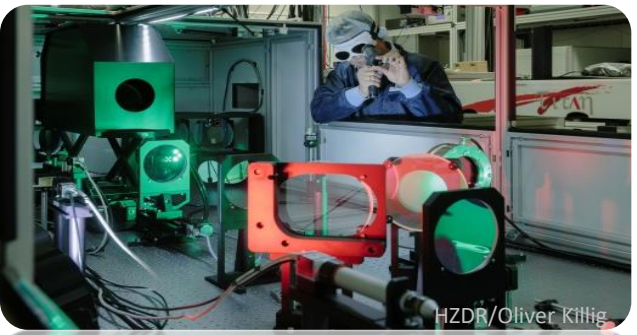
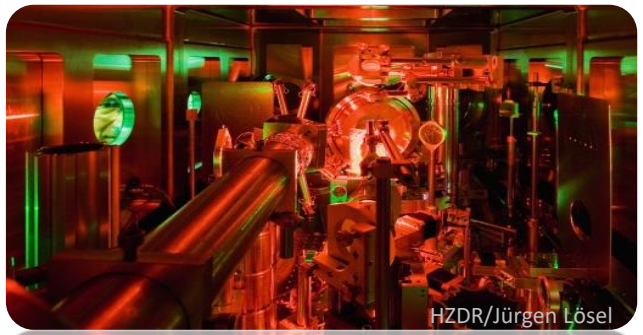
Diagnosing relativistic transparency onset in high-energy laser-driven proton acceleration experiments

Laser-Plasma Acceleration Workshop 2025

14. April 2025

Ischia Island





K. Zeil, C. Bernert, G. Casati, T. E. Cowan, N. P. Dover, I. Göthel, H. Kiriyama, T. Kluge, A. Kon, K. Kondo, F. Kroll, C. Liu, J. Metzkes-Ng, Z. Najmudin, M. Nishiuchi, F. Paschke-Bruehl, R. Pausch, T. Püschel, V. Rana, M. Rehwald, H. Sakaki, **M. E. P. Umlandt**, **M. Vescovi**, P. Wang, T. Ziegler, U. Schramm

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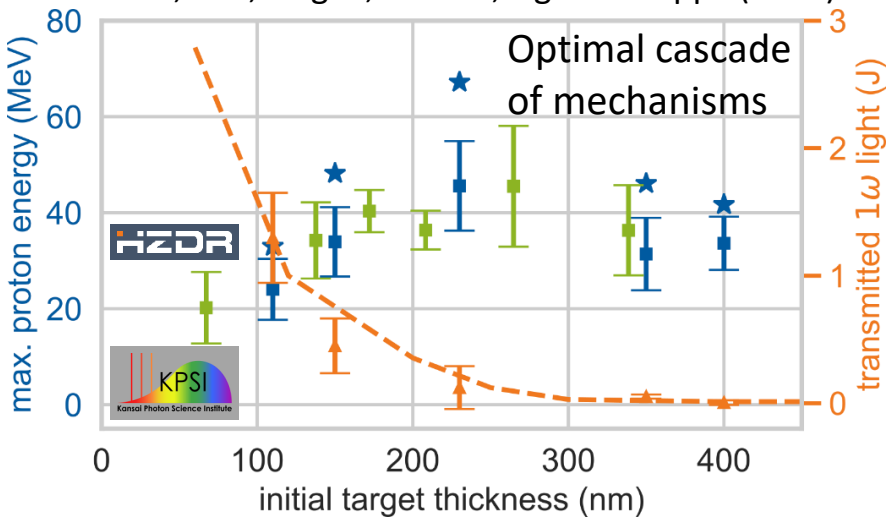
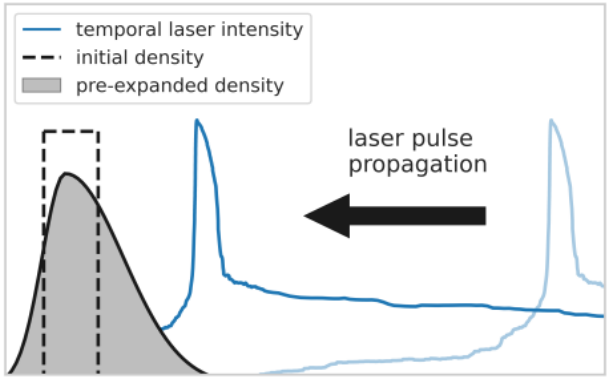
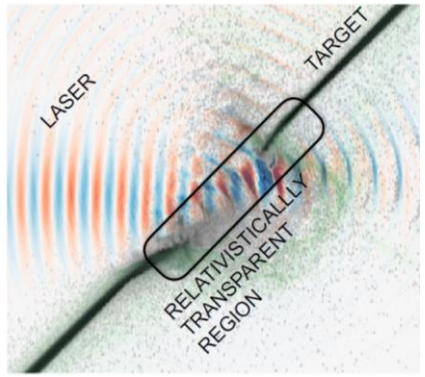
Optimal target thickness and transparency onset

Dover, N.P., Ziegler, T. *et al.*; Light Sci. Appl. (2023)



