Nuclear Physics in Slovak Republic: Overview and Vision

Presented by:

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Member of Presidium of Slovak Academy of Sciences

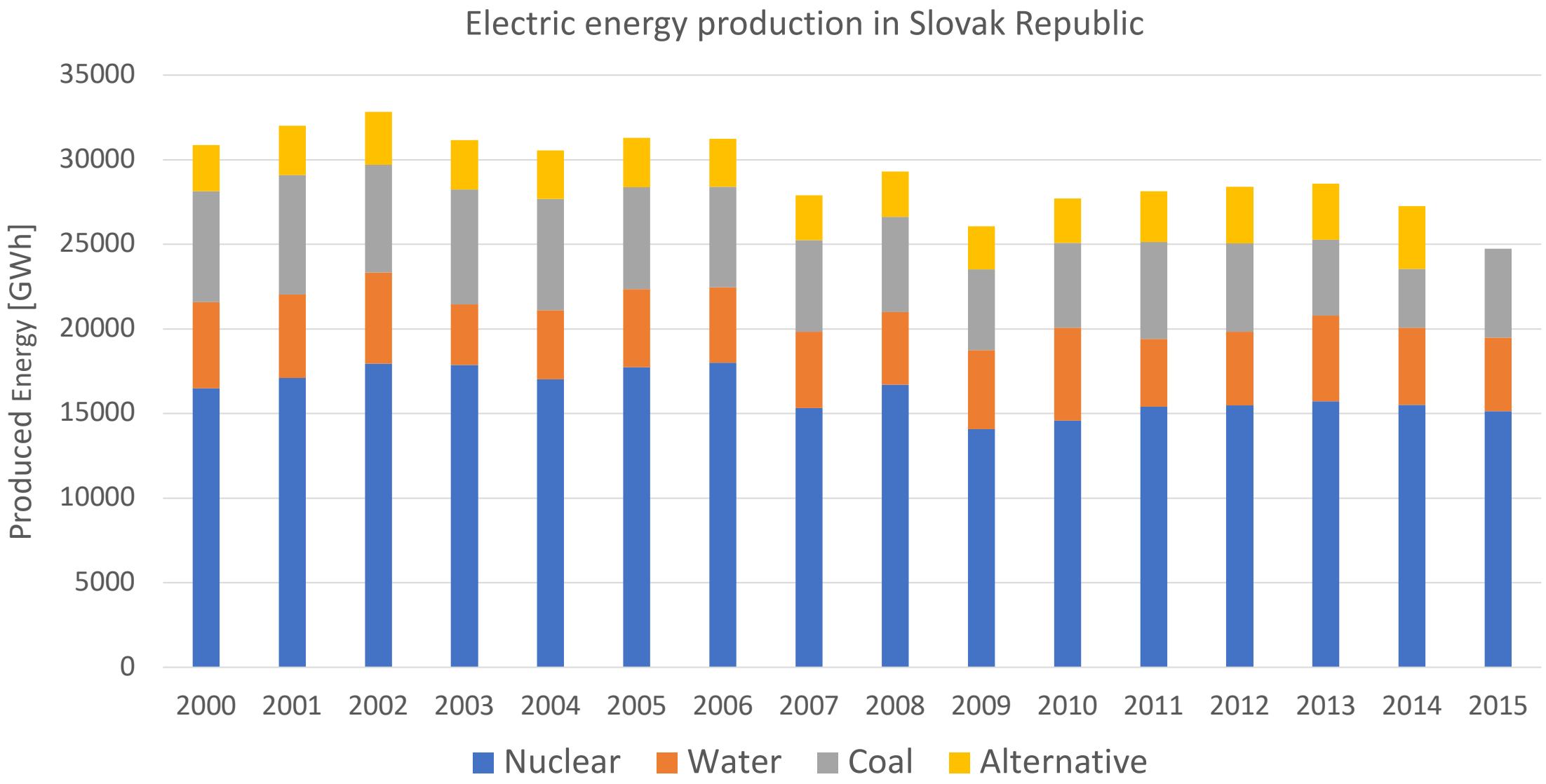
On behalf of:

Institute of Physics, Slovak Academy of Sciences

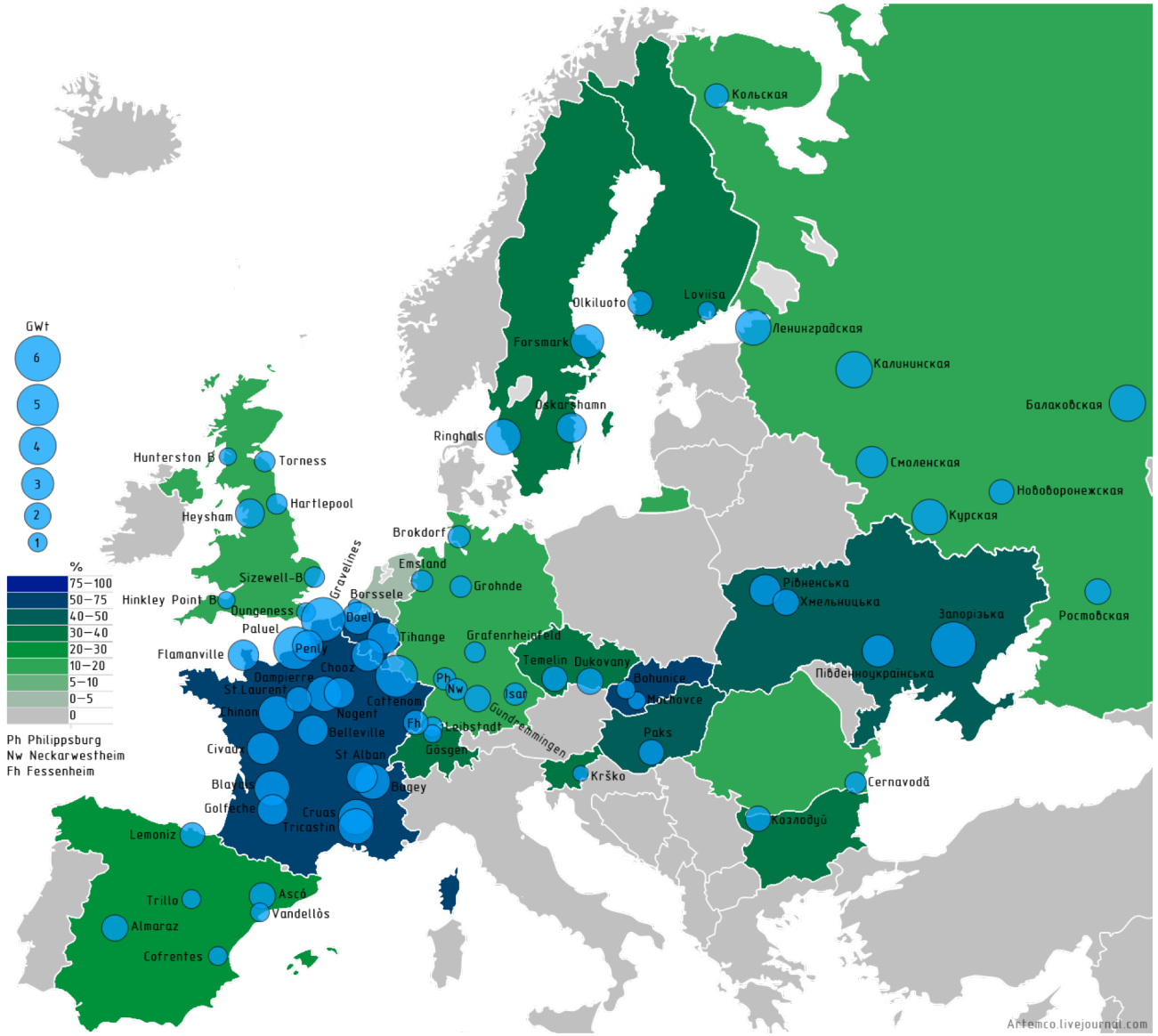
Faculty of Mathematics, Physics, and Informatics, Comenius University

Faculty of Materials Science and Technology in Trnava, Slovak University of Technology

