Introduction to Level-1 Analysis for the STAR Detector Trigger System

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1 Introduction

This short document is intended to provide an introduction to the development program for level 1 trigger algorithms. I describe here a developing analysis chain which is being used to test trigger algorithms for functionality and to investigate their effectiveness in increasing physics information density in the STAR detector data stream.

In general terms we are presently manipulating momentum transport 'by hand' in one or more collision event generators based on a few simple models for possible anomalous QCD behavior in nucleus-nucleus collisions. Special events generated in this way, and ordinary events for comparison, then pass through a GEANT detector model to produce a hit distribution in the trigger detector system.

The hit distributions are binned according to some binning model related to detector structures to form multiplicity distributions. These distributions are then passed through an autocorrelation and power spectrum analysis in which an attempt is made to minimize the system response to 'ordinary' events. The collection of ordinary events or its parametric representation is called the null hypothesis.

Features of the power spectrum such as statistical quantities are then used to form various 'pattern spaces.' These are two or more dimensional spaces in which it is hoped that special events can be distinguished from ordinary events in a quantitative way, and in such a way as to provide information on the details of the anomalous QCD process which produced them.

Finally, by defining special regions of acceptance within a pattern space we can define a flexible trigger criterion which is fast and which permits emphasis within the data stream on certain classes of exceptional events.

Initial efforts have emphasized analysis of one-dimensional multiplicity distributions. It is expected that much of this work can be carried over to two-dimensional multiplicity and energy distributions, especially applicable for EM calorimeter data.

2 Collision Models and QCD Anomalies

Standard collision models are represented by the various phenomenological event generators currently available (FRITIOF, VENUS, HIJET, HIJING, RQMD, etc.). At this time none of these models predicts 'anomalous' QCD behavior which might arise from emergent nonperturbative QCD processes. The generators are based on perturbative QCD theory and simple models of color string dynamics, and have been tuned on data from a variety of collision systems not expected to exhibit anomalous QCD effects because of low particle or energy densities. They differ quantitatively in degree of momentum stopping, heavy quark production, particle distributions, etc. The output of a generator is a particle list.

In some sense which is not yet very clear we want to be sensitive to emergent QCD phenomena within the collision process which begin to occur at sufficiently high particle/energy density. This includes characteristics of the color confinement-deconfinement phase transition, anomalous stopping on the gluon field, emergent structure due to the nonabelian property of the gluon field, etc. This is related to the increase and flow of entropy among color fields during the collision.

In Fig. 1 the 'QCD model space' represents a collection of possible scenarios for production of anomalous QCD behavior. We hope that although initially this collection is somewhat *ad hoc* this model set will increase in sophistication and eventually become part of an elaboration of the event generator system. Each anomaly model must be parameterized in a clear way in order to fully test quantitatively the trigger system sensitivity to the model. A sample of various QCD anomalies are then produced from each model and added to the event generator process in a manner consistent with more fundamental physical principles such as perturbative QCD and thermodynamics.

3 The Trigger Detector Simulation

The particle list (including particle properties such as momentum and decay scheme) serves as input to a Monte Carlo (MC) simulation of the detector system, of which certain fast particle detectors constitute the trigger system detectors. The standard detector response simulation MC code is GEANT, which contains particle decay properties, interaction cross sections, energy loss models and a data base containing the geometrical and material specifications for a specific detector system. The considerable output from GEANT includes specification of particle trajectories, secondary particle production, and hits made by particles in detector segments. Hit locations are specified by the parameters η and ϕ where ϕ is simply the azimuth angle about the collision axis, and the pseudorapidity η is a dimensionless coordinate which approximates the relativistic rapidity parameter y over part of its range and is a direct measure of the polar angle of emission of a particle, with η=0 on the plane normal to the collision axis through the collision vertex.

Part of the development task for the trigger system analysis chain is the process of proper modeling of trigger detector responses. Trigger detector contributions to efficiency and variance production must be carefully modeled to minimize information loss and incorporation of bias.

4 Binning

The distribution of particle hits on trigger detectors is specified in principle on the two-dimensional space (η,ϕ). For any further processing this distribution must be binned. Binning may occur in part automatically as a result of detector segmentation, or it may be carried out within an analysis algorithm, or there may be some combination of these two methods. The details of the binning, including the bin distribution on (η,ϕ), constitute the binning model. In principle there is an optimum binning arrangement, depending on the nature of the information anticipated in the particle hit distribution. Optimum binning is usually not attainable because of basic limitations in the detector system.

