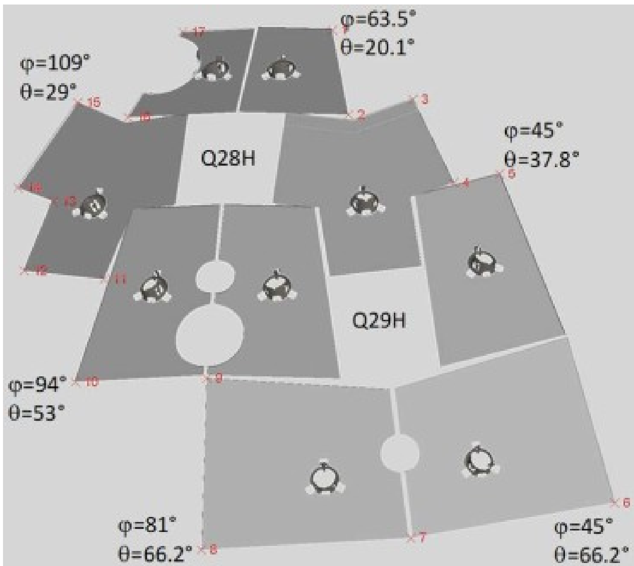
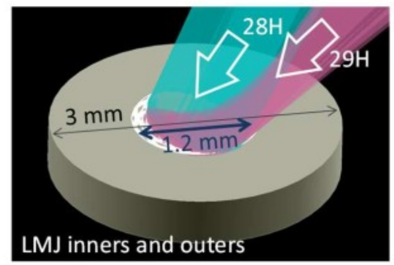
Experimental determination of SRS mechanisms in large, directly driven, ICF plasmas on the LMJ

Unique diagnostics

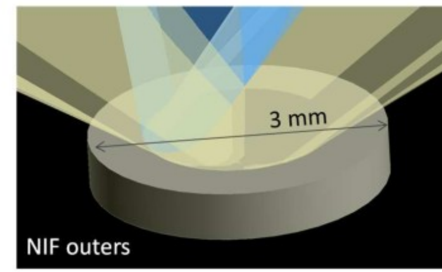


Fusion-scale plasmas

LMJ focal spots:
Inners and Outers:
0.76mm×0.4mm (FWHM)



NIF focal spots:
Inners: 1.7mm×1.2mm (FWHM)
Outers: 1.2mm×0.7mm



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2nd LMJ-PETAL User's Meeting
Hilton Garden Inn Bordeaux Centre
June 8-9, 2023

Summary

The goal is to employ the unique diagnostics available on LMJ to conclusively identify *and quantify* the active SRS mechanisms in direct drive plasmas

- **Quantify total amount of SRS scattered and its correlation with hard x rays (hot electrons)**
- **Identify and quantify the individual contributions from back-scatter, side-scatter, and multi-beam processes**
- **Provide a data set that can be used for the development and testing of reduced (in-line) models of SRS***
- **Advance theoretical understanding; e.g., identify regions of absolute and convective instability**
- **Compare with NIF planar LPI platform****

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* ELPSE: Eikonal Laser Plasma Simulation Environment
** M. Rosenberg *et al*., Phys. Plasmas 27, 042705 (2020)
A.A. Solodov *et al*., *ibid* 052706

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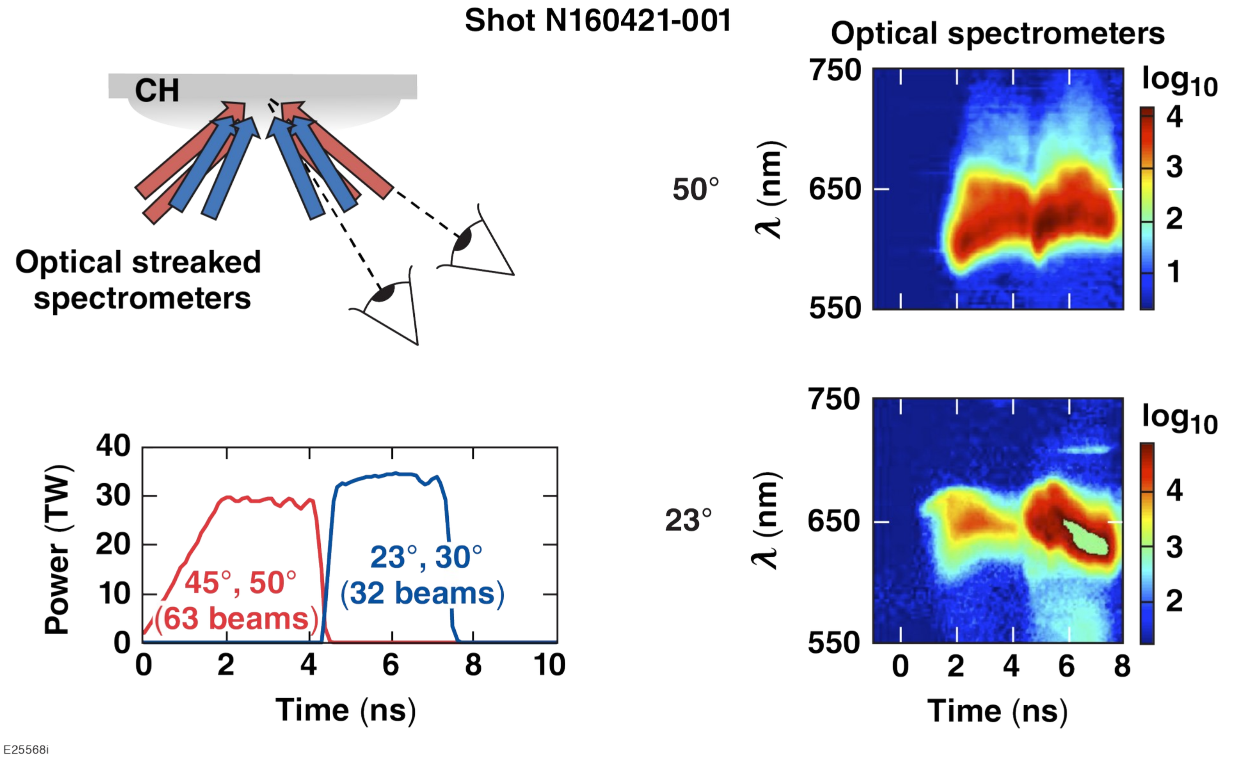
We will quantify the total amount of SRS light and its correlation with hard x-ray signatures

