High Multiplicity Clustering Using the Barrel Shower Max Detector at STAR

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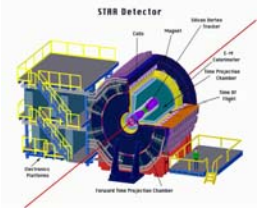
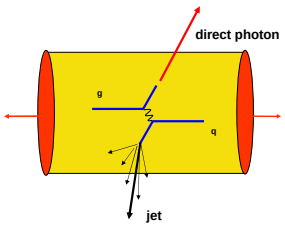
Solenoid Tracker at RHIC - STAR



The goal of RHIC (Relativistic Heavy Ion Collider) is to study matter at extremely high energy densities and temperatures. By colliding two beams of gold nuclei head on at 99.995% the speed of light, matter is created that is so dense that quarks and gluons become deconfined in what is known as the Quark Gluon Plasma (QGP). The STAR detector offers 4π coverage with a number of subsystems which can be used to gather data from these collisions.

γ-Jet Analysis

• During the initial collisions, before the medium evolves into a QGP, hard scattering can occur resulting in back-to-back partons with a large amount of energy. In some cases, a (direct) photon can be produced back-to-back with a parton.



• The hard-scattered parton fragments into a "jet" (or cone) of hadrons.

• As the jet moves through the evolving medium, it loses energy. Since the direct photon does not interact via the strong force, it moves through the medium unaffected.

• The initial energy of the jet can be taken to be equal to the energy of the direct photon. By measuring energy loss of the jet, it can be determined how the parton was affected by the medium.

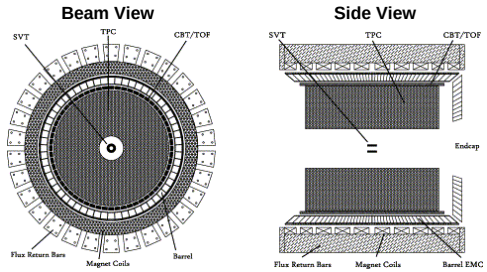
π^0 Decay

To perform such an analysis, direct photons must be distinguished from background photons, which are dominated by the decay of π^0 into two photons. At high π^0 energy, the two photons are produced with a small opening angle.

In heavy-ion collisions this becomes a challenging task because of the enormous amount of background. A clustering algorithm should be optimized for a high-multiplicity environment.

Barrel Electromagnetic Calorimeter

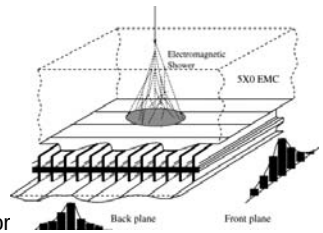
Using the unique structure of STAR's Barrel Shower Max Detector (BSMD), located in the Barrel Electromagnetic Calorimeter, a clustering algorithm was developed which is well suited for heavy-ion collisions.



The BEMC consists of 120 modules, which cover a range of $-1<\eta<1$ and $0<\varphi<2\pi$. Each module is divided into 40 towers. These towers are made up of 21 layers of scintillator and 20 layers of lead.

Barrel Shower Max Detector

• The BSMD is located within the tower at a depth of 5.6 radiation lengths after 5 layers of lead and scintillator. Each of the 120 modules is further subdivided in the BSMD giving a total of 18000 η segments and 18000 φ segments.



• This position resolution is optimal for high-multiplicity clustering because it allows precise location of photon energies within the tower.

How the Algorithm Works

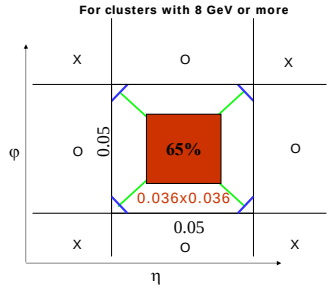
• The algorithm begins by searching through η and φ strips to find energies above a predefined threshold, and then identifies the tower which contains the strips with the highest energy above threshold.

• Once the hit is found, the eight nearest towers are considered.

• The positions of these towers are compared to find the neighboring tower nearest to the registered hit.

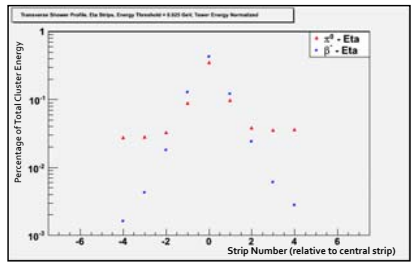
• The location of the hit is determined using the high position resolution of the BSMD. Based on this information, the algorithm decides whether to use strip data from 1 or 2 towers

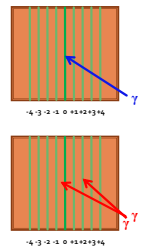
Schematic of Central Tower and 8 Neighboring Towers



Transverse Shower Profile

• From the information gathered by the strips, a transverse shower profile is generated with high enough resolution that decay photons can be separated from direct photons.





• This graph shows a simulated energy profile around the central strip for π^0 photons and a direct photon.

Code Modularization

Improvements made for implementation into the STAR library:

- Replaced 48 if statements with 2 do while loops.
- Gave the user an option to define threshold energy and eliminated hard-coded values as well as redundant loops.
- Used pre-defined functions to replace 10 if-statements.
- Created a structure which made it possible to replace 117 variables with a 3x3 array and eliminate 24 if-statements.

Benefits of work:

- Flexibility for individual use.
- Improved readability.
- Compliance with STAR coding standards.