Automated conditioning algorithm

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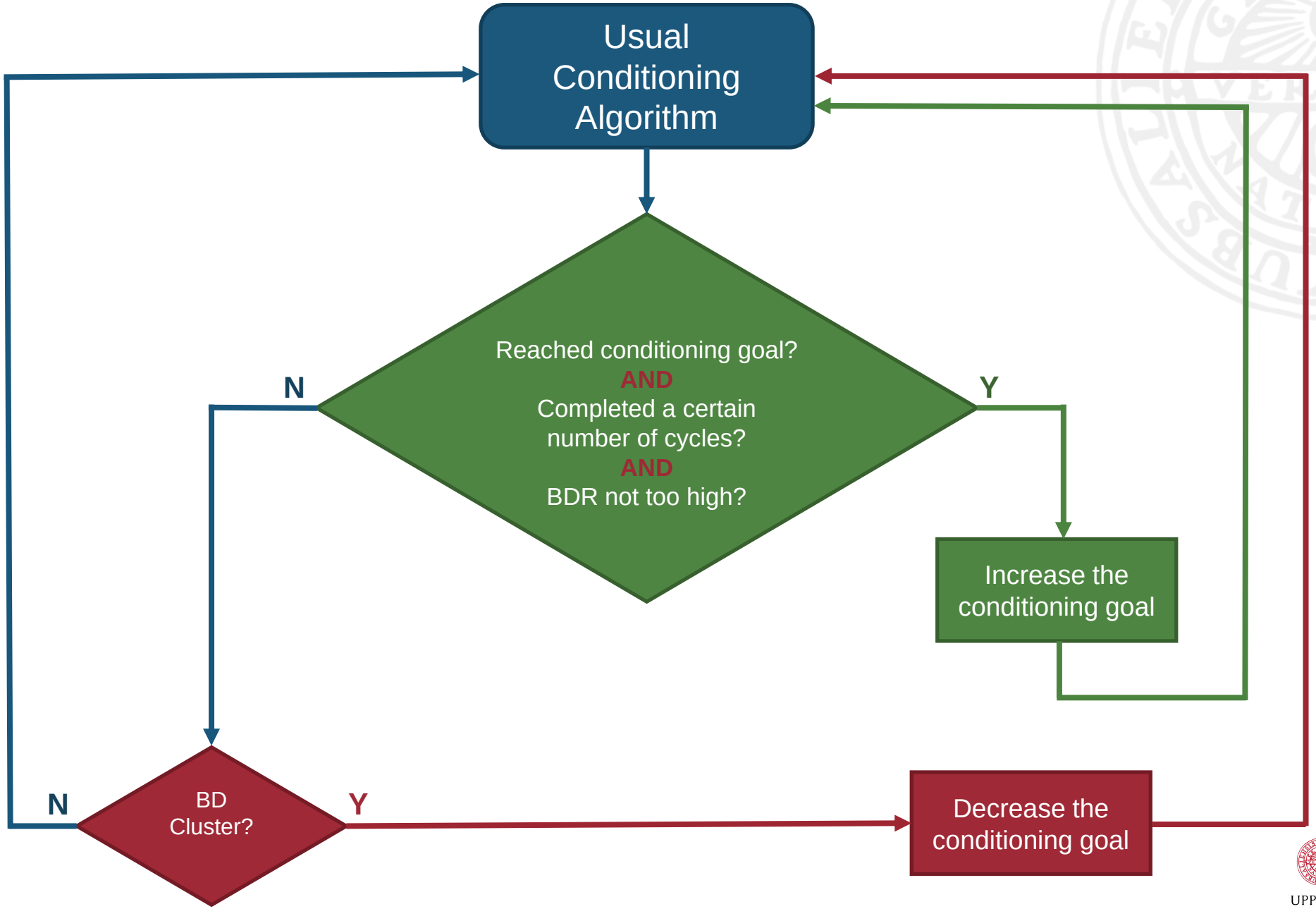
Basic idea



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Data from 056 RFQ Nb, conditioned at CERN

Reached conditioning goal?

