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Converting the Börekci Energy Field into a quantum teleportation platform: a pre-experimental design study

Hasan Börekci

hborekci@hotmail.com.tr

HB ZECHMANN Medical Company

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Abstract

Almost all quantum teleportation experiments operate at the microscale, while macroscopic, fully isolated experimental volumes remain scarce. This design study converts the cavity-magnet version of the Börekci Energy Field (BEF) — a 226 m³ underground cavity enclosed by a 50 MV electron-arc energy shell and a 1 PW annular laser, with electromagnetic and radiological attenuation below 10^{-12} — into a platform for trapped-ion quantum teleportation (BEF-T). The live payload of the parent design is replaced by an ultra-high-vacuum quantum module, and the 2 T cavity field is re-tasked as the confinement field of Penning traps (cyclotron frequency ≈ 3.4 MHz for $^{9}Be^{+}$). Three experiments are defined: D1, atomic-state teleportation across 8 m inside the cavity; D2, teleportation from the interior to an exterior node across the operating energy shell, using entanglement distributed by fibre before the run; and D3, a delayed-classical-channel protocol in which the two Bell-measurement bits are recorded inside the sealed 24-hour run and the correction is applied afterwards, yielding an entanglement-enhanced probe of the ξ parameter of the parent proposal (predicted optical-qubit phase accumulation ≈ 5×10^{-3} rad per day at ξ = 1). Strict physical limits — no faster-than-light signalling, no macroscopic teleportation — are stated.

Introduction

Quantum teleportation transports a quantum state, not matter: a shared entangled pair, a Bell measurement at the source, two classical bits and a local correction at the receiver transfer an unknown state exactly, while the source copy is necessarily destroyed by the no-cloning theorem and the transfer can never outrun the classical bits [1, 2]. Since the first photonic demonstration [3], the internal states of single ions have been teleported deterministically from atom to atom [4, 5], and photonic teleportation has been carried over 1,400 km to orbit [6]. All of these experiments, however, live at the microscale: single photons, single ions, small ensembles. Large, life-scale, fully isolated experimental volumes in which quantum protocols can be exercised are scarce — a gap this paper addresses with a concrete design.

The Börekci Energy Field (BEF) is the author's pre-experimental proposal of a fully isolated apparatus: a stationary 226 m³ interior enclosed by an energy shell formed by a 50 MV electron arc and a 1 PW annular laser, behind walls that attenuate electromagnetic and radiological transmission below 10^{-12}, in a sealed room under a mountain [7]. The parent papers treated the apparatus as a gravitational-time-dilation testbed — via a parametrised metric term with a single testable parameter ξ (ξ = 1 recovers standard physics) — and as a Bethe–Heitler positron source [7, 8]. The present paper asks a third question: what does this apparatus offer quantum teleportation, and what does a teleportation-suitable conversion look like?

Two observations frame the answer honestly. First, the popular notion of teleportation — matter vanishing here and appearing there — does not exist in physics; what can be teleported is the state, received by a carrier particle of the same species. Because same-isotope atoms are fundamentally identical, an atom whose state has been transferred exactly is physically indistinguishable from 'the

atom itself having moved'; in that precise sense atomic-state teleportation is the teleportation of the atom. Second, the BEF energy shell itself supplies no teleportation resource: entangled pairs born in the shell decohere within nanoseconds. BEF's genuine contribution is not the shell but the volume the shell protects — Faraday-dark, radiologically silent, thermally stable and vibration-isolated. The design below turns that volume into a quantum node.

Results

The BEF-T conversion: payload change and field re-tasking

The conversion retains the parent apparatus unchanged — outer capsule (Ø16 m, 150 t, 0 atm), elliptical inner capsule (12 m pole-to-pole, 90 t, layered SiC-SiC/W-steel/Pb/water walls), energy shell (50 MV arc, 1 PW annular laser, 0.1 atm Pb vapour), stationary cavity electromagnet (N at the interior ceiling, S at the floor, 2 T total) and the 24 h operating scheme — and changes only the payload. The live payload of the parent design (a 9 kg pig) is replaced by a sealed ultra-high-vacuum column (< 10^{-10} mbar) on a vibration-isolated platform on the cavity axis: node A (an ion trap plus the interior optical clock) at the top, node A' (a second ion trap) at the bottom, with the ~ 8 m free optical path between them serving as the photonic link (Fig. 1). The ethics burden disappears: nothing in the system is alive.

