

(Some ideas on a possible)

Interpolation of quarkonium calculations at the LHC

J.P. Lansberg
Paris Sud XI - IPNO

First Retequarkonii Workshop
October 25th-28th 2010
Nantes France

Motivations in view of the LHC PbPb runs

- One needs a pp baseline to extract hot-nuclear-matter effects

Motivations in view of the LHC PbPb runs

- One needs a pp baseline to extract hot-nuclear-matter effects
- Typical theoretical uncertainties on models (100-500 % ?)
larger than expected nuclear effects (10-50 %)

Motivations in view of the LHC PbPb runs

- One needs a pp baseline to extract hot-nuclear-matter effects
- Typical theoretical uncertainties on models (100-500 % ?)
larger than expected nuclear effects (10-50 %)
- No pp measurement at 2.76 TeV at present time (nor planned)

Motivations in view of the LHC PbPb runs

- One needs a pp baseline to extract hot-nuclear-matter effects
- Typical theoretical uncertainties on models (100-500 % ?)
larger than expected nuclear effects (10-50 %)
- No pp measurement at 2.76 TeV at present time (nor planned)
- Measurements exist however for $\sqrt{s} = 200$ GeV, 1.8 TeV, 7 TeV

Motivations in view of the LHC PbPb runs

- One needs a pp baseline to extract hot-nuclear-matter effects
- Typical theoretical uncertainties on models (100-500 % ?)
larger than expected nuclear effects (10-50 %)
- No pp measurement at 2.76 TeV at present time (nor planned)
- Measurements exist however for $\sqrt{s} = 200$ GeV, 1.8 TeV, 7 TeV
- Beside purely empirical fits of data, hence interpolation,

can one reduce the theoretical uncertainties of models

using the data ?

Motivations in view of the LHC PbPb runs

- One needs a pp baseline to extract hot-nuclear-matter effects
- Typical theoretical uncertainties on models (100-500 % ?)
larger than expected nuclear effects (10-50 %)
- No pp measurement at 2.76 TeV at present time (nor planned)
- Measurements exist however for $\sqrt{s} = 200$ GeV, 1.8 TeV, 7 TeV
- Beside purely empirical fits of data, hence interpolation,

can one reduce the theoretical uncertainties of models

using the data ?

- By looking at the theory, can one get more confidence in a choice of a functional form used for the interpolation/fit ?

Theoretical uncertainties of quarkonium production models

- Uncertainties on **universal**¹ parameters
- Uncertainties from the **scales** (μ_F, μ_R) and the **masses**
- Uncertainties from **PDFs**

¹or claimed to be

Theoretical uncertainties of quarkonium production models

- Uncertainties on **universal**¹ parameters
 - CEM: $f_{J/\psi}, \dots$
 - NRQCD: CO matrix elements
- Uncertainties from the **scales** (μ_F, μ_R) and the **masses**
 - Fixed order evaluations are not complete computations

- Uncertainties from **PDFs**

¹or claimed to be

Theoretical uncertainties of quarkonium production models

- Uncertainties on **universal**¹ parameters
 - CEM: $f_{J/\psi}, \dots$
 - NRQCD: CO matrix elements
- Uncertainties from the **scales** (μ_F, μ_R) and the **masses**
 - Fixed order evaluations are not complete computations
 - Depend on these unphysical scales

- Uncertainties from **PDFs**

¹or claimed to be

Theoretical uncertainties of quarkonium production models

- Uncertainties on **universal**¹ parameters
 - CEM: $f_{J/\psi}, \dots$
 - NRQCD: CO matrix elements
- Uncertainties from the **scales** (μ_F, μ_R) and the **masses**
 - Fixed order evaluations are not complete computations
 - Depend on these unphysical scales
 - This dependence “accounts” / “comes” from
not-yet known higher-order contributions
- Uncertainties from **PDFs**

¹or claimed to be

Theoretical uncertainties of quarkonium production models

- Uncertainties on **universal**¹ parameters
 - CEM: $f_{J/\psi}, \dots$
 - NRQCD: CO matrix elements
- Uncertainties from the **scales** (μ_F, μ_R) and the **masses**
 - Fixed order evaluations are not complete computations
 - Depend on these unphysical scales
 - This dependence “accounts” / “comes” from
not-yet known higher-order contributions
 - No solid reason for these to be \sqrt{s} independent
- Uncertainties from **PDFs**

