



**FIRST RESULTS FOR
X(3872) PRODUCTION IN pp COLLISIONS AT 7 TeV
WITH THE CMS EXPERIMENT**

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on behalf of the CMS Collaboration

Quarkonium production : Probing QCD at the LHC
Wien, April. 21st 2011



X(3872) and Hadron Colliders

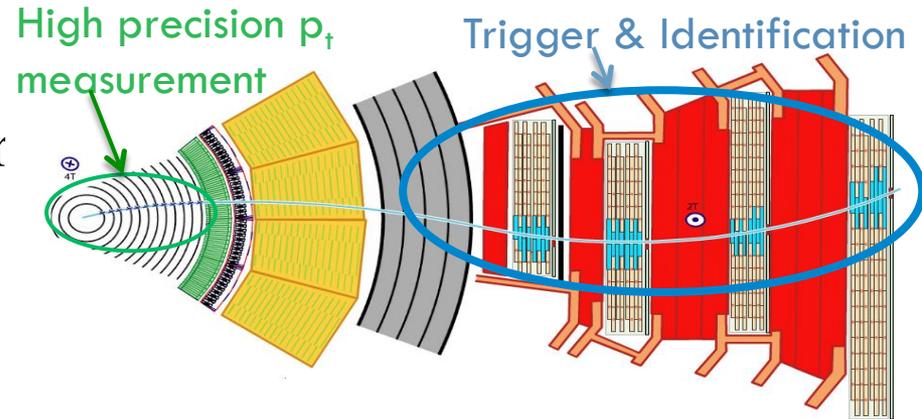


- After 8 years since its discovery the nature of the X(3872) resonance is still unknown.
- Results from the Tevatron have shown the good contribution that experiments at hadron colliders can give.
- At the LHC we have the possibility of making studies in a new energy regime.
- NRQCD predictions exist for the production cross section of the X(3872) in pp collisions at the LHC.

- Establish a clear signal of the X(3872) using the data taken by CMS during the first year of LHC operation.
- Measure the inclusive cross section ratio w.r.t. the $\psi(2S)$ signal in the same decay channel $J/\psi \pi^+\pi^-$, with the J/ψ going to 2 muons.

$$R = \frac{\sigma(pp \rightarrow X(3872) + \textit{anything})BR(X(3872) \rightarrow J/\psi\pi^+\pi^-)}{\sigma(pp \rightarrow \psi(2S) + \textit{anything})BR(\psi(2S) \rightarrow J/\psi\pi^+\pi^-)}$$

- Muon are reconstructed combining information from the central tracker and the muon system, achieving a momentum resolution of $\sim 1\%$ for low p_T .

