STAR-Note #123

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Calibration of STAR Zero Degree Calorimeters

High Energy collisions of nuclei usually lead to the emission of evaporation neutrons from both "beam" and "target" nuclei. At the RHIC heavy ion collider with 100GeV/u beam energy, evaporation neutrons diverge by less than 2 milliradians from the beam axis. The purpose of the STAR zero degree calorimeters (ZDC's) is to detect neutrons emitted within this cone along both beam directions and measure their total energy. The ZDC coincidence of the 2 beam directions is a minimal bias selection of heavy ion collisions, which makes it useful as an event trigger. This ZDC coincidence used at level zero in the data stream will greatly enrich the set of events being recorded on tape. Of interest to this work is the calibration of ZDC timing information, used to make the trigger decisions, with z-vertex data obtained by the Time Projection Chamber (TPC).

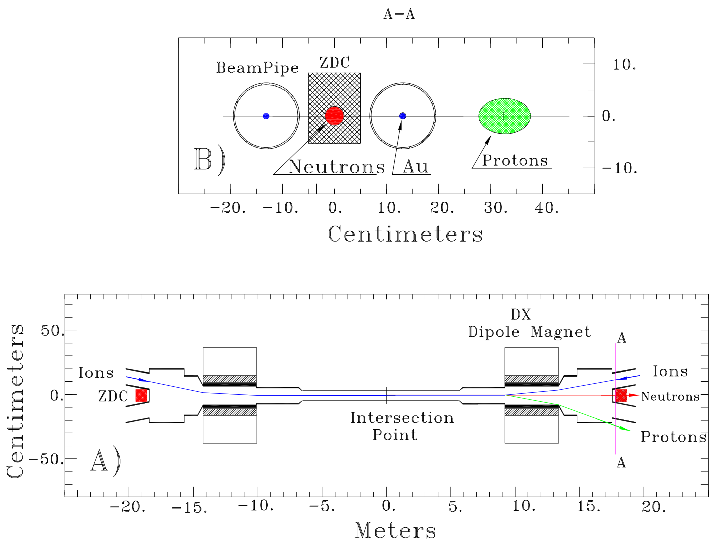

FIG. 1. Plan view of the collision region and "beam's eye" view of the zdc location indicating deflection of protons and charged fragments.

In the event of a high energy collision the evaporated neutrons follow a tangental path with respect to that traced by the beam of ions, as illustrated in fig.1 [1]. These neutrons then impinge on the ZDC in their respective direction, setting off an electrical pulse proportional to their total energy (or the total number of neutrons interacting with the calorimeter). Fig.2 shows how the single neutron peak, occuring in this case at 65 GeV, is clearly distinguished by the ZDC's. This pulse triggers a logic signal when its height exceeds the threshold of a discriminator, and thus initiating time measurements.

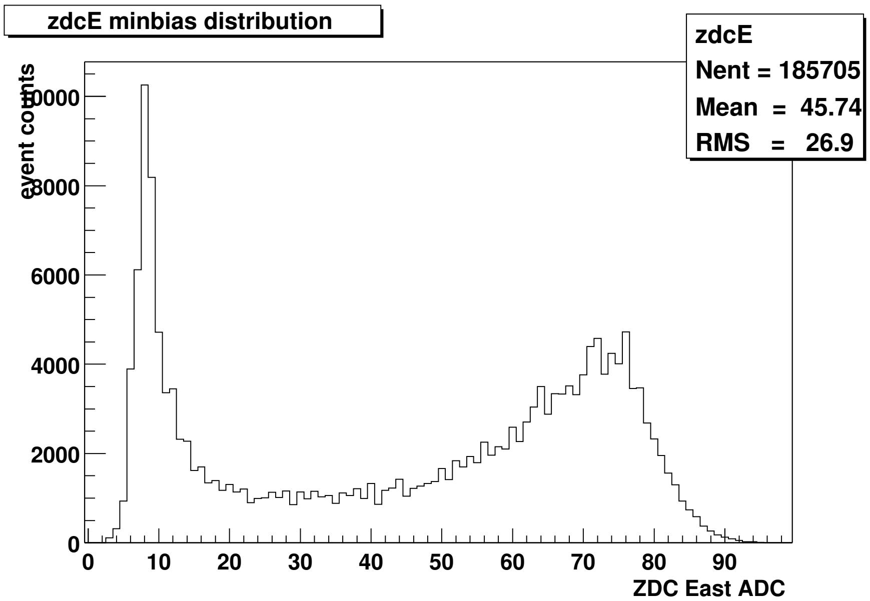

FIG. 2. The histogram shown above was generated by looking at minimum bias runs (without pedestal subtraction). The single neutron peak can be clearly identified by the ZDC's.

