MAX-PLANCK-INSTITUT
FÜR PHYSIK

Plasma Light Locality and Growth Rate Analysis

Presented by Jan Mezger

Contents

- Plasma light measurements show evolution of SM along the plasma
- (Mostly) Consistent with wakefield physics

- Measurements as a function of plasma length (using plungers) indicate:
  - Locality for low signal amplitude (low bunch charge)
  - Non-locality for high signal amplitude (high bunch charge)
- Seeding has a big influence on the evolution of SM (not only phase but amplitude)
- DPS measurements (most likely) local

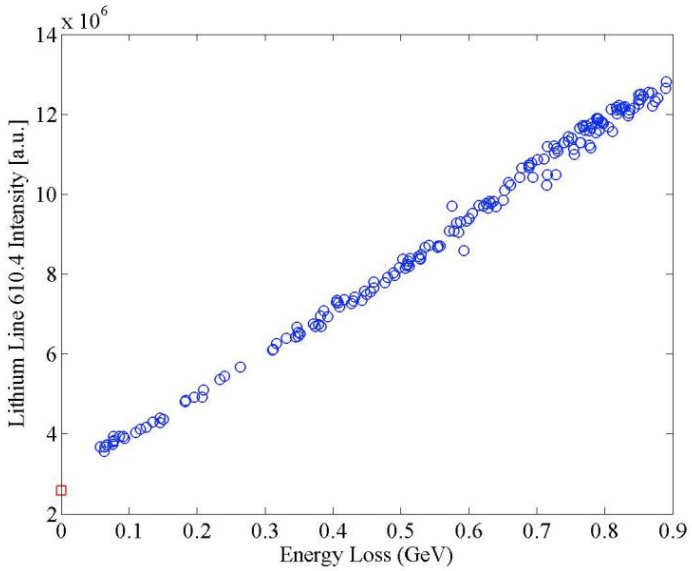
- Growth rates extrapolated from plasma light profiles
- Dependency on N_p and n_{pe} consistent with expected trend

Plasma Light - Recap

Plasma Light Diagnostic

- Amount of emitted light proportional to energy deposited by drive bunch

→ Measuring evolution of wakefields along the plasma



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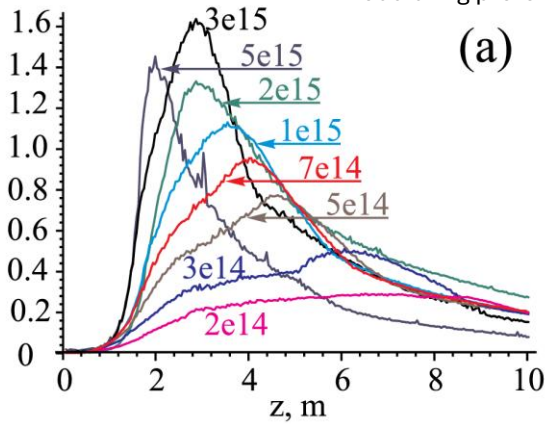

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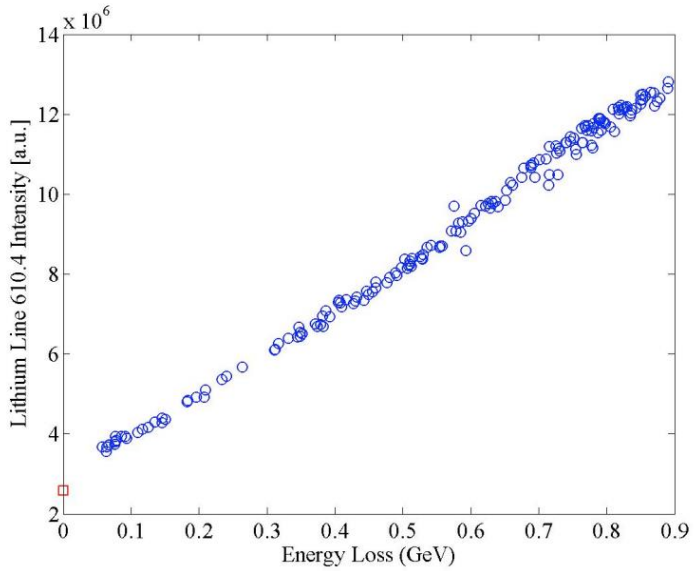
DPS (2 wide angle cameras):

→ Results agree with expectations



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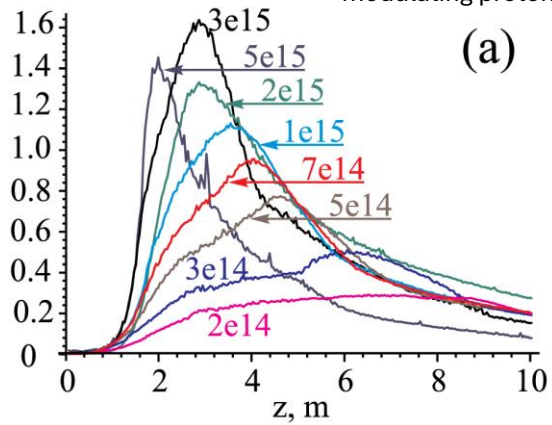

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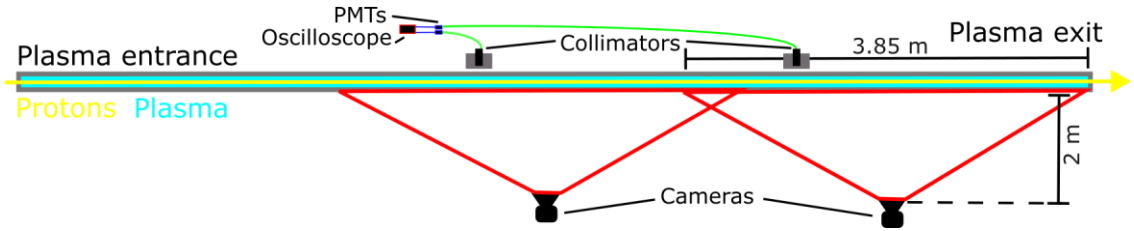
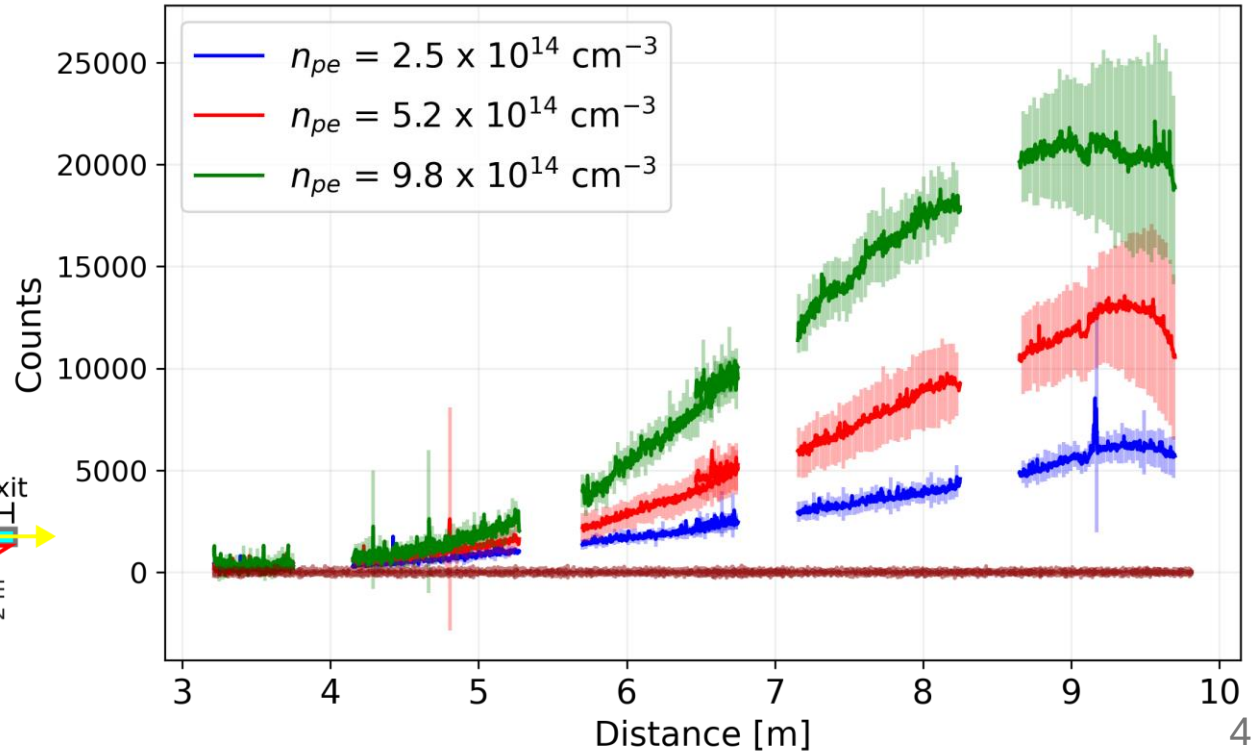




