Steady-state and Perturbative Transport Measurements in NSTX

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Summary of proposed research

I **Measurements of steady-state impurity content/profiles using the USXR/TGS system**

II **Perturbative impurity transport using gas puffs and USXR/TGS**

III **Perturbative χ_e measurements using USXR/GEM arrays as detector and MHD events for T_e perturbation**

IV **Perturbative D_i / χ_e measurements using embedded pellets to produce *internal* particle source/T_e perturbation**

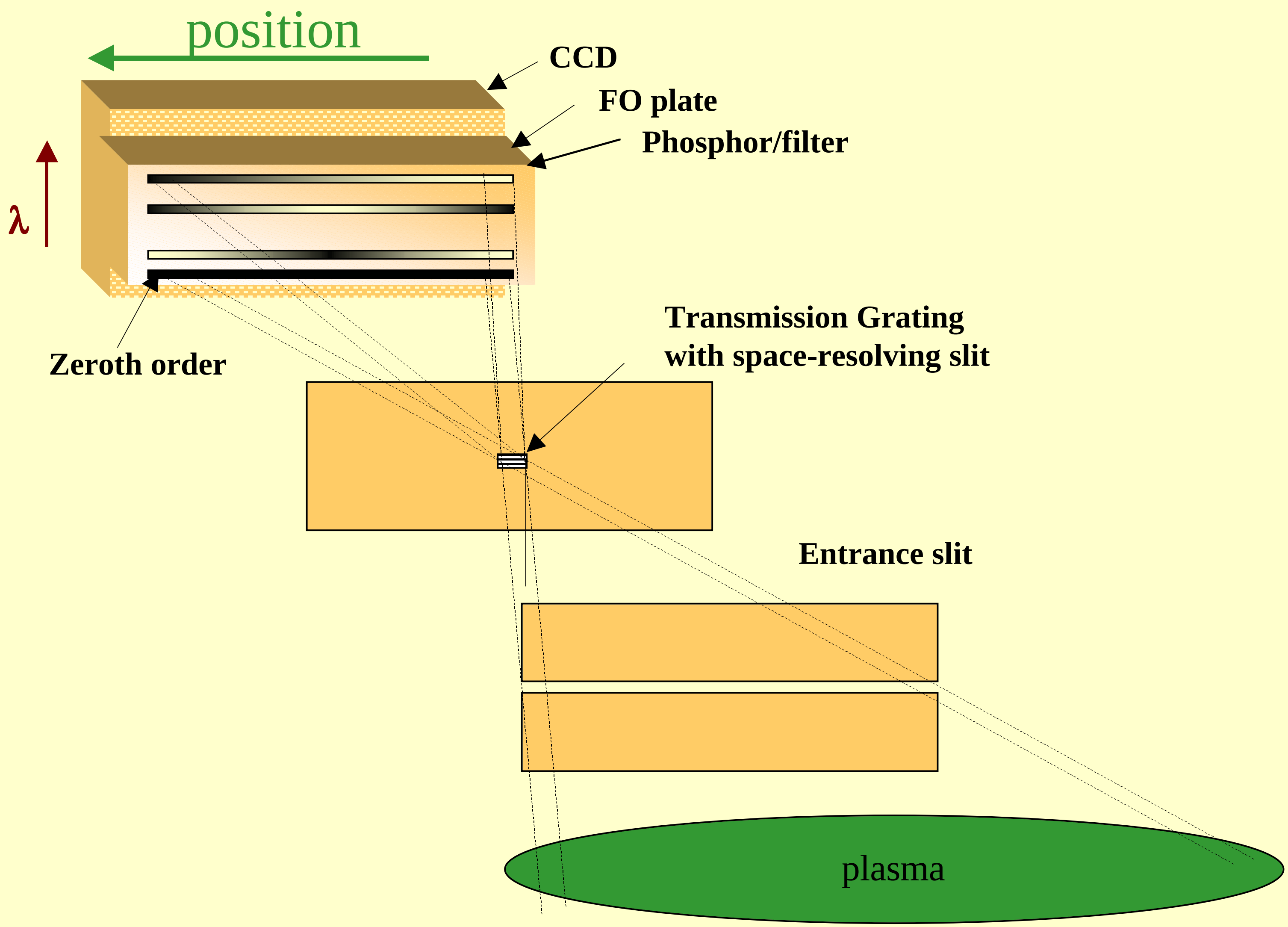
Steady-state impurity content/profiles using USXR/TGS

