Unbound states of ^{32}Cl relevant for novae

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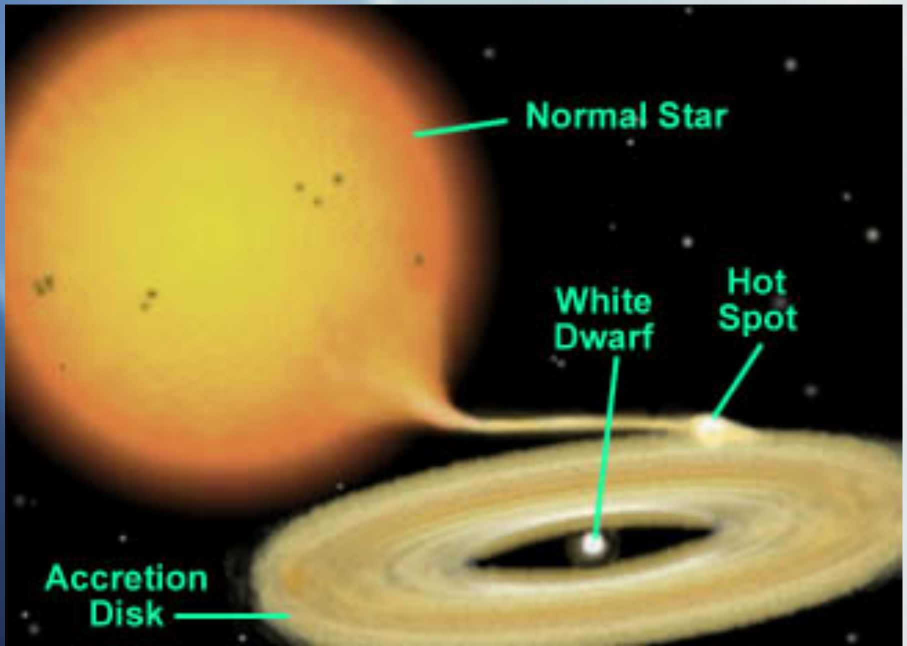
Nuclei in Cosmos, Heidelberg July 2010

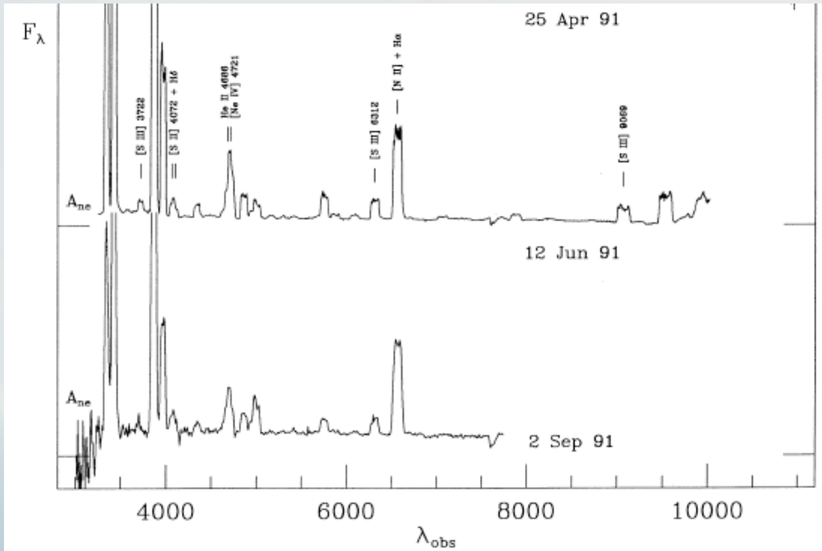
Novae



- cataclysmic binary
- accretion of hydrogen onto the surface of a white dwarf star from its companion star

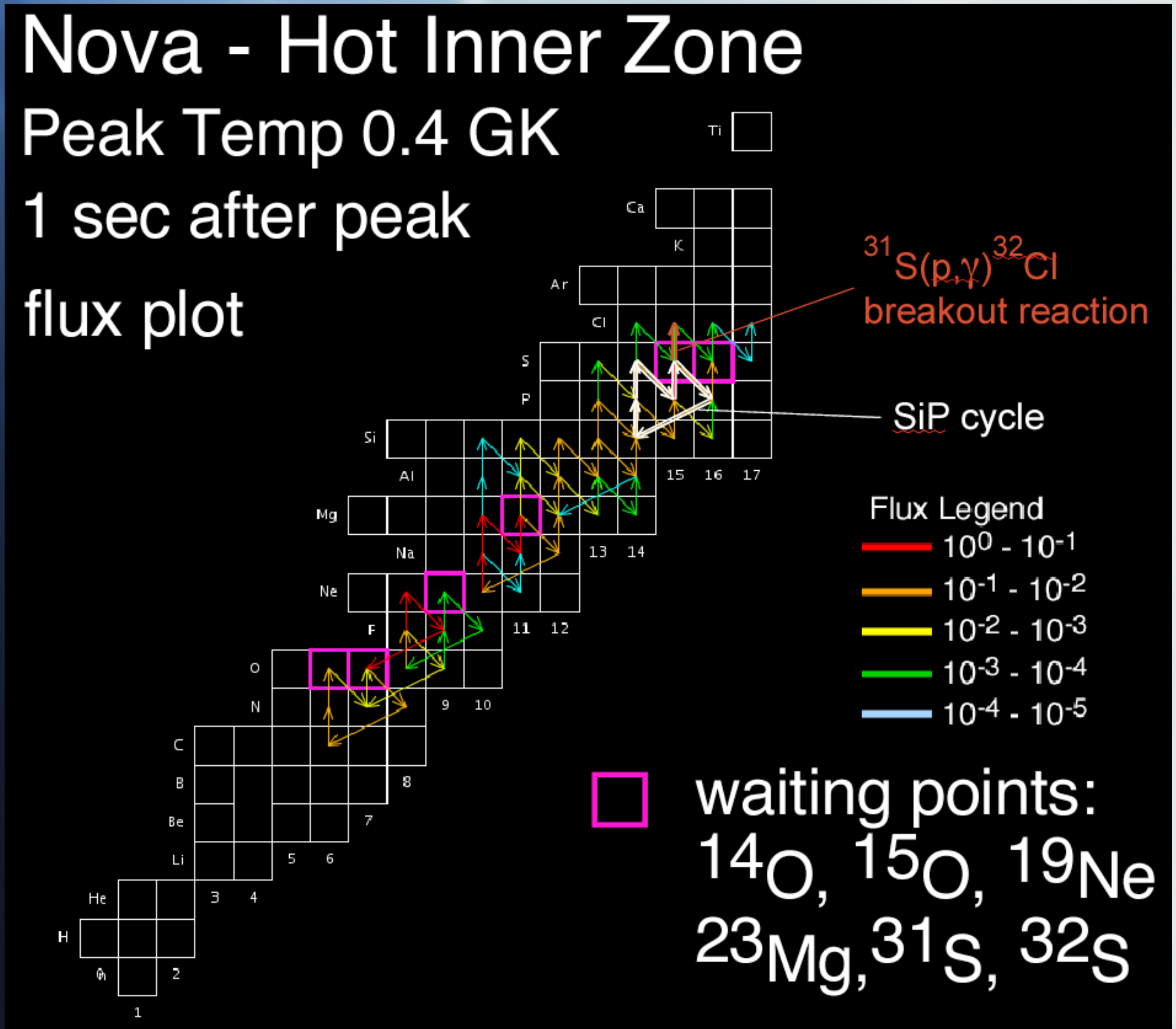
- thermonuclear reactions produce a huge increase in luminosity
- followed by the ejection of matter

