AGS and AGS Booster performance

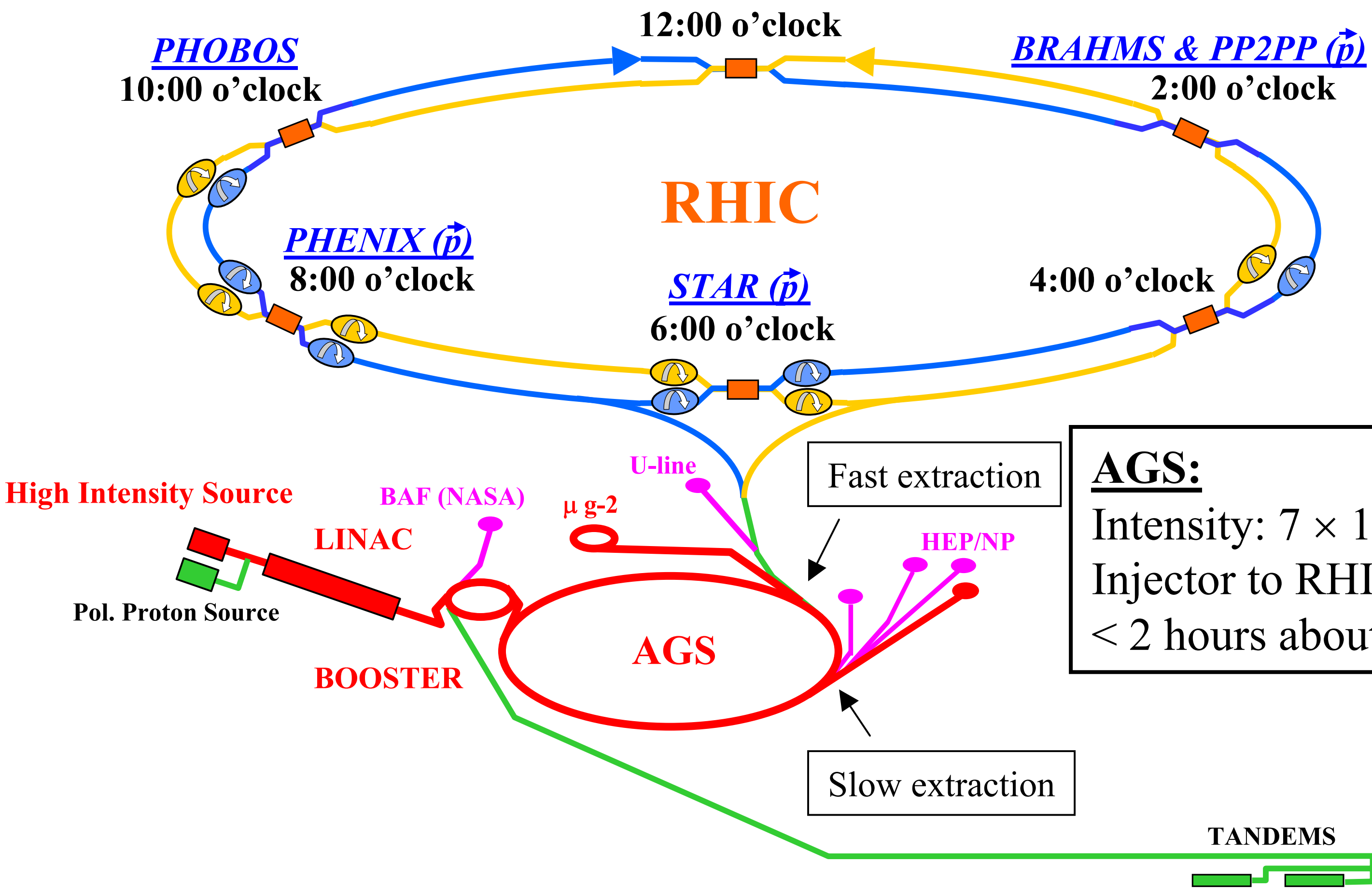
Present performance for fixed target program

AGS intensity upgrades

BROOKHAVEN
NATIONAL LABORATORY

Thomas Roser
Snowmass 2001
June 30 - July 21, 2001

AGS/RHIC Accelerator Complex



AGS:

Intensity: 7×10^{13} protons/pulse

Injector to RHIC:

< 2 hours about every 10 hours

200 MeV Linac performance

- 120×10^{12} H^- per pulse at 7.5 Hz
- H^- source, RFQ, LEBT, Tank 1, Tank 9:

H^- source	35 keV	80 mA
RFQ	750 keV	60 mA
LEBT	750 keV	45 mA
Tank 1	10 MeV	38 mA
Tank 9	200 MeV	37 mA

- $\varepsilon_{norm} = 10\ \pi$ mm mrad
- $\Delta E \approx \pm 1.2$ MeV
- RF chopper at 750 keV

