HSMDIS

INFN.LNS
&
INFN.LNL

DIPARTIMENTO
di MATEMATICA
e INFORMATICA

HSMDIS

High Stability Microwave Discharge Ion Source

Team: Lorenzo Neri; Luigi Celona; Santo Gammino; Ornella Leonardi; Giuseppe Castro; Andrea Miraglia; Andrea Busacca; Francesco Grespan; Michele Comunian; Luca Bellan; Carlo Baltador; Giovanni Russo; Sebastiano Boscarino; Armando Coco.

05/04/2022

Background of HSMDIS project

PS-ESS was fully commissioned at LNS and performance were validated by ESS personnel

Requirement	Value	**Measurement done for configurations that satisfy the ESS stability requirements**	**Comments**
Total beam current	>90 mA	40 - 140 mA	✓
Nominal proton beam current	74 mA	40 - 105 mA	✓
Proton beam current range	67-74 mA	40 - 105 mA	✓
Proton fraction	>75%	Up to 85%	✓
Pulse length	6 ms	6 ms	✓
Pulse flat top	3 ms	3 ms	✓
Flat top stability	±2 %	< ±2 % up to 1.5%	✓
Pulse to pulse stability	±3.5 %	< ±3.5 % up to 3%	✓
Repetition rate	14 Hz	14 Hz	✓
Beam energy	75±5 keV	75 keV	✓
Energy adjustment	±0.01 keV	±0.01 keV	✓
Transverse emittance (99%)	1.8 pi.mm.mrad	1.06 pi.mm.mrad @ 82 mA	✓
Beam divergence (99%)	<80 mrad	50 mrad @ 82 mA	✓
Start-up after source maintenance	32 hours	32 hours	✓

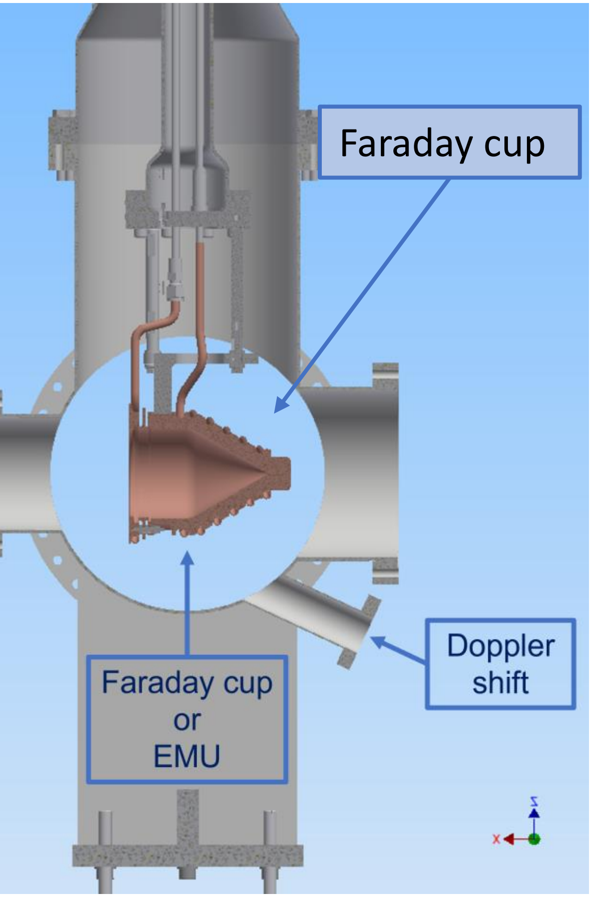
Second source with second part of the commissioning was not needed

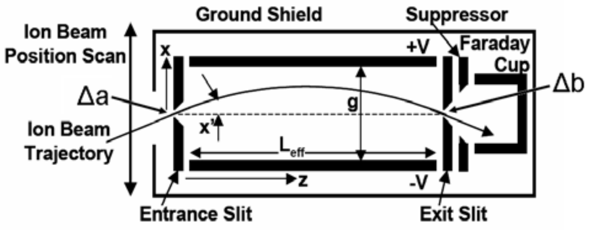
2018-02-01 Source fully assembled in Lund by INFN-LNS team

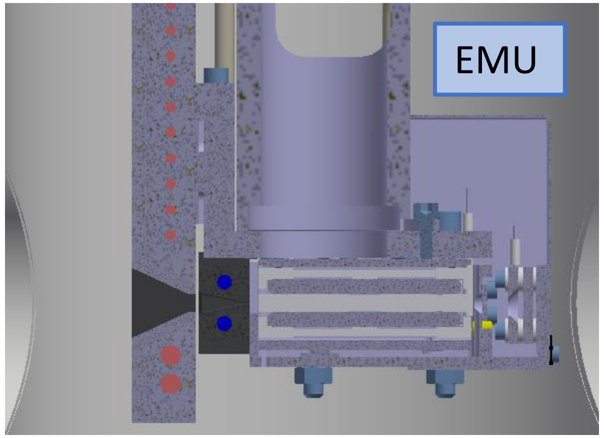
PS-ESS Team: L. Neri, L. Celona, S. Gammino, A. Miraglia, O. Leonardi, G. Castro, G. Torrisi, D. Mascali, M. Mazzaglia, L. Allegra, A. Amato, G. Calabrese, A. Caruso, F. Chines, G. Gallo, A. Longhitano, G. Manno, S. Marletta, A. Maugeri, S. Passarello, G. Pastore, A. Seminara, A. Sparta, S. Vinciguerra.

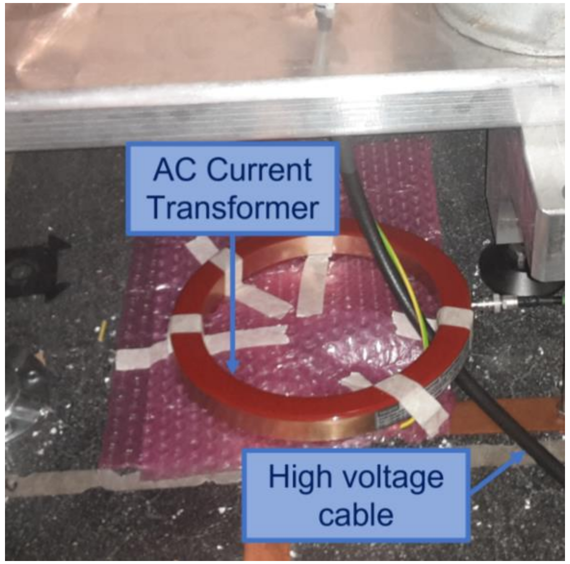
Acknowledgment to LNS Accelerator Division, Technical Division, Administration and External Funds.