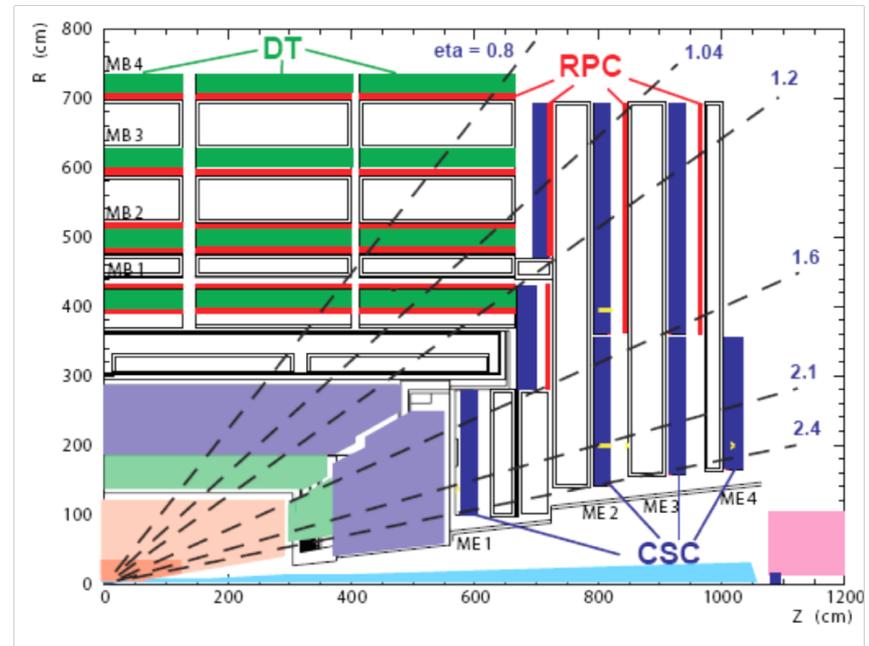


- The acceptance region is

$$p_t > 3.3 \text{ GeV} \quad \text{for} \quad |\eta| < 1.3$$

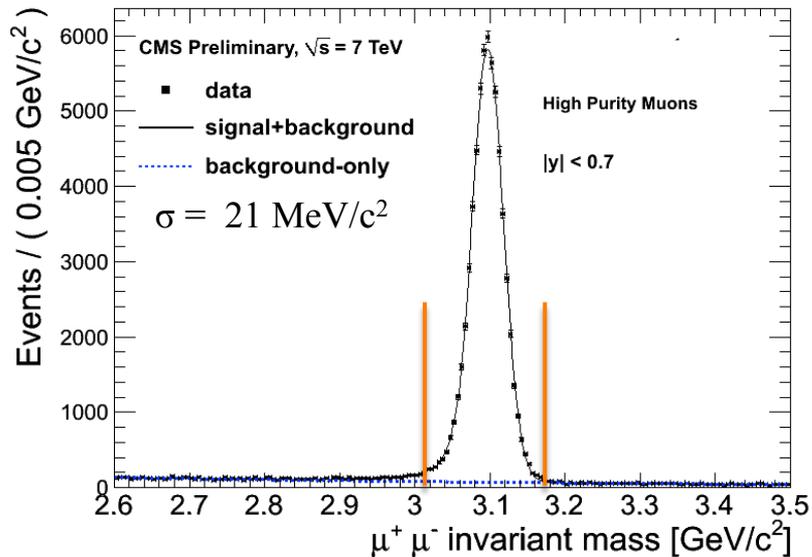
$$p > 2.9 \text{ GeV} \quad \text{for} \quad 1.3 < |\eta| < 2.2$$

$$p_t > 0.8 \text{ GeV} \quad \text{for} \quad 2.2 < |\eta| < 2.4$$

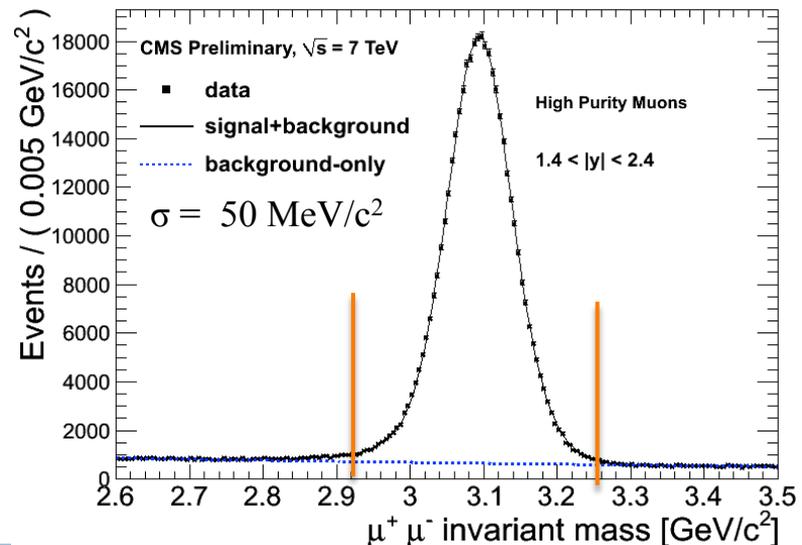


- Around 1 million J/ ψ are reconstructed combining 2 opposite-charge good quality muons that have fired a **Double Muon trigger path**, with no minimum transverse momentum requirement.
- The final selection is made in mass windows that reflect the detector resolution in the different dimuon rapidity regions.

