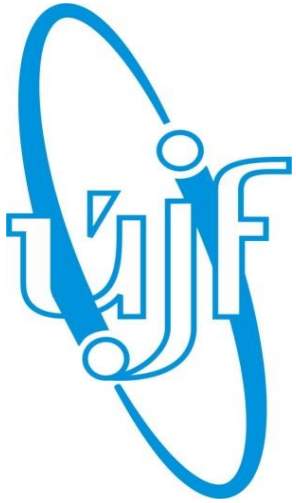
Czech contribution to neutrino experiments

V. Vorobel
Charles University in Prague, FMP

- Direct neutrino mass measurement – KATRIN
- Accelerator neutrino NOvA
- Reactor neutrino – Daya Bay, JUNO
- Sterile neutrino DANCE
- Double beta decay – NEMO3, SuperNEMO
- Small scale experiments TGV



KATRIN experiment - model independent search for the neutrino mass

Czech participant: Nuclear Physics Institute of the Czech Acad. Sci., Řež near Prague

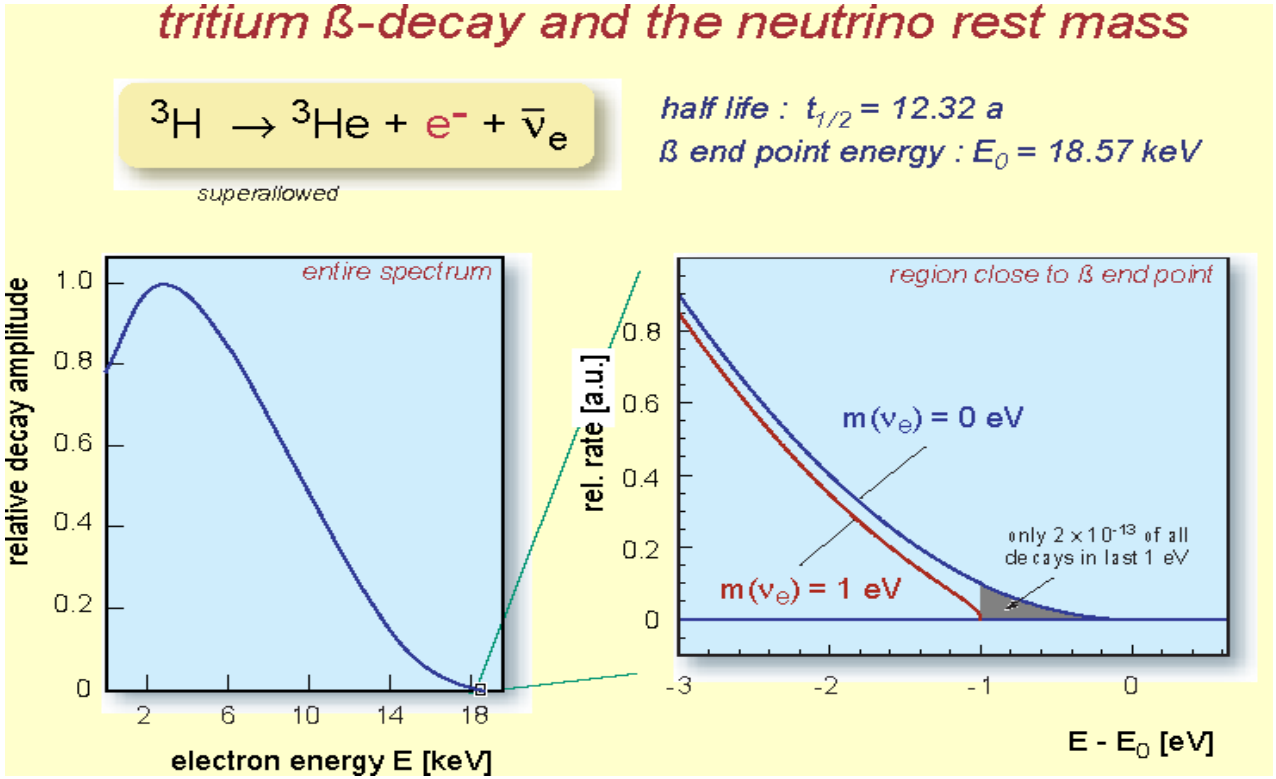
Local and KATRIN websites:

http://ojs.ujf.cas.cz/katrin/

http://www.katrin.kit.edu/

KATRIN - Karlsruhe Tritium Neutrino Experiment:

direct β-spectroscopic search for m_ν



Measured quantity :

$$m_{ve}^2 = \sum_i |U_{ei}|^2 \cdot m_i^2$$

Neutrino mixing matrix elements

Mass eigenstates

theoretical decay amplitude:

$$dN/dE = K \times F(E_e, Z+1) \times p_e \times (E_e+m_e) \times (E_0-E_e) \times [\,(E_0-E_e)2 - m_{ve}^2\,]^{1/2}$$

