STAR Note 326

CTB/TOF Detector Simulation

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Abstract

We have developed software packages to simulate the performance of the TOF and CTB detectors using GSTAR, G2T and the STAF framework. We have simulated the performance of the CTB. Data from testing CTB trays using cosmic rays is compared to simulated results. Multiplicity resolutions for AuAu events are estimated.

Description

The Central Trigger Barrel (CTB) measures the multiplicity of charged particles at the outer radius of the TPC and provides that information to the Level 0 trigger. It consists of 240 scintillators in 120 trays forming a cylindrical cover of the TPC. For a full description see Ref [1]. The Time of Flight system (TOF) extends the dynamic range of particle identification. It consists of trays of identical dimension to the CTB with 50 slats per tray and would replace part or all of the CTB. For a more detailed description see Ref [2].

The physical principles involved in producing and measuring signals in the CTB and the TOF are very similar. The main differences between the two detectors are the dimensions of the scintillators and the readout electronics. Taking into account this similarity, we have chosen to treat both detectors with common software modules. The module control parameters allows us to switch between them. We will refer to this common *software* detector as CTF (Central Time of Flight). The simulation is performed in two steps. The former consists in running the GSTAR/G2T programs. GSTAR is the STAR detector simulation program based on GEANT[3]. It tracks particles produced at the collision point through the STAR detector. GSTAR outputs information about particle hits in the different sensitive parts of the detector. G2T (GEANT to Tables) transforms the GSTAR output into a file with an appropriate format to be read by STAF[4]. The G2T output for CTF is a set of hits of all particles going through the scintillators. Table 1 shows the variables saved for each of the CTF hits. As can be noted, the position and energy deposited are stored among other variables

The second step of the detector simulation process is performed in STAF. It consists in transforming those GEANT hits with physical information into detector signals. These signals should be equivalent to what the CTB/TOF will produce in the actual experiment. For the CTF

[1] www.bonner.rice.edu/bonner/CTBMwwwOct31/CTBM_postFDR.html, *Description of the Central Trigger Barrel*.
[2] www.bonner.rice.edu/star/tof/index.html, *Proposal*, for additional TOF simulation see: P. Yepes, *Time of Flight Performance*, SN 208 (1995); S. Paganis and P. Yepes, *High P_t Physics with the TOF*, SN 209 (1995).
[3] GEANT Simulation Package, CERN Program Library Long Write-up W5013.
[4] STAR: Standard Analysis Framework, http://www.rhic.bnl.gov/STAR/html/ssd_l/staf_l/STAF-current/staf.html.

two STAF packages are needed in this task: the geometry package, CTG, and the detector response simulation package, CTS. CTG defines the geometry parameters needed for the other CTF packages. CTS transforms the GSTAR output into a set of simulated ADC and TDC values.

Variable	*Description*
Id	Primary key
Next_tr_hit_p	Next CTF hit produced by the same track
Track_p	Pointer to track that produced this hit
Volume_id	GEANT Volume Id
De	Deposited Energy
Ds	Track length inside scintillator
P(3)	Track Momentum at CTF
S_track	Track Length at CTF
Tof	Track Time of Flight at CTF
X(3)	Impact spatial coordinates

Table 1: Variables saved for each particle impact in the scintillator of CTF.

There are two procedures to generate the ADC signal. A parameter in the CTS module allows the selection of exponential or parametric response as appropriate. In both cases the resolution of the ADC is 256 channels.

Exponential

The scintillator response is assumed to depend only on the distance from the hit to the photo-mulitiplier. The ADC signal for each scintillator is calculated using the expression:

$$I_{ADC}=D(E_d\ \alpha\ \varepsilon\ S\ \exp\ (\ -\ L\ /\ \lambda\ )$$

where the meaning of the different symbols can be found in Table 2. The symbol D() expresses the digitization of the quantity within brackets. The digitization is performed taking into account the number of channels of the ADC.

