Upsilon Production Cross Section in pp collisions at $\sqrt{s}$ = 7 TeV arXiv:1012.5545

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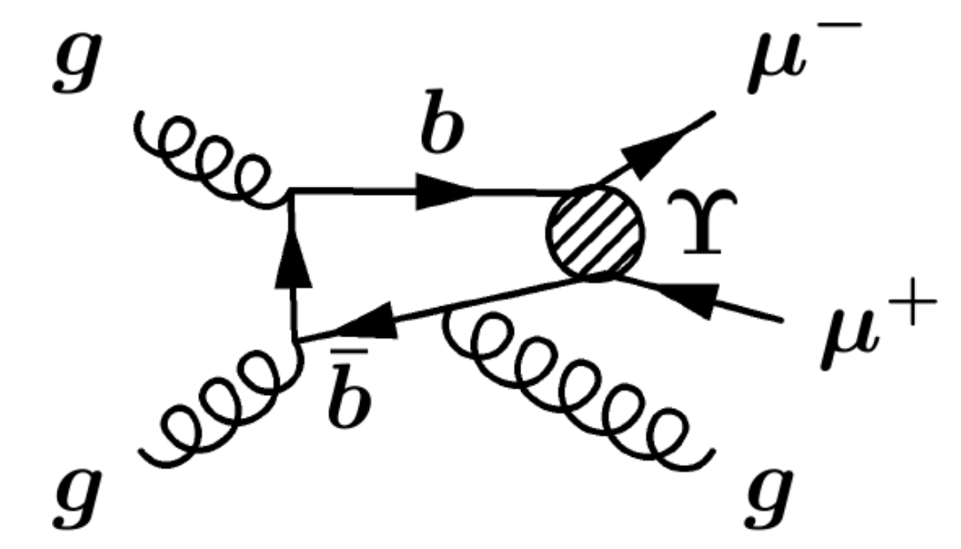
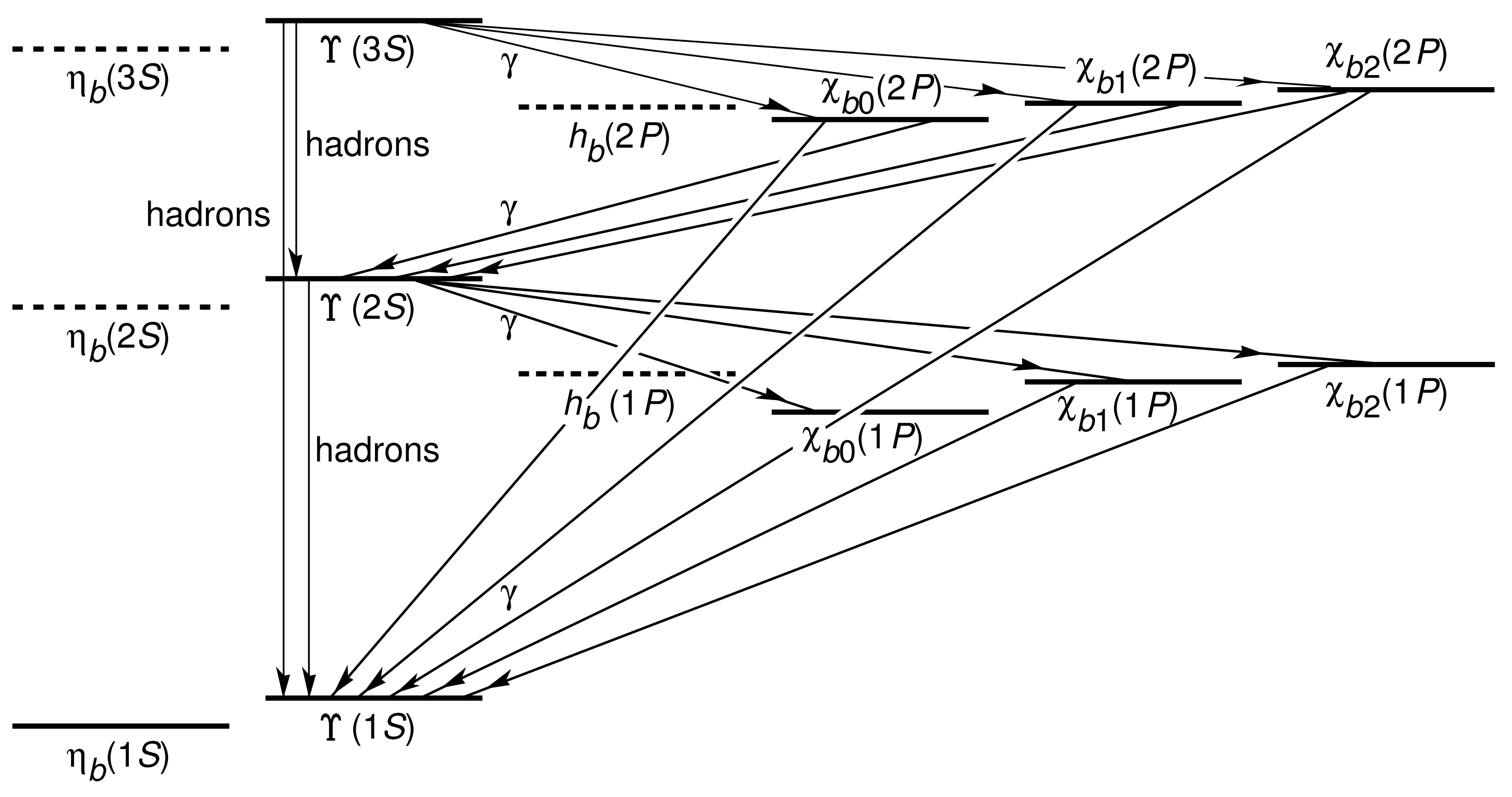
Introduction



