

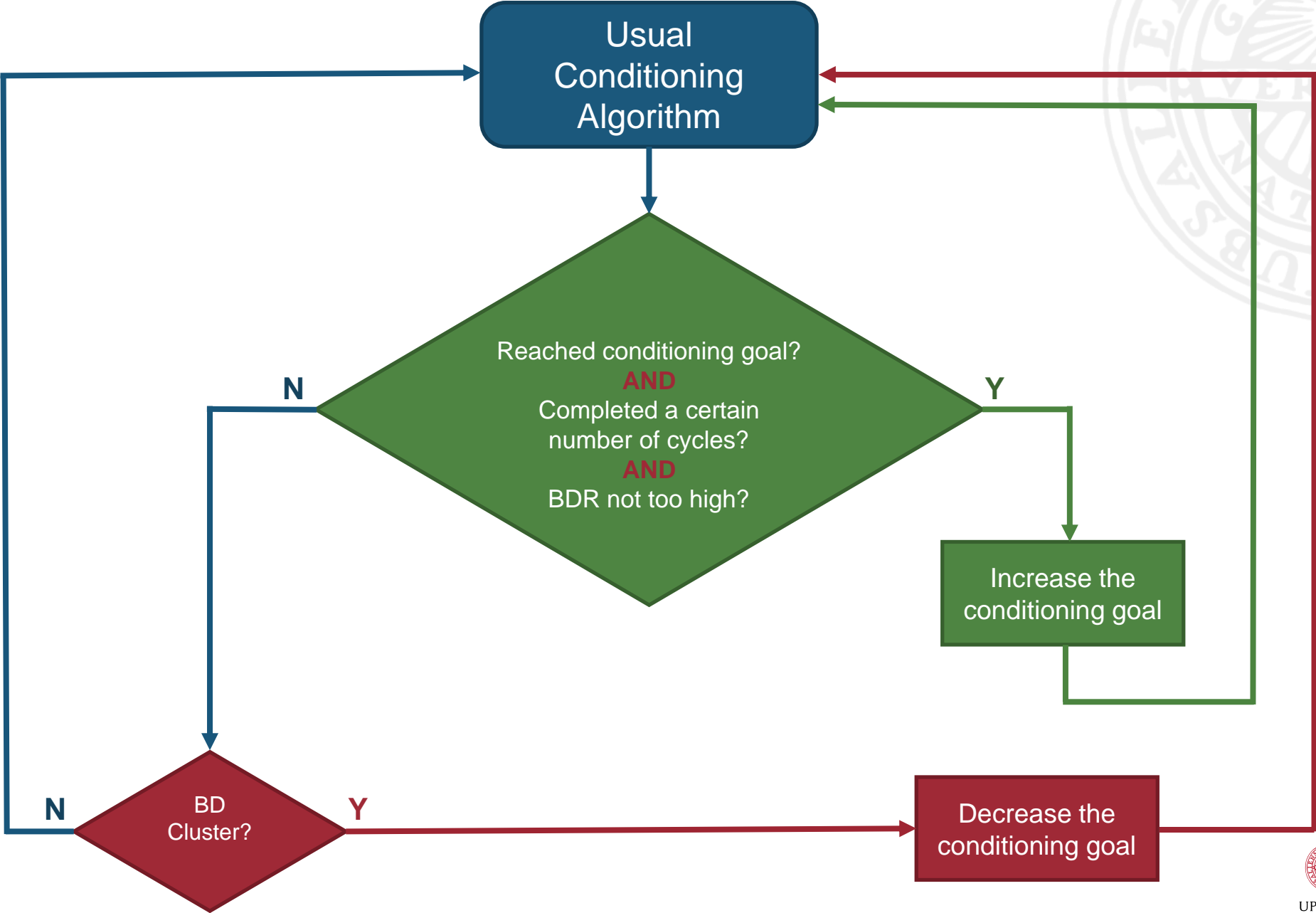


# Automated conditioning algorithm

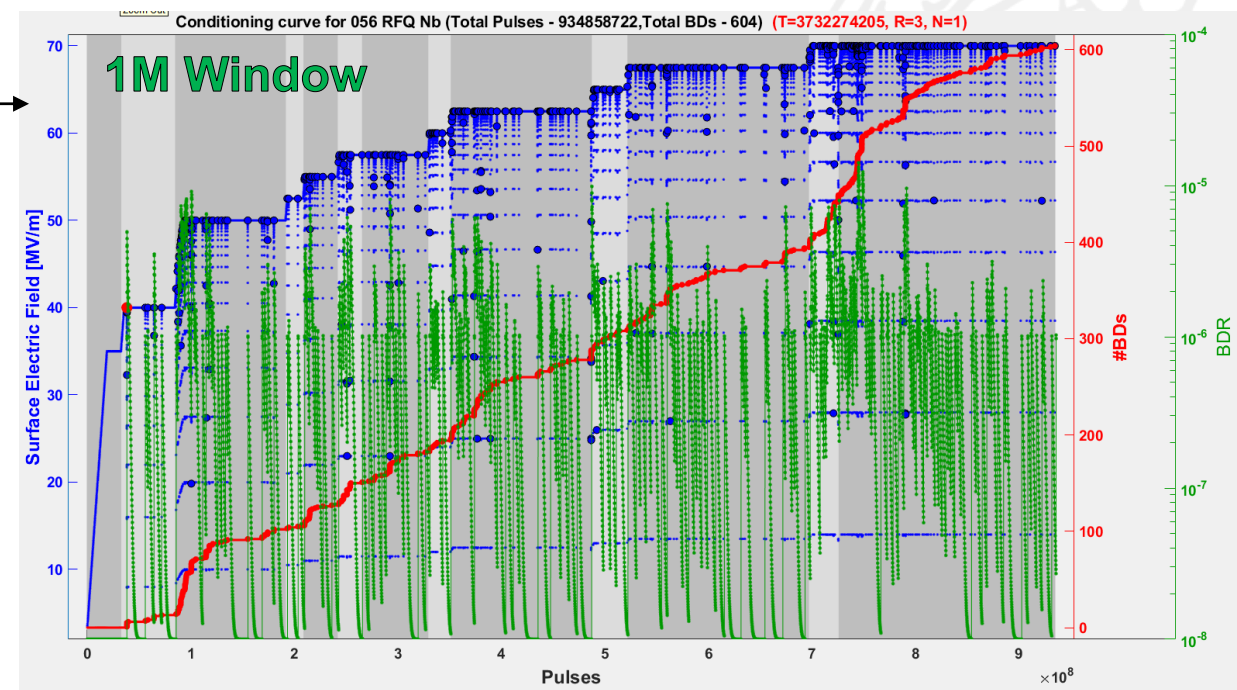
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# Basic idea



