

Electron production with Copper photocathodes

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Motivation

AWAKE run2c parameters	beam energy (MeV)	bunch charge (pC)	emittance (mm · mrad)
injector 1: seeding e-line	18	100 - 600	2 - 5
injector 2: witness e-line	150	100	2

“Update on electron sources”, AWAKE Coll. Meeting, March 2025

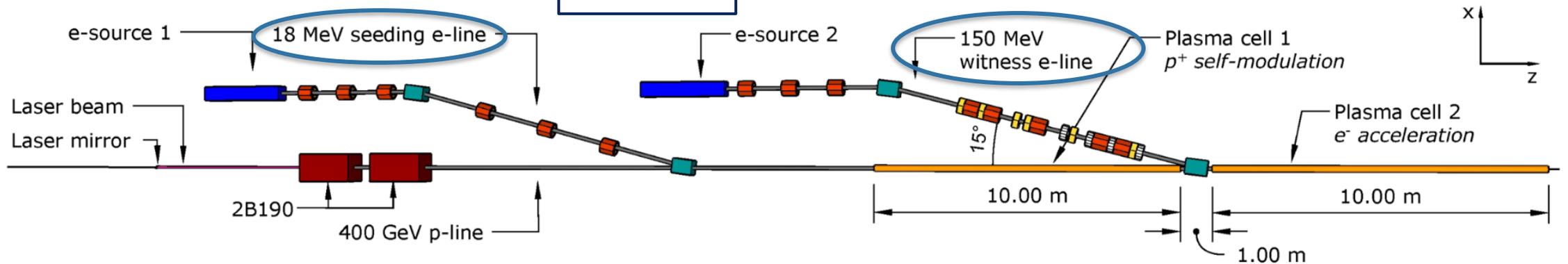


- Cs₂Te as baseline as in run2b
- Cu photocathodes OK for commissioning phase?

10⁻¹¹ mbar

10⁻⁸ mbar

Cu backplate as electron source:
Charge production tests at CTF2 showed single bunch charge up to 800 pC



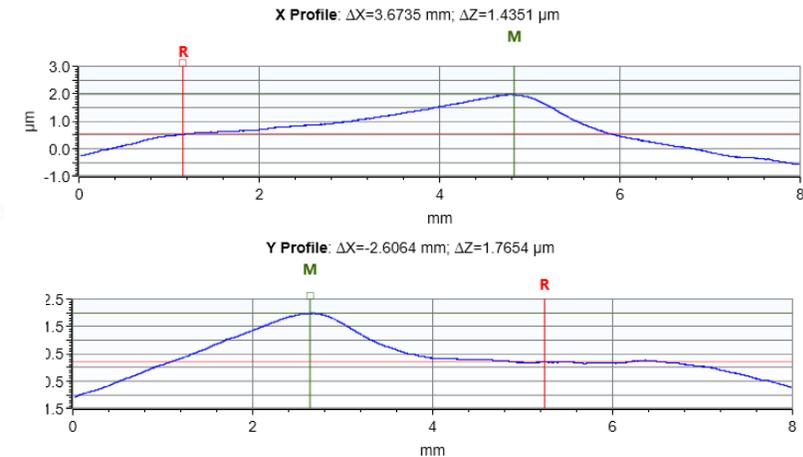
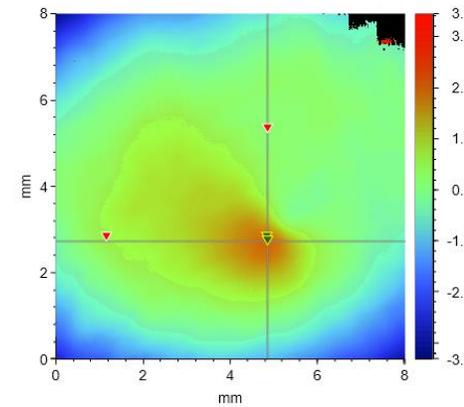
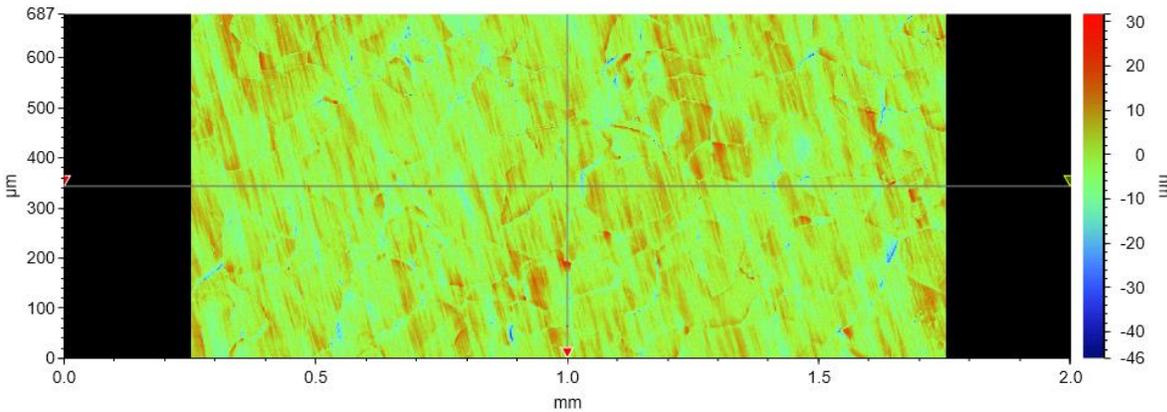
R. Ramjiawan et al., “Design of the proton and electron transfer lines for AWAKE Run 2c”, 2023

