

National Laboratory of Cyclotrons: a two-center (Krakow-Warsaw) facility in Poland

Warszawa



Kraków



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Krakow, Poland*



COMEX5 International Conference
September 14-18, 2015
Kraków, Poland

Brief history of cyclotron laboratories in Poland

Kraków

| | | |
|-------------|------------------------------------|--|
| 1956 | Cyclotron U-48 (home built) | – <u>Henryk Niewodniczański</u> , Jagiellonian University |
| 1958 | Cyclotron U-120 | – Institute of Nucl. Phys. (IFJ) |
| 1988 | Cyclotron AIC-144 | – Institute of Nucl. Phys. (IFJ) |
| 2012 | Cyclotron PROTEUS C-235 | – CCB Institute of Nucl. Phys. PAN |

Warsaw

| | | |
|-------------|-------------------------|---------------------------------|
| 1998 | Cyclotron U-200P | – Heavy Ion Lab. Univ of Warsaw |
|-------------|-------------------------|---------------------------------|

National Laboratory of Cyclotrons (NLC)



created in 2011

Warszawa

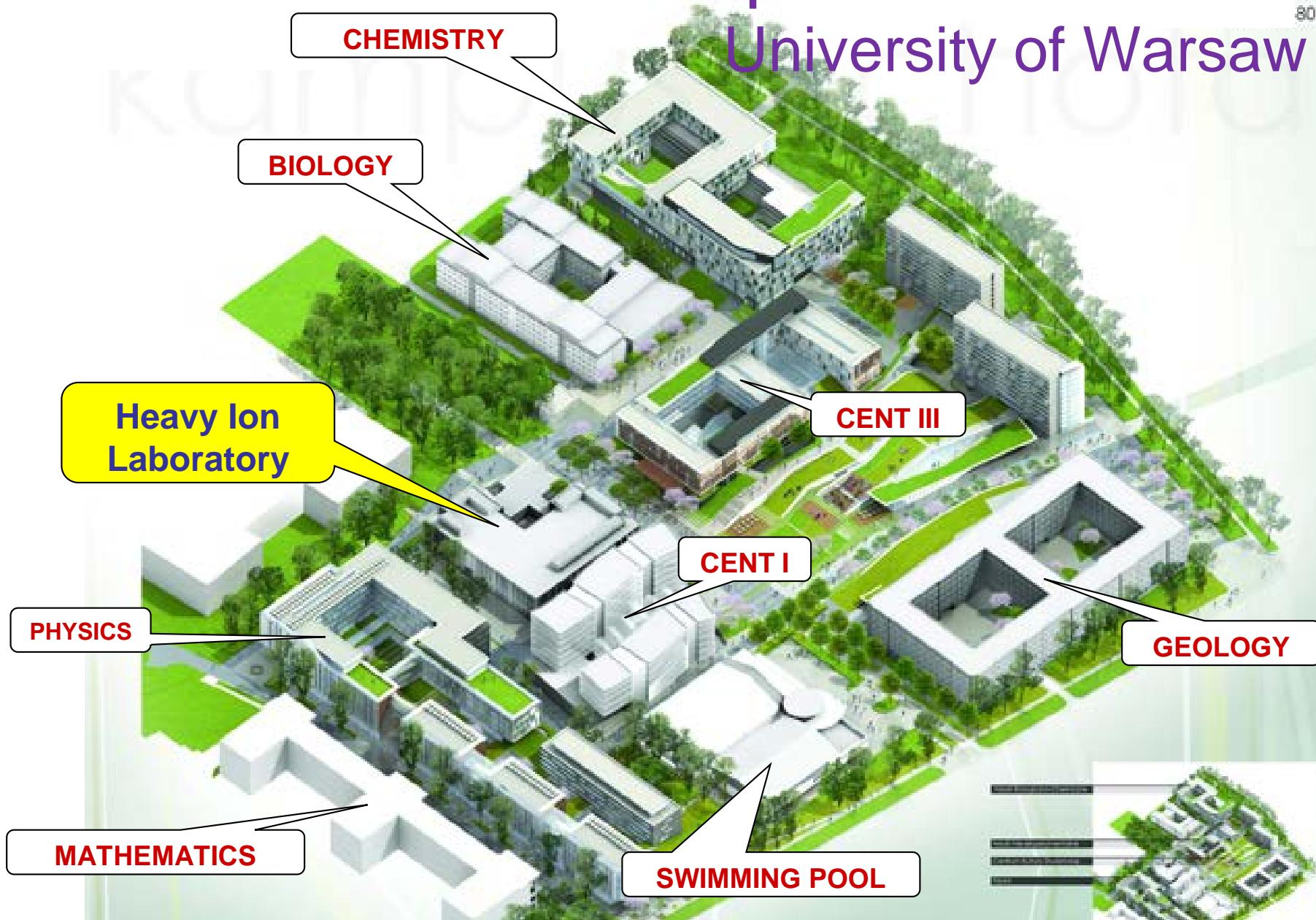
Kraków



Scientific Campus Ochota

University of Warsaw

80





Heavy Ion Laboratory, University of Warsaw (HIL UW)



(Środowiskowe Laboratorium Ciężkich Jonów – **SLCJ**)

(courtesy of Krzysztof Rusek and Jerzy Jastrzębski)





Heavy Ion Laboratory, University of Warsaw



Staff

Scientists – 13 (physicists and chemists)

PhD students – 7

Technicians – 35

Administration - 8



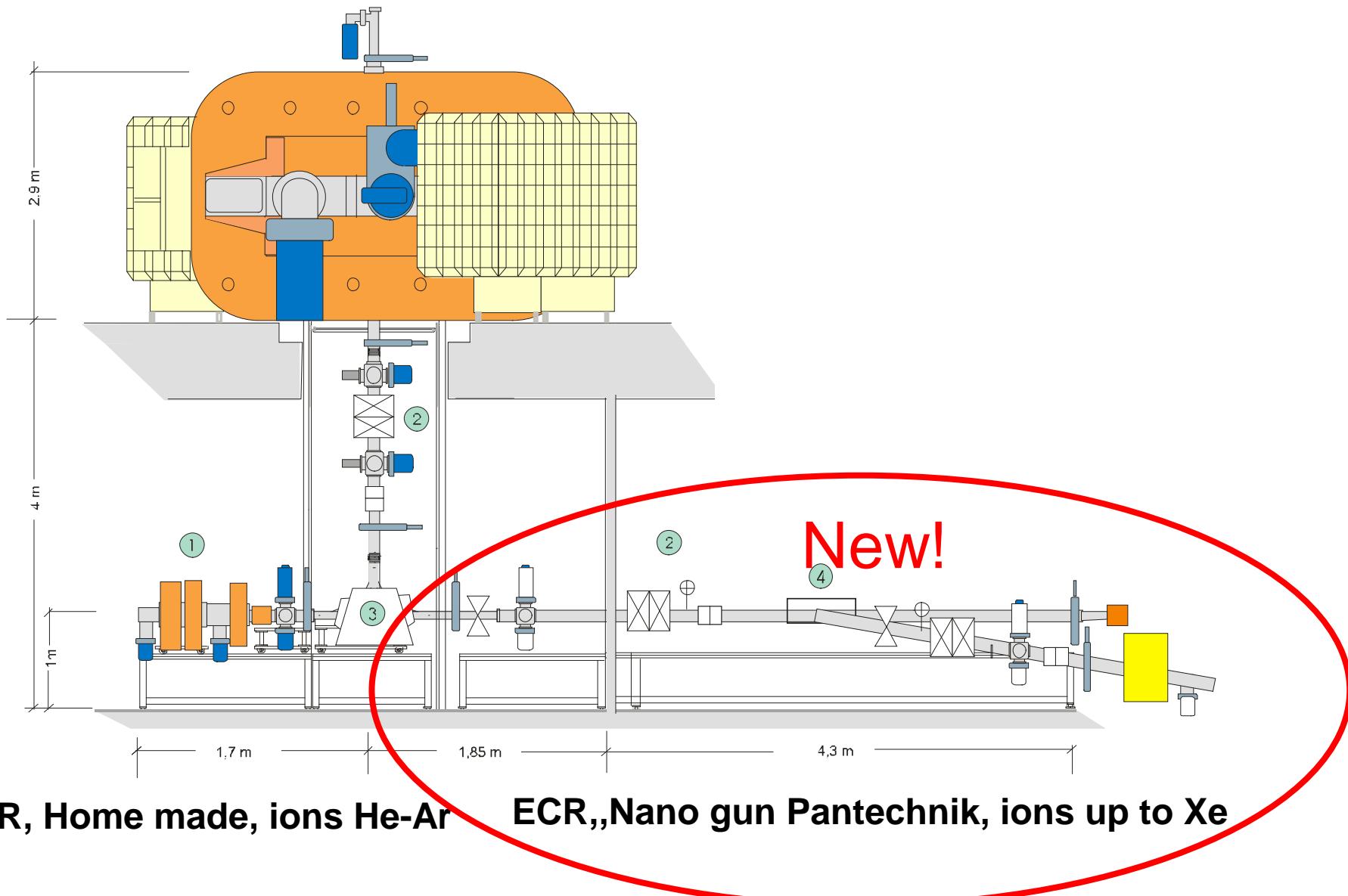
Cyclotron U-200P at HIL UW in operation since 1994



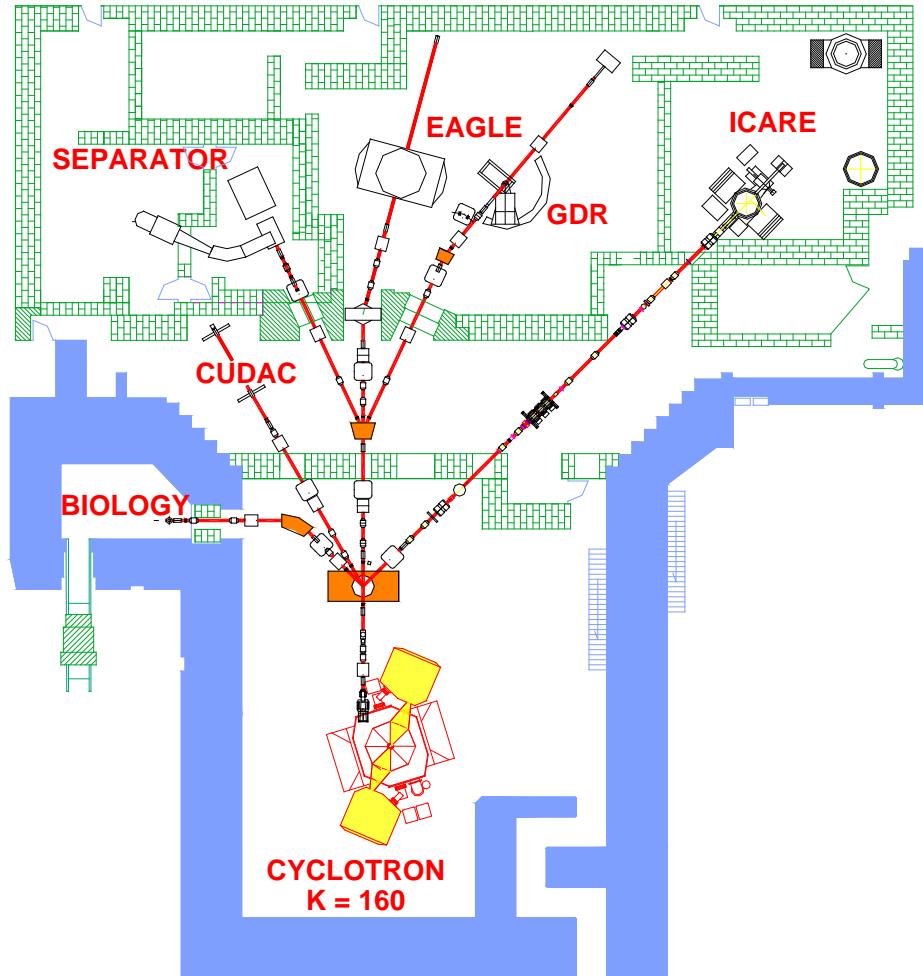
Isochronous cyclotron

- diameter 200 cm; $K_{\max}=160$
- ion sources: ECR, 10 GHz, 14 GHz
- beams from He to Xe;
- energy range 2 – 10 MeV/nucl.

