# PC Polarization

# Production Cell Performance

## (for targets used in $A_1^n$ experiment)

ifarm working dir:

/group/c-polhe3/Users/mychen/GitLab/N2_dilution_a1n/python_jupyter/Pol_Inter_mychen.ipynb

Polarization interpolate with run time

$$P_{TC}^{run_n} = P_{TC}^{init} + \left(P_{TC}^{end} - P_{TC}^{init}\right)\frac{T_{run_n}^{midpoint} - T_{nmr}^{init}}{T_{nmr}^{end} - T_{nmr}^{init}}$$

Notes:

- offline_database dir:

  /group/c-polhe3/Users/mychen/GitLab/N2_dilution_a1n/offline_A1n_mychen/database/

- Input files:

  /group/c-polhe3/Users/mychen/GitLab/N2_dilution_a1n/offline_A1n_mychen/database/NMR_List_wEPics_a1n.csv

  /group/c-polhe3/Users/mychen/GitLab/N2_dilution_a1n/offline_A1n_mychen/database/NMR_List_wFits_corr_a1n.json

  /group/c-polhe3/Users/mychen/GitLab/N2_dilution_a1n/offline_A1n_mychen/database/an1_runlist.csv

  /group/c-polhe3/Users/mychen/GitLab/N2_dilution_a1n/online_input/rundb_shms_corr.json

  /group/c-polhe3/Users/mychen/GitLab/N2_dilution_a1n/online_input/rundb_hms_corr.json

- EPR and NMR AFP loss spreadsheet: (based on results in Melanie's Thesis)

  https://docs.google.com/spreadsheets/d/e/2PACX-1vSEIGiKaXQAqT4-nDXOkL_3mtBq-Yyw27-grzy3izcezABwSIcR2VwmrFlUAHEQzreIWBc7A8NEXq8z/pub?output=xlsx

- Output files:

  /group/c-polhe3/Users/mychen/GitLab/N2_dilution_a1n/offline_a1n/(s)hms_pol.csv

- Check all NMR signals and remove failed NMR measurements:

  /group/c-polhe3/Users/mychen/GitLab/N2_dilution_a1n/offline_a1n/hms_pol_bad_Mingyu.xlsx

# Production Cell Performance

(for targets used in $A_1^n$ experiment)

## Polarization Equations:

Assumption: although AFP losses are different in different chamber, the average AFP loss will equalized.

$$P_{TC}^{init} = \frac{S_{PC}^{upsweep}\beta^2 + S_{PC}^{downsweep}\beta}{2} C_{PC}^{EPR} C_{TCPC}$$

$$P_{TC}^{end} = \frac{S_{PC}^{upsweep} + \left(S_{PC}^{downsweep}/\beta\right)}{2} C_{PC}^{EPR} C_{TCPC}$$

- β is whole cell polarization loss:

$$\beta = 1 - \frac{\alpha_{PC} n_{PC} V_{PC} + \alpha_{TC} n_{TC} V_{TC}}{n_{PC} V_{PC} + n_{TC} V_{TC}}$$

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- $C_{PC}^{EPR}$ is EPR calibration constant.
- $C_{TCPC}$ is polarization ratio between TC and PC.

## Interpolate Equations:

Note: polarization interpolate with run time

$$P_{TC}^{run_n} = P_{TC}^{init} + \left(P_{TC}^{end} - P_{TC}^{init}\right) \frac{T_{run_n}^{midpoint} - T_{nmr}^{init}}{T_{nmr}^{end} - T_{nmr}^{init}}$$

# Results in Melanie's Thesis

## (for targets used in $A_1^n$ experiment)

## NMR/EPR calibration constants:

Table 4.6: NMR/EPR calibration constants for each cell for each field configuration.

| Cell | Field Configuration (°) | CC (%/mV) |
|---|---|---|
| Dutch | 90 | 6.03 ± 0.13 |
| | 180 | 9.62 ± 0.68 |
| Big Brother | 90 | 5.56 ± 0.42 |
| | 180 | 8.38 ± 0.14 |