As illustrated in fig.3, the initial time in a measurement depends on the strength of the pulse, with a large pulse initiating the time measurement earlier than a small one. This effect is accounted for by performing a Slewing correction, that is, examining the correlation between the time measurement made by the ZDC's (with a factor subtracted to remove dependence on vertex position along the z-axis) and the strength of their respective pulses. After executing the correction, a correspondence between z-vertex data from the TPC and the time

difference between the east and west ZDC's is established.

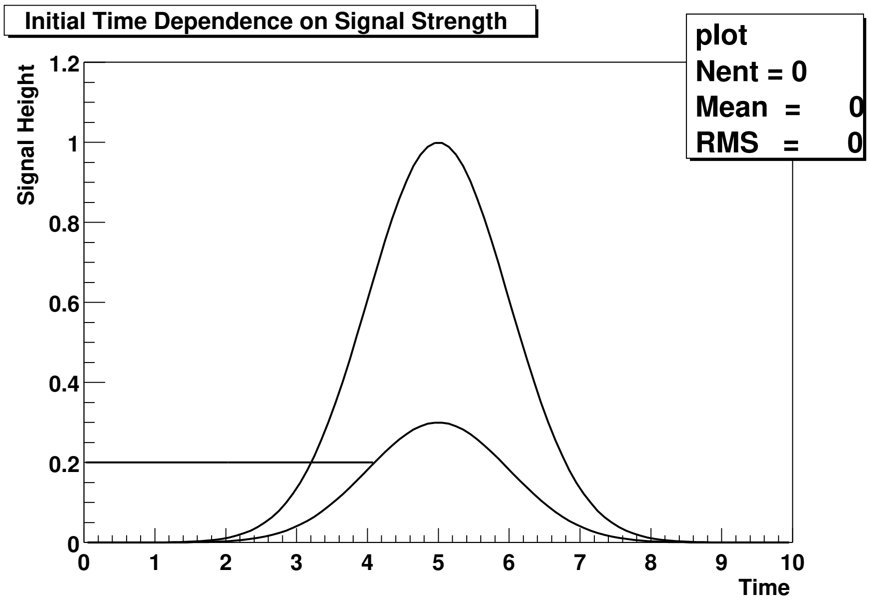

FIG. 3. The horizontal line indicates the threshold strength at which time measurements are initiated.

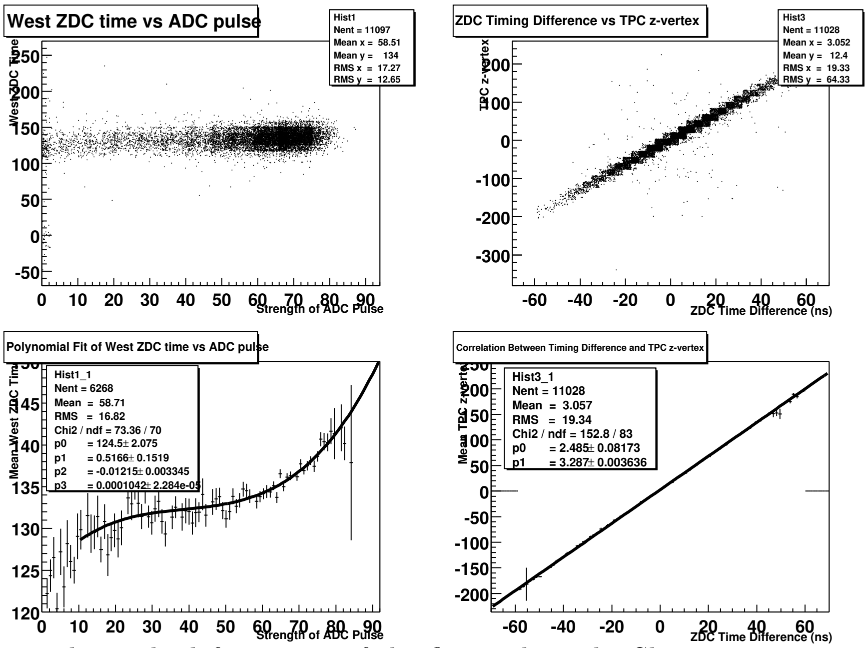

FIG. 4. The panels on the left portion of the figure show the Slewing correction. Those on the right portion of the figure show how the correspondence between ZDC timing information and TPC z-vertex position is established.

Using the time difference between east and west ZDC's in conjunction with the parameters obtained in the calibration, we can then calculate the position of primary vertices along the z-axis as determined by the ZDC's. Fig.4 shows some of the steps taken in the calibration procedure. A more detailed summary of the calibration procedure is given in the Appendix at the back of this paper.

