Synchrocyclotron

Summary: Cyclotrons don't have those simple magnetic fields as used in all published calculations, but as soon as you calculate or simulate it based on all the moving particles involved, there is no need for mass increase or relativity, but the results simply match the new simple formula described in this theory. Even w orse, now konw ing this, adding relativistic effects yield w rong results ..

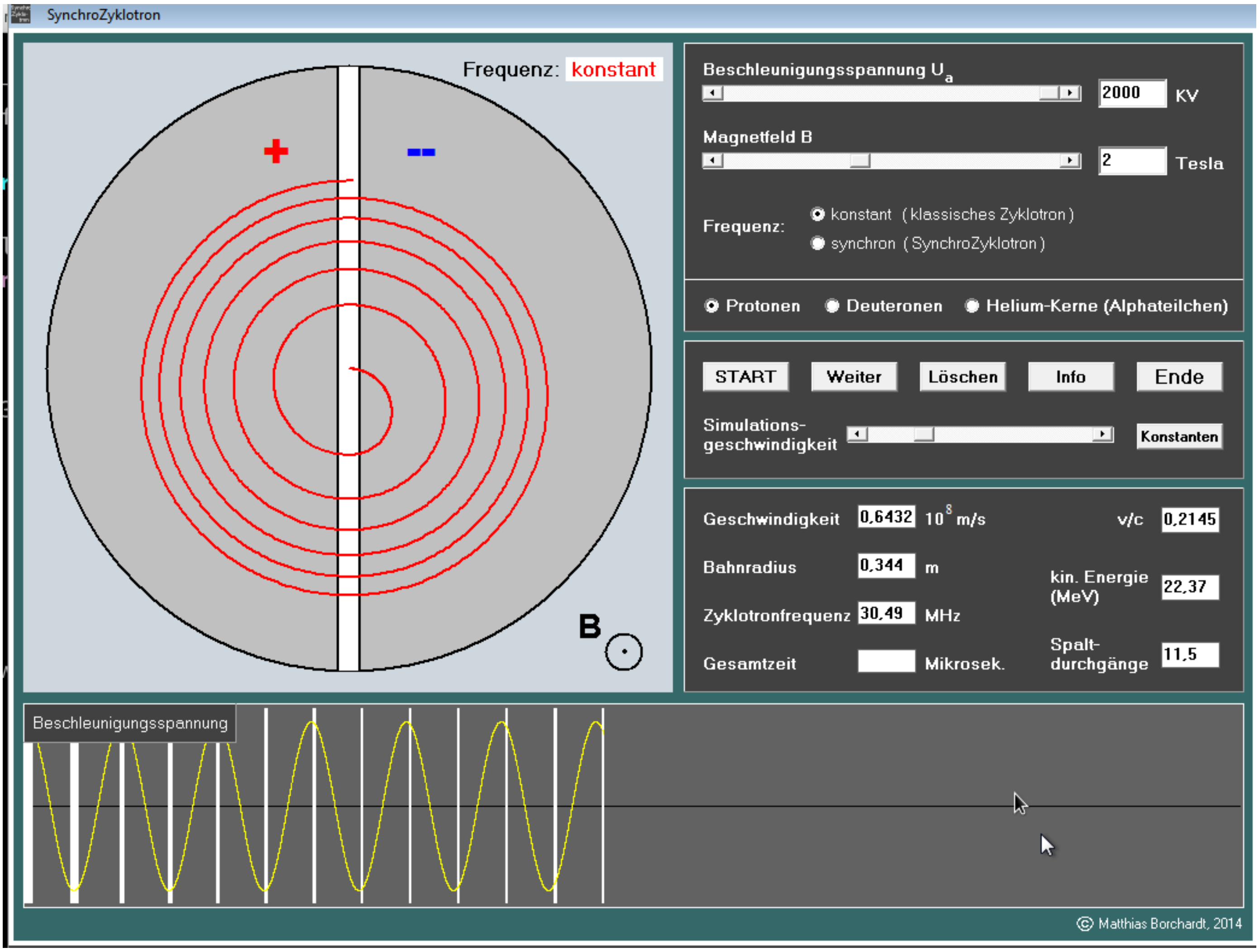
The major forces that w ere formerly ignored, result from the different amount and speed of electrons at the outer edge around the 2 half-circled electric conductors, w hich introduce asymmetric and different new forces depending on the radius and thus adding up to the observed behaviour w ithout relativity.

