Measurement of Muons from Heavy Flavor Decays in *pp* Collisions at 14 TeV with the ALICE-Muon Spectrometer at the LHC

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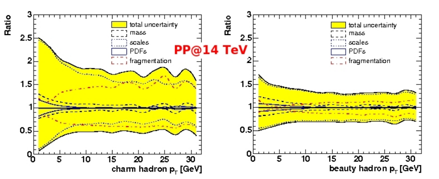
Motivations

Testing NLO pQCD with Heavy Flavors



Large theoritical uncertainties come from,

1. quark mass (m_Q),
2. parton density parametrisation (PDF),
3. fragmentation parameter,
4. perturbative uncertainty from scale variations.

σ_{pp}^{HF} is the Baseline for $\sigma_{AA/pA}^{HF}$

1. $\sigma_{pp}^{HF}/\sigma_{pA}^{HF}$, (anti-)shadowing (gluon PDF in nucleus)
2. $\sigma_{pp}^{HF}/\sigma_{AA}^{HF}$, energy loss (medium dissipative properties)

Resonance Yields

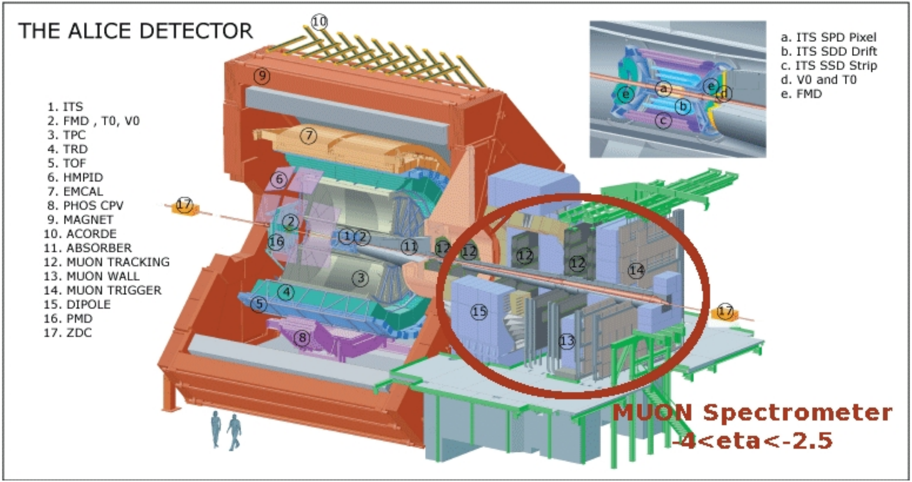
1. normalisation for $\sigma^{J/\Psi}$ & σ^{Υ} in pA and AA
2. understanding $N(B \to J/\Psi)/N(\mathrm{direct}\ J/\Psi)$ via σ^B

Understanding Energy Loss Effects

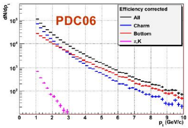
$$R_{AA}(p_t, \eta) = \frac{1}{< N_{coll} >} \times \frac{d^2 N_{AA}/dp_t d\eta}{d^2 N_{pp}/dp_t d\eta}$$

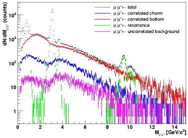
1. $\frac{R_{AA}^{D}(p_t)}{R_{AA}^{h}(p_t)} \simeq \frac{4}{9}$, color charge effect
2. $\frac{R_{AA}^{B}(p_t)}{R_{AA}^{D}(p_t)}$, mass effect at high p_t region

ALICE Detector Overview



Method





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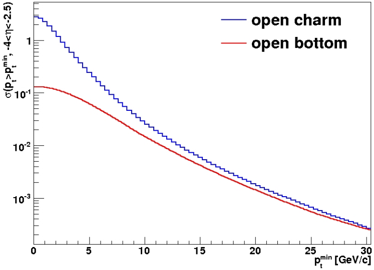
pp @ 14 TeV



1. Extract $N_{\mu^{\pm}/\mu^{-}\mu^{+}\leftarrow B/D}$ from "data".
2. Correct for integrated luminosity, detection efficiency and acceptance.
3. Correct for decay kine. (F_{MC} calculation).
4. Get differential integrated B & D hadron cross sections.

$$\sigma^{B/D}(p_t>p_t^{min},-4<\eta<-2.5) = \frac{N_{\mu^{\pm}/\mu^{-}\mu^{+}\leftarrow B/D}(\Phi^{\mu^{\pm}/\mu^{-}\mu^{+}})}{\int Ldt}\times\frac{1}{\epsilon}\times\left[\frac{\sigma^{B/D}(p_t>p_t^{min})}{\sigma^{B/D}(\Phi^{\mu^{\pm}/\mu^{-}\mu^{+}})}\right]_{MC}$$

$$= \frac{N_{\mu^{\pm}/\mu^{-}\mu^{+}\leftarrow B/D}(\Phi^{\mu^{\pm}/\mu^{-}\mu^{+}})}{\int Ldt}\times\frac{1}{\epsilon}$$

$$\times\quad F^{MC}_{\mu^{\pm}/\mu^{-}\mu^{+}\leftarrow B/D}(\Phi^{\mu^{\pm}/\mu^{-}\mu^{+}},p_t^{min})$$

*$\Phi^{\mu^{\pm}/\mu^{-}\mu^{+}}$ denotes a special kinematic phase space of $\mu^{\pm}/\mu^{-}\mu^{+}$.

