Microcoulomb-Class Laser-Plasma Accelerator on OMEGA EP

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[3] C. G. R. Geddes *et al.*, Nature 431, 538 (2004).
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A microcoulomb-class, high-conversion-efficiency laser-plasma accelerator (LPA) was demonstrated on OMEGA EP

- Produced electron beams have:
  - Maximum energies >200 MeV
  - Divergences as low as 32 mrad
  - Charges that exceed 700 nC
  - Laser-to-electron conversion efficiencies up to 11%

- Total charge in the electron beam scales with both a_0 and plasma density

* J. L. Shaw *et al.*, in review Scientific Reports

Collaborators

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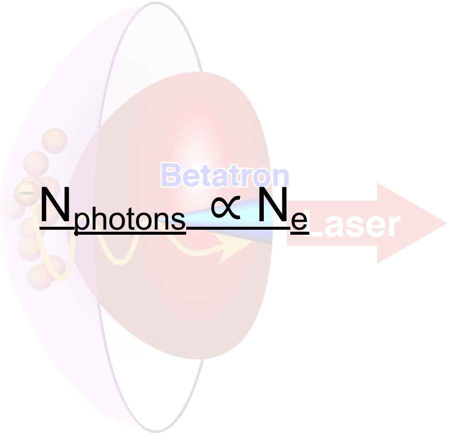
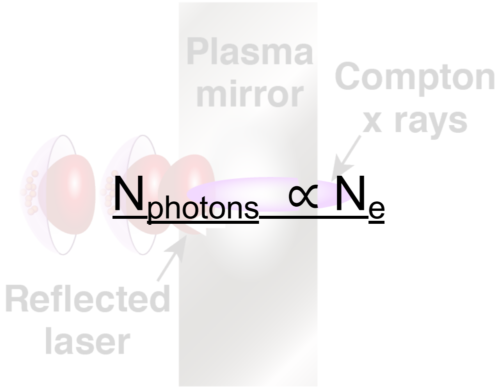
Motivation

LPAs driven by kJ-class lasers can provide compact sources of high-energy electrons for conversion to photons and positrons



$N_{photons} \propto N_e$



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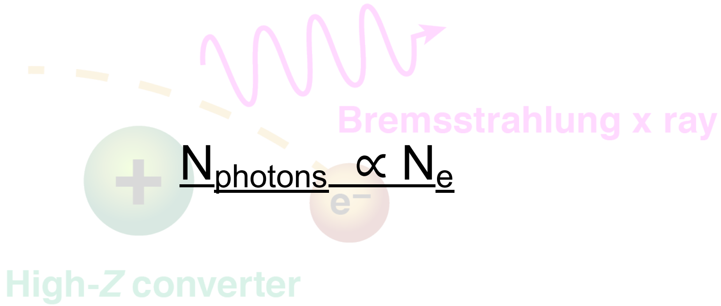

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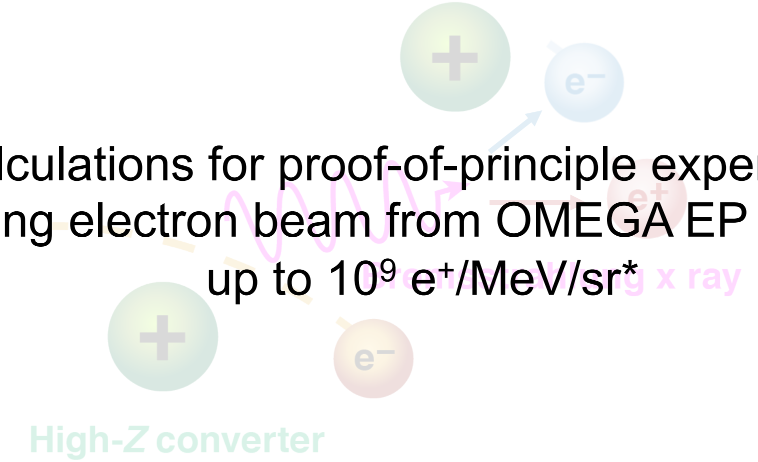
Hard, Bright X Ray Sources

