Intermittent small scale turbulence during ELM mitigation on EAST

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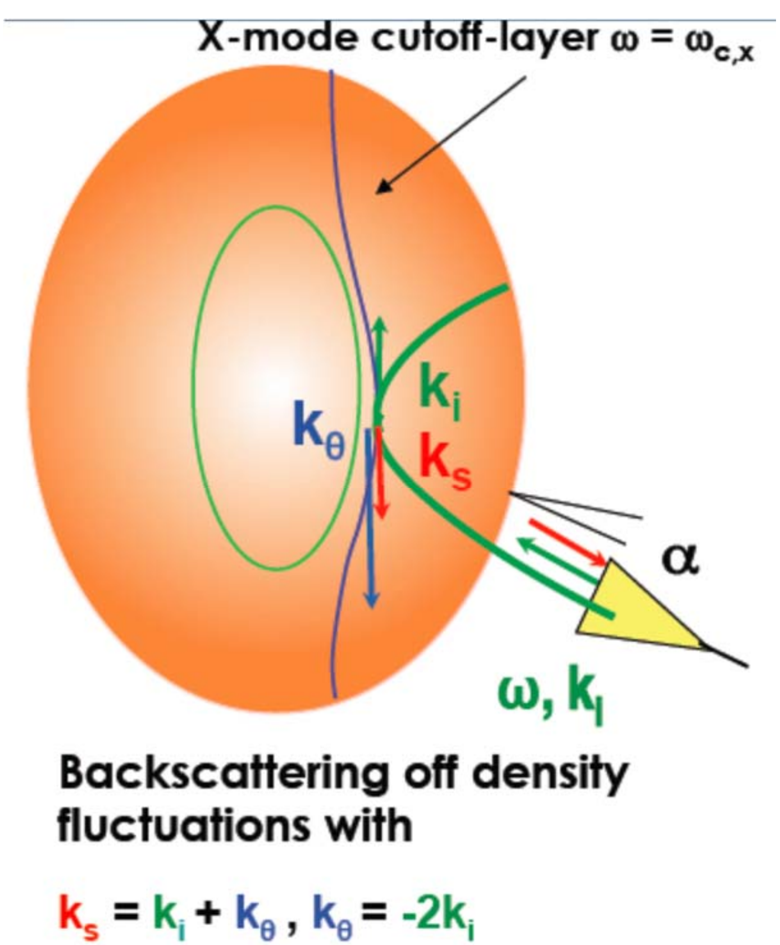
Outline

- Doppler reflectometer on EAST
- ELM mitigation through supersonic molecular beam injection (SMBI)
- Turbulence evolution during ELM mitigation
- Summary and future plan

Doppler Reflectometer on EAST



- A microwave beam is launched from a transmitting antenna into the plasma at a finite tilt angle θ with respect to the normal to the cutoff surface, the beam is both reflected and Bragg scattered;

- To the monostatic system, the Bragg diffraction equation gives wave vector of the scattering fluctuation:

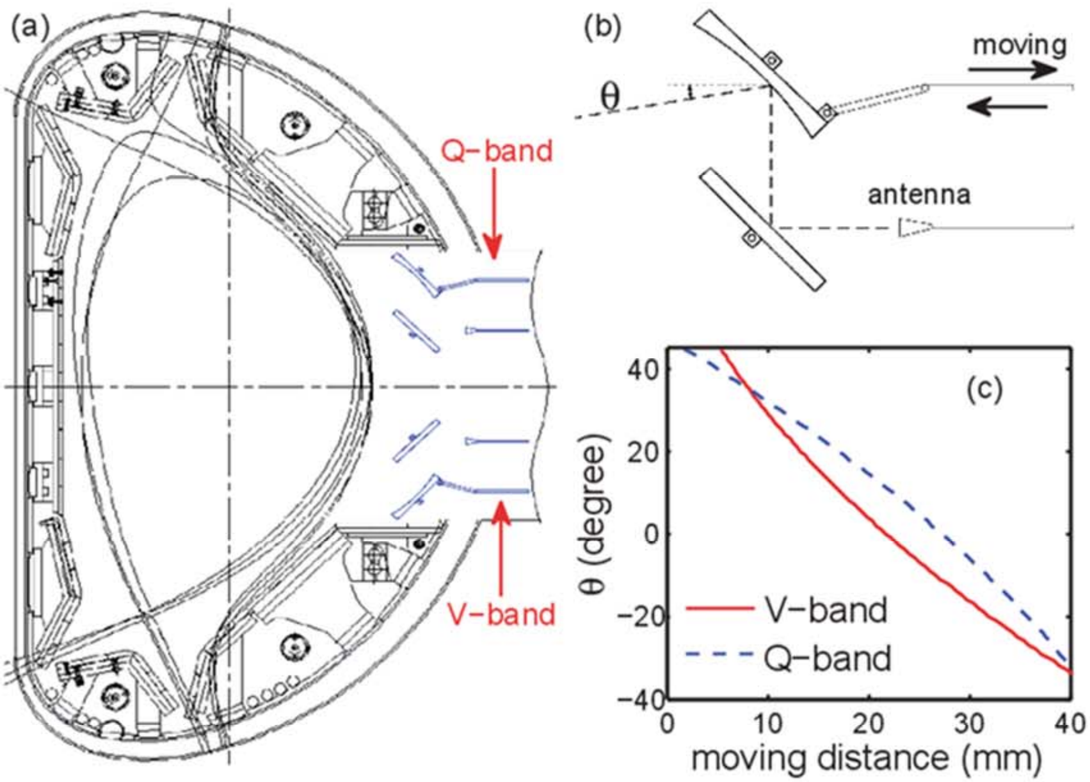
$$k_{\perp} = 2k_0 \sin\theta$$

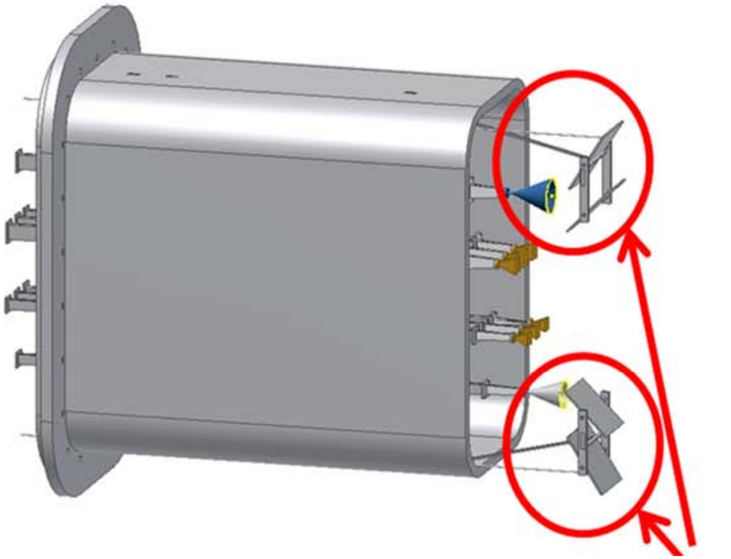
k_0 is the probing wavenumber;

