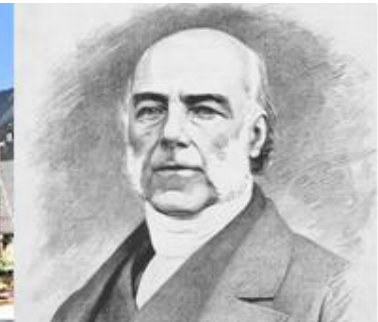


Czech participation in the Underground Laboratory LSM

Rastislav Hodák (IEAP, CTU in Prague)

French-Czech "Barrande"
Nuclear Research Workshop



Honfleur (FR), April 24th - 26th, 2019



INSTITUTE
OF EXPERIMENTAL
AND APPLIED
PHYSICS
CTU IN PRAGUE

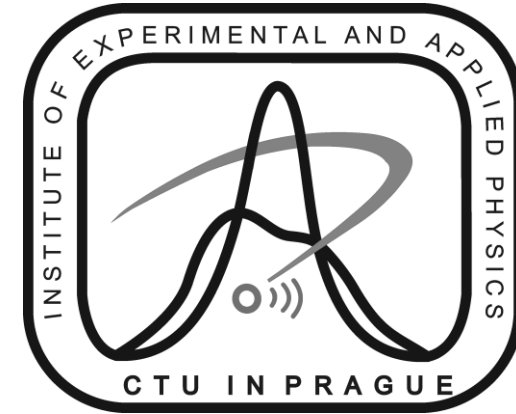


Institute of Experimental and Applied Physics, CTU in Prague

- founded in 2002

Research fields:

- R&D of semiconductor pixel detectors (Timepix type)
- Accelerator particle physics (Van de Graaff accelerator)
- Neutrino physics
- Astroparticle physics – dark matter, cosmic rays
- Applied nuclear spectroscopy
- Applications in biology, medicine, material sciences
- Theory and phenomenology in high energy physics
- Outreach and education → MX-10 particle camera + book of exercises



Address:

Bethlehem Palace
Husova 240/5
110 00 Prague 1
Czech Republic

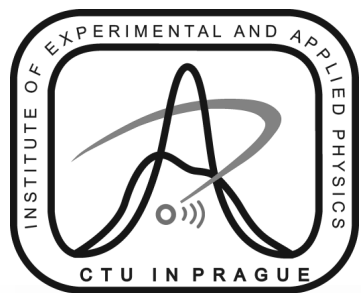


A) Underground Laboratory LSM → included into Roadmap of Czech RIs

Period: 2016-2022
 Hosting institution: IEAP CTU in Prague
 Participating institution: National Radiation Protection Institute
 Budget: 2017-2019 = 13,92 mil. CZK (~ 542 kEUR)
 Purpose: Service to other users of LSM (open access)

B) Operational program MEYS – Science, Research, Education → support of our research connected with RI LSM-CZ

Period: 2017-2019 (with the possibility to continue up to 2022)
 Hosting institution: IEAP CTU in Prague
 Participating institution: National Radiation Protection Institute
 Total budget: 19,997 mil. CZK (~ 780 kEUR)
 Research: Theory of $\beta\beta$ decay and DM; experiments of $\beta\beta$ decay (SuperNEMO, TGV, OBELIX); R&D of CdZnTe detectors; zero dose in radiobiology



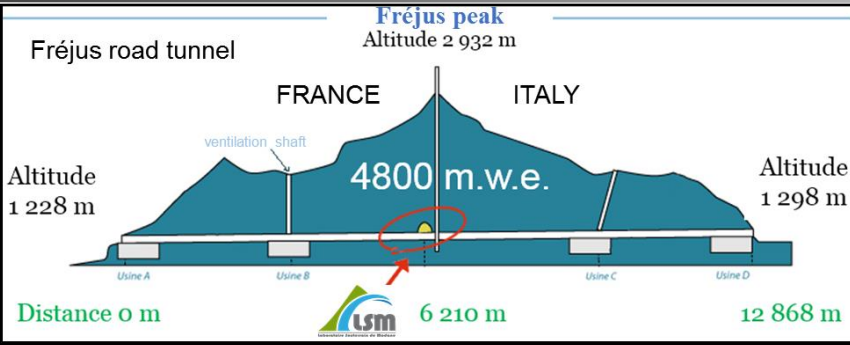
Basic facts about LSM

- **operators:** CNRS/IN2P3 and Grenoble-Alpes Univ.
- **the LSM staff:** 12 persons including a research team of 4 people, headed by **Arnaud Lucotte**
- **users:** 200 researchers from 40 laboratories from France, Russia, Czech Republic, UK, Germany, USA, Slovakia, Japan, Ukraine, Greece
- **Agreement of International Associated Laboratory JOULE:** LSM, JINR Dubna, CTU in Prague and CU (Bratislava), since 2005
- **outreach:** 3 500 visitors per year in our outreach space for general public