- Set voltage == Conditioning goal

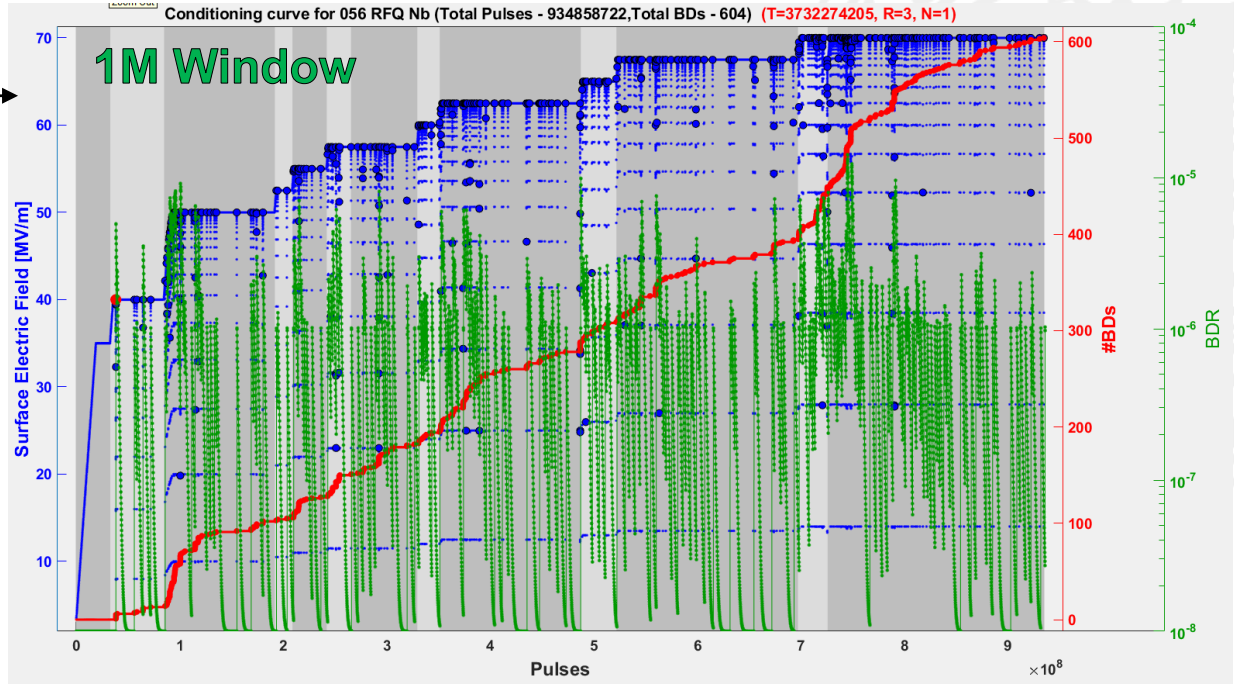
Completed certain number of cycles?

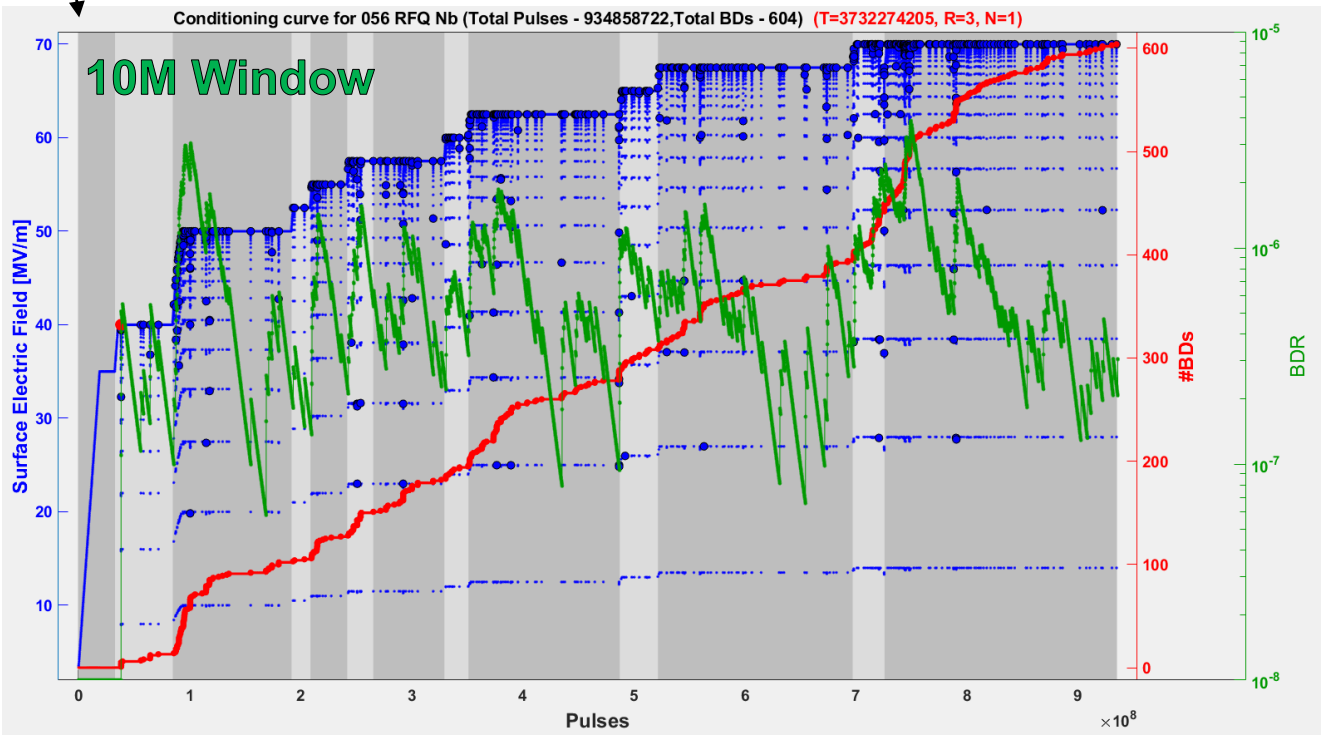
- Count the cycles done at the conditioning goal
- Do not include cycles with BD
- Do not include cycles done after reaching CG, but done at lower voltages, due to the usual feedback algorithm
- Do not include small ramping cycles
- Not necessarily consecutive cycles! The counter resets only if CG is changed
- Minimum # of cycles: 100-200

