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RHIC Abort Kicker Prefire Report

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In an attempt to discover any pattern to prefire events, abort prefire kicker data from 2007 to the present day have been recorded. With the 2014 operations concluding, this comprises 8 years of prefire data. Any activities that the Pulsed Power Group did to decrease prefire occurrences were recorded as well, but some information may be missing. The following information is a compilation of the research to date.

1 Prefire overview

For every run prefires occurred when the abort kicker power supplies were operated at 22kV or higher. The majority of the species were polarized protons (PP) or gold (Au). Other ions accelerated were copper (Cu), uranium (U), deuteron (D) and helium (He). Table 1 describes how prefires are related to the species being accelerated and the voltages used for each species.

Table 1 RHIC Operating Modes and RHIC abort kicker prefires

Run	*Energy GeV/nucleon	*Species	Days	Abort Voltage kV	Prefire Yellow	Prefire Blue
2007	100	Au-Au	128	27	12	18
2008	100	Au-D	82	27/22	2	3
2009	250	PP-PP	60	27	1	9
2010	100	Au-Au	89	26	7	12
2011	250	PP-PP	91	27	8	3
	100	Au-Au	49	27	5	4
2012	255	PP-PP	37	27	1	0
	96	U-U	28	26	2	0
	100	Au-Cu	43	26/22.8	5	1
2013	255	PP-PP	116	27	13	8
2014	100	Au-Au	96	26	12	6
	100	Au-He	22	26/27(three modules)	2	0

*Operation data are from http://www.agsrhichome.bnl.gov/RHIC/Runs/index.html.

Low energy modes are not listed in Table 1 because we never had a prefire while in those modes, except for one in 2009 at 11kV caused by a failed redundant trigger module. Chart 1 shows the total number of prefires experienced in the entire 8 year period and the numbers of prefires occurring in each run.

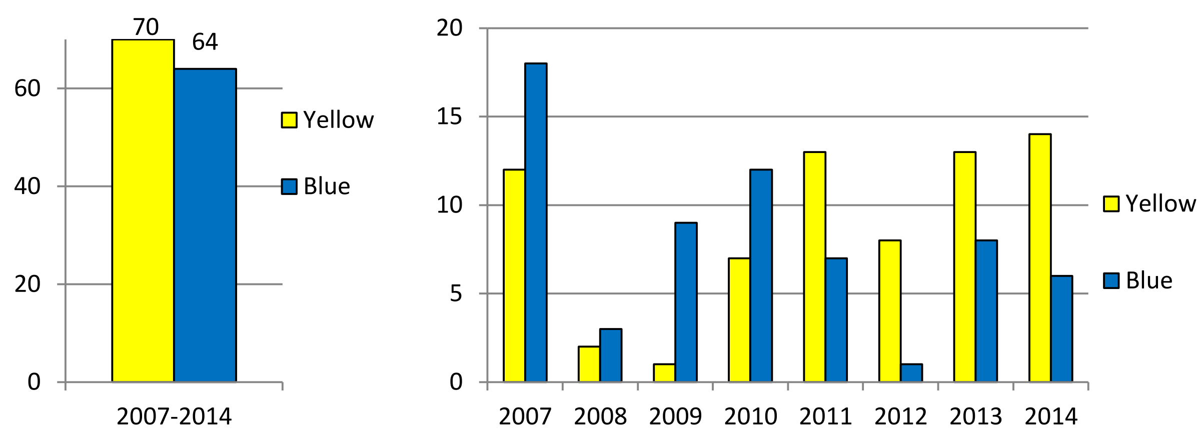


Chart 1 Yellow and Blue Prefires from 2007 to 2014

In terms of total prefires occurring during the period of this study, yellow and blue are very close.

Over the years, prefires of the blue abort kickers seem to decrease while those of the yellow do not.

From 2007 to 2010, yellow had less prefires than blue for each run. Starting in 2011, yellow experienced more prefires than blue.

2007 had the most prefires, a total of 30. But during 2008, the next run, there were only 5.