Previous planar NIF experiments showed that the SRS occurred at a level that is problematic for directly-driven laser fusion**

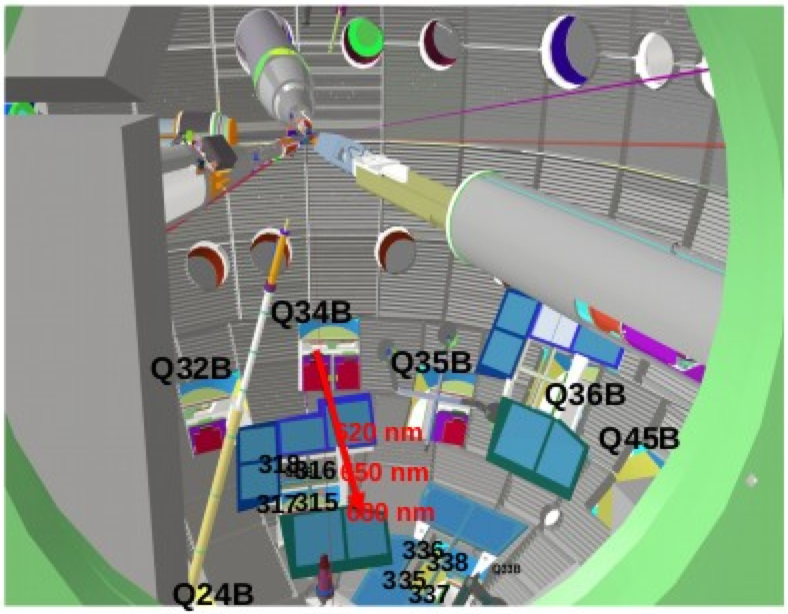


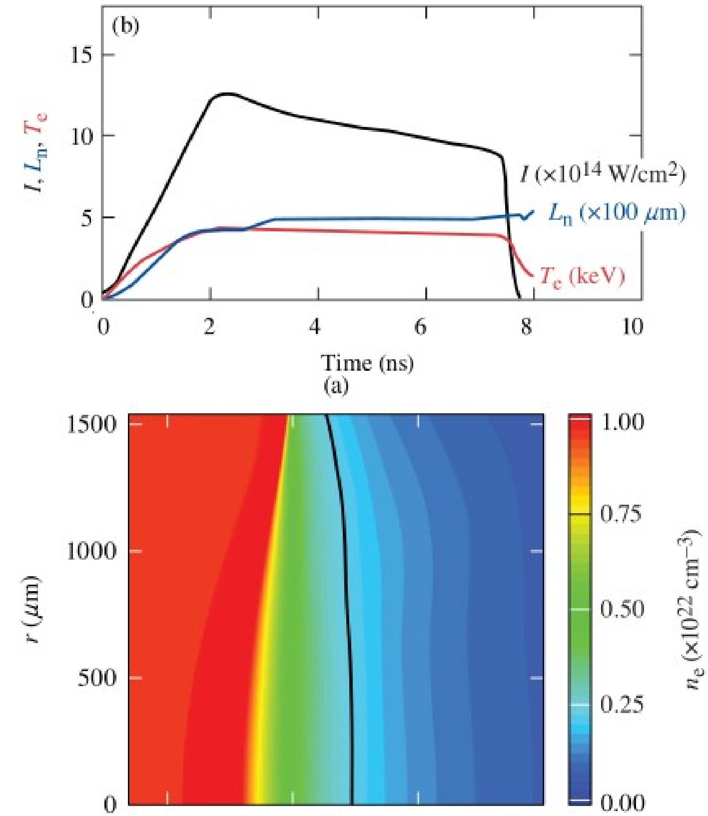
Observation at 50° can only be sidescatter. Tangential SRS sidescatter theory* predicts scattered light wavelength independent of beam angle, as observed.

*P. Michel *et al*., Phys. Rev. E **99**, 033203 (2019).
** M. Rosenberg *et al*., Phys. Plasmas 27, 042705 (2020)
A.A. Solodov *et al*., *ibid* 052706

On the NIF planar LPI platform, scattered light information was limited to the FABS locations

Angular dependence of SRS scattered light investigated by rotating the target (23° and 50° FABS)





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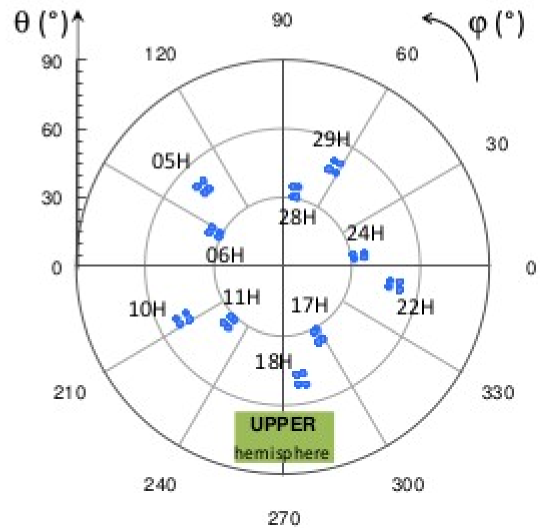
Interaction conditions will be similar to those obtained on the NIF planar LPI platform

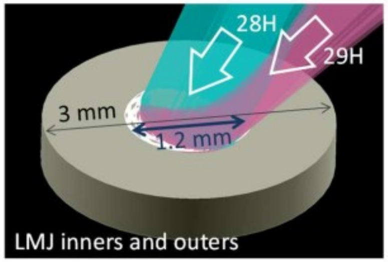
- **Rad-hydro calculations are pending**