Plasma Light - Recap

Plasma Light Diagnostic

- Amount of emitted light proportional to energy deposited by drive bunch

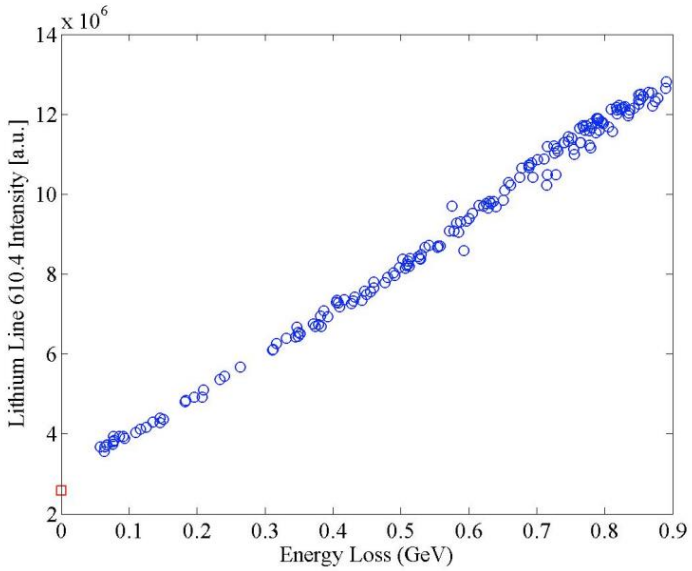
→ Measuring evolution of wakefields along the plasma

DPS (2 wide angle cameras):

→ Results agree with expectations

VPS (10 cameras at 10 view ports):

→ Results agree with expectations… sometimes



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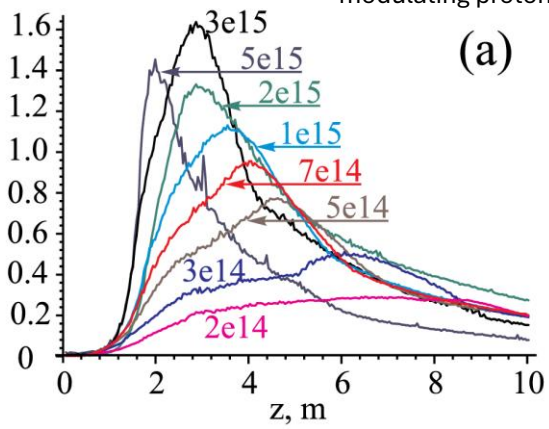
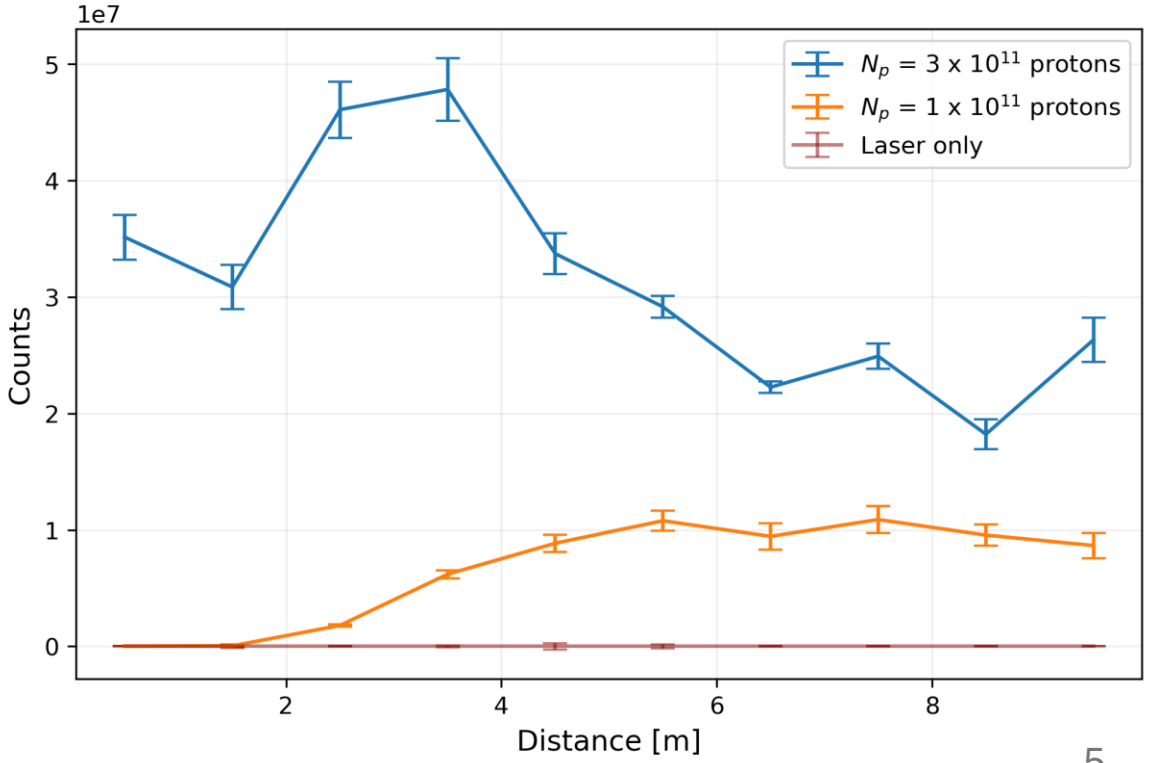




