Brookhaven National Laboratory

BNL-102208-2014-TECH

RHIC/AP/100;BNL-102208-2013-IR

Integrated System Tests: AtR and Sextant

S. Peggs

June 1996

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

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RHIC/AP/100
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Introduction

Apart from the cover page, this note consists of the "Integrated System Tests" presentation given to the Machine Advisory Committee on June 17, 1996. Having compiled various pieces of information into one place, it seemed sensible to distribute it more broadly, as reference document useful in:

1. Summarizing physics results from the 1995 AtR tests
2. Documenting preparations for the 1996 Sextant Test

As a compilation, it embodies the work of many people, who are not formally acknowledged in the author list, or anywhere else in the paper. Despite this, sincere thanks go to all contributors, direct and indirect.

MAC 96
June 17, 1996

Integrated System Tests

Steve Peggs

AtR Test Physics Results (T. Satogata)

1. AtR test timeline
2. Optics: design versus measurement
3. Physical & momentum apertures
4. Emittance measurements

The Sextant Test

1. RHIC "Sextant Scope"
2. AGS running schedule
3. Sextant test timelines
4. The Sextant Test "Cabal"
5. Sextant beam test projects
6. Sextant commissioning strategy
7. System Commissioning
8. Injection element threading
9. Software: applications, managers, & utilities
10. Power supplies
11. Coordinate conventions

Software: applications, managers, & utilities

The following lists are based on the activities of the Controls Task Force, its working groups, and the Cabal. The lists emphasize code that needs creation, or further development, beyond the AtR code releases.

MANAGERS

Minimum for Sextant test:

TS	Orbit/BPM Manager
TD	BLM Manager
ST	Flag/VPM Manager
FP/JK	DC Magnet Manager

Ramp Managers:

JK	Gamma T manager
JK	Ramp Manager
JK	MADC manager for ramps
FP	RTDL manager
DP	RF Manager

by ACS:

SS	Alarm
DS	Logging Service

Desirable:

Timeline Manager
Optics Manager
MADC manager for instrumentation

APPLICATIONS

Minimum for Sextant test:

WF	Orbit Acquisition/Display/Archive
TD	BLM Acquisition/Display/Archive
ST	Flag Profile Acquisition/Display/Archive
FP	DC Magnet Control
JK	Ramp Editor
TS	Sequencer
WF	Injection Area Threading
VM	Radon Transformation [AGS prototype]
NT	Emittance Measurement/Comparison
DP	BBat RF analysis and inverse BBat

by ACS:

RO	General Save/Restore
SS	General Alarm and Notification Display
DS	General Plotting (live and archived data)
RO	Time line diagnostics

Desirable:
compare ramps
compare step stones
compare magnet currents (as f() of time)
Optics Measurement/Comparison/Matching

UTILITIES

	Netscape for doc and database interfacing
WM	Plot_atr
WM	Online transfer matrix calculations/lookup
WM	Phone list, pager lookup

System Commissioning

Table 1: Commissioning of the SEXTANT

SYSTEM	Commissioner	Applicat. Code	PET page/ADO	Hardware
BPM	Todd Satogata	Wolfram Fischer	Bob Olsen	Tony Ryan
Loss Monitors	Pat Thompson	Ted D'Ottavio	Ted D'Ottavio	Rich.Witkover
Current Monitors	Pat Thompson	Ted D'Ottavio	Ted D'Ottavio	
Beam Permit Link	Dejan Trbojevic	Pet Page	Bob Olsen	G. Conkling
Timing	Waldo MacKay	Pet Page	Tom Clifford	
Collimators	Pat Thompson	Pet Page	Zal Maldonado	G. Conkling
Injection	Waldo MacKay	Wolfram Fischer		
kicker				Tuozzolo/Pappas
Lambertson				
Flags	Roger Connolly	Steve Tepikian	Larry Hoff	Rich.Witkover
Power Supply DC	Fulvia Pilat	Fulvia Pilat	Bruce Martin	George Ganetis
Data Base	Garry Trahern	Garry Trahern		

Table 2: Scheduling

Month	May	June	July
BPM Todd Satogata Wolfram Fischer	Wolfram Fischer:	Modification of the existing BPM application	Modification of the existing BPM application
Loss Monitors and Current Monitors Pat Thompson			
Beam Permit Link D. Trbojevic	Bob Olsen:Driver for the V120 module,ADO for the driver access	PET-Page to allow control of the driver	Interface to allow events masks associations
Timing Waldo MacKay			
Collimators Pat Thompson			
Injection Waldo MacKay		Wolfram Fischer: Injection Application	Injection Application
Flags Roger Connolly	Steve Tepikian: Writing UI Tools wrapper on Xrt-3D graphics widget for 3D plotting	Writing a set of libraries -read and copy to SDS files and shared memory	Three programs:fpmControl (USER control-FLAG),fpm-Manager(talks to hardw.) fpmGraph(data display)
Power Supply DC Fulvia Pilat	Fulvia Pilat: Magnet Transfer Functions	Power Supply data base table DBsort-program	Magdisplay,Magman - modification of the existing program and make get-asynch, Ado
Data Base Garry Trahern	Garry and Ted D'Ottavio: FEC/Ado configuration and interface start	Configuration Data: Optics/Beamline Namelookup	Configuration Data: Consol/application data

Table 3: Scheduling

Month	August	September	November
BPM Todd Satogata Wolfram Fischer	Modification of the existing BPM application	TESTING?	
Loss and Current Monitors Pat Thompson			
Beam Permit Link Dejan Trbojevic			
Timing Waldo MacKay			
Collimators Pat Thompson			
Injection Waldo MacKay	Wolfram Fischer Injection Application	TESTING	
Flags Roger Connolly	Steve Tepikian: Establishing Glish communication between the three programs	Testing with existing flags	Testing with all flags
Power Supply DC Fulvia Pilat	TESTING		
Data Base Garry Trahern			

The AGS to RHIC Transfer Line Commissioning

Thursday, Feb 8, 1996

I. Background

* Beamline layout and description.
* Timeline.
* AGS preparation and injection conditions.
* "First beam's light", gratuitous T-shirt plug.

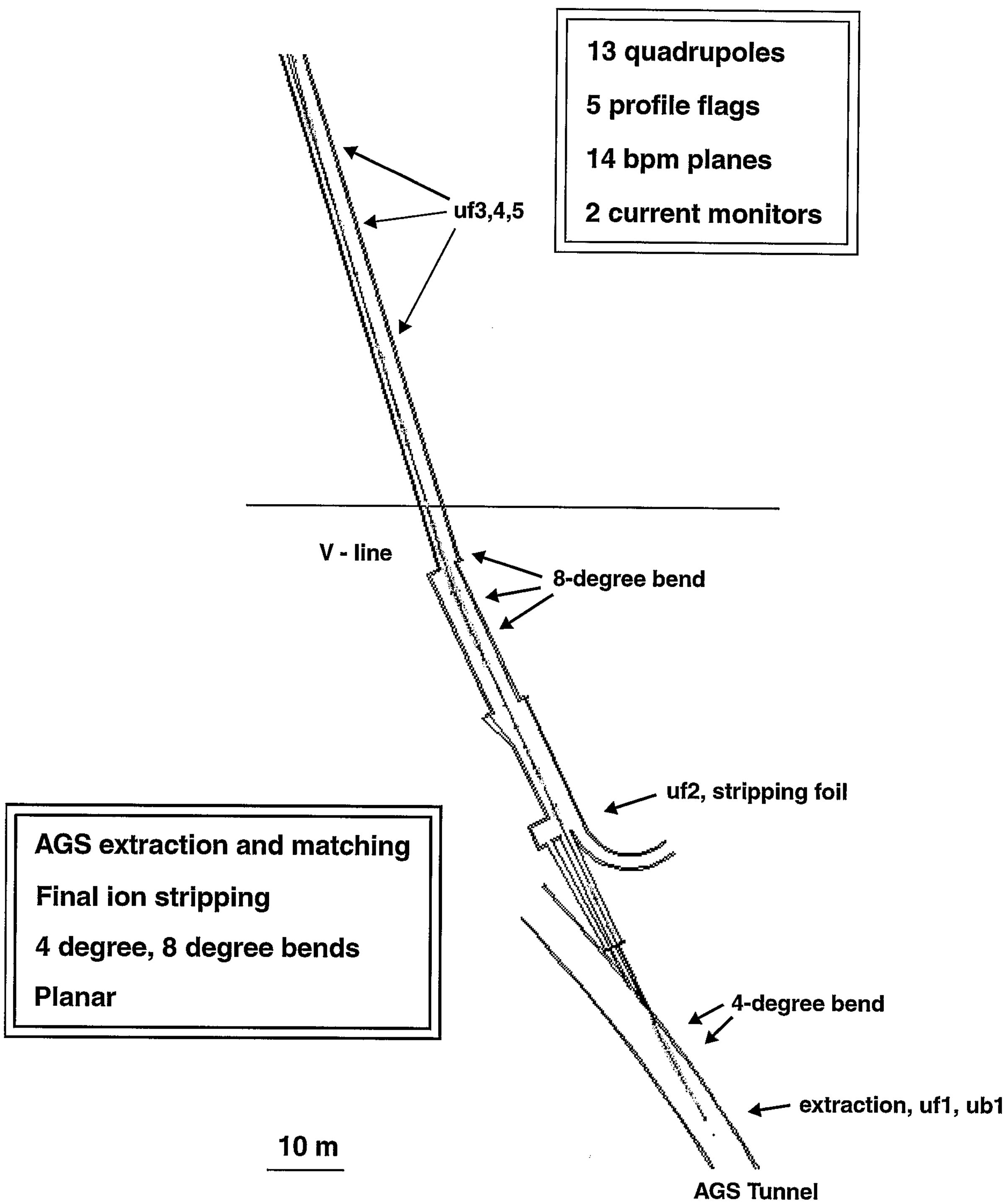
II. Physics/Performance Results

* Beamline optics, beamline-specific parameters.
  - Design optics, beamline instrumentation.
  - Matrix elements, optics measurements.
  - Line and beam dispersions...
    - ...from varying ATR magnet "γ", or rigidity.
    - ...from varying AGS extracted beam momentum.
  - Apertures, beam momentum size.
* Beam-specific parameters, delivered from AGS and through line.
  - Transverse emittance, ε...
    - ...measurement methods.
    - ...sensitivities to errors, flag emittance blowup.
    - ...summary of measurement results.
  - Intensity, correlations to injection offset, and stability.
  - Bunch length, longitudinal emittance, and beam energy.

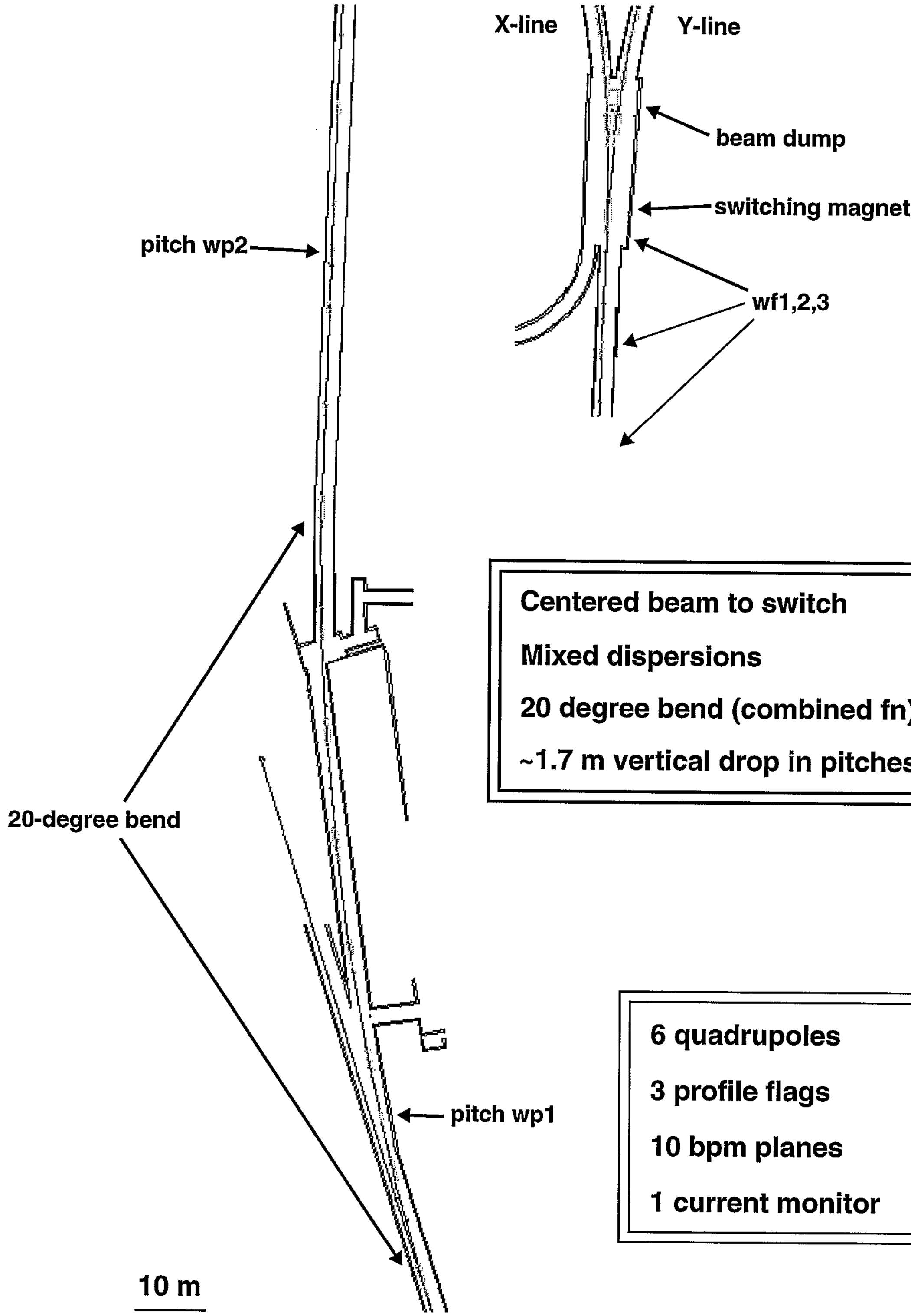
III. Summary

"Those without whom...": ATR shift crews; shift leaders Steve Peggs, Waldo MacKay, Jie Wei, Jorg Kewisch, Dejan Trbojevic; RHIC Controls group; AGS crews, crew leaders, machine physicists; RHIC techs and accelerator systems group...

