The Injectors

(Tandem / TtB / Booster / AGS / AtR)

Past Performance

Expectations and Plans

Gold:

Intensity, emittance transverse, emittance longitudinal

Protons (not polarization specifically)

Intensity, emittance transverse, emittance longitudinal,

Gold / Deuterium - status

RHIC Retreat 2002
L Ahrens

GOLD - Intensity

(Benjamin Steski,+and of course Zeno)

When the systems are tuned up, the injectors meet the design goal – 1e9 gold ions / RHIC bunch with a bit to spare. (Fig. 1 and 2)

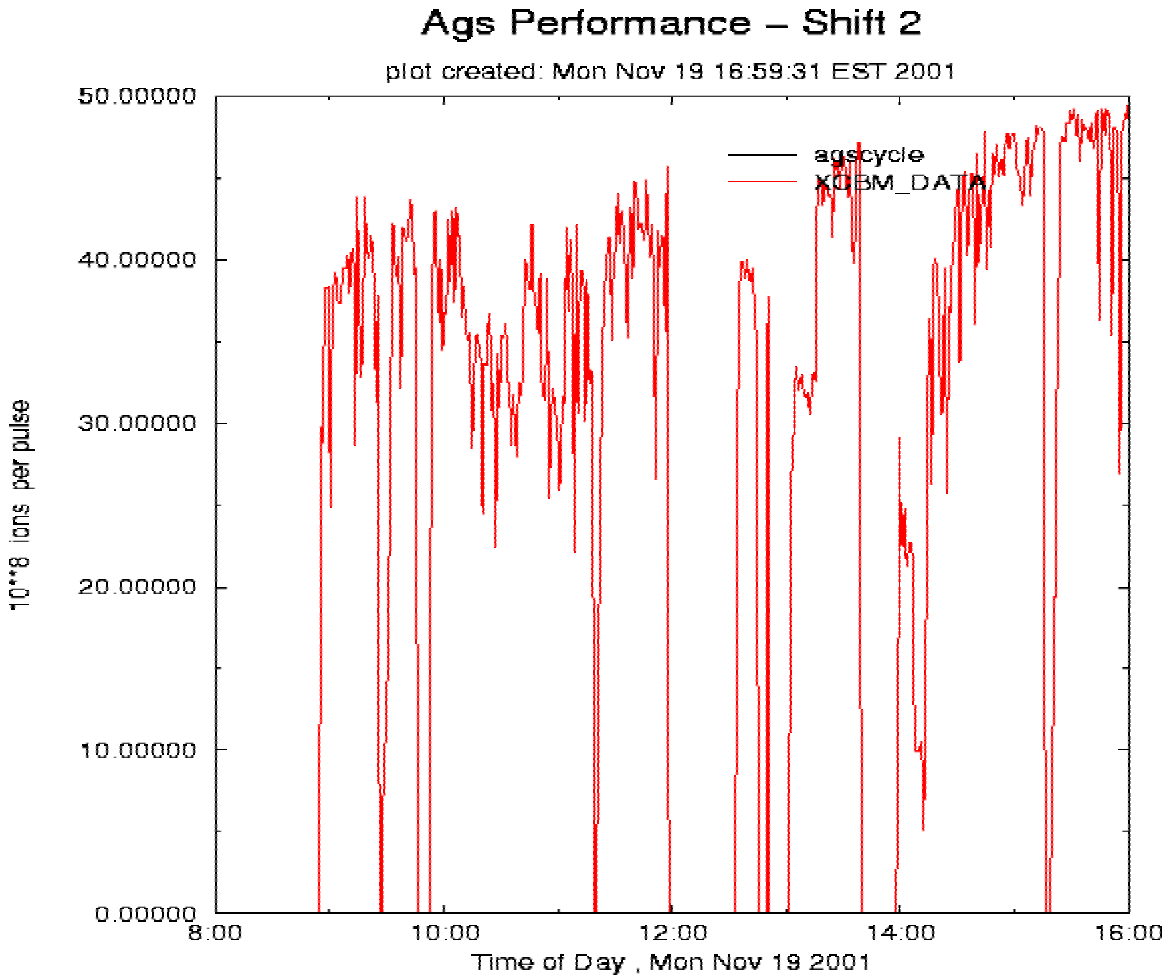

Figure 2 **AGS Gold Intensity 19 Nov 01 Ions available for 4 RHIC Bunches**

This plot presents the total gold ion intensity (40 = 4e9 ions) available for transfer into 4 RHIC buckets, measured just before extraction from the AGS.

