Trigger efficiency

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Abstract. This is part of a set of notes related to the run 10 analysis of ρ^0 meson production and the measurement of a diffraction pattern off the Au nuclei.

1. Paper title

Coherent Diffraction off Au Nuclei Measured at RHIC with ρ^0 Mesons Detected with the STAR Setup.

2. Introduction

The data collected during run 10 for Ultra Peripheral Collisions (UPC) was selected using two triggers: UPC_Main and UPC_Topo. This note relates to the work done on UPC_Main. We will also do some studies on the UPC_Topo, a trigger that is still under developement. The run 10 definition of the UPC_Main trigger is presented in Fig. 1

To extract the efficiency of the UPC triggers we need access to a data stream that contains a trigger defined in a way such that it includes conditions that are common to our triggers and no conditions that would exclude them. Those triggers should start by being "minimum biased". The STAR menu trigger has three of those triggers: ZeroBias, MinBias_Monitor and ZDC_monitor. The first one is a truly unbiased trigger built only on RHIC clock, but it is run with a very high scale down (10^7). The MinBias_monitor includes requirements that the VPD detector fired above some threshold on both East and West side, such condition conflicts with vetoes imposed on our triggers at high rapidity and excludes the use of this trigger as our baseline. The ZDC_monitor trigger, whose definition is shown in Fig. 2 is the trigger of choice. It also has a high scale down (typically 2000)

3. Data Sets

UPC output trees (picoDst's) where generated explicitely to extract the UPC_Main trigger efficiency out of the recorded data during Au+Au collisions at 200 GeV in the center of mass. The input dataset are files storing data from the st_physics streams of the DAQ system.

The generation of the UPC output trees was done within the frame of our StPeCMaker class. The actual trigger work is performed in an instance of the StPeCTrigger class. The driver used to submit the jobs to STAR scheduler was: ../UPC/run10AuAu200/triggerEfficiency/submitFromFileCatalogue.xml:

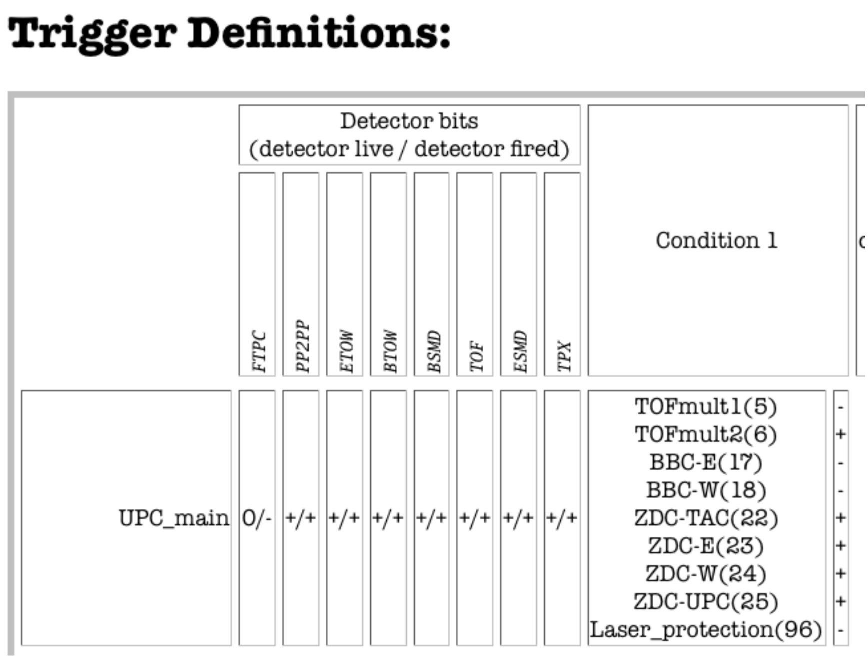
```
<?xml version="1.0" encoding="utf-8" ?>
<job maxFilesPerProcess="50" minFilesPerProcess="1" filesPerHour="100"
fileListSyntax="xrootd" >
<command>
starnew
cd /star/u/ramdebbe/UPC/run10AuAu200/triggerEfficiency

root4star -q -b /star/u/ramdebbe/UPC/run10AuAu200/triggerEfficiency/doMuEvent_mudstInput.C\(
\"$SCRATCH/$JOBID.tree.root\"\)
</command>
      <stdout URL="file:/star/data05/scratch/ramdebbe/$JOBID.out"/>
      <stderr URL="file:/star/data05/scratch/ramdebbe/$JOBID.err"/>

<input URL="catalog:star.bnl.gov?production=P10ik,trgsetupname=AuAu200_production,filetype=d
storage=local,filename~st_physics,runnumber[]11060001-11062074" nFiles="all" />

      <output fromScratch="*.root" toURL="file:/star/data01/pwg/ramdebbe/run10AuAu200tree/
        TriggerEfficiency/" />
</job>
```

The output generated during those jobs produced two files stored at this moment in: /star/data01/pwg/ramdebbe/run10AuAu200tree/TriggerEfficiency/day65_66_nMwcHits.root and day60_62_nMwcHits.root these file were produced with data collected during days 60, 61, 62, 65 and 66.



