Van de Graaff (VdG) Accelerator

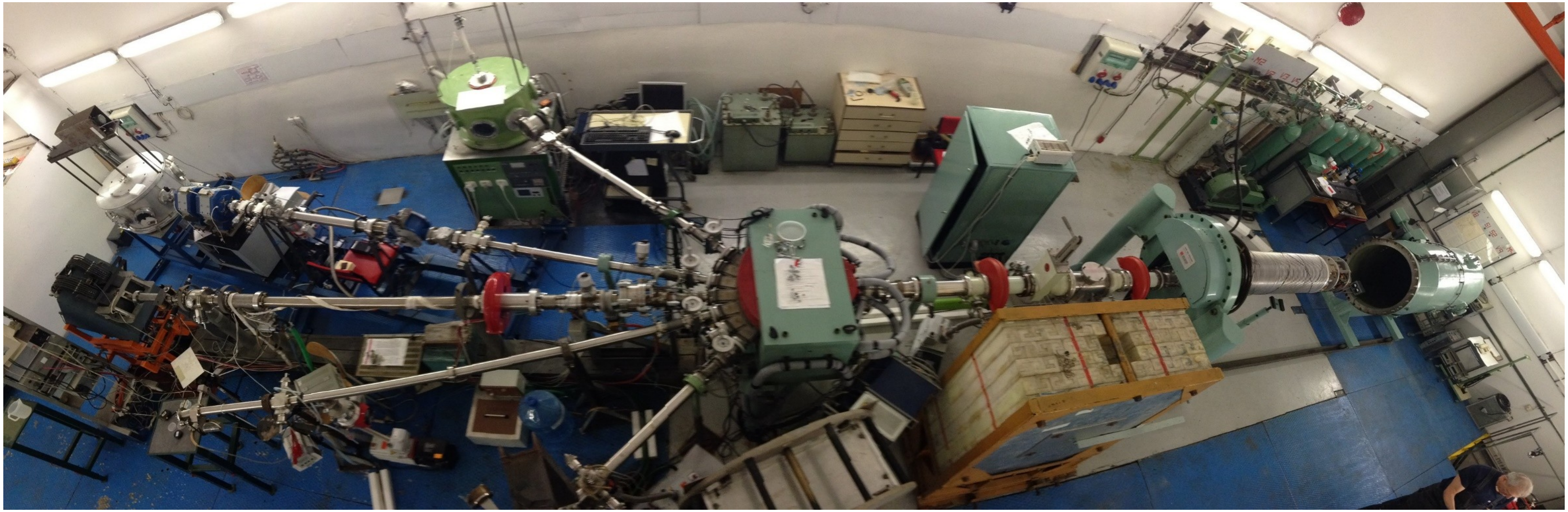
IEAP, CTU in Prague

Day with particle and astroparticle research infrastructures, October 17th 2022, Prague

presented by Rudolf Sýkora

VdG: bird's-eye view

http://aladdin.utef.cvut.cz/projekty/vdg/



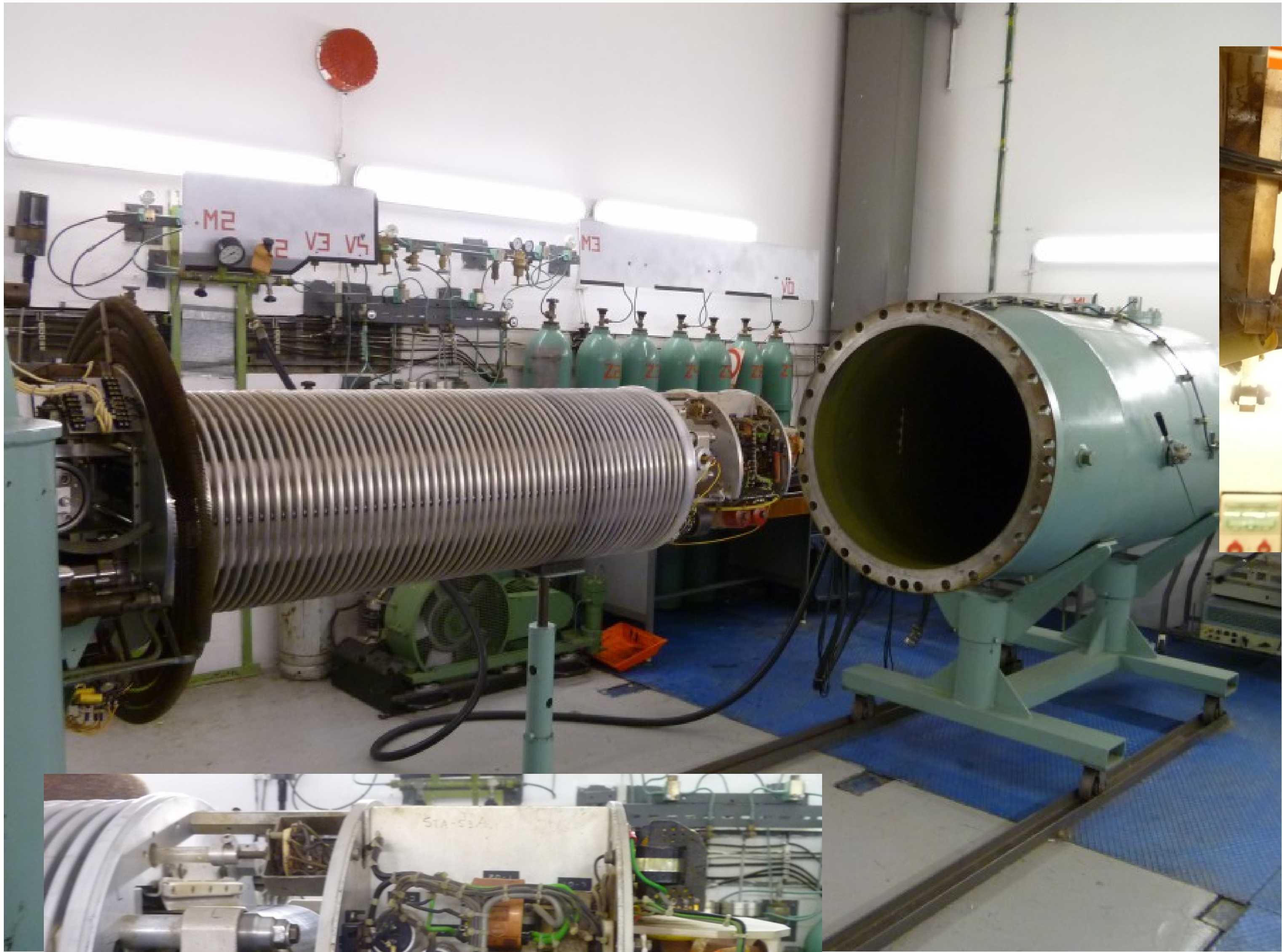
- RI's heart: HV Engineering Europa B.V. Van de Graaff from 1980
- accelerates (ions of) $^{1}H_{(2)}$, $^{2}H_{(2)}$, ^{4}He, recently ^{14}N
- energy 200 – 2500 keV / charge
- beam currents 0.1 – 10 μA

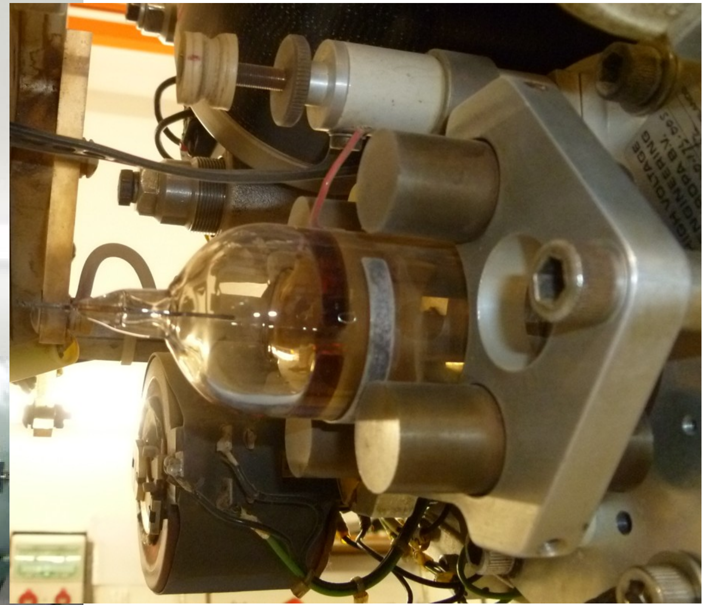
HI since 2010: IEAP CTU (before: Charles University, Faculty of Mathematics and Physics)

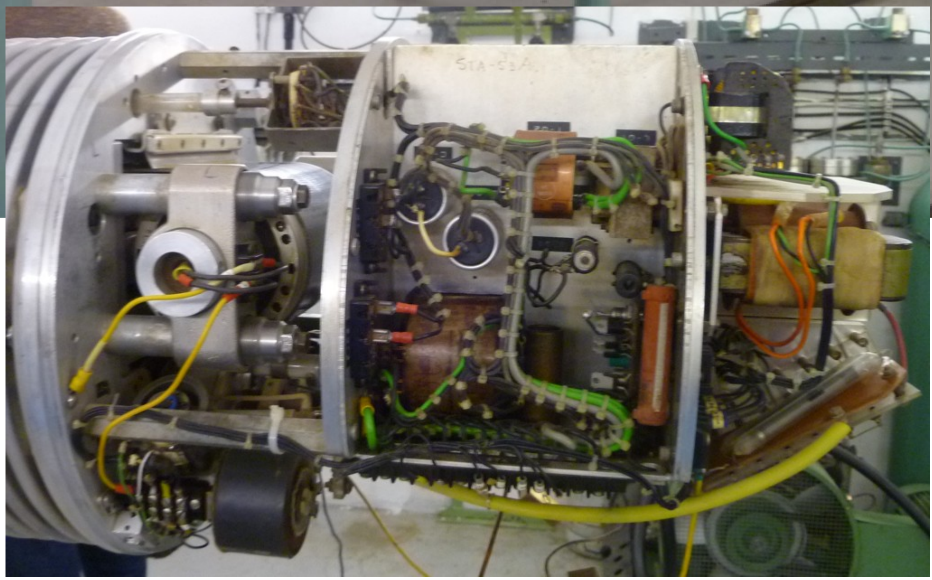
AED
Emergency defibrillator

IEAP CTU
VdG
VdG Accelerator

on CZ RI roadmap since 2012 with open access







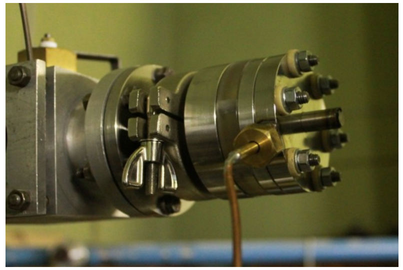
NB. the only such accecerator at the Czech univestities

A simple and understandable device →
suitable and open to student excursions

VdG: bird's-eye view, cont'd

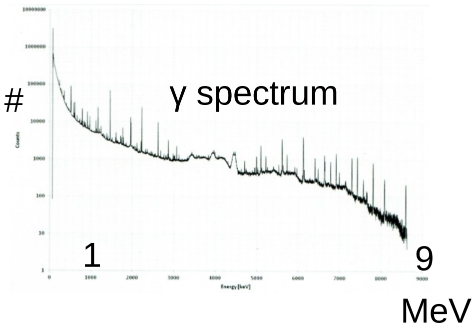
Not just the accelerator…

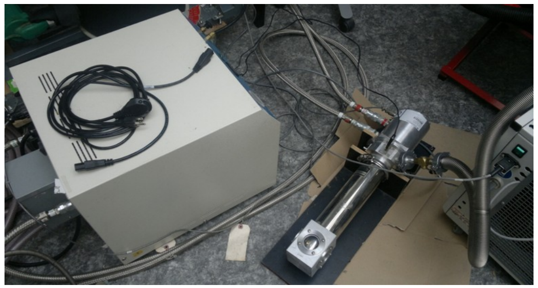
… but rather a **multipurpose complex research laboratory**



Apart from charged accelerated particles we provide, e.g.:

- monoenergetic **neutrons** (*p*-T, *d*-D, *d*-T reactions); neutrons from AmBe
- source of **low-energetic** (30 keV and upwards) charged particles (electrostatic separator)
- **radionuclide emitters** like ^{22}Na, ^{55}Fe, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{241}Am, ...
- ESA-certified **wide-spectrum γ-source** (AmBe $\xrightarrow{n}$ Cl or Fe)
- related **detector systems** (plastic/liquid scintillators, NaI, BGO, Si, SiC, CdTe, NaI(Tl), HPGe, …, pixel) for all participating particles
- 10K apparatus for low-temperature opto-electronic measurements





bird's-eye view, cont'd: Staff / Money / Outputs

NB. VdG is (but we should rather learn saying *was*) one of the few **purely-Czech** RIs in physical sciences: **no -CZ** in its name, not a part of a (usually much bigger) international project (although with international collaboration)

(gross numbers follow)

If you visit VdG lab, you will **most probably** (at maximum) find:

- operators: 1 (2)
- engineers: 1 (1)
- scientists: 3 (6)

budget ~ 6 mil. CZK /year
(240k EUR /year)

projects 70% & HI 30%

papers: operator + HI: 2 /year
ext. users: 2 /year

patents: 3 in the last 6 years
industry fees to HI ~ **1 mil. CZK /year**

In **2016–2019** VdG was supported by **RI VdG** [*running of the RI*] as well as **OP VVV** [*investments, own research*] projects.

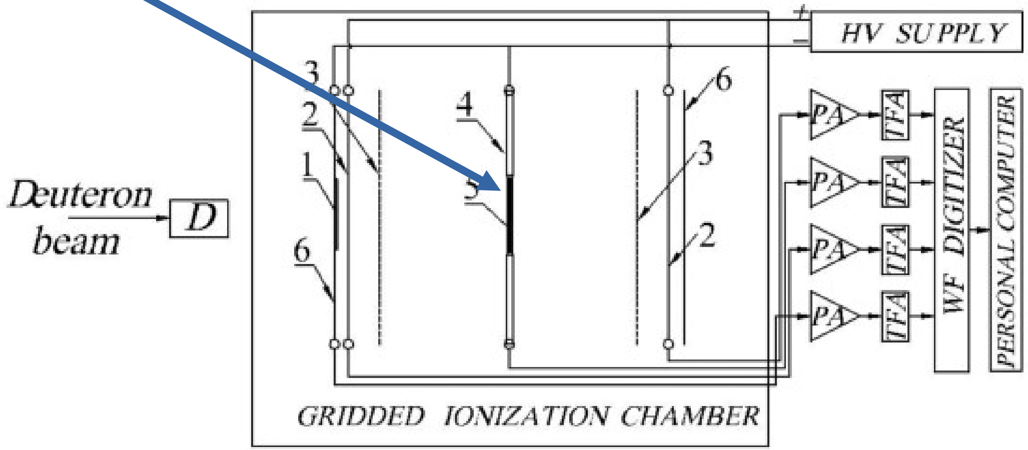
Since 2020, only **RI VdG** continues (LM2018108), **4.4 mil. CZK /year** (180k EUR /year) [*only running, no investments nor own research*].

ENDS this year...

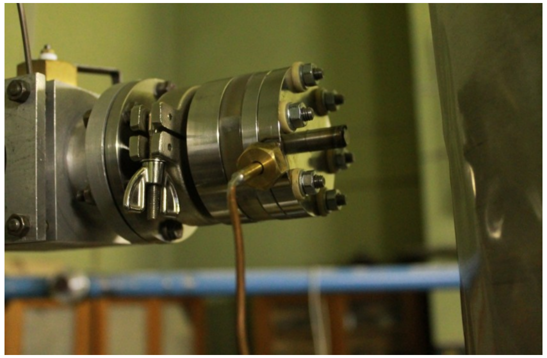
Research until quite recently (2020)...

Research at RI had **3** main **pillars** (these were the subject of OPVVV):

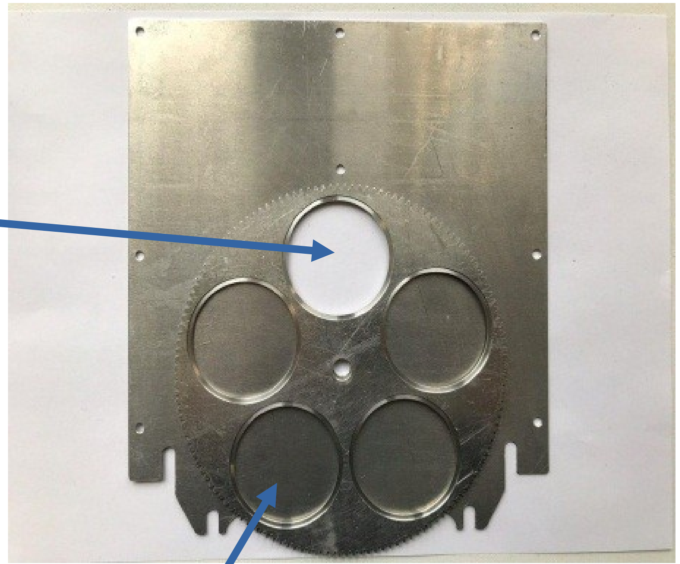
1. **two** "3+3" **projects** with JINR Dubna, **Russia**, focussed on basic research of nucleon–nucleon interaction:
   - production of **polarized *n*⁰** followed by measurement of polarization-dependency of *n-p* and *n-d* cross-sections,
   - precise measurements of cross-sections of ***n*⁰-induced reactions** in various targets ^{6}Li, ^{14}N, ^{35}Cl, ^{91}Zr, ^{148}Sm, ^{171}Y (long-term stability of construction materials)



n^0-induced reactions: few more pictures



gaseous D target

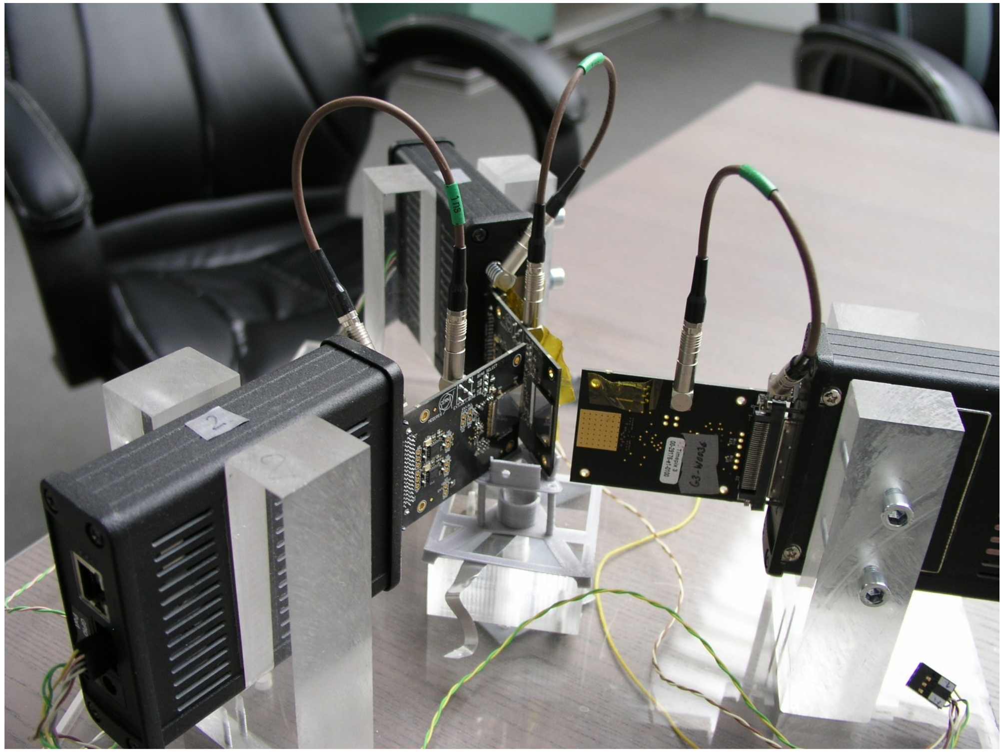


targets ^{35}Cl, ^{14}N, ^{6}Li, ^{91}Zr, ^{148}Sm
calibration: ^{234}U, ^{238}U

Research until recently, cont'd

2. studies to estimate **nucleosynthesis** rate in stellar environment (astrophysics), NPI CAS, Řež, ČR; $^{26}Mg(d,p)^{27}Mg$ below 2 MeV

3. **testing of detectors** designed within the institute (detector physics; Timepix family), other IEAP-driven research programme



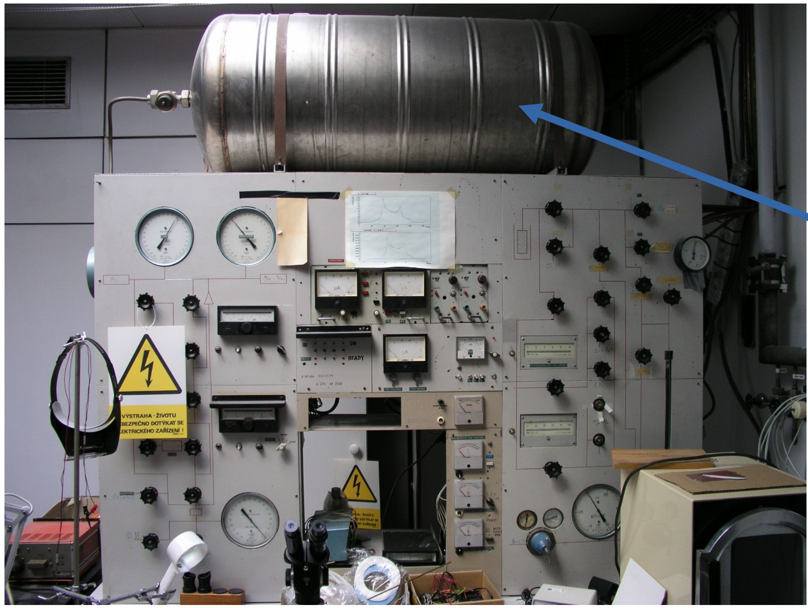
Today

Ad 1) production of polarized n^0, n^0-induced reactions

- first, there was the COVID-19 **pandemic** → **no travelling in 2020, 2021**
- when the pandemic subsided: **fall 2021**, both groups from JINR **visited RI once**
- 2022: war

  → *fruitful* cooperation has been forcibly terminated

- although we may, in theory, progress slightly on our own, there is little hope we can progress substantially because of, most importantly, lack of manpower, but also due to lack of specific knowledge, e.g.



target cooling
cryo part

Gifford-McMahon
^3He – ^4He mixing
cycle

$T < 50$ mK

Today, cont'd

Ad 2) nucleosynthesis (*n*,γ), (*p*,γ) (conducted more or less exclusively by NPI Řež)

- did not progress much (lack of manpower at NPI) already before 2020
- attempt to restart the cooperation, but to no avail
- the stalled has effectively changed to ended

Ad 3) testing of detectors, research by IEAP,

- **continues without limitations**, laboratory is perpetually ready to accept (and accustom to) requests
- new branches of interest and experiments, see below

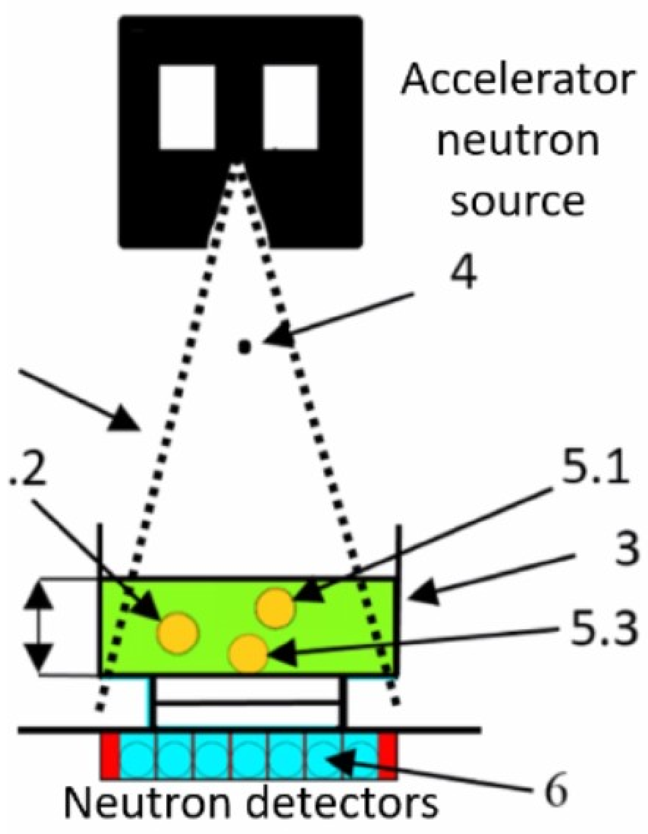
- **two out of three “pillars” have essentially collapsed**
- **we have lost almost all international cooperation (1 user from Slovakia left)**
- **what remains at the moment are essentially our own research programmes**

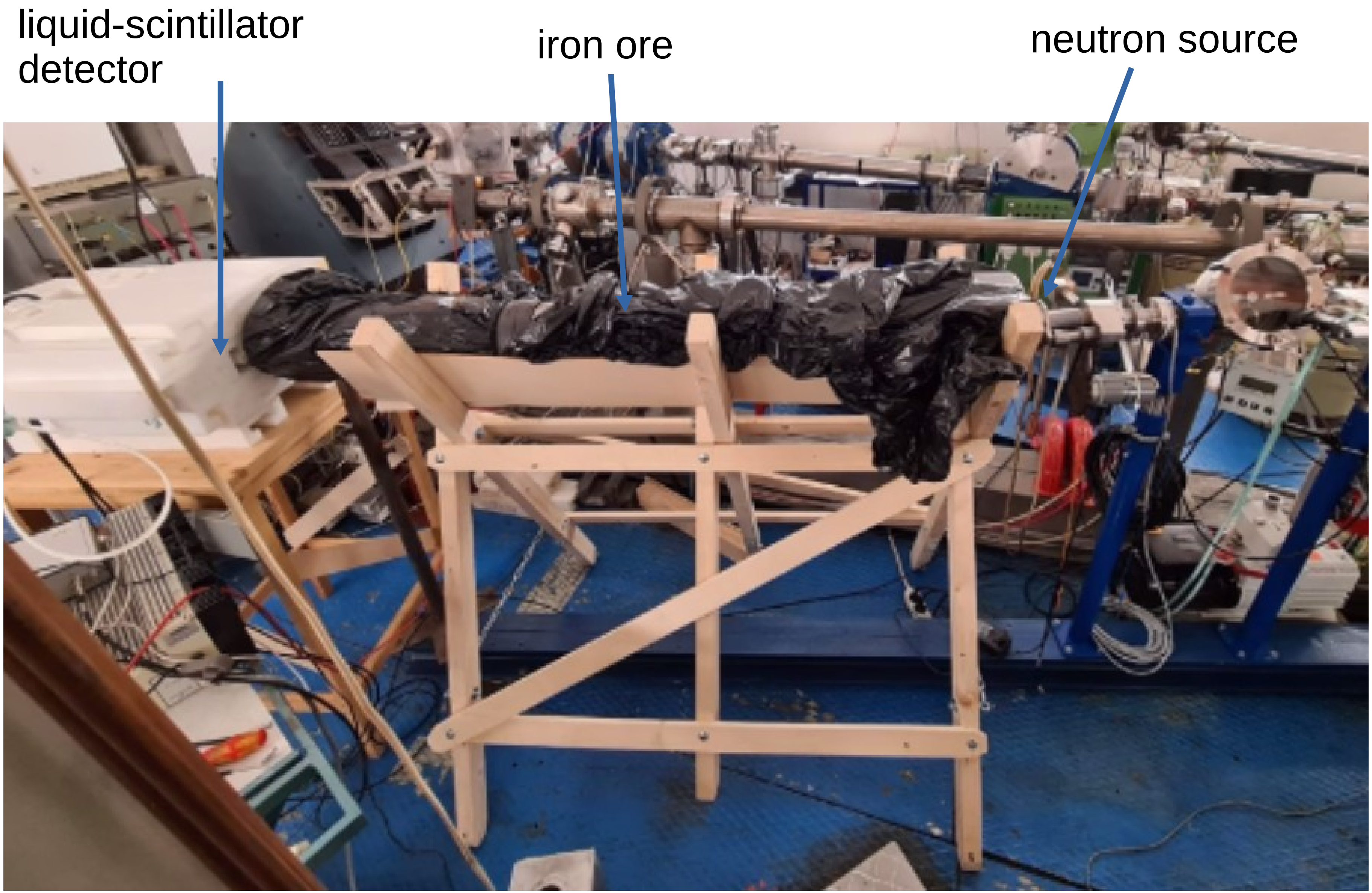
Let us now turn to *some positives* for a change

