Testing the performance of *frozen-spin* HD with electron beams at the UITF

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IBC *watch*: a host of people,… ☺

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Beam Raster: F. Barbosa, C. Cuevas, W. Gunning, W. Lu

ACC *support*: a host of people,… ☺

\+ …

Preliminary Summary of HDice tests at the UITF

- Run 2 (Oct 27 – Nov 9/2020) with *non-frozen-spin* HD :

  - verified simulated beam energy loss by measuring the temperature rise in the cryostat

  - set the gain of a new 3KHz spiral raster so that the beam would cover the full HD target

  - tuned the NMR to monitor target polarization using an HD sample with short polarization build-up time

    ⬄ HD rapidly came to the equilibrium polarization determined by the field and temperature, ~ 1%

    ⬄ **discovered that the HD temperature with beam (0.2 – 0.3 K) was significantly higher than the temperature of the cryostat (<0.1 K) ⬄ heat was not efficiently removed**

      ➢ the electron beam will dissociate HD molecules (with 2 *paired* electrons) into H and D atoms, each with an *unpaired* electron ⬄ potential *paramagnetic sources*

      ➢ at IBC temperatures, these paramagnetic electrons are polarized and don't hurt

      ➢ but at higher temperatures (or lower fields), the electron polarization drops and they can cause proton depolarization

Preliminary Summary of HDice tests at the UITF

- Run 3 (Nov 23 – Dec 17/2020), using two *frozen-spin* HD targets, with ~30% polarization:

⇔ *the consequence of higher temperatures:*

- dP/dt under different holding fields:

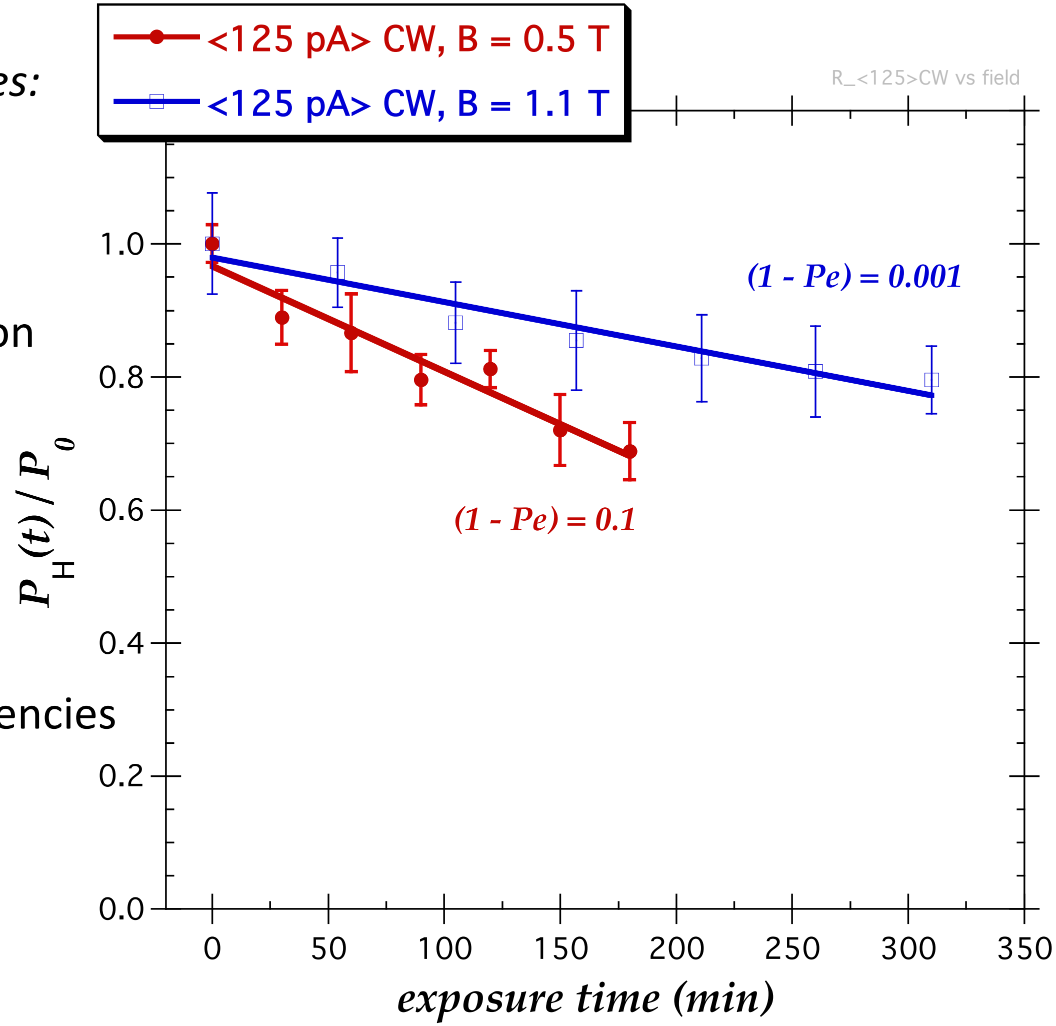
  - same current ⇔ same temperature

  ⇔ different atomic electron polarization

- **High HD temperatures (> 200 mK) result in only partial atomic electron polarization**

