CONCLUDING REMARKS*

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These "concluding remarks" should have been made by somebody else - namely by John Rekstad. Unfortunately he could not come. Imagine: I'd planned to come to Zakopane to enjoy *the beautiful weather* here and to occasionally listen to a talk. And then I got that e-mail from Rafał Broda. *And he uses this argument*: "You know better than anybody else what it means when an important speaker cancels his engagement at the last moment". **Well**, indeed, I have gone through such a miserable experience a few times, so I was kind of **soft**.

Not a summary, just some impressions, some **concluding remarks**, says Rafał reassuringly. *Oh, well!...*

I agreed. Now I try to be a good pupil of this School. The first question then is: what did I learn? What was I supposed to learn as a good student?

The clue is contained in the title page: TRENDS ... So the answer is: I should have learnt what are **the trends in nuclear physics!**

So I listen to the talks and study the program and the first thing I notice is that *these nuclear physicists like their experimental toys* very much, but they apparently are rather timid in doing the *theory*.

There were 26 lectures presenting the experimental nuclear physics and only three on the theory (or four if we include the rather special case of the wave packets of Rozmej). The ratio of the seminars is similar or even worse.

Conclusion: Shortage of theoreticians!

If this is a trend then I dare say this is an unfortunate one.

I also notice a correlation: all the names of the lecturers on nuclear theory end with -ski or -cki (Świątecki, Sobiczewski, Dobaczewski). In the case of the seminar speakers there were some exceptions to this rule (like Jensen, Kirchner), but in general the rule holds (Błocki, Pomorski, Magierski,...).

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After having listened to more talks I decided that the main trend in nuclear physics is

Sharpen your tools, guys!

At least this seems to have been the motto - explicit or implicit - of more than half of the presentations. So let's have a quick look at some of these tools.

One of the *main tools of nuclear physics* since the very early days has been **the SHELL MODEL.**
It is remarkable how considerable has the effort of our community been and still is to look for improvements of this tool. Lately, this effort has been stimulated by another trend — to study the nuclei *FAR-OFF the STABILITY.*

The shell model is one of the tools to provide a guidance in this venture. Thus, we witness a very large experimental effort to provide data on nuclei in vicinity of the doubly magic nuclei, those not yet reached or difficult to reach, like ^{100}Sn, ^{132}Sn or ^{56}Ni, as well as the familiar ^{208}Pb.
A large body of first class work related to this quest have been presented here.

There are other *tools.* I group them together in the list below. I'll give extra comments to some of them.

SHARPEN YOUR TOOLS

• Shell model	*C.T.Zhang* (^{132}Sn), *K.H.Maier* (^{100}Sn) also seminars: *J. Kownacki, M. Górska M. Palacz, ...*
• Big Ge arrays + ancillary detectors	*D. Bazacco* (Euroball) *R. Diamond* (Gammasphere)
• Reactions to produce n-rich nuclei	*I.Y. Lee* (Deep inelastic collisions) *W.R. Phillips* (Fission)
• Charge particle emission	*G. Viesti*
• Radioactive beams	*M. Pfützner*
• Ion traps	*H.-J. Kluge*
• Recoil-gated α-tagged γ-rays study of n-rich nuclei	*R. Julin*
• Special techniques: quadrupole moments with level mixing method	*Leuven group*

The BIG ARRAYS. This is a trend in itself. The impressive potential of these devices has been nicely discussed here, as well as were examples of the present output. On the other hand, the *motivations* have seldom been mentioned and if so then in retrospect rather than in terms of the *new physics*. I have no doubts that such physics ought to emerge from the work with these new, very powerful tools. It is a worthy challenge to imagine what this new physics could be. At the moment I guess that SERENDIPITY is the word.

Let me come back to the TRENDS.

TRENDS IN NUCLEAR PHYSICS

- Shortage of theoreticians
- Sharpen your tools
- Nuclei far-off stability
- Fast rotation
- Bulk properties
- Dynamics of nucleus-nucleus collisions (probing the phase diagram)
- Nuclear physics for our customers:
  - astro-nuclear physics
  - solid state physics
- Big labs

The next item on my list has already been metioned: the NUCLEI FAR-OFF STABILITY. This is an important one. Several dedicated accelerators are being built under this flag, large experimental facilities are being assembled. There are two main thrusts: to extend the beta stability valey towards the superheavy elements and to climb the slopes of the valey up to the drip lines.

We have learnt from Adam Sobiczewski that there is an extended superheavy peninsula (not an island!) and that it exists solely thanks to the shell effects. Moreover, these (deformed) shell efects and the spontaneous fission mechanism are now so well under control that the fission lifetimes for nuclei in the peninsula can be predicted to a very impressive accuracy of about one order of magnitude. The experimenters have been coming lately with a new inhabitant of the peninsula every other month and, lo-and-behold, each time they did so Adam just said: "I told you so!"

How well can we climb the β - stability valey has been shown by Marek Pfützner. I recall two of his pretty transparencies: one is the Z vs N chart of nuclei, showing that we are now climbing the proton rich side up to the drip line, but we have a long way to go on the astrophysically important neutron rich side. From Pfützner's impressive "Collection of FRS short stories" I recall another transparency, showing the precious three events of ^{78}Ni on the experimental ΔE vs A/Z chart. While I fully agree with Pfützner when he says that "the real physics starts when we can study the properties of new nuclei, not when we just find them", still this is a very promising development.

FAST ROTATION is the next trend. The two main topics discussed here were the properties of superdeformed nuclei and the magnetic rotation. Several lectures devoted to these subjects have together made quite an extensive specialized workshop. I list these lectures below with a selection of highlights mentioned in a telegraphic style.

