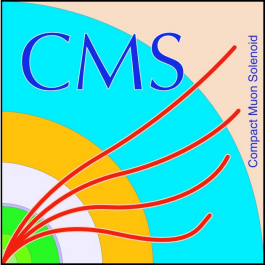

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CMS Measurement of Upsilon Production at 7 TeV

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Overview

New!

- Upsilon production models and puzzles
- Data selection and measurement procedure
- Use of polarization to compute acceptance
- Fitting procedure
- Results

Production Models

- Theoretical problem: describe hadronization to form colorless quark anti-quark pair
- Models: k_t factorization, Color Singlet Model, NRQCD re-fitting procedure
- Models predict different p_T dependence of the cross section

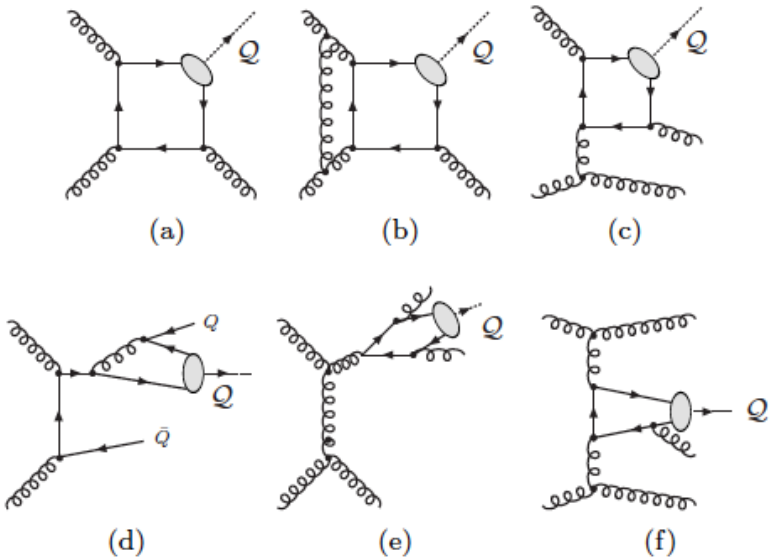
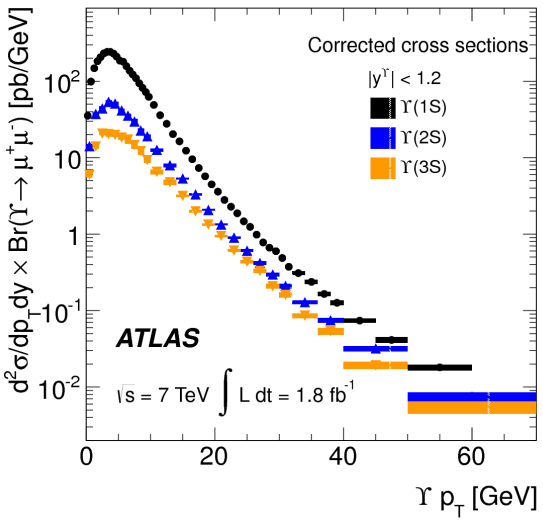


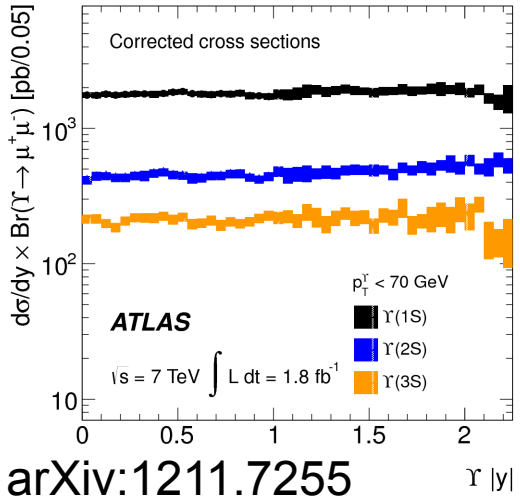
FIG. 1: Representive diagrams contributing to Υ hadroproduction at orders α_S^3 (a), α_S^4 (b,c,d), α_S^5 (e,f). See discussions in the text.

