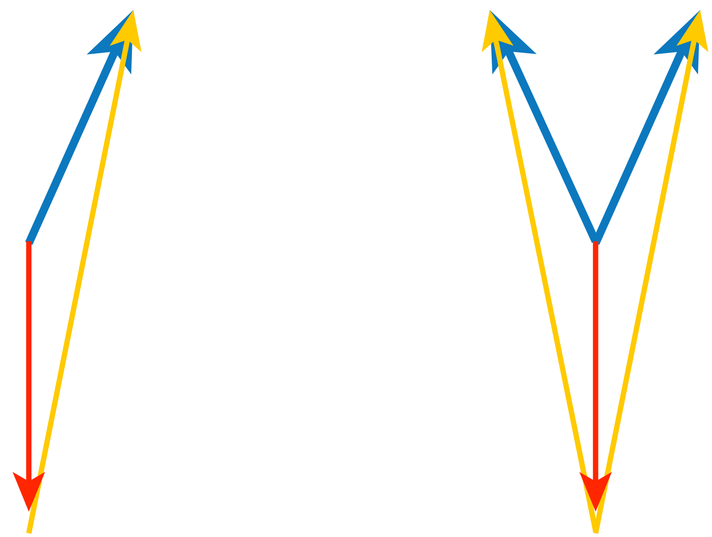
Multibeam Interaction Processes Relevant to Direct-Drive Inertial Confinement Fusion

UR LLE



Single-beam interactions

Multibeam interactions sharing a common daughter wave

W. Seka
University of Rochester
Laboratory for Laser Energetics

44th Annual Anomalous Absorption Conference
Estes Park, CO
8–13 June 2014

University of Rochester

Summary

Most laser–plasma interaction processes work well in multibeam geometry sharing a daughter wave*

- **Common features**
  - lower thresholds
  - higher gains
  - nonuniformly distributed interaction regions
- **Multibeam two-plasmon decay (TPD) is firmly established****
- **There are indications of multibeam stimulated Brillouin scattering (SBS) backscatter*****
- **Multibeam stimulated Raman scattering (SRS) has been reported for indirect-drive inertial confinement fusion (ICF)† and is now also appearing in direct-drive experiments**

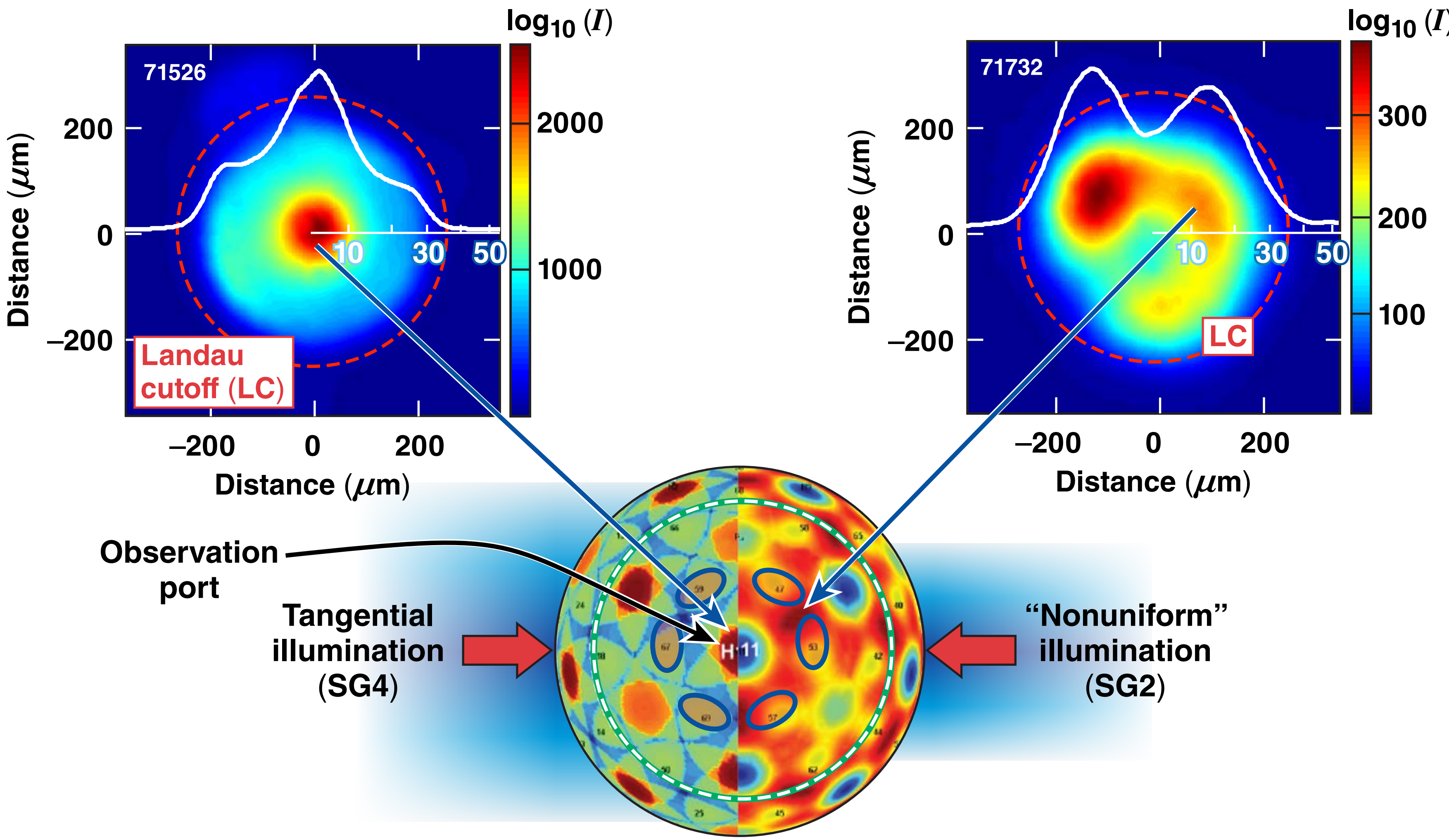
*J. F. Myatt *et al*., Phys. Plasmas 21, 055501 (2014).
**C. Stoeckl *et al*., Phys. Rev. Lett. 90, 235002 (2003).
***R. K. Kirkwood *et al*., Phys Rev E. 84, 026402 (2011).
†R. K. Kirkwood, LLNL, private communication (2014).

