Scattering of EC beams by turbulent density fluctuations and its impact for DEMO

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KDII#8 Final meeting

Outline

Task description

Task description for 2020

Actual task description

- Carry out poloidal scan for launch position
- Use more physics-oriented way to illustrate results

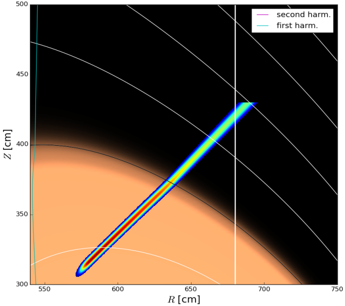
To finish the project

- Assess the necessary power to mitigate NTMs

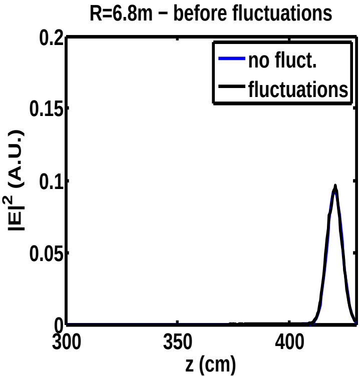
Working at the moment
Finished

Background and 2019

Beam-broadening in ITER

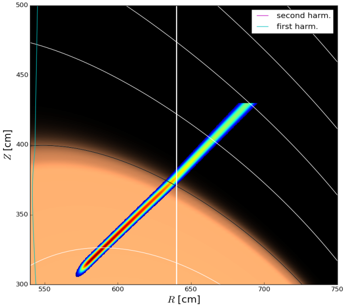


EC beam w/o fluctuations in ITER



Cross-section of beams w/ and w/o fluctuations

Beam-broadening in ITER



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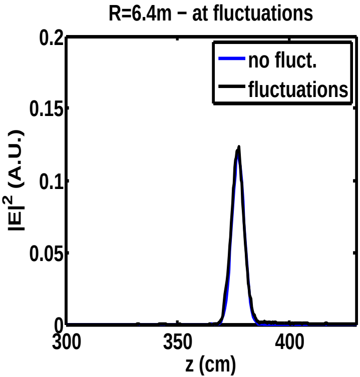

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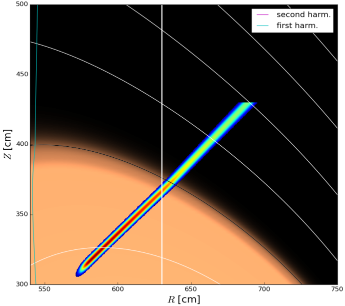

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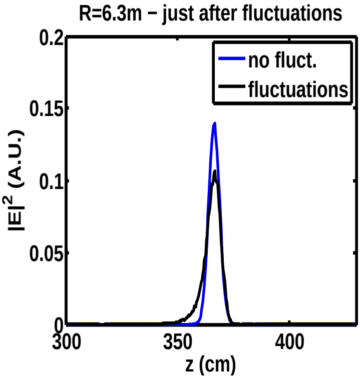

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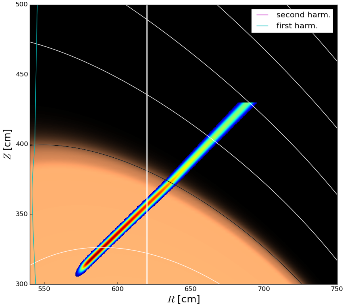

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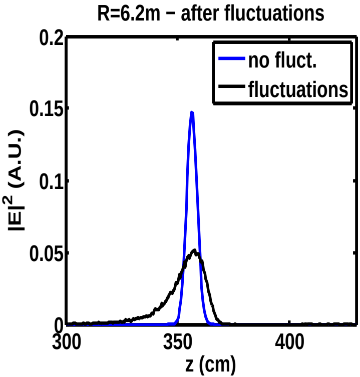

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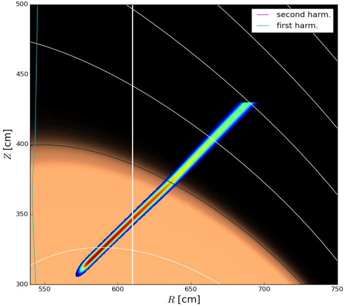

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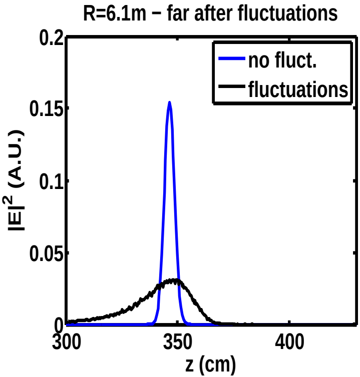


Cross-section of beams w/ and w/o fluctuations

EC waves in DEMO

EC system planned at equatorial port

→ Beam traveling through outer midplane, short propagation in turbulent layer

- Beam enters plasma at the peak of fluctuations (explained below)
- Long propagation after fluctuations