Central Barrel Region



Forward Endcap Region



- We select two opposite-charge tracks of good quality, within a ΔR cone of 0.7 around the J/ψ direction.
- A four-track vertex fit is performed, where the invariant mass of the $\mu^+\mu^-$ system is constrained to the PDG J/ψ mass.
- We keep all candidates with vertex fit probability $> 1\%$ and in a mass range between 3.6 and 4.0 GeV.
- We study the kinematic region $p_T(X) > 8$ and $|y(X)| < 2.2$

- The mass spectrum is fitted with unbinned log-likelihood
- Mass values are compatible with the PDG values
- CMS fit results:

$$m_{\Psi(2S)} = 3685.9 \pm 0.1 \text{ MeV}$$

$$\sigma_{1 \Psi(2S)} = 8.1 \pm 0.6 \text{ MeV}$$

$$\sigma_{2 \Psi(2S)} = 3.3 \pm 0.3 \text{ MeV}$$

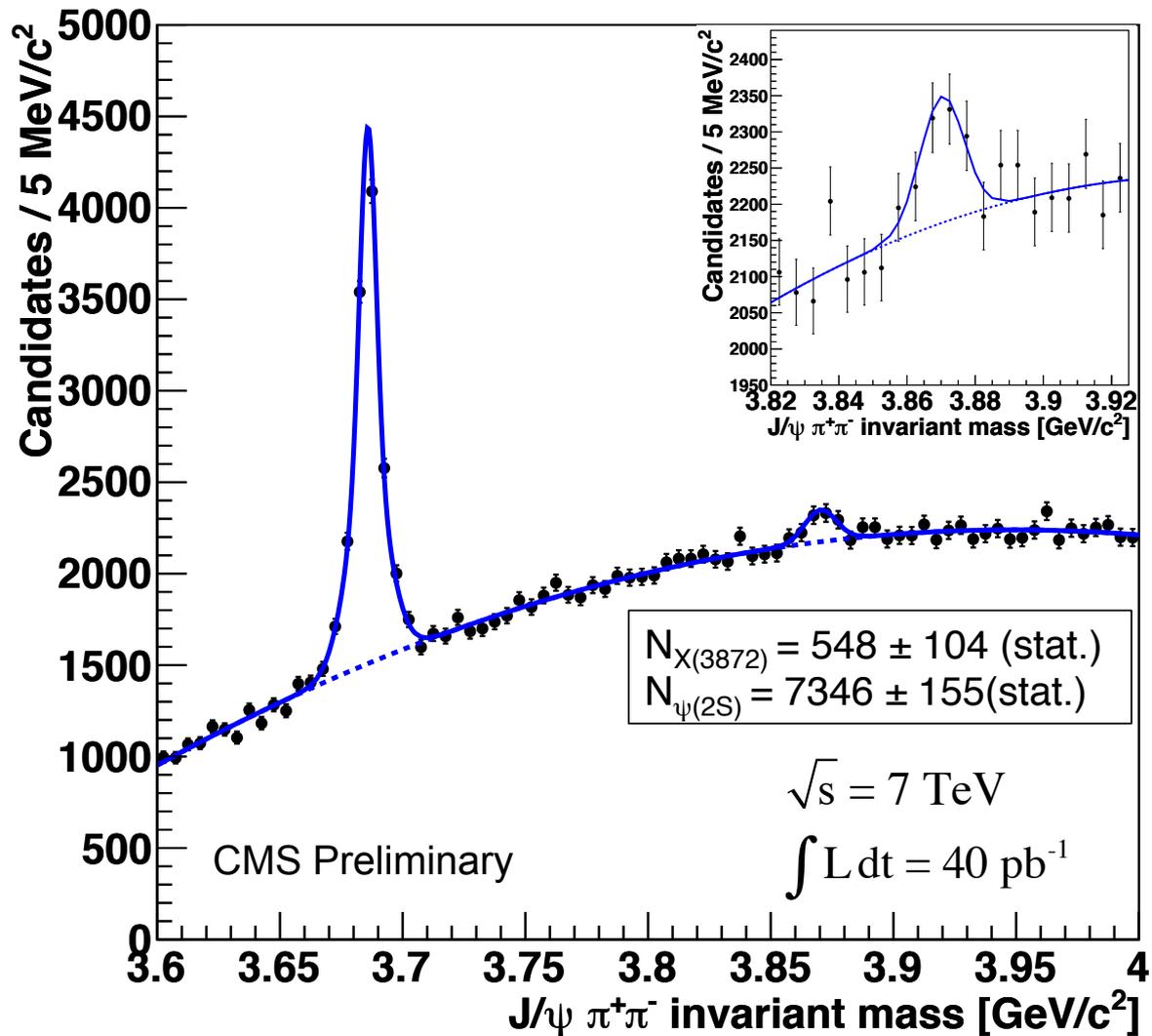
$$m_{X(3872)} = 3870.2 \pm 1.9 \text{ MeV}$$

