High energy physics in Slovakia

Branislav Sitar

Chair of the Slovak-CERN committee

RECFA meeting

Open session

Bratislava 18.5.2018

Topics

- High energy and Nuclear physics in Slovakia
- Financial scheme, students and young physicists
- CERN activities
- GRID computing on WLCG
- Nuclear physics: ISOLDE, GSI, FAIR, JINR Dubna
- Neutrino physics
- Accelerators in Slovakia
- XFEL activities
- Astroparticle physics
- Theory in Slovakia
- CERN industrial return
- Outreach

Slovakia

Area: 49 035 km^2

Number of inhabitants: 5.43 mil.

8 regions

HEP centers in Slovakia:

- Around 250 HEP and Nuclear Physicists
- 100 CERN users

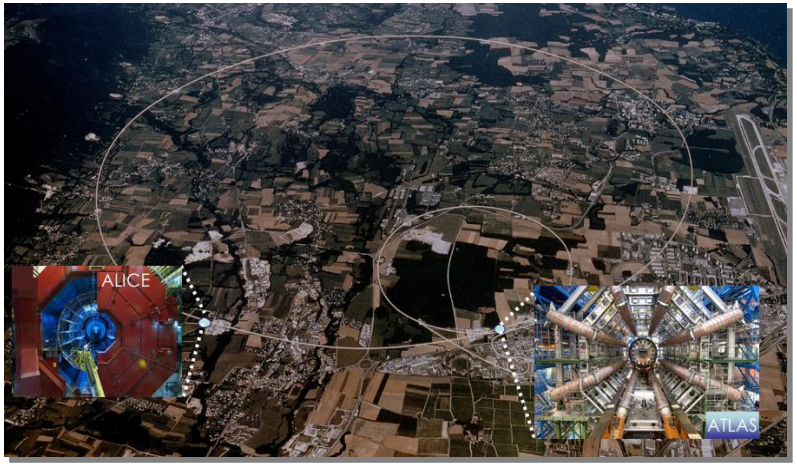
Slovakia at CERN

Slovakia is a CERN Member State from 1993

High-energy physics research is carried out mainly at institutes:

- Comenius University Bratislava, FMFI
- Institute of Physics of the Slovak Academy of Science, Bratislava
- Institute of Experimental Physics of the Slovak Academy of Sciences, Košice
- Šafárik University Košice
- Technical University Košice
- Universities: Banská Bystrica, Žilina

According a long-term Conception efforts are concentrated on participation in the LHC experiments **ATLAS** and **ALICE**



Organization and financing of research at CERN in Slovakia

- Slovakia takes part in experiments at CERN: ATLAS, ALICE, ISOLDE, NA 62
- Supervisor and funding agency for Slovak activities at CERN is the Ministry of education, science and sport of Slovak Republic
- Coordination of CERN activities: Slovak Committee for Cooperation with CERN
- Annual Slovak contribution to the CERN budget is ≈ 5.5 MCHF, which represents ≈ 0.5 % of the CERN budget
- Ministry of education, science and sport of Slovak Republic supports experiments at CERN by ≈ 800 k EUR annualy.
- Grant scheme for students and Post docs for stages at CERN was provided by Ministry of education in 2014-2016. 23 students worked at CERN for several months

Other High energy and Nuclear physics activities in Slovakia

- FNAL: CDF
- DESY: XFEL
- Neutrino experiments: NEMO, JUNO, Baikal GVD
- GSI Darmstadt: FRS, SHIP,
- FAIR Darmstadt: NUSTAR, Super FRS
- JINR Dubna
- Accelerators in Slovakia
- Theory
- Astroparticle physics: JEM-EUSO, Observatory at Lomnický štít

Organization and financing of HEP and Nuclear physics in Slovakia

- Supervisor and funding agency for Slovak HEP and NP activities is Ministry of education, science and sport of Slovak Republic

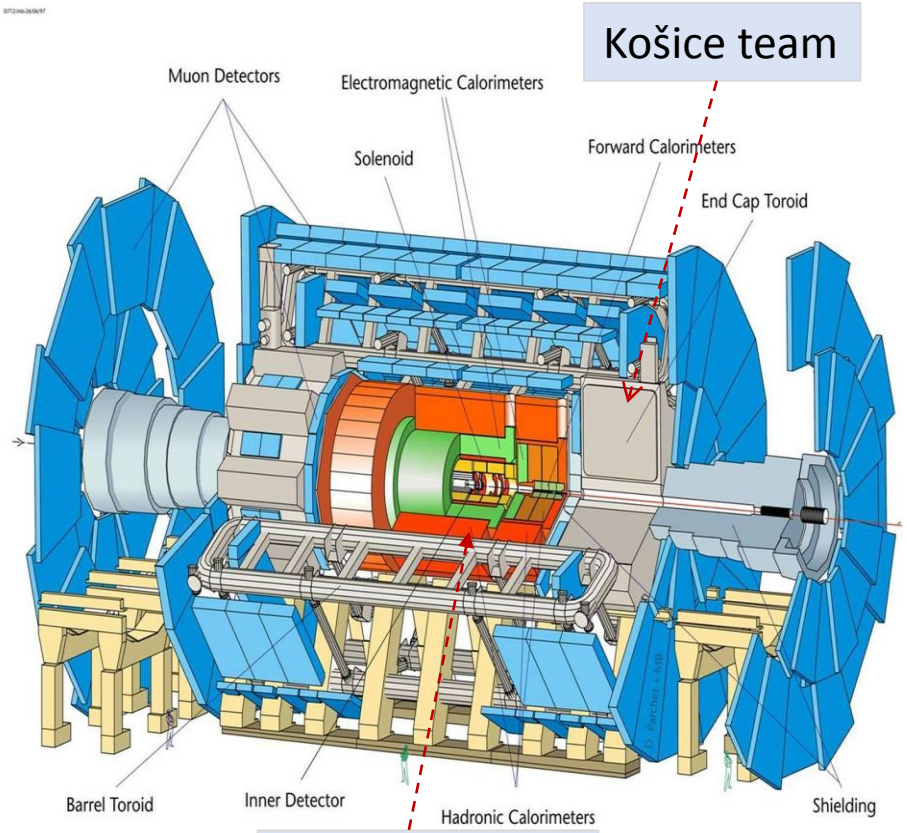
- JINR Dubna and XFEL have special funds from Ministry of education

