Baldin ISHEPP XXIV, September 17-22, 2018

COHERENT DIBARYONS

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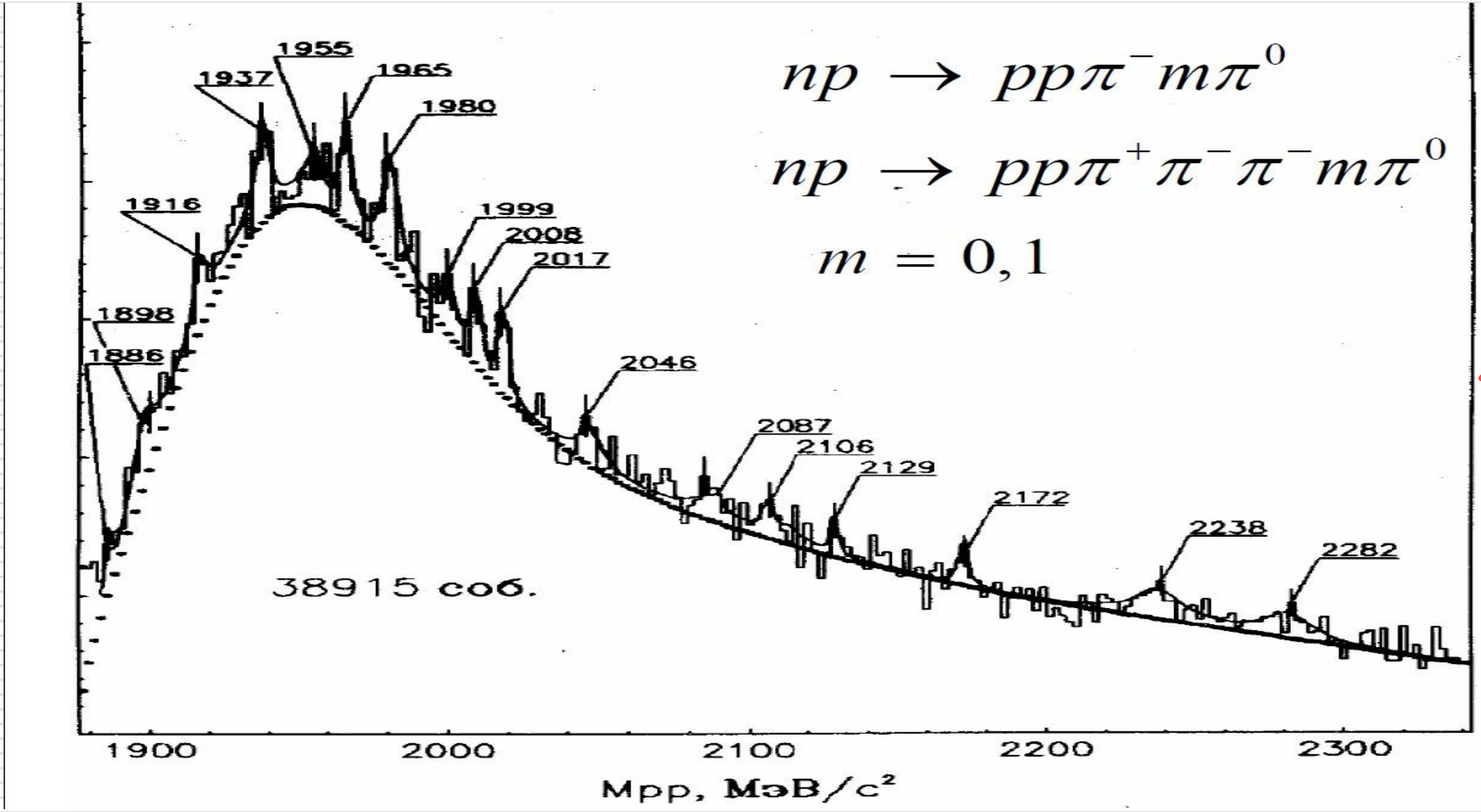
Yu.A. Troyan, *Fiz. Elem. Chastits At. Yadra 24, 683 (1993).*



