Searches for Dark Matter
and
topics related to underground laboratories

Agnieszka Zalewska

ApPEC meeting, Warsow, 3.07.2006

- Polish participation in searches for Dark Matter
- Possible location for the underground laboratory in Poland
- Measurements of natural radioactivity in the European underground labs within the ILIAS project

Polish participation in searches for Dark Matter

Experiments/projects with Polish participation

1. **Super-Kamiokande**
   Warsaw University: D.Kiełczewska, J.Zalipska (PhD)
   publication Phys. Rev. D70 (2004) 083523

2. **WARP (Wimp Argon Programme) at Gran Sasso**
   Institute of Nuclear Physics PAN in Cracow, A.Szelc (PhD-100%)
   1 conference presentation by ASz, 2 collaboration papers in a process of publishing, software for testing photomultipliers, data analysis

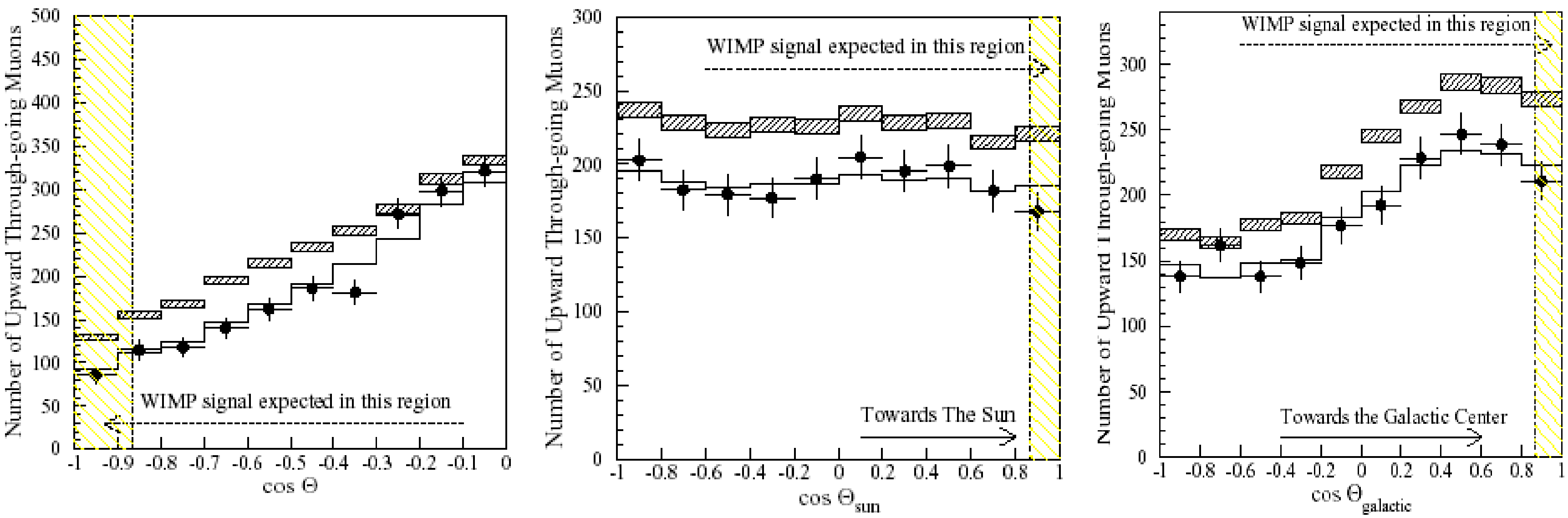
3. **ArDM (Argon Dark Matter) at Canfranc**
   Institute for Nuclear Problems in Warsaw, P.Mijakowski (PhD-100%) + small contributions of senior physicists
   1 conference presentation by PM, neutron simulations

4. **AMS**
   Institute of Nucear Physics PAN in Cracow, M.Sapiński (a postdoc contract in the Rome AMS group, 1 conference presentation by MS

Dark Matter search in SuperKamiokande

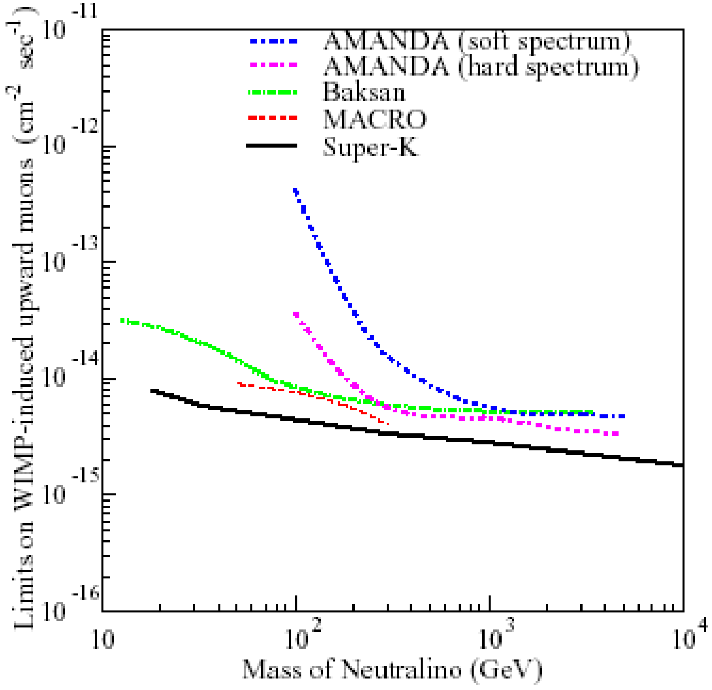
Indirect search using neutrino-induced upward through-going muons, looking for an excess of high energy muon neutrinos from WIMP annihilations in the Sun, the core of the Earth and the Galactic Center as compared to the number from the atmospheric neutrino background

No statistically significant excess was seen

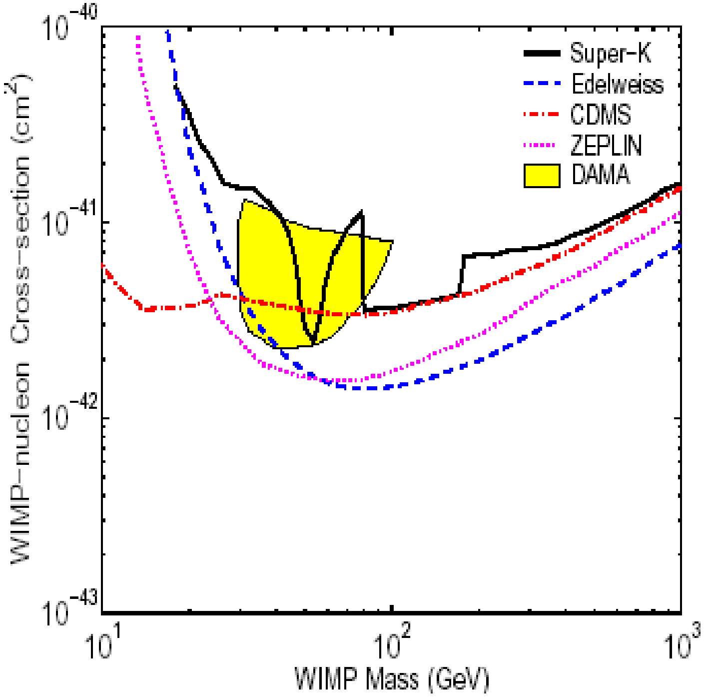


Core of the Earth — Sun — Galactic Center

Dark Matter search in SuperKamiokande



SuperK WIPM-induced muon flux limits from Earth as a function of WIMP mass

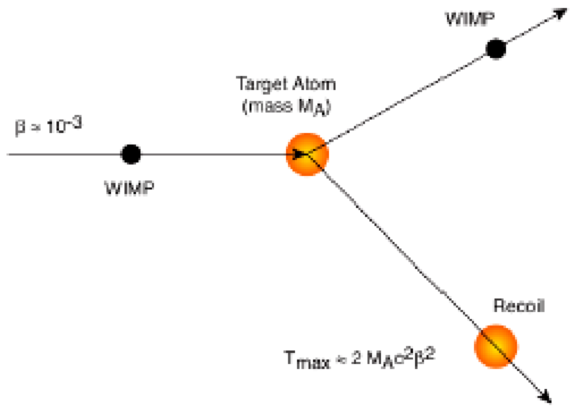


SuperK 90% exclusion limit As compared to other exps

Dark Matter search in WARP

2.3 l prototype is taking data since April 2004, 100 l detector under construction, operational at the end of 2006