BDR not too high?

- BDR calculated with a window of 1M has large fluctuations over short timescales
- Calculate an additional BDR with a window of 10M pulses
- Larger window → capture the behavior over a larger timescale
- BDR threshold: 1E-6 (very relaxed condition)
- We can also start with a lower threshold and increase the threshold manually as the voltage increases
- The increase in conditioning goal is mostly controlled by the minimum number of cycles and not by the BDR

Usual increase in CG: 2.5 – 5 MV/m





BD Cluster?

- Cluster → Short timescales
- Cluster conditions:
  - Usual BDR (calculated with 1M pulses) > 2E-5

    AND
  - A certain number of cycles have been done after the last decrease in CG

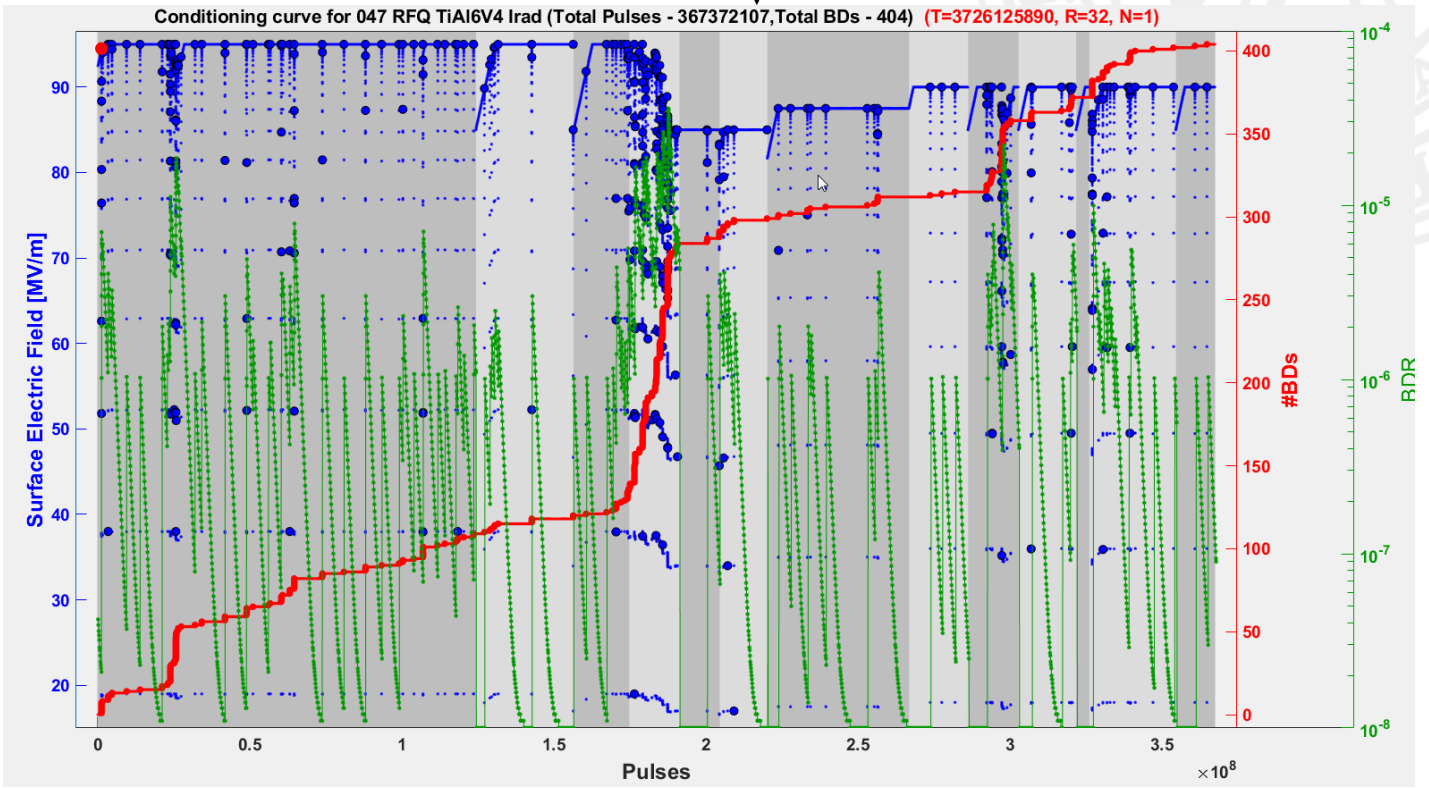
- These cycles DO include cycles with BD
- If we do not impose the last condition, we risk lowering the voltage twice