Trigger Definitions:

	Detector bits (detector live / detector fired)								Condition 1	
	FTPC	PP2PP	ETOW	BTOW	BSMD	TOF	ESMD	TPX		
UPC_main	0/-	+/+	+/+	+/+	+/+	+/+	+/+	+/+	TOFmult1(5) TOFmult2(6) BBC-E(17) BBC-W(18) ZDC-TAC(22) ZDC-E(23) ZDC-W(24) ZDC-UPC(25) Laser_protection(96)	- + - - + + + + -

Figure 1. Diagram showing the definition of the UPC_Main trigger. Information from the detectors included (+/+) in the "Detector bits" columns is included in the st_upc data stream whenever this triggers fires. The actual definition of the trigger is listed with 9 bits as explained later in the text.

Figure 2. Diagram showing the definition of the ZDC_monitor trigger. Information from the detectors included (+/+) in the "Detector bits" columns is written into the st_physics data stream whenever this triggers fires. The actual definition of the trigger is listed with 4 trigger bits, three of them related to ZDC TDC and ADC conditions. The time conditions (ZDC_TAC) is a time window cut equivalent to a wide vertex location along the beam line. The ADC condition requires signal above threshold (1 neutron) on both East and West ZDCs. The fourth bit protects against acquiring physics data while the TPC laser system is active.

4. Analysis

The "process" method of the StPeCTrigger class uses a combination of information extracted from the StMuDst which carries the complete reconstructed event in a condensed format as well as information that was presented to the trigger system before the Level 0 decision was built. The trigger information is accessed via StTriggerData (which is nowadays a STAR standard to access such objects):

```
const StTriggerData * trigData;
trigData =  const_cast< StTriggerData *> (mudst->event()->triggerData());
unsigned short lastDSM0 = trigData->lastDSM(0);
unsigned short lastDSM1 = trigData->lastDSM(1);
```

Ideally the information available in the StTriggerData class should be sufficient to extract the efficiency of any particular trigger, we decided to also look at the StMuDst information in order to gain a better understanding of the trigger.

The trigger information we need for this study is stored in two 16 bit wide words available in the StTriggerData object: lastDSM0 and lastDSM1. The correspondence between bits in these words and detector outputs can be in found [1] where one first selects "Run2010" followed by "TCU input bits 2010A". Additional trigger information can be found in [2].

The StPeCTrigger class needed some updating before embarking in these efficiency studies. All changes have been made in the header file and the "process" method which reads input in the StMuDst format. The process method wich reads in StEvent format will be updated accordingly in a near future. The details of trigger decisions is read from an StTriggerData object. We pass trigger status words for UPC_Main and ZDC_monitor to the trg_3000 and trg_3001 words of the trigger branch in the output tree respectively. The "lastDSM0" and "lastDSM1" words mentioned above are paseed to the output leaves trg_2000 and trg_2001 respectively. The number of actual TOF hits is read from the input with the StMuDst::numberOfTofHit() method. This number is the actual number of TOF cells with signal within a predetermined time window, in contrast with the information one gets from the trigger objects (StTriggerData::tofMultiplicity()) wich is built on the multiplicity on 8 cells ganged together. The number of TOF hits is written to the output tree using the word nCtbHits which was used for a detector that was replaced by the TOF system and the TOF multiplicity used by the trigger system is stored in the nMwcHits leaf. Detailed information about the BBC small tiles has also been added to the trigger branch of the output trees in 18 element arrays that carry TDC and ADC information for individual PMTs.

4.1. Trigger word and bit definitions

The first 16 bits of the trigger word (available in lastDSM0) carry information about the TOF detector. In particular, bit 5 corresponds to the logic: !TOFmult1 which translates into $n_{hits}^{TOF} \leq 6$. Bit 6 to is set by TOFmult2 which translates into $n_{hits}^{TOF} > 1$. The TOF condition that make part of the UPC_Main trigger is then $2 \leq TOF_{hits} \leq 6$. More details about the TOF detector and the way its hit multiplicity is presented to the trigger system can be found in [4]. The next set of trigger bits relevant to the UPC triggers (16-31) can be accessed in the lastDSM1 word. Bits 17 and 18 are used to set a veto with the sum of ADCs of all small BBC counters from the East and West side respectively. More details about the BBC detectors can be found in [3]. Bit 22 is set whenever the time difference between East and West ZDC counters falls within a predetermned window. This condition imposes an actual cut on the z coordinate of the vertex to be accepted. Bits 23 and 24 are set whenever the ADC sum of the East and West ZDC counters have a value such at least one beam neutron has been detected. Bit 25 is set for events where both ZDCs have sum ADC with values smaller to a threshold corresponding to six beam neutrons. These ZDC conditions on the UPC_Main trigger is: $1n \leq ZDC_{sum}^{East} \leq 6n \cap 1n \leq ZDC_{sum}^{West} \leq 6n$