## NMR/EPR calibration systemic uncertainty:

Table 5.31: Sources of error that affect the $^3$He target polarization.

| $^3$He Target Quantity | % Error (Type) |
|---|---|
| $^{39}$K - $^3$He $\kappa_0$ | 0.8 (Relative) |
| $^3$He PC and TC Densities | 2.0 (Relative) |
| $N_2$ Dilution | 0.3 (Relative) |
| PC Temperature | 5.0 (Absolute) |
| TC Temperature | 2.0 (Absolute) |
| NMR/EPR Calibration Constants (Statistical) | 2.0 / 7.0 (Relative) |

## NMR AFP loss:

Table 4.5: AFP losses per NMR-AFP sweep, in percentage, for the pumping chamber (PC) and target chamber (TC) of each cell, for each field configuration. There is a relative 20% uncertainty for each.

| Cell | Field Configuration (°) | AFP Loss in PC (%) | AFP Loss in TC (%) |
|---|---|---|---|
| Dutch | 90 | 0.90 | 0.90 |
| | 180 | 2.00 | 0.90 |
| Big Brother | 90 | 0.90 | 0.90 |
| | 180 | 1.70 | 0.40 |

- A systematic uncertainty of $\Delta P_b / P_b \leq 2.2\%$ and $\Delta P_t / P_t \leq 4\%$ was applied to each x bin.

$C_{TCPC}=0.996$

$\Delta C_{TCPC}=0.002$

## PC/TC Temperature and Density:

Table 4.2: $^3$He number densities of the pumping and target chambers after correcting for the temperature deviating from room temperature, at which the fill density was measured, and their estimated internal temperatures. The PC's was found from the temperature test, and the target chamber's from the average of the 5 RTD readings [4].

