

RUHR-UNIVERSITÄT BOCHUM

Energy loss of intergalactic pair beams

Studying instabilities with a PiC code

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Pair beam creation by blazars

- Some AGN produce TeV Photons
- TeV Photons interact with the EBL
- $e^- + e^+$ -beams with TeV energies are created

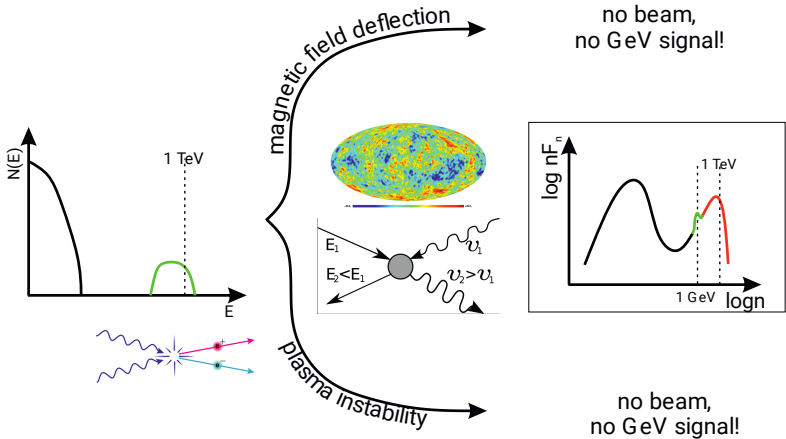
Resulting radiation

Pair beams will

- Compton up-scatter photons (GeV signal?)
- get deflected by magnetic fields (no GeV signal?)

However, this largely ignores plasma effects

Physical motivation



Neglected plasma effects

Pair beams drive instabilities

- heating the background
- relaxing the beam distribution
- removing energy available for cascade

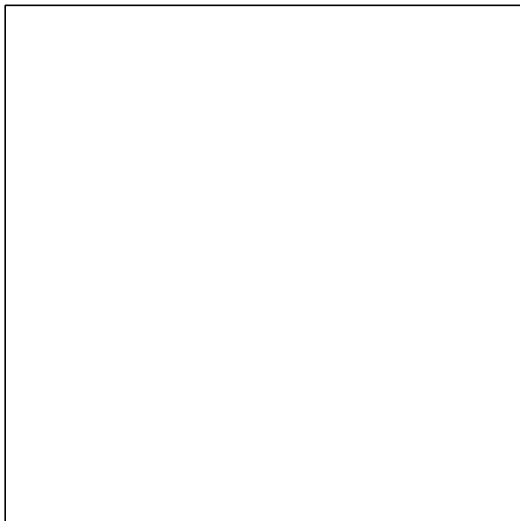
Schlickeiser et. al. 2012

Starting with a proton-electron background + pair beam, quasilinearly

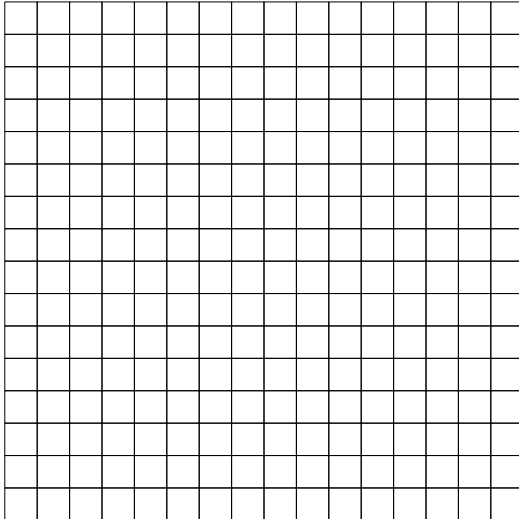
- determined (maximum) growth rate for electrostatic fluctuations
- estimated nonlinear effects (backreaction)