- For example:
  - Cluster, BDR = 2E-5
  - Decrease conditioning goal by 5MV/m
  - Secondary BD
  - Decrease the conditioning goal a second time

- Therefore, we need to wait a few cycles (10 - 20) to see if BDR goes down before decreasing again

- **Decrease by 5 – 10 MV/m**

Data from 047 RFQ TiAl6V6 Irad, conditioned at CERN



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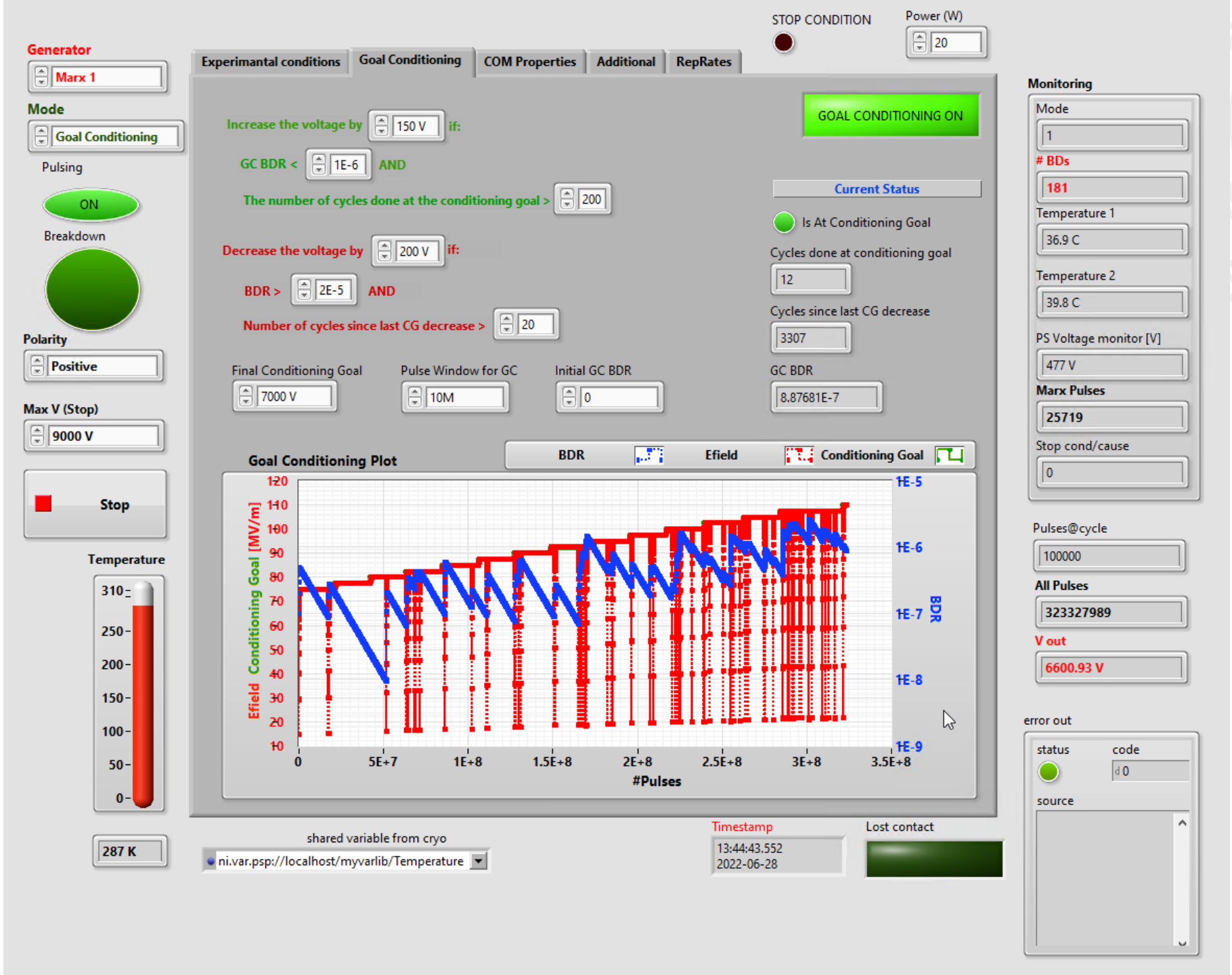

