LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

CENTRE FOR ADVANCED LASER APPLICATIONS

CALA

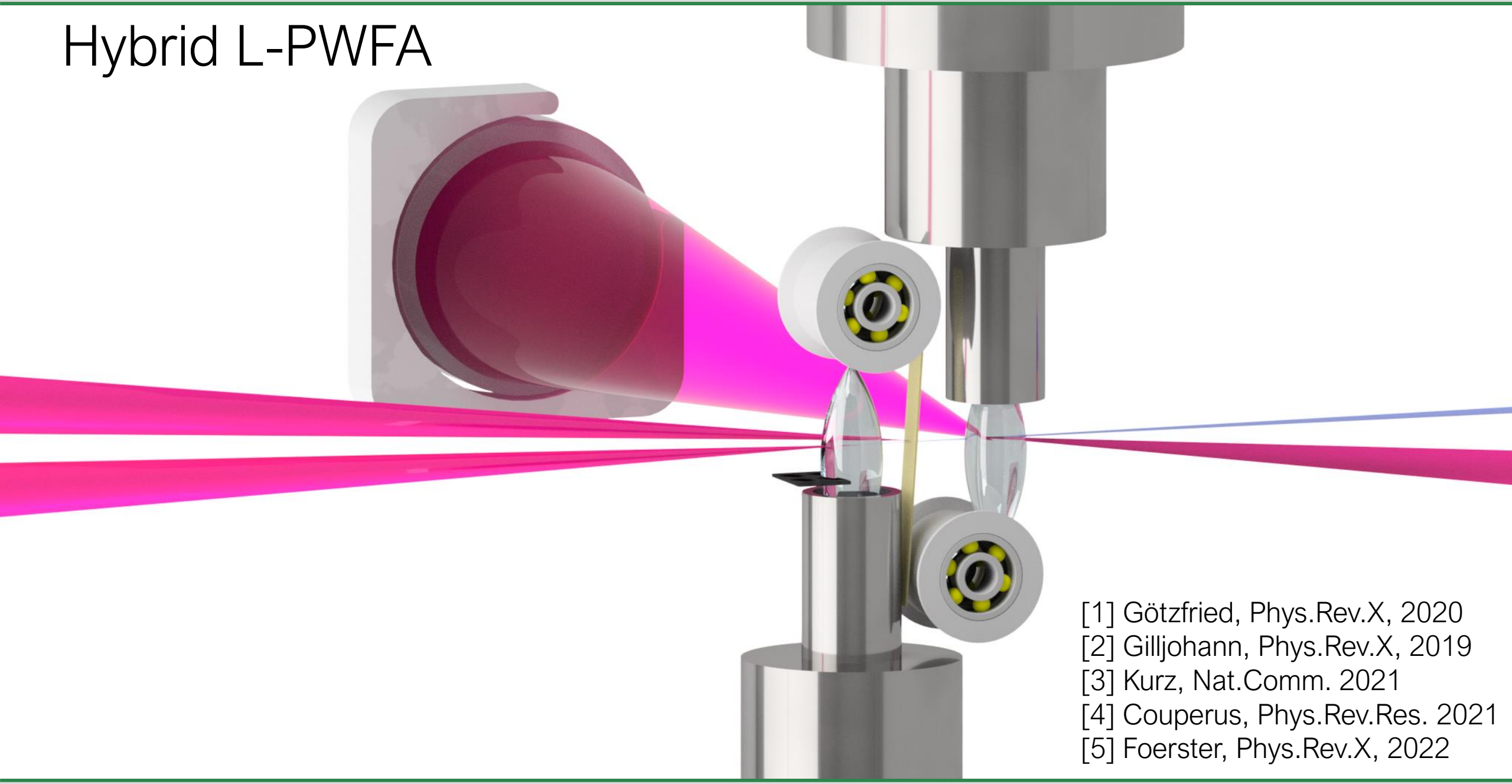
Increasing the energy of high-quality electron bunches from a hybrid L-PWFA

Moritz Foerster

(LMU Munich, Karsch group)

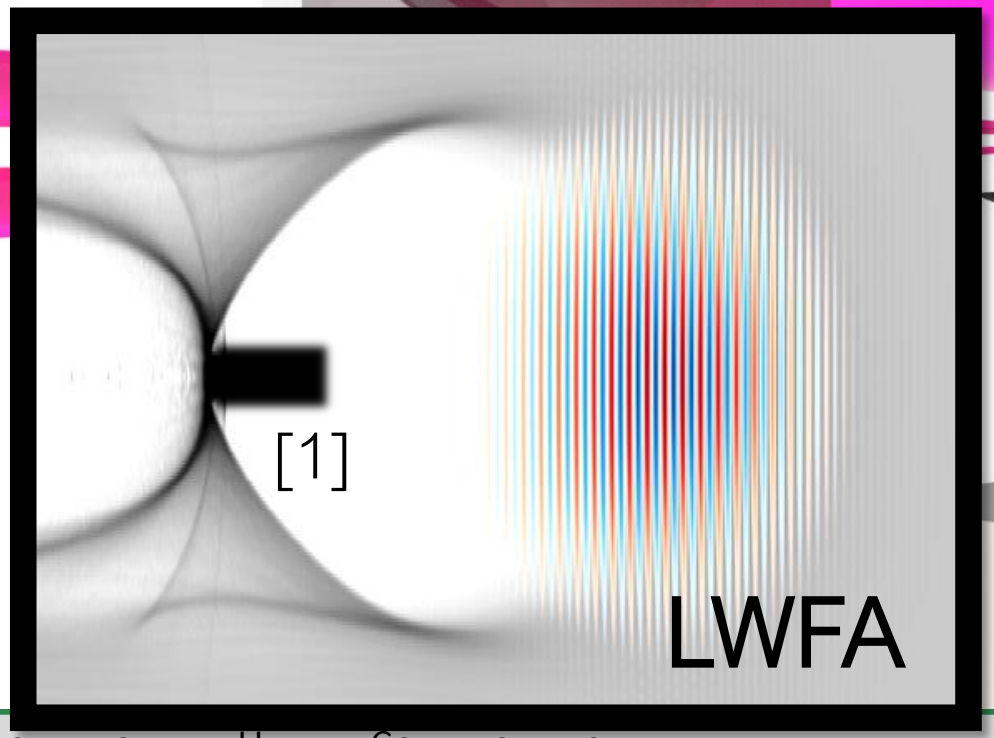
on behalf of the
Hybrid Collaboration:

Hybrid L-PWFA



[1] Götzfried, Phys.Rev.X, 2020
[2] Gilljohann, Phys.Rev.X, 2019
[3] Kurz, Nat.Comm. 2021
[4] Couperus, Phys.Rev.Res. 2021
[5] Foerster, Phys.Rev.X, 2022

Hybrid L-PWFA



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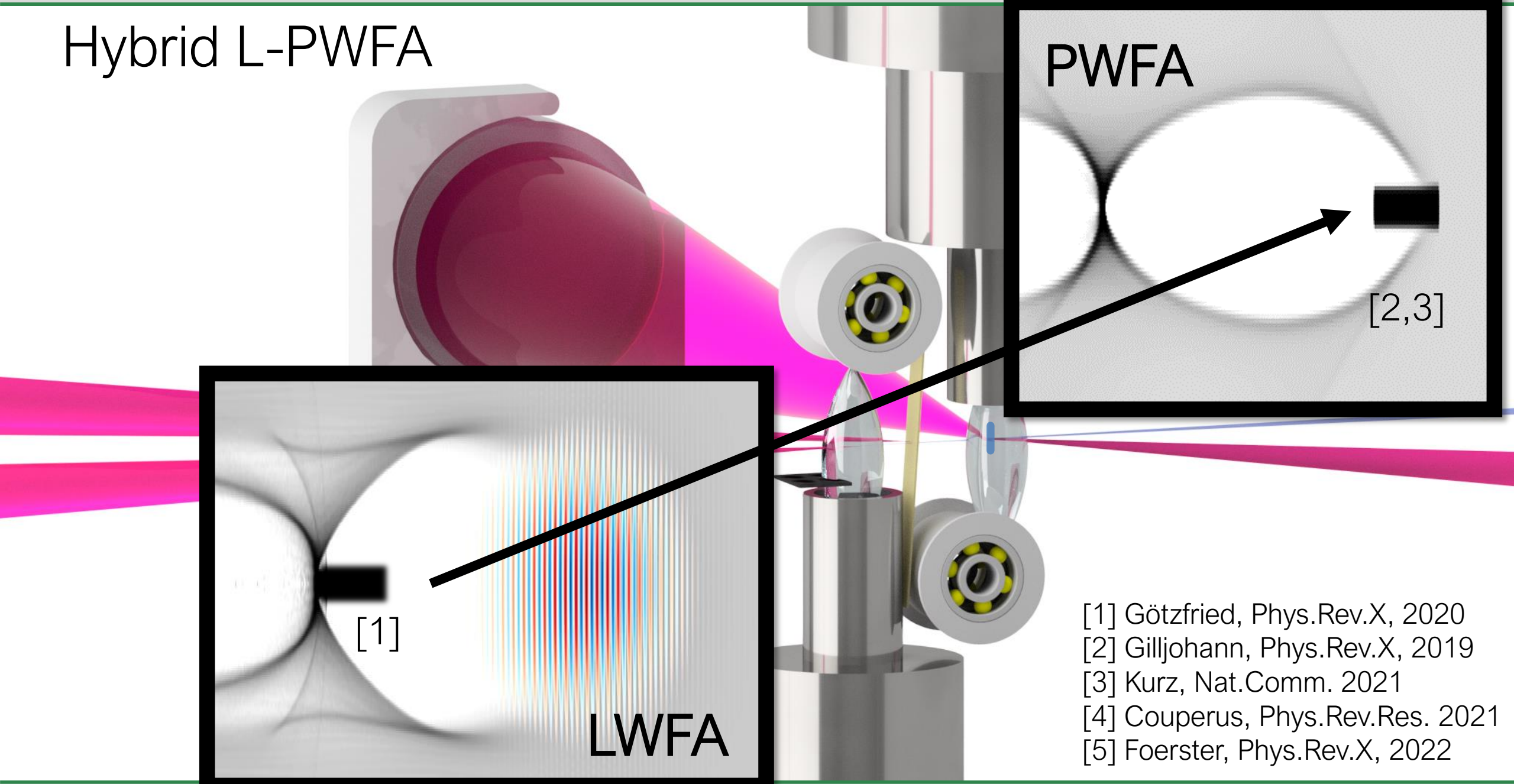

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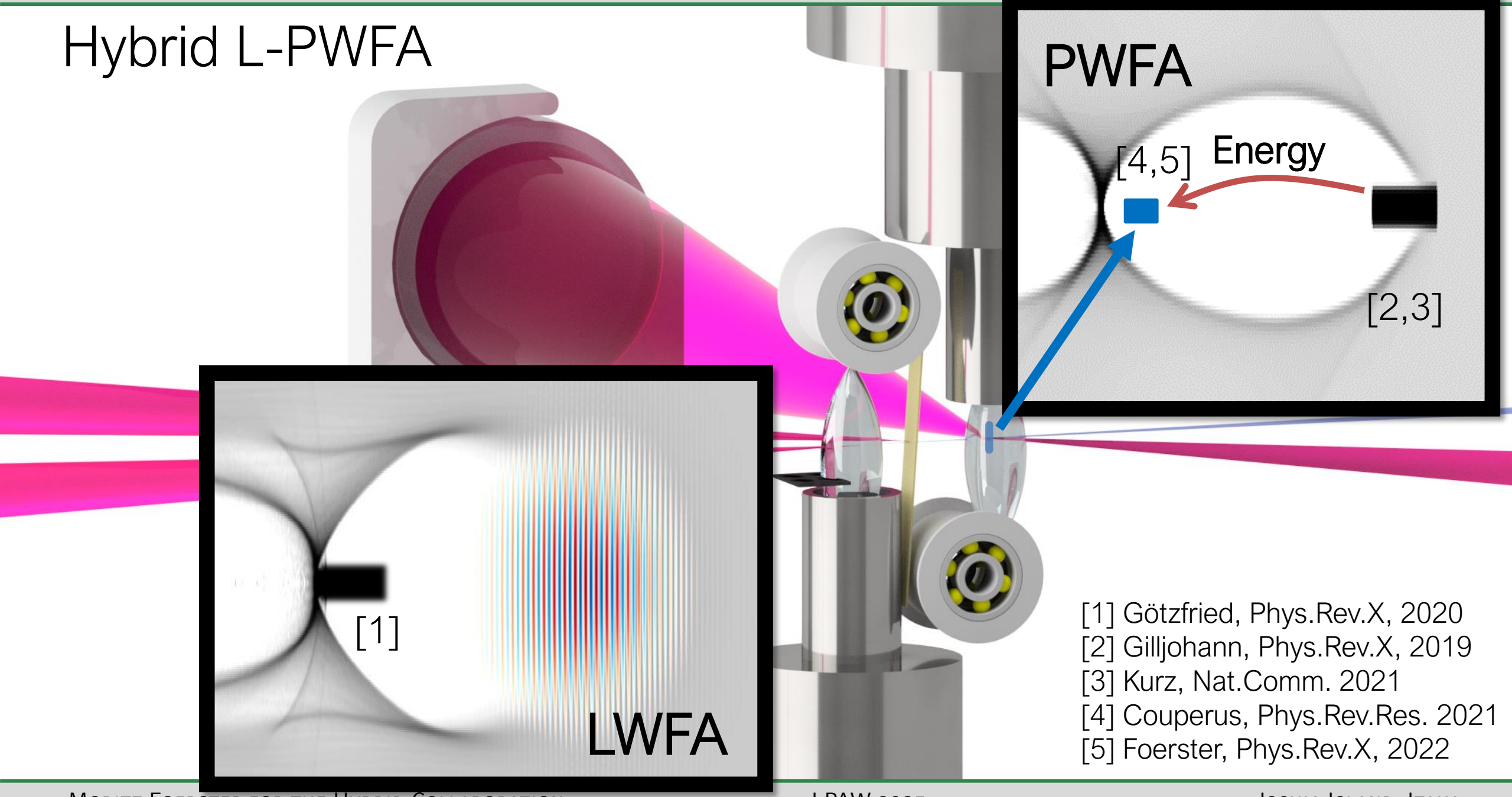