The difference between the z-vertex determined by the TPC and the z-vertex determined using ZDC time information can serve as good measure of the resolution capabilities of the ZDC. Fig.5 shows the distribution of the difference between the two subsystems (run 204), before performing the calibration, exhibiting a σ_z = 6.93 cm. After carrying out the calibration procedure a σ_z = 3.18 cm is observed (run 204), as shown in fig.6, which pertains to an increase in resolution by more than 50%.

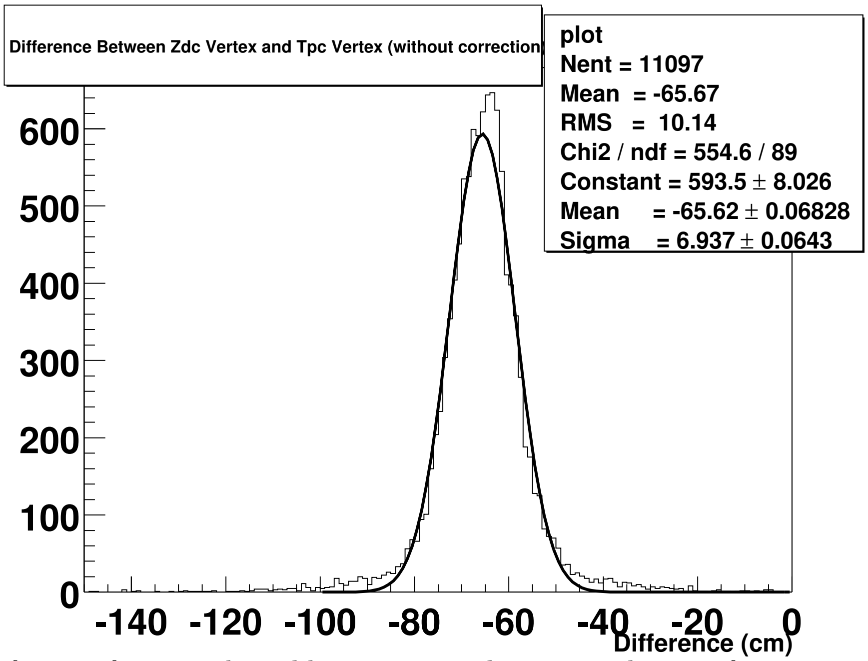

FIG. 5. Before performing the calibration procedure, a resolution of 6.93 cm is obtained.

The z-vertex determined by the ZDC's, with a resolution on the order of a few centimeters, is a very important measurement for the STAR experimental physics program. Users will be able to select events that occur near z = 0 cm,

allowing for the same acceptance on the left and right portions of the STAR detector. Maximizing acceptance will insure that most of the detector volume of STAR calorimeter subsystems, such as Silicon Vertex Tracker (SVT), is used. The SVT has inner layers up to $| z | = 12$ cm, thus having virtually no acceptance for collisions outside this range of z.

The TPC's ability to determine the location of primary vertices is very limited for peripheral collisions, where the number of tracks produced is very low. For these low multiplicity events, ZDC's will still be able to make accurate measurements and therefore improving the efficiency for finding primary vertices.

