Very preliminary studies of background gas charge dynamics in the IPNS RCS

J. C. Dooling

Argonne National Laboratory, Argonne, IL 60439, USA

presented to the

Midwest Accelerator Physics Collaboration Meeting
September 30-October 1, 2003
Fermi National Accelerator Laboratory
Ionization and Neutralization

• Ave. pressure in IPNS RCS: 1-2 µT N₂
• RCS $\tau_n \sim 0.5$ ms at injection; acceleration period: 14 ms
• At PSR, $\tau_n \sim 20$ ms; store period: <1 ms
• In the Booster, 0.5 µT H₂O, $\tau_n \sim 2$ ms at injection; acceleration period: 32 ms
• RCS at 4E12 injected, $n_g$ is 2 orders greater than $n_b$
Beam electric field and potential

- Assuming a uniform beam, radius $r_b=1.5$ cm and wall radius, $r_w=3.8$ cm
- $3\times10^{12}$ protons
- Bunching factor and frequency folded into peak current
PAPS IPM Data

- IPM profiles respond to pressure and bias
- Gaussian fit to data tracks horizontal position (Pie) electrode centroid
- Ionization bursts observed at injection and after phase modulation (PM)
- BW~5 kHz
RFA data

- Injection

- Scrambler

injection begins at 344 µs and ends near 420 µs

a) \( t=448 \mu s \)

b) \( t=528 \mu s \)
Pie data—H position near PM. Noise increases significantly

- 9 ms

- 10 ms
Higher Frequency Spectra
500 MS/s, 20 μs window, 10 kS

- No scrambler
- With scrambler
Conclusions from last meeting (June ‘03)

- Electrons present, so are ions (plasma)
- PM modifies plasma channel, adds stability
- Large electron signals usually not observed
  - Rarely at injection, more often after scrambler
  - Add magnetic shielding to RFA

Include background ions in simulations, especially when intense electron signals suggest significant neutralization.

Diagnostics to look directly at or near the beam region
  e.g., interferometry, spectroscopy, Langmuir probes, Rogowski coils
Initial modeling of background ions

Random, uniform initial distribution of charge
KV velocity distribution, based on initial temp.
Predictor-Corrector (2\textsuperscript{nd} order time steps)
Ions move in the E-field imposed by the beam
(round, uniform density, \(a=1.5\ \text{cm}, \ r_w=3.8\ \text{cm}, \) no time structure yet, density scaled by BF)
Modeling Results

Mass 14, singly-charged ions, near injection
(10,000 macro charges)
Modeling Results, con’t

electrons, near injection (10,000 macro charges)

number or density (a.u.)

scaled density

0 ns

5.55 ns

10 eV

r (m)
Modeling Results, con’t

electron density evolution, near injection
(10,000 macro charges)
electron density evolution, near injection
(10,000 macro charges)

time (s)

scaled density (a.u.) or velocity (m/s)

$10^6$

$10^7$

$10^8$

$10^9$

$10^{10}$

$5.55 \text{ ns}$

$100 \text{ eV}$

$v_1$

$v_2$

$n_e$
Other work

• Recent papers in PRST-AB:
  – Bosch (http://prst-ab.aps.org/abstract/PRSTAB/v6/i7/e074201) proton beam stabilization with intensity
  – Rumolo et al. (http://prst-ab.aps.org/abstract/PRSTAB/v6/i8/e081002) included electron focusing but only for cold electrons—no temperature dependence
Further work

• Add longitudinal bunch shape
• Include background space-charge
• Include interaction between species (through the electric field)
Acknowledgement

• This work is made possible by the IPNS Accelerator Operations Group, the IPNS and MSD Divisions, and DOE support.