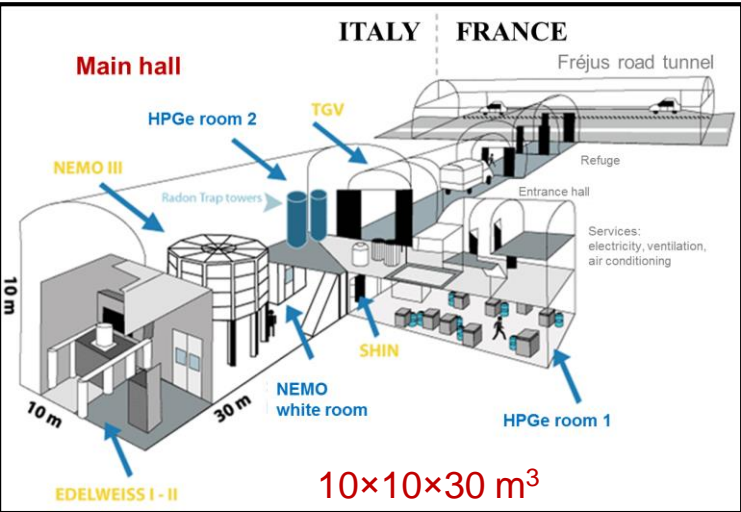
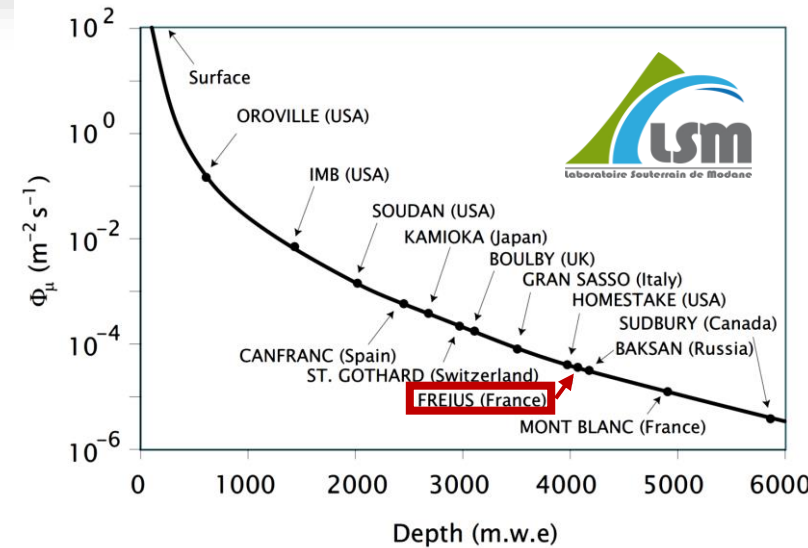


Cooperation of Czech side

- Czech Technical University in Prague, National Radiation Protection Institute, Charles University, Nuclear Physics Institute of the CAS
- 45 scientists, engineers and students (at present, 7 PhD. students)
- aim → cooperation on construction and operation of experimental and infrastructural facilities
- representation of CR in Scientific Board of LSM, in experiments and HPGe community (for detailed information see: lsm.utef.cvut.cz)



- Road tunnel Fréjus (F-I border)
- Depth of ~ 4 800 m.w.e. (muon suppression ~ 10^6)
- Muon flux: $4 \times 10^{-5} \mu.m^{-2}.s^{-1}$
- Neutron flux: $4 \times 10^{-2} n.m^{-2}.s^{-1}$ (fast);
 $1.6 \times 10^{-2} n.m^{-2}.s^{-1}$ (thermal)
- Radon: $15 Bq.m^{-3}$



Main hall



HPGe room 1

List of activities of Czech team in LSM

- 1) Experiments **NEMO-3/SuperNEMO**
- 2) Experiment **TGV (Telescope Germanium Vertical)** and **SPT (Silicon Pixel Telescope)**
- 3) **HPGe spectroscopy**
- 4) **LSM infrastructure**
- 5) **Automatic system for HPGe detectors**



