Monte Carlo Studies of Electron Collisions in Rb Spin-Exchange Cells

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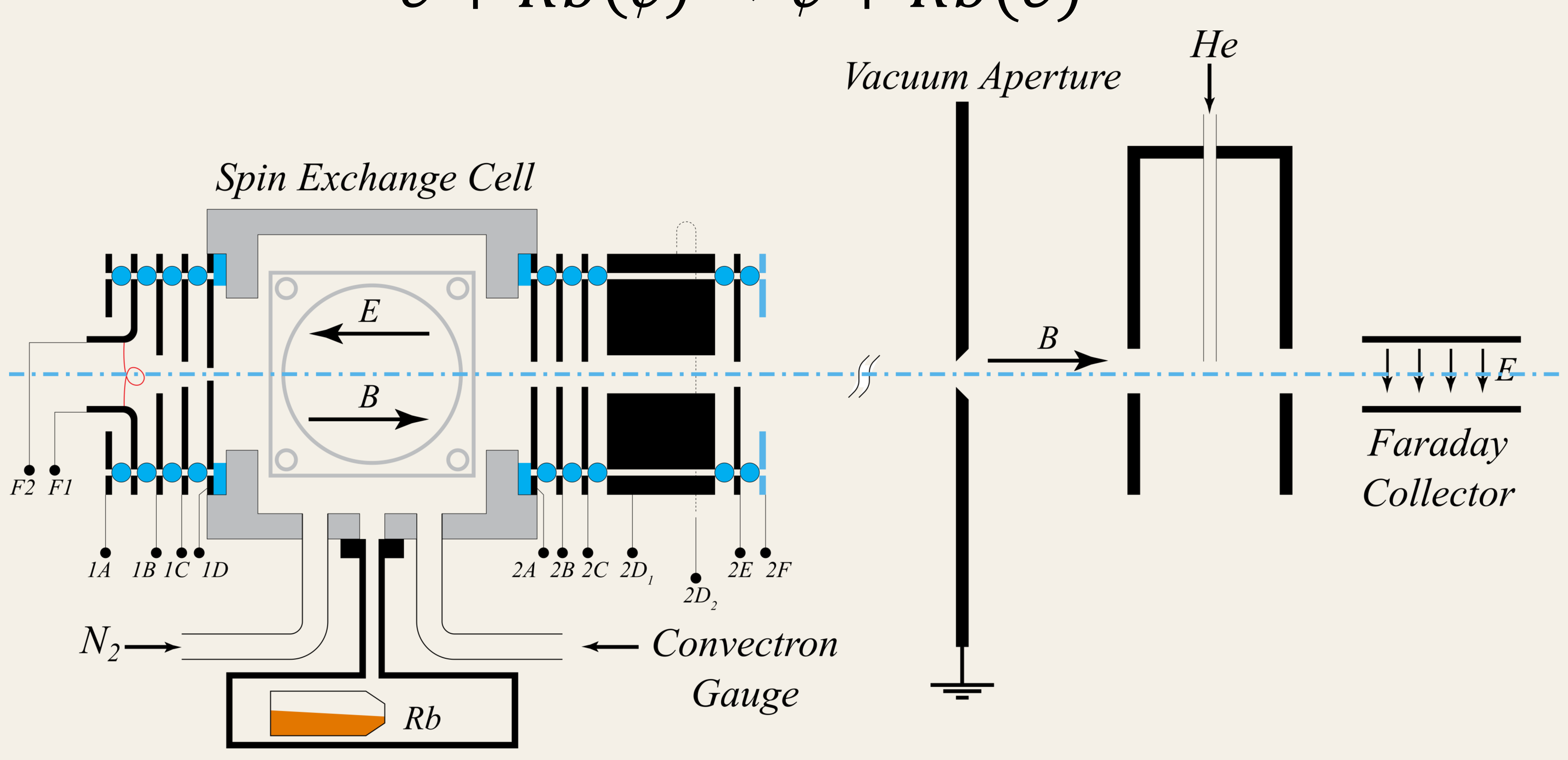
Rubidium Spin Filter

Activated GaAs sources of spin-polarized electrons are difficult to operate, requiring ultra-high vacuum systems and months of training.

