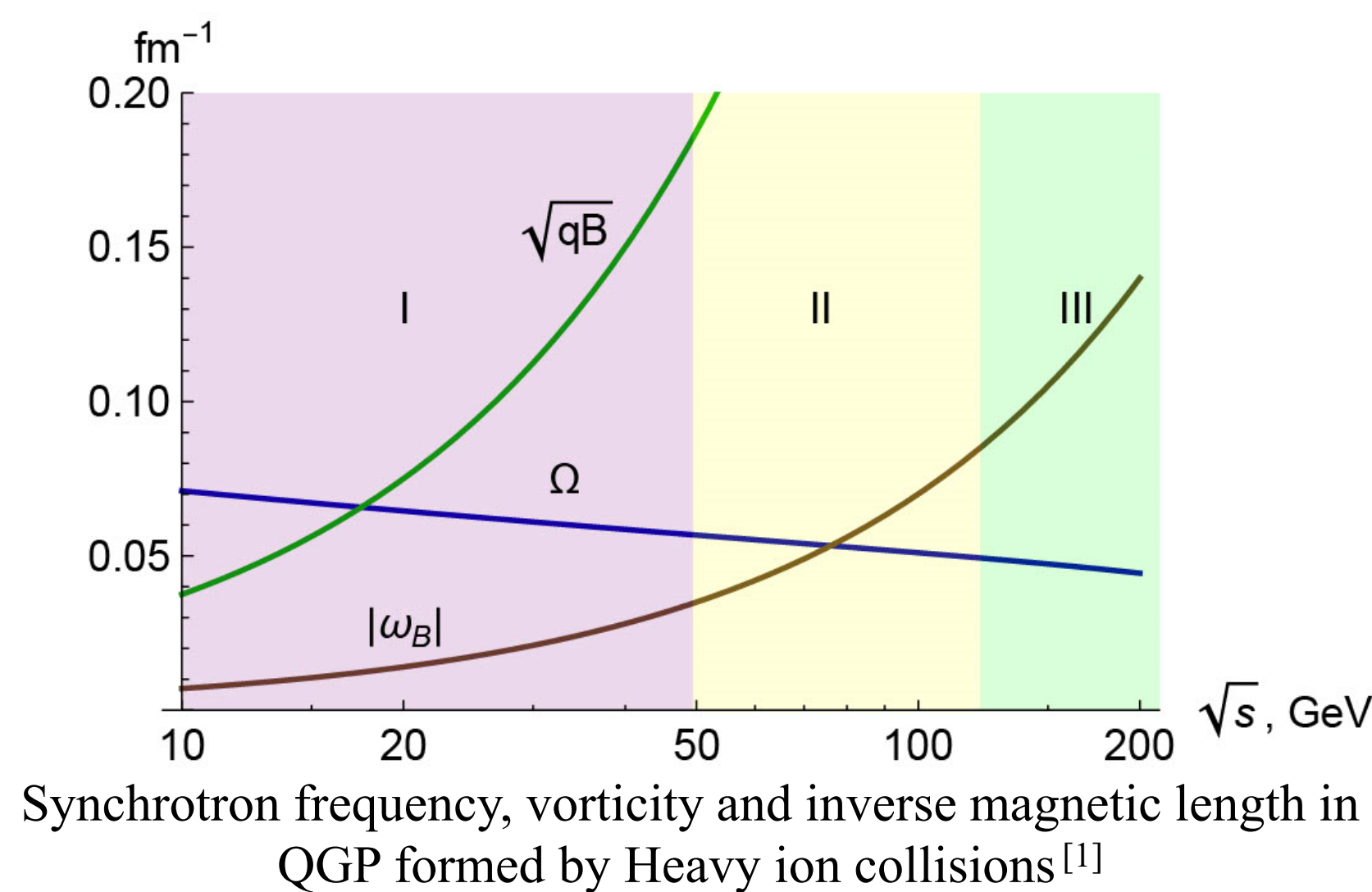


Photon radiation by rotating systems in magnetic field

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Motivation

- Quark-Gluon Plasma in Heavy Ion collisions possess high vorticity and subject to intense magnetic field.



