Plasma rotation measurement using Li-BES

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Workshop FTTF 2019

1. Motivation
2. Present experimental setup
3. Measurement techniques
   a. 2 point measurement
      i. Cross-correlation method
      ii. Cross-phase method
      iii. Correction on tilted structures
   b. 1 point measurement
      i. ACFW method
4. Present results
5. Future plans
   a. reduced beam diameter
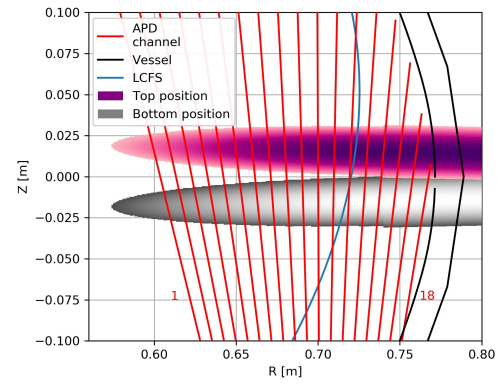   b. toroidal rotation

Poloidal rotation:

- velocity shear -> turbulence suppression
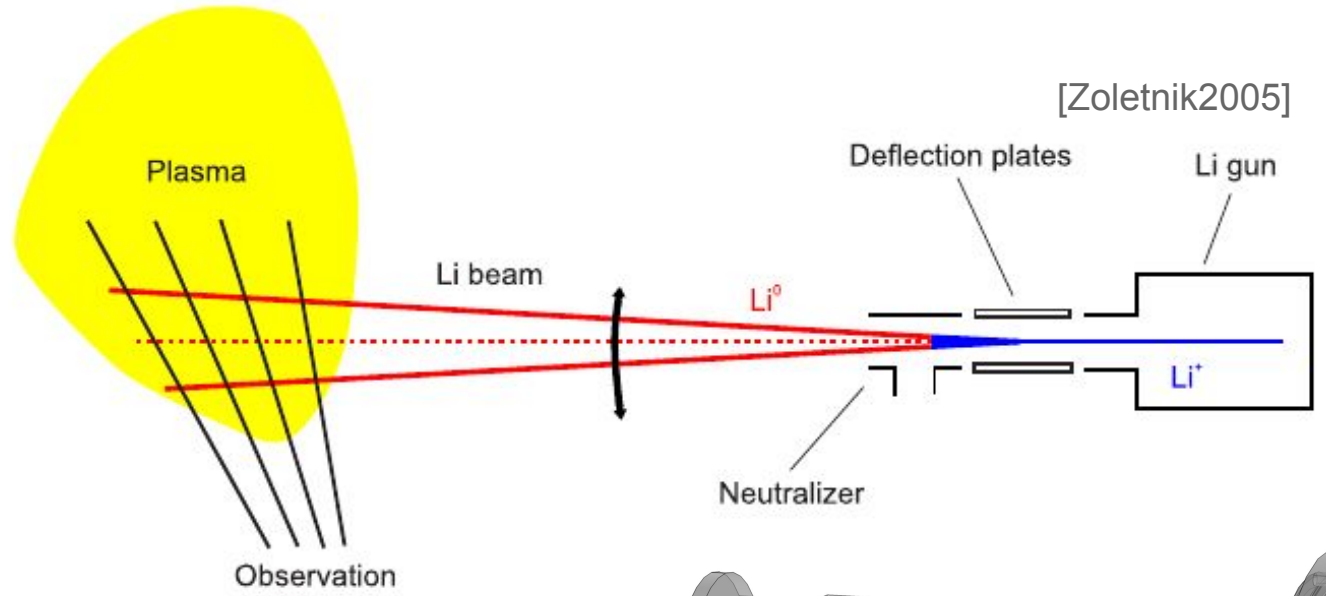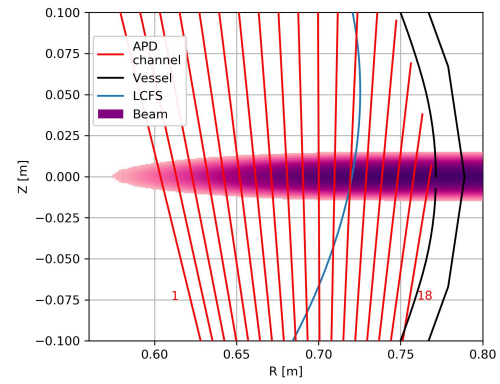- campaigns: LCO, L-H transition, GAMs