4.2. Offline cuts

The efficiency of the triggers used to collect UPC data, particularly the UPC_Main trigger efficiency studied in this report, is obtained by selecting minimum bias events (events that fired the ZDC_monitor trigger) wich satisfy conditions imposed offline that mimic as closely as possible the definition of the trigger being studied. The efficiency is then simply the number of events wich have the correct bits set in the lastDSM0 and lastDSM1 words, divided by the number of events selected with the offline conditions.

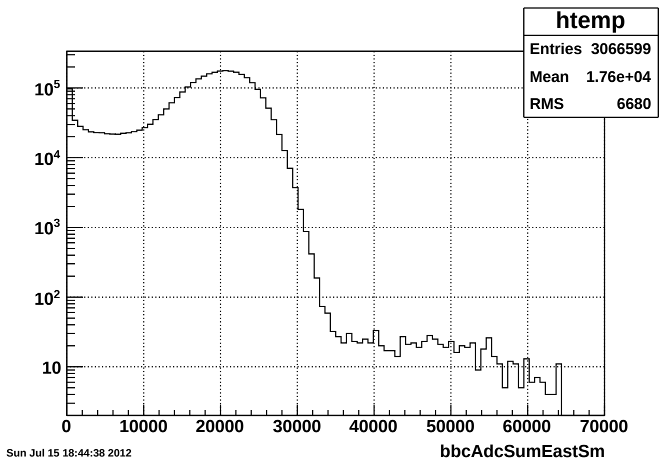


Figure 3. The sum of ADC's for all small BBC tubes on the East side. No trigger conditions are imposed in these events.

4.2.1. BBC The BBC information is inserted to the UPC_Main trigger as a veto excluding any hits on the small BBC detectors. As stated in the snippets of trigger definitions extracted from the RunLog page shown in figures 8 and 9 the BBC small tube veto can be implemented offline looping over all 18 PMTs on East and West BBC systems respectively. A PMT is said to have a hit if its ADC has a value greater than the threshold set at 20 ADC channels. That ADC information is also validated with a time conditions: $100 < TDC < 2300$. The ADC value from PMTs with "hits" is then summed and a final threshold on that sum determines if the BBC small tubes had one or more hits. The definition of the BBC veto is then: offline sum of PMT satisfying the threshold conditions listed above should be smaller than 50 channels.

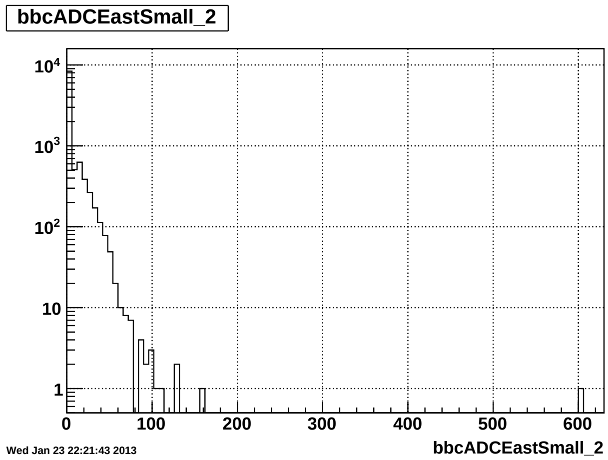


Figure 4. The ADCs recorded in the small BBC photomultiplier number 2 on the East side for events that fired the UPC_Main trigger.

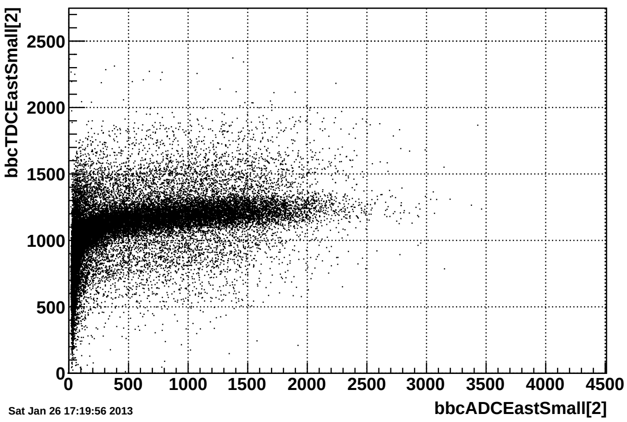


Figure 5. Correlation between TDC and ADCs recorded for the small BBC photomultiplier number 2 on the East side BBC. (No trigger conditions.)

