RHIC II / LHC Comparisons

Tony Frawley
Florida State University

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Goals and scope

My first attempt to quantify and compare the size of the heavy flavor signals at RHIC II and at LHC.

Of course, because the energies are quite different, we hope to see different **physics effects** at RHIC II and LHC. But we should be able to estimate the size of the heavy flavor signals at the two colliders, to see which physics probes should be accessible.

There are many caveats on the numbers I will show - the detectors are complex, and in some cases do not exist yet. I have tried to include as much realism as possible in all estimates, often by assuming that PHENIX reality factors (which I am most familiar with) apply to all detectors.

I have not yet had time to understand capabilities for hadronic decay channels - eg. $D \rightarrow K\pi$, $\chi_c \rightarrow J/\psi$ + hadrons, or Drell-Yan, and **so will discuss only quarkonia**.

RHIC II Assumptions and sources

RHIC II performance estimates by BNL CAD department:
http://rhicii-heavy.bnl.gov/doc/RHIC_II_Luminosity_Roser.xls

PHENIX acceptances and efficiencies from various PHENIX internal notes.

STAR acceptances and efficiencies from private communication by Thomas Ullrich.

“ New Detector” acceptances and efficiencies from **“Expression of interest for a comprehensive new detector at RHIC”, P. Steinberg et al. , August 2004.**

LHC Assumptions and sources

LHC performance estimates from: **"Luminosity Determination in ALICE", Andreas Morsch, September 2002.**

ALICE acceptance and efficiency from: **hep-ph/0311048**

CMS acceptance and efficiency from:
Hard Probes in Heavy Ion Collisions at the LHC: Heavy Flavor Physics hep-ph/0311048 (chapter 9).

Cross sections

Main source is $d\sigma/dy$ vs energy predictions from CEM for J/ψ, ψ' and Υ: “Quarkonium production in heavy ion collisions”, R. Gavai et al., **hep-ph/9502270**

Detectors

PHENIX:

See talk by Vince Cianciolo on PHENIX RHIC II capabailities.

STAR:

See talk by Jamie Dunlop on STAR RHIC II capabilities.

RHIC New Detector:

See talk by Manuel Calderon on New Detector proposal for RHIC II

ALICE and CMS baseline detectors.

See: “Hard Probes in Heavy Ion Collisions at the LHC: Heavy Flavor Physics:” hep-ph/0311048

Coverages

Detector	Signal	η	p_T
PHENIX	e	-0.35 to 0.35	> 0.2 GeV/c
PHENIX	μ	1.2 to 2.2, -1.2 to -2.4	
STAR (barrel EMC)	e	-1.0 to 1.0	> 0.2 GeV/c ?
RHIC ND	e	-3.0 to 3.0	> 1.5 GeV/c
RHIC ND	μ	-3.0 to 3.0	> 1.5 GeV/c
ALICE	e	-0.9 to 0.9	> 5.2 GeV/c (ee)
ALICE	μ	2.5 to 4.0	
CMS barrel	μ	-0.8 to 0.8	> 3.5 GeV/c
CMS endcap	μ	-2.4 to 2.4	

PHENIX / STAR / New RHIC Detector

Quarkonia

12 week **p+p run at 200 GeV** at RHIC II - **238 pb^{-1}** sampled
Numbers are expected yields after background subtraction

Signal	PHENIX	$\|\eta\|$	STAR	$\|\eta\|$	ND	$\|\eta\|$
$J/\psi \rightarrow ee$	55,000	< 0.35	1,598,00	< 1	5,094,500	< 3
$J/\psi \rightarrow \mu\mu$	470,000	1.2-2.4			5,094,500	< 3
$\psi' \rightarrow ee$	990	< 0.35	28,812	< 1	92,000	< 3
$\psi' \rightarrow \mu\mu$	8,450	1.2-2.4			92,000	< 3
$\chi_c \rightarrow ee\gamma$	3,630	< 0.35	?			
$\chi_c \rightarrow \mu\mu\gamma$	139,000	1.2-2.4				
$\Upsilon \rightarrow ee$	210	< 0.35	8,300	< 1	17,600	< 3
$\Upsilon \rightarrow \mu\mu$	530	1.2-2.4			17,600	< 3

PHENIX / STAR / New RHIC Detector

Quarkonia

12 week **d+Au run at 200 GeV** at RHIC II - **446 nb^{-1}** sampled
Numbers are expected yields after background subtraction

Signal	PHENIX	$\|\eta\|$	STAR	$\|\eta\|$	ND	$\|\eta\|$
$J/\psi \to ee$	30,000	< 0.35	880,000	< 1	1,560,000	< 3
$J/\psi \to \mu\mu$	248,000	1.2-2.4			1,560,000	< 3
$\psi' \to ee$	540	< 0.35	15,900	< 1	28,100	< 3
$\psi' \to \mu\mu$	4,650	1.2-2.4			28,100	< 3
$\chi_c \to ee\gamma$	1,970	< 0.35	?		241,000	< 3
$\chi_c \to \mu\mu\gamma$	76,300	1.2-2.4			241,000	< 3
$\Upsilon \to ee$	185	< 0.35	8,200	< 1	8,700	< 3
$\Upsilon \to \mu\mu$	470	1.2-2.4			8,700	< 3

PHENIX / STAR / New RHIC Detector

Quarkonia

12 week **Au+Au run at 200 GeV** at RHIC II - **18 nb^{-1}** sampled
Numbers are expected yields after background subtraction
STAR charmonium from minbias only (50 Hz)

