Beam Formation Studies on the CERN IS03b H⁻ Source

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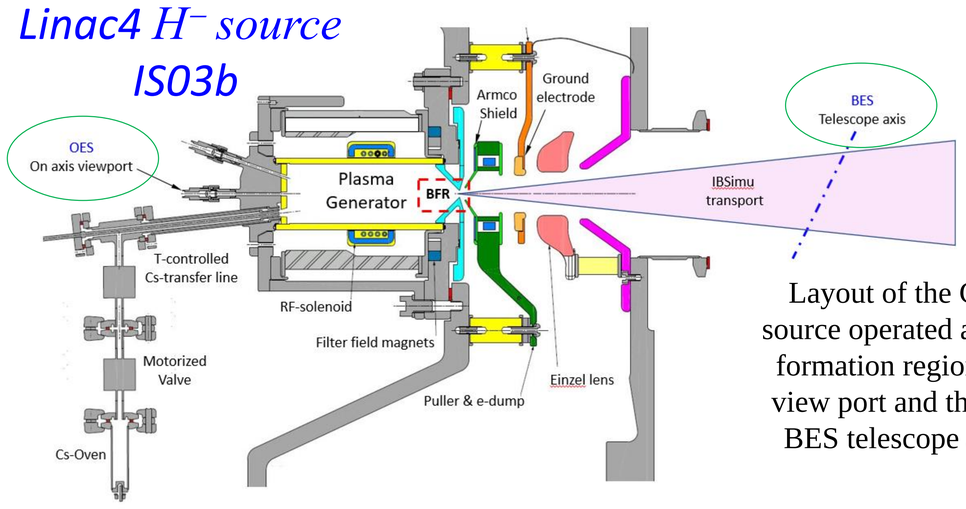
Asymmetries in CERN's Linac4 H⁻ source :
The source's plasma is of the Radio Frequency Inductively Coupled Plasma type (RF-ICP), without magnetic cusp. Vertical downward oriented filter- and electron dump-dipolar magnetic fields expand over the plasma chamber, beam-formation, beam-extraction and electron dump regions and induce *B-field horizontal asymmetry*. The H⁻ beam is generated via combined volume and caesiated plasma surface modes, the latter induces a radial asymmetry characterized by an increased current density close to the plasma electrode surface; *I-density radial asymmetry*

- *An ONIX model to simulate beam formation of the Linac4 H⁻ source is being developed by* A. Vnuchenko et.al., poster **# 74**

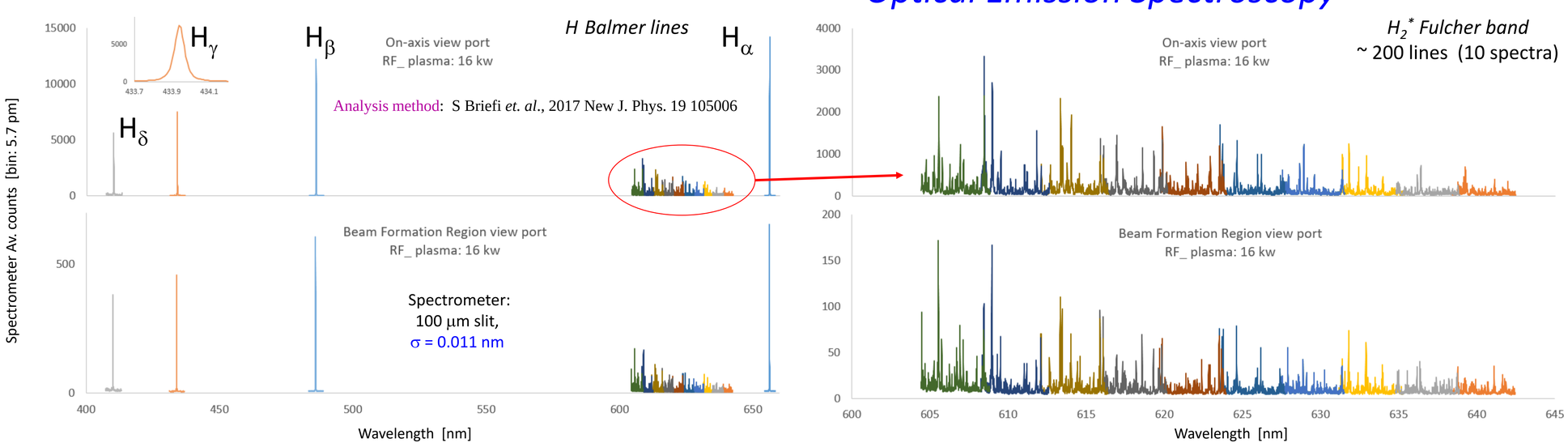
Aims and goals of this contribution:
- Develop beam diagnostics methods and collect data to :
  - ✓ Provide plasma parameter benchmarks of the plasma bulk and of the beam formation region via Optical Emission Spectroscopy (OES)
  - ✓ Measure Beam Emission Spectroscopy (BES) closest to the H⁻ source
  - ✓ Develop a 2D Beam profile measurement technique to complement the Emittance measurement.
- Future work:
  - ❑ Validate the plasma parameters input to ONIX
  - ❑ Extract from ONIX simulations the phase space of the H⁻ and electron beams
  - ❑ Transport the "ONIX" beam using IBSimu to the diagnostics locations
  - ❑ Compare the simulated beam projections to BES, Profile and Emittance measurement and analyse the impact of asymmetries on the beam formation process and beam properties.