What did we do during that shutdown? In blue PFN #2 and #4 modules (which had 7 prefires each), the CX3575C thyratron, the 5uF/40kV capacitor, and eight 0.39uF/45kV capacitors were replaced. Interestingly in yellow the prefires dropped down from 12 to 2 without any components being changed except the 5uF/40kV capacitor in blue #2 in the middle of the run.

2 Prefire and species

Table 2 below explores the relationship between prefires, species and length of the runs. There were 23 and 20 prefires for yellow and blue respectively with PP in 304 days; and 47 and 44 prefires with ions other than PP in 537 days. On average there was a prefire every 7.1 days for PP and 5.9 days for other species.

Table 2 Species and Prefires

(a)Prefires for PP

Run	Energy GeV/nucleon	Species	Days	Prefire Yellow	Prefire Blue
2009	250	PP-PP	60	1	9
2011	250	PP-PP	91	8	3
2012	255	PP-PP	37	1	0
2013	255	PP-PP	116	13	8
Total			304	23	20

(b) Prefires for ions other than PP

Run	Energy GeV/nucleon	Species	Days	Prefire Yellow	Prefire Blue
2007	100	Au-Au	128	12	18
2008	100	Au-D	82	2	3
2010	100	Au-Au	89	7	12
2011	100	Au-Au	49	5	4
2012	96	U-U	28	2	0
	100	Au-Cu	43	5	1
2014	100	Au-Au	96	12	6
	100	Au-He	22	2	0
Total			537	47	44

3 Prefires and time of occurrence with relation to ramp and flat top

A prefire may occur either during the charging voltage ramp or the charging voltage flat top. The ramp means the particles are being accelerated in the RHIC rings. A regular ramp takes about 4.5 minutes. The flat top means the acceleration process is completed and the beams are circulating in the RHIC rings. A normal flat top lasts 8 to 10 hours. The ramp and the flat top are shown in Figure 1.

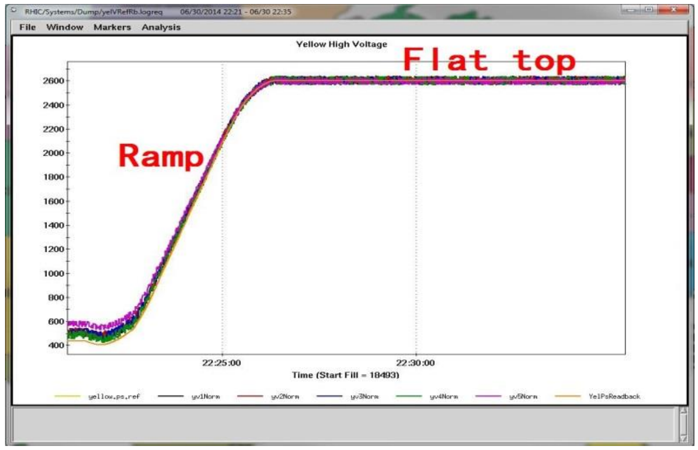


Figure 1 Abort kicker charging voltage ramp and flat top of a run

Table 3 explores prefires with relation to the ramp and flat top.

Table 3 Time of prefire occurrence

Time of Prefire	Yellow	Blue
Ramp	22	22
Flat top <5 minutes	15	11
Flat top 5-30 minutes	10	12
Flat top>30 minutes	23	19
Total	70	64

Chart 2 is a graphic representation of Table 3.

