JOINT INSTITUTE FOR NUCLEAR RESEARCH

The influence of collective effects on the eta-mesic nucleus formation

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The nucleus is usually considered as solid systems in nuclear reactions at high energies. . This approach is justified in most cases. The interaction energy of objects is many times larger excitation energy of the nuclei. The view becomes more difficult when the energy of an elementary particle is small. In this case, the excitation of the nucleus can play a key role.

Consider the process of capture of slow mesons in nuclear forces the target nucleus in the magical reactions on the example of p+A=d+(A-1)+meson reactions. In this type of reactions is the pickup of a single nucleon from the target nucleus and the produce of the meson. The momentum of the incident proton and deuteron formed must be the same, and the difference in kinetic energy is used for the production of the slow pion. In the process of interaction between the nucleus of the target is not a passive observer. Under the influence of electric and nuclear forces the nucleus to deform. It is easy to assume that the action of the Coulomb forces will lead to the displacement of charged and neutral particles. Indeed, this behavior of nuclei is well known and has a name giant nuclear resonance (GR). GR has its own quantum number and can have a significant impact on the reaction.

Giant nuclear resonances occur systematically in most, if not all, nuclei, with oscillation energies typically in the range of 10–30 MeV. Among the best-known examples is the giant electric dipole (E1) resonance, in which all the protons and all the neutrons oscillate with opposite phase producing a large time-varying electric dipole moment.

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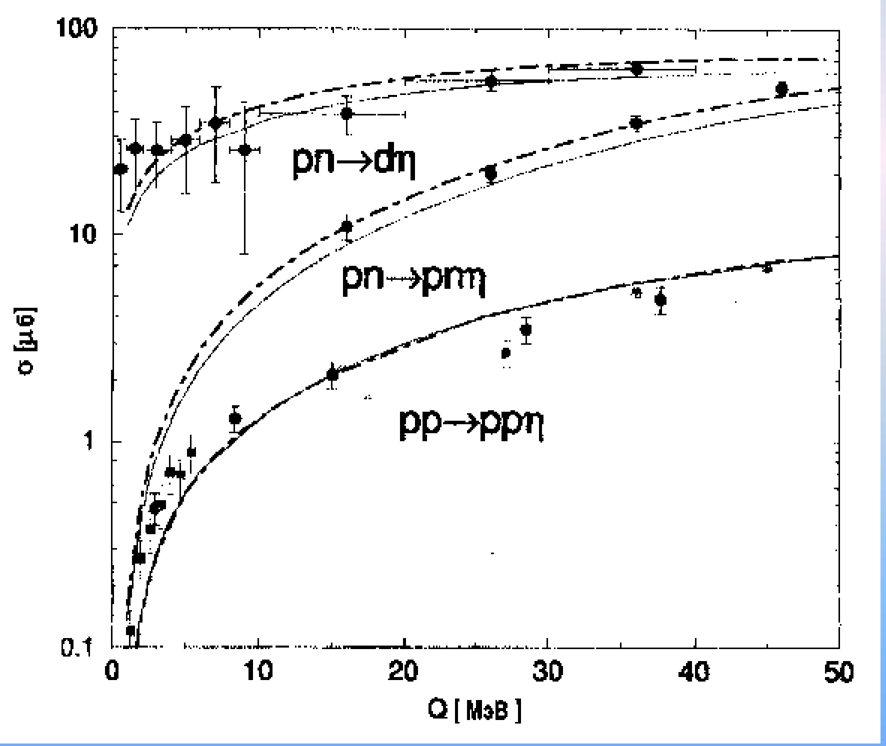
Kinematical characteristics
Method of identification

$$p+A \rightarrow d+\eta_{\,p=0}+(A\text{-}1)_{p=0}$$

$$d+A \rightarrow t+\eta_{\,p=0}+(A\text{-}1)_{p=0}$$

$$d+A \rightarrow {}^{3}He+\eta_{\,p=0}+(A\text{-}1)_{p=0}$$

Production of hmesons in nucleon-nucleon collisions
V. Baru,
PHYSICAL REVIEW C **67**, 024002 (2003)



$$p+A \rightarrow n+p+{}_{\eta}(A-1)$$

$$E_p > E_d \quad ; \quad P_{d--} = P_t$$

$$E_p - E_d = M_\eta \; E_d > E_t$$

$$\eta + (A\text{-}1) \rightarrow (A\text{-}1)_\eta$$

$$M_A >> M_\eta$$

$$E_A > E_\eta \Rightarrow E_A - E_\eta = \omega > 0$$

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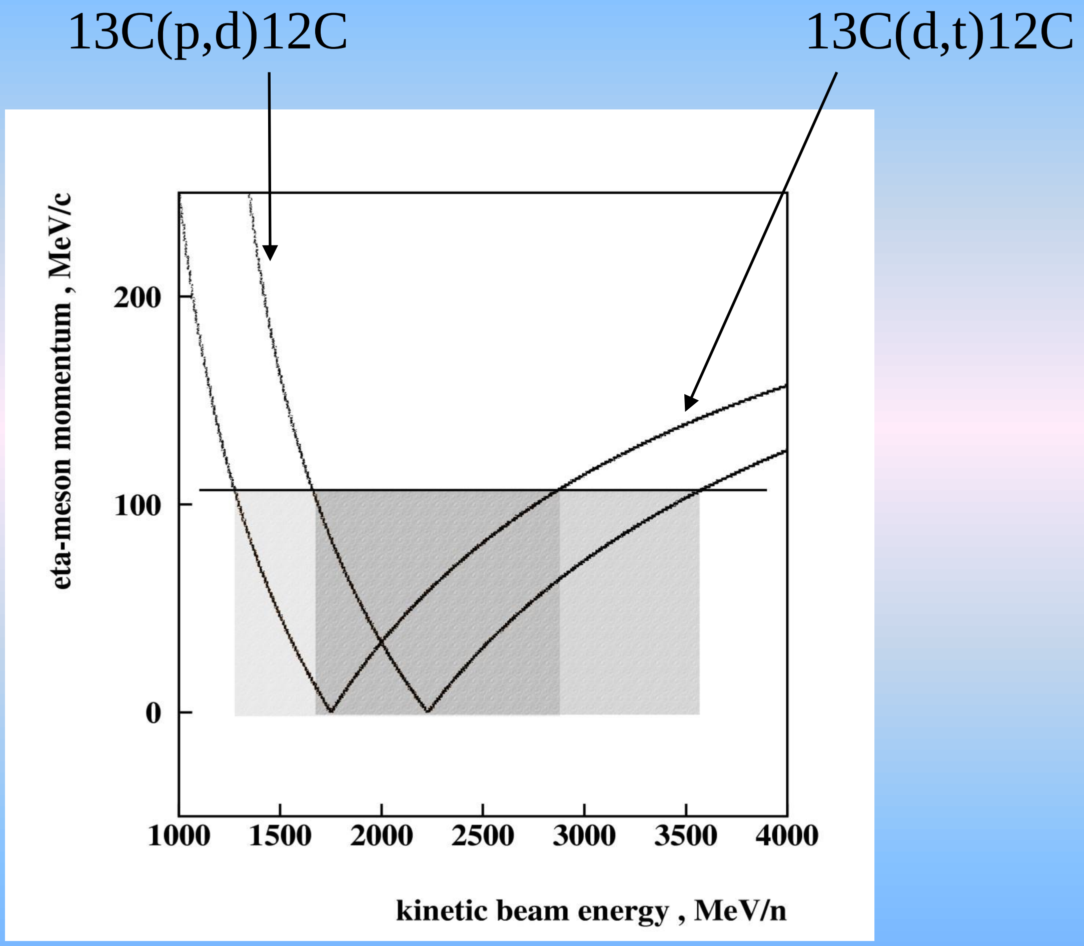
Kinematic of recoil-free transfer reaction



