Beta-delayed neutron emission from photo-fission fragments produced at ALTO: outlook of the experimental program at TETRA

Yuri Penionzhkevich

Fadi Ibrahim

David Verney

Sergey Lukyanov

Matthieu Lebois

Nikolay Arsenyev

Alexey Severyukhin

Brigitte Roussière

Vladimir Smirnov

JINR DUBNA

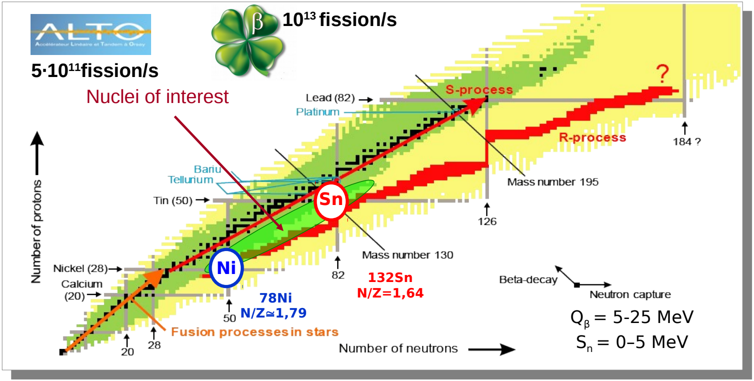
IJCLab Irène Joliot-Curie

GANIL laboratoire commun CEA/DRF CNRS/IN2P3

presenter: Dmitry Testov

Beta decay of neutron rich nuclei

- Shorter-lived nuclei
- β-delayed neutron-emission is becoming the dominant process
- β-delayed multi neutron-emission



Reactor control and decay heat calculations

r — process calculations

Nuclear Structure

History

Nuclear Physics A 701 (2002) 87c–95c

RIB production with photofission of uranium

Yu.Ts. Oganessian *, S.N. Dmitriev, J. Kliman, O.A. Maslov, G.Ya. Starodub, A.G. Belov, S.P. Tretiakova

Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, 141980 Dubna, Moscow region, Russia

History

Nuclear Physics A 701 (2002) 87c–95c

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Yu.Ts. Oganessian et al. / Nuclear Physics A 701 (2002) 87c–95c 93c

ALTO accelerator complex
(ex-IPN Orsay)
50 MeV 10μA

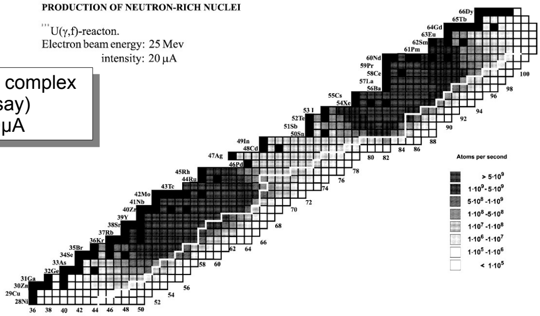
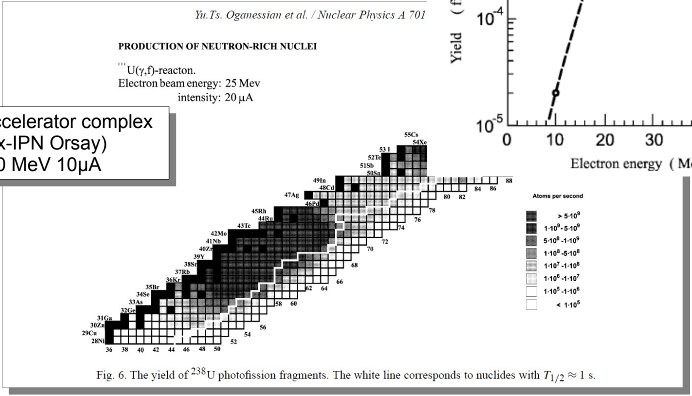


Fig. 6. The yield of ^{238}U photofission fragments. The white line corresponds to nuclides with $T_{1/2} \approx 1$ s.

History



Nuclear Physics A 701 (2002) 8

RIB production with photofi

Yu.Ts. Oganessian *, S.N. Dmitriev, J.
G.Ya. Starodub, A.G. Belov, S

Yu.Ts. Oganessian et al. / Nuclear Physics A 701

PRODUCTION OF NEUTRON-RICH NUCLEI

U(γ,f)-reacton.
Electron beam energy: 25 Mev
intensity: 20 μA

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ALTO accelerator complex
(ex-IPN Orsay)
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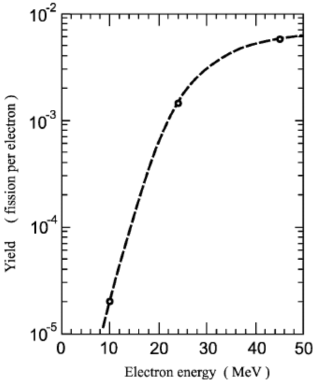

History

Nuclear Physics A 701 (2002) 87c–95c

RIB production with photofission of uranium

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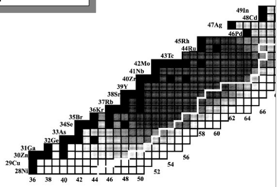


Fig. 6. The yield of ^{238}U photofission fragments. The

Ancestor of TETRA
modular detection system
(JINR Dubna)

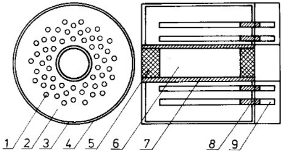
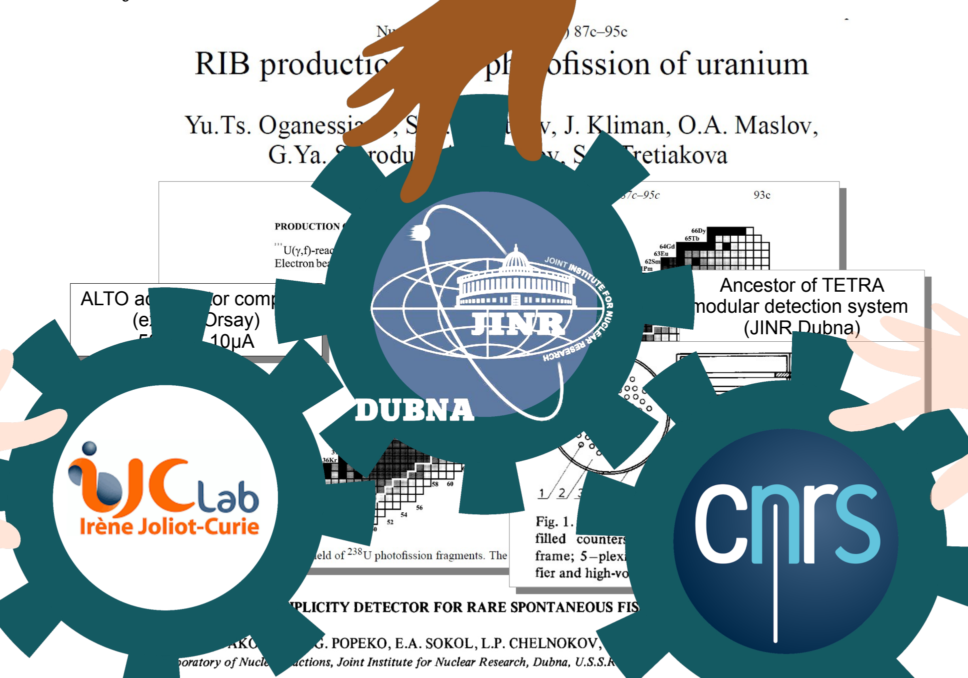