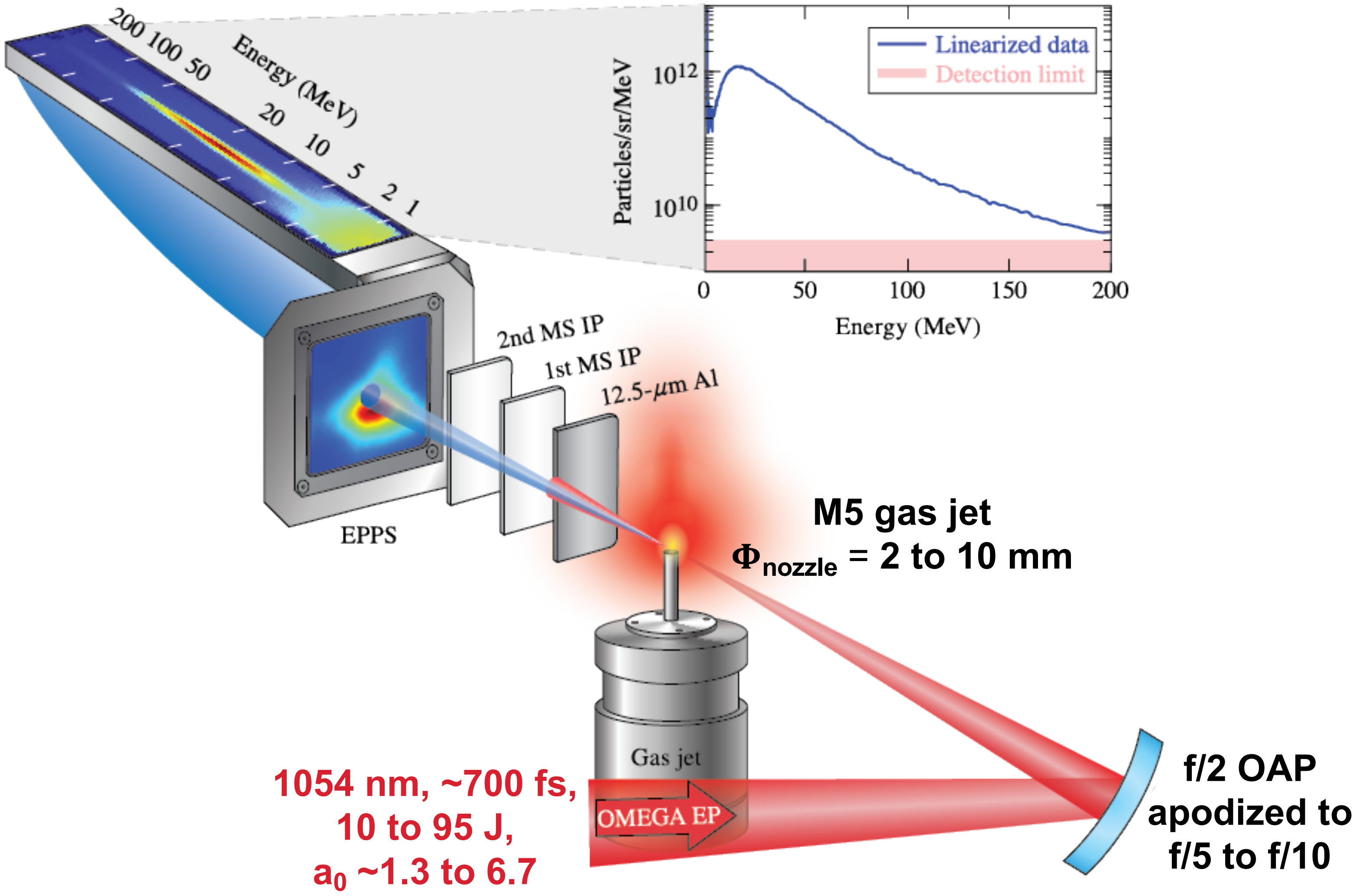


Calculations for proof-of-principle experiments using electron beam from OMEGA EP predict up to 10^9 e^+/MeV/sr*