$$\sigma_{X(3872)} = 6.3 \pm 1.3 \text{ MeV}$$

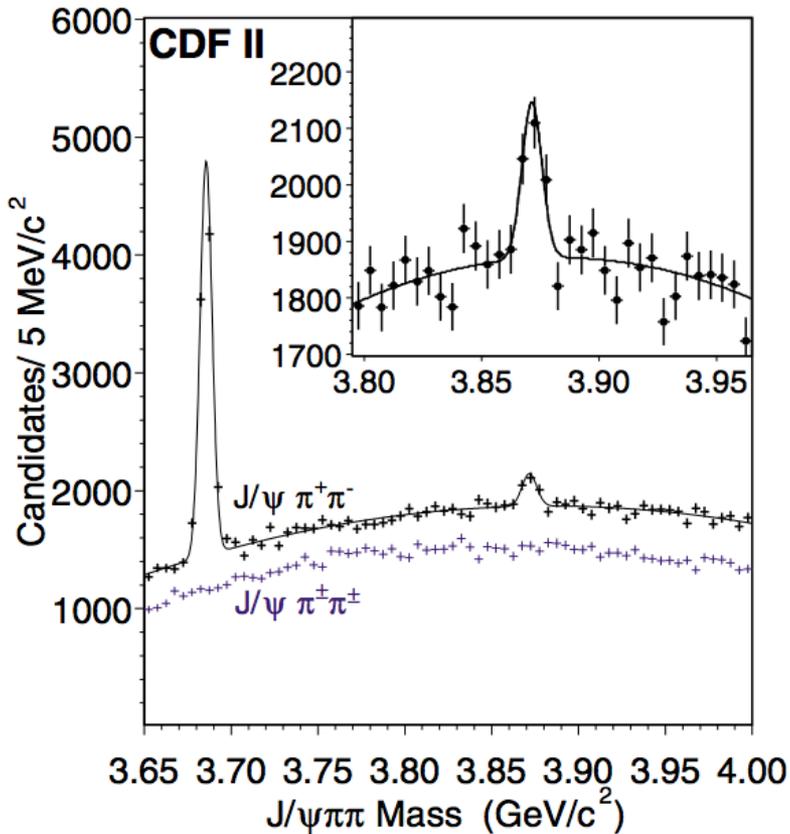
- PDG values:

$$m_{\Psi(2S)} = 3686.09 \pm 0.04 \text{ MeV}$$

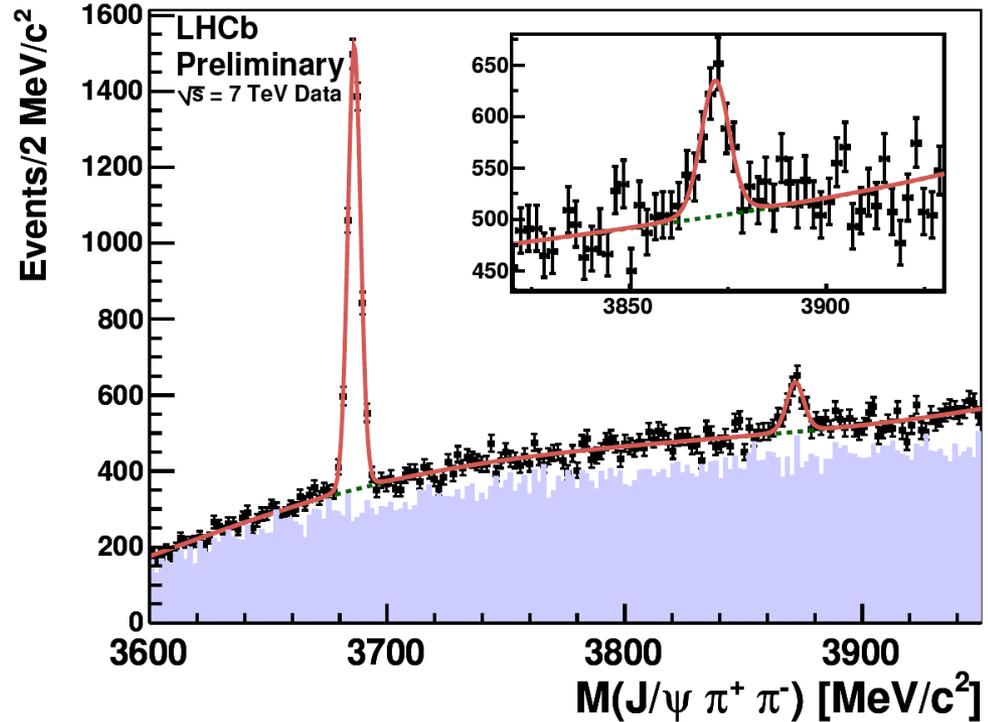
$$m_{X(3872)} = 3871.56 \pm 1.9 \text{ MeV}$$



Comparison with other experiments



Similar statistics as first CDF publication (220 pb^{-1}), still far from latest results using 2.4 fb^{-1}



LHCb result (presented on Monday) using 34.8 pb^{-1}

- ① Identify the fiducial region for the measurement from MC simulation
 - Sufficient acceptance found for candidate $p_T > 8$ and $|y| < 2.2$
- ② Extract from the $J/\psi \pi^+ \pi^-$ invariant mass spectrum the $\psi(2S)$ and $X(3872)$ yields

- ③ Calculate the ratio

$$R = \frac{\sigma(pp \rightarrow X(3872) + \text{anything}) \times \text{BR}(X(3872) \rightarrow J/\psi \pi\pi)}{\sigma(pp \rightarrow \psi(2S) + \text{anything}) \times \text{BR}(\psi(2S) \rightarrow J/\psi \pi\pi)} = \frac{N_{X(3872)}}{N_{\psi(2S)}} / C$$

- ④ The correction factor C takes into account the kinematical differences of the decay products; obtained from Monte Carlo studies.
 - $X(3872)$ obtained in Pythia 6 setting mass of χ_{c1} ($J^{PC}=1^{++}$) to 3.872 GeV.
 - Both particles considered unpolarized and decayed with EvtGen.

$$C = \frac{A_{J/\psi}(X) \cdot \varepsilon_{J/\psi}(X) \cdot A_{\pi\pi}(X) \cdot \varepsilon_{\pi\pi}(X)}{A_{J/\psi}(\psi') \cdot \varepsilon_{J/\psi}(\psi') \cdot A_{\pi\pi}(\psi') \cdot \varepsilon_{\pi\pi}(\psi')}$$

The terms are:

- **Acceptance of J/ψ ($A_{J/\psi}$)**

Fraction of all the generated J/ψ with 2μ in acceptance region.

- **Efficiency of J/ψ ($\varepsilon_{J/\psi}$)**

Fraction of J/ψ with 2μ in acceptance region, triggered and reconstructed.

