“Reaction studies about the Q-value influence on the production of superheavy elements”

Reimar Graeger

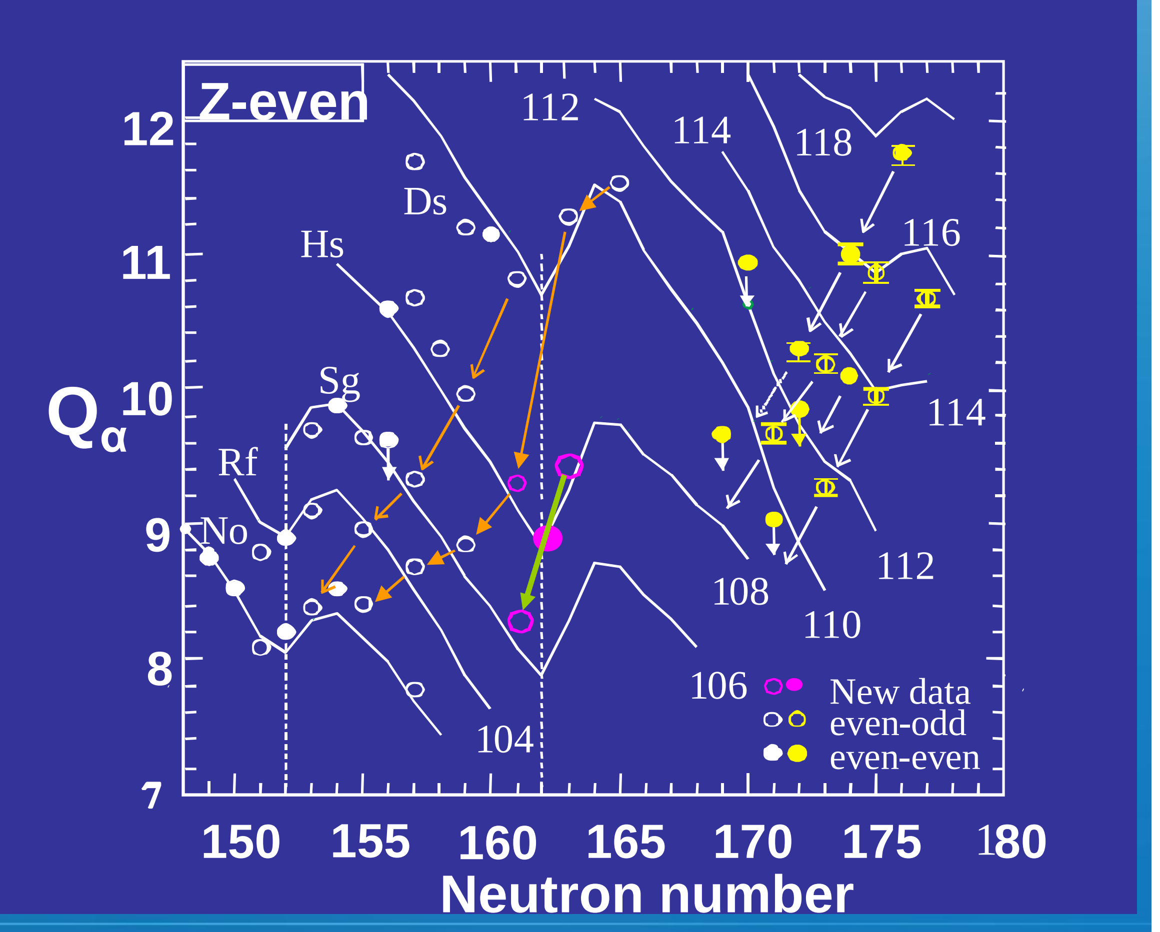
Seventh Workshop on the chemistry of the heaviest elements

Mainz, Germany

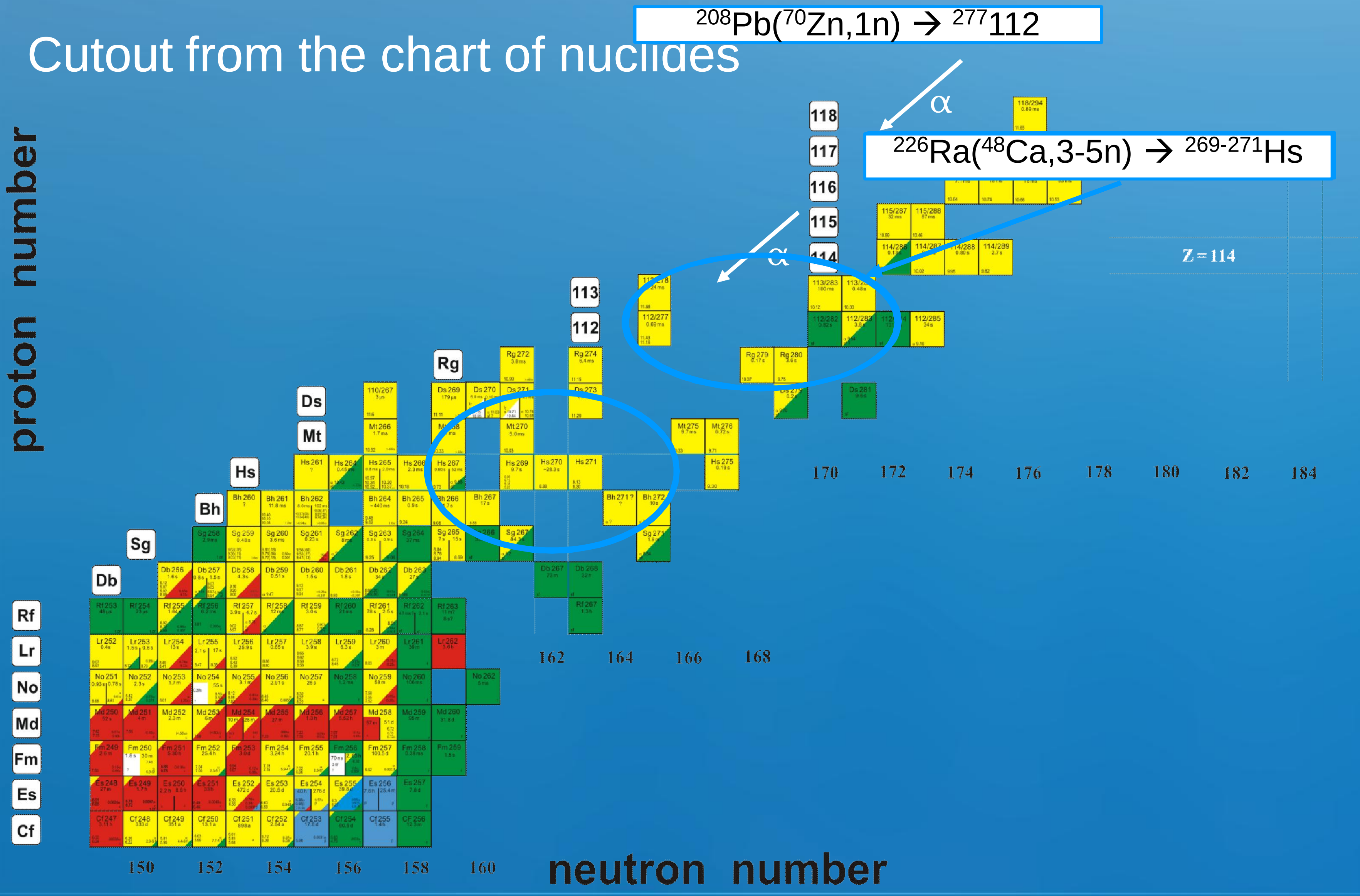
October 11th - 13th, 2009

Hs - Element 108

- Transactinide – group VIII element
- ^{270}Hs is double magic nucleus with closed deformed shell at Z=108, N=162
- Forms volatile tetroxide – HsO_4 – very high yield of chemical separation!
- First synthesized at GSI (Darmstadt) in year 1984 **^{208}Pb(^{58}Fe, 1n)^{265}Hs**

