Measurements of level densities in hot nuclei

Letter of Intent

Measurements of level densities from compound nuclear reactions

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→ **Submitted to the LNL PAC**

Level density and CN population

$$\sigma_b(\varepsilon_a, \varepsilon_b) = \sum_{J\Pi} \sigma_a^{\mathrm{CN}}(\varepsilon_a) \frac{\Gamma_b(U, J, \Pi, E_k, I_k, P_k)}{\Gamma(U, J, \Pi)} \ ,$$

$$\frac{d\sigma}{d\varepsilon_b}(\varepsilon_a, \varepsilon_b)$$

$$= \sum_{J\Pi} \sigma_a^{\mathrm{CN}}(\varepsilon_a) \frac{\sum_{IP} \Gamma_b(U, J, \Pi, E, I, P) \rho_b(E, I, P)}{\Gamma(U, J, \Pi)} \quad (2)$$

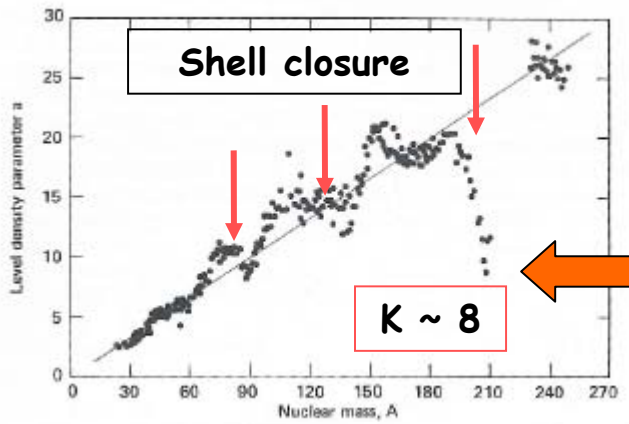
with

$$\Gamma(U, J, \Pi) = \sum_{b'} \left(\sum_{I'P'} \int_{E_c}^{U - B_{b'}} dE' \Gamma_{b'}(U, J, \Pi, E', I', P') \right.$$

