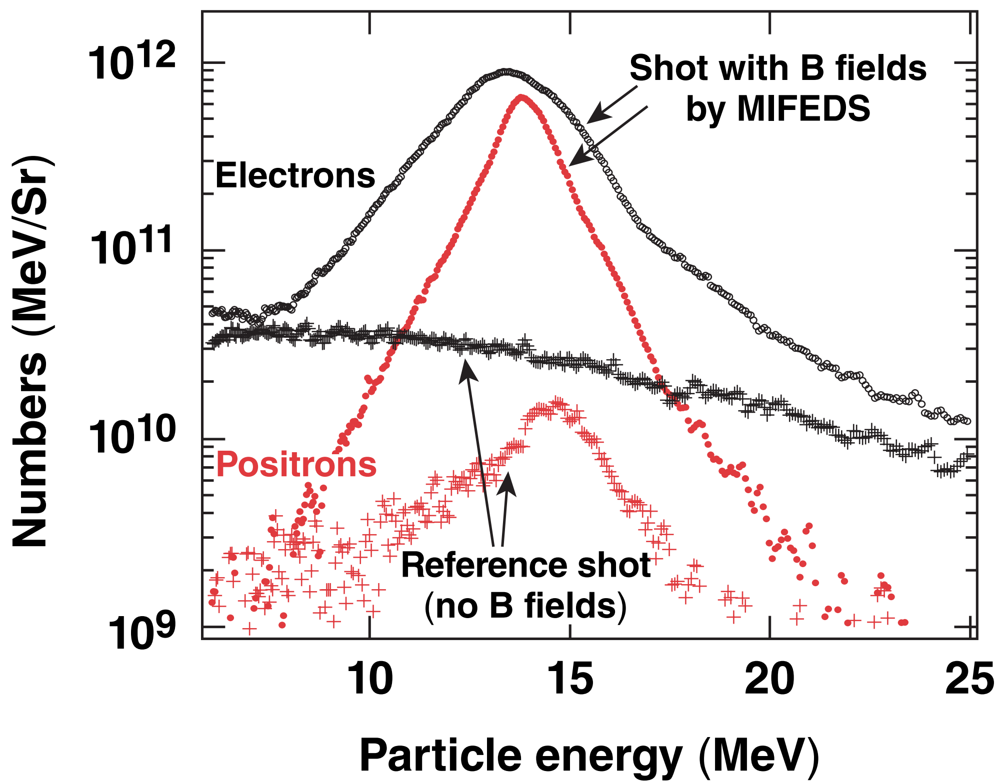
Collimation of a Positron Beam Using an Externally Applied Axially Symmetric Magnetic Field



D. H. Barnak
University of Rochester
Laboratory for Laser Energetics

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Summary

Magnetic collimation results in a quasi-neutral electron–positron beam

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- A loop-current magnetic lens is used to collimate the electron–positron beam
- Different particle energies are collimated by varying the field strength and the target-to-lens distance
- Electron and positron beams can be separated by a coil translation or tipping and tilting