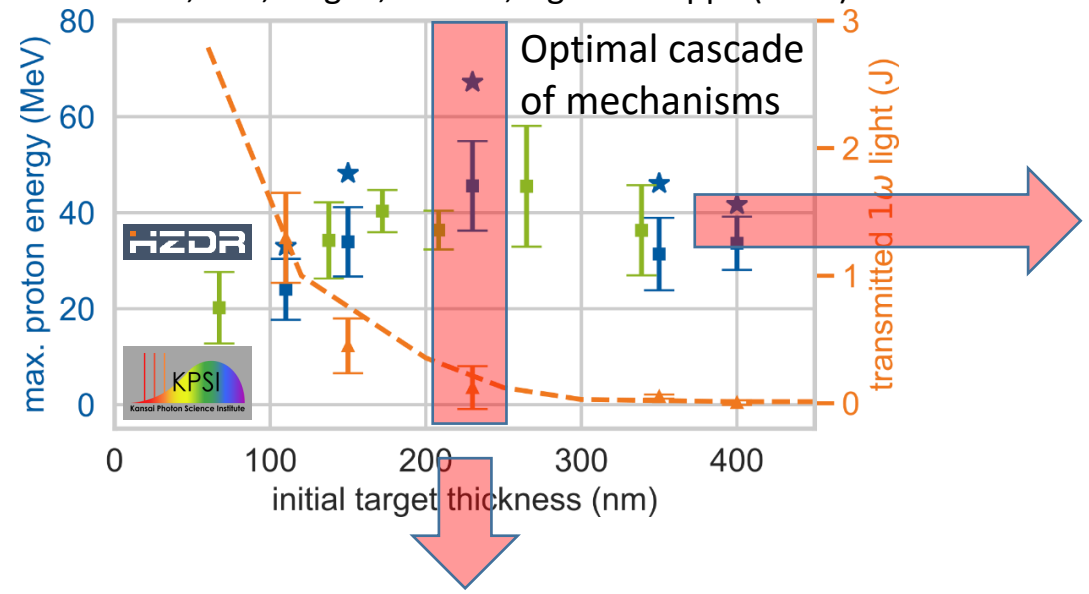


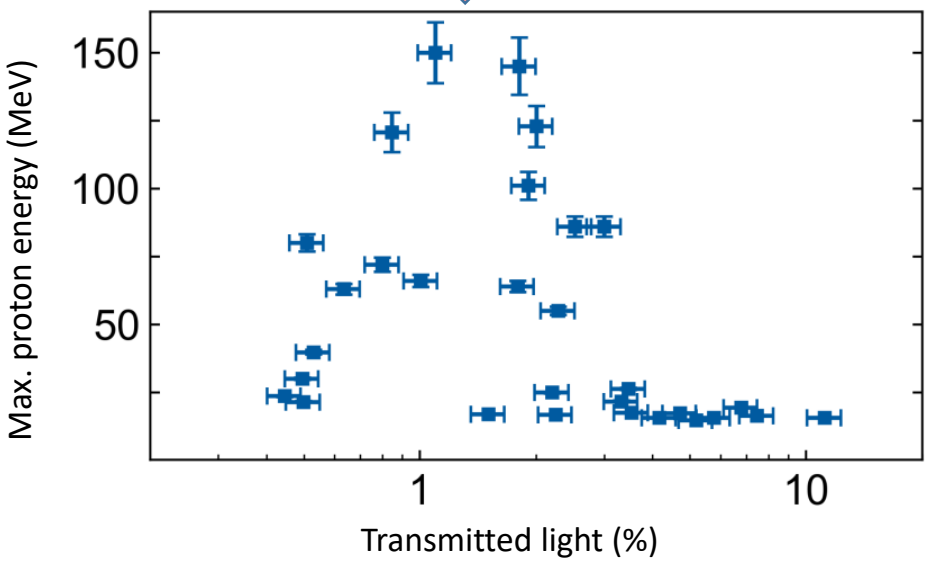


d'Humieres, E. *et al.*; Phys. Plasmas (2005); Henig et al., Phys. Rev. Lett. (2009); Yin, L. *et al.*; Phys. Plasmas (2011); Higginson, A *et al.*; Nat. Commun. (2018); Gonzales-Izquierdo, B. *et al.*; Appl. Sci. (2018); And many more …

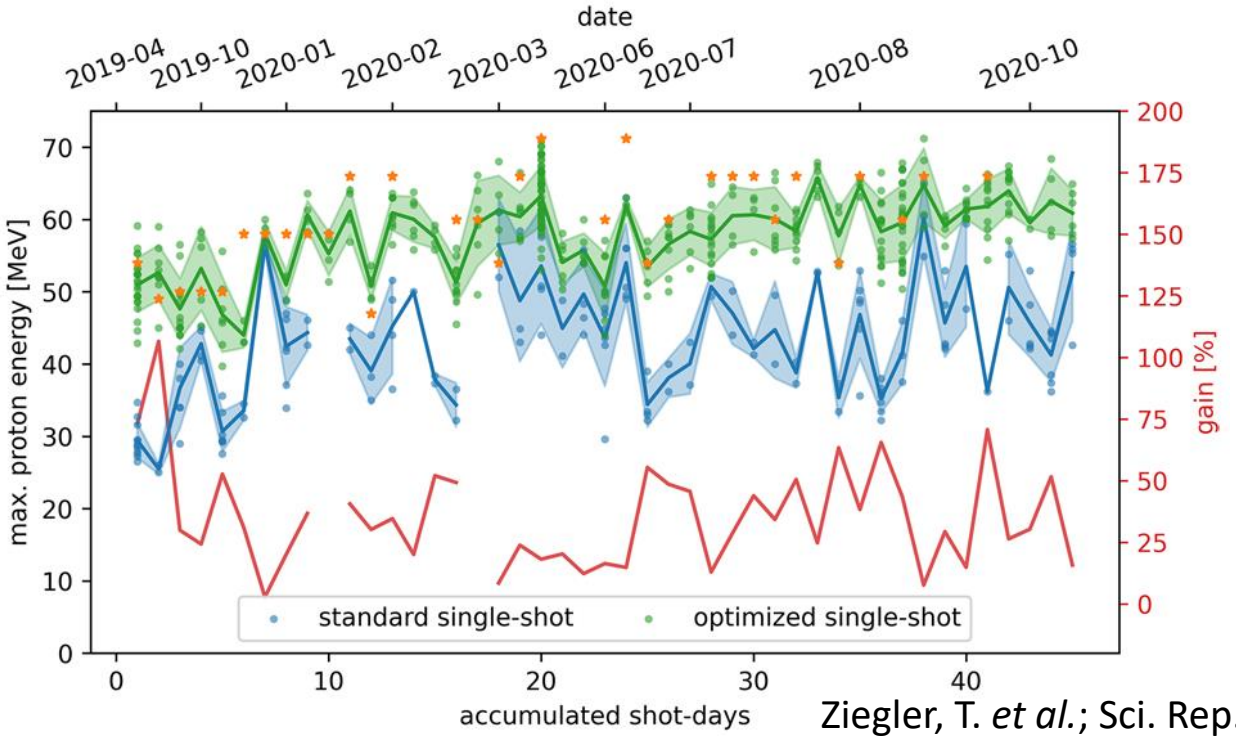
Two challenging regimes to be better controlled …

Dover, N.P., Ziegler, T. *et al.*; Light Sci. Appl. (2023)



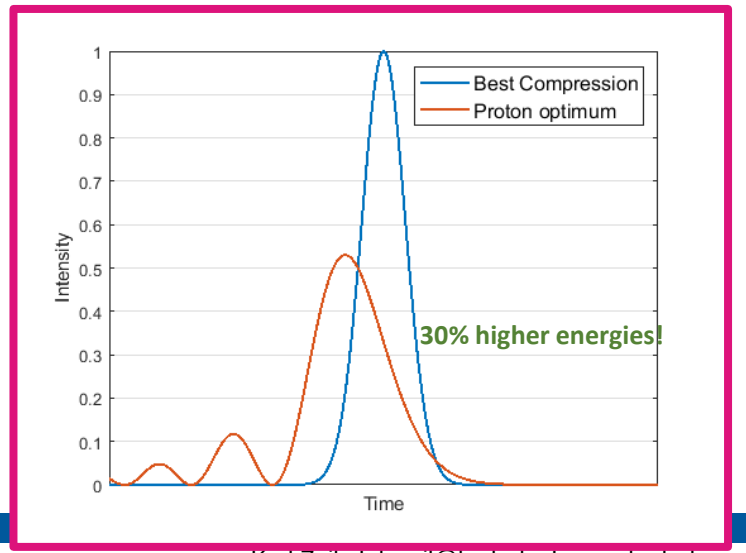


Ziegler, T. *et al.*; Nat. Phys. (2024)