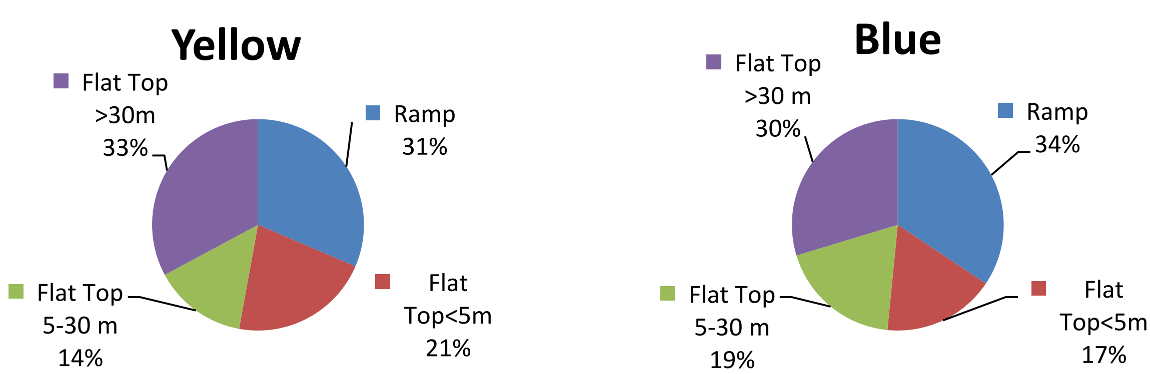


Chart 2 Yellow and Blue Prefire Time of Occurrence

For both yellow and blue, about 1/3 of all prefires occurred during the ramp, and another 1/3 of all prefires occurred more than 30 minutes in to the flat top. The prefires occurring during the ramp and during the first 5 minutes of the flat top represent about 50% of the total. We believe that this statistic is worth investigating because 50% of all prefire events occurring during the first 10 minutes of a run that can last 8-10 hours is a relatively significant number.

4 Prefires by module position

Table 4 enumerates the number of prefires vs. the PFN location over time. For each individual kicker module, there is a unique pattern of prefires. Chart 3 is a graphic representation of total prefires listed in Table 4.

Table 4 Prefires for each module

	Y1	Y2	Y3	Y4	Y5	B1	B2	B3	B4	B5
2007	0	1	3	1	7	1	7	1	7	2
2008	0	1	1	0	0	0	0	0	2	1
2009	0	0	0	1	0	2	0	1	5	1
2010	1	5	1	0	0	4	4	0	1	3
2011	0	2	1	2	8	3	1	0	2	1
2012	1	1	0	2	4	0	1	0	0	0
2013	1	3	2	6	1	3	2	0	0	3
2014	0	7	1	3	3	0	0	0	4	2
Total	3	20	9	15	23	13	15	2	21	13

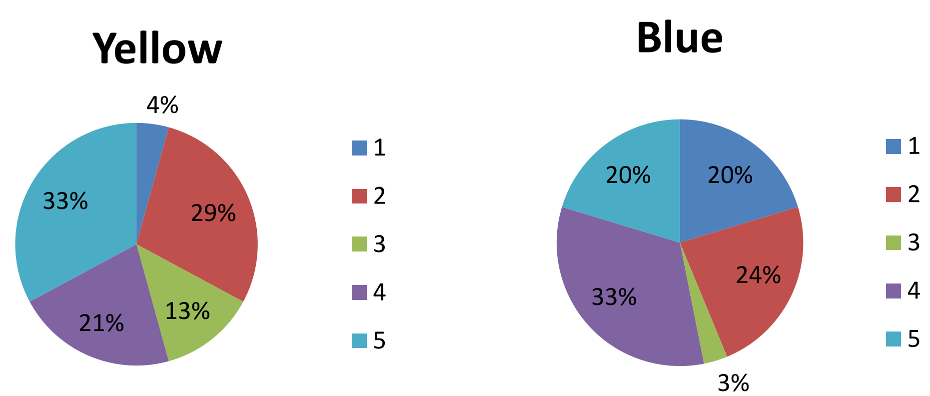


Chart 3 Percentage of total prefires in individual Yellow and blue modules

One module each in yellow and blue had very few prefires. Yellow #1 and blue #3 had only 3 and 2 prefires respectively in the last 8 years. The components in these two modules were seldom changed, while in other modules, such as yellow #2, #4, blue #2, #4, major components had been changed, and some components had been changed more than once.

5 Prefire occurrence vs. average radiation

A radiation survey was conducted in 2013. The results are shown in Table 5.

Table 5 Radiation survey results (unit: mR/Hr)

	Y1	Y2	Y3	Y4	Y5	B1	B2	B3	B4	B5
2013	0.9	0.4	0.1	0.5	0.5	2.4	1.0	0.23	0.05	0.05

There does not appear to be a correlation between the radiation survey results and prefires.

