

# Study of Cold Nuclear Matter effect with prompt $D_s$ meson production in pPb collisions at LHCb

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## CONTENTS

1	Introduction	2
2	LHCb advantage in heavy ion physics	2
2.1	Paragraphs . . . . .	2
2.2	Math . . . . .	3
3	Results and Discussion	3
3.1	Subsection . . . . .	4
3.2	Figure Composed of Subfigures . . . . .	5

## LIST OF FIGURES

Figure 1	An example of a floating figure . . . . .	4
Figure 2	A number of pictures. . . . .	6

## LIST OF TABLES

Table 1	Table of Grades . . . . .	5
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## ABSTRACT

The productions of prompt  $D_s$  mesons in proton-lead collisions in the forward and backward configurations are studied. The data are collected with the LHCb detector with  $\sqrt{s_{NN}} = 5\text{TeV}$ (proton beam energy is 4000 GeV,lead beam energy is 1500 GeV). The forward (backward) rapidity range  $1.5 < y^* < 3.5$ ( $-4.5 < y^* < -2.5$ ), the  $p_T$  range  $0 < p_T < 10\text{GeV}/c$ . The paper will introduce my work this semester.

## 1 INTRODUCTION

Ultra-relativistic heavy-ion collisions are used to study the nuclear matter at high temperature and pressure where the formation of the Quark Gluon Plasma (QGP), a state of matter which consists of asymptotically free quarks and gluons, occurs. Open heavy flavours and quarkonia are produced at the early stages of the collision and might interact with the deconfined medium, making them ideal probes of the QGP. It was indeed predicted that in hot nuclear matter, charmonia are suppressed due to color screening of the heavy quarks potential. Quarkonia can also be suppressed in absence of the QGP formation by Cold Nuclear Matter (CNM) effects. Proton-Nucleus collisions (pA or Ap), which are interesting by themselves, are therefore essential to interpret Nucleus-Nucleus data in order to disentangle QGP effects from CNM effects in those collisions. The main CNM effects affecting quarkonium production include initial-state nuclear effects on the parton densities, the initial-state parton energy loss and final-state energy loss, the final-state absorption of the pre-resonant heavy quark pair by the spectator nucleons albeit small at LHC and the final-state interaction of the quarkonium with the produced medium.

## 2 LHCb ADVANTAGE IN HEAVY ION PHYSICS

- LHCb is specialised in heavy flavour precision physics, beauty and charm:
  - Optimised for low pile-up collisions (ie low multiplicity):
    - \* Precise reconstruction of production and decay vertices: time dependent CP violation
    - \* Correlations between particles: flavour tagging
- Some characteristics of the experiment make it attractive for measurements in Heavy ion physics too:
  - Instruments fully the forward region:  $2 < \eta < 5$
  - Precise vertexing: separation of prompt production from B decay products
  - Precise tracking: reconstruction down to  $p_T = 0$
  - Particle identification: full reconstruction of hadronic decays of charm or beauty, such as  $D_0 \rightarrow K\pi$

### 2.1 Paragraphs

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**PARAGRAPH DESCRIPTION** Sed commodo posuere pede. Mauris ut est. Ut quis purus. Sed ac odio. Sed vehicula hendrerit sem. Duis non odio. Morbi ut dui. Sed accumsan risus eget odio. In hac habitasse platea dictumst. Pellentesque non elit. Fusce sed justo eu urna porta tincidunt. Mauris felis odio, sollicitudin sed, volutpat a, ornare ac, erat. Morbi quis dolor. Donec pellentesque, erat ac sagittis semper, nunc dui lobortis purus, quis congue purus metus ultricies tellus. Proin et

quam. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Praesent sapien turpis, fermentum vel, eleifend faucibus, vehicula eu, lacus.

**DIFFERENT PARAGRAPH DESCRIPTION** Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Donec odio elit, dictum in, hendrerit sit amet, egestas sed, leo. Praesent feugiat sapien aliquet odio. Integer vitae justo. Aliquam vestibulum fringilla lorem. Sed neque lectus, consectetur at, consectetur sed, eleifend ac, lectus. Nulla facilisi. Pellentesque eget lectus. Proin eu metus. Sed porttitor. In hac habitasse platea dictumst. Suspendisse eu lectus. Ut mi mi, lacinia sit amet, placerat et, mollis vitae, dui. Sed ante tellus, tristique ut, iaculis eu, malesuada ac, dui. Mauris nibh leo, facilisis non, adipiscing quis, ultrices a, dui.