Color Single Model
arXiv:0806.3282v2

Previous measurements

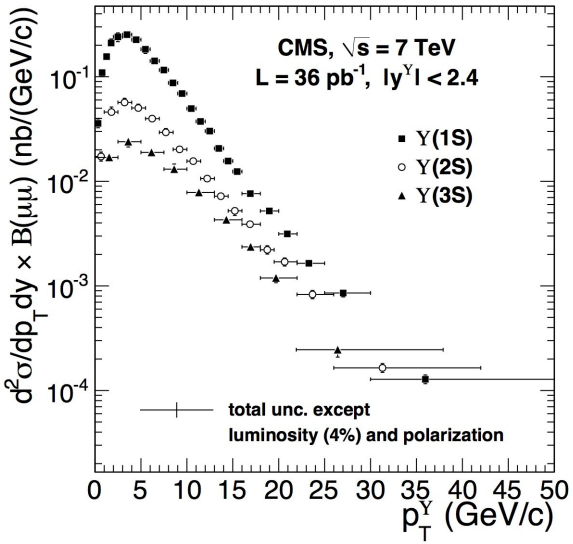
ATLAS

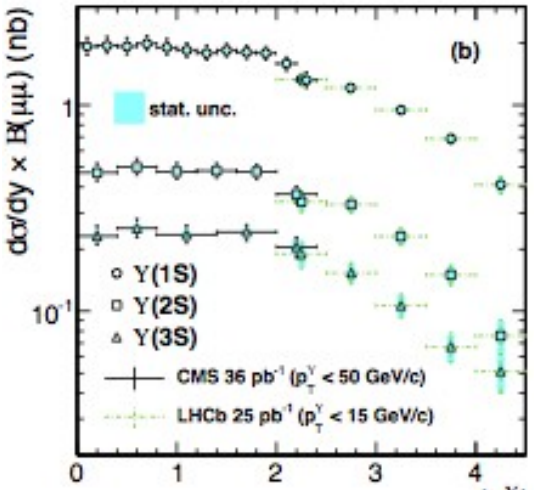




arXiv:1211.7255

CMS

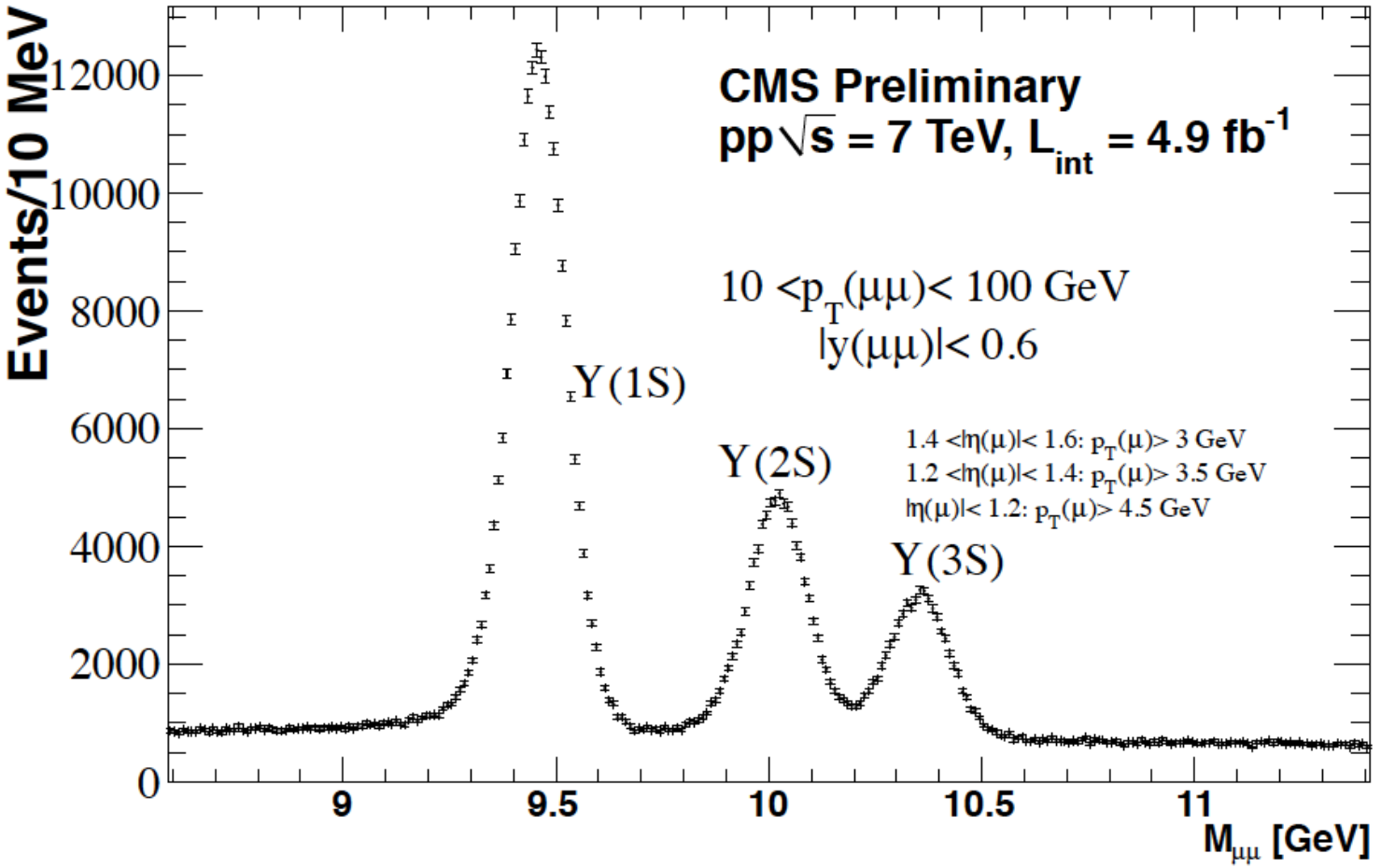




arXiv:1303.5900

- p_T dependence: cross section peaks near 4 GeV, then falls off rapidly
- Rapidity dependence: flat to around |y|=2.0
- Our physics emphasis is on the shape of differential cross section as a function of p_T to the highest value of p_T possible

