

# Nuclear Physics and Large Facilities

## Collaboration with facilities

ISOLDE

nTOF

GANIL/SPIRAL2

JINR Dubna

Jaromir Mrazek  
NPI Rez

## Czech facilities

Van de Graaff accelerator - IEAP CTU

U120M cyclotron - NPI Rez (CANAM)

Tandetron - NPI

Reactor - RC UJV, NPI beamlines

Theory - NPI, MFF CU, CTU Ostrava

R.I. support

# ISOLDE

Experimental studies of the fundamental properties of electroweak interactions – search for new time reversal invariant components (scalar, tensor) forbidden in the Standard model

- IS431, IS433 on NICOLE and WITCH
- Isolde coll.+D.Zakoucky from NPI Rez (4 people at peak),  
HPGe LHe detectors - development, operation
- collaboration K.U.Leuven, Univ. Munster, CERN, Rez

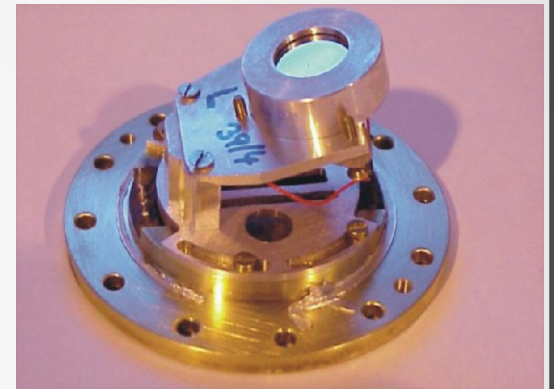
*Golovko et al, Phys.Rev. C 81, 054323 (2010) .. ~14 publ. from 2007*

Collection of  $^{83}\text{Rb}$  for calibration sources for Katrin

- Drahos Venos et al. NPI Rez, (see talk of V.Vorobel)
- IS80, IS500 from 2008-2012

Properties of low-lying intruder states in  $^{34}\text{Al}$  and  $^{34}\text{Si}$  sequentially populated in beta-decay of  $^{34}\text{Mg}$

- a follow-up experiment on observation  $1^+$  state in  $^{34}\text{Al}$  in GANIL
- IS530 in 2012, collaboration GANIL/Bucharest/NPI Rez, J.Mrazek



# n-TOF

## Study of photon strength functions

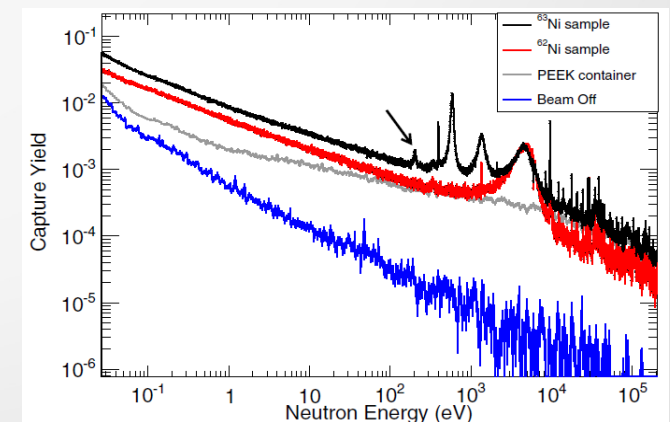
- level density models are calibrated by the level density observed with neutron resonances
- measurements using T.A. Calorimeter on EAR1, tests on EAR2, Monte Carlo simulations, fine tuning models
  - M. Krticka, F. Becvar, J.Kroll and students from MFF CU
  - further collaborations with LANL

*Lederer et al., PRL **110**, 022501 (2013) -Neutron Capture Cross Section of Unstable  $^{63}\text{Ni}$ : Implications for Stellar Nucleosynthesis*

*effect on Cu, Ni, and Zn production*

*EPJ A **49**: 27 (2013)*

Measurement of  $(n, \gamma)$  cross section using a 32 mg  $^{241}\text{Am}$  sample with high activity of 4 GBq