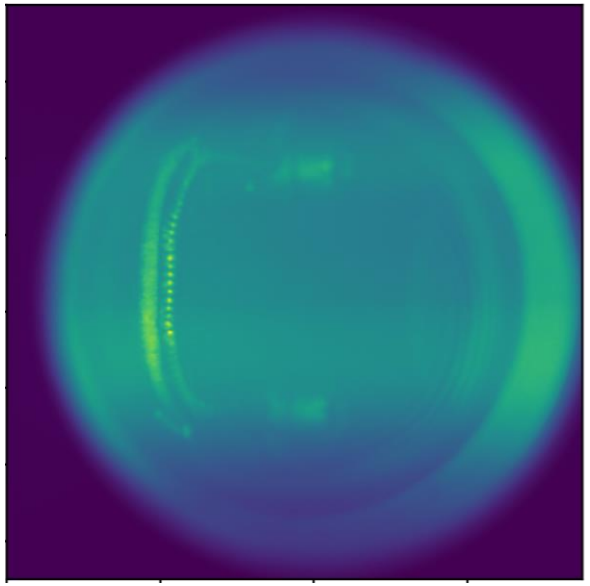
Validating locality

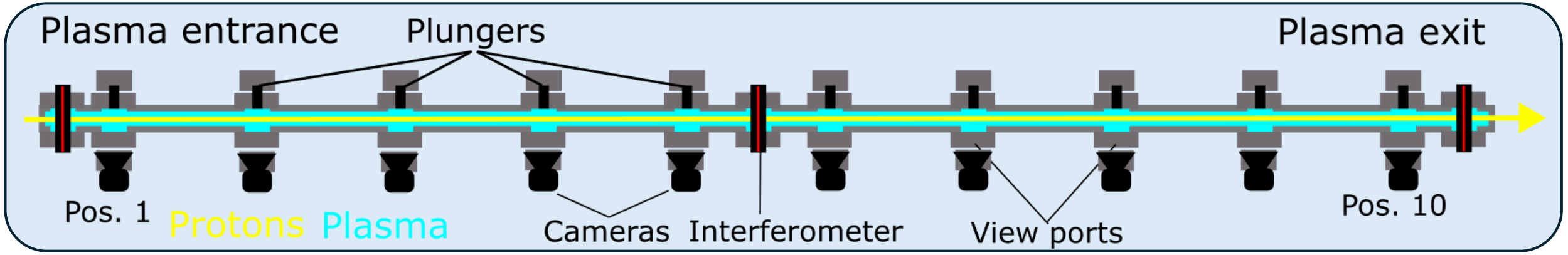
Plungers with laser dump foil:

- Laser can be stopped at every view port position (0.5m to 9.5m)

→ Laser dump scan

Camera Image – Dump out





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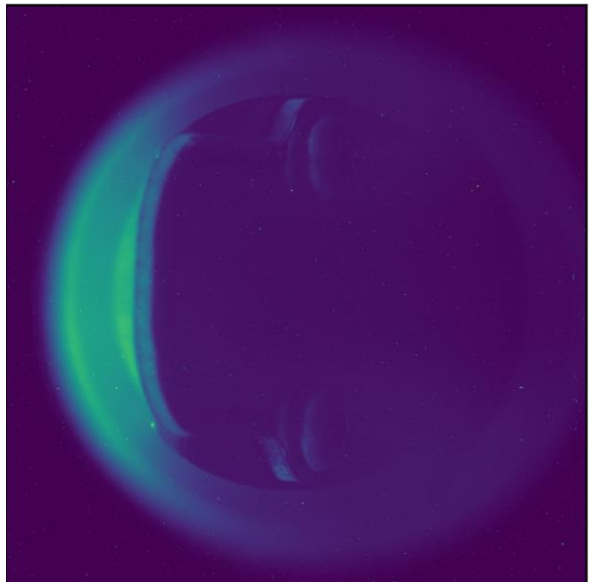

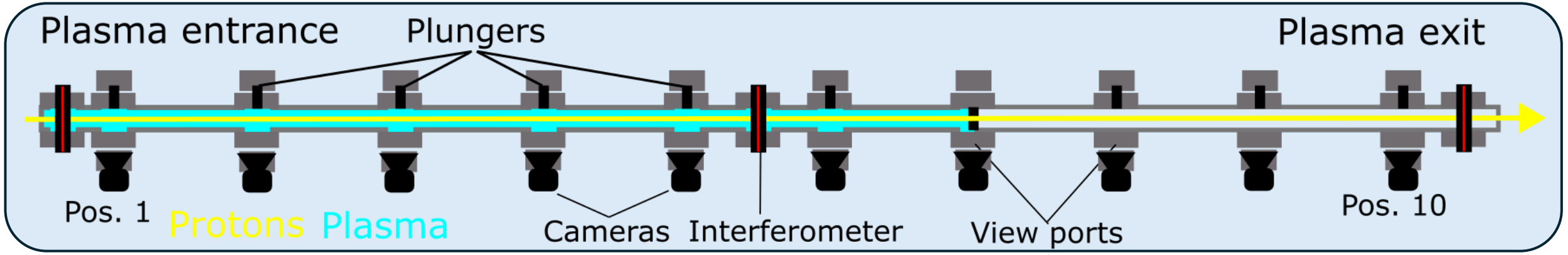

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Plasma Light locality:

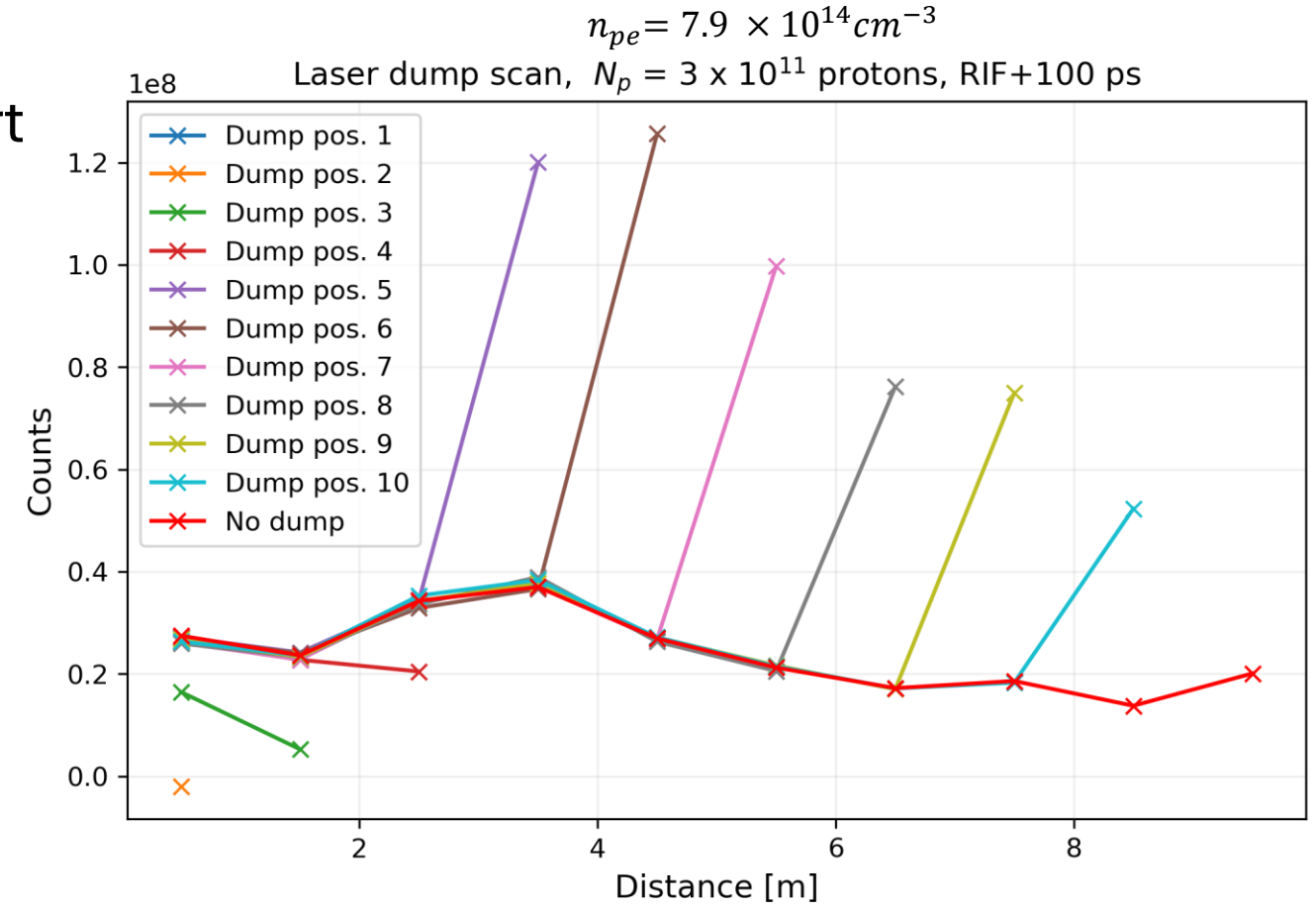
- If signal changes upstream when changing plasma downstream