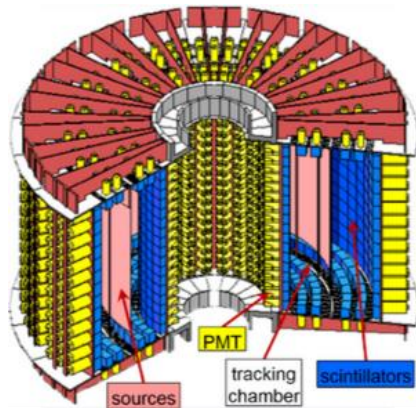
view from road tunnel

NEMO-3 (Neutrino Ettore Majorana Observatory) → 2003 – 2011

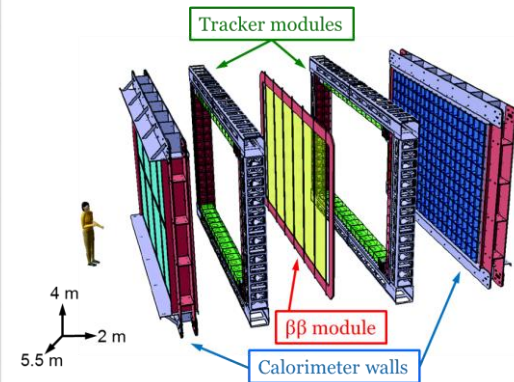
- precise measurement of $2\nu\beta\beta$ and limits on $0\nu\beta\beta$ for ^{100}Mo , ^{82}Se , ^{116}Cd , ^{130}Te , ^{150}Nd , ^{96}Zr , ^{48}Ca
- detection technique – calorimetry and tracking
- NEMO collaboration (since 1989) – France, UK, CR, Russia, USA, Slovakia, Japan, Ukraine

SuperNEMO → installation 2017-2018/commissioning 2019

- measurement of $0\nu\beta\beta$ (→ effective neutrino mass) for ^{82}Se
- detection technique – calorimetry and tracking



NEMO3		→	SuperNEMO	
^{100}Mo			^{82}Se (^{150}Nd or ^{48}Ca)	
7 kg	isotope mass		100+ kg	
18 %	signal efficiency		> 30 %	
$^{208}\text{Tl} \sim 20 \mu\text{Bq/kg}$ $^{214}\text{Bi} < 300 \mu\text{Bq/kg}$ $\text{Rn} \sim 5 \text{ mBq/kg}$	contaminations in the source foil Rn in the tracker		$^{208}\text{Tl} \sim 2 \mu\text{Bq/kg}$ $^{214}\text{Bi} < 10 \mu\text{Bq/kg}$ $\text{Rn} \leq 0.2 \text{ mBq/kg}$	
$\sim 15 \% @ 1 \text{ MeV}$	Calorimeter FWHM		$\sim 8 \% @ 1 \text{ MeV}$	
$T_{1/2}(0\nu\beta\beta) > 2 \times 10^{24} \text{ y}$ $\langle m_\nu \rangle < (0.3 - 0.9) \text{ eV}$	half-life sensitivity effective neutrino mass		$T_{1/2}(0\nu\beta\beta) > 1 \times 10^{26} \text{ y}$ $\langle m_\nu \rangle < (0.04 - 0.11) \text{ eV}$	



IEAP responsibilities: calorimeter (improvement of scintillators properties), tests of calibration sources, passive shielding, radon programme, theory (nuclear matrix elements), supporting frame, selection of radiopure materials, data analysis of ^{100}Mo and ^{150}Nd

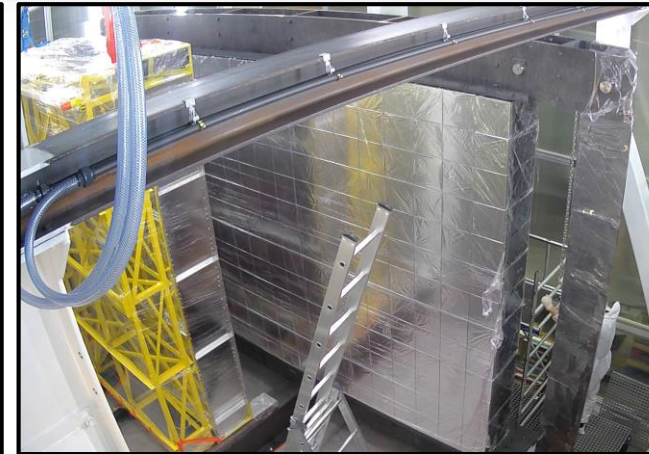
Cotutelle PhD programme: Miroslav Macko (thesis defended in December 2018)



