

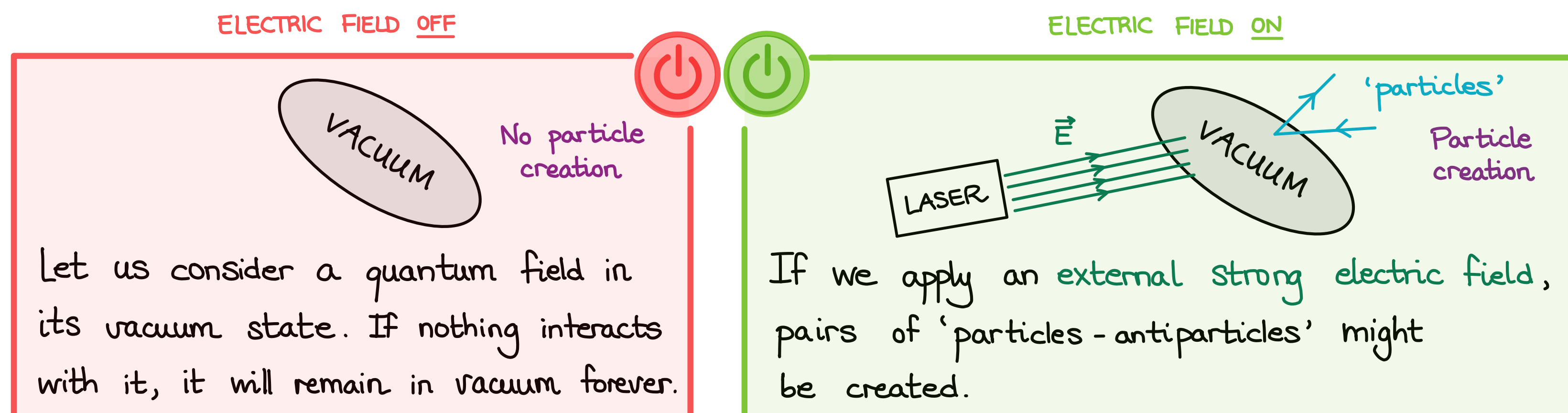
What is a particle? : The Schwinger effect

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What is the Schwinger effect?

The Schwinger effect is a phenomenon in which 'particles' are created out of vacuum when we apply a strong electric field.



To create an 'electron-positron' pair we need electric strengths larger than the critical Schwinger limit : $E \sim 10^{18}$ V/m.

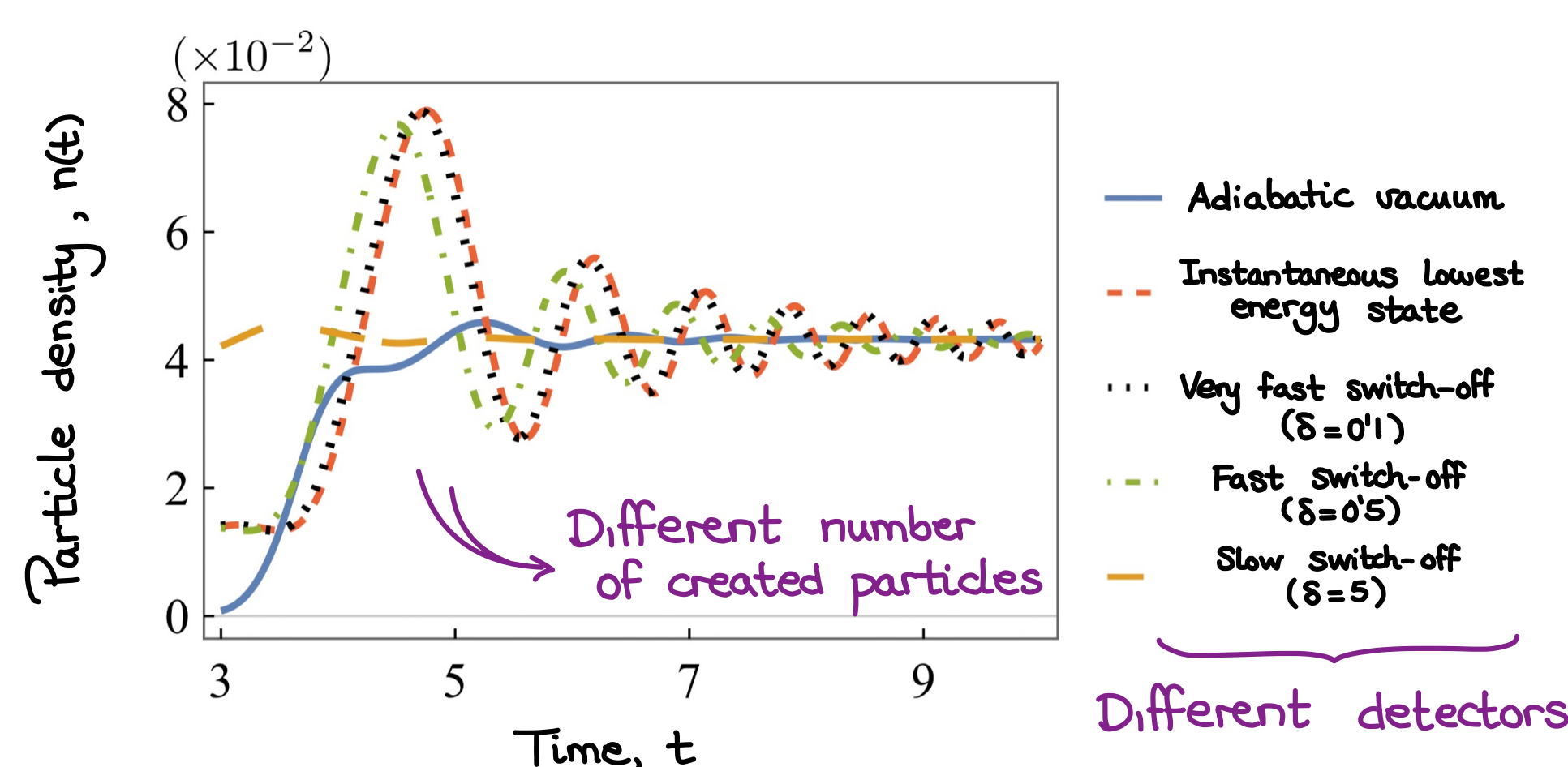
Why is it interesting?