ATR Layout: AGS extraction and U-line



ATR Layout: W-line to beam dump



Centered beam to switch

Mixed dispersions

20 degree bend (combined fn)

~1.7 m vertical drop in pitches

6 quadrupoles

3 profile flags

10 bpm planes

1 current monitor

ATR Commissioning Timeline

Summary: Commissioning November 6 to December 18, 1995.

Nov 6	Evening, full shifts begin.
	Extraction through U-line and first flag images in hours.
Nov 7	Context switching, quad pumping begin.
Nov 9	20-degree bend scan, beam to wf3 and dump. (~60 hours)
Nov 11	Measure momentum aperture of AGS with bumps off.
Nov 17	Coalescing studies in Booster; systematic U-line scans.
Nov 19	W-line scans with flags; hysteresis procedures in place.
Nov 20	Emittance blowup from thin flags measured to be 10%.
	Intensity up to roughly $2x10^7$.
Nov 21	U-line bpms verified as accurate to 0.3 mm.
Nov 22	W-line bpms partly working. Move to uf2 as stripper.
	U-line dispersion with varying AGS extraction energy.
	AGS septum aperture measured.
	First current monitor working.
Nov 26	First emittance measurements, ε_x=40 π mm mrad.
	All current monitors working.
Nov 27	Orbit steering, difference orbits measured, BCM calib.
Nov 28	New colescing scheme makes BPMs fail.
Nov 30	Bunch width and $\Delta p/p$ with h=8 coalescing measured.
	2-flag/quad emittance measurement.
Dec 4-13	Deionizing filter installed backwards - down time!
Dec 14	W-line dispersion with varying AGS extraction energy.
Dec 16	Beamline dispersion measured by varying line γ.
Dec 17	Careful multiflag emittance measurements.
Dec 18	End of run

Online data summary

* 1.1 Gb of data, almost entirely flag data at ~500 kb each.
* Approximately 400 orbits archived with ATR magnet settings.
* Daily ATR logs later on WWW for accessibility.

ATR Commissioning: The AGS Role

I. Intensity, Quad Pumping

* Bunch coalescing schemes moved AGS from h=12 to h=8. Changed timing and bunch shapes but provided intensity boost by factor of 3-4.

Initial Intensity:	**< 10^7 ions**	h=12
Final Intensity:	**~ 2.5 x 10^8 ions**	h=8
Design Intensity:	**10^9 ions**	

* "Quad Pumping", exciting longitudinal quadrupole mode in AGS and extracting when beam is short and intense, allows ATR BPMs to start working at intensities of 1-2 x 10^7 ions.

II. "On-demand" Context Switching

* ATR commissioning parasitic on normal AGS heavy ion run. Little dedicated time means longer run.

* New challenge for AGS controls - PPM.

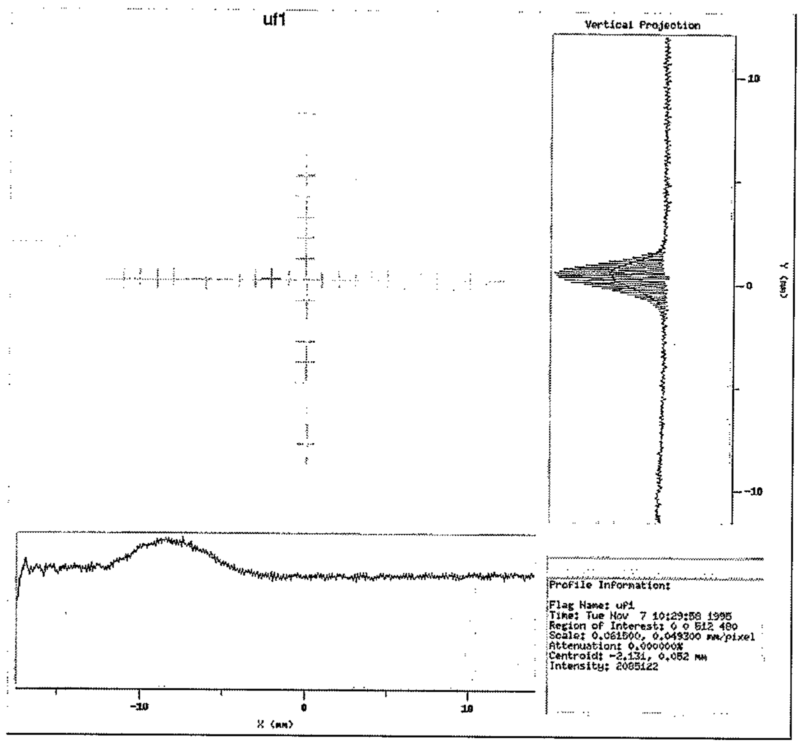
* Some problems in AGS/Booster with successive shot after ATR request.

III. Cameraderie!

ATR Commissioning: “First Beam’s Light”

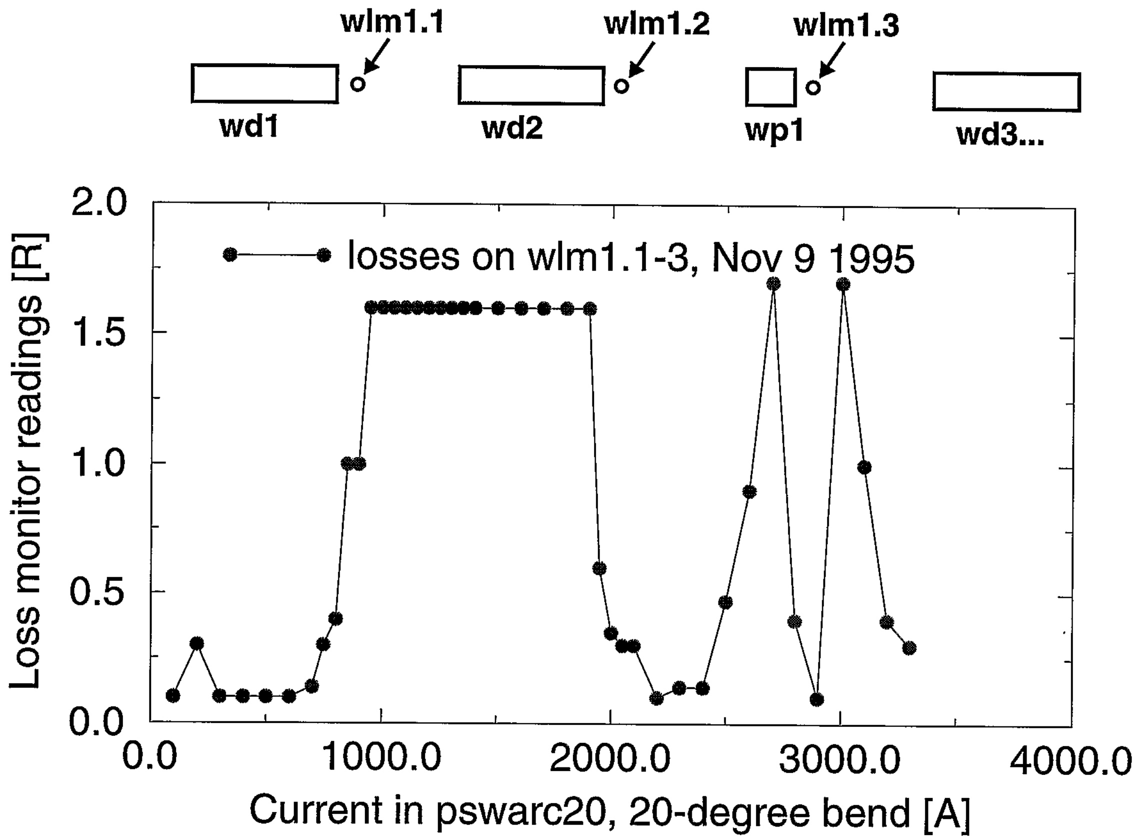
Nov 6, 1600: Start regular commissioning shifts

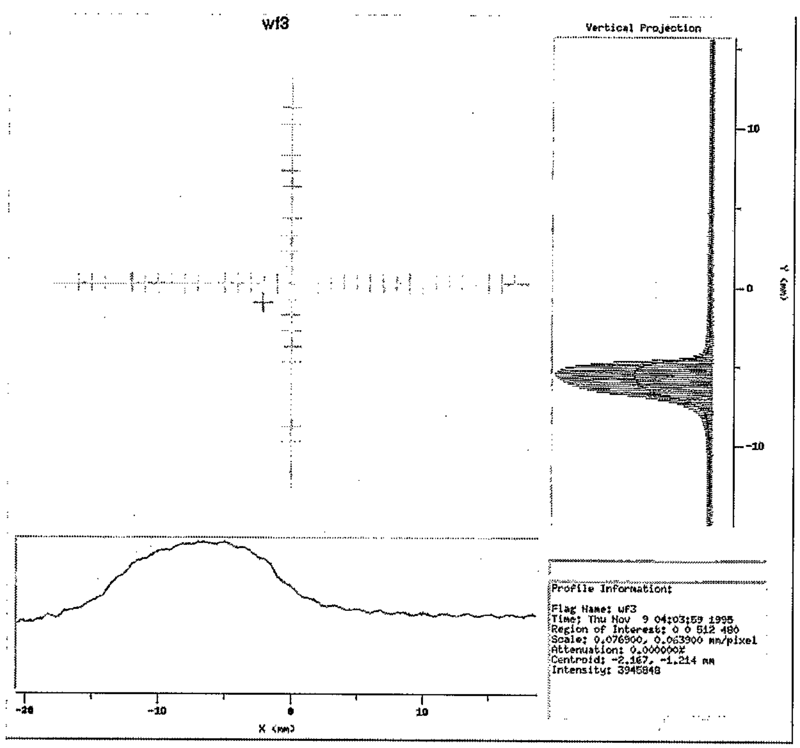
Nov 7, 1100: First beam images on flag uf1 - extraction observed.



Nov 9, 0215: W-line 20-degree arc requires fine tuning.

ATR Commissioning - Tuning the 20 degree bend

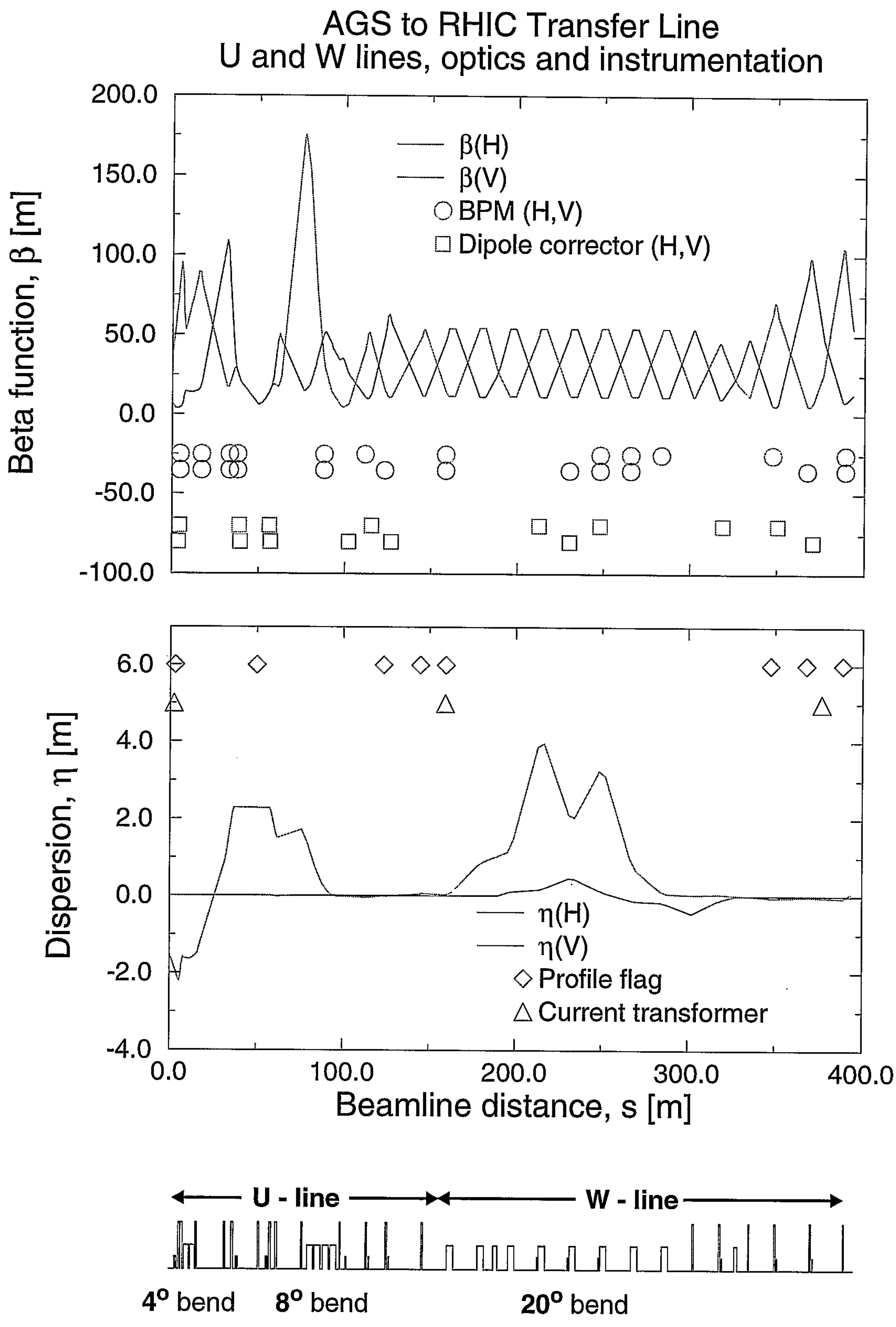




Beam to dump

Nov 9, 0400

ATR Commissioning: Design Optics



Transfer Function Measurements - Methods

*** Measured transfer matrix elements M_{12} from correctors to monitors:**

$$\begin{pmatrix} x \\ x' \end{pmatrix}_{monitor} = \begin{bmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{bmatrix} \begin{pmatrix} x \\ x' \end{pmatrix}_{corrector}$$