Data sample



- CMS 2011 data corresponding to 4.9 fb^{-1}
- Collected dimuons with dedicated Upsilon trigger

Cross section measurement

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$$\left.\frac{d\sigma\left(pp \to \Upsilon(\mathrm{nS})\right)}{dp_T}\right|_{|y|<0.6} \times \mathcal{B}\left(\Upsilon(\mathrm{nS}) \to \mu^+\mu^-\right) = \frac{N^{\mathrm{fit}}_{\Upsilon(\mathrm{nS})}(p_T)}{L_{int} \cdot \Delta p_T \cdot \epsilon(p_T) \cdot \mathcal{A}(p_T)}$$

- Measure differential cross section times branching fraction to muons

L_{int}: Integrated luminosity $= 4.9\ \mathrm{fb}^{-1}$
Δp_T: Bin width
$N^{\mathrm{fit}}_{\Upsilon(\mathrm{nS})}(p_T)$: Upsilon yield in each p_T bin
$\epsilon(p_T)$:Efficiency of trigger, reconstruction, and analysis selections
$\mathcal{A}(p_T)$: Acceptance

Acceptance

- Acceptance: fraction of Υ decays where the muons meet the kinematic requirements
- Polarization changes the muon angular distribution:

$$w = \frac{3/(4\pi)}{3+\lambda_\theta}\left(1+\lambda_\theta \cos^2\theta + \lambda_\phi \sin^2\theta \cos 2\phi + \lambda_{\theta\phi} \sin 2\theta \cos\phi\right)$$

θ,φ are the polar and azimuthal angles of μ^+ measured with respect to the z axis in the chosen polarization frame

- We use the CMS measured polarization to re-weight the muon angular distribution in determination of the acceptance from Monte Carlo simulation

Polarization

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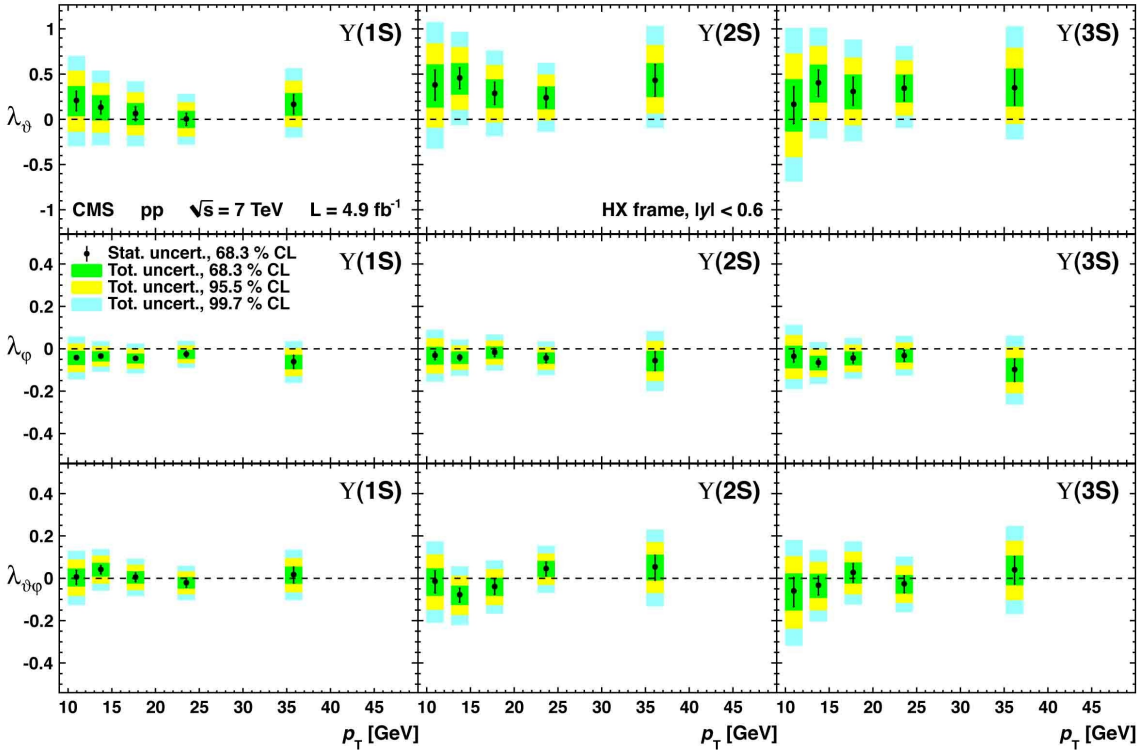
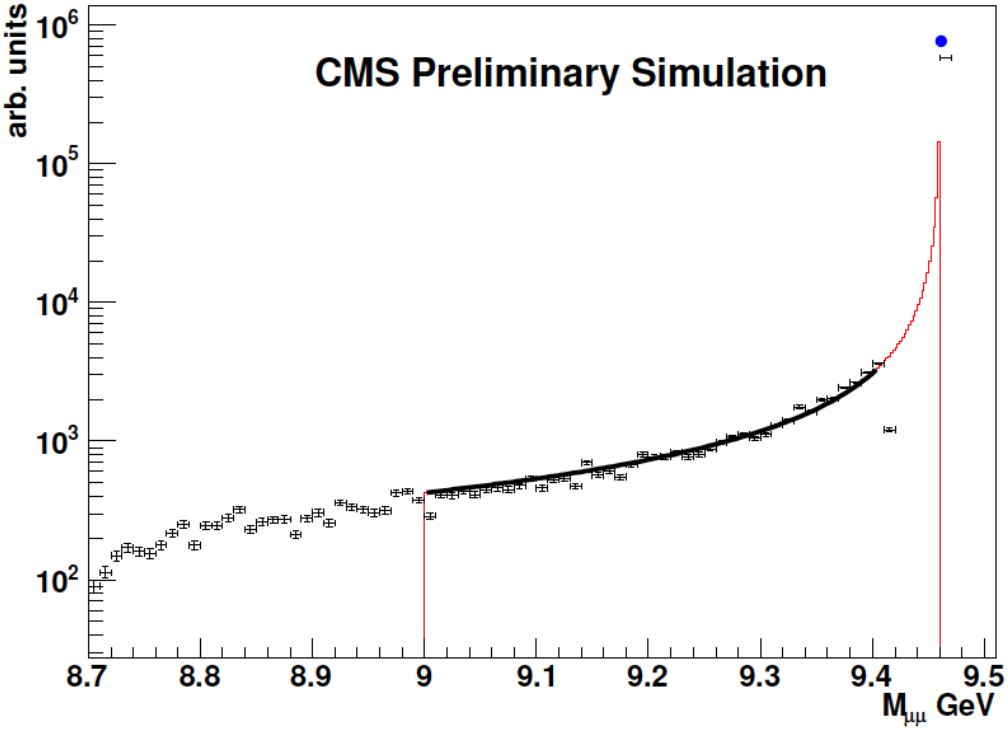
PRL 110 (2013) 081802

