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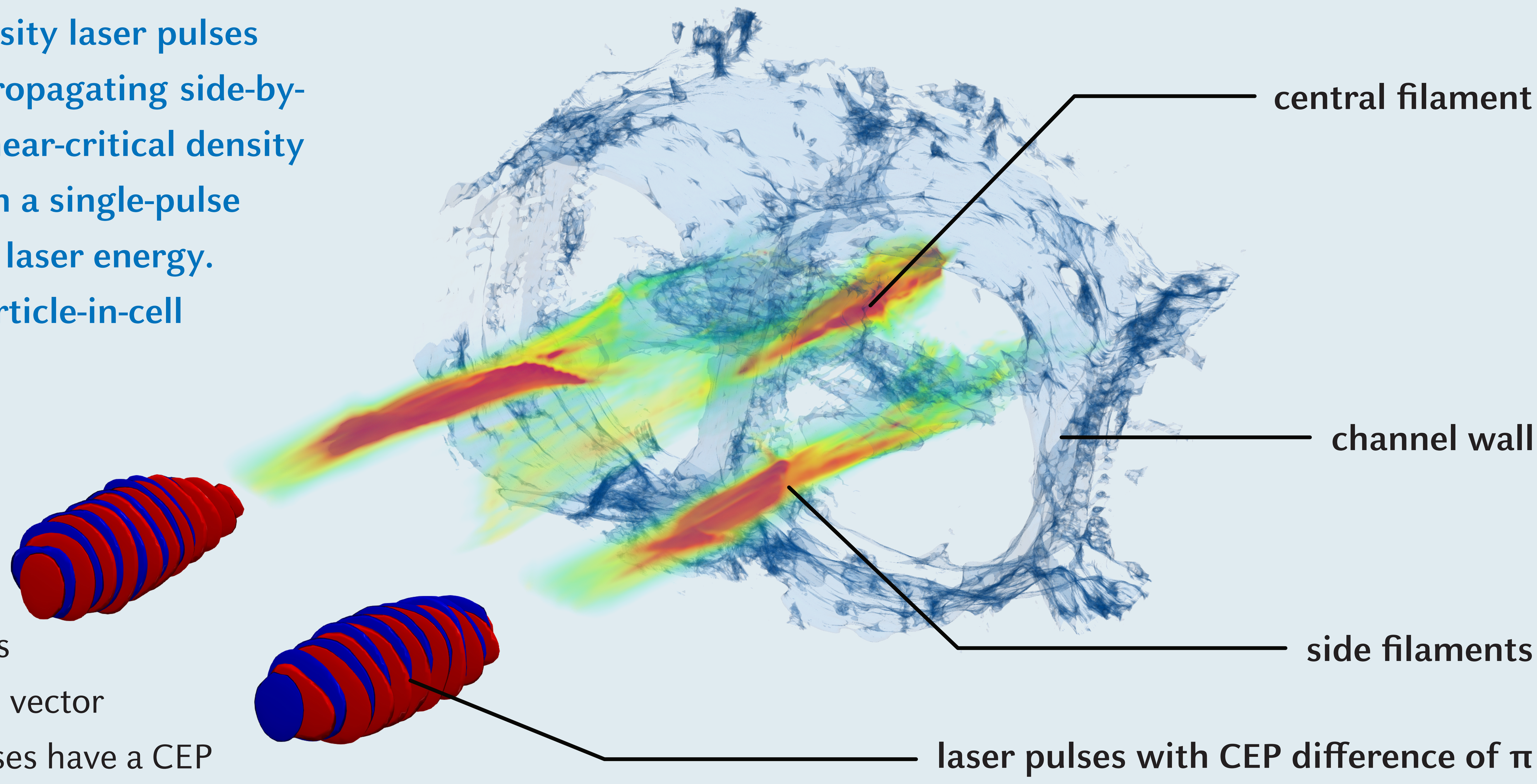
Acceleration of spin-polarized proton beams from a dual-laser pulse scheme

We present a setup consisting of two high-intensity laser pulses with a carrier envelope phase difference of π propagating side-by-side [1]. Their interaction with a spin-polarized near-critical density target yields higher charge and polarization than a single-pulse Magnetic Vortex Acceleration setup of the same laser energy. The proposed scheme is studied by means of particle-in-cell simulations for various laser intensities.



Setup

Two Gaussian laser pulses propagate through a HCl target side-by-side. The two pulses have a focal spot size of 4 μm and duration of 26.7 fs; their centers are separated by Δy = 8 μm. The normalized laser vector potential is varied in the range a_0 = 25-100. The pulses have a CEP difference of π.

