Mistaking interpretation of Bell's inequality and (future) quantum physics

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Basic points:

Classical interpretation of Schroedinger equation
Demonstration of mistaking interpretation (Bell)
Emergence of hydrogen atom?
Importance of proton structure

1. **Copenhagen quant. mech. - basic story**
2. **Mistaking assumption in Bell's inequality**
3. **Two assumptions of Bell**
4. **Schroedinger equation and classical physics**
5. **Evolution of physical thinking since Middle Age**
6. **Emergence of quantum states**
7. **Elastic p-p scattering and proton structure**
8. **Concluding remarks**

Schrödinger equation and (future) quantum physics; in
"Advances of quantum mechanics" (ed. P.Bracken), InTech Publisher,
http:/www.intechopen.com, (April 2013), pp. 105-132.

1. Copenhagen quantum mechanics - story

1927 - Bohr: Copenhagen quantum mechanics
(Schroedinger equation and additional assumptions)

1932 - vonNeumann: No hidden variables in Schroedinger equation

1935 - Einstein: Interaction at distance (ontologically impossible)
(Gedankenexperiment - detection of two decay particles)

1952 - Bohm: hidden variable in Schroedinger equ.
($\Longrightarrow$ 2 quantum alternatives: Eistein vs. Bohr)

1964 - Bell: inequality for 4 coincidence measurements

$$\| < - - |^{\alpha} - - - o - - - |^{\beta} - - > \|$$

$$\boxed{B \;=\; a_1b_1 + a_1b_2 + a_2b_1 - a_2b_2 \leq 2} \qquad \text{(hidden-var.)}$$

2 photons through two polarizers and two detectors:

1982 - Aspect et al.: experimental results
- Bell's inequality violated (Einstein's alternative excluded)
- approximatively Malus law: $P(\alpha, \beta) = \cos^2(\alpha - \beta)$

$\Longrightarrow$ victory of Bohr's Copenhagen alternative !?

However: several mistakes! Einstein's alternative fully acceptable
main mistake: Bell's inequ. valid in classical physics only!!

- Einstein-Bohr controversy and theory of hidden variables; NeuroQuantology (section: Basics of Quantum Physics) **8** (2010), issue 4, 638-45
- Einstein-Bohr controversy after 75 years, its actual solution and consequences; "Some applications of quantum mechanics" (ed. M.R.Pahlavani), InTech Publisher (February 2012), pp.409-24
- The assumption in Bell's inequalities and entanglement problem; J. Comp. Theor. Nanosci. 9 (2012), 2018-20
- Schrödinger Equation and (Future) Quantum Physics, "Advances in Quant. Mech." (ed. P.Bracken), InTech Publ. (April 2013), 105-32.

2. Mistaking assumption in Bell's inequality

EPR experiments

$$\| < - - |^{\alpha} - - - - -o - - - - -|^{\beta} - - > \|$$

Bell's inequality (for 4 different coincidence measurements - 2x2)

$B \;=\; a_1 b_1 + a_1 b_2 + a_2 b_1 - a_2 b_2 \leq 2$ The influence of spin eliminated!

In fact: more different limits of B (under divers assumptions)

See Bell's operator method: M.Hillery, B.Yurke: Bell's theorem and beyond; Quantum Semiclass. Optics 7, 215-27 (1995)

a_j and b_k corresponding operators: $0 \;\leq\; |\langle a_j \rangle|, \quad |\langle b_k \rangle| \;\leq\; 1$
Hilbert space: $\mathcal{H} \;=\; \mathcal{H}_a \otimes \mathcal{H}_b$

$\mathcal{H}_a$ and $\mathcal{H}_b$ - subspaces corresponding to individual polarizers

Upper limits of $|\langle B \rangle|$ (for different commutation relations)

- $[a_j, b_k] \neq 0, \quad [a_1, a_2] \neq 0, \quad [b_1, b_2] \neq 0$
  $\langle BB^+ \rangle \leq 12, \quad |\langle B \rangle| \leq 2\sqrt{3}$ (Copenhagen alternat.)
- $[a_j, b_k] = 0$ and $[a_1, a_2] \neq 0$, $[b_1, b_2] \neq 0$
  $\langle BB^+ \rangle \leq 8, \quad |\langle B \rangle| \leq 2\sqrt{2}$ (Einstein's alternative)
- a_j and b_k commuting mutually
  $\langle BB^+ \rangle \leq 4, \quad |\langle B \rangle| \leq 2$ (classical physics)

$\Longrightarrow$ only classical alternative excluded by EPR experiments!

