Astrophysical Implications of Low Energy Resonances in $^{22}Ne + \alpha$

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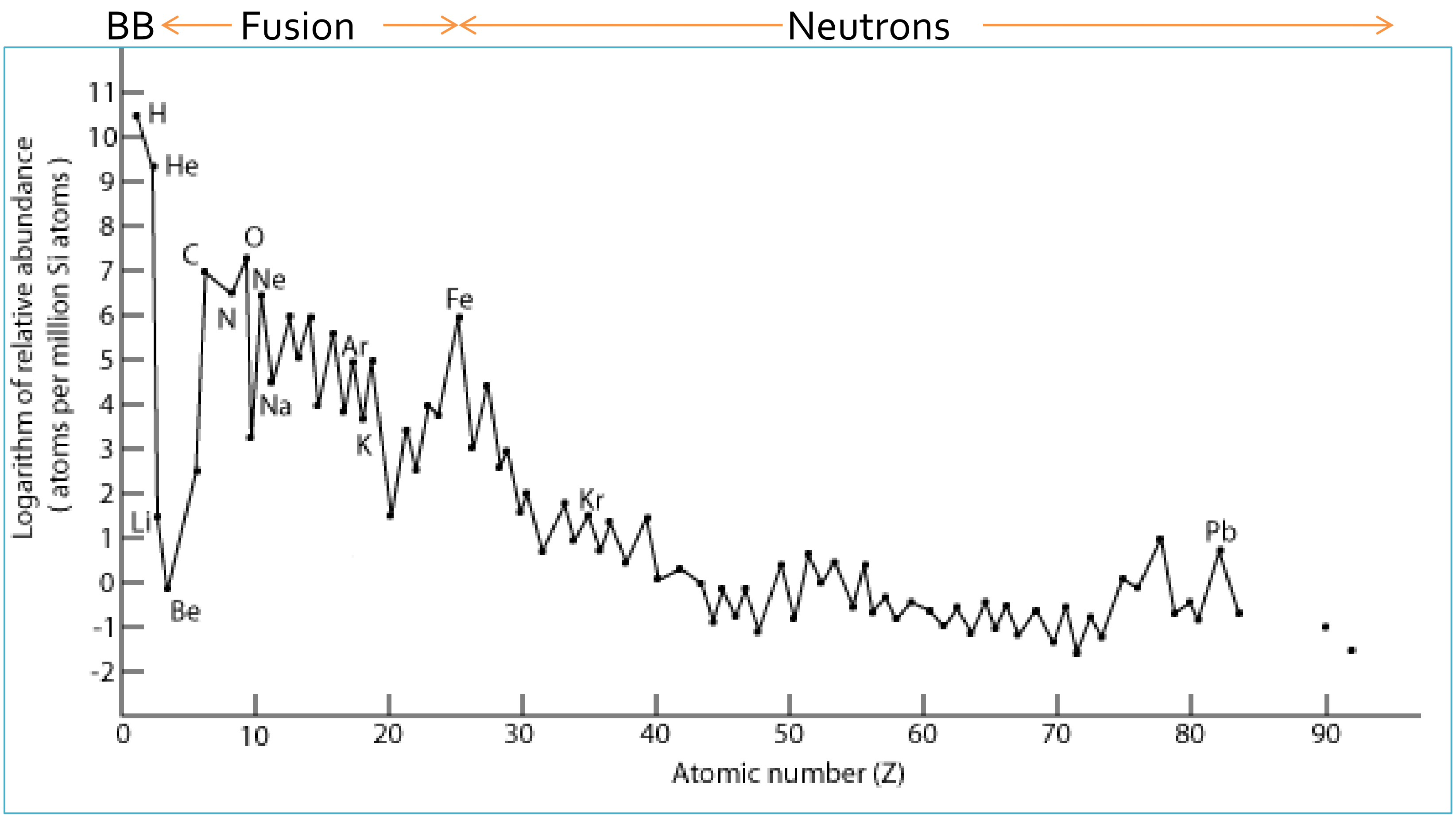
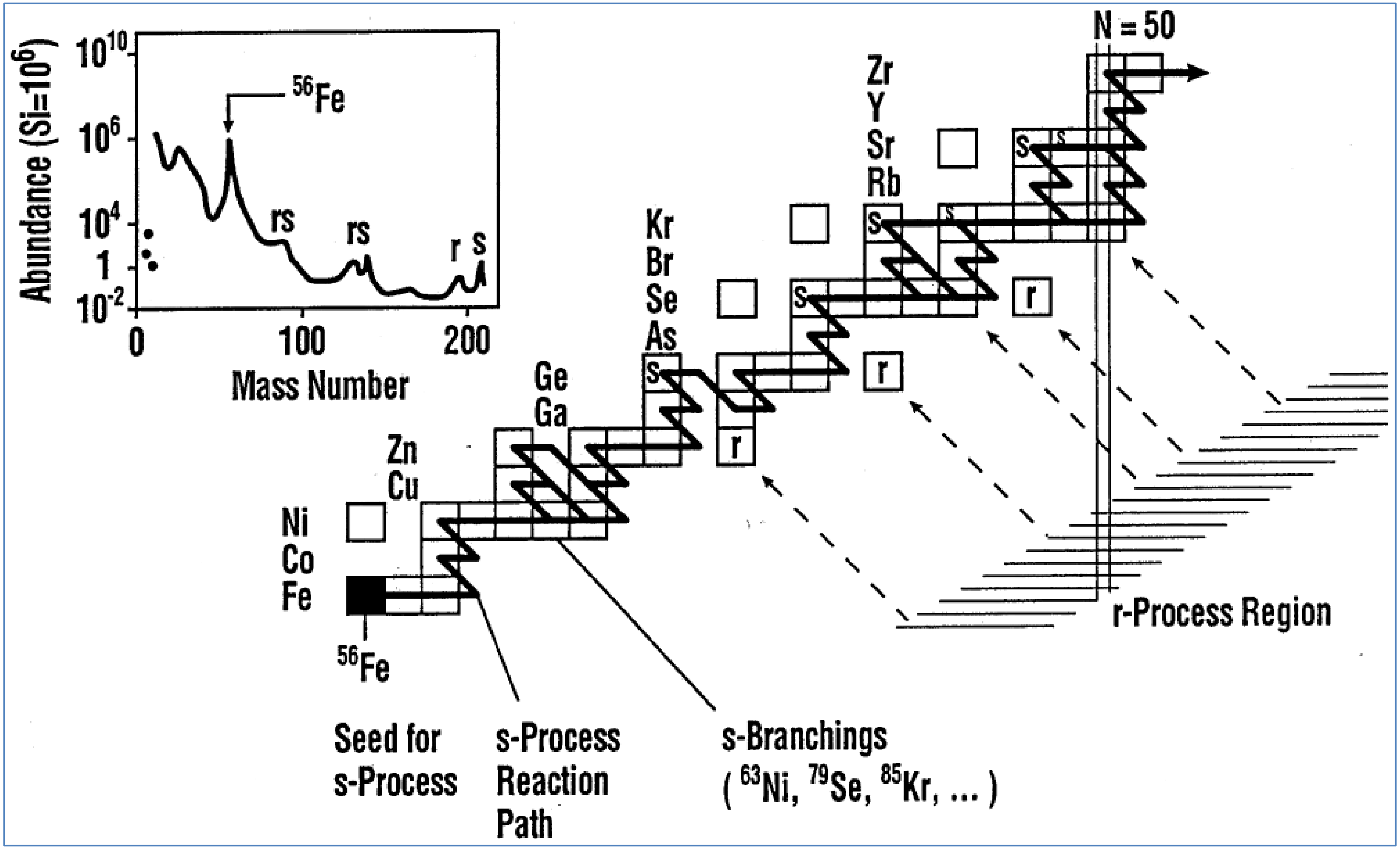
Nucleosythesis Above the Iron Peak

