Horizon 2020 ERA Chair project „Expanding Potential in Particle and Radiation Detectors, Sensors and Electronics in Croatia – PaRaDeSEC”

http://paradesec.irb.hr

Neven Soić
Rudjer Boskovic Institute
PaRaDeSEC project manager
Mission:

- Excellent science
- Strong involvement in higher education
- Leading contribution to the growth of the national economy

Vision:

- Croatian EU centre of scientific excellence

Largest research institute in Croatia
900 employees, 350 permanent, 250 postdocs and PhD students, multidisciplinary
RBI overview

5% of Croatian researchers
30% of Croatian Q1 publications
40% of Croatian Horizon2020 funds
50% of Croatian Nature Index

PHYSICS
- Experimental physics
- Material physics
- Theoretical physics
- Electronics

CHEMISTRY
- Organic chemistry and biochemistry
- Material chemistry
- Physical chemistry

LIFE SCIENCES
- Molecular biology
- Molecular medicine

ENVIRONMENT
- Sea and environment

ICT
- Computer science

Center for sea research
RBI – leader in Croatia in all competitive projects

A significant additional funding from ESIF is expected by the end of 2017:
- Centres of excellence
- Contres of competence
- Horizon 2020 (ERA Chair, Twinning)

New projects, millions of Euros
Physics laboratories

hadronic spectroscopy
astroparticle physics
electromagnetic and weak interactions
high energy physics
hadronic physics
ion beam interactions
Low-level Radioactivities
nuclear analytical methods
nuclear physics
Experimental physics
Optoelectronics and Visualisation
Information Communication, Science and Technology

Laboratory for optics and thin films
Laser and Atomic Physics
Particle Physics and Cosmology
Solid State Physics
Theoretical and Mathematical Physics
Theoretical Physics
Molecular Physics
Semiconductors
Thin Films
Physics of Materials
Computational Biology and Bioinformatics
information systems
Stochastic Signals and Processes
Electronics
Computer Science
Nuclear structure and dynamics:
- exotic phenomena (pairing and clustering)
- structure of neutron-rich nuclei
- the reaction mechanisms at low energy
- the interaction between deformed and loosely bound nuclei
- the production mechanisms of neutron-rich nuclei

Nuclear astrophysics: carbon – carbon burning

COST Action CA16117
Chemical Elements as Tracers of the Evolution of the Cosmos
Exotic modes of clustering - nuclear molecules strongly bound clusters (α-particle) + weakly bound neutrons.

Reactions induced by weakly bound projectiles at energies around the Coulomb barrier.

Measurements at:
RBI, Zagreb
LNL - INFN, Padova
LNS - INFN, Catania
GANIL, Caen
IPNO, Orsay
TRIUMF, Vancouver
Oak Ridge National Lab

Equipment worth 1 M€
state-of-the-art detection systems: silicon + neutron + gamma detector arrays

vacuum chambers at RBI and INFN – LNL, Padova, Italy
Measurements at:
RBI, Zagreb
LNL - INFN, Padova
LNS - INFN, Catania
GANIL, Caen
IPNO, Orsay
TRIUMF, Vancouver
...
6 SSSD 65 μm + 6 SSSD 1500 μm Micron Semiconductor
Transfer reactions among heavy ions

✓ A study of multiple particle transfers.
✓ The transition from quasi elastic to deep inelastic processes.
✓ Production of neutron rich nuclei.
✓ A study of the residual interaction - correlations

A study of properties near shell closure:
✓ single particle states
✓ coupling of the particle/ hole to the collective boson

Nuclear Shell Structure

PRISMA+CLARA/AGATA set-up
Experiments (mostly CERN-based):
Energy frontier: CMS @ LHC (6 FTE)
Axion Search: CAST/IAXO (2.5 FTE)
NA61/SHINE: Heavy Ions/Hadron production (~ 1 FTE)
Neutrinos: OPERA (~ 1 FTE)
Astro photons: MAGIC/CTA (2-3 FTE)

Strengths:
• Impact in collaborations both in physics output and detector operations
• Excellent network of international collaborations

