Preliminary simulation of CERN's LINAC4 H^- source beam formation

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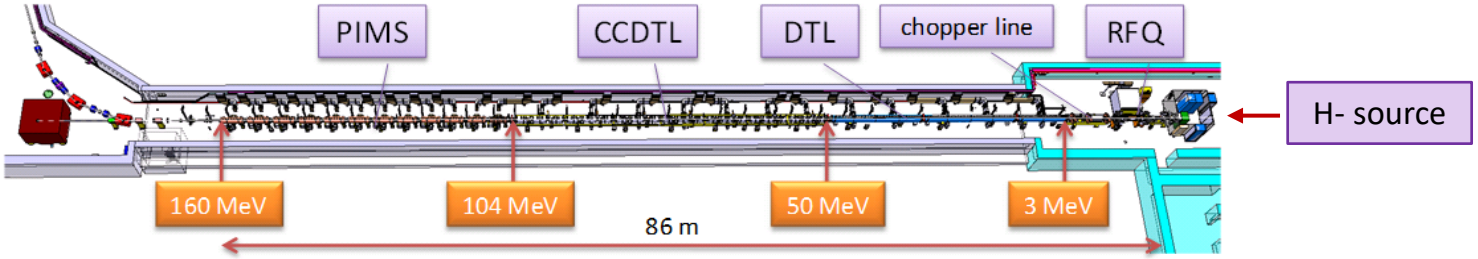
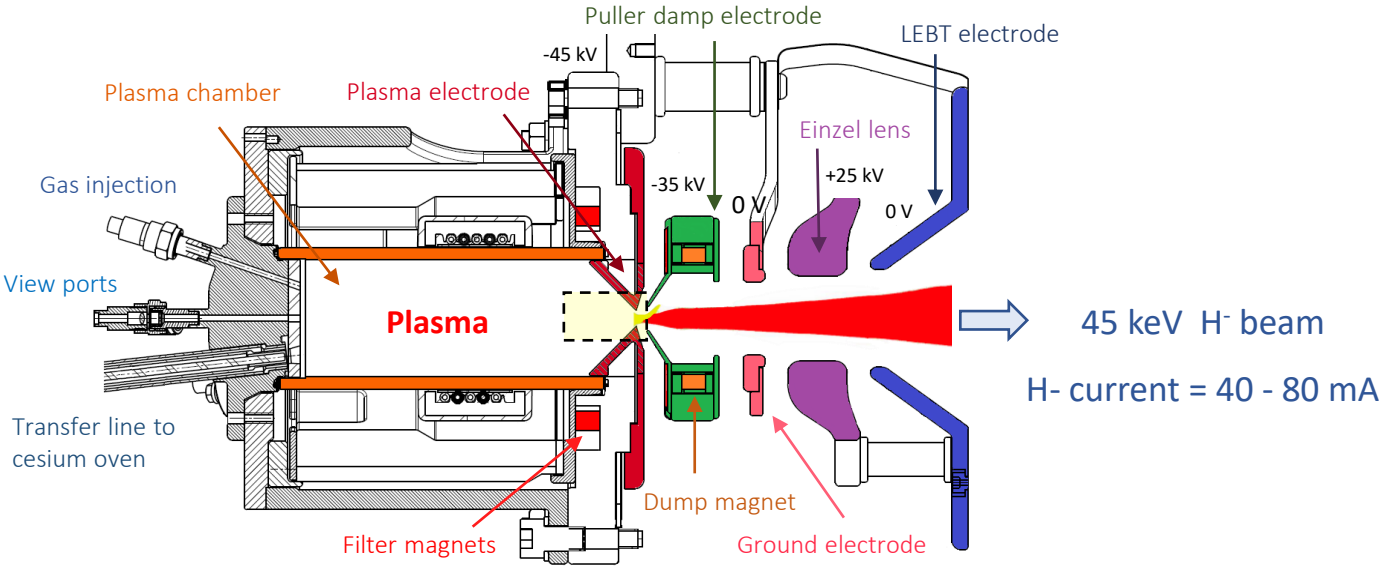
Introduction

- The **Linac4 is the new injector complex (160 MeV)** of the **LHC**, replacing Linac2.