$$\Delta x_{monitor} = M_{12}\,\Delta x'_{corrector} \qquad M_{12} = \sqrt{\beta_1 \beta_2}\,\sin(\psi_{monitor} - \psi_{corrector})$$

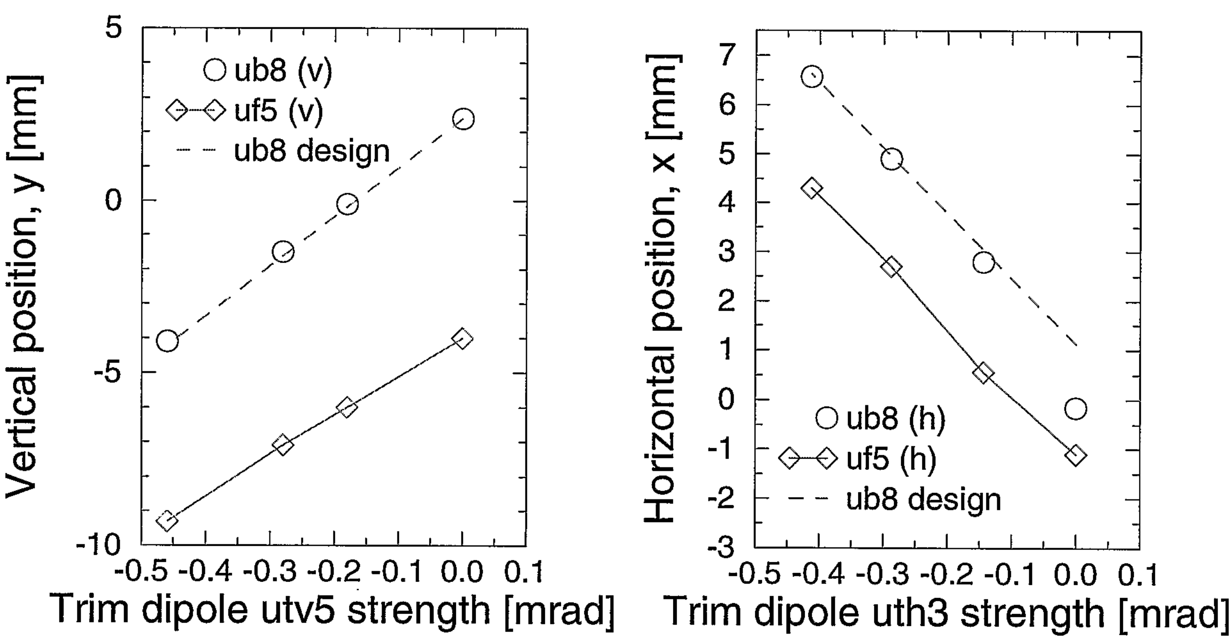
*** Examine orbit differences when single correctors are varied:**

1. Provides powerful diagnostic, only simple modeling is needed.
2. Insensitive to initial conditions, clean orbit threading.
3. Sensitive to many error conditions.

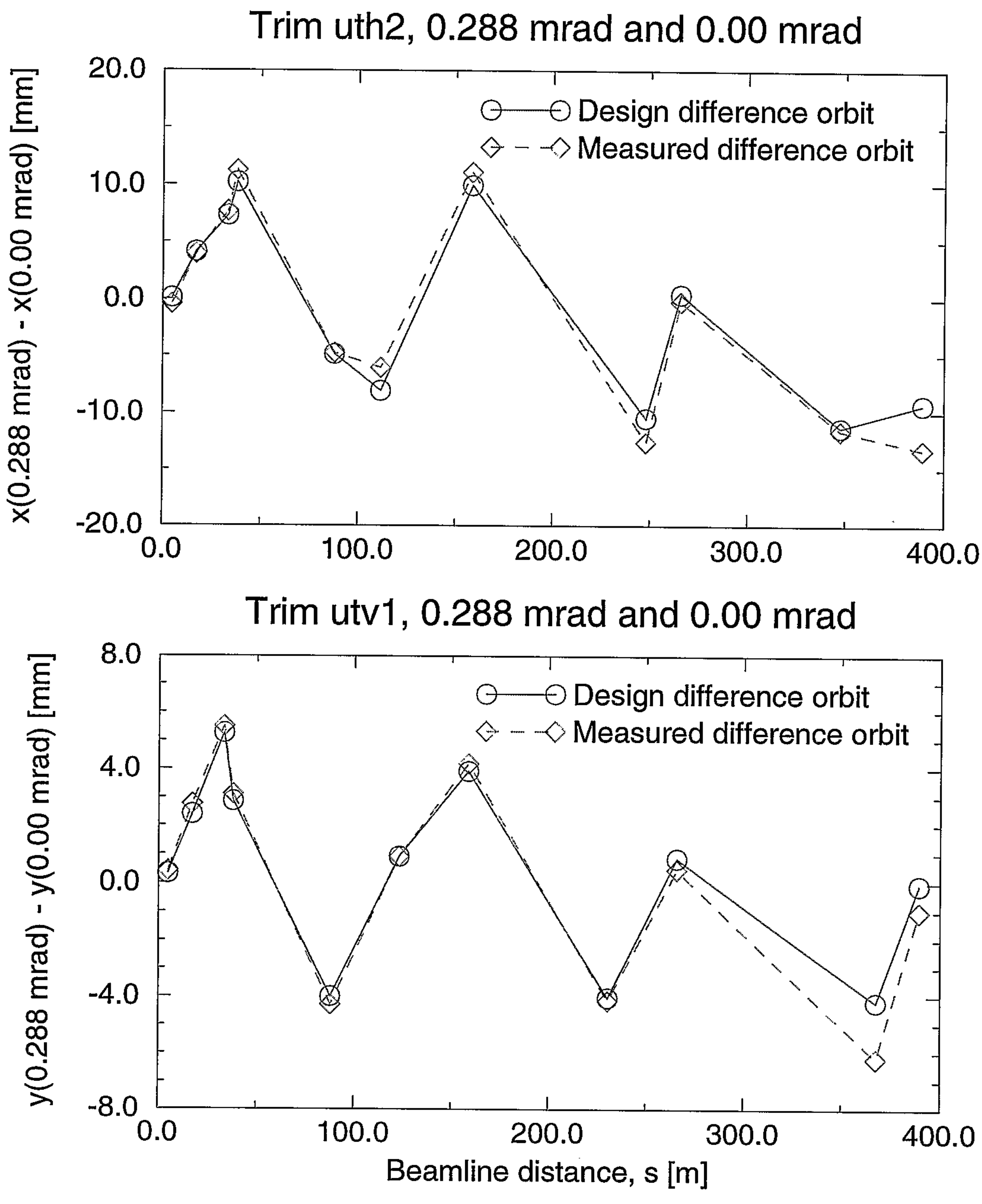
*** BPM and corrector polarities confirmed.**

* ubv6 BPM polarity reversal discovered

* Factor of 2 in U-line trim dipole transfer functions discovered.

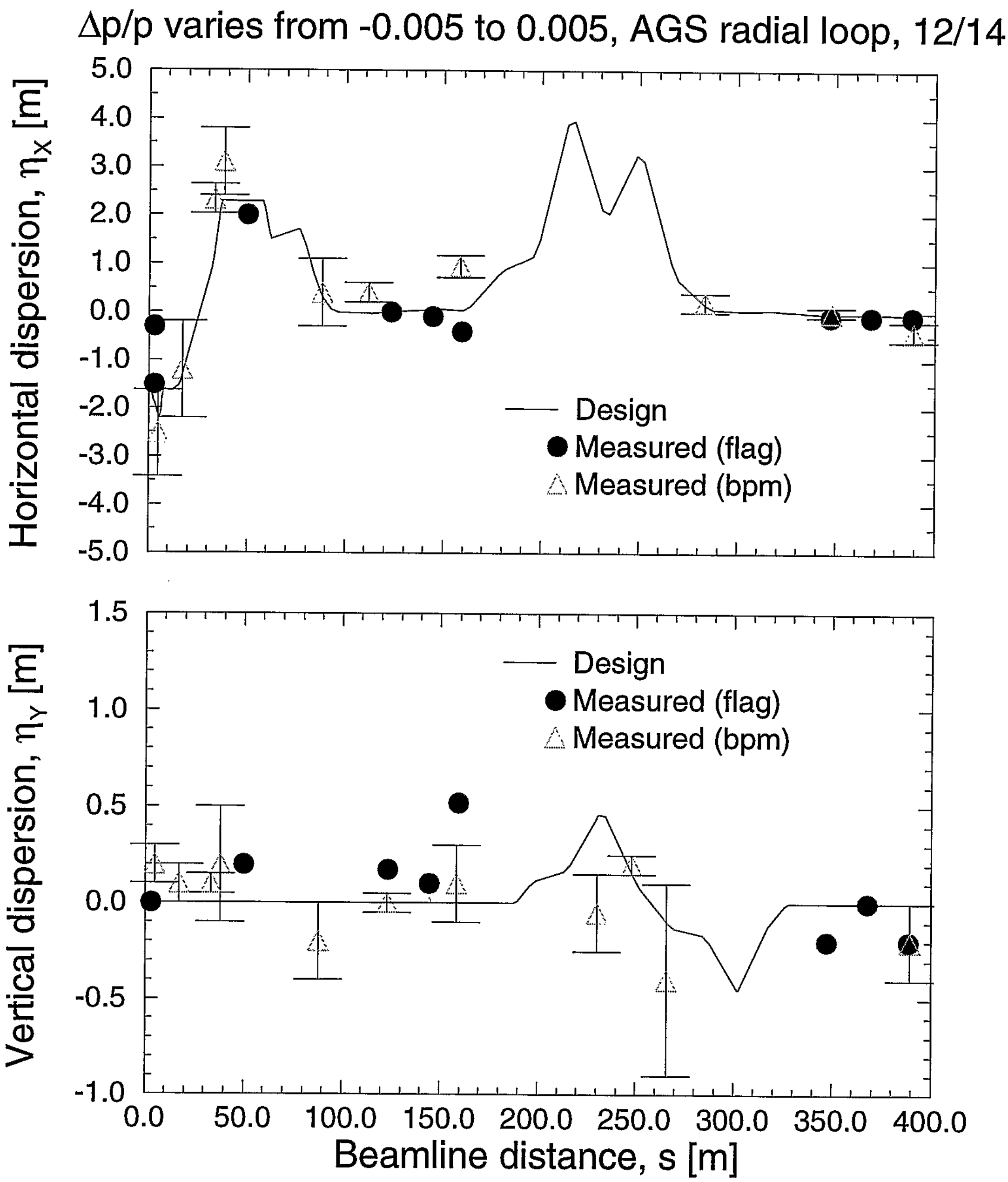


Difference Orbits - Simulation vs Measurement



*** Difference orbits measured and compared to simulation - agreement to several percent.**

ATR Commissioning: Dispersion Measurements



*** Measurements from varying AGS radial loop, extraction energy: "Reasonably" consistent measure of beam dispersion.**

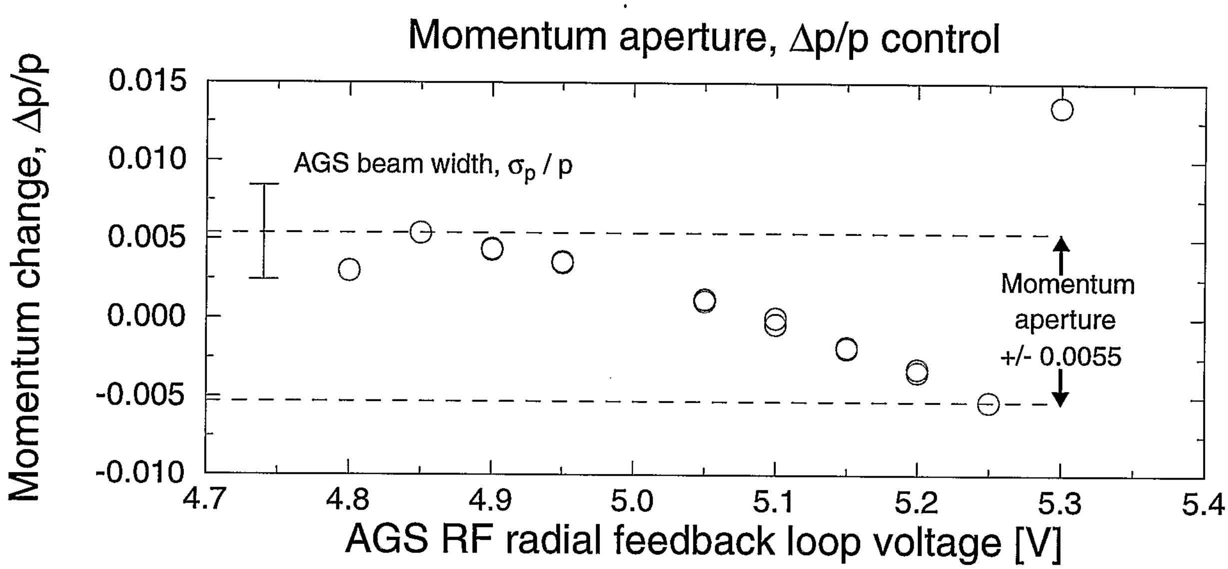
*** Measurements from varying AtR magnet strengths still being analyzed.**