Role of nuclear industry in Slovak republic



Role of nuclear industry in Slovak republic



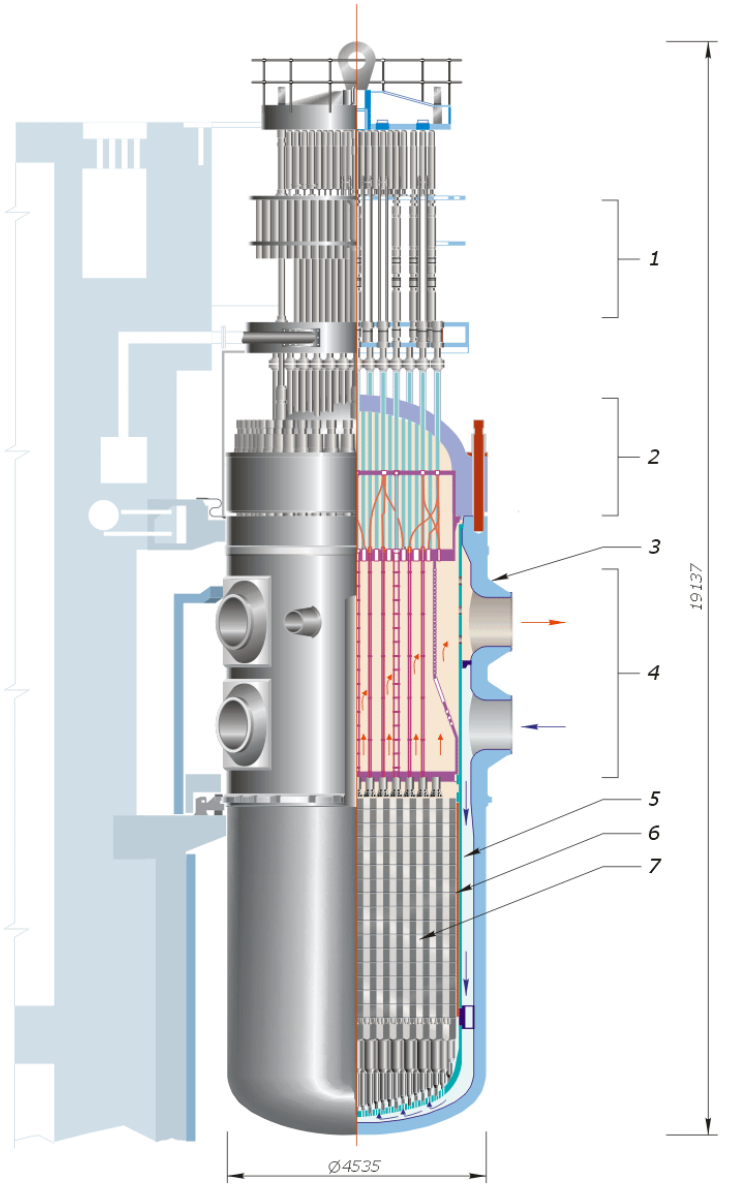
Nuclear reactors in Slovak Republic

- **Active VVER-440 pressurized-light-water reactors:**
  - 2 at Jaslovské Bohunice V2 site: 2x 505 MW
  - 2 at Mochovce site: 2x 471 MW

- **VVER-440 reactors under construction:**
  - 2 at Mochovce site

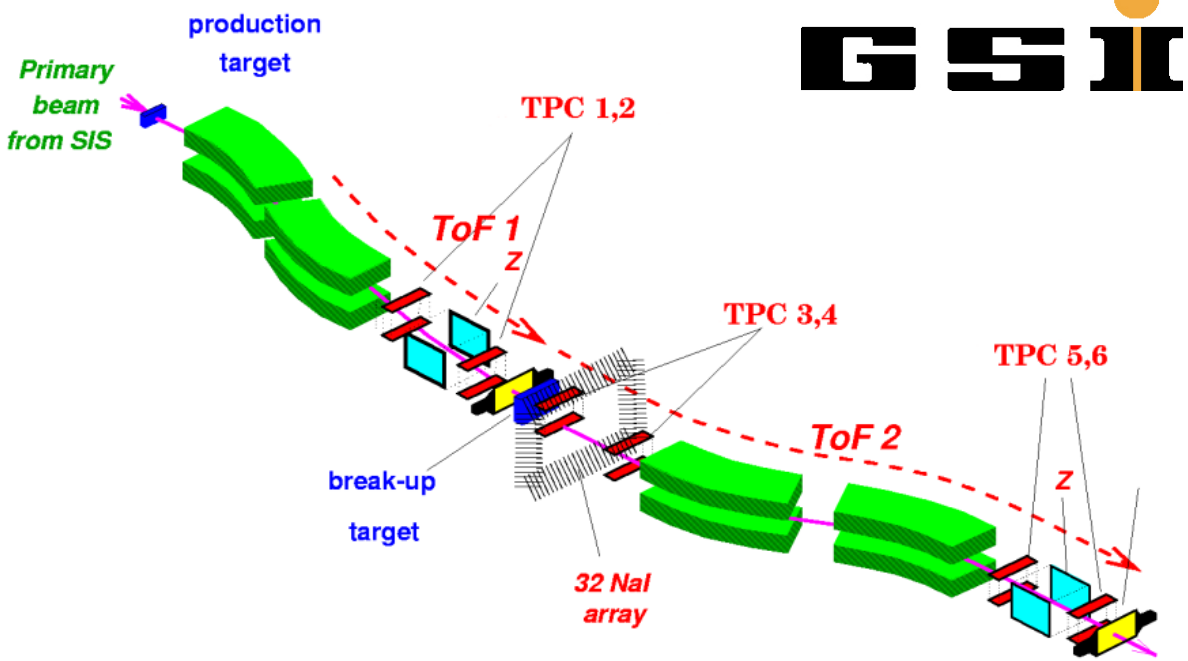
- **Decommisioned reactors:**
  - 2 VVER-440 reactors in Jaslovské Bohunice V1 (political decision)
  - A1 in Jaslovské Bohunice (CO_2-cooled, heavy-water moderated reactor:
    partial core meltodown, INES-4 rated, accident in 1977

Experimental nuclear physics research is very imporant to produce highly qualified personnel (not only) for nuclear industry



Bratislava group on Fragment Separator FRS (GSI Darmstadt)

- Faculty of Mathematics, Physics, and Informatics, Comenius University (active at FRS since 1994)
- Head of group: Branislav Sitár
- Infrastructure contribution:
  - Tracking TPC detectors on FRS
  - Development and testing a new tracking detector Twin TPC for NUSTAR collaboration at Super FRS at FAIR
- Participation on many far-from stability studies
- Personnel: 3 senior-research scientists
- Publication activity: within FRS collaboration
- Typical journals: Phys. Rev. Lett., Phys. Rev. C, Phys. Lett. B, and conference proceedings



Bratislava group on Fragment Separator FRS (GSI Darmstadt)

- A. A. Lis, *et al. incl.* **B. Sitár, P. Strmeň, I.Szarka** et al (FRS Collaboration): β-delayed three-proton decay of ^{31}Ar. Phys. Rev. C 91, 064309 (2015) p. 1-6

- I. Mukha, *et al. incl.* **B. Sitár, P. Strmeň, I.Szarka** et al (FRS Collaboration): Observation and Spectroscopy of New Proton-Unbound Isotopes ^{30}Ar and ^{29}Cl: An Interplay of Prompt Two-Proton and Sequential Decay. Phys. Rev. Lett. 115, 202501 (2015) p. 1-6

- Y. K. Tanaka, *et al. incl.* **B. Sitár, P. Strmeň, I.Szarka** et al (FRS Collaboration): First Results on Experimental Search for **η'**(958) Mesic Nuclei with the ^{12}C(p,d) **r**eaction. Acta Phys. Polon. B48 (2017) 1813-1818