Linac4 H⁻ source IS03b

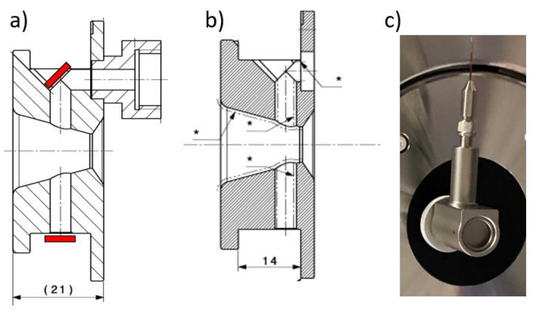


Layout of the Cusp free IS03b H⁻ source operated at Linac4. The beam formation region, the OES on-axis view port and the orientation of the BES telescope axis are indicated.

Optical Emission Spectroscopy

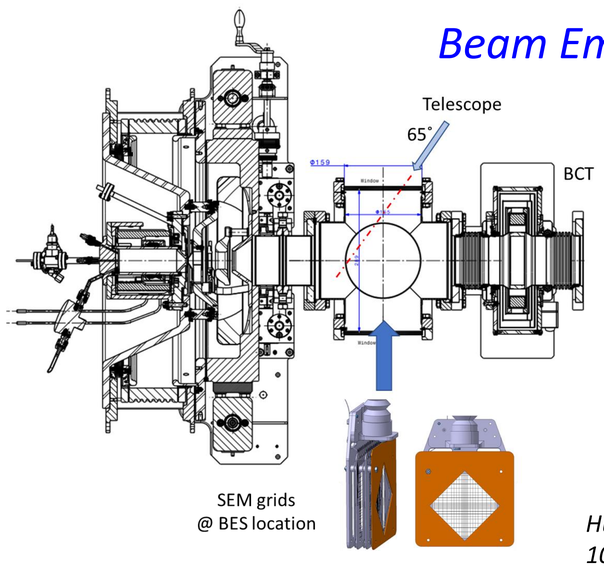


OES Al-mock-ups of the PE75 plasma electrode, Flat and 45 deg. Mirrors illustrated in a) transport the light to a lens focussing the light onto an optical fibre c). The 20 μm black anodized surface are indicated with a star in b).

