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May 2016

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U.S. Department of Energy

USDOE Office of Science (SC), Nuclear Physics (NP) (SC-26)

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C-A/AP/565
May 2016

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RHIC Polarization Decay in FY15 pp Run due to Polarization Profile Development

H. Huang, P. Adams

(Dated: May 23, 2016)

The decay over time of ratio between polarization profile and beam profile has been analyzed in Ref.[1]. A follow up question is if we can get the decay of polarization profile and beam profile separately. With the beam profiles obtained from Ion Profile Monitor (IPM), this analysis was done and the results are analyzed. The results show that the contribution from polarization profile and beam profile is similar for yellow ring, but the contribution from polarization profile is much stronger in blue ring, which is consistent with lower polarization Blue ring.

I. POLARIZATION PROFILE DEVELOPMENT

The polarization profile and beam profile ratio R is defined as [2]

$$R = \left(\frac{\sigma_b}{\sigma_p}\right)^2, \quad (1)$$

where σ_b is for the beam profile, and σ_p is for the polarization profile. Gaussian beam distribution is assumed. For beam with depolarizing schemes in both x and y planes, there are two different R values for the two planes. They can be different in general, but the observation is that both are about the same in AGS and RHIC. For round polarization profiles in both planes, the whole beam polarization P_{ave} is given by

$$P_{ave} = \frac{P_0}{(1+R)^2} \quad (2)$$

where P_0 is the polarization with zero emittance. As the recent analysis[1] shows, the R values are linearly going up against time in RHIC stores. This means that the polarization of the whole beam is going down with time (Eq. 2). As Eq.(1) shows, the whole beam polarization loss can come from two sources: either the transverse emittance increase or the polarization profile reduction. The second one is due to the high order depolarization resonances at store energy. One natural question is if the polarization profile dependence on time can be estimated from these data. Since emittance dependence on time can be derived from RHIC IPM measurement, the dependence of polarization profile on time can be derived. This analysis can provide quantitative information on the sources of polarization losses.

As a simple estimation, we assume round beam profile and round polarization profiles. Furthermore, the time dependence of these quantities are assumed as linear function. The R values vs. time in store can be linearly fitted as function of time:

$$R \approx R_0(1 + a_r t) \approx \left[\frac{\sigma_{b0}(1 + a_b t)}{\sigma_{p0}(1 - a_p t)}\right]^2 \quad (3)$$

or

$$\sqrt{R_0} \sqrt{(1 + a_r t)} \approx \frac{\sigma_{b0}(1 + a_b t)}{\sigma_{p0}(1 - a_p t)}. \quad (4)$$

In general, emittance will grow over time and polarization profile will be sharper over time. With above equation, both a_b and a_p will be positive numbers. The polarization profile dependence on time can be derived as

$$\sigma_{p0}(1 - a_p t) = \frac{\sigma_{b0}(1 + a_b t)}{\sqrt{R_0} \sqrt{(1 + a_r t)}} \quad (5)$$

$$\approx \frac{\sigma_{b0}}{\sqrt{R_0}} \left[1 + \left(a_b - \frac{a_r}{2}\right)t\right] \quad (6)$$