- If the reflection grating (or fluctuating plasma) moves with velocity, a Doppler shift ω_D could be detected;

Doppler Reflectometer on EAST

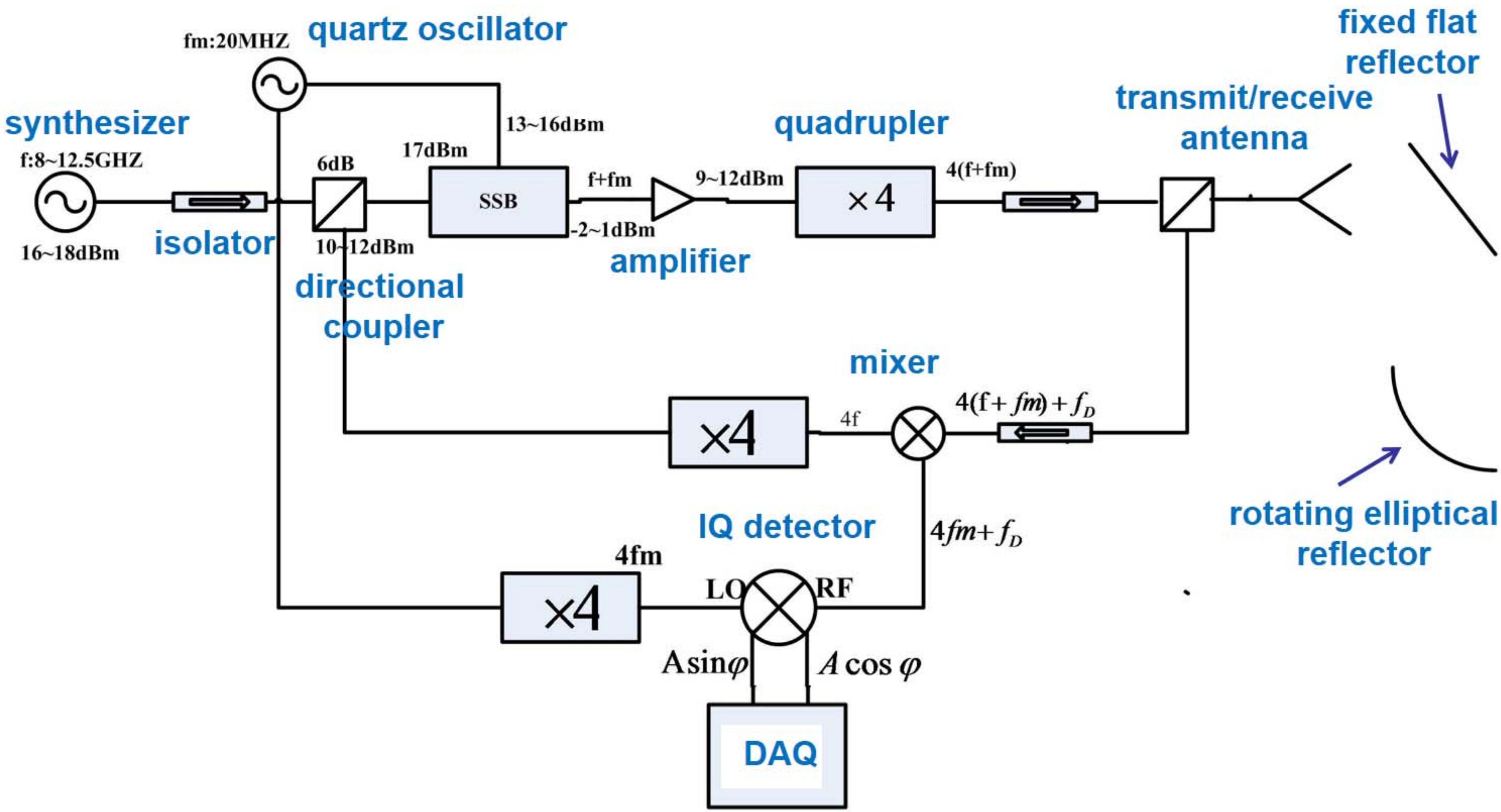
optical system and injecting angle control