¹or claimed to be

Theoretical uncertainties of quarkonium production models

- Uncertainties on **universal**¹ parameters
 - CEM: $f_{J/\psi}, \dots$
 - NRQCD: CO matrix elements
- Uncertainties from the **scales** (μ_F, μ_R) and the **masses**
 - Fixed order evaluations are not complete computations
 - Depend on these unphysical scales
 - This dependence “accounts” / “comes” from
not-yet known higher-order contributions
 - No solid reason for these to be \sqrt{s} independent
 - The uncertainties from the mass should be more correlated
- Uncertainties from **PDFs**

¹or claimed to be

Theoretical uncertainties of quarkonium production models

- Uncertainties on **universal**¹ parameters
 - CEM: $f_{J/\psi}, \dots$
 - NRQCD: CO matrix elements
- Uncertainties from the **scales** (μ_F, μ_R) and the **masses**
 - Fixed order evaluations are not complete computations
 - Depend on these unphysical scales
 - This dependence “accounts” / “comes” from
not-yet known higher-order contributions
 - No solid reason for these to be \sqrt{s} independent
 - The uncertainties from the mass should be more correlated
- Uncertainties from **PDFs**
 - Reducible ?

¹or claimed to be

One “easy” and ideal case

LO NRQCD study by P. Artoisenet

- Easy:

- Ideal:

One “easy” and ideal case

LO NRQCD study by P. Artoisenet

- Easy:
 - The cross-section computation very fast for various scales
- Ideal:

One “easy” and ideal case

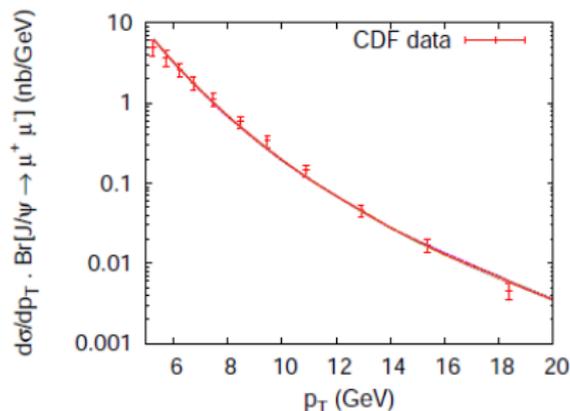
LO NRQCD study by P. Artoisenet

- Easy:
 - The cross-section computation very fast for various scales
 - The cross section depends linearly on the LDMEs
- Ideal:

One “easy” and ideal case

LO NRQCD study by P. Artoisenet

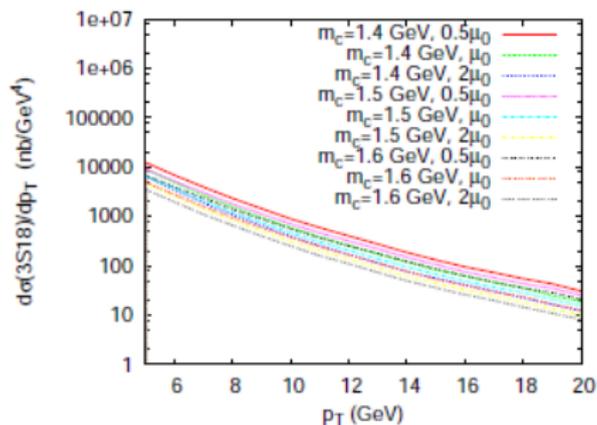
- Easy:
 - The cross-section computation very fast for various scales
 - The cross section depends linearly on the LDMEs
- Ideal:
 - Fit of the LDME is good (virtue of the model (thanks to 2 parameters))



One “easy” and ideal case

LO NRQCD study by P. Artoisenet

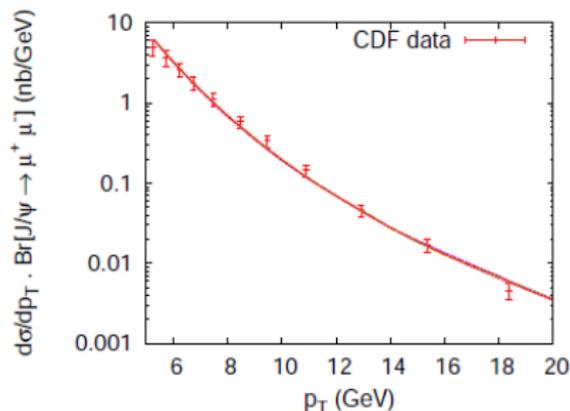
- Easy:
 - The cross-section computation very fast for various scales
 - The cross section depends linearly on the LDMEs
- Ideal:
 - Fit of the LDME is good (virtue of the model (thanks to 2 parameters))
 - Uncertainties on μ and m_c do not affect the P_T slope (at LO !)