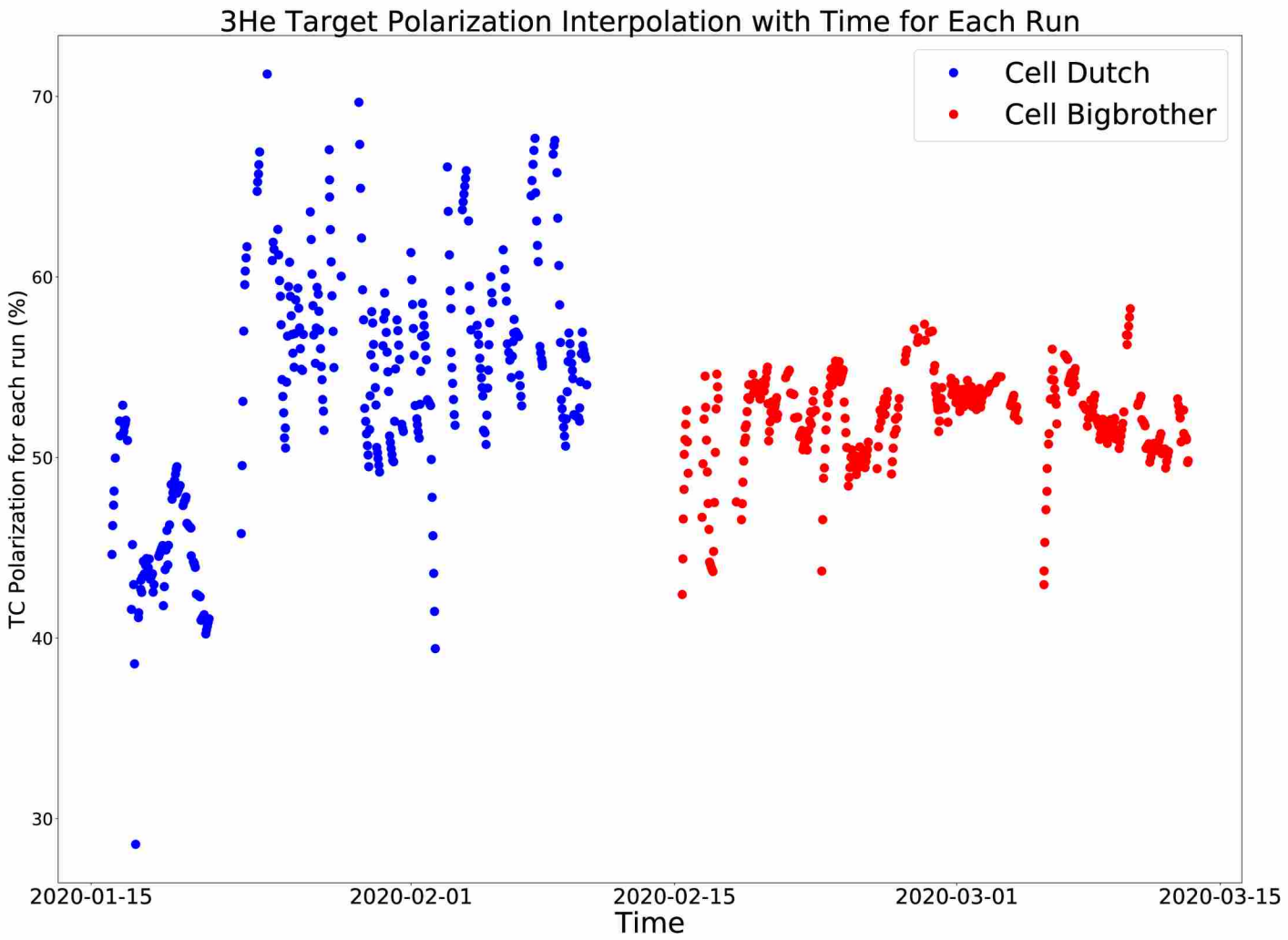
| Cell | $T_{PC}$ (°C) | $T_{TC}$ (°C) | $n_{PC}$ (amg) | $n_{TC}$ (amg) |
|---|---|---|---|---|
| Dutch | 245 ± 5 | 37 ± 1 | 6.563 ± 0.131 | 10.936 ± 0.219 |
| Big Brother | 245 ± 5 | 31 ± 1 | 6.011 ± 0.120 | 10.241 ± 0.205 |

## PC/TC Volume:

| Cell | $^3$He $\rho_{fill}$ (amg) | $V_{PC}$ (cc) | $V_{TC}$ (cc) | $V_{TT}$ (cc) | Entrance Window Thickness ($\mu$m) | Exit Window Thickness ($\mu$m) |
|---|---|---|---|---|---|---|
| Dutch | 7.759 ± 0.125 | 180.68 | 68.02 | 19.78 | 134.142 ± 0.063 | 143.475 ± 0.072 |
| Big Brother | 7.091 ± 0.119 | 184.65 | 63.32 | 20.49 | 138.196 ± 0.059 | 100.874 ± 0.070 |

# Production Cell Performance

## (for targets used in $A_1^n$ experiment)




- Use EPR/NMR calibration constants in Melanie's thesis

# Results in Melanie's Talk March 2021

(for targets used in $A_1^n$ experiment)

