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## Mechanisms and dynamics of unipolar arcs in magnetized plasmas

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# Mechanisms and dynamic of unipolar arcs

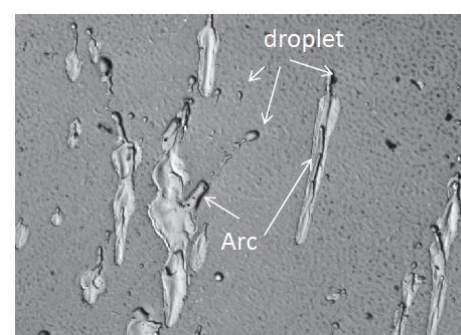
C. Djerroud<sup>a,\*</sup>, F. Brochard, J. Moritz, J. Ledig, E. Faudot, G. Marcos, J. Martin and L. de Poucques

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## Introduction

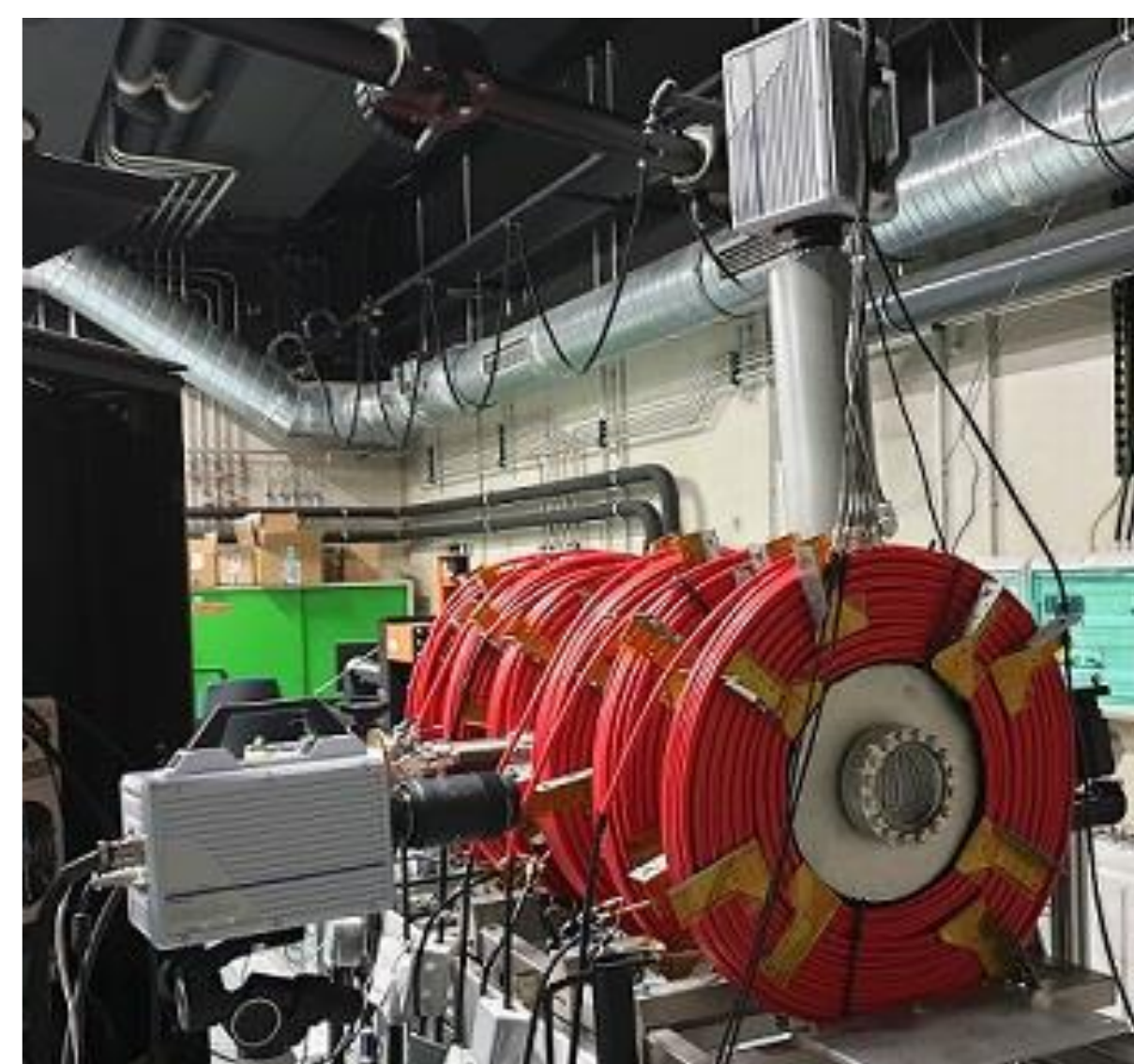
- Unipolar arc = arc between a plasma and a surface in contact with it [1]
- Main cause of wall erosion & impurity formation in fusion devices with metal PFCs [2,3]
- Impact of unipolar arcs on tungsten surfaces not well known [4]
- Many difficulties in the experimental investigations: spatial/temporal scales involved
- In this presentation: our first experimental results on the triggering of unipolar arcs
- Our aim: to provide more reliable input parameters & to assess the validity of models => better understanding of the mechanism/dynamic & consequences of unipolar arcs



