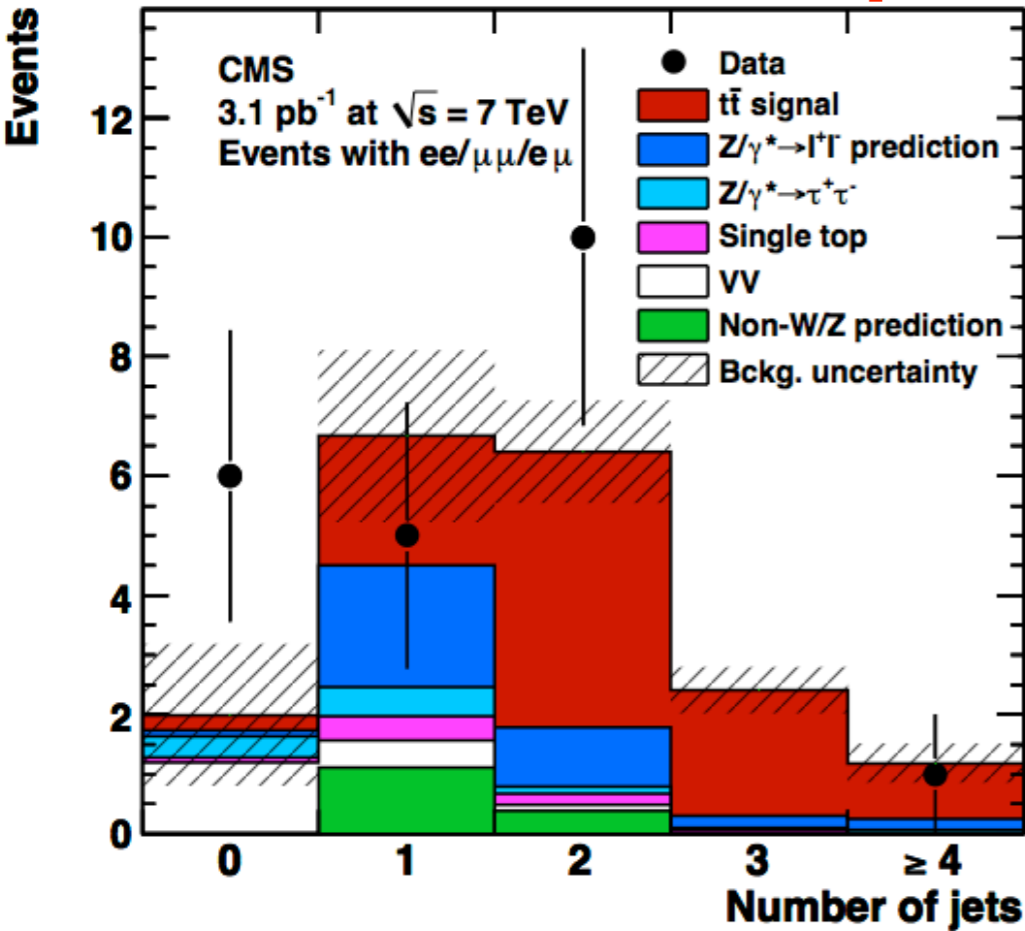
Top Pairs: Dilepton Channel

Accepted by PLB

arXiv:1010.5994 [hep-ex]

3.1 pb⁻¹

2 Leptons, ≥2 Jets, Missing E_T



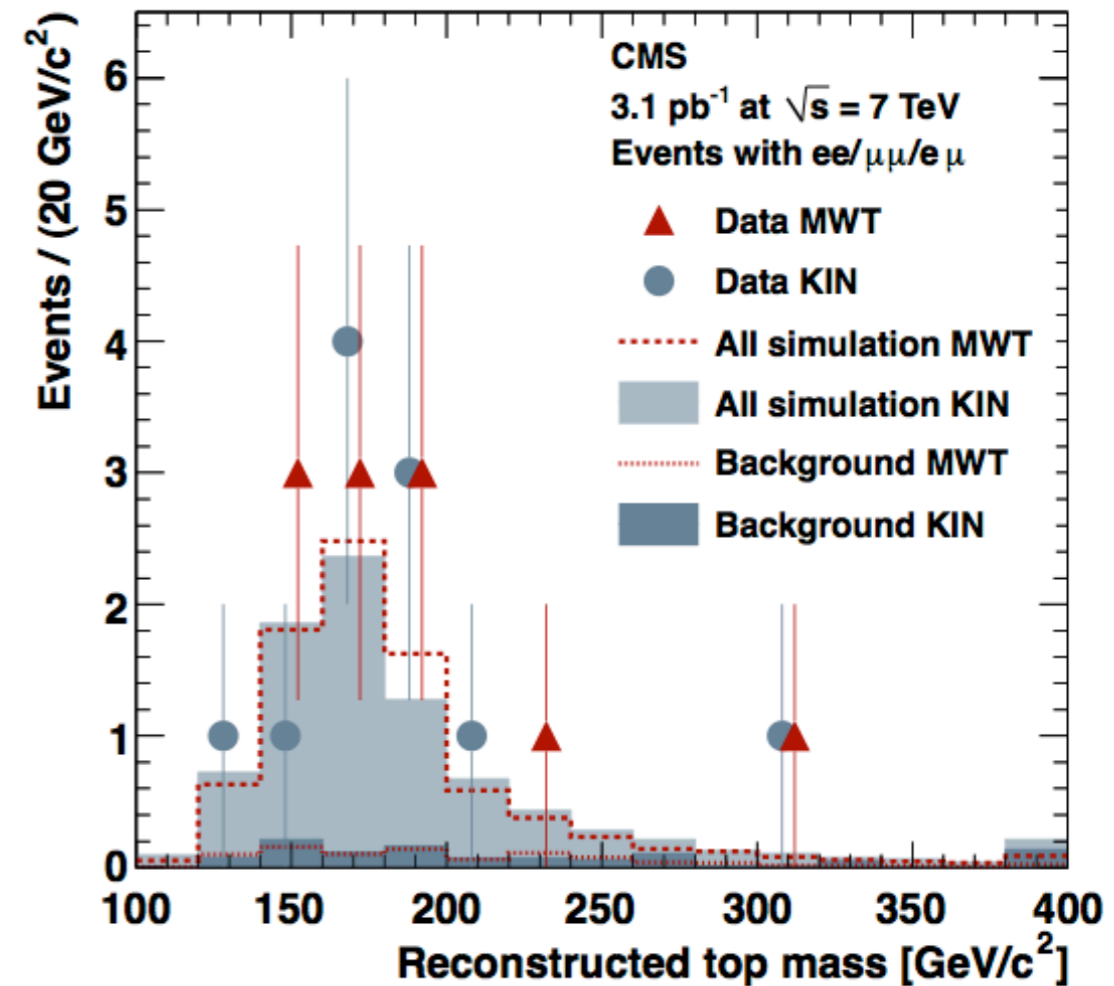
First LHC top pair cross-section measurement:

$$\sigma(pp \rightarrow t\bar{t}) = 194 \pm 72(\text{stat}) \pm 24(\text{syst}) \pm 21(\text{lumi}) \text{ pb}$$

Consistent with theory prediction

Reconstructed Top Mass in good agreement with simulation prediction

Top Mass measurement with full 2010 pp dataset in preparation



Two-Particle Angular Correlations

Published in

J. High Energy Phys. 09 (2010) 091

First **surprising** result from the LHC:
Observation of Long-Range Near-Side
Angular Correlations in pp Collisions

MinBias

(b) MinBias, $1.0\text{GeV}/c < p_T < 3.0\text{GeV}/c$

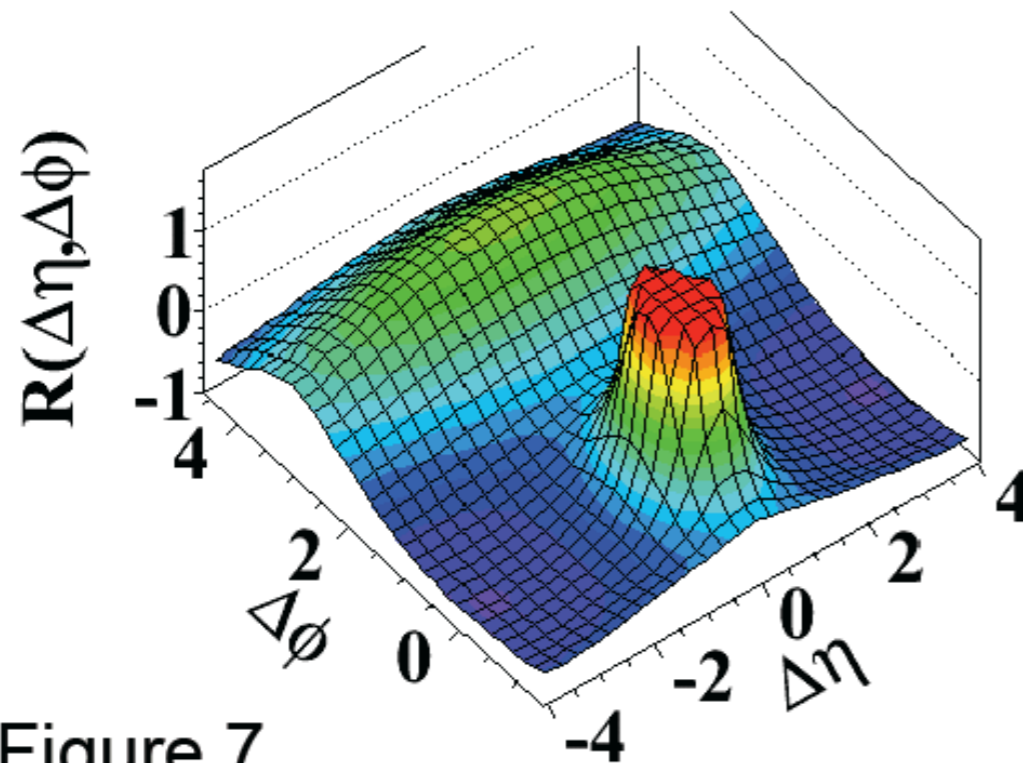
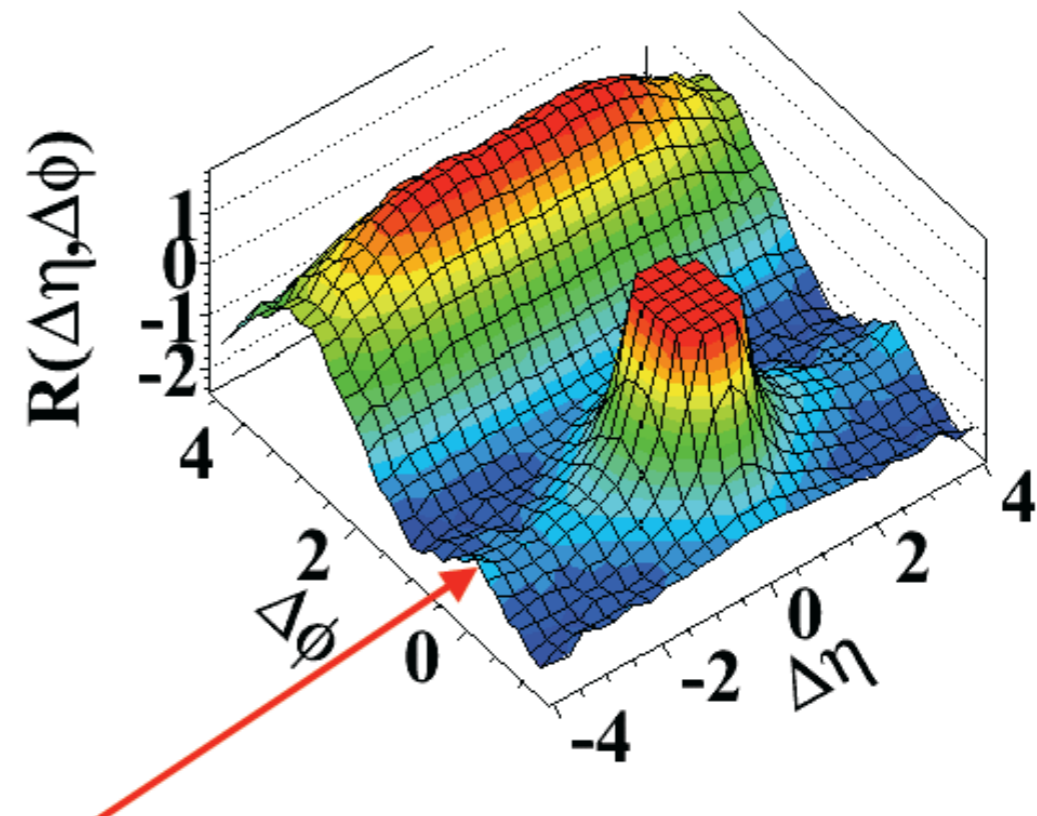


Figure 7

high multiplicity ($N > 110$)

