

# Neutrino physics

**Jan Kisiel**

*Institute of Physics, University of Silesia,  
Katowice, Poland*

*many thanks to Polish Neutrino Group  
(especially to E.Rondio and A.Zalewska for discussions on the final  
shape of this presentation)*

# Polish neutrino group

- **2000 – during Kraków Epiphany conference start of the Polish neutrino group (Katowice, Kraków, Warszawa and Wrocław), idea to join together one of CNGS neutrino experiments**
- **since 2001 – work for the ICARUS exp., participation in the detector tests in Pavia**
- **2006 – entire Polish neutrino group joined T2K experiment**
- **regular meetings: ~ twice per year**
- **common proposals to funding agencies,**
- **organization of 2 Epiphany conferences (2006 and 2010), neutrino sessions during Matter to the Deepest conferences, Max Planck Symposium and Winter Students School (2009)**
- **Presently: 38.4 FTE, including 13.3 PhD**
- **15 PhD theses completed, 7 ongoing, >20 diploma theses**
- **outreach for local communities**

- **T2K**
- **ICARUS**
- **Gerda**
- **Borexino**
- **SK/MINOS**
- **LAGUNA / LAGUNA LBNO**
- **ISOTTA**
- **SUNLAB**
- **Theory**

Polish participation since 2006

Institutions in Poland:

- Katowice: US
- Kraków: IFJ PAN
- Warszawa: NCBJ, PW, UW
- Wrocław: UWr

Participants:

- 21 staff, 9 Ph.D. students
- PhD thesis (diploma thesis): 10 (5) completed, 9 (2) ongoing

Main contribution to:

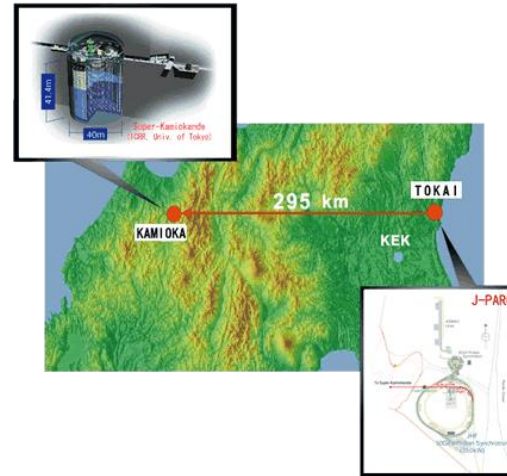
- Design optimisation, construction, installation, maintenance and software of SMRD subdetector in the near station ND280.  
Cost of detector components (~ 350 000 PLN, ~ 100k CHF) + 16 man-months for the installation, 22.5 months of technical support during construction

Main responsibilities at present:

- Software development and analysis of ND280 data
- Participation in the data taking, regular and expert shifts

Financing - adequate:

- First grant 2007-2011 (including extensions)
- NCN grant, 2012-2014



# T2K – Polish contribution: SMRD subdetector

## Detector design

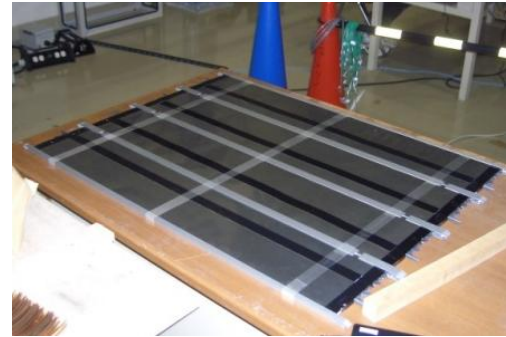
- optimisation of modules' placement (MC studies)
- MPPC measurements
- cooling system optimisation
- temperature measurement
- construction of mechanical support for modules