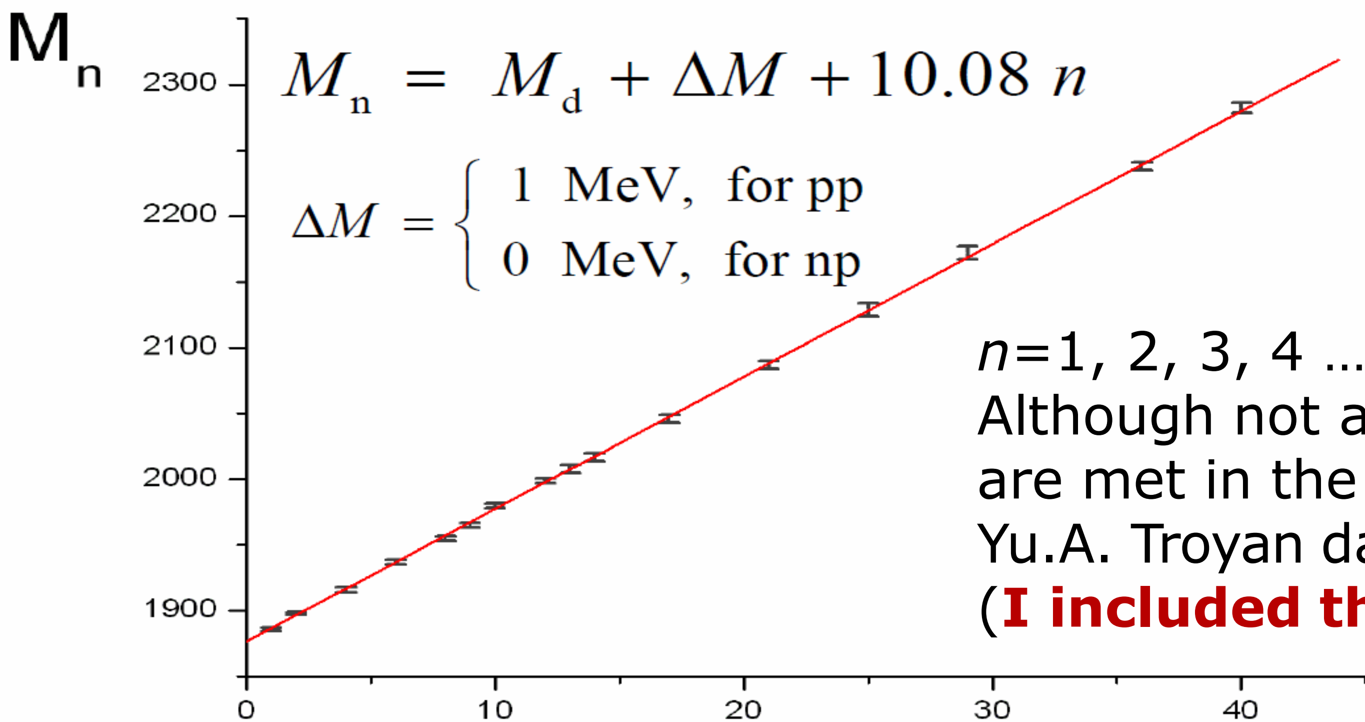
$$np \to pp\pi^- m\pi^0$$

$$np \to pp\pi^+\pi^-\pi^- m\pi^0$$

$$m = 0, 1$$

Interpolation formula for Troyan's dibaryons, ΔM=1 MeV

Mass spectrum

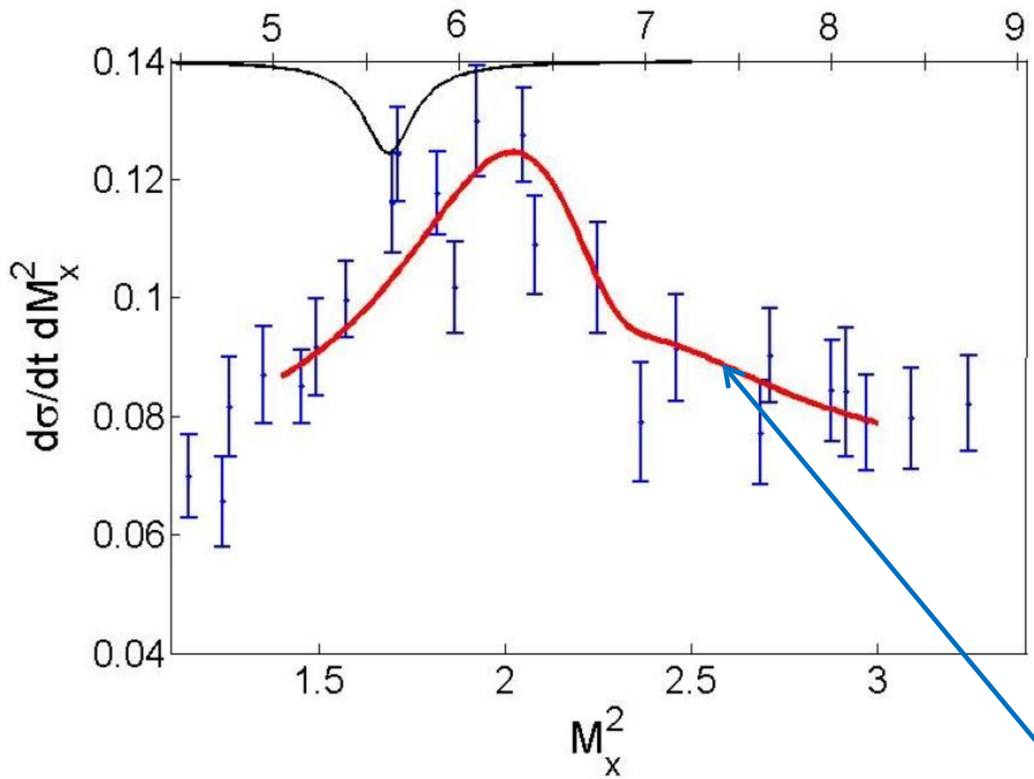


n=1, 2, 3, 4 … ?
Although not all *n* are met in the Yu.A. Troyan data (**I included them**)

ΔM= 0 MeV A.M. Baldin et al., 1979

Baldin group experiment (BGE):

Сообщение ОИЯИ 1-12397, 1979, АМ Балдин, ВК Бондарев, АН Манятовский, НС Мороз, ЮА Панебратцев, АА Повторейко, СВ Рихвицкий, ВС Ставинский, АН Хренов