(d) $N > 110$, $1.0\text{GeV}/c < p_T < 3.0\text{GeV}/c$



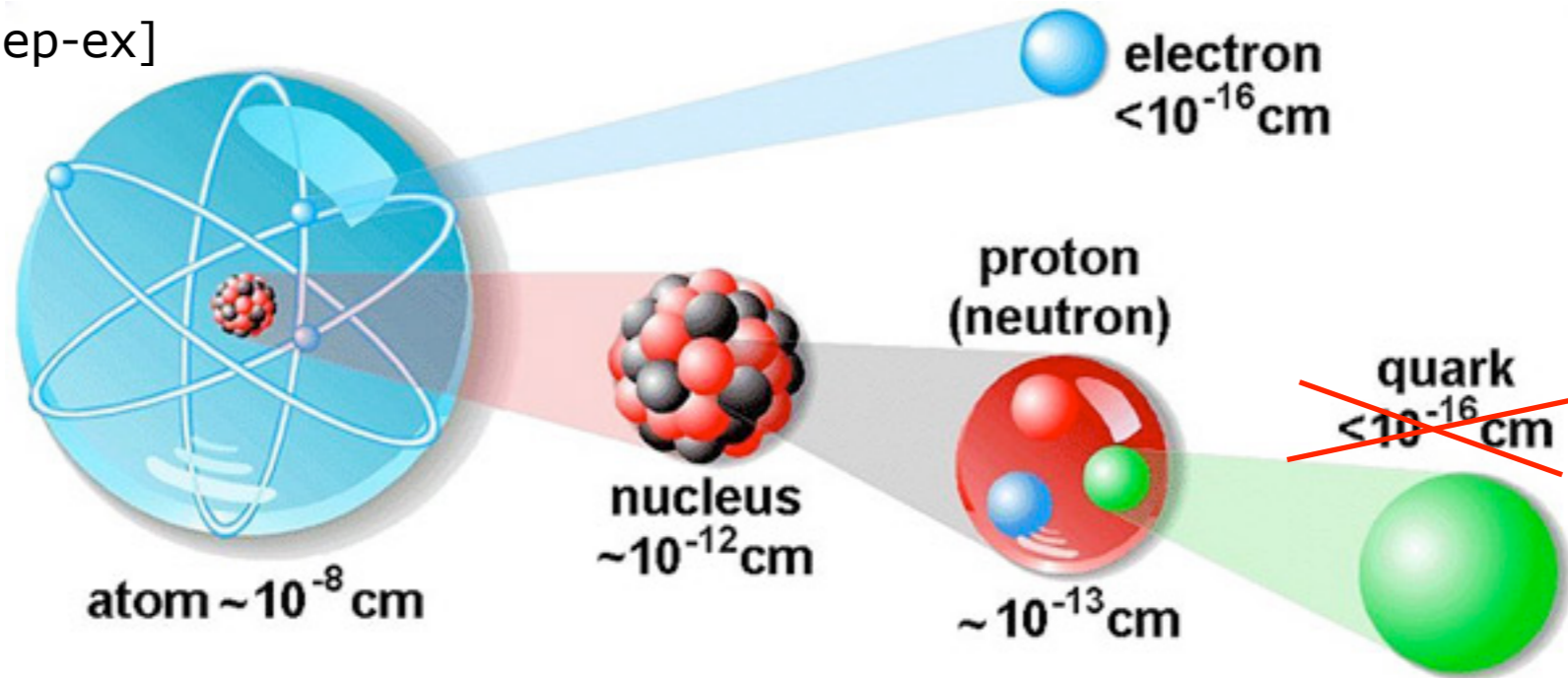
No conclusive explanation yet , sizeable impact on scientific community!

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Search for Quark Compositeness

Accepted by PRL

arXiv:1010.4439 [hep-ex]

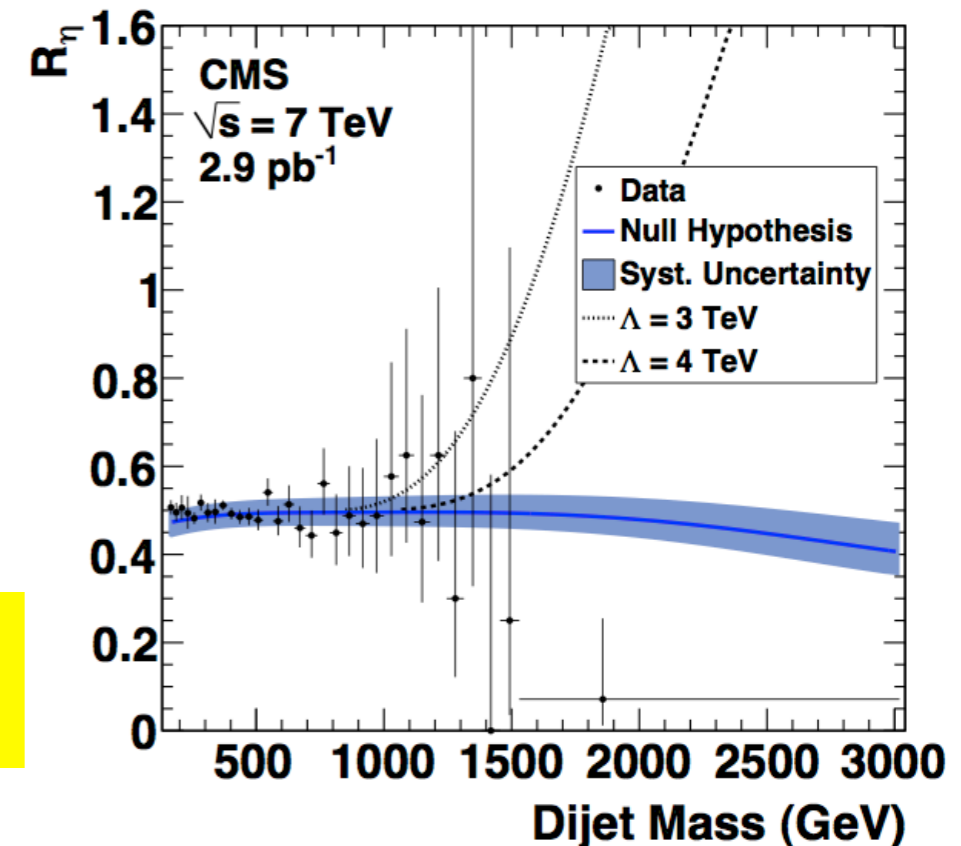


Dijet Centrality Ratio

Ratio of number of events with two leading jets within $|\eta| < 0.7$ to the number with both leading jets within $0.7 < |\eta| < 1.3$

Sensitive to Quark Sub-Structure

exclude quark compositeness at energy scales of $\Lambda < 4.0$ TeV at the 95%CL

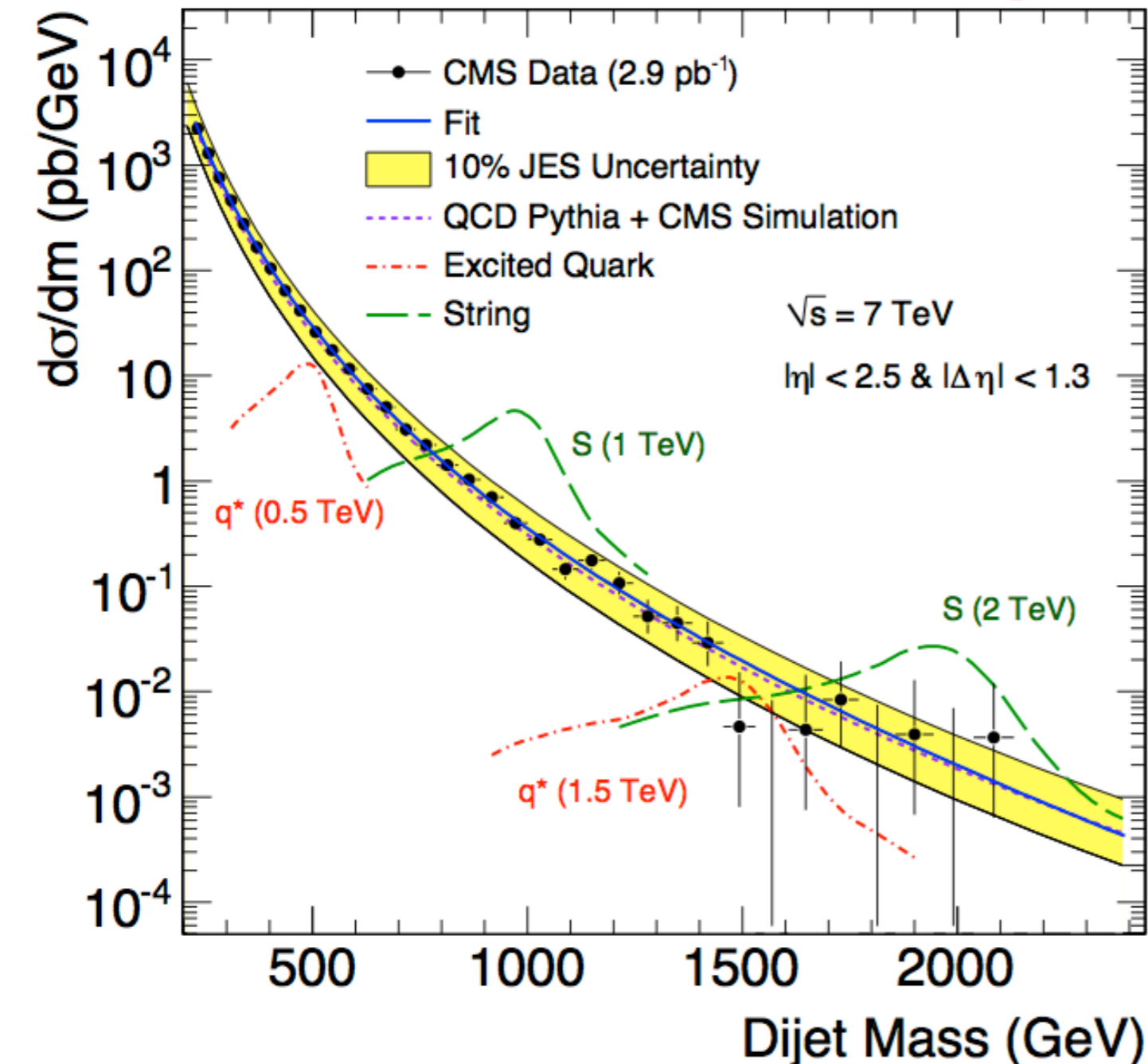


Search for Heavy Dijet Resonances

Published in

Phys. Rev. Lett. 105, 211801

2.9 pb⁻¹



Dijet mass differential cross section is sensitive to coupling of **new massive particles** to quarks & gluons

**95% CL mass limits for new particles decaying to parton pairs:
String resonances > 2.5 TeV; Excited quarks > 1.58 TeV; ...**