→ Numerical assessment necessary

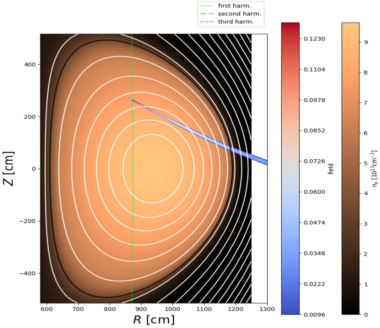
- In this presentation, design of DEMO1 2018 considered
- Differences to 2019 design insignificant **for EC broadening**

DEMO studies 2019

EC beam modeling

WKBeam model based on TORBEAM inputs

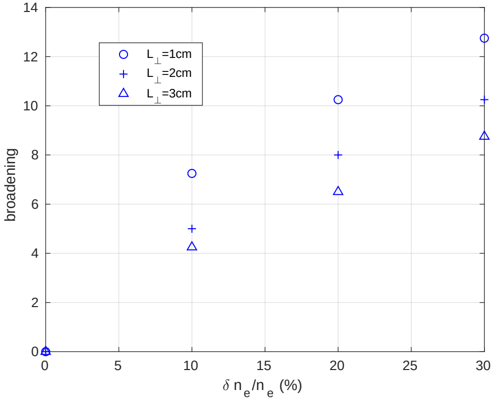
- Inputs from earlier TORBEAM analysis
- Fluctuation model identical to ITER



EC beam in DEMO (no fluctuations)

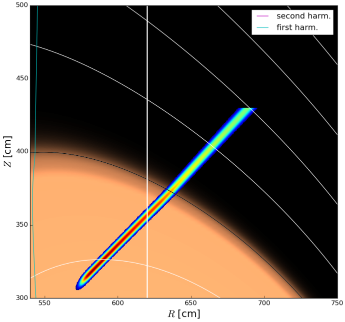
Dependency on fluctuation amplitude and correlation length

- Run 30k rays for the scans
- Scanned F and $L_\perp$
- Broadening defined as the relative increase in FWHM of deposition profile
- Single 1MW beam considered, no overlapping of the beam lines!

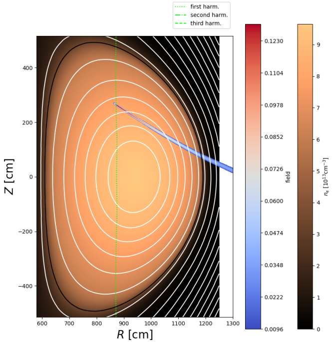


Explanation for the large broadening

- Distance in the transport layer comparable to ITER ($\approx$ 20cm)
- Distance from the transport layer (δs) to resonance surface plays a key role
  - In ITER, δs<1 m
  - In DEMO, δs>2 m
  - Beam has loads of time to diffusive
  - Possible solutions: upper port, resonance layer towards low field side...



EC beam w/o fluctuations in ITER



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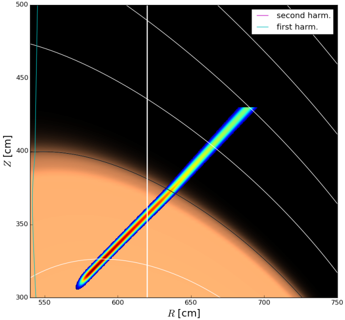
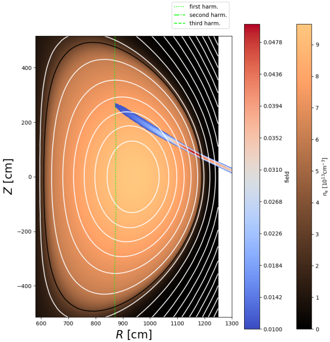


EC beam w/o fluctuations in ITER

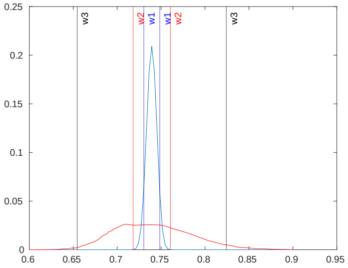


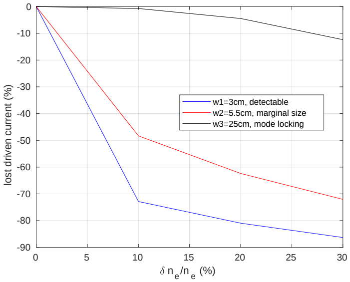
EC beam with fluctuations (20%, 2cm) in DEMO

DEMO studies 2020

From beam broadening to lost current

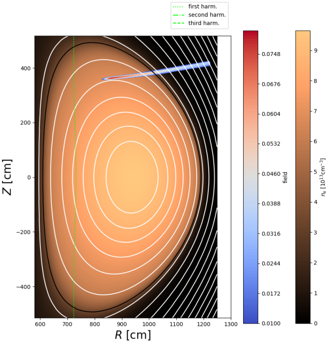
- NTMs are mitigated by current driven inside the island
- Beam broadening might not be optimal way to illustrate this
- Instead, integrate the current inside a radial domain (idea by O. Sauter)
- Three scales: w1:detectable size (3cm), w2: marginal size/fastest growing (5-6cm), and w3: locked mode (25cm)



