Local transport diagnostic for NSTX using USXR imaging of Tracer-Encapsulated Solid Pellet Injection

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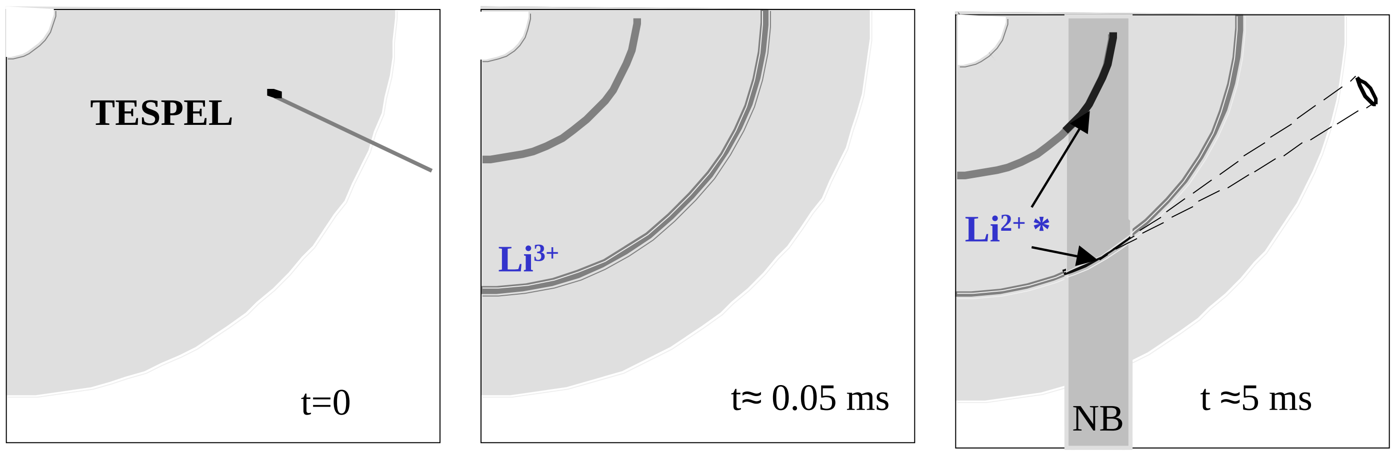
TESPEL Proposal

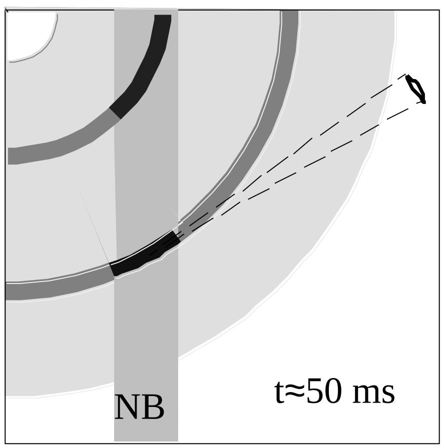
- Basic idea:
  - Inject low-Z (Li) impurity on narrow ($\Delta r \approx 1$ cm) zone of flux surfaces ('internal gas puff')
  - Obtain local transport coefficients from $N_{Li^{3+}}(r,t)$ evolution

- How does it work:
  - 100-250 µm Li pellet embedded in ≈ 50 µm plastic shell (Tracer-Encapsulated Solid Pellet)
  - Simple pellet injector
  - Pellet technique already demonstrated at CHS and LHD

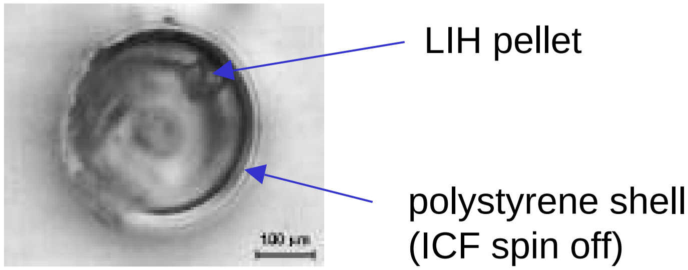
- $N_{Li^{3+}}$ to be measured using USXR/FUV Diagnostic (JHU)