Collaborators

G. Fiksel, P.-Y. Chang, R. Betti, and D. D. Meyerhofer

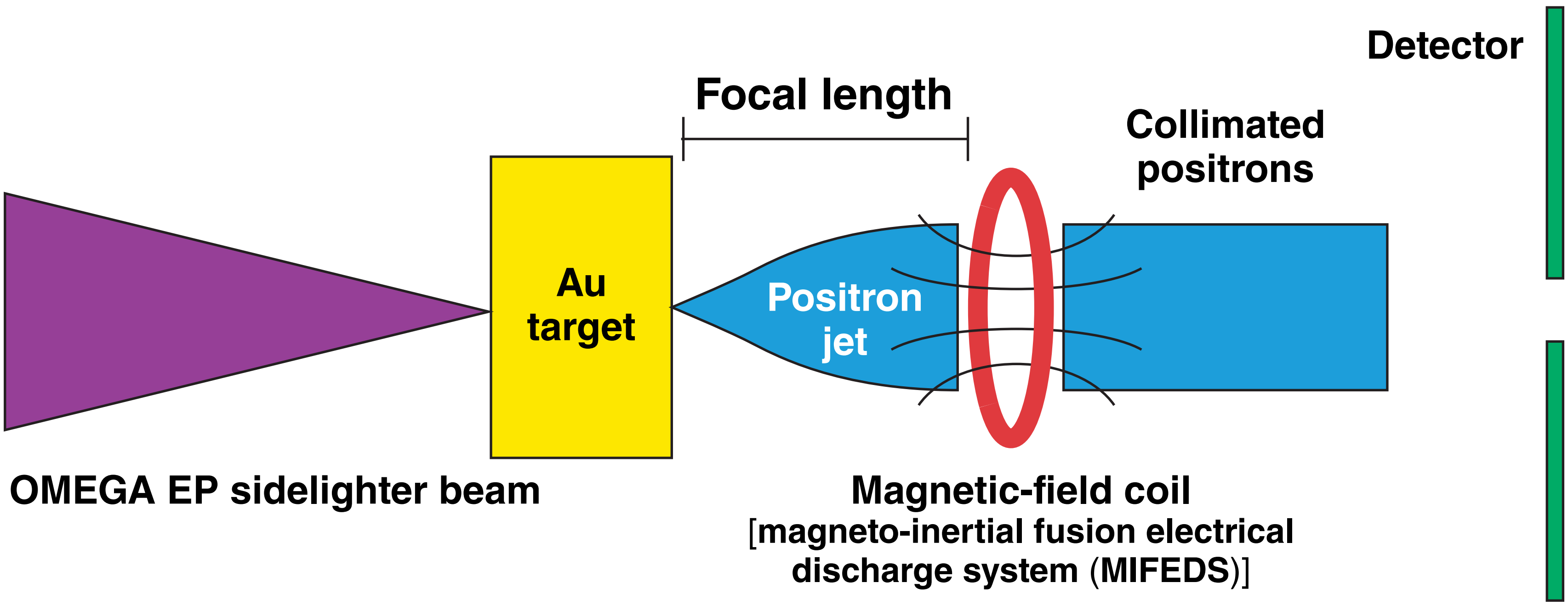
University of Rochester
Laboratory for Laser Energetics

H. Chen, G. J. Williams, S. Kerr, and J. Park

Lawrence Livermore National Laboratory

Positrons are collimated using an axisymmetric magnetic field

- A divergent positron source is produced by illuminating a high-Z target with a short-pulse laser



- A focal length is defined as the distance between the target and coil that yields a collimated beam

*H. Chen *et al.*, Phys. Rev. Lett. 102, 105001 (2009).

A focal length can be determined for an axisymmetric magnetic field as a function of energy

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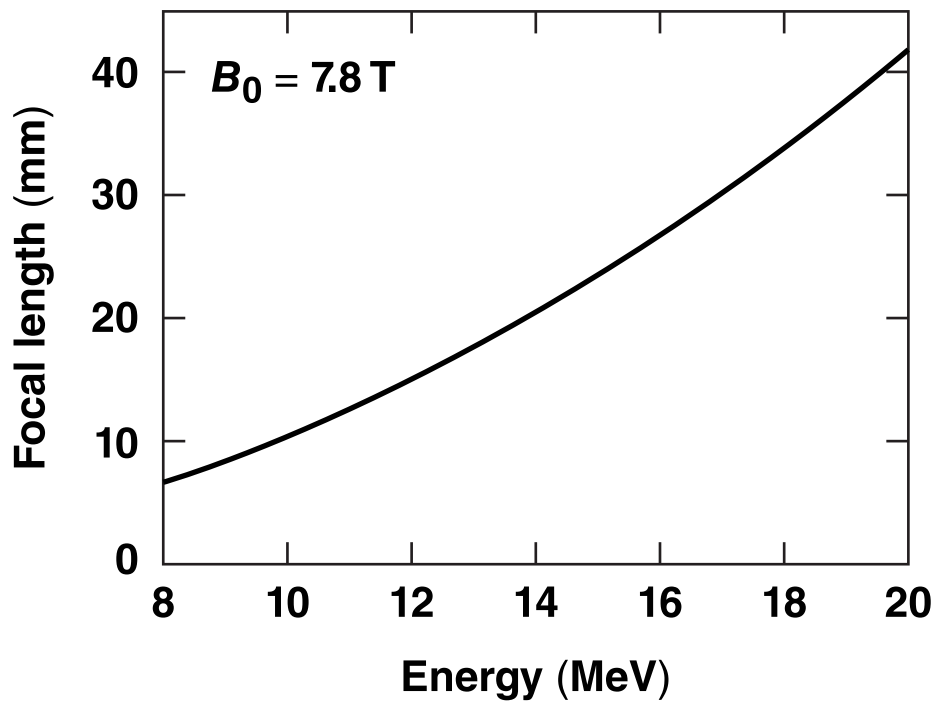
- **Focal length can be expressed in terms of particle energy**