Outlook

- Metrology, installation and conditioning
- Experimental setup: the AWAKE UV laser beam delivery
- Electron production at different pulses duration
- Emittance measurements
- Conclusions

Copper photocathode selection and installation

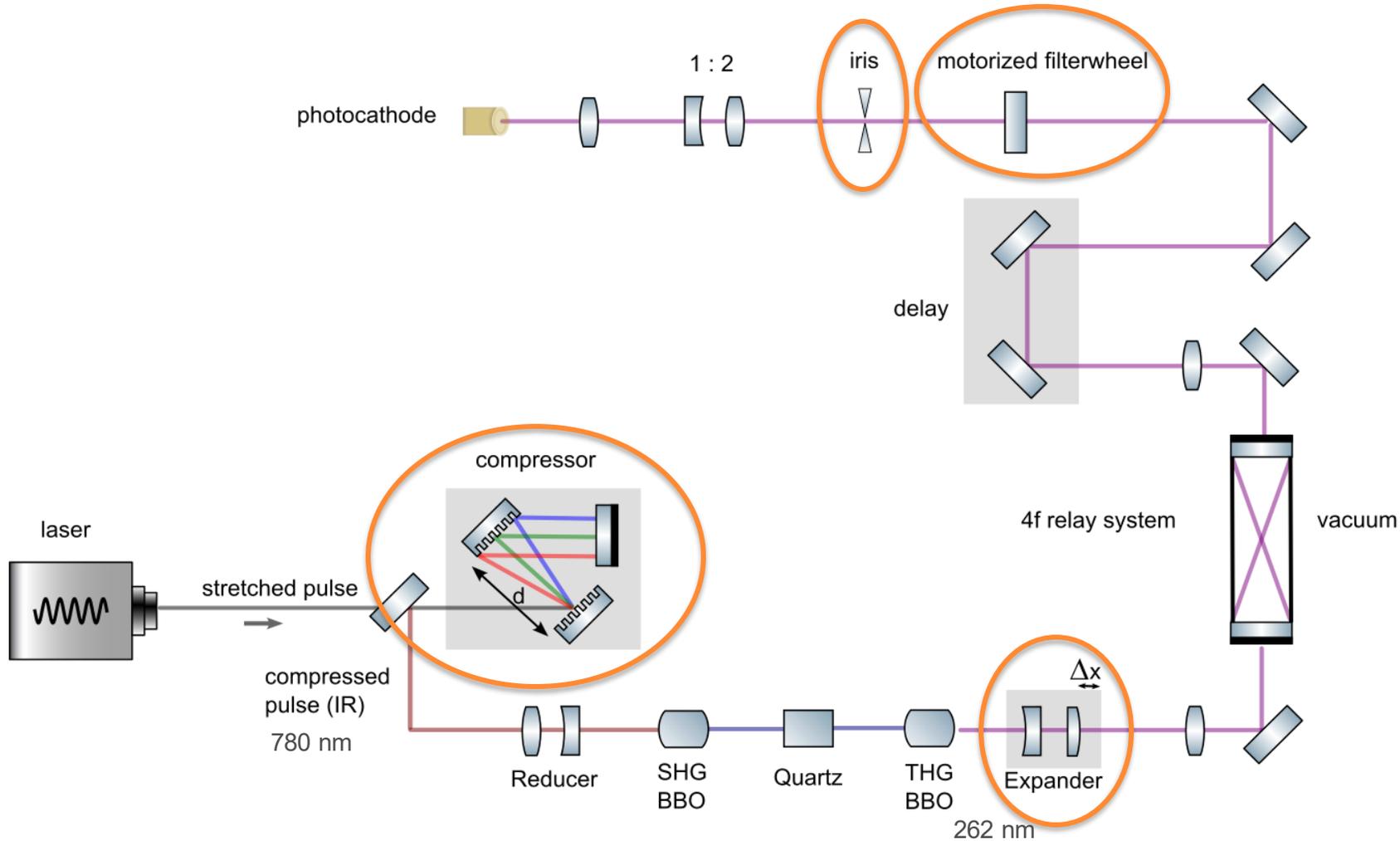
- Metrology study on different plugs to assess conformity (roughness and peak to valley)
 - Average surface roughness $R_a < 0.02 \mu\text{m}$: mirror-like surface
 - Acceptable peak to valley



- Installation (UHV transport carrier connection, removal and storage of Cs_2Te plug)
- Conditioning (Steffen) very smooth, few breakdowns with Cu

EDMS.3290584 J3099629

Optical scheme of UV laser beam delivery



Tunable “knobs”:

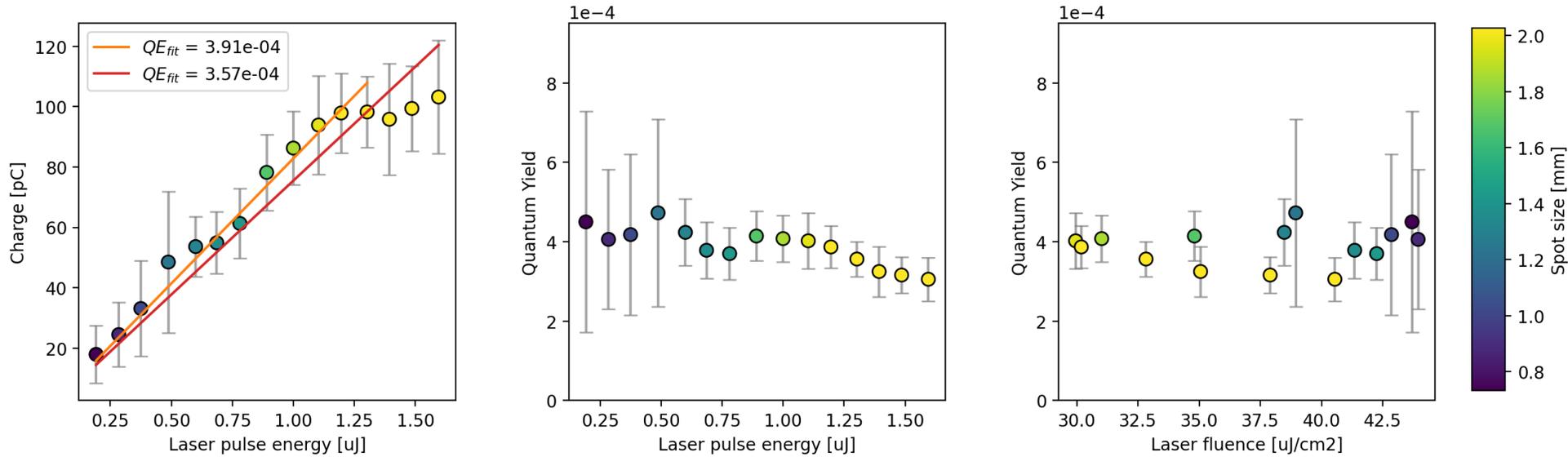
- compressor (d) :
➔ pulse length
- Telescope (Δx) :
➔ spot on iris
- Iris (motorized aperture):
➔ cut off beam
- Filter wheel:
➔ pulse energy

Copper photocathode tests

1. “Usual” laser conditions, as for Cs₂Te:
 - RMS pulse length = 1.2 ps
 - Maximum attenuable laser pulse energy ~ 1.6 uJ
2. Increasing laser pulse energy by changing pulse duration:
 - Compressor retuned to shortest pulses: ~100 fs
 - Maximum attenuable laser pulse energy ~ 8.5 uJ
3. Adjust UV telescope to tune photon density:
 - Vary fluence to improve charge production and emittance

1. "Usual" laser conditions

- Start testing with the same laser conditions as used for Cs₂Te photocathodes
- We vary the incident laser energy using a motorized iris to change the laser spot size



Charge production: 120 pC

Quantum yield: $\sim 4 \cdot 10^{-4}$ @ 262 nm

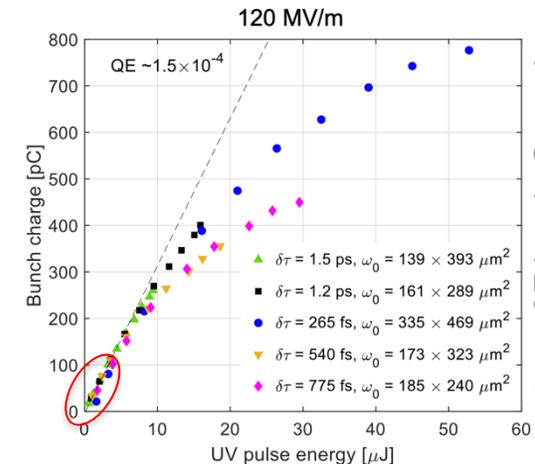
No saturation

To compare:

- QE for Cu photocathode at 266 nm: 10^{-5} to 10^{-4}
- Recent Cu test at CTF2 at 257 nm: $QE \sim 1.5 \cdot 10^{-4}$

$$QE = \frac{\# \text{ electrons}}{\# \text{ photons}}$$

$$= \frac{Q}{q_e} \cdot \frac{h \cdot \nu}{E}$$



courtesy of Eduardo Granados

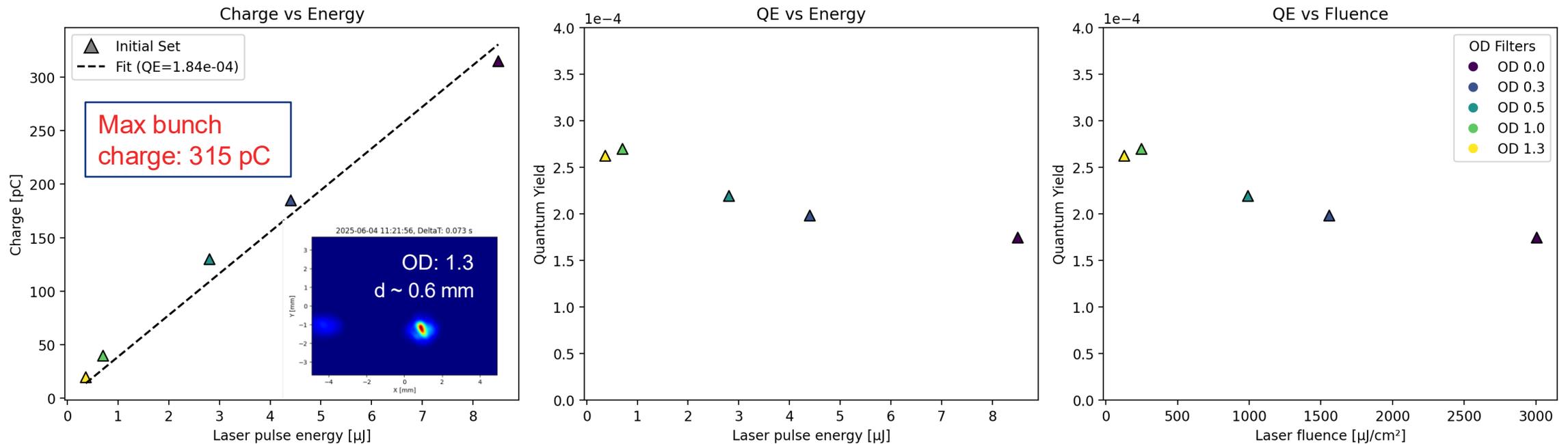
2. Increasing laser energy by changing pulse duration