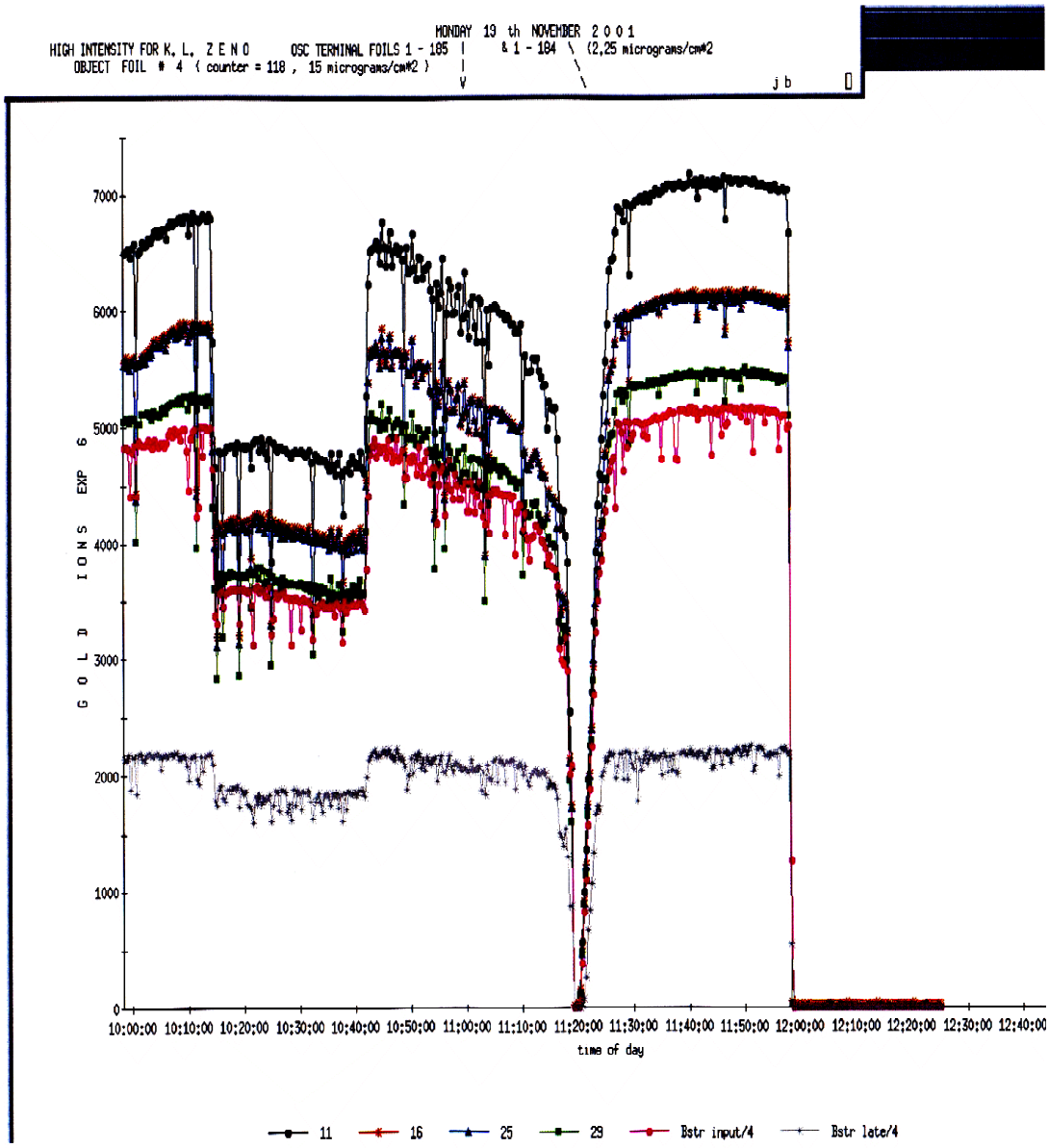

Figure 1 "Typical" TtB and Booster Gold Intensity 19Nov01

What is plotted is the number of gold ions available to fill a single RHIC bunch as a function of time over a two-hour period. The lines: intensity (1000 = 1e9 ions) for a given time or AGS cycle measured at five points along the TtB = Tandem to Booster transfer line and the lowest line measured in the Booster at the end of the Booster acceleration cycle. Going 'down' the page is moving later in a given acceleration cycle.

Gold - Intensity

run year:	'Booster Input' (TtB output)	Boo Late		AGS Late	
	$x10^9$	$x10^9$		$x10^9$	
2000	**16**	**7.8**	(49%)	**4.0**	(25%)
2001	**21**	**9.6**	(46%)	**5.2**	(24%)

Intensity available from AGS for 4 RHIC bunches

Intensity in Booster – not against a hard wall

"tuning" time at highest intensity essential

successful commissioning of MP6 – the 2nd Tandem Van de Graaff !!

intensity not casually available

more teaching of Operations by Operations

Mode Switching complicates life

Future "factors of two" – near term – the Brennan scheme from Retreat 2000?