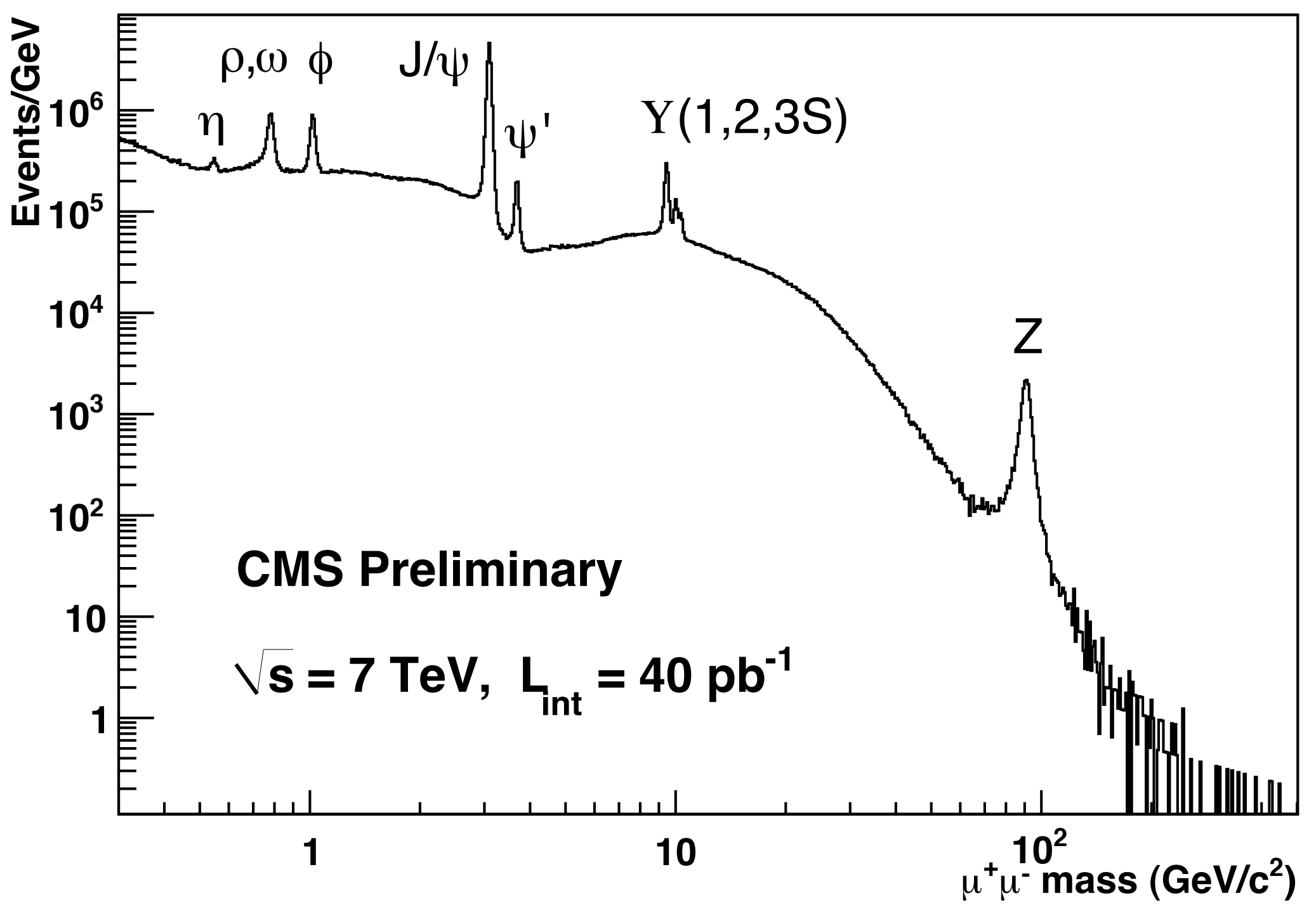
The hadroproduction of quarkonia is not understood. None of the existing theories successfully reproduces both the differential cross section and the polarization measurements of charmonium and bottomonium states.