The polarization profile increase (reduction of σ_p) factor a_p is given by

$$a_p = -\left(a_b - \frac{a_r}{2}\right) \quad (7)$$

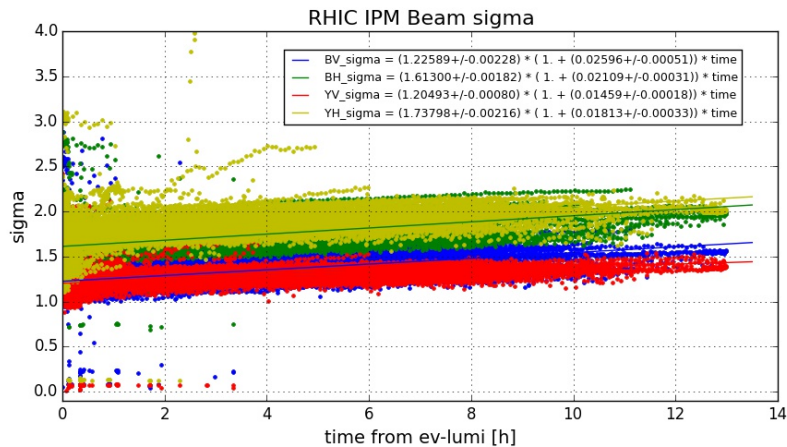


FIG. 1: The beam sigmas from RHC IPM in both rings for all physics stores in run15 pp running period. The linear fits are for data points with store time up to 13 hours. A similar fit with data limited to store time less than 9 hours shows similar results, as the contribution from beyond 9 hours contributes very little.

	R_0	a_r	σ_b	a_b	a_p
Blue H	0.0621±0.011	0.216±0.056	1.613±0.002	0.0211±0.0003	
Blue V	0.0772±0.011	0.161±0.037	1.226±0.002	0.0260±0.0005	
Ave. Blue	0.0700±0.008	0.178±0.031	1.462±0.001	0.0224±0.003	0.0666± 0.0160
Yellow H	0.0752±0.0018	0.064±0.006	1.738±0.002	0.0181±0.0003	
Yellow V	0.0659±0.0166	0.085±0.057	1.205±0.001	0.0146±0.0002	
Ave. Yellow	0.0751±0.0018	0.064±0.006	1.270±0.001	0.0154±0.0002	0.0166±0.0030

TABLE I: Averaged decay parameters for blue and yellow rings. They are highlighted as bold cases. Other parameters are listed for reference.

II. RESULTS AND ANALYSIS

The beam sizes at IPM locations are different from the ones at polarimeters due to the different beta functions. But the relative time dependence slope (a_b) should be the same. We can use the slopes derived at IPM locations for the analysis of beam profiles at polarimeter locations. The beam sizes from IPM in both rings are plotted in Fig.1. Although the beam sizes may be different at the polarimeter locations, the relative slope of the beam size change should be the same. The initial beam sizes are similar in both rings for both planes. For the same ring, the slopes of both planes are similar, too, which justifies to average the two slopes for the analysis. It should be noted that only slopes are used in this analysis, not the initial values of the beam sizes. With the averaged slopes for beam profiles derived from IPM data, the slopes of polarization profiles are derived. They are listed in Table I. The R_0 is listed to show that indeed they are similar in x and y directions. The σ_b values are listed to show that they are consistent in both rings. It does not matter what the true σ_b value is, only the slope a_b matters. For yellow ring, the contributions from beam emittance growth (a_b) and polarization profile decay (a_p) are similar. For blue ring, the contribution from a_p is three times of that from a_b , which indicates stronger effect from higher order depolarizing resonance effect in blue. It should be noted that only a_b and a_p are used to derived the polarization decay slope a_p .

III. SUMMARY

Ideally, we would like to have quadratic term for R's time dependence. The data quality probably only can give us first order fit, unfortunately. The polarization loss has two sources: emittance growth, and the polarization loss due to (high order) depolarizing resonances. The contributions from the two sources are quantified from this analysis. As the results shows, more polarization loss in blue is correlated to much stronger effect from depolarizing resonances. In addition, the blue polarization decay problem is two folds: somewhat faster emittance growth but mainly stronger effect from depolarizing resonances at stores. It is worthwhile to consider polarization simulation study to compare with these results.

Acknowledgment

The authors would like to thank W. Fischer for suggestions to carry out this study. The authors would also like to thank O. Eyser, A. Poblaguev, B. Schmidke and G. Webb for offline polarization data.

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- [1] H. Huang, P. Adams, C-A/AP/558, (BNL, 2016).
[2] W. Fischer and A. Bazilevsky, Phys. Rev. STAB **15**. 041001(2012).