

NUCLEAR PHYSICS IN CROATIA AND NIKOLA

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In 1932 J. Chadwick discovered the neutron and during next several years it was established that there is a short ranged force among protons and neutrons, 100 times stronger than the electromagnetic force, and that force is spin dependent and charge independent, with small breaking. Development of accelerators facilitated studies of nuclear reactions and neutron induced process opened the nuclear era. Many great physicists contributed: Heisenberg, N. Bohr, Wigner, Bethe, Peierls, Fermi, Cockcroft, Walton, Lawrence. **One can conclude that NUCLEAR PHYSICS was born in the 1930ties.**

This year we celebrate the 300th anniversary of the birth of Ruđer J. Bošković (1711-1787) - author of the universal force, which represent - to some extent - forces responsible for the structure of matter. Bošković was highly regarded by J.J. Thompson and Maxwell and Leon Lederman ranks Bošković among Newton, Faraday and Planck. Though Croatia had several outstanding scientists in the late 19th century: A. Mohorovičić and D. Gorjanović-Kramberger, and though Physics Department was established at the University of Zagreb in late 19th century, there was no research in nuclear physics until late 1950ties. In 1950 Ivan Supek founded the Ruđer Bošković Institute (RBI).

Institute was first conceived as the theoretical physics institute, but its founders (Supek, Paić, Grdenić et al) soon realized that it should include experimental physics, chemistry, electronics and biomedicine. Therefore, Supek sent several of his students from University of Zagreb abroad to get their PhDs, to Birmingham [Ilakovac, Knapp and Petravić], to Rochester [Šlaus] and MIT [Cindro].

Beginning of nuclear physics in Croatia is linked with five of us. We were all born around the time that nuclear physics was born. When I speak about Nikola, about his role in building this edifice of nuclear research in our country, I inevitably speak from a very personal viewpoint. Throughout all this period from 1950 to now, though our research focused on different area - and I never worked in heavy-ion physics which is the topic of this symposium - we, particularly Nikola and I were strongly interconnected. My talk is not an objective presentation of Nikola's contribution to nuclear physics research. Nor it is complete. It is definitely inadequate in heavy-ion physics. It is more a description of our lives together through 50 years - sprinkled by joy of research, by fun playing waterpolo in a small pond and badminton, frustration of lack of funds and bureaucratic impediments, by our own achievements and failures. I am aware that it is as if I were present in Nikola's life, but I was, as he was in mine.

In 1957 M. Paić and his collaborators built the CW 200 keV accelerator and produced 2 MeV neutron using the reaction ${}^2\text{H}(d,n){}^3\text{He}$. Three years later 14 MeV neutrons were produced using ${}^3\text{H}(d,n){}^4\text{He}$. Detection system, amplifiers and multichannel, multi-dimensional analyzers were developed by Kuo et al, Souček et al, and Radeka et al.

Though Ilakovac, Knapp, Petravić, Šlaus and Cindro published their research done abroad as early as 1956, **the first publication on research done in Zagreb** is:

N. Cindro, I. Šlaus, P. Tomaš, B. Eman: The ${}^{16}\text{O}(n,\alpha){}^{13}\text{C}$ Reaction by the Thin Crystal Method, Nucl. Phys. **22** (1961) 96-100.

Nikola Cindro was born Aug 31, 1931, Split. Though both born in Split in the same year (less than a month apart) Nikola and I met when we enrolled as students at the University of Zagreb in 1950 and from then on, we were in many ways inseparable: friends, colleagues, competitors, as we called each other “my favorite enemy”. We studied in our cold, small rented rooms, became assistants to Prof. V. Glaser in 1953 and then graduated in October 1954 - Nikola in applied math and I in theoretical physics, but both having the same mentor Ivan Supek and the same subject: Bohr-Mottelson model. We did some calculation resulting in our first conference paper at the Natural Scientists of Yugoslavia Congress (Zagreb, 1954).

Nikola and I shared our first office in 1954 in the first building of the RBI, and then moved to another office and finally in 1962 to two nearby offices - office that I still use today. Supek sent me to University of Rochester (1956) and one year later (since he was drafted to go to military service) Nikola to MIT to get our PhDs in experimental physics. Though at two different universities, our PhD theses dealt with the same problem: optical model applied to elastic scattering of deuterons (albeit, different incident energies and different nuclei). Both of us did our research abroad and both got our PhDs at the University of Zagreb.

At RBI we had only 14 MeV neutrons and we started research in nuclear reaction mechanisms, nuclear spectroscopy and nuclear forces. Though our first paper (1961) was a joint paper, we soon formed two groups and both groups became internationally recognized as Zagreb schools. Several young physicists joined our groups and the list of those who got their Ph.D. under Nikola’s mentorship is long starting with Petar Kulišić. Nikola was the first among us who published the review article:

N. Cindro, A survey of fast-neutron reactions, *Rev. Mod. Phys.* **38** (1966) 391

Nikola extended his research from neutron physics to heavy-ions and from what is now called low energy to intermediate energy. Numerous papers present his activity and a good example is his review paper:

N. Cindro, Resonances and nuclear molecular configurations in heavy-ion reactions, *Ann. Phys.* **13** (1988) 289.

Nikola organized several international conferences and summers schools, and was invited to give several invited talks at international conferences.

RBI became internationally well-known in early 60ties primarily based on research in nuclear physics, that extended to nuclear chemistry, nuclear instrumentation and nuclear medicine. Nikola’s role is outstanding! He established excellent collaborations with CEN Saclay, CE Bruyères-le-Châtel, Los Alamos National Laboratory, Oak Ridge National Laboratory, NCSR Demokritos, CNR Strasbourg, GSI Darmstadt and nuclear physics centers in Italy Legnaro and Catania.

Nikola’s activities extend beyond initiating and developing nuclear physics research in Croatia.

- 1) Electro-engineering faculty in Split formed its Physics Section and Nikola was one of the first lecturers, later professor. Today, University of Split is an excellent center of the high-energy physics, and roots certainly go to Nikola. Nikola was also professor at the Technical faculty of the University of Zagreb. He wrote the first textbook for students at faculty of engineering in Croatian language.
- 2) Postgraduate studies in Croatia started at RBI in 1957 and Nikola was among the first lecturers/professors from 1960 till 2000/2001.

- 3) The European Physical Society (EPS) was established in 1969 (inaugural conference in Florence) and RBI became one of the first institutional member (CERN was another) and Nikola was delegated as RBI representative to the EPS Council. Later he was elected Executive Committee member and in 1973 he was elected Vice-president of the EPS.
- 4) In early 1980ties subscriptions to scientific journals were practically terminated. Through our membership in EPS and APS some of us continued to have access to scientific literature and we initiated a weekly news "Selected for you", and Nikola was one of the leading persons in our Editorial Board. These news were later distributed to all scientists in Croatia.
- 5) Nikola's family are Croatian aristocracy mentioned already in the 13th century. He was very proud of that, often telling me about his ancestors leading the defense of Klis (fortress town close to Split), his family tree and coat of arm displayed at the entrance of his family estate at the outskirts of Split. In early 1990ties he was one of the founders of the Croatian aristocracy association.

Nikola always emphasized social responsibility of scientists as demonstrated by these and many other Nikola's activities (he was engaged in university professors' and researchers' trade union in the late 1960ties and 1970ties and he liked to speak about his time in Paris during the 1968).

His presence in our physics research, in RBI and his impact in our community is constantly present.

Krapinske Toplice, 18th of September 2011

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