- Here we study the effect of rotation on radiation emitted by a single particle in a magnetic field (synchrotron radiation.)^[2]

Formulation of the Problem

- Hamiltonian for the rotating system is

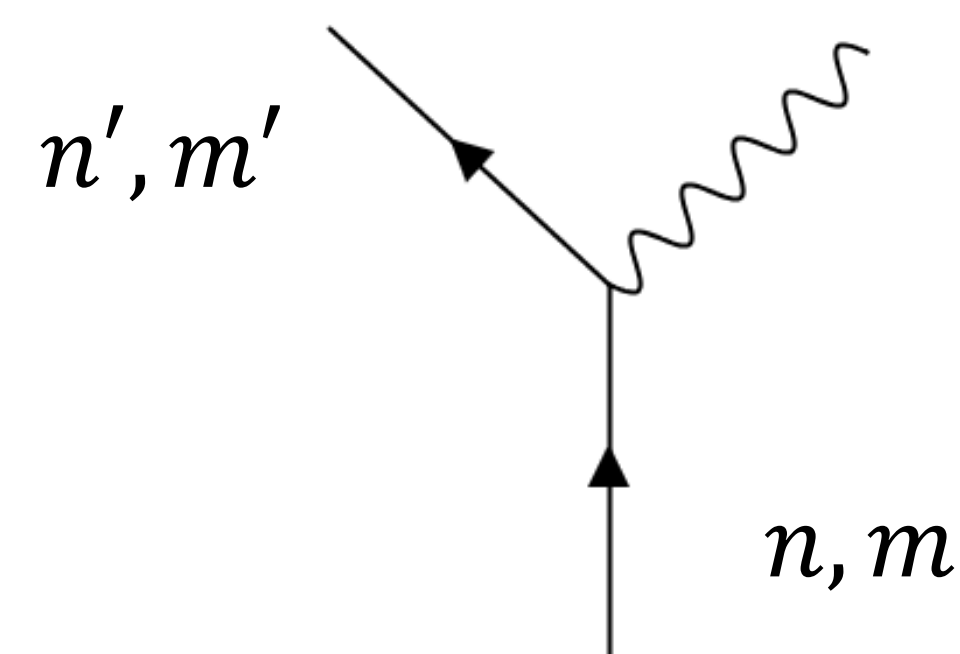
$$H = H_0 + \Omega J_z$$

(rotation and magnetic field is along Z axis) H_0 is Hamiltonian without rotation of a single particle in a magnetic field.

- Eigen states are labelled by the principal quantum number n , longitudinal momentum p_z and magnetic quantum number m . There is degeneracy in m when $\Omega = 0$.
- Synchrotron radiation is emitted when there is a transition from one level to another.
- Rotation lifts the degeneracy in m by adding to the energy of each level by $m\Omega$.
- Rotating frames have a causal boundary where corotating particles approach the speed of light. The size of the boundary decreases with angular speed.
- We assume angular speed is small enough that the causal boundary is far away than the characteristic length scale of the system (magnetic length.)

Calculation

- We calculate the amplitude of the process: (in $\hbar = c = M = 1$ units)



- Summing and Integrating over the final states we obtain the differential and total radiation intensity.