Both quantum theories acceptable!?

(Einstein's alternative preferred by experimental data)

3. Two assumptions of Bell

$$\| < - - |^{\alpha} - - - - - o - - - - - |^{\beta} - - > \|$$

First derivations of inequality:

1964 - Bell: assumption - $a(\alpha) = b(\pi - \alpha)$
(exclusion of probability behavior)

1971 - Bell:

$$P_{\alpha,\beta} - P_{\alpha,\beta'} = \oint \mathrm{d}\lambda\, [a_\alpha(\lambda) b_\beta(\lambda) - a_\alpha(\lambda) b_{\beta'}(\lambda)]$$

$$\oint \mathrm{d}\lambda\, [a_\alpha(\lambda) b_\beta(\lambda) a_{\alpha'}(\lambda) b_{\beta'}(\lambda) - a_\alpha(\lambda) b_{\beta'}(\lambda) a_{\alpha'}(\lambda) b_\beta(\lambda)] = 0$$

$$P_{\alpha,\beta} = P_{\alpha,\beta'}$$

Inequalities of Boole (1862):

$$\max\{p_1, p_2, ..., p_n\} \le P(A_1 \cup A_2 \cup .... \cup A_n) \le \min\{1, p_1 + p_2 + ... + p_n\}$$

$$\max\{0, p_1 + p_2 + ... + p_n - n + 1\} \le P(A_1 \cap A_2 \cap .... \cap A_n) \le \min\{1, p_1, p_2, ..., p_n\}$$

- for any probabilistic system

E. E. Rosinger: George Boole and the Bell inequalities; /arXiv:quant-ph/0406004

M.V.Lokajíček, V.Kundrát, J.Procházka: Schroedinger equation and mistaking interpretation of Bell's inequality, http:/arXiv:1305.5503(2013)

4. Schroedinger equation and classical physics

Schrödinger (1925): inertial motion = classical physics

Schrödinger eq. (without assumptions of Bohr) - fully acceptable

$\Longrightarrow$ equivalent to Hamilton eqs. + superpositions
(only smaller set of admissible states!)
- latent assumption: corresponding Hilbert space

Derivation of Schrödiger equation from Hamilton equations

- U.Hoyer: Synthetische Quantentheorie; Georg Olms Verlag, Hildesheim (2002)
- H.Ioannidou: A new derivation of Schrödinger equation; Lett. al Nuovo Cim. 34, 453-8 (1982)

Necessary to distinguish

- **General solutions**
  $i\hbar\frac{\partial}{\partial t}\psi(x,t) = H\psi(x,t), \qquad \psi(x,t) = \lambda(x,t)\, e^{\frac{i}{\hbar}\Phi(x,t)}$
- **Basic solutions**
  $\psi_E(x,t) = \lambda_E(x)\, e^{-iEt}, \quad H\lambda_E(x) = E\lambda_E(x)$
  $\Longrightarrow$ identical with solutions of Hamilton equations;
  not oppositely: in the case of discrete energy spectrum!
  (smaller set of allowed states)

M.V.Lokajíček: Schroed. equ., classical phys. and Copenhagen quant. mechanics; New Advances in Physics 1 (2007), 69-77;
see also /arxiv/quant-ph/0611176

General solutions:

$i\hbar\frac{\partial}{\partial t}\psi(x,t) = H\psi(x,t), \qquad \psi(x,t) \;=\; \lambda(x,t)\, e^{\frac{i}{\hbar}\Phi(x,t)}$

"pure" states – basic solutions only (Hamilton solutions)

"mixed" states – superpositions of basic solutions

If non-classical characteristics not added:

- **Schrödinger equation** $\Longrightarrow$ Hamilton eq. + superpositions

  $\psi(x,t) = \sum_E c_E\, \psi_E(x,t); \qquad |c_E|^2 \;=\;$ classical probability

- basic (pure) states – orthogonal (Hamilton equations)

  $\Longrightarrow$ **"mixed" states $\equiv$ classical superpositions**

- <u>microscopic</u> as well as <u>macroscopic</u> objects (probability distrib.)

Schroed. equ. applicable also:

If non-classical characteristics of matter objects added!

(e.g. spins - simple generalization!)