## EPR/NMR Calibrations throughout $A_1^n$ Production Running

**Preliminary**

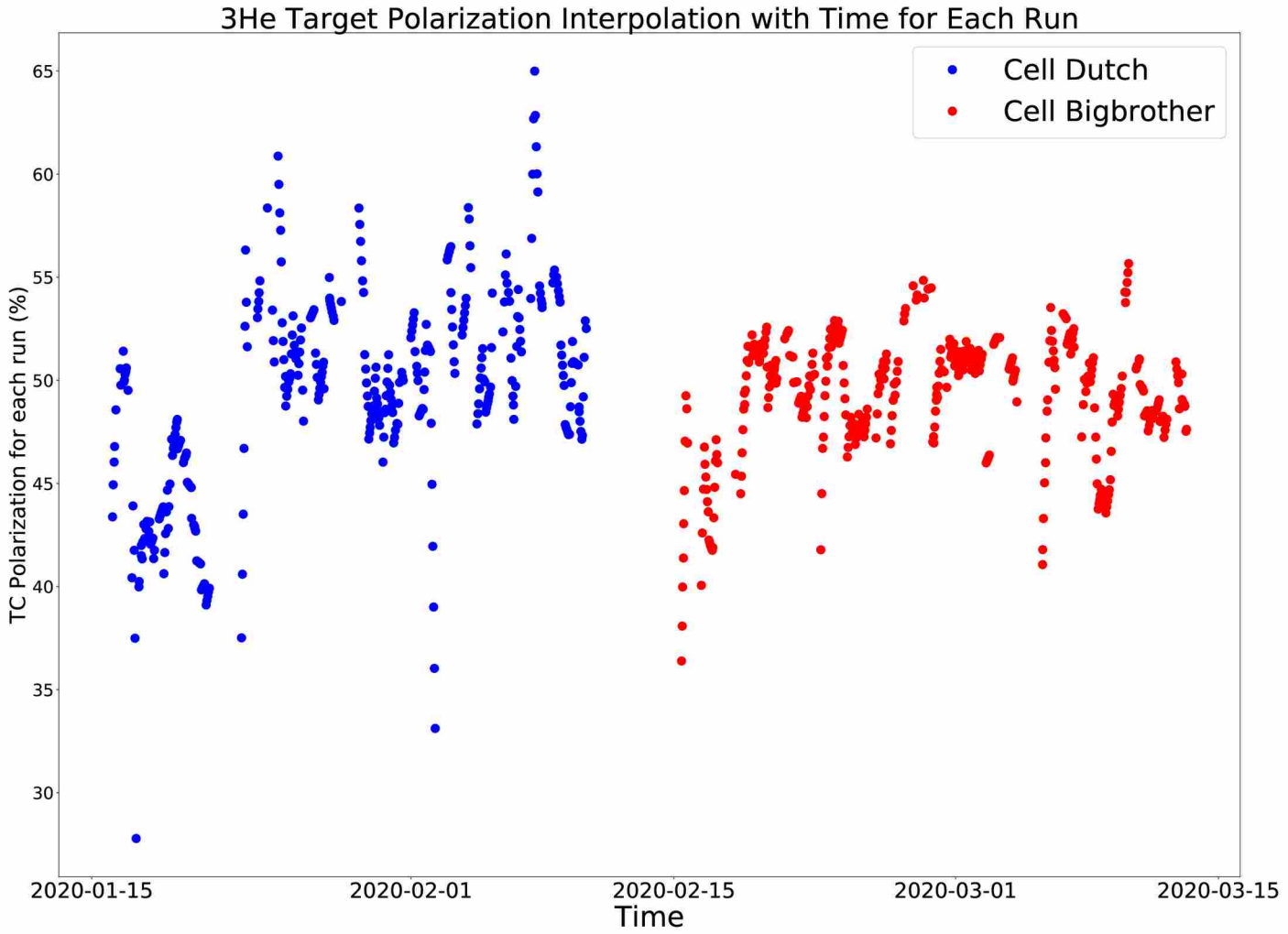
| Cell | Date | Field Direction (°) | AFP Loss (%) | Offline CC (%/mV) | Meets Precision Goal? ( < 3%) |
|---|---|---|---|---|---|
| Dutch | 1/11/20 | 180 | 1.26 | $9.35 \pm 0.68$ | x |
| Dutch | 2/10/20 | 90 | 1.20 | $4.94 \pm 0.13$ | ✓ |
| Big Brother | 2/12/20 | 180 | 1.19 | $8.11 \pm 1.08$ | x |
| Big Brother | 2/13/20 | 90 | 1.146 | $4.77 \pm 0.42$ | x |
| Big Brother | 3/03/20 | 180 | 1.19 | $8.01 \pm 0.14$ | ✓ |
| Big Brother | 3/13/20 | 180 | 1.19 | $7.78 \pm 0.14$ | ✓ |
| *Austin* | *3/22/20* | *180* | *1.20* | *$7.35 \pm 0.13$* | ✓ |