Measurements of the Υ resonances are particularly important since the theoretical calculations are more robust than for the charmonium family due to the heavy bottom quark and the absence of b-hadron feed-down. Measurements of quarkonium hadroproduction cross sections will allow important tests of several alternative theoretical approaches.

The **Large Hadron Collider (LHC)** will produce high transverse momentum (p_T) Υ at a large rate and has the potential to discriminate between the emerging new models.

The **Compact Muon Solenoid (CMS)** experiment is a general-purpose detector used to investigate a wide range of physics. Detecting muons is one of CMS's most important tasks. Upsilon decays to muon pairs play an important role in the detector calibration and alignment.



CMS rediscovering the Benchmarks of the Standard Model

Analysis Strategy

Cross Section Definition

$$\frac{d^2\sigma\left(pp \to \Upsilon(nS)X\right)}{dp_T\, dy} \cdot \mathcal{B}\left(\Upsilon(nS) \to \mu^+\mu^-\right) = \frac{N_{\Upsilon(nS)}(\mathcal{A},\varepsilon)}{\mathcal{L}\ \cdot \Delta p_T \cdot \Delta y}$$

- $\mathcal{A}$ - detector acceptance
- ε - identification, trigger and tracking efficiencies
- $N_{\Upsilon(nS)}(\mathcal{A},\varepsilon)$ - corrected yield of Upsilon candidates
- $\mathcal{L}$ - integrated luminosity
- Δp_T - Upsilon transverse momentum bin size
- Δy - Upsilon rapidity bin size

Event Selection

- Events passing a trigger requiring two muons at the hardware trigger level without any explicit p_T cuts
- Two muons with opposite charge in the mass window (8,14) GeV/c^2
- Vertex χ2 probability > 0.001
- Longitudinal separation between two muons < 2 cm
- Each muon satisfies:
  - $p_T > 3.5$ GeV/c if $|\eta| < 1.6$,
  - $p_T > 2.5$ GeV/c if $1.6 < |\eta| < 2.4$,
  - passing track quality cuts