5 The Multiplicity Distribution

The set of numbers which result from binning the particle hit distribution is the multiplicity distribution, which is also defined on the same two-dimensional space (η,ϕ), but at discrete values of the two indices. This distribution forms the basis for subsequent analysis leading up to the trigger decision. The presumption is that an ordinary event (part of the null hypothesis) will produce a multiplicity distribution that, within some statistical variation, is consistent with the null hypothesis representation. What one would like to emphasize is those events whose multiplicity distribution differs significantly from that of an ordinary event. Thus, one looks for an analysis which results in a measure of distance between the event in question and the set of ordinary events. It is desirable that this measure of distance be as nonspecific as possible so as to minimize bias. It is further desirable that the measure of distance be defined on a space of some reasonable complexity so as to be able to distinguish a number of details of any QCD anomaly mechanism.

6 Correlation Analysis

An autocorrelation analysis is performed on the multiplicity distribution. The basic purpose of such an analysis is to determine the degree of internal structure in the multiplicity distribution, where minimum structure would correspond to a random distribution of hits. To emphasize the presence or absence of structure a differential autocorrelation is defined. The purpose is to define a quantity which is minimal in magnitude in the case of a purely random distribution, or one arising from an ordinary event. A significantly nonzero differential autocorrelation indicates that something exceptional has occurred. Further, the differential quantity contains detailed information on the nature of the exception.

7 Power Spectrum Analysis

By carrying out a Fourier transformation on the autocorrelation one obtains the power spectrum of the multiplicity distribution. This usually greatly condenses the representation of any information contained in the multiplicity distribution, and this condensation is the chief motivation for carrying out the transformation. For instance, a 100 bin multiplicity distribution requiring 100 numbers or degrees of freedom for its representation may be completely represented by only a few bins and numbers in the corresponding power spectrum. This example presumes something about the width of the power spectrum of basic information representing the underlying QCD anomaly. We have reason to believe that this width (the band width) is limited. Or in other words we expect to need sensitivity to only a small number of degrees of freedom in the anomaly.

8 Moment Analysis

Optimum extraction of information from the power spectrum will require simulation studies. However, obvious initial parameters to study are the distribution moments and the phase of the distribution. (The phase is nonzero for this 'power spectrum' because a generalized formulation of the autocorrelation is used which is not symmetric about the center, and which therefore results in a complex Fourier transformation.) Various combinations of spectrum moments and phase can be used to define pattern spaces, in which simulation events are distributed as point sets, and in which trigger selection regions can be defined.

9 Pattern Space

These are metric spaces defined in terms of statistics of the power spectrum. In a pattern space we expect events corresponding to the null hypothesis to form a localized point set corresponding to minimal response (such as total power). This volume of the pattern space can be eliminated from the trigger acceptance so that, except for some prescaled rate, these events are rejected from the data stream.

By varying the type of QCD anomaly model, and its parameters, the pattern space may be mapped out for sensitivity to this type of anomaly. Certain pattern space definitions may be more suitable for particular models. It is conceivable that the trigger system may contain definitions of several precalibrated pattern spaces with acceptance cuts defined in each.

Calibration of a pattern space consists of operating the trigger analysis chain with a significant number of events and a sample of model parameters sufficient to make a correspondence or comparison between the pattern space response and the model parameter space.

10 Conclusion

Our goal is to establish an analysis system which can examine charged particle multiplicity distributions and quickly determine whether they are 'interesting' by some standard criteria and with some statistical significance, and if so in what general way they are interesting. The analysis system must be flexible or adaptable so that it can be easily reconfigured on the basis of new information. And the system must be capable of calibration in terms of a set of models so that trigger criteria may be established on a quantitative basis.

The analysis system based on power spectrum analysis is not unique. It is chosen as a beginning because of the great deal of work already done in the area of electrical signal analysis, which has similarity to the multiplicity trigger problem. Other analysis techniques include fractal dimension analysis, maximum entropy analysis, negative binomial distribution analysis, etc. These alternatives will be examined for utility and related to power spectrum analysis during the course of this work.