Solid line – results of WASA-at-COSY, M=2.37 GeV, Γ=0.07 GeV

d+d → X+d

P = 8.9 GeV

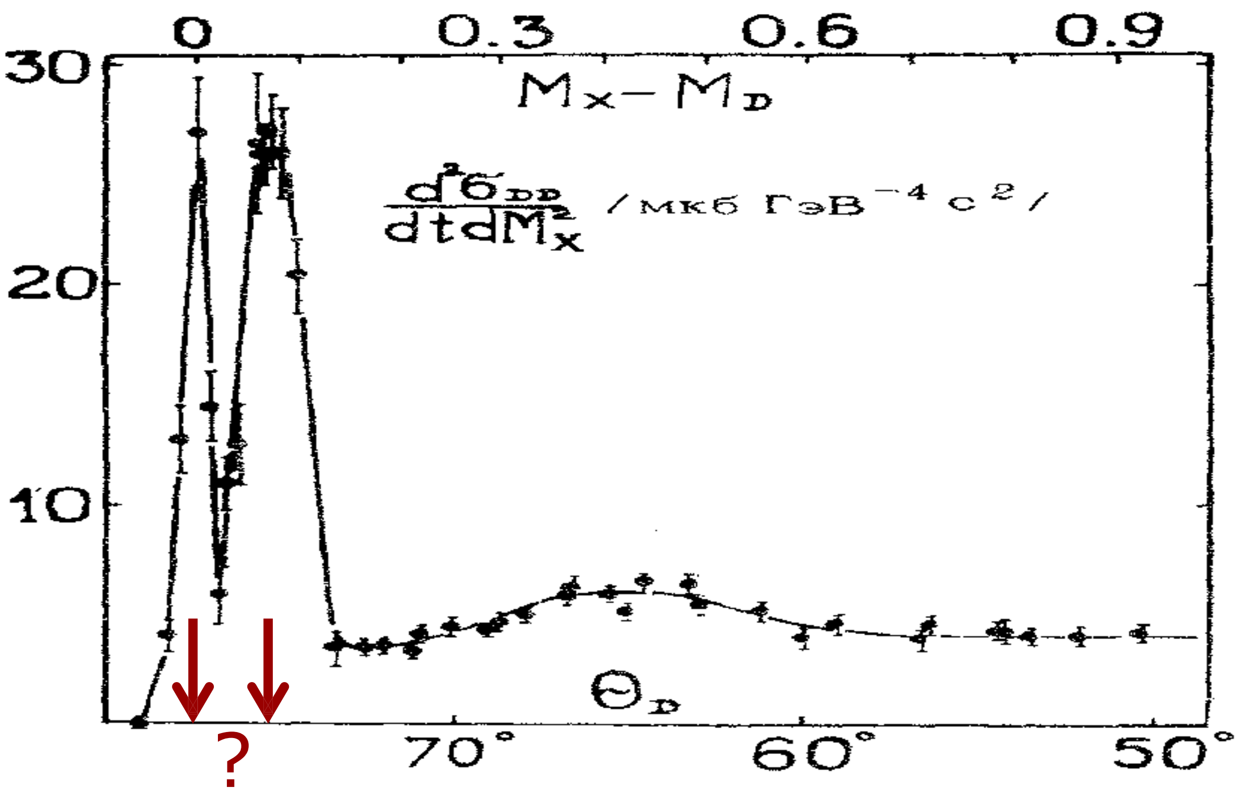
t= - 0.5 GeV^2

Excited state of deuteron was predicted already in 1979!

Calculations by B.F.K. and Jan Pribish, Baldin ISHEPP XXII, 2014

Two peaks from BGE, which were not analyzed before

A.M. Baldin et al. Differential Elastic Proton-Proton,Nucleon-Deuteron and Deuteron-Deuteron Scatterings at Big Transfer Momenta, JINR Communication,1-12397, 1979



d+d $\rightarrow$ X+d

P = 8.9 GeV

t= - 0.5 GeV^2

Spectrum assumption

Reaction	KAM	dibaryon masses
X+D→Y+D	1916→1884	1916, 1886
	1926→1895	1926, 1896
	1936→1905	1936, 1906
	1946→1916	1946, 1916
	1956→1927	1956, 1926
	1966→1938	1966, 1936
	1976→1948	1976, 1946
	1986→1959	1986, 1956
	2047→2024	2047, 2027
	2057→2034	2057, 2037
	2067→2045	2067, 2047
	2077→2056	2077, 2057
	2087→2066	2087, 2067
	2097→2078	2097, 2077
	2107→2087	2107, 2087
	2118→2099	2118, 2097
	2128→2109	2128, 2107
	2138→2120	2138, 2118
	2148→2131	2148, 2128
	2158→2141	2158, 2138

Total correspondence Between Troyan's and Baldin's group data!

The first peak

KAM – kinematically allowed masses,
dibaryon masses – according to

$$M_n = M_d + 10.08\, n$$

Levels of a quantum oscillator?

Spectrum assumption

Reaction	KAM	dibaryon masses
X+D→Y+D	1886→1966	1886, 1966
	1896→1977	1896, 1976
	1916→1998	1916, 1997
	1926→2009	1926, 2007
	1936→2019	1936, 2017
	1946→2030	1946, 2027
	1997→2084	1997, 2087
	2007→2095	2007, 2097
	2017→2105	2017, 2107
	2027→2116	2027, 2118
	2037→2127	2037, 2128
	2047→2137	2047, 2138
	2057→2148	2057, 2148
	2067→2158	2067, 2158
	2077→2169	2077, 2168
	2087→2179	2087, 2178
	2097→2190	2097, 2188
	2107→2200	2107, 2198

See details in B.F.K.,J. Pribish, Baldin ISHEPP XXII, 2014

The second peak

All dibaryons in the range from 1886 to 2198 MeV/c^2 may be met in deuteron

Suggestions prompted by Troyan and Baldin group experiments (TE and BGE, accordingly)

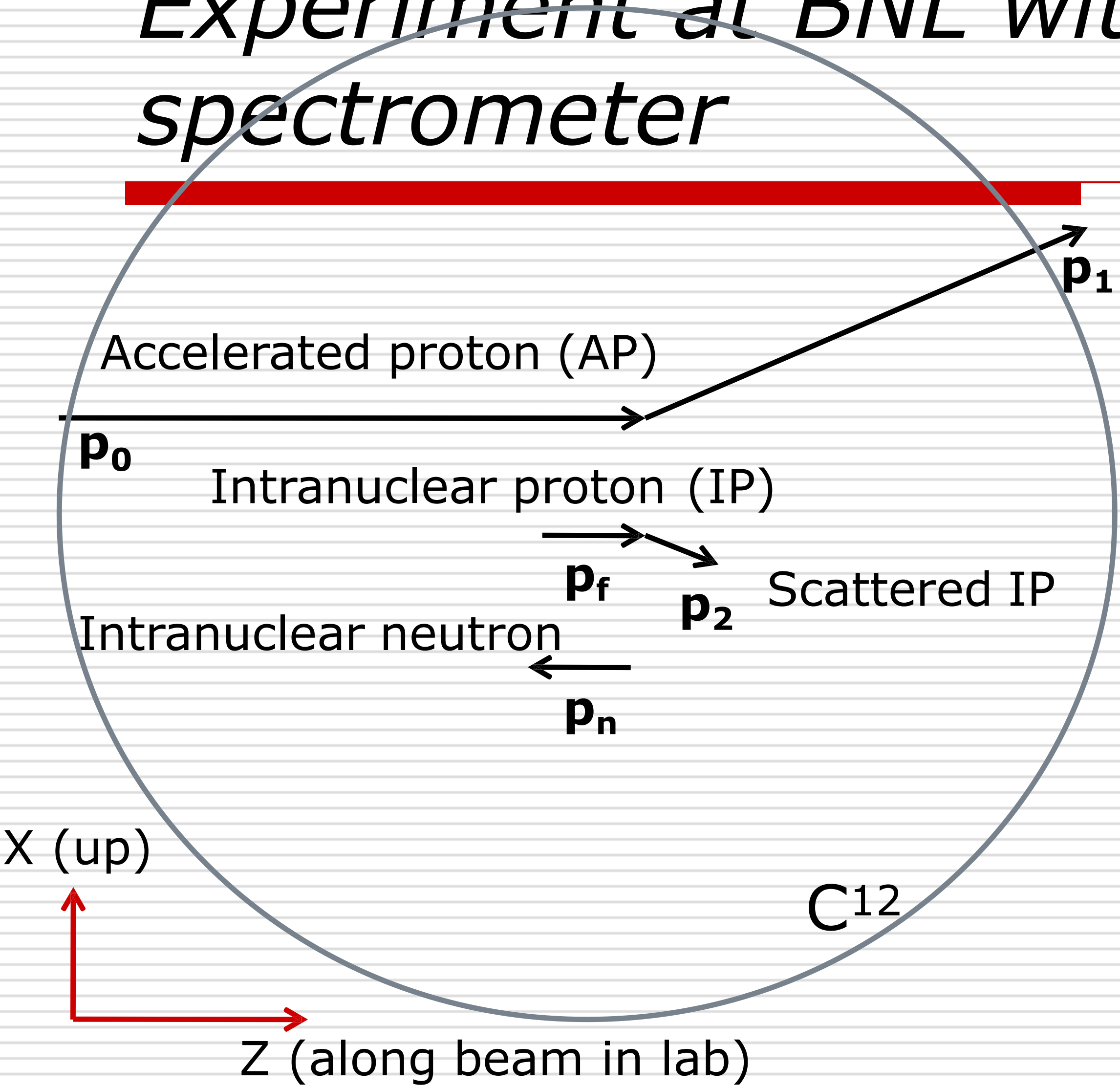
1. **Indications of existence of equidistant quantum oscillator levels in compressed two-nucleon systems with level separation $\hbar\omega \approx 10$ MeV were obtained.**