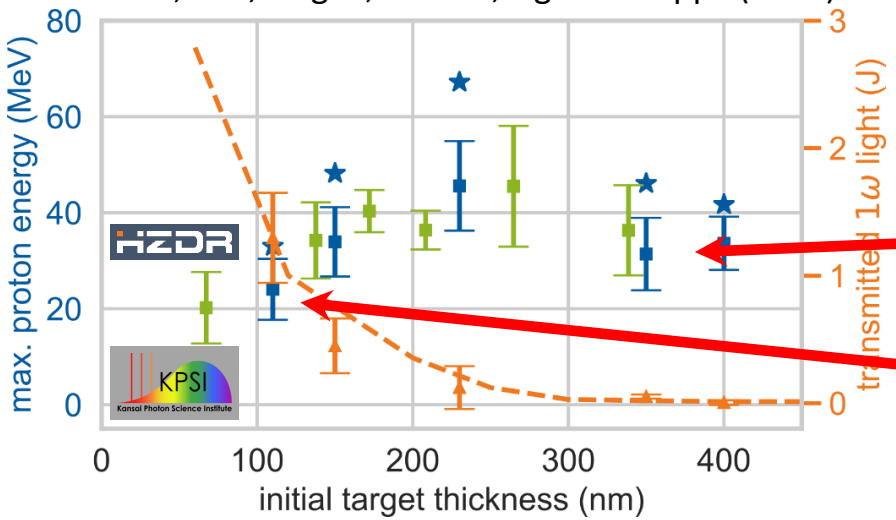
Ziegler, T. *et al.*; Sci. Rep. (2021)

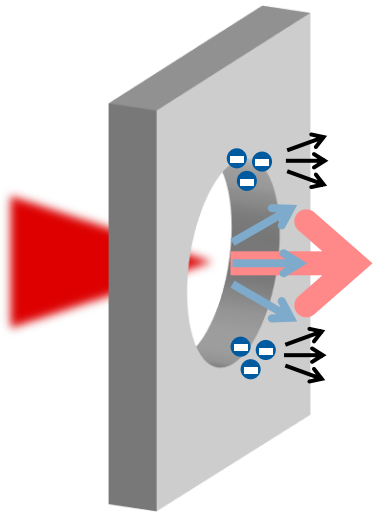
- Cause of fluctuations?
- Characteristics of individual shots on target?
  → More diagnostics needed!



Diagnosing reflected, transmitted and emitted light components

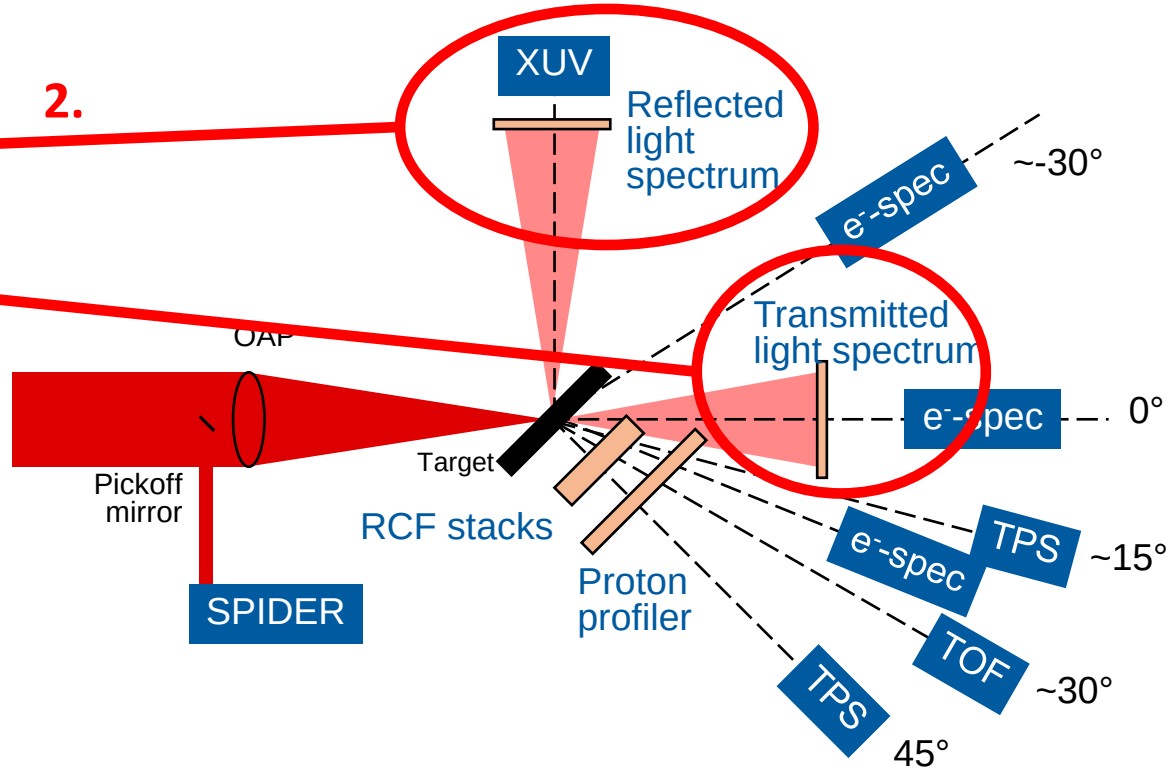
Dover, N.P., Ziegler, T. *et al.*; Light Sci. Appl. (2023)





Many components involved:

- Laser light & harmonics
- Self-phase modulation
- Plasma emission
- Coherent & incoherent transition radiation
- …