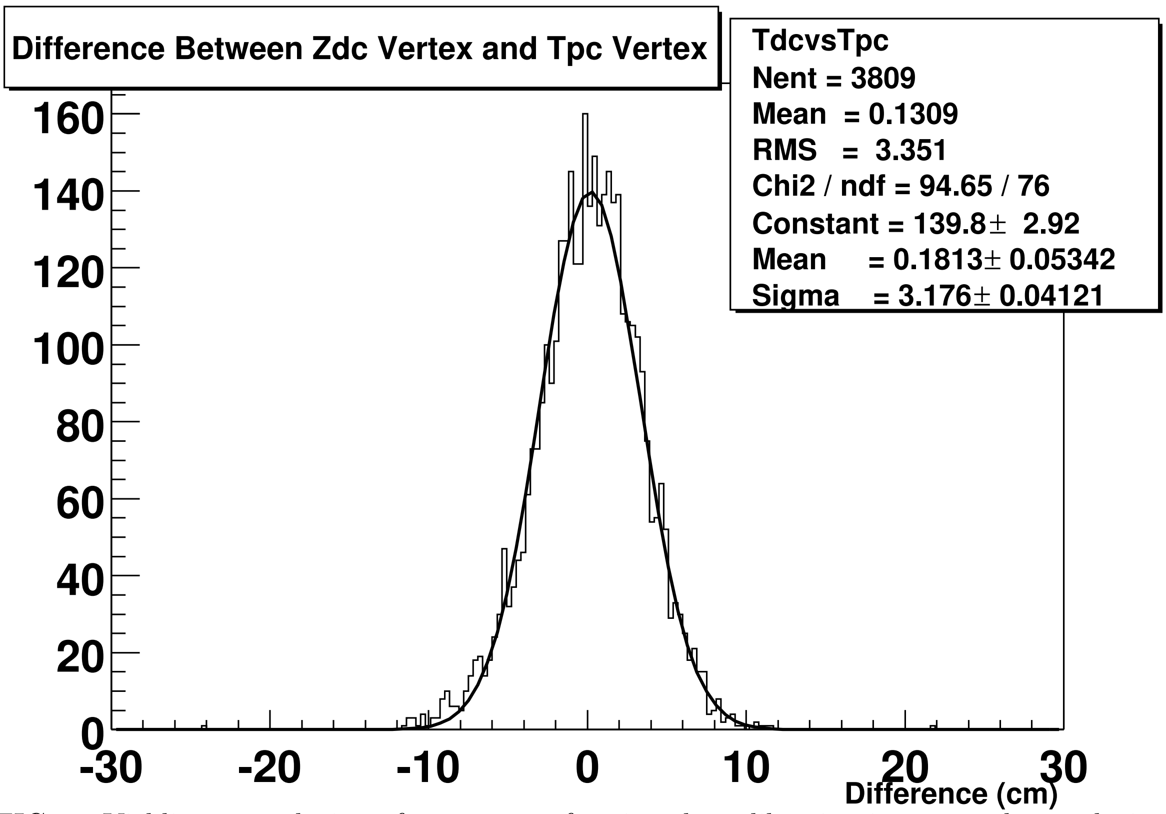

FIG. 6. Yielding a resolution of 3.18cm, performing the calibration improves the resolution by more than 50%.

Appendix

The calibration procedure was carried out for a number of runs. Table I lists the ten calibration parameters obtained for each calibration. The parameters EAP0, EAP1, EAP2, EAP3, WAP0, WAP1, WAP2, WAP3 were generated by applying the Slewing correction to the east and west ZDC's, respectively. Parameters VPAR and OFF establish the correspondence between the timing difference from the ZDC's and the TPC z-vertex. The resolution is listed for each calibration as well.

Table I. Calibration Parameters and Resolution.

Run	EAP0	EAP1	EAP2	EAP3	WAP0	WAP1	WAP2	WAP3	VPAR	OFF	Res(cm)
204	145.87	0.316	-0.0060	5.29e-05	124.46	0.53	-0.0122	0.0001	3.29	1.98	3.176
210	166.59	0.98	-0.019	0.00013	151.97	0.529	-0.010	7.78e-05	3.306	-4.086	3.883
212	133.54	0.627	-0.013	0.00010	117.28	0.632	-0.014	0.00011	3.32	2.94	4.379
218	118.71	1.95	-0.0518	0.00045	120.33	-0.15	0.0030	6.9e-06	3.338	-5.36	4.184
220	131.61	0.761	-0.0200	0.00018	112.96	0.56	-0.016	0.0001	3.32	2.13	3.556

Table II outlines the cuts used to generate the calibration parameters for each run. The parameters tE_{min}, tW_{min}, aE_{min}, and aW_{min} pertain to minimum values imposed on the time and ADC pulses from the east and west ZDC's. With the parameter $|z|$ we require that events occur between a certain region along the z-axis. The parameters ctW_{min}, ctW_{max}, ctE_{min}, ctE_{max} pertain to values imposed on the expression (*time*-z/3.3), which is used to look at the correlation between the time and the strength of the ADC signals, where *time* corresponds to the TDC pulse from east and west ZDC's. The parameter *delta* pertains to the requirement imposed on the absolute value of the corrected time difference between the east and west ZDC's. Finally, *diag* corresponds to the absolute value of the expression (*time**3.3 - z), where *time* corresponds to the corrected time difference between the east and west ZDC's.

Table II. Cuts used to generate calibration parameters.

Run	tE_{min}	tW_{min}	aE_{min}	aW_{min}	$\|z\|$(cm)	ctW_{min}	ctW_{max}	ctE_{min}	ctE_{max}	delta	diag
204	20	20	10	10	30	110	160	130	180	60	60
210	20	20	10	10	22	140	180	100	260	45	60
212	20	20	10	10	35	110	150	80	230	60	25
218	20	20	10	10	20	90	140	90	180	60	40
220	20	20	10	10	30	100	140	110	170	60	30

[1] Clemens Adler, Alexei Denisov, Edmundo Garcia, Michael Murray, Herbert Strobele, Sebastian White. THE RHIC ZERO DEGREE CALORIMETER, Nucl. Instrum. Meth. A461:337-340,2001.