Simulation of Longitudinal Electron Cooling of 20 GeV Proton Beam at EicC

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EicC Plan and Its Physics Goals

Based on the HIAF (the Heavy Ion High Intensity Accelerator Facility, approved in 2015 in China), the IMP is proposing to build a high luminosity polarized EIC facility in China, EicC, to carry out the frontier research on nucleon structure studies.

The EicC will be constructed in two stages, i.e. EicC-I and EicC-II.

EicC-I and EicC-II accelerator design parameters.

Accelerator	Electron beam	Proton beam	$\sqrt{S}$	Luminosity ($\mathrm{cm^{-2}s^{-1}}$)
EicC I	$2.8 \sim 5$	$12 \sim 20$	$15 \sim 20$	$2 \sim 4 \times 10^{33}$
EicC II	$5 \sim 10$	$60 \sim 100$	$35 \sim 63$	1×10^{35}

Energy unit in GeV.   Both electron and ion beams are polarized.

Electron Ion Collider in China.

Background

- **High** Brightness
- **High** Quality of proton beam in the storage ring
- **High** Experiments efficiency
- **Long** Lifetime of proton beam in the storage ring

Key parameters affecting cooling time

- **Storage ring**: Betatron function, dispersion

- **Proton beam**: Energy, initial emittance, momentum spread

- **Electron cooling device**: Magnetic field strength, parallelism, cooling length

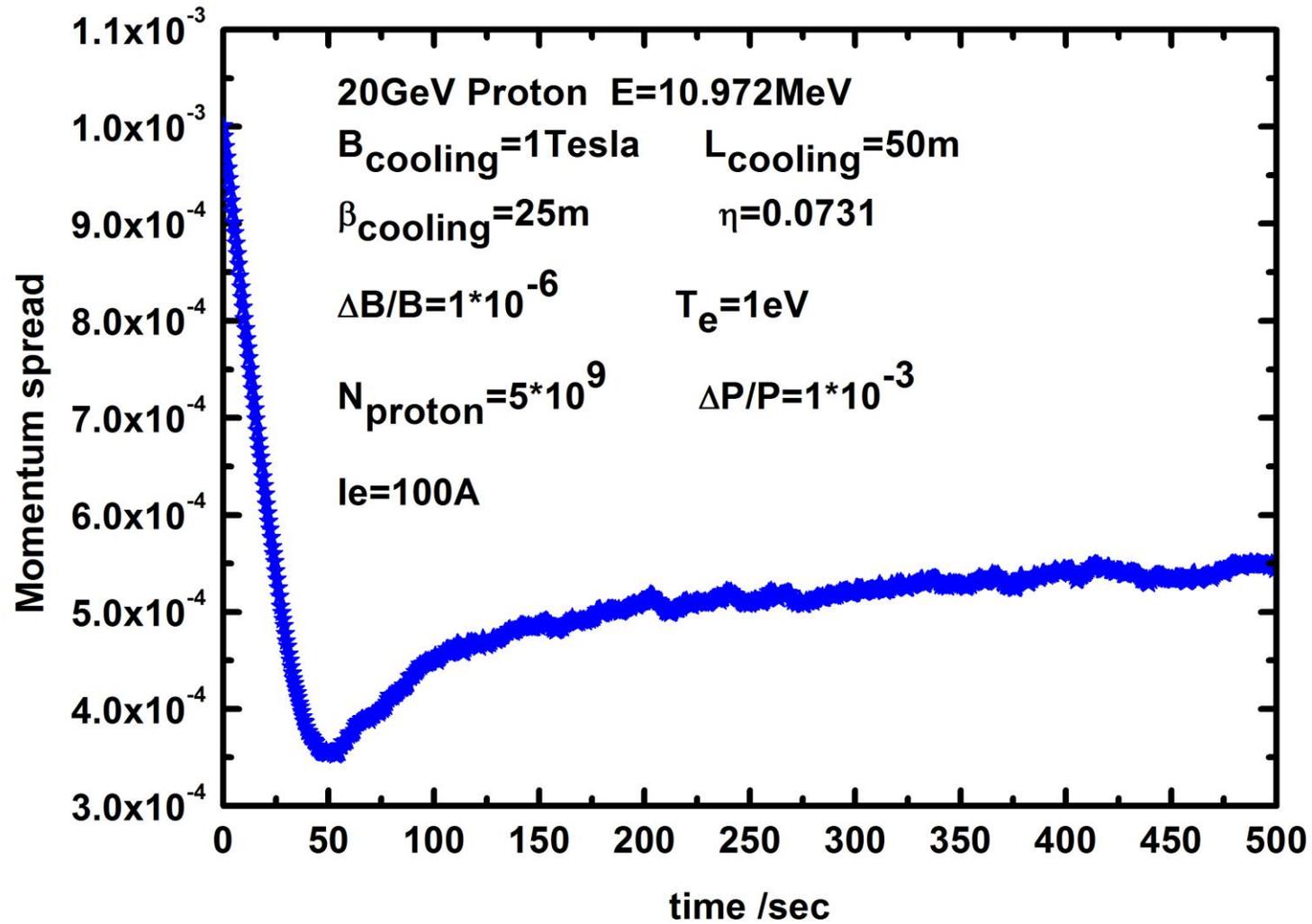- **Electron beam**: Radius, density, transverse temperature

Figure 1: A typical longitudinal cooling process.