Fig. 1. Diagram of the neutron multiplicity detector: 1 – ^{3}He-filled counters; 2, 7, 8 – plexiglass; 3 – cadmium; 4 – steel frame; 5 – plexiglass taps; 6 – cavity for sample; 9 – preamplifier and high-voltage circuit.

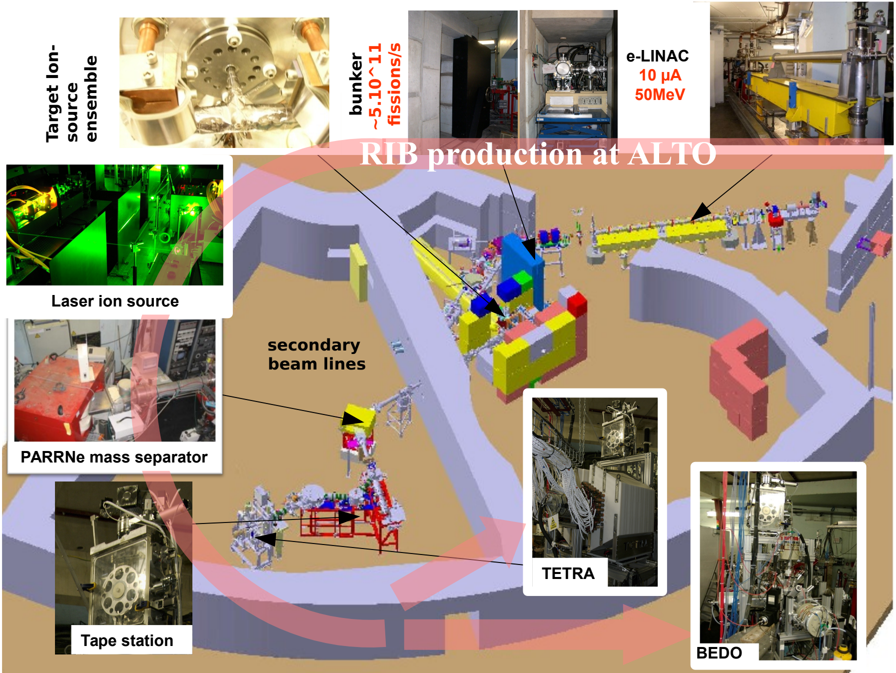
A NEUTRON MULTIPLICITY DETECTOR FOR RARE SPONTANEOUS FISSION EVENTS

G.M. TER-AKOPIAN, A.G. POPEKO, E.A. SOKOL, L.P. CHELNOKOV, V.I. SMIRNOV and V.A. GORSHKOV
Laboratory of Nuclear reactions, Joint Institute for Nuclear Research, Dubna, U.S.S.R.

History


87c–95c
Yu.Ts. Oganessi
J. Kliman, O.A. Maslov,
Tretiakova
93c
Ancestor of TETRA
modular detection system
(JINR Dubna)
10µA
JINR
JOINT INSTITUTE FOR NUCLEAR RESEARCH
DUBNA
IJCLab
Irène Joliot-Curie
cnrs
Fig. 1.
G. POPEKO, E.A. SOKOL, L.P. CHELNOKOV,
Joint Institute for Nuclear Research, Dubna, U.S.S.R

Beta-decay experimental setup at ALTO



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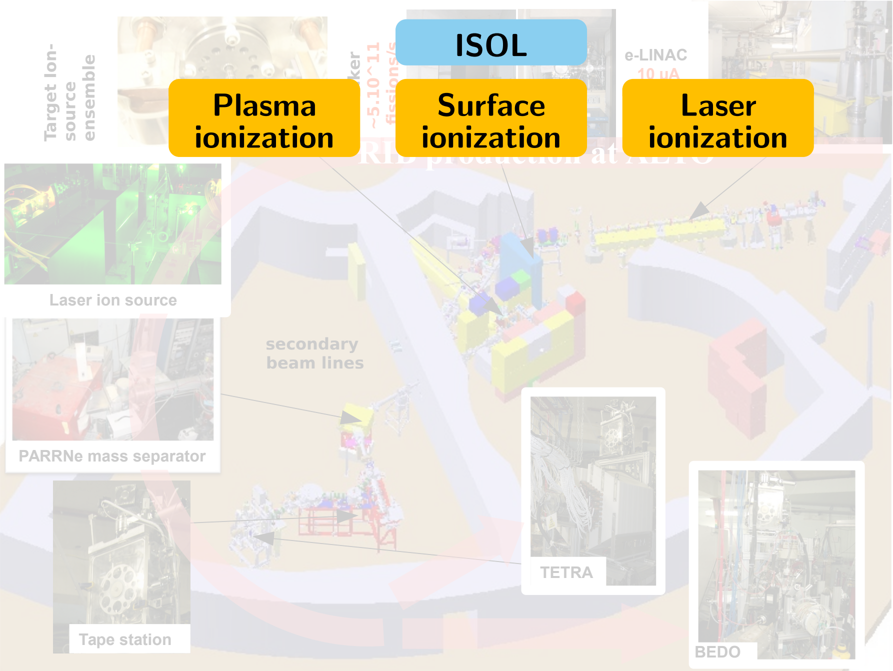