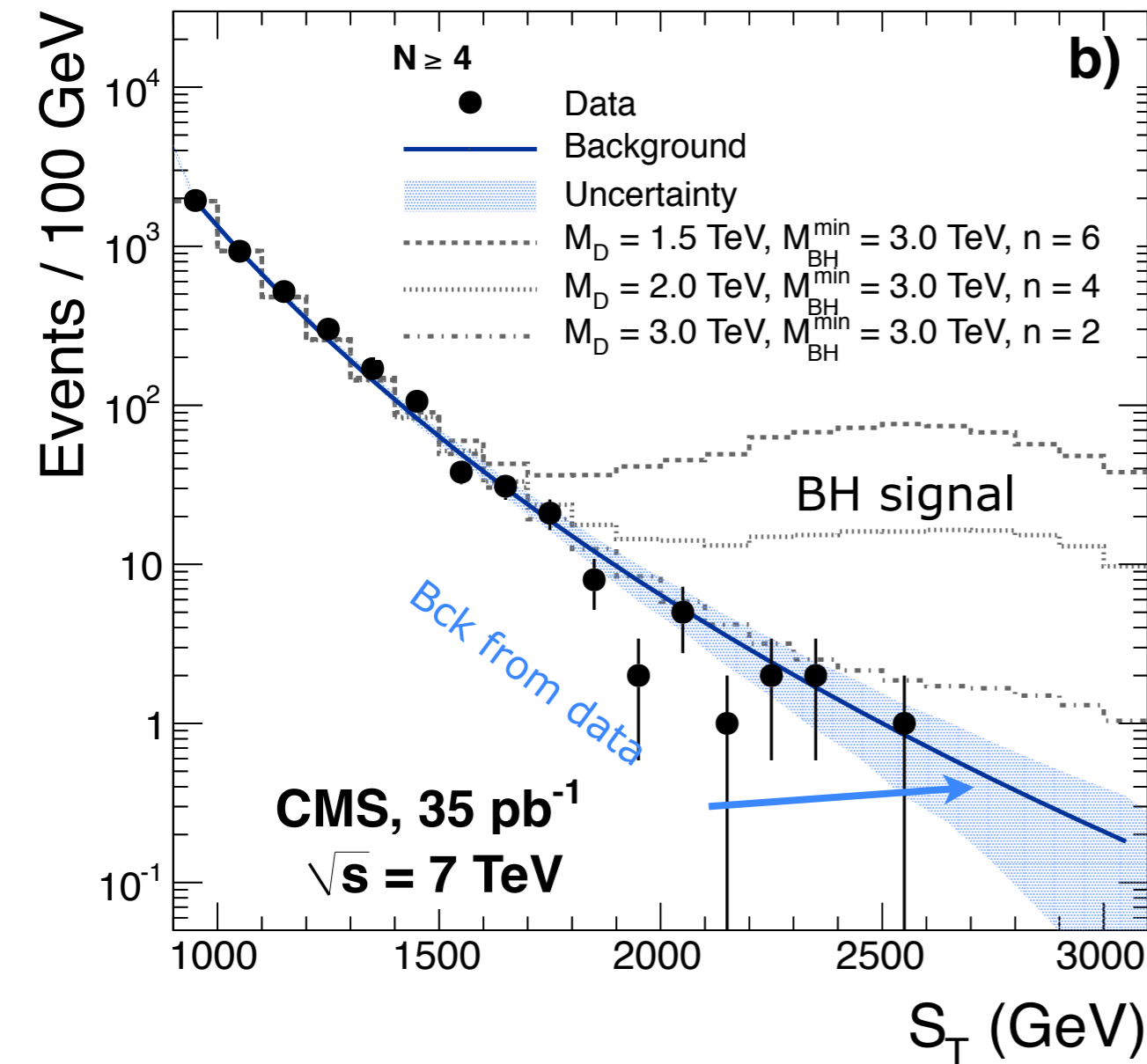
Search for Microscopic Black Holes

Submitted to PLB

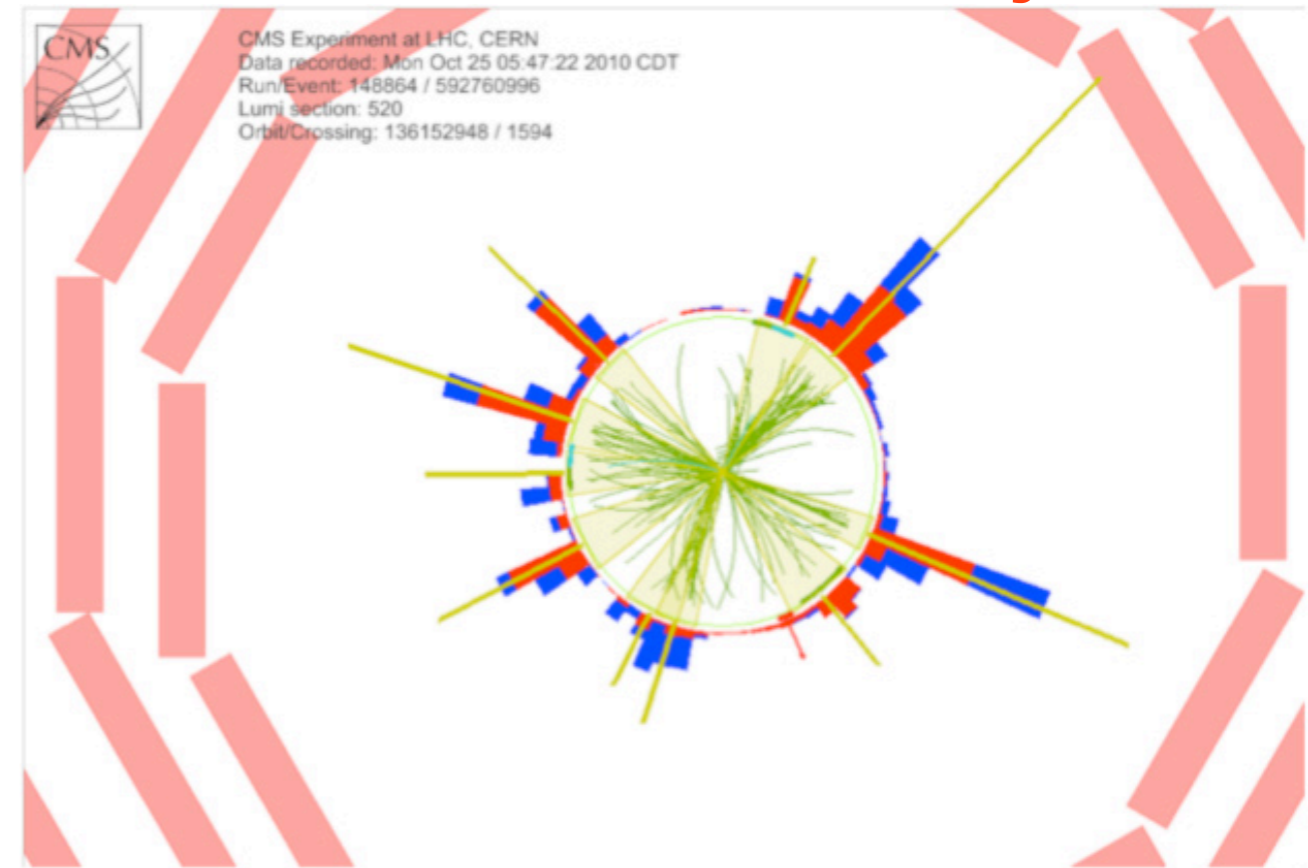
arXiv:1012.3375 [hep-ex]

Extra dimensions?!

Decay into highly-energetic multiparticle final states
The first search for black holes at a particle accelerator



Candidate event with 10 jets



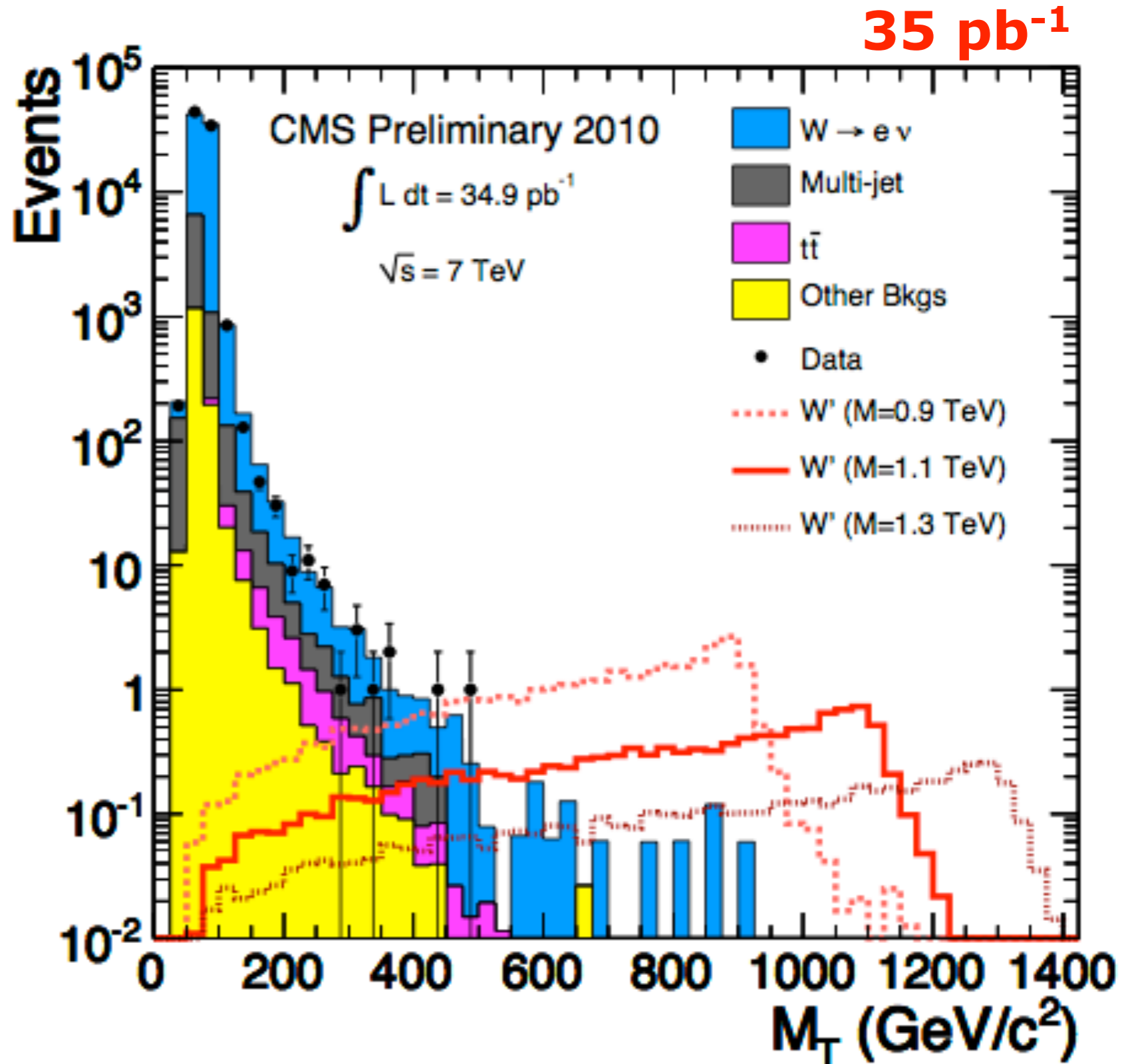
Set limits of 3.5-4.5 TeV on the minimum black hole mass

W': Hint for Extra Dimensions

Search for $W' \rightarrow e\nu$

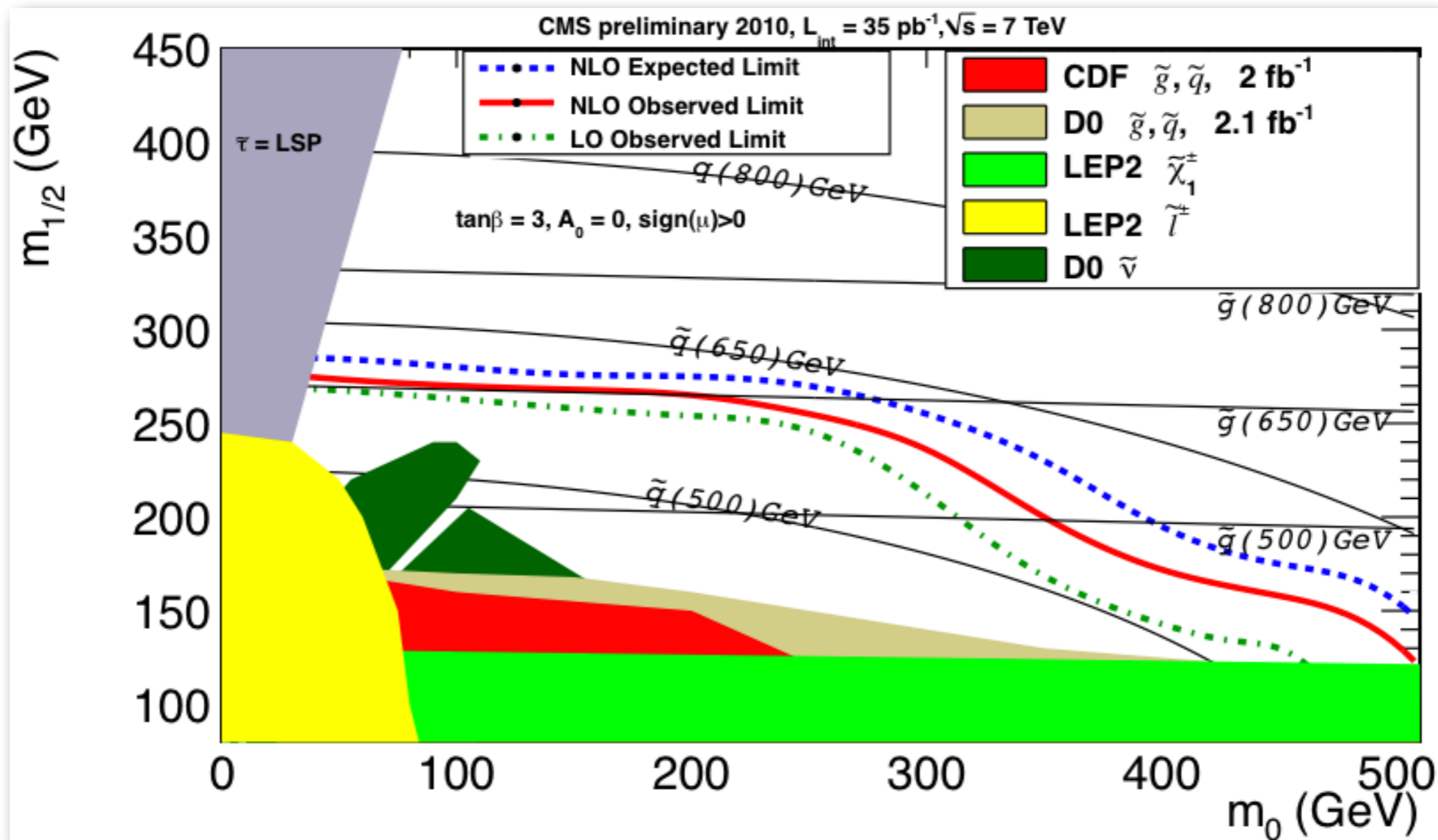
Very massive W' Bosons would indicate the existence of extra dimensions

95% CL mass limit $m_{W'} < 1.3$ TeV for W' Bosons with standard model-like couplings and branching fractions



First SUSY Result at the LHC!

Search for high mass squark & gluino production in events with large missing transverse energy and two or more jets



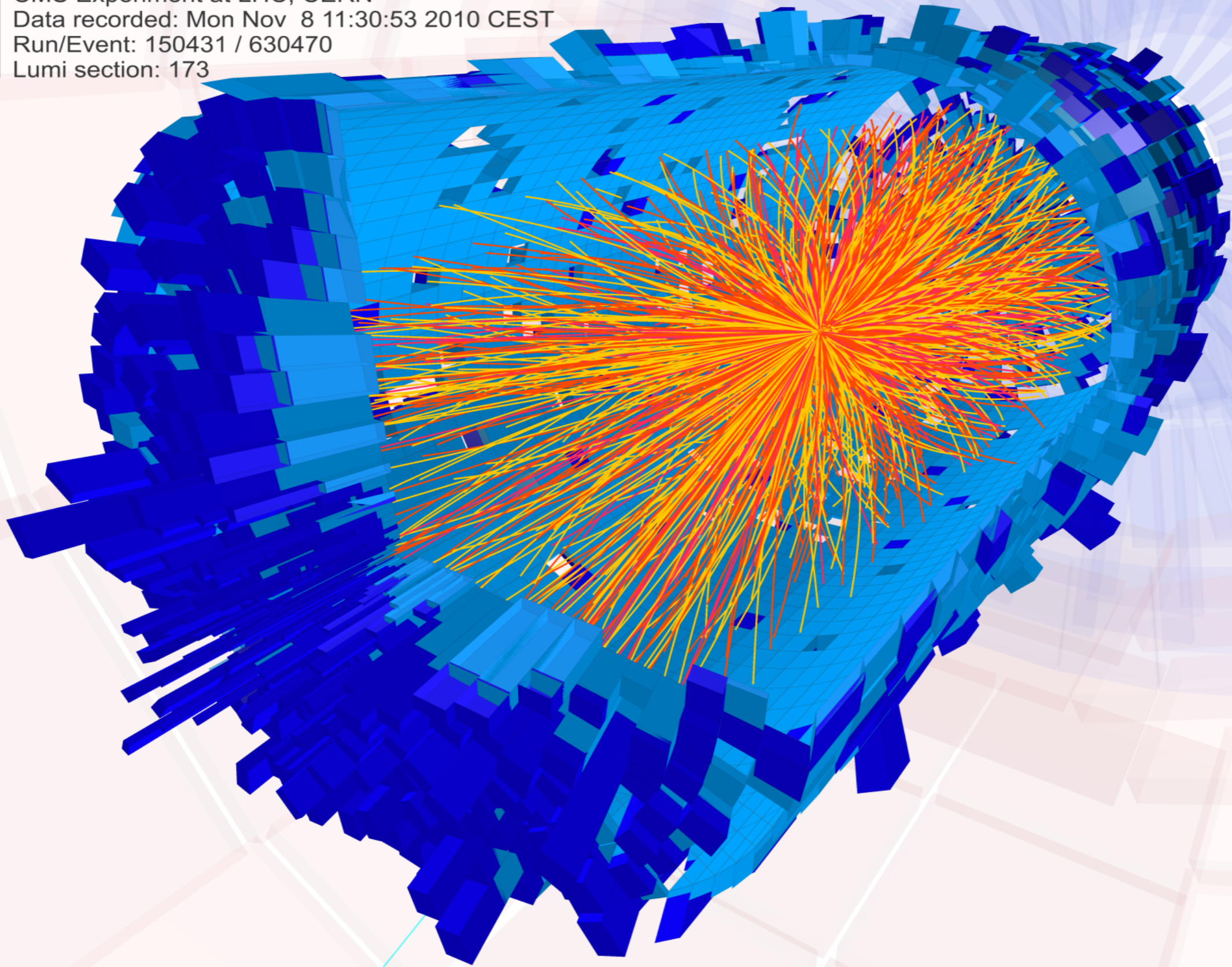
Expanded the excluded range established during the last 20 years (!) by \sim factor of two with only 35 pb^{-1} !

