Design of DIVO: a new diagnostic system to evaluate the ion velocity distribution functions in fusion devices

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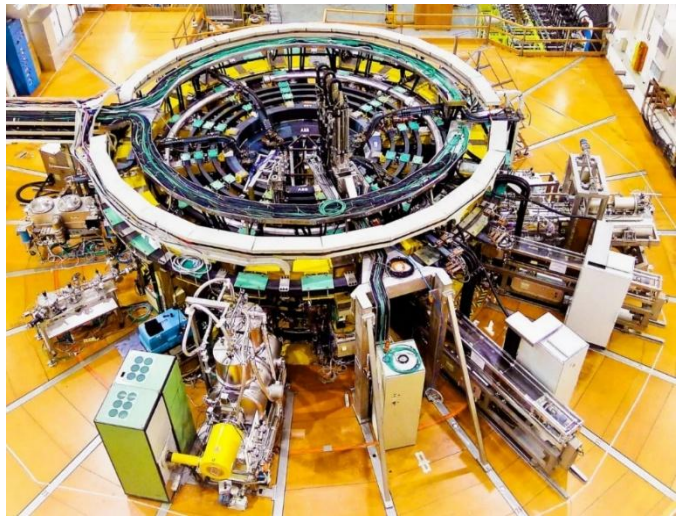
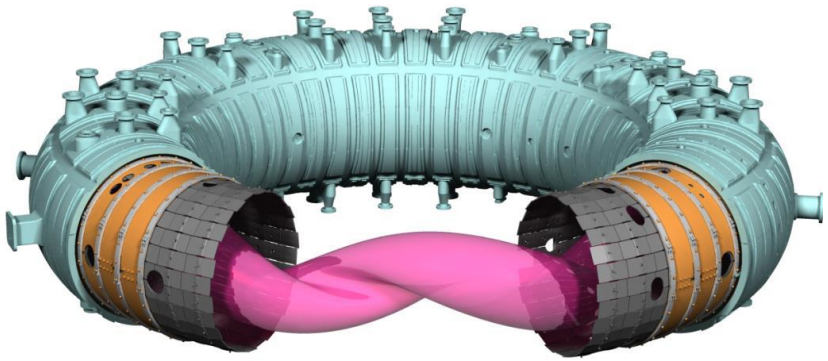
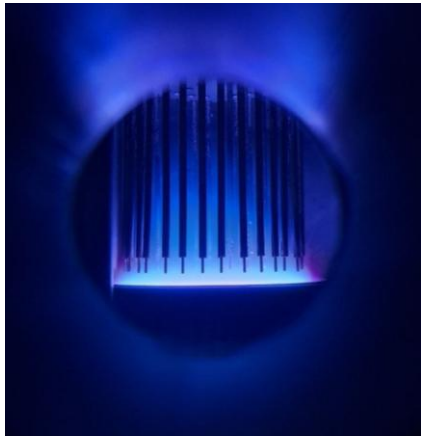
RFX-mod2





