Influence of neutron enrichment on de-excitation properties of palladium isotopes

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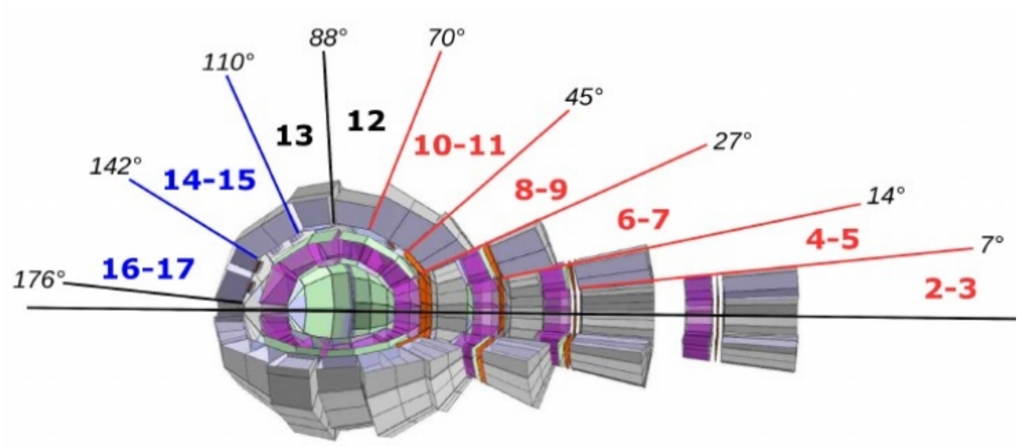
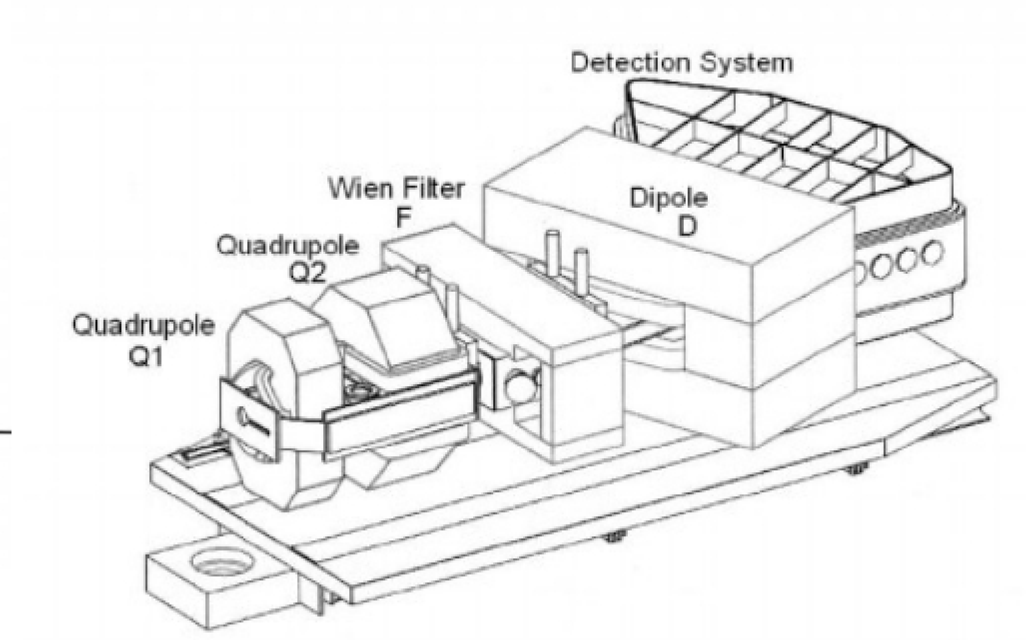
INDRA-VAMOS @ GANIL