- **Acceptance \times Efficiency for pions ($A_{\pi\pi} \cdot \varepsilon_{\pi\pi}$)**

Fraction of $X(3872)$ or $\psi(2S)$, with a triggered and reconstructed J/ψ , passing the whole selection.

- C components are separately determined from X and $\psi(2S)$ MC simulation for both prompt and non-prompt components.

- From the fit to the invariant mass distribution:

$$N_{X(3872)} = 548 \pm 104 \text{ (stat.)}$$

$$N_{\psi(2S)} = 7346 \pm 155 \text{ (stat.)}$$

- Assuming the contribution from non-prompt processes to be 30%, the correction factor is found to be:

$$C = 0.872 \pm 0.015$$

- The cross section ratio is then measured to be:

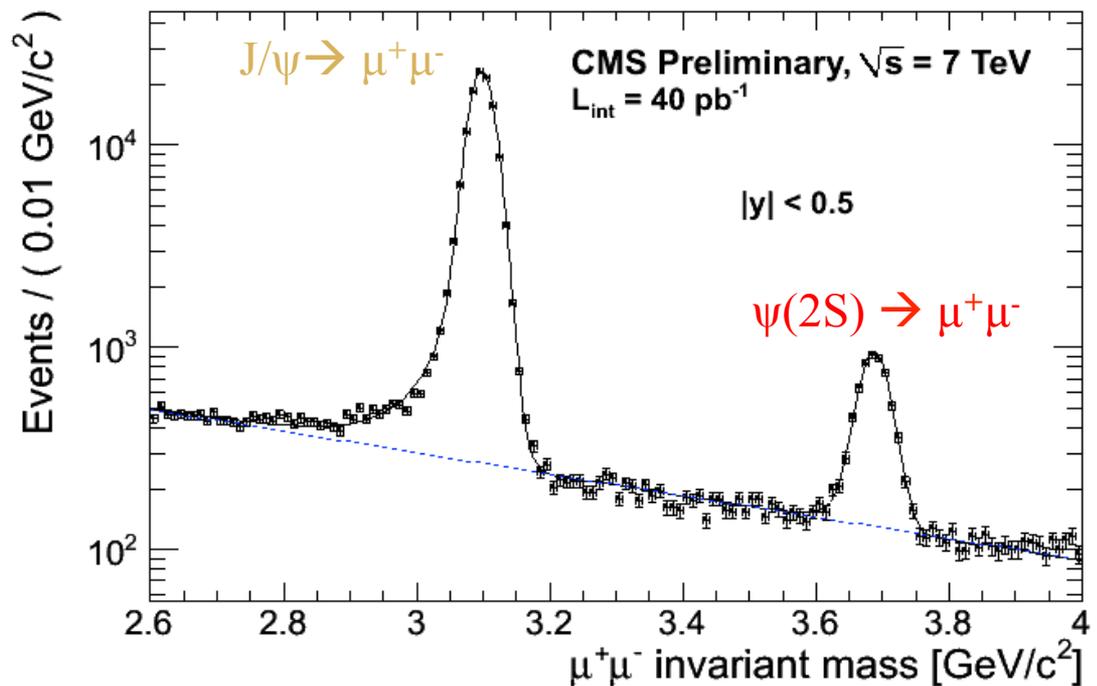
$$\mathbf{R = 0.087 \pm 0.017 \text{ (stat.)}}$$

- Background parameterization and signal extraction **5.3%**
- Variation of the the non-prompt fraction for X(3872) and $\psi(2S)$ in a range $30\% \pm 20\%$ **6.0%**
- Lack of knowledge of the X(3872) production mechanism **3.5%**
 - Study on the effect of changes in the X(3872) p_T shape
- Uncertainty due to limited statistics in MC samples **1.8%**
- Uncertainty on the pion tracking efficiency **4.0%**
 - Data-driven cross check comparing the decay channels
 $\psi(2S) \rightarrow J/\psi\pi^+\pi^-$ and $\psi(2S) \rightarrow \mu^+\mu^-$

Total systematic uncertainty: **10%**

- Check the value for $A_{\pi\pi}(\psi') \cdot \varepsilon_{\pi\pi}(\psi')$ comparing the decay channels $\psi(2S) \rightarrow J/\psi \pi^+ \pi^-$ and $\psi(2S) \rightarrow \mu^+ \mu^-$ in our fiducial region.