## Installation

Software calibration and reconstruction

Efficiency analysis

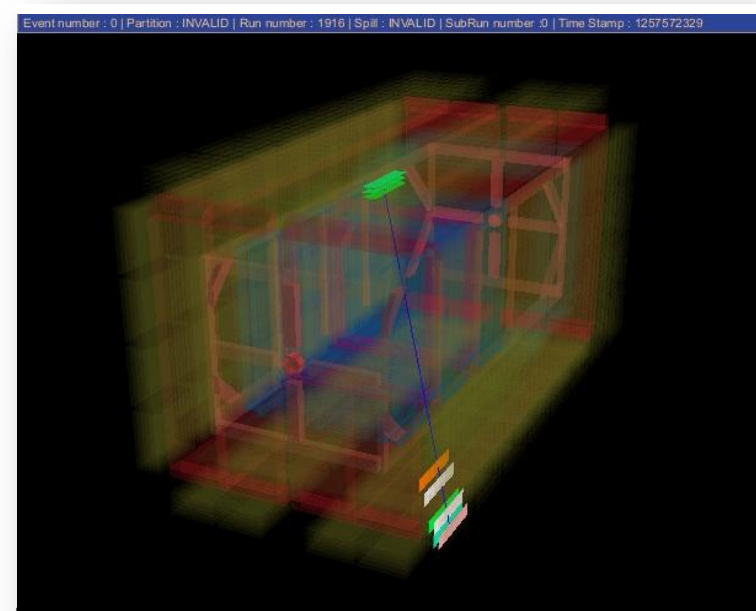
Expert shifts



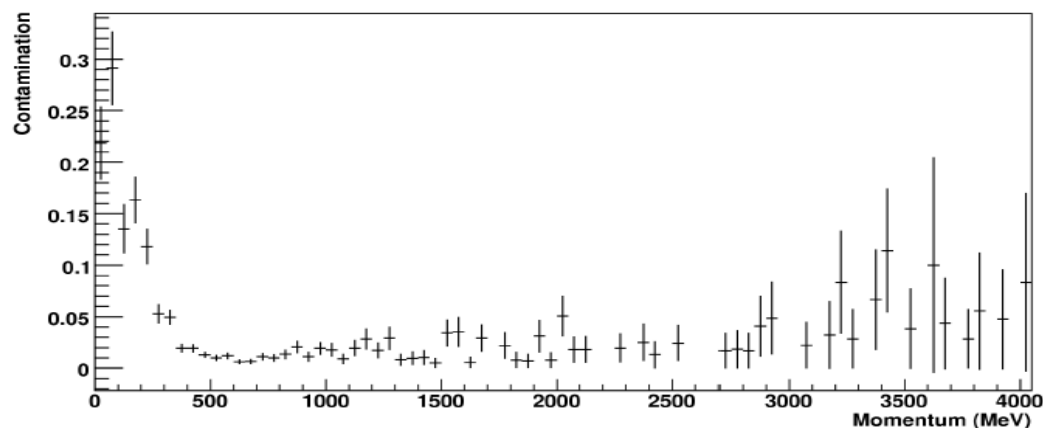
# T2K – Polish contribution: ND280 analyses

- **Modelling neutrino interactions:**  
development of the neutrino interaction simulation package - NuWro
- **CCQE and  $CC\pi^0$  reactions studies**
- **Cosmic muons**
- **Out-of-bunch bg studies**
- **Neutrino interactions before near detector**
- **Magnet and ECAL bg studies**

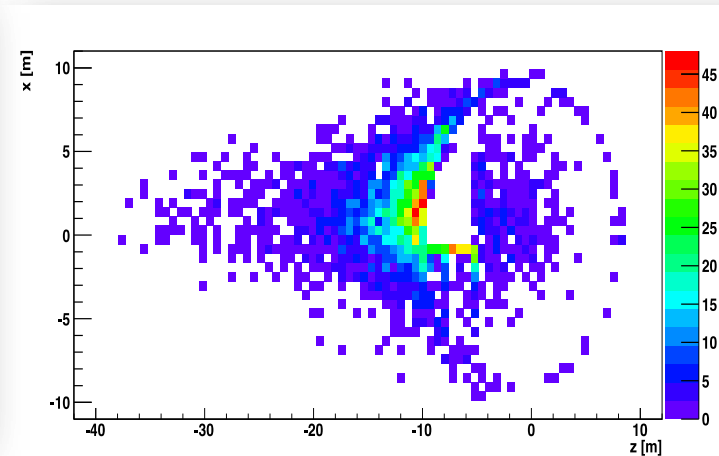
## Cosmic muon in SMRD



## Magnet muon contamination in the tracker



## Interaction vertices of muons entering the detector from outside





# ICARUS T600 (LAr TPC) experiment in LNGS

Participation since 2000

Institutions in Poland:

- Katowice: US
- Kraków: IFJ PAN
- Warszawa: NCBJ, PW

Participants:

- 10 staff, 4 students, 1 support
- PhD thesis (diploma thesis): 5 (13) completed, 1 (2) ongoing

Main contributions:

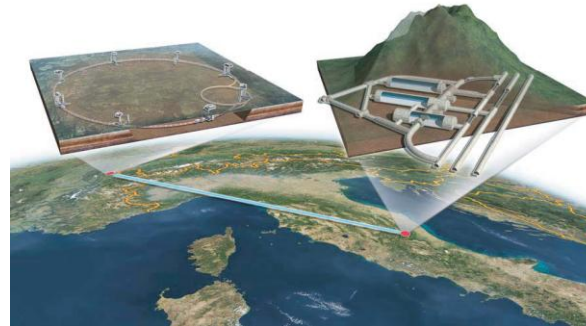
- Work on the installation of the detector in the Gran Sasso laboratory, modification and tests of electronic read-out units, installation and tests of read-out chain - 11 man-months
- Construction of the equipment for wire production ~ 350k PLN (~ 100k CHF),
- Analysis of EM cascades and pi0 production with test data (published)

Main responsibilities at present:

- Work on the automatic reconstruction of the events, 2 persons working permanently in Gran Sasso, 1 paid with Polish funds - 18
- Visual scanning of collected events and participation in data taking,
- Pi0 analysis with CNGS data

Financing:

- 2002-2008 (with extensions), adequate
- 2009-2011 without financing, participation possible thanks to Italian support (FAI funds, no running costs),
- Grant for 1 person, 18 months, working in Gran Sasso
- Proposal submitted to NCN, financing for 2012-2014 asked

