NSTX-U

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Comparison between Simulation and NSTX Measurements using Synthetic Reflectometry

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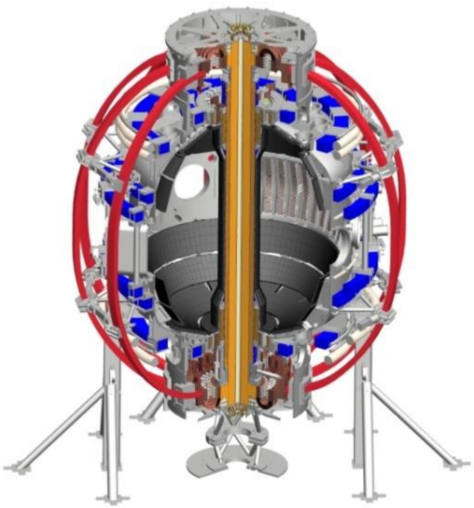


Synthetic reflectometry has been applied to plasma simulation code to compare with experimental results

- A synthetic reflectometry code (FWR2D/3D [1]) has been interfaced to a gyro-kinetic PIC code (XGC-1[2]).
  - XGC-1 is a first principle code, self-consistently calculates fluctuations
  - Use measured equilibrium profiles as input, no free parameters

- The result has been compared with measurements from the edge in NSTX.

- The comparison shows a fair agreement in both local fluctuation levels and radial correlation lengths.

[1] E. J. Valeo et al Plasma Phys. Control. Fusion 44 (2002) L1–L10
[2] S. Ku et al Nucl. Fusion 49 (2009) 115021

Density fluctuations from XGC-1 are used in reflectometer simulations with the FWR codes

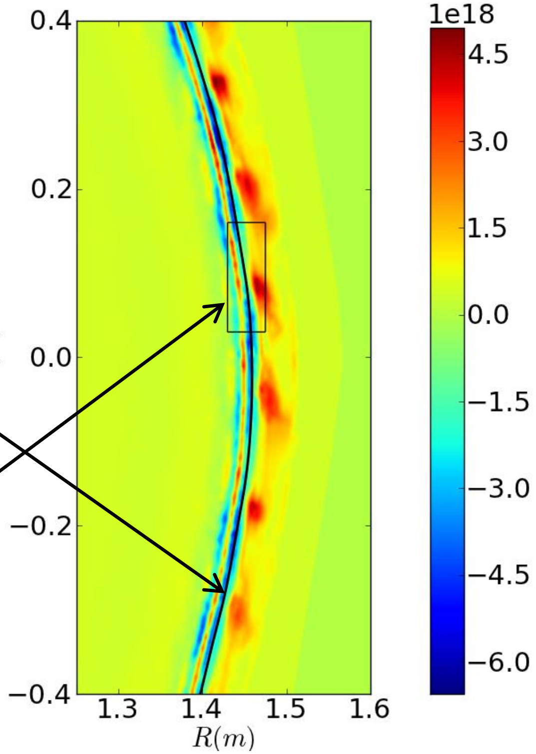
- XGC-1
  - Self consistent, global simulation of fluctuations
  - Full-f, kinetic electrons, nonlinear
- FWR2D/3D
  - Full wave reflectometer codes in 2D/3D Cartesian geometry
  - Calculates reflection patterns in presence of density fluctuations