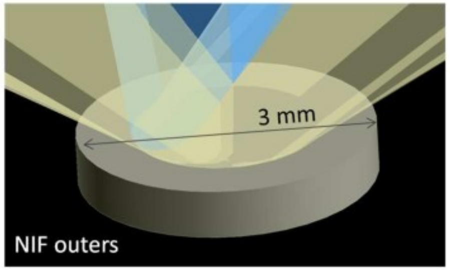


Energy/power limitation to manage damages on the optics in 2024: 13.5 kJ per quad/4.5 TW per quad (270 kJ total)

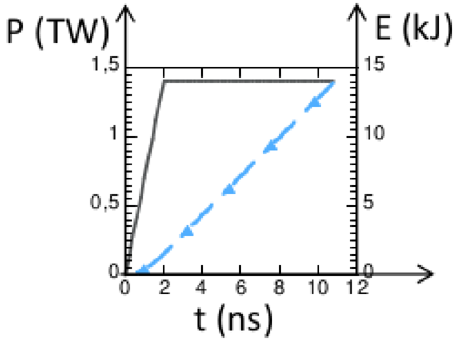
LMJ focal spots:
Inners and Outers:
0.76mm×0.4mm (FWHM)

NIF focal spots:
Inners: 1.7mm×1.2mm (FWHM)
Outers: 1.2mm×0.7mm



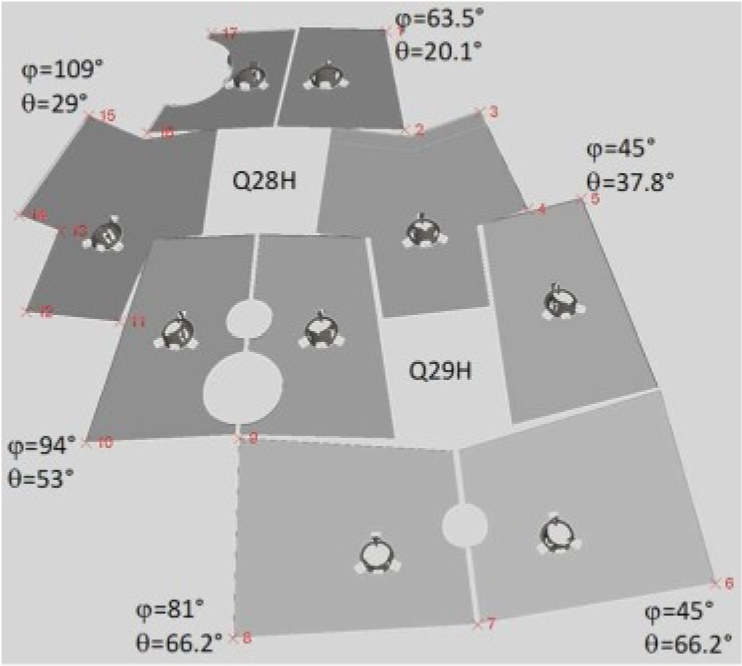


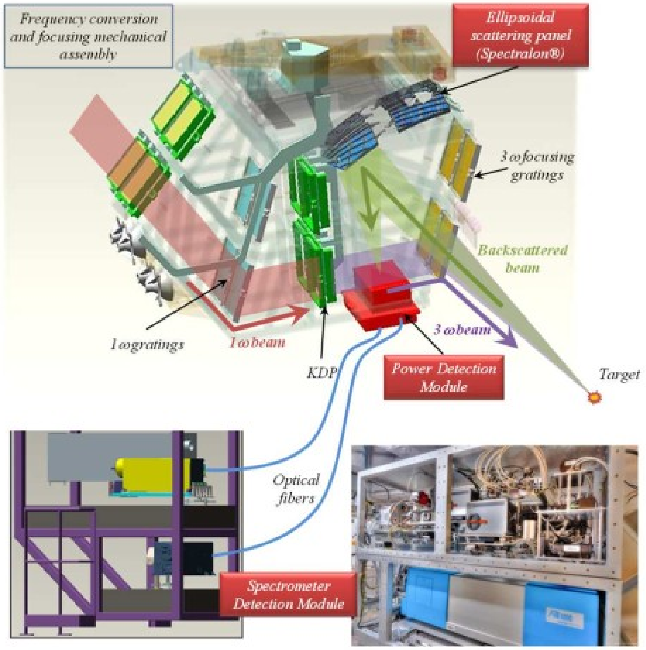
$I_{tot}=2.6\times10^{15}$ W/cm^2



The LMJ angular coverage of scattered light is superb - by virtue of the NBI and associated diagnostics

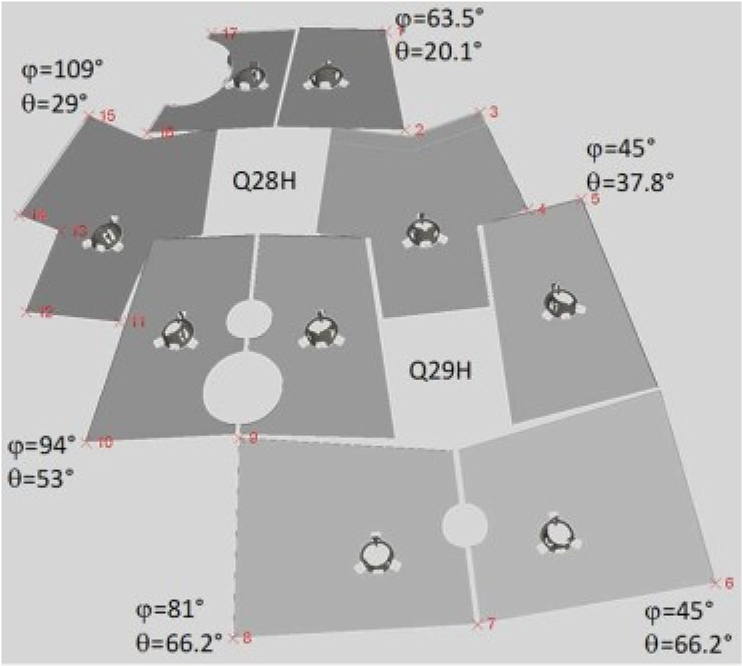
- The NBI covers a very broad range of scattering angles around Q28H and Q29H; FABS installed in Q23H (33° quad)