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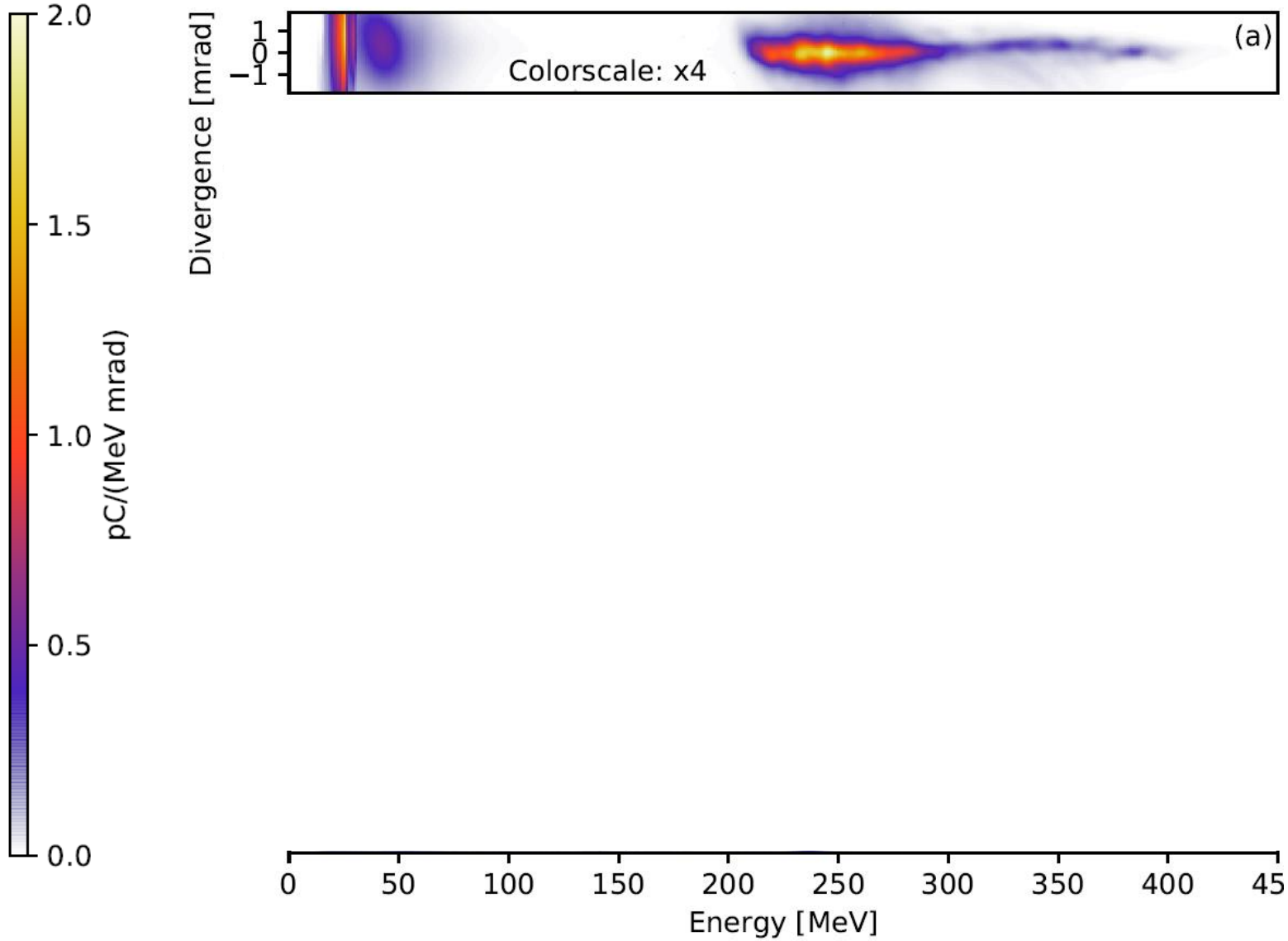
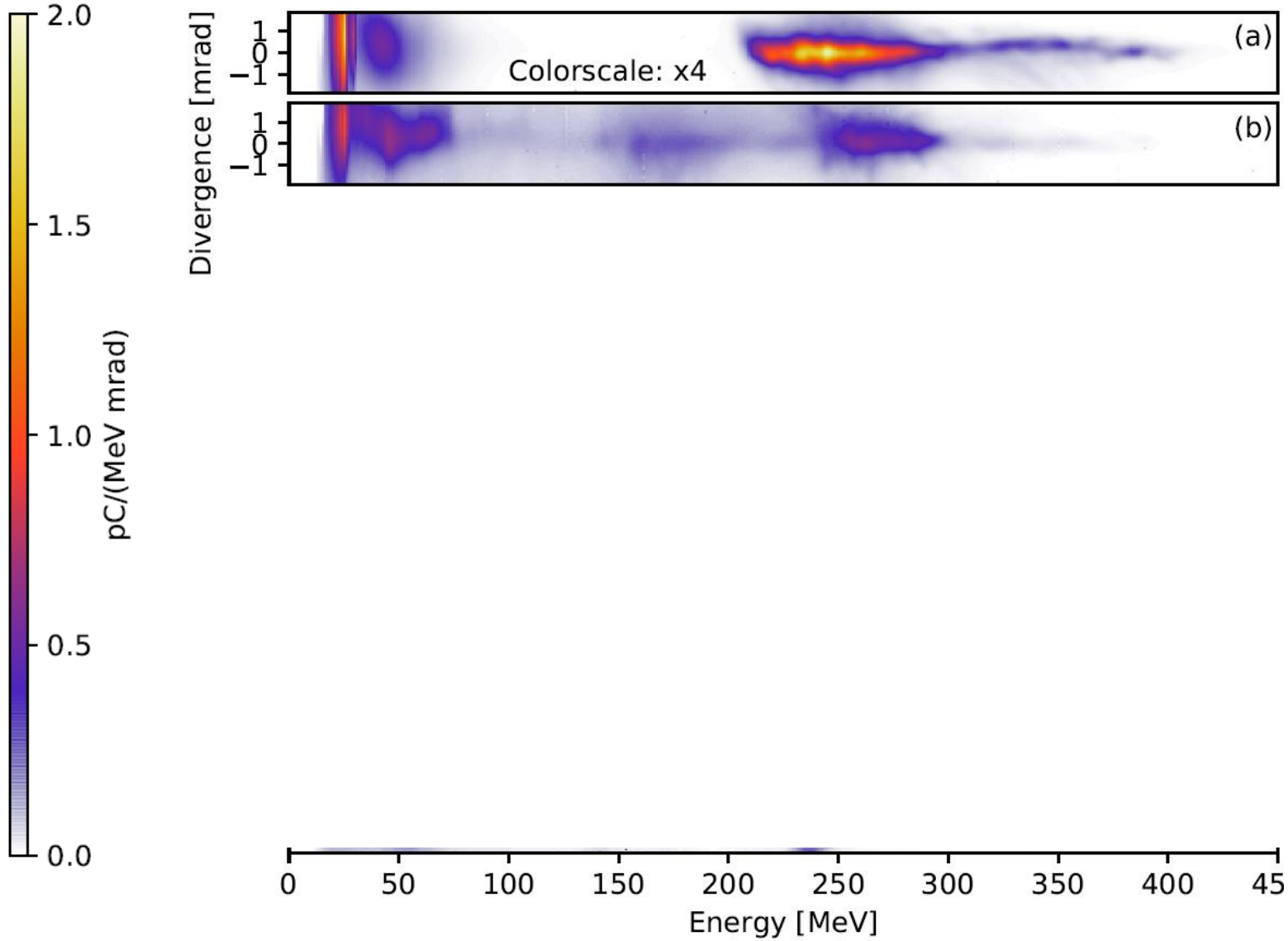


Driver
(LWFA Reference)

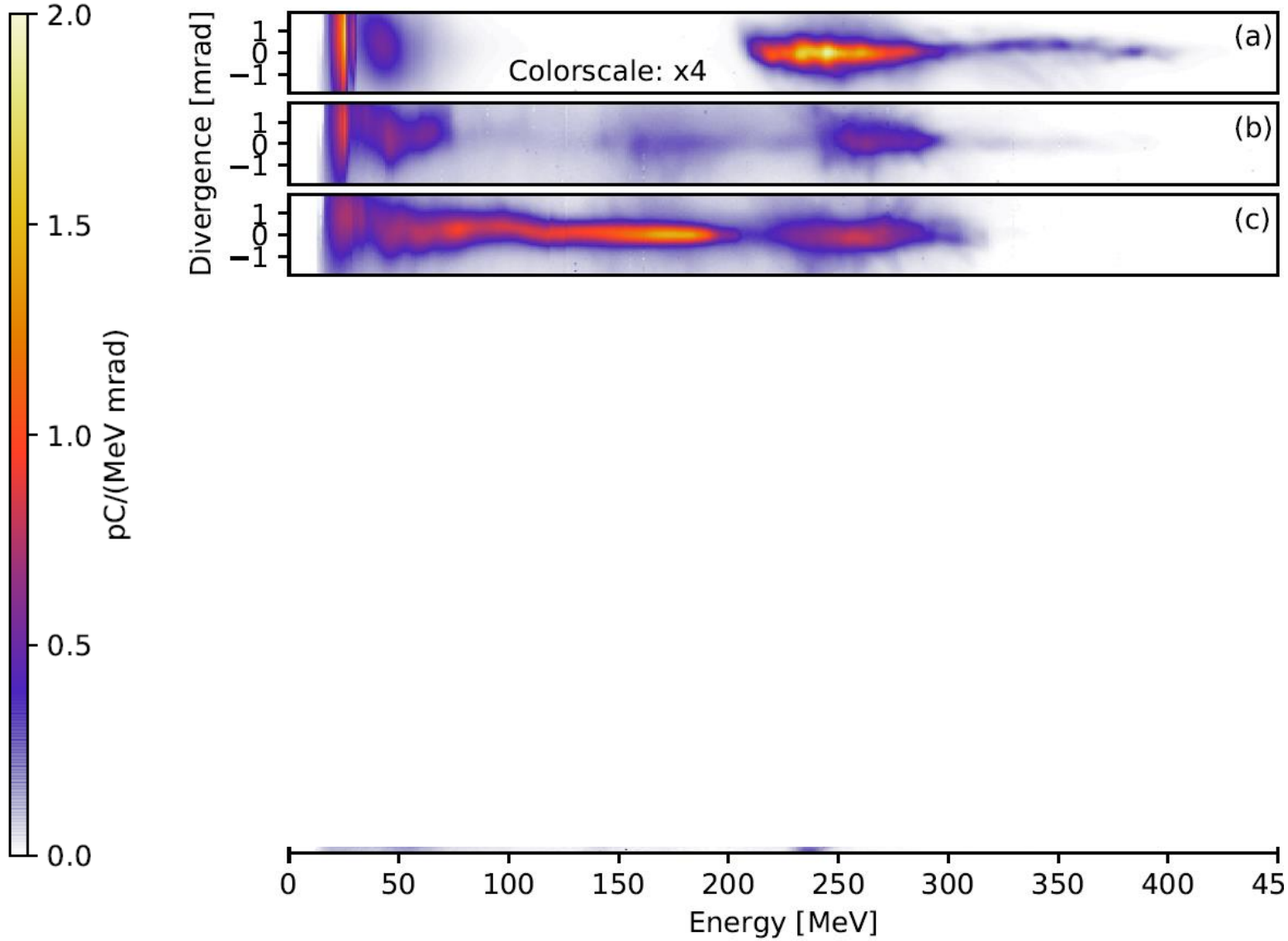
Hybrid L-PWFA



Driver
(LWFA Reference)

PWFA on

Hybrid L-PWFA

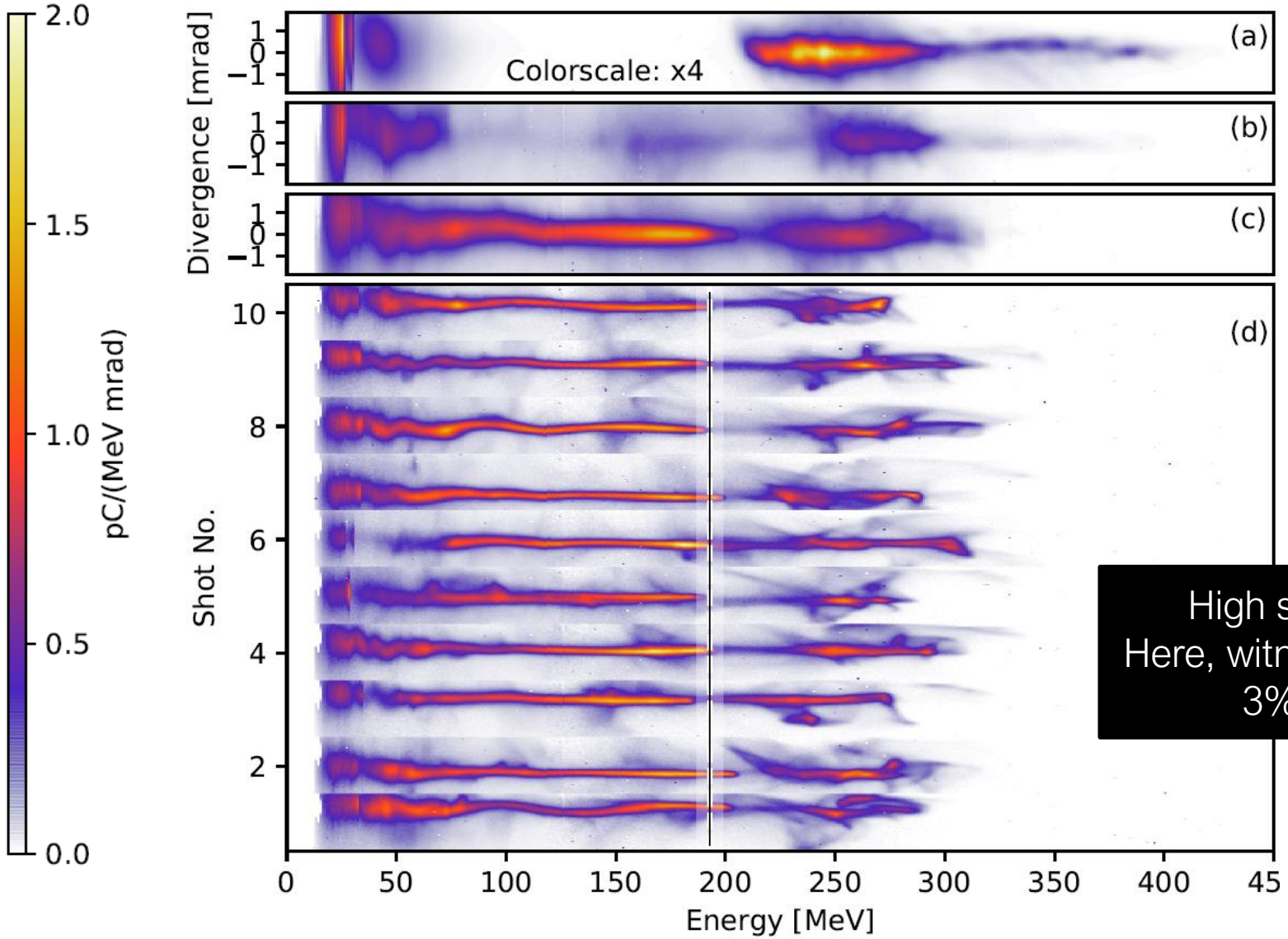


Driver
(LWFA Reference)