# GANIL/SPIRAL2

Long term (~1995) collab. GANIL/Orsay/Dubna/Bucharest/Rez

Properties of nuclei far from stability, evolution and collapse of magic numbers

- Z.Dlouhy, NPI Rez

Later (**2007+**) - emphasis on SPIRAL2

\* astrophysical reactions,

\* neutron generators (in NFS/SPIRAL2), 2 MoU,

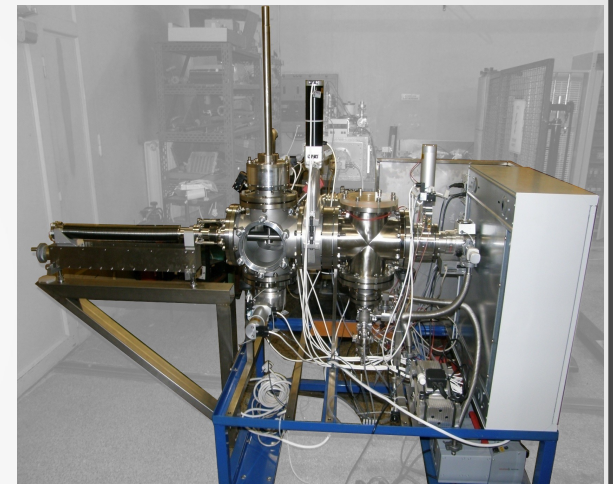
\* charged particle activation in (NFS... first run in 2016)

+ virtual laboratory FR-CZ LEA NuAG 2011-2014, renewal 2015-2018

-includes computing and grids (J.Ch.), theory (P.A.)

(J.Mrazek NPI, J.Chudoba IoP, P.Alexa CTU Ostrava)

*M.Assie, Phys.Lett. B 712, 198 (2012) - Spectroscopy of  $^{18}\text{Na}$ : Bridging the two-proton radioactivity of  $^{19}\text{Mg}$   
~ 25 publ from 2007*



# JINR Dubna

One year grants from the support from Ministry of Foreign Affairs two calls per year, avg. sum/project ~ 5-30 k\$ - support of common tasks **in Dubna**

senior physicists on long term stay (J.Adam, A. Kovalik, Z.Hons etc...)

students+postdocs (~5 in nucl.phys.) in Dubna (support grants of I.Stekl IEAP)

- grants on ADTT (supervision of V. Wagner NPI)

MASHA (C.Granja - Timepix, Medipix), ACCULINA ( V.Chudoba, SU Opava)

complementary experiments on U120M cyclotron in NPI Rez - cross sections of  $^2H$  vs.  $^6He$  @Coulomb barrier (halo), clusters in He-Be nuclei (V.Kroha NPI)