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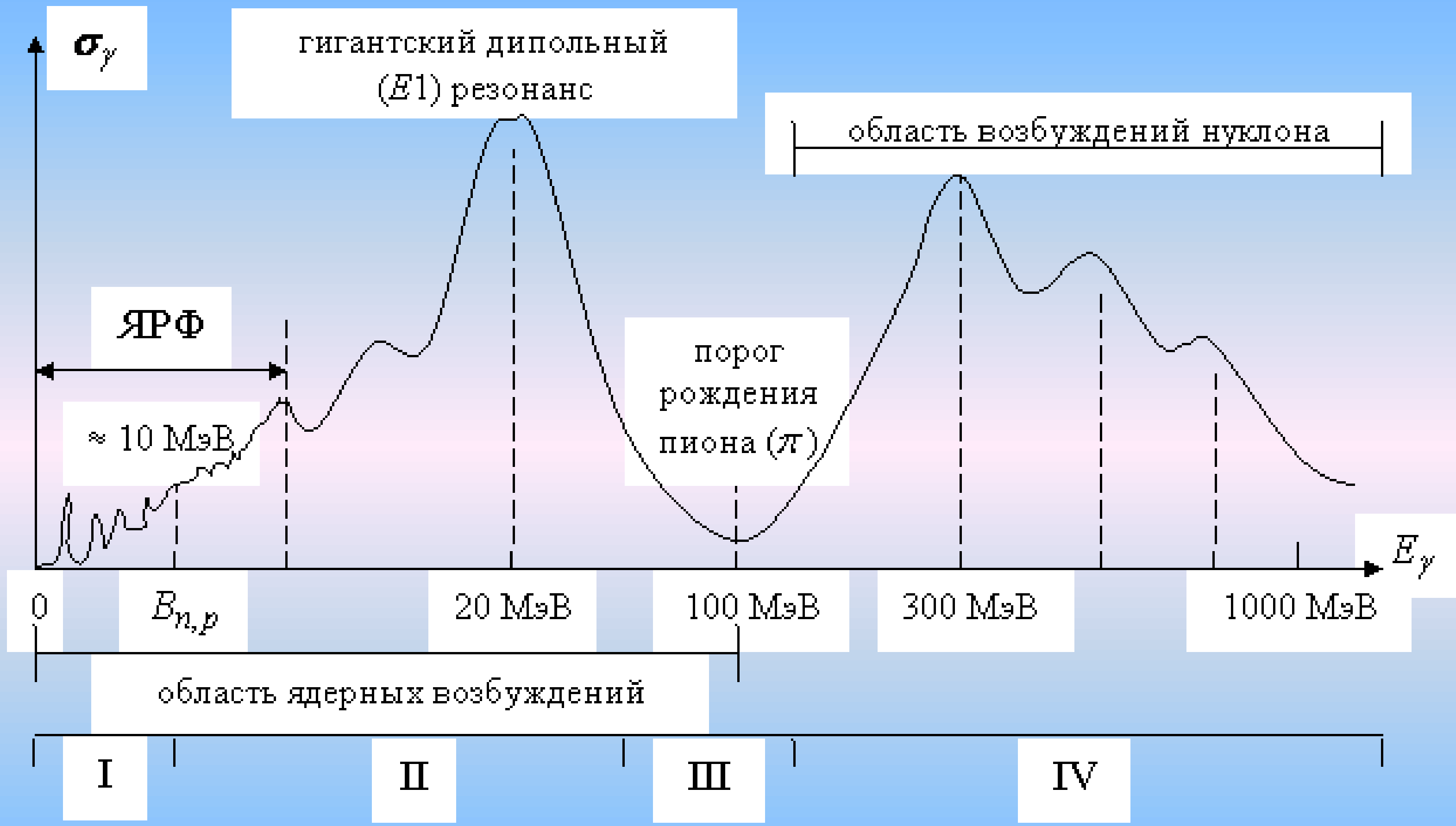
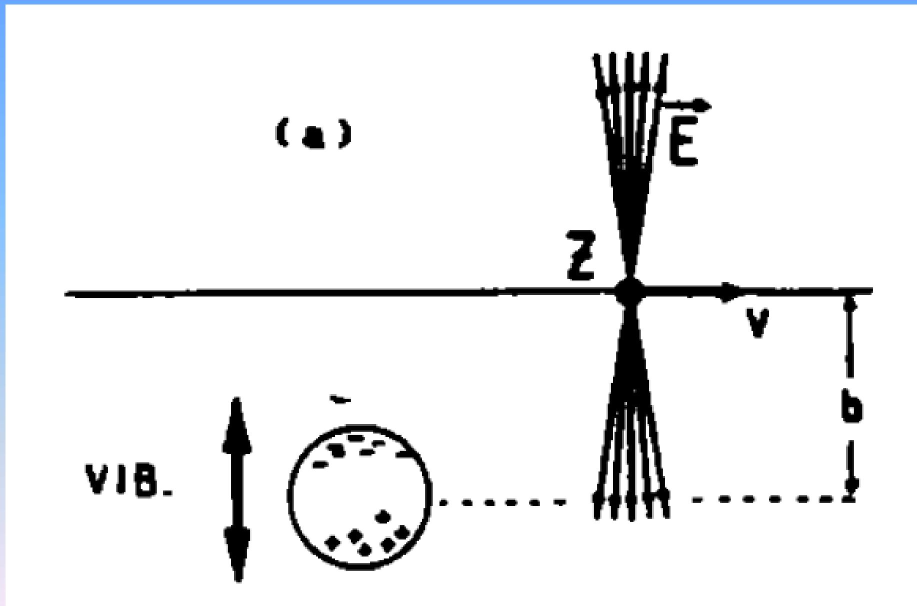
Schematic representation of the photon absorption cross-section by atomic nuclei at photon energies up to 1 GeV

