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AGS TUNE JUMP SYSTEM TO CROSS HORIZONTAL DEPOLARIZATION RESONANCES OVERVIEW*

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Abstract

Two partial snakes overcome the vertical depolarizing resonances in the AGS. But a new type of depolarizing intrinsic resonance from horizontal motion appeared. We reduce these using horizontal tune jumps timed to these resonances. We gain a factor of six in crossing rate with a tune jump of 0.05 in 100 µs. Two quadrapoles, we described in 2009 [7], pulse 42 times, the current matching beam energy. The power supplies for these quads are described in detail elsewhere in this conference [4]. The controls for the Jump Quad system is based on a BNL designed Quad Function Generator. Two modules are used; one for timing, and one to supply reference voltages. Synchronization is provided by a proprietary serial bus, the Event Link. The AgsTuneJump application predicts the times of the resonances during the AGS cycle and calculates the power supply trigger times from externally collected tune and energy versus time data and the Low and High PS voltage functions from a voltage to current model of the power supply. The system was commissioned during runs 09 & 10 and is operational. Many beam effects are described elsewhere [3].

INTRODUCTION

Physics Background

With two partial snakes in the AGS, extraction intensity and polarization reached higher levels but the stable spin direction moves away from vertical, and a new kind of horizontal depolarizing resonances have been observed [1]. They happen with following conditions: $G\gamma = N \pm Qh$ where $G = (g - 2)/2 = 1.7928$ is the gyromagnetic anomaly of the proton, and γ is the Lorentz factor, N is an integer and Qh is the horizontal tune [2, 3]. With Qh = 8.70, and AGS injection at $G\gamma = 4.5$ the first resonance is at $G\gamma = -4 + Qh = 4.7$ and the last at: $G\gamma = 54 - Qh = 45.3$. The total number of the resonances in this energy range is 82. The depolarization from each one of them is tiny but the overall effect is about 10% polarization loss.

Correction Method

To overcome these depolarizing resonances, two pulsed quadrapoles that change the horizontal tune by + then -0.05 in 100µs are installed in horizontal β-max sections. The sections are three quarters of a wave length or 1.5 beta waves apart to reduce lattice distortion. This allows us to cross the resonances more quickly by jumping the horizontal tune. In general, the spin tune is equal to $G\gamma$ value, save near the integers they deviate due to the presence of partial snakes. Fig. 1 shows, the tune jump making the resonance crossing speed faster. It also demonstrates that the tune jump must be up at N - Qh and down at N + Qh.

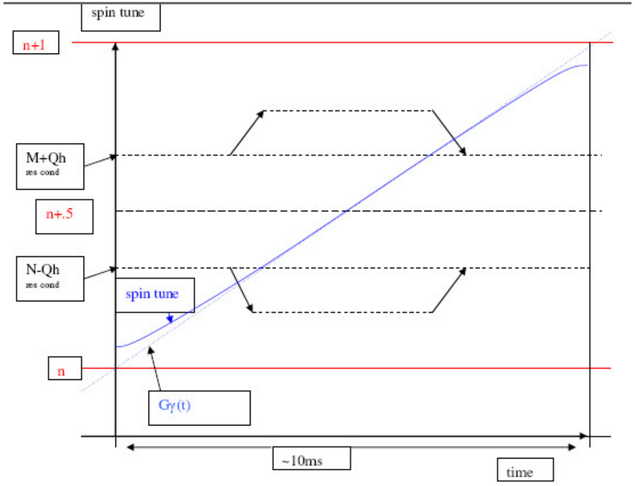

Figure 1: The sketch of tune jump of a pair of resonances (indicated by the dotted lines).

During normal acceleration, the rate of change of $G\gamma$ is 100/s and we now cross the resonance six times faster. Thus Qh must change at a rate of 500/s. The resonances are crossed during the 100 us fall or rise. Each quad causes a tune jump of 0.025. At full energy the rigidity goes from 8 to 80 T-M and beta at the quads is 20 meters thus the quad strength goes from 0.125 to 1.25 T, stepping up by 0.03 T for each of the 42 pulses.

Current Status

The magnets and power supplies were installed in 2009 and the systems commissioned through 2010. They are now operational and have increased to polarization over the whole beam by about 10%.