$$f = \frac{4}{\int dz\left[qB_z/\gamma m_0 v_z\right]^2}\ *$$

$$f \sim E^2$$



Positron collimation acts as an energy selector; electrons are collimated the same as positrons.

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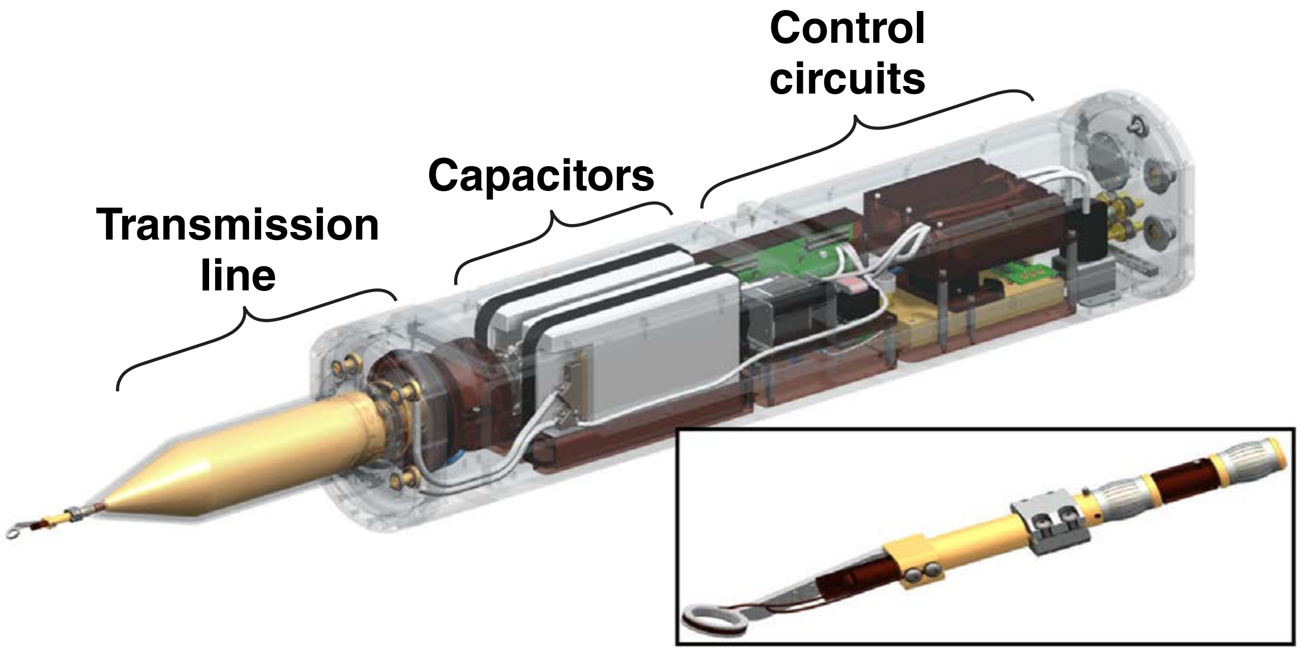
*H. Chen *et al*., Phys. Plasmas 21, 040703 (2014).

