Nuclear Instruments and Methods in Physics Research A 759 (2014) 23–28

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

The STAR Vertex Position Detector

W.J. Llope [a,*], J. Zhou [a], T. Nussbaum [a], G.W. Hoffmann [b], K. Asselta [c], J.D. Brandenburg [a], J. Butterworth [a], T. Camarda [c], W. Christie [c], H.J. Crawford [d], X. Dong [e], J. Engelage [d], G. Eppley [a], F. Geurts [a], J. Hammond [c], E. Judd [d], D.L. McDonald [a], C. Perkins [d], L. Ruan [c], J. Scheblein [c], J.J. Schambach [b], R. Soja [c], K. Xin [a], C. Yang [f]

[a] Rice University, Houston, TX 77005, United States
[b] University of Texas, Austin, TX 78712, United States
[c] Brookhaven National Laboratory, Upton, NY 11973, United States
[d] University of California, Berkeley, CA 94720, United States
[e] Lawrence Berkeley National Laboratory, Berkeley, CA 94720, United States
[f] University of Science & Technology of China, Hefei 230026, China

ARTICLE INFO

Article history:
Received 26 March 2014
Received in revised form
15 April 2014
Accepted 29 April 2014
Available online 14 May 2014

Keywords:
Vertex Position Detector
Time resolution
fast timing
STAR experiment
RHIC

ABSTRACT

The 2×3 channel pseudo Vertex Position Detector (pVPD) in the STAR experiment at RHIC has been upgraded to a 2×19 channel detector in the same acceptance, called the Vertex Position Detector (VPD). This detector is fully integrated into the STAR trigger system and provides the primary input to the minimum-bias trigger in Au+Au collisions. The information from the detector is used both in the STAR Level-0 trigger and offline to measure the location of the primary collision vertex along the beam pipe and the event "start time" needed by other fast-timing detectors in STAR. The offline timing resolution of single detector channels in full-energy Au+Au collisions is ~100 ps, resulting in a start time resolution of a few tens of picoseconds and a resolution on the primary vertex location of ~1 cm.

1. Introduction

In full-energy, $\sqrt{s_{NN}} = 200$ GeV, Au+Au collisions at the Relativistic Heavy-Ion Collider (RHIC), pulses of tens to hundreds of photons from π^0 decays stream outwards from the primary collision vertex at the speed of light and very close to the beam pipe. A detector capable of measuring the arrival times of these photons can thus provide important information for event triggering, especially on the location of the primary vertex along the beam pipe, and on the time that the event occurred relative to free-running master clocks used by other fast timing detectors in the experiment. In the Solenoidal Tracker at RHIC (STAR) [1], the first detector capable of such measurements that was implemented was the "pseudo Vertex Position Detector" (pVPD) [2]. This system consisted of two identical assemblies of three readout detectors, one on each side of STAR (east and west), with each assembly mounted immediately outside the beam pipe. The pVPD worked well in full-energy Au+Au collisions [2]. However, for lighter beams such as p+p and also Au+Au beams at lower beam energies, the efficiency of the pVPD for providing the vertex location and the event time degraded due to the relatively lower multiplicities of very forward prompt particles in such collisions. To address this, the pVPD was upgraded to increase the readout detector channel count on each side of STAR in the same acceptance. This detector is called the Vertex Position Detector (VPD).

Unlike the pVPD, the VPD has been fully integrated into the STAR trigger system. The VPD provides the primary detector input to the STAR minimum bias trigger in A+A collisions. Each VPD assembly measures up to nineteen times in each event. These times are thus available, both online and offline, to measure the location of the primary vertex along the beam pipe, Z_{vtx}, via the following equation:

$$Z_{vtx} = c(T_{east} - T_{west})/2 \tag{1}$$

where T_{east} and T_{west} are the times from each of the two VPD assemblies and c is the speed of light. The event "start time," which is needed by the STAR Time-of-Flight (TOF) and Muon Telescope Detector (MTD) [3] systems to perform particle identification at mid-rapidity, is given by

$$T_{start} = (T_{east} + T_{west})/2 - L/c \tag{2}$$

where L is the distance from either assembly to the center of STAR.

One motivation for the increased channel count from the pVPD to the VPD in the same angular acceptance was to increase the efficiency of the detector for recording hits in single events. Another important motivation involves the fact that the

* Corresponding author.
E-mail address: llope@rice.edu (W.J. Llope).

http://dx.doi.org/10.1016/j.nima.2014.04.080
0168-9002/

experimental resolution on either T_{east} or T_{west} used in Eqs. (1) and (2) improves like $1/\sqrt{N}$, where N is the number of channels on each side that were hit by prompt particles. That is, taking T_{east} or T_{west} as the average over all channels hit by prompt particles in an event results in a resolution on, *e.g.*, Z_{vtx}, given by

$$\sigma(Z_{vtx}) = (c/2)\sigma_{\Delta T} = (c/\sqrt{2})\sigma_T = (c/\sqrt{2})\sigma_0/\sqrt{N} \quad (3)$$

where T is T_{east} or T_{west}, $\sigma_{\Delta T}$ is the resolution of the time difference T_{east}–T_{west}, σ_T is the resolution on T_{east} or T_{west}, and σ_0 is the time resolution of a single readout detector. The larger channel count in the VPD thus allows an averaging over a larger number of lit channels and hence an improved performance for measuring both Z_{vtx} and T_{start}. The larger number of readout channels also provides more time values in the same acceptance, allowing one to better recognize which times are prompt and which times should be rejected as (delayed) outliers. The rates for such non-prompt hits are nearly negligible in full-energy Au+Au collisions, but are significant for p+p and lower energy Au+Au collisions.