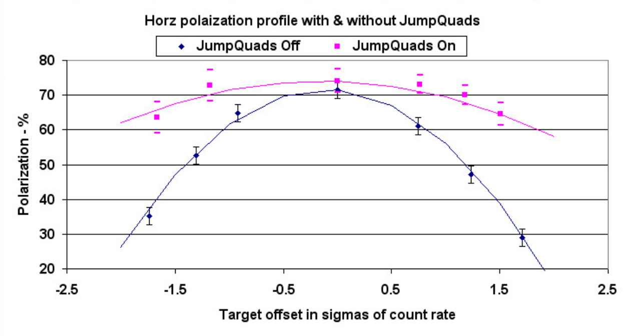

Figure 2: Polarization as a function of position of vertical target, with and without JumpQuads on.

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A Collider's data rate goes as $P^4 * I^2$ where P is polarization and I is intensity. Therefore, a 10% increase in polarization results in a 46% increase in data quality.

SYSTEMS

Magnets and Supplies

The magnets and cables have operated without problems for two years. In the power supplies, the high voltage charging times is now controlled by the timing system and an interlock has been added to the low voltage supply to trip it if the output of the filter exceeds a safe voltage (and thus peak current) for the IGBT switch. More detail is given in another paper here [4].

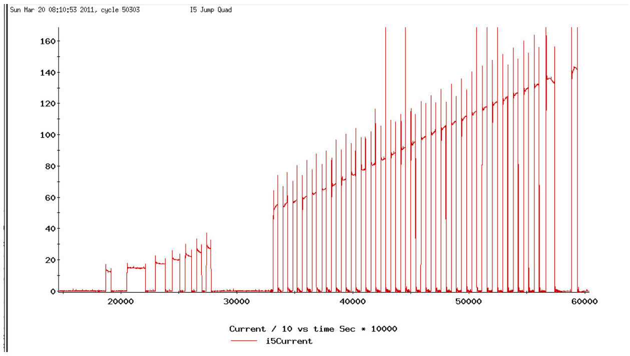


Figure 3: Current vs. time in an AGS cycle, the gap is around transition where the beam is less well behaved. The first and last pulses as they only jump one resonance. The early and late pulses are longer due to lower gamma dot.

Controls Hardware

Control for the AGS Tune Jump System is provided via BNL designed boards located in a VME chassis, the standard controls platform used in the Collider-Accelerator Department (C-AD). Timing synchronization is provided through a combination of the AGS Event Link and the AGS Gauss clock.

The AGS Event Link is a BNL proprietary 10Mbs serial timing bus used to distribute timing information to all AGS equipment locations. Events and clocks derived from this link are used to initiate hardware operations such as state changes, data acquisitions, and modifying system settings.

The heart of the AGS Tune Jump control system is a pair of Quad Function Generators, VME modules with the C-AD designation V233.

A V233 can be configured to provide up to 32 individual channels of timing data. Each channel can generate a unique series of pulses, with timing provided by and an internal or external clock, and start/stop control provided by an Event Link. The timing signals are made available at the backplane of the VME chassis.

A V233 can also be configured to provide up to four channels of digitized reference voltages, called setpoints, transmitted sequentially over fiber at a rate determined by an on-board or externally provided clock. The setpoints transmitted by the V233 are received, decoded, and transformed into an actual reference voltage by a PSI, (Power Supply Interface), and used for power supply control. In addition, PSIs collect readback and status data from their power supply, and send it back to the V233 over a separate fiber link. The V233 stores this data, and provides it to the VME processor on demand.

In the AGS Tune Jump System, all timing starts with the first V233, configured to provide timing data. Starting and stopping the V233 is accomplished by decoding events on the AGS Event Link. The AGS Gauss clock is used to sequence the timing pulses. Six channels of timing pulses are generated, defined as Start, Stop, Jump+, Jump-, Cycle End, and Setpoint Advance. Another custom VME module, the V195, collects the first five of these signals on the VME backplane, and transmits them fiber optically to the quadrapole power supply locations, where they are converted back to electrical signals and used as control signals.

The last timing signal, Setpoint Advance, is used as the external clock input to the second V233. As before, the AGS Event Link provides the start/stop control. The second V233 transmits setpoints to four PSIs, connected directly to the four quadrapole power supplies. The setpoints generated by this V233 are sequenced by the Setpoint Advance timing signal, converted by the PSIs, and used as reference voltages for the four quadrapole power supplies.