→Plasma light signal non-local

- No change

→Locality validated

Example of non-local signal:



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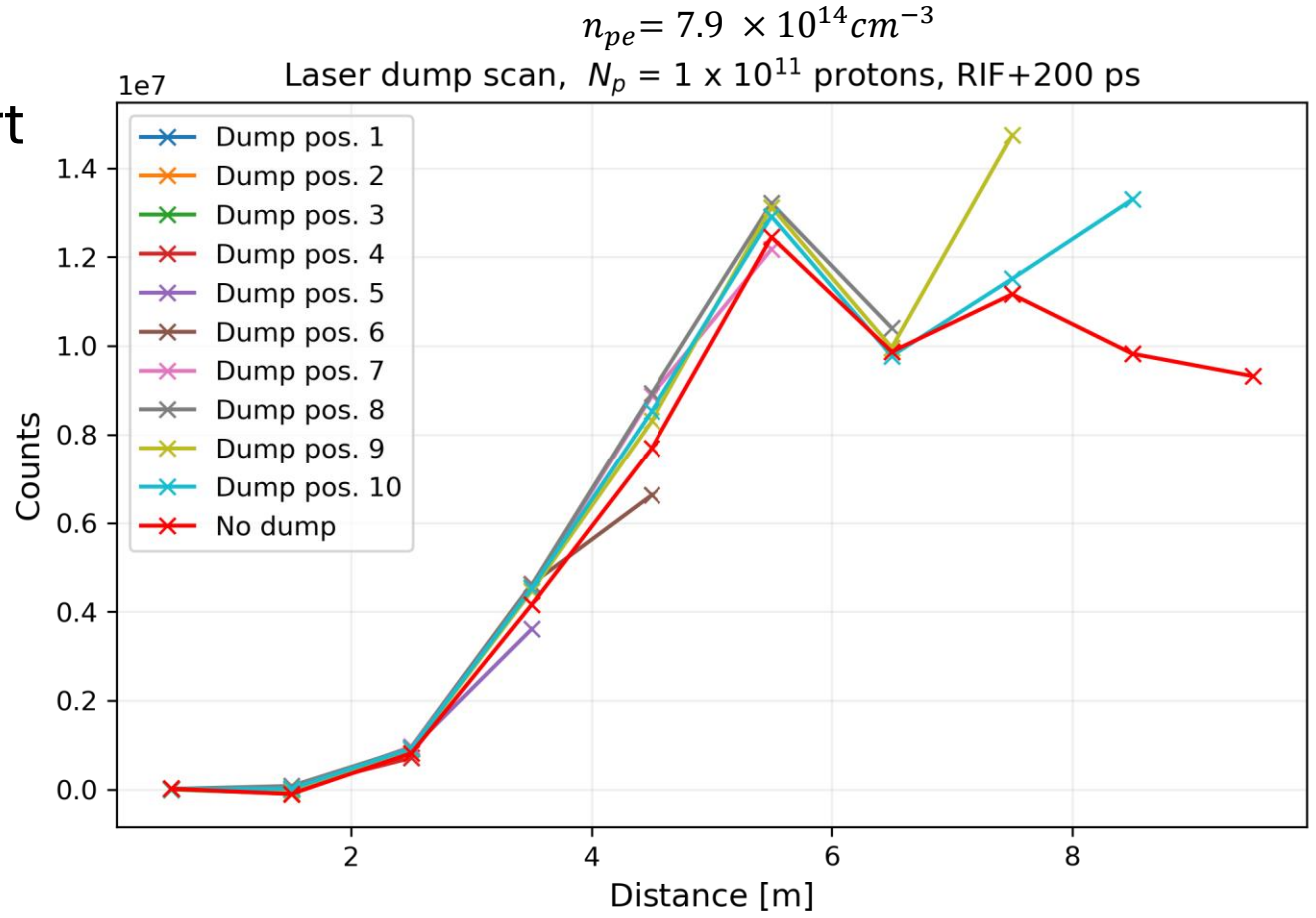
Example of local signal:



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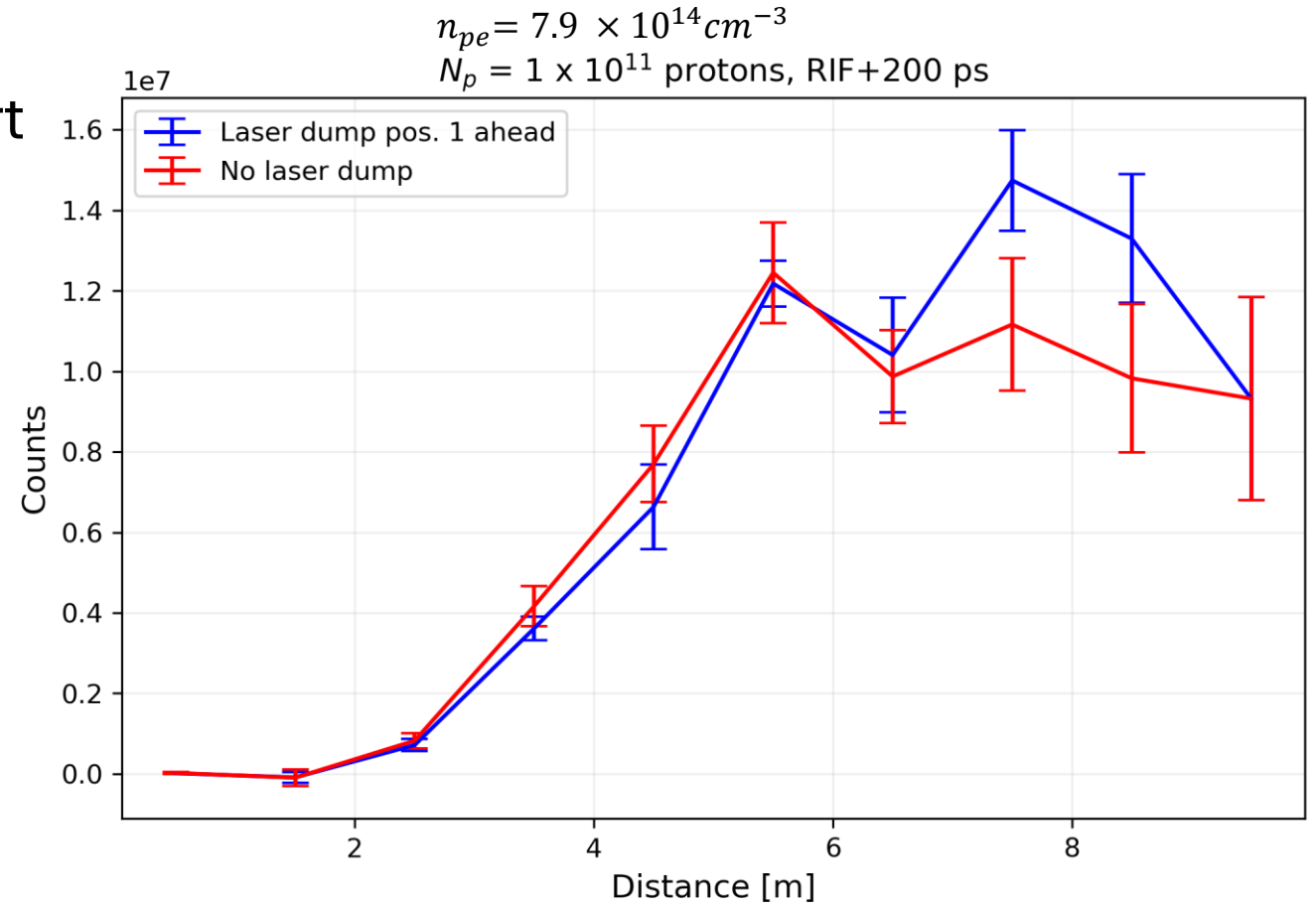
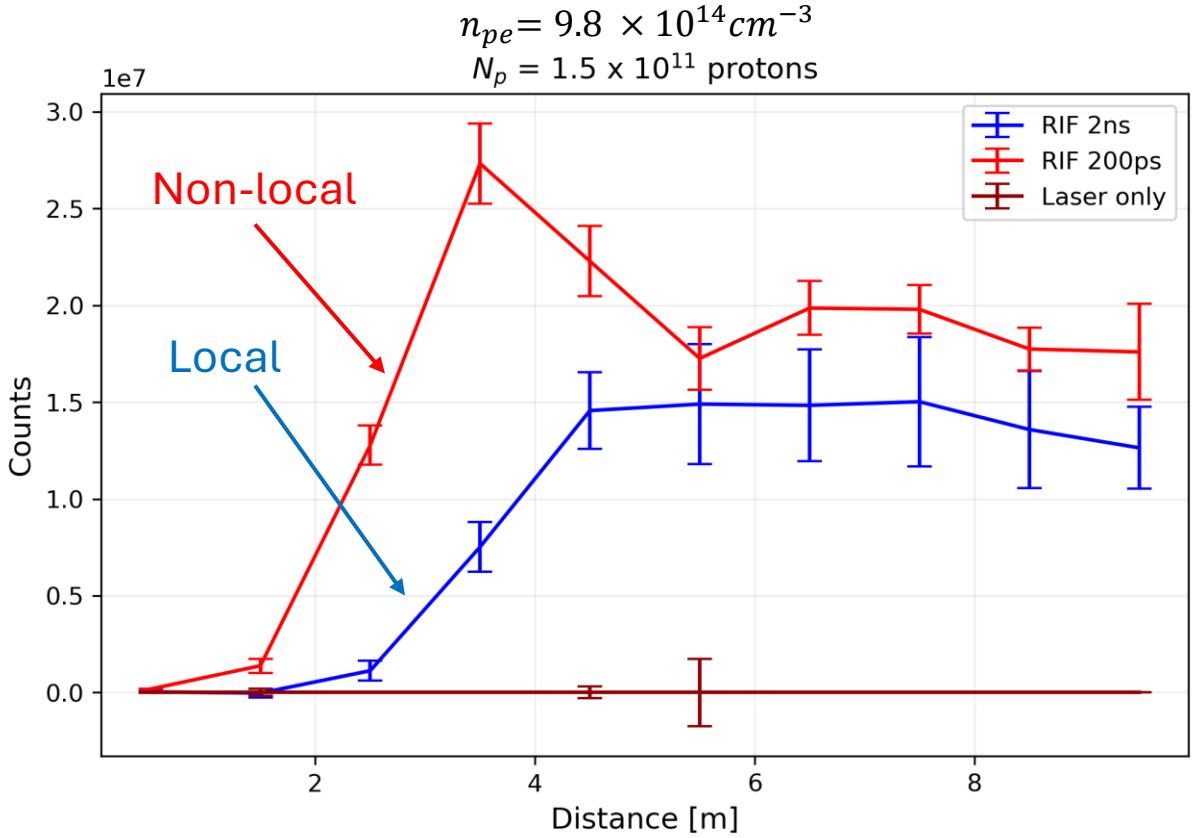
Measurement points 1 ahead of plunger position with error bars :