Apertures, Momentum and Physical

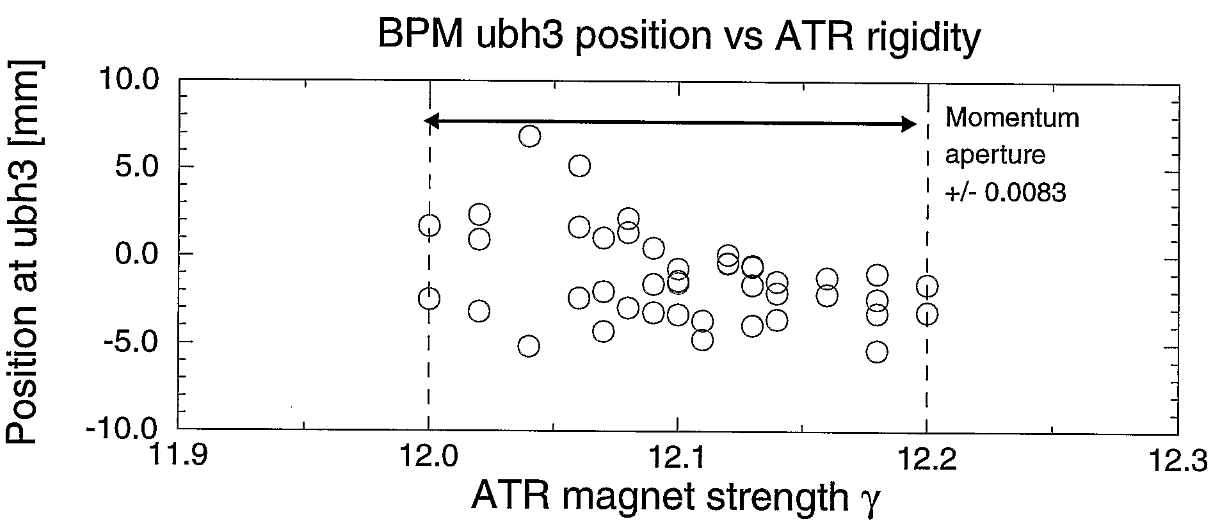
*** AGS momentum aperture during AtR injection flat porch (Nov 11):**

$$\frac{\Delta p}{p} = \pm 8 \times 10^{-3}$$ AGS, AtR injection (no bumps)

*** AGS septum momentum aperture:**

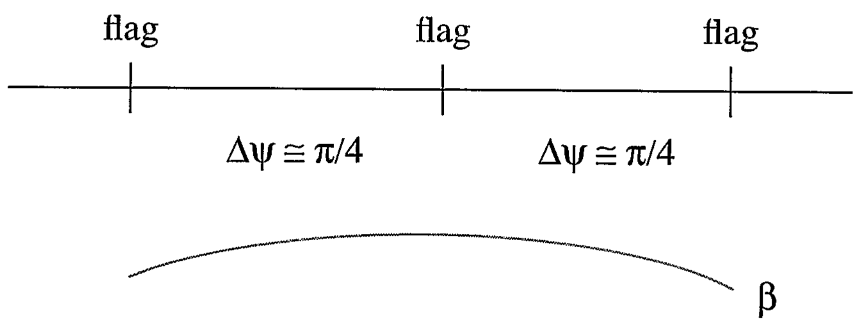


*** AtR aperture:**



Measurements of Beam Parameters: Methods

* **Three flags fitted to beam ellipse at reference point.**
  * Three-parameter 'minimal' solution in each plane.
  * Susceptible to measurement errors of ~20%.
  * Relies on known transfer matrices between all flags.
  * "Quick" and systematic, does not perturb lattice.



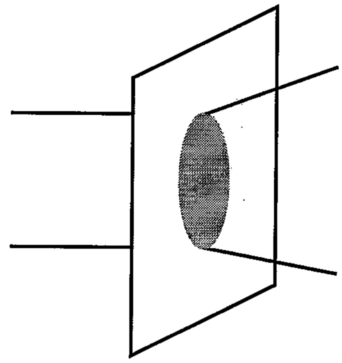
* **Two flags and quad, tune to minimum beam width** (α=0) **on one flag.**
  * Susceptible to measurement errors of ~20%.
  * Relies on drift lengths and quad strength calibration.
  * "Slow", requires quad strength changes.

* **One flag and quad, fit beam size at flag against quad strength.**

* **Use many flags, vary no quads.**

Flag Measurement Sensitivities, Emittance Blowup

$$\begin{pmatrix}\sigma\\ \sigma'\end{pmatrix} \Rightarrow \begin{pmatrix}\sigma\\ \sigma' + \Delta\sigma'\end{pmatrix}$$



$$\Delta\varepsilon = \frac{1}{2}\beta\,\Delta\sigma'^2$$

*** Flags have angular dispersion, $\Delta\sigma'^2$:**

Thick flags (uf1, uf2)	~57 mrad	(1 mm Al O_2)
Thin flags (all others)	~19 mrad	(2 mil Gd_2O_2S:Tb)

*** Emittance growth from scattering in flags:**

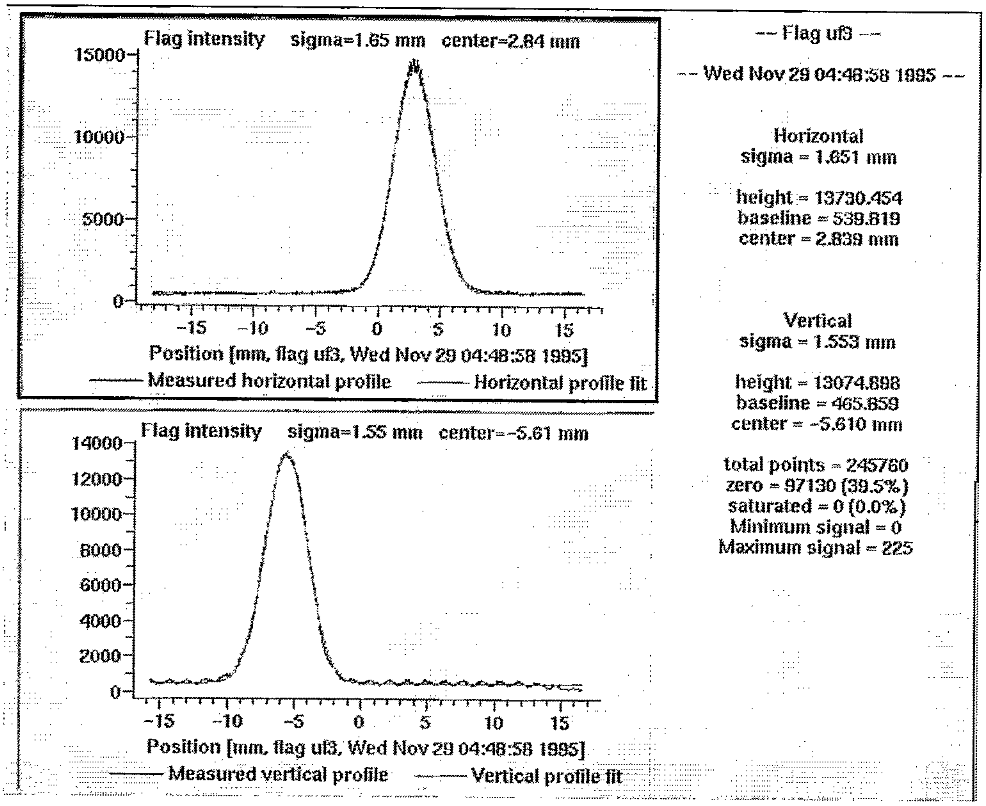
Thick flags:	59% (uf1, H)	4.3% (uf1, V)
	7.1% (uf2, H)	7.1% (uf2, V)
Thin flags:	1% (wf2, H) to 12% (wf3, H)	

*** Emittance growth predictions are consistent with observations.**

Emittance Measurements - Online Tools, Limitations

* Careful flag tuning is required! (CCD camera saturation, frame grabber dynamic range...)

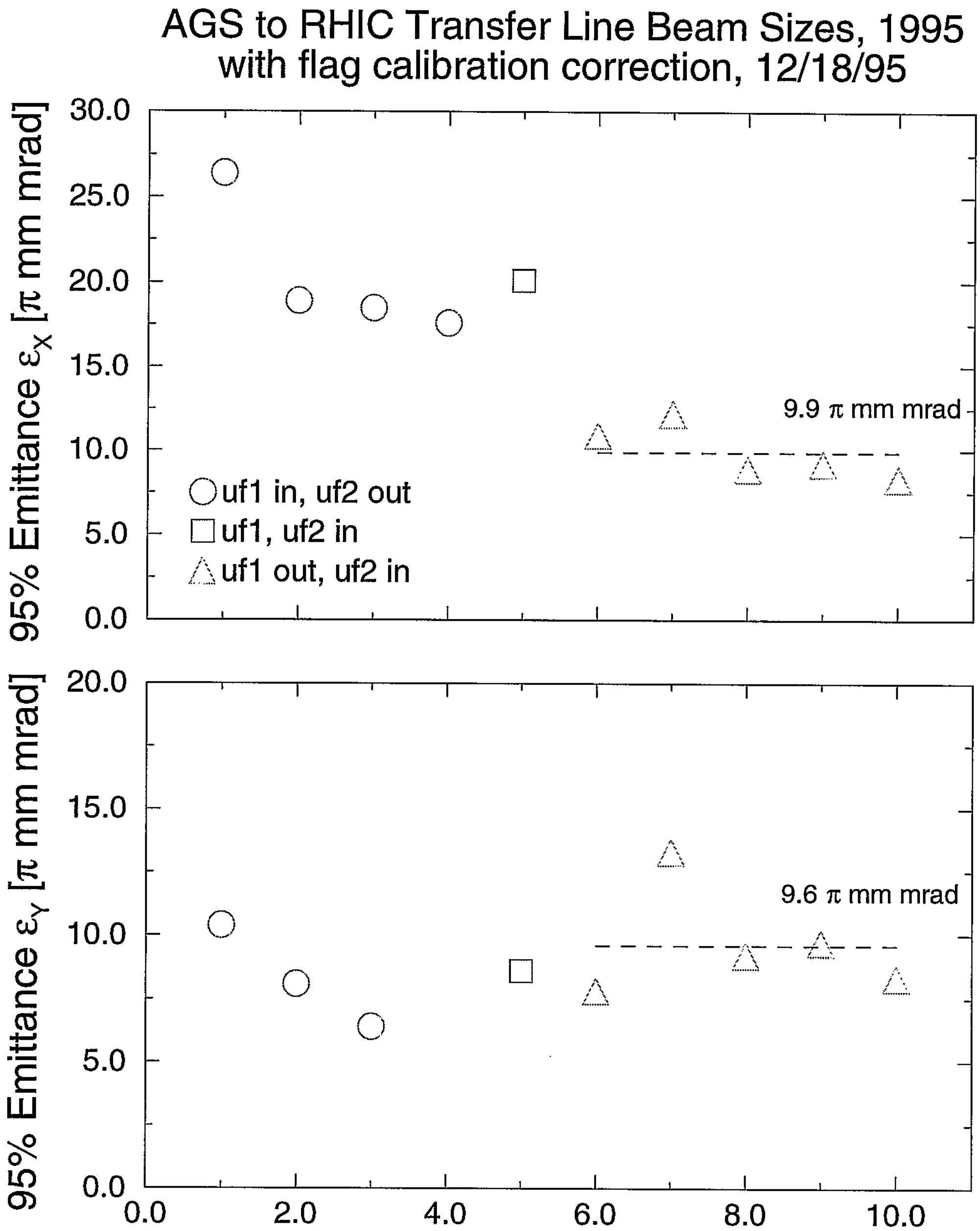
* Online profile archival and fits available:



* Measurements with many flags "in" can be inconsistent for emittance measurements due to emittance growth at each. Flipping single flags in and out is tedious, but necessary.

