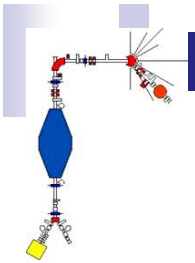


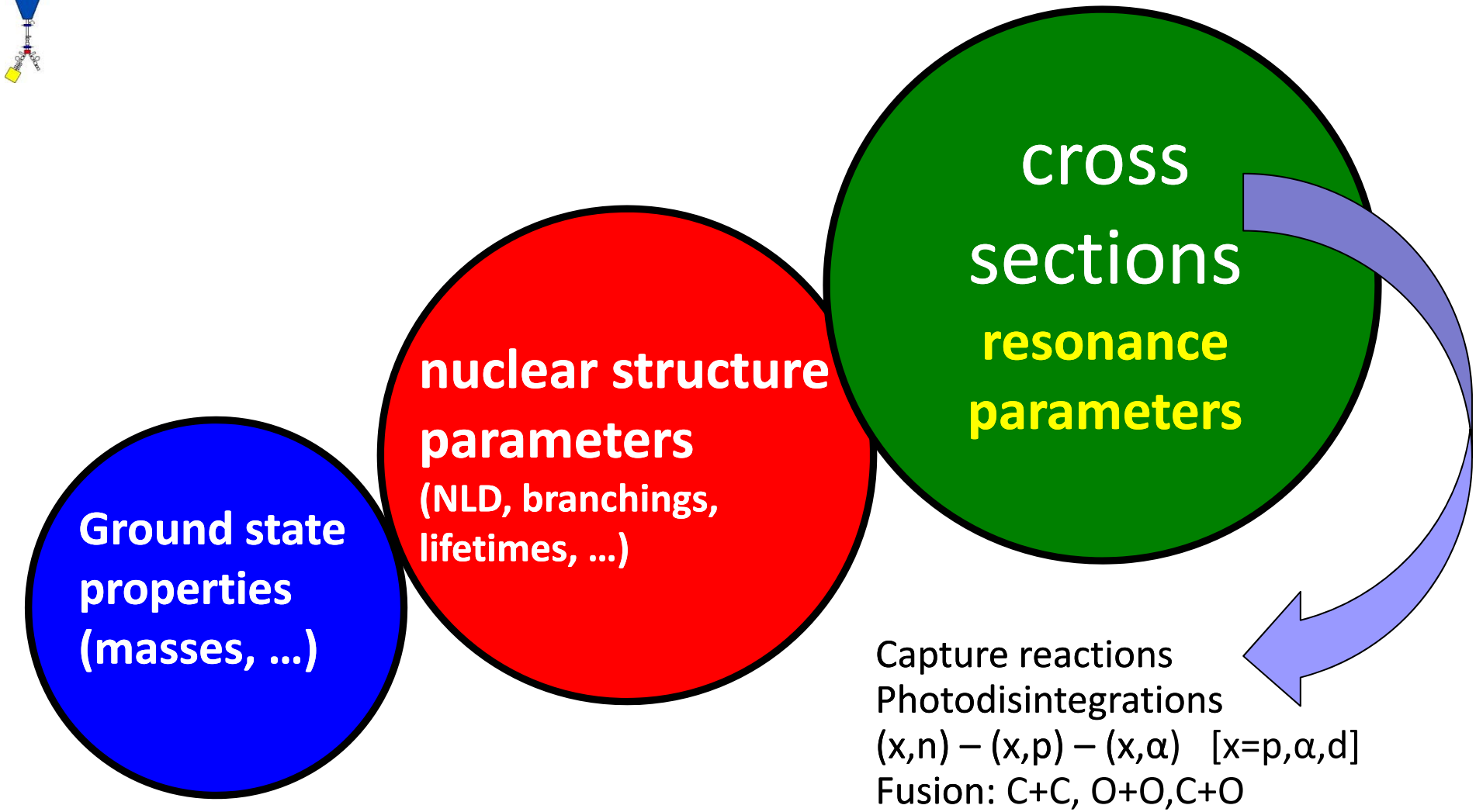
Gamma calorimeters for experimental studies relevant to explosive nucleosynthesis

Sotirios V. Harissopulos

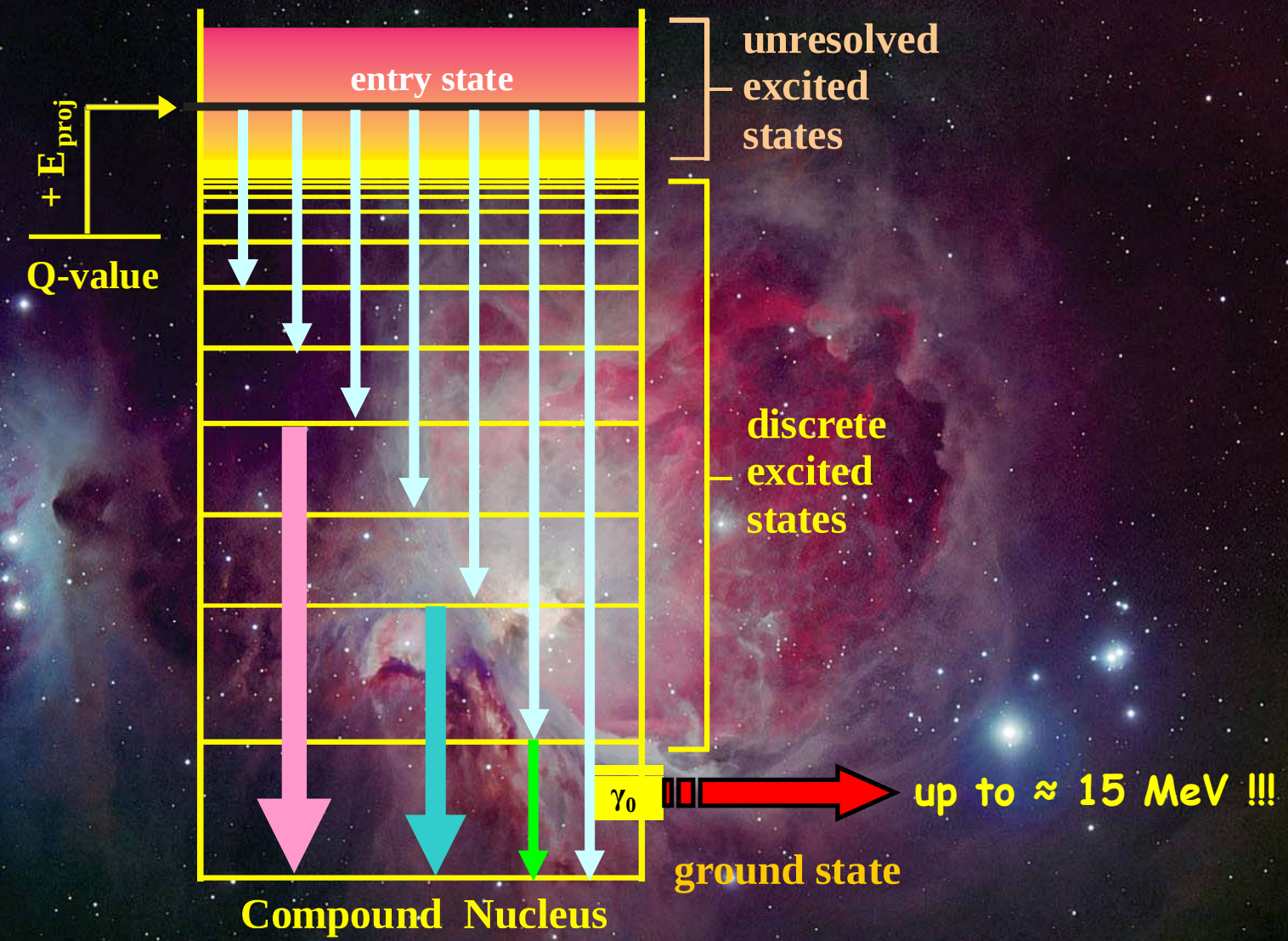
LIBRA / Tandem Accelerator Laboratory, NCSR "Demokritos", Athens, GR

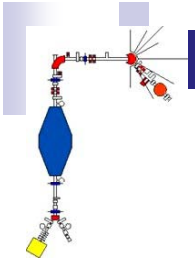
sharisop@inp.demokritos.gr


Tandem Accelerator Lab., NCSR "Demokritos"- Athens
P. Demetriou, A. Lagoyannis, M. Axiotis , A. Spyrou, S. Galanopoulos, P. Tsagari,
V. Foteinou, G. Provatas and T. Konstantinopoulos
EP3-Bochum
H.W. Becker, C. Rolfs
IfS-Stuttgart
M. Fey, R. Kunz, J.W. Hammer
IKP-Köln
A. Zilges, A. Dewald, K.O. Zell, P. von Brentano and the MINIBALL Collaboration
GANIL :
F. de Oliveira and P. Ujic
JYFL-Jyväskylä
R. Julin. P. Jones, T. Sajavara, H. Koivisto
IAA-ULB
S. Goriely


cross sections
resonance parameters
nuclear structure parameters
(NLD, branchings, lifetimes, …)
Ground state properties (masses, …)
Capture reactions
Photodisintegrations
(x,n) – (x,p) – (x,α) [x=p,α,d]
Fusion: C+C, O+O,C+O
Fission