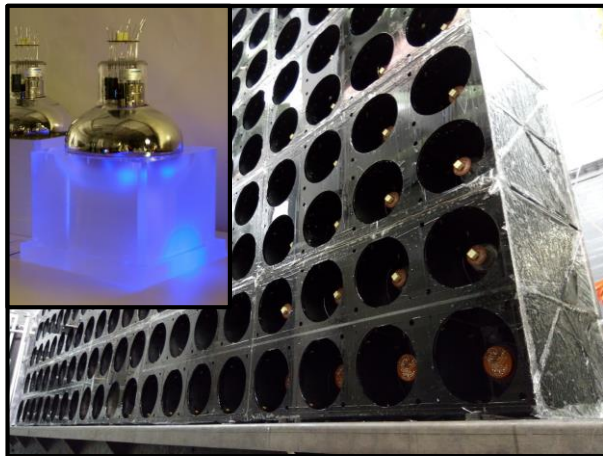
supporting frame



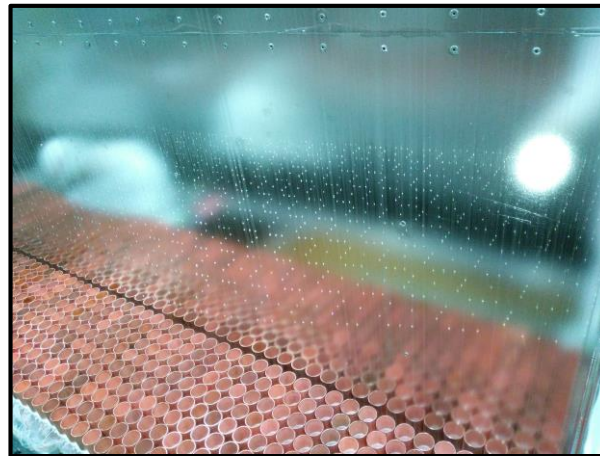
clean tent



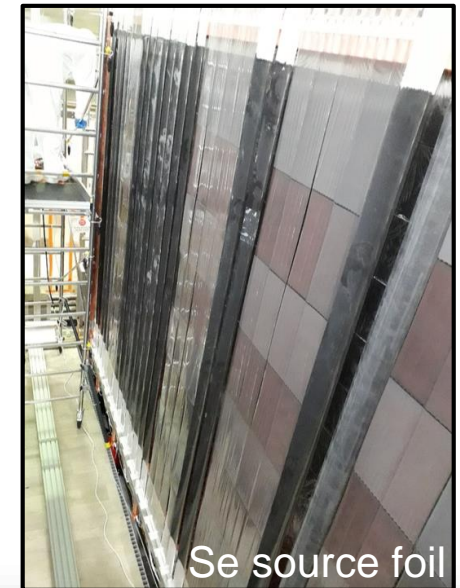
calorimeter wall



calorimeter wall

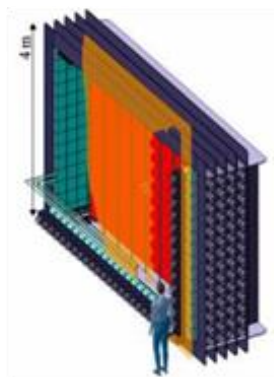


tracker



Se source foil

Background reduction and rejection



=



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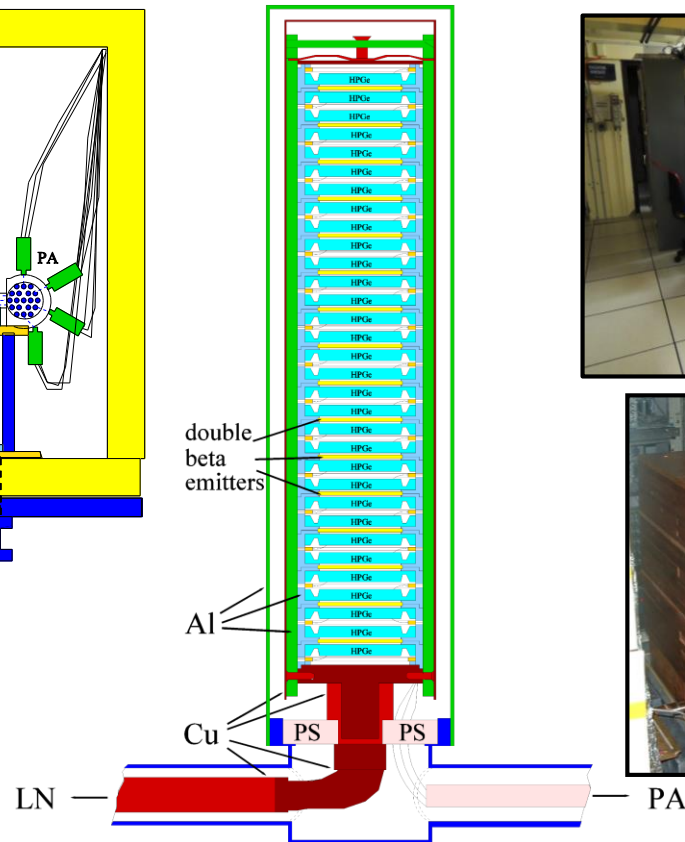
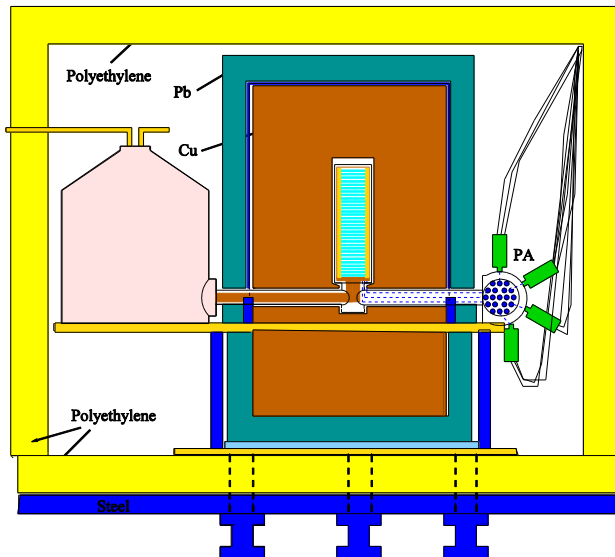
100 Bq

SuperNEMO
Demonstrator Module