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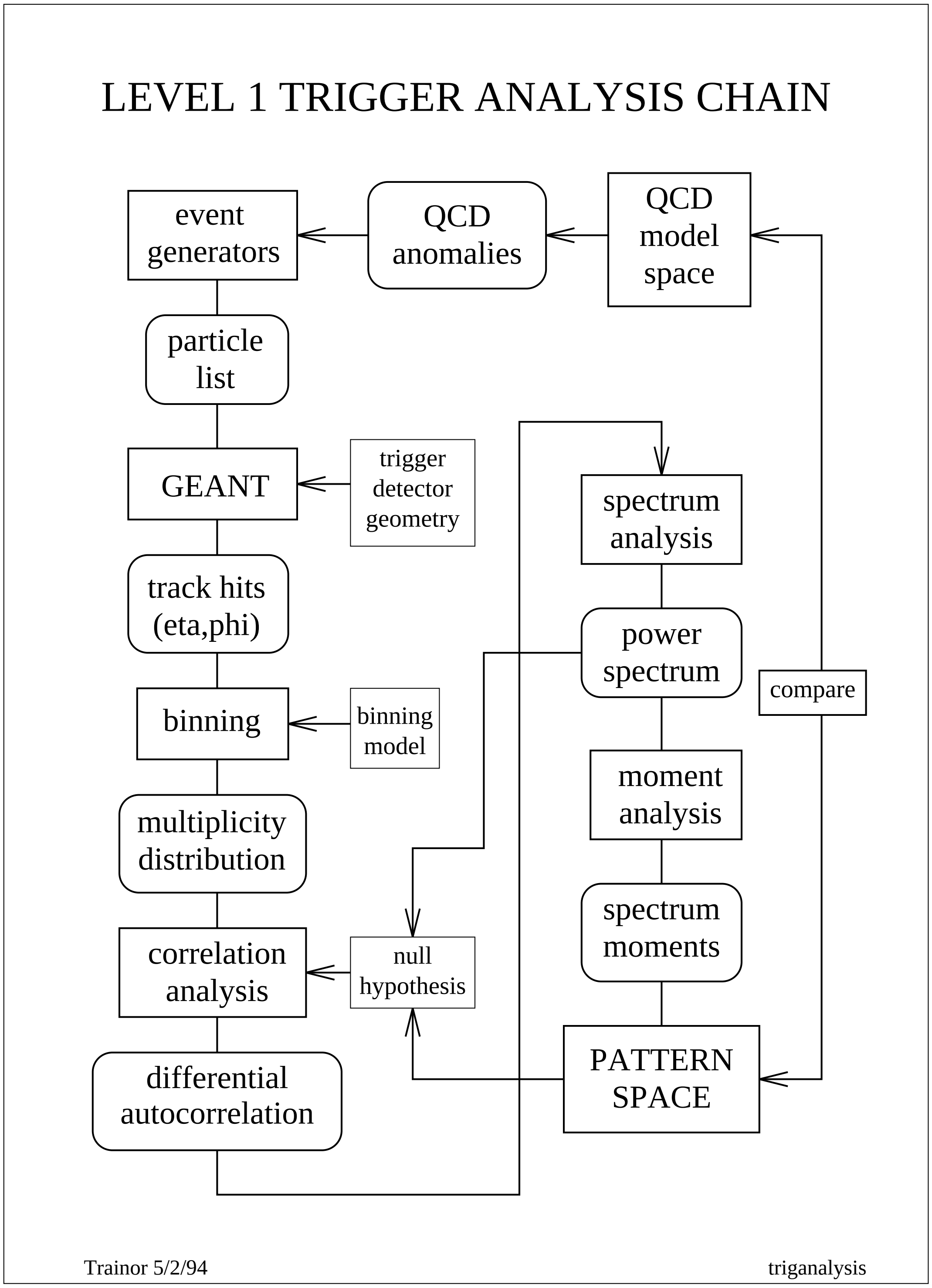
LEVEL 1 TRIGGER ANALYSIS CHAIN
event generators
QCD anomalies
QCD model space
particle list
GEANT
trigger detector geometry
spectrum analysis
track hits (eta,phi)
power spectrum
compare
binning
binning model
moment analysis
multiplicity distribution
spectrum moments
correlation analysis
null hypothesis
differential autocorrelation
PATTERN SPACE
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Figure 1: