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Vacuum Pressure Considerations on the Performance and Lifetime of Negative Ion Sources

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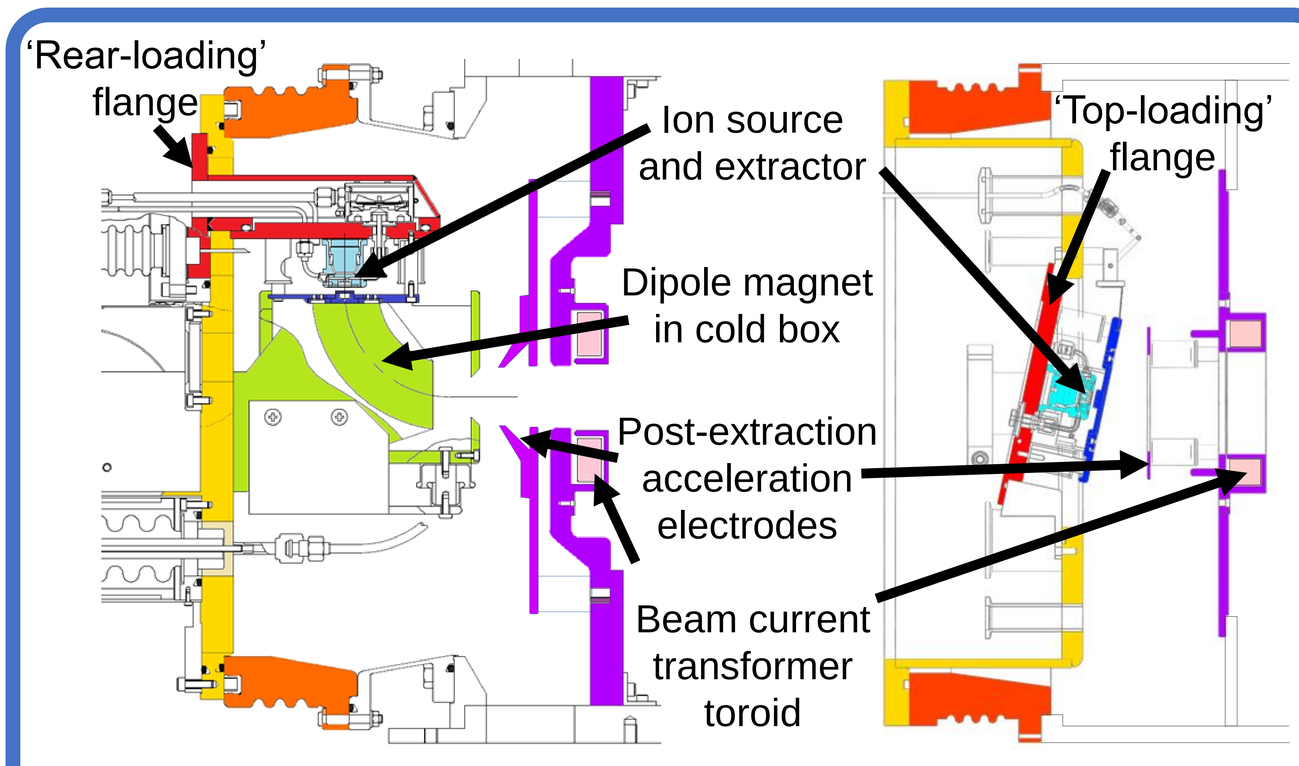
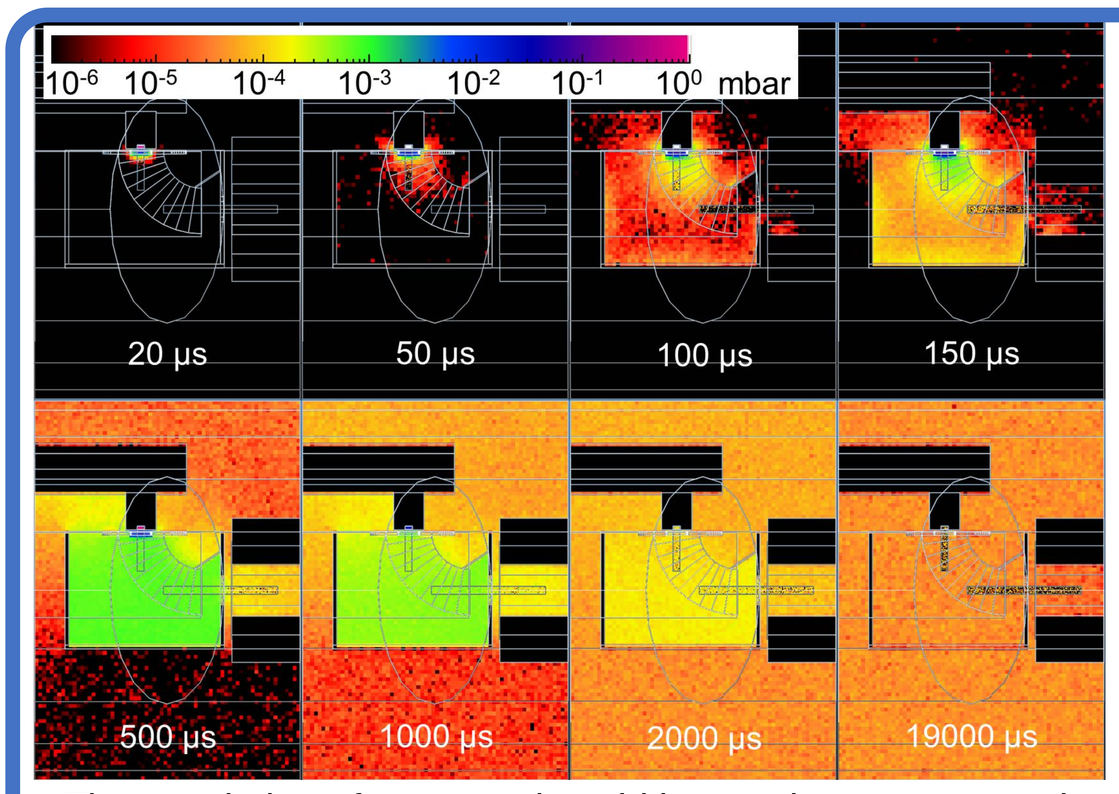
Executive Summary