<u>**However:**</u>

Emergence of quantum states (e.g. hydrogen atom) ?

<u>**Some new approach required!**</u>

(see next slides)

5. Physical thinking since Middle age

Aristotle (384-322) – ontological approach (knowledge basis)

First millennium: in Europe - mainly Plato

Middle age: ontological approach through Islam (Spain)
Albert the Great (1206-1280)
Thomas Aquinas (1225-1274)

Classical physics ($\Rightarrow$ whole contemporary civilization)
G. Galilei (1564-1642)
I. Newton (1643-1727)
W.R.Hamilton (1805-1865) - theoretical mathematical basis

However (concurrently):
R. Descartes (1596-1650) - refusal of ontology
\+ positivism $\Longrightarrow$
reason interpretation of physical phenomena
(overestimation of human reason)

L. Boltzmann (1867) - probability distribution

N. Bohr (1913) - atom levels (two phenomenological postulates)
N. Bohr (1927) - Copenhagen quantum mechanics

However:
Classical physics - ontological approach (realistic causality)
Preceding results - necessary return to this ontological basis
Schrödinger equation - extended classical probability description
- existence of quantum matter objects
- realistic causality
- matter emergence (first cause?)
- quantum state emergence ?? - hydrogen atom?

6. Emergence of quantum states

Free particles:

electron o $\rightarrow$ $\leftarrow$ proton o

always: hydrogen atom emerging!

Necessary:

- short-ranged repulsive force existing - or -
- impenetrability of proton

In both cases: structure and dimension of proton required!

First case:
How to explain the stability of hydrogen atom?

Second case:
Weak adhesive force?
Effect of Coulomb force - or - additional weak contact force?

Proton dimension and structure?

Collision processes? – elastic p-p collision!

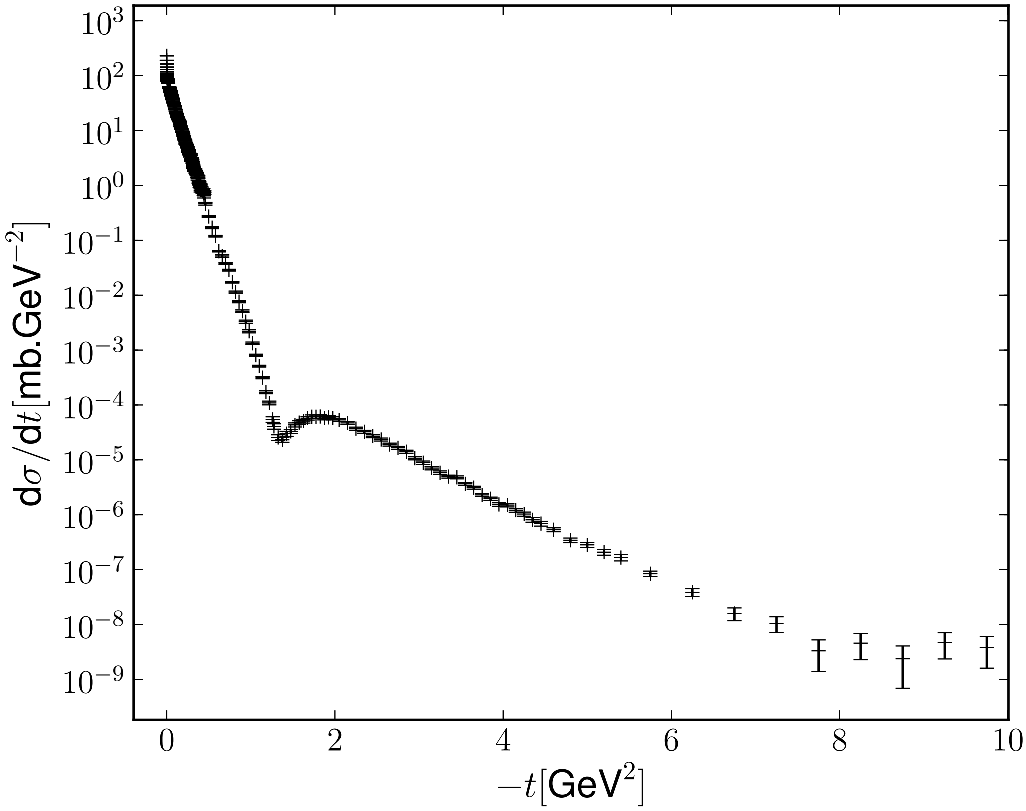
Peripheral elastic collision and our new probabilistic model