PWFA on

PWFA on + witness injected

Hybrid L-PWFA



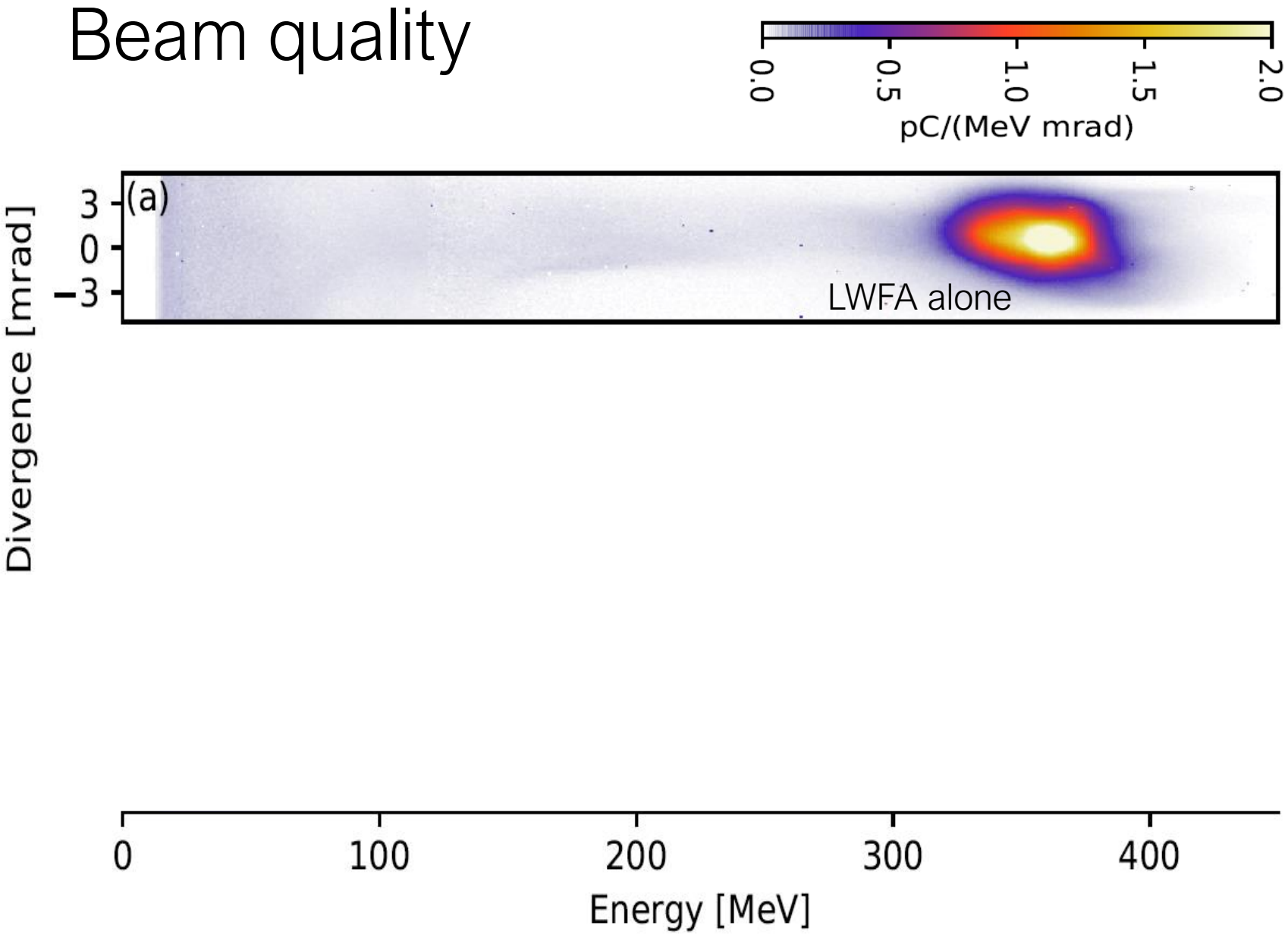
Driver
(LWFA Reference)