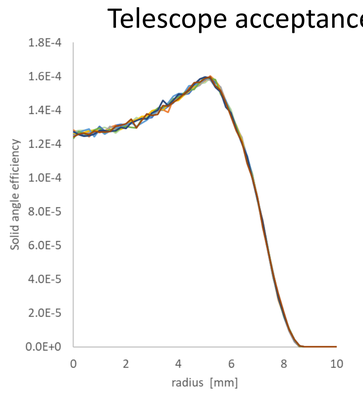


View axis: 7 mm from PE-aperture | 3.4 mm from PE-aperture closest to Meniscus | OES Light capture hole, ϕ 5 mm

Beam Emission Spectroscopy



Telescope acceptance



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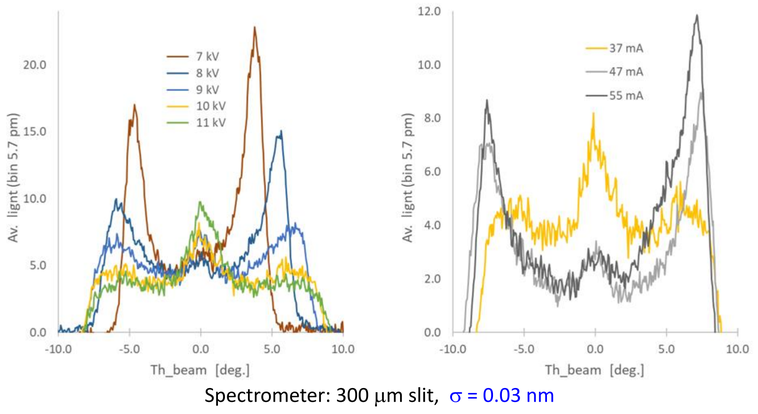
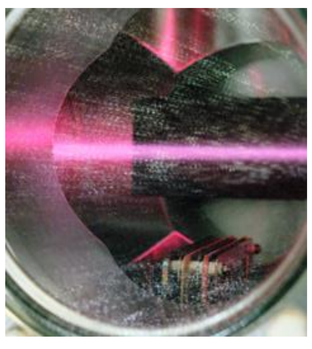
Beam angular distributions derived from the spectra of doppler shifted H_α line emitted by 45 keV H⁻ ions neutralized in flight to H* by interaction with a 2×10^{-2} Pa H_2 pressure