- Cosmic Abundance



Nucleosythesis Above the Iron Peak



F. Kappeler, et.al Review of modern physics, Vol 83, 2011

S-process In Stars

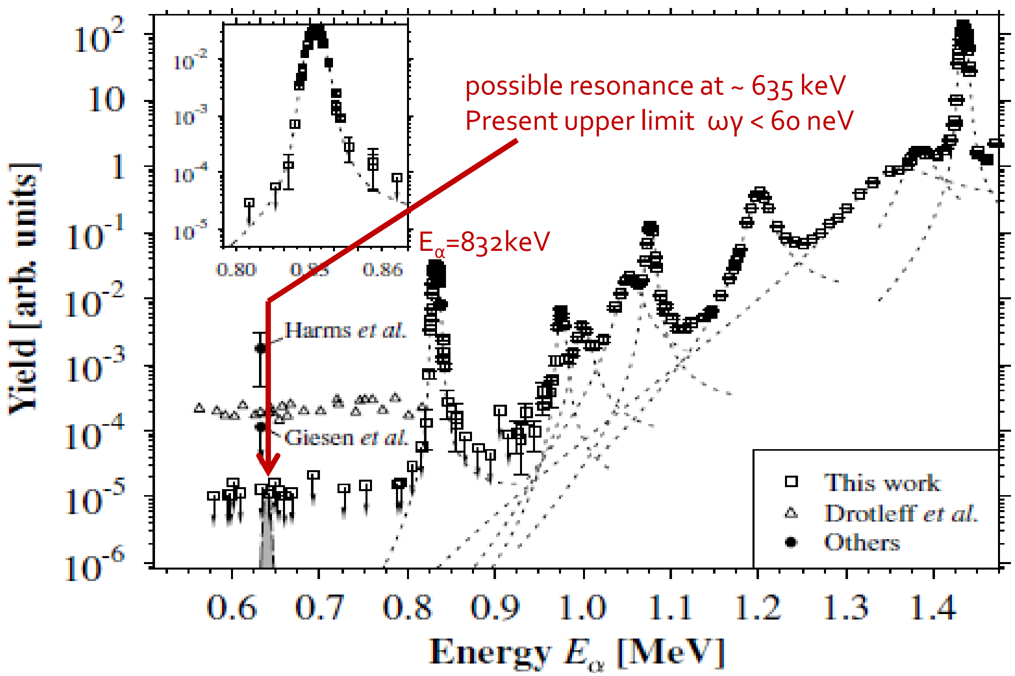
weak component	*main* component
$A \approx 60$ to 100	$A \approx 100$ to 209
Core He burning in massive stars	Shell He burning in low mass AGB stars
$T = 0.3$ GK	$T = 0.1$ GK
$N_n \sim 10^6\ /cm^{-3}$	$N_n \sim 10^7\ /cm^{-3}$
s-process at kT = 25 KeV	s-process at kT = 8 KeV
$^{22}Ne(\alpha,n)^{25}Mg$	$^{13}C(\alpha,n)^{16}O$

Neutron Sources For *Weak* S-component

- **$^{22}Ne(\alpha, n)^{25}Mg$** ($Q = -0.482 MeV$)
  - Effective burning temperature $T_9 \geq 0.3$
  - Gamow window: 300 keV < E_{cm} < 900 keV
  - Competing reaction **$^{22}Ne(\alpha, \gamma)^{26}Mg$** ($Q = 10.612$ MeV) may reduce the neutron production significantly at the same T_9 condition.
- **Question:**
  - The efficiency of **$^{22}Ne(\alpha, n)^{25}Mg$** as a neutron source for *weak* component of s-process in the stellar environment?

Direct Measurement of $^{22}Ne(\alpha,n)^{25}Mg$

- Direct Measurement $^{22}Ne(\alpha,n)^{25}Mg$
  - Extremely difficult due to the high Coulomb barrier for low energy α-particles

