Nuclear physics in Slovakia : CERN, GSI, Dubna

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Present status:

- No domestic state-of-the-art facility
- No state-of-the-art facility in neighboring countries
- Long-term under-funding of science
- International collaboration is the only practical solution
- Membership in CERN, JINR, possibly FAIR
- Typically smaller groups collaborating independently

Overview of results of collaborating groups follows

IS466 Collaboration

Andrei Andreyev

(IKS Leuven + UWS Paisley)

Nick Bree

Thomas Cocolios

Jan Diriken

Jytte Elseviers

Mark Huyse

Paul Van den Bergh

Piet Van Duppen

Jarno Van De Walle

RILIS & ISOLDE

Robert Page

Stanislav Antalic

M. Veselský, M. Venhart

Katsuhisa Nishio

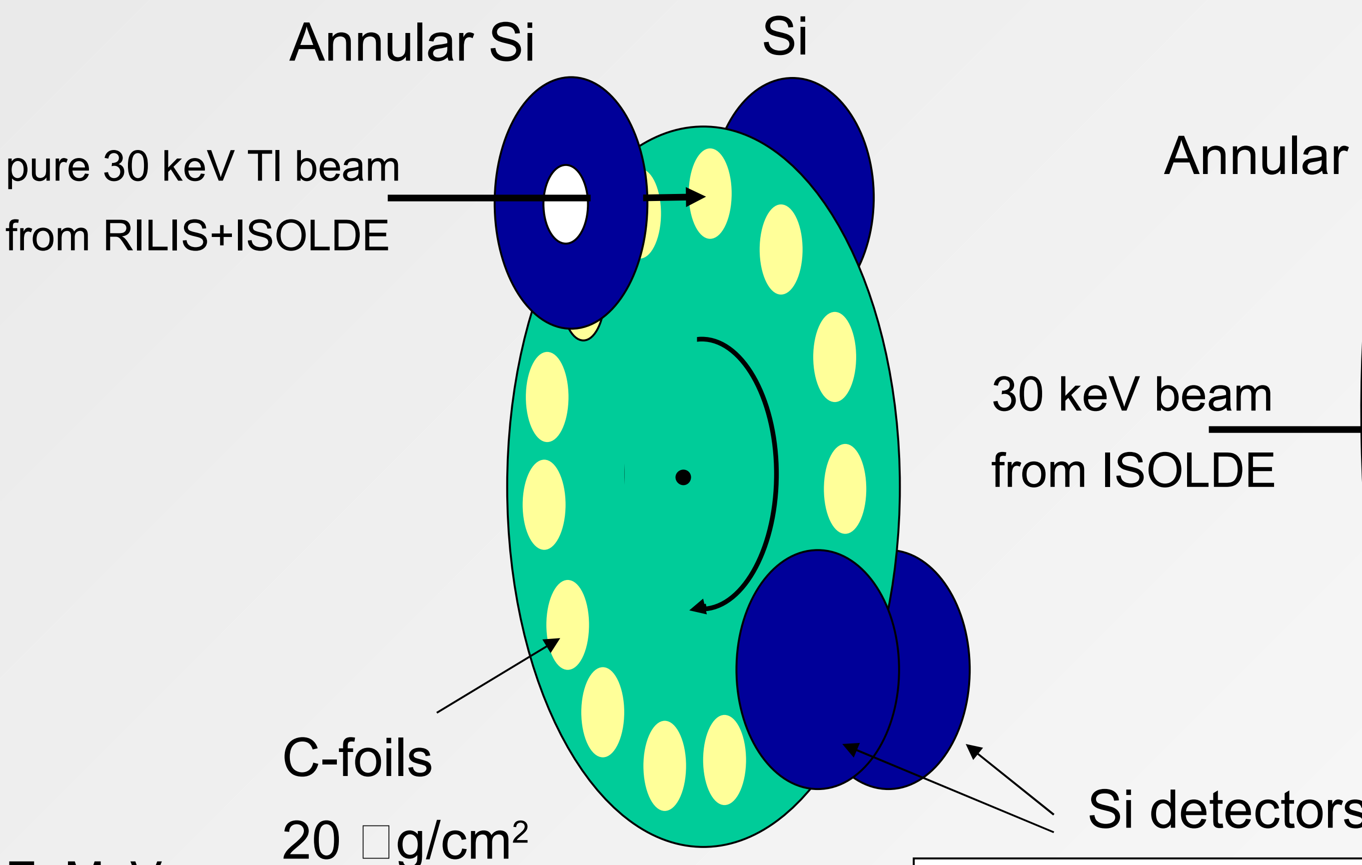
U. Koster (*ILL, Grenoble, France*)

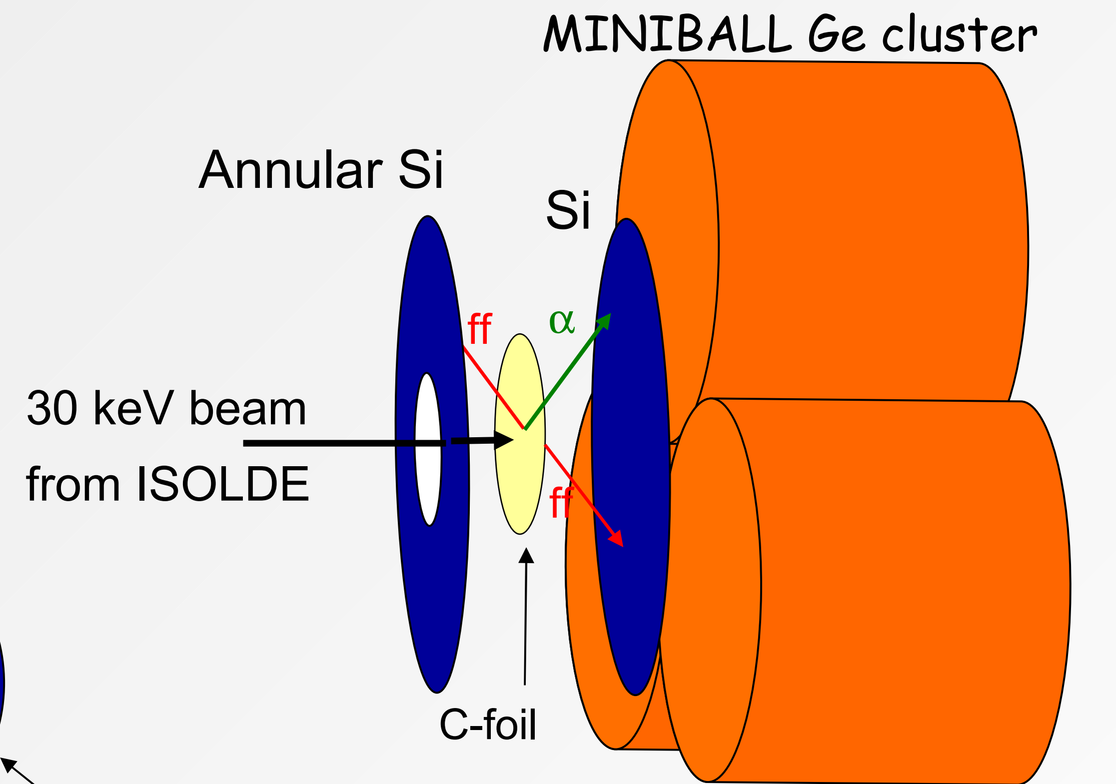
S. Franchoo (*IPN, Orsay, France)*

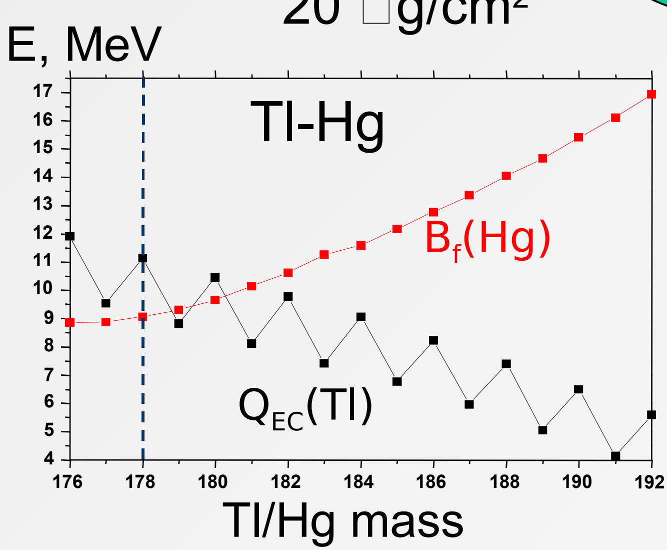
S. Vermote, C. Wagemans (*University of Gent, Belgium*)

I. Tsekhanovich (Manchester University, UK)

IS466: ECDF of ^{180}Tl isotope at ISOLDE (31 may-6 June 2008)







Setup: Si detectors from both sides of the C-foil

- **Simple setup & DAQ:** 4 PIPS (1 of them – annular)
- Large geometrical efficiency (up to 80%)
- 2 fold fission fragment coincidences
- ff-gamma coincidences
- Digital electronics (5 DGF modules)