mirrors

Doppler Reflectometer on EAST

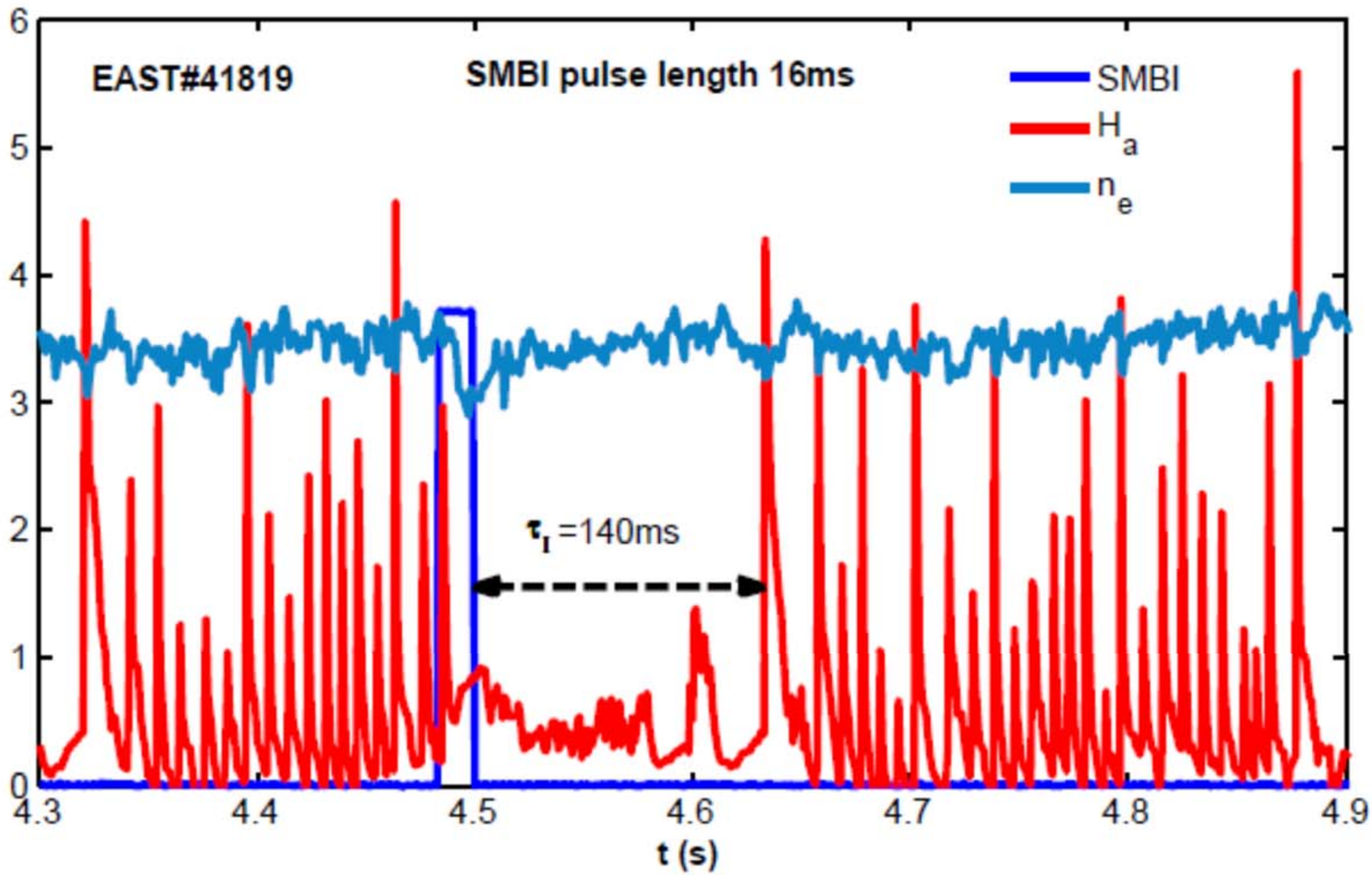


monostatic, corrugated antenna, heterodyne system, X-mode only, Q&V bands

ELM mitigation through SMBI on EAST