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Heavy Ion (Pb-Pb) Collisions

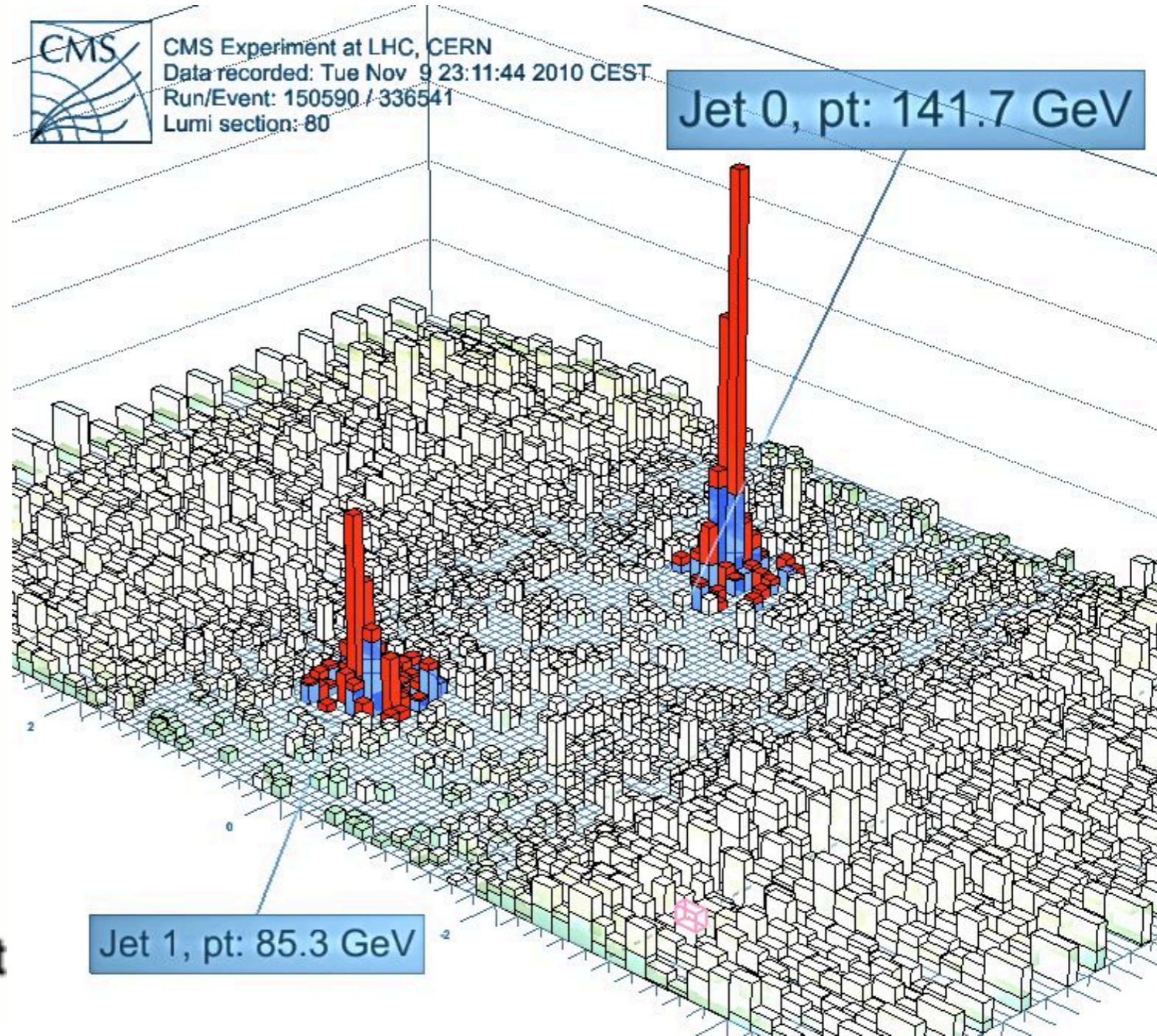
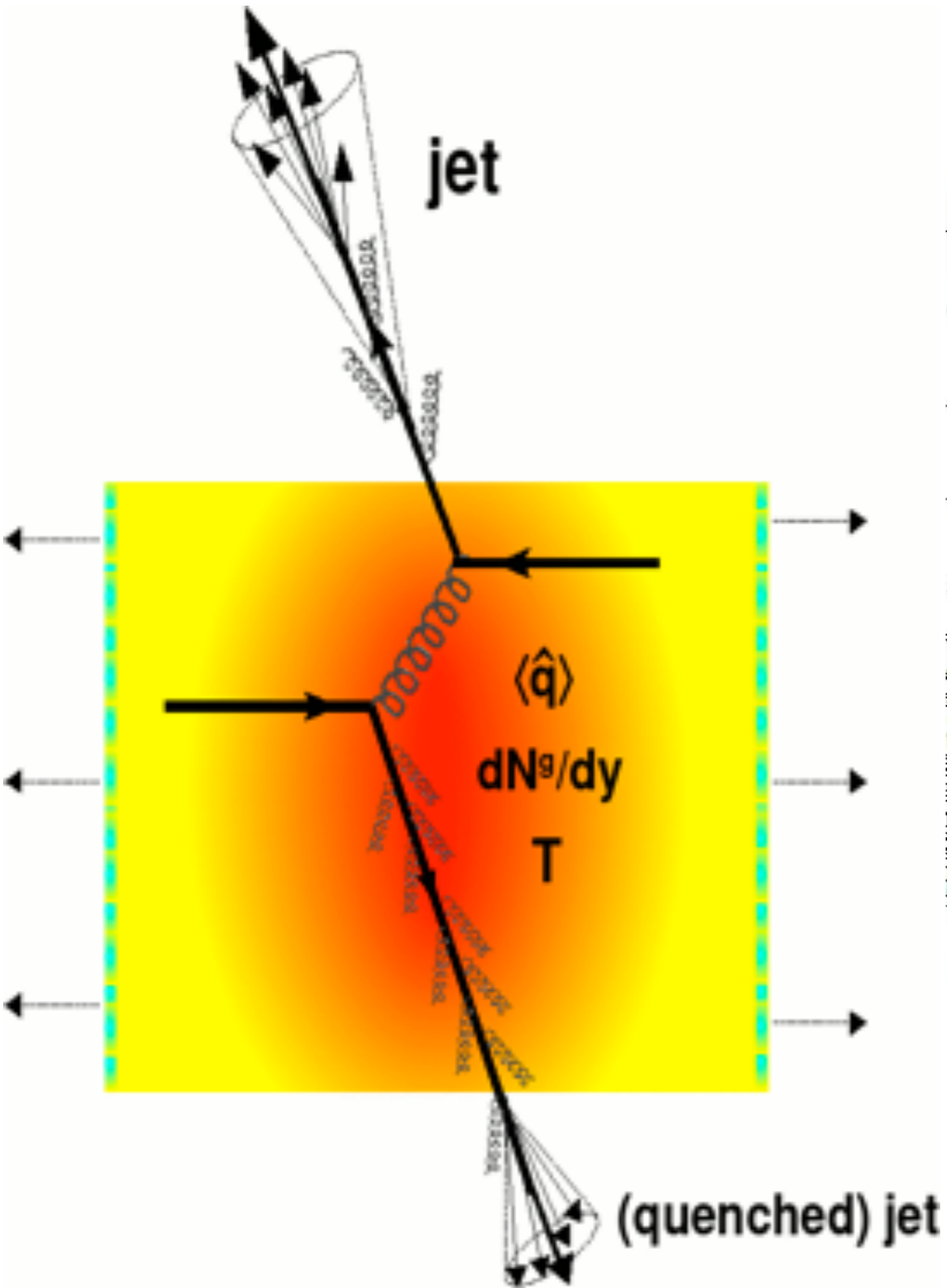


CMS Experiment at LHC, CERN
Data recorded: Mon Nov 8 11:30:53 2010 CEST
Run/Event: 150431 / 630470
Lumi section: 173

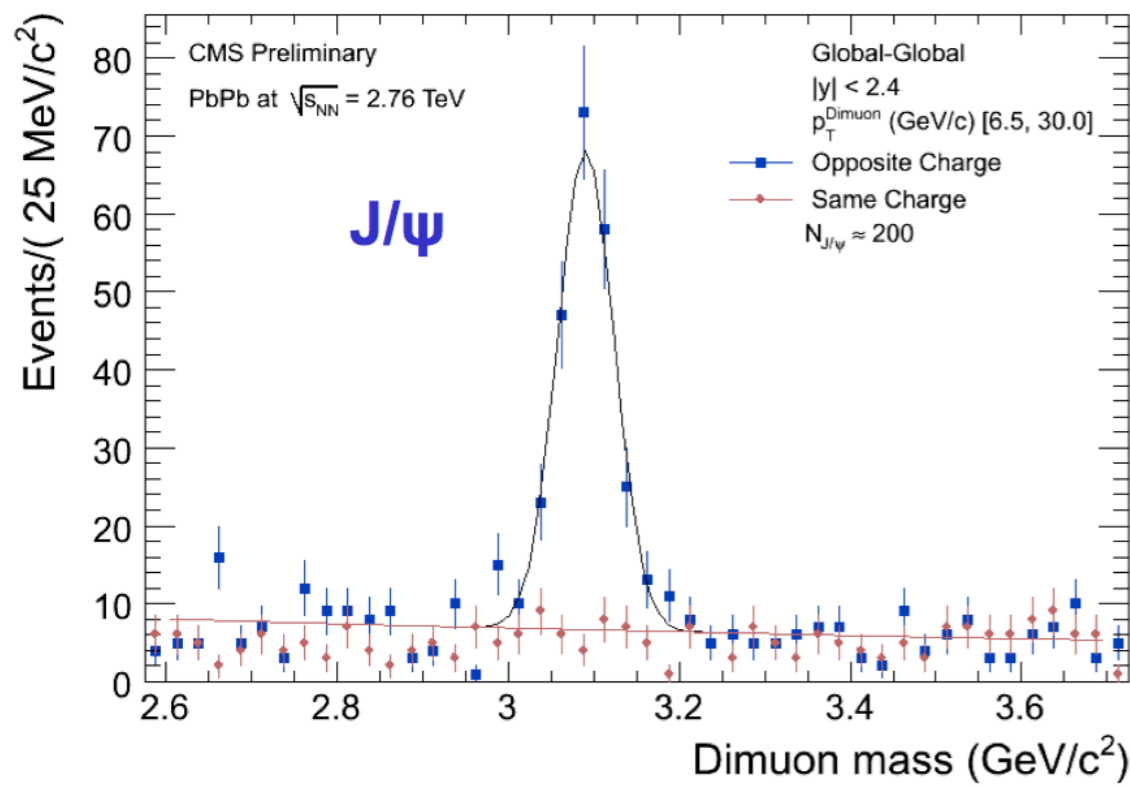
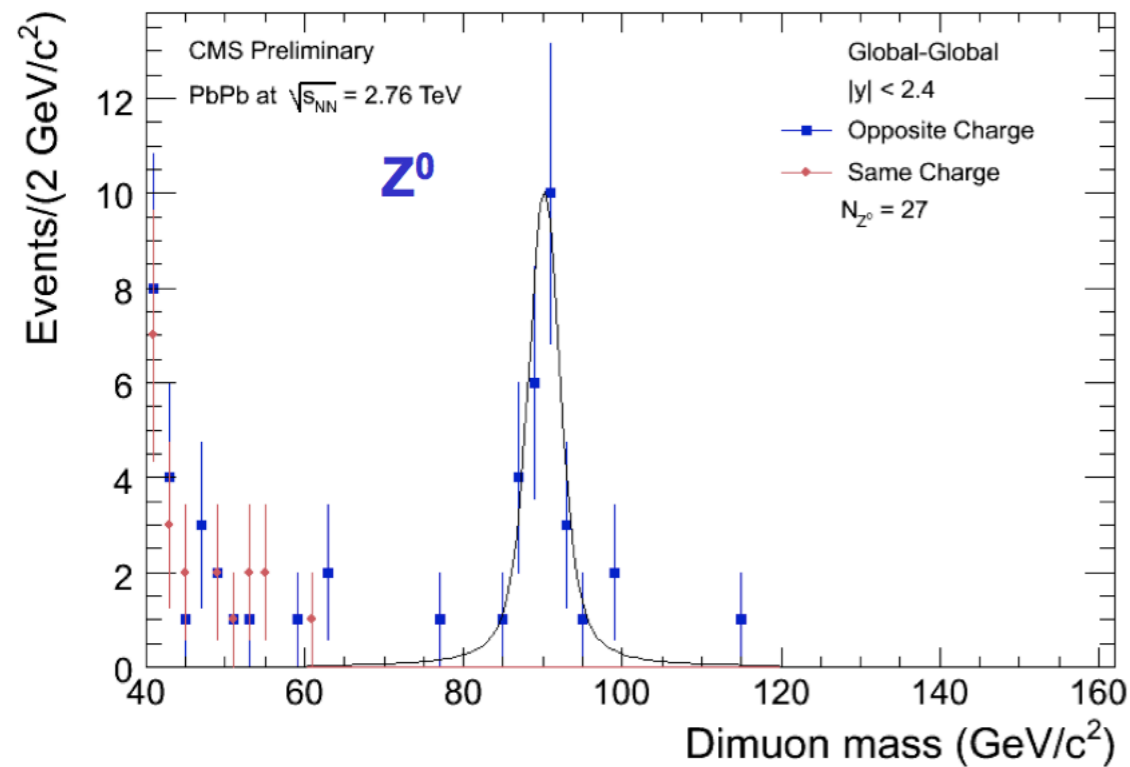