The result of the software sum is shown in Fig. 10 for the small BBC tubes on the East side. The threshold for the BBC veto that is part of the UPC_Main trigger is set at channel 50.

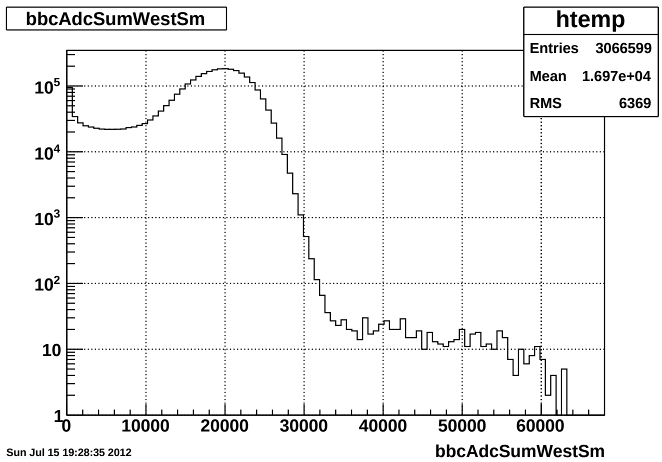


Figure 6. Same sum of ADCs as Fig. 3 but this time for the small BBC tubes on the West side.

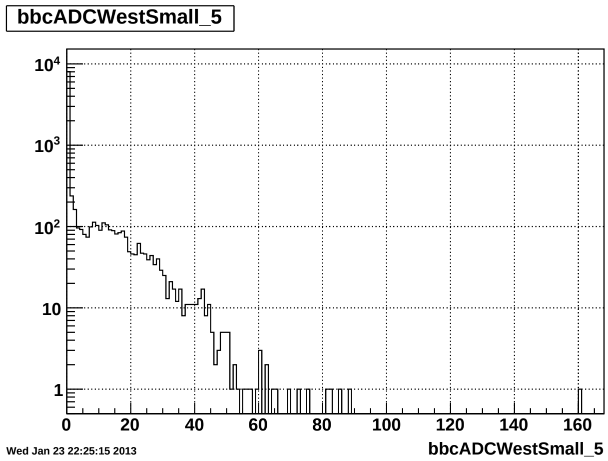


Figure 7. ADC distribution recorded for the small BBC tube number 5 on the west side for events that fired the UPC_Main trigger.

BBCsmall-WestADCsum-th (8)	-1	50
BBCsmall-WestTAC-select (8)	-1	0
BBC_QT_E_Sm_ADC_Th (9)	20	5

Figure 8. ADC thresholds used for the definition of a hit or more ($ADC > 20$ channels) in the small PMTs of the BBC detector system. The sum of ADCs from PMT with hits has the threshold $ADCsum > 50$ to select events with hits in the BBC small tubes.

BBC_QT_E_Sm_TAC_Max (9)	-1	2300
BBC_QT_E_Sm_TAC_Min (9)	-1	100

Figure 9. Time window definition ($100 < TDC < 2300$) used in the definition of a "hit" in any of the small BBC tubes.

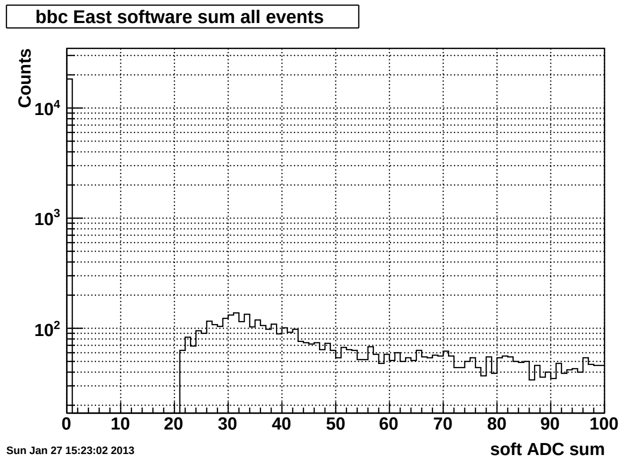


Figure 10. This distribution shows the offline sum of ADCs from small PMTs on the East BBC. In order to be included in the sum a PMT must have a signal corresponding to an ADC above channel 20. A cut imposed on this software sum at channel 50 defines the BBC veto in the UPC_Main trigger.

4.2.2. ZDC There are four trigger bits related to the ZDC detectors (available in the lastDSM1 word). Bit 22 indicates that the difference in time between the earliest East and West ZDC elements falls within a predetermined window. This condition is equivalent to a vertex z coordinate cut and is irrelevant to our present work because the same condition is applied to all triggers. Bits 23 and 24 are related to cuts on ADC sums of both ZDC detectors that translate into "one or more beam neutron detected". And finally, bit 25 is an upper limit on both ZDC detector which translates into the condition: "no more than 6 beam neutrons detected" in any ZDC.