Data from 056 RFQ Nb, conditioned at CERN



### Reached conditioning goal?

- Set voltage == Conditioning goal

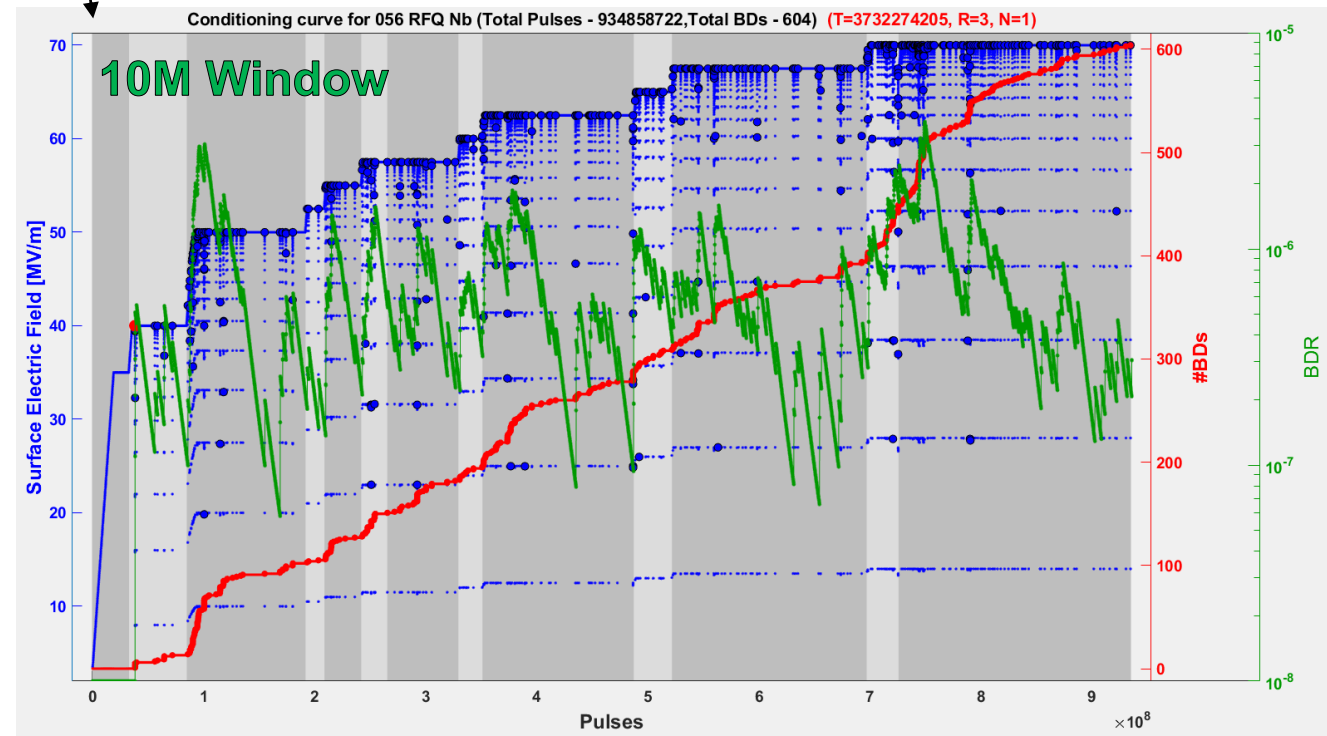
