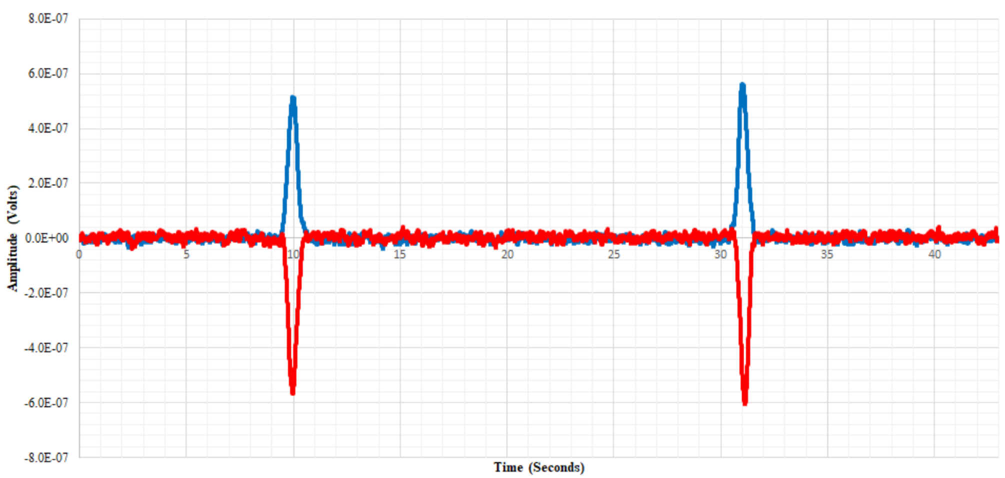
mid-Run 3 status summary

(*Dec 2/20*)

- Nov 18th - double transfer of frozen-spin *eHD60* target:
  - Oxford Dilution Fridge (DF) → Production Dewar (PD) for ref NMR
  - PD → In-Beam Cryostat (IBC) in cave-2
- Nov 21st – *Adiabatic Fast Passage* (**AFP**) to invert spin populations (X.Wei, T. O'Connell, K.Wei)

  → aligns H spin with polarized atomic electrons → eliminates *hyperfine mixing*



Run 3 UITF status update – Nov 29 – Dec 2/20

- Nov 23 - Run 3 starts with beam on frozen-spin target *eHD60*

- modes of NMR polarization sampling

High-field :

- irradiate the target at 1.1 T holding field
- periodically, ramp down to 0.9 T with beam on (requires adjusting the raster size)
- NMR at 0.9 T on the 3/2 λ resonance
- ramp back to 1.1 T with beam on (adjusting the raster amplitude)

Low-field :

- irradiate the target at 0.45 T holding field (larger raster amplitude)
- periodically, ramp up and down 200 g for NMR, passing through the 3/2 λ resonance
- NB: while raster fills the target, the 0.45 T is no longer sufficient to refocus all of the scattered electrons into the dump ⇔ 16% are lost in the magnet walls

Run 3 UITF status update – Nov 29 – Dec 2/20

- our *charge* from the ERR:

"demonstrate in a 7 day run that the HD polarization can survive for 50 days, within a factor of 2 (ie. 25 days) , at the RG-H luminosity of 1 nA on 5 cm of HD (or 2 nA on 2.5 cm)"

<u>Planned UITF Test conditions</u>:

- *3/4 nA* at UITF + applied heat

  → T_{IBC} = **160 mK** → T_{HD} = 175 mK

- *1.5 nA* at UITF + applied heat

  → T_{IBC} = **245 mK** → T_{HD} = 265 mK

<u>Corresponding RG-H conditions</u>:

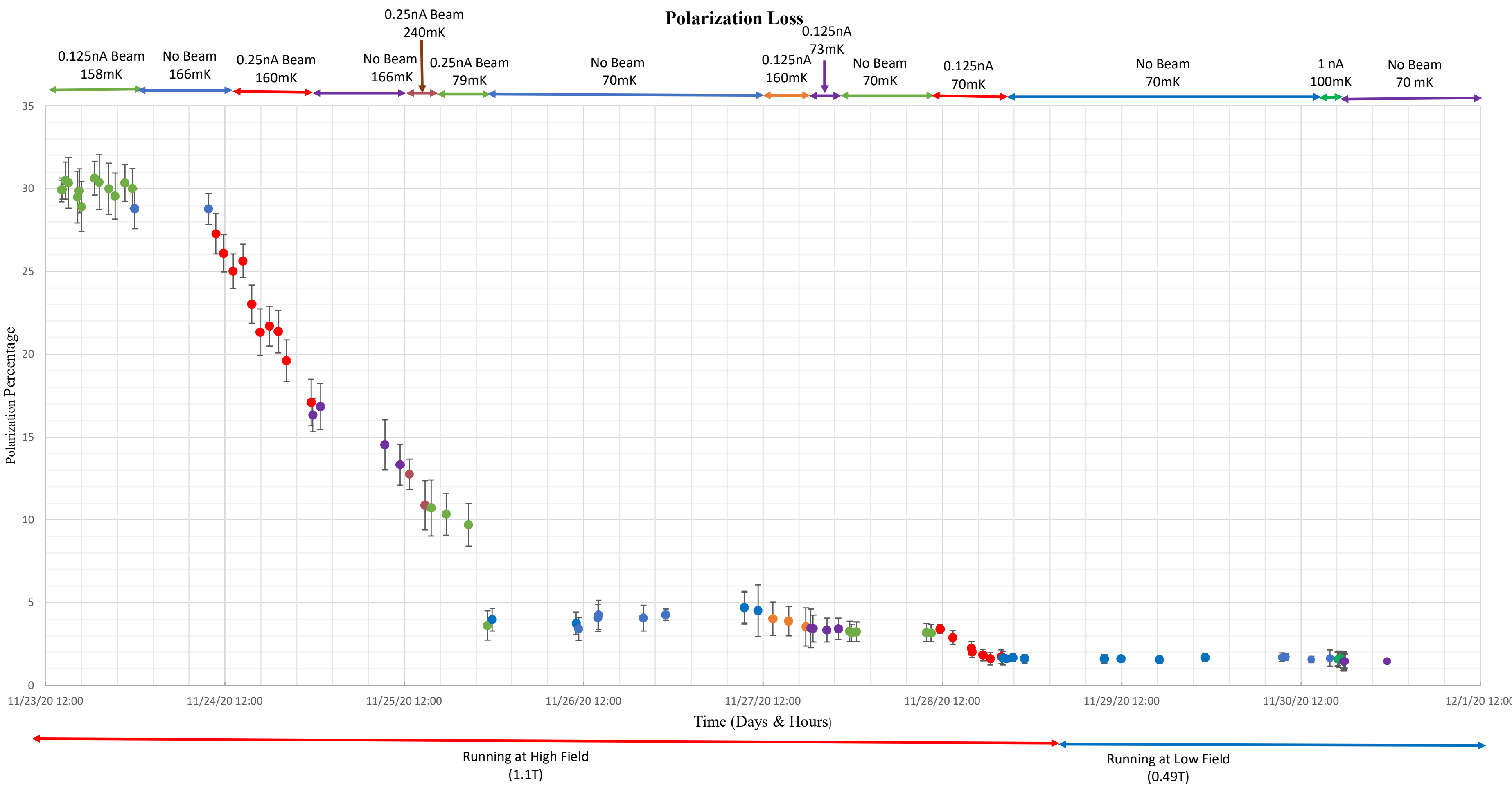
- 1 nA in Hall-B → T_{HD} = 175 mK

- 2 nA in Hall-B → T_{HD} = 265 mK

⇔ Started with low currents,
adding heat to the IBC to reach the test temperatures