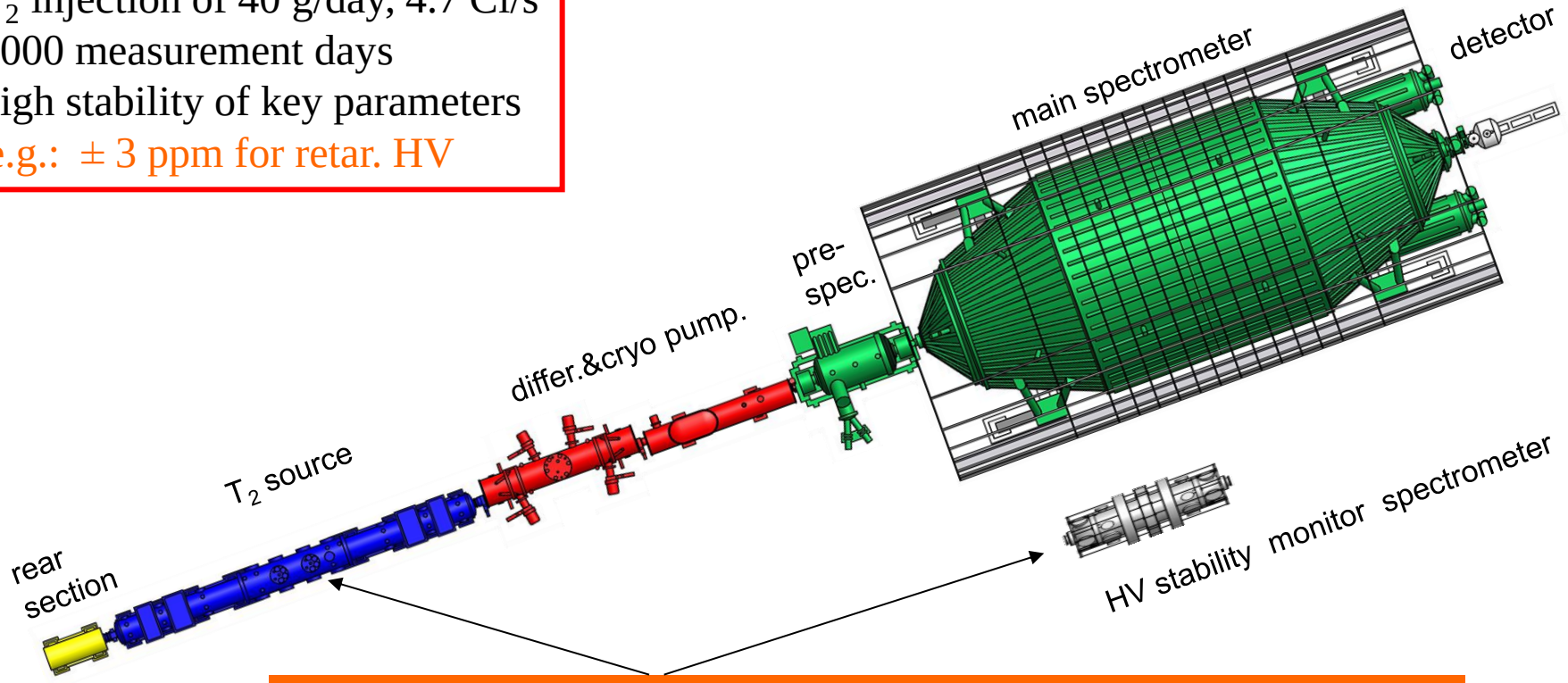
Sensitiviy after 1000 measuring days:

m_ν **< 0.2 eV** at 90 % C.L. if no effect is observed

m_ν **= 0.35 eV** would be seen as **5σ effect**

KATRIN setup - with MAC-E filter spectrometers

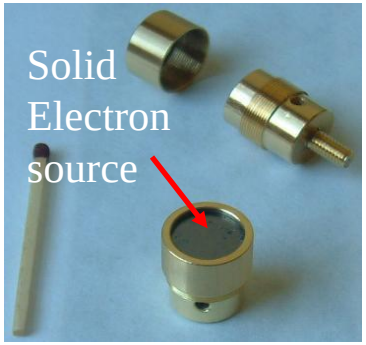
For sensitivity of 200 meV:
-high resolution: 0.9 eV
-high luminosity: 19% of 4π
-low detector back.: 10 mHz
-T_2 injection of 40 g/day, 4.7 Ci/s
-1000 measurement days
-high stability of key parameters
e.g.: ± 3 ppm for retar. HV



calibration & monitoring electron sources are developed at NPI

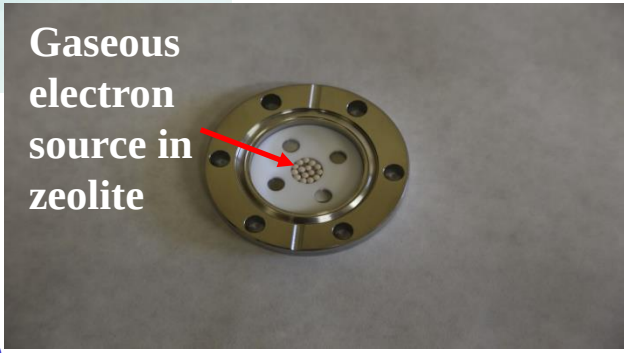
KATRIN – NPI: relations, manpower, funding, tasks

- With institutions from Germany, Russia, USA NPI is a founder of KATRIN
- O. Dragoun and D. Vénos are members of the KATRIN Collaboration Board
- D. Venos is co-leader of the task Calibration and Monitoring



- Collaborators in 2014

Name	Position	KATRIN FTE (%)
Dragoun O.	Scientist	60
Hanč P.	Engineer	10
Kovalík A.	Scientist	10
Lebeda O.	Scientist	5
Ryšavý M.	Scientist	80
Sentkerestiová J .	Scientist	75
Slezák Martin	Student	50
Špalek A.	Scientist	20
Stanislav J.	Technician	10
Vénos D.	Scientist	100



- Funding in 2014 in k€:

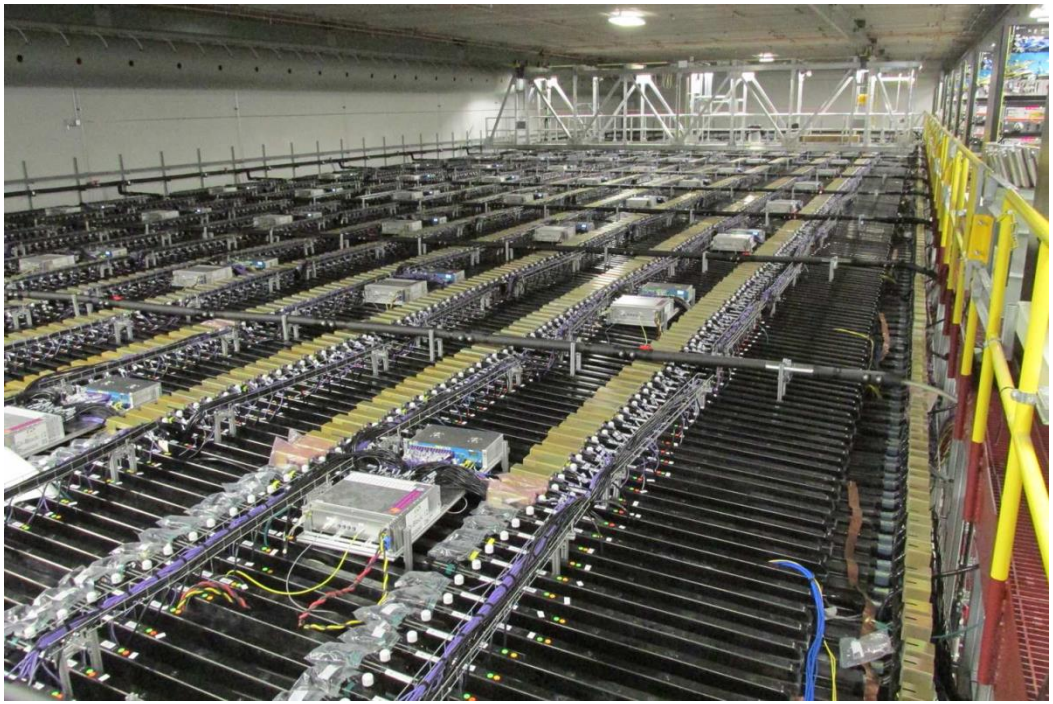
Personnel 4.2 FTE - 104, operational - 33, indirect - 31, in total - 168