Cold plasma experiments



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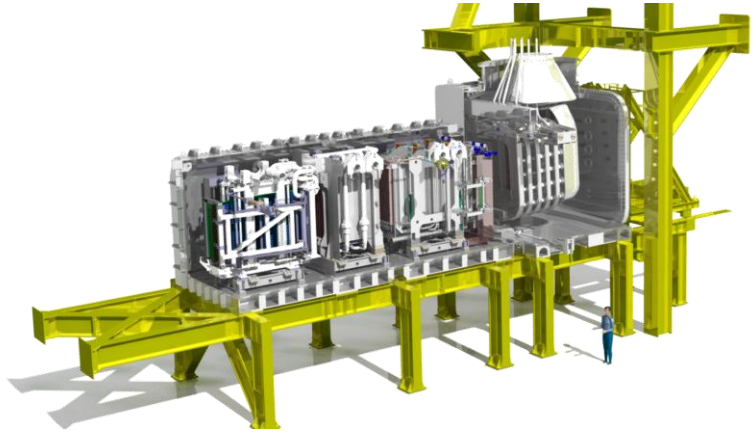
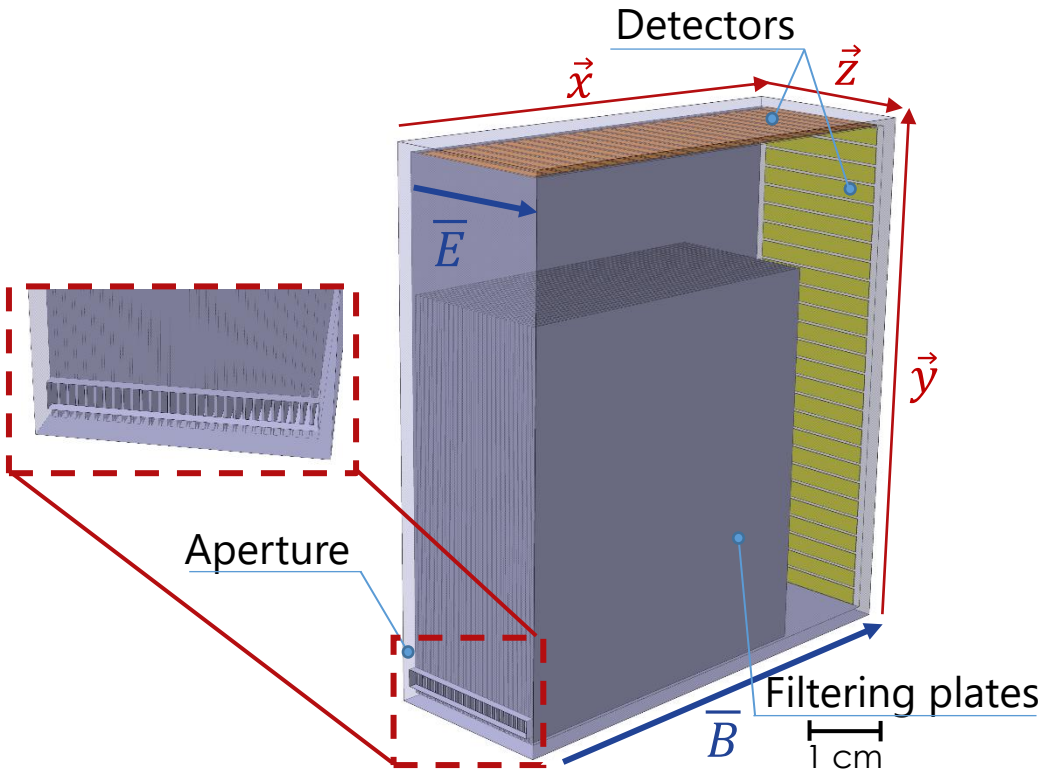