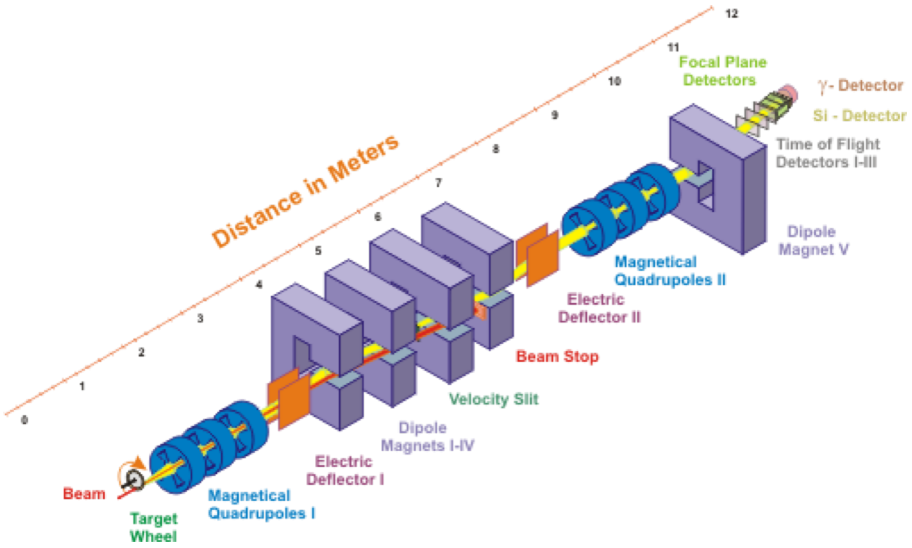
- K. Itahashi, *et al. incl.* **B. Sitár, P. Strmeň, I. Szarka** et al. (FRS Collaboration): Excitation spectra of Carbon Nuclei near η' emission threshold. J. Phys. Conf. Proc.13, 020030 (2017), p. 1-4

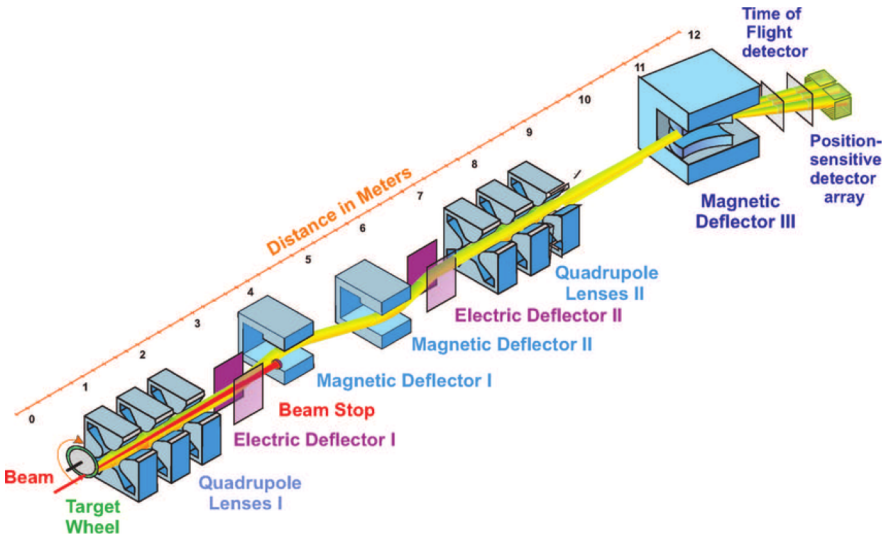
- K. Itahashi, *et al. incl.* **B. Sitár, P. Strmeň, I. Szarka** et al. (FRS Collaboration): Search for η' Mesic Nuclei in GSI/FAIR. J. Phys. Conf. Proc.17, 082008 (2017), p. 1-6

- F. Garcia, *et al. incl.* **M.Pikna, B. Sitár, P. Strmeň,** et al. Twin GEM-TPC prototype (HGB4) beam test at GSI and Jyvaskyla – a development for the Super-FRS at FAIR 2016. Proc. of IEEE Nuclear Science Symposium (NSS/MIC/RTDS), Strasbourg, France (2017) p. 1-5

Nuclear structure group at Comenius University

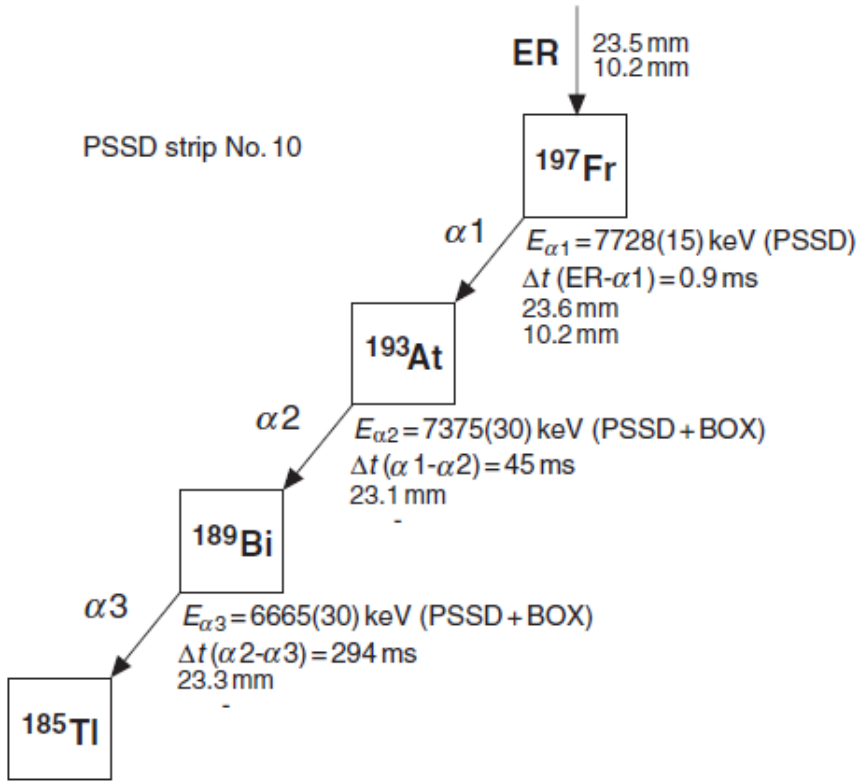
- Faculty of Mathematics, Physics, and Informatics, Comenius University (active at FRS since 1994)
- Established by: Štefan Šáro (1933 - 2013)
- Head of the group: Stanislav Antalic
- Personnel: 1 senior research scientist, 1 post-doctoral researcher, 1 PhD. student, undergraduate students
- GSI-SHIP, GANIL, JINR Dubna (Vassilissa separator), ISOLDE
- Data analyses of experiments
- Publication activity: regularly publishing as first or important co-author: topics are various
- Attracting students (from Comenius University)

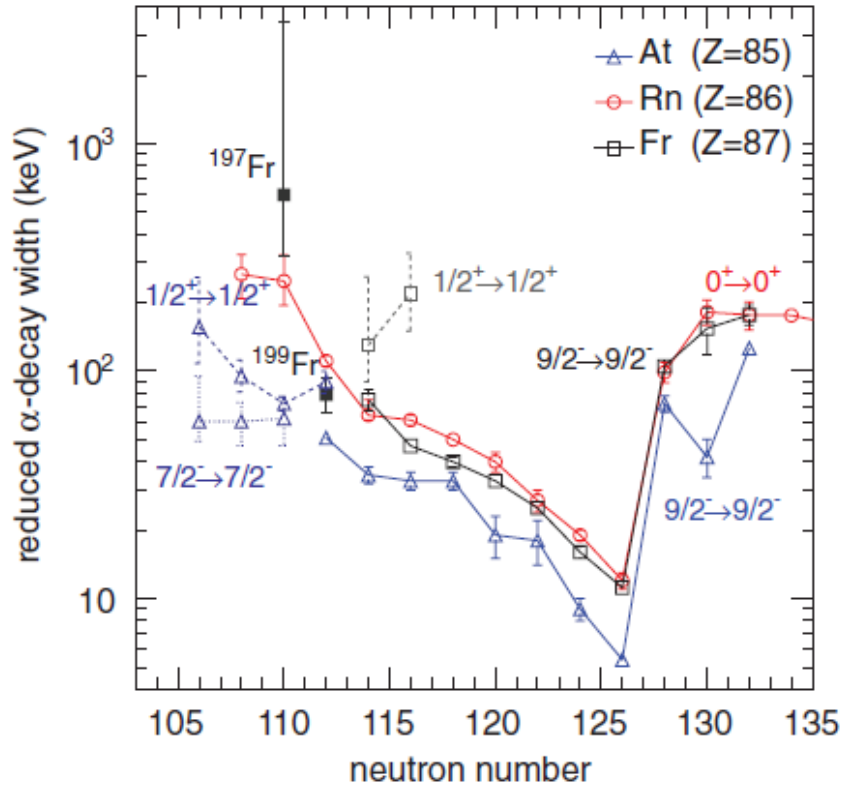




Identification of very-neutron deficient ^{198,197}Fr at GSI-SHIP

- Correlation technique developed for super-heavy elements
- High sensitivity: only 1 event of ^{197}Fr isotope identified