### Completed certain number of cycles?

- 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



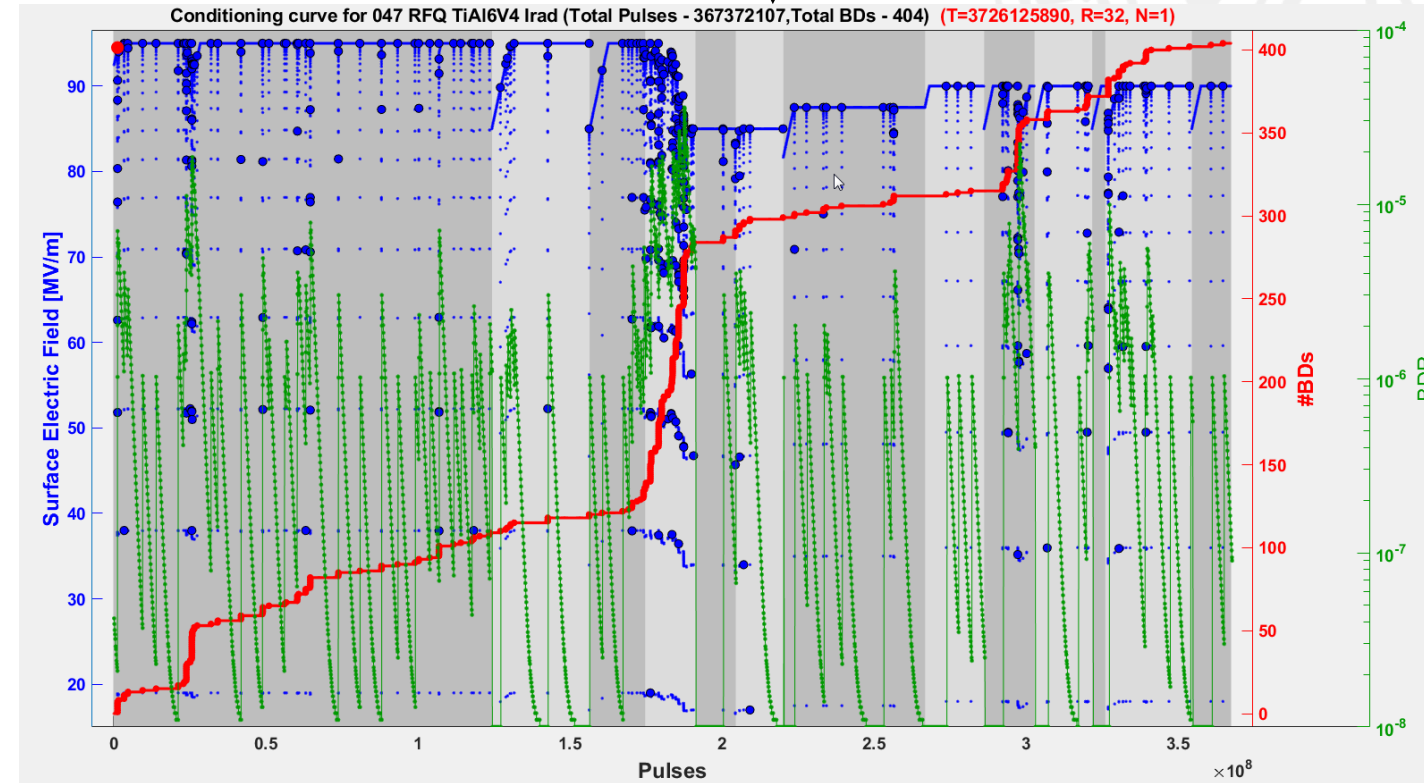
# BD Cluster?