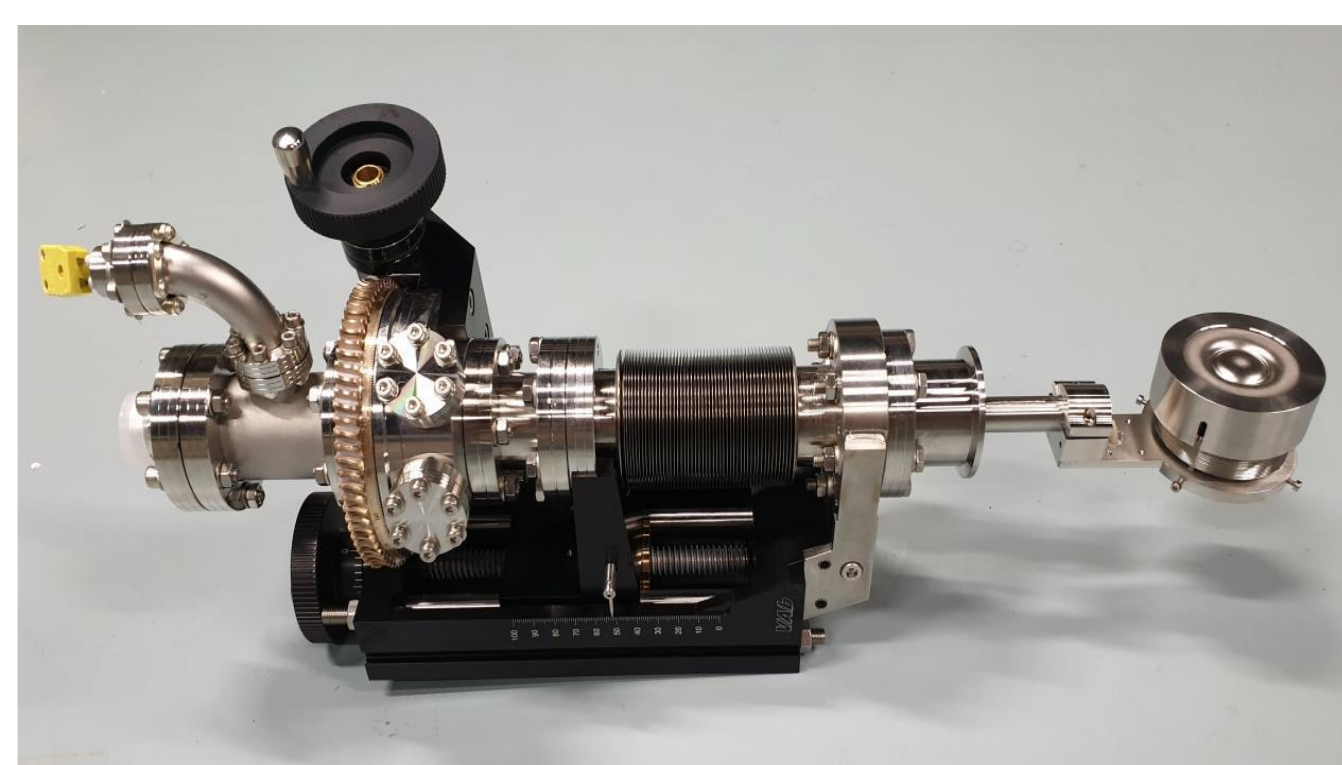
Post-mortem analysis of AUG PFCs, showing unipolar arc traces and droplets [3]