One “easy” and ideal case

LO NRQCD study by P. Artoisenet

- Easy:
 - The cross-section computation very fast for various scales
 - The cross section depends linearly on the LDMEs
- Ideal:
 - Fit of the LDME is good (virtue of the model (thanks to 2 parameters))
 - Uncertainties on μ and m_c do not affect the P_T slope (at LO !)



One “easy” and ideal case

LO NRQCD study by P. Artoisenet

- “Experimental” uncertainties
 - Data uncertainties \rightarrow LDME “exp” uncertainties
 - Linearly affect the prediction at any \sqrt{s}

	upper edge	lower edge
$\langle \mathcal{O}_8(^3S_1) \rangle (10^{-3} \times \text{GeV}^3)$	3.34	2.29
$\langle \mathcal{O}_8(^1S_0) \rangle (10^{-2} \times \text{GeV}^3)$	7.73	5.09

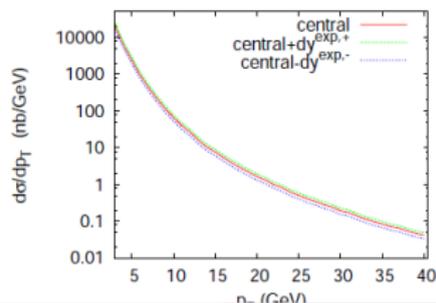
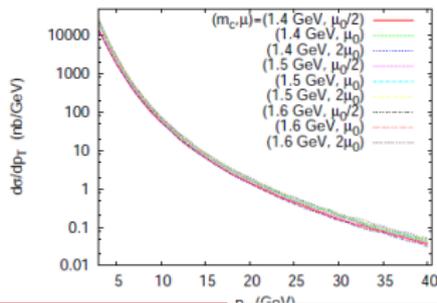
Table 2: Values of the color-octet LDME's extracted from the fit to the upper and lower edge of the errorbars reported by the CDF collaboration. The mass of the charm quark

and the poles are set to their central values: $m_c = 1.5 \text{ GeV}$, $\mu = \mu_0$

One “easy” and ideal case

LO NRQCD study by P. Artoisenet

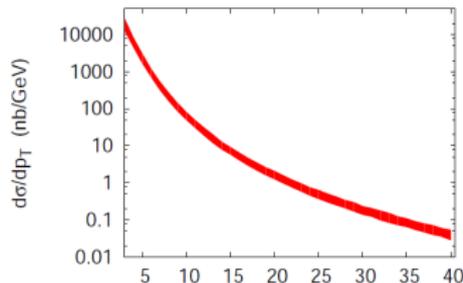
- “Experimental” uncertainties
 - Data uncertainties \rightarrow LDME “exp” uncertainties
 - Linearly affect the prediction at any \sqrt{s}
- “Theoretical” uncertainties
 - Theory uncertainties \rightarrow LDME “th” uncertainties + σ_{QQ} variation
 - Fix μ 's and re-run at any \sqrt{s} with the corresponding LDMEs
- Combine this in quadrature



One “easy” and ideal case

LO NRQCD study by P. Artoisenet

- “Experimental” uncertainties
 - Data uncertainties \rightarrow LDME “exp” uncertainties
 - Linearly affect the prediction at any \sqrt{s}
- “Theoretical” uncertainties
 - Theory uncertainties \rightarrow LDME “th” uncertainties + σ_{QQ} variation
 - Fix μ 's and re-run at any \sqrt{s} with the corresponding LDMEs
- Combine this in quadrature



Within this approach:
global theoretical
uncertainties: factor of 2

Caveats

Independent scale variations

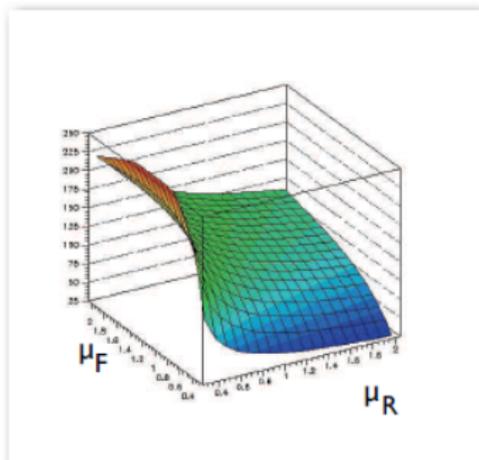
Sometimes, varying scales together can be **very** misleading!