## 2.2 Math

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$$\cos^3 \theta = \frac{1}{4} \cos \theta + \frac{3}{4} \cos 3\theta \quad (1)$$

Fusce mauris. Vestibulum luctus nibh at lectus. Sed bibendum, nulla a faucibus semper, leo velit ultricies tellus, ac venenatis arcu wisi vel nisl. Vestibulum diam. Aliquam pellentesque, augue quis sagittis posuere, turpis lacus congue quam, in hendrerit risus eros eget felis. Maecenas eget erat in sapien mattis porttitor. Vestibulum porttitor. Nulla facilisi. Sed a turpis eu lacus commodo facilisis. Morbi fringilla, wisi in dignissim interdum, justo lectus sagittis dui, et vehicula libero dui cursus dui. Mauris tempor ligula sed lacus. Duis cursus enim ut augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo. Quisque egestas wisi eget nunc. Nam feugiat lacus vel est. Curabitur consectetur.

**Definition 1** (Gauss). To a mathematician it is obvious that  $\int_{-\infty}^{+\infty} e^{-x^2} dx = \sqrt{\pi}$ .

**Theorem 1** (Pythagoras). *The square of the hypotenuse (the side opposite the right angle) is equal to the sum of the squares of the other two sides.*

*Proof.* We have that  $\log(1)^2 = 2 \log(1)$ . But we also have that  $\log(-1)^2 = \log(1) = 0$ . Then  $2 \log(-1) = 0$ , from which the proof.  $\square$

## 3 RESULTS AND DISCUSSION

Reference to Figure 1 on the following page.

Suspendisse vitae elit. Aliquam arcu neque, ornare in, ullamcorper quis, commodo eu, libero. Fusce sagittis erat at erat tristique mollis. Maecenas sapien libero, molestie et, lobortis in, sodales eget, dui. Morbi ultrices rutrum lorem. Nam elementum ullamcorper leo. Morbi dui. Aliquam sagittis. Nunc placerat. Pellentesque tristique sodales est. Maecenas imperdiet lacinia velit. Cras non urna. Morbi eros pede, suscipit ac, varius vel, egestas non, eros. Praesent malesuada, diam id pretium elementum, eros sem dictum tortor, vel consectetur odio sem sed wisi.

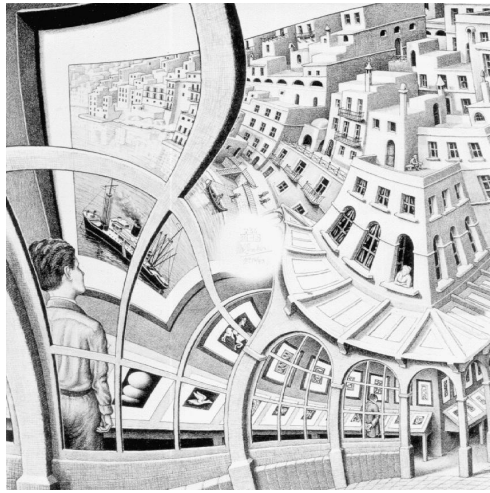


Figure 1: An example of a floating figure (a reproduction from the *Gallery of prints*, M. Escher, from <http://www.mcescher.com/>).

### 3.1 Subsection

Sed feugiat. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Ut pellentesque augue sed urna. Vestibulum diam eros, fringilla et, consectetur eu, nonummy id, sapien. Nullam at lectus. In sagittis ultrices mauris. Curabitur malesuada erat sit amet massa. Fusce blandit. Aliquam erat volutpat. Aliquam euismod. Aenean vel lectus. Nunc imperdiet justo nec dolor.

#### 3.1.1 Subsubsection

Etiam euismod. Fusce facilisis lacinia dui. Suspendisse potenti. In mi erat, cursus id, nonummy sed, ullamcorper eget, sapien. Praesent pretium, magna in eleifend egestas, pede pede pretium lorem, quis consectetur tortor sapien facilisis magna. Mauris quis magna varius nulla scelerisque imperdiet. Aliquam non quam. Aliquam porttitor quam a lacus. Praesent vel arcu ut tortor cursus volutpat. In vitae pede quis diam bibendum placerat. Fusce elementum convallis neque. Sed dolor orci, scelerisque ac, dapibus nec, ultricies ut, mi. Duis nec dui quis leo sagittis commodo.