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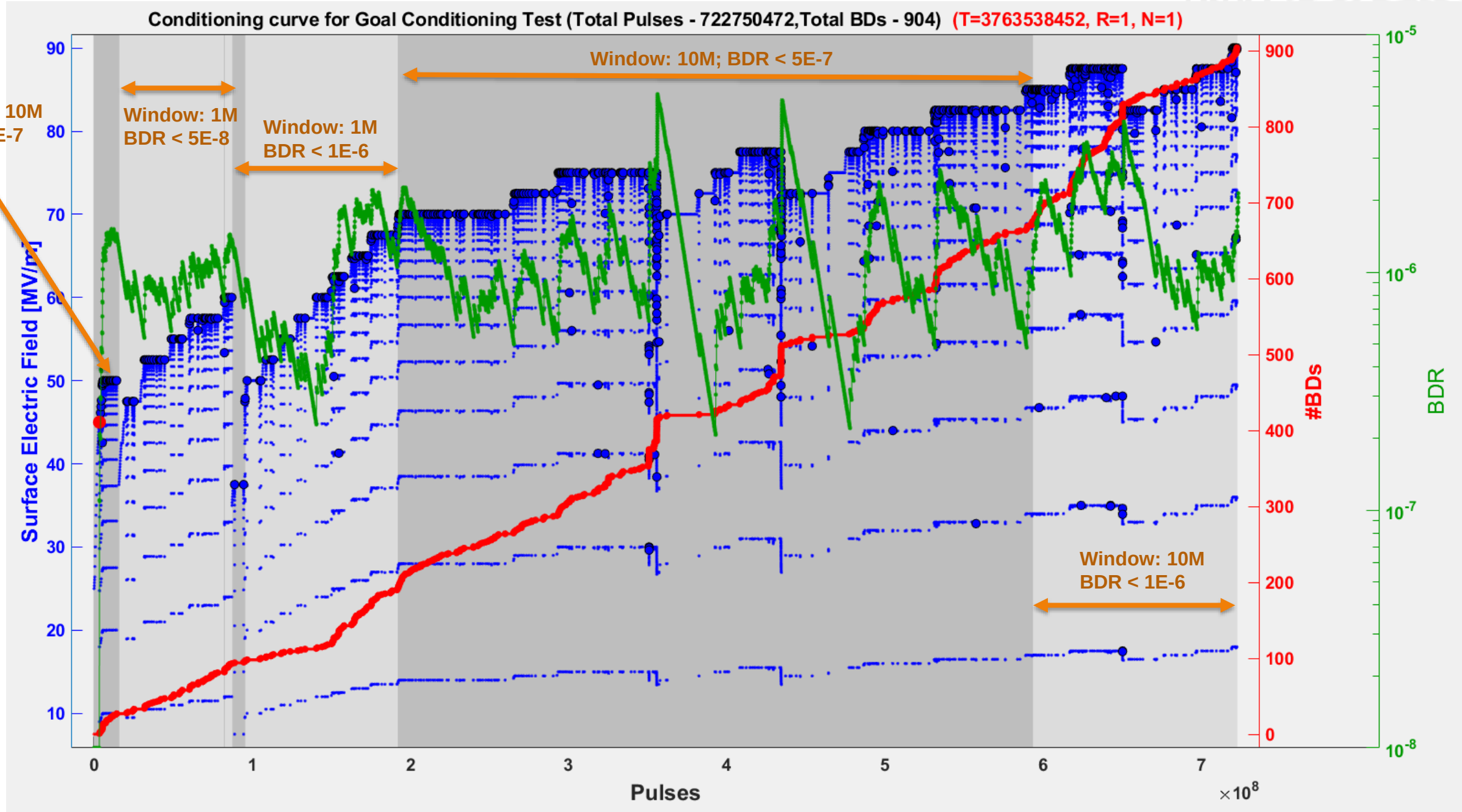
