Single-shot spectrometer with pointing angle correction for laser-driven electron beams featuring pointing instability and transverse inhomogeneity

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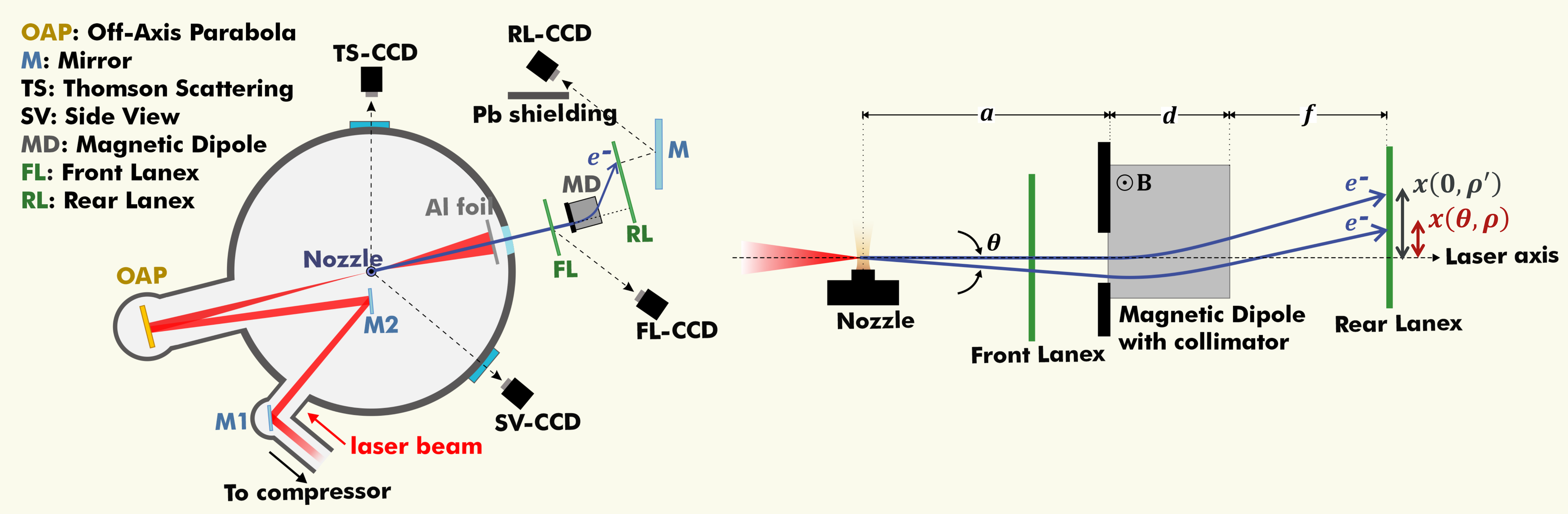
ABSTRACT

Electron beams produced via Laser Wakefield Acceleration are notoriously known for their pointing instability, which makes the retrieval of the energy spectrum via magnetic spectrometers prone to energy miscalculations. Here, we demonstrate an improved scheme of a previously published spectrometer employing two scintillating screens and a magnetic dipole in between. The first screen provides the pointing angle and is placed upstream of the dipole, while the second one is installed behind the dipole for energy measurements. A collimator is coupled with the dipole allowing only a portion of the beam to be detected, resulting in an improved energy resolution. For the electrons entering the collimator, a numerical procedure is laid out to retrieve the exact entrance angle of each transverse beamlet, which in turn allows a weighted sum procedure to be carried out to retrieve the final spectrum. Since the first scintillator screen used in our setup results in the impinging electrons being scattered, we performed Monte Carlo simulations to account for this effect. We finally corrected the observed spectrum to retrieve the actual one at the position of the vacuum chamber exit.

SPECTROMETER SETUP



Deflection when considering the pointing angle:

$$x(\theta,\rho) \approx \left(\frac{a}{2}+b\right)\left(\frac{a}{\rho}\right)+\left[(a+b+c)+\left(\frac{a}{2}+\frac{3b}{2}\right)\left(\frac{a}{\rho}\right)^2\right]\theta+\frac{1}{2}\left[\left(\frac{3a}{2}+3b\right)\left(\frac{a}{\rho}\right)\right]\theta^2$$

is the same as:

$$x(\theta,\rho) = x(0,\rho')$$

with ρ' the misread gyroradius. Solving then for ρ:

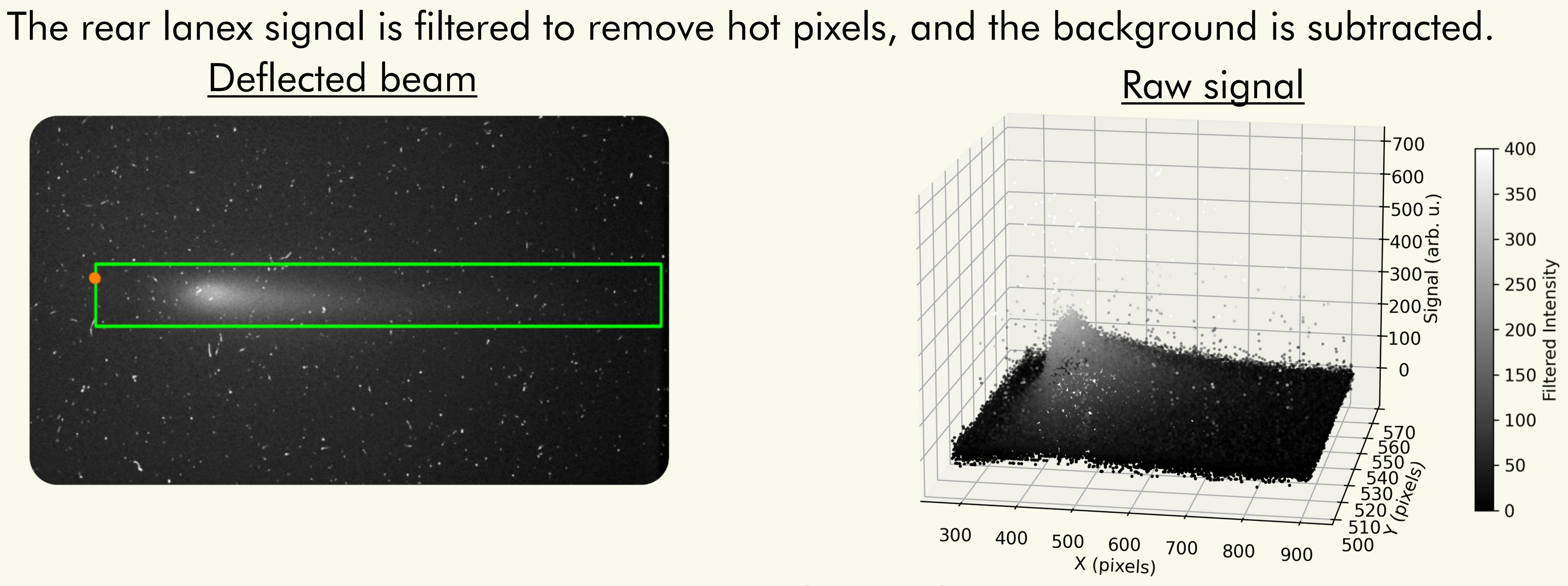
$$\rho = \left|\frac{\sqrt{A^2+DF}+A}{F}\right|$$

where:

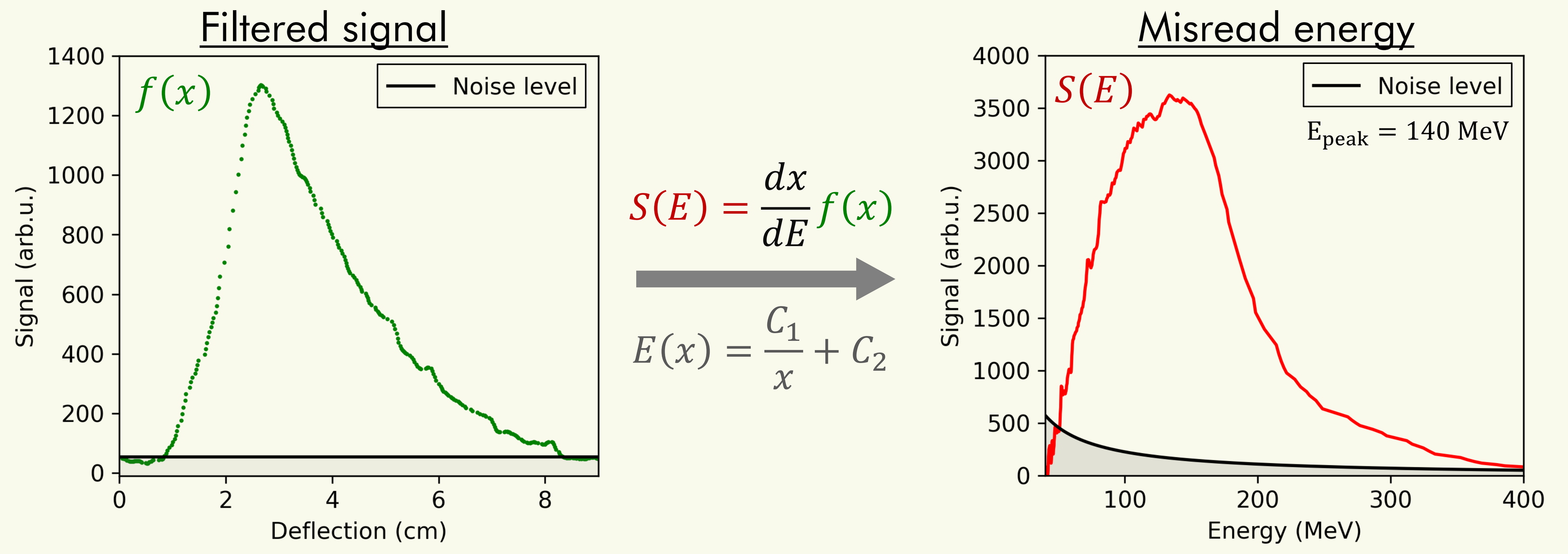
$$A = \rho'(d^2+2df)(3\theta^2+2),$$
$$D = 4d^2\theta\rho'(d+3f),$$
$$F = -8\rho'\left(a+d+f-\frac{d^2+2df}{2\theta\rho'}\right).$$