E494S

$^{34,36,40}Ar+^{58,60,64}Ni$

12.7-13.5 AMeV

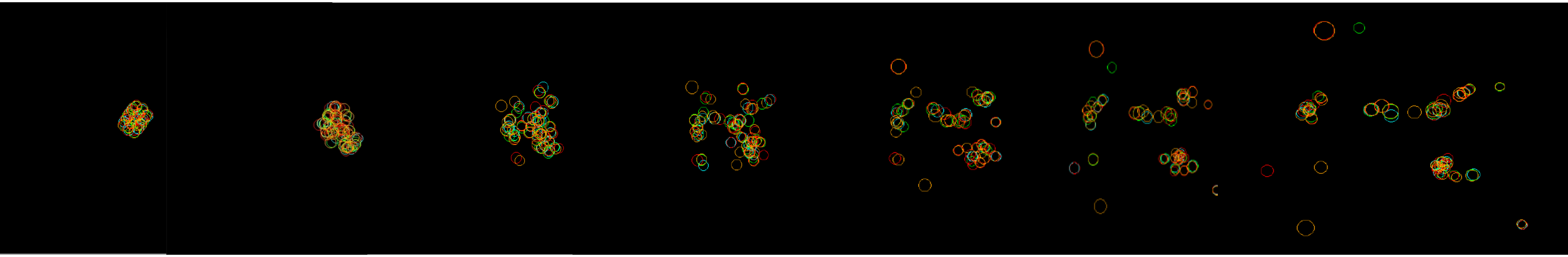
E503

$^{40,48}Ca+^{40,48}Ca$

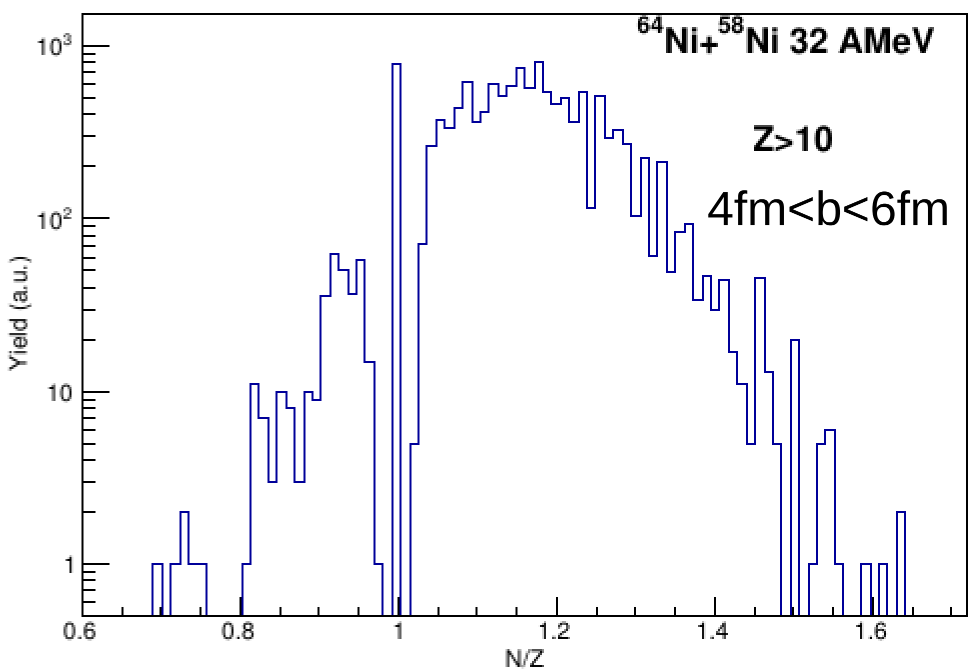
35 AMeV

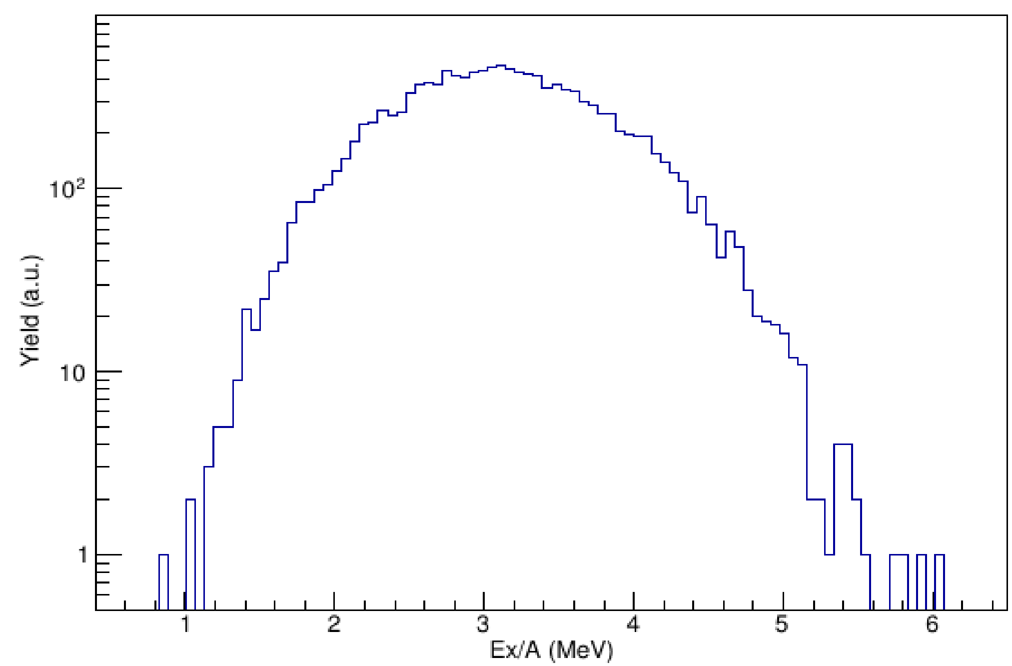
Level density

AMD simulation $^{64}Ni+^{58}Ni$ 32 AMeV b=4.7 fm



0 fm/c 50 fm/c 100 fm/c 150 fm/c 200 fm/c 250 fm/c 300 fm/c





Level density

Fermi-gas level density expression

$$\rho_{FG}(E_x, J) = (2J+1)\left(\frac{\hbar^2}{2I}\right)^{3/2}\frac{\sqrt{a}}{12}\frac{\exp\left(2\sqrt{aU}\right)}{U^2}, U = E_x - E_{rot}(J)$$

$a =$ level-density parameter

- Level density parameter is extrapolated from low excitation energy experiments
- For heavy ion collisions at intermediate energies, excitation energy of primary fragments is around 3-5 MeV per nucleon
- Experimental results are necessary to evaluate the dependence with excitation energy and isospin