Toroidal rotation:

- spontaneous or NBI induced
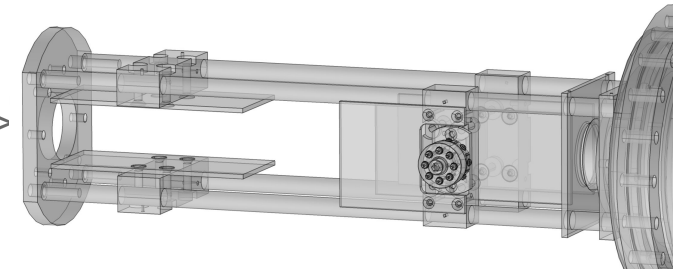- tearing modes -> mode locking -> disruption (often)
- campaigns: RMP
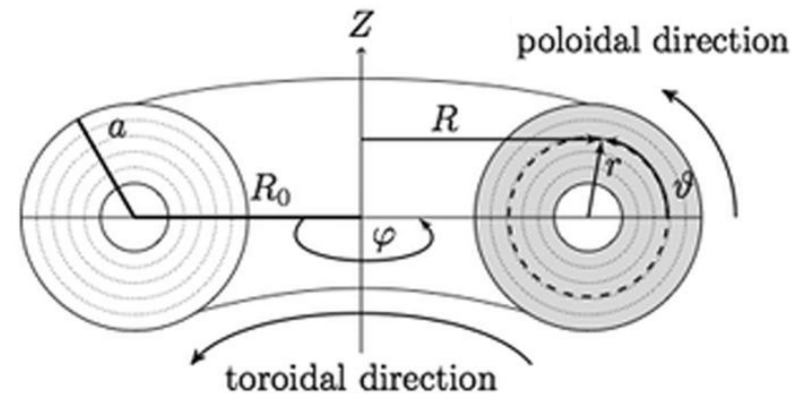
Beam deflection up to 400 kHz

Continuous beam
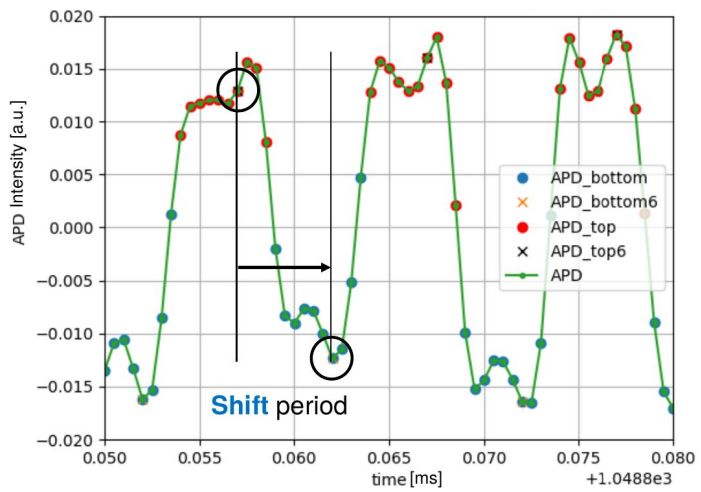

[Zoletnik2005]

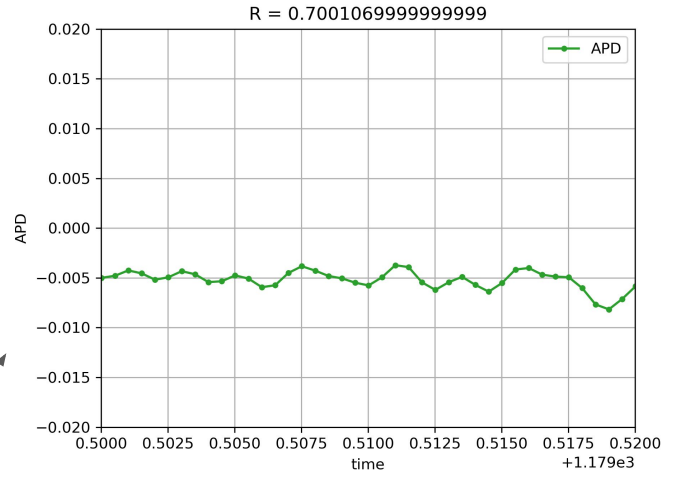Two pairs of ----->
deflection plates

Depends on number of poloidal positions at given radial position:

- Deflected beam - 2 point measurement:
    - Cross-correlation method [Zoletnik2009]
   - Cross-phase method [Zoletnik2009,Eliseev2012]

Bandpass (1 kHz, 500 kHz) filtered signals

- Continuous beam - 1 point measurement:
    - Velocity fluctuation measurement
    - Autocorrelation function width technique (ACFW) [Zoletnik2009, Bencze2006]
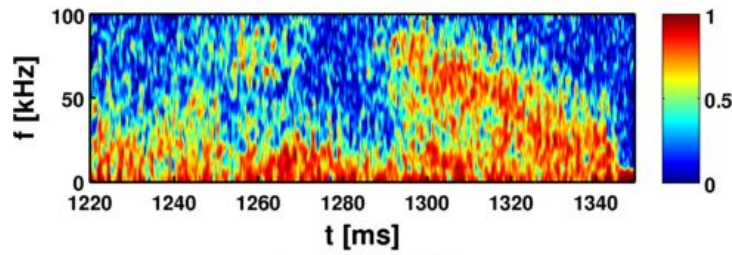
- CCF for virtual beams
- BES time resolution ~ time delays -> fitting of CCF
- time delay between point = shift of CCF maxima
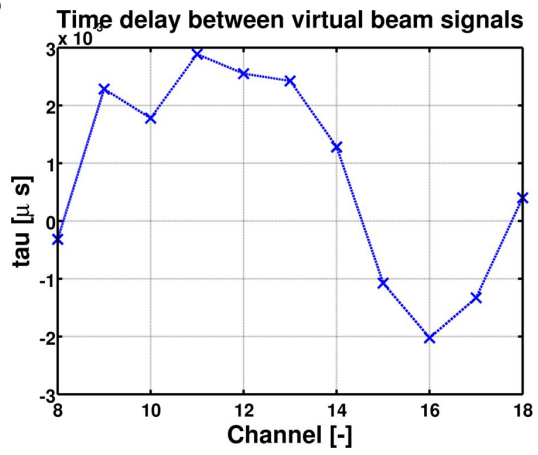- quasi 2 point measurement -> virtual time shift
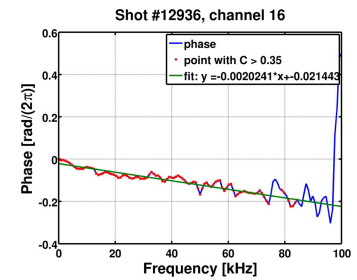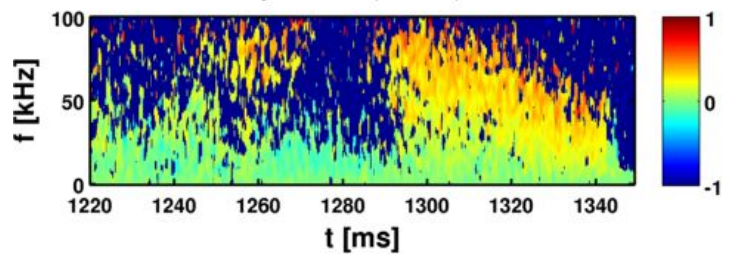- velocity = distance/delay
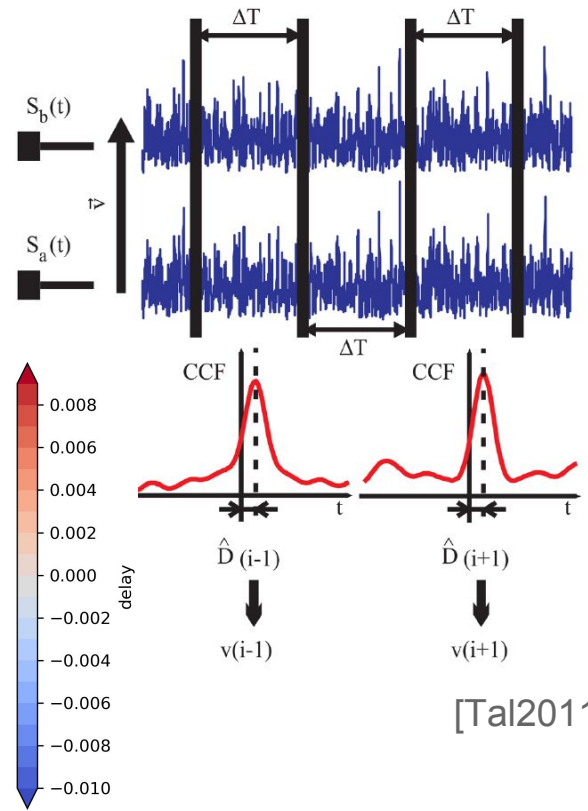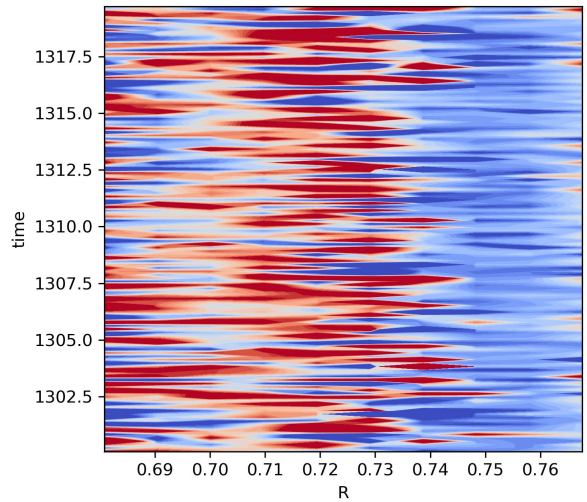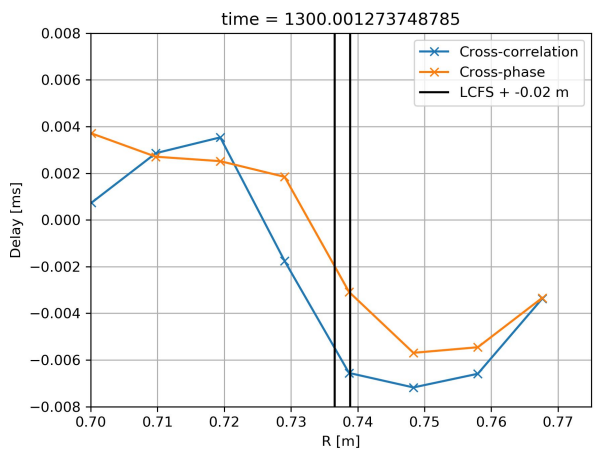
[Tal2011]