- **USXR arrays + GRITS + HULLAC/MIST modeling package useful for intrinsic impurity content/Z_{eff} profile estimates**

- **Good reasons to continue and improve the USXR analysis (e.g., in/out asymmetries in the impurity density invisible to CHERS, injected impurity transport)**

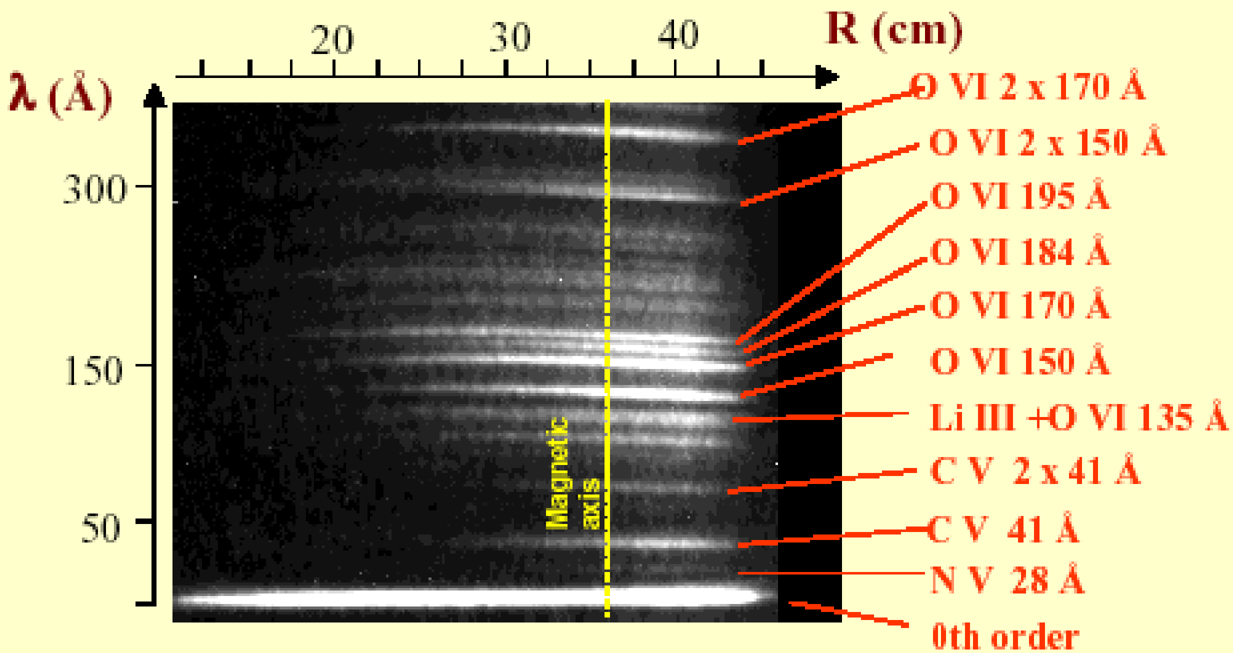
- **New multi-chordal Transmission Grating Spectrometer (TGS) will be deployed for improved analysis of intrinsic and injected impurities**