Level density

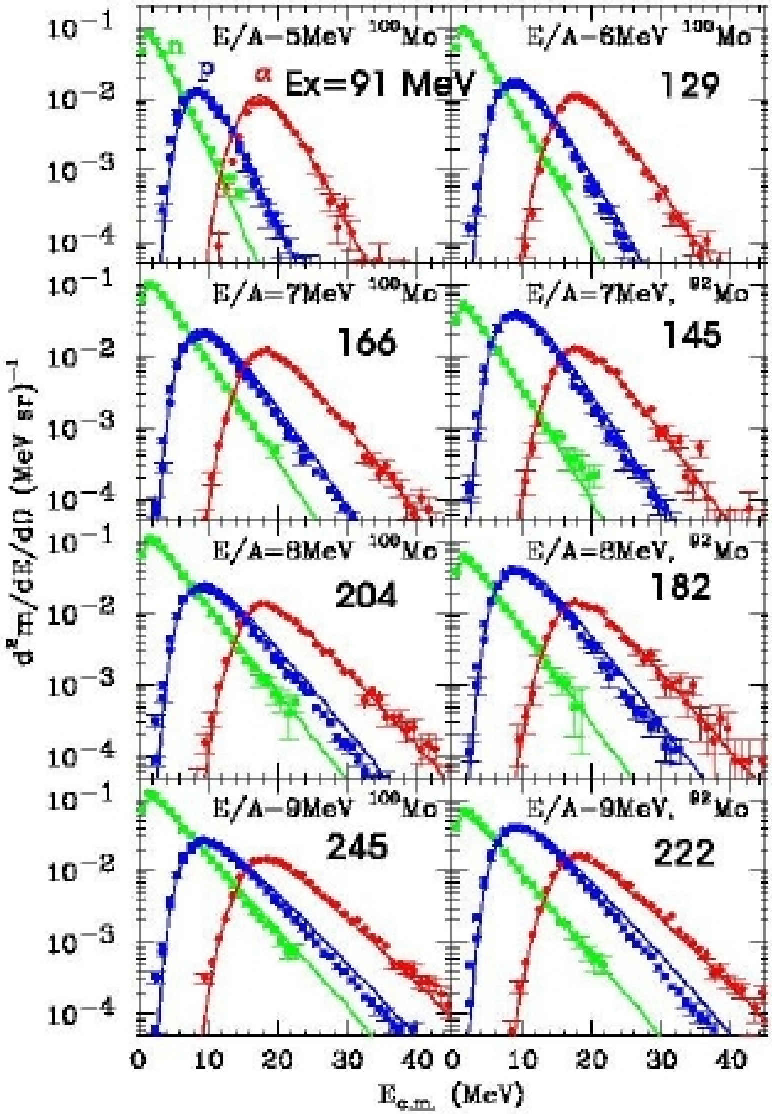
- Excitation energy

$$\rho(U,J) \propto \exp[2\sqrt{a(U)\,U}]/U^2$$

$$a(U) = \frac{A}{K + \kappa \frac{U}{A}}$$

$$\text{fit } K = 7 \text{ MeV}^{-1}, \kappa = 1.3$$

0.55 MeV<Ex/A<1.55 MeV



* Charity, R. Temperature and isospin dependencies of the level-density parameter

Variation with the isospin ?

$$FG\ model\ a \approx mA\left[1-\frac{1}{9}\left(\frac{N-Z}{A}\right)^2\right]$$

$$a = \alpha A / exp[\beta(N-Z)^2],$$

$$a = \alpha A / exp[\gamma(Z-Z_0)^2].$$

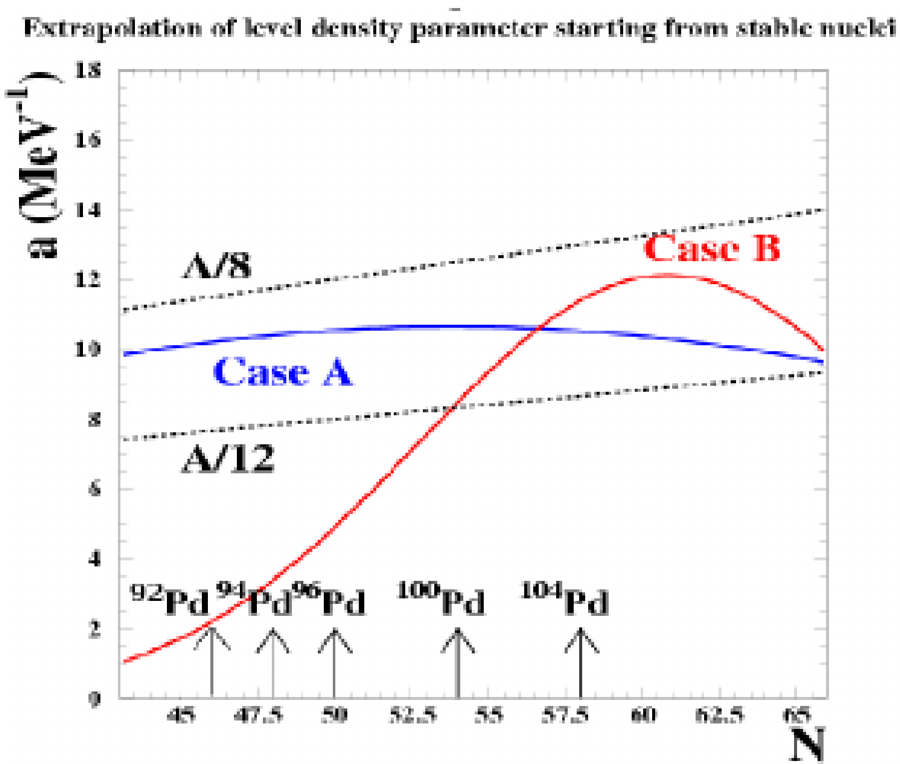


Fig. 1. Evolution of the level density parameter according to two different parametrisations for different Pd isotopes (see Ref.[4]). Experimental values $A/8$ and $A/12$ obtained for low and high excitation energies respectively [6] are also reported.

