CLIC Crab Cavity Post-Mortem analysis

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23. 03. 2016

Outline

- **Introduction**
- **Objective**
- **Cutting and Nomenclature**
    - Marks and pollution induced by Post-Mortem cutting
    - Cleaning (degreasing)
    - General appearance of the surface after cleaning
- **Distribution**
    - BD distribution in the iris
    - BD location Vs E-Field
    - BD location Vs H-Field
    - BD location Vs Sc-Field
    - Facing irises (same cell)
- **Acquisition**
    - Imaging
    - Marking
    - Counting
- **Catalogue of features related with breakdown activity**
    - Comparison with other tested structures
    - Craters
    - Worm Like Features (WLF)
- **Summary of observations**

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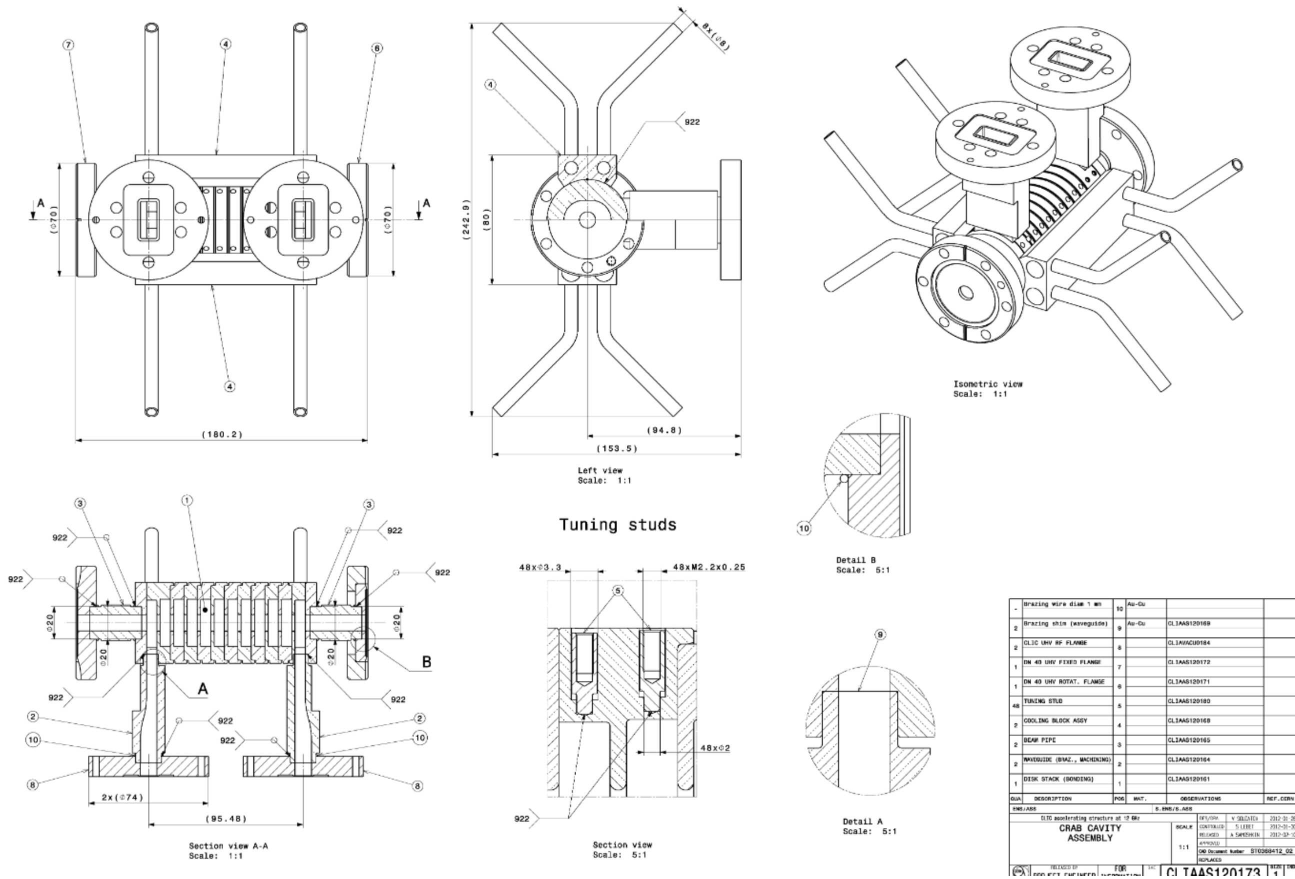
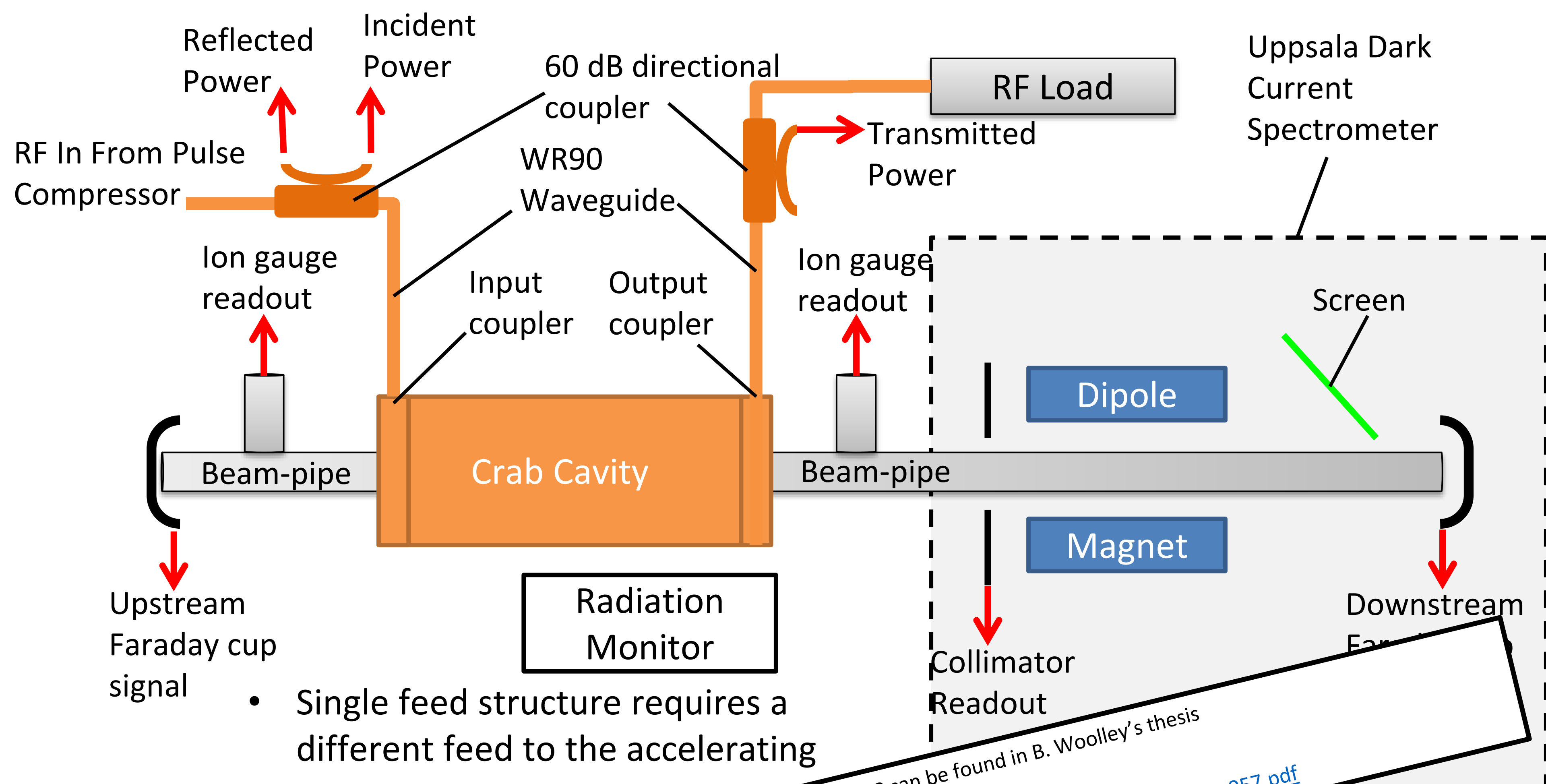
CLIC Crab Cavity

- Tested at Xbox 2
- Finished in June 2015



Courtesy of B. Woolley

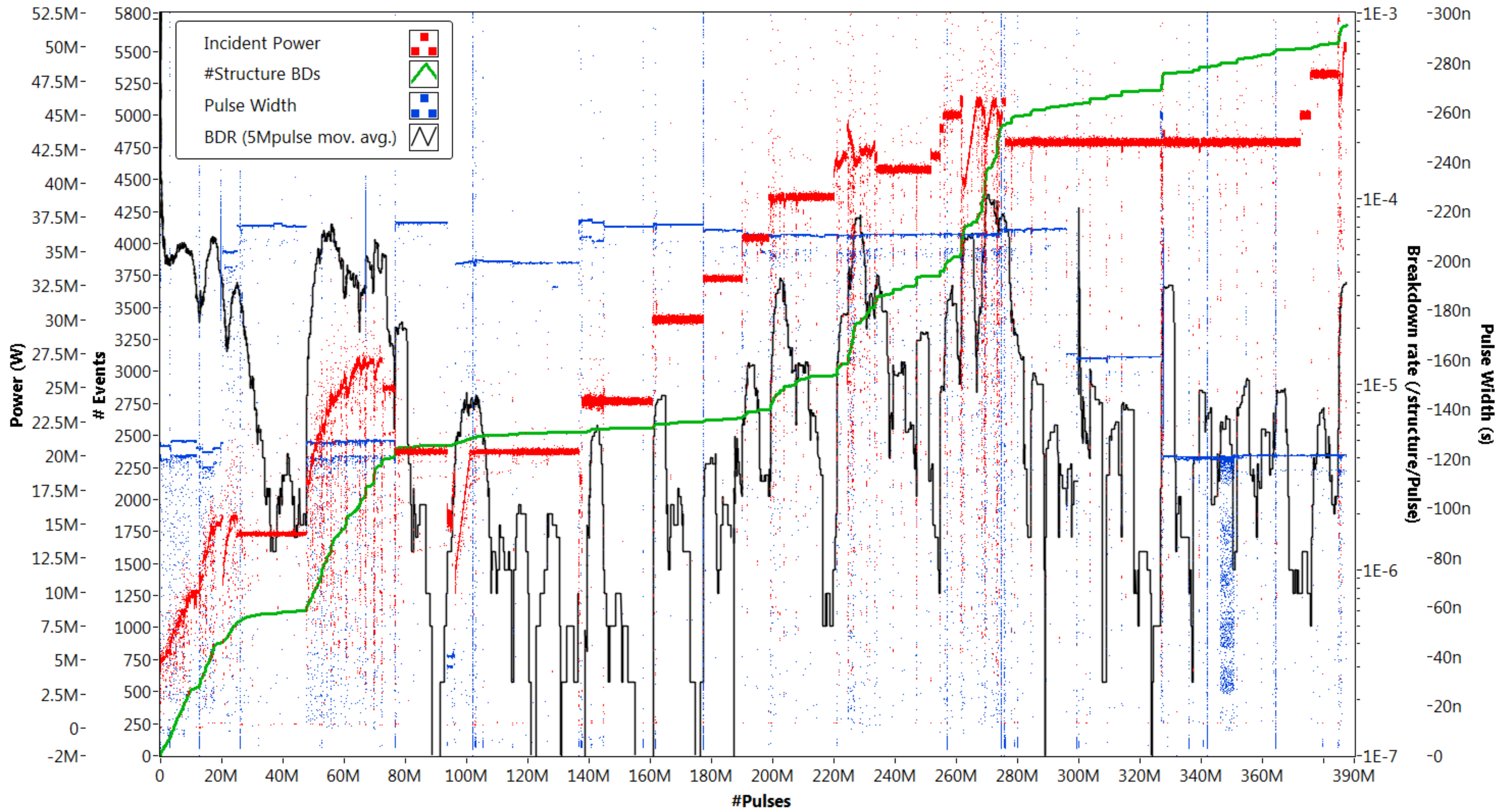
Xbox-2 Diagnostics



- Single feed structure requires a different feed to the accelerating structures.
- We can take adva… diagnostics with th… current spectromet…

More information about CLIC CC can be found in B. Woolley's thesis
http://eprints.lancs.ac.uk/76926/
or https://indico.cern.ch/event/358352/contribution/8
or http://accelconf.web.cern.ch/AccelConf/IPAC2015/papers/wepha057.pdf

Full Processing History



Structure has seen almost 390 million pulses with over **5700 breakdown events**.
Performed well above the operating limit of 13.35 MW: 43MW, 200ns flat-top, BDR 3e-6.
Peak power reached: 51 MW, 100 ns flat-top, BDR 3e-5.

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Objective

- Breakdown features (BDs) observation.
  - Are they similar to those in monopole structures.
- Macroscopic observation of BDs.
  - How are they distributed in the iris?
  - Distribution relation in the cell
  - Comparison against E-field, H-Field and Sc-Field

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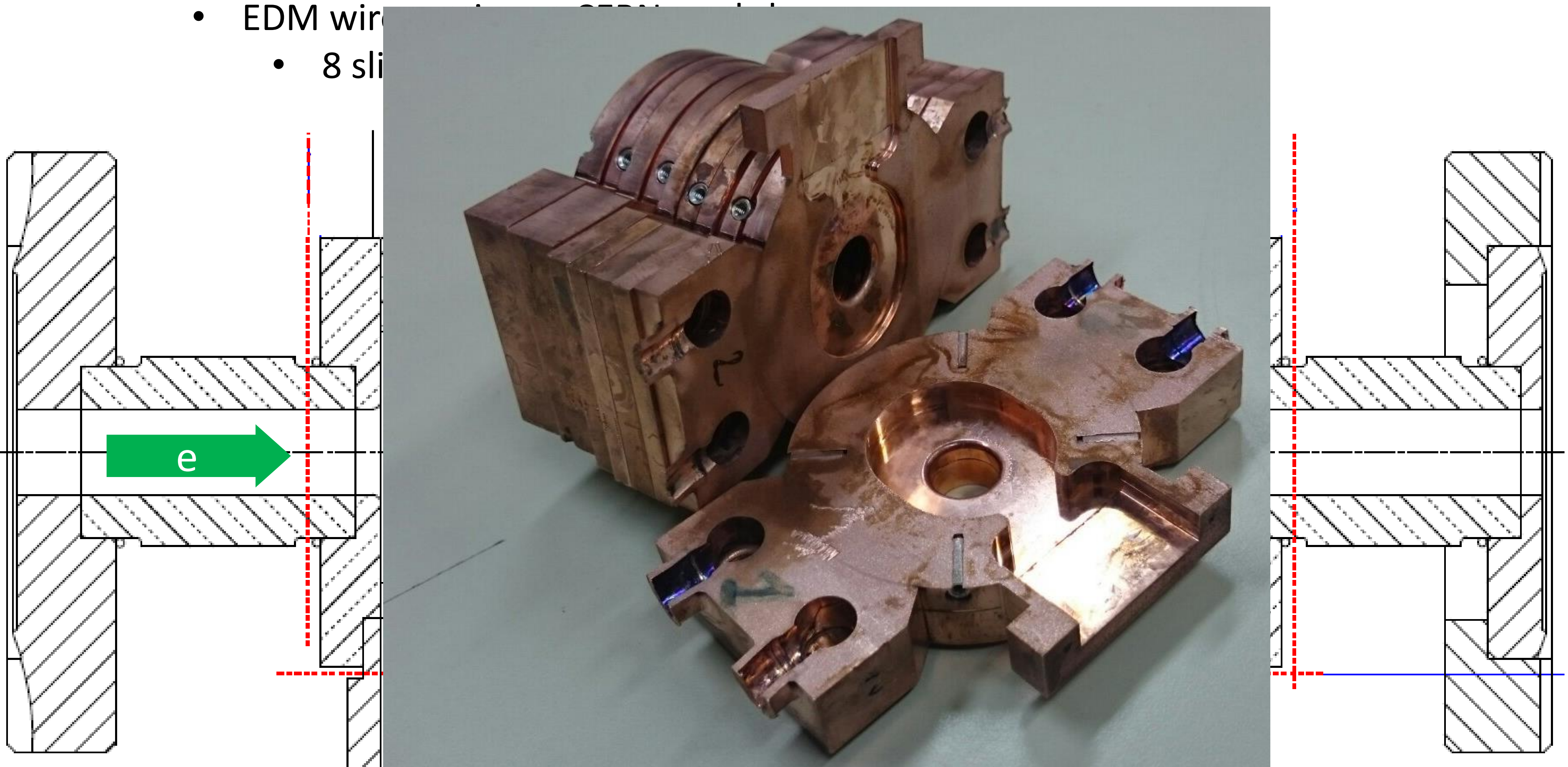
Cutting and nomenclature

- EDM wir
  - 8 sli



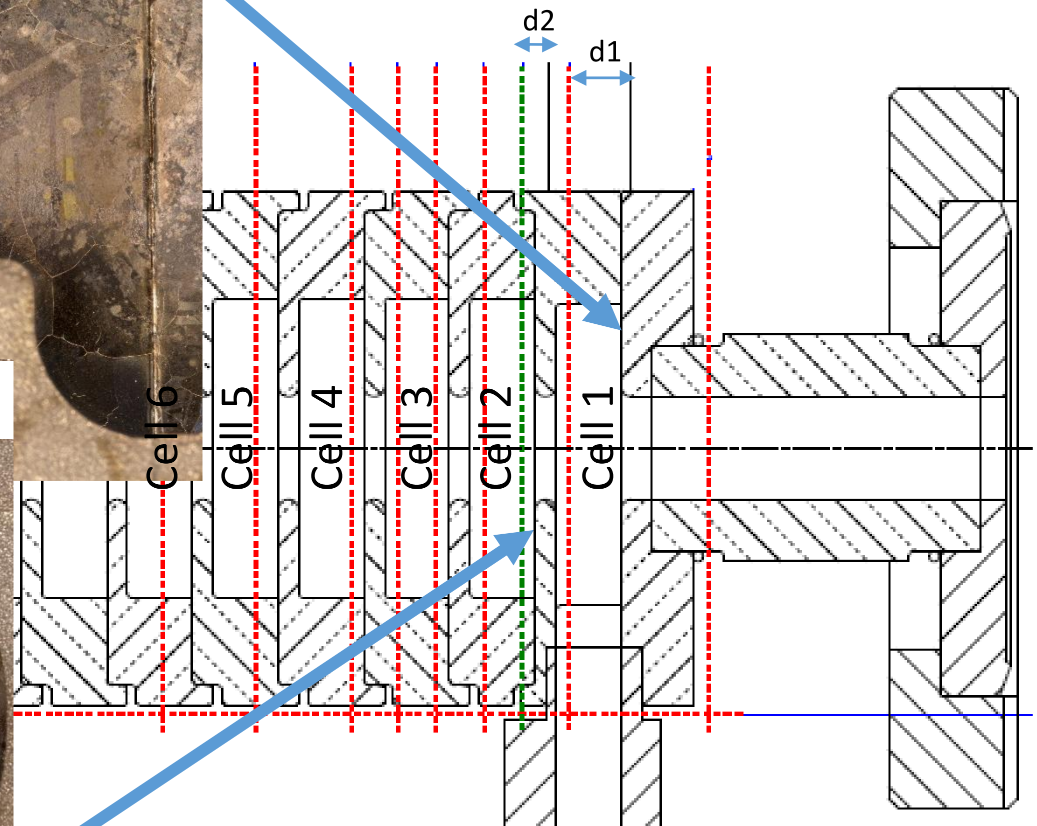
Iris 1 = Iris in the INPUT side
Iris 2 = Iris in the OUTPUT side

Example: Cell 4 – Iris 1

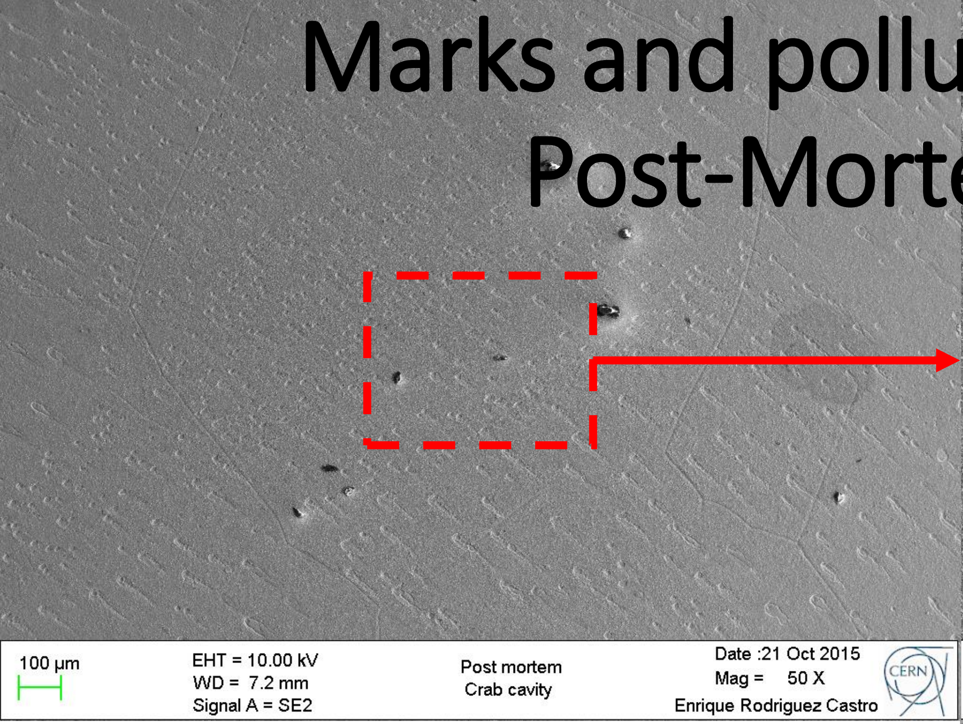
Cell 1 Iris 1 (Far from wire during cutting)

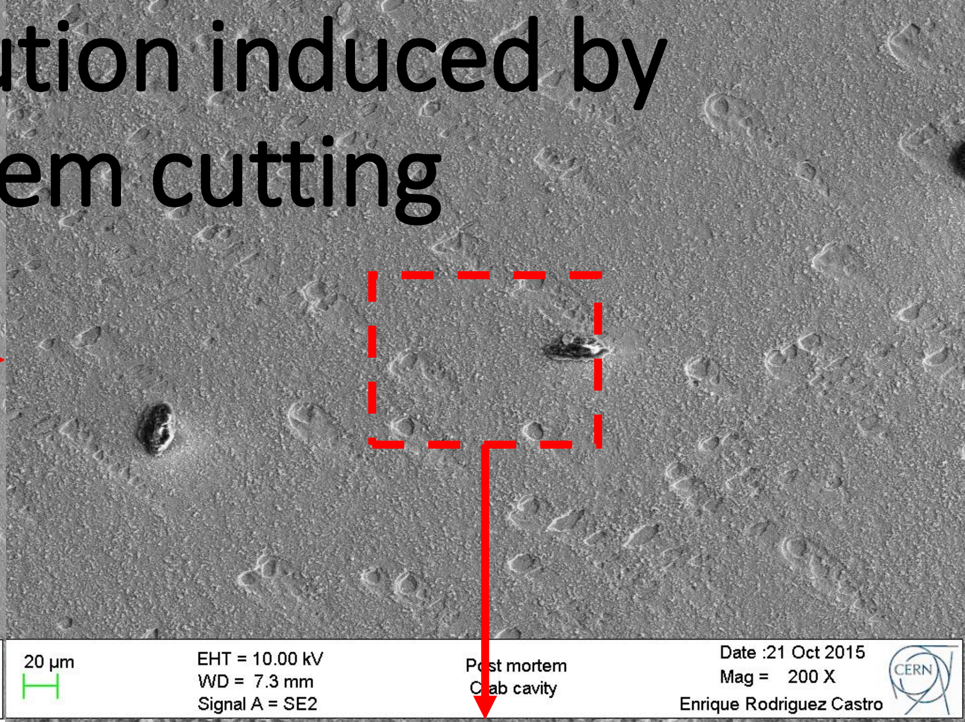
Cell 2 Iris 1 (Close to wire during cutting)

