Bose–Einstein correlations of charged hadrons

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- Reation between position and momentum space
- Correlation function (C_2 / SR)
- Results & Analysis
- Summary and conclusion

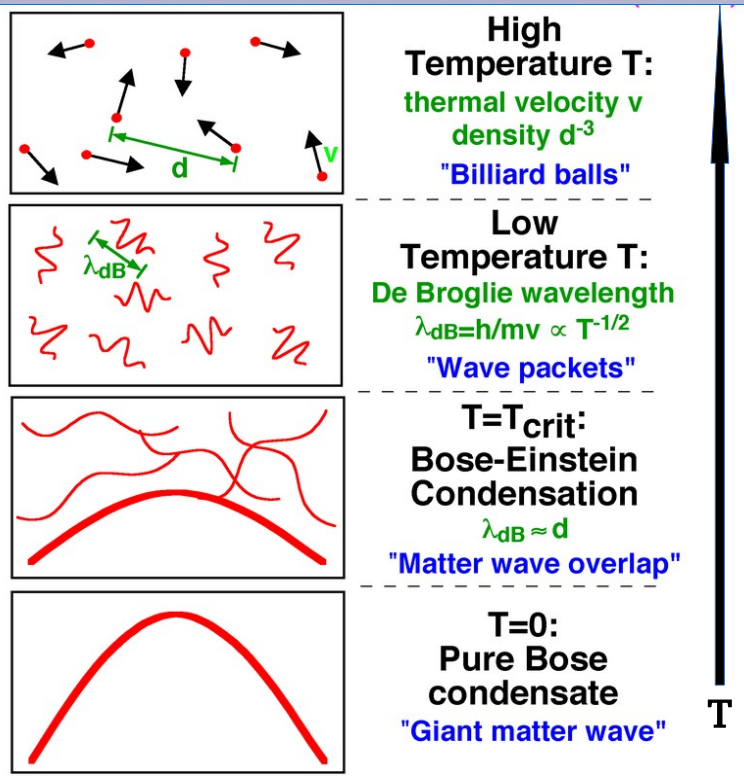
Introduction

- Bose Einstein Correlations (BECs) are statistical in nature, use to probe the size and shape of the particle emitting region in high energy collision.
- This technique helps to know about the size of the emission region at freeze-out stage.
- PP collision were performed at energy 0.9 TeV, 2.36 TeV, 2.7 TeV, 7 TeV and 13 TeV
- In this studies, the correlations were measured in terms of invariant relative momentum with theoritical analysis model Pythia8 and AMPT.

$$q_{\mathrm{inv}}^2 = -q^\mu q_\mu = -(k_1 - k_2)^2 = m_{\mathrm{inv}}^2 - 4m_\pi^2$$

The correlations of the particles are measured for PP collision at 13 TeV energy and for heavy ion collisions at RHIC energis and LHC energies.

Bose-Einstein Condensate



When tem (T) is high, the inter atomic spacing (d) is big

$$\frac{p^2}{2m} = \frac{3}{2}k_B T \qquad p = \sqrt{3mk_B T} \qquad \lambda_T = \frac{h}{p} = \frac{h}{\sqrt{3mk_B T}}$$

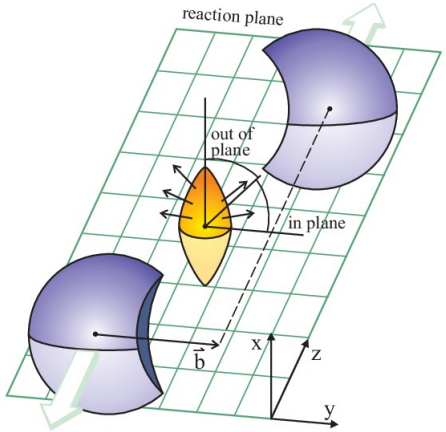
$d \approx \lambda_T$ Particle wave are starting to overlap each other

$\lambda_T \gg d$ We can not distinguish b/w atoms

- Boson particles allow Bose-Einstein Statistics (multiple identical bosons to occupy the same quantum state). The wave functions of the particle overlap with each other.
- To measure the BE correlations boson particles are used

Particle Collision

- In high energetic particle collision, the overlap region is like an almond shaped, leading to spacial anisotropy in geometry.
- Anisotropy in geometry leads to variations in energy density, with higher density in the shorter direction of the almond shape creates high pressure.
- Exand the system more quickly in this direction.
- Particles are more accelarate in this direction.
- With expansion of the system the spacial anisotropy decrease, momentum anisotropy increase.