PWFA on

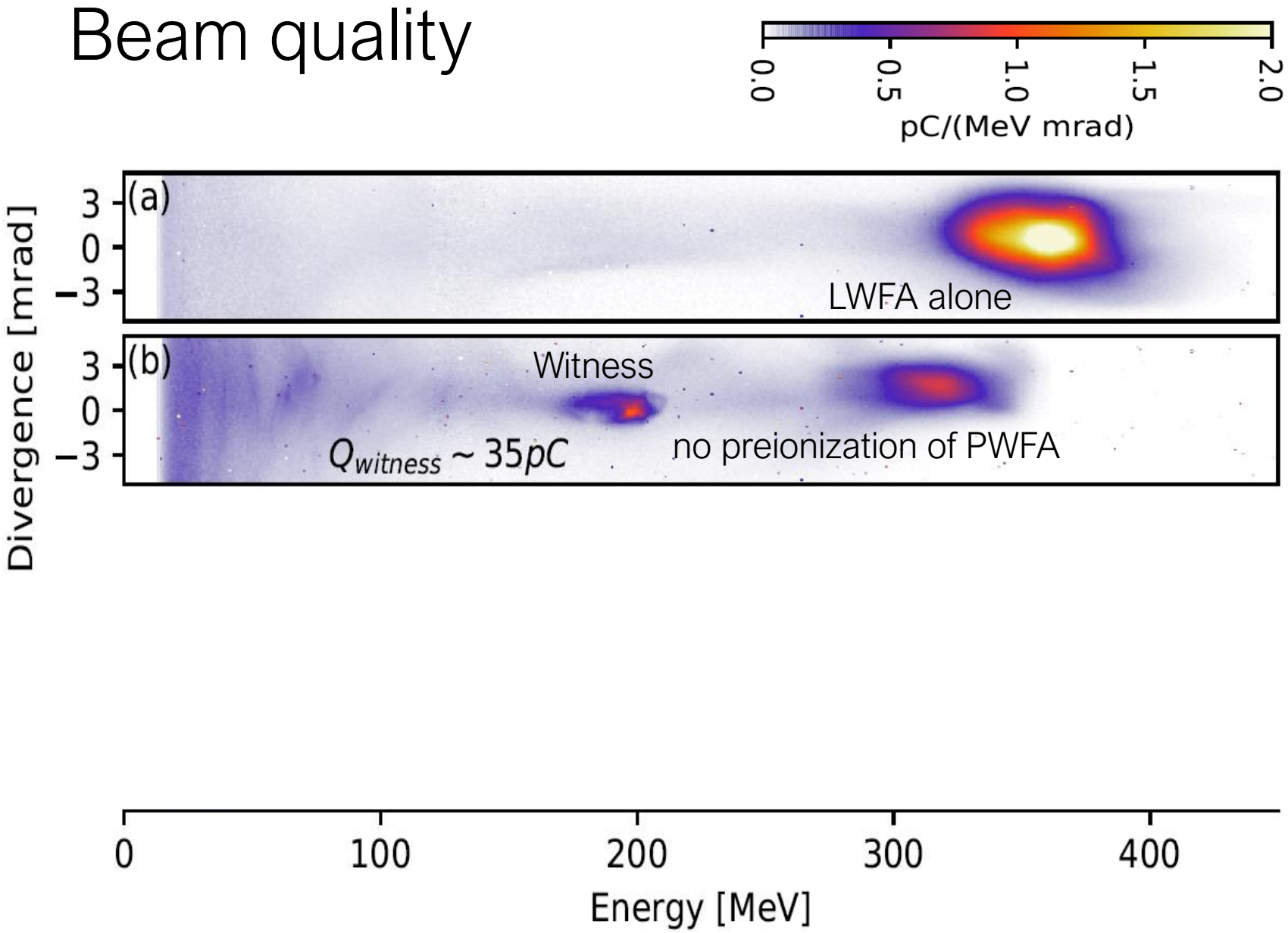
PWFA on + witness injected

High stability:
Here, witness energy
3% std

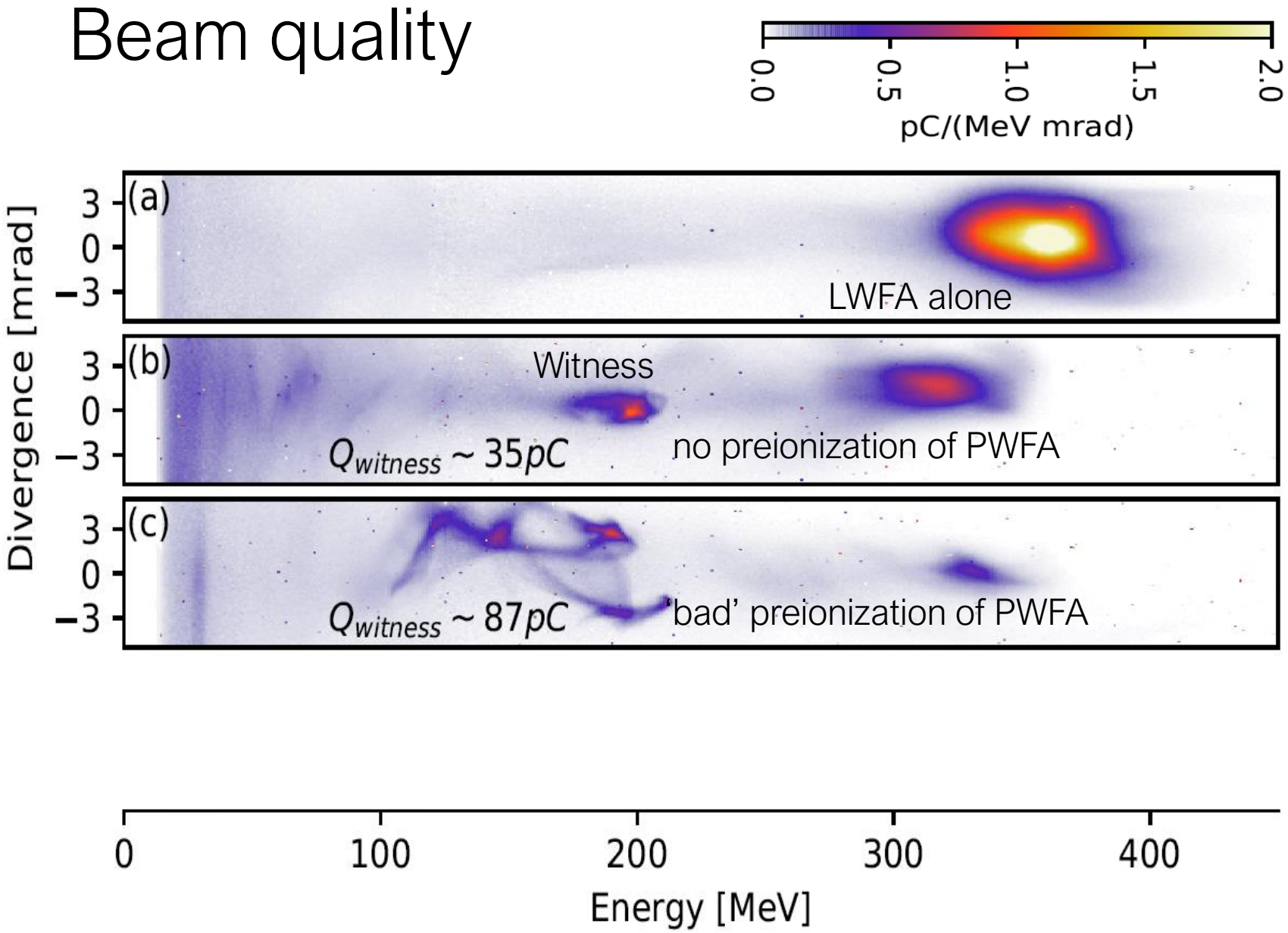
Beam quality



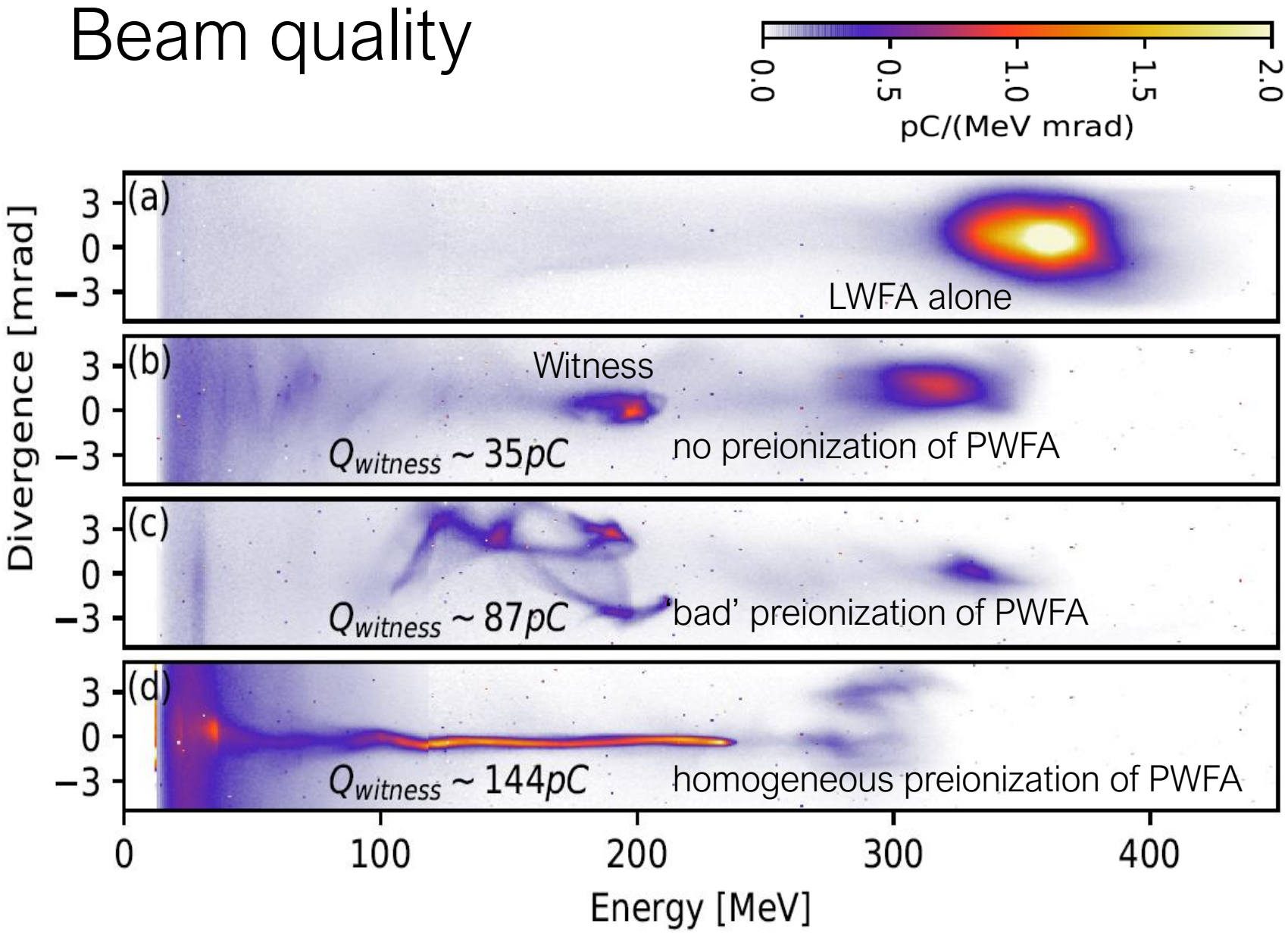
Beam quality

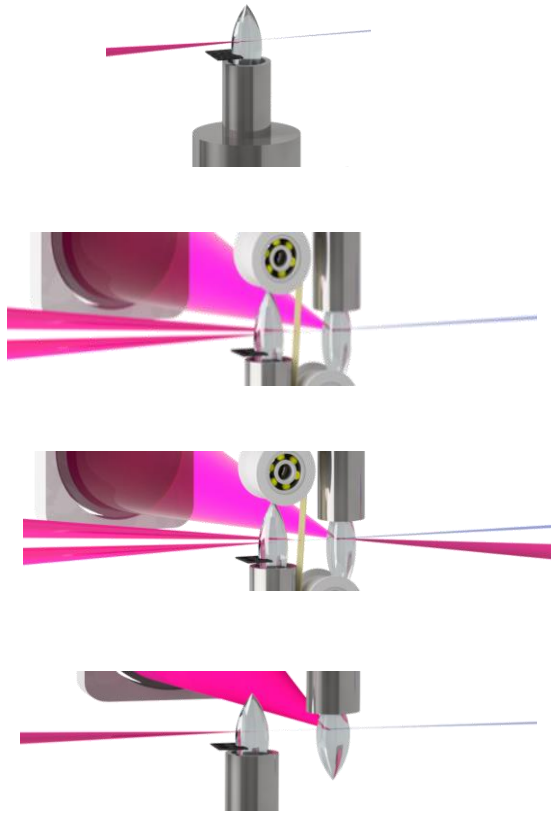


Beam quality



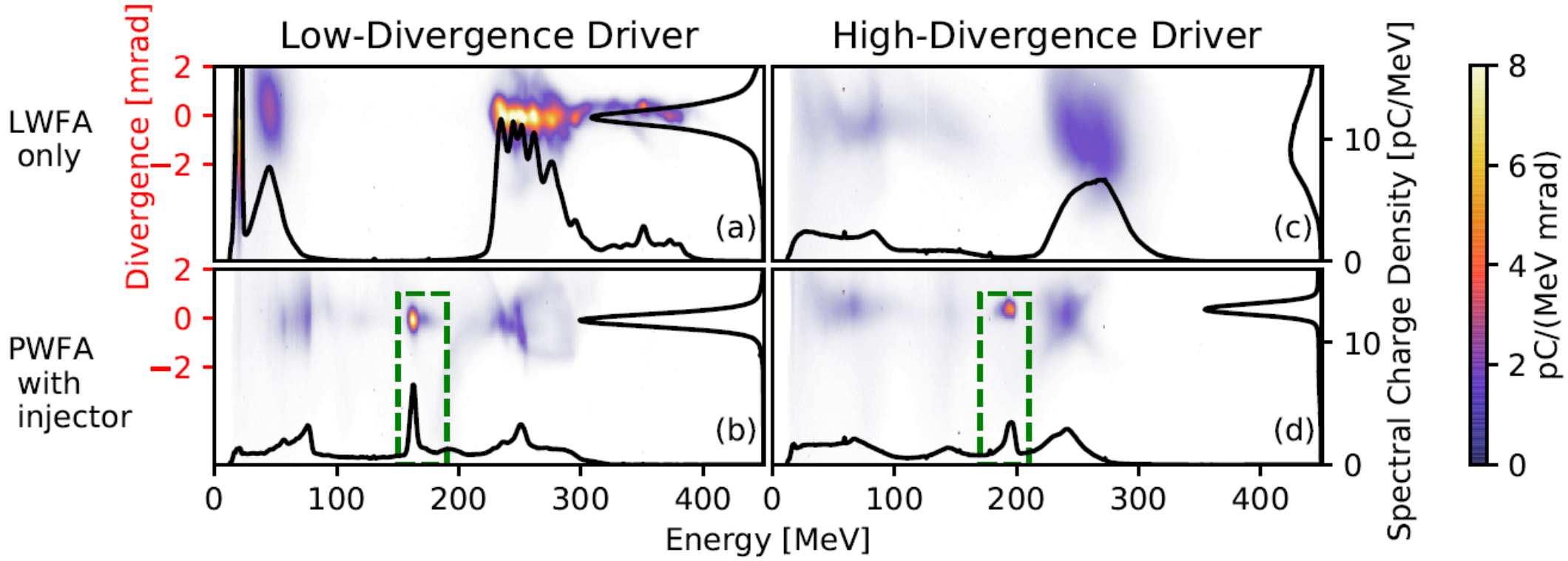
Beam quality





Beam quality

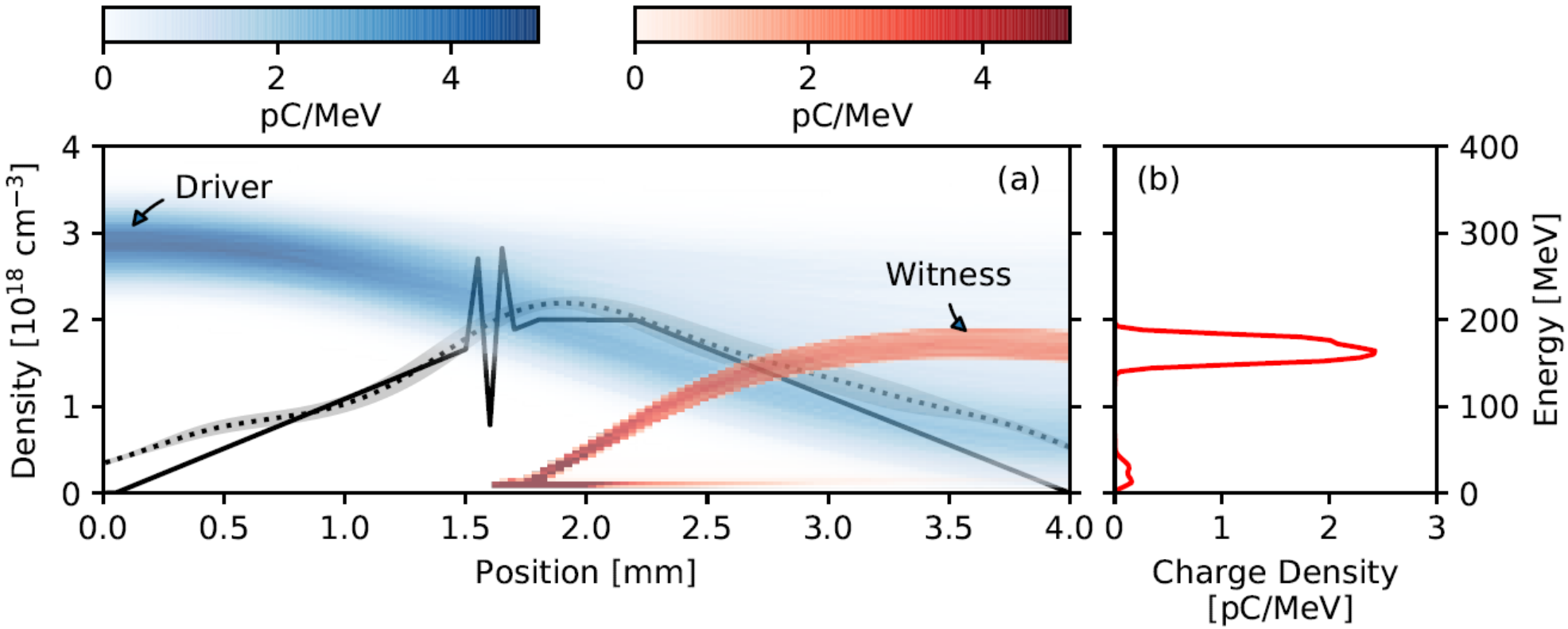
- Net gain in angular-spectral charge density[1]
  - Useful for applications



[1] Foerster, Phys.Rev.X, 2022

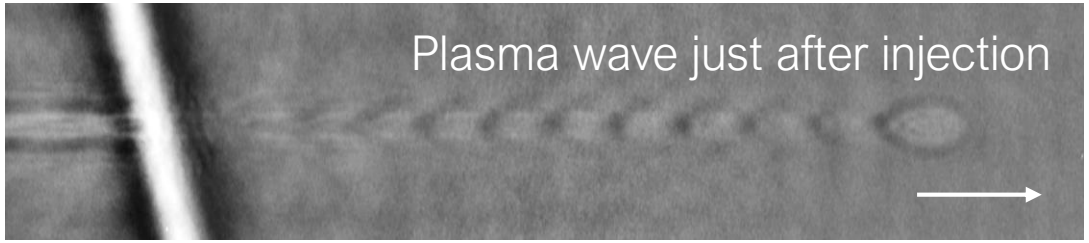
Increasing witness energy

- Avoid mistakes
  - Here: non-ideal plasma density profile



Increasing witness energy

- Avoid mistakes
  - Here: too long PWFA target
    - Depletion



Probing data: F. Haberstroh et al., to be submitted

Increasing witness energy

- Avoid mistakes
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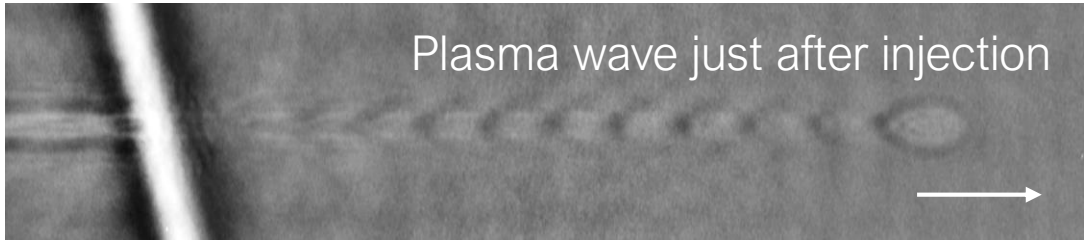

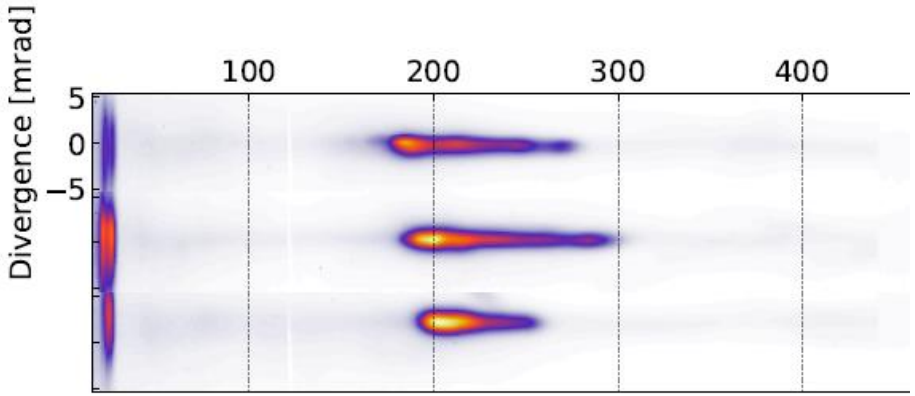

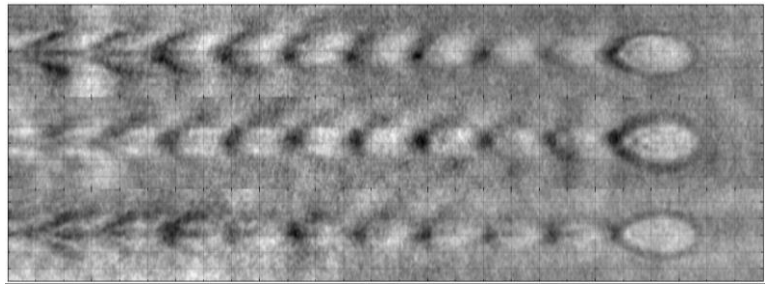

Plasma wave at the end of the PWFA target

Probing data: F. Haberstroh et al., to be submitted

Increasing witness energy

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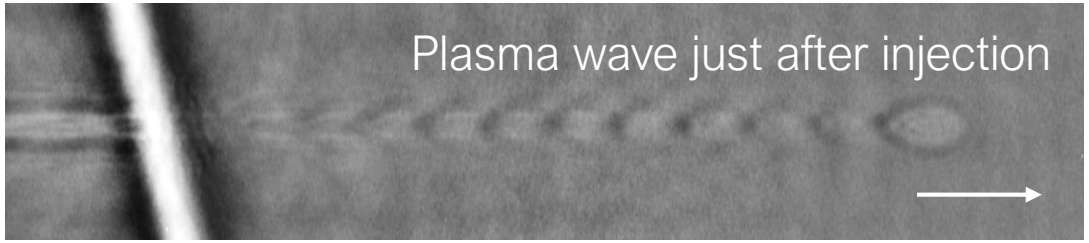
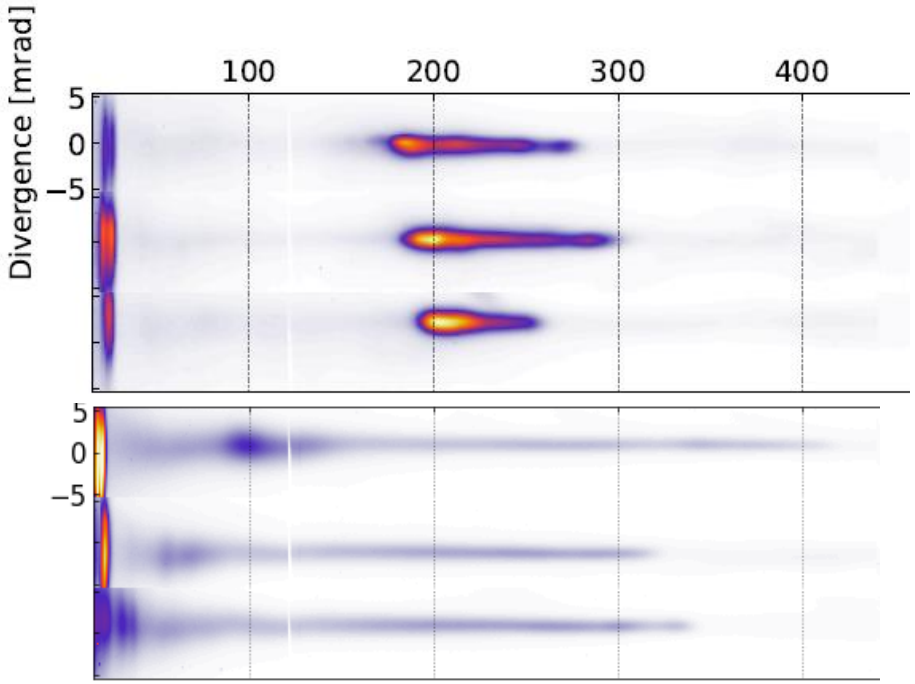
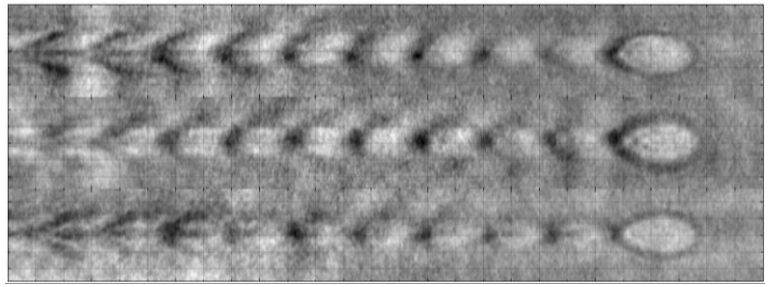
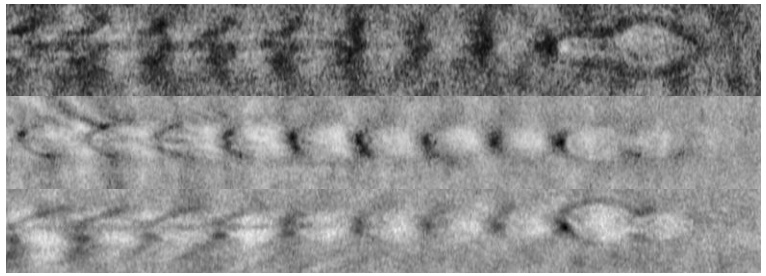