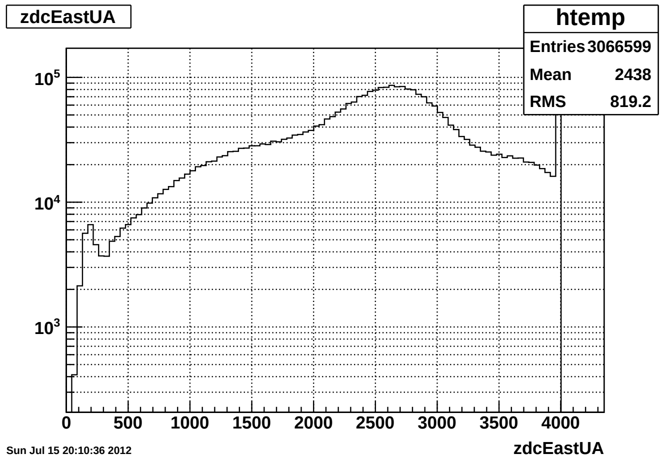


Figure 11. Unattenuated ADC sum for the East zdc calorimeters for all events collected. The single neutron peak is present at low ADC values and the signal saturates at channel 4000.

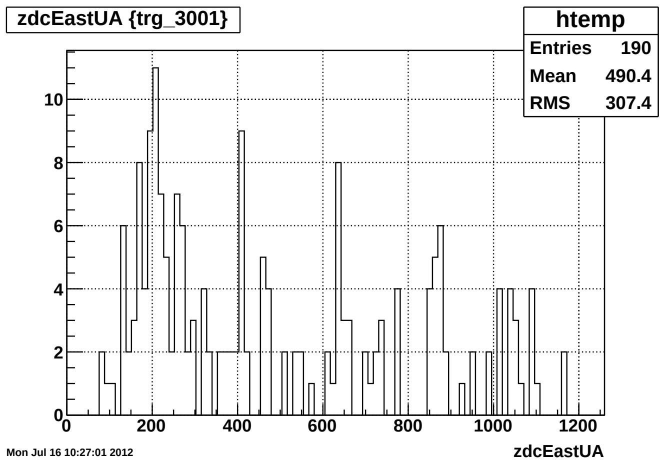


Figure 12. Unattenuated ADC sum for the East ZDC calorimeter for events that fired the UPC_Main trigger.

Looking at the distributions shown in figures 12 and 14 which show the unattenuated ADC sums for events that fired the UPC_Main one sees that the appropriate offline conditions that mimics bits 23-25 would be: $50 < zdcEastUA < 1200$ and $50 < zdcWestUA < 1200$.

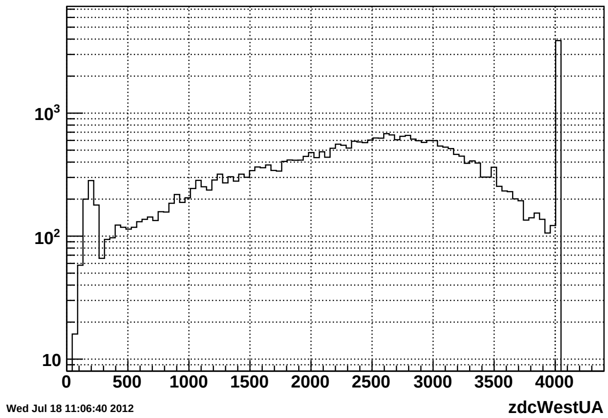


Figure 13. Same as Fig. 11 but filled with the sum of ADC from the ZDC West calorimeter for all events.

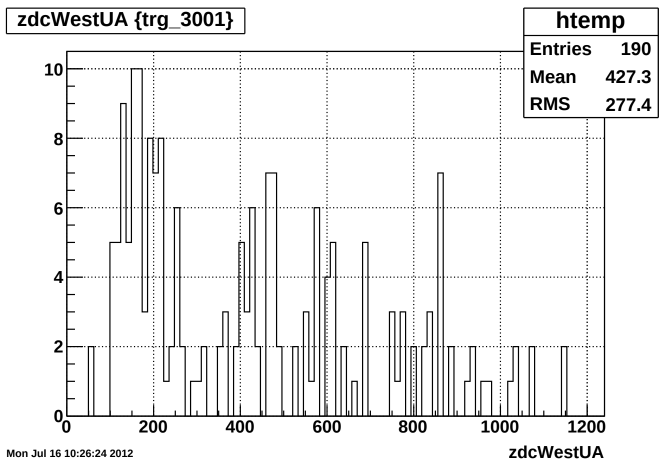


Figure 14. Unattenuated sum of ADCs for the West ZDC for events that satisfy the UPC_Main trigger.