$d_1 >> d_2$

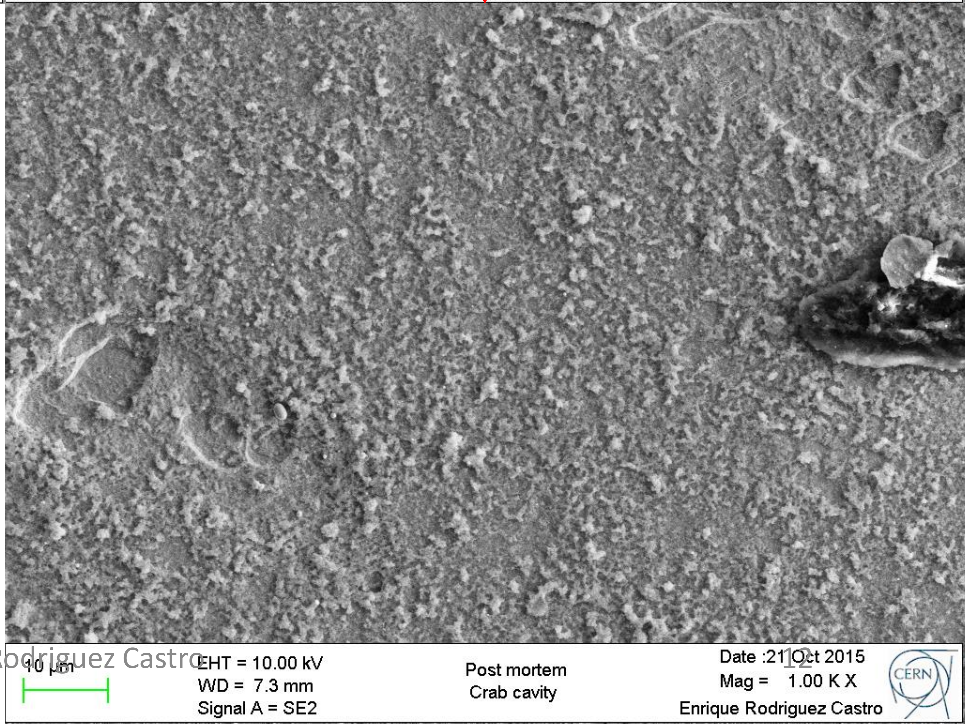


Marks and pollution induced by Post-Mortem cutting

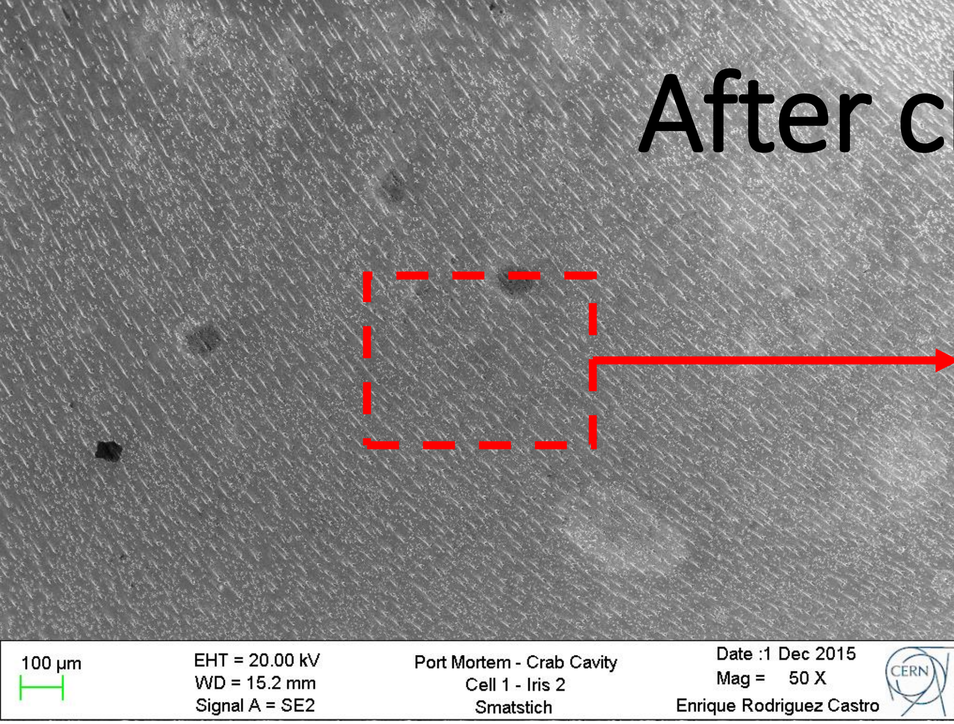


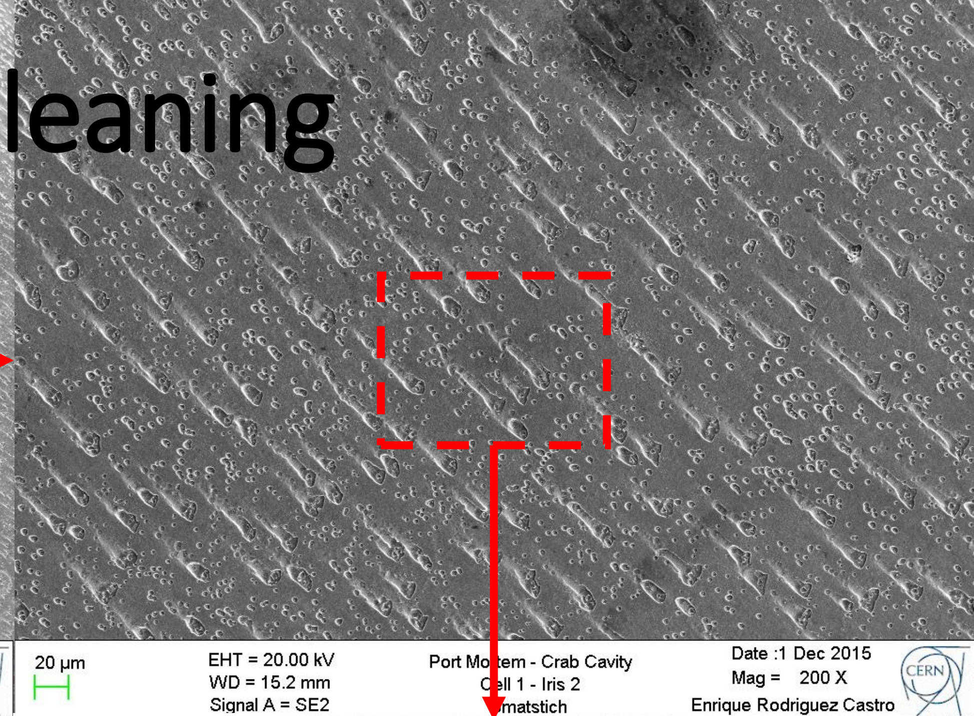


Pollution on the surface ➔ degreasing

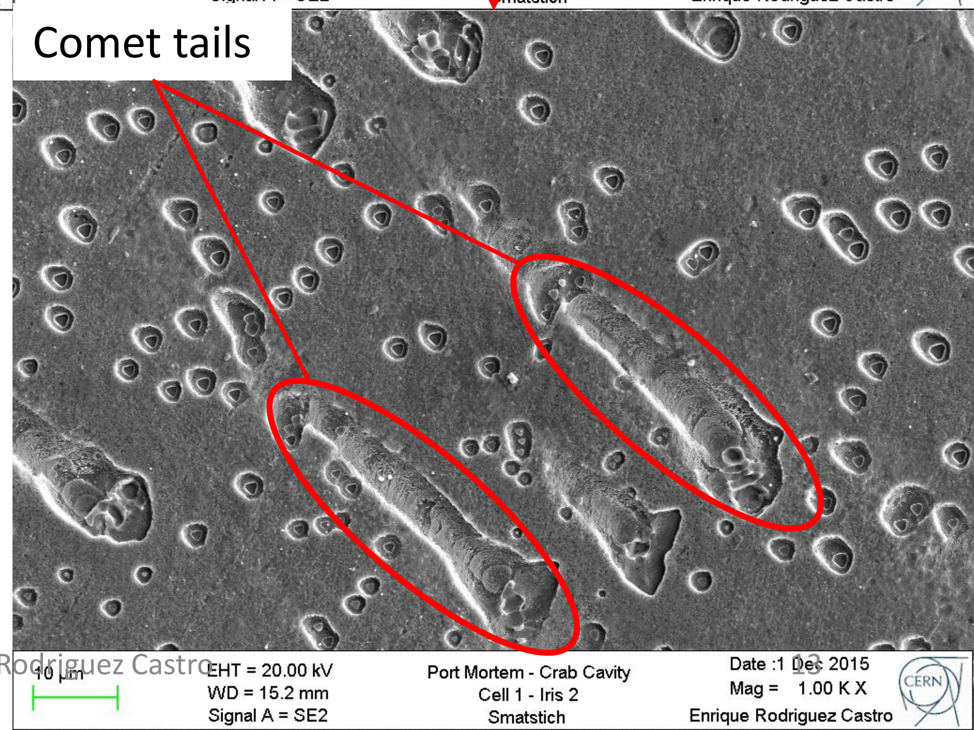


After cleaning

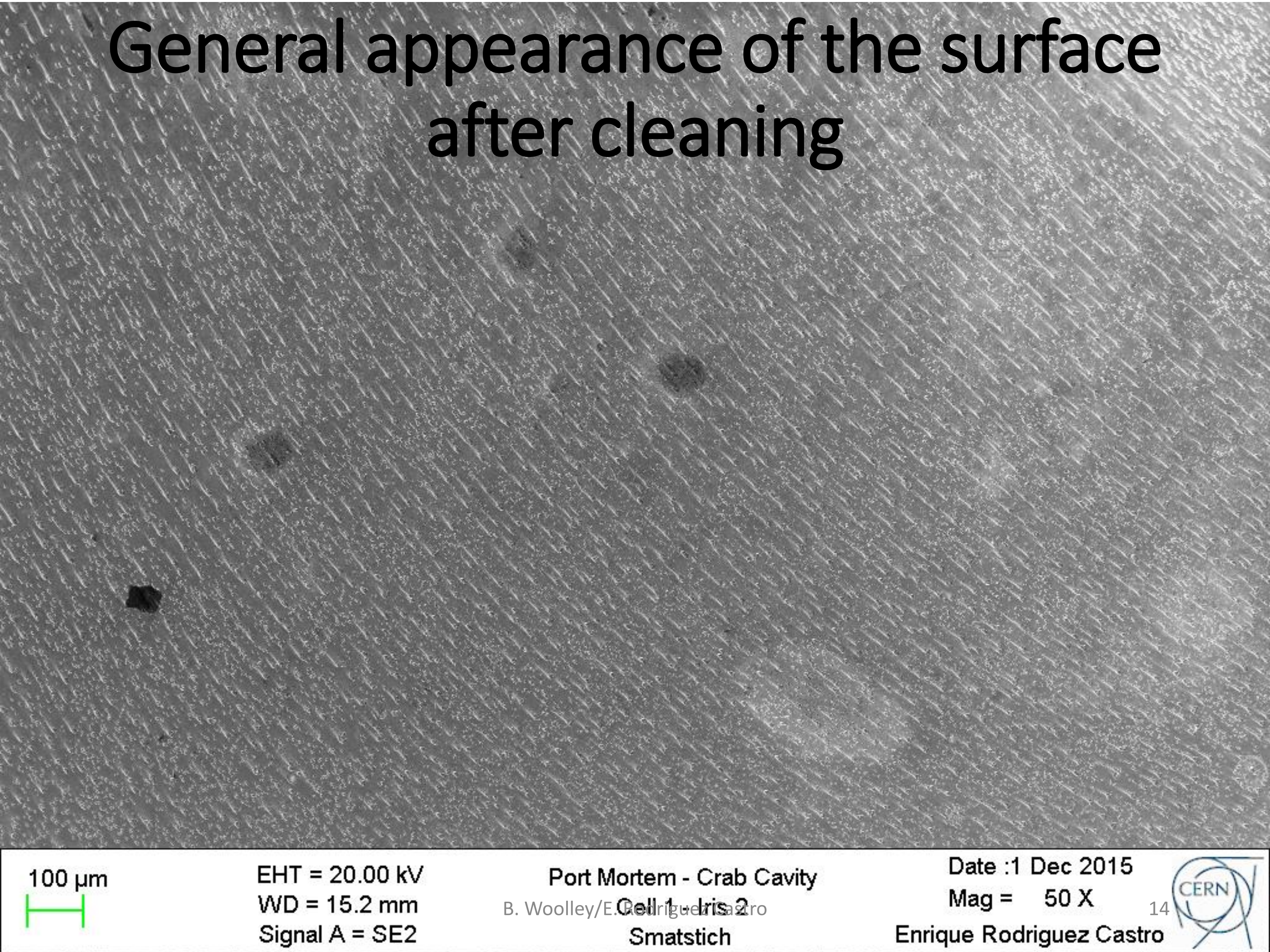




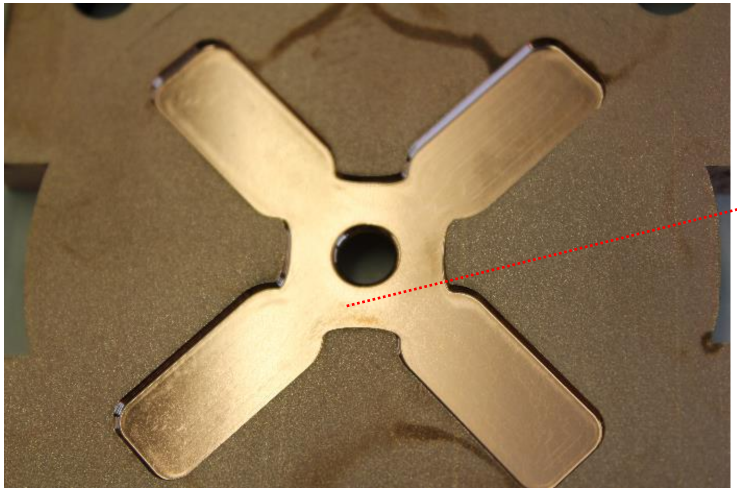
- Comet tails covering all the surface.

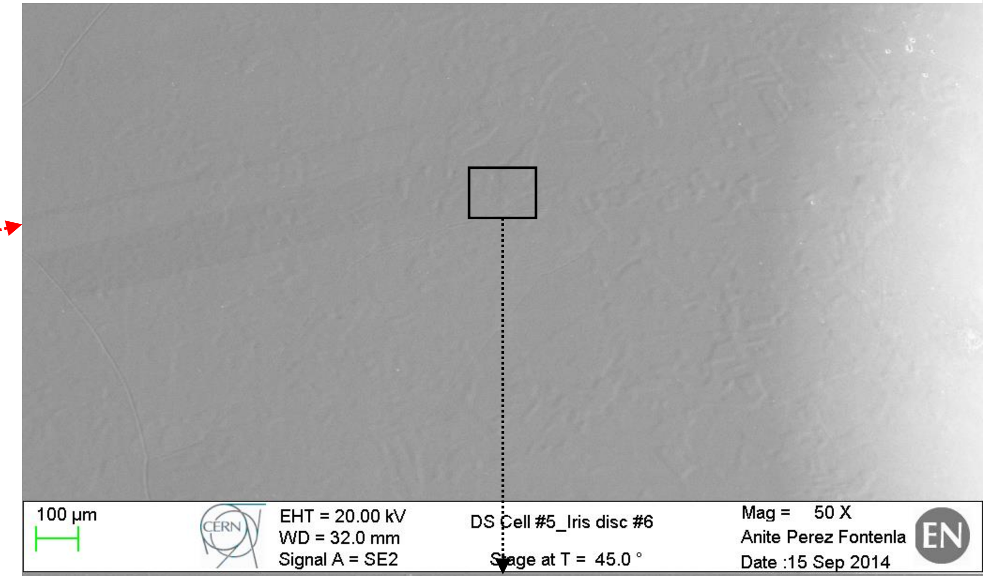


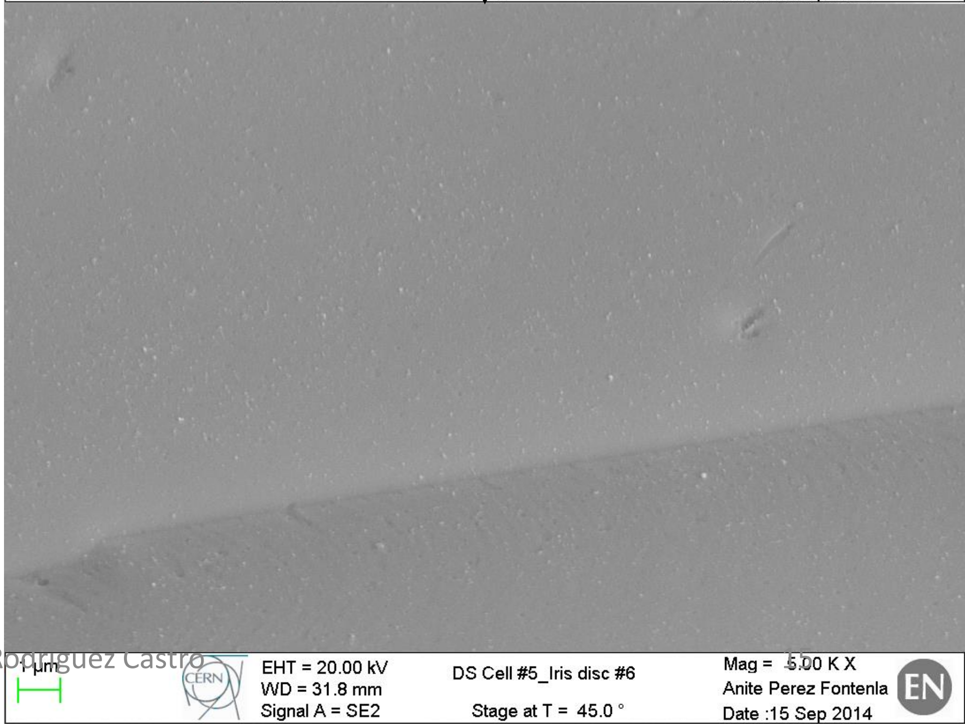
General appearance of the surface after cleaning



TD24 R05

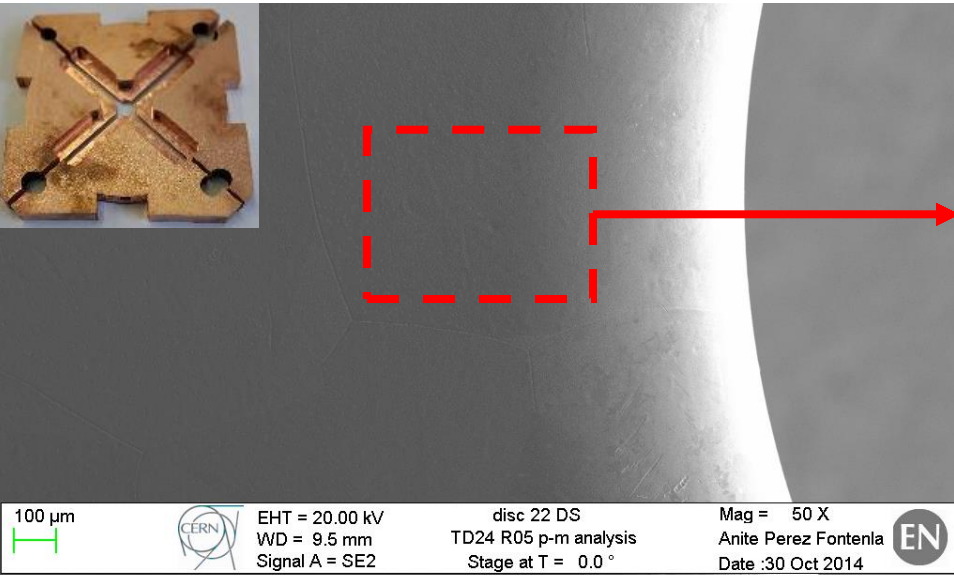


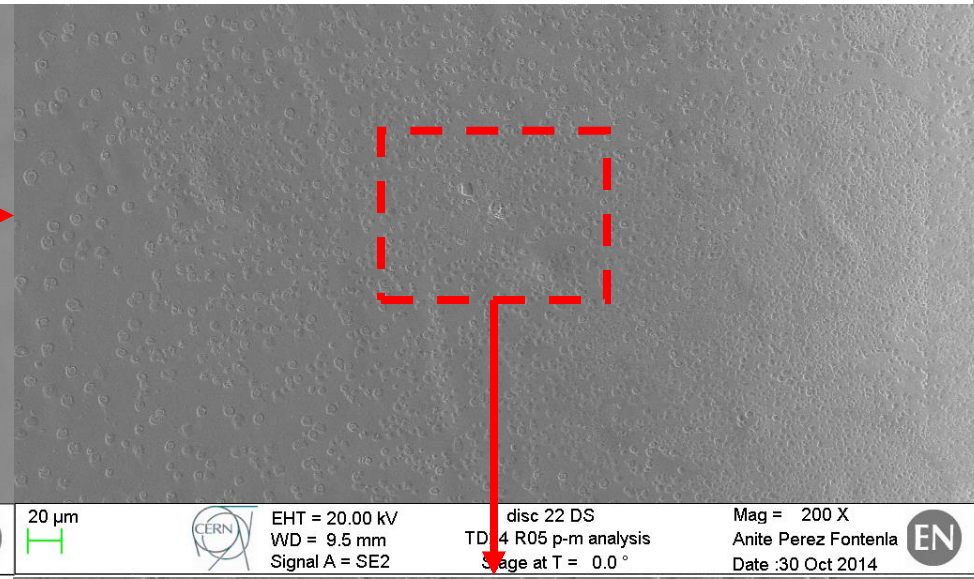




- EDM wire cutting (2014 Post Mortem analysis TD24 R05)

TD24 R05





- Marks induced by subsequent cuttings performed by EDM wire cutting (2014 Post Mortem analysis TD24 R05)

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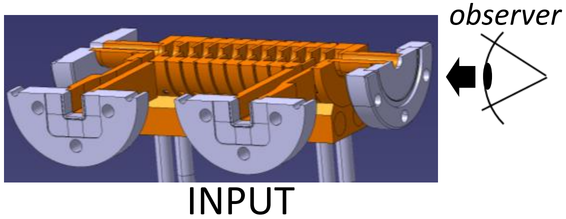
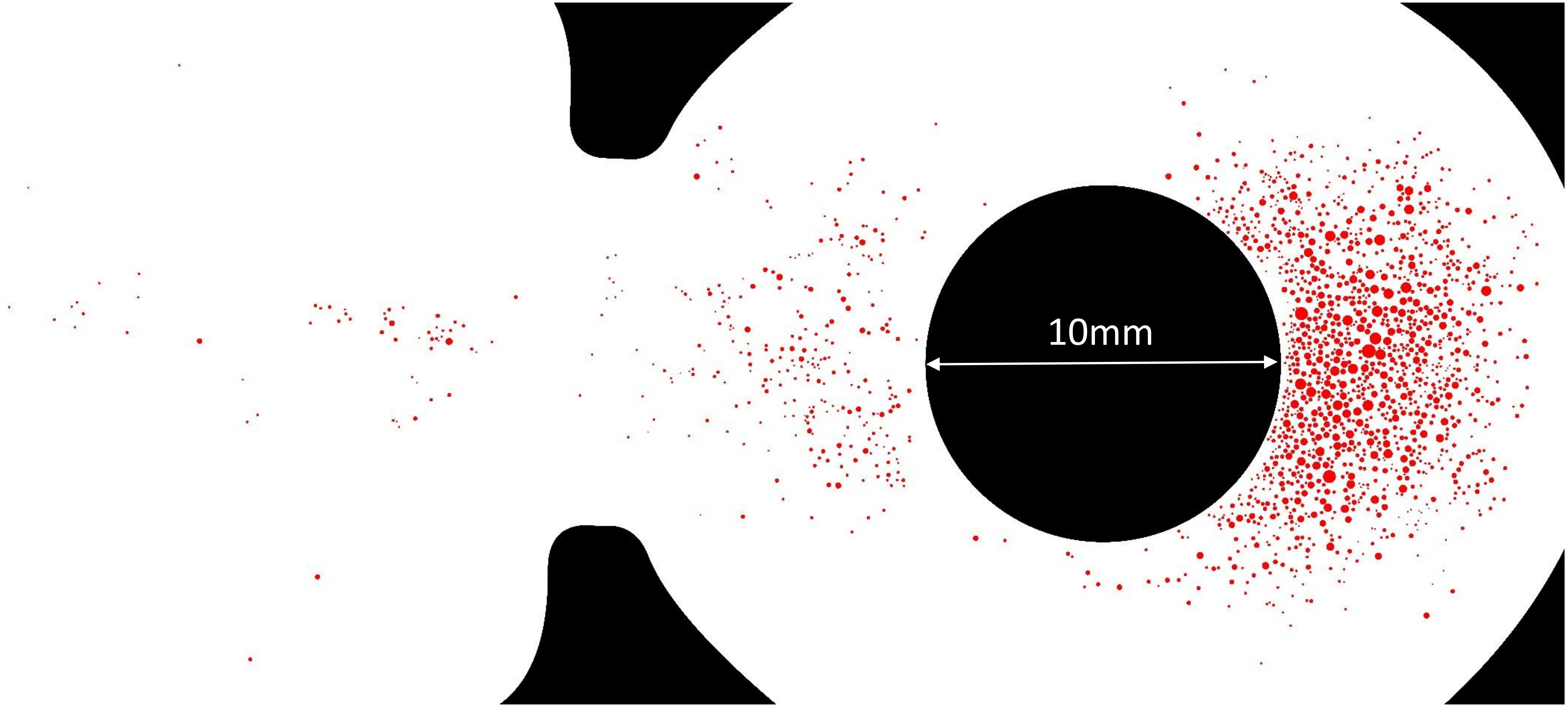
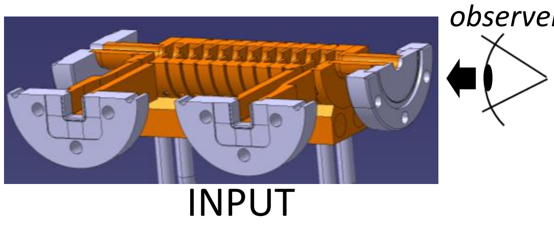
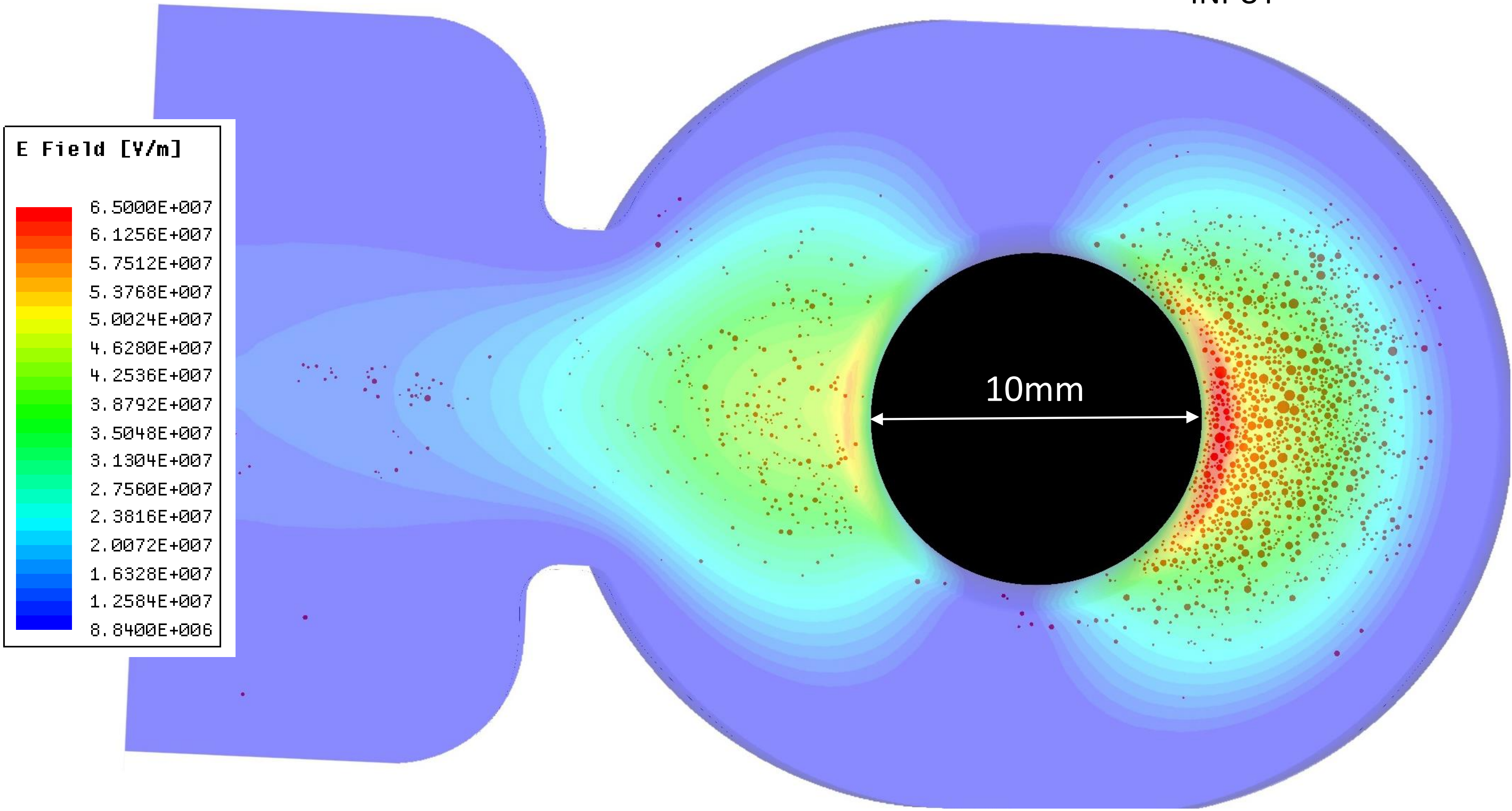