Positron Sources

*Calculation courtesy G. J. Williams

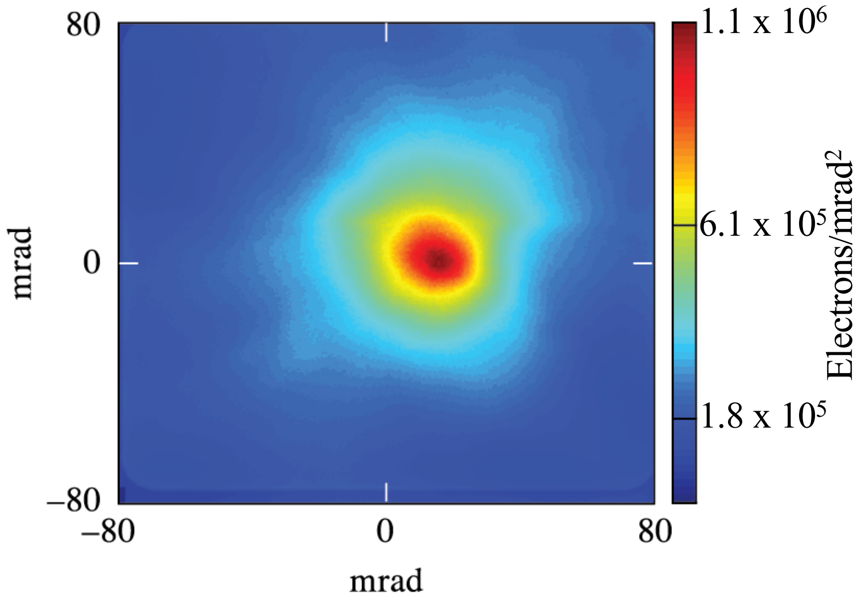
LPA experiments based on self-modulated laser wakefield acceleration (SMLWFA) and direct laser acceleration (DLA) were performed on OMEGA EP