MISREAD SPECTRUM

The rear lanex signal is filtered to remove hot pixels, and the background is subtracted.

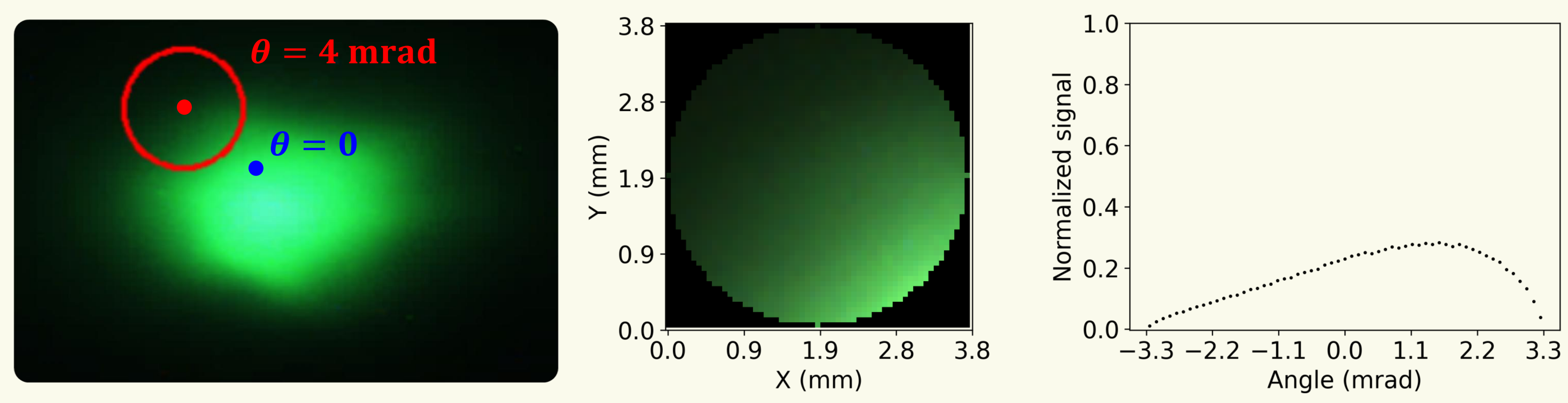


The screen is then calibrated to convert signal from deflection space to energy space.

