Integrated data analysis to improve T_e and Z_{eff} measurement on NSTX-U

NSTX-U Collaborators Research Plans Meeting

D. J. Den Hartog and L. M. Reusch

THE UNIVERSITY of WISCONSIN MADISON

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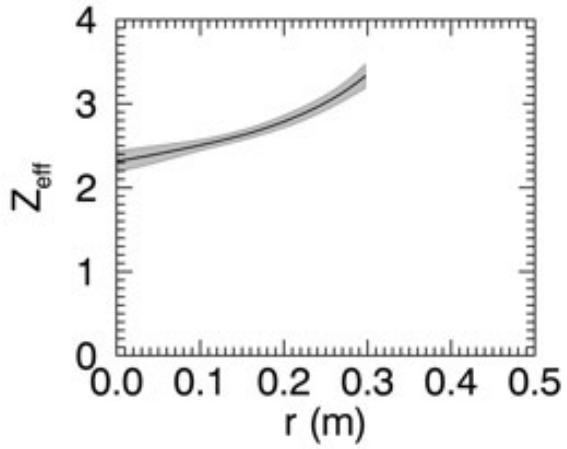
We aim to improve T_e and Z_{eff} measurement on NSTX-U using integrated data analysis (IDA).

- As an analysis approach, IDA provides a framework
  - to overcome measurement limitations
  - to maximize the usefulness of the information recorded by a set of diagnostics
- As fusion experiments become more complex, maximum scientific value must be extracted from data
  - in full nuclear environments, severe limitations will be imposed on diagnostics
- Over the next three years, we will concentrate on
  - increasing the accuracy, precision, and resolution (both spatial and temporal) of T_e and Z_{eff}
  - by using data from the Thomson scattering, SXR, CHERS, and other diagnostics as appropriate and available
- Will also assist with implementation of new high-rep-rate laser for TS
  - will touch on this briefly in the last slide

Integrated Data Analysis (IDA) provides a framework to deal with measurement limitations.

- The goal of IDA is
  - to combine data from heterogeneous and complementary diagnostics,
  - considering all dependencies within and between diagnostics,
- in order to obtain the most reliable results in a transparent and standardized way.

- In addition, IDA enables formation of "meta-diagnostics," which combine information from various instruments to produce unique measurements.
  - Z_{eff} on MST obtained by combining information from CHERS and SXR:



- Quantitative model discrimination is also part of IDA
  - Example: determined effect of unknown impurities on Z_{eff} measurement

Integrated Data Analysis is often accomplished using a Bayesian statistical framework.

- IDA proceeds with a series of steps:
  - Identify uncertainties and quantify with probability distribution functions (PDF)
  - Combine all relevant information within a probabilistic framework
    - include diagnostic models and prior knowledge
    - develop a forward model for measurement
    - marginalize out nuisance parameters such as systematic effects
  - Search parameter space, which is often high-dimensional
  - Final result is the marginal posterior PDF of the quantity of interest

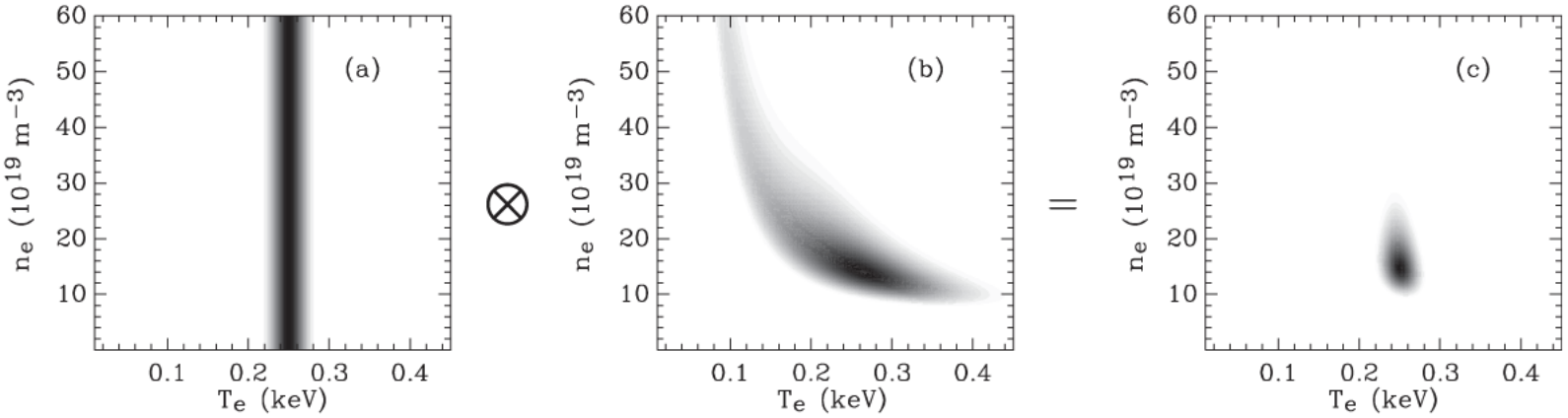


Illustration of IDA application from R. Fischer *et al.*, *PPCF* **45**, 1095 (2003)

This project will develop IDA expertise, with emphasis on new methods of multi-diagnostic and multi-parameter analysis.

- IDA requires both computational and instrumentation knowledge
  - straddles experiment and computation
  - this “analyst” skillset likely to be in increasing demand as fusion experiments grow in size and complexity

- In addition to immediate goals for work on NSTX-U, we plan to
  - Engage with community of IDA experts
    - part of new IAEA Technical Meeting series
    - connect to other IDA communities such as planetary search
  - Develop analyst expertise, and begin to integrate training into university curriculum
  - Encourage fusion diagnostic development and operation

New high-rep-rate laser for NSTX-U Thomson scattering has been built by UW-Madison Physical Sciences Laboratory.

- Ahmed Diallo is principal scientist for this project
  - Will be described in detail on May 26
  - We will assist with implementation of laser on NSTX-U

- Laser will have three operating modes
  - Baseline: 30 Hz
  - Slow burst: 1 kHz rep rate for at least 50 ms
  - Fast burst: at least 10 kHz rep rate for at least 5 ms

- Typical laser sequence for TS data collection:
  - shot starts with laser operating at 30 Hz
  - 30 Hz operation interrupted for pulse-burst sequence
    - 1 or 10 kHz burst
  - cool-down, then resume 30 Hz

Summary

- Over the next three years, we will concentrate on increasing the accuracy, precision, and resolution (both spatial and temporal) of T_e and Z_{eff}

- Year one goals:
  - Set up framework for IDA
    - Become familiar with relevant NSTX-U diagnostics
    - Develop forward models for diagnostics, characterize uncertainties
  - Assist with implementation of high-rep-rate TS laser

- Staff:
  - Prof. Daniel Den Hartog (20%)
  - Dr. Lisa Reusch (50%)
  - Grad student beginning January 2017
- Staff based at UW-Madison, with regular visits to PPPL

- We welcome feedback on priority (e.g., work on Z_{eff} first?)