Connection with position and momentum space via F.T

The wave functin Ψ (x) in position space is connected to the momentum space ϕ (q),

$$\phi(q) = \frac{1}{\sqrt{2\pi\hbar}} \int \psi(x) e^{-ipx/\hbar} dx$$

Particle momentum become observable in final state distribution

Correlations between particles (SR)

In momentum space the correlations, SR are measures with respect to relative momentum,

The mathematical term of the correlation,

$$\mathrm{SR}(q_{\mathrm{inv}}) \equiv C_2(q_{\mathrm{inv}}) = \left(\frac{\mathcal{N}_{\mathrm{ref}}}{\mathcal{N}_{\mathrm{sig}}}\right) \left(\frac{\mathrm{d}N(q_{\mathrm{inv}})_{\mathrm{sig}}/\mathrm{d}q_{\mathrm{inv}}}{\mathrm{d}N(q_{\mathrm{inv}})_{\mathrm{ref}}/\mathrm{d}q_{\mathrm{inv}}}\right) =$$

Probability of finding the no of pairs from the same event particles with respect to invariant relative momentum

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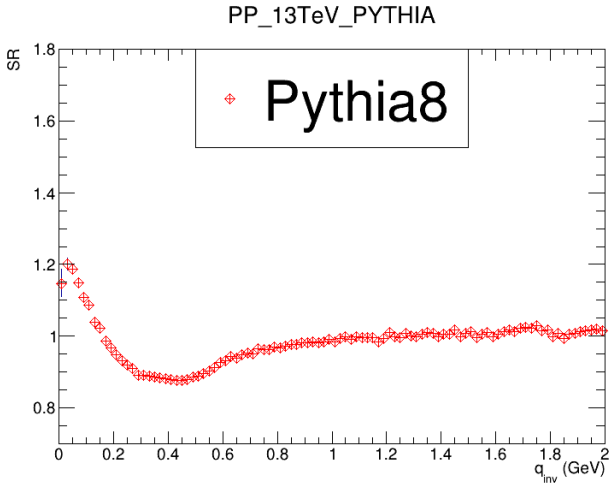
Probability of finding the no of pairs from the mixed event particles with respect to invariant relative momentum

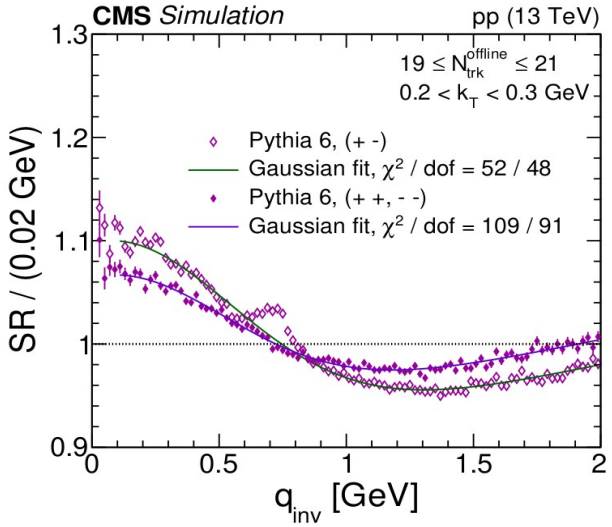
If the SR > 1, enhance the quantum statistical effect, the partcles are correlated with each other.

