My memories about Lénárd Pál and our collaboration

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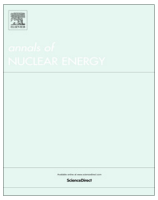

Author's foreword to "My memories about Lénárd Pál and our collaboration"

The following article is an English translation of a contribution I wrote about our collaboration with L. Pál for the journal "Fizikai Szemle" (Physical Review) of the Hungarian Physical Society (Pázsit, 2015). It was published in 2015, on the occasion of Lénárd Pál's 90th birthday. Its English translation is published here with permission from the Editor of Fizikai Szemle.

I have to add that since the paper was originally written to the Hungarian scientific community, in some formulations one can sense that the author assumed that the readers are familiar with certain persons or events, but which may not be similarly obvious to foreign readers. Efforts were taken to slightly revise such occurrences in the text, but since I also wanted to preserve the spirit of the original writing, many such pieces may have left unchanged. I hope the readers will have an understanding for this.

Reference

Pázsit, Imre, 2015. To work together with Lénárd Pál (In Hungarian: Együtt dolgozni Pál Lénárddal). Fizikai Szemle 55 (11), 367–371.

Imre Pázsit

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My memories about Lénárd Pál and our collaboration

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I have known Lénárd Pál since my days as a university student, but we started working together only several decades later. At the university he lectured kinetic theory for the physics students, but since he was not affiliated to the university, rather to the Central Research Institute for Physics (Hungarian acronym: KFKI), we did not have a possibility to meet him spontaneously, as we did with the other lecturers. On the other hand, after graduation, I have got into contact with him directly and indirectly in many ways, and this influenced my career significantly.

I started my PhD studies in 1972 in KFKI, at the Department of Reactor Physics in the Atomic Energy Research Institute (one of the four divisions of KFKI). My advisor was George Kosály (who later left Hungary and became a professor at the University of Washington). In turn, George himself had been a PhD student of Lénárd, even if in another subject (solid state physics). In this way, I got immediately an indirect contact with and some knowledge about Lénárd; George had an uncountable number of stories and memories from his own time as his PhD student.

During the time of my PhD, I met Lénárd only once, when he, in his capacity as the Director of KFKI, visited the Department of Reactor Physics. It was his habit to visit each room and talk with everyone about the current work they were doing. With my room-mate and fellow PhD student László Meskó, who sadly passed away too early, we were surprised how much Lénárd was familiar with our PhD subjects. I even remember a useful piece of advice he gave me in connection with my subject, of which I had good use later on.

The first more significant contact came about in 1975, on the occasion of my PhD defense, and this was due to my own adviser, George Kosály. At that time in Hungary nuclear engineering, and in particular the special branch of it which constituted my PhD topic, namely neutron noise-based power reactor diagnostics, was not an independent discipline. Hence the subject of my PhD exam (one had to pass an exam in two physics topics, one of them from the area of the PhD work) became nuclear physics, with the reasoning that this was the closest area, even if my thesis did not contain any nuclear physics at all. Therefore the choice of the examiners, and in particular that of the chairman of the committee, who would decide the subject of the exam, was very important. George managed to arrange that Lénárd, the founder and internationally acclaimed leading scientist of neutron fluctuations (branching processes) in multiplying media, became the chairman.

This solution had the huge advantage that instead of pure nuclear physics, the main topic of the exam was concentrated to reactor and neutron physics, as well as to random processes in nuclear reactors. On the other hand, this came at the "price" that I had to prepare myself very carefully from Lénárd's pioneering works, with which he laid the foundation of the branching processes in nuclear reactors. But this was a price well worth to pay, of which I have had enormous advantages in the continuation, and which also laid the grounds of our productive and enjoyable collaboration several decades later. Namely, the treatment of branching processes with master equations, which previously was used for the determination of the reactivity in low power reactors ("zero power reactor noise", where the term "zero" refers to low power), had a huge upswing in the past few decades. It played a dominant role both in the development of reactivity determination methods in accelerator driven subcritical systems (ADS), as well as in the development of passive non-intrusive methods for identifying and quantifying fissile material from the statistics of the detection of neutrons and gamma photons for safeguards purposes.