Collaborators

J. F. Myatt, J. Zhang, R. W. Short, J. A. Delettrez, D. H. Froula, D. T. Michel, A. V. Maximov, V. N. Goncharov, and I. V. Igumenshchev

University of Rochester
Laboratory for Laser Energetics

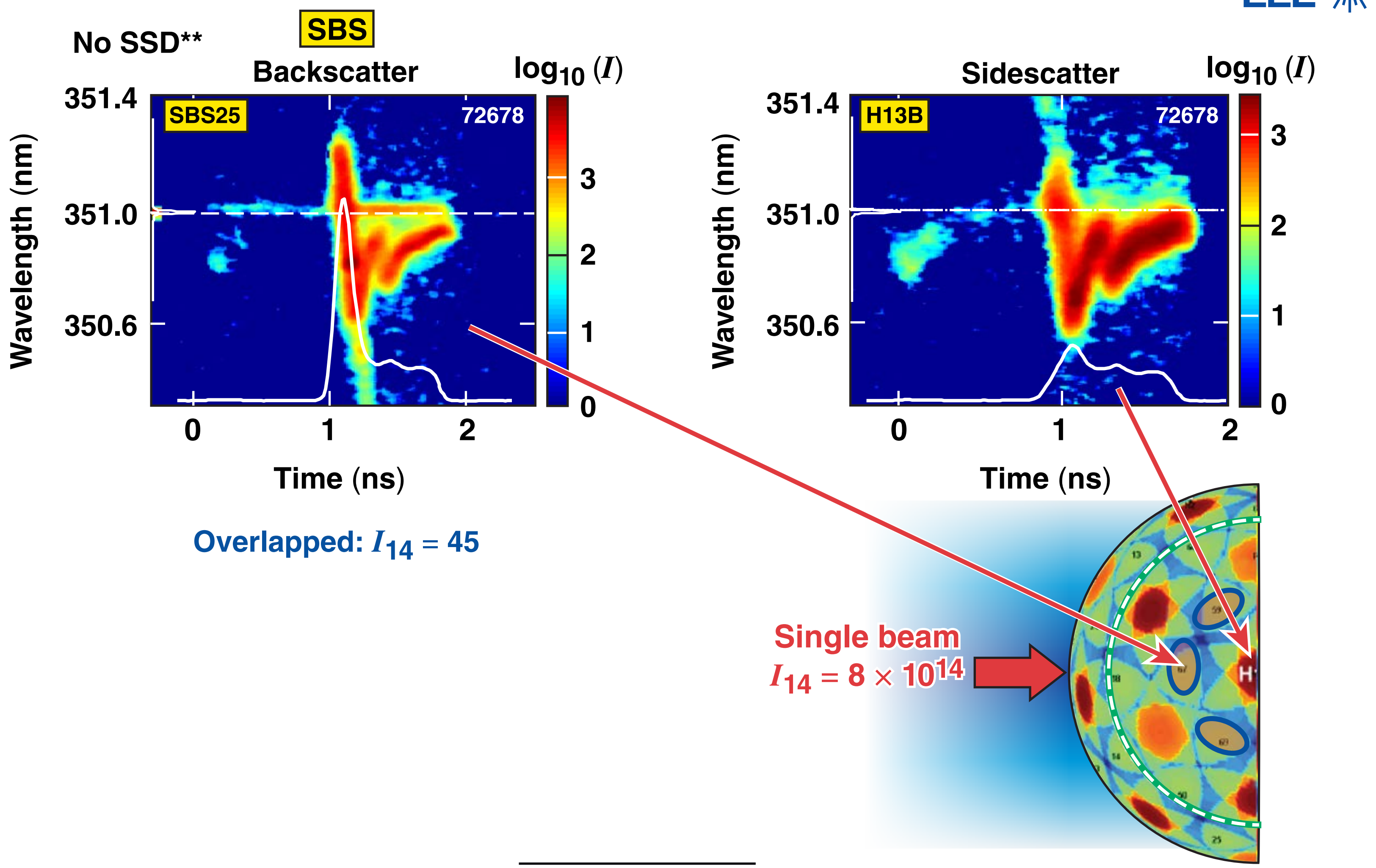
Experimental evidence for multibeam TPD* is most easily seen in $\omega/2$ images



E23140

*For more on multibeam TPD: see J. F. Myatt's talk and R. W. Short's talk, this conference.

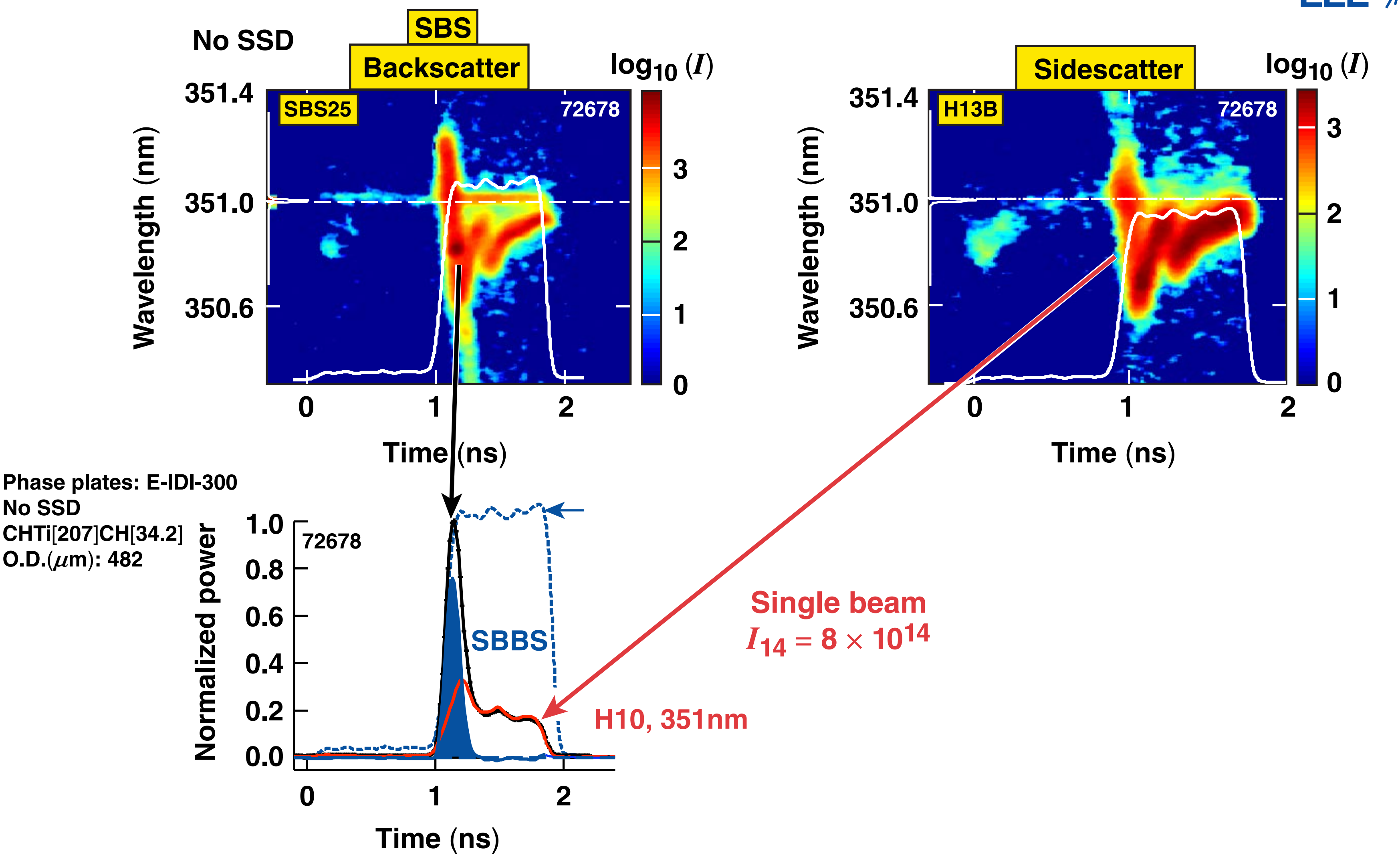
SBS backscatter* occurs at high intensities during the rise of the main laser pulse



*These results are based on strong shock experiments discussed in more detail in W. Theobald's invited talk, this conference.