Run 3 UITF status update – Nov 29 – Dec 2/20

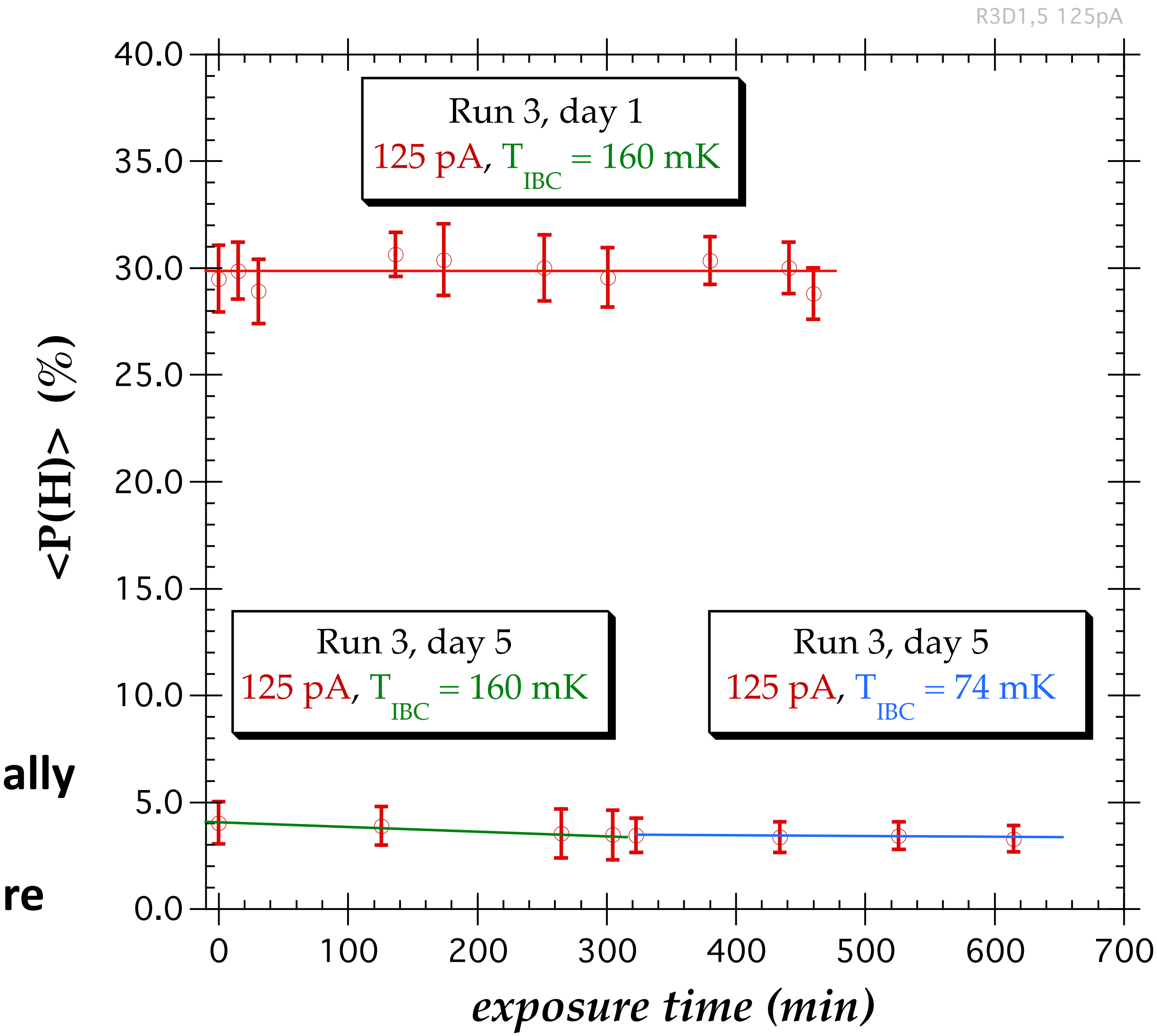
- Nov 23 - Run 3 starts with beam on frozen-spin target *eHD60*
- *overview* of all measurements with eHD60:



Run 3 UITF status update – Nov 29 – Dec 2/20

A closer look

- Nov 23 - start with 1/8 nA on frozen-spin target *eHD60*



- **at 1/8 nA, there is essentially no polarization loss at any relevant temperature**