The gas target is 200 μm long and has a density of $n_H = n_{Cl} = 0.0122 n_{cr}$. All Hydrogen atoms have been pre-polarized, i.e. $s_y = 1$ [2]. Spin precession is tracked according to the T-BMT equation:

$$\frac{\mathrm{d}\mathbf{s}}{\mathrm{d}t} = -\mathbf{\Omega}\times\mathbf{s}$$

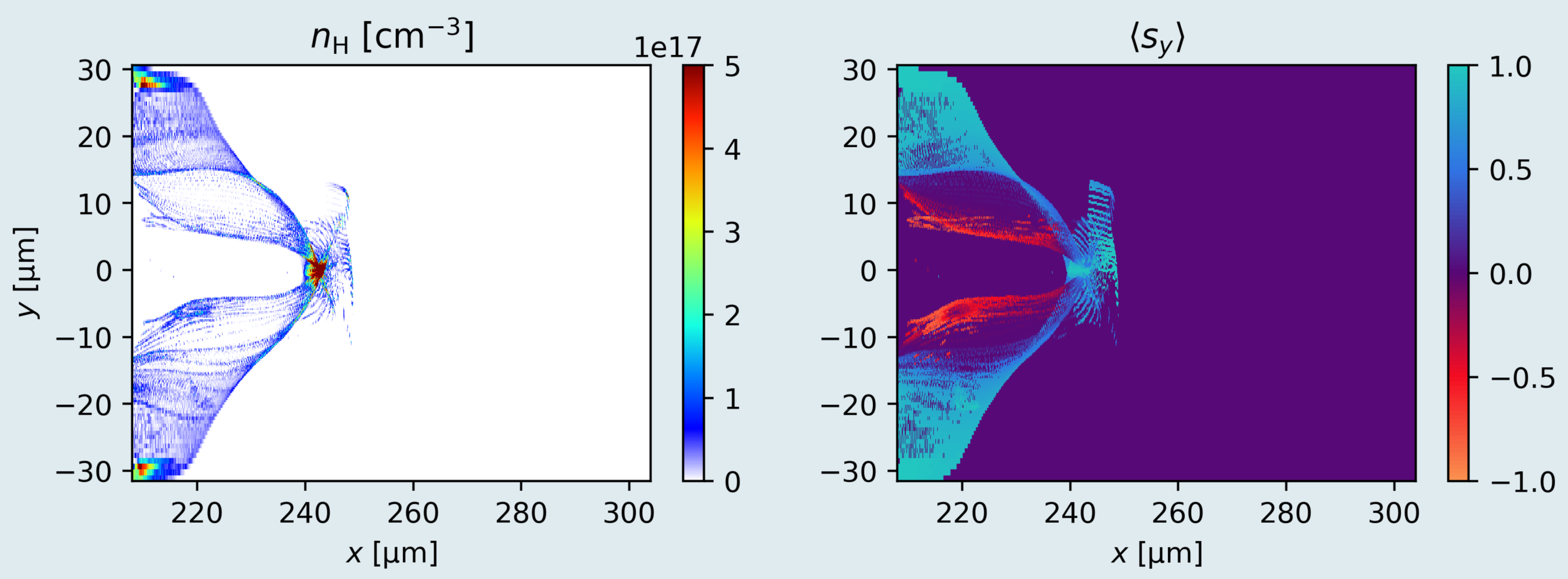
$$\mathbf{\Omega} = \frac{qe}{mc}\left[\Omega_B \mathbf{B} - \Omega_v \left(\frac{\mathbf{v}}{c}\cdot\mathbf{B}\right)\frac{\mathbf{v}}{c} - \Omega_E \frac{\mathbf{v}}{c}\times\mathbf{E}\right]$$

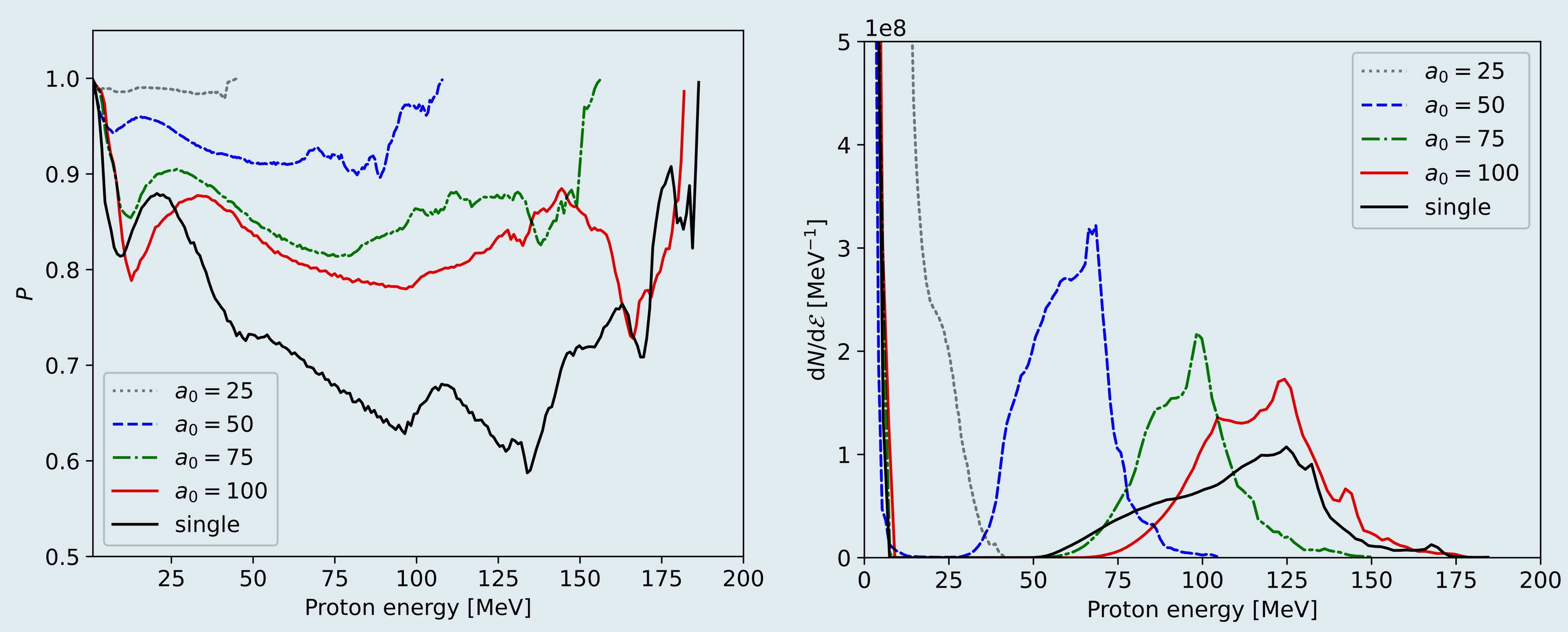
$$\Omega_B = a + \frac{1}{\gamma}\,, \qquad \Omega_v = \frac{a\gamma}{\gamma+1}\,, \qquad \Omega_E = a + \frac{1}{1+\gamma}$$