The uniform 2 T axial field, which in the live-payload version carried only hypothesis motivation, becomes functional hardware: a Penning trap confines charged particles with exactly such a strong uniform axial field plus a weak electrostatic quadrupole. At 2 T the cyclotron frequency of $^{9}Be^{+}$ is $f_c = qB/2\pi m \approx 3.4$ MHz — the ordinary operating regime of Penning-trap qubit crystals. Field-insensitive clock transitions protect qubit coherence from residual field fluctuations; mu-metal-shielded Paul traps inside the module are an allowed alternative. Table 1 maps every component of the parent design to its BEF-T role.

Table 1
Mapping of components from the parent design to BEF-T.

Component	Role in the parent (live-payload) version	Role in BEF-T
226 m³ cavity	Habitat of the live payload	Fully isolated quantum laboratory (UHV module + 1 atm environment)
2 T cavity magnet	Hypothesis motivation; MRI-class reference field	Confinement field of the Penning traps ($^9Be^+$: $f_c \approx 3.4$ MHz)
Interior optical clock	Time-dilation measurement	Same, plus qubit phase reference (the D3 probe)
Walls (Pb + W-steel, $< 10^{-12}$)	Radiation protection	Decoherence armour for qubit coherence
Energy shell	Source of the metric hypothesis	Unchanged; the barrier crossed in D2 and the subject of the ξ probe
Fibre feedthrough	—	Pre-run entanglement distribution; sealed during the run
Interior camera + lighting	Animal-welfare monitoring	Module diagnostics; shuttered during interrogation windows

Experiment D1: atomic-state teleportation across 8 m inside the cavity

D1 is a direct scale-up of the 2004 trapped-ion experiments [4, 5]: the internal state of an ion at A is teleported to A' over the A–A' entangled pair and the module-internal classical line. The run is repeated with the shell off (quiet mode) and at full power; the fidelity difference between the two conditions directly measures the shell's acoustic and magnetic leakage into the qubits. Target fidelity is > 0.90 against the classical bound of 2/3. D1 requires only demonstrated technology.

Experiment D2: teleportation across the operating energy shell

Before the run, the shielded single-mode fibre feedthrough in the inner-capsule wall is opened; ion–photon entanglement generated at node A is converted, photon-to-ion, into A–B ion–ion entanglement at an exterior node B with its own trap and reference clock. After a sufficient number of pairs is banked in hyperfine memory qubits — whose coherence times have reached the hour scale — the feedthrough is sealed. While the shell runs at full power, no photon, electron or classical signal crosses between interior and exterior: pre-shared entanglement is the only channel through which quantum information can pass. A state at A is then teleported to B, the Bell measurement performed inside, the correction applied after the run. Standard quantum mechanics predicts unambiguously that entanglement is sensitive only to decoherence of the particles themselves, not to intervening matter; D2 tests this prediction under total

electromagnetic blackout, and any deviation would itself be a discovery. Success criterion: post-run-corrected fidelity above the classical bound.

Experiment D3: delayed classical channel and the teleportation-based ξ probe

Because teleportation cannot in any case be completed before the classical bits arrive, delaying their delivery costs nothing physically. In D3 the two Bell-measurement bits are written, time-stamped, to an interior recorder during the sealed 24 h run; the record leaves the cavity only after unsealing, and B applies the correction then. The total-isolation premise of the parent experiment is thereby preserved intact.