TESPEL technique





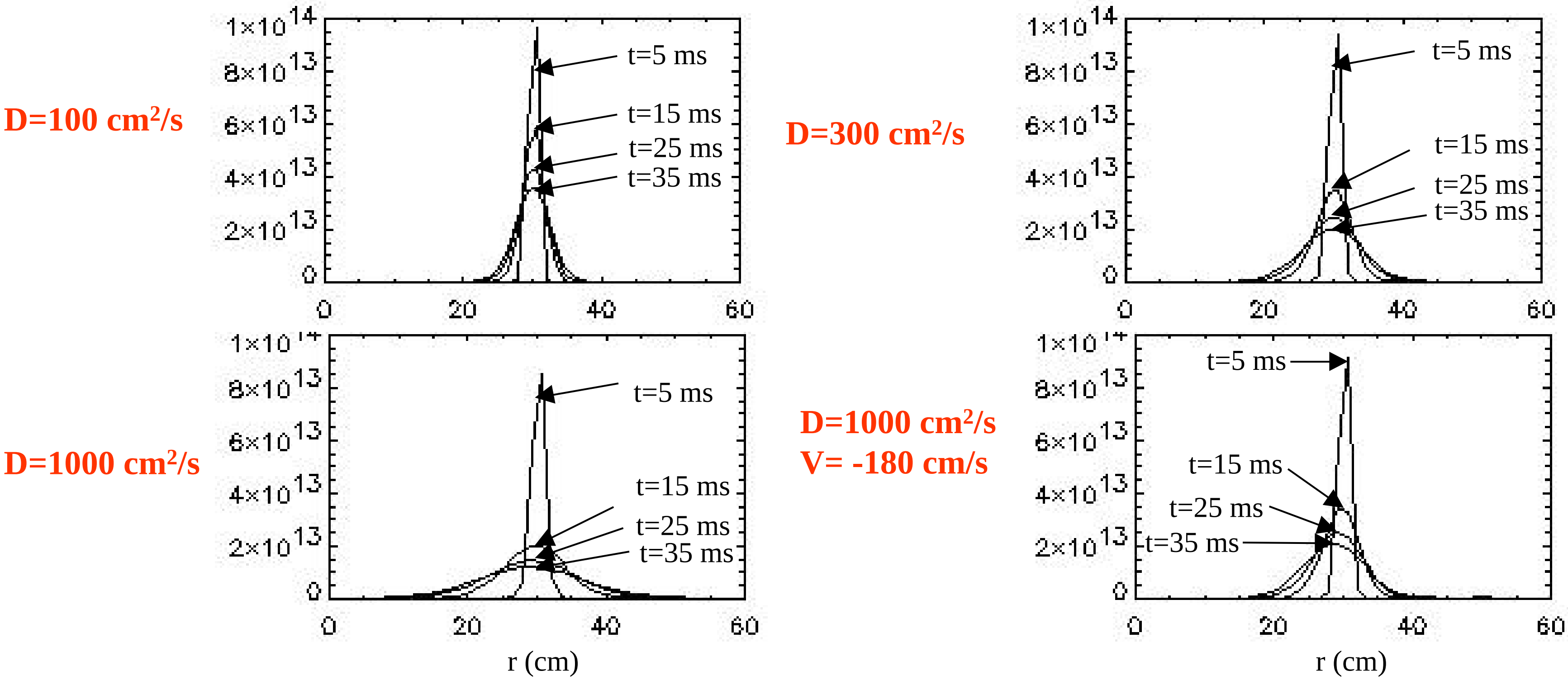
K. V. Khlopenkov and S. Sudo, RSI ***69****, 1998*



- Limited pellet perturbation $\Delta N_e/N_e(0) \approx$ 5- 10 %
- $\Delta r_{Li} \approx$ 1-1.5 cm (LHD), $N_{Li^{3+}}(r) \approx$ 0.1 - 1% $N_e(r)$
- Pellet deposition radius controlled by V_{launch}
- Transport measurement late after injection