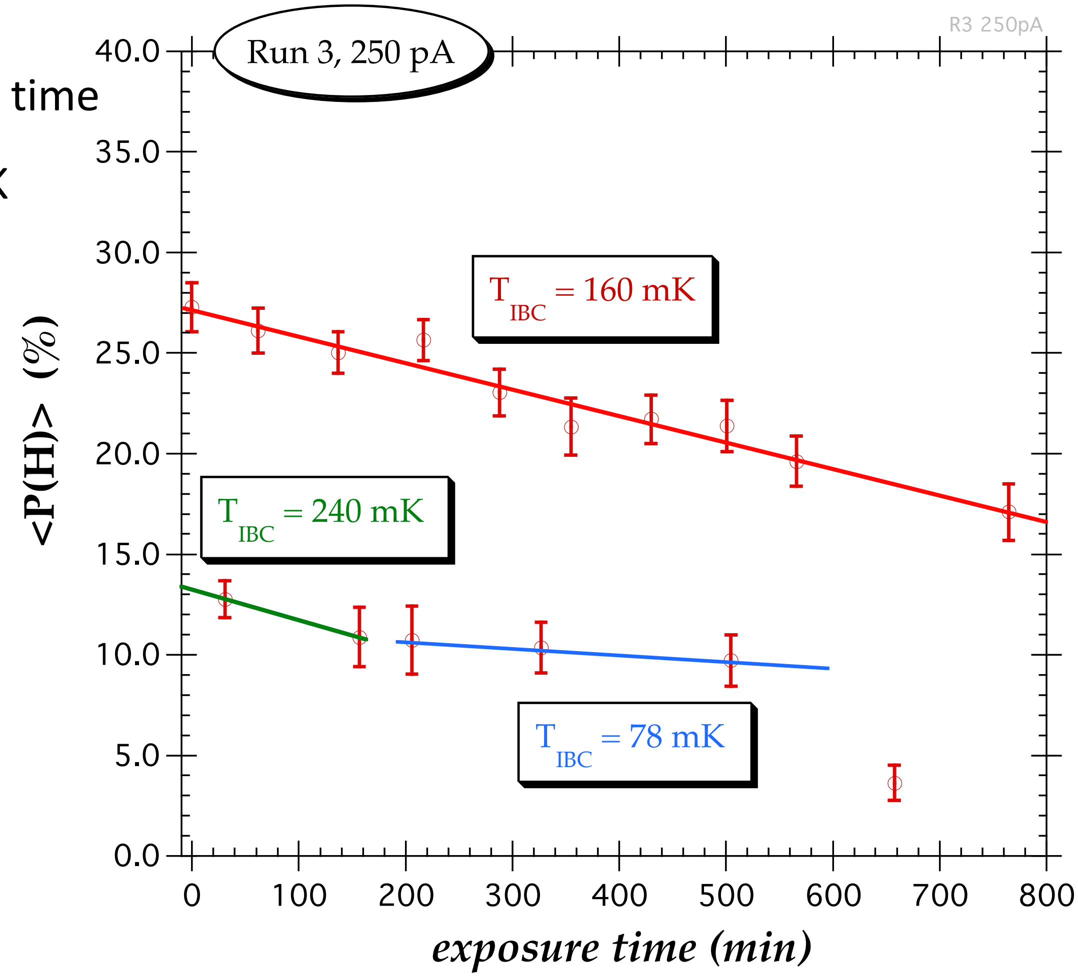
Run 3 UITF status update – Nov 29 – Dec 2/20

