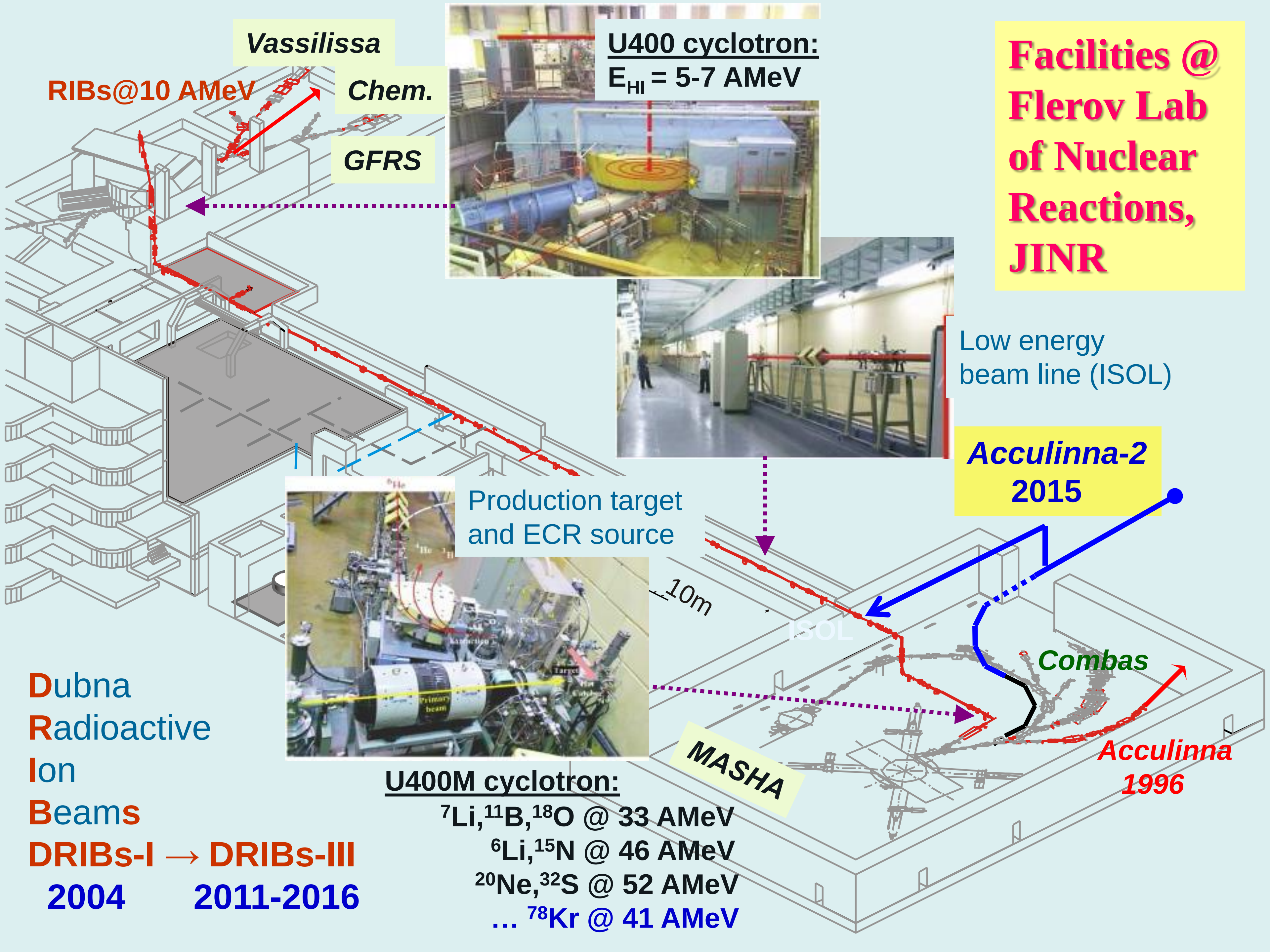
Study of light exotic systems and super heavy elements in JINR

Andrey Fomichev[a]

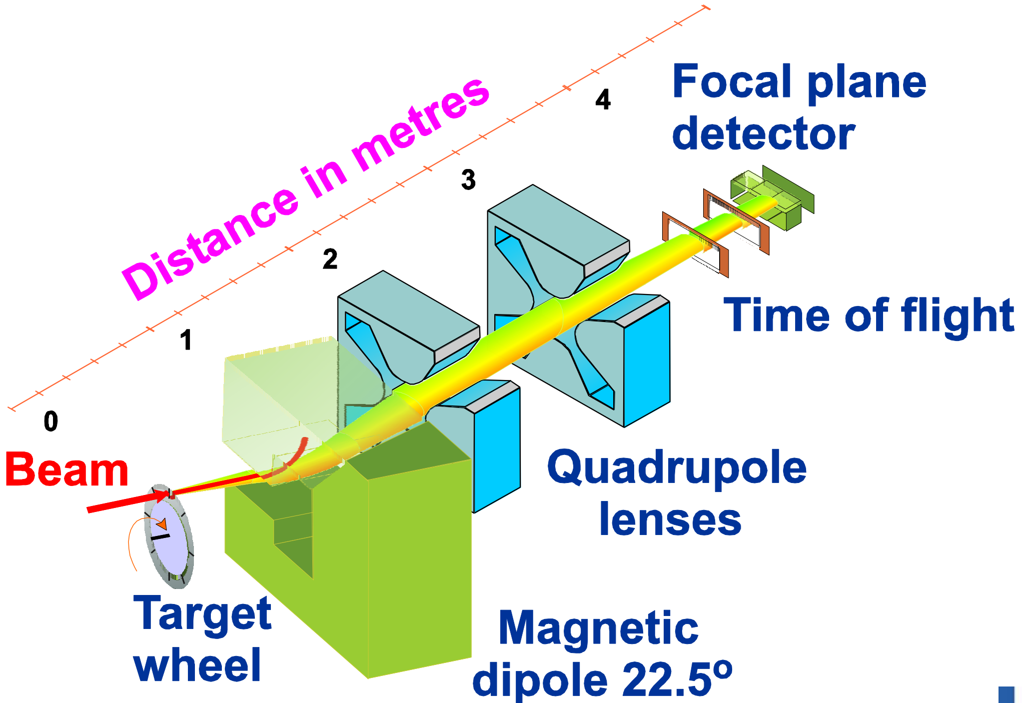
for ACCULINNA Collaboration [http://aculina.jinr.ru/]

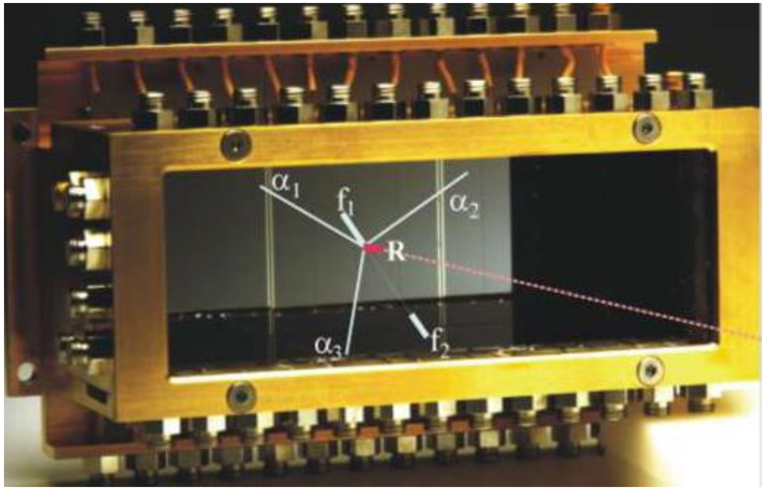
a – *Flerov Laboratory of Nuclear Reactions, JINR, Dubna, Russia*
b – *Institute of Physics, Silesian University in Opava, Czech Republic*
c – *Bogolyubov Laboratory of Theoretical Physics, JINR, Dubna, Russia*
d – *GSI Helmholtzzentrum fur Schwerionenforschung, Darmstadt, Germany*
e – *Russian Research Center "The Kurchatov Institute", Moscow, Russia*
f – *Institute of Nuclear Physics PAN, Krakow, Poland*
g – *Skobel'tsyn Institute of Nuclear Physics, Moscow State University, Russia*
h – *Faculty of Physics, University of Warsaw, Warsaw, Poland*
i – *Fundamental Physics, Chalmers University of Technology, Goteborg, Sweden*
j – *All-Russian Research Institute of Experimental Physics, Sarov, Russia*
k – *Ioffe Physical Technical Institute, St. Petersburg, Russia*

JINR - APCTP meeting, Bolshie Koty, July 14-18, 2013


Facilities @ Flerov Lab of Nuclear Reactions, JINR
Vassilissa
RIBs@10 AMeV
Chem.
GFRS
U400 cyclotron:
E_{HI} = 5-7 AMeV
Low energy beam line (ISOL)
Acculinna-2 2015
Production target and ECR source
10m
ISOL
Combas
MASHA
Acculinna 1996
U400M cyclotron:
$^{7}Li,^{11}B,^{18}O$ @ 33 AMeV
$^{6}Li,^{15}N$ @ 46 AMeV
$^{20}Ne,^{32}S$ @ 52 AMeV
… ^{78}Kr @ 41 AMeV
Dubna
Radioactive
Ion
Beams
DRIBs-I → DRIBs-III
2004 2011-2016

Dubna Gas Filled Recoil Separator





Lawrence Livermore National Laboratory

JINR FLNR 114 Flerovium Dubna

THE UNIVERSITY of TENNESSEE UT KNOXVILLE

OAK RIDGE NATIONAL LABORATORY
Managed by UT-Battelle for the Department of Energy

VANDERBILT UNIVERSITY

Pure Appl. Chem., Vol. 83, No. 7, pp. 1485–1498, 2011

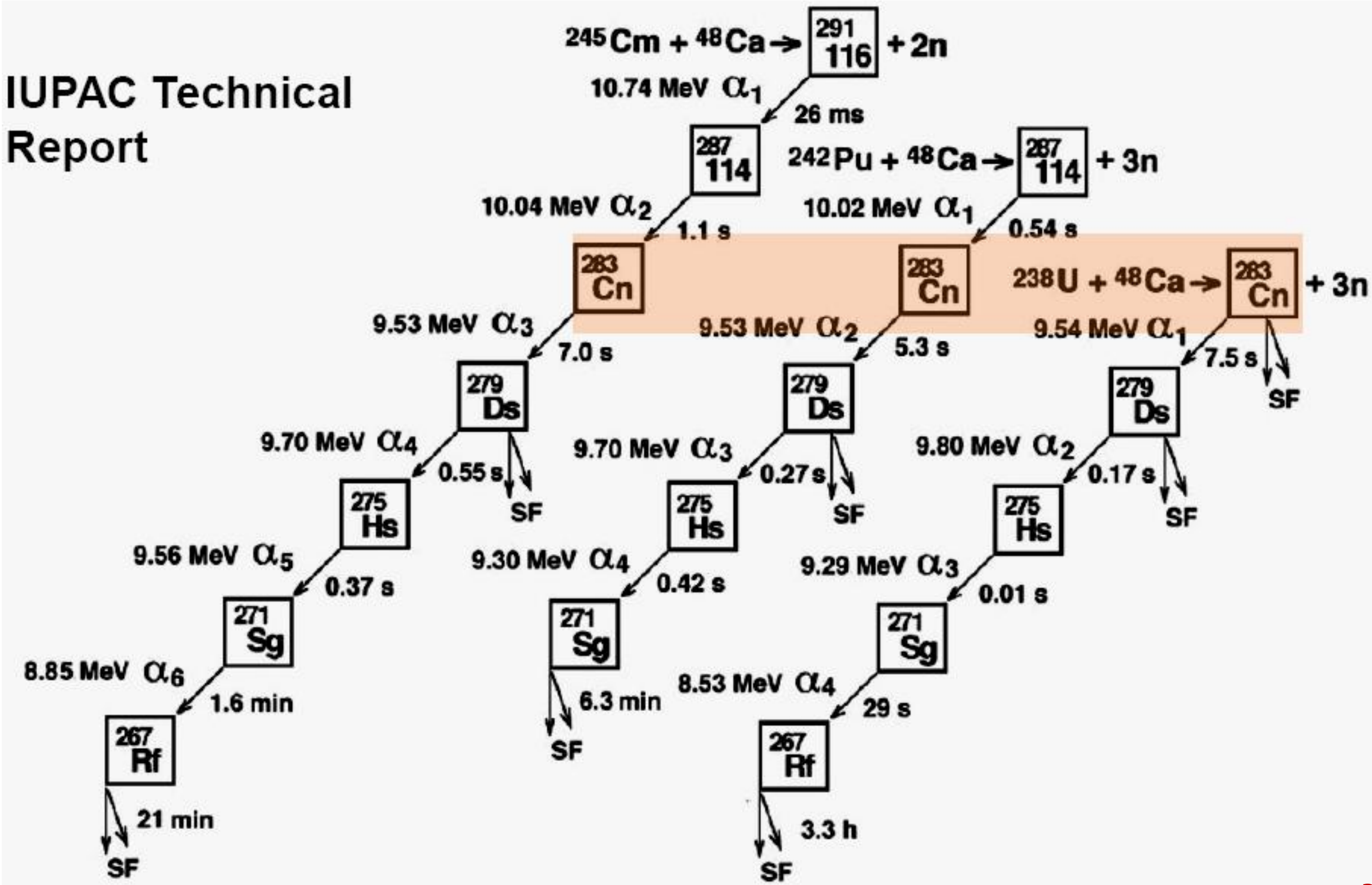
Discovery of the elements with atomic numbers greater than or equal to 113 (IUPAC Technical Report)

In accordance with the criteria for the discovery of elements previously established by the 1992 IUPAC/IUPAP Transfermium Working Group, and reinforced in subsequent IUPAC/IUPAP JWP (Joint Working Party) discussions,

It was determined that the Dubna-Livermore collaborations share in the fulfillment of those criteria both for elements $Z = 114$ and 116.

IUPAC officially approved the name Flerovium, with symbol Fl, for the element of atomic number 114 and the name Livermorium, with symbol Lv, for the element of atomic number 116. Priority for the discovery of these elements was assigned, in accordance with the agreed criteria, to the collaboration between the JINR (Dubna, Russia) and the LLNL (Livermore, USA).

Evidence in the cases of elements Z = 113, 115, and 118 have not met the criteria for discovery.



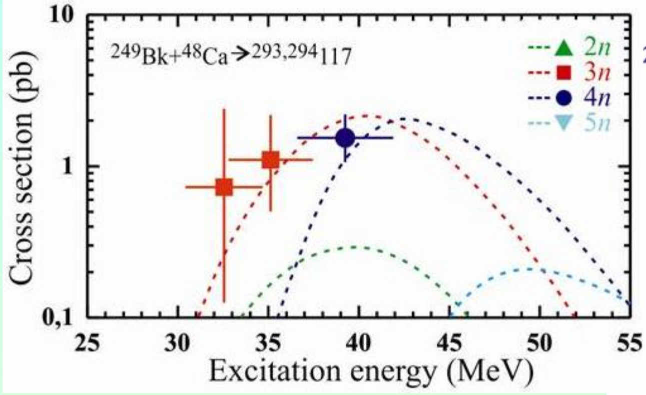
For the elements Z=114 and 116, the establishment of the identity of the isotope ^{283}Cn by a large number of decaying chains, originating from a variety of production pathways essentially triangulating its A, Z character enables that nuclide's use in unequivocally recognizing higher-Z isotopes that are observed to decay through it.

The JWP notes extended decay chains that include ^{283}Cn and descendants for the identification of ^{287}114 from ^{48}Ca+^{242}Pu fusion and of ^{291}116 from ^{48}Ca+^{245}Cm fusion and recommends that the Dubna-Livermore collaboration be credited with discovery of new elements with Z=114 and 116.

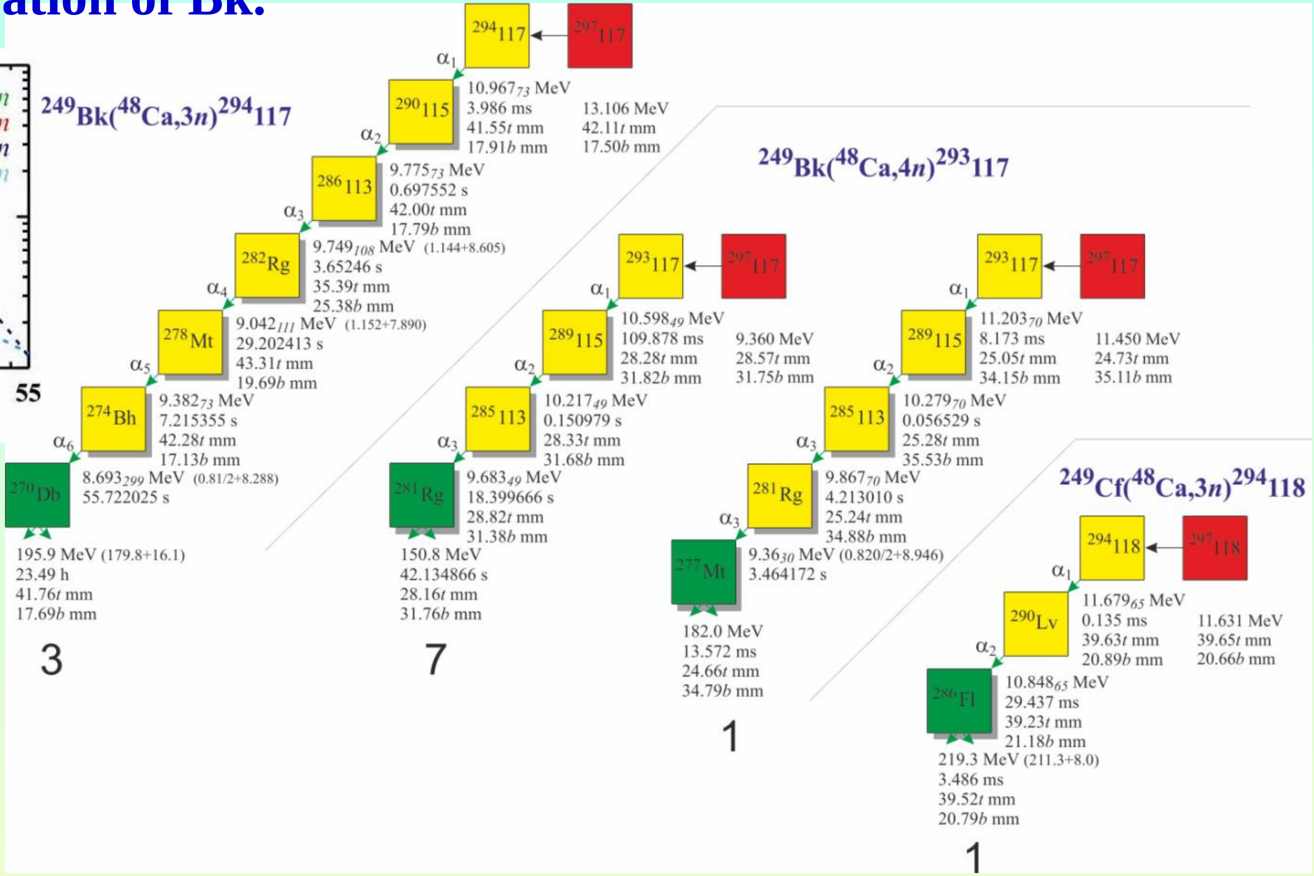
2012: Confirmation of the 117th!

The data collected in 2012 on synthesis of the 117th element with a new target ^{249}Bk completely confirm results of 2010.

3 chains of disintegration in 3n the channel and 8 chains in 4n the channel are observed. Besides, in the experiment one chain is obtained which corresponds to disintegration of the 118th element. The chain is found in reaction on ^{249}Cf which is a product of disintegration of Bk.

