

STAR Zero Degree Calorimeter

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Zimní škola FJFI 2020, Bílý Potok

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STAR DETECTOR





VPD







WHERE IS ZERO-DEGREE CALORIMETER?



- East (ZDC-E)
- West (ZDC-W)
- Between RHIC beam pipes





Nucl.Instrum.Meth.A470:488-499,2001





WHERE IS ZERO-DEGREE CALORIMETER?

- In RHIC tunnel, 18 m from center of the STAR detector
- Between RHIC beam pipes







WHERE IS ZERO-DEGREE CALORIMETER?

- In RHIC tunnel, 18 m from center of the STAR detector
- Between RHIC beam pipes









HOW DOES ZDC WORK AND LOOK LIKE?



- Detection of spectator neutrons after collision of nuclei in RHIC
- Conversion of ultra-relativistic neutrons in tungsten
 - Shower of charged particles
- Cherenkov light in PMMA fibers
 - Charged particles faster than light (in PMMA)
- Light collected by PMTs
 - Amount of light proportional to deposited energy
- ZDC = 6 identical modules
 - 3 east, 3 west





Nucl.Instrum.Meth.A470:488-499,2001





HOW DOES ZDC LOOK LIKE?







NUCL SCI TECH (2016) 27: 126





HOW CAN BE ZDC USED?

- **1. RHIC monitoring**
 - Measurement of luminosity
 - ZDC detection rates (east, west, AND)
 - Used while steering beams for collisions at STAR
- 2. Trigger
 - Decide if a good A+A collision occurred and give signal to other detectors to read out signal
- 3. Collision centrality determination
 - Number of spectator neutrons is inversely proportional to collision centrality
 - More central collision less spectator neutrons and vice versa
 - Not used at STAR at the moment
- 4. Pileup correction
 - Correction of charge particle multiplicity in TPC



HOW LARGE ARE ZDC RATES AT STAR?

- Example for Run16 Au+Au@200GeV
- Typical measured rate is 70 kHz for Run16
- RHIC also monitors BBC and VPD rates

*		rich	scaler.adl		- +							
RICH Scaler Rates in Hertz												
reading												
BBC E	0.000	Ye	llow Back	0.000 F	Ring Bufi							
BBC W	0.000	Bl	ue Back	0.000	• 10							
BBC And	0.000	ZE	OC E	1.000	10							
ZDC And	0.000	ZĽ	OC W	1.000								
VPD E	89.8	00	ZDCE-nokil	1	1.800							
VPD W	3.70)0	BBCAn	d Trig	0.000							
VPD E*W	27.3	00	ZDCAn	d-nokill	0.000							
ZDCW-nokill	0.60)0	MTD		0.000							
-0.115				P	Plots							
1												



Jan Vanek: STAR ZDC

HOW DOES ZDC TRIGGER STAR?



next run #21013013

previous run #21013011

Information for run: 21013012

<u>Run Log</u> <u>Back to Calender</u>

All Details No No Texperiments Detector No No Periments Detector No Periments No Construction No Periments No Periments No Periments P	Trigger Info Run Inf	o Thresholds										
name	All Details No Details main Requirements Detectors Overlaps PS Setup Emulation											
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Hole +TOFmul0 +PD-L	ninbias_withetof <u>(history)</u>		2	710018	1.0000	3.00K	1.06K	510.08K	0.0000	physics	more	
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	erobias <u>(history)</u>		59	9300	9.34M	1.0000	9.34M	1.73K	0.0000	zerobias	more	



HOW DOES ZDC TRIGGER STAR?