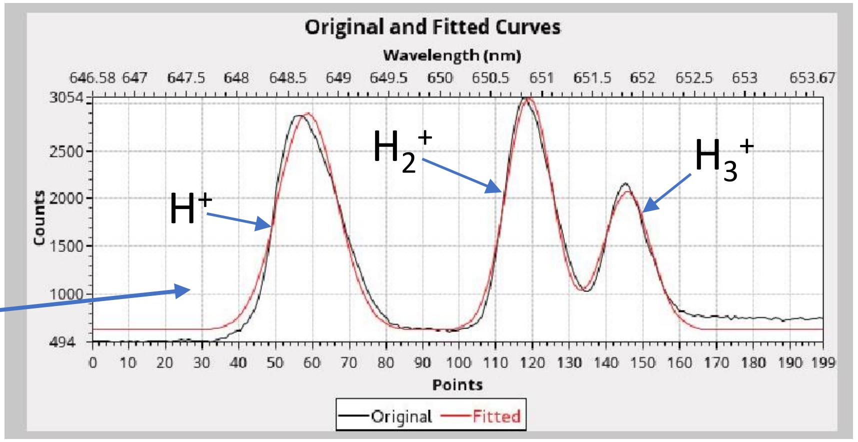
PS-ESS first experimental setup











Doppler Shift of Hydrogen Balmer α ray at 656.3 nm

Diagnostics

Faraday cup for beam current measurement: 80 mm diameter, precision ±0.2 mA, 1 Ms/s

ACCT for the measurement of the total beam current extracted: bandwidth from 3Hz to 1MHz, droop compensation circuit, 1 Ms/s, accuracy 0.1%, precision ±0.2 mA

EMU (Alison scanner) for the emittance measurement: precision 0.1 mm, precision 0.2 mrad, 1 Ms/s, precision ±0.2 mA

Doppler shift for the H^+, H_2^+ and H_3^+ fraction measurement: precision 1%

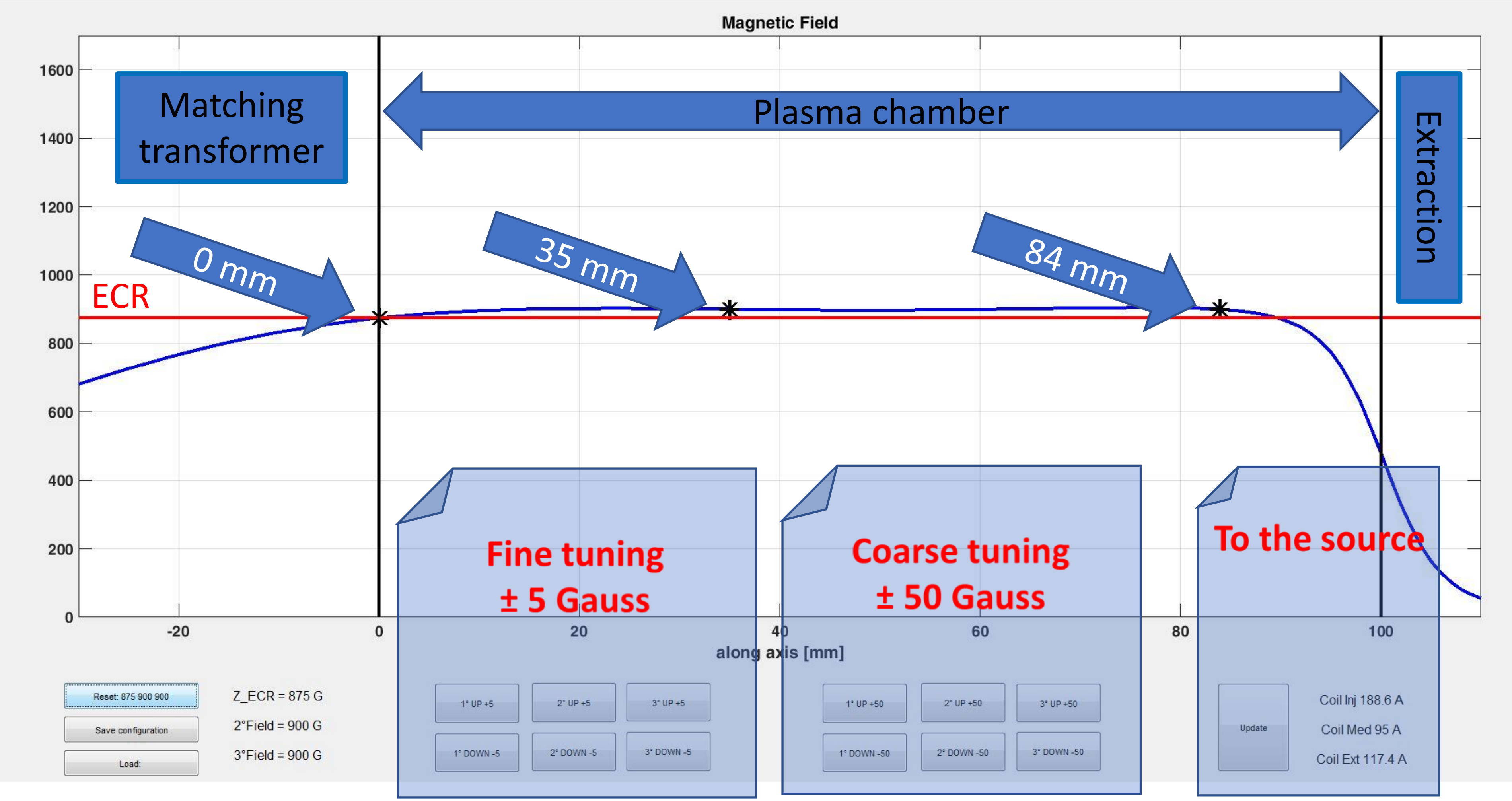
Describe source configuration exposing physic correlation with the magnetic field

Source configuration:
- Coil 1
- Coil 2
- Coil 3
- Microwave power
- Gas flux

OBSOLETE

Physics says that **only Magnetic field is directly correlated to source behaviour** and not the coil currents