2. **Energy of the ground state of the oscillator is equal to $\hbar\omega/2 + \hbar\omega/2$, which means that it is consist of one degree of freedom oscillating in (x-y)-space, or it consists of two independet one-dimensional oscillators.**

Remark:

The ground state was observed as dibaryon with mass = 1.886±0.001 GeV/c² by Yu.A. Troyan and may be also extracted from the paper of A.M. Baldin et al. as particle X in the processes: X+d→ Y+d, d+X→d+d, d+X→ X+d, X+X→X+d, X+X → Y+d.

Experiment at BNL with EVA spectrometer



Model of Quasifree Knockout (MQK): IP is knocked out by AP, neutron is a freely outgoing particle.

Experimentally observed mean values and fluctuations of P_z^{cm} and P_z^{rel} can be explained by the Fermi motion in C^{12}.

MQK and SRC agrees with the experiment for P_z^{cm} and P_z^{rel}.

J. Aclander et al Phys. Lett. B 453, 211 (1999)
A. Tang et al Phys. Rev. Lett. 90, 042301 (2003)

Calculation of P_z^{cm} and P_z^{rel} in MQK framework

In framework of the Model of Quasifree Knockout $\boldsymbol{P}^{cm}$ and $\boldsymbol{P}^{rel}$ may be found as follows*):

$\boldsymbol{P}^{cm} = \boldsymbol{P}_f + \boldsymbol{P}_n$,

$\boldsymbol{P}^{rel} = \boldsymbol{P}_f - \boldsymbol{P}_n$,

where $\boldsymbol{P}_f$ *is supposed momentum of the intranuclear proton, IP, before its interaction with the accelerated proton, AP,*

$\boldsymbol{P}_f = \boldsymbol{P}_1 + \boldsymbol{P}_2 - \boldsymbol{P}_0$

and $\boldsymbol{P}_i$ *being momenta of the secondary protons,* $i=1,2$.

*) *A. Tang et al Phys. Rev. Lett. 90, 042301 (2003)*

Results of our kinematic analysis

We **confirm** the results of EVA kinematic analysis for the longitudinal projection of momenta (in z-direction in the picture). We found a disagreement of the Model of Quasifree Knockout with the experiment for P_x^{cm} and P_x^{rel} (in vertical direction)*).

Compare:

$$\langle P_z^{\mathrm{cm}}\rangle \approx 0,\ \sigma_z^{\mathrm{cm}} \approx 0.1,\ \langle P_z^{\mathrm{rel}}\rangle \approx 0.3,\ \sigma_z^{\mathrm{rel}} \approx 0.1,$$

$$\langle P_{x_{\mathrm{cm}}}\rangle \approx 0,\ \sigma_{x_{\mathrm{cm}}} \approx 0.6,\ \langle P_{x_{\mathrm{rel}}}\rangle \approx 0.6,\ \sigma_{x_{\mathrm{rel}}} \approx 0.2,$$

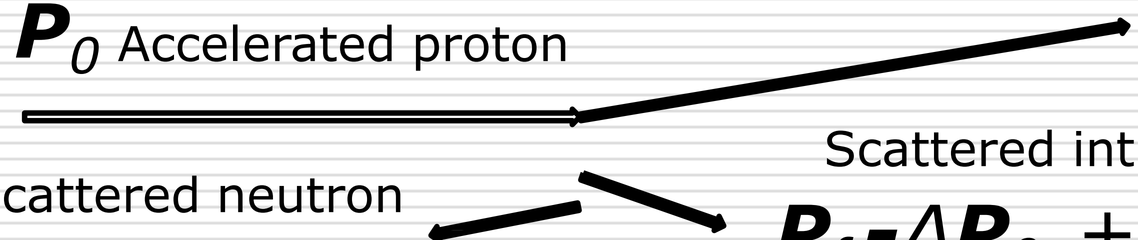
hereafter all values are in **GeV/c**.

*) *B. Kostenko, J. Pribiš, V. Filinova, PoS (Baldin ISHEPP XXI) 105*

Can interaction between intranuclear p and n explain the difference?

$\boldsymbol{P_0+\Delta P_0=P_1}$ Scattered proton

$\boldsymbol{P_0}$ Accelerated proton



Scattered intranuclear proton

Scattered neutron

$\boldsymbol{P_n-\Delta P_f = P'_n}$

$\boldsymbol{P_f-\Delta P_0\ +\Delta P_f = P_2}$

This leads to new values: $\boldsymbol{P'_f = P_1 + P_2 - P_0 = P_f + \Delta P_f}$

$\boldsymbol{P'^{\,rel} = P'_f - P'_n = P_f - P_n + 2\Delta P_f}$ – ***different!***

$\boldsymbol{P'^{\,cm} = P'_f + P'_n = P_f + P_n = P^{\,cm}}$ – ***the same!***

Why fluctuations of P'^{cm}_x and P^{cm}_z are so different?!