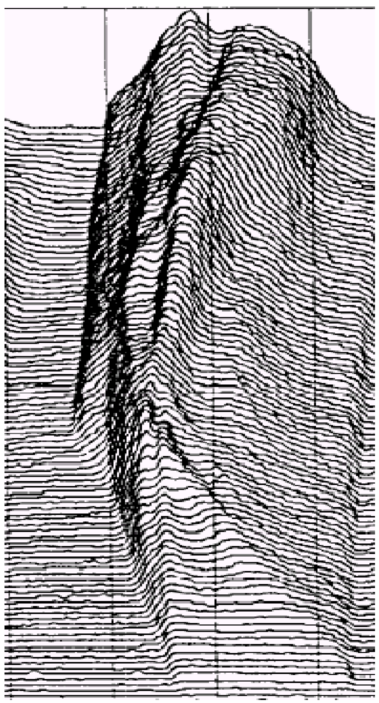
BROOKHAVEN
NATIONAL LABORATORY

Booster performance

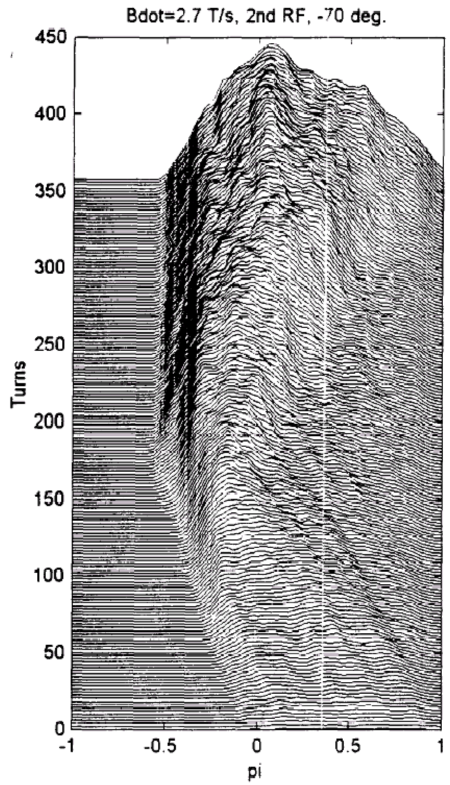
- 15×10^{12} protons per pulse (peak: 23×10^{12})
- Injection: horizontal painting, vertical missteering
  360 turns, chopped to 180 - 270 dergees
  B dot = 3 T/s
- $\varepsilon_{norm} \approx 50\ \pi$ mm mrad
- RF: 45 kV (h=1), 22 kV (h=2)
- B dot max = 9 T/s
- Eddy current correction coils driven by back-leg windings