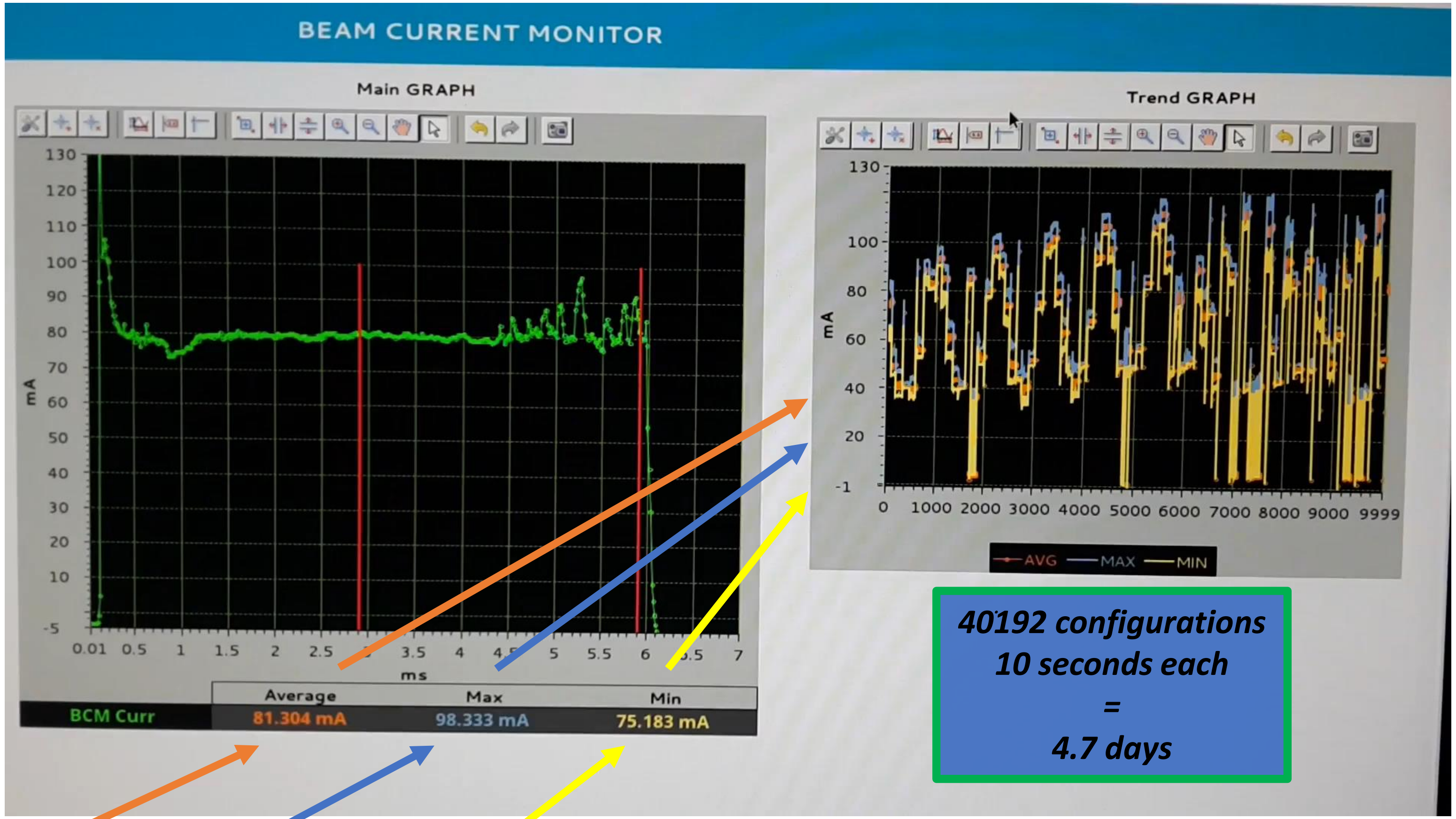
Source configuration:
- B Field @0mm
- B Field @35mm
- B Field @84mm
- Microwave power
- Gas flux



Comsol 🡐 Matlab 🡒 EPICS

Semi-automatic characterization tool

Objective: numerical characterization instead of subjective qualitative optimization



40192 configurations
10 seconds each
=
4.7 days

In the graphical interface: average, maximum and minimum are evaluated, and the trend showed for the beam pulse between 2.9 ms and 5.9 ms .

From plasma modelling :

Field @ 0 mm ==> 835:20:975 G
Field @ 35 mm ==> 795:40:1395 G
Field @ 84 mm ==> 675:40:1995 G
H2 flow ==> 2:1:5 SCCM
RF power ==> 600:200:1200 W

40192 configurations

From evidence of stable configurations:

Field @ 0 mm ==> 795:20:1015 G
Field @ 35 mm ==> 515:40:1075 G
Field @ 84 mm ==> 235:40:1075 G
H2 flow ==> 3.35:0.25:3.85 SCCM
RF power ==> 550:50:650 W

15480 configurations

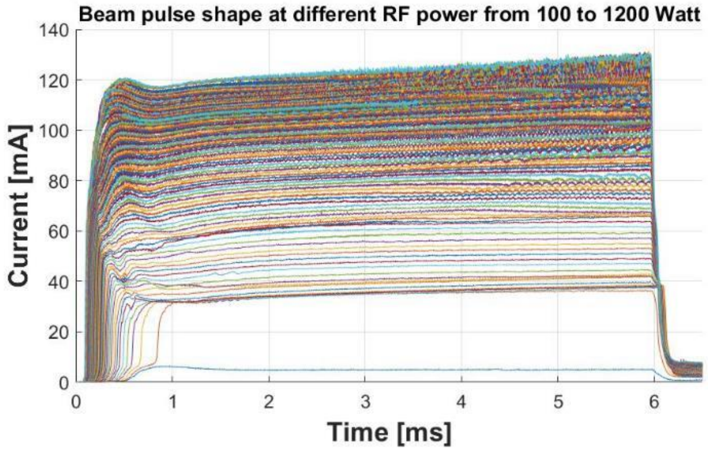
With Doppler Shift Measurement:

H2 flow ==> 3.5 SCCM
RF power ==> 175:75:325 W

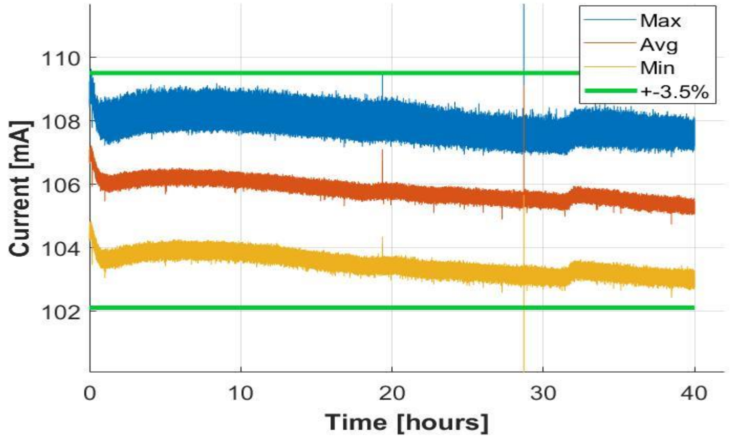
5160 configurations

The capability to satisfy ESS requirement…

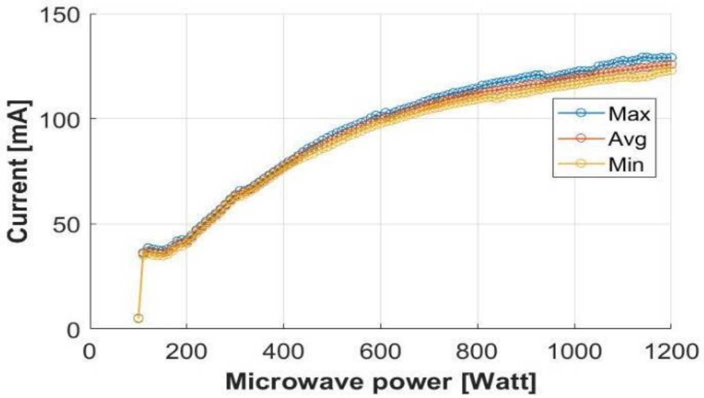
Intra-pulse stability < ±2%

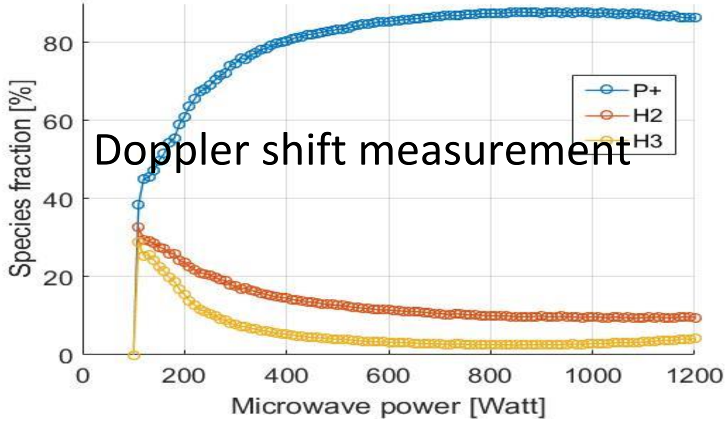


Pulse to pulse stability < ± 3.5%



Minimum proton current range 67-74 mA





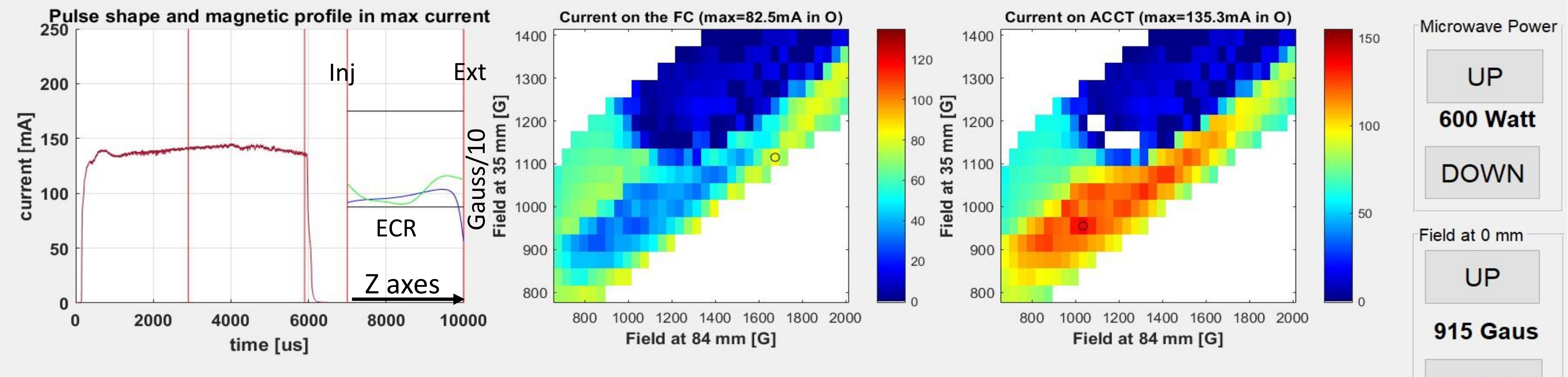
Doppler shift measurement

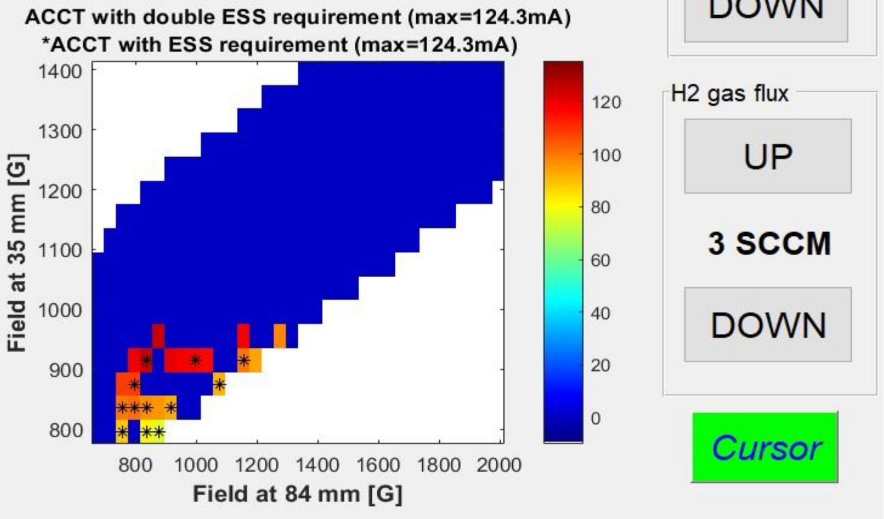
The capability to satisfy ESS requirement…
…stopped the pressure on analysis

As a coin have always two sides there are always pros and cons for each event

We started the analysis of the data collected during the commissioning(2017) only in 2021

Visualization of collected data





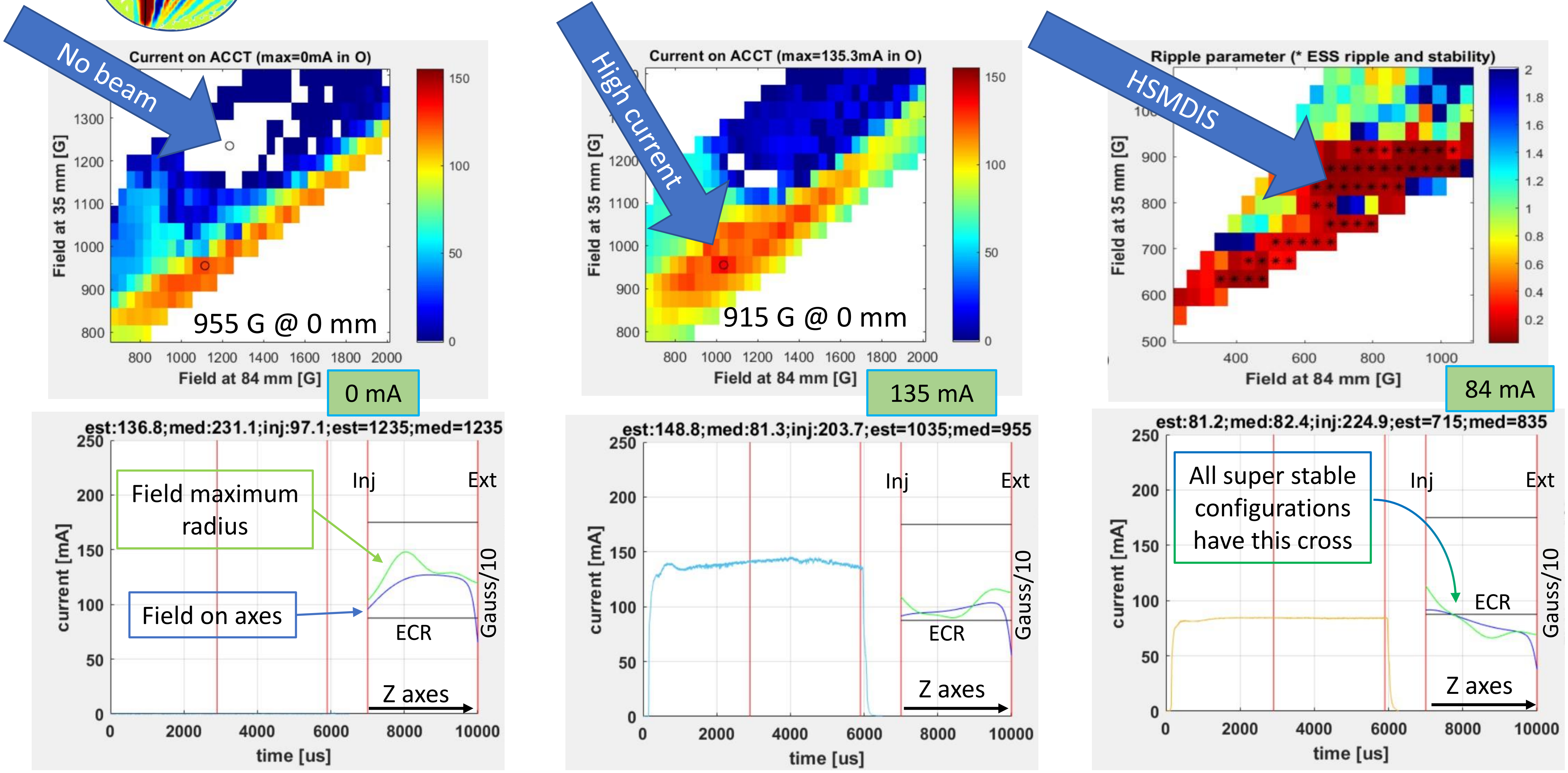
ESS requirements:

- The beam pulse current variation <2.0% of flat top mean current
- The flat top mean current variation <3.5% from pulse to pulse.