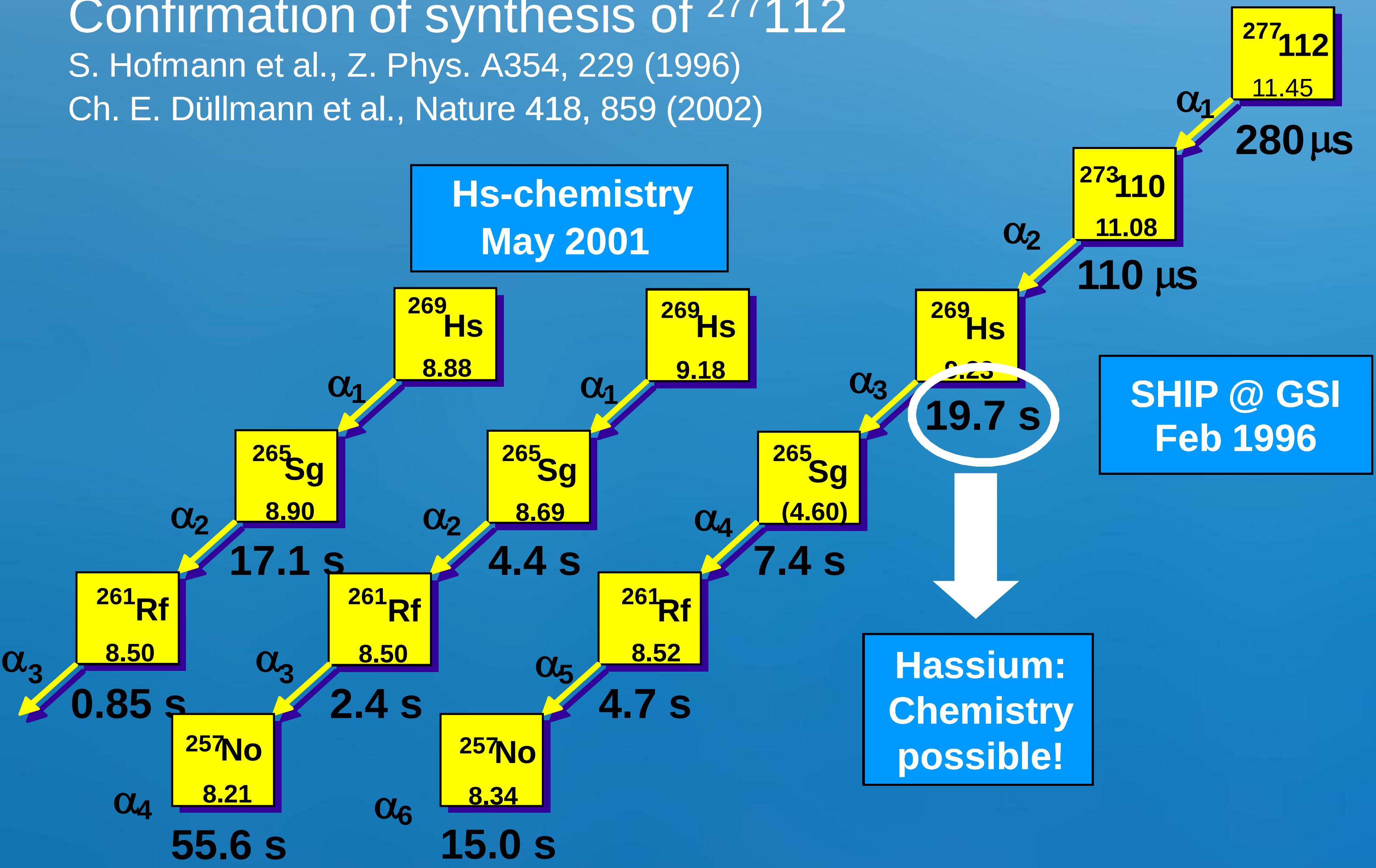


Cutout from the chart of nuclides



Confirmation of synthesis of $^{277}112$

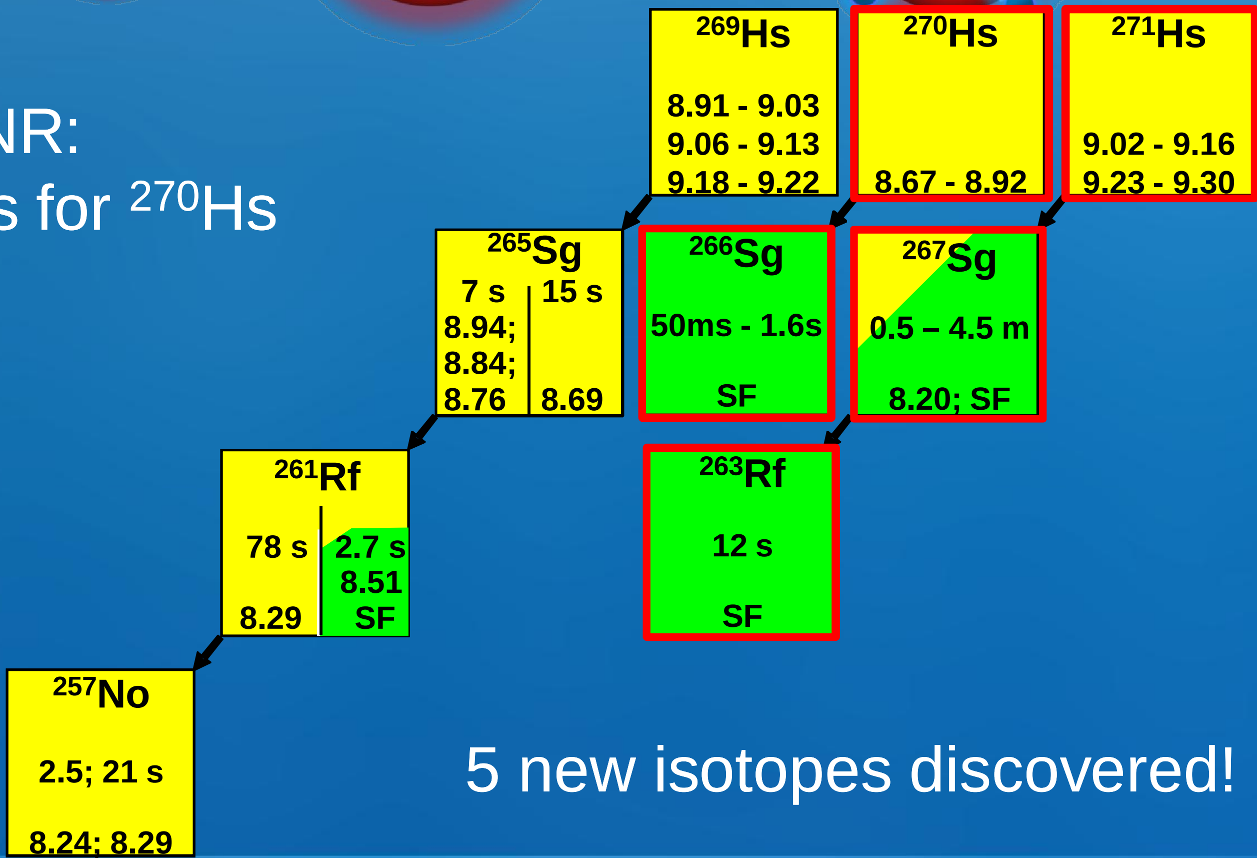
S. Hofmann et al., Z. Phys. A354, 229 (1996)
Ch. E. Düllmann et al., Nature 418, 859 (2002)



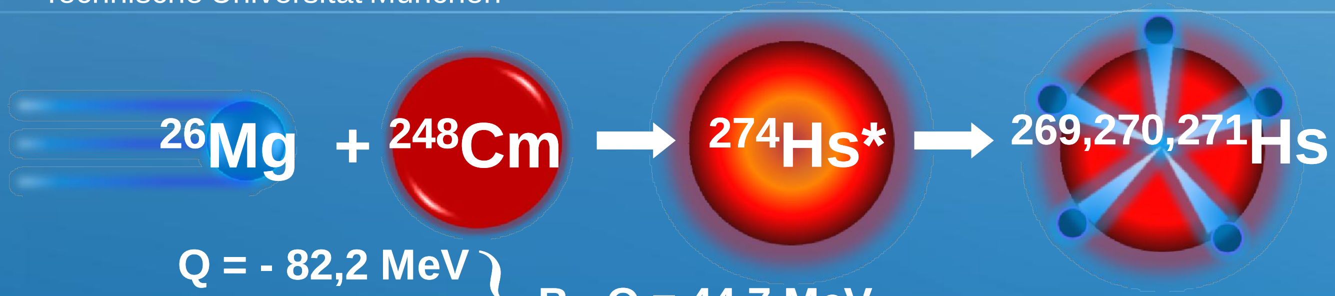
Doubly Magic Nucleus ^{270}Hs

J. Dvorak et al., Phys. Rev. Lett. **97**, 242501 (2006)

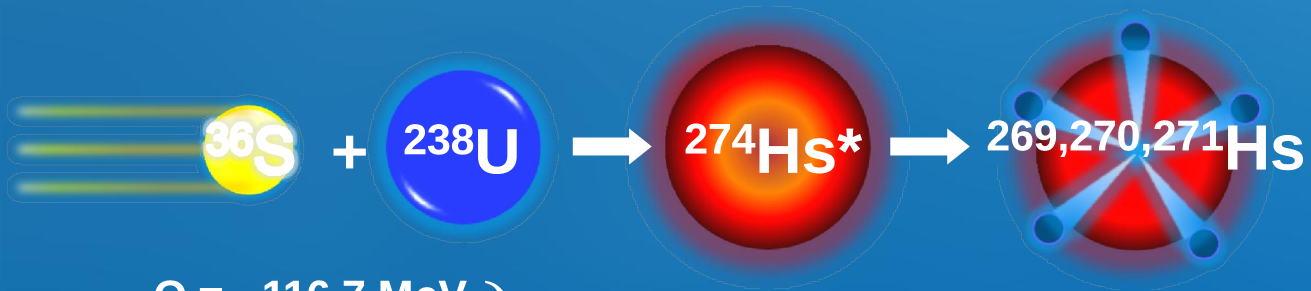
July 2008 at FLNR:
Decay properties for ^{270}Hs confirmed!