M.V.Lokajíček, V.Kundrát, J.Procházka: Schroedinger Equation and (Future) Quantum Physics, in "Advances in Quantum Mechanics" (ed. P.Bracken), InTech Publisher, http:/www.intechopen.com (April 2013), 105-132.
J.Procházka, V.Kundrát, M.V.Lokajíček: Probabilistic model of elastic proton-proton collisions; submitted to Phys. Rev. D (April 2013)

7. Elastic p-p scattering and proton structure

Elastic proton-proton scattering

Measurement: CERN ISR collision energy of 52.8 GeV
interval $|t| \in (0.00126, 9.75)$ GeV^2



Differential (Coulomb + hadron) cross section:

$$\frac{\mathrm{d}\sigma^{C+N}(t)}{\mathrm{d}t} = \frac{\mathrm{d}\sigma^{N}(t)}{\mathrm{d}t} + \frac{\mathrm{d}\sigma^{C}(t)}{\mathrm{d}t}$$

$$\frac{\mathrm{d}\sigma^{N}(t)}{\mathrm{d}t} = \sum_j r_j \frac{\mathrm{d}\sigma_j^{N}(t)}{\mathrm{d}t}$$

- probability of individual collision channels: $r_j = p_k p_l$

$$\frac{\mathrm{d}\sigma_j^{N}(t)}{\mathrm{d}t} = 2\pi\ \bar{b}_j(t)\ P_j^{\mathrm{el}}\left(\bar{b}_j(t)\right)\ \frac{\mathrm{d}\bar{b}_j(t)}{\mathrm{d}t}$$

$\bar{b}_j(t)$ - average value of impact parameter at corresponding t
(more general model being prepared:
correlating an interval of t to given b)

$P_j^{\mathrm{el}}(b)$ - probability of elastic scattering at corresponding b:

$$P_j^{\mathrm{el}}(b) = P_j^{\mathrm{tot}}(b)\ P_j^{\mathrm{rat}}(b)$$

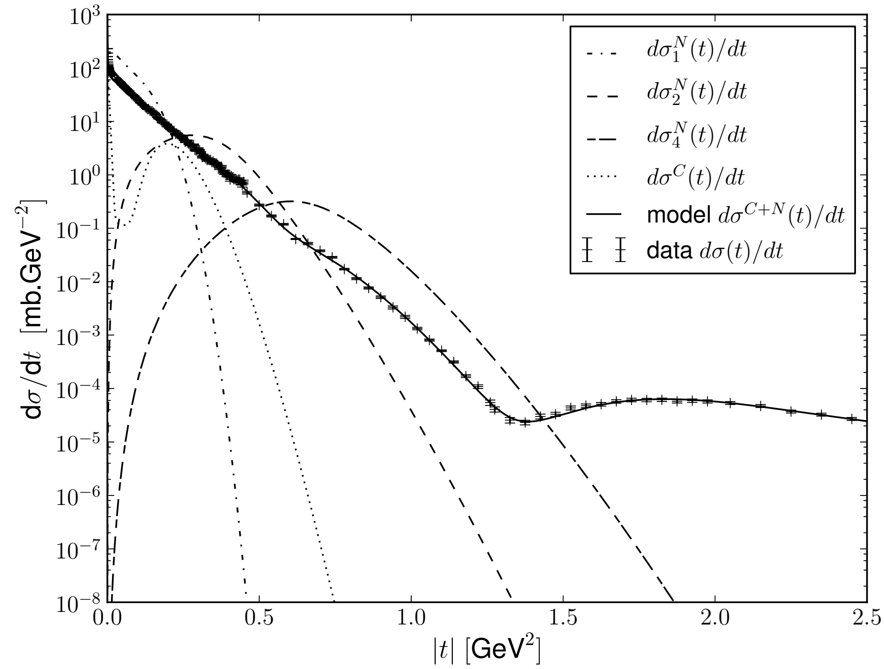
$P_j^{\mathrm{tot}}(b)$ - collision probability at given b
$P_j^{\mathrm{rat}}(b)$ - ratio of elastic and cotal collison at given b