γ – decay pattern of a compound nucleus

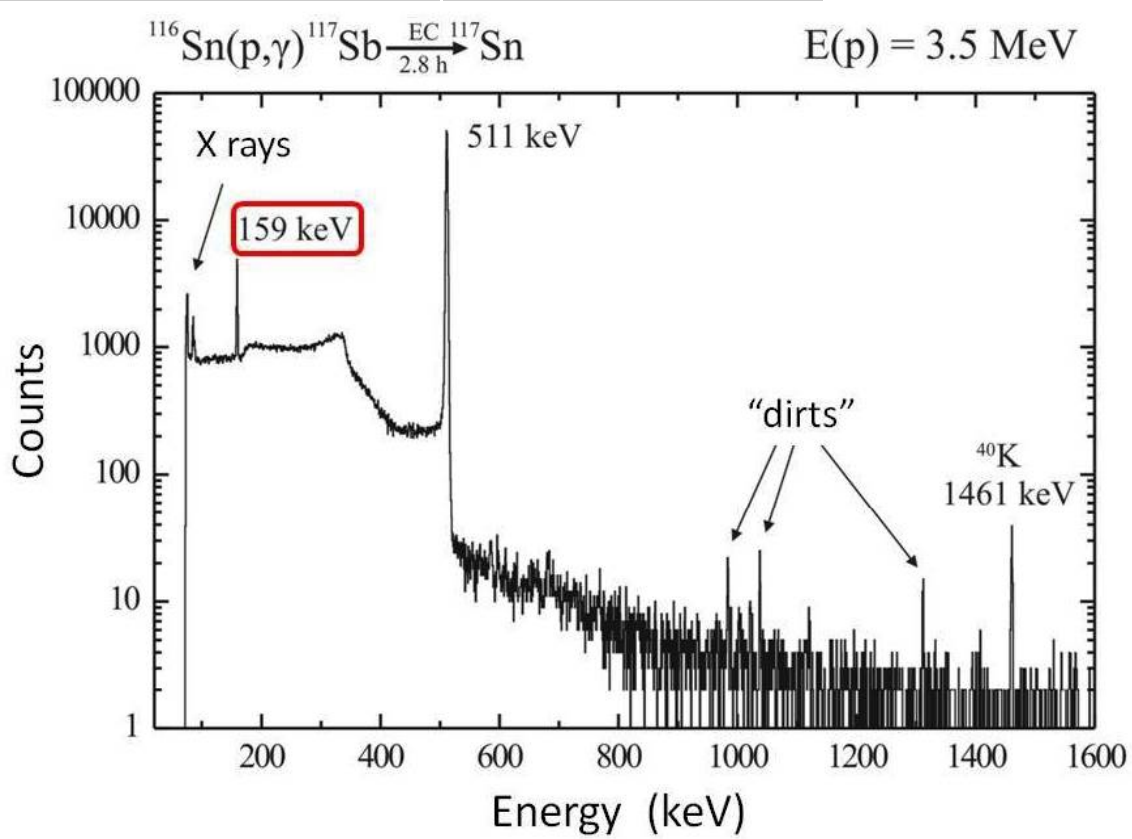




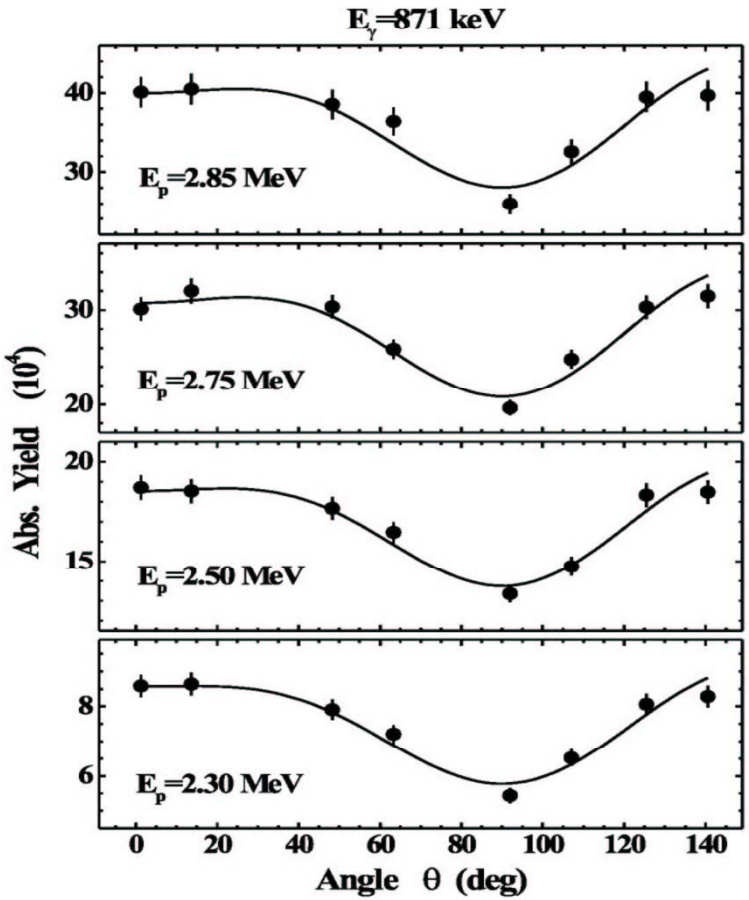
Capture-reaction cross-section measurements: Direct methods

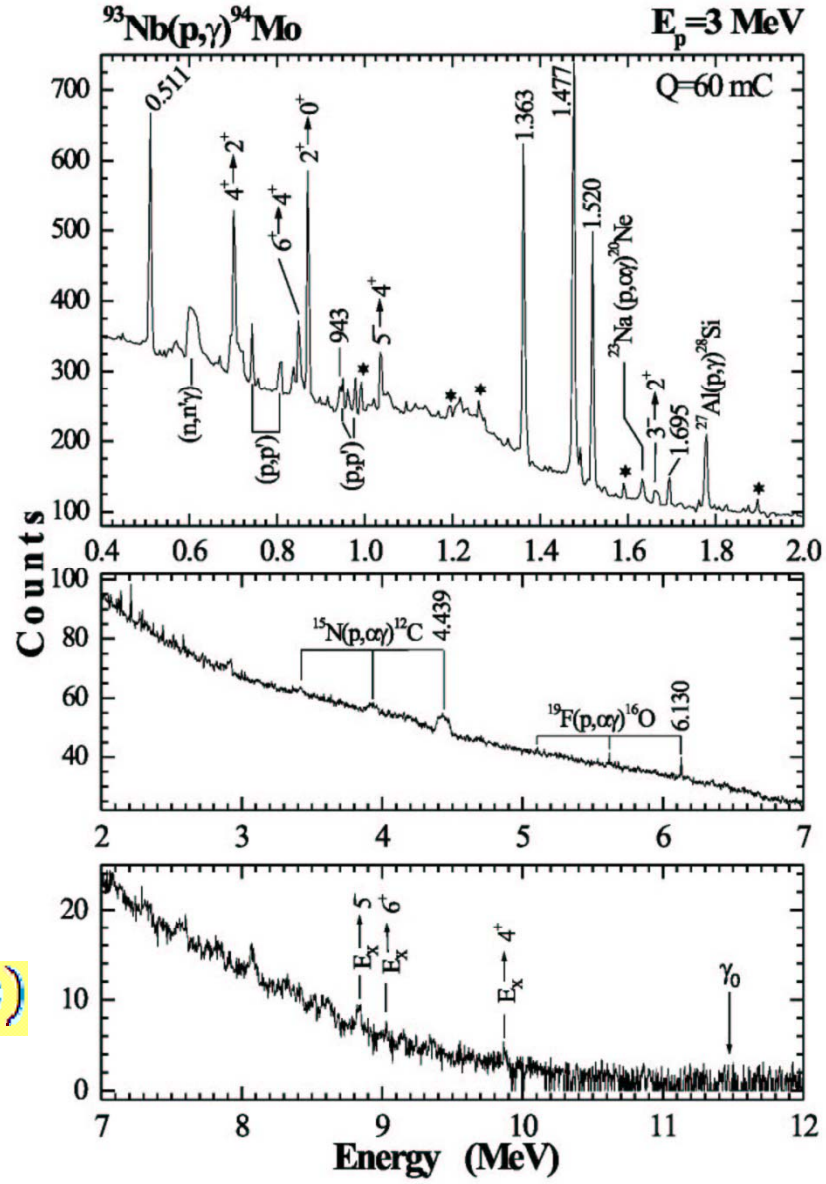
	OFF – BEAM activation measurements	IN–BEAM γ-angular distribution measurements
reaction to study	final nucleus must be unstable	any
target	enriched or natural	enriched
backing	If, then low-Z (C, Al, …)	If, then high-Z (Ta, Au, …)
detectors	normal size HPGe (ε≈30%)	large-volume HPGe (arrays) (ε≥70%)
γ rays to detect	in most cases $E_\gamma \leq 2$ MeV	up to $E_\gamma \approx 15$ MeV

	OFF – BEAM activation measurements	IN–BEAM γ-angular distribution measurements
reaction to study		
target		
backing		
detectors		
γ rays to detect		