- The polarization parameters λ_θ, λ_φ, and $\lambda_{\theta\varphi}$ in the helicity frame are consistent with a constant as a function of p_T
- We fit a constant to the measured points using 95.5% confidence level total uncertainties



- The fit parameters and uncertainties are used to compute the polarization-corrected acceptance

Line-shape determination



- Line-shape used for fitting was determined by evaluating the expression below
- m_i was sampled from the final-state radiation mass shape on the left
- ζ approximates the detector effects on the mass error

$$\mathcal{F}(m; c_w, \delta m) = \frac{1}{N} \sum_{i=1}^{N} \frac{1}{\sqrt{2\pi} c_w \zeta_i} e^{-(m - m_i - \delta m)^2 / 2 c_w^2 \zeta_i^2}$$

Fitting the mass spectrum

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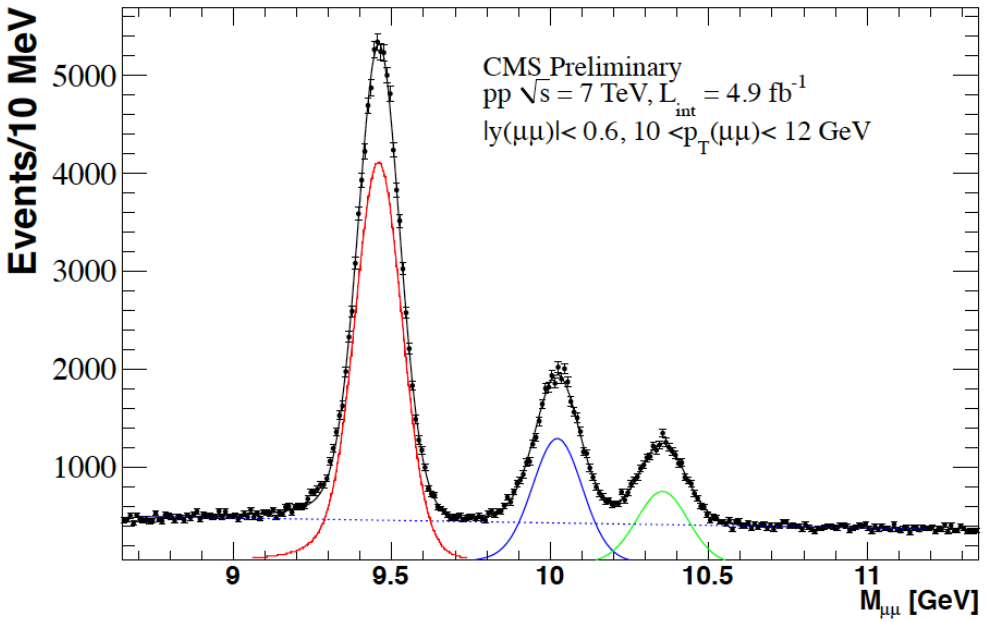
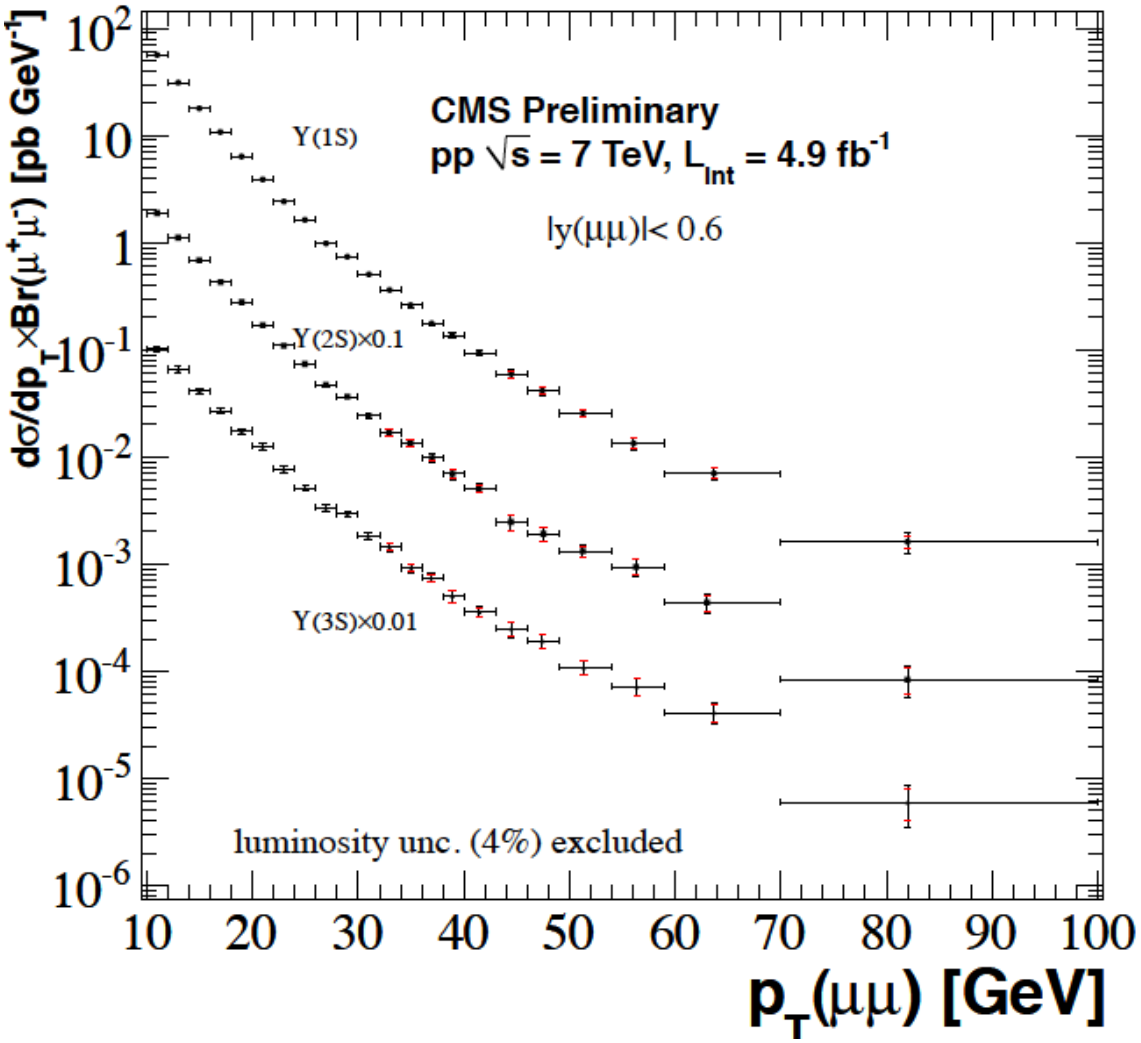
- Use Chebyschev polynomials to describe the background
- Determine optimum highest order Chebyschev from yield stability as mass range is varied



$$N(M_{\mu\mu}) = S_1[\mathcal{F}(M_{\mu\mu};c_w,\delta m)_{\Upsilon(1S)} + r_{21}\mathcal{F}(M_{\mu\mu};c_w,\delta m)_{\Upsilon(2S)} + r_{31}\mathcal{F}(M_{\mu\mu};c_w,\delta m)_{\Upsilon(3S)}] + \sum_{i=0}^{n_{max}} b_i T_i(x_i)$$