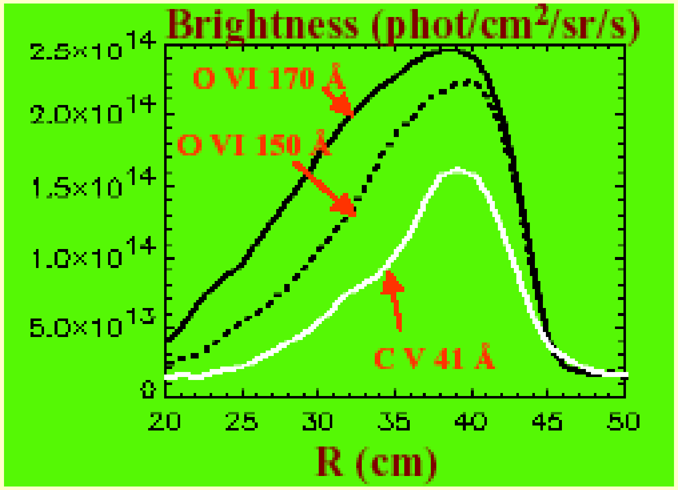
Multi-chordal Transmission Grating Spectrometer



Example space-resolved spectrum from CDX-U

- 10 ms integration
- $\Delta r \approx a/10$
- $T_{e0} \approx 65$ eV
- $n_{e0} \approx 3\ 10^{13}\ cm^{-3}$





Role of perturbative transport measurements on NSTX

- **Perturbative transport measurements should play central role in NSTX**

- **Power balance (PB) analysis may remain uncertain due to ion/electron heating, or coupling anomalies**

- **Perturbative transport separately probes the ion and electron channels**

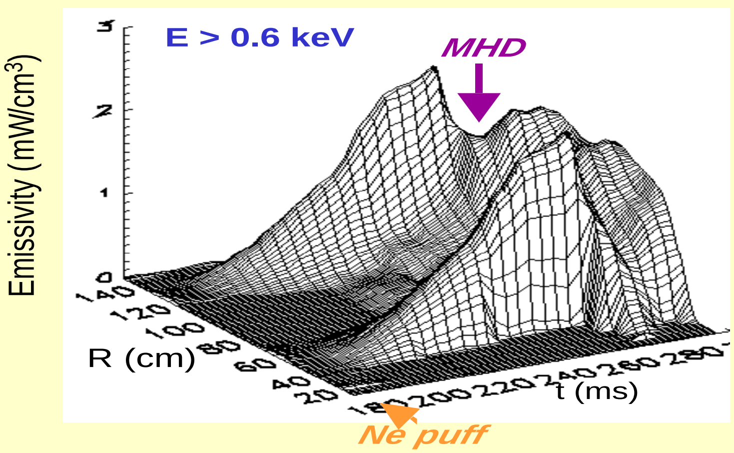
- **The fundamental PB assumption: Flux = χ x Gradient not granted in NSTX, non-diagonal terms could be important (e.g., heat pinch driven by beam-ion friction, *W. Houlberg*)**

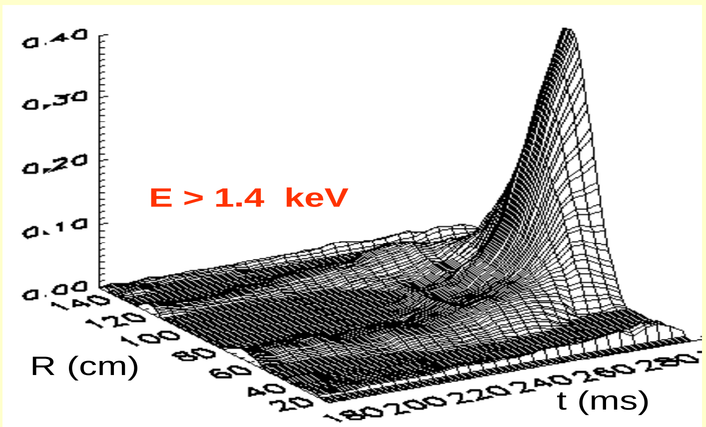
- **Perturbative measurements probe the diagonal contributions (*Lopes Cardozo, PPCF 1995*)**

- **Magnitude of non-diagonal effects from χ^{PB} and $\chi^{perturb}$ comparison**