Optical spectra of Nova Herculis

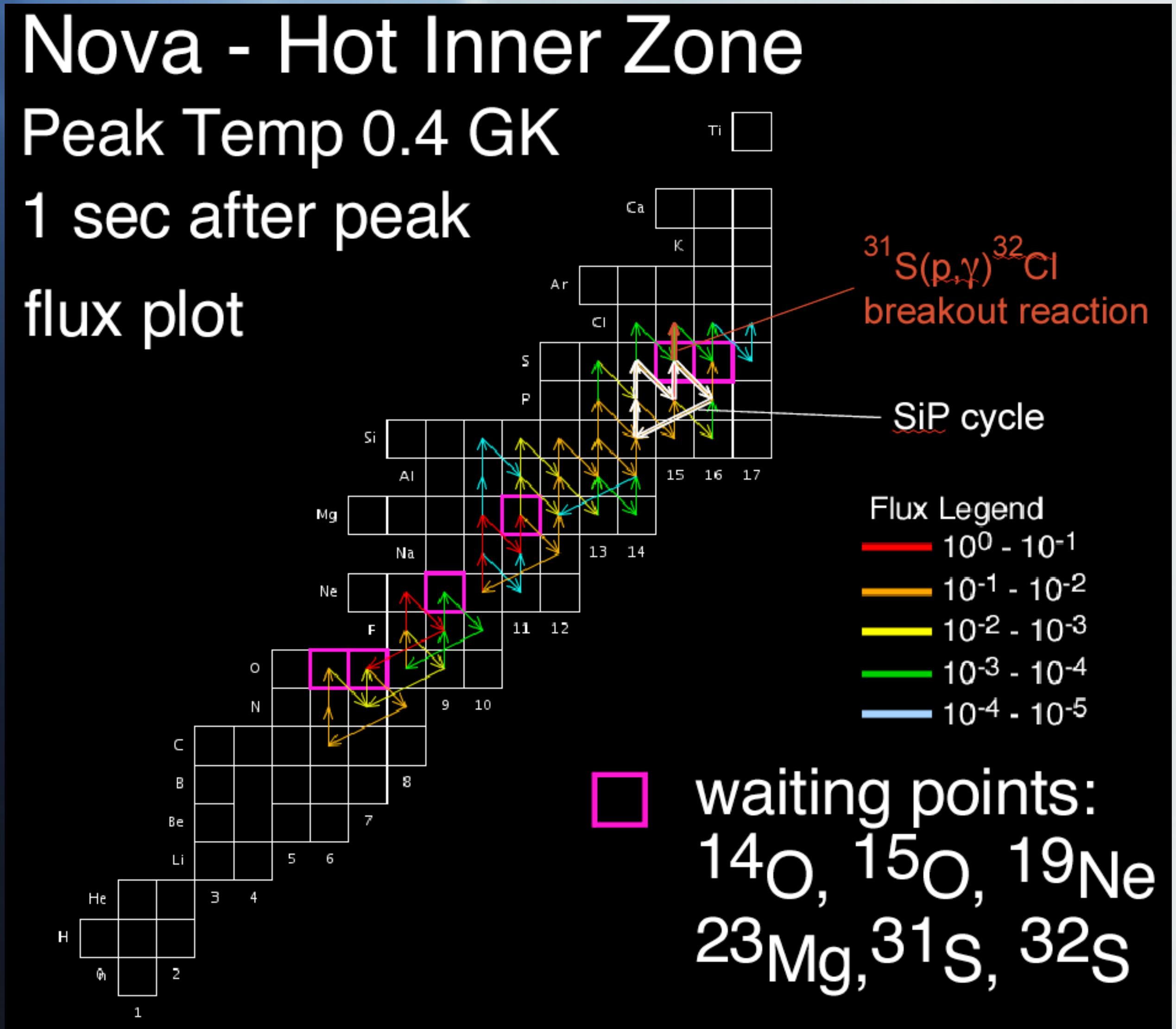


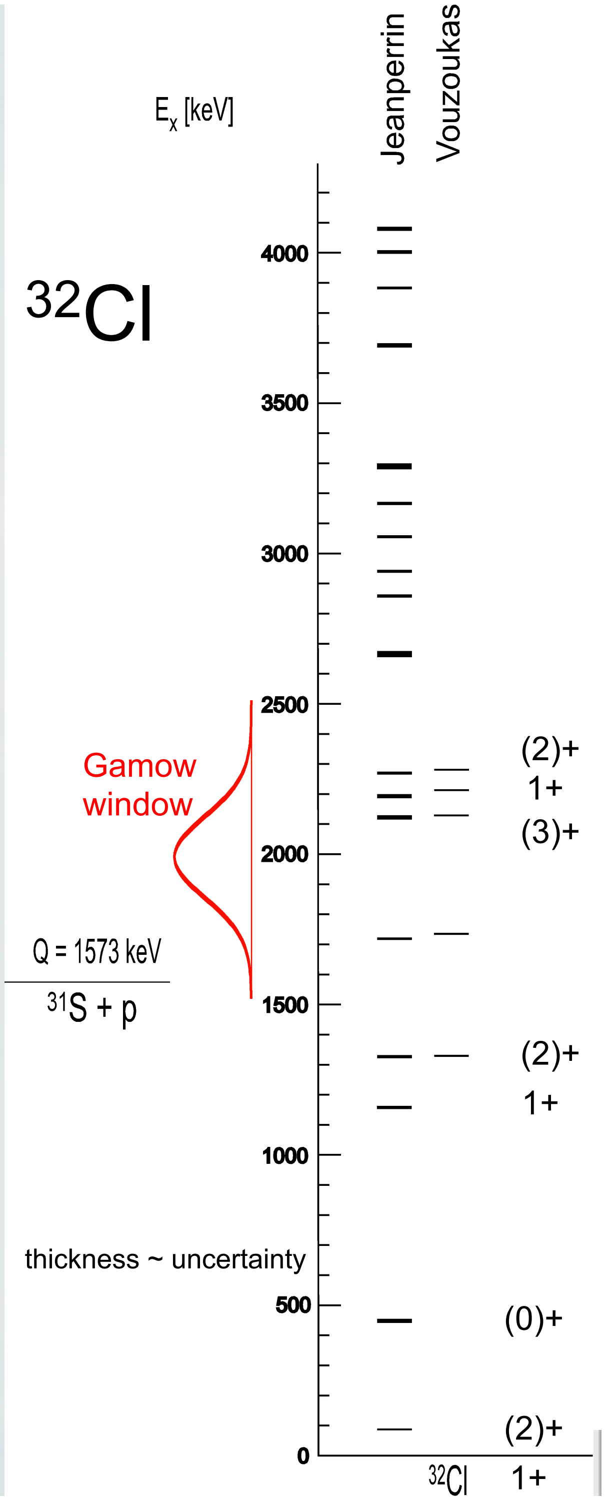
R.E. Williams, M.M. Phillips and M. Hamuy, Ap. J. Sup. Ser. 90 (1994) 297

$^{31}S(p,\gamma)^{32}Cl$ Reaction



$^{31}S(p,\gamma)^{32}Cl$ Reaction

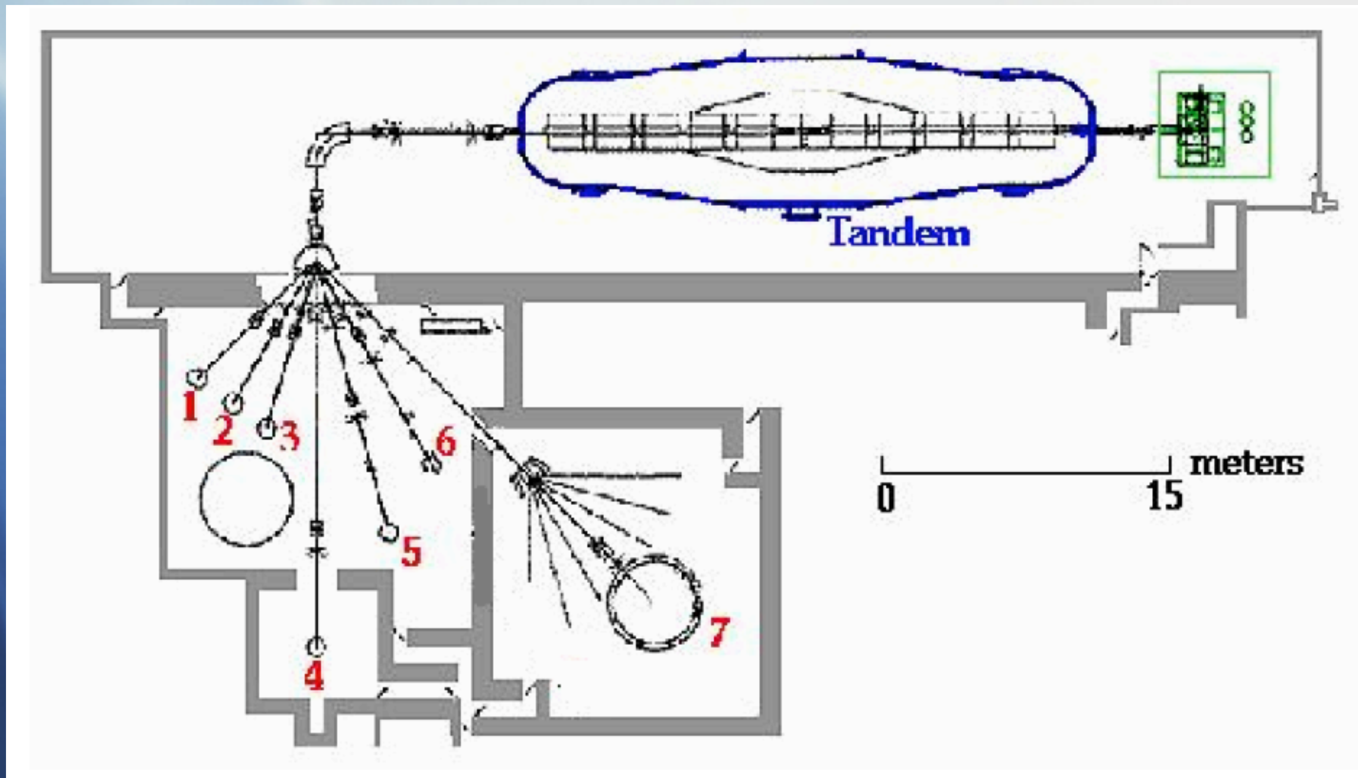




$^{32}S(^{3}He,t)^{32}Cl$ Charge Exchange Reaction
^{3}He beam

- used to populate excited states in ^{32}Cl

- 30 MeV ^{3}He beam delivered by the tandem Van de Graaff accelerator at WNSL, Yale

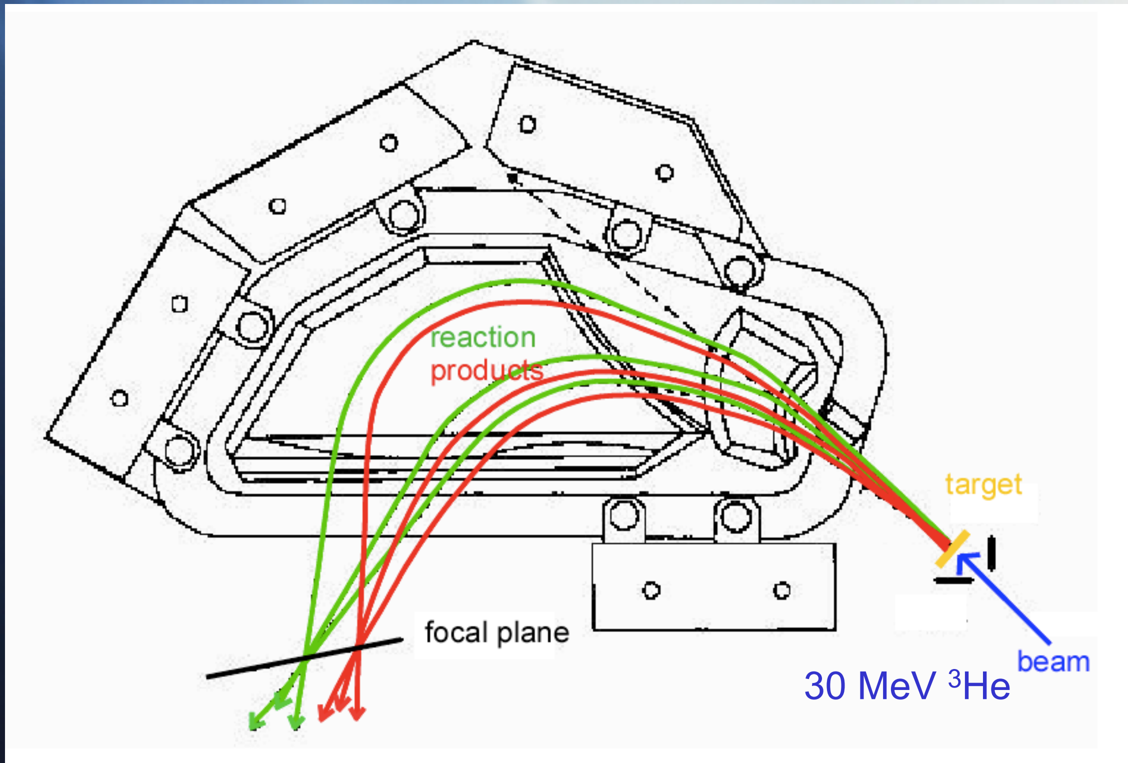


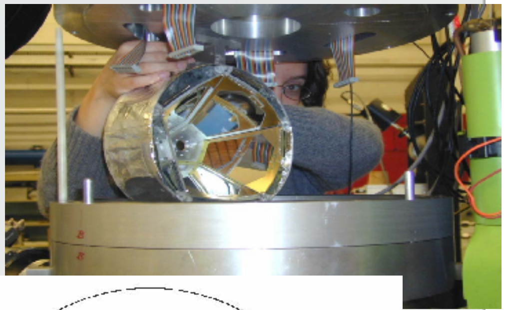
$^{32}S(^{3}He,t)^{32}Cl$ Charge Exchange Reaction
Sulfur target