~100 fs
8.5 μJ

Higher intensity
(higher energy + shorter pulse)



- quantum yield smaller (space charge, beam loading)
- higher charge produced



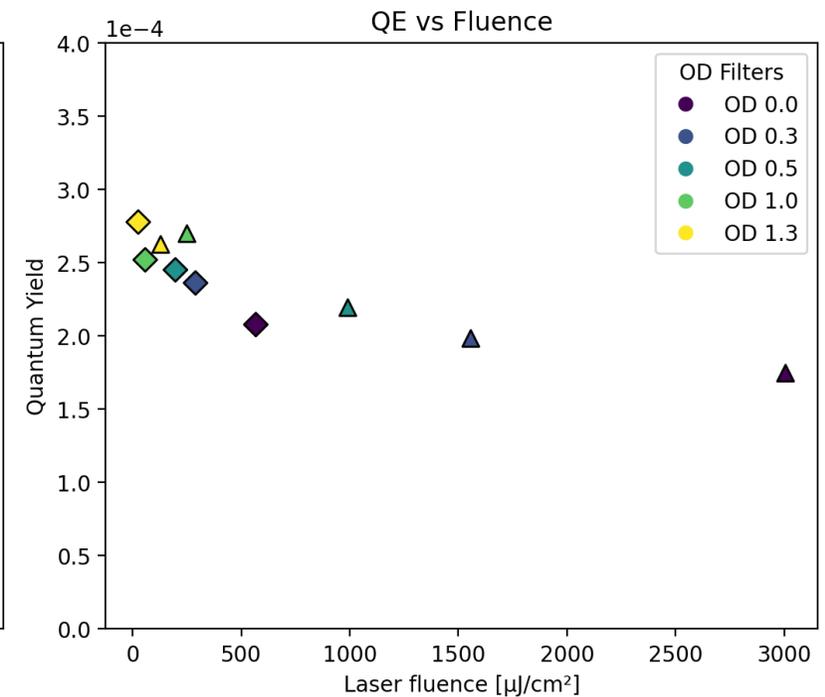
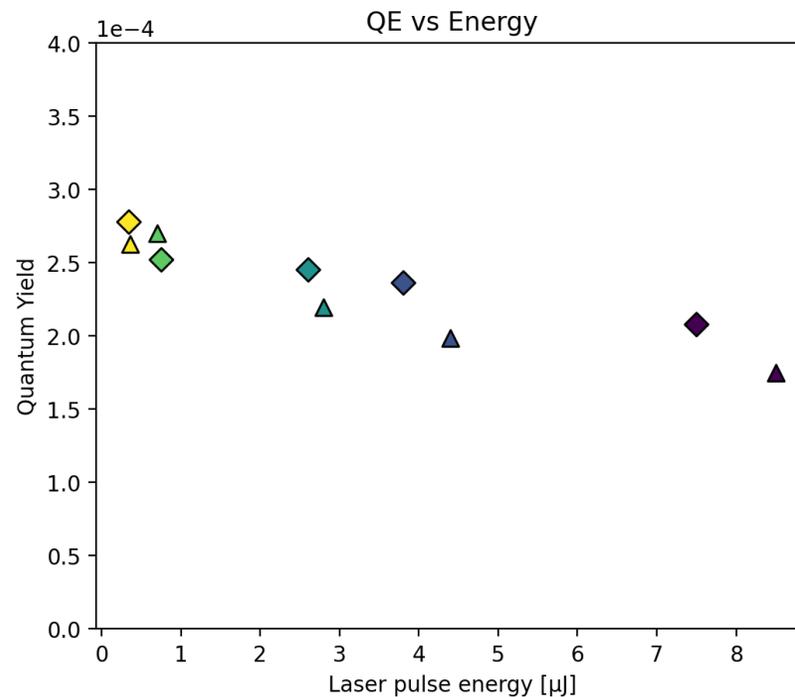
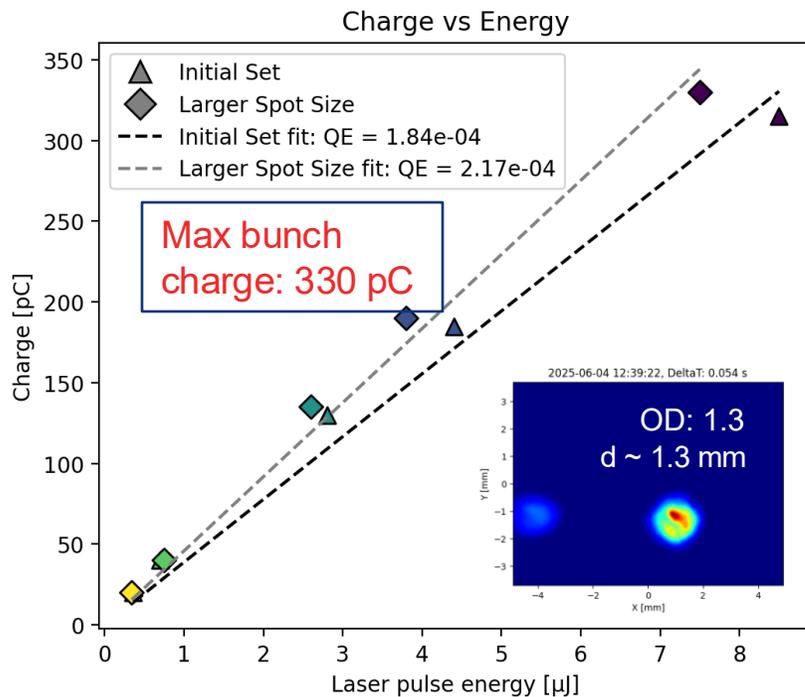
- Iris kept in open position to achieve higher charge
- We apply OD filters to reduce laser fluence