EPPS: electron–positron–proton spectrometer
OAP: off-axis parabola

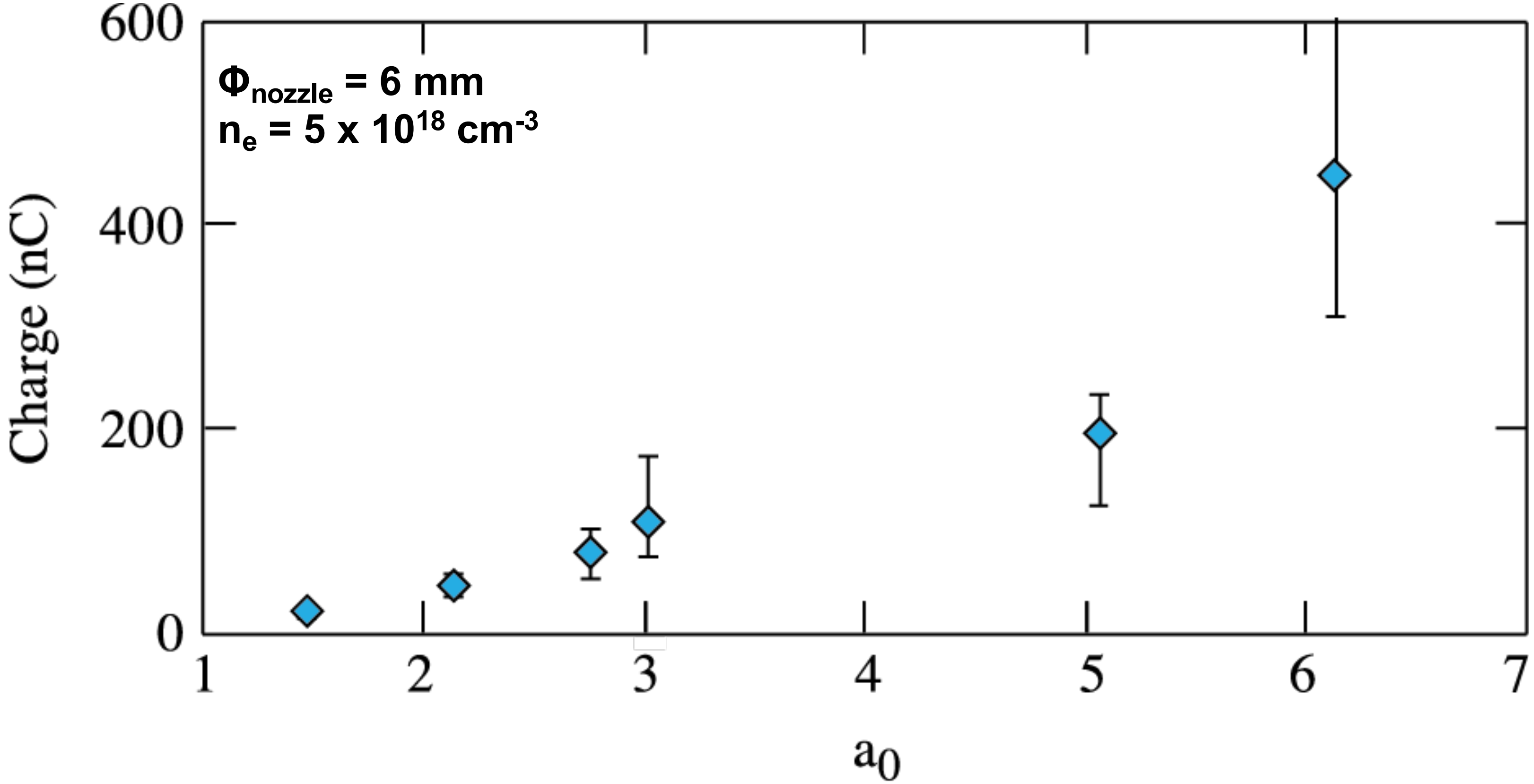
Electron beams with divergences as low as 32 x 39 mrad were measured

Lowest-Divergence
- a_0 = 4.4
- Φ_{nozzle} = 10 mm
- n_e = 1.1 x 10^{19} cm^{-3}
- Pointed 8 mrad



Highest-Charge
- a_0 = 6.6
- Φ_{nozzle} = 6 mm
- n_e = 7.5 x 10^{18} cm^{-3}

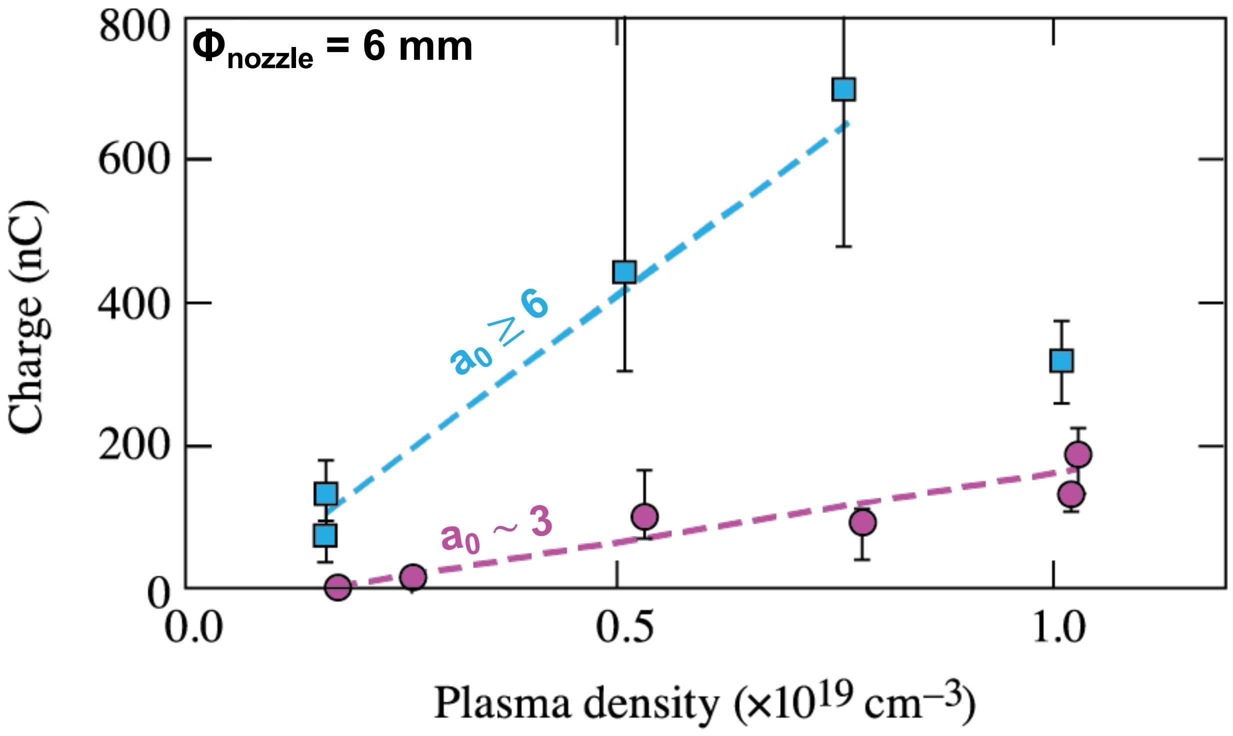
Total charge in the electron beams scales approximately linearly with a_0