- Other HEP or Nuclear Physics activities are financed form regular funding agencies as VEGA or APVV

- Collaboration with European laboratories in the framework of ESFRI: CERN, XFEL, FAIR, Spiral 2

Experiment ATLAS: Slovak cluster's activities

It is a multi-purpose particle collider detector (covering up to $|\eta|=5$, $L \approx 10^{34}\,cm^{-2}s^{-1}$);
Aimed at *pp* collisions at $\sqrt{s}$ = **14 TeV** (7TeV×7TeV);
$\sqrt{s}$ =7 TeV (2010), 8 TeV (R1012) , 13 TeV (2015)



Bratislava team: 6 physicists, 7 PhD students, 1 technician, 3-5 students

Activity: Hadronic Tile calorimeter
- ✓ DQ coordinator for TileCal,
- ✓ development of software for TileCal DQ

Participation in Data taking shifts

Košice team: 4 physicists, 1PhD student, 4 engineers

- ✓ important responsibilities for electronics calibration of the full LAr ATLAS calorimetry
- ✓ performance studies of various aspects of the LAr calorimetry, data preparation tasks

Organized conferences:
- ✓ Physics in Collisions in Štrbské Pleso, High Tatras, 2012
- ✓ ATLAS Hadron Calibration Workshop in Bratislava, September, 2015
- ✓ Overview ATLAS Meeting in Bratislava, Oct. 2017

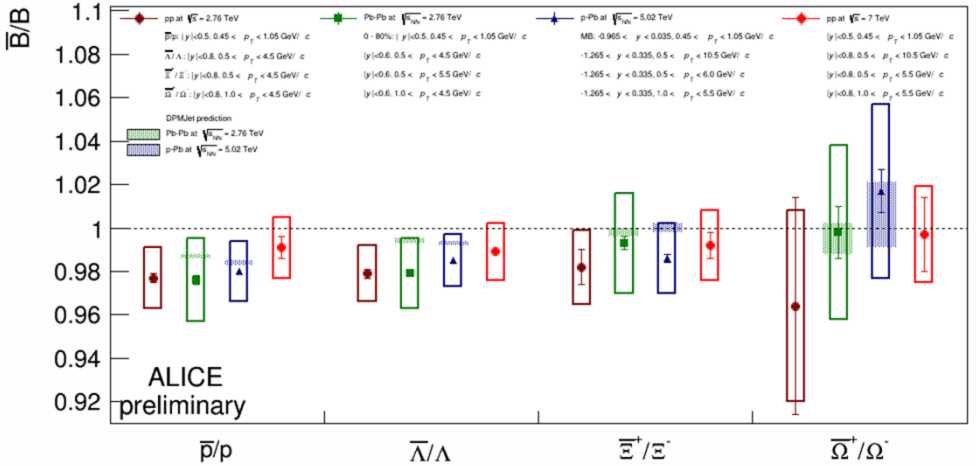
ATLAS: Slovak cluster (Bratislava + Košice) physics analyses

- **Top quark physics studies:**
  - ✓top quark charge, SM top quark with charge +2/3 confirmed (JHEP 11 (2013) 031)
  - ✓top quark decay width (Γtop), direct measurement of Γtop at 8 TeV (Eur. Phys. J. C 78 (2018) 129
  - ✓charge asymmetry in ttbar production, preliminary results at 13 TeV, 36 fb^{-1} obtained → publication expected using data of 80fb^{-1}.
  - ✓Top quark mass in dilepton channel –top mass reconstructed at 8 TeV (20.2fb^{-1})preliminary results are in ATLAS internal note
  - ✓Associated production of ttbar Z (Z→□□, ttbar – all hadronic), analysis at 13 TeV,36 finished – publication is expected soon.
  - ✓Boosted top and W boson objects – top and W boson taggers created; publication is under preparation.
- **Intrinsic charm in proton** – ATLAS □+jet published results analysed on presence of intrinsic charge in proton – publication sent to Phys. Rev. Lett.
- **Soft QCD: Bose-Einstein correlations** – space time characteristic of hadronization process at 7 TeV analysis published (EPJC 75 (2015) 466), at 13 TeV analysis finished – under scrutiny of EdBoard.