5 new isotopes discovered!



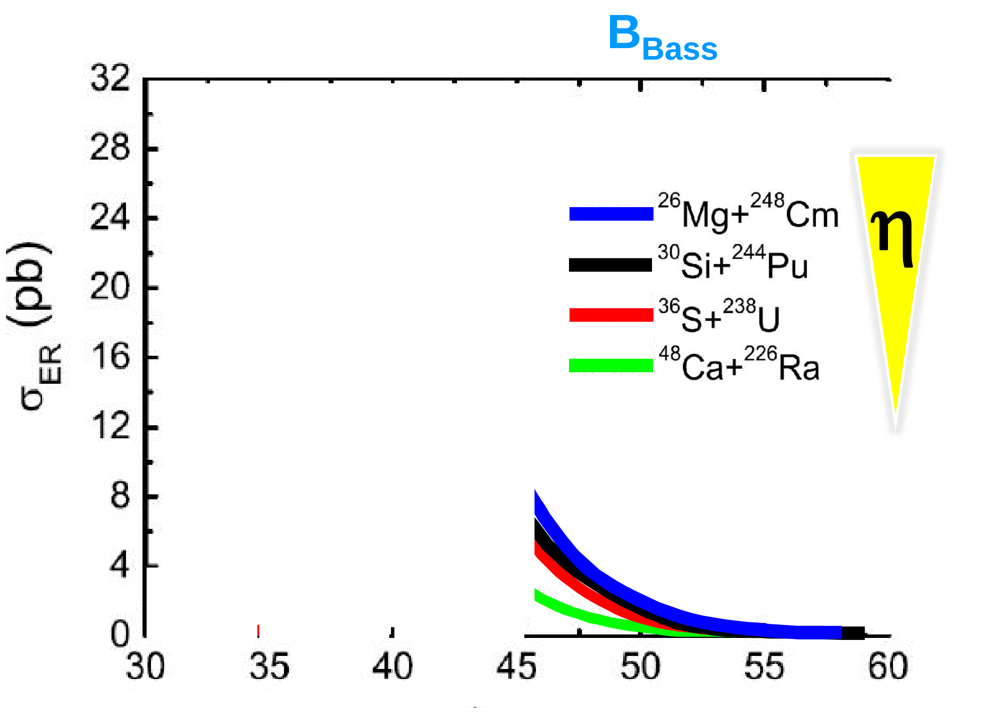
Q = - 82,2 MeV
B = 126,9 MeV
} B - Q = 44,7 MeV



Q = - 116,7 MeV
B = 159,1 MeV
} B - Q = 42,4 MeV

Q = - 153,9 MeV
B = 187,0 MeV
} B - Q = 33,1 MeV

4n-channel Excitation functions (^{270}Hs)



From Ch. E. Düllmann

$$\sigma_{EVR} = \underbrace{\sigma_{capt} * P_{CN}}_{\sigma_{CN}} * W_{sur}$$

σ_{CN} ~ P_{CN} ~ asymmetry

Above the barrier:

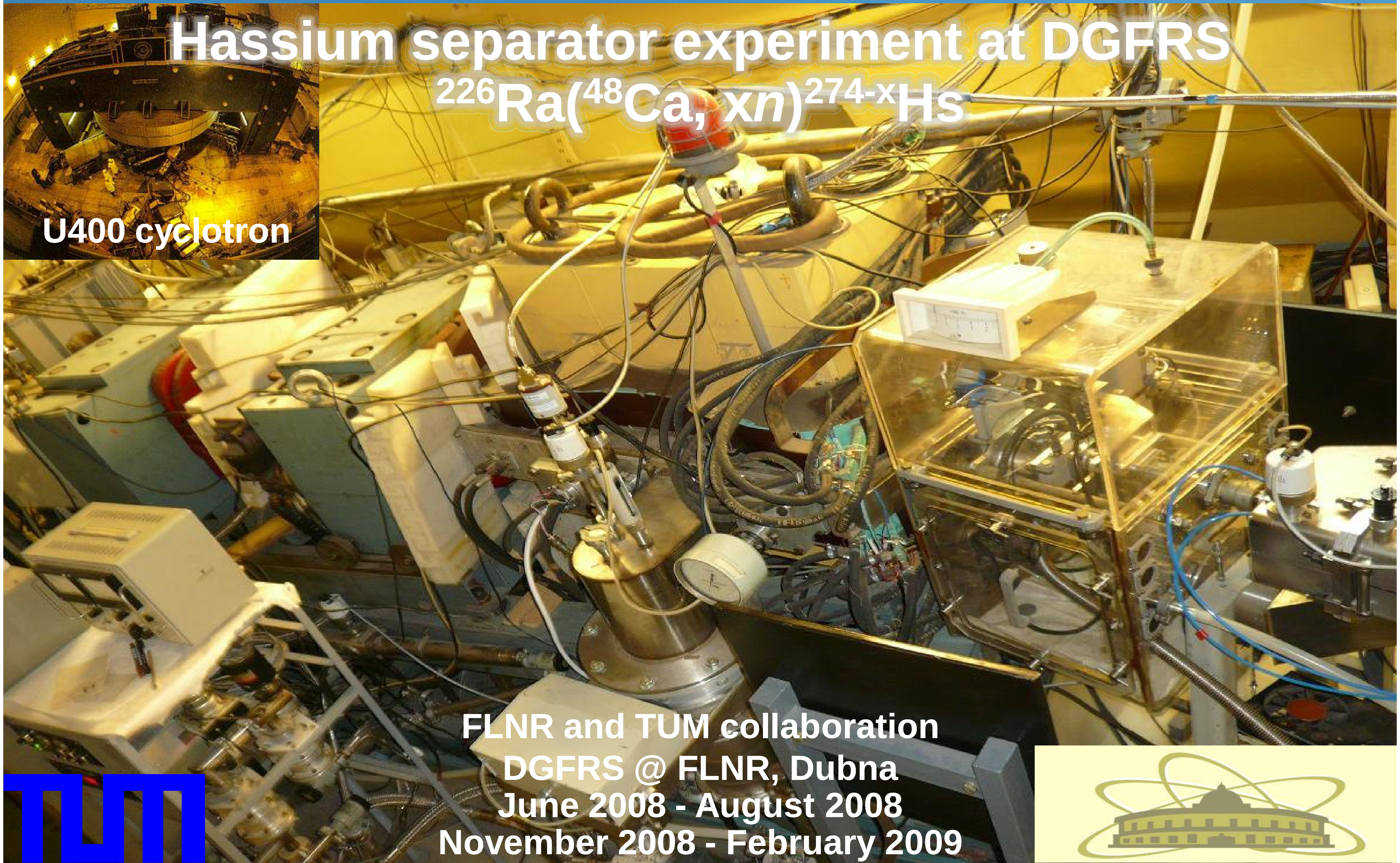
$\sigma_{EVR} \sim \eta$

Below the barrier:

$\sigma_{EVR} \sim (B_{Bass} - Q) \sim$ Q-value

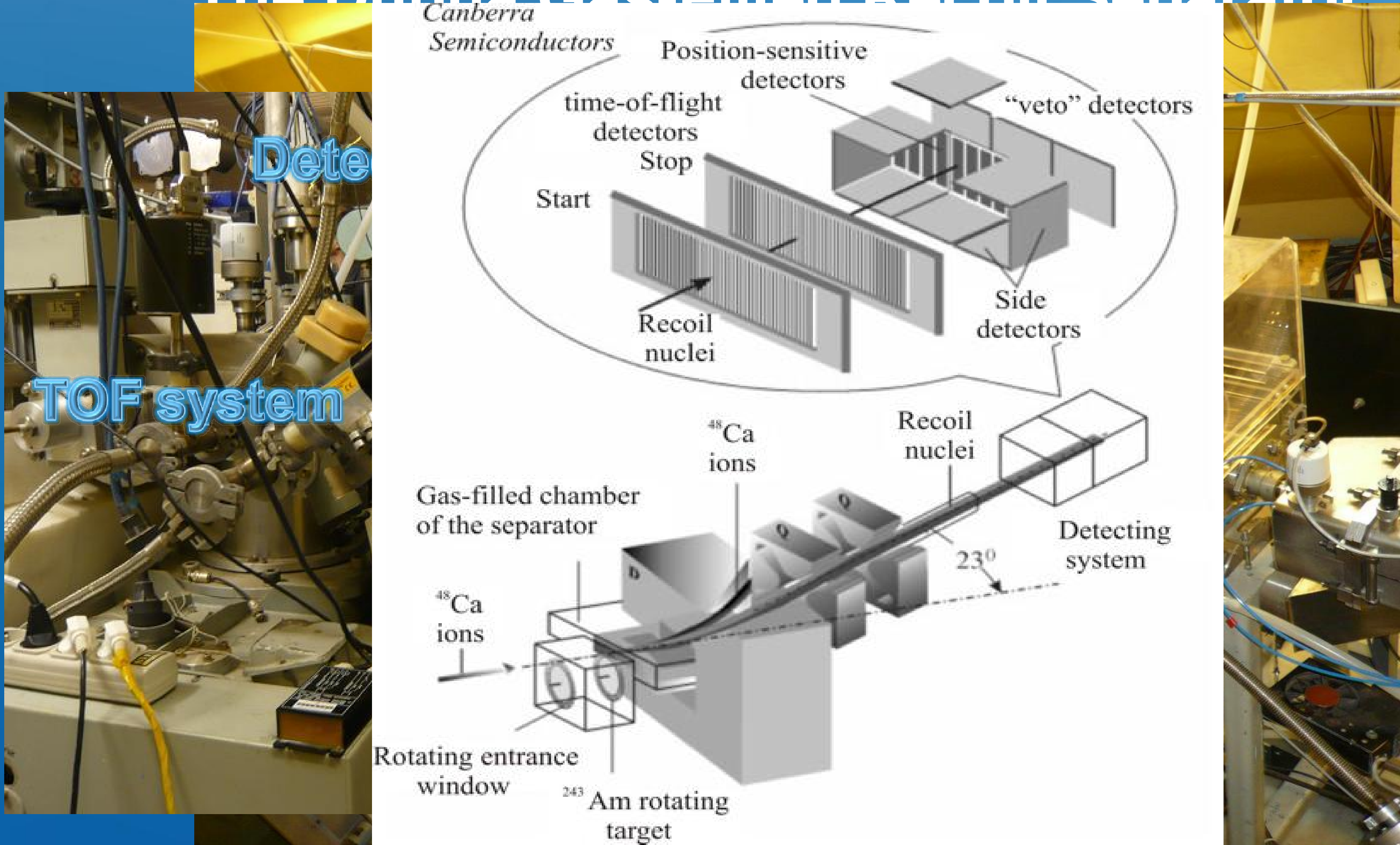
*Z.H. Liu and J.-D. Bao, Physical Review C **74**, 057602 (2006)*

Hassium separator experiment at DGFRS
$^{226}Ra(^{48}Ca, xn)^{274-x}Hs$



FLNR and TUM collaboration
DGFRS @ FLNR, Dubna
June 2008 - August 2008
November 2008 - February 2009

Experimental setup:
The Dubna Gas-Filled Recoil Separator



^{226}Ra(^{48}Ca, x*n*)$^{274-x}$Hs: experimental details

Beam: ^{48}Ca @ 0.7-1.1 pμA (typical intensities)

Target: 234 μg/cm^2 ^{226}RaO (1st experiment)

Targetwheelarea: 36 cm^2 362 μg/cm^2 ^{226}RaO (2nd experiment)

Backing: 1.5 μm Ti

Detector:

detection efficiency: ε_α = 87%

ε_{SF} ~ 100%

energy resolution: 50-110 keV (FWHM, α-particles, FPD)

130-310 keV (FWHM, α-particles, side)

position resolution: 1.1-1.9 mm (α-particles, FPD)

0.6-1.6 mm (SF, FPD)

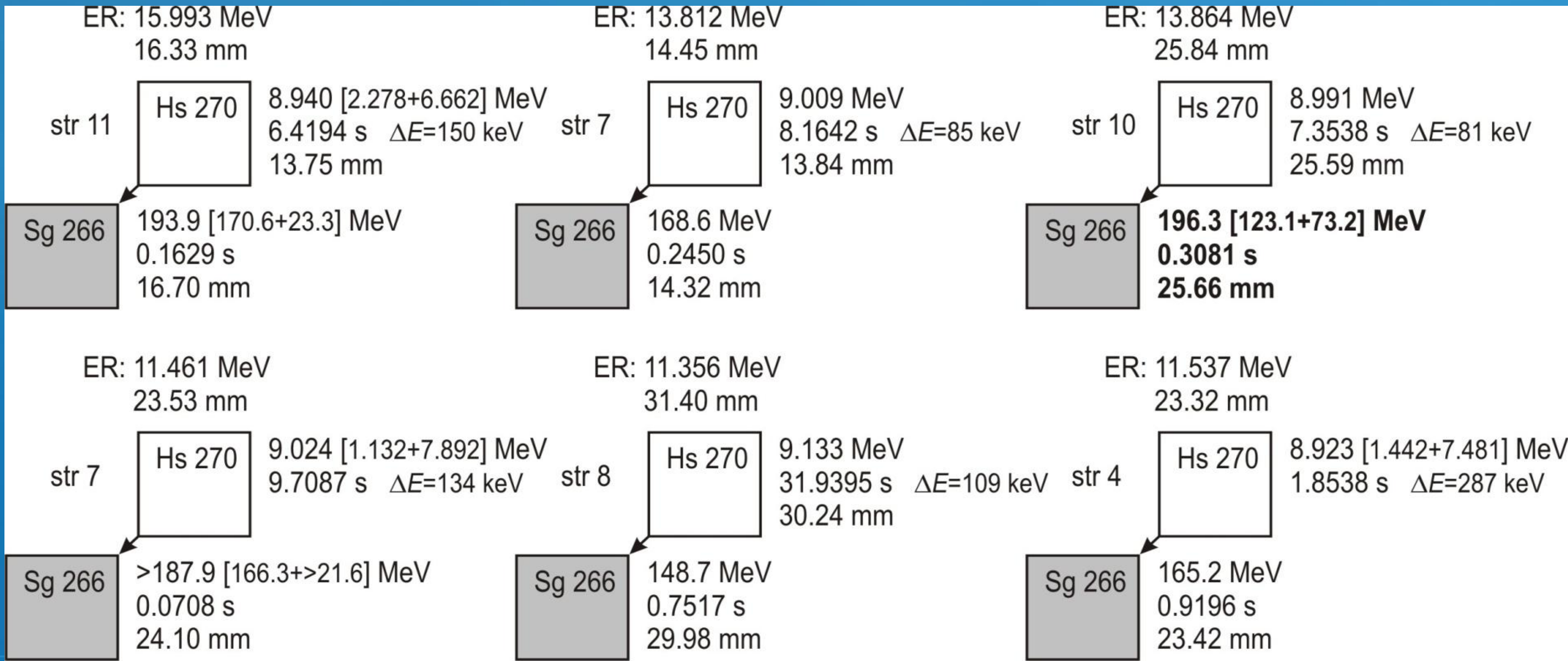
2.0-3.5 mm (α-particles, E_α > 3 MeV, side)

3.4-5.8 mm (α-particles, E_α < 3 MeV, side)

