PhD Open Days

Momentum and Spin Control in nonlinear Breit-Wheeler Pair Creation

Bernardo Barbosa (bernardo.barbosa@tecnico.ulisboa.pt)
PhD in Physics

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Introduction

Recent developments in high-power laser facilities will enable **prolific electron-positron pair creation** when pulses with intensities above $10^{23}\ \mathrm{W/cm^2}$ are collided against an **ultra-relativistic electron beam**. Having control over the created pairs is of utmost importance for future applications, namely the **momentum** and **spin** of the particles.

Laser Fields

In the strongly quantum regime, created pairs will both move and precess in the laser.

Despite radiation reaction, the final transverse **momentum** can still be linked to the initial transverse **vector potential** and the final **spin** orientation to the initial **magnetic field** direction.

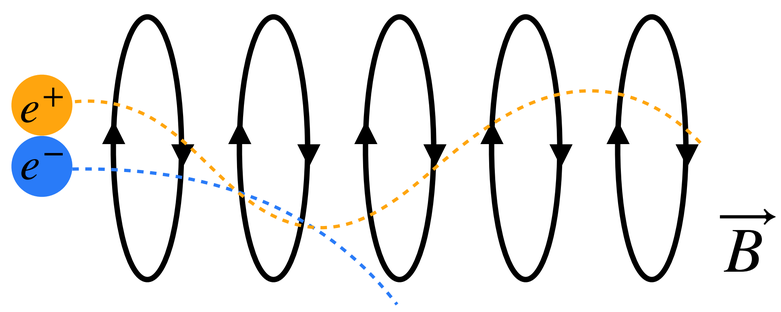
$$\vec{p}_{can} = m\vec{v} + q\vec{A} \qquad U = -\vec{m}\cdot\vec{B}$$

$$\vec{p}_{\perp f} \approx q\vec{A}_{\perp 0} \qquad \vec{s}_{\perp f} \approx sgn(q)\,\vec{e}_{B_{\perp 0}}$$

Plasma Channel Fields

Strong lasers can also ionize a gas and greatly accelerate electrons (e.g., LWFA, DLA, etc.).

Electron motion forms strong azimuthal magnetic fields — **betatron** motion.

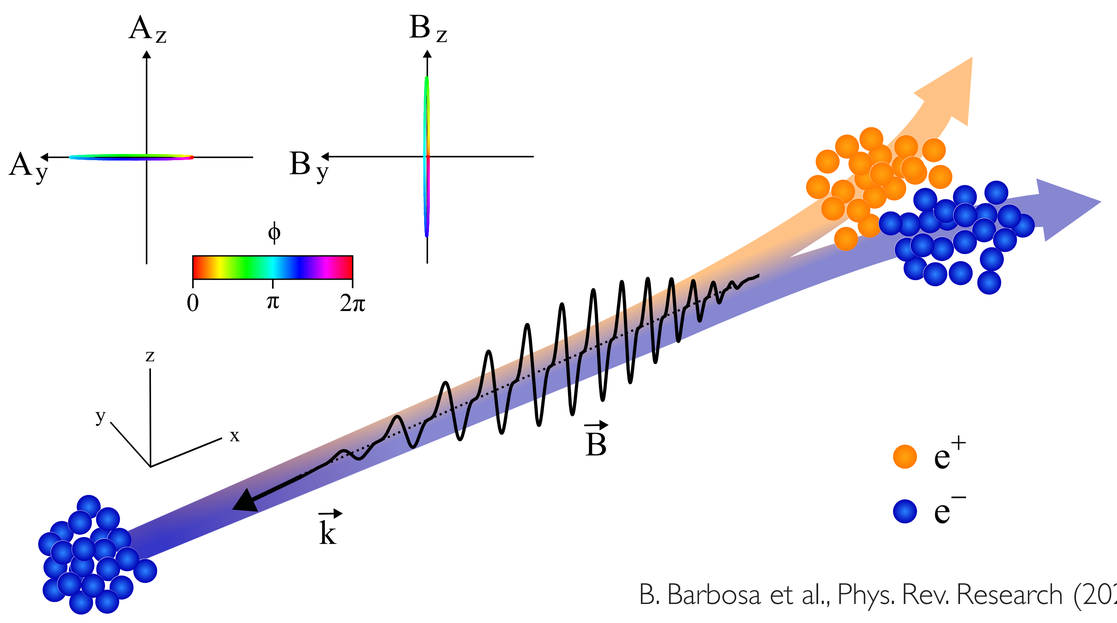


$$\omega_\beta = \frac{\omega_p}{\sqrt{2\gamma}}$$

Charge-dependent behaviors — useful for polarization and detection, and crucial to preserve spin