What's been done so far: **significant** cross-checking with online results and statistical error estimation for every $A_1^n$ & $d_2^n$ EPR/NMR calibration

| | | | EPR | AFP Loss | Temperature Correction | Spin up time constant | PC Density | TC Density | PC Volume | TC Volume |
|---|---|---|---|---|---|---|---|---|---|---|
| Cell | Kin | Field | | | | | | | | |
| Dutch | 30 | 90 | 4.94,0.13 | 0.9,0.9 | 200.2,7 | 6.0 | 6.563,0.131 | 10.936,0.219 | 180.68,0.01 | 68.02,0.01 |
| | | 180 | 9.35,0.68 | 2.0,0.9 | 241.2,2.1 | NaN | 6.563,0.131 | 10.936,0.219 | 180.68,0.01 | 68.02,0.01 |
| BigBrother | 30 | 90 | 4.77,0.42 | 0.9,0.9 | NaN | 6.0 | 6.011,0.120 | 10.241,0.205 | 184.65,0.01 | 63.32,0.01 |
| | | 180 | 8.01,0.14 | 1.7,0.4 | 244.9,2.2 | NaN | 6.011,0.120 | 10.241,0.205 | 184.65,0.01 | 63.32,0.01 |

# Production Cell Performance

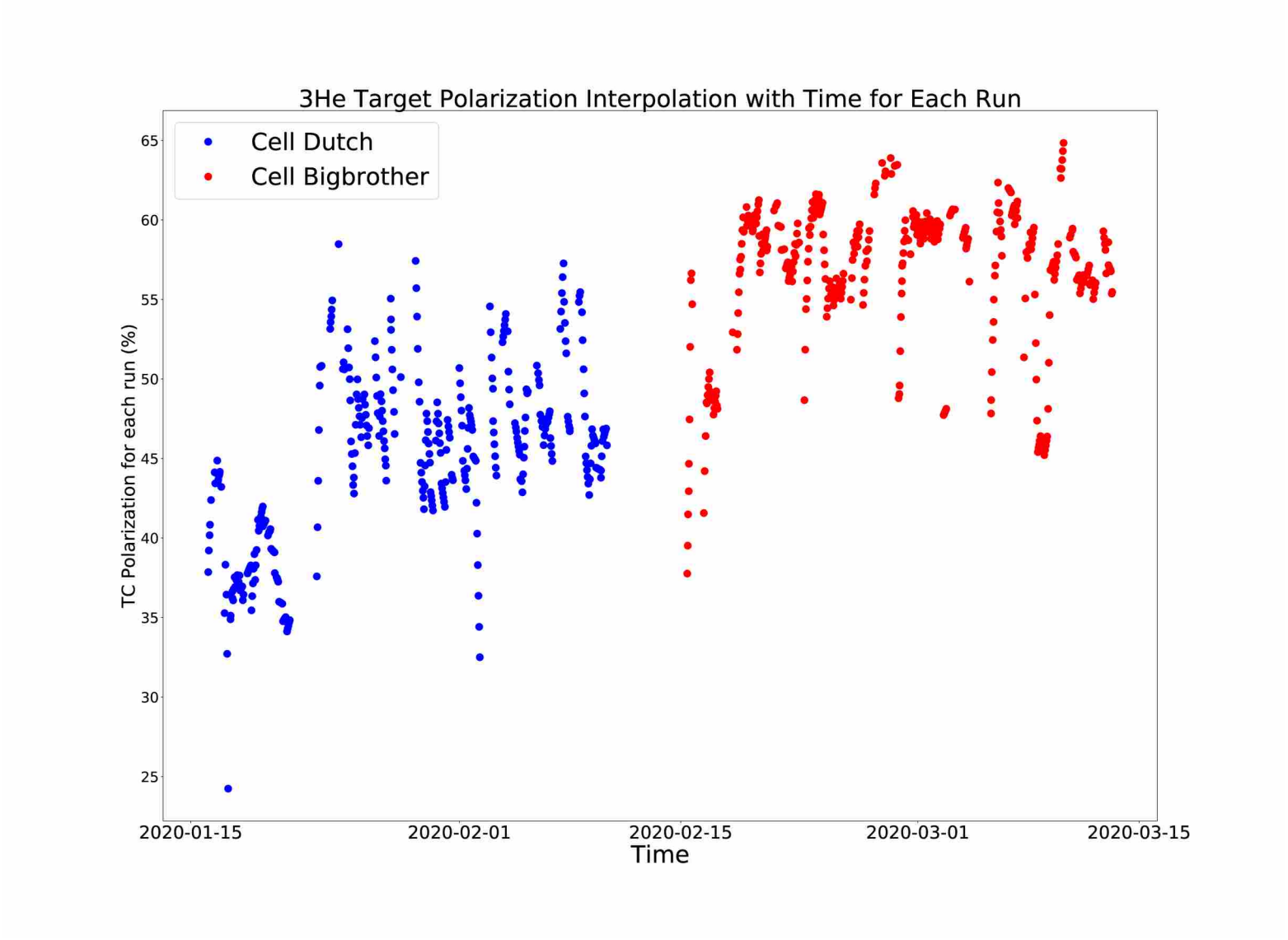
(for targets used in $A_1^n$ experiment)