6 What do we do when there is a prefire with no clearly discernible cause?

We usually do one or both of two things before accessing the RHIC ring: (1) condition the modules, and (2) lower the thyratron reservoir voltages.

Are these procedures effective?

By checking the prefire history, we found that on occasion, during the conditioning or a few hours after the conditioning, there was another prefire. We also found that sometimes a few hours after reservoir voltages were decreased, there was a prefire. This is understandable, because there are several factors which may contribute to prefires, such as the thyratron self-firing, radiation triggering the thyratron, a loose connection, high voltage break-down, etc. Because of these factors, it is not clear whether performing the above mentioned two procedures is effective or not.

The same applies to our other procedures, such as replacing the thyratrons, replacing the 5uF/40kV capacitors, replacing 0.39uF/45kV capacitors, etc.

For now, for lack of better procedures, we recommend we continue to do what we have been doing.

7 What is the solution to the prefires?

As was mentioned before, there was not a single prefire at the voltage of 11kV or less except the one caused by a failed trigger module. One solution we can suggest is the installation of a higher voltage thyratron. The thyratrons currently in use are CX3575C, 60kV. A higher voltage rating thyratron, CX1193C, for example, is rated at 130kV, and might resist prefiring. There are some concerns, however, such as the larger size may cause more prefires if radiation is the cause of prefires, or that thyratron may not be triggered at low injection voltage.

Jianlin Mi also had a solution. He suggests adding one more abort kicker module in each ring, thus reducing the HV by 1/6 of 26kV, i.e., 4.3kV. But this would require significant changes in the RHIC ring.

8 Summary

From the previous data we may conclude that

(1) Abort kickers don't prefire at low energy modes (PFN voltages<11kV) except for component failure.
(2) Heavy ions appear to make the abort kickers more likely to prefire than polarized protons.
(3) About 50% of prefires occurred within the first 10 minutes of a run.
(4) One PFN module each in blue and yellow had very few prefires. This may be related to position in the beam line and is worthy of investigation. Perhaps we should consider swapping yellow PFN#1 with PFN#2, and blue PFN#3 with PFN#4.

References:

[1] RHIC run overview, http://www.agsrhichome.bnl.gov/RHIC/Runs/ .

[2] Analysis of RHIC beam dump pre-fires, W Zhang, etc, 2011 Particle Accelerator Conference (PAC'11), http://www.bnl.gov/isd/documents/75266.pdf .

Attachments:

1. Abort Kicker area radiation survey in 2013.

BNL RADIOLOGICAL SURVEY FORM

Bldg. #: RHIC ☐ **Routine**
Location: 1010 Kickers ☒ **Special** Request
Date/Time: 2-25-13 1800 ☐ **RWP#**

Smear Survey Results (DPM/100cm²)

	^3H	$\beta-\gamma$	α				
1.	N/A			16.	N/A		
2.				17.			
3.				18.			
4.				19.			
5.				20.			
6.				21.			
7.				22.			
8.				23.			
9.				24.			
10.				25.			
11.				26.			
12.				27.			
13.				28.			
14.				29.			
15.				30.			

Masslinn Survey Results (DPM/LAS)

1.	N/A			8.	N/A		
2.				9.			
3.				10.			
4.				11.			
5.				12.			
6.				13.			
7.				14.			

Legend: ○ Smear Location ☐ Masslinn Location
Δ Airborne
xxx=Contact Reading
xxx y / zzz — zzz=Reading@ 30cm
y= Radiation Type