WIMP-Ar elastic scattering

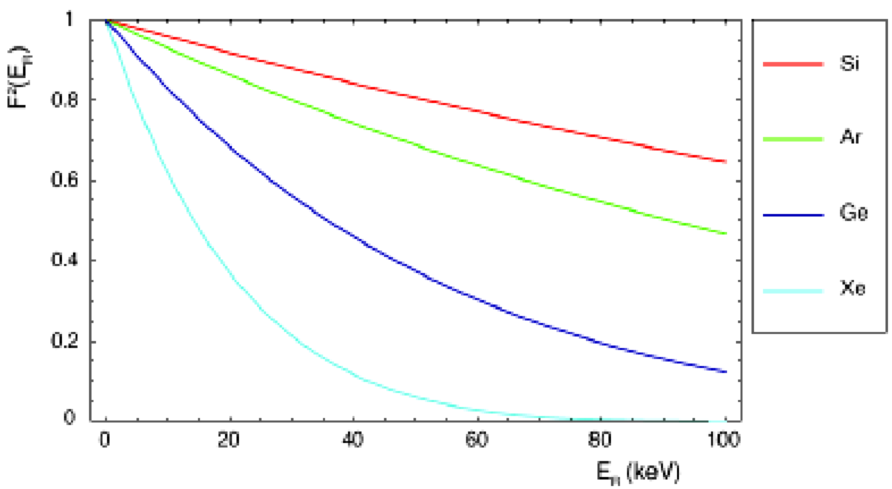


$$R(E_1, E_2) = \int_{E_1}^{E_2} c_1 \frac{R_0}{E_0 r} e^{-c_2 \frac{E_R}{E_0 r}} F_A^2(E_R)\, dE_R$$

Argon recoil energy is in the range $E_R \sim 10 \div 100$ keV

Coherent cross section behave as A^2 (A=40 for Argon)

Spin-independent form factor since natural Argon is composed by spinless isotopes



A.Cocco, Neutrino 2006

The WARP detection technique

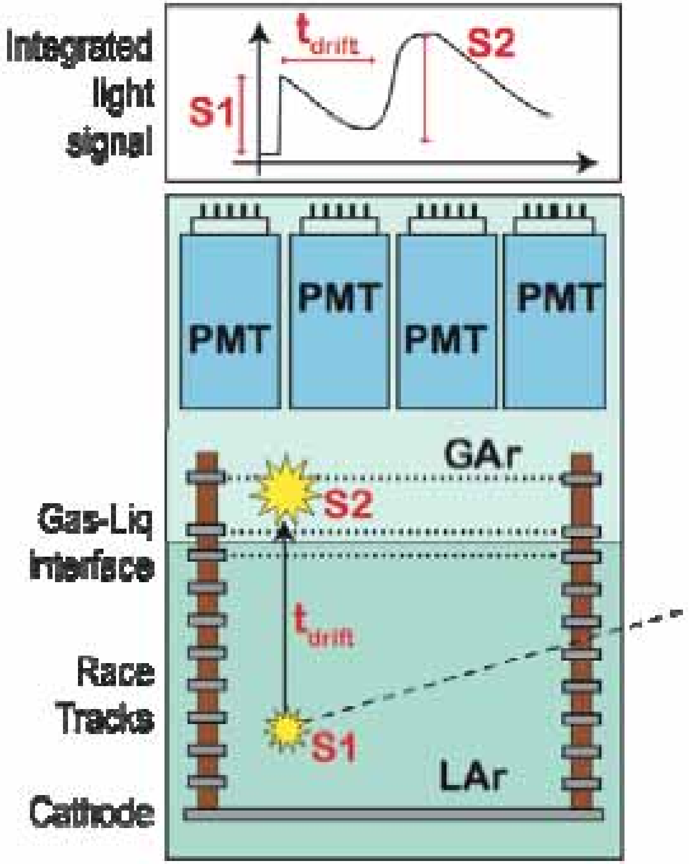
"Identification of the nature of a particle interacting within a double phase Argon detector by means of the simultaneous measurement of the produced scintillation and ionization" (WARP Letter of Intent 1999)

In liquid Argon for energy depositions in the range of interest for Dark Matter searches (20-100 keV) we have that

- the amplitude of the first signal (S1)
- the pulse shape of the first signal (S1)
- the amount of free electrons that drift toward the multiplication grids (S2)

strongly depend on the nature of the ionizing particle (Ar recoil, electron, heavy ion, etc)

These quantities can be used to characterize WIMP induced Argon recoils

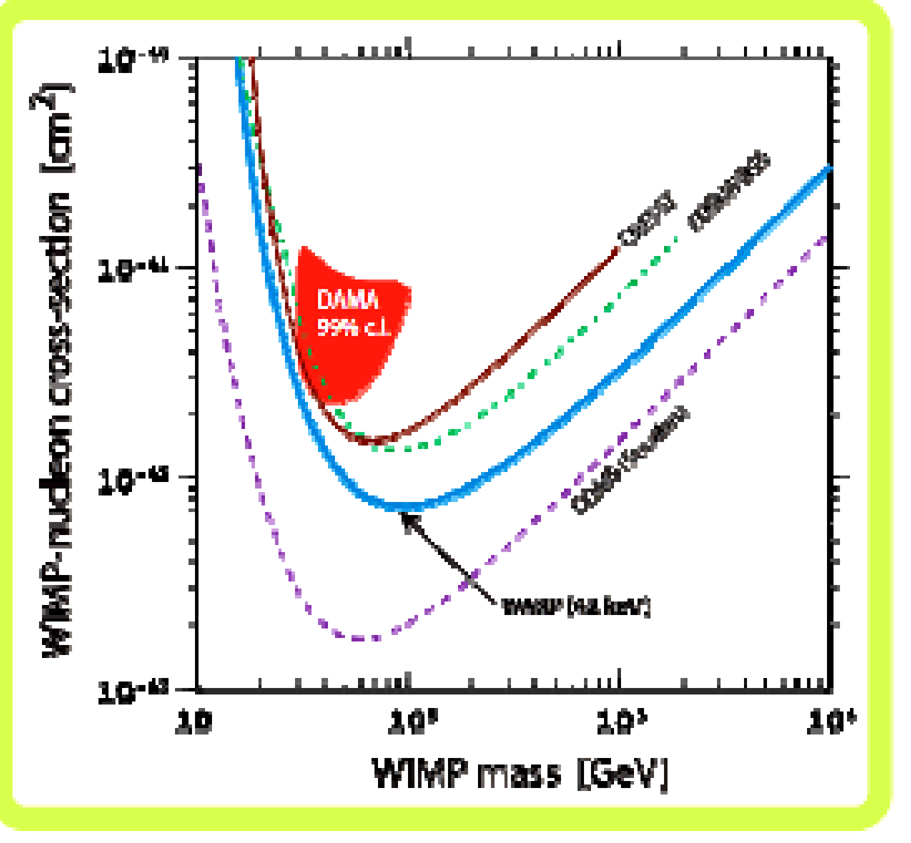


Results of WIMP search
90% C.L. upper limit

No recoil-like events are observed above 42 keV$_{ion}$ in a total fiducial exposure of 96.5 kg x day (2.8 x 10^7 trigger)

The evaluated 90% C.L. upper limit for spin-independent interaction, in the standard WIMP scenario, is plotted. Energy resolution due to statistical fluctuations and to a non uniform light collection has been taken into account

The dominant systematic effect is due to uncertainties on scintillation yield. An error of 15% on Y_{Ar} corresponds to a variation of 20% @ Mw=100 GeV /c^2 and of 30% @ Mw=50 GeV/c^2



Dark Matter searches in ArDM

Elastic scattering reaction:

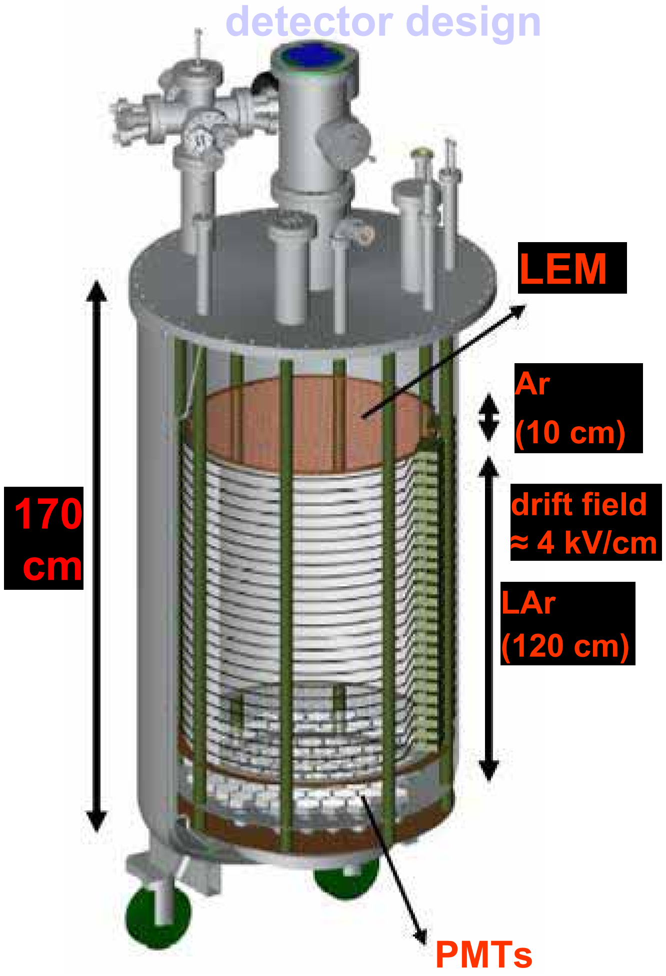
$$\chi + Ar_{at\ rest} \rightarrow \chi + Ar_{recoil}$$

- Measurement of the recoils of target nuclei [10-100 keV].
- Recoil energy → scintillation & ionization of Argon

GOAL: independently detect the light (PMTs) and the charge (Large Electron Multiplier)

- light/charge ratio allows to discriminate background events (e/γ vs. nuclear recoils)

ArDM@CERN



ArDM prospects:

TIME SCALE:

- **2006**: assembly of detector at **CERN**; test on surface
- **2007**: transport to the Underground Laboratory (**Canfranc**, Spain); installation in experimental hall and mounting of infrastructure + neutron shield
- **2007**: first data taking

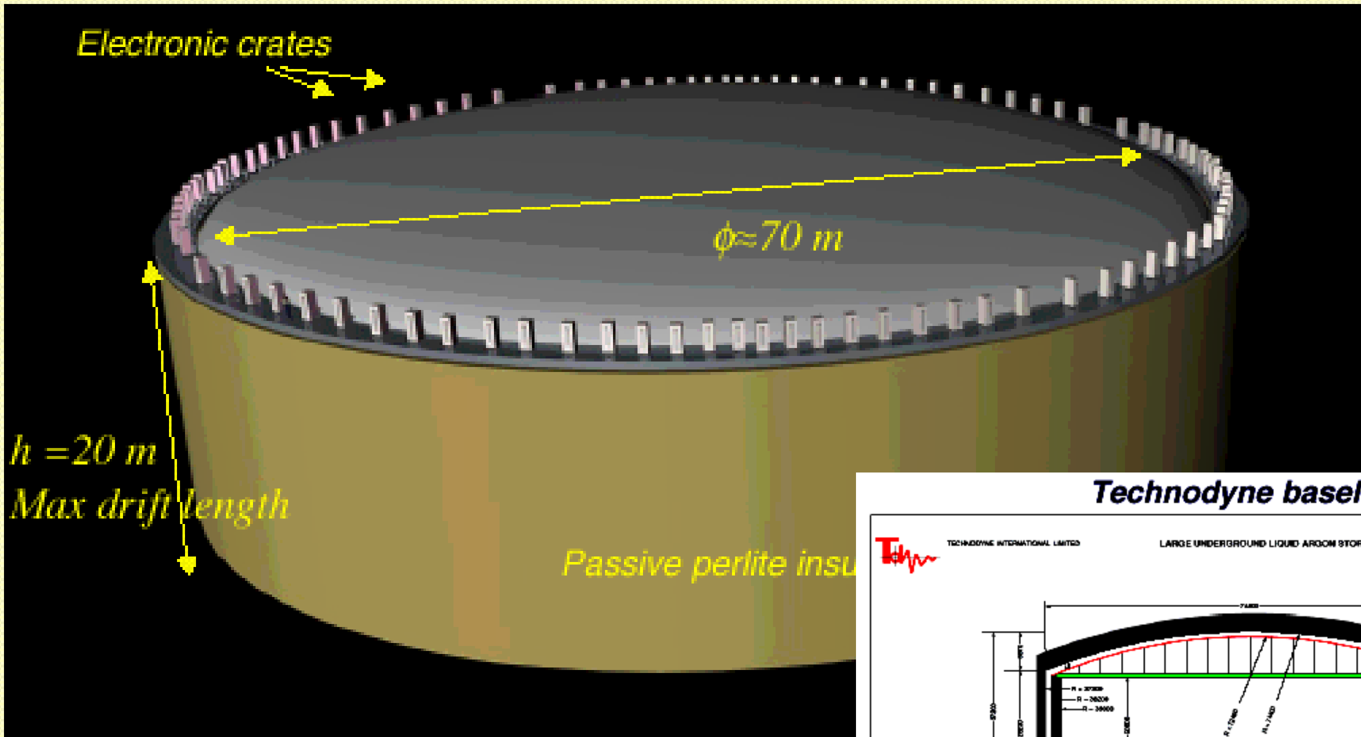
CANFRANC LAB (2450 m w.e.)

pictures: E.Coccia@TAUP05

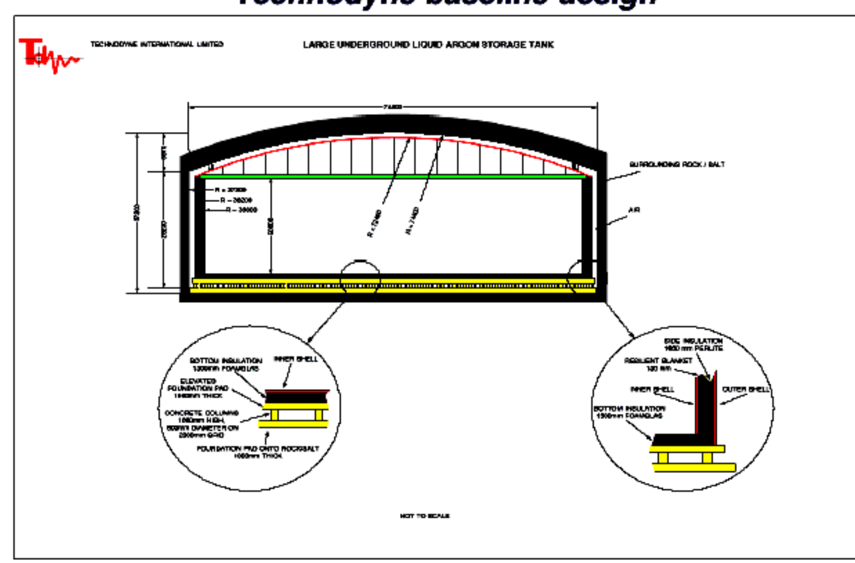
Underground laboratory in Poland in the Polkowice-Sieroszowice mine?