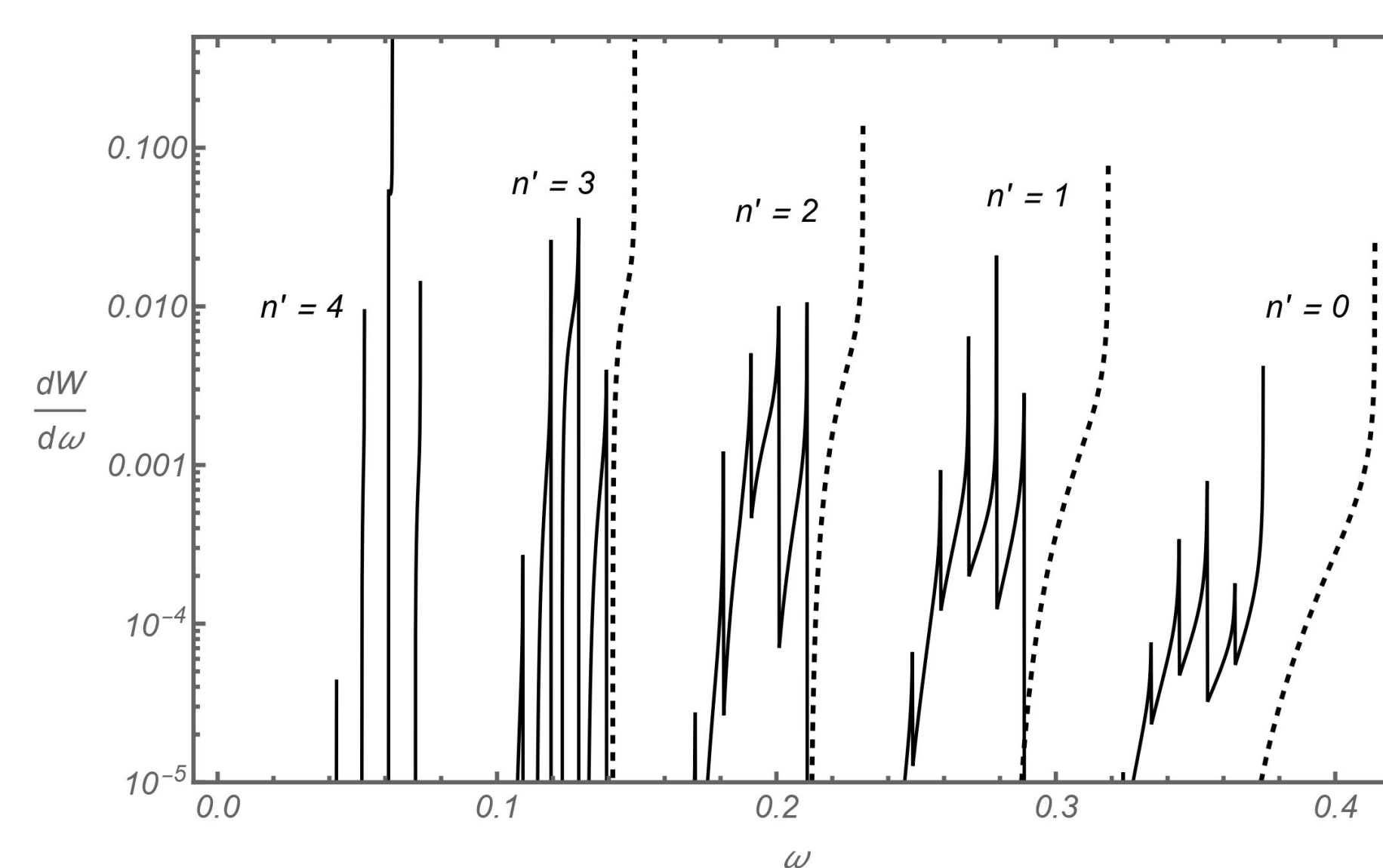
- The total radiation intensity is

$$W_t = \frac{q^2}{4\pi} \sum_{n',a'} \int_0^\pi \frac{d\theta}{2} \frac{\omega_0^2 \sin\theta}{1 + \frac{\omega_0 \cos^2\theta}{E' - m'\Omega}} (\Gamma_{n,a}^{(0)} + h\Gamma_{n,a}^{(1)})$$