- increased current to 1/4 nA on frozen-spin *eHD60*

⇔ sharp decrease in polarization with time

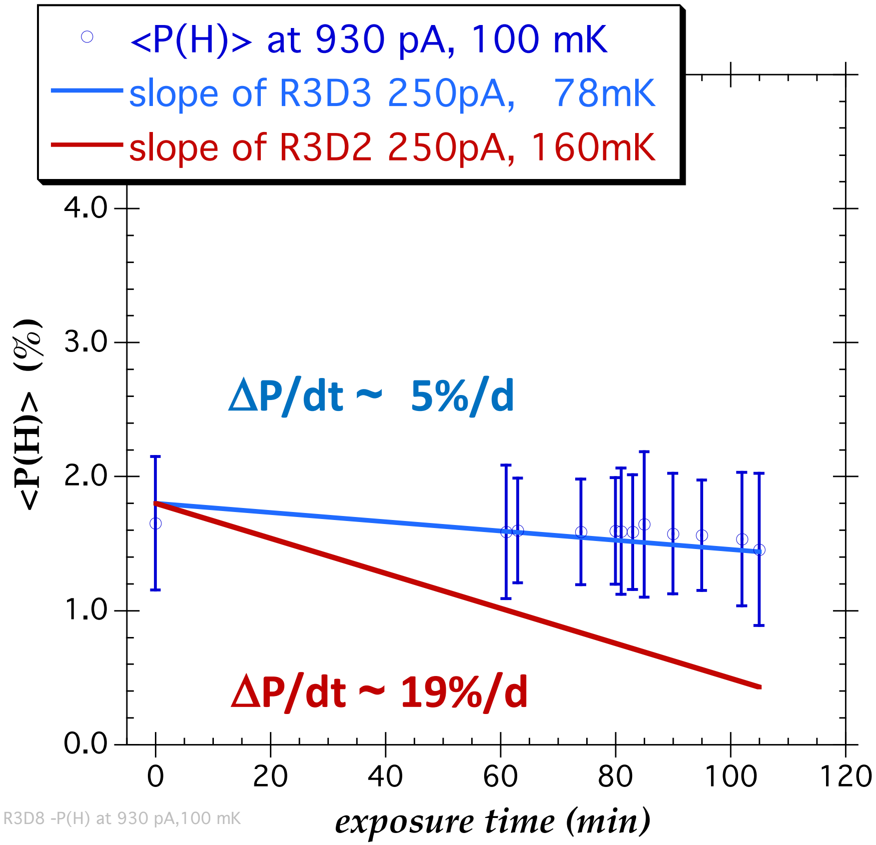
- same slope at 160 mK and 240 mK

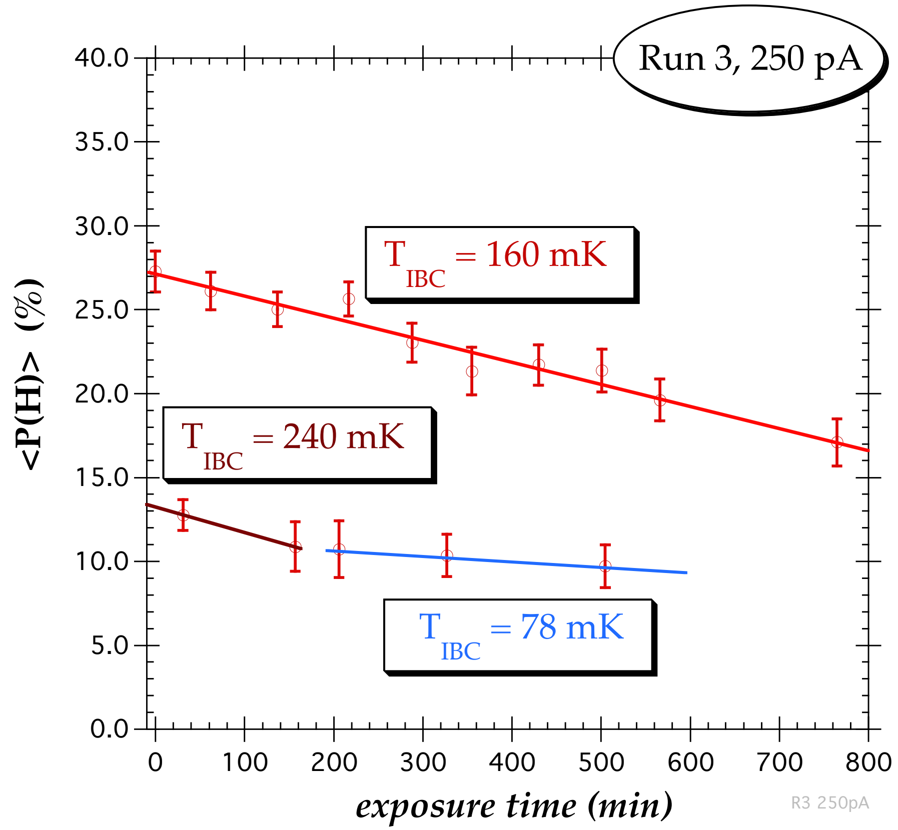
- significantly less, almost flat at 78 mK (base temp with beam)



Run 3 UITF status update – Nov 29 – Dec 2/20

- test at ~ **1 nA** (R3,D8: 11/30/20)





⬄ Polarization lifetime is considerably increased at lower temperatures, ~ independent of current