previous run #21013011

Information for run: 21013012

<u>Run Log</u> Back to Calender

Trigger Info Run Info Thresholds																
All Details No Details main Re	quirements	Detectors Overla	aps PS S	etup Emulati												
name			daqid	offline id		ps	expected r	ate	scaler	rate	evts	tap	e rate	stream		
ninbias <u>(history)</u>				710010	1.0000		3.00K		1.06K		619.47K	0.0000		physics	more	
minbias <u>(history</u>)> Re quirements:			+TOFmult0 +EPD-TAC +EPD-E +EPD-W -Laser-prote	ection	or 4	+TOFmult0 +VPD-TAC +VPD-E +VPD-W Laser-protect	on	or +ZI +ZI +ZI -La	DC-TAC DC-E DC-W Iser-protection	1	L1: Accept	L2: I2-emc	-ped	L4: Accept	move	hide
ninbias_withetof <u>(history)</u>			2	710018	1.0000)	3.00K		1.06K		510.08K	0.0000		physics	more	
minblas	s_withetof <u>(histo</u>	<u>ry) = Requirements:</u>	+TOFmult0 +EPD-TAC +EPD-E +EPD-W -Laser-prote	ection	or	+TOFmult0 +VPD-TAC +VPD-E +VPD-W -Laser-prote	ction	or	+ZDC-TAC +ZDC-E +ZDC-W -Laser-protec	ction	L	1: ccept	L2: Accept	L4: Accept	more	hide
ninbias grift <u>(history)</u>			4	710019	60.00		50.00		1.05K		10.32K	0.0000		physics	more	
ninbras-hlt70 <u>(history)</u>			12	710012	emulat	ted					114.26K	0.0000		physics	more	
1	1.000	v	19.001			P	UUIK		010	COLUMN 1	, in the second s			לייאן 👘	5165 1	<u> </u>
+TOFmult0 +EPD-TAC :+EPD-E +EPD-W -Laser-protection	or	+TOFmult0 +VPD-TAC +VPD-E +VPD-W -Laser-protee	ction		or	+ZDC-T +ZDC-E +ZDC-V -Laser-J	AC V protection			L1: Acce	pt	L2: I2-emc	-ped		L4: Accept	1
2	11 000	0				11	OCN		lc 1 ^			n nnn		يتظحول وروري	ninn	
/pd (history) /pd-tac (history) /pd-tac-tofmult0 (history) /dd-tac-tofmult0 (history) /dd-tac-tofmult0 (history) mb_epdcomponent (history) mb_vpdcomponent (history) mb_zdccomponent (history) /estLaserFire (history)			24 25 26 27 28 29 34 35 36 54	710807 710808 710809 710810 710810 710812 710015 710006 710006 710007 55	50.00 50.00 300.00 20.00 1.0000 1.0000 1.0000 10000)))))))))))	20.00 4.00 1.2333 3.50 7.00M 700.00 0.000 0.000		1.61K 588.95 539.46 11.75 6.50 625.45 539.46 11.75 0.0000		12.34K 5.66K 5.50K 4.00 39.00 527.83K 275.06K 784.00 1.0000	0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000		physics physics physics physics physics physics physics physics physics physics	more more more more more more more more	
estLaserProtect (<u>history</u>)			55	56	1000.0	MOO			0.0000			0.0000		physics	more	
zerobias (history)											2 2 2 1 4					





HOW CAN ZDC MEASURE CENTRALITY?



- Measurement of number of spectators of A+A collision
- Central collisions
 - Very few or no spectators
 - All nucleons participate in collision
 - High particle multiplicity in STAR detector
- Mid-central
 - Destruction of bounds between spectators
 - Increasing number of spectators with decreasing centrality
 - Opposite trend for charged particles in STAR
- Peripheral
 - Nuclei nearly intact, but excited
 - Emission of single or a few neutrons
 - Low multiplicity in both ZDC and STAR





STAR trigger group (accessed on 01/17/20): https://www.star.bnl.gov/public/trg/

17.01.2020



HOW TO DEAL WITH PILEUP USING ZDC?

<Tracks per



- Number of charged tracks in TPC increases with collision rate
 - TPC is slow detector
- How slow?
 - Highest drift velocity of electrons = 5.5 cm/µs
 - TPC length = 420 cm
 - Readout frequency max. approx. 26 kHz
- More important for small systems (d+Au, p+Au)
 - Collision rates up to 1.2 MHz (d+Au)





HOW TO PREPARE ZDC FOR NEW RUN?

- Part of service task of PhD. students from FNSPE and NPI
 - Lukas Kramarik, Jan Vanek, (Miro Simko)
- 1. Check ZDC high voltage (HV) and electronics
 - All photomultipliers (PMTs) are working?
 - Do we see signal from the PMTs?
 - Is the electronics working?
- 2. Calibrate ZDC gain by adjusting HV
 - Gain of each ZDC tower
 - Balance between towers of ZDC
 - Single neutron peak (SNP)
 - Balance between east and west ZDC module





HOW TO CHECK AND CONTROL ZDC HV?







• Expectation:

 STAR is a 21st century, state-of-the-art experiment a has the most modern and sophisticated electronics. It will for sure look something like this:







- Reality:
 - STAR is a 21st century, state-of-the-art experiment, but now has often quite outdated and old electronics and it actually, it looks like this:









- Check that signal goes through the whole electronics
 - Connect pulser (small frequency generator) to various places of the read-out electronics circuit





- Check that the electronics works
 - Connect pulser to input to the electronics so that it simulates coincidence between ZDC-E and ZDC-W
 - ZDC-AND at the same rate as on single towers
 - RICH scalers show the correct rates (information for RHIC)



HOW TO CALIBRATE ZDC?