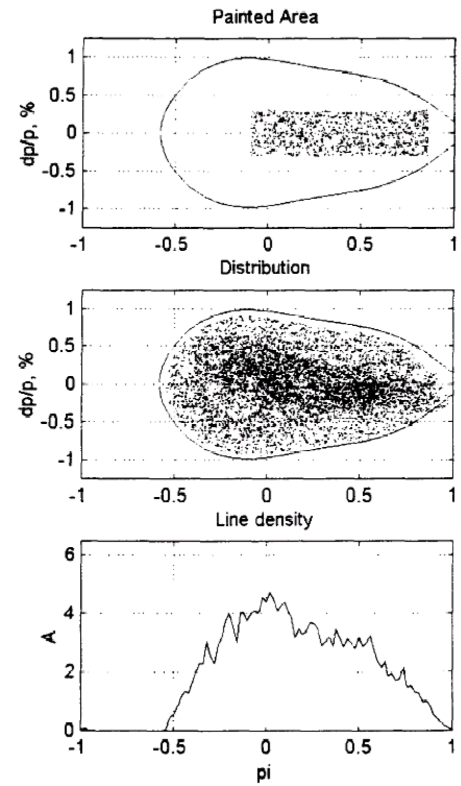
H^- injection into the Booster

Measurement



Simulation





Injected:
23×10^{12} ppb
1.3 eVs
18×10^{12} /eVs

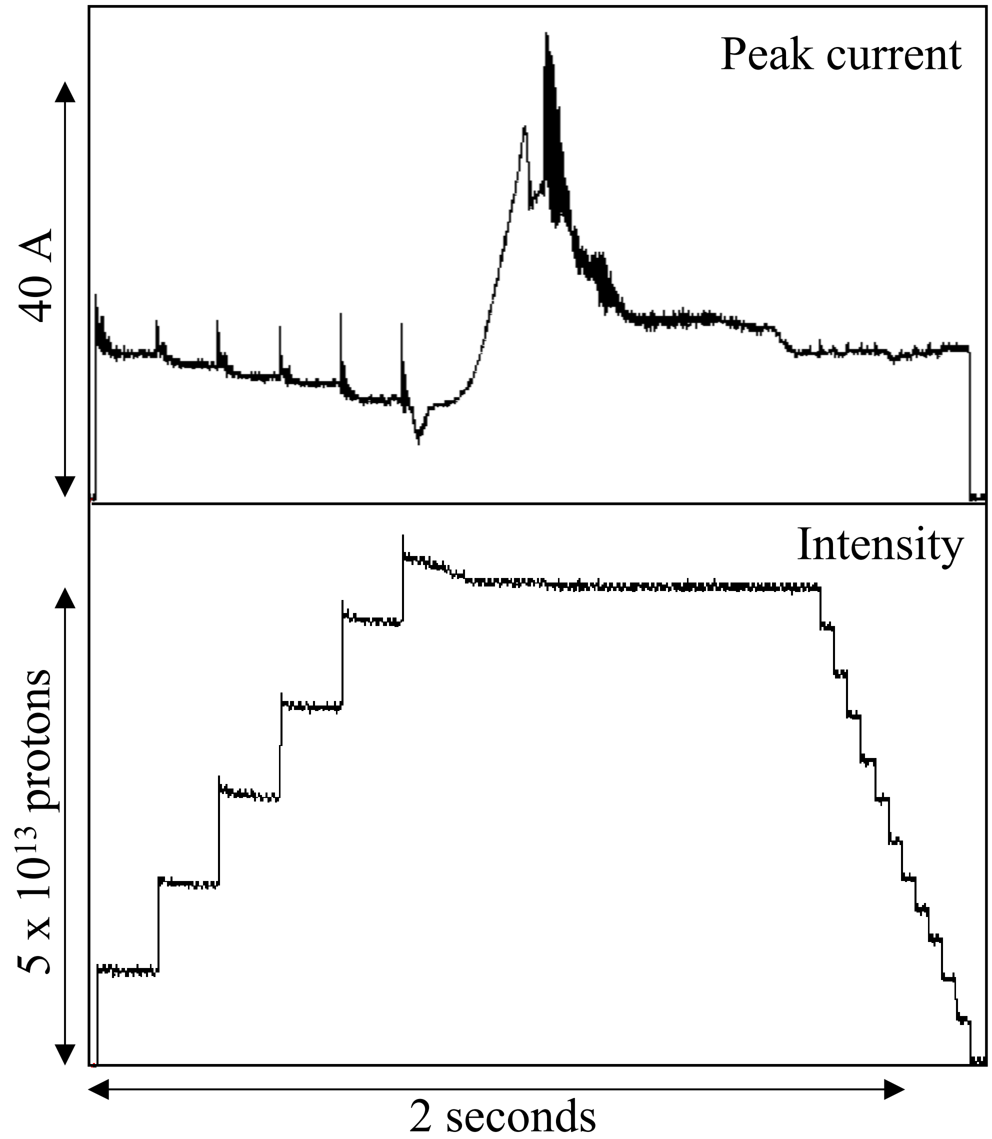
Circulating:
17×10^{12} ppb
3.0 eVs
5×10^{12} /eVs

High B dot gives effective long. phase space painting.
Injection period is approx. equal to synchrotron period.

BROOKHAVEN
NATIONAL LABORATORY

AGS performance for g-2 operation

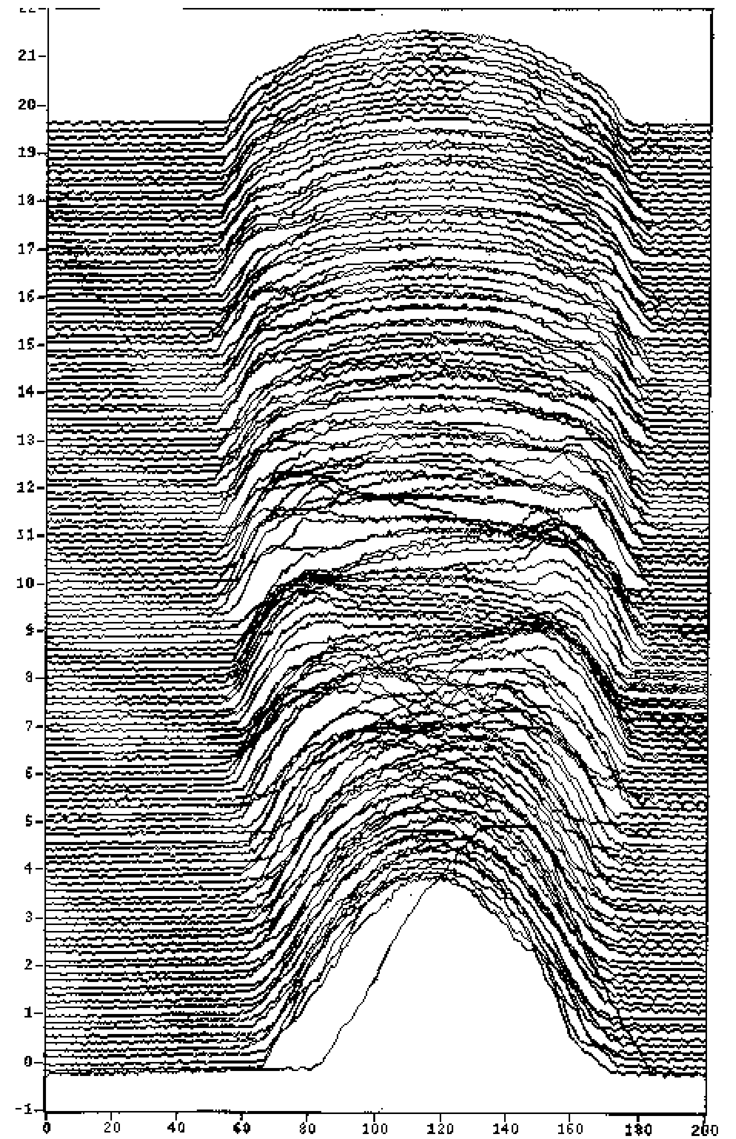
- 6 single bunch transfers from Booster
- Peak intensity reached: 72×10^{12} ppp
- Bunch area: 3 eVs at injection
  10 eVs at extraction
- Intensity for g-2 ops: $50\text{-}60 \times 10^{12}$ ppp
- Strong space charge effects during accumulation in AGS
- 2nd order transition energy jump limits available momentum aperture.
- Chromatic mismatch at transition causes emittance dilution
- Dilution needed for beam stability