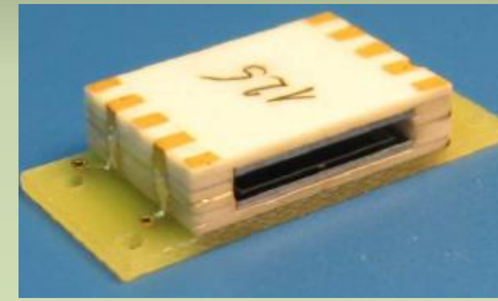


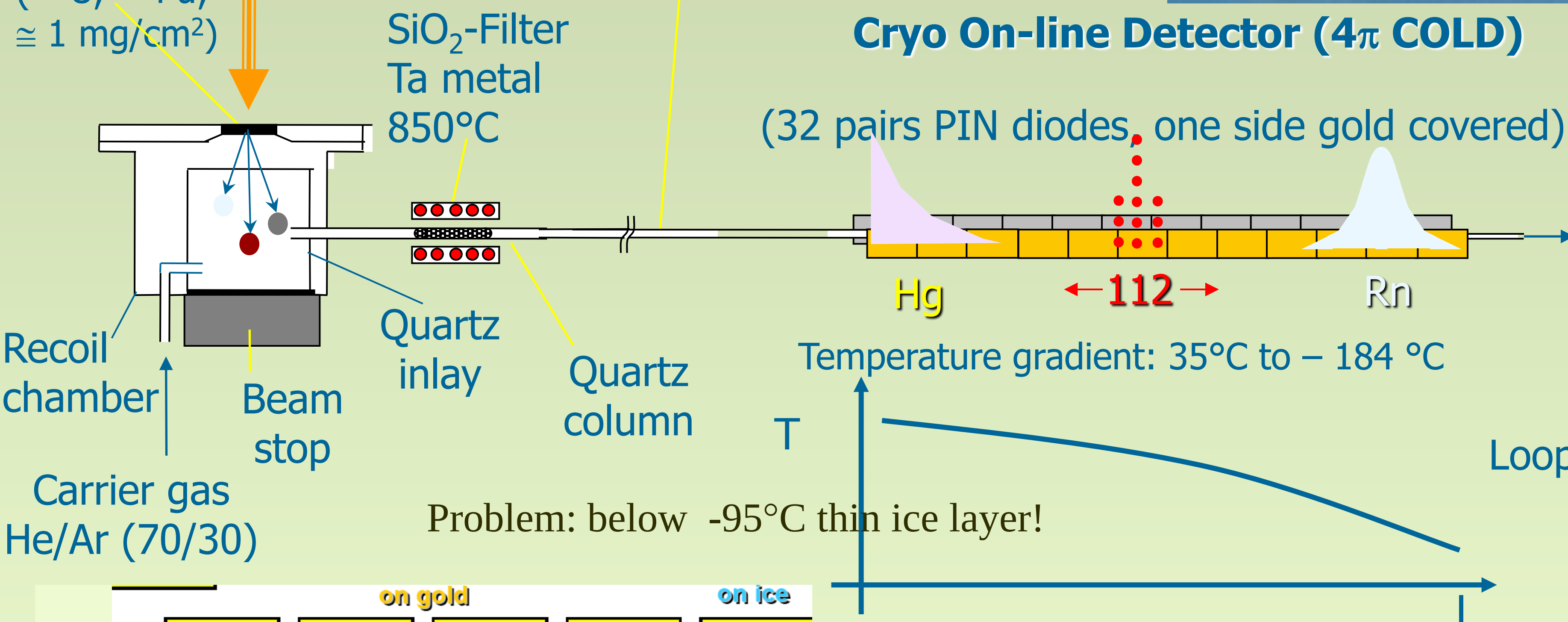
The excitation function for the full sum of the events received in two experiments

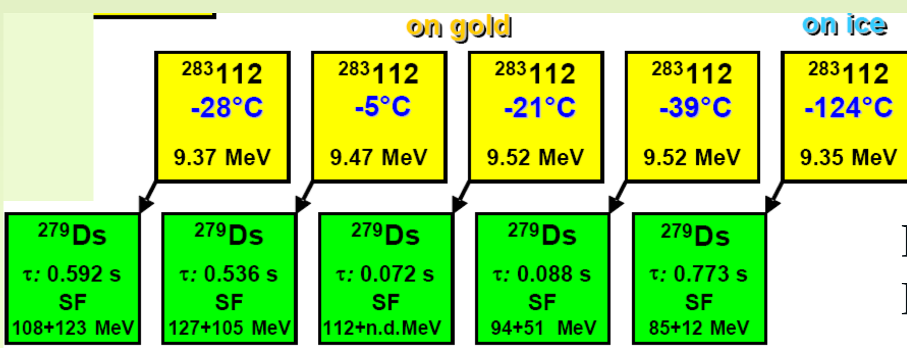


Chemistry of the elements 112 & 114

Collaboration between FLNR and Paul Scherrer Institute



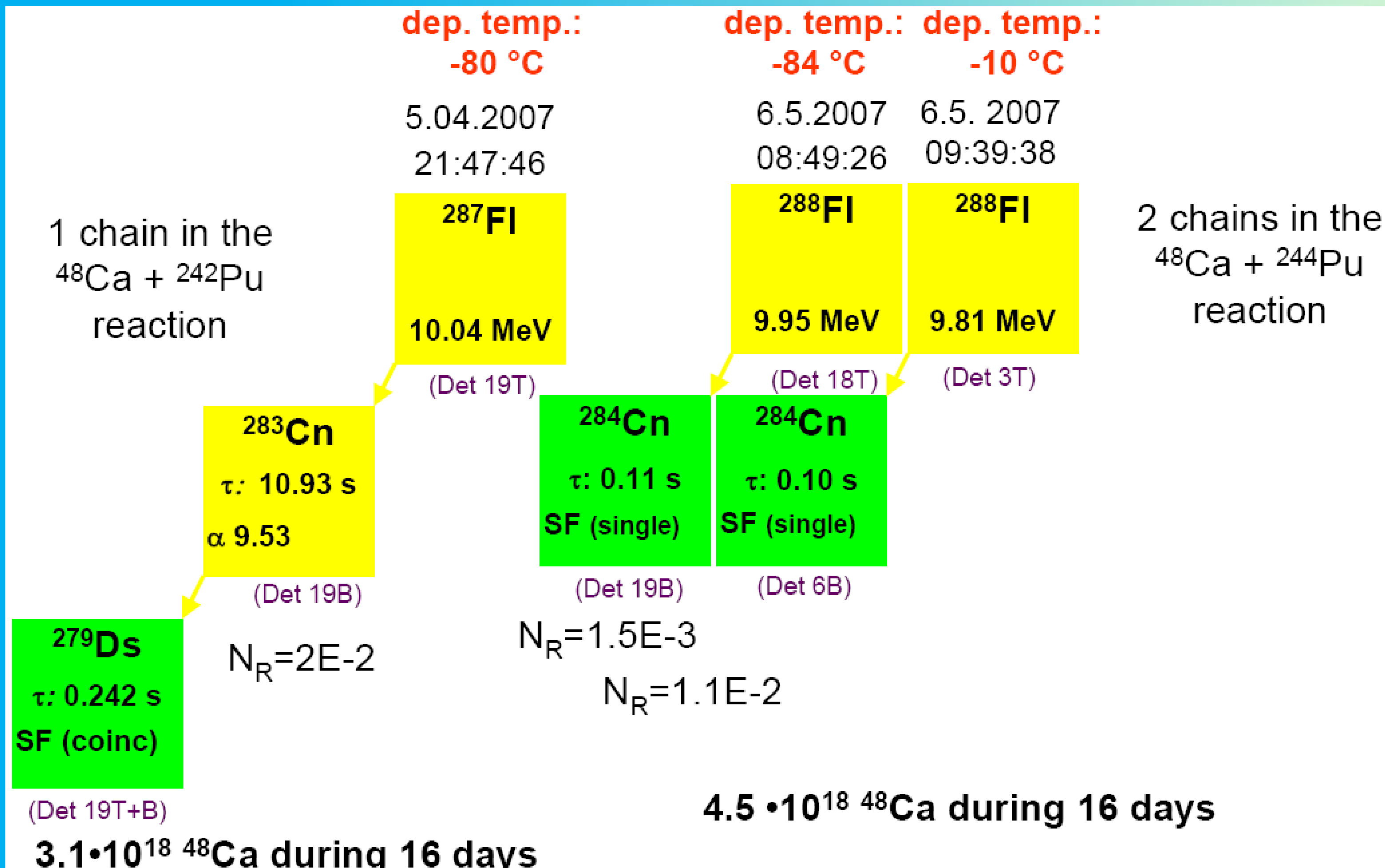




R. Eichler *et al.* TAN07 and Angew. Chem. Int. Ed. 2008, 47, 3262 –3266

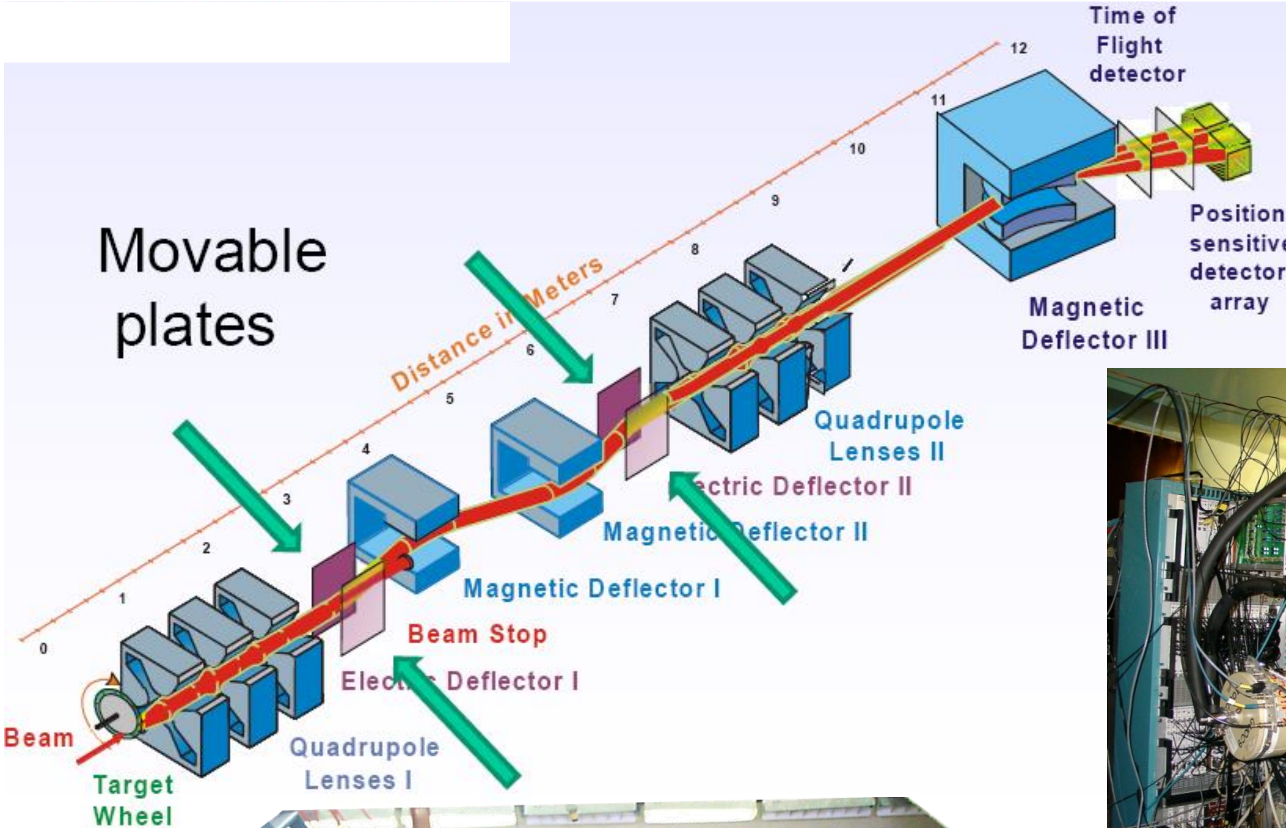
Flerovium (Z=114) Experiments: results PSI-Dubna @ 2007

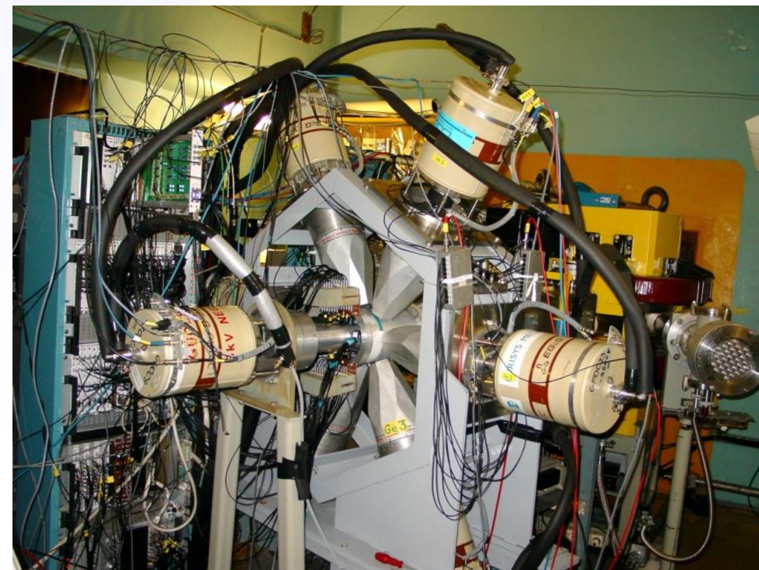
PSI-FLNR-LLNL-ITE-FZD Collaboration

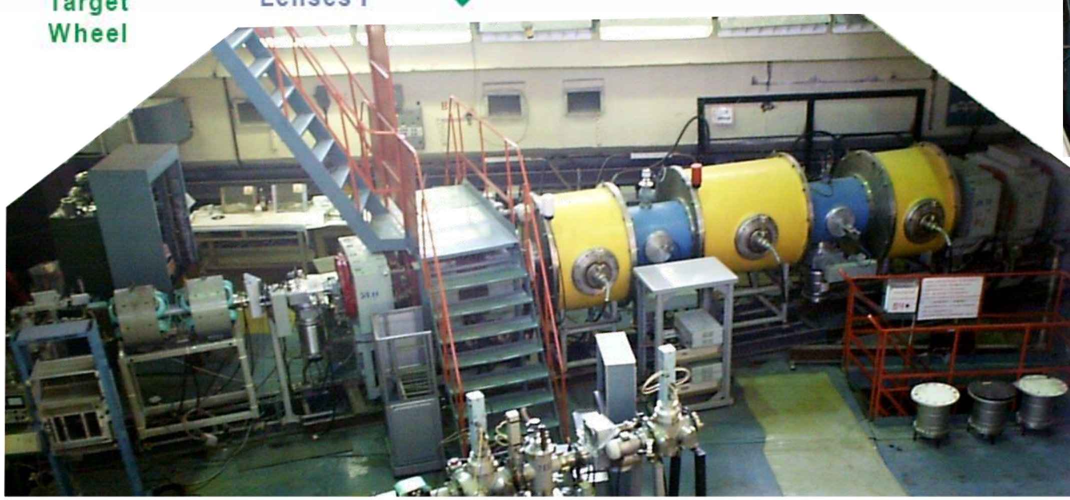


R. Eichler et al., Radiochim. Acta 98, 133 (2010)

Electrostatic separator VASSILISSA

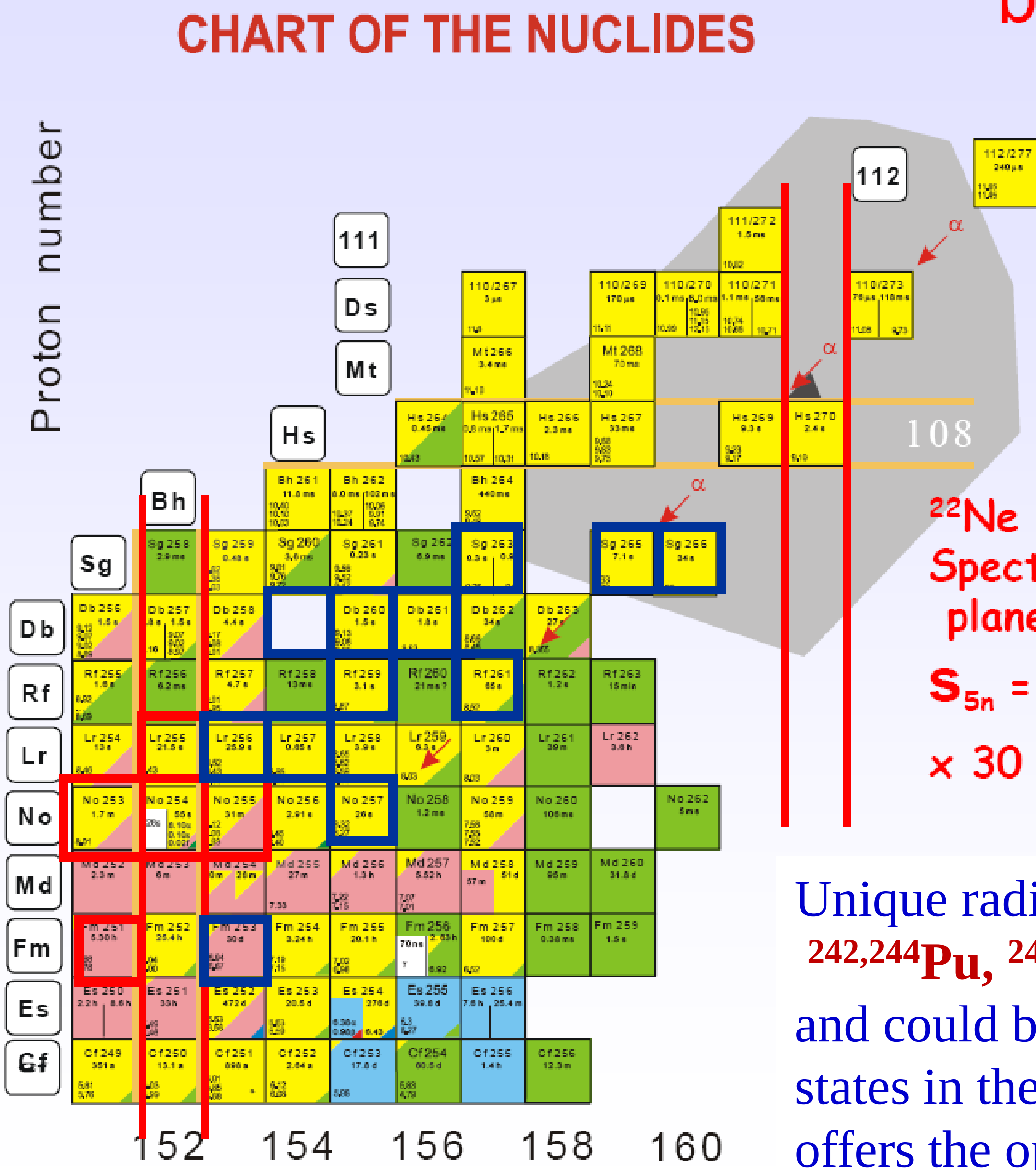






GABRIELA - Gamma Alpha Beta Recoil Investigation with the Electromagnetic Analyser

Possible spectroscopy experiments with stable beams and exotic targets



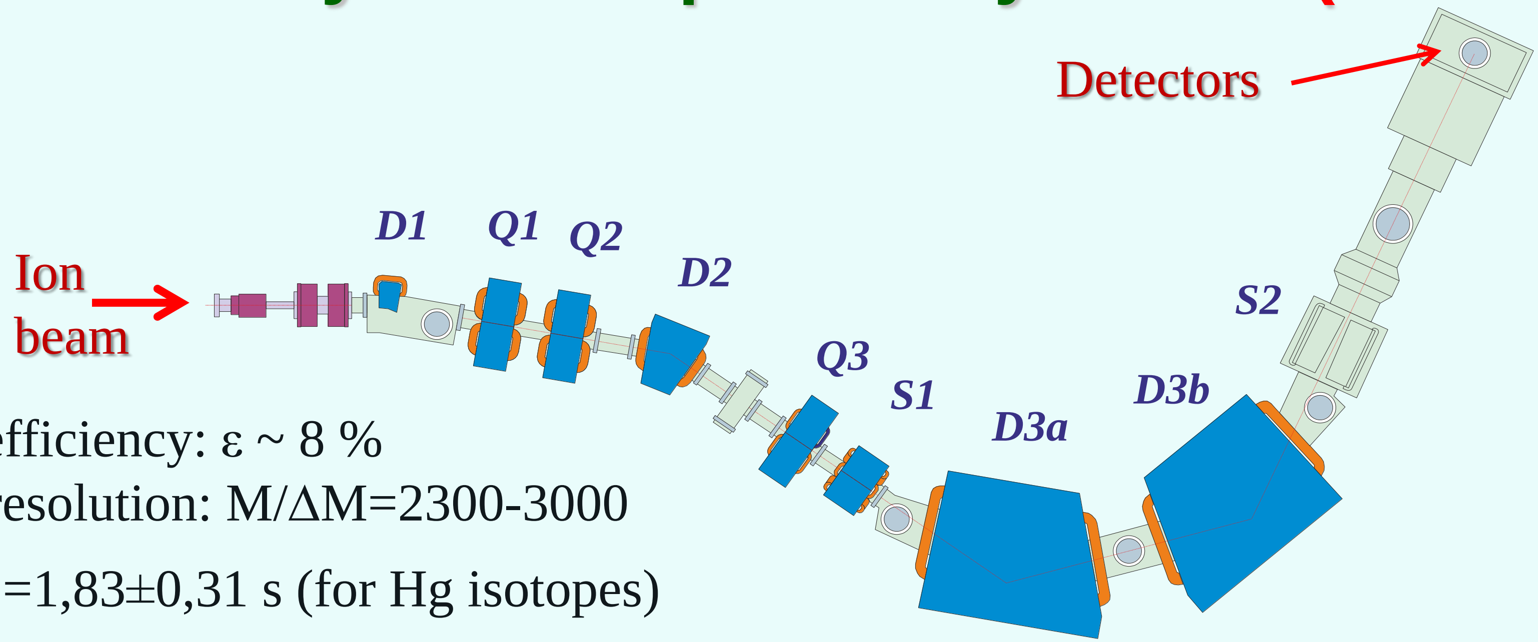
$^{22}Ne + ^{242}Pu \rightarrow ^{259}Rf + 5n$

Spectroscopy experiments at the focal plane of separator.

S_{5n} = 5nb, S_a = 50 /day (I_{Ne} = 1pmA) × 30 days = 1500 a's

Unique radioactive targets, such as ^{242,244}**Pu**, ^{243}**Am**, ^{248}**Cm** are available in Dubna and could be used in order to populate excited states in the heavy neutron rich nuclei. This offers the opportunity to give insight into the single neutron and proton structure.