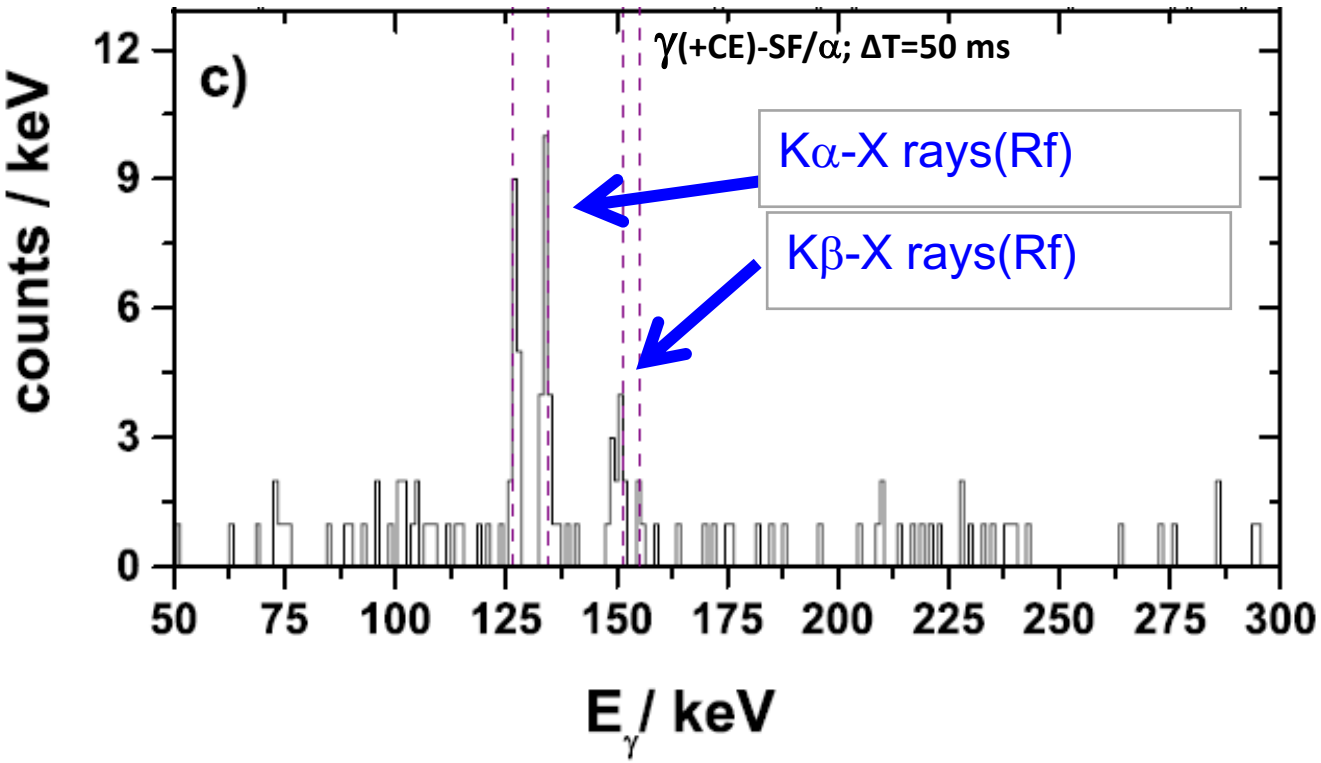




Z. Kalaninová *et al.* Phys. Rev. C **87**, 044335 (2013).

Fission studies of ^{258}Rf isotope

- Production in ^{50}Ti+^{209}Bi $\rightarrow$ ^{258}Db + 1n
- 8.5 days of beamtime, ≈ 3000 nuclei of ^{258}Db



F.P. Hessberger *et al.*, Eur. Phys. J. A **52**, 328 (2016)

- ^{258}Db decay via beta decay to ^{258}Rf (spontaenous fission)
- Characteristic X rays observed
- First direct identification of proton number of isotope decaying via spontaneous fission
- Very important option for superheavy elements
- Screaming for measurement of the BEGe detector (same efficiency and factor of 3 lower detection limit, i.e., 3 times more information is gained during the same beam time)

Department of Nuclear Physics, Institute of Physics

- Institute of Physics, Slovak Academy of Sciences
- Head of the group: Martin Venhart
- Other members:
  - Stanislav Hlaváč (director of Institute of Physics)
  - Martin Veselský (head of Scientific council of Institute of Physics)
- Personnel: 8 senior research scientists, 3 post-doctoral researchers, 7 PhD. students, undergraduate students
- Active at ISOLDE and JINR Dubna (MASHA facility), spokespersons of experiments at ISOLDE (independent research programmes)
- Spokespersons of experiments at other user facilities (University of Jyväskylä and iThemba Labs)
- Operates own Tandetron facility in Piešťany (Accelerator and detection technique)
- Infrastructure at ISOLDE: TATRA spectrometer

Department of Nuclear Physics, Institute of Physics

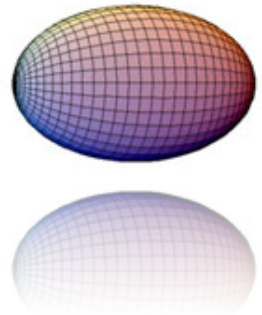
- Research topics:
  - Experiments with radioactive-ion beams
  - Nuclear structure of atomic nuclei: shape coexistence in nuclei
  - Nuclear dynamics (nuclear reactions and fission)
  - Tandetron facility (near future): inelastic scattering of particles (measurements of life times of excited states)

ISOLDE facility

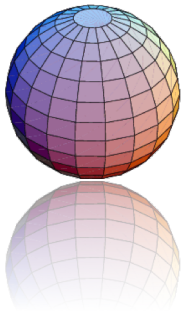
- World-leading radioactive-ion beam facility active at CERN since 1966
- Slovak republic member since 2016: MoU signed by minister Juraj Draxler
- Importance of ISOLDE for Slovakia:
  - Allows to perform independent research led by scientists from Slovakia
  - Leading of experimental programs in very well accepted by general public
  - Interdisciplinary and multidisciplinary research
  - Future task: to attract medical and material scientists from Slovakia to do experiments at ISOLDE
- Experiments IS521 (nuclear structure) and IS581 (nuclear fission) led by Institute of Physics
- IS581: Fission barriers are essential of understanding
- Institute of Physics and Comenius University actively participates also other experiments in collaboration with foreign institutions (KU Leuven, University of York)