Weaknesses:
• Fragmentation (small groups)
• Too little work on instrumentation
Astrophysics @ RBI

recently hired young returnee group in forming phase
main activity LOFAR

RBI recently joined LSST
recruitment of new staff
other groups support
ION BEAM ANALYSIS (characterisation)

**ANALYSIS** (elements, isotopes) with **MeV ION BEAMS** - (nA, pA)
- elements - x-rays (**PIXE**)
  - backscattering (**RBS**)
  - recoil (**ERDA**)
- isotopes - nuclear reactions
  - γ - rays (**PIGE**)
  - particles (**NRA**)

**CHARACTERISATION** (density, charge transport, crystal structure, morphology,…) with **MeV SINGLE IONS** - (fA)
- density - transmitted ions (**STIM**)
- charge transport - charge pulse (**IBIC**)
- crystal structure - **channelling**
- morphology - secondary electrons (**SEI**)
ION BEAM ANALYSIS & NUCLEAR MICROPROBE

IDEAL RADIATION SOURCE (FOR DETECTOR TESTING - IBIC)

1. IONS
   - p, α, Li, C, O,..

2. ION RATE
   - Currents 1 - 10⁹ p/s

3. RANGE (E)
   - from 1 to 500 μm

4. ION POSITION
   - focusing and scanning

Frontal IBIC

Lateral IBIC
LOCAL ACCELERATOR COMPLEX – LARGEST EXPERIMENTAL COMPLEX IN CROATIA

Only TNA lab in Croatia
Only ERIC in Croatia
Center of excellence for advanced materials and sensors

synthesis of advanced materials and structures, particularly those that can be applied in other domains of basic and applied science

a) photonics and quantum optics,
b) graphene and related 2D structures
c) new functional materials
d) ion beam physics and technology.

Expect perhaps 5 million Euros, starting 2017
Open Scientific Infrastructural Platform For Innovative Applications in The Economy And Society: O-ZIP

60 million Euro project that will enable the Croatian industry to be based on science and innovation

Part of the Operational programme 2014 - 2020

BIOMEDICINE

ENVIRONMENT AND SEA

ADVANCED MATERIALS/ RADIATION TECH.

ICT

Basis for a brain gain to RBI and all of Croatia
H2020 ERA Chairs

H2020 Spreading Excellence and Widening Participation

„... assistance and expertise is needed for low performing Member States to improve their research and innovation systems ...“

„... those pockets of excellence to enter and remain on the framework programmes grid...“

„... Horizon 2020 introduces specific measures for spreading excellence and widening participation through engaging those who could commit more towards the EU research and innovation effort. This will greatly enhance competitiveness.“
H2020 ERA Chairs

**ERA Chairs**

„...will bring outstanding researchers to research organisations that have high potential for research excellence.”

„... institutions should mobilise support from different funding sources, including from the European Structural and Investment Funds, to invest in facilities and infrastructures in the context of Smart Specialisation Strategies ...”

„... will support eligible research organisations to attract and maintain high quality human resources and implement the structural changes necessary to achieve excellence on a sustainable basis.
H2020 ERA Chairs

*Results of the 1*st* Horizon 2020 ERA Chairs call*

88 submitted proposals, 41 above the threshold (10/15)
13 projects funded – success rate 15%

**Country**
- Croatia 1
- Cyprus 2
- Estonia 3
- Poland 2
- Portugal 4
- Romania 1

**Research field**
- Chemistry & Physics 3
- Environment 2
- Mathematics & Engineering 1
- Life sciences & medicine 5
- Economy & Social sciences 2

PaRaDeSEC: 13
Excellence: 4.5
Impact: 4.0
Implementation: 4.5
PaRaDeSEC

Expanding Potential in Particle and Radiation Detectors, Sensors and Electronics in Croatia

Research in particle, astro-particle & nuclear physics, nuclear astrophysics and interdisciplinary research (ion beams, radiation)
PaRaDeSEC

Large, complex and expensive scientific equipment

Institutions significantly contributing to development & construction of equipment have large impact & reputation

Large international collaborations – scientists, engineers, technicians – multidisciplinary approach

Large investments needed – returned by increased innovations, new technologies & knowledge transfer to economy

RBI researchers actively involved in international collaborations, their contribution recognized, but minor RBI contribution to development & construction of equipment