Perturbative transport measurement

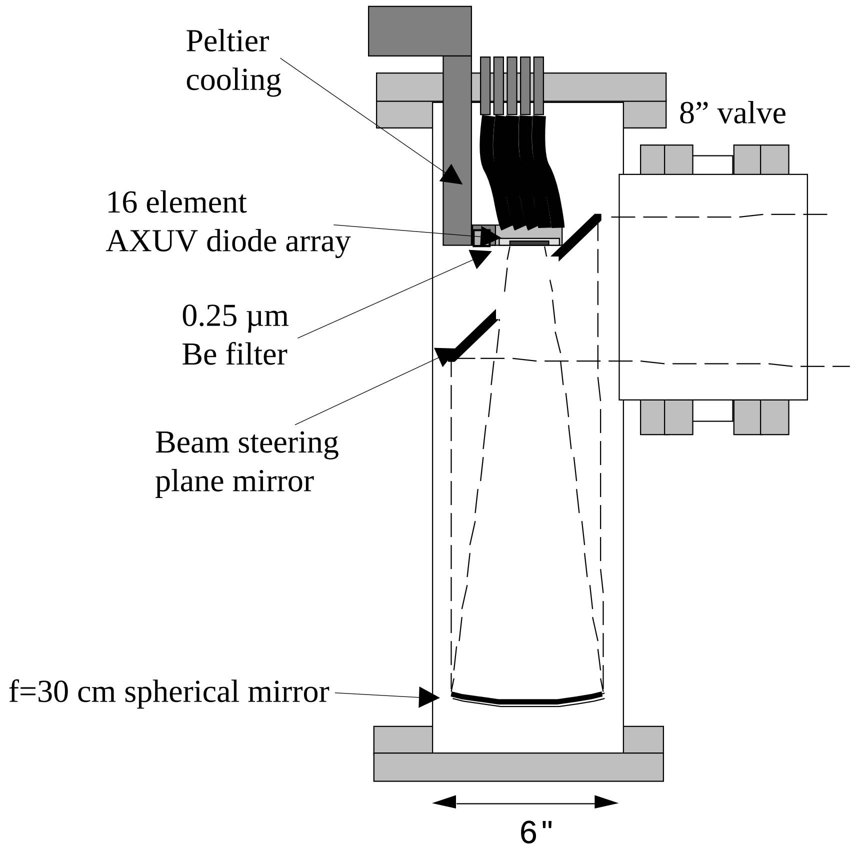
Li^{2+} 135 Å (n=1-2) CX excited emissivity (photons/cm^3/s)

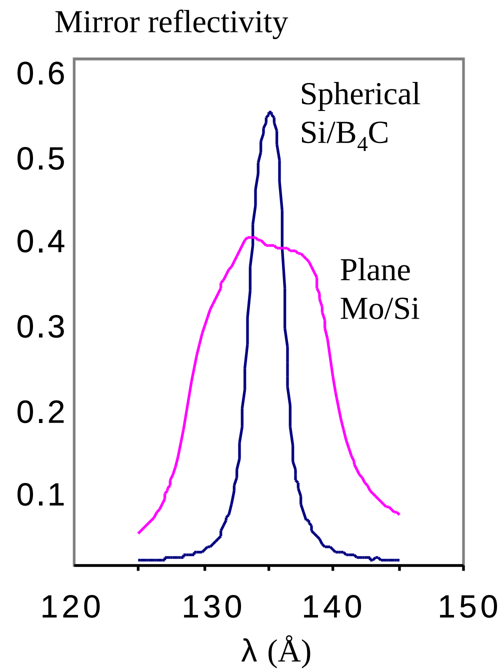


- Accurate and local measurement of both transport coefficients from Li^{3+} profile

  (1% Li at t=0, r=30 cm in a=65 cm, $N_e(0)=5\ 10^{13}\ cm^{-3}$, $T_e(0)=1.5$ keV, $N_H=4\ 10^8\ cm^{-3}$)
- Li transport close to that of the working ions
- Li shell extent ≈ 15-20 cm, required resolution $\Delta r \leq 1$cm, $\Delta\tau \leq 1$ ms