TATRA spectrometer

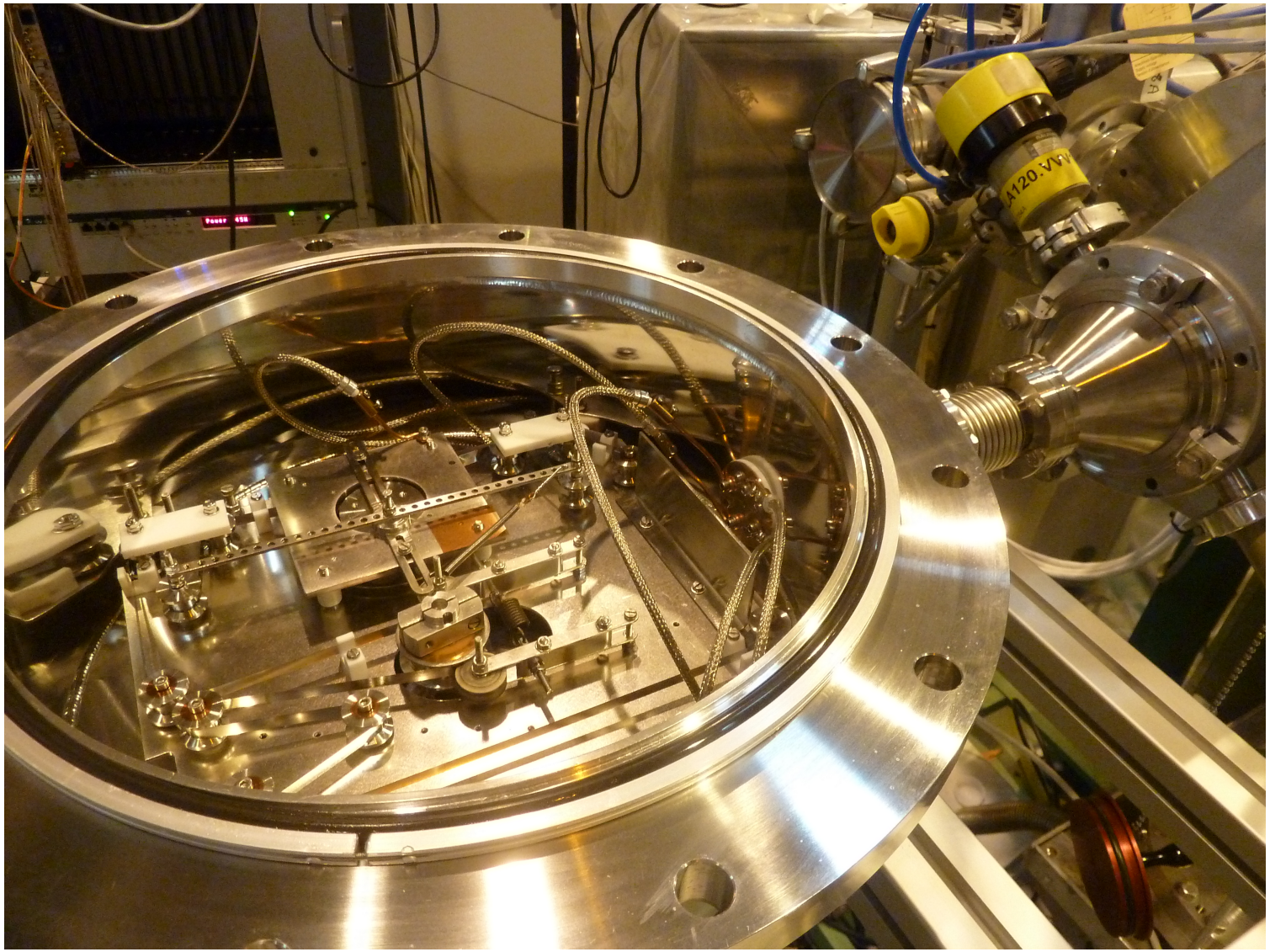
- Designed for the IS521 experiment
- Task: create sample of short-lived radioisotope and transport it to the detection station
- Challenge: detection of conversion electrons with high resolution simultaneously with gamma rays
- Only few groups in the world are (were) able to run such experiments routinely



- Primary goal of TATRA: study the structure of odd-Au isotopes
- Large density of excited states caused that all attempts to study these isotopes failed
- Why to study them: one of the most illustrative example of the shape coexistence

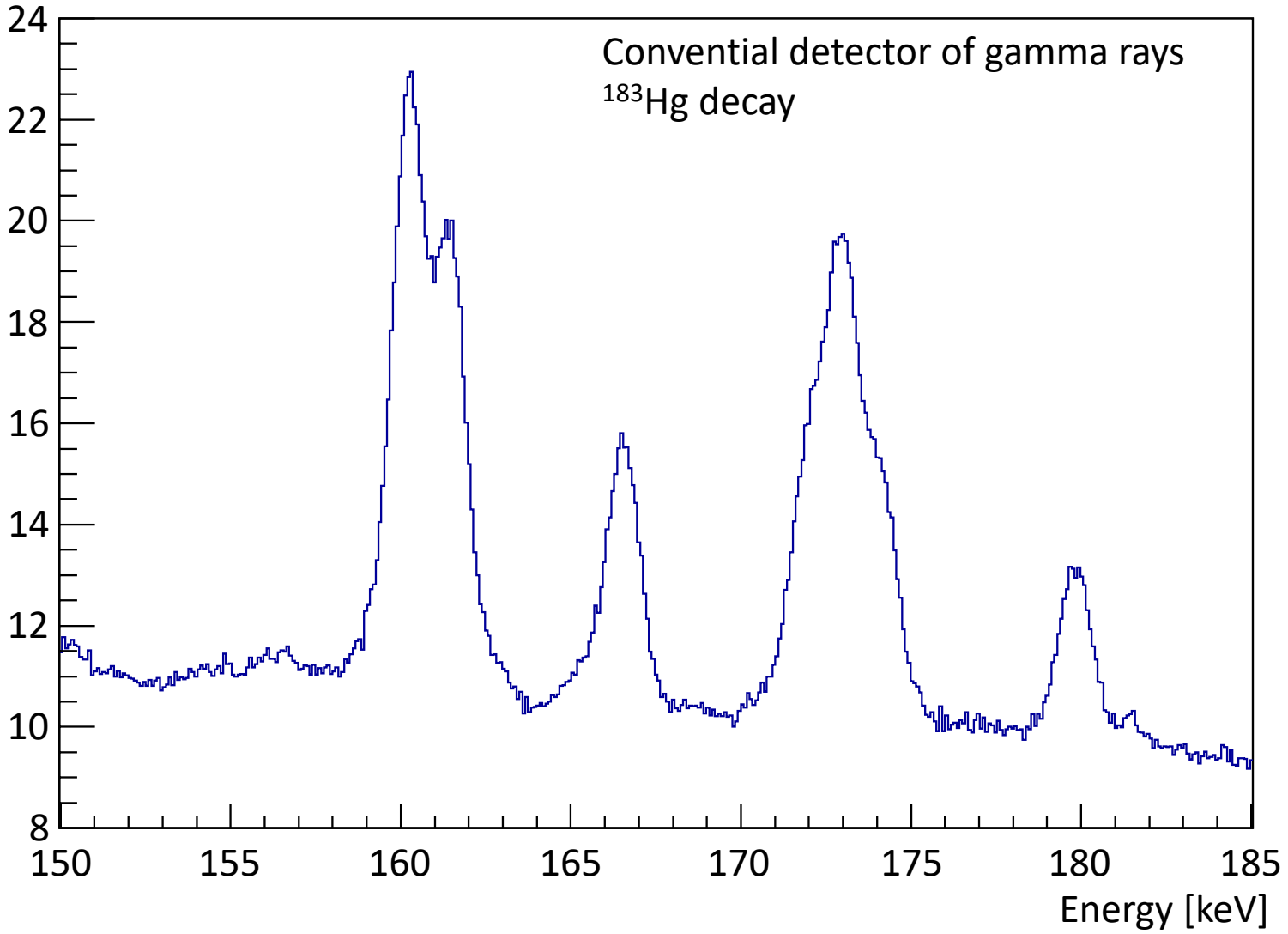


TATRA at ISOLDE



- Rapidly quenched material: metallic glass is used to transport radioactive samples (deposition of ISOLDE beam)
- Operated at 10^{-8} mbar
- Very good resolution for conversion electrons
- Broad Energy Germanium detector (first-time used for nuclear structure)
- **International context:**
  - TATRA used by CRIS experiment at ISOLDE (KU Leuven)
  - TATRA-inspired system under development at iThemba (MoU signed)

Broad Energy Germanium (BEGe) detector: reason of success of TATRA



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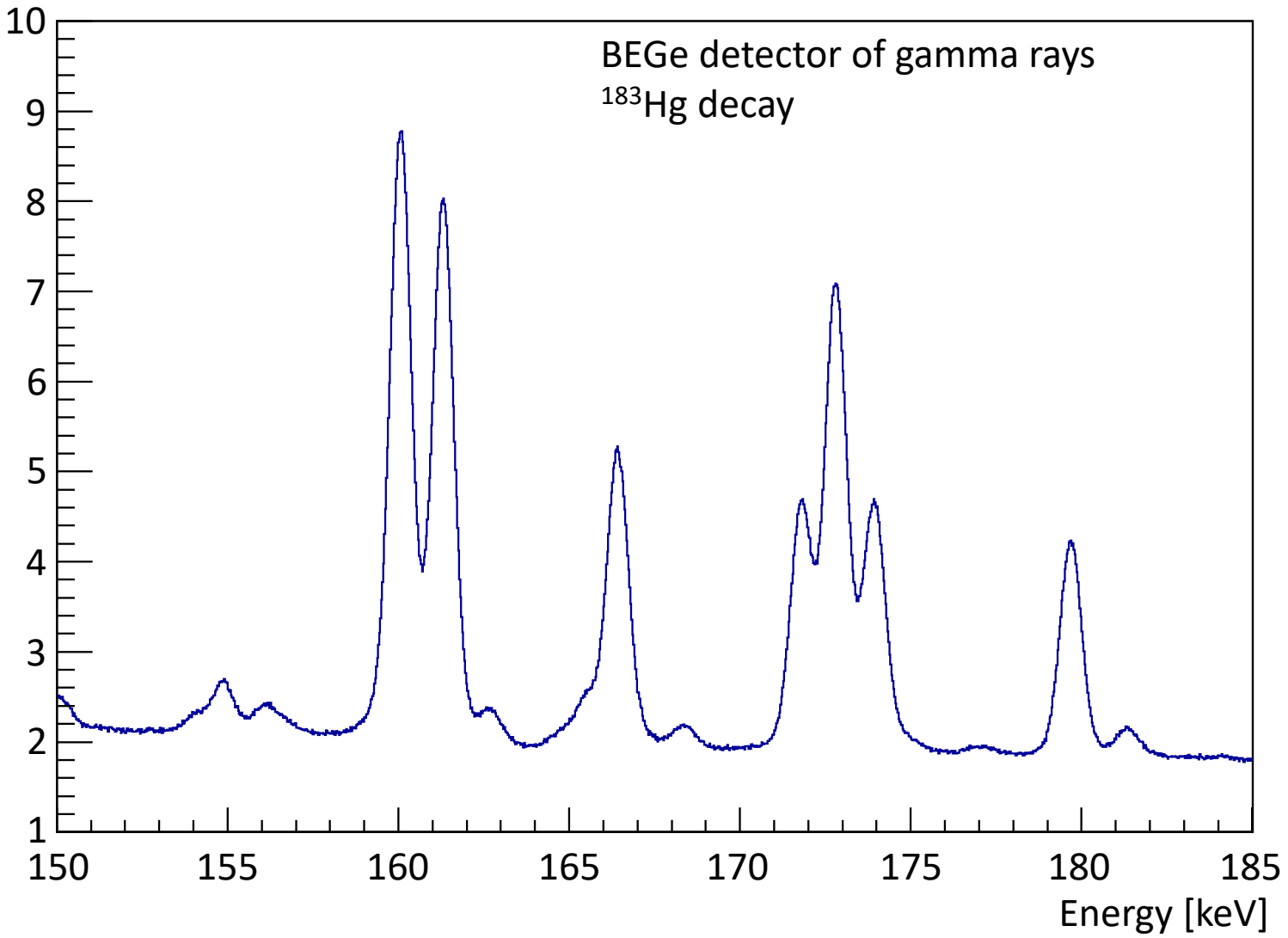
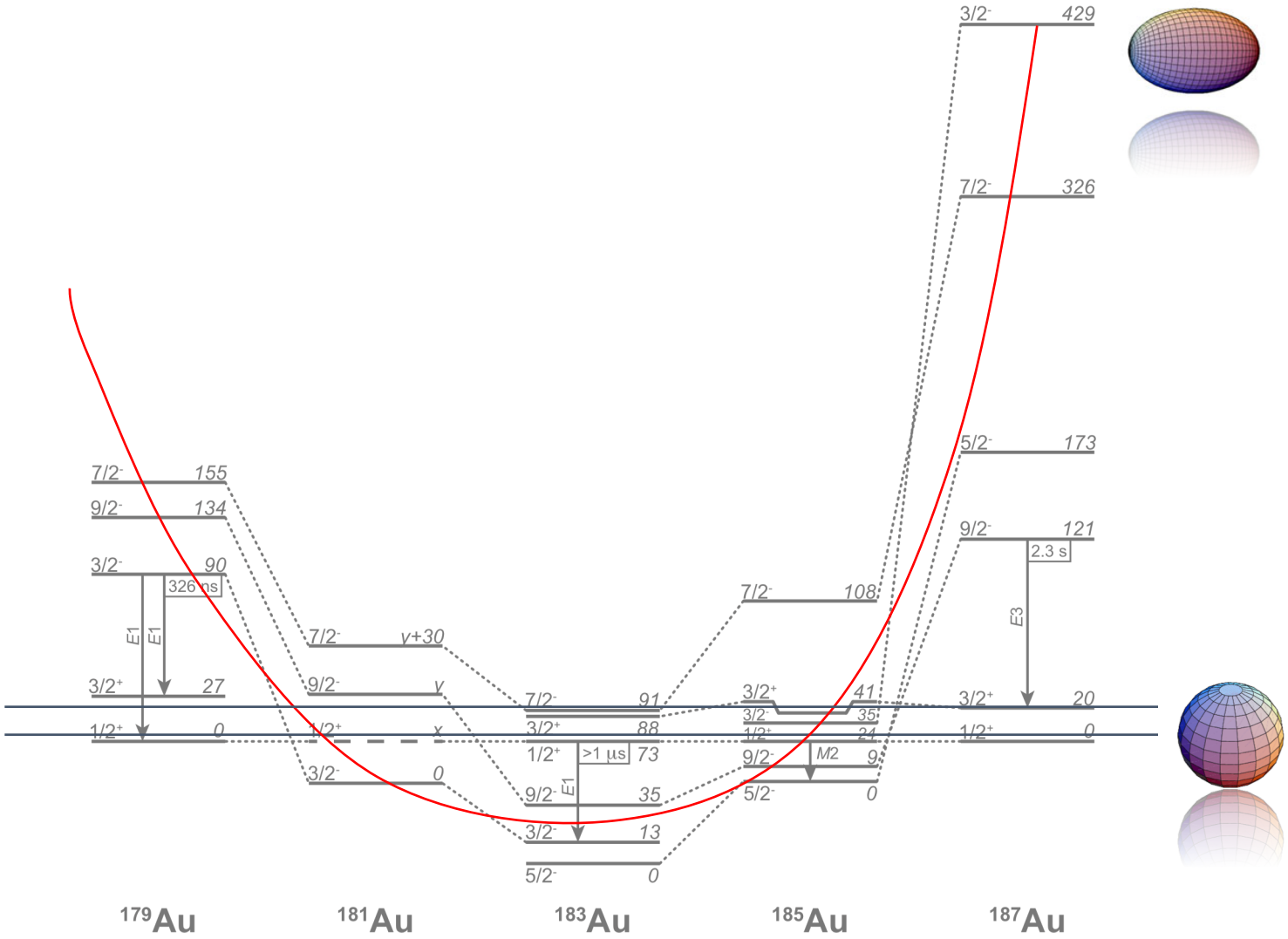