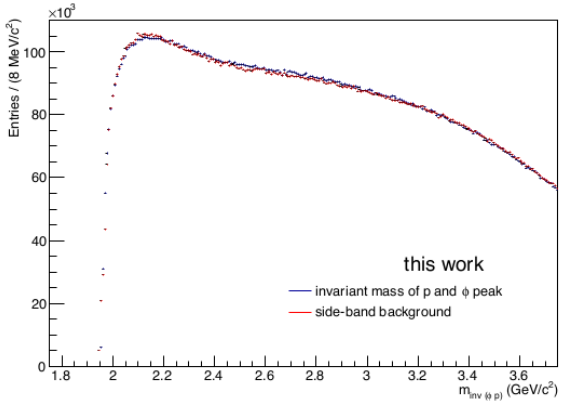
Participation of Bratislava group on ALICE physics

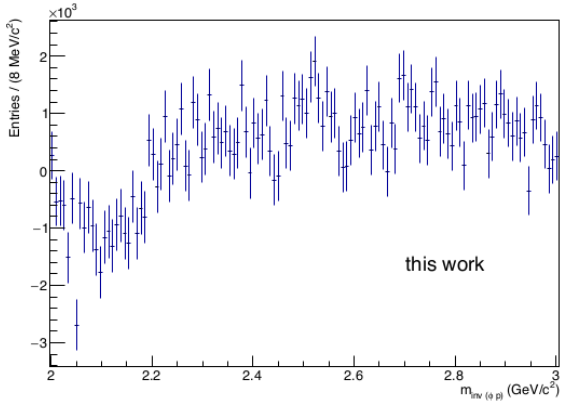
Bratislava team: 5 physicists, 1 PhD student, 1 technician, 2 students

Midrapidity antibaryon-to-baryon ratios in Pb-Pb and p-Pb collisions measured by the ALICE experiment



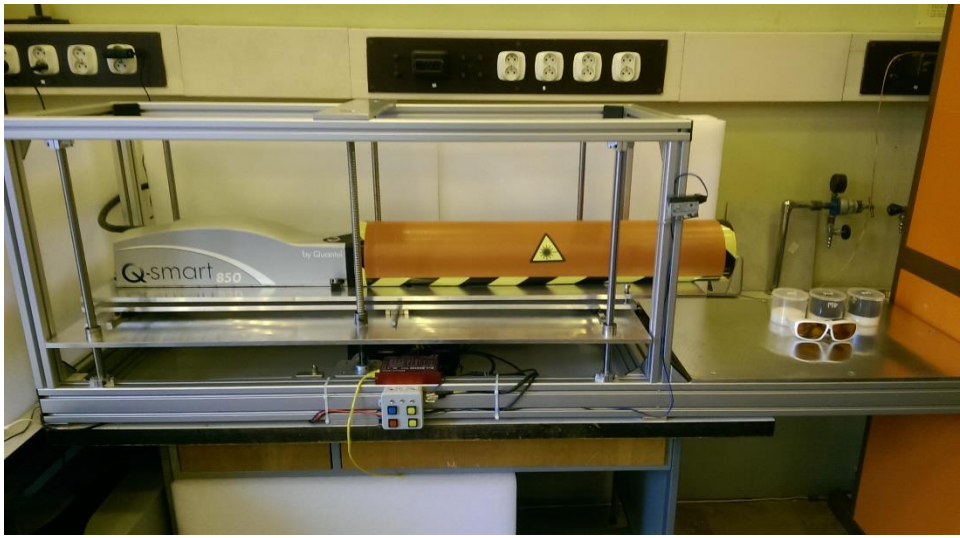
Pentaquark search on the ALICE experiment



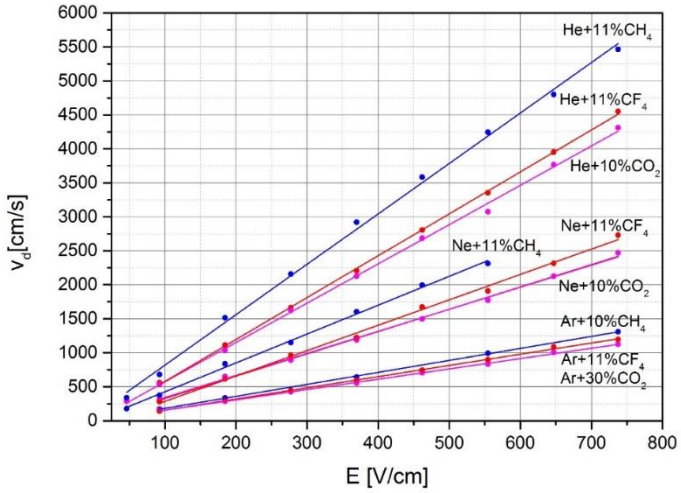


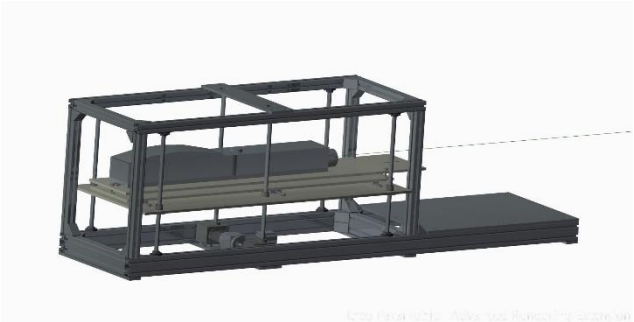
Bratislava group activities in ALICE TPC upgrade