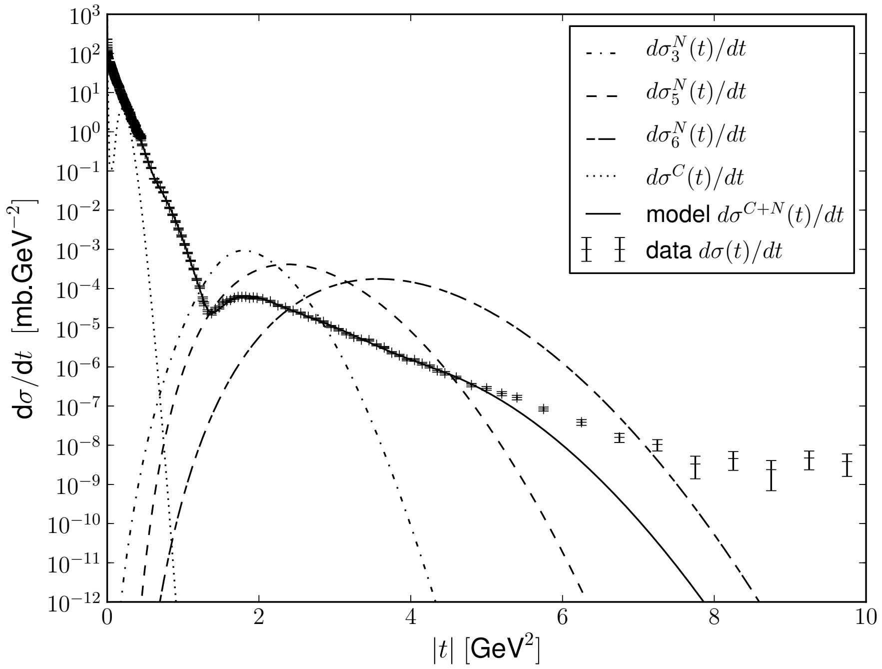
Free parameters: 3 monotone function for any j
probabilities p_k and maximal cross dimensions d_k

Maximal effective impact parameters in individual collision channels:

$$B_j = (d_k + d_l)/2, \qquad P_j^{\mathrm{tot}}(b > B_j) = 0$$

+ mathematical description of Coulomb effect





Comment to figures:

full line = final fit in the interval $-t \in (0.00126,\ 5.0) GeV^2$

dotted line = Coulomb effect;   other lines = nucleon collision channels

Channel numbers j: $j \equiv (k, l)$

numbers in brackets: proton states according decreasing dimension d_k

Main characteristics of individual collision channels:

j		1	2	3	4	5	6	$\sum_{j=1}^{6}$
k,l		1,1	1,2	2,2	1,3	2,3	3,3	
r_j	[1]	0.36	0.29	0.059	0.11	0.043	0.0080	0.87
B_j	[fm]	1.970	1.960	1.951	1.955	1.945	1.939	-
$\sigma_j^{\mathrm{tot,N}}$	[mb]	86.9	57.0	55.3	44.9	33.7	32.5	-
$\sigma_j^{\mathrm{el,N}}$	[mb]	16.5	1.56	6.96×10^{-4}	0.116	5.22×10^{-4}	3.04×10^{-4}	-
σ_j^{inel}	[mb]	70.4	55.5	55.3	44.8	33.7	32.5	-
$r_j\sigma_j^{\mathrm{tot,N}}$	[mb]	31.7	16.7	3.25	4.86	1.46	0.260	58.2
$r_j\sigma_j^{\mathrm{el,N}}$	[mb]	6.03	0.456	4.08×10^{-5}	1.26×10^{-2}	2.26×10^{-5}	2.43×10^{-6}	6.49
$r_j\sigma_j^{\mathrm{inel}}$	[mb]	25.7	16.2	3.25	4.84	1.46	0.260	51.7

Assumptions:

- peripheral elastic collision
- existence of different proton states
- monotony of three functions of b in individual collision channels

(- average impact parameter for any t)

8. Concluding remarks

Main conclusions after removal basic mistakes:

- **Schrödinger equation** represents generalization of classical physics involving probability behavior description and other characteristic of individual matter objects
- However, it is not possible to describe **causal emergence** of corresponding quantum states on the basis of contemporary theory
- The simple **interaction at distance** between matter objects seems to be insufficient; some **other characteristics** of interacting objects should be taken into account
- **New collision model** has been shortly demonstrated making it possible to establish some other characteristics of proton on the basis of elastic collisions (existence of internal states and their maximum dimensions)