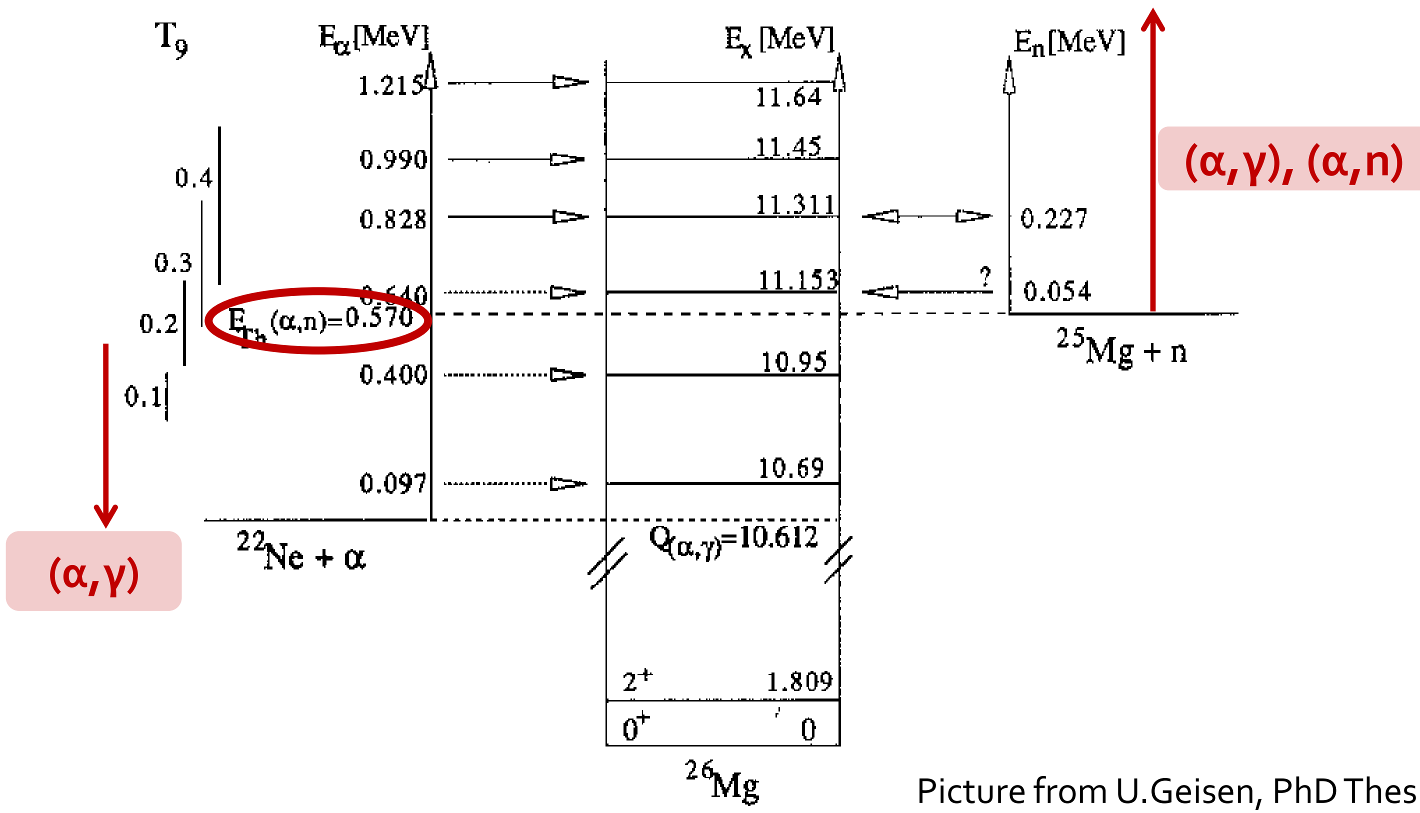


? Low energy resonances

M. Jaeger, et.al, Phys.Rev.Lett 87, 202501(2001)

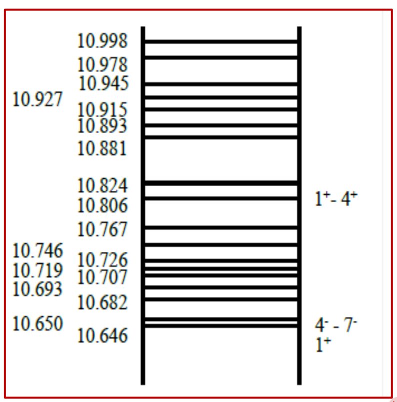
^{26}Mg Level Scheme

- ^{22}Ne(α, n)^{25}Mg and ^{22}Ne(α, γ)^{26}Mg proceed through excited states in the compound ^{26}Mg