-far term (5 years) EBIS?

Gold emittance – transverse

into AGS “must” be small

never see growth coming into / while in AGS - apparently some sort of damping (neat stuff ...)

shot-to-shot trajectory stability through AtR issues:

G10 kicker

H10 septum

AtR bpms have the info, better tools would speed up keeping things right

(quantify the gain vs cost?)

Twiss parameters from flags in AtR - ongoing

experimental input (from RHIC) as to the optical match into RHIC

would be the bottom line

Gold emittance – longitudinal

Historically this dimension traded in to increase bunch intensity

Keeping as small as possible **should** constrain Booster injection

AGS (debunch/rebunch 24->4) – makes the bunches equal

AtR - stability: energy and phase

energy = stability of AGS extraction magnetic field

still learning, Siemens/Westinghouse

better understanding of diagnostics – need more automation

phase

hard (target bucket length .16 AGS bucket length)

shot-to-shot 'jitter' expected – loops correcting

plan – quieter AGS by redoing extraction bumps – less work for the rf loops

Is there an issue needing work over the 56 bunches of a single fill?

Polarized Protons – intensity and longitudinal beam size

Intensity not the issue (with Anatoli's source)

one cycle of protons out of:

Linac	5×10^{11}
Booster	5×10^{11}
AGS	2×10^{11}
AtR	$(.8 – 2) \times 10^{11}$

note:
(2×10^{11} in 110 bunches would put us up against the RHIC OSL)

Longitudinal emittance is an issue

for pol in AGS and to fit in RHIC buckets

two bunches, rf h=2, in Booster and keep only one in AGS

'unnecessary' wear and tear on pol source

plan (partial)

h=1 in Booster and with fast chopping

didn't work with pol source input (?)

stay tuned for AGS injection strategy with new polarimeter

Polarized Protons – transverse beam size

Important – for polarization, for RHIC intensity

No magic – careful tuning at transfers

AGS vertical transverse damper effective
(from pue response anyway)

Is growth necessary to maintain polarization in AGS at high intensity?

A complication present during the last run – mm amp 60Hz motion in two sextupoles - from a new bump power supply – maybe important

AGS transverse Diagnostics

exist but labor intensive.

Multiwires/flags in and out; MW, IPM inside - is the picture consistent?

Other PP Issues

polarized tuning in AGS lives or dies by the internal polarimeter.

The planned CNI polarimeter in AGS will make a huge difference.

The Deuterium/Gold Scenario (Kip Gardner +)

No showstoppers from the Injectors ‘in principal’

TtB magnet settings must be changed

perhaps this sets min time

preliminary with-beam tests encouraging

Different Users for the Injectors – standard stuff

BtA – upstream magnets change – as with ‘mode switching’

AtR – upstream magnets change.

Other issues – RSC constraints

More General Injector Issues

Integration

(RHIC – AGS – Booster) ok – lots of forces sharing

Tandem – physically apart need better communication

encouraged strategies to optimize efficiency

Logging

keeping track of the injectors – correlated to RHIC activity

Getting measurements into applications – organized collecting

Getting numbers out of applications and making them GPM accessible

Polarized proton runs push this, and provide concrete examples

history -manual spreadsheet - semi automatic spreadsheet

Modeling

example: predicted betatron tunes aware of the ‘live’ machine (the settings of e.g. quads, sextupoles, radius – and measurements of e.g. main magnet field, beam radius)

NOTES PAGE Gold Intensity

Not easy to make much improvement on the .25 overall efficiency ratio:

1) 50% in Booster - 35 turn multiturn injection – filling up Booster in transverse phase space.

2) 50% in BtA and AGS - foil stripping in BtA – expect/measure 65% in desired charge state

Booster intensity constrained by injection losses degrading vacuum and causing further losses. However, this 'saturation' seems to move up given sufficient high intensity "tuning" time (Au^{32+})

Successful commissioning this run of the 2nd tandem Van de Graaff (MP6) allowed such tuning without high concern about "running out of foils".

Tools available but not the time to close on a test of effect of chopping the Tandem beam into existing Booster buckets. (motivated by the need to avoid any losses)

Booster diagnostics: get an orbit measuring system again next run!

If Tandem can further increase its output intensity, with some will come across

Tandem has an on going effort to increase voltage gradient at the source

Reliability, stability of high intensity?

1) intensity not casually available – better understanding / continuing teaching of Operations by Operations

2) Mode switching complicates life – first as a competition for time, but apparently some aspects of SEB setup reduce AGS acceptance 5% effect.

Future "factors of two" – near term – the Brennan scheme from Retreat 2000?
-far term (5 years)- what is the status of EBIS?

EBIS: half length system has met design goals => full length system would match intensity from Tandem. Different constraints, few turn injection, larger emittance, more growth potential, but requires what is significant money to build. Motivation should be the money to be saved ... in the long run?