**Smoothing by spectral dispersion

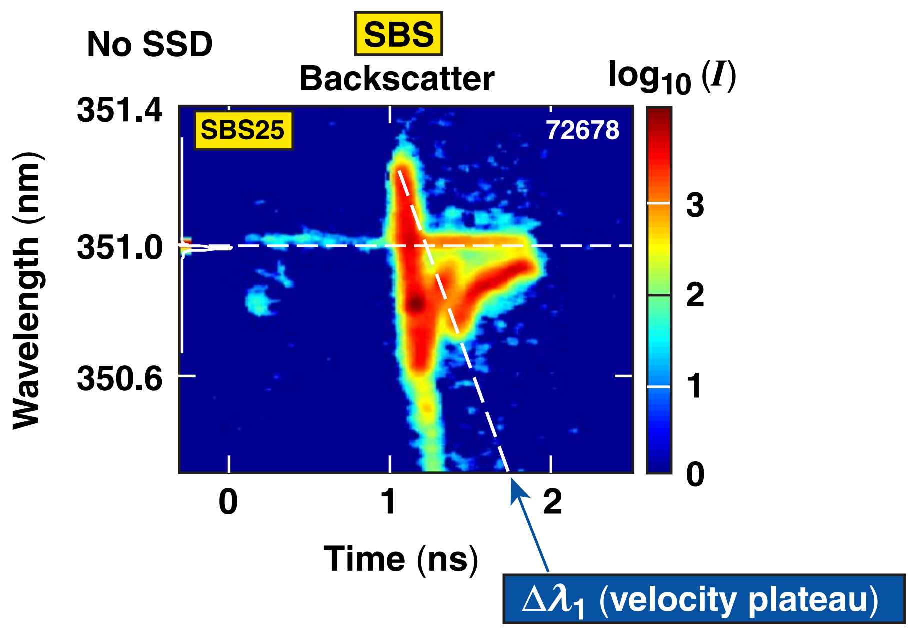
SBS backscatter occurs at high intensities during the rise of the main laser pulse