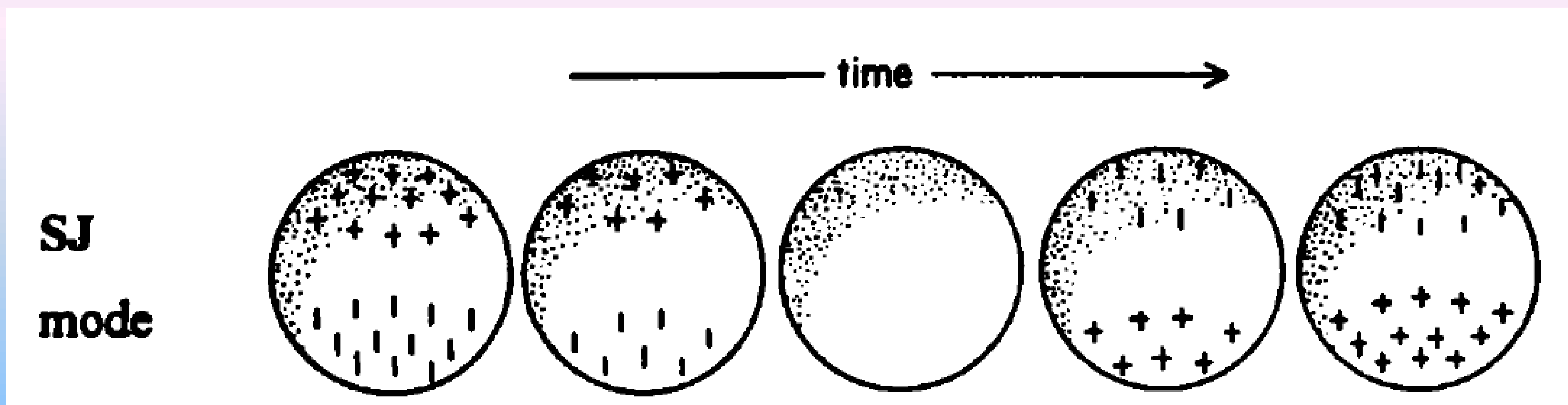


http://nuclphys.sinp.msu.ru/index.html

Ишханов Б.С., Капитонов И.М. "Гигантский дипольный резонанс атомных ядер"



Schematic illustration of the electric field create by a relativistic heavy ion traveling on a straight line. This electric field may excite the giant dipole mode.
(G.P. Baur and C .A. Bertulani, Phys . Rep . 163 (1988) 299)



Shematic picture of the GDR in the Steinwedel and Jensen model. (H.Steinwedel and J.H.D. Jensen, Z . Nat. 5a (1950) 413)

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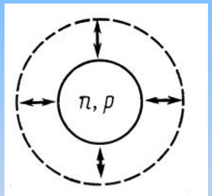
Nuclei exitation