Controlled dilution at AGS injection

Longitudinal emittance dilution
at AGS injection through mismatch
followed by smoothing with
high frequency (93 MHz) cavity.

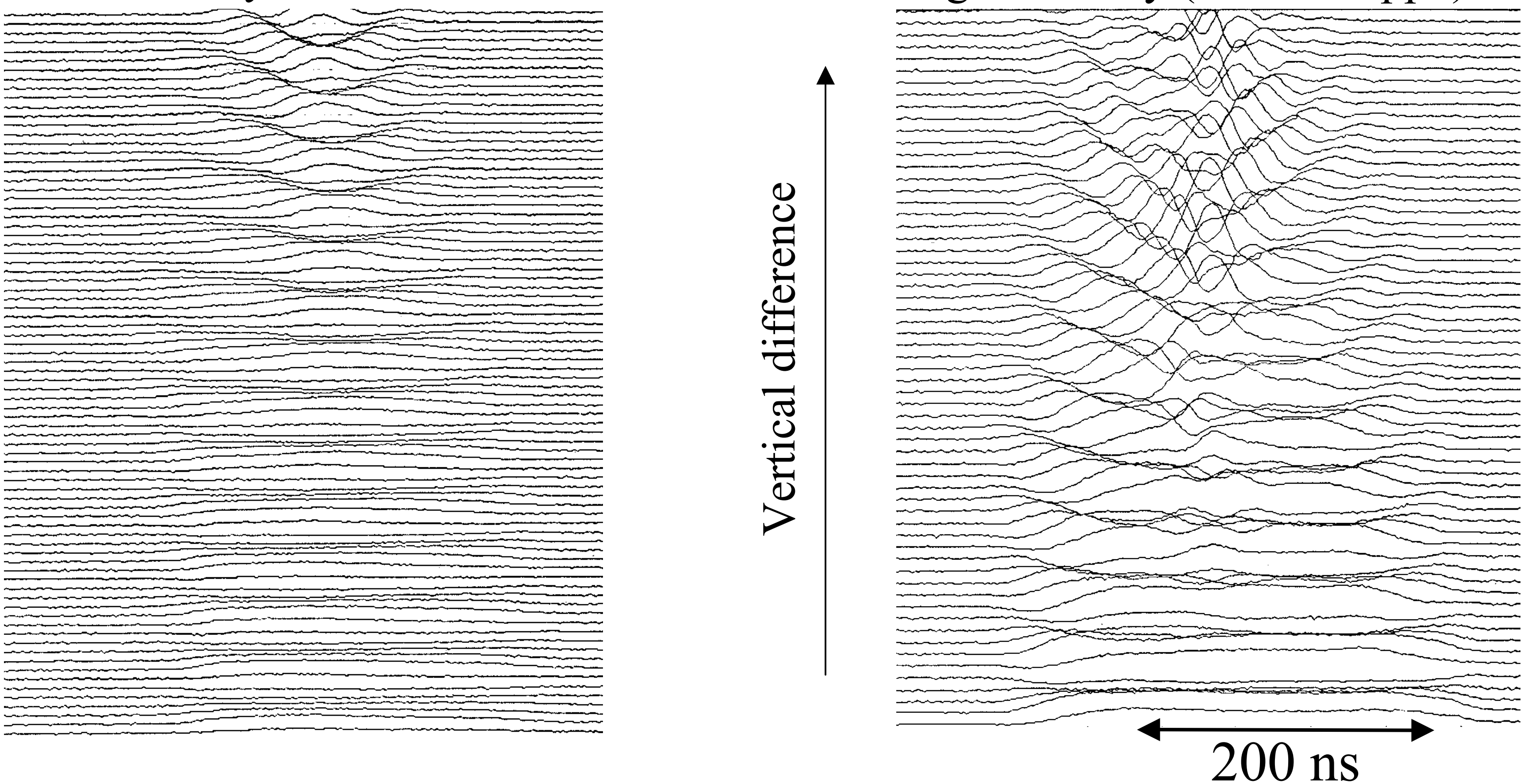
Needed to avoid excessive
space charge tune spread and
coupled bunch instabilities.