Parametric

In this case the ADC signal is calculated according to:

$$I_{ADC}=D(E_d\ \alpha\ \varepsilon\ S\ F(L,z)\ G(t_f)\ )$$

Where:

- F(L,z) is the scintillator response as a function of the longitudinal (L) and transverse (z) position on the scintillator surface. This function, depicted in Figure 1, was obtained from experimental measurements using a radioactive source at Rice University[5].
- G(t) gives the fraction of the signal integrated by the ADC as a function of the time interval between the signal and the gate end. The function was obtained by evaluating the PM signals in test with a radioactive source. G(t) is depicted in Figure 2.

[5] www.bonner.rice.edu/bonner/CTBMwwwOct31/CTB_postFDR.html *Development and Production Testing for 10 Prototype CTB Trays.*

The final step in the ADC signal simulation is common to the two procedures just explained. It consists in adding a pedestal with a certain fluctuation. Pedestals and their widths can be varied for each channel through parameters in the simulation program. The default values are a pedestal with a mean value of 5 channels and a dispersion of half a channel.

	DESCRIPTION	***DEFAULT***
E_d	Deposited Energy	N/A
L	Length from impact to PMT	N/A
t_f	Time of flight	N/A
z	Hit transverse position in scintillator	N/A
α	Conversion from GeV to photons	10^7
ε	Photocathode efficiency	20%
S	Fraction surface seen by PMT	25%
β	Surface losses	27%
λ	Attenuation Length	380 cm
d_s	Inverse speed of light in scintillator	80. ps cm^{-1}
R_g	Random gaussian Distribution	N/A
σ_t	Time resolution parameter	3.0 ps $cm^{-1/2}$

Table 2: Variables used in the simulation of the CTF detector response.

For the TOF, the TDC signal is calculated according to the expression:

$$TDC = D(t_f + d_s\ L + R_g\, \sigma_t\, L^{1/2})$$

Where:

- t_f: particle arrival time at the scintillator,
- L: distance from the scintillator to the PM,
- d_s: inverse of the speed of light in the scintillator,
- R_g: is a random generator with a Gaussian distribution with null mean value and unit width.
- σ_t: Time resolution obtained from test data.
- D: Indicates digitization according to the number of TDC channels.

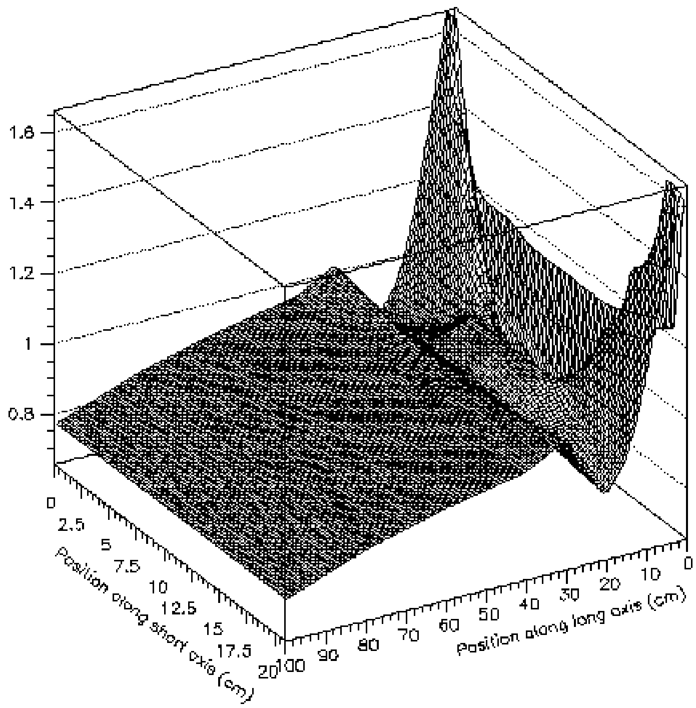

Figure 1: Scintillator response as a function of position.