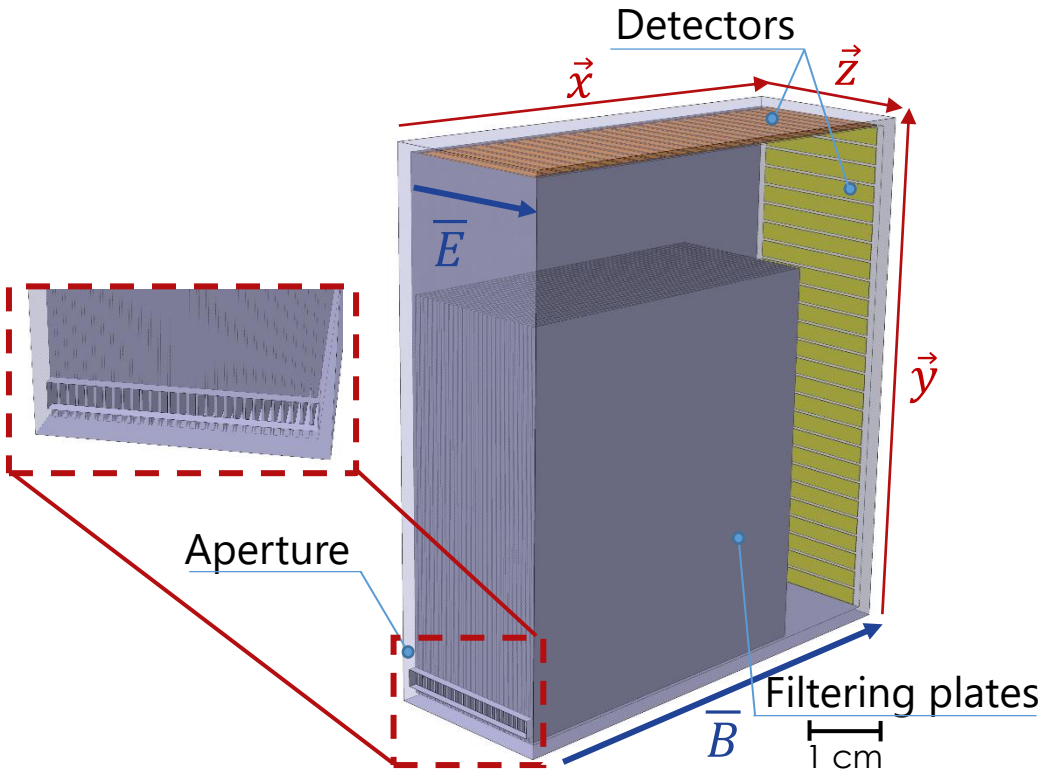
DIVO - Introduction

- DIVO (Diagnostic for Ion Velocity Observation) resolves the two components of the ion velocity, parallel and perpendicular to the magnetic field, allowing for the **reconstruction of the ion velocity distribution functions in velocity space**.
- VDF fundamental to understand dynamical processes associated to kinetic effects, ion acceleration, and heating mechanisms, such as **magnetic reconnection** and also to strong **turbulence activity**.



DIVO - Introduction

- DIVO is used at the plasma edge of fusion machines. The proposed design is optimized for RFX-mod2.
- **Numerical simulations** are run to optimize the **design** of the device, as well as to assess its expected velocity resolution, to define its operational range, and to compute its characteristic geometrical factor.



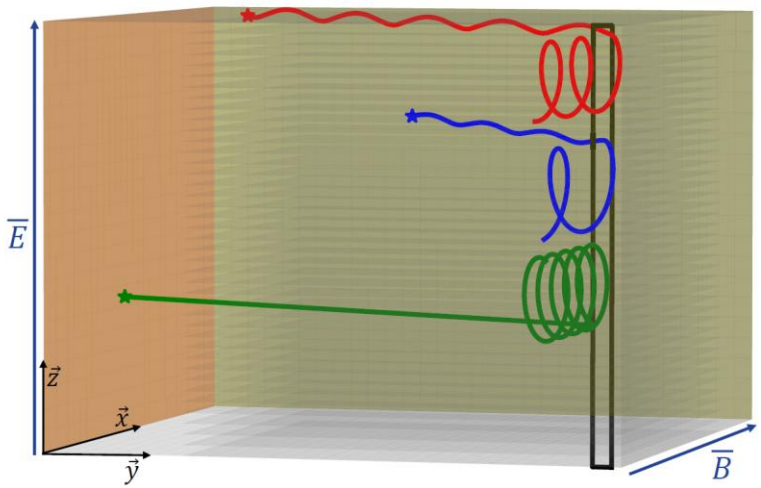
DIVO - Working Principle

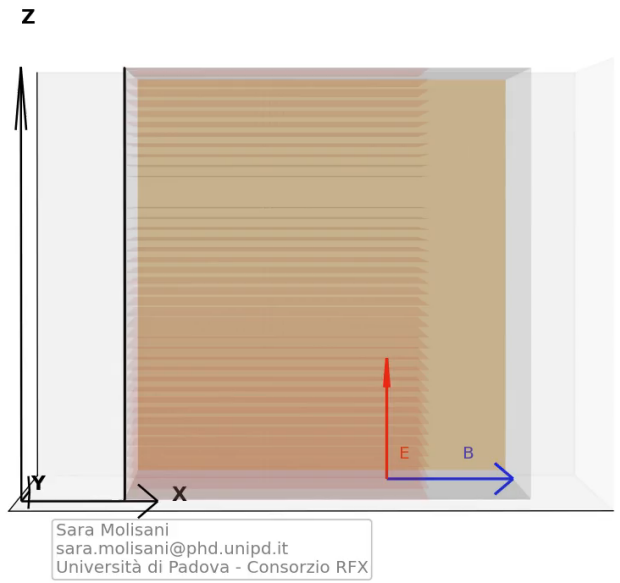
- Balance between the electric and the Lorentz forces, with the aim of **interrupting the Larmor gyration** of the ions

$$m\frac{d\vec{v}}{dt} = q\left(\vec{E} + \vec{v} \times \vec{B}\right) \longrightarrow v_{\perp} = \frac{E}{B}$$