$^{93}Nb(p,\gamma)^{94}Mo$

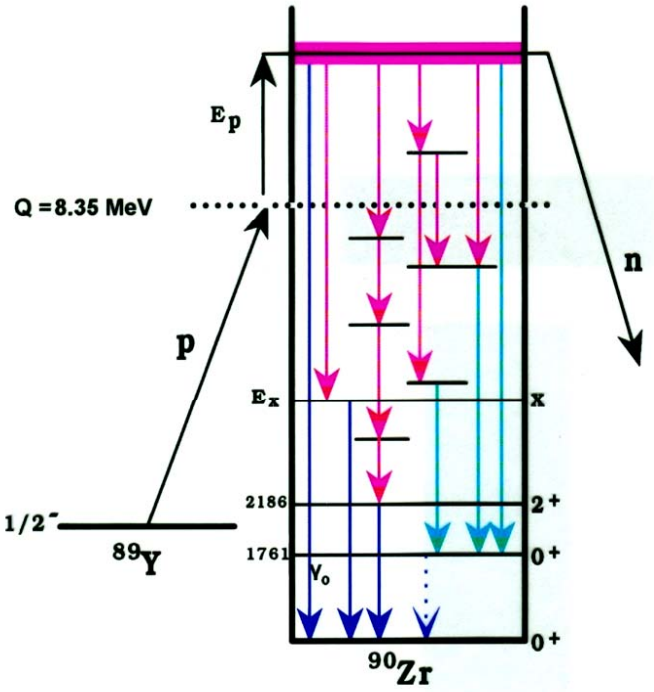


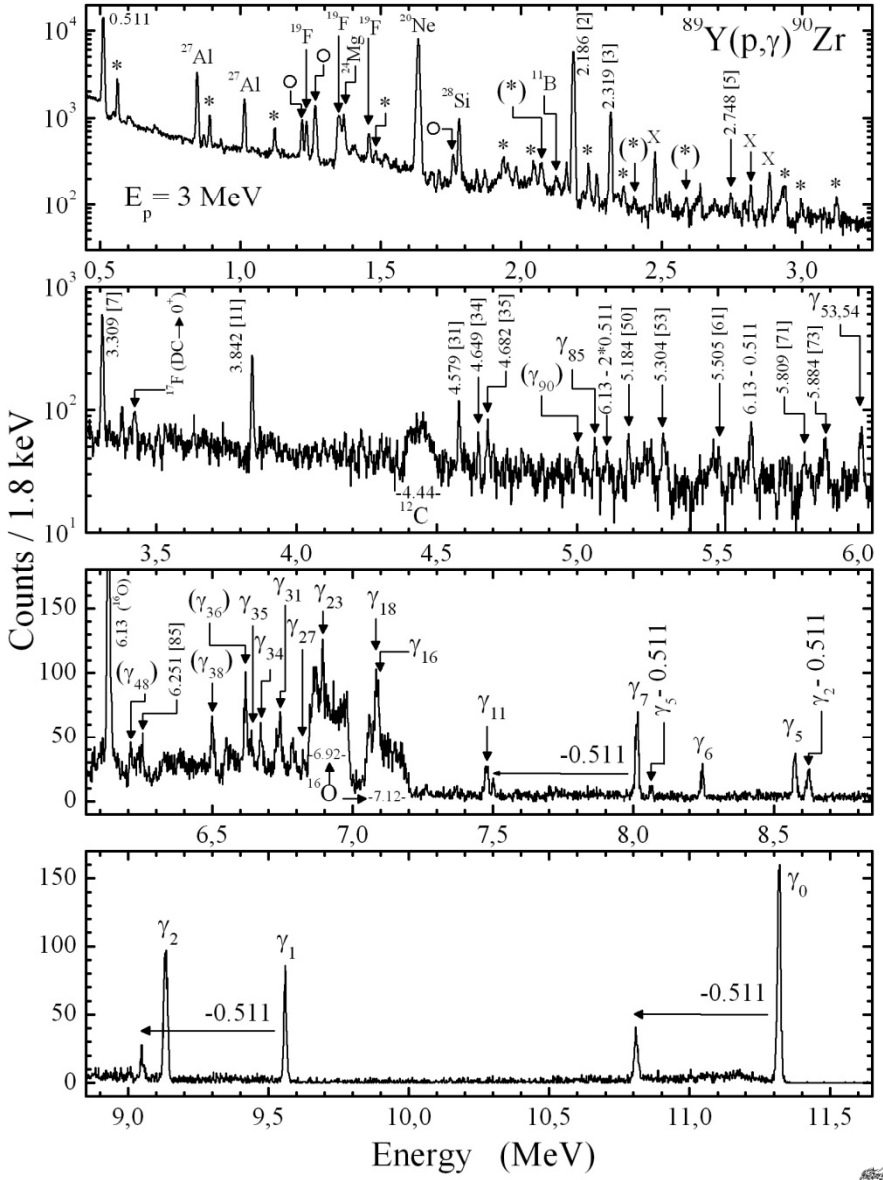


$$W(\vartheta) = A_0\left(1 + a_2 P_2(\cos\vartheta) + a_4 P_4(\cos\vartheta)\right)$$

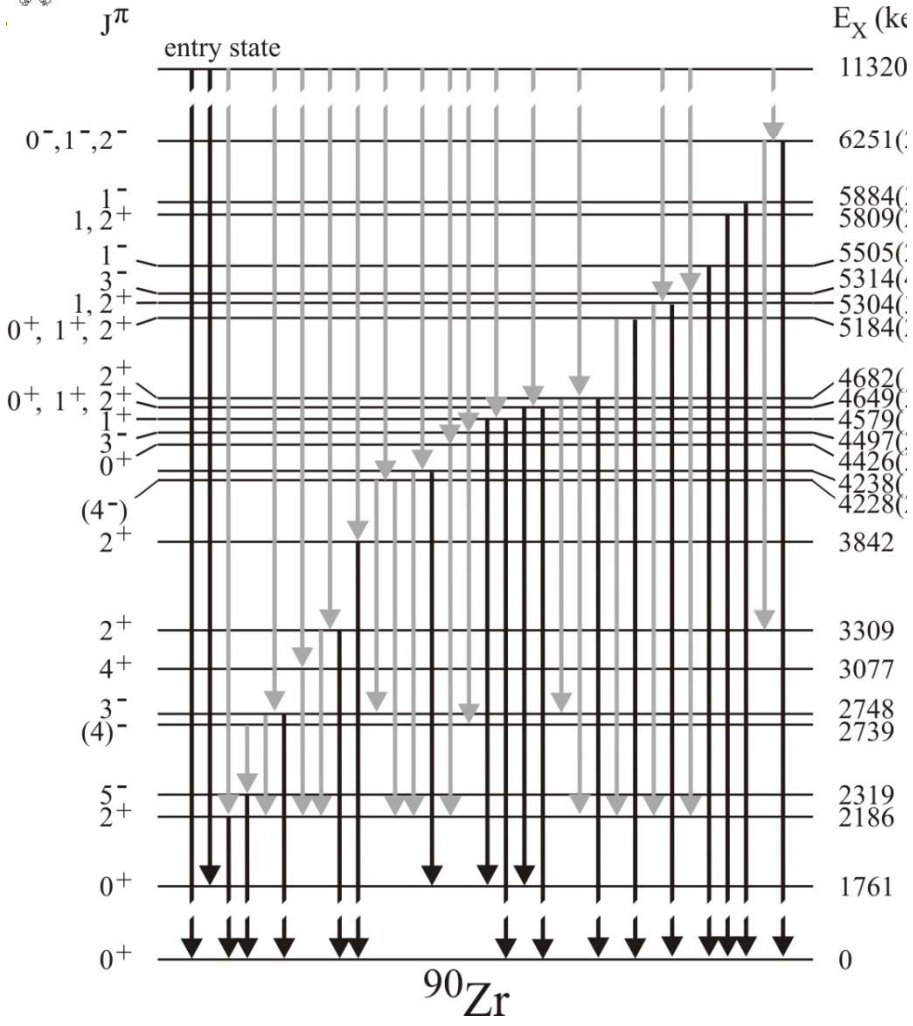
$$\sigma = \frac{A}{N_A N_p \xi} \sum_j (A_0)_j$$

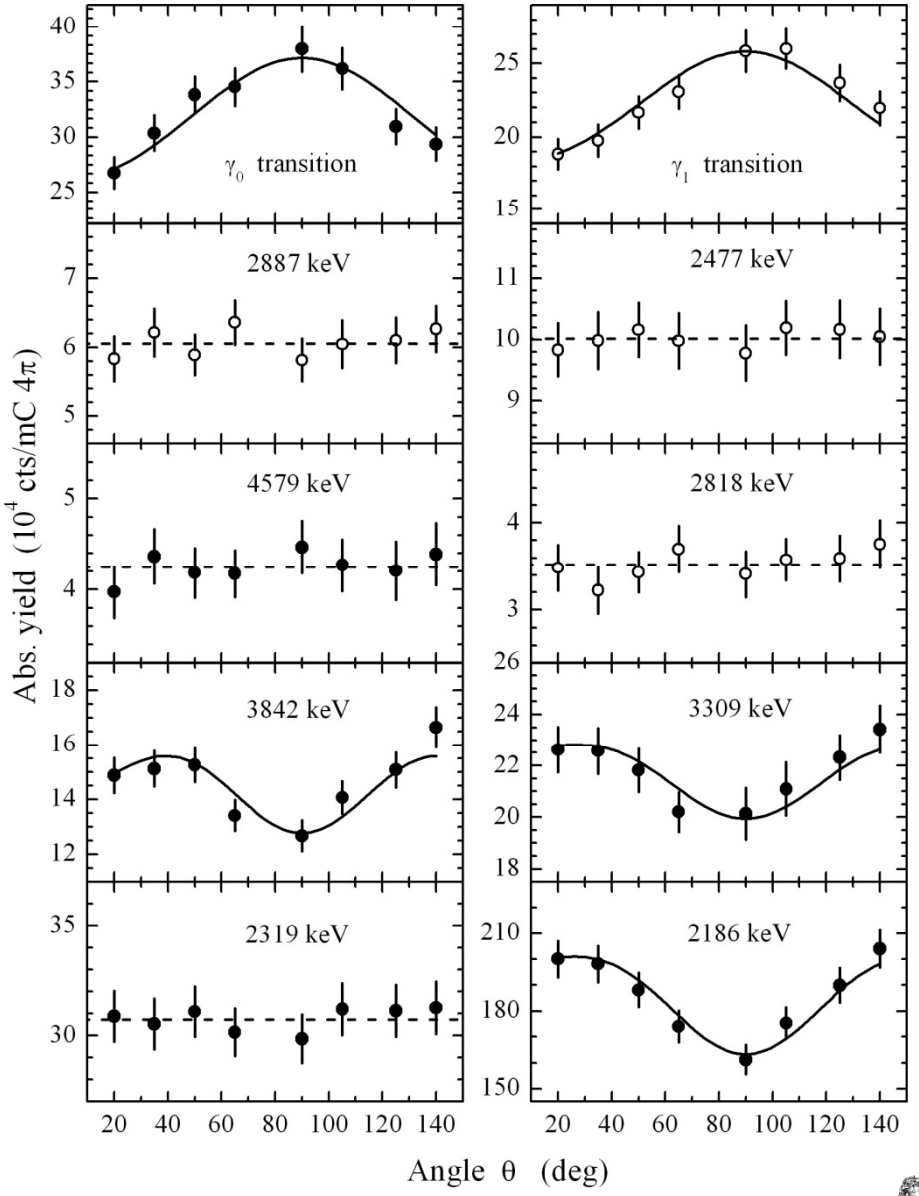
$^{89}Y(p,\gamma)^{90}Zr$: γ – angular distribution measurements