Same trend was observed for:

- 6-mm-dia. nozzle at n_e = 1, 2, and 3 x 10^{19} cm^{-3}
- 4-mm-dia. nozzle at n_e = 1 x 10^{19} cm^{-3}
- 10-mm-dia. nozzle at n_e = 0.2, 0.5, 1, and 3.5 x 10^{19} cm^{-3}

The ideal regime for producing high-charge electron beams for this SMLWFA-based LPA is for $n_e \sim 1 \times 10^{19}$ cm^{-3} or less.

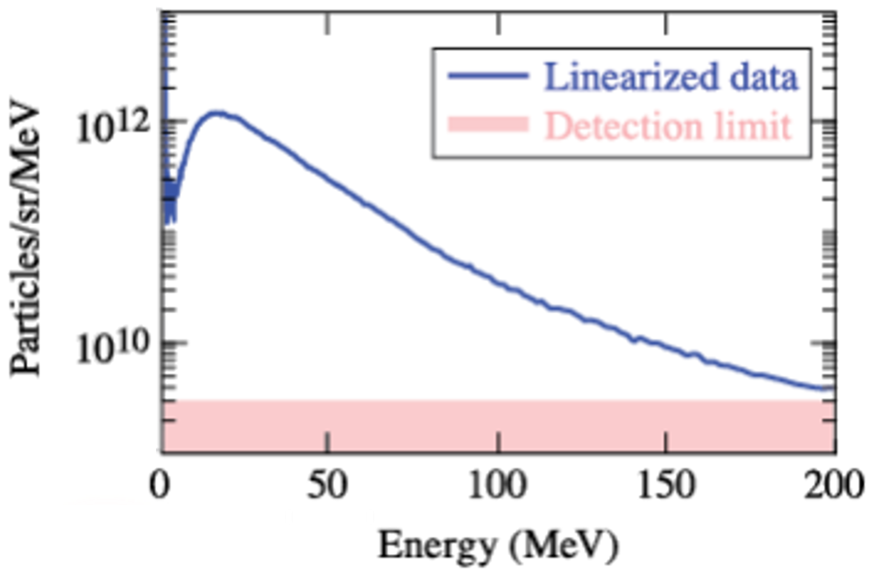


Electron beams with charges up to 707 ± 429/224 nC were measured

Laser-to-electron conversion efficiencies up to 11% were observed

- **The weighted average electron energy of the representative electron spectrum from this experiment is 17.9 MeV**

- **Using this energy, the 707 nC electron beam corresponds to a conversion efficiency from laser energy to electron energy of 11%**