3. Tuning photon density by adjusting the telescope

Larger spot size

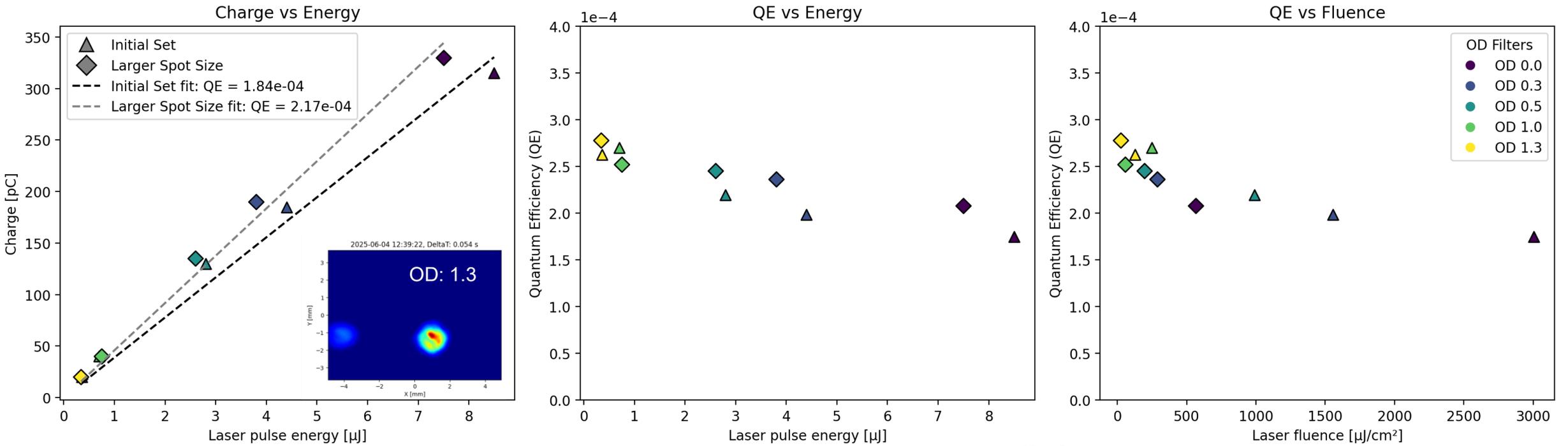


Lower photon density → lower fluence → higher QE?



Extracted charge increases only slightly.

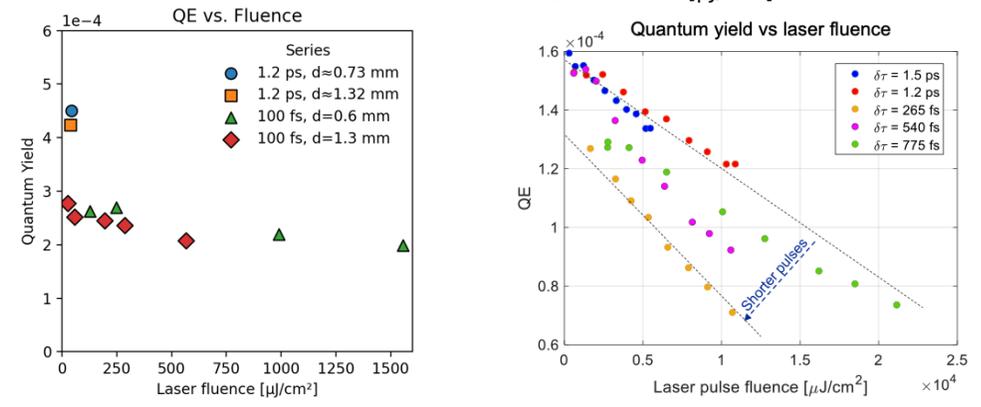
3. Tuning photon density by adjusting the telescope



Maximum charge “only” 330 pC: effect of **short pulse length** (space charge, beam loading)



Need a UV stretcher!