Signal	PHENIX	$\lvert\eta\rvert$	STAR	$\lvert\eta\rvert$	ND	$\lvert\eta\rvert$
$J/\psi \rightarrow ee$	44,600	< 0.35	4,000	< 1	4,290,000	< 3
$J/\psi \rightarrow \mu\mu$	395,000	1.2-2.4			4,290,000	< 3
$\psi' \rightarrow ee$	800	< 0.35	80	< 1	77,300	< 3
$\psi' \rightarrow \mu\mu$	7,100	1.2-2.4			77,300	< 3
$\chi_c \rightarrow ee\gamma$	2,930	< 0.35	?			
$\chi_c \rightarrow \mu\mu\gamma$	116,800	1.2-2.4				
$\Upsilon \rightarrow ee$	400	< 0.35	16,400	< 1	34,600	< 3
$\Upsilon \rightarrow \mu\mu$	1,040	1.2-2.4			34,600	< 3

Aside: 500 GeV p+p at RHIC II

12 week **p+p run at 500 GeV** at RHIC II - **1195 pb^{-1}** sampled
Numbers are expected yields after background subtraction
Dramatic increases due to higher cross sections **and** luminosity!

Signal	**PHENIX**	$|\eta|$
$J/\psi \rightarrow ee$	609,000	< 0.35
$J/\psi \rightarrow \mu\mu$	5,483,000	1.2-2.4
$\psi' \rightarrow ee$	11,000	< 0.35
$\psi' \rightarrow \mu\mu$	99,000	1.2-2.4
$\chi_c \rightarrow ee\gamma$	103,000	< 0.35
$\chi_c \rightarrow \mu\mu\gamma$	3,980,000	1.2-2.4
$\Upsilon \rightarrow ee$	3,030	< 0.35
$\Upsilon \rightarrow \mu\mu$	7,700	1.2-2.4

ALICE / CMS

Quarkonia

1 month **p+p run at 5500 GeV** at LHC - **3 pb^{-1}** sampled
Numbers are expected yields after background subtraction
ALICE p+p luminosity limited by rate. **CMS p+p luminosity?**

Signal	**ALICE**	$\lvert\eta\rvert$	**CMS**	$\lvert\eta\rvert$
$J/\psi \to ee$	> 5.2 GeV/c	< 0.9		
$J/\psi \to \mu\mu$	135,900	2.5-4.0	17,219	< 2.4
$\psi' \to ee$	> 5.2 GeV/c	< 0.9		
$\psi' \to \mu\mu$	2,450	2.5-4.0	310	< 2.4
$\chi_c \to ee\gamma$				
$\chi_c \to \mu\mu\gamma$				
$\Upsilon \to ee$	830	< 0.9		
$\Upsilon \to \mu\mu$	520	2.5-4.0	3,010	< 2.4

ALICE / CMS

Quarkonia

1 month **p+Pb run at 5500 GeV** at LHC - **110 nb^{-1}** sampled
Numbers are expected yields after background subtraction
ALICE p+Pb luminosity limited by rate. **CMS p+Pb luminosity?**

Signal	**ALICE**	$\|\eta\|$	**CMS**	$\|\eta\|$
$J/\psi \to ee$	> 5.2 GeV/c	< 0.9		
$J/\psi \to \mu\mu$	676,432	2.5-4.0	85,700	< 2.4
$\psi' \to ee$	> 5.2 GeV/c	< 0.9		
$\psi' \to \mu\mu$	66,202	2.5-4.0	1,550	< 2.4
$\chi_c \to ee\gamma$				
$\chi_c \to \mu\mu\gamma$				
$\Upsilon \to ee$	6,326	< 0.9		
$\Upsilon \to \mu\mu$	3,954	2.5-4.0	22,960	< 2.4

ALICE / CMS

Quarkonia

1 month **Pb+Pb run at 5500 GeV** at LHC - 500 μb^{-1} sampled
Numbers are expected yields after background subtraction
Luminosity limit from Alice rate for Pb+Pb. **CMS luminosity higher?**

Signal	ALICE	$\|\eta\|$	CMS	$\|\eta\|$
$J/\psi \rightarrow ee$	> 5.2 GeV/c	< 0.9		
$J/\psi \rightarrow \mu\mu$	208,600	2.5-4.0	26,400	< 2.4
$\psi' \rightarrow ee$	> 5.2 GeV/c	< 0.9		
$\psi' \rightarrow \mu\mu$	3,760	2.5-4.0	480	< 2.4
$\chi_c \rightarrow ee\gamma$				
$\chi_c \rightarrow \mu\mu\gamma$				
$\Upsilon \rightarrow ee$	2,990	< 0.9		
$\Upsilon \rightarrow \mu\mu$	1,870	2.5-4.0	10,800	< 2.4

Comments/Conclusions

LHC detectors will also have p+p measurements at 14 TeV.

I have not attempted to quantify the signal/background ratios for the various quarkonia signals. The S/B ratio is best for PHENIX at RHIC II in central arms, but PHENIX also has the smallest signals. All signals are expected to be statistically usable, but the significance will be reduced by background pairs in some cases.

Y yields are large and mass resolution good for ALICE, CMS and ND.

Y yields are large but masses not resolved for STAR.

Y yields are smaller and mass resolution good for PHENIX (with VTX).

Charmonium yields are as good or better at RHIC II as in Alice.

It should be possible to do quarkonium physics at RHIC II and LHC.