Perturbative impurity transport using gas puffs

- **Neon penetration measurements with USXR arrays in L-mode, NBI discharges show almost no Neon diffuses past r/a ≈ 0.6-0.7**





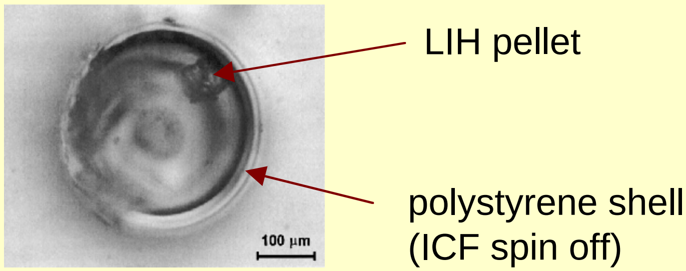
- **Similar measurements in H-mode could probe change in *core* transport between L- and H-; however, edge barrier penetration an issue**

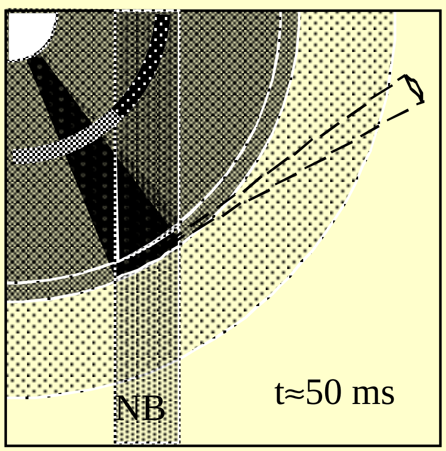
- **RF discharges also of interest**

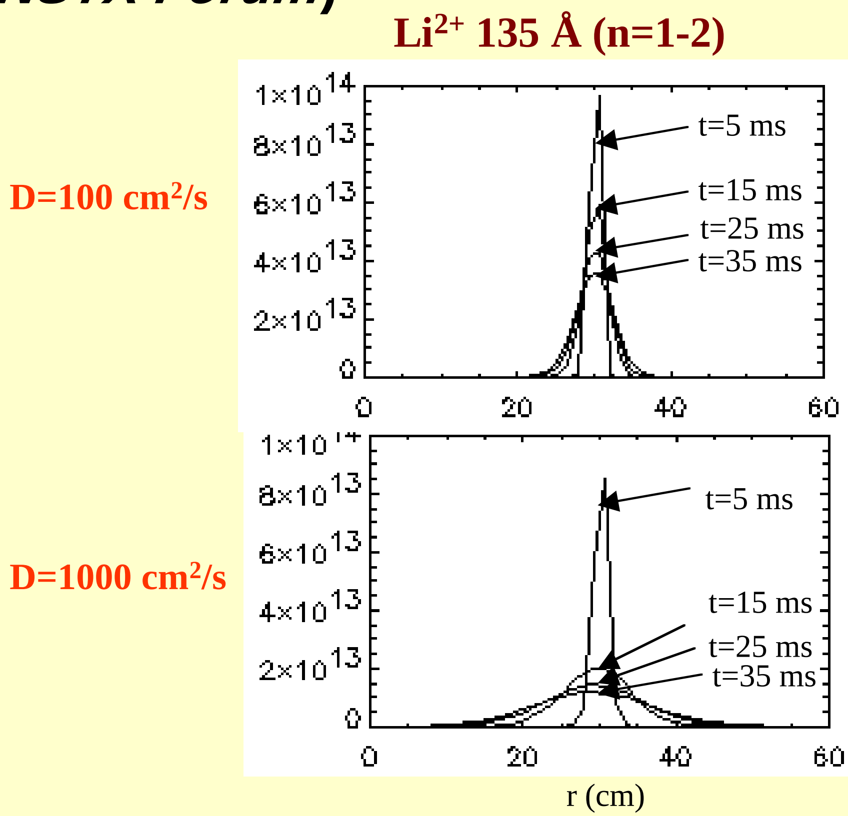
- **Main difficulty: transport time scale > duration of high performance plasma conditions (e.g., high confinement at high beta)**