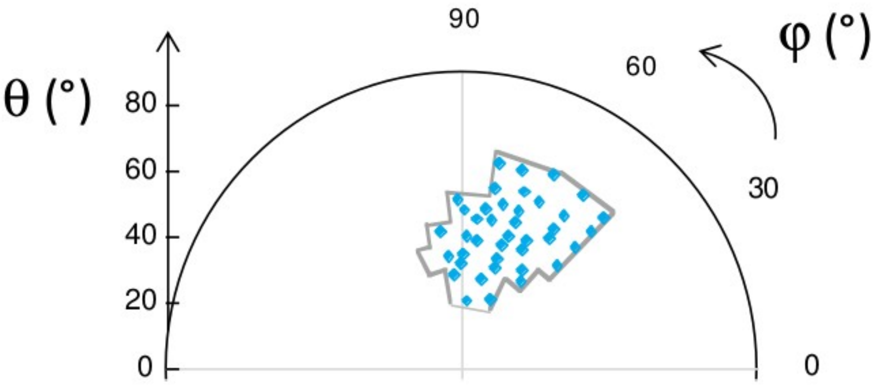




The LMJ angular coverage of scattered light is superb - by virtue of the NBI and associated diagnostics

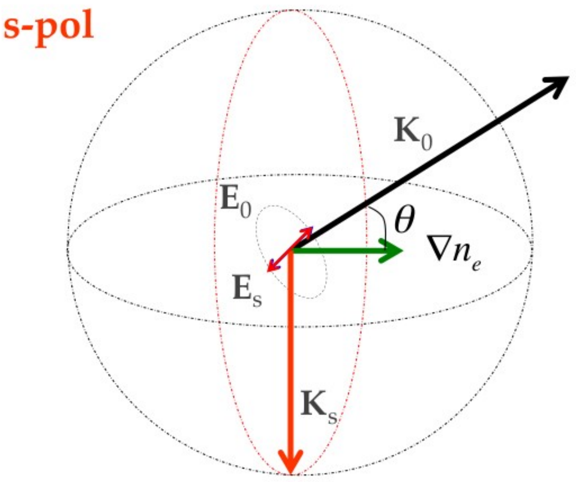
- Time resolved signals are available at 40 locations on the NBI





Stimulated Raman side-scattering processes can be discriminated on the basis of their angular and spectral properties

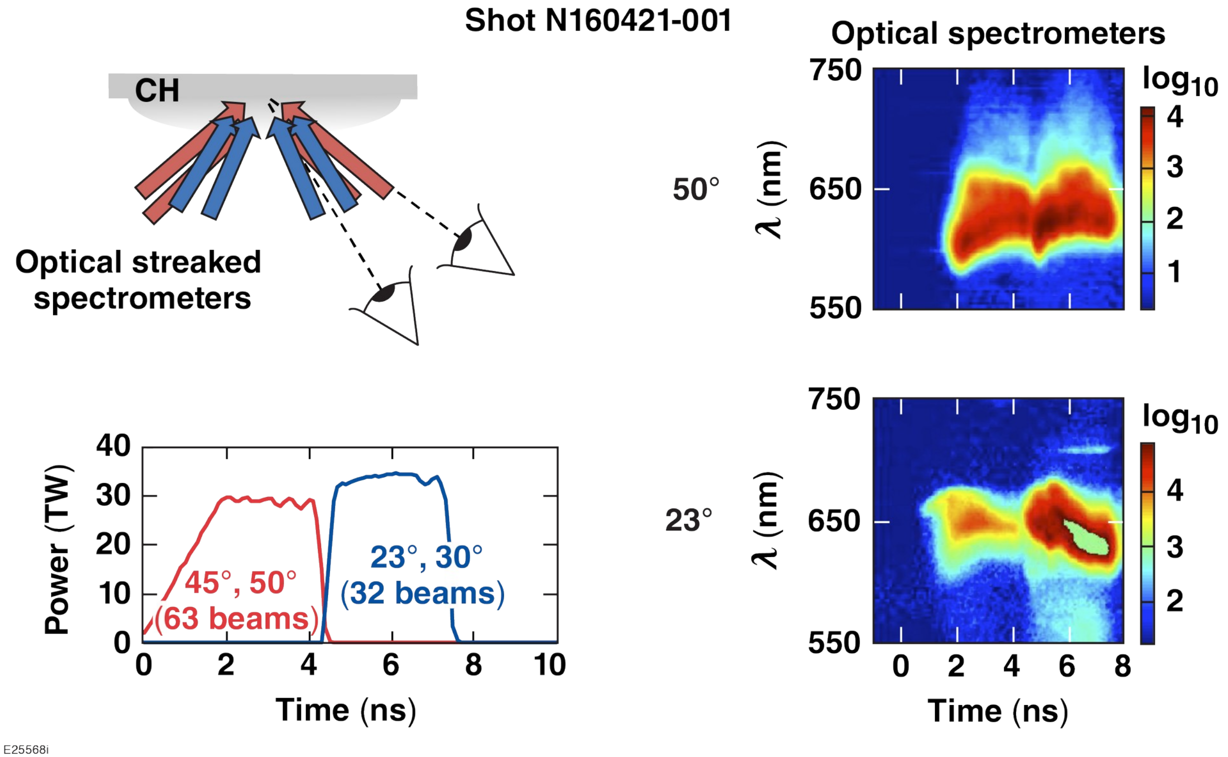
- SRS side scattering occurs at the turning point of the scattered light wave
- For side scatter in a planar 1-D plasma, the scattering angle corresponds to density of origin (turning point)
- Simple calculations indicate that single beam side scatter will be observable on the NBI and the Q28H and Q29H FABS
- Detailed ray tracing will be performed



*P. Michel *et al*., Phys. Rev. E **99**, 033203 (2019).