$$\times \rho_{b'}(E', I', P')$$

$$\left. + \sum_k \Gamma_{b'}(U, J, \Pi, E_k, I_k, P_k) \right) . \quad (3)$$

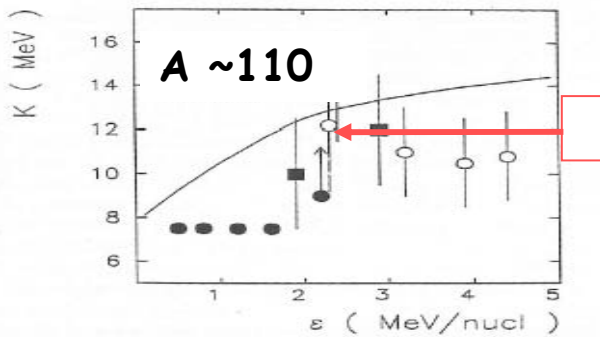
Nuclear Level density studies

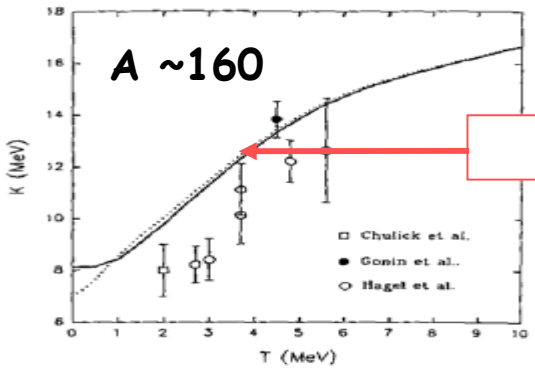


$$\rho(U) = \frac{\sqrt{\pi}}{12} \frac{\exp(2\sqrt{aU})}{a^{1/4} U^{5/4}}$$

$$a = \frac{1}{6}\pi^2 g(\varepsilon_F)$$

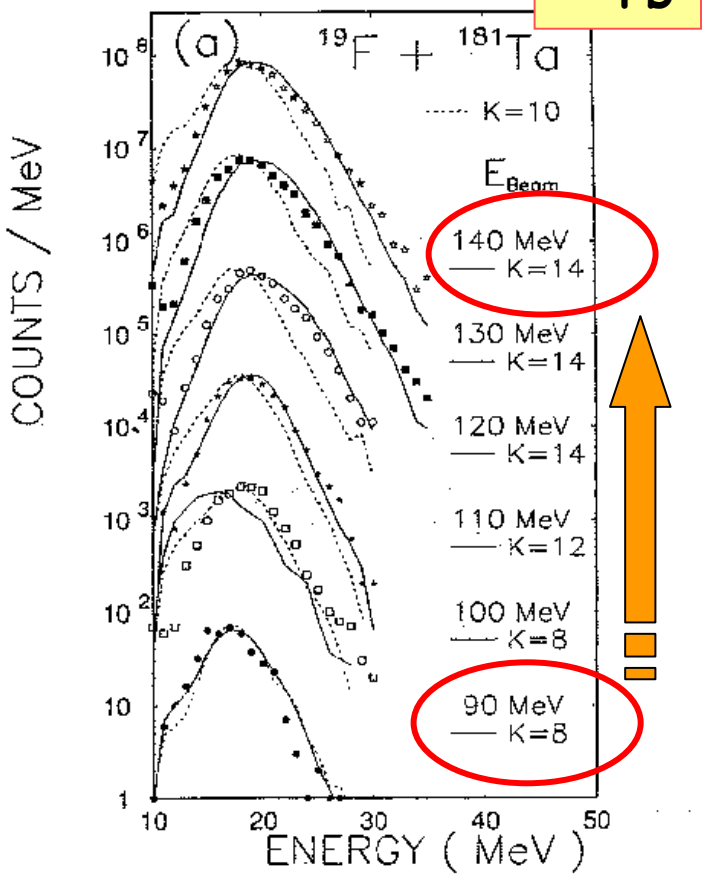
$$K = \frac{A}{a}$$





Spectra of α

^{200}Pb



D. Fabris et al., PRC 50 (1994)

Isospin Effects on Nuclear Level density

1) $a = \alpha A$
2) $a = \alpha A / \exp[\beta(N-Z)^2]$
3) $a = \alpha A / \exp[\gamma(Z - Z_0)^2]$

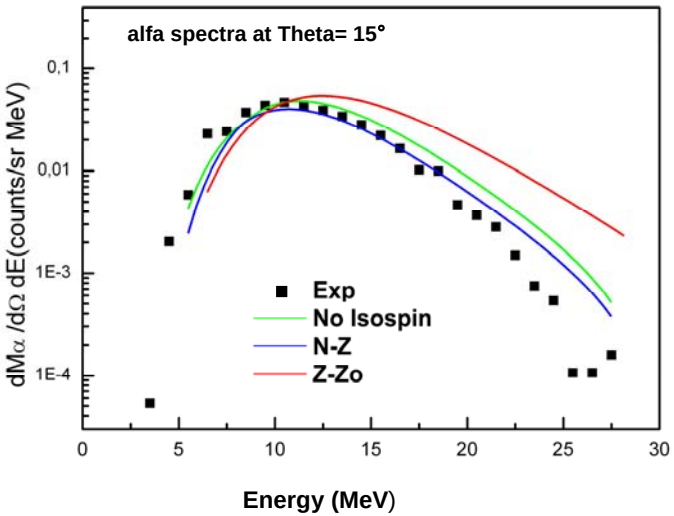
Al-Quraishi et al., PRC 63 (2001) 065803

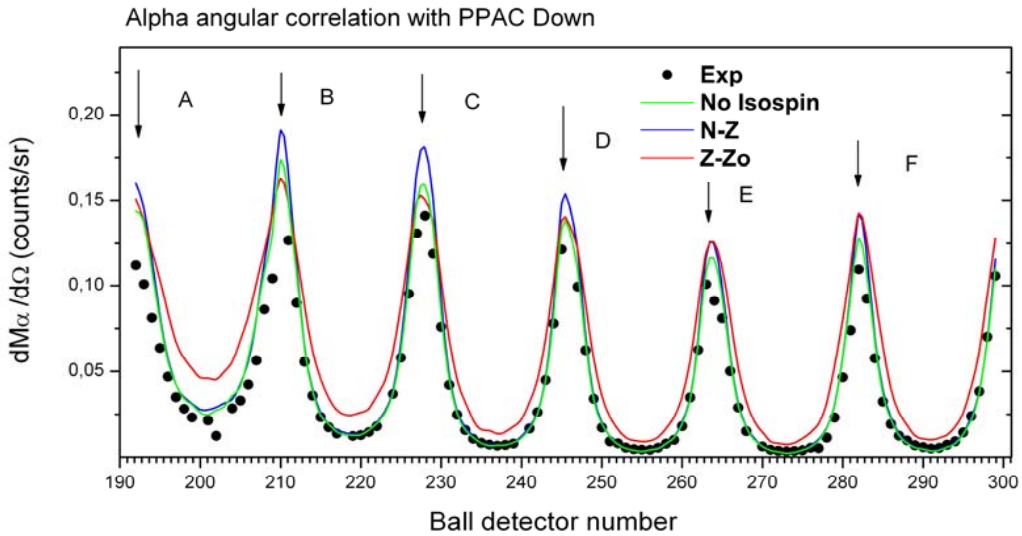
Al-Quraishi et al., PRC 67 (2003) 015803

How this parameterization works at higher excitation energy ?

$^{32}S + ^{107}Ag \rightarrow ^{139}Eu$ (E_x=90 MeV)

8πLP@LNL



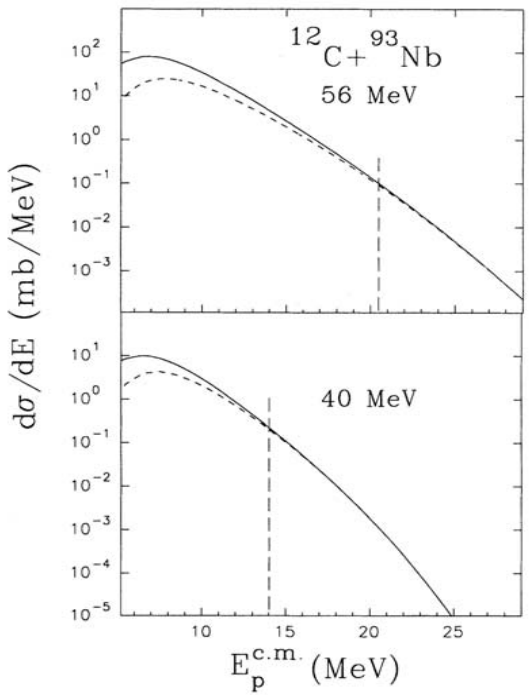


No evidence of Z-Zo effects

No possible to discriminate between st. and N-Z

Measurement of the Level Density (I)

At moderate excitation energies of the CN, the high energy part of the particle spectrum arises mainly from the first step decay.