BROOKHAVEN
NATIONAL LABORATORY

Vertical coherence at AGS injection

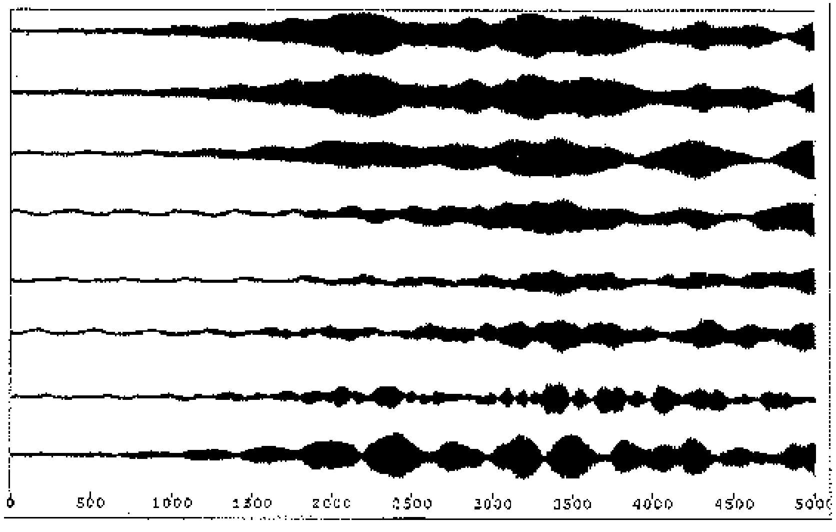
Low intensity | High intensity (13×10^{12} ppb)

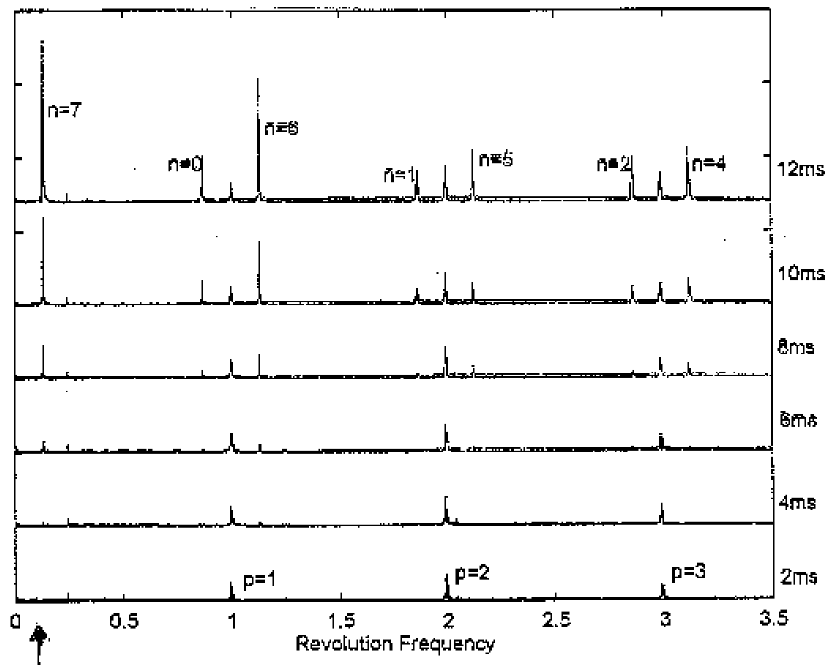


Coherent space charge tune shift varies along bunch:
$0 \rightarrow \sim 0.1$ at bunch center

BROOKHAVEN
NATIONAL LABORATORY

Coupled bunch instability at AGS injection



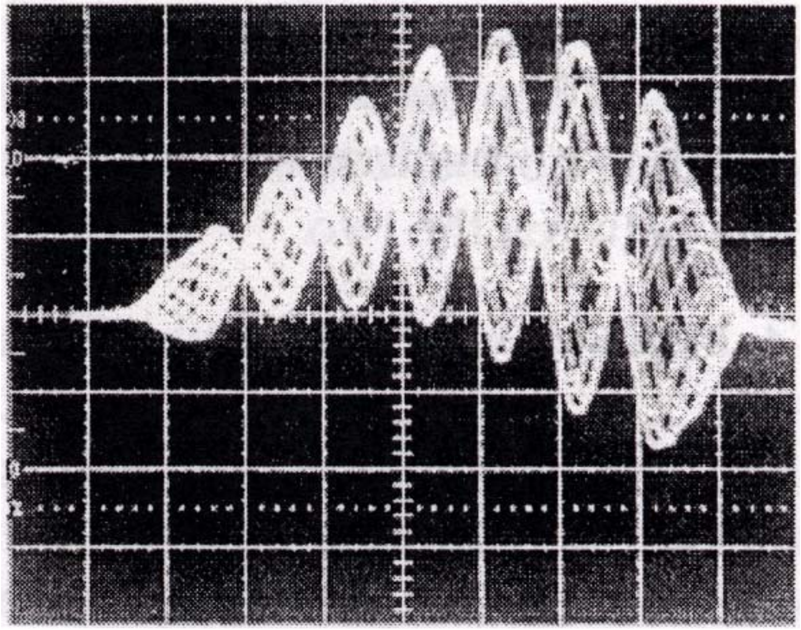


Strong resistive wall coupled bunch instability
Requires broad band transverse damper