Side scatter SRS light was observed on the NIF planar LPI platform

The contribution of SRSS to the total scattering and hot electron production is not currently known**



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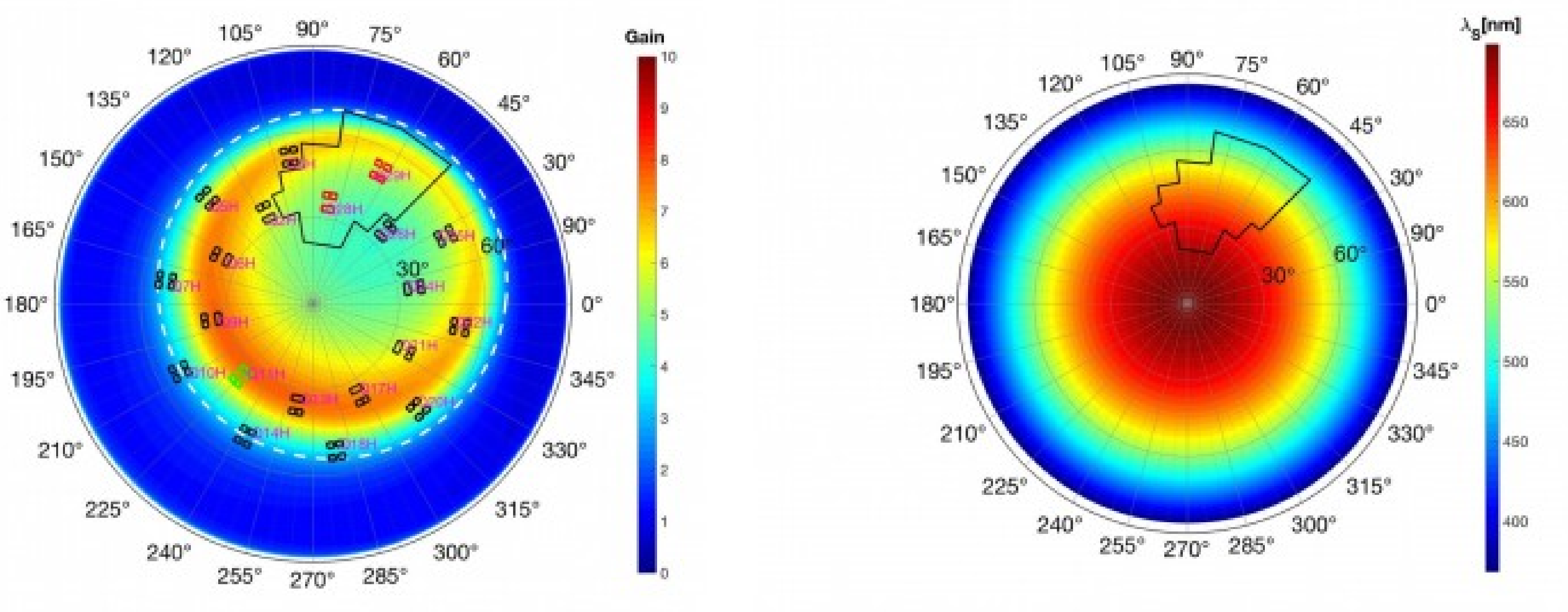
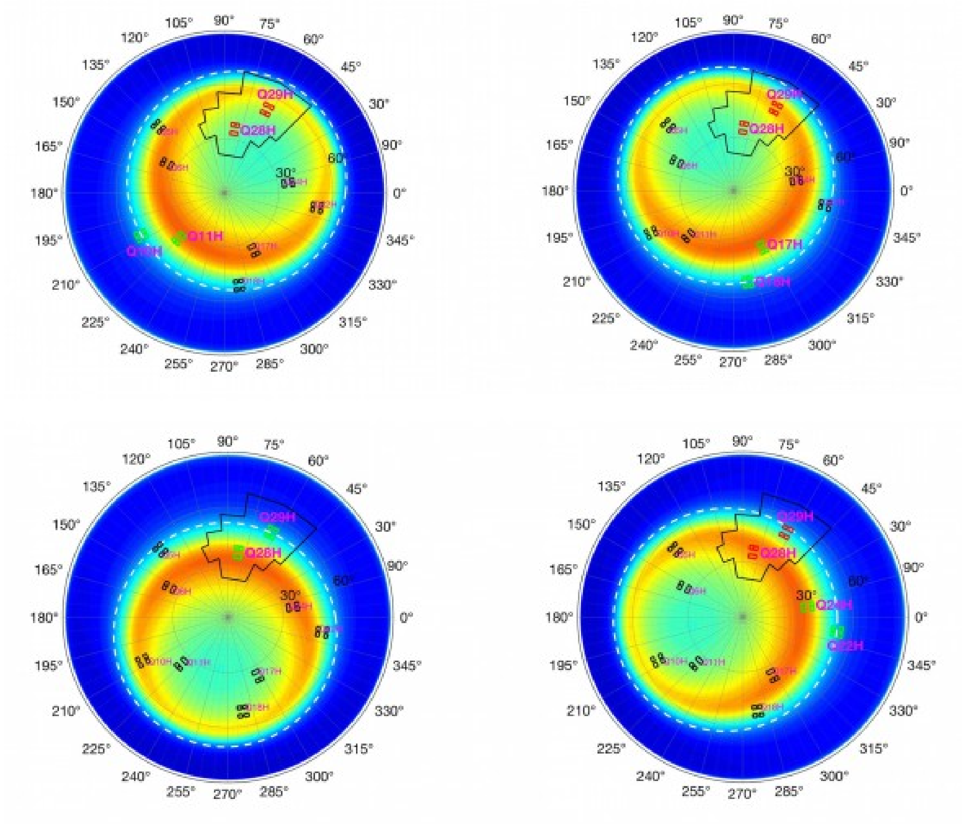
The LMJ Calculations show that single quad side scatter will be observable on the NBI

- Spectral information can be obtained on Q28H (Q11H side scatter shown)
- For side scatter the scattering angle corresponds to density of origin