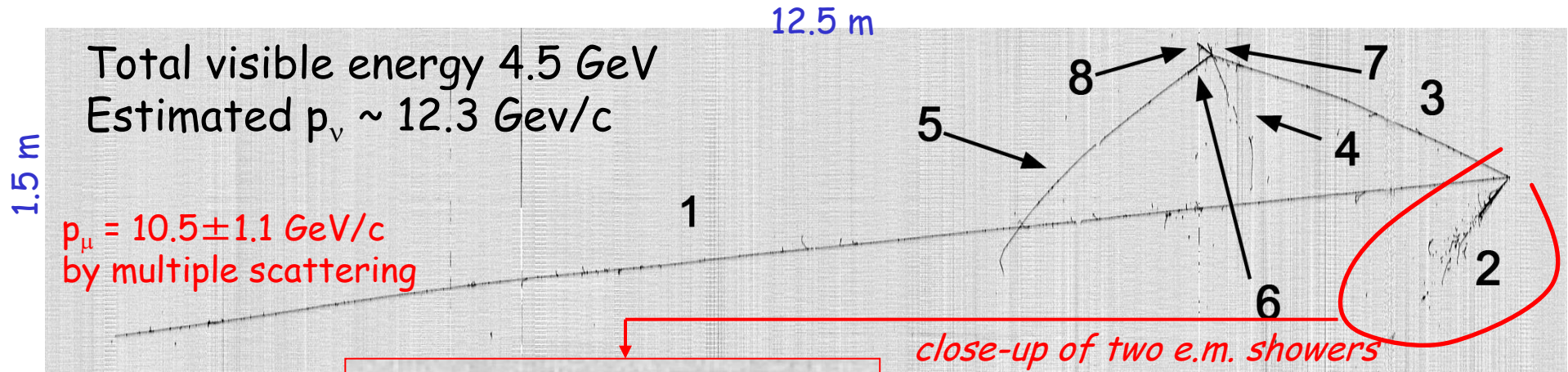


# ICARUS: Polish equipment for wire production





# LAr-TPC: event reconstruction (Run 9927 Event 572)

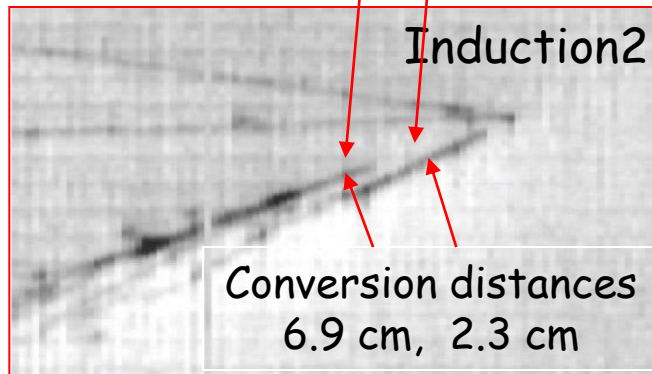
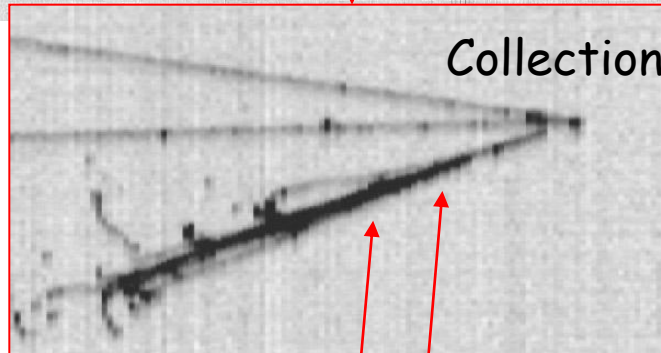


**Primary vertex (A)**

very long  $\mu$  (1),  
e.m. cascade(2),  
pion (3).

**Secondary vertex (B)**

The longest track (5) is a  $\mu$  coming from stopping k (6).  
-  $\mu$  decay is observed.



Track	$E_{\text{dep}}[\text{MeV}]$	cosx	cosy	cosz
1 ( $\mu$ )	2701.97	0.069	-0.040	-0.997
2 ( $\pi^0$ )	520.82	0.054	-0.420	-0.906
3 ( $\pi$ )	514.04	-0.001	0.137	-0.991
<b>Sec. vtx.</b>	797.			
4	76.99	0.009	-0.649	0.761
5 ( $\mu$ )	313.9			
6 (K)	86.98	0.000	-0.239	-0.971
7	35.87	0.414	0.793	-0.446
8	283.28	-0.613	0.150	-0.776

$$M_{\gamma\gamma}^* = 125 \pm 15 \text{ MeV}/c^2$$

# The GERDA Experiment in LNGS



□ **Participation since 2005**

□ **Institutions in Poland:**

➤ **Kraków: IF UJ**

□ **Participants:**

➤ **3 staff, 1 PhD student, 1 support**

➤ **PhD thesis: 2 ongoing**

□ **Main contributions:**

- **Investigation of new background reduction techniques,**
  - **behavior of noble gases at cryogenic temperatures,**
  - **radioactive ions in cryogenic gases,**
  - **surface cleanliness of Cu/steel/Ge and removal of radioactive traces**