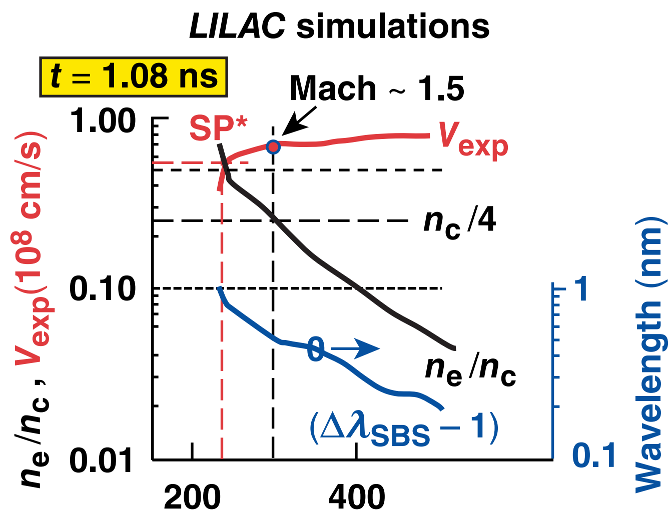


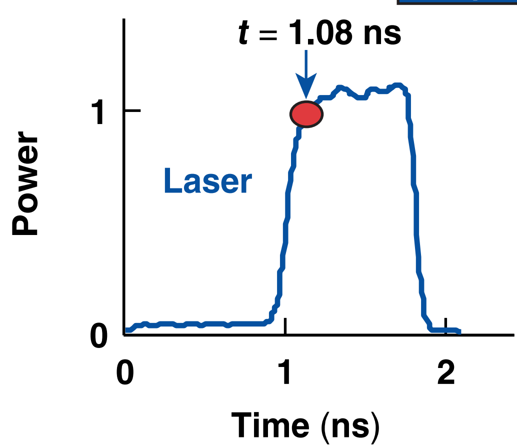
~15% instantaneous SBS backscatter

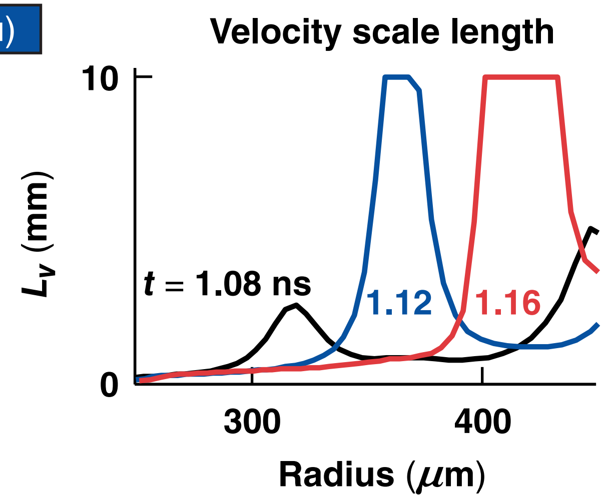
E23235

Spectral shifts of SBS backscatter reflect evolving plasma conditions





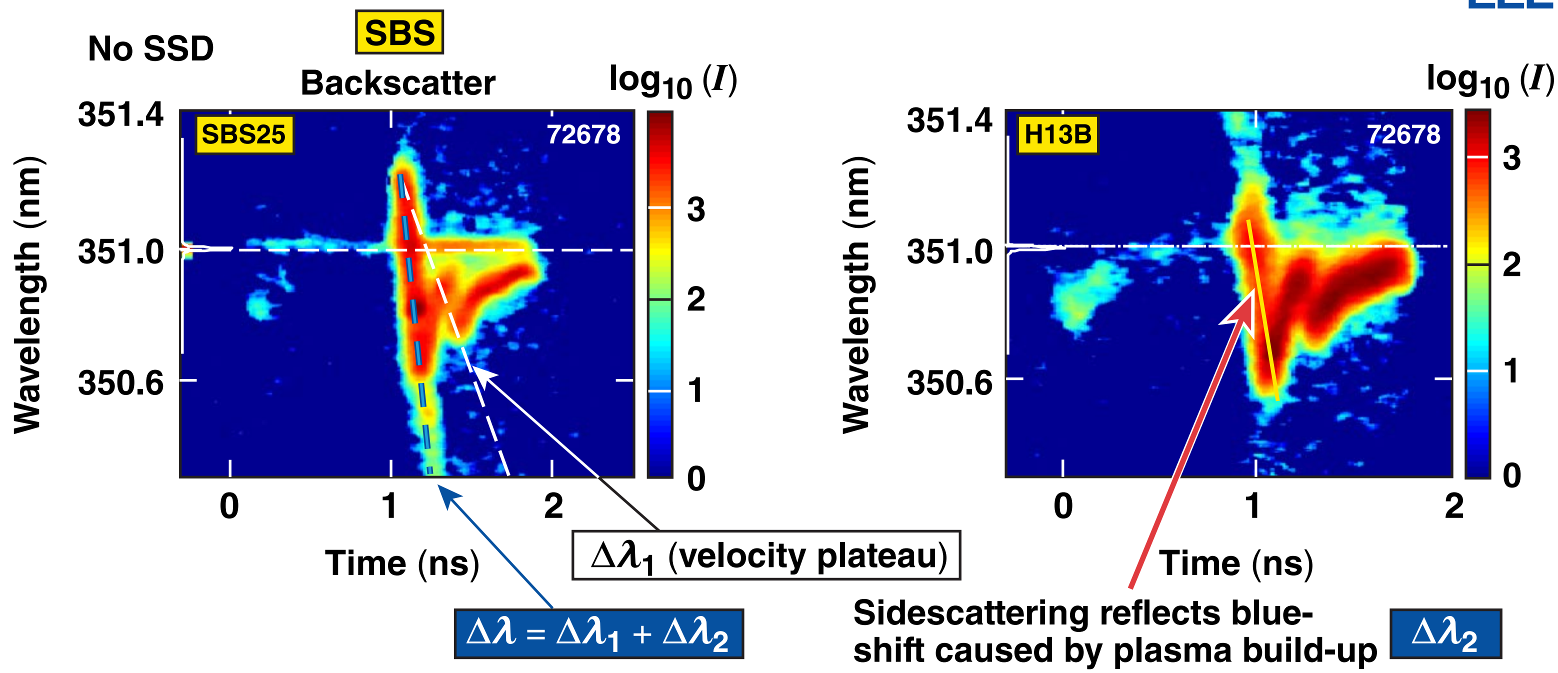




E23143a

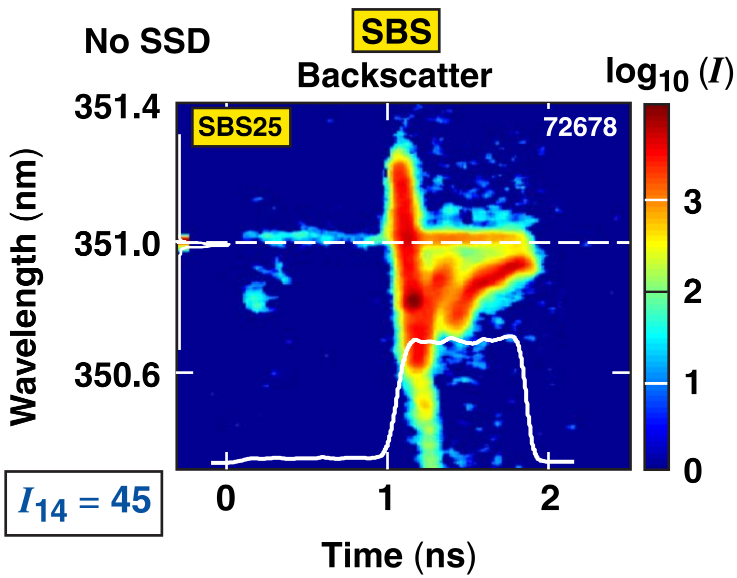
*SP = sonic point

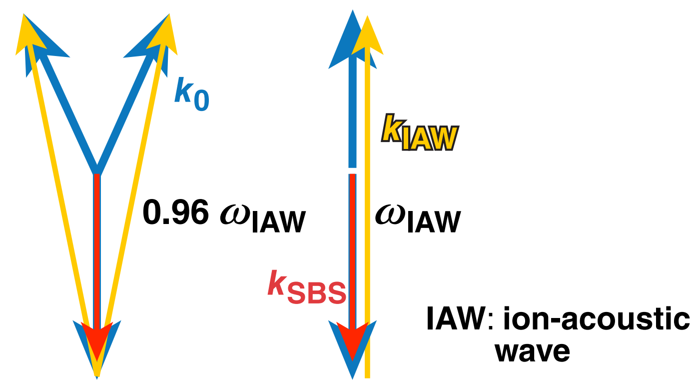
Summing blue-shifts caused by plasma build-up *and* plasma conditions agrees with observations



- Wavelength shifts correspond to hydro simulations
- SBS gains at velocity plateaus are large
- Full simulations are in progress

Single- and multiple-beam backscatter SBS may occur simultaneously and may be enhanced by speckle