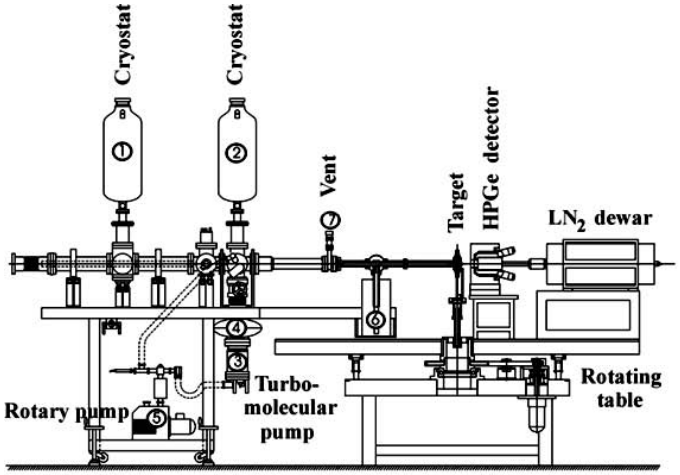


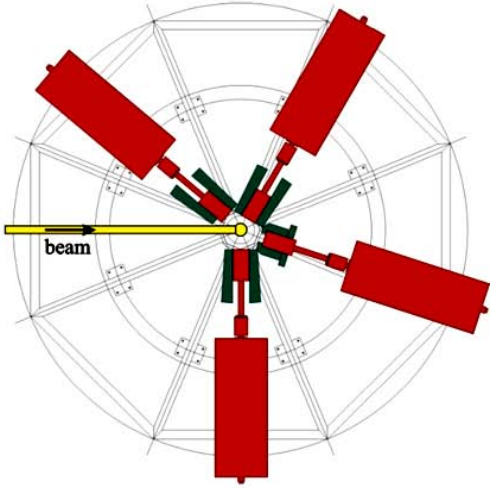
$^{89}Y(p,\gamma)^{90}Zr$: γ – angular distribution measurements

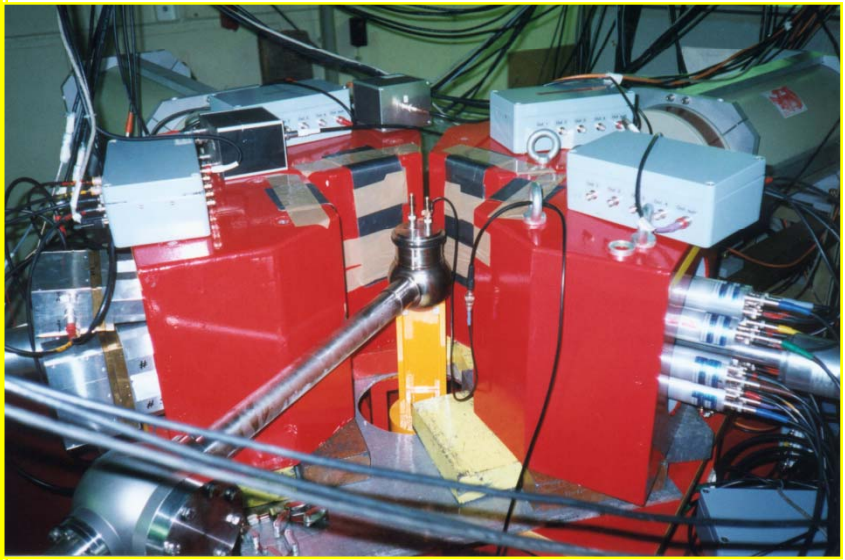


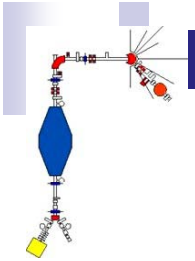


γ – angular distribution measurements @ IfS Stuttgart





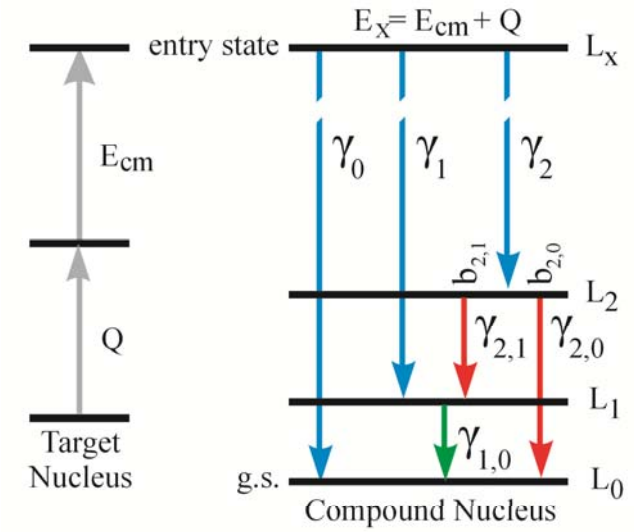


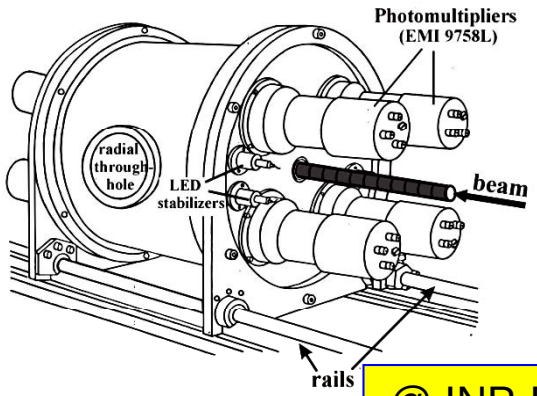


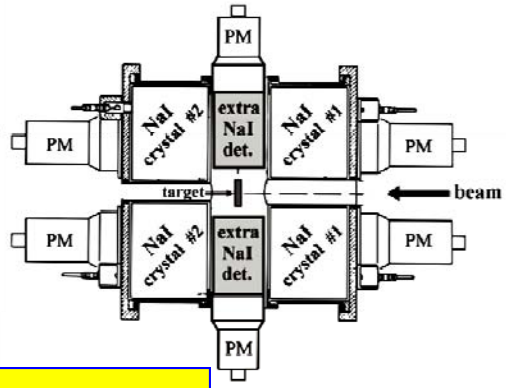
Capture-reaction cross-section measurements: Direct methods

	OFF – BEAM activation measurements	IN–BEAM γ-angular distribution measurements	IN–BEAM angle-integrated measurements
reaction to study	final nucleus must be unstable	any	any
target	enriched or natural	enriched	enriched
backing	If, then low-Z (C, Al, …)	If, then high-Z (Ta, Au, …)	If, then depends on the Q-value !
detectors	normal size HPGe (ε≈30%)	large-volume HPGe (arrays) (ε≥70%)	4π calorimeters [large NaI(Tl)] (ε≈100%)
γ rays to detect	in most cases $E_\gamma \leq 2$ MeV	up to $E_\gamma \approx 15$ MeV	up to $E_\gamma \approx 25$ MeV