Figure 1. Lénárd Pál's first measurement in magnetics in the KFKI, after his return to Budapest from the Lomonosov University in Moscow in 1953.

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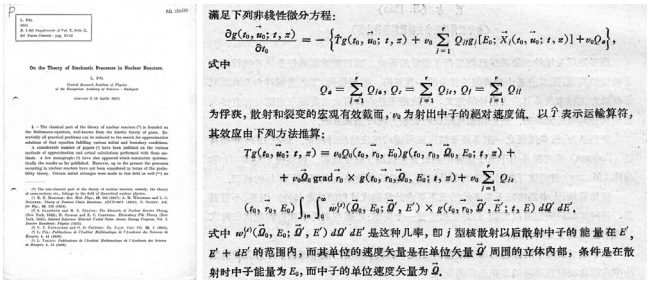
At the time of my PhD exam in 1975 I was still only a passive observer and interpreter of this area. One step towards the more active contributions was when the Solid State Physics Division of the Hungarian Physical Society organised an autumn school at Mátrafüred on stochastic processes and their applications. From my department at KFKI, one of our leading researchers, Zoltán Szatmáry was invited to give a talk. Due to another commitment he could not attend the meeting, and so he passed on the invitation to me, which I gladly accepted. At the meeting I simply presented the basic theory of stochastic neutron transport, based on Lénárd's work. One year later, a "Physics Study Circle" School was organised in Dunaújváros, where I gave a similar contribution, and the lectures given at the School were published in form of lecture notes. By this I got my first publication in the field, even if it was not about my own research results.

My first publication in the field of branching processes came in 1980. It was the result of a joint work with Mike Williams, who was my host during an 11-months IAEA fellowship in 1979 at QMC London. It was not within traditional reactor physics, rather about the statistics of radiation damage induced by atomic collision cascades. From that time, I worked sporadically with the application of branching processes to atomic collisions. However, the main emphasis of my work was on a different type of neutron fluctuations, namely neutron noise in high power reactors. This type of neutron noise is given rise by the space- and time-dependent fluctuations of the reactor material (such as vibration of control rods, two-phase flow etc.), and the objective of the work is to diagnose these processes from the induced neutron noise ("power reactor neutron noise diagnostics").

The decisive event which led to the start of my collaboration with Lénárd was my participation in the 25th International Meeting on Reactor Noise (IMORN) in 1994. The IMORN series (originally called Informal Meeting on Reactor Noise) was of European origin and held annually in Europe, and I had been a regular attendee since 1977. At the beginning the meetings concerned mostly the theory of zero power reactor noise and its applications, but during the years the emphasis was shifted to power reactor noise diagnostics. The IMORN in 1994 was a "jubilee" meeting, the 25th of the series, which the first (and only) time was held outside Europe, at the NCSU in Raleigh, North Carolina. To emphasise the anniversary character of the meeting, the organisers arranged a special "nostalgia" session, endorsing the participants that whoever had an interesting story, anecdote, a memorable event to tell, related to the history of the IMORN series, or about the research field, should give an informal contribution. At that point I felt that it would be worth mentioning some internationally known Hungarian achievements, starting with the works of the late Lajos Jánossy (on the theory of fluctuations in cosmic electron-photon showers by the regeneration point technique), through the seminal work of Lénárd Pál on neutron fluctuations (the famous "Pál-Bell equation), to the results of George Kosály in power reactor diagnostics (the existence and the role of the local component of neutron noise in boiling water reactors). Naturally, I could not help bragging with the fact that at my PhD defence I had Lénárd Pál himself as the Chair of my PhD committee; and moreover, as to enhance the "exotic" flavour of the topic, I showed some of the original works of Lénárd, which were published in the Hungarian periodical Acta Physica Hungarica in Russian.