$\tilde{n}_e$

from XGC-1

separatrix

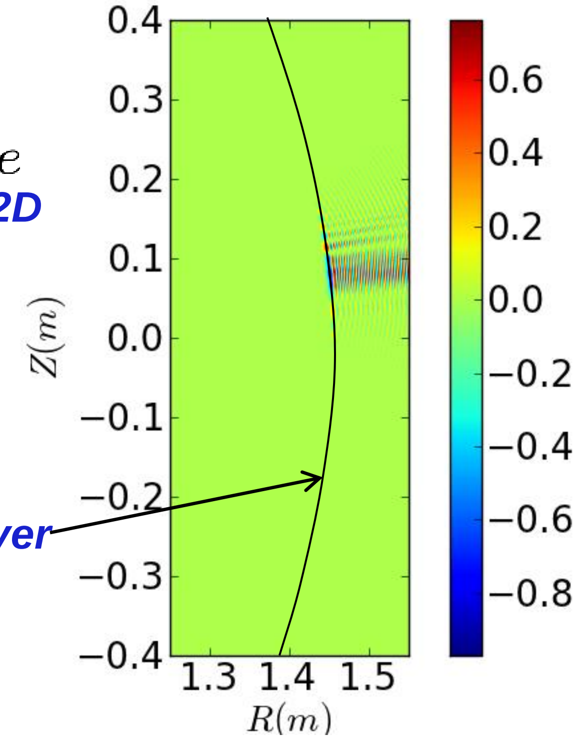
Reflection occurs in this region



$\tilde{E}_{re}$

from FWR2D

Reflection layer

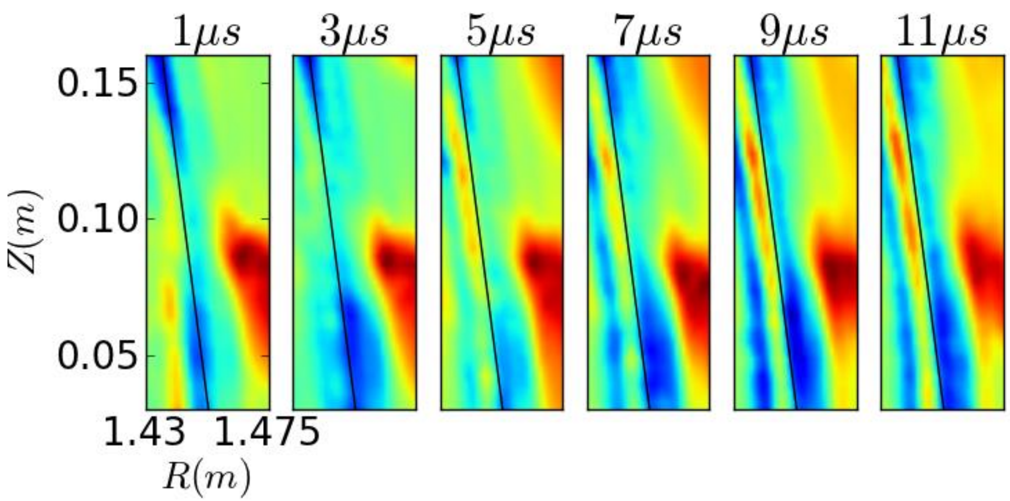


Mapping from density fluctuation to reflected electric field is needed to compare simulation with experiment

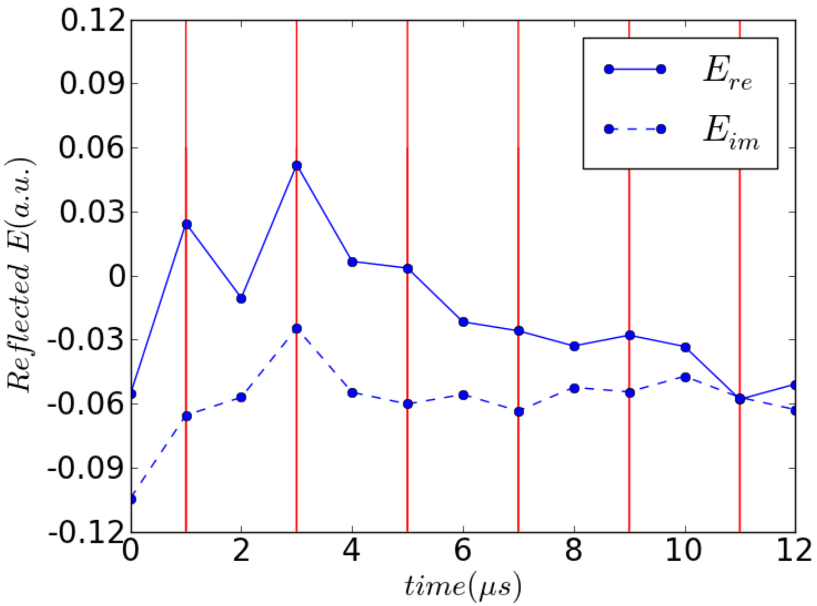
- XGC-1 gives time series of density fluctuations: $\frac{\tilde{n}}{n}$
- In experiment we measure a time series of the reflected electric field at the receiver: $\tilde{E}$
- The map from density fluctuations $\frac{\tilde{n}}{n}$ to the measured electric field $\tilde{E}$ is non-linear!
- Synthetic reflectometer code is able to take the simulated density fluctuations from XGC-1 and map them to electric field fluctuation.