The origin of this study

A 100 kton liquid Argon TPC detector



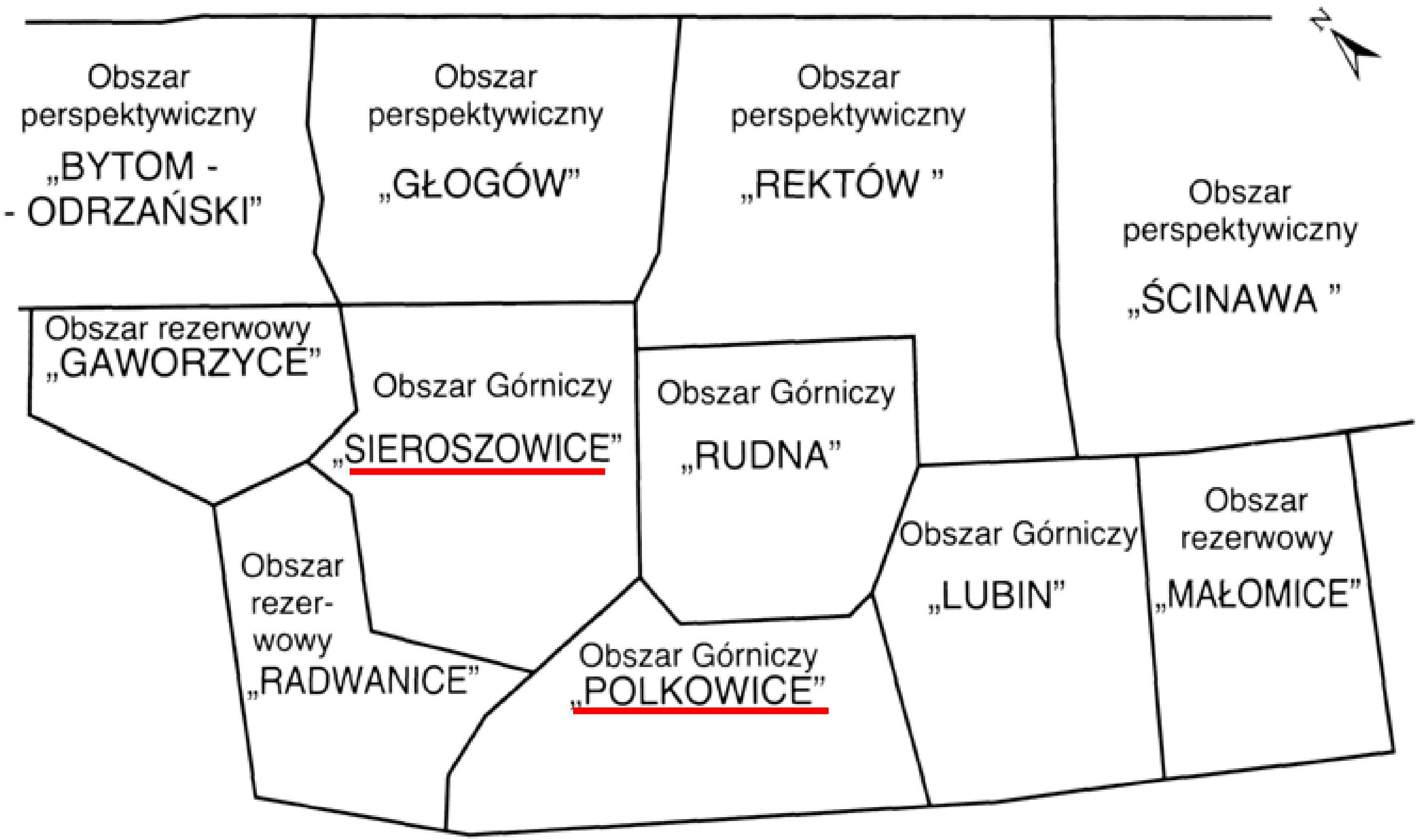
Technodyne baseline design



A.Rubbia
hep-ph/0402110

Near Wrocław, south-west of Poland

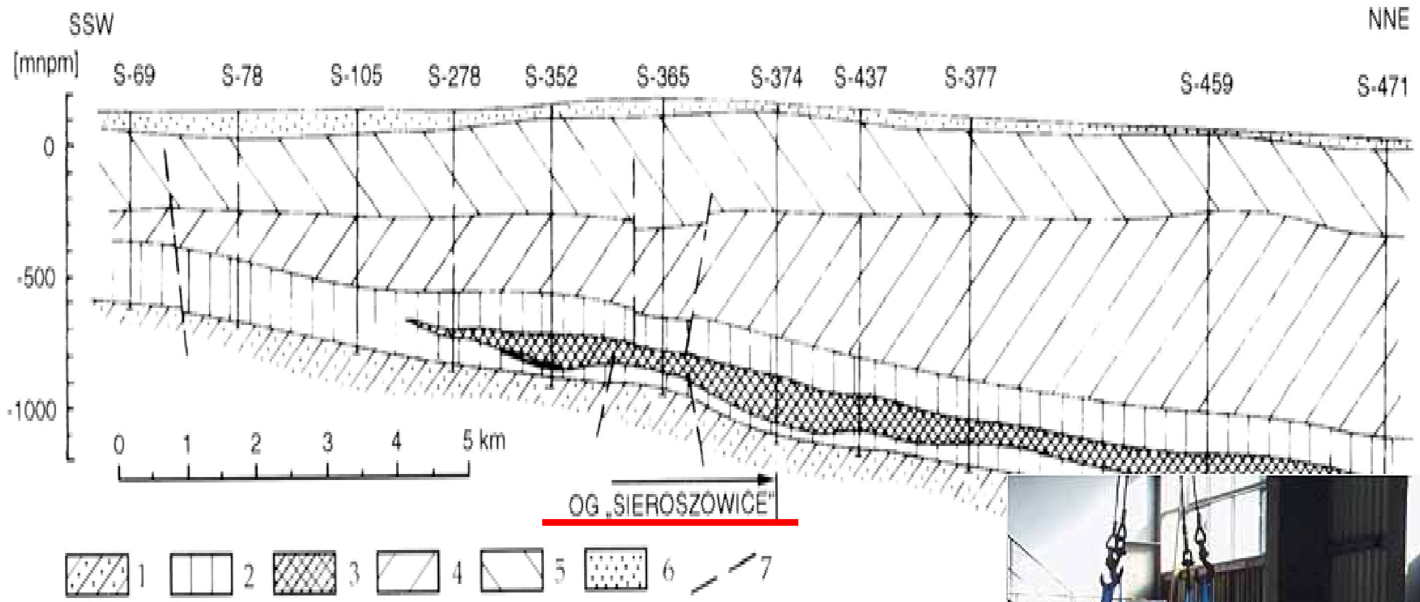
Region of copper mines



Copper – 6th position in the world's exploitation ranking

Silver – 2nd position

... But also salt mines



Przekrój geologiczny poprzeczny

1. Czerwony spągowiec; 2. formacja cechsztyńska; 3. pokład soli kamiennej
trzeciorzęd; 6. czwartorzęd; 7. przypuszczalne dyslokacje uskokowe

Polkowice-Sieroszowice mine - salt cavern

Volume
(100x15x20) m^3

depth 900-950 m
from a surface
(~2500 m.w.e.)

salt layer ~70 m
thick

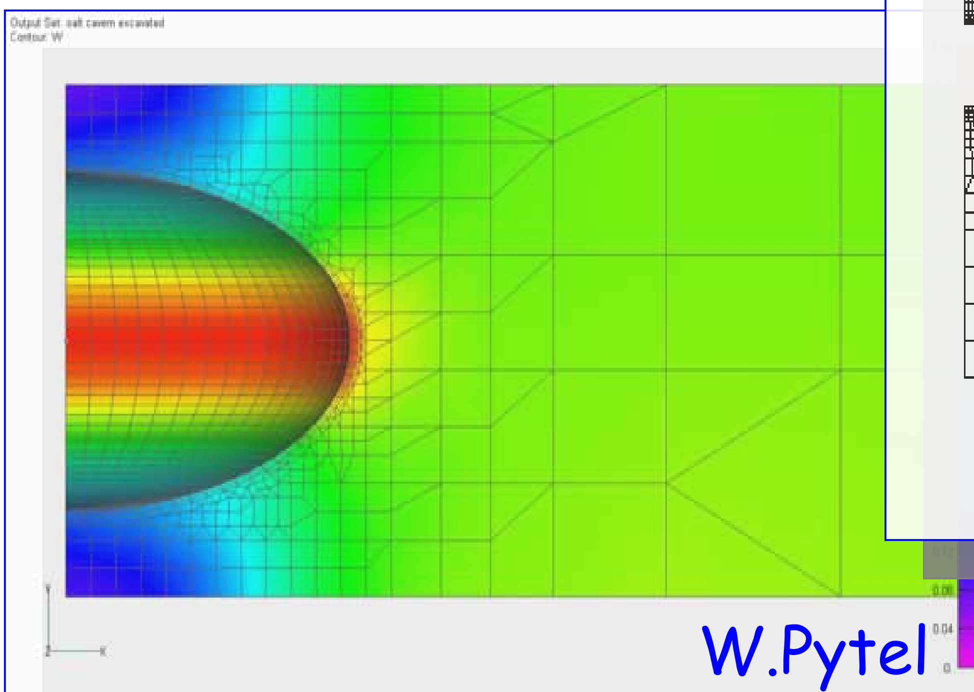
temperature ~35^{0}C

Two questions:

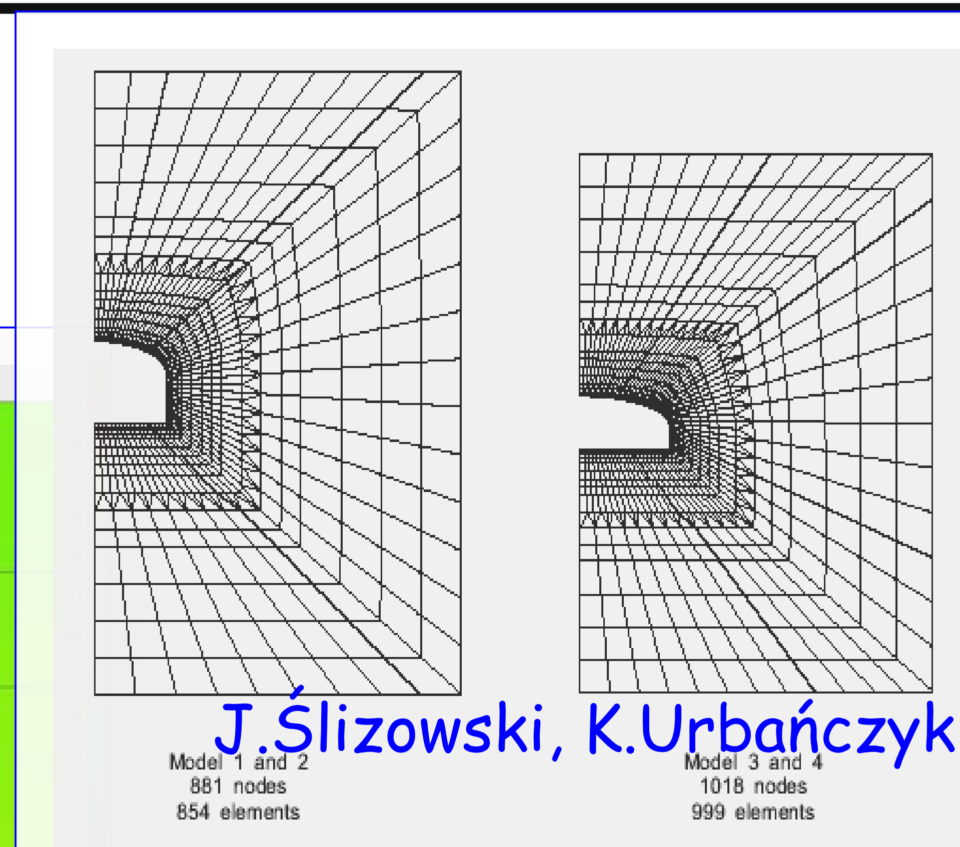
1. Can one dig a huge stable cavern in salt at a depth of ~900 m?
2. Can one make use of the existing cavern?

Answer to question 1: geomechanical simulations

Requirement: a cavern with a diameter 70-100m and stable for 30 years



W.Pytel

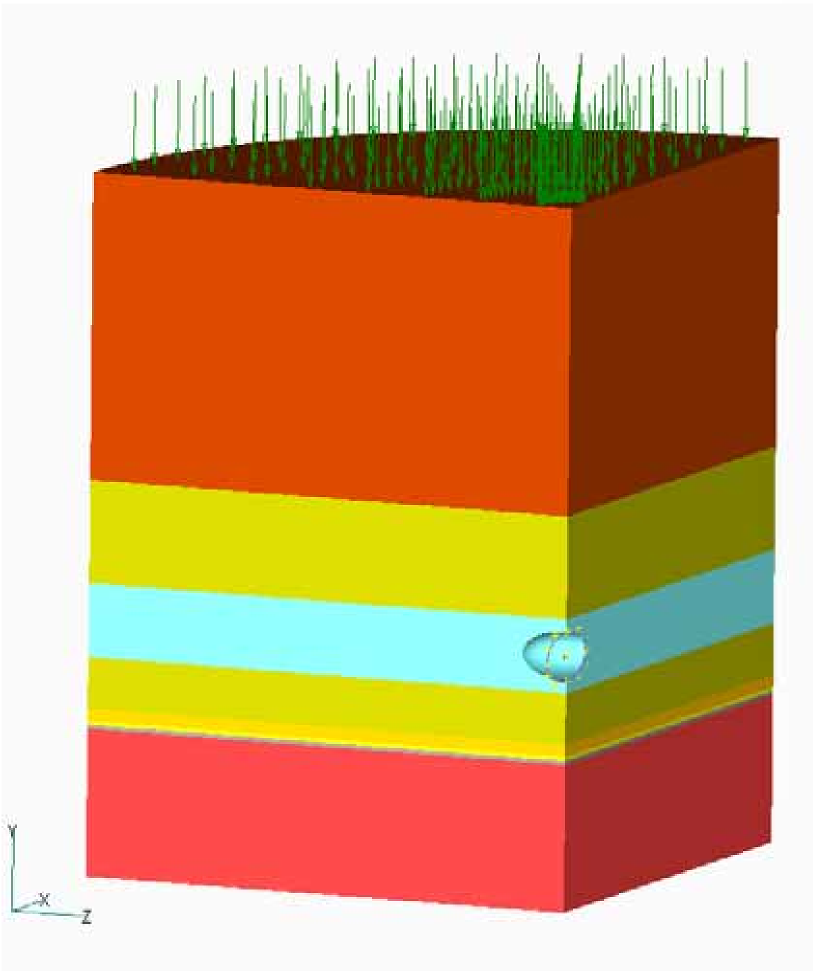


J.Ślizowski, K.Urbańczyk

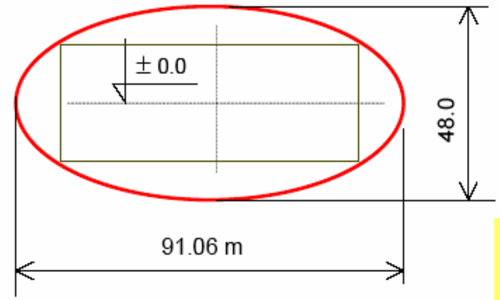
Two independent analyses

W.Pytel

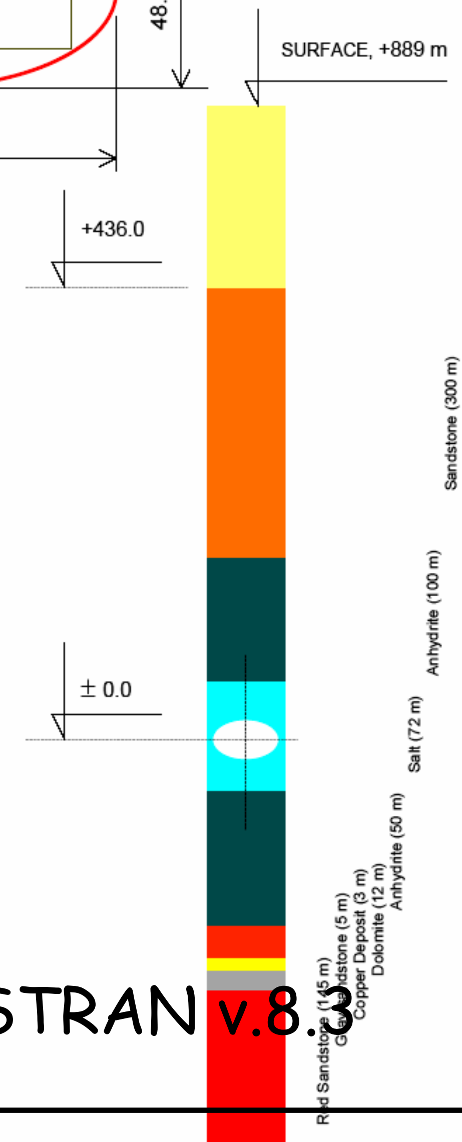
Technical University and CUPRUM, Wrocław