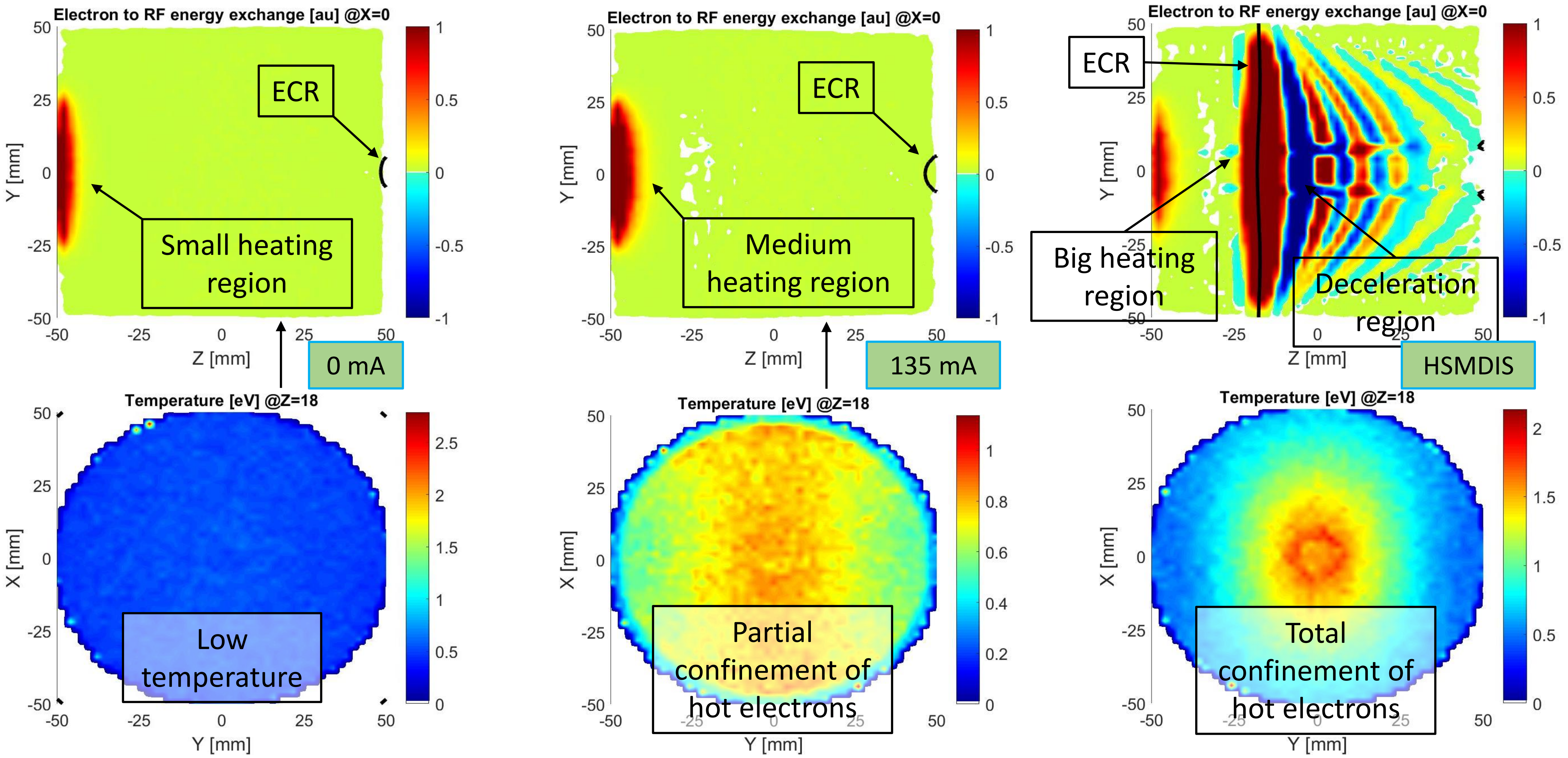
We introduce a **Ripple parameter** to quantify how much the beam is noisy:

- Standard deviation between beam current and 6th order polynomial fit of the flat top part