Level density

Fusion-evaporation reactions

Constant excitation energy ≈ 2.9 AMeV

N/Z between 1 and 1.26

Beam	Target	E_{beam}	CN	E_{exc}	v_{rec}	N/Z
		(MeV/A)		(MeV/A)	(cm/ns)	
^{34}Ar	^{58}Ni	13.5	^{92}Pd	2.889	1.888	1
^{36}Ar	^{58}Ni	13.3	^{94}Pd	2.882	1.942	1.04
^{36}Ar	^{60}Ni	13.3	^{96}Pd	2.919	1.901	1.09
^{40}Ar	^{60}Ni	12.7	^{100}Pd	2.9	1.982	1.17
^{40}Ar	^{64}Ni	12.7	^{104}Pd	2.879	1.905	1.26

INDRA-VAMOS

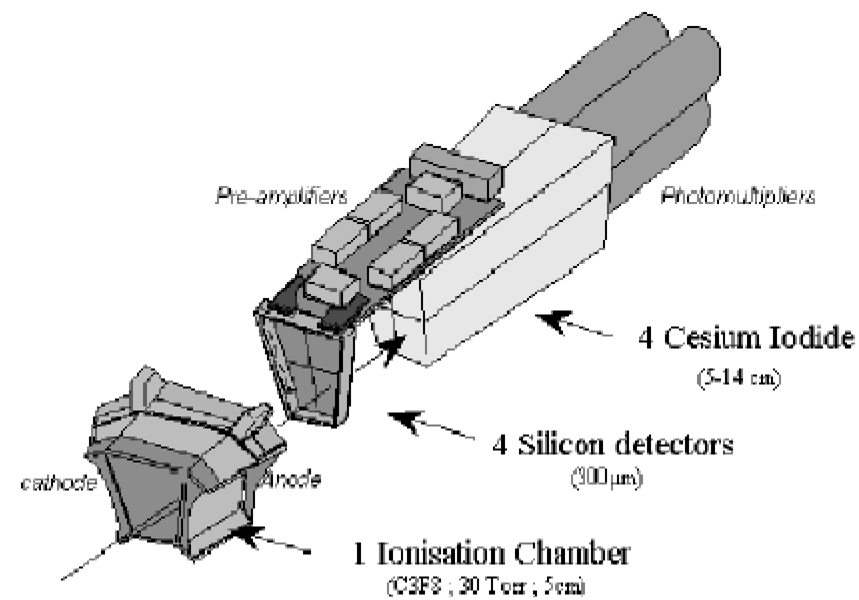
INDRA

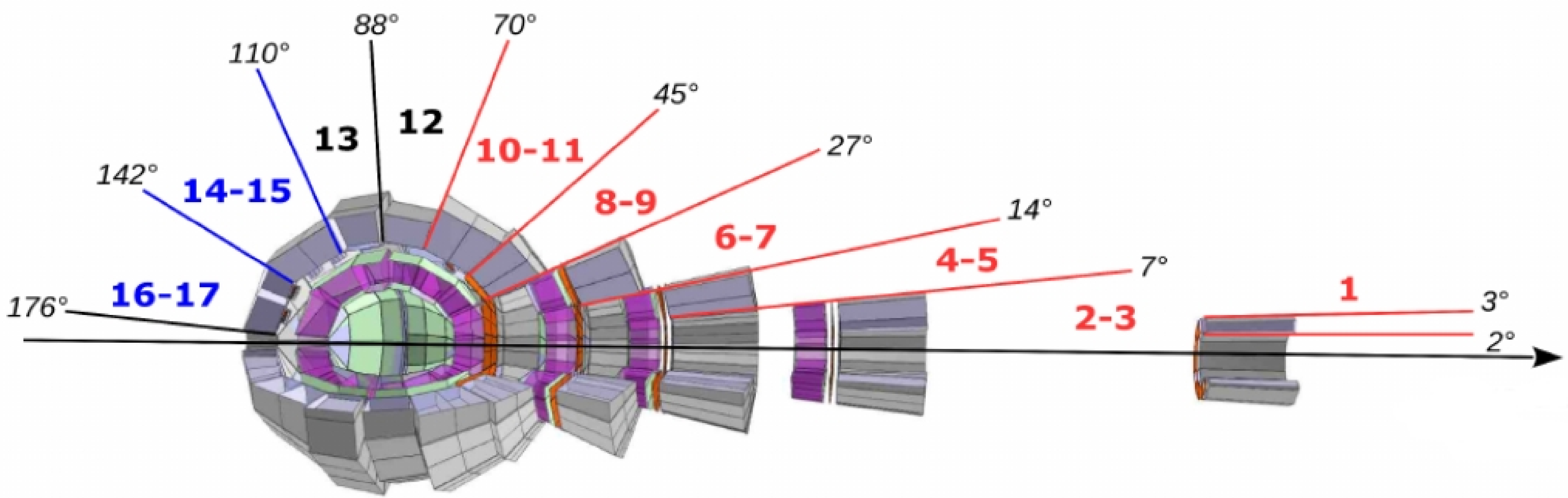
-17 rings, 336 modules

-Covers a solid angle of 90 % of 4π sr

-First 3 rings removed for VAMOS

-LCPs identification





VAMOS

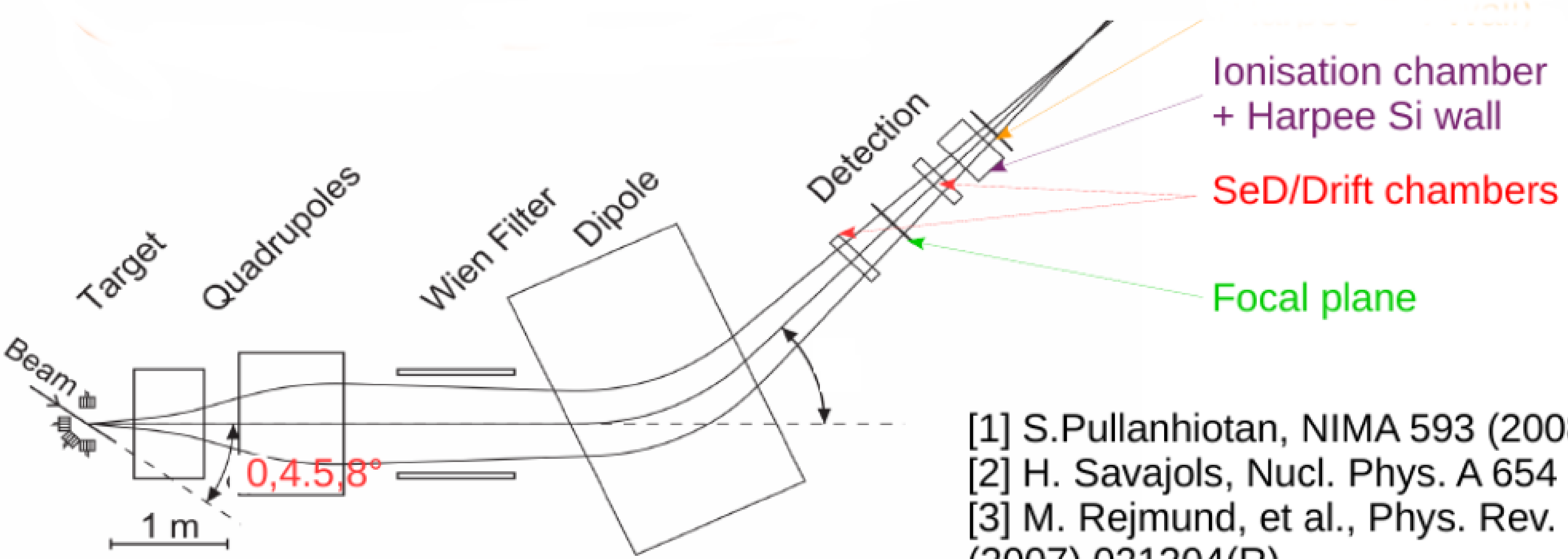
-CN residue identification

-βρ settings : 0.540-0.818 Tm

-θ settings : 0°, 1.5°, 2°, 4° and 8°

Operational features of VAMOS

Horizontal acceptance	−125 to +100 mrad
Vertical acceptance	±160 mrad