1. Ellipsoidal shape of salt cavern (half-axes are as follows: a = 45.53 m, b = 24.0 m)



2. Applied geological log:

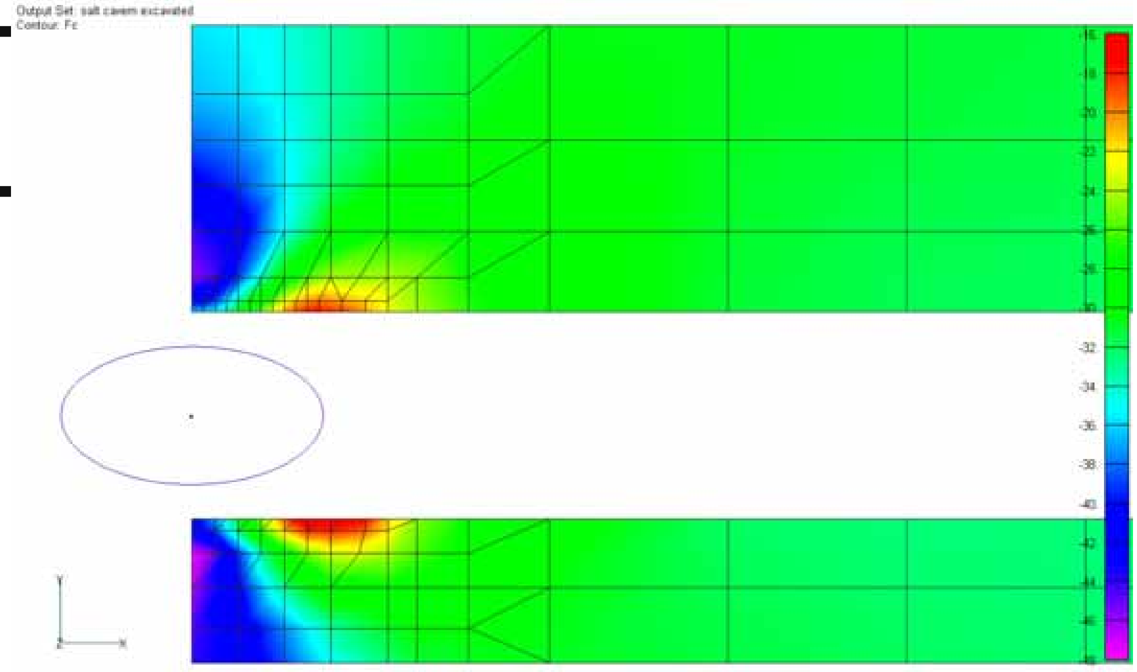


3D finite element analysis with the NE/NASTRAN v.8.3

ApPECC, 3.07.2006

[1] Reduction factor F = 0.25 was applied (in-situ value)

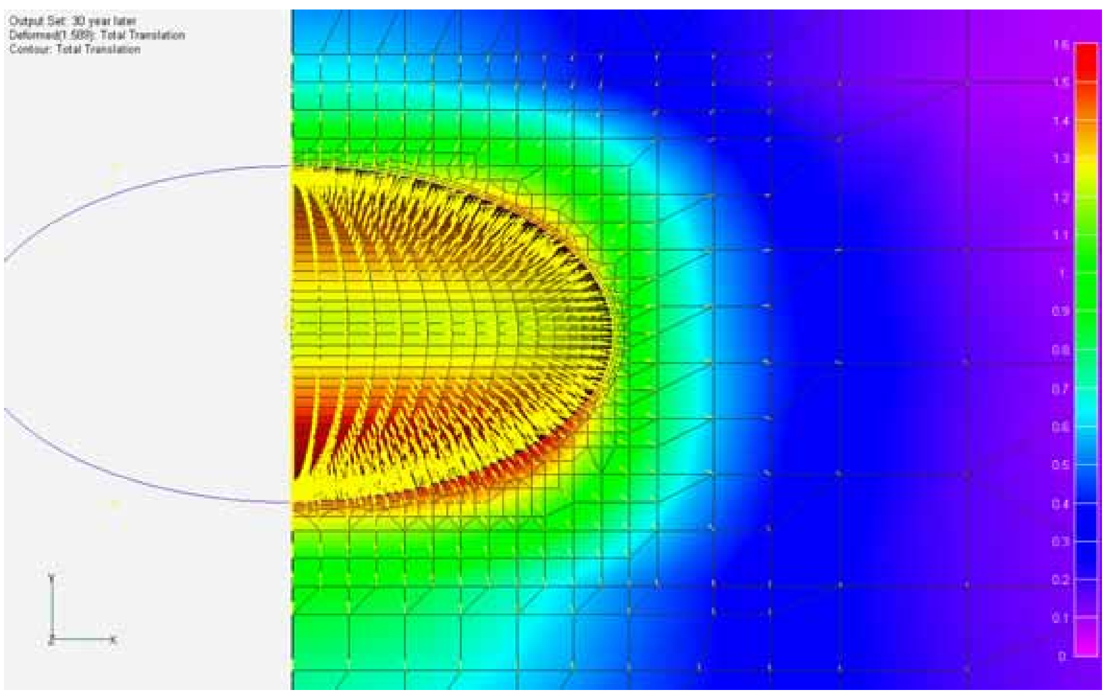
W.Pytel



Main conclusions:

Stable big chamber possible in salt

Anhydrite stable after excavation



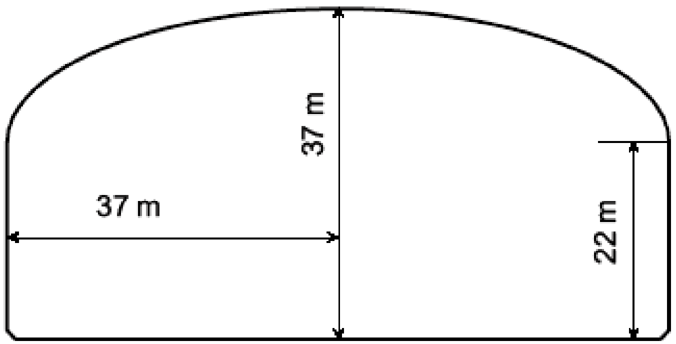
Walls movement after 30 years - by 1.5 m, instant movement after excavation 0.145 m

J.Ślizowski, K.Urbańczyk

Mineral and Energy Economy Research Institute PAN, Kraków

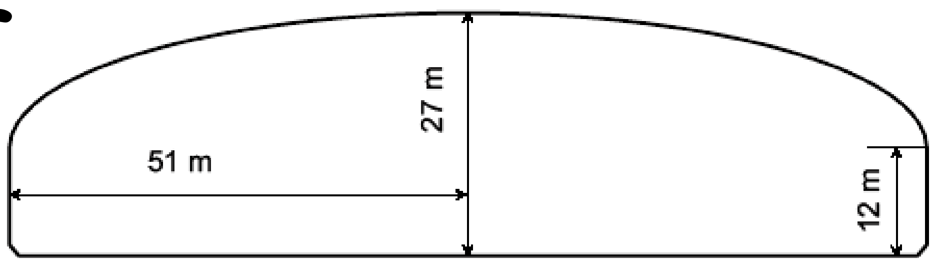
- Two cavern geometries
- Two assumptions about the salt viscous creep
- → 4 models considered
- Depths: 400, 500, 600, ..., 1000 m