Our alternative source uses spin-exchange interactions with optically-pumped Rb to create a beam of spin-polarized electrons.

$$e + Rb(\not{e}) \rightarrow \not{e} + Rb(e)$$



Thermionically emitted electrons from the filament (F1/F2) propagate through the Spin Exchange Cell, which contains N_2 and polarized Rb. The electron current passing through the cell picks up a net spin polarization, which is analyzed with a helium polarimeter and Faraday Collector.

Benefits of N_2 buffer gas[1]:

- Thermalization of the electrons, more Rb spin exchange
- Vibrational quenching of Rb*
- Reduces depolarizing Rb-wall collisions

Unexpected contribution of liberated electrons from ionization at high energies[2]

⇒ Need for better understanding of collision dynamics

Monte Carlo Simulation

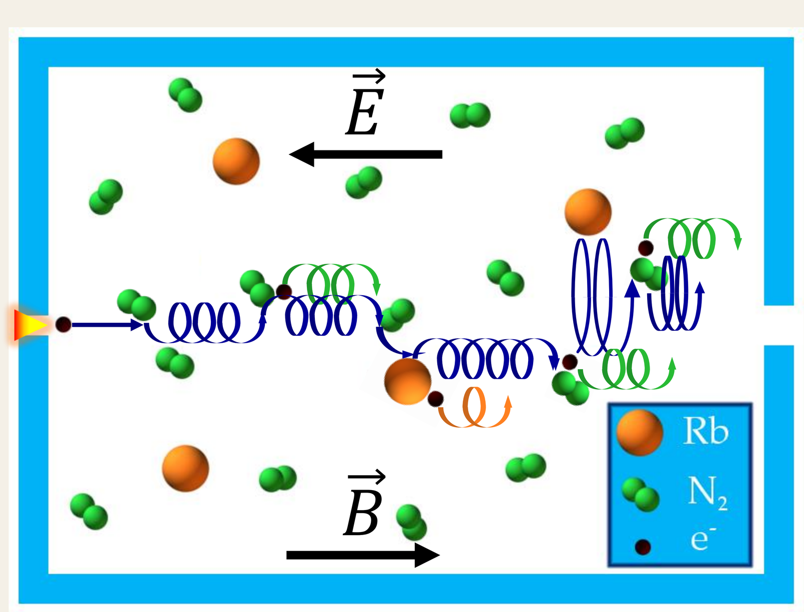
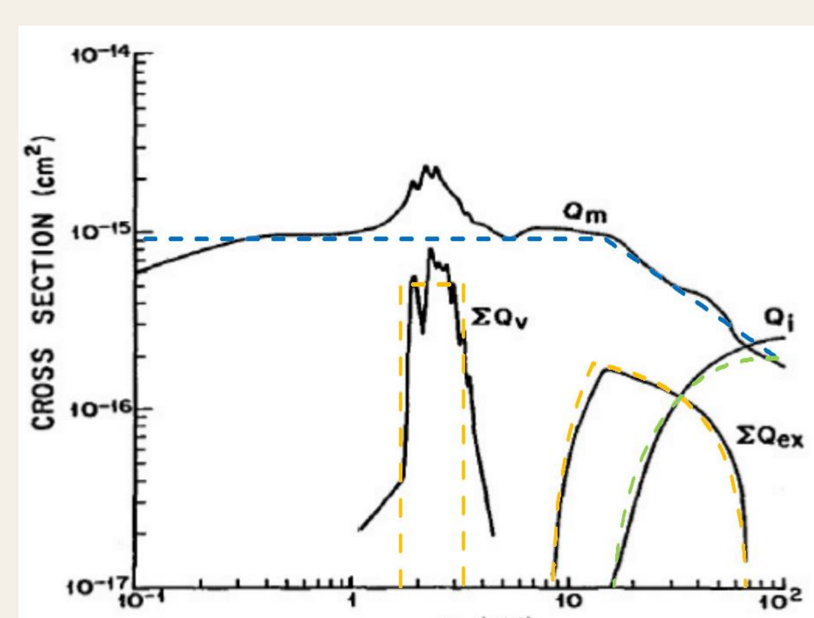