Momentum acceptance	±5% (at 25 msr)
M/q resolution	~0.6%
Maximum rigidity $B\rho$	1.6 T-m
Deflection angle θ_{dipole}	0–60° (variable)
Flight path length	~760 cm
Target—quadrupole distance	40–120 cm (variable)
Angular rotation	0–60°



[1] S.Pullanhiotan, NIMA 593 (2008)
[2] H. Savajols, Nucl. Phys. A 654 (1999)
[3] M. Rejmund, et al., Phys. Rev. C 76 (2007) 021304(R)

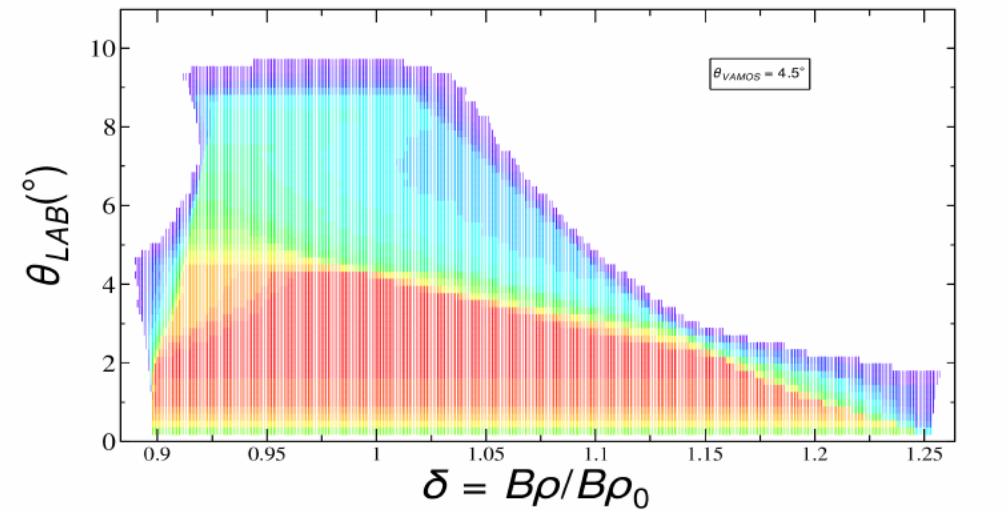
VAMOS acceptance from ZGOUBI

For the same system

- **≠ *Bρ*** settings
- ***≠ VamosAngle (Θ_{VAMOS})***

Set of transmission coef. for a given system, (Θ_{VAMOS})

$\{ T(\delta, \theta_{LAB}) \}$



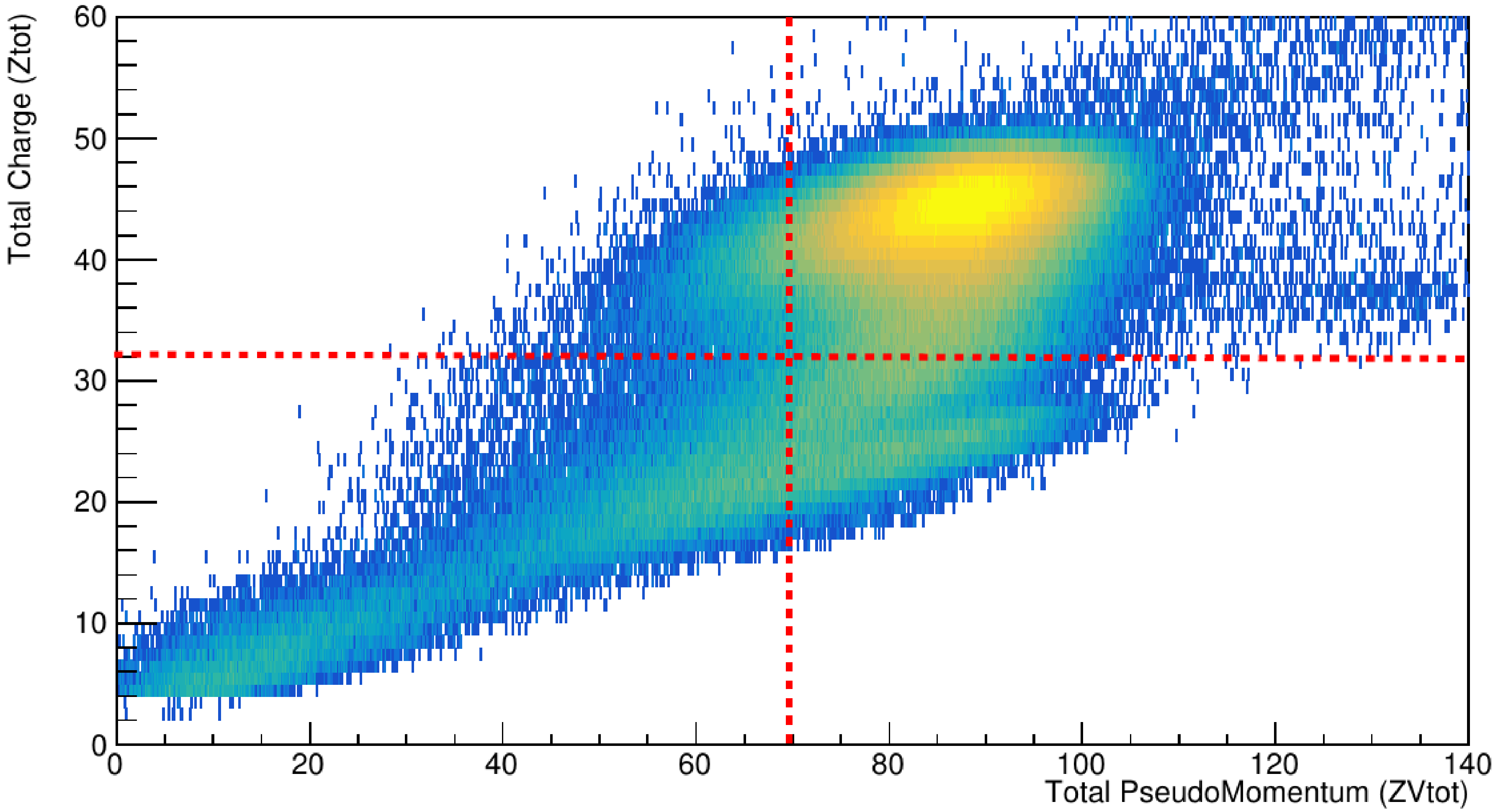
Correction overlap in ($B\rho_0$,Θ_{VAMOS}) settings
=
Weight to apply on event by event basis

$$\frac{1}{W} = \frac{\sum_{B\rho_0, \Theta_{VAMOS}} T(\delta, \theta_{LAB}) * Stat_{INDRA}}{\sum_{B\rho_0, \Theta_{VAMOS}} Stat_{INDRA}}$$