A. Spyrou *et al.*, PRC 76, 015802 (2007)

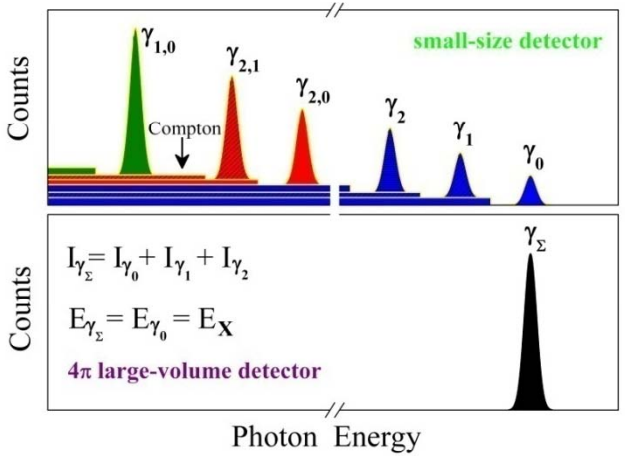


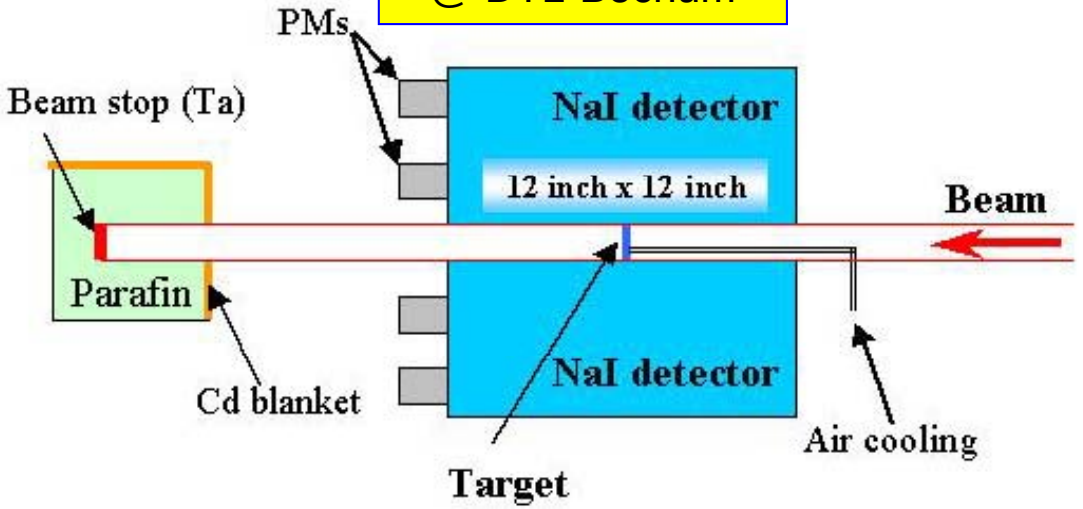




@ INP-Demokritos

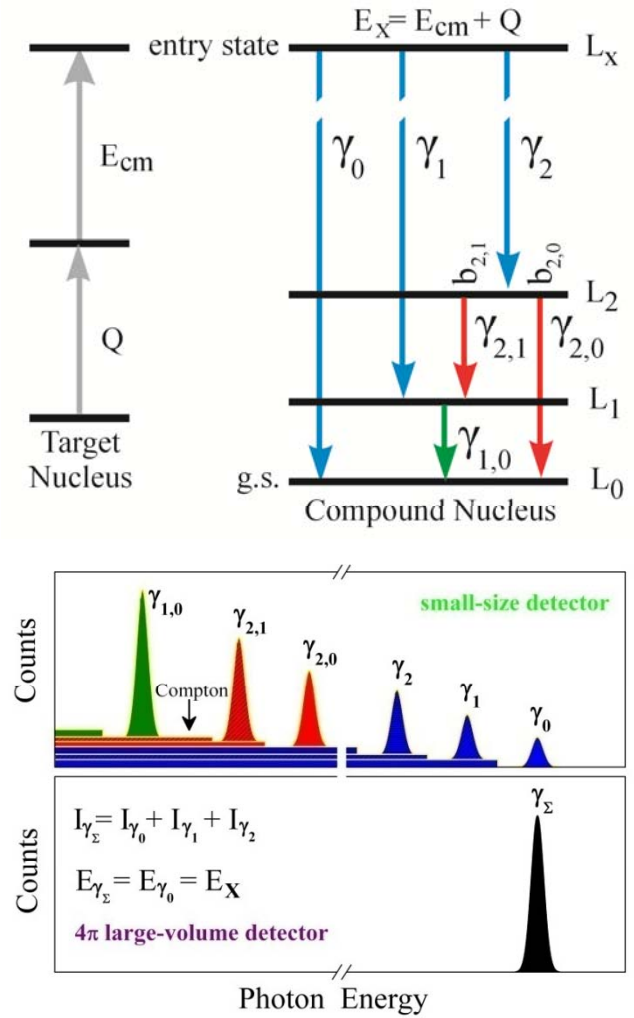
@ DTL-Bochum

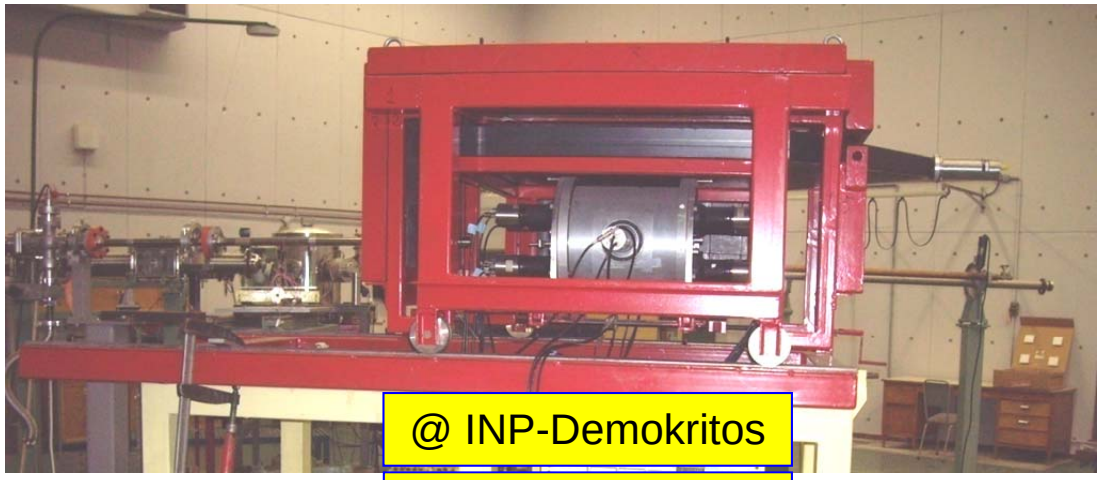




The 4π γ – summing method

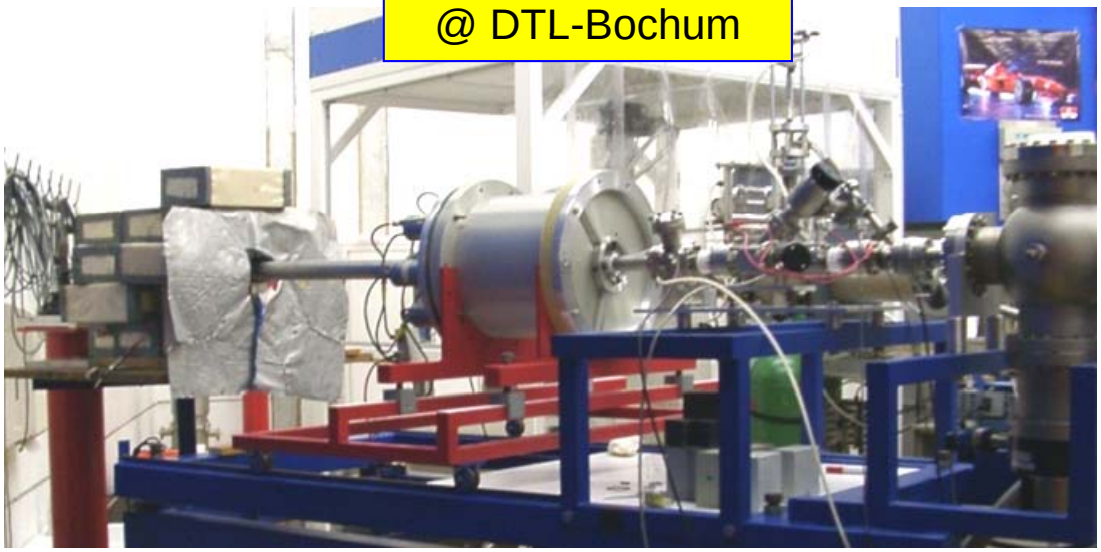
A. Spyrou *et al.*, PRC 76, 015802 (2007)