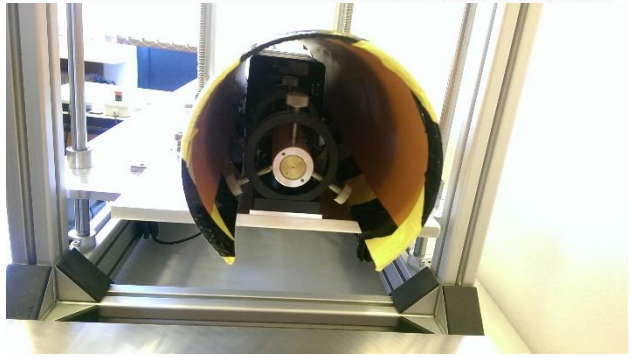
Detector laboratory with Nd: YAG laser has been built



Ion mobility measurements in different gas mixtures







Activities of Košice ALICE team

7 physicists, 8 engineers, 9 PhD, 5 students from
Institute of Experimental Physics, Slovak Academy of Sciences
Faculty of Science, P. J. Šafárik University
Technical University Košice

Main activities:

- A system of the remote access to the LHC data (AMANDA3-DARMA)
- Detector control system for the Internal Tracking System (RUN3)
- Electronic modules and special cables for the Central Trigger Processor
- (RUN3)
- The software for the Trigger Data Quality Monitoring for the RUN2
- LHC interface - on-line luminosity monitoring and DAQ for the Van der Meer scans
- LHC grid

- Strange and multi-strange particle production in p-p and Pb-P bcollisions at various LHC energies
- Angular correlations between strange and non-strange particles in p-p collisions at 13 TeV
- φ meson polarisation in p-p and Pb-Pb collisions
- Normalization cross section measurement using Van der Meer scans

World LHC Computing Grid clusters in Slovakia

- Slovakia has two clusters (Bratislava and Košice), forming one “Slovak cluster” as part of WLCG
- Smooth running, without any big interruption over last years, with pledged capacities CPU: 12800 *HEPSpec06* and disk: 1.3 PB regularly delivering to ATLAS and ALICE also over pledge capacities

at FMFI Bratislava

at IEP SAS Košice

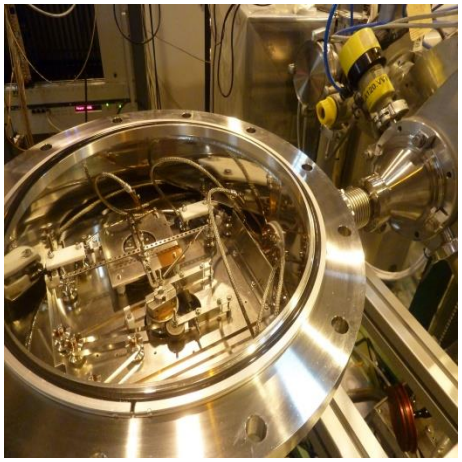
WLCG in Slovakia

- Memorandum with WLCG was signed at the end of 2012
- Delivered capacity is around 2% of ALICE and 1% os ATLAS overall capacities
- Both farms are financed from the operational budget of ATLAS and ALICE teams, no special or outside financing
- In Košice, where we have the common computing room with institute infrastructure, the part of EU grant was used for infrastructure improving (cooling and generator)
- Working with SANET (national academic networking provider) on improving the network capacities
- National grid project and small HPC installations are not used, because they ask for operational payments (electricity and man power were not part of grants used to built this installations)

ISOLDE facility

- Slovak republic member since 2016

- 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



- Experiments IS521 and IS581 led by Institute of Physics SAS

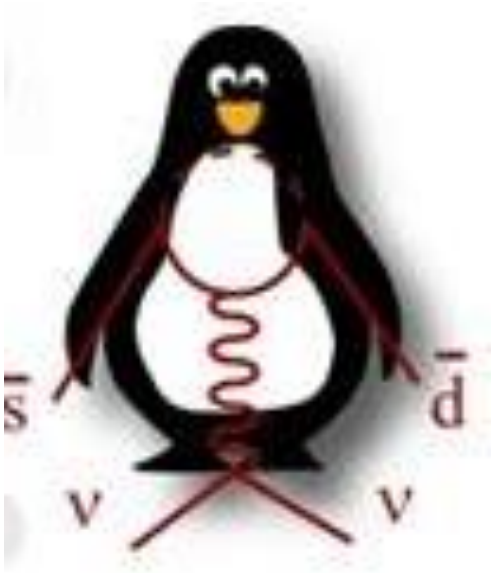
- TATRA spectrometer: unique device to perform simultaneous spectroscopy of conversion electrons and gamma rays with high resolution

- First ever use of the Broad Energy Germanium detector for fundamental research

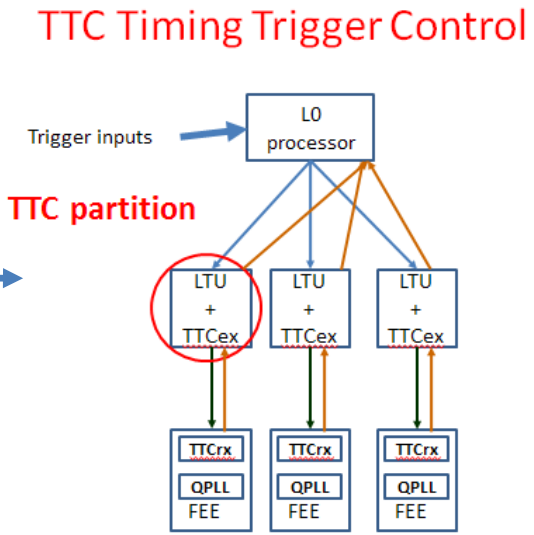
- Institute of Physics SAS and Comenius University actively participates also other experiments in collaboration with foreign institutions (KU Leuven, Univ. of York)