- cross-coherence & cross-phase of virtual beams
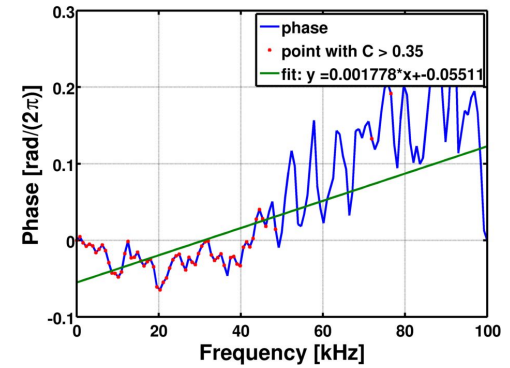- fitting of phase/frequency slope
- time delay = phase/2*pi*frequency
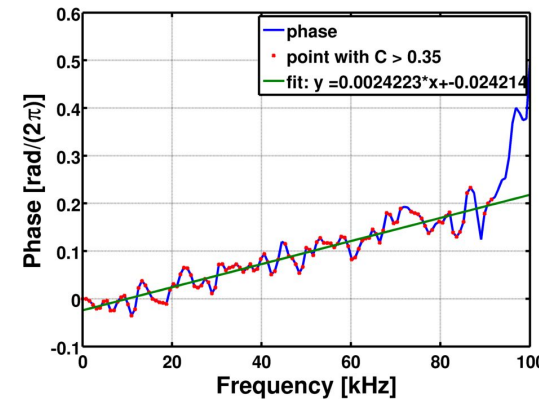

#12936 - coherence between virtual beams

phase/π (C>0.4)