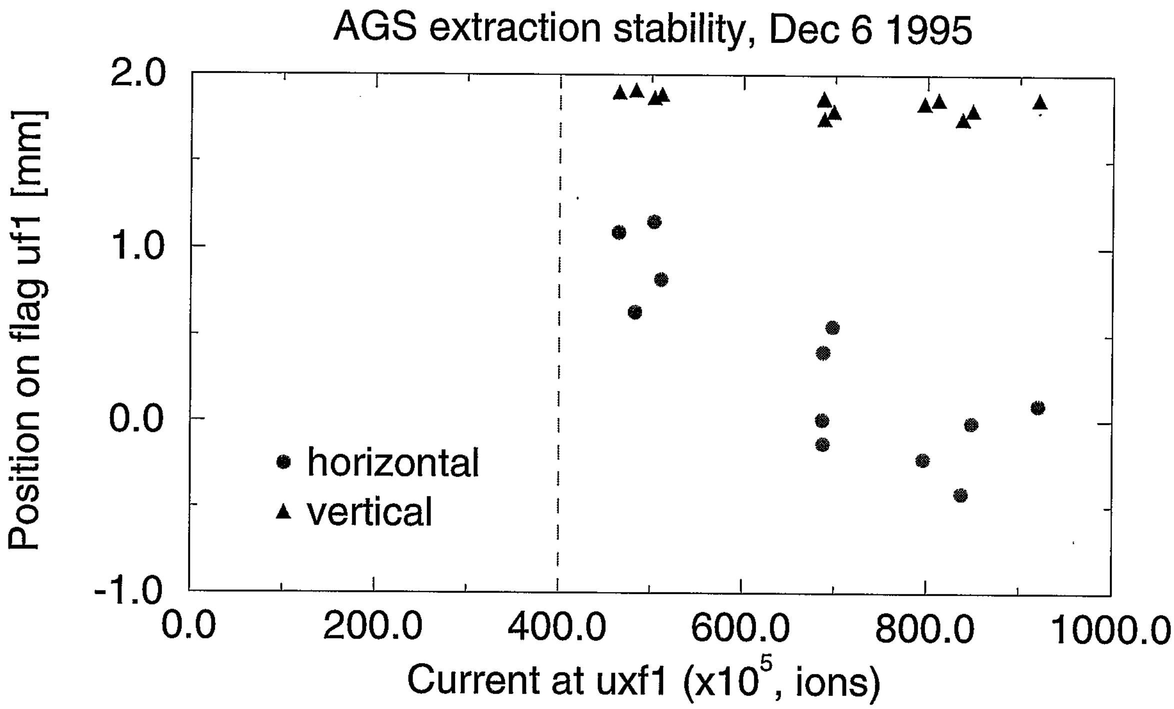
* uf1 or uf2 must be in to strip beam fully, giving some emittance growth.
  uf1: used at first to observe injection conditions, consistency.
  uf2: used later in run to minimize emittance growth.

Emittance Measurements -- Summary



* **More data remains to be analyzed from late in the run, though results appear consistent with above.**

ATR Commissioning: AGS Extraction Stability



* **Below 4×10^7 ions AGS radial loop would not lock in h=8 mode, and no beam was accelerated or extracted.**

* **There appears to be a definite correlation between extracted bunch intensity and extraction position. (Injection drift over course of a foil?)**

* **Ignoring correlation, horizontal injection stability is ± 0.5 mm. Design manual implies maximum injection variation from kicker is approximately ± 0.4 mm.**

ATR Commissioning '95: Summary

*** General**

* Instrumentation and controls very productive throughout.
Be proud!

* Installation perfect - magnet survey, polarities, etc.

* "Online" analysis tools assisted shift productivity.

*** Beamline Optics**

* Transfer functions of line, M_{12}, are within several percent of design.

* Measured beam dispersions throughout line are reasonable, to within optical matching to AGS.

* Transfer line momentum aperture is 1.6%, very close to that of AGS.

*** Delivered Beam Properties**

* Beam $\gamma = 12.1 \pm 0.1$; energy is 10.33 GeV/amu. This is slightly below design of $\gamma = 12.63$ and 10.83 GeV/amu for gold.

* Intensities for Au^{77} ranged from 1×10^7 ions to 2.5×10^8 ions.

Design intensity is 1×10^9 ions.

* Beam $\sigma_p/p = 0.3\%$; injection septum aperture is roughly ~1.1%.

* Bunch length at high intensity is approximately 20 ns, close to design of 17 ns.

* Injected beam transverse emittances are 10 π mm mrad in each plane, matching design. Three different methods of measuring emittance are consistent.

* Emittance blowup on flag uf1 agrees with theoretical prediction of 60%.

RHIC Sextant Test Scope

Jack & Mike
10/18/95

General

The overall goal of the sextant test, scheduled for the fourth quarter of CY96, is to verify the machine design and sub-system performance by transporting a low intensity beam from AGS into RHIC. The beam will be sent down the injection line, through the right bend and across the outer ring of the 4 & 5 o'clock sectors through a single 28 MHz RF cavity and into a temporary beam dump located downstream of Q4 near the 4 o'clock intersection region.

There will be two complete arc sextant's worth of magnets comprising both rings from the triplet cryostat assembly at 6 o'clock to the triplet cryostat assembly at 4 o'clock. The only elements not needed for the test will be the DX magnets. Dummy cryostats, non standard length quads and dipoles, warm/cold transitions and warm regions will all be used. Both rings will be cold for the sextant test although power supplies will only be available on the ring with beam. Items and systems commissioned for the beam injection tests will be used for the sextant test, i.e. no decommissioning of equipment.

Warm vacuum regions for both rings will be installed in the Q3-Q4, D7 & D9 locations as needed to accommodate the ring hardware and temporary beam dump.

The RHIC 24.8kW refrigerator will be used to provide forced flow and recooler cooling to the magnets in the sextant according to design. The test affords the opportunity to operate and debug all major cryo mechanical and electrical subsystem equipment types in preparation for colliding beams.

Power supplies capable of RHIC ramp rates to 5500 Amperes will reside in their final locations at 4 o'clock. Since a single sextant of magnets has an inductance similar to the full ring quadrupole circuits the main quadrupole supplies will be used for the test. Connections to the magnets will be simplified by running the main quads and dipoles in series. Tunnel alcoves will house dipole corrector supplies and quench detection electronics. There will be no interaction region tuning supplies or other higher order circuits in the sextant i.e. 8 cm correction dipoles only. Single prototype sextupole and I.R. tuning quad supplies will be available.

Main control system front end electronics will be available at the sextant alcoves, 6 and 4 o'clock service buildings, 1005H, the injection line houses and the LLRF room. Main control will be located in the AGS MCR similar to the injection tests.

Beam instrumentation will install single pass beam position and loss monitor systems in the sextant to provide beam information to the MCR. Prototype ring BPM and BLM systems will be available. A current monitor and profile monitor will be placed upstream of the dump.

Safety systems installed in the tunnel for the sextant test will be similar in design to that previously used for the Injection line tests. While crash and access control subsystems will be extended to cover the sextant, an additional oxygen deficiency hazard system will be added for safety of tunnel personnel. Critical devices will be required for the sextant test.

A single operational 28 MHz accelerating RF cavity and power system will be installed in the correct location at 4 o'clock in the outer ring. An embryonic LLRF system will be available in the 1004 support building.

Preparation for Test

Installation Section

1. Install and position arc and insertion magnets, close interconnects and leak check cryostat assemblies
2. Design, procure and install dummy insertion magnet cryostats
3. Design, procure Q 1,2, 3 and D0 triplet cryostats, install magnets and cryostats in tunnel

4. Locate beam dump system at 4 o'clock, downstream of Q4
5. Finalize procedures for magnet cryostat installation and removal

Magnet Electric Section
1. Procure cold crossing bus for installation in transfer lines
2. Set up main quad power supplies (ramp and flattop) at 4 o'clock
3. Install quench protection and detection systems
4. Connect alcove dipole correction supplies (39ea.)
5. Pull cable into tunnel overhead trays
6. Complete tray to and in service buildings

Cryogenics Section
1. Install VJRR, valve boxes, VJR, and sextant warm header piping
2. Locate PLC's and cryogenic temperature linearization system at 4 and 6 o'clock service buildings and in the tunnel
3. Write applications software for ring control
4. Train personnel and test run the RHIC refrigerator and distribution system.

Vacuum Section
1. Install electrical services in the tunnel for pumps and vacuum system electronics
2. Install 485 data highway and PLC equipment in the tunnel and at 4 and 6 o'clock
3. Install cryostat insulating vacuum pumps and gauging for the sextant test
4. Leak check interconnect and insulating vacuum system of sextant cryostats
5. Install temporary beam dump downstream of Q4
6. Install warm vacuum regions

Beam Instrumentation Section
1. Provide a single pass BPM system capable of supplying numerical beam position output to VME shared memory
2. Supply a beam loss monitor system capable of providing numerical beam loss informatic.. to VME shared memory
3. Set up a beam current transformer and profile monitor downstream of Q4 at 4 o'clock
4. Install and commission prototype ring BPM and BLM systems

Control System Section
1. Pull fiber optic cable to tunnel alcoves, 4 and 6 o'clock equipment, service buildings, injection kicker buildings, cryogenic control room in 1005, and LLRF building
2. Terminate fiber optic cables and install network hardware at above locations
3. Install and test control system front end crates in above locations
4. Install at each location the event clock, machine data link, WFG's, MADC's and digital I/O as appropriate
5. Event clock encoding will take place in the AGS MCR
6. Integrate cryogenic, vacuum and LLRF systems into the control system
7. Implement machine data link to all locations transmitted from 4 o'clock
8. Install beam abort/quench link to all locations and implement AGS beam inhibit
9. Provide injection kicker synchronized trigger and transient waveform recording
10. Prototype data logging, alarms, save/restore and parameter plotting features at the console level

Injection Section
1. Install and commission complete injection line to Q8 in sector 5
2. Install and commission injection kicker in sector 5

Safety Systems Section
1. Extend crash and access control systems from injection area to include tunnel sectors 4 &5
2. Interconnect injection and tunnel programmable logic controllers

3. Install and connect the oxygen deficiency monitoring system to the safety network
4. Write and validate ODM and other applications software
5. Safety systems training and certification for operations personnel
6. Define and implement the critical devices for the crash system
7. Temporary beam dump radiation monitoring

RF Section
1. Install one completely operational 28 MHz cavity system in the outer ring at 4 o'clock
2. Install those portions of the LLRF system in both the AGS and RHIC needed to demonstrate phase locking and bucket selection
3. Provide synchronized injection kicker trigger to the event clock

Section Test Plans

Magnet Electric Section
1. Monitor transfer line cold crossing busses and superconductor splices for quenching
2. Since power supply is running at full rated inductance for the first time, monitor and measure current regulation and stability over a range of values, sub harmonic reduction and wave form generation control
3. The quench protection system will be tested from low to high currents
4. Tests will be carried out to confirm that the quench detection system is noise immune, has ample sensitivity and is fully integrated with the protection system when monitoring a sextant of RHIC magnets
5. Verify dipole corrector power supplies and polarities
6. Test prototype sextupole and I.R. quadrupole tuning supplies
7. Demonstrate ramping and storage functions

Cryogenics Section
1. After magnets are cold and at operating temperature, look for flow or other related instabilities that could denote the presence of thermo acoustic oscillations
2. Look for high heat load in any of the cryo equipment
3. Measure the total heat load as compared to design values for the portion of the system under test
4. Review the adequacy of the operator interface design, valving arrangements and the general effectiveness of the control system
5. Monitor for long term contamination of the circulating helium gas streams and identify the source of any impurities
6. Document warm-up and cooldown performance of the sextant

Vacuum Section
1. Install leak detector and look for helium leaks during sextant cool down
2. When magnet temperature nears operating, use QRGAs to measure helium pressure gradients
3. Check out vacuum instrumentation and control system
4. Demonstrate system meets warm vacuum specifications

Beam Instrumentation
1. Measure beam current transmission and losses
2. Compare measured transverse profile at end of the sextant with the expected profile
3. Verify calibration of correctors and cold beam position monitors
4. Measure magnet quench levels with fast beam loss and measure beam loss radiation distribution

Control System Section

1. Test LAN timing and link control subsystems at and by location
2. Test front end control electronics and integrate separate control subsystems located in alcoves, service and equipment buildings
3. Monitor control system performance