BROOKHAVEN NATIONAL LABORATORY

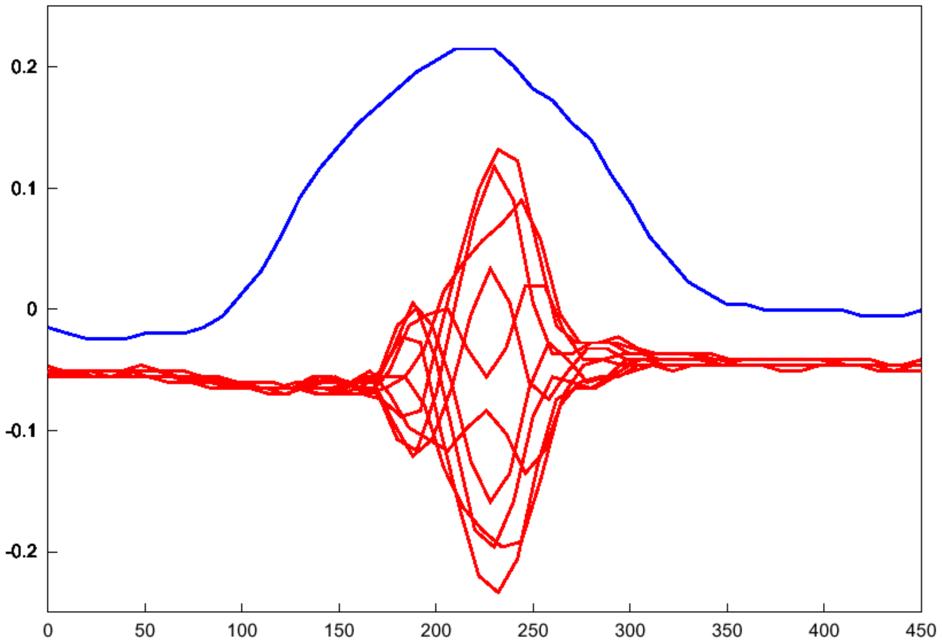
“Slow” head-tail instability at injection

CERN PS



1×10^{12} protons per bunch
Detailed study of coupling to damp head-tail instability (Metral et al)

BNL AGS



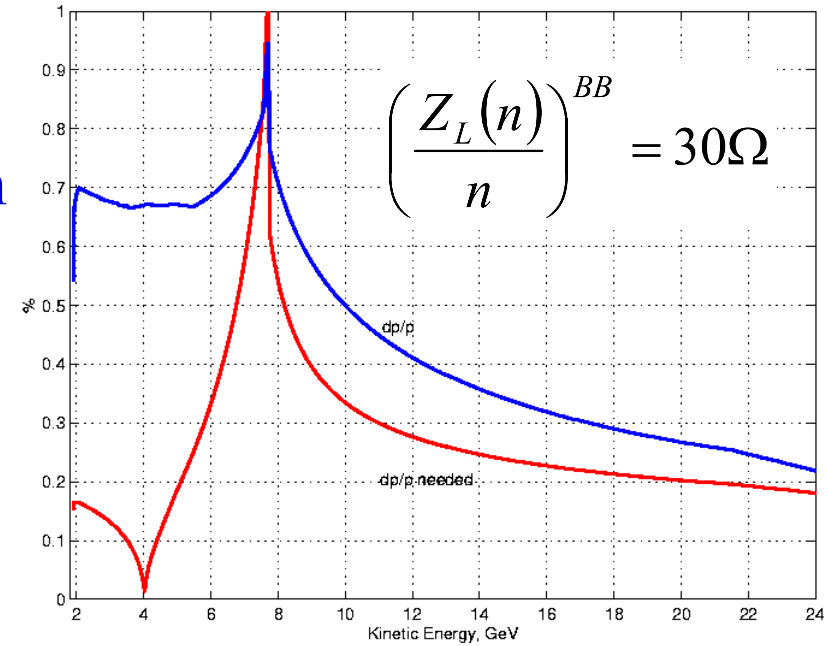
12×10^{12} protons per bunch
0.2 second growth rate
Threshold from coherent s.c. tune shift
Short wake field (broad band impedance)

BROOKHAVEN
NATIONAL LABORATORY

Longitudinal microwave stability

Proton bunches are longer than vacuum chamber diameter.
Use coasting beam threshold with peak current:

$$\left(\frac{\Delta p}{p}\right)^2 = \frac{eI_{peak}}{E|\eta|}\left|\frac{Z_L(n)}{n}\right|$$



Impedance includes broad band and space charge impedance.
Mostly of concern at transition energy. Use transition energy jump.