Pi/Pf=$(-1)^{-L}$

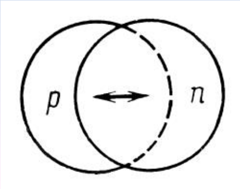
Pi/Pf=$(-1)^{-L+1}$

E0



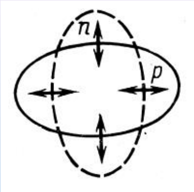
W=80$A^{-1/3}$MeV

E1



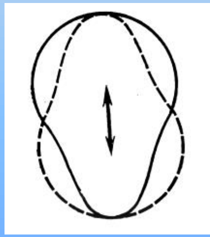
W=78$A^{-1/3}$MeV
Γ=3 -10MeV
9<A<203

E2



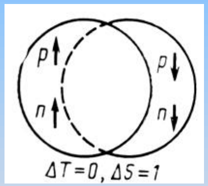
W=63$A^{-1/3}$MeV
Γ=6 - 3MeV
14<A<208

E3

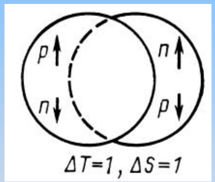


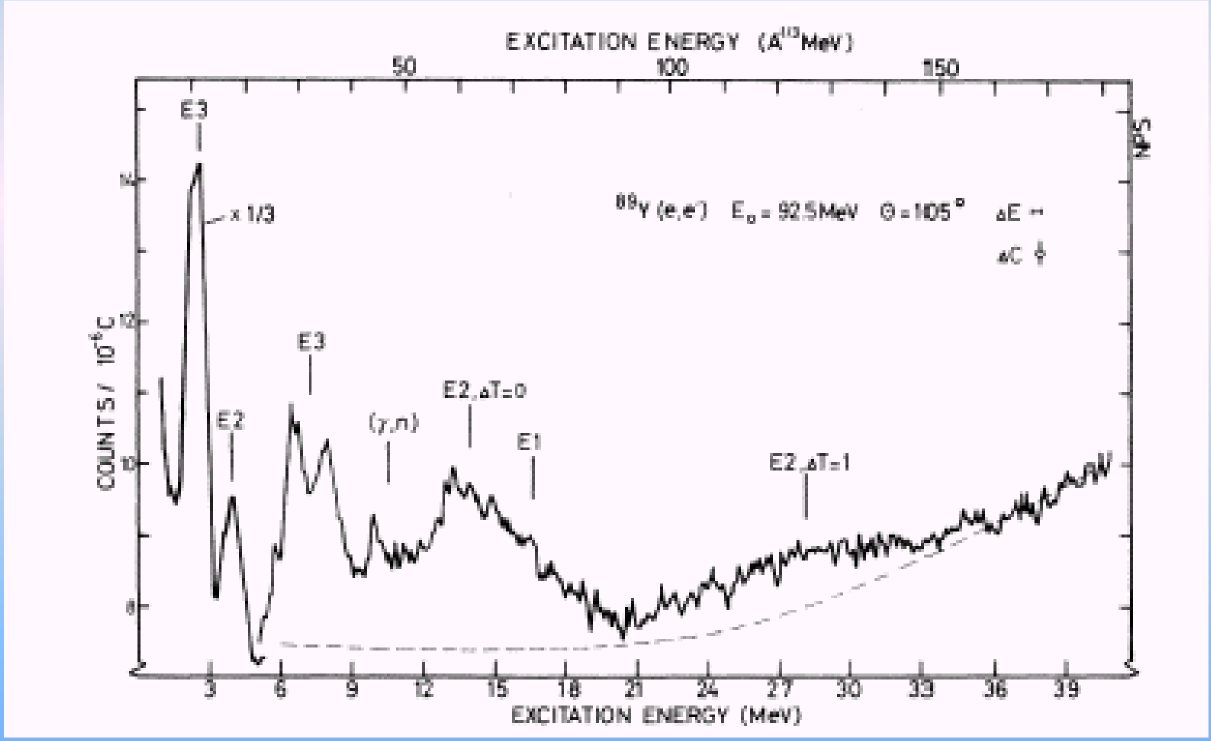
W=32$A^{-1/3}$MeV
Γ=2.2MeV
60<A<208

M1



M2





Spectrum of 92.5-MeV electrons scattered at 105°

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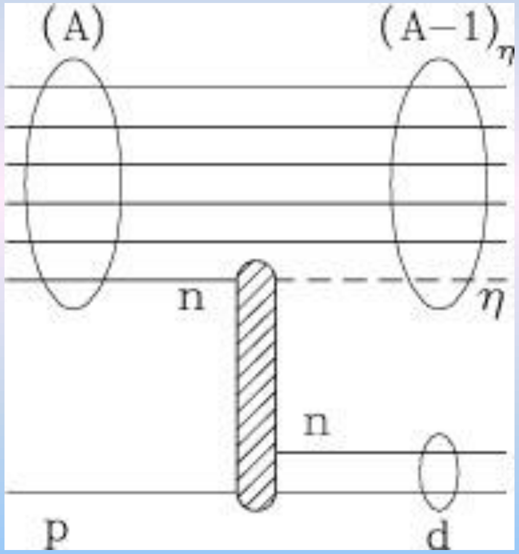
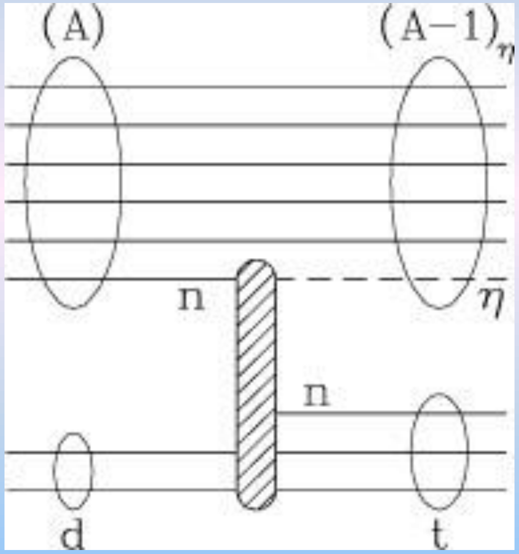
Numerical calculation

$$p+A \rightarrow d+\eta_{p=0}+(A\text{-}1)_{p=0}$$

$$d+A \rightarrow t+\eta_{p=0}+(A\text{-}1)_{p=0}$$

$$d+A \rightarrow {}^3He+\eta_{p=0}+(A\text{-}1)_{p=0}$$





The names with masses are of baryons that decay strongly. The spin-parity J^P (when known) is given with each particle. For the strongly decaying particles, the J^P values are considered to be part of the names.

P	1/2+
n	1/2+
N(1440)	1/2+
N(1520)	3/2−
N(1535)	1/2−
Δ(1232)	3/2+

LIGHT UNFLAVORED MESON
(S = C = B = 0)

I^G (J^{PC}) PARITY (P)

$\pi^{\pm}$ 1^- (0^-)
π^0 1^- (0^{-+})
η 0^+ (0^{-+})

Parity conservation

$$d+A \rightarrow t(0^{o})+\eta_{p=0}+(A\text{-}1)_{p=0} \rightarrow t(0^{o})+(A\text{-}1)_{\eta}^{*}(S_{11})$$

$$P_p P_A(-1)^{L0}=(-1)P(-1)^{L}=(+1)P_{(A-1)}P_{GR}P_{(Res.)}$$

A	E(MeV)	Pt/Pd	L_0	L	Resonas
12	4070	1.00024	5	4	E1,S_{11}
13	3828	1.00026	5	4	E1, S_{11}
27	3899	1.00019	2	4	E2,M1
63	3810	1.00015	0	3	E1,E3, S_{11}
65	3793	1.00015	1	3	E2,M1
107	3765	1.00012	0	3	E1,E3, S_{11}
109	3758	1.00012	0	3	E1,E3, S_{11}
182	3724	1.00011	1	3	E2,M1