MIFEDS provides an axially symmetric magnetic field capable of positron collimation

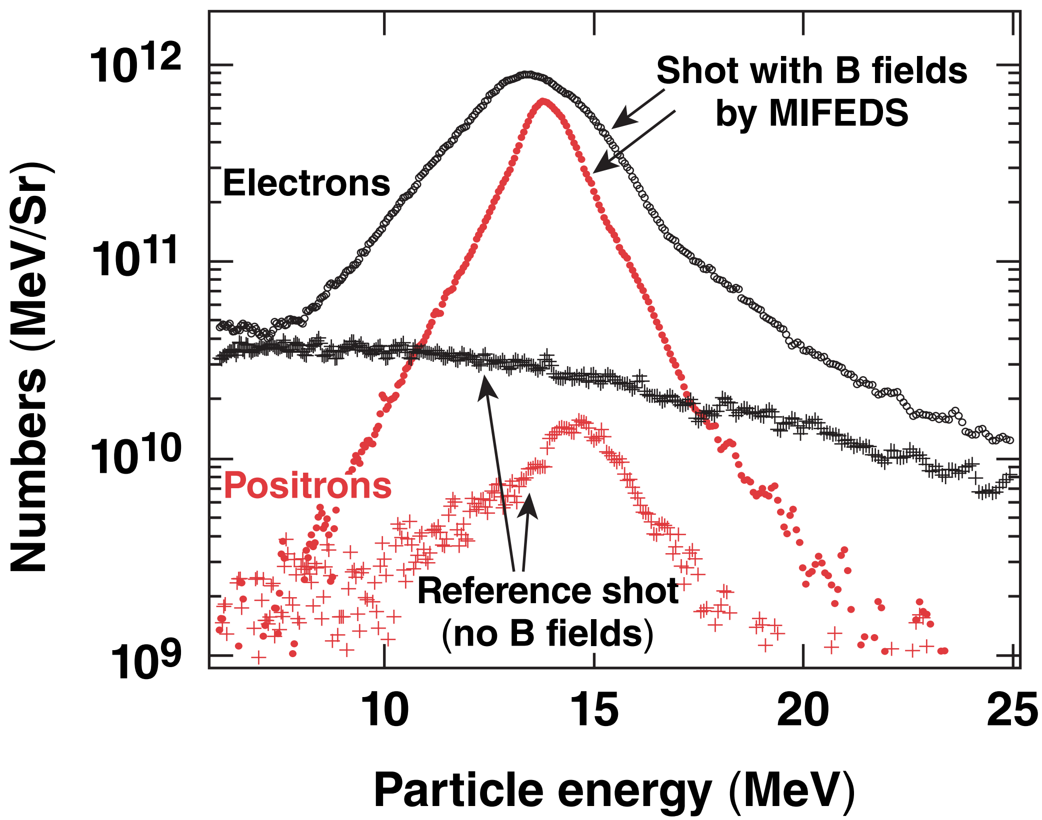
- MIFEDS generates tens of kiloamps



MIFEDS has been successfully deployed on the OMEGA, OMEGA EP, and Titan Laser Systems.

Positron beam collimation produces a nearly quasi-neutral electron–positron plasma

- **Positron and electron density is increased roughly two orders of magnitude at peak energy**