## Experimental device

- Experiments carried out in the ALINE device [5]
- Stainless steel cylindrical magnetized chamber
- 100cm long, 30cm in diameter
- Tunable RF plasma (10kHz-250MHz, up to 600 W)
- Equipped with rotatable and biasable manipulators by Cryoscan ©
- Possibility of heat pulses (45W IR Laser)



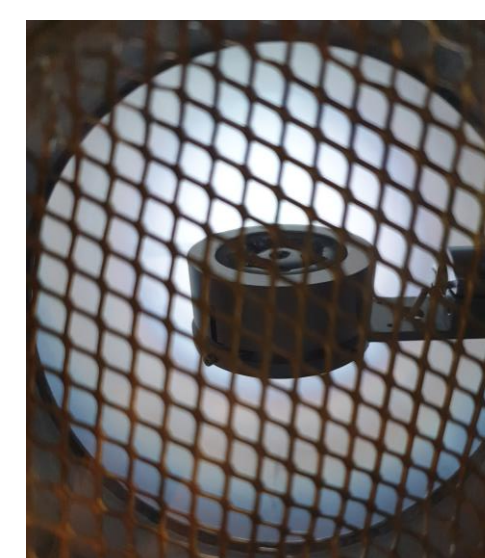
The ALINE device (IJL)