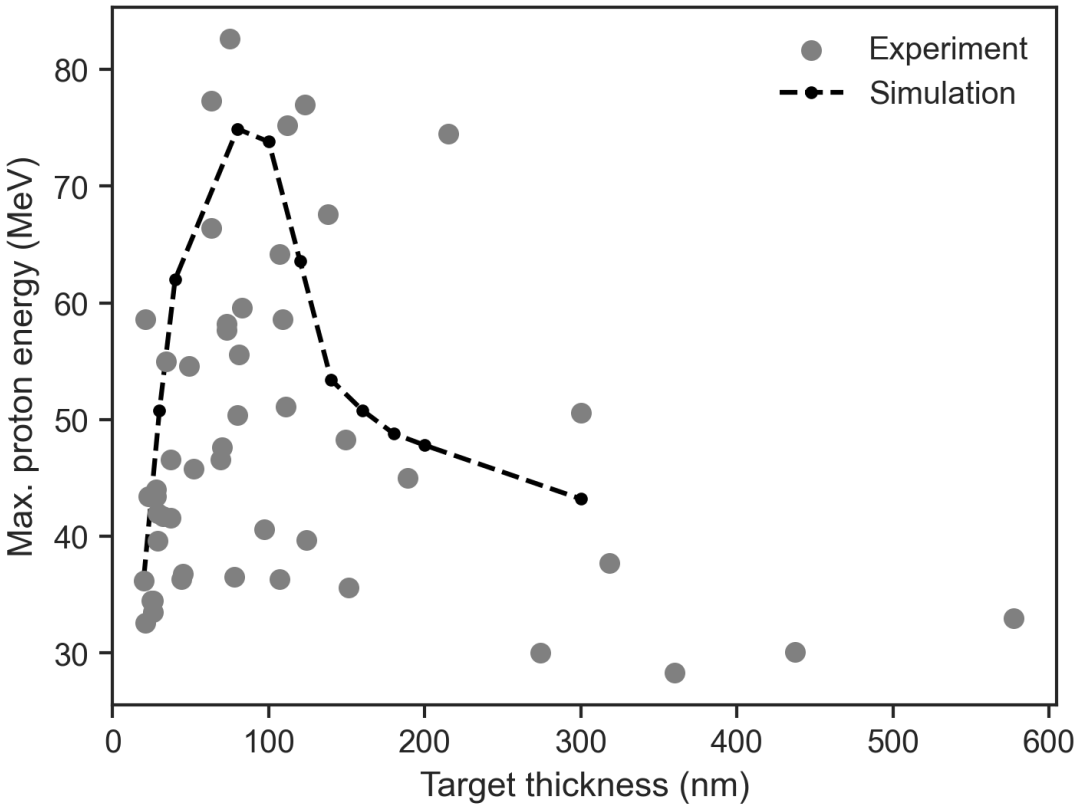


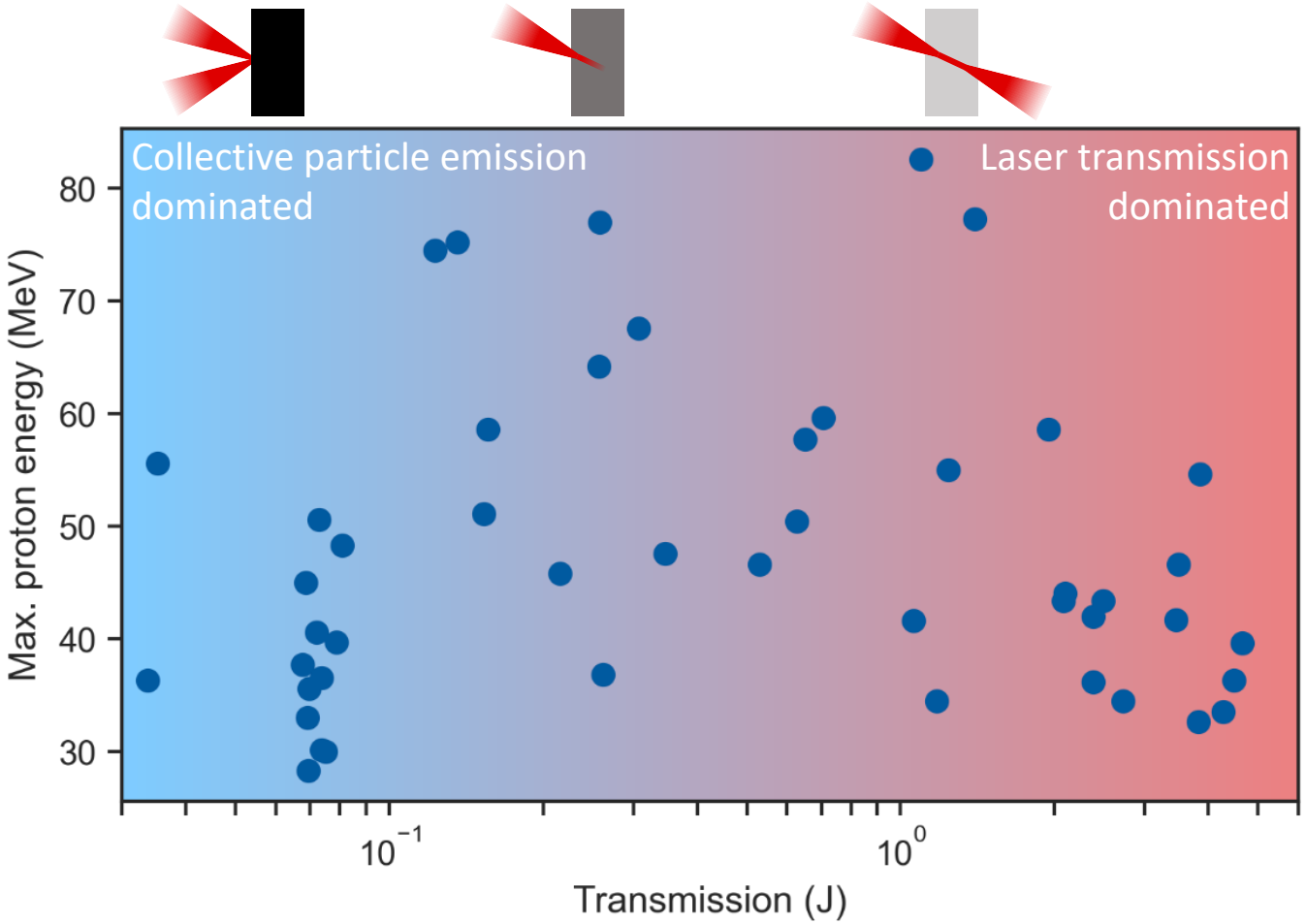
Palaniyappan, S. *et al.*: Nat. Phys. (2012); Gonzalez-Izqierdo, B. *et al.*; Nat. Phys. (2016)

Duff, M. J. *et al.*; Sci. Rep. (2020); Williamson, S.D.R. *et al.*: Phys. Rev. Appl. (2020), Wei, W.-Q. POP (2025)