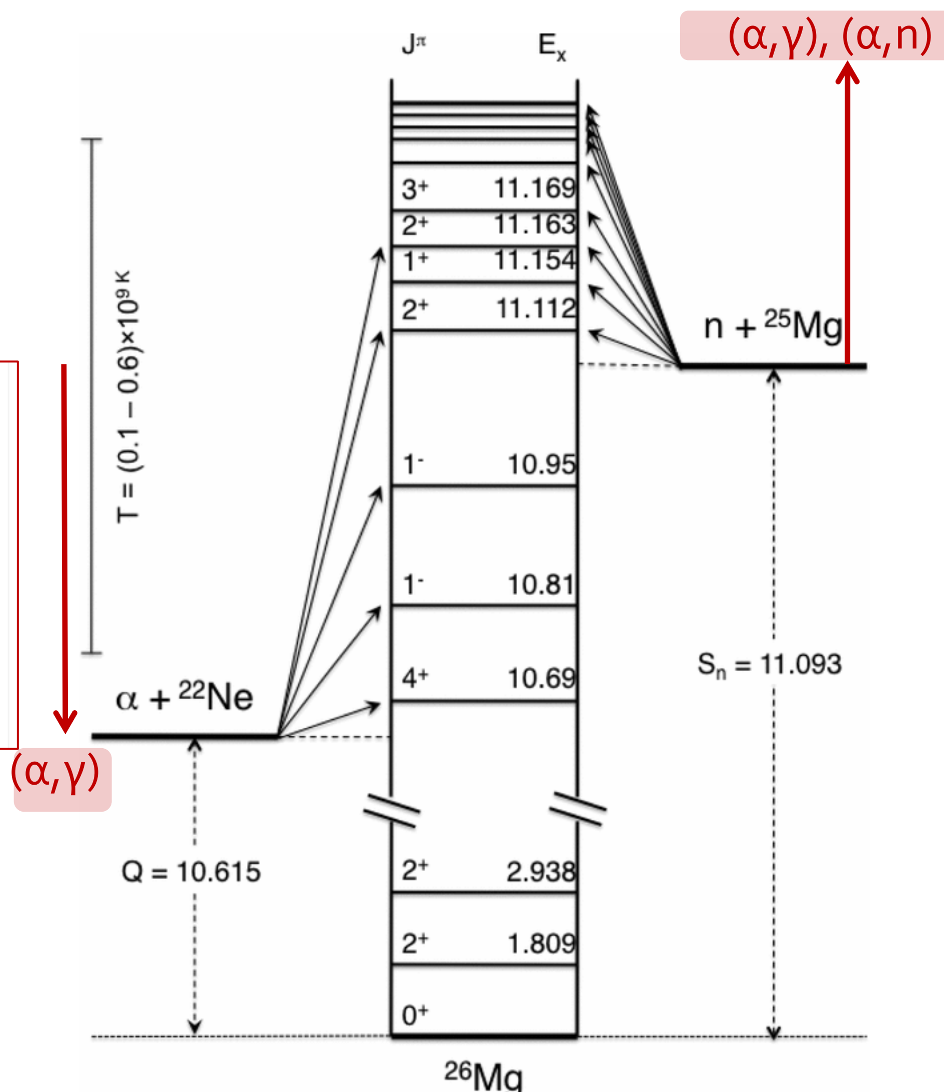
Picture from U.Geisen, PhD Thesis, 1992

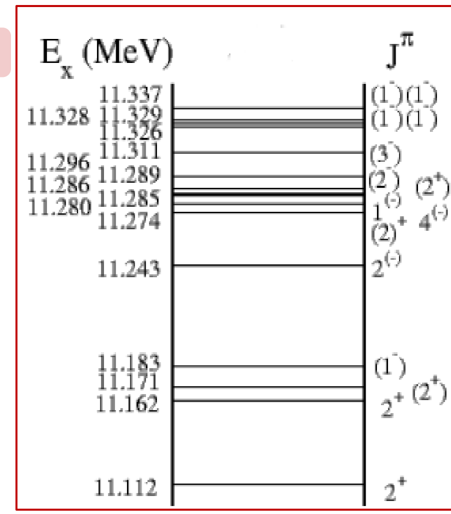
Measurement Of Compound ^{26}Mg



Mainly studied by (p,p')

? J^{π}, Γ_{tot}, Γ_{α}, Γ_{γ}





Well studied by (n,n_{tot}), (n,γ)

⇨ J^{π}, Γ_{tot}, Γ_{n}, Γ_{γ}

Challenges of the Measurement

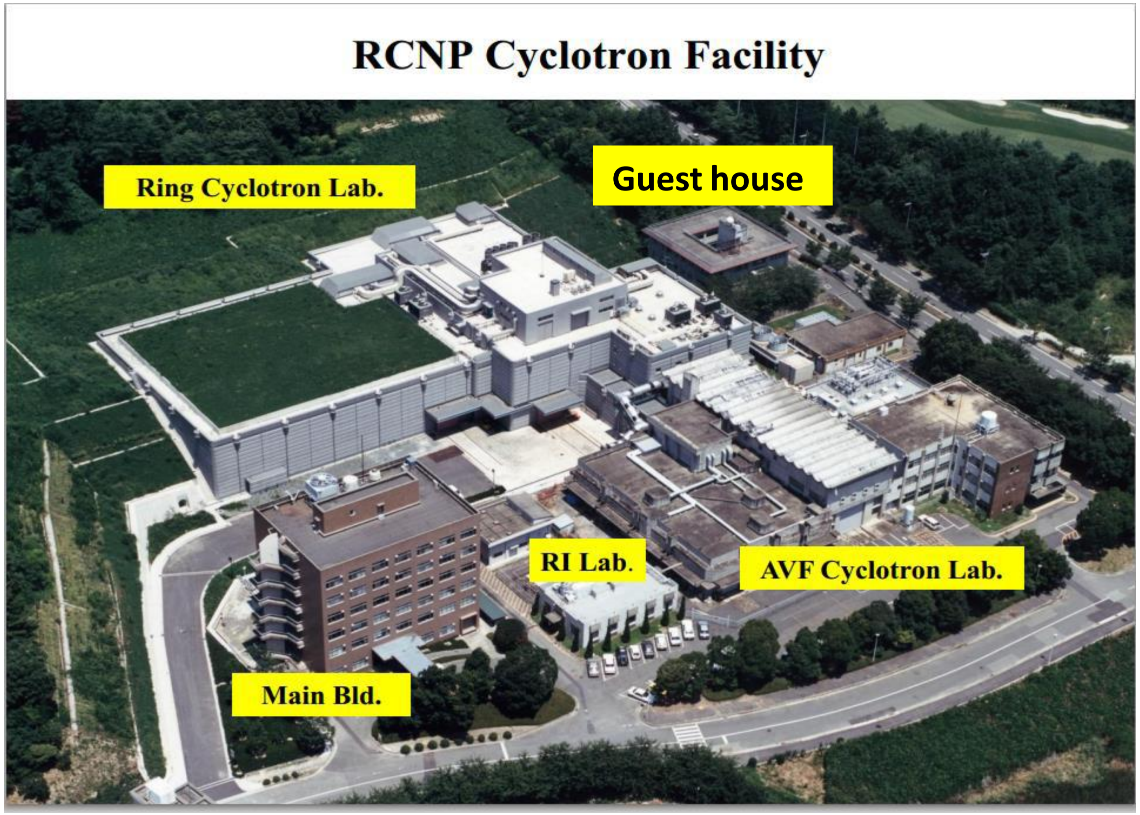
- Large states density of ^{26}**Mg** at the astrophysically important excitation energies above the α-threshold.
  - Bad resolution and missing possible states
- Large uncertainties on reaction rate.

Solution? $^{25}Mg(d,p)^{26}Mg$

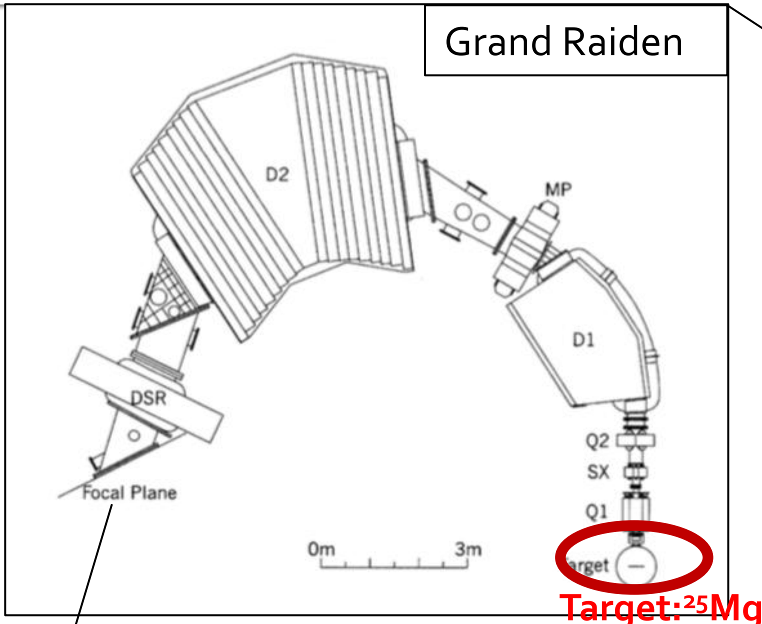
- 56 MeV deuteron beam to populate ^{26}Mg states about 1 MeV above the α-threshold.
- High resolution measurement can by realized by the high resolution spectrometer.
- Determine **L** by measuring the angular distribution.
- Neutron transfer reaction.