number BTof hits	Offline Selected	correct bit pattern	bit 5 set	bit 6 set
43	257	49	8	57
30	257	49	8	57
20	255	48	7	55
10	249	48	3	51
9	245	47	0	47
8	242	45	0	45
7	241	44	0	44
5	227	36	0	36

Table 1. This table shows the number of ZDC_monitor found to satisfy several conditions as the number of TOF hits used in the "Offline Cuts" is changed. The first column lists the number of TOF hits, the second column has the number of ZDC_monitor events that satisfy the conditions, the third column has the number of events with the UPC_Main trigger bits. The last two columuns show the number of events satisfiying the offline conditions and having bits 5 and 6 set, respectively. This table was filled with information extracted from day 67.

4.2.3. TOF This trigger study started using the TOF information extracted from the StMuDst data because of a concern about time window conditions inposed on trigger TOF hits that would be difficult to reproduce or will unavailable in the muDst format of the data reconstruction output. The use of StMuDst TOF information produced low values of the trigger efficiency mainly because as will be shown below, it is hard to translate the multiplicity thresholds used in the trigger into well defined number of actual TOF hits. We have finally returned to the TOF information that the trigger system uses (available in StTriggerData::tofMultiplicity) where the definition of offline cuts is trivial and the results are consistently showing a fully efficient UPC_Main trigger. For completeness and to report all the work done to reach this final conclusion, we still describe the stUdies done using the StMuDst TOF information.

As hinted above, the TOF information available to the trigger system and the one available after the full event is reconstructed is not identical. The trigger counts one "hit" as a sum (OR) of 8 TOF cells. The offline condition for the TOF detector is set to: $2 \leq nTofHits < 7$ but we have a choice on where to get the value of nTofHits, from the fully reconstructed event, or from the trigger data.

In order to investigate the correct definition of the TOF offline cuts on the StMuDst TOF multiplicity we processed the same ZDC_monitor events using multiplicities ranging from some decently high number (43) down to 5 and looked at how many of those events fired trigger bit 5 which corresponds to the upper limit $nTofHits < 7$. Table 1 shows that, if one were to use the StMuDst TOF multiplicity the upper limit on the multiplicity should be set at no more than 9 hits.

Unfortunately, setting a StMuDst TOF multiplicity at the value of 9 hits produced an overall efficiency as low as 20% with the BBC and ZDC components of the UPC_Main trigger showing 100% efficiency.

The correlation between the TOF information obtained from the StMuDst fully reconstructed event and the one available in the trigger data presented in figures 17 and 18 shows why the efficiency is so low. Even though the correlation in hadronic events shown in Fig. 17 is well defined, for UPC events (Fig. 18) an event with some number of trigger TOF hits (from 2 to 6 inclusive) may have a smaller number of TOF hits in the reconstructed event (StMuDst), or what is more important for this particular study, the number of reconstruted TOF hits can be several times the TOF multiplicity found in the trigger data. Because of such wide correlation, putting a higher cut in StMuDst TOF multiplicty violates the $nTofHits < 7$ condition of the

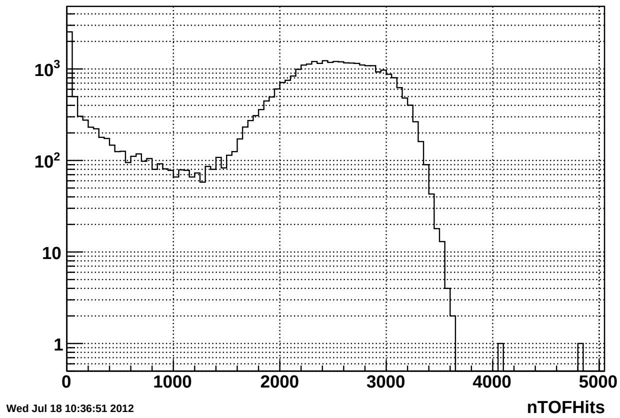


Figure 15. The number of TOF hits read with StMuDst::numberOfTofHits() in events with no trigger conditions.

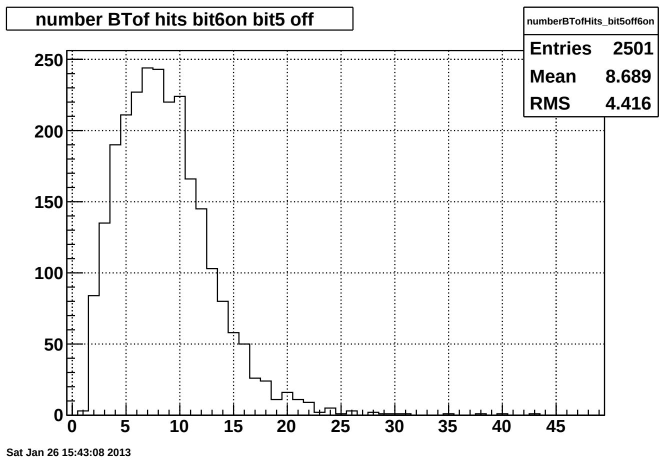


Figure 16. The number of TOF hits in events that fired that had trigger bit 6 on and bit5 off.

trigger.