Results

The two pulses each create their own channel in which Magnetic Vortex Acceleration (MVA) occurs. Additionally, they induce a strong longitudinal electric field in the space between them which is able to accelerate protons. This central proton bunch is ejected out of the target and compressed laterally due to the prevalent electromagnetic fields. Since the protons are shielded from field inhomogeneities, the accelerated beam remains spin-polarized to a high degree.

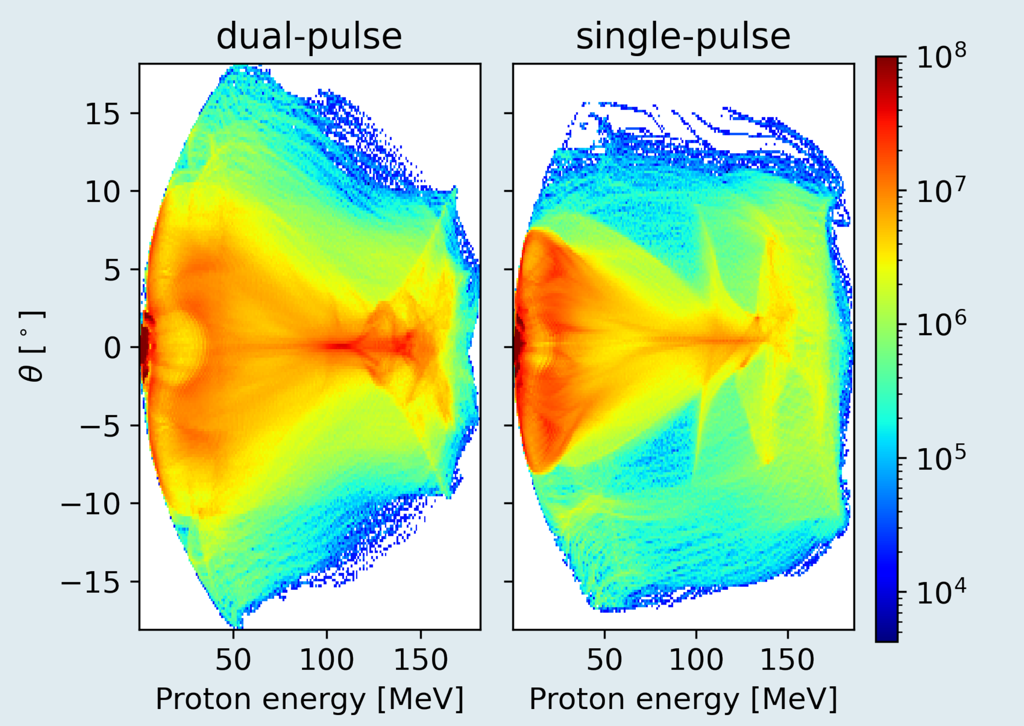
In the case of a_0 = 100, 0.76 nC of protons are accelerated to a peak energy of 124 MeV with a beam polarization of 77%.





Comparison to a single-pulse setup

A single laser pulse with a_0 = 141 and the same pulse duration and focal spot size is used. The dual-pulse setup with a_0 = 100 delivers not only better energy spread, but also higher spin polarization and charge: for the single pulse, the accelerated 0.61 nC exhibit only 64% beam polarization. Further, the single-pulse scheme exhibits a kink in the angular distribution indicating some instability which is suppressed for the dual-pulse setup.



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References
[1] L. Reichwein et al., *Phys. Rev. Accel. Beams* **25**, 081001 (2022)
[2] M. Büscher et al., *High Power Laser Sci. Eng.* **8**, e36 (2020)