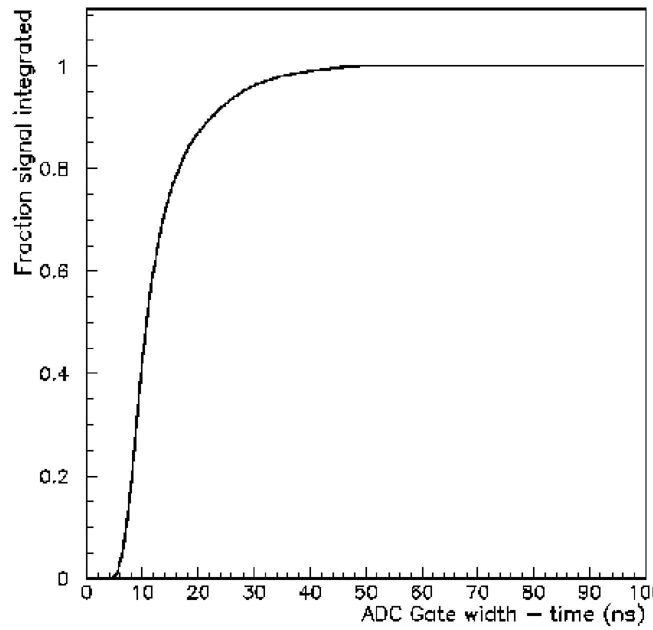

Figure 2: Fraction of the signal integrated as a function of the time interval between the impact and the gate end.

The default values of the parameters are indicated in Table 1. As in the ADC case, the final TDC value is obtained by adding an offset with a fixed mean value and certain dispersion. Both parameters are controllable from the simulation program. The default values are the same as for the ADC case.

Cosmic Ray Test

The first ten trays built at Rice University were tested with cosmic rays. Trays were triggered by the coincidence of two other trays. The trigger trays were placed above and below the tray being tested. A cosmic ray coming down vertically would see a complete overlap of the three scintillators. This setup was simulated with a special geometry file in GSTAR. A set of cosmic rays with the proper energy and angular distribution[6] was generated and processed through the full simulation chain: GSTAR, G2T and CTS. Figure 3 shows the signal amplitude for data and Monte Carlo. There is a reasonable agreement. However as can be observed the Monte Carlo distribution is slightly narrower than the experimental results.

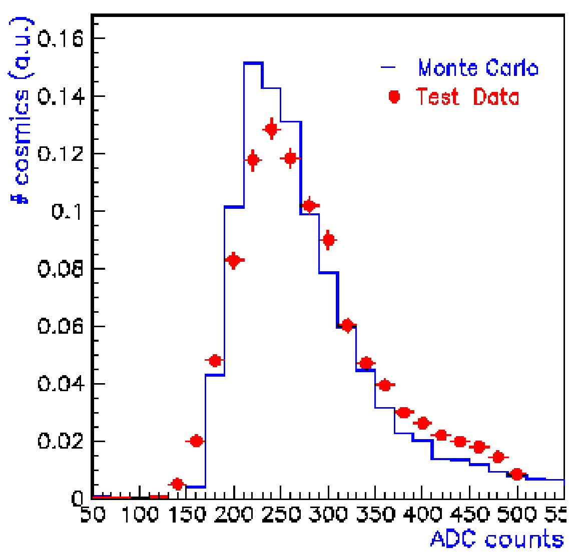

Figure 3: Amplitude of the signal produced by cosmic rays in the CTB trays: data (full circles) and Monte Carlo (histogram).

[6] Eleanor Judd provided the cosmic ray generator.

Heavy Ion Collisions

The CTB response in AuAu collisions at 200 GeV/A center of mass energy was studied utilizing HIJING events. First we have focused on central collisions with an impact parameter, b, smaller than 3 fm. These are the interactions with highest multiplicity. Figure 4 depicts the number of impacts per slat. As can be observed, the distribution peaks at multiplicity ten. The energy deposited in a slat by all particles traversing it is shown in Figure 5.