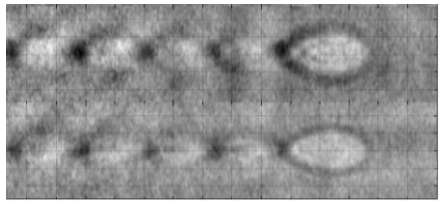
Plasma wave at the end of the PWFA target

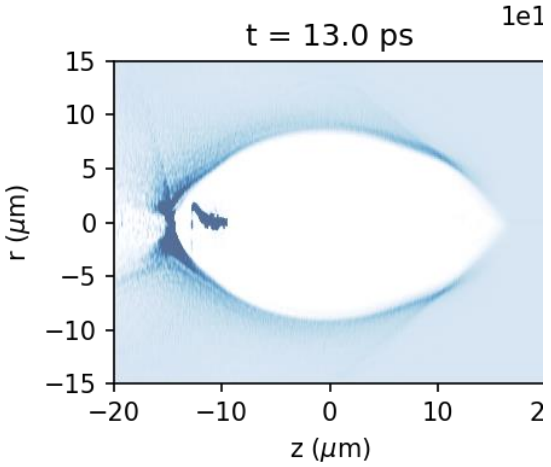
Driver depleted
First bubble shrinks

Probing data: F. Haberstroh et al., to be submitted

Increasing witness energy

- Driver depletion also visible in PIC simulations

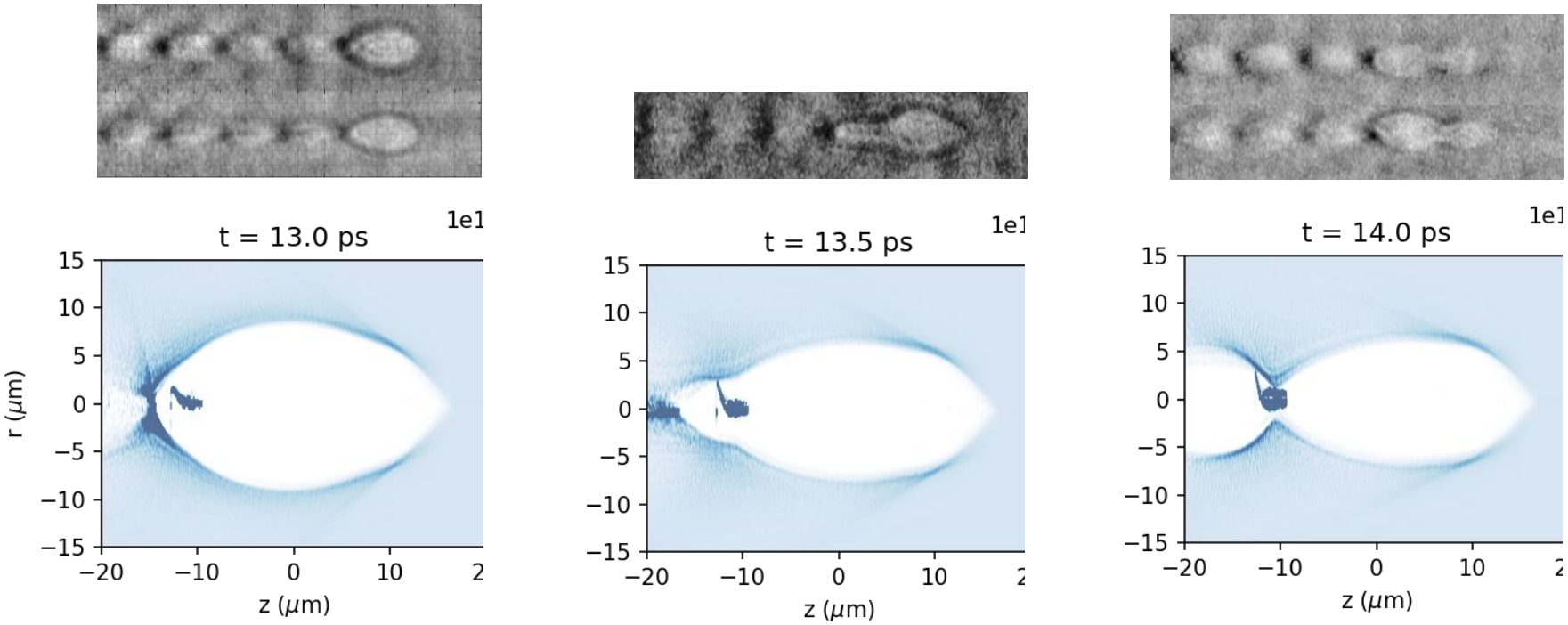




Witness still gains energy

Increasing witness energy

- Driver depletion also visible in PIC simulations



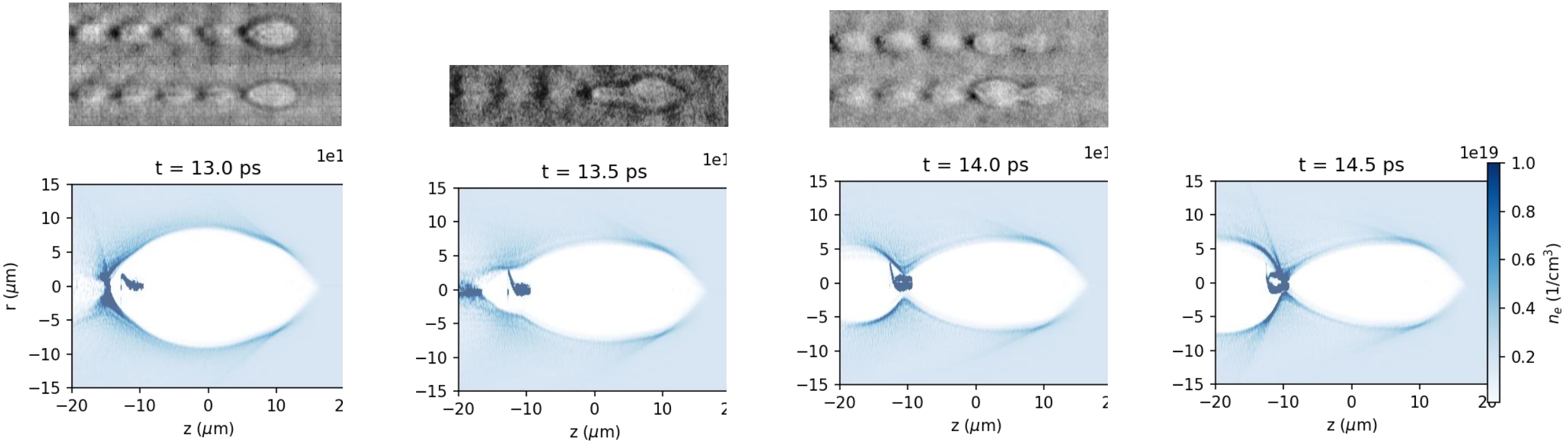
Witness still gains energy

Driver depletes

Simulations provided by J. Zirkelbach

Increasing witness energy

- Driver depletion also visible in PIC simulations



Witness still gains energy

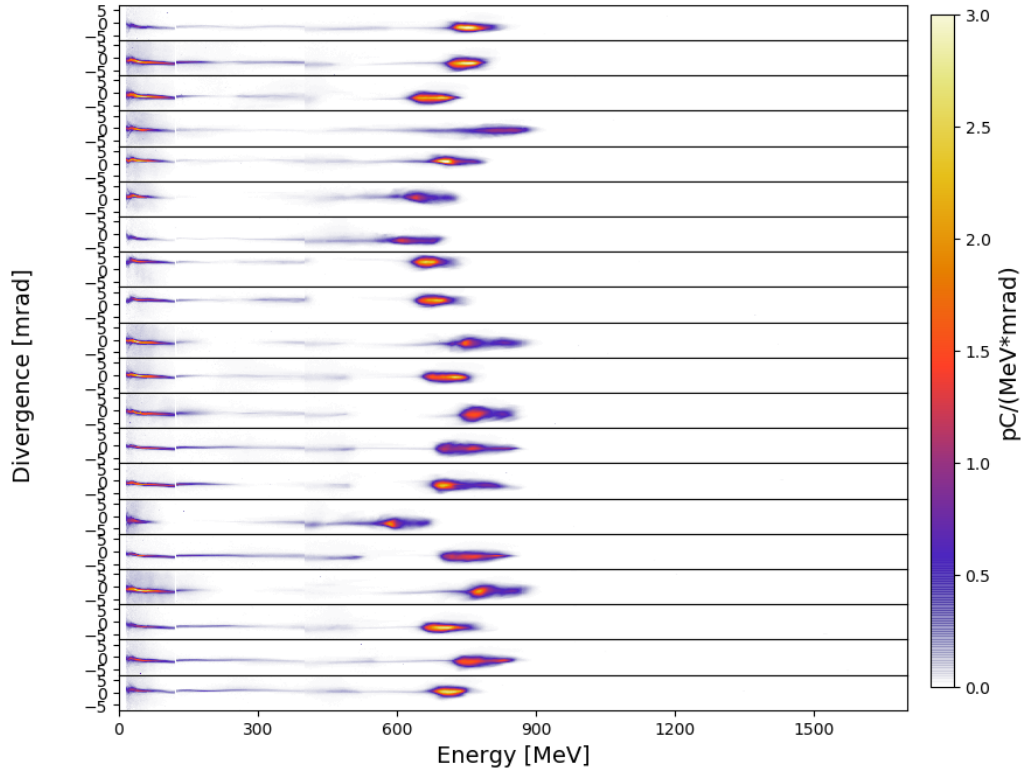
Driver depletes

Witness looses energy

Simulations provided by J. Zirkelbach

Latest experiments

Driver-generation:
- LWFA using ~10J, 30 fs laser
- Self-truncated ionization injection (STII) in a 15mm slit nozzle (H2 + 2% N2)



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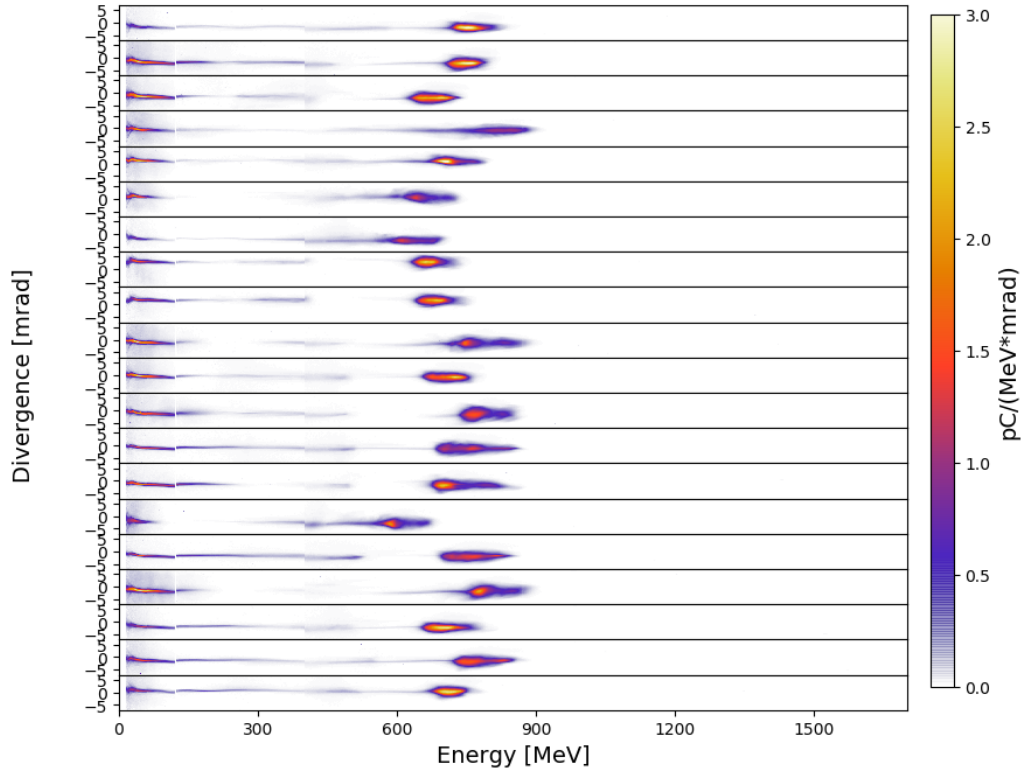
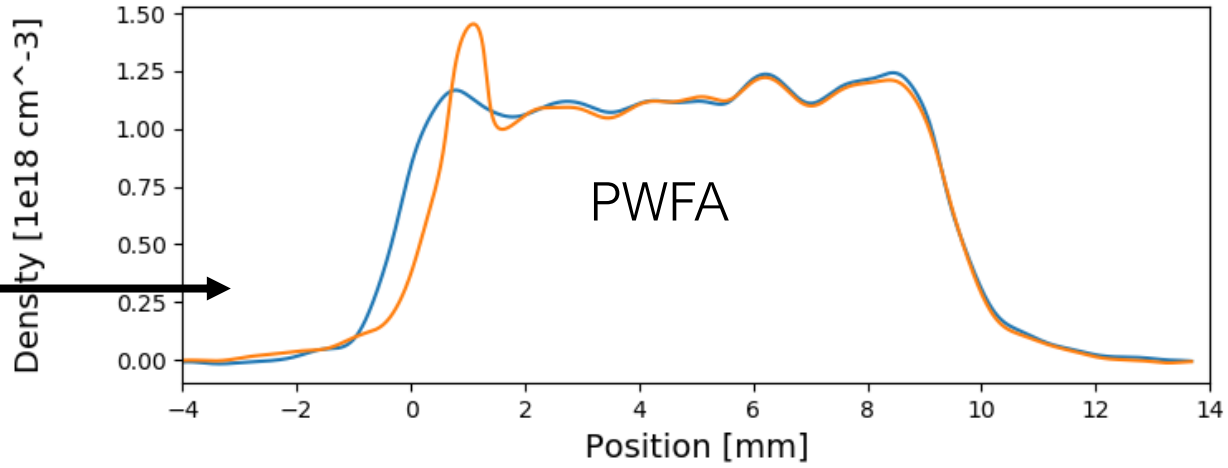