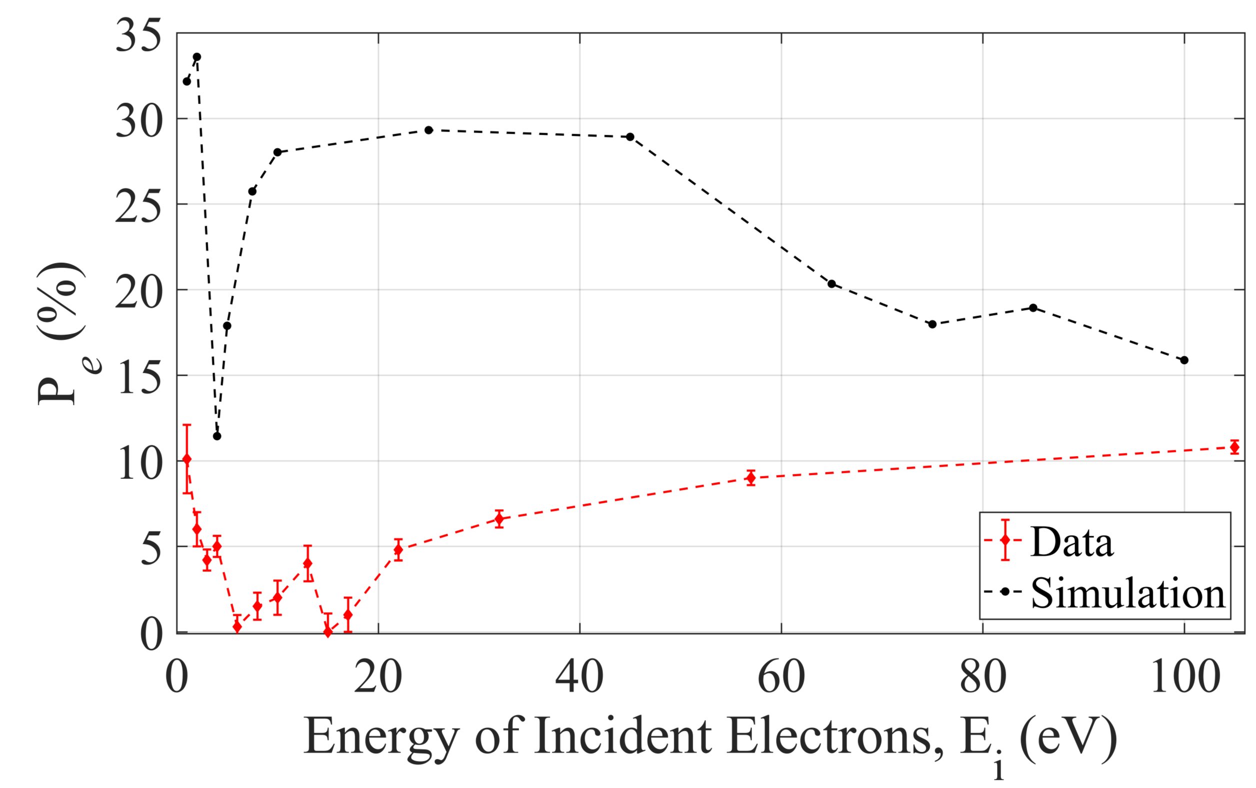
Illustration of electron propagation through the Spin Exchange Cell. Typical values: $E = 100\ V/m$, $B = 270\ G$.



Cross-sections of nitrogen (solid) compared to cross-sections used in the Monte Carlo simulation (dotted). Figure adapted from [3].