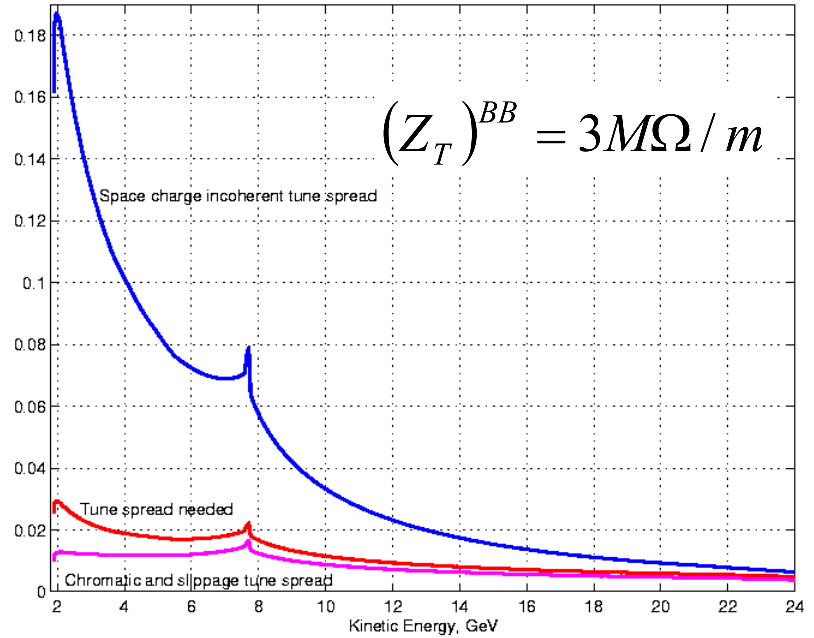
BROOKHAVEN NATIONAL LABORATORY

Transverse microwave stability

Limits electron bunch brightness.
Never observed in proton machines.
Effective threshold using peak current (Zhang and Weng):

$$\Delta\nu = \frac{eI_{peak}R}{4\pi E\nu_{\beta}}|Z_T|$$

Includes space charge both in impedance and tune spread.



More careful analysis also shows that space charge indeed tends to stabilize this instability (Ng and Burov, Blaskiewicz)
Some evidence that individual bunches "disappear" at high energy.

BROOKHAVEN NATIONAL LABORATORY

Bunch compression

Non- adiabatic methods for bunch compression:

- Slow reduction of rf voltage followed by quick increase. Bunch is compressed after quarter synchrotron period.
- Move bunch to unstable fixpoint and let bunch stretch out. Then move back and wait a fraction of a synchrotron period to compress bunch.
- Move transition energy quickly to beam energy and accelerate head and decelerate tail of bunch. Then move transition energy away ($\eta \neq 0$) and let bunch compress.

Adiabatic methods for bunch compression:

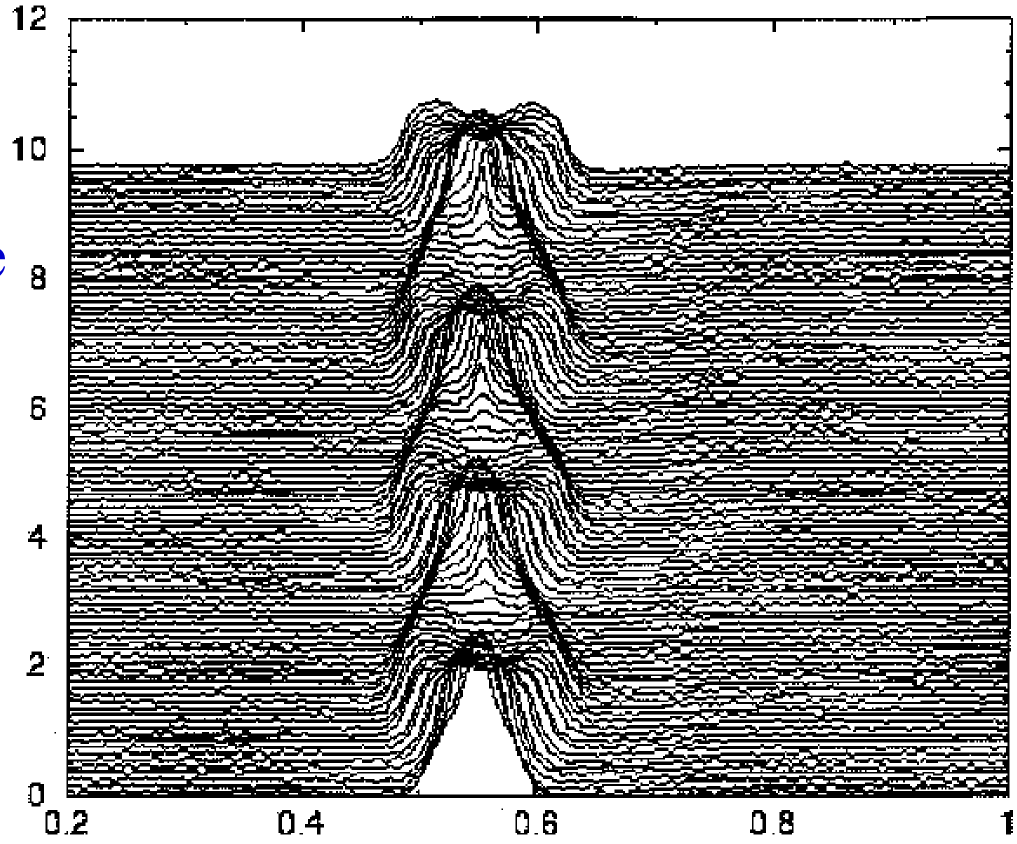
- Slowly increase rf voltage (Needs very high voltage)
- Move transition energy slowly to beam energy (very slow!)
- Slowly increase amplitude of modulation of rf voltage with modulation frequency close to twice the synchrotron frequency.