Separator efficiency: ε_{DGFRS} = (40±5)%

Yu.Ts. Oganessian *et al.*, to be published

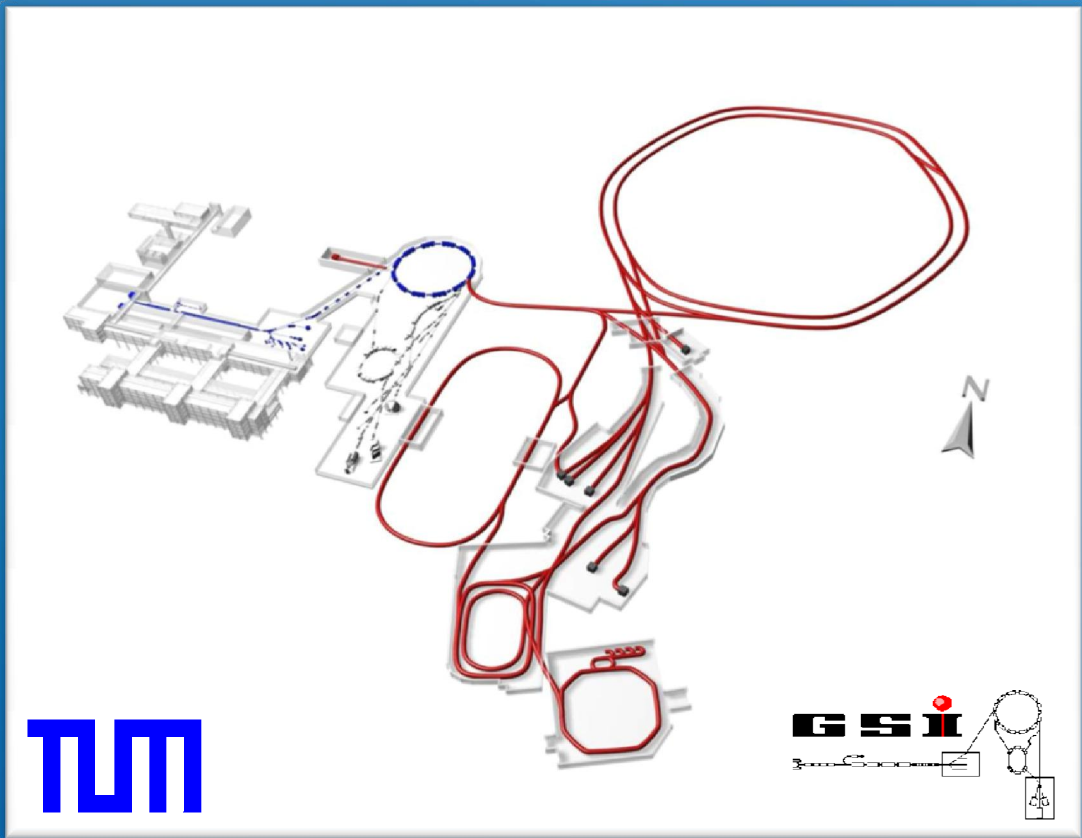
Target thickness (mg/cm²)	E_{beam} (MeV)	E^* (MeV)	Beam dose 10^{18}
0.23 0.36	228.5	34.2-38.1	2.9 3.3
0.23 0.36	233.5	38.0-42.5	3.0 1.1
0.36	240.5	44.0-48.1	2.3



Yu.Ts. Oganessian *et al.*, to be published

Hassium chemistry experiment at GSI

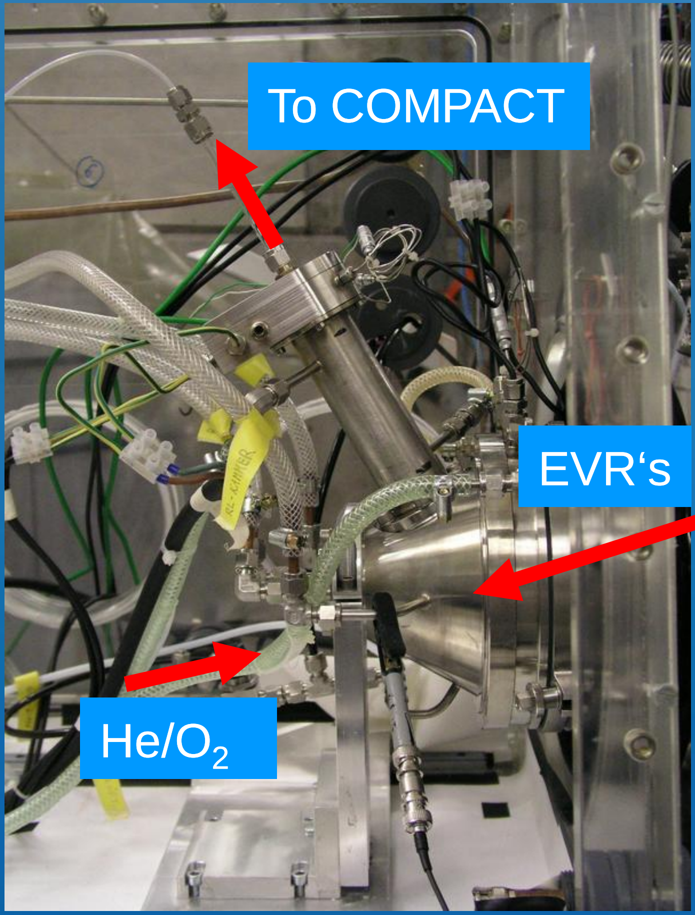
$^{238}U(^{36}S, xn)^{274-x}Hs$



UNILAC GSI, Darmstadt

30. 04. 2008 – 14. 05. 2008

Hs production and separation



Recoil chamber and oven

ARTESIA
target wheel

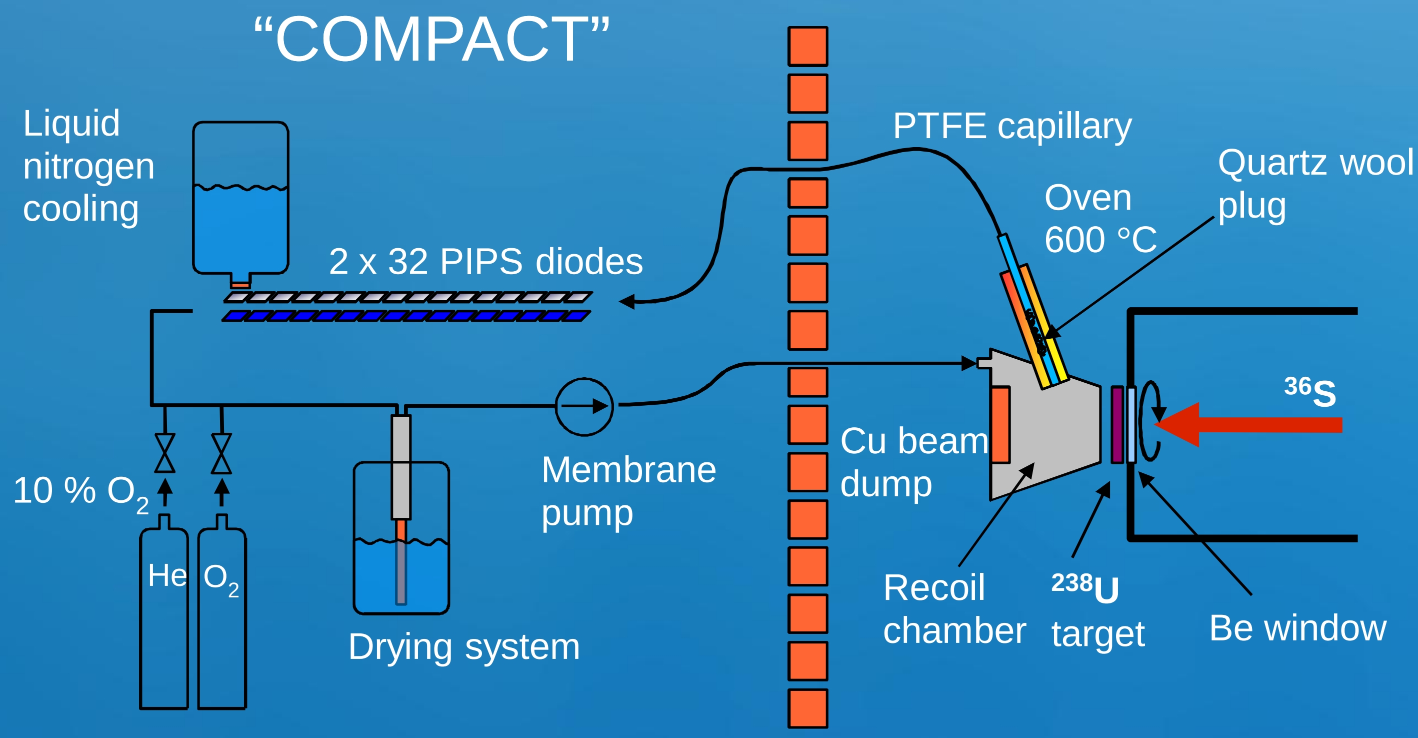
UNILAC GSI Darmstadt

Target: $^{238}U_3O_8$ (1.8 mg/cm^2, 1.6 mg/cm^2, 1.5 mg/cm^2)
$^{238}U_{metal}$ (1.0 mg/cm^2 each)