Shot #12936, channel 16

Shot #12936, channel 10

Shot #12936, channel 13

Time delay between virtual beam signals

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- Radially propagating tilted structures [Guszejnov2013]
- 4 unknown variables, 6 equations (4 independent)

$$\left\langle \hat{D} \right\rangle = \frac{\frac{v_u \delta u}{\sigma_U^2} + \frac{v_w \delta w}{\sigma_W^2}}{\kappa^2}$$

TEXTOR #113917
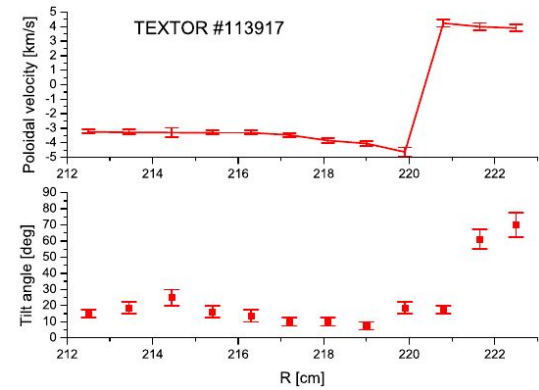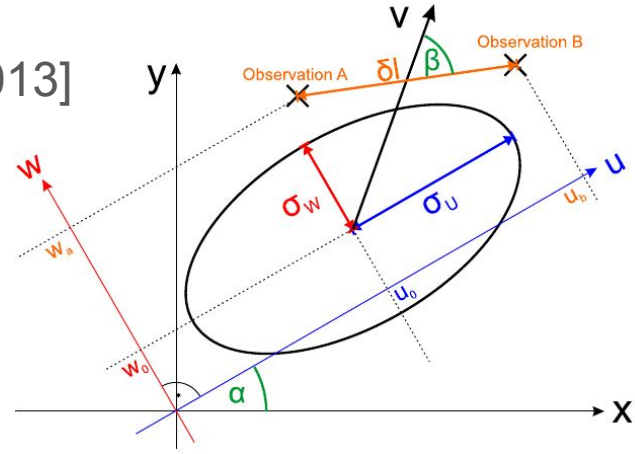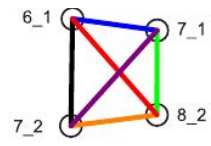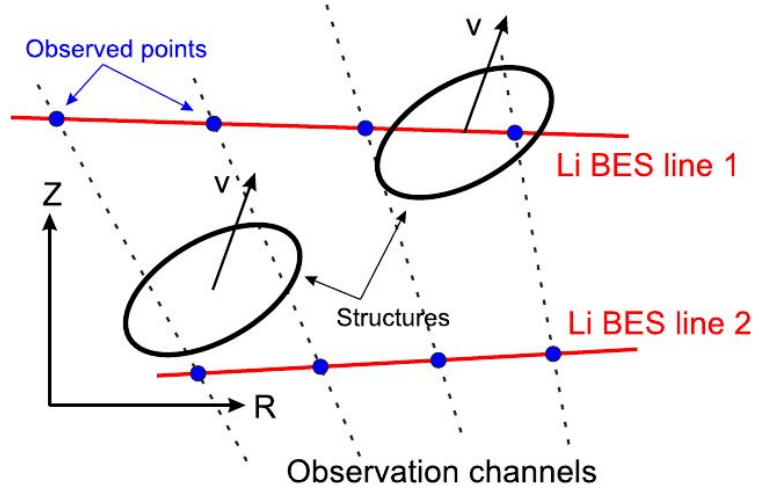
- Autocorrelation function of signal
- FWHM of ACF peak
- Size of the plasma structures fixed $\tau_{life} >> \tau_v$ -> change of the FWHM ~ change in velocity
- Spectrum of FWHM time evolution