- 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



Generator

Marx 1

Mode

Goal Conditioning

Pulsing

ON

Breakdown



Polarity

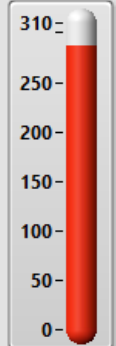
Positive

Max V (Stop)

9000 V

Stop

Temperature



287 K

Experimental conditions Goal Conditioning COM Properties Additional RepRates

Increase the voltage by 150 V if:

GC BDR < 1E-6 AND

The number of cycles done at the conditioning goal > 200

Decrease the voltage by 200 V if:

BDR > 2E-5 AND

Number of cycles since last CG decrease > 20

Final Conditioning Goal

7000 V

Pulse Window for GC

10M

Initial GC BDR

0

GC BDR

8.87681E-7

STOP CONDITION



Power (W)

20

GOAL CONDITIONING ON

Current Status

Is At Conditioning Goal

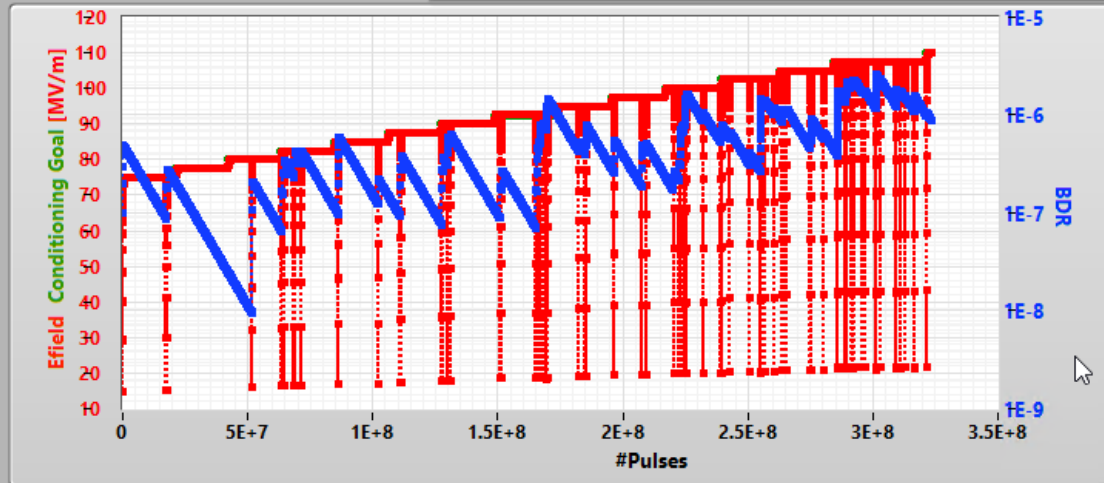
Cycles done at conditioning goal

12

Cycles since last CG decrease

3307

Goal Conditioning Plot



shared variable from cryo

ni.var.psp://localhost/myvarlib/Temperature

Timestamp

13:44:43.552  
2022-06-28

Lost contact



Monitoring

Mode

1

# BDs

181

Temperature 1

36.9 C

Temperature 2

39.8 C

PS Voltage monitor [V]