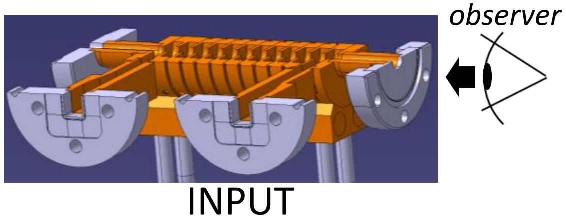
Number of sites BD sites = 1681

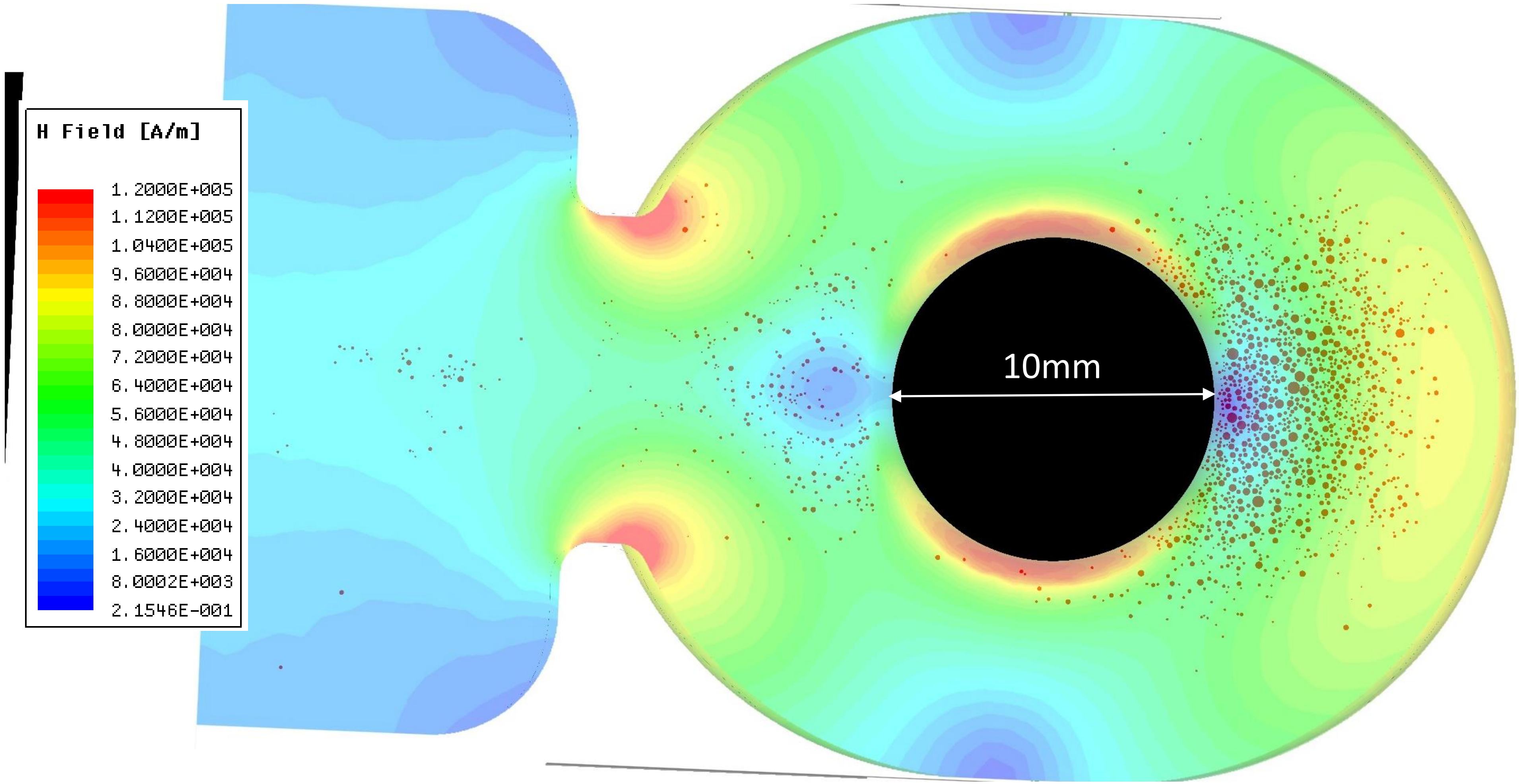
Cell 1 – Iris 1 Vs E-Field



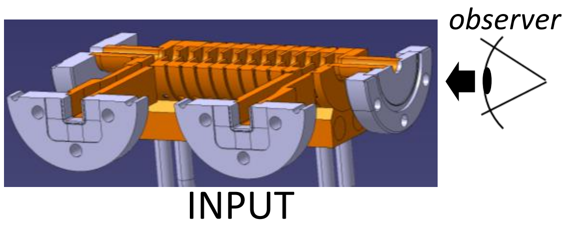


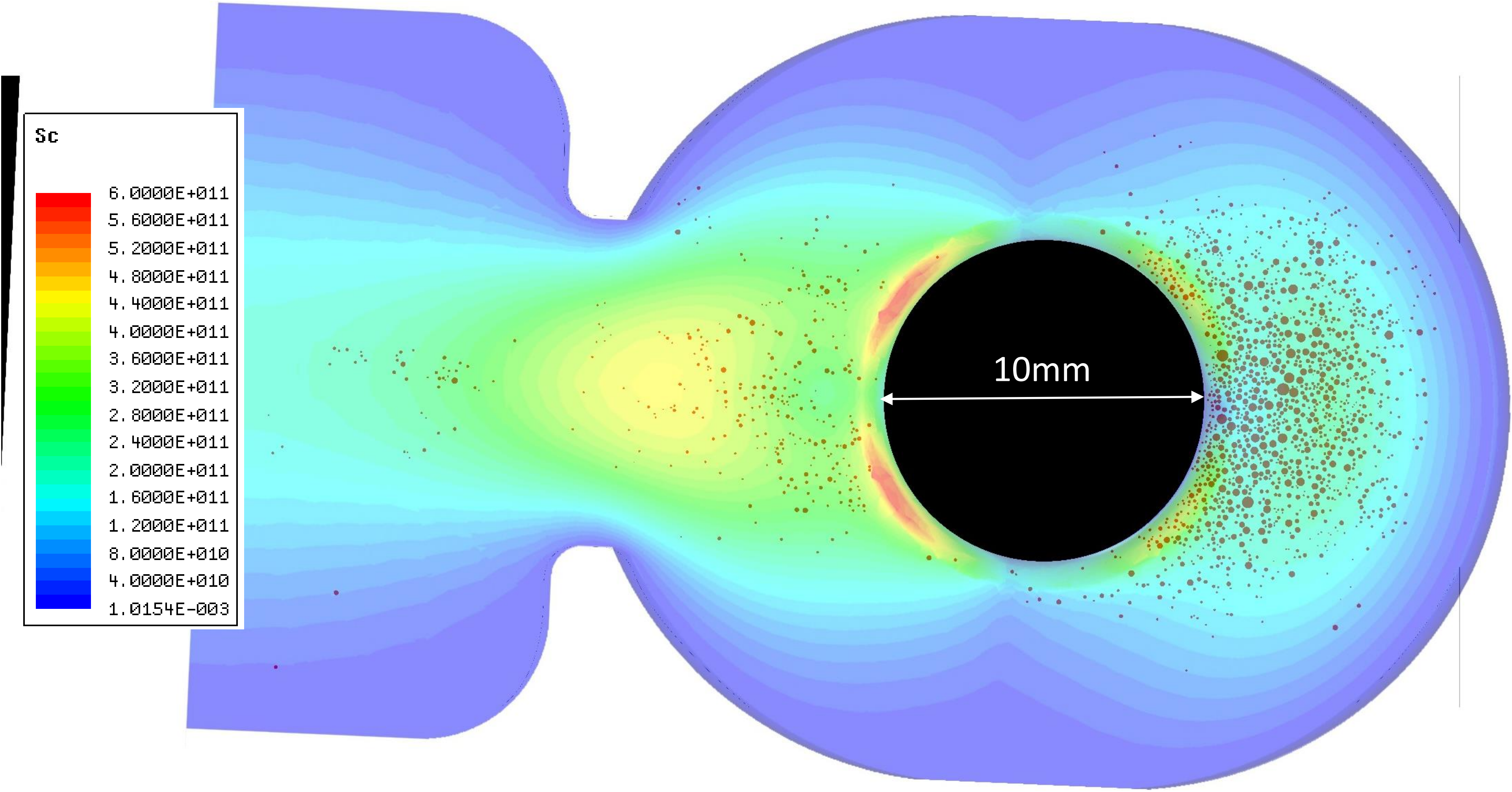
Cell 1 – Iris 1 Vs H-Field



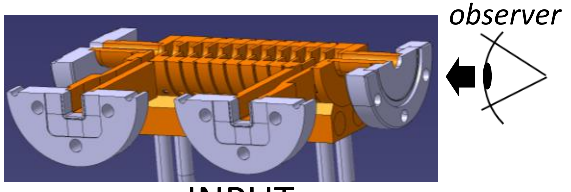


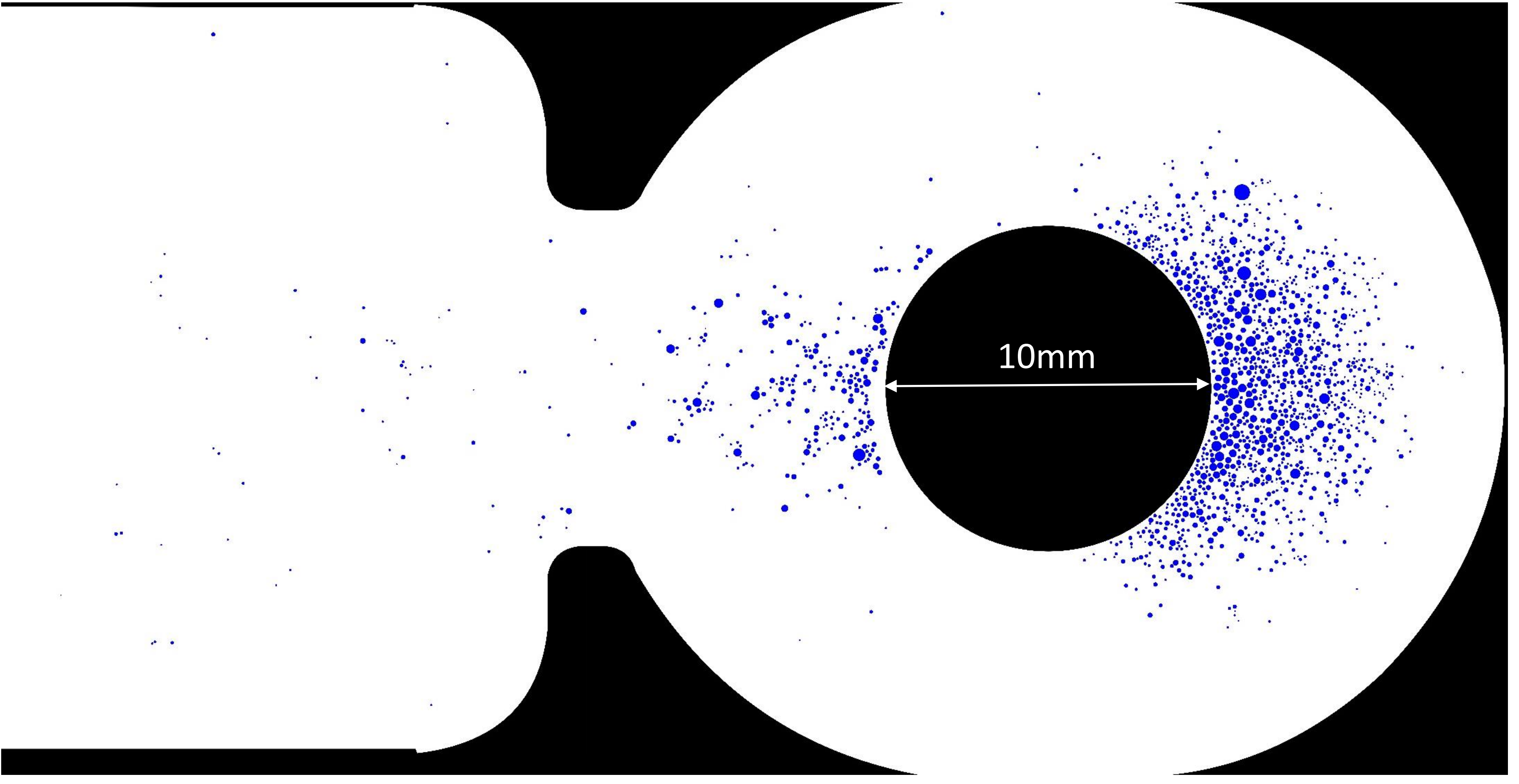
Cell 1 – Iris 1 Vs Sc-Field





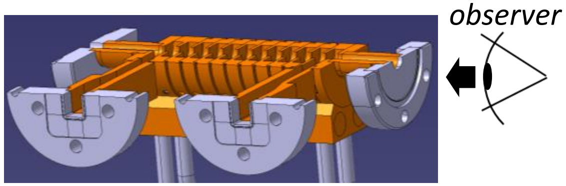
Cell 1 – Iris 2

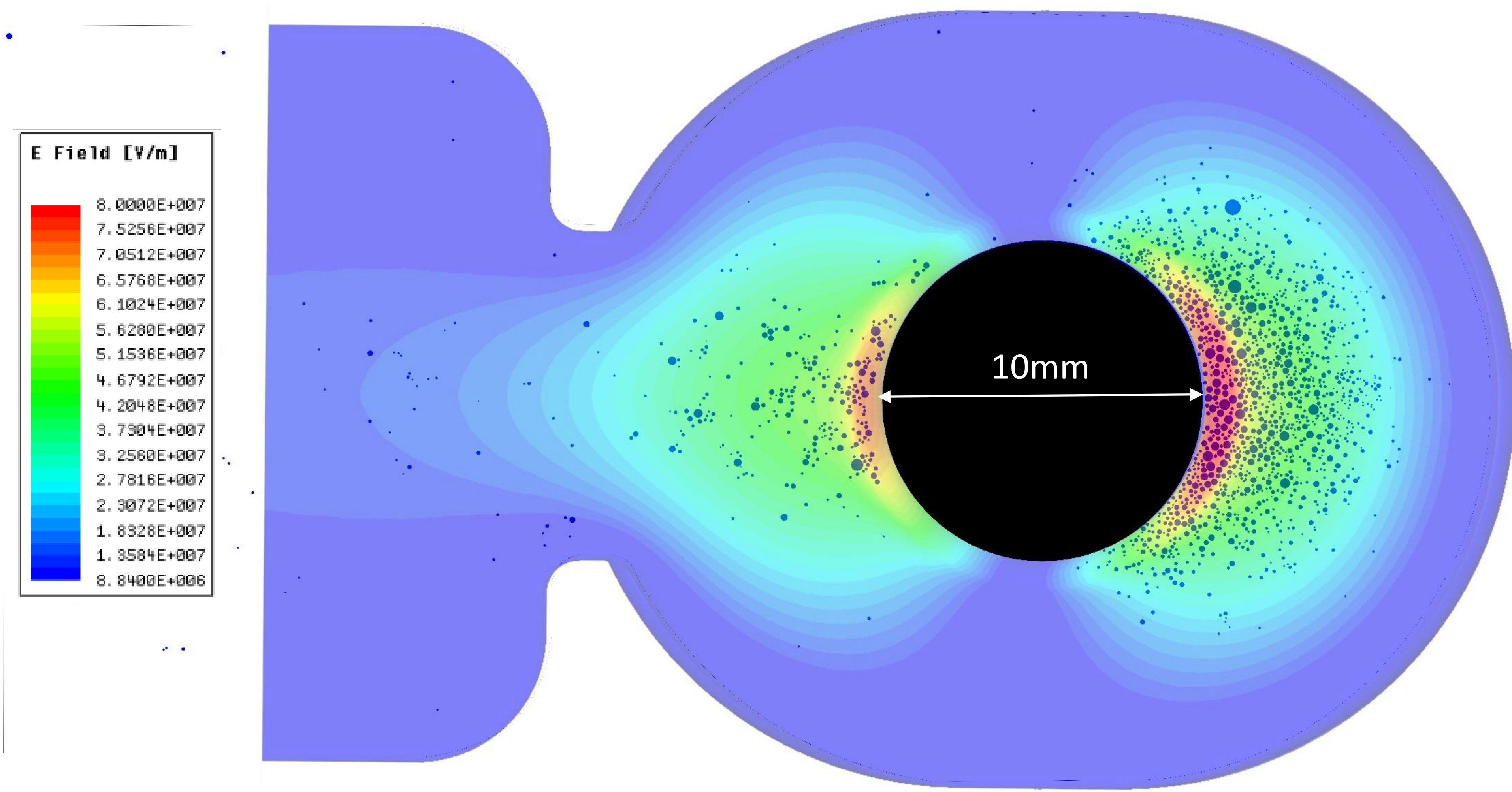




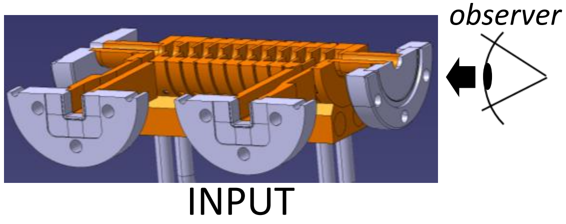
Number of sites BD sites = 1573

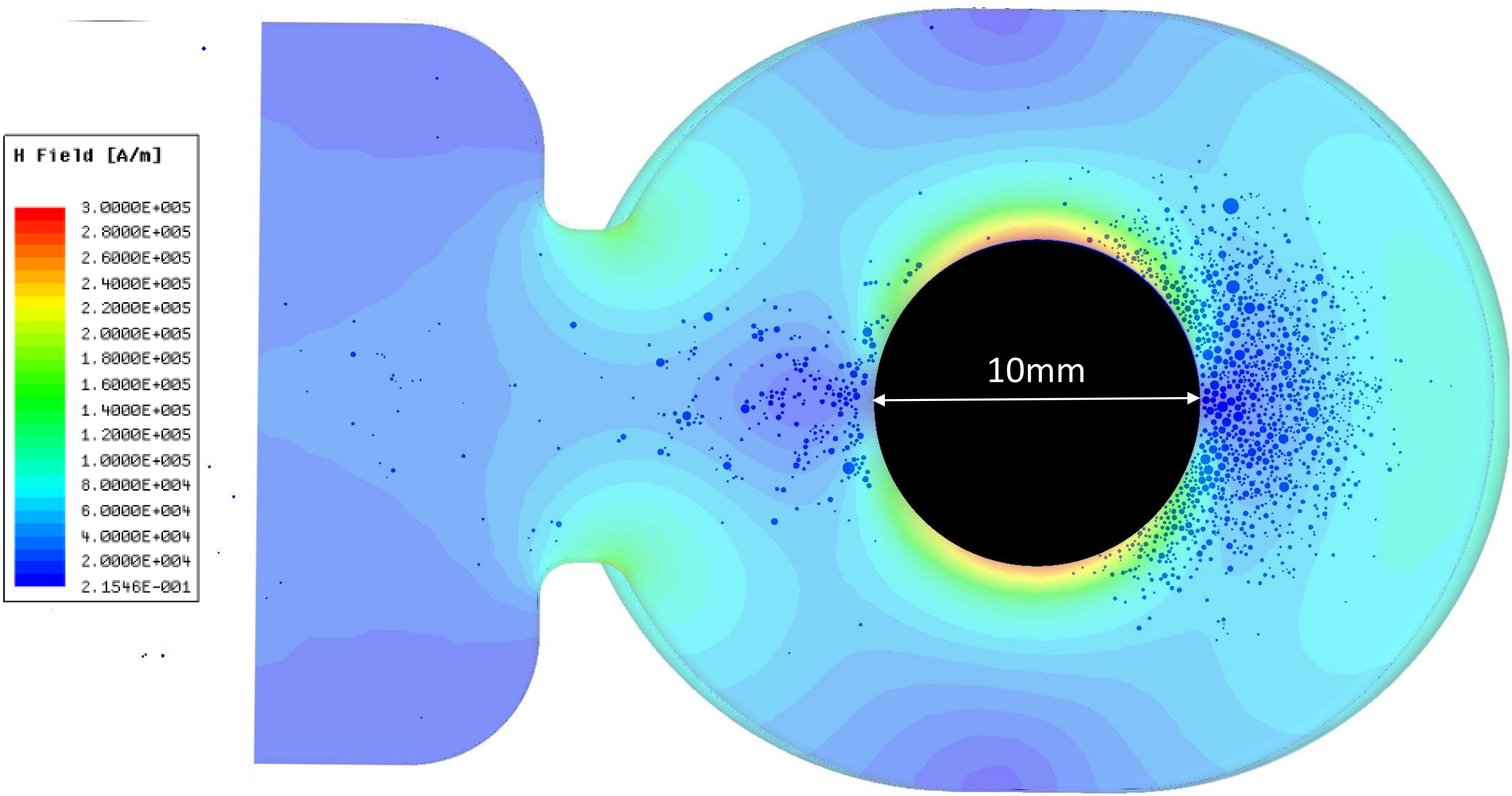
Cell 1 – Iris 2 Vs E-Field



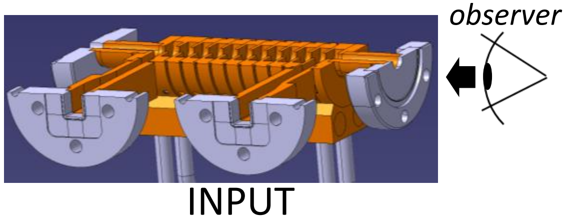


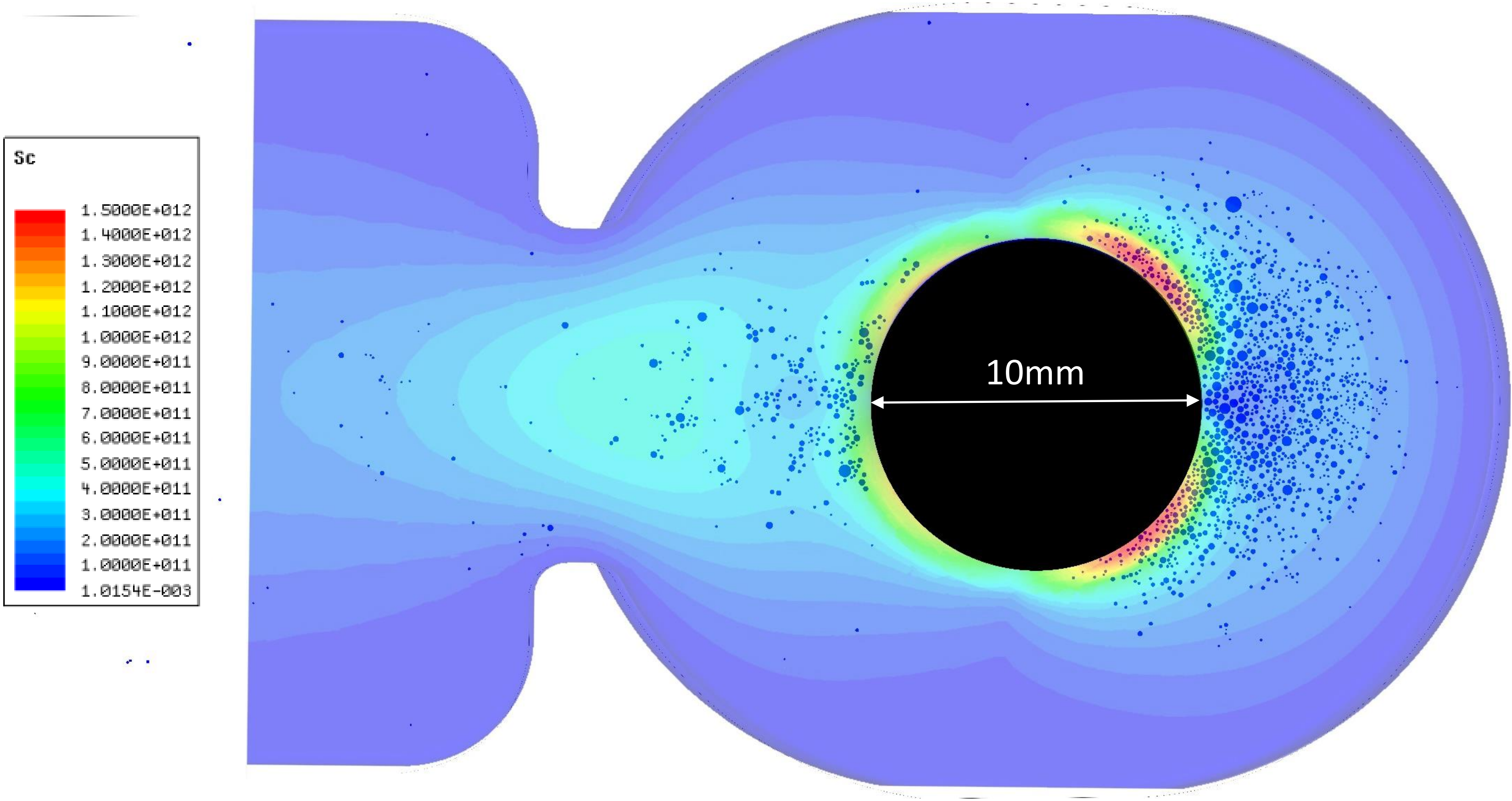
Cell 1 – Iris 2 Vs H-Field



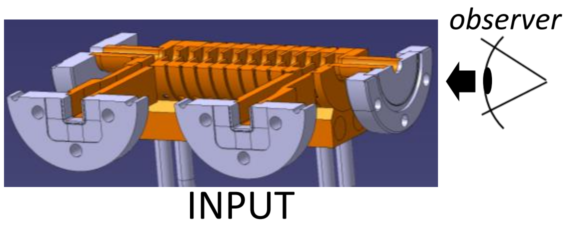


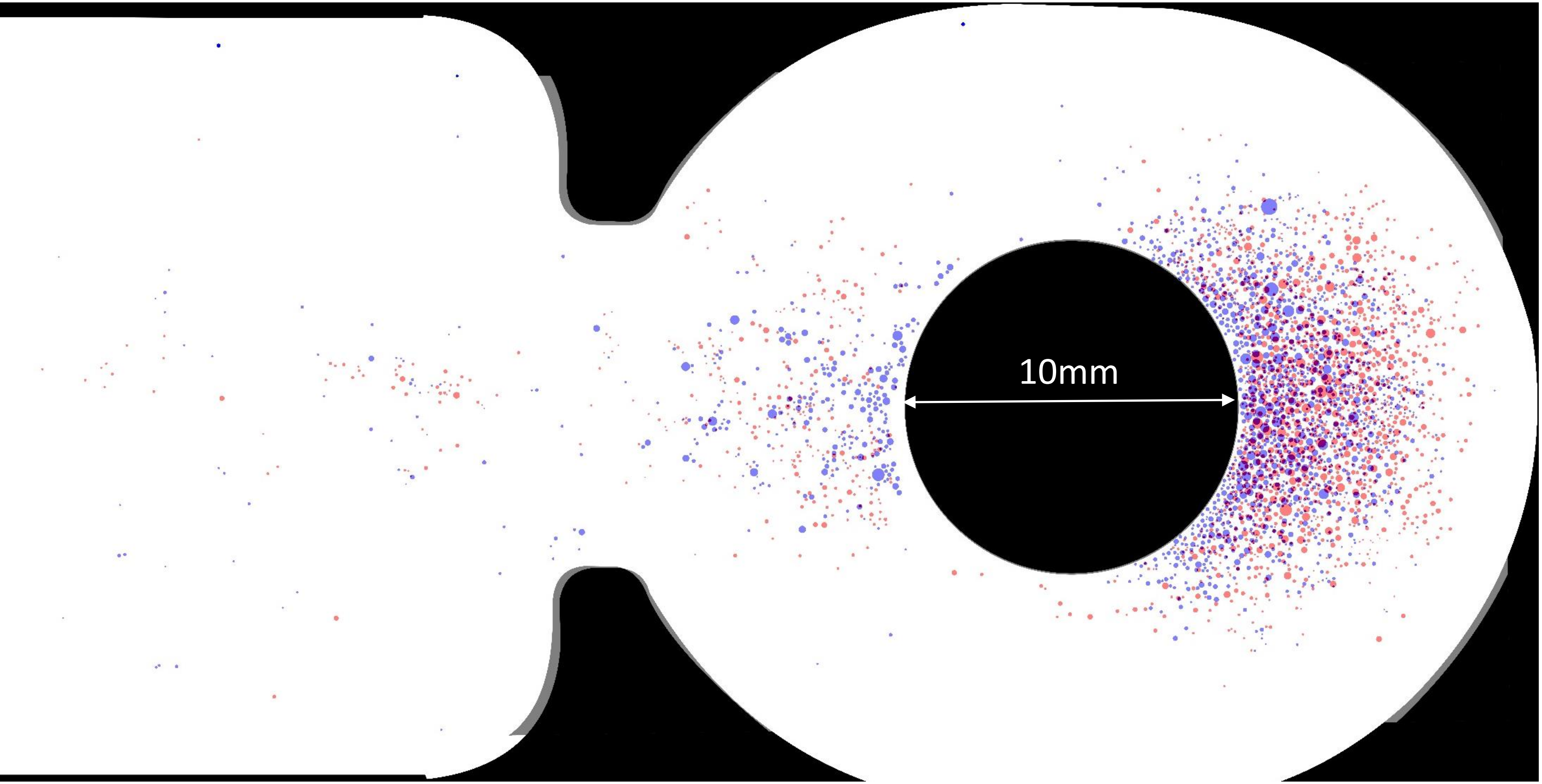
Cell 1 – Iris 2 Vs Sc-Field



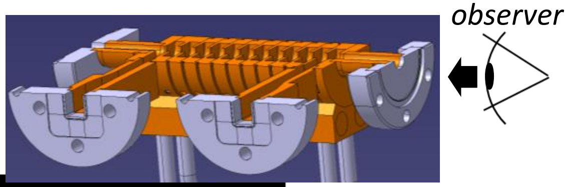