Target manipulator installed on ALINE

### In situ diagnostics:

- Stereoscopic fast imaging
- IR thermography
- Langmuir and RFA probes
- OES

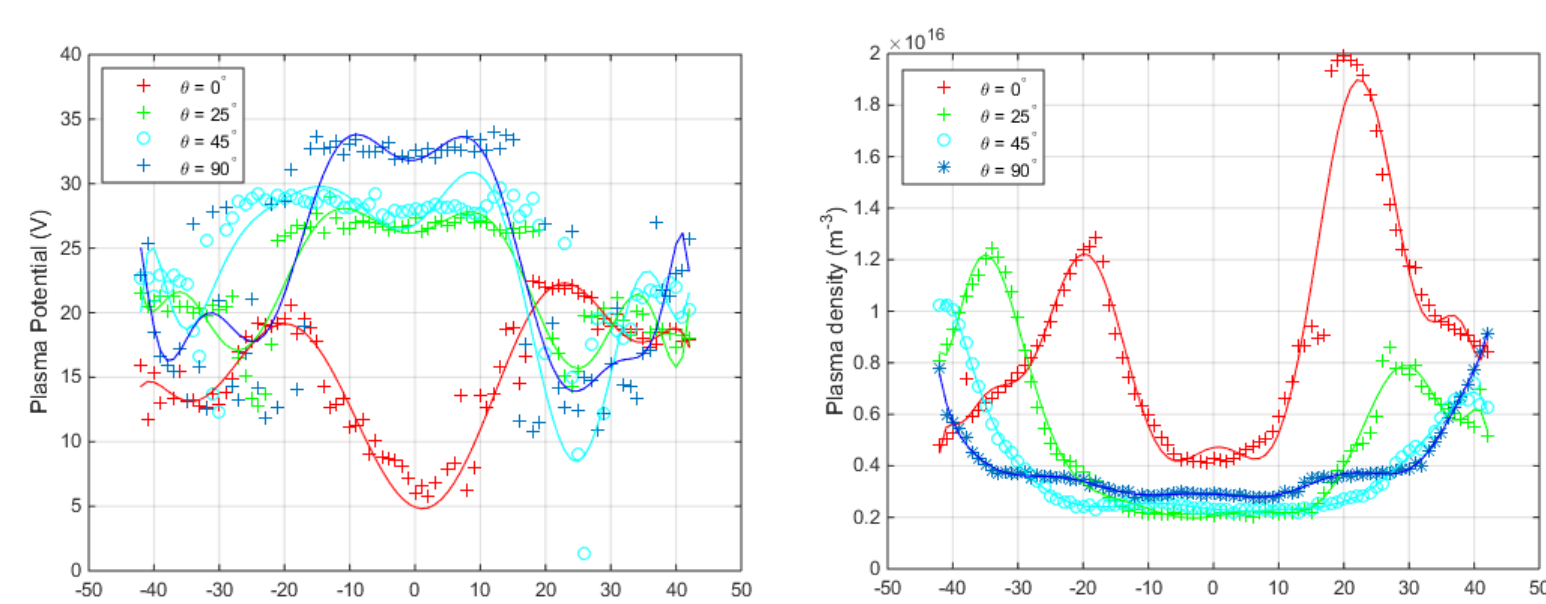


W target sample immersed in He plasma

### Experimental conditions

Gas	Ar,He
Working pressure	$10^{-3} - 10^{-1}$ mbar
Plasma densities	$10^{15} - 10^{17} m^{-3}$
Magnetic Field	up to 0.1 T
$\lambda_{De}$ (mm)	0.03 - 0.3
$r_{Te}^e$ (mm)	0.03
$r_{Ti}^i$ (mm)	1
$T_e$ (eV)	1-5
$T_i$ (eV)	~0.02

Typical plasma parameters in ALINE



Examples of plasma density and potential profiles obtained in ALINE for different angles between the cathode and the magnetic field

## Conclusions & Perspectives

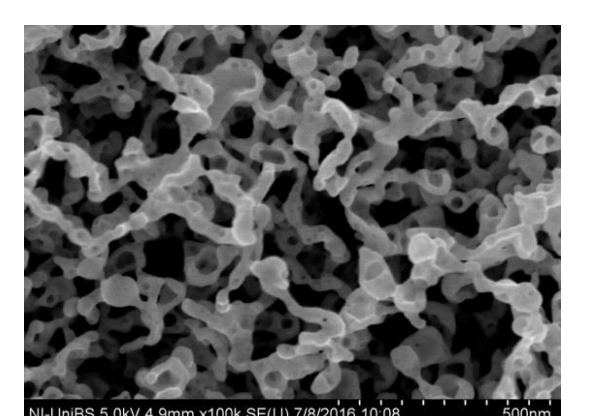
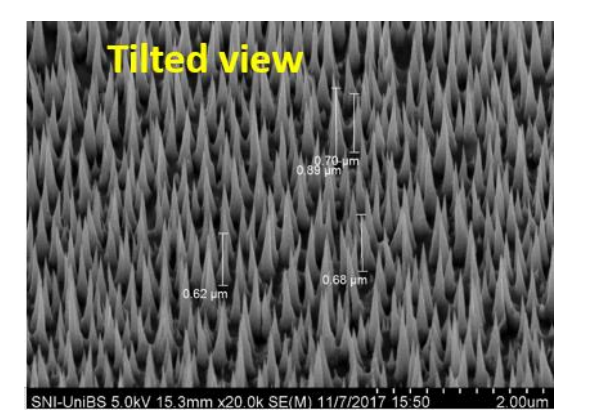
- Versatile and well-diagnosed experiment for the investigation of unipolar arcs
- Various ways to trigger arcs on different surfaces: excitation by plasma pulse, laser pulse, biasing
- Experiments have just started: statistical investigation to come
- Modelling: 2D PIC code under development (see PB027, this conference)
- Participation to WEST C4 campaign for investigations in more fusion-relevant conditions
- Application to various PFC's, including mirror cleaning applications with Univ. Basel.