Jet Quenching in HI Collisions

Significant dijet imbalance

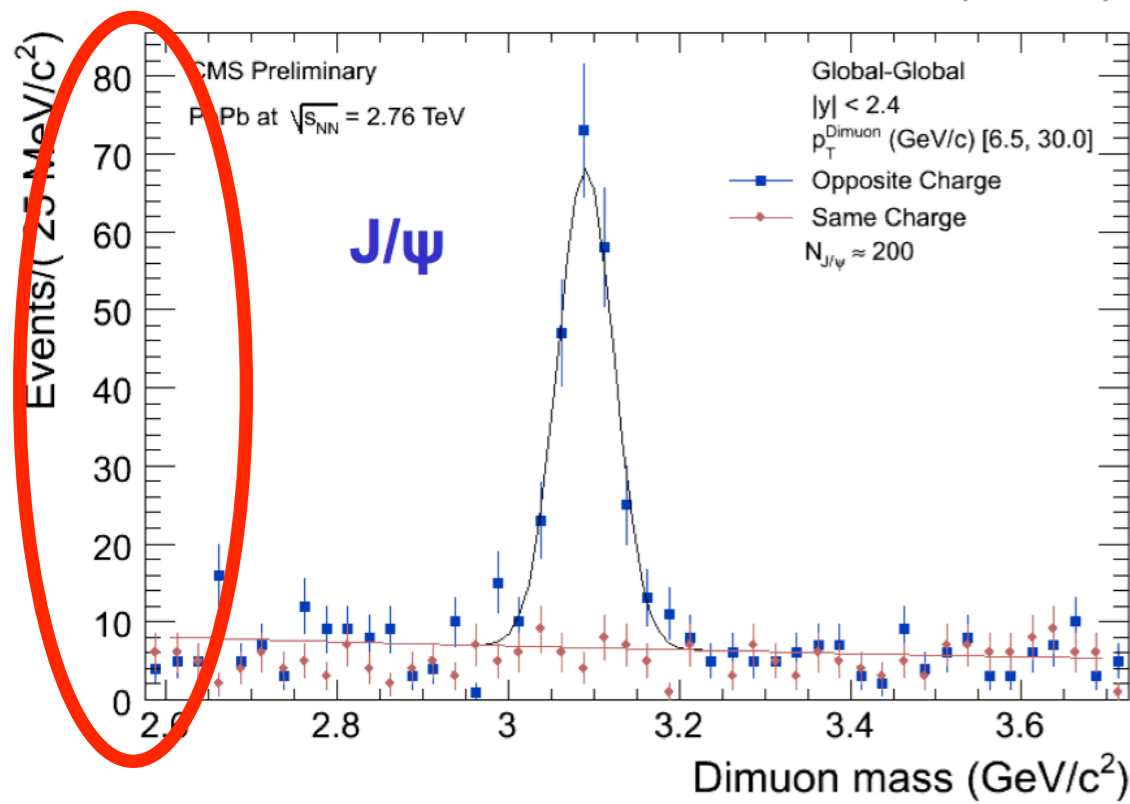
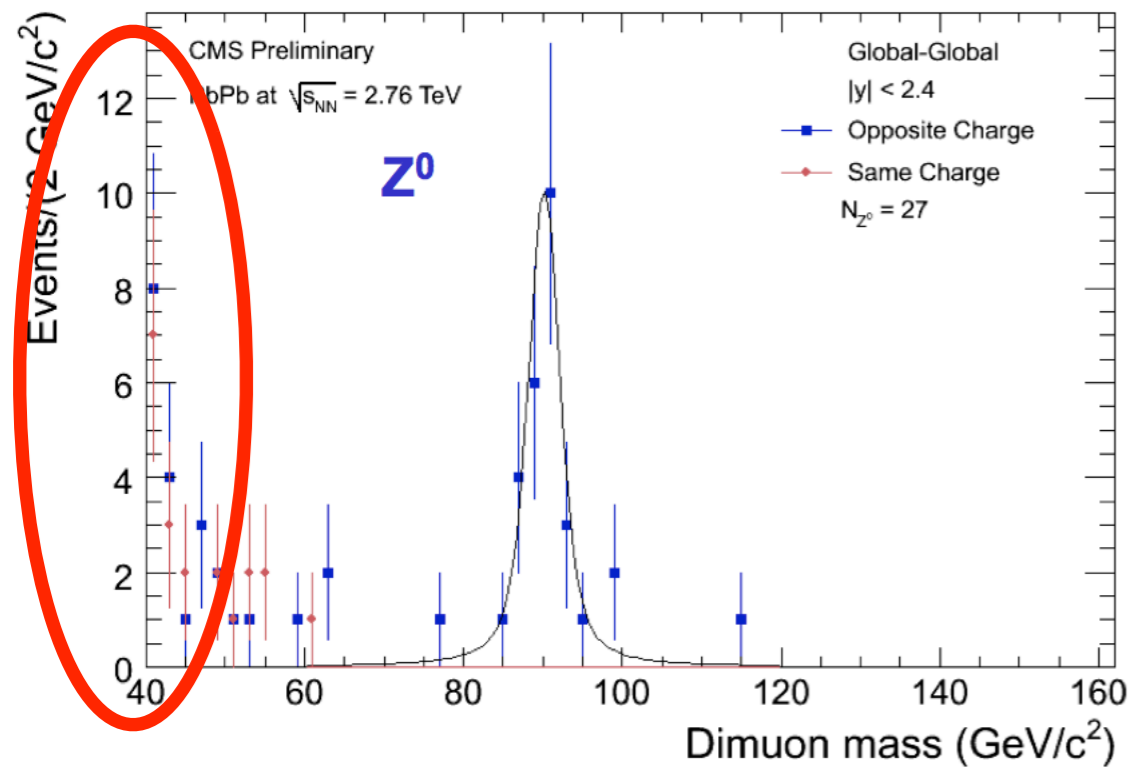


Di-Muons in HI-Collisions

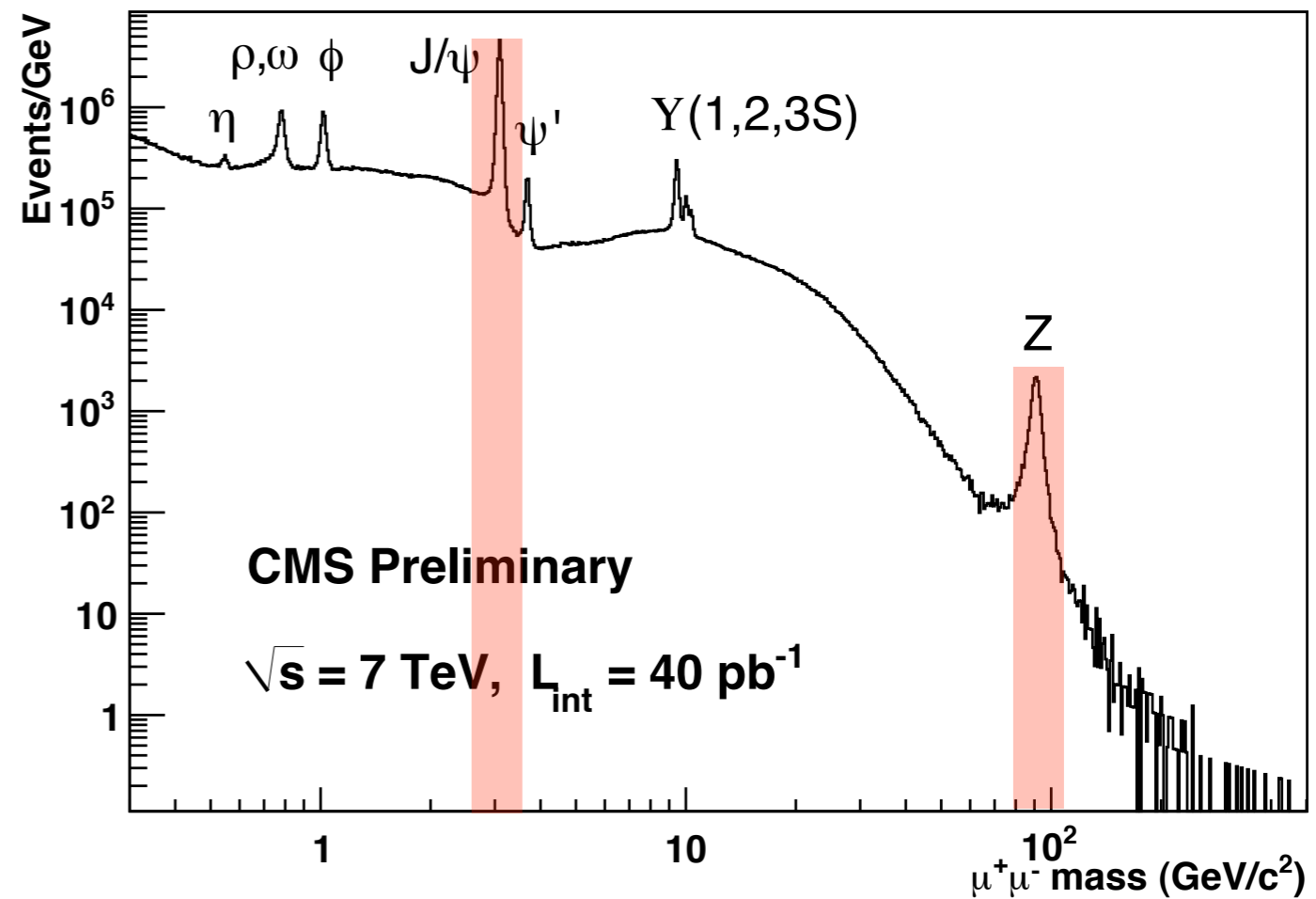


First Observation of Z Bosons in HI Collisions!

Di-Muons in HI-Collisions



... recall: pp!

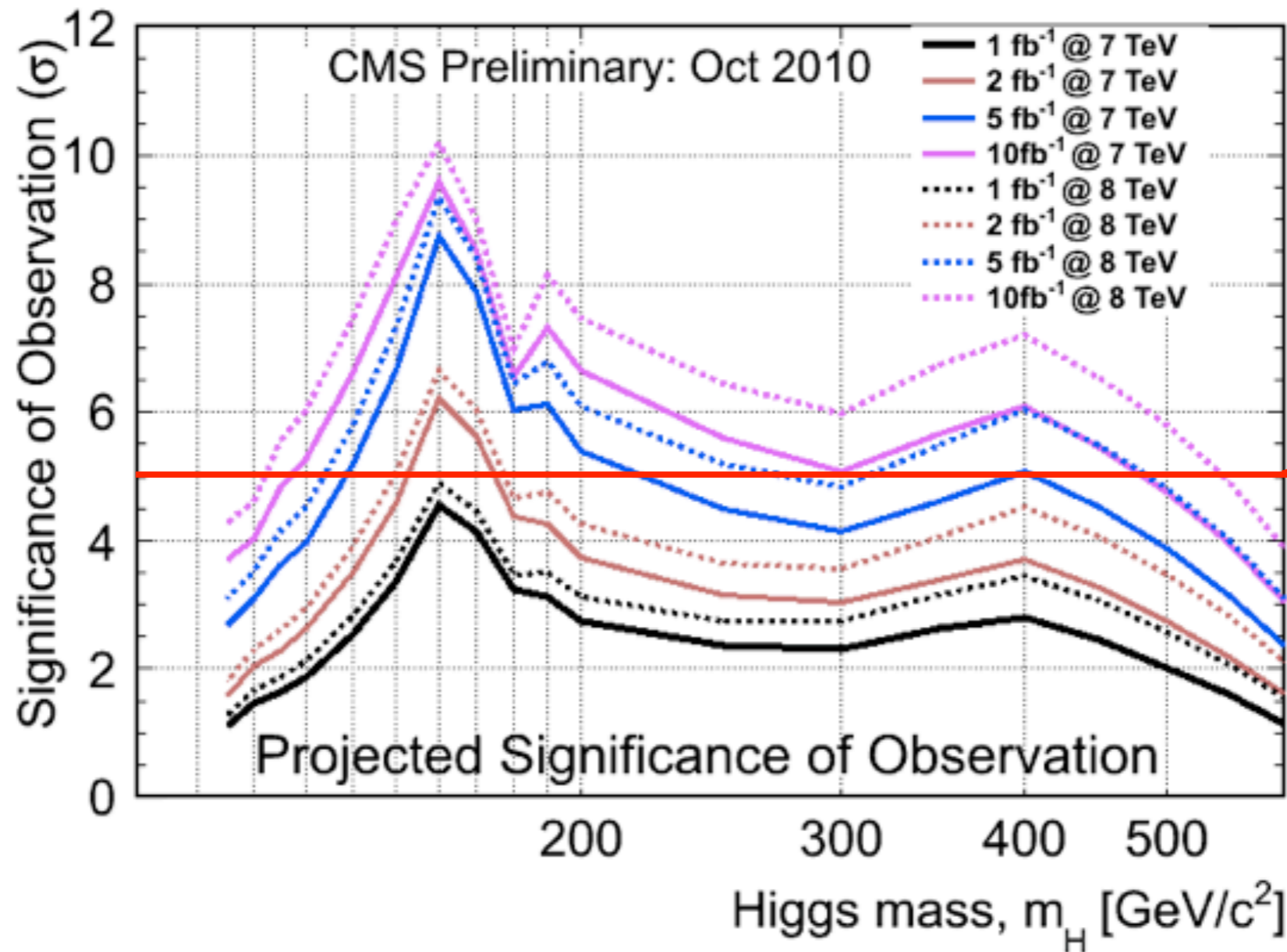


First Observation of Z Bosons in HI Collisions!