Case in point: bottom cross section at the LHC:

$$\sigma(|y| < 1): 122 > 120 > 115 \mu\text{b}$$

$0.5 < \mu_{R,F}/\mu_0 < 2$

Only a $\pm 4\%$ uncertainty when varying the scales together.....



$$\sigma(|y| < 1): 178 > 120 > 75 \mu\text{b}$$

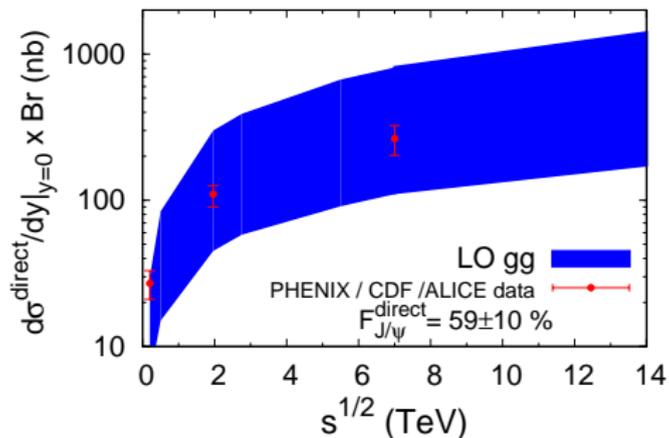
$0.5 < \mu_{R,F}/\mu_0 < 2 \ \&\& \ 0.5 < \mu_R/\mu_F < 2$

...which becomes a $\pm 40\%$ one when going off-diagonal!

Slide by M. Cacciari, CTEQ MCnet School, 2008

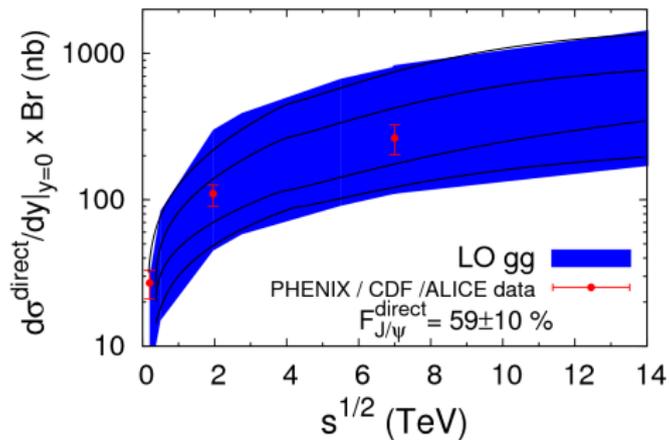
Playing blindly with the parameters of a model to fit the data

- Illustration the CSM LO (admittedly not the best to start with, but ok ...)



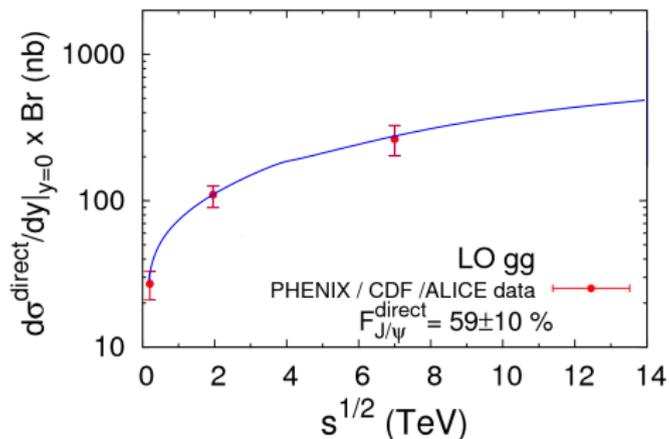
Playing blindly with the parameters of a model to fit the data

- Optimistic scenario



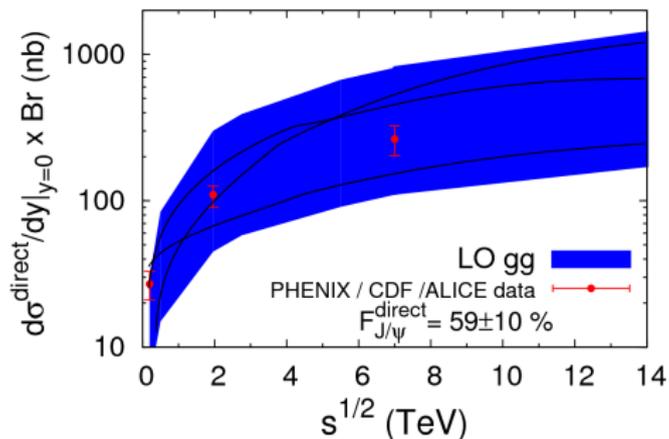
Playing blindly with the parameters of a model to fit the data

