Strangelet search at RHIC

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Abstract. Two position sensitive Shower Maximum Detector (SMDs) for Zero-Degree Calorimeters (ZDCs) were installed by STAR before run 2004 at both upstream and downstream from the interaction point along the beam axis where particles with small rigidity are swept away by strong magnetic field. The ZDC-SMDs provides information about neutral energy deposition as a function of transverse position in ZDCs. We report the preliminary results of strangelet search from a triggered data-set sampling 100 million Au+Au collisions at top RHIC energy.

Strange Quark Matter (SQM) is a hypothetical state that consists of approximately equal numbers of $u$, $d$ and $s$ quarks. It has lower energy than ordinary nuclear matter that we are familiar with, thus it might be the true ground state of baryonic matter \cite{1,2} and absolutely stable. The search for small lumps of SQM (“strangelets”) has been performed on earth and in cosmos \cite{3}, as well in heavy ion experiments \cite{4}. So far its existence is not confirmed.

In heavy ion experiments, there are three models of strangelet production mechanism, namely, coalescence \cite{5}, statistical thermal production \cite{6} and distillation \cite{7} via the created Quark Gluon Plasma (QGP). The first two models usually yield lower strangelet cross section than the last one. In the distillation process, if a QGP is created in the hot and dense fireball of heavy ion collisions, it could lose energy by meson-emission (distillation) and end up with a matter in its ground state – strangelet.

Since a strangelet consists of approximately equal numbers of $u$, $d$ and $s$ quarks, it can have a large baryon number and, a much lower charge-over-mass ratio than an ordinary nucleus. At RHIC experiments, if a strangelet is produced in central Au+Au collisions where a QGP is expected to be created, it will deposit a large signal in one of the Zero Degree Calorimeters (ZDCs) \cite{8}. Particles with small rigidity are swept away by strong magnetic field produced by the dipole magnets, which are located in front of ZDCs and are used to bend beams. Only neutral or close-to-neutral particles, like strangelets, can survive the strong magnetic field and reach ZDCs. At ZDCs, the acceptance of strangelets depends on their rigidities and transverse momentum, and, because of the rectangular shape of ZDCs, slightly depends on their emitted azimuthal angles. The left panel of Figure \ref{fig:acceptance} shows an example of the acceptance. Although our set up requires a strangelet to have large rigidity in order to be detected, it requires

‡ For the full author list and acknowledgements see Appendix ”Collaborations” in this volume.
loosely on strangelet’s proper life time. The right panel of Figure 1 shows our sensitivity
to strangelets’ proper life time, as a function of mass. While most efforts of strangelet
search in heavy ion experiments look for strangelets with proper life time > 50 ns, we
can detect strangelets that live much shorter than that. It is also worth to note that this
is the first time to search for strangelet at RHIC energies, which, in the center of mass
frame, are at least four times larger than energies of strangelet search experiments done
in the past. The other difference between our efforts and past experiments is that, we
focus at very forward production while most other experiments looked for strangelets
around mid-rapidities.

![Figure 1](image)

**Figure 1.** (left) Acceptance at ZDCs particles with a azimuthal angle of 180 degrees
in laboratory. (right) ZDCs’ sensitivity to strangelets’ proper life time, as a function
of mass.

Note that a cluster of neutrons can give large signal in ZDC just like strangelets
do, but the signals from neutron clusters are more dispersed due to the fer mi motion of
spectator neutrons. This is shown by the Geant simulation in Figure 2. In the Figure,
the hits deposition in one layer of the ZDC (out of 260 in total) is projected to the Y
axis (both X and Y axes are perpendicular to the beam direction). Due to the normal
$p_T$ distribution among spectator neutrons, the hits are dispersed along the Y axis. The
same simulation repeated for a strangelet shows a prominent peak and less dispersion
(right panel). Thus one can distinguish a strangelet event from normal events if, in
addition to the total energy deposit in ZDCs, the transverse position information of
energy deposition at ZDCs can be obtained.

In the Fall of 2003 STAR installed Shower Maximum Detectors (SMD) sandwiched
(same acceptance as ZDCs) in between the first and second modules of each existing
STAR ZDCs. Each SMD (east and west) consists of two scintillating plastic planes, one
of 7 vertical slats of and another of 8 horizontal slats. These two SMDs provide event-
by-event information on the transverse position of the spectator neutrons produced in
the collision thus allow us to perform the strangelet search. Besides strangelet search,
the installation of ZDC-SMDs was motivated by a few other topics, which are beyond
the interest of this paper, like flow, spin etc.

To maximize the possibility of of strangelet discovery, we select central events
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Figure 2. Simulation of a normal event (left) and a strangelet event (right).

with high ZDC signals. As mentioned above, the strangelet production through the distillation process via the creation of a QGP, which is more likely to happen in central events, is expected to have larger chance than the other two processes. Another reason of doing so is that ZDC signals for normal central events are less saturated, which makes it easy to identify an events with abnormally high ZDC signals. During run 2004 two special triggers for strangelet search were implemented. The trigger conditions at level zero (L0) are that, the signal from Central Trigger Barrel (CTB) has to be greater than 23000 counts to select central events, and the sum of both ZDCs (east and west) signals has to be greater than 130 counts to select events that have large energy deposition in ZDCs. The total rejection obtained with this trigger is 99.97% over minimum bias events. In addition to the L0 trigger, a level three (L3) trigger was implemented to reject 70% of the events that have passed the L0 trigger. The L3 trigger is done by the following: for each ZDC, on the graph of ZDC signal versus total CTB sum, a curve is made above the band that consists of minimum bias events, with the curvature following the shape of the band. Events that appear to be below the curve are rejected. The curve can be shifted up and down to tighten or loosen the rejection. In total we have recorded 167k events with the L3 trigger, so far only 11.6k (7% of the total) of them are reconstructed by the data production chain of STAR. For those events that are reconstructed, a Quality Assurance (QA) cut is applied to remove possible events from pile-up. The QA cut is made as the following: On the distribution of difference between the reconstructed position of primary z vertex (along the beam line) from offline tracking, and that from the timing information recorded by the Beam Beam Counters (BBCs), events that appear to be two sigma (from the gaussian fit on the same distribution for normal events) away from zero are rejected. This cut reduces the
The final result is presented in Figure 3. The plot shows the distribution of rms from SMD in Y direction versus that in X direction. If a strangelet is created in the collision and reaches one of the ZDC-SMDs, it is expected to produce a spike in SMD and show up in the bottom-left corner in one of the two panels. However, the plot shows that the rms distribution for both SMDs are well converged, no events with abnormally low rms are observed. Based on that, collecting our events number and trigger rejections, we set a upper limit of $2 \times 10^{-8}$ with 90% confidence level for the strangelet production in forward region at RHIC. Since the plot is based on only 7% of the total statistics obtained, we might tighten that limit further in the future.

In summary, we have demonstrated the capability of STAR for strangelet search, with the recently installed ZDC-SMDs. Based on 7% of the total statistics obtained during run 2004, we set up a upper limit for strangelet production of $2 \times 10^{-8}$ with 90% confidence level. This is the first attempt at a strangelet search at RHIC.

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