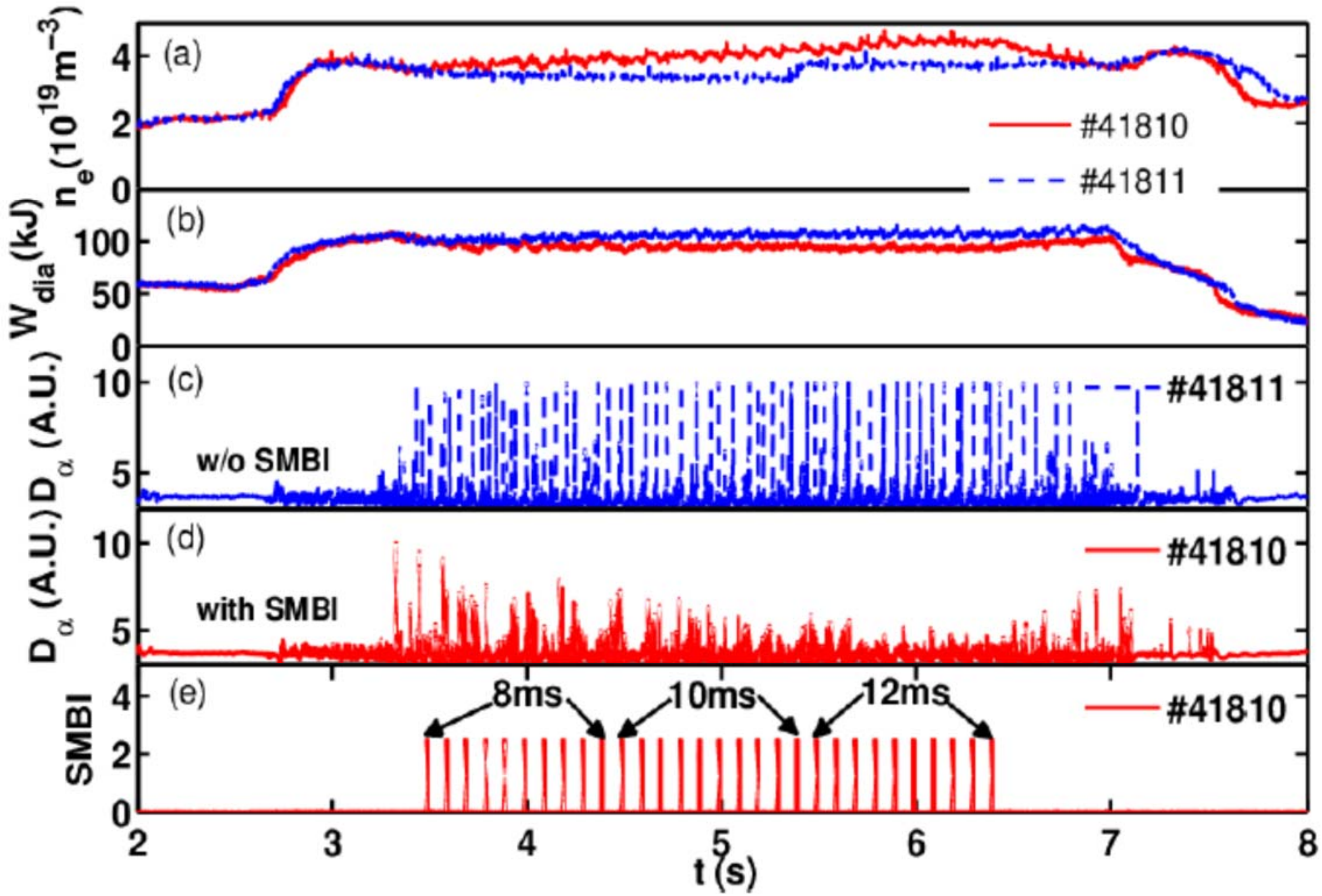
ELM mitigation through single SMBI

- Single pulse: when the pulse length >=16ms



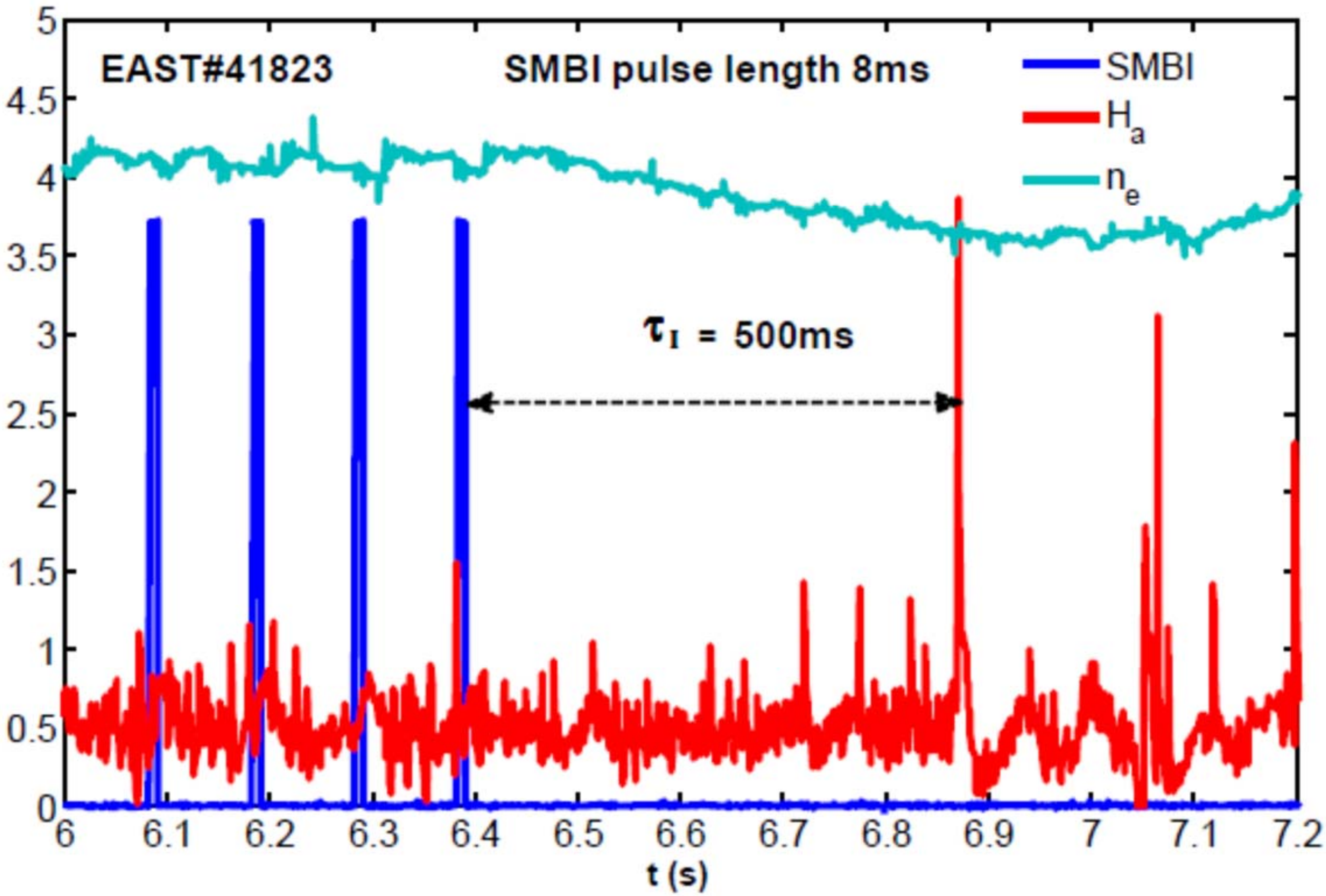
ELM mitigation through Multi-pulse SMBI

- Multi-pulse:

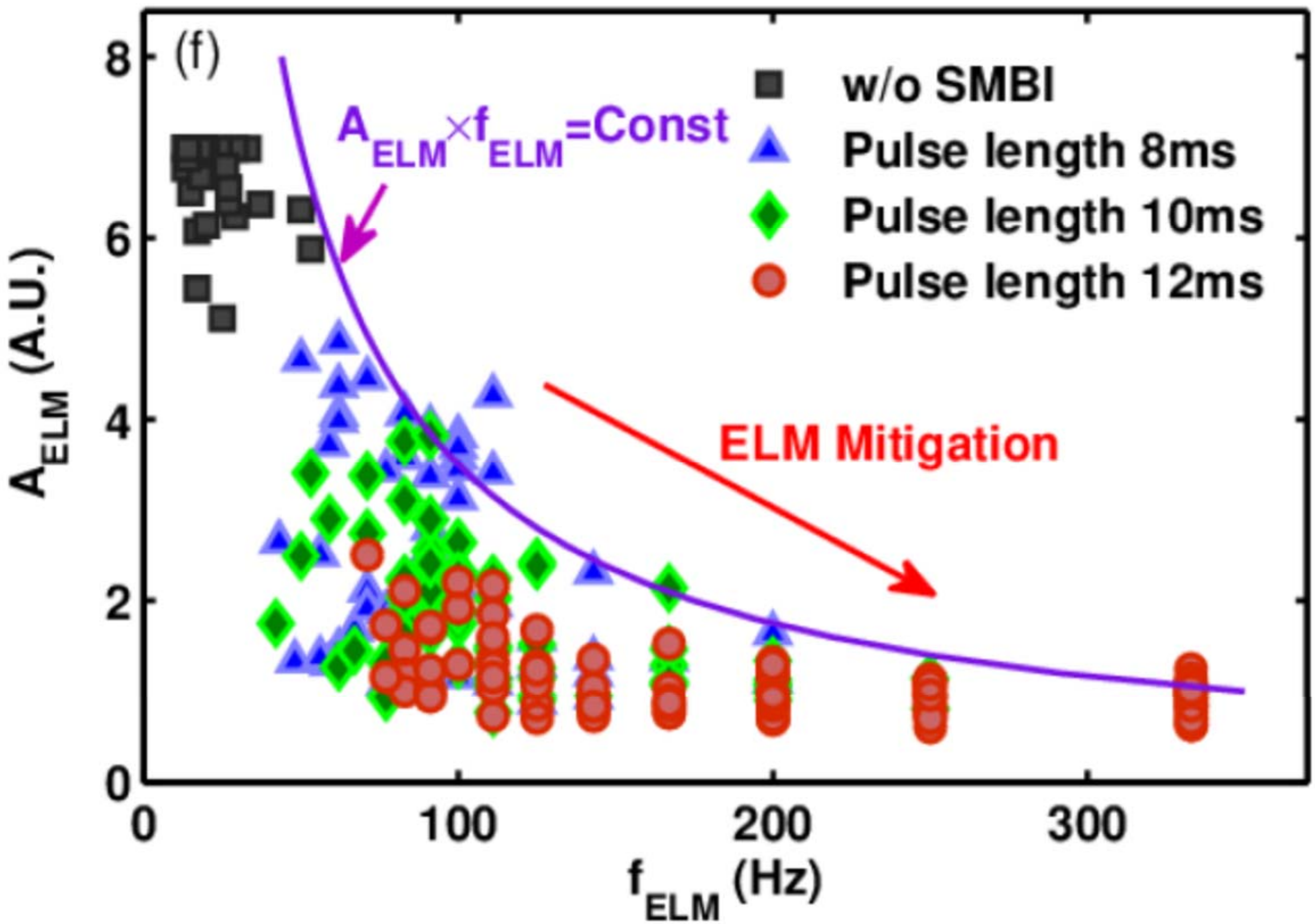


Influence time

- Influence time also changed during multi-pulse

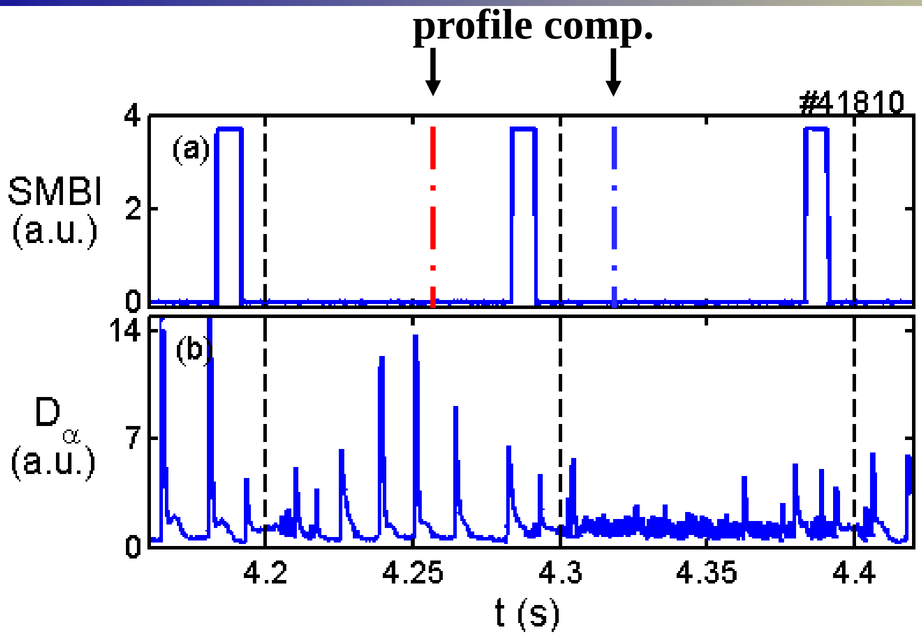


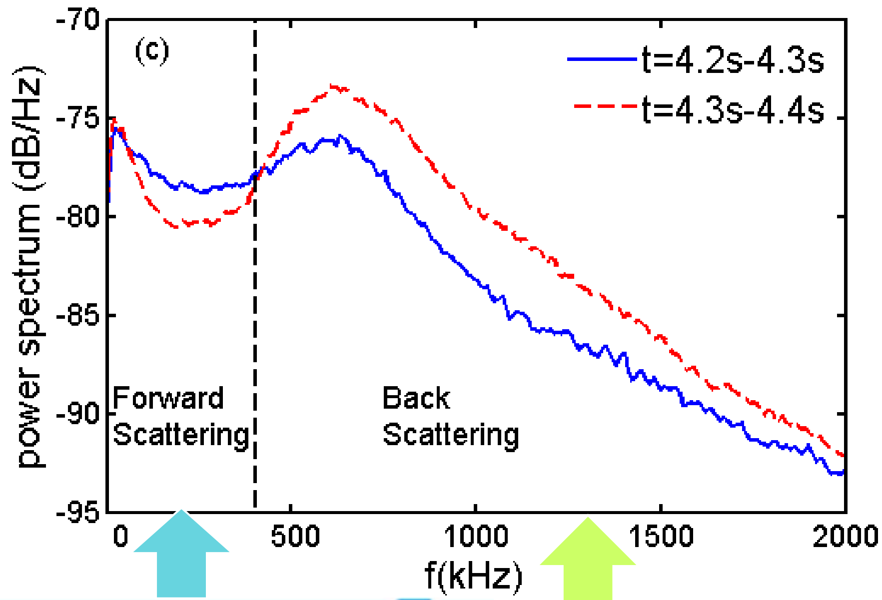
Relation between ELM frq. and amp.