Summary/Conclusion

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- Total charge in the electron beam scales with both a_0 and plasma density

- Electron beams show promise as a path to MeV-class radiography sources and improved flux for broadband sources of interest at high-energy-density science facilities

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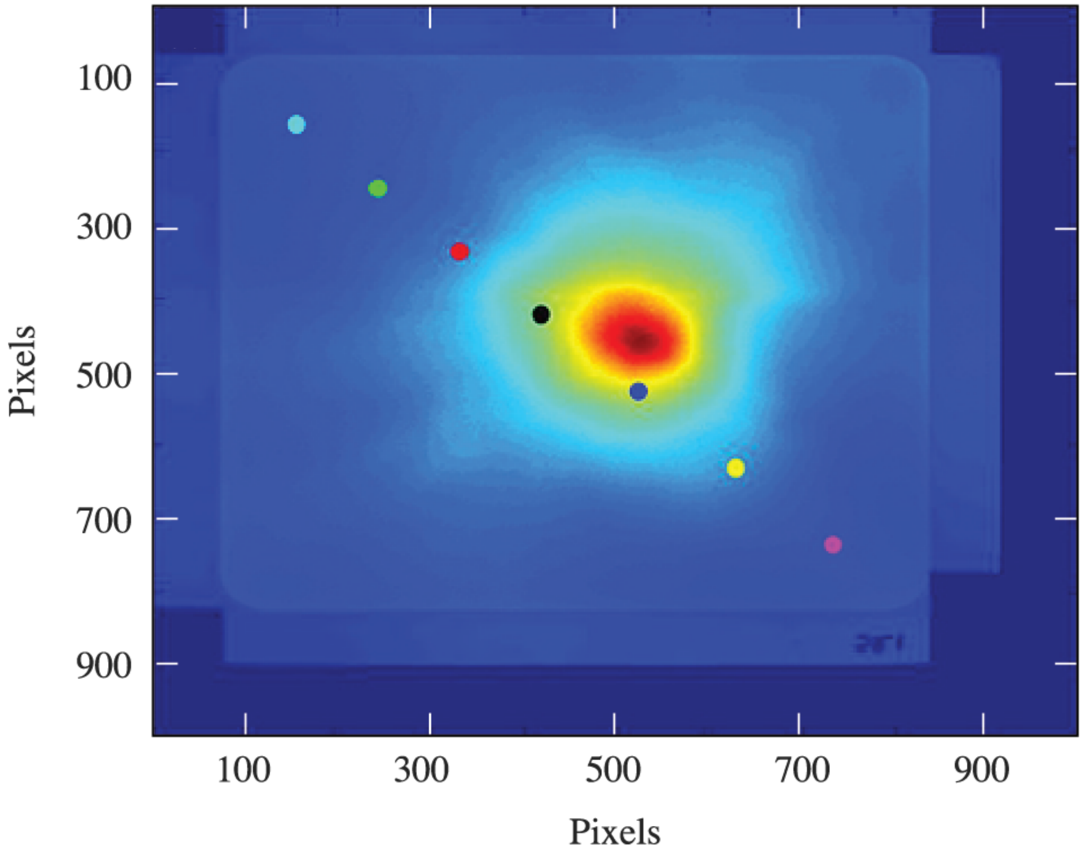
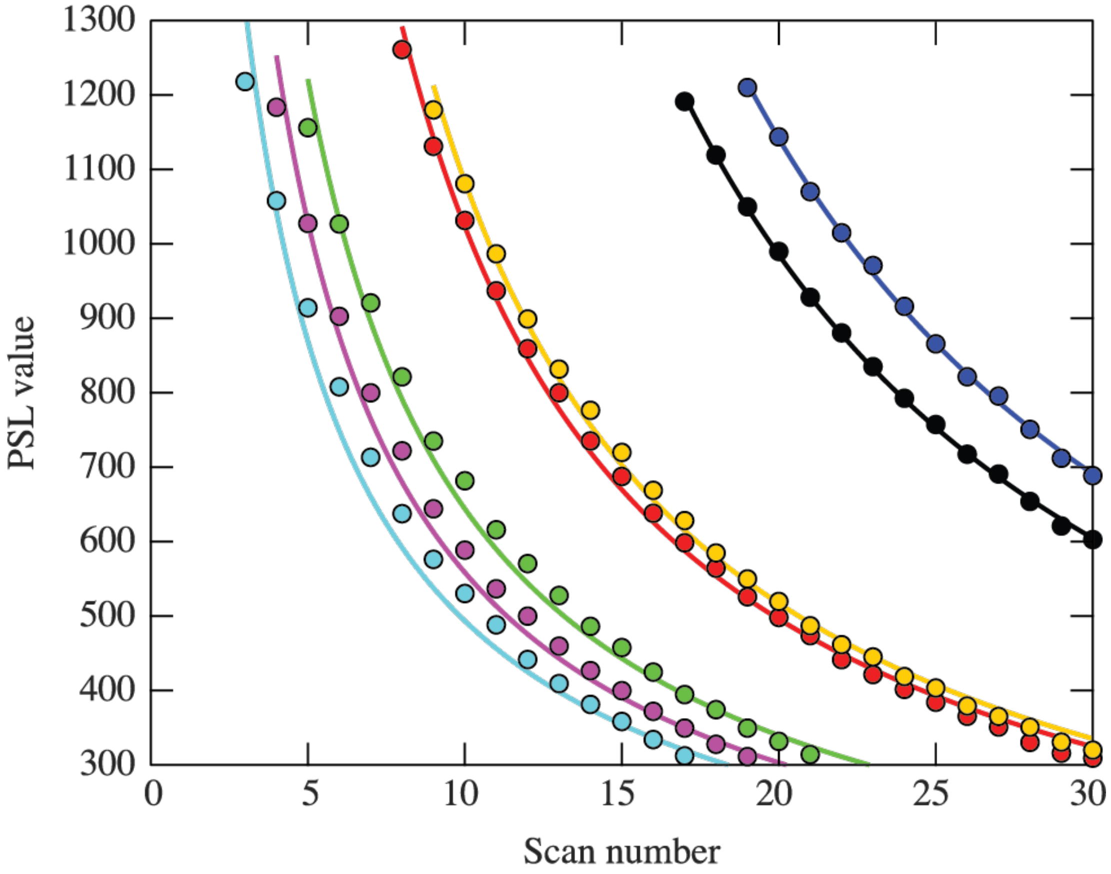
Charge Measurement Technique