courtesy of Eduardo Granados

Outlook

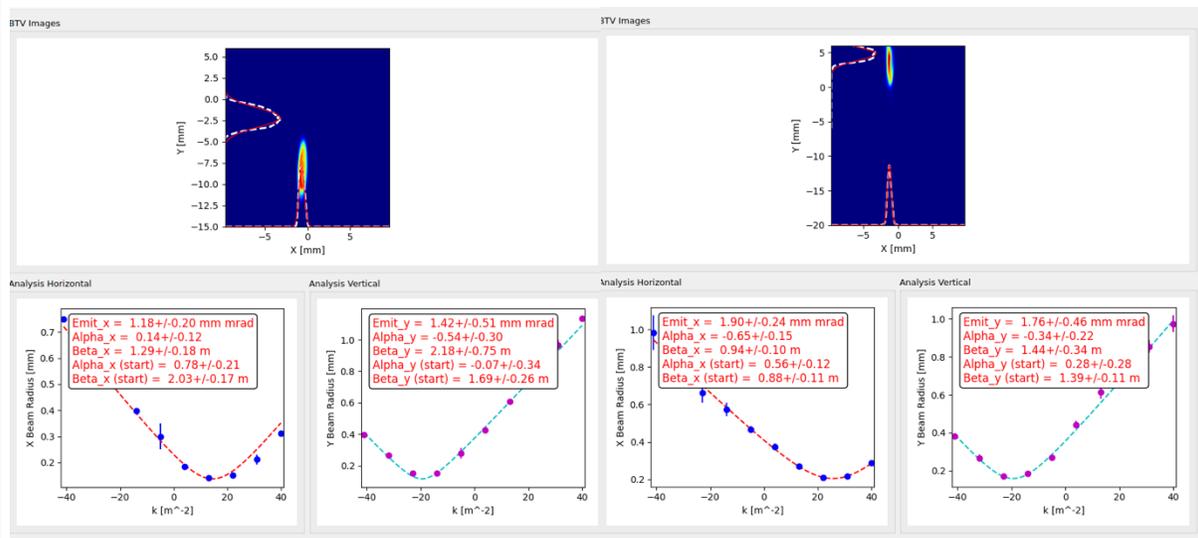
- Metrology, installation and conditioning
- Experimental setup: the AWAKE UV laser beam delivery
- Photocathode tests: electron production at different pulse duration
- **Emittance measurements**
- Conclusions

Emittance scans at different spot sizes

Iris closed

1.2 ps

100 fs



Q= 15 pC
 $\epsilon_{xy} = 1 - 1.5 \text{ mm} \cdot \text{mrad}$

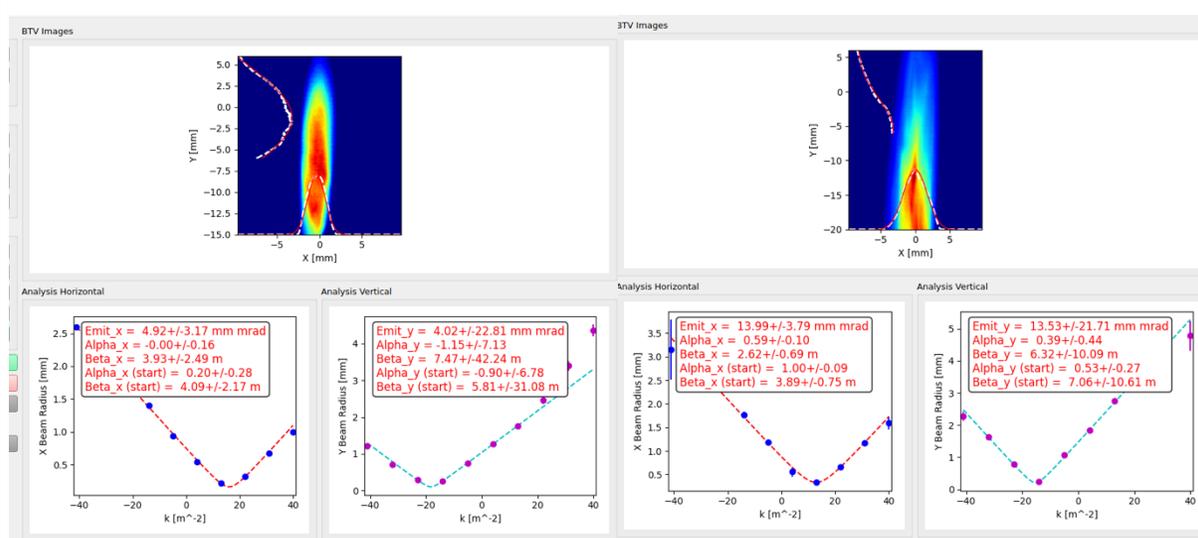
Q= 60 pC
 $\epsilon_{xy} = 2 \text{ mm} \cdot \text{mrad}$