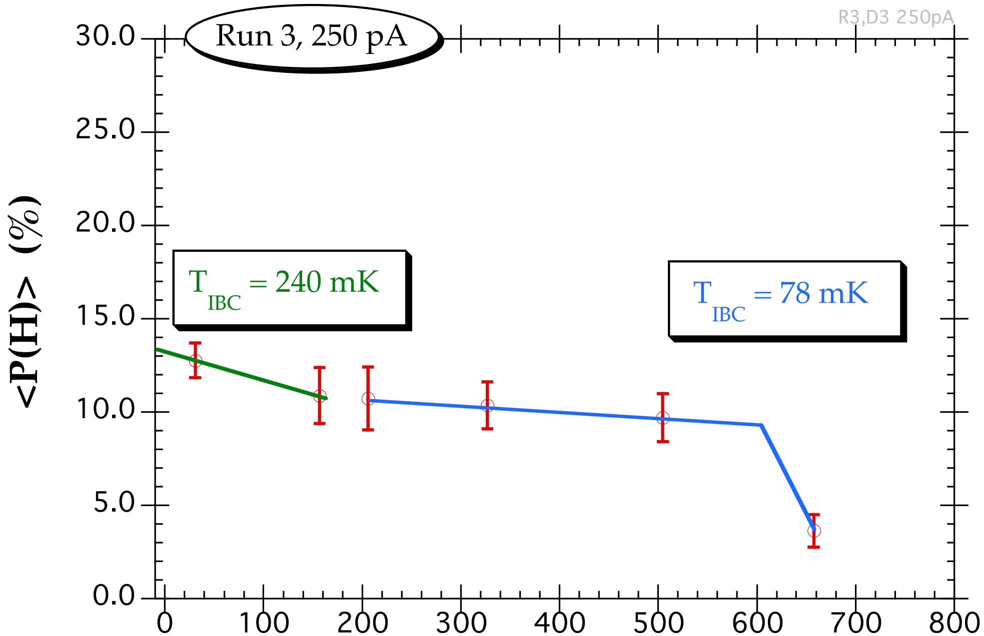
- 1/4 nA on frozen-spin *eHD60* at 78 mK