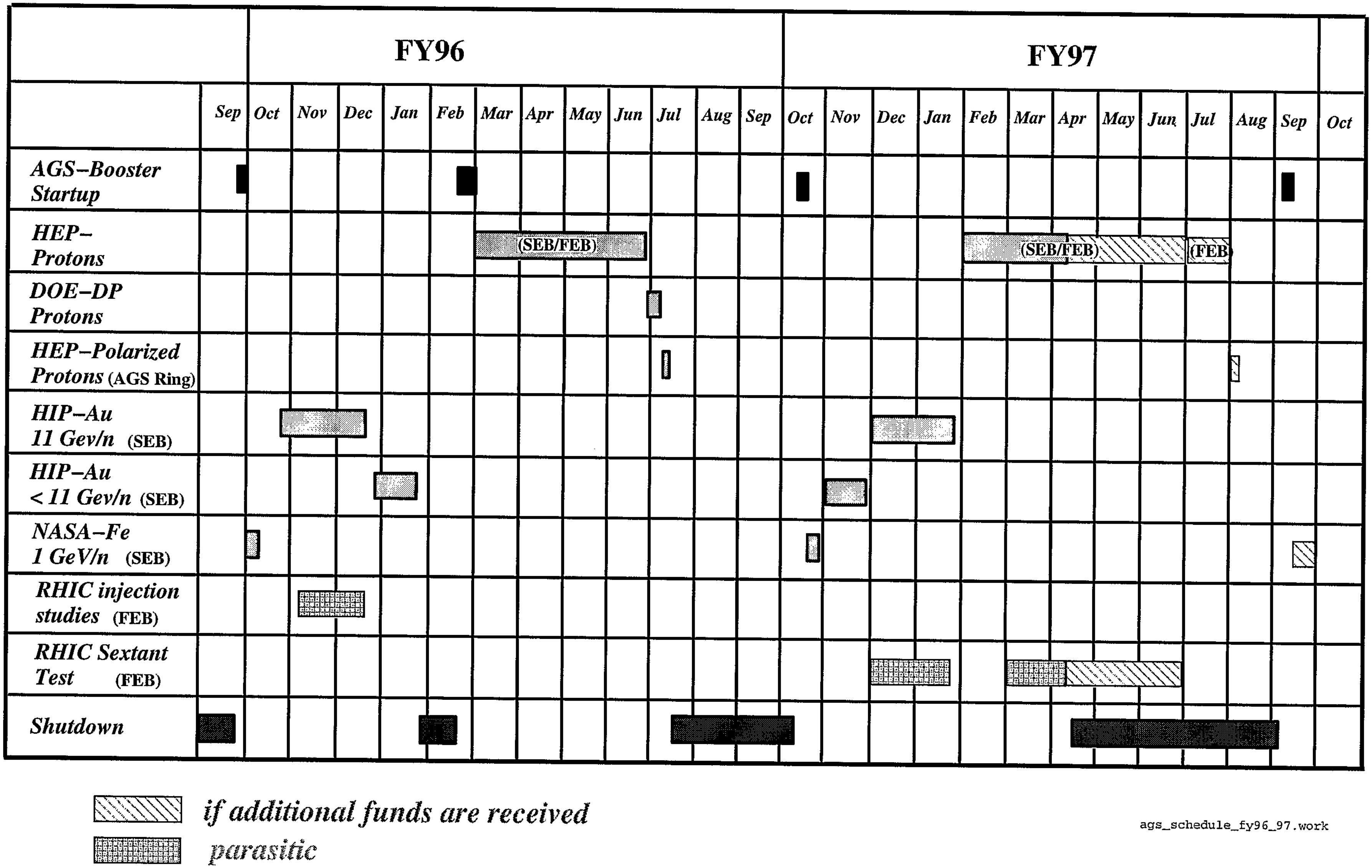
Safety Systems Section

1. Test RHIC extensions to injection crash and gate access control systems
2. Validate PLC interconnection network and network software design
3. Test and validate design of tunnel ODH system

Accelerator Physics Section

1. Define magnet positions and locations in the lattice
2. Magnetic field quality monitoring and sorting if necessary
3. Application level software to:
   steer beam to the end of the sextant(BPM's, BLM's, dipole corr.)
   optical calibration (phase advance /cell, transfer functions)
   WFG ramping (energy ramp, gamma-t jump, ...)
   injection first turn tuning - prototype
4. Beam quality measurements
   shot to shot variations
   beam ellipse at end of sextant
5. Sequencing and Software Integration
   high level sequencing (coordination of multiple apps - proto)
   low level sequencing (interprocess communication)
   stable high level environment (sds, graphics, ..- with Controls)
   rudimentary database integration (configuration <-> optics)

FY96–97 AGS Schedule (4 June 96, Subject to Change)



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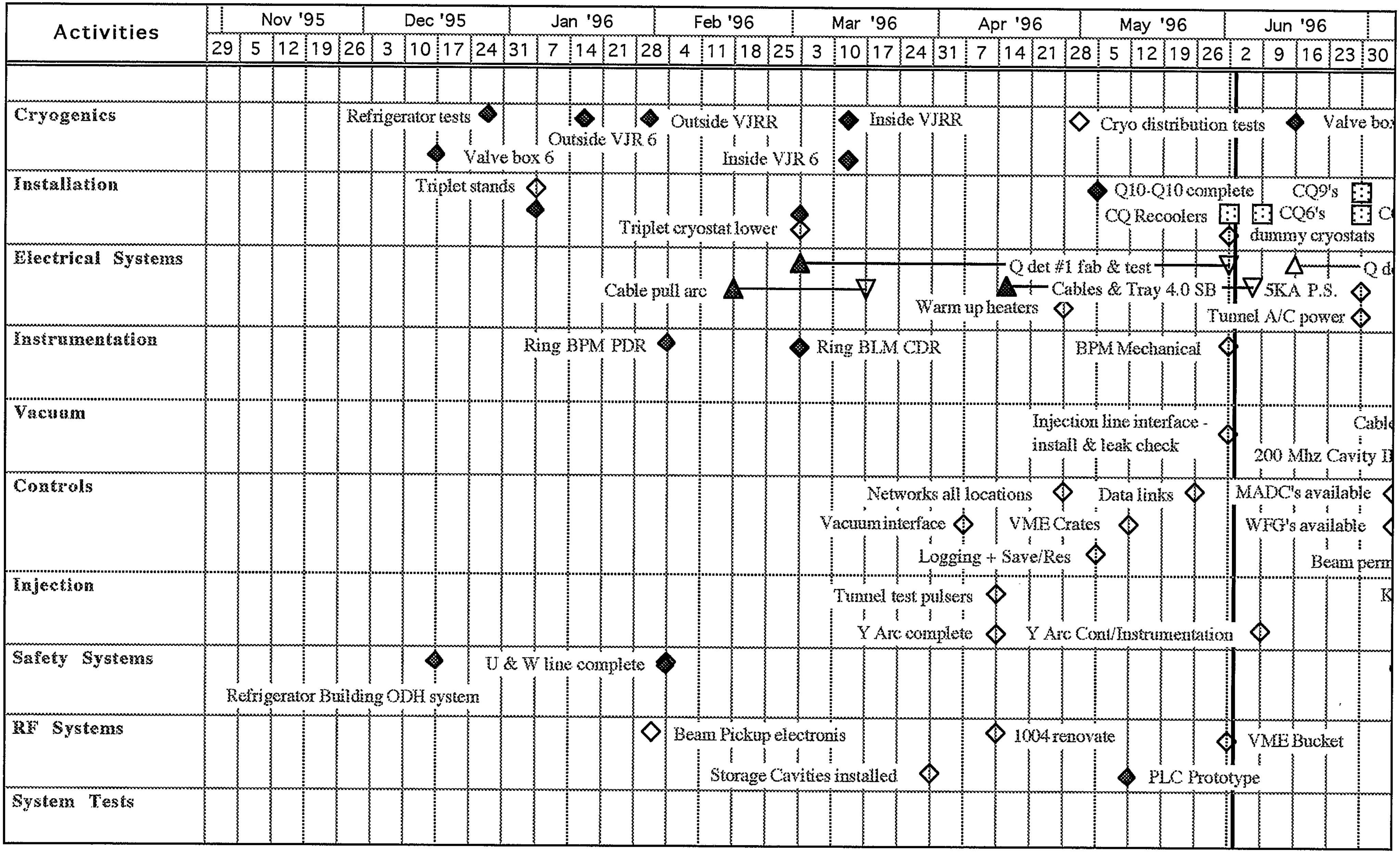
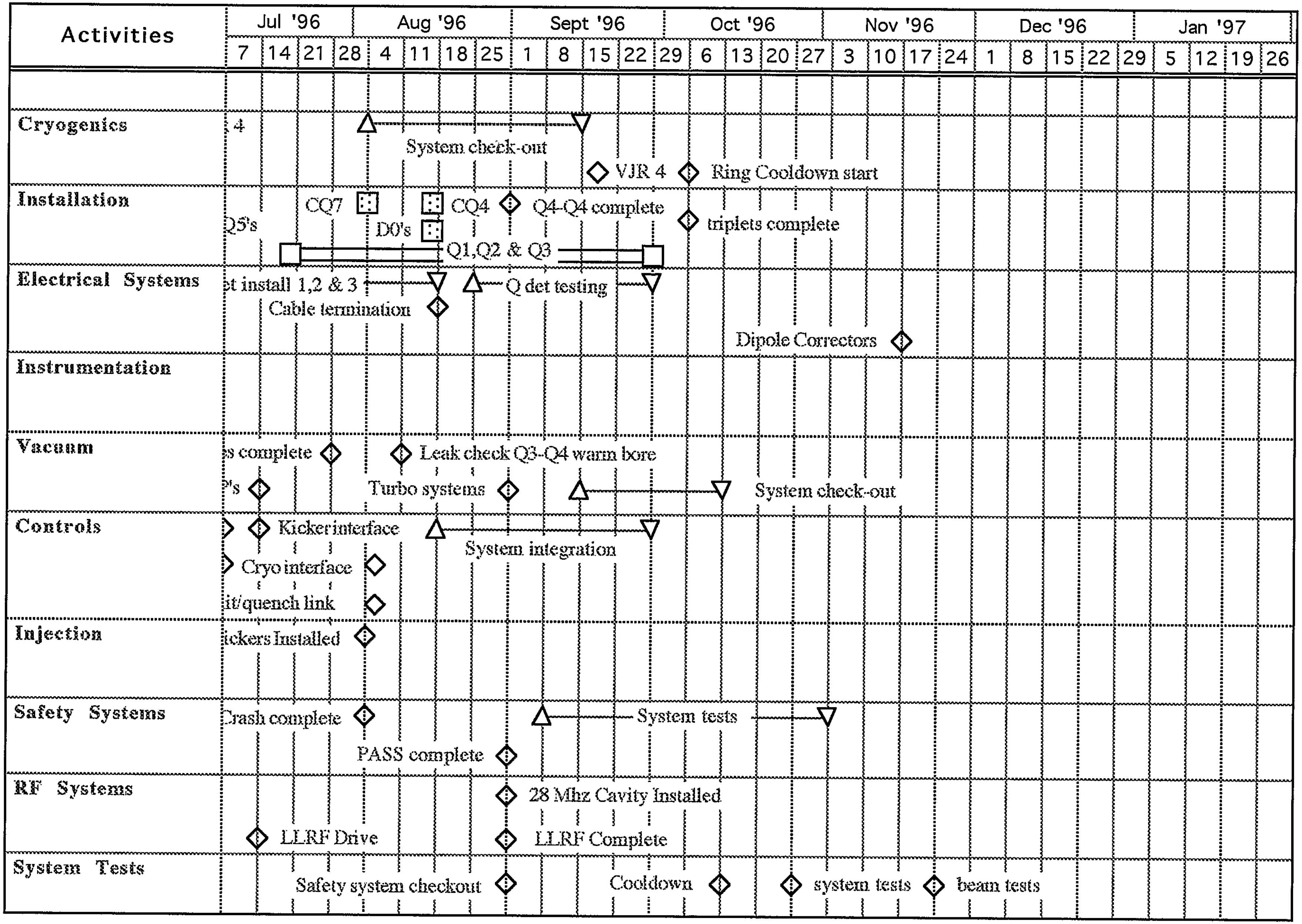
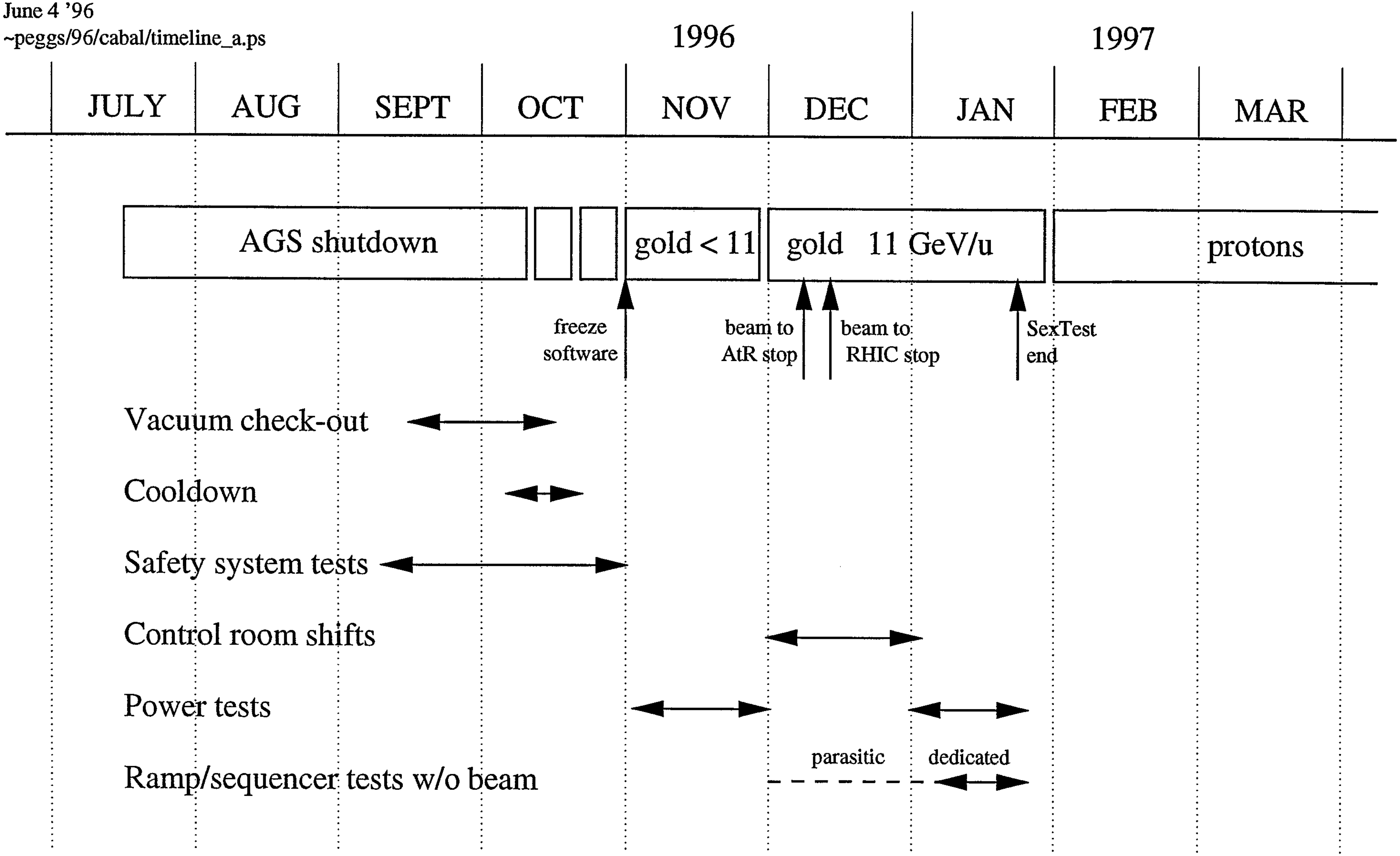