# Czech facilities



# Van de Graaff - IEAP CTU

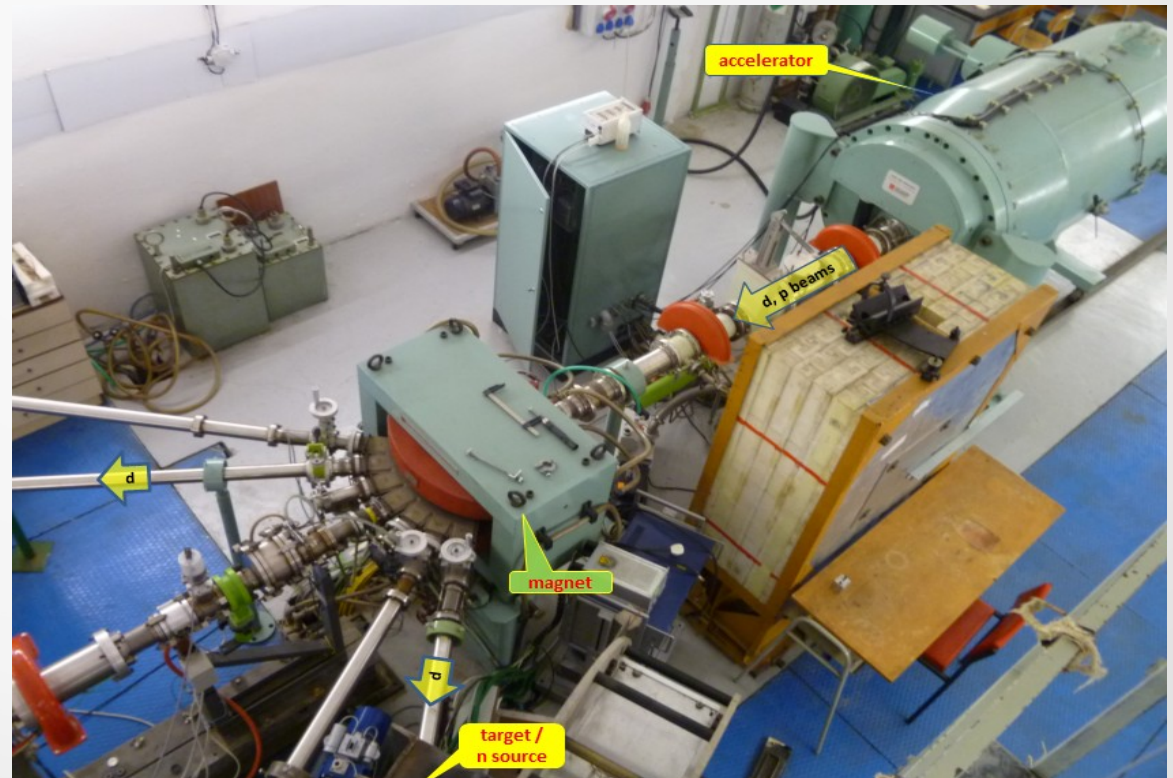
Institute of Experimental and Applied Physics of Czech Technical University

$E = 0.3 - 2.5 \text{ MeV}$ ;  $I = 0.5-50 \mu\text{A}$

p,d, $^4\text{He}$ ;  $^3\text{He}$  (future)

Neutrons: tunable mono-energetic fast

- ❑ Nuclear analytical techniques (PIXE, RBS) - *FNSPE CTU*
- ❑ Production of mono-energetic neutrons (testing, calibration of neutron-sensitive devices, detectors for space)
- ❑ Tagged neutrons