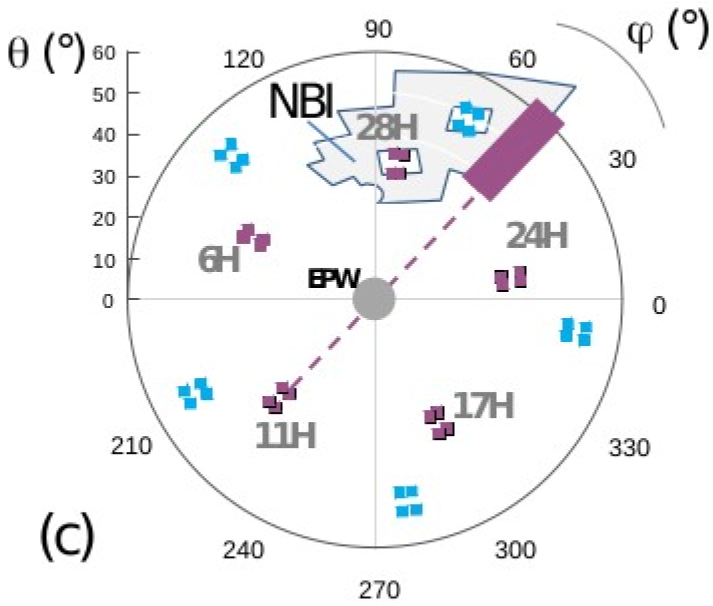
Truncating the pulse of a single quad will allow its contribution to be quantified

- **Gain predictions for SRS side scatter as a function of angle for a single beam (green)**
- **Excellent angular coverage for single beam SRSS scattering can be obtained by delaying different pairs of quads in turn (Q11H, Q17H, Q28H, and Q24H)**
- **Good interception of NBI and FABS**



Multi-beam scattering processes can also be discriminated by their angular properties

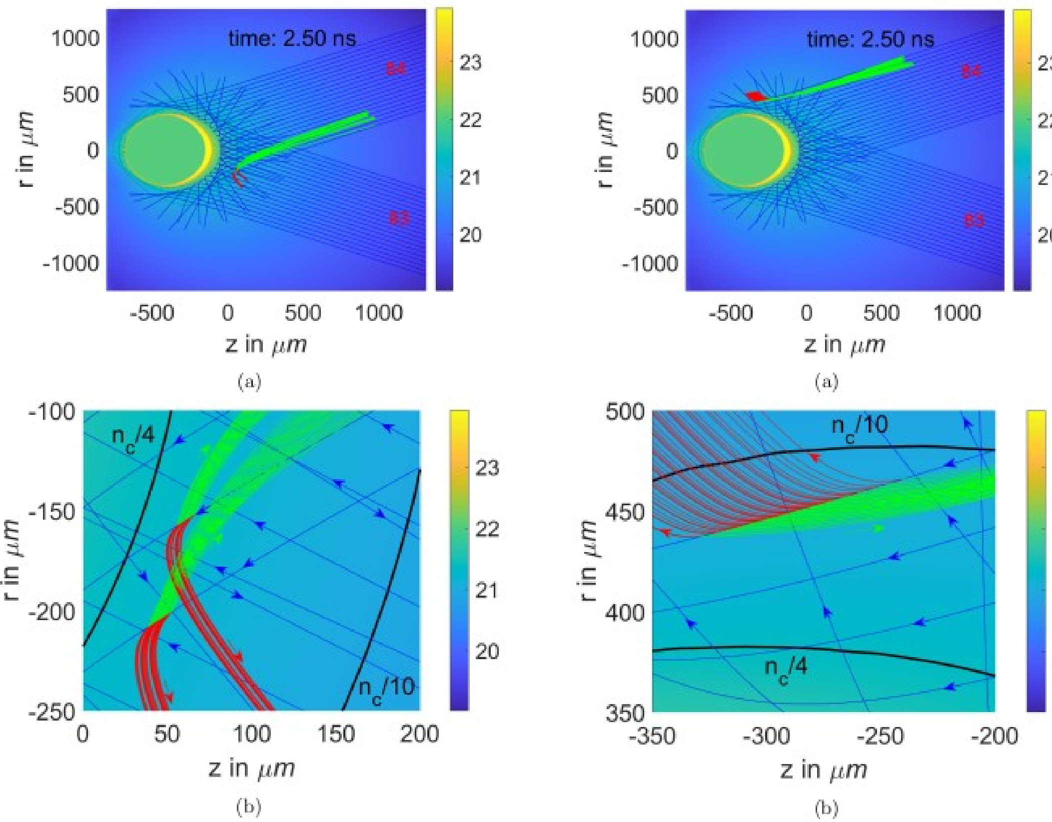
- **For example, collective full 33° cone SRS with a common EPW will scatter light from Q11H onto the NBI**
- **The above can also be side scatter; this will be identifiable because it will have a polar angle of 55°; truncated quad also**



Model development

The data set will be analysed with *ELPSE* and used to aid in the further development and testing of inline models for rad-hydro codes

- **The plasma profiles will be computed by the DEA/DIF Co-PIs using the TROLL code* and by the LLE Co-PIs using the DRACO code**
- **Scattered light predictions will be made using the Eikonal Laser-Plasma Simulation Environment (ELPSE**)**



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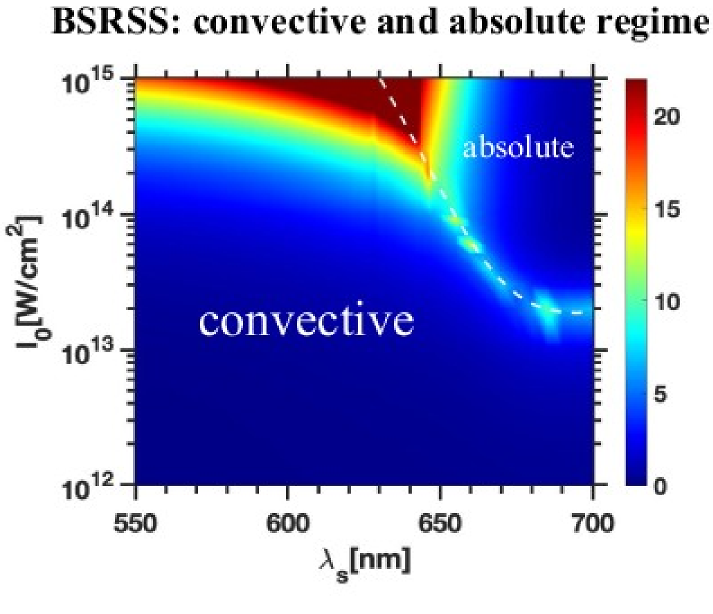
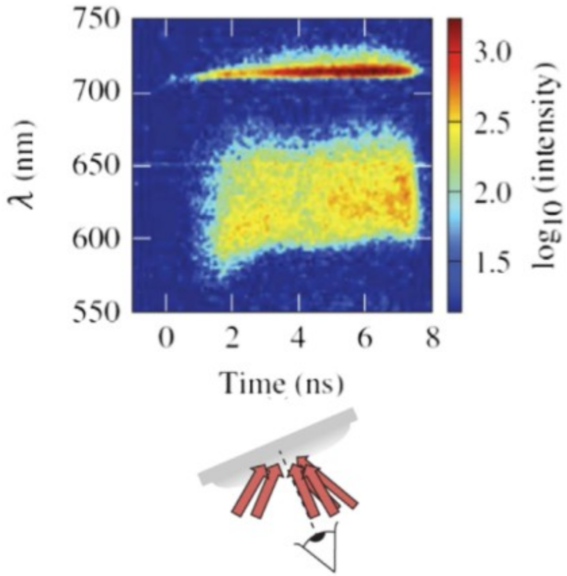
*E. Lefebre *et al*, Nucl. Fusion **59**, 032010 (2019)
S. Hironaka *et al*., Phys. Plasmas **30, 022708 (2023).