➤ **LArGe – construction of the detector,**

➤ **LArGe - implementation of the slow control system,**

➤ **Analysis of the data (GERDA/LArGe),**

➤ **Participation in the data taking (GERDA/LArGe),**

□ **Financing:**

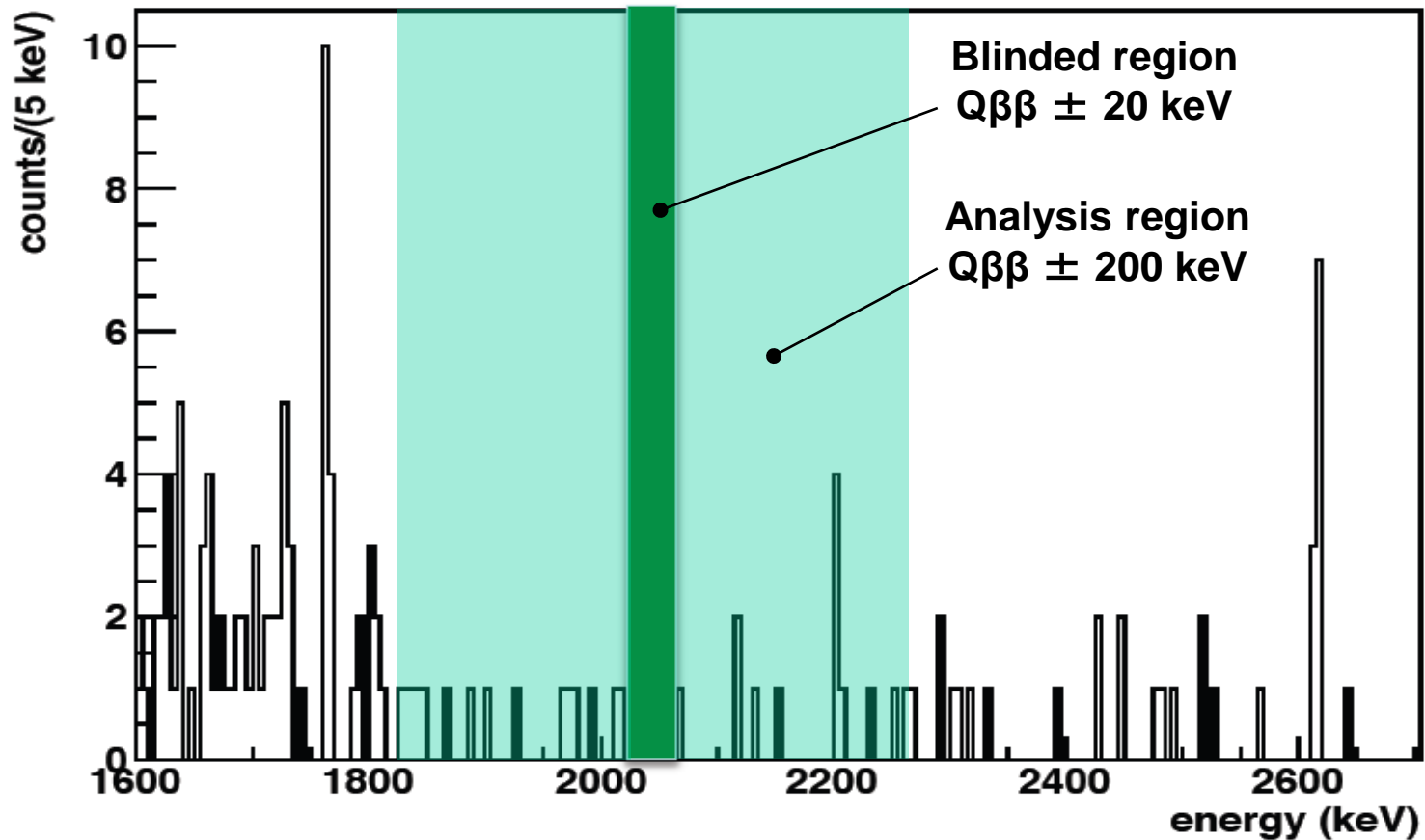
➤ **NCN grant (2011-2014), adequate**



# GERDA Phase I is running!



Enriched detectors, 3.801 kg × year



current background index:  $0.017^{+0.009}_{-0.005}$  cts/(keV kg y)

# The BOREXINO Experiment in LNGS



- Participation since 1995

- Institutions in Poland:

  - **Kraków: IF UJ**

- Participants:

  - **3 staff**

  - **PhD thesis (Diploma thesis): 3 (5) completed**

- Main contributions:

  - **Background reduction,**

  - **Detector radiopurity control,**

  - **Neutrino speed measurement (hardware),**

  - **Data analysis in various aspects,**

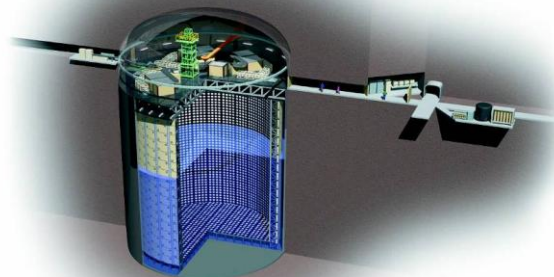
  - **Participation in the data taking,**

- Financing:

  - **Proposal submitted to NCN, financing for 2012-2014 asked**



# The Super-Kamiokande (SK) Experiment



- [ ] **IMB - First neutrino experiment with Polish participation (D.Kiełczewska, UW)**
- [ ] **SK - participation from the beginning, (D.Kiełczewska, UW)**
  
- [ ] **Institutions in Poland:**
  - **Warszawa: NCBJ**
- [ ] **Participants:**
  - **1 staff**
- [ ] **Main responsibilities:**
  - **Analyses searching for neutrinos from Dark Matter interactions (PhD thesis)**