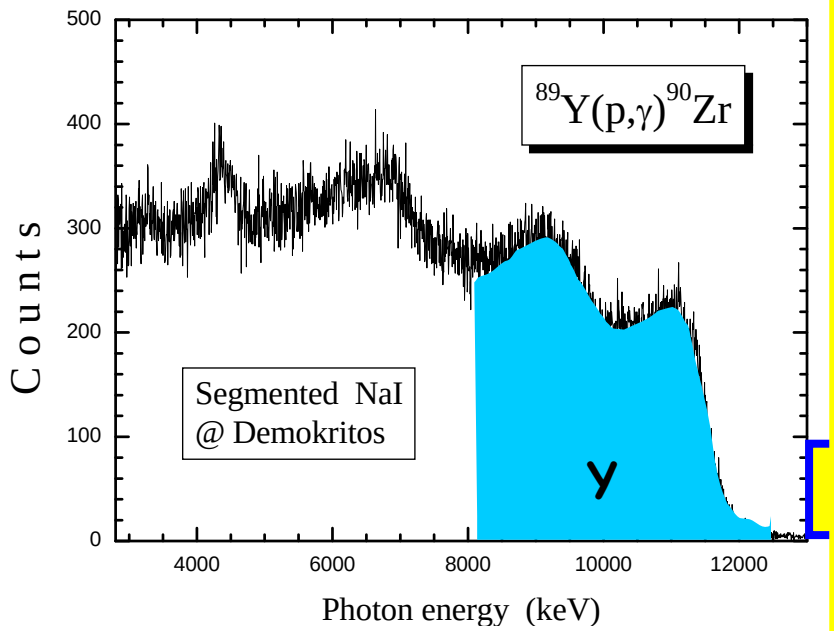


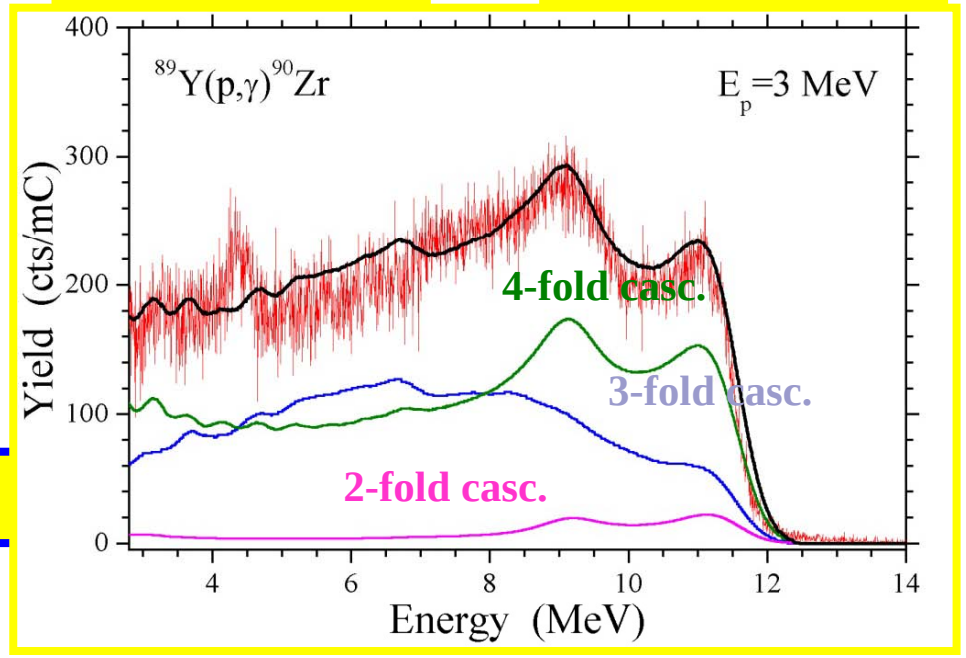
@ INP-Demokritos

@ DTL-Bochum

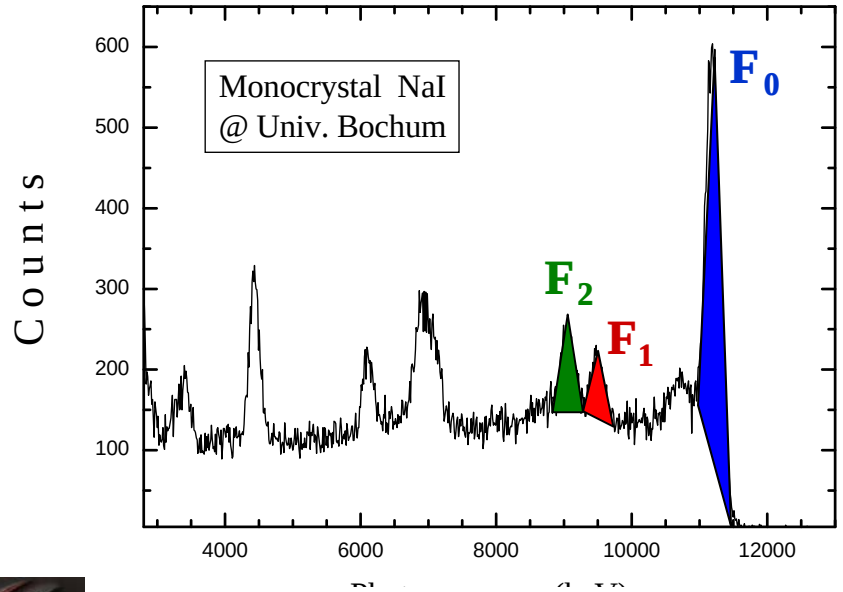


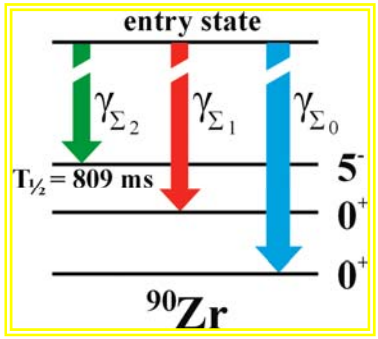
$^{89}Y(p,\gamma)^{90}Zr$ cross sections using the 4π γ – summing method





P. Tsagari et al., PRC 70, 015802 (2004)





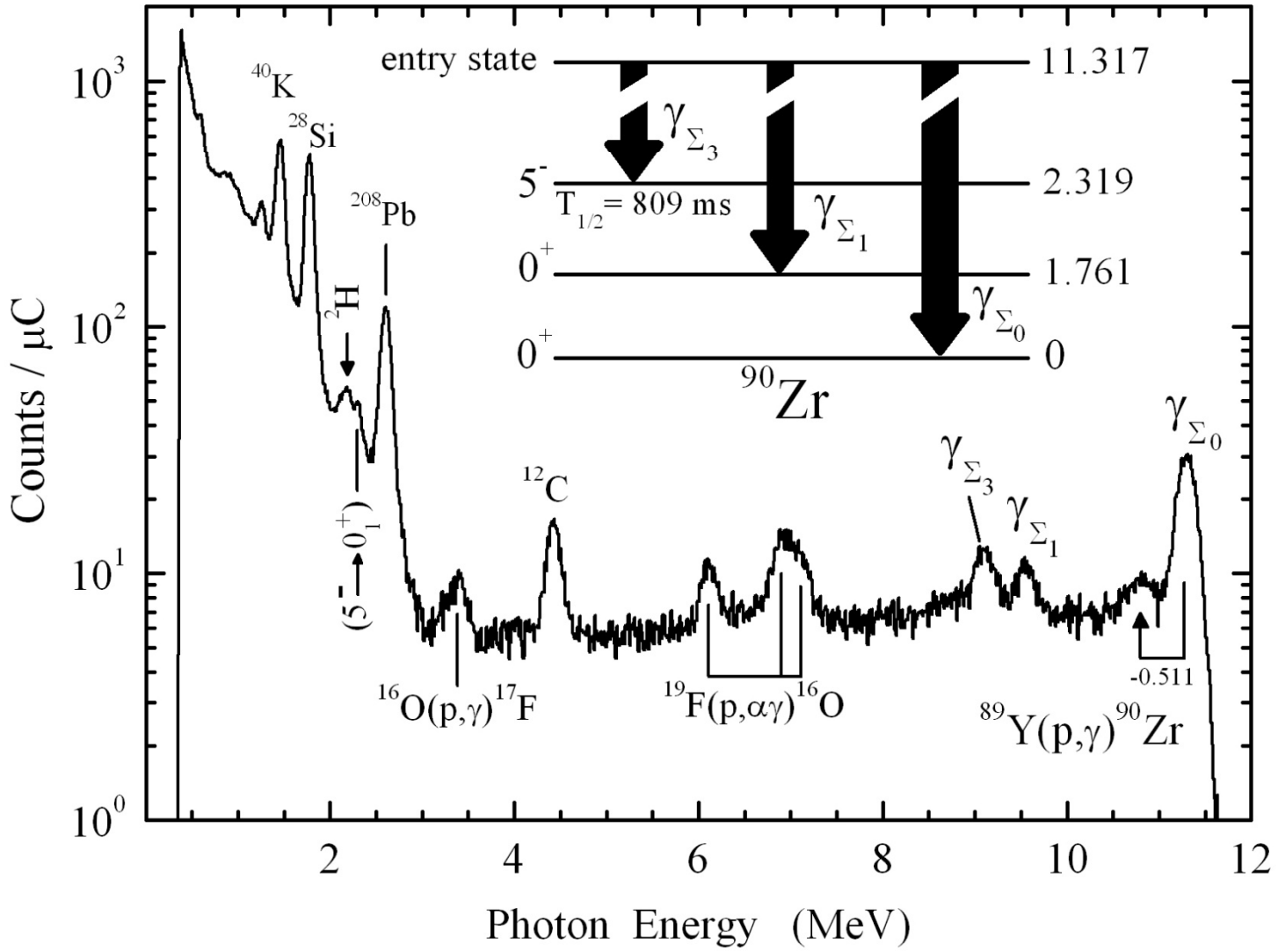
$Y_0 = F_0 / (N_{proj} \times \varepsilon_0)$

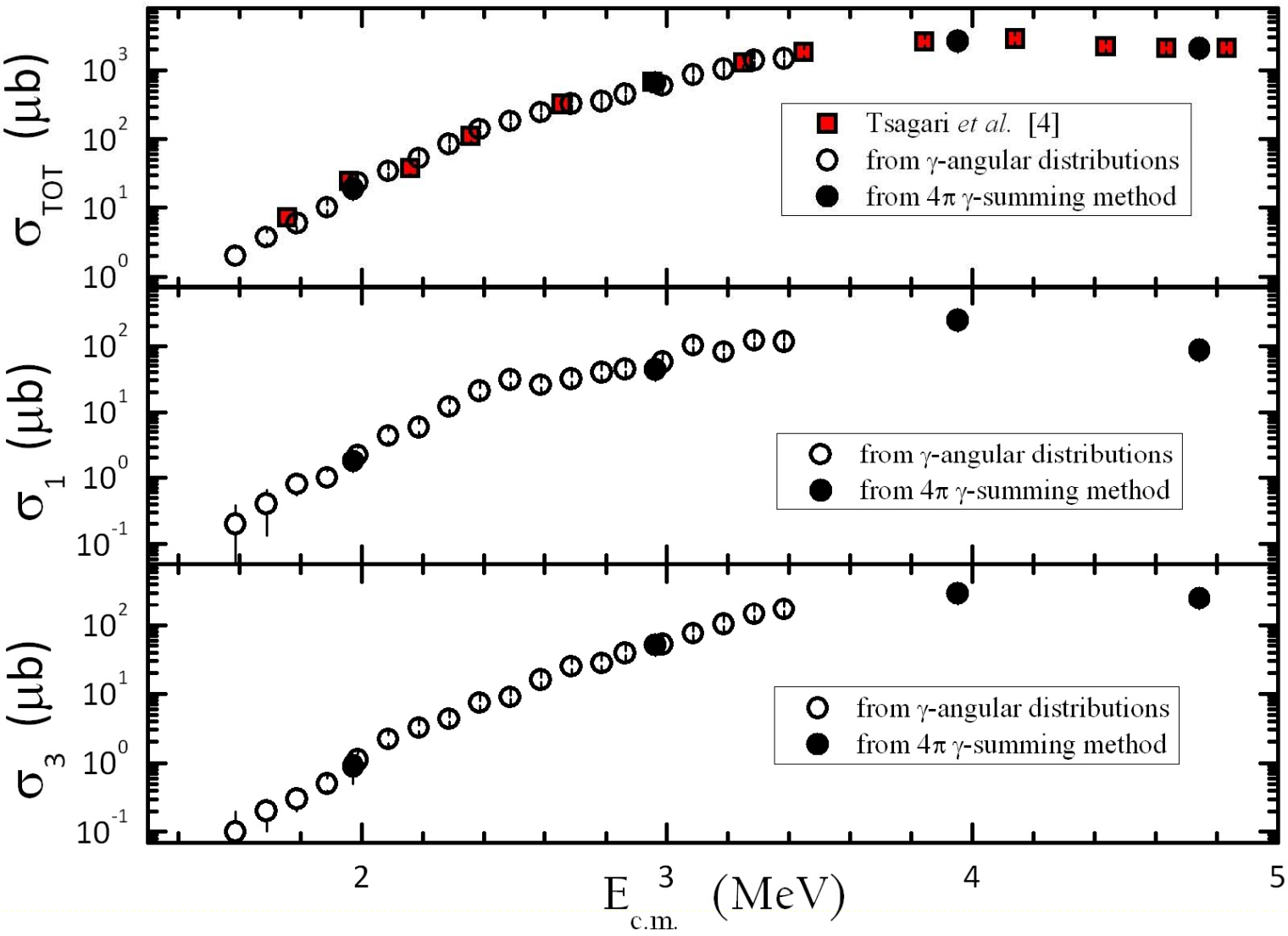
$Y_1 = F_1 / (N_{proj} \times \varepsilon_1)$