Results

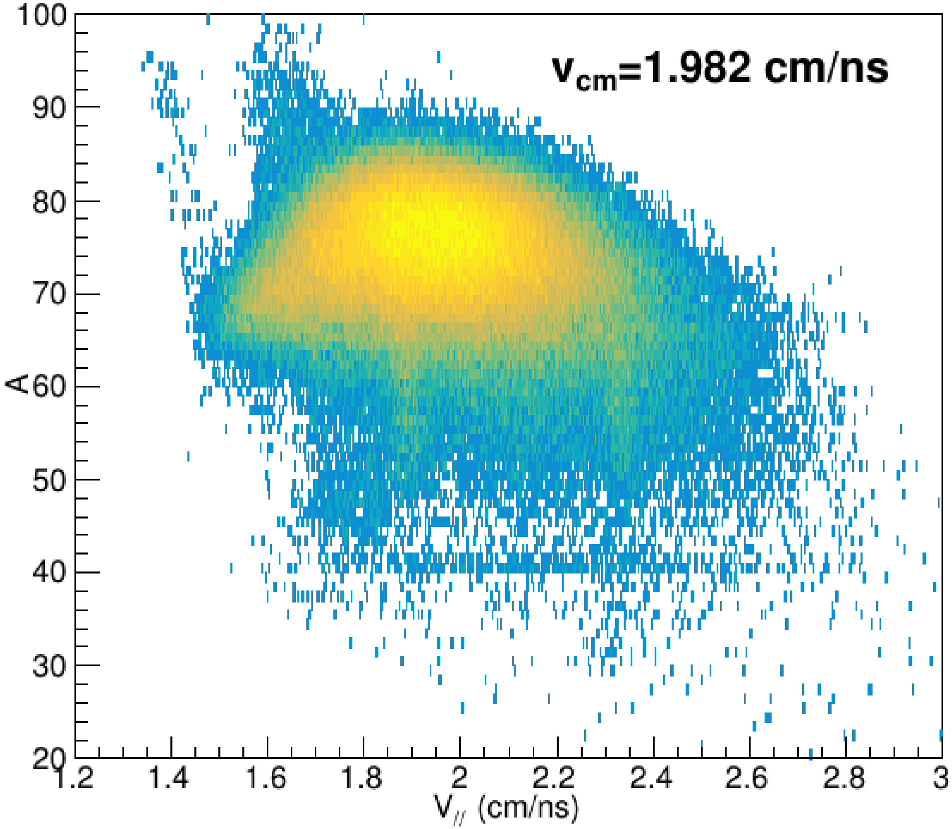
Events selection

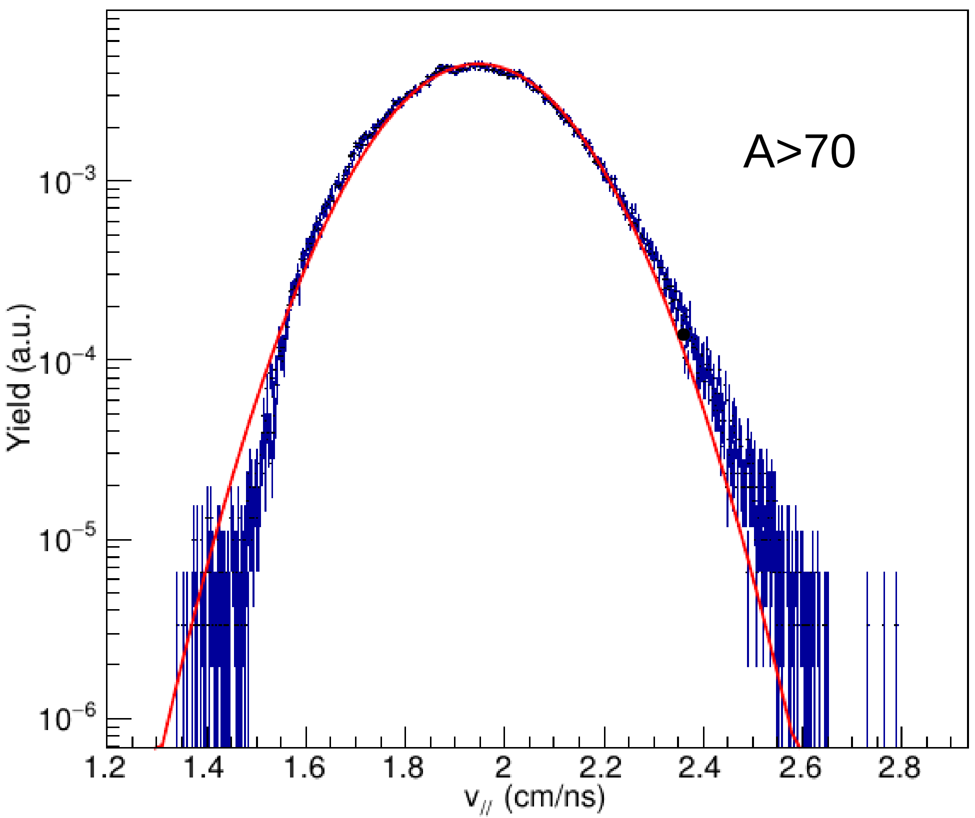
- Ztot>=32
- ZVtot/ZVbeam>80 %



Fusion-evaporation

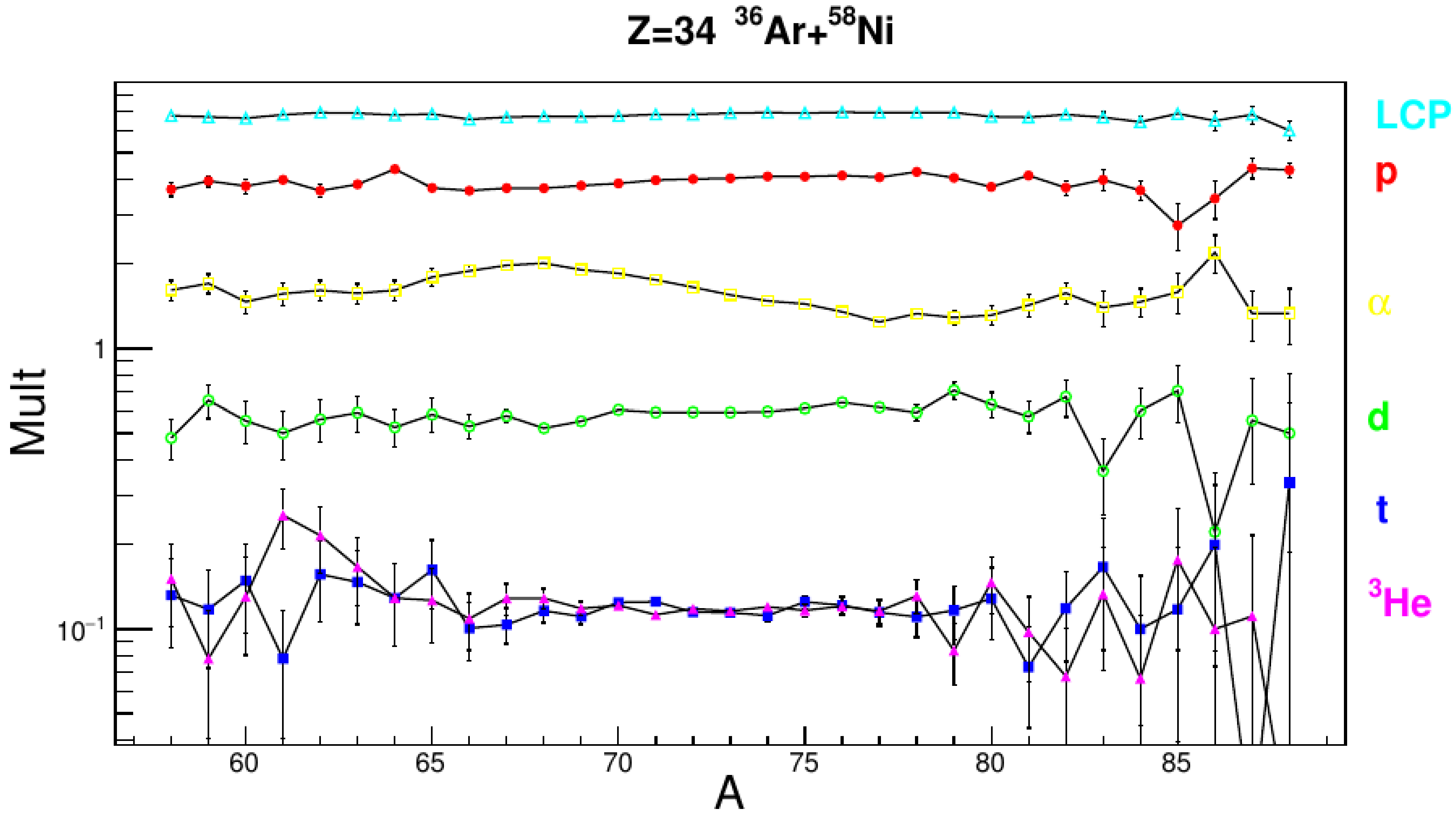
$^{40}Ar + ^{60}Ni$ 12.7 AMeV



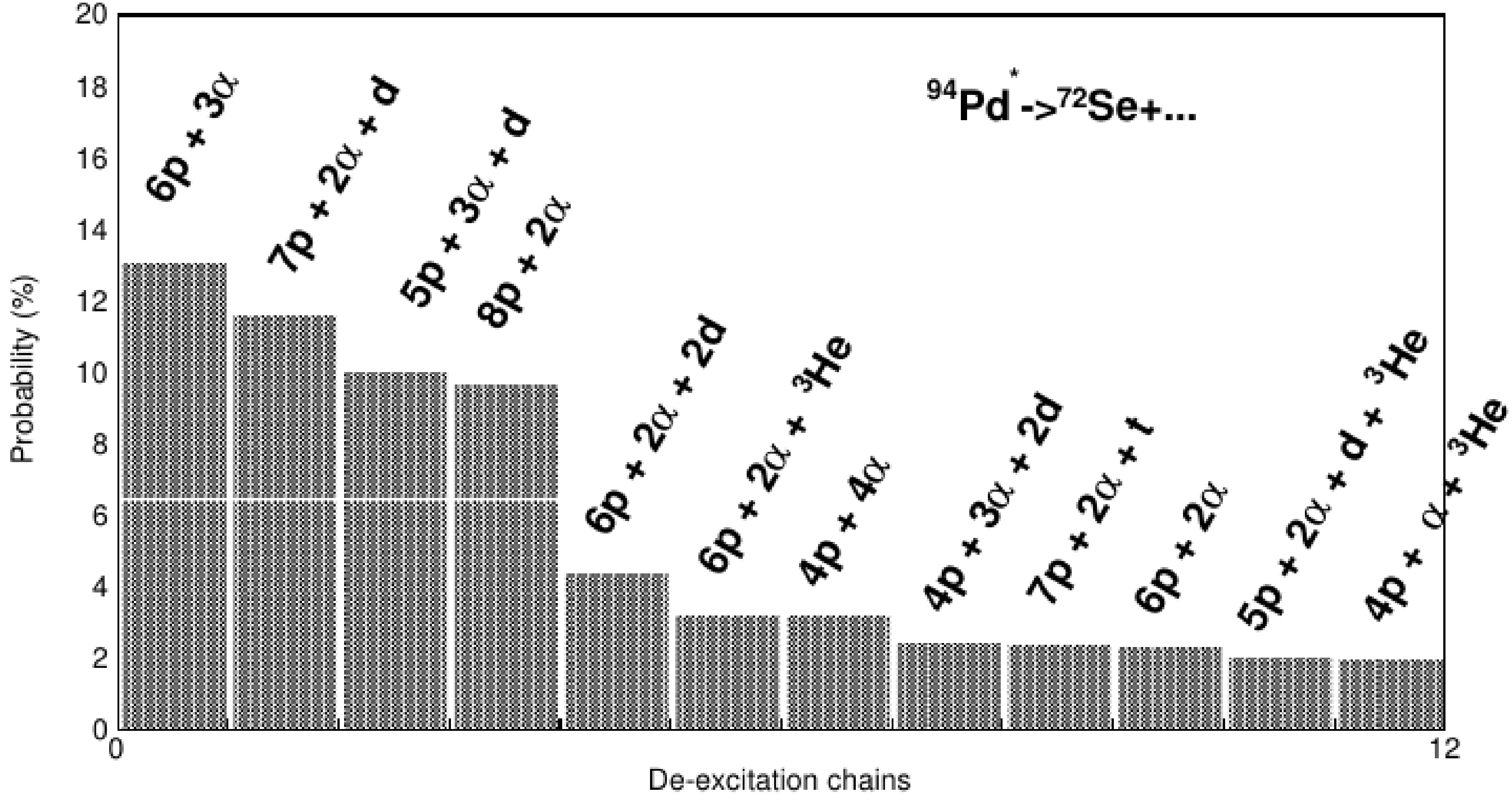


Results

Multiplicity



Results

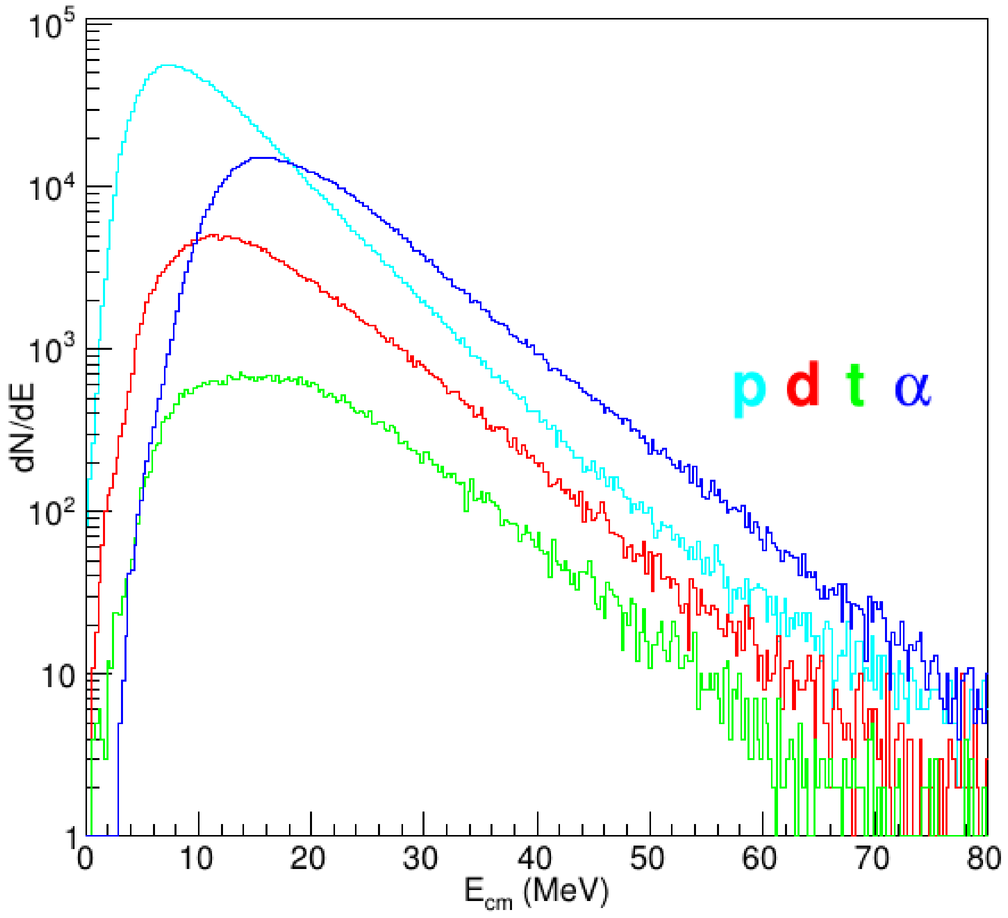


