Electrons and gas versus high brightness ion beams

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Outline of presentation

• High Current Experiment (HCX) with diagnostics
• Electrons in only 4 quads can perturb beam
• Measure each source of electrons
• Measure electron emission and gas desorption
• Desorption energy scaling – electronic sputtering
• Desorption vs. angle of incidence – what is it trying to tell us?
• Plans
HCX instrumented to carry out electron cloud and gas desorption experiments

Experiment and simulation find sufficient electrons can degrade beam in only 4 quadrupole magnets
All sources of electrons can be measured

1. Ionization of gas by beam

2. Electron emission from beam tube

3. Axial current of electrons from end of linac

Gas desorption / electron emission measurements – journey towards understanding and mitigation

Gas-electron source diagnostic (GESD) [Originally to calibrate halo loss]

If target surface roughened by glass-bead blasting – grazing incidence ions hit rims of craters.
GESD electron emission coefficient (EEC) varies with \(\cos(\theta)^{-1}\)

- Simple model gives \(\cos(\theta)^{-1}\)
  - Electrons in material gain energy from beam ions \(dE/dx\)
  - Electrons from depth \(> \delta\) (\(\delta \sim 1\) nm) cannot leave surface
  - Ion path length in depth \(\delta\) is \(L\)
    \[ L = \delta / \cos(\theta) \]
- Results depart from this near grazing incidence where the distance for nuclear scattering is \(< L^1\)

\[ L = \delta / \cos(\theta) \]


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Discovery – copious gas desorption in accelerators due to electronic sputtering*

"it is very important to gain a better understanding of the theoretical aspects of the heavy-ion induced desorption phenomena, ..."

ICFA Workshop on Beam Induced Pressure Rise in Rings (Dec. 2003) Summary of Working Group I on \(e^+\) and Ion Desorption.


* Suggested by Thomas Schenkel, LBNL EBIT

Gas desorption scales with electronic component of \(dE/dx\)

GSI augments VNL results. Consistent with model we suggested in 1/03 visit.
Scaling with 1st-2nd power of dE/dx is similar to electronic sputtering from insulators.

![Graph showing scaling with dE/dx](image)

Mystery – Why does desorption vary so little with ion angle of incidence?

**Gas desorption Vs angle for K+ energies of 50 keV to 1 MeV**

Desorption by 800 MeV Pb ions similar at CERN (E. Mahner, PRST-AB 6, 013201 (2003.).)

* Suggested by Thomas Schenkel, LBNL EBIT

![Graph showing gas desorption](image)
What is the effect of ion angle of incidence on desorption telling us?

- Atomic scale roughness could explain non-1/cosθ desorption; but e-emission is 1/cosθ from same surface!
- Monolayers of adsorbed gas on surface: same model that explains e- vs. angle predicts 1/cosθ.
- Oxide layers: also 1/cosθ.
- Dust on surface: cross-section of each dust particle is approx. independent of angle of incidence, but impinged surface area & number of dust particles in beam scale as 1/cosθ.
- Inclusions in material: similar to dust on surface?
- Is desorption independent of angle of incidence, with apparent dependence due to ion scattering, resulting in a second impact?

![Graph showing desorption coefficient vs. angle from normal](image)

Plans

- Minimize local sources of electrons to clearing electrodes
- Study electron particle balance for each source: ionization, beam-tube, end-wall
- Effect on beam of electron accumulation from each source
- Measure velocity distribution of desorbed gas, photon spectrum(?)
- Develop mitigation schemes
- Continue to compare experiment with simulation – Goal is a validated predictive capability