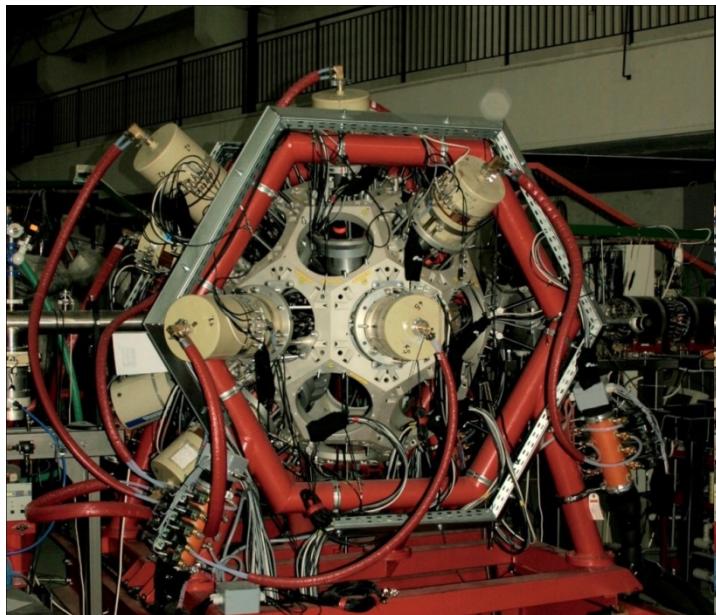
Cyclotron U-200P and ion sources



Detector systems at HIL UW



Central European Array for Gamma Levels Evaluations EAGLE γ -ray spectrometer



EAGLE can host
up to 30 HP Ge detectors

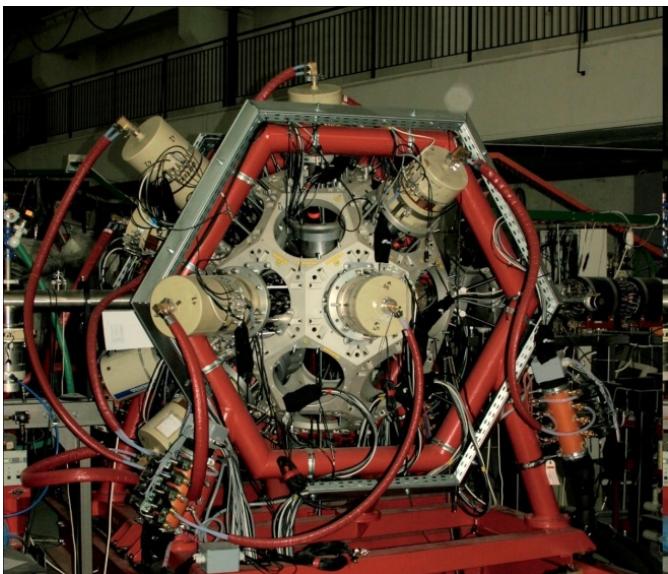
EAGLE can be coupled with:

- ◆ Internal conversion electron spectrometer ULESE
- ◆ Bucharest-Köln Plunger
- ◆ 60-element BaF₂ gamma-ray multiplicity filter
- ◆ Scattering chamber with 100 PIN-diode charged particle detectors
- ◆ 4 π charged particle multiplicity filter (Si-ball)

In 2012 – 2013 EAGLE was equipped with 20 GAMMAPOOL detectors from IPN Orsay

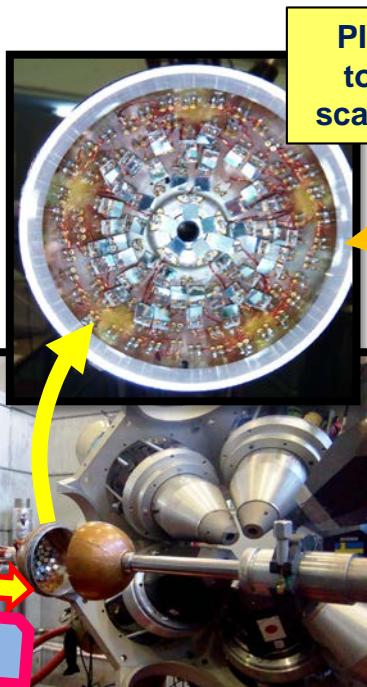
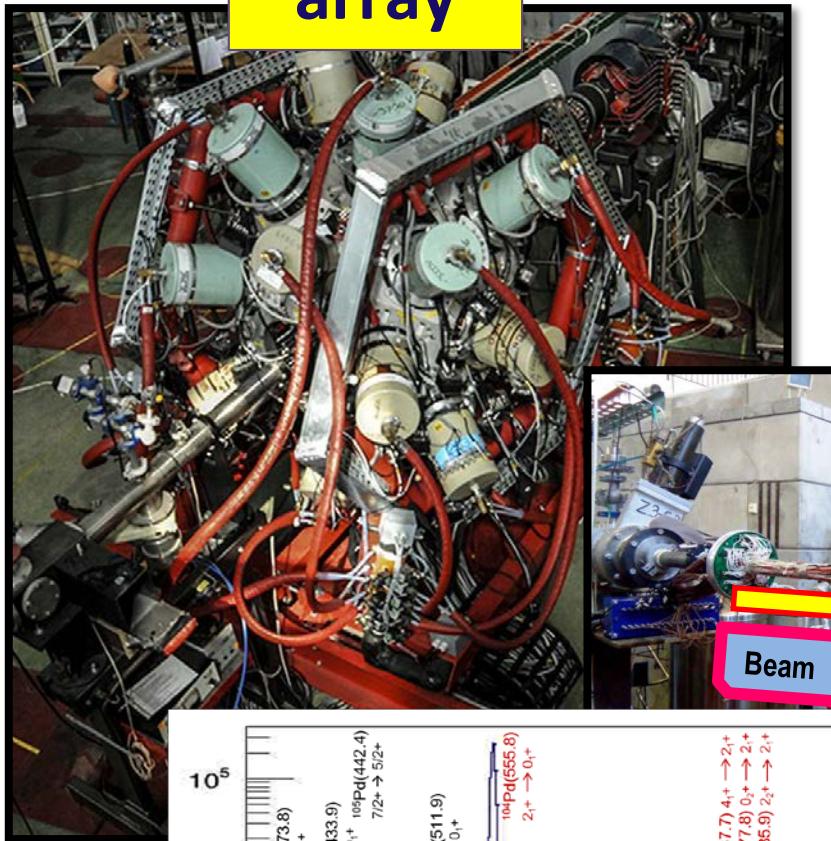
Research program with EAGLE

- **Search for chiral symmetry breaking by DSAM and RDDS (^{132}La , $^{122,124,126,128}\text{Cs}$)**
- **Non-spherical and non-axial shapes by using COULEX (e.g., $^{96,98,100}\text{Mo}$, ^{104}Pd , ^{110}Cd)**
- **Violation of K-selection rules by gamma and internal conversion electron spectroscopy (^{132}Ce , ^{130}Ba , ^{134}Nd , ^{184}Pt , ^{186}Hg)**
- **Spectroscopy of ^{42}Ca produced in the $^{12}\text{C}(^{32}\text{S},2\text{p})^{42}\text{Ca}$ reaction**
- **Lifetimes of low spin levels in ^{140}Sm**

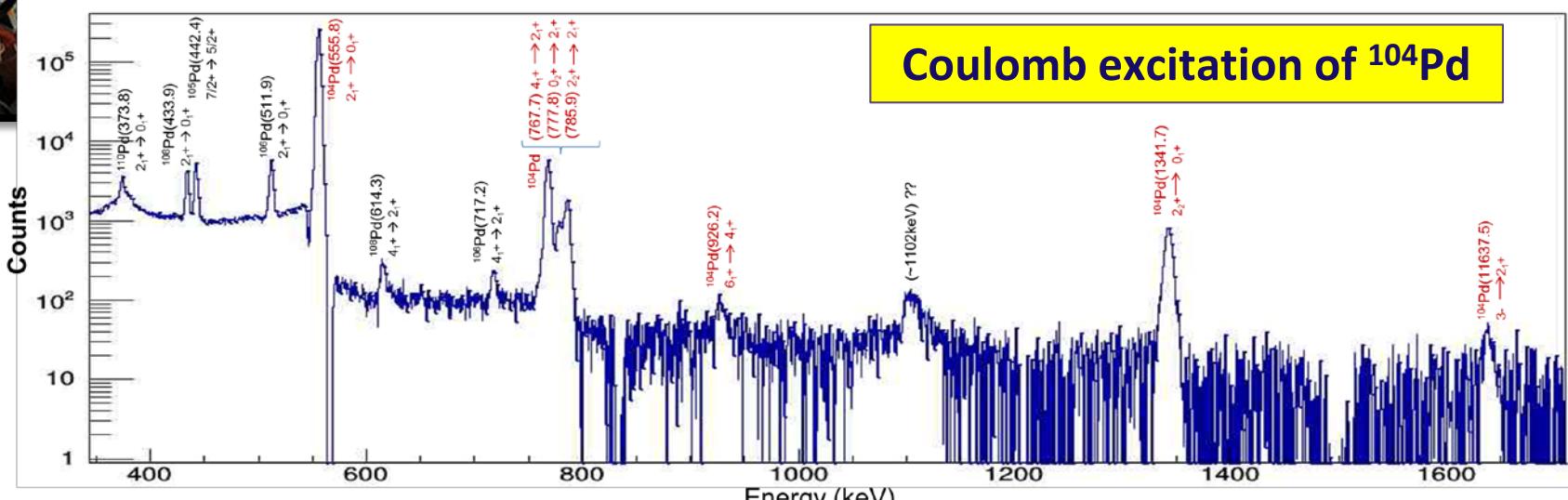
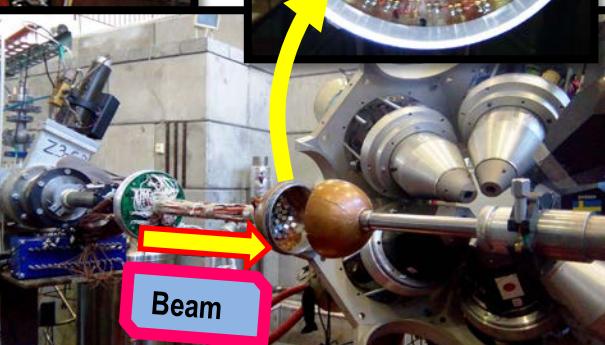


EAGLE array

$^{32}\text{S}(91 \text{ MeV}) + ^{104}\text{Pd}$

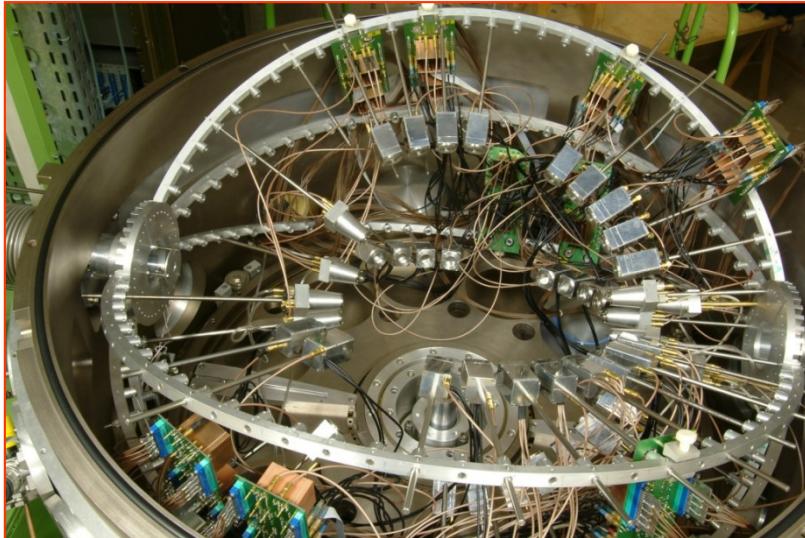


PIN-Diode array
to detect back-
scattered particles



Charged particle detector system **ICARE**

Moved from IReS Strasbourg - first experiments in 2007

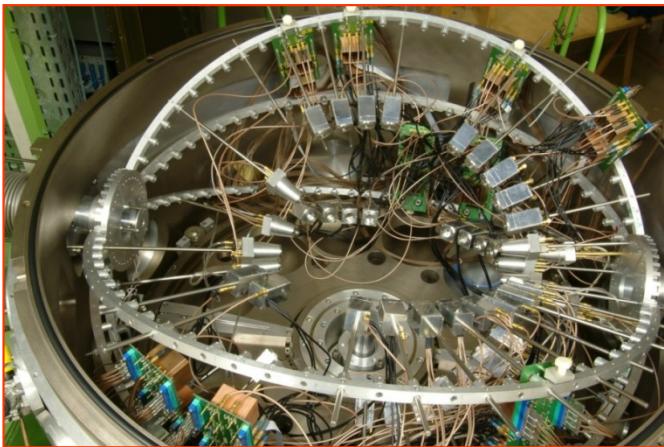


8 telescopes
 $\Delta E(\text{gas}) + E(\text{Si})$

24 telescopes
 $\Delta E(\text{Si}) + E(\text{CsI})$

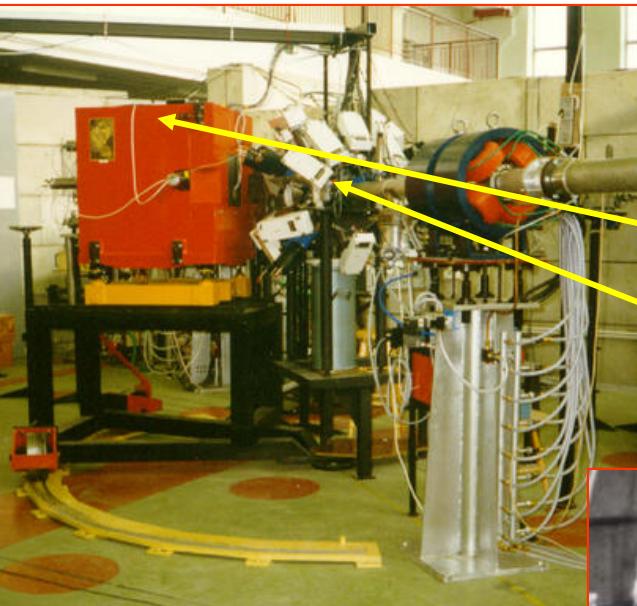
16 telescopes
 $\Delta E(\text{Si}) + \Delta E(\text{Si}) + E(\text{CsI})$