- Image plates (IPs) have a known response per electron given the electron energy *,**
- It is therefore straightforward to scan the IPs and retrieve the charge of the incident electron beam
- The photostimulated luminescence (PSL) measured by the second front image plate was integrated and a constant conversion factor was used (0.026 PSL/electron)
- Total measured charge reported was determined within the solid angle of the front image plates
  - For the highest-charge shot only, the EPPS detector was located at a distance of 47.63 cm from target chamber center (solid angle of 26 msr)
  - For the remainder of the shots, the EPPS sat at 56.52 cm (solid angle of 18 msr)
  - The charge in the highest-charge shot contained in the 18 msr aperture is 600 ± 185/162 nC.

* Boutoux, G. *et al.* Rev. Sci. Instrum. **86**, 113304 (2015).
** Tanaka, K. A. *et al.* Rev. Sci. Instrum. **76**, 013507 (2005).

Charge Measurement Technique, Continued.





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Charge Measurement Technique, Continued.

- Decay of the PSL signal takes the form of a power distribution $PSL = \alpha N^{\beta}$
  - PSL = signal
  - N = number of scans of the image plate.
- Decay of the PSL signal was fit with the power distribution to recover the fit parameters α and β
- Fit parameters from the seven points are averaged to produce an average decay of the signal on the image plate for each scan
- Total signal can then be recovered via the ratio $PSL_{scan1}/PSL_{scanN} = \alpha(1)^{\beta} / \alpha N_{unsat}^{\beta} = 1/N_{unsat}^{\beta}$
  - N_{unsat} = # of scans required to unsaturate IP