# The MINOS/MINOS+ Experiment

- [ **Institutions in Poland:**
  - **Warszawa: UW**
- [ **Participants:**
  - **1 staff**
  - **1 diploma thesis completed, 1 ongoing**
- [ **Main contribution:**
  - **Development of track reconstruction**
  - **Tau Appearance study**
- [ **Main responsibilities:**
  - **Event scanning**
  - **Participation in data taking**
- [ **Financing:**
  - **Grant from Ministry of Science and Higher Education**



**LAGUNA: Large Apparatus for Grand Unification and Neutrino Astrophysics:**

- FP7 funded LAGUNA „Design Study” proposal (2008-2011). Grant Agreement No. 212343.

- Detailed investigation of the feasibility of a deep underground „megaton-scale” detector. Three technologies (Water Cerenkov, Liquid Argon and Liquid Scintillator) and seven potential European sites (Sieroszowice in Poland) considered.



## □ Institutions in Poland:

- Kraków: IFJ PAN, coordinating participation of Polish neutrino groups
- Wrocław: KGHM Cuprum (industrial partner)

## □ Main contribution / main responsibilities:

- Full feasibility study for Sieroszowice site including geomechanical simulations, safety, environmental and socio-economic analysis, and cost studies
- Outreach - documentation for general public

## □ Financing:

- FP7 grant, (2008 - 2011)

(continuation with LAGUNA LBNO: 2011-2014)