Research program with ICARE



- **Studies of fusion barriers height distribution**
- **Investigations of reactions with light nuclei**
- **Reactions of astrophysical interest**

Other detection systems at SLCJ

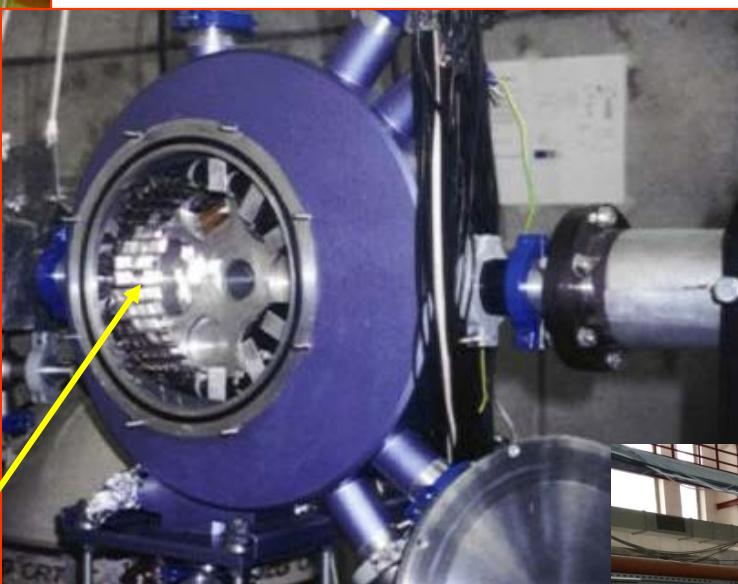


JANOSIK

for detection of high-energy
gamma rays

CUDAC

PIN-diode charged
particle detector array



- Ion source
- Helium jet
- Mass separator
- Detection system



HIL UW as an User Facility

~ 90 users per year
- national (60%)
- foreign (40%)

~ 3000 hours of beam time per year
~ 70% for nuclear physics experiments

Beam time is allocated by the SLCJ Director based on the recommendation of the International Program Advisory Committee

PAC Members:

Dimitar Balabanski (Univ. of Sofia, Bulgaria)

Konrad Czerski (Univ. of Szczecin, Poland)

Piotr Bednarczyk (IFJ PAN)

Gilles de France (GANIL, Caen, France)

Zenon Janas (Univ. of Warsaw, Poland)

Nicholas Keeley (NCBJ, Poland)

Rainer Lieder (Univ. of Bonn, Germany)

Piotr Magierski (Warsaw University of Technology, Poland)

Leszek Próchniak (Maria Curie-Sklodowska Univ., Poland)

Brunon Sikora (Univ. of Warsaw, Poland)

Wladyslaw Trzaska (Univ. of Jyväskylä, Finland)

Applications

Isotopes production for medical use at the K=160 cyclotron



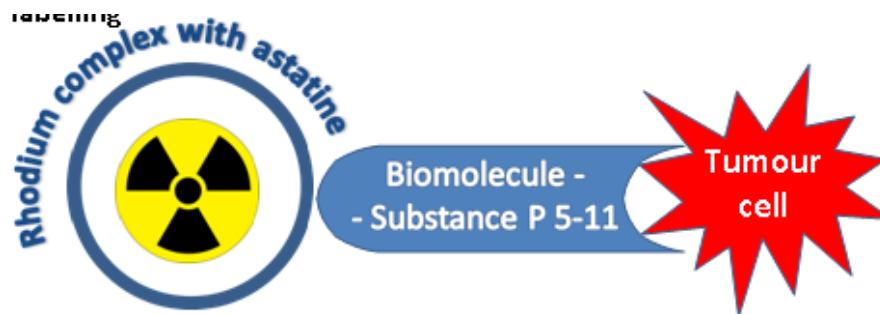
internal target station

Radioisotopes presently investigated

- ^{211}At with the reaction $^{209}\text{Bi}(\alpha,2n)$;
 $^{40}\text{Ca}(\alpha,n)$;
- ^{43}Sc
 $^{42}\text{Ca}(d,n)$;
 $^{42}\text{Ca}(\alpha,2n)$;
 $^{44}\text{Ca}(p,n)$;
- ^{44}Sc
 $^{70}\text{Ge}(\alpha,2n)$;
- $^{72}\text{Se}/^{72}\text{As}$
 $^{100}\text{Mo}(p,2n)$.
- ^{99m}Tc

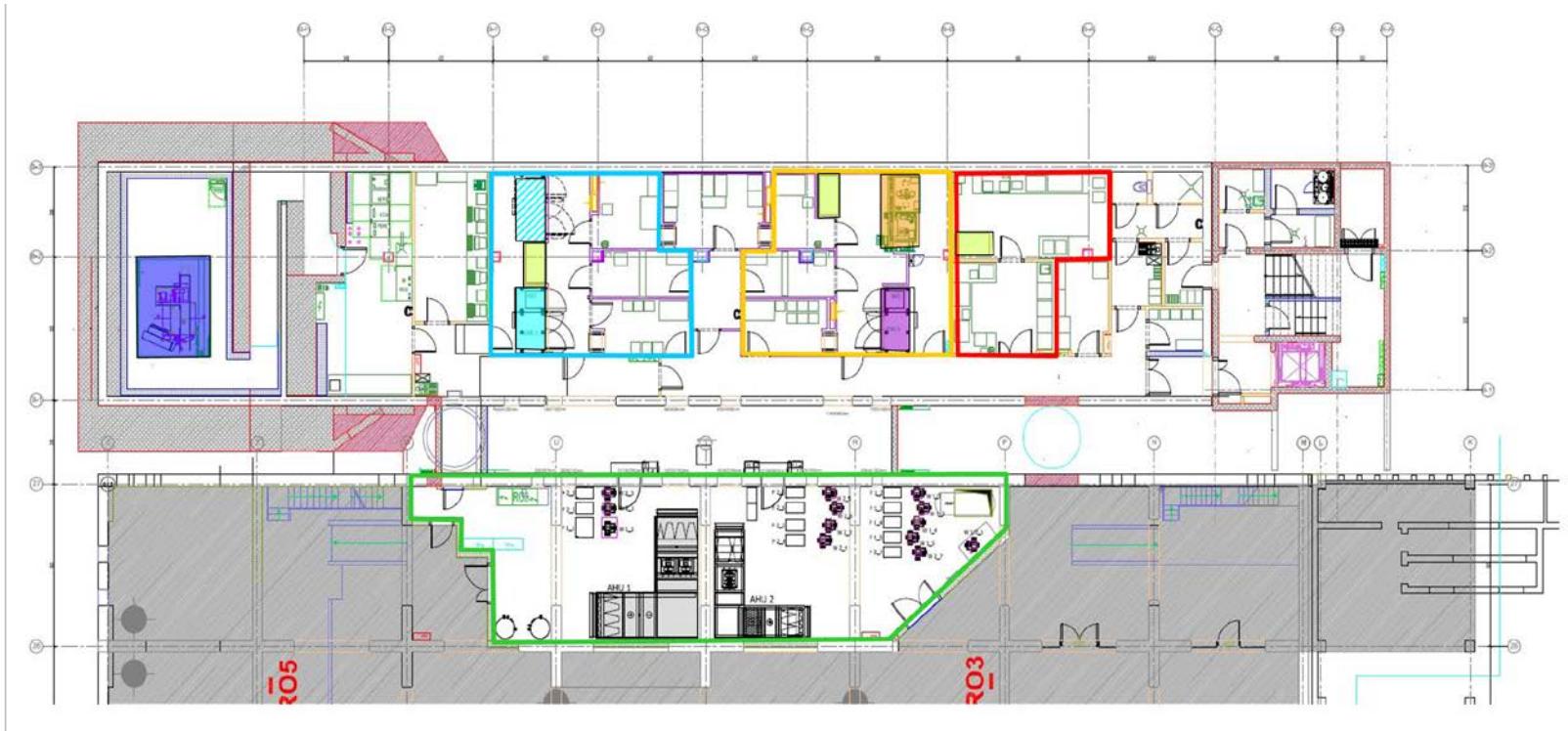
Targeted Alpha Therapy (TAT)

^{211}At (7h) produced in $^{209}\text{Bi}(\text{alpha},2\text{n})^{211}\text{At}$ at 30 MeV bombarding energy, extracted and bound a peptide with high affinity to the receptors of glioma cancer cells



Radiopharmaceuticals Production and Research Center (RPRC) at Heavy Ion Lab. UW

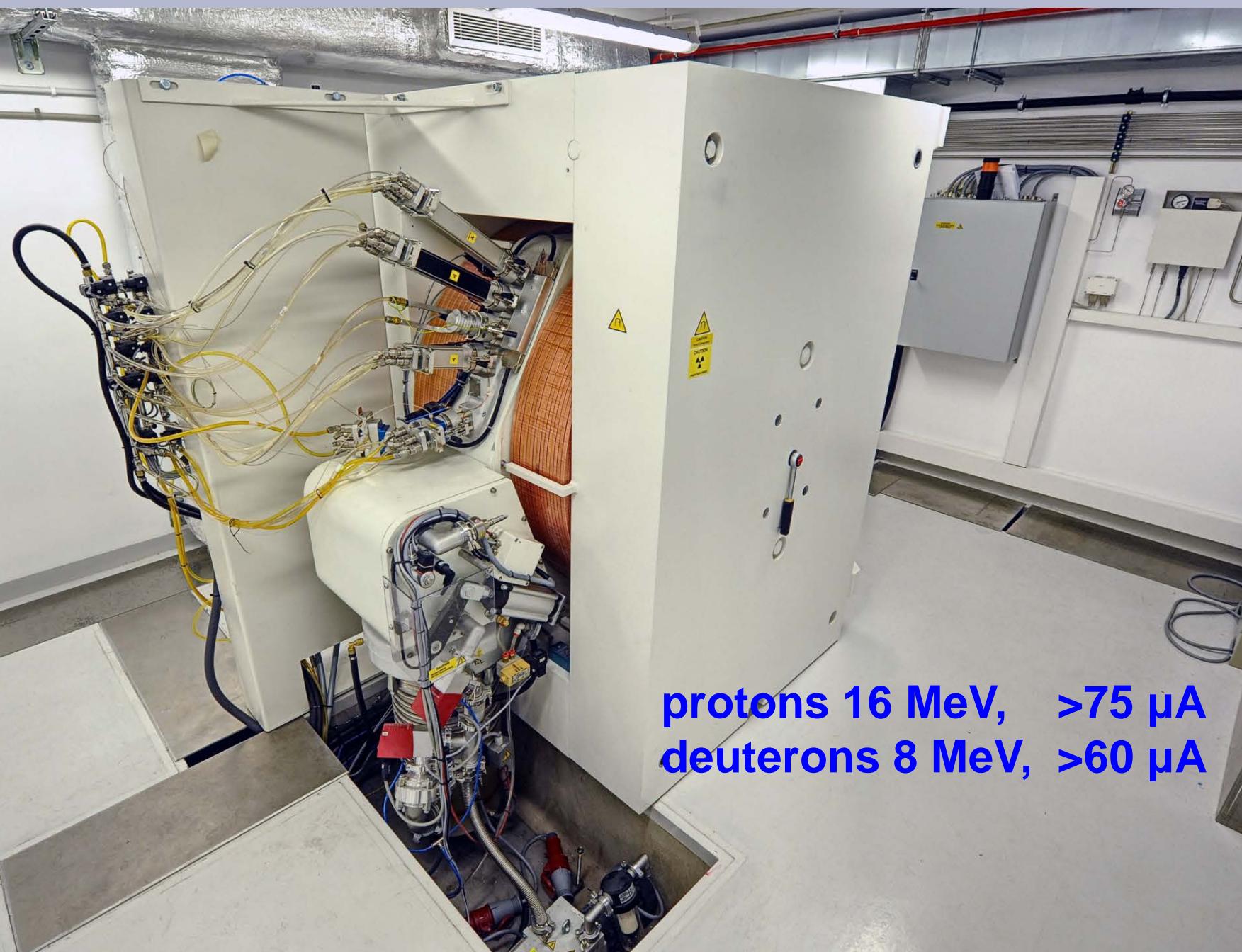
Opened 15.05.2012



Layout of the Radiopharmaceuticals Production and Research Centre

Production of radioisotopes for
the Positron Emission Tomography:
 ^{18}F , ^{11}C , ^{15}O