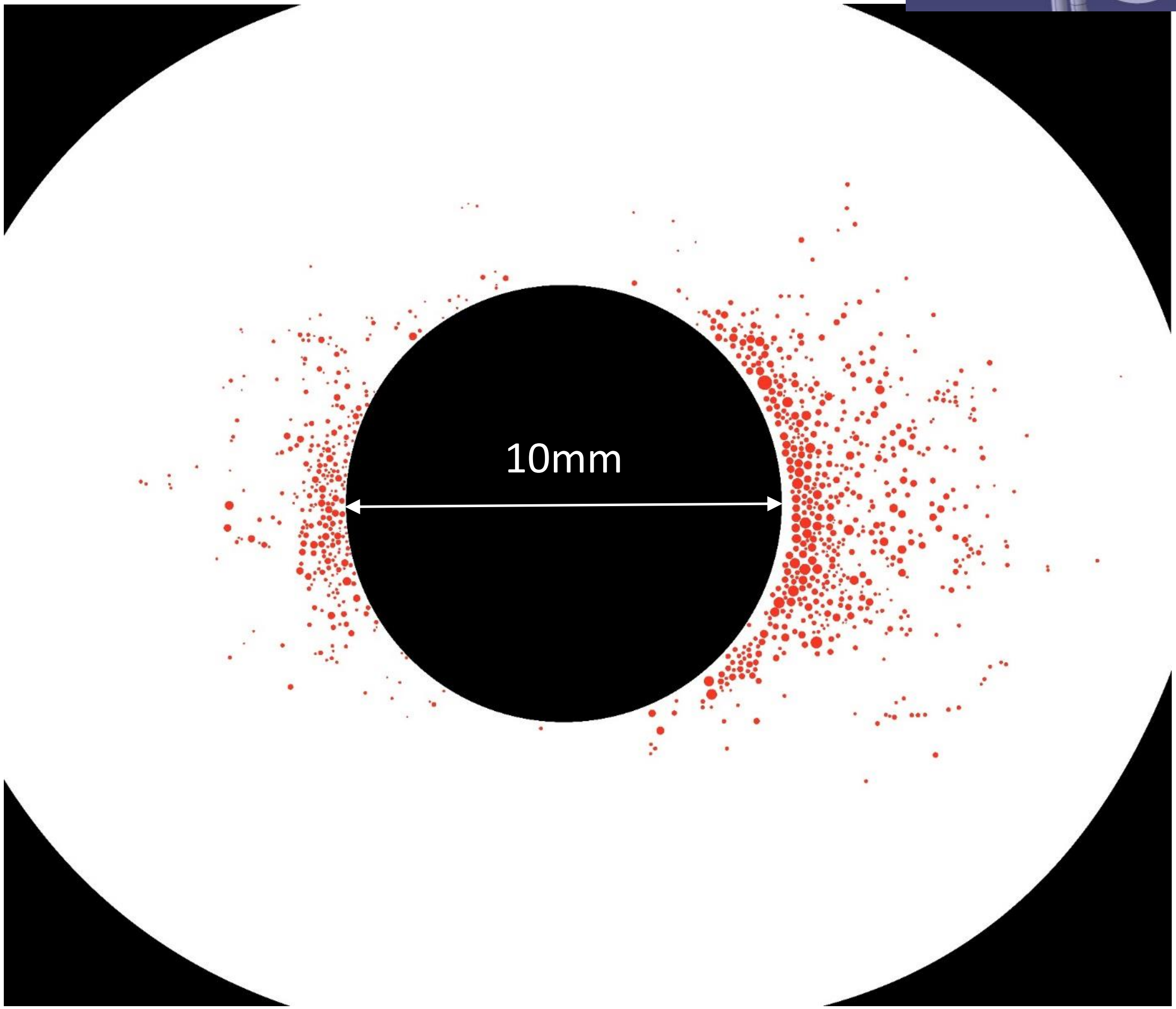
Cell 1 – Iris 1 Vs Cell 1 – Iris 2





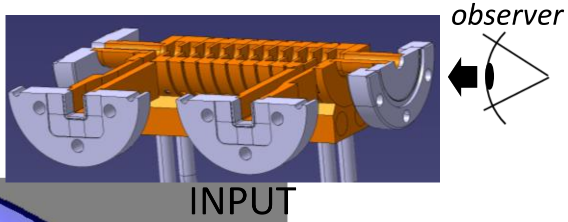
Cell 2 – Iris 1

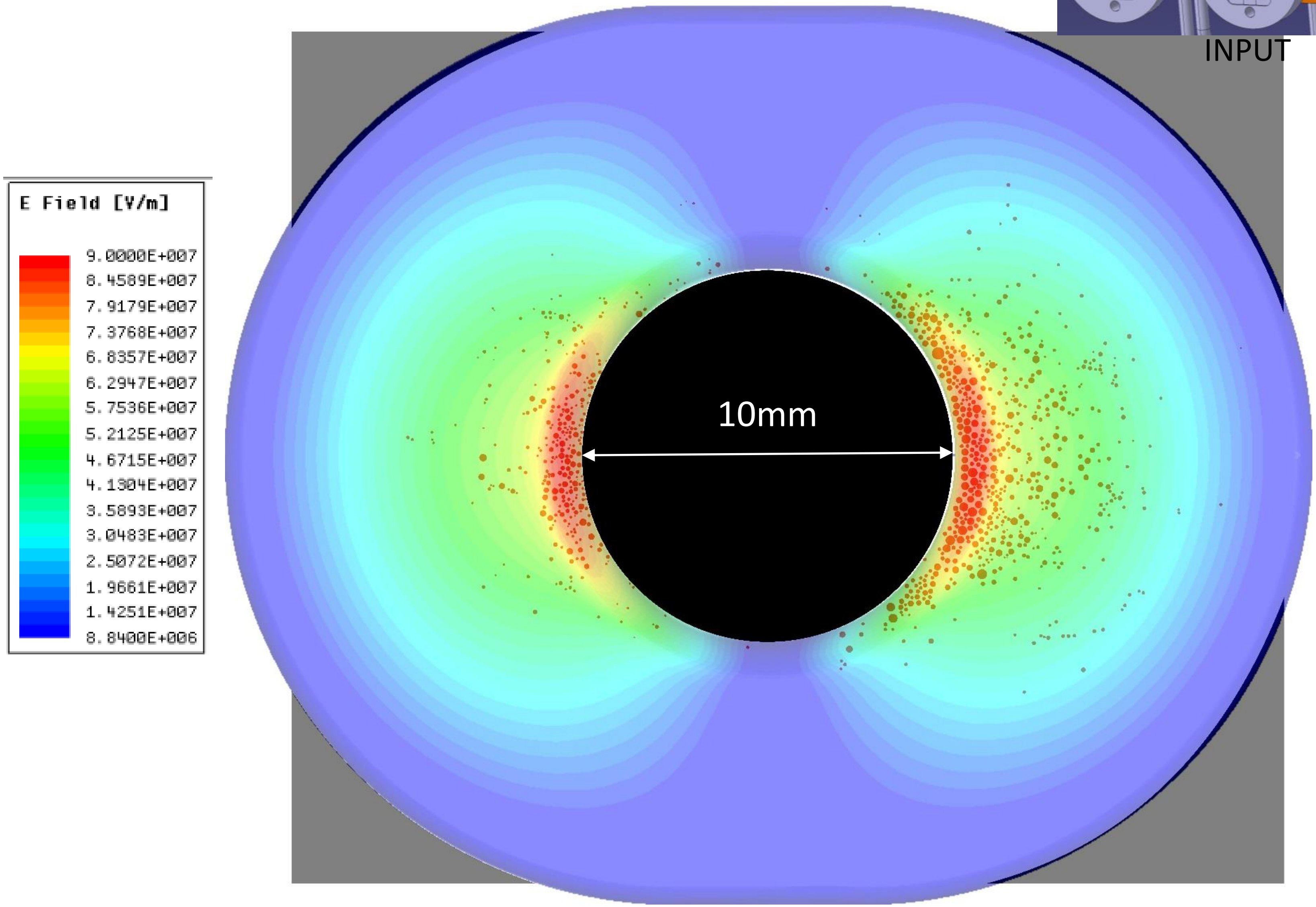




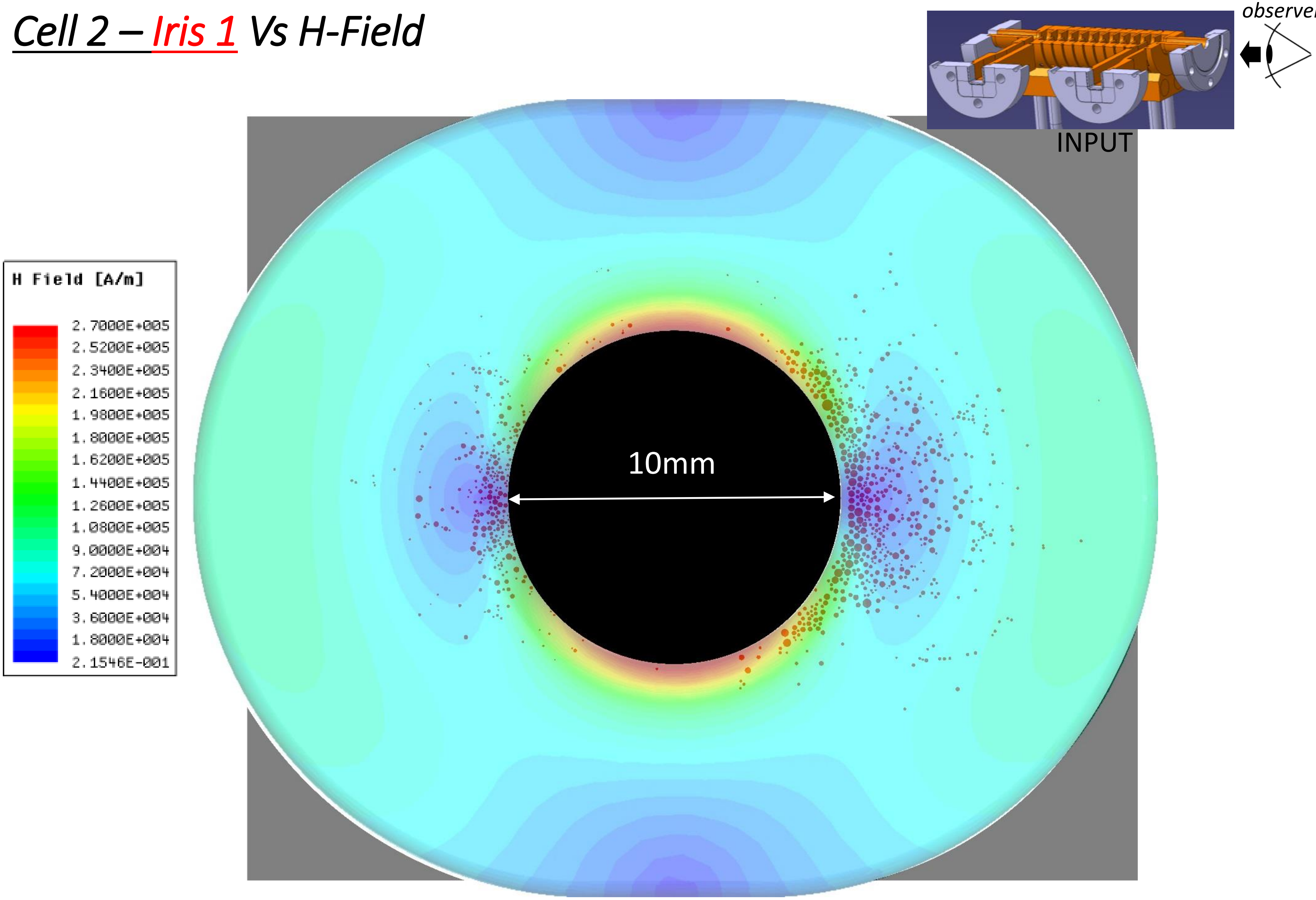
Number of sites BD sites = 917

Cell 2 – Iris 1 Vs E-Field

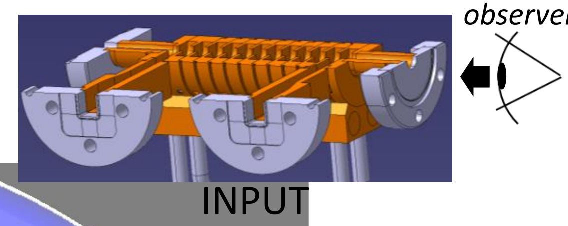


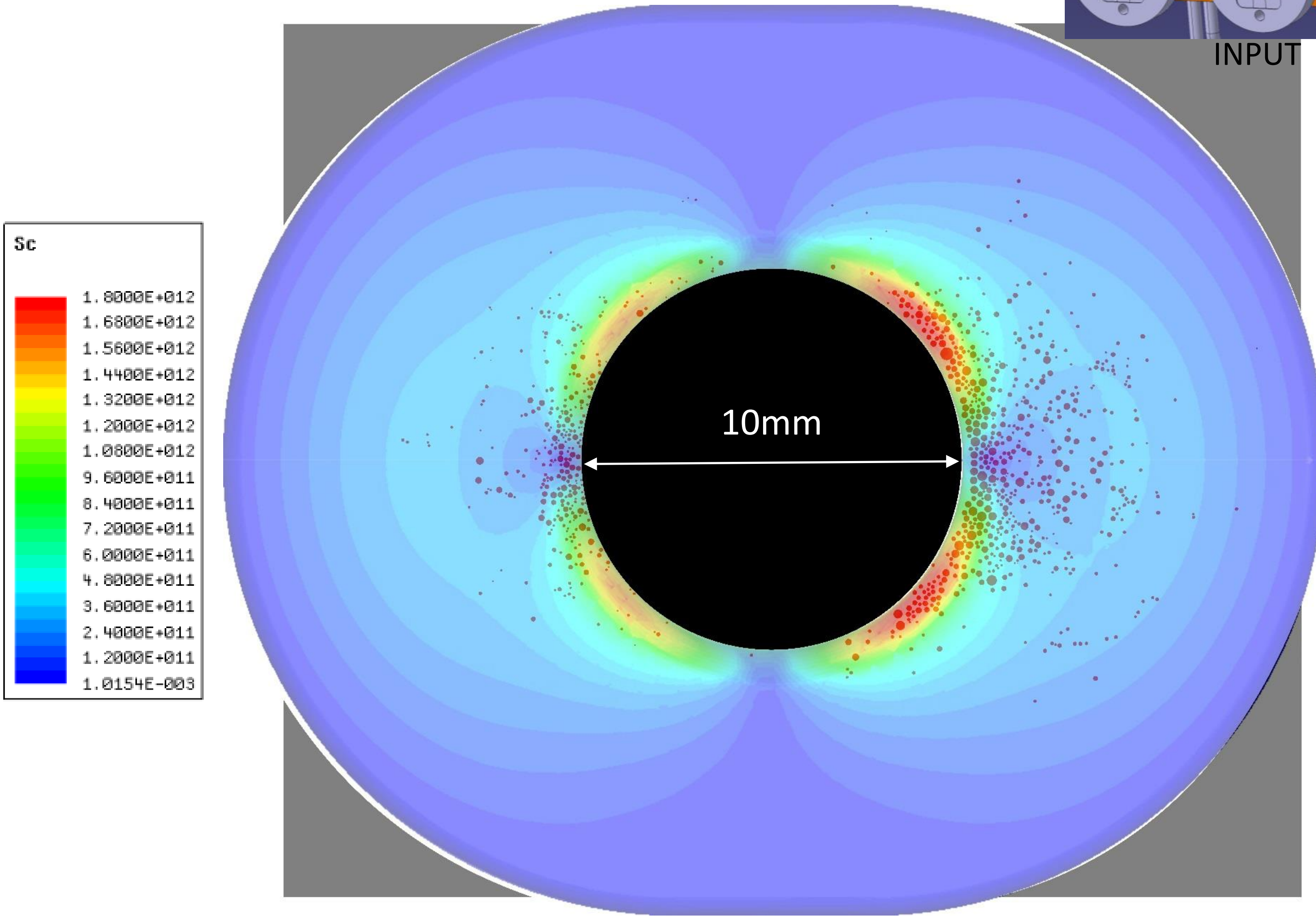


Cell 2 – Iris 1 Vs H-Field

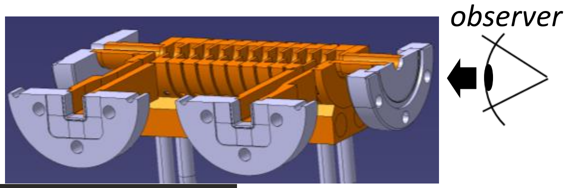


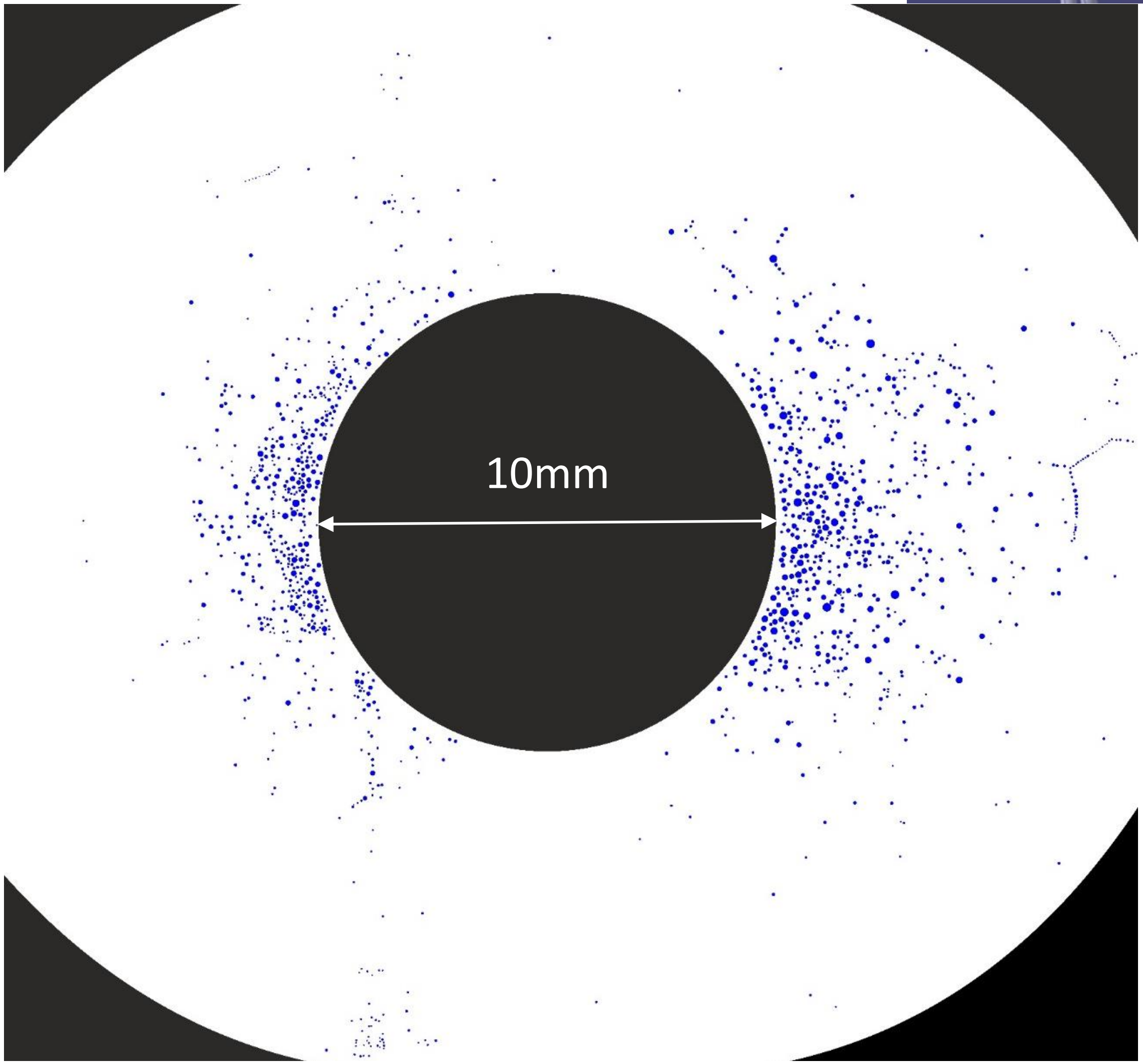
Cell 2 – Iris 1 Vs Sc-Field





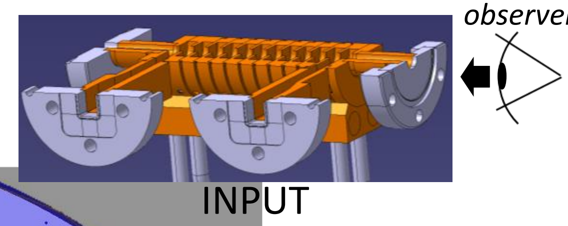
Cell 2 – Iris 2

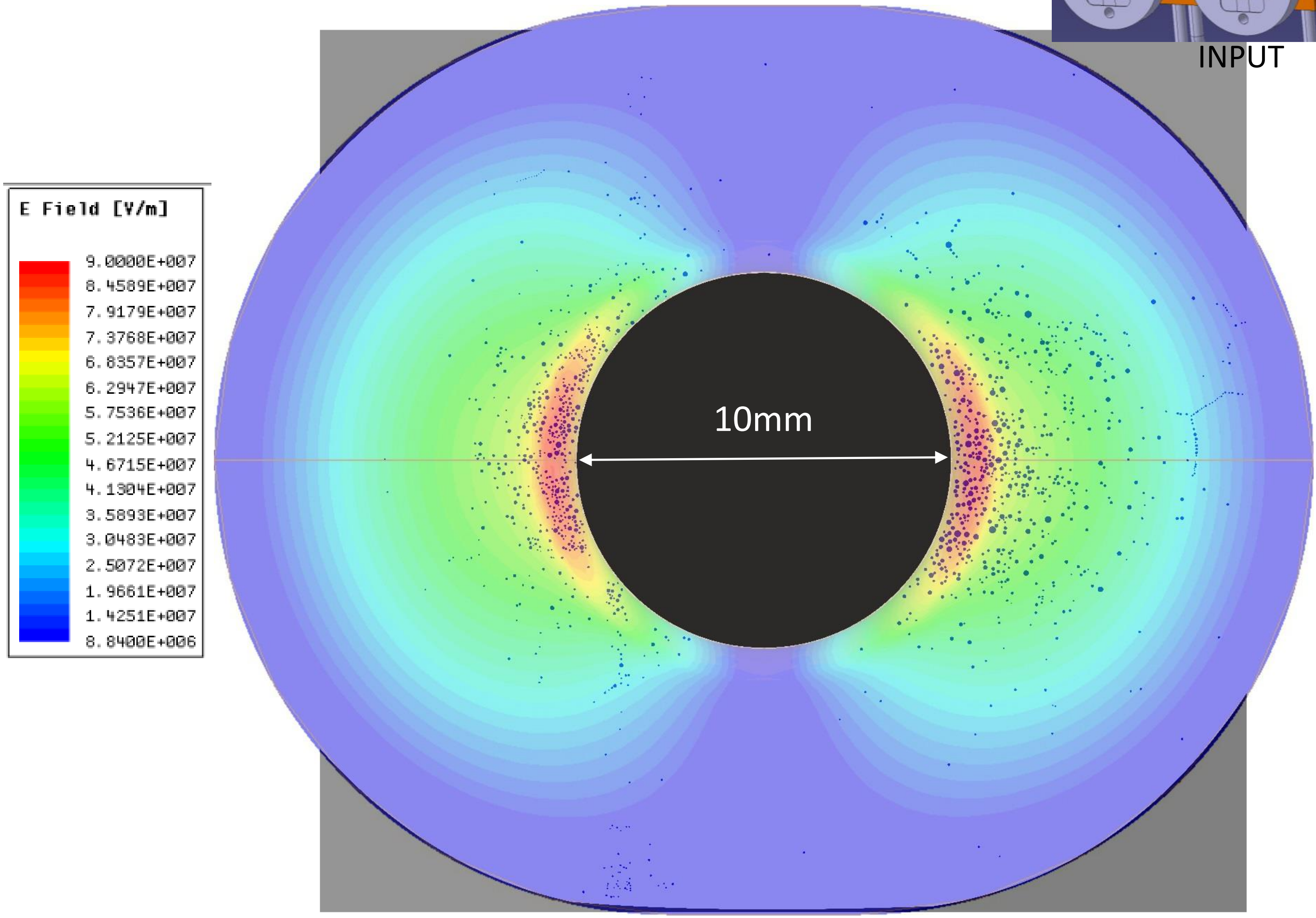




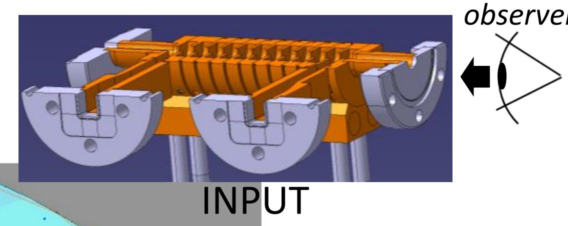
Number of sites BD sites = 1305

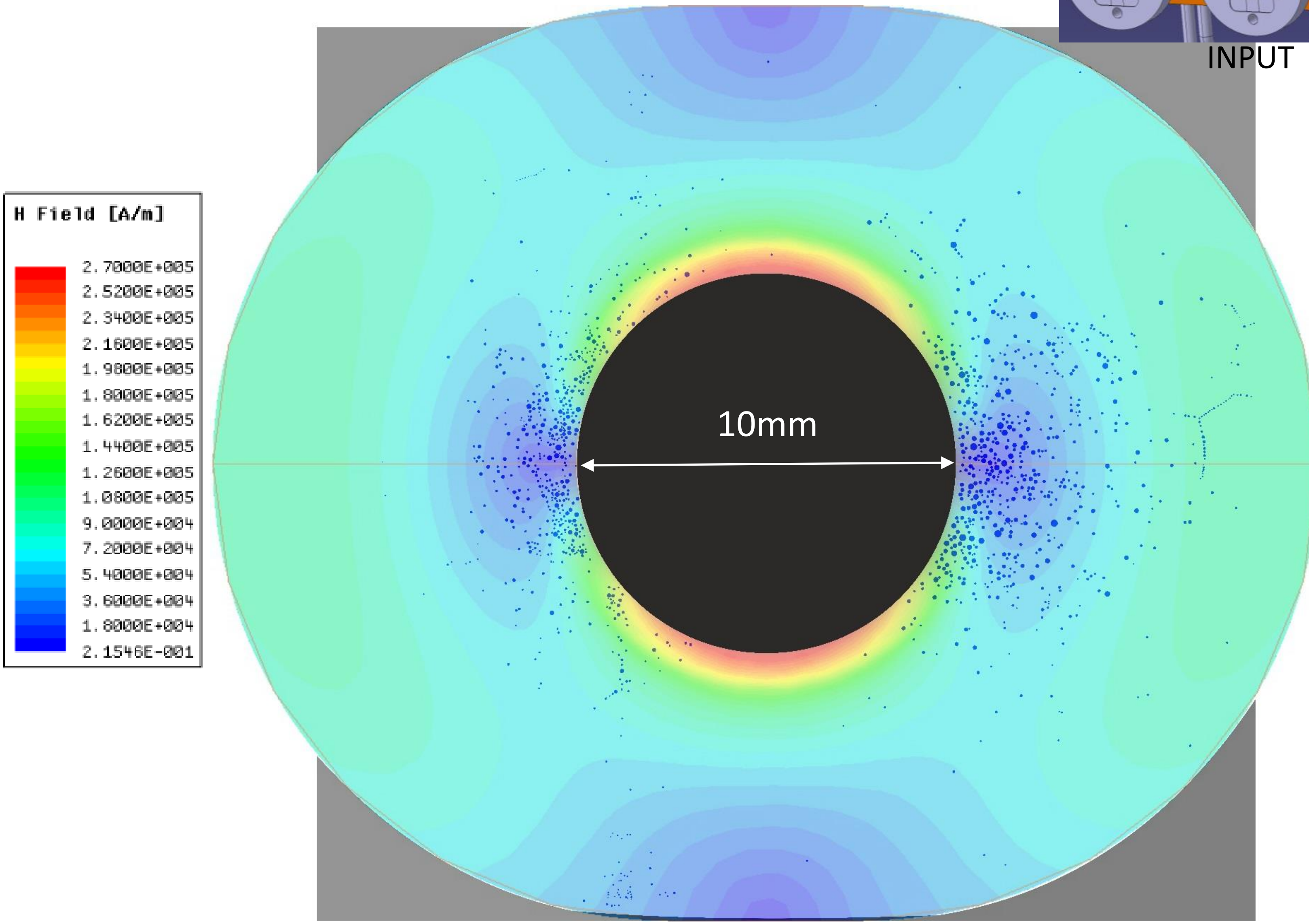
Cell 2 – Iris 2 Vs E-Field



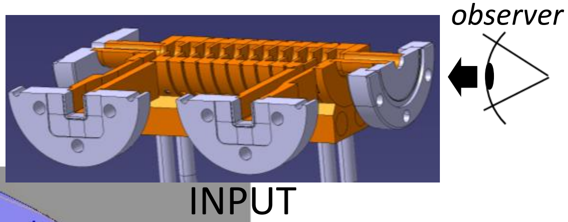


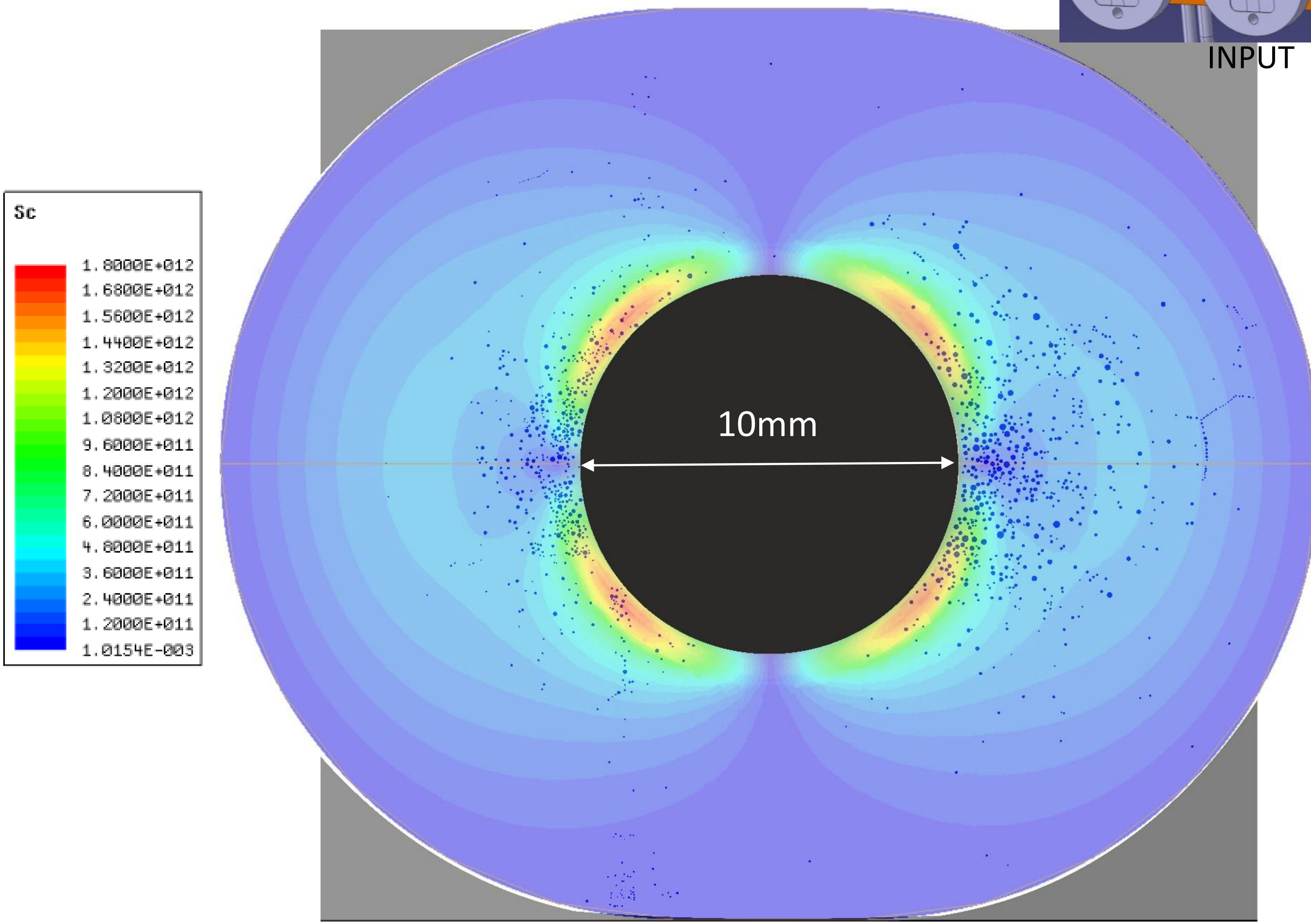
Cell 2 – Iris 2 Vs H-Field