Uncertainty relation $\Delta E \cdot \Delta t \sim \hbar$

More exact relation for $P'^{\,cm}$ is

$$P'^{\,cm} = P'_f + P'_n = (P_f + \delta_1 + \Delta P_f) + (P_n + \delta_2 - \Delta P_f).$$

Here δ_1 and δ_2 are the quantum uncertainties of the momenta of particles ***f*** and ***n*** (information about this state is not accessible directly to the external observer). Therefore, estimation of *x*-component of momentum of the particles implies usage of the energy conservation law*). This leads inevitably to **uncontrollable change of particle's velocity*)**, $\Delta v_x \sim \hbar/(\Delta P_x\, \Delta t)$, where Δt is a duration of the interaction between the **quasiclassical object (projectile deuteron here)** and the particle, ΔP_x is a precision of the momentum measurement, $\Delta P_x \approx \sigma_x^{rel}$. Taking into account that $\Delta v_x \approx \sigma_x^{cm}/m$, $m \approx 2$ GeV/c², we obtain a rather realistic value $\Delta t \approx 10^{-23}$ s.

*) *L.D. Landau, E.M. Lifshits, Quantum Mechanics,1974 § 44.*

An explanation of the BGE results, which follows from the EVA data

$\hbar\omega \approx 10$ MeV

target

d+X→d+d,
X+X→Y+d.

Reactions

Y+X→Z+d were not considered

projectile

X+d →Y+d

Due to the relation $\Delta E \cdot \Delta t \sim \hbar$, the uncertainty of the target deutron energy during the interaction time $\Delta t \approx 10^{-23}$ sec is 66 MeV, and of the projectile deutron, due to relativistic effect of the time dilation, is ~320 MeV. This means that the initial states of the target deuteron may be the first 6 oscillator levels (including the ground state). The projectile deuteron may be approximately at the first 32 its oscillator levels. This is in a good agreement with the observed contribution of only <u>2 oscillator levels</u> (including the ground state) in the reactions with the excited target deuteron. The projectile deuteron were registered up to <u>31 excited state</u> due to the relativistic effect of time dilation.

EVA: Why the effect of measurement of $\boldsymbol{P}^{cm}$ is not seen for z-direction?

Answer. The scattering takes place in the transverse plane and **the longitudinal components of momentum are not influenced by the interaction**. They are the same as before interaction. In the EVA experiment, we measure **only the transverse component** of $\boldsymbol{P}_f + \boldsymbol{P}_n$. Compare this with a remark concerning necessity to measure each component of particle's momentum independently in the gedanken experiment described in the *Landau and Lifshits* book, *§ 44.*

EVA: Why the effect of measurement is not seen for $\boldsymbol{P'}^{\mathrm{rel}}$?

Answer

The exact expression for $\boldsymbol{P'}^{\mathrm{rel}}$ is

$\boldsymbol{P'}^{\mathrm{rel}} = \boldsymbol{P'}_f - \boldsymbol{P'}_n = (\boldsymbol{P}_f + \boldsymbol{\delta}_1 + \Delta\boldsymbol{P}_f) - (\boldsymbol{P}_n + \boldsymbol{\delta}_2 - \Delta\boldsymbol{P}_f) = = (\boldsymbol{P}_f - \boldsymbol{P}_n) + 2\Delta\boldsymbol{P}_f,$

where $\Delta\boldsymbol{P}_f$ is the momentum transfer from n to p. In this case, the quantum uncertainties of proton and neutron momenta in an intermediate state (which are unobserved directly) are taken with different signs, $|\boldsymbol{\delta}_{1x} - \boldsymbol{\delta}_{2x}| = 0.2 < |\boldsymbol{\delta}_{1x} + \boldsymbol{\delta}_{2x}| = 0.6$, and almost compensate each other.

Important note: ***Kinematics of experiment selects events in which $\langle P_x^{rel} \rangle = |(P_f - P_n)_x| < \langle P_z^{rel} \rangle = |(P_f - P_n)_z|$ due to the preferable choice of the intranuclear proton rapidly running away from the incident particle (because of cross-section dependense on $\sqrt{s}$). The neutron in SRC pair is usually suggested to move in the opposite direction with a speed comparable to proton one.***

EVA: Strange "p-n scattering" in the transversal plane

Let us compare $\langle P'_{z_{rel}} \rangle \approx 0.3$ and $\langle P'_{x_{rel}} \rangle \approx 0.6$. We see that

$$\langle P'_{x_{rel}} \rangle > \langle P'_{z_{rel}} \rangle.$$

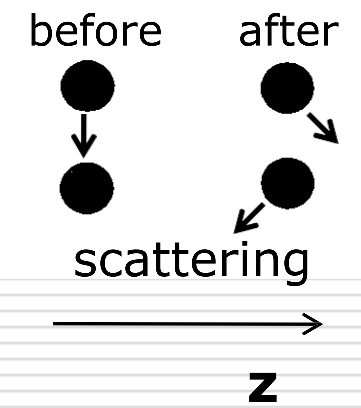
This may be only due to a difference in a x- and z-components of $2\Delta\boldsymbol{P}_f$, where $\Delta\boldsymbol{P}_f$ is a momentum transfer between intranuclear n and p (see the previous slide). Most likely estimation is $2\Delta\boldsymbol{P}_{fz} \approx 0$ and $2\Delta\boldsymbol{P}_{fx} > 0.3$. In other words, the **whole momentum transfer lies in the transversal plane!** This is very strange because the p-n scattering itself was initiated before by the projectile particle–p collision along z-direction. This means that p was incoming on n also along the transversal plane. Thus, for any **usual** p-n scattering we should expect something diametrically opposite: $\Delta\boldsymbol{P}_{fx} \approx 0$, $\Delta\boldsymbol{P}_{fz} \neq 0$ (see picture in the next slide for visualization).