Monday, June 3, 1996



Monday, June 3, 1996

June 4 '96
~peggs/96/cabal/timeline_a.ps



SCENARIO A: back-to-back AtR and RHIC beam shifts, with gold

1) This scenario has significant contingency against schedule slippage

March 19, 96
steve peggs
~peggs/sextant/cabal.list

SEXTANT TEST MANAGEMENT STRUCTURE

0) Sextant Test Coordinator — Steve P
   Meet regularly with the following principal actors

1) Injection & Extraction Systems — Waldo M
   AGS liaison physicist
   restore beam to AtR dump
   AtR/RHIC matching
   Lambertsons & kickers
   radiation safety & fault studies

2) AtR and Sextant Beam Tests — Jie Wei
   prepare offline analysis tools
   exercise AtR optics variants
   thread beam to RHIC dump
   measure RHIC phase advance per cell, etc
   test magnet polarities with beam

3) Sextant System Tests (without beam) — Jorg K
   Ramps & sequencing
   WFG and RTDL assignments
   RF coordination: low level, ramping
   Cryo and vacuum group contact

4) Sextant System Commissioning — Dejan T
   Track ring systems & their commissioners

Notes

1) Note that the schedule calls for 90 days of refrigerator running time, and only 30 days of beam time. As many activities as possible will be performed without beam.

2) Beam time in the AtR and in the RHIC sextant may arrive in an asynchronous fashion. Flexibility and care will be necessary in scheduling beam goals and shifts.

3) Attempts will be made to use early AtR beam to debug new hardware (BLM, BPM electronics, et cetera).

List of Sextant Beam Test Projects

Jie Wei, BNL, May 31, 1996

(Minimum)

1. Initial beam threading (J. Wei)

   initial beam threading to the sextant beam dump;

   beam profile at the sextant beam dump

2. Emittance measurement I (N. Tsoupas)

   semi on-line multi-shot measurement with automated tools (Flagon or like);

3. Alternative ATR lattice (N. Tsoupas)

   ATR lattice setup with 60° phase advance between flags

4. Longitudinal phase space re-construction (V. Mane)

   Longitudinal phase space re-construction with RADON transformation on AGS

5. Joint ATR-RHIC96 lattice (W. MacKay)

   generate a joint ATR-RHIC96 lattice from separate optics database;

   define continuous s coordinates and ideal lattice functions

6. Optics measurement and comparison (J. Wei)

   transfer matrix element measurement and comparison;

   phase advance;

   lattice function measurement and comparison.

7. Sextant injection I (W. Fischer)

   injection aperture;

   sextant kicker noise and timing study;

kicker stability study;

comparison between kicker and Y05-TV9 steering

8. Documentation of AGS machine configuration (K. Brown)

   AGS IPM transverse beam profile and emittance with space charge modification;

   AGS LabView longitudinal profile and momentum spread;

   AGS extaction current

9. Dispersion measurement (J. Wei)

   dispersion measurement and scan of AGS momentum aperture at extraction by varying beam radial position in AGS;

   line momentum aperture scan and line dispersion measurement by systematically varying magnet strength

10. Pulse-to-pulse stability analysis (W. MacKay)

    injection position (using flags and BPMs);

    position (using flags and BPMs) relative to injection position;

    beam current (using current transformer);

    beam profile (using flags).

11. Magnet installation offset (P. Thompson)

    magnet installation offset analysis and comparison with Survstat;

    CQS offset (e.g., CQS 112 at I05Q11 up to 4 mm);

    selection of cadidates to be disassembled after the sextant test

12. Quench study (D. Trbojevic)

    quench test with magnets at full (top-energy) current

13. Stripping foil study (N. Tsoupas)

    comparison between striping foil and flag UF2

14. Orbit flattening (T. Satogata)

    orbit flattening for both ATR and the sextant

(Desirable)

15. Magnet hysteresis study

    hysteresis analysis and comparison with pre-installation measurement

16. Magnetic integral transfer function study

    ITF analysis and comparison with Magstat

17. Comparison between flag profile and IPM profile

18. Matching of ATR lines to desired values

19. Aperture scan

20. Emittance measurement II

    flag thickness calibration and one-shot measurement

21. Sextant injection II

    optics matching between ATR and RHIC96;

Note:

1. The name attached to the minimum list is the one responsible for the task, no necessary the only one to work on the task.

2. The task includes pre-beam planning, necessary software development, beam test, and post analysis.

Sextant Commissioning Strategy

The commissioning consists of tests with and without beam. The majority of tests are without beam and include:

- cool-down of the sextant magnets,
- heat-load measurements,
- magnet ramping.

Due to the complexity of the system and nature of these tests, it is not easy to predict the actual time-scale for the tests with beam. The plan is to run parasitically during part of the FY96-97 AGS running period. It is likely that the cryo-system tests without beam will not be completed before the end of the Fall gold run, so we may need to commission the sextant with protons after January. We expect to use some amount of gold beam parasitically in the U and W lines to finish off some of the 1995 ATR commissioning list, as well as for some testing of prototype instrumentation for RHIC.

Expected beam intensity limits

For beam tests to the W line dump, the limits will be the same as for the 1995 ATR injection commissioning:

- 10^8 gold ions per AGS cycle.

After the fault studies for the U, and W line section of the ATR have been completed, these limits may be raised.

Beam tests must conform to the operational safety limits of the *RHIC Safety Assess Document* which in turn follows the *Beam Loss Scenario in RHIC* **AD/RHIC/RD-52** by M. Harrison and A. J. Stevens. It is expected that a single bunch of 10^{11} at injection energy will **not** quench a magnet. The hourly average beam to the sextant must be kept within 10^{11} protons/minute; basically one bunch per minute.

Outline of tests

- Things to do before beam tests (ATR & Sextant) before cool-down:
    - check cooling water on magnets in ATR (U, W, Y)
    - ramp magnets (ATR and Sextant)
    - check polarities of magnets (New magnets in Y line and where possible in Sextant)
    - pump down lines and check vacuum
    - check interlocks on power supplies
    - check other hardware
        - BPM's (beam position monitor) cables and electronics.
            - RHIC prototype BPM electronics.
        - BLM's (beam loss monitors).
            - RHIC prototype BLM electronics.
        - flags: read back pictures with calibration lights.

        - collimators (ATR): check motor control and location read-backs.
        - current transformers and electronics.
        - timing system: check signals.
        - injection kickers.
        - ionization profile monitor prototype.
        - stripping foil: check motor control and location read-back.
    - Test software and control system.
    - Test ramping and reversing of switching magnet **swm**.
        - The reversing switch must be LOTOed to only allow beam to the dump or down the Y-line before any tests with beam.
    - Test and certify safety system.
        - For protons, the coinjection transformer in the BTA line must be certified. This transformer is to prevent FEB extraction of high intensity beams into the U-line beyond the V-line split.
    - Get documentation and training procedures in order.
    - Pass all the review hurdles.
    - Verify that all training has been performed.
- Cool-down tests of cryo-system without beam:
    - Measure cool-down rate.
    - Measure sextant warmup rate. (Perhaps this should be done after all the other cold tests.)
    - Measure heat load.
    - Measure quench propagation by inducing a quench with heaters.
    - other tests?
- Power supply of sextant magnets with cold magnets and without beam.
    - Ramp main busses up to storage energy.
    - Measure the impedance matching of magnet busses to power supplies.
    - Study interaction of differential quad buss supply with main supply.
    - Ramp trim supplies.
    - Test typical ramps for RHIC operation
        - acceleration ramp including gamma-t jump
        - reset cycle
        - rebucketing with rf cavities
    - other tests?
- With gold beam to W-line dump:
    - Thread beam down the U- and W-lines and shake down the upgraded software/controls.
    - Finish fault studies for U, and W lines (< 10^{10} charges/pulse).
    - Remeasure the pulse stability from the AGS (up to 10^{11} charges/pulse).
        - beam current.
        - position.
        - profile on flags.
    - Try other lattice tunes.
    - Test beam threading algorithm for automatic tuning of trajectory.
    - Make improved emittance measurements.
        - Try with 60^{o} phase advance between flags (3 of them).
        - Try to calibrate flag thicknesses for single pulse emittance measurements.
    - Tune the U-line quads to best match the desired values going into the W-line.
        - There was a slight deviation from the model after the 20^{o} bend.

- Tune the W-line quads to best match the desired values just upstream of **swm** (switch magnet).
    - Note that the dispersion just upstream of the switch magnet should be zero.
- Test the prototype ionization profile monitor.
- Use a gold foil to strip the last electrons from the gold ions.
- Use collimator **uc1** to select a narrow momentum slice and attempt to measure the momentum spread.

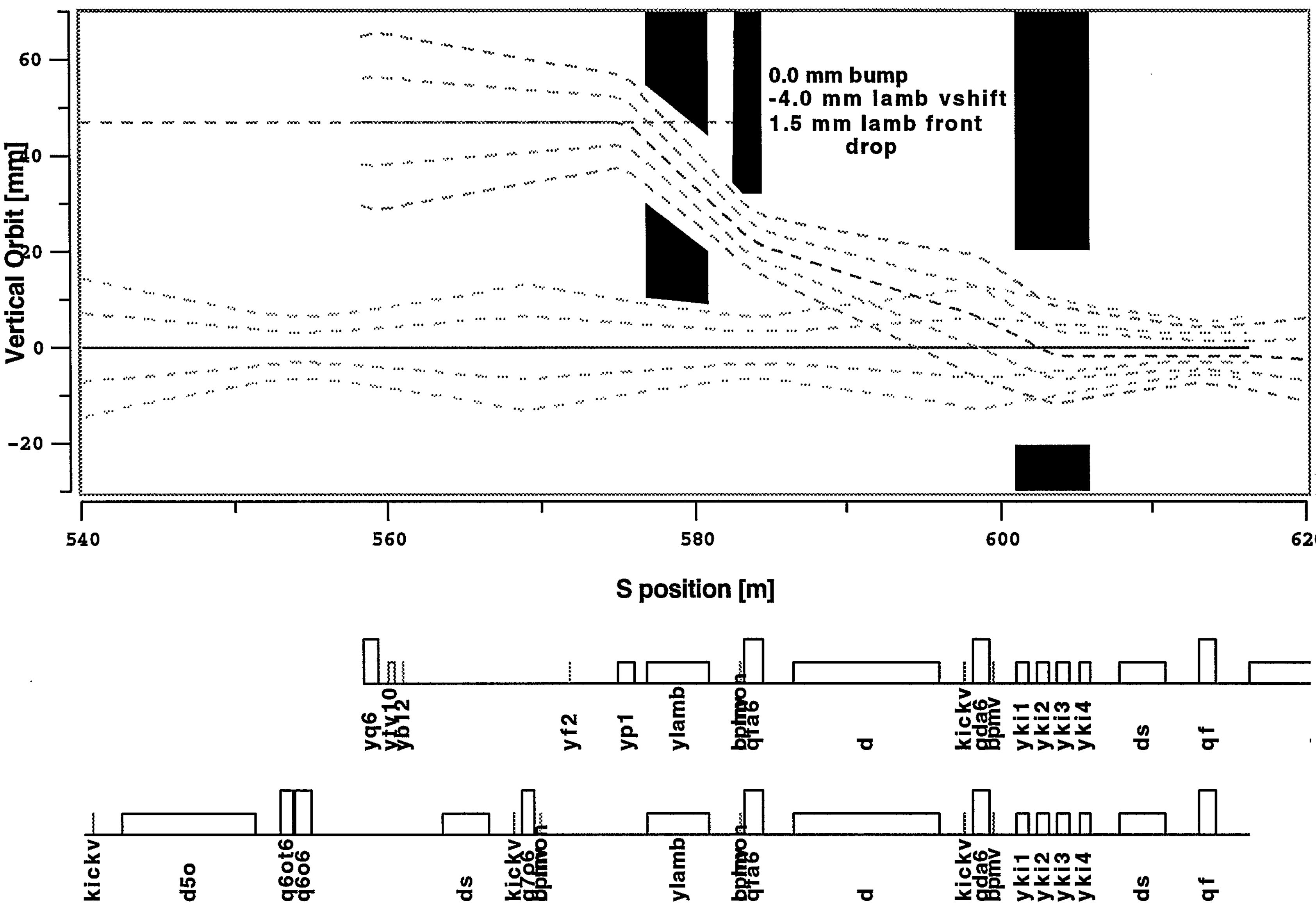
- With beam in sextant:
  - Thread beam down the Y-line (< 10^{10} charges/pulse).
  - Do fault studies for Y-line (< 10^{10} charges/pulse).
  - Tune the vertical injection with
    - vertical steering magnets **ytv10** and **yp1**,
    - shunt power supplies on **yd31** and **ylamb**,
    - kicker magnets (timing and current settings). Use timing delays and vertical steering magnet **yo5-tv9** to scan the kicker field profile in time.
  - Thread beam down the sextant to the 4 o'clock dump **yo4-dmp** (< 10^{10} charges/pulse).
  - Do fault studies for sextant (< 10^{10} charges/pulse).
  - Test automatic beam threading algorithm on sextant.
  - Measure beam pulse-to-pulse stability on flag **yo4-f3**
    - with injection kickers,
    - with **yo5-tv9** used instead of injection kickers.
  - Study effects of injection kicker noise on instrumentation.
  - Measure optics transfer matrix elements in sextant:
    - steering and focusing components,
    - phase advances,
    - dispersion components.
  - Measure aspect ratio of beam profile on flag **yo4-f3** and compare with model.
  - Check the matching from the Y-line into the sextant.
  - Test multiple transfers per AGS cycle (30Hz bunches).
  - Quench test: How many bunches in rapid succession at injection does it take to quench a magnet?
  - Other tests?