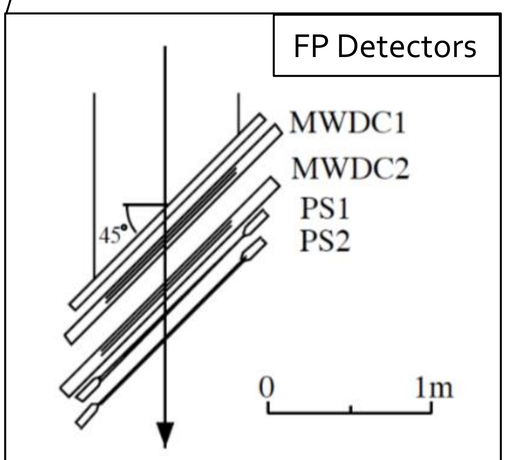
Experiment in RCNP

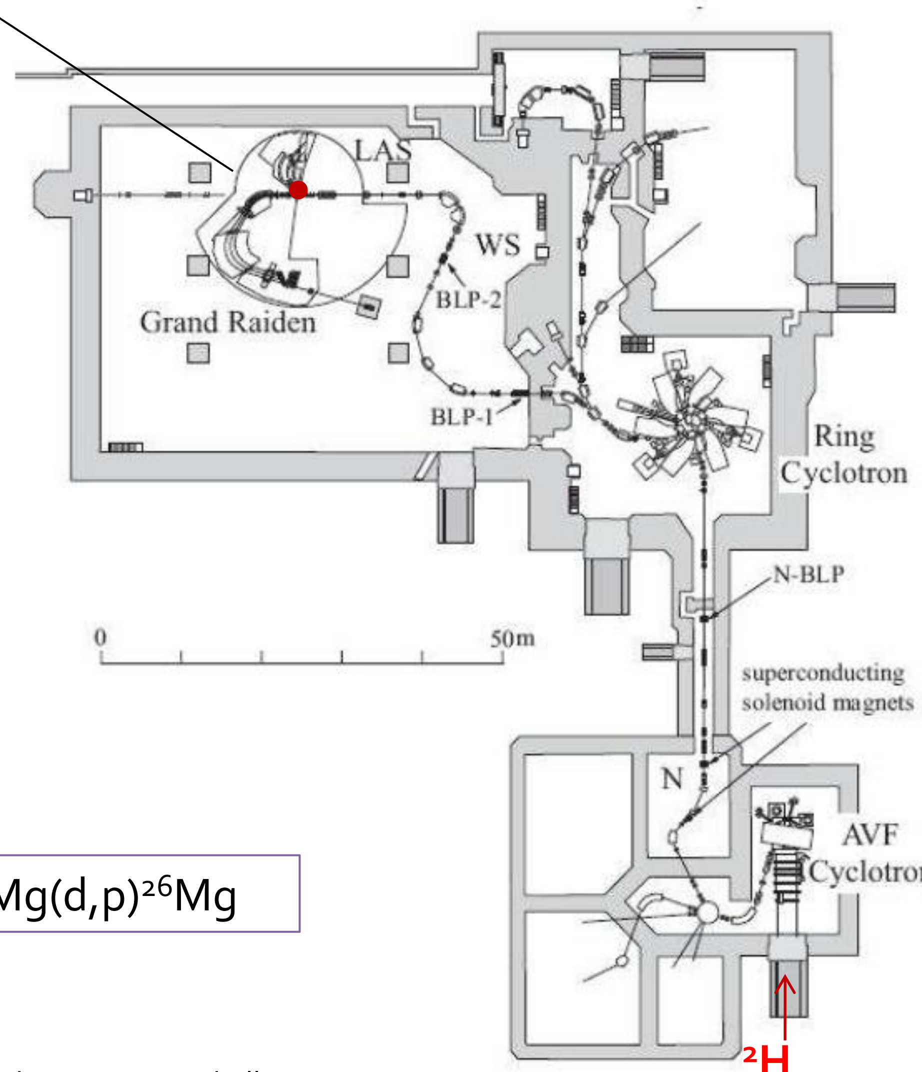
- Research Center for Nuclear Physics (RCNP) In Osaka University, Osaka, Japan