Bratislava participation in NA62: Ultra-rare kaon decays

3 physicists + 5 students , collaboration started in 2010



fourteen subdetector systems



Software for LTU + TTCex TTC interface:

Two regimes:

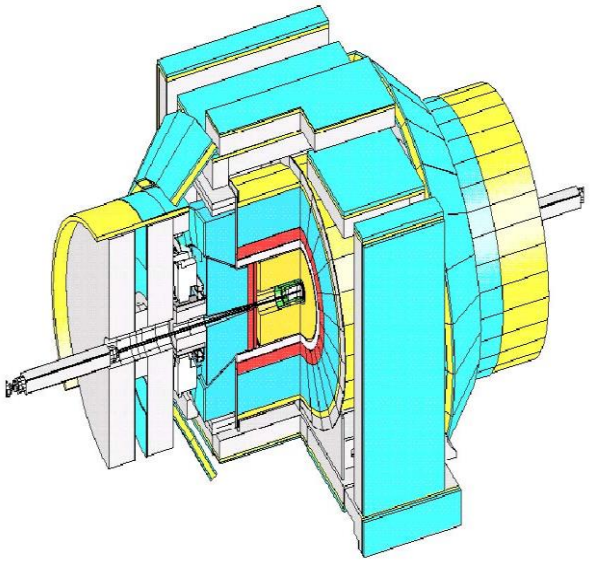
- **global: communication of properly synchronized trigger information to subdetectors**
- **standalone: emulation of trigger sequences to debug communication with frontend electronics**

Expertise in supersymmetric models and physics beyond standard model (beyond the penguin diagram shown above)

Joint Slovak team in the CDF experiment

CDF stopped data taking in 2011 - physics analysis continued Bratislava (P. Bartos, O. Majersky and S. Tokar) and Košice (J. Antos, R. Lysak) joint Slovak team worked in heavy flavour and top quark:

- Top quark determination – exotic quark with charge -4/3 excluded at 95% C.L. (Phys. Rev. D88 (2013) 032003)
- Forward-Backward asymmetry in bb production – the asymmetry found to be compatible with the SM prediction (Phys. Rev. D 93 (2016) 112003)
- A lot of work as Reading institute and „Godparents“ (expert scrutiny of other analyses)



Present activity:

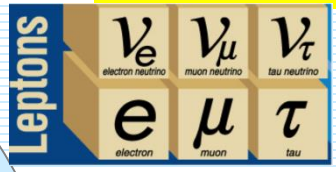
- ✓ Bratislava team work on determination of the top quark mass in lepton+jets mode using the full CDF statistics.)
- ✓ Two students (D. Babál, J Senderák) joined to the analysis.
- ✓ Result is expected during 2018.

Summary of groups active in experimental nuclear physics

- **Faculty of Mathematics, Physics, and Informatics, Comenius University Bratislava (2 groups)**
  - **Fragment Separator FRS at GSI, Super FRS in FAIR at Darmstadt:**
    - 3 senior research scientists and 0 students
    - Infrastructure contribution: Development of tracking TPC detectors for FRS
    - Participation on experiments with exotic nuclei
    - Development of Twin TPC as a tracking detector for Super FRS on FAIR
  - **SHIP at GSI Darmstadt, JINR Dubna, ISOLDE and GANIL (France):**
    - 1 senior research scientist, 1 post-doc and 1 PhD. Student
    - Participation on experiments
    - Data analysis

- **Institute of Physics, Slovak Academy of Sciences**
  - Active at ISOLDE, University of Jyväskylä, iThemba Labs, JINR Dubna
  - 7 senior research scientists, 3 post-docs, and 6 PhD. students
  - Spokespersons of experiments (2 at ISOLDE, 2 at University of Jyväskylä, and 1 at iThemba)
  - Development of TATRA spectrometer for use at radioactive-ion beam facilities

Slovak neutrino physics groups in Slovakia



F. Šimkovic
R. Dvornický
D. Štefánik
P. Maták
L. Fajt
M. Macko

Theory

NEMO

Baikal GVD

JUNO

T. Blažek
P. Maták
V.Černý ...

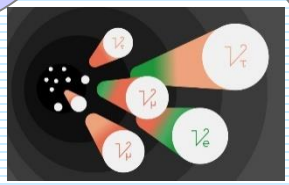
NA62

P. Povinec
R. Breier

NEMO

B. Pastirčák

Baikal GVD



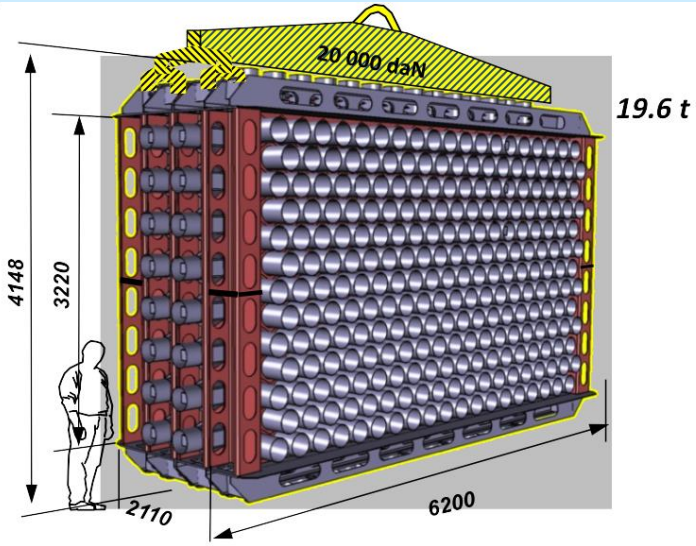
Financial support

MINISTERSTVO ŠKOLSTVA, VEDY, VÝSKUMU A ŠPORTU SLOVENSKEJ REPUBLIKY

AGENTÚRA NA PODPORU VÝSKUMU A VÝVOJA

Nemo3/SuperNemo exp.