The parent proposal's central question — whether the interior spacetime tempo separates measurably from the exterior — can be restated in qubit language: the interior qubit's phase evolves at the interior tempo. Even at $\xi = 1$ the difference is non-zero: the interior clock falls 1.93×10^{-18} s behind the exterior per 24 h (Methods), which for an optical-frequency qubit ($f \approx 4.3\times10^{14}$ Hz) is an accumulated phase $\Delta\varphi = 2\pi f\Delta\tau \approx 5\times10^{-3}$ rad; for a 10 GHz hyperfine qubit the same offset is only $\sim 10^{-7}$ rad, which is why D3 is built on an optical qubit. Following the quantum-network-of-clocks approach [9], joint analysis of repeated Ramsey windows over the banked A–B pairs can push the interior/exterior frequency comparison beyond the standard quantum limit, adding an entanglement-enhanced channel — alongside the parent design's three-clock protocol — for bounding ξ. If $\xi \gg 1$ were realised, the phase shift would be large and D3 would catch it first; if not, D3 tightens the upper bound with quantum-metrological sensitivity.

The shell's entangled products are not a teleportation resource

The shell produces $\sim 3.06\times10^{17}$ momentum- and spin-correlated e^+e^- pairs per 24 h and polarisation-entangled 511 keV annihilation photon pairs [8] — by raw count among the largest entanglement production rates anywhere. As a teleportation resource this inventory is worthless: usable entanglement must be captured, stored and addressed, whereas shell pairs scatter $\sim 10^6$ times per second and decohere within nanoseconds, and MeV-scale particles cannot be addressed as qubits with present technology. The shell's entangled inventory is therefore a diagnostic channel (511 keV coincidence counting independently gauges the positron yield), not a resource; BEF-T's teleportation resource is the optical-ion entanglement generated and protected in the cavity.

Discussion

The significance of BEF-T is the scale gap it addresses. Teleportation and entanglement experiments to date live in the quantum realm — single photons, single ions, atomic ensembles — while at the macro scale, in large isolated volumes of life-relevant size, experimental platforms are scarce. BEF-T is, to the

author's knowledge, the first concrete design that carries standard trapped-ion teleportation protocols into a macroscopic (226 m^3), fully isolated environment that in its parent version even hosts a living payload. D1 and D2 stand on their own as publishable results — teleportation in the most isolated volume yet constructed, under total electromagnetic blackout — regardless of the outcome of the ξ probe.

The strict limits deserve equal prominence. (i) No matter is transported: a same-species carrier waits at the receiver, and only the state moves — though by the identical-particles argument this is physically equivalent to teleporting the atom. (ii) Nothing is faster than light: the protocol cannot complete without the classical bits, whose delivery BEF-T deliberately postpones by 24 h. (iii) No macroscopic teleportation: a single cell is ~ 10^{14} atoms and a pig ~ 10^{26}; measuring and transferring their joint quantum state requires a state space whose dimension exceeds the atom count of the observable universe — the obstacle is measurement mathematics, not engineering. (iv) The shell produces but cannot preserve entanglement. (v) The D3 probe does not assume $\xi \gg 1$; it measures ξ, and $\xi = 1$ (standard physics) is the null expectation. The ξ parametrisation itself is speculative and is offered as a falsifiable target, not as a claim.

Practically, removing the live payload removes the ethics burden while leaving the energy budget unchanged (6.7 MW; 160.8 MWh ≈ $12,900 per 24 h run), and the cavity's conditions — static 2 T field, < 10^{-12} radiation background, thermal and vibrational stability — are close to ideal for quantum hardware. Fully isolated node time is itself a leasable resource for metrology institutes and quantum-network developers, so the economic backbone of the parent proposal survives the conversion. The design's feasibility risks are concentrated where they should be: in the engineering of the parent apparatus itself, which remains a pre-experimental proposal; the quantum module, by contrast, requires only demonstrated ion-trap technology.

Methods

Parent apparatus parameters

The cavity-magnet BEF design [7] encloses a stationary interior of 226 m^3 within an elliptical inner capsule (12 m pole-to-pole, 90 t; wall layers 90 cm SiC-SiC, 90 cm W-steel, 100 cm Pb, 30 cm water) inside an outer capsule (Ø16 m, 150 t, evacuated; 150 cm SiC-SiC, 50 cm water, 90 cm W-steel) in a sealed underground chamber. The energy shell is a 50 MV electron arc (50–200 μA start, 0.5–2 mA sustained) with a 1 PW annular laser and 0.1 atm Pb vapour; combined wall attenuation is below 10^{-12} across the electromagnetic and radiological spectrum. A stationary electromagnet with N pole at the interior ceiling and S pole at the floor provides a 2 T axial field throughout the cavity. The system operates continuously for 24 h per run.