Assumption prompted by the EVA experiment

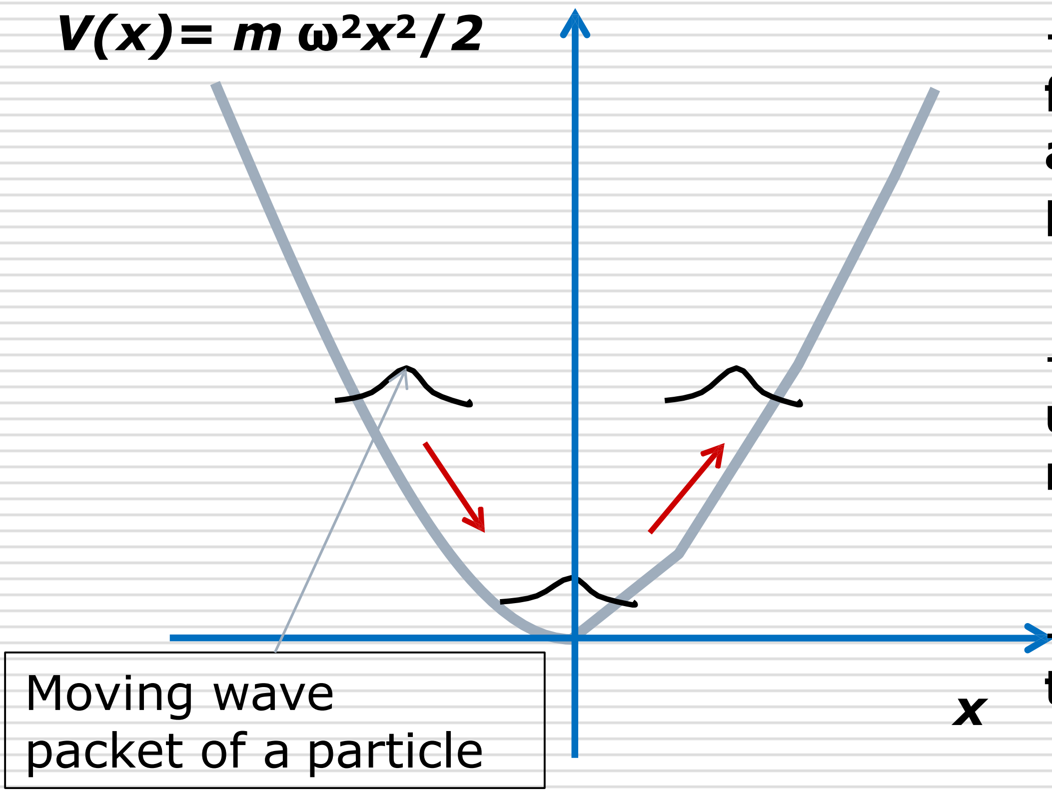
The EVA experiment gives an evidence for a possibility of inner excitations of quarks degrees of freedom of the p-n lump (комок) in the transversal plane after its collision with a projectile.

The proton and neutron in the lump after their scattering on each other do not acquire a visible longitudinal relative momentum (see EVA data for P_z^{rel} which is in a good agreement with the intranuclear Fermi motion, P_F=0.22). This means that momentum of the excitation in the lump is completely localized in the transversal plane. This coincides with the suggestion of the ***two-dimensional*** *oscillator excitations following from TE and BGE.*

This process cannot be interpreted as p-n scattering: compare with the usual p-n scattering shown in the picture, where we expect P_z^{rel} =0 before scattering and $P_z^{rel} \neq 0$ after it.



Coherent state of 1-D harmonic oscillator



E. Schrödinger, 1926

$$d^2\langle x(t)\rangle/dt^2 + \omega^2\langle x(t)\rangle = 0$$

-classical equation of motion for the mean position of a particle in the oscillator ponential,

$$\Delta x(t)\Delta p(t) = \hbar/2$$

-the minimally possible uncertainties of position and momentum of the particle,

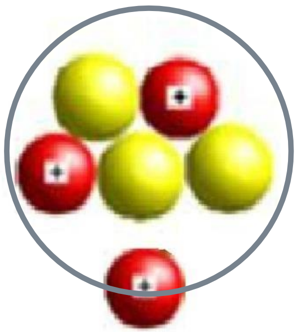
$$w_n = e^{-\langle n\rangle}\langle n\rangle^n/n!$$

- the Poisson distribution to find the particle with energy

$$E_n = \hbar\omega\,(n+1/2)$$

in a superposition of states with different energies.

Parameters of our 2-D oscillator



Effective mass of oscillating quark

$m_{eff}=m_q\,(m_d - m_q)/m_d=0.276$ GeV/c^2.

Kinetic energy of transversal motion

$$T=\sqrt{m_{eff}^2+0.6^2}-m_{eff}=0.385$$

Localization of the packet in momentum and usual spaces

$\Delta p_x\sim\Delta p_y\sim 0.053$, $\Delta x\sim\Delta y\sim 1.88$ fm< r_d =2.13 fm

(may be estimated using ħω/2 ≈ 0.005).

Coherent states of 2-D harmonic oscillator. Case 1.

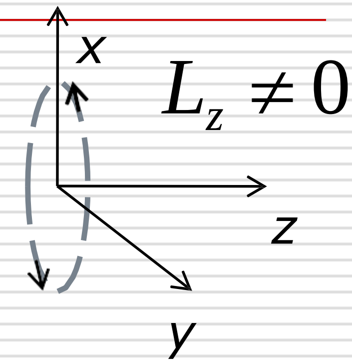
For 2-D case the coherent state is a superposition of different levels of two oscillators:

$$|\alpha_1,\alpha_2\rangle = \exp(-(|\alpha_1|^2+|\alpha_2|^2)/2)\sum_{n_1,n_2=0}^{\infty}\frac{\alpha_1^{n_1}\alpha_2^{n_2}}{\sqrt{n_1!n_2!}}|n_1,n_2\rangle.$$

In the general case $|\alpha_1|^2 \neq |\alpha_2|^2$. Probability to find dibaryon with mass $M_n = M_0 + 0.01\,n$ is given by

$$w_n = \exp(-|\alpha_1|^2-|\alpha_2|^2)\sum_{n_1+n_2=n}\frac{|\alpha_1|^{2n_1}|\alpha_2|^{2n_2}}{n_1!n_2!}.$$

Case 1 corresponds to $L_z=0$



Lissajous figures in classical physics:
two periodic motions with equal frequences give a periodical circular motion.
It is not the case here. In the coordinate representation we have two independent 1-D oscillators:

$$\langle q_1, q_2 | n_1, n_2 \rangle = \psi_{n_1}(q_1)\psi_{n_2}(q_2), \quad \psi_n(q) = C_n H_n(q/\sqrt{\hbar})\exp(-q^2/\hbar)$$

Explanation: δφ δN ≈ 1 (Dirac). In state $|\alpha_1, \alpha_2\rangle$ numbers of particles (excitations) in *x*- and *y*-oscillators are known exactly: $N_x = |\alpha_1|^2, N_y = |\alpha_2|^2$. This implies that relative phase between *x*- and *y*-oscillations is totally undefined and no circular motion arises.