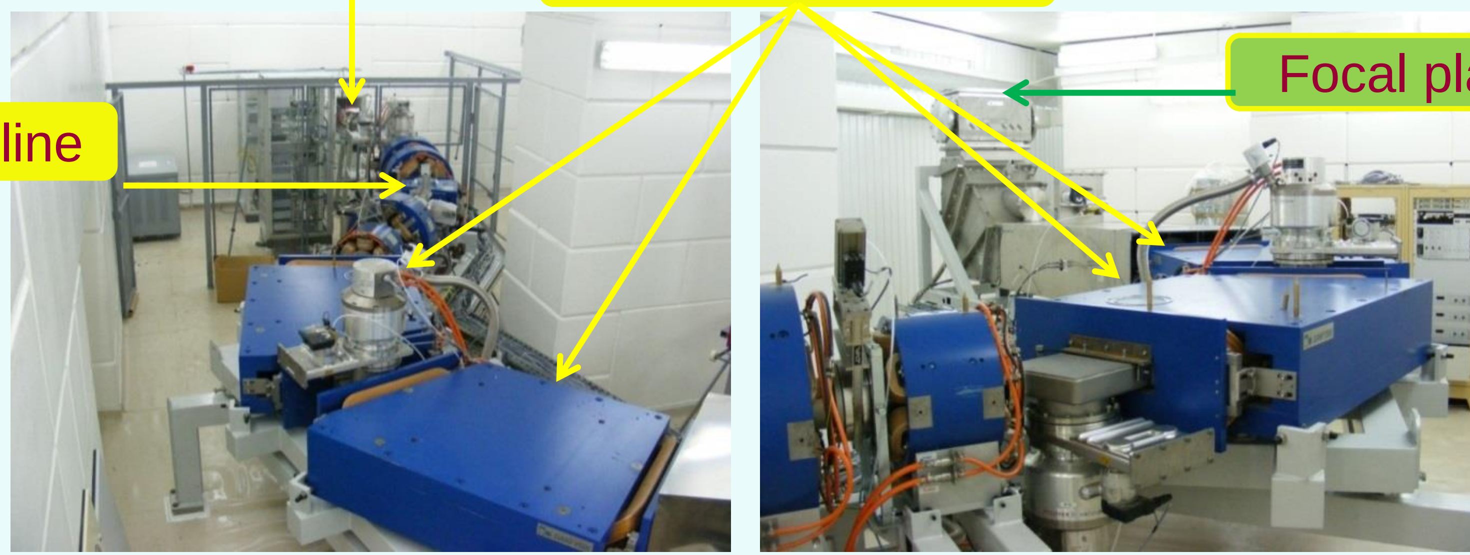
Mass Analyzer of Super Heavy Atoms (MASHA)



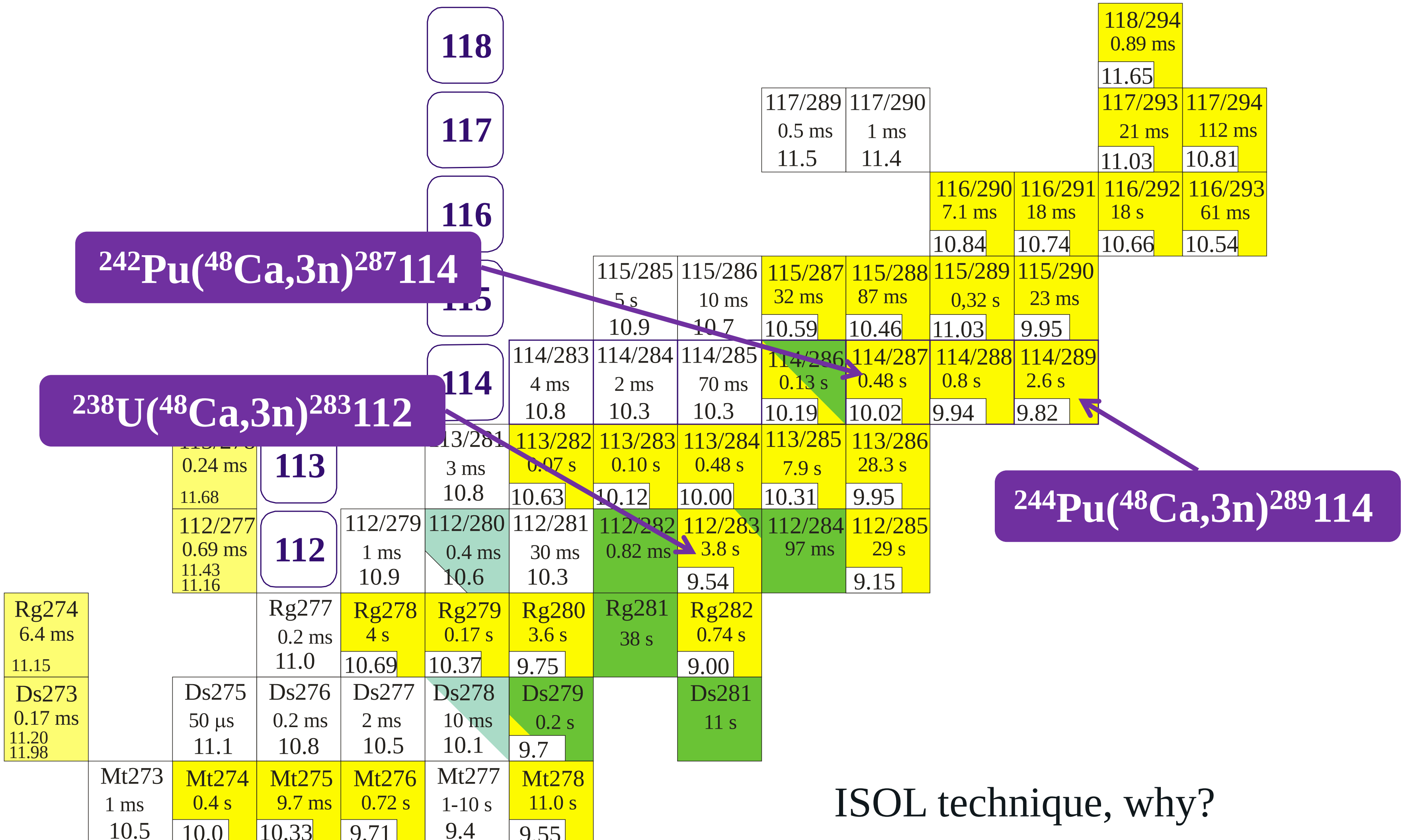
Total efficiency: ε ~ 8 %

Mass resolution: M/ΔM=2300-3000

$\langle\tau_{diff}\rangle$=1,83±0,31 s (for Hg isotopes)



First experiments for mass measurement of SHE

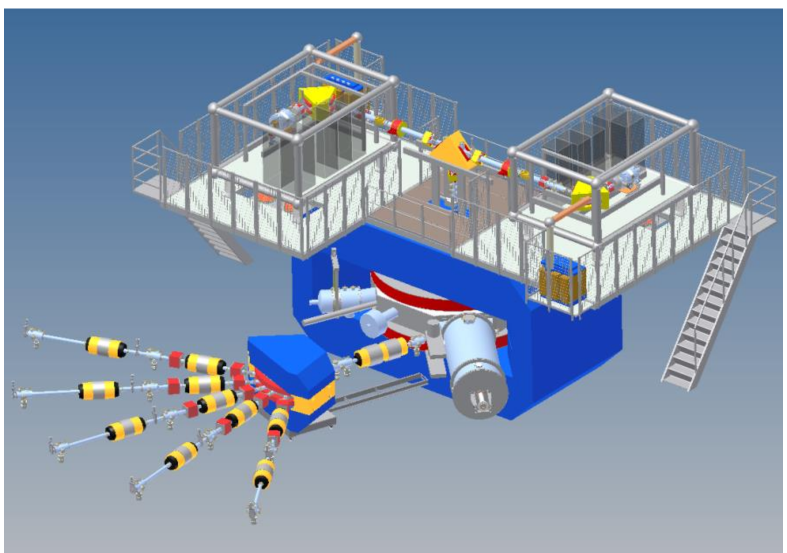


ISOL technique, why?

- Lifetime for some SHE isotopes $\geq$ 0.5 s
- 112 and 114 elements have high volatility

Status of factory for SHE on 01/07/13

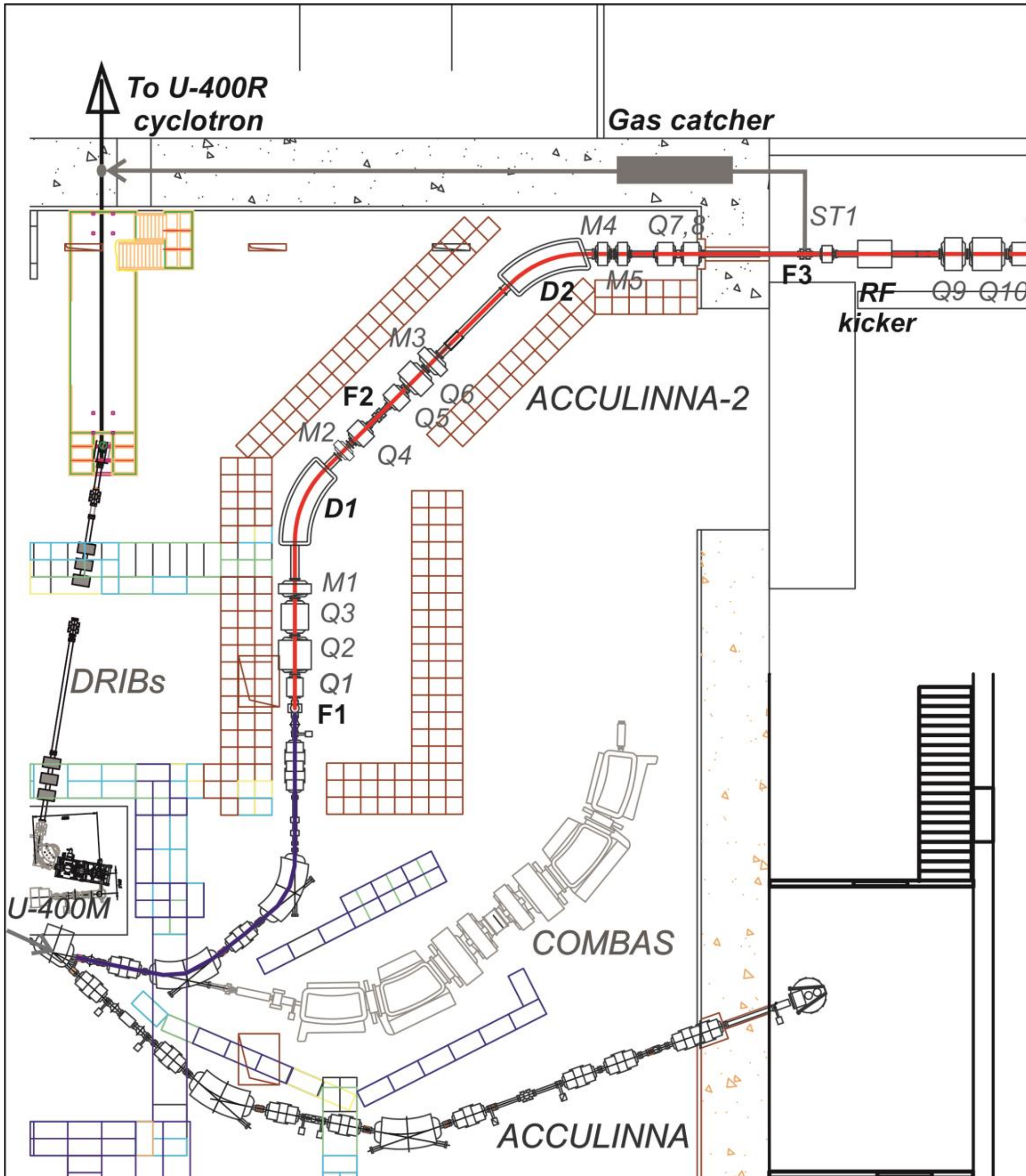
- Synthesis and study of properties of superheavy elements
- Search for new reactions for SHE-synthesis
- Chemistry of new elements



DC280 (expected)

Ion	E, MeV/A	I, pps
^{18}O	8	$1x10^{14}$
^{40}Ar	5	$6x10^{13}$
^{48}Ca	5	$1.2x10^{14}$
^{54}Cr	5	$2x10^{13}$
^{58}Fe	5	$1x10^{13}$
^{124}Sn	5	$2x10^{12}$
^{238}U	7	$5x10^{10}$

Long-range plan for research with RIBs at JINR



ACCULINNA-2 step by step:

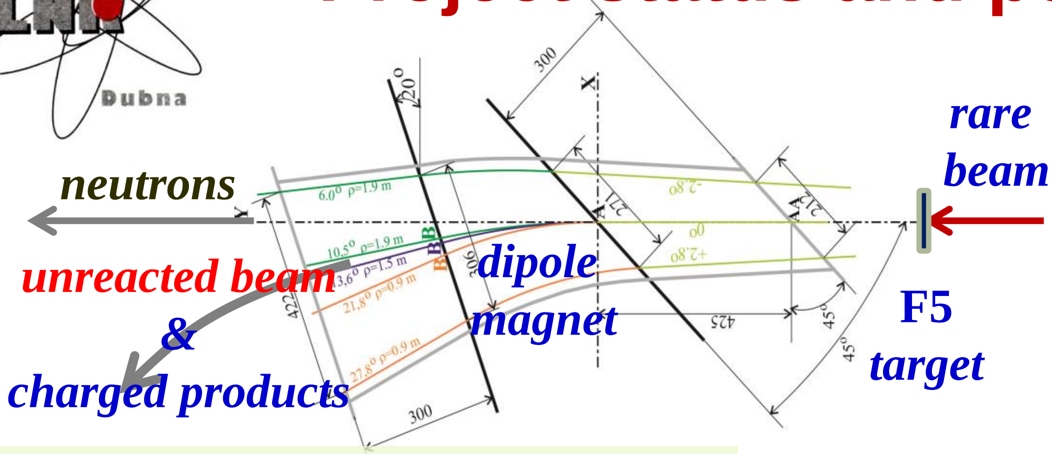
Stage 1. Fully commissioning (RF-kicker excepted) at the end 2014 via Contract with Sigmaphi dated on 28.09.2011.

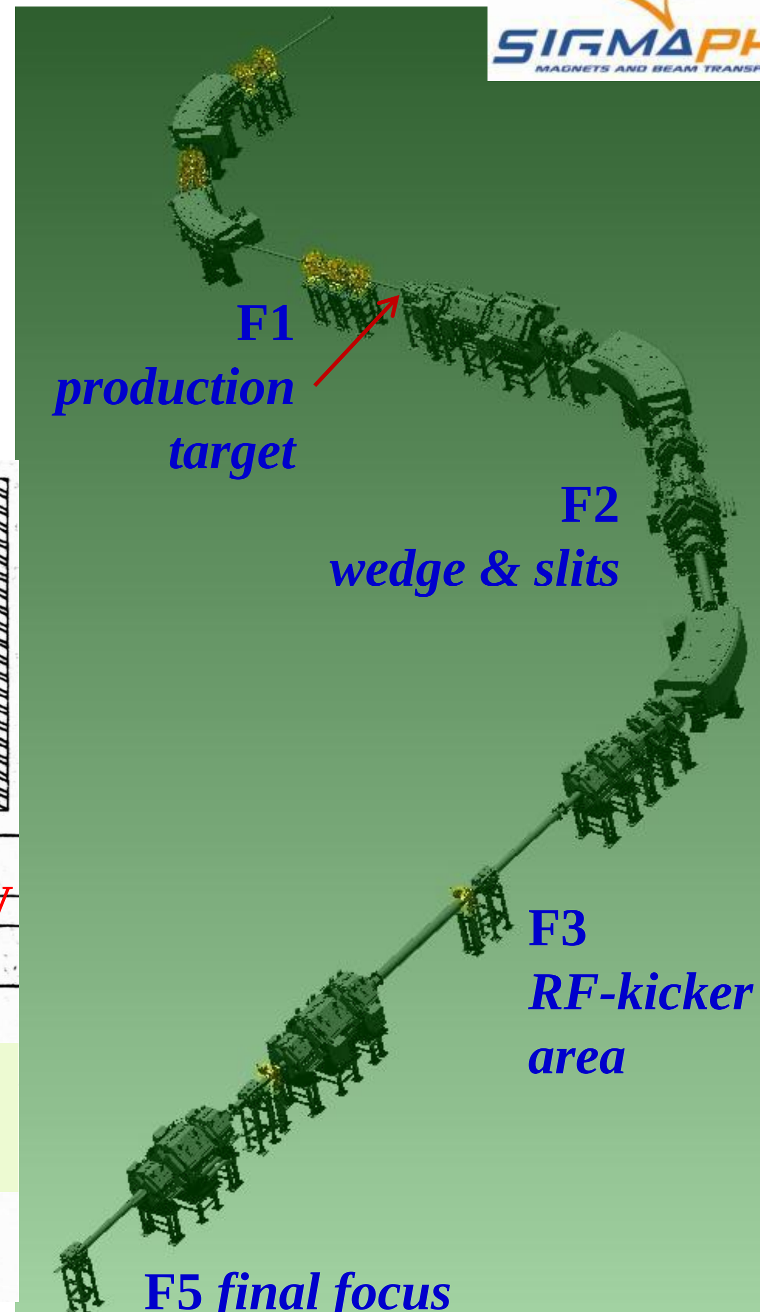
Stage 2. Accelerator upgrade and equipment addition (RF-kicker, zero angle spectrometer, tritium target, modern detectors). First experiments starting from 2015.

Stage 3. ISOL complex upgrade (reconstruction of U-400 cyclotron, gas catcher and related environment). After 2014.