USXR Telescope for Li $^{2+*}$ 135 Å





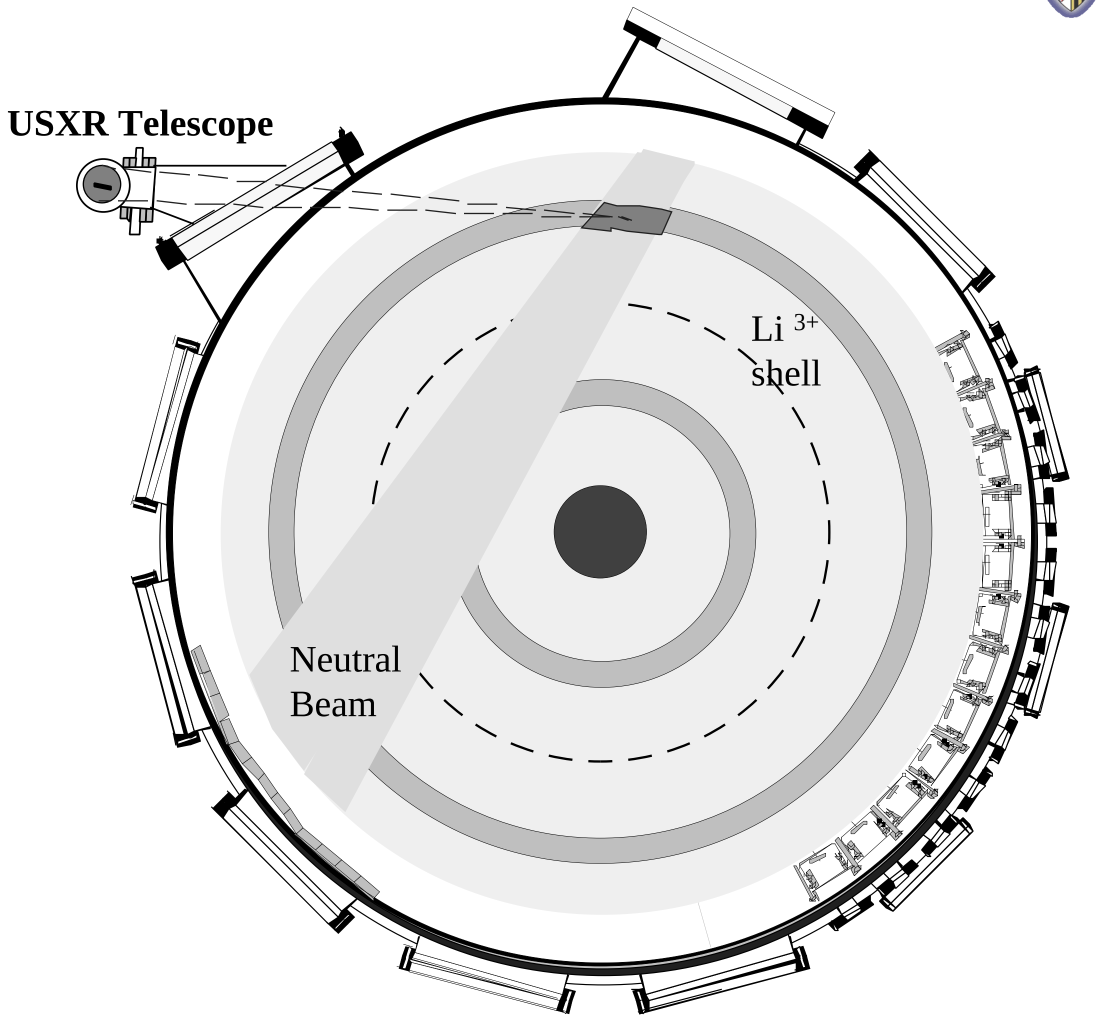
- Li measurement in the USXR or FUV, due to fast CX rate decrease in Li :

1-2 (135 Å)≈10^{14}, 2-3 (728 Å) ≈ 10^{13}, 4-5 (4500 Å) < 10^{12} ph/cm^2/sr/s (1% Li, 20 cm beam)

- A few Å spectral resolution sufficient (no parasitic edge emission)
- A several inch X-ray telescope can ‘see’ the turbulence temporal and spatial scales:

$\Delta r \leq 1$cm, $\Delta B/B \geq 0.1$-0.2 % at 500 kHz bandwidth

Proposed view for 6” USXR Telescope



- Planar X-ray mirror steers telescope field of view to radius of TESPEL shell

Transport and turbulence with TESPEL

- TESPEL probes the local particle flux:

$$\frac{\partial N_{Li^{3+}}}{\partial t} = -\Gamma_{Li^{3+}} + \cancel{Source_{Li^{3+}}} - \cancel{Sink_{Li^{3+}}} \approx 0$$

- Simultaneous measurement of local N_{Li} flux and density fluctuations with the USXR telescope

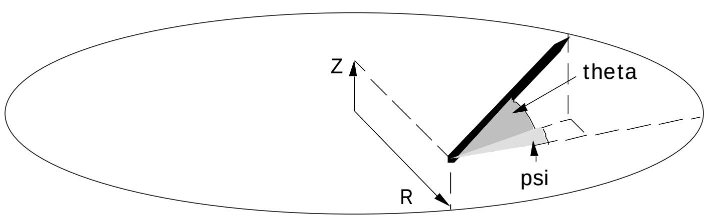
- 2-D imaging of TESPEL fluctuations also conceivable:

80 nA/pixel with AXUV, 3 vis. photons/X-ray with CsI

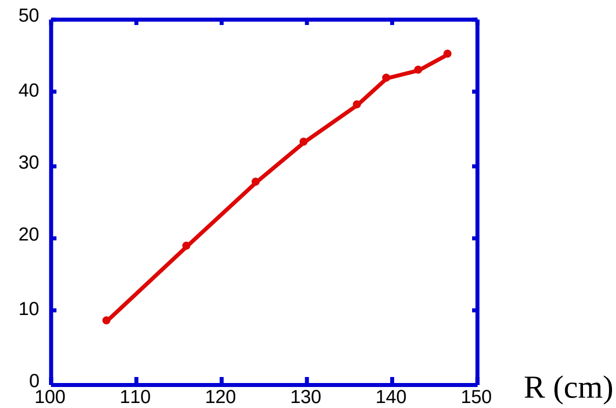
- FUV solution also developed

Measurement issues

- Li^{2+} 'plume' negligible for r/a < 0.75 (w_b/λ_{ion} << 1)
- 135 Å spectral region relatively clean (except blend with C VI n= 2-4, ≈ 10^{13} photons/cm^2/sr/s)
- Field line pitch main obstacle for turbulence imaging



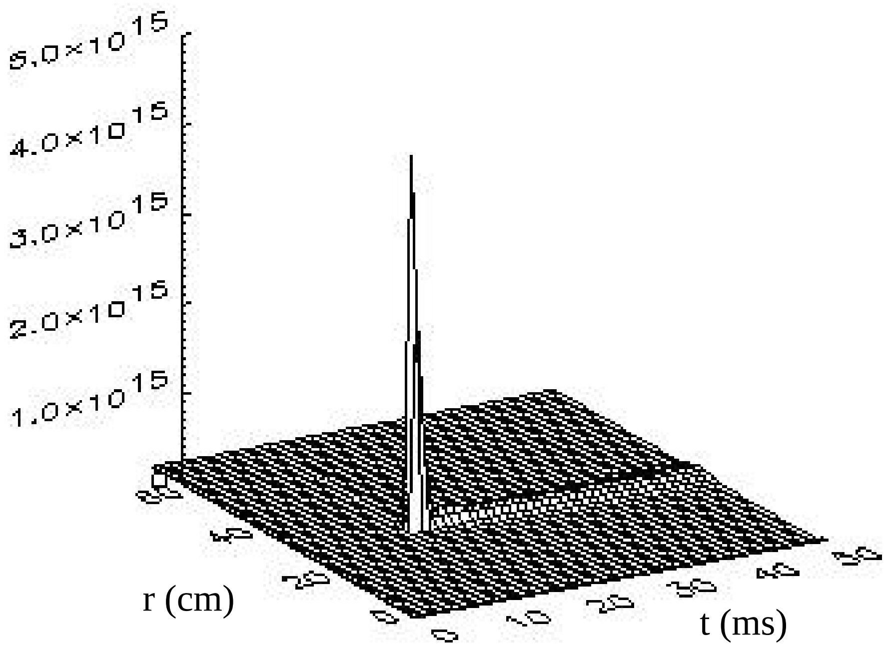
EFIT theta for shot #104349 (1 MA, 4.5 kG)



- Diagnostic NB highly desirable for NSTX/ST physics

Other diagnostics: flux tube imaging

Collisionally excited Li^{2+} 135 Å emissivity (photons/cm^3/s)