There is the potential to observe regions of both absolute and convective SRSS

SRS side-scatter can be an absolute instability*



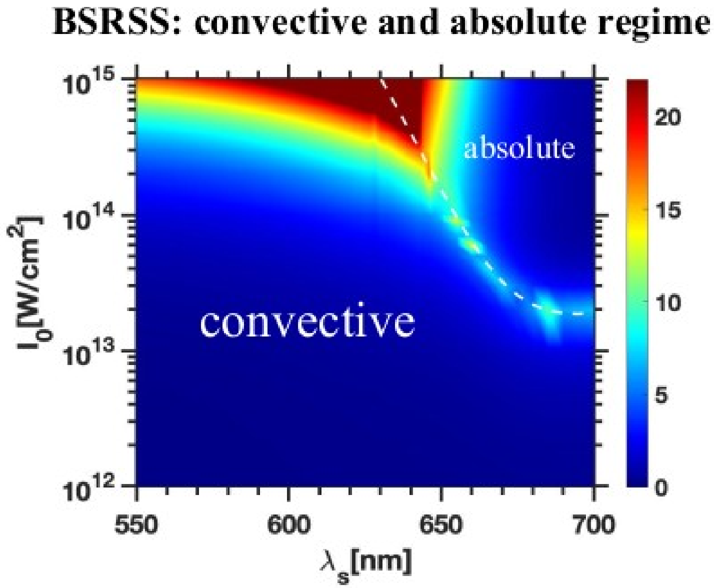


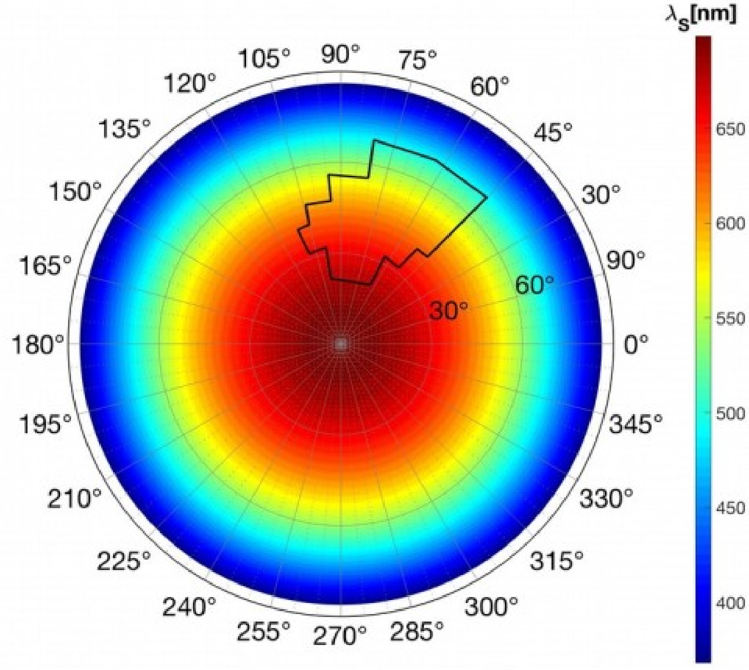
*M. J. Rosenberg et al., PRL **120**, 055001 (2018)*

*B.B. Afeyan & E.A. Williams, Phys. Fluids 28, 3397 (1985)
*P. Michel *et al*., Phys. Rev. E **99**, 033203 (2019).

A tilted-target shot will allow the transition from absolute to convective SRS to be observed

- **Tilting the target will allow observation of scattering process occurring in the near quarter critical region**