850 J
10-ps pulse
at 1054 nm
***B* = 7.8 T**

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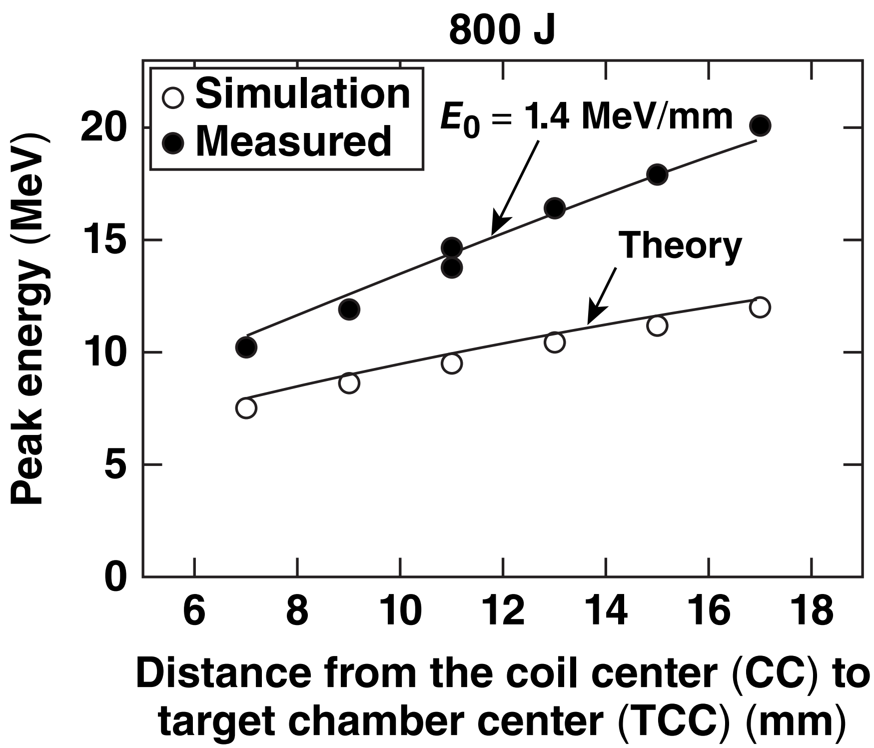
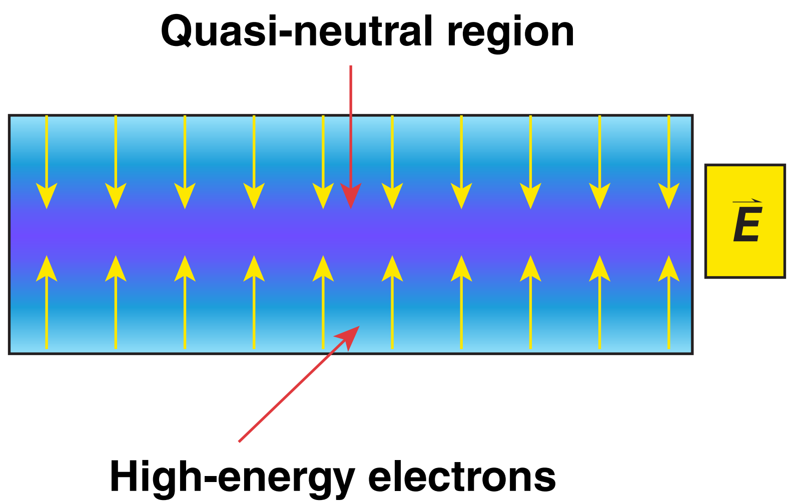
H. Chen *et al*., Phys. Rev. Lett. 21, 040703 (2014).

Collimation is observed at higher positron energy than predicted and is accounted for by a radial electric field

- A charge imbalance arises from uncollimated high-energy electrons





- For an electron density ~10^{14} and a radius of 5 mm, we can estimate an electric field of ~3 MV/mm