- emittance ✔
- charge ✘

Iris open

1.2 ps

100 fs

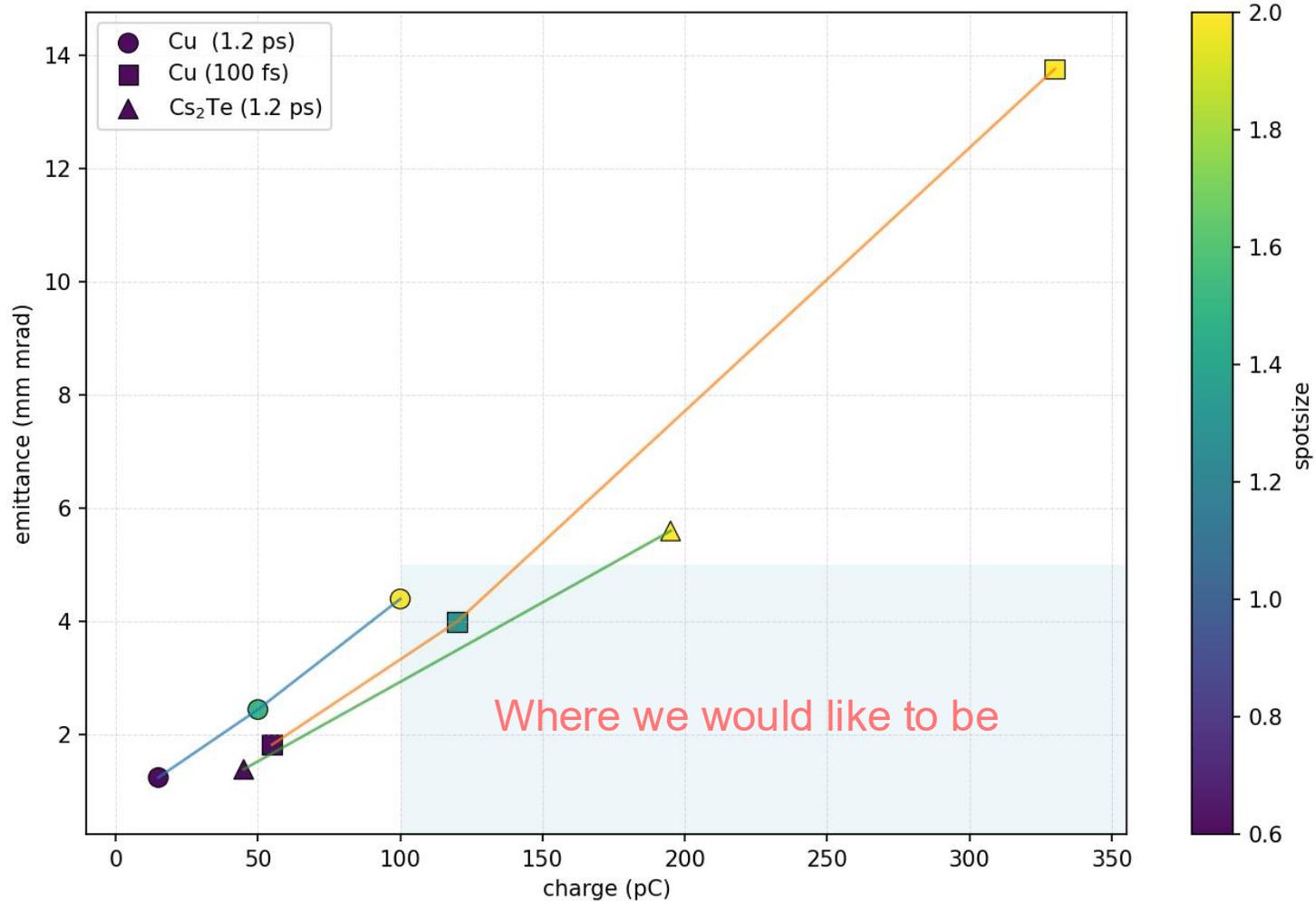


Q= 100 pC
 $\epsilon_{xy} = 4 - 5 \text{ mm} \cdot \text{mrad}$

Q= 330 pC
 $\epsilon_{xy} = 13 - 14 \text{ mm} \cdot \text{mrad}$

- emittance ✘
- charge ✔

Emittance analysis



- Emittance grows rapidly when iris is open, as for Cs₂Te.
- With the current setup we need to open the iris to achieve enough charge.