- A generic ion experiences the force due to E and B and **oscillates and drifts** for E × B. If $E = -v_{\perp}B$ is satisfied, the ion **travels straight** till it impacts a detector

- $v_{\perp}$ is selected by the specific electric field that is applied and by the filtering plates
- $v_{//}$ is measured from the arrival position on the detectors

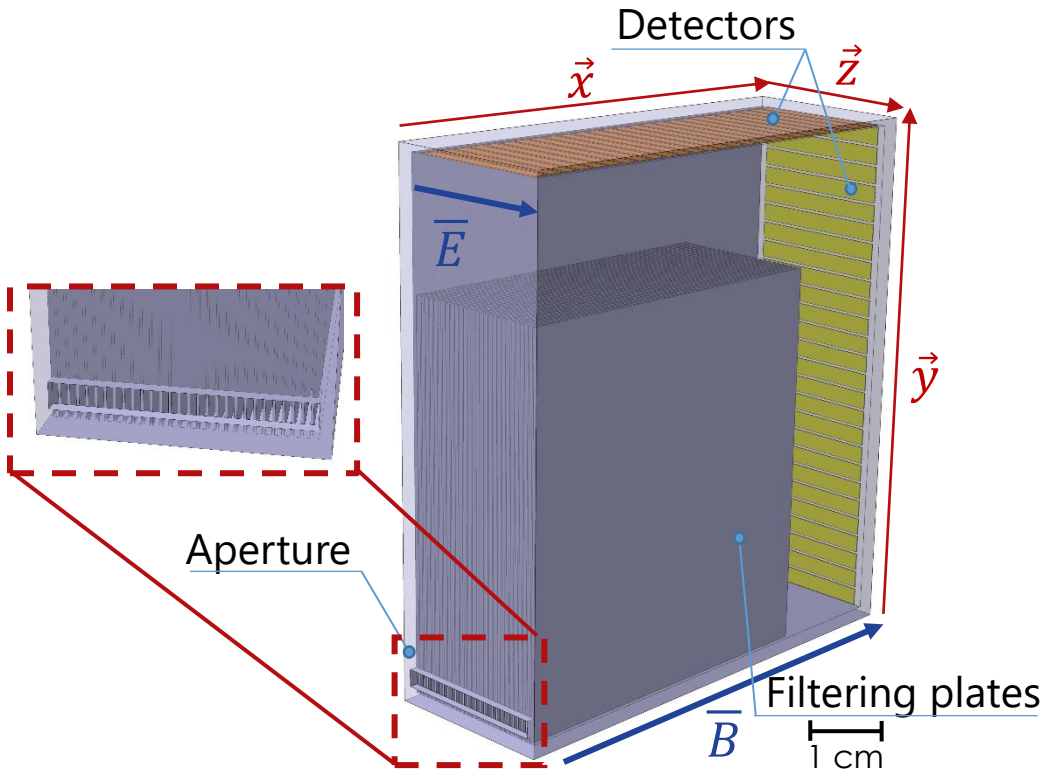


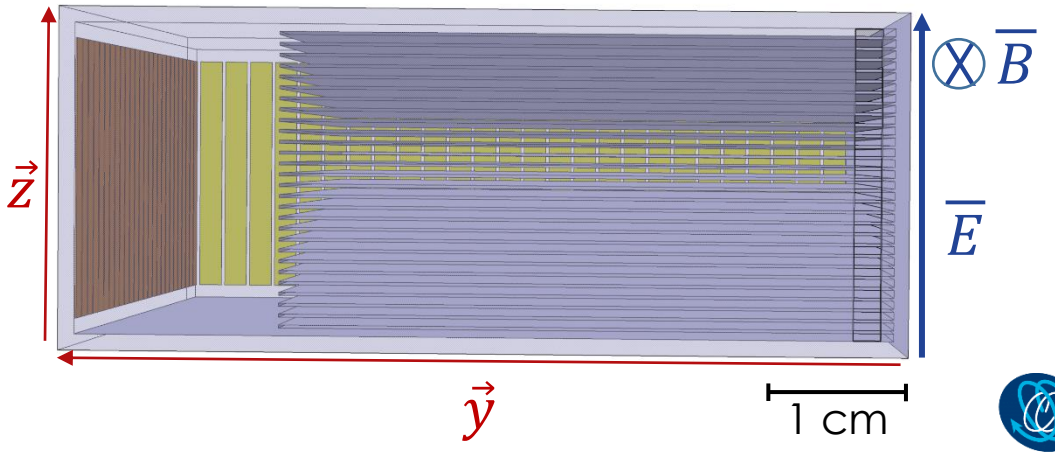


DIVO - Design

Key components of the device:

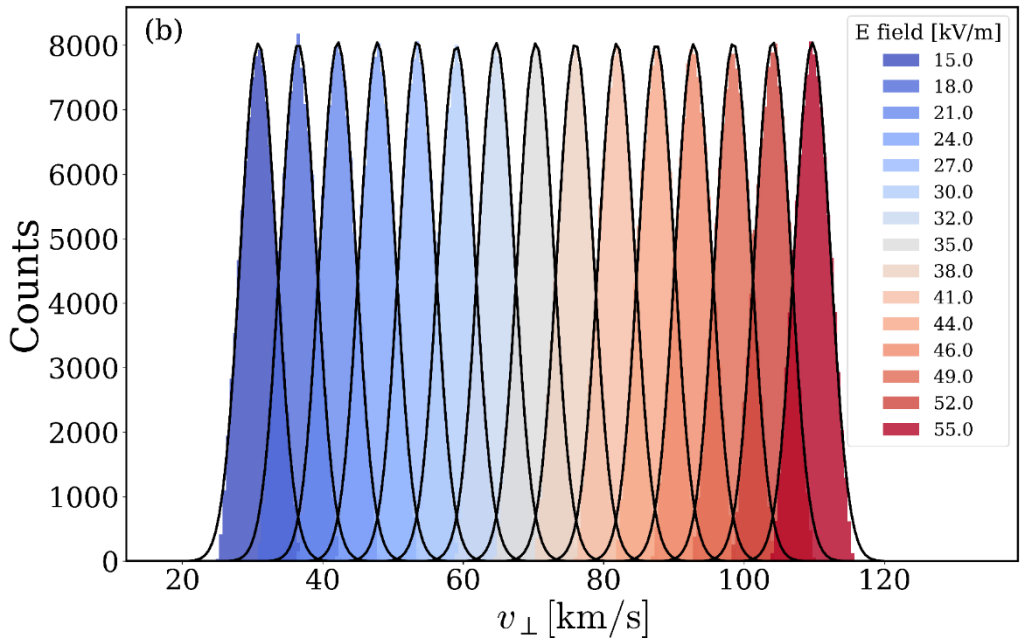
- Thin **aperture** perpendicular to the main magnetic field direction
- Metallic **filtering plates** with small gap to filter the ions
- 2 arrays of **miniaturized Faraday cups**, placed on two screens, to **detect** the landing position of the ions
- 2 electrodes to apply a uniform perpendicular **E field** of the order of kV/m





DIVO - Velocity resolution

- Individual particle simulations: define particle and **compute trajectory** in the geometry of the device
- For a given plasma configuration (gas and B field), simulations at optimized applied E field: get $(v_{//}, v_{\perp})$ of particles detected on the two screens
- On each detector of width Δx, **Gaussian transmission curve**



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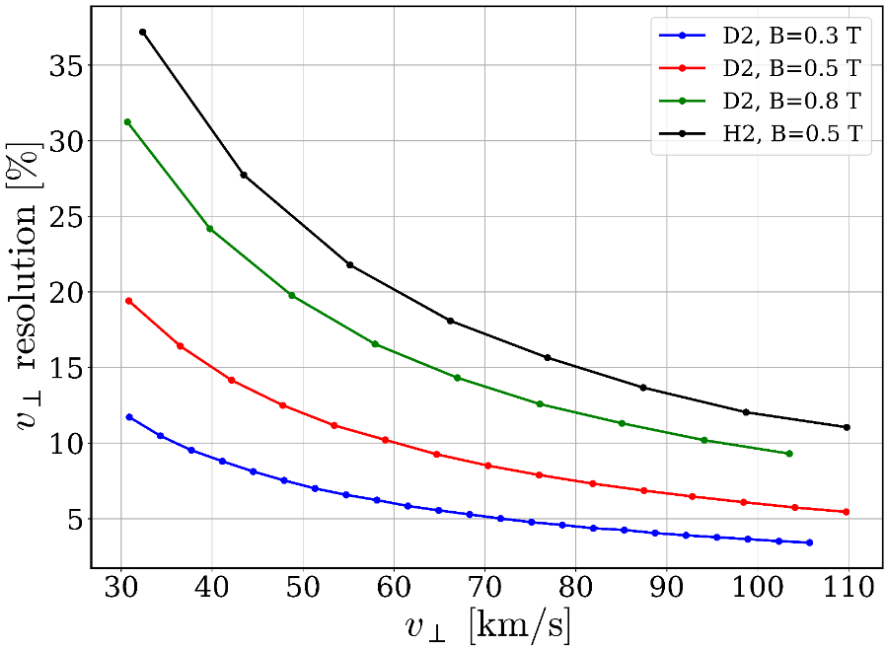
- From FWHM get velocity resolution $v_{\mathrm{RES}}[\%] = \dfrac{v^{\mathrm{FWHM}} \cdot 100}{v_{\mathrm{mean}}}$
- The $v_{\perp}$ **resolution is strongly related to the Larmor radius**, because of the fixed spacing between the filtering plates.