35 tons

1 kg of bananas

TGV (Telescope Germanium Vertical) → since 1990

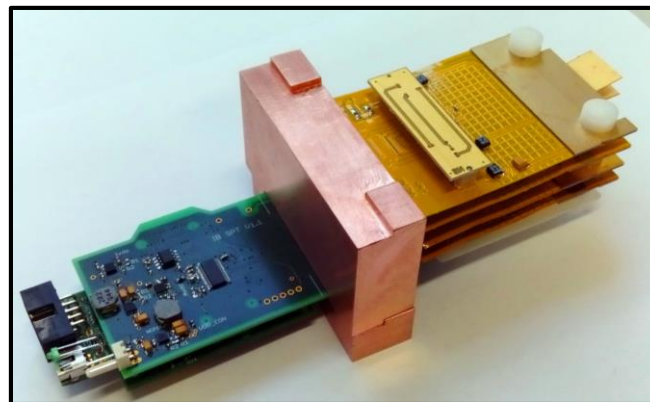
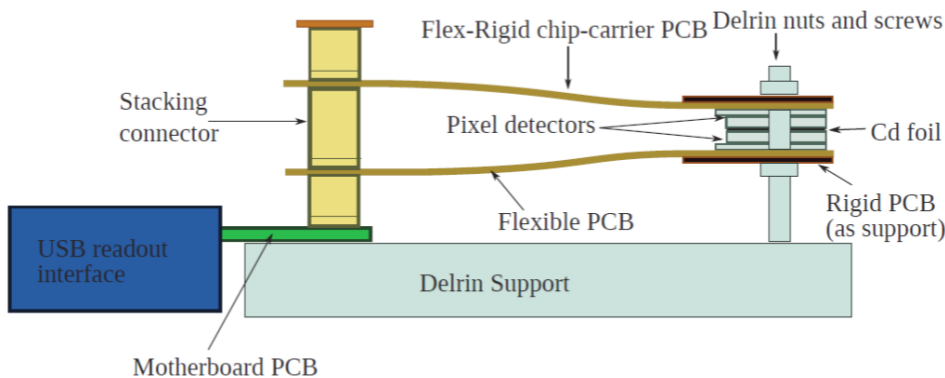
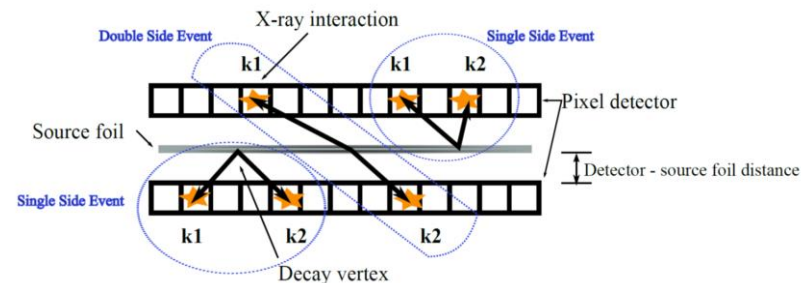
- measurement of $2\nu\beta\beta$ in ^{48}Ca (phase I) and $2\nu\text{EC}/\text{EC}$ in ^{106}Cd (phases II and III)
- detection technique – **gamma spectroscopy** with planar **HPGe detectors**
- TGV collaboration - IEAP CTU, JINR Dubna, CSNSM Orsay and CU in Bratislava