Longitudinal cooling

- **The longitudinal cooling behaviour is different from the transverse one. After the balance is achieved in the transverse direction, the transverse emittance remain unchanged. But the longitudinal momentum spread shrink rapidly at the beginning and then bounces back from the bottom.**
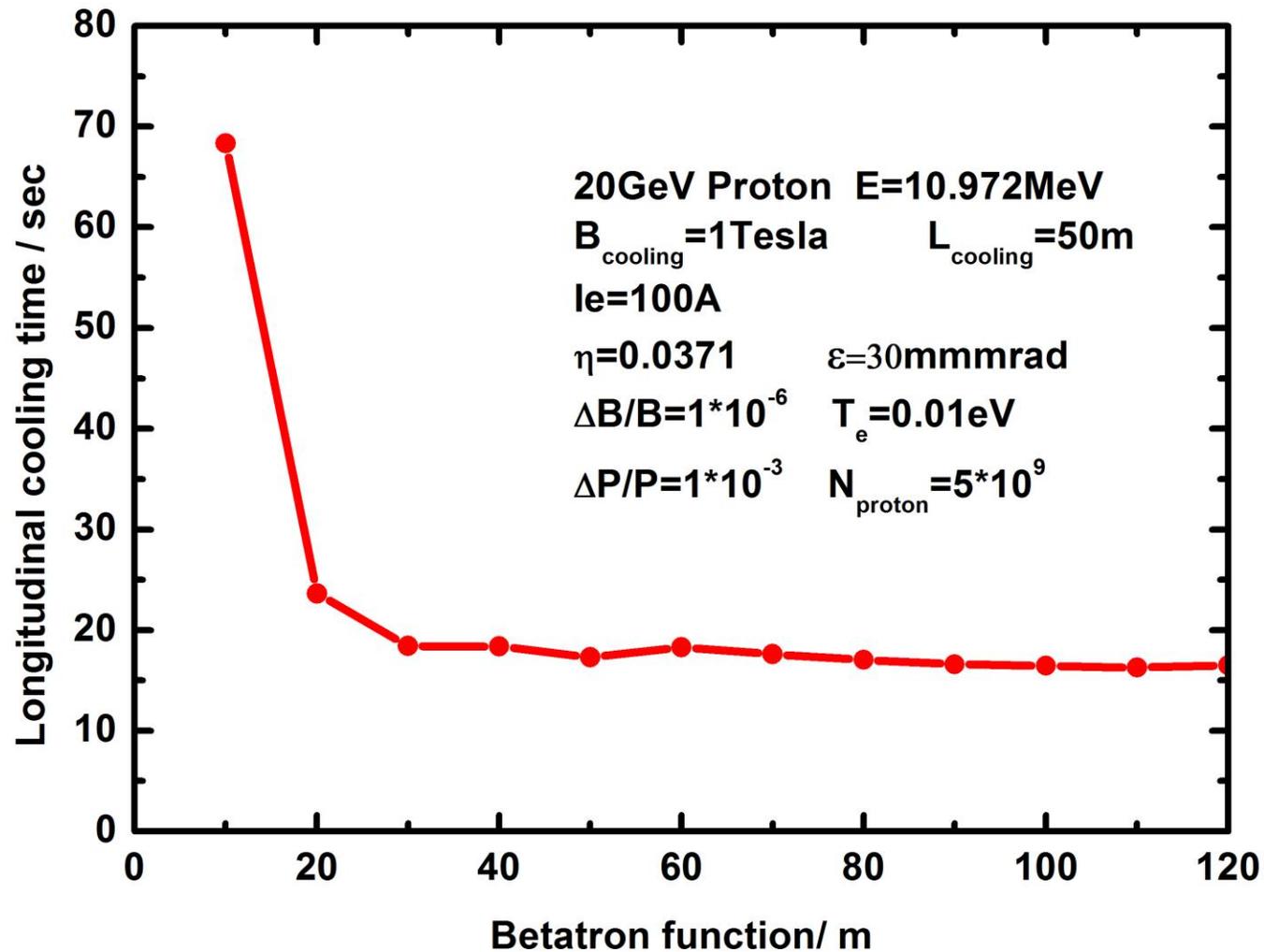
Longitudinal cooling time

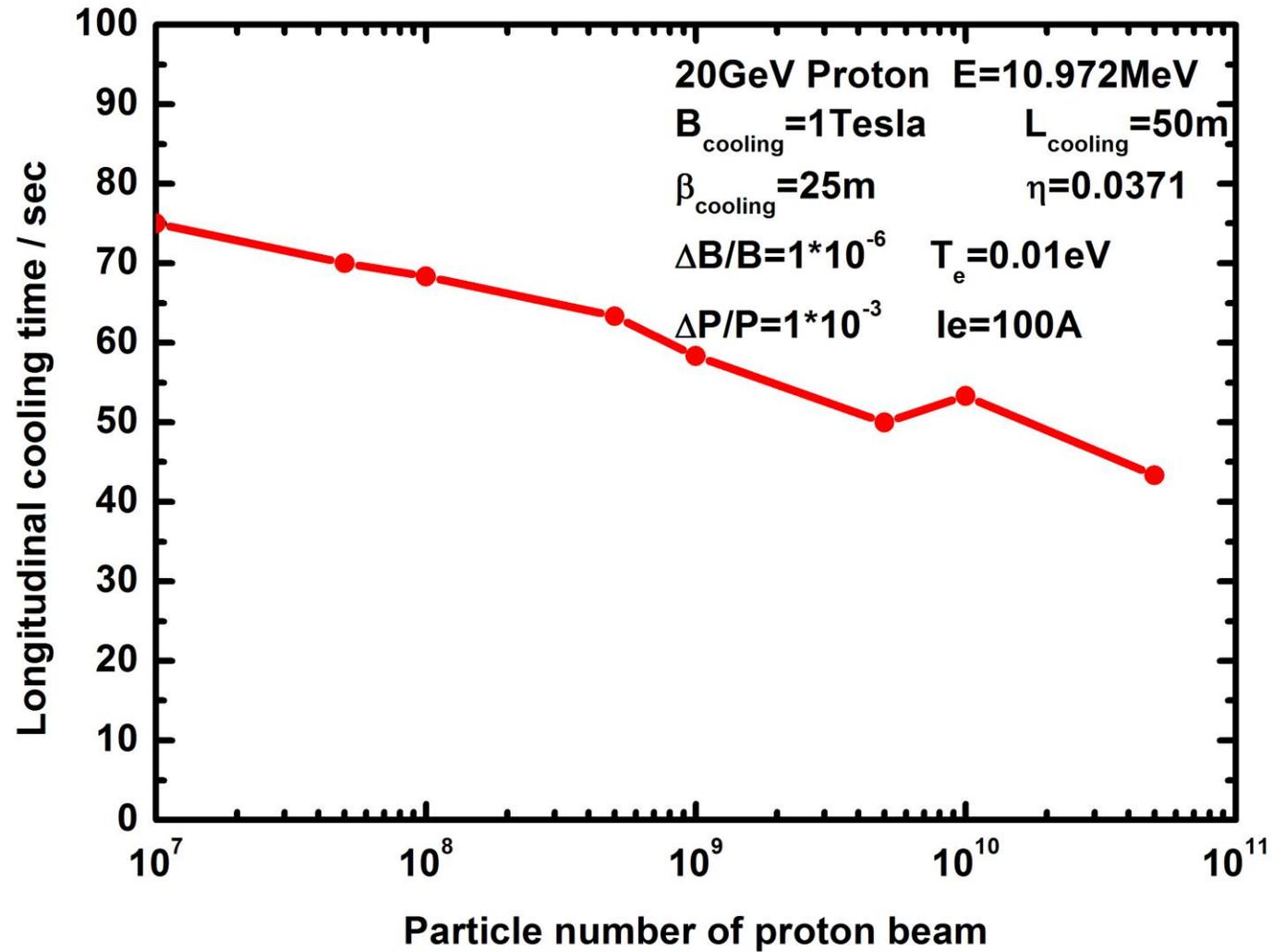**Figure 2: The longitudinal cooling time as a function of the Betatron function in the cooling section.**

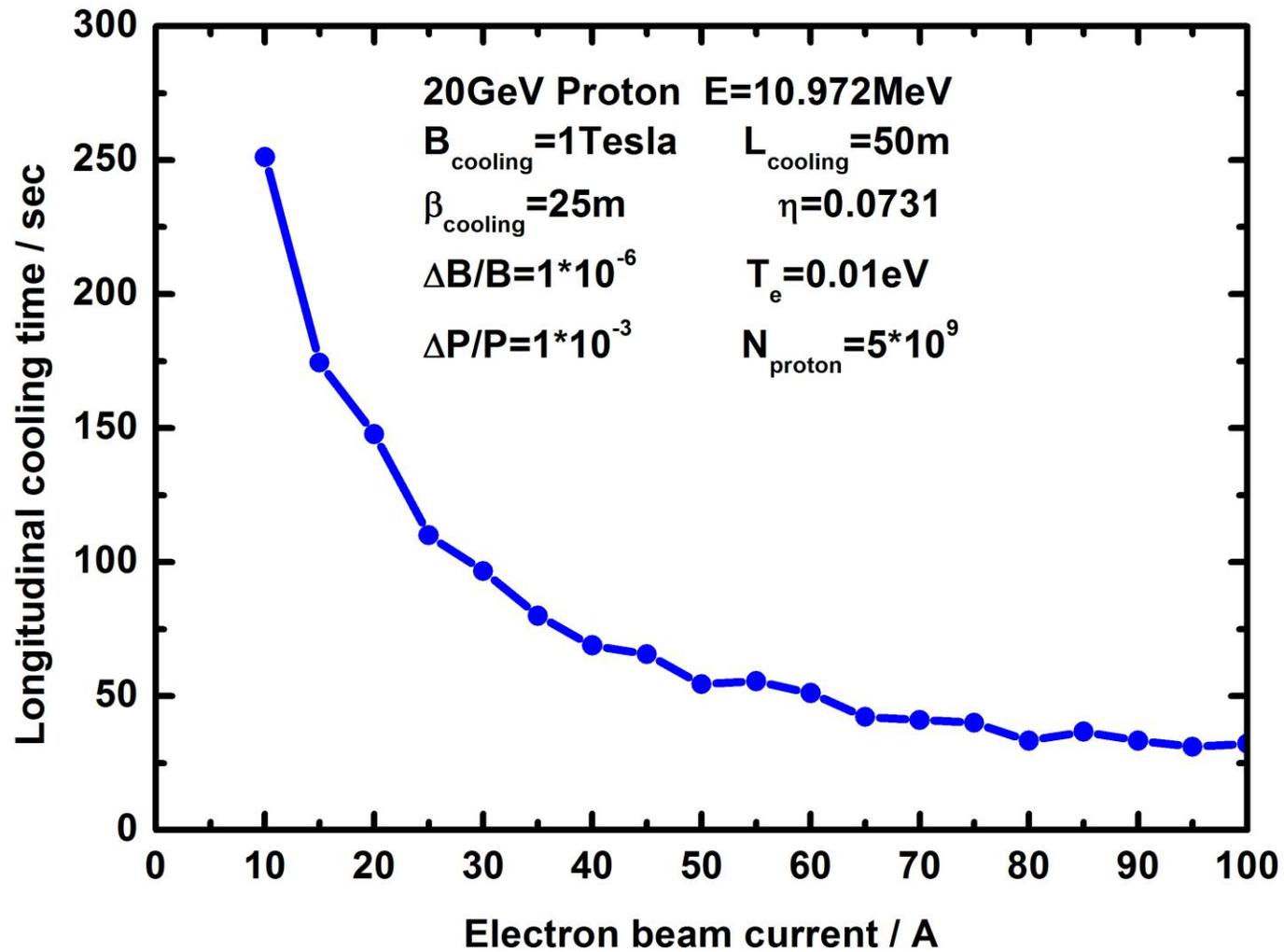**Figure 3: The longitudinal electron cooling time as a function of the particle number in the proton beam.**

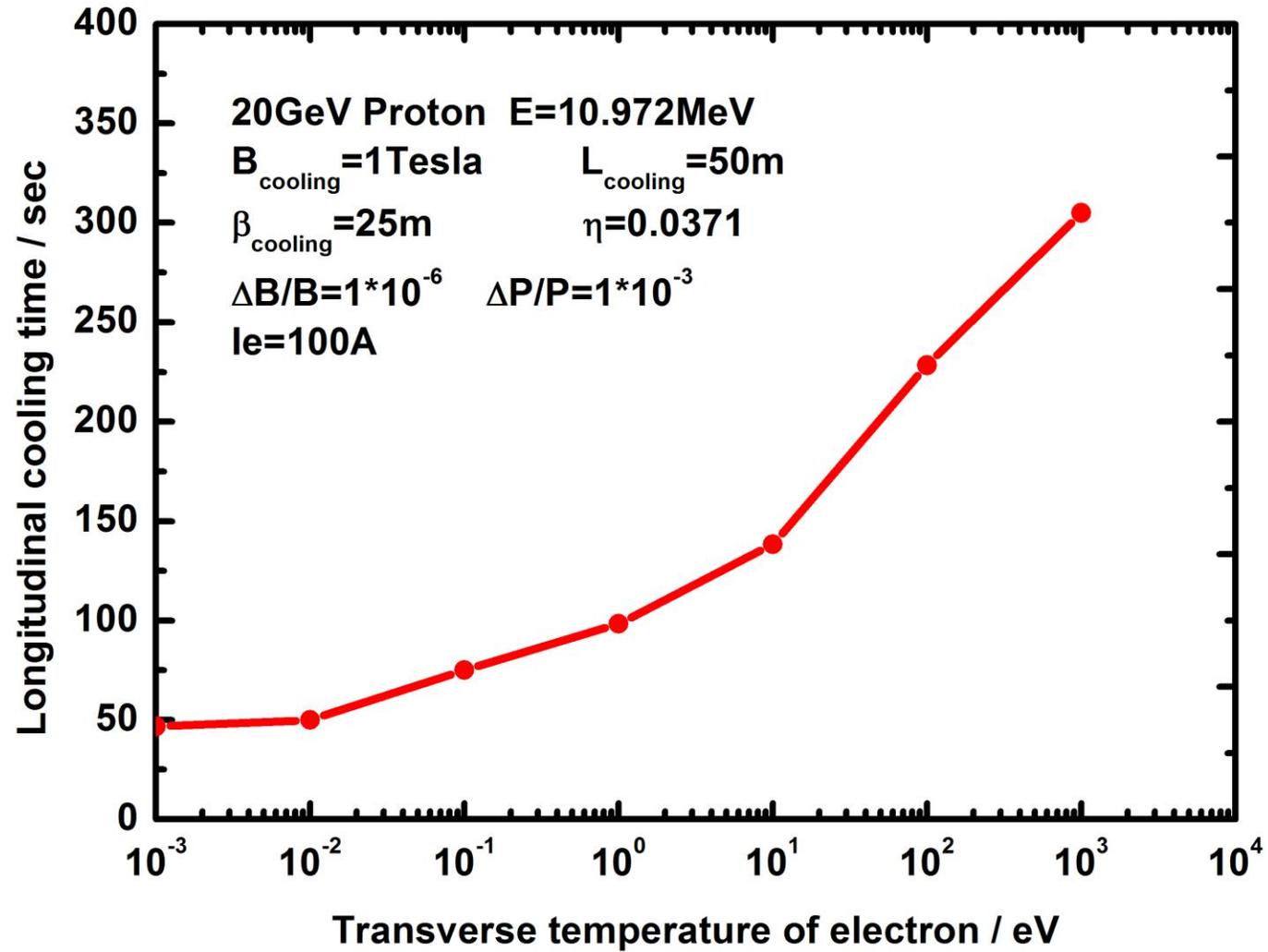**Figure 4: The longitudinal cooling time as a function of the electron beam current.**

Figure 5: The longitudinal cooling time depends on the transverse temperature of the electron beam.
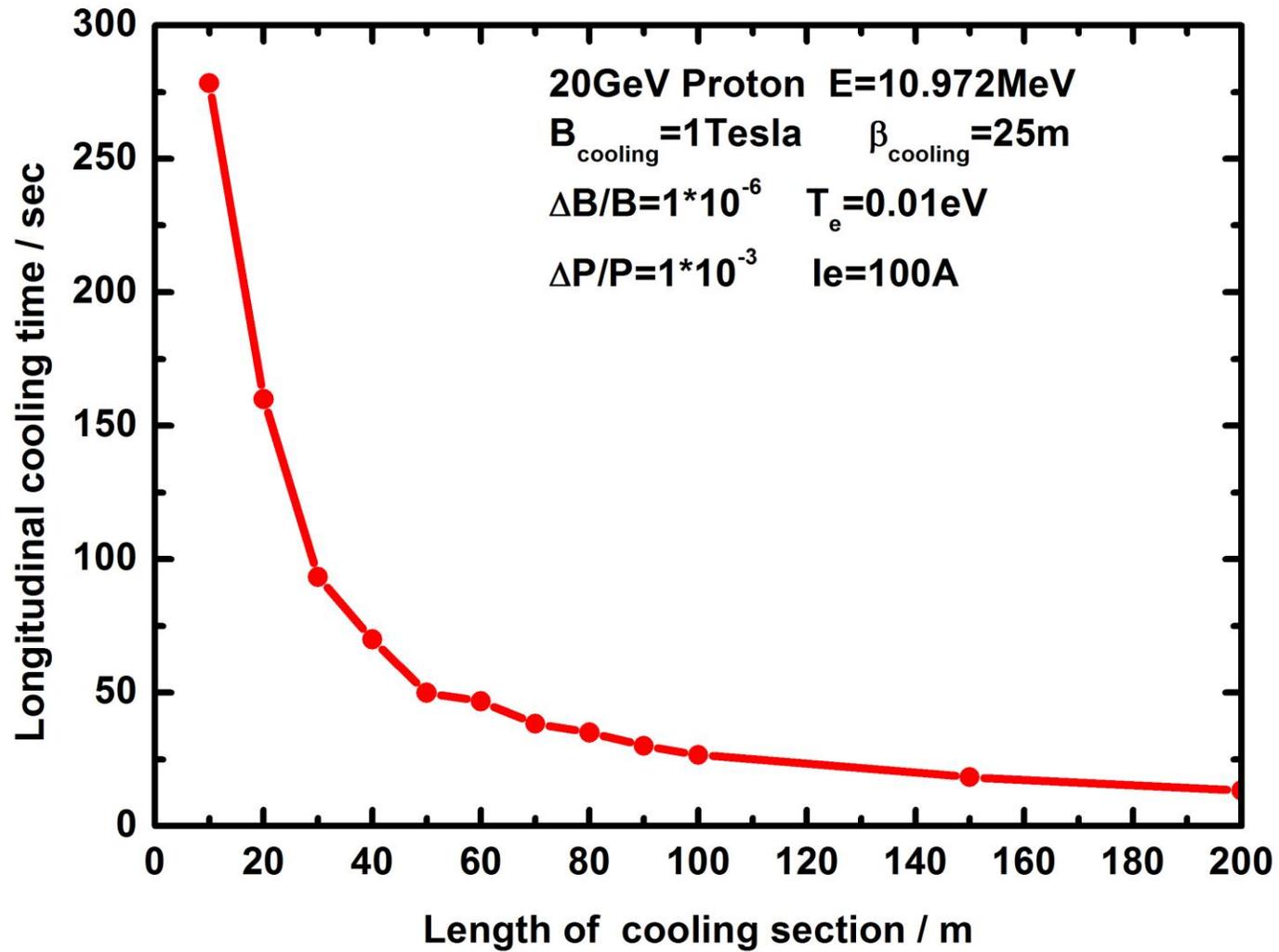
Figure 6: The longitudinal cooling time varies as a function of the length of the cooling section
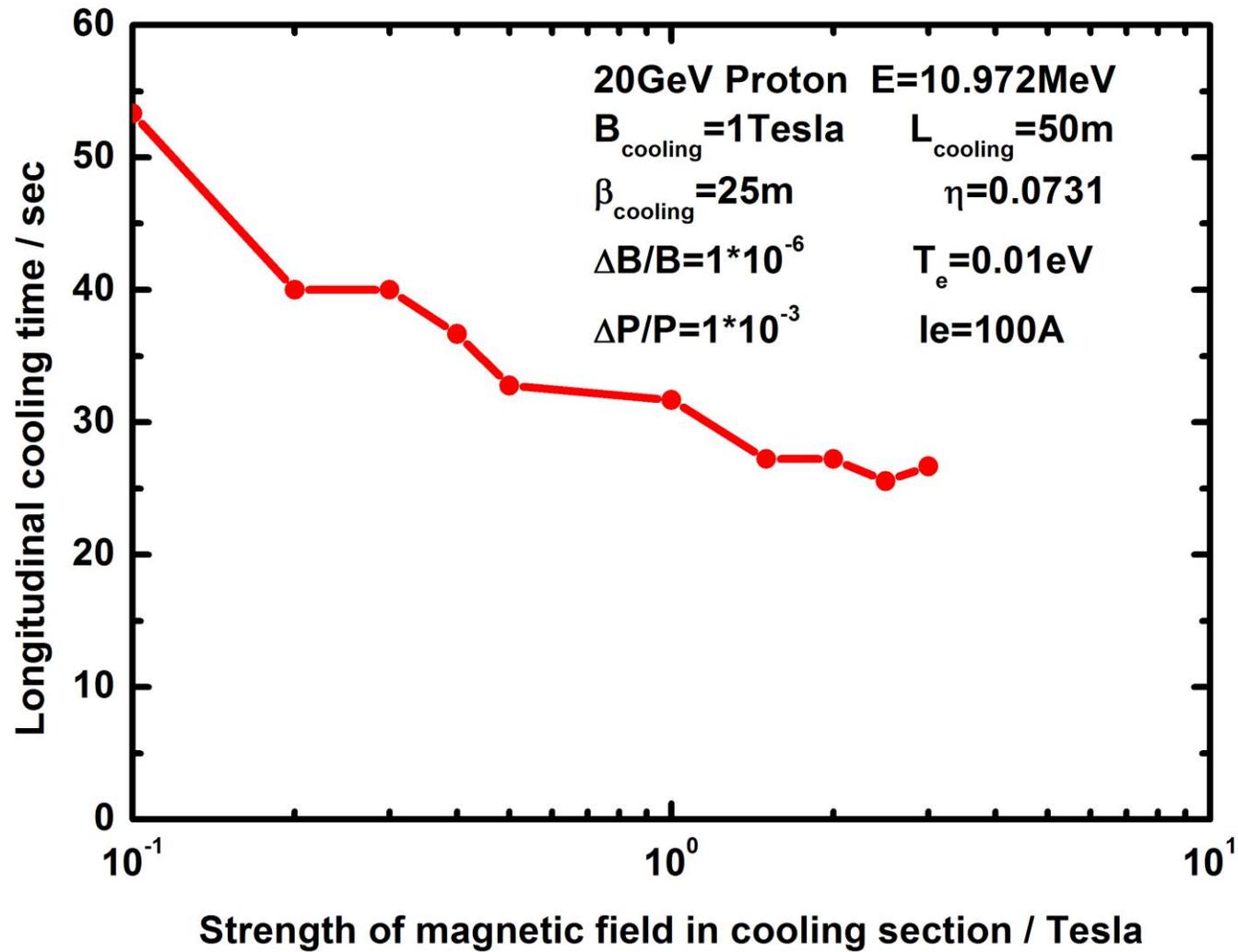
Figure 7: The longitudinal cooling time as a function of the magnetic field strength in the cooling section.
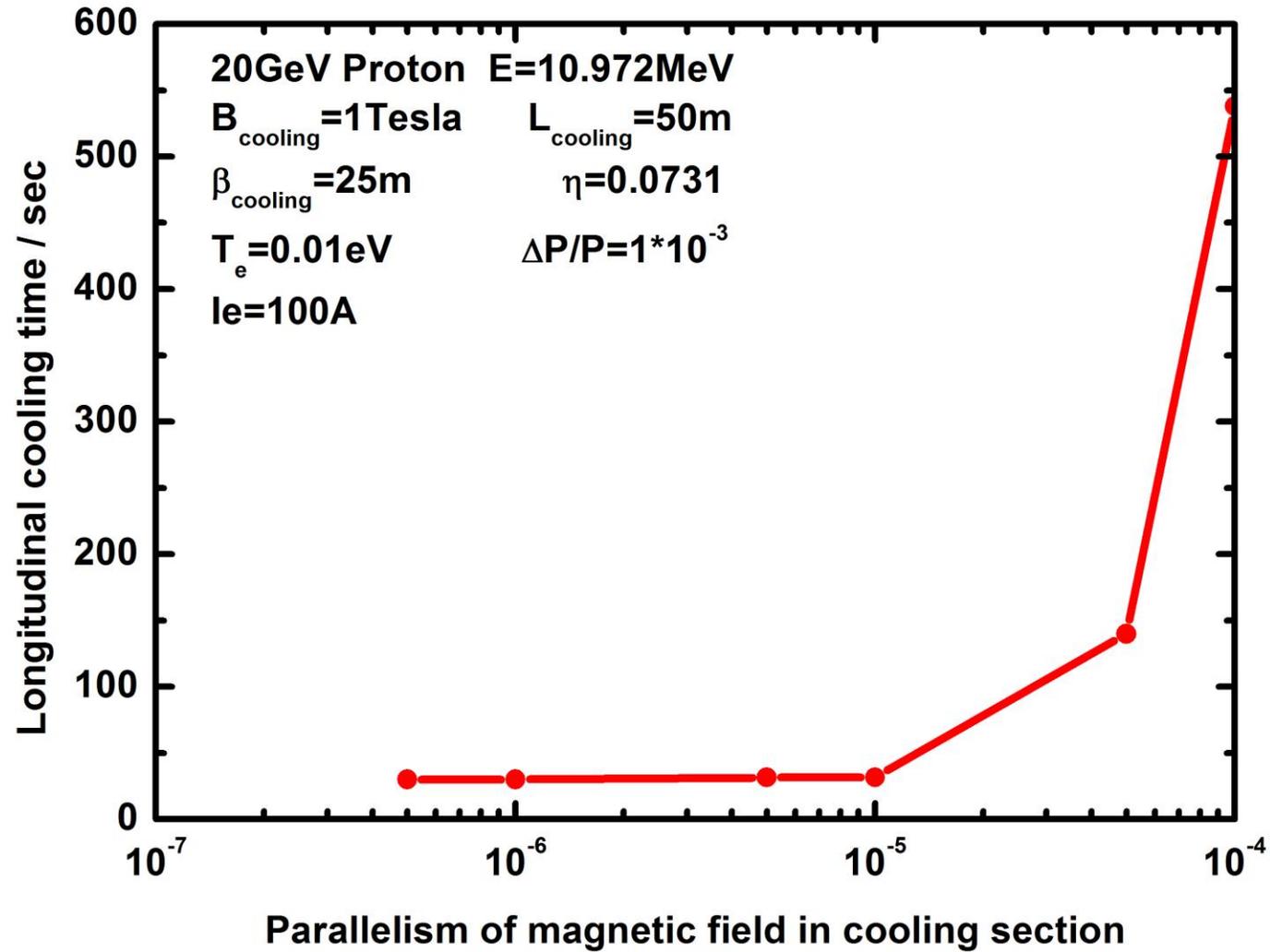
Figure 8: The longitudinal cooling time as a function of the parallelism of the magnetic field in the cooling section.