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Search for the Higgs Boson

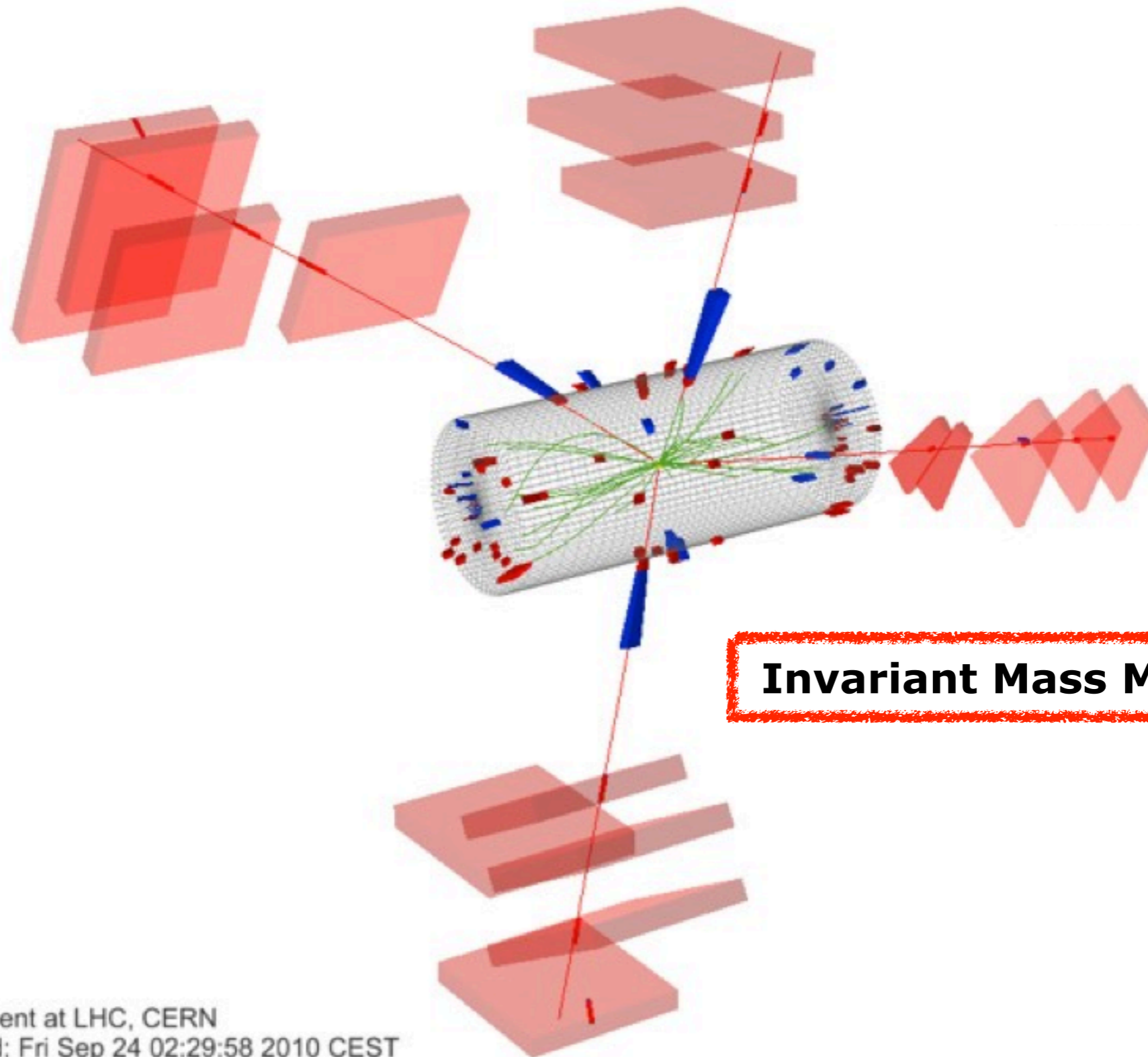
We don't know the mass of the Higgs Boson!
Evaluated the CMS discovery potential 2011 with the simulation



Discovery

with 10fb^{-1} @ $\sqrt{s}=8$ TeV CMS can discover the Higgs Boson in the mass range $\sim 115-600$ GeV!

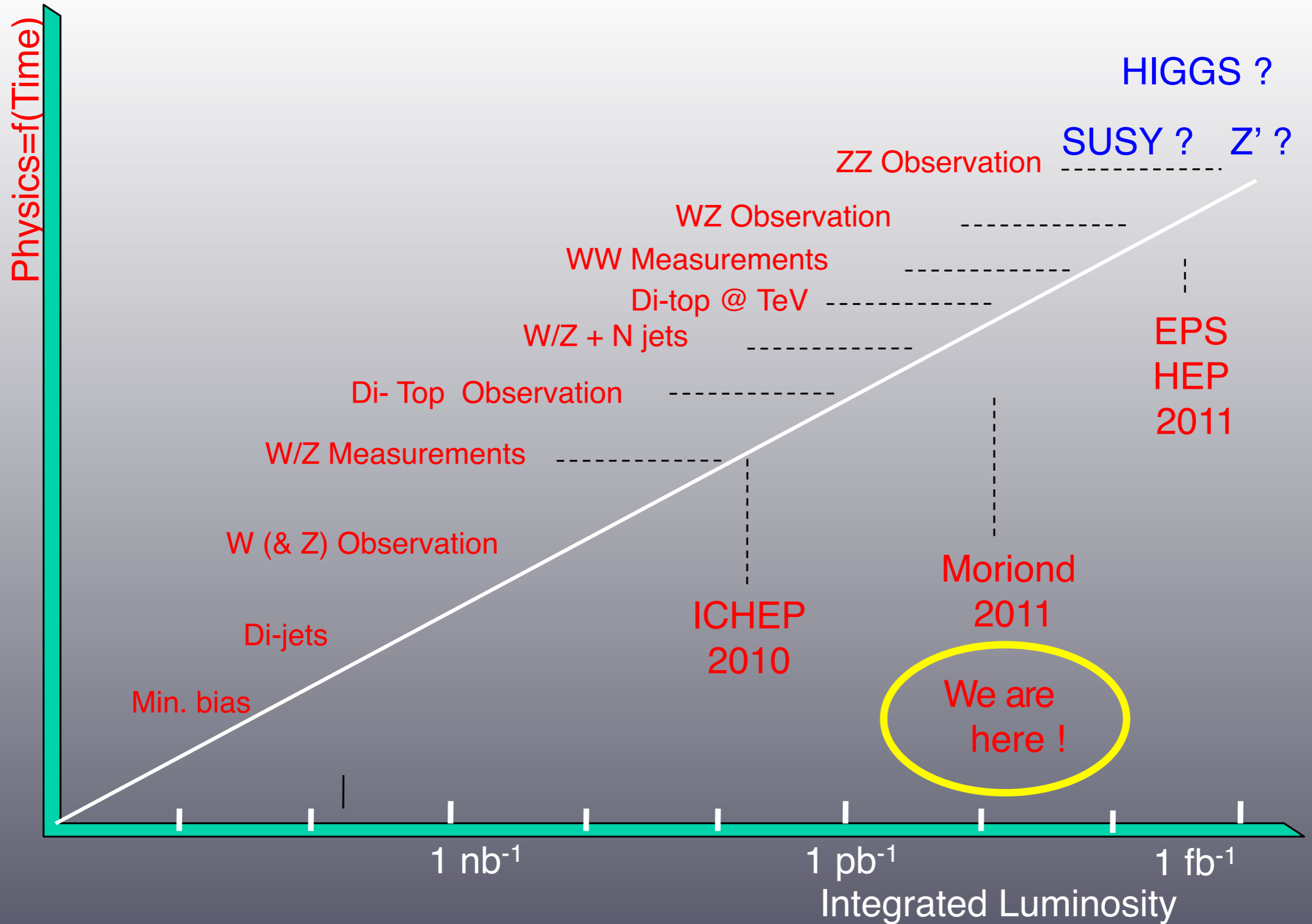
First $(Z^0 \rightarrow \mu^+ \mu^-)(Z^0 \rightarrow \mu^+ \mu^-)$ Candidate



Invariant Mass $M_{4\mu} = 201$ GeV

CMS Experiment at LHC, CERN
Data recorded: Fri Sep 24 02:29:58 2010 CEST
Run/Event: 146511 / 504867308

CMS Physics Objectives through 2011



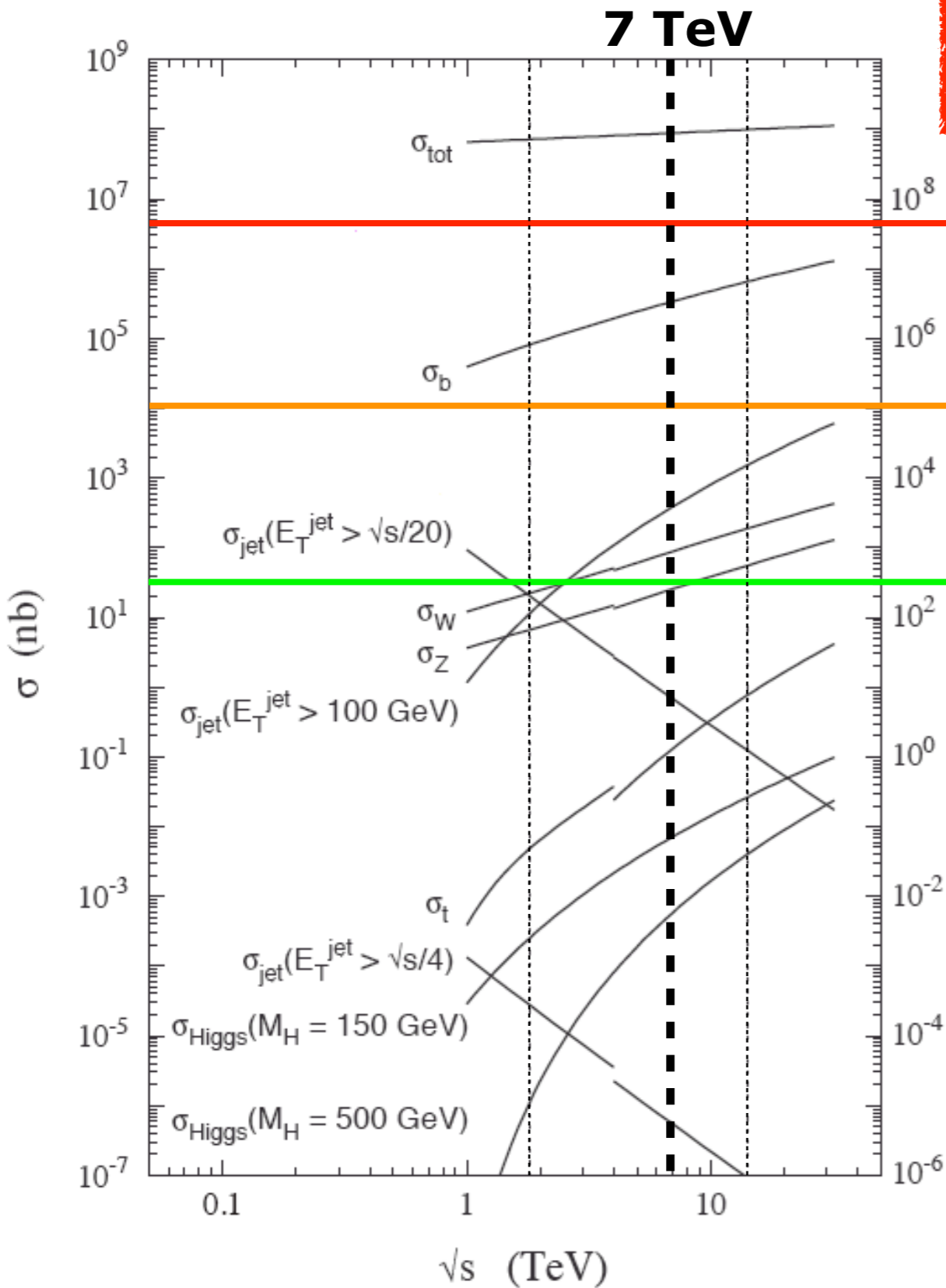


Thank you!

BACKUP

Level-1 and High-Level Trigger

CMS selects events employing two trigger levels: **L1 (Hardware)** & **HLT (Software)**



L1

40 MHz Level-1 Input Rate

HLT

100 kHz HLT Input Rate

Storage

~300 Hz Data-Logging Rate

~40 Million events occurring each second, trigger system must select the most interesting $O(100)$ in quasi-realtime

Events which are not selected are lost forever!!