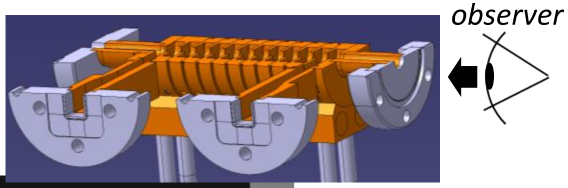


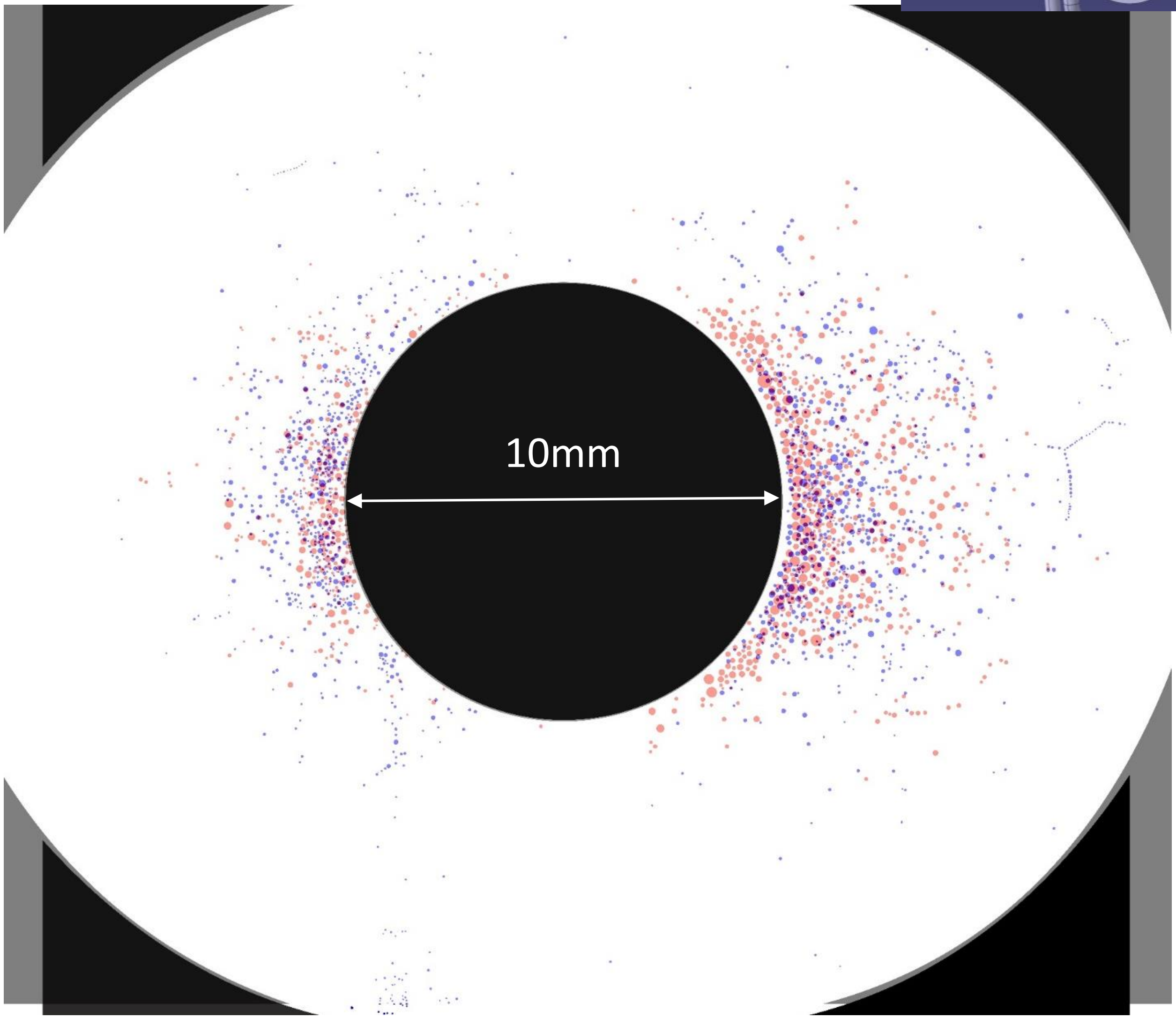
Cell 2 – Iris 2 Vs Sc-Field



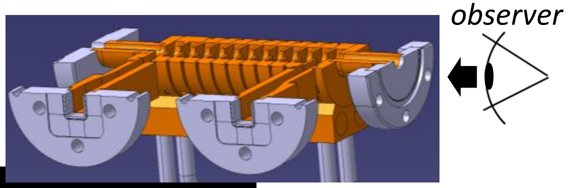


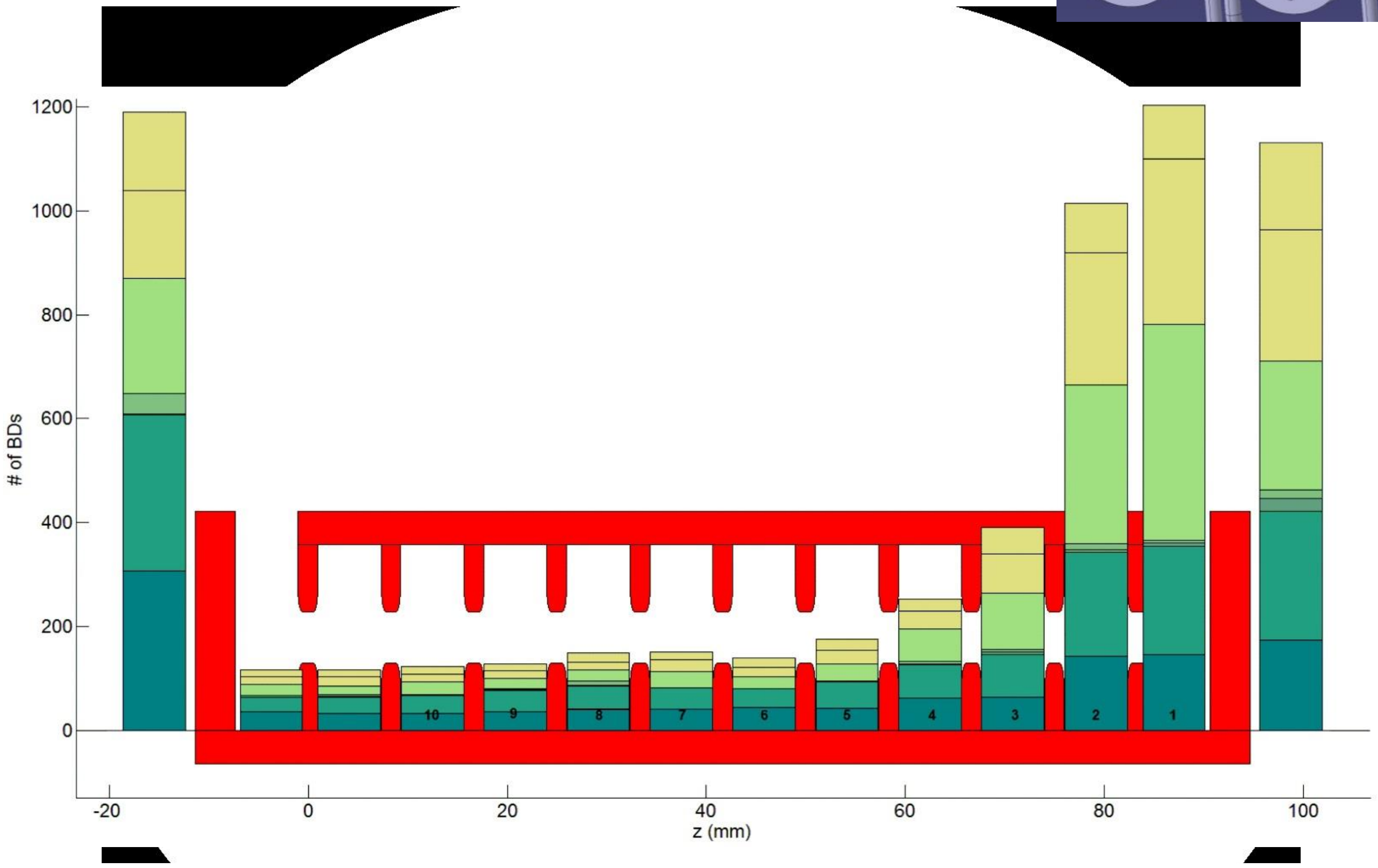
Cell 2 – Iris 1 Vs Cell 2 – Iris 2





Cell 3 - Iris 1

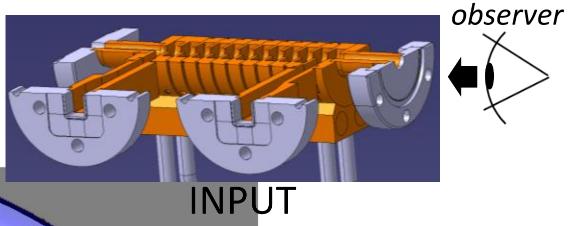


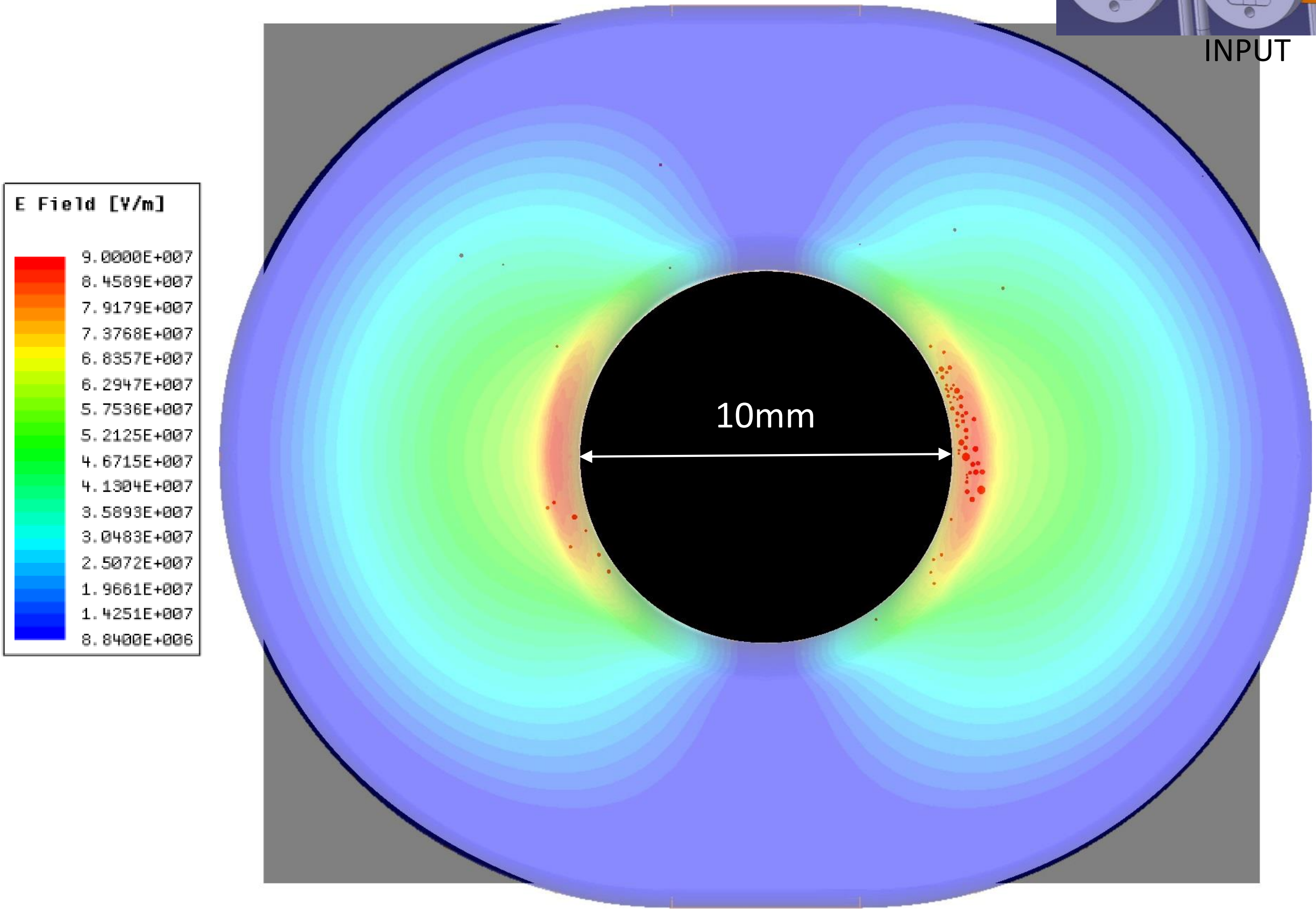


Histogram of the BD cell location, along with the month in which the BD occurred.

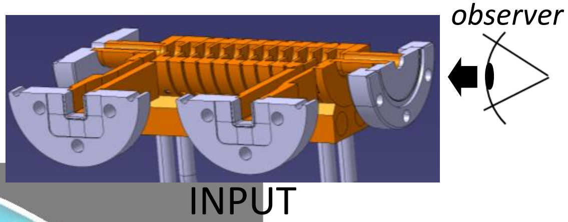
Number of sites BD sites = 69

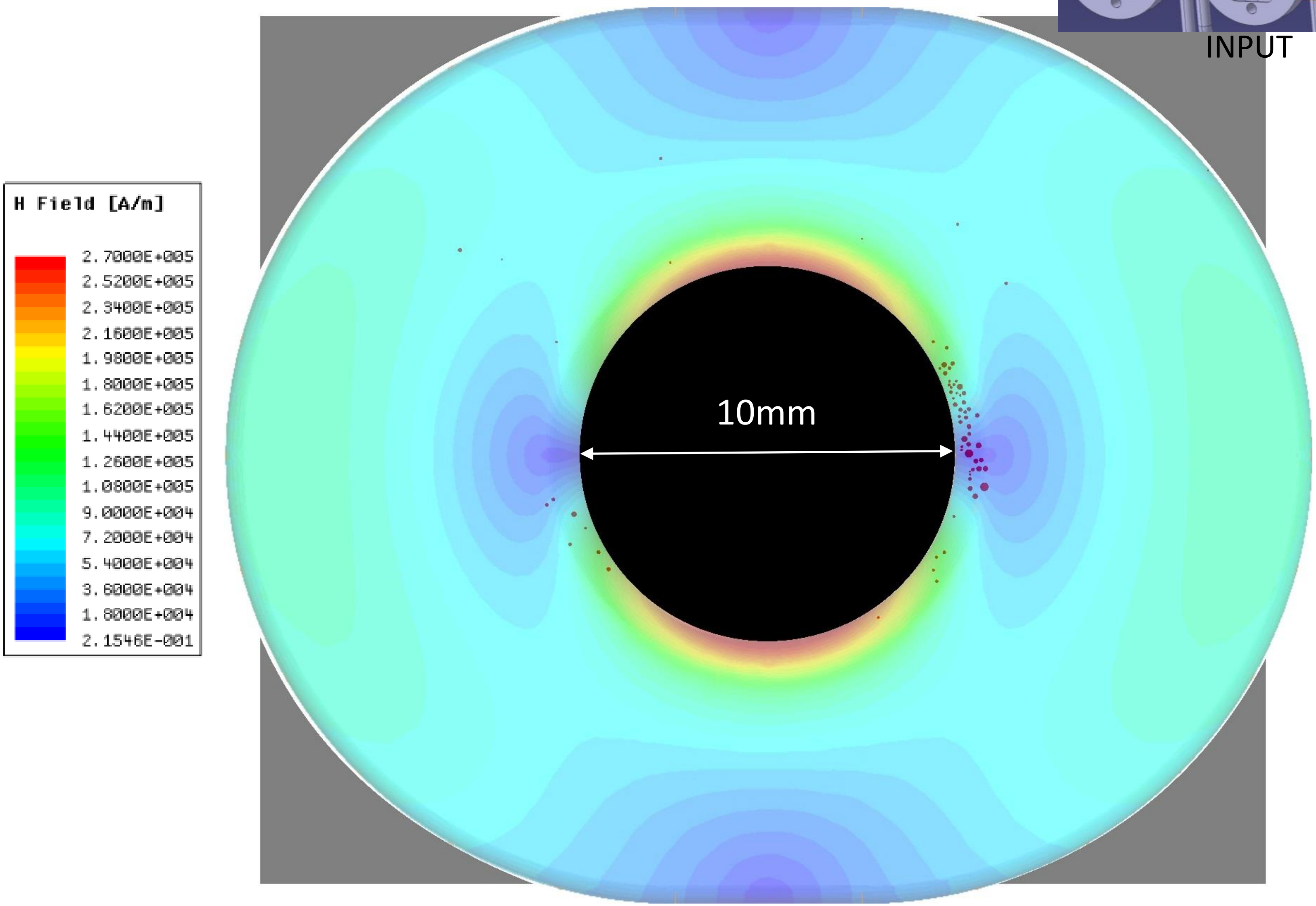
Cell 3 – Iris 1 Vs E-Field



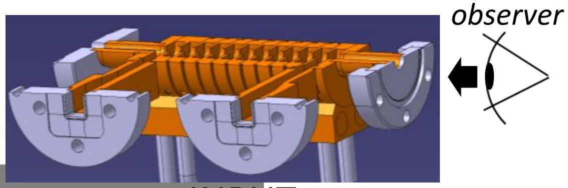


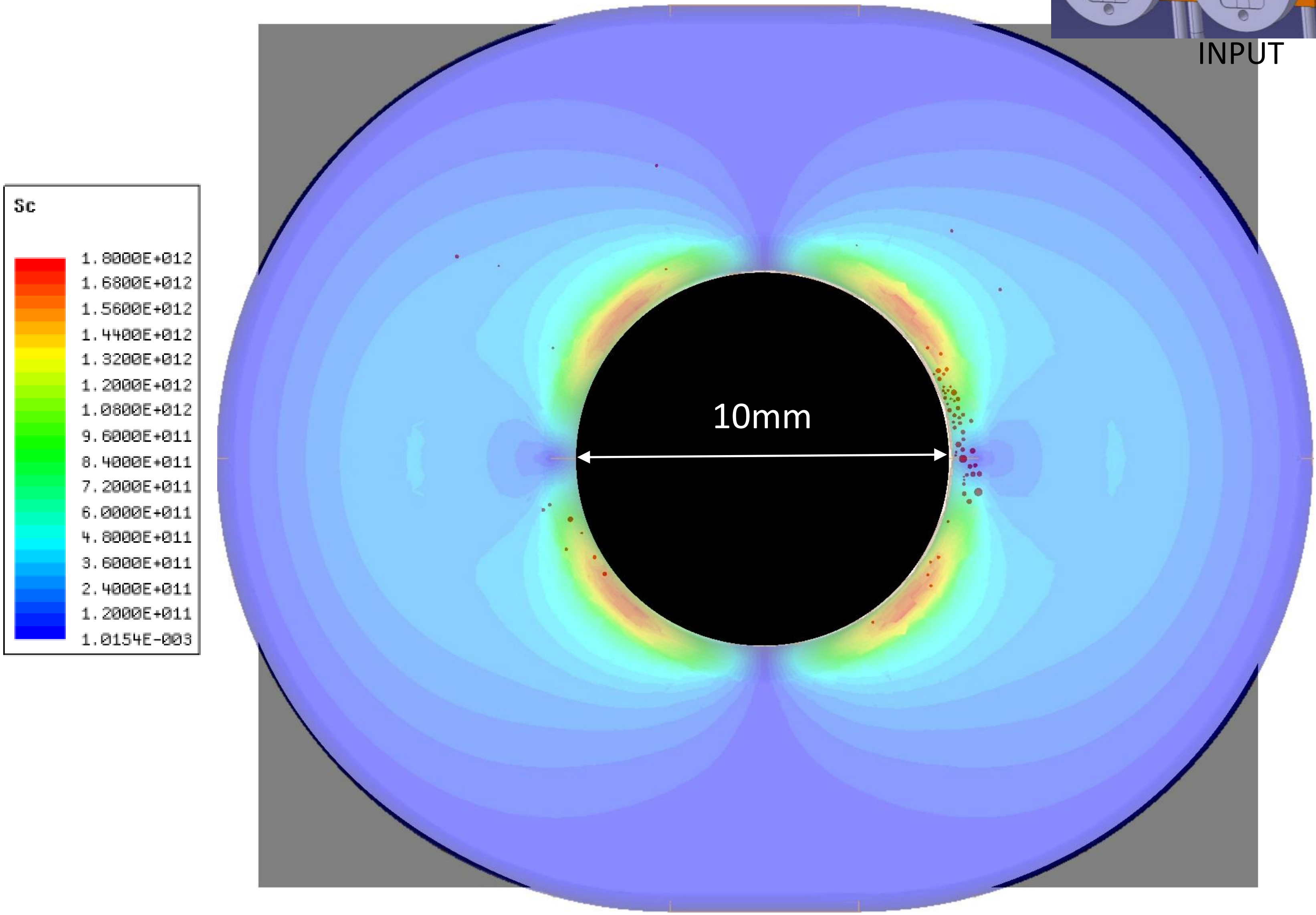
Cell 3 – Iris 1 Vs H-Field





Cell 3 – Iris 1 Vs Sc-Field





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  - BD distribution in the iris
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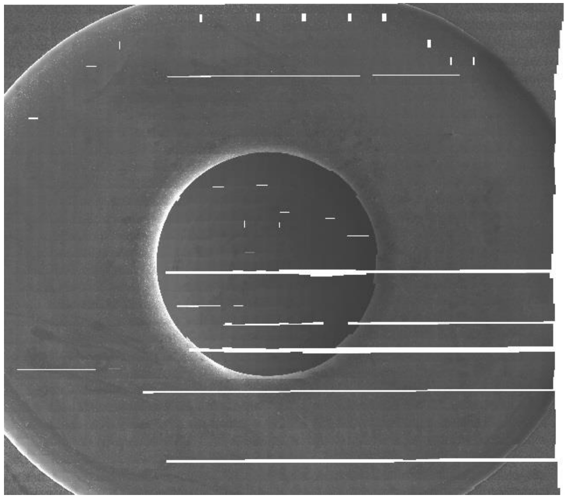