- Determine the number of
 - $\psi(2S) \rightarrow \mu^+ \mu^-$
 - $\psi(2S) \rightarrow J/\psi \pi^+ \pi^-$
- Correct the ratio for
 - branching ratios (PDG)
 - acceptances and efficiencies of J/ψ and $\psi(2S)$ in two muons



- Results consistent with the values obtained from Monte Carlo studies

- CMS established a clear X(3872) signal using 2010 data

- The measurement of the ratio of cross sections

$$R = \frac{\sigma(pp \rightarrow X(3872) + \text{anything})BR(X(3872) \rightarrow J/\psi\pi^+\pi^-)}{\sigma(pp \rightarrow \psi(2S) + \text{anything})BR(\psi(2S) \rightarrow J/\psi\pi^+\pi^-)}$$

yields:

$$\mathbf{R = 0.087 \pm 0.017 (stat) \pm 0.009 (syst)}$$

Available as CMS public document:

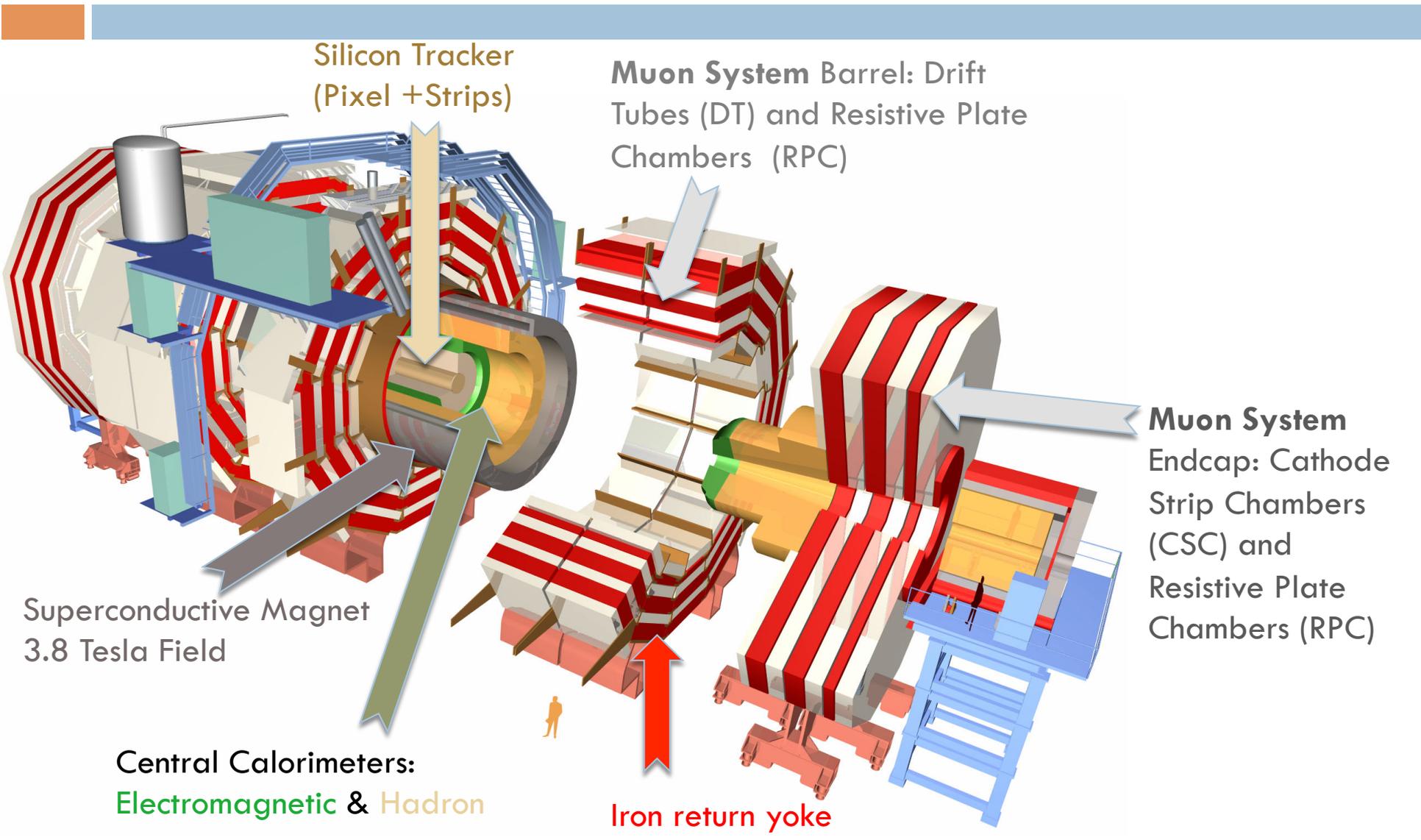
<http://cms-physics.web.cern.ch/cms-physics/public/BPH-10-018-pas.pdf>