FAST ROTATION

1. Superdeformation
a) Identical bands
role of intruder bands (*G. de France*)
heroic (hidden symmetry), non-heroic (accidental cancellation) explanation (*T.L. Khoo*)
b) Linking transitions
at last honest spectroscopy in the second well!(*R. Diamond, T.L. Khoo*)
linkage to other problems of physics;
chaos - order - chaos - order (*T.L. Khoo*)
c) Additivity (*J. Dobaczewski*)
"charge moments calculated with respect to the doubly magic SD core of ^{152}Dy can be expressed very precisely in terms of contributions from the individual hole and particle orbitals".
2. Magnetic rotation (*R. Diamond*);
Rich new data, elegant explanation by S. Frauendorf

As an extra comment I would like to remind you the transparency extracted from the lecture of Dobaczewski on the additivity of quadrupole moments in SD bands. The illustration is for the ^{152}Dy case. I think this is very instructive.
While the studies of nuclear structure in the deformed well seem to be coming of age, the magnetic rotation is still a youngster. It was amusing to reflect that superdeformed bands have been predicted theoretically with

good precision prior to experiment while the magnetic rotation has been stumbled upon rather unexpectedly. *Serendipity* again!
BULK PROPERTIES. According to Władek Świątecki all you ever wanted to know about nuclei can be accurately calculated with a judicious use of the nuclear Thomas Fermi model. In fact it seems that all you have to do is just add the shell corrections. The masses, the radii, the fission barriers, the compressibilities, the ..., you name it. It seems, however, that there is a disquieting, unsatisfactory situation with the extrapolation of the mass formula. This has been emphasized both by Świątecki and by Kluge. Various fromulae give drastically different predictions when we go away from stability. There is an obvious need of data.
Fission, after more than 50 years of study, still holds a lot of mysteries. These have been discussed by Wozniak, Phillips, Heinz, Cub, Trzaska and others. The time scale controversy for fission of a hot system, discussed by Wozniak, was particularly intriguing.
Of the *Giant Collective Modes* there were two cases studied: the GDR vs temperature of Thoennessen and the double phonon GDR of Aumann. The former represents a nice progress in disentangling the temperature and the spin effects in GDR in hot nuclei. The latter is important conceptually. The unexpected narrow width of the double phonon bump awaits an explanation.
The DYNAMICS of NUCLEUS-NUCLEUS COLLISIONS continues to be high on the list of topics to be studied. Another name for this is "probing the phase diagram". I remind you one such diagram, shown by Pochodzalla plotting the baryon density vs temperature. As a good physician, Dr. Pochodzalla has come equipped with a nice thermometer. Mind you, our patient the nucleus is a tricky one and you never quite know not only what kind of a thermometer to use but also where to stick it. Calorimetry seems to be the answer. Could this be recommended to the human medicine as well?

The nucleus-nucleus collisions in the low energy regime were also discussed by Peter ("the latest from INDRA"), by Wozniak and K. Grotowski. Wozniak has refreshingly reminded us about the fundamental problems of physics common in fragmenting nuclei as well as in shattering dinner plates. Even chirping of the crickets and flashing of the fire-flies obey the Arhenius law, we learn. With Grotowski we have had an excursion to the exotic territory of toroidal, bubble and disc nuclei, which might conceivably be formed in some collision events.

Then J.J. Gaardhoje took us on a "faster than light" ride: the ultra-relativistic nucleus-nucleus collisions. "Non plus ultra", was the ancients'

warning for trespassers to the other world, "there's nothing beyond!". According to my school physics "ultra-violet" means "beyond violet". The ultra-relativistic thus must refer to tachyons!
Let's be more modest and talk about "extreme relativistic" instead. Whatever the terminology, it was interesting to speculate about the information on the processes in the early universe, hopefully to be inferred from the nucleus-nucleus collisions. The main difference, says Gaardhoje, is the time scale: the early universe has had lots of time, say a few μs, while the nucleus-nucleus collision happens in 10^{-23} - 10^{-22} s. I have particularly appreciated one statement of Gaardhoje: " ... don't sell the quark-gluon plasma as the main thing – there should be enough interesting (and new!) physics even without this concept!" We have to learn, however, how to ask the right questions, how to pull the needed needle out of the hay-stack when we observe a couple of thousand particles in a single nucleus-nucleus collision.
An important trend in our trade nowadays is to serve our customers. Apart from various applications of nuclear science which could be mentioned, there are important relationships with other fields of science. The most challenging one, undoubtfully, is that with astrophysics. It was inspiring to see the detailed, familiar γ-ray spectroscopy applied to the stellar objects, as presented by P. Auger, and to learn how far-reaching conclusions could be drawn from a single observation of the ^{26}Al γ-line coming from the sky.
The scope of some of these space born experiments can be illustrated with one of Auger's transparencies showing the sketch of the INTEGRAL cosmic laboratory, to be launched soon. Our "BIG ARRAYS" of the EUROBALL type look very modest in comparison.
Another big customer is the Solid State physics. One representative here was the amusing story of Takahashi about the snowbballs in superfluid He.
There are of course a number of other trends and stories to be remembered, other concluding remarks to be made. There is one **ultimate conclusion** that I want to formulate at the end:
it seems that

after all this sharpening of the tools
NUCLEAR PHYSICS is at the stage **just before**
a BIG LEAP FORWARD!

And I wish to thank the Organizers of this School for making this message clear to us in an excellent way.
Let me also use this opportunity to invite everybody to the next event in the Polish "Schools of Physics" calendar, that is to the Mazurian Lakes School in Piaski next year.