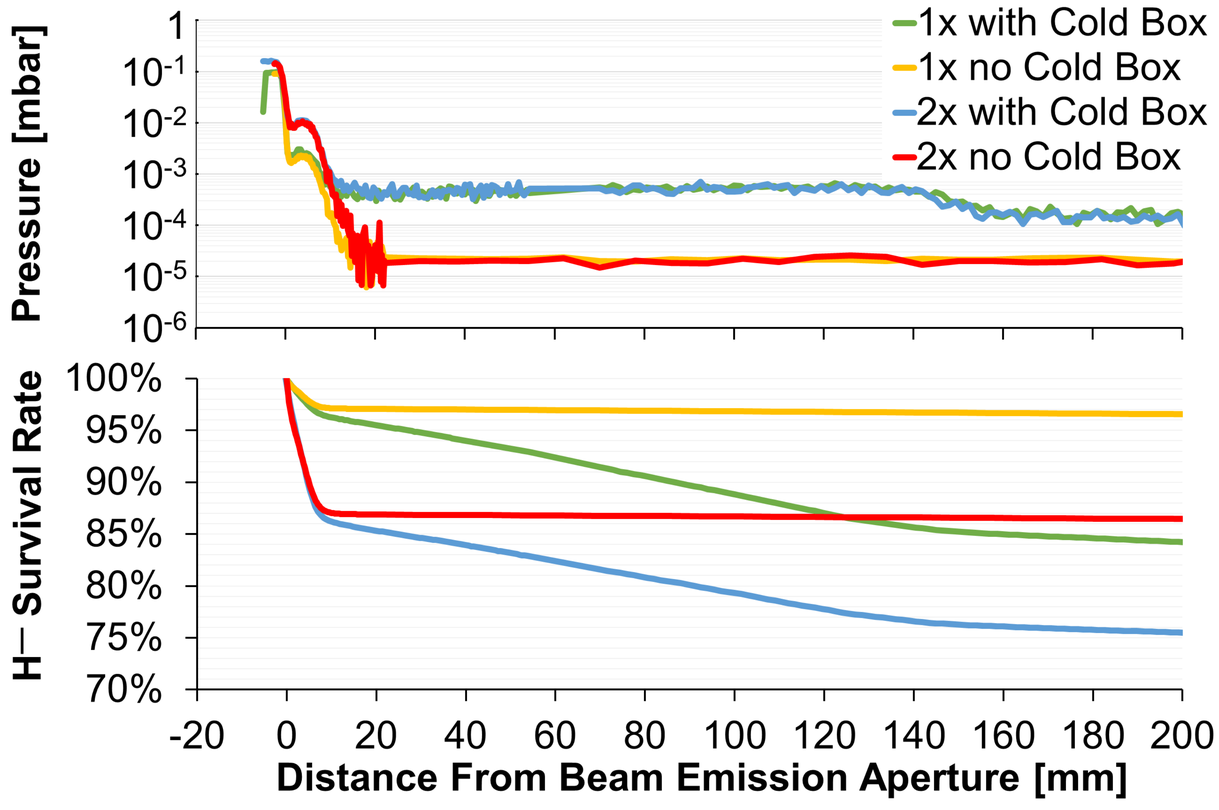
- Negative ions are very fragile and easily stripped by poor vacuum pressure. Effort should be made to improve pumping efficiency.
- Depending on the vacuum setup, up to 20% of beam current may be lost purely due to vacuum pressure, all other things being equal.
- Back-streaming positive ions are produced from residual gas ionisation. Experiments show clear erosion pattern from positive ions.
- Where every milliamp counts in negative ion sources, as well as lifetime and reliability, vacuum quality should be prioritised.