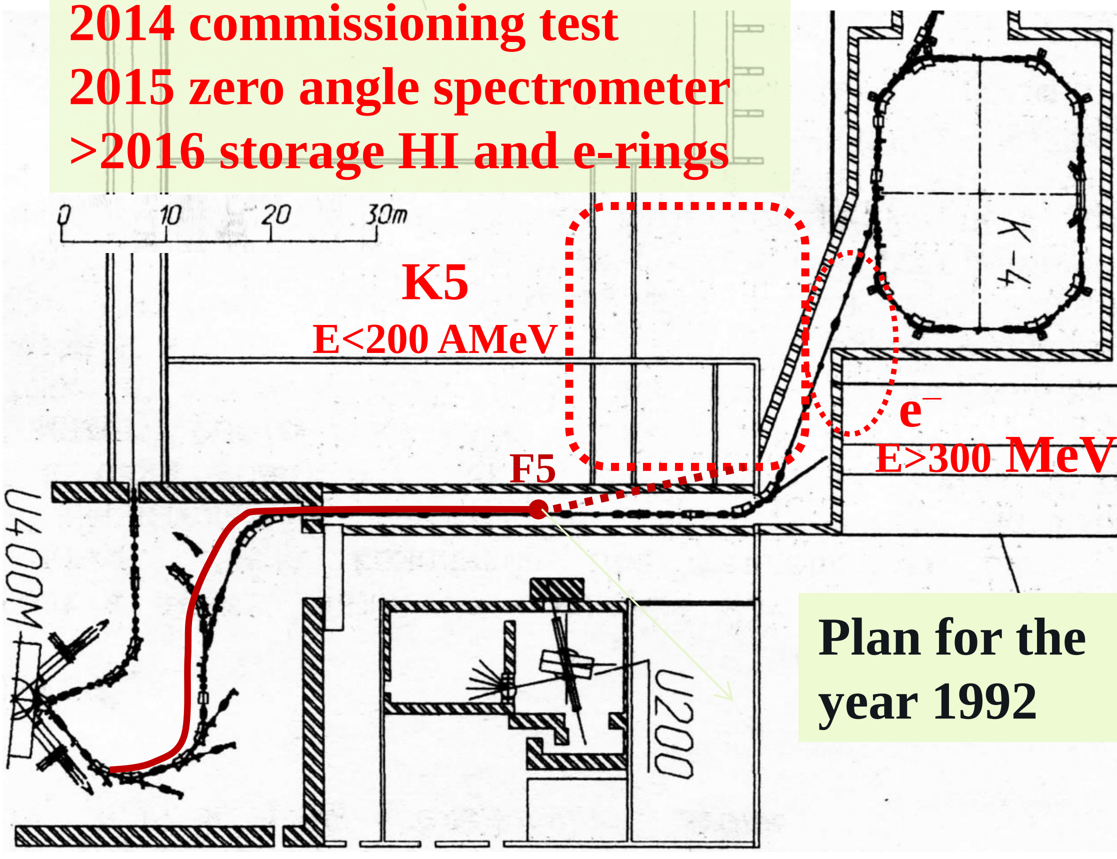
http://aculina.jinr.ru/

Project status and perspectives





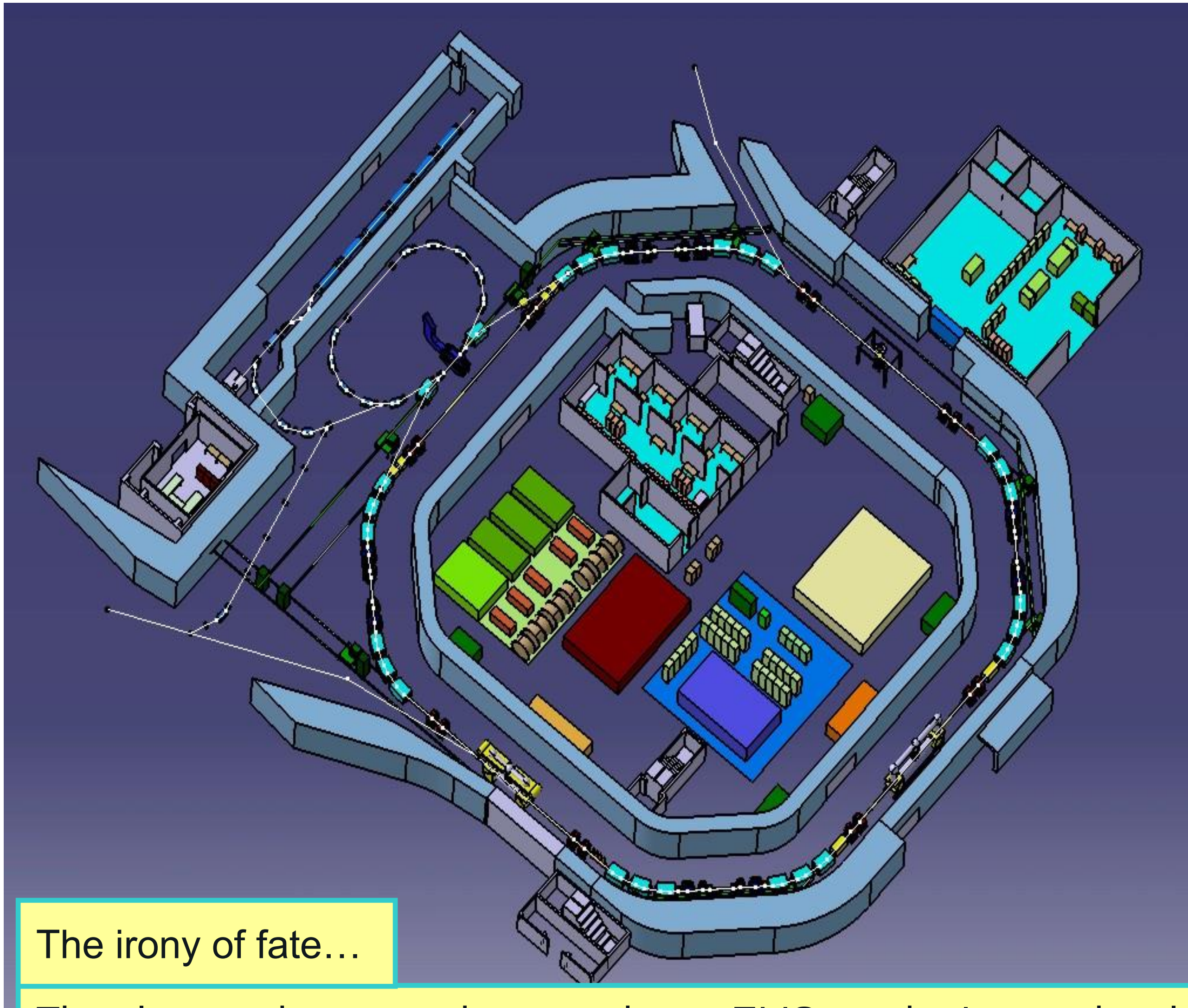
2014 commissioning test
2015 zero angle spectrometer
>2016 storage HI and e-rings



Plan for the year 1992

ELISe : *ELectron-Ion Scattering experiment*

!! A first technical proposal for an electron-ion collider was made ~20 years ago at FLNR JINR [Yu.Ts. Oganessian *et al.*, Z. Phys. A341 (1992) 217]



- **300-500 MeV electrons**
- **200-740 MeV/u RIBs**
- **<200 MeV/u <=> K5**

- **achievable luminosity:**
  10^{25}-10^{30} $cm^{-2}s^{-1}$
  depending on ion species
  10^{24}-10^{27} $cm^{-2}s^{-1}$ <=> K5

e-spectrometer setup at the interaction zone

&

detection system for RI in the arcs of the ring

The irony of fate…

The electron–ion scattering experiment ELISe at the International Facility for Antiproton and Ion Research (FAIR)—A conceptual design study *A.N. Antonov et al.,* NIM **A637** (2011) 60

Why electron scattering ?

- **Pointlike particle**

- **Pure electromagnetic probe**
  ⇒ formfactors F(q)
  ⇒ elastic scattering

- **F(q) transition formfactors**
  ⇒ high selectivity to certain multipolarities
  ⇒ inelastic scattering

- **Large recoil velocities**
  ⇒ full identification (Z,A) complete kinematics

- **Bare ions (no atomic background)**

Physics goals

- **Charge distribution of exotic nuclei (radius, diffuseness, higher moments...)**
  req. luminosity: > 10^{24} cm^{-2} s^{-1}
- **Selective electromagnetic excitation plus spectroscopy, fission, ... studies. Full identification of electric & magnetic multipolarities and of the final state**
  (*new* collective *soft* modes)
  req. luminosity: about 10^{28} cm^{-2} s^{-1}
- **Quasi-free scattering (single-particle structure)**
  req. luminosity: about 10^{29} cm^{-2} s^{-1}

The possibility such kind research at FLNR has been recently discussed inside NUSTUR community and it was supported.

Estimations for Acculinna-2 RIBs

Day-1 exp.

HI	I, pμA	E, A·MeV	RIB	E, A·MeV	I, pps/pμA	Purity, %
^{7}Li	5	34	^{6}He	21.7	4.1×10^{7}	99
			^{6}He	6	2.1×10^{5}	99
			^{7}Be	22.4	5.9×10^{5}	70
^{11}B	5	33	^{8}He	21.9	8.6×10^{4}	99
			^{8}He	15.6	3.7×10^{4}	99
			^{8}B	15.8	2.2×10^{6}	28
^{15}N	2 => 5	47	^{11}Li	33.2	7.2×10^{3}	99
^{18}O	1.5 => 3	48	^{11}Li	31.3	7.4×10^{3}	81
			^{14}Be	34.6	1.6×10^{3}	99
			^{15}B	32.1	4.3×10^{5}	97
			^{16}C	28.8	2.8×10^{7}	99
^{20}Ne	1.5 => 5	54	^{13}O	24.2	1.5×10^{6}	10
			^{14}O	22.8	3.4×10^{7}	54
			^{17}Ne	29.0	5.4×10^{6}	69 vs 0.5
^{36}S	0.1 => 3	49	^{24}O	23.4	2.5×10^{3}	62
			^{14}Be	29.2	3.8×10^{3}	67
			^{17}C	25.0	1.1×10^{5}	78
			^{18}C	25.5	1.9×10^{4}	11
^{32}S	0.1 => 3	52	^{24}Si	11.3	7.2×10^{3}	31
			^{27}S	21.7	3.7×10^{2}	2 vs 0.02

← ^{7}H (^{11}Li, 33.2 A·MeV)

← ^{16}Be (^{14}Be, 34.6 A·MeV)

← ^{17}Ne (^{17}Ne, 29.0 A·MeV)

← ^{26}S (^{24}Si, ^{27}S)

Proposed day-1 experiments are based on our existing experience

Collaboration: historical point of view

^{5}H was a result of successful cooperation GANIL-FLNR-KI-RIKEN

Superheavy Hydrogen ^{5}H

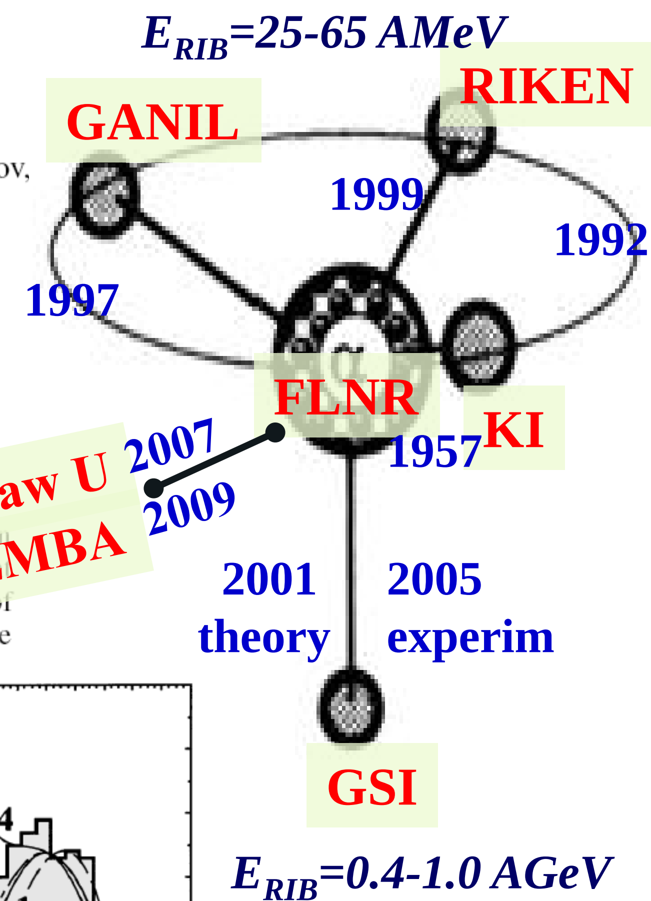
A. A. Korsheninnikov,* M. S. Golovkov,*,† and I. Tanihata
RIKEN, Hirosawa 2-1, Wako, Saitama 351-0198, Japan

A. M. Rodin, A. S. Fomichev, S. I. Sidorchuk, S. V. Stepantsov, M. L. Chelnokov, V. A. Gorshkov, D. D. Bogdanov, R. Wolski,‡ G. M. Ter-Akopian, and Yu. Ts. Oganessian
JINR, 141980 Dubna, Moscow region, Russia

W. Mittig, P. Roussel-Chomaz, and H. Savajols
GANIL BP 5027, F-14076 CAEN cedex 5, France

E. A. Kuzmin, E. Yu. Nikolskii,§ and A. A. Ogloblin
Kurchatov Institute, Kurchatov square 1, 123182 Moscow, Russia
(Received 27 March 2001; published 13 August 2001)

Experimental search for ^{5}H using a secondary beam of ^{6}He has been performed. The transfer reaction ^{1}H(^{6}He, ^{2}He)^{5}H was studied by detecting two protons emitted from the decay of ^{2}He. A peak consistent with a ^{5}H resonance at 1.7 ± 0.3 MeV above the $n + n + t$ threshold was observed, with a width of 1.9 ± 0.4 MeV. The angular distribution of the ^{1}H(^{6}He, ^{2}He)^{5}H reaction was measured as well as the energy correlation of the two protons.



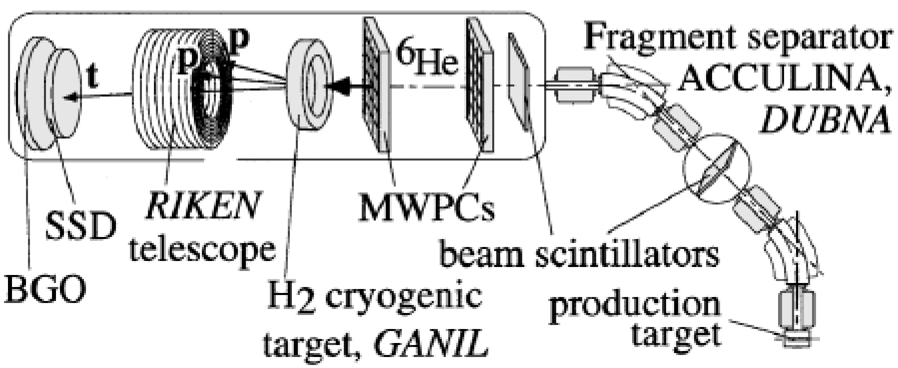
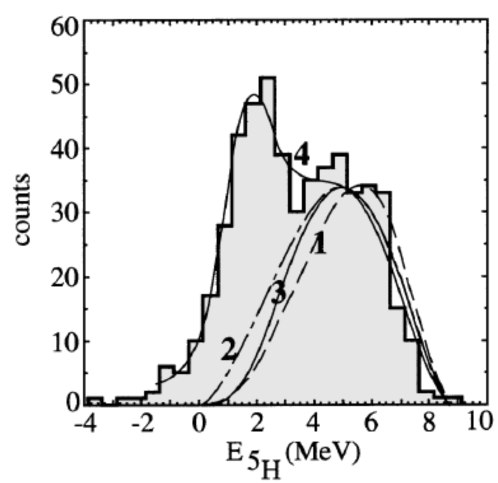


FIG. 1. Scheme of the experimental setup.



Spectrum of ^{5}H from the reaction p(^{6}He, ppt).

Phys. Rev. Lett. **87**, 092501 (2001)

Key stone for common successful research at Acc-2 in collaboration with foreign institutes

1. Competent manpower

tandem between theory and experiment

2. Modern equipment and methods

decay in flight via vertex method + GADAST + OTPC
tritium target, transfer reactions and correlation measurements in full angular range $\theta_{c.m.}$

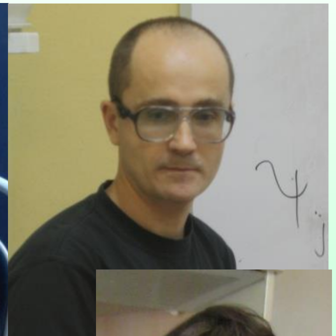
↓↓↓↓↓

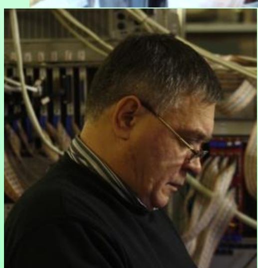
3. Complimentary study of exotic nuclei:

a) ^{12}O, ^{16,17}Ne, ^{19}Mg, ^{26,27}S, ^{34}Ca, etc.

b) ^{7}H, ^{10}He, ^{11}Li, ^{16}Be, ^{26,28}O, etc.

People






THEORY

JINR, FLNR: LG, Yu. Parfenova, P. Sharov

JINR, BLTP: S. Ershov, I. Egorova

Geteborg University: M. Zhukov

EXPERIMENT

JINR, FLNR: A. Fomichev, M. Golovkov, S. Sidorchuk, G. Ter-Akopian, A. Bezbakh, R. Wolski, A. Gorshkov, V. Gorshkov, R. Slepnev, G. Kaminski, S. Krupko, V. Chudoba, P. Jaluvkova

Kurchatov Institute: E. Nikolskii, E. Kuzmin

RNFC Sarov: A. Yukhimchuk, S. Filchagin, A. Kirdyashkin

PTI St. Petersburg: V. Eremin

Warsaw University: M. Pfutzner, W. Dominik, Z. Janas, K. Miernik, S. Mianowski

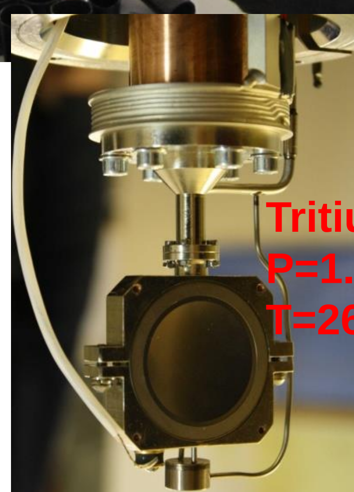
GSI, Darmstadt: H. Simon, I. Mukha, Ch. Scheidenberger



Equipment

- ✓ Cryogenic tritium and ^{3}He targets, solid targets ^{14}C, Ti-T(0.3-5 mg/cm^{2})
- ✓ Stilbene detectors; planar Si detectors for beam monitoring and $E_{residual}$
- ✓ Optical Time Projection Chamber (active target mode – H_2, D_2, ^{3}He)
- ✓ CsI & Si arrays (collaborations with CALIFA @ R^{3}B, EXL; HYDE @ LEB)

CsI(Tl) 15 cm + PMT
←← GADAST



Tritium
P=1.07 bar
T=26^{O} K

stilbene based detectors:
crystal ∅ 80 mm x 50 mm
ETE9822B & XP4312B
64 units ↓↓

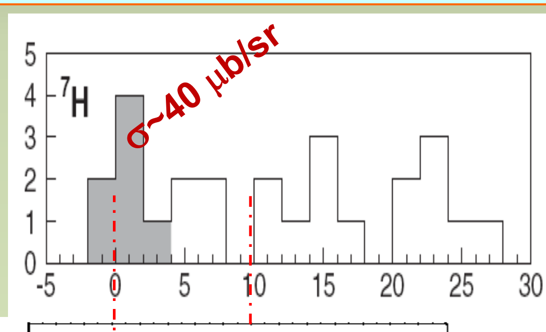
^{7}H: Experimental evidence for the existence

Probably ^{8}He in not so good projectile to populate amorphous ^{7}H

^{12}C(^{8}He,^{13}N)^{7}H

E=15.4 AMeV

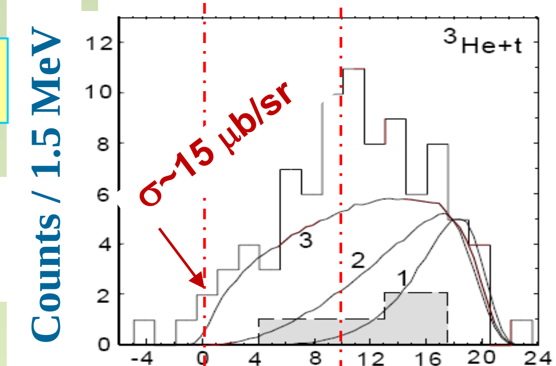
Caamano et al., PRL 99(2007)



d(^{8}He,^{3}He)^{7}H

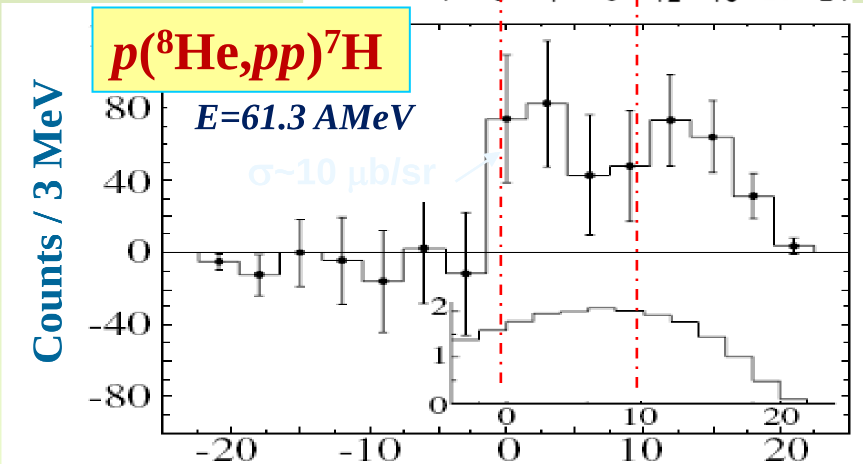
E=42 AMeV

Nikolskii et al., PRC 81(2010)



p(^{8}He,pp)^{7}H

E=61.3 AMeV

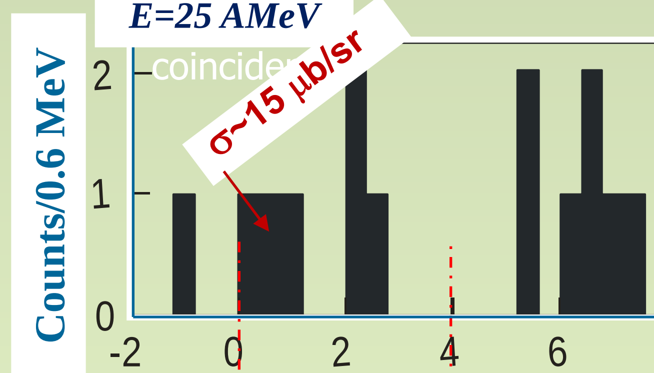


Korsheninnikov et al., PRL 90(2003)

Golovkov et al., EXON-2006 p.32

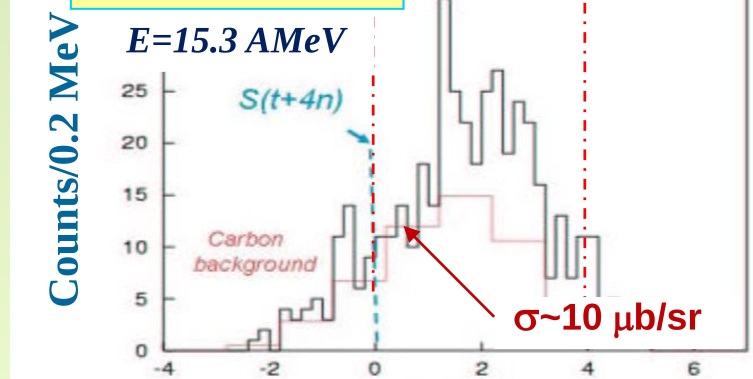
d(^{8}He,^{3}He)^{7}H

E=25 AMeV



d(^{8}He,^{3}He)^{7}H

E=15.3 AMeV



Fortier et al., EXON-2006 p.3

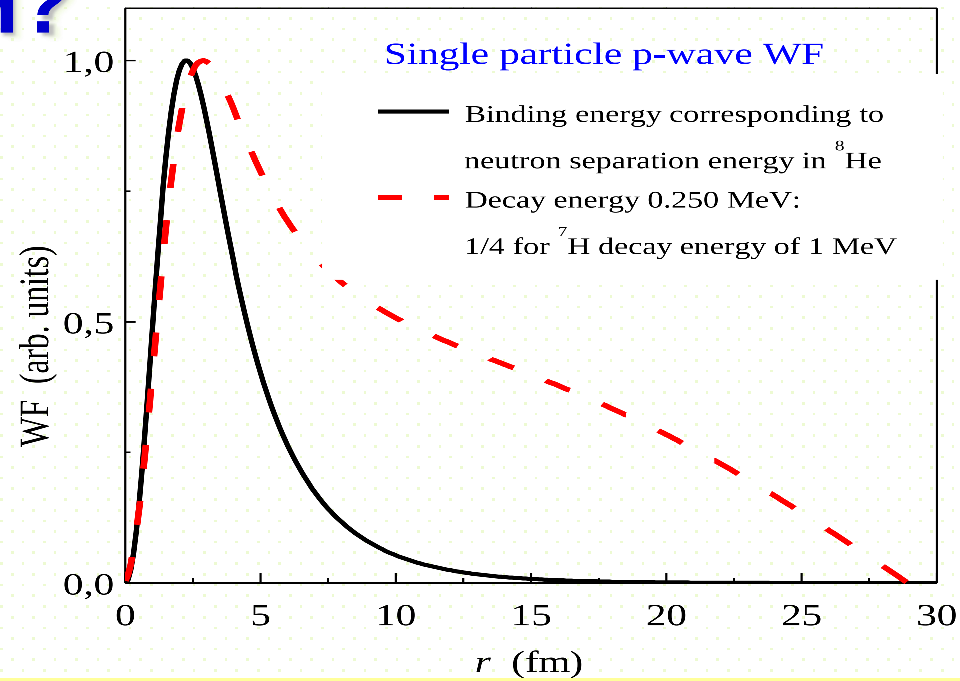
How to understand ^7H?