Validating locality

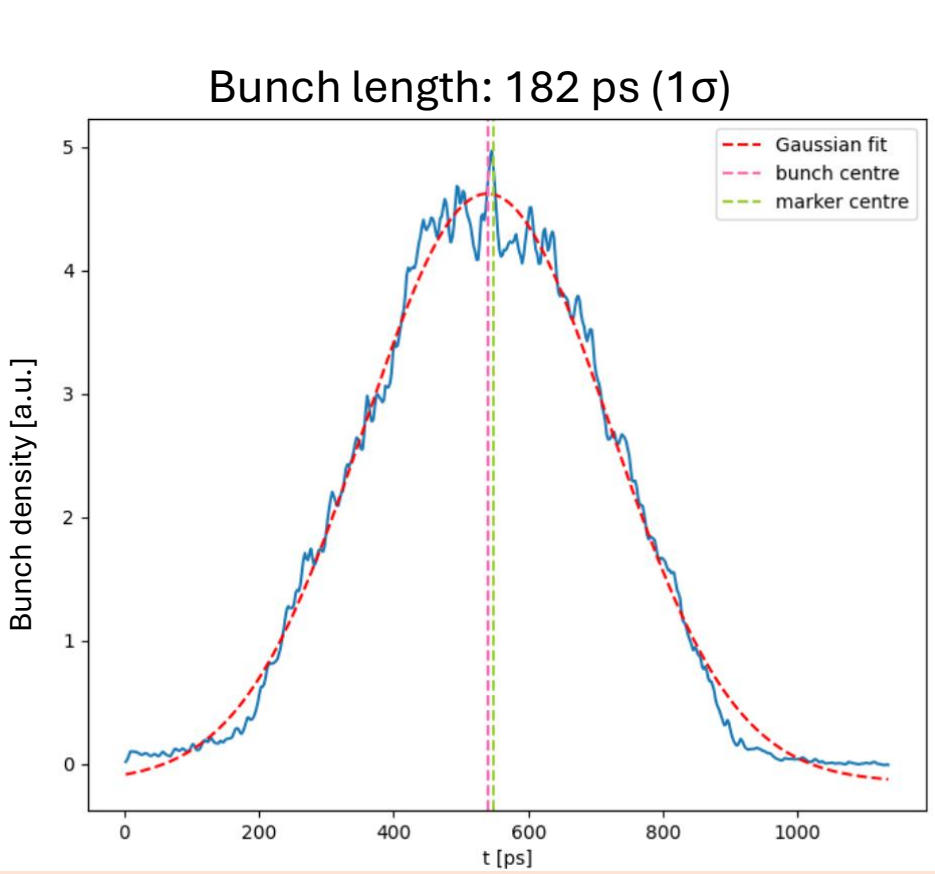
- No change in signals with/without dumps validates locality of plasma light
  - $n_{pe} = 7.9 \times 10^{14} cm^{-3}, N_p = 1 \times 10^{11}$
  - $n_{pe} = 9.8 \times 10^{14} cm^{-3}, N_p = 1 - 1.5 \times 10^{11}$
  - $n_{pe} = 4 \times 10^{14} cm^{-3}, N_p < 1 \times 10^{11}$