The mentioning of the name and works of Lénárd, together with my personal experience and acquaintance with him, induced a frenetic response, if one may use this phrase, an unexpectedly intense interest. But it was understandable. At that time, Lénárd had already long been a "living legend" in this field, but one whom the members of the IMORN community, except the Hungarian ones, have never met personally, not even on conferences. After the session, I got a long row of questions of the type "Did you really meet this legendary person?" "How old is he?" "Is he still active?" "What does he work on currently?" and so on. One participant from the U Mass Low told me that he had read each and every line of Lénárd's all publications (he even managed to get a translation of the papers published in Russian); Lénárd's works were his "Bible". The intensity of this event appeared simply surrealistic.


On the Theory of Stochastic Processes in Nuclear Reactors.

L. Pál.

满足下列非线性微分方程：

$$\frac{\partial g(t_0,\vec{u}_0;\,t,\tau)}{\partial t_0} = -\left\{\hat{T}g(t_0,\vec{u}_0;\,t,\tau) + v_0\sum_{j=1}^{r} Q_{jH}[E_0;\,\vec{X}_j(t_0,\vec{u}_0;\,t,\tau)] + v_0 Q_a\right\},$$

式中

$$Q_a = \sum_{j=1}^{r} Q_{ja},\ Q_r = \sum_{j=1}^{r} Q_{jr},\ Q_t = \sum_{j=1}^{r} Q_{jt}$$

为俘获，散射和裂变的宏观有效截面，v_0 为射出中子的絕对速度值。以 $\hat{T}$ 表示运輸算符，其效应由下列方法推算：

$$Tg(t_0,\vec{u}_0;\,t,\tau) = v_0 Q_t(t_0,\vec{r}_0,E_0)g(t_0,\vec{r}_0,\vec{\Omega}_0,E_0;\,t,\tau) +$$
$$+ v_0\vec{\Omega}_0\,\mathrm{grad}_{\vec{r}_0}\times g(t_0,\vec{r}_0,\vec{\Omega}_0,E_0;\,t,\tau) + v_0\sum_{j=1}^{r} Q_{jt}$$
$$(t_0,\vec{r}_0,E_0)\int_{4\pi}\int_0^{\infty} w^{(j)}(\vec{\Omega}_0,E_0;\,\vec{\Omega}',E')\times g(t_0,\vec{r}_0,\vec{\Omega}',E';\,t,E)\,d\Omega'\,dE',$$

式中 $w^{(j)}(\vec{\Omega}_0,E_0;\,\vec{\Omega}',E')\,d\Omega'\,dE'$ 是这种几率，即 j 型核散射以后散射中子的能量在 E'，$E'+dE'$ 的范围内，而其单位的速度矢量是在单位矢量 $\vec{\Omega}'$ 周围的立体内部，条件是在散射时中子能量为 E_0，而中子的单位速度矢量为 $\vec{\Omega}$。

Figure 2. The first page of the seminal publication of Lénárd Pál in the Il Nuovo Cimento in 1958, and a copy of the Chinese translation of the paper, which appeared a few months later, without the knowledge of the author.

It was then and there that the idea and the decision was born that I simply must channel this overwhelmingly impressive interest and respect in both directions. On one hand, I need to make Lénárd aware of it; on the other, I must give an opportunity to the neutron noise community to meet Lénárd.