- Simulation of Spin Exchange Cell region
- Simple model produces qualitatively similar data
- Explore how electrons are produced in Spin Exchange Cell

Electron Polarization



The above experiment was conducted with $n_{Rb} = 10^{13}\ cm^{-3}$ and $P_{N_2} = 130\ mTorr$. Lines serve to guide the eye.

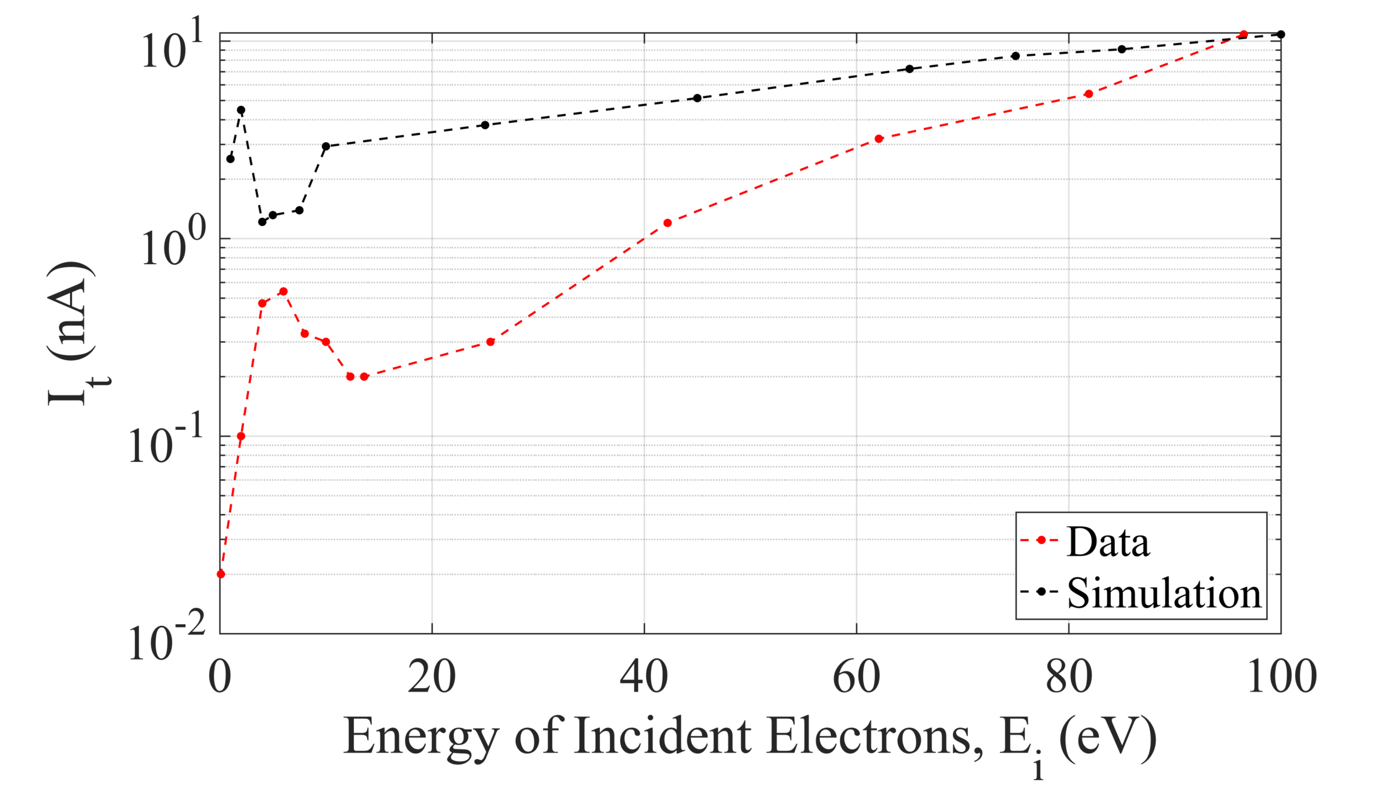
In the simulation:

- **Decrease** of P_e at **high** E_i caused by the large number of electrons from N_2 ionizing collisions