**WORD** Definition

**CONCEPT** Explanation

**IDEA** Text

Etiam euismod. Fusce facilisis lacinia dui. Suspendisse potenti. In mi erat, cursus id, nonummy sed, ullamcorper eget, sapien. Praesent pretium, magna in eleifend egestas, pede pede pretium lorem, quis consectetur tortor sapien facilisis magna. Mauris quis magna varius nulla scelerisque imperdiet. Aliquam non quam. Aliquam porttitor quam a lacus. Praesent vel arcu ut tortor cursus volutpat. In vitae pede quis diam bibendum placerat. Fusce elementum convallis neque. Sed dolor orci, scelerisque ac, dapibus nec, ultricies ut, mi. Duis nec dui quis leo sagittis commodo.

- First item in a list
- Second item in a list
- Third item in a list

3.1.2 Table

Aliquam lectus. Vivamus leo. Quisque ornare tellus ullamcorper nulla. Mauris porttitor pharetra tortor. Sed fringilla justo sed mauris. Mauris tellus. Sed non leo. Nullam elementum, magna in cursus sodales, augue est scelerisque sapien, venenatis congue nulla arcu et pede. Ut suscipit enim vel sapien. Donec congue. Maecenas urna mi, suscipit in, placerat ut, vestibulum ut, massa. Fusce ultrices nulla et nisl.

Table 1: Table of Grades

Name		
First name	Last Name	Grade
John	Doe	7.5
Richard	Miles	2

Reference to Table 1.

3.2 Figure Composed of Subfigures

Reference the figure composed of multiple subfigures as [Figure 2 on the following page](#). Reference one of the subfigures as [Figure 2b on the next page](#).

Nulla in ipsum. Praesent eros nulla, congue vitae, euismod ut, commodo a, wisi. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Aenean nonummy magna non leo. Sed felis erat, ullamcorper in, dictum non, ultricies ut, lectus. Proin vel arcu a odio lobortis euismod. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Proin ut est. Aliquam odio. Pellentesque massa turpis, cursus eu, euismod nec, tempor congue, nulla. Duis viverra gravida mauris. Cras tincidunt. Curabitur eros ligula, varius ut, pulvinar in, cursus faucibus, augue.

Nulla mattis luctus nulla. Duis commodo velit at leo. Aliquam vulputate magna et leo. Nam vestibulum ullamcorper leo. Vestibulum condimentum rutrum mauris. Donec id mauris. Morbi molestie justo et pede. Vivamus eget turpis sed nisl cursus tempor. Curabitur mollis sapien condimentum nunc. In wisi nisl, malesuada at, dignissim sit amet, lobortis in, odio. Aenean consequat arcu a ante. Pellentesque porta elit sit amet orci. Etiam at turpis nec elit ultricies imperdiet. Nulla facilisi. In hac habitasse platea dictumst. Suspendisse viverra aliquam risus. Nullam pede justo, molestie nonummy, scelerisque eu, facilisis vel, arcu.

Curabitur tellus magna, porttitor a, commodo a, commodo in, tortor. Donec interdum. Praesent scelerisque. Maecenas posuere sodales odio. Vivamus metus lacus, varius quis, imperdiet quis, rhoncus a, turpis. Etiam ligula arcu, elementum a, venenatis quis, sollicitudin sed, metus. Donec nunc pede, tincidunt in, venenatis vitae, faucibus vel, nibh. Pellentesque wisi. Nullam malesuada. Morbi ut tellus ut pede tincidunt porta. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam congue neque id dolor.

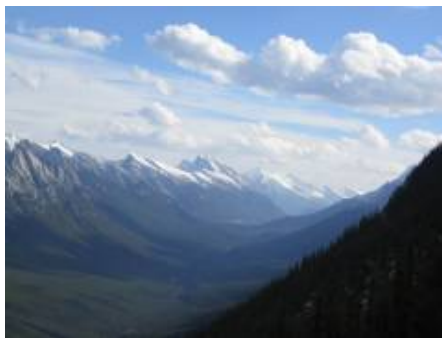
Donec et nisl at wisi luctus bibendum. Nam interdum tellus ac libero. Sed sem justo, laoreet vitae, fringilla at, adipiscing ut, nibh. Maecenas non sem quis tortor eleifend fermentum. Etiam id tortor ac mauris porta vulputate. Integer porta neque vitae massa. Maecenas tempus libero a libero posuere dictum. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Aenean quis mauris sed elit commodo placerat. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Vivamus rhoncus tincidunt libero. Etiam elementum pretium justo. Vivamus est. Morbi a tellus eget pede tristique commodo. Nulla nisl. Vestibulum sed nisl eu sapien cursus rutrum.



(a) A city market.



(b) Forest landscape.



(c) Mountain landscape.



(d) A tile decoration.

Figure 2: A number of pictures with no common theme.