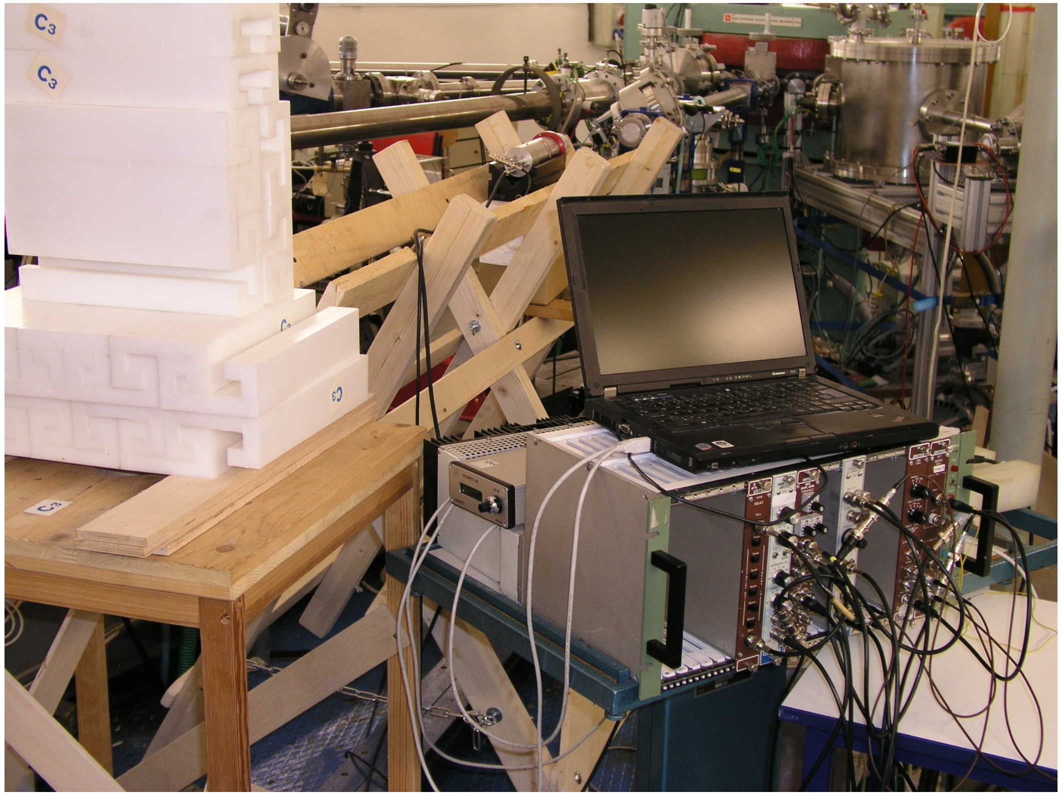
Experiment with our colleagues from the Slovak University of Technology in Bratislava, Marko Fulop, Andrea Šagátová

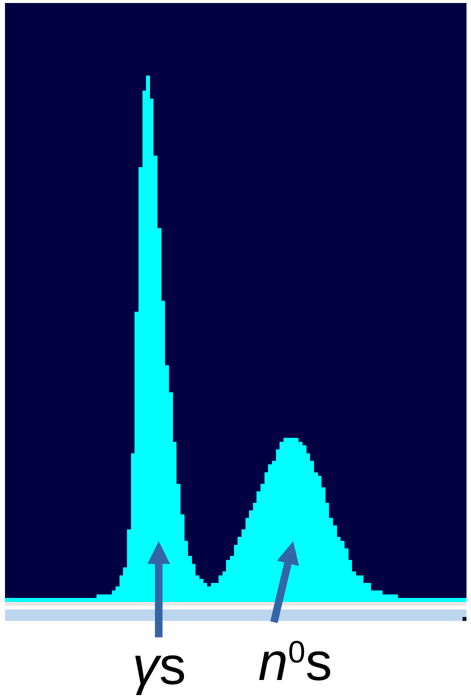
- detection of illegal cigarette boxes in iron-ore cargo:

?



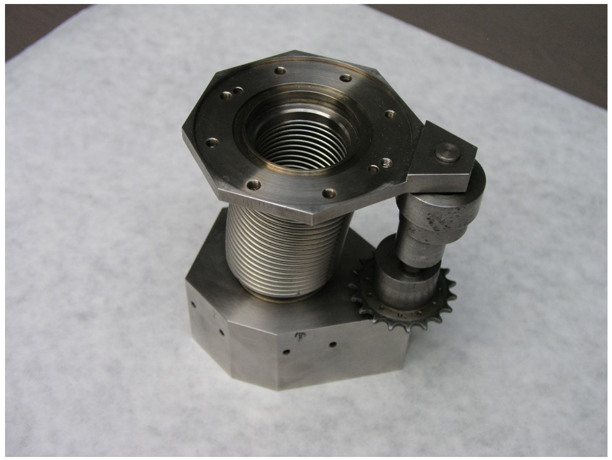

liquid-scintillator detector
iron ore
neutron source





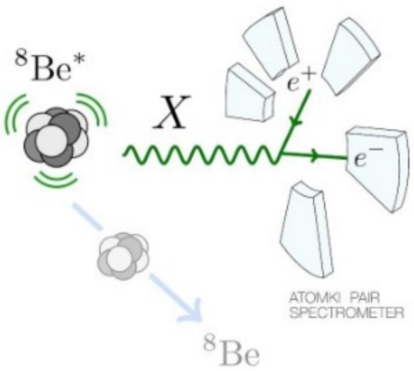
NIM-module-based electronics (with analog pulse-shape γ-n^0 discrimination)

tritium-target holder

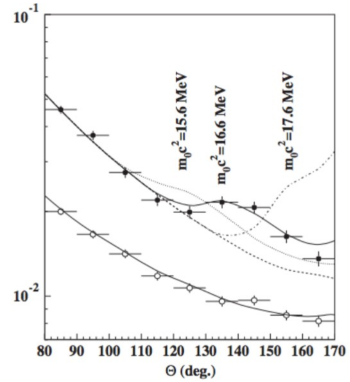


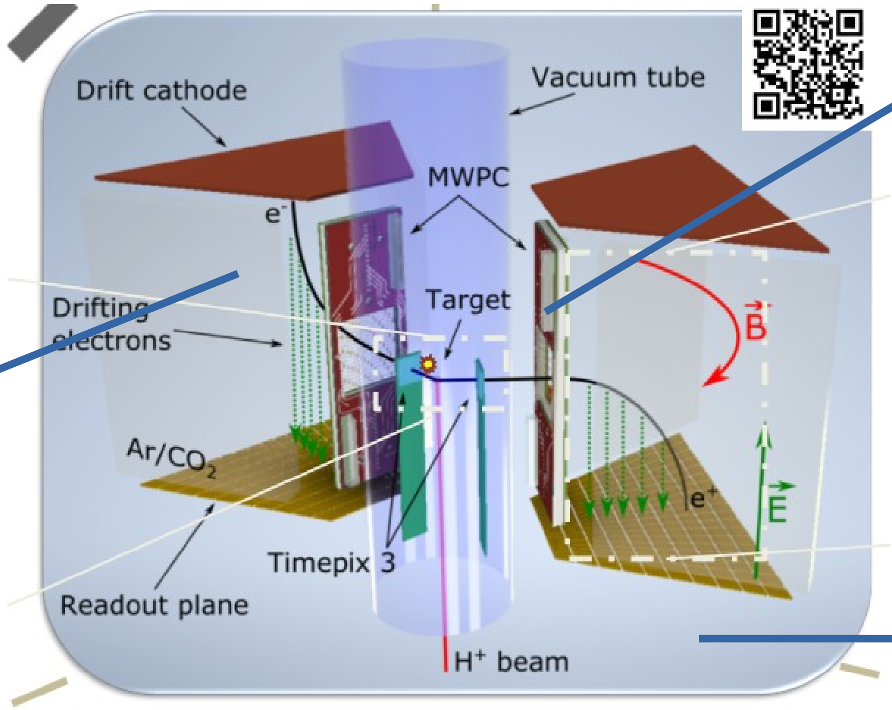
Our X17 Experiment, Hugo Luz *et al.*, 3y GAČR project 21–23

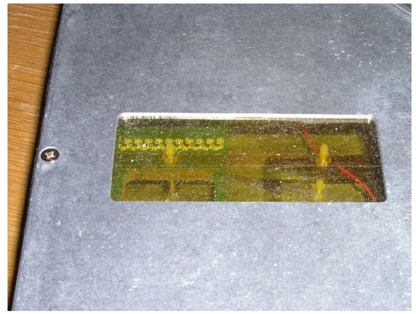
(you heard him in the morning; poster yesterday)

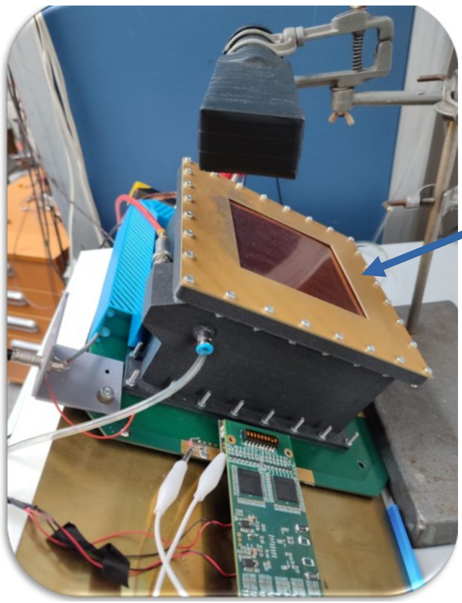


- building e^+e^- detector to search for ATOMKI anomaly
- essentially 3 different time-synchronized detectors
- work for a *group*, **our main physics programme**



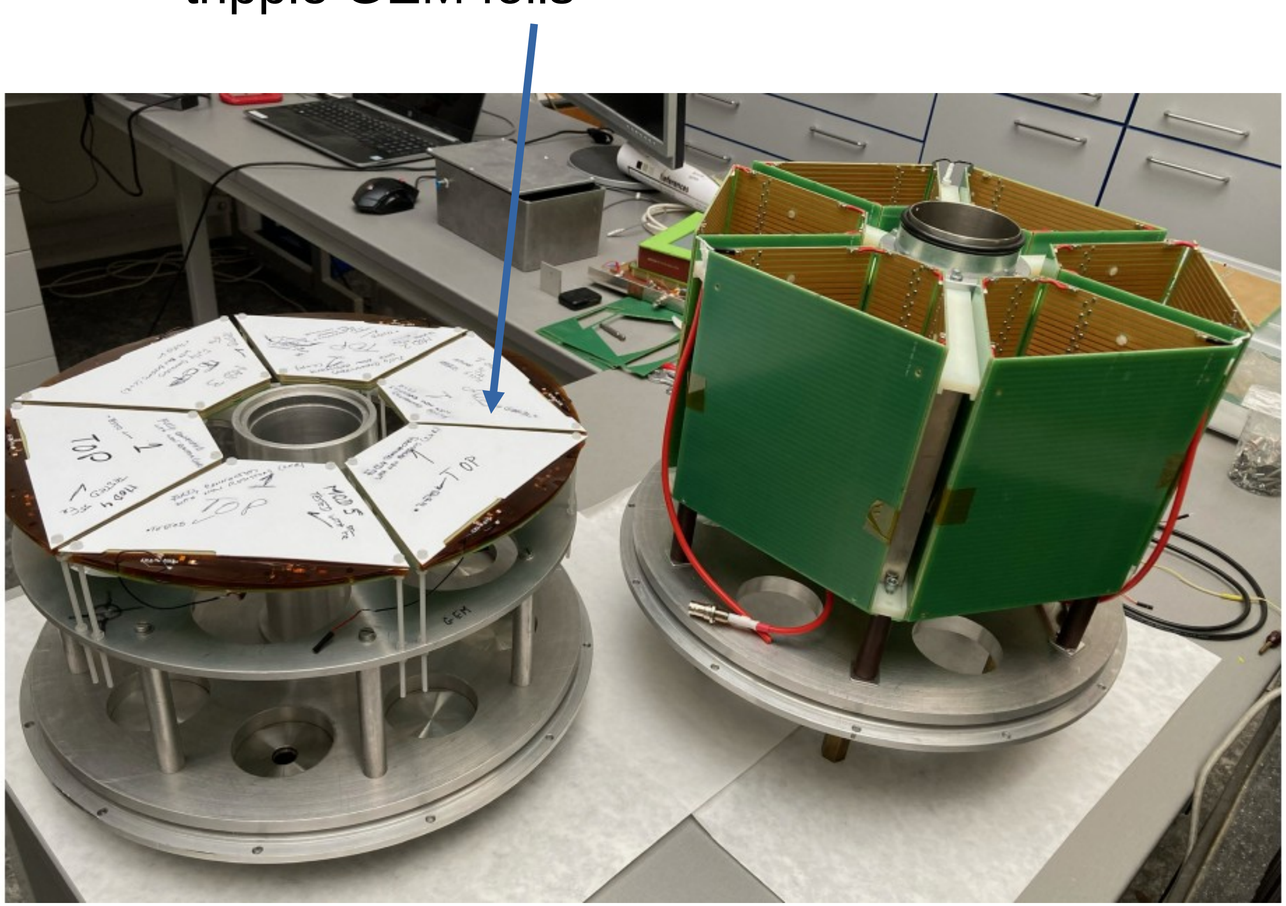


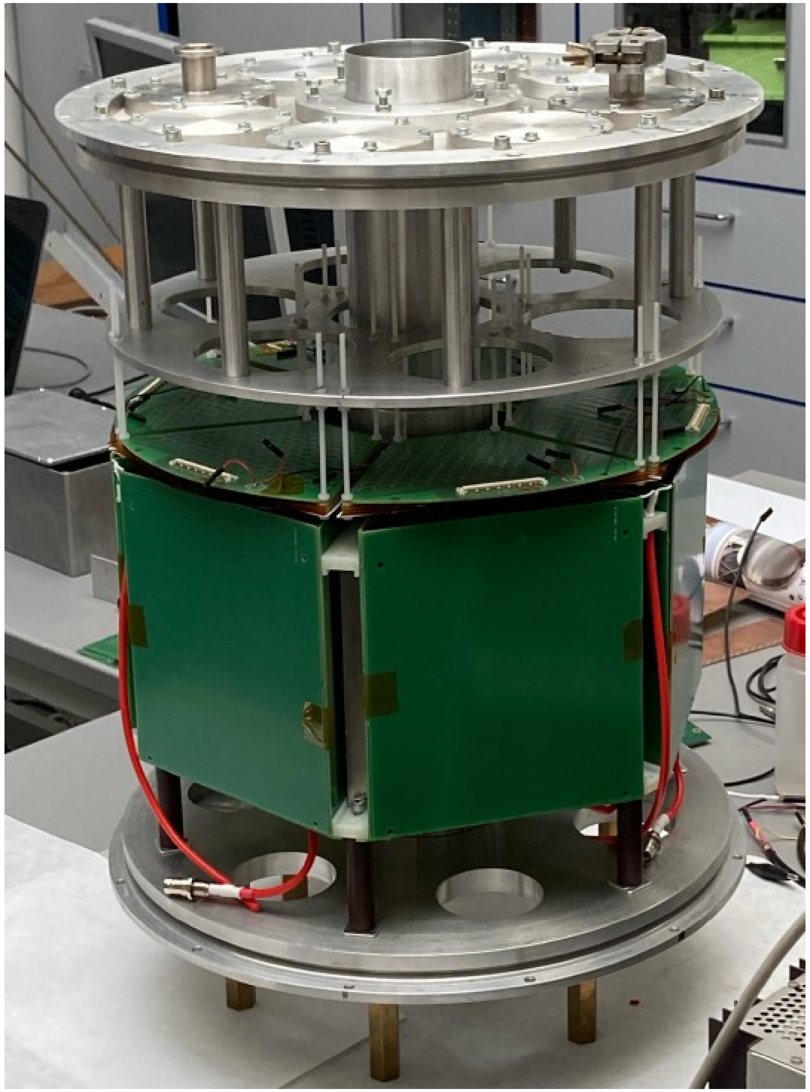


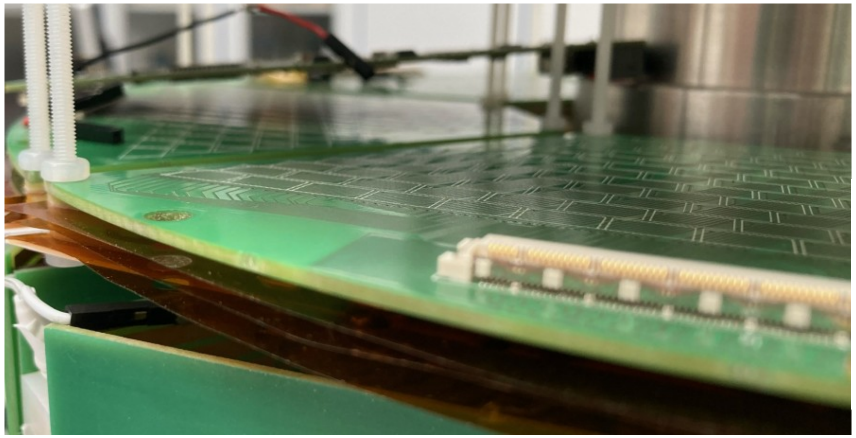


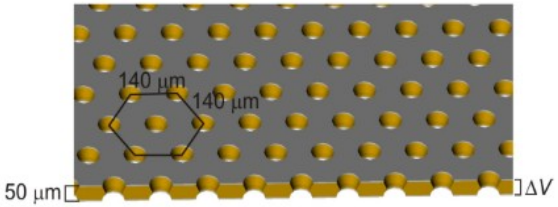
TPC prototype

NB. new branch inside IEAP: gaseous detectors tripple GEM foils

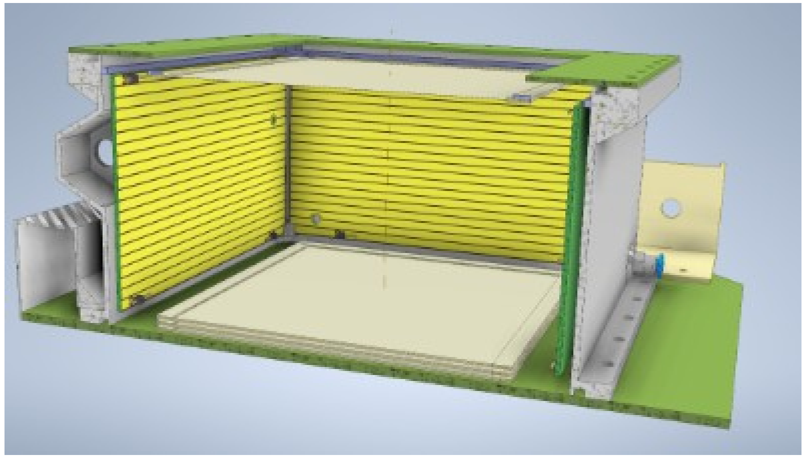


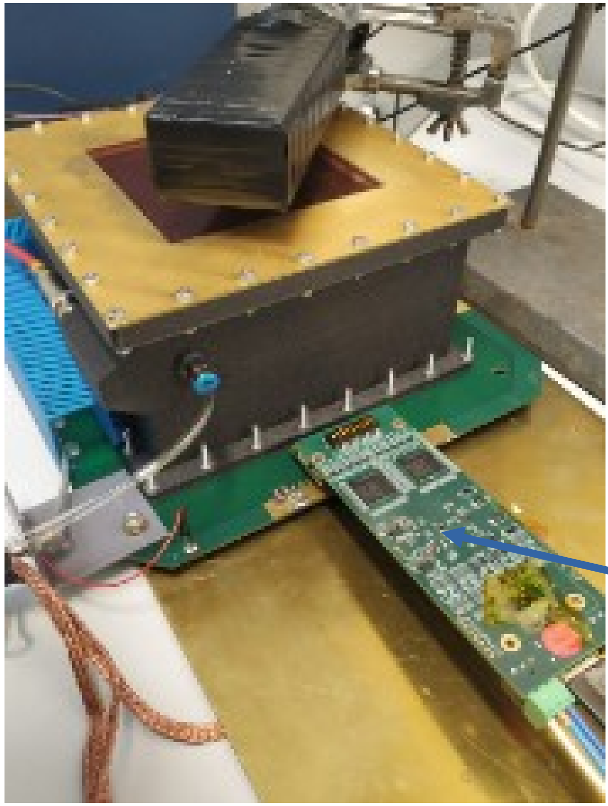


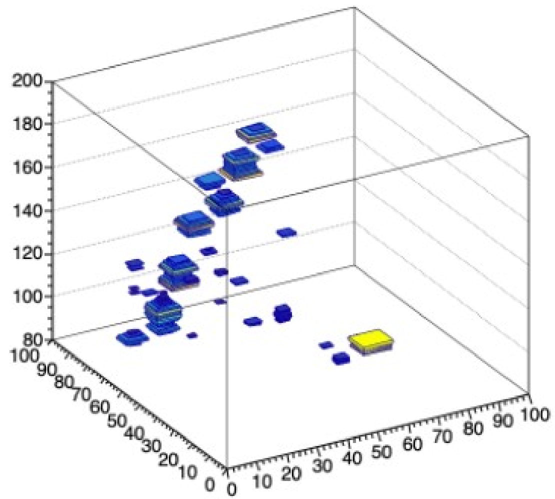


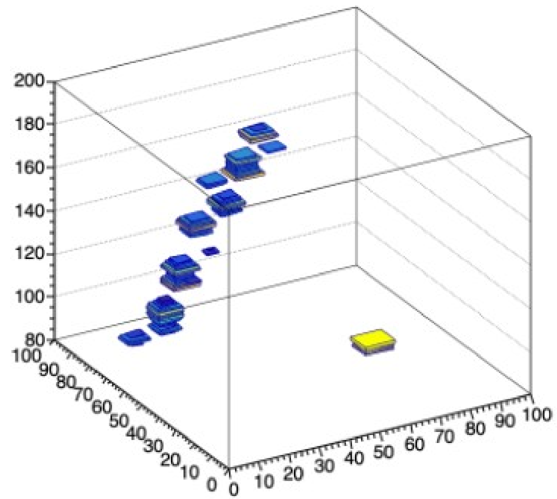


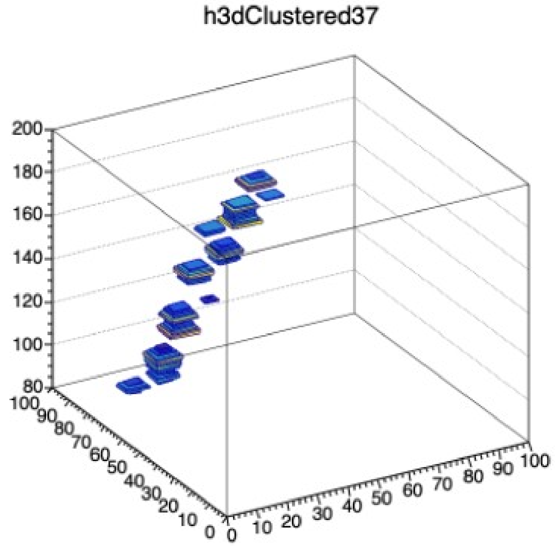
One more view... … not CERN

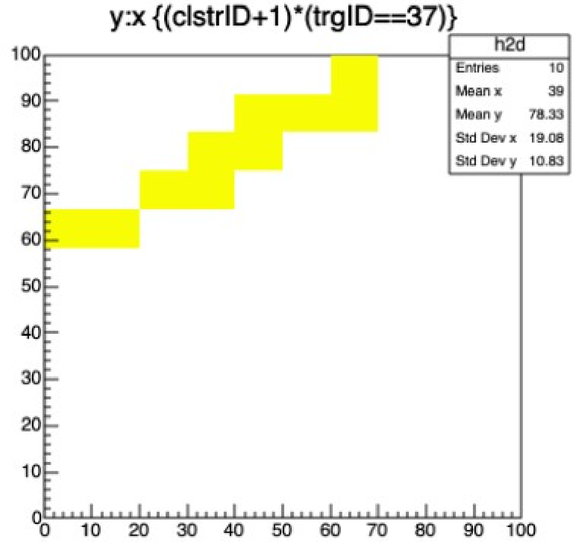






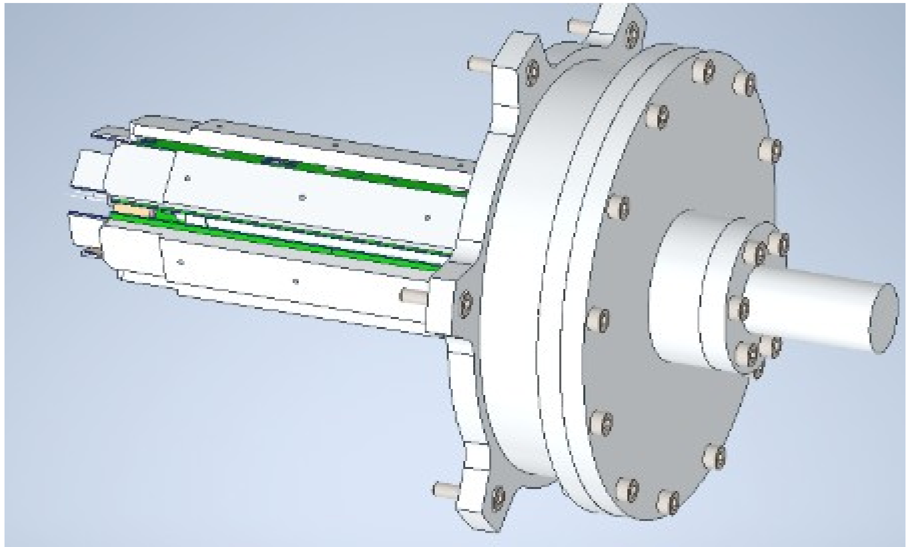


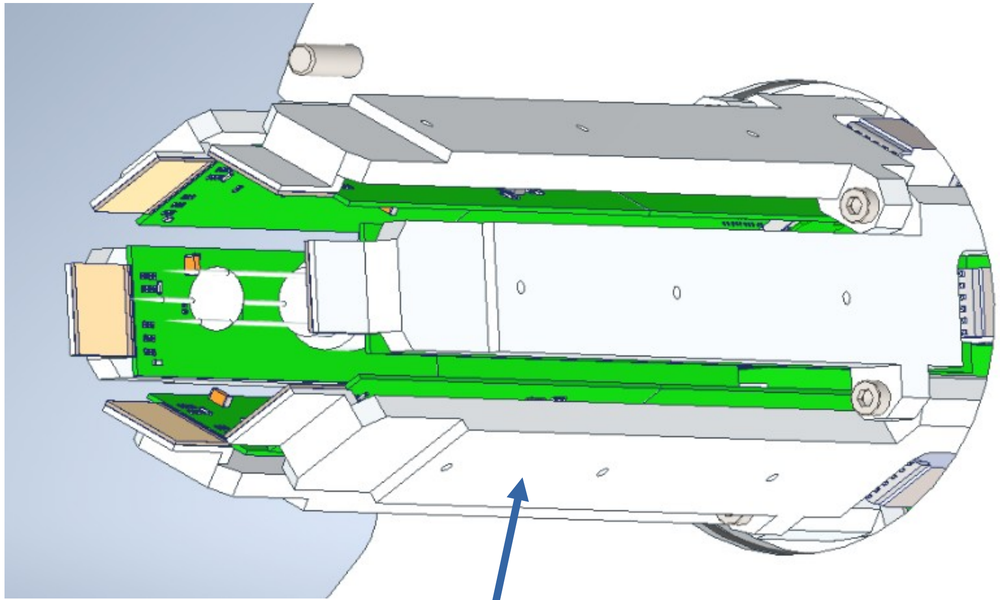




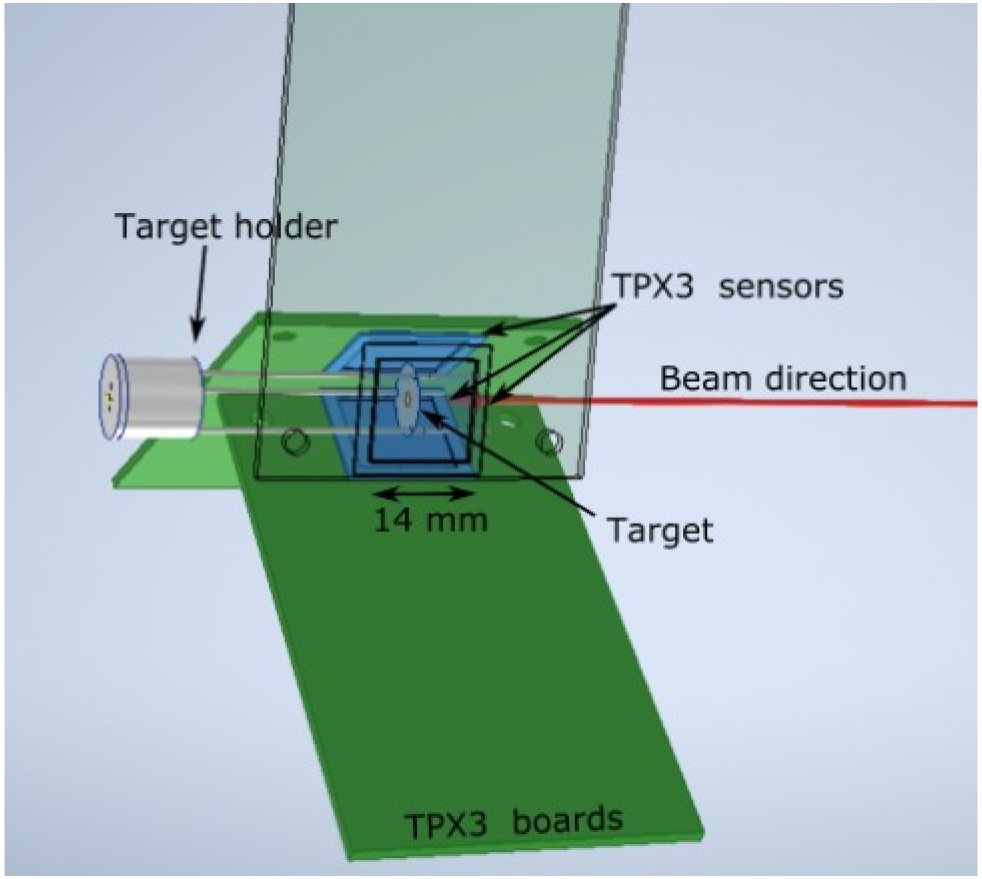
readout with the **SAMPA chip** (developed for ALICE)

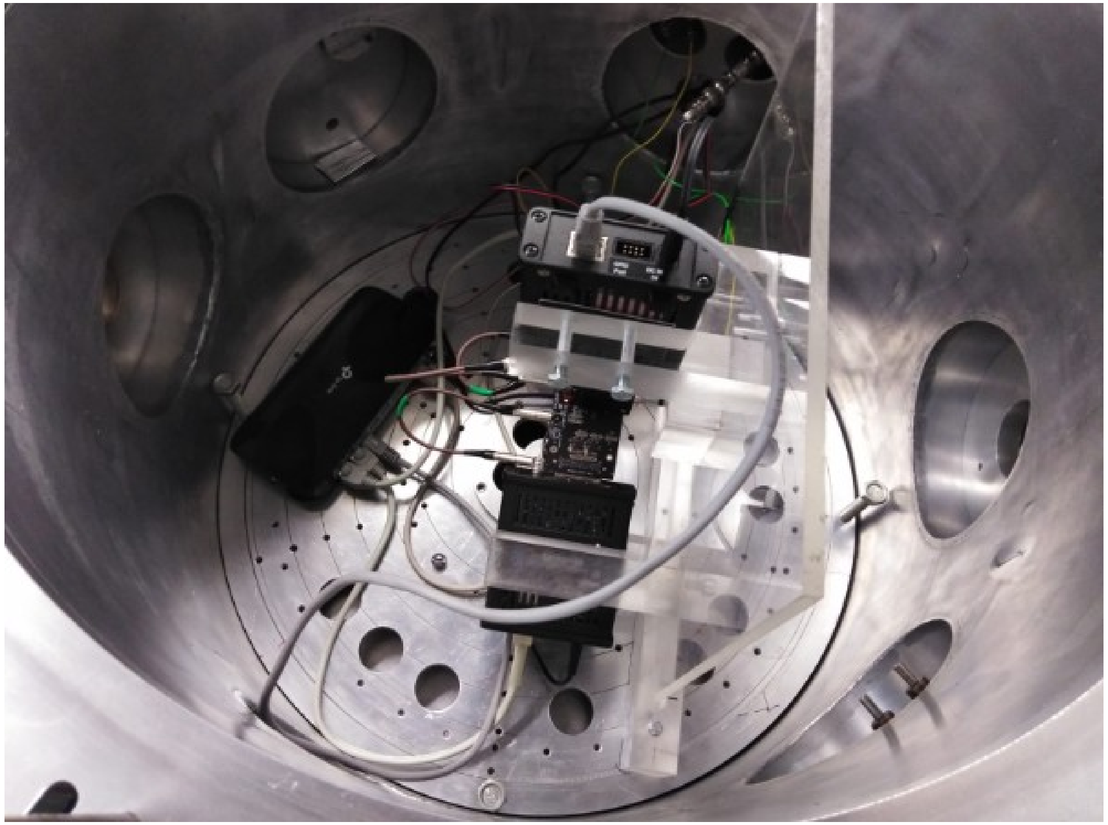
...learning to reconstruct tracks

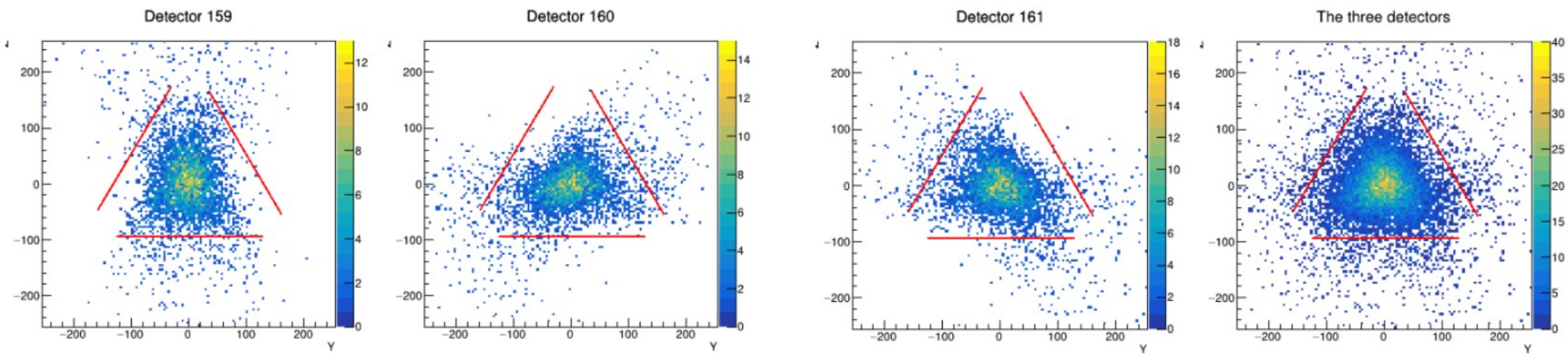




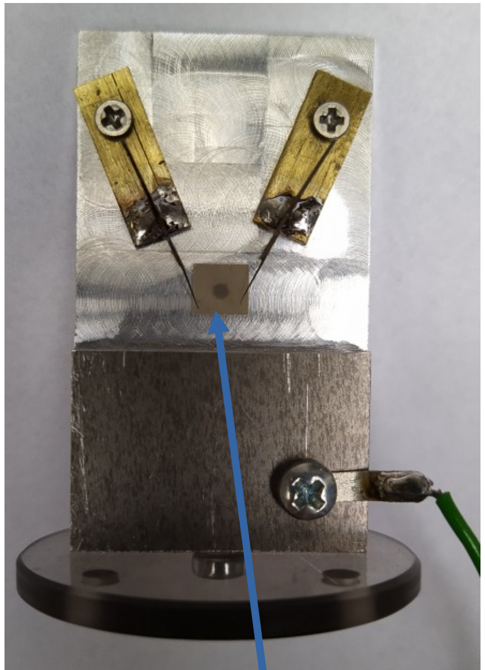
new chipboard developed at the University of West Bohemia, Pilsner


Target holder
TPX3 sensors
Beam direction
14 mm
Target
TPX3 boards

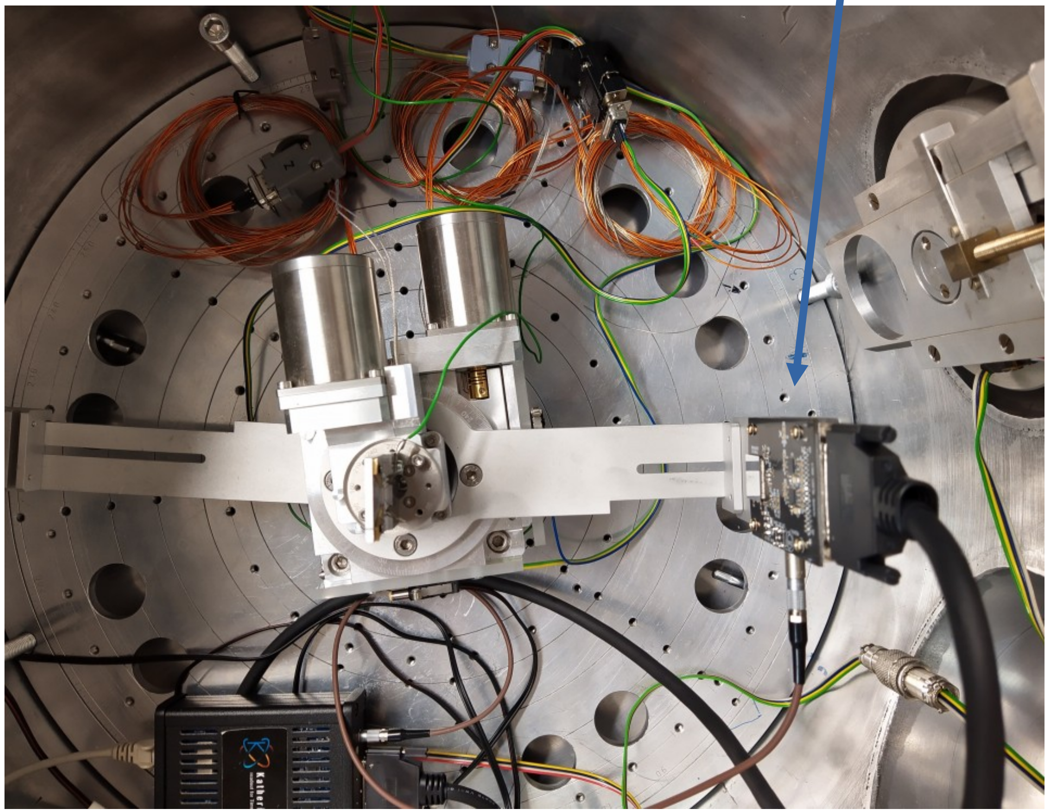


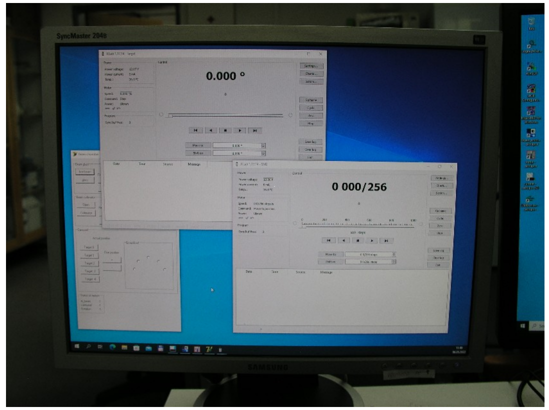

Detector 159
Detector 160
Detector 161
The three detectors
Y

Very recently: attempts to study effects of *channelling* of accelerated ions inside crystals, using Timepix3 as a detector, by Eric David Bosne of IEAP



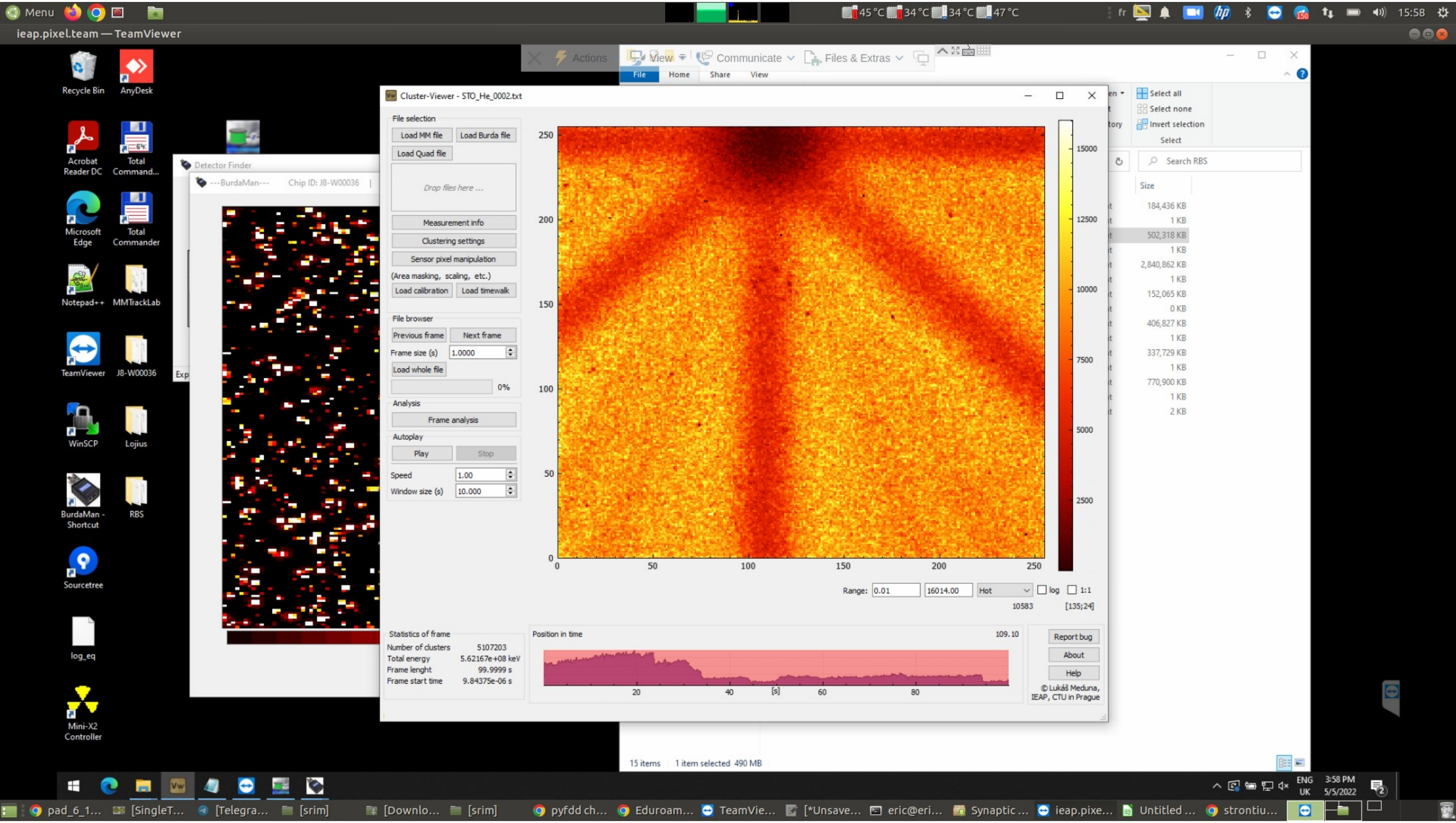
crystal holder





remote motor control

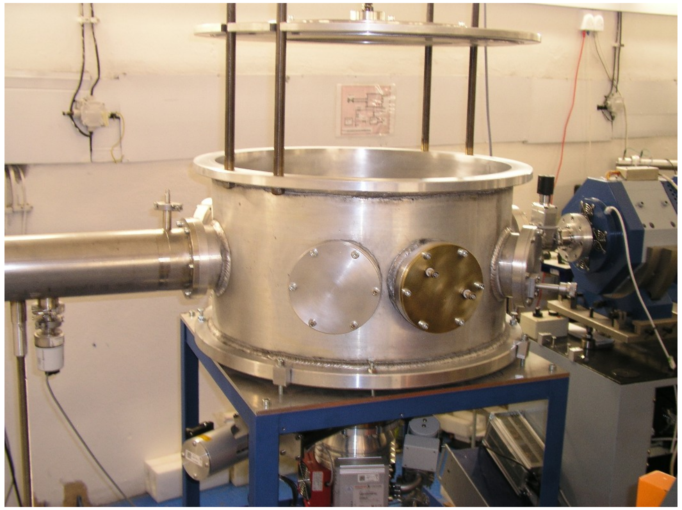
measurements yield patterns like:

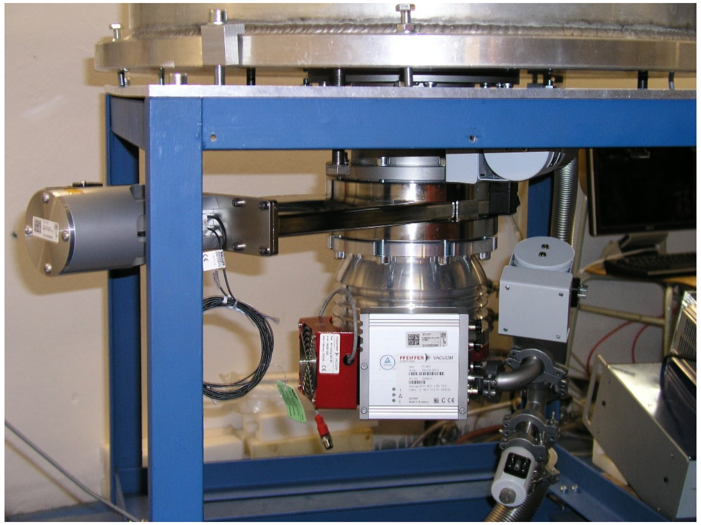


... we hope this will lead to some long-term programme

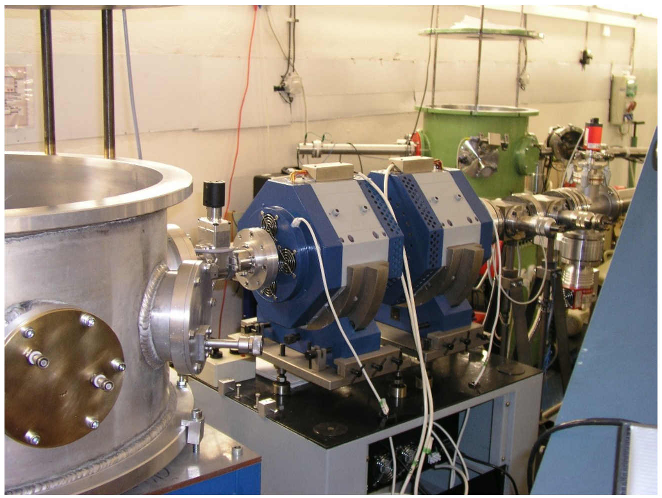
Very recently #2: seeking potential use for our machine we contacted people who run the tandetron in Řež, A. Macková; there may be some interest to cooperate

- in some sense the two machines are complementary (beam energy / current)
- interest in ion implantation at low energies (< 1 MeV)
- H, He, N (!), ...??
- we are preparing the abandoned beamline with the "silver" chamber

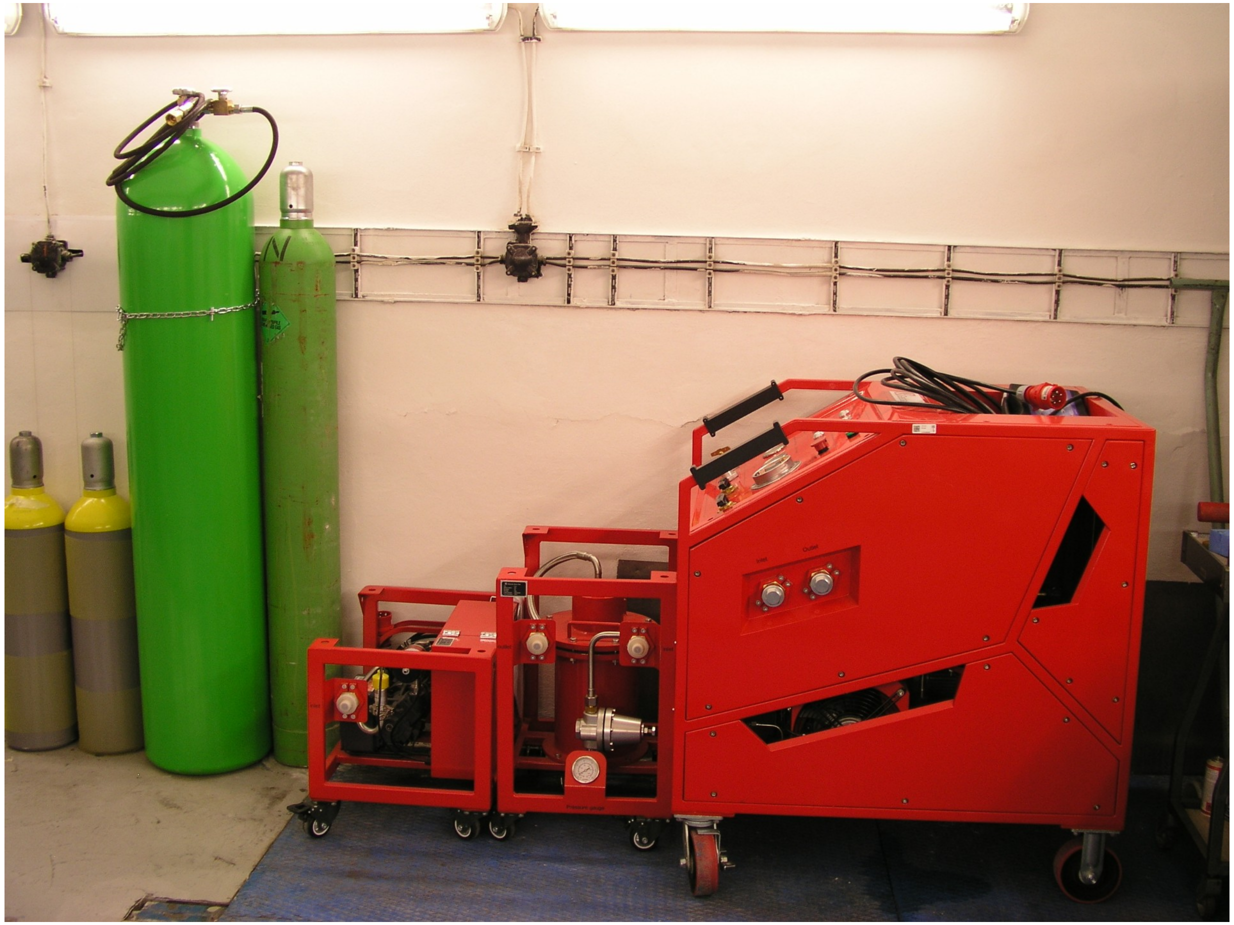




quadrupoles → dipoles ?



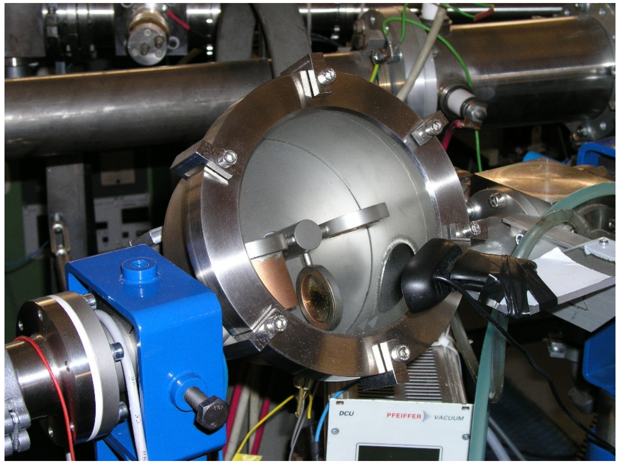
RI upgrades:



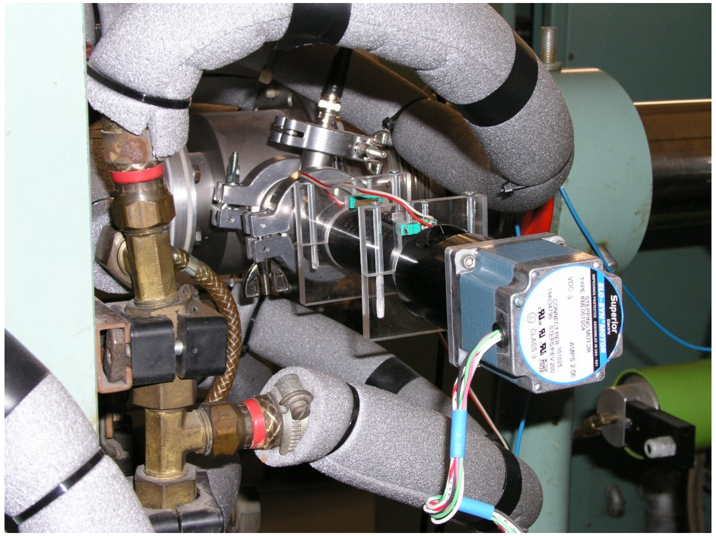
VS

- $CO_2 + N_2 + SF_6 \rightarrow$ pure SF_6 tank gas (≈ 60 kg)
- simpler setup, higher achievable energies
- lower pressure in the tank (12 $\rightarrow$ 5 atm.)

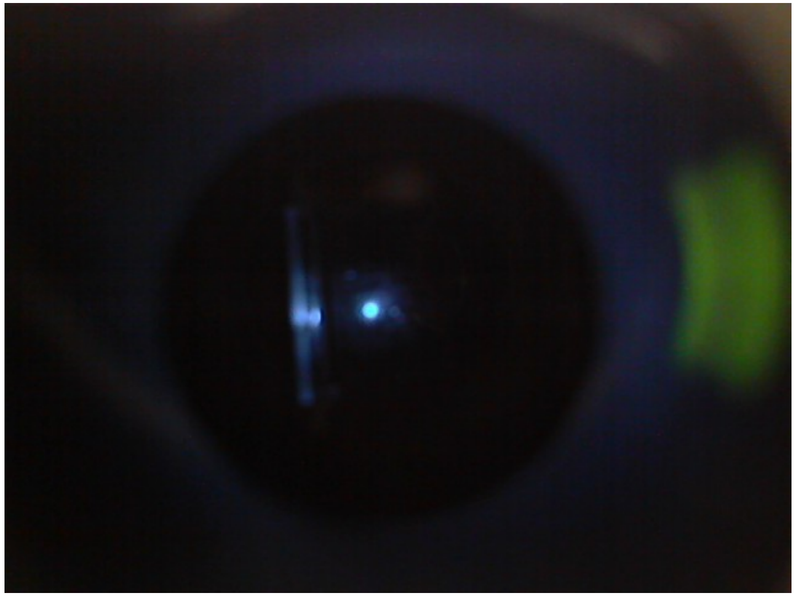
RI upgrades, cont'd:



new beam monitor / aperture / Faraday cup on L1

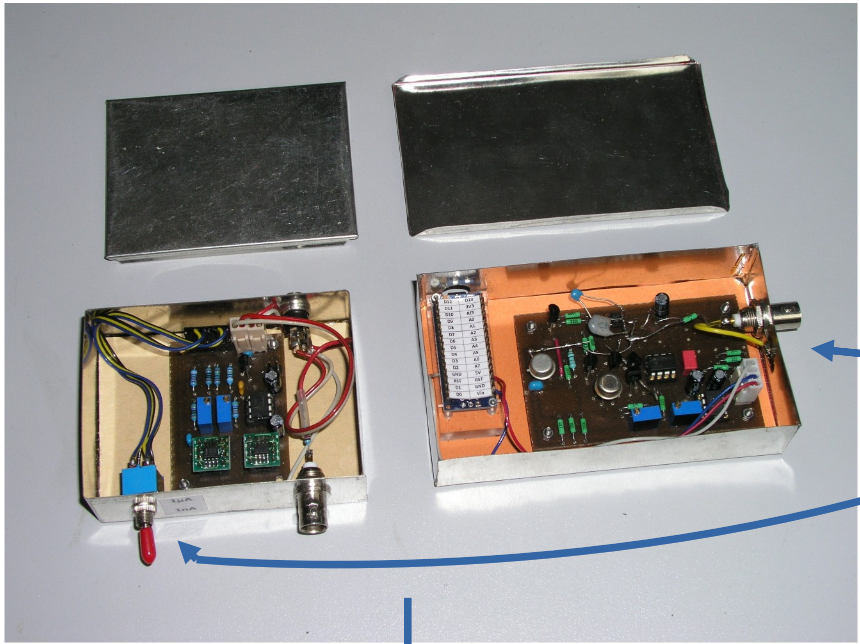


beam monitor / variable apertures
in front of deflection magnet



well focused beam of
500-keV protons

RI upgrades, cont'd:



- measurement of electric currents at various places down the beam
- basic: 1 nA – 100 μA (factor 10^5, without switching ranges)
- also available in pA range
- calibration sources 1 nA, 1 μA
- in-house development, few hundreds of Kč

Formal matters

RI VdG 2021 evaluation, international-comittee report conclusion:

Please specify what recommendations for the future (up to 5 top priority) do you give to the LRI as regards addressing the weaknesses that you identified during the evaluation process.

Specific recommendations include:

- The accelerator should be replaced by a new facility with modern technology (state-of- the-art) within the proposed time (no later than 2024/25). When specifying the new accelerator, it should be ensured that it is complementary to the systems available in the Czech Republic and in Europa. A modern system with a specialized orientation increases the attractiveness for users and for the training of students and PhD students. To support a larger number of undergraduate / PhD students, the number of FTEs for scientists and / or engineers should be increased.
- By increasing the attractiveness of the facility and the activities to draw more users (dedicated user workshops and presentations at international conferences), a moderate overbooking could be achieved. The selection of user experiments and the allocation of beam time should be made by an international evaluation panel, which would need to be established. This can improve the quality of the scientific output, the profiling of the facility and the international visibility. A strengthening of the interaction/collaboration with local companies is strongly encouraged.

RI VdG 2021 evaluation, international-comitteee report conclusion, cont'd:

- To evaluate and improve the efficiency of the system, corresponding key data such as the planned beam time, delivered beam time, the overbooking factor, downtimes, the number of publications per beam time, etc. should be reported.
- The budget for investments to maintain and improve the performance of the system as well as for the beamline and laboratory equipment should be increased significantly so that the experiments can be carried out on a modern technical level with international standards. This would also increase the attractiveness for international users.

In conclusion: The review panel is impressed with the excellence of the LRI VdG, which deserves a high grade for performance in almost all categories. Yet, the apparatus most likely will fail in the foreseeable future. It should not simply be repaired. The review panel would like to see a detailed justification and strategic plan, as well as realistic cost estimate for an upgrade or replacement. The current ideas are not sufficiently elaborated and justified. The review panel recommends that the facility is run for another 3 years or so, and that in the meantime a detailed plan is worked out that would allow research in this area, which is deemed essential for the overall scientific enterprise of the Czech Republic be made ‚fit for the future'.

Overall grade:	**3 – Good**

NB. financing grade-3 RI is unlikely

Opinions

- the future is open, financing from MEYS as RI will almost surely be discontinued
- new accelerator?
  - *strategic* decision, relevant question concerning its (I) *programme*, (II) *manpower*
  - at this moment I hardly see the win, putting modernization (reliability) aside
- *current accelerator is good enough* for many purposes
- we should become less dependent on ‘breastfeeding’ (and bureaucracy) from MEYS (to run RI as a service) and shift to ***actively-driven projects on our side*** (both research and applied) to provide necessary money; fortunately, ***some projects*** (as I showed) ***do*** (slowly) ***appear***
- we should try to offer our knowledge and services to a wider community (how?!); NB. many similar accelerators shut down, ours was essentially passed to us from Charles University; however, there still other old machines worldwide that have found niche projects

André Cortez

Let’s believe in our hard workers,

… in our bright future ...

… and our unrivalled continuity.

Ivan Wilhelm, 14. 10. 2022
"father" of the accelerator

Thank you for your attention

BACKUP SLIDES FOLLOW

Illustration: results in 2021

a) List of R&D results achieved by the operator of the LRI (i.e. host/beneficiary as well as partner institutions/other participants of the LRI project) in 2021 (corresponds to "RIV")

The enhancement of the portfolio and quality of services provided by the LRI is partially documented via introduction of functional samples / prototypes (detailed at VdG webpage aladdin.utef.cvut.cz/projekty/vdg/):

A. Z. Kohout, R. Sýkora, *Optical remotely-controlled accelerator-beam monitor with beam electric-current measurement;* prototype, CTU in Prague (2021)

B. H. N. da Luz, A. Cortez, G. Grossi, *Time projection chamber operating with SAMPA front-end;* prototype, CTU in Prague (2021)

C. H. N. da Luz, *Position-sensitive multiwire proportional counter with delay-line readout;* prototype, CTU in Prague (2021)

D. T. Slavíček, *Laboratory apparatus for humidity and Li-content measurement of sand samples;* functional sample, CTU in Prague (2021)

E. M. Veselský, T. Slavíček, *N-type HPGe detector system;* functional sample, CTU in Prague (2021)

F. Z. Kohout, *System of accelerator cooling-water flow measurement;* functional sample, CTU in Prague (2021)

Illustration: results in 2021, cont'd

b) Number of R&D results and 10 top R&D results achieved by users of the LRI in 2021

Research articles:

The number of research articles in 2021 was severely diminished due to the pandemic – the infrastructure was essentially closed to researchers.

A. E. Sansarbayar et al., *Cross sections for the Cl-35(n, alpha) P-32 reaction in the 3.3–5.3 MeV neutron energy region,* Phys. Rev. C, **104**, 044620 (2021), DOI: 10.1103/PhysRevC.104.044620

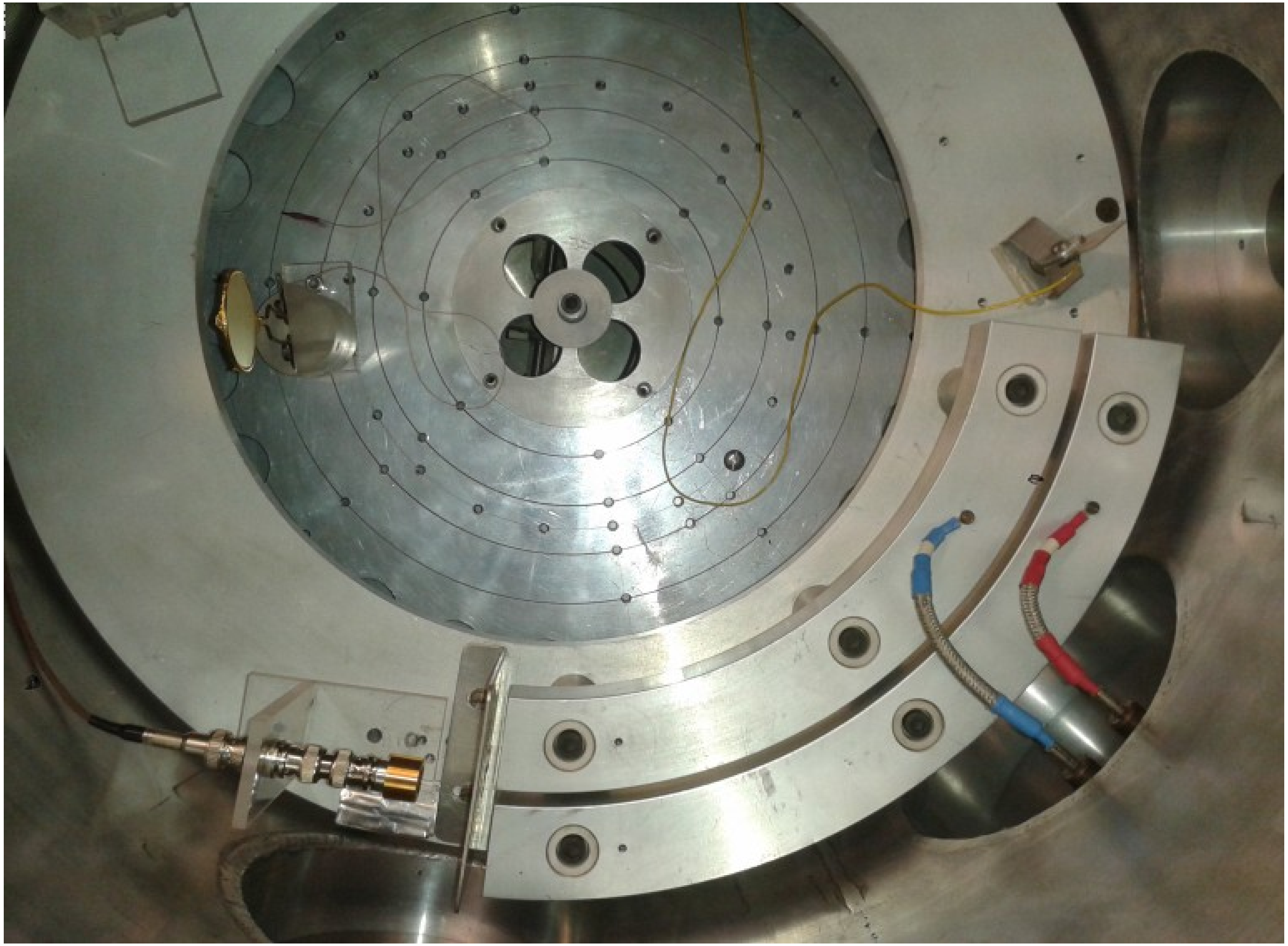
B. B. Bergmann et al., *Experimental study of the adaptive gain feature for improved position-sensitive ion spectroscopy with Timepix2,* JINST, **17**, C01025 (2022; received by JINST and presented at conferences in 2021), DOI: 10.1088/1748-0221/17/01/C01025

C. P. Rubovič et al., *Measurements of D–D fusion neutrons generated in nanowire array laser plasma using Timepix3 detector,* Nucl. Inst. and Methods in Phys. Research, **A985**, 164680, (2021), DOI: 10.1016/j.nima.2020.164680

Functional samples: *(detailed at VdG webpage aladdin.utef.cvut.cz/projekty/vdg/)*

D. Y. Gledenov, I. Chuprakov, E. Sansarbayar, *Ionization chamber with a set of changeable targets;* functional sample, CTU in Prague (2021)

E. Y. Gledenov, I. Chuprakov, E. Sansarbayar, *New set of solid deuterium targets;* functional sample, CTU in Prague (2021)



Own research (OP VVV) cont.

Ad 3) detector physics:

- Recently, preliminary tests to operate Timepix3 detectors together with **Katherine readouts inside a vacuum** chamber have been successfully completed.
  (*cf*. the ATOMKI experiment below).

- **NGSDuo** (supported by EUREKA/EUROSTARS grant): tests of high-volume **CdZnTe** 11x11-pixel detector (better sensitivity to γs than Timepix, sensitive also to *ns*, especially with Gd coating); application in radioactive-material seeking.

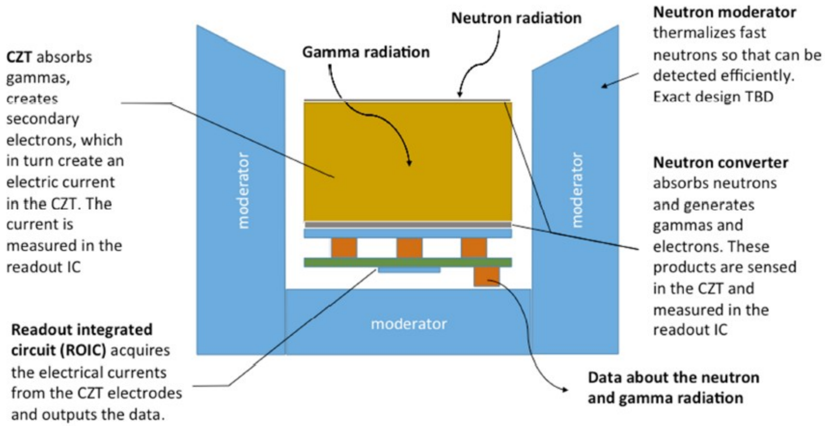
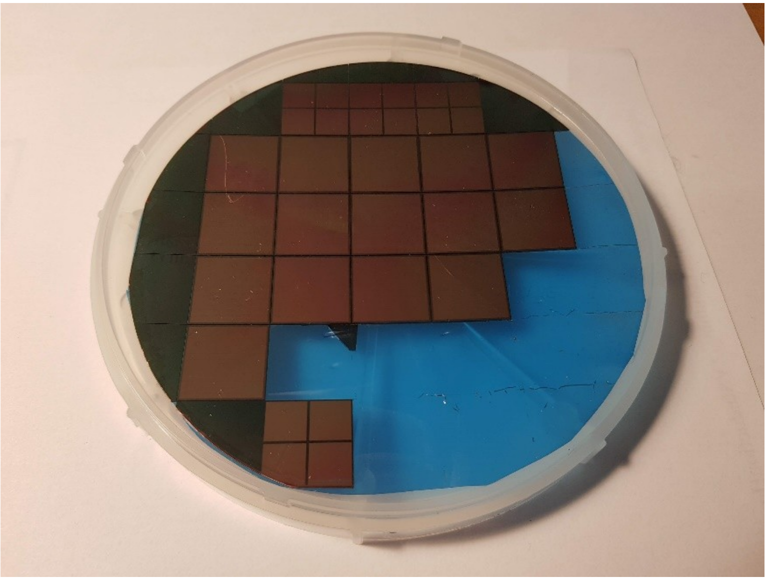
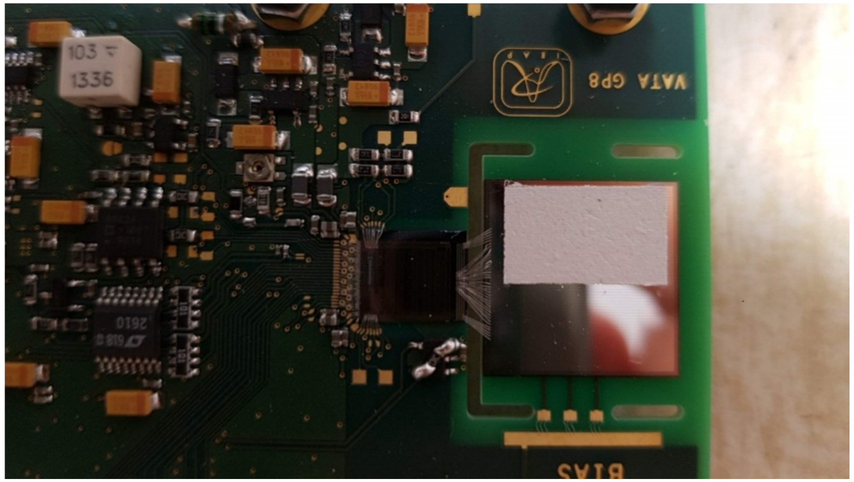
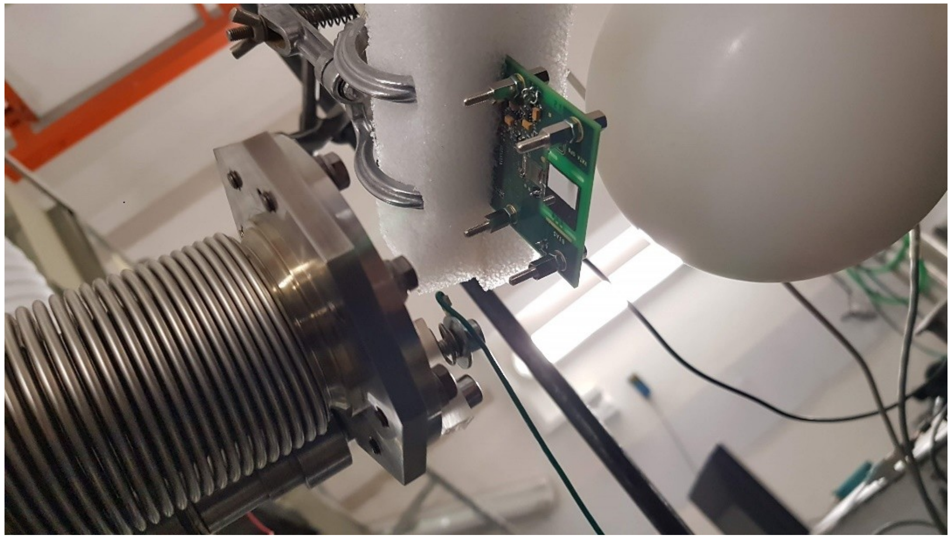


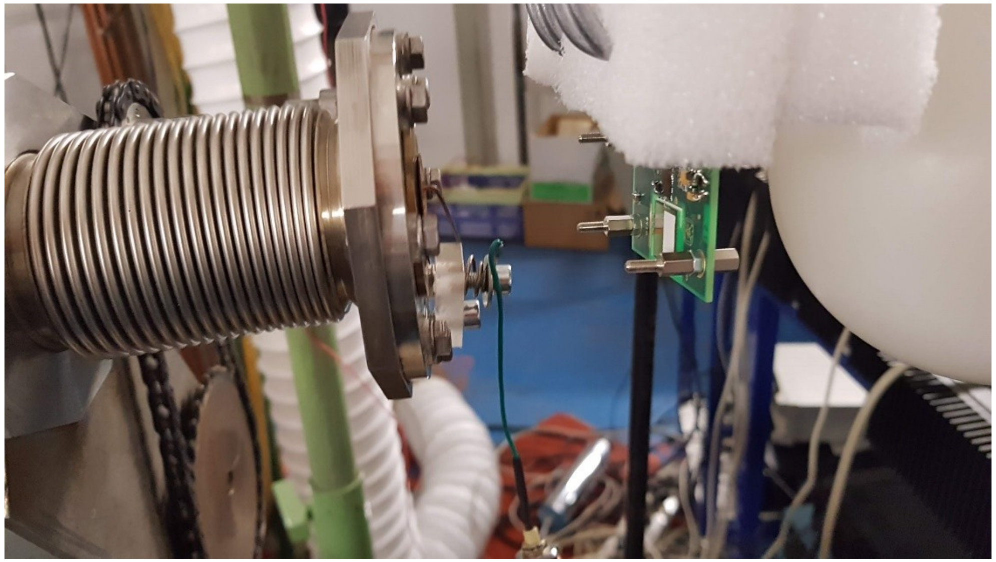
Figure 1: NGSduo principle of radiation detection.

- Tests of **SiC strip detectors** (new material; is it better wrt. their radiation and temperature-strain hardness compared to pure Si?) are undergoing. Tests of the material are done with 128 channel charge sensitive readout developed in **AD-BANG** project supported by Czech-Norwegian research programme)









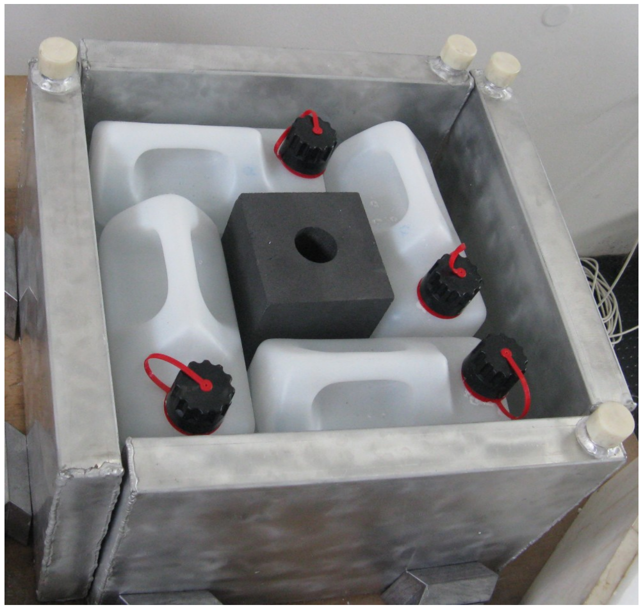
Progress as expected.

Stationary
And
Portable

ESA-certified

Calibration γ-Ray Stations

- portable one now lent to IKI, Moscow, for callibration of MGNS (Mercury Gamma-ray and Neutron Spectrometer)

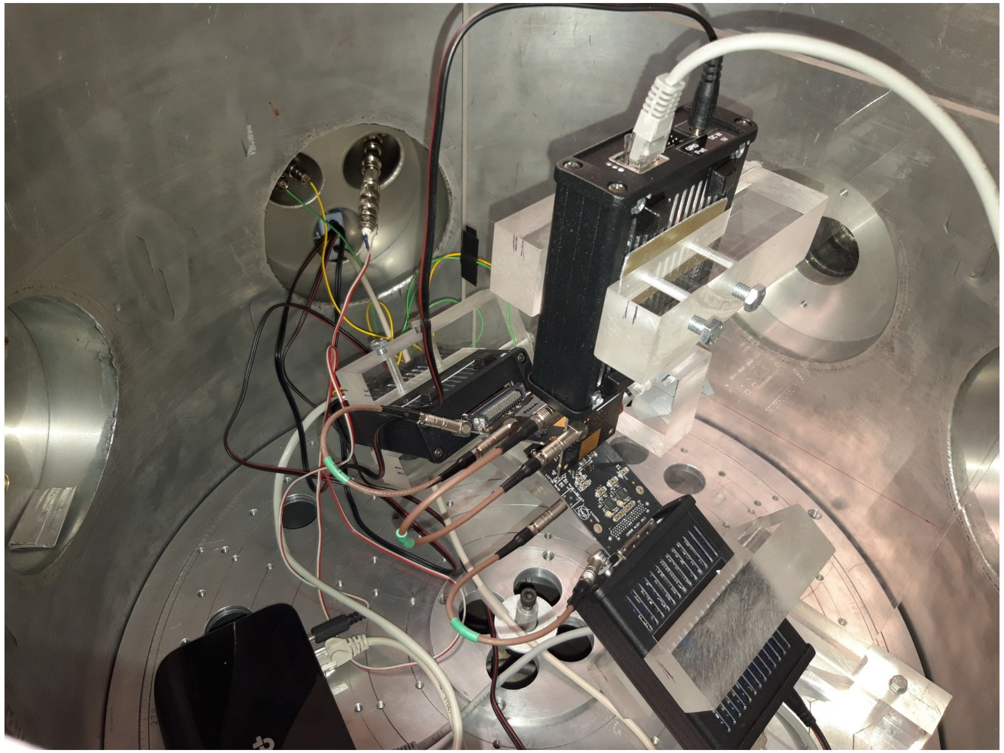


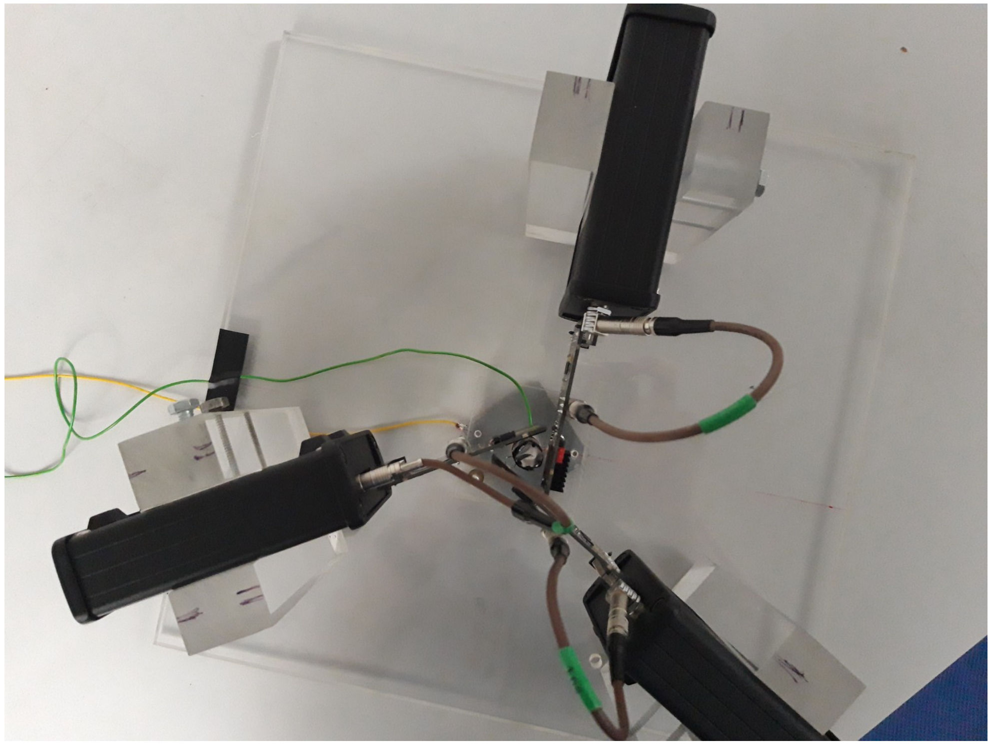
Own research (OP VVV) cont.

Activity outside the 3 pillars:

The ATOMKI experiment: anomaly seen in angular distribution of e+e- pairs emerging from deexcitation of a ^{8}Be nucleus (resonantly created by proton bombardment of ^{7}Li atoms)

Cooperation on the project with University in Montreal, Canada (V. Zacek)





Upgrade and new equipment   cont.

experiment-specific equipment:

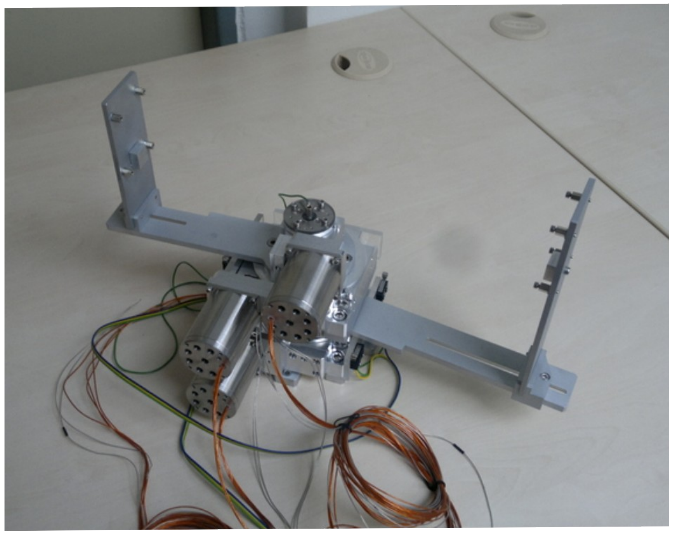
- polarized neutrons

microwave-signal generator
(NMR cooling)

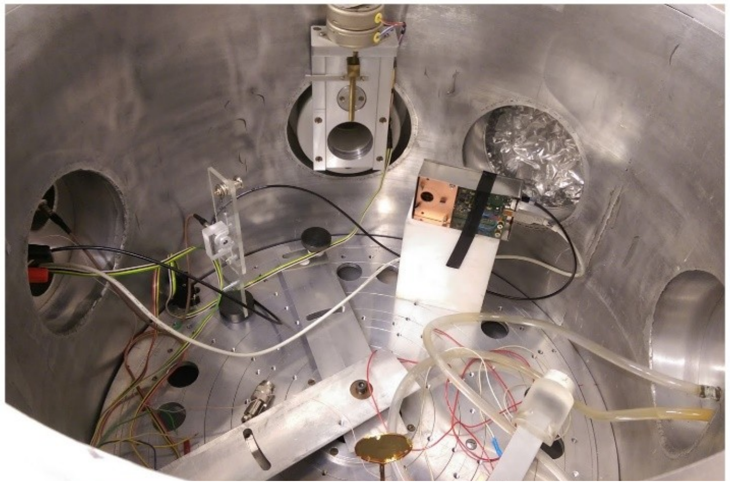
+

power supply for the
superconducting magnet
(not show here)

- RBS
  & ERDA

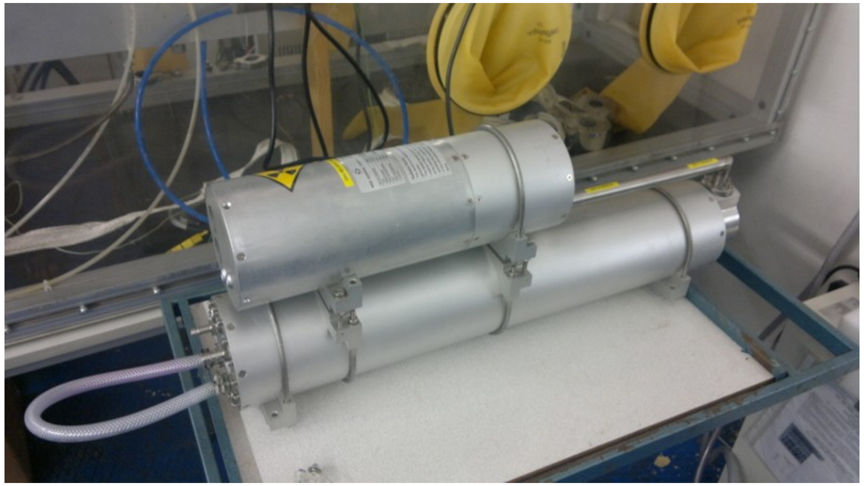


motorized holder for 2 detectors, for measurements
in vacuum chambers, replaces



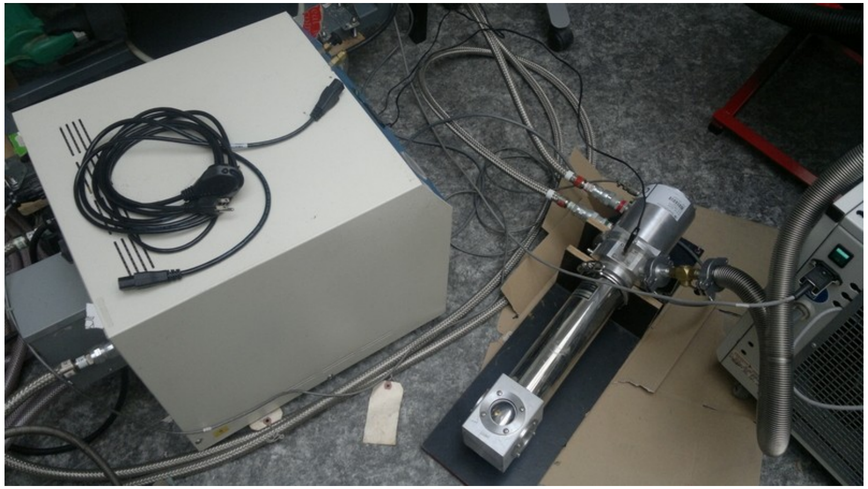
Upgrade and new equipment   cont.

for new experiments:



pulsed neutron source

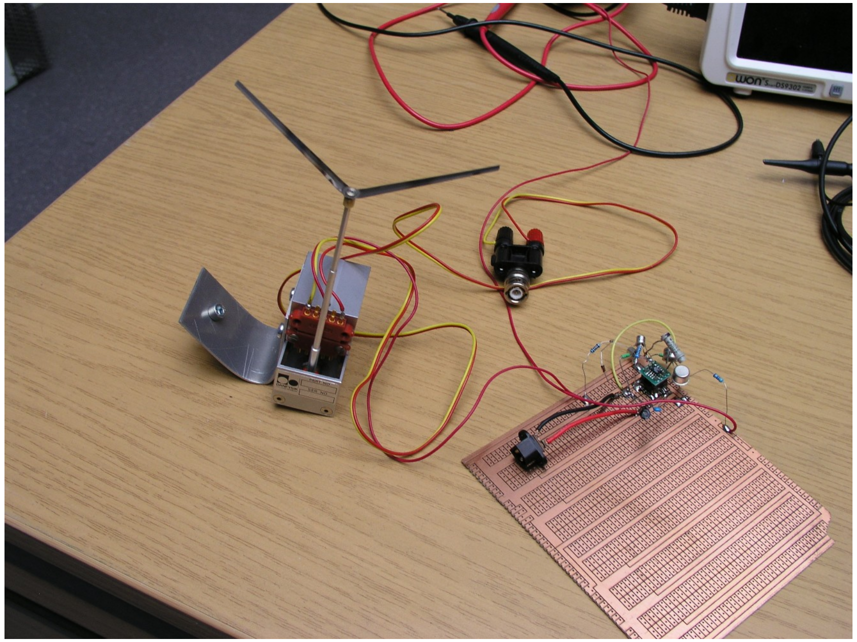
(property of ITAM, but situated at VdG, hopefully operational in the forseeable future)



10K (Helium closed-cycle) apparatus
(for opto-electronical studies)

RI upgrades, cont'd:

- we used to use these Ortec 439 digital current integrators before, now we are quite happy with our new devices



- oscillating beam-position monitor to be possibly used to control the ion implantation process (position + focus control)