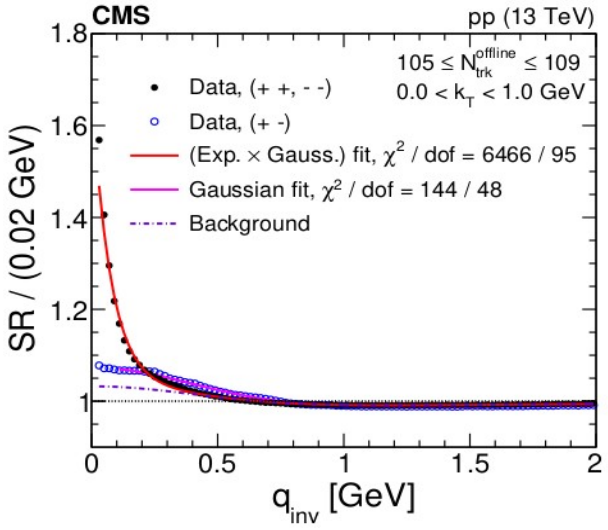
The correlations between the particles are measured for the all positive signed pions with respect to their relative momentum.

Results & Analysis

SR Calculation for PP collision (13TeV) with Pythia8







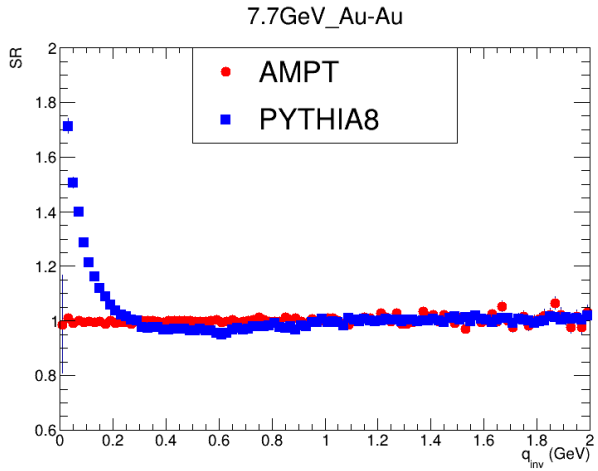
- Red dotted line indicates the correlations for positive pions.
- The pythia8 results quite impresive than pythia6 with compared to cms data.

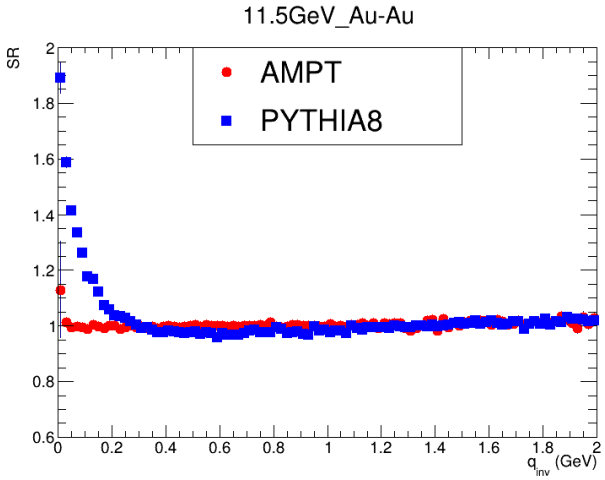
The SR > 1 for $q_{inv} < 0.2$,

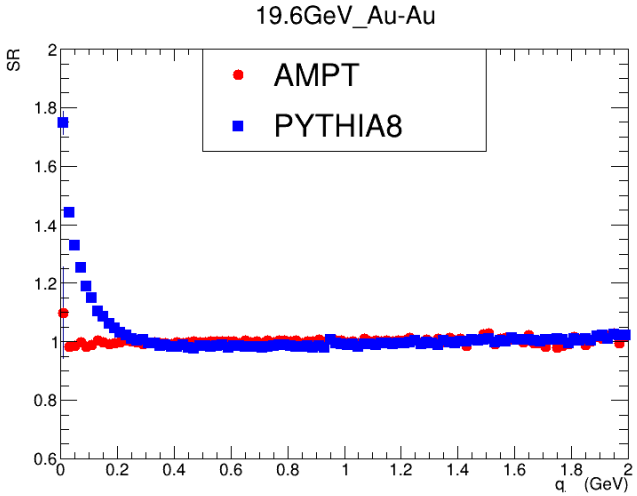
particles are correlated to each other when thier momentum are nearly equal.