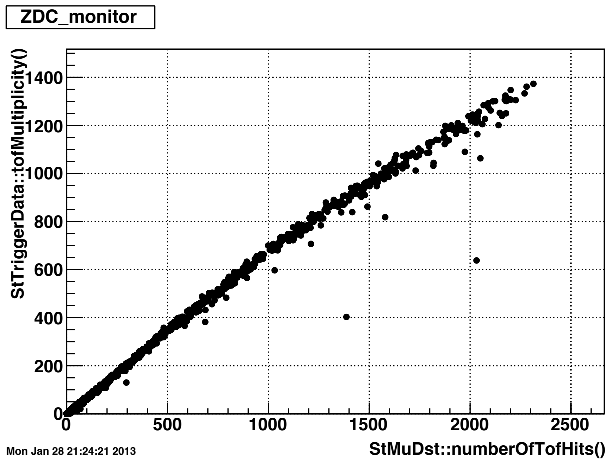


Figure 17. The number of TOF hits as seen by the trigger system (read from StTriggerData) versus the number of actual hits in the TOF detector (read from StMuDst). The correlation is filled with ZDC_Monitor triggered events.

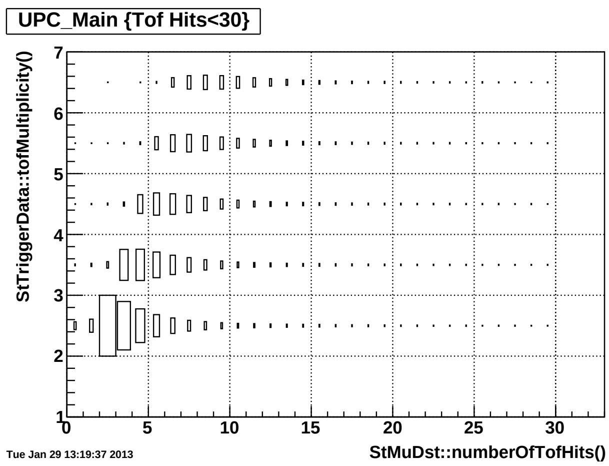


Figure 18. The number of TOF hits as seen by the trigger system (read from StTriggerData) versus the number of actual hits in the TOF detector (read from StMuDst). This correlation is filled with events triggered by UPC_Main.

5. Results and discussion
All MuDst files that contained events from the st_physics stream which where recorded on days 60,61,62,65 and 66 have been used to do this trigger study. Fig. 19 shows the bit patterns for the lastDSM0 word for events that fired the UPC_Main trigger. Bits 5 and 6 are related to TOF and as expected the first one is never set (all UPC events have less or equal than 6 TOF hits) and bit 6 is set in all events (more than one hit in TOF).Fig 20 shows the bit pattern for the "lastDSM1" word. Bits 17,18 are related to the BBC small tubes veto. Bit 22 to 25 are related to the ZDC conditions.

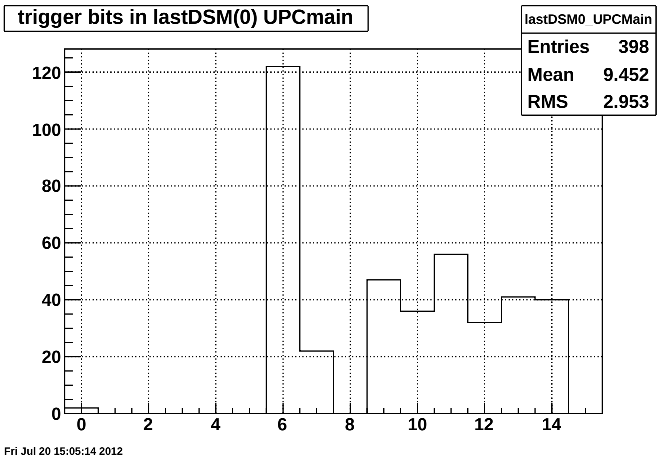


Figure 19. The first trigger word showing the bits for UPC_Main firing events.