- Tasks:
- development of solid electron source $^{83m}Kr/^{83}Rb$ for HV monitoring – **FINISHED**
  energy drift of monitoring 17.8 keV line < 0.3 ppm/month (5 x better than requested)
- development of gaseous electron source $^{83m}Kr/^{83}Rb$ for calibration – ON GOING

Numi Off-axis ν_e Appearance experiment

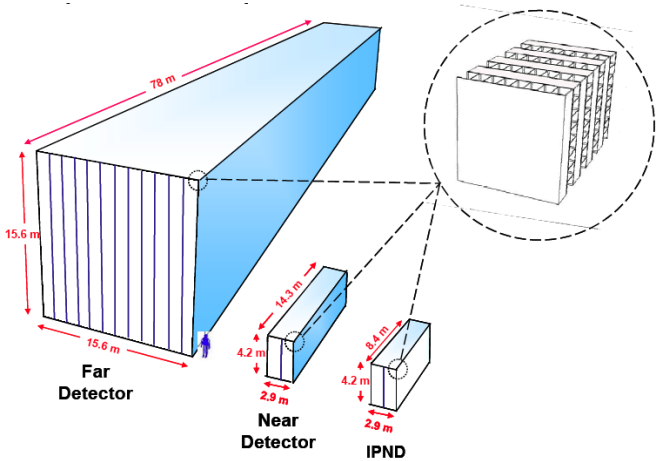
Czech participants:

- Physics Institute ASCR
- FMP Charles University in Prague
- FNSE Czech Technical University in Prague



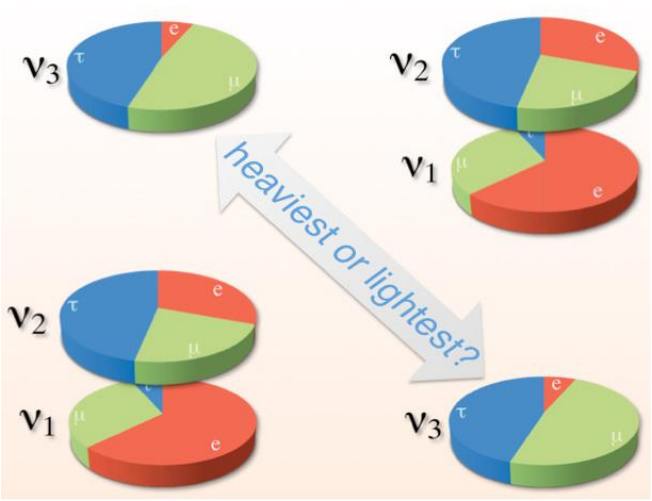
NOνA experiment

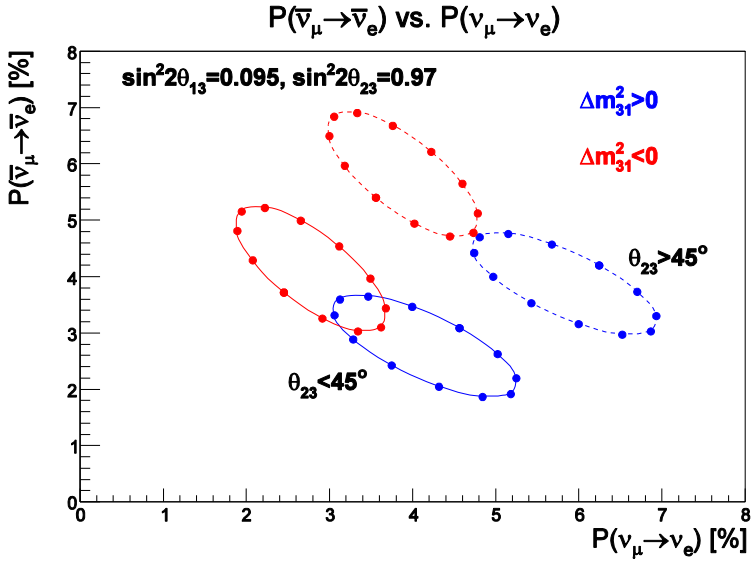
- neutrino experiment at Fermilab (flagship of FNAL neutrino programme)
- 2 detectors made of PVC cells filled with mineral oil and scintillator
  - Near Detector - at FNAL, 1km from target, weight 330 tons, 20k channels
  - Far Detector at Ash River Minnesota, 810 km from target, weight 14000 tons, 344k channels
- both detectors built with identical technology, PVC cells filled with scintillating mineral oil, light collected by optical fibers and read by APD
- both detectors completed and instrumented in summer 2014
- beam of ν_μ neutrinos with E ~ 2 GeV
- beam power : currently ~300kW, should go up to 700kW
- detection of neutrino oscillations $\nu_\mu \rightarrow \nu_e$ and measurement of their parameters



NOνA motivation

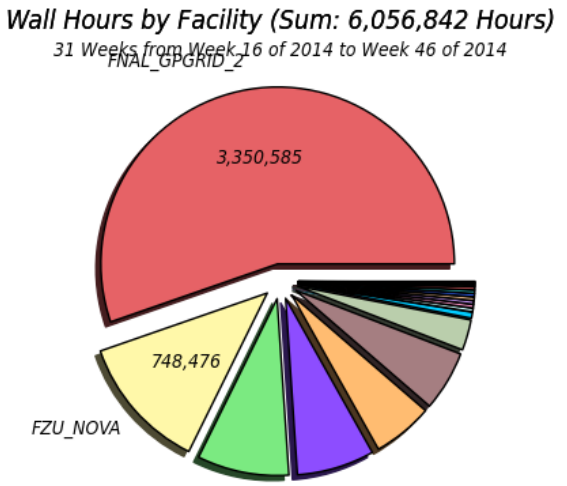
- neutrino mass hierarchy
- CP violation in neutrino sector (δ_{CP})
- θ_{23} octant
- measurement of other oscillation parameters
- neutrino cross sections
- exotics (supernova neutrinos, magnetic monopoles, dark matter, sterile neutrinos ...)