Case2 : States with $L_z \neq 0$. Translation from linear into circular polarization language

The state $|n_1, n_2\rangle$, in terms of creation and annihilation operator describing *x*- and *y*-oscillator excitations, is $|n_1, n_2\rangle = \frac{a_1^{\dagger n_1} a_2^{\dagger n_2}}{\sqrt{n_1! n_2!}} |0,0\rangle$.

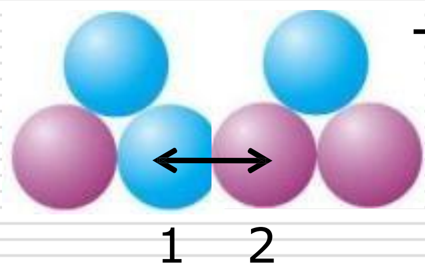
Let's introduce operators describing excitations with negative and positive helicities:

$a_+ = (a_1 + ia_2)/\sqrt{2}, \ a_- = (a_1 - ia_2)/\sqrt{2}$. Corresponding basis vectors are now $|n_+, n_-\rangle = \frac{a_+^{\dagger n_+} a_-^{\dagger n_-}}{\sqrt{n_1! n_2!}} |0,0\rangle$. They are eigenvectors of operator $L_3 = q_1 p_2 - p_1 q_2 = a_-^{\dagger} a_- - a_+^{\dagger} a_+$ and describe the oscillator

Hamiltonian in the similar way as a_1 and a_2: $H = \hbar\omega(a_+^{\dagger} a_+ + a_-^{\dagger} a_- + 1)$

Wave functions $\langle r, m = -n_+ + n_- | n_+, n_- \rangle$ *can be found by solving the Schrödinger equation in the cylindrical coordinates.*

Two-quark excitations



The state $|\alpha_1, \alpha_2\rangle$ has <u>another natural interpretation</u> 1 and 2 are numbers of constituent quarks in colliding nucleons. This state has also <u>zero</u> orbital momentum and energy of the ground state = ħω.

It is possible to construct a coherent state describing <u>orbital excitations</u> of two quarks simply replacing subscripts 1 by + and 2 by − in the previous formula for $|\alpha_1, \alpha_2\rangle$. Explicitly*):

$$|\alpha_+, \alpha_-\rangle = \exp(-(|\alpha_+|^2 + |\alpha_-|^2)/2) \sum_{n_+, n_- = 0}^{\infty} \frac{\alpha_+^{\ n_+} \alpha_-^{\ n_-}}{\sqrt{n_+! n_-!}} |n_+, n_-\rangle.$$

In this case dibaryon with mass $M_n = M_0 + 0.01\ (n_+ + n_-)$ is a coherent superposition of states with different inner angular momentum, $L_z = m = n_- - n_+$.

Generalized coherent excitations

A.Perelomov, Generalized Coherent States and Their Applications, Springer, 1986

$$K = a_1 a_2,\; K^{\dagger} = a_1^{\dagger} a_2^{\dagger},\; K_0 = (a_1^{\dagger} a_1 + a_2^{\dagger} a_2 + 1)/2$$

(It is possible to describe orbital excitations too changing subscripts $1 \to +, 2 \to -$)

$$\left[K_0, K\right] = -K,\; \left[K_0, K_{\dagger}\right] = K_{\dagger},\; \left[K, K_{\dagger}\right] = 2K_0 \Rightarrow su(1,1)\text{ algebra}$$

Generalized coherent state*⁾: $\left|\zeta\right\rangle = (1-|\zeta|^2)^k \exp(\zeta K^{\dagger})\left|0\right\rangle_k =$

$$= (1-|\zeta|^2)^k \sum_{m=0}^{\infty} \left[\frac{\Gamma(m+2k)}{m!\Gamma(2k)}\right]^{1/2} \zeta^m \left|k, k+m\right\rangle,\; k = 1, \frac{3}{2}, 2, \frac{5}{2}, \ldots$$

Here k describes energy of the ground state of the oscillator (may be different):

$$H\left|k, k+m\right\rangle \equiv 2\hbar\omega K_0\left|k, k+m\right\rangle = 2\hbar\omega(k+m)\left|k, k+m\right\rangle \Rightarrow E_0 = 2\hbar\omega k.$$

$w_m = (1-|\zeta|^2)^{2k} \dfrac{\Gamma(m+2k)}{m!\Gamma(2k)} |\zeta|^{2m}$ – Probability to observe a dibaryon with mass $M_{2N} + 2\hbar\omega(k+m)$

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*⁾ Compare with definition of the usual coherent states: $\left|\alpha\right\rangle = \exp(-|\alpha|^2/2)\exp(\alpha a^{\dagger})\left|0\right\rangle$

Generalized coherent excitations of two independent oscillators

$$K_\xi = a_\xi^2/2,\ K_\xi^\dagger = \left(a_\xi^\dagger\right)^2/2,\ K_{0\xi} = (a_\xi^\dagger a_\xi + a_\xi a_\xi^\dagger)/4 \ \text{ and similarly for } K_\zeta .$$

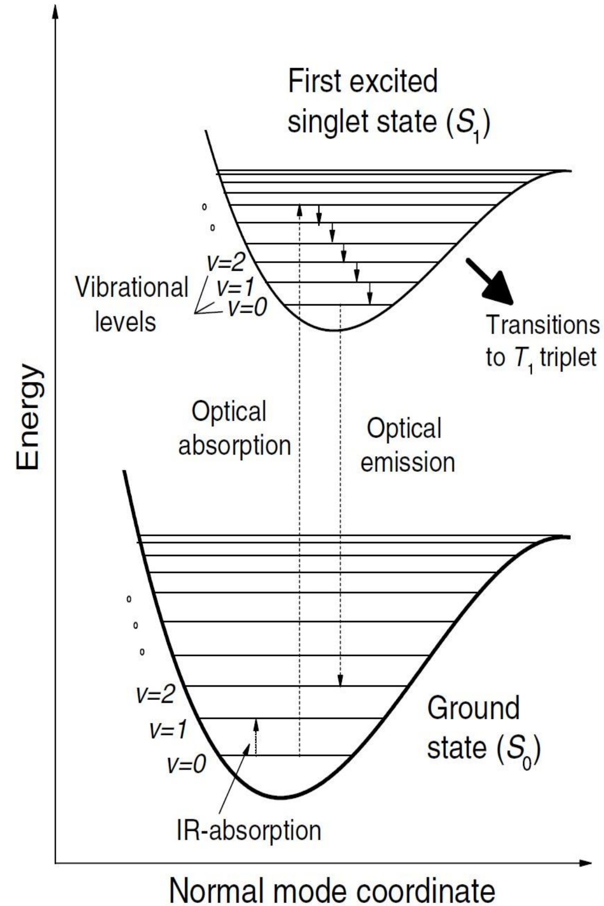
$$\left|\xi\right\rangle\left|\zeta\right\rangle = (1-\left|\xi\right|^2)^{k_\xi}(1-\left|\zeta\right|^2)^{k_\zeta}\exp(\xi K_\xi^\dagger)\left|0\right\rangle_{k_\xi}\exp(\zeta K_\zeta^\dagger)\left|0\right\rangle_{k_\zeta} =$$