Search for Microscopic Black Holes

Submitted to PLB

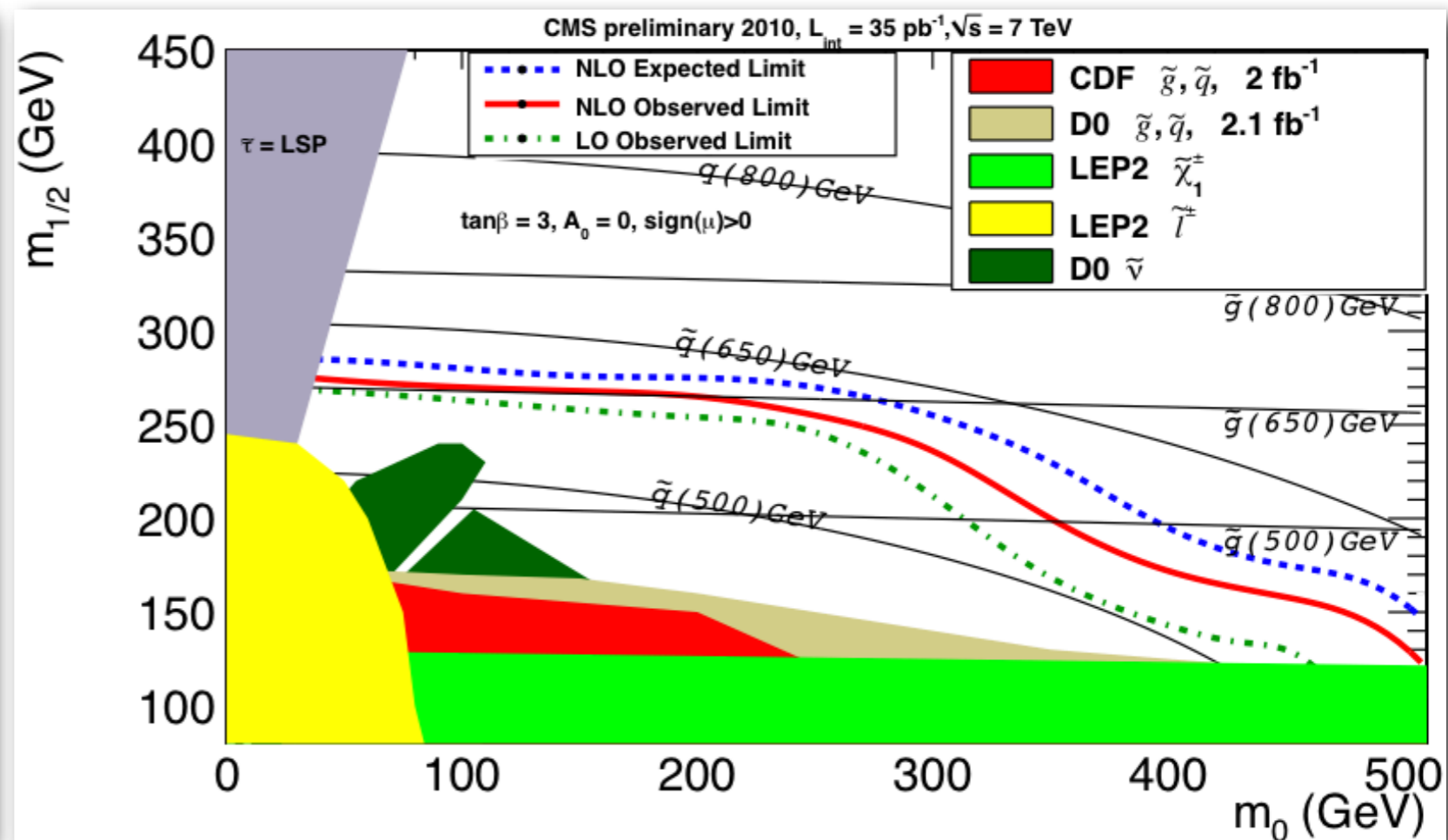
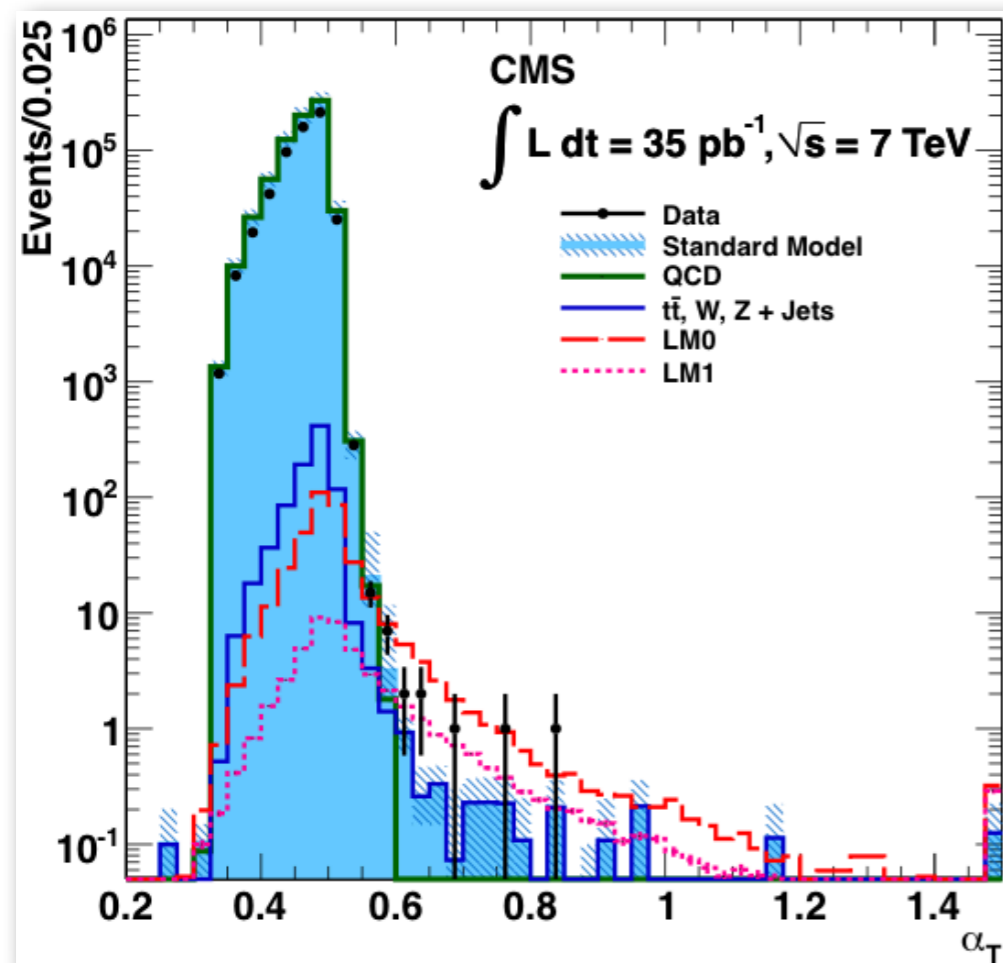
arXiv:1012.3375 [hep-ex]

- **Decay into highly-energetic multiparticle final states dominated by multijets**
- **Main background is from QCD multijets; can't be reliably estimated from Monte Carlo**
- **Developed a novel method to estimate it from data, proving the invariance of $S_T = \sum E_T^j$ w/ the multiplicity**
- **The first search for black holes at a particle accelerator**

Set limits of 3.5-4.5 TeV on the minimum black hole mass

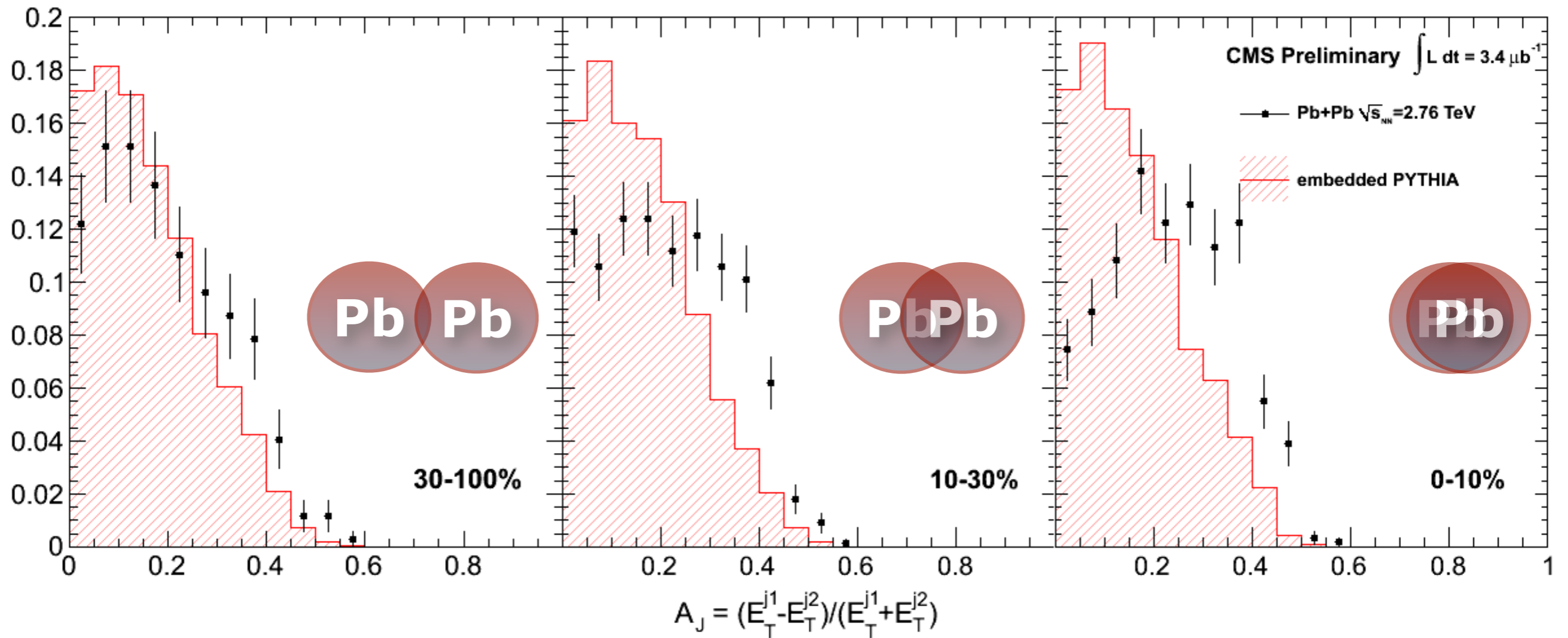
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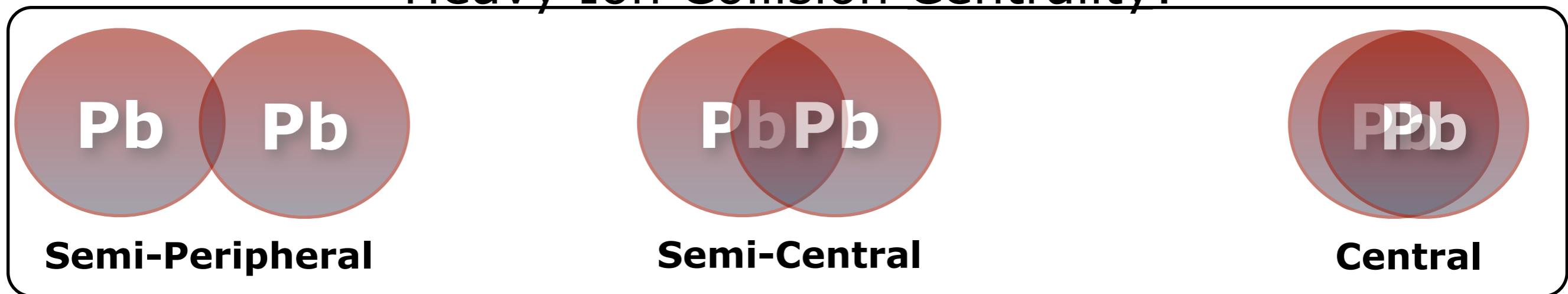


