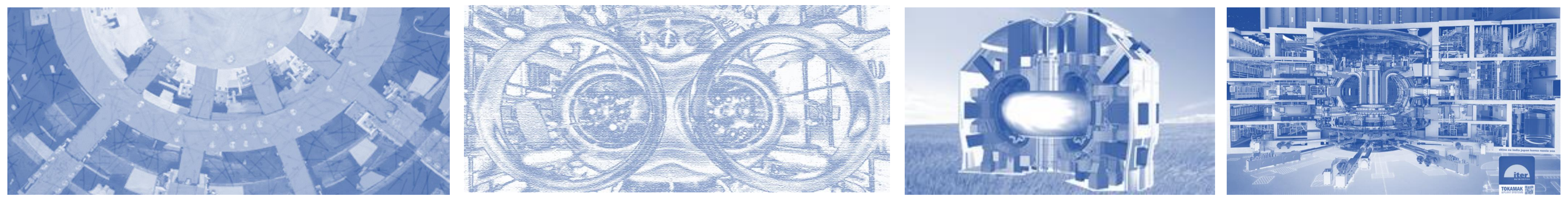

Phase-space characterization of SPIDER beam using an Allison type emittance scanner

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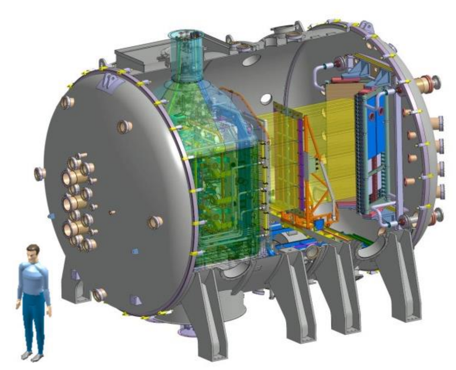
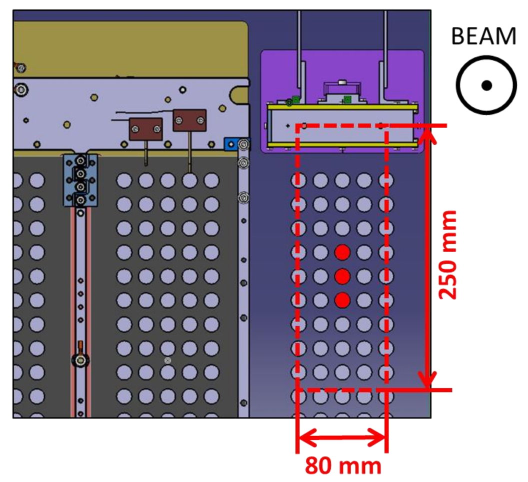
INTRODUCTION

SPIDER [1] is the prototype RF ion source for ITER Heating and Diagnostic Neutral Beams
- Up to 350 A/m² of H^- with an energy up to 100 keV, multibeamlet, electrostatic accelerator
- Currently operating in "isolated beamlet" configuration (28 apertures)
- H/DNBs have strict requirements on beam optics (divergence $< 7\ mrad$ e-fold)

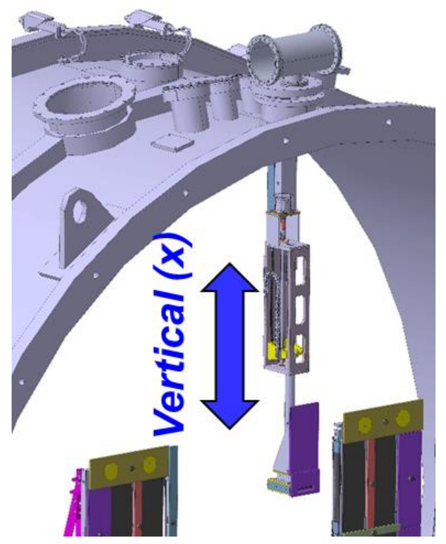
There are several diagnostics [2] to assess beam divergence (BES, CFC tiles, optical cameras)
- No simultaneous measure of beamlet position and velocity distributions
- An Allison emittance scanner [3] was developed and installed in the source
- It directly measures the vertical phase-space distribution of the beamlets in the top segment