Experiment in RCNP





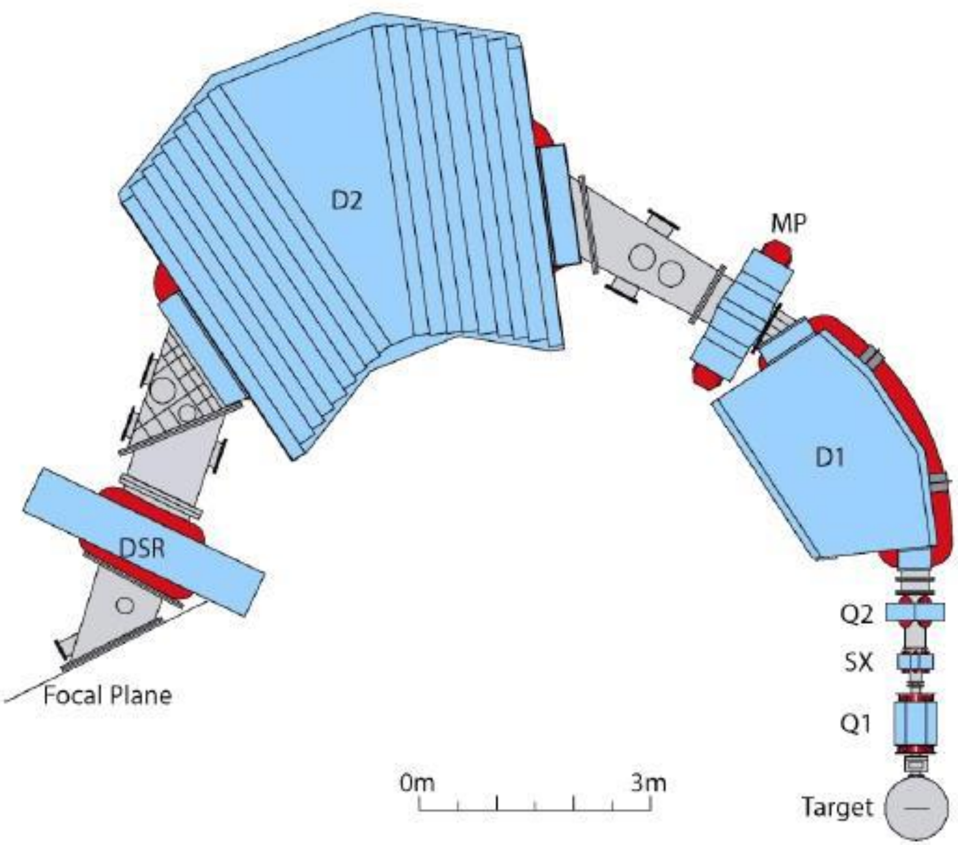


^{25}Mg(d,p)^{26}Mg

Floor plan of the experiment hall at RCNP

Experiment in RCNP

- Grand Raiden Spectrometer



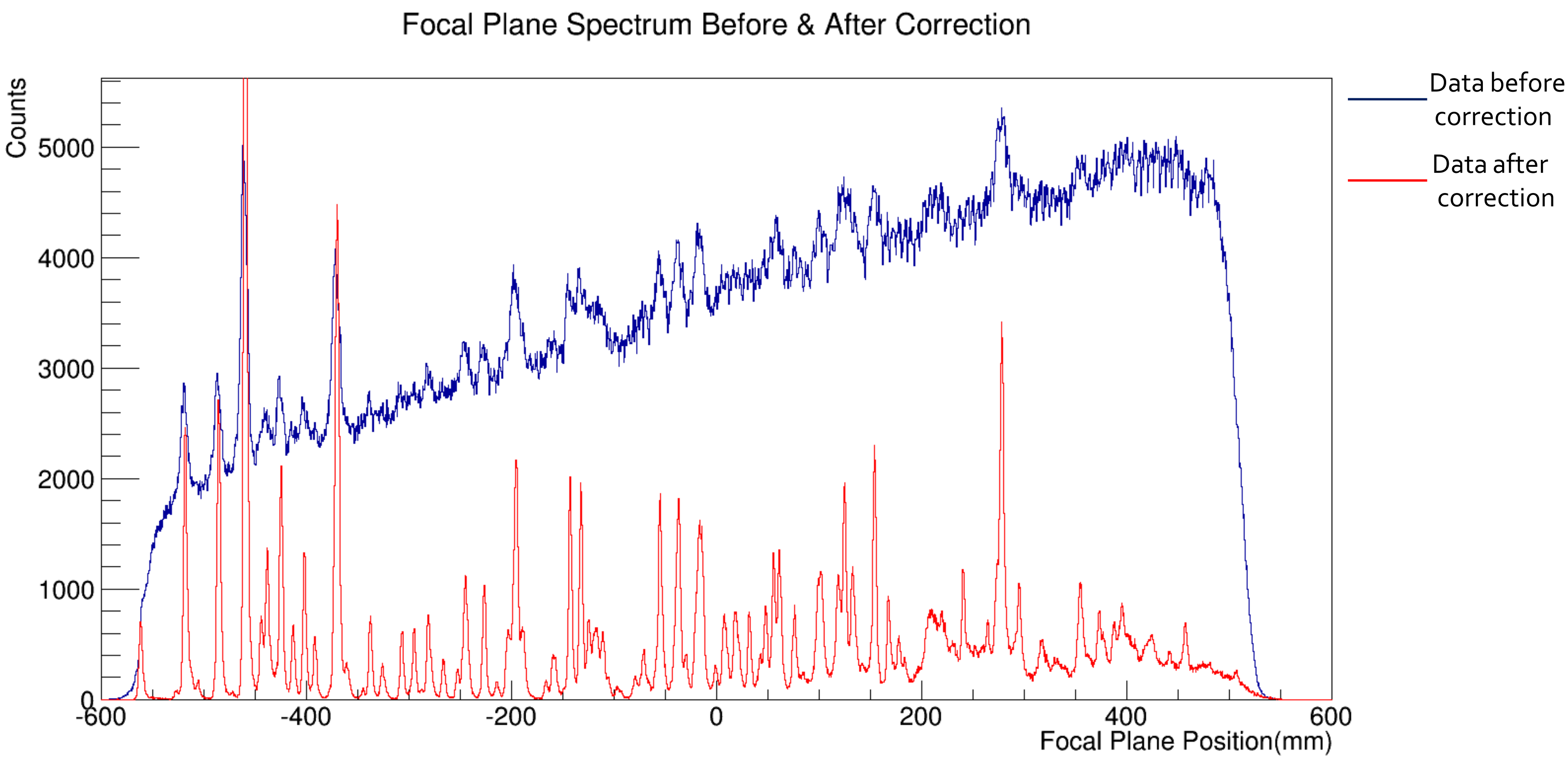
Ion-optical properties	
Mean orbit radius	3 m
Focal plane length	150 cm
Maximum magnetic field strength	1.8 T
Maximum rigidity	5.4 Tm
Vertical magnification (M_y)	5.98
Horizontal magnification (M_x)	-0.417
Momentum dispersion (D_x)	15.45 m
Momentum resolution (dp/ p)	37,000
Momentum acceptance	2.5%
Solid Angle	~5.6 msr

Experiment $^{25}Mg(d,p)^{26}Mg$

- July 2015 @ RCNP

Reaction of Interest	$^{25}Mg(d,p)^{26}Mg$
Beam Energy	56 MeV
States of Interest	^{26}Mg states about 1 MeV above the α-threshold
Targets	^{25}Mg(1 mg/cm^2, 97.8%), ^{24}Mg(1.2mg/cm^2), ^{12}C(1mg/cm^2), Mylar(^{16}O)
Finite angle measurement	5° to 40° in 5° increment
Zero degree measurement	GR spectrometer at 0.5° to reduce the huge background at 0(still covers 0°)