This paper is organized as follows. Section 2 describes the design of the detectors and the electronics. Section 3 describes the configuration of the system for a new RHIC beam, the offline calibration of the detectors, and the start-timing and Z_{vtx} performance. Finally, Section 4 presents the summary and conclusions.

2. Design

The VPD exists as two identical detector assemblies, one on the east and one on the west of STAR. The design of these assemblies is described in Section 2.1. Each of the nineteen detectors used in each assembly is composed of a Pb converter followed by a fast, plastic scintillator which is read out by a photomultiplier tube (PMT). The signals from the nineteen detectors in each assembly are digitized independently by two different sets of electronics which are described in Section 2.2.

The detector was first installed in advance of the 2007 RHIC run. The bases for the PMTs were revised (as described in Section 2.1 below) before the 2008 RHIC run. The detector has been used without additional modifications in every RHIC run since then.

2.1. Detectors

Each VPD assembly consists of nineteen detectors, a side view of which is shown in Fig. 1. Each detector housing is a 2 inch (5.08 cm) outer diameter and 0.049 in. (0.125 cm) thick aluminum cylinder with 3/8 inch (0.953 cm) thick aluminum front and back caps. Inside this cylinder is a 0.25 in. (0.635 cm) non-conducting spacer, then the active elements consisting of a 0.25 inch (1.13 radiation lengths) Pb converter, and a 1 cm thick scintillator (Eljen EJ-204) coupled to a 1.5 inch (3.81 cm) diameter Hamamatsu R-5946 mesh dynode PMT via RTV-615 optically transparent silicone adhesive. The PMTs used in the VPD were taken from the TOFp detector [2] after it was decommissioned in 2005.

The PMT dynode voltages are provided by a conventional linear resistive base. An initial version of these bases was used in the 2007 RHIC run, and the detectors performed well, but there was some “ringing” in the trailing edge of the PMT line shapes. This slightly complicated the offline slewing corrections, but did not affect the timing performance. In 2008, these bases were revised. No changes were made to the component values or connections, but the placement of these components was revised to minimize the lengths of the traces inside each PMT base circuit board. The excessive trace lengths in the previous version of the bases resulted in enough distributed inductance to cause the trailing edge ringing, which was completely removed in the final bases.

A wire connects the PMT cathode pin to a 0.005 inch (0.0127 cm) thick aluminum cylinder which extends past the active elements. Another wire is used to connect the aluminum cylinder to the lead converter. In this way, the active elements are enclosed on all but one side by an electrostatic shield. This shield is electrically isolated from the active elements inside and the aluminum outer cylinder outside by several layers of Kapton tape. The output coaxial connector shield is isolated from the detector housing and the high voltage ground but is indirectly connected via a 1 kΩ resistor. This prevents the (inductive) shield of the coaxial signal cable from forming an undesirable resonant circuit with the (capacitive) electrostatic shield and detector housing while maintaining the high voltage ground return path.

Each VPD assembly consists of two rings of readout detectors and is mounted to the I-beam that supports the STAR beam pipe. A front view of one of the VPD assemblies is shown in Fig. 2. The outer diameter of the beam pipe at this distance is 5 in. An assembly exists as two semi-annular “clam-shells” that enclose the beam pipe. These are bolted together and are held in place by Delrin support blocks which attach to a horizontal mount plate which is clamped to the beam pipe support I-beam. The beam pipe and I-beam are at a different (dirty) electrical ground than the experiment, so the Delrin support blocks both hold the assembly in place and electrically isolate it.

The two assemblies are mounted symmetrically with respect to the center of STAR at a distance of 5.7 m. The nineteen detectors in each assembly subtend approximately half of the solid angle in the pseudo-rapidity range of $4.24 \le \eta \le 5.1$. When viewed from the rear and looking towards the center of STAR, the detectors are numbered 1–10(11–19) counter-clockwise starting from the lower right in Fig. 2 in the inner(outer) ring.

2.2. Electronics

The signals from the VPD detectors are digitized by two different sets of electronics. A schematic view of the components that are involved is shown in Fig. 3.

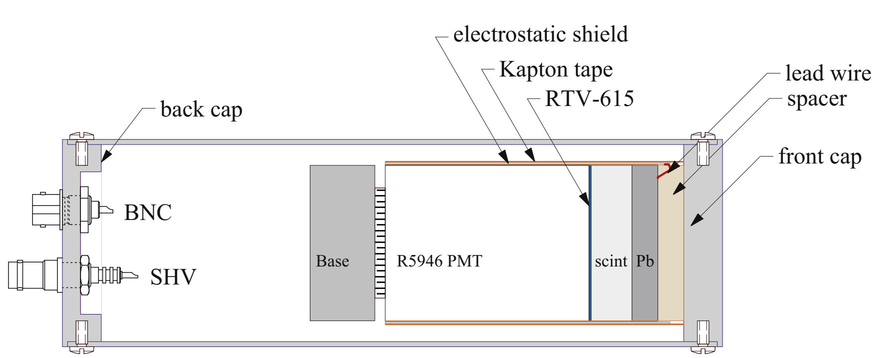

Fig. 1. A schematic side view of VPD detector.