Test conclusions numerically

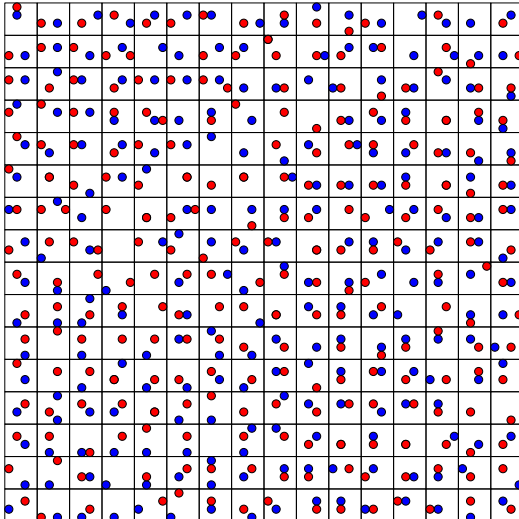
Particle-in-Cell



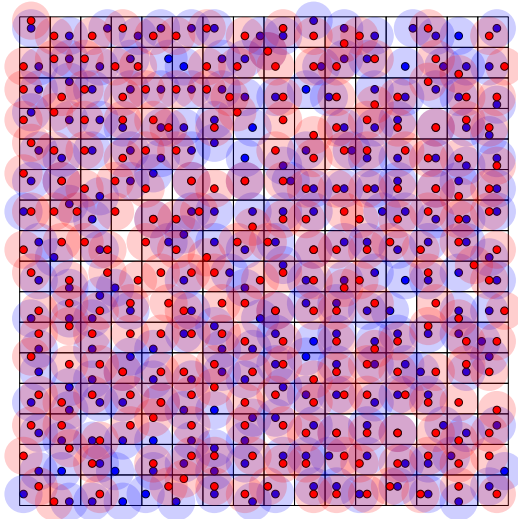
Particle-in-Cell



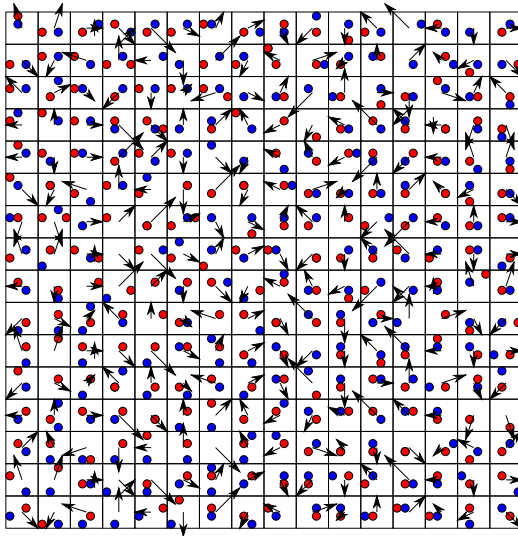
Particle-in-Cell



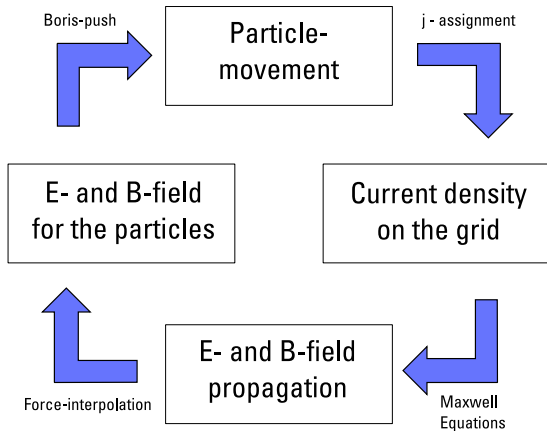
Particle-in-Cell



Particle-in-Cell



Particle-in-Cell



Drawbacks

- Small timesteps
- Small cell sizes
- Noise scales with $1/\sqrt{\#\text{particles}}$
- Significant computational resources needed

Benefits

- Self-consistent simulations
- Microphysical processes are included
- Electric and magnetic fields directly accessible
- Particles' velocity and position available
- Temporal evolution

Parameters

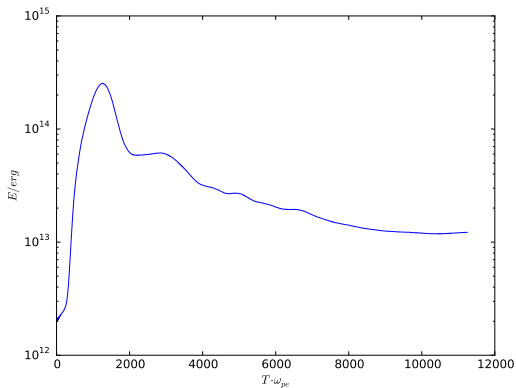
Growth rate γ is varying slowly with critical parameters

$$\gamma \propto \frac{n_{\text{beam}}^{1/3} n_{\text{background}}^{1/6}}{\Gamma_{\text{beam}}^{1/3}}$$