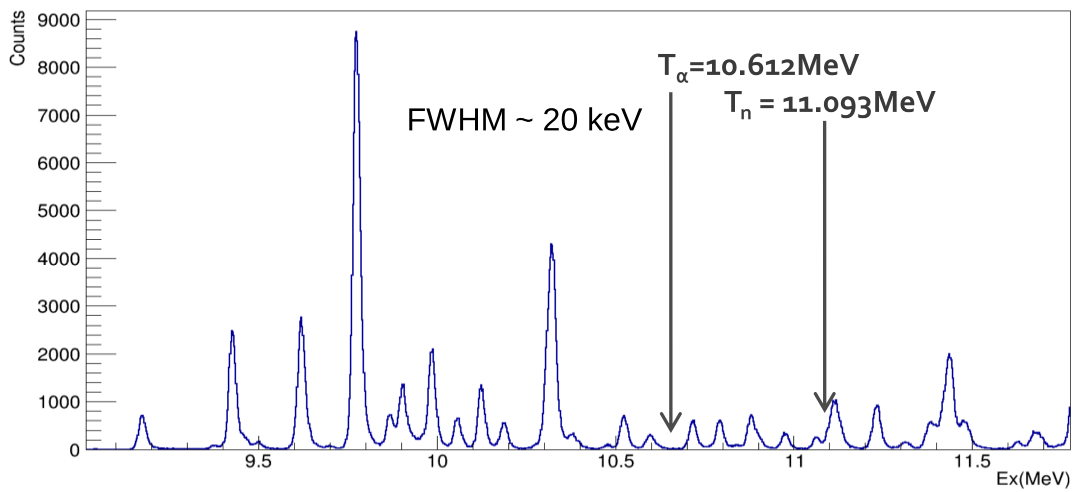
Better Resolution by correction of focus

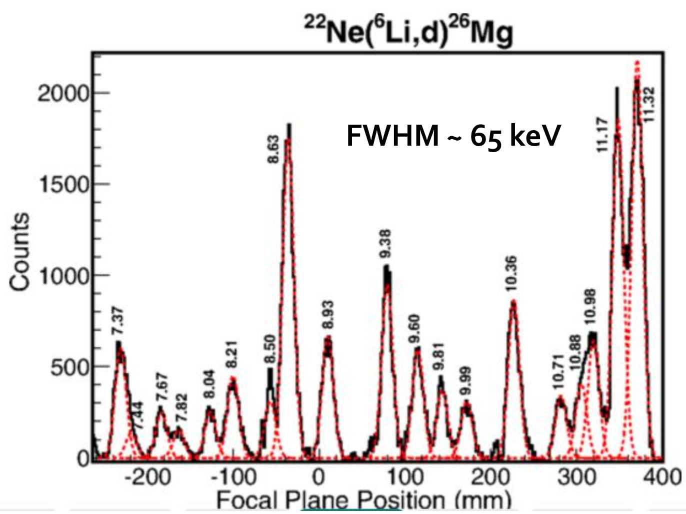


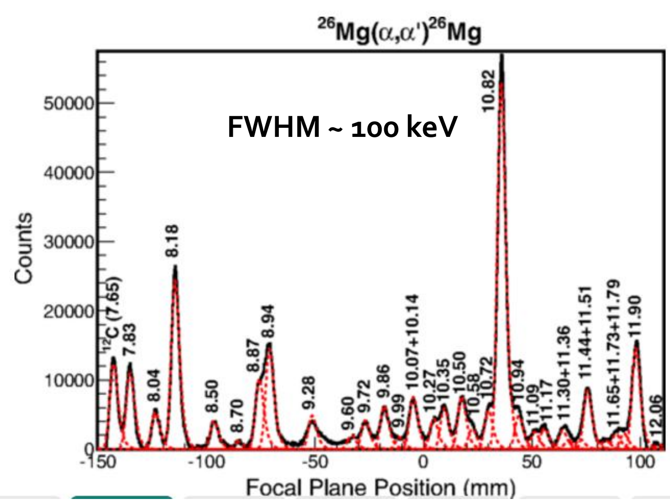
Example data from high energy level states of ^{26}Mg @ 0.5^{o}