PETtrace high current medical cyclotron, K=16.5 GE



**protons 16 MeV, >75 μ A
deuterons 8 MeV, >60 μ A**

Education

- Teaching the UW students
- International Workshops on Acceleration and Applications of Heavy Ions, duration: two weeks, 2011, 2012, 2013
- Summer School on Acceleration and Applications of Heavy Ions, duration: one week, 2012, 2013
- Polish Workshops on Acceleration and Applications of Heavy Ions, duration: one week, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014





Heavy Ion Laboratory, University of Warsaw

- National nuclear physics laboratory
open for external users
- Involved in teaching
- Developing medical applications

More on: www.slcj.uw.edu.pl

National Laboratory of Cyclotrons



created in 2011



Kraków



The Henryk Niewodniczański Institute
of Nuclear Physics,
Polish Academy of Sciences
Kraków, Poland





The Henryk Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences Kraków, Poland

Founded in 1955

Now:

~500 employees: ~210 scientists: 50 full prof., 40 assoc. prof., 120 researchers

6 divisions / 27 departments

International PhD School: ~90 students

Main Research Fields:

Particle physics

Nuclear physics

Solid state physics

Applications

Status:

IFJ PAN has the status of „Centre of Excellence in Physics in Poland”

(consortium with UJ, AGH and IFPiK) – only one in Poland

and

highest category among research institutions in Poland A+

Creation of the Cyclotron Center Bronowice (CCB) at IFJ PAN

Phase I of the National Center for Hadron Radiotherapy



European Structural Funds

UNIA EUROPEJSKA
EUROPEJSKI FUNDUSZ
ROZWOJU REGIONALNEGO



Cyclotron Center Bronowice (CCB)

March 2011 Just before the start



Cyclotron Center Bronowice (CCB)

April 2011



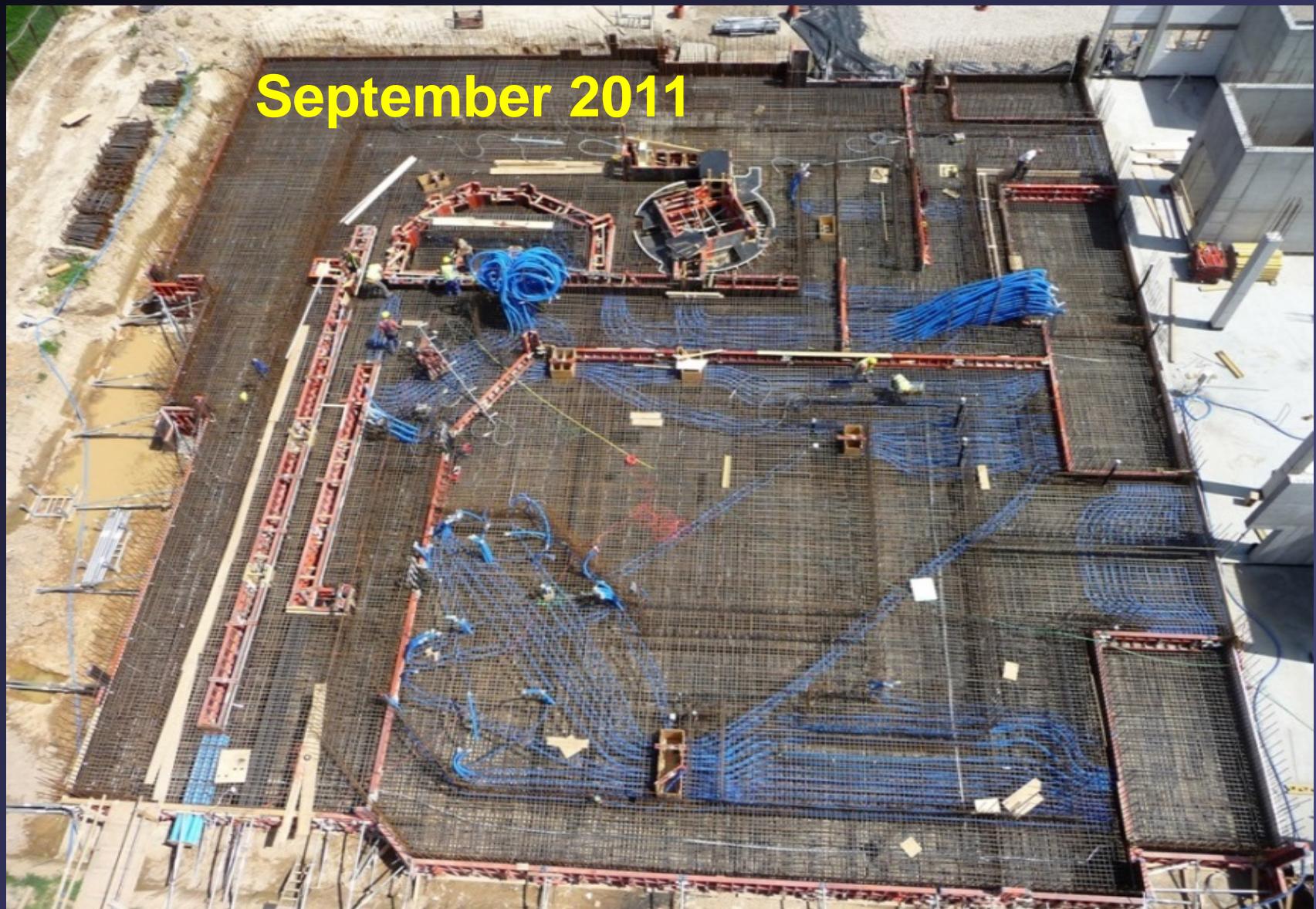
Paweł Olko

Magdalena Zydek

Marek Jeżabek

Adam Maj

Cyclotron Center Bronowice (CCB)



Cyclotron Center Bronowice (CCB)

February 2012



Cyclotron Center Bronowice (CCB)



September 2013

Cyclotron Center Bronowice (CCB)



September 2014

Cyclotron Center Bronowice (CCB)

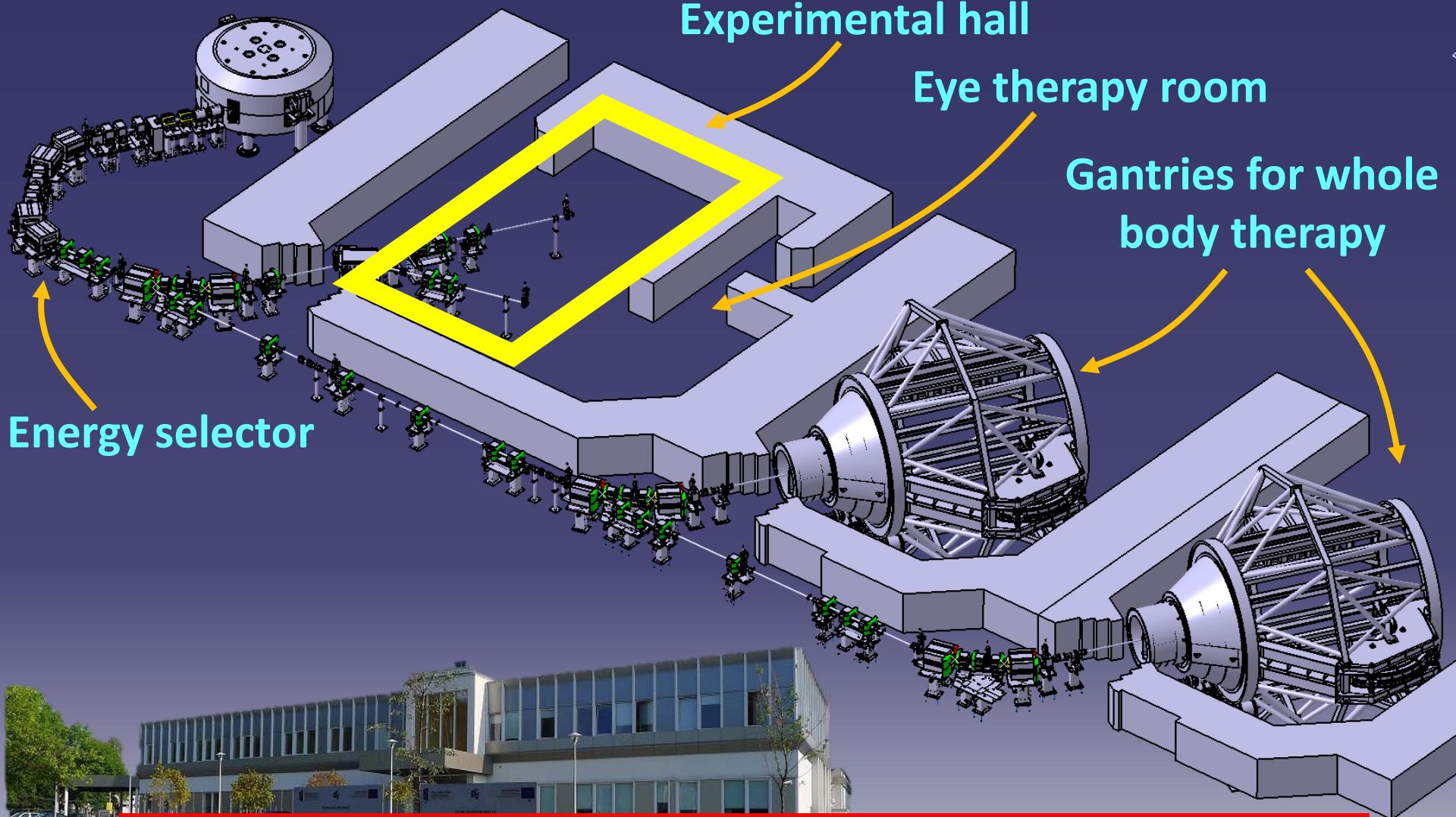
**Cyclotron PROTEUS C-235 (IBA Company)
commisioned in December 2012**

beam: protons 70 – 230 MeV, $\Delta E/E < 0.7\%$
beam current: 0.1 nA - 500 nA

Although the primary objective of the facility is **proton cancer therapy**, extensive research program at this cyclotron has been prepared in the field of **nuclear physics, radiobiology, dosimetry and medical physics**.

Cyclotron
PROTEUS-235

Layout of the beam delivery at CCB



Total cost (buildings, cyclotron, eye therapy room, 2 gantries): 62 M€
(85%: EU, 15%: PL)

Research at CCB

(Coordinator: Adam Maj)

Users Board

Chair: S. Kistryn

International Advisory Committee

Chair: M. Harakeh

Experimental Program Committee

(Coordinator: M. Kmiecik)

Electronics and Data Acquisition Group

(Coordinator: M. Ziębliński)

Infrastructure Group

(Coordinator: M. Ziębliński)

Institutions involved in research at CCB

Foreign institutions

- University of Milano,
- IPN Orsay,
- GANIL
- LNL Legnaro/Padova,
- KVI Groningen,
- Physikzentrum RWTH Aachen,
- ATOMKI Debrecen,
- RIKEN
- IPHC Strasbourg
- IEM CSIC of Madrid

- Univ. of Santiago di Compostela
- Tech. Univ. of Munich
- Nigde Univ., Turkey
- IFIN-HH Bucharest
- JINR, Dubna,

Polish institutions

- IFJ PAN
- Jagiellonian University (UJ),
- University of Silesia (US),
- University of Warsaw (UW)