1



Model 1 and 2

2

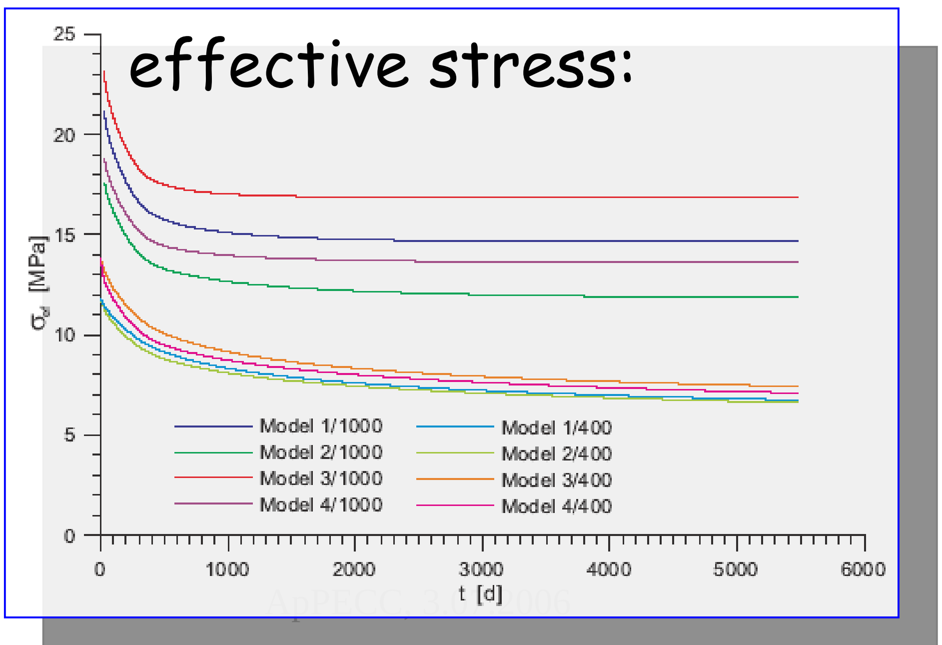


Model 3 and 4

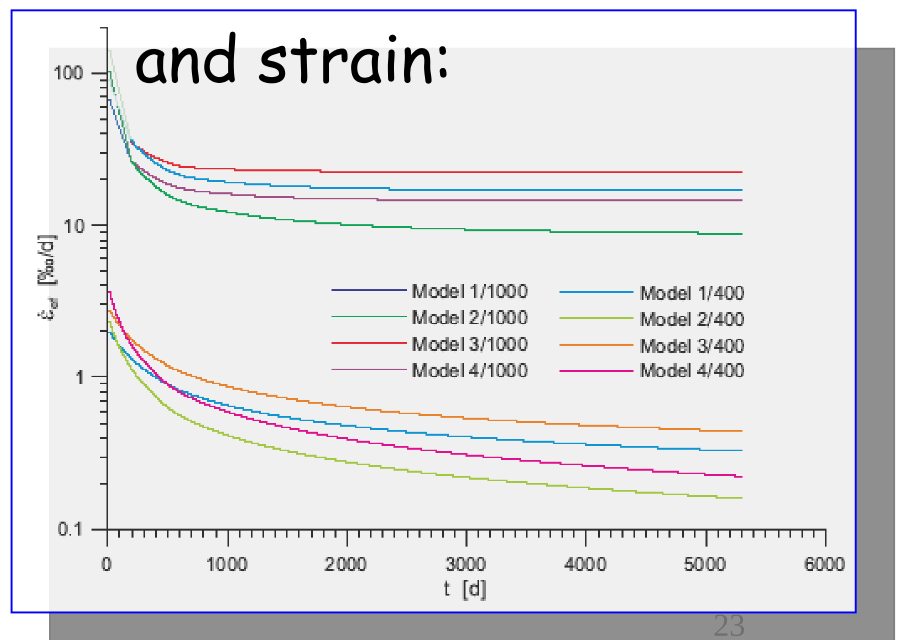
Results of the simulations

- Dependence on the cavern geometry is rather weak
- Depth is crucial
- Cavern of geometry 1 could be safely placed at a depth of 650 m, cavern of geometry 2 at 700 m

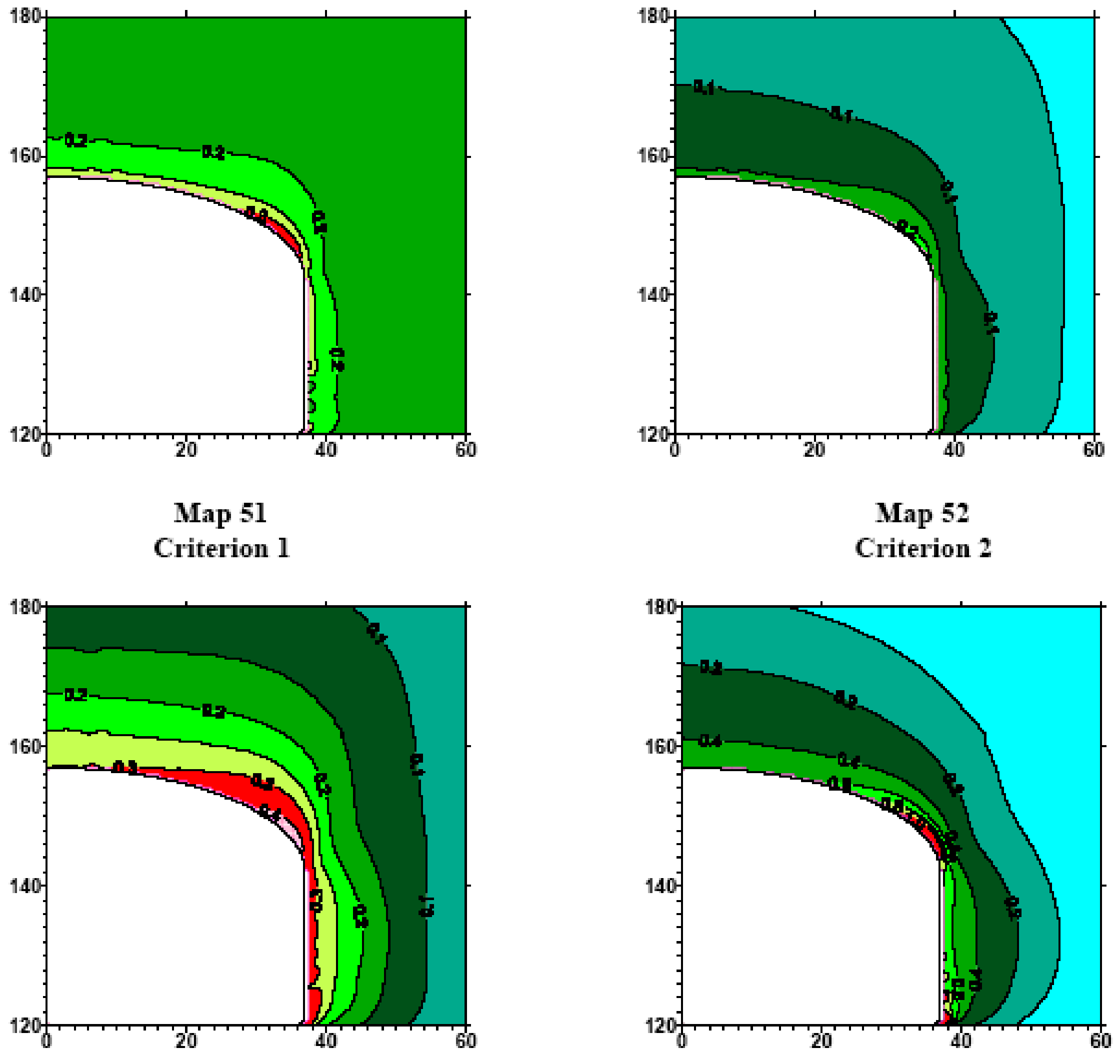
effective stress:



and strain:



Effort coefficient distribution (after 30 years)
Rozkład współczynników wytężenia (po 30 latach)
model 2/700



Map 51
Criterion 1

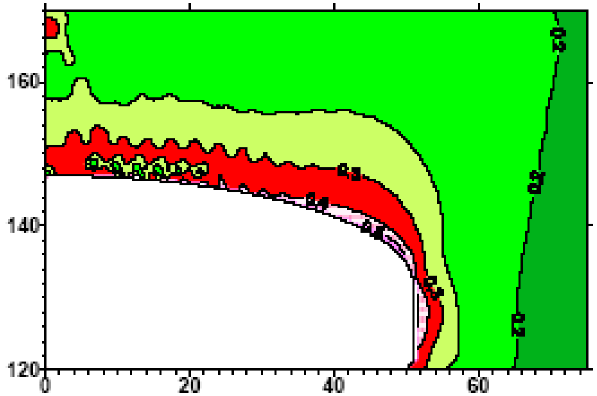
Map 52
Criterion 2

Map 53
Criterion 3

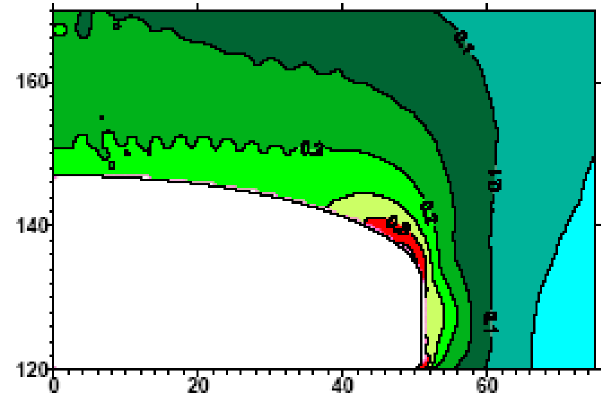
Map 54
Criterion 4

AI

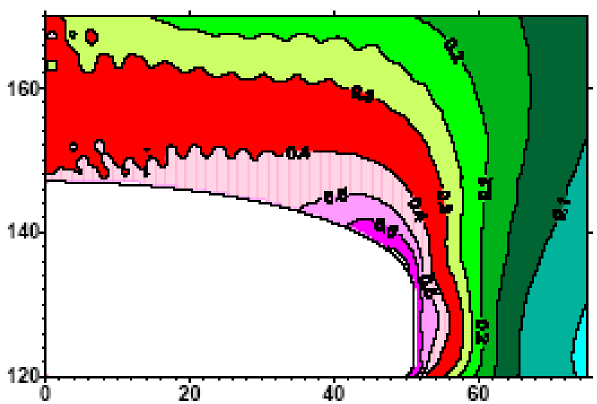
Effort coefficient distribution (after 30 years)
Rozkład współczynników wytężenia (po 30 latach)
model 3/1000



