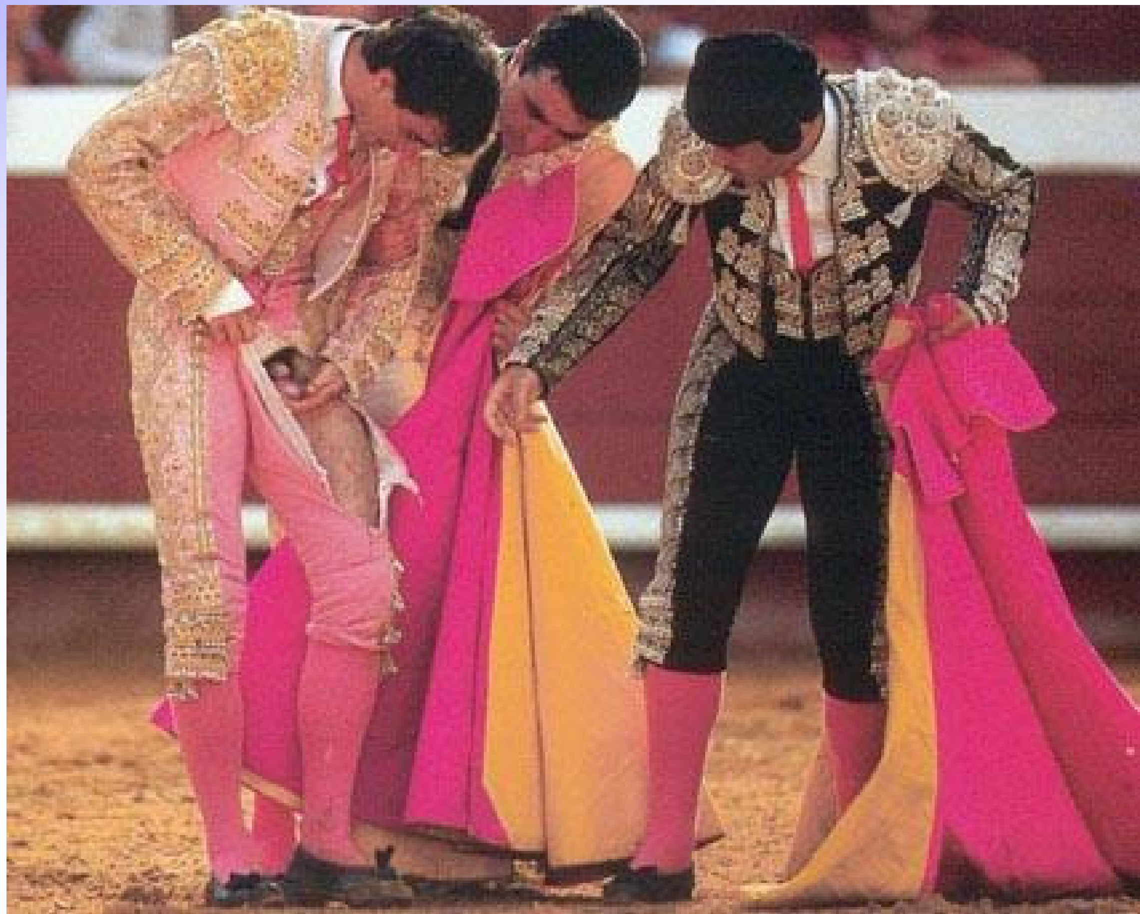
If you do non-mainstream front-end research you could sometimes be attacked by the „old bulls“ in the field ...



Scotty,

dekodieren sie den Funkspruch der Klingonen, schicken sie eine verschlüsselte Nachricht zur Föderation und bereiten Sie den Transporterraum zum Beamen vor.

Das geht nicht Käpt‘n. Unser Vorrat an verschränkten Photonen ist aufgebraucht.

What is the use of Entanglement?