LINAC 4: schematic layout

- **H^- ion source at Linac4 (IS03b):** «volume» and «plasma surface» production of H^- ions.



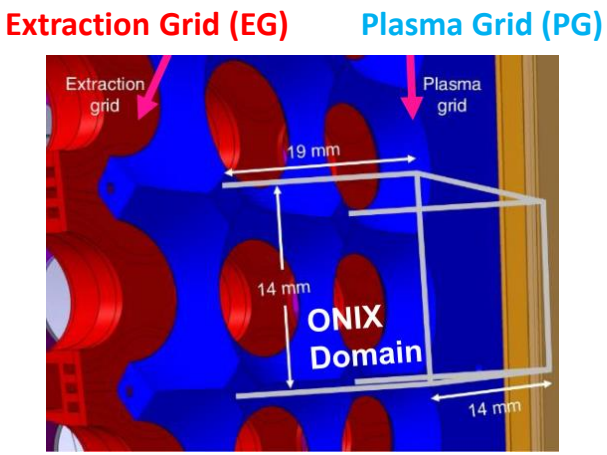
Goal: Investigate the H^- beam formation processes and their impact on beam properties.

Simulation model

ONIX (Orsay Negative Ions eXtraction):

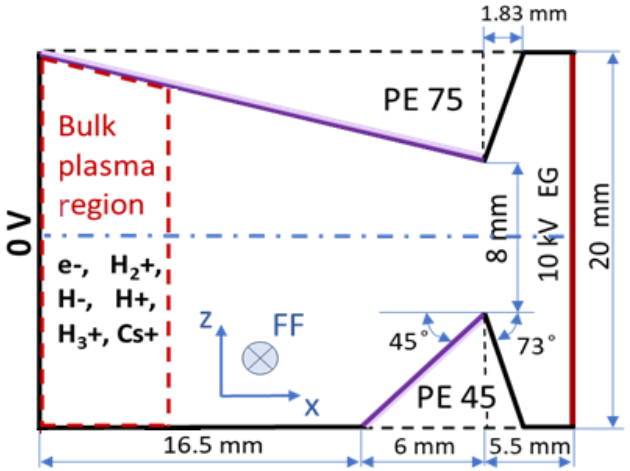
- 3D Particle-in-Cell (PIC) Monte Carlo Collision (MCC) code developed by LPGP-Orsay for simulating the **formation and extraction of H^- ions** and co-extracted electrons in negative ion sources for **ITER's** Neutral Beam Injector (NBI).

Fraction of ITER beam injector **extraction system:**



1280 apertures per injector

Simulation domain of CERN IS used in ONIX:



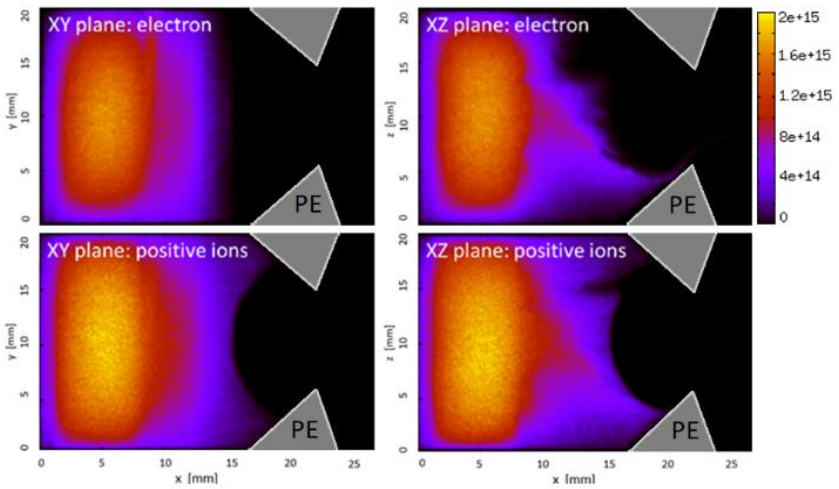
- ✓ 2013 - applied for low spatial resolution applications with non-symmetrical boundaries;
- ✓ 2019 - described plasma physics has become more complex.