Strengthening RBI impact & reputation and increasing research quality ↔ development & construction of detectors, sensors & electronics – **Center for detectors, sensors & elektronics - CDSE**

- Contribution to international collaborations + strengthening local accelerator and other facilities
PaRaDeSEC

Center: equipment, staff, knowledge & experience are needed

- Large number of smaller international projects: IAEA, FP6, FP7
- The most important FP7 REGPOT project Particle detectors - „Upgraded Facility for Development of Silicon and Diamond Particle Detector Systems“ funded by EC with 1.32 M€
- RBI is multidisciplinary institution: all required scientific fields for development & construction of these equipment for fundamental & interdisciplinary research & applications
- RBI implements significant structural changes following practice and regulations of the best scientific institutions in Europe
PaRaDeSEC

Structural changes objectives

- larger impact & reputation in international research community
- more innovations & knowledge transfer to economy
- increased research quality
- multi & interdisciplinary research approach

Increased RBI impact on society
PaRaDeSEC

Employ at RBI excellent world expert in the research field as Center & project leader, 4 world experts for a core team

Strengthen RBI position in international research community

Strengthen RBI role in realization of nacional smart specialization strategy (O-ZIP) & speed up structural changes at RBI

Enlarge RBI capacities for multi-disciplinary applications & transfer of knowledge & experience to economy

Project objectives
### PaRaDeSEC

**Funding EC 2 434 500 €, total 2.7 M€**

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<tr>
<th>Aim</th>
<th>Amount €</th>
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<tr>
<td>Staff</td>
<td>1 544 000</td>
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<tr>
<td>Equipment</td>
<td>200 000</td>
</tr>
<tr>
<td>Knowledge &amp; experience transfer, education of young researchers, dissemination</td>
<td>296 000</td>
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<tr>
<td>Other expenses, dissemination, communication, science popularisation</td>
<td>124 000</td>
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<td>Indirect expenses</td>
<td>541 000</td>
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PaRaDeSEC

Related projects

- RBI proposal for EU structural funds O-ZIP “Open scientific infrastructural platforms for innovative applications in economy and society” listed in Operational program competitiveness & cohesion (60 M€)

- RBI+IF scientific Center of excellence for advanced detectors & sensors CEMS – structural funds (5 M€)

- H2020 project AIDA2 Advanced European Infrastructures for Detectors at Accelerators

- H2020 project EuroFusion European Consortium for the Development of Fusion Energy

- CERIC - Central European Research Infrastructure Consortium

- At the moment eight national research projects (HrZZ)

- H2020 Twinning projekt RBI-T-WINNING theoretical physics

- NATO SPS project E-SICURE
RBI will through CDSE work on development of the new generation of detectors & sensors for CERN (new 3D pixel detectors)
The largest H2020 project (≈ 850 M €)

RBI is the project partner (≈ 473 K €)

Involved in work packages:

- WP PFC (Plasma facing components for ITER and DEMO)
- WP JET2 (Plasma facing components at JET tokamak)
- WP MAT (Fusion materials)
- WP EDU (Education)
- Fusion materials testing
- Research on plasma erosion of material
- Material resistance to fast neutrons
- Functional and other materials

JET (Joint European Torus, UK)
3D diamond
Efficiency and current transient structure in time
with Alex Oh, University of Manchester, UK

Interstrip region - DSSSD
Investigation of reverse polarity pulses with INFN, IT

HADES
- radiation damage in start CVD diamond det.
with J. Pietraszko, GSI

CCE reduced to 0 due to polarization

DOI - diamond on iridium & polarization
University of Augsburg & GSI, D
with E. Berderman
PaRaDeSEC

Project impact

Formation of sustainable Center for detectors, sensors & electronics, independent RBI unit which will continue its work after the project end

Organisation and working environment at RBI similar to ones at the best scientific institutions in Europe

Improved research quality in particle, astroparticle, nuclear and applied physics

Realisation of national smart specialization strategy

Improved research quality in multi- and inter-disciplinary research, knowledge & technology transfer to economy
CDSE - Center for detectors, sensors & electronics

Independent RBI unit collaborating with other organisational units

National center for development of particle & radiation detectors, sensors for research & applications and associated electronics

CDSE will be open facility collaborating with all stakeholders in science, education, national & local administration & industry

Partners: PMF & FER UniZ, IF, all university units in related subjects, high-tech companies

CDSE will enable larger and higher quality utilisation of EU funds from Horizon 2020 & ESIF
### What was crucial for the success?