## Experimental set-up

- 2 inches target samples mounted on rotatable manipulator
- Several kinds of target material (W, Mo, Ti, Al/Fe..)

### Preparation of samples:

- Manual deposition of W micron-sized dust samples
- Microtexturation (FeAl40 and soft metals) by surface nitriding
- W, Mo... deposits in HiPIMS (possibility to trap various gases: Ar, He, D)
- W fuzz, Ti nanopikes (provided by Univ. Basel)



Ti nanopikes (top) and W fuzz (bottom) prepared in Univ. Basel

**Pre-characterization of samples:** Scanning Electron Microscopy, Profilometry

### Measurements

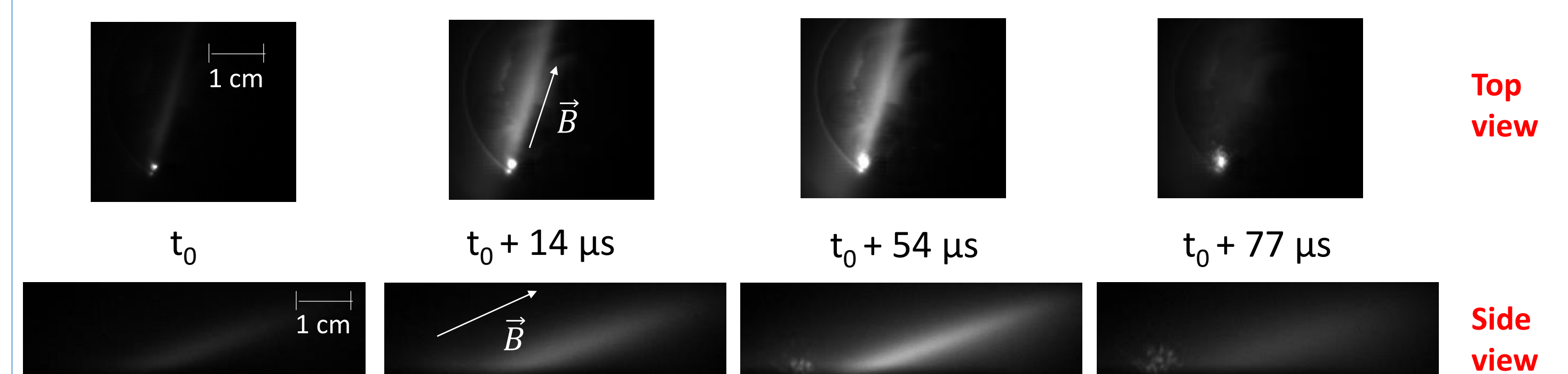
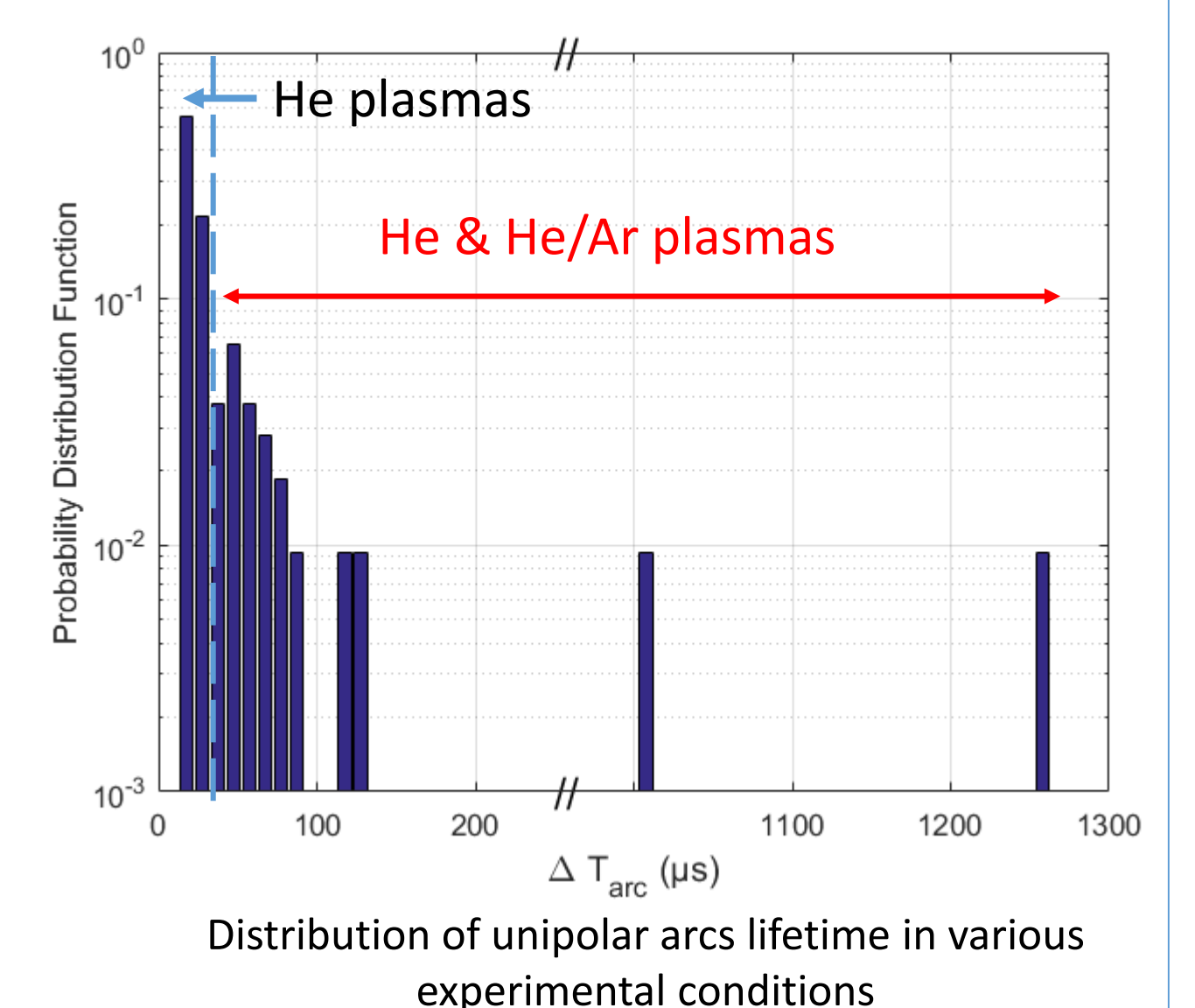
- Samples exposed under various plasma conditions (profiles deduced from probe meas.)
- Fast visible imaging to detect and characterize unipolar arcing (advanced analysis with APREX TRACK software [6])
- OES to characterize sputtered impurities
- IR camera (target surface temperature)
- Unipolar arcs threshold
- Lifetime and dynamics
- Impurity and droplets rates
- Droplet velocities
- Input parameters for simulations (J. Moritz, PB027)

### Post-mortem analysis :

- sample Degradation/Erosion (SEM, profilometry, FIB)

## Experimental Results

- Only preliminar results, low statistics: 107 arcs
- Wide distribution of arc lifetime (best time resolution so far: 3.8  $\mu$ s, 250 ns in close future)
- Influence of plasma & surface properties going to start after improvements in the set-up
- Preliminar observations suggest that dust rates are correlated with arc lifetime



Stereoscopic imaging of a unipolar arc on a W sample with pre-deposited W dust

## References

- [1] Barengolts et al, *Nuclear Fusion* 50 (12), 12500 (2010)
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- [5] E. Faudot et al., *Review of Scientific Instruments* 86, 063502 (2015)
- [6] R. Baude & M. Deseure, <http://www.aprex-solutions.com>