#20511; ch:4
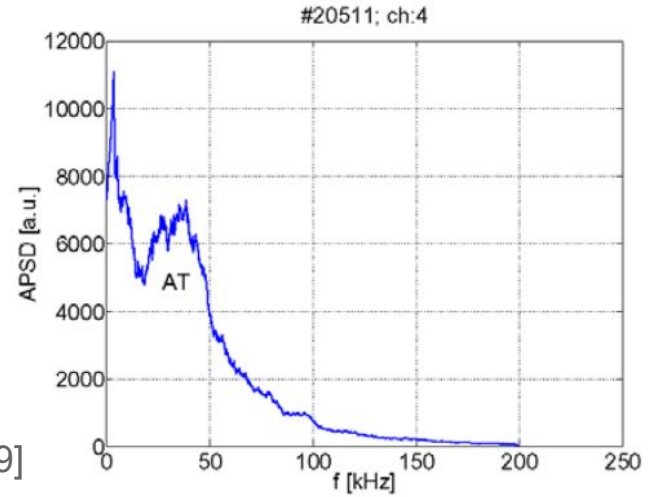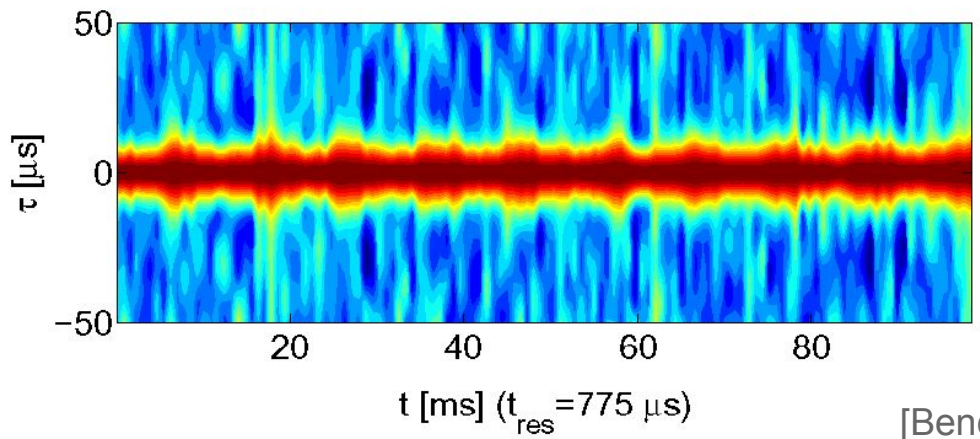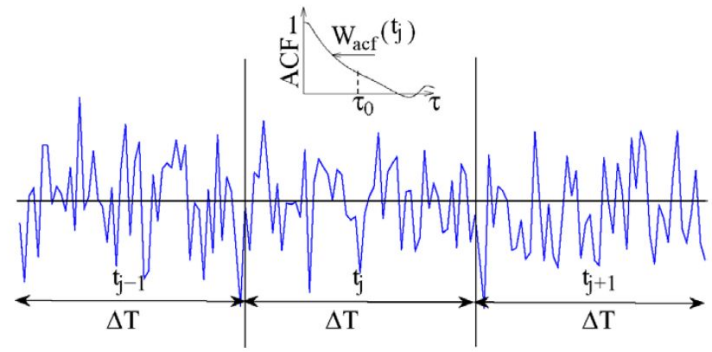
[Bencze2009]

- During lifetime of the Li-beam only 22 useful shots
- Development of Matlab code stopped
- New python code for cross-phase and cross-correlation method under development
- EMTRAIC 2018