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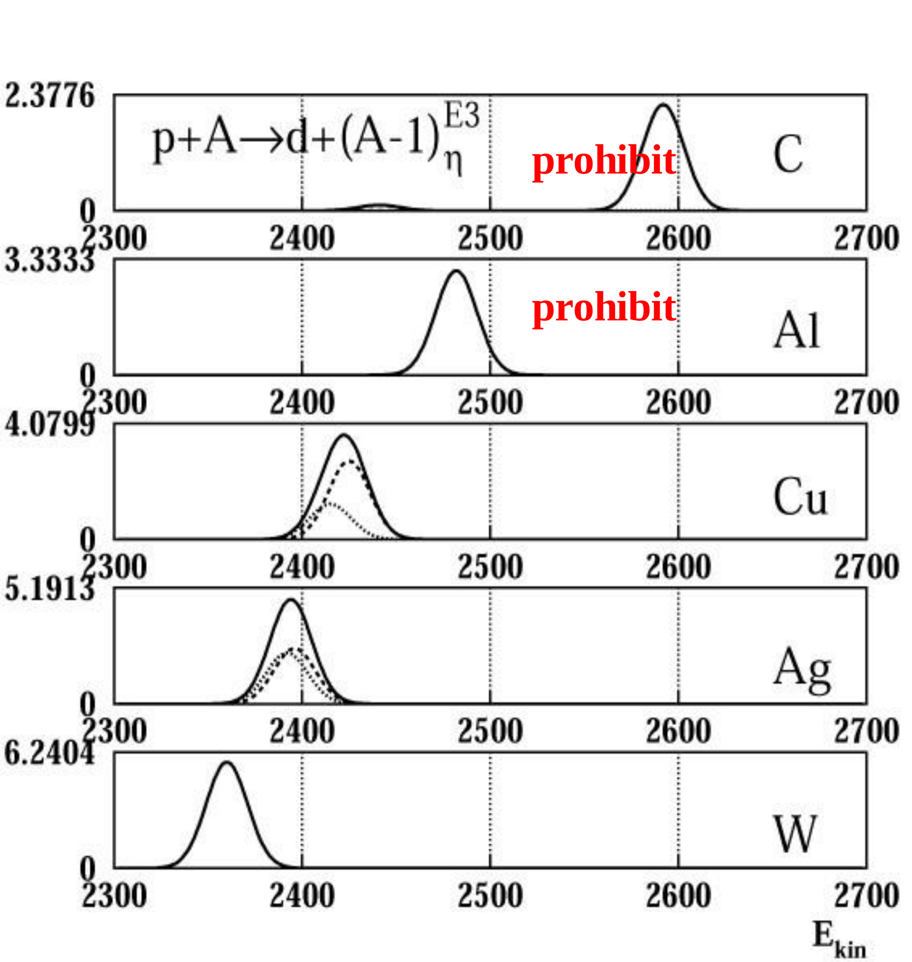
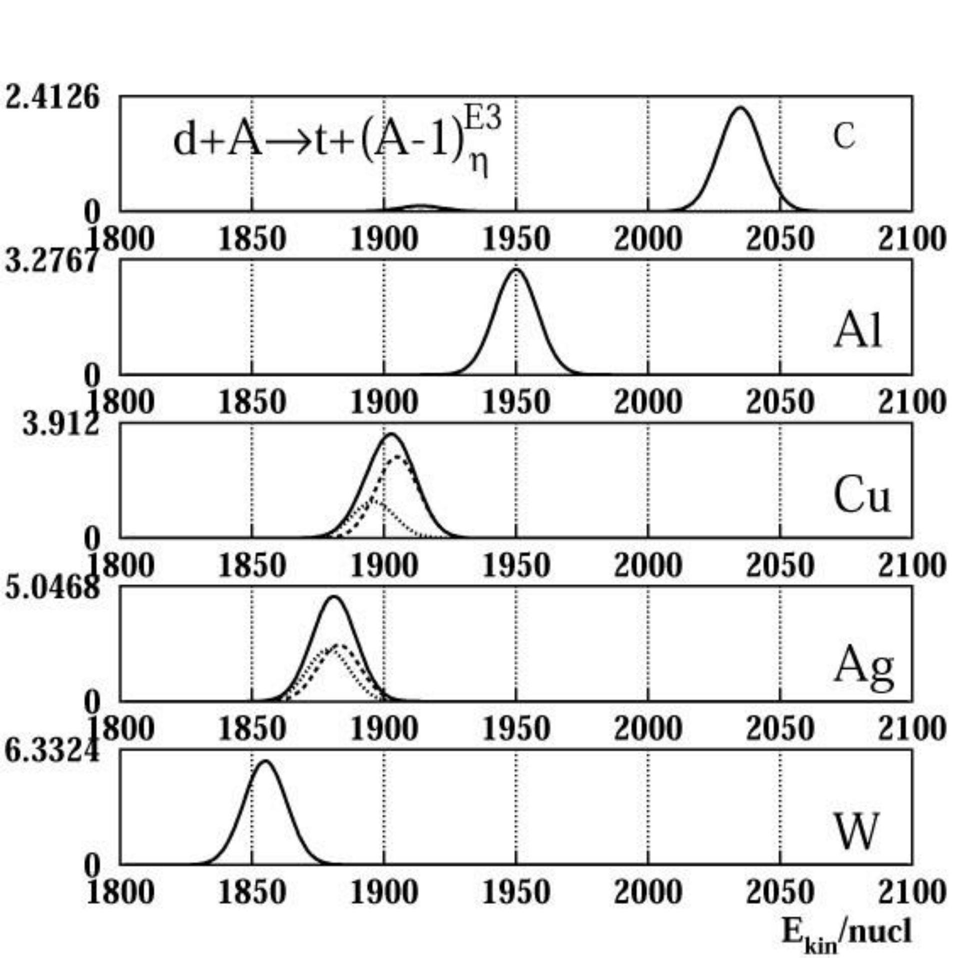
Numerical calculation

$$d+A \to t+\eta_{p=0} +(A\text{-}1)_{p=0}$$

$$p+A \to d+\eta_{p=0}+(A\text{-}1)_{p=0}$$

$$d+A \to {}^3He+\eta_{p=0} +(A\text{-}1)_{p=0}$$



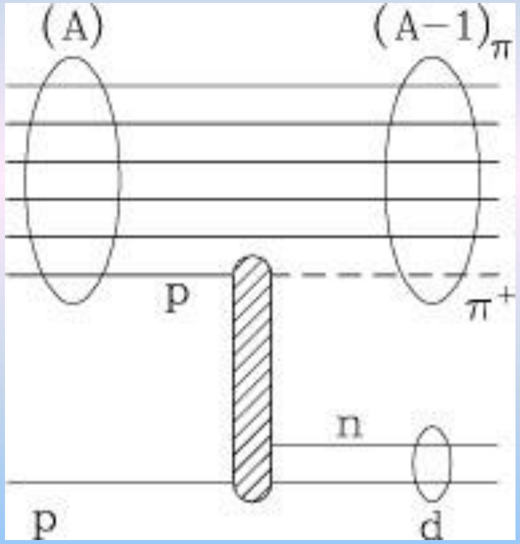


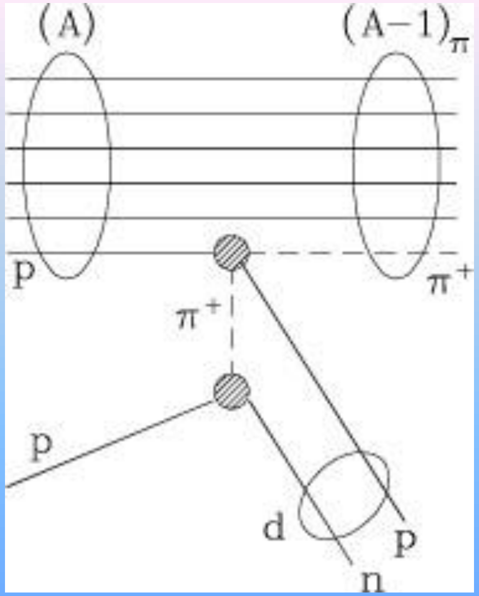
Numerical calculation

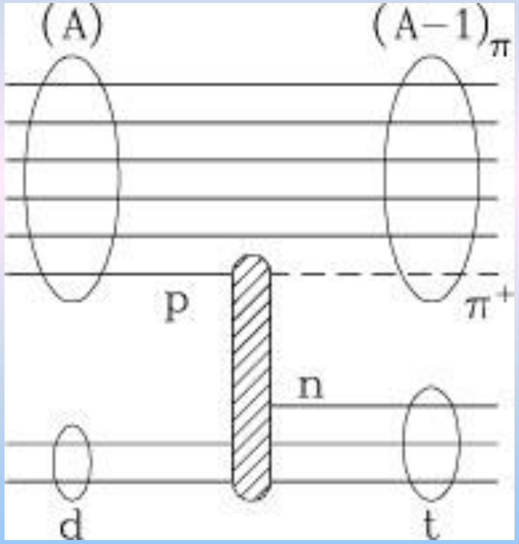
$$d+A \rightarrow t + \pi_{p=0} + (A\text{-}1)_{p=0}$$

$$p+A \rightarrow d + \pi_{p=0} + (A\text{-}1)_{p=0}$$

$$d+A \rightarrow {}^3He + \pi_{p=0} + (A\text{-}1)_{p=0}$$







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Parity conservation

$p+A \rightarrow d(0^{o}) + \pi_{p=0} + (A\text{-}1)_{p=0} \rightarrow d(0^{o}) + (A\text{-}1)_{\pi}^{*}$