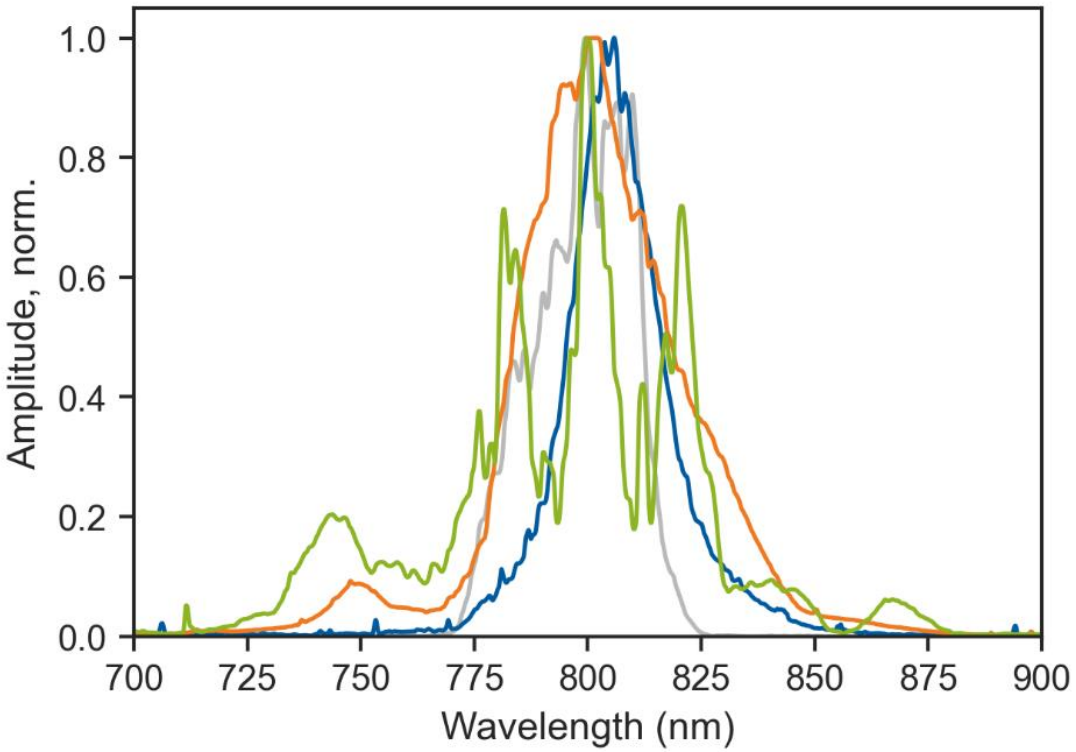
J-Karen experiment – Transmitted light at transparency onset

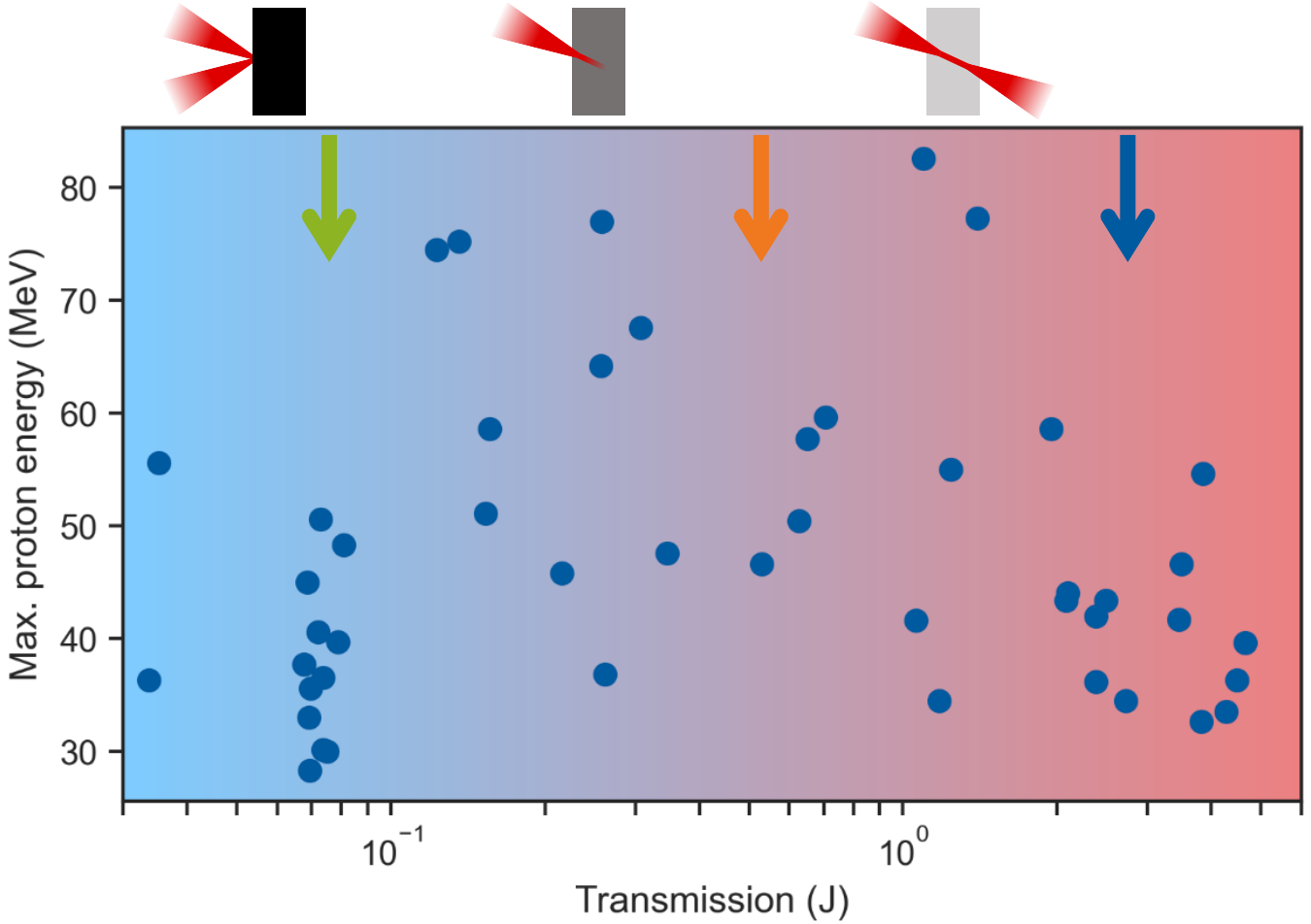
J-KAREN-P (KPSI): 40fs, 3×10^{21} W cm^{-2}
plasma mirror contrast, formvar foils (230nc)