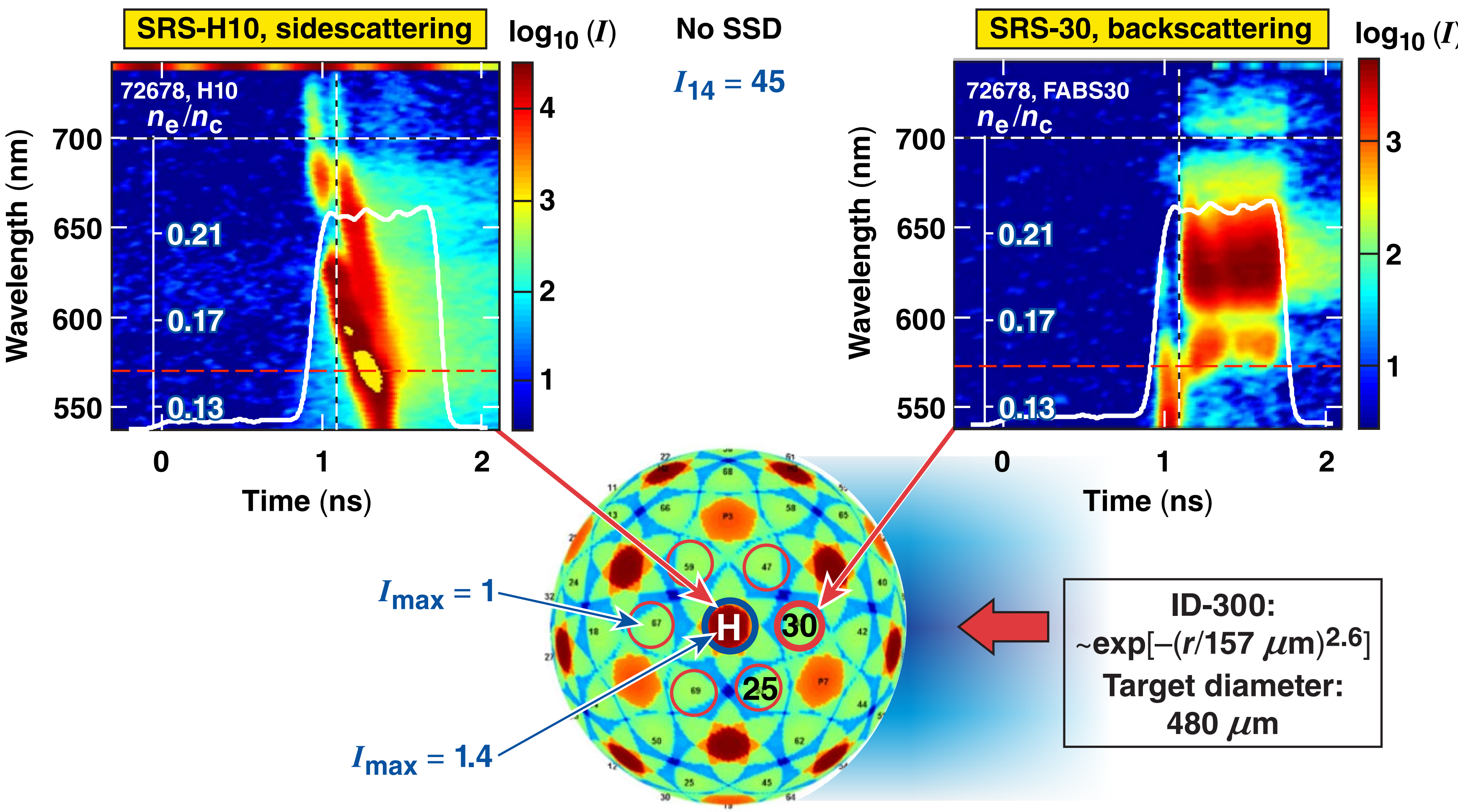


- The instantaneous SBS reflectivity (~15%) may be ~4× larger at the center of the beam
- Multibeam SBS is not observed in HEX ports
- Speckle or filamentation may be significant contributors to SBS backscattering

E23144

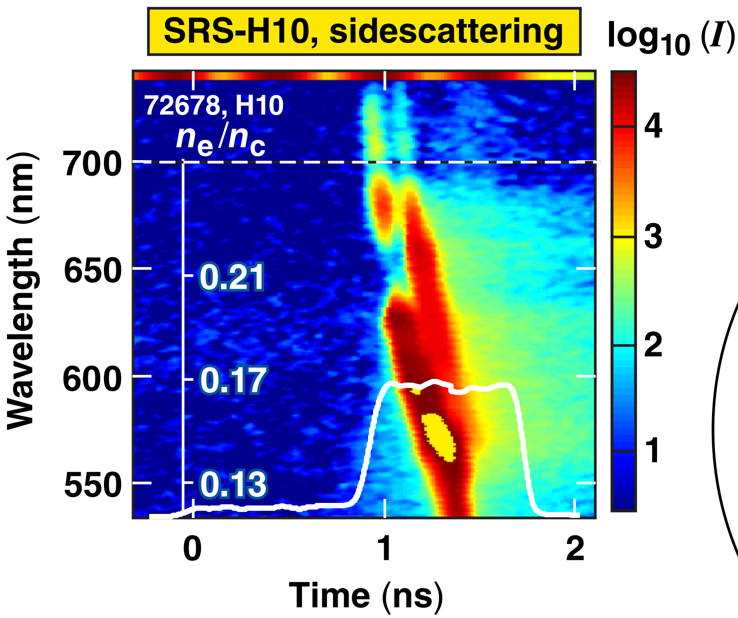
R. K. Kirkwood *et al*., Phys. Rev. E 84, 026402 (2011).

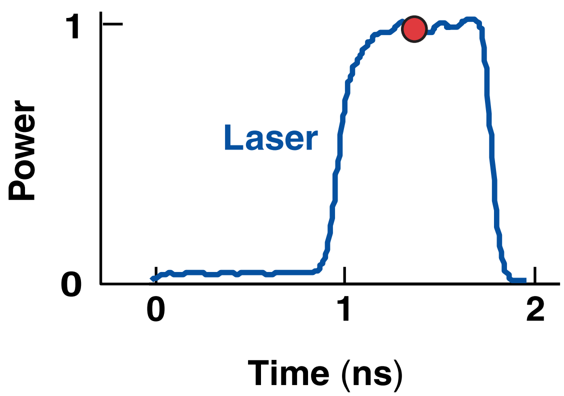
Distinct Raman features are observed in backscattering and sidescattering at high intensities