Synchrocyclotrons successfully compensate for this, but the explanation is a different one.

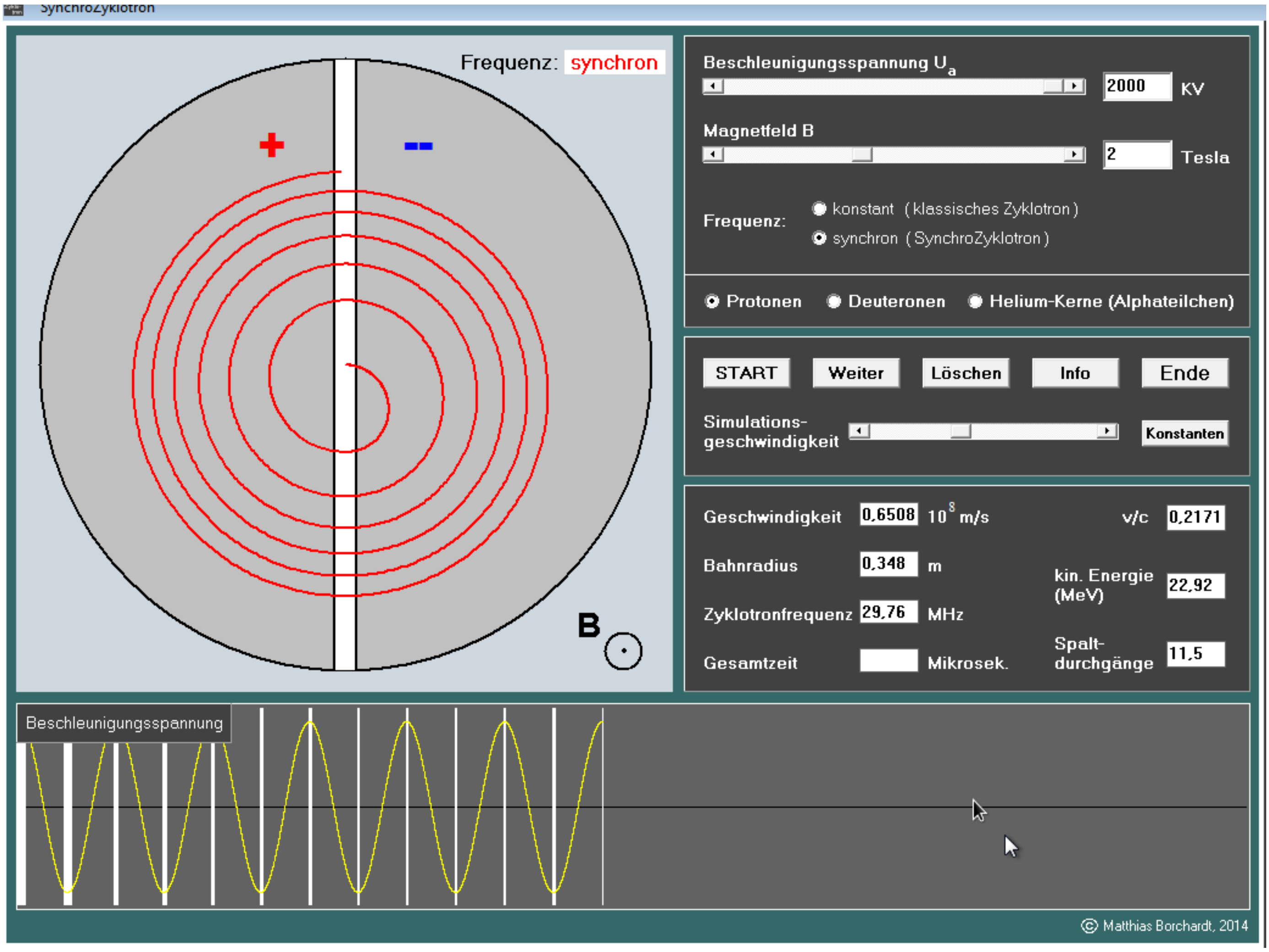
Detailed description:

Know n observations show , that a simple 'classical' calculation, as used in Cyclotrons, does not w ork for higher energies w here v gets close to c. Synchrocyclotrons solve this problem and yield better results as they adopt the frequency (decreasing the frequency at higher velocities).