Input Data

Data Properties

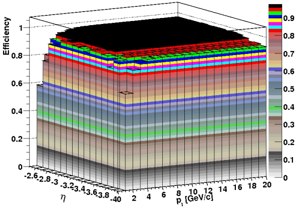
PDC06 (Physics Data Challenge 06) data are used.

single muons ($\mu^{\pm}$)

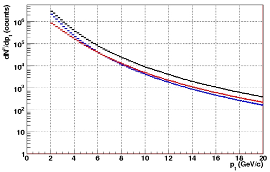
1. single muon trigger (at least one moun in $-4 < \eta < -2.5$ with $p_t > 0.5$ GeV)
2. 7.8×10^8 single muon events
3. 2 GeV$<p_t<$10 GeV
4. extrapolate to 2 GeV$<p_t<$20 GeV

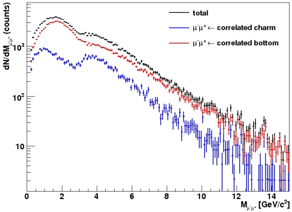
correlated un-like sign dimuons ($\mu^-\mu^+$)

1. dimuon trigger (at least two muons in $-4 < \eta < -2.5$ with $p_t > 0.5$ for each muon)
2. 2.5×10^6 correlated dimuon events
3. 1.5 GeV$<p_t<$18 GeV



1. Assuming the contribution of $\mu^{\pm}/\mu^-\mu^+ \leftarrow$resonances and un-correlated background are subtracted perfectly.
2. p_t dis. of $\mu^{\pm}$ and $M_{\mu^-\mu^+}$ dis. of correlated $\mu^-\mu^+$ are corrected by detection efficiency (p_t and η dependent).
3. $N_{\mu^{\pm}/\mu^-\mu^+\leftarrow D}$ are corrected with factor 11.2/5.67 to satisfy HvQMNR calculations.





$\mu^{\pm}/\mu^-\mu^+ \leftarrow (J/\Psi, \rho \ldots) \leftarrow Q$ are not considered.
Statistics corresponding to data taking scenario, $L = 10^{30}\text{cm}^{-2}\text{s}^{-1}$, $t = 10^6$s.
Fitting the total dis. of p_t (single muon) and $M_{\mu^-\mu^+}$ (correlated $\mu^-\mu^+$) to get the $N_{\mu^{\pm}/\mu^-\mu^+\leftarrow D/B}(\Phi^{\mu^{\pm}/\mu^-\mu^+})$.

Extraction of the $N^{\mu^{\pm}/\mu^{-}\mu^{+}\leftarrow B/D}(\Phi^{\mu^{\pm}/\mu^{-}\mu^{+}})$

I. Fitting Formula

$$(T - B)\cdot(f_c + R \times f_b)$$

- T, total number of $\mu^{\pm}/\mu^{-}\mu^{+}$ ←HF.
- $B = N_{\mu^{\pm}/\mu^{-}\mu^{+}\leftarrow B}$, $R = \frac{N_{\mu^{\pm}/\mu^{-}\mu^{+}\leftarrow B}}{N_{\mu^{\pm}/\mu^{-}\mu^{+}\leftarrow D}}$.
- f_c and f_b are the normaliszed shape functions.

II. Shape Functions for $\mu^{\pm}$ p_t dist.

$$f_{c/b} = c \times \frac{1}{(1 + (p_t/a)^2)^b}$$

- both the $\mu^{\pm}$ p_t dis. from charm and bottom use the some shape function
- a, b and c are free parameters

III. Shape Functions for $M_{\mu^{-}\mu^{+}}$ dist.

$$f_c = p0\cdot\exp[-\frac{1}{2}(\frac{x-p1}{p2})^2] + p3\cdot\exp[-\frac{1}{2}(\frac{x-p4}{p5})^2] + p6\cdot\frac{1+p7\cdot(x-p8)}{[p9^2+(x-p8)^2]^{p10}}$$

$$f_b = p0\cdot\exp[-\frac{1}{2}(\frac{x-p1}{p2})^2] + p3\{\frac{1+p4\cdot(x-p5)}{[p6^2+(x-p5)^2]^{p7}} + p8\cdot\exp[-\frac{1}{2}(\frac{x-p9}{p10})^2]\}$$