Possible cause

- In the case of high-energy electron cooling, the longitudinal velocity of the electron beam was much greater than the transverse velocity. In the cooling simulation, the same time interval was used for both transverse and longitudinal. Electron beams travelled at **different path lengths** during the same time interval in the transverse and longitudinal directions. This may be the cause of the unexpected results in the simulations.

Possible cause

- Due to longitudinal velocity mismatch or magnetic field parallelism, the **projection** of longitudinal velocity in the transverse direction will also be much greater than the transverse velocity of the electron beam. Therefore, in the longitudinal direction, the parameter requirements are more precise and the matching degree is high.
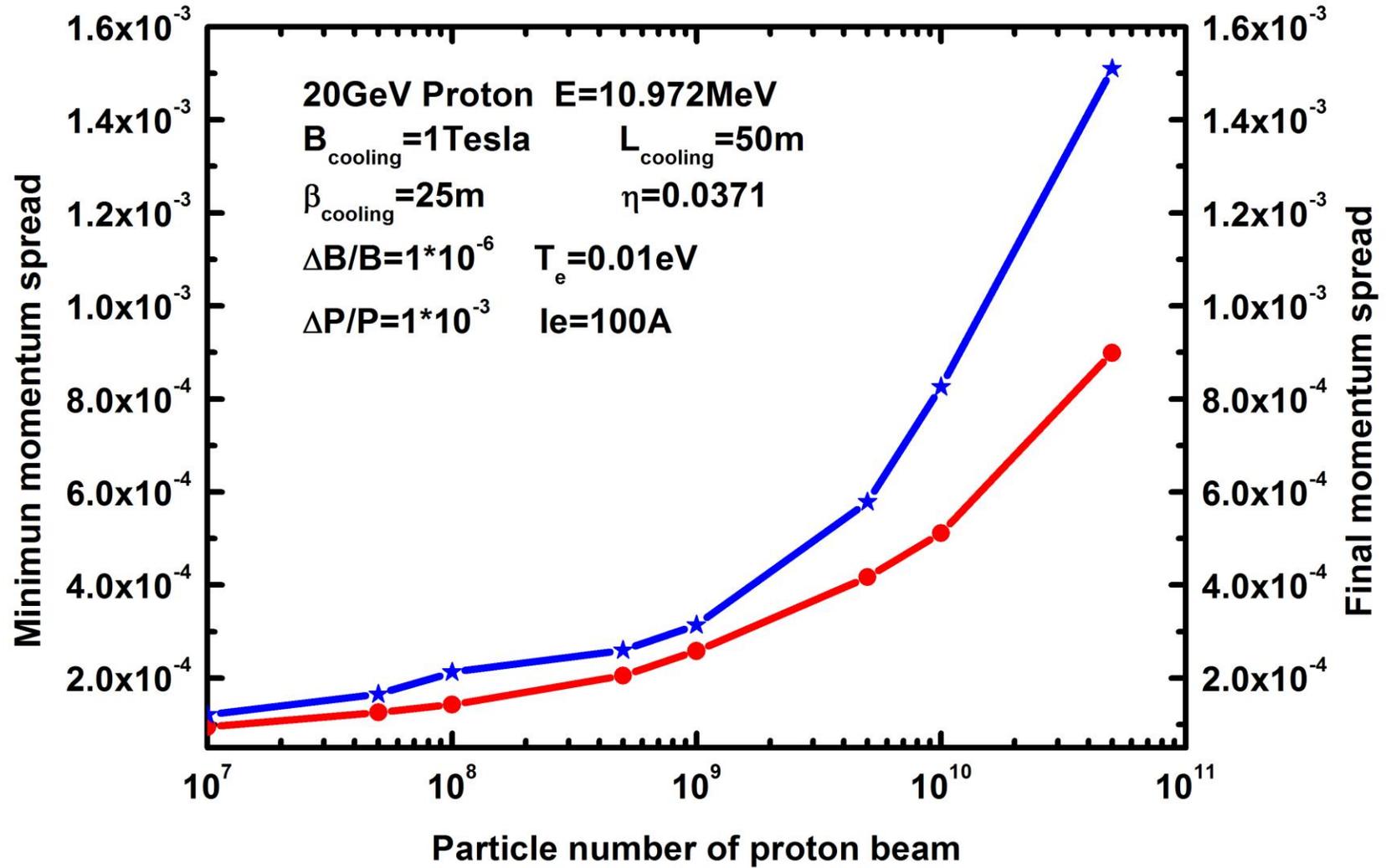
Minimum and final momentum spread

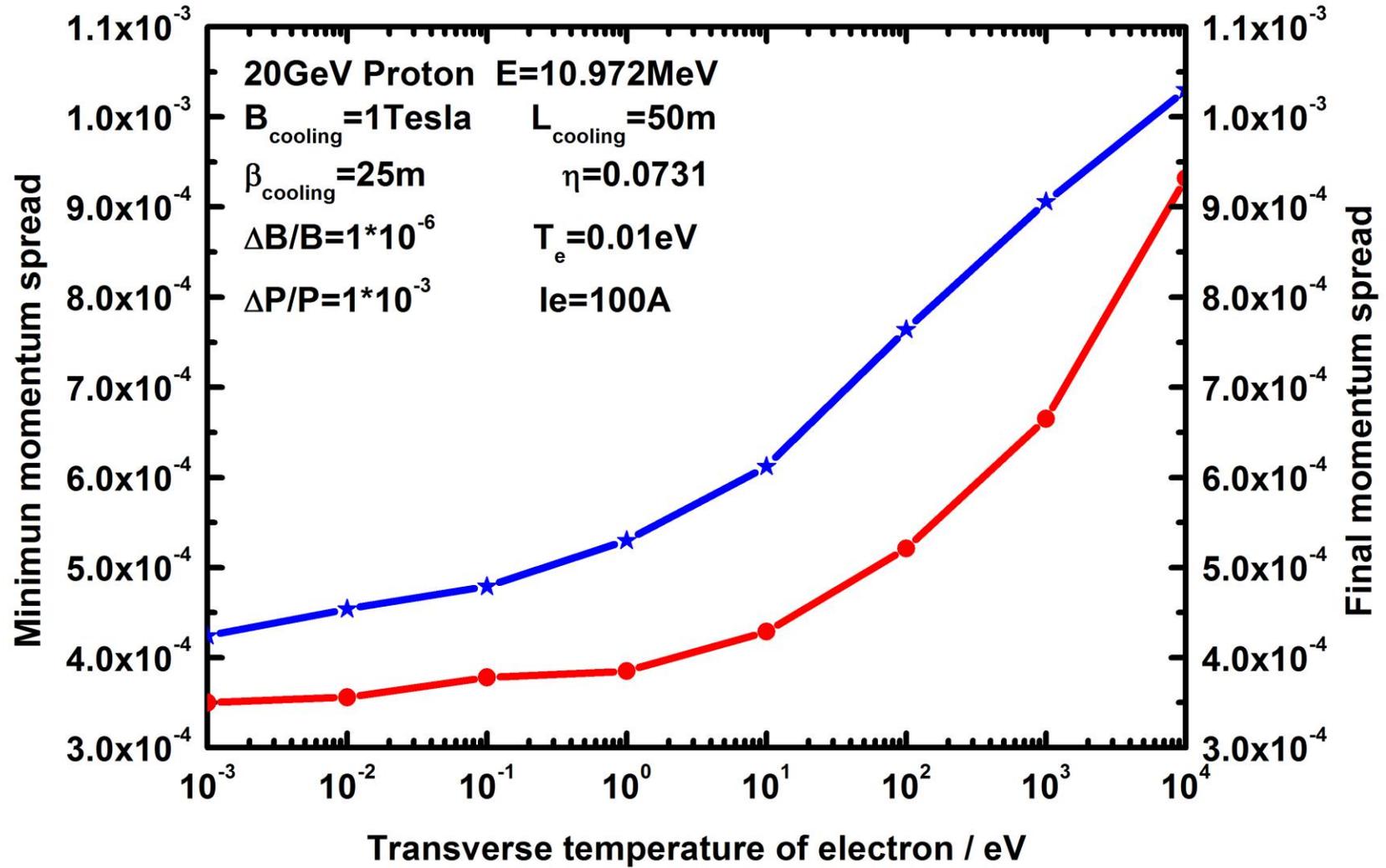**Figure 9: The minimum and final momentum spread as a function of the particle number.**