Physical programme, software, construction



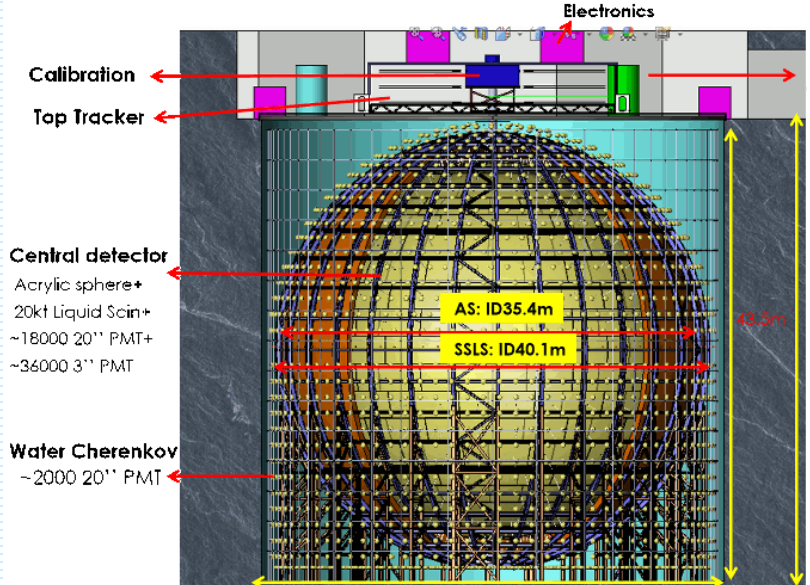
Baikal GVD

Time, charge, amplitude calibration

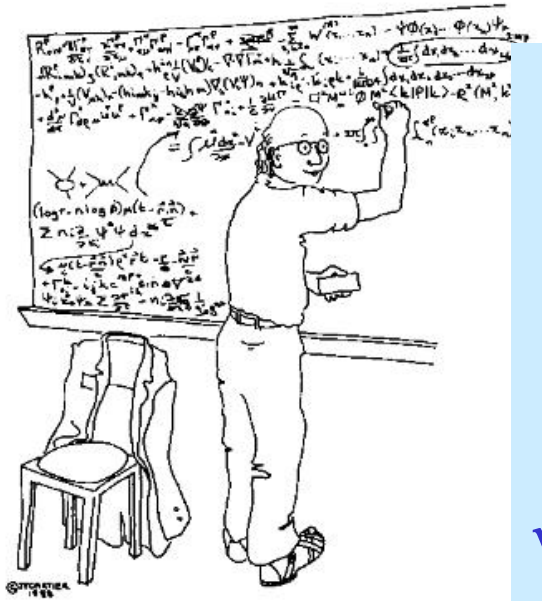
Construction of the ν–telescope on lake Baikal

JUNO exp.

Software development, data analysis, ν–spectrum



Theory



"At this point we notice that this equation is beautifully simplified if we assume that space–time has 92 dimensions."

Absolute ν-mass
CP violation
sterile neutrinos
ν-oscillation
ν-mixing
0νββ-decay
forbidden β-decays
ν–magnetic moments
non-standard ν-interactions

HEP theory in Slovakia

- 5 institutions,

about 20 active physicists & students

Topics worked on:

- hot and dense matter (lattice, equation of state, compact stars, heavy ion phenomenology)
- hadron structure in reactions (EW formfactors, quark structure, hadronic production)
- neutrino physics (neutrinoless double beta decay)
- beyond standard model (strong electroweak symmetry breaking)
- theoretical developments (light front formulation)

European XFEL & Slovakia

- European XFEL - most brilliant coherent X-ray source driven by superconducting LINAC (build & maintained by DESY)
- Slovakia is regular shareholder of E-XFEL (1%+ share), covered from Slovak ESFRI budget
- Slovak application focus - mainly in structural dynamics studies of biomedical interest (proteins and bio particles including cells) - SFX and XBI user consortia at E-XFEL, SPB experimental workstation
- material research (MID) in future
- opportunities for next generation of Slovak scientists to join world-class research groups
- (semi)regular SFEL schools (80+ people) coorganised with E-XFEL

Accelerator activities in Slovakia

Activities in the past:

- **2012 – Senec – CERN Accelerator School on Ion Sources –** Slovak University of Technology in Bratislava (STU) – head of the LOC – Márius Pavlovič;