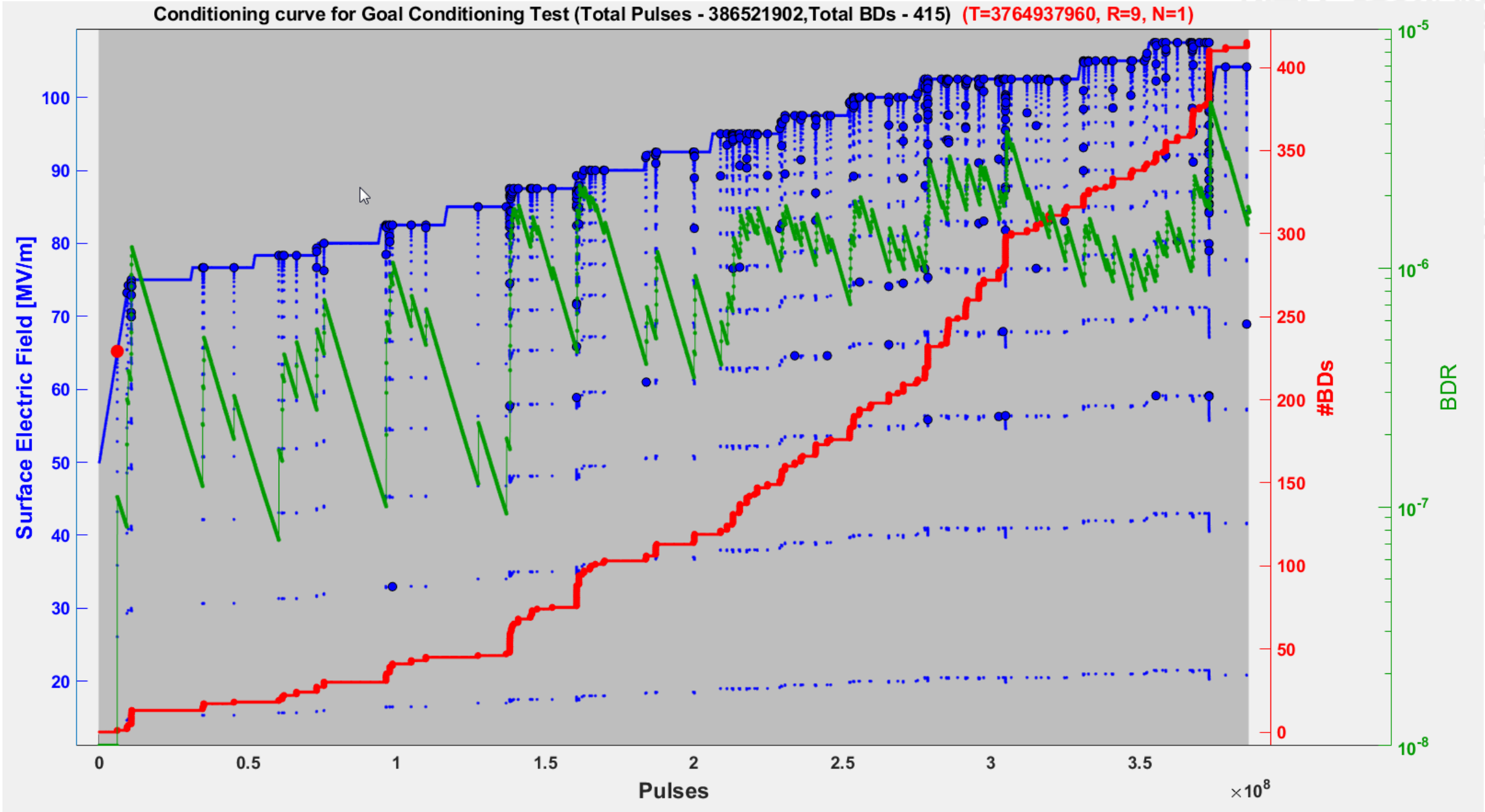
Our data (Electrode 030) - RT