- STAR
- The ADC value is proportional to energy deposited in the ZDC and HV applied to the PMTs
 - Energy deposition given by energy of neutron fixed (100 GeV)
 - Need to set HV so that:
 - The total gain is sufficient for electronics
 - ZDC-E and ZDC-W have the same total ADC value for SNP
 - Individual towers have to have ADC values in ratio of 6:3:1
- 1. Request dedicated run to collect data for calibration
- 2. Compare ADC values for individual towers
- 3. Fit total ZDC-E and ZDC-W ADC sum to determine position and width of the SNP and double neutron peak
- 4. Compare total ADC values for ZDC-E and ZDC-W
- 5. Adjust voltages and repeat, if needed _{zpc}



Jan Vanek: STAR ZDC

HOW TO CALIBRATE ZDC?



Single tower ADC distributions for ZDC-E







HOW TO REPAIR ZDC IF IT GOES WRONG?

- What can go wrong?
 - Anything (everything?)
 - ZDC has been designed and built 20 years ago and it was intended for much lower luminosities for much shorter time
 - Current issues:
 - PMTs: vacuum, magnetic field protection, radiation damage, connectors (HV, LV)
 - Slowly rising required operating voltage reaching/at maximum
 - PMMA fibers: mostly radiation damage loss of transparency lower light gain
 - Would require new ZDC from scratch
 - Potential issues
 - Cables: cables going from/to ZDC to/from STAR, optical ling from ZDC electronic to RHIC
 - Electronics: replacement?



HOW TO REPLACE ZDC PMTs?



- Get a new/used replacement PMTs
 - New ideal but quite expensive and have to match specification
 - Used free, BNL/STAR has many, many used parts, but usually are old
- About 100 PMTs from BRAHMS is/was available
 - In 2018 we decided to use the opportunity to replace bad PMTs in ZDC







HOW TO SELECT REPLACEMENT PMTs?

- Replace just bad PMTs?
 - Find the same type and compare performance
- Replace all 6 PMTs with a different type?
- Check of performance
 - Signal pulse height vs. light
 - Gain and its linearity
 - Pulse rise time
 - After-pulsing











HOW DID WE SELECT REPLACEMENT PMTs?



- Measured gain of all replacement and ZDC PMTs
- Selected candidates
 - High gain PMTs with reasonably low after-pulsing