Czech group contribution to NOvA

Design and production of APD testing devices (black boxes), long term APD tests, environmental sensor system, detector commissioning, module painting, oil filling, pressure tests, run coordinator, software production, DAQ software management, slow control, MC production, data analysis.



Physics Institute ASCR

- scientists: M. Lokajicek, J. Zalesak
- technicians: I. Polak, J. Kvasnicka, J. Zuklin, Z. Kotek, Va. Zamazal, Vl. Zamazal
- IT expert: Jan Svec

FMP Charles University in Prague

- scientists: K. Soustruznik, P. Tas
- technician: J. Palacky
- students: T. Nosek, Z. Jelinkova

FNSE Czech Technical University in Prague

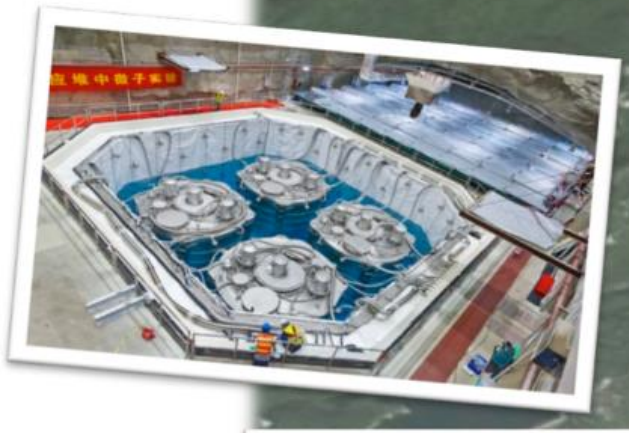
- scientists: J. Smolik, F. Jediny, P. Vokac, V. Linhart, T. Vrba

Daya Bay Reactor Antineutrino Oscillation Experiment

Czech participant: FMP Charles University in Prague

The Daya Bay Experiment

- 17.4 GW_{th} power
- 8 operating detectors
- 160 t total target mass

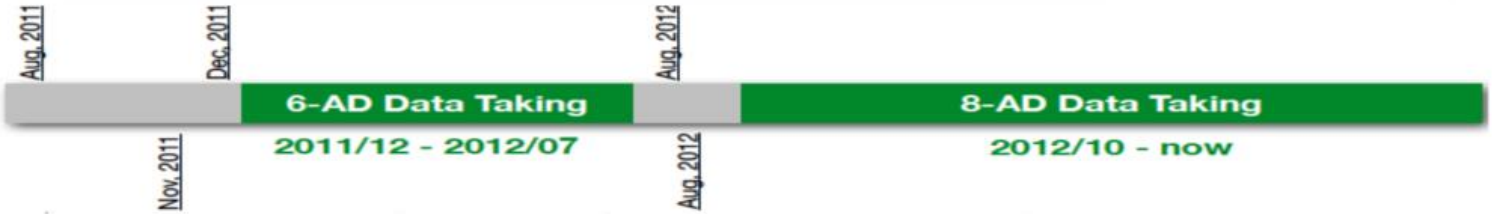


EH3
EH2
LA2
LA1
EH1
DYB

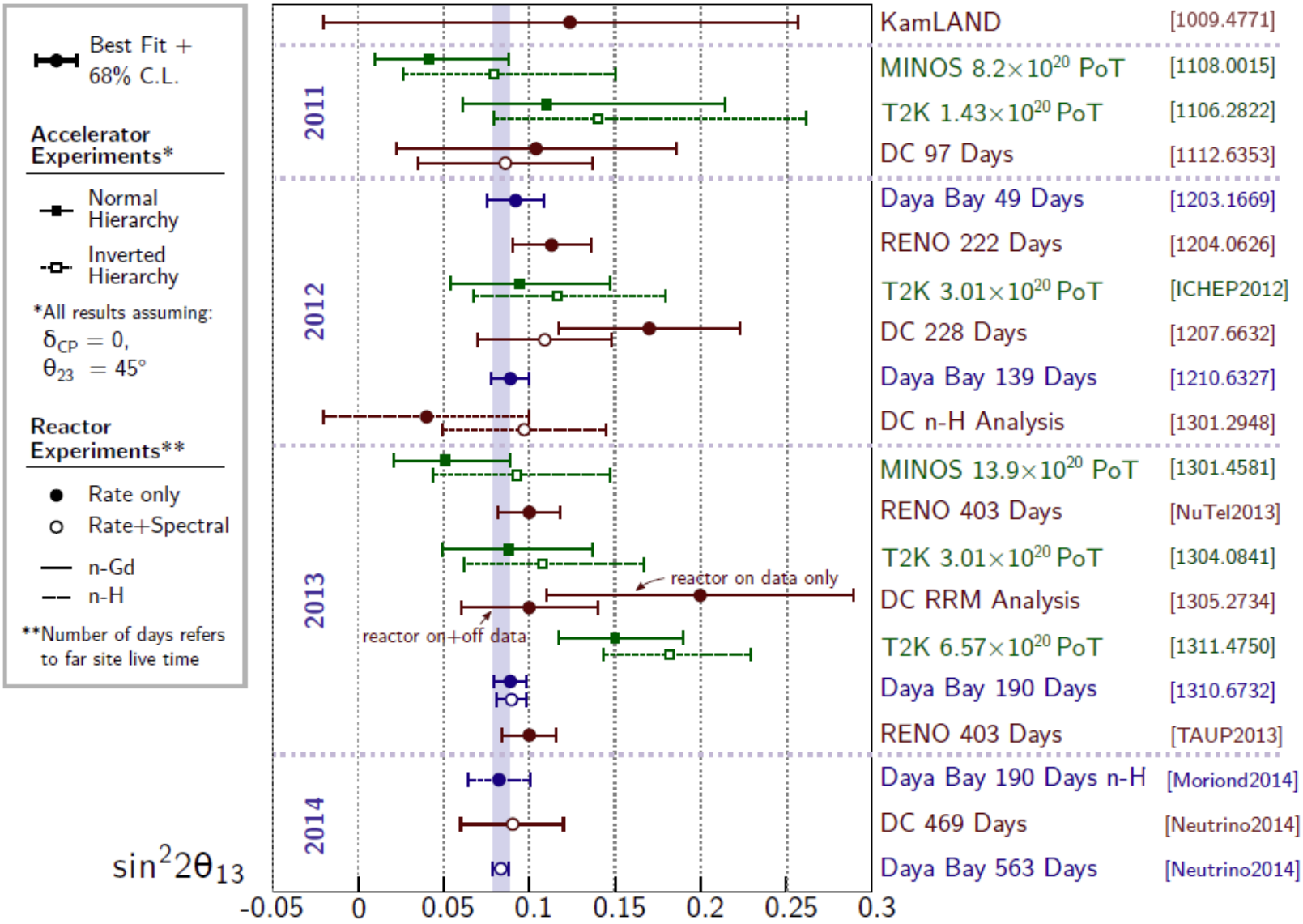
DYB: Daya Bay
LA1: Ling Ao 1 power plant
LA2: Ling Ao 2 power plant