One last VME module, the V102 Decoder Module, provides a Backup Discharge Pulse.

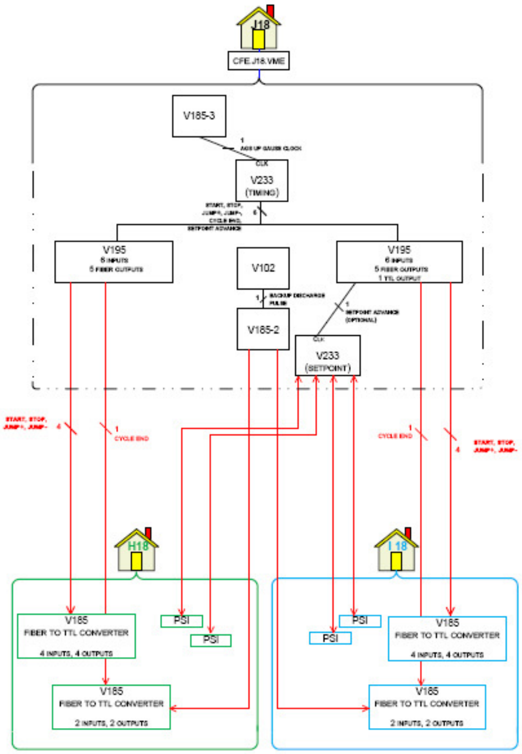
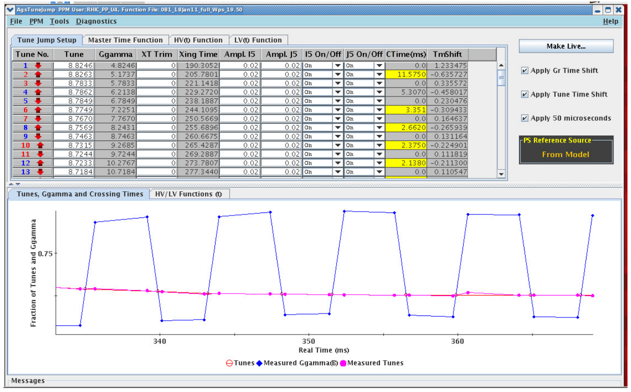


Figure 4: Layout of the control system.

Applications Program

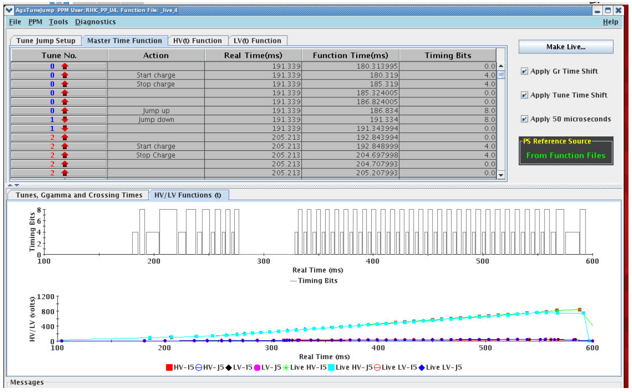
The momentum is measured up the ramp using both frequency and radius and guide field and radius, then converted to G-gamma [5]. The frequency and radius measurements are averaged over times longer than the desired precision of 100 µs, so their starts are offset. As β goes from 0.91 to 0.99 during AGS acceleration and only gamma from frequency and radius is affected by β, the two systems cross calibrate each other. The offsets, calibration measurements, and time sets are all stored and archived in the control system. The Horizontal tunes are then measured before and after the resonance crossing times. This information is then fed to the TuneJump application. The application then displays this data, and interpolates the exact crossing time.