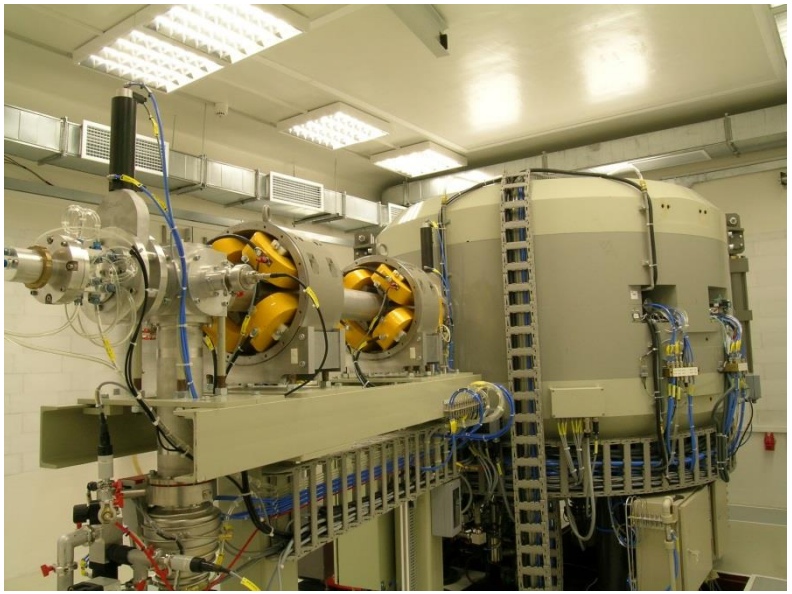
- **Beam-loss criteria for high-power heavy-ion accelerators –** accelerator R&D collaboration of STU with GSI Darmstadt, European FP7 INTAS collaboration, 4 people from STU involved (1 PhD thesis completed), 15 scientific papers published from 2007 to 2015; collaboration still active depending on the SIS18 beam-time for irradiation experiments;

Ongoing Accelerator R&D Activities:

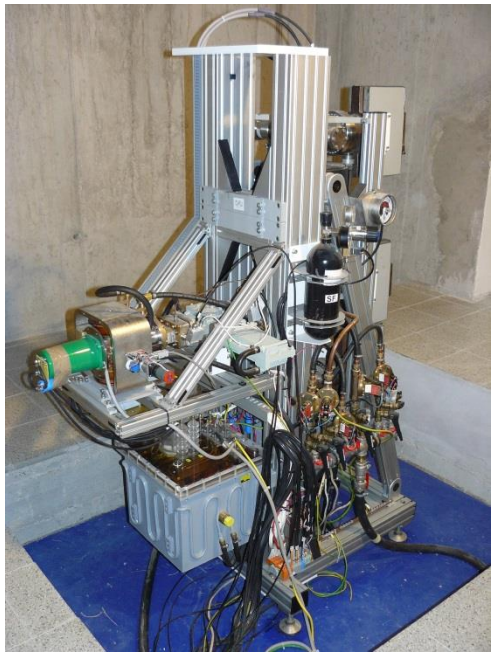
- **Long-term collaborations:**
  - European XFEL, GmbH – 2 PhD students from STU participate on development of a beam-line detector; official leaders of collaboration: Pavol Sovák, Karel Saksl from TU Košice; Winter schools on synchrotron radiation run regularly in Slovakia;
  - JINR Dubna – regular exchange of experts; 4 people from Slovak Academy of Sciences involved in development of transmission photocathodes for the hollow-cathode assembly of a Pierce-structure DC electron gun;
- **Projects in Slovakia:**
  - Development of beam-transport systems for rotating gantries of light-ion medical accelerators – 2 people from STU involved, collaboration with MedAustron foreseen.

Accelerator school in Slovakia:

- Introduction to Accelerator Physics, High Tatras, September 2019



CYCLONE 18/9 at BIONT, Inc., Bratislava

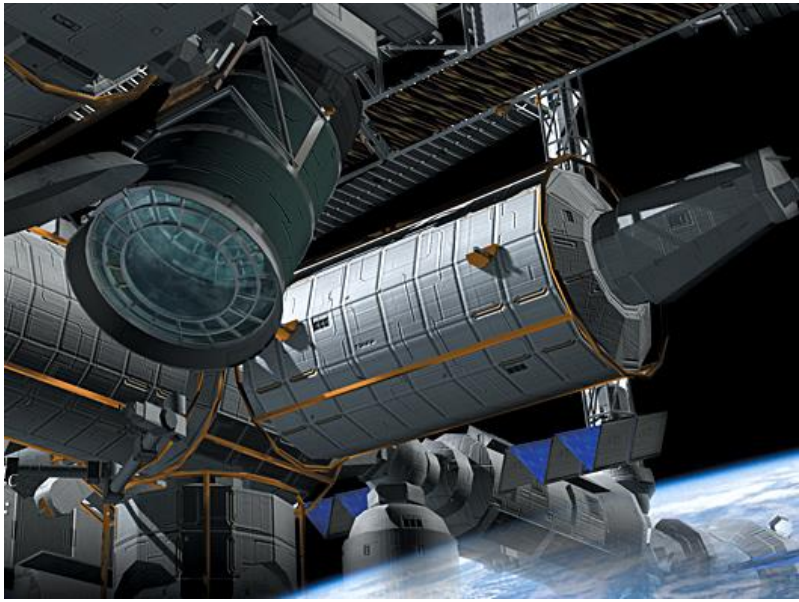


5 MeV electron accelerator of Slovak Health University in Trenčín

6 MV Tandetron at STU, Trnava

3 MV Tandem Pelletron, UK Bratislava

Astroparticle physics in Slovakia



JEM-EUSO

- **E**xtreme **U**niverse **S**pace **O**bservatory (EUSO) on the **J**apanese **E**xperiment **M**odule (JEM) on the International Space Station (>2020)
- 16 Countries, 93 Institutes
- Slovakia member since 2008 (IEP SAS since 2008, TUKE since 2015)