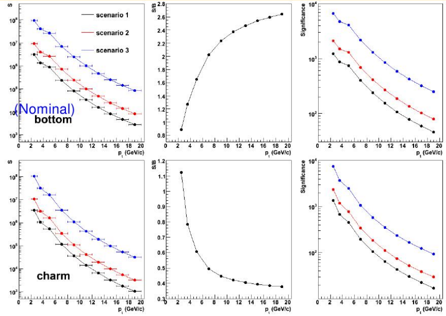
IV. Extraction of the (di)muon Yield from B & D Hadron Decay

$$N_{\mu^{\pm}/\mu^{-}\mu^{+}\leftarrow B}(\Phi) = B\cdot\int_{\Phi^{\mu^{\pm}/\mu^{-}\mu^{+}}} dx\cdot f_b(x), \quad N_{\mu^{\pm}/\mu^{-}\mu^{+}\leftarrow D}(\Phi) = B/R\cdot\int_{\Phi^{\mu^{\pm}/\mu^{-}\mu^{+}}} dx\cdot f_c(x)$$

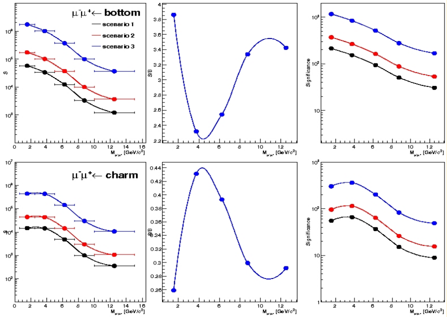
$\Phi = \Phi^{\mu^{\pm}/\mu^{-}\mu^{+}}$ is the special kinematic phase space $\mu^{\pm}/\mu^{-}\mu^{+}$.

Extraction of the $N^{\mu^{\pm}/\mu^{-}\mu^{+}\leftarrow B/D}(\Phi^{\mu^{\pm}/\mu^{-}\mu^{+}})$

Data Extrapolation for single muons



Data Extrapolation for $\mu^{-}\mu^{+}$



Three kinds of Data Taking Scenarios

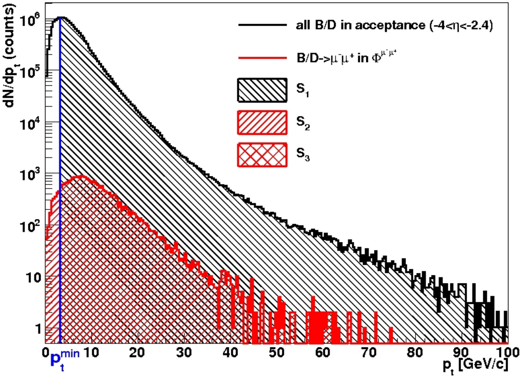
- scenario one, $L = 10^{30}\text{cm}^{-2}\text{s}^{-1}$, $t = 10^{6}\text{s}$, $N_{pp} = 7 \times 10^{10}$
- scenario two, $L = 3 \times 10^{30}\text{cm}^{-2}\text{s}^{-1}$, $t = 10^{6}\text{s}$, $N_{pp} = 2.1 \times 10^{11}$
- scenario three, $L = 3 \times 10^{30}\text{cm}^{-2}\text{s}^{-1}$, $t = 10^{7}\text{s}$, $N_{pp} = 2.1 \times 10^{12}$

Large yield and significance expected even with scenario one.

Calculation of $F_{MC}^{\mu^{\pm}/\mu^{-}\mu^{+}\leftarrow B/D}(p_t^{min},\ \Phi^{\mu^{\pm}/\mu^{-}\mu^{+}})$

$$F_{MC}^{B/D} = F_{\mu^{\pm}/\mu^{-}\mu^{+}\leftarrow B/D}(\Phi^{\mu^{\pm}/\mu^{-}\mu^{+}}, p_t^{min}) = \frac{\sigma^{B/D}(p_t > p_t^{min})}{\sigma^{B/D}(\Phi^{\mu^{\pm}/\mu^{-}\mu^{+}})} = \frac{N^{B/D}(p_t > p_t^{min})}{N^{B/D}(\Phi^{\mu^{\pm}/\mu^{-}\mu^{+}})}$$

$$N^{B/D}(\Phi^{\mu^{-}\mu^{+}}) = N^{H\bar{H}\rightarrow\mu^{-}\mu^{+}}(\Phi^{\mu^{-}\mu^{+}}) + N^{H\rightarrow\mu^{-}\mu^{+}}(\Phi^{\mu^{-}\mu^{+}})$$



1. $N^{B/D}(p_t > p_t^{min}) = S_1$
2. $N^{B/D}(\Phi^{\mu^{-}\mu^{+}}) = S_2$
3. p_t^{min} is determined by setting $S_3/S_2 \approx 90\%$, which is used to minimize the model dependence of the spectrum shape.