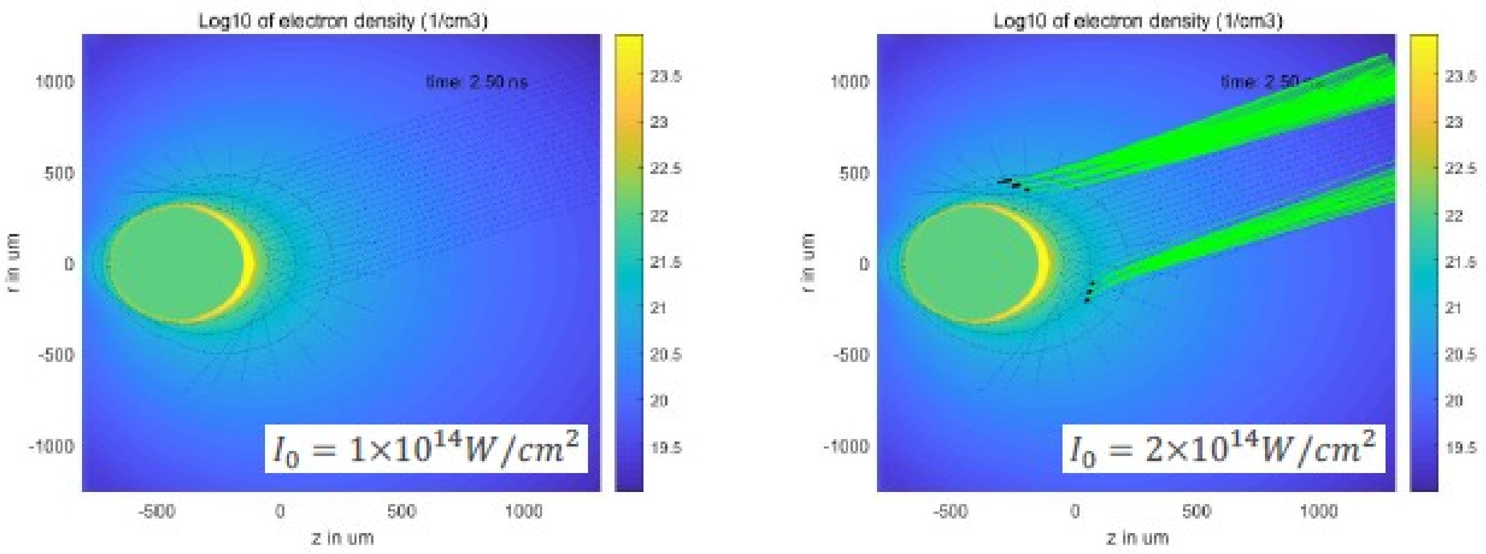


*Chengzhuo Xiao "Unified theory of absolute side scattering in inhomogeneous plasma", NO07.00015 (APS-DPP).

Advance Understanding

The *ELPSE* code will also be used to make predictions for the transition from absolute to convective instability

- **The figure below shows theory simulations of light generated by absolute SRSS in OMEGA EP experiments***
- **Similar work is being done for predicted LMJ hydrodynamics**



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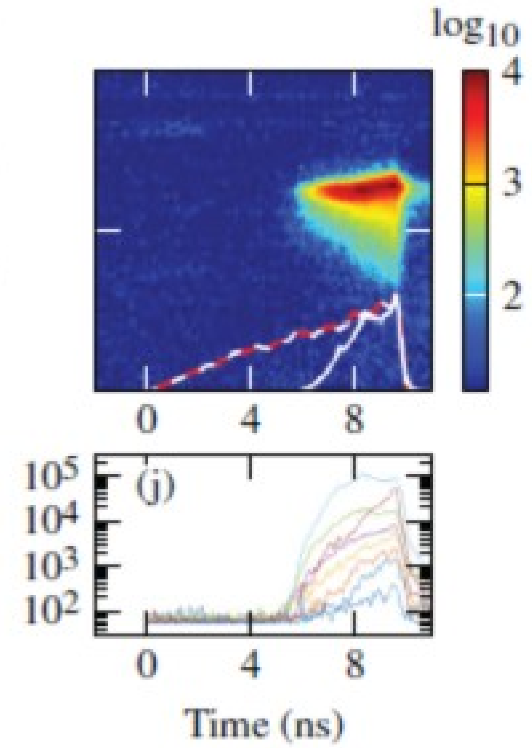
*M.Rosenberg *et al*., Phys. Plasmas **30**, 042710 (2023);
S. Hironaka *et al*., Phys. Plasmas **30**, 022708 (2023).

A shot with a "ramped" laser pulse can be used to compute convective gains and identify absolute instability

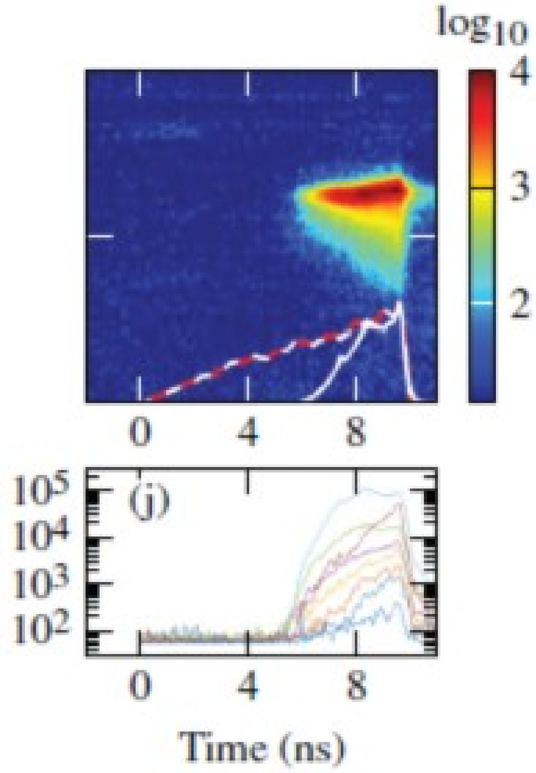
- **The amount of scattered light of a given frequency can be determined as a function of the incident intensity**
- **An exponential dependence indicates linear convective amplifier whose gain can be determined**
- **Linear (weaker) dependence indicates nonlinear saturation which is associated with absolute instability**
- **NIF only identified absolute SRS backscatter – but suggestive of absolute side scatter...**



* M. Rosenberg *et al*., Phys. Plasmas 27, 042705 (2020)
A.A. Solodov *et al*., *ibid* 052706

A comparison will be made between the new results obtained on LMJ with those previously obtained on NIF*

- **Limited data set for "ignition scale conditions" (reproducibility)**
- **LMJ polarization is different**
- **There is potential for an indirect measurement of hydrodynamics and transport as we will have a time-dependent measurement of scattering over wide angles (refraction)**



* M. Rosenberg *et al.*, Phys. Plasmas 27, 042705 (2020)
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Summary/Conclusions

The goal is to employ the unique diagnostics available on LMJ to conclusively identify the active SRS mechanisms in direct drive plasmas

- **Quantify total amount of SRS scattered and its correlation with hard x rays (hot electrons)**
- **Identify and quantify the individual contributions from backscatter, side-scatter, and multi-beam processes**
- **Provide a data set that can be used for the development and testing of reduced (inline) models of SRS***
- **Advance theoretical understanding; identify regions of absolute and convective instability**
- **Compare with NIF planar LPI platform****
- **Serendipity (transport)?**

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* ELPSE: Eikonal Laser Plasma Simulation Environment
** M. Rosenberg *et al*., Phys. Plasmas 27, 042705 (2020)
A.A. Solodov *et al*., *ibid* 052706