In the data:

- **Increase** of P_e at **low** E_i caused by dramatic increase in e^--Rb spin-exchange cross section[4]

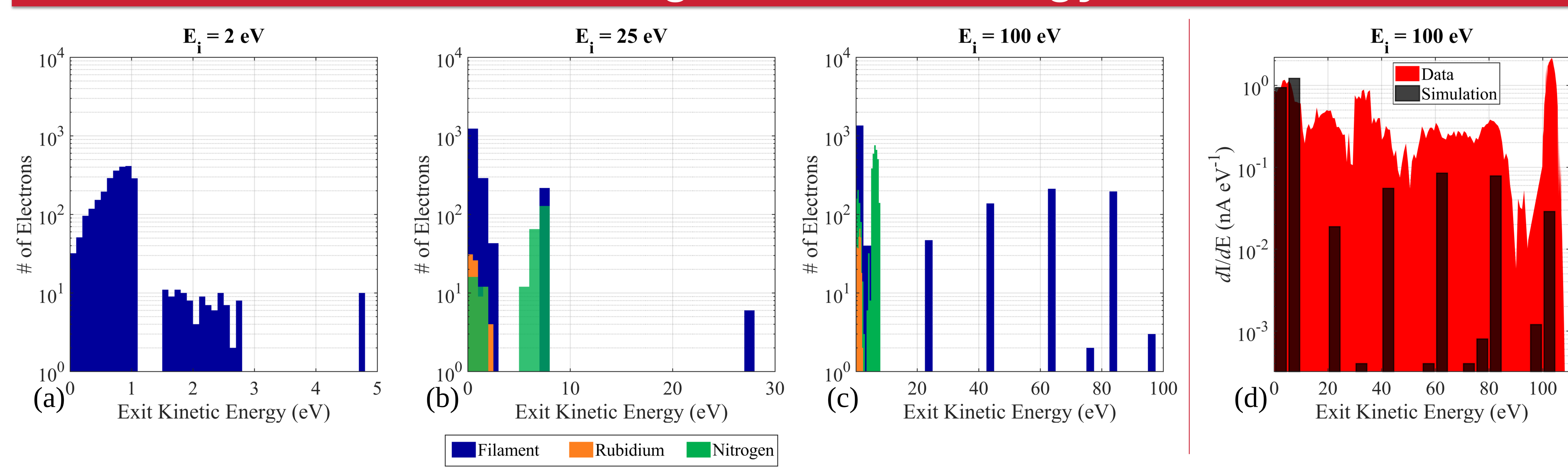
Transmitted Current



The above experiment was conducted with $n_{Rb} = 10^{13}\ cm^{-3}$ and $P_{N_2} = 130\ mTorr$. Simulation values were normalized to the maximum current at 100 eV. Lines serve to guide the eye.

- Initial peak and subsequent fall in I_t reproduced by simulation
- Rise in I_t with increasing E_i occurs due to increase in nitrogen-ionizing collisions

Exiting Electron Energy



(a-c) These histograms show simulation data for $n_{Rb} = 10^{13}\ cm^{-3}$ and $P_{N_2} = 130\ mTorr$.

(d) Comparison between the experimental data obtained by analyzing the electron beam with a retarding field and the distribution of the electron energies obtained from the simulation. Again, these data were collected for $n_{Rb} = 10^{13}\ cm^{-3}$ and $P_{N_2} = 130\ mTorr$.

Low energy (2 eV):

- Electrons thermalize resulting in many spin exchange collisions
- Number of exiting electrons is limited by the number of filament electrons

High energies (25 eV and 100 eV):

- Ionization and multiple collisions are possible, resulting in additional electrons from Rb and N_2

- Examination of retarding field data in (d) reveals several promising "peaks" which correspond to filament electrons losing energy by ionization
- The peak at 30 eV is spurious, resulting from a change in scale of the electrometer used to measure current

References

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[4] C. Bahrim, U. Thumm, and I.I. Fabrikant, Phys. Rev. A **63**, 042710 (2001).

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