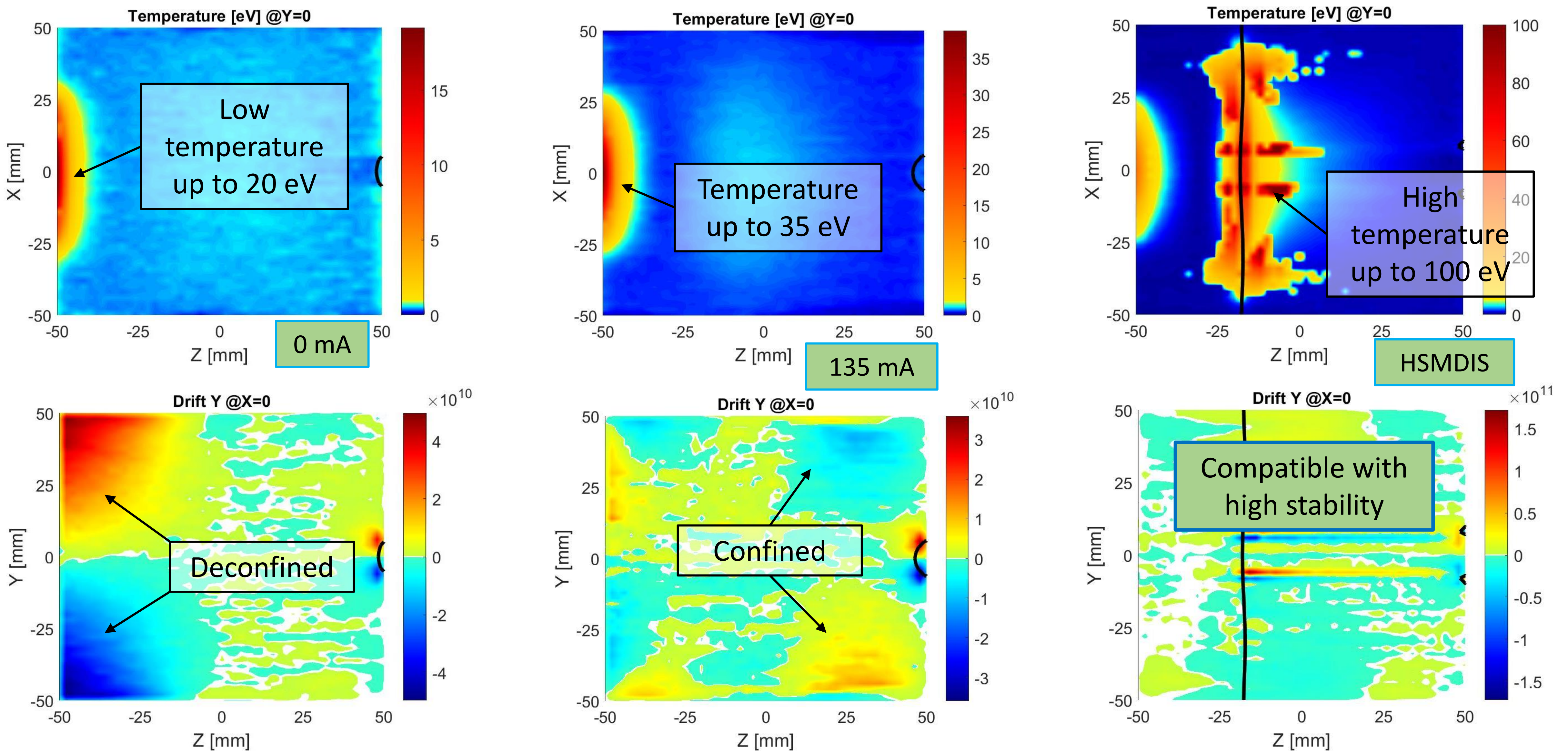
The most relevant source behaviors



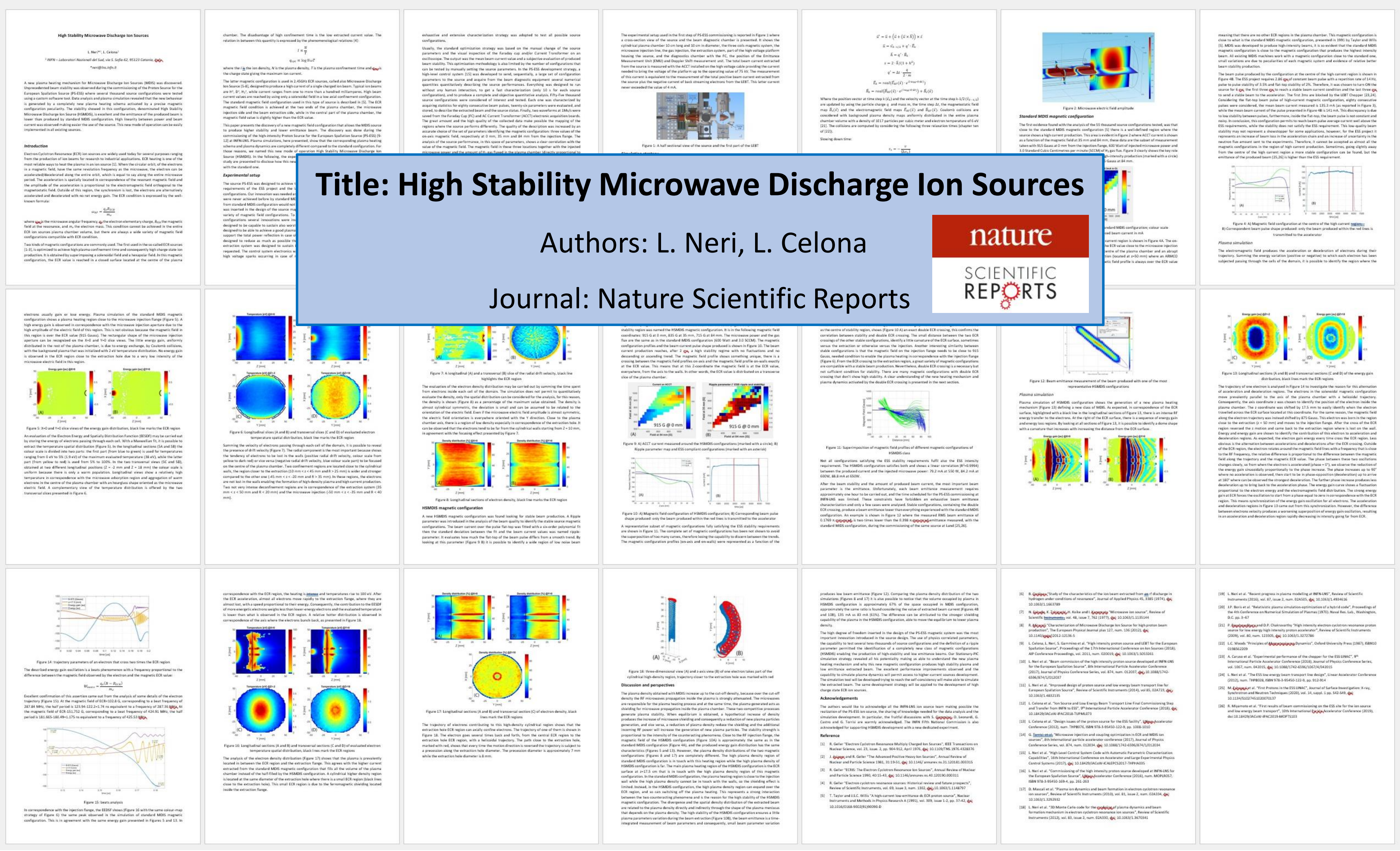
Plasma simulations with one Stationary-PIC iteration



Plasma simulations with one Stationary-PIC iteration



HSMDIS first pubblication

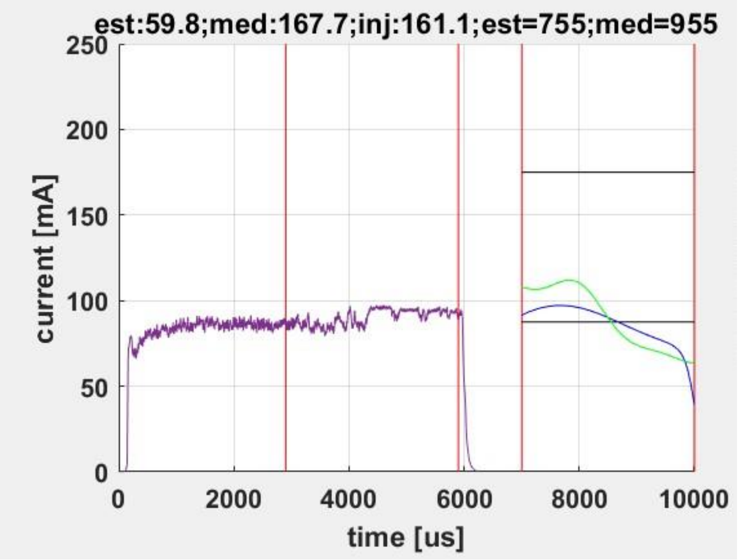


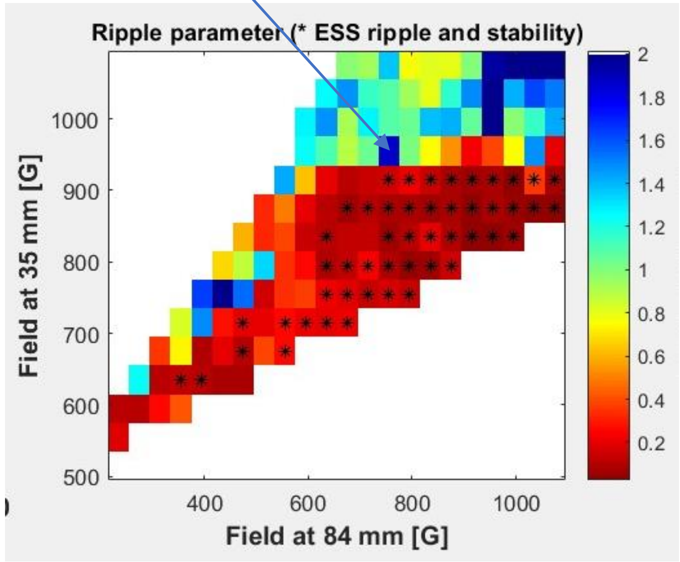
Title: High Stability Microwave Discharge Ion Sources

