Heavy ion physics at the LHC

R. Vogt[1,2]
[1] *Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, CA*
[2] *Department of Physics, University of California, Davis, CA*

The ion-ion center of mass energies at the LHC will exceed that at RHIC by nearly a factor of 30, a completely new energy domain. Some highlights of this new physics domain are presented here [1]. We briefly describe how these collisions will provide new insights into the high density, low momentum gluon content of the nucleus expected to dominate the dynamics of the early state of the system. We then discuss how the dense initial state of the nucleus affects the lifetime and temperature of the produced system. Finally, we explain that, at the LHC, 'rare' processes, hard probes, calculable in perturbative quantum chromodynamics, QCD, are abundant. High momentum jets and Υs will be produced with high statistics for the first time in heavy ion collisions.

A fast nucleus may be envisioned as valence quarks surrounded by sea quark and gluon fields. Although these partons carry only a small fraction, x, of the total nucleon momentum, their density is very high. As the beam energy is increased, the lowest x values probed decreases while the density increases. At forward rapidities, the x values probed are further decreased, as seen in Fig. 1.

At these high gluon densities where x is low and the 4-momentum transfer squared, Q^2, is moderate, the Q^2 evolution of the gluon densities is no longer linear. Instead, in the regime $1.5 \leq Q^2 \leq 10$ GeV^2 and $10^{-5} \leq x \leq 5 \times 10^{-3}$, nonlinear evolution of the parton densities dominates. At still smaller x, the gluon density is so large that it saturates the available phase space.

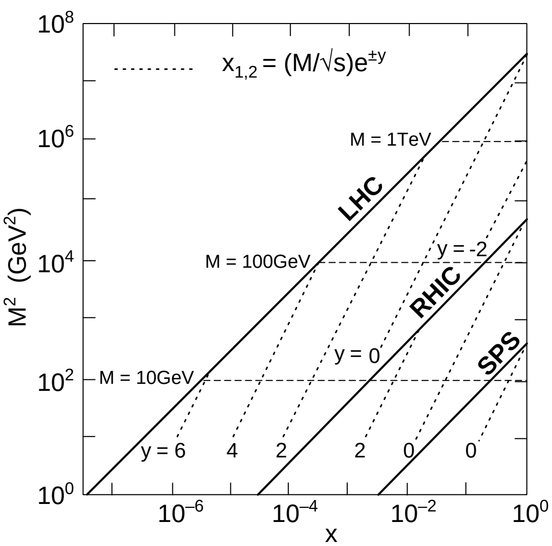

FIG. 1: The $Q^2 = M^2$ reach in x for the SPS, RHIC and the LHC. Lines of constant rapidity are indicated.

Nuclear parton distributions are modified relative to those of the free proton. However, the measurements are not very sensitive to the gluon distributions and, at low x, are limited to nonperturbative Q^2. At the LHC, the low x region is in the perturbative regime. Effects of modified parton density evolution should manifest themselves most strongly at low Q^2. Thus charm is an important probe of small x, low Q^2 gluons. LHC measurements can probe the different regimes of parton evolution.

Hard probes, such as high-p_T jets and photons, quarkonia, and $W^\pm$ or Z^0 bosons, dominate particle production at the LHC. At these high energies, the cross sections are large enough for detailed systematic studies.

Table I gives the minimum bias jet and gauge boson rates in the region $|\eta| \leq 2.4$ as well as the total $Q\overline{Q}$ and quarkonium rates in Pb+Pb collisions at $\sqrt{s_{NN}} = 5.5$ TeV and pPb collisions at $\sqrt{s_{NN}} = 8.8$ TeV.

	Pb+Pb $\sqrt{s_{NN}} = 5.5$ TeV $\mathcal{L} = 5 \times 10^{26}$/cm^{2}s		pPb $\sqrt{s_{NN}} = 8.8$ TeV $\mathcal{L} = 1.4 \times 10^{30}$/cm^{2}s	
Process	Yield/10^6 s	Ref.	Yield/10^6 s	Ref.
$\|\eta\| \leq 2.4$				
> 50 GeV jet	2.2×10^7	[2]	1.5×10^{10}	[3]
> 250 GeV jet	2.2×10^3	[2]	5.2×10^6	[3]
Z^0	3.2×10^5	[4]	6.8×10^6	[3]
W^+	5.0×10^5	[4]	1.1×10^7	[3]
W^-	5.3×10^5	[4]	1.1×10^7	[3]
all phase space				
$c\overline{c}$	9.0×10^{10}	[5]	2.0×10^{12}	[5]
$b\overline{b}$	3.6×10^9	[5]	8.2×10^{10}	[5]
$J/\psi \to \mu^+\mu^-$	2.4×10^7	[6]	5.5×10^8	[6]
$\Upsilon \to \mu^+\mu^-$	1.5×10^5	[6]	3.5×10^6	[6]
$\Upsilon' \to \mu^+\mu^-$	3.7×10^4	[6]	8.4×10^5	[6]
$\Upsilon'' \to \mu^+\mu^-$	2.2×10^4	[6]	5.2×10^5	[6]

TABLE I: The yield of hard probes in a 10^6 s LHC run.

We have presented only a few of the exciting new physics opportunities at the LHC. The LHC will certainly turn lead-lead collisions into golden data.

[1] R. Vogt, Nucl. Phys. **A752**, 447c (2005).
[2] A. Accardi et al. (2003), hep-ph/0310274.
[3] A. Accardi et al. (2003), hep-ph/0308248.
[4] R. Vogt, Phys. Rev. **C64**, 044901 (2001).
[5] R. Vogt, Int. J. Mod. Phys. **E12**, 211 (2003).
[6] M. Bedjidian et al. (2003), hep-ph/0311048.