Verschränkte Photonen bzw. verschränkte Zustände (entangled states) sind Hilfsmittel, welche völlig neue Techniken ermöglichen:

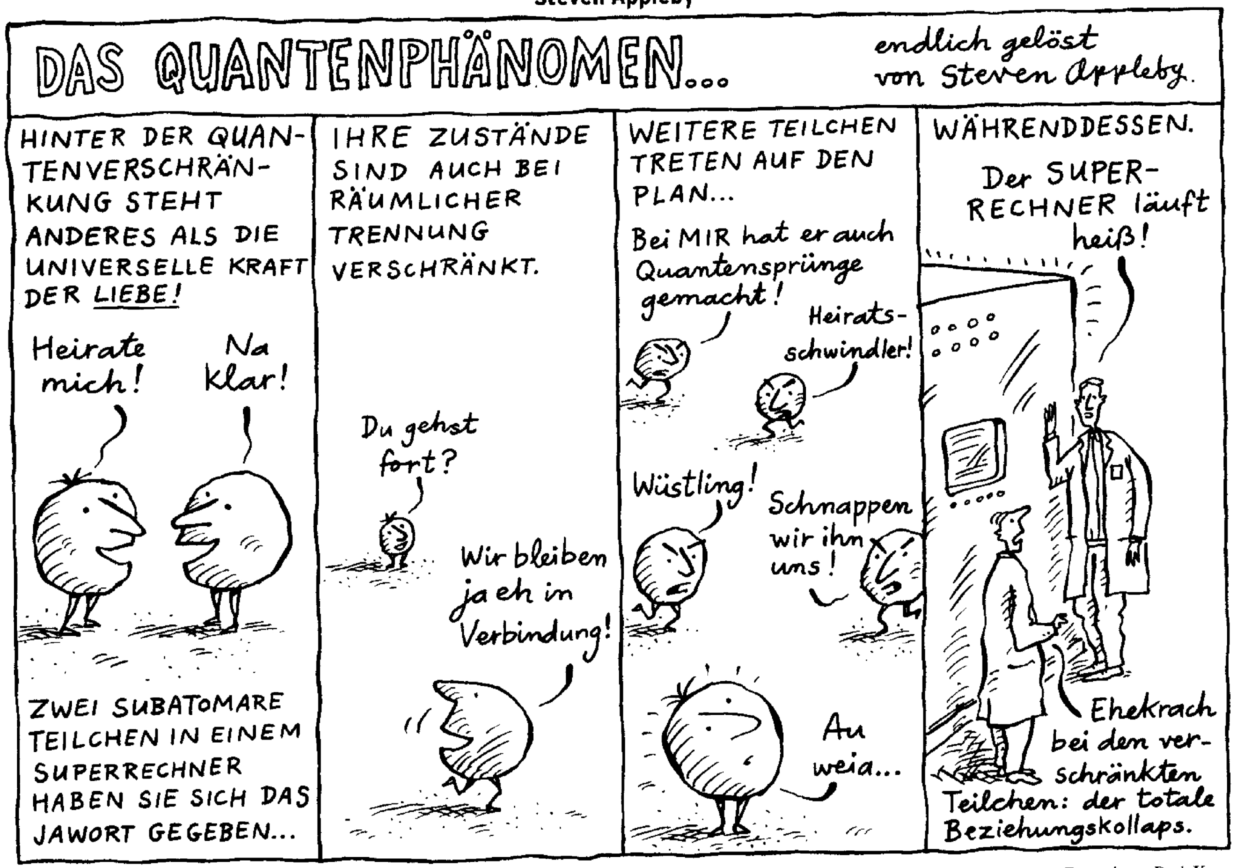
- Quantenkryptographie
- Quantumcomputer

und sogar

- Teleportation

DA LACHT DAS LABOR

Steven Appleby



Deutsch von Ruth Keen

Zu meinen aktuellen Forschungen

nachfolgend der Vortrag,

den ich im Rahmen des

38th Symposium on Mathematical Physics

in Torun, Polen, gehalten habe.

When is a statistical operator separable?

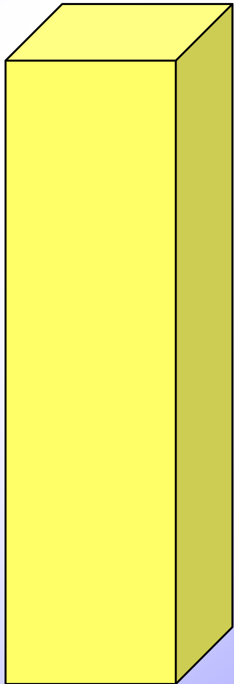
It depends on the definition of separability.

But – the definition of separability depends on the **interpretation** of QM, because the interpretation defines the realm of the thinkable things.

operational int.

Günter Ludwig:
QM is the theory about measuring.

doing
(anthropocentric)



ontic int.

Erwin Schrödinger, Thomas Krüger:
QM is the theory of a part of the world.

