Time evolution of magnetic field during heavy ion collision

Dhanpat Sharma[1*] and Suneel Kumar[2]
[1] Deptartment of Physics and Astrophysics,
Central University of Haryana, Mahendergarh - 123031, INDIA

Introduction

In present era, scientific community is impatiently interested in nanotechonology, which is conventional molecular matter. Without a doubt, nanoparticles have excellent electrical, thermal, and mechanical properties. However, in order to meet future demands, a shift from nanotechnology to femtotechnology will be required. Heavy ion collision (HIC) has emerged as a beacon of hope over the years and to meet these needs, the magnetic field due to HIC is a very good application. Kharzeev et al. [1] have demonstrated that HICs at the Large Hadron Collider and the Relativistic Heavy Ion Collider can produce the greatest magnetic field ever attained in a terrestrial laboratory. It is observed that the order of magnetic field due to HIC is in order of 10^{16} gauss [2, 3] which is much higher than the terrestrial laboratory that make it great wave of interest. Due to wide application area in energy and defence sector magnetic field cemented its position in present enchanting research outcomes. It has the potential to bring out the revolution in these fields and it make us giddy with enthusiasm to conduct study in this area.

Isospin Quantum Molecular Dynamics

Isospin molecular dynamics model (IQMD) is the improved version of the Qunatum molecular dynamics(QMD) which provide much more concise experimental results and successfully explain the N-body correlations. Model includes nuclear equation of state with the inclusion of quantum features, Pauli blocking and interaction potential. In this model each nucleon considered to be a Gaussian wave packet. The model evolves three step namely Initialization, Propagation and N-N collisions. The wave function for the i^{th} nucleon is

$$f_i(\mathbf{r},\mathbf{p},t) = \frac{1}{\pi^3\hbar^3}\, e^{-(\mathbf{r}-\mathbf{r_i}(t))^2\frac{2}{L}}\, e^{-(\mathbf{p}-\mathbf{p_i}(t))^2\frac{L}{2\hbar^2}}. \tag{1}$$

where $\mathbf{r_i(t)}$ and $\mathbf{p_i(t)}$ is the mean position coordinate and mean momentum respectively. The Gaussian width L is taken to be a representation of the particle interaction range. In order to achieve the highest level of stability the system dependency of L has been included to IQMD.

Results and Discussion

The simulations has been carried out by using dynamical framework of IQMD [4] model. In this work, time evolution of the magnetic field at various impact parameter range as well as the variation of nuclear stopping with impact parameter has been shown by using equation 2 and 3 respectively. These results has been simulated for 500 runs.

$$e\boldsymbol{B}(\boldsymbol{r},t) = \frac{e^2}{4\pi\epsilon_0 c}\sum_n Z_n \frac{c^2 - v_n^2}{\left(cR_n - \boldsymbol{R}_n\cdot\boldsymbol{v}_n\right)^3}\boldsymbol{v}_n\times\boldsymbol{R}_n \tag{2}$$

where Z_n is the nth particle's charge number; $\mathbf{R_n} = \mathbf{r} - \mathbf{r_n}$is the relative distance between the field point $\mathbf{r}$ to the position $\mathbf{r_n}'$ of n^{th} particle travelling with velocity v_n at the retarded time $t_{rn} = t - |\mathbf{r} - \mathbf{r_n}(t_{rn})|/c$. The summation is applied to all of the charged particles.

Nuclear stopping is defined as the [5]

$$R_P = \frac{2}{\pi}\frac{\left(\sum_i |p_\perp(i)|\right)}{\left(\sum_i |p_\parallel(i)|\right)} \tag{3}$$

Here, $p_\perp(i)$ is the transverse momentum of the i^{th} nucleon and $p_\parallel(i)$ is momentum in z direction. The correlation between the nuclear stopping and the magnetic field has been

*Electronic address: dhanpatsharma95@gmail.com

TABLE I: Friction of participant as a function of impact parameter bin at 600 MeV/nucleon.

Bin no.	Geometrical range	Frac. of participants
1	$0< \hat{b} \leq 0.28$	0.9718
2	$0.28< \hat{b} \leq 0.39$	0.7618
3	$0.39< \hat{b} \leq 0.48$	0.5916
4	$0.48< \hat{b} \leq 0.56$	0.4824
5	$0.56< \hat{b} \leq 0.62$	0.2946
6	$0.62< \hat{b} \leq 0.76$	0.1541
7	$0.76< \hat{b} \leq 0.88$	0.0503
8	$0.88< \hat{b} \leq 0.99$	0.0366

shown for different range of impact parameter. As we go toward the higher impact parameter bin, number of participants starts decreasing which results in less transfer of energy from participant zone to the spectator zone. figure

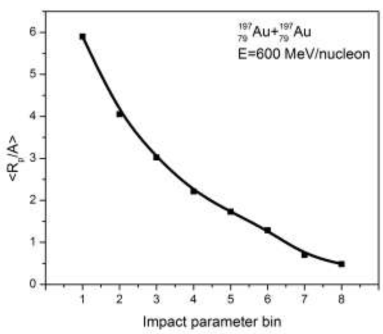

FIG. 1: Variation of nuclear stopping with impact parameter bin at 600 MeV/nucleon for $^{197}_{79}Au$+$^{197}_{79}Au$.

Nuclear stopping is an computational tool which gives the information about the amount of longitudinal energy converting into transverse energy. It probes the nuclear properties of matter at extreme conditions of temperature and pressure. The Fig. 1. shows the variation of nuclear stopping with the different impact parameter bin. It is decreasing as we go towards higher impact parameter bin due to very less number of participating nucleons.

In Fig. 2., the variation of magnetic field with the time at 600 MeV/nucleon for different impact parameter bin has been shown. Initially, the magnetic field increases and reaches its peak value around 30 fm/c for very short duration due to small interaction time between the nucleons. Then, it decreases rapidly and almost saturates.

figure

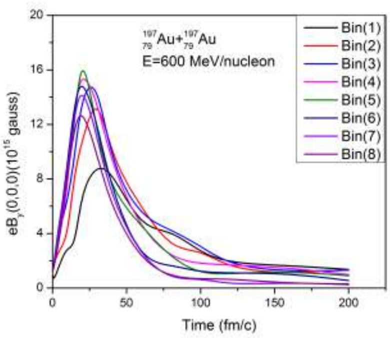

FIG. 2: Variation of magnetic field $eB_y(0,0,0)$ with time at 600 MeV/nucleon for different impact parameter bin for $^{197}_{79}Au$+$^{197}_{79}Au$.

As we go towards higher impact parameter bin, the magnitude of peak value of magnetic field increases upto bin(5) and then it starts decreasing due to lack of participant zone. Therefore, transfer of energy does not take place from participant to spectator which results in less accelerated charged nucleons. So, the peak value of magnetic field starts decreasing for much higher impact parameter.

Acknowledgments

Special thanks to Prof. Rajeev K. Puri for giving access to his various computer programs for the current work.

References

[1] D. E. Kharzeev et al., Nucl. Phys. A **803**, 227 (2008).

[2] Xin-Li Zhao et al., Phys. Lett. B **792**, 413-418 (2019).

[3] Li Ou et al., Phys. Rev. C **84**, 064605 (2011).

[4] C. Hartnack et al., Eur. Phys. J. A **1** 151 (1998).

[5] Deepshikha, S. Kumar. Nucl. Phys. A, **983** 240251 (2019)