27.3.2015

RECFA visit in Czech Republic 2015

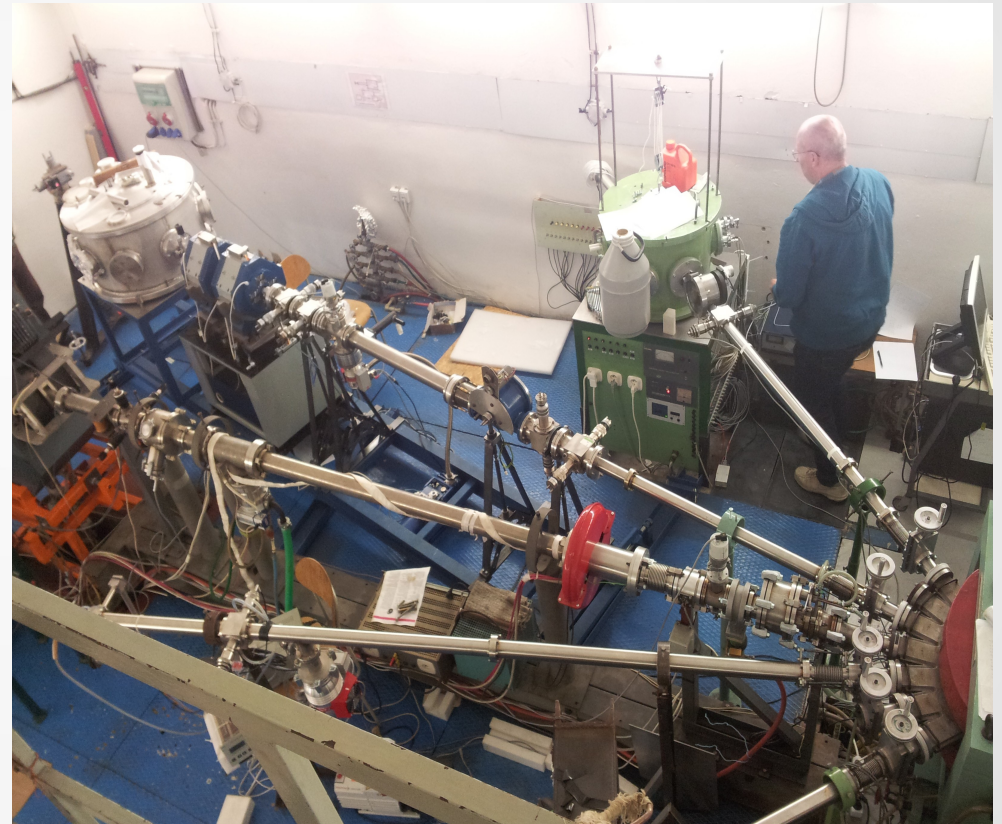
# Van de Graaff - IEAP CTU

Institute of Experimental and Applied Physics of Czech Technical University

Polarized neutrons, polarized frozen target  
(spin physics) - Y.Usov, JINR Dubna

Fast neutron induced nuclear reactions  
(tunable energy, low intensity)  
Tagged neutron beam - I.Wilhelm, MFF CU

Beam line for sub-Coulomb measurements  
astrophysical implications, ANC method  
- J.Mrazek NPI Rez

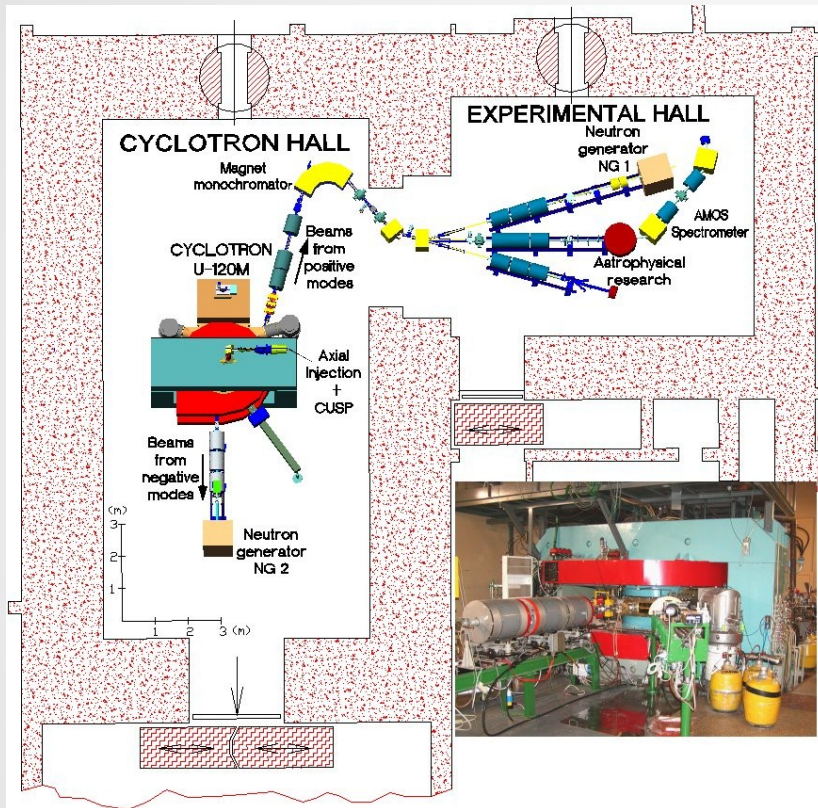


2 dedicated physicists (C.Granja, V.Kral) + 4 students + externals



# U120M cyclotron in NPI ASCR

a part of CANAM research infrastructure



accelerated ions	energy [MeV]	extracted currents [ $\mu$ A]
$H^-$	6 - 38	15 - 35
$H^+$	6 - 38	3
$d^+$	11 - 20	3
${}^3\text{He}^{2+}$	16 - 55	3
${}^4\text{He}^{2+}$	22 - 40	3