Better Resolution by correction of focus

^{26}Mg High Energy Levels

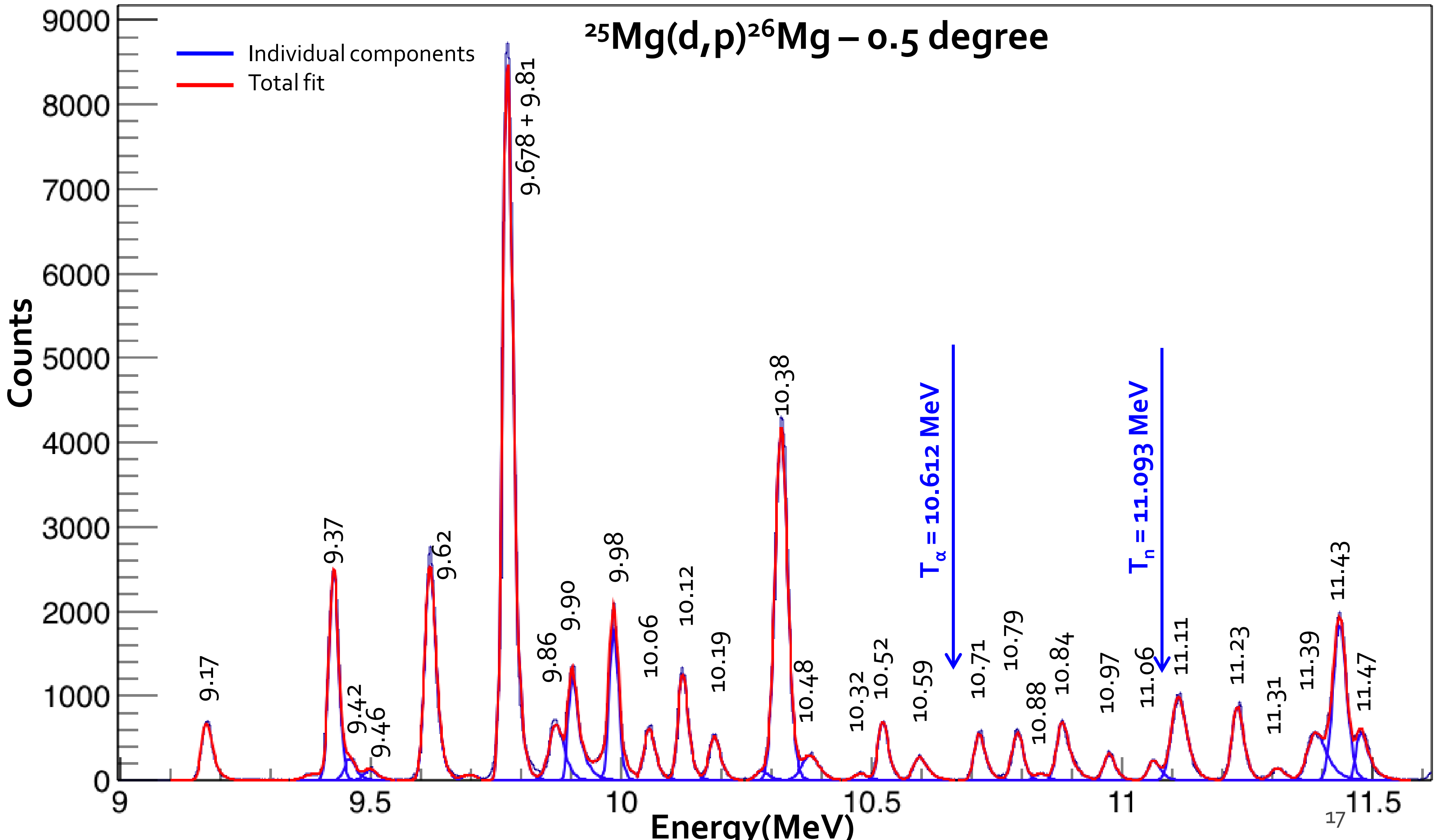






R.Talwar, et.al, Phys. Rev. C **93**, 055803 ,2016

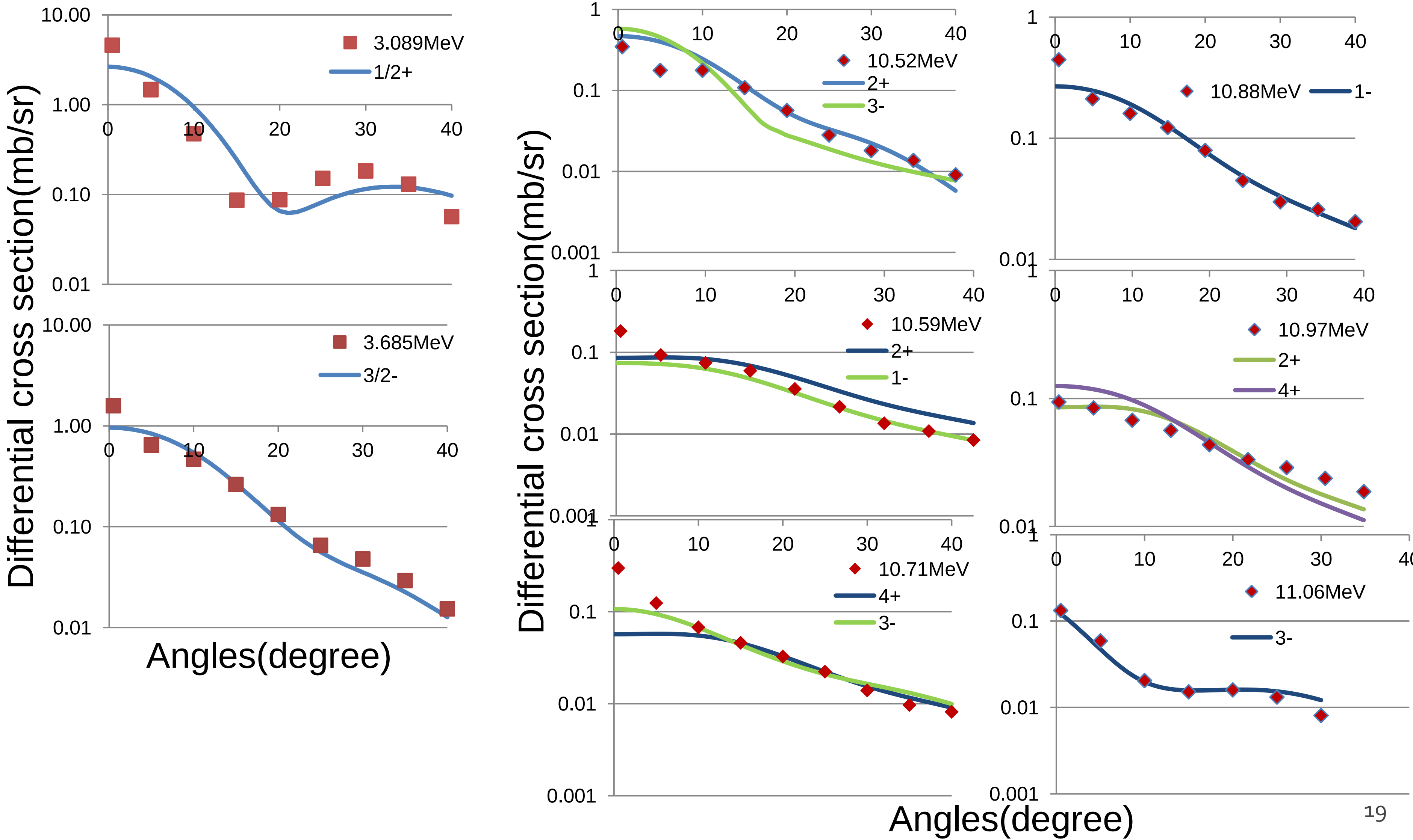
^{26}Mg Spectrum: High Energy Levels



^{26}Mg Spectrum: High Energy Levels

Ex(this work)/MeV	Ex(Cujec.et.al)/MeV	Diff/keV
10. 377	10. 36	10
10. 523	10. 52	10
10. 479	10. 48	−1
10. 596	10. 59	6
10. 716	10. 70	16
10. 975	10. 98	5
11. 065	11. 07	5
11. 113	11. 12	−7
11. 170	11. 17	0
11. 232	11. 22	10
11. 388	11. 38	8
11. 435	11. 45	−15
11. 479	11. 48	1
11. 311	11. 31	1

Differential Cross Sections(prelim.)



Acknowledgement

- Notre Dame Group:
  - G.P.A. Berg, Y. Chen, J. Görres, H.S. Jung, A.Long, R.Talwar, M. Wiescher
- RCNP Group:
  - S.Adachi, H.Fujita, Y.Fujita, G.Gey, K.Hatanaka, T.Ito, C.Iwamoto, O.H.Jin, B.Liu, S.Noji, A.Tamii