- Precursor experiments: CNES EUSO balloon (2014), TA-EUSO (2015-2016), NASA EUSO-SPB balloon (2017), Mini-EUSO (2018), EUSO-SPB 2 balloon (>2020), K-EUSO (>2020)

Main Science Objectives:

- identification of UHECR sources

- measurement of the energy spectra of individual sources

- measurement of the trans-GZK spectrum

Astrophysics for Energies > 5 × 10^{19} eV

Exploratory objectives:

- discovery of UHE neutrinos

- discovery of UHE Gamma-rays

- study of the galactic and local extragalactic magnetic field

IEP SAS Department of Space Physics: Detached Laboratory at Lomnický štít

- Long term measurement of cosmic rays (CR) by neutron monitor (NM) with high statistics and temporal resolution at Lomnický štís (LS) 2636 m. a.s.l. 1982-2018
- Analysis of quasi-periodic and irregular CR variations and comparison with parameters of interplanetary space, Earth's magnetosphere, state of atmosphere; relations of fluxes of low energy CR to space weather effects (SW); changes of magnetospheric transmissivity for CR; CR modulation in heliosphere according to exp. data; development of new devices or their parts for satellite/space probe observations of suprathermal particles in magnetosphere, in interplanetary space and in other space plasma populations; analysis of satellite/space probe data with the aim to contribute to understanding sources, acceleration mechanisms, transport, losses in magnetosphere and role of the particles in SW effects; update of measurements at LS including SEVAN, dosimetric observations, study of CR relations to atmospheric electricity.

Cosmic rays models

- Modulation of cosmic rays in Heliosphere. Numerical, stochastic, finite difference and analytical models development. Models to describe CR distribution/spectra in heliosphere

- Cosmic rays in magnetosphere

Physics education in Slovakia

Declarative role of physics at our school system

Why school reform doesn't work

Current challenges for better future

- Inquiry based science education
- Education for information society (National project IT Academy)

Skills development and formative assessment

Where we need to help

- Lack of physics teacher
- Enhancing the scope of physics teaching
- School physics laboratories

Promoting physics in society: 50-60 lectures/yr + media

Slovak teachers and students at CERN 2011-2017

- Slovak teachers of phsics regularly attend courses at CERN
- Every year several busses with high school students visit CERN

Slovak students and PhD students at CERN

- A grant scheme of the Ministry of education allowed 10 students and young physicists stay at CERN several months in 2014 and 13 students and young physicists stay at CERN several months in 2015-2016

- The program at CERN was highly effective - students and young physicists worked with top class supervisors, obtain a lot of knowledge and produced interesting results useful also for CERN collaborations

- Slovak Committee for cooperation with CERN appreciate this scheme and supports its prolongation and enlargement to more students

Students	2011	2012	2013	2014	2015	2016	2017
Adminstrative			0	1	2	3	0
Technical			0	0	0	0	0
Doctoral			0	2	1	0	0
Fellow			4	2	4	1	4
Summer			4	3	3	3	5

Outreach

Slovakia is a founding member of International Particle Physics Outreach Group (IPPOG) Collaboration (Dec 2016)

Main outreach activities for high schools include IPPOG run, IPPOG supported or IPPOG inspired events.

International Particle Physics Masterclasses 400-500 participants at 7 universities annually

National Cascade projects competition 10-15 high school teams make 15 min presentations on particle physics in their schools, total audience 300 - 400 students/year

Beamline for Schools international competition ~ 2 teams/year, team from Vranov n. Topľou among best 20 – Cosmic Pi detector for school as prize

Particles for You (IPPOG international competition) Winner: Ľudovíta Štúra high school in Zvolen, Slovakia constructed a low-cost Paul ion trap

Slovak National Teacher Programme was successfully revived in 2017 with support of Ministry of Education

Web portal „Svet častíc“ (World of Particles) supports Outreach and Communications activities (maintained by I. Melo)


Slovakia Return Coeficient 2011 - 2017
Value R
2
1,8
1,6
1,4
1,2
1
0,8
0,6
0,4
0,2
0
0,43
0,61
0,31
0,39
0,4
0,41
1,85
1
2
3
4
5
6
7
2011 - 2017

Biggest deliveries from Slovakia to CERN
2011 - 2017

IT-3713 Supporting system of the RF-structures

Winner : VVÚ ZŤS Košice, Slovakia

DO-26 035 High resolution linear actuators

Winner : VVÚ ZŤS Košice, Slovakia

Bel Power Solution z Dubnice n. Váhom

DO-26 295 Hydraulic tractors

Winner : VVÚ ZŤS Košice, Slovakia

Conclusion

- Slovak HEP community actively participate in CERN on ATLAS, ALICE, ISOLDE and NA 62 experiments.

- Work of students and young physicists at CERN was highly effective and useful. The scheme should continue in the future.

- Number of Slovak CERN users raised form 80 in 2011 to 100 in 2017, from which majority are young students and physicists.

- Slovak physicists are active in other European Laboratories as GSI, FAIR, XFEL, NEMO, JUNO, Baikal GVD, astroparticle and nuclear physics experiments.

- Knowledge transfer from CERN and other European laboratory to Slovakia should be improved.


Thank you for attention