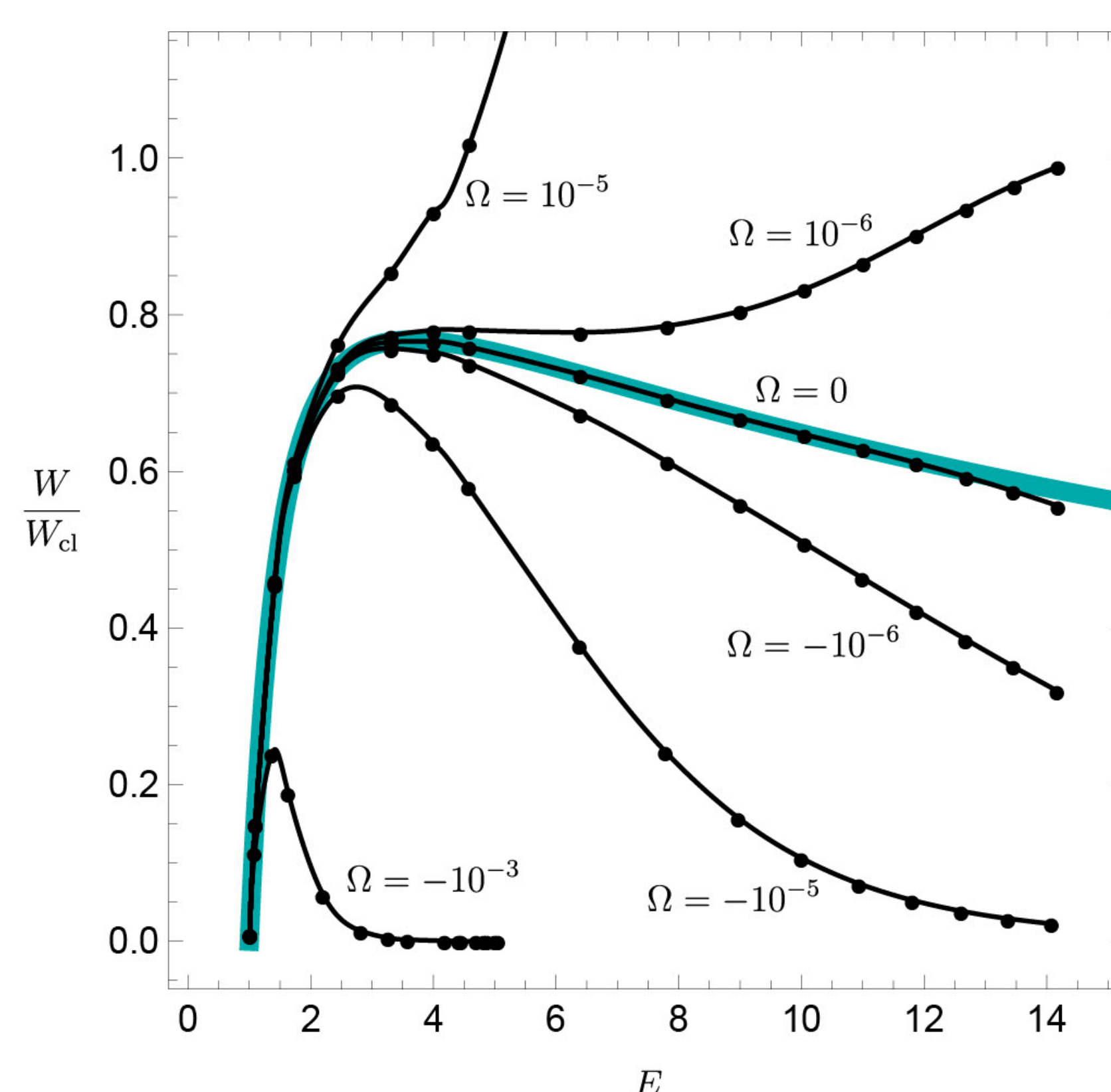
where $\Gamma_{n,a}^{(0)}, \Gamma_{n,a}^{(1)}$ depends on θ and energy, E . h is the helicity of the photon. ω_0 is the resonant frequency.