# SUNLAB (Sieroszowice UNDERground LABoratory) – in the Polkowice-Sieroszowice copper mine

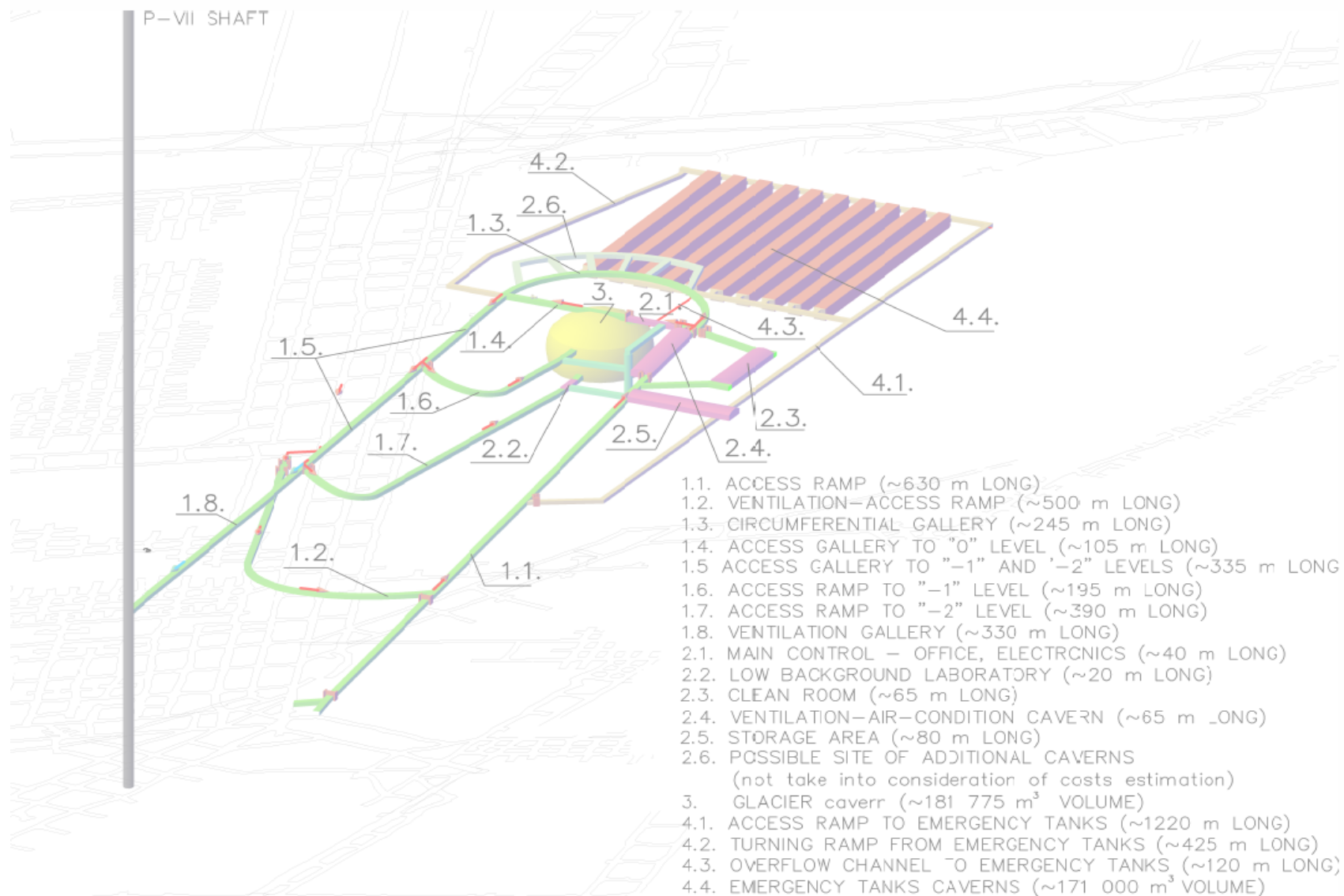


- South-west of Poland,
- 90 km north-west from Wrocław,
- Belongs to the KGHM Polska Miedź S.A. holding



## SAFETY AND TECHNICAL ASPECTS

### VENTILATION

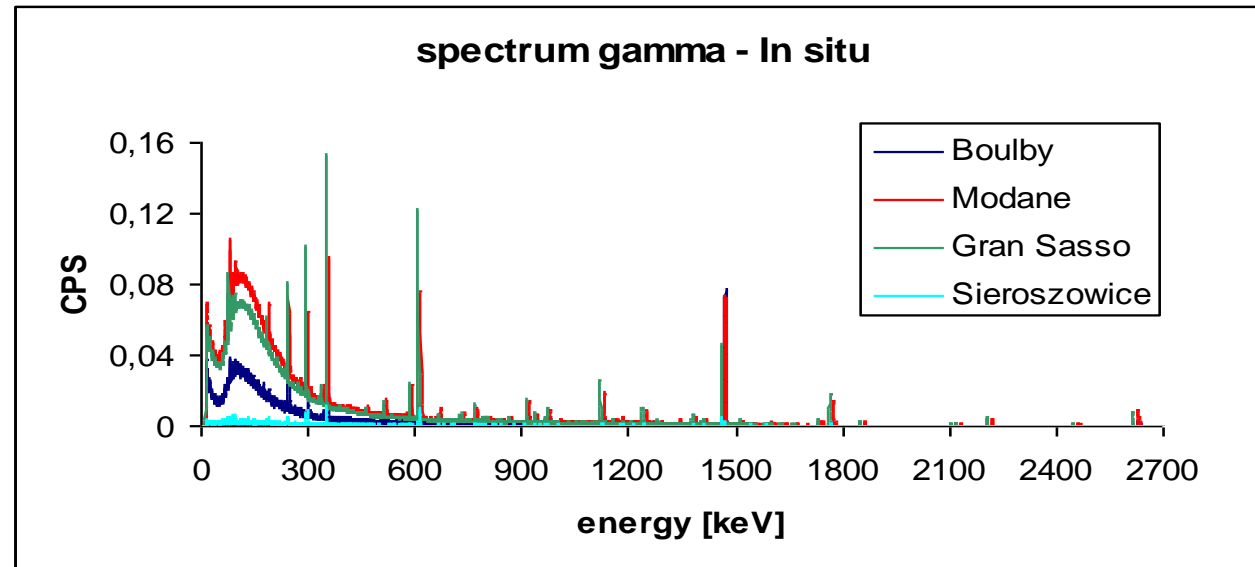
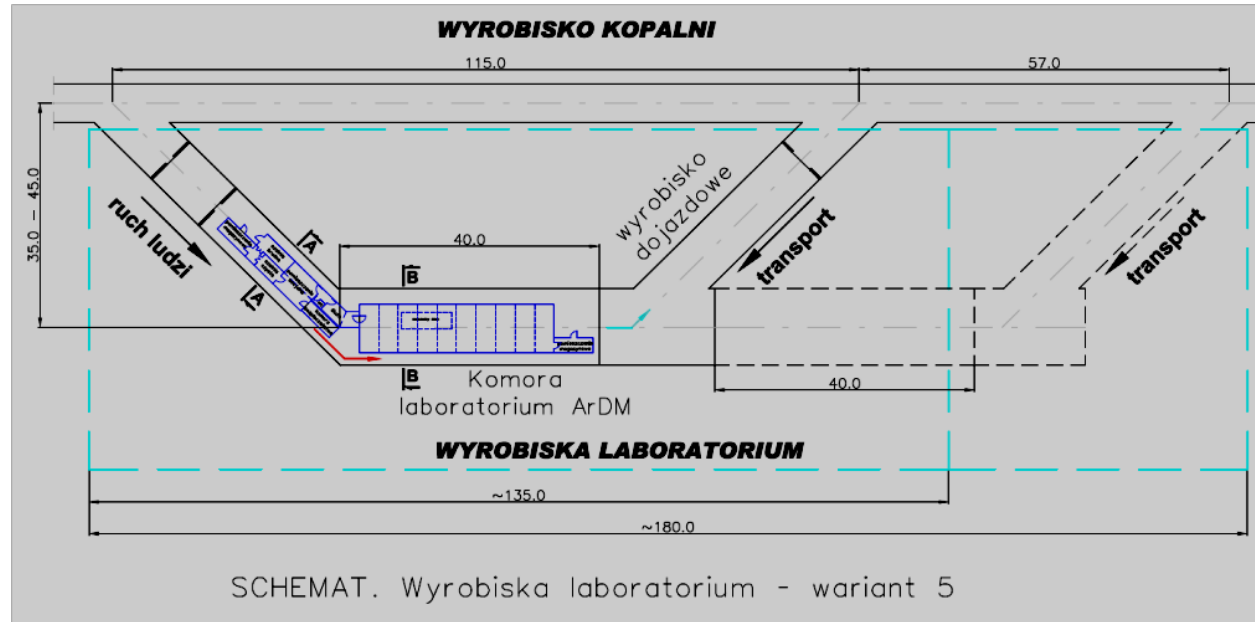