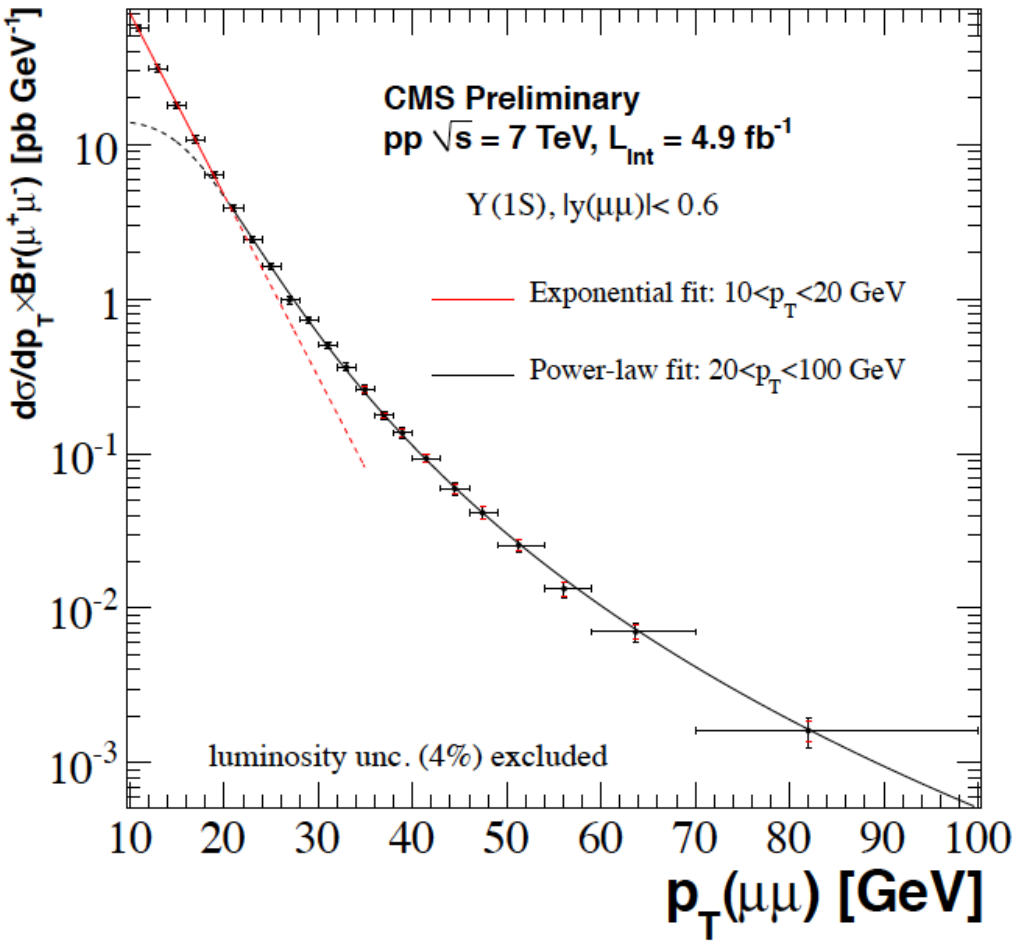
$\mathcal{F}(M_{\mu\mu};c_w,\delta m)$: unit area data-driven line-shape
δm and c_w: momentum scale corrections
$T_i(x_i)$: background model described using Chebyschev series
S_1: $\Upsilon(1S)$ yield
r_{21} $[r_{31}]$: measured $\Upsilon(2S)/\Upsilon(1S)$ $[\Upsilon(3S)/\Upsilon(1S)]$ yields

Result



- Differential cross section as a function of p_T for all three Upsilon states measured to p_T = 100 GeV

Interpretation



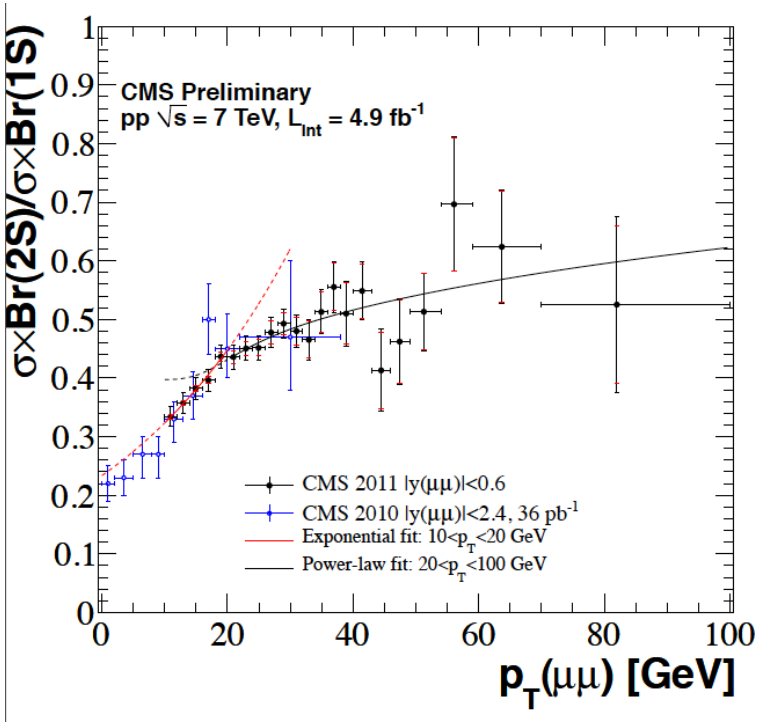
- Exponential: $p_T < 20$GeV
- Fit cross section to power-law:

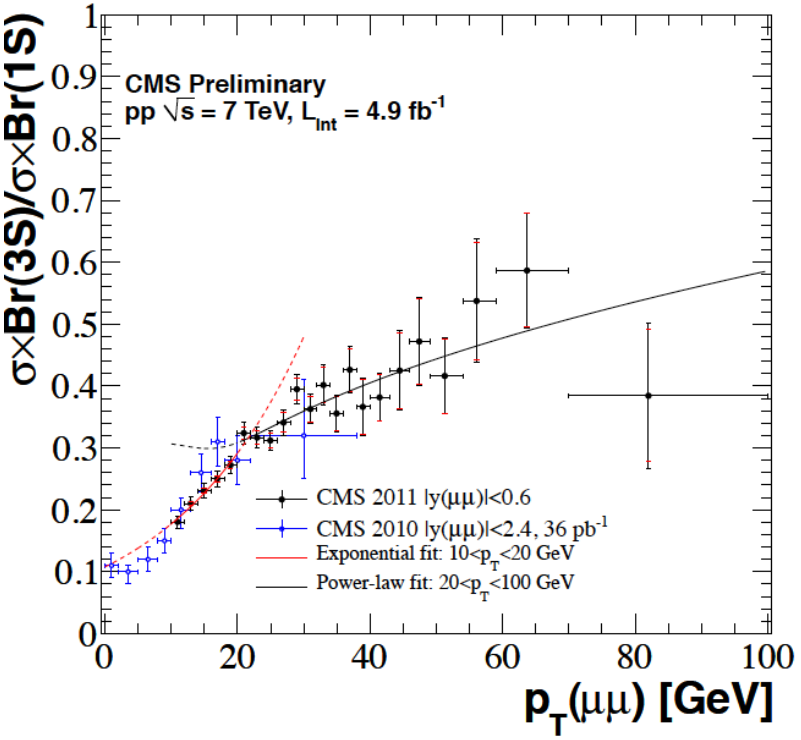
$$f(p_T) = \frac{A}{C + (\frac{p_T}{p_o})^{\alpha}}$$

p_T > 20 GeV
p_o = 20 GeV

- A, C & p_o are normalization terms
- α describes the p_T shape, is similar for all three states
- Change in slope suggests a change in production mechanism

Cross Section Ratio Results

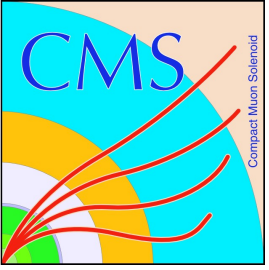




- New results (closed circles) are consistent with previous CMS 2010 measurement done with 36 pb-1 (open circles)
- Curves are the ratio of exponential and power-law fits to the cross section
- Production ratios tend to flatten where there is a change from exponential to power-law

Conclusions

- We have measured the Υ(nS) differential cross sections for p_T = 10-100 GeV
- CMS polarization measurements were utilized to compute the acceptance
- A change in the slope of the differential cross sections from an exponential to power-law is observed
- All three Upsilon states exhibit similar cross section behaviors
- https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsBPH



Backup slides

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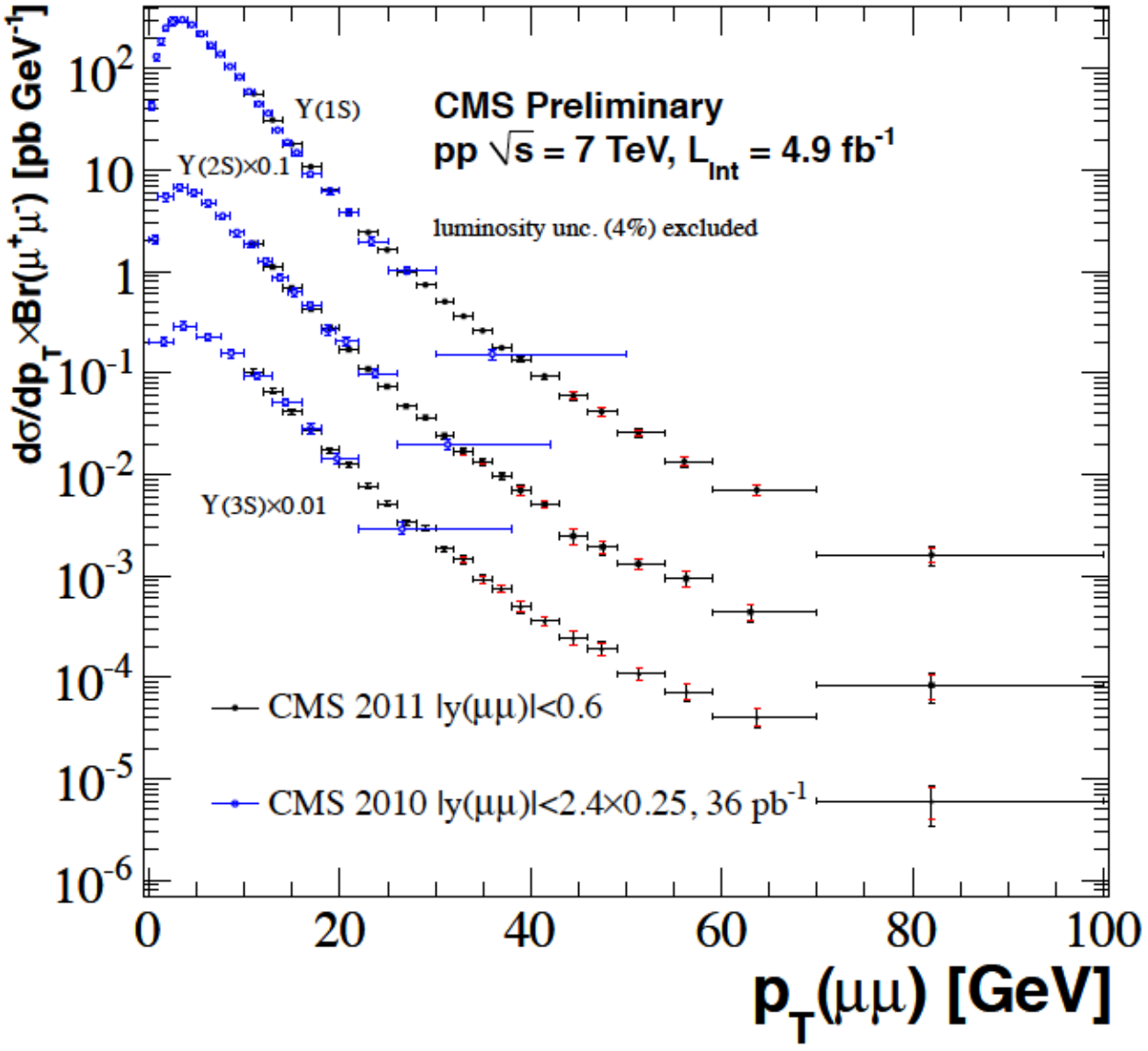
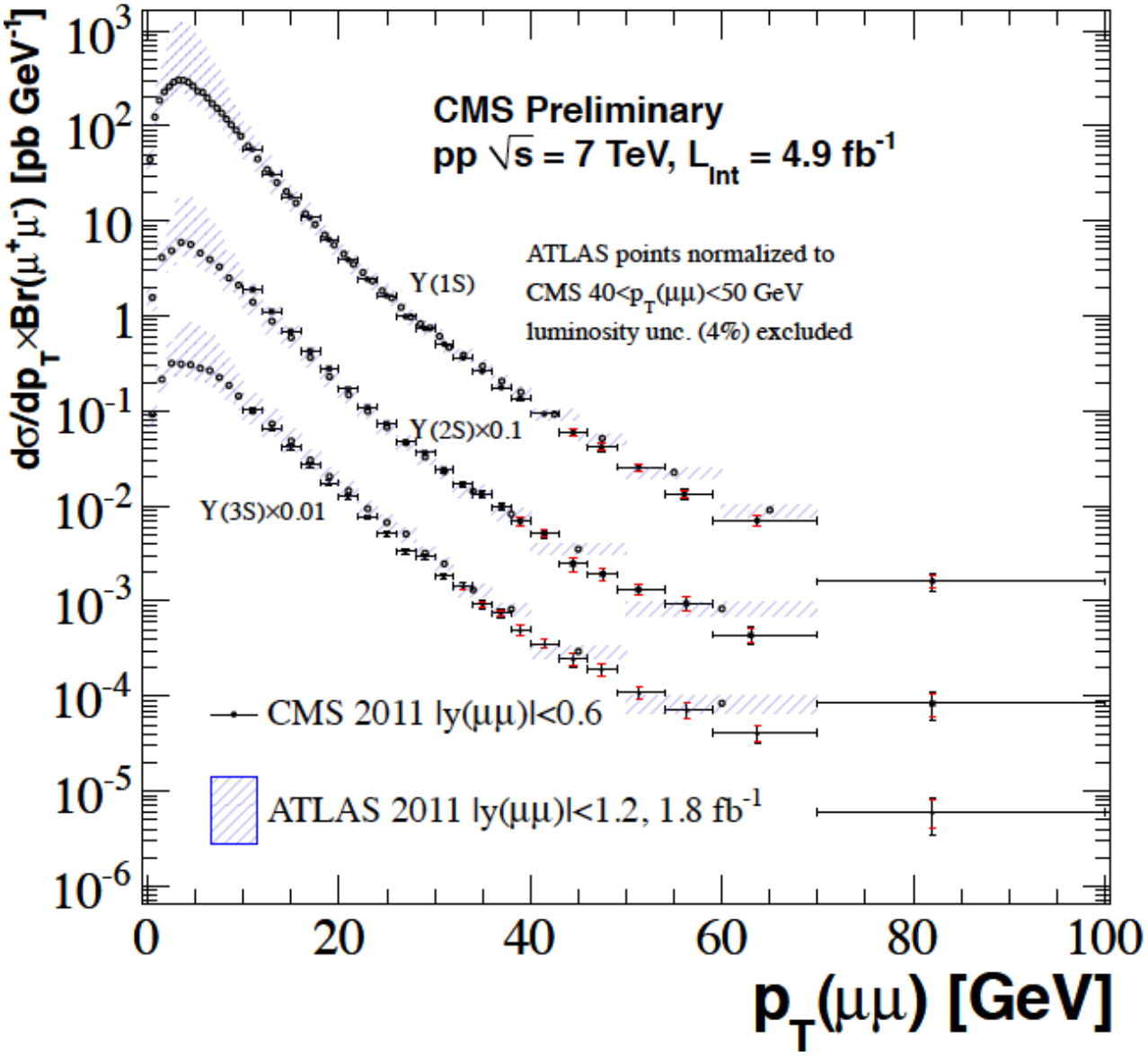
Comparison to CMS 2010



Comparison to ATLAS



Sample fits

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