SPIDER ALLISON SCANNER

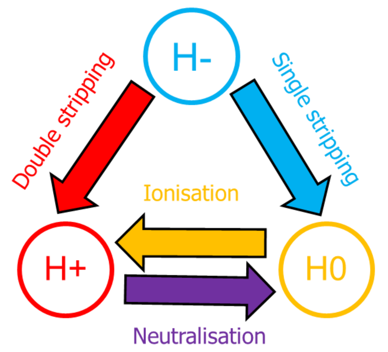


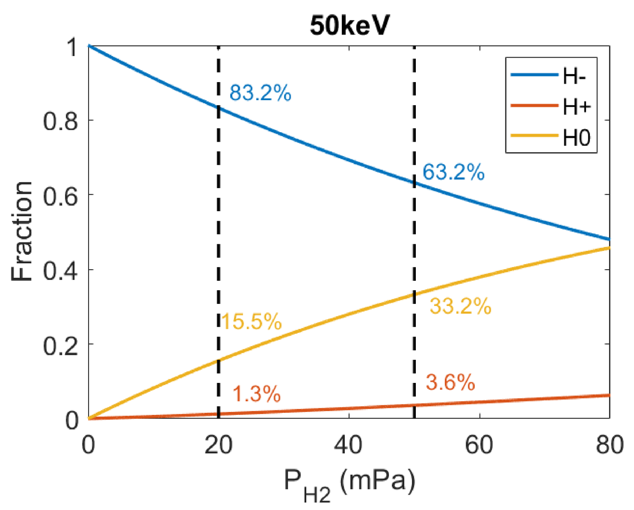
- Placed at $600\ mm$ from the grounded grid [4]
- Centered on a top beamlet group
- Total vertical run of $330\ mm$ ($250\ mm$ exposed to the beam)
- Linear speed of $15\ mm/s$, with resolution of $15\ \mu m/step$, requiring 4s to scan 1 beamlet row
- Geometrical acceptance: $\pm 123\ mrad$
- Angular resolution: $0.6\ mrad$
- 12 bit ADC current meter, with noise as low as $50\ nA$
- Currently it can measure three neighboring beamlets

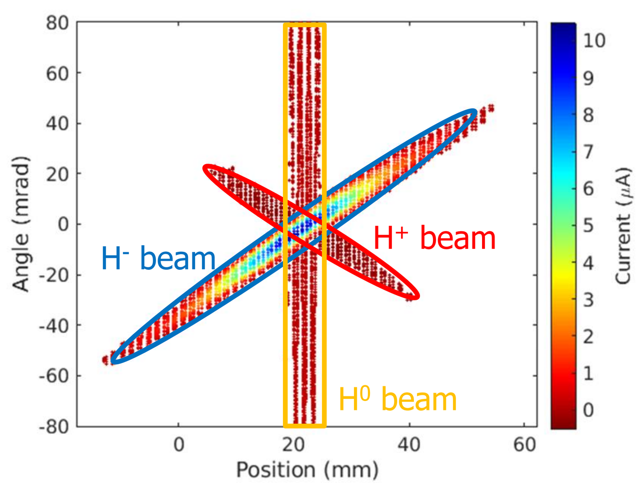


DETECTION OF STRIPPED PARTICLES

- Pressure in the vessel is between $20-50 mPa$
- Significant amount of stripped negative ions ($H^0 \to H^0, H^+$) for a beam energy between $20-50 keV$ [5]