477 V

Marx Pulses

25719

Stop cond/cause

0

Pulses@cycle

100000

All Pulses

323327989

V out

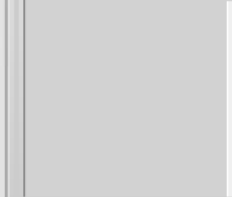
6600.93 V

error out

status code

0

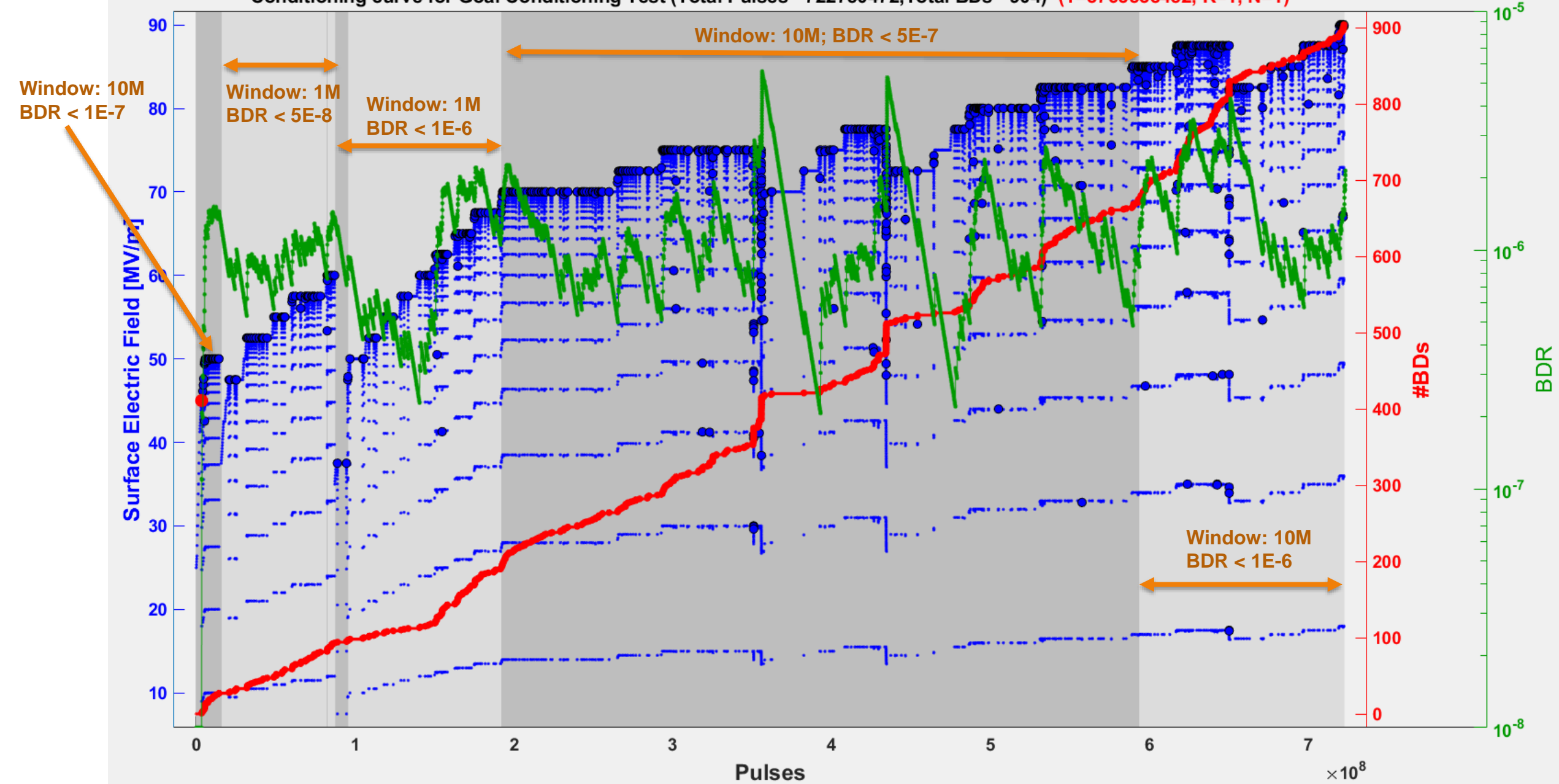
source