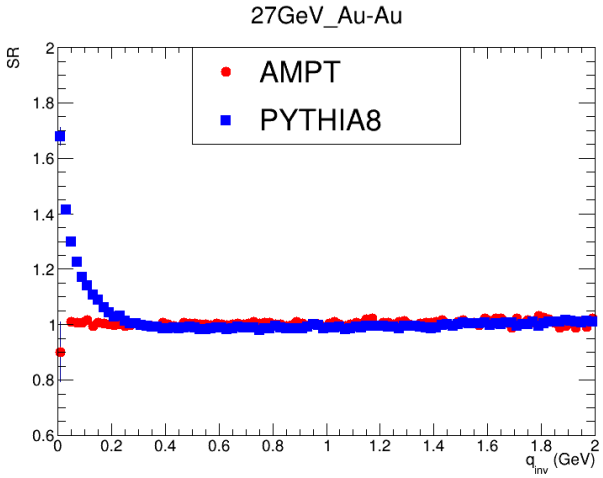
Equal momentum particles are emitting from same energy gradiant of the fireball

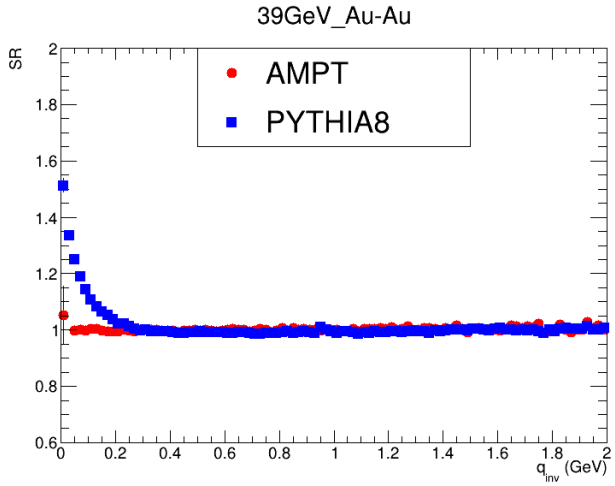
SR Calculation for Heavy ion Collisions in RHIC & LHC Energies with Pythia8 and AMPT model