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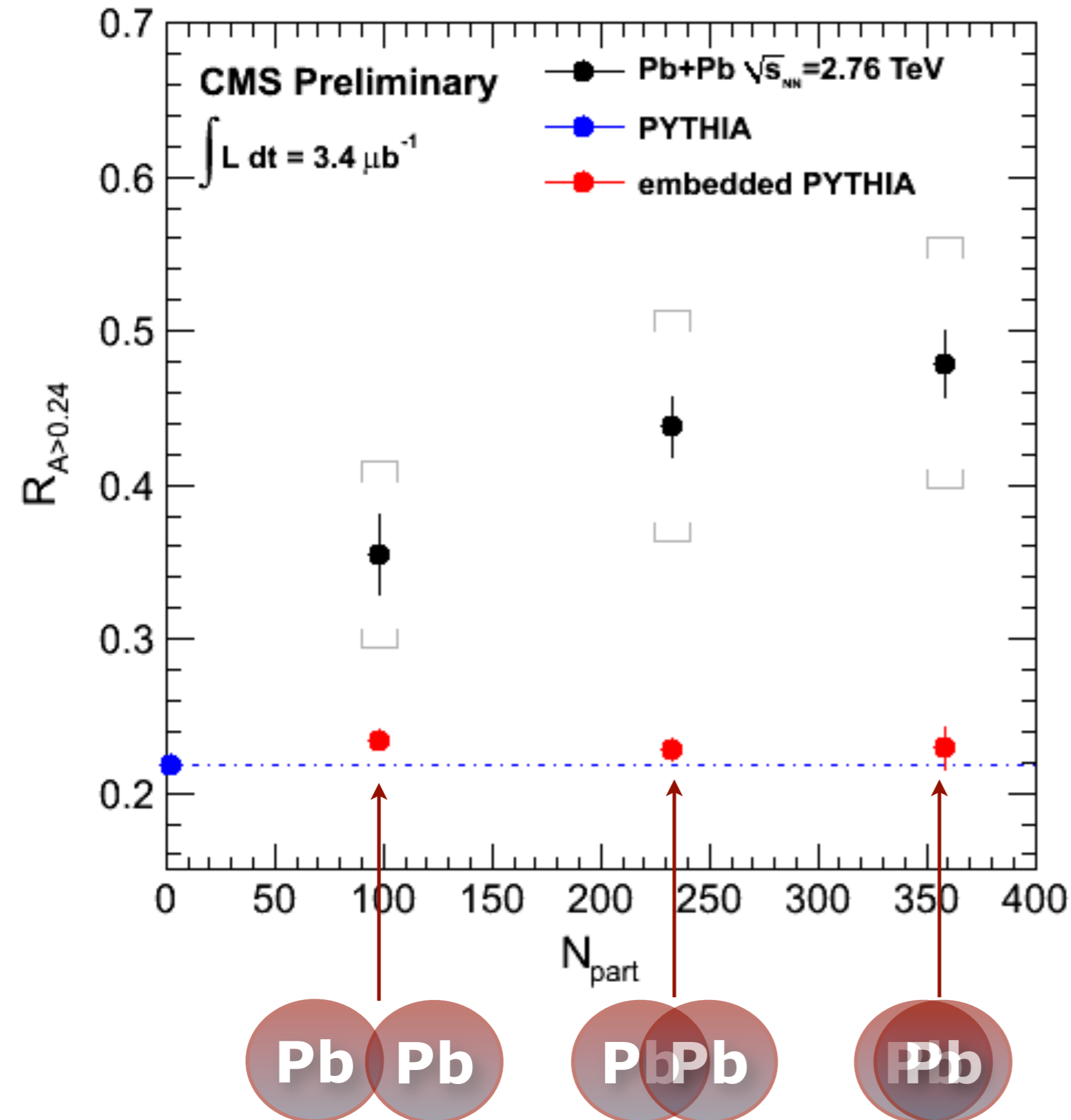
Jet Quenching in HI Collisions



Heavy Ion Collision Centrality:

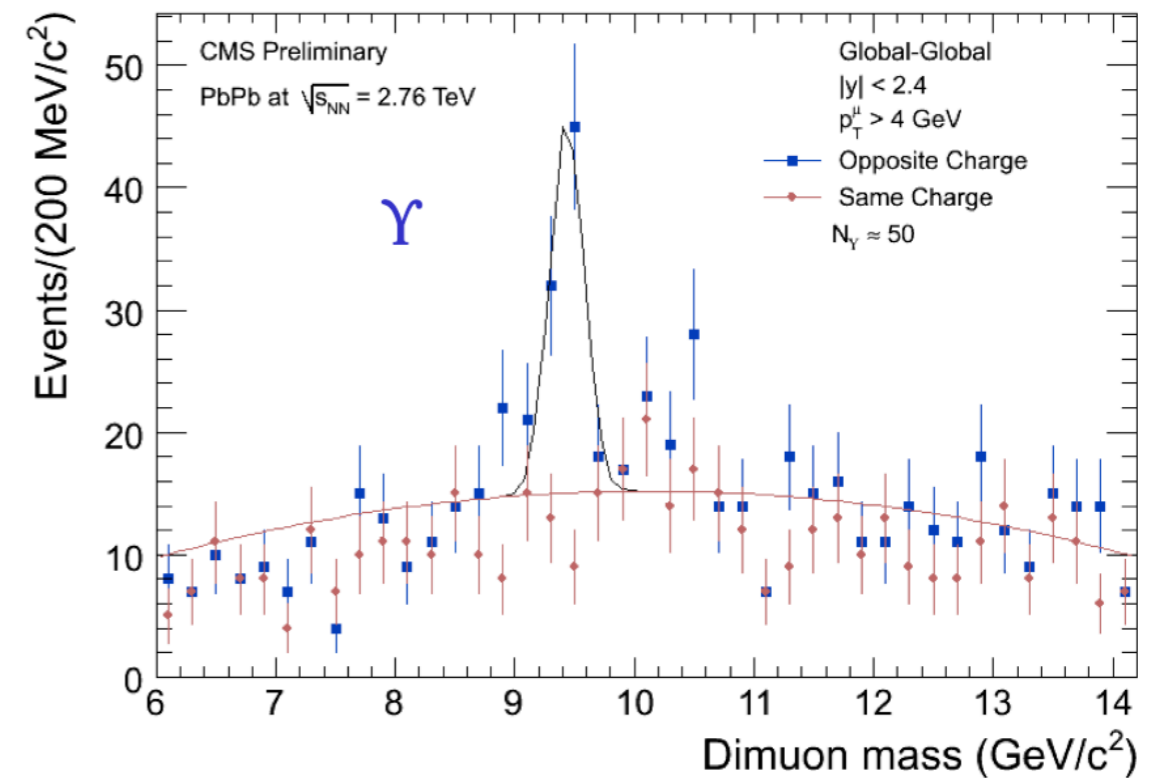
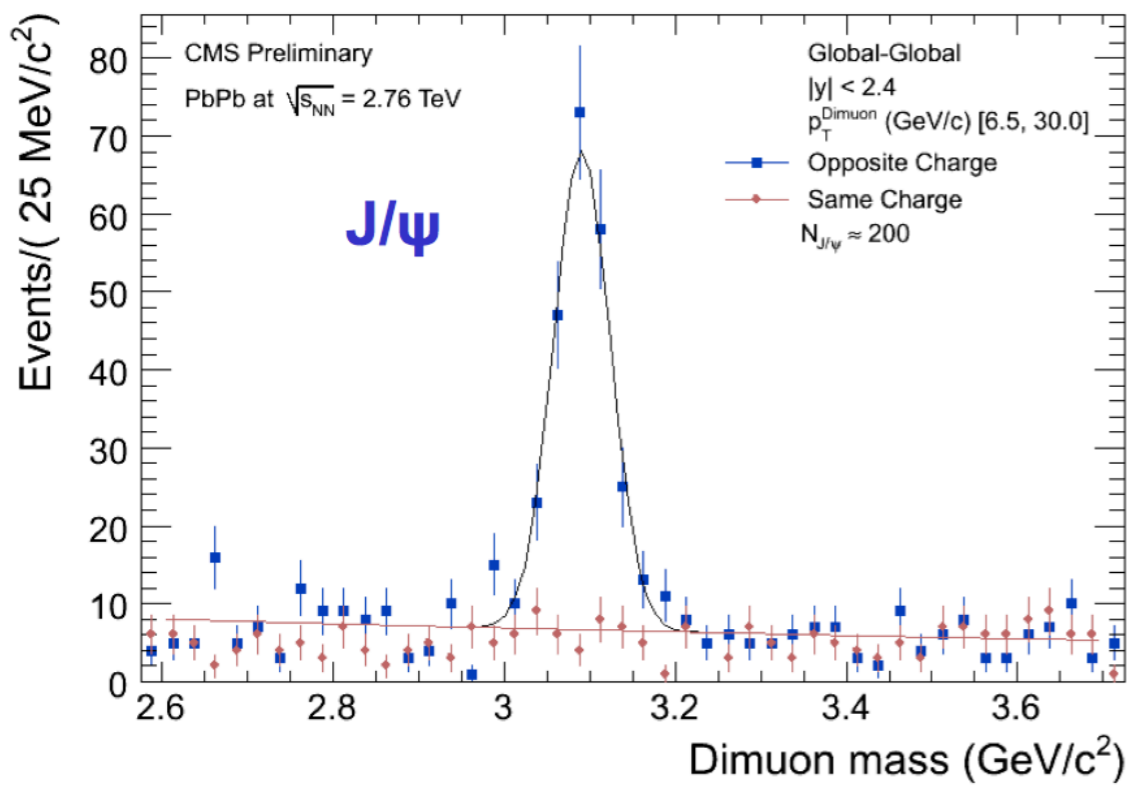
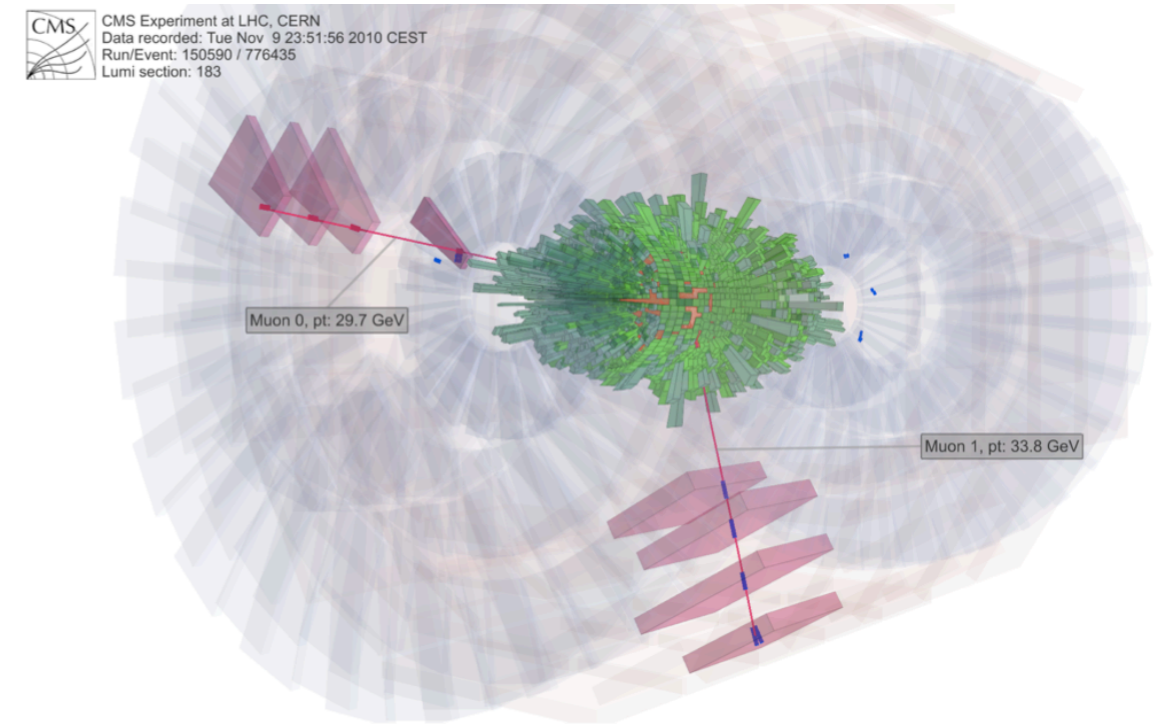
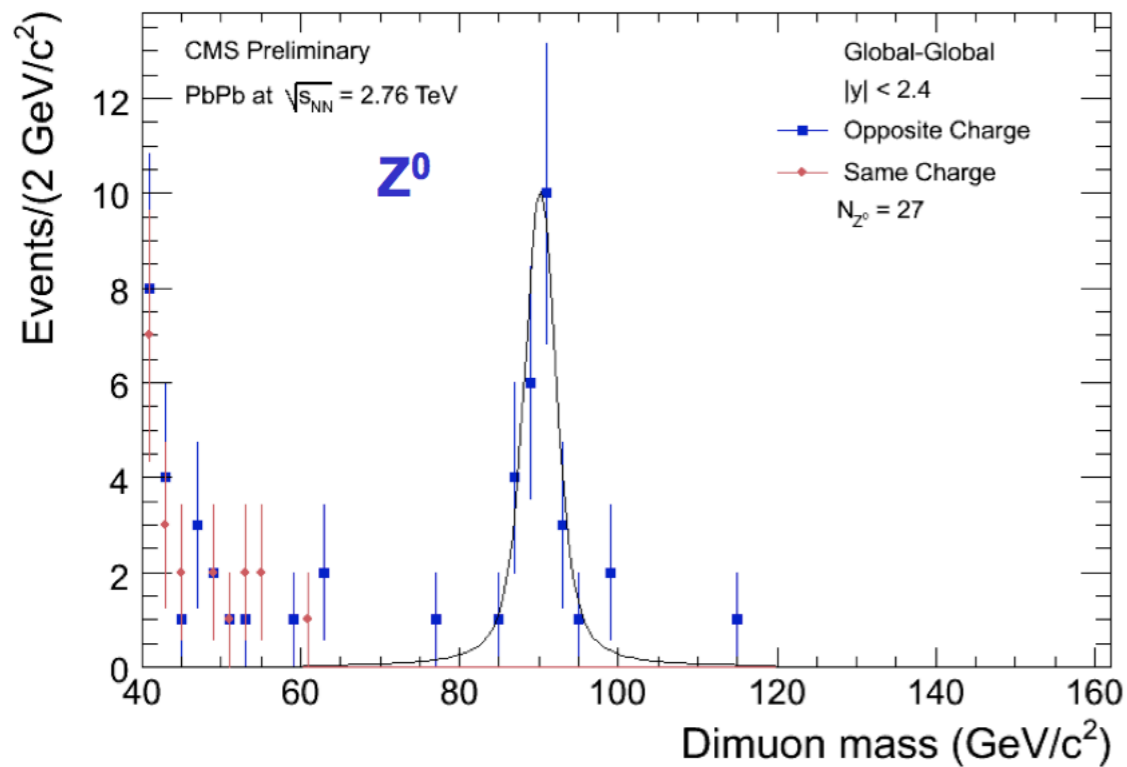


Jet Quenching in HI Collisions



- Fraction of jets with imbalance larger than 0.24
- As a function of number of participating nucleons averaged over centrality bin

Di-Muons in HI-Collisions



First Observation of Z Bosons in HI Collisions!