box	type	ID	Puse height	Puise width	height (m ^{US}	width Inel	ref, and tested foal	after peak [ne1	mer-puse height	note	Supply vi
6	type	44935	232	47.9	1360	28	-7.6	274	minor	1000	250
5	H2421-01	AA1802	132	47,0	1440	20.2	-1,0	274	minor		250
5	112401-01	AA2001	336	42.4	1440	2.0,2		214	no after-neak		250
6	H2421.01	AA1070	194	92,9	1440				no aner-peak		200
6	112401-01	AA1100	1020	47.6	1520			221	minor?		250
6		AA1604	212	47,0	1530			2.31	in the second se		250
		A.1075	424	40.0	1540			090	madum		2.50
6		AA1270	929	40,0	1540			232	medium	hered .	250
0	H2424	AA717			1540					bad	200
9	H2431	66.00	200	c0.	1540		40			Ded	250
9	H2431	AA1281	320	50	1460		-10				250
9	H2431	AA762	156		1460						250
9	H2431	AA1280	164		1460						250
12		881			1460						250
12		AA1683	288		1460			236	medium		250
12		AA884	100		1460						250
12		AA852	212		1540						250
12		AA2091	280		1540				0.86 (bad enough)		250
12		AA1444	228		1590						250
12	H1161	old ZDC right 2	1150	50	1590		12,4	500			250
12		882	156		1590						250
12		AA1954	470		1590			224			250
12		883	156		1590						250
12		AA1805	276		1640						200
6		AA1353	240		1640						250
0		A 1079	240		1640						250
0		AA1070	144		1640						250
6		AA1031	84		1640						250
6		AA1150	148		1640						250
6		AA1327	356		1640				medium-large		250
6		AA1482	264		1640				large		250
6		AA1139	176		1640				medium		250
6		AA1115	272		1640				large		250
6		AA879	280		1640				medium-large		250
6		AA1269	236		1640				medium-large		250
6		AA831	104		1640						250
6		AA1073	424		1640				large		250
6		AA909	120		1640						250
14		AA2316	196		1550						250
14		AA2005	100		1650						250
14	10424.00	A \$ 1600	124		1000						200
14	H2431-02	PA1523	100		1550						250
14		66/0/31	164		1560						290
14		AA2828	408		1550				medium		250
14		AA2907	216		1550						250
14		AA2914	300		1550						250
14		AA2909	740		1550				medium		250
14		AA1779	132		1550						250
14		AA1783	348		1550						250
14		AA819	76		1550						250
14	H1161	RB2950	770		1550				medium		250
14	H1161	RB3199	960		1550				small		250
14	h1161	RB3205	690		1550						250
14	H1161	RC2198	1280		1550				large		250
14	H1161	RC1975	1420		1550				large		250
14	H1161	BC2141	1340		1550			500			250
14	L11101	D03111	490		1550			000			250
	HING	DB2207	400		1000						200
14	HIIGI	RB3207	660		1550						250
11	H1101	RESTOC	680		1550						250
11	H1161	RB3256	510		1550						250
11	H1161	R62937	1230		1550				large	V-characteristic -> sheet 2	250
11	H1161	RB4329	1000		1550						250
11	H1161	RB3303			1550					bad HV connector	250
11	H1161	RB3306	1210		1550						250
11	H1161	ZC5021	1740		1550				large		250
11	H1161	ZC5072	256		1550						250
11	H1161	ZC4668	470		1550						250
11	H1161	ZC5451	350		1550						250
11	H1161	ZC4827	770		1550						250
11	H1161	RB3156	550		1550						250
11	H1161	RB3112	470		1550						250
11	H1167	RB1234	560		1550						250
11	H1167	PB3140	1010		1550				madium		2.00
11	HEARD	RC7834	570		1660				meurum	had no fin	200
44	HG410	DC782F	580		1550		10		madium	2.4 M/	250
11	H6410	HU/835	580		1550		10		medium	2,4 KV	240
11	H6410	RC7828	580		1550						240
11	H6410	RC7830			1550					bad	240
11	H6410	RC7833	800		1550						240
11	H6410	RC7836	850		1550						240
11	H6410	RC7814	248		1550						240
11	H6410	RC7838			1550					bad data connector	240
	H6410	RC7837	980		1550						240
11	H6410	RC7839			1550					bad	240
11	H6410	RC7798	800		1550					244	240
11 11 11	1104113	DC7941			1550					had	240
11 11 11	HEAT	RG-7041			1550					DeO	240
11 11 11 11	H6410	DOTE: NOT			1004					DBC	240
11 11 11 11 11	H6410 H6410	RC7827	700	40.1	1000	07.1	10.0	0.00	0.0		A
11 11 11 11	H6410 H6410 H1161 ?	RC7827 ZDC old 1	788	49,4	1250	27,4	13,2	642	6,2		250
11 11 11 11 11	H6410 H6410 H1161 ? H1161 ?	RC7827 ZDC old 1 ZDC old 2	788 668	49,4 50,6	1250 1300	27,4 27,4	13,2 12,4	642 556	6,2 2,7		250 250
11 11 11 11 11	H6410 H6410 H1161 ? H1161 ?	RC7827 ZDC old 1 ZDC old 2	788 668	49,4 50,6	1250	27,4 27,4	13,2 12,4	642 556	6,2 2,7		250

HOW DID WE TEST REPLACEMENT PMTs?



- After-pulsing and gain linearity test
- Variable light input
 - Voltage applied to diode
- Same applied voltage
 - U = 2.6 kV
- Old PMT
 - Low after-pulsing
 - Low gain
- Replacement PMT
 - Low after-pulsing
 - Good gain







Replacement H2431-50





HOW DID WE REPLACE PMTs?

STAR

- Selected 2 replacement PMTs
- PMTs in ZDC-E-1 and ZDC-W-1 stayed in place
 - Good gain and low after-pulsing
- Tower ZDC-E-2 got PMT from ZDC-E-3
 - Both ZDC-E-2 and ZDC-E-3 were not good, but only 2 good replacement PMTs were available
- Towers ZDC-E-3 and ZDC-W-3 got replacement PMTs

	Ν	PMT	Voltage 2016 [V]				
Final voltages for run 2018							
	1	same	2444				
East:	2	swapped from E3	2633				
	3	new AA1783	2329				
	1	same	2431				
West:	2	same	3072				
	3	new H2431-50	2101				









THANK YOU FOR ATTENTION





Jan Vanek: STAR ZDC





BACKUP

Jan Vanek: STAR ZDC

17.01.2020



TOF MATCHING EFFICIENCY

Pion TOF matching efficiency for Run16 Au+Au@200GeV

h_pi_tof_eff