  ⇔ flipping electron spins have Fourier components at the H-Larmor frequencies

  ⇔ significant dP/dt

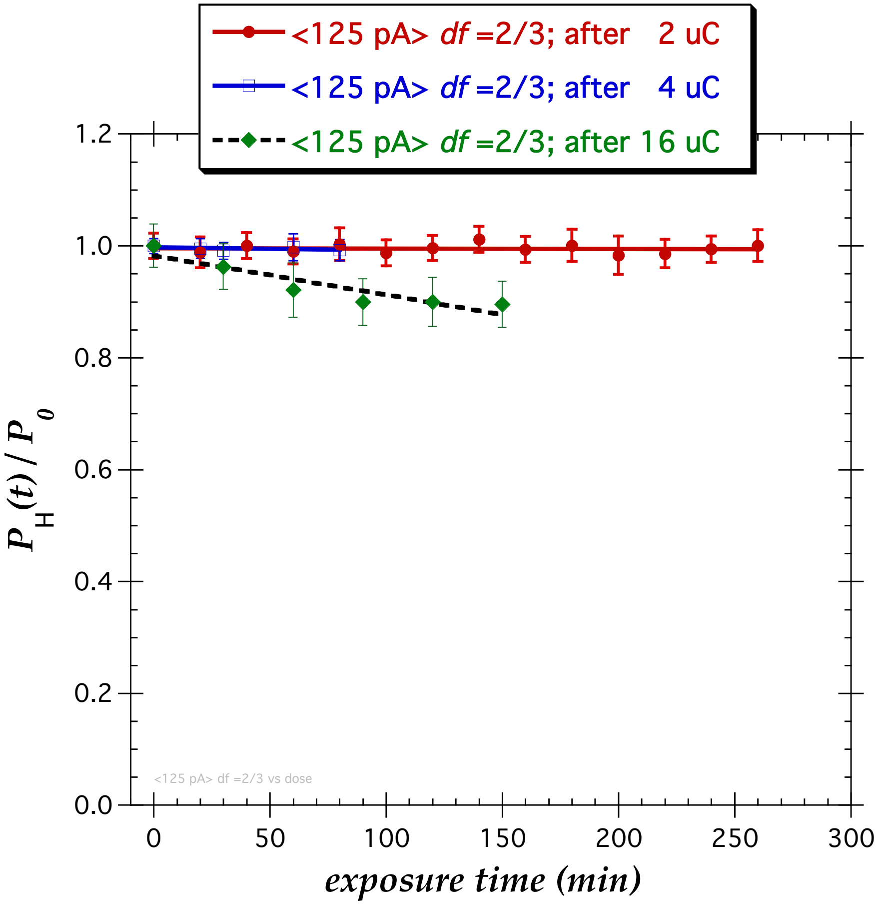


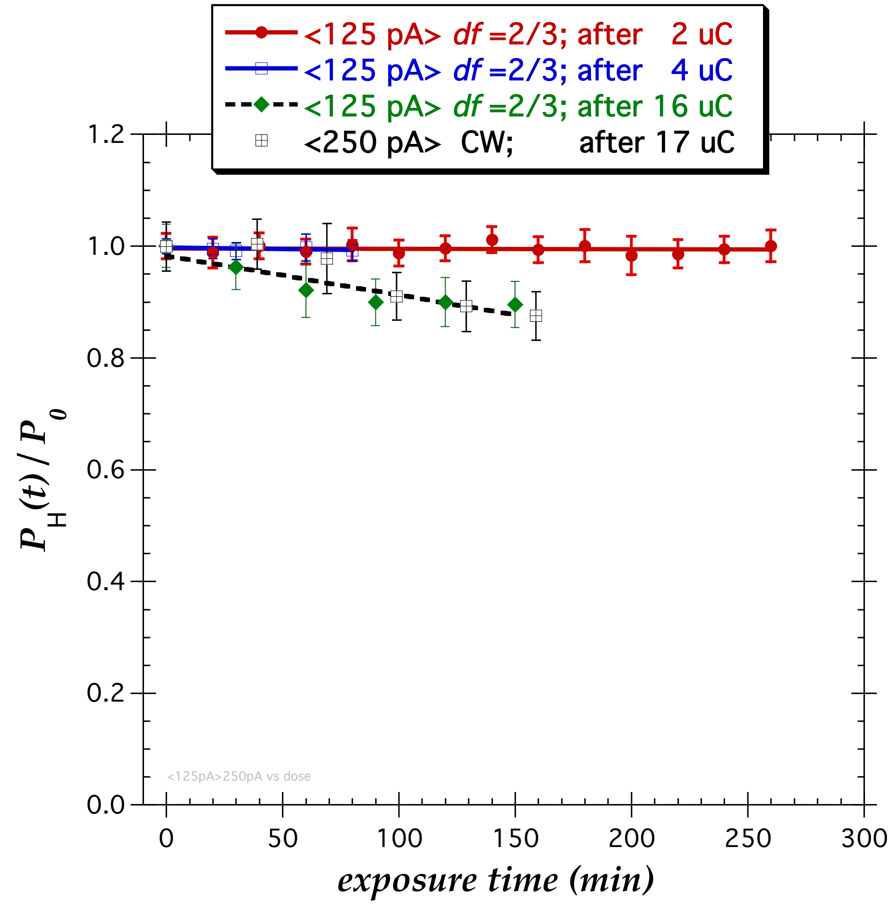
ref – intended goal:

at 100 mK & 1.1 T, (1 - Pe) = 5 e-7

Preliminary Summary of HDice tests at the UITF

- results with 1 tesla holding fields, starting with low currents:



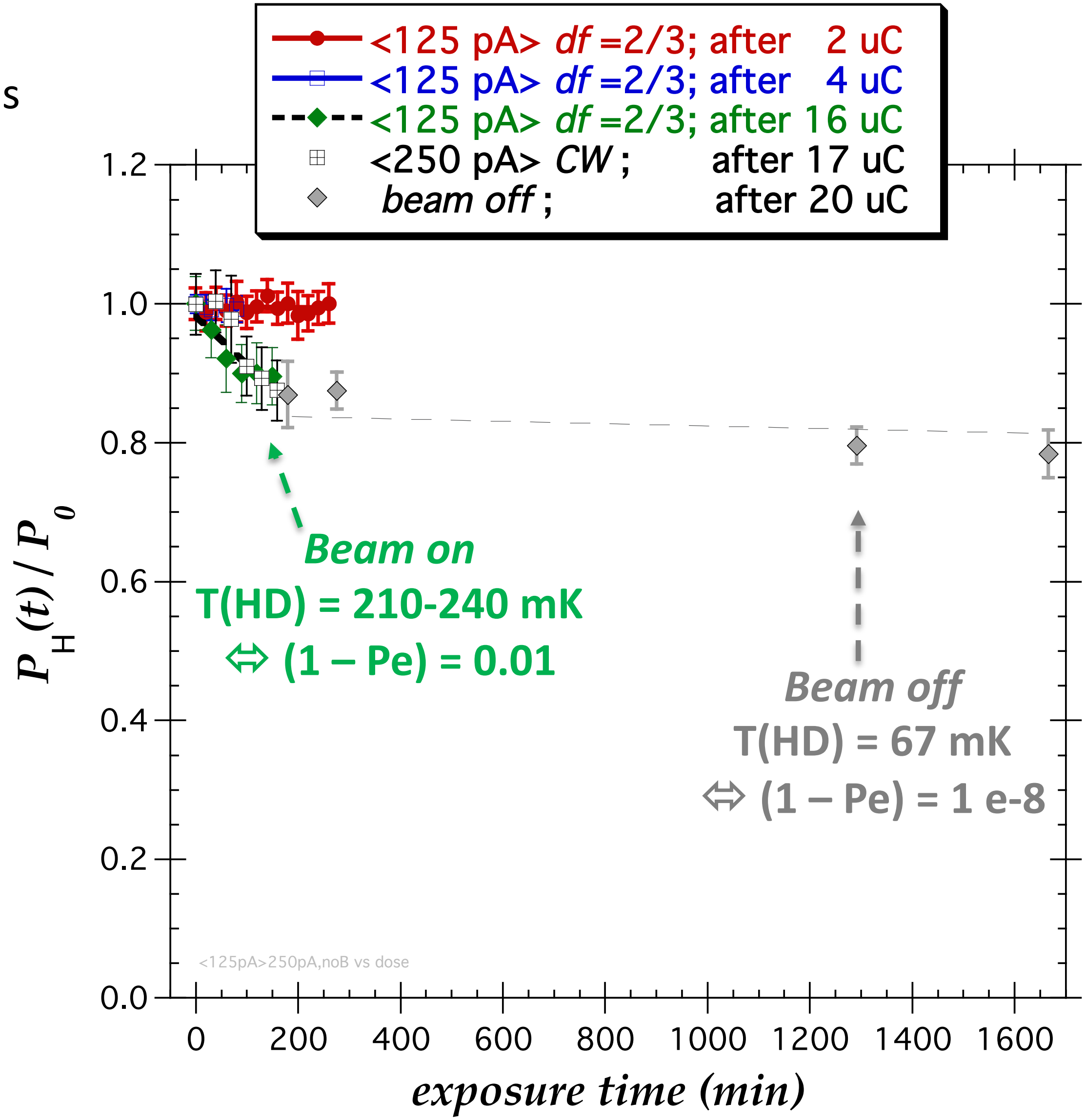


- **initially, polarization is constant with time;**
- **after ~ 10 uC, a decay slope develops**

Preliminary Summary of HDice tests at the UITF

- but, take away the beam, and the polarization decay stops
- atomic electron polarization is a very strong function of temperature

⇔ with beam-off, the HD cools and unpaired electrons become polarized again



HDice@UITF

Preliminary Summary of HDice tests at the UITF

Preliminary model:

- beam causes dissociation of some HD into H and D atoms (the chief "*radiation damage*")
- but beam heating is dissipated slower than expected, causing higher target temperatures

⬄ H & D atomic electrons are not as polarized as they should be

⬄ solve the heat problem, and the HD lifetime should dramatically increase

- **Nonetheless, the present state of HDice is not ready to support the required luminosity of the RG-H experiments without further R&D**

- Hall-B is now actively planning on alternatives (*eg.* NH_3) and evaluating the trade-offs

- In parallel, HDice will continue at least limited studies to investigate the origin of the reduced heat transmission in targets observed at the UITF

  – *eg*. measuring the conductivity of aluminum cooling wires at low temperatures (needed for a student thesis, in any case)