Figure 10: The minimum and final momentum spread as a function of the transverse temperature of the electron.
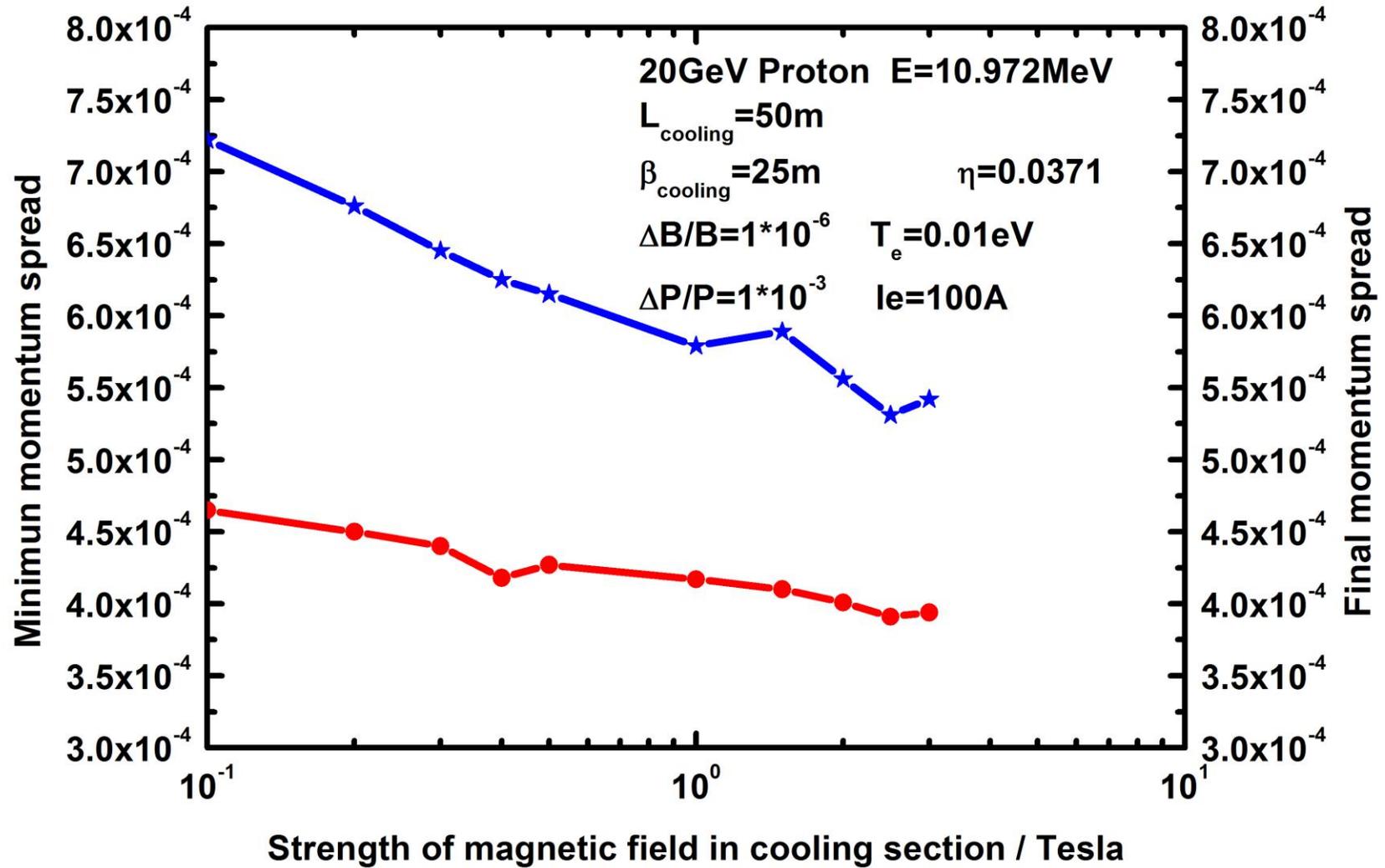
Figure 11: The minimum and final momentum spread as a function of the magnetic field strength in the cooling section
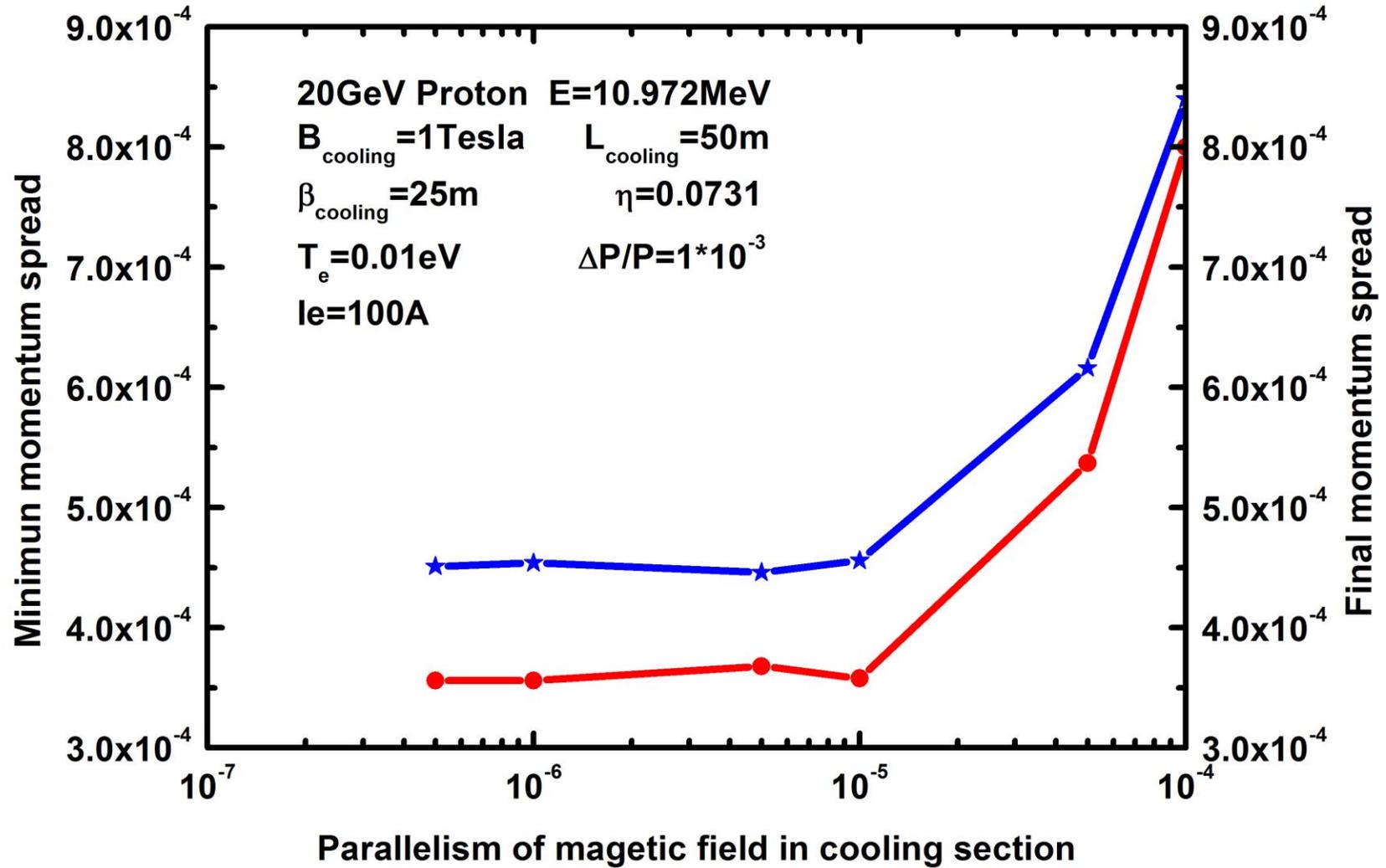
Figure 12: The minimum and final momentum spread as a function of the parallelism of the magnetic field in the cooling section

High energy electron cooling

- The longitudinal cooling behavior is different from the transverse one
  - Optimized carefully and compromise each other
  - Dispersive cooling
  - Multi-stage cooling

Summary

- The longitudinal cooling time can be shortened with the help of proper configuration of the parameters, such as smaller initial emittance and electron transverse temperature, higher magnetic field strength, parallelism of magnetic field in the cooling section, longer length of electron cooling section, stronger electron beam current, and proper beta function in the cooling section.

Financial Support

Thanks for your attention!

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