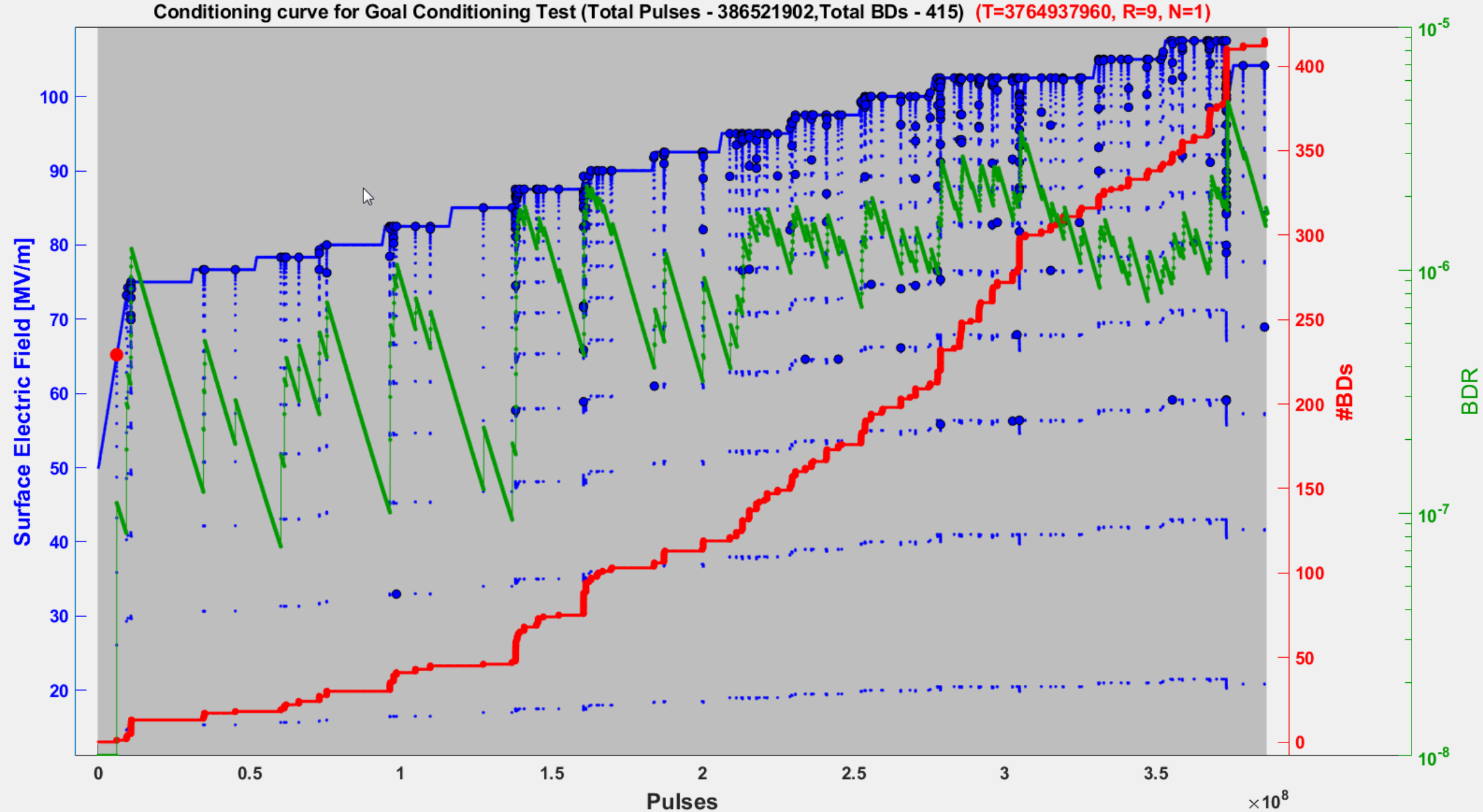
# Our data (Electrode 030) - RT

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

Conditioning curve for Goal Conditioning Test (Total Pulses - 722750472, Total BDs - 904) (T=3763538452, R=1, N=1)