$d+A \rightarrow t(0^{o}) + \pi_{p=0} + (A\text{-}1)_{p=0} \rightarrow t(0^{o}) + (A\text{-}1)_{\pi}^{*}$

$$P_p P_A (-1)^{L0} = (-1) P (-1)^{L} = (+1) P_{(A\text{-}1)} P_{GR} P_{(Res.)}$$

A	E(MeV)	Pd/Pp	L_0	L	Resonas
12	**370**	**1.00066**	**6**	**1**	E2,M1
13	**374**	**1.00070**	**6**	**1**	E2,M1
27	**368**	**1.00052**	**4**	**2**	E2,M1
63	**341**	**1.00040**	**3**	**1**	**E1,E3,**M2
65	**349**	**1.00040**	**3**	**2**	E2,M1
107	**343**	**1.00034**	**3**	**1**	**E1,E3,**M2
109	**345**	**1.00034**	**3**	**1**	**E1,E3,**M2
182	**344**	**1.00029**	**3**	**2**	E2,M1

A	E(MeV)	Pt/Pd	L_0	L	Resonas
12	**548**	**1.00076**	**5**	**1**	E1,M2
13	**554**	**1.00074**	**5**	**1**	E1,M2
27	**545**	**1.00063**	**2**	**2**	E2,M1
63	**504**	**1.00050**	**0**	**1**	E1,**E3,** M2
65	**515**	**1.00049**	**1**	**1**	E2,M1
107	**507**	**1.00041**	**0**	**1**	E1,**E3,** M2
109	**509**	**1.00041**	**0**	**1**	E1,**E3,** M2
182	**508**	**1.00035**	**1**	**1**	E2, M1

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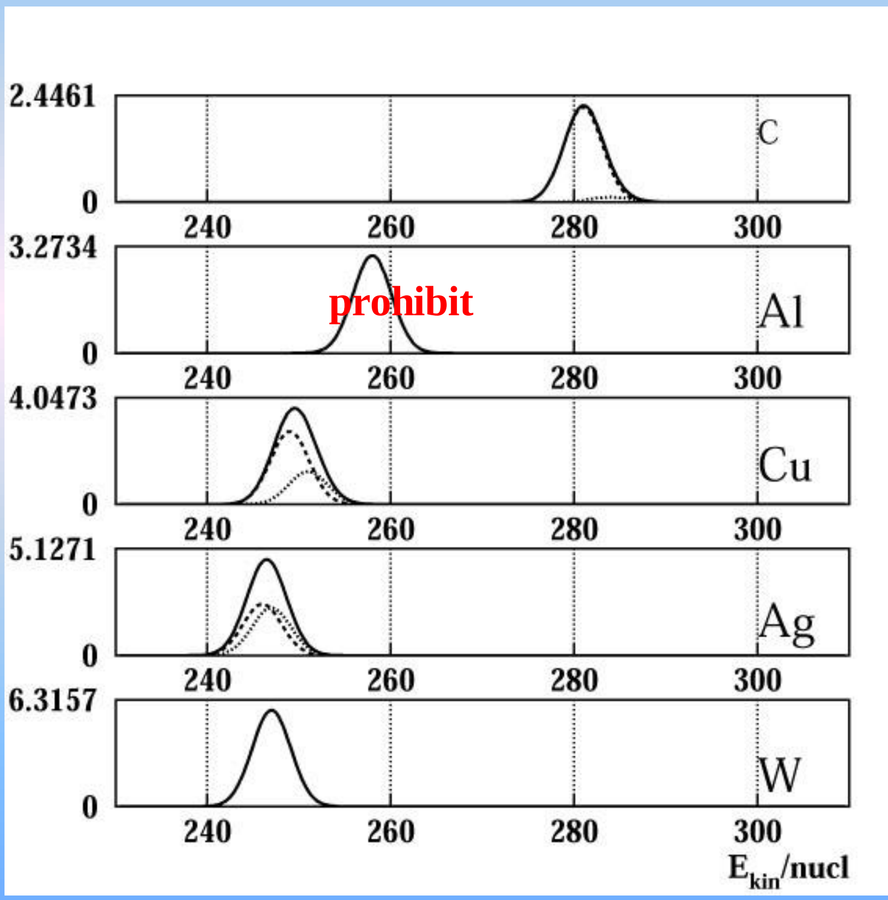
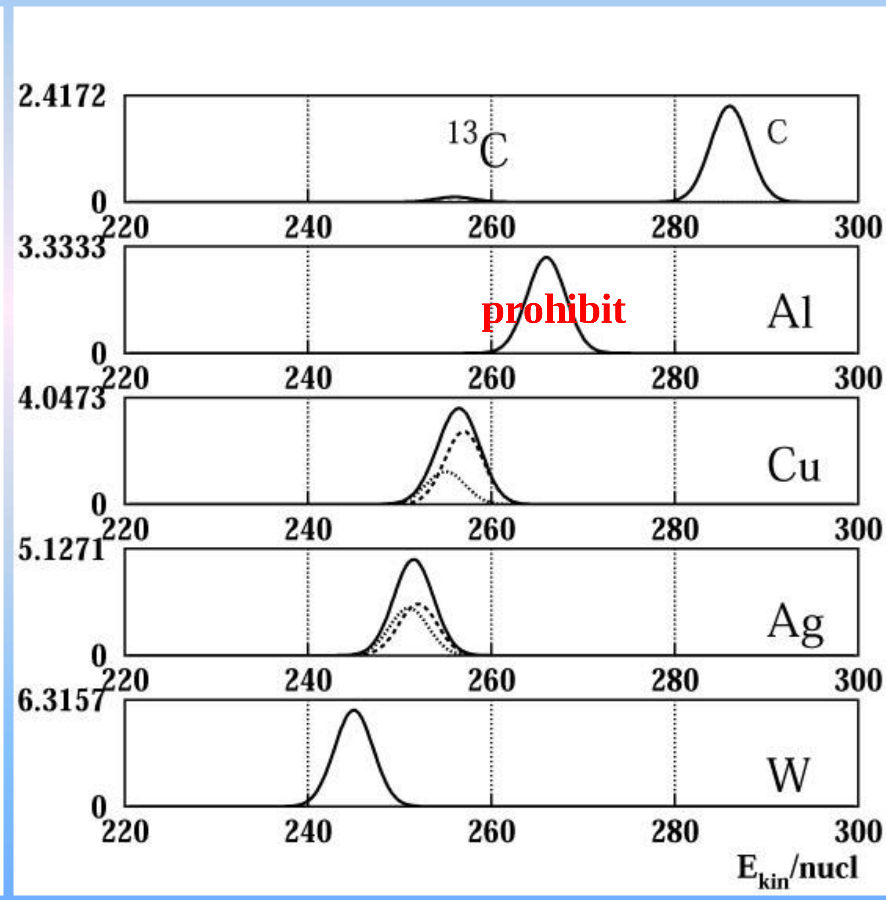
$d+A \rightarrow {}^3He+ \pi_{p=0} +(A-1)_{p=0}$