The opportunity for this appeared in 2002, when my Department in Chalmers hosted the 8th (and to this date last) SMORN meeting (acronym from the original name "Specialists' Meeting on Reactor Noise"). The highlight of the conference was that we asked Lénárd to give a special invited lecture at the opening plenary session. To our thorough joy, Lénárd accepted the invitation. His daughter, Kata, accompanied him to the trip, which was a great help for Lénárd, without which the trip would not have come about, and for which we organisers were rather grateful to her. Lénárd gave a memorable talk with the title "Neutron Noise and Random Trees – Links Between Past and Present" (Pál, 2003). He told the story that, starting with his participation at the first, famous Geneva Conference on the Peaceful Uses of Atomic Energy (1955), what kind of inspirations made him to start studying the fluctuations in neutron chains. To this he had good pre-requisites, because between 1950 and 53 he listened to lectures of Kolmogorov in Moscow. During the Geneva Conference he talked about this subject with Eugene Wigner, who invited him to a dinner, and it was then he came to the conclusion that in stochastic transport, one has to use the backward form of the master equation (the Kolmogorov or Chapman-Kolmogorov equation). In the rest of his talk, Lénárd described his then current results on the study of the properties of random trees.

We continued to keep active contact after the conference, to the extent that I told Lénárd a problem which occupied me for quite some time, in the hope that it will raise his interest. This concerned the fact that the two areas of neutron noise, the theory of branching processes in low power systems (treated with master equations) and the power reactor noise (handled with the Langevin equation) constituted two completely separate areas, treated with different mathematical tools. At that time I had already long been thinking of writing a book which would embrace both of these areas of neutron fluctuations, but I felt the lack of a link between them. I was looking for a "bridge" between the two fields, a method, with which a general description of the neutron fluctuations in a system randomly varying in time, in which hence both the zero power neutron noise and the power reactor noise are simultaneously present, can be given by master equations. I felt I was already on the right track for binary fluctuating systems

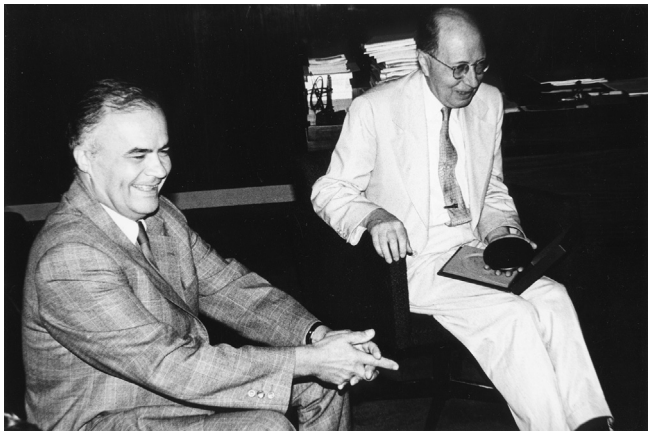


Figure 3. In the KFKI, together with Eugene P. Wigner, the 1963 Nobel Laureate in Physics (for his contributions to the theory of the atomic nucleus and the elementary particles, particularly through the discovery and application of fundamental symmetry principles).

Figure 4. L. Pál in conversation with I. M. Frank, Nobel Laureate in Physics in 1958 (for the discovery and interpretation of the Cherenkov-effect) at the Hungarian Academy of Sciences.

(jumping randomly between two states), but there were numerous questions to be clarified, including the generalisation of the method to continuous variations of the medium.

Much to my delight, Lénárd got interested in the problem. With the carefulness and attention to details, which was his trademark, he started to solve the whole problem from scratch. Due to his scrutiny, we soon realised that the path on which I was trying to progress, namely the use of the backward-type equations (which is also the basis of the Pál-Bell equation), is not applicable for media changing randomly in time. This in itself was a new insight, a kind of "symmetry breaking" if you like, which had already been observed in other Markovian branching processes but had not been realised in connection with neutron chains. After having understood the limitations of the backward approach, we solved the problem with the use of the forward master equation formalism (Pál and Pázsit 2006, 2007).

After that I felt that the scene was set for the writing of the planned noise book. Since at that point we had already been working for quite some time together, it was a natural thing to ask Lénárd what he thought of writing a book together? Of course, I asked him, but before I tell his answer, I have to tell an anecdote.