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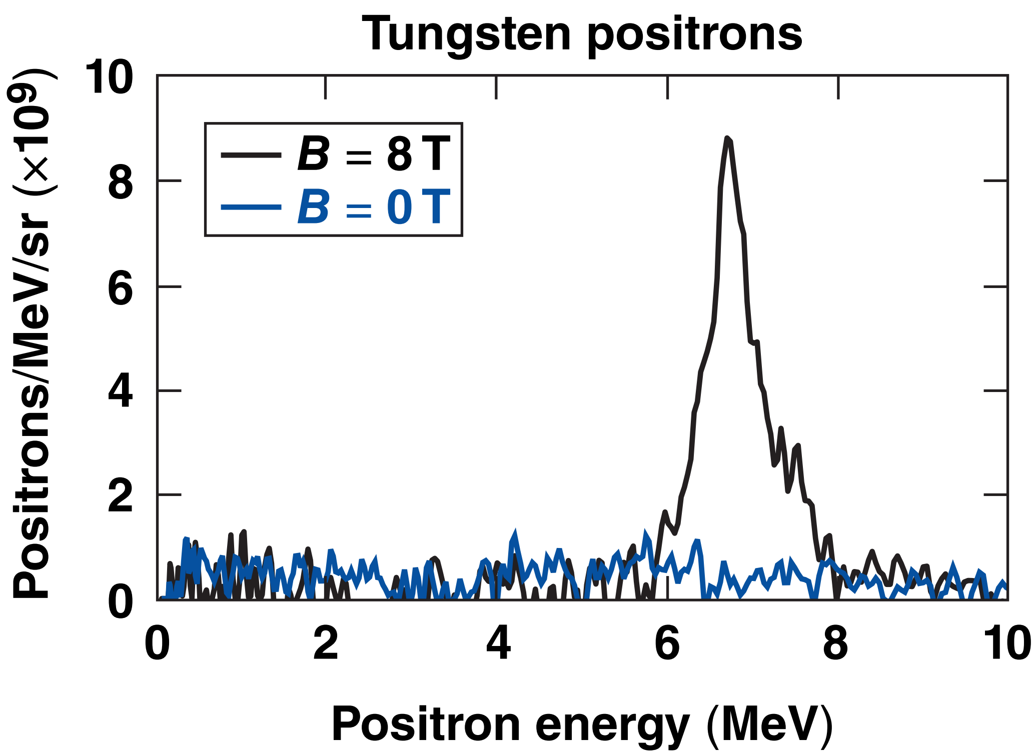
Positron collimation was observed on some shots at the Titan Laser Facility

- Strong collimation was achieved for lower-energy particles produced by Titan



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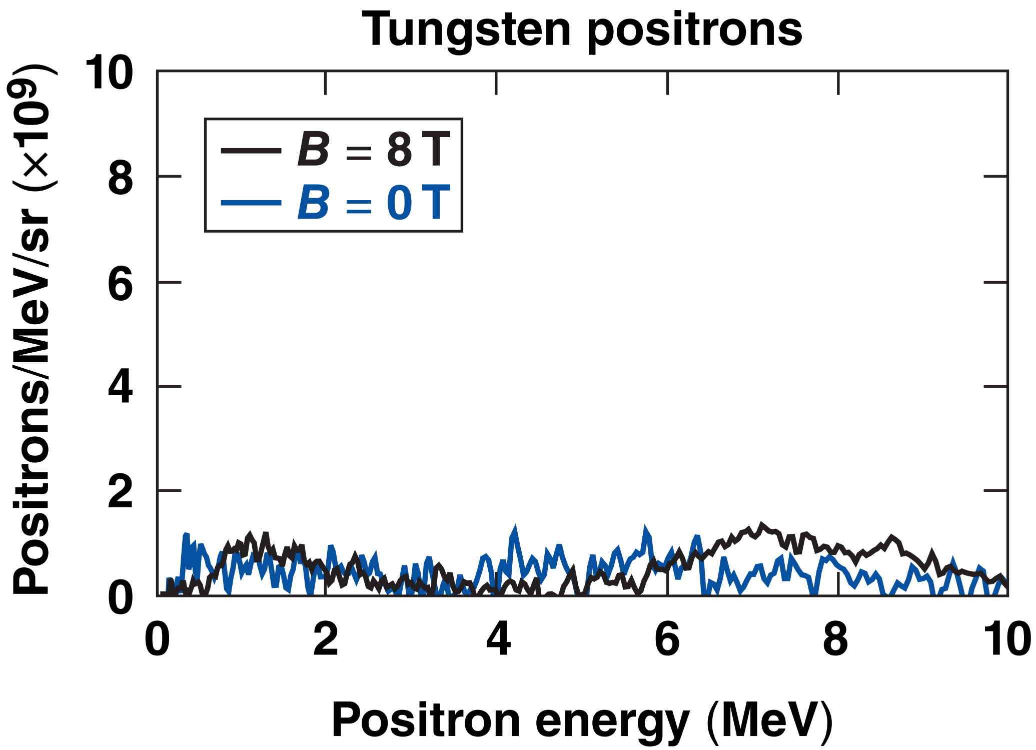
Not all shots demonstrated the same collimation

- **Using the same material, magnetic-field strength, and target-to-coil distance, the same positron signal was not reproduced**



Coil tip/tilt and translation can account for positrons being deflected away from the detector.