$d+A \rightarrow t+ \pi_{p=0} +(A-1)_{p=0}$





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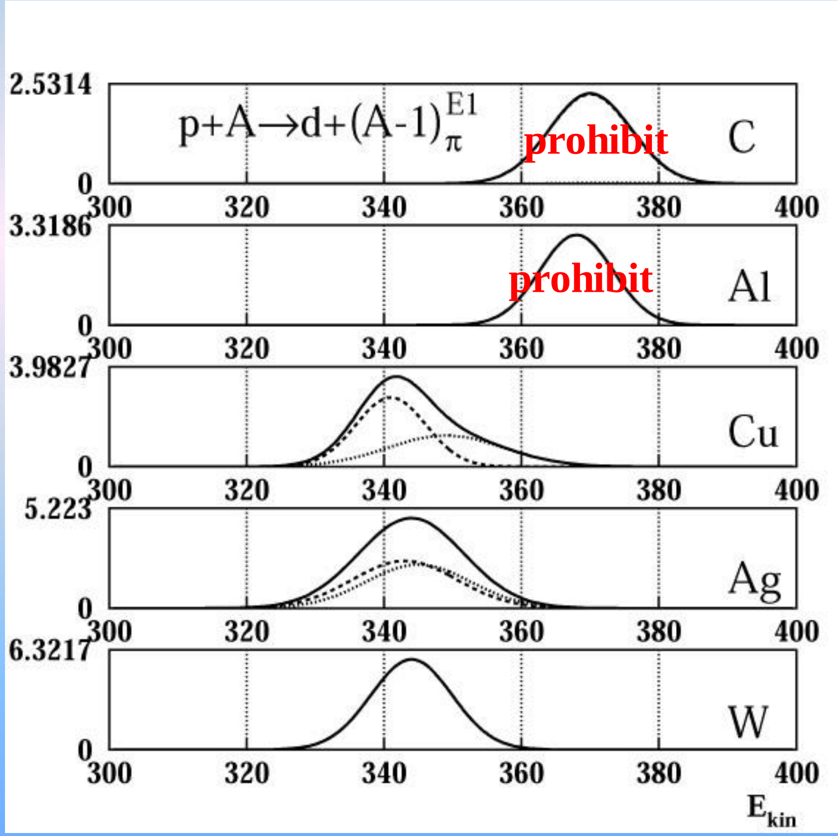
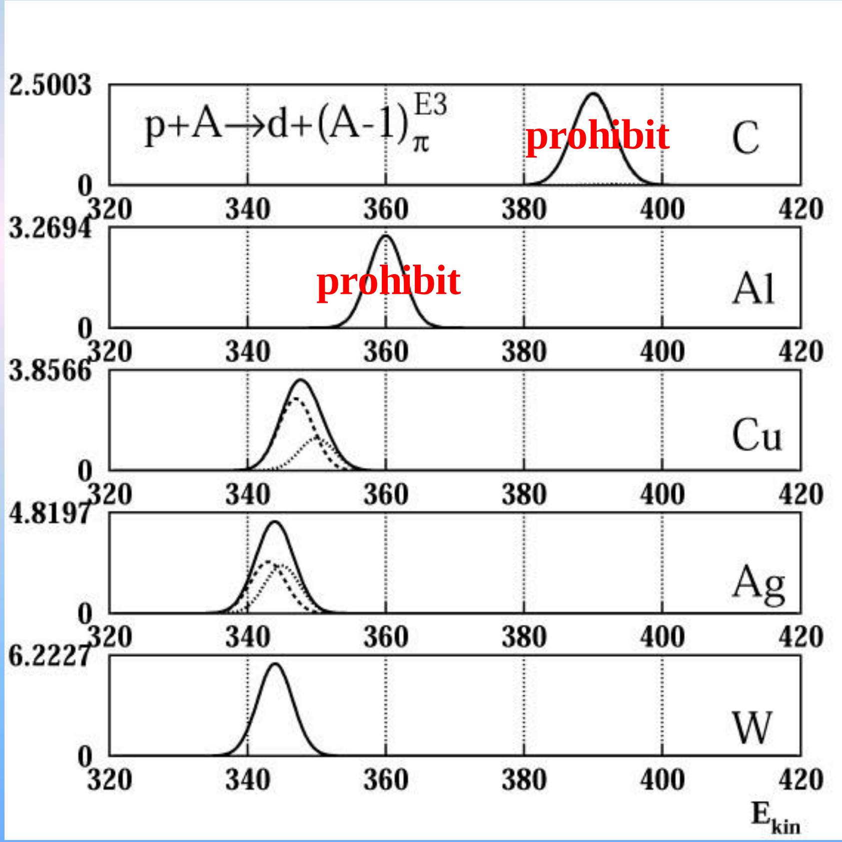
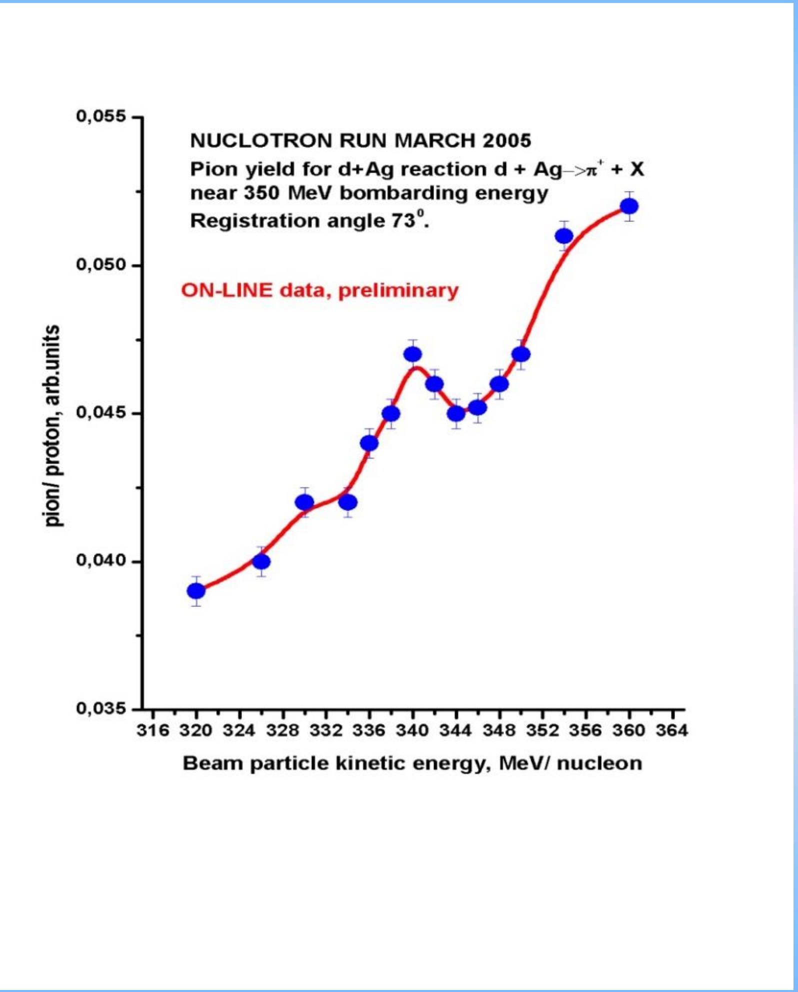
Numerical calculation