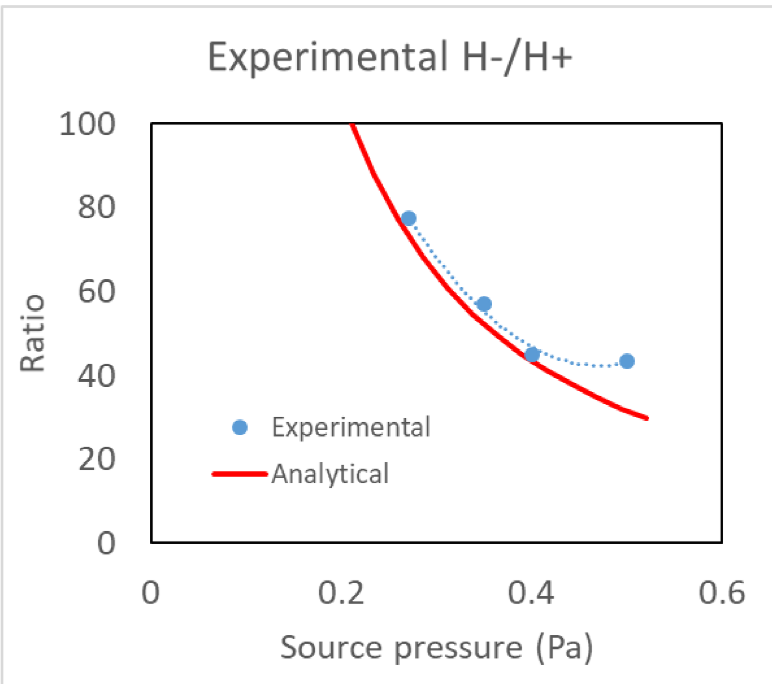


- Oppositely charged particles are detected at opposite angles by the emittance scanner, as expected [6]
- The neutral particles are detected by backscattering of neutrals on the Faraday cup collector → no angular dependence and low intensity (<1% of the main beam)
- The H^-/H^+ ratio is in good agreement with the expected values

To find the fractions, the system is

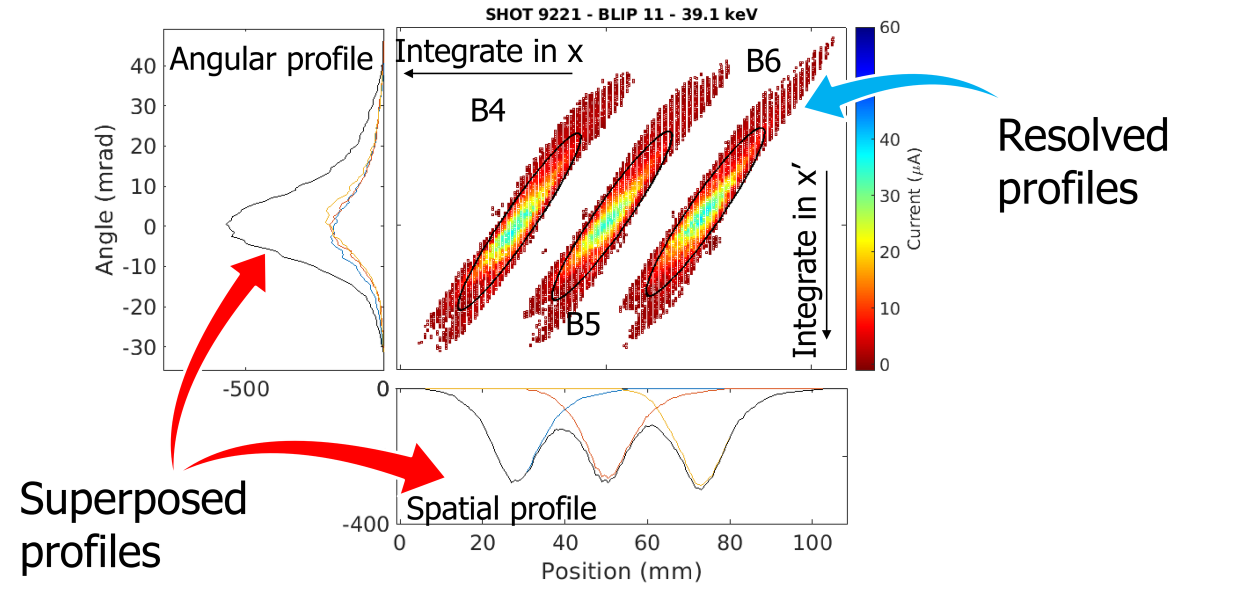
$$\begin{cases} dI_-(t) = -n_g I_-(\sigma_{ss}(E)+\sigma_{ds}(E))vdt \\ dI_+(t) = -n_g I_+\sigma_{cx}(E)vdt + n_g(I_-\sigma_{ds}(E)+I_0\sigma_{iz})vdt \\ dI_0(t) = -n_g I_0\sigma_{iz}(E)vdt + n_g(I_-\sigma_{ss}(E)+I_+\sigma_{cx})vdt \end{cases}$$

with σ_{ss}, σ_{ds}, σ_{iz}, σ_{cx} the cross sections for single stripping, double stripping, ionization and neutralization, energy dependent.