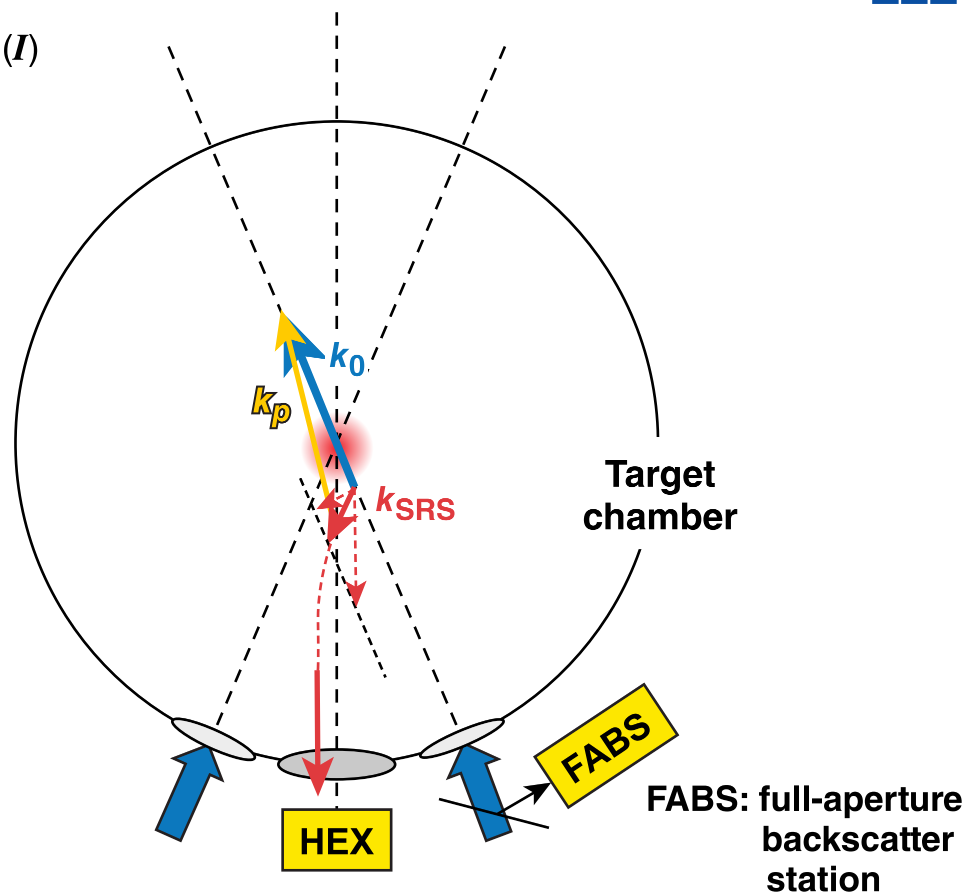


E23145

Single-beam SRS sidescattering is possible but unlikely to have sufficient gain

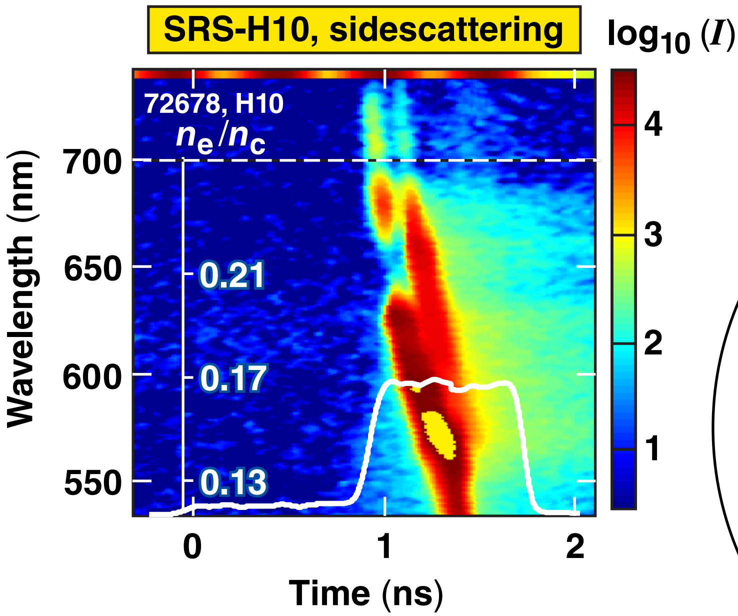


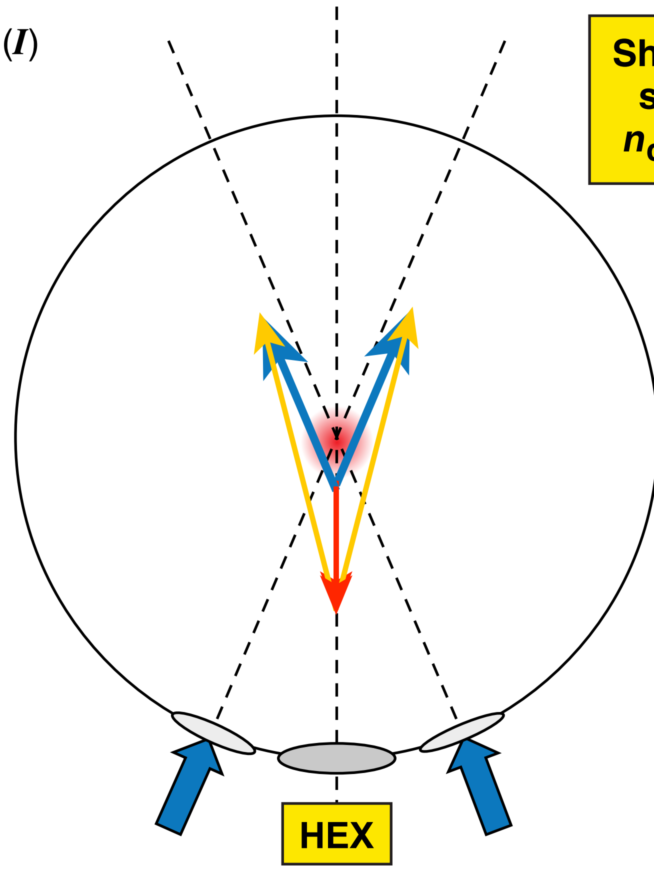




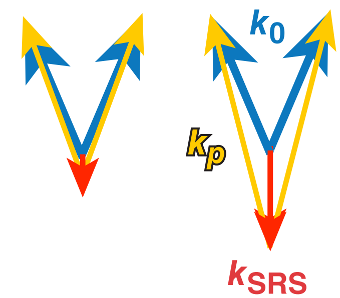
E23148

Multibeam SRS with shared electromagetic (EM) waves is the only viable process for H10 observations