Acceptance

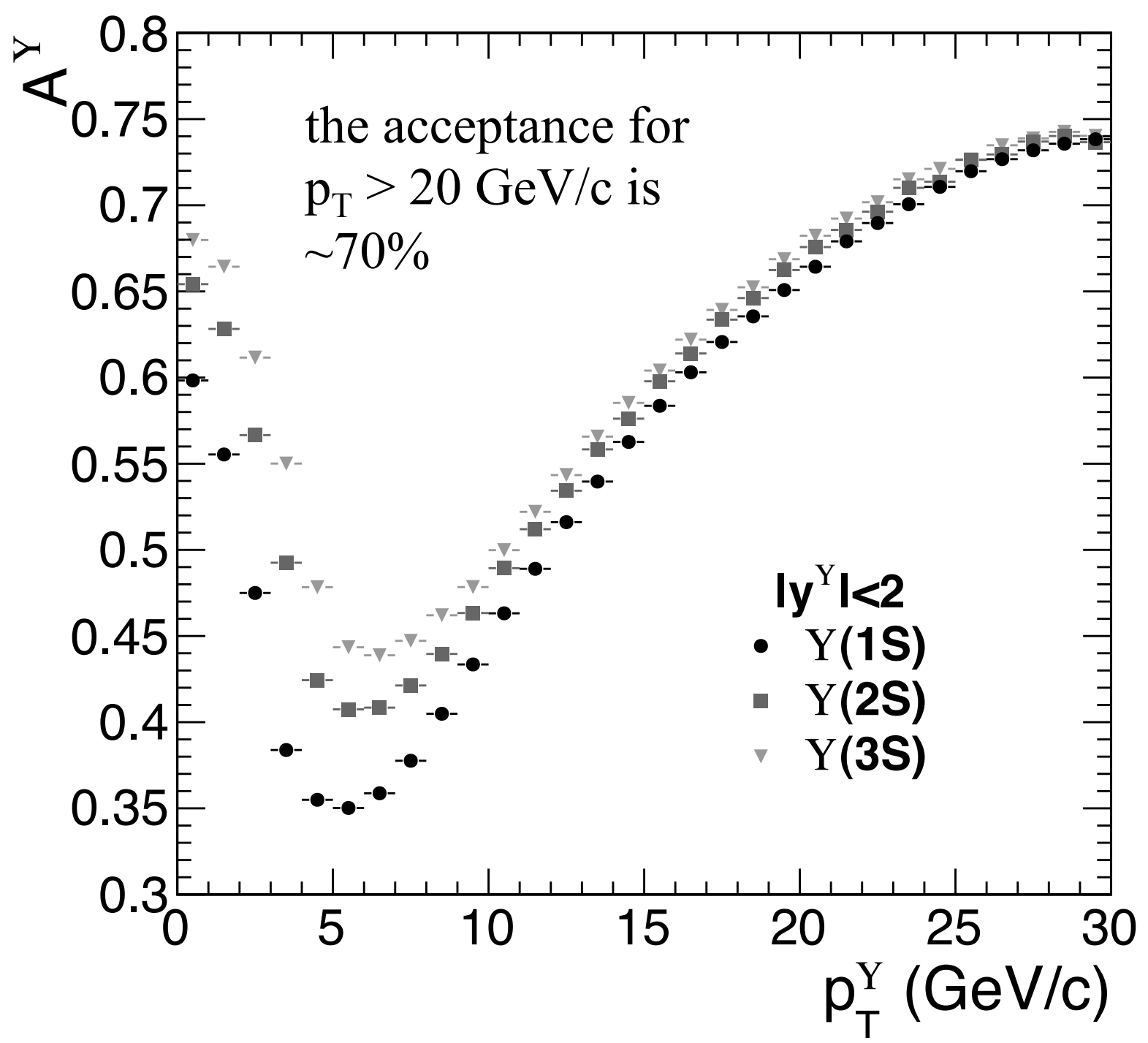
$$\mathcal{A}^{\Upsilon}(p_T, y) = \frac{N^{\Upsilon}_{\rm rec}(p_T, y)}{N^{\Upsilon}_{\rm gen}(p_T, y)}$$

- $N^{\Upsilon}_{\rm gen}(p_T, y)$

  number of generated Upsilons
- $N^{\Upsilon}_{\rm rec}(p_T, y)$

  number of Upsilons reconstructed in the same (p_T, y) cell using the reconstructed variables rather than the generated ones