Possible explanation for low ^7H population in reactions with ^8He

Unusual spectroscopic suppression

Extreme long range character of ^7H continuum WF

Possible structural shift $[p^4] \rightarrow [s^2p^2]$ in the subbarrier region



Very low overlap between bound single particle WF in initial nucleus and typical single-particle continuum WF in ^7H.
The total spectroscopic factor for ^7H is 4-th power of this overlap!!

Possible way out:

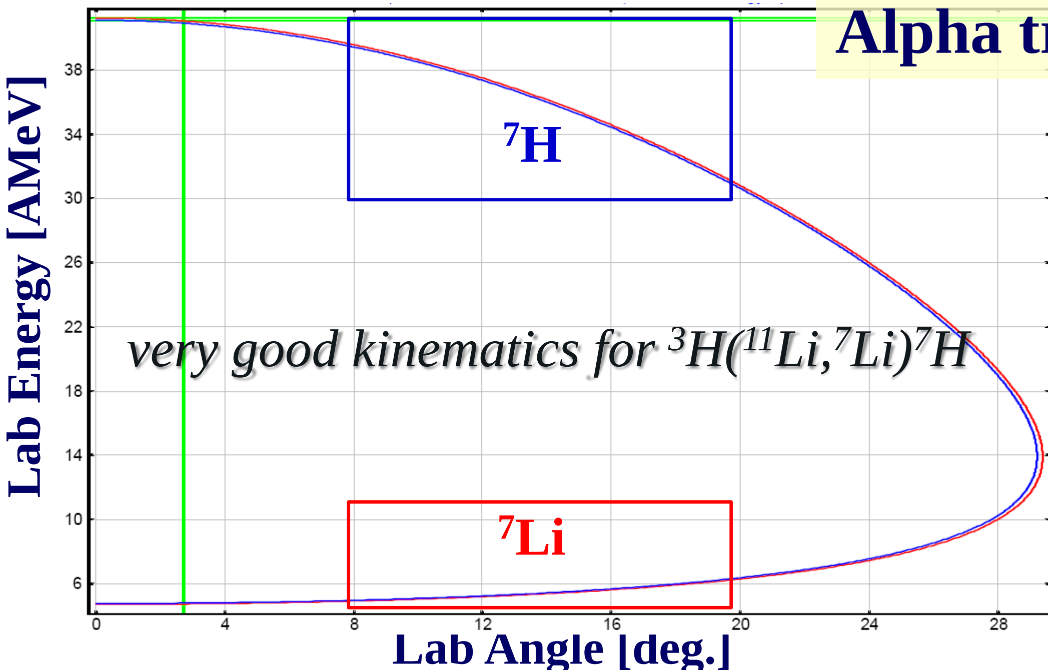
population of ^7H from nuclei with extreme radial extent of WF

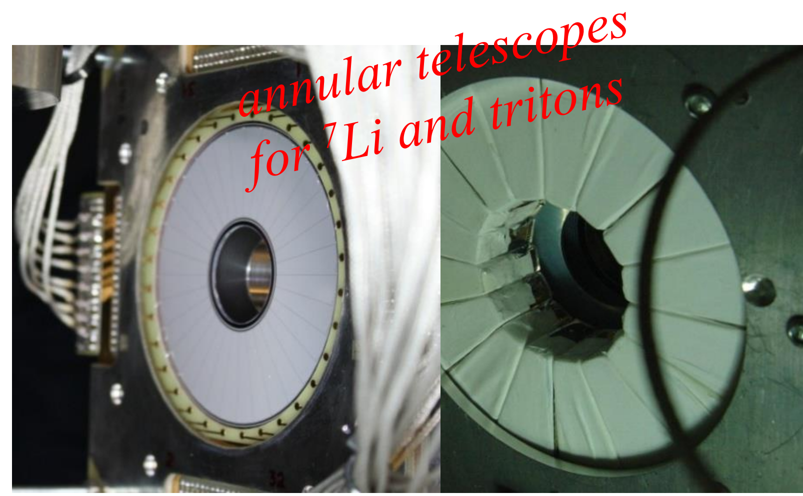
Alpha knockout and transfer reactions from ^{11}Li seems to be most attractive:

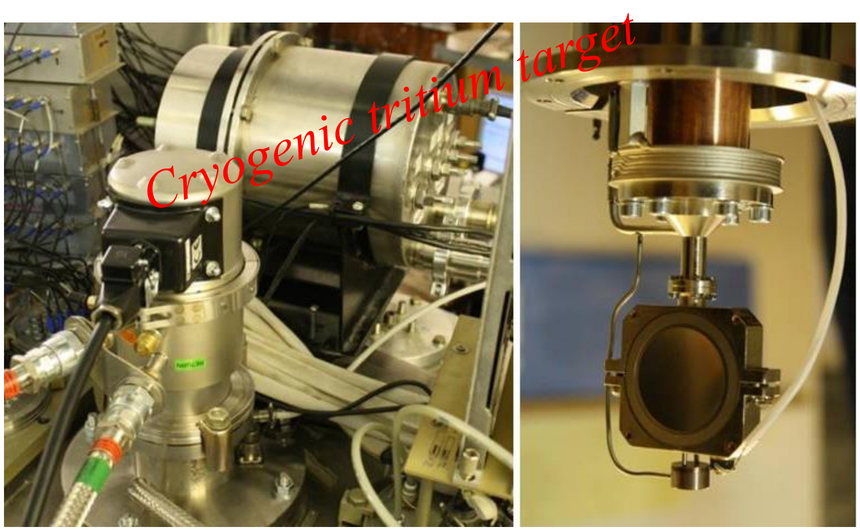
$\alpha(^{11}Li, 2\alpha)^7H$, $^3H(^{11}Li, ^7Li)^7H$

^{7}H via ^{11}Li

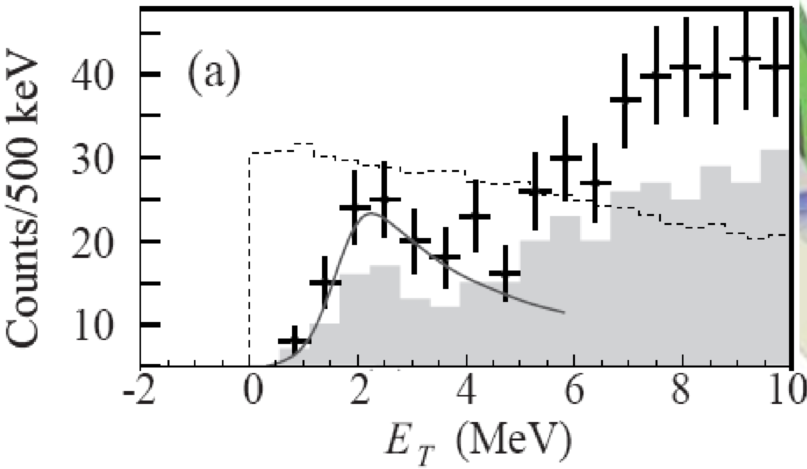
Acculinna-2: ~10^4 ^{11}Li/s @ 30 AMeV
Alpha transfer from ^{11}Li on ^{3}H

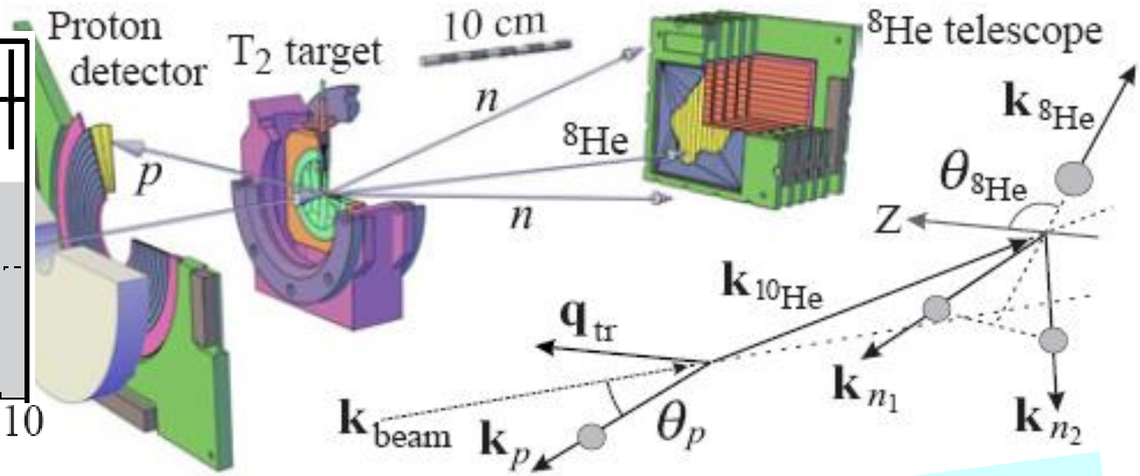






^{10}He: ^{3}H(^{8}He,p)^{10}He

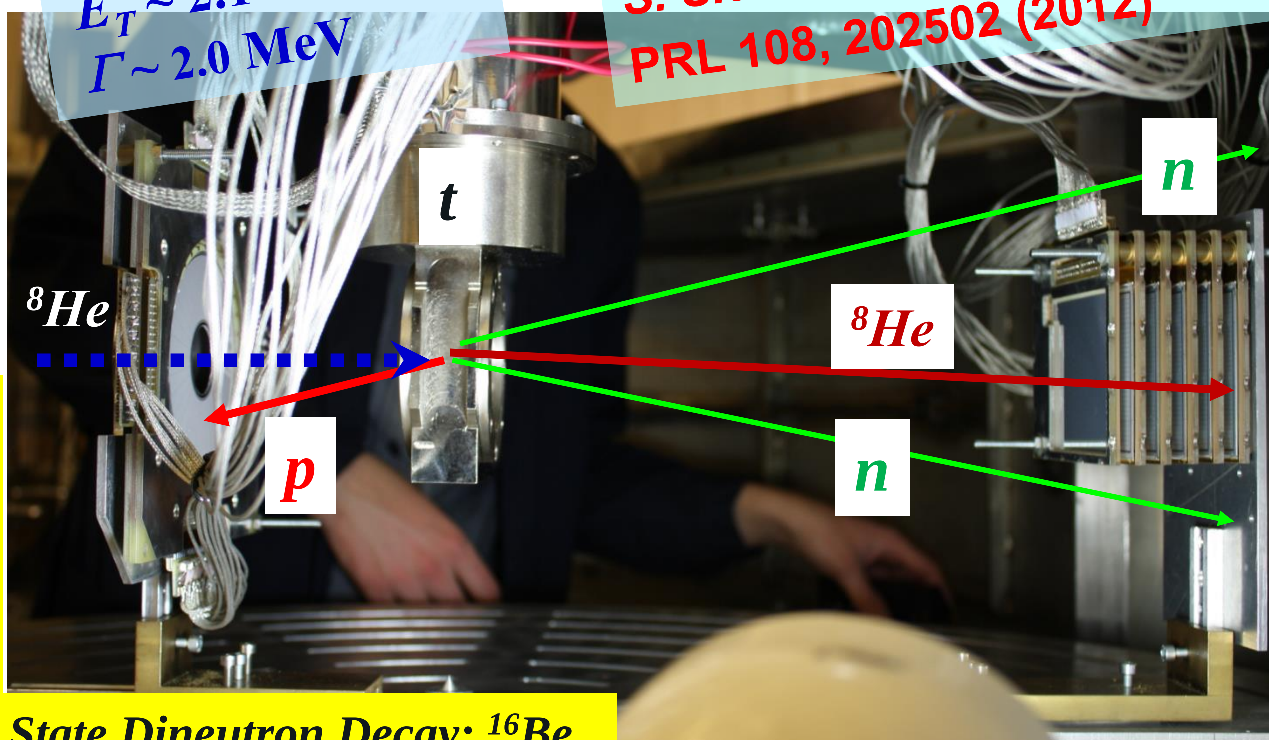




$E_T \sim 2.1\pm0.2$ MeV
$\Gamma \sim 2.0$ MeV

S. Sidorchuk et al.,
PRL 108, 202502 (2012)

^{8}He beam:
E ~ 23 A·MeV
I ~ 15000 s^{-1}
Tritium target:
6 mm thick @ 99.7 %
0.92 atm @ 26 K



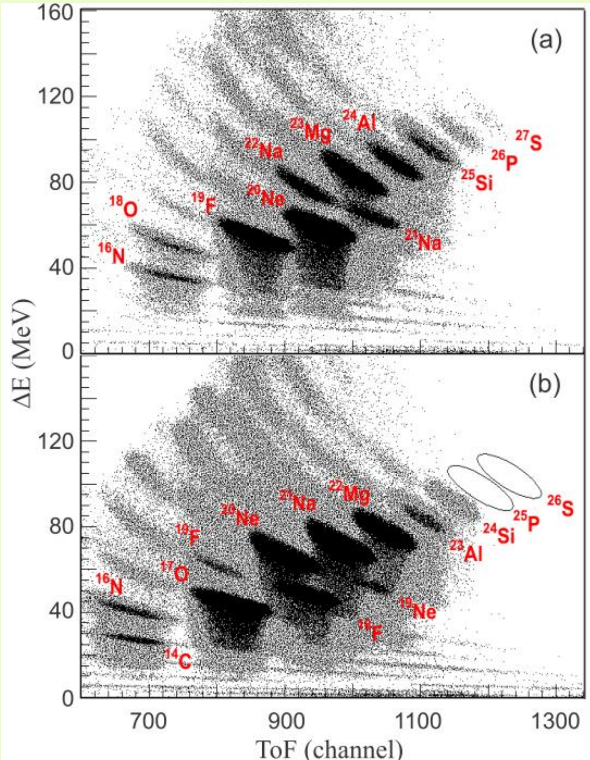
^{16}Be prospect:

^{3}H(^{14}Be,p)^{16}Be

PRL 108, 102501 (2012)

First Observation of Ground State Dineutron Decay: ^{16}Be

Search for ^{26}S in fragmentation ^{32}S(50 AMeV) + Be



A. Fomichev *et al.*, IJMPE **20** (2011) 1491

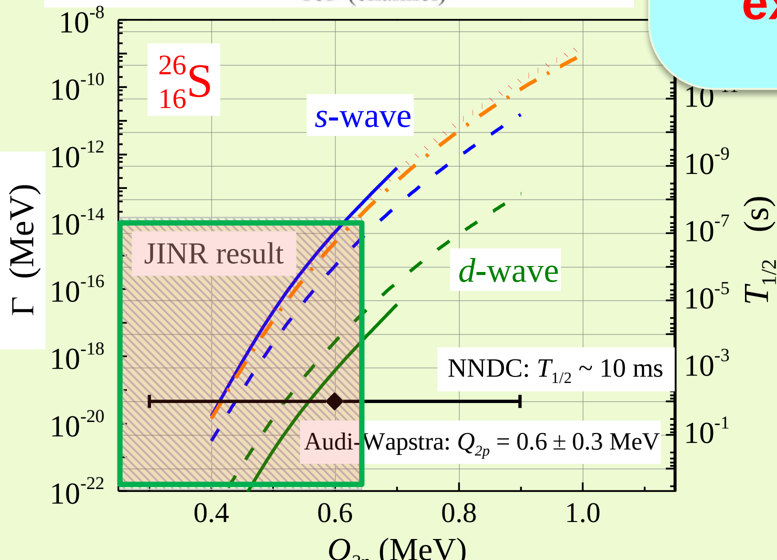
NNDC: $T_{1/2}$ ~ 10 ms

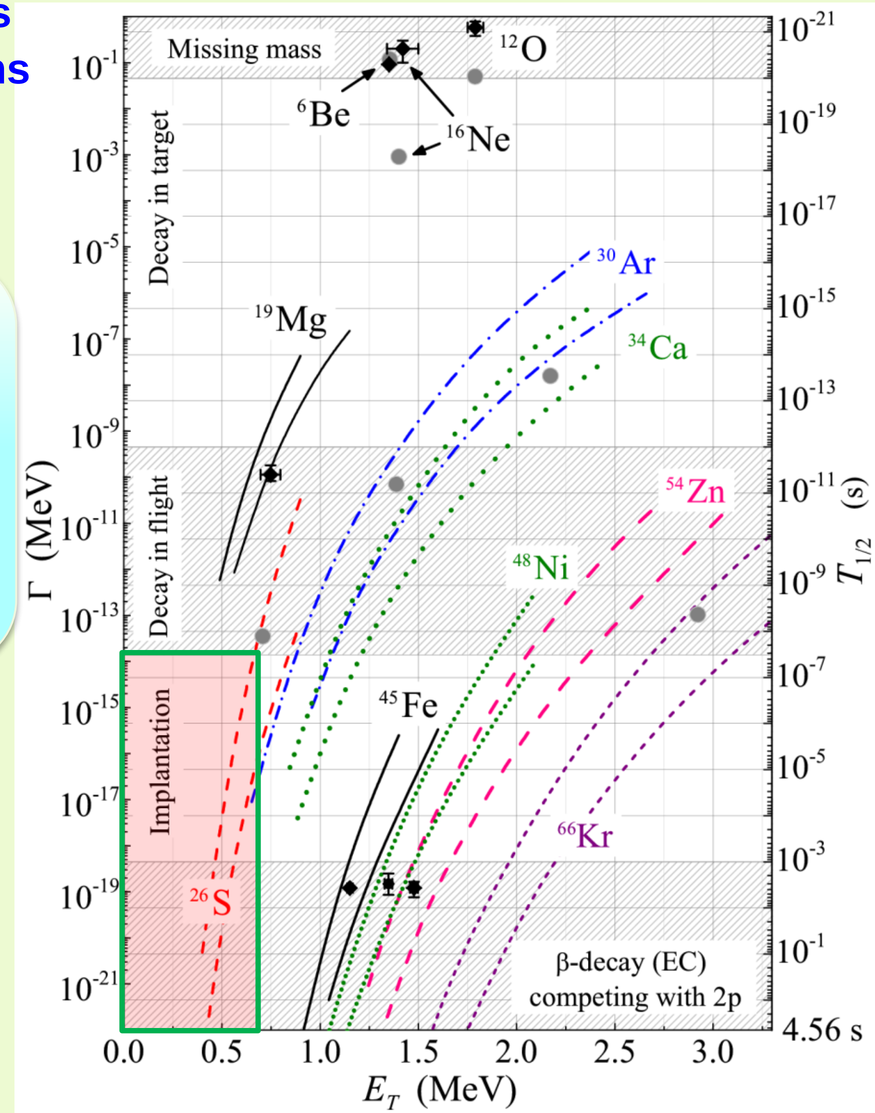
ToF_{F1-F4} ~ 0.0003 ms

$T_{1/2}$ < 80 ns,

Q_{2p} > 640 keV

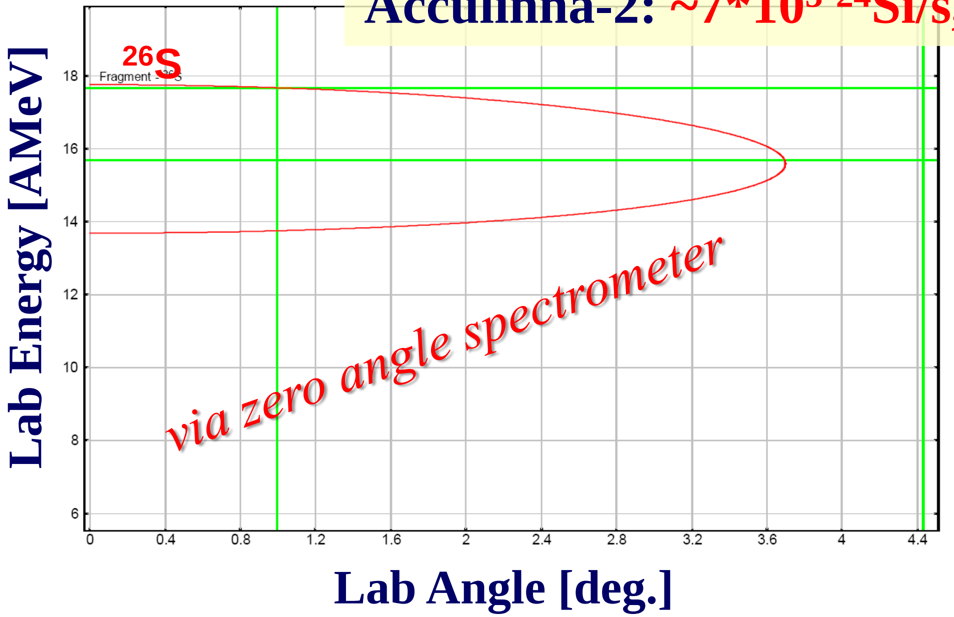
Further search for ^{26}S in different technique is expected