Mangled by Waldo MacKay (waldo@bnl.gov)
Last update: 25 April, 1996.

Injection Application

- Monitoring elements:
  - for O1 horizontal (AtR) : ybh8 and yb10 ($\Delta\mu_x = 0.3/2\pi$)
  - for O1 vertical (AtR) : ybv9 and yb11 ($\Delta\mu_y = 0.3/2\pi$)
  - at qf8 : bh8 and bv8 (physical space)
  - at qd9 : bv9
  - for O2 horizontal (RHIC): bh10 and bh12 ($\Delta\mu_x = 0.8/2\pi$)
  - for O2 vertical (RHIC): bv11 and bv13 ($\Delta\mu_y = 0.8/2\pi$)
- Correction elements:
  - horizontal (AtR) : yth9 and ylamb ($\Delta\mu_x = 0.3/2\pi$)
  - vertical (AtR) : yp1 and yki ($\Delta\mu_y = 0.2/2\pi$)
  - additional elements in yline
  - horizontal (RHIC): th8 (only for sextant test)
  - vertical (RHIC): tv9 (only for sextant test)
- Coordinate system: AtR yline

Vertical Beam Orbit - ATR to RHIC lambertson region - 2.5 sigma contours - 10 pi Au beam



Kicker

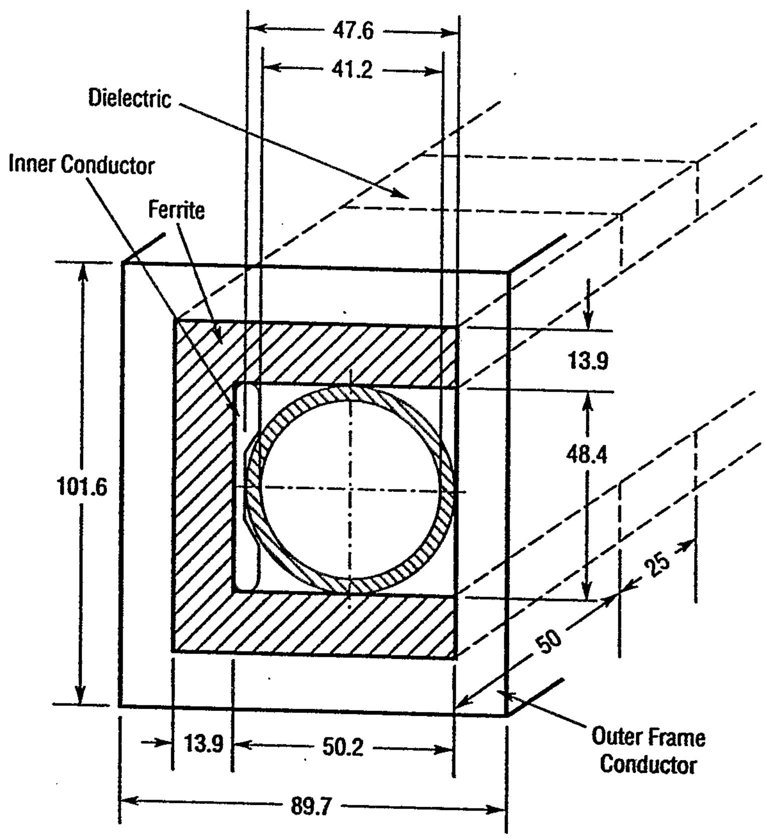
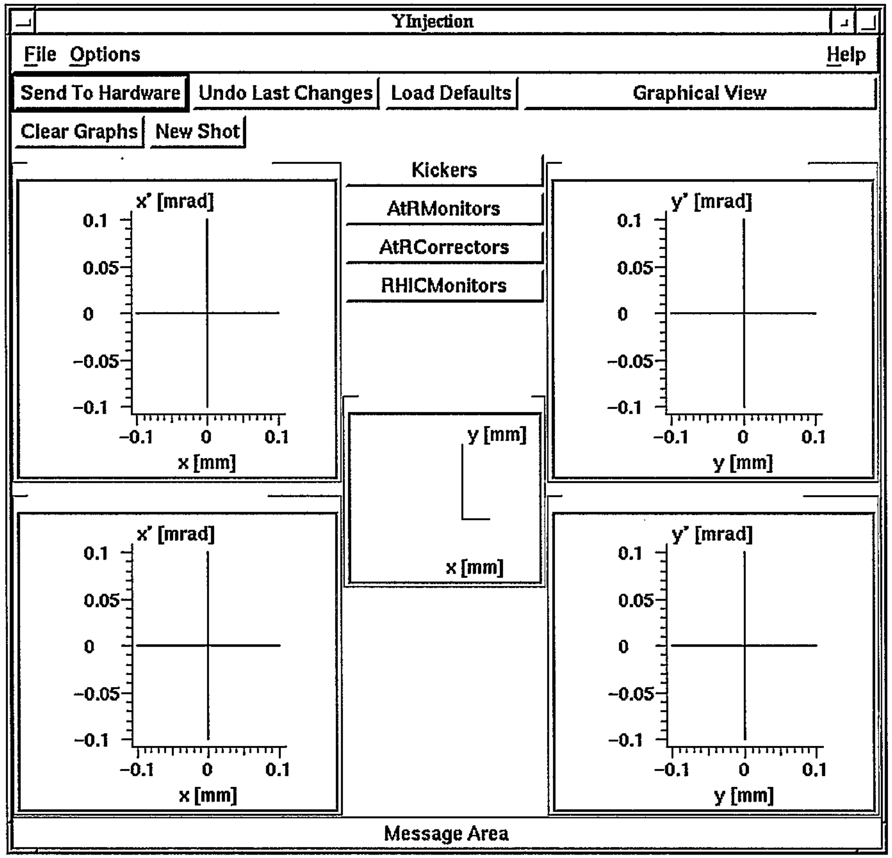


Figure 1: RHIC Injection Kicker Geometry (mm)

- 1 power supply
- 4 charge lines with 4 high voltage switches
- 4 delay times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Undo Last Changes
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Clear Graphs
New Shot
Kickers
AtRMonitors
AtRCorrectors
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Message Area

Relativistic Heavy Ion Collider
Brookhaven National Laboratory

Date: April 8, 1996

To: George Ganetis, Bob Lambiase
From: Dejan Trbojevic, Jorg Kewisch, Waldo Mackay, Steve Peggs

Subject: Power Supplies for the Sextant Test

Cc: Mike Harrison, Jie Wei

This memo quotes back to you two gentlemen the inventory of sextant test power supplies that you have provided us, and upon which we are making our commissioning plans. For example, we DO intend to exercise the single transition quad power supply. The list is as follows:

Table 1: Sextant test power supplies

Power Supply	Count
Main power supplies (5 kA)	2
Shunt PS (50 V, 300 A)	1
Transition quad PS	1
Dipole corrector power supplies (50 A)	33
Spare corrector power supplies (50 A)	7

It appears that the only potentially controversial issue is in the use of the 2 main power supplies, and the "Shunt power supply", to independently control the dipole current, the current through D arc quads, and the current through F arc quads. We hope to have this independent flexibility whenever there is beam in the sextant, and assume that this will not conflict with other tests (like a study of cross coupling between power supply regulators) that can be performed without beam.

Table 2: Nominal magnet excitations

Magnet	Excitation [A]
Dipole	545
D quads	532
F quads	515

According to our calculations, the nominal current settings at gold injection are as shown in Table 2.

These values apply when the horizontal (vertical) phase advance per cell is 80.7 (85.5) degrees. Ideally, we would like to be able to vary the common phase advance per cell between, say, 60 degrees and 100 degrees. Very approximately, the quadrupole strength scales linearly with this variable, and so we are interested in a quadrupole excitation range between about 350 A and 700 A (with the dipole excitation held constant).

We would be obliged if you would inform us whether this is possible and reasonable, from your point of view.

June 4 '96
/home/owl/public/SexTest/main_power_supplies

To: RAP
From: Steve Peggs, Jorg Kewisch, Bob Lambiase

Re: Sextant Power Supplies: Dipole, QF, and QD

Cc: George Ganetis, Mike Harrison, Waldo Mackay

This memo establishes the nominal configuration of power supplies that will be used to power the main RHIC magnets - dipoles, QF, and QD quadrupoles - during the sextant test. It is consistent with a RAP memo to Bob Lambiase, dated April 9, 1996, that also contains more details about other power supplies, and which is available for viewing as "/home/owl/public/SexTest/sextant_ps.ps"

The main magnets will be powered differently during

1) power tests without beam, and
2) beam tests and software ramping tests

Power tests

For the power tests, a single 5 kA power supply will drive, in series, all main magnets in EITHER the Blue line OR the Yellow line. This supply is actually a main quad power supply, but it will see a large enough total inductance for realistic quench testing, et cetera.

$$I_{dipole} = I_{QF} = I_{QD} = I_1$$

where

$$0 < I_1 < 5\ \text{kA} \quad \text{(main quad PS)}$$

There are only enough quench protection circuit cards to test one sector (Blue or Yellow) at a time.

Beam tests and software ramp tests

For the beam and software tests, 3 power supplies will be used, as follows:

$$I_{dipole} = I_1$$
$$I_{QF} = I_2 + I_3$$
$$I_{QD} = I_2$$

where

$$0 < I_1 < 5\ \text{kA} \quad \text{(main quad PS)}$$
$$0 < I_2 < 700\ \text{A} \quad \text{(or a PS with a similar max current)}$$
$$-50 < I_3 < 50\ \text{A} \quad \text{(dipole corrector PS)}$$

The inductance seen by the 5 kA supply is low enough, in this configuration, to allow full speed ramping.

A second 5 kA may become available as early as October 96, or as late as January 97. While this second main PS might be useful, it is not necessary for succesful testing.

Relativistic Heavy Ion Collider

Brookhaven National Laboratory

Date: June 5, 1996

To: RAP

From: Peggs, Trbojevic, Kewisch, Mackay, Wei

Subject: Coordinate Conventions for the Sextant Test

Cc: Mike Harrison

There is, understandably, some confusion about coordinate conventions at the interface between the Y-line and the Yellow Sextant Test sextant. This memo interprets the agreed upon conventions addressed in RHIC/AP/12 and RHIC/AP/70, responding to recent additional discussions.

1. Both the Y frame (Yellow ring, clockwise) and the A frame (AtR frame going from AGS towards RHIC) are Right Handed frames, consistent with the usual MAD frame. Positive "x" is to the left.
2. Most Yellow applications, such as global closed orbit correction, are expected to use the Y frame
3. Some Yellow applications, such as injection element tuning, may extend the A frame out into the Yellow ring
4. An application writer may pick one or the other corrdinate frame for display purposes, but not both, and not a third convention. The coordinate frame chosen must be clearly stated
5. The optics database "rhic96" will be converted to include only Clock Wise (CW) beam lines
6. Namespace, in 1996 and 1998+, will consistently use CW s_{blue} and CW s_{yellow} coordinates, as now
7. In 1996, conversion TO an A frame optics model using CCW s_{atr} throughout, FROM CW s_{yellow} data sources, will occur "downstream" of namespace