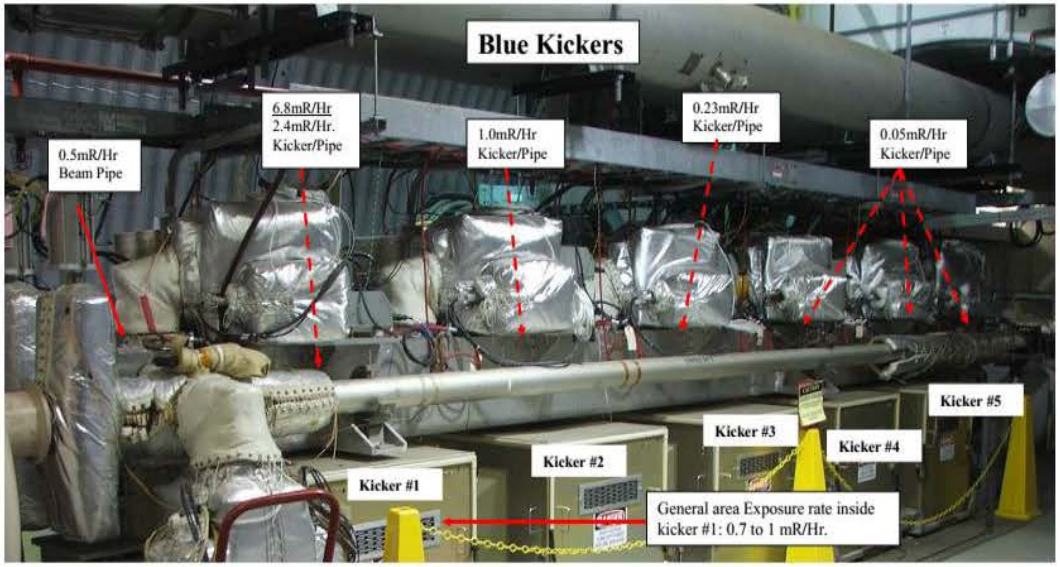
Exposure Rates (Highest)		Airborne Contamination		
Contact	6.8mR/Hr.	Time	µCi/cc	%DAC
General Area	2.4mR/Hr.	N/A	N/A	N/A

☐ All Exposure Rates are in mR/hr and taken at 12 inches (30 cm) unless otherwise noted.

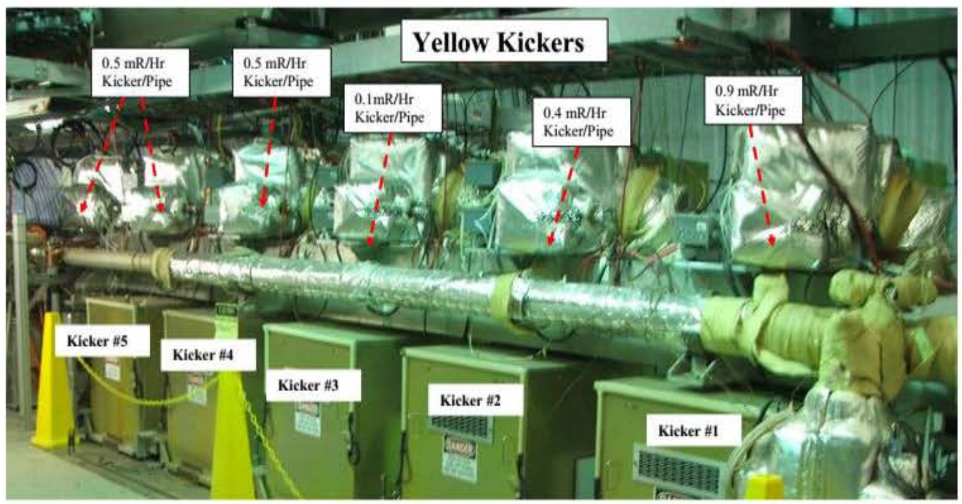
Model	telepole	Model 19	N/A
Serial #	093	291420	
Cal Due Date	8-3-13	5-2-13	
Source Checked (Yes or No)	y	y	

Form FS-1000.1

File Code: FS72SR.09



Front view, with cover removed, of blue kicker #1. General area dose rates: 0.8 to 1.7mR/Hr



Exposure rates on capacitors removed from blue kicker #1
Small white cylinder shaped capacitor: 150/30 µR/Hr.
Large square shaped capacitor: 24µr/Hr.

Surveyed By: Fintan Woods 2-25-13
Signature/Date

Reviewed By:
Signature/Date