Research at CCB

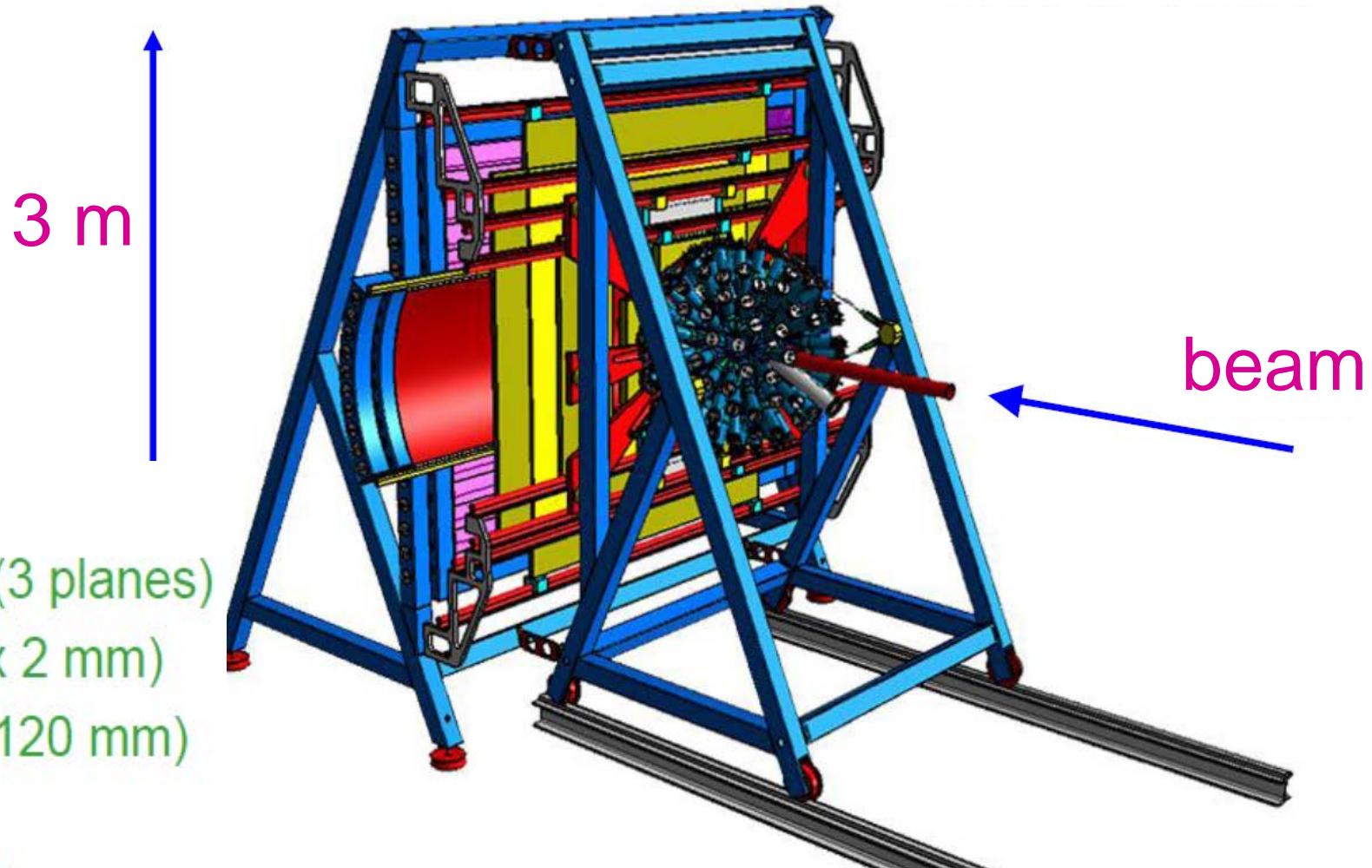
CCB International Advisory Committee



Detection systems at CCB

Big Instrument for Nuclear reaction Analysis (BINA)

Moved from KVI to Krakow : Stanisław Kisztyn,
IF UJ, Krakow



Wall:

- MWPC (3 planes)
- ΔE (24 x 2 mm)
- E (20 x 120 mm)

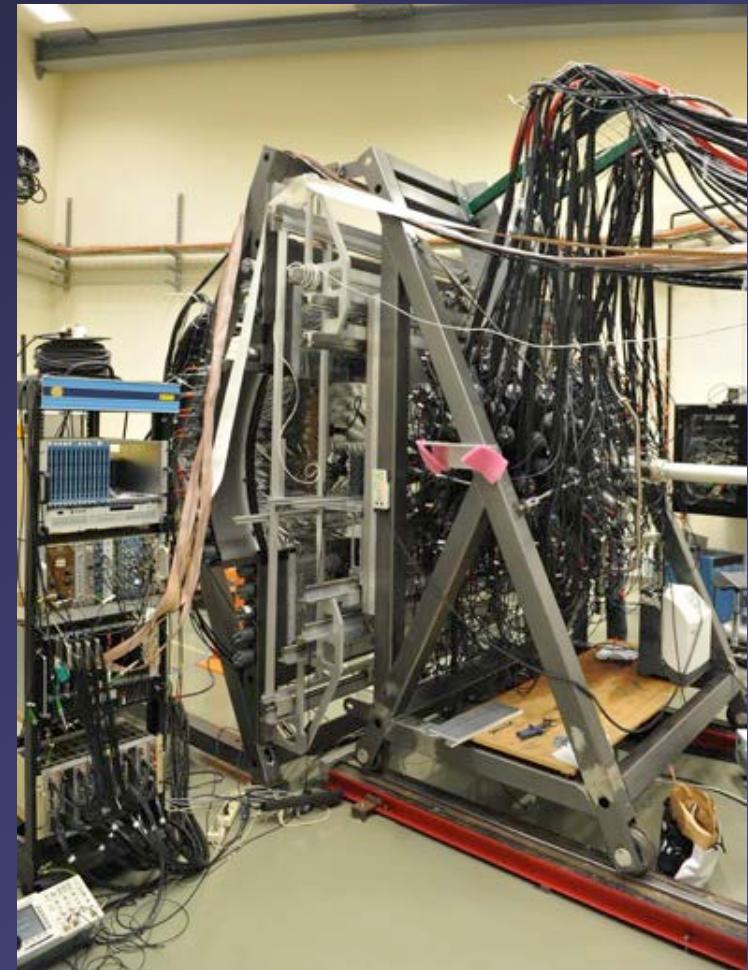
Ball:

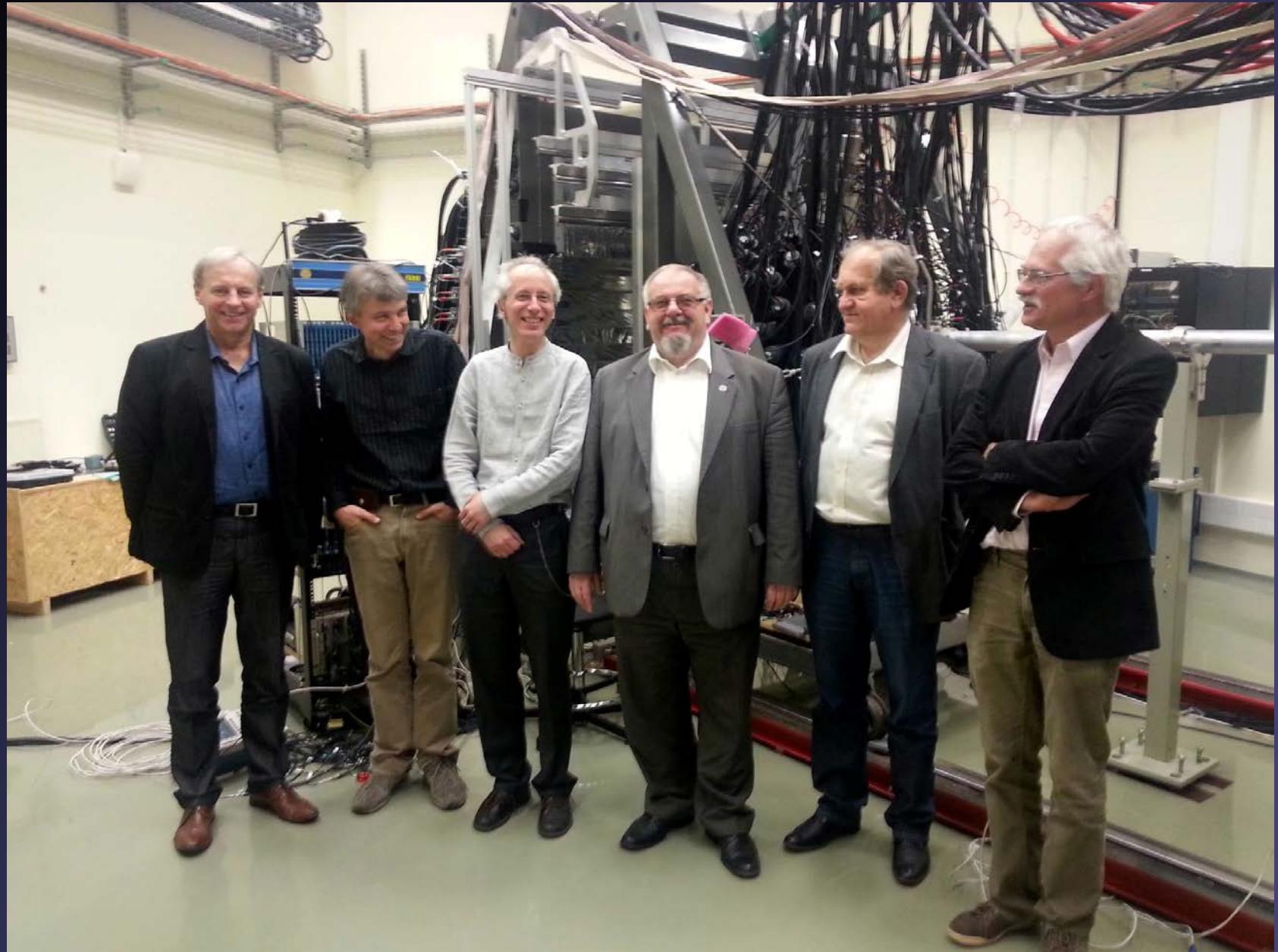
- Phoswich
(149 x 90/30 mm)