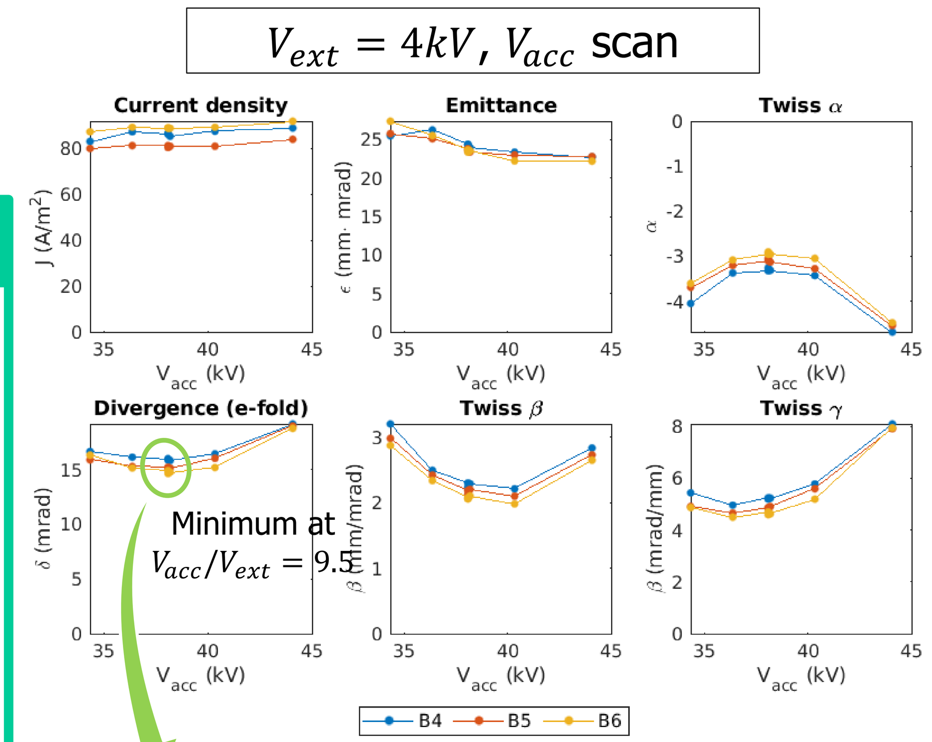
SPIDER BEAMLET OPTICS

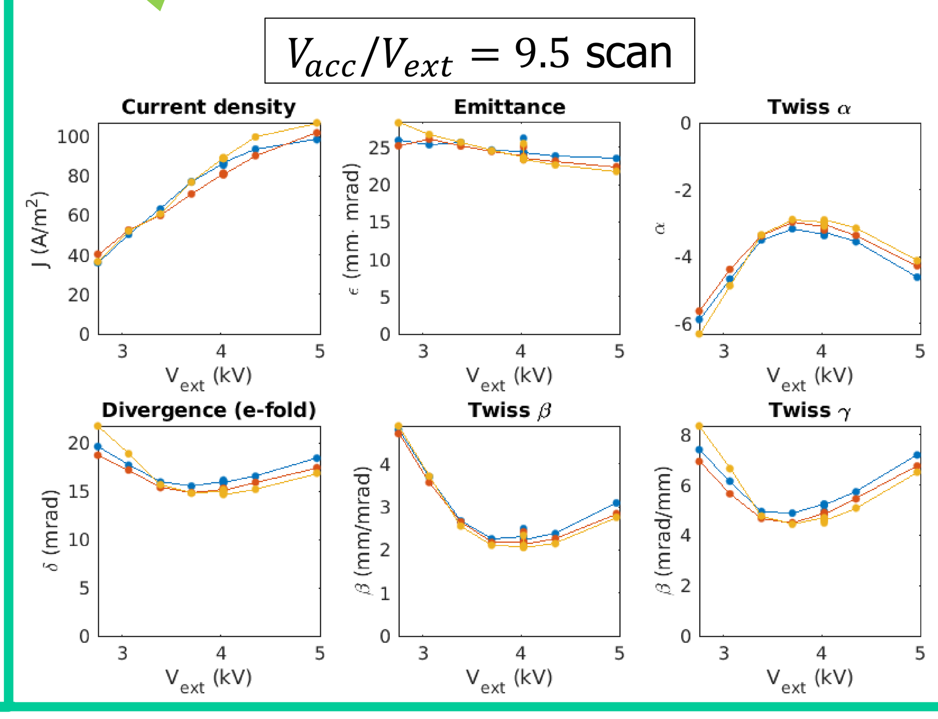
$V_{ext}=3.7kV$, $V_{acc}=35kV$, $P_{RF}=4\times 45kW$, $p=0.4Pa$, $B_{filter}=1.6mT$, $V_{PG}=33.7V$, $V_{BP}=26.6V$