In this study the true multiplicity, N_t, is defined as the number of primary tracks reaching the CTF. Figure 6 shows N_t versus the measured multiplicity, N_m, for 10,000 HIJING AuAu minimum bias events. The multiplicity resolution, defined as the ratio N_m/N_t, is presented in Figure 8 for central events, b<2 fm. The resolution as a function of multiplicity, number of primary particles reaching the CTB, is presented in Figure 8. As can be observed, the resolution ranges from 18% for multiplicity 100 to 3% for the most central events.

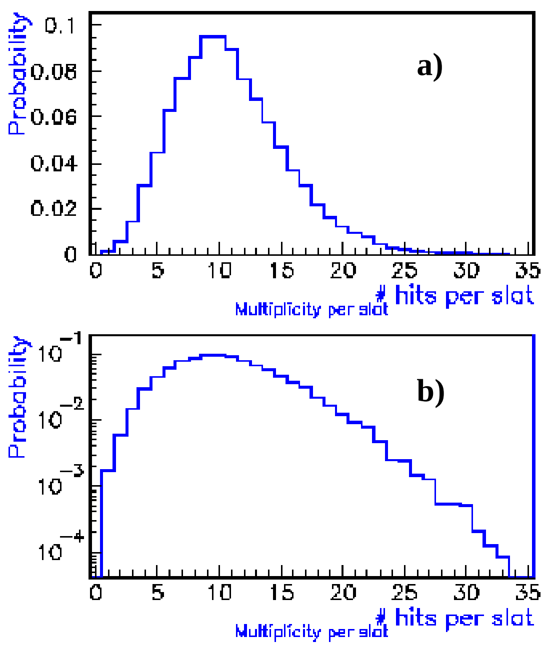

Figure 4: Number of impacts in a CTB slat in central (b<3 fm) AuAu HIJING interactions in linear (a) and logarithmic (b) scales.

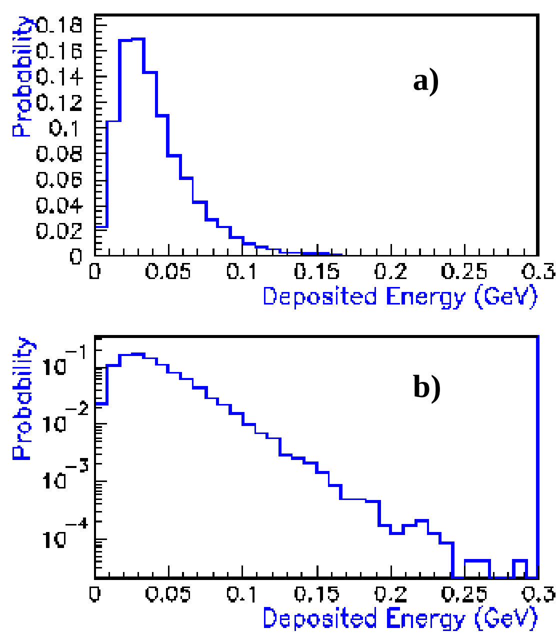

Figure 5: Energy deposited in a CTB slat in central (b<3 fm) AuAu HIJING interactions in linear (a) and logarithmic (b) scales.