Beam: $^{36}S^{5+}$ @ 256.4 MeV (lab) (I_{typ} ~ 350 pnA)

Detector: 2 x 32 PIPS diodes (ΔE = 50 keV FWHM)

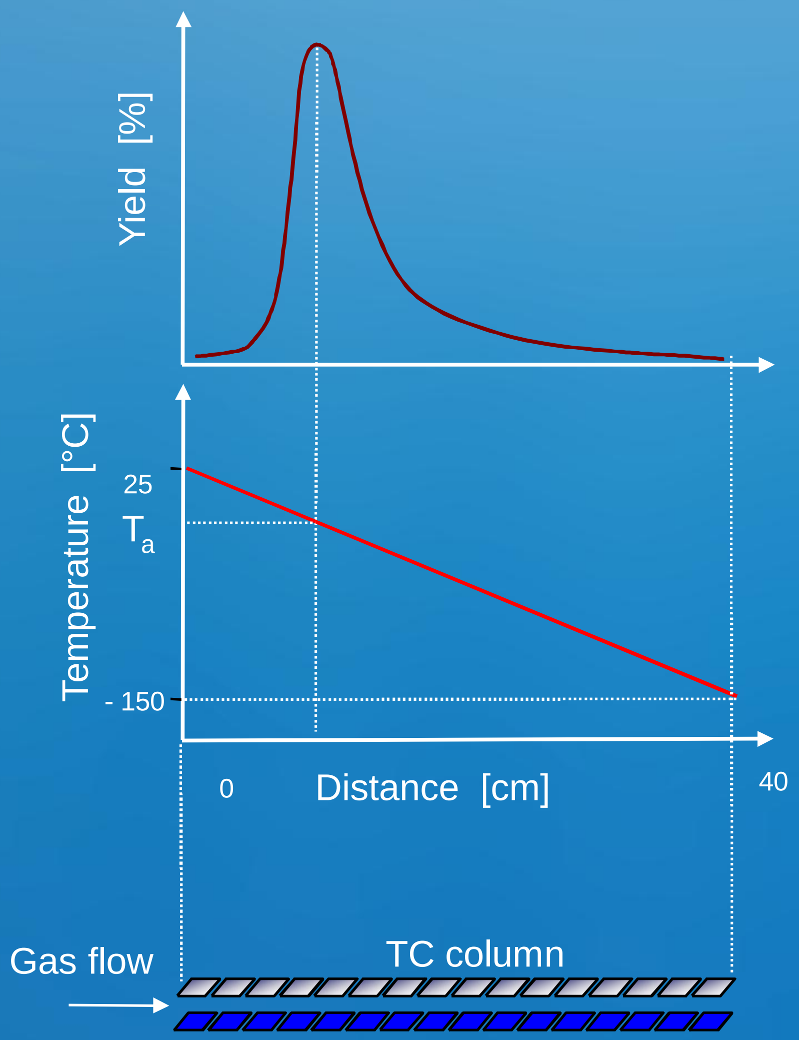
Experimental setup



Overall efficiency 50 %

Thermochromatography

- Longitudinal negative temperature gradient is established along the thermochromatography (TC) column
- Different species borne by carrier gas are slowed down and deposited at different positions (temperatures) in TC column according to their volatilities
- From the adsorption temperature T_a the value of the adsorption enthalpy ΔH_{ads} can be evaluated
- Standard sublimation enthalpy ΔH_{subl} can be evaluated based on the empirical correlation



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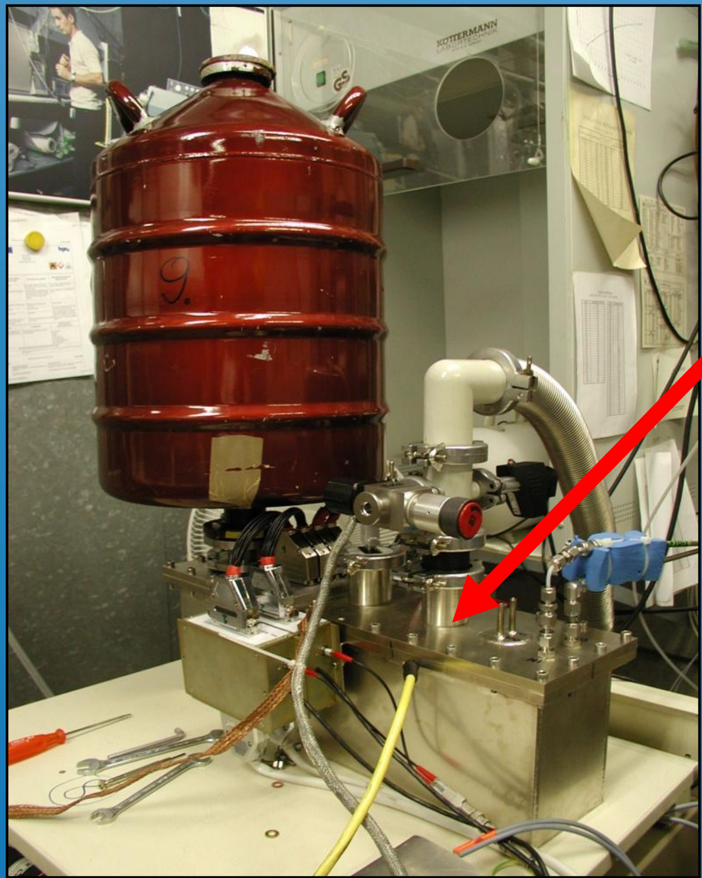
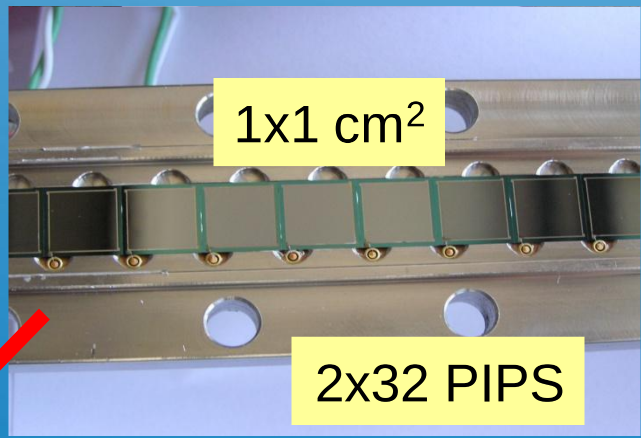
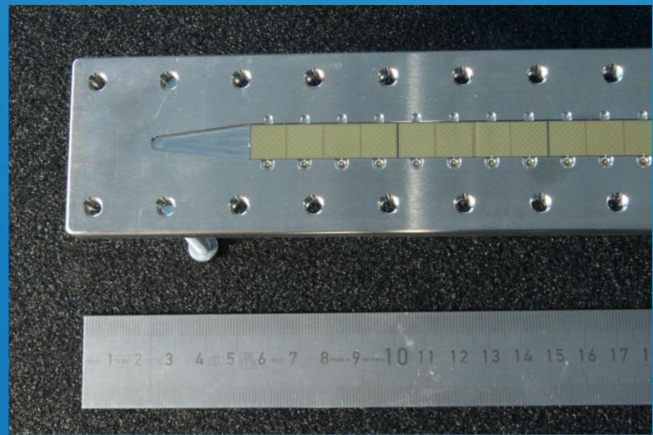
“COMPACT”

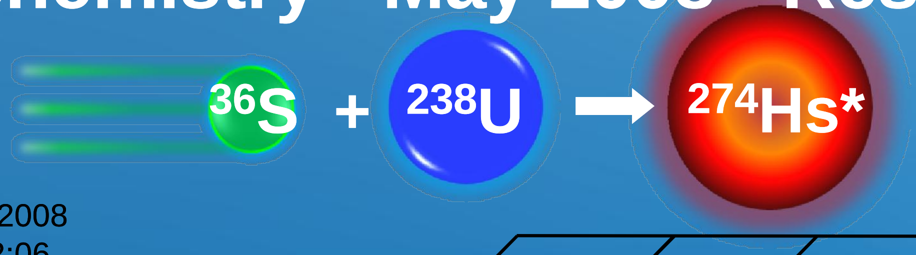
Cryo
On-line
Multidetector for
Physics
And
Chemistry of
Transactinides