IEAP responsibilities: installation and maintenance of the TGV setup, participation in data collection and data analysis

SPT (Silicon Pixel Telescope) → since 2014

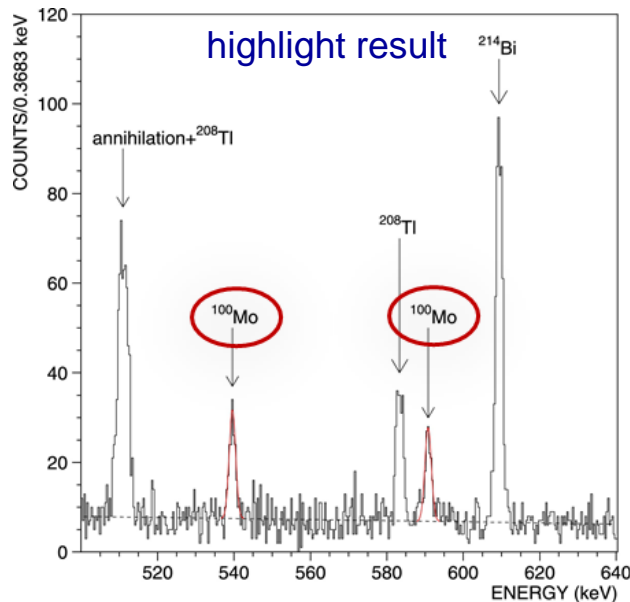
- measurement of $2\nu\text{EC}/\text{EC}$ in ^{106}Cd
- detection technique – **Si pixel detectors** →
- SPT collaboration - IEAP CTU and JINR Dubna



IEAP responsibilities: R&D and production of the SPT setup, installation of the setup and shielding in LSM, background runs and ^{nat}Cd measurements, data collection and data analysis

OBELIX spectrometer → since 2011

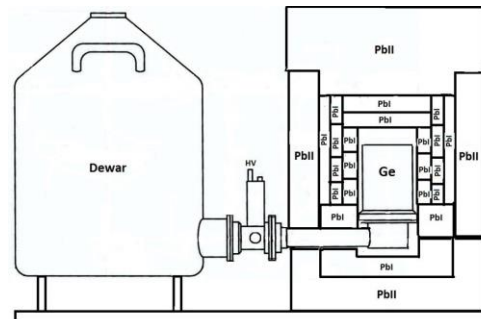
- measurement of different **double beta decay** processes and **ultra-low activity samples**
- detection technique – **gamma spectroscopy** with **low-background high-volume** (600 cm³) **HPGe** detector (rel. efficiency of 162 %)
- OBELIX collaboration - IEAP CTU, JINR Dubna and LSM Modane



$$T_{1/2}^{2\nu\beta\beta} (0_{g.s.}^{+}({}^{100}\text{Mo}) \rightarrow 0_{1}^{+}({}^{100}\text{Ru})) =$$