The laboratory ventilation system (red arrows – fresh air)

W.Pytel, KGHM Cuprum, December 2009

# SUNLAB: project of the Polish underground laboratory

- Expressed interest from 12 Polish research institutions
- Location in the salt layer of the thickness of 70-100m, at the depth of about 1000m, in a very low natural radioactivity environment
- Conceptual design and cost estimate of small laboratory (main experimental hall: 30m long, 7m wide and 8m high) has been done
- Laboratory oriented towards studies of isotopic pure materials, calibration of dosimeters and dark matter searches
- Proposal accepted in the Polish Road Map for Research Infrastructures in 2011.**





# ISOTTA (ISOTope Trace Analysis)

Advanced Techniques for the Production, Purification and Radio-Purity Analysis of Isotopically Enriched Sources for Double Beta Decay. The **main objective** of the project is to create the conditions for the safe procurement (in terms of radiopurity of the final source) of a large amount (at the 100 kg – 1 ton scale) of isotopically enriched material for the performance of a next generation 0v-DBD experiment.



## [ Institutions in Poland:

- Katowice: US
- Kraków: IFJ PAN, UJ
- Łódź: NCBJ

## [ Participants:

- 5 staff, 1 student, support according to the tasks,

## [ Main contribution / main responsibilities:

- Analysis of enriched samples,
- Design studies and construction of detector prototypes,
- Studies of neutron shield efficiency,
- Work for the SUNLAB location in ZG Polkowice-Sieroszowice

## [ Financing:

- NCBiR grant, (2012-2014), ASPERA call for proposals, project duration – 36 months, started: 01.01.2012

# Theory of neutrinos



## [ Institutions in Poland (groups):

➤ Wrocław: UW

➤ Katowice: US

## [ Participants:

➤ Katowice: 3 staff, 3 PhD students, support according to the tasks,

➤ Wrocław: 3 staff, 2 PhD students

## [ Main contribution:

➤ Katowice: neutrino oscillations, new physics, neutrino mass problem

➤ Wrocław: neutrino interactions with nuclei, NUWRO – Wrocław neutrino interaction simulation package

## [ Financing:

➤ Katowice: 2 NCN grants, 2010-2012, new proposal submitted to NCN

➤ Wrocław: also within T2K project