Odd-Au isotopes studies using TATRA



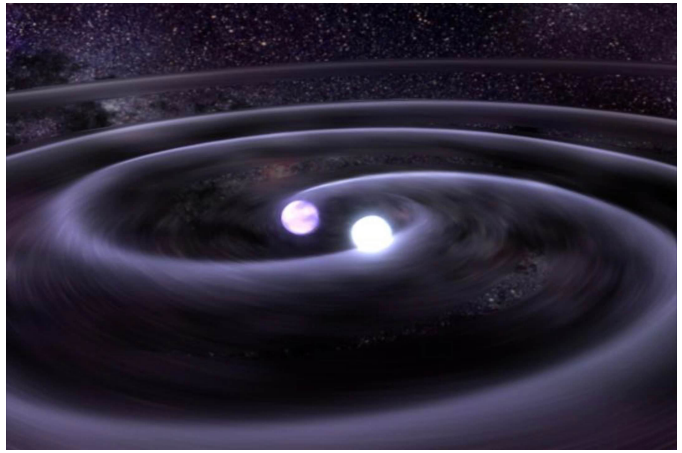
- Parabolic trend for deformed structures established
- Attempts in past failed: insufficient energy resolution
- Test for nuclear models

M. Venhart *et al.*, J. Phys. G. **44**, 074003 (2017).

IS581 at HIE-ISOLDE

- HIE-ISOLDE: recent upgrade of ISOLDE: radioactive-ion beam post-accelerated up to 10 MeV/A
- IS581 (spokesperson: Martin Veselsky)
- Direct measurement of fission barriers of heavy fissile unstable nuclei
- Information essential for understanding of nucleosyntesis of thorium, and uranium (r-process)
- Repeatedly mentioned in NUPECC Long-Range plan

- Best candidates so-far are recently neutron mergers (via gravitational waves)



Very deformed structure in ^{177}Au

- Experiment performed at University of Jyväskylä
- Jurogam2 array of germanium detectors
- ^{177}Au isotope studied (20 neutrons away from stability)
- Strongly deformed structure observed: not expected something like that so far from stability
- Result immediately attracted best nuclear theorists from Bordeaux and Brussels
- Do we really understand the odd-Au isotopes?

RAPID COMMUNICATIONS

PHYSICAL REVIEW C **95**, 061302(R) (2017)

De-excitation of the strongly coupled band in ^{177}Au and implications for core intruder configurations in the light Hg isotopes

M. Venhart,[1,*] F. A. Ali,[2,3,†] W. Ryssens,[4] J. L. Wood,[5] D. T. Joss,[2] A. N. Andreyev,[6,7] K. Auranen,[8] B. Bally,[9] M. Balogh,[1] M. Bender,[10,11] R. J. Carroll,[2] J. L. Easton,[12] P. T. Greenlees,[8] T. Grahn,[8] P.-H. Heenen,[4] A. Herzáň,[2,8] U. Jakobsson,[8] R. Julin,[8] S. Juutinen,[8] D. Kĺč,[1] J. Konki,[8] E. Lawrie,[12] M. Leino,[8] V. Matoušek,[1] C. G. McPeake,[2] D. O'Donnell,[2,‡] R. D. Page,[2] J. Pakarinen,[8] J. Partanen,[8] P. Peura,[8] P. Rahkila,[8] P. Ruotsalainen,[8] M. Sandzelius,[8] J. Sarén,[8] B. Sayği,[2] M. Sedlák,[1,13] C. Scholey,[8] J. Sorri,[8] S. Stolze,[8] A. Thornthwaite,[2] J. Uusitalo,[8] and M. Veselský[1]

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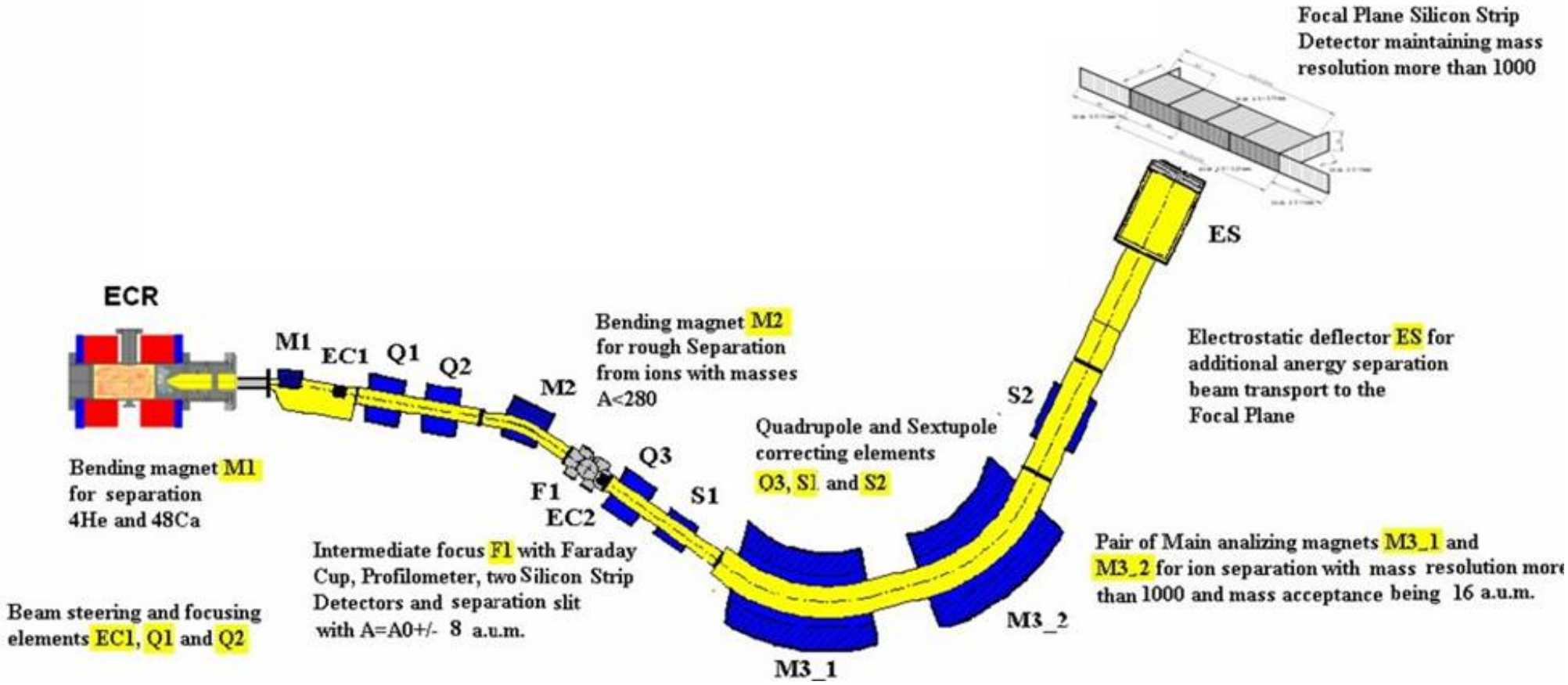
JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

MASHA separator at Flerov Laboratory

- Designed to establish mass numbers of superheavy elements
- Very rare events needs to be mass separated and identified



Question

- Does it makes sense to construct small scale facilities?

NUPECC Long Range Plan 2017

"**Small and medium scale accelerator facilities** in Europe play and will continue to play a crucial role in the joint effort of understanding nuclear structure."

"Europe has many **small and medium scale facilities** that are mostly associated with and/ or run by universities. The presence of unique instrumentation and the availability of a large variety of stable beams at these facilities, combined with easy access, offers the possibility of forefront research in specific areas of fundamental and applied nuclear physics. **They are also important for the training and education of the next-generation researchers as well for the development and testing of new instruments and techniques.**"

"Other **small and medium scale facilities**, often university based, should be supported for their specific programmes, for the development of new instruments and also to provide education and training of the next generation of researchers."

Presented on November 27, 2017
University Foundation
Brussels

Two frontiers in nuclear physics

1. Studies of “exotic“ nuclei and rare processes, e.g., search for isotopes far from stability: important (technology development engine), pioneering for physics, but do not reveal nuclear structure in great detail (large experimental uncertainties)

2. Precision measurements: high statistics is needed and many effects are precisely addressed (e.g., detection efficiencies): such programmes require long measurements, often with repetitions based on the data analysis. This (almost) cannot be done at user facilities like ISOLDE.