Teleportation protocol

The protocol is that of Bennett et al. [1]. Nodes A and B share a Bell pair (e.g. $|\Phi^+\rangle$); A performs a joint Bell-basis measurement on the unknown qubit $|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$ and its half of the pair, obtaining one of four outcomes (two classical bits); B applies the corresponding Pauli correction (I, X, Z or XZ), after which B's qubit is exactly $|\psi\rangle$. The source state is destroyed by the measurement [2], and the protocol is incomplete until the classical bits arrive. In BEF-T the classical channel for D3 is implemented as a time-stamped interior record read out after the 24 h run.

Penning-trap operating point

The cyclotron frequency in the 2 T cavity field is $f_c = qB/(2\pi m)$. For $^9Be^+$ ($m = 9.012$ u, $q = e$): $f_c \approx 3.4$ MHz. Axial confinement is provided by a weak electrostatic quadrupole superimposed on the cavity field inside the UHV module; qubit states are encoded on field-insensitive clock transitions.

Phase-accumulation estimate for D3

The parent design's weak-field metric term predicts, at $\xi = 1$, an interior–exterior proper-time offset of $\Delta\tau \approx 1.93\times10^{-18}$ s per 24 h run (dominated by the mass term of the parent potential; the field-energy term is ~ 12 orders smaller) [7]. A qubit precessing at optical frequency f accumulates relative phase $\Delta\varphi = 2\pi f\Delta\tau$; with $f \approx 4.3\times10^{14}$ Hz, $\Delta\varphi \approx 5.2\times10^{-3}$ rad per run. The same $\Delta\tau$ on a 10 GHz hyperfine qubit gives $\Delta\varphi \approx 1.2\times10^{-7}$ rad. Entanglement-assisted Ramsey comparison across the banked A–B pairs follows the scheme of ref. [9].

Entanglement banking and sealing

Ion–photon entanglement generated at A is transmitted through a shielded single-mode fibre feedthrough in the inner-capsule wall and converted to A–B ion–ion entanglement at the exterior node before each run; pairs are stored in hyperfine memory qubits with hour-scale coherence. The feedthrough is physically sealed for the duration of the run, restoring the parent design's isolation premise. Bell-measurement outcomes are recorded on an interior time-stamped store and read out after unsealing.

Use of AI assistance

Large-language-model assistance was used for checking calculations, collating background literature, drafting text and preparing figures under the author's direction; the author verified all physical content, formulas and numerical values and takes full responsibility for the manuscript.

Data availability

All parameters and formulas needed to reproduce the calculations are given in the paper. Preprint versions of this manuscript (English and Turkish), the design figure and narrated explainer videos are openly archived on Zenodo at https://doi.org/10.5281/zenodo.21964777 (CC BY-NC-ND 4.0). The parent proposal is available as a preprint at https://doi.org/10.21203/rs.3.rs-9999735/v1, with its media archive at https://doi.org/10.5281/zenodo.21871677 (CC BY-NC-ND 4.0).

Declarations

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Author contributions

H.B. conceived the apparatus and its teleportation conversion, developed the theory, performed all calculations, prepared the figure and wrote the manuscript.

Competing interests

The author is the founder and R&D Director of HB ZECHMANN Medical Company and has filed a patent application covering the BEF system. The company had no role in the design, analysis or writing of this study.

Additional information

Correspondence and requests for materials should be addressed to H.B. This manuscript has been posted as a preprint on Zenodo (DOI 10.5281/zenodo.21963768); a Turkish-language version is included in the same record.