- A~ 100, E_{proton}= 13 – 20 MeV predominantly from 1st step
- Typical range of applicability E_X= 5 – 25 MeV

TABLE I. Experimental information and input and output parameters. $E_p^{c.m.}(90\%)$ is proton c.m. energy at which 1st step contribution is 90%. E_x^{max} is maximum E_x in residual nuclei up to which NLD is extracted. δa is A/a where A is the mass number of the residual nuclei

Reaction	E_{beam} (MeV)	E_X^{CN} (MeV)	σ_{fus} (mb)	L_0^{CN}	$E_p^{c.m.}(90\,\%)$ (MeV)	E_X^{max} (MeV)	δa (MeV)
	40	35.0	188	10	14.0	16	8.9±0.3
$^{12}C+^{93}Nb$	45	39.4	515	18	16.0	18	8.5±0.3
$\rightarrow p+^{104}Pd$	50	43.9	779	23	18.0	21	8.7±0.3
	56	49.1	1039	28	20.5	24	9.1±0.6
$^{12}C+^{103}Rh$	53	46.3	633	21	19.5	24	9.2±0.4
$\rightarrow p+^{114}Sn$							

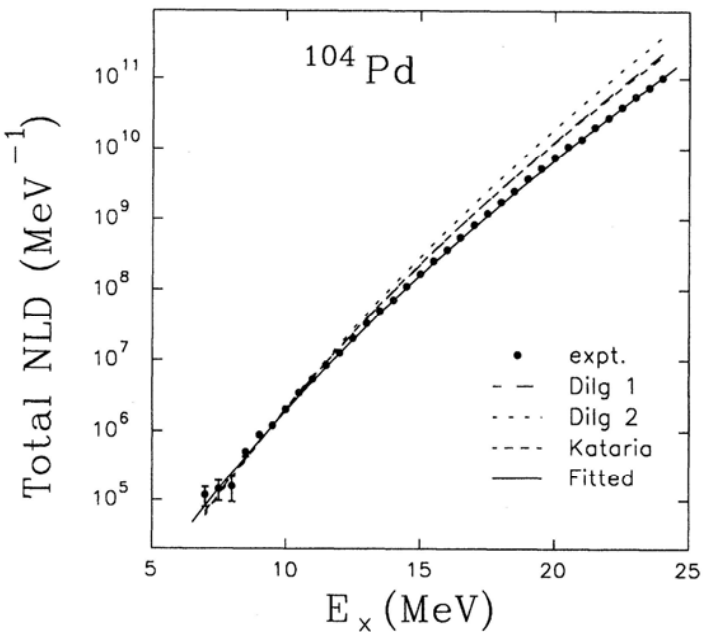
D.R. Chakrabarty et al., PRC 51 (1995)

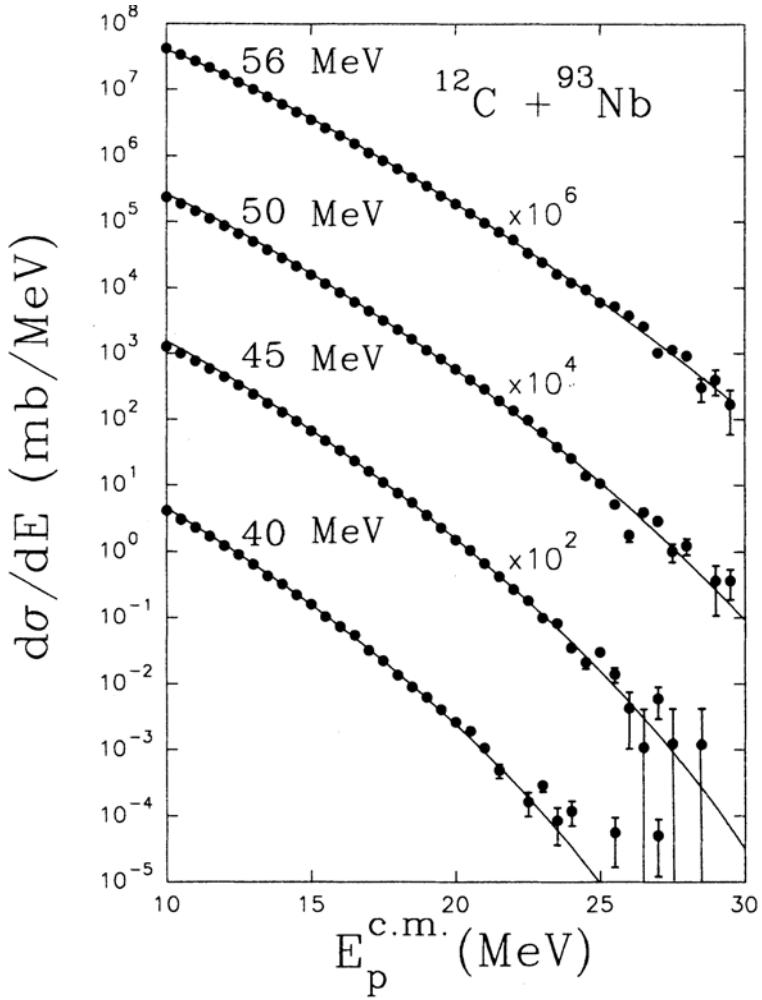
Measurement of the Level Density (II)