- ✓ ONIX has been modified and adapted for modelling:
  - standard IS03 (PE45);
  - dedicated prototype (PE75) to set radial metallic boundary conditions.

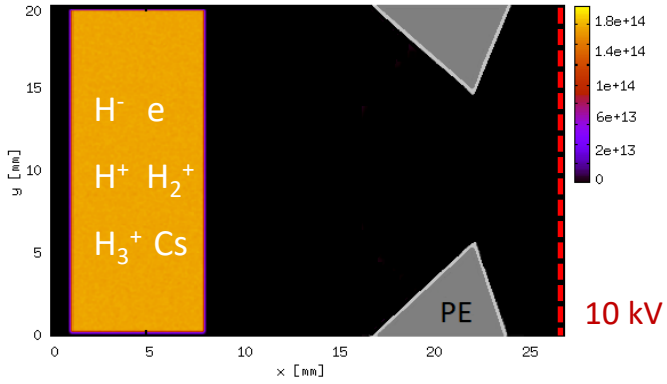
Simulation result of beam formation

- **Plasma parameters used in the simulation:**
  - bulk plasma density of $\mathbf{10^{16}\ m^{-3}}$;
  - plasma composition and energy distributions:

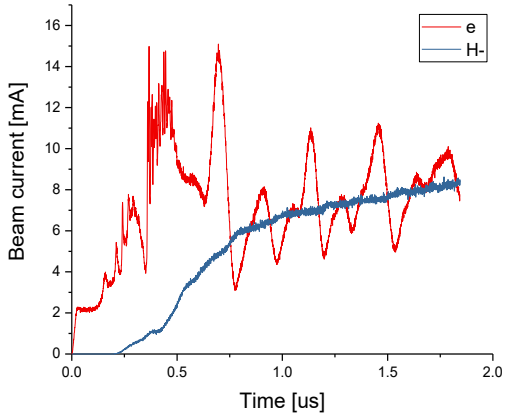
    50% H^- (0.8 eV), 50% e (1 eV), 70% H^+(0.8 eV), 20% H_2^+ (0.1 eV), 10% H_3^+ (0.1 eV).
  - H^- emission rate: $j_{NI\ surface}$ = 550 A m^{-2}
  - Extraction potential: 10kV
- The simulation performed on a **CERN cluster** using 20 CPUs (total 360 cores) takes 14 days representing 1.8 µs real time.



Density maps of electron and positively charged particles (H^+, H_2^+, H_3^+), where filter field generates asymmetry.



Initial **density distribution** (t_0 – plasma start)



Time evolution of the extracted H^- and co-extracted electron currents.

Conclusion - Outlook

✓ A **modified** version of **ONIX code** successfully tested with a **single extraction aperture and non-periodic boundary conditions** at low plasma density.

NEXT steps:

- **Refinements of the initial conditions** rely on analysis from Optical Emission Spectroscopy (OES) of beam formation region at the Linac4 ion source test stand.
- Simulation of **higher plasma densities**, requiring high performance computers.
- Using ONIX results (initial beam phase-space distribution) as input parameters to beam transport simulations codes (e.g., IBSimu).
- **Comparison** of the **simulation** results of ONIX and the **diagnostics** output: Beam Emission Spectroscopy (BES), beam emittance and beam profile.

REFERENCES:

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