The anecdote is one out of the uncountable stories which are circulating about the "Martians", i.e. those legendary physicists of Hungarian origin, born at the beginning of the previous century. In the present case it is about Eugene Wigner. Unfortunately, I cannot give the source where I read about it or tell from who the story is originated. Allegedly, a younger colleague of Wigner said this once: "This Wigner is a terrible bloke. If one gets a new idea, works a lot on it, and then wants to get his opinion about it, then Wigner, after having listened to the problem, says after some time of thinking: »Yes, this is indeed an interesting problem, I too have thought of it«. And then he opens a drawer, and takes out a note, which describes the complete and perfect solution of the problem".

Irrespective of whether or not the story about Wigner is true, I can attest to it that one easily gets a similar impression with Lénárd. It is difficult to tell him any matter in this field which he would not recognise, or even had dealt with. Usually, he would immediately list the most relevant major articles and books in the field. In my concrete case, when I asked if he felt like writing a book on neutron fluctuations, his immediate reply was "I have already written that book". And, even if he did not take out a note from his drawer, he opened a file on his PC, in which the complete theory of zero power noise was described with full mathematical rigour. Although it was written in Hungarian, and dealt only with the theory of branching processes, but otherwise in a form nearly suitable to be sent to the printers.

We saw it immediately that one very easily could append to this material all those developments of the method regarding concrete applications with which I was working in the preceding years, notably reactivity measurements in accelerator driven subcritical systems, as well as applications in nuclear safeguards. It was also immediately clear that this combined material was fully enough for a complete book, hence the theory and application of power reactor noise would not fit in either subject-wise or what regards the volume of the book, despite that the long-sought link between the two fields, i.e. the master equation treatment of the neutron fluctuations in a time-varying medium, was already available. This latter though fit in thematically and got indeed included in form of a separate chapter. The book would consist of two parts, the theoretical foundations and the concrete applications. What remained was to translate the first part to English, write up the second part, and of course to find a publisher and negotiate the acceptance of the book for publication.

In the translation of Lénárd's note to English we received indispensable help from my wife Maria. It was also logical that, in view of my advisory editorial board membership at Annals of Nuclear Energy, the negotiations with the selected publisher, Elsevier, fell on me.

For a book proposal to be submitted, one had to supply various types of information, including a synopsis, title, list of authors etc. Regarding the order of the authors, this was completely obvious to me. Not only because of the alphabetic order, but also regarding the significance and the quality of the contributions, including the international standing of the authors in the trade, I could not possibly imagine any other order than Pál – Pázsit. This is how I sent the first draft of the book proposal to Lénárd.

The response came immediately "with return of post" (naturally by e-mail): "Dear Imre, please change the order of the authors immediately. This is your book, your idea, not to mention that meriting aspects are not relevant to me any longer. It is you who will have to deal with the publisher, read the proofs etc. Everything points to the fact that you should be the first author". And on that point he would not yield, whatever hard I tried.

This reminds me to another story. Weisskopf describes quite enthusiastically an episode in his book, on the occasion that he managed to publish an article with E. Wigner, in which the authors were listed in alphabetic order, so he was the first author: "show me one more lucky person, whose last name begins with "W",

Figure 5. L. Pál in conversation with János Szent ágothai (President of the Hungarian Academy of Sciences) and A. M. Prokhorov (Nobel Prize in Physics in 1964, for fundamental work in the field of quantum electronics, which has led to the construction of oscillators and amplifiers based on the maser-laser principle).

and yet becomes the first author in a paper, in which he has a Nobel laureate as a co-author!". Then, what should I say, having a co-author of Lénárd Pál's calibre, becoming the first author, despite the alphabetic order, and not even in a paper, but on a book (Pázsit and Pál, 2008)??