- Use EPR/NMR calibration constants in Melanie's talk March 2021

# Production Cell Performance

## (for targets used in $A_1^n$ experiment)



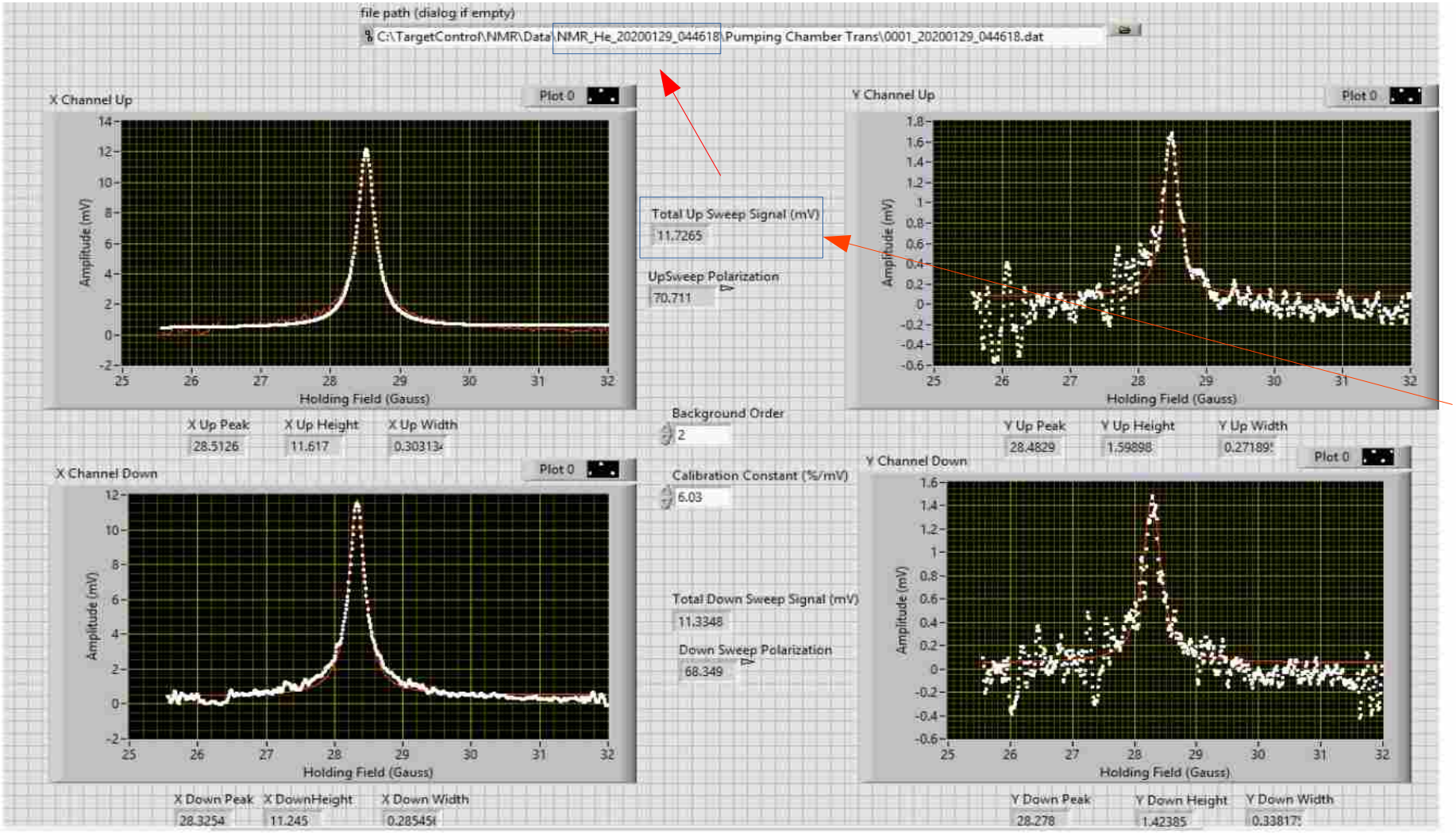

- Use EPR/NMR calibration constants from Junhao's Spread sheet:

| | | | | | |
|---|---|---|---|---|---|
| BigBrother | 30 | 90 | 4.95 0.9,0.9 | | 6 |
| | | 180 | 9.33 1.7,0.4 | 244.9,2.2 | |
| Dutch | 30 | 90 | 4.95 0.9,0.9 | 200.2,7 | 6 |
| | | 180 | 8.16 2.0,0.9 | 241.2,2.1 | |

# Backup Slides

# Production Cell Performance

## (for targets used in $A_1^n$ experiment)




For NMR signal_upsweep=11.7265 mV

(online analysis)

Some correction are done fitting the NMR signal by Junhao

- Cell Dutch Tran NMR PC signal on Hclog for online analysis

```
In [70]: hms_pol_db.loc[2864:2866,('start_pc_NMR','stop_pc_NMR','start_fdr','end_fdr')]
Out[70]:
```

| | start_pc_NMR | stop_pc_NMR | start_fdr | end_fdr |
|---|---|---|---|---|
| 2864 | [[10.70061071901526, 0.04785115595836136], [11... | [[1.675245754749509, 0.01796047514459843], [1... | NMR_He_20200128_063150 | NMR_He_20200128_091204 |
| 2865 | [[12.31629075382952, 0.04136607031563337], [12... | [[5.718352670771553, 0.007078005101874827], [5... | NMR_He_20200129_044618 | NMR_He_20200129_125015 |
| 2866 | [[12.31629075382952, 0.04136607031563337], [12... | [[5.718352670771553, 0.007078005101874827], [5... | NMR_He_20200129_044618 | NMR_He_20200129_125015 |