Transmission Spectra

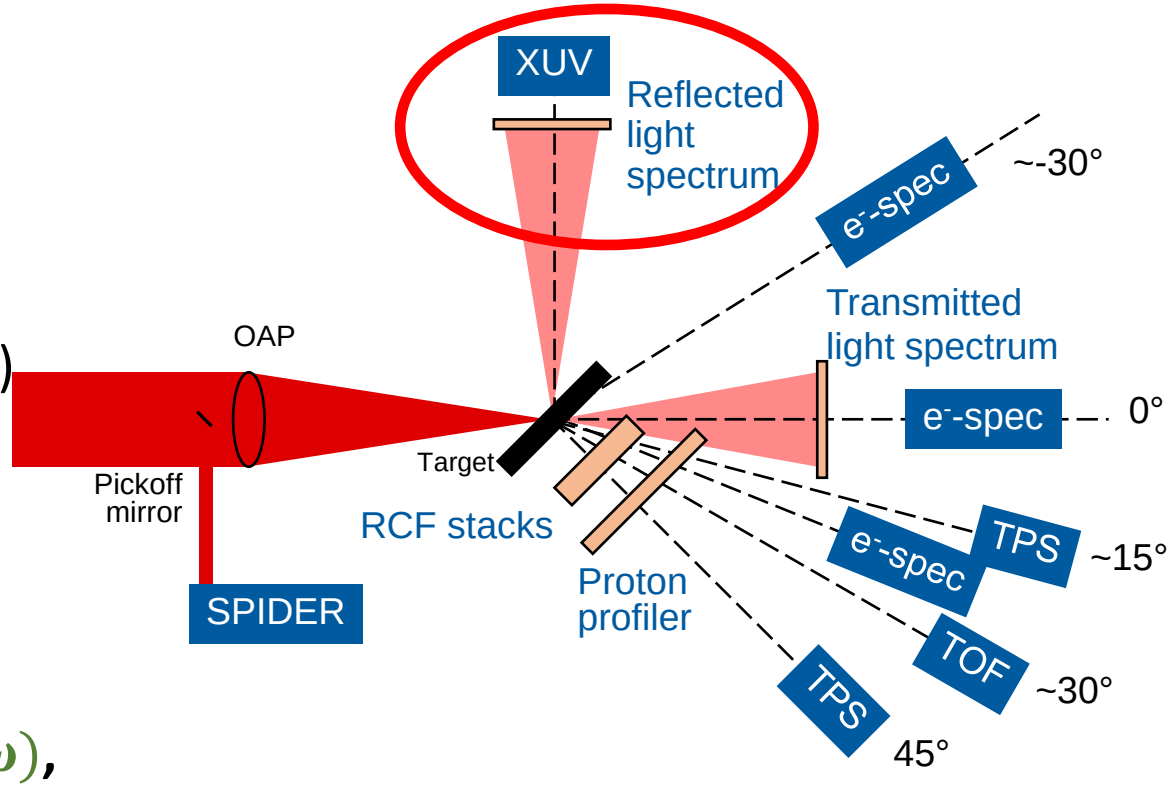




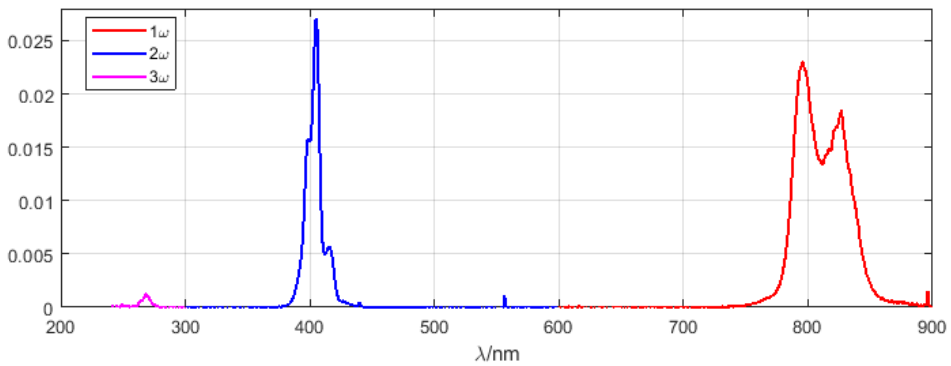
Target:	no target	transmissive	intermediate	opaque
Spectrum:	Fine-features	smooth	smooth, broad	broken, broad

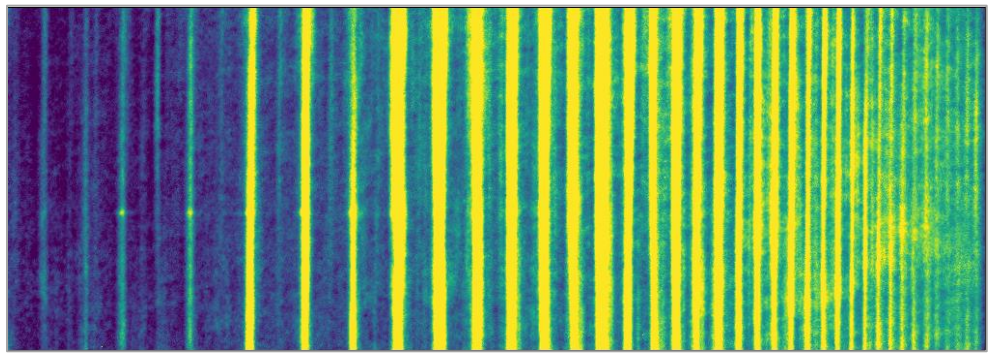
Reflected light and acceleration performance

- **DRACO, λ=810nm, 30fs FWHM, I~5x10^{21} W/cm^2** plasma mirror cleaned contrast
- Target: plastic 250nm, AOI 45° (remain overdense)
- Generation and measurement of harmonics: 1ω, 2ω, 3ω + ~(15-47)ω



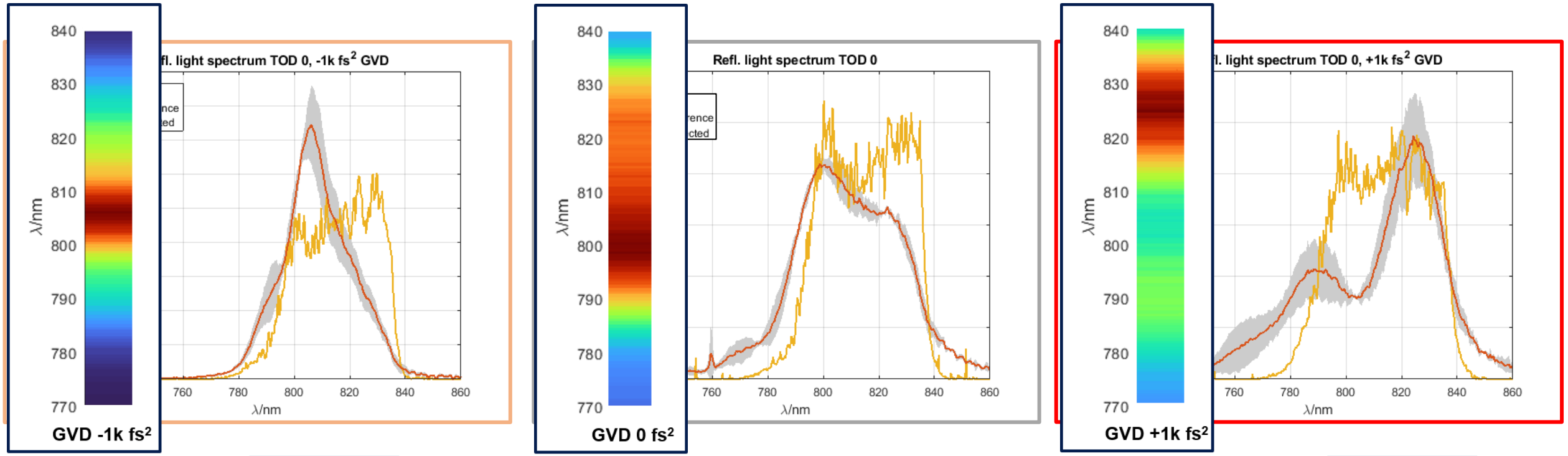
Goal: Characterize reflected light for different $\Phi(\omega)$, relevant for acceleration