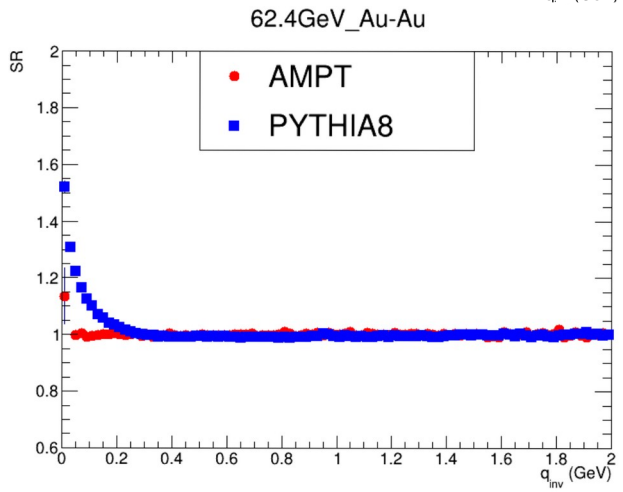




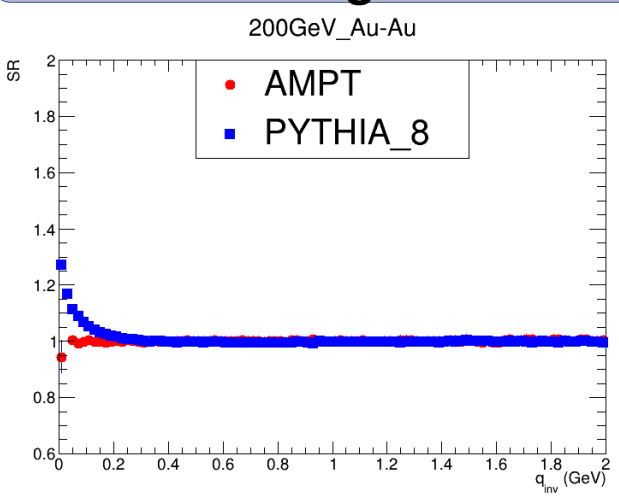


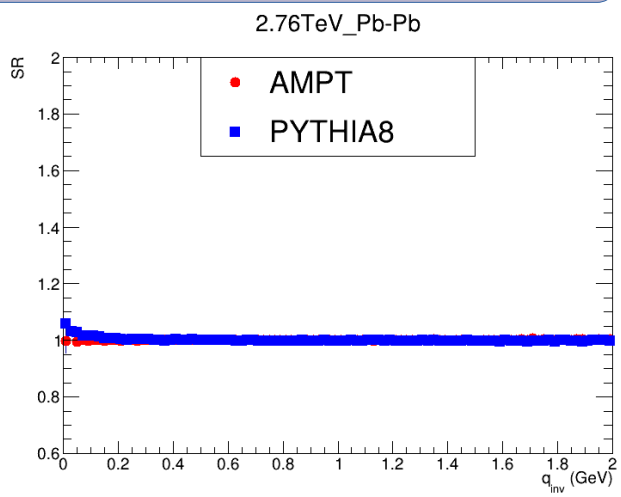


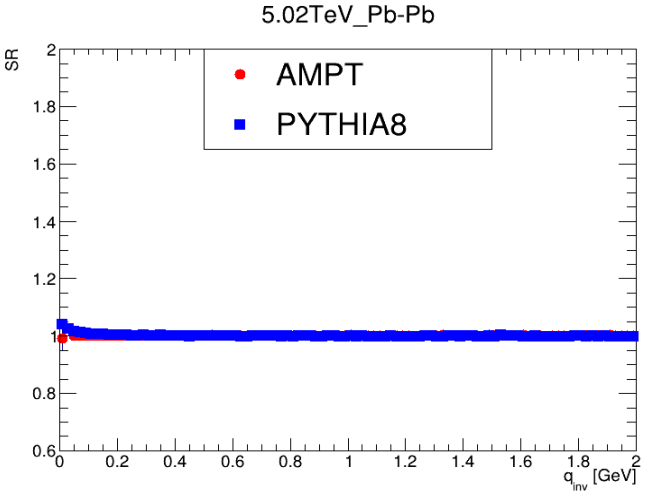




SR Calculation for Heavy ion Collisions in RHIC & LHC Energies with Pythia8 and AMPT model