Experiments show that the behaviour is similar to w hat w e w ould get w ith relativistic mass-increase of the moving particles as show n in simulation 1 and 2:
(* Simulations made w ith the simulator from http://w w w .mabo-physik.de/zyklotron.html)



Simulation 1: relativistic calculation with constant frequency
You can see that the yellow voltage-line slowly gets out of sync with the rotation-frequency (white lines indicating slit-crosses)



Simulation 2: relativistic calculation with adapted frequency
Here the voltage frequency decreases slowly, thus keeping the highest and lowest voltages in sync with slit-crosses

This new theory instead simply calculates the velocity, and thus the observed decreasing frequency, w ith a (not too simple) classical approach. The caveat is this: After any particle crossing the acceleration-slit (in this diagrams at the very top or bottom of its circular path), the accelerating voltage still applies in the opposite direction, and thus decelerating the particle. Of course this deceleration is not w ith the same amount of acceleration but (1) decreasing as the voltage decreases, and (2) distributed along a longer path (half the circle).

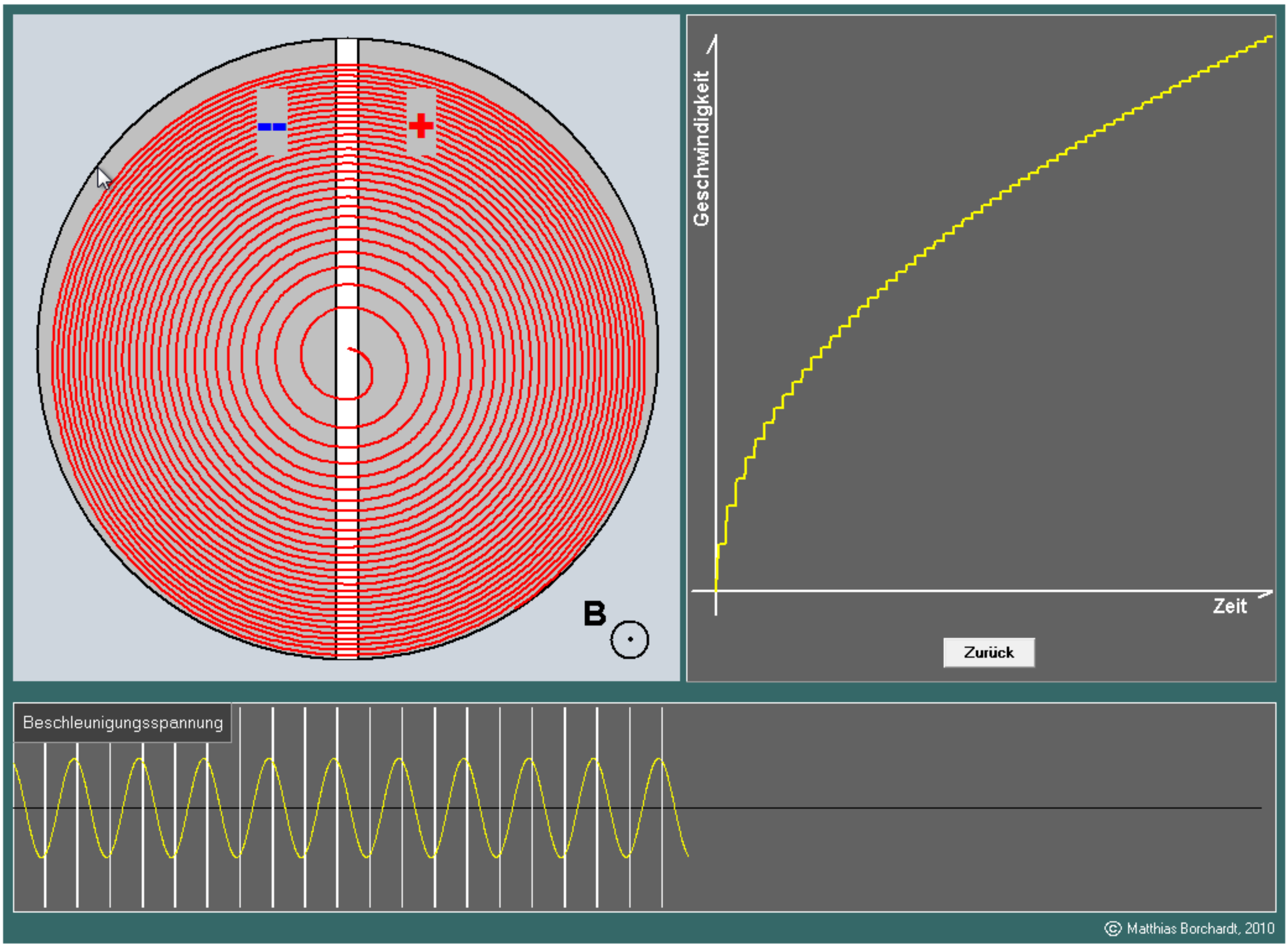
It seems that this simple but obvious fact hasn't yet been applied to the classical calculations.