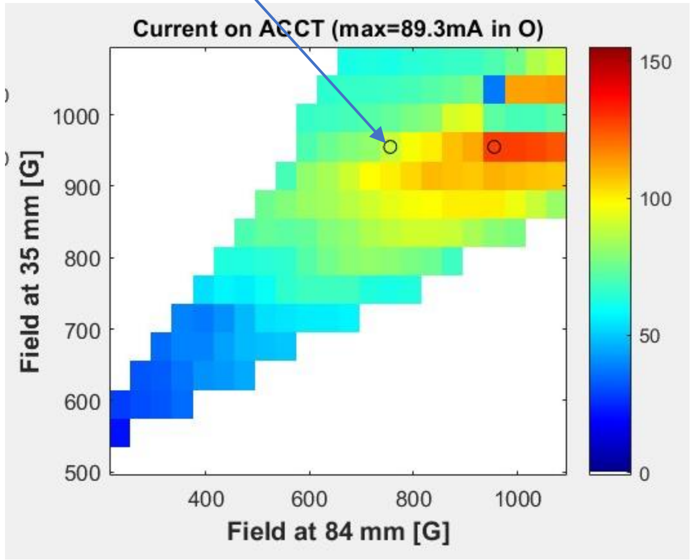
Authors: L. Neri, L. Celona

Journal: Nature Scientific Reports

Not stable configuration with magnetic configuration close to HSMDIS one







PS-ESS commissioning shows experimental physics correlation between magnetic field configurations and source behaviours

HSMDIS Task 1_1: Better understanding of plasma mechanism at the base of the different source behaviors

HSMDIS Task 1_2: Identify source configuration for maximized stable beam current production

HSMDIS

High Stability Microwave Discharge Ion Source

Three Years Project 2022-2024

WP1: PS-ESS commissioning data analysis

Task 1_1: Better understanding of plasma mechanism at the base of the different source behaviors (All)

Task 1_2: Identify source configuration for maximized stable beam current production (Neri, Celona, Gammino)

Task 1_3: Study correlation between beam emittances and magnetic configurations (Leonardi, Bellan)

Task 1_4: Understanding plasma mechanism for H_2^+ and H_3^+ production (Castro)

Task 1_5: Study observed plasma instability at 71KHz and impact on the accelerator (Grespan, Neri)

Task 1_6: Virtual Langmuir probe (Baltador, Castro, Neri, ESS Bilbao MoU)

WP2: Plasma and beam extraction simulation

Task 2_1: Code optimization with C functions and PETSc (Busacca, Coco, Boscarino, Russo)

Task 2_2: Implementation of Stationary-PIC loop (Neri, Comunian)

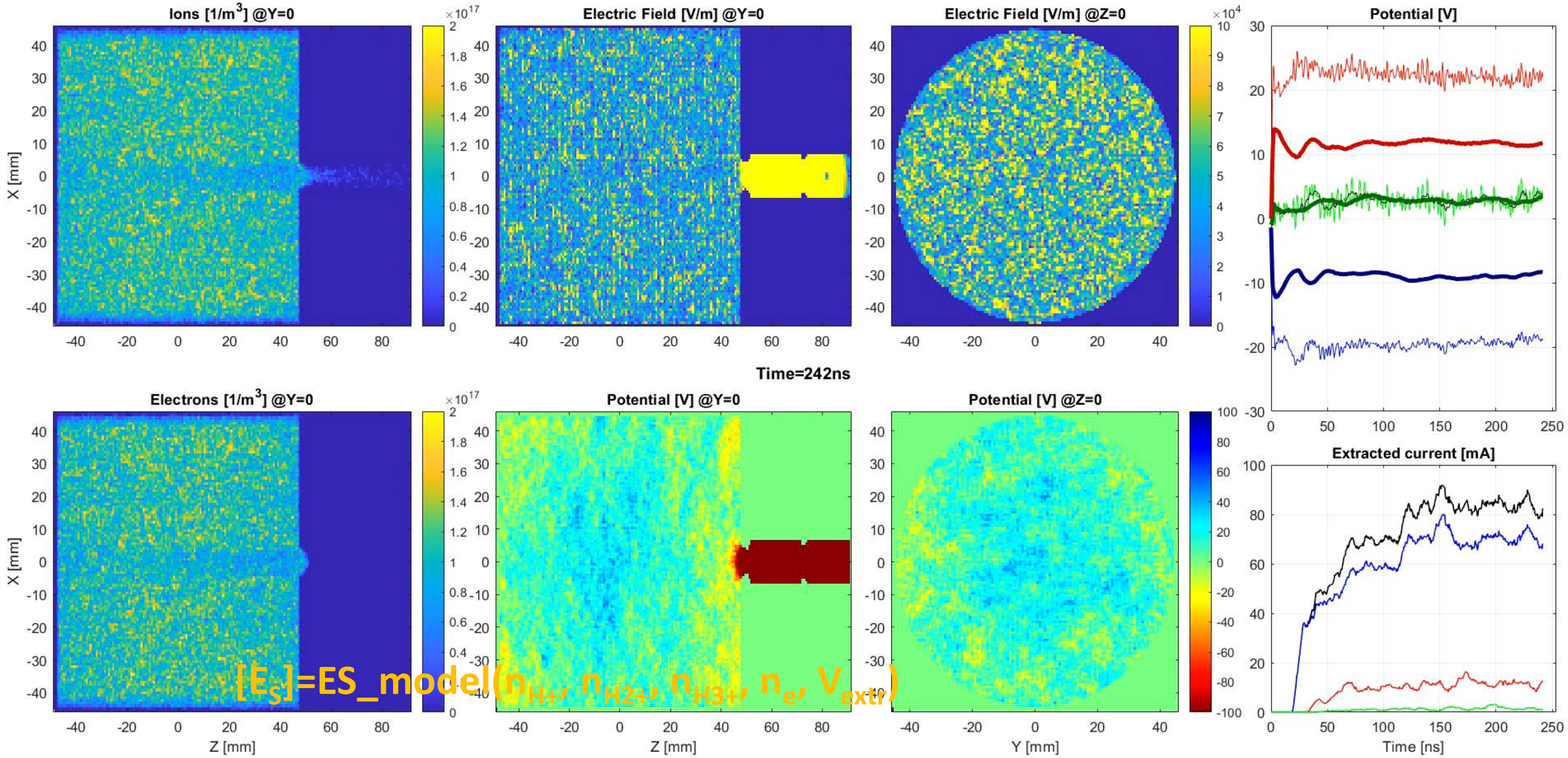
Task 2_3: Extend collision rates and ionization processes libraries (Castro, Neri)