$$=(1-\left|\xi\right|^2)^{k_\xi}(1-\left|\zeta\right|^2)^{k_\zeta}\sum_{m=0}^{\infty}\left[\frac{\Gamma(m+2k_\xi)}{m!\Gamma(2k_\xi)}\right]^{1/2}\xi^m\left|k_\xi,k_\xi+m\right\rangle\sum_{n=0}^{\infty}\left[\frac{\Gamma(n+2k_\zeta)}{n!\Gamma(2k_\zeta)}\right]^{1/2}\xi^n\left|k_\zeta,k_\zeta+n\right\rangle,$$

$k_\xi, k_\zeta = 1/4$ or $3/4$, independently, describe possible ground states of oscillators, corresponding to different representations of SU(1,1).

Production of the coherent dibaryons (CD) in N-N collisions

Analogy with ion vibrations in molecules:



At high excitation energy, a potential of interaction between nuclei changes abruptly due to rearrangement of the electron cloud surrounding them. The potential of interaction may be approximated by parabola of the second order near its minimum. This leads to formation of the <u>harmonic oscillator vibration levels</u> of the molecular constituents (ions).

Production of CD: a model of the first-order phase transition

Analogy: molecule → 6q system, nuclei → constituent quarks, potential → boson field which quarks can emit and absorb.

$$H = \left[a_1^\dagger a_1 + a_2^\dagger a_2 + 1 \right] \hbar\omega \rightarrow$$

$$H(\alpha_1, \alpha_2) = \left[a_1^\dagger a_1 + a_2^\dagger a_2 + 1 - \left(\alpha_1 a_1^\dagger + \alpha_1^* a_1 \right) - \left(\alpha_2 a_2^\dagger + \alpha_2^* a_2 \right) + |\alpha_1|^2 + |\alpha_2|^2 \right]$$

Here the first two additional terms describe interaction between the oscillators and the boson fields of amplitudes α_1 and α_2, the last two are energy of the boson fields created during N-N interaction. We may rewrite the Hamiltonian in an equivalent form

$$H(\alpha_1, \alpha_2) = \left[(a_1 - \alpha_1)^\dagger (a_1 - \alpha_1) + (a_2 - \alpha_2)^\dagger (a_2 - \alpha_2) + 1 \right] \hbar\omega.$$

Thus we obtain the usual harmonic oscillator Hamiltonian with replacement

$$a_i^\dagger \rightarrow (a_i - \alpha_i)^\dagger, a_i \rightarrow (a_i - \alpha_i).$$

A model of the first-order phase transition (continuation)

These new creation and annihilation operators obey the same commutation relations as usual ones (because α_i are complex numbers). Furthermore, eigenstates of the new Hamiltonian may be expressed through eigenstates of the old one (the Stone-von Neumann theorem for Heisenberg-Weyl's group). One may define the ground state of the new Hamiltonian in exactly the same way as it was done before. Namely, we should change the relation

$$a_1 a_2 |0,0\rangle = 0$$

by

$$(a_1 - \alpha_1)(a_2 - \alpha_2)|0,0\rangle_{\text{new}} = 0.$$

It may be checked that the solution of this equation is as follows

$$|0,0\rangle_{\text{new}} = |\alpha_1, \alpha_2\rangle = \exp(-(|\alpha_1|^2 + |\alpha_2|^2)/2) \sum_{n_1,n_2=0}^{\infty} \frac{\alpha_1^{n_1} \alpha_2^{n_2}}{\sqrt{n_1! n_2!}} |n_1, n_2\rangle,$$

which is the **2-D Glauber coherent state** described before.

Production of CD: a model of quantum mechanical evolution

Hamiltonian taking into account interaction of the quark oscillator with an inner boson field ξ produced in N-N interaction:

$$H = 2\hbar\omega K_0 + i(\xi K^\dagger - \xi^* K) = H_0 + H_{\text{int}}.$$

Evolution operator in the interaction representation is

$$U(0,\Delta t) = \exp(-iH_{\text{int}}\Delta t) = \exp(\xi\Delta t K^\dagger - \xi^*\Delta t K) \equiv \exp(\zeta K^\dagger)\exp(\beta K_0)\exp(\gamma K),$$

where ζ , β and γ are some known functions of $\xi\Delta t$. In particular*),

$$|\zeta| = \tanh(\xi\Delta t), \quad \beta = \ln\ \cosh|\xi\Delta t| = -\ln(1-|\zeta|^2).$$

Using $K\,|0\rangle_k = 0$, it is easy to find

$$U(0,\Delta t)|0\rangle_k = (1-|\zeta|^2)^k \exp(\zeta K^\dagger)|0\rangle_k \equiv |\zeta\rangle$$

which is the generalized coherent state described above.

*) See *A.Perelomov, Generalized Coherent States and Their Applications.*

Conclusion

1.In the Troyan and Baldin group experiments, there are encouraging evidences for registration of **quark oscillator levels excitations** in the compressed 2-nucleon systems.

2. Data of EVA experiment give a transparent hint about possibility of **dibaryon formation** in proton-SRC scattering. They are also in agreement with **Landau-Peierls energy-time uncertainty relation**.

3. Estimation of **time of quantum measurement** of P^x_{cm}, $\Delta t \approx 2\ 10^{-23}$ s, is in a good correspondence with the Baldin group's data on d-d interactions.

4. Further measurement of EVA type may shed light on possibility of two types of **phase transitions 2N $\longrightarrow$ 6q,** which are connected with creation of different bosonic fields inside the system. Corresponding information may be contained in distribution on the coherent dibaryon masses.