- 1 Modern laser facilities are approaching the critical Schwinger limit. An experimental realization may be close.
- 2 While perturbative Quantum Electrodynamics is well experimentally tested (e.g. in accelerators), the Schwinger effect is nonperturbative.
- 3 The Schwinger effect shares its core mechanism with other particle creation phenomena in gravitational scenarios. We can understand general aspects of Quantum Field Theory in Curved Spacetimes.

How many particles are being created?

It depends! Different detectors can measure different number of created particles.

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- The system is maximally symmetric.
 - The concepts of particle and quantum vacuum are unambiguous (i.e. Poincaré).
 - All detectors measure the same vacuum.
- The electric field breaks maximal symmetry.
 - We lose the absolute notions of particle and quantum vacuum.
 - Different detectors can measure different vacua.



In the past, the electric field is off and the vacuum looks like Poincaré for all detectors.

In the future, the electric field is on and there are ambiguities.

RESULTS

QUESTION : Are these ambiguities in the notion of particle actually physical?
OUR ANSWER : YES. They are related to the infinitely many ways of measuring.

INFINITE CONCEPTS OF PARTICLE

INFINITE WAYS OF MEASURING THE PARTICLE DENSITY

INFINITE WAYS OF SWITCHING OFF THE ELECTRIC FIELD

Vacuum as the 'lowest energy state'

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- The (renormalized) Hamiltonian is time-independent.
 - We define the quantum vacuum as the eigenstate with the lowest possible energy.

- The Hamiltonian depends explicitly on time.
- There is no eigenstate that minimizes energy at all times. However, at each time we can still define an instantaneous notion of vacuum that minimizes the energy. Nevertheless, in certain backgrounds this vacuum can lead to generation of infinite particles.

RESULTS

STATES OF LOW ENERGY

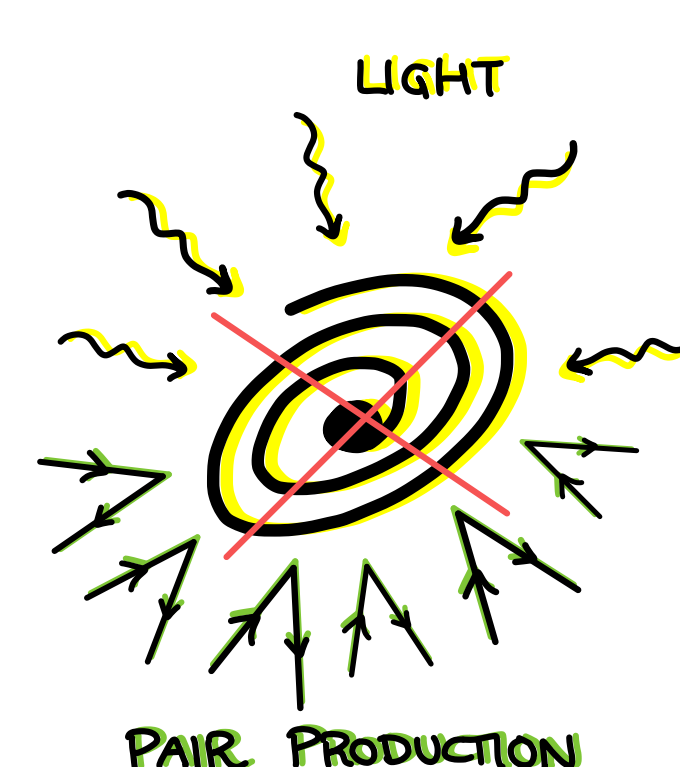
- They minimize the smeared energy in a time interval.
- They have fantastic mathematical and physical properties.
- They were previously used in cosmology and we have extended their use for the Schwinger effect.

There cannot be such thing as a black hole of light

A 'Kugelblitz' - German word for 'ball lightning' - is a theoretical black hole formed by concentrating an extreme amount of radiation (no matter).

RESULTS

We have proved that it cannot be created. Indeed, in order to generate a 'Kugelblitz' one would need to concentrate electric strengths much more intense than the critical Schwinger limit: the Schwinger effect would dissipate energy, making its formation impossible.



The Schwinger effect forbids the concentration of light

References

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- Á. Álvarez-Domínguez, L.J. Garay, M. Martín-Benito; States of low energy in the Schwinger effect; J High Energy Phys. 93 (2023).
- Á. Álvarez-Domínguez, L.J. Garay, E. Martín-Martínez, J. Polo-Gómez; There cannot be such thing as a Kugelblitz (to be published).
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