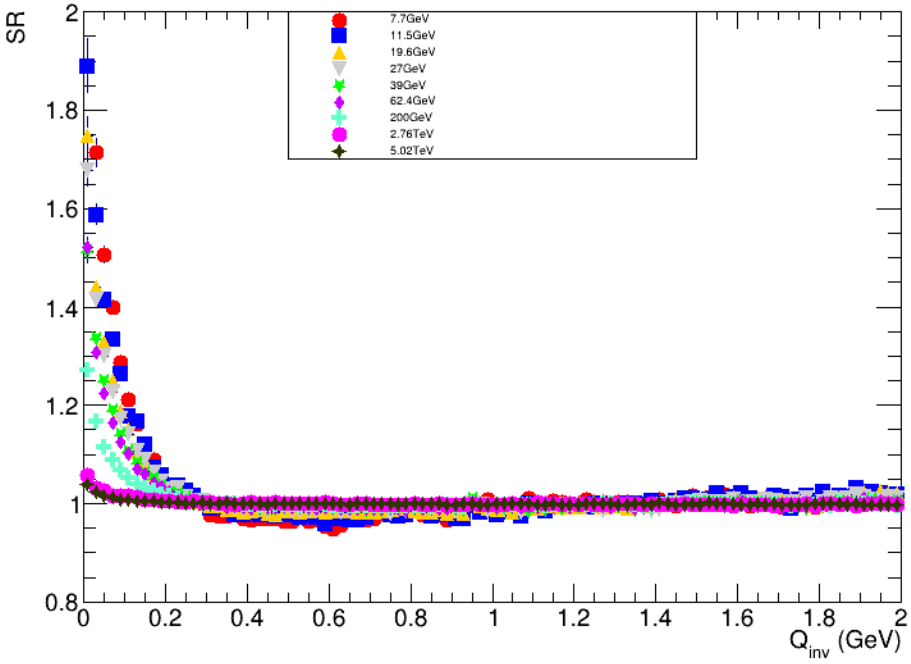




- In Pythia, the particles shows the correlations (for relative invariant momentum (q_{inv}) < 0.2).
- Pythia has a string “BoseEinstein=on”, enhance the the probability of producing the correlated particles.
- In AMPT model, there is nothing like this string, which can enhance the correlations between particles, gives a stringht line at SR = 1.
- No correlations are found in this model

BECs for all Energies

Pythia8



with increasing the energy the SR is decreasing

At low collision energy, the size of the fireball is small, enhance the quantum statistical effect, wave functions are overlap with each other.

The the correlation is more sharper.

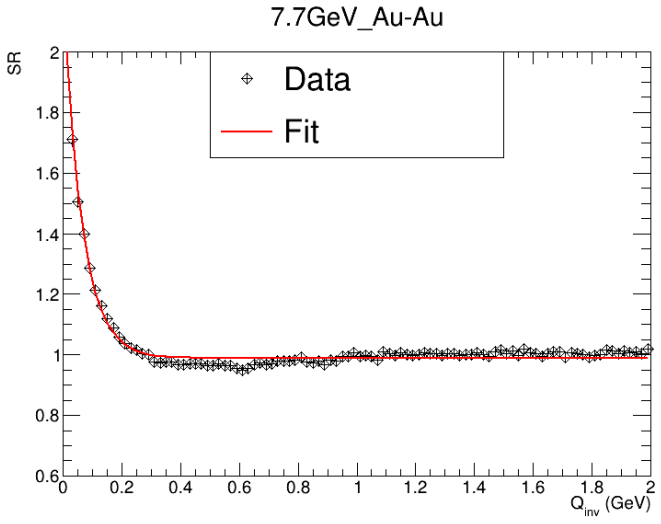
At high collision energy, the size of the fireball is expanding more rapidly, decresing the probability of the overlapping wave funcions.

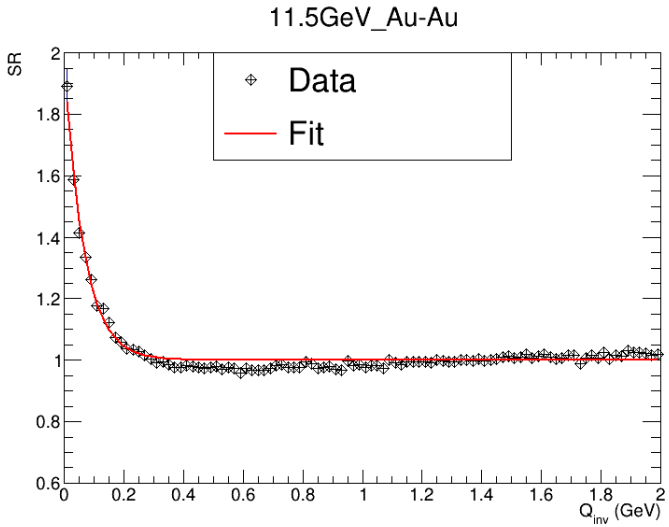
The correlation is diluted.