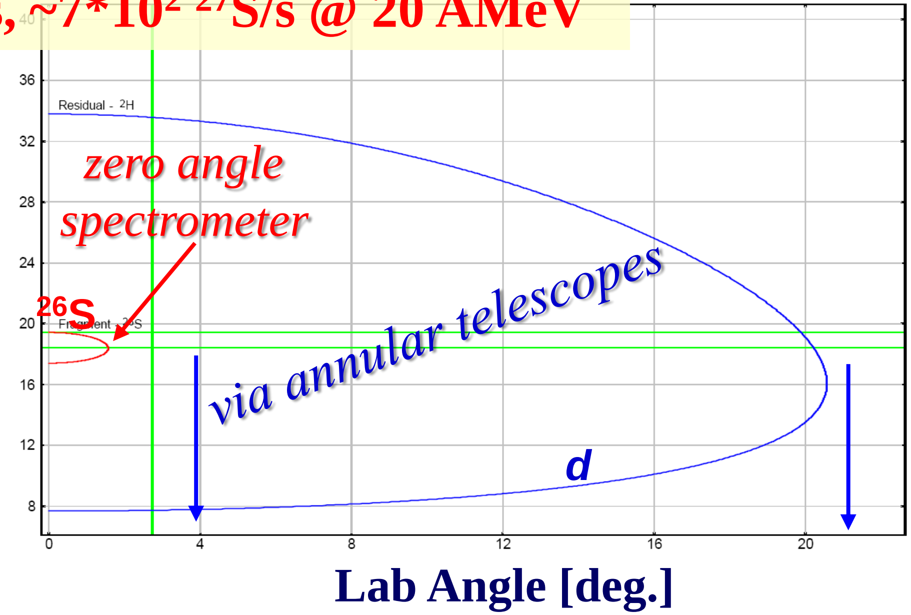


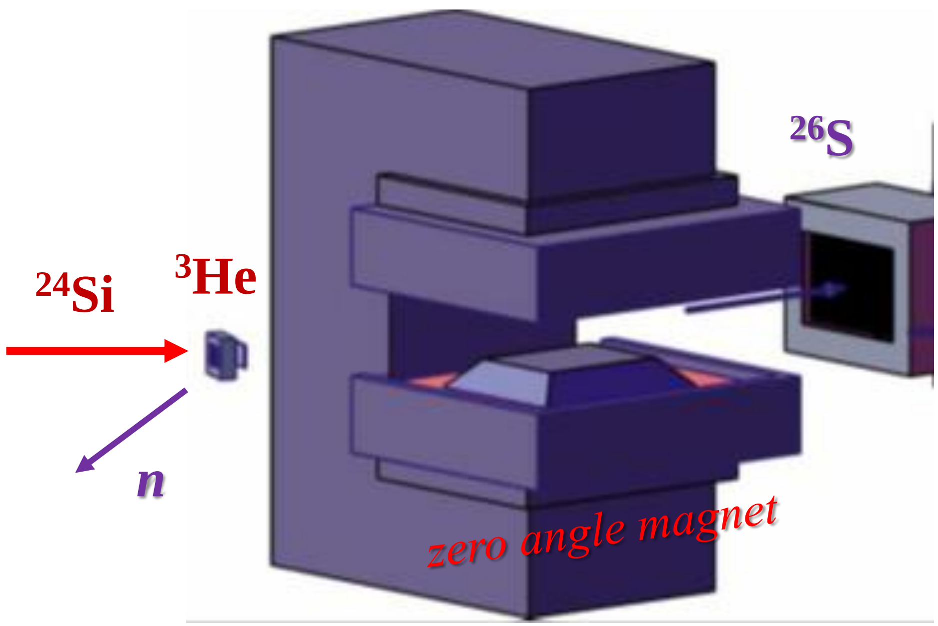


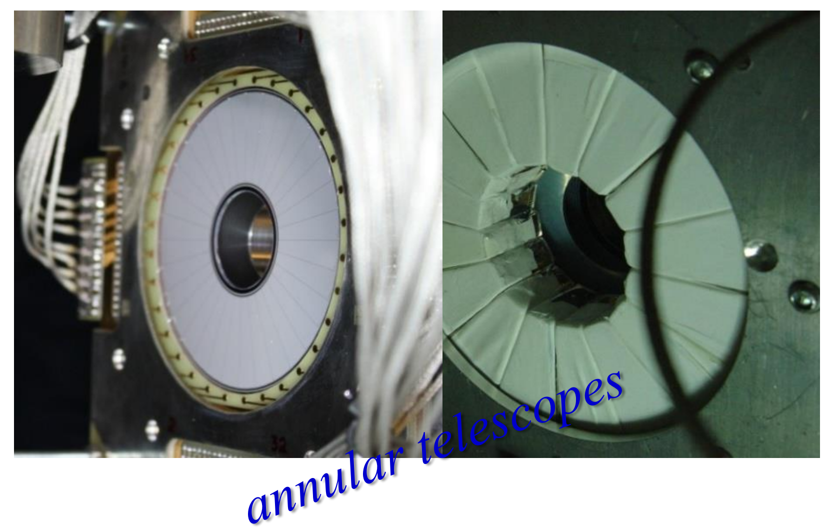
^{26}S: $^{24}Si + {}^{3}He \Rightarrow {}^{26}S + n$ *and* $^{27}S + p \Rightarrow {}^{26}S + d$

Acculinna-2: ~$7 \cdot 10^{3}$ ^{24}Si/s, ~$7 \cdot 10^{2}$ ^{27}S/s @ 20 AMeV



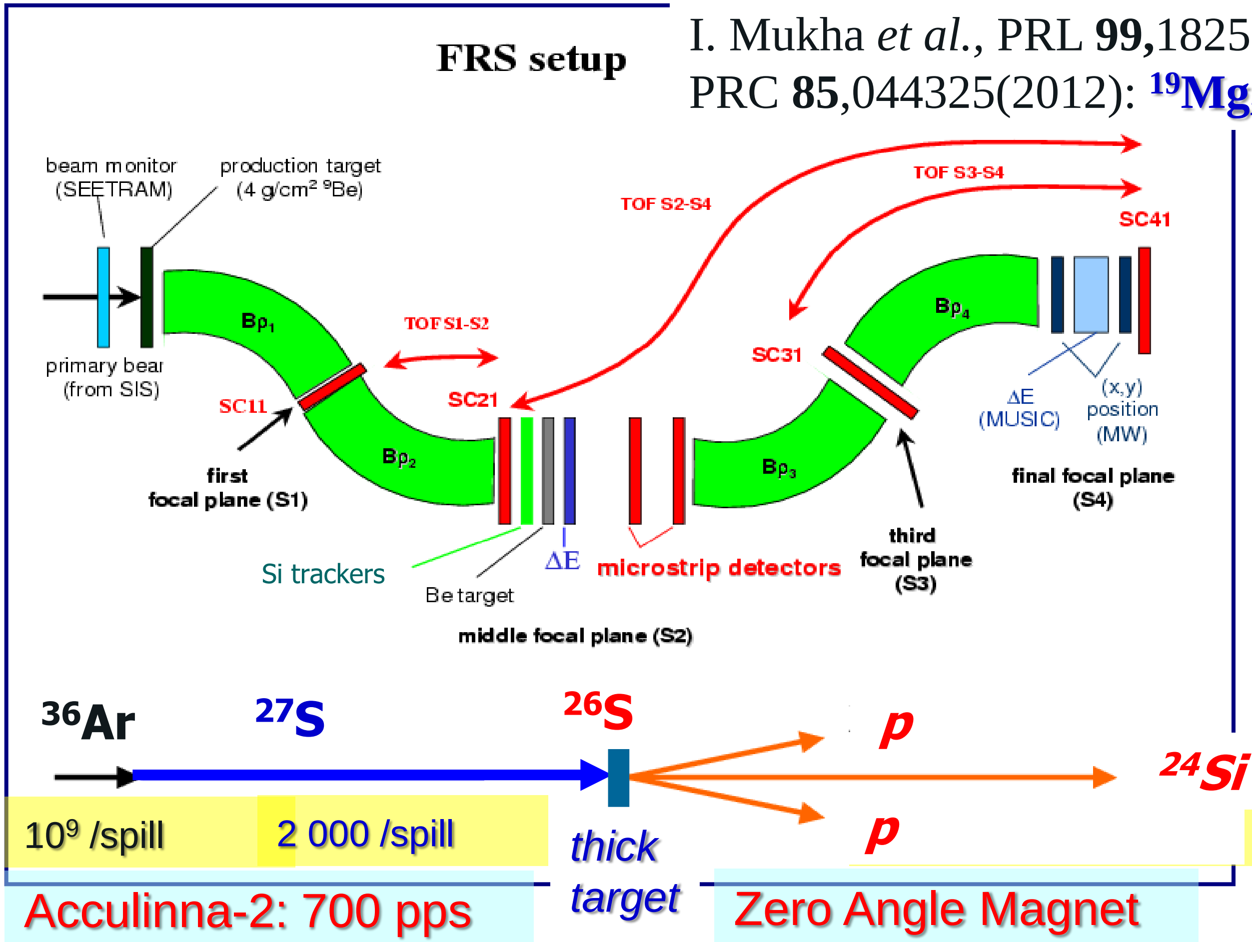


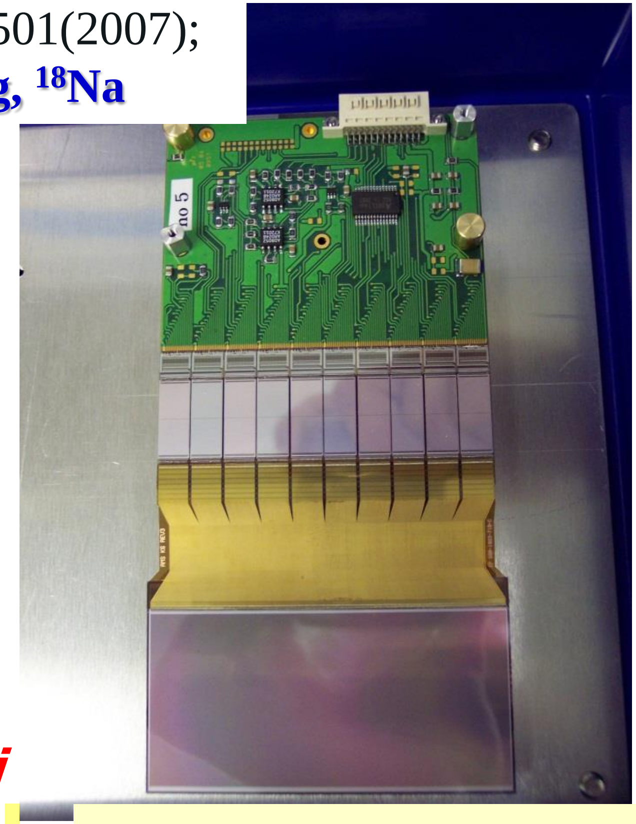




Perspectives with decay in-flight technique at Acculinna-2

I. Mukha *et al.*, PRL **99**,182501(2007); PRC **85**,044325(2012): ^{19}Mg, ^{18}Na





FLNR is now involved into μ-strips business

i **wide range for $T_{1/2}$: from 0.1 ps up to 10 ps**

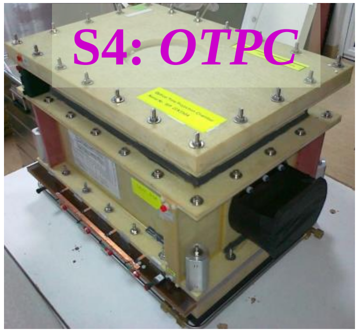
ii **correlations between two protons and core-proton**

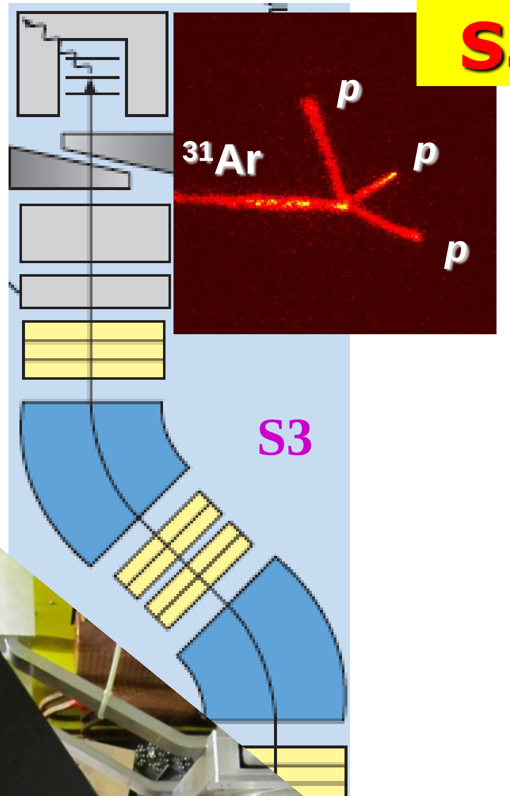
iii **work with "cocktail" beam measuring several nuclides per run**

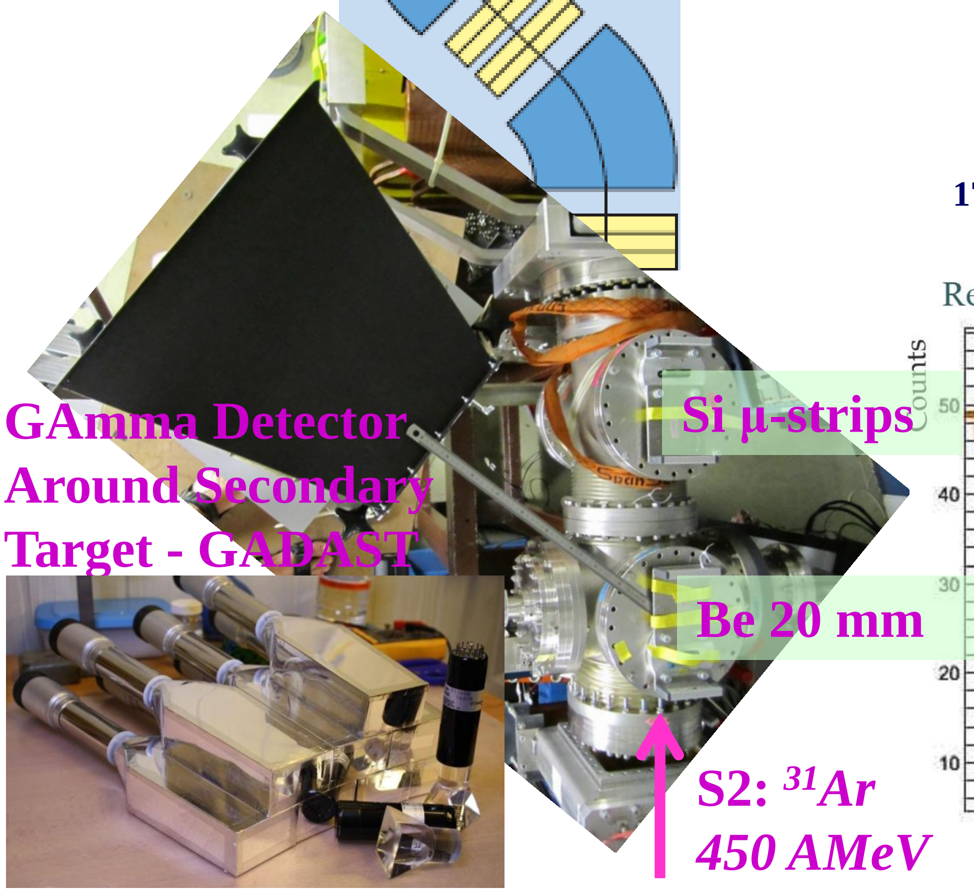
iv **decay mechanism and structure of ^{26}S (^{30}Ar, ^{34}Ca etc.)**

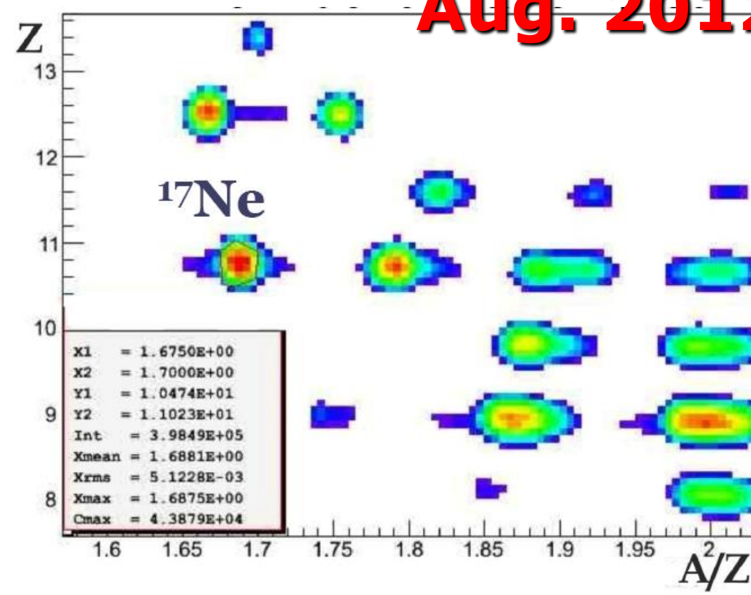
S388 – 3 methods on one run

Aug. 2012



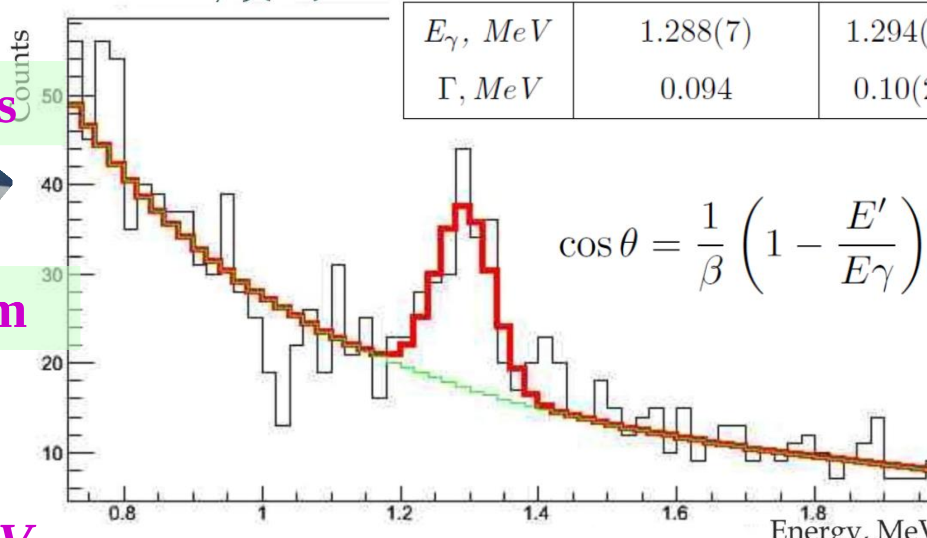






^{17}Ne spectrum with Doppler correction

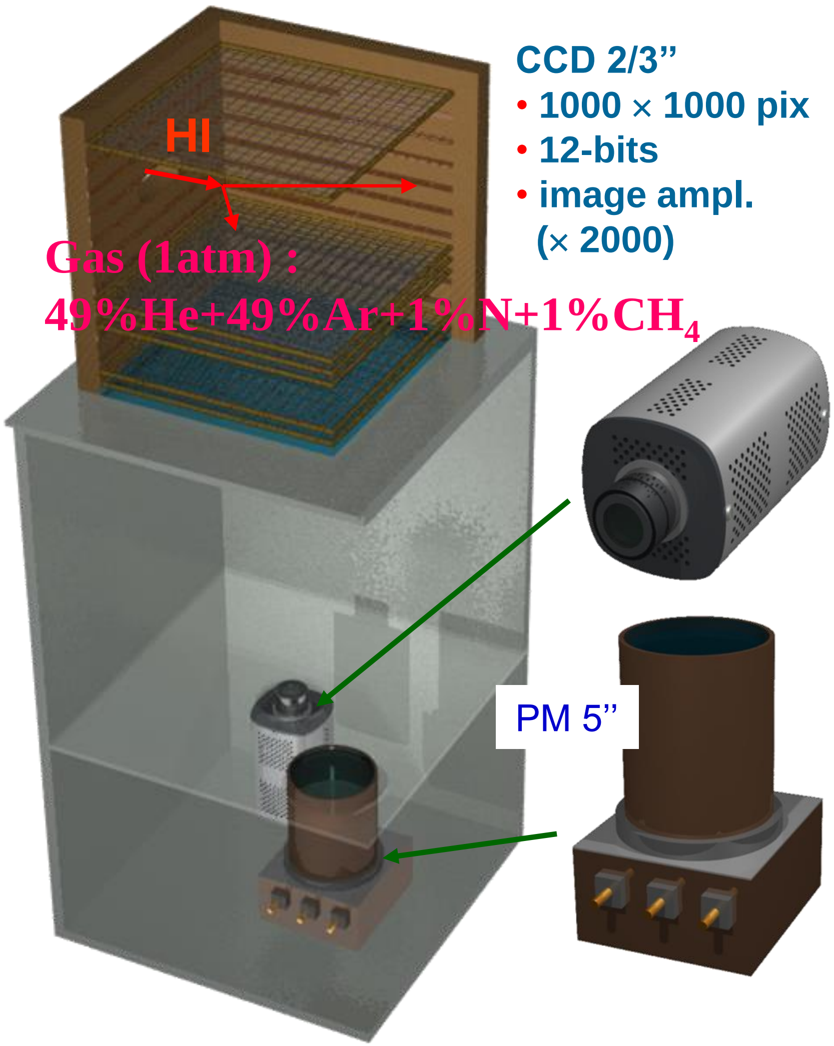
Quantity	Reference data	Our data
E_γ, MeV	1.288(7)	1.294(8)
Γ, MeV	0.094	0.10(2)



$$\cos\theta = \frac{1}{\beta}\left(1 - \frac{E'}{E\gamma}\right)$$

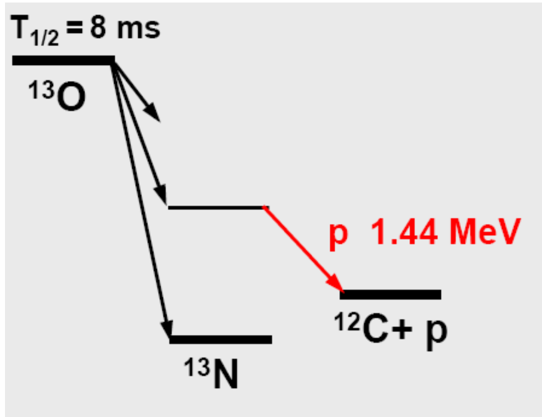
Optical Time Projection Chamber (OTPC) is an effective tool for the study of rare decay modes of exotic nuclei