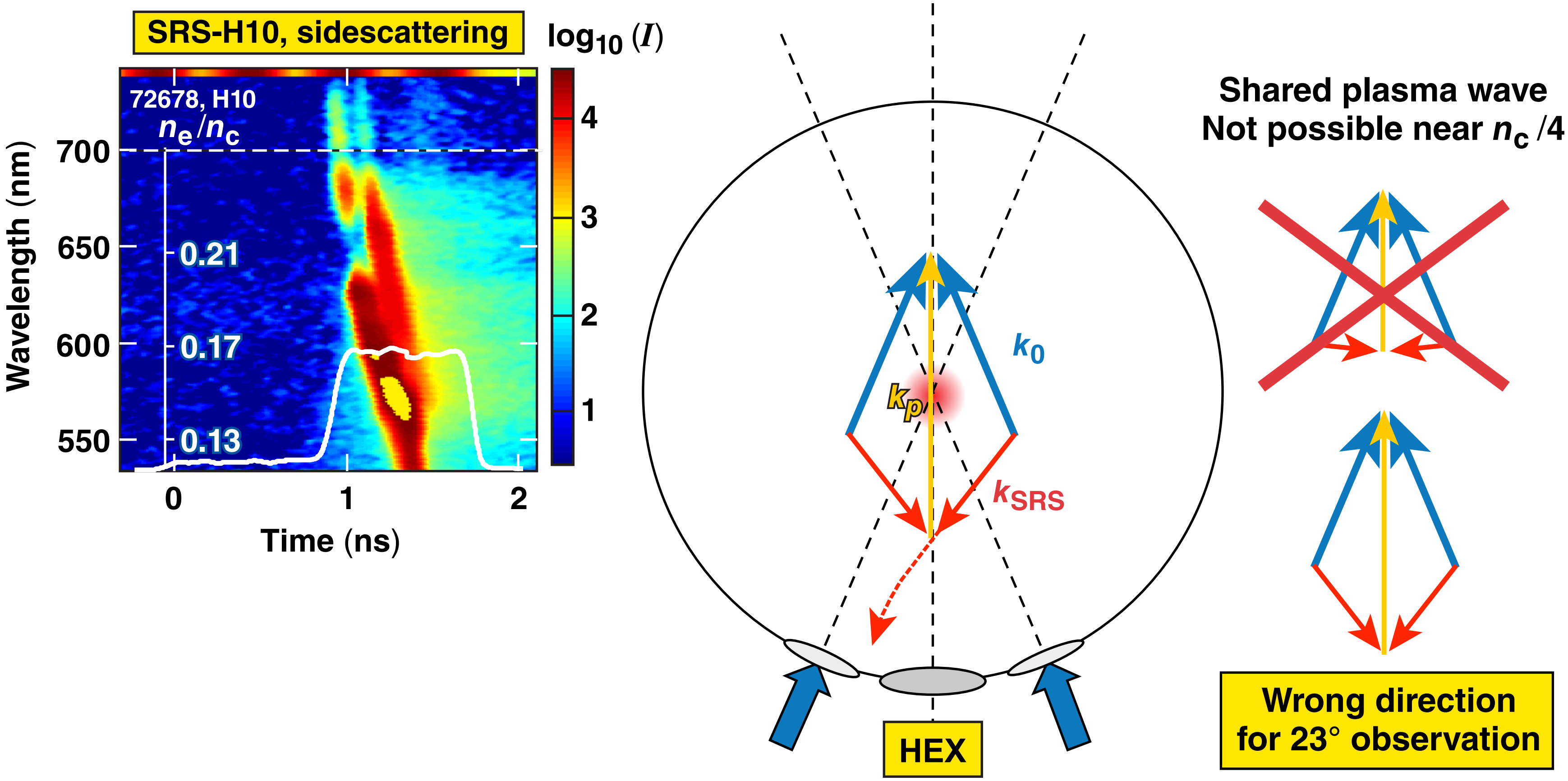


Shared EM SRS waves seamlessly go from $n_c/4$ to Landau cutoff



- Speckle cannot enhance SRS gain for these configurations

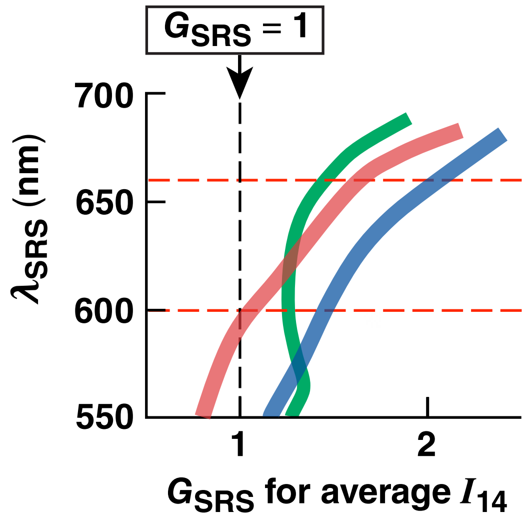
Multibeam SRS with shared plasma waves for H10 observations is restricted in density space

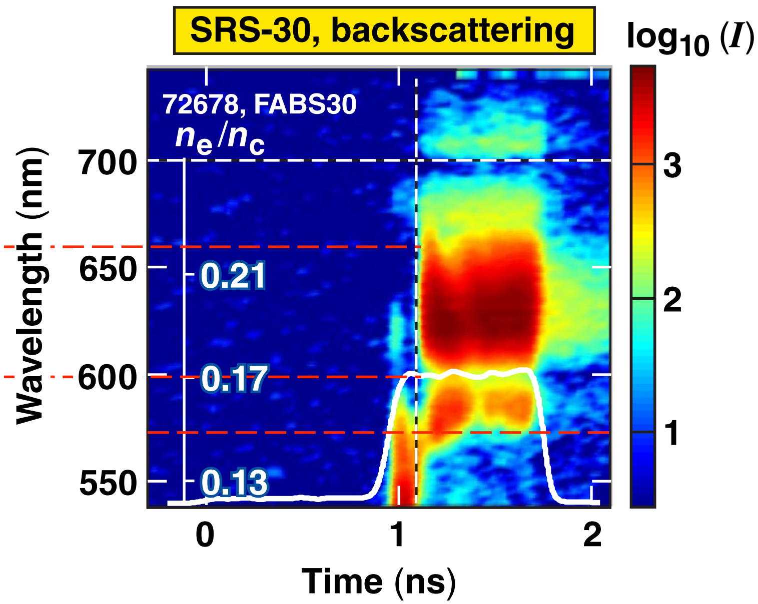


- SRS phase matching and refraction limit this process
- Speckle cannot enhance SRS gain in this configuration

E23148b

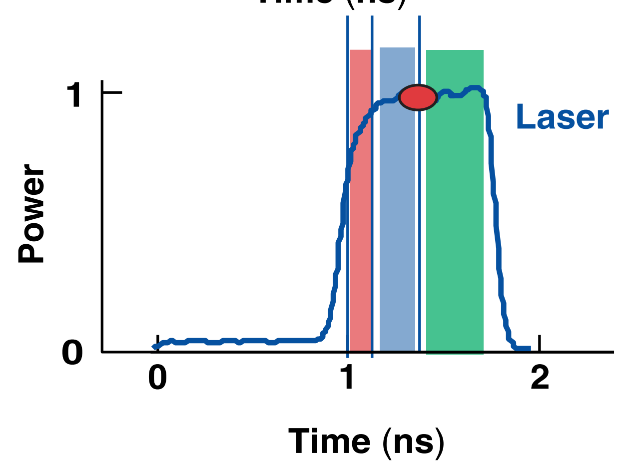
SRS gain calculations using *LILAC* plasma parameters inadequately model the observed spectra





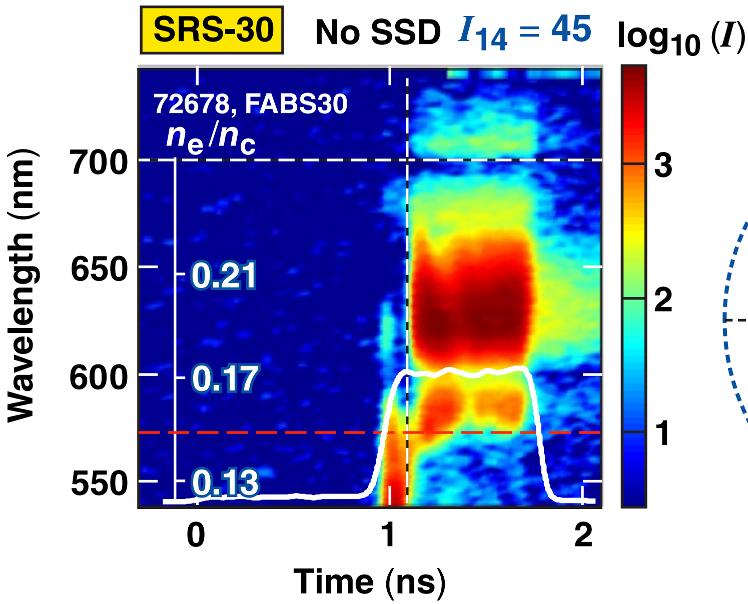
$$G_{SRS} \cong \frac{I_{14} L_{\mu}}{7917}\left(2 + \sqrt{\frac{1 - 2\sqrt{\frac{n}{n_c}}}{1 - \frac{n}{n_c}}} + \sqrt{\frac{1 - \frac{n}{n_c}}{1 - 2\sqrt{\frac{n}{n_c}}}}\right)$$