"Poloidal" velocity for virtual beam distance 2 cm
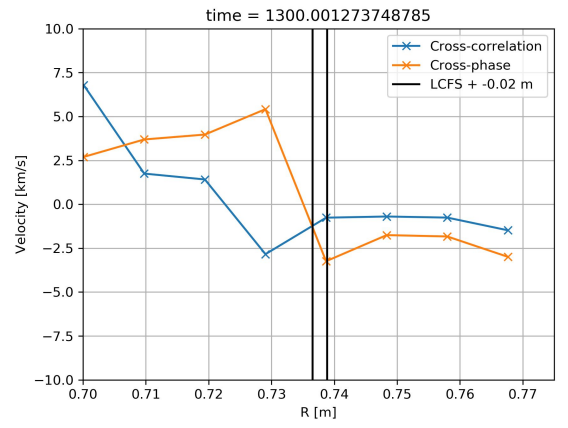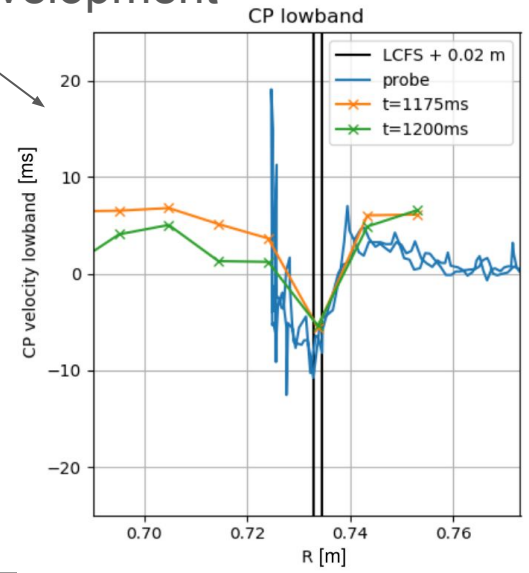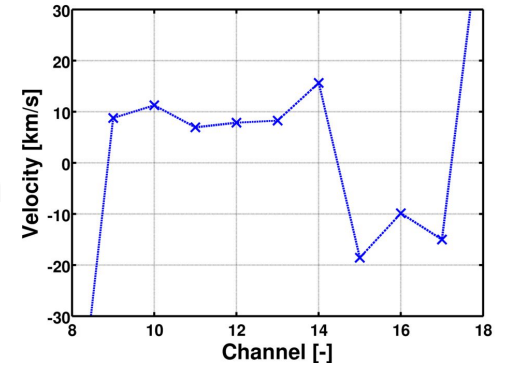
1. Linear diameter reducer
    - poloidal deflection with reduced beam
    - beam positions not overlapping
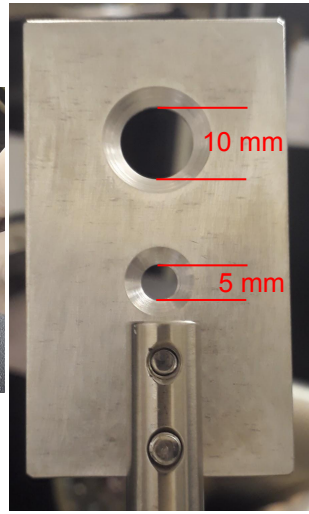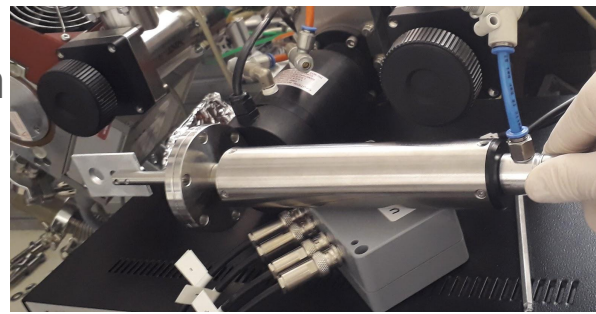
2. Toroidal deflection above APD detector
    - 2x2 grid on flux surface
    - maybe not possible with unreduced beam

3. Finish code development. Steven Thomas data analysis during SUMTRAIC 2019

[Bencze2006] Bencze, A., et al. "Observation of zonal flow-like structures using the autocorrelation-width technique." *Plasma physics and controlled fusion* 48.4 (2006): S137.

[Guszejnov2013] Guszejnov, Dávid, et al. "Determination of structure tilting in magnetized plasmas—Time delay estimation in two dimensions." Physics of Plasmas 20.6 (2013): 062303.

[Eliseev2012] Eliseev, Leonid, et al. "Two point correlation technique for the measurements of poloidal plasma rotation by heavy ion beam probe." Plasma and Fusion Research 7 (2012): 2402064-2402064.

[Tal2011] Tal, Balazs, et al. "Cross-correlation based time delay estimation for turbulent flow velocity measurements: Statistical considerations." *Physics of Plasmas* 18.12 (2011): 122304.

[Zoletnik2005] Zoletnik, S., et al. "Two-dimensional density and density fluctuation diagnostic for the edge plasma in fusion devices." *Review of scientific instruments* 76.7 (2005): 073504.

[Zoletnik2009] Zoletnik, S., et al. "Poloidal flow velocity measurement at the edge of the TEXTOR tokamak using quasi-twodimensional Lithium Beam Emission Spectroscopy", EPS Conference on Plasma Physics 2009 (EPS 2009)