The unpolarized Upsilon acceptance integrated over rapidity as a function of p_T

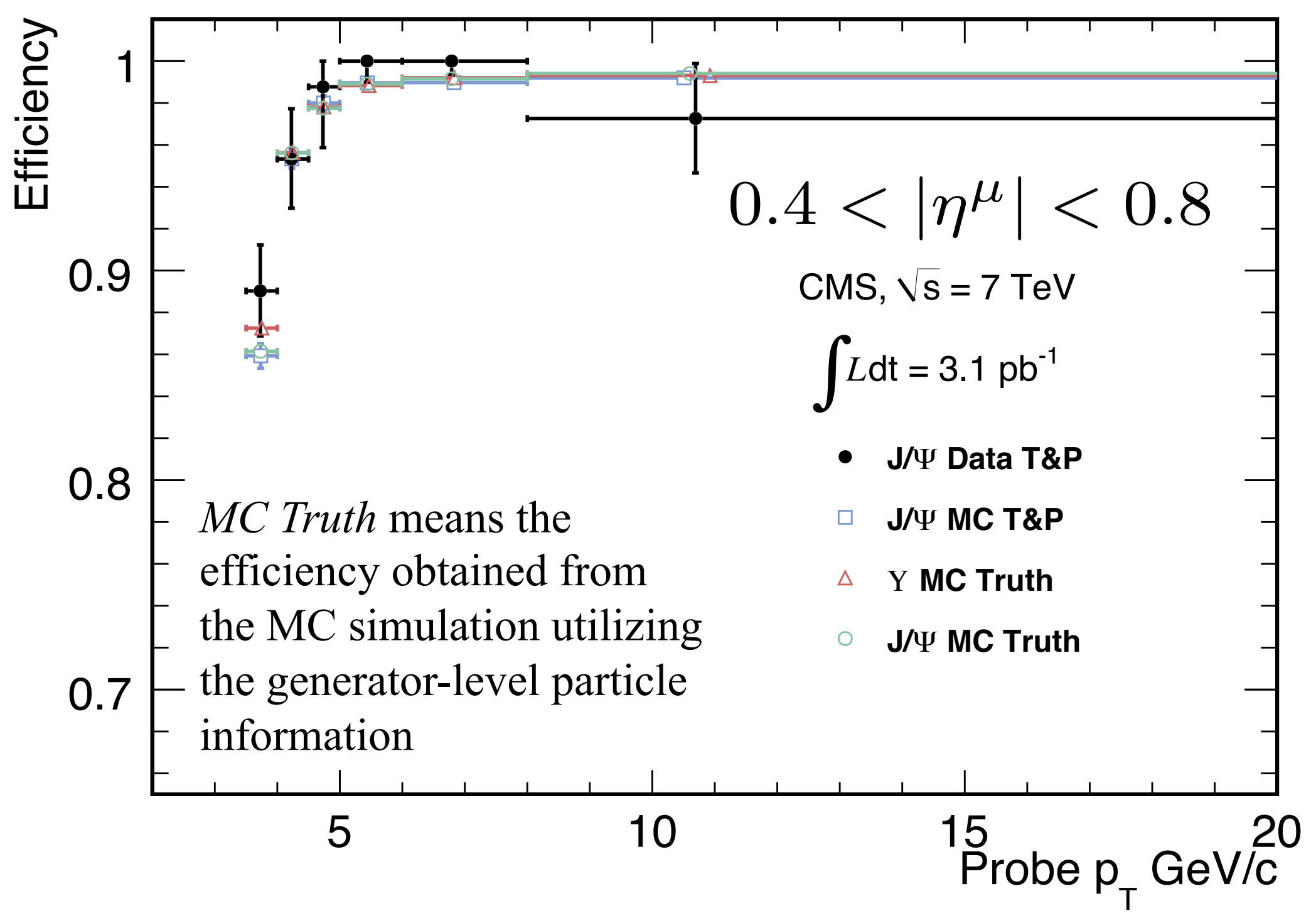


Muon Efficiencies

$$\varepsilon(\text{total}) = \varepsilon(\text{trig}|\text{id}) \cdot \varepsilon(\text{id}|\text{track}) \cdot \varepsilon(\text{track}|\text{accepted})$$
$$\equiv \varepsilon_{\rm trig} \cdot \varepsilon_{\rm id} \cdot \varepsilon_{\rm track}$$

- Muon identification efficiency (ε_{id}) and trigger efficiency (ε_{trig}) : measured with the Tag and Probe (T&P) data-driven method utilizing the large-yield Jpsi data sample
- Muon tracking efficiency (ε_{track}) : determined in part with a track-embedding technique, and in part with T&P to measure track quality criteria