Measurement of the LD for a specific nucleus

$$\rho_{exp}(E_X) = \left[\frac{\rho_{cal}(E_X)}{\sigma_{cal}(E_p^{c.m.})}\right]\sigma_{exp}(E_p^{c.m.}),$$

$$E_X = E_X^{CN} - S_p - E_p^{c.m.}$$

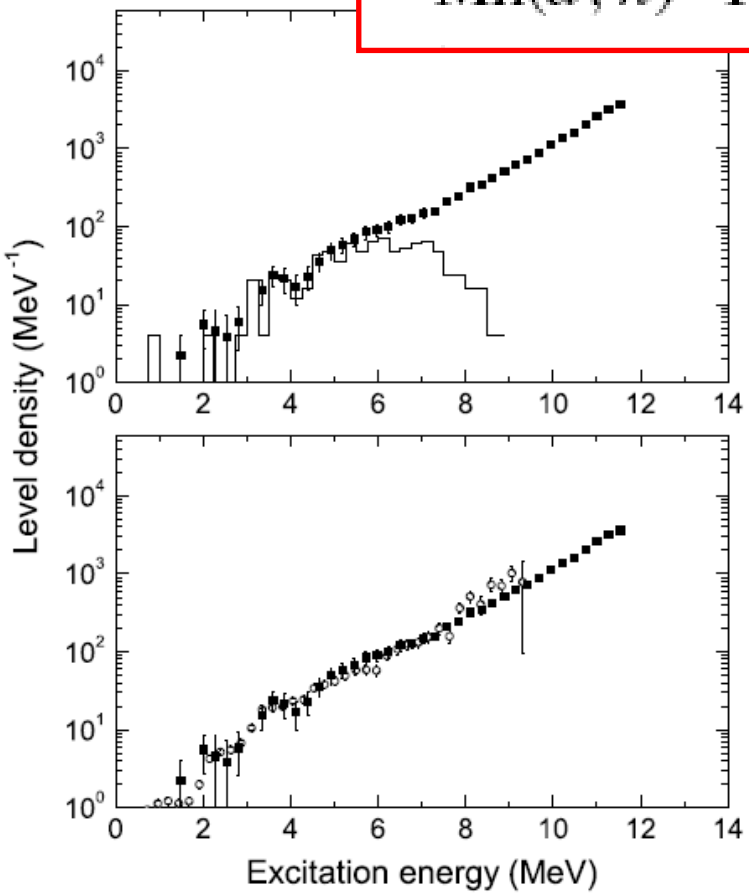




D.R. Chakrabarty et al., PRC 51 (1995)