Installation of BINA at CCB and first tests

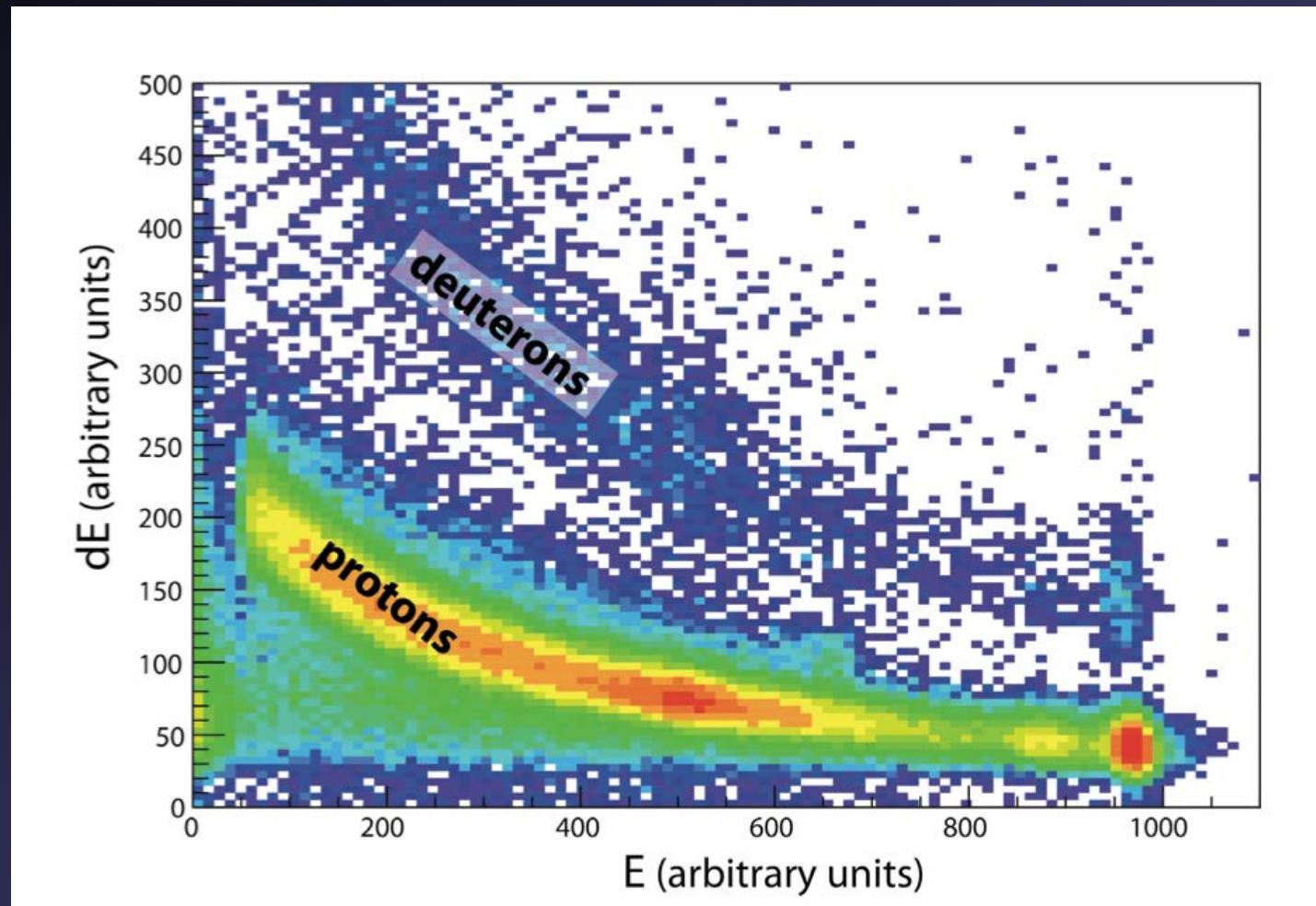
Coordinator: A. Kozela, IFJ PAN

Jagiellonian University, IFJ PAN, University of Silesia, KVI Groningen





Inauguration of BINA at CCB, July 16, 2013



BINA particle identification spectrum

Research program with BINA at CCB

Dynamics of few-nucleon systems

S. Kistryn, E. Stephan, A. Kozela et al.

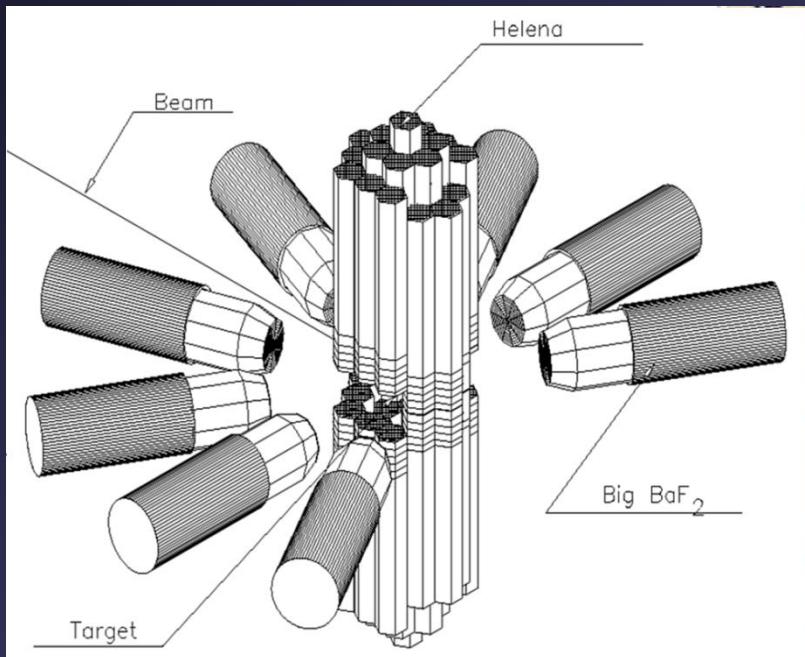
- *Jagiellonian University, Kraków*
- *IFJ PAN*
- *University of Silesia, Katowice*
- *KVI Groningen*

HECTOR array and clusters of the PARIS array

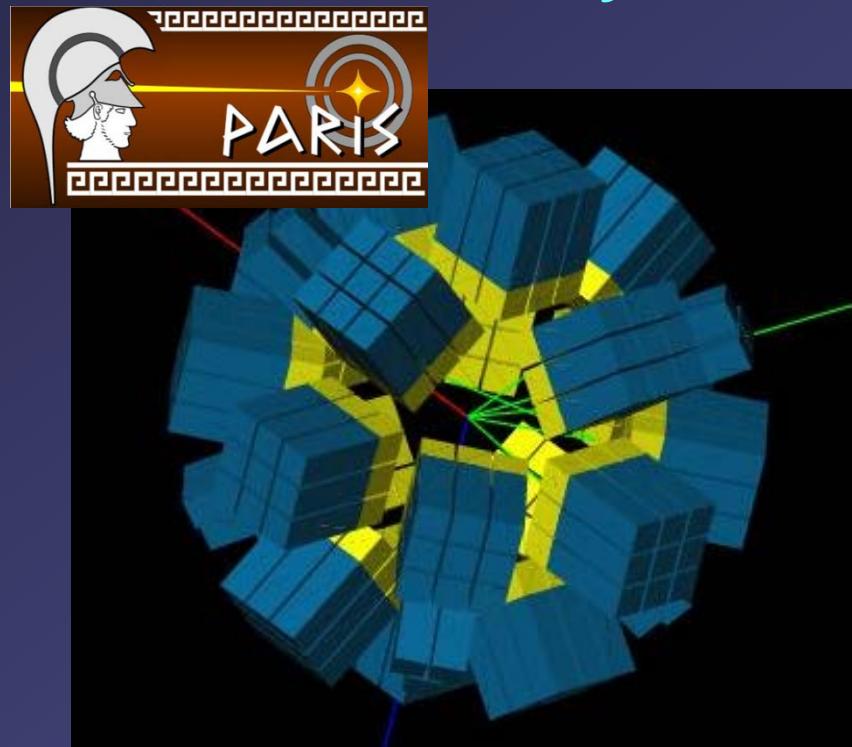
Coordinators: A. Maj, IFJ PAN

A. Bracco, Univ. of Milano

HECTOR array



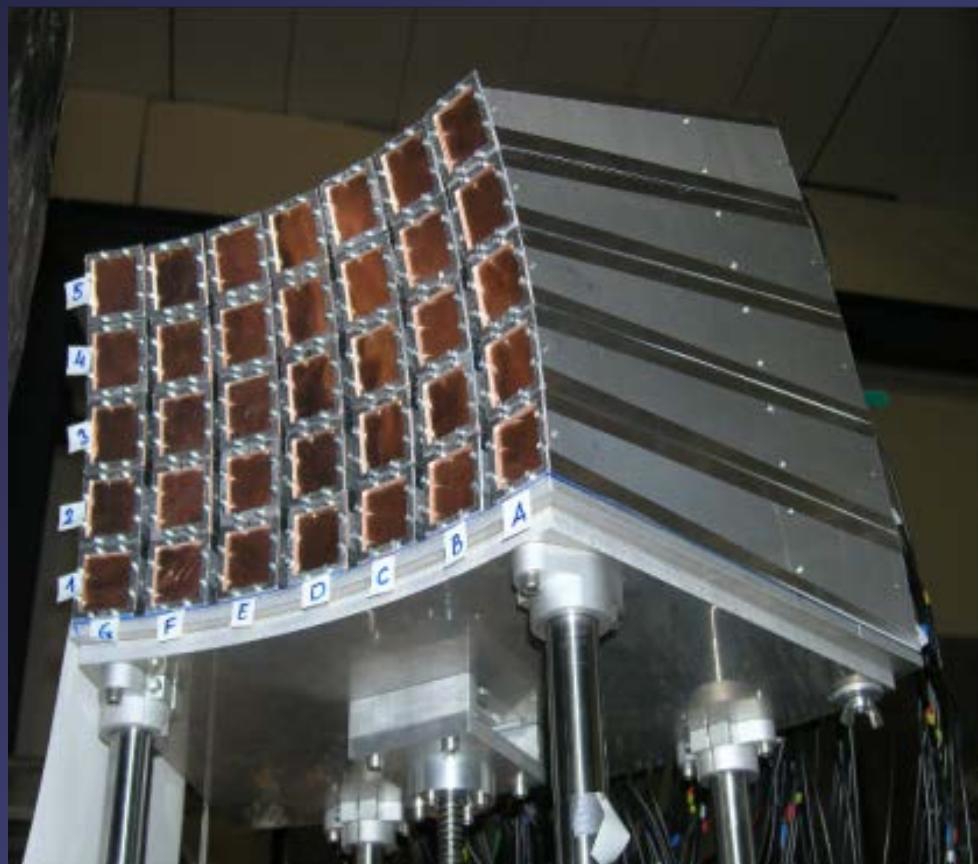
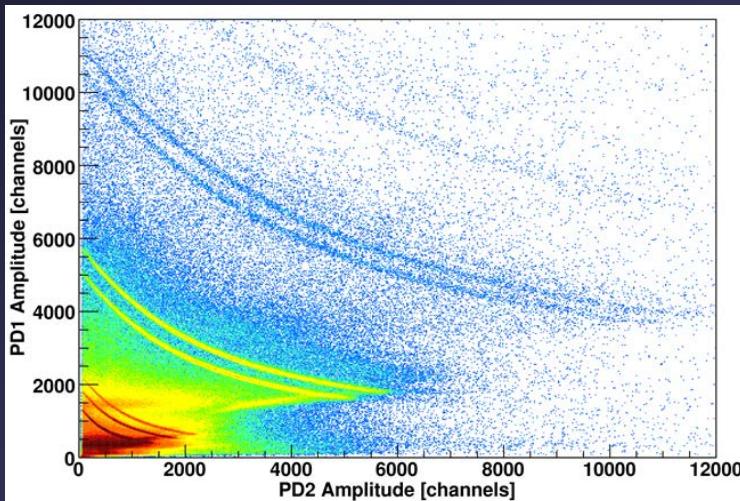
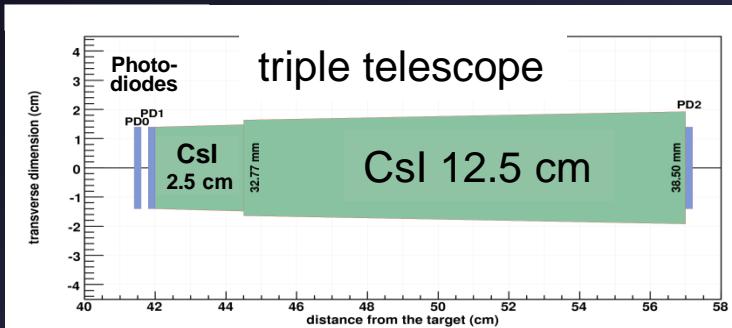
PARIS array



**The HECTOR array arrived at CCB from GSI in May 2014
(after the AGATA@GSI campaign)**



KRATTA (Kraków Triple Telescope Array) multi-module array for charged particle detection Coordinator: J. Łukasik (IFJ PAN)

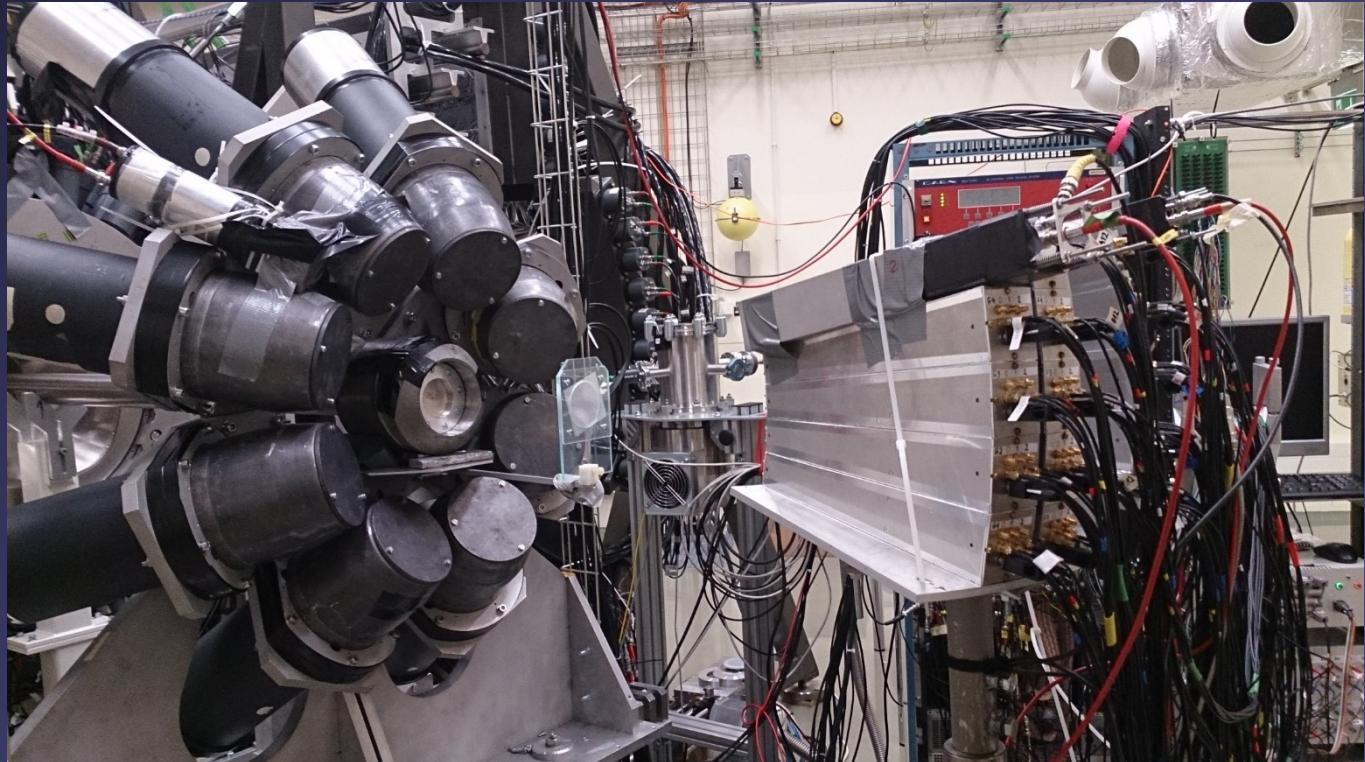


Research program with HECTOR / PARIS coupled to KRATTA

Studies of gamma decay of high-energy excitations, including resonances PDR, GDR, GPV, IAR, in reactions induced by the 70-230 MeV protons