Muon Identification Efficiency

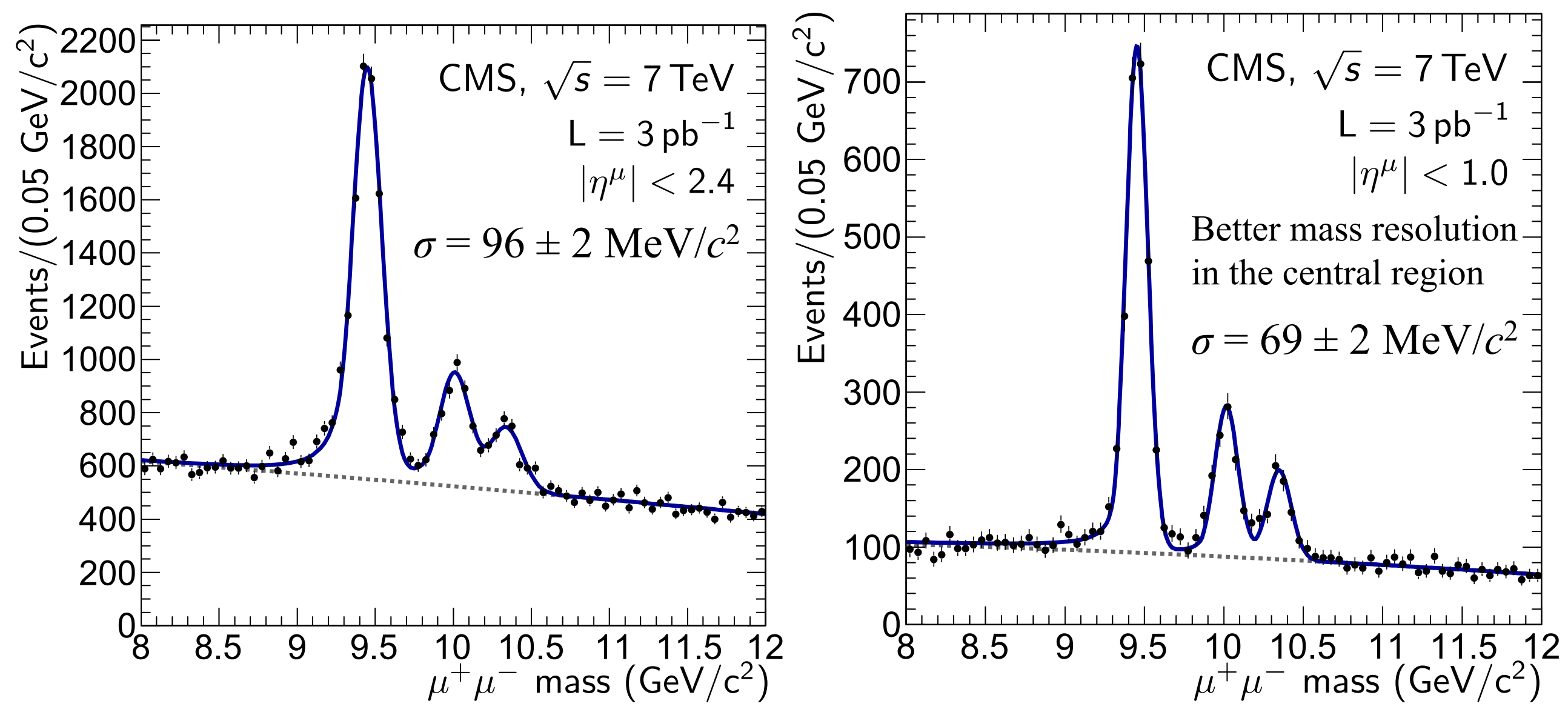


MC Truth means the efficiency obtained from the MC simulation utilizing the generator-level particle information