$^{94}Pd^* \rightarrow {}^{72}Se + \ldots$
6p + 3α
7p + 2α + d
5p + 3α + d
8p + 2α
6p + 2α + 2d
6p + 2α + ³He
4p + 4α
4p + 3α + 2d
7p + 2α + t
6p + 2α
5p + 2α + d + ³He
4p + α + ³He
Probability (%)
De-excitation chains
0
2
4
6
8
10
12
14
16
18
20

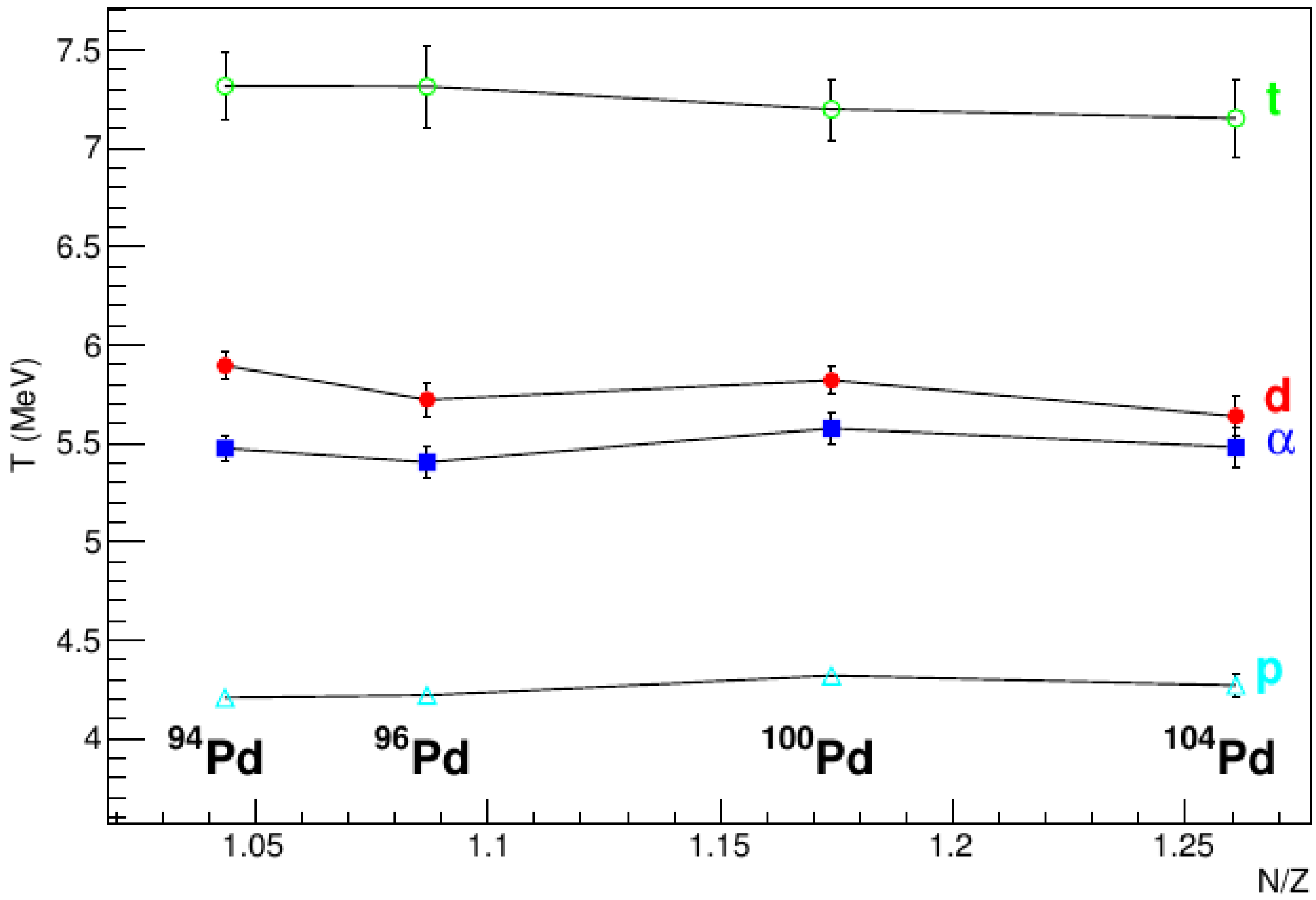
Level density parameter from evaporation spectrum