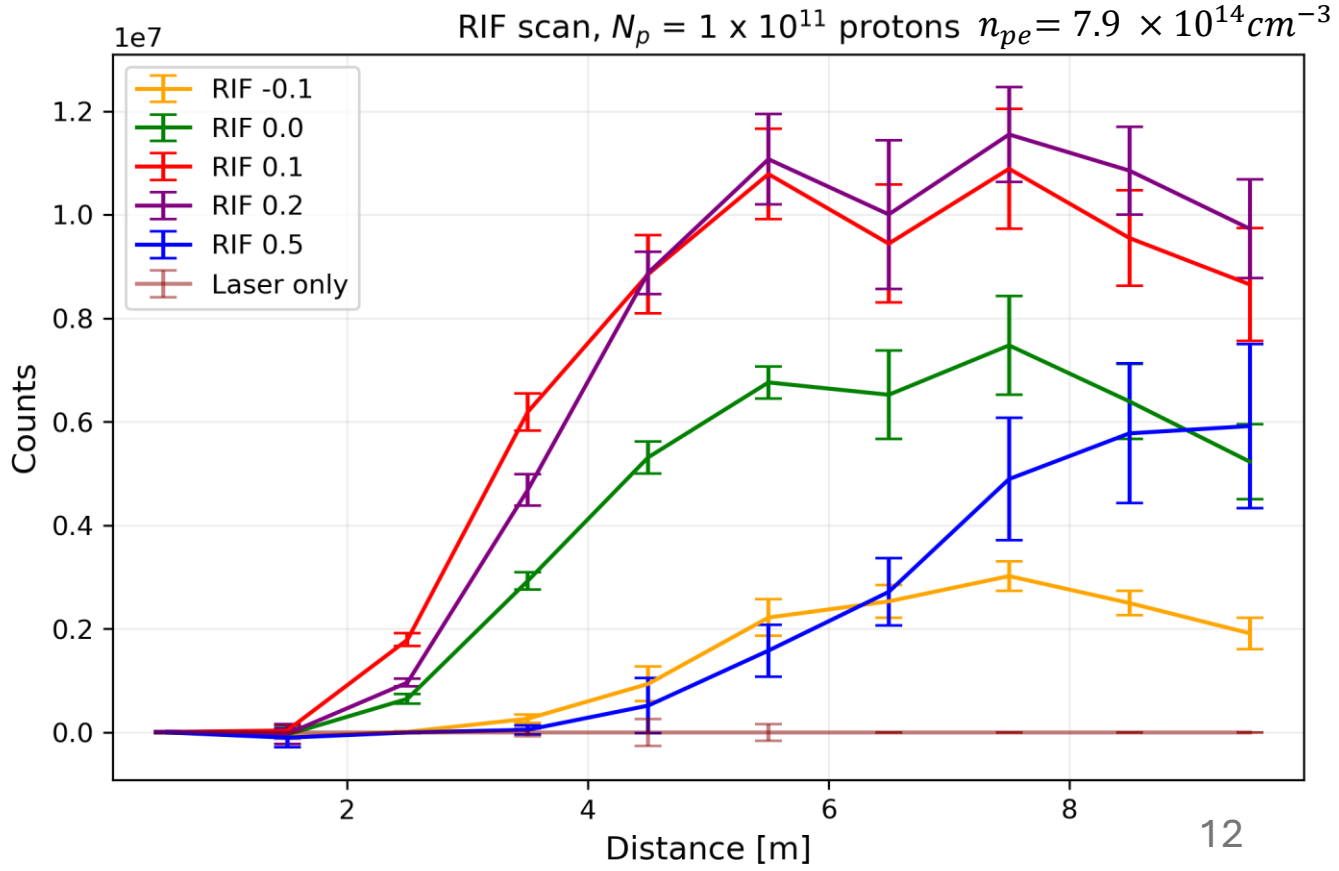


- Threshold could be at some signal amplitude
- Threshold lower for lower density

Seeding

- Seed wakefields induced by propagating the laser together with proton bunch
- RIF position – position of the laser relative to proton bunch center
- Threshold SSM-SMI ~ 0.3 ns (0.2 ns → 0.5 ns)

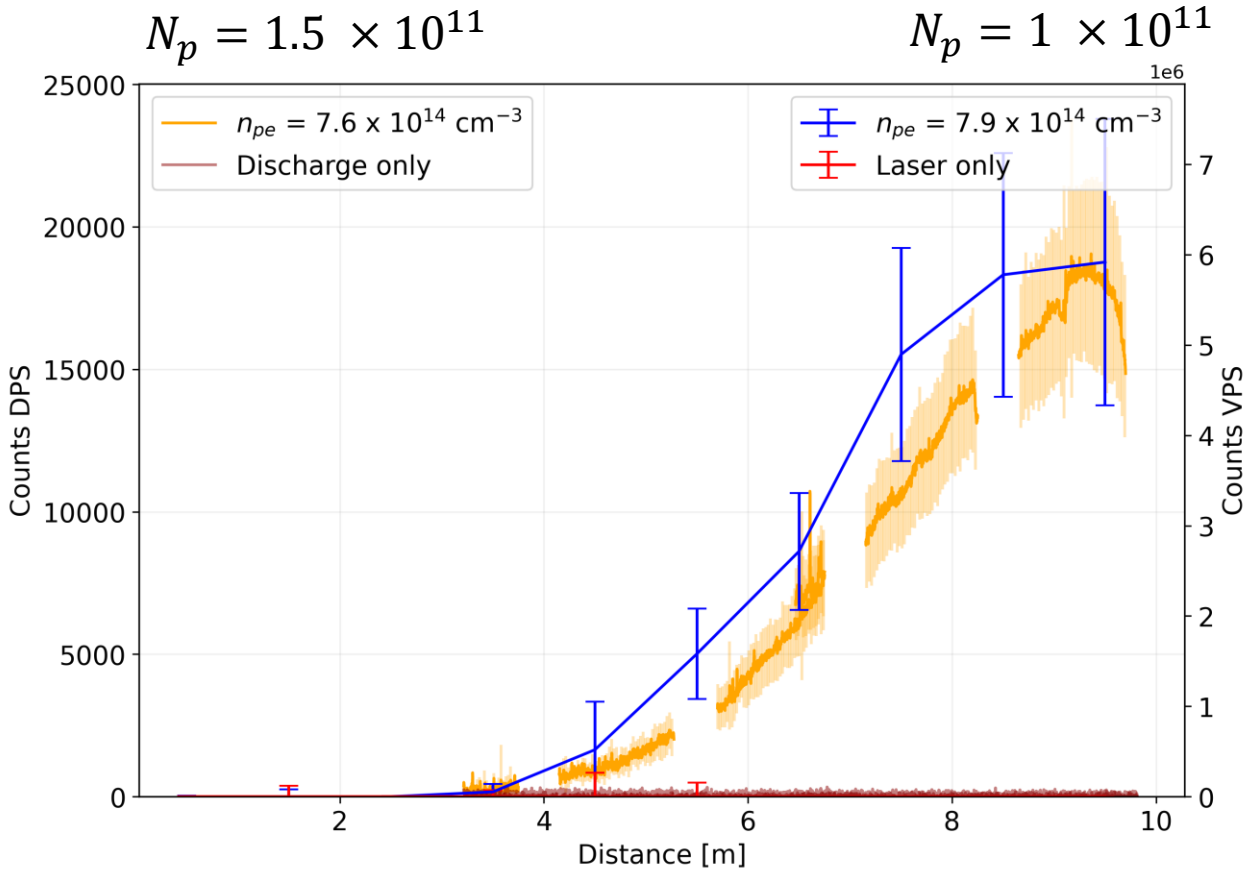




Comparison to DPS

- DPS – no seeding (always SMI)
- SMI case of VPS in local regime looks very similar to DPS
- SMI case of VPS in non-local regime looks very different from DPS

→ Indication that DPS measurements do not have the same problem.