DYB Near Hall (EH1):
363 m from DYB
98 m overburden
LA Near Hall (EH2):
481 m from LA1
526 m from LA2
112m overburden

Far Hall (EH3):
1615 m from LA1
1985 m from DYB
350 m overburden



Daya Bay results comparison with other experiments

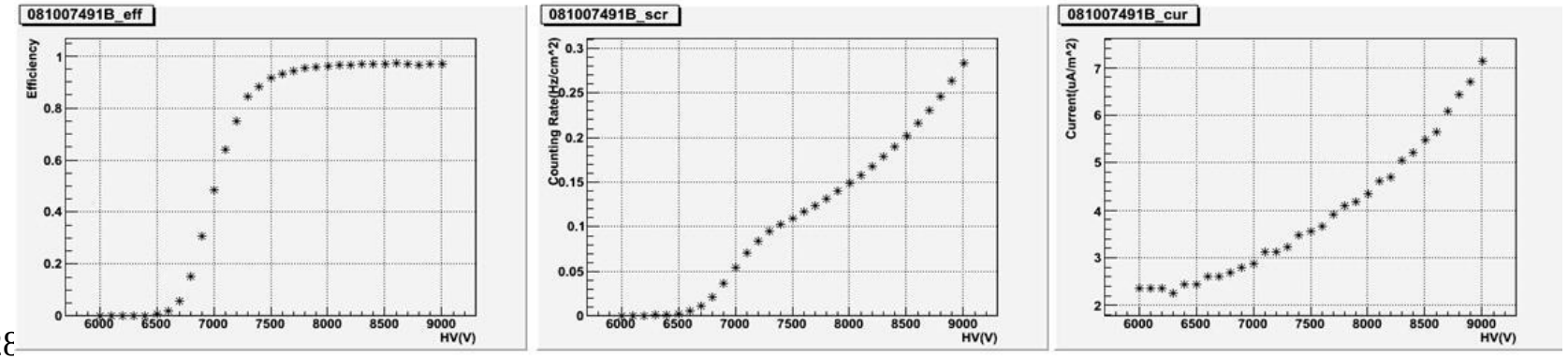


Czech group contribution to Daya Bay

Cosmogenic background expertise, muon detector testing and installation, RPC testing station built at Prague, data analysis – non-standard interaction investigation.

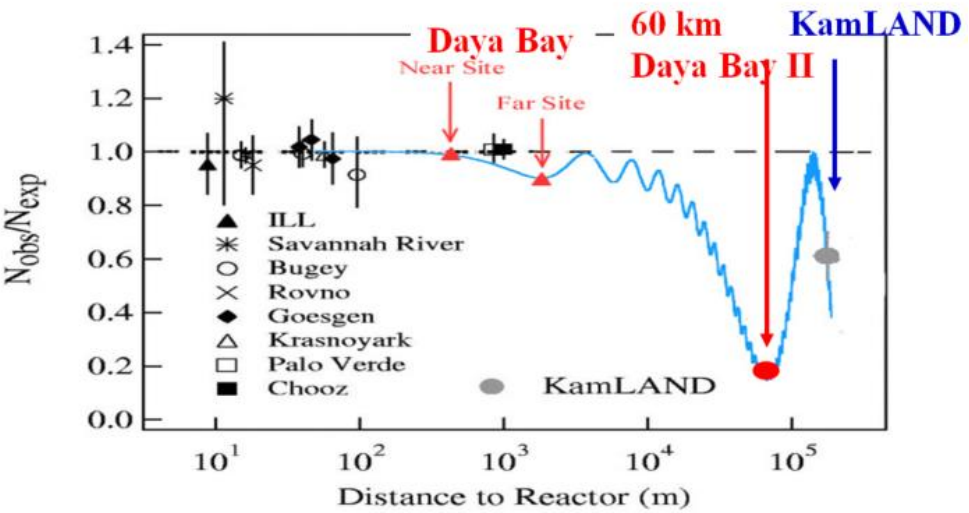
Manpower:
Scientists: R. Leitner, V. Vorobel
PhD students: V. Pec, B. Roskovec

Typical results of HV scan of RPC efficiency, single rate and dark current:

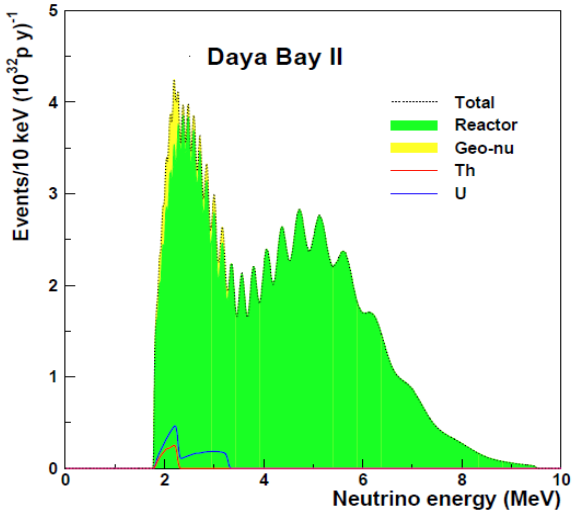


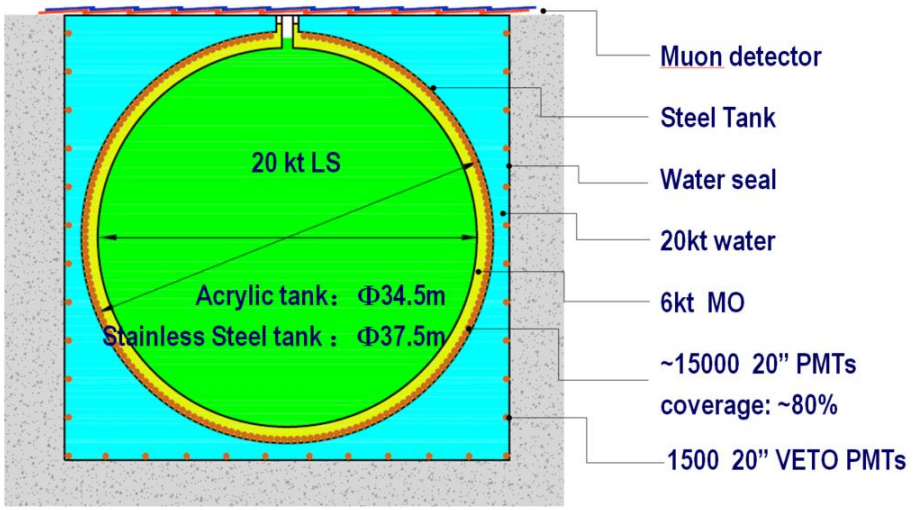
(a) (b) (c)

JUNO Experiment



- **20 kton LS detector**
- **2-3 % energy resolution**
- Rich physics possibilities
  - ⇨ **Mass hierarchy**
  - ⇨ **Precision measurement of 4 mixing parameters**
  - ⇨ **Supernovae neutrino**
  - ⇨ **Geoneutrino**
  - ⇨ **Sterile neutrino**
  - ⇨ **Atmospheric neutrinos**





FMP CU is JUNO member since 2014 – the same time when JUNO collaboration was officially established.
The plan is to contribute to JUNO in a similar way as to Daya Bay - cosmogenic background expertise, R&D of muon detector, investigation of liquid scintillator, detector testing, installation, shifts, data analysis.

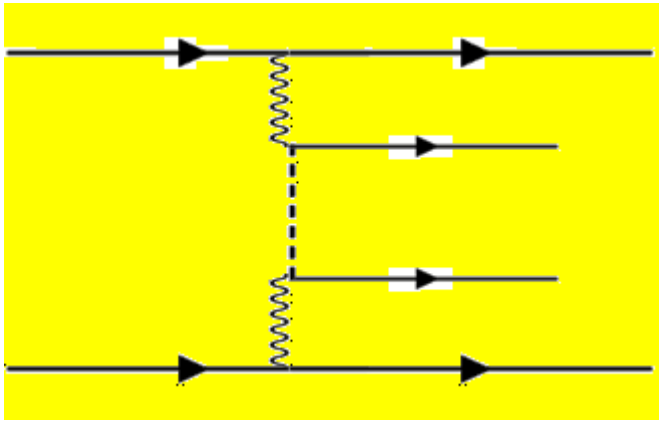
NEMO-3 and SuperNEMO experiments

Neutrinoless double beta decay – not only

Czech participants:

IEAP Czech Technical University in Prague

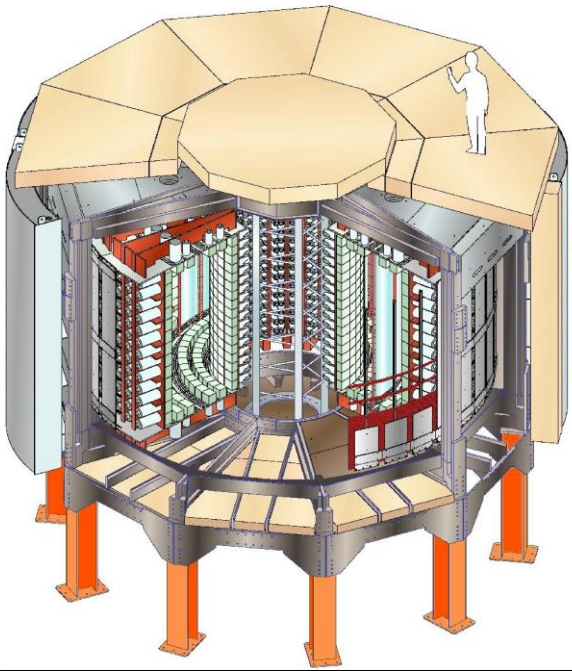
FMP Charles University in Prague

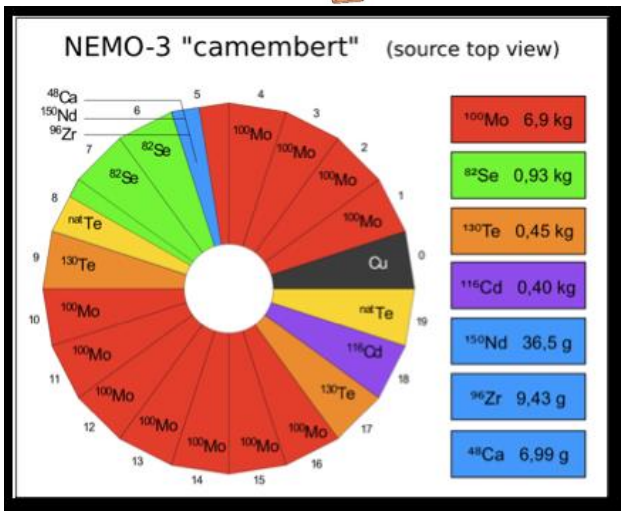


NEMO-3 experiment

Fréjus Underground Laboratory : 4800 m.w.e.

20 sectors





Probe of neutrino nature.