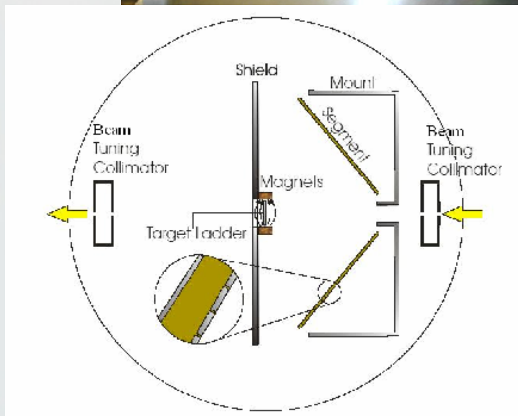
- used to populate excited states in ^{32}Cl

- thin (~300μg/cm^2) ZnS targets made by the evaporation technique on a carbon backing at ORNL

$^{32}S(^{3}He,t)^{32}Cl$ Charge Exchange Reaction
t detection by Enge Spectrograph at Yale



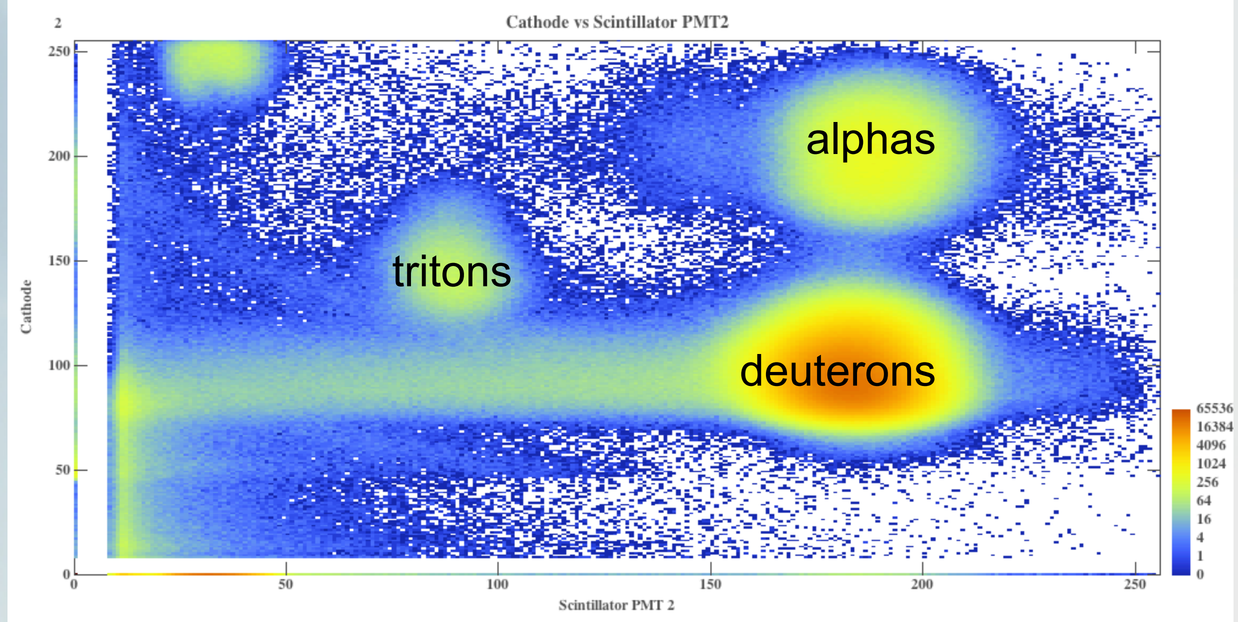




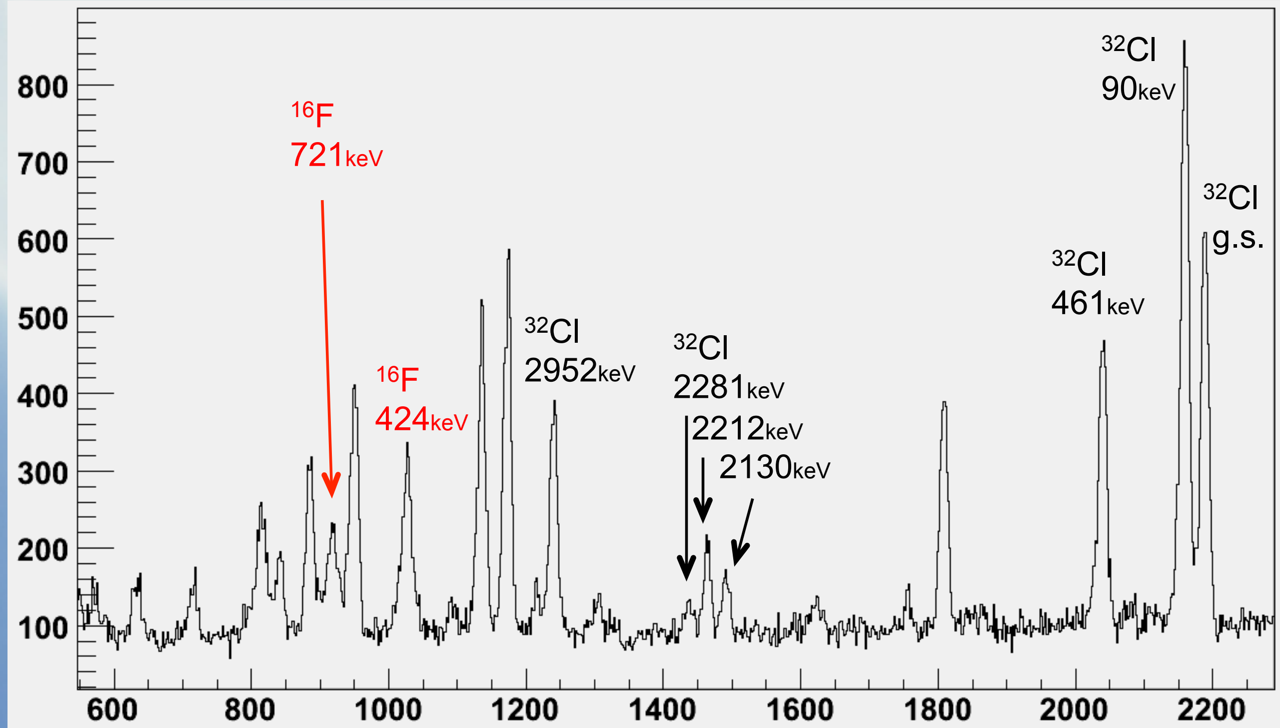
- YLSA - silicon strip detector array
- for protons emitted from excited states in ^{32}Cl

- gas-filled, position sensitive ionization drift chamber
- plastic scintillator

Spectra



E vs. ΔE particle identification spectrum



Focal plane position spectrum gated on tritons

Targets:

- ZnS 350 μg/cm^2
- ZnS 240 μg/cm^2
- Si 300 μg/cm^2

Angles:

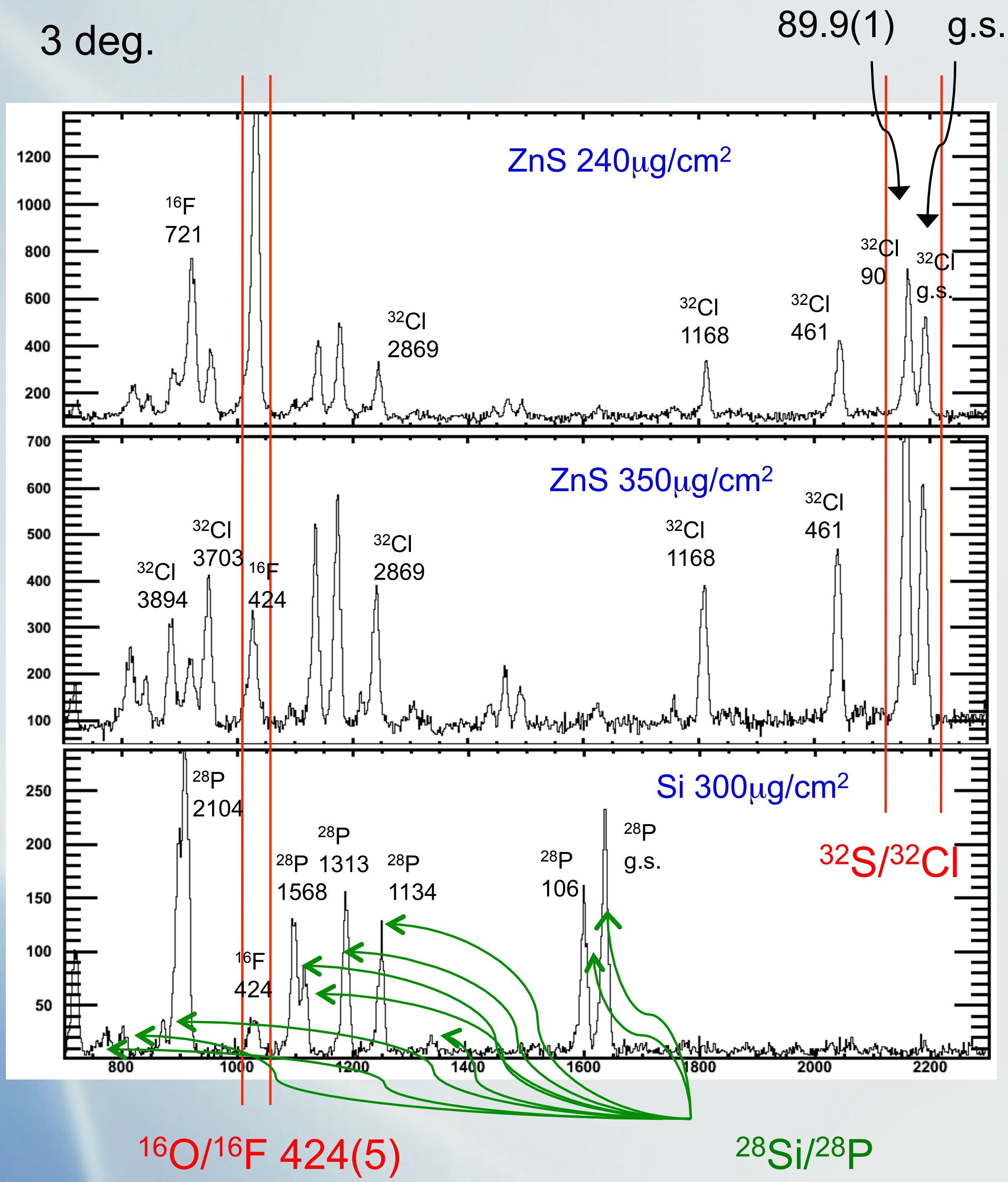
- 3, 5, 10, 20 deg

Triton spectra - calibration

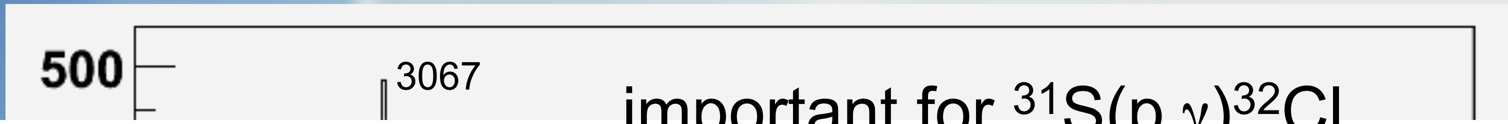
triton Bρ ~ position

t energy calculated
- energy losses
- kinematics

new mass values for ^{28}P and ^{32}Cl
C.Wrede et al.
PRC 81, 055503



New state in ^{32}Cl - 2610(3) keV (a part of a doublet)



important for $^{31}S(p,\gamma)^{32}Cl$ at X-ray burst temperatures

EXPLOSIVE HYDROGEN BURNING OF ^{27}Si, ^{31}S, ^{35}Ar, AND ^{39}Ca IN NOVAE AND X-RAY BURSTS

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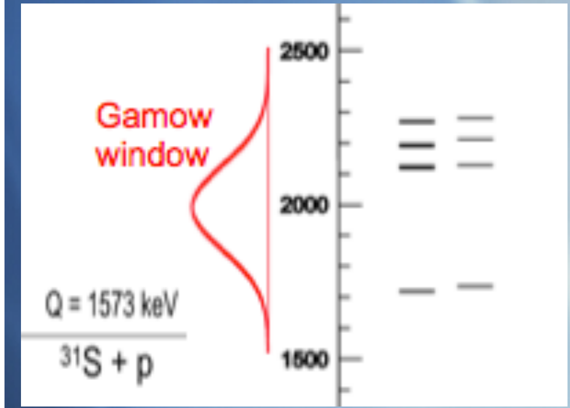
Received 1998 April 24; accepted 1999 May 28