PWFA target:
10mm slit nozzle (H2)
wire-generated shock for injection

From LWFA



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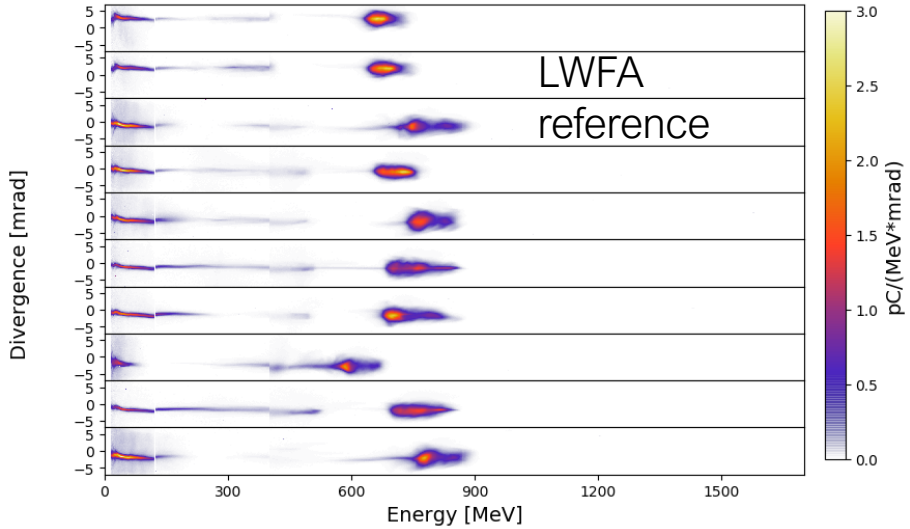

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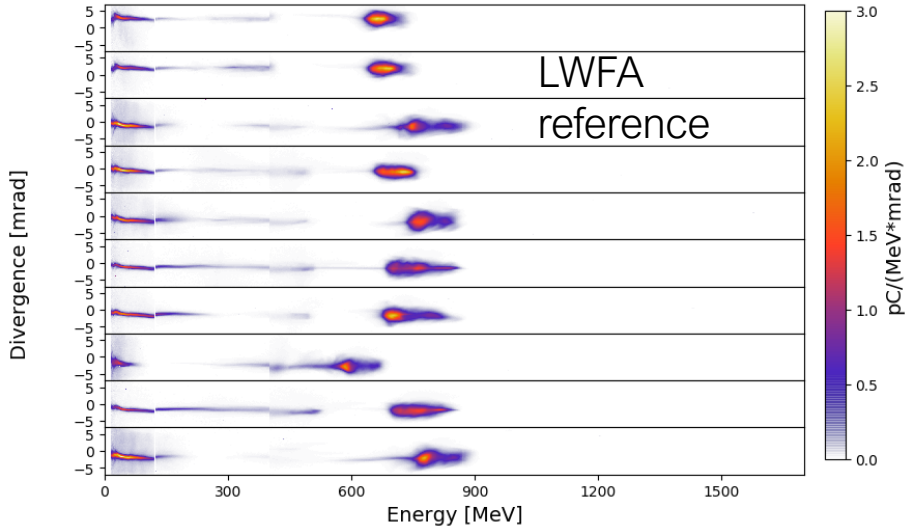

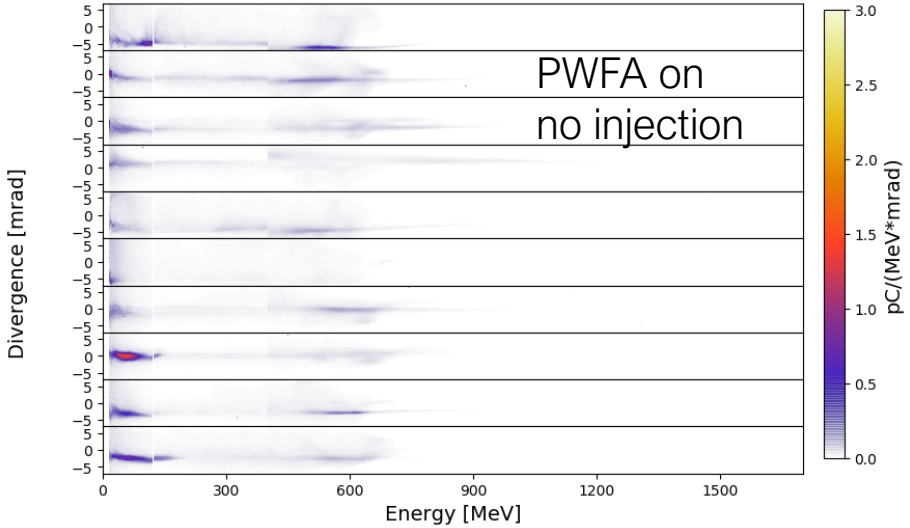

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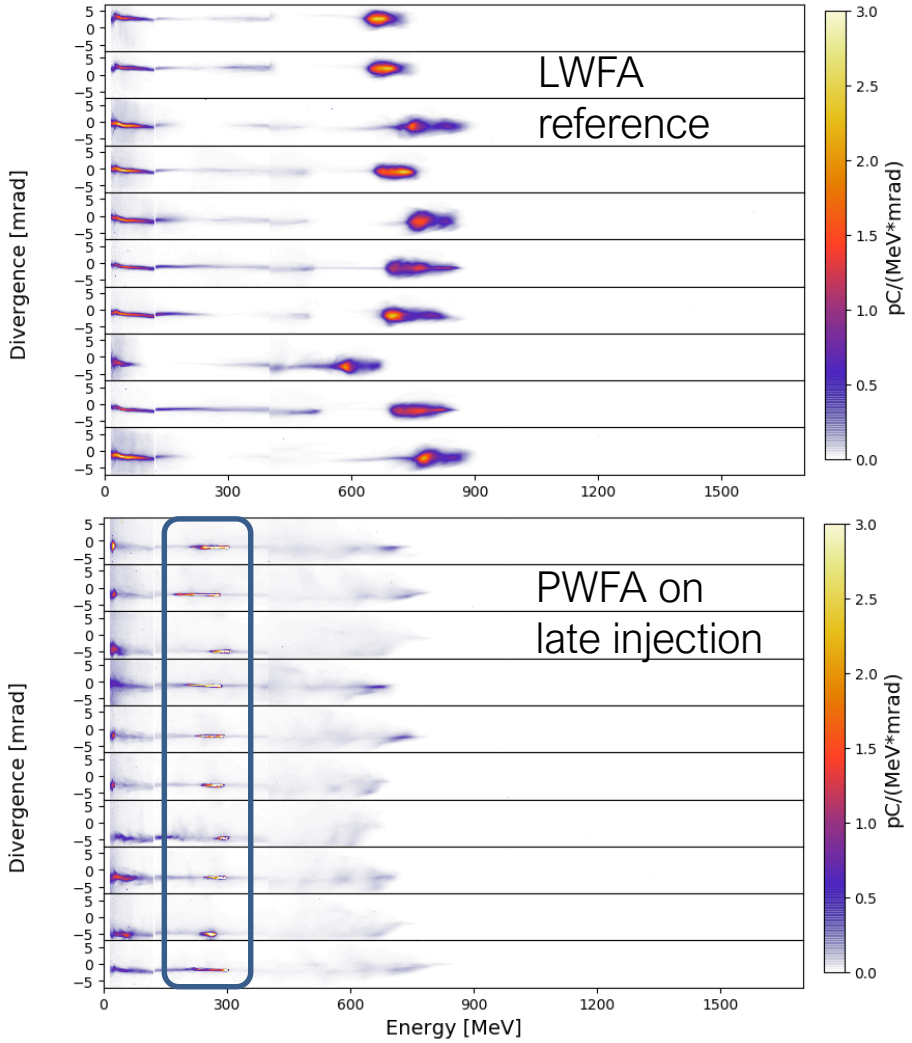

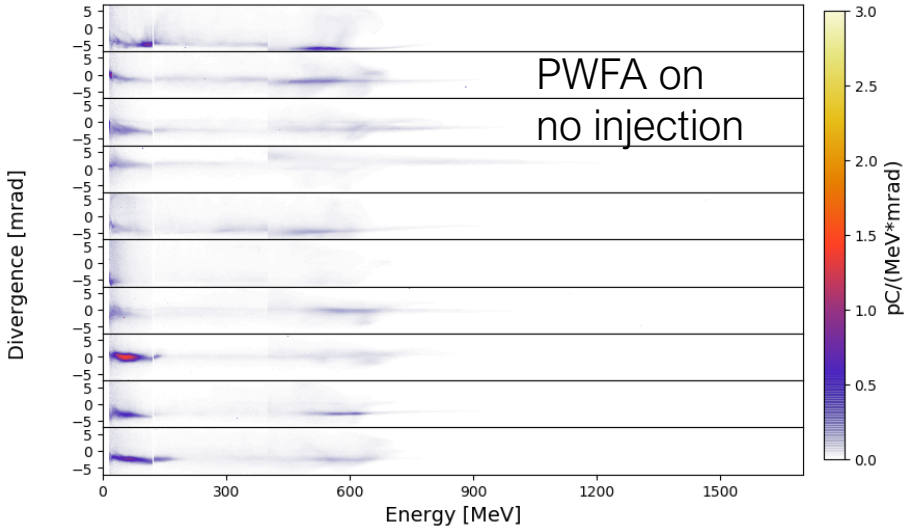

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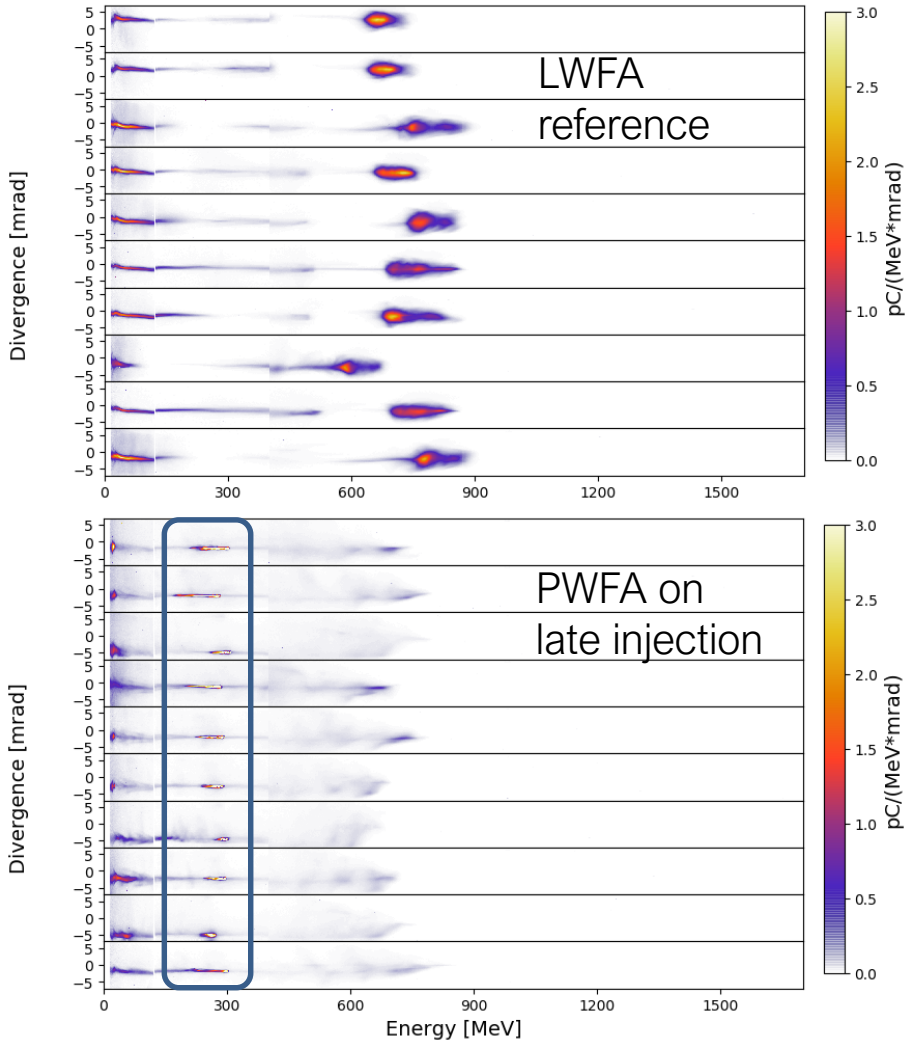