Neutrinos are Majorana fermions (particle ≡ antiparticle) if ββ0ν takes place ⇒ See-Saw mechanism, Leptogenesis, Baryon asymmetry, CP violation

Source: 10 kg of ββ isotopes, cylindrical, S = 20 m^2, 60 mg/cm^2

Tracking detector: drift wire chamber operating in Geiger mode (6180 cells)

Calorimeter: 1940 plastic scintillators coupled to low radioactivity PMTs

Magnetic field: 25 Gauss

Gamma shield: Pure Iron (18 cm)

Neutron shield: borated water (~30 cm) + Wood (Top/Bottom/Gaps between water tanks)

Able to identify e^-, e^+, γ and α–delayed

From NEMO-3 to SuperNEMO

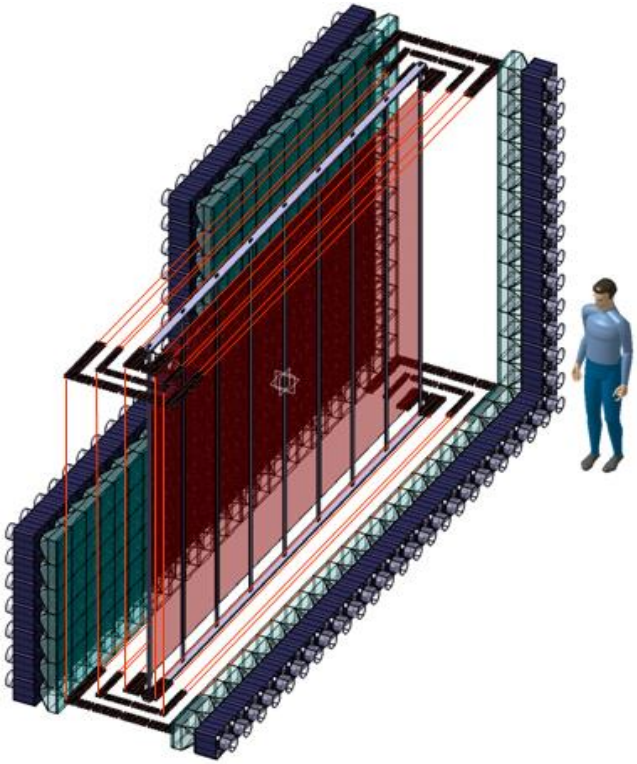
NEMO-3 successful experience allows to extrapolate tracko-calo technique on larger mass next generation detector to reach new sensitivity level.

$$T_{1/2}^{0\nu}(y) \propto \frac{a\varepsilon}{W} \times \sqrt{\frac{M \times t}{N_{BGR} \times \Delta E}}$$

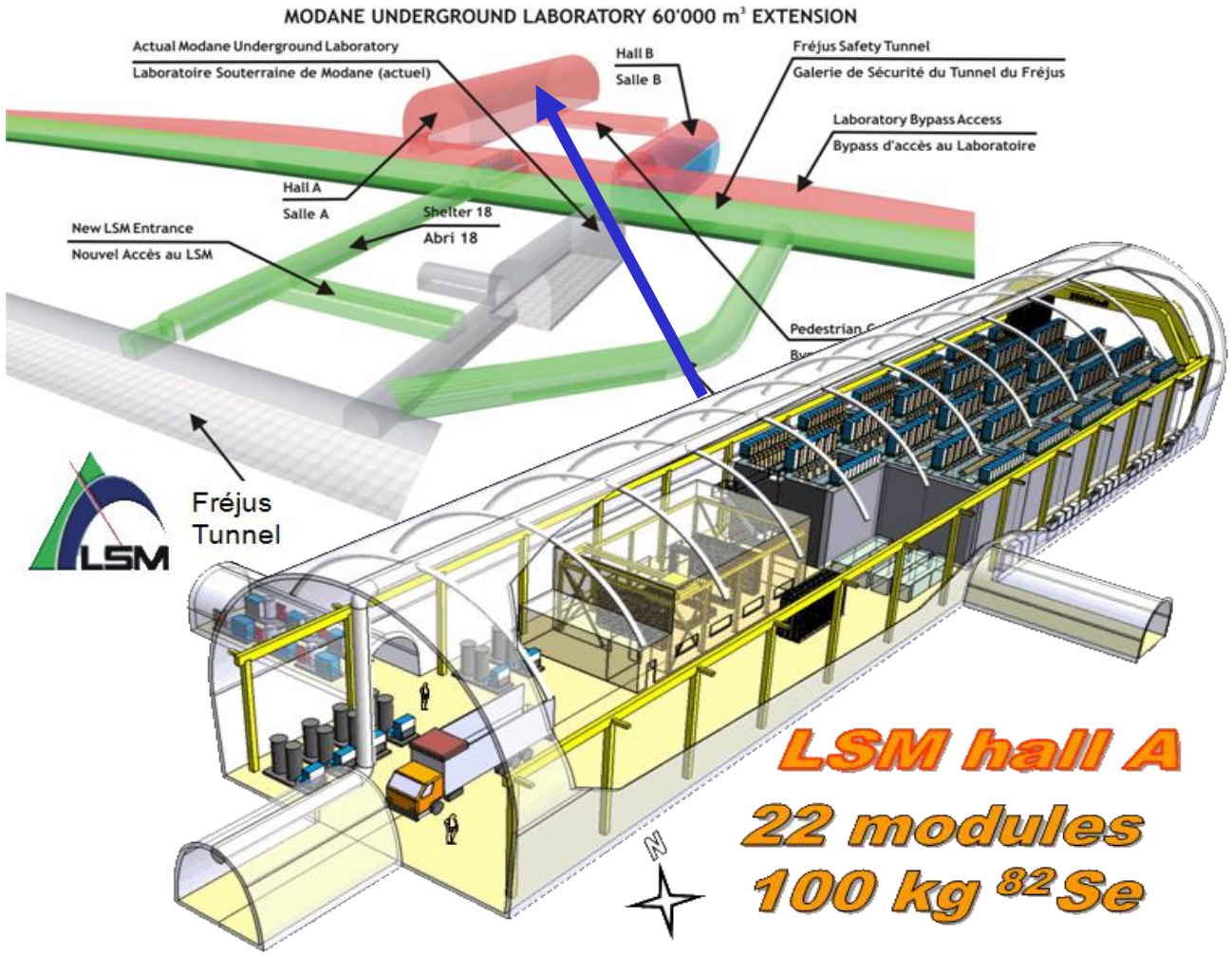
NEMO-3	⇒	SuperNEMO
^{100}Mo, 7kg	Isotope, mass	^{82}Se,100-200 kg
^{208}Tl: < 20 μBq/kg ^{214}Bi: < 300 μBq/kg	Background in ββ-foil	^{208}Tl: < 2 μBq/kg ^{214}Bi: < 10 μBq/kg
8%	Efficiency	30%
8% @ 3 MeV	Energy resolution (FWHM)	4% @ 3 MeV
$T_{1/2} > 2 \times 10^{24}$ y $\langle m_\nu \rangle < 0.3 – 0.8$ eV	Sensitivity	$T_{1/2} > 1\text{-}2 \times 10^{26}$ y $\langle m_\nu \rangle < 40 – 100$ meV