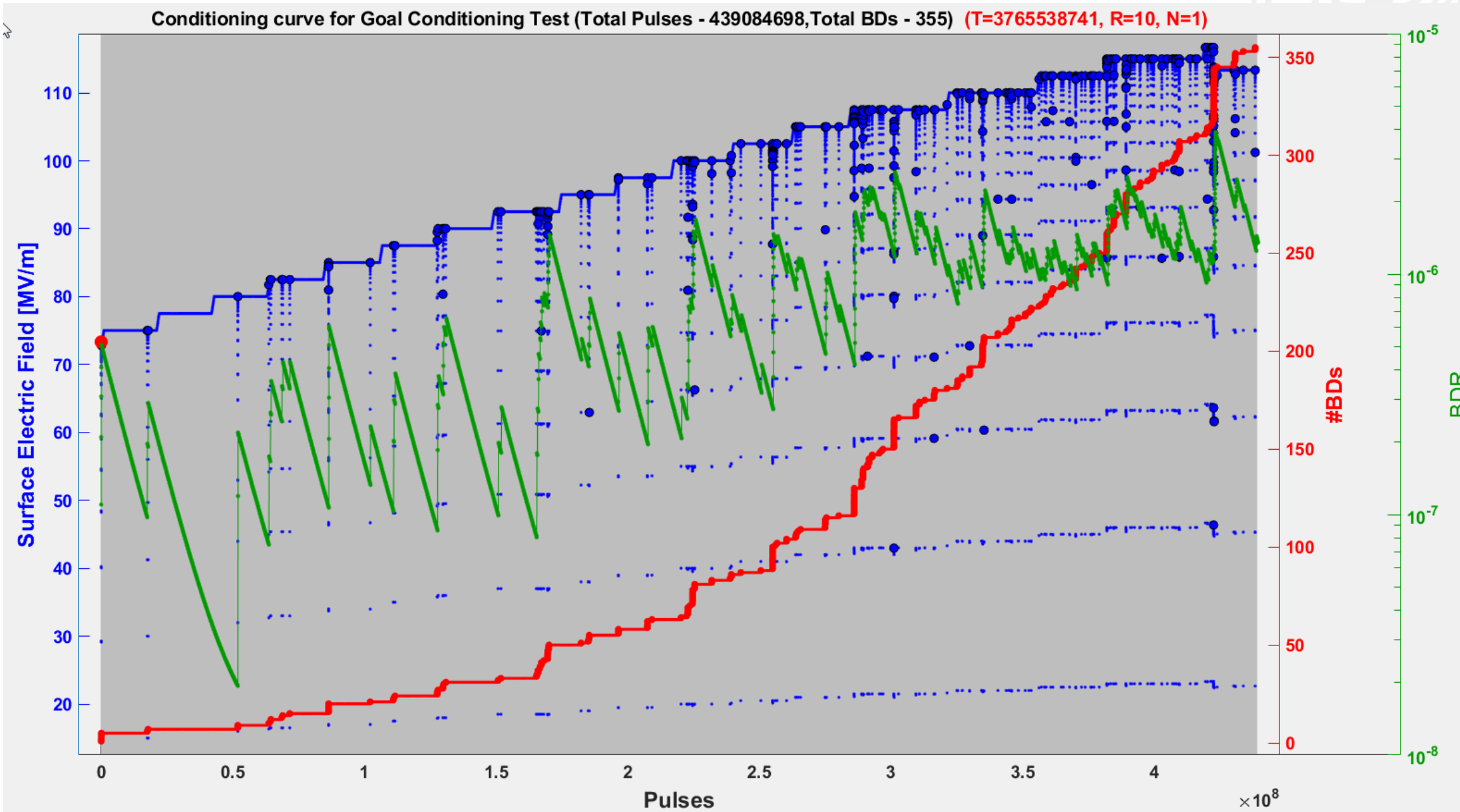


# Our data (Electrode 030) – 4K – First conditioning run



# Our data (Electrode 030) – 4K – Reconditioning