Turbulence during ELM mitigation

Power density spectra



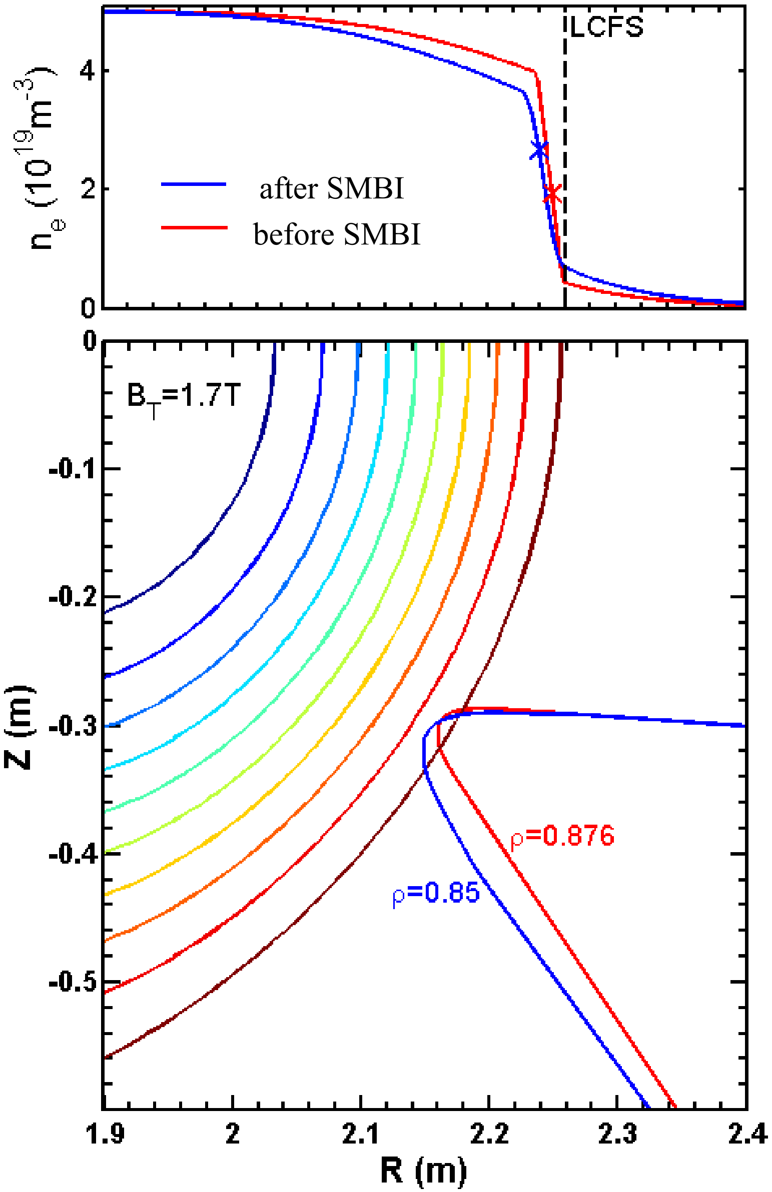


Forward Scattering
- No spatial localization
- Δk_θ=0.8 cm^{-1}
- Large scale turbulence

Back Scattering
- Localized at ρ_c=0.9±0.05
- k_θ=7.3 cm^{-1}
- Small scale turbulence

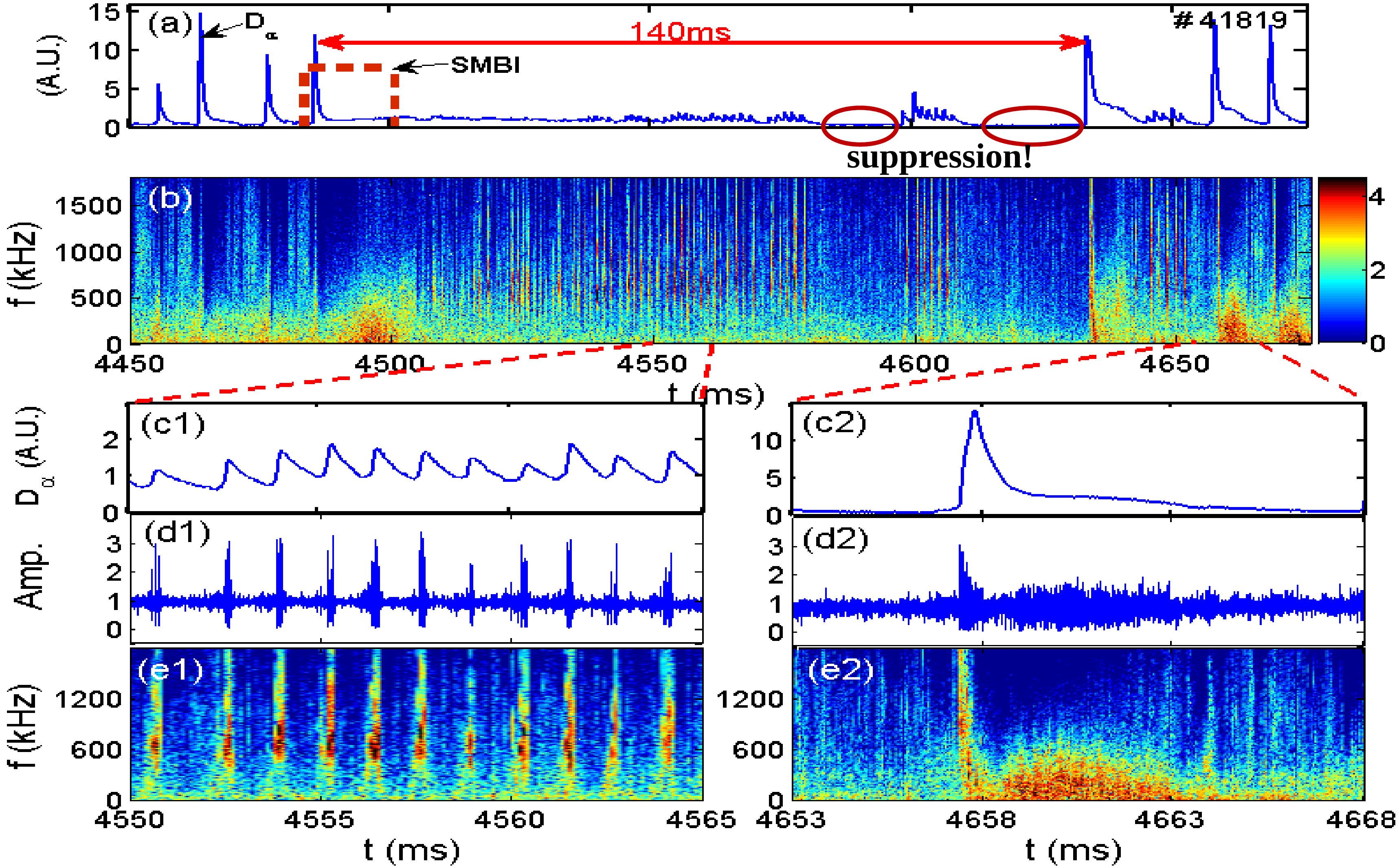
- Significant changes on power density spectra of reflectometer complex signals ($I+iQ=Ae^{i\varphi}$) ;