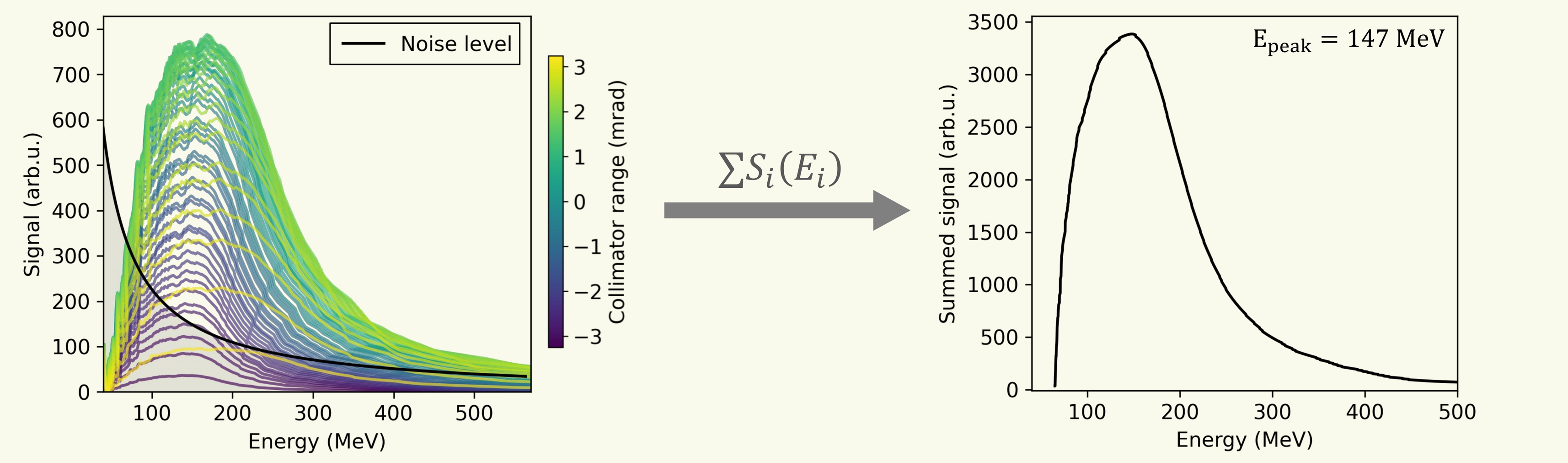


POINTING ANGLE CORRECTION

The front lanex screen is used to calculate the pointing angle and the position of the collimator.

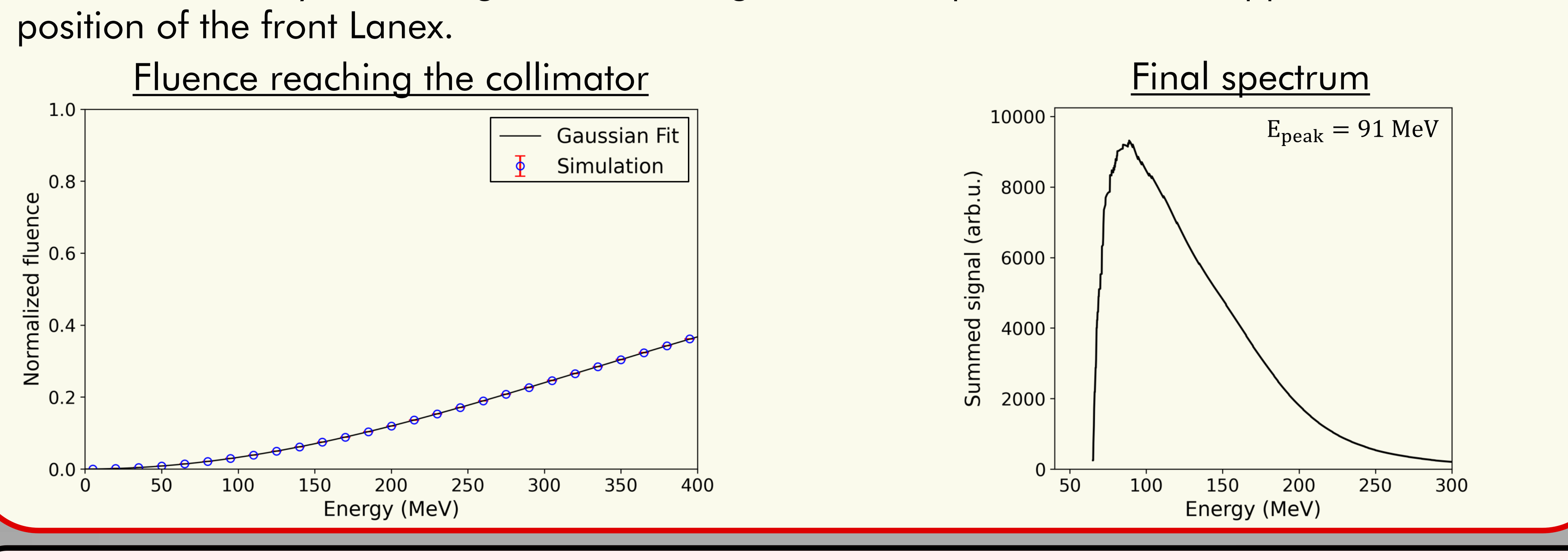


Each pixel column represents a spectrum weighted by its brightness. Summing all the collected spectra (above noise level) gives the final energy spectrum.



SCATTERING CORRECTION

The series of aluminum foil, mylar window and Lanex screen affects the divergence of the electron beam. By simulating their scattering effect, the spectrum can be approximated to the position of the front Lanex.



CONCLUSIONS

- Accurate representation of the energy spectrum requires consideration of the pointing angle.
- Scattering effects from materials placed between the electron source and the spectrometer affect the beam divergence and thus the energy measurement.
- A compact two-screen spectrometer has been developed that can correct the energy while simultaneously providing on-shot results.

REFERENCES

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