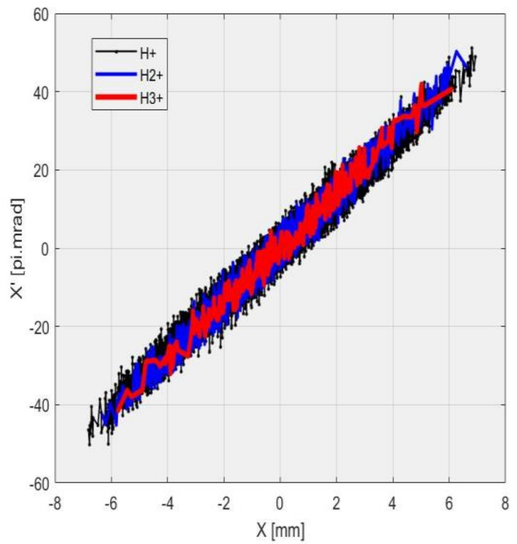
WP3: Design of hardware upgrades

Task 3_1: Design of new compact source with extraction systems for H^+ , H_2^+ , H_3^+ , D^+ (Miraglia)

Task 3_2: PS-ESS upgrade for deuterium production (Neri, Leonardi, GANIL MoU)

Task 2: Implementation of Stationary-PIC ion source simulation tool





$[E_S]=ES\_model(n_{H+}, n_{H2+}, n_{H3+}, n_e, V_{extr})$

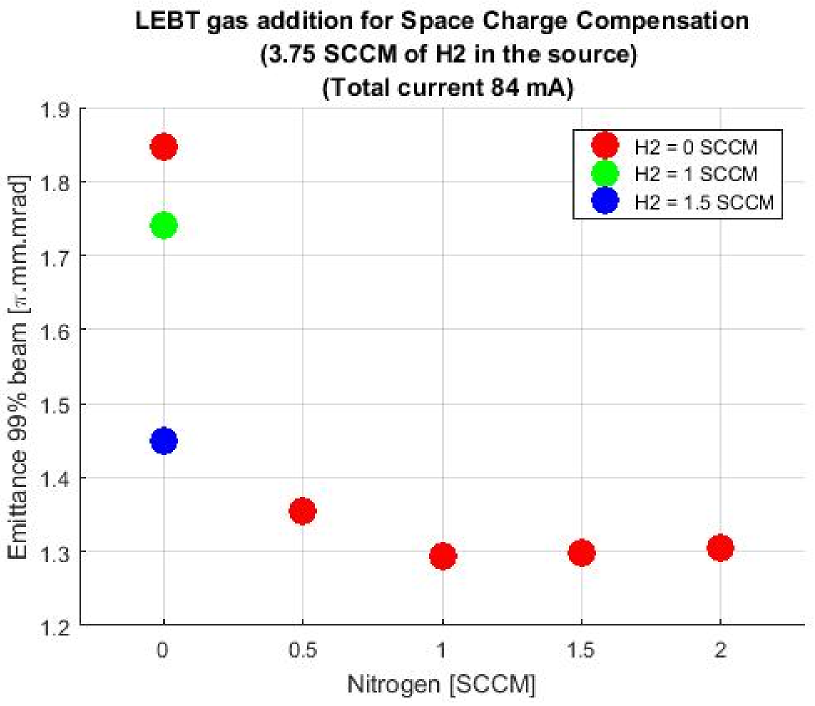
$[xi_{H+}, xi_{H2+}, xi_{H3+}, x_{ie}]=Ionizations(n_e, T_e, n_{H+}, n_{H2+}, n_{H3+}, n_n)$

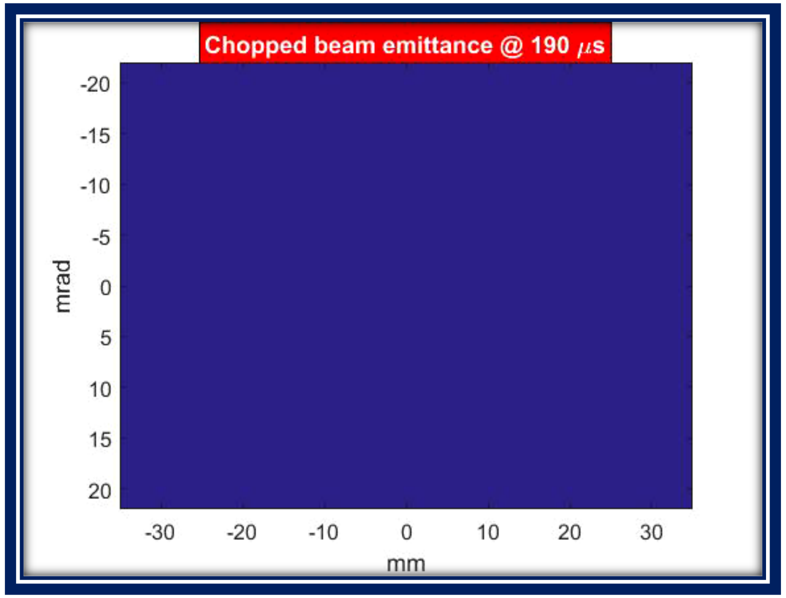
$[E_{RF},B_{RF}]=RF\_model(n_e, T_e)$

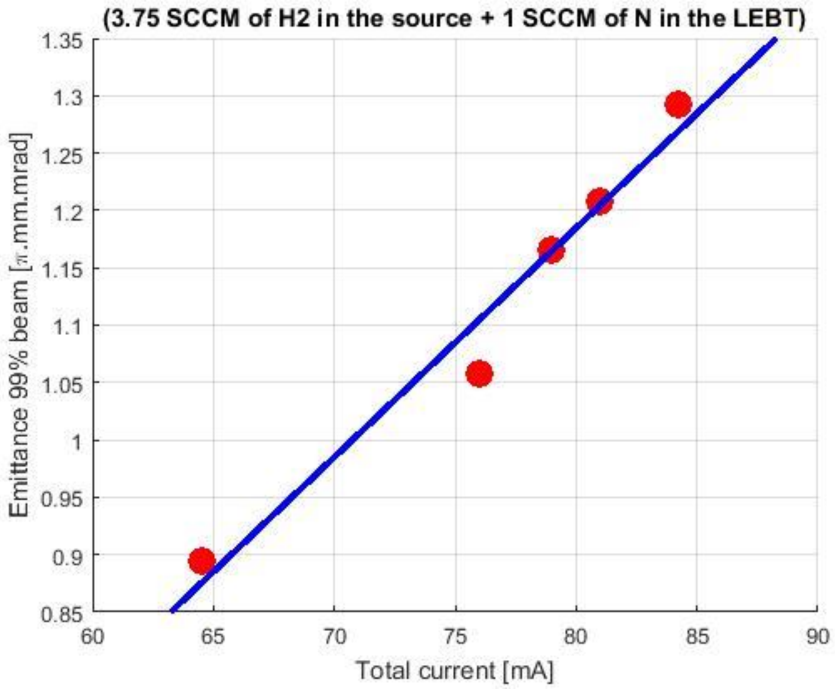
$[C]=Collisions(n_e, T_e, n_{H+}, n_{H2+}, n_{H3+}, n_n)$

$[n_e, T_e, n_{H+}, n_{H2+}, n_{H3+}]=Boris\_mover(xi_{H+}, xi_{H2+}, xi_{H3+}, xi_e, B_S , E_S , E_{RF} , B_{RF}, C)$

Emittance versus: gas addition in the LEBT, time evolution and total extracted current







Data will be analysed and compared with ion source simulation tool and LEBT transport model in presence of space charge problem

Grazie per l’attenzione