SuperNEMO basic design

SuperNEMO module



20 modules, each of them hosts:
- **5 kg of source foil (^{82}Se, 40mg/cm^2)**
- **2000-3000 Geiger channels**
- **600 Calorimeter channels:**
  PVT Scintillator + 8" PMT



SuperNEMO is the favorite project to be hosted in the new LSM laboratory (hall A)

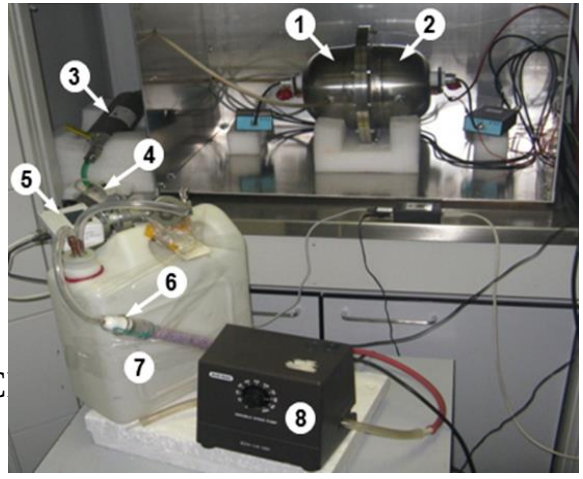
Czech contribution to NEMO-3 / SuperNEMO

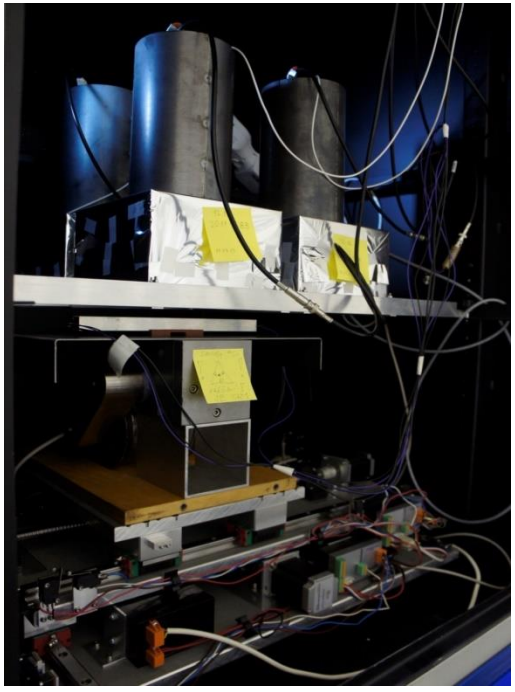
NEMO-3:
Neutron shielding – MC and production; anti-radon facility at LSM, supporting construction, data analysis 100Mo, 140Nd.

SuperNEMO:
Scintillation detectors – R&D and testing; complex radon program, low radioactivity measurements, supporting construction of 1-st module, theory.

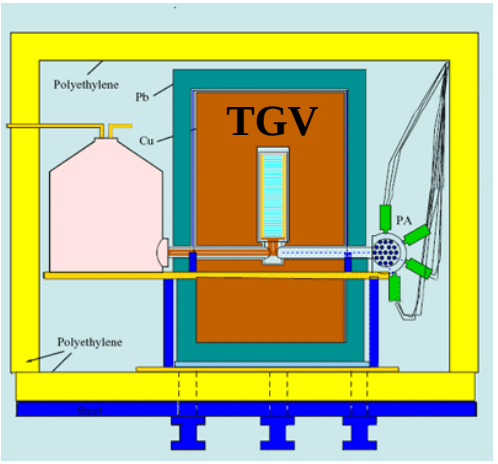
Organization of conference MEDEX every 2 years from 1997, Pontecorvo Summer School 2015.

IEAP Czech Technical University in Prague
Scientists: I. Stekl, J. Jerie, P. Benes, V.Bocanov, R. Hodak, P. Cermak
Technician: P. Pridal
Phd students: F. Mamedov, E. Rukhadze
FMP Charles University in Prague
Scientist: V. Vorobel
PhD student: A. Zukauskas





Small scale experiments – TGV, SPT, OBELIX



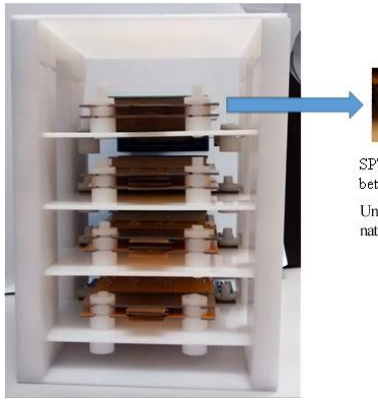
Czech participant:

IEAP Czech Technical University in Prague

Location: LSM Modane

- **Telescope Germanium Vertical (TGV)** double beta decay ^{48}Ca, double electron capture ^{106}Cd.

- **Silicon Pixel Telescope (SPT)** is devoted to the measurement of double electron capture (EC/EC) in ^{106}Cd and to the application of the advanced detection technique, pixel detectors in double beta decay.



SPT

SPT detection unit, with natural Cd in between detectors

Unité de détection SPT, avec du cadmium naturel entre les détecteurs

- **OBELIX** - low background Ge detector, sensitive volume of 600 cm^3 installed in LSM Modane. Rare nuclear processes accompanied by emission of γ−quanta, such as 0νEC/EC resonant decay of ^{106}Cd , two-neutrino double beta decay to the excited states of daughter nuclei (^{100}Mo, ^{150}Nd), measurements of radioactive contaminations of various samples for NEMO-3, SuperNEMO, TGV.

Thank you for your attention