Spectator induced electromagnetic effects in heavy-ion collisions and space-time-momentum conditions for pion emission

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Our model: PRC 95 (2017) 2, 024908; PRC 99 (2019) 2, 024908;
EM part: PRC 102 (2020) 1, 014901
The model

Bricks collide...  

$1 \times 1 \text{ fm}^2$

... and form fire streaks

with rapidity from $E-p$ conservation

Each fire streak fragments independently in pions

$\frac{dn}{dy} \sim A \cdot (E_s^* - m_s) \cdot \exp\left(\frac{-(y - y_s)^2 + \epsilon^2}{n \sigma_y^2}\right)$

$\pi^-$ in NA49 Pb+Pb @ 158 GeV

Peripheral

Central

Available energy  Fire streak rapidity

Total fire streak energy  Sum of brick masses

$b = 9.72 \text{ fm}$

$b = 8.41 \text{ fm}$

$b = 6.64 \text{ fm}$

$b = 4.74 \text{ fm}$

$b = 2.55 \text{ fm}$
Results

- We fix the pion emission time from the fire streaks and initial position of the pion relative to the spectator.
- We assume that the pion creation time increases with the excitation energy of the fire streak, we take:
  \[
  \tau = a(E_s^* - m_s) + \tau_0
  \]
- The configuration with the expanding spectator ($\beta_R = 0.2$) gives the best description. K. Mazurek, A. Szczurek et al., PRC 97, 024604 (2018)
Particle flow in momentum space (results)

- We fit NA49 and WA98 experimental data for $v_1$ and $v_2$ and include them to the initial conditions of the system

NA49 data: C. Alt et al., PRC 68, 034903 (2003)

WA98 data: H. Schlagheck, NPA 663, 75 (2000)

- We find no effect for $v_2$ but a non-negligible effect for $v_1$:

![Graphs showing particle flow](image)
Vorticity of fire streaks

- Fire streaks rotate for a given small angle $\alpha$

- After rotation the fire streak follows its modified trajectory until pions are emitted from the fire streak

- The pion emission point is shifted in transverse and longitudinal direction with respect to the case with no rotation

- The size of the shift increases with increasing $\alpha$ and $\tau$

- Rotation by $\alpha = 1.75$ deg gives a good description of the experimental data on $v_1$!

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Vorticity (results)

- No significant change is visible with respect to the case with no rotation.

- Due to the small total angle allowed by the experimental data on $v_1$, vorticity includes only a small displacement of the pion emission points.
Summary

We introduced the model of the longitudinal evolution of the system, which

- explains the centrality dependence of pion yields and rapidity spectra in Pb+Pb collisions

We implemented the initial conditions for pion production provided by our model to study the electromagnetic effects in peripheral Pb+Pb collisions

- rather small pion creation times have been necessary to describe the data on electromagnetic effects, which concern faster pions (0.5<\(\tau\)<2 fm/c)
- configuration with the expanding spectators gives the best description of the data
- inclusion of directed flow gives a non-negligible effect, whereas elliptic flow shows no effect
- vorticity of fire streaks results in the presence of directed flow (see PRC 102 (2020) 1, 014901 for more details), but has little effect on the electromagnetic distortion of pi+/pi- ratios
Thank you!

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