BEING

operational definition of separability

non existet

ontic definition of separability

Ability to separate parts of a whole so that the whole in itself is unaffected, i. e., the whole must be the sum of its parts.

operational definition of a separable state

A state that can be prepared by means of local operations and classical communication (LOCC).

ontic definition of a separable state

(self-evident)

$$H = H_A \otimes H_B$$

$$\rho_s^{\text{op.}} := \sum_i w_i \, \rho_{A,i} \otimes \rho_{B,i}$$

vs.

$$\rho_s^{\text{ontic}} := \rho_A \otimes \rho_B$$

Disadvantages of the operational definition:

1) difficult to see whether a given operator is separable, i. e., special separability criteria needed

2) separable operator = superposition instead of product (In QM non-interacting entities are always represented by (direct) products, not by superpositions!)

Problem as soon as you are not a **pure** operationalist.

Entanglement

A. Einstein, B. Podolsky, and N. Rosen, Phys. Rev. **47**, 777 (1935)

principle of
REALITY +
principle of
SEPARABILITY

⇓

QM incomplete!

→ Omit the pr. of separability!

Erwin Schrödinger
1935

Separability in a mathematical sense or separability in a physical sense?

Entanglement can be viewed either as

operator non-separability
(two definitions)

or as

non-locality:
$$\Delta \leq 2$$

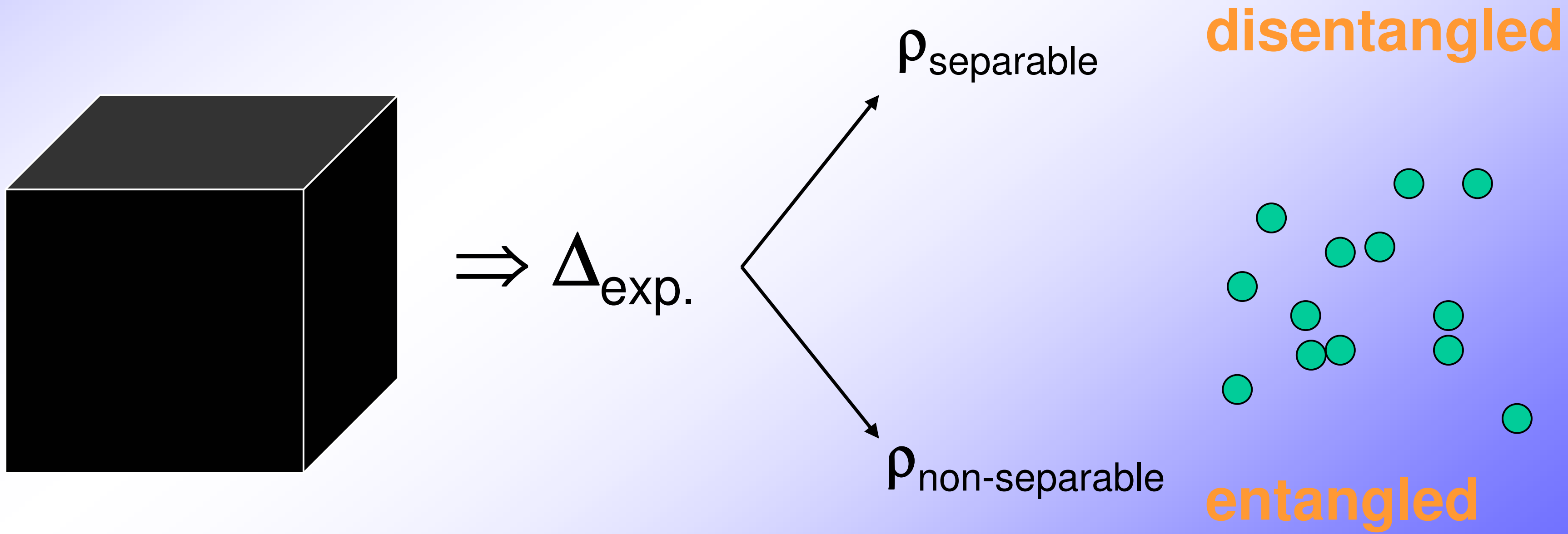
What is the connection?

$$\Delta := |O(\boldsymbol{a},\boldsymbol{b}) - O(\boldsymbol{a},\boldsymbol{b}')| + |O(\boldsymbol{a}',\boldsymbol{b}) + O(\boldsymbol{a}',\boldsymbol{b}')|$$

$$O(\boldsymbol{a},\boldsymbol{b}) = \mathrm{Tr}\{\mathrm{P}(\boldsymbol{a},\boldsymbol{b})\ \rho\}$$

Choose expt.l conditions so that

$\Delta_{\text{separable}} \neq \Delta_{\text{non-separable}}$.



dim H = 2 x 2

How to measure (non-)separability?

$$S = -\,\mathrm{Tr}\,(\rho \ln \rho)$$ ☹ ☺

$\rho_0 := \rho_A \otimes \rho_B$	separable
$\rho_1 := w\, \rho_{A,1} \otimes \rho_{B,1} + (1-w)\, \rho_{A,2} \otimes \rho_{B,2}$	separable
$\rho_2 := \rho_{singlet}$	non-separable
$\rho_3 := \varepsilon\, \rho_2 + (1-\varepsilon)\, \rho_0$	it depends*
$\rho_4 := \varepsilon\, \rho_2 + (1-\varepsilon)\, \rho_1$	it depends*

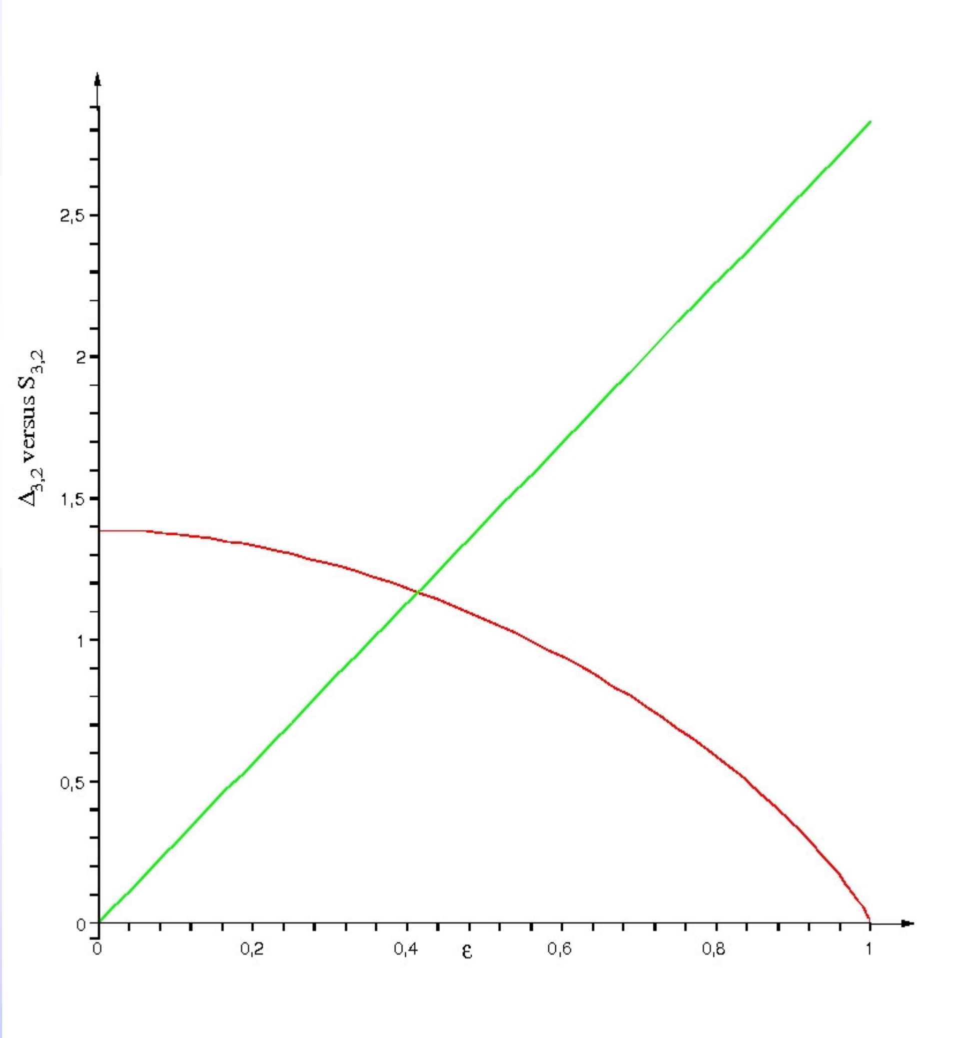
* iff the operational definition is used

$$\rho_0 := 1/4\,(A_{11}\otimes B_{11} + A_{11}\otimes B_{22} + A_{22}\otimes B_{11} + A_{22}\otimes B_{22})$$

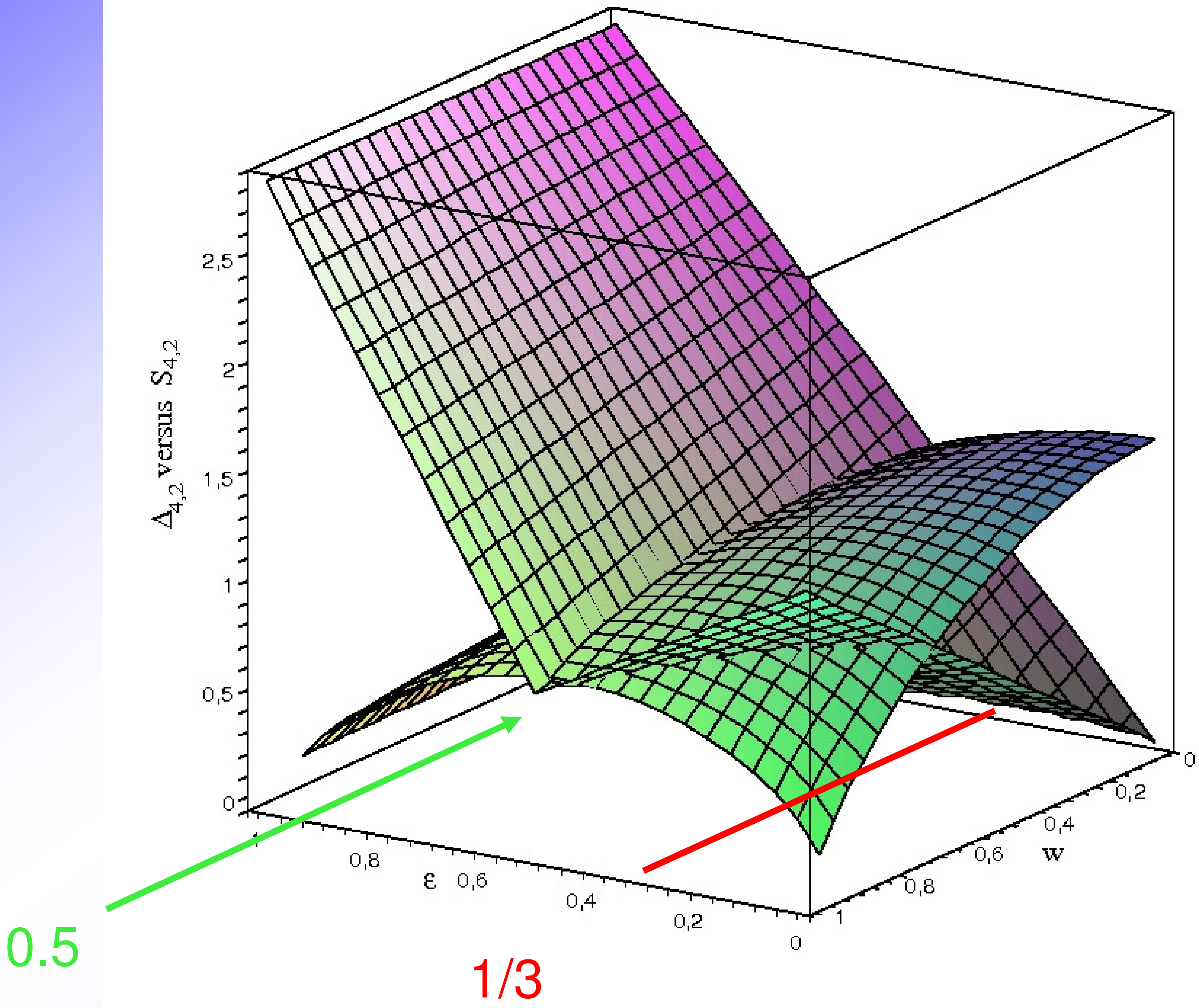
$$\rho_1 := w\, A_{11}\otimes B_{11} + (1-w)/4\,(A_{11}\otimes B_{11} + A_{11}\otimes B_{22} + A_{22}\otimes B_{11} + A_{22}\otimes B_{22})$$

$$A_{kl} := |k\rangle\langle l|$$

ρ_3



ρ_4



$\Delta_{4,2}$ versus $S_{4,2}$
2,5
2
1,5
1
0,5
0
0,8
ε 0,6
0,4
0,2
0
1
0,8
0,6
0,4
0,2
0
w
0.5
1/3