FWR2D/3D is used to map XGC1 simulated density fluctuations to reflected E field

$\tilde{n}_e(t)$ *from XGC1 near the reflection*



$\tilde{E}_{refl}$ *from FWR2D for the corresponding channel*



Now, we need to compare synthetic E field and measured E field.

Statistical methods are used to compare the synthetic signal with the observed signal in the experiment

- Coherent Signal $|g|$
  - Single channel analysis
  - A measure of fluctuation level

    $|g| \to 0$: Large fluctuations

    $|g| \to 1$: Small fluctuations

$$g \equiv \frac{\langle \tilde{E} \rangle}{\sqrt{\langle |\tilde{E}|^2 \rangle}}$$

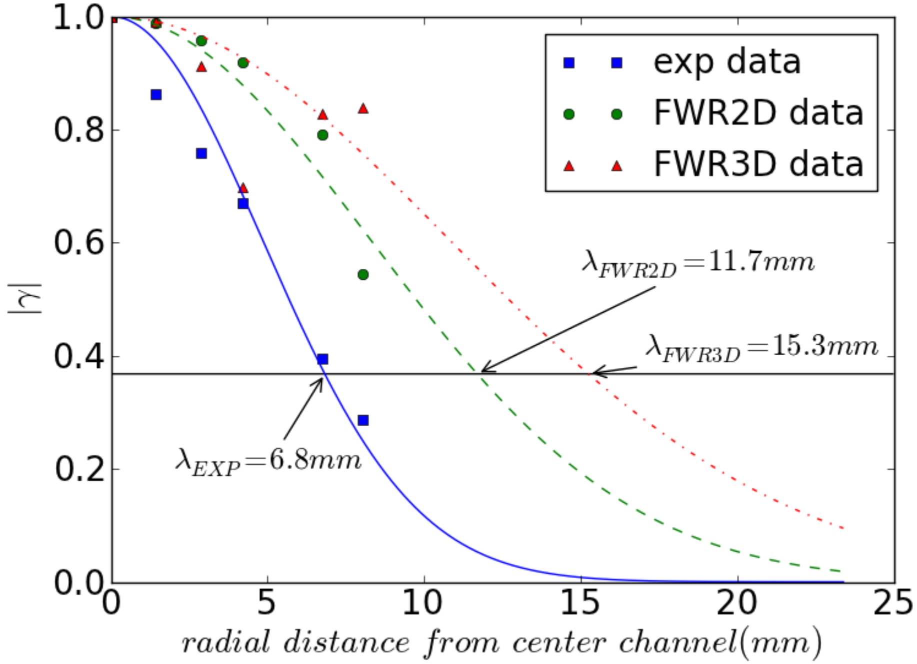
- Cross-correlation $|\gamma|$
  - Correlation between two channels $\leftrightarrow$ correlation between two radial locations

$$\gamma_{ij} \equiv \frac{\langle \tilde{E}_i^* \tilde{E}_j \rangle}{\sqrt{\langle |\tilde{E}_i|^2 \rangle \langle |\tilde{E}_j|^2 \rangle}}$$