Adiabatic quadrupole bunch pumping

Compression factor ~ 2

Multiple extractions possible

Non-linearities don't limit the maximum possible compression factor.

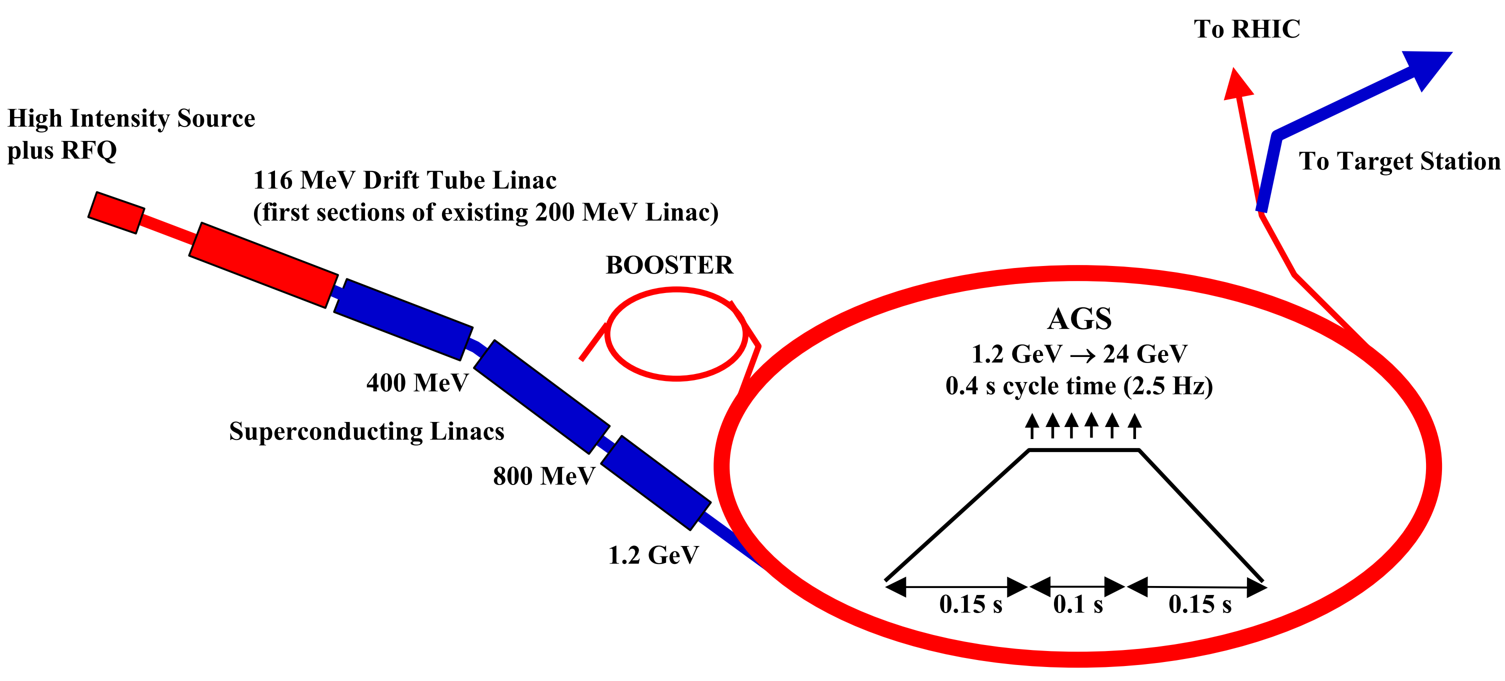


AGS intensity upgrades

Needed upgrades

- 1.2 GeV superconducting linac extension for direct injection of 1×10^{14} protons per pulse into AGS
  - low beam loss at injection
  - high repetition rate possible
  - further upgrade to 1.5 GeV and 2×10^{14} protons per pulse possible
- 2.5 Hz AGS repetition rate
  - triple existing main magnet power supply and magnet current feeds
  - double rf power and accelerating gradient
  - further upgrade to 5 Hz possible

AGS proton driver layout



BROOKHAVEN
NATIONAL LABORATORY

AGS proton driver parameters

	present AGS	0.4 MW AGS	1 MW AGS
Total beam power [MW]	0.14	0.4	1.00
Beam energy [GeV]	24	24	24
Average current [μA]	6	17	42
Cycle time [ms]	2000	1000	400
No. of protons per fill	0.7×10^{14}	1×10^{14}	1×10^{14}
Average circulating current [A]	4.2	5.9	5.9
No. of bunches at extraction	6	6	6
No. of protons per bunch	$\sim 1 \times 10^{13}$	1.7×10^{13}	1.7×10^{13}
Total bunch area [eVs]	15	5	5
Time betw. extr. bunches [ms]	33	20	20

BROOKHAVEN
NATIONAL LABORATORY

Summary

- Very successful operation for the g-2 experiment
- Operation with 7×10^{13} slow extracted protons planned for RSVP
- Upgrade to 400 kW and 1 MW beam power feasible