Results

- Spectrum of the radiation for certain initial states

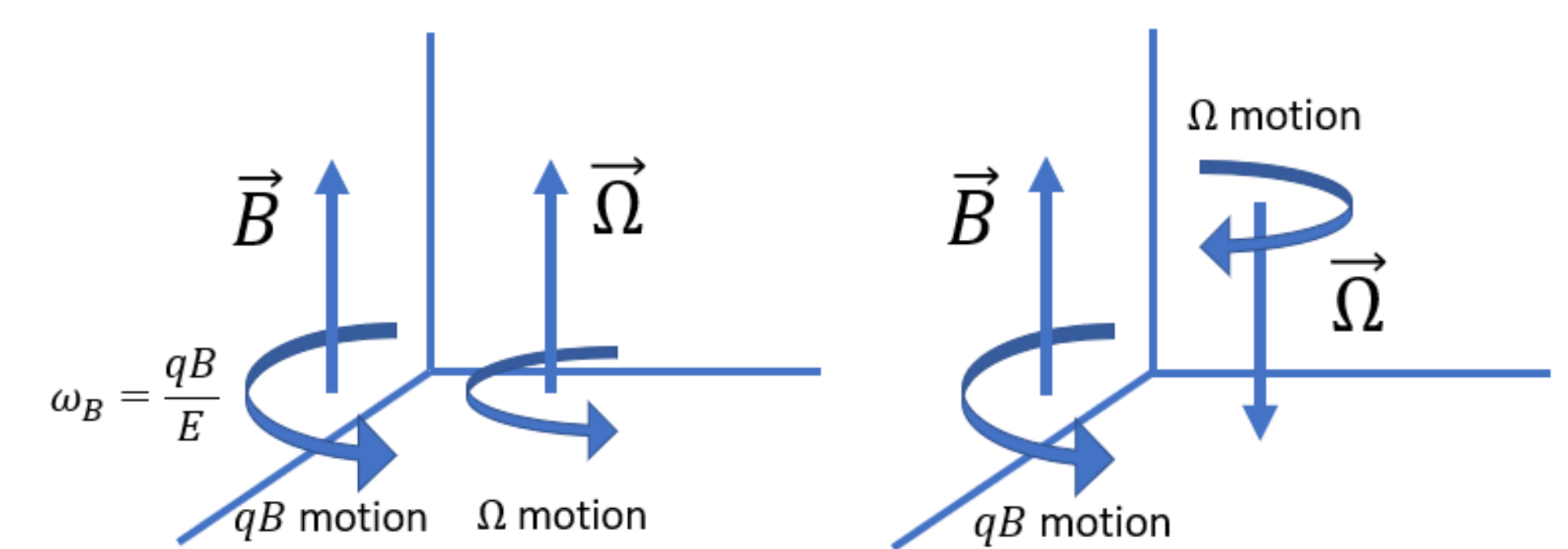


- Total Radiation intensity:



Conclusions

- Rotation can enhance or suppress the synchrotron radiation intensity.
- For negative charges, radiation is enhanced when magnetic field and rotation are parallel and suppressed when anti-parallel and vice-versa for positive charges.
- Classically the result can be understood in terms of effective rotation: for negative charges, when \mathbf{B} and $\mathbf{\Omega}$ are aligned, Synchrotron frequency ($\omega_B = \frac{qB}{E}$) adds to the rigid rotation.



Effective rotation experienced by an electron when \mathbf{B} and $\mathbf{\Omega}$ are parallel and anti-parallel

- From the results, if the enhancement factor from zero rotation $\sim a(E)$, the suppression factor $\sim \frac{1}{a(E)}$.
 - For a collection of rotating charges like QGP, the number of photons emitted is roughly
- $$N(\Omega) = \frac{1}{2} \left(a(E) N^+(\Omega = 0) + \frac{1}{a(E)} N^-(\Omega = 0) \right)$$
- where N^+ represents number of photons from charges with $qB\Omega < 0$ and N^- that with $qB\Omega > 0$.
- Thus for large a we can expect an overall enhancement of Synchrotron radiation in QGP due to rotation.

References

- [1] Buzzegoli, M., Kroth, J.D., Tuchin, K., & Vijayakumar, N. (2023). Photon radiation by relatively slowly rotating fermions in magnetic field. arXiv:2306.03863
- [2] Buzzegoli, M., Kroth, J.D., Tuchin, K., & Vijayakumar, N. (2022). Synchrotron radiation by slowly rotating fermions. Physical Review D. arXiv:2209.02597