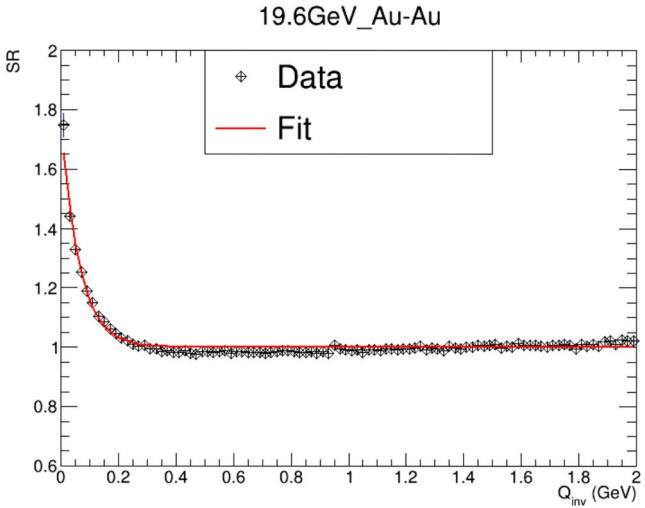
Fit the correlation function

Levy fit is using to fit the functions. Levy fit: $C_2(q_{\text{inv}}) = 1 + \lambda \exp(-q_{\text{inv}} R)$ c_2 = correlation function, λ = correlation strength,

R = source radius: Use fit parameter, *f(x) = 1 + [0]*exp(-x*[1]); X --> momentum, [0] --> λ, [1] --> R*