Coordinators: Maria Kmiecik, IFJ PAN
Silvia Leoni, Univ. of Milano
Franco Camera, Univ. of Milano

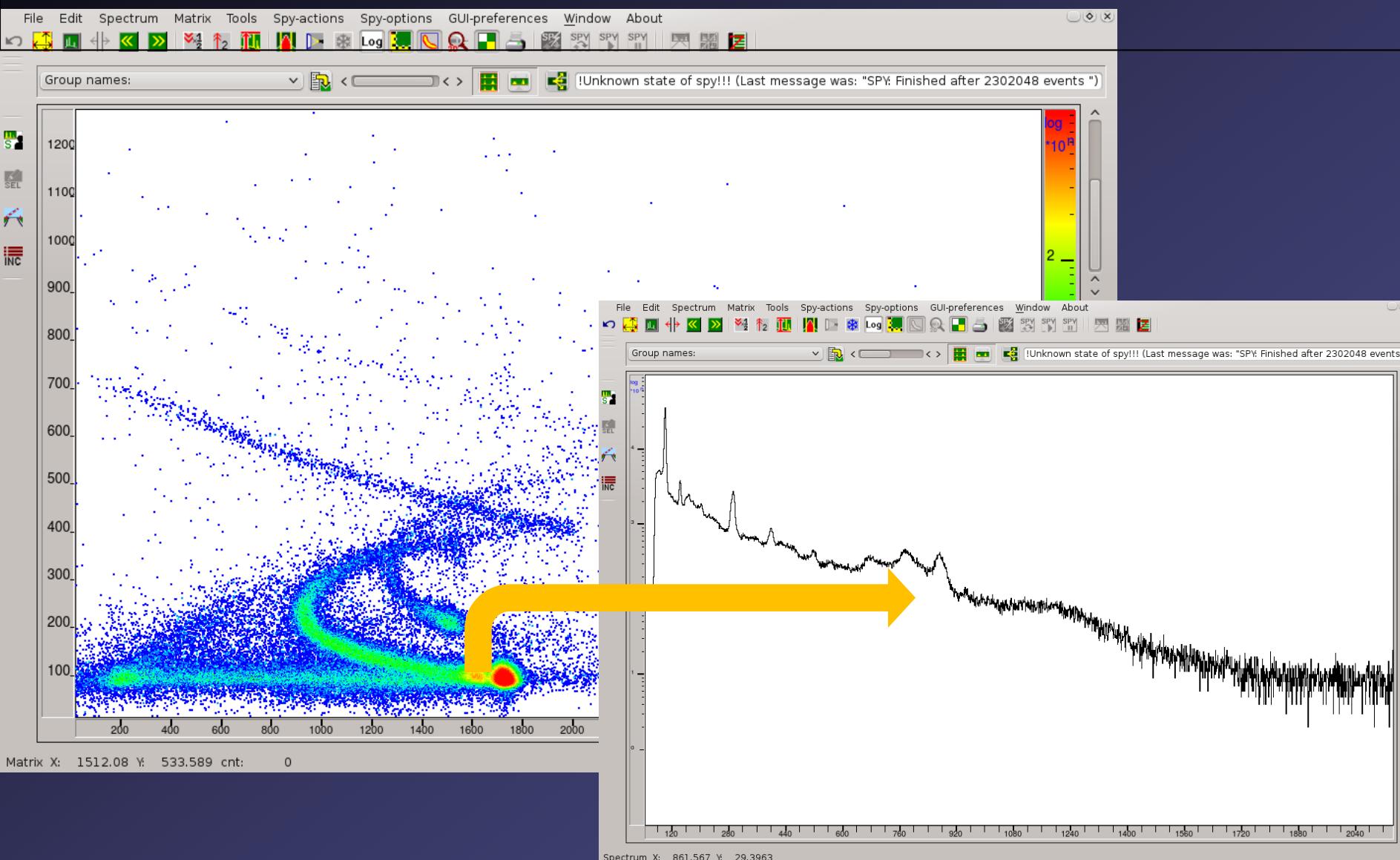
Test measurement
of the
HECTOR-KRATTA
detector system
October 2014



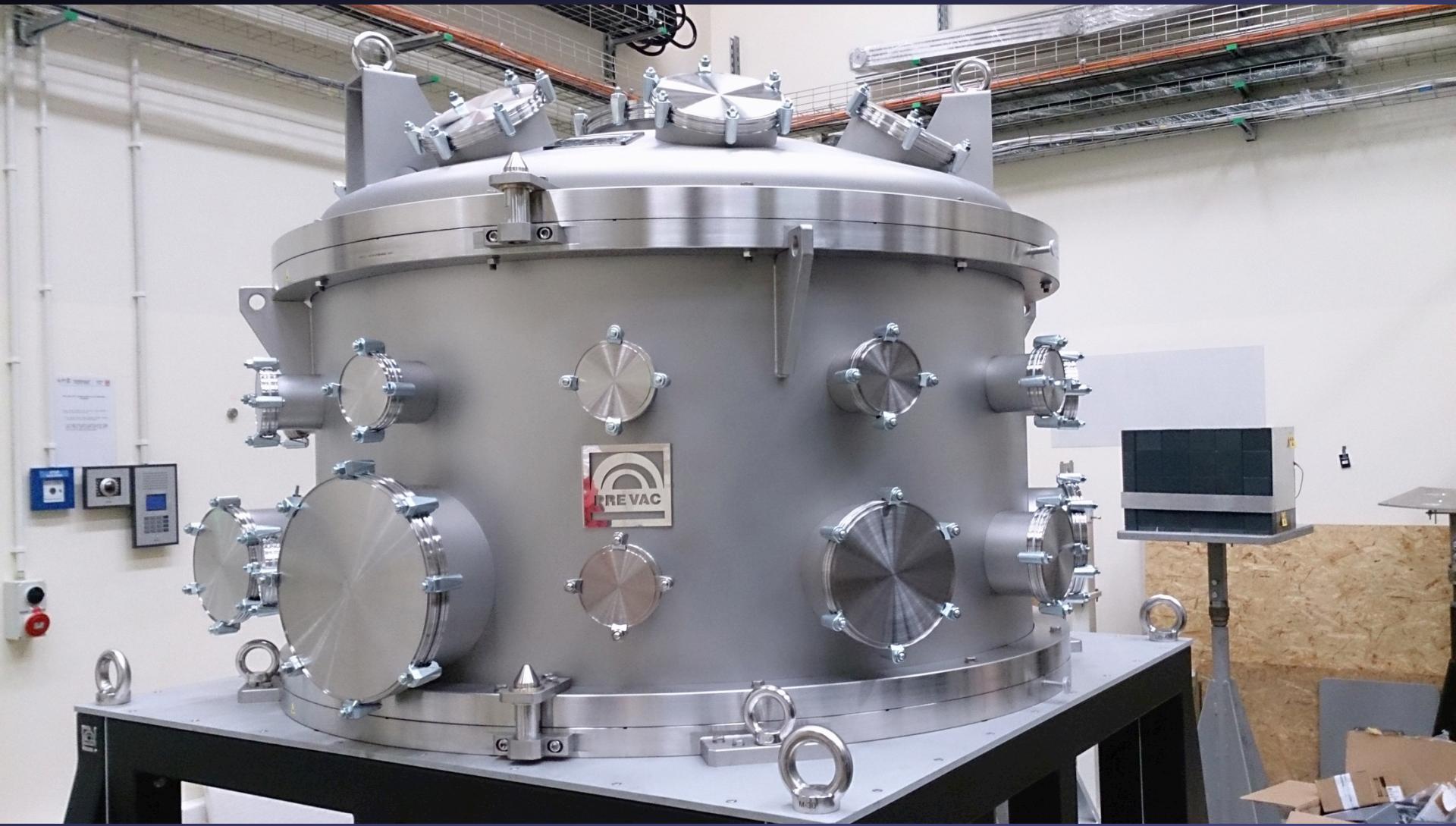
Test measurement of the HECTOR-KRATTA detector system

October 2014

$p(70 \text{ MeV}) + {}^{12}\text{C}$ and $p(150 \text{ MeV}) + {}^{208}\text{Pb}$



Large reaction chamber



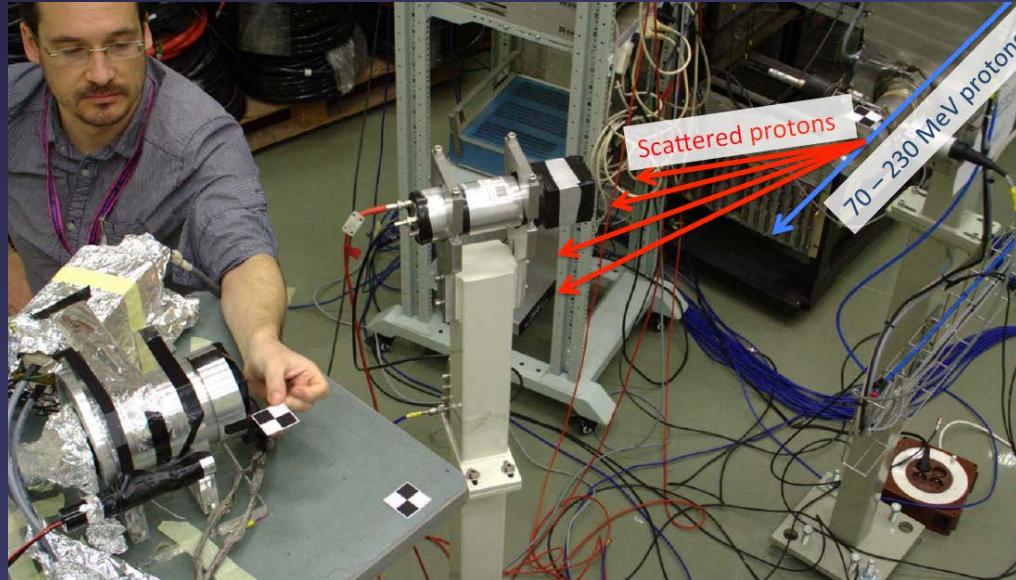
Scintillator detector tests

Tests of various LaBr_3 detectors
(CALIFA and PARIS)

have been performed at CCB in March 2013
(within GANAS@NUPNET project)

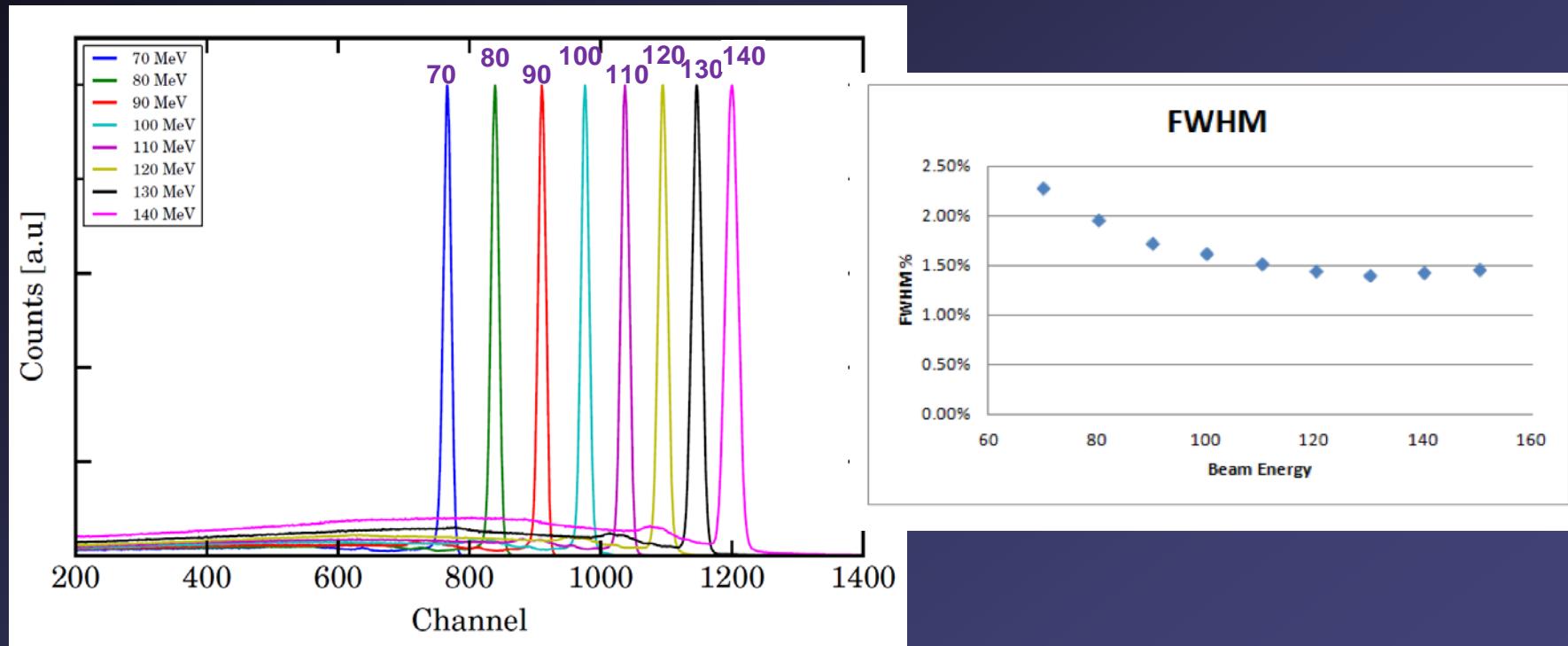
38 physicists participated from:

Orsay, Madrid, Milano, Munich, Strasbourg, Santiago
di Compostela, Bucharest, Debrecen, Nigde, Tokyo, Warsaw, Kraków



First proton spectra from the Ti(p,p') reaction measured at CCB with the LaBr₃ detector

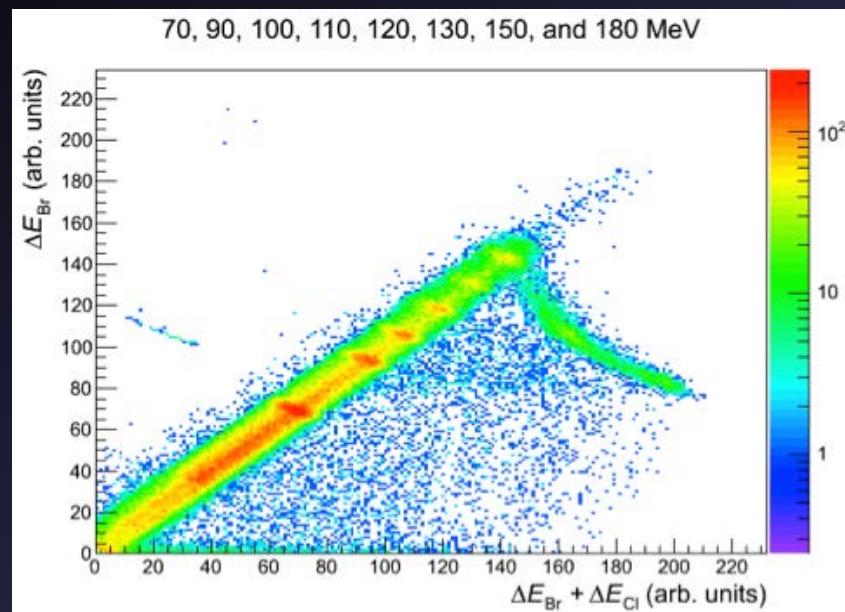
M. Ziębliński, B. Szpak, M. Krzysiek, A. Maj, W. Męczyński et al., IFJ PAN
F. Camera, S. Brambilla, A. Giaz, Univ. and INFN Milano



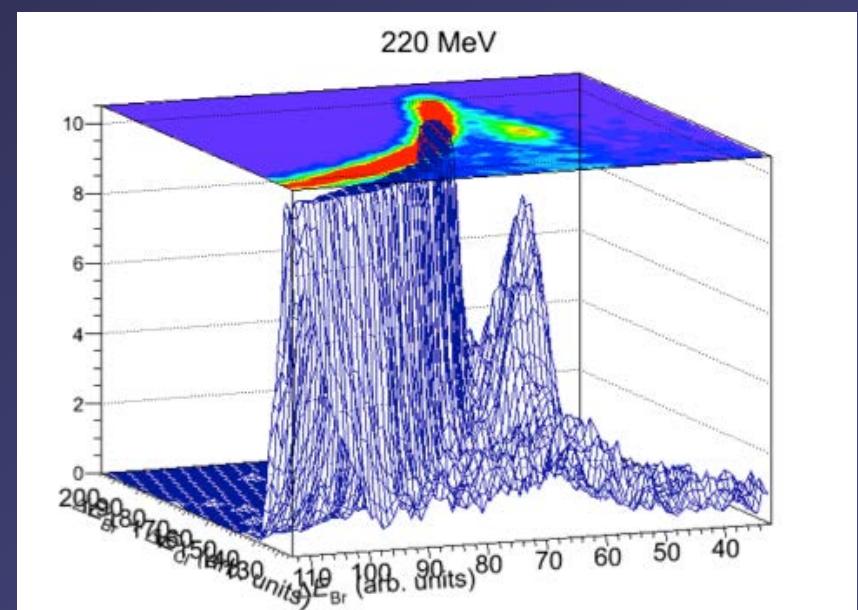
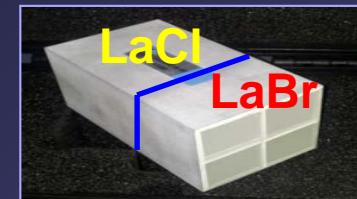
Spectra of protons at different beam energies measured with a 2"x2"x2" LaBr₃:Ce crystal at 5 deg. relatively to the beam axis.

LaBr/LaCl Phoswich

(courtesy of O. Tengblad)



LaBr/LaCl Phoswich



Foreign users (March 2013 - October 2014)

- Spain (Madrid, Santiago): **15 participants, 120 person-days**
- Germany (Darmstadt, Munich, Aachen): **13, 81**
- Italy (Milano): **6, 70**
- France (Orsay, Strasbourg, Ganil): **8, 37**
- Sweden (Goeteborg, Lund): **3, 33**
- Romania (Bucharest): **3, 21**
- Hungary (ATOMKI): **2, 36**
- Turkey (Nigde): **1, 6**
- Russia (Dubna): **1, 7**

In total:

52 users, 400 person-days (400-500 hours of beam-time)

Mesurements at CCB have important assets:

- excitation functions in a wide proton energy range: 70 – 230 MeV
- quick alternation between different beam energies (seconds);
- quick changes of beam intensity (seconds)

A call for Letters of Intent and Proposals of research projects at CCB was issued in July 2014 and a numer of applications have been submitted:

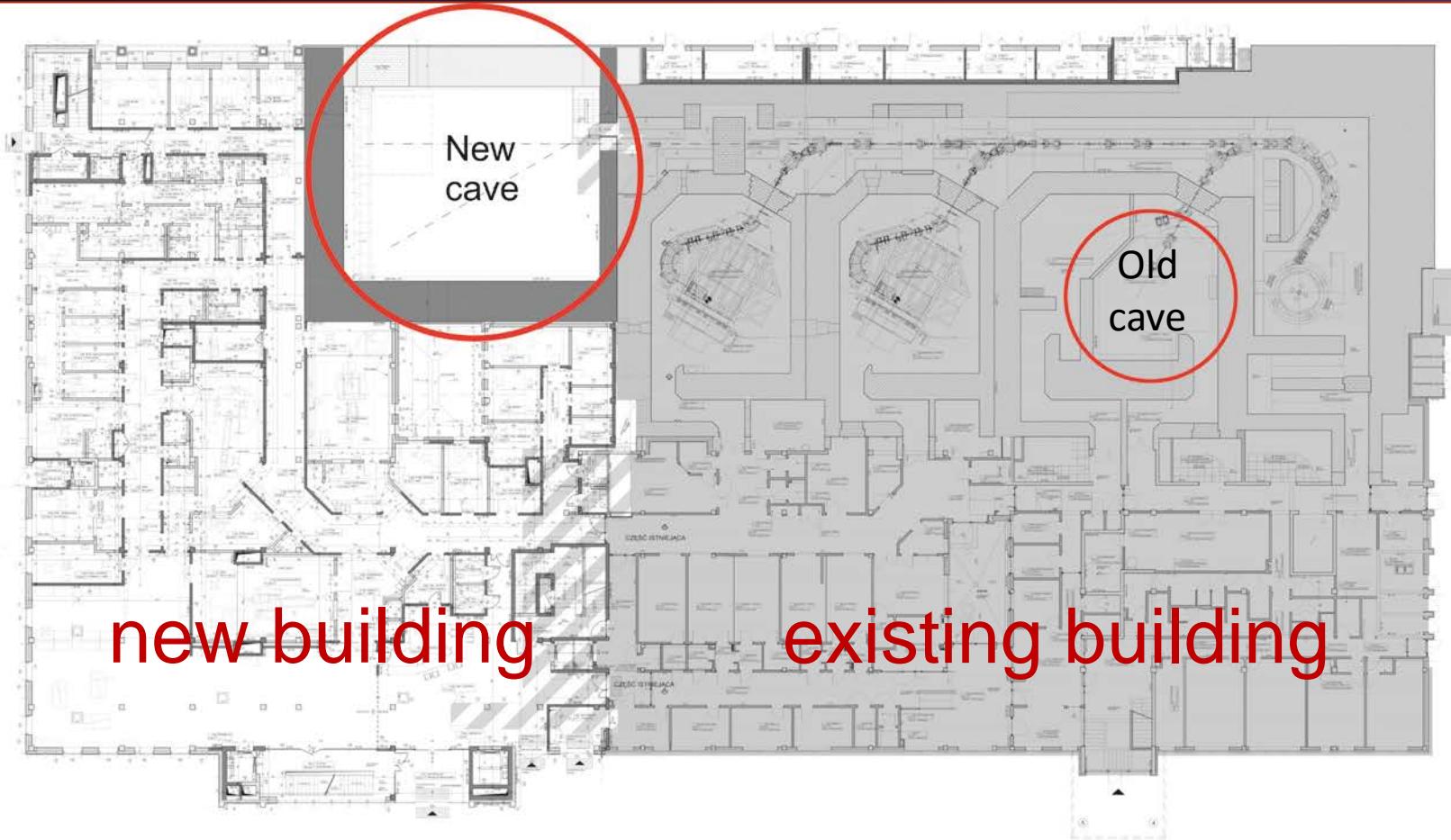
- Gamma decay from high-lying states and giant resonances excited via $(p,p'\gamma)$ at beam 70-200 MeV ([F. Crespi](#), [M. Kmiecik](#) *et al.*)
- Dynamics of few-nucleon systems ([E. Stephan](#), [A. Kozela](#), [S. Kistryn](#) *et al.*)
- Study of deeply bound $1s$ -proton-hole state decay in ^{11}B and 2α -cluster wavefunction in ^{12}C by using $^{12}\text{C}(p,2p)^{11}\text{B}$ and $^{12}\text{C}(p,p\alpha)^8\text{Be}$ reactions ([A. Bracco](#), [B. Fornal](#), [N. Cieplicka](#) *et al.*)
- Investigation of the mechanism of proton-induced reactions leading to the continuum ([B. Kamys](#), [D. Mancusi](#), [C. Schmitt](#) *et al.*)
- Physics of the bremsstrahlung photons in nuclear processes ([S. Maydanyuk](#) *et al.*)
- Proton irradiation of CALIFA detection modules at CCB ([D. Cortina-Gil](#), [J. Cederkall](#), [B. Szpak](#) *et al.*)
- Investigation of gamma emission in experimental modelling of hadron therapy ([A. Magiera](#), [A. Wrońska](#) *et al.*)



!

The National Laboratory of Cyclotrons
is among 10 European institutions that received
status of
Transnational Access Facility
within the HORIZON2020 ENSAR2 Project

New experimental hall at CCB - project



New experimental hall at CCB - project





SUMMARIZING:



The two Polish nuclear physics laboratories, **SLCJ (HIL)** in Warsaw and **IFJ PAN** in Krakow, operating in the frame of **National Laboratory of Cyclotrons**, pursue fundamental research in **nuclear physics** and are heavily involved in **medical applications** of nuclear physics.

The nuclear physics research programme at **NLC** (near valley of stability, low spins) is **complementary** to the programmes of **large-scale European nuclear physics laboratories** (exotic nuclei)

The investigations carried out in Warsaw and Kraków are in many aspects complementary to each other - at **CCB** high-energy proton beam is available while at **SLCJ**, beams of heavier nuclei, from boron to xenon, can be accelerated.

Transnational Access Facility
within the HORIZON2020 ENSAR2 Project

A quote from Maria Skłodowska-Curie:

A scientist in his laboratory is also a child confronting natural phenomena that impress him as though they were fairy tales.



Maria Skłodowska-Curie

1867-1934

Nobel Prizes:

1903 – physics

1911 – chemistry