- less problematic values can be chosen initially
- as long as the assumptions are not violated
- low beam / background energy ratio

Results

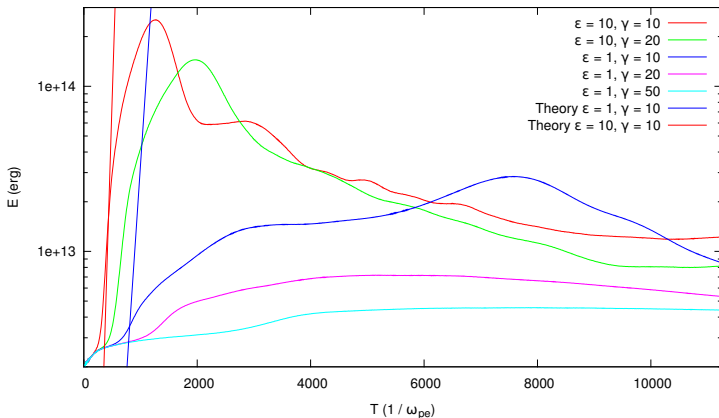
Energetic beam: $E_{\text{beam}}/E_{\text{bg}} = 10$, $n_{\text{beam}}/n_{\text{bg}} = 2.5 \times 10^{-4}$, $\Gamma = 10$



Electric field energy over time

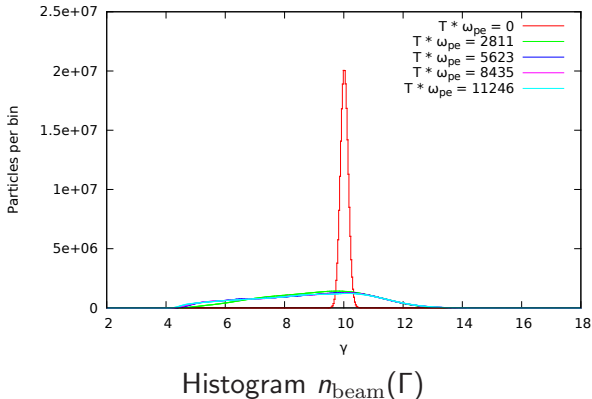
Results

Comparison with theoretical results



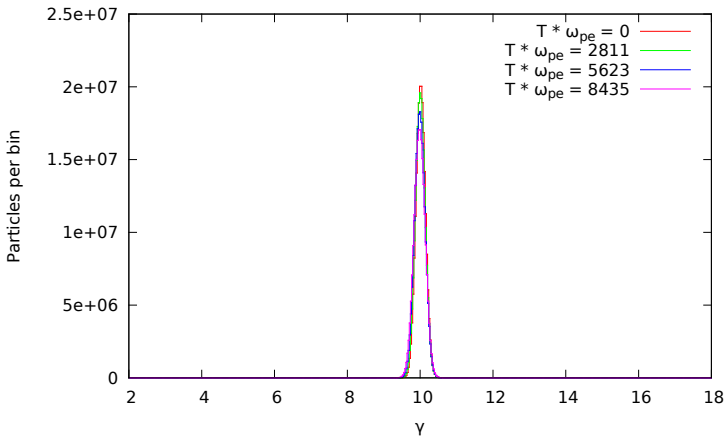
Results

Energetic beam: $E_{\text{beam}}/E_{\text{bg}} = 10$, $n_{\text{beam}}/n_{\text{bg}} = 2.5 \times 10^{-4}$, $\Gamma = 10$



Results

Weak beam: $E_{\text{beam}}/E_{\text{bg}} = 0.1$, $n_{\text{beam}}/n_{\text{bg}} = 2.5 \times 10^{-6}$, $\Gamma = 10$



Conclusions

- Interesting parameter regime is problematic
- Simulations low energy ratio suggest a broadening, but no vanishing of the beam
- Kinetic instabilities may not suppress a GeV signal