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Figures

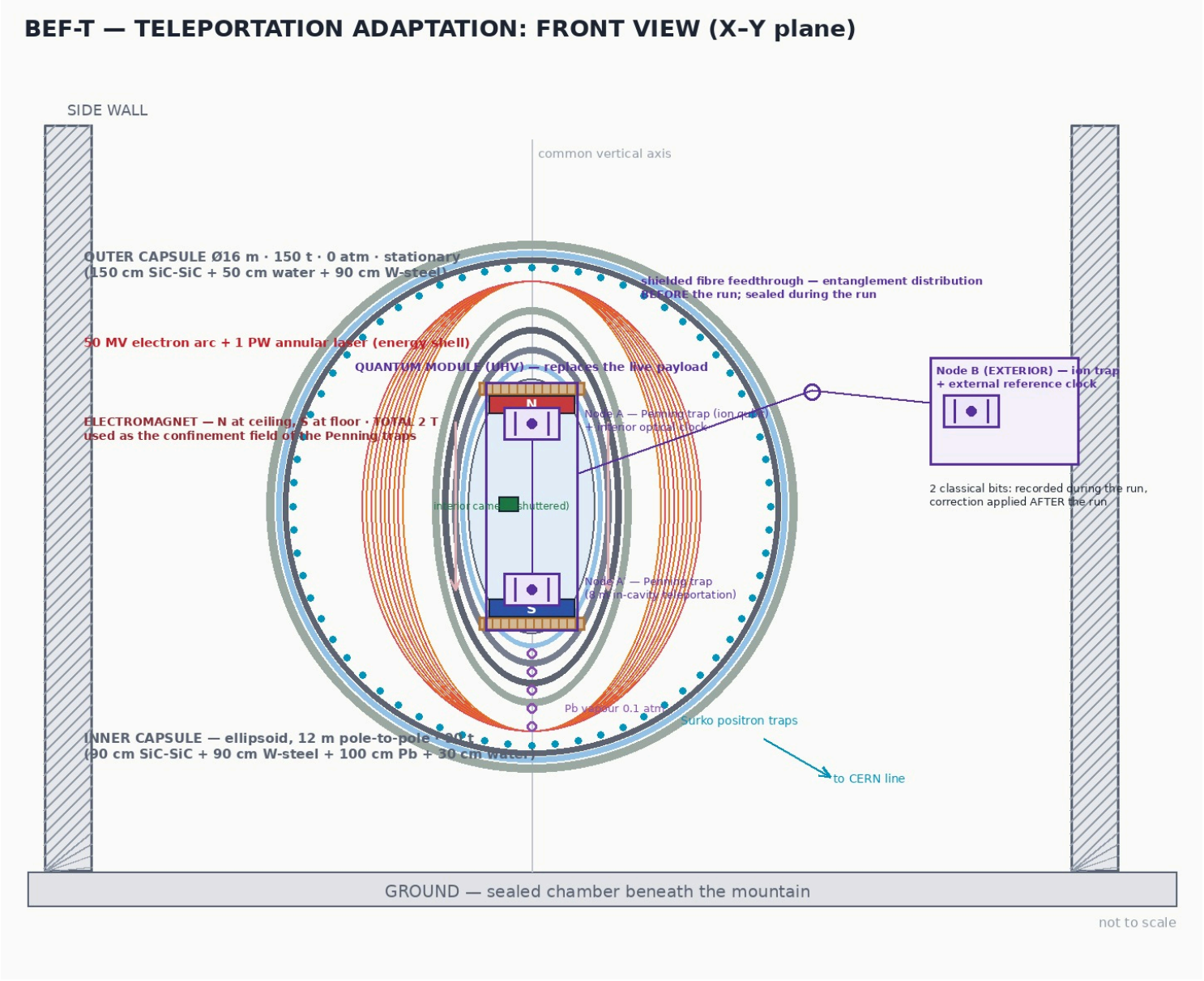


Figure 1

BEF-T front view. The ultra-high-vacuum quantum module in the 226 m³ cavity carries Penning-trap nodes A (top, with the interior optical clock) and A' (bottom); the stationary cavity electromagnet (N at ceiling, S at floor, 2 T total) provides the trap confinement field; the shielded fibre feedthrough (sealed during the run) distributes A–B entanglement to the exterior node B before the run. The energy shell (50

MV arc + 1 PW annular laser), the layered capsules and the Surko-trap layer are unchanged from the parent design. Not to scale.