+ ions  $\Delta E/E \sim 5 \cdot 10^{-4}$

Development and operation (~15)

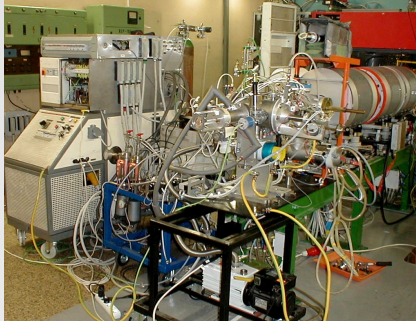
Nuclear astrophysics + neutron generators group (~ 12 (-3)res. + 6 tech.)

Radiopharmacs group (~5 res. + 10 tech)

# U120M cyclotron - CANAM

- astrophysical reactions by indirect methods using  $^3\text{He}$  and  $^2\text{H}$ 
  - **ANC** method, direct radiative capture, reactions of CNO cycle and above  
*A.Mukhamedzhanov et al., Phys.Rev. C 84, 024616 (2011) - ANC for  $^{14}\text{C}(d, p)^{15}\text{C}$*
  - Trojan Horse method** - coll. with group of C.Spitaleri INFN-LNS Catania  
*A.Tumino et al., Phys.Lett.B 700 (2011)111, Astrophys.J. 785, (2014)96 - Determination of  $d(d,p)$   $d(d,n)$  r. rates*  
V. Kroha, J.Mrazek et al.
- excitation functions in charged particle reactions using activation method  
future radiopharmacs, cyclotron production of  $^{99}\text{Tc}$  ( $^{100}\text{Mo}(p,2n)^{99\text{m}}\text{Tc}$ ) O.Lebeda  
**materials for IFMIF** like devices, complete **theoretical** approach from IFIN-HH  
E.Simeckova
- **neutron activation** on neutron generators (F4E, databases) P.Bem, M.Majerle
- detector and electronics tests for ATLAS, ALICE, CBM, GANIL/SPIRAL2  
(+production tests), nanodiamond's tests, biological research etc.

# U120M cyclotron - neutron generators - CANAM



## High-power broad-spectrum neutron generator



integral flux up to  $10^{11} \text{ cm}^{-2} \text{ s}^{-1}$

IFMIF like white spectrum with a mean energy of 14 MeV and extension up to 32 MeV