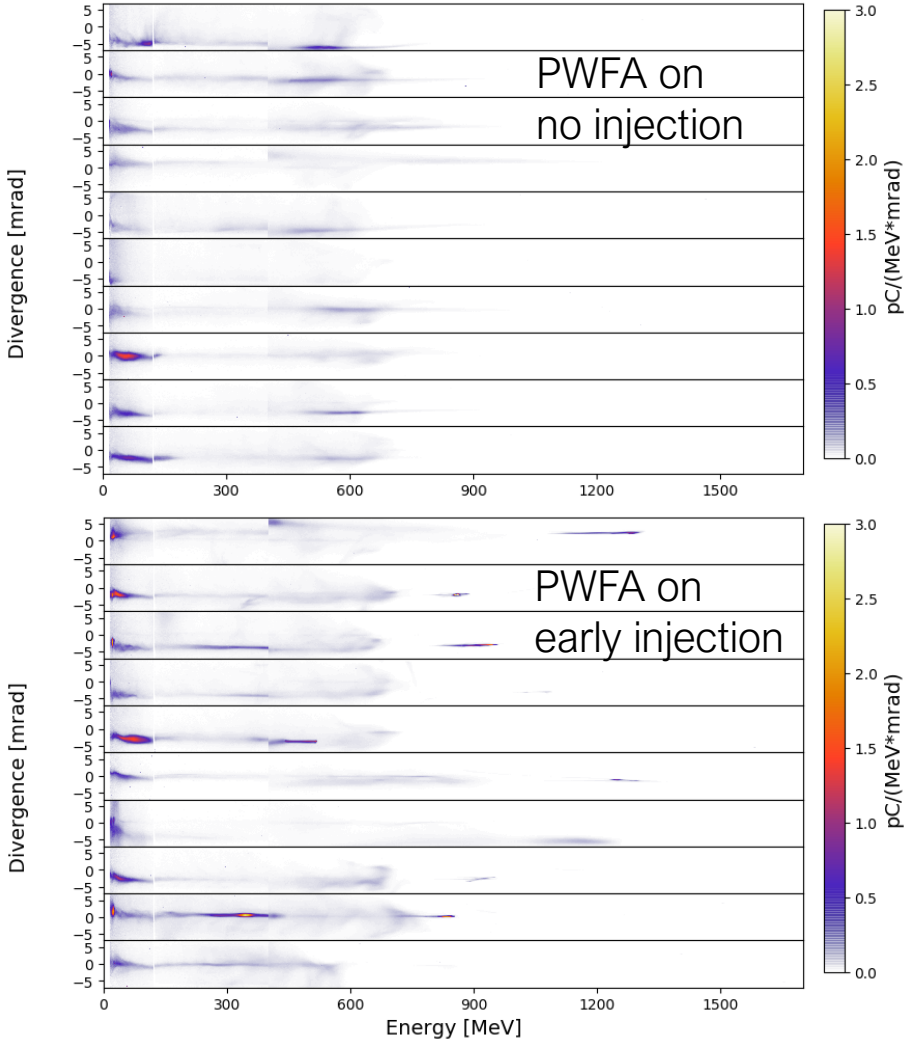

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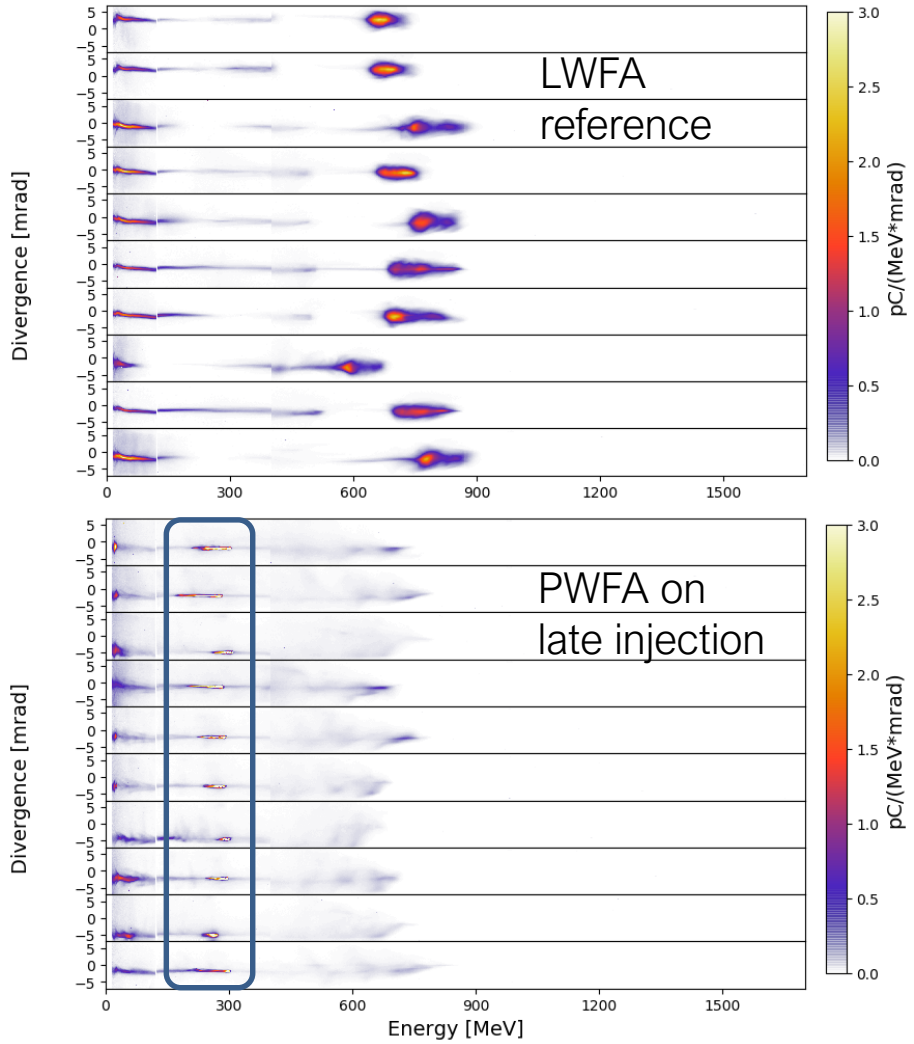

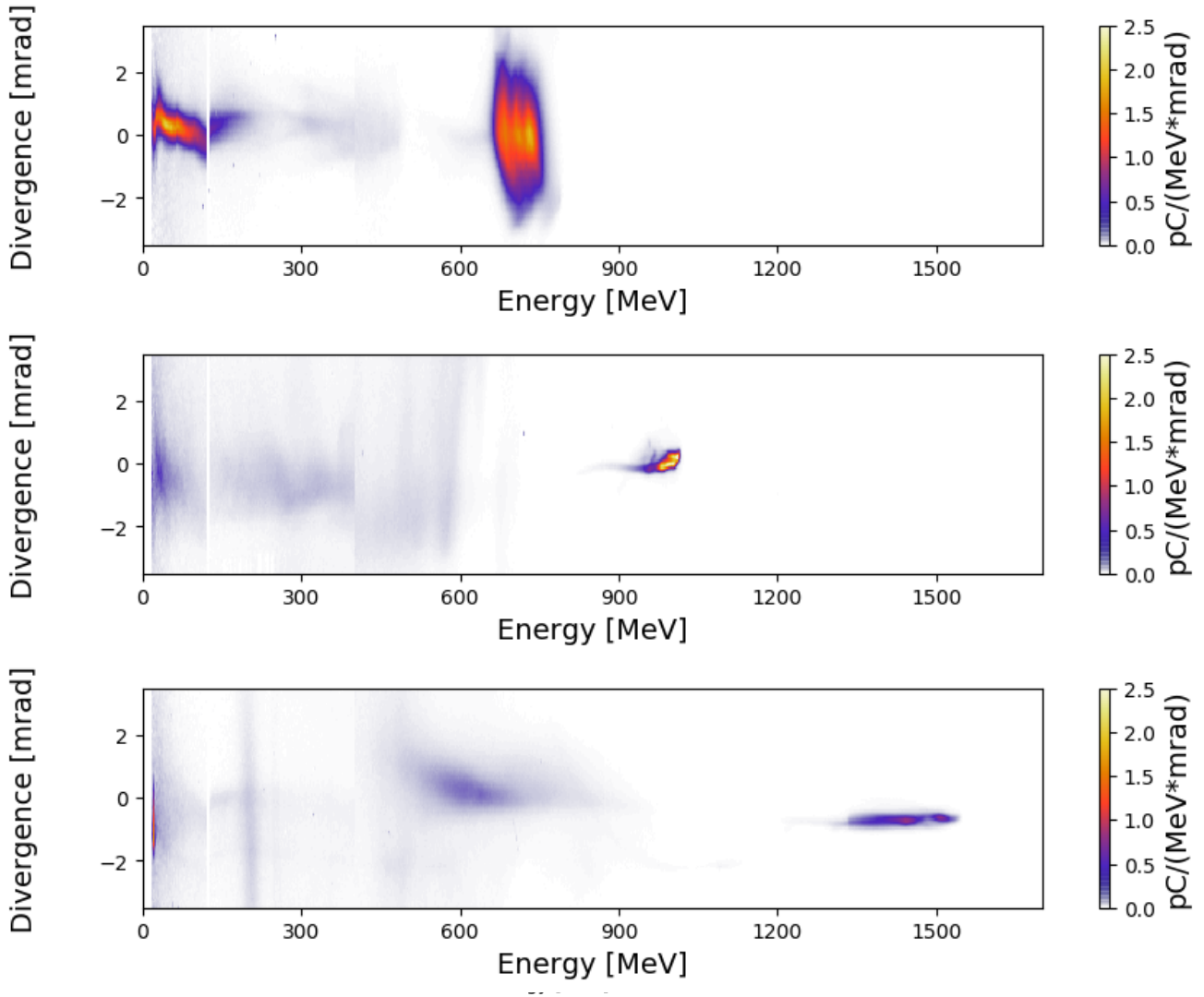

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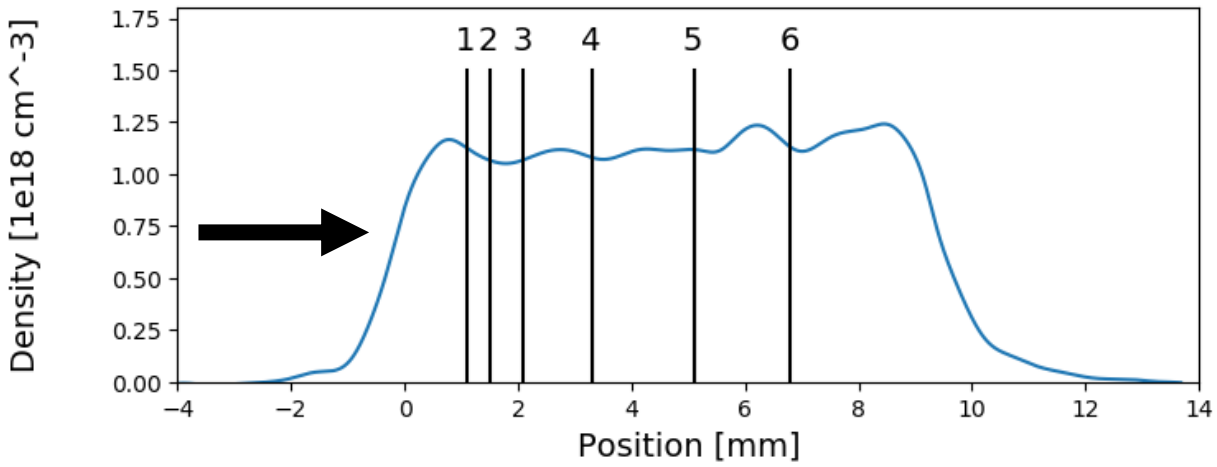
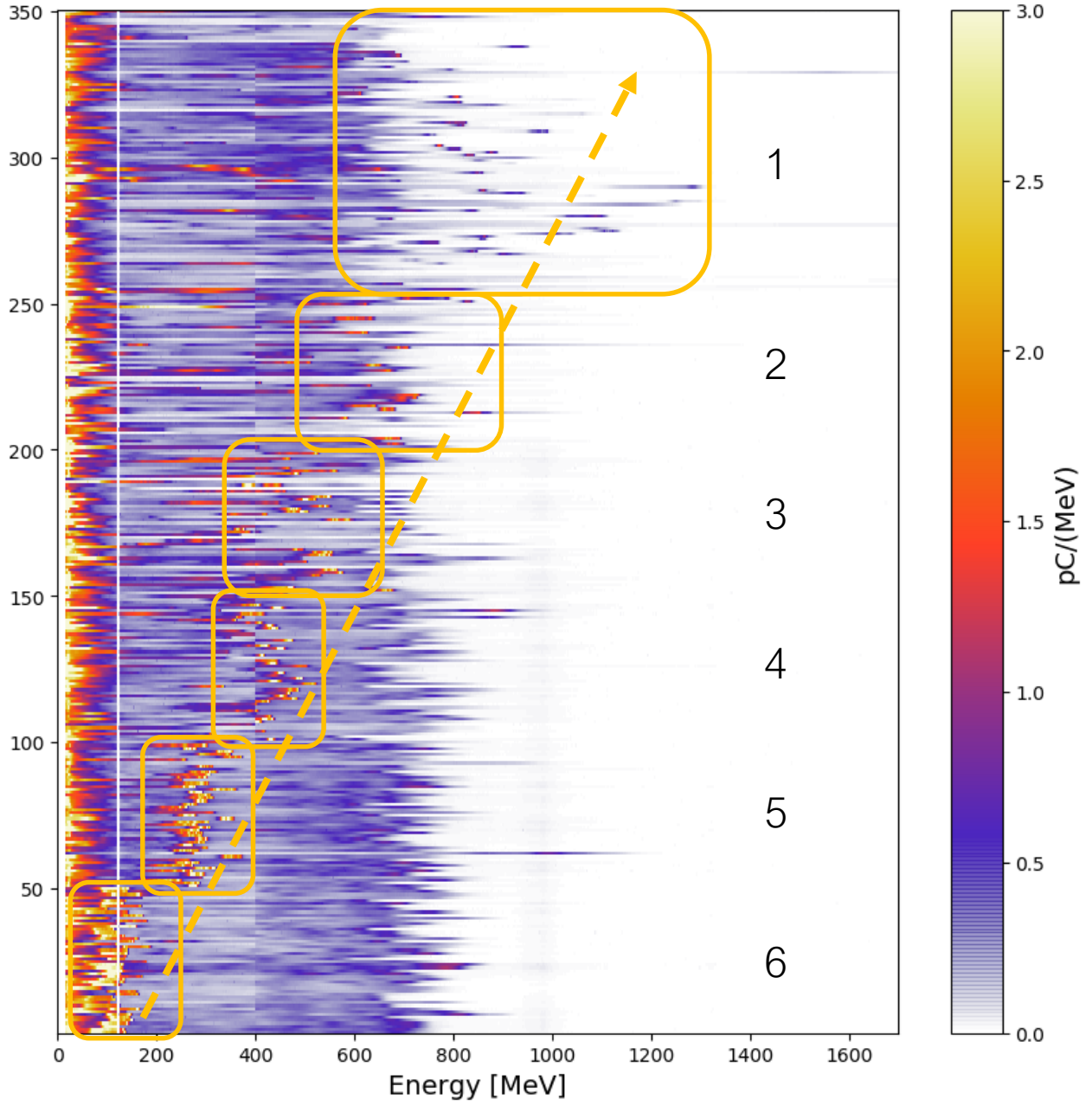
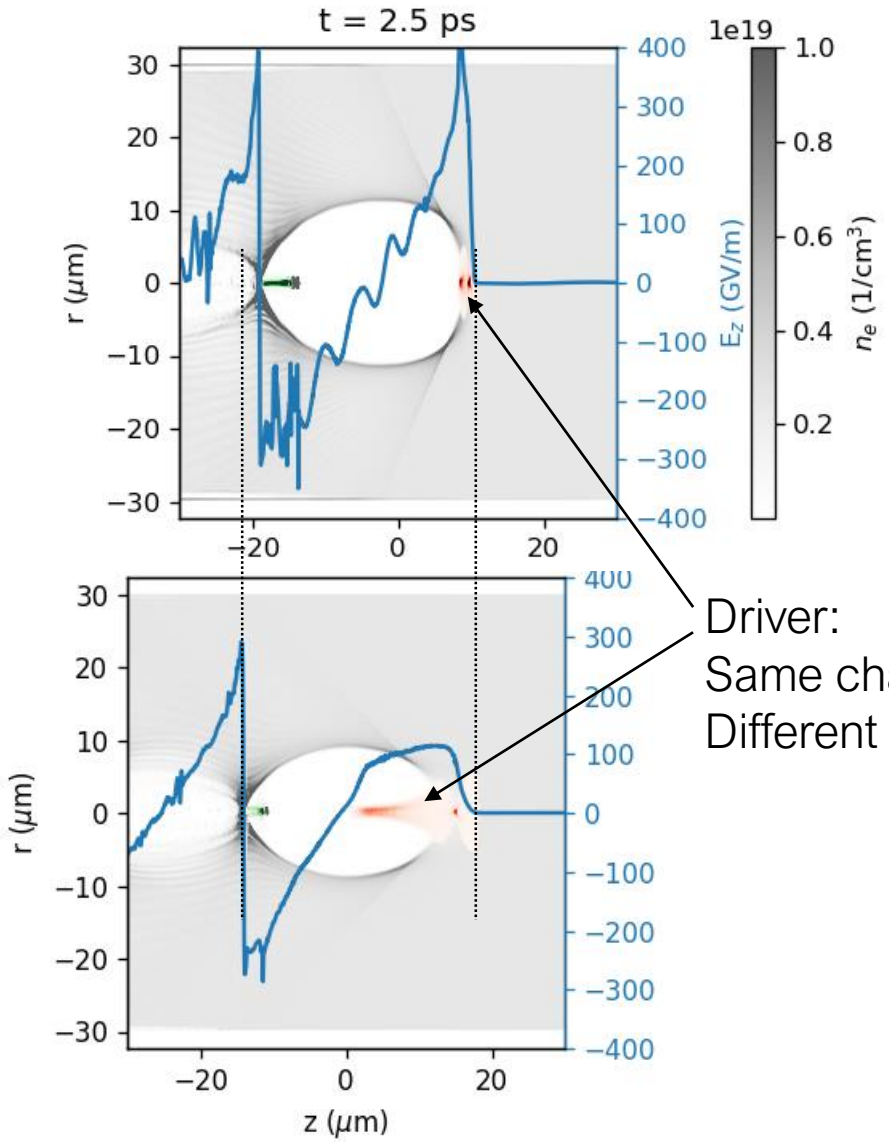