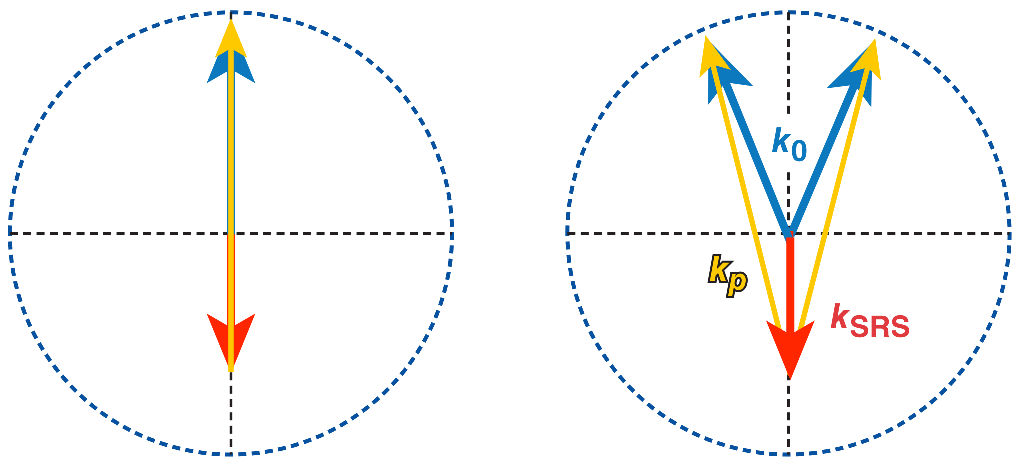
- Multibeam SRS required for adequate gain
- Speckle and filamentation are likely contributors



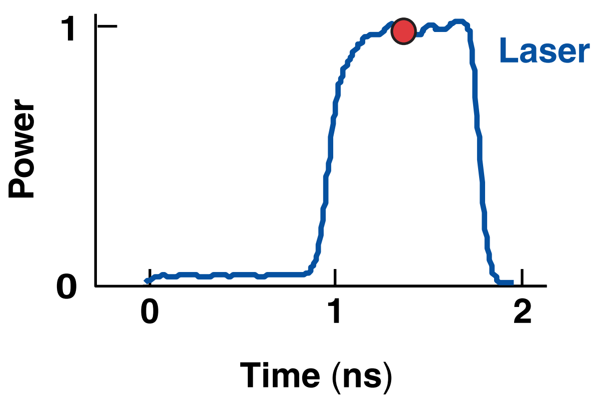
E23239

Multibeam SRS sharing an EM wave is a likely process also for backscattering



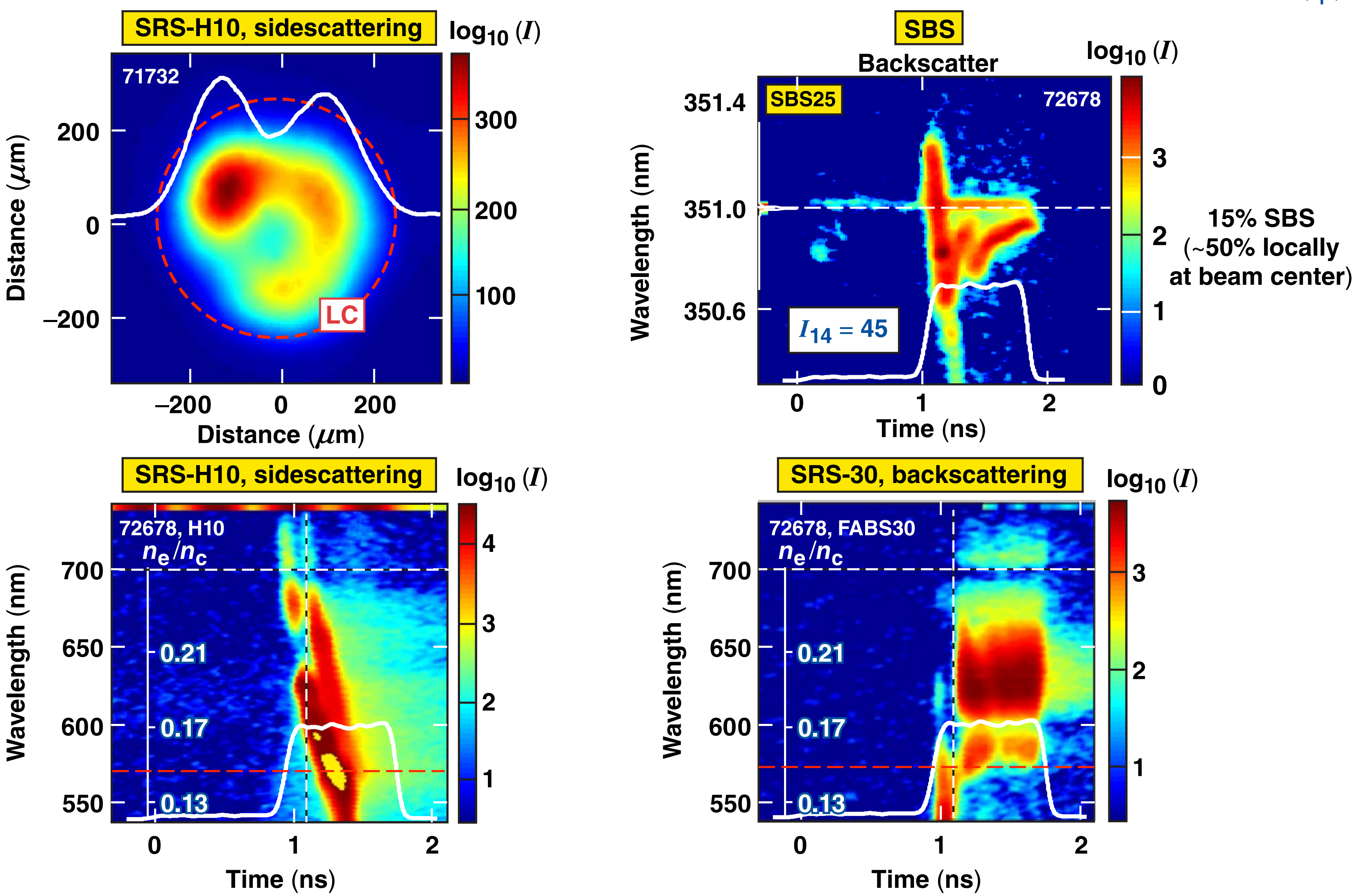


$$\omega_p^2 = \omega_{pe}^2 + 3\nu_{th}^2 k_p^2$$



- These processes are resonant at nearly the same density
- Smooth transition from $n_c/4$ to Landau cutoff for both processes
- Speckle can enhance SRS gain significantly

The special requirements of multibeam interaction processes lead to nonuniform spatial distribution



Summary/Conclusions

Most laser–plasma interaction processes work well in multibeam geometry sharing a daughter wave*

- Common features
  - lower thresholds
  - higher gains
  - nonuniformly distributed interaction regions
- Multibeam two-plasmon decay (TPD) is firmly established**
- There are indications of multibeam stimulated Brillouin scattering (SBS) backscatter***
- Multibeam stimulated Raman scattering (SRS) has been reported for indirect-drive inertial confinement fusion (ICF)† and is now also appearing in direct-drive experiments

*J. F. Myatt *et al.*, Phys. Plasmas 21, 055501 (2014).
**C. Stoeckl *et al.*, Phys. Rev. Lett. 90, 235002 (2003).
***R. K. Kirkwood *et al.*, Phys Rev E. 84, 026402 (2011).
†R. K. Kirkwood, LLNL, private communication (2014).