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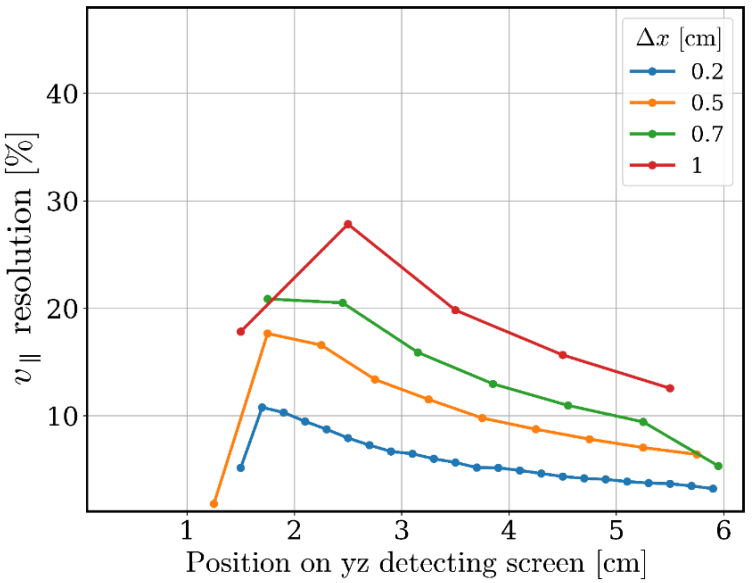
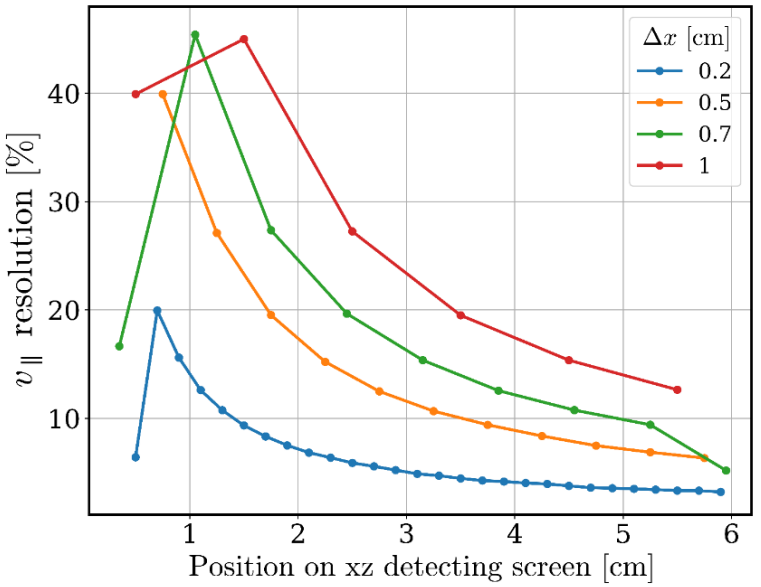
- The $v_{\perp}$ resolution is strongly related to the Larmor radius, because of the fixed spacing between the filtering plates.
- The $v_{//}$ resolution strongly depends on the **size and number of detectors**