$$= 7.5 \pm 0.6 \text{ (stat)} \times 10^{20} \text{ years}$$

$$= 7.5 \pm 0.6 \text{ (syst)} \times 10^{20} \text{ years}$$



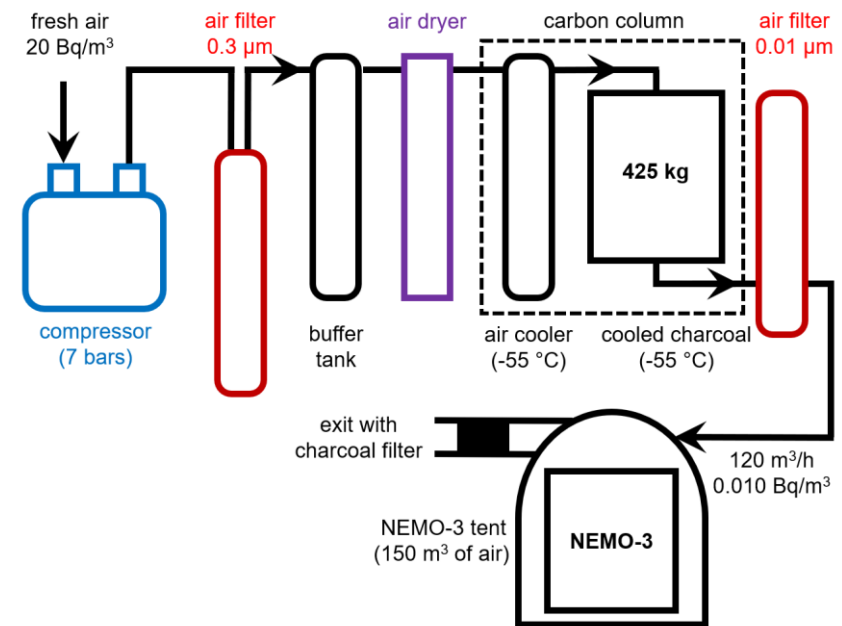
IEAP responsibilities: installation and maintenance, calibration runs, background measurements and different measurements with various low activity samples, data analysis

Anti-radon facility → Since 2004 (for NEMO-3 purposes)

- providing clean **air** for experiments with **radon activity $< 10 \text{ mBq/m}^3$**
- success transfer of R&D into production → ATEKO company produced facilities → 2.73 mil. EUR)



anti-radon facility



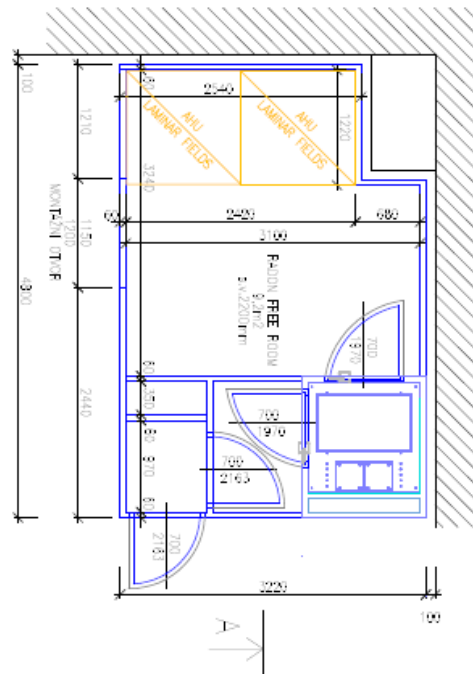
IEAP responsibilities: R&D and production of anti-radon facility, installation and maintenance

Clean room in LSM (ISO 5, zero-dose environment for biology)

- anti-radon system and clean room (ISO 5) already installed in NRPI
- in 2018 → installed in LSM (4.3 x 3.2 x 3.2 m³)
- **suppression** of **all types** of **radioactivity** (including radon) for biological studies
- price ~ 110 kEUR
- patent application



clean room

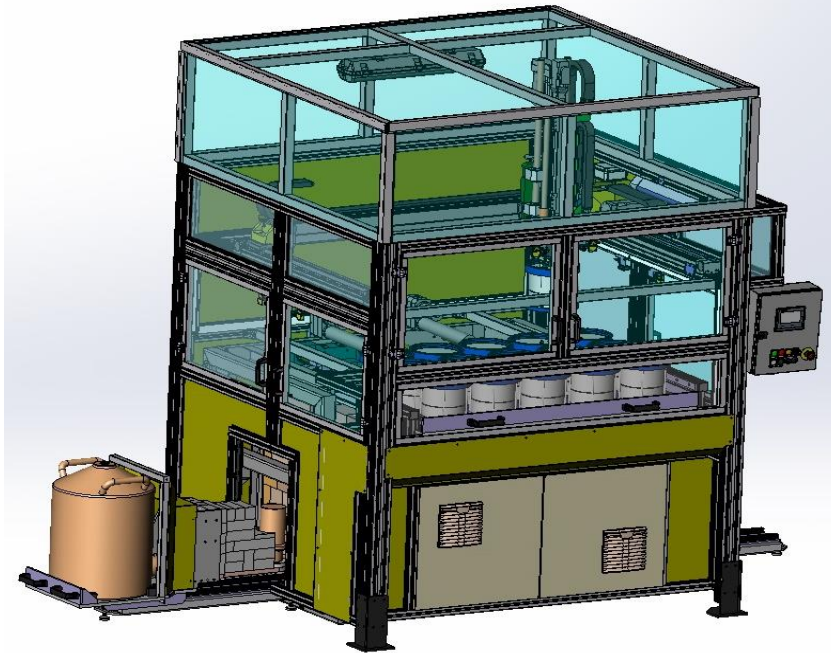
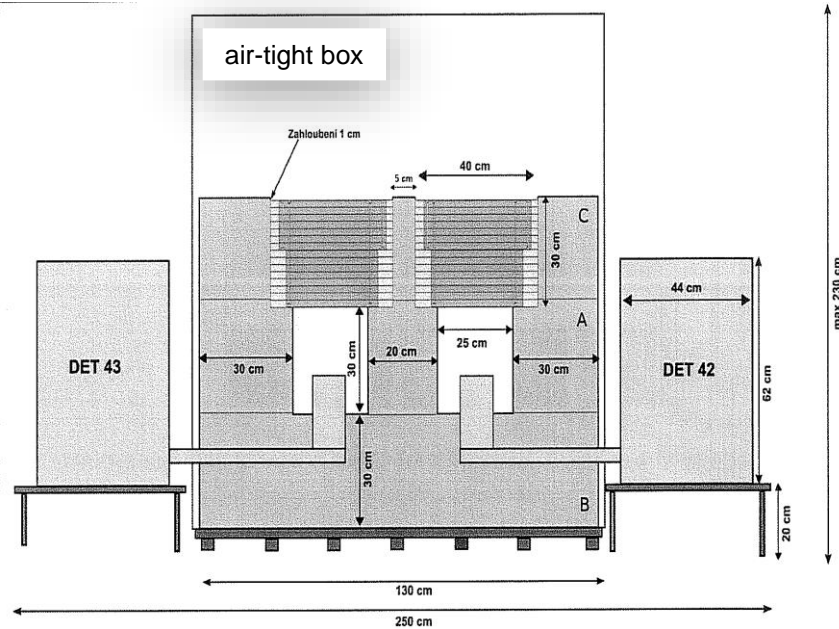


50 l radon detector

IEAP responsibilities: R&D and production of ISO 5 clean room, installation and maintenance

Automatic system for charging of samples for HPGe detectors

- dimensions → 2.5 x 2.3 x 1.5 m³
- produced by NUVIA a.s. company
- installation in LSM → autumn 2019



IEAP responsibilities: R&D of automatic system, maintenance

Most important future plans (CR and LSM)

a) Infrastructure:

- extension of clean room: for biologists, DM search with DAMIC experiment (damic.uchicago.edu)
- installation of automatic system for charging of samples for HPGe detectors
- R&D of cleaning system for gas purification in tracking detector of SuperNEMO
- installation of 2 new ultra-low background HPGe detectors (IDEFIX - 600 cm³, efficiency 162%; second one financed and run by NRPI)
- **active participation in the LSM extension – future project on EU level !!!**

b) Scientific:

- finishing and running of SuperNEMO demonstrator (shielding), cooperation on construction of other modules of SuperNEMO, data processing, further development of the theory of double beta decay (strong group of theoreticians in IEAP)
- use of pixel detectors in double beta decay
- increase of our participation in new collaborations, LEGEND (⁷⁶Ge), PICO (DM)
- biological research

c) Educational:

- summer schools (Pontecorvo Neutrino School → Romania 2019 (theor.jinr.ru/~neutrino19))
- international conference MEDEX'19 (Nuclear Matrix Elements → Prague (medex19.utef.cvut.cz))
- regular organization of SuperNEMO collaboration meetings

Benefits for the Czech side

- participation in attractive research programme, progressive technologies (transfer to industry)
- education of students and young researchers
- improvement of home infrastructure (attracts researchers from abroad to CR)
- regular (every 2 years) organization of international conference (MEDEX)



Thank you for the attention

LSM extension proposals

- New cavity with the volume of 11 000 m³
- SuperNEMO, EURECA, TGV, HPGe spectroscopy etc.