- Optimistic scenario



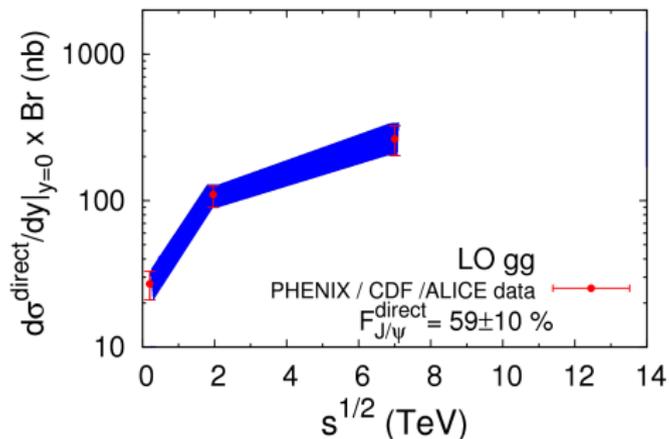
Playing blindly with the parameters of a model to fit the data

- Likely scenario:



Playing blindly with the parameters of a model to fit the data

- Likely scenario: do we need a model for that ?

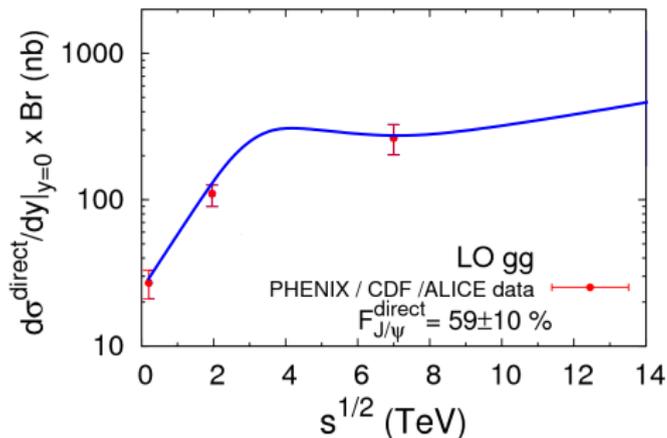


Playing blindly with the parameters of a model to fit the data

- Pessimistic scenario: no curve goes through the experimental points
New ingredient needed ... with unexpected effects ?

Playing blindly with the parameters of a model to fit the data

- Pessimistic scenario: no curve goes through the experimental points
New ingredient needed ... with unexpected effects ?



Playing blindly with the parameters of a model to fit the data

For (μ_F, μ_R) , all this implies that the behaviour of one curve for one set of (μ_F, μ_R, m) is not much modified by higher-order computations

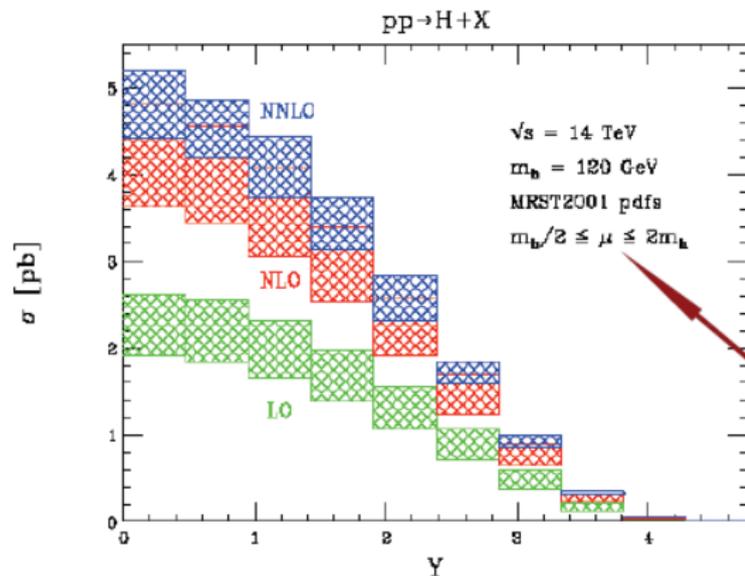
Playing blindly with the parameters of a model to fit the data

For (μ_F, μ_R) , all this implies that
the behaviour of one curve for one set of (μ_F, μ_R, m) is not much modified
by higher-order computations

Nothing tells us that this is true !

Warnings

Theoretical uncertainty: an example



NB. This example shows that the center of the NLO band has nothing to do with the most accurate theoretical prediction.

Theoretical uncertainty bands are not gaussian errors!

Slide by M. Cacciari, CTEQ MCnet School, 2008