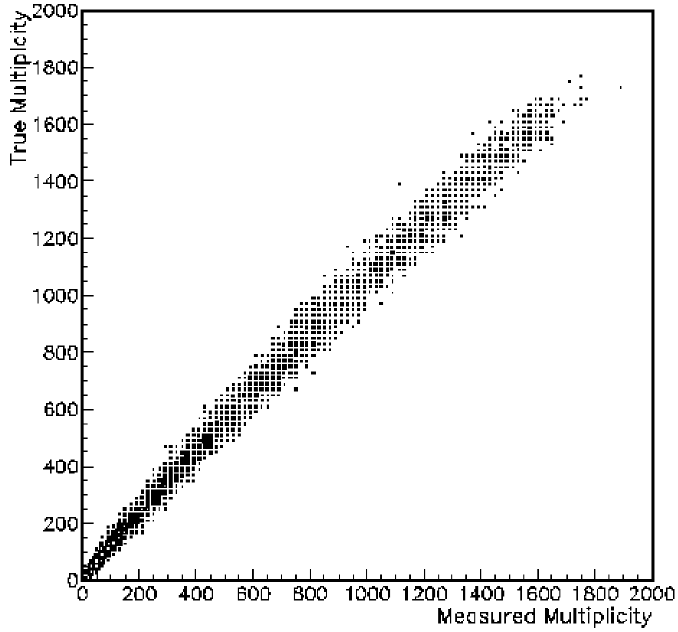

Figure 6: True versus measured multiplicity for minimum bias AuAu HIJING events. True multiplicity is defined as the number of primary particles reaching the CTB.

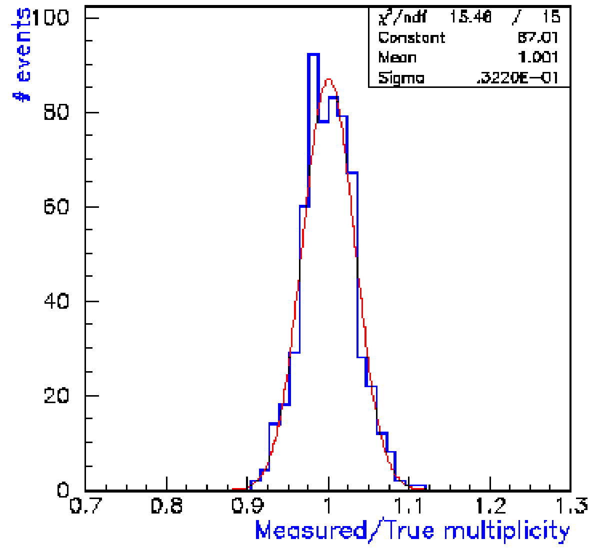

Figure 7: Resolution of true versus measured multiplicity for central (b<3fm) AuAu HIJING events. True multiplicity is defined as the number of primary particles reaching the CTB.

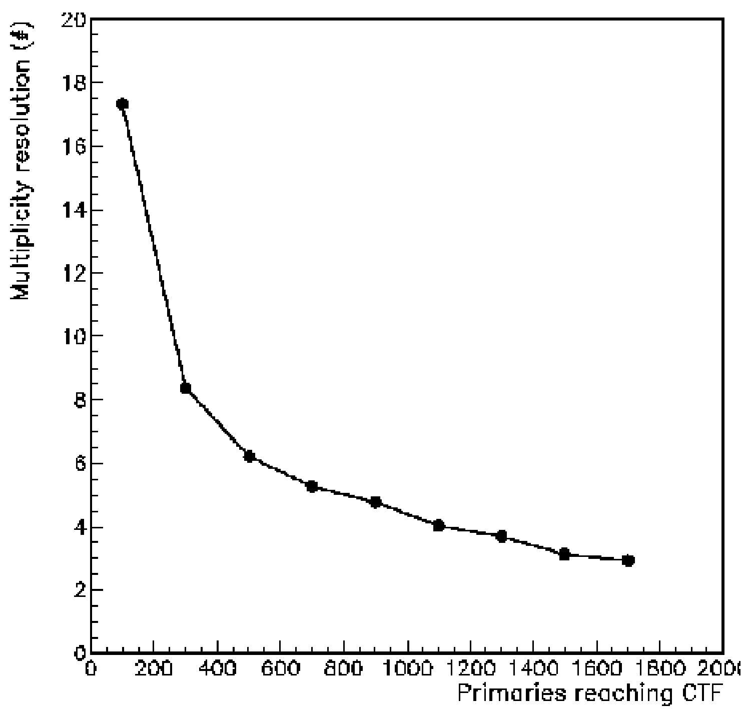

Figure 8: Multiplicity resolution versus the number of primary particles reaching the CTB. A sample of 10,000 minimum bias HIJING was utilized in the calculation.