Hs-chemistry - May 2008 - Results



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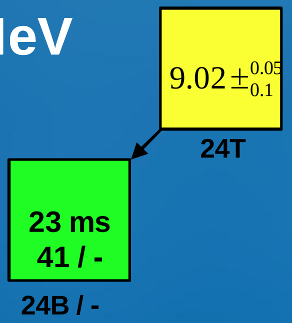
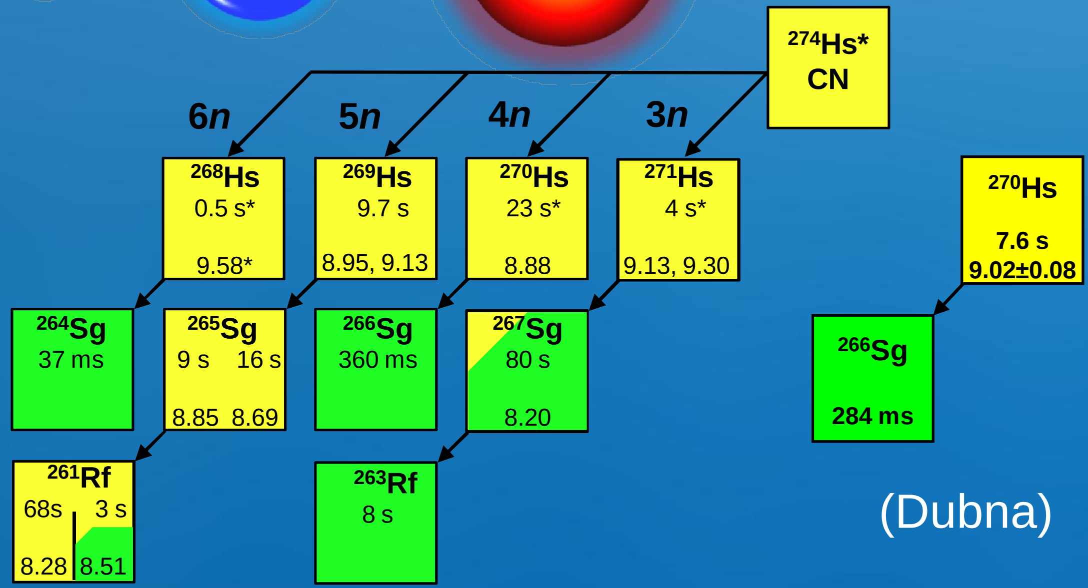
E* = 51±3 MeV





Random rates:

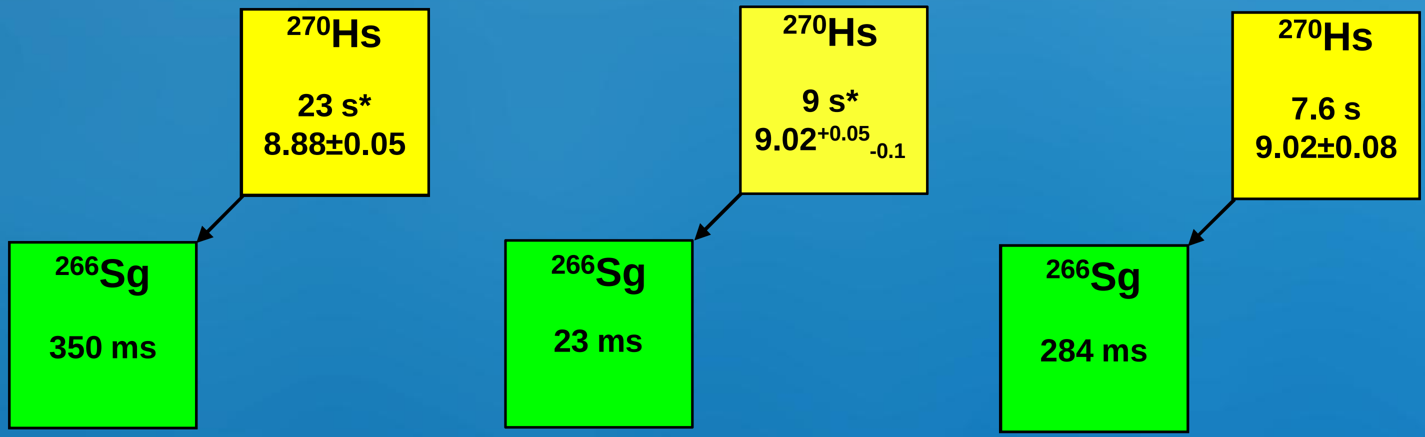
Δt = 300 s (^{267}Sg: $T_{1/2}$ = 80 s)
8.0 MeV < E_α < 10.0 MeV
E_{SF} > 15 MeV

decay chain	E* = 38 MeV	E* = 51 MeV
α·α·α·α	$7.08\cdot10^{-4}$	$3.12\cdot10^{-3}$
α·α·SF	$4.61\cdot10^{-3}$	$1.67\cdot10^{-3}$
α·SF	$1.6\cdot10^{-2}$	$4.6\cdot10^{-2}$

$$\sigma_{EVR}\ (4n) = 0{,}8^{+2{,}6}_{-0{,}7}\ \text{pb}$$

^{270}Hs summary of experiments:

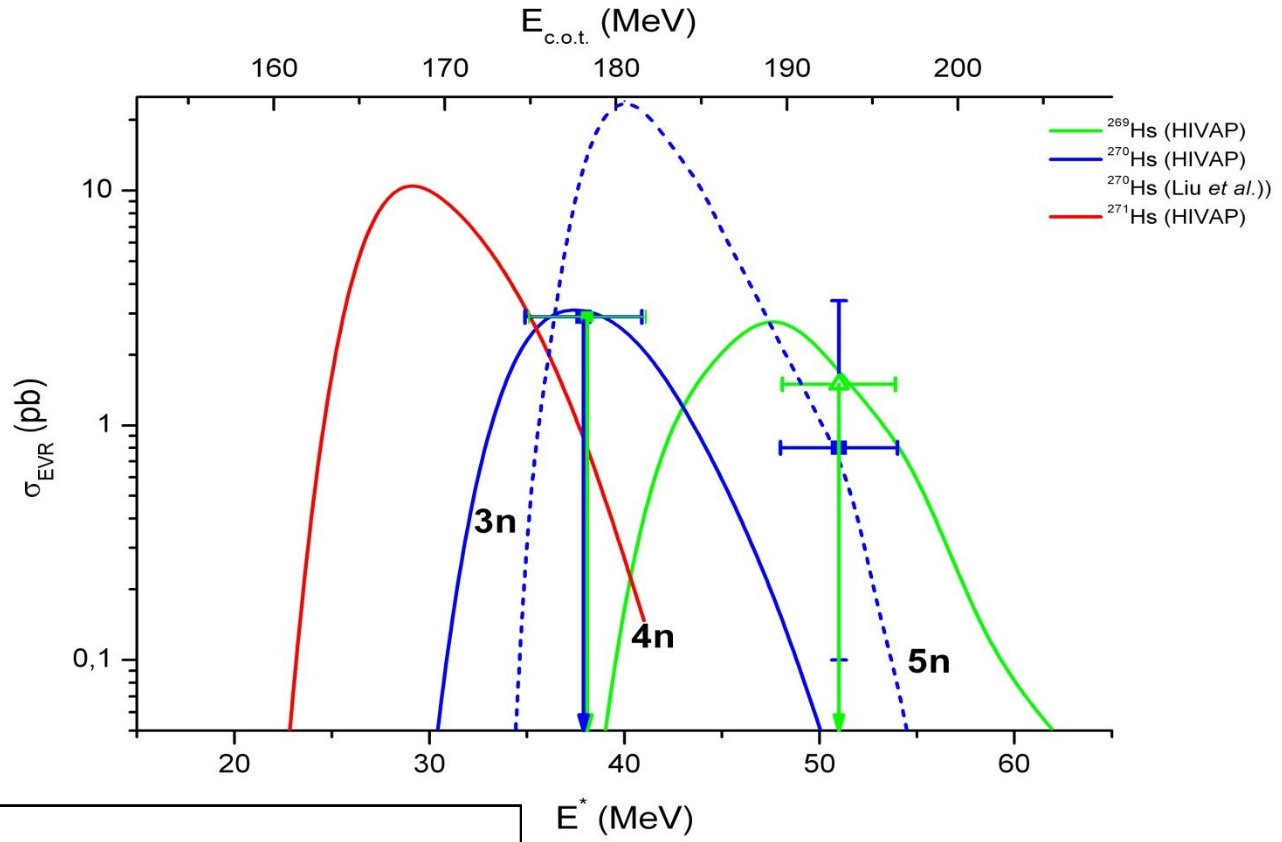
$^{26}Mg + ^{248}Cm$: | $^{36}S + ^{238}U$: | $^{48}Ca + ^{226}Ra$:



* $\log_{10} T_{1/2} = a\, Z\, (Q_a - E_i)^{-1/2} + b\, Z + c$

A. Parkhomenko, A. Sobiczewski
Acta Physica Polonica 36, No. 10 (2005)

Excitation function: $^{238}U(^{36}S, xn)^{274-x}Hs$

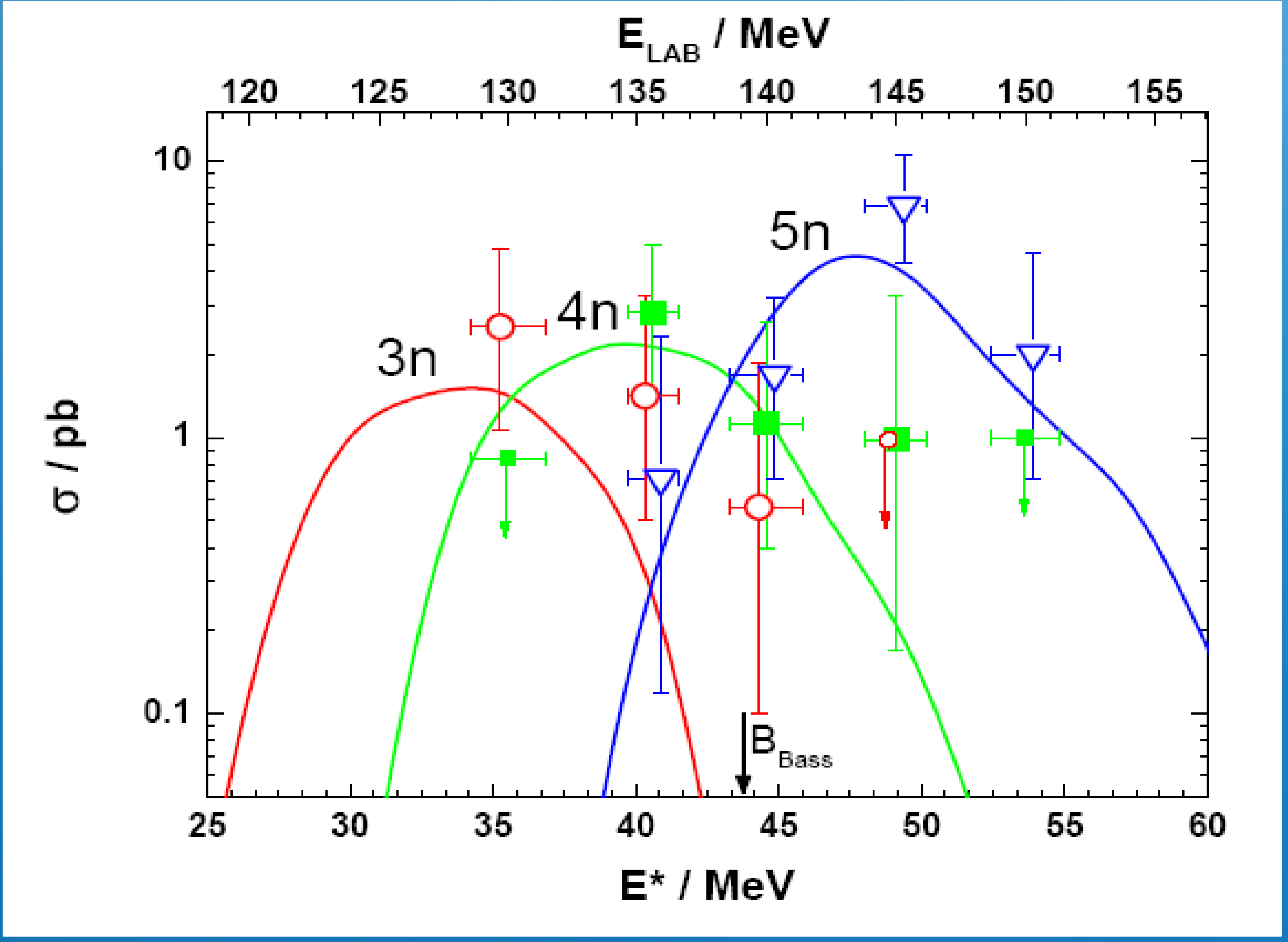


σ_{EVR} (4n) = $0{,}8^{+2{,}6}_{-0{,}7}$ pb

(Errors and limits corresponds to 68% confidence level)

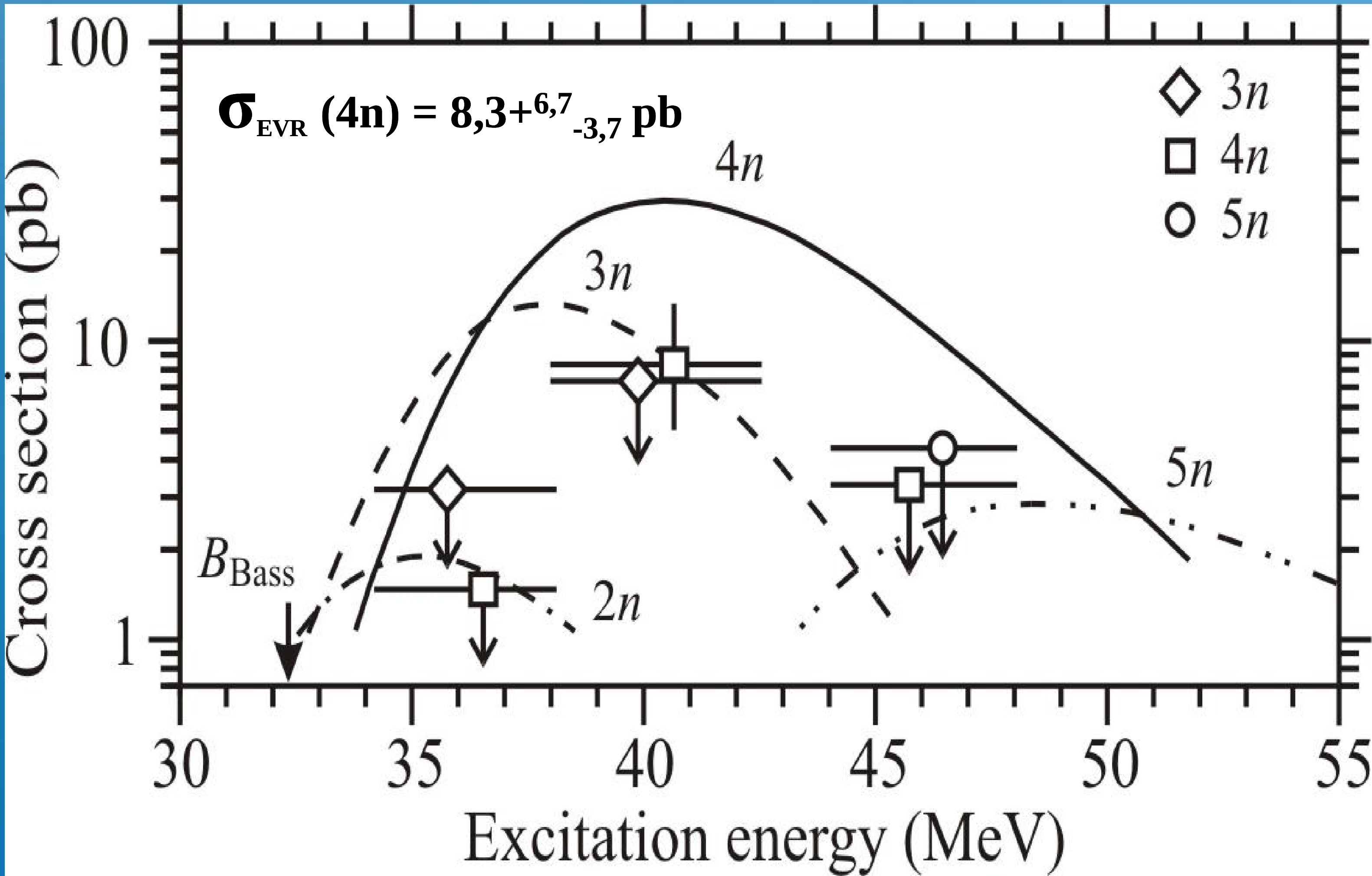
Paper in preparation

Excitation function: $^{248}Cm(^{26}Mg, xn)^{274-x}Hs$



J. Dvorak *et al*., Phys. Rev. Lett. **100**, 132503, 2008

Excitation function: $^{226}Ra(^{48}Ca, xn)^{274-x}Hs$ @ FLNR



Preliminary

Calculations: V. Zagrebaev, W. Greiner, Phys. Rev. C **78**, 034610, 2008
Exp. Data: Yu.Ts. Oganessian *et al*., to be published

A. Gorshkov
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