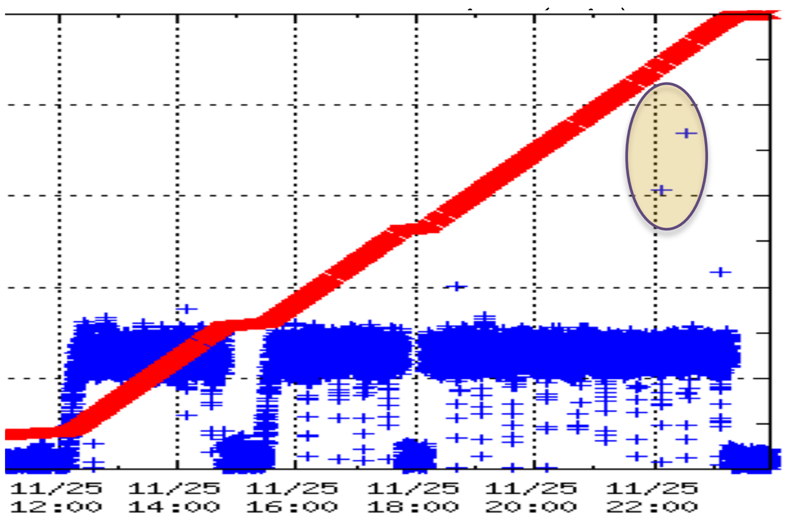
⇔ ~ flat for 7 hr, then sudden big drop

⇔ possible correlation with current spike,…BUT

- study on R3D8 (11/30/20) suggests this is just a coincidence

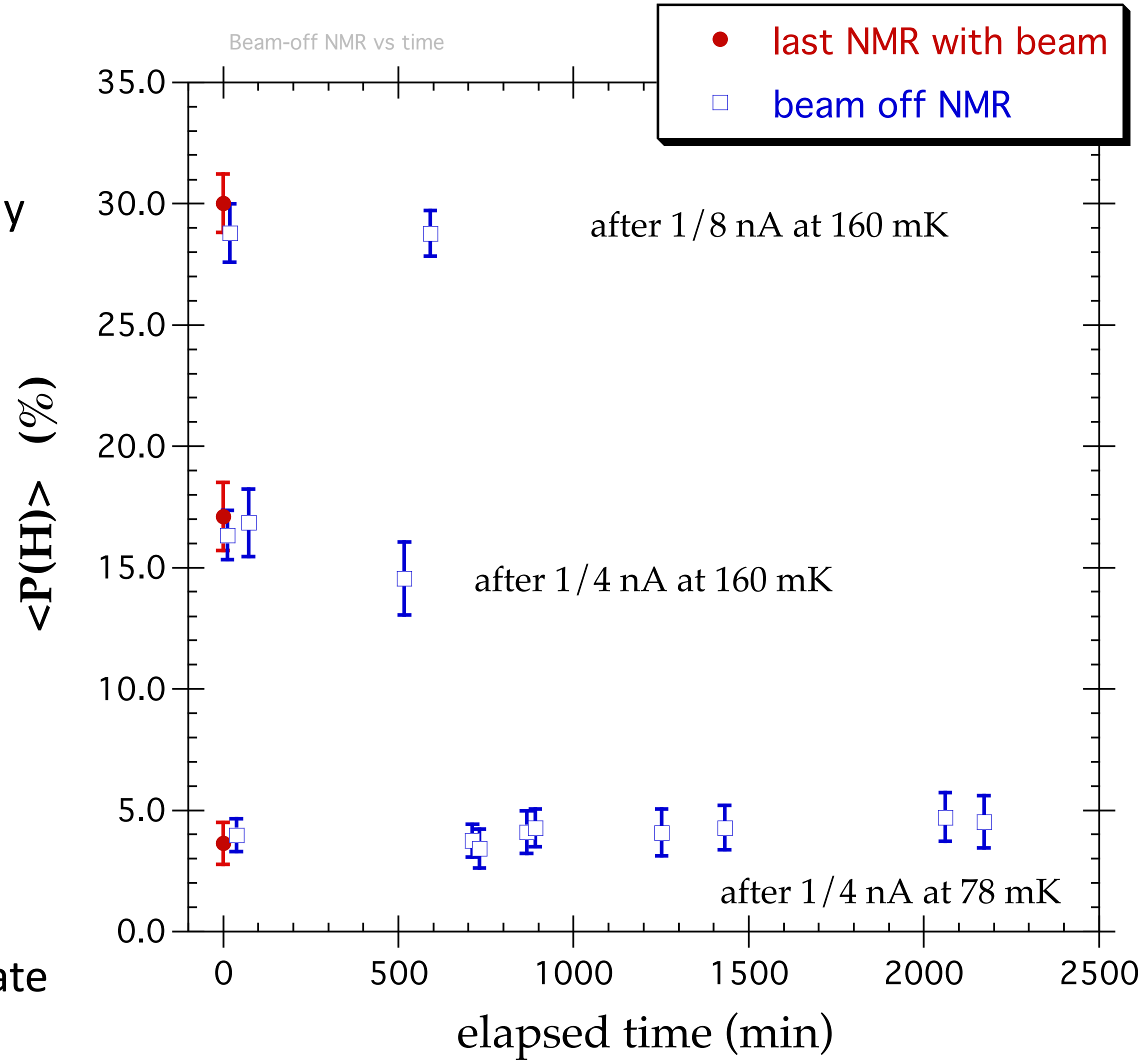
⇔ In any case,
data suggests a charge buildup in the HD,
that is suddenly released,
causing polarization loss





Run 3 UITF status update – Nov 29 – Dec 2/20

- Run 2 observed a suppressed NMR with a short T_1 target
  - either screened NMR, or real loss that grows back quickly after beam is stopped
- Run 3: with frozen-spin HD, after *AFP* spin flip,
  - no evidence for screening;
  - some evidence for slight drop in 8 hr overnight
  - after several days of irradiation, and significant polarization loss, the HD is still in a frozen-spin state



Run 3 UITF status update – Nov 29 – Dec 2/20

Next Steps – isolating depolarizing effects:

eg. Incomplete atomic electron polarization following ionization or dissociation

- spin flips of single, unpolarized electrons have Fourier components that can flip H

