1. INTRODUCTION

1.1. Formation Process of QGP is a BIG QUESTION in HIC

1.2. Previous Studies on Quark Production via Schwinger Mech.

- Longitudinal expansion (broken expansion) of the flux tubes
- Presence of magnetic fields in parallel to electric fields, whose effects on the Schwinger mech., are NOT understood well in previous studies.

2. THEORY

2.1. Formulation

- Following simplifications are assumed hereafter:
  1. U(1) gauge theory with \( N_f = 1 \) fermion
  2. Homogeneity in space: Boost invariance & transverse symmetry
  3. Single flux tube with infinite length in the transverse direction
  4. Longitudinal EM-field at initial time \( \tau_0 = (0,0,E) \), \( B(0,0,B) \)

3. RESULT I – WITHOUT Backreaction \( g=0 \) (Analytical)

3.1. Longitudinal Distribution \( d^2N/dydy/\Delta \) \( \tau_1 \) \( \text{[fm}^{-2}\text{]} \)

3.2. Number Density \( dN/dy/\Delta \) \( \text{[fm}^{-2}\text{]} \)

- The density is consistent w/ Schwinger’s formula for small \( n \) (\( m_f \)), while it has a power-law tail \( \sim (m^2 + 2gB)/gE \) for large \( n \) (\( m_f \)).

- Lowest Landau contribution (\( n=0 \)) dominates the particle production.
- Larger particle production \( gB \) for increasing \( gB \).
- Very fast quark production: \( dN_d/dy/\Delta \leq 1 \) \( \text{fm}^{-2} \) particles are produced at \( \tau \approx 0.2 \text{ fm} \), which roughly corresponds to the quark production.

4. RESULT II – WITH Backreaction \( g \neq 0 \) (Numerical)

4.1. Longitudinal Distribution \( d^2N/dydy/\Delta \) \( \text{[fm}^{-2}\text{]} \)

- The oscillation is "flattened" with increasing mass.

4.2. Number Density \( dN/dy/\Delta \) \( \text{[fm}^{-2}\text{]} \)

- The oscillation never decays: Rotational sym., always holds due to the simplification 2.3.3 (i.e., \( f=0 \)).
- Faster decay and slower oscillation with increasing mass.

5. SUMMARY

The quark production in the early stage dynamics of HIC based on the Schwinger mechanism is extensively studied.

1. Effects of the longitudinal expansion and the longitudinal magnetic fields on the Schwinger mech., which are the missing pieces of previous studies, are clarified.
2. The Schwinger mech. can explain a fast quark production and, combining w/ the experimental result on the multiplicity, it suggests that the classical gluon fields should have decayed very fast (though we did not say anything about its physics).
3. The backreaction effects from the produced quarks are also investigated, and an approximate formula is obtained in the LLL approximation and the massless limit.

There are several topics (energy density, pressure, anomalous current, etc) which I could not cover in this poster. If you are interested in these topics, feel free to ask me!