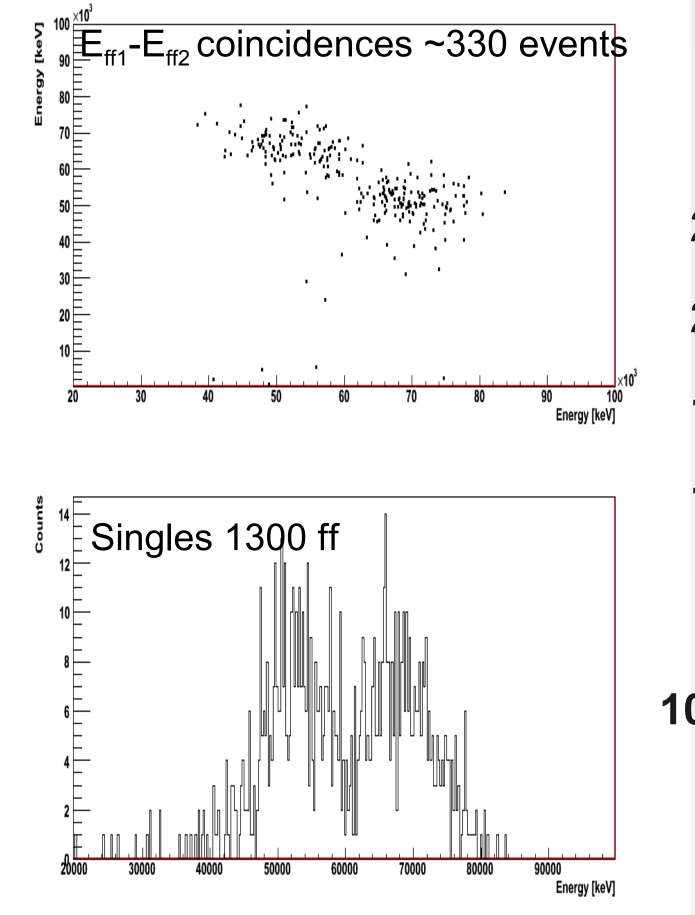
IS466: ECDF of ^{180}Tl

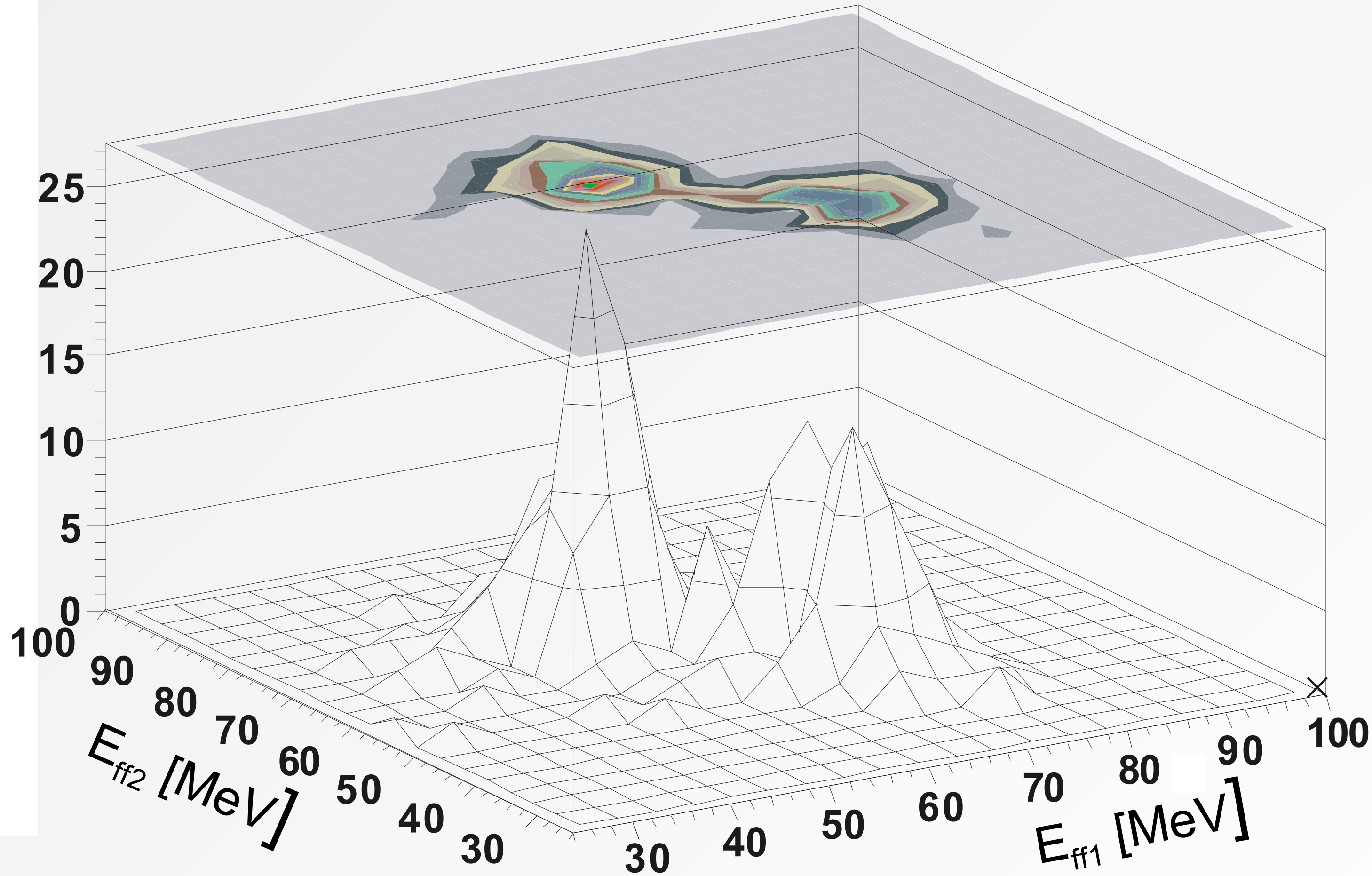
Before the IS466 experiment: How ^{180}Hg (Z=80, N=100, N/Z=1.25) fissions?

Expected: <u>SYMMETRICAL</u> mass split in two semi-magic ^{90}Zr(Z=40,N=50, N/Z=1.25)

IS466: NO! ASYMMETRICAL energy (thus, mass) split!

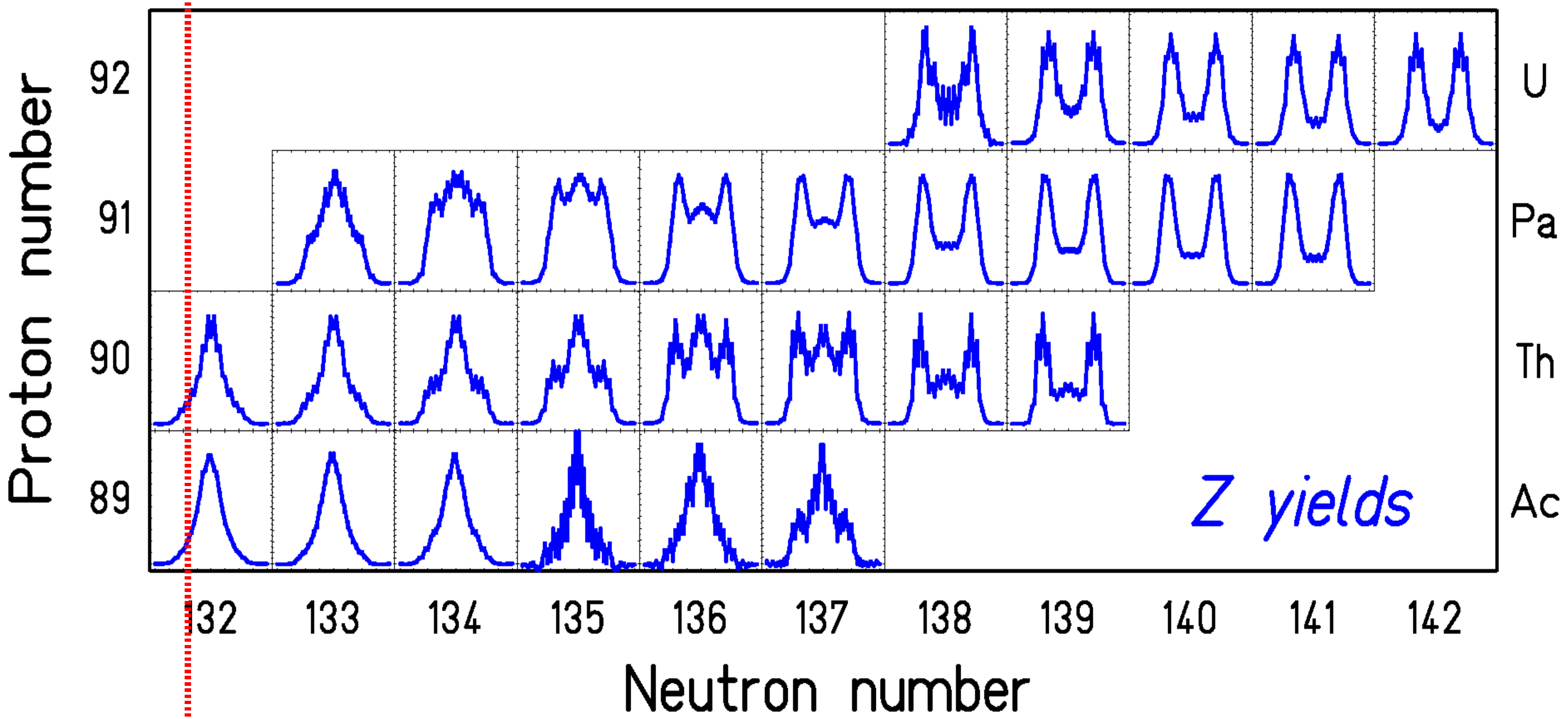
Favorable shell structure does not determine the mass split !!!





First such case observed.

Fission into two semi-magic fragments disfavored ?
Looking back : Results from FRS, GSI



Schmidt et al., NPA 665 (2000) 221

132 = 50 + 82

Transition between symmetric and asymmetric mode close to N=132 !!!

Letter of Intent to the
ISOLDE and Neutron Time-of-Flight Experiments Committee
for experiments with HIE-ISOLDE

Transfer induced fission of heavy radioactive beams

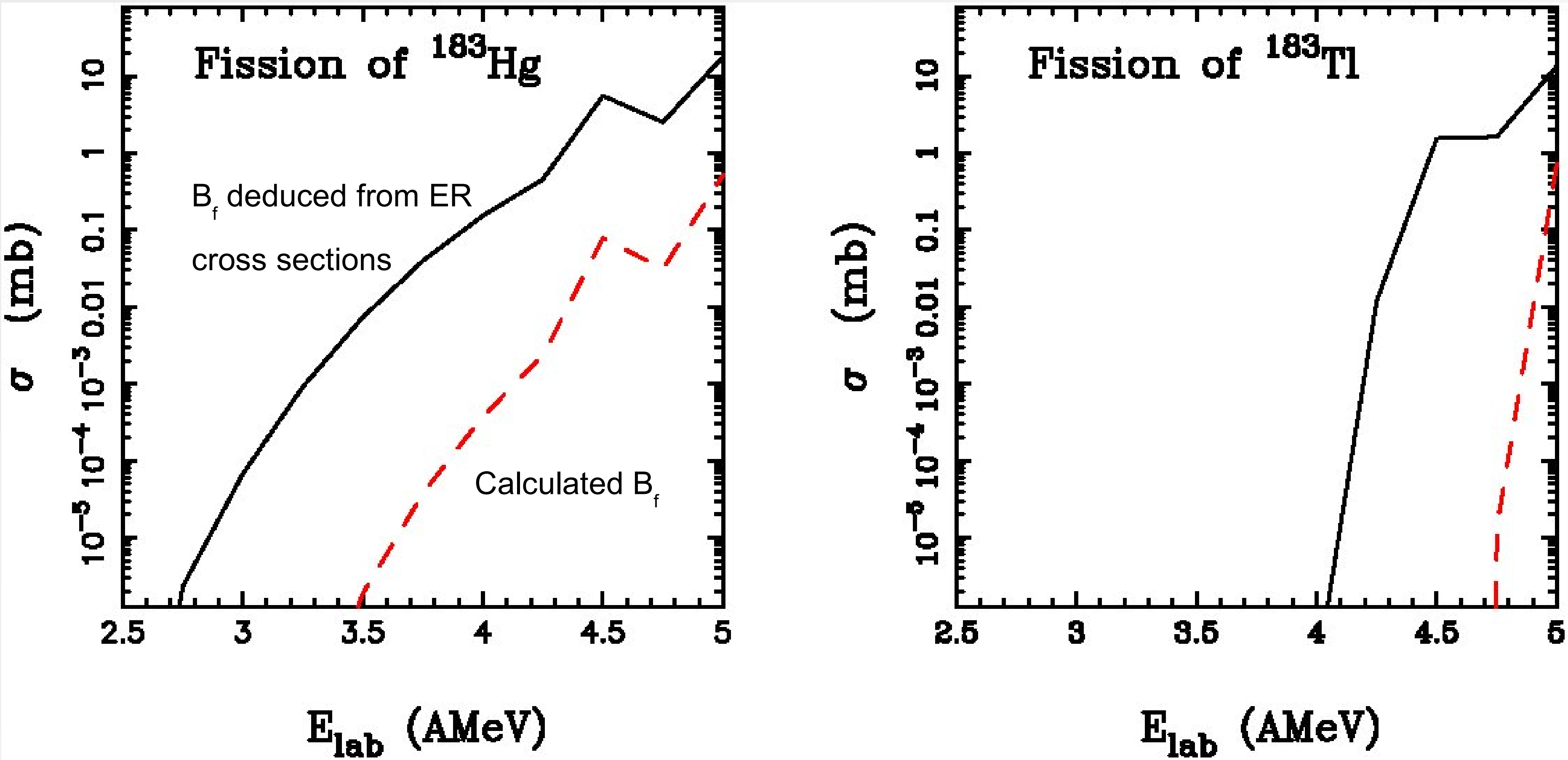
Slovak Academy of Sciences ***Bratislava*** (M. Veselsky, M. Venhart, J. Kliman, L. Krupa)
University ***Bratislava*** (S. Antalic, Z. Kalaninova)
CERN*-ISOLDE* (J. Pakarinen)
KU ***Leuven*** (M. Huyse, P. Van Duppen, R. Raabe)
University of ***West Scotland*** (A. Andreyev, J.F. Smith)
University of ***Athens*** (G.A. Souliotis)

Spokesperson: M. Veselsky (***Bratislava***)
Local contact person: J. Pakarinen (***CERN****-ISOLDE*)

Abstract

Transfer induced fission is proposed as a tool to study low energy fission of exotic heavy nuclei. Fission cross sections in transfer reactions calculated for the radioactive beams show strong sensitivity to fission barrier height and thus offer possibility to determine it in experiment. The long lasting question concerning the fission barrier heigth as a parameter of statistical calculations, relevant e.g. for production of super-heavy nuclei, can be addressed. Depending on determined fission barriers and corresponding fission rates, transfer induced fission will offer a more general tool to study the low energy fission of heavy exotic nuclei at the ISOLDE. Complementary to fission studies, spectroscopic investigations can be carried out for the most prominent transfer reactions products.

Transfer induced fission at HIE-ISOLDE



Primary goal: to determine fission barriers where unknown, which is anywhere except the beta-stability line.
HIE-ISOLDE will provide unique opportunity for that.

IS521: Simultaneous spectroscopy of γ rays and conversion electrons: Systematic study of *E*0 transitions and intruder states in close vicinity of mid-shell point in odd-Au isotopes

S. Gmuca, J. Kliman, L. Krupa, K. Petrik, **M. Venhart** and M. Veselsky

Institute of Physics, Slovak Academy of Sciences, Bratislava

T. E. Cocolios and J. Pakarinen

CERN-ISOLDE

J. L. Wood

Georgia Institute of Technology, Atlanta, USA

S. Antalic and Z. Kalaninova

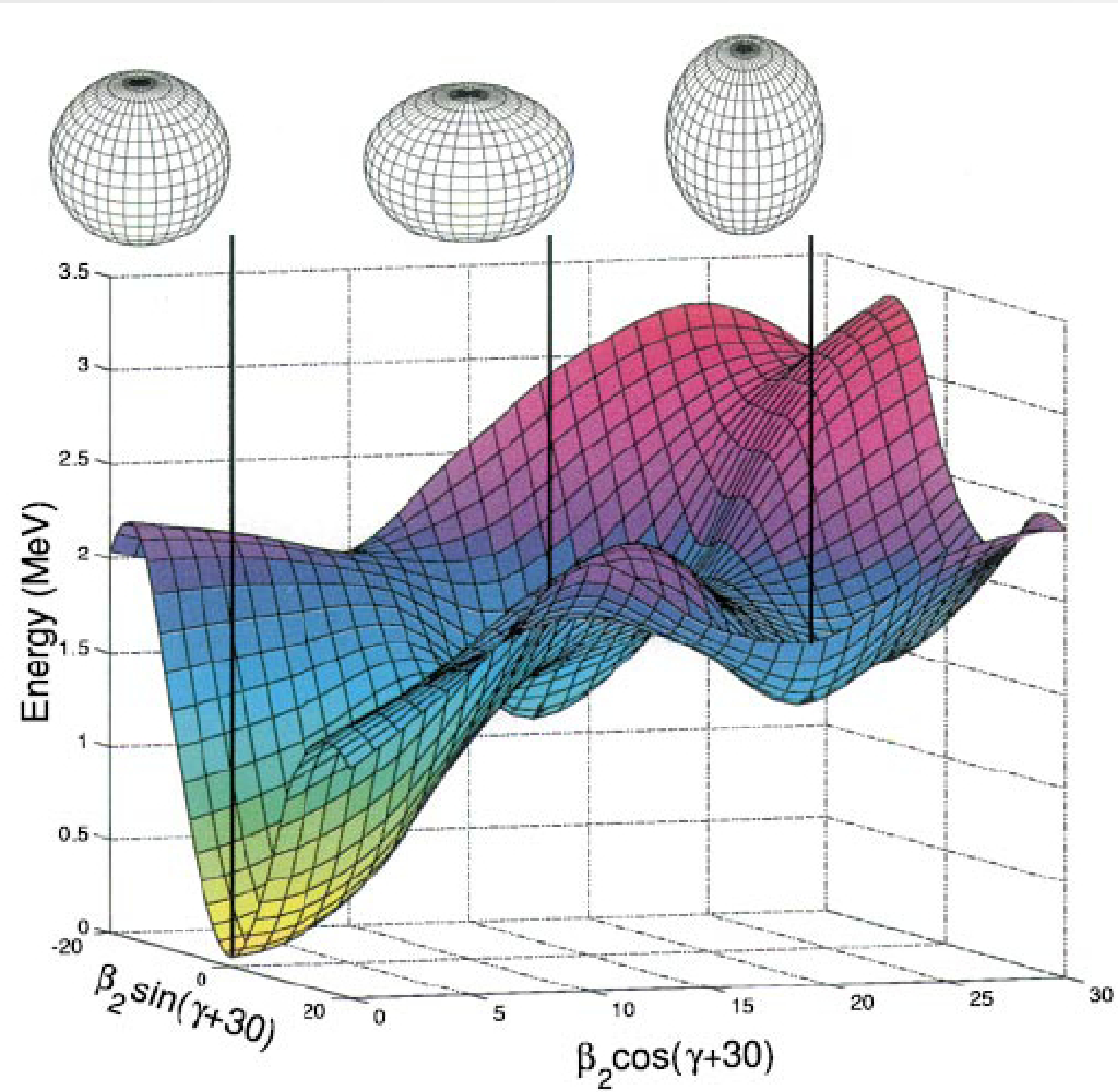
Comenius University, Bratislava

P. A. Butler, D. T. Joss and R. D. Page

University of Liverpool, UK

4 days of beamtime approved by the Research Board

Shape coexistence in atomic nuclei



- Existence of excited states with different deformation in the same nucleus
- Illustrative example: ^{186}Pb: Triplet of differently shaped 0^+ states was observed at low-energy (< 500 keV)
- Might occur in every atomic nucleus

WITHOUT UNDERSTANDING OF SHAPE COEXISTENCE WE DON'T UNDERSTAND ATOMIC NUCLEI AT ALL

Why to study Au isotopes?

Because gold is unique !

- 4 types of coexisting structures
- Shape coexistence occurs at very low energy
- Coexisting structures can be populated by ISOLDE beams
- CERN/ISOLDE is a unique facility for such measurements

Beyond IS521

- long-term program of precise γ-electron measurements
- detailed GEANT4 simulations

SASc-ISOLDE

Autumn Workshop on GEANT4

Casta-Papiernicka, Slovakia

9/10 – 12/10, 2011

- Aim of the workshop: Impart the knowledge on GEANT4 package
- In low-energy nuclear physics: Using of GEANT4 is relatively low in Europe
- Simulations are extremely powerful tool
- Common project: Slovak Academy of Sciences + CERN/ISOLDE

Confirmed lecturers:

E. Farnea (Padova)

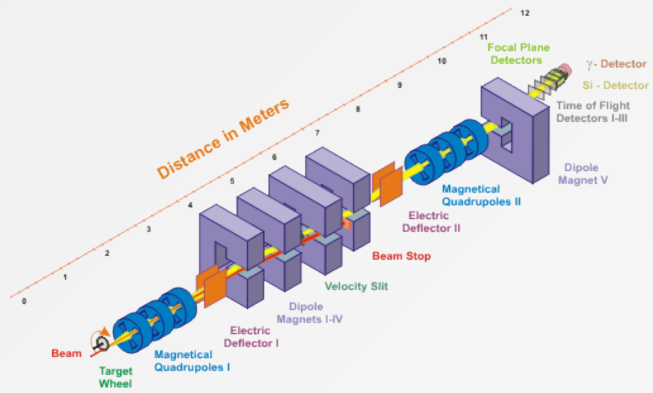
G. Soti (Leuven)

V. Ivantchenko (CERN/ESA)

M. Labiche (Daresbury)

http://awg.sav.sk

25/5/2011 – 10 registered participants

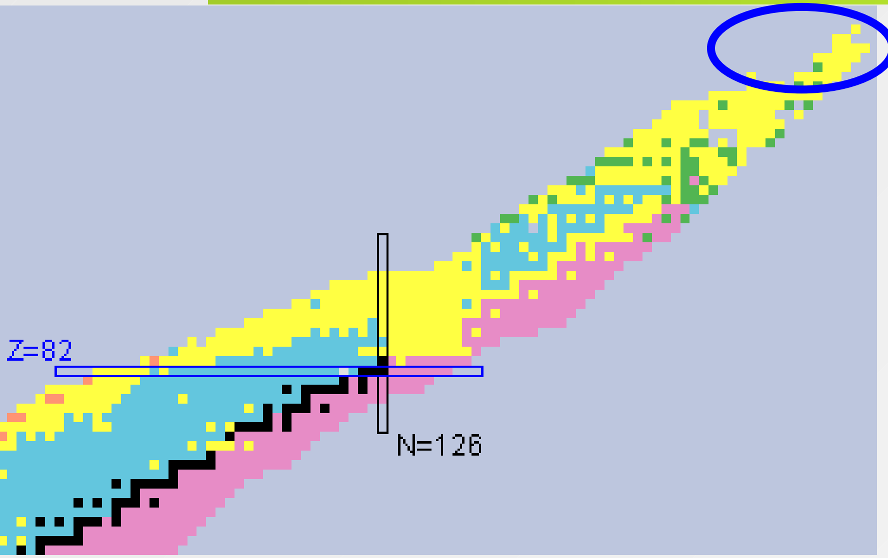


Nuclear structure research at SHIP in GSI Darmstadt

Stanislav Antalic
Štefan Šáro

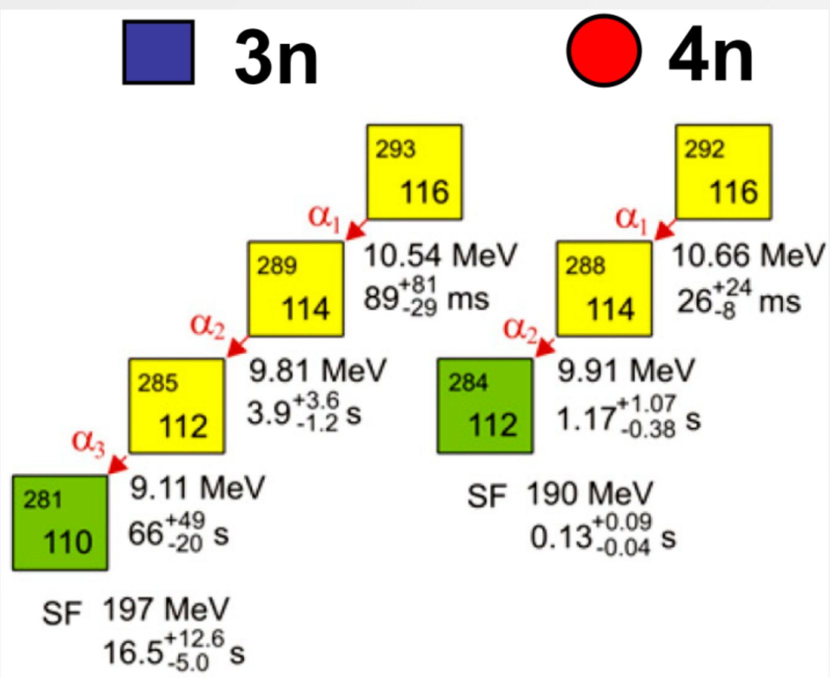
Comenius University Bratislava

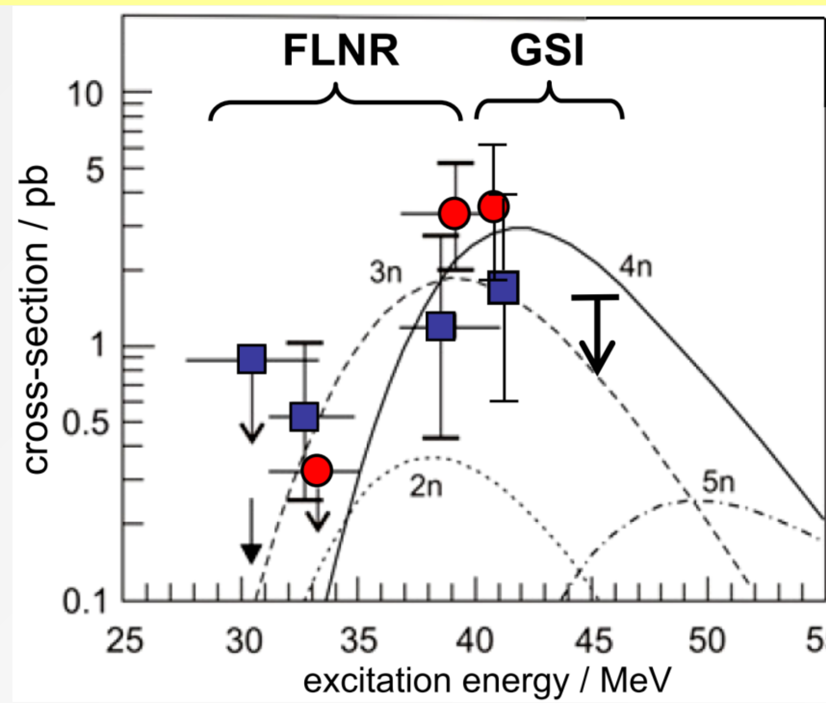
Studies of superheavy nuclei



2006 – succesful run with the reaction
$^{48}Ca+^{238}U \rightarrow ^{286}112^{*}$
S. Hofmann et al. EPJ A32, 251 (2007)

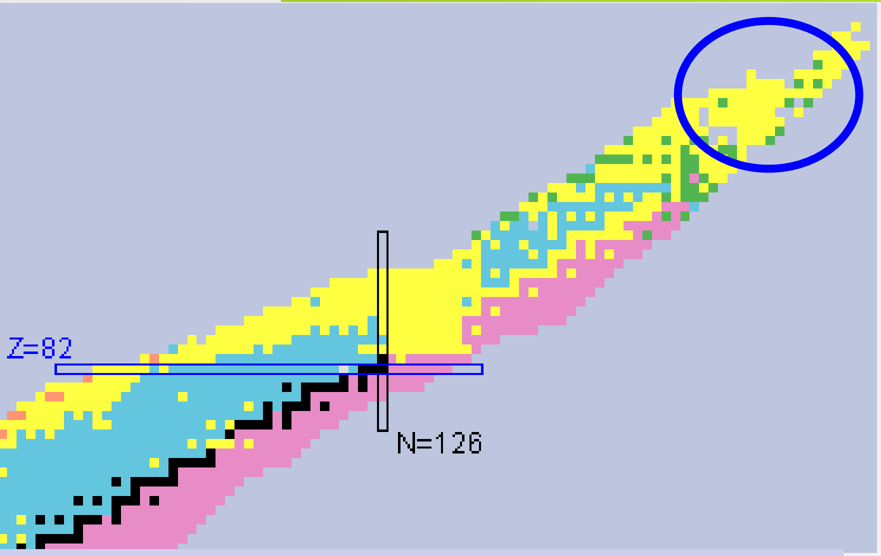
2010 – production of $^{293}116$ and $^{292}116$ in
$^{48}Ca+^{248}Cm \rightarrow ^{296}116^{*}$





Theory: V. Zagrebaev, W Greiner (2008)
Experiments: Yu. Ts. Oganessian et al. (2000,2001, 2004)
S. Hofmann et al. (2010)

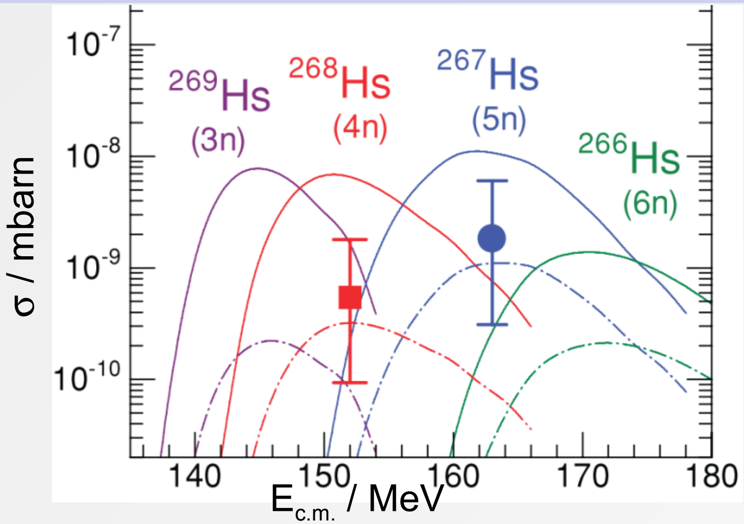
Reaction studies for heaviest nuclei



Search for new projectile-target combinations with high yield

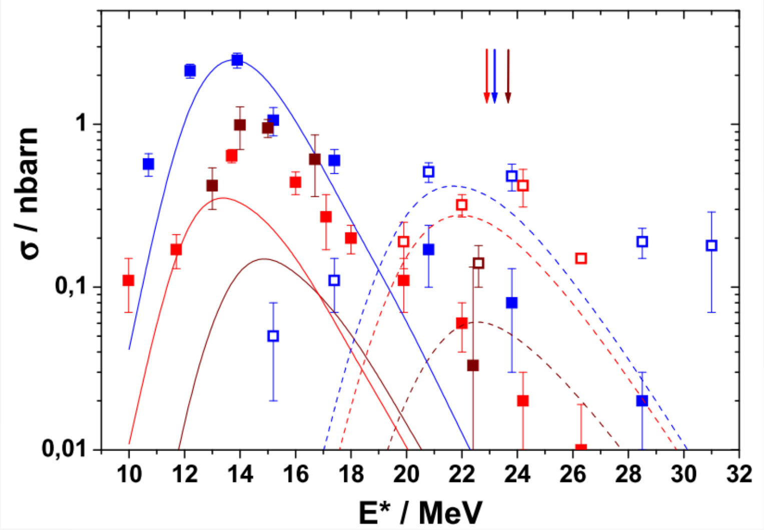
Attempt to produce more neutron rich nuclei using trans-uranium targets

Example: Reaction $^{34}S+^{238}U$ and production of ^{268}Hs



K. Nishio et al. PRC 82, 024611 (2010)

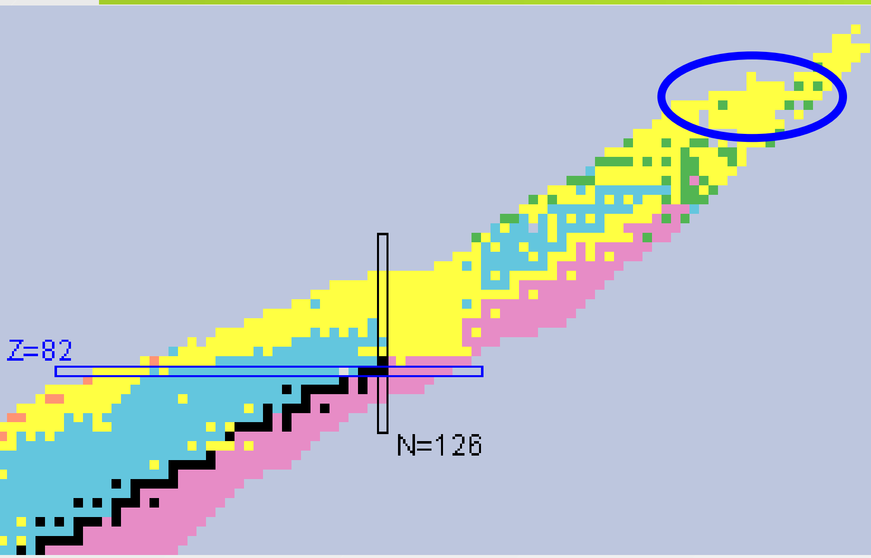
Example: cross-sections for $^{259,260,261}Sg$



Blue: $^{54}Cr+^{208}Pb$; Red: $^{54}Cr+^{207}Pb$; Wine $^{54}Cr+^{206}Pb$

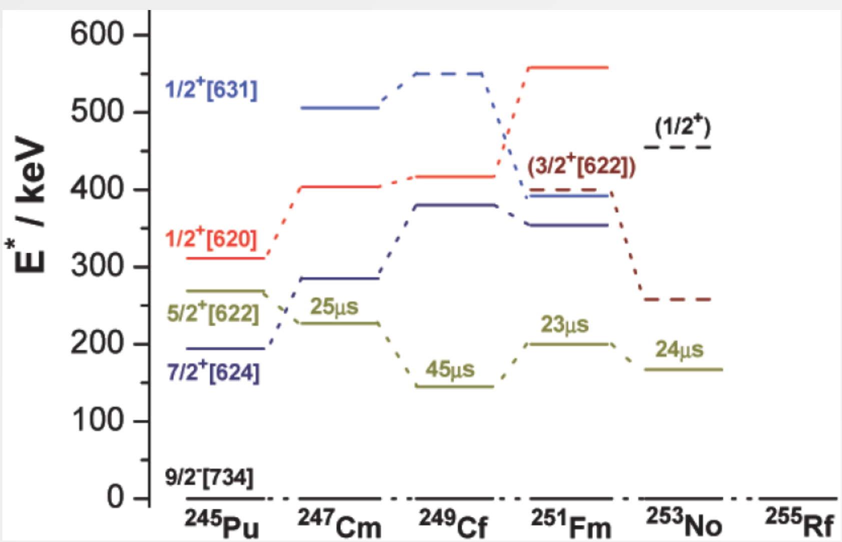
F.P.Hessberger et al. GSI Sc. Report 172 (2010)

Nuclear structure above fermium (Z>100)



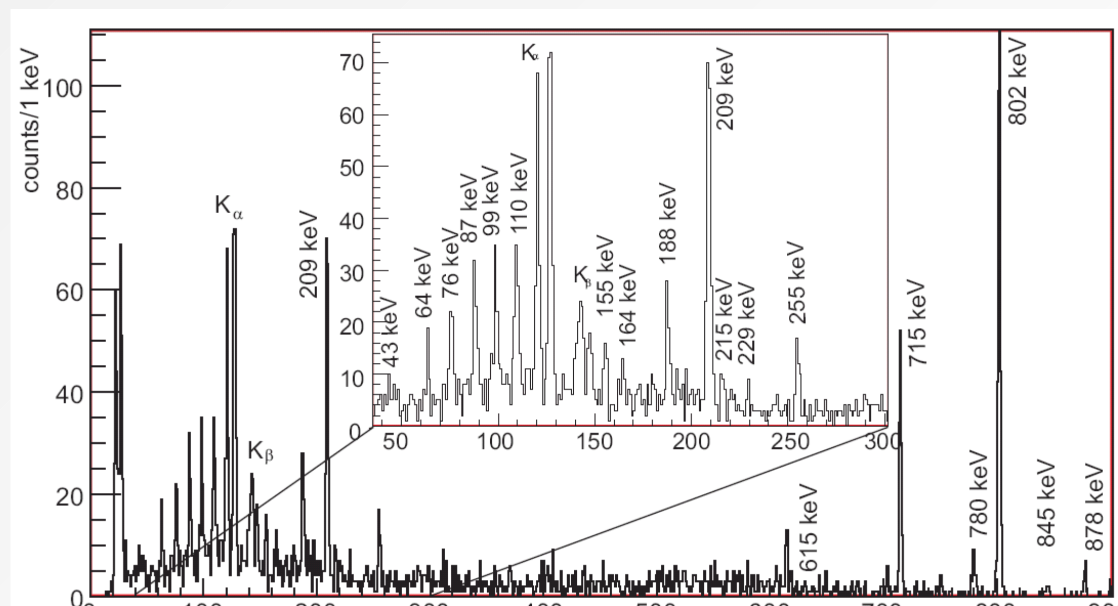
- Detailed decay spectroscopy of very heavy systems with more than 250 nucleons (^{254,255}Lr, $^{251-255}$No, ^{257}Rf, ^{261}Sg …)
- Pioneering gamma decay spectroscopy
- Single particle level systematic
- Nuclear isomers

Example: N=151 isotones



B. Streicher et al. EPJ A45, 275 (2010)

Example: *K* isomer in ^{253}No



S. Antalic et al. accepted for EPJ A (2011)

Bratislava group on Fragment Separator FRS and developments for Super FRS

FMFI (group of Prof. Sitar)
Comenius University Bratislava

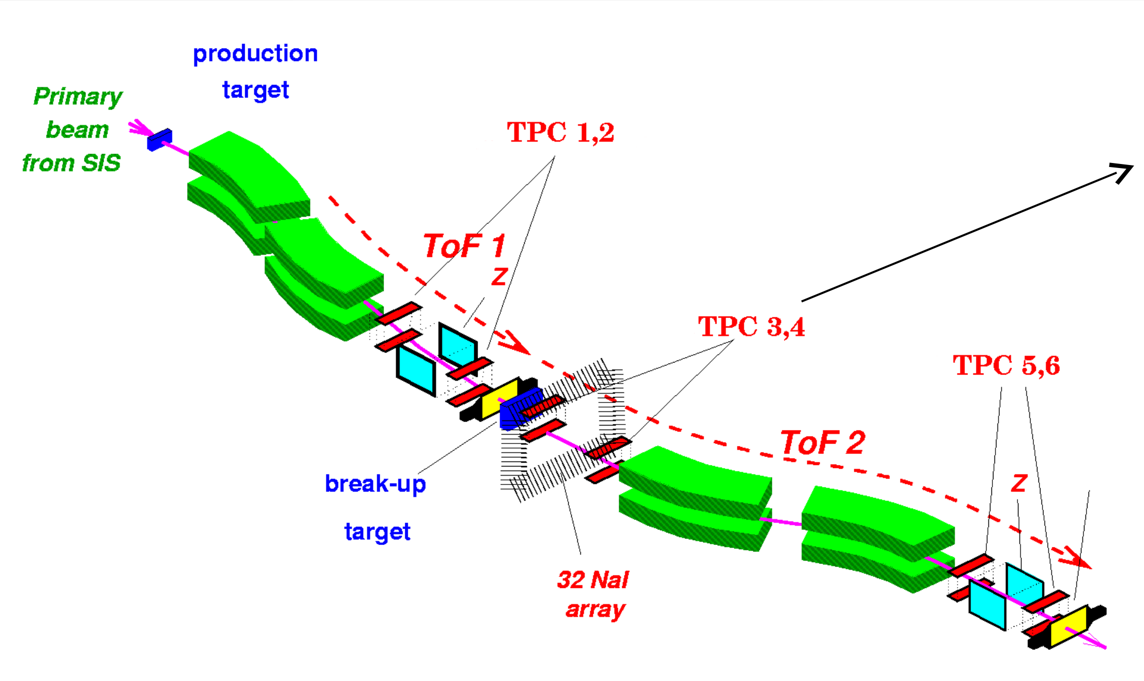
Cooperation with GSI Darmstadt from 1994

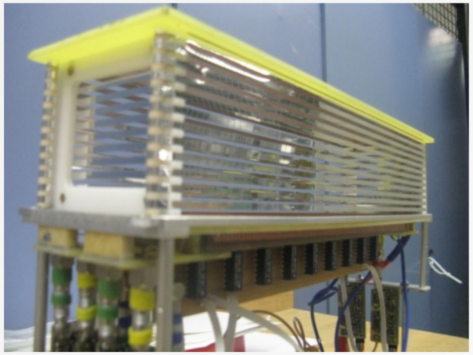
5 physicists and engineers + PhD students

- Hardware contribution: tracking detectors

Participation on many experiments on FRS

Schematic view of the Fragment separator
with TPC detectors developed by Bratislava group

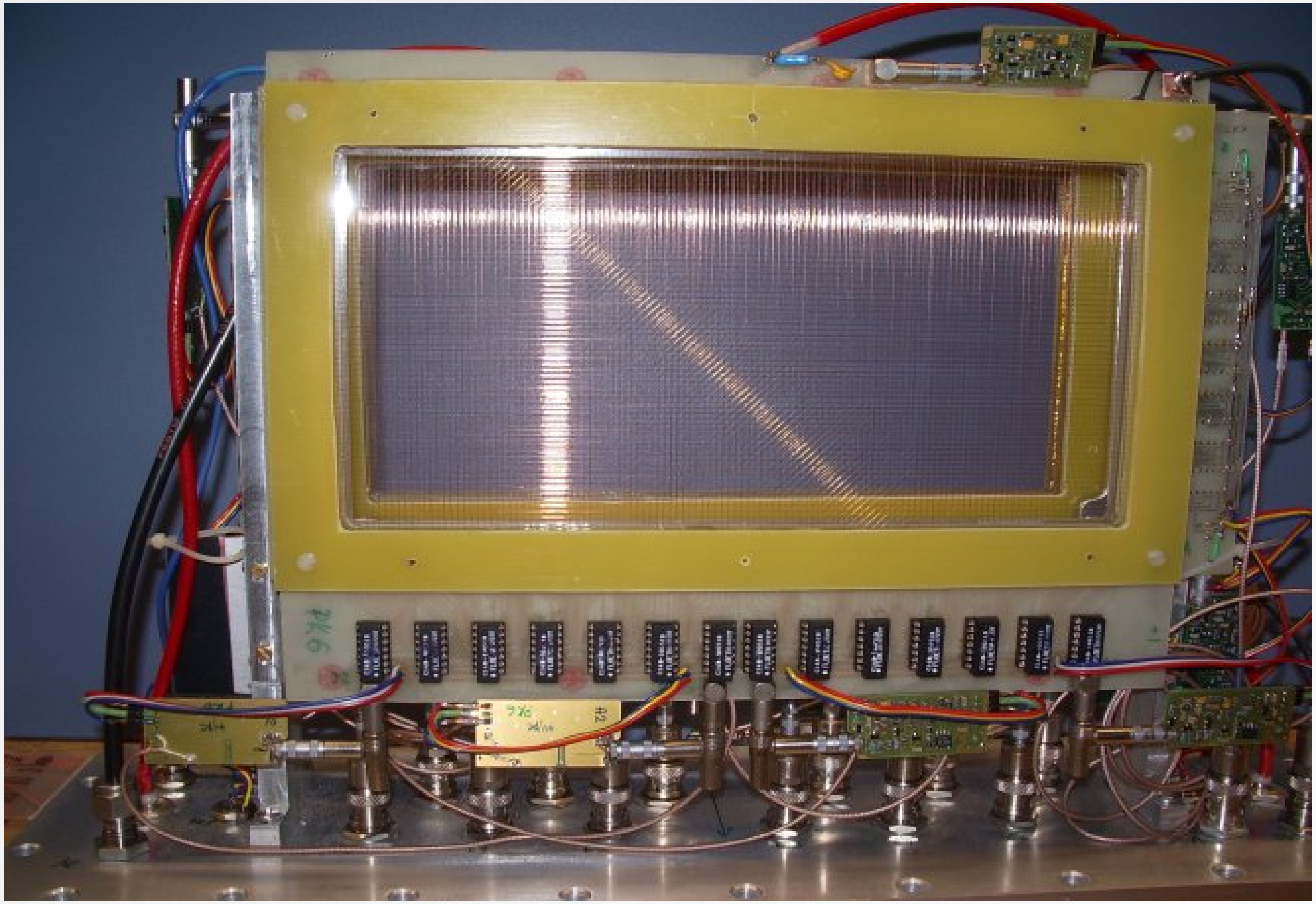




View of the TPC developed in Bratislava used on FRS

Tracking on FRS is fully covered by detectors produced at Bratislava

Beam Profile Monitor for FRS produced by Bratislava group



Most important physics results achieved at FRS

- Interesting results on the proton and **neutron halo structure of exotic nuclei** were achieved at the Fragment separator GSI Darmstadt
- Systematic study of nuclear radii and production cross sections for Be, B, C, N, O and F isotopes from proton to neutron drip lines was performed.
- Nuclear radii of ^{17,19}B and ^{14}Be has been measured. A nuclear structure "core + 2 neutrons" fits the best the data for ^{17}B and ^{14}Be nuclei
- Clear evidence of a **proton halo structure** of ^{8}B nucleus has been found, in experiments with ^{8,10}B production.
- Study of longitudinal momentum distribution of ^{16,18}C fragments after one neutron removal from ^{17,19}C shows that the ^{19}C ground state is a less developed one neutron halo state
- Investigation of **new isotopes** produced with a high-intensity Uranium beam has been performed.
- New **closed nuclear shells with 16 neutrons**, instead of usual 20 neutrons were found in the region close to the neutron drip line
- Spherical symmetry has been discovered in the double magic nucleus ^{24}O

Institute of Physics activities @GSI

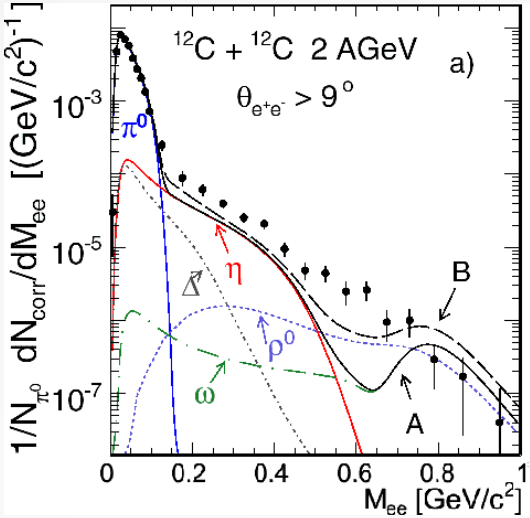
High Acceptance Di-Electron Spectrometer HADES

HADES

IoP SAS was grounding member of the collaboration

Contribution to the HADES Time-of-flight spectrometer

After four years of absence we are in process of becoming again the member of collaboration => contribution to electromagnetic calorimeter



HADES limitation was low count rate capability → only experiments with light system (like $^{12}C + ^{12}C$) possible

After electronics upgrade in 2010 $^{197}Au + ^{197}Au$ prepared

FAIR facility

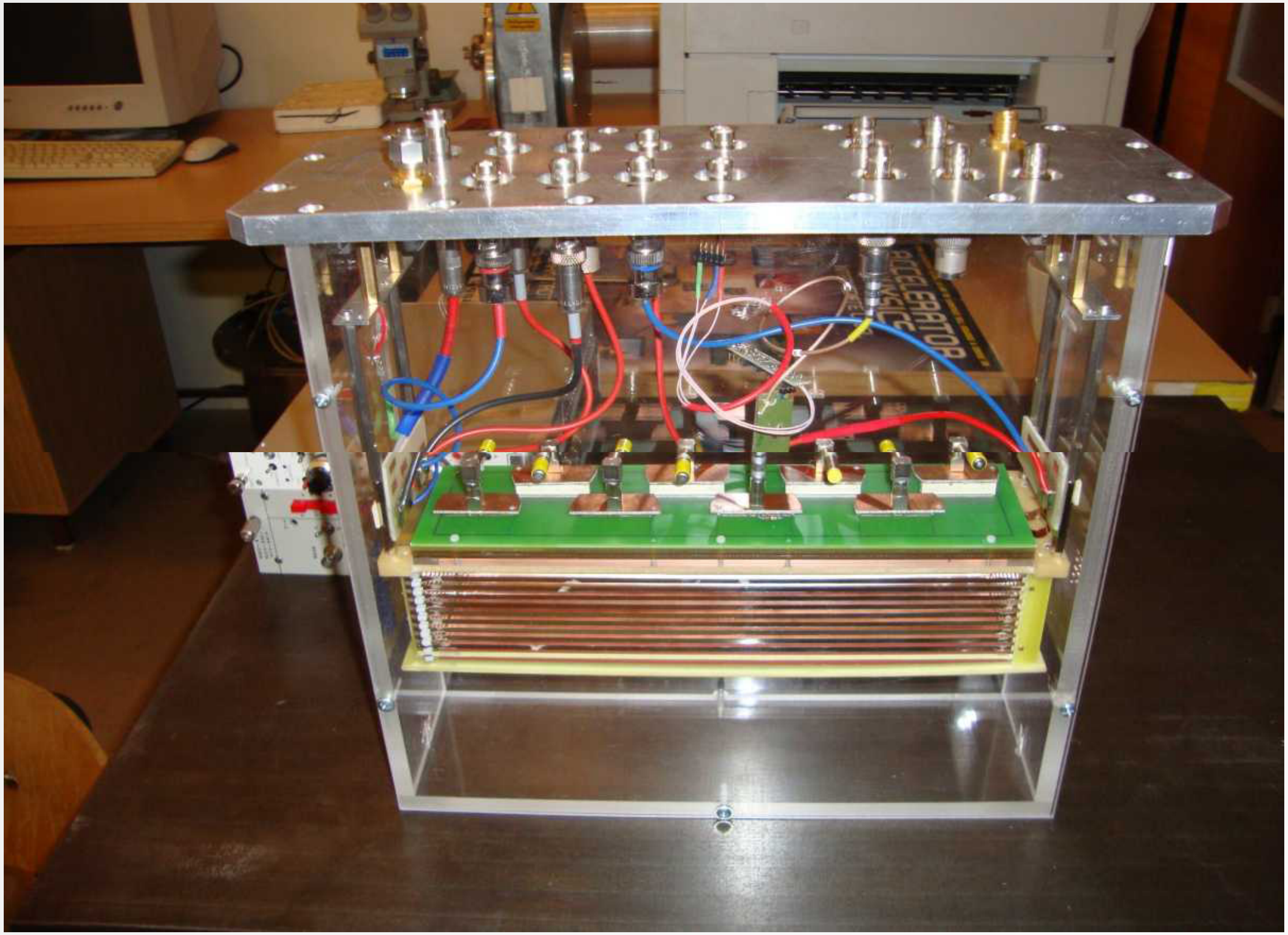
Slovakia signed Memorandum of Understanding but postponed membership

General discussion on membership in ESFRI facilities started again in Slovakia in 2011. Intended membership in FAIR GmbH – 2012

Drawback -> membership in JINR , CERN, X-FEL, argumentation that nuclear physics is favorized in Slovakia

Our argument -> XFEL, FAIR facilities are multidisciplinary

Bratislava group of Prof. Sitar was encharged by NUSTAR collaboration to develop tracking for Super FRS on FAIR



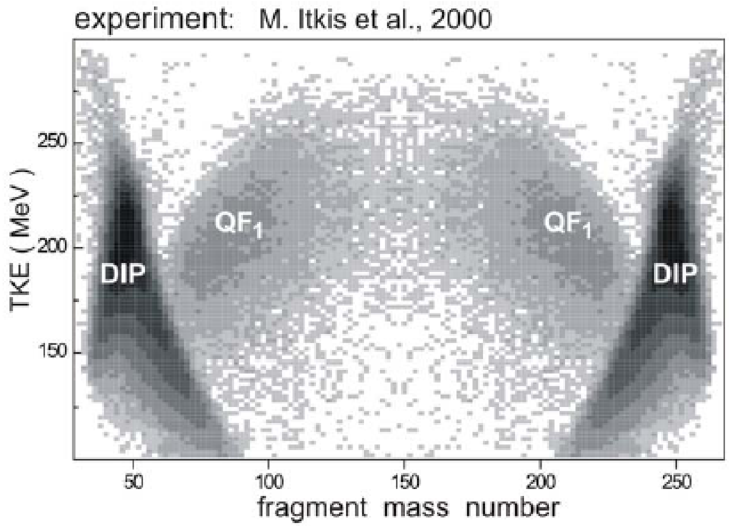
GEM TPC prototype prepared for tests

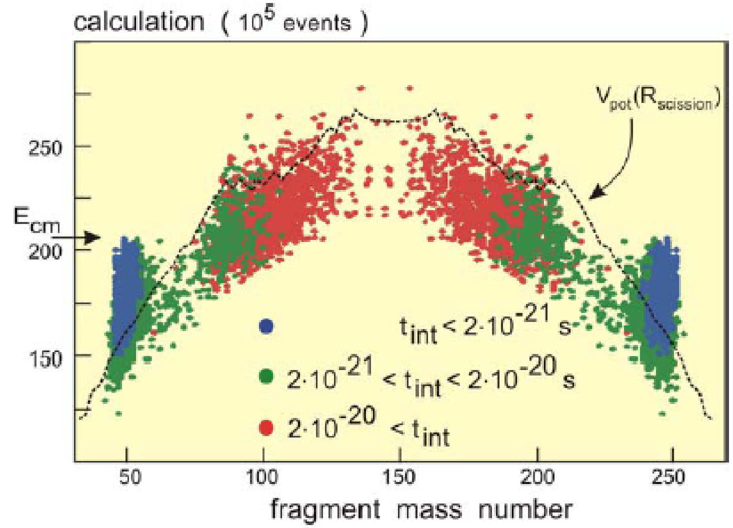
SHE studies at LNR JINR Dubna

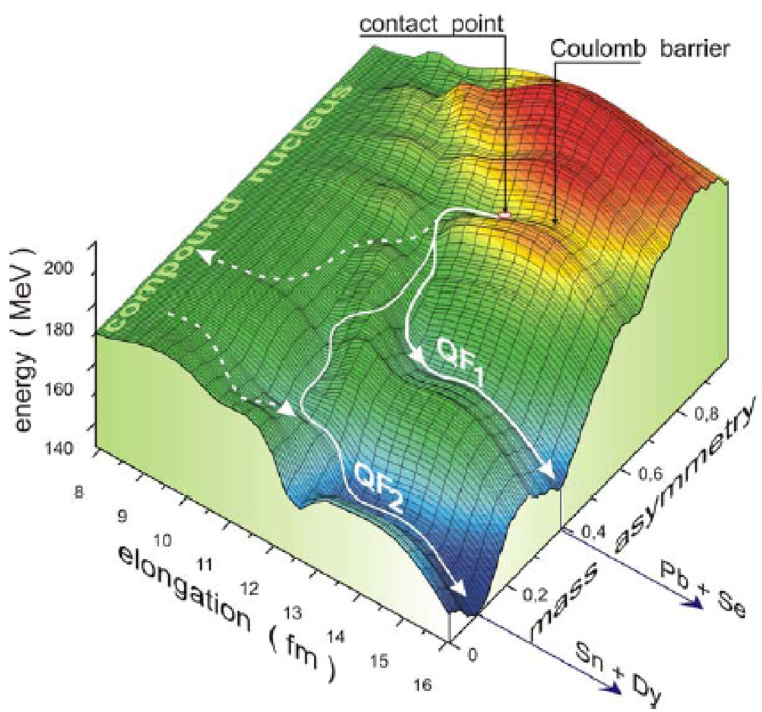
J. Kliman, L. Krupa
Department of Nuclear Physics

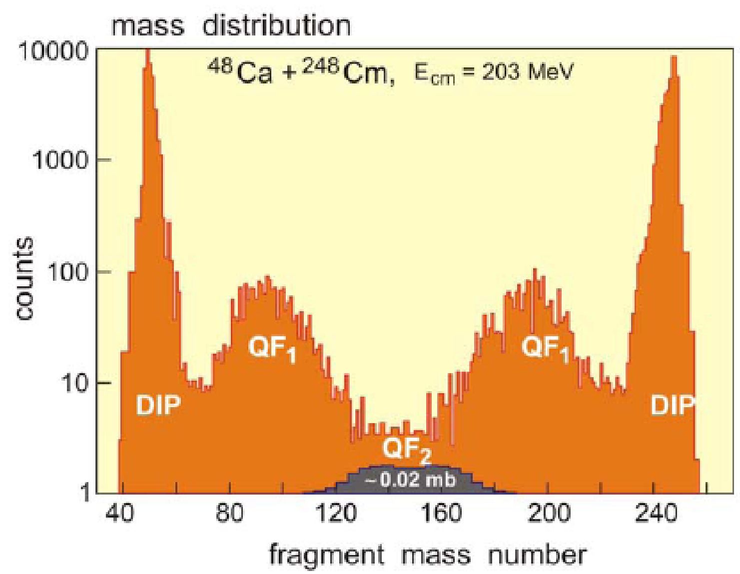
Institute of Physics, Slovak Academy of Sciences, Bratislava

Quasi-Fission process: e.g. $^{48}Ca + ^{248}Cm$

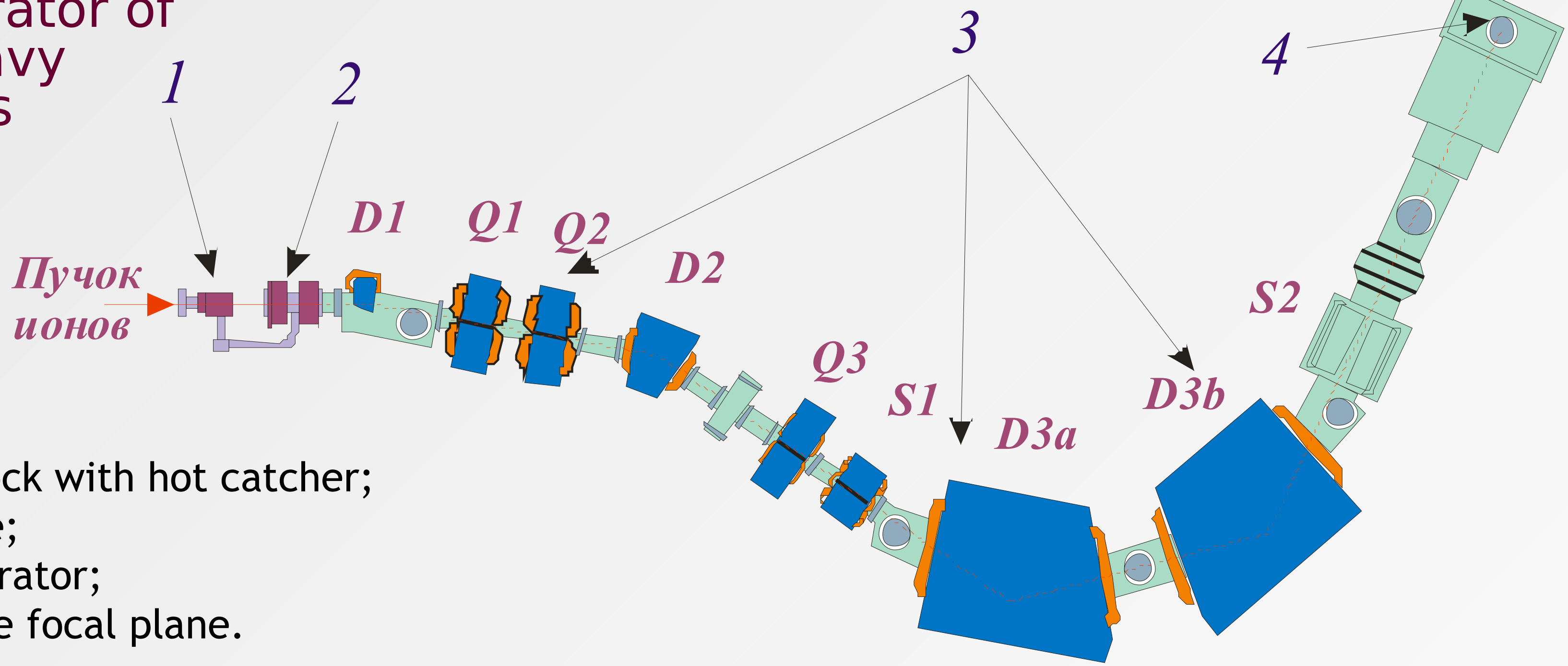








MAss **S**eparator of **H**eavy **A**toms



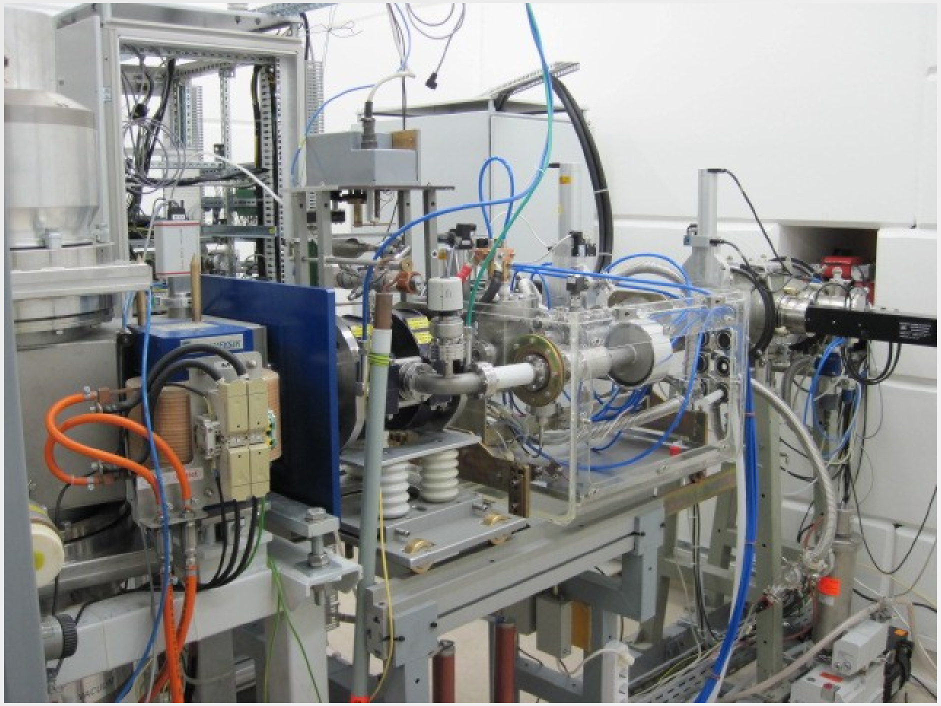
1 – Target block with hot catcher;
2 – Ion source;
3 – Mass separator;
4 – DAQ in the focal plane.

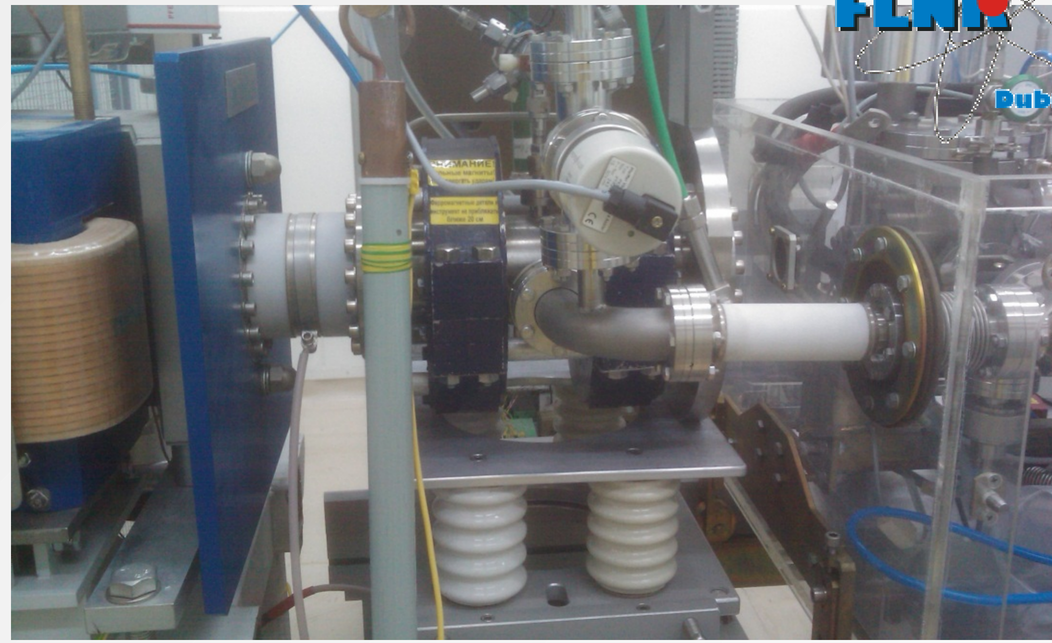
General ion-optical parameters:

Range of energy variation, kV	15-40
Range of *Br* variation, Tm	0.08-0.5
Mass acceptance, %	+/-2.8
Angular acceptance, mrad	+/-14
Diameter the ion source exit hole, mm	5.0
Horizontal magnification at F1/F2	0.39/0.68
Mass dispersion at F1/F2, mm/%	1.5/39.0
Linear mass resolution at F1	75
Mass resolution at F2	1300

Device of choice for SHE production in the foreseeable future !

JINR FLNR Dubna



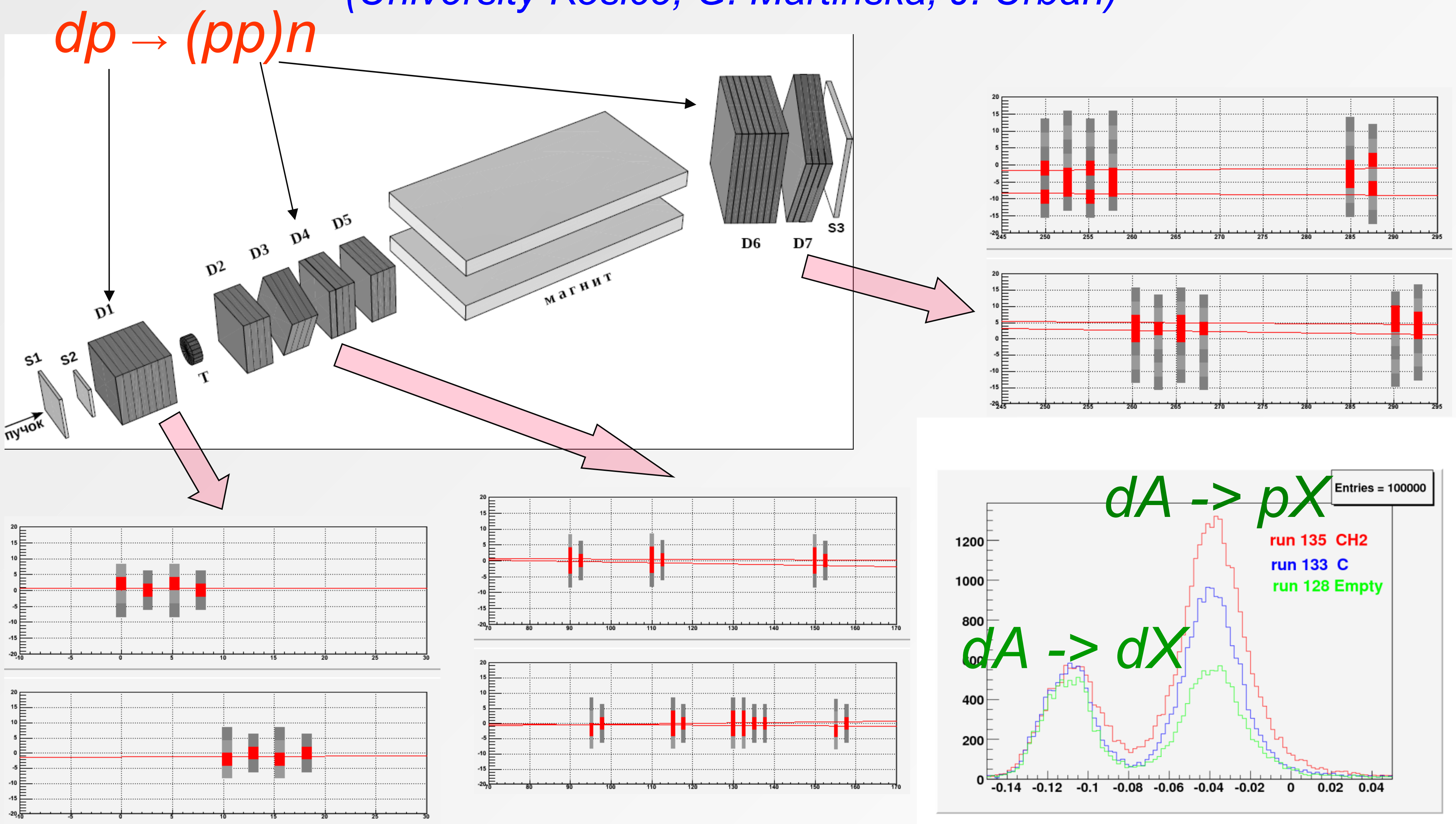


Charge - exchange processes in the deuteron - proton collisions

STRELA setup

JINR – Slovakia *collaboration*

(University Košice, G. Martinska, J. Urban)

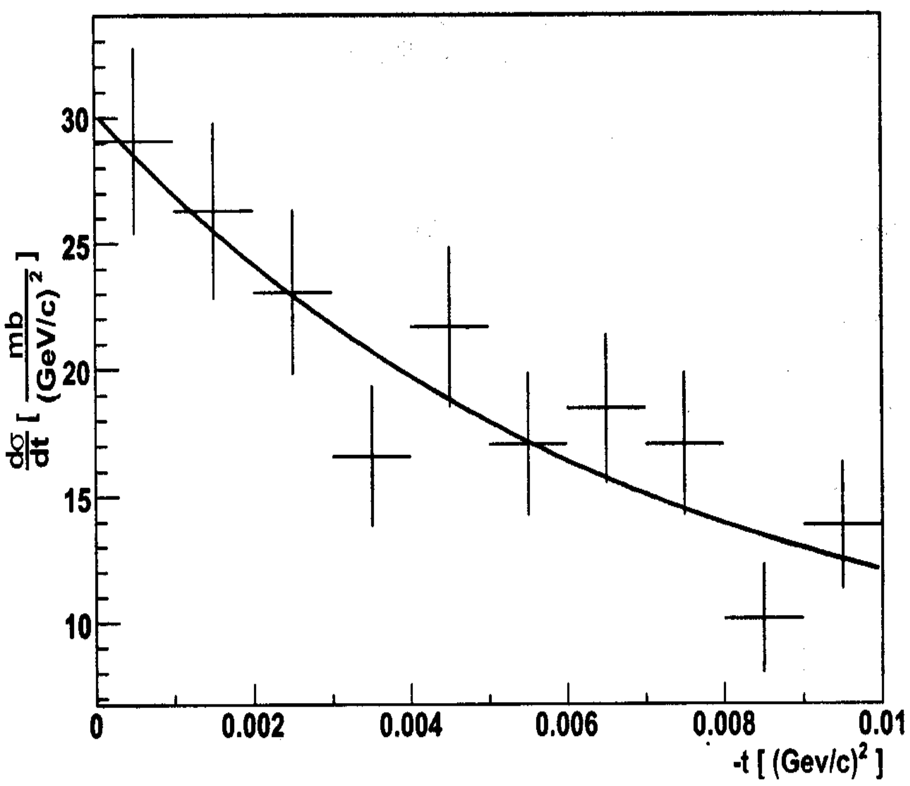


The dp→(pp)n Charge Exchange Channel Experimental results

Extrapolation of the dp→(pp)n differential cross section to t=0 :

$d\sigma/dt(t=0) = 30.2 \pm 4.1\ mb/(GeV/c)^2$

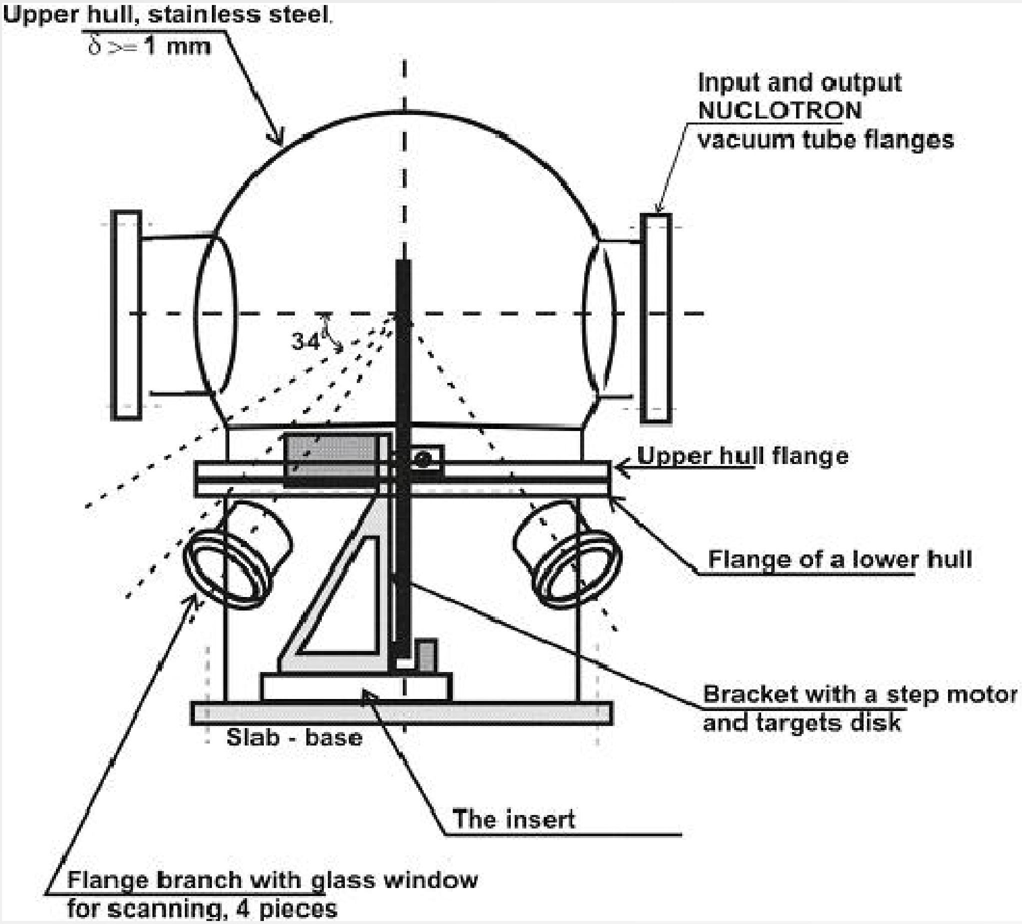
To be compared with the spin-flip part of np→pn (the CE break-up reaction of the unpolarized deuteron on the unpolarized proton-target in the forward direction is determined by the spin-flip part of the np→pn CE process at 0 scattering angles. Deuteron acts as a spin filter !)



The dp→(pp)n Charge Exchange Channel

- The obtained ratio of the charge exchange differential cross sections at t=0 for ***d p →(p p) n*** and ***np → pn*** reactions **R = 0.55 ± 0.08** testifies the prevailing contribution of the spin-dependent part to the ***np → pn*** cross section scattering
- Continuation of researches at higher energies on ***STRELA*** set up is in progress

Internal Target Station at Nuclotron



Veksler and Baldin Laboratory of High Energy Physics, JINR, Dubna:

S. V. Afanasiev,

Yu. S. Anisimov,

A. I. Malakhov,

V. A. Krasnov

Institute of Physics, SAS, Bratislava,

Š. Gmuca,

J. Kliman,

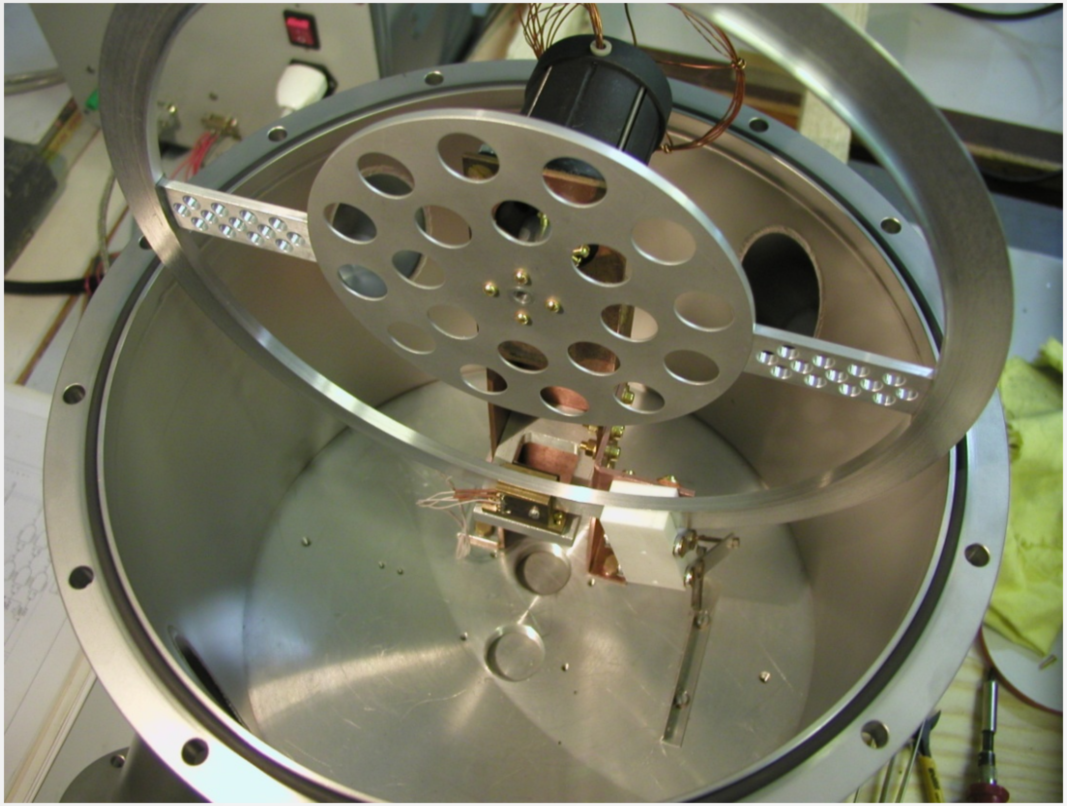
V. Matoušek,

M. Morháč,

I. Turzo

Internal Target Station at Nuclotron

- **Automation of experiments in nuclear physics:**
  - Control of autonomous experimental device (Internal target station at the main beam of Nuclotron accelerator at JINR, Dubna)
  - The Internal Target Station is well suited for the study reactions of the d − p interaction at large angles in the center of mass system.



Target holder for 6 targets

DELTA Laser calibration system

The construction of the DELTA laser calibration and stabilization system.

Summary

- wide range of activities related to collaboration with international nuclear physics centers
- preservation and further expansion of international collaboration is crucial for the future of low energy nuclear physics in Slovakia