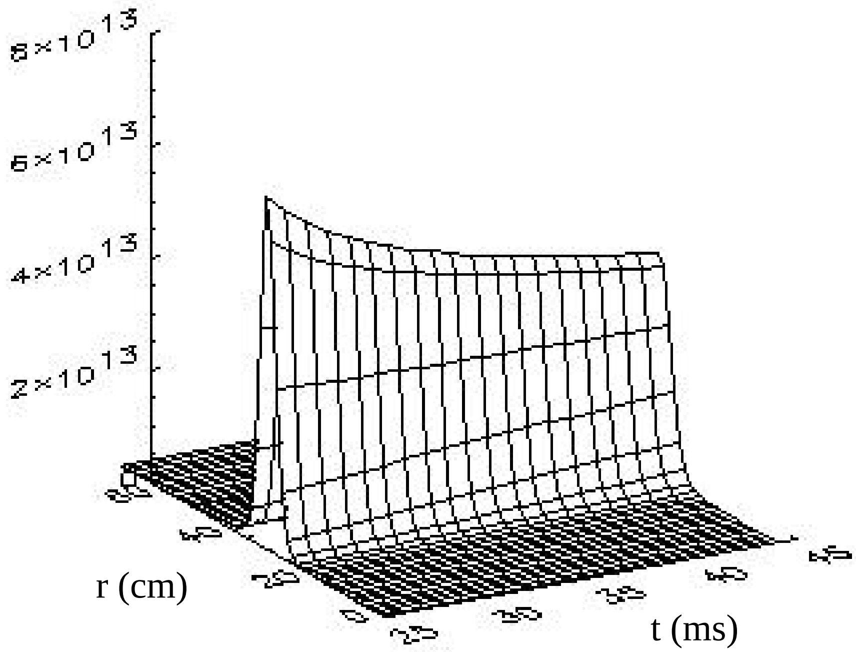


- Bright, narrow and field aligned Li^{2+} 135 Å plume at TESPEL injection time: $\tau_{ion} \approx 0.05$ ms, $\lambda_{ion} \approx 3$ m << πRq in NSTX

- Internal B_P /B_T measurement possible with the USXR Telescope

Flux surface imaging

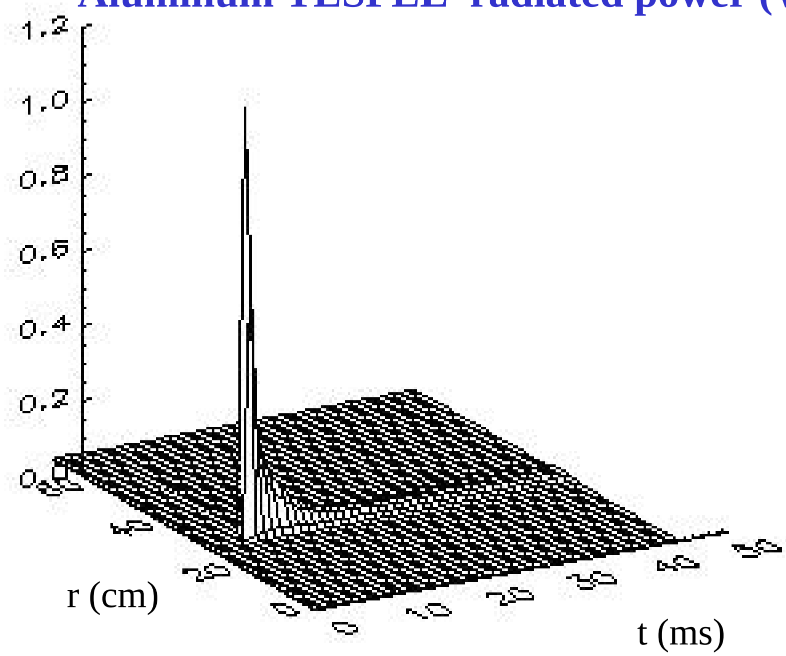
Aluminum TESPEL SXR line emissivity (photons/cm^3/s)



- Bright, long lasting SXR line emission on narrow flux shell with higher-Z TESPEL, due to longer ionization times ('flux surface staining')
- NSTX plasma sufficiently robust for ≈ 0.5-1% % Al in a few cm layer
- Tangential imaging of SXR shell:
  - Equilibrium mapping without tomographic inversion
  - MHD mode inboard structure (otherwise very difficult in ST geometry)

‘Internal cold pulse’

Aluminum TESPEL radiated power (W/cm^3)



- Strong, localized internal ‘cold pulse’ possible with higher-Z TESPEL
- Internal cold pulse would propagate both inward and outward
- Sawtooth based transport measurements of lesser applicability in NSTX (q(0) >1)

Summary

- We propose applying TESPEL and USXR/FUV diagnostics for transport studies on NSTX
- Other important TESPEL diagnostics are possible
- Collaboration based on JHU-PPPL-NIFS(Japan) expertise
- Development will benefit the whole fusion program (not only ST research)