Systematic Error Estimation

Method for Single muons

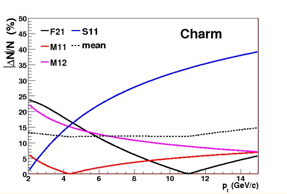
1. Choosing different perturbative scales and quark masses to generate new kinematics distributions for B & D hadrons. $\star$[hep-ph/0601164]
2. Using different fragmentation functions within the hadronization process. [$\star$]
3. Re-fit the new $\mu^{\pm}$ p_t spectrum, which from heavy hadron decay, with the same fitting formula.
4. R fixed within 60%, only combination with $\chi^2/NDF < 100$.

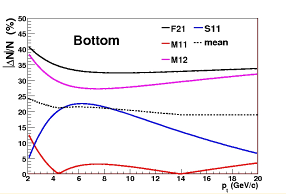
Method for correlated $\mu^-\mu^+$

1. Shape functions ($f_{c/b}$) are changed by adjusting their fitting parameters handly.
2. Re-fit the total $M_{\mu^-\mu^+}$ with the new fitting functions.
3. The shapes which lead R changing beyond 60% are discarded.

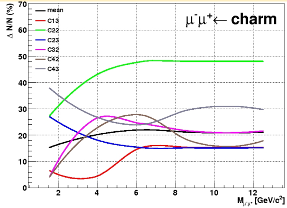
Systematic Error Estimation

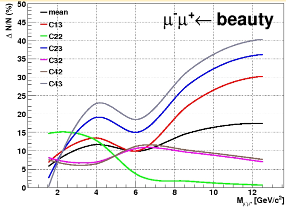
Mean value of sys. error for single muons





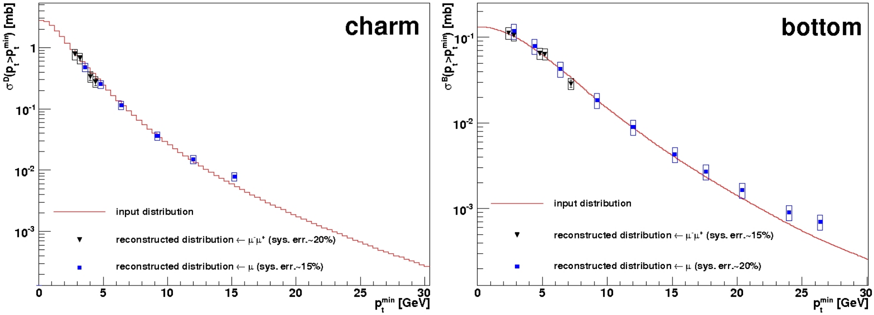
Mean value of sys. error for correlated $\mu^-\mu^+$





1. $$\frac{\Delta N}{N} = \frac{|N_{syst.} - N_{perf.}|}{N_{perf.}}$$
2. Syst. errors are almost independent with p_t of $\mu^\pm$ and $M_{\mu^-\mu^+}$ of correlated $\mu^-\mu^+$.
3. single muon case, syst. error ~ 15% for charm ~ 20% for beauty
4. correlated $\mu^-\mu^+$ case, syst. error ~ 20% for charm ~ 15% for beauty
5. Our measurement should allow to constrain models.

Results



1. Input distributions are well reconstructed by our method.
2. Nice agreement between single muon and dimuon channels.
3. Statistics errors are negligible even in the so-called scenario one.
4. Systematics errors are 20% for B and 15% for D in the single muon channel and, 15% for B and 20% for D in the dimuon channel.
5. 82% (17%) of σ^B (σ^D) are reconstructed via single muons and, 84% (33%) of σ^B (σ^D) are reconstructed via dimuons.
6. Our measurements allow to cover the p_t range from 2 GeV to 25 GeV (3 GeV to 15 GeV) for bottom (charm) component.

Conclusion & Outlooks

Conclusion

1. The measurement of the B & D hadron cross sections in pp collisions at the LHC is an important benchmark for,
   - NLO pQCD calculation,
   - pA and AA collisions.
2. The B (D) hadron cross section can be extracted for 2 (3) GeV$< p_t^{min} <$ 25 (15) GeV.
3. Statistical errors are negligible and systematics errors are about 15% and 20%, depending on the physics channel.
4. Our results are strongly model dependent.

Outlooks

1. Realistic background (π & K) subtraction, an other source of error on the muon yield in particular at low p_t, work progress.
2. Measurement of the B & D hadron cross section in pp collisions at 10 TeV.

Thanks!