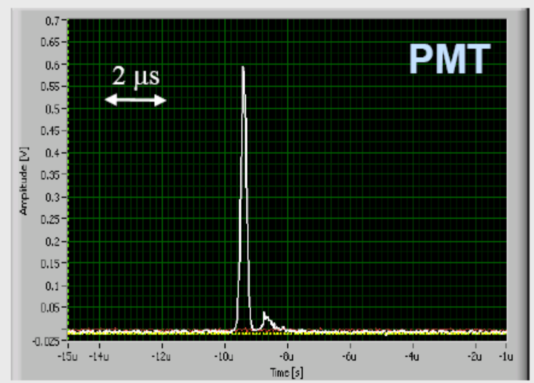
$T_{1/2}$: 1-500 ms

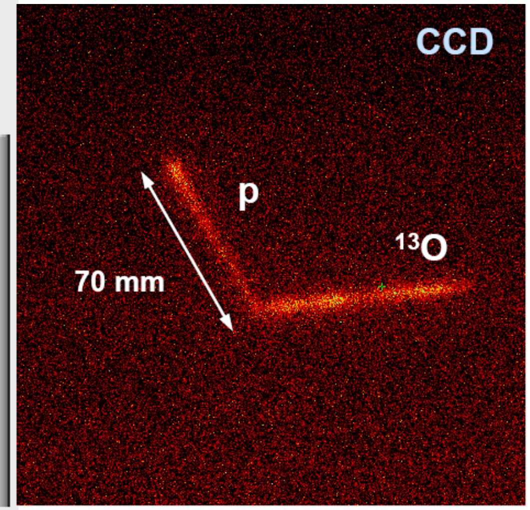


CCD 2/3''
- 1000 × 1000 pix
- 12-bits
- image ampl. (× 2000)

Gas (1atm) : 49%He+49%Ar+1%N+1%CH_4







^{43}Cr, ^{45}Fe, ^{48}Ni @ MSU

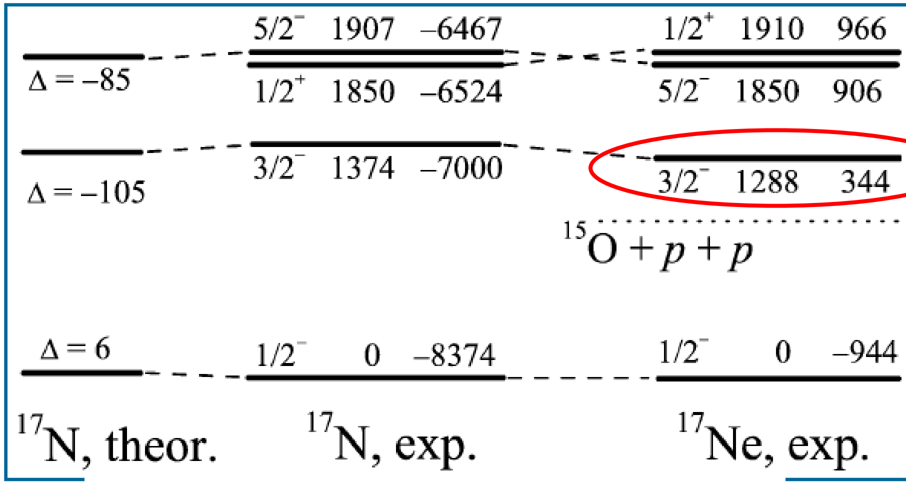
^{31}Ar @ GSI; ^{6}He @ CERN

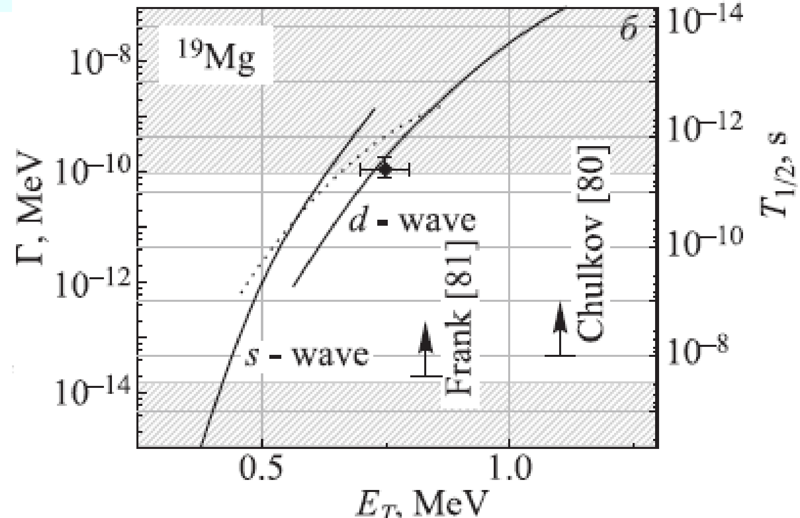
^{8}He, ^{14}Be, ^{27}S @ FLNR

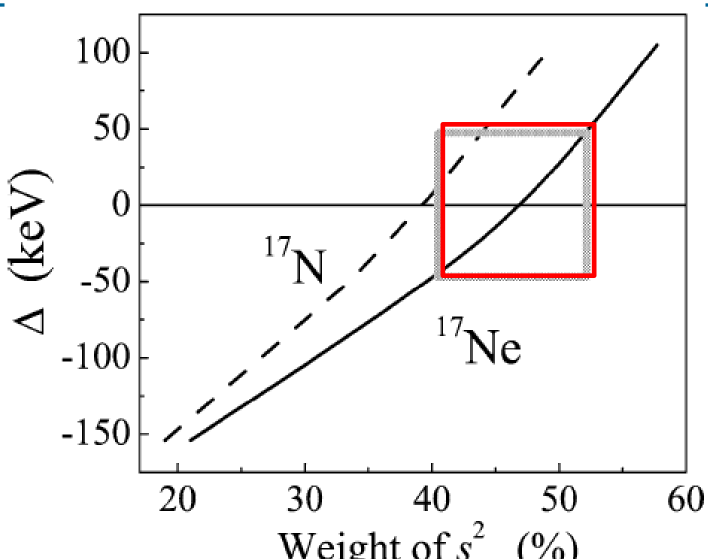
M. Ćwiok et al., IEEE TNS, 52 (2005) 2895
K. Miernik et al., NIM A581 (2007) 194

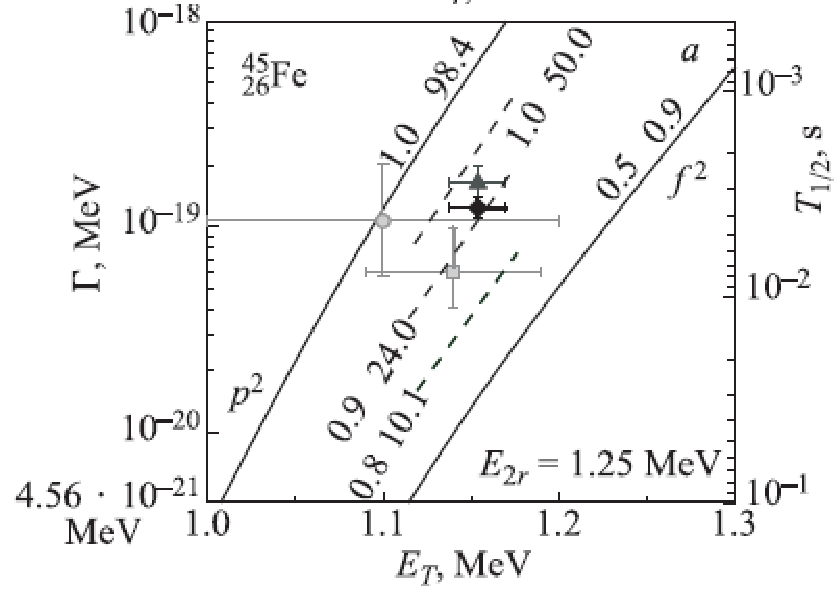
^{17}Ne

- *All condition for 2p decay from 1st excited state ^{17}Ne*
- *Theoretical estimation is $\Gamma_{2p}(^{17}Ne^*) < 6\times10^{-15}$ MeV*
- *Agreement between theory and experiment for 2p-decay from ground state of ^{19}Mg, ^{45}Fe, ^{48}Ni, ^{54}Zn*



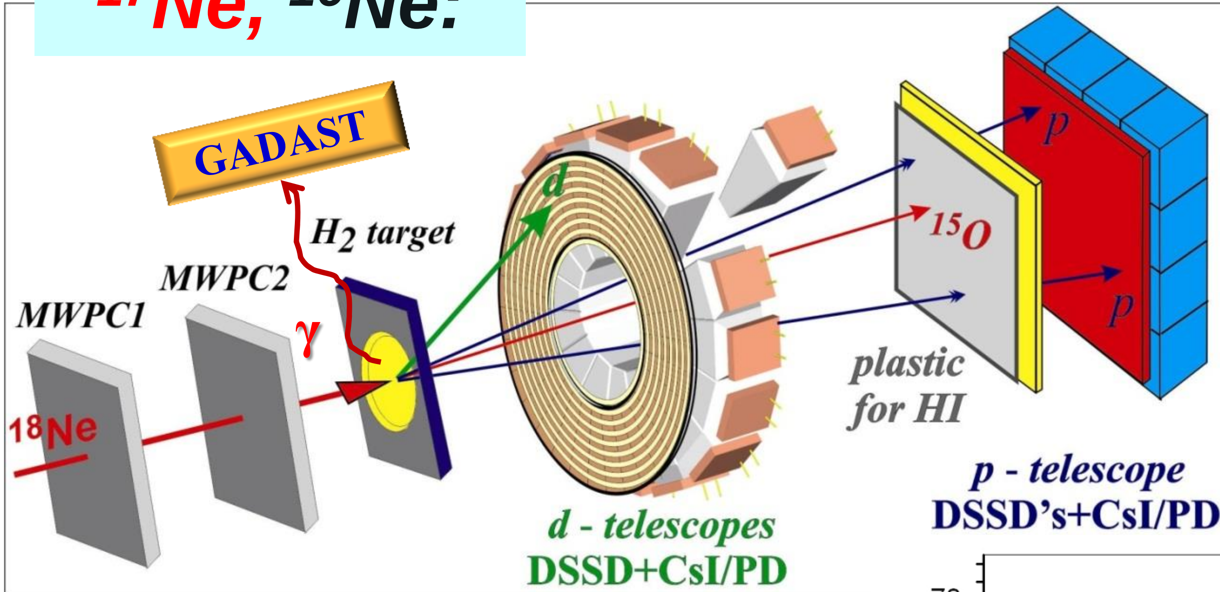






Grigorenko, Mukha, Zhukov, NPA713 (2003) 372;
Grigorenko, Zhukov, PRC76 (2007) 014008; Григоренко, ЭЧАЯ, Т.40 (2009) 1273

^{17}Ne, ^{16}Ne:



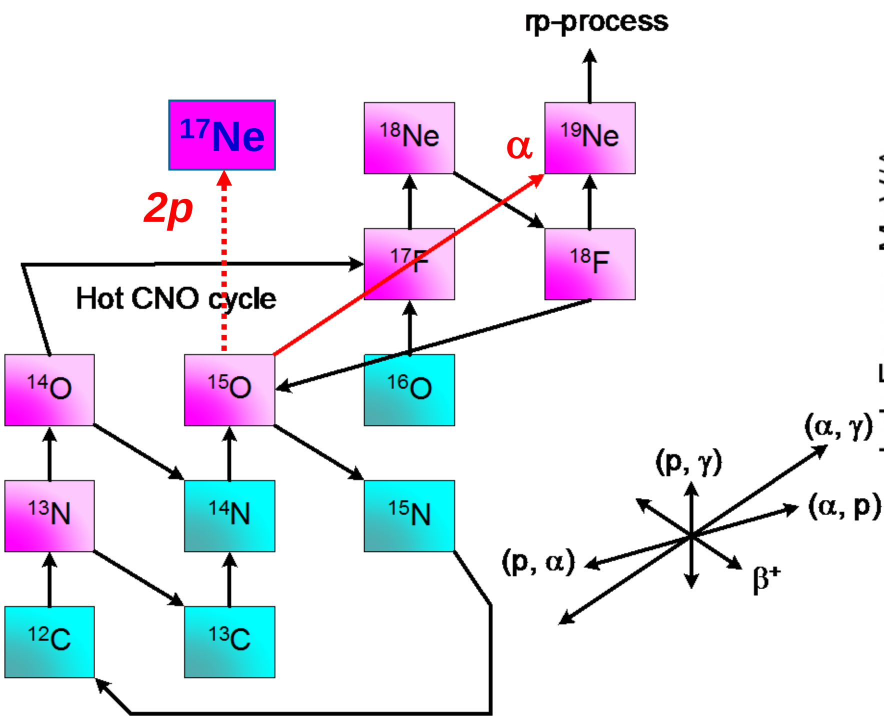
p(^{18}Ne,d)^{17}Ne

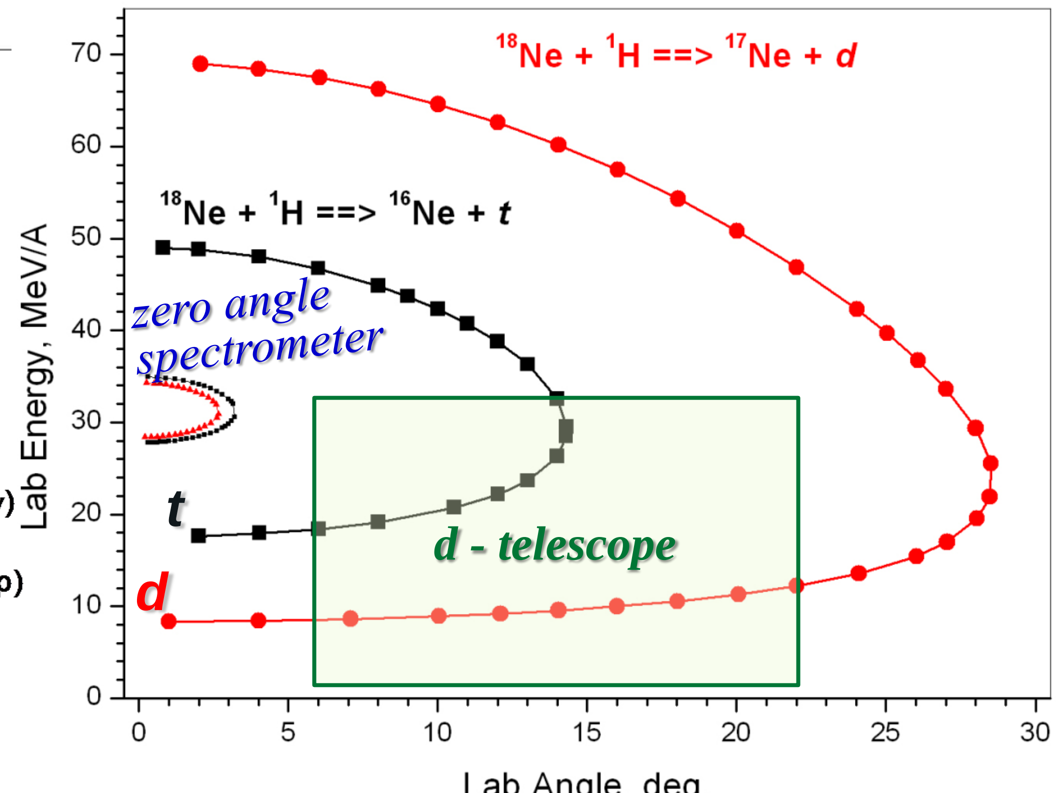
^{15}O(2p,γ)^{17}Ne

3/2⁻ at 1288 keV (Q_{2p}=344 keV)

p(^{18}Ne,t)^{16}Ne

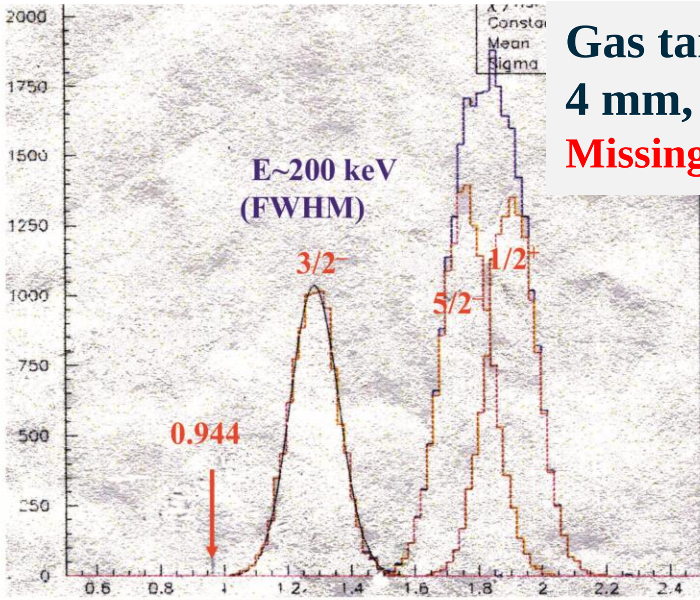
Level structure for ^{16}Ne

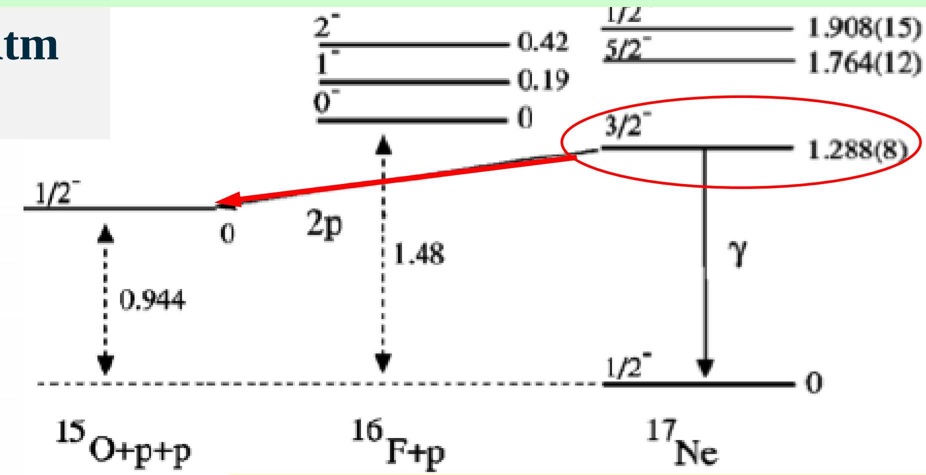




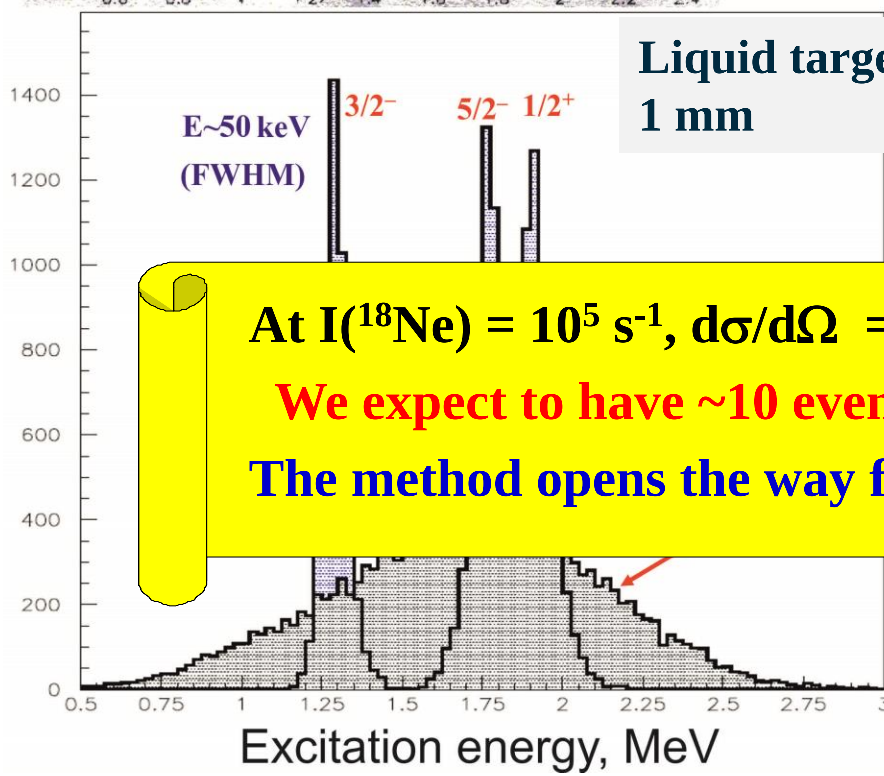
Simulation: $p(^{18}Ne,d)^{17}Ne$@35AMeV