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Target and coil misalignment causes deflection off-axis and charge-species separation

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- A small shift off-axis can be represented in the canonical momentum equation as

$$M_{\phi} = qr_0 A_{\phi}(0) = \gamma m_0 v_{\phi}(\infty) r$$

- This means there is some nonzero v_{ϕ} at infinity, causing particles to drift; the sign of v_{ϕ} depends on q, which causes charge separation

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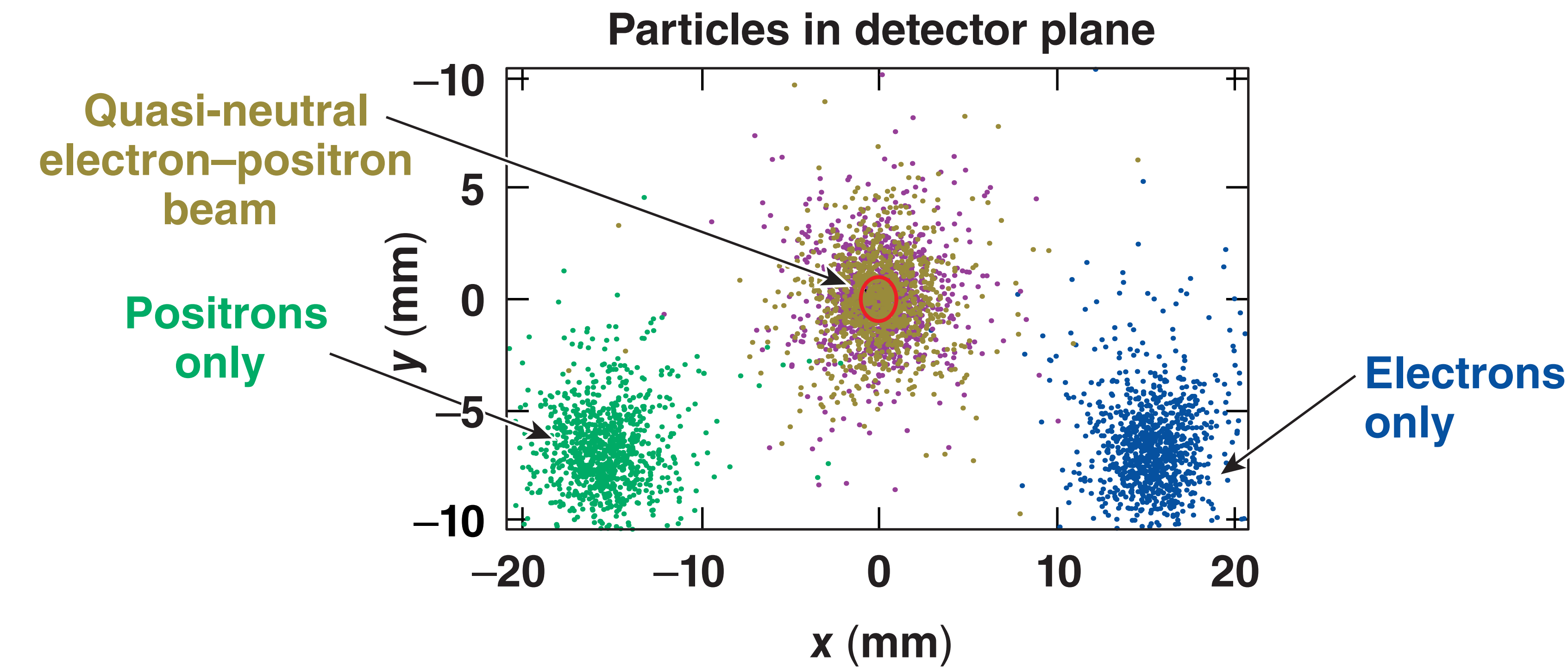
Collimation remains the dominant effect close to the coil, resulting in two collimated charge-separated beams

- Separate electron and positron beams are generated when the magnetic lens is positioned at the focal length and tilted by 2° in the *y–z* plane



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Summary/Conclusions

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