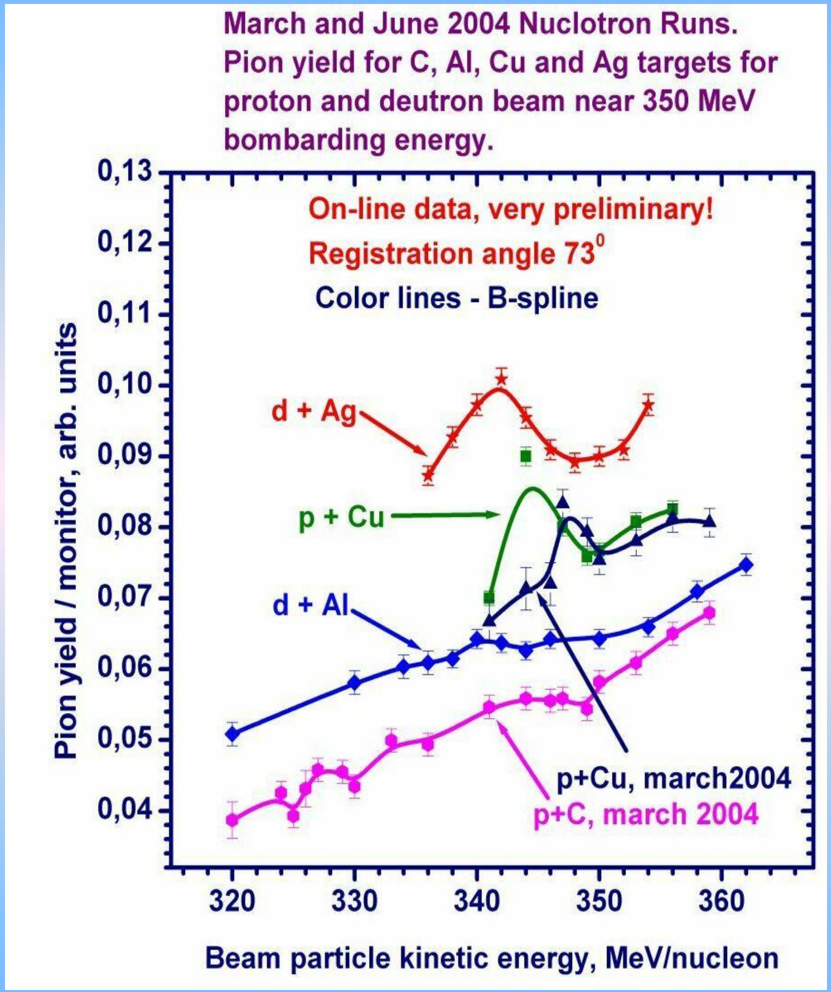
$$p+A \rightarrow d+\pi_{p=0}+(A\text{-}1)_{p=0}$$





Energy scan of pions yield for pA and dA interactions. *«DELTON» data.*





Yu.S.Anisimov, S.Gmuca, V.A.Krasnov, et. all, *XVII International Baldin Seminar on High Energy Physics Problems, Dubna, Russia, Sept.27 - Oct.2, 2004*.

Analysis of the reaction

By analyzing the reaction of the resonant formation pions we can assume that: since both reactions p+A and d+A form resonances at the same initial energies and these energies agree perfectly with the calculation for the p+A reaction, the formation of the resonance in the d+a reaction occurs at the quasi-free nucleon.

- $p+A \rightarrow d+\pi_{p=0}+(A\text{-}1)_{p=0}$
- $d+A \rightarrow d+n+\pi_{p=0}+(A\text{-}1)_{p=0}$ **or** $d+A \rightarrow d+p+\pi_{p=0}+(A\text{-}1)_{p=0}$

Consequently, it can be assumed that the resonance capture of the ETA-meson will take place in the same reactions.

- $p+A \rightarrow d+\eta_{p=0}+(A\text{-}1)_{p=0}$
- $d+A \rightarrow d+n+\eta_{p=0}+(A\text{-}1)_{p=0}$ **or** $d+A \rightarrow d+p+\eta_{p=0}+(A\text{-}1)_{p=0}$

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Conclusions

- It is necessary to take into account the collective excitation of the nucleus choosing the reaction of the formation of ETA-nuclei .
- The laws of conservation help to fix the meson in the nuclei.
- Reaction $p+A \to d+\eta_{p=0}+(A\text{-}1)_{p=0}$ $\left(d+A \to d+N+\eta_{p=0}+(A\text{-}1)_{p=0}\right)$ more prefer for study.
- Reaction $p+A \to d+\pi_{p=0}+(A\text{-}1)_{p=0}$ for meson nuclei formation may be used for test.

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