ANALYSIS METHOD

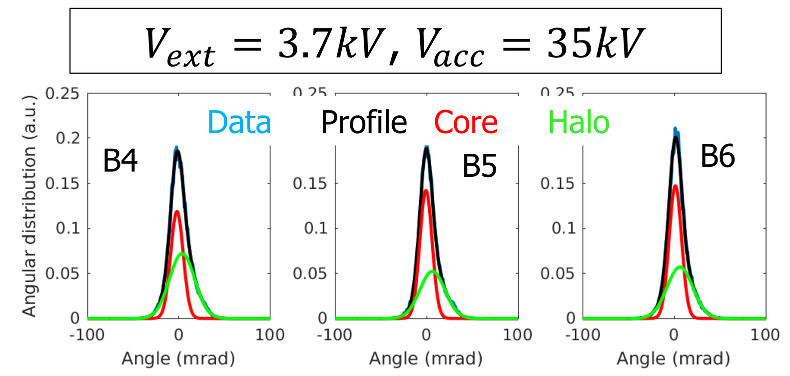
- The three beamlets are identified with an automatic procedure (neglecting H^+ and H^0)
- The Twiss parameters are calculated from the covariance matrix
- The beamlet current is estimated by integrating in the 2D phase-space
- Position and angular projections are obtained by integrating in the other coordinate

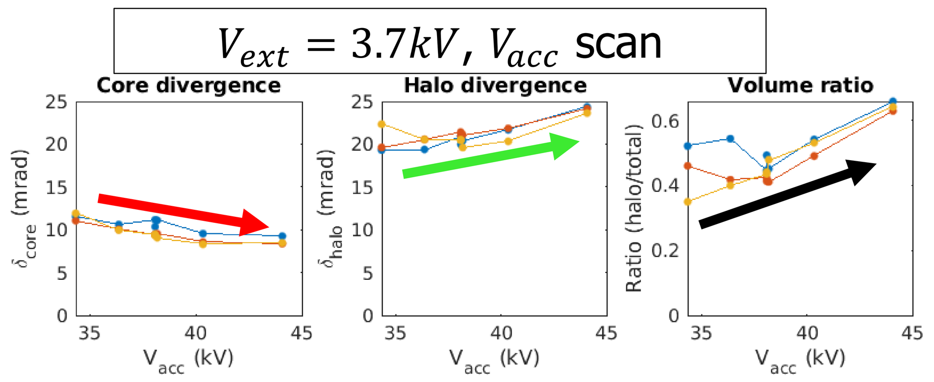




NON-LINEARITIES IN THE DISTRIBUTIONS

- Angular profile: presence of asymmetric tails
- First attempt: superposition of two bidimensional gaussians (*core*, with lower divergence, and *halo*, with larger divergence).
  - Start from fitting the spatial and angular profiles separately and then combine them to obtain the emittance of the two gaussians
  - The volume is defined as the product of the emittance and amplitude of the gaussians.





Core divergence reaches values as low as $8mrad$, but correspondingly the halo contribution to the total current increases. However, with this approach it was not possible to correctly reproduce the tails of the measured phase-space distribution (which appear *swallow-tail* like), and further investigations are ongoing.

CONCLUSIONS

- The SPIDER Allison scanner proved capable to directly measure the phase-space structure of SPIDER neighboring beamlets.
- It measures a stationary point of Twiss parameters and divergence at a ratio $V_{acc}/V_{ext}=9.5$, in agreement with the design values.
- The presence of non-linearities was highlighted, and a first attempt to interpret them as *core* and *halo* was made, showing a decrease of core divergence with acceleration voltage, and an increase of the halo component, which becomes dominant.
- Further investigations will assess the origin of the non-linearities, also with the use of ray-tracing simulations.

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