Acquisition of Images

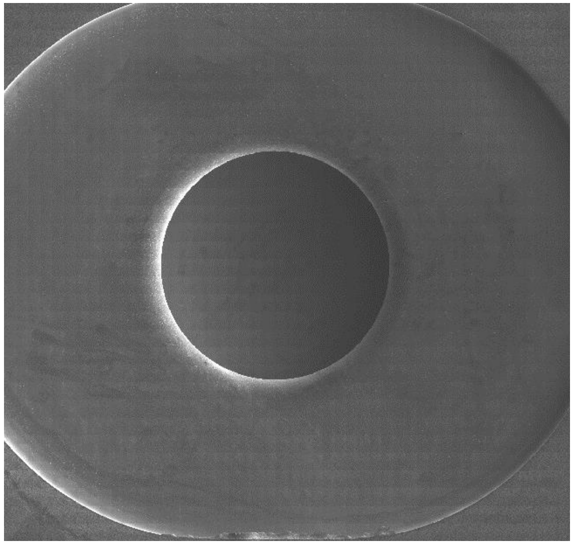
Multi-Scan with SEM

Acquisition of each global image (≈16h to 24h):

- Input Cell 5000 images/Iris
- Rest of Cells ≈ 3000 images/iris

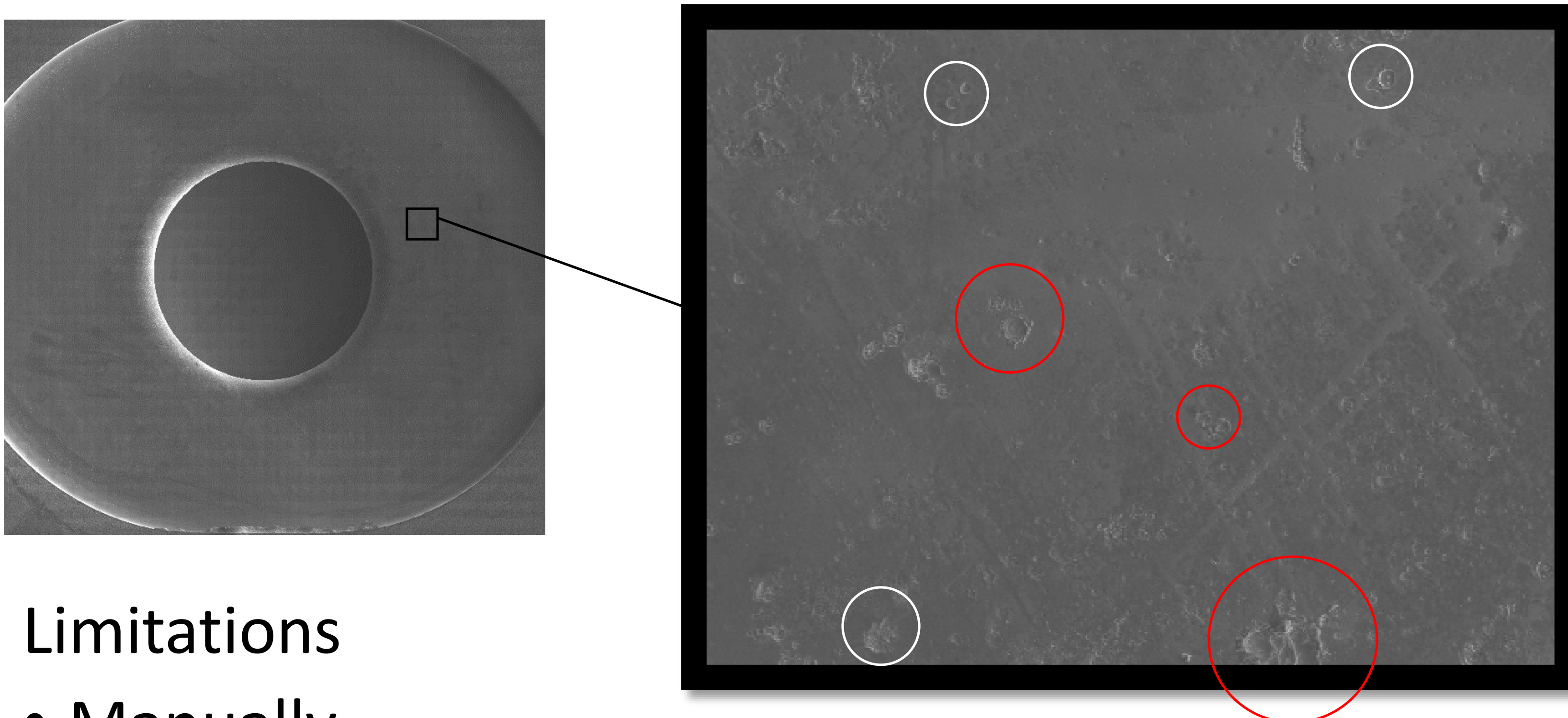


SmartSEM-SmartStitch ZEISS



Stitching with MATLAB

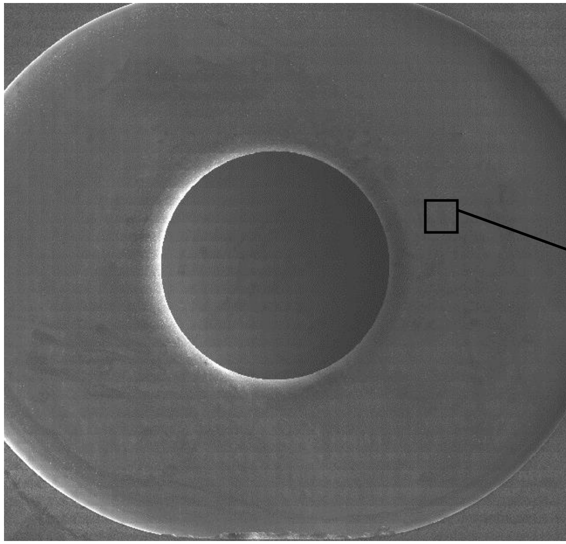
Counting of features

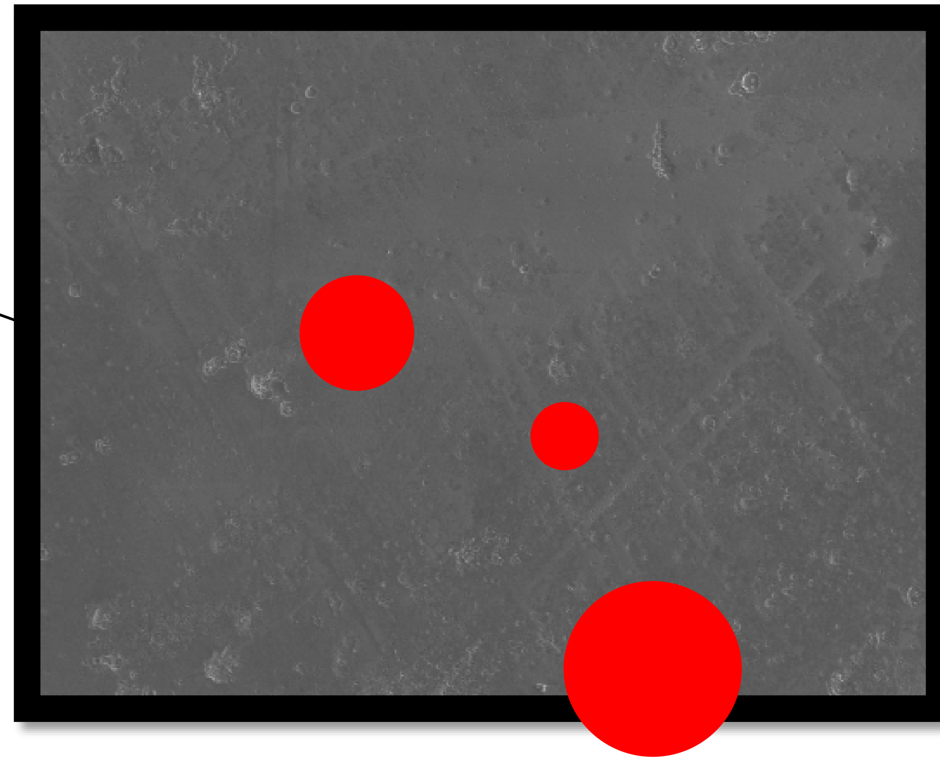


Limitations

- Manually
- Thousands of sites
- Conservative counting due to BD overlapping / various in the same site…
- Difficult due to surface state

Marking





Limitations

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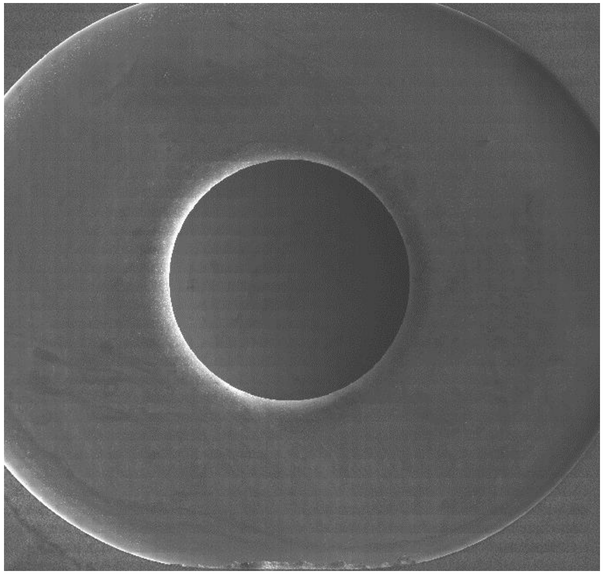
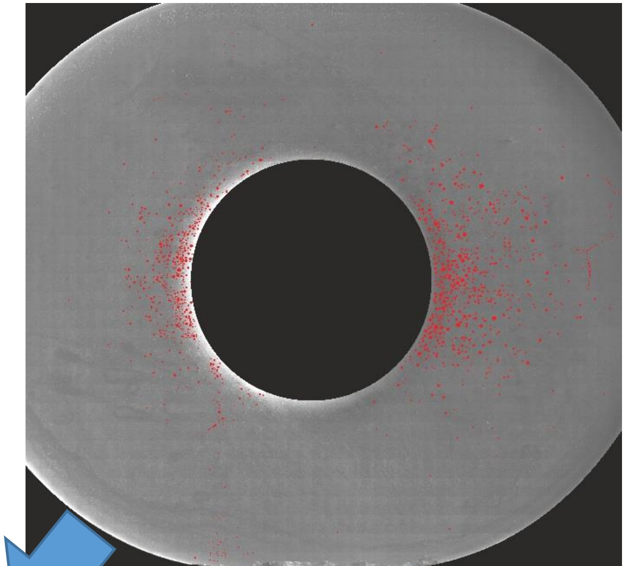
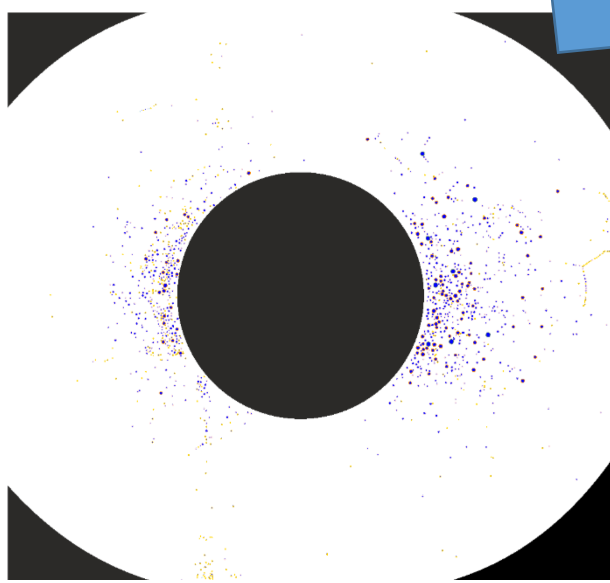
- Thousands of sites
- Conservative counting due to BD overlapping / various in the same site…
- Difficult due to surface status

