# APS talk idea

## Real-time control and estimation in tokamaks with machine learning accelerated predictive models

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# Machine-learning techniques enable **faster versions of integrated modeling** modules needed **for real-time applications**

- Predictive TRANSP simulations can take hours per simulation second
- **NUBEAM** is a Monte Carlo code that calculates the effect of neutral beams on the plasma (heating, current drive, torque)
  - Often takes >50% of TRANSP calculation time
- Machine learning approaches enable the development of **NubeamNet**

Boyer et al., *Nuclear Fusion*, 2019
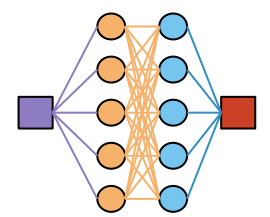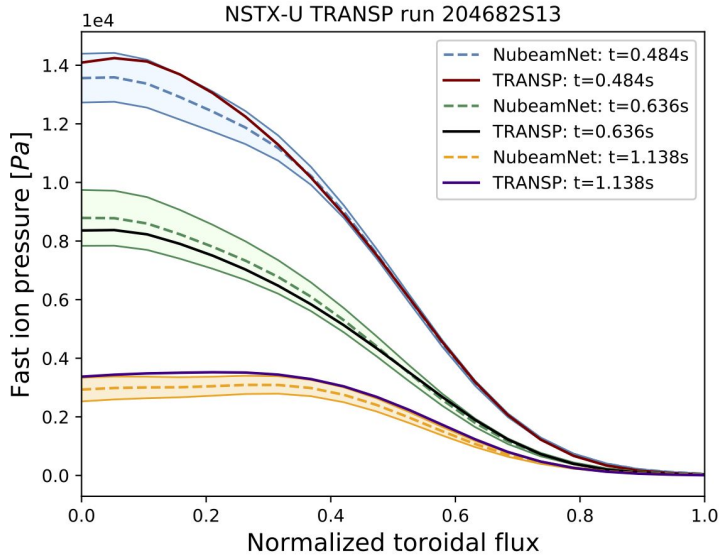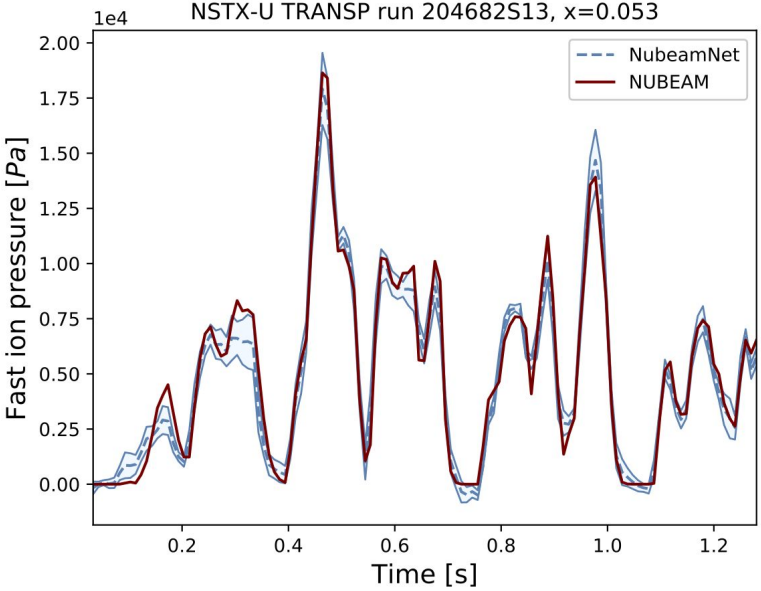


NubeamNet is ~5-6 orders of magnitude faster than NUBEAM!

**Temporal filtering** to account for beam ion slowing down

**Principal component analysis** to extract key features from spatially distributed data
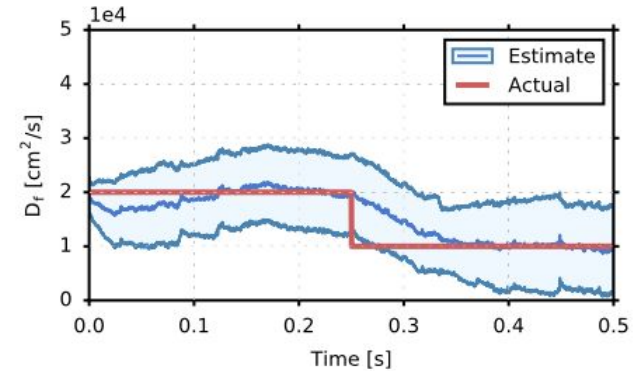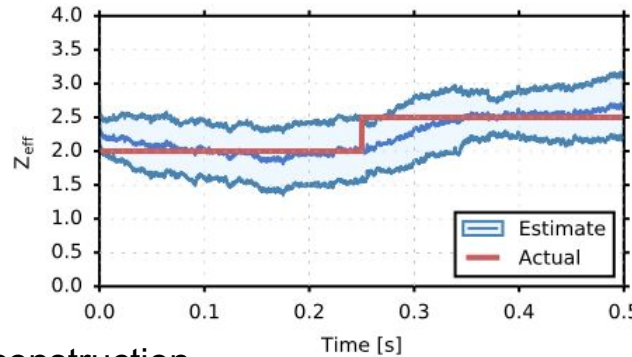
**Neural network ensembles** to improve estimates and enable assessment of uncertainty

# Results and ongoing work to present

- Design,
- Optimization
- Implementation
- Valid region analysis
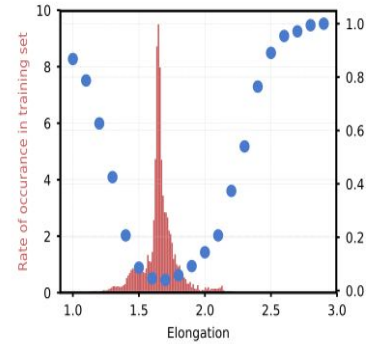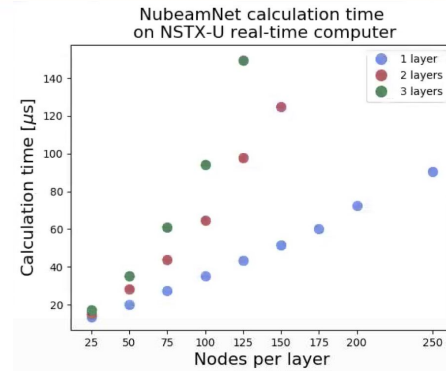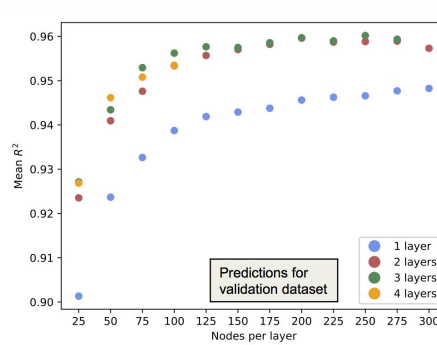


- Real-time current profile estimation
- Real-time estimation of Zeff and Df using neutron rate and CP estimation



- Neural networks for profile and equilibrium modeling

- Working on coupling into real-time (or at least near-real-time) scenario model

Reconstruction
Neural network



Bootstrap current

Para/diamagnetism