bunch charge (pC)	emittance (mm · mrad)
100 - 600	2 - 5

Required charge and emittance



More laser power to reach higher energy in a confined laser spot

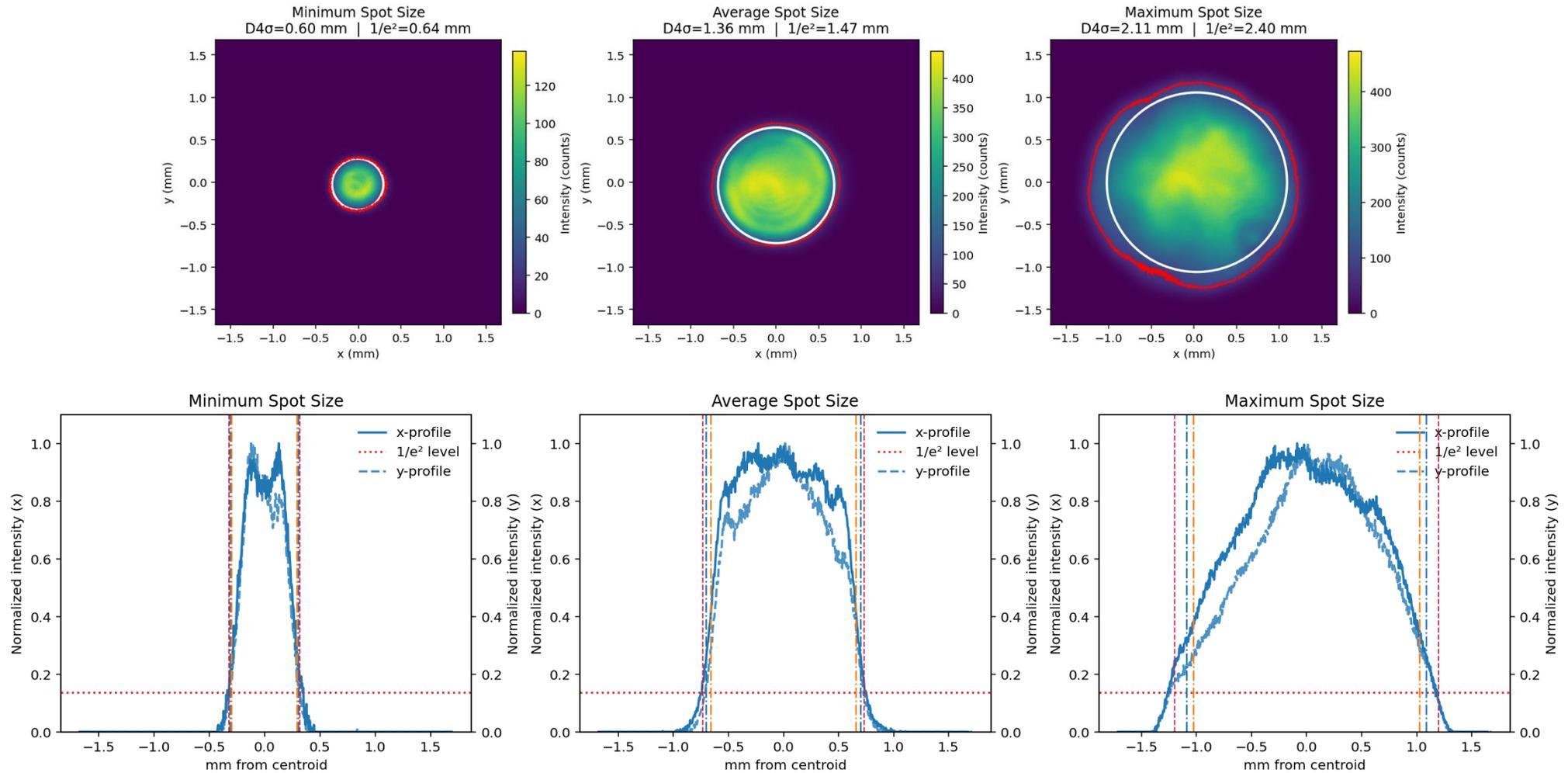
Conclusions

- Good quantum yield with Cu photocathodes: $QE \sim 3 \cdot 10^{-4}$
 - Comparable with tests at CTF2 (slightly higher..)
 - Beam can be transported along the line
 - Stricter laser requirements for Cu photocathodes
 - Enough laser power to have higher energy in a smaller laser spot
 - Operating with short laser pulses degrades QE → UV stretcher needed to increase pulse length
 - UV beam profile needs to be improved → Beam cleaner, beam filtering
- Cu photocathodes can be used as an alternative to Cs_2Te to reduce complexity in the commissioning phase
 - Recommended to keep the capability to integrate Cs_2Te on the e-seeding line

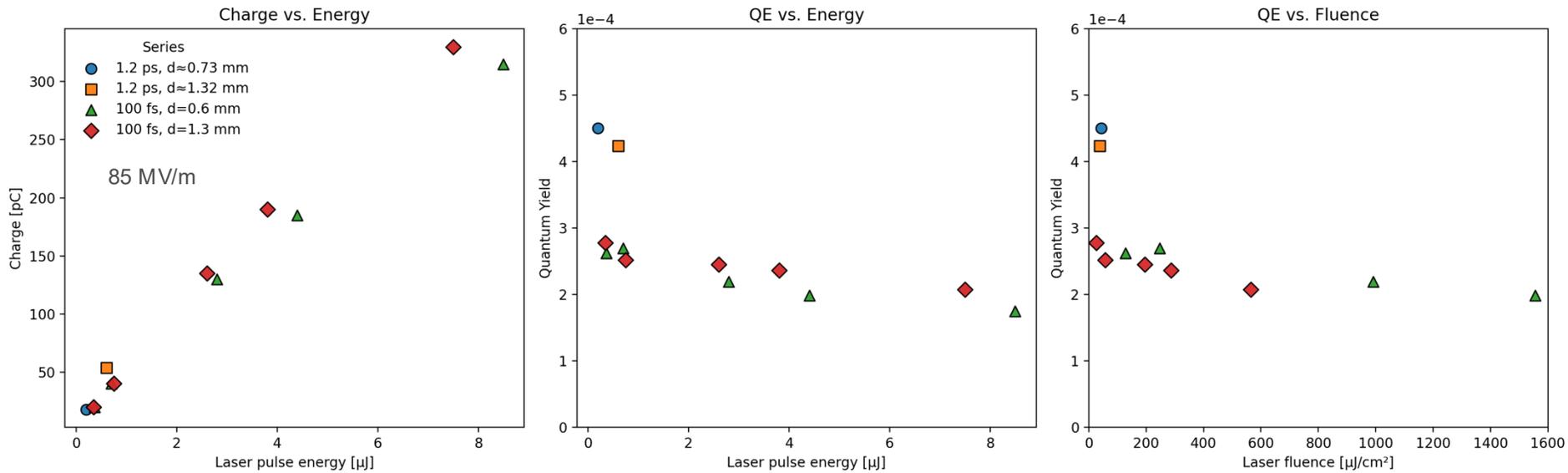
Thank you for your attention



Laser beam spot size: image analysis



Results for different datasets in AWAKE PHIN gun



- Charge production comparable with CTF2 in the same energy range, not yet in saturation regime
- Higher quantum yield in PHIN gun with respect to CTF2 (higher quality Copper cathode?)
- Lower quantum yield at shorter laser pulses
→ need a UV stretcher

CTF2 tests