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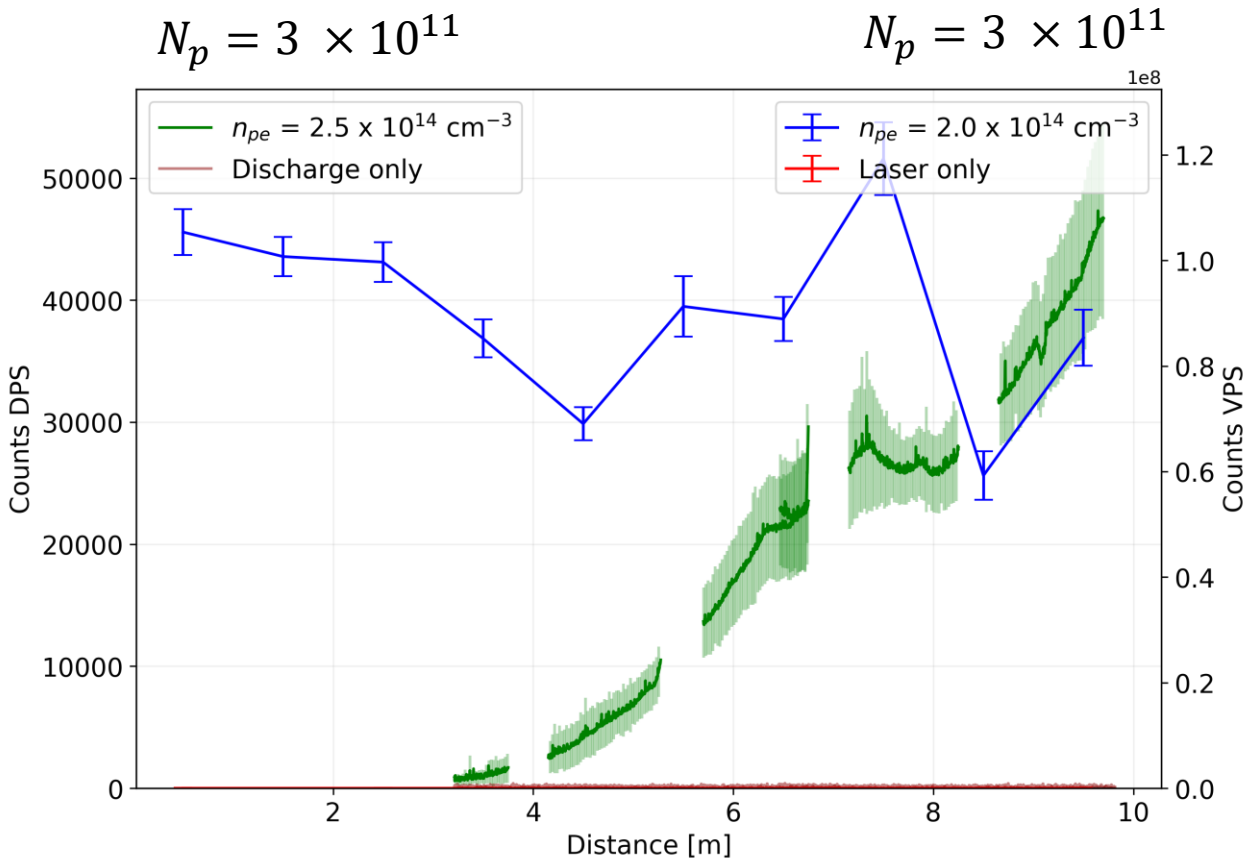
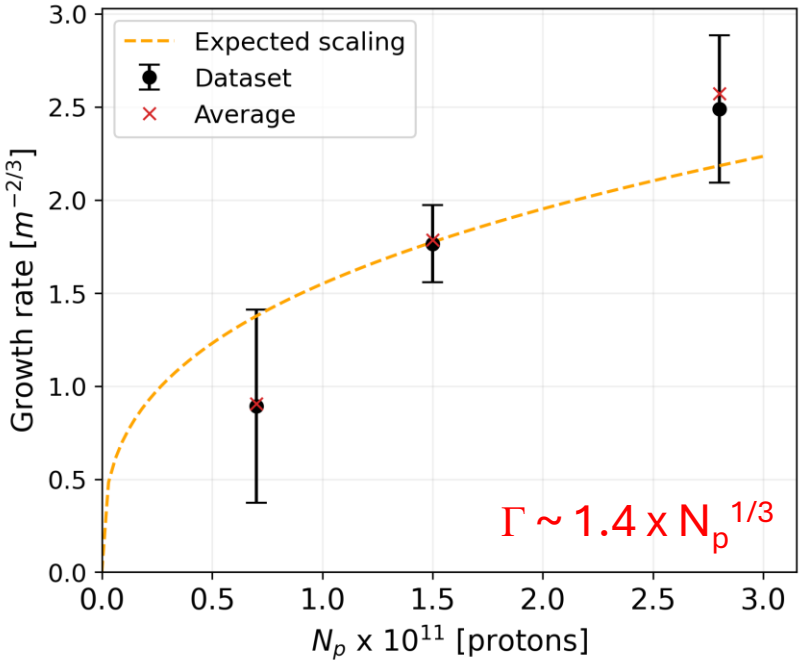


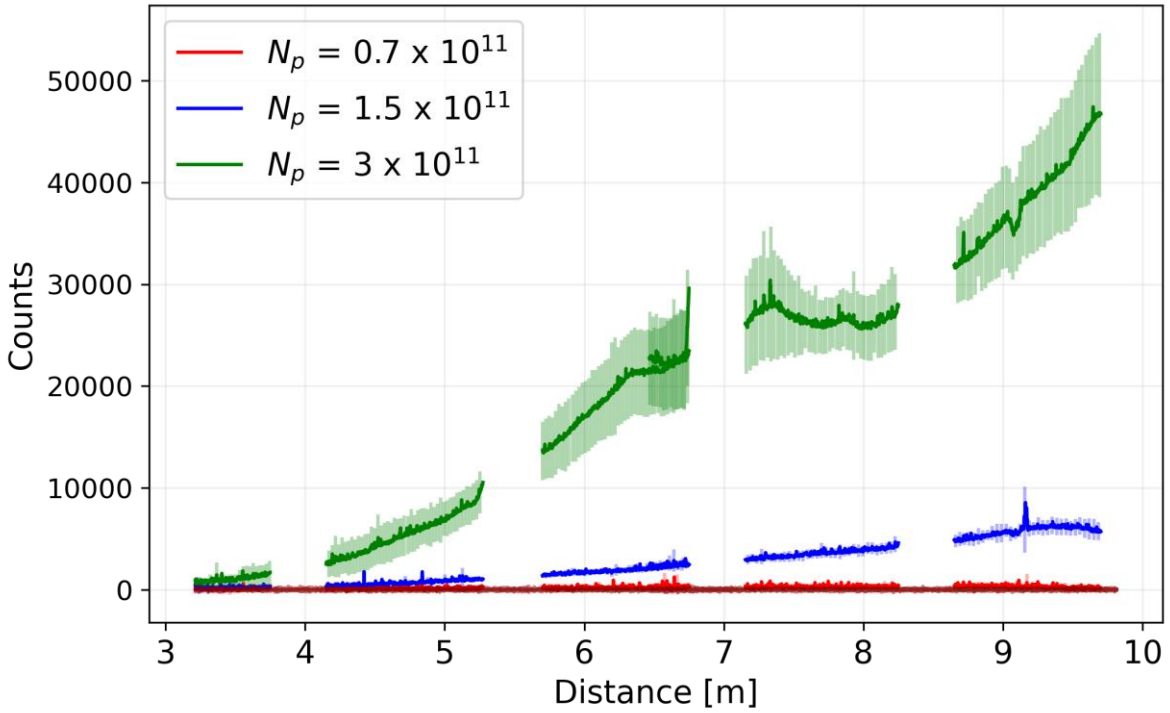
Growth rate analysis

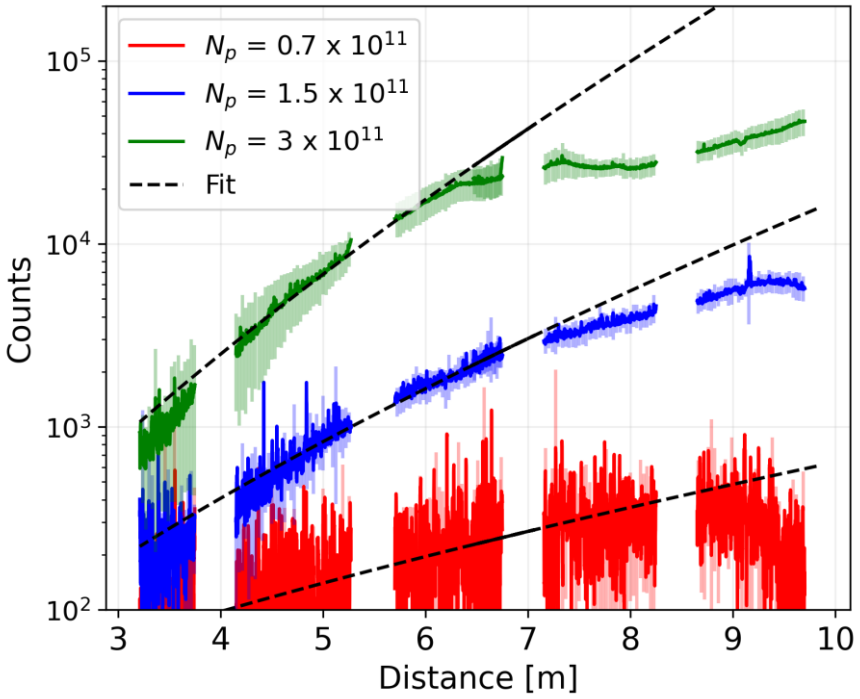
- Plasma density:
  $n_{pe} = 2.5 \times 10^{14} cm^{-3}$
- Measured growth: $\Gamma \sim 1.4 \times N_p^{1/3}$