Gas target:
4 mm, 27 K, 4 Atm
Missing mass



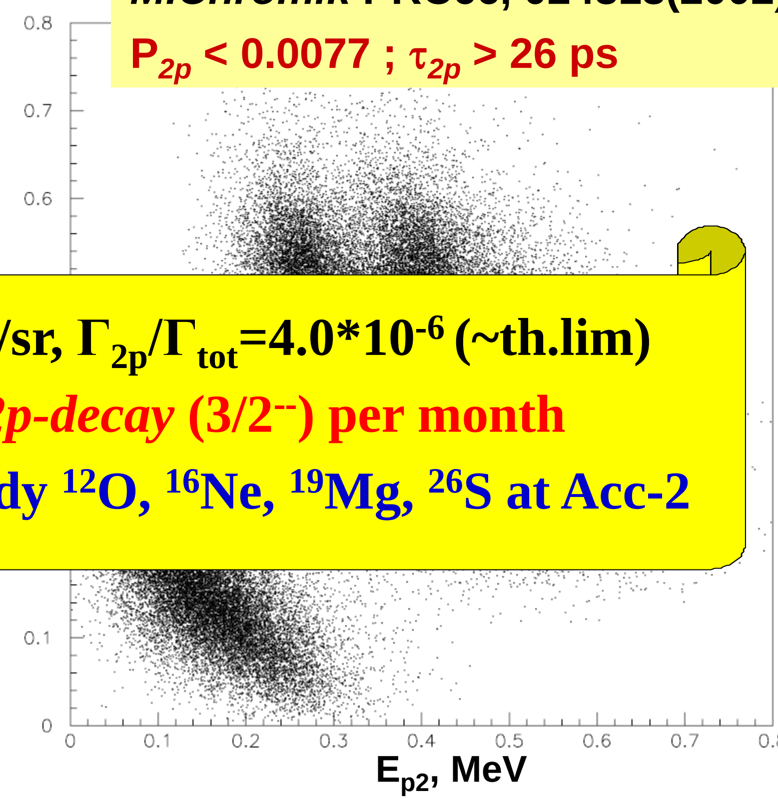


Liquid target:
1 mm



M.Chromik **PRC66, 024313(2002)**

P_{2p} < 0.0077 ; τ_{2p} > 26 ps



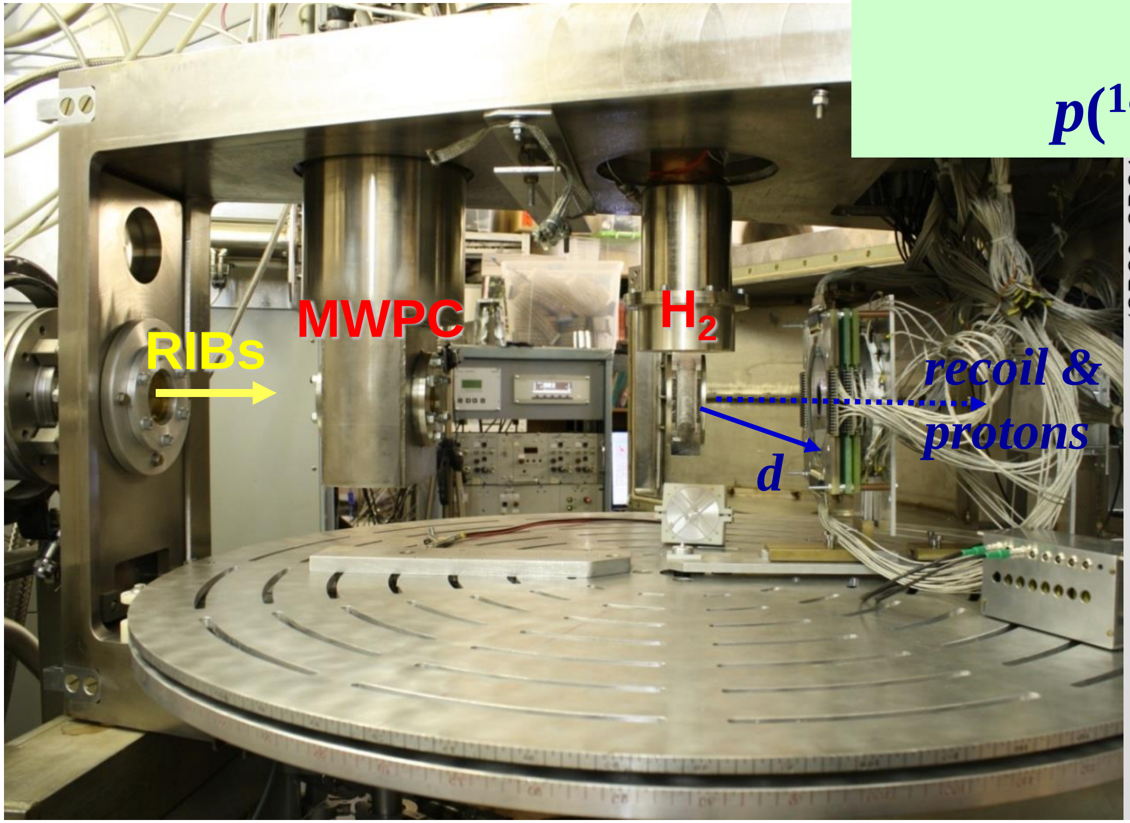
At I(^{18}Ne) = 10^5 s^{-1}, dσ/dΩ = 1 mb/sr, Γ_{2p}/Γ_{tot}=4.0*10^{-6} (~th.lim)

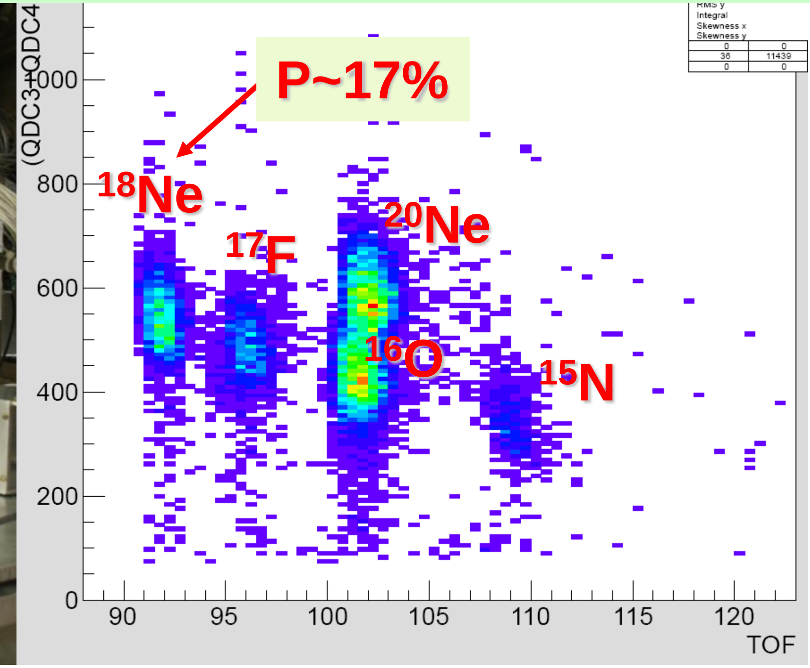
We expect to have ~10 events of *2p-decay* (3/2⁻) per month

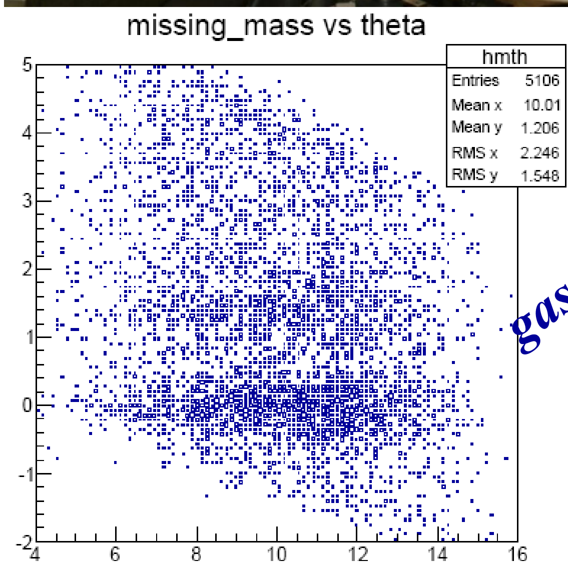
The method opens the way for study ^{12}O, ^{16}Ne, ^{19}Mg, ^{26}S at Acc-2

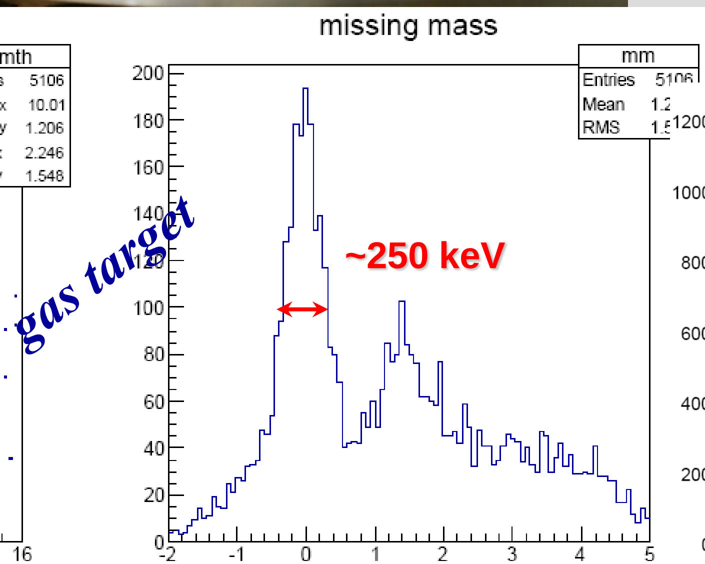
Preliminary results

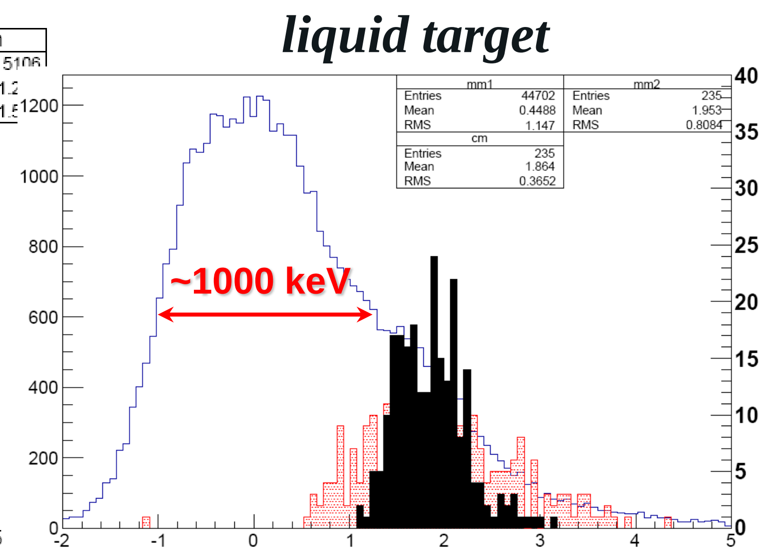
p(^{18}Ne,*d*)^{17}Ne@35AMeV











*   Summary   *

In the frame of the DRIBs-III project future study of light exotic systems and super heavy elements is foreseen.

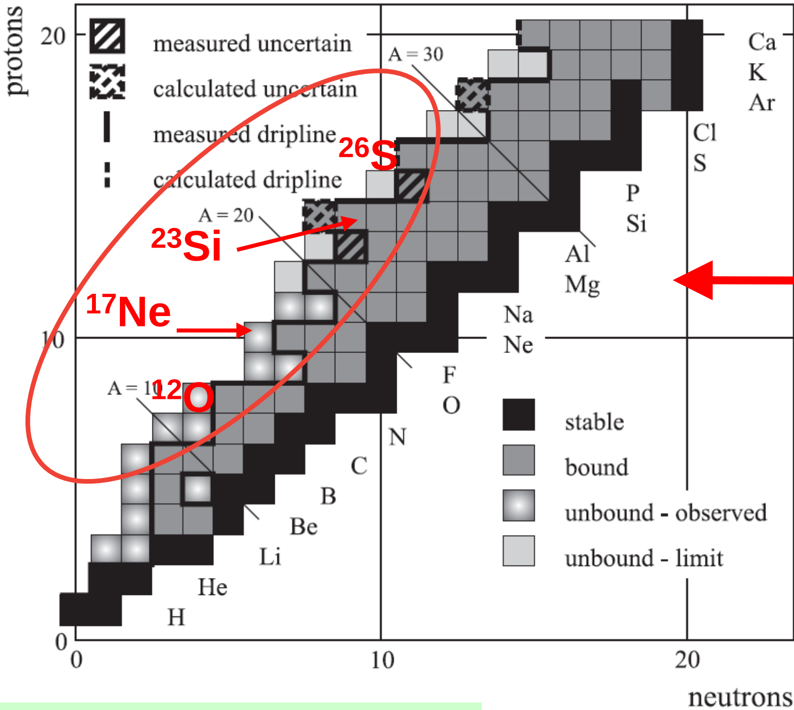
Building of the factory (new DC-280 cyclotron and related setups) for SHE is in a progress. Commissioning test is in 2016.

A new more powerful facility ACCULINNA-2 intended for the radioactive ion beams production is going on and will be put into operation in 2015. Conceptual design report for A-e collisions is going on to be realized in 2017-2022.

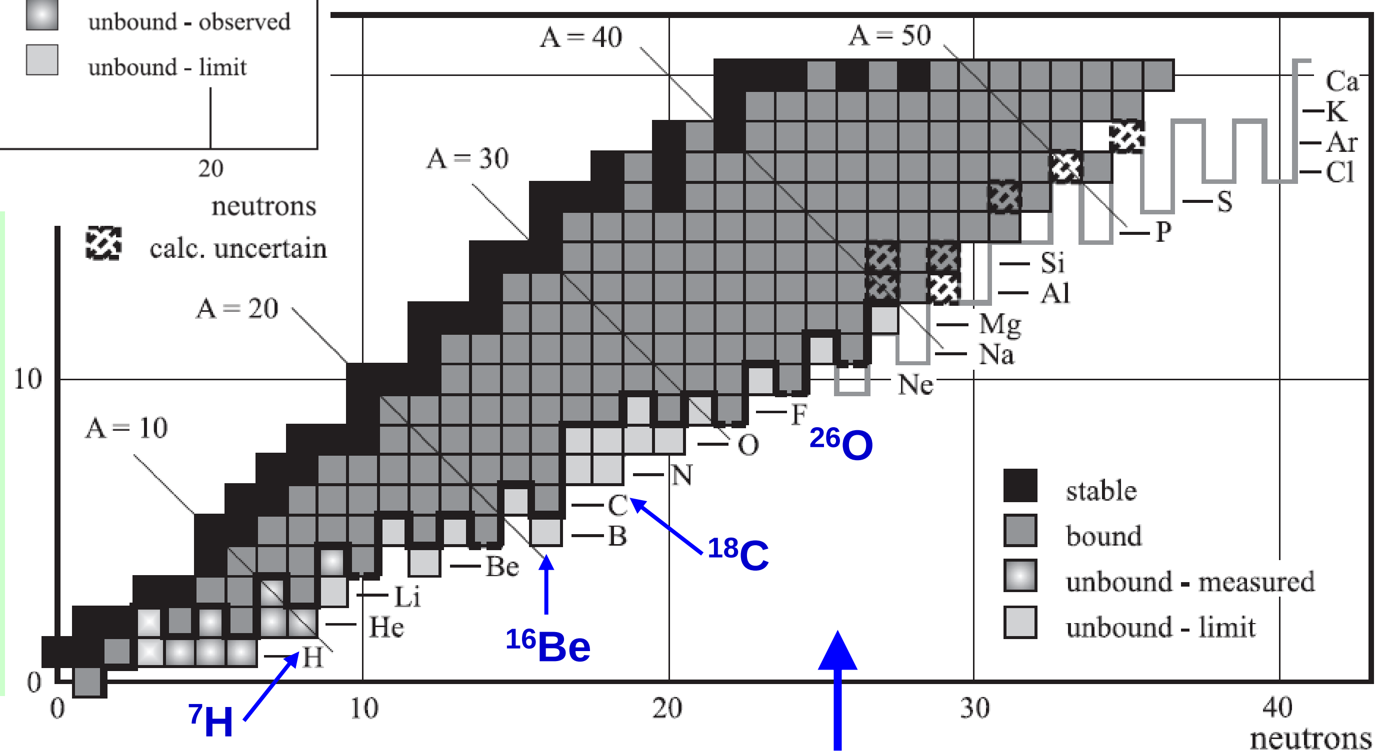
RIB scientific program implies an extensive use of advantages of low energy RIB's (E~10-50A MeV), cryogenic gaseous targets (including tritium) and modern technique for the study of light exotic nuclei with Z<20.

Day-1 experiments aimed on the studies of the structure of proton rich nuclei ^{12}O, ^{16,17}Ne, ^{19}Mg, ^{26,27}S and extremely neutron rich isotopes like ^{7}H, ^{10}He, ^{11}Li, ^{16}Be, ^{19}C, ^{26}O are proposed.

Day-1 experiments



one, two and three proton decays of ^{12}O, ^{16,17}Ne, ^{26,27}S using the modern methods: decay in flight, OTPC, correlations in transfer reactions



Advantages:

relative simplicity in preparing, experience in data analysis and theoretical background → →
effective and fast results

structure of neutron rich nuclei ^{7}H, ^{14,16}Be, ^{18,19}C, ^{25,26}O etc with the use of cryogenic tritium target and ^{36}S & ^{48}Ca intensive primary beams

Characteristics of existing and new in–flight RIB separators

(ΔΩ and Δp/p are angular and momentum acceptances, Rp/Δp is the first-order momentum resolution when 1 mm object size is assumed)

	ACC / ACC-2 FLNR JINR	RIPS / BigRIBS RIKEN	A1900 MSU	FRS / SuperFRS GSI	LISE3 GANIL
ΔΩ, msr	0.9 / 5.8	5.0 / 8.0	8.0	0.32 / 5.0	1.0
Δp/p, %	± 2.5 / ± 3.0	± 3.0 / 6.0	± 5.5	± 2.0 / 5.0	± 5.0
Rp/Δp	1000 / 2000	1500 / 3300	2915	8600 / 3050	2200
Bρ, Tm	3.2 / 3.9	5.76 / 9.0	6.0	18 / 18	3.2 - 4.3
Length, m	21 / 38	27 / 77	35	74 / 140	19(42)
E, AMeV	10÷40 / 6÷60	50÷90 / 350	110÷160	220÷1000/1500	40÷80
Additional RIB Filter	No / RF-kicker	RF-kicker / S-form	S-form & RF- kicker	S-form / Preseparator	Wien Filter

☻ **ACCULINNA-2 will compatible with RIPS: it's more extended and operating at low energy domain E_{RIB} ~ *6-60 AMeV* with Z_{RIB} = *1-36***

☻ ☻ **inexpensive project / conditions to work with tritium target / experience**