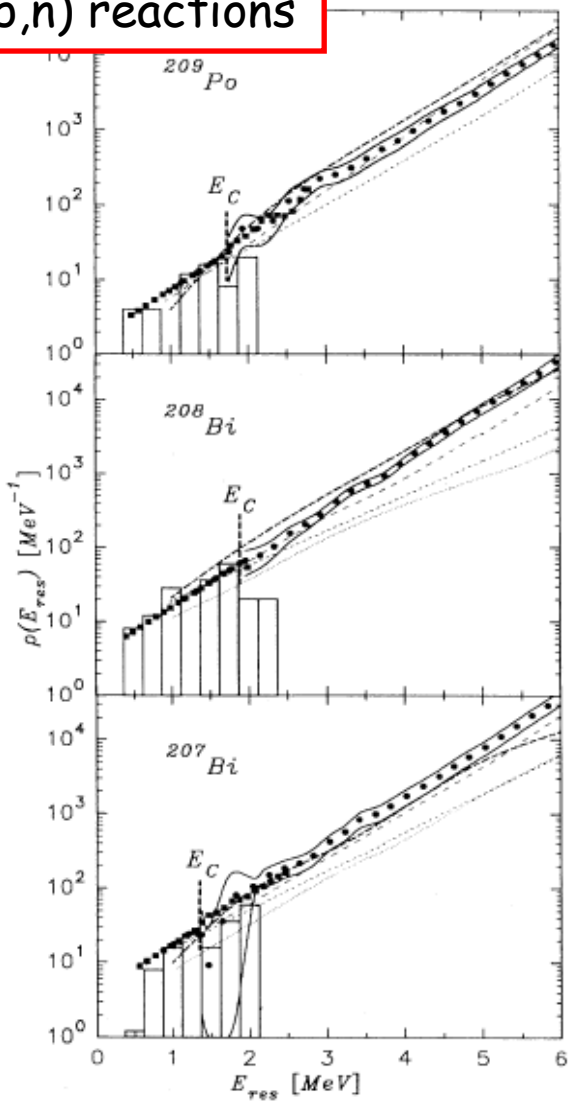
Measurement of the Level Density (II)

$^{55}\mathrm{Mn}(d,n)^{56}\mathrm{Fe}$



A.V. Voinov et al., PRC 74 (2006)

(p,n) reactions



A. Wallner et al., PRC 51 (1995)

Systems Proposed and Experimental Needs

Projectile energy, MeV	Reaction	Compound Nucleus Excitation Energy, MeV
40	$^{12}C + ^{74}Ge$	45
53	$^{16}O + ^{70}Ge$	45
93	$^{28}Si + ^{58}Ni$	45
40	$^{12}C + ^{49}Ti$	48

Table 1. List of possible reactions to be studied at the Laboratori Nazionali di Legnaro.

^{86}Sr
^{86}Zr
^{86}Mo
^{61}Ni

- Light particle spectra with high precision over many decades
- Angular distributions
- CN contribution tagging (ER residues detection)

Detectors at LNL:

GARFIELD, **8πLP** (charged particles) and **RIPEN** (neutrons)

60 MeV ^{16}O + ^{58}Fe → ^{74}Se

Bombarding energy (MeV)	60.00
Center of mass energy (MeV)	47.03
Compound nucleus excitation energy (MeV)	52.349
Q-value of reaction (MeV)	5.322
Compound nucleus recoil energy (MeV)	12.973
Compound nucleus recoil velocity (cm/ns)	5.820e-01
Compound nucleus velocity/c	1.940e-02
Beam velocity (cm/ns)	2.692e+00
Beam velocity/c	8.973e-02

60 MeV ^{16}O + ^{58}Ni →^{74}Kr

Bombarding energy (MeV)	60.00
Center of mass energy (MeV)	47.03
Compound nucleus excitation energy (MeV)	44.394
Q-value of reaction (MeV)	-2.633
Compound nucleus recoil energy (MeV)	12.973
Compound nucleus recoil velocity (cm/ns)	5.820e-01
Compound nucleus velocity/c	1.940e-02
Beam velocity (cm/ns)	2.692e+00
Beam velocity/c	8.973e-02