Perturbative particle transport using TESPEL pellet

- **TESPEL technique (*Sudo et al., LHD*) solves the time scale/penetration problem by creating strong <u>internal</u> gradient of test particle (Li^{3+}) (*see JHU contribution at previous NSTX Forum*)**







- **Simple pellet injector (non-cryogenic)**
- **Development of USXR/VUV diagnostic through JHU/LHD collaboration**
- **Visible measurement ? (Strong PPPL CHERS expertise)**

Perturbative χ_e measurements using the USXR arrays

- χ_e measurements using SXR emission long standing technique (*Callen and Jahns 1977*)

- The USXR system in 'two-color' configuration can provide 1-D estimate of 'cold pulse' ΔT_e

- Proposed USXR upgrade for 'two-color' *tomography* and 2-D measurements *(see JHU MHD presentation)*

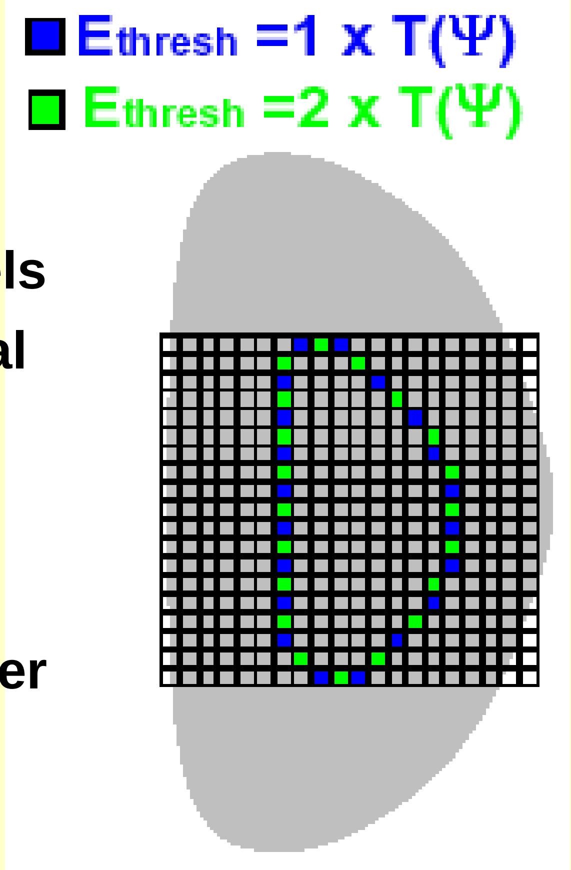
- MHD perturbations: sawteeth, ELMs, minor reconnections

- Edge perturbations: LBO, supersonic gas jet (*V. Soukhanovskii, last Forum*)

- TESPEL also successfully used on LHD to produce localized *internal cold pulse* for accurate χ_e measurements at $q > 1$

Perturbative χ_e measurements using the GEM array

• 2-D tangential GEM detector operated in 'threshold scan' mode can provide approximate map of T_e iso-surfaces, much like a 2-D PHA system (see D. Pacella's contribution at this Forum)



•By alternating 'high' and 'low' threshold pixels on a T_e iso-surface, one could follow the radial and poloidal heat pulse propagation

• GEM 'ΔT_e calibration' could also be used in the USXR system for measurements on shorter time scale

Summary

• **We propose a systematic program of perturbative transport experiments, for comparison with the power balance transport estimates**

• **Diagnostics are, or will be at hand for the impurity and electron measurements; the GEM detector will enable new techniques**

• **TESPEL technique would allow documenting slow ion transport in shorter duration high performance plasmas, as well as enable internal cold pulse generation for χ_e measurements at $q > 1$**

• **Perturbative ion thermal transport measurements are also feasible (e.g., Sasao *et al* 1992), based on PPPL CHERS expertise**