Only precision measurements are really putting nuclear models under serious pressure.

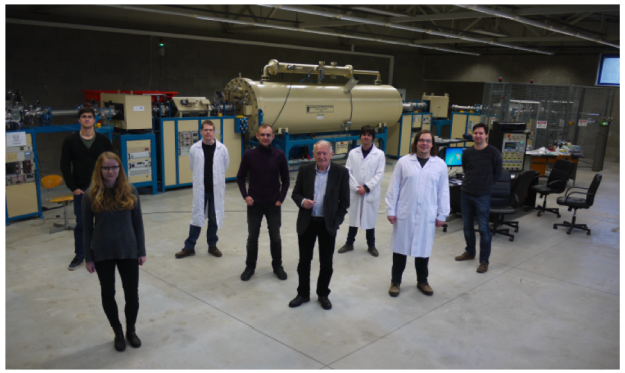
Infrastructural investments in Slovak Republic

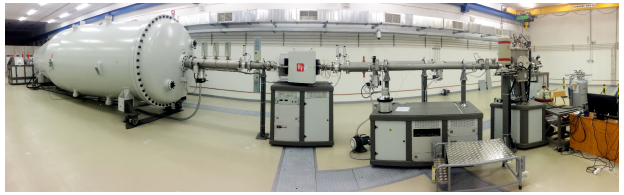
3 new accelerator facilities in Slovakia (funded from Structural funds of European Union)

1. **Advanced Technologies Research Institute in Trnava**
   6 MV Tandetron machine, 500 keV implanter
   Ion-beam modification of materials, ion-beam analyses

2. **Faculty of Mathematics, Physics, and Informatics, Comenius University in Bratislava**
   3 MV Pelletron machine,
   Accelerator mass spectrometry, PIXE and PIGE analyses

3. **Institute of Physics, Slovak Academy of Sciences, facility located in Piešťany**
   2 MV Tandetron machine, high flux, nanosecond pulsing is foreseen
   Nuclear structure, inelastic particle scattering, nuclear astrophysics





Expansion of Department of Nuclear Physics

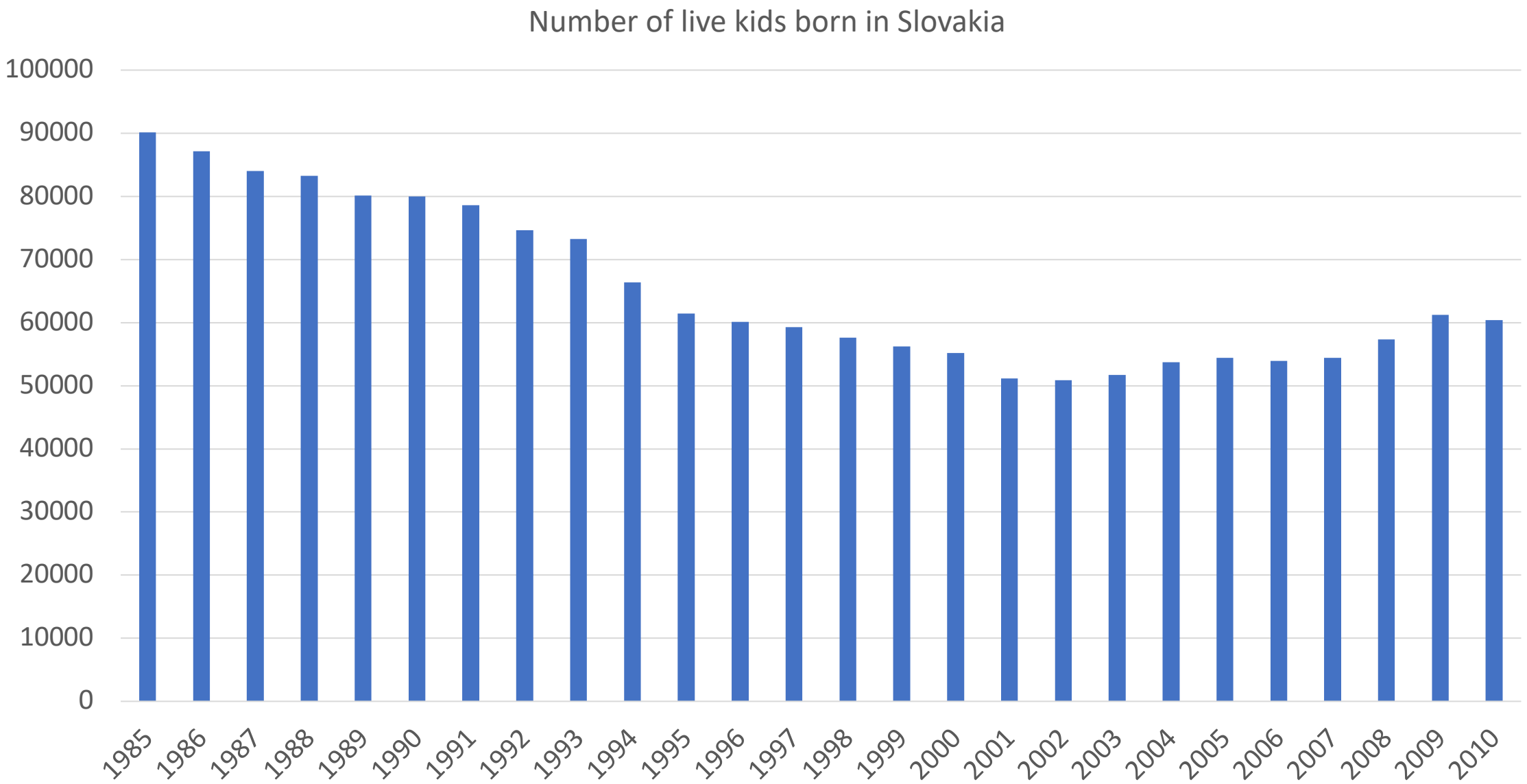
- When I returned to Slovakia in 2010: Department of Nuclear Physics had:
  - 1 PhD. student,
  - 0 master and bachelor students
  - I was the only post-doc

- Situation in 2018 (I became Head of Department in September 2013):
  - 7 PhD. students (one more already accepted)
  - 3 post-docs (4 more post-docs were working here but left)
  - FTE of staff in retirement age reduced
  - 1 post-doc and 1 PhD. student (accepted one) is foreigner

Work with high-school students

- It is enormously important for us to get young students into the research
- Slovak Academy of Sciences created several mechanisms to do it:
  - Roadshow of young researchers at high schools
  - Conference of high school students that were successfull in international competitions (like Beamline for schools, etc.)
  - Nuclear physicists are in!
- High school student was working on TATRA spectrometer at Institute of Physics, and became co-author of the study of ^{183}Hg decay at ISOLDE

Demography of Slovakia: problem



Goal: increase internationalization of groups

- Due to demography situation: there will be serious lack of students in Slovakia in next 10 years
- Solution: internationalization of research groups
- There is (almost) no use of modern communication channels to present possibilities of work in Slovakia
  - www.euraxess.com:
    - Today: 9 positions from Slovakia (none from HEP or nuclear physics)
    - For comparison: 90 from Czech Republic, 845 from Poland
- Positive examples: Institute of Electrotechnics and Institute of Materials and Machine Mechanics
- Department of Nuclear Physics: 1 post-doc from India, newly accepted student from Kazakhstan
- With this policies we want to significantly increase number of young researchers at Department of Nuclear Physics

Funding

- Existing funding in Slovakia can only sustain the present status
- Our goals are more ambitious

- Possible sources of additional funding:
  - European Research Council grants
  - Absence of funding schemes similar to Hungarian Momentum Programme (Hungary has 65 ERC grants)
  - Absence of schemes to cover excellent but not funded ERC applications (A or B grade in 2nd round)
  - The same applies to H2020 (FP9) calls
- Diversity of research: search for applications of fundamental research results: collaboration with other disciplines