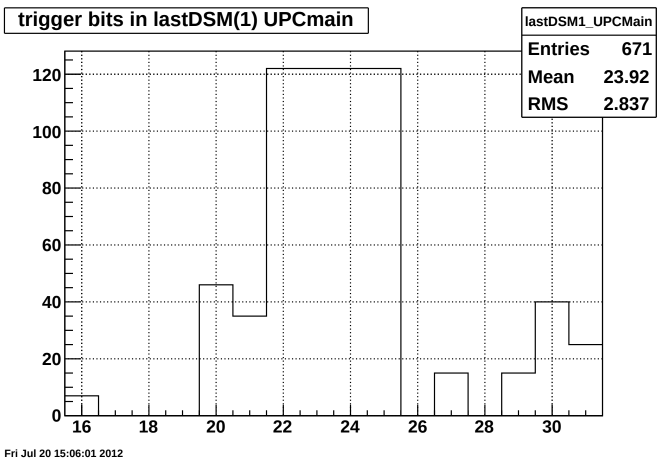


Figure 20. Second trigger word (lastDSM1) for events that fired the UPC_Main trigger.

The number of ZDC_monitor events that satisfy the offline conditions described in 4.2 is equal to 256. When we use the trigger system TOF multiplicty to define the TOF conditions, all of those events had the correct bit pattern (defining the UPC_Main trigger):
bit pattern: —- –11 11– -00- —- —- -10- —-
Details about the bits set or not set in those events can be seen in Fig. 21 where bit 5 has no entries as expected and the counts on bit 6 reach up to 256. Figure 22 shows no entries in bits

17 and 18 indicating that our offline definition of the BBC veto is correct, while the bits related to the ZDC calorimeters are fully efficienct.

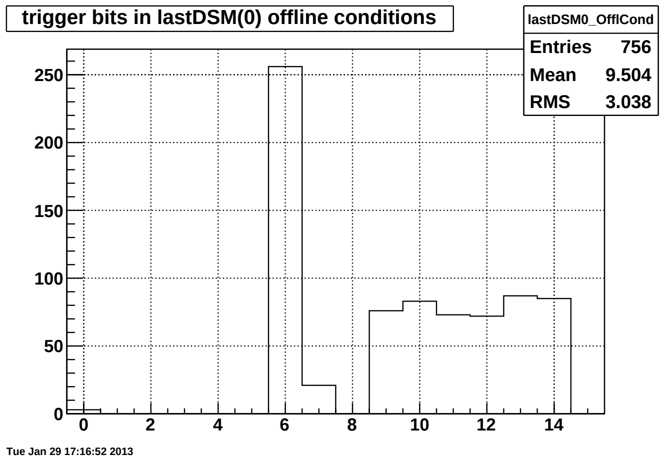


Figure 21. The first trigger word (lastDSM0) which carries TOF information related to the UPC_Main trigger in bits 5 and 6. The histogram is filled with events that satisfy the offline conditions. All events that satisfy the offline cuts have bit 6 set.

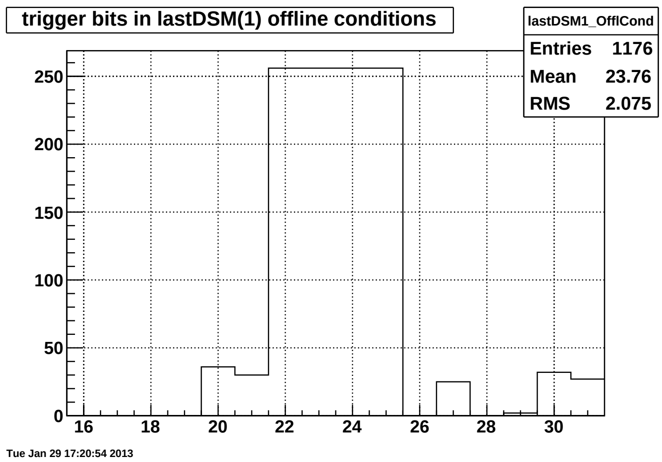


Figure 22. Second trigger word (lastDSM1), which carries BBC and ZDC information related to the UPC_Main trigger, is filled with ZDC_monitor events that satisfy the offline conditions. No entries ae seen in bits 17 or 18 corresponding to the BBC vetoes on East and West sides respectively, and all the ZDC bits have 256 entries

In summary, the UPC_Main trigger efficiency was extracted from data collected on run 10 (Au+Au collisions at 200 GeV). In a combined analysis that includes data collected in days 60 to 66, the number of ZDC_monitor events that satisfy the offline cuts is equal to 256 and all of those events have the correct (UPC_Main) bit pattern. The efficiency for that particular trigger is thus found to be equal to 100%.

References

[1] STAR Trigger information `http://www.star.bnl.gov/public/trg/`.

[2] Nucl. Instrum. Meth. A 499 (2003) 766.
[3] STAR BBC detector information http://www.star.bnl.gov/public/bbc/.
[4] STAR TOF Proposal http://www.star.bnl.gov/public/tof/publications/TOF_20040524.pdf.