- Final Electric Field Now: 90 MV/m
- Final Electric Field In 2019: ~88 MV/m

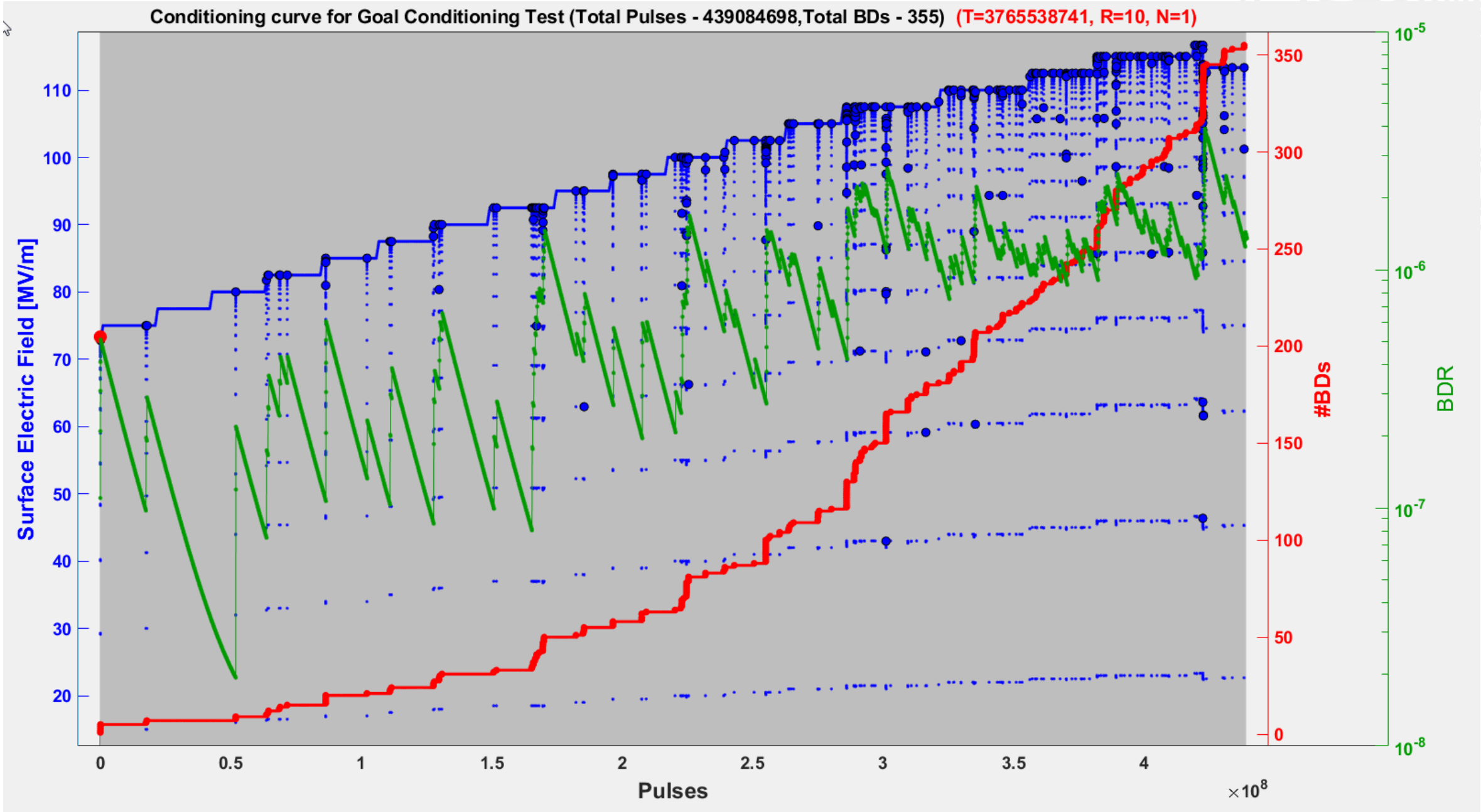


Our data (Electrode 030) – 4K – First conditioning run



Our data (Electrode 030) – 4K – Reconditioning

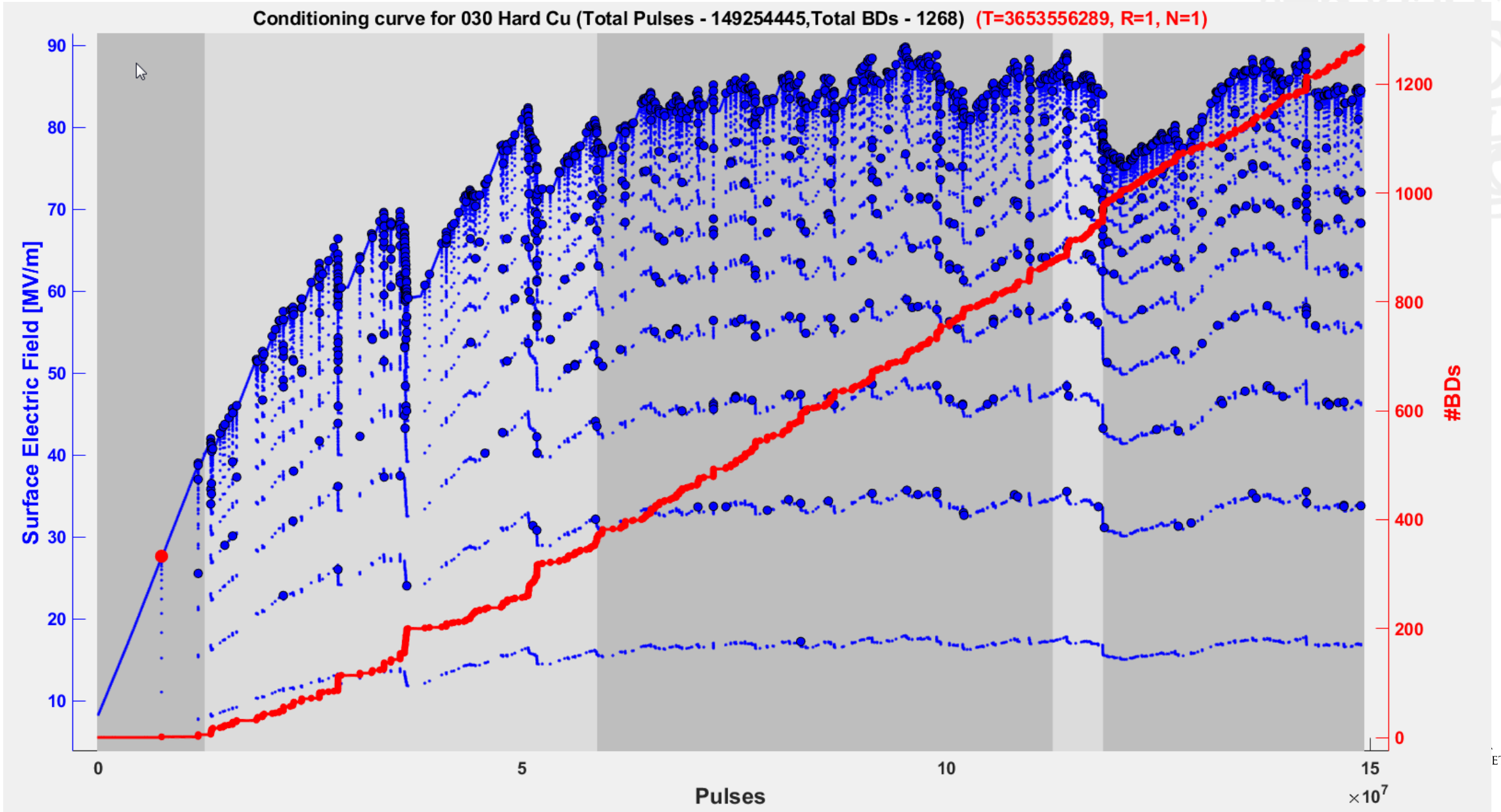
- Final Electric Field Now: 115 MV/m
- Final Electric Field In 2019: ~110 MV/m



Conclusions

- We have implemented and tested an automated version of the algorithm used at CERN
- Using this algorithm, we obtain good conditioning curves, comparable to the ones obtained at CERN
- Issue: somewhat arbitrary parameters and conditions:
- Do more pulses at lower voltage have the same effect as less pulses done at higher voltages? After which number of pulses does this stops being true?
- When running the algorithm manually, the operator checks whether the rate of breakdowns “stabilized”, not whether the BDR is lower than a certain threshold. This is not very important in our case: we can modify manually the BDR threshold as the voltage increases.
- Even if the BDR threshold is not increased, we obtain good results because $BDR \sim E^{30}$. For example, if BDR stabilized at 5E-7, we are already at $\left(\frac{5E-7}{1E-5}\right)^{1/30} = 90\%$ of the saturation voltage.
- In any case, this algorithm is an improvement over the usual algorithm (the one with a constant conditioning goal)
- We would like to use this algorithm to condition the Nb electrodes

Extra Slides – 2019 Conditioning (RT)



Extra Slides – 2019 Conditioning (4K)