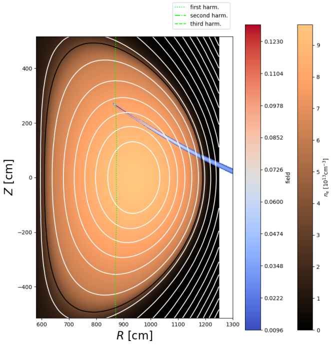


Poloidal scan of the launcher

- Earlier study (using TORBEAM) used ITER-like launcher position
- Notification of old WKBeam inputs, almost zero toroidal angle!
- Decided to study four different launcher configurations
  - Position 1: Old 2019 position, EP (almost) perpendicular propagation
  - Position 2: Upper port, with current drive
  - Position 3: EP, with current drive
  - Position 4: EP, aiming at low field side (using 146 GHz instead of 170 GHz)
- Study beam broadening for these



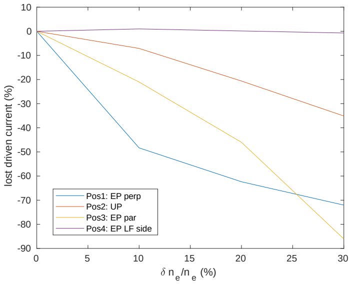
Geometry for position 2.

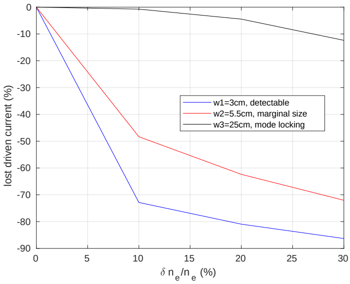


Geometry for positions 1, 3 and 4.

Poloidal scan of the launcher

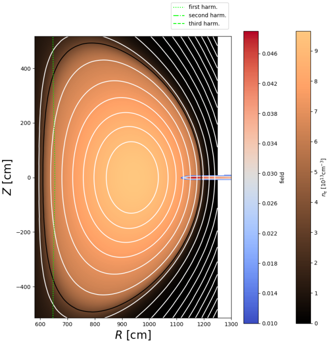
- For clarity, plot only w2 results here (w1 and w3 are similar)
- Original position by far the worst!
- Difference between position 1 and 3 surprisingly large
- Reasoning (momentum conserved, restrictions from dispersion relation): larger $N_{||}$ smaller but more frequent reflections
- Upper port further improves the situation
- EP with low field side absorption leads to (numerically) **zero broadening**

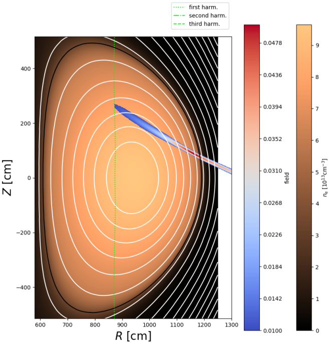




Concluding remarks for the poloidal scan

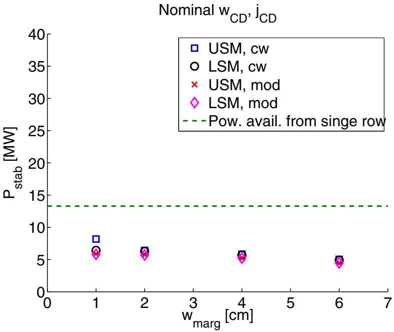
- UP gives a good option physics-wise
- EP with LF side absorption would be the safest option
- Geometry again: deposition profile defined by the length of absorption
- Problems with lower frequency, which is another issue

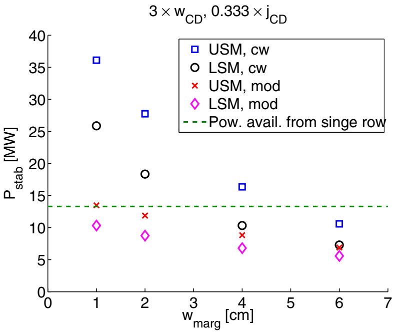




Moving from beam broadening/lost current to NTM mitigation

- Reminder: this part outside task description
- Use Rutherford equation solver to assess the power requirement for full mitigation
- Involves number of input parameters, work still partly ongoing
- Ideally, carry out a scan over marginal island size, so far only single cases





Power requirements for NTM control - very preliminary!!!

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- Ideally, carry out a scan over marginal island size, so far only single cases
- Note, pos 4 is not optimized for NTM mitigation!

Pos	Freq (GHz)	Cur peak (MA/m^2)	broadening (x w_0)	$P_{EC}(MW)$
1	170	1.8e-3	6	>150
2	170	5.3e-3	3	42
3	170	7.8e-3	3	27
4	146	3.0e-3	1	60

Thank you for your attention!

Any questions?