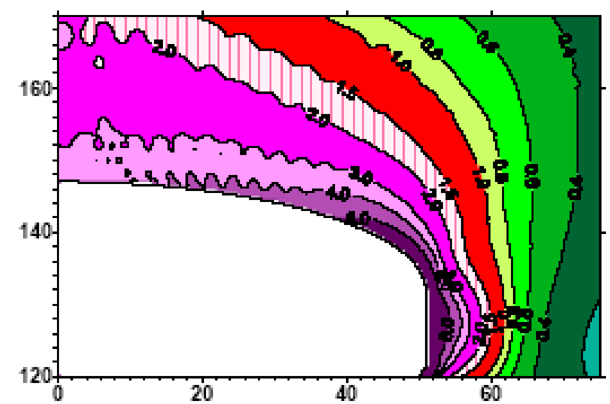
Map 71
Criterion 1



Map 72
Criterion 2



Map 73
Criterion 3



Map 74
Criterion 4

Very important

Wall movements for one of the existing chambers have been monitored since 1997 by the mine staff

Answer to question 2:

Natural radioactivity measurements in the existing cavern

J. Kisiel, J. Dorda, A. Konefał

University of Silesia, Katowice

M.Budzanowski, S.Grabowska, K.Kozak, J.Mazur, J.W. Mietelski, M.Puchalska, A.Szelc, E.Tomankiewicz, A. Zalewska,

IFJ PAN Kraków

α and γ measurements of salt

(J.W.Mietelski, E.Tomankiewicz, S.Grabowska)

Tabela 1. Wyniki stężenia substancji radioaktywnych w badanych próbkach soli z kopalni Sieroszowice.

Radionuklid [Bq/kg]	1	2	3	4
^{238}U	0.40±0.06	0.34±0.05	0.10±0.02	0.14±0.02
^{234}U	0.38±0.06	0.33±0.05	0.14±0.02	0.14±0.02
^{230}Th	0.29±0.05	0.34±0.06	0.10±0.03	0.19±0.03
Średnio sz. U	*0.357*	*0.337*	*0.113*	*0.157*
^{232}Th	0.09±0.03	0.08±0.02	0.03±0.02	0.11±0.02
^{235}U	0.015±0.006	0.015±0.007	<0.005	0.008±0.004
^{40}K	nd	nd	nd	2.1±0.3

Measurements from March 2006

Salt:

U-238:	0.0165+-0.0030 Bq/kg
U-234:	0.0225+-0.0030 Bq/kg
Th-232:	0.008+-0.001 Bq/kg
K-40:	4.0 +-0.9 Bq/kg

Anhidrite:

U-238:	0.82+-0.10 Bq/kg
U-234:	0.76+-0.09 Bq/kg
Th-232:	0.52+-0.15 Bq/kg
Th-230:	1.26+-0.24 Bq/kg

LAGUNA project (Large Apparatus for Grand Unification and Neutrino Astrophysics)

Preparation for the design study within 7FP for future big underground detectors filled with water, LAr and liquid scintillator („3 liquids”)

Polish groups from Cracow, Katowice, Warsaw and Wrocław:

→ Continuation of the feasibility studies for the Polkowice-Sieroszowice site

→ Proton decay in Liquid Argon – study for the ICARUS experiment, extrapolation to a big detector mass (1 PhD at INP, Cracow)

Dose measurements with TL detectors

Integration time: 8 months from the 23rd of March till the 22nd of November 2005

1.8 nGy/h, similar for all 11 sets of detectors
(for comparison – in Cracow at 1m under a surface it is 65 nGy/h)

M.Budzanowski
M.Puchalska

Radon measurements

Mostly due to a pumping of the external air through a ventillation system → aging of this air could be needed

Results from point 1

		Resolution	Mean:	(Min – Max)
Radon–222	[Bq/m^3]	1	19 ± 5	(10 ÷ 38)
Temp.	[°C]	0.1	33.6	(33.3 ÷ 34.0)
Air Pressure	[mbar]	0.1	1038	(1037 ÷ 1039)
Humidity	[%]	0.1	23	(22 ÷ 26)

Conclusions for Polkowice-Sieroszowice

1. Digging a big cavern in salt of the Polkowice-Sieroszowice mine may be feasible but more detailed studies should continue

In particular:

→ What is the maximal chamber which could be safely placed at a depth of ~900 m?

2. Natural radioactivity is very low

But:

→ The background due to h.e. muons at 2500 m.w.e. should be understood

→ Evaluation of neutrino fluxes from „neighbouring" reactors should be evaluated

Detailed simulations of the neutron background have started to understand better the potential of the Polkowice-Sieroszowice site

Measurements of natural radioactivity in European underground labs within the ILIAS project

J. Kisiel, J. Dorda,

University of Silesia, Katowice

What has been done?

- Gran Sasso Lab. (December 2004):

  in-situ measurements, radon emission from the surface, water samples measurements,
- Boulby Lab. (August 2005):

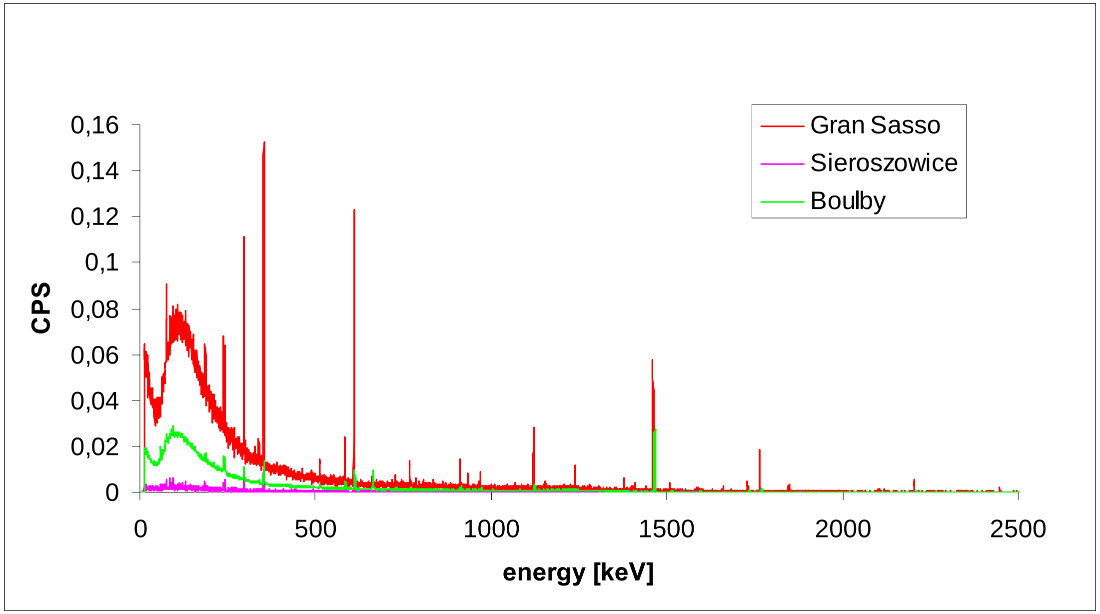
  in-situ measurements, radon emission from the surface,

  rock samples measurements,
- Sieroszowice/Poland, salt chamber:

  in-situ measurements, radon emission from the surface,

  rock samples measurements.

Net Count Rate [cps] – in situ mesurements



In situ measurements: GS, Boulby, Sieroszowice

Integral background counting rates

Energy [keV]	Gran Sasso	Boulby	Sieroszowice
50-2700	57.68 (0.05)	17.00 (0.01)	2.30 (0.02)