$$E_r(z) = E_{r,0} e^{z\Gamma(z)}$$

$$\Gamma \propto N_p^{\frac{1}{3}}, \ \Gamma \propto z^{-\frac{1}{3}}$$



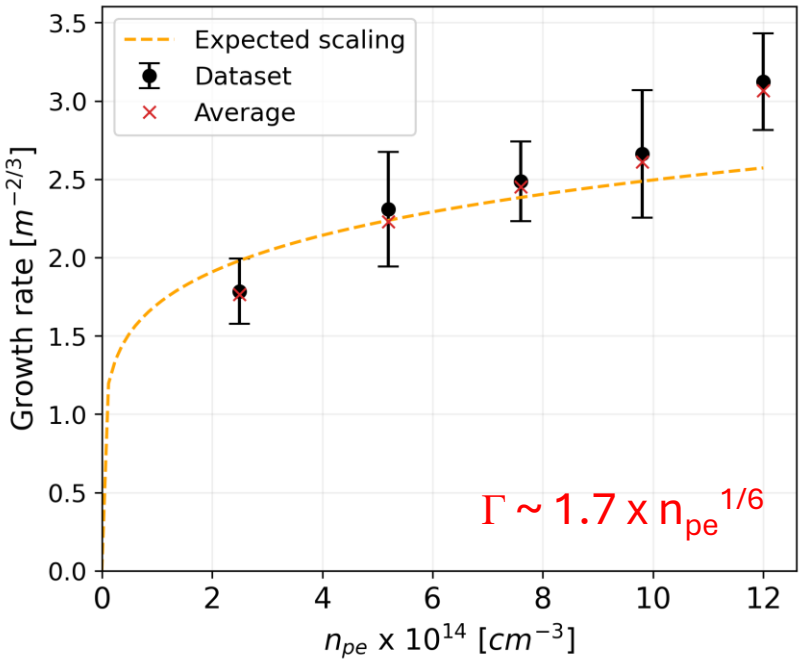


fit function:

$$f(x) = a\, e^{\Gamma z^{\frac{2}{3}}}$$

Growth rate analysis

- Bunch population:
  $N_p = 1.5 \times 10^{11}$ protons
- Measured growth: $\Gamma \sim 1.7 \times n_{pe}^{1/6}$



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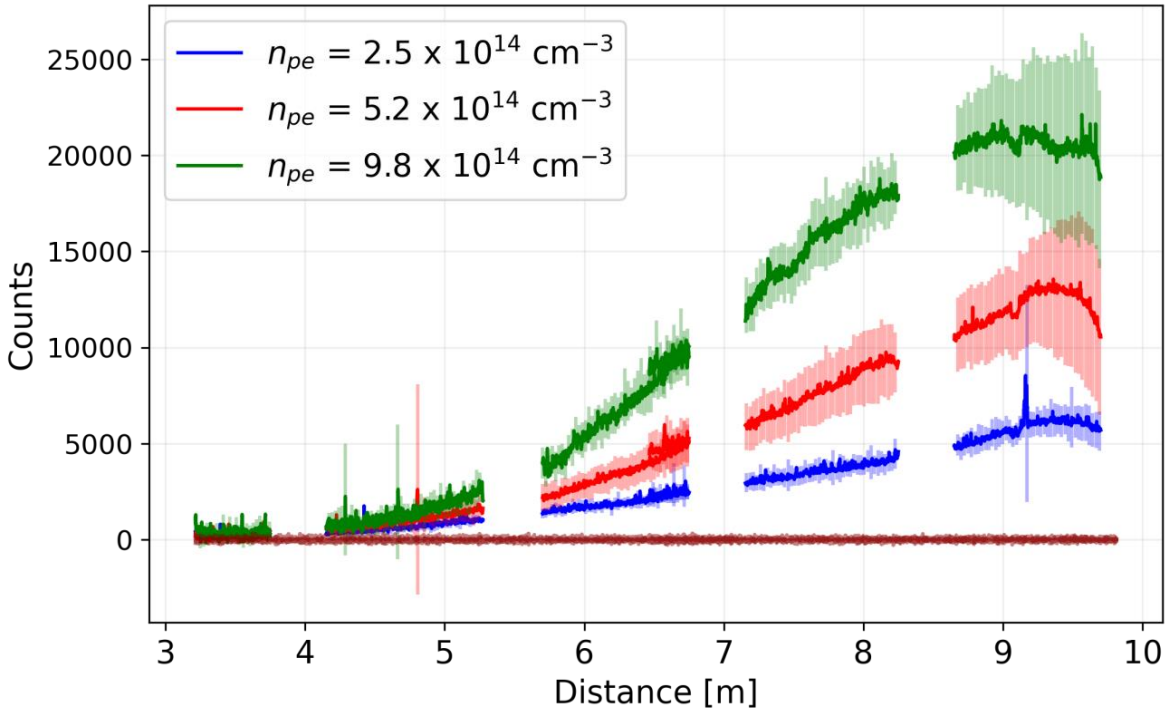

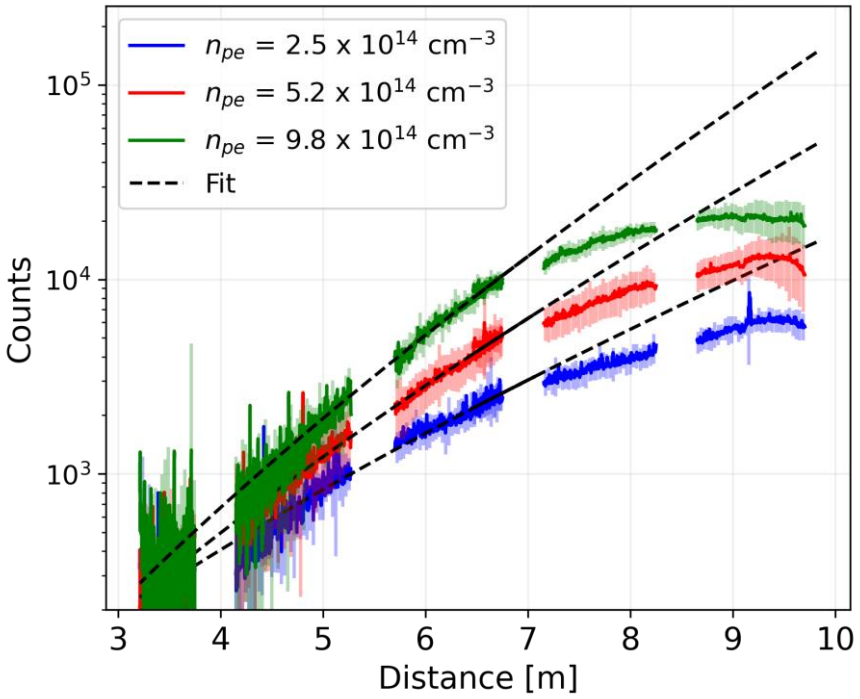

fit function:

$$f(x) = a\, e^{\Gamma z^{\frac{2}{3}}}$$

Conclusion

- When local: plasma light profiles show the evolution of SM along the plasma
- In the VPS local only for low signal amplitude
- In the DPS (most likely) local even for high signal amplitude
- When not seeded and local: VPS and DPS signals look very similar
- Growth rates follow expected trend