Cross Section Measurement with $\int L dt$ = 3/pb at 7 TeV

Dimuon Mass

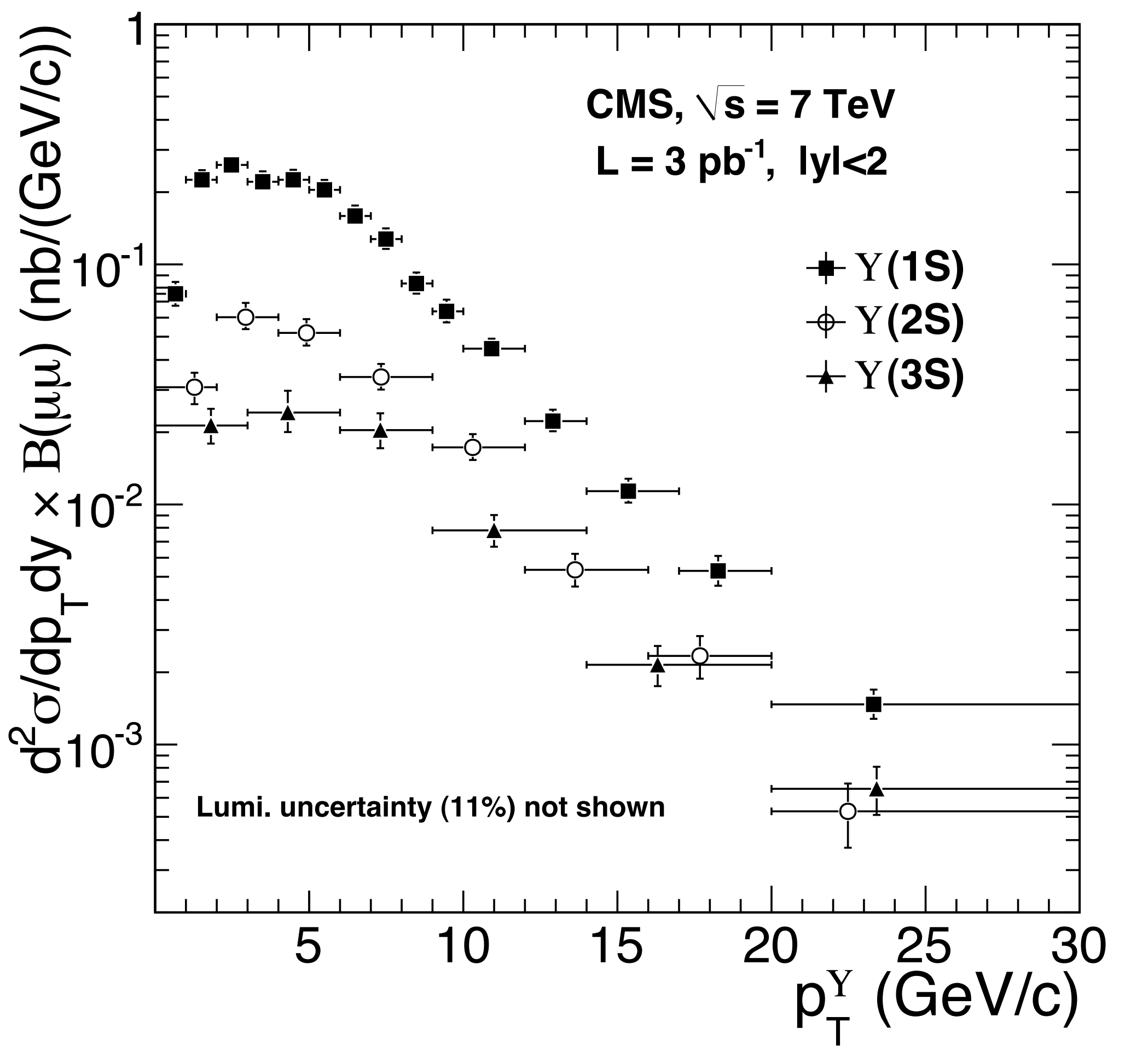
- Upsilon candidates are weighted to account for acceptance, identification and trigger efficiencies
- Extended unbinned maximum likelihood fit
- Three crystal ball Upsilon resonances with a polynomial background
- Same resolution function for the three Upsilons
- Relative mass differences between Upsilon peaks fixed to PDG values



CMS has excellent mass resolution

Systematic Uncertainties

- The determination of the luminosity normalization is made with an uncertainty of 11%
- Unknown production polarization
- Statistical uncertainty in acceptance and efficiencies measurements
- Tag and Probe bias
- Electromagnetic Final State Radiation
- Choice of probability distribution functions for the signals and background



Results

The Υ(nS) production cross section at 7 TeV integrated over the rapidity range |y| < 2:

$$\sigma(\text{pp} \to \Upsilon(1S)X) \cdot \mathcal{B}(\Upsilon(1S) \to \mu^+\mu^-) = 7.37 \pm 0.13(\text{stat.})^{+0.61}_{-0.42}(\text{syst.}) \pm 0.81(\text{lumi.})\,\text{nb}$$
$$\sigma(\text{pp} \to \Upsilon(2S)X) \cdot \mathcal{B}(\Upsilon(2S) \to \mu^+\mu^-) = 1.90 \pm 0.09(\text{stat.})^{+0.20}_{-0.14}(\text{syst.}) \pm 0.24(\text{lumi.})\,\text{nb}$$
$$\sigma(\text{pp} \to \Upsilon(3S)X) \cdot \mathcal{B}(\Upsilon(3S) \to \mu^+\mu^-) = 1.02 \pm 0.07(\text{stat.})^{+0.11}_{-0.08}(\text{syst.}) \pm 0.11(\text{lumi.})\,\text{nb}$$

References

[1] CMS Collaboration, "Upsilon production cross section in pp collisions at $\sqrt{s}$ = 7 TeV", CMS-BPH-10-003