Counting







Analysis of the mask with *Zeiss Axio Visio – Particle analyser* for an automatic counting of the features

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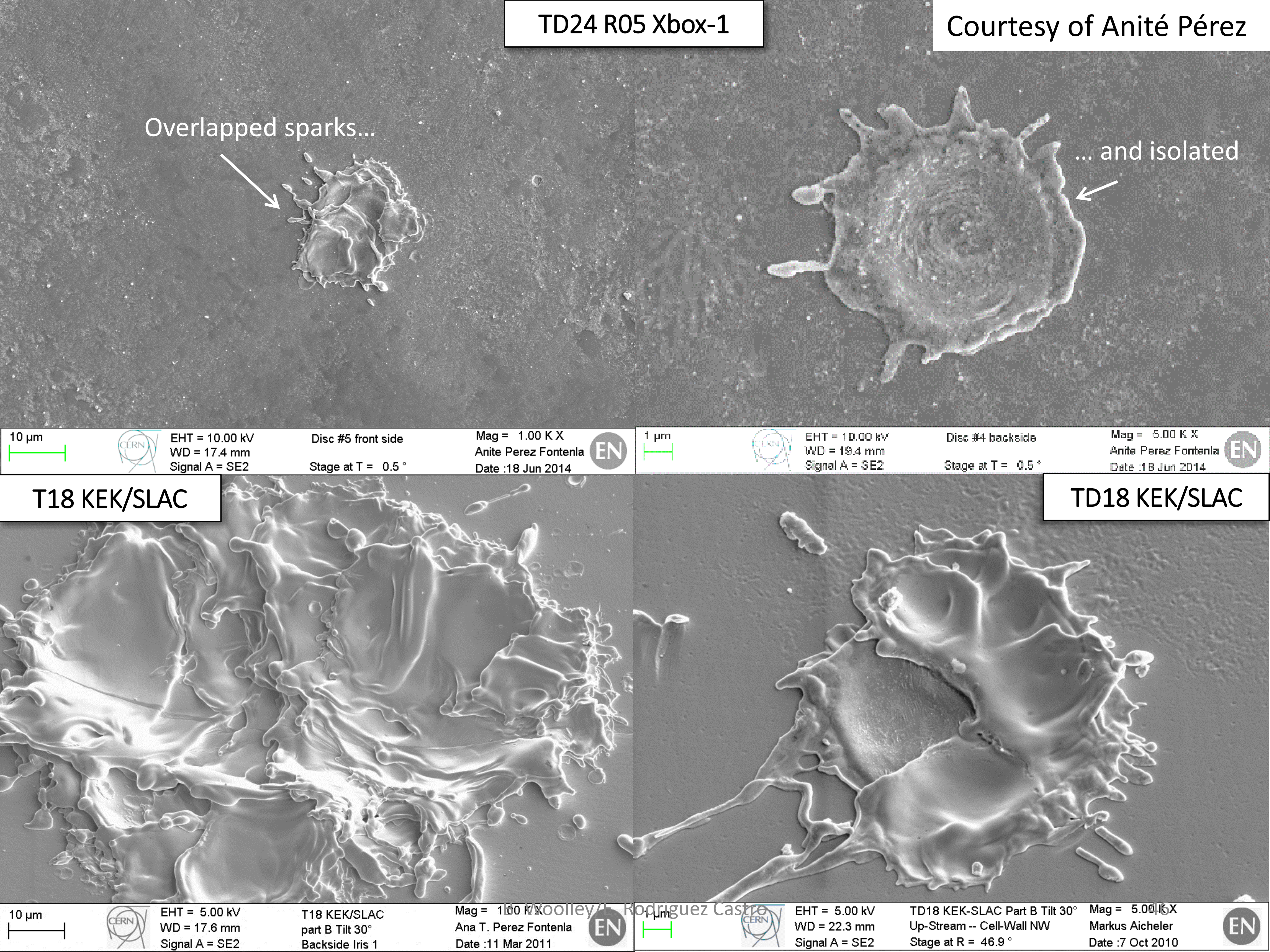
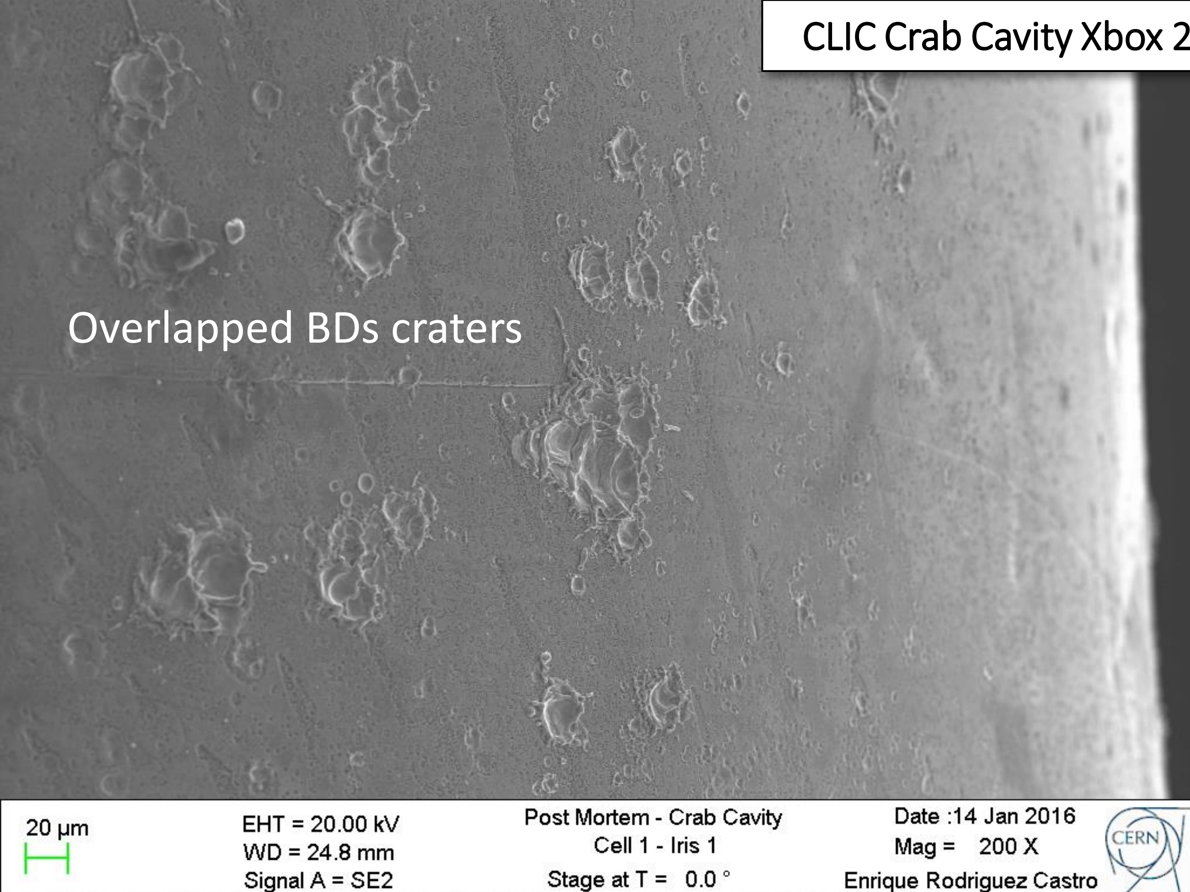
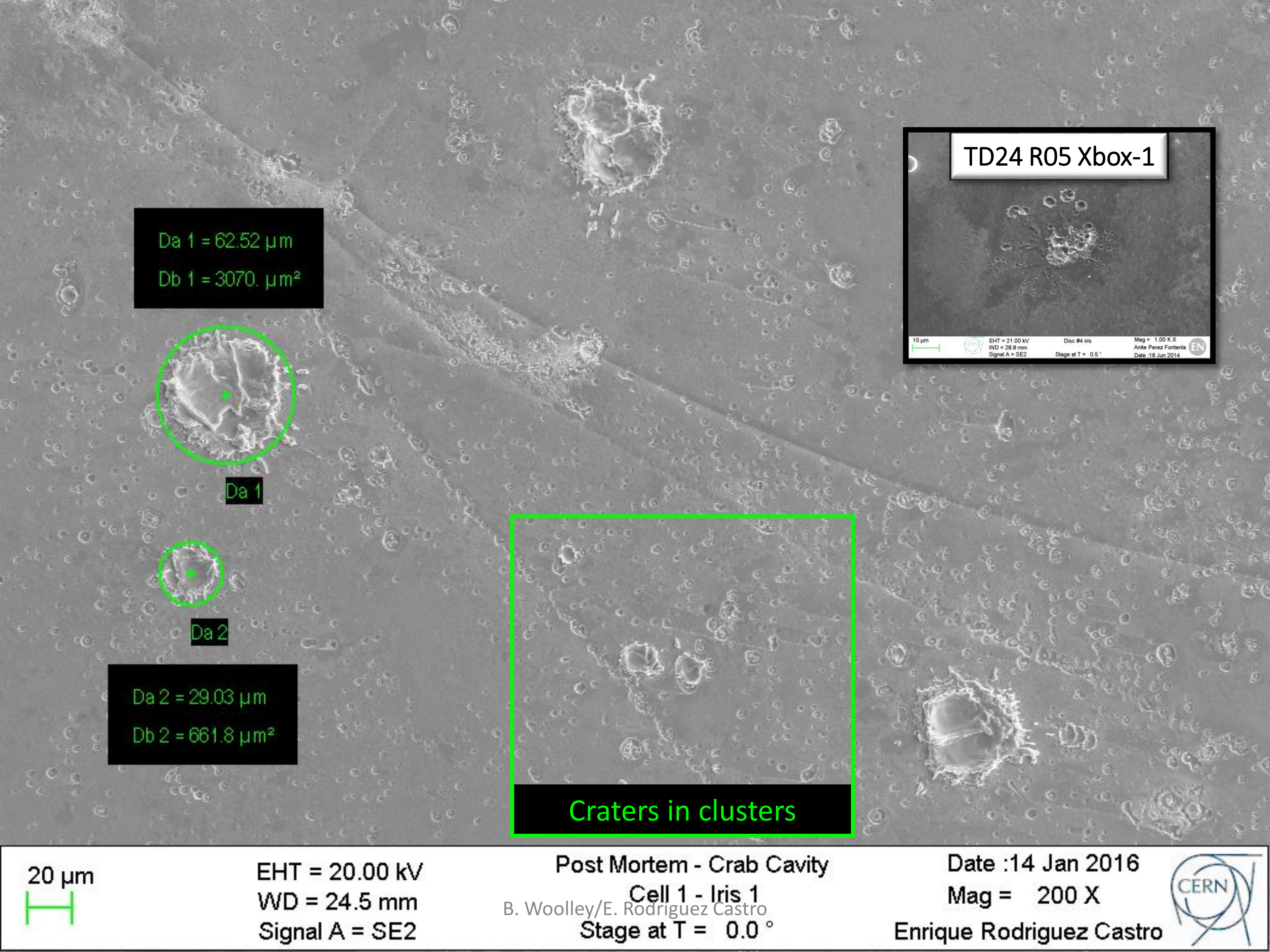

TD24 R05 Xbox-1
Courtesy of Anité Pérez
Overlapped sparks…
… and isolated
10 µm
EHT = 10.00 kV
WD = 17.4 mm
Signal A = SE2
Disc #5 front side
Stage at T = 0.5 °
Mag = 1.00 K X
Anite Perez Fontenla
Date :18 Jun 2014
1 µm
EHT = 10.00 kV
WD = 19.4 mm
Signal A = SE2
Disc #4 backside
Stage at T = 0.5 °
Mag = 5.00 K X
Anite Perez Fontenla
Date :18 Jun 2014
T18 KEK/SLAC
TD18 KEK/SLAC
10 µm
EHT = 5.00 kV
WD = 17.6 mm
Signal A = SE2
T18 KEK/SLAC
part B Tilt 30°
Backside Iris 1
Ana T. Perez Fontenla
Date :11 Mar 2011
1 µm
EHT = 5.00 kV
WD = 22.3 mm
Signal A = SE2
TD18 KEK-SLAC Part B Tilt 30°
Up-Stream -- Cell-Wall NW
Stage at R = 46.9 °
Markus Aicheler
Date :7 Oct 2010

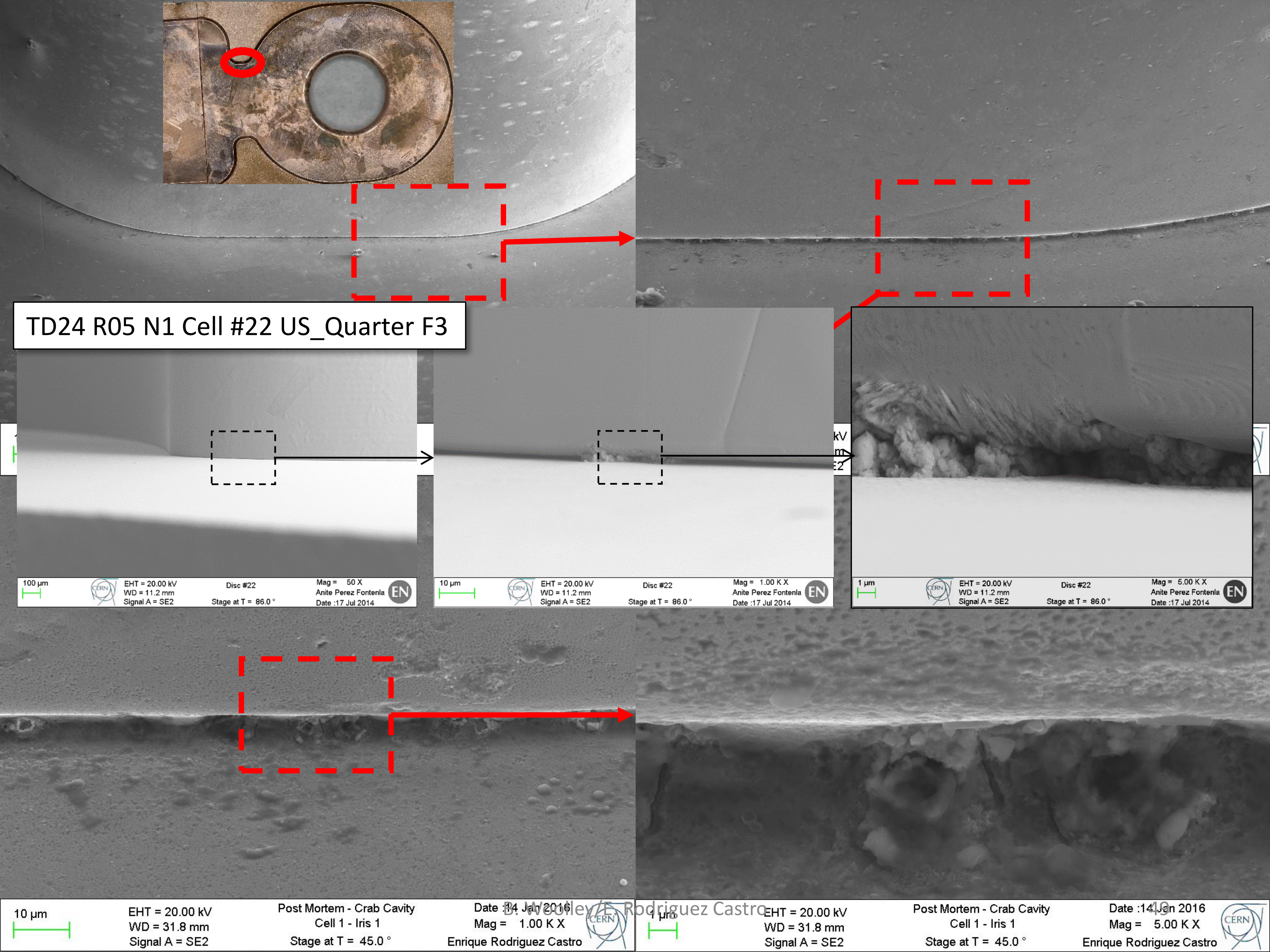
CLIC Crab Cavity Xbox 2

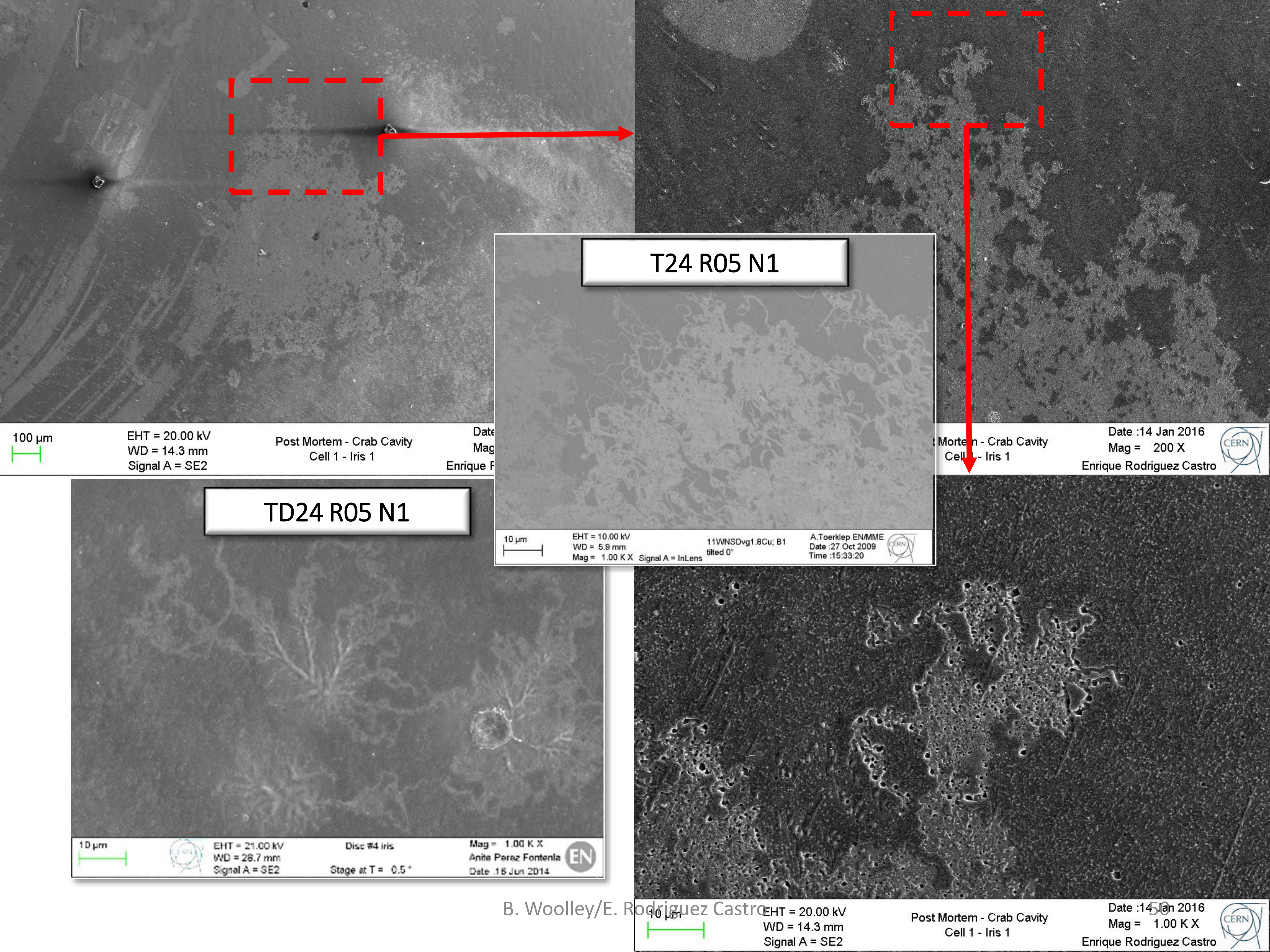


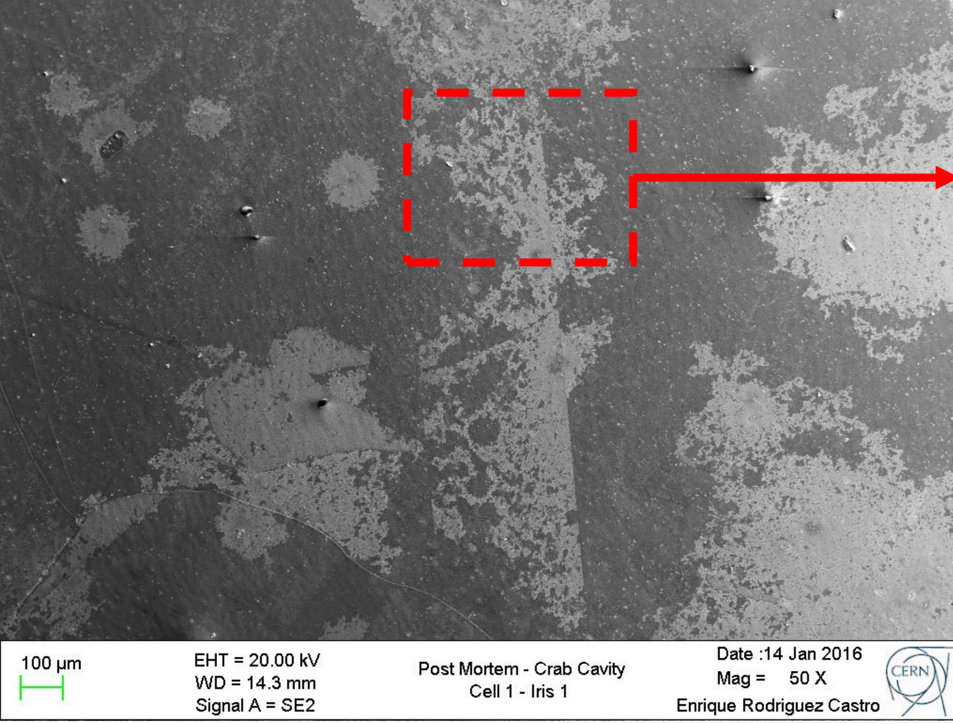


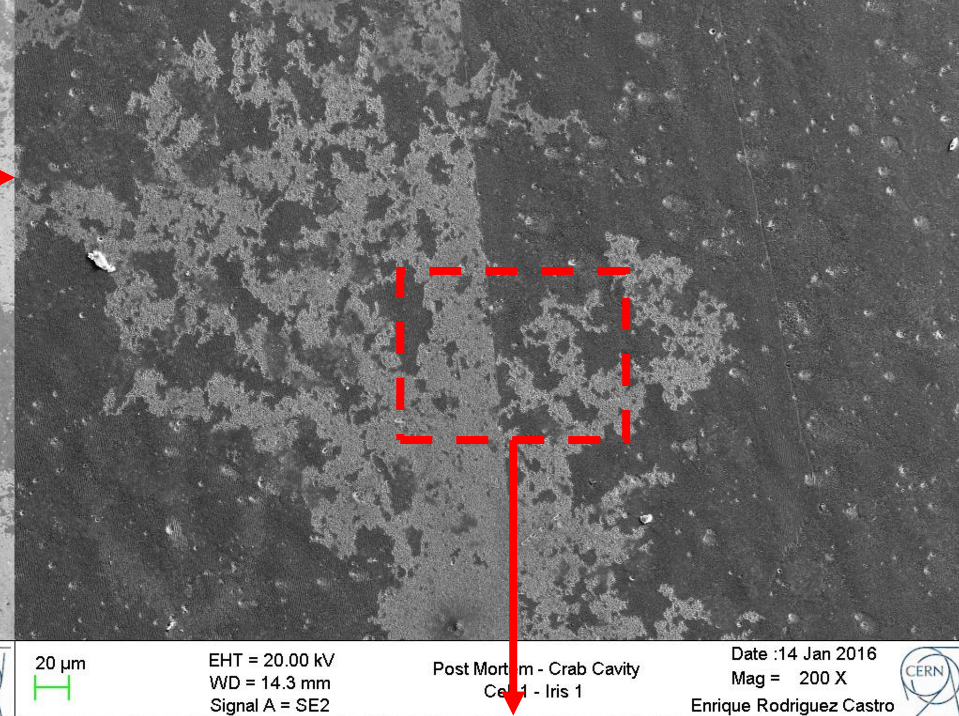
B. Woolley/E. Rodriguez Castro

TD24 R05 N1 Cell #22 US_Quarter F3

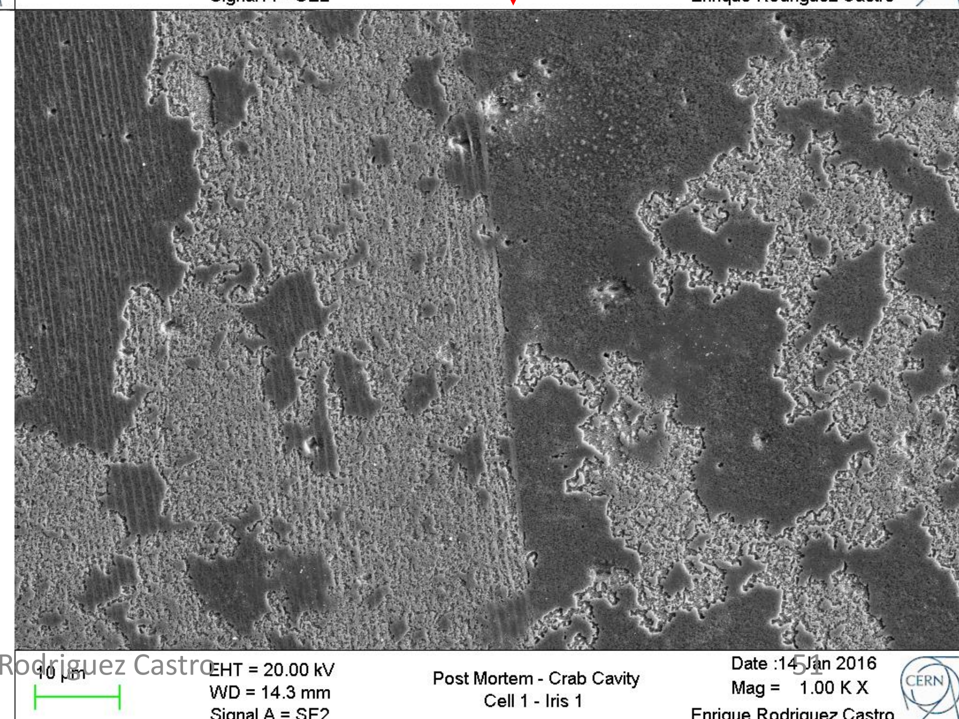



100 µm
EHT = 20.00 kV
WD = 14.3 mm
Signal A = SE2
Post Mortem - Crab Cavity
Cell 1 - Iris 1
Date :14 Jan 2016
Mag = 200 X
Enrique Rodriguez Castro
T24 R05 N1
10 µm
EHT = 10.00 kV
WD = 5.9 mm
Mag = 1.00 K X
Signal A = InLens
11WNSDvg1.8Cu; B1
tilted 0°
A.Toerklep EN/MME
Date :27 Oct 2009
Time :15:33:20
TD24 R05 N1
10 µm
EHT = 21.00 kV
WD = 28.7 mm
Signal A = SE2
Disc #4 iris
Stage at T = 0.5 °
Mag = 1.00 K X
Anite Perez Fontenla
Date :16 Jun 2014
EHT = 20.00 kV
WD = 14.3 mm
Signal A = SE2
Post Mortem - Crab Cavity
Cell 1 - Iris 1
Date :14 Jan 2016
Mag = 1.00 K X
Enrique Rodriguez Castro