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



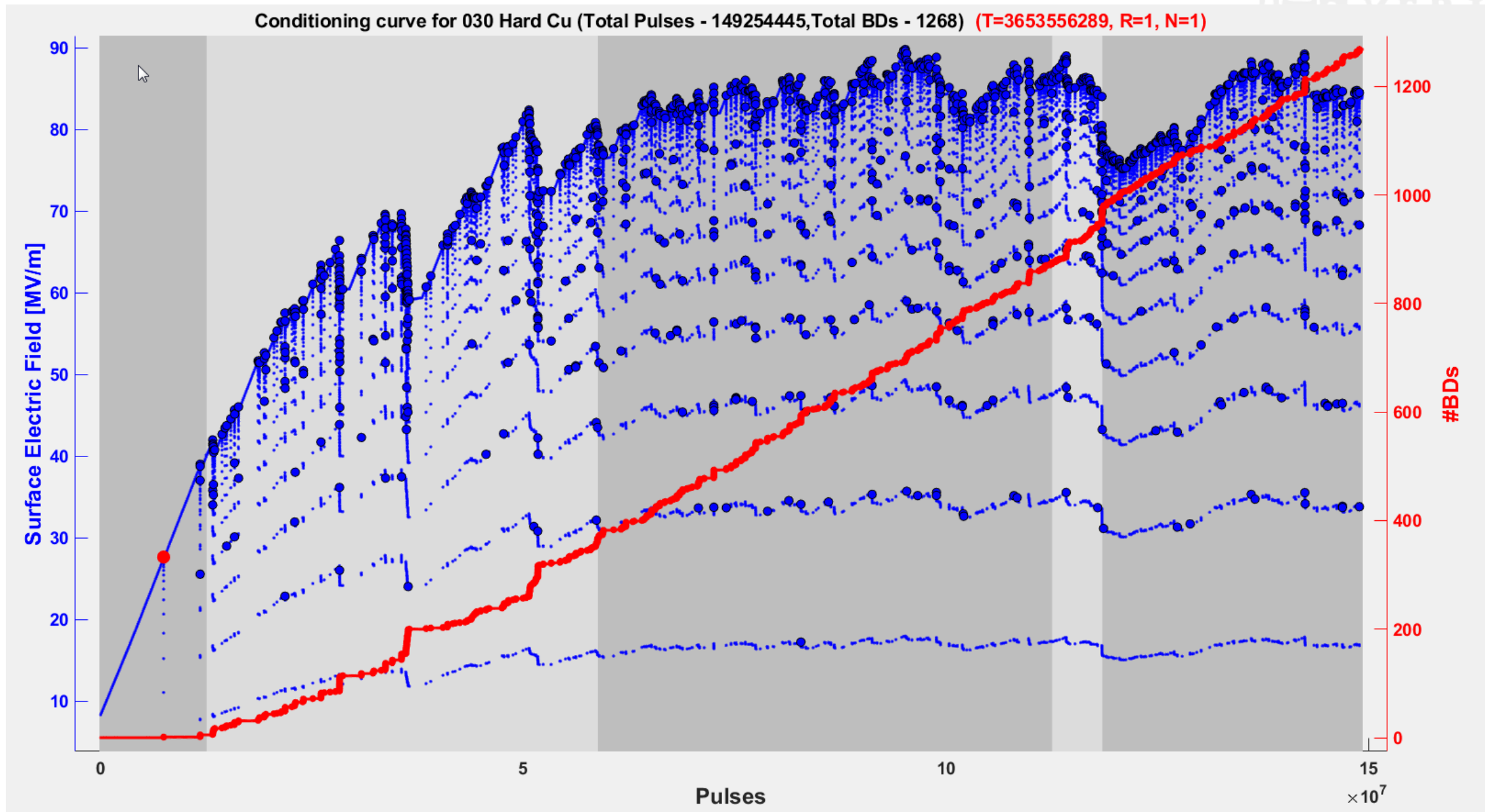


# Conclusions

- 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)