Ray-tracing results before and after SMBI



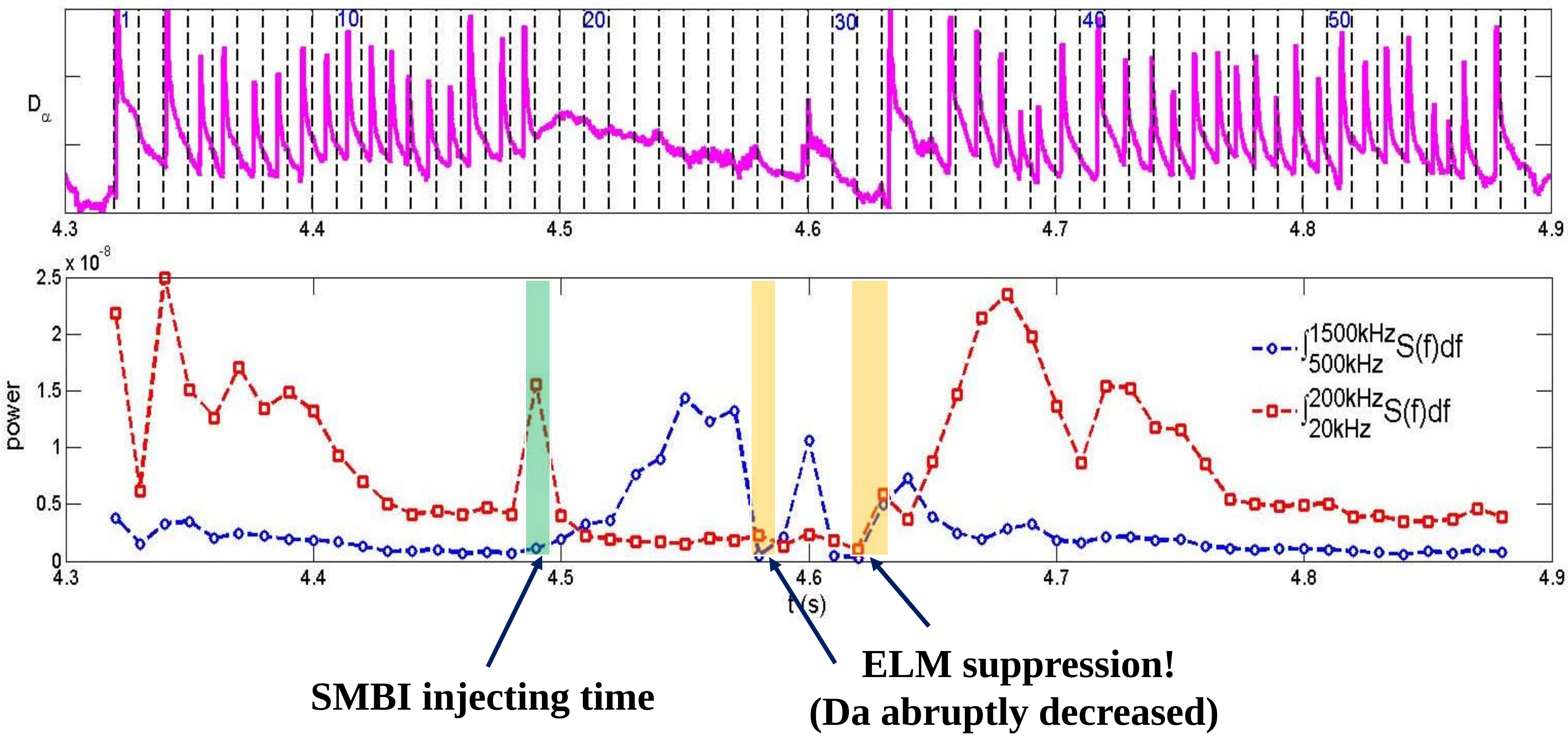
- The cut-off layer changed little before and after SMBI;
- Ray-tracing of 74GHz;
- Both at pedestal region;
- Radial position change below 1cm;

Time-frequency spectra



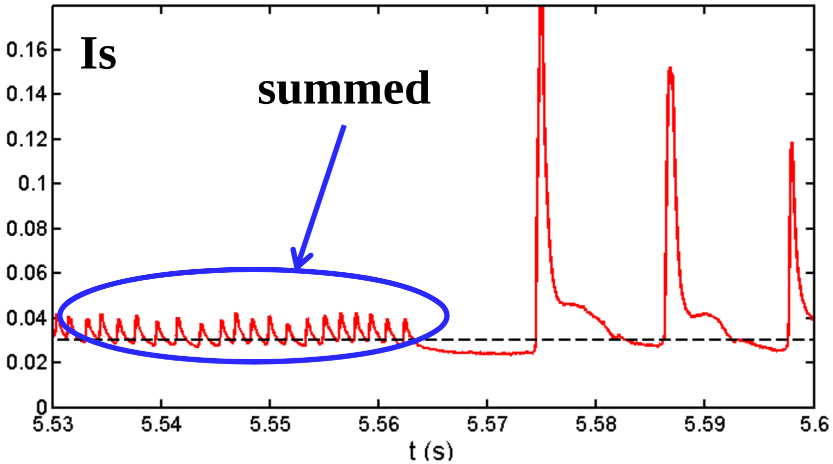
- The small scale turbulence is intermittent during ELM mitigation;

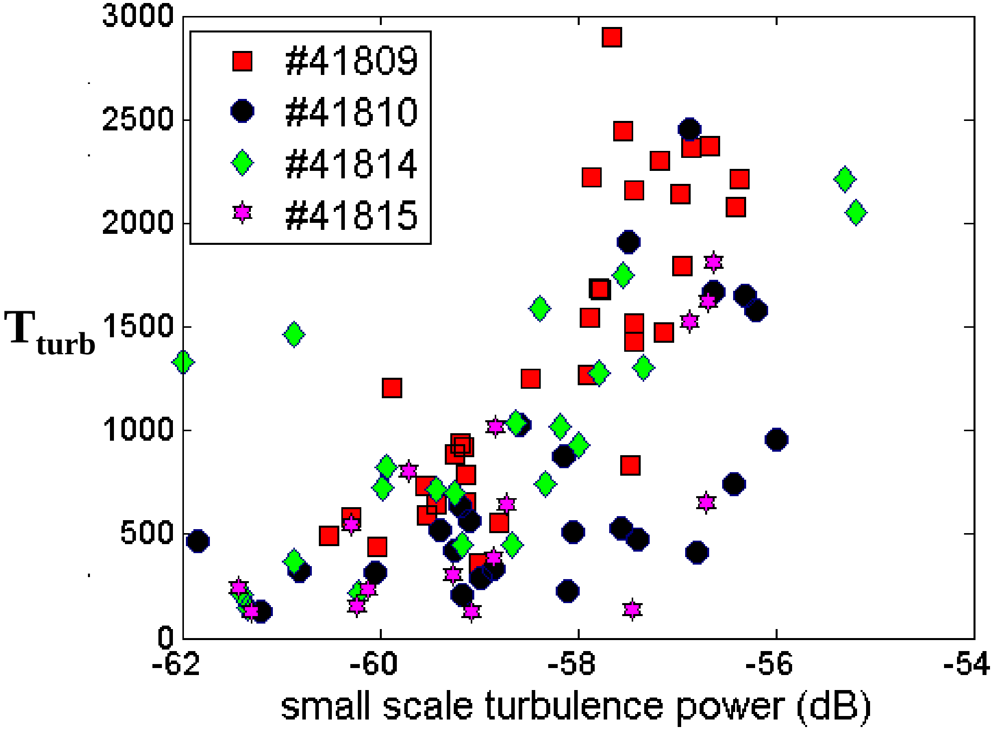
Small scale vs. large scale turbulence



- Except the three special moments, we could see obvious reverse relation between low frequency power and high frequency power;