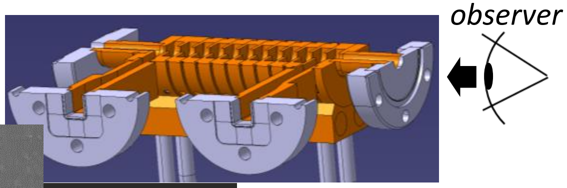


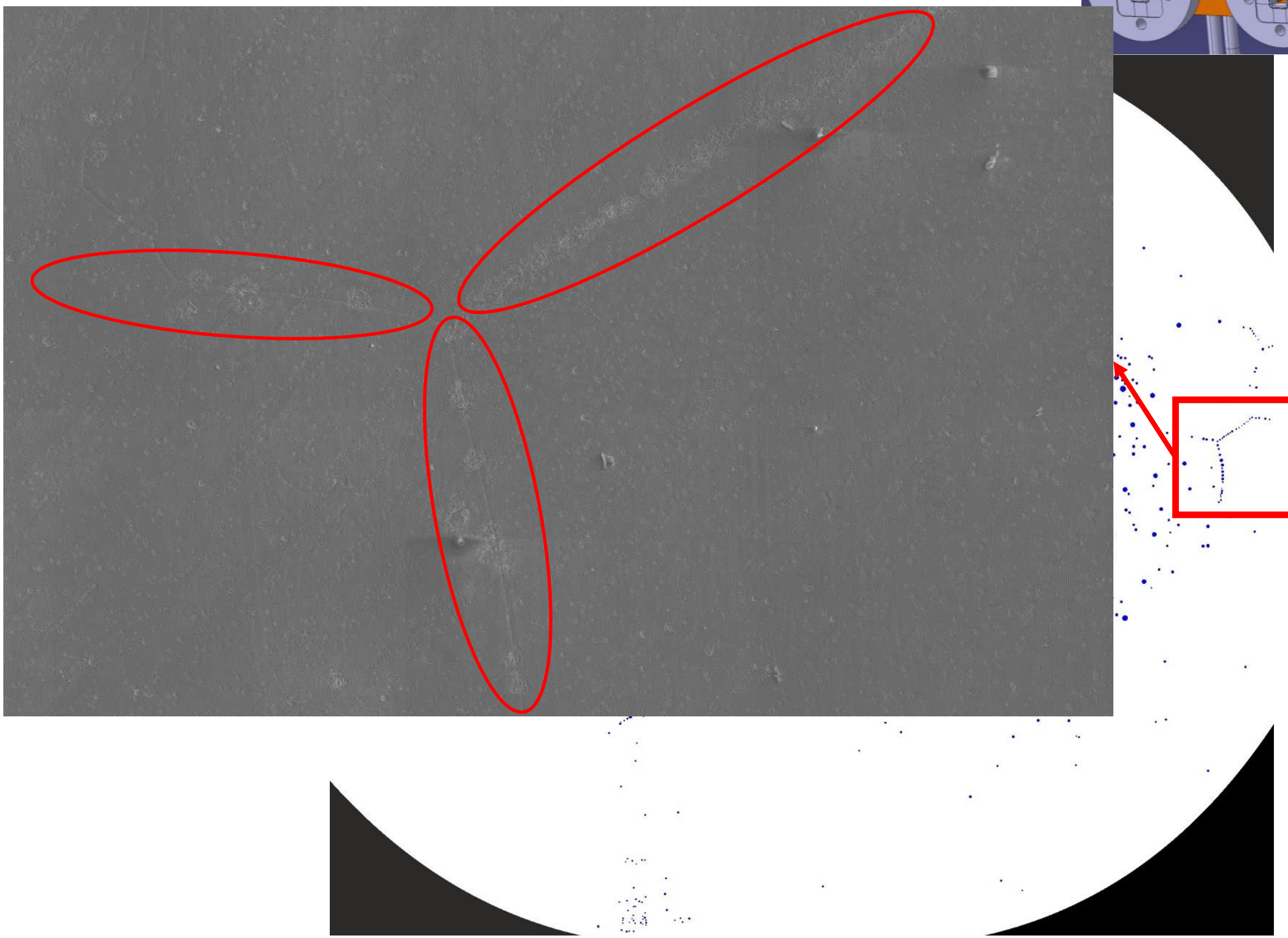


Stopped in grain boundary

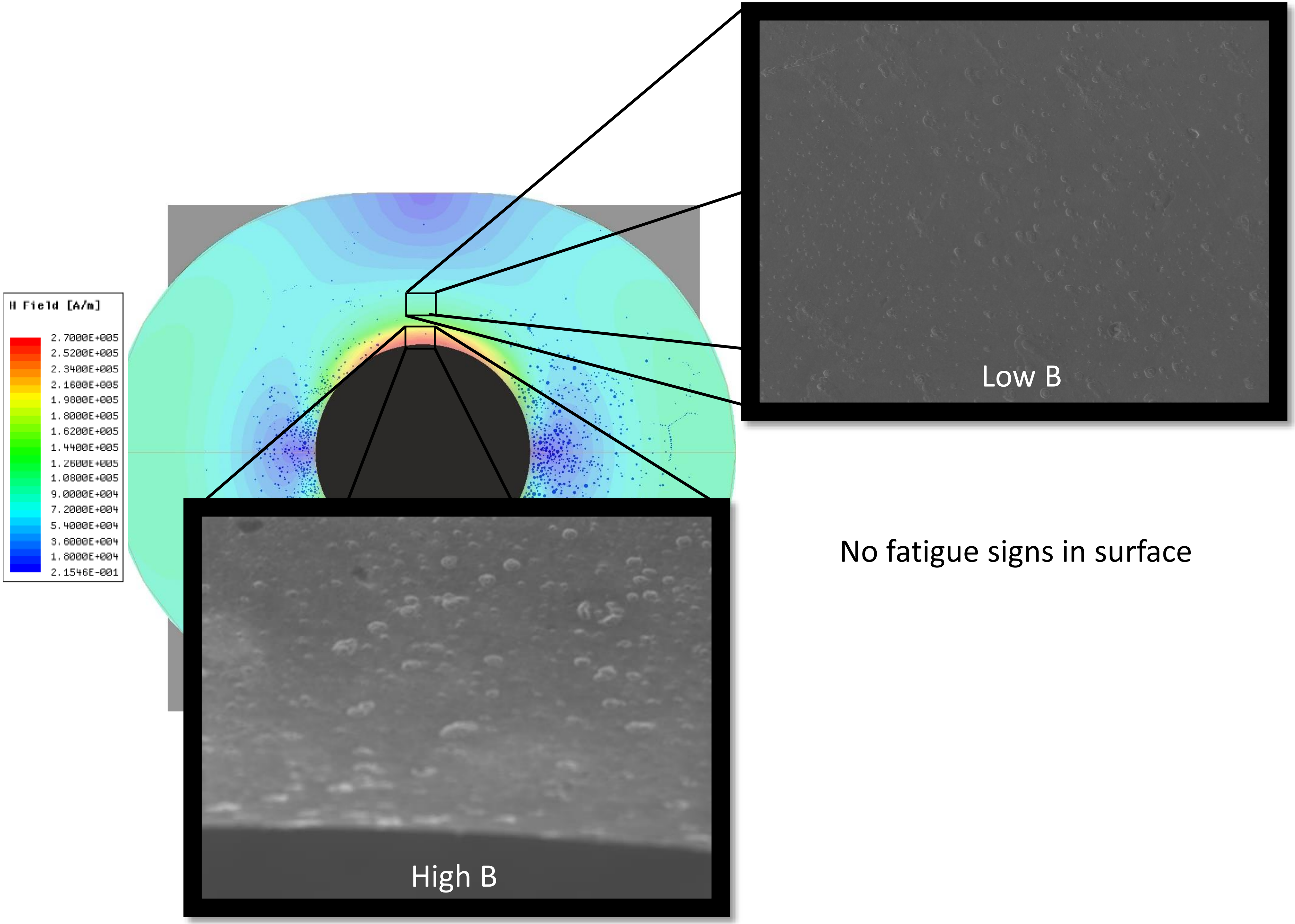


Cell 2 – Iris 2





Number of sites BD sites = 1305



No fatigue signs in surface

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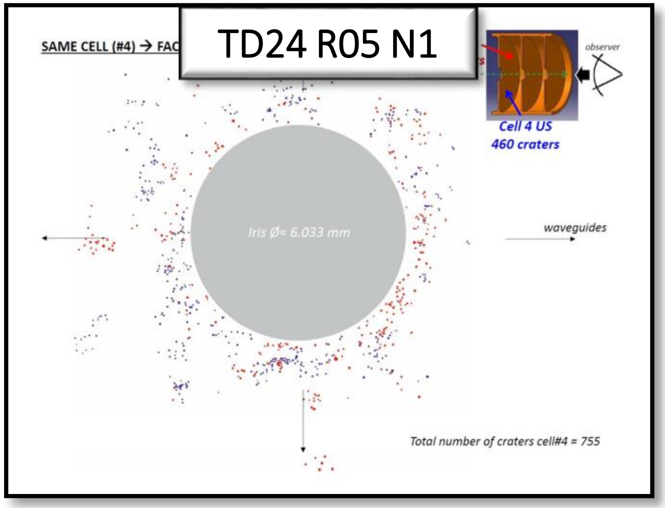
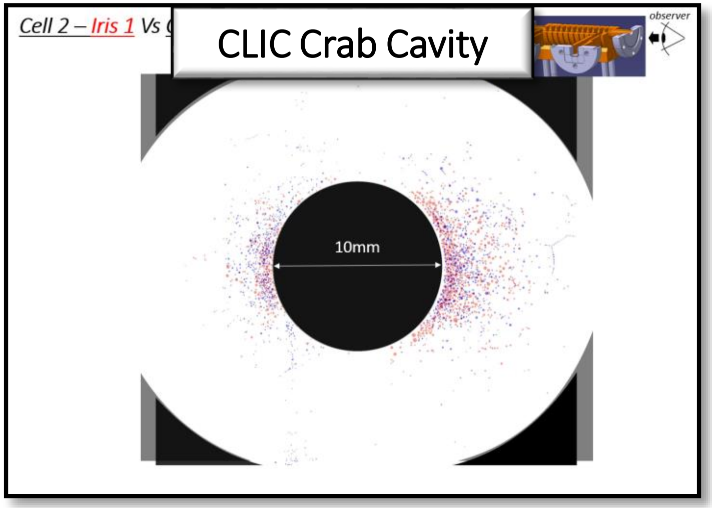
Summary of observation

- Distribution of BDs is different than in monopole structures





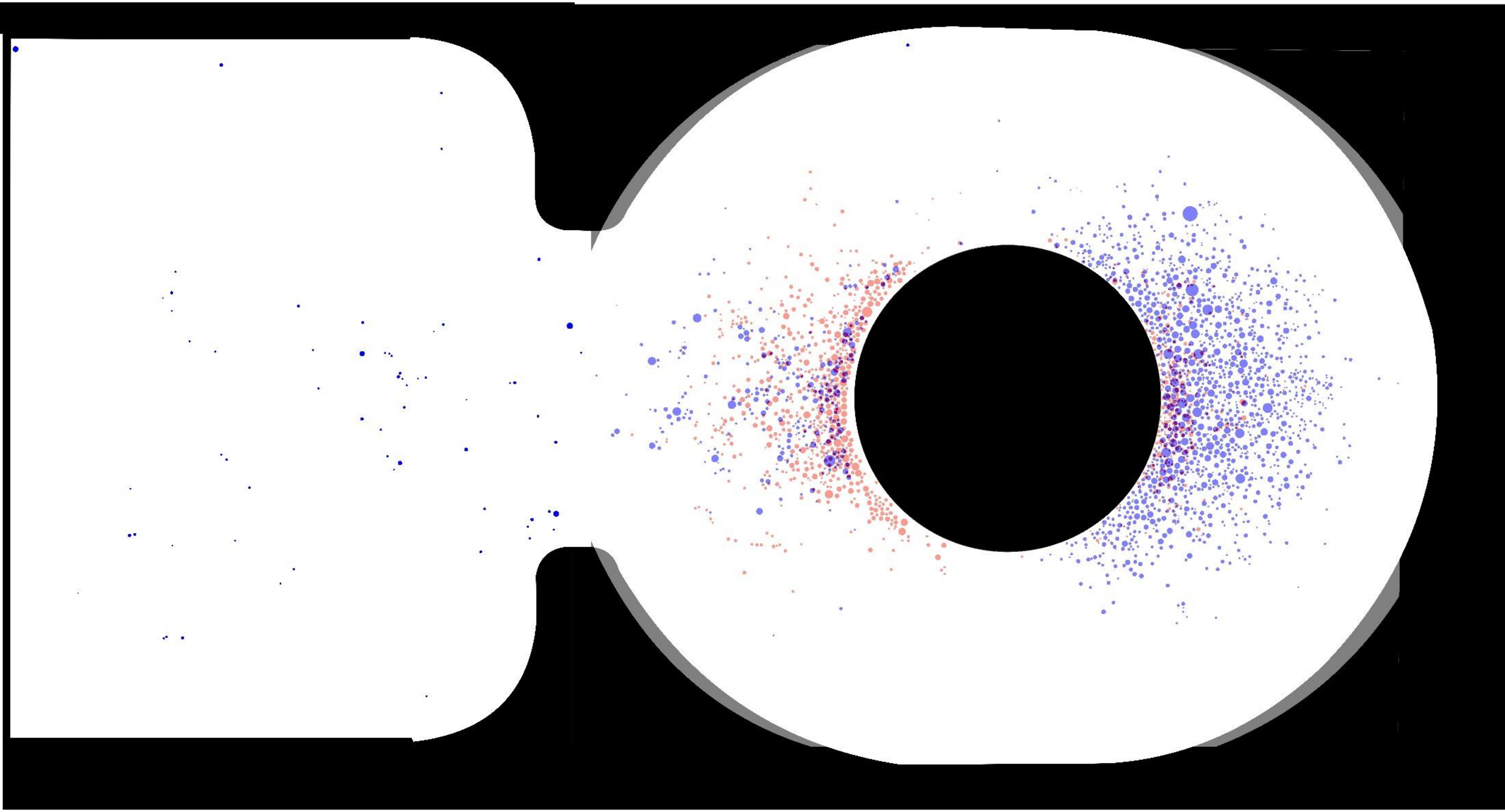
- Craters and features have same morphology that those in monopole structures
- BDs number drops significantly after firsts cells
  - To be confirmed with the complete observation (on going)

Thank you for your attention.

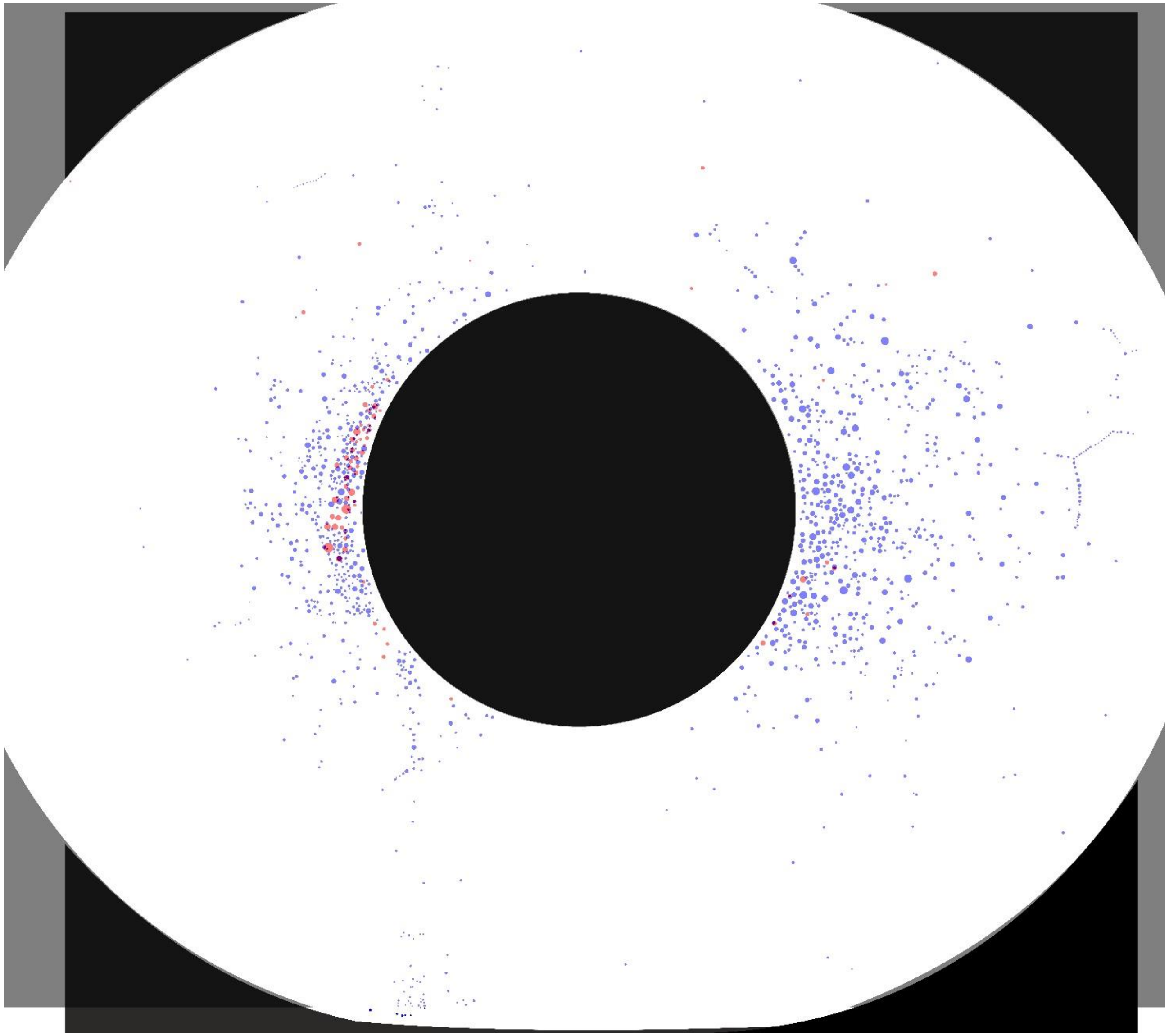
Questions?

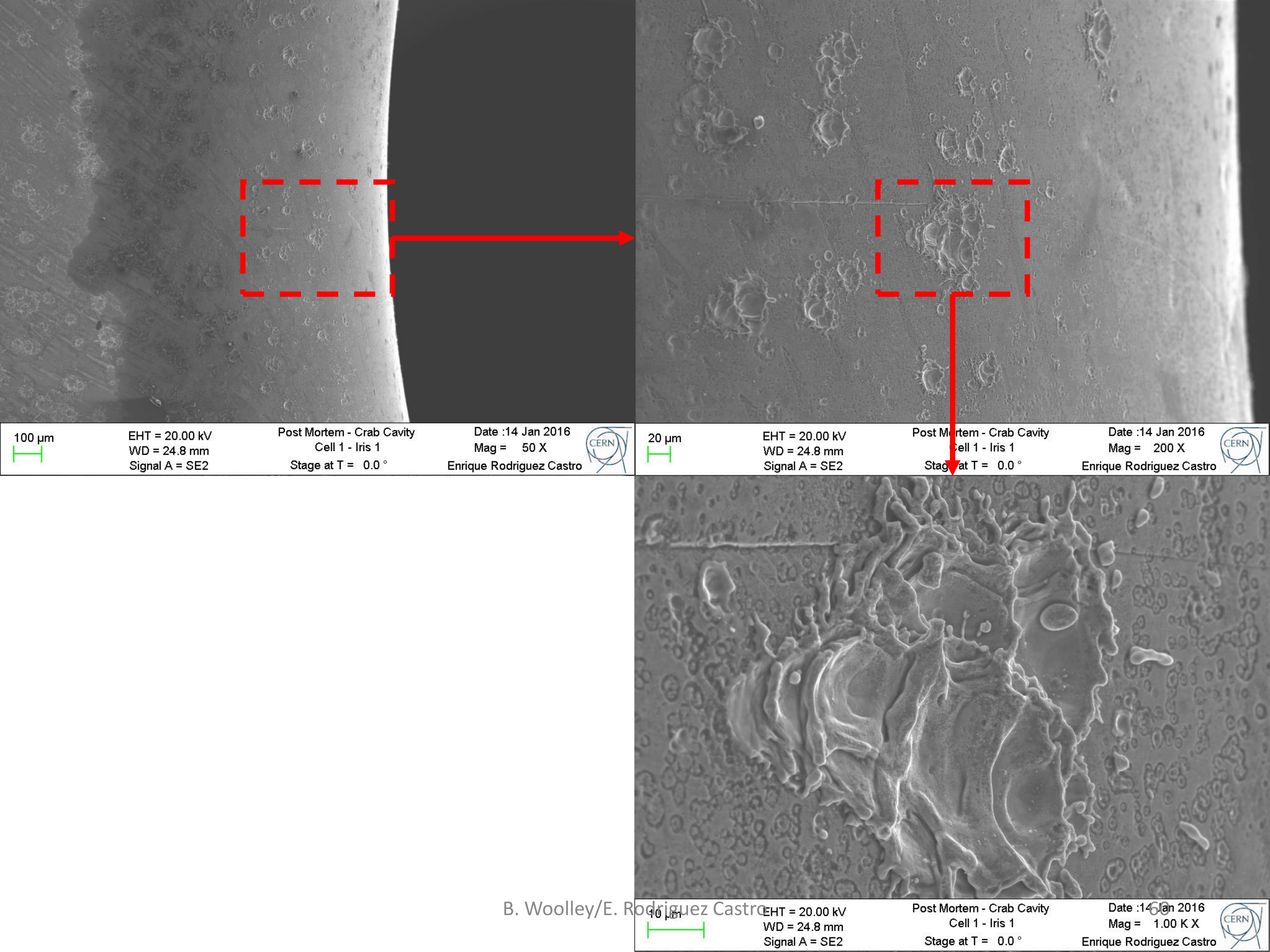
Extra Slides

Cell 1 – Iris 2 Vs Cell 2 – Iris 1



Cell 2 – Iris 2 Vs Cell 3 – Iris 1




100 µm
EHT = 20.00 kV
WD = 24.8 mm
Signal A = SE2
Post Mortem - Crab Cavity
Cell 1 - Iris 1
Stage at T = 0.0 °
Date :14 Jan 2016
Mag = 50 X
Enrique Rodriguez Castro
CERN
20 µm
EHT = 20.00 kV
WD = 24.8 mm
Signal A = SE2
Post Mortem - Crab Cavity
Cell 1 - Iris 1
Stage at T = 0.0 °
Date :14 Jan 2016
Mag = 200 X
Enrique Rodriguez Castro
CERN
10 µm
EHT = 20.00 kV
WD = 24.8 mm
Signal A = SE2
Post Mortem - Crab Cavity
Cell 1 - Iris 1
Stage at T = 0.0 °
Date :14 Jan 2016
Mag = 1.00 K X
Enrique Rodriguez Castro
CERN