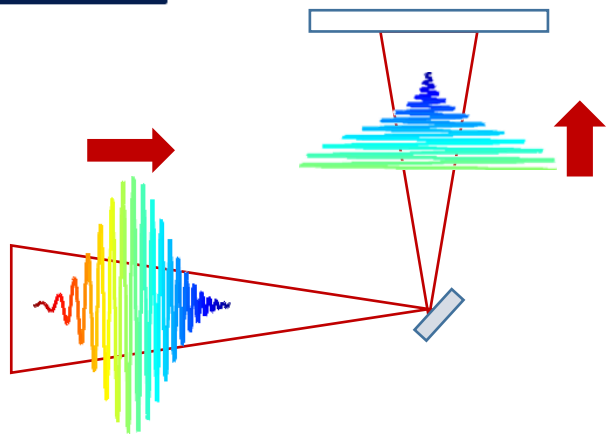




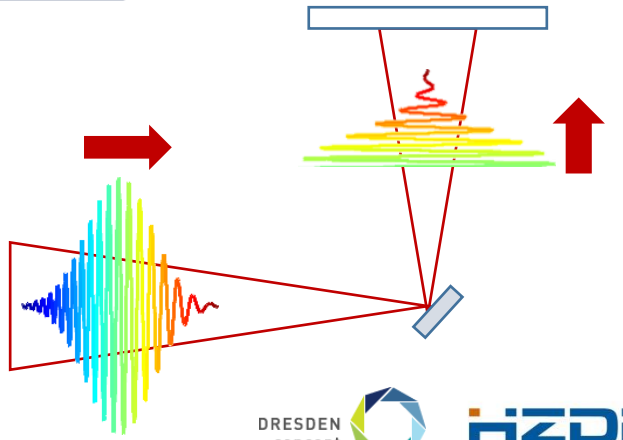
14ω 47ω

Target reflection: observation during GVD scan

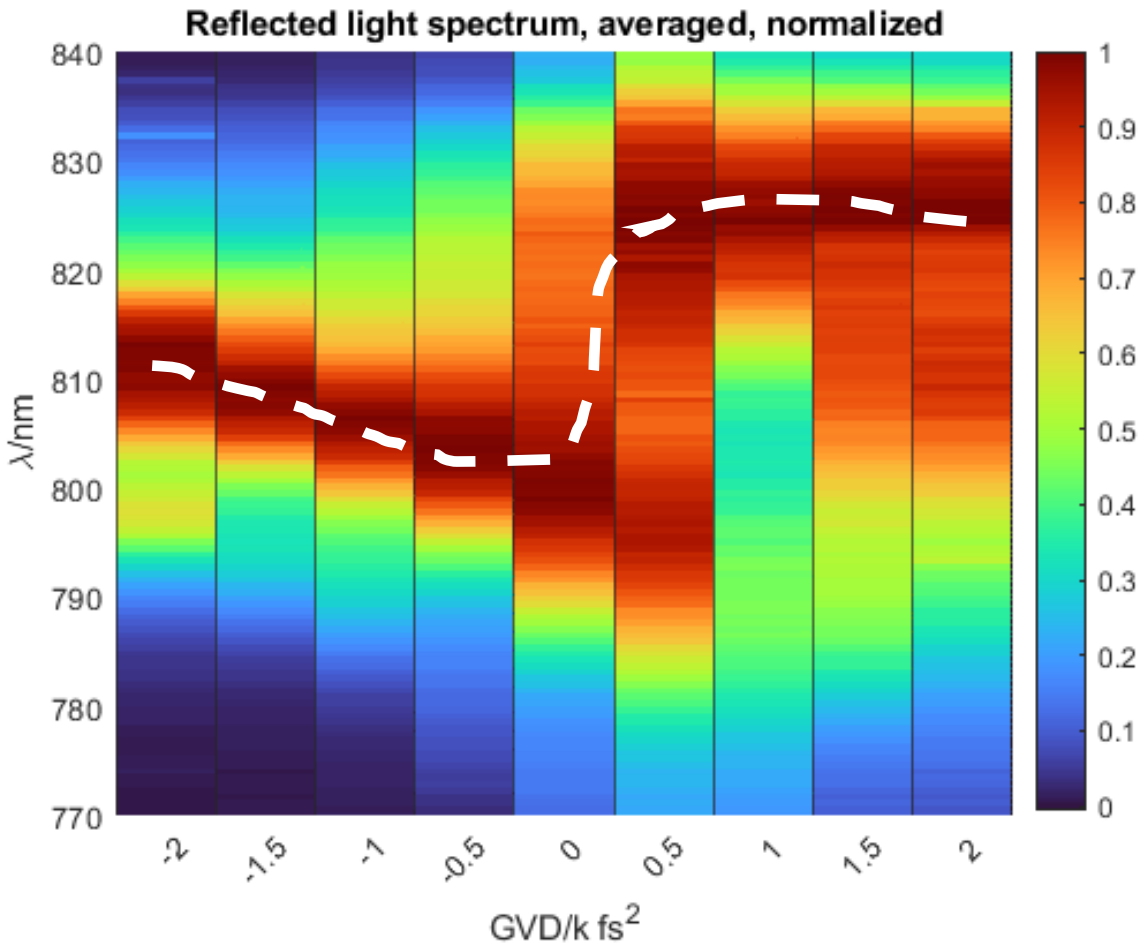


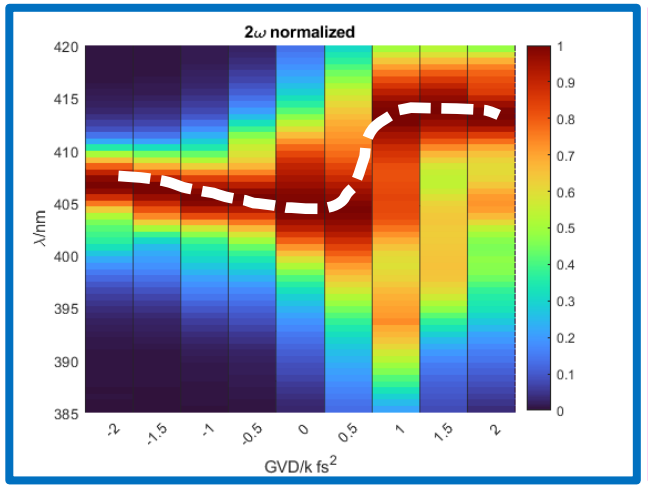


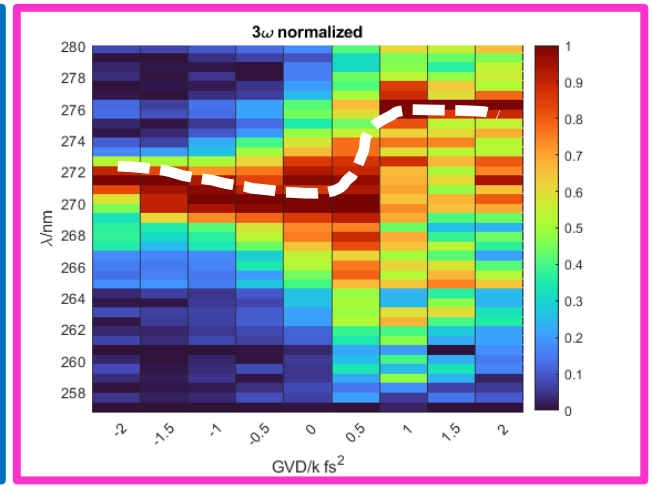
Though no transparency,
front surface changing fast in time
from high “reflectivity” to low:
Gating effect