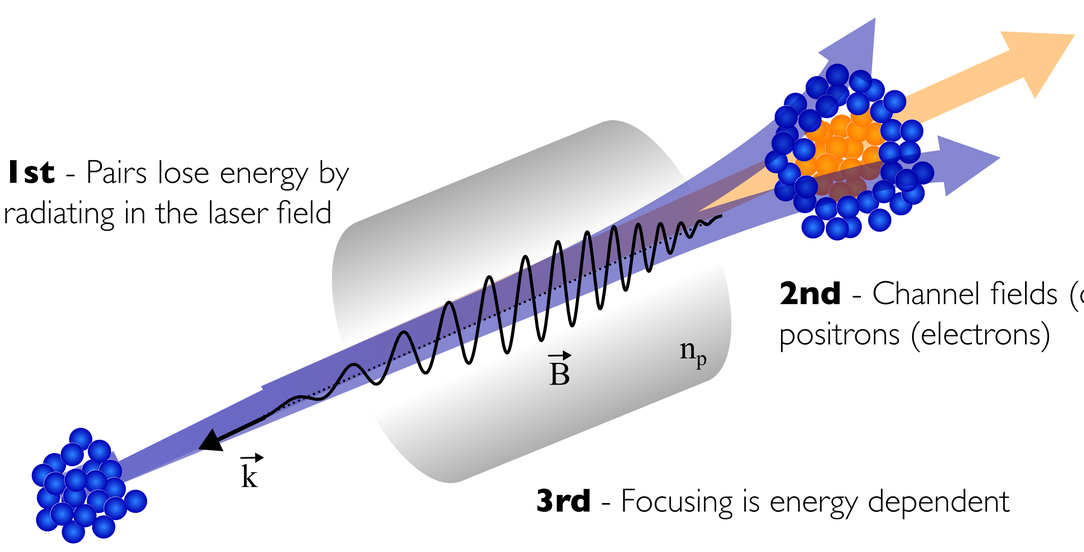
Momentum Control of the Outgoing Pairs

Asymmetry comes from the **second harmonic**



B. Barbosa et al., Phys. Rev. Research (2024)

Asymmetry comes from the **channel B field**

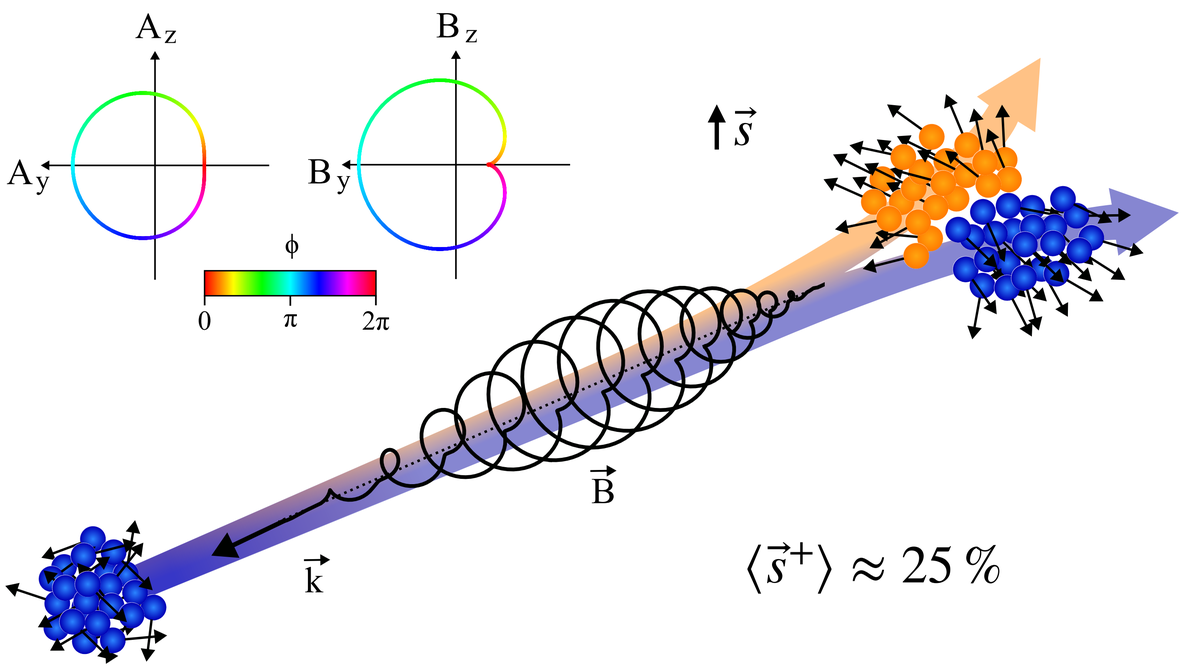


B. Barbosa et al., in preparation (2026)

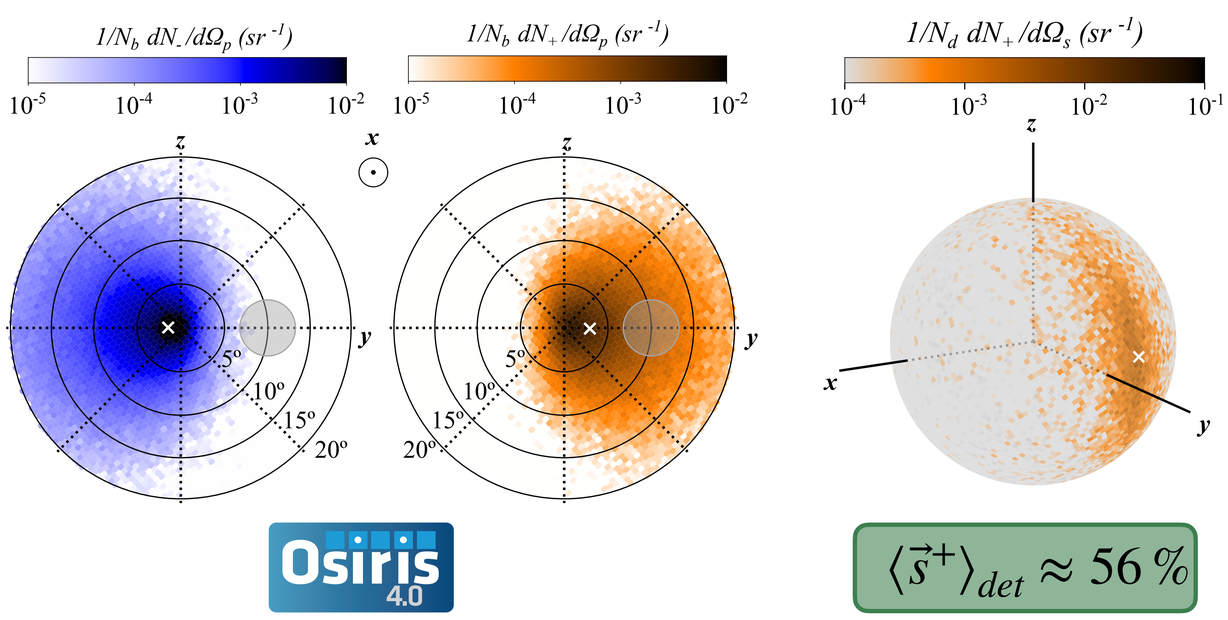
Figure 1: Left: Setup using a bichromatic field resulting in two distinct beams of electrons and positrons **Right**: Setup using a monochromatic field and a background plasma to focus positrons

Momentum Control AND Spin Control with Circularly Polarized Bichromatic Fields

Two asymmetries from the two perpendicular degrees of freedom!



$$\langle \vec{s}^{+} \rangle \approx 25\,\%$$



Osiris 4.0

$$\langle \vec{s}^{+} \rangle_{det} \approx 56\,\%$$

B. Barbosa et al., in preparation (2026)

Figure 2: Left to Right: Scheme. Angular distribution of outgoing electron (blue) and positron (orange) momentum, alongside the placement of a detector (grey). Angular distribution of the detected positron spin

TÉCNICO UNIVERSIDADE DE LISBOA

Supervisor: Marija Vranic
PhD in Physics

phdopendays.tecnico.ulisboa.pt