$$U = aT^2$$

$$\frac{d\sigma}{dE} \propto (E - Cb) \exp\left(\frac{-(E - Cb)}{T} \right)$$



Level density parameter from evaporation spectra

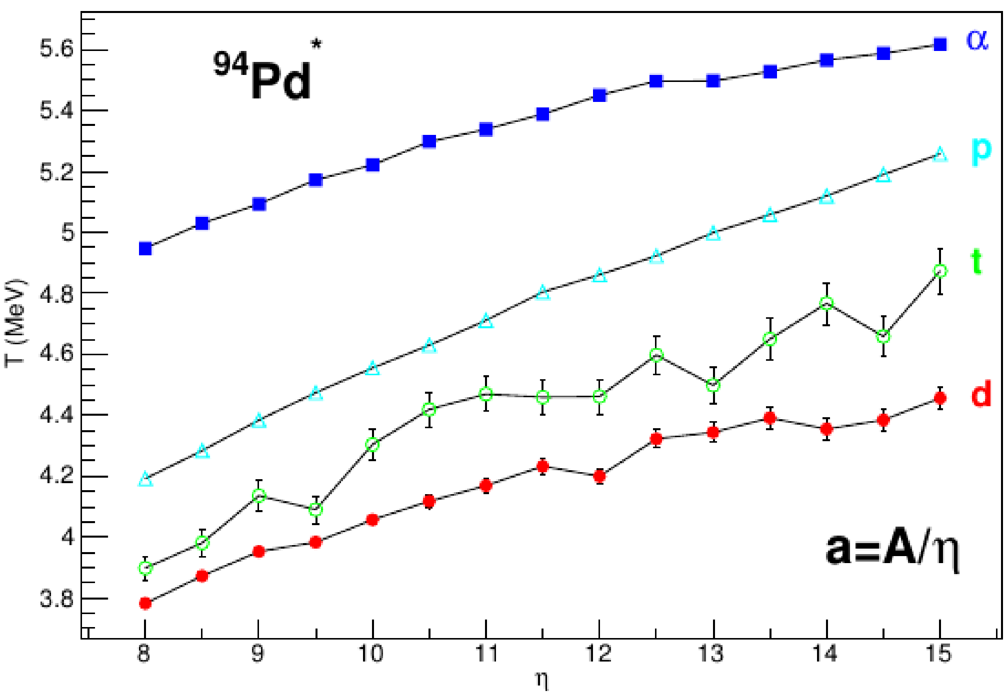


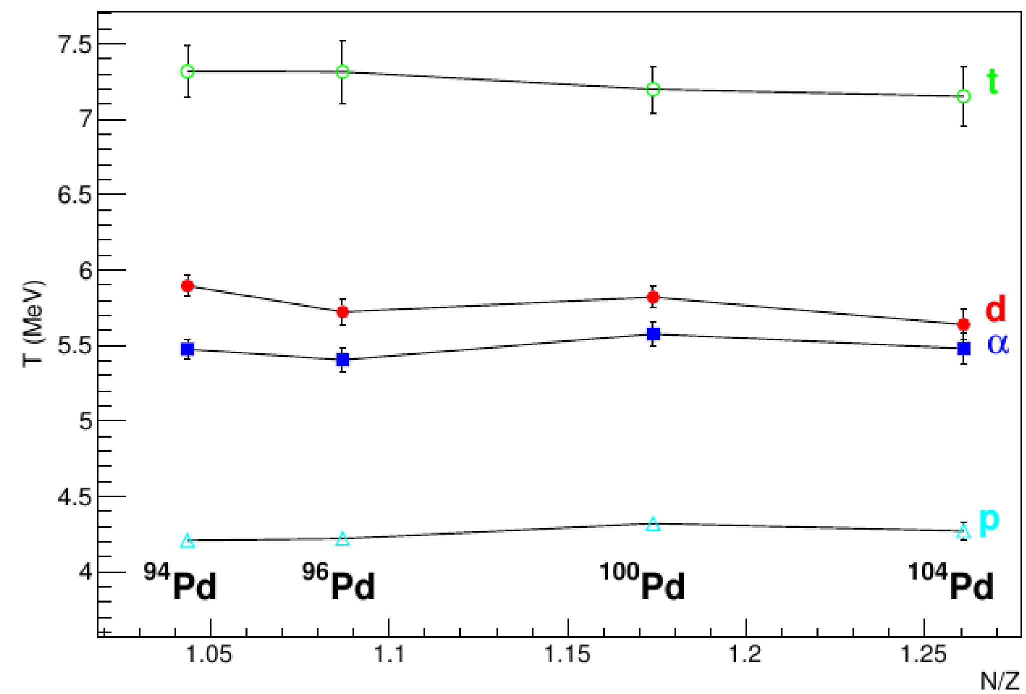
Results

Gemini++

Full Hauser-Feshback calculations

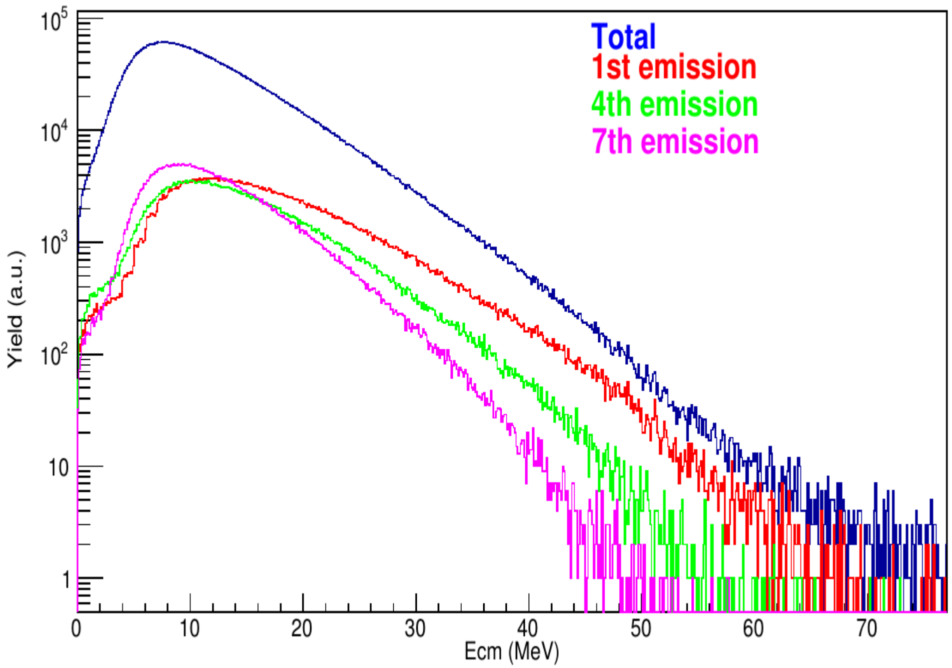
Evaporation up to ^{10}Be

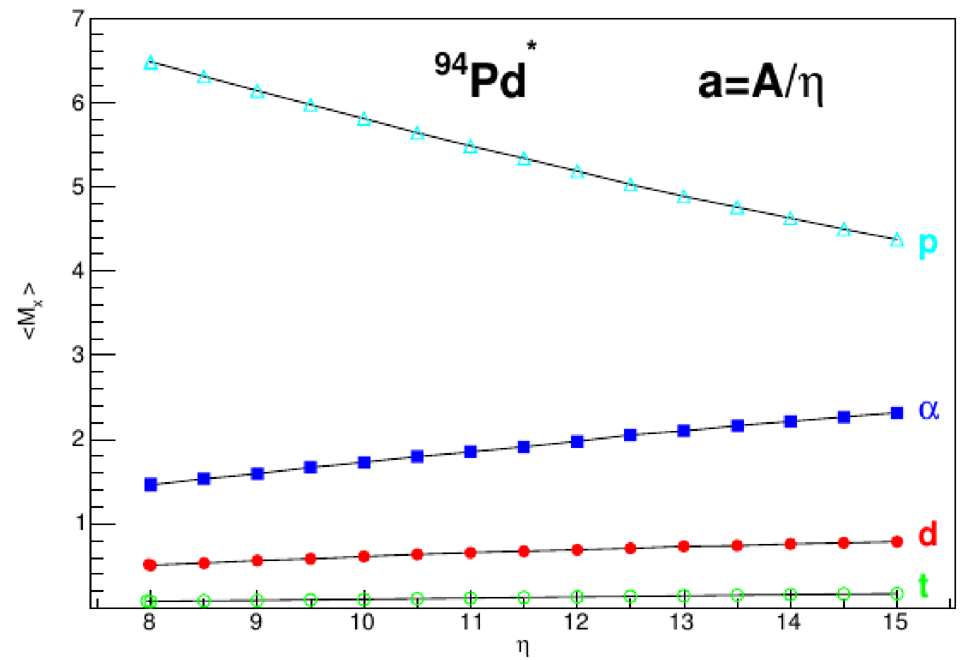


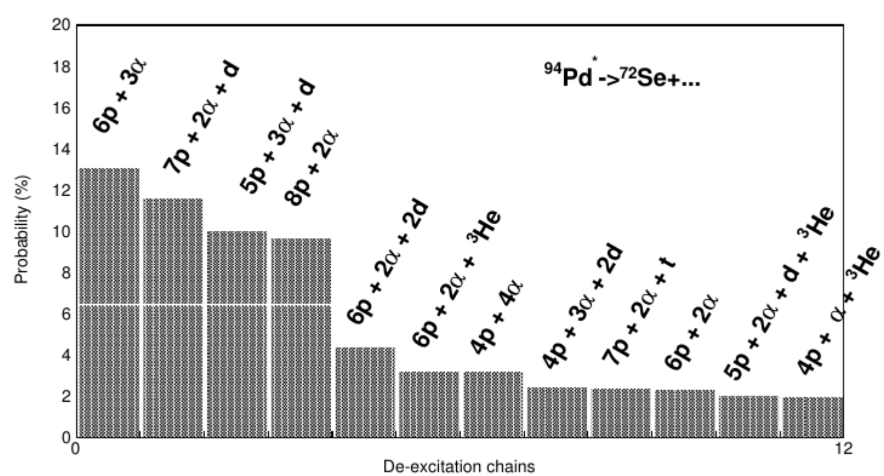


Results

Sequential decay







Conclusion

- **Coupling of INDRA and VAMOS gives unique results**

- **Mass identification of the residue with VAMOS gives new ways to study de-excitation properties**

- Thank you for your attention !