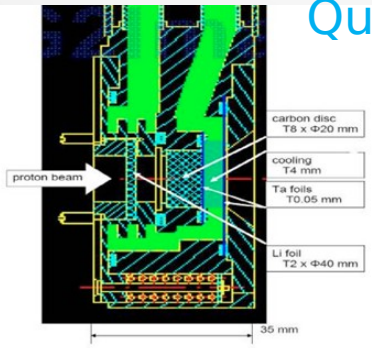


## Variable-energy broad-spectrum neutron generator

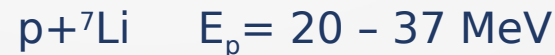


integral flux: up to  $10^{11} \text{ /sr/s}$

mean energy: 4 - 12 MeV



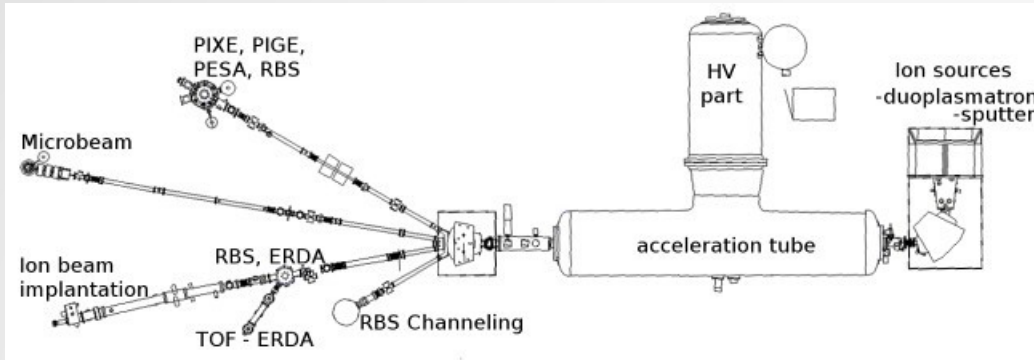
## Quasi-monoenergetic neutron generator



peak energy: up to 36 MeV

neutron flux density in the QMN peak:  
up to  $10^9 \text{ n/cm}^2/\text{s}$

# Tandetron - CANAM



terminal voltage 200 kV - 3 MV

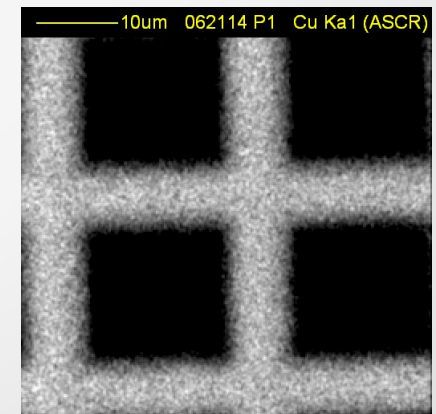
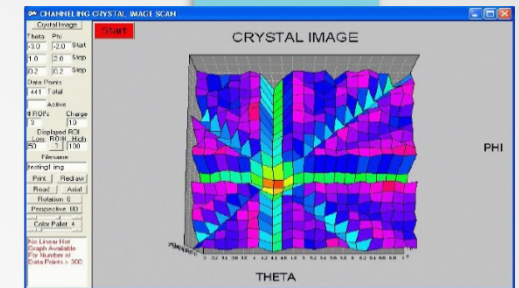
ions H - Au