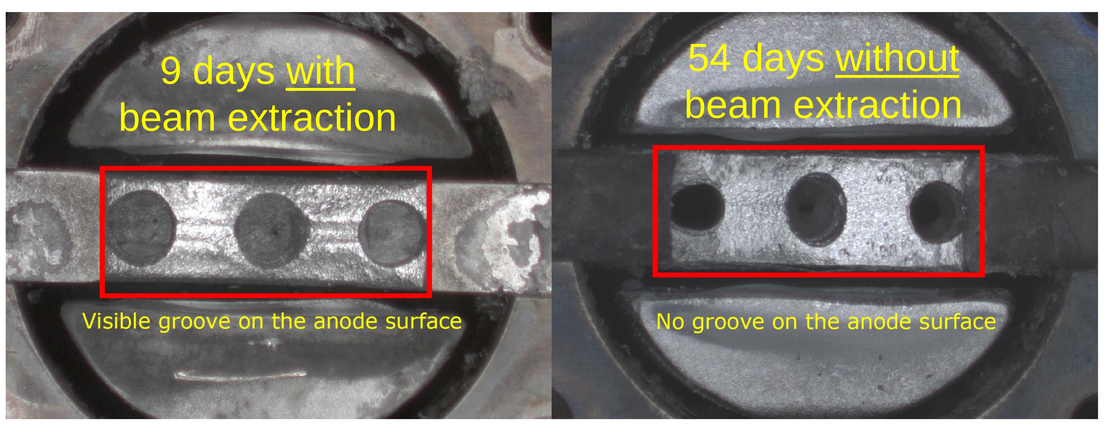
- Standard ISIS operational setup includes a 'cold box' caesium trap.
- Convoluted pumping route through cold box leads to poor vacuum.
- Up to 40% beam loss on dipole magnet poles inside cold box.
- Additional ancillary hardware required to support cold box & magnet.
- Different setup tested with no cold box: much better beam & vacuum.



- Time evolution of pressure in cold box and vacuum vessel
- 200 µs H_2 gas pulse fills cold box over much longer timescale
- H_2 flow chosen so average pressure matches that measured
- Beam extracted between 500-2000 µs sees ~$5x10^{-4}$ mbar
- Pressure without cold box in 'top-loader' setup is ~50x lower



- Pressure profile measured along beam flightpath at time = 800 µs
- H^- survival calculated using pressure and stripping cross section
- 2x source large losses at extraction due to larger emission aperture
- Cold box large losses due to long drift through high pressure region



- Microscope images of Penning source molybdenum anode
- Backstreaming positive ions accelerated into ion source
- Clear groove cut when extractor on; no groove when off
- Erosion clearly depends on stripping losses and pressure

Recommendations:

- Give higher consideration to pumping during source design
- Simulate vacuum pressure profile for different configurations
- Aim for < $5x10^{-5}$ mbar as soon as possible after extraction
- Consider shifting gas pulse timing to reduce beam stripping
- Calibrate beam current results to account for stripping