Remaining limitations

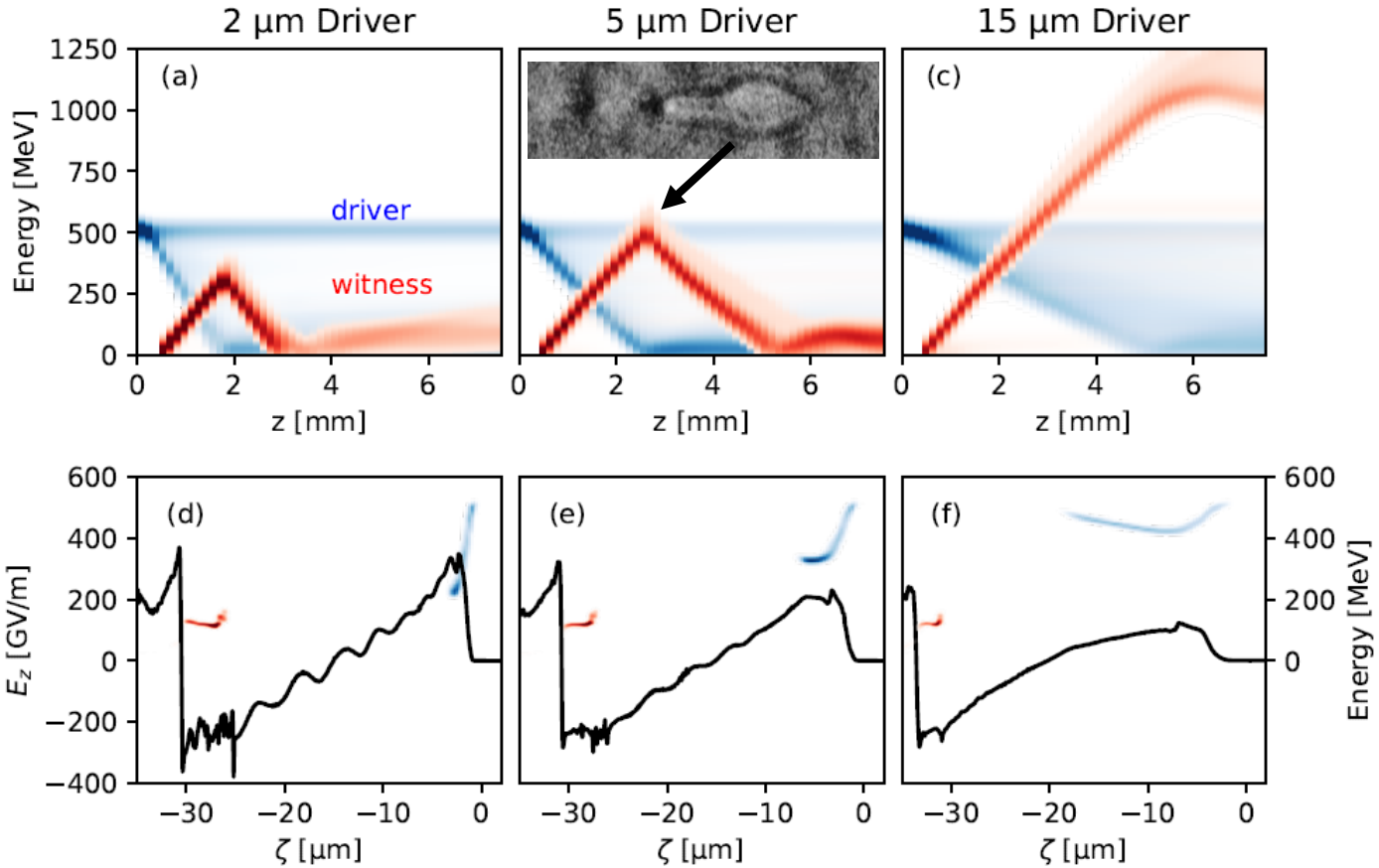
- Drive beam determines wakefield
- Flatter field for longer drive beam
- Sets depletion length



Simulations provided by J. Zirkelbach

Future plans

- Drive beam shaping



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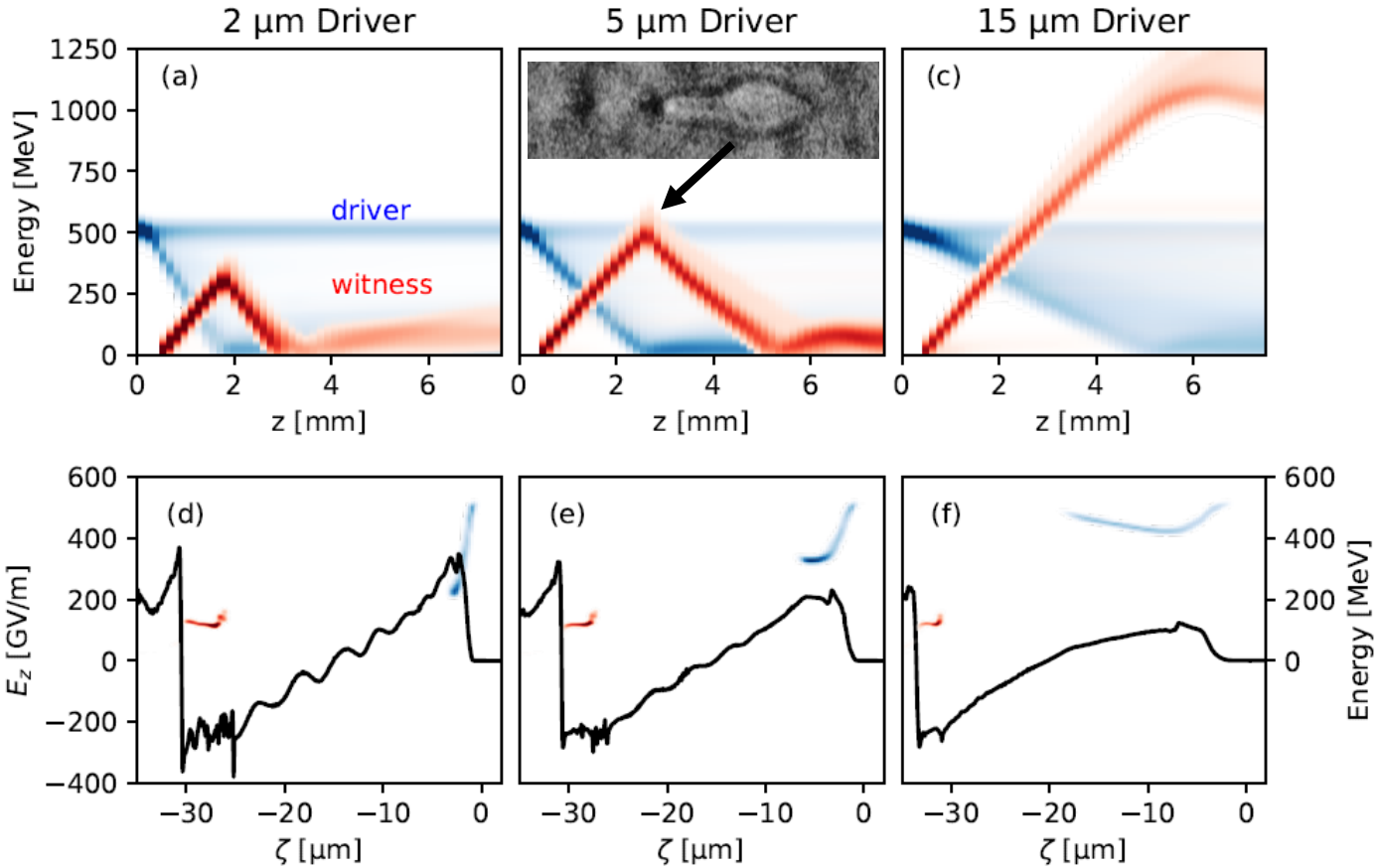


Typical LWFA beams are short [1,2] :
~5-15 fs/~2-5µm

Not ideal for our densities
of ~2x10^{18} 1/cm^3

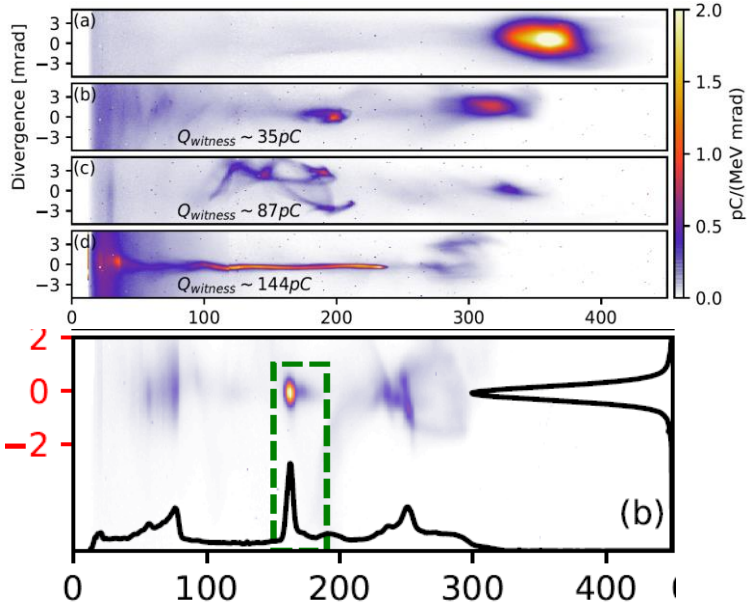
Experiments at higher density
unsuccessful

-> Generate longer drive beams

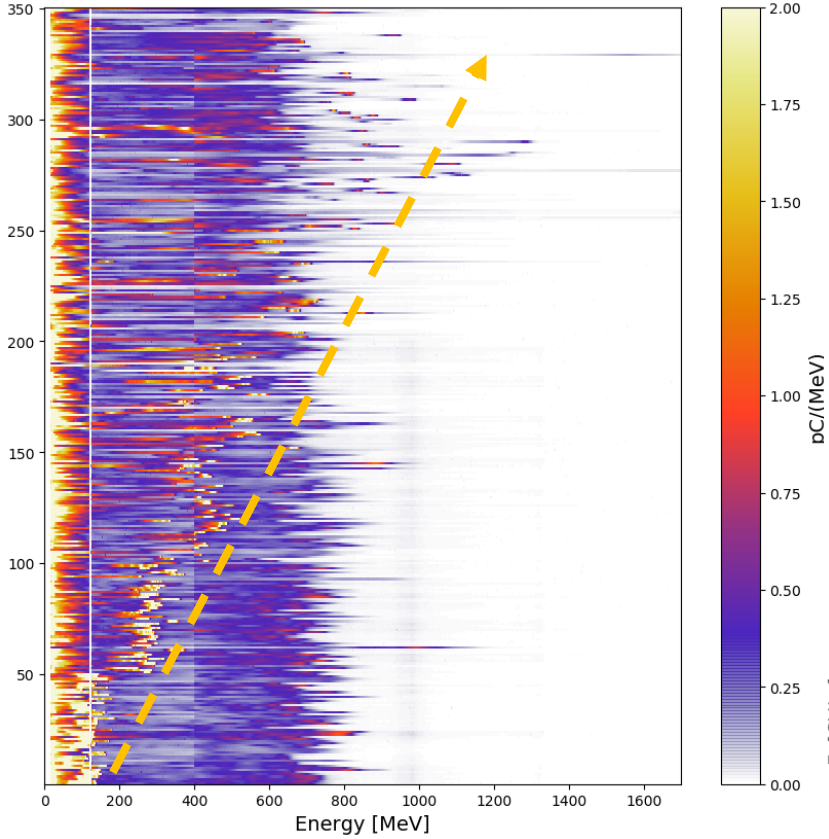
[1] Heigoldt, Phys.Rev.A.B., 2014
[2] LaBerge, Nat.Phot., 2024

Questions?

High-quality beams,



accelerated to high energies,



and still ideas to improve!