Additionally the impact of Bremsstrahlung due to this additional acceleration/deceleration might add yet another decrease in overall speed/energy/frequency.

Result: This effect can be explained much easyer with this theory than with relativity.

Incomplete classical approach

The follow ing simulation is from another program w hich uses only classical calculations (w ithout relativity).



Simulation 3: Classical calculation accompanied with a velocity-time-diagram on the right side. Here you can easily spot, that the horizontal sections are horizontal, and thus are not accounting the deceleration/acceleration effect along the circular path.

In reality classical calculations would show a decelerating effect during a quarter of the circular path until the voltage hits 0 (zero), and then another (now accelerating) effect during the second quarter of the circular path. The resulting velocity at the next slit thus might be the same in both calculations, but the time needed to reach the next slit clearly is different as with this deceleration/acceleration pattern the velocity during this path is lower, thus lowering the frequency.

Additionally Bremsstrahlung might add yet another effect which hasn't been applied in this simulation.

The exact mathematical formula has yet to be calculated to demonstrate similar results to observations.

relativistic theories for the synchrocyclotron

arguments for relativistic mass-increase (now refuted ..)

relativistic mass-increase 1:

cited from: Project Gutenberg's LRL Accelerators, by Lawrence Radiation Laboratory

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Fortunately, Drs. Veksler and McMillan showed that relatively low dee voltages can be used to accelerate ions to very high energies. This is possible if the oscillatorfrequency is continuously decreased to keep it in synchronism with the decreasing rotational frequency of the ions. This would allow an ion to make many revolutions without becoming out of phase. This principle of phase stability was experimentally verified with the 37-inch cyclotron before being incorporated into the design of the 184-inch machine. Because it utilizes this principle, this machine has usually been referred to as a "synchrocyclotron" or "frequency-modulated cyclotron." However, it is sometimes called simply a "cyclotron."

[...]

In reaching an energy of 730 Mev a proton, for example, makes 75,000 revolutions in just 6 milliseconds (msec). It travels a distance of 450 miles and attains a velocity of 152,000 miles per second, or 82% of the speed of light! During this brief journey its mass increases 75%, giving very convincing evidence for the validity of Einstein's theory. Similar data for other ions may be found in the appendix.

relativistic mass-increase 2:

cited from https://www.physics.rutgers.edu/cyclotron/talks/ACCELERATORS.ppt

K. R. MacKenzie and V.B. Waithman demonstrated the relativistic effect with the 27-inch [turned 37-inch] cyclotron by severely tapering the magnet poles simulating the relativistic increase in mass. They modulated the RF frequency with a rotating capacitor, to sweep through the RF band corresponding to the resonance conditions of a particle increasing in mass. This variation on the cyclotron was named the Synchro-Cyclotron.

Upon first try an intense pulse of beam arrived at the collector at the end of every modulation cycle.

relativistic mass-increase 3:

cited from: https://uspas.fnal.gov/materials/11SBU/Cyclotrons.pdf

Relativistic mass increase imposes an upper limit to the classical w eak-focusing
cyclotron - on the order of 10 MeV protons.
There are a few w ays to over come this limitation

I. The Synchrocyclotron: Let the RF frequency w decrease as the energy increases
- Utilize the same magnetic field as the w eak focusing cyclotron
- Relies on Phase Stability ! (much low er DEE voltage)
The center is relativistically correct in the center
During acceleration the RF frequency changes w ith the mass increase
The frequency change is alw ays synchronously matched to the mass increase