Working on the book brought up another memory. My own PhD advisor in KFKI, George Kosály who passed away in 2009, had many anecdotes from his own PhD study time with Lénárd as advisor. One of these stories goes like this: "At the beginning of my PhD studies, I got a seemingly simple task from Lénárd, which he had already solved. Thus, this was just an exercise, since I even got his solution. I sat down immediately to solve the problem, but much to my surprise, I got a different result. I went through the calculations again, but I got exactly the same result. I checked it a number of more times, and I always received unmistakably the same result, which did not agree with Lénárd's. I could not delay more with my reply, even if it was very embarrassing to tell Lénárd that he was wrong, but in the end, I had to go to his office to show him my result. You should have seen that enormous interest which

Figure 6. Talking with Piotr Kapitsa, Nobel Laurete in Physics in 1978 (for his basic inventions and discoveries in the area of low-temperature physics), in the KFKI.

shone up on his face, when he said: let us see where you made the error!"

This anecdote, whose message can be interpreted in various ways, often came up to me when I started working with Lénárd. Because, whatever the anecdote may suggest, I had to realise the fact that Lénárd is a person who de facto never makes a mistake, or at most with a frequency, which would be tolerated even in the safety design of nuclear reactors. Our book serves as an example of this. After the publication of the book, we noticed numerous misprints and typos in the part which I wrote, but in the part which arises from the original script of Lénárd, practically none.

With the publication of the book, our joint work has naturally did not end at all, rather it has continued uninterrupted. There is constantly an actual problem on which we work together, and the absolute highlight of every trip to my home town Budapest is the couple of days I spend with Lénárd, in order to finish up the writing of the currently actual paper. And the problems we work on are not "hobby activities for retired persons", since we were lucky to be able to identify and solve a number of interesting and basic problems in the field. We managed to identify and correct a basic flaw in the generally cited and referred derivation of the non-destructive passive methods of multiplicity counting in nuclear safeguards (Pázsit et al., 2009). We extended a couple of methods, previously derived to energy-independent cases, to two energy groups. Based on previous work of Lénárd, stored in notes, we published two extensive review articles (the statistical theory of slowing down of neutrons (Pál and Pázsit, 2010), and the statistical treatment of detector dead time (Pál and Pázsit, 2012)), containing even some new and previously unpublished results. Our latest work is related to the fact that in the statistical theory of the continuous current of fission chambers ("Campbelling techniques"), from the beginnings up to date, the treatment is based on the assumption that the detection events are independent and follow a simple Poisson process. In a multiplying medium this assumption is not true, and its use incurs that valuable information on the system is lost. Quite recently we solved the generalisation of the statistical theory of fission chamber signals for the case of non-independent (correlated) incoming events (detections), which opens completely new application possibilities in both safeguards and reactor diagnostic methods (Pál and Pázsit, 2015).

The above described problems can most often be handled analytically, but with rather involved derivations, which lead to extensively long formulae during the calculation of the higher order moments. In such a work the use of the symbolic manipulation codes, in our case that of Mathematica, offers substantial advantages. This leads me to a comment which does not refer strictly to research work, but one which might be still interesting. In the community of researchers working with theoretical problems, and especially above my generation, the motivation for keeping pace with all subtleties of programming and the new developments of information technology is "not unlimited", so to speak. About Lénárd it suffices to say that he not only uses but handles both LaTeX and Mathematica at the level of a system programmer. Regarding the latter, I use his illustrations and figures, created with refined aesthetics to our joint papers, also as good examples to my PhD students. And this is not all. The most stable fix point of each week is when we have our Thursday morning skype call. For sure, Lénárd is completely up-to-date with all developments of computing, text processing and information technology.

It is my hope that in this small piece I managed to lend some insight into the mood of our collaboration, and to how productive and pleasing it is. I wish we can continue our joint work in this spirit and with this productivity for a long time to come, to the joy of both of us. Happy 90th birthday, Lénárd!

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