$Y_2 = F_2 / (N_{proj} \times \varepsilon_2)$

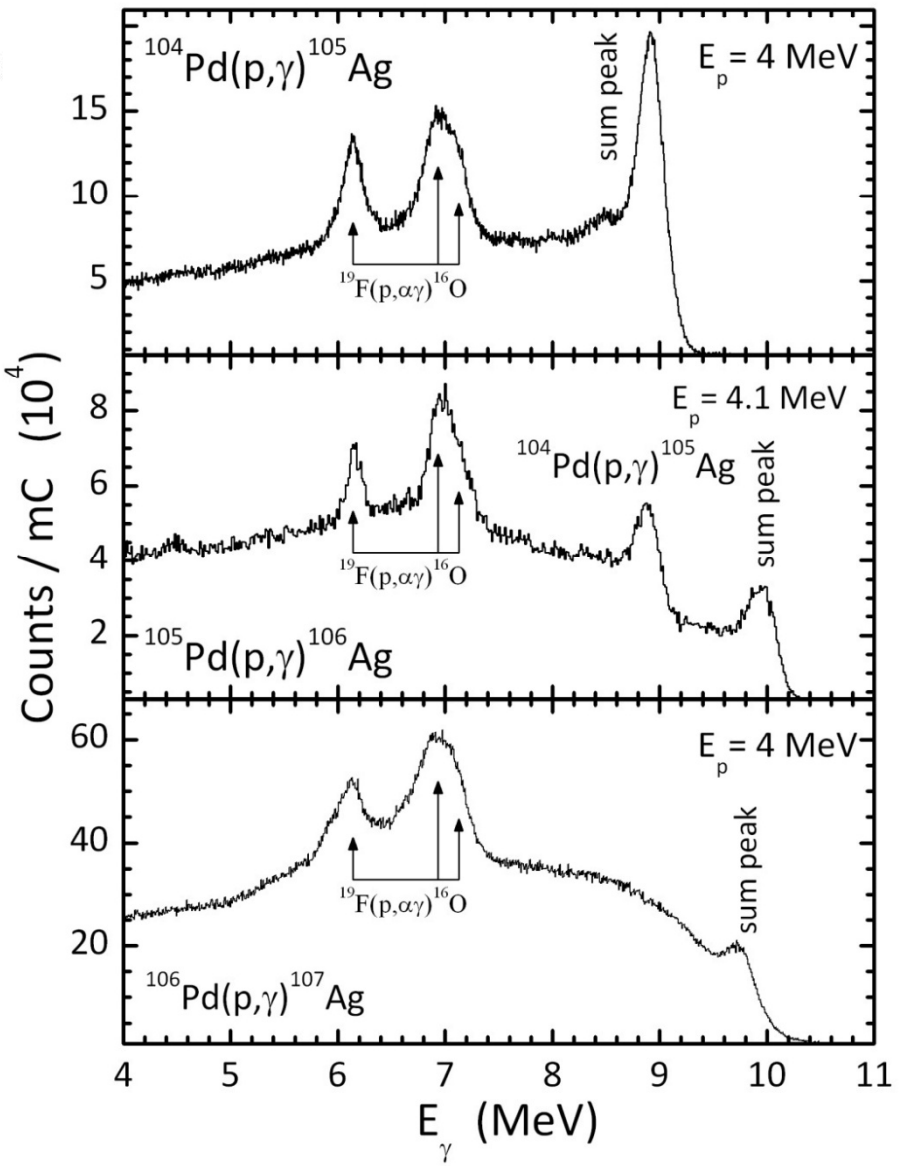
$Y_{TOT} = Y_0 + Y_1 + Y_2$

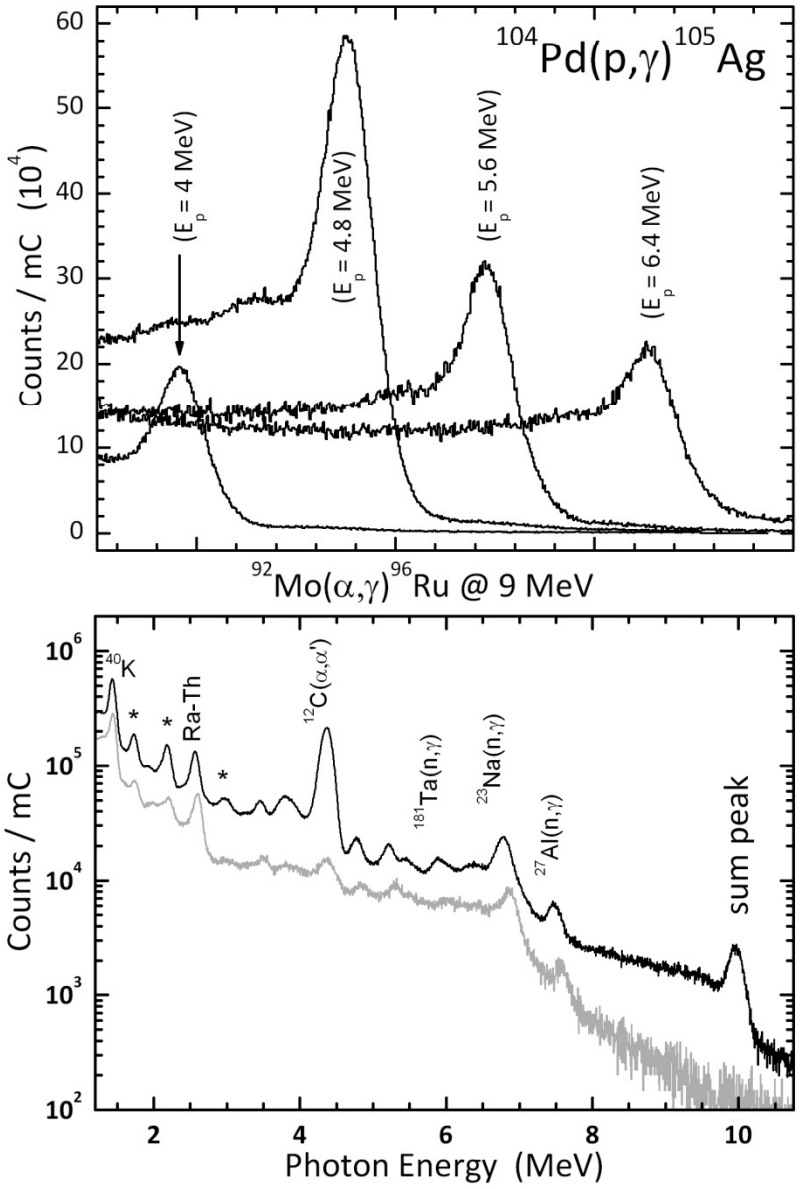
$$\sigma_{TOT} = (A/N_A)\,(Y_{TOT} / \xi)$$


Counts / μC
Photon Energy (MeV)
entry state
11.317
2.319
1.761
0
5⁻
T1/2 = 809 ms
0⁺
0⁺
90Zr
γΣ3
γΣ1
γΣ0
40K
28Si
208Pb
2H
(5⁻→0⁺1)
12C
16O(p,γ)17F
19F(p,αγ)16O
89Y(p,γ)90Zr
-0.511

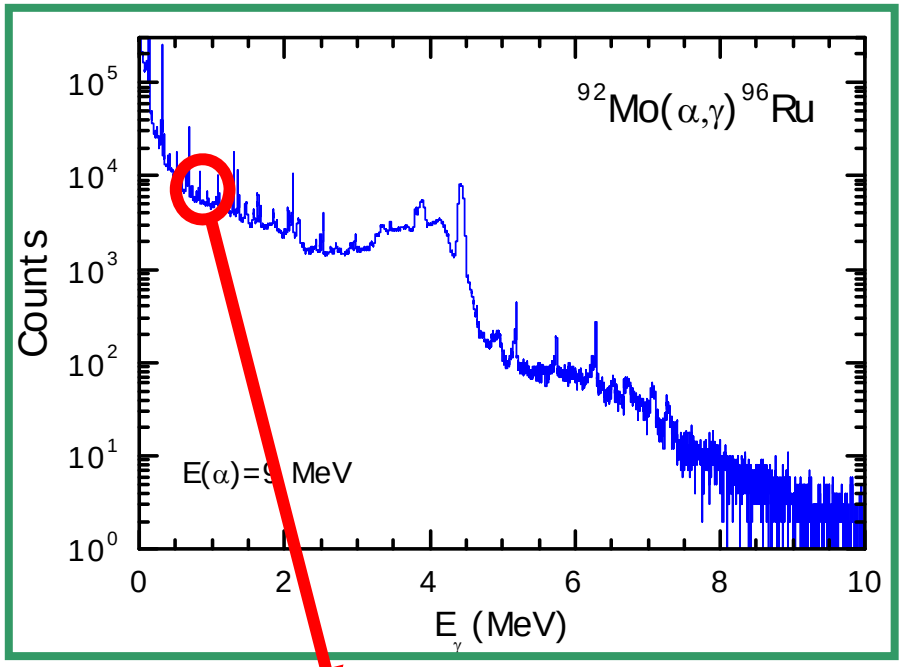

σ TOT (μb)
σ 1 (μb)
σ 3 (μb)
Tsagari et al. [4]
from γ-angular distributions
from 4π γ-summing method
from γ-angular distributions
from 4π γ-summing method
from γ-angular distributions
from 4π γ-summing method
E c.m. (MeV)