might affect the energy output

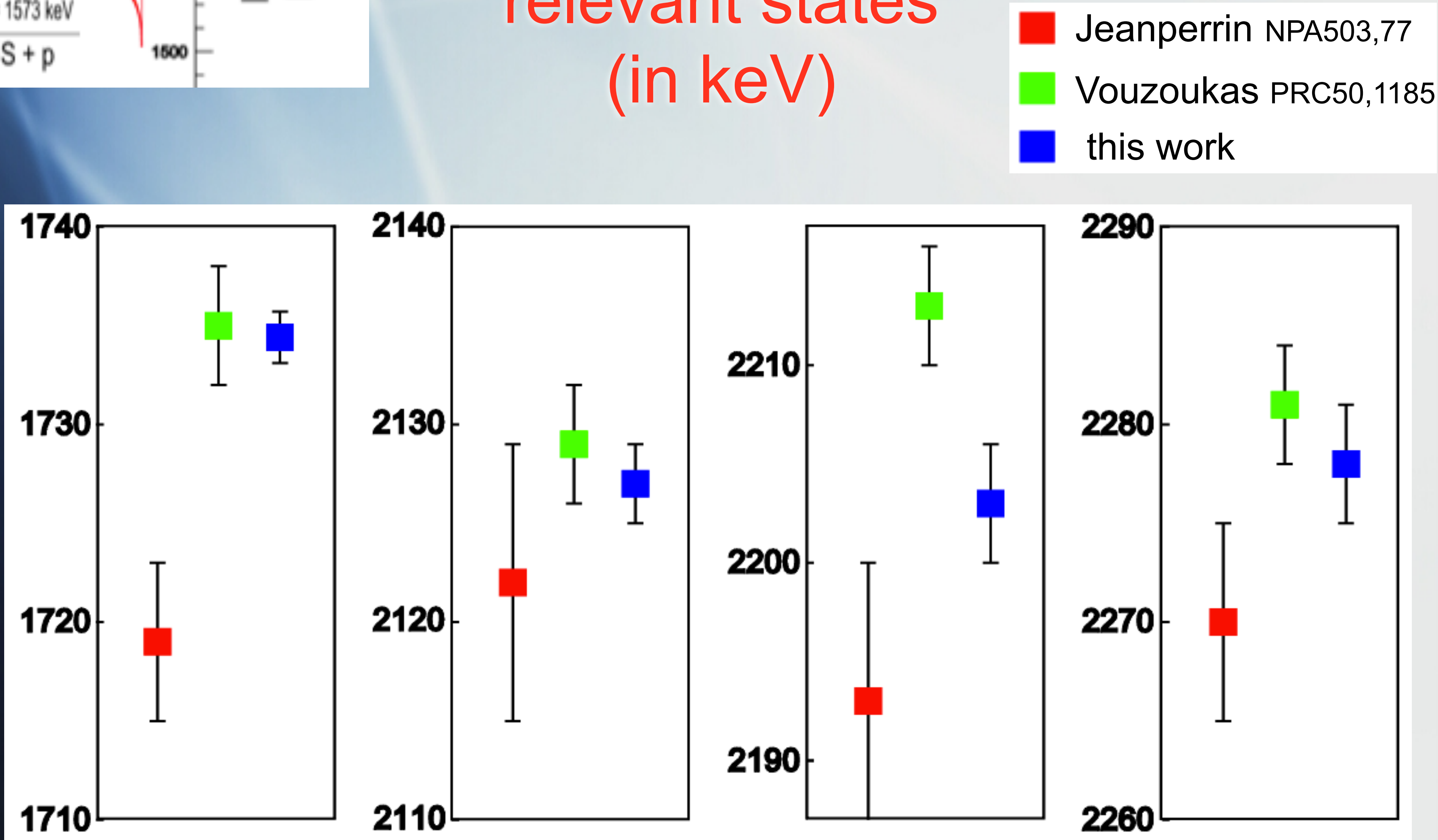
Parikh et al. ApJ Supl.S.178, 110

						$\omega\gamma$ (eV)
					10^{-3}	4.6×10^{-11}
					10^{-3}	1.3×10^{-3}
					10^{-2}	1.2×10^{-2}
					10^{-3}	3.4×10^{-3}
2574^{c}	2740	1^+_4	999	5.1×10^0	3.3×10^{-2}	2.4×10^{-2}
2676 ± 10......	2658	2^+_4	1101 ± 12	4.9×10^0	5.5×10^{-2}	6.8×10^{-2}
2869 ± 5.......	3005	3^+_3	1294 ± 9	1.2×10^1	6.5×10^{-3}	1.1×10^{-2}
2952 ± 5.......	3264	2^-_1	1377 ± 9	2.7×10^3	4.0×10^{-3}	5.0×10^{-3}
3067 ± 5.......	3443	4^-_1	1492 ± 9	5.4×10^1	1.7×10^{-3}	3.8×10^{-3}
3177 ± 5.......	3320	3^-_1	1602 ± 9	5.6×10^1	2.4×10^{-3}	4.2×10^{-3}
3301 ± 10......	3444	2^+_5	1726 ± 12	...^{d}	1.7×10^{-2}	$<2.2 \times 10^{-2}$
3397^{c}	3149	4^+_1	1822	...^{d}	1.1×10^{-3}	$<2.5 \times 10^{-3}$

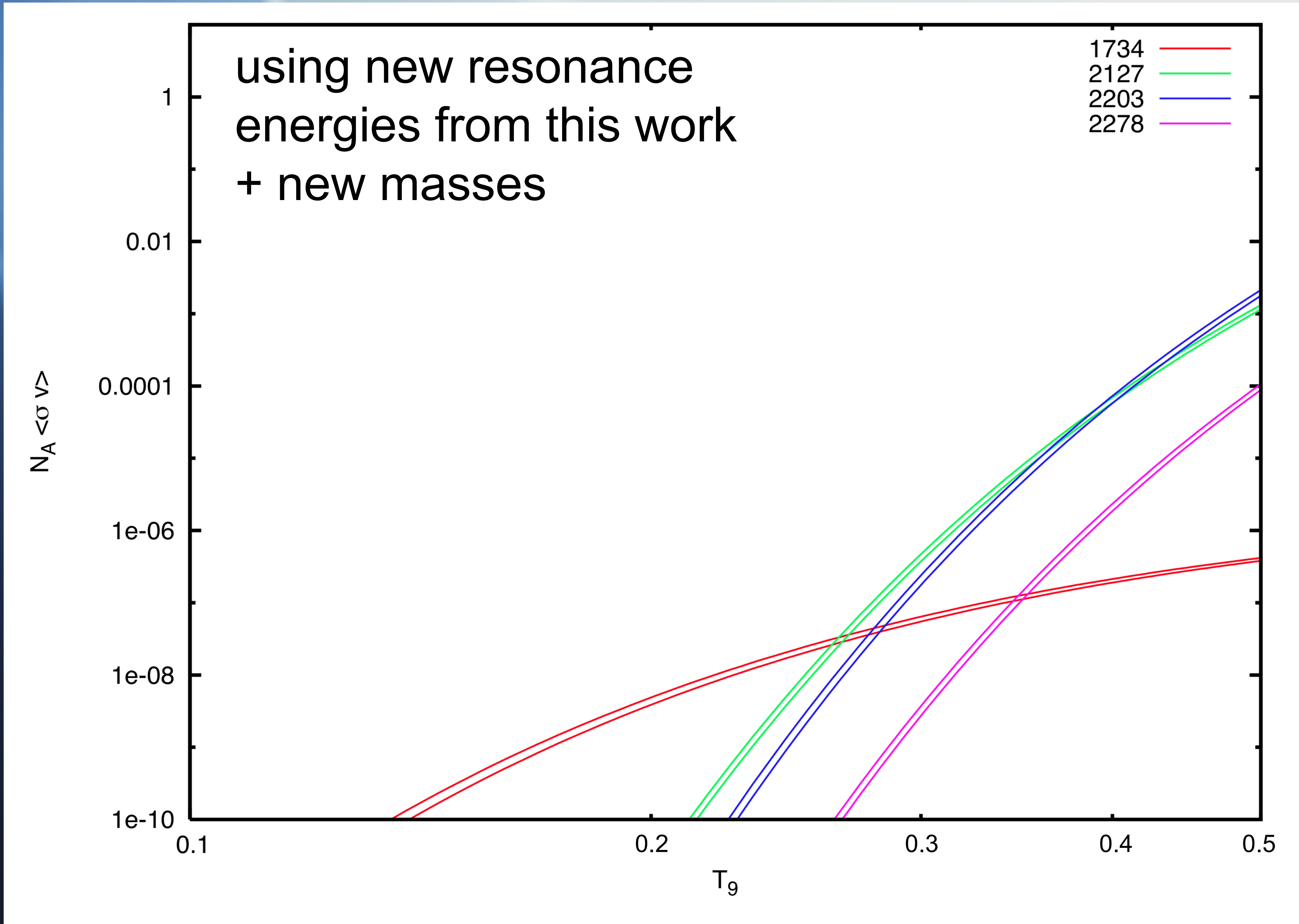
[a] Experimental values, adopted from Endt 1998.
[b] Calculated from first column using $Q_{p\gamma} = 1574.7 \pm 6.9$ keV (Audi & Wapstra 1995).
[c] State has not been observed experimentally. The E_X value is estimated by using the IMME (eq. [11]). The estimated uncertainty is 50 keV (§ 2.2).
[d] Value is not estimated, since the spectroscopic factor S of the ^{32}P mirror state has not been measured. The upper limit for $\omega\gamma$ is calculated with $\omega\gamma \leq \omega\Gamma_\gamma$ (since $\Gamma_p/\Gamma \leq 1$).



Results – energies of novae-relevant states (in keV)

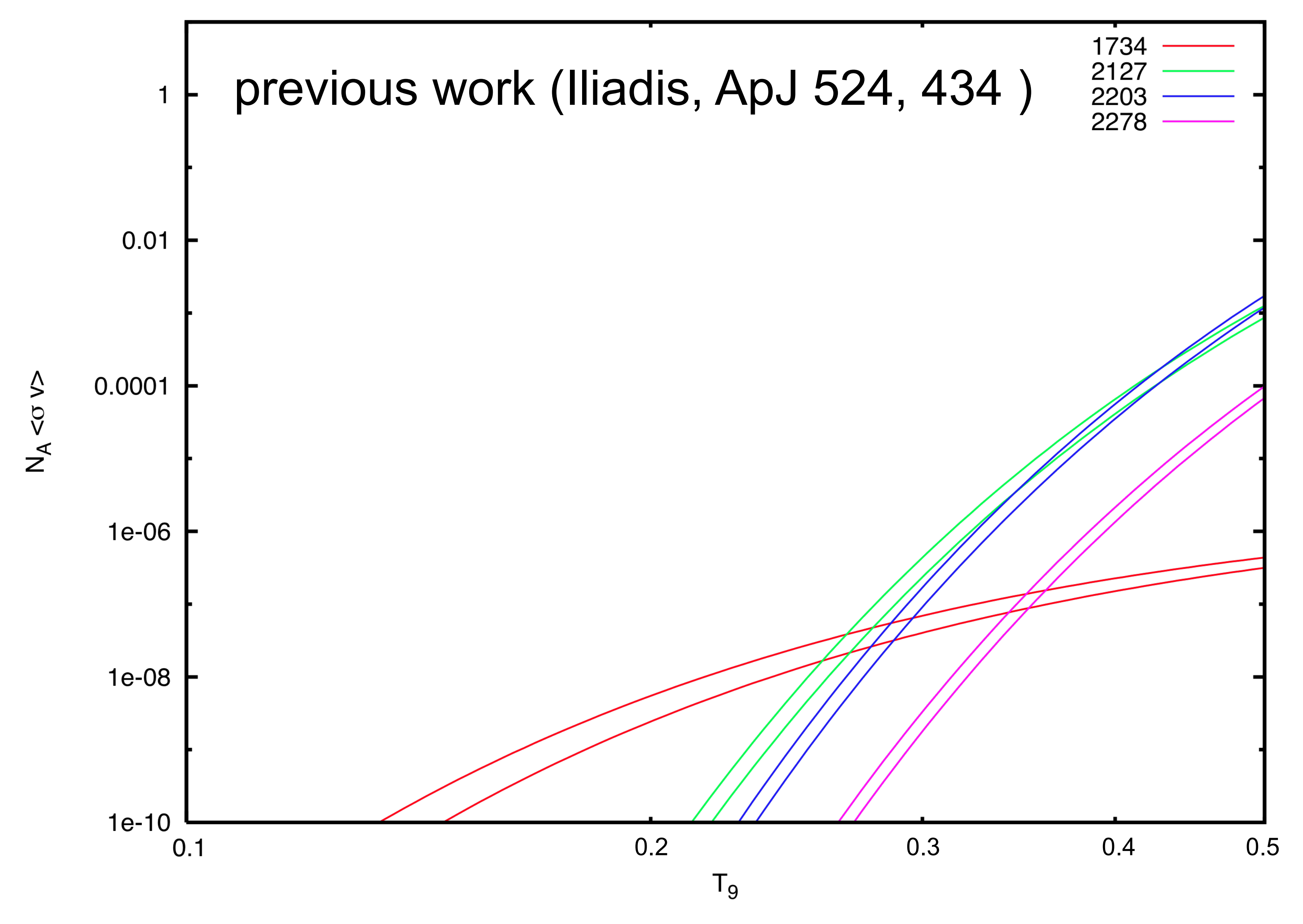


Resonance Reaction Rates

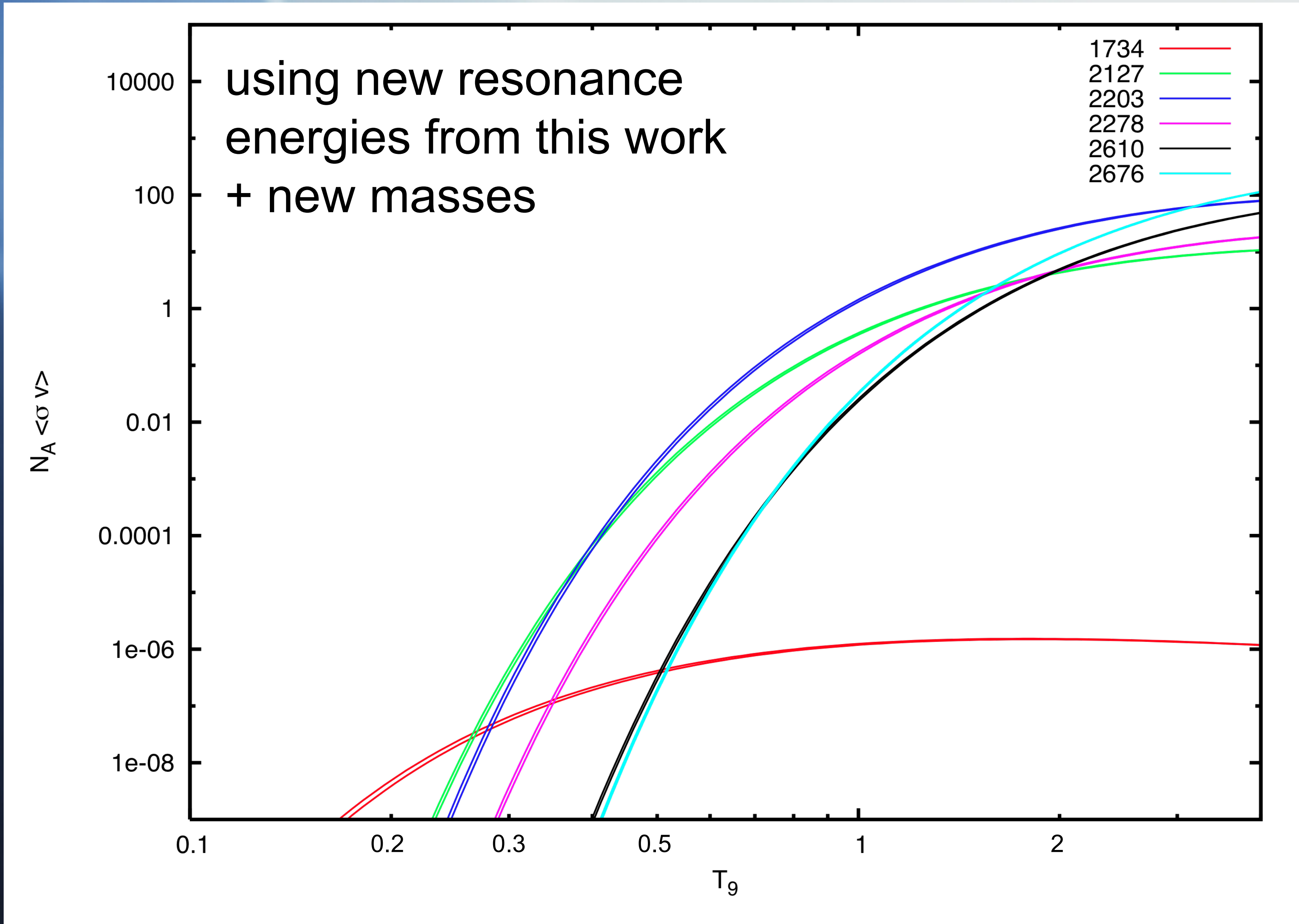


ωγ taken from Iliadis et al., ApJ 524, 434

Resonance Reaction Rates