Small scale turbulence and transport

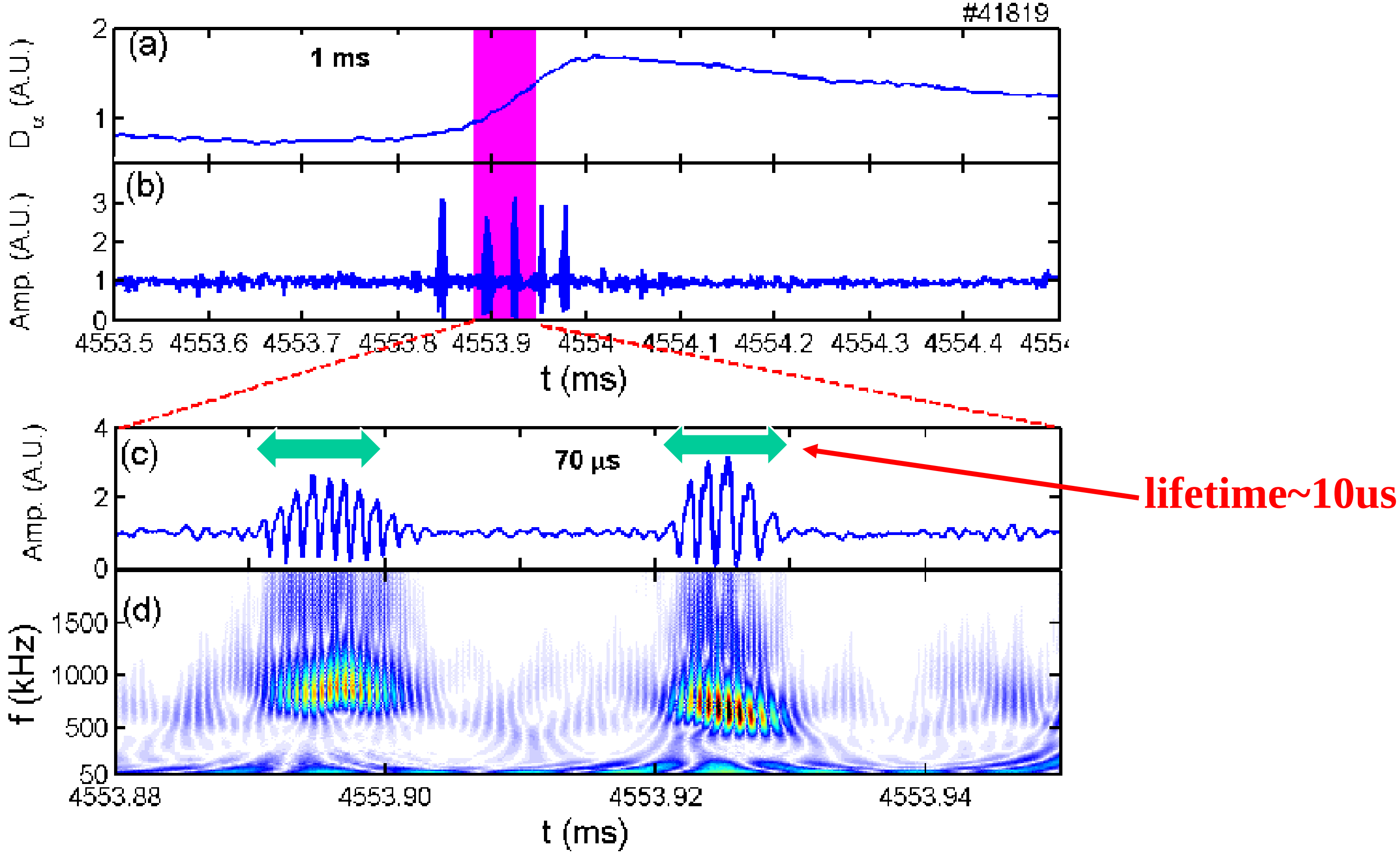




- Define T_{turb} as particle numbers arriving divertor ;
- T_{turb} is calculated by integrating divertor particle flux over dozens of milliseconds;
- A strong increase of T_{turb} with the small scale turbulence intensity;

Only include the time periods during ELM mitigation

Structure of the small scale turbulence



- During ELM mitigation, every small spike of Da/Is corresponds to several intermittent pulses on reflectometer amplitude signal, every pulse/oscillation package last ~10us;

Small scale turbulence features

- Pedestal region, k_θ=6-10cm^{-1}, m=100-300, n=20-60;
- intermittent, correspond with small spikes on Da/Is, lasting about 1ms;
- $\upsilon_\theta = \frac{2\pi f_D}{k_\theta} = \frac{2\pi * 700kHz}{k_\theta} = 4 - 7km/s$, similar with local ExB velocity, which means small phase velocity;
- Anti-correlated with large scale turbulence power;
- Strongly correlated with particle numbers on divertor, probably enhance outward particle flux;

Discussion

- The scale range and radial range of the small scale turbulence?
- Nature of the turbulence? Why intermittent?
- Whether is the phenomena general during ELM mitigation by other methods?
- The role of small scale turbulence during ELM mitigation? One more factor in peeling-ballooning mode?
- Influence time is determined by what?

Future plan

- Density profile reflectometer with 10us time resolution will be installed on EAST this year;
- 8-channel Doppler Reflectometer (collaborated with UCLA) will also be installed this year;
- SMBI, LHCD, Lithium injection, RMP could all be used for ELM mitigation on EAST now;

Thanks!