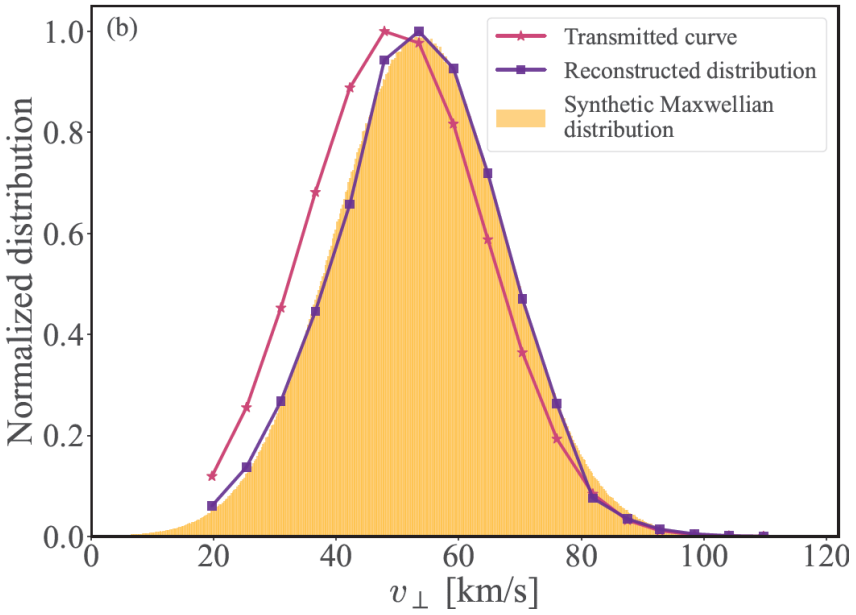


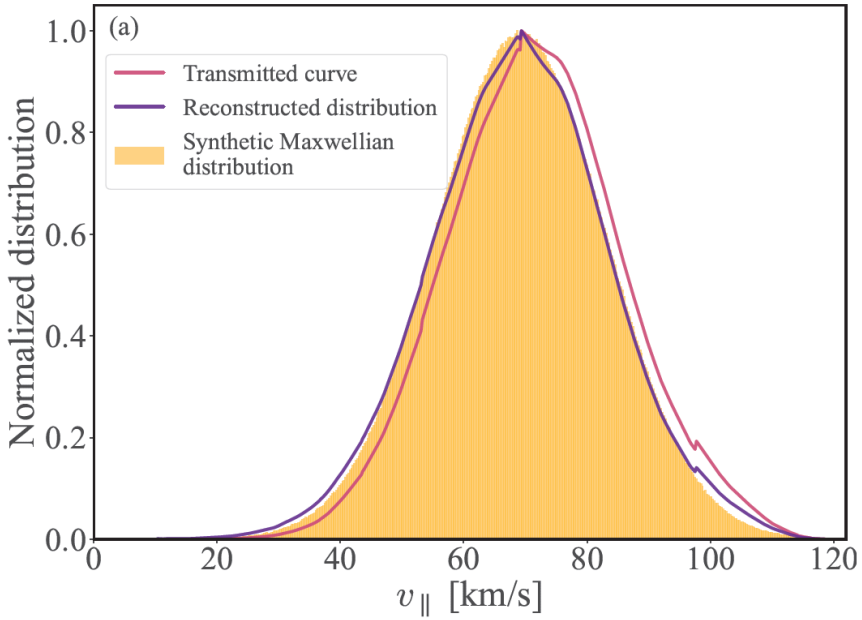
DIVO: Reconstruction of Maxwellian VDF

- Input: synthetic 2D Maxwellian through the device $f(v_{\parallel}, v_{\perp})$
- Output: detected counts C
- Known: Geometric factor of device

$$f(v_{\parallel}^0, v_{\perp}^0, \theta^0) \sim \frac{C(v_{\parallel}^0, v_{\perp}^0, \theta^0)}{G(v_{\parallel}^0, v_{\perp}^0, \theta^0)\ v_{\perp}^{0^2}\ v_{\parallel}^{0^2} \Delta t}$$

- Rescale the counts and **reproduce the original VDF**





Conclusions

- Fast ions measurements are fundamental to diagnose magnetic reconnection in fusion machines
- DIVO can reconstruct the ion VDF in velocity space
- It can be adopted in different kinds of magnetized plasmas where ions have a gyro-radius of few mm or cm.

Thank you!