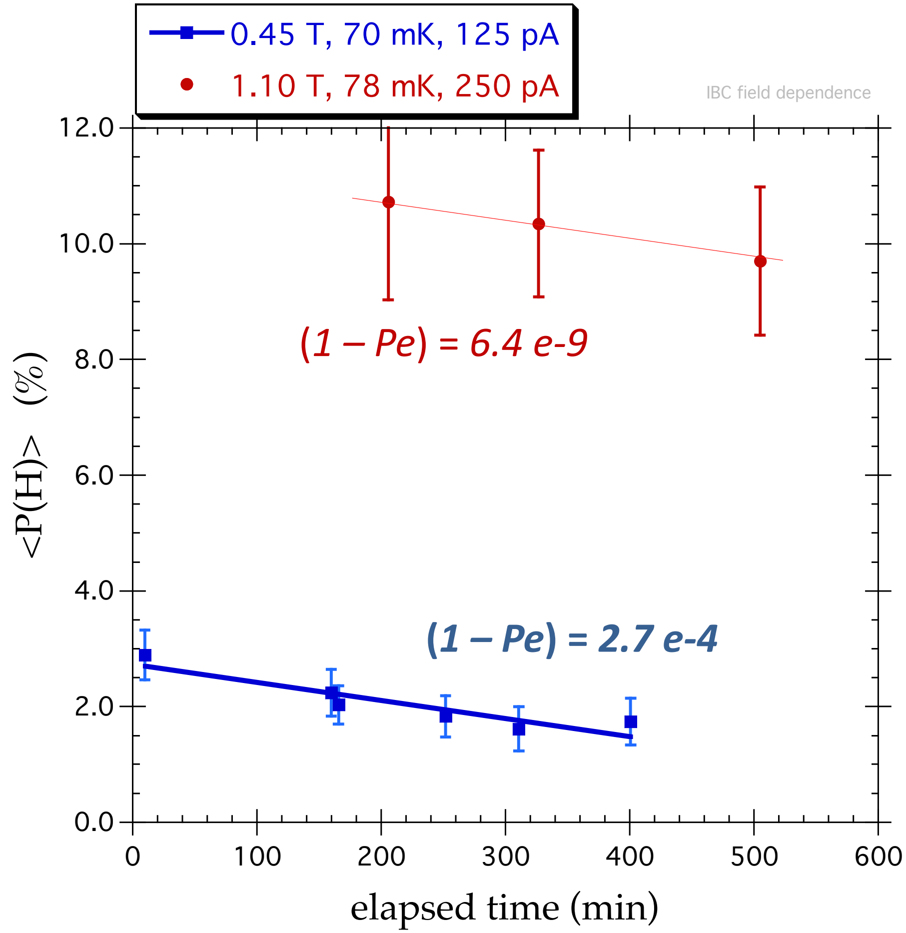
- most data taken at **1.10 T holding field**

  ⇔ (1 – Pe) = 6.4 e-7 % at 78 mK

- test at **0.45 T holding field**

  ⇔ (1 – Pe) = 6.7 e-2 % at 78 mk

  - could have the same slope (*prelim*), but need new data sets with smaller errors



- yet more dramatic will be a test at 0.45 T and 160 mK where

  ⇔ (1 – Pe) = 4.0 %

Run 3 UITF status update – Nov 29 – Dec 2/20

New (repeat) problem:

- during R3,D8 (Nov 30/20) run at high $^3He/^4He$ cooling flow, dilution capillary became partially blocked (again ☹). Either a small leak that was missed in the leak-check, or particulate matter (dust). There is no time to completely warm the IBC for a leak-check.
  ⬄ repeat Nov 11 procedure of warming & flushing the dilution unit.

Goals for the coming week(s):

- Nov 30 – end run with the first HD target ✓
- Dec 1 – extract target eHD60 from the IBC, and begin warmup of IBC dilution unit ✓
- Dec 6 – expect to reestablish cold temperatures with high cooling flow
- Dec 7 – expect to transfer eHD 66: DF → PD → IBC
- Dec 8 – resume Run 3
  – runs under various conditions to (try to) separate depolarization mechanisms

Run 3 UITF status update – Nov 29 – Dec 2/20

Possible directions with some potential:

- ***beam blanking* to let accumulated charge dissipate**:

  - *Sombrero2* raster cycles at 3 KHz – *ie.* every 1/3 ms
  - UITF gun allows blocking the laser for one interval within a 5 ms window, during which there are 15 raster cycles

⇔ block the laser 1/3 of the time, for 5 (1.66 mS) out of 15 raster cycles (5 ms)

  - *ie*. 10 raster cycles on, 5 off, 10 on, 5 off, …
  - preparing test for the restart of run 3
  - if this shows promise, we could vary the ON/OFF ratio
  - disadvantage ⇔ lower average duty factor

- **maintain the target at as low as possible a temperature with beam**
  - from the 1st frozen-spin target data, this clearly slows the loss rate
  - plan to test during Run 3, but the range of the study will be limited by the cooling-flow limitations of the IBC
  - present IBC, even with properly functioning high-flows, cannot meet this requirement with 10 GeV beams in Hall-B

Outlook:

- best scenario: suppose *beam blanking* provides a large gain
  - even then, limited cooling flows in the IBC would likely preclude the tests demanded by the ERR committee to lift the *C1* designation for the RG-H experiments

- only alternative is lower operating temperatures
  - range of Run 3 tests will be limited by cooling flow problems
  - even if this looks like an *in principle* solution, the dilution refrigerator in the present IBC does not have the capability of meeting such demands of a 10 GeV beam in Hall-B (and high-power dilution cooling is a *big project*)

⇔ HDice may not be a straight-forward solution for RG-H ☹