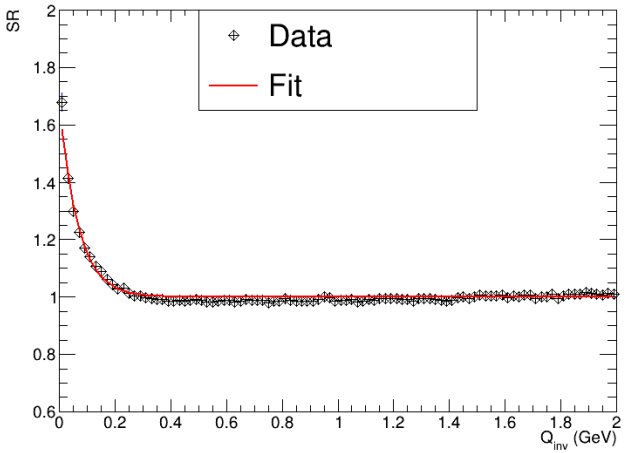




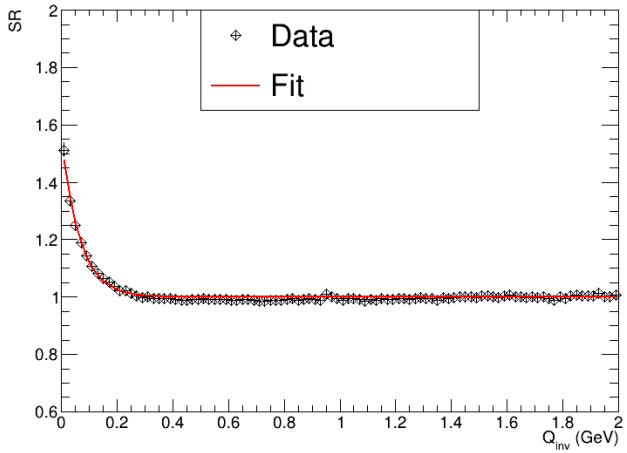


Fit the correlations with Levy parameter

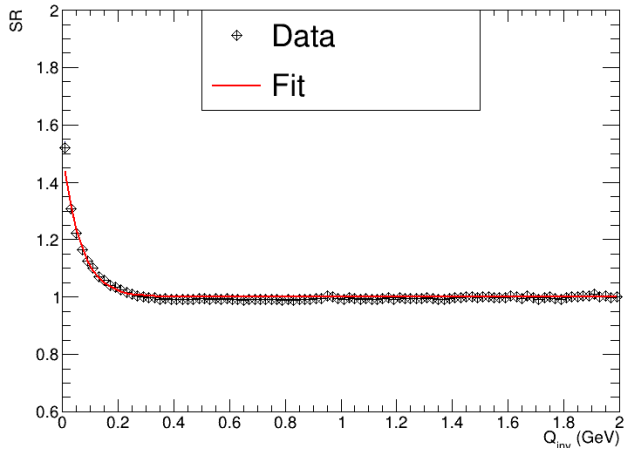
27GeV_Au-Au



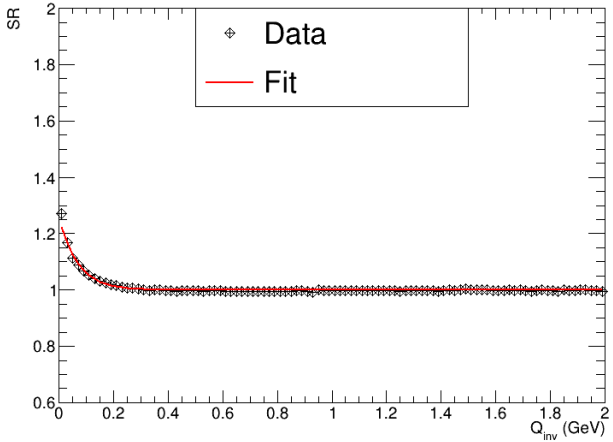
39GeV_Au-Au



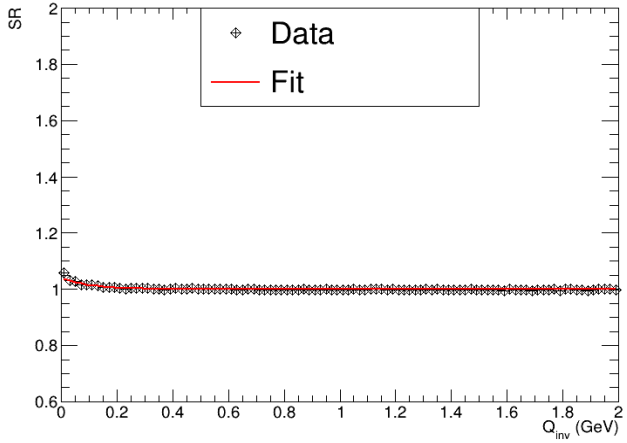
62.4GeV_Au-Au



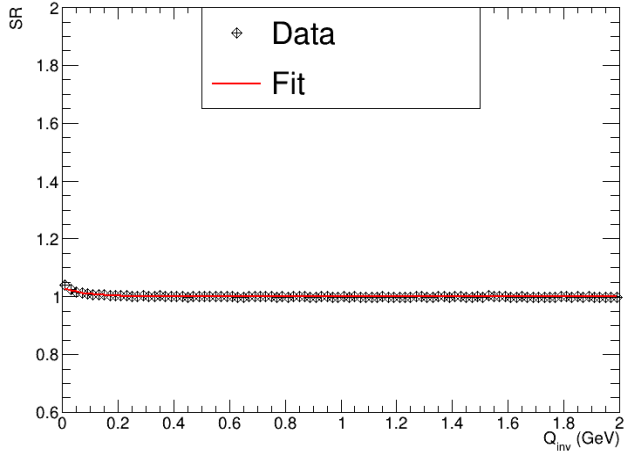
200GeV_Au-Au



2.76TeV_Pb-Pb



5.02TeV_Pb-Pb



Summary & Conclusions

- In P-P collisions and Heavy ion collisions, particles shows the correlations in Pythia8 model, AMPT model does not shows any corelation.
- The correlation strength between particles are weaken with increasing the energy.
- Correlations can be fitted with the Levy fitting parameter.
- R can be calculated from the fitting curves, which provide the size and geometry of the particle-emitting region at the freeze-out stage in high-energy collisions.
- The radius (R) of the source at the freeze-out stage for heavy ions lies between 9.2 to 15.3 fm.

Thank You