ion energies 400 keV - 24 MeV

ion currents nA -  $\mu$ A

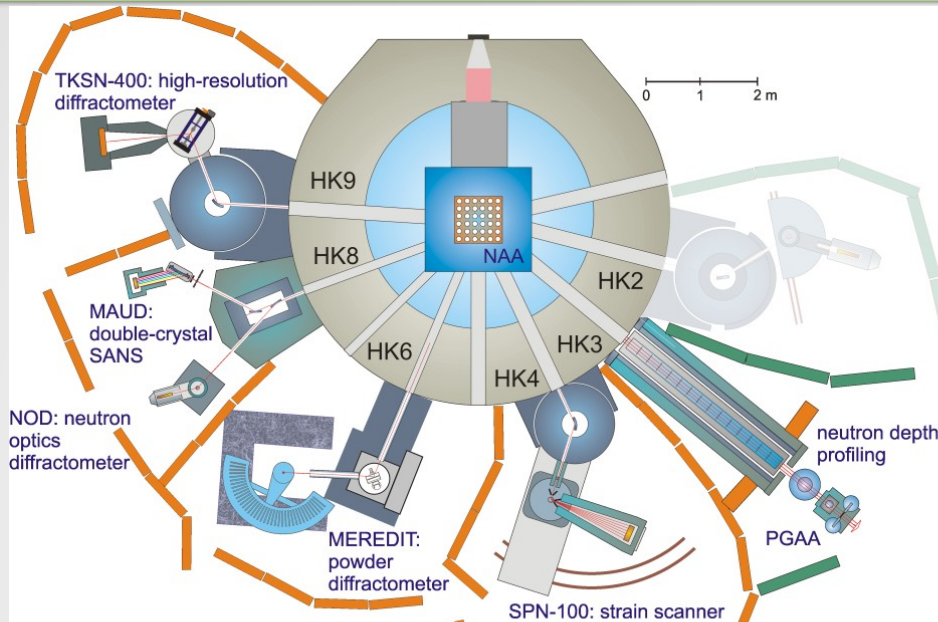
# Tandetron - CANAM

- RBS Rutherford Back-Scattering
- RBS channeling
- ERDA Elastic Recoil Detection Analysis
- Time of Flight (TOF)-ERDA
- PIXE Particle Induced X-Ray Emission spectroscopy
- PIGE Particle Induced Gamma-Ray Emission spectroscopy
- PESA Proton Elastic Scattering Analysis
- External beam
- Ion Micro-beam
- Ion implantation



C,N,O,Si

# Neutron physics laboratory - CANAM



LVR-15 research reactor operated by  
**the Research Centrum Řež, Ltd.**  
thermal power 10 MW  
max. flux  $10^{14}$  n/s/cm<sup>2</sup>

**Thermal neutron facility for study of  $\gamma$ - $\gamma$   
coincidences from (n, $\gamma$ ) reactions:**

I. Tomandl cooperation

with M. Krτικά MFF CU, students

- 1) *Investigation of Photon Strength Functions (PSF) by means of Two-Step Cascade (TSC) method - in collaboration with Charles University (MFF)*
  - PSFs in <sup>95</sup>Mo – study of recently reported low-energy enhancement of PSF: *Phys. Rev. C* 77 (2008) 054319.
  - PSFs in <sup>160</sup>Tb : *Int. J. of Mod. Phys.* 20 (2011) 526-531.
- 2) *Nuclear structure studies via level and  $\gamma$ -decay scheme construction*
  - nuclear structure <sup>187</sup>W, <sup>188</sup>Re, <sup>183</sup>W, <sup>125</sup>Sn

# Theory

## **NPI Rez**

### **Hadrons and Baryonic systems**

Hypernuclei and exotic atoms, member of project SPHERE, 7<sup>th</sup> FP

active group of J.Mares - approx. 10 young people, 35 years avg

**Nuclear structure** - J.Dobes - collective models, IBA; P. Vesely- RPA, TDA approach...

## **MFF CU , CTU Ostrava**

**Degrees of freedom of spherical and deformed nuclei (low lying states, gigantic resonances and multipolarities)**

- J. Kvasil (MFF CU), P. Alexa (CTU Ostrava), P.Vesely

### **Quantum and classical chaos in atomic nuclei**

- P. Cejnar, M. Macek, P. Stransky ( team of MFF CU)

*P. Cejnar, J. Jolie, R.F. Casten- Rev. Mod. Phys. 82 (2010) 2155 - Quantum phase transitions in the shapes of atomic nuclei ;*

# Support of Research Infrastructures

- Ministry of Education Youth and Sport (MEYS) dedicated support
  - Van de Graaff of IEAP **2012-2016**
  - CANAM of NPI (**TR24** cyclotron, protons)
- A call for period **2016-2022**, in total for **all R.I.** in CR ~ 30 ME/year
  - support of Czech R.I. (negotiations for CANAM, VdG IEAP, ...)
  - support of Czech participation in European R.I.
    - SPIRAL2-cz, FAIR-cz (opportunity for NuSTAR), ....





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Thank you

# Some answers

CANAM budget - 1.6ME from MEYS, 0.8 ME other sources

Qualified estimate - sum of the above people

# exp.nuclear physicists ~ 25, 10 PhD.

NPI Rez in total ... 80 physicists, 30 PhD students

Funding -GACR, MEYS (Contact), TACR (RF), F4E, ENSAR-EWIRA, ESA ...

students - we hunt amongst nuclear engineering students

age gap - retirement ( -4 researches soon)