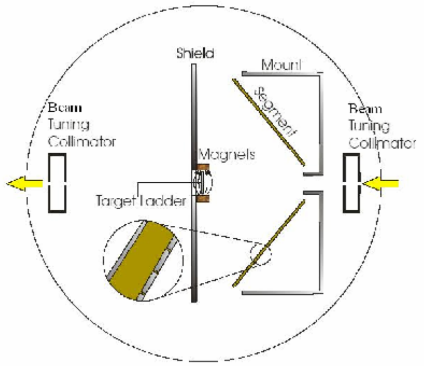


Resonance Reaction Rates



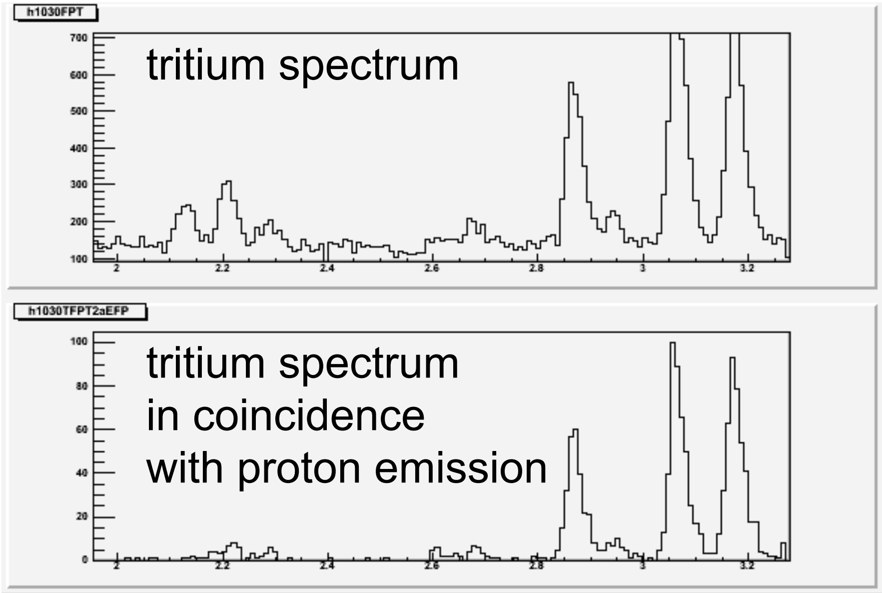
$\omega\gamma$ taken from Iliadis et al., ApJ 524, 434

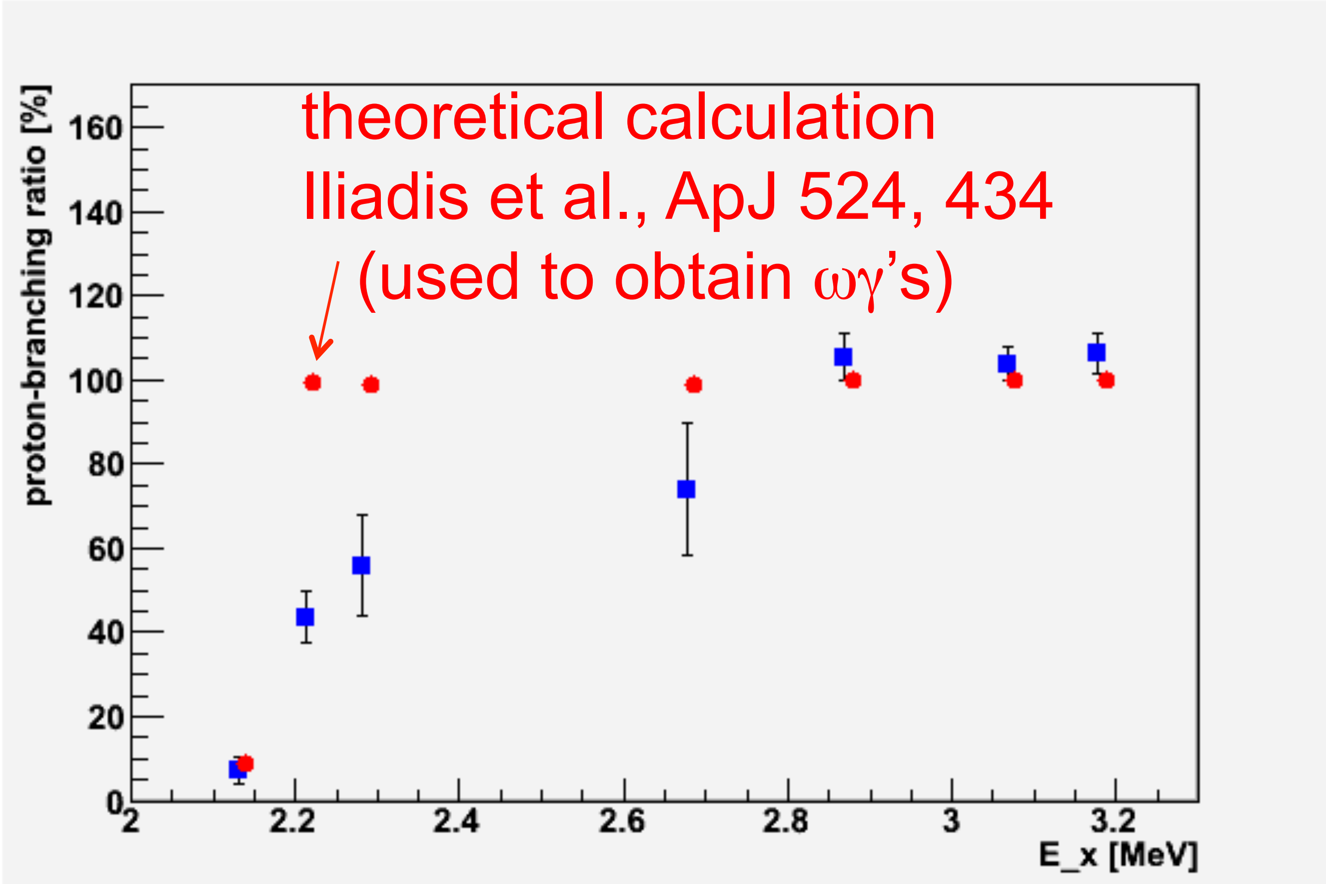
Proton emission of ^{32}Cl*