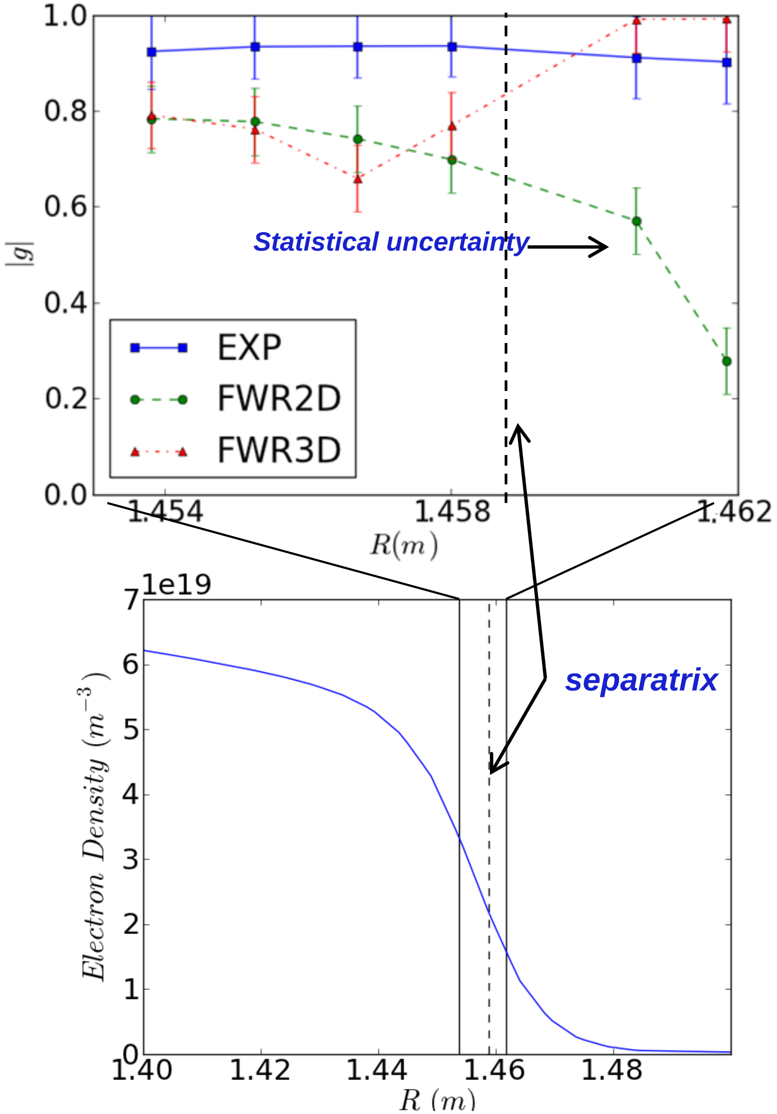
$|\gamma| \to 1$: Highly correlated channels, fluctuation spatial scale might be larger than the distance

Coherent signal and cross correlation show fair agreement between self-consitent simulation and experiment

Cross correlation



Coherent signal



XGC-1 simulation can be further improved

- Collisional effects
  - More damping → Lower fluctuation level
  - May lead to better agreement in coherent signal
- Neutral source from the wall
  - Neutrals play a significant role near the edge
  - May change the spatial structure
- External heating and particle injection
  - Sustain the nonlinearly saturated state for longer, provide a larger statistical ensemble, lower the statistical uncertainties.
- Electro-magnetic modes

XGC1 calculated fluctuation level and radial correlation length are both in fair agreement with experiment

- Synthetic reflectometry is used to compare plasma simulation result with experiment.

- For the NSTX case we studied, XGC-1 result is in fair agreement with experimental observations.
  - Reflected signal's radial correlation length agrees within roughly a factor of 2
  - Implied fluctuation level also agrees fairly well.

- Future work:
  - More comprehensive XGC-1 run (described in the previous slide)
  - Interface the reflectometry code to other simulation codes (GTS, GTC, M3D-C1, GENE, GYRO, etc.)