- More detailed studies will be performed with 2011 statistics
- A measurement of the $\psi(2S)$ cross section will soon become available

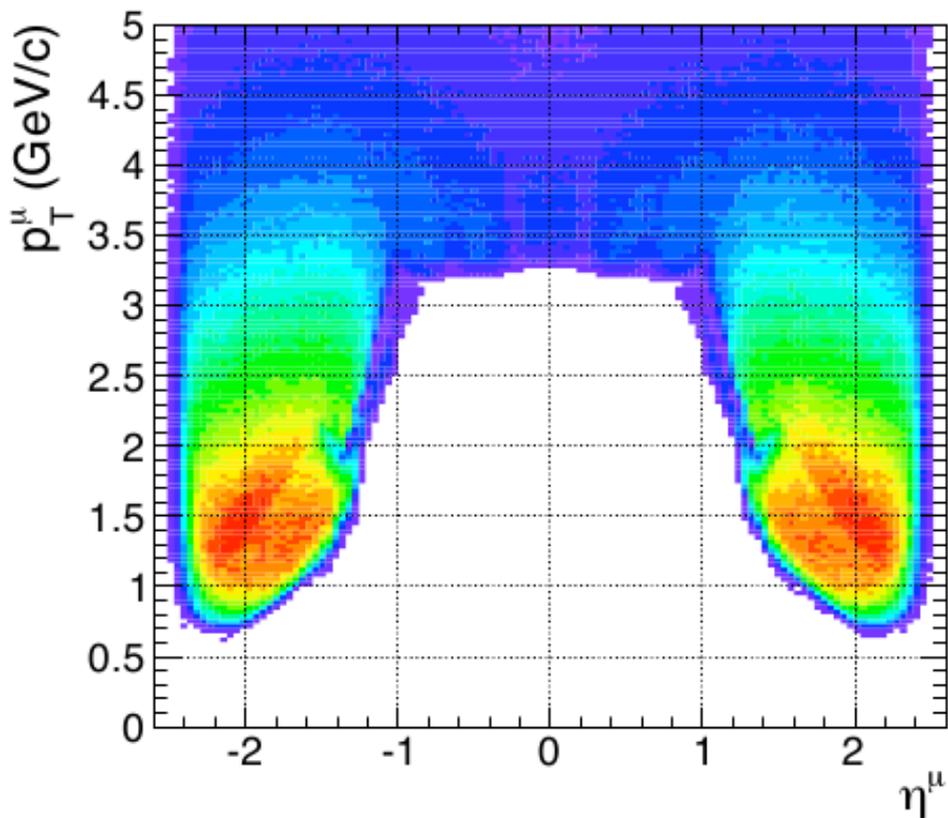


BACKUP

CMS Experiment



Single Muon



J/ ψ