NMR_List_wFits_corr_a1n.json

- For NMR signal with folder NMR_He_20200129_044618 NMR signal upsweep=12.3162 mV (offline data base) (5% higher)

- Cell Dutch Tran NMR PC signal amplitude on ifarm for Junhao Offline database

# Production Cell Performance

(for targets used in $A_1^n$ experiment)

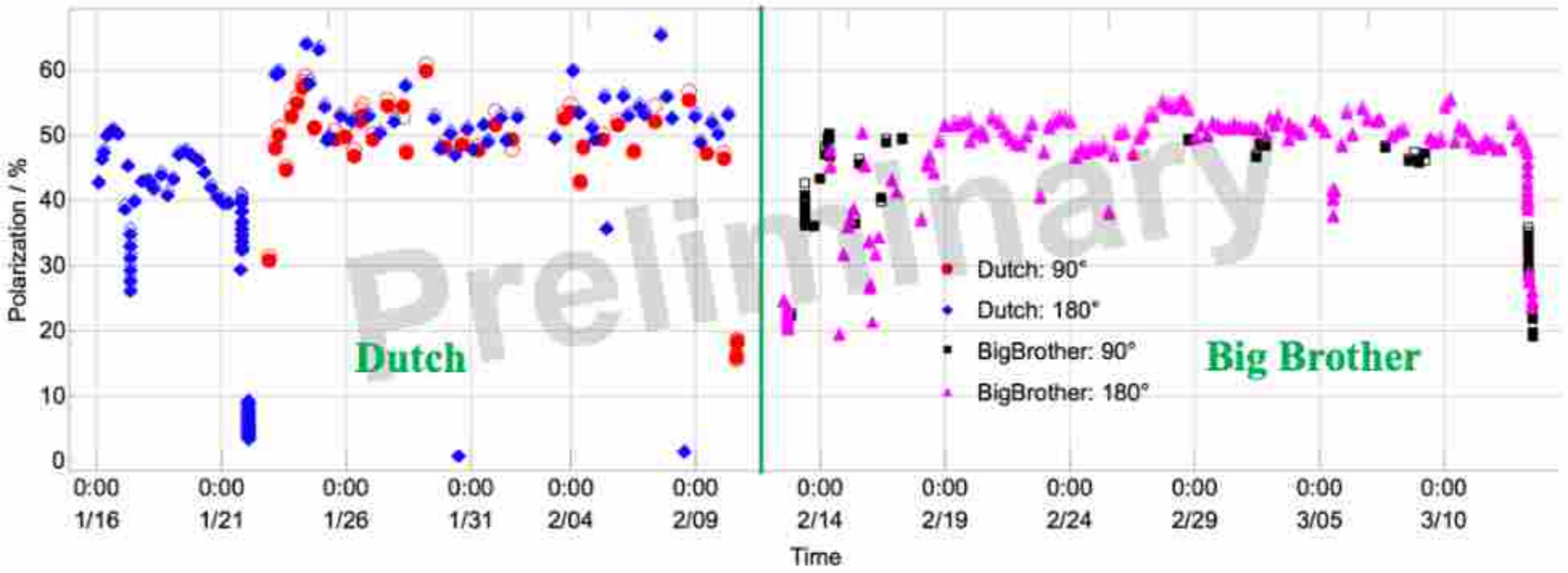



Figure 4.21: $^3$He target polarization (within the pumping chamber) throughout E12-06-110 production data-taking. Credit to Junhao Chen.

Values from Junhao's Spread sheet:

| | | | | | |
|---|---|---|---|---|---|
| BigBrother | 30 | 90 | 4.95 0.9,0.9 | | 6 |
| | | 180 | 9.33 1.7,0.4 | 244.9,2.2 | |
| Dutch | 30 | 90 | 4.95 0.9,0.9 | 200.2,7 | 6 |
| | | 180 | 8.16 2.0,0.9 | 241.2,2.1 | |

- Preliminary results put in the Melanie's thesis.