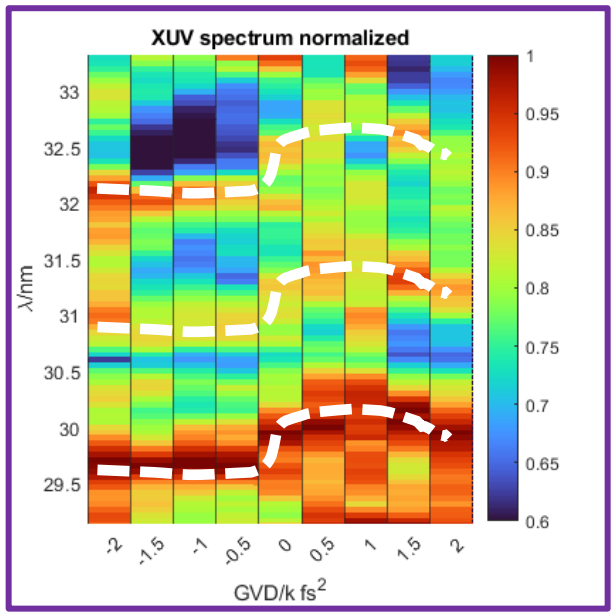


Target reflection: observation during GVD scan



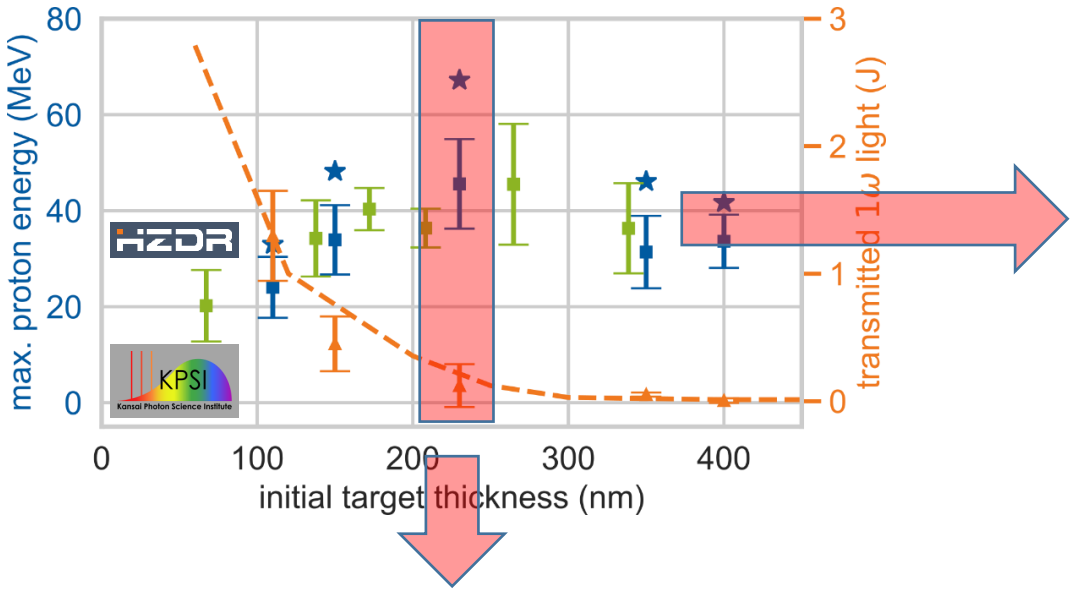


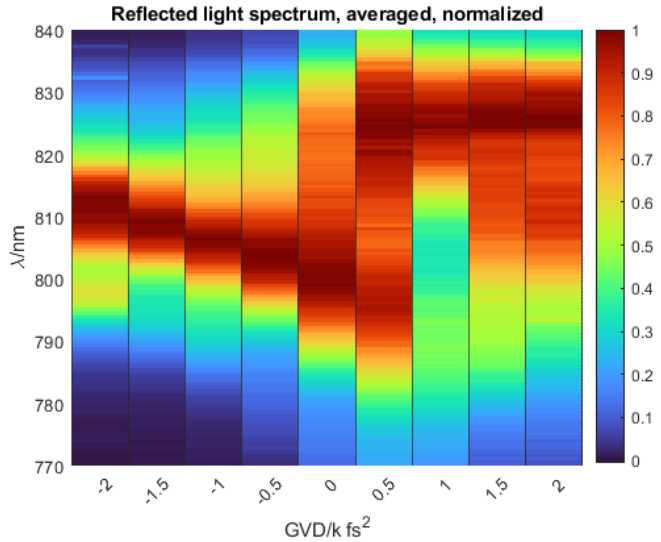




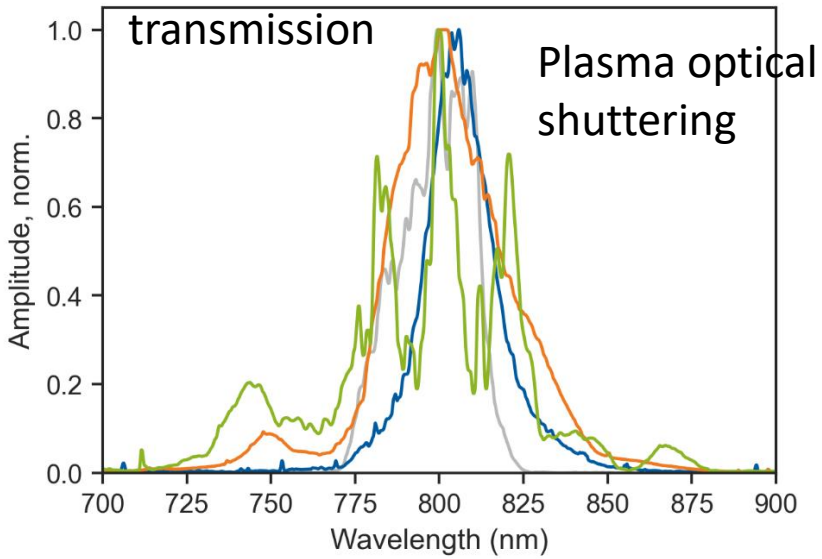
- Similar gating in Harmonics

Conclusion and work in progress





Specularity gating



- Plasma induced gating effects manipulates transmitted and reflected light spectrum
- Correlation to proton acceleration performance
- Next step: with laser parameters like spectral and spatial phase for individual shots