NOTES Gold emittance transverse

The basic transverse size was not expected to be an issue – and for the most part it isn't. We never see emittance increase in AGS. This itself is a mystery, but we take it. Despite this, one potential emittance deterioration is associated with trajectory stability at the end of AtR

We had periods of trouble with both the AGS extraction kicker and septum – required "expert" involvement. AtR needs some extension of existing tools to allow quick diagnosis of "jitter" sources, and by Operations.

Nick Tsoupas et al. learning slowly about AGS extraction from measurements in AtR. Nick presents a consistent picture of the effects of our extraction strategy (way to the outside to get a path length that matches RHIC).

RHIC instrumentation – the injection program, (and potentially the RHIC IPM) can give valuable feedback on AGS extraction stability – needs to allow correlations with AGS and over the "55" bunch injection.

NOTES Gold longitudinal emittance

Relaxing the basic longitudinal size requirements (along with the rather changed acceleration strategy now followed) allowed the present (acceptable) intensity situation.

Is the present longitudinal size a constraint on RHIC operations?

Booster injection/capture has to remain consistent with a small longitudinal emittance product. This translates into as adiabatic a capture process as possible and so lobbies for injection at very low dB/dt.

Stability of the AGS gold bunch **energy** and **phase** over a 55 bunch fill is a basic issue

Energy – AGS magnetic field stability. This we are still learning about. The injection program gives feedback. Also AGS instrumentation (average orbit measurement) gives feedback. Need better tools for Operations to run the show.

Phase – this should be a very hard problem – since the target in the RHIC bucket is very small relative to the AGS bucket. How good is the match? The injection program maybe knows now – over the 55 bunches.

however, one step to make the space cleaner should be in place for the next run- less destabilizing extraction bumps in the AGS. This should simplify the work of phase locking AGS to RHIC.

NOTES pol proton intensity, longitudinal emittance

We injected into h=2 longitudinal structure. The linac momentum spread sets the best we can do, especially without fast chopping. Fast chopper - lack of functionality with the beam from the polarized source – a puzzle. More work to understand if we can reduce the linac momentum spread at this low intensity is useful – linac beam into HEBT.

However, the loss of half the beam between Booster and AGS is not fundamental but is driven by longitudinal beam size concerns. (2 bunches in 2 h=2 buckets in the Booster but only one kept for acceleration in AGS)

Source reliability would benefit from removing this 50% loss.

NOTES proton transverse

This was at least for a time a big issue during the past run, given the "3 meter" optics and the apertures at the RHIC dump kickers.

Perhaps the large transverse size is a requirement for high polarization from the AGS. The size grows in association with the driving of the beam with the ac dipole. This strategy allows polarization to survive the stronger intrinsic resonances.

Perhaps not. We are not comfortable with at least one aspect of the last run, a horizontal orbit bump powered throughout the cycle to keep the beam near the AGS beam scraper was not well controlled – was causing rather large oscillations throughout the acceleration cycle both horizontally (locally at the dump) and in both betatron tunes.

Diagnostics to keep track of the beam size exist (AGS IPM, AGS multiwire, AtR flags). Such measurements want to be automated but are always hard.

Other PP Issues

polarized tuning in AGS lives or dies by the internal polarimeter. The planned CNI polarimeter in AGS will make a huge difference.

NOTES deuterium – Au

From the point of view of the injectors there appear to be no showstoppers in the plans to fill RHIC with both gold and deuterium.

Tandem: The rigidity of the TtB line must be changed going from deuterium to gold. A partial test (moving the magnets away from the gold setting and then putting them back) gave encouraging results – at worst some small further TtB tuning was necessary. This will have to become Operational and of course specifically with deuterium and gold.

Booster: appears able to accelerate both species without new issues.

BtA: only the magnets upstream of the gold stripping foil will require different currents.

AGS: no new issues expected here.

AtR: only upstream of the gold stripping foil will magnet currents need changing.

The sort of gymnastics carried out for "Mode Switching" during the last run – using a Sequencer to keep things under control - should allow us to do this without any crisis.

Notes general
Integration:

Booster and AGS more or less by default – since all in MCR. Tandem is more of a problem.

Why does Tandem always wait until we are ready to fill before making a foil change? Zeno: maybe Tandem should not inhibit after a fill until they are happy that the foil is optimized. To do this right would it take time away from the Mode Switch?

Logging:

The injectors run on a very different time base from RHIC. We are still struggling with what sort of additional logging is appropriate. For polarized protons we started a “spreadsheet” of numbers, rather small number (~30) of discreet measurements, to define the setup from the point of view of polarization - some beam measurements, some function setpoints. Getting this set automated is a big job because many of the numbers are not immediately accessible to GPM.