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<th><strong>Excellence</strong></th>
<th><strong>Impact</strong></th>
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<td>Good international scientific relevance and reputation</td>
<td>Well demonstrated enhancement of the RBI capabilities</td>
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<tr>
<td>Well adjusted objectives</td>
<td>Well described positive impact on research level – both basic and applications</td>
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<tr>
<td>Clear and concise SWOT analysis</td>
<td>Well described contributions to the objectives of national S3</td>
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<td>Credible and realistic action plan for structural changes</td>
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<th><strong>Implementation</strong></th>
<th><strong>European Structural Funds</strong></th>
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<td>Large experience from previous FP projects</td>
<td>Well explained relation with the O-ZIP project &amp; national S3</td>
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<td>Effective and properly presented work plan</td>
<td>Success of the O-ZIP proposal</td>
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<td>Coherence between SWOT analysis and work plan</td>
<td>Involvement in a number of other proposal for ESF</td>
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*PaRaDeSEC is not isolated project, it is an important part of the RBI strategy*
PaRaDeSEC team

Project start: 01. 07. 2015.
Era Chair employed: 01. 04. 2016.
Jaakko Härkönen (born 1972, PhD 2001.) silicon detector technology & applications of the semiconductor radiation detectors in various research fields, CMS silicon upgrade, around 100 publications in peer-reviewed journals on semiconductor processing, High Energy Physics instrumentation, semiconductor material characterization and radiation hardness of silicon detectors.

ERA Chair team: 4 researchers
- Andrey Starodumov (b. 1962, PhD 1995) empl. 04. 2017, CMS Silicon pixel detector upgrade, test & calibration procedures development, quality control & assurance in CMS Phase 1 upgrade
- Valery Chmill (b. 1963, PhD 2006), empl. 05. 2017, R&D studies on new silicon based photo-detectors (SiPM)
- Matti Kalliokoski (b. 1979, PhD 2012), emp. 11. 2017, development and optical quality assurance of GEM & Si detectors
Resources at Ruđer Bošković Institute

- Purchased basic R&D infrastructure
  - Wire bonder
  - Probe station
  - Parameter analyzer up to 500V
  - Scanning TCT setup
- We already have
  - Accelerator lab
  - Gamma irradiation facility
  - Neutron generator
- At RBI material physics and chemistry sections
  - Large selection of spectroscopic tools (PL, DLTS, Raman etc)
Partners and international collaboration

- CMS group of Helsinki Institute of Physics (HIP)
- Ioffe Polytechnical Institute (PTI)
- Center for Semiconductor Detectors (ZXMD) of University of Xiangtan (XTU)
- Many groups with CERN RD50
- Micronova facility in Espoo, Finland.

SnPb solder bumps on CMS pixel ROC

Jaakko and Zheng Li in Xiangtan October 8th 2016

Detector wafers coming out of furnace in Micronova clean room
Research interests and on-going projects – small pixels
Pixels for X-ray and neutron detection

- Applications:
  - Nuclear safety
  - Medical imaging
  - Neutron spectroscopy
  - CdTe Pixel detector, 4000 pixels in 1cm²
  - Flip Chip bonded into CMS (PSI46dig) CMOS ASIC
  - Read-out at 40MHz
Applications of Atomic Layer Deposition for radiation detectors

- Electron accumulation termination by negative oxide charge
- Thin film metal bias resistors
- Surface and edge passivation of CdTe
Current collaborations

Silicon Pixel detectors: PSI, Villingen, ETH Zurich

Diamond membranes: various applications, CEA (F), JAEA (Japan)

Figure 7. The ROC pixel detector is placed in front of the nozzle extracting the 2 MeV proton beam in air (left). Very first results collected by pixel detector using proton 2 MeV beam in air (right).

Current collaborations

FP7 projects: Particle Detectors SPIRIT

Bilateral with Japan

Diamond membranes: various applications, CEA (F), JAEA (Japan)

- dosimetry
- thin transmission detector
- battery