Variation of extraction field & *Variation of beam intensity*



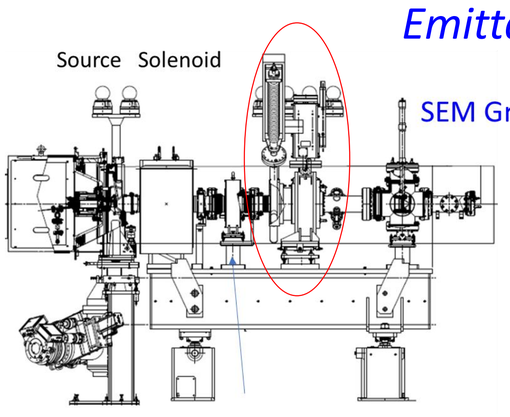
Spectrometer: 300 μm slit, σ = 0.03 nm

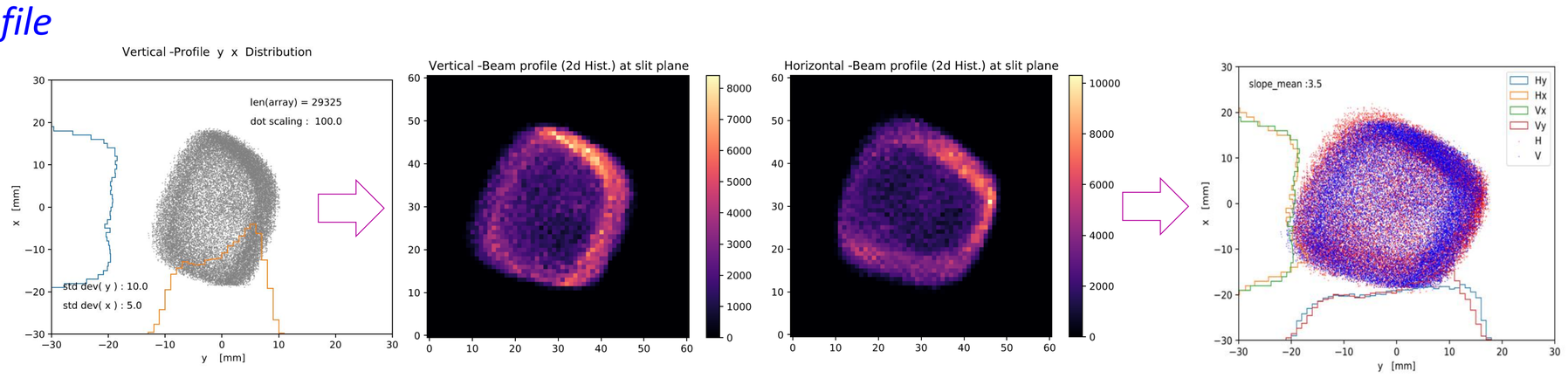
BES requires a minimum beam intensity (> 20 mA) and BES-data were acquired without Einzel Lens. The beam show typical angular distribution of up to 9° and drifts over 400 mm before crossing the telescope acceptance region (close to cylindrical, Φ12 mm) where the beam size is one order of magnitude larger.



Focussed H⁻ beam passing through H2 residual gas after the E-meter at the location of the SEM grids

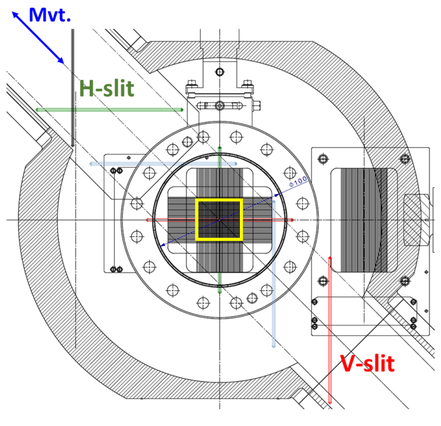
Emittance and Profile

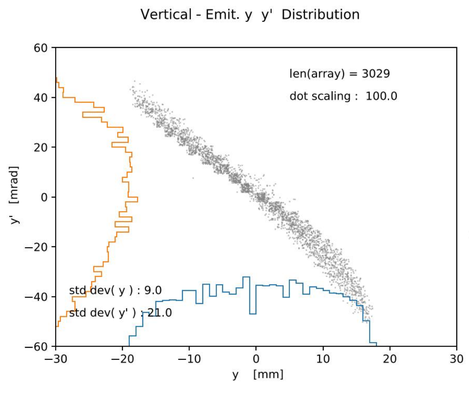




E-P-meter : Slit-Grids distance: 200 mm
Grids: 40 active wires, interval: 0.75 mm
Effective meas. surface : 30 × 30 mm²

Profile: Beam simulation will be compared to the profile x-y distributions, however, the H⁻ beam must be converging to match the detection active surface, and a scaling is applied to correct for the 200 mm drift and obtain the beam shape at the slit plane.





While extracting beam parameters form xx', yy' emittance projections how could one possibly prove a hollow beam ?

Results Conclusion and Outlook:
- New Beam diagnostics methods were developed and operated at the Linac4 test stand
- Data were collected over a broad parameter space, (H⁻, D⁻, p, P_RF, H_2_pulse, E_extr.)
  - ✓ Optical Emission Spectroscopy (OES) of bulk plasma and for the first time of the beam formation region
  - ✓ Beam Emission Spectroscopy (BES) closest to the H⁻ source
  - ✓ 2D Beam profile measurement and standard Emittance measurement.
- Future work:
  - ❑ Analysis of the OES results
  - ❑ Develop new plasma electrode geometries optimized to match ONIX simulation constraints.
  - ❑ Develop a setup providing Horizontal and Vertical BES viewports
  - ❑ Run ONIX at nominal plasma densities and compare simulation to measurement…