Tune No.	Tune	Ggamma	XT Trim	Xing Time	Ampl. I5	Ampl. J5	I5 On/Off	J5 On/Off	CTime(ms)	TmShift
1 ↓	8.8246	4.8246	0	190.3052	0.02	0.02	On	On	0.0	1.233475
2 ↑	8.8263	5.1737	0	205.7801	0.02	0.02	On	On	11.5750	-0.635727
3 ↓	8.7833	5.7833	0	221.1418	0.02	0.02	On	On	0.0	0.335572
4 ↑	8.7862	6.2138	0	229.2720	0.02	0.02	On	On	5.3070	-0.458017
5 ↓	8.7849	6.7849	0	238.1887	0.02	0.02	On	On	0.0	0.230476
6 ↑	8.7749	7.2251	0	244.1095	0.02	0.02	On	On	3.351	-0.309433
7 ↓	8.7670	7.7670	0	250.5669	0.02	0.02	On	On	0.0	0.164637
8 ↑	8.7569	8.2431	0	255.6896	0.02	0.02	On	On	2.6620	-0.265939
9 ↓	8.7463	8.7463	0	260.6675	0.02	0.02	On	On	0.0	0.131164
10 ↑	8.7315	9.2685	0	265.4287	0.02	0.02	On	On	2.3750	-0.224901
11 ↓	8.7244	9.7244	0	269.2887	0.02	0.02	On	On	0.0	0.111819
12 ↑	8.7233	10.2767	0	273.7807	0.02	0.02	On	On	2.1380	-0.211300
13 ↓	8.7184	10.7184	0	277.3440	0.02	0.02	On	On	0.0	0.110547

Figure 5: A detail of the display of fraction remainder of G-gamma and Horizontal Tune.

It then calculates the exact firing time of the pulse start and end to place the crossing in the middle of the 100 µs ramp. The time to turn on and off the HV capacitor charging is then calculated providing the maximum charging time while allowing the IGBT′s to fully deionize before being stressed by high voltage.



Tune No.	Action	Real Time(ms)	Function Time(ms)	Timing Bits
0 ↑		191.339	180.313995	0.0
0 ↑	Start charge	191.339	180.319	4.0
0 ↑	Stop charge	191.339	185.319	4.0
0 ↑		191.339	185.324005	0.0
0 ↑		191.339	186.824005	0.0
0 ↑	Jump up	191.339	186.834	8.0
1 ↓	Jump down	191.339	191.334	8.0
1 ↓		191.339	191.343994	0.0
2 ↑		205.213	192.843994	0.0
2 ↑	Start charge	205.213	192.848999	4.0
2 ↑	Stop Charge	205.213	204.697998	4.0
2 ↑		205.213	204.707993	0.0
2 ↑		205.213	205.207993	0.0

Figure 6: Timing function display, with HV capacitor charging shown as a level 4 and magnet pulse as an 8.

The voltage functions are calculated using models of the HV & LV supplies including their networks and load. The HV supply charges the capacitor which pulses the magnet in 100 µs to current by switching on the SCR. When at current an IGBT switches the current to the 2 Farad capacitor charged by the LV supply. This supply′s function is more of a problem in that there is a 5 Hz undamped LC filter on the output and the load is pulsing at different pulse lengths and different currents. Thus the model must account for future loads. Also the LV supply is a phase controlled 6 phase rectifier feeding a large capacitor and lacks the ability to accept inverse current, thus the rectifiers will stop conduction if the output is less than the 2F capacitor voltage.

When hand trimmed functions are used, the application can save them from the function generators, and latter reload them without remodeling the settings.

COST SAVINGS

There was little time and money to create this system. Using old magnet cores from decommissioned beam lines, which were slightly radioactive and thus had negative value, eliminated the design and core construction. This was a big saving in time and cost. Making the shims only 30% iron with longitudinal laminations also had big cost and time savings. Using qudraplex cable rather than coax was less expensive and required less labor to run from the power supplies to the magnets. The large low voltage supplies were also recycled from decommissioned beam lines as well as the magnets we used as chokes. Lastly, the bellows vacuum chambers we use are much less expensive than ceramic and work well at our rise times. Many details of this system we're given previously [7].

CONCLUSIONS

The TuneJump system has worked well and has caused little trouble save for the perturbations in the lattice having such a large effect due to our need to run with the vertical tune within a few thousandths of the integer tune. As these problems were mostly sorted out by correcting the 6th harmonic orbit distortions which caused a large 18 theta beta wave [5,6]. Also running with minimal chromaticity reduces emittance growth. There are still small beta waves which are being addressed. The timing of the pulses is still being investigated, but as each crossing causes minimal polarization loss, this is a lengthy process.

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