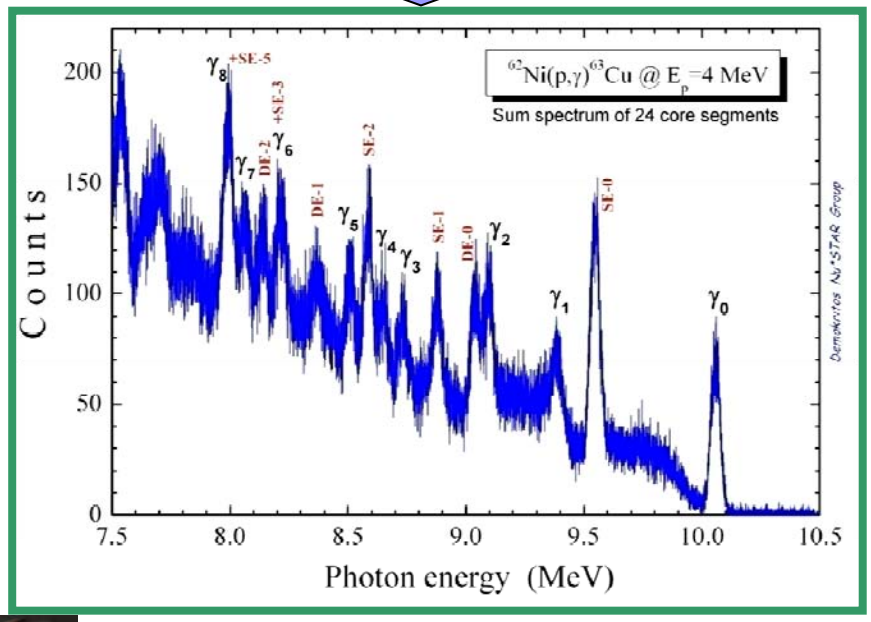
typical angle-integrated spectra

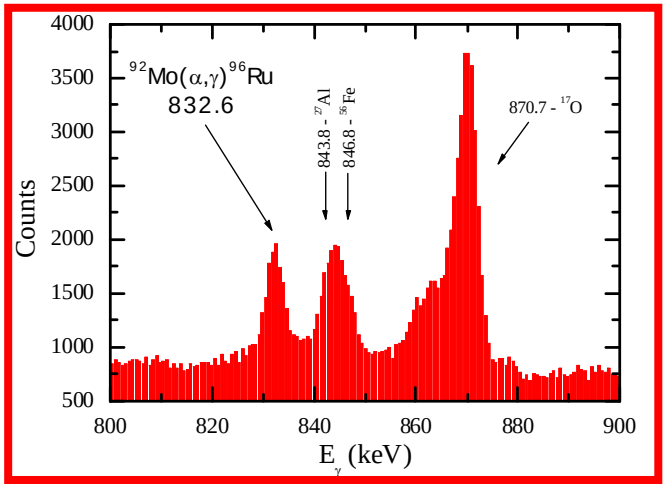




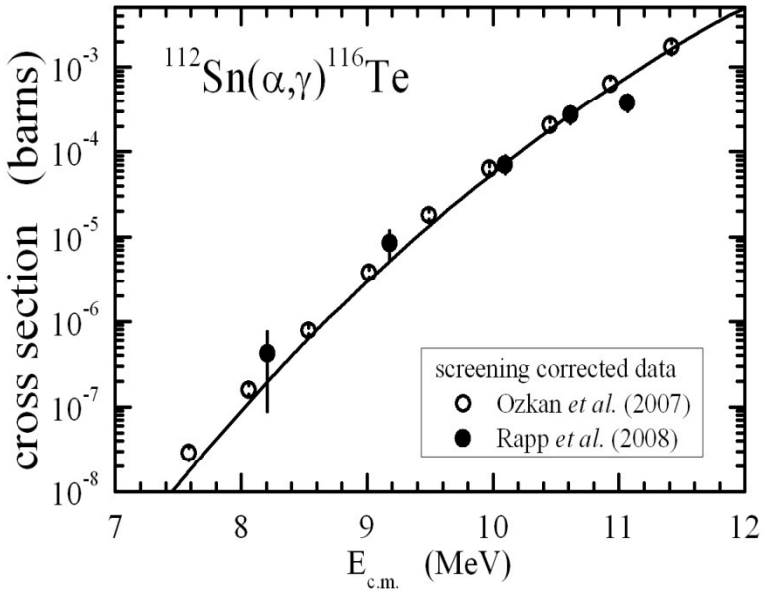
MINIBALL: typical (p,γ) and (α,γ) singles spectra

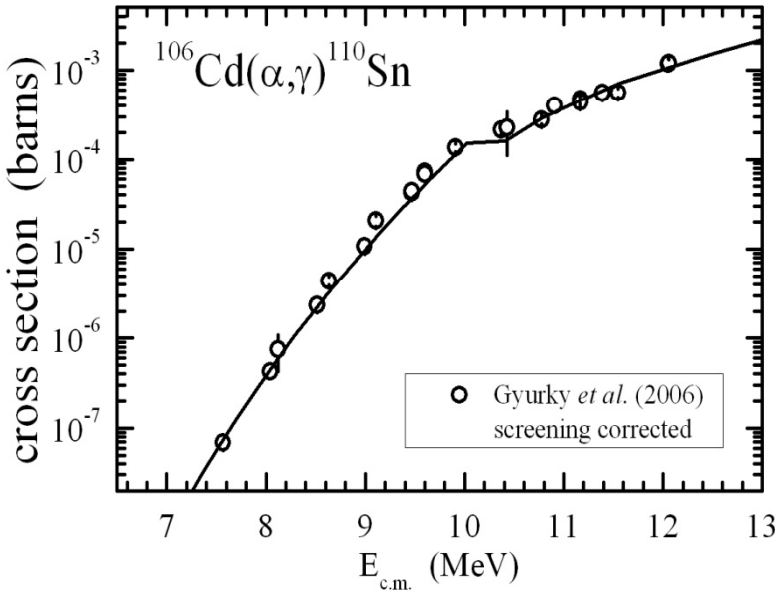






(α,γ) reactions : comparison with HF predictions



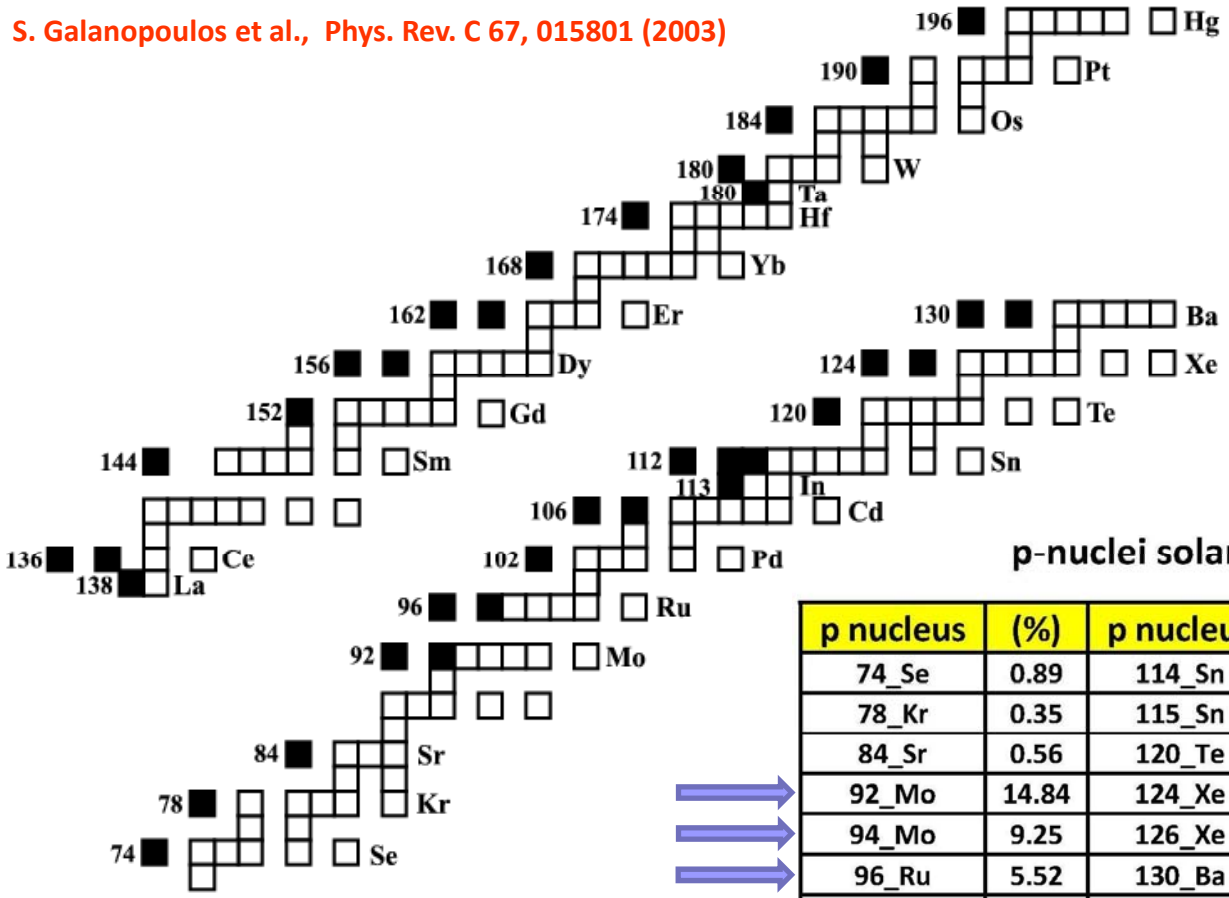


Solid line : cross sections predicted by the DG[2] alpha-OMP-III

by P. Demetriou, C. Grama, and S. Goriely, Nucl. Phys. A 707, 253, 2002

p-nuclei solar abundances

S. Galanopoulos et al., Phys. Rev. C 67, 015801 (2003)



p-nuclei solar abundances

p nucleus	(%)	p nucleus	(%)	p nucleus	(%)
74_Se	0.89	114_Sn	0.65	156_Dy	0.06
78_Kr	0.35	115_Sn	0.34	158_Dy	0.10
84_Sr	0.56	120_Te	0.096	162_Er	0.14
92_Mo	14.84	124_Xe	0.10	164_Er	1.61
94_Mo	9.25	126_Xe	0.09	168_Yb	0.13
96_Ru	5.52	130_Ba	0.106	174_Hf	0.162
98_Ru	1.88	132_Ba	0.101	180_Ta	0.012
102_Pd	1.02	138_La	0.09	180_W	0.13
106_Pd	1.25	136_Ce	0.19	184_Os	0.02
108_Cd	0.89	138_Ce	0.25	190_Pt	0.01
113_In	4.3	144_Sm	3.1	196_Hg	0.15
112_Sn	0.97	152_Gd	0.20		