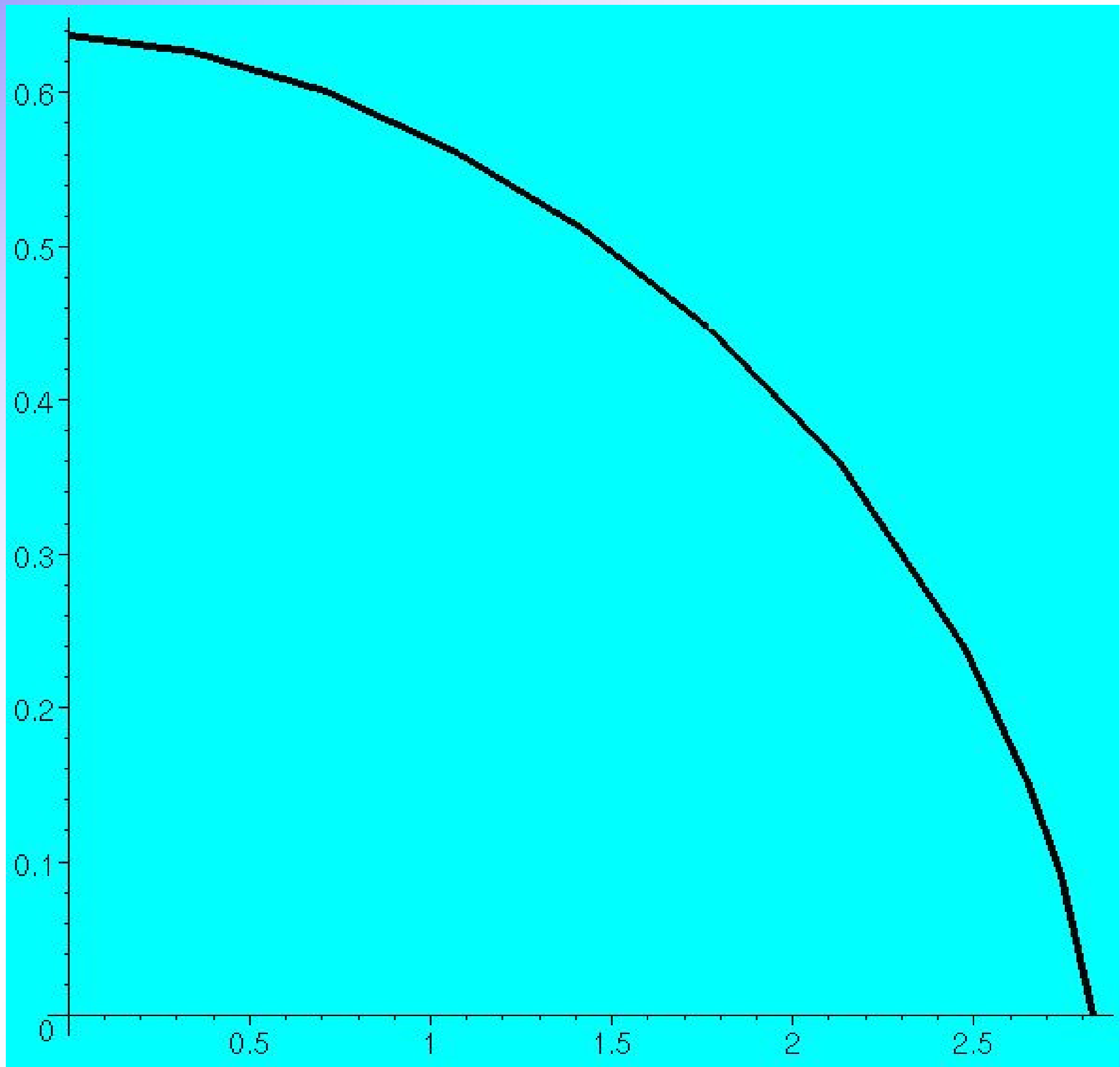
Result 1

Separability according to the operational definition often depends on some parameters. The character switch, however, is **neither** seen in $\boldsymbol{S}$ nor in $\boldsymbol{\Delta}$.

So, what's the nutritive value of the operational definition???

$$\Delta \quad \text{vs.} \quad S-(1-\mathrm{Tr}\rho^2)$$

ρ_3, corrected entropy (y-axis) vs. Δ



Result 2

We found a nice hint for the functional relation between Δ and the von Neumann entropy corrected for mixedness.

Maybe now the „old bulls“ will only understand

... Ωορκ ιν Προγρεσσ

- but it simply means: work in progress!

first successful application to quantum teleportation:
Turk. J. Phys. **30**, 137 (2006) and Phys. Scripta **74**, 190 (2006)