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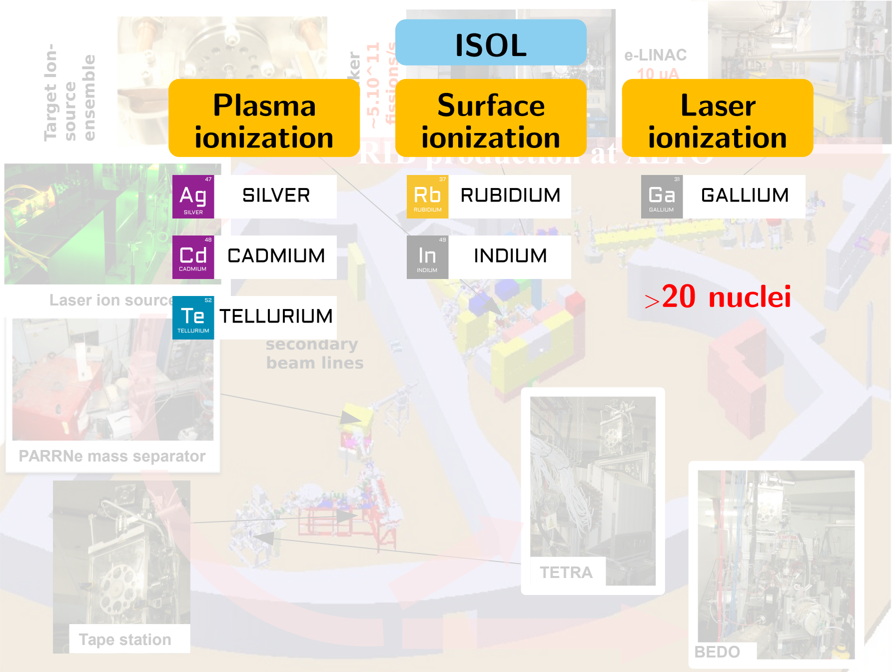

ISOL

Plasma ionization	Surface ionization	Laser ionization
Ag (47) SILVER	Rb (37) RUBIDIUM	Ga (31) GALLIUM
Cd (48) CADMIUM	In (49) INDIUM	
Te (52) TELLURIUM		

>20 nuclei

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1. Measurements of $\mathbf{P}_{1n,2n,\ldots}$, $\mathbf{T}_{1/2}$ with high precision
2. neutron-tagged γ-ray (decay) spectroscopy ;
3. Absolute branching ratio in β-decay of neutron rich nuclei

Beta-decay experimental setup at ALTO

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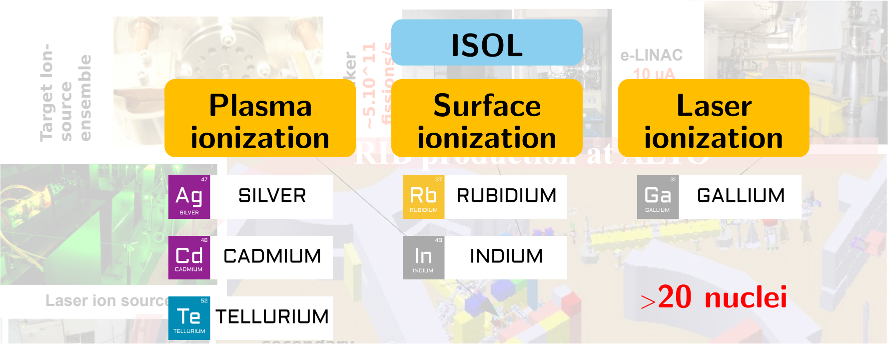
D. Testov, A. Severyukhin et al., Eur. Phys. J. A 57:59 (2021)
D. Verney, D. Testov et al., Phys. Rev. C 95 054320 (2017)
A. Severyukhin, N. Arsenyev, I. Borzov, E. Sushenok, Phys. Rev C 95, 034314 (2017)
D. Testov, D. Verney, Yu. Penionzhkevich et al., JINST 14 P08002 (2019)
D. Testov, D. Verney, B. Roussiere et al., Nucl. Inst.&Meth. A 815 96 (2016)
D. Testov, E. Kuznetsova, J.N. Wilson JINST 10 P09011 (2015)

Beta-decay experimental setup at ALTO



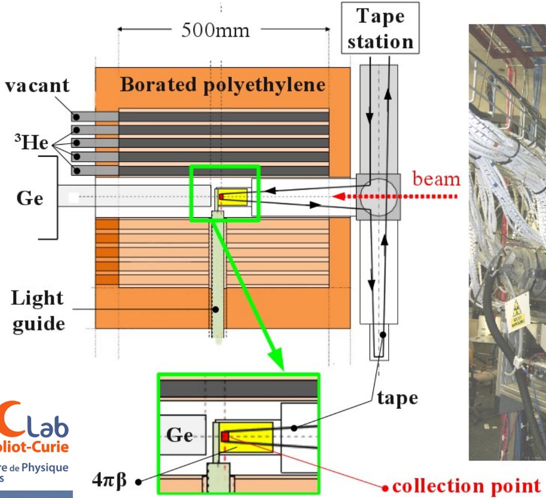
Accepted proposals at ALTO:

Study of beta-decay properties of neutron-rich Ag isotopes at the r-process path (D. Testov)

Meson-exchange enhancement of first-forbidden beta transitions in neutron-rich Sn nuclei near closed shell (F. Didierjean)

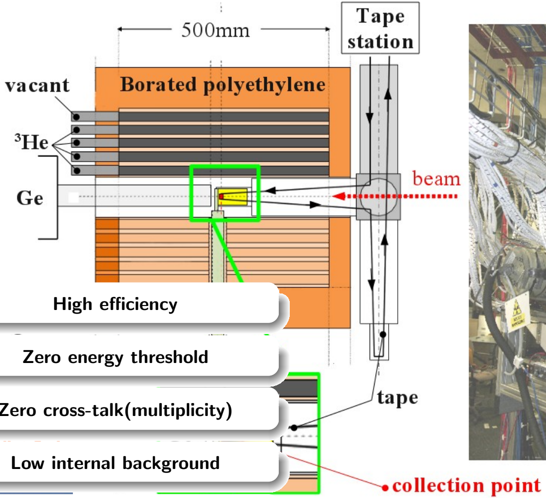
D. Testov, A. Severyukhin et al., Eur. Phys. J. A 57:59 (2021)
D. Verney, D. Testov et al., Phys. Rev. C 95 054320 (2017)
A. Severyukhin, N. Arsenyev, I. Borzov, E. Sushenok, Phys. Rev C 95, 034314 (2017)
D. Testov, D. Verney, Yu. Penionzhkevich et al., JINST 14 P08002 (2019)
D. Testov, D. Verney, B. Roussiere et al., Nucl. Inst.&Meth. A 815 96 (2016)
D. Testov, E. Kuznetsova, J.N. Wilson JINST 10 P09011 (2015)

TETRA at ALTO



$\epsilon_n \sim 52\%$ (^{252}Cf)
$\epsilon_\gamma \sim 1\%$ (1.3 MeV)
$\epsilon_\beta \sim 60\%$

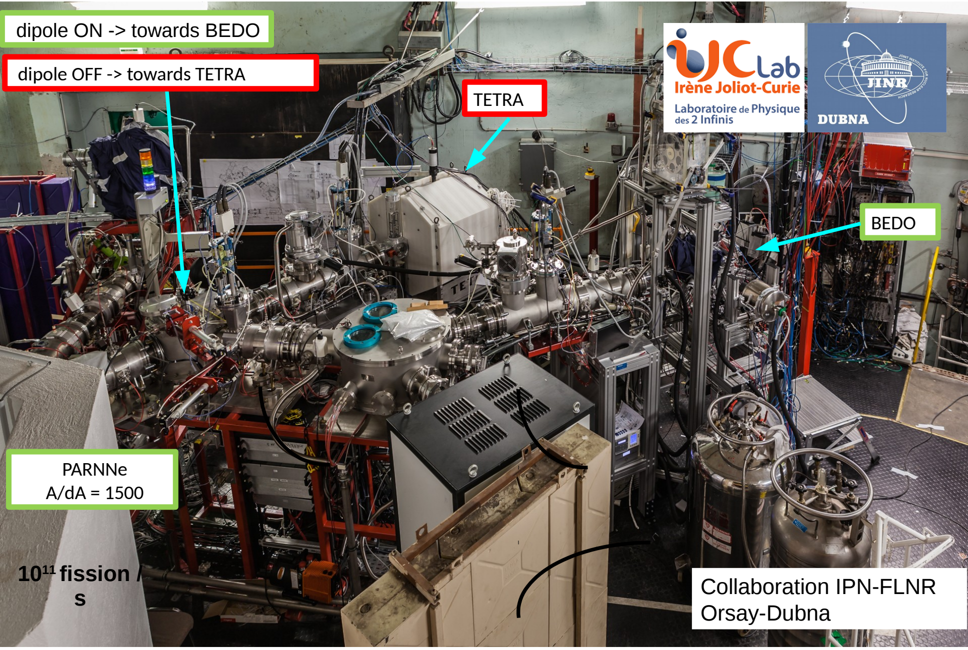
TETRA at ALTO



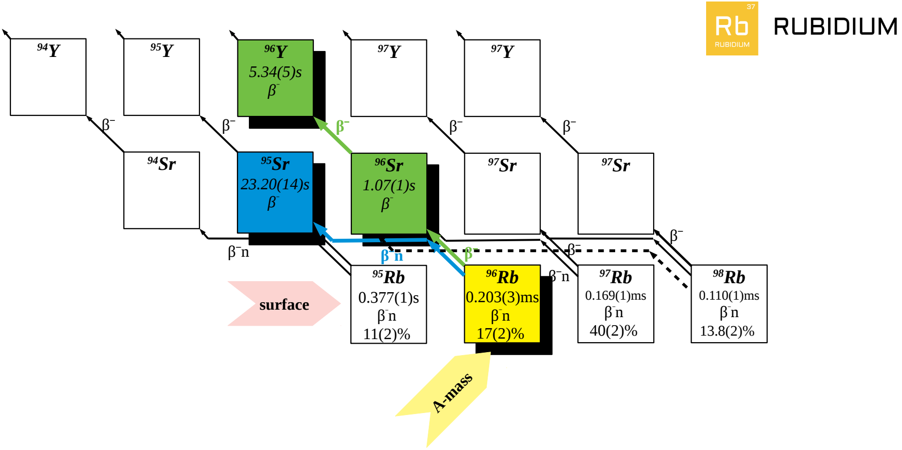
- High efficiency
- Zero energy threshold
- Zero cross-talk(multiplicity)
- Low internal background
- Perfect gamma separation
- Easy in use/ geometry

$\epsilon_n \sim 52\%$ (^{252}Cf)
$\epsilon_\gamma \sim 1\%$ (1.3 MeV)
$\epsilon_\beta \sim 60\%$

TETRA and BEDO in sequential mode



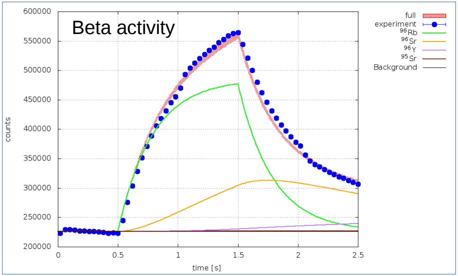
Validation of TETRA: ^{96,97}Rb

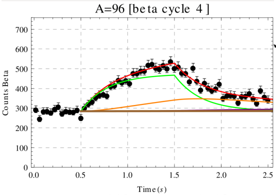


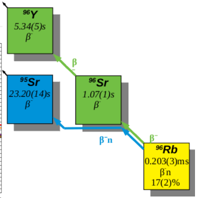
Surface ionization

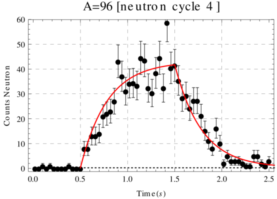
Cycle-by-cycle proccessing for ^{96}Rb

Systematic Errors









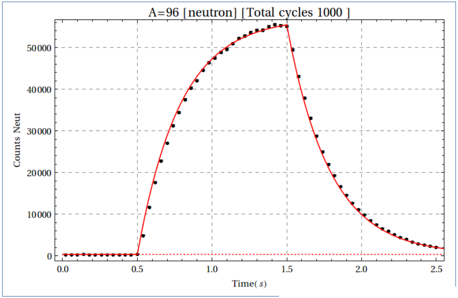
$P_{n1} = 12(1.1)\%$

$\Phi = 3.4(2) \times 10^4/s$

Solutions of Bateman Equations for the statistic from the *cycle 4*

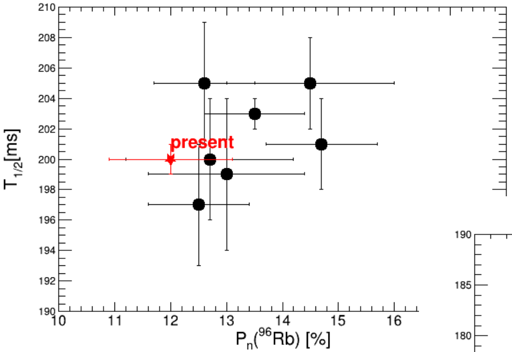
$P_{n1} \sim 16.3\%$ $\Phi \sim 11900/s$

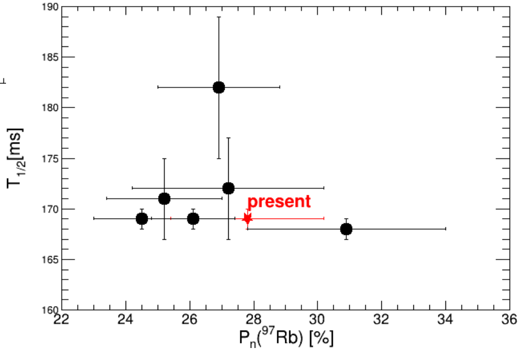
X 1000
(number of cycles)



$T_{1/2}(^{96}Rb) = 0.203(2)ms$

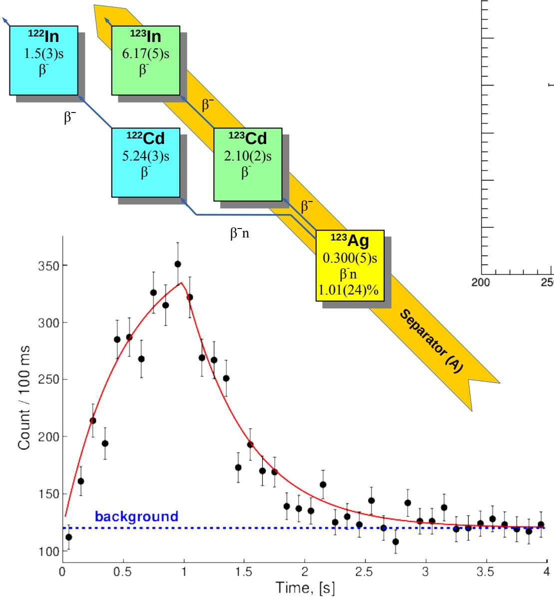
Results: ^{96}Rb and ^{97}Rb

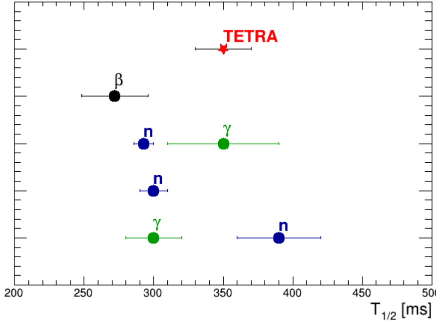




D. Testov et al 2019 JINST 14 P08002

Beta delayed neutron decay of ^{123}Ag





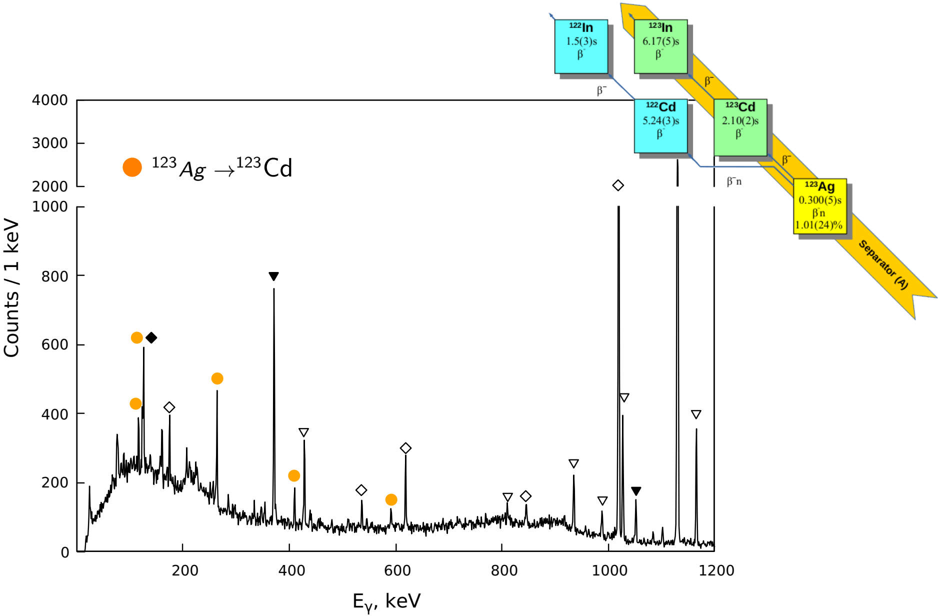
n - $T_{1/2}$ by neutron activity

β - $T_{1/2}$ by β activity

γ - $T_{1/2}$ by γ activity

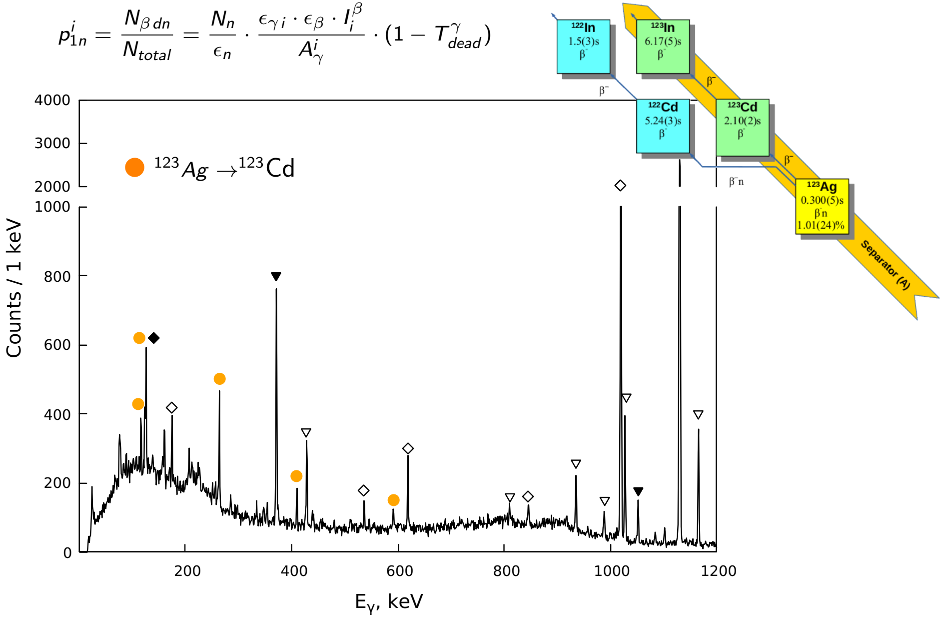
Plasma ionization

Beta delayed neutron decay of ^{123}Ag



Beta delayed neutron decay of ^{123}Ag

$$p_{1n}^{i} = \frac{N_{\beta\, dn}}{N_{total}} = \frac{N_n}{\epsilon_n} \cdot \frac{\epsilon_{\gamma\, i} \cdot \epsilon_\beta \cdot I_i^\beta}{A_\gamma^i} \cdot (1 - T_{dead}^{\gamma})$$



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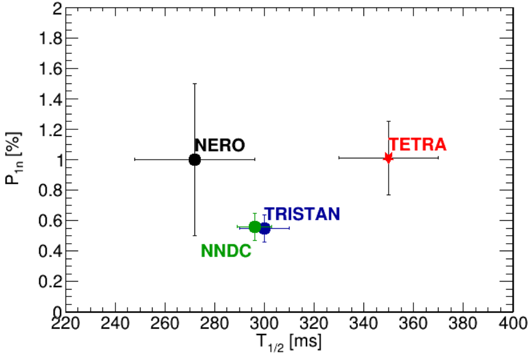
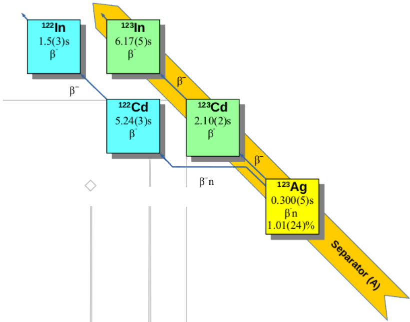
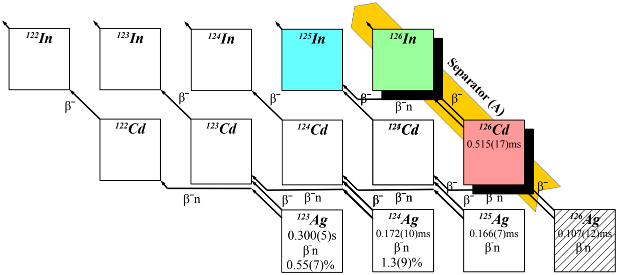
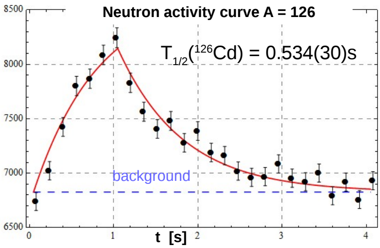


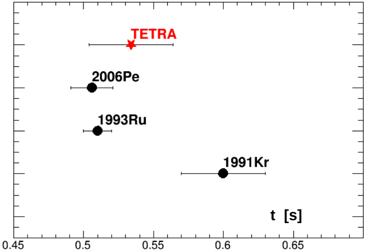


D. Testov et al., Eur. Phys. J. A (2021) 57 59

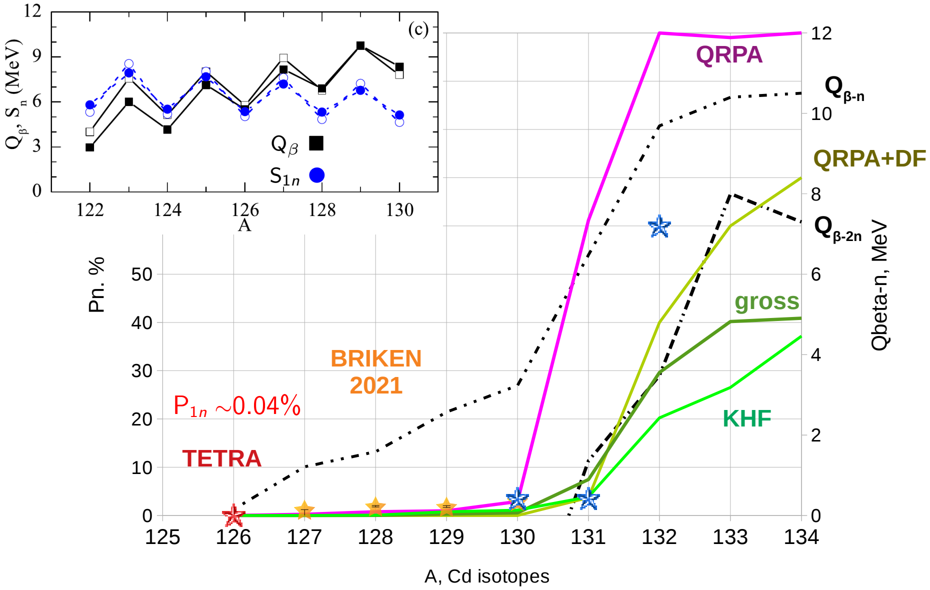
Experiments on the mass-separated beams







First neutron precursor on Cd isotope chain



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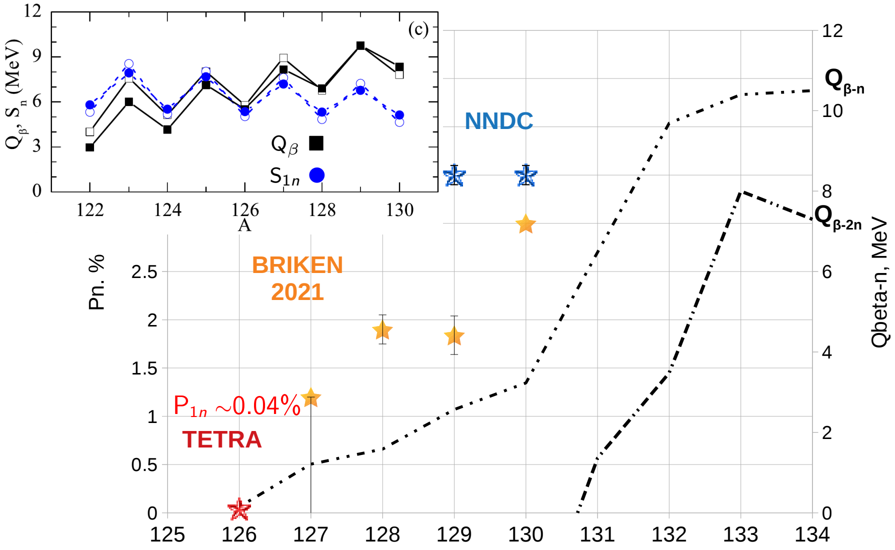
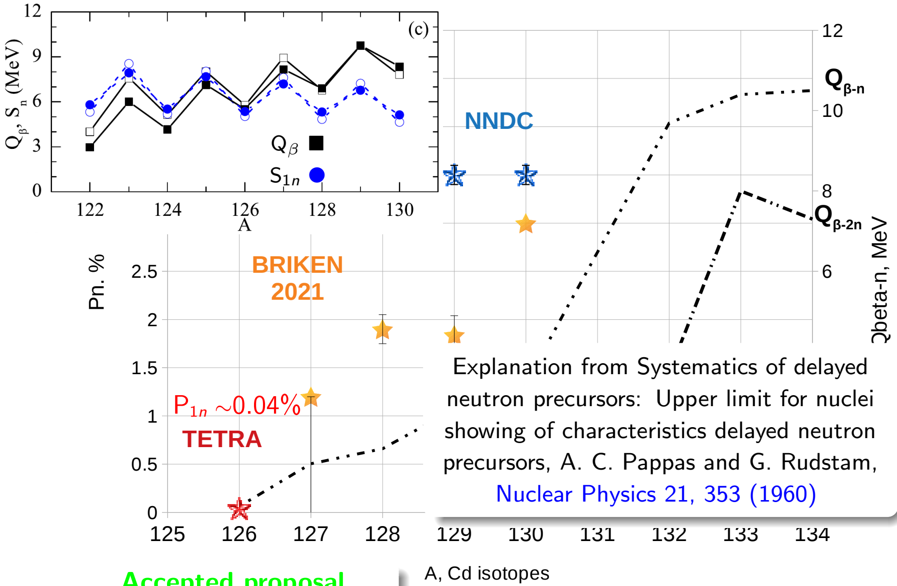


Accepted proposal

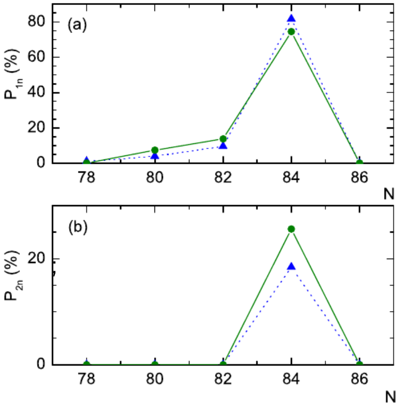
First neutron precursor on Cd isotope chain



Explanation from Systematics of delayed neutron precursors: Upper limit for nuclei showing of characteristics delayed neutron precursors, A. C. Pappas and G. Rudstam, Nuclear Physics 21, 353 (1960)

Accepted proposal

Multi neutron emission of Cd isotopes

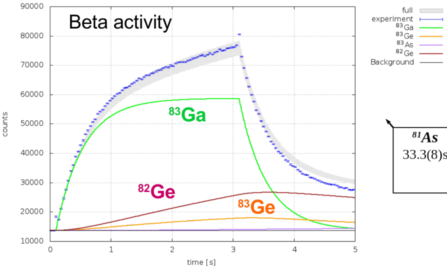


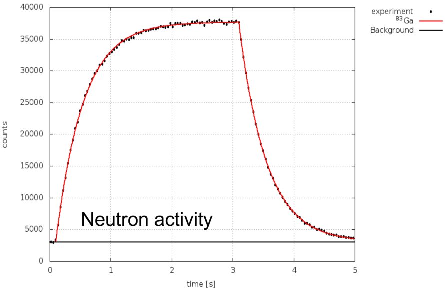
A. Severyukhin, N. Arsenyev, I. Borzov, E. Sushenok, Phys. Rev C 95, 034314 (2017)

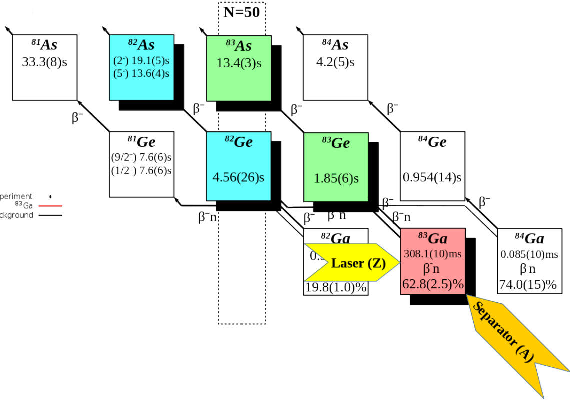
An influence of the phonon-phonon coupling (PPC) on the β-decay half-lives and multi-neutron emission probabilities is analyzed within the microscopic model based on the Skyrme interaction with tensor components included. The finite-rank separable approximation is used in order to handle large two-quasiparticle spaces. The even-even nuclei near the r-process paths at $N = 82$ are studied.

Maximal P_{1n} and P_{2n} values are obtained in the case of ^{132}Cd.
For ^{126}Cd, a nonzero probability of the neutron emission is found.

Crossing N=50 shell [^{83}Ga]

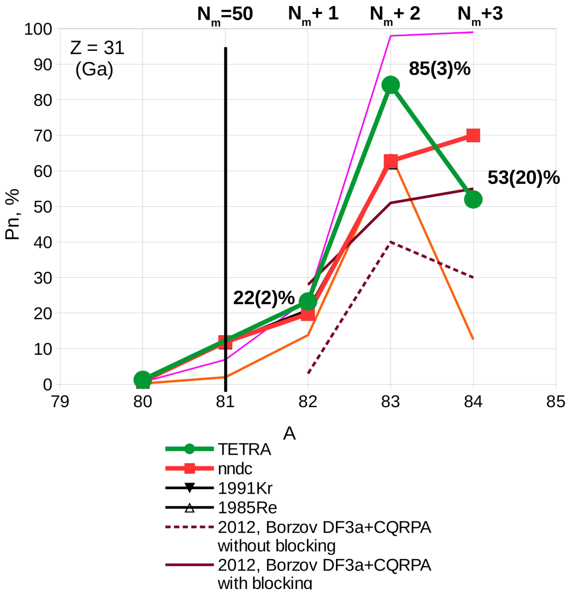






$T_{1/2}(^{83}Ga)=0.312(1)ms$, $P_{1n}(^{83}Ga)=84(2)\%$, $\Phi=\sim400/s$

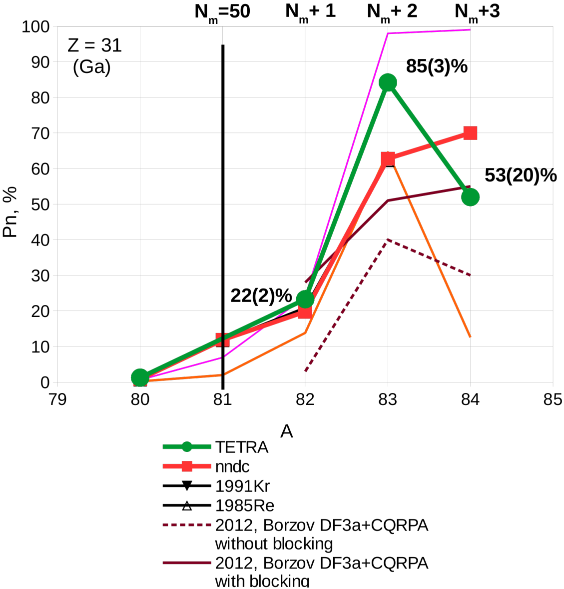
What is the situation near Nm=50 ?



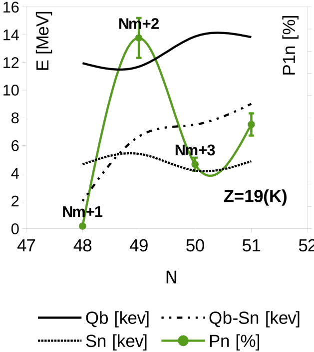
What is near $N_m = 50$?

Oscillations?

What is the situation near Nm=50 ?



	N_m=28	N_m+1	N_m+2	N_m+3	
emitter	48Ca	49Ca	50Ca	51Ca	
S_n=	9952	5146	6360	4821	
precursor		48K	49K	50K	51K
Q_β=		11940	11688	13861	13820#
$Q_{\beta n}$=		1988	6542	7501	9002
P_n=		1.14%	86%	29%	47%



To take home

β-delayed neutron-emission crossing the N = 50, N = 82

1. Measurements of $P_{1n,2n,\ldots}$, $T_{1/2}$
2. Absolute branching ratio in β-decay of neutron rich nuclei
3. neutron-tagged γ-ray (decay) spectroscopy

DUBNA JINR

IJCLab Irène Joliot-Curie

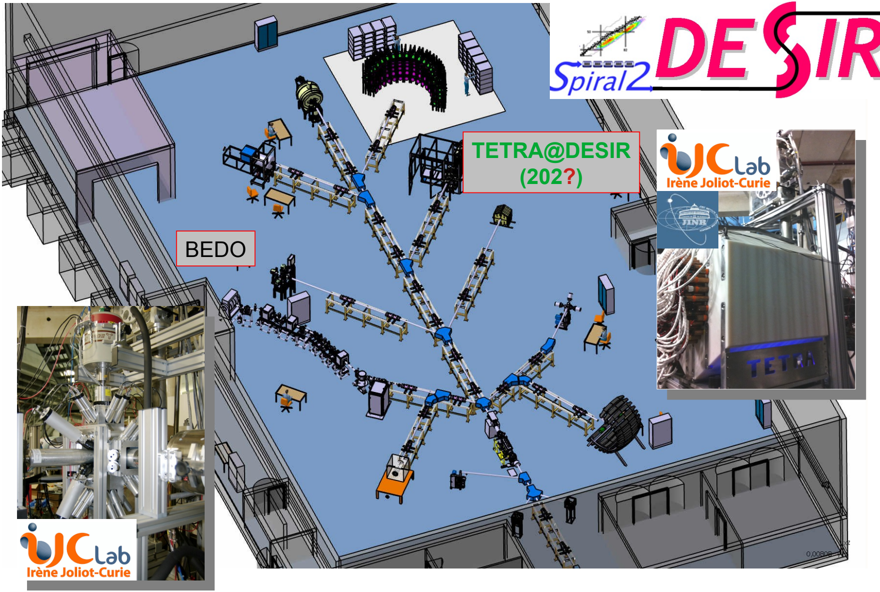
Performed studies (at ALTO):

1. $^{92-103}$Rb (surface)
2. $^{80-84}$Ga (laser)
3. $^{123-125}$Ag (A-separated beams)

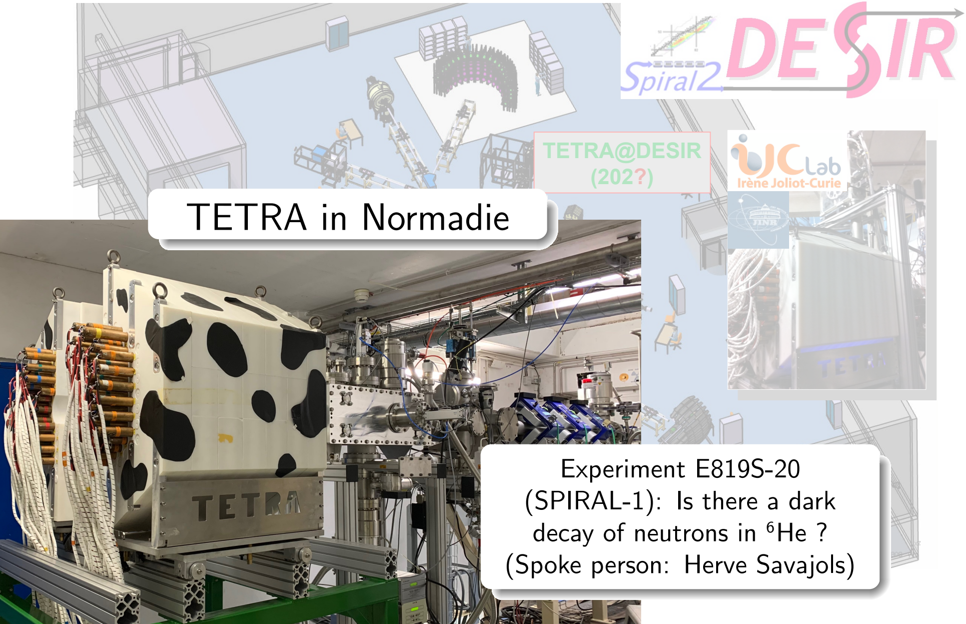
The experimental data allows to tune theories:

- Forbidden decays crossing N=50, 82
- Validate β-decay / β-delayed (multi-)neutron emission calculations for the odd-A nuclei within the DF3a+CQRPA framework with the fixed parent ground-state spin-parities;
- β-transition calculations between the np-nh states within the extended FRSA framework.
- to extend possibilities of spin-parity determination;
- to validate the beyond mean-field predictions of np-nh structure induced suppression of the feeding to particular states in the product nuclei

BEDO&TETRA is a part of DESIR (SPIRAL-2) project



TETRA at SPIRAL-1 beam line



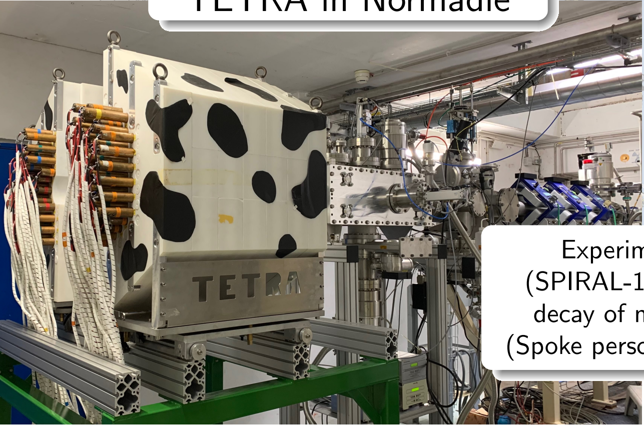
TETRA in Normadie

Experiment E819S-20 (SPIRAL-1): Is there a dark decay of neutrons in ^{6}He ? (Spoke person: Herve Savajols)

Thank you for you attention!

TETRA@DESIR
(202?)

TETRA in Normadie



Experiment E819S-20 (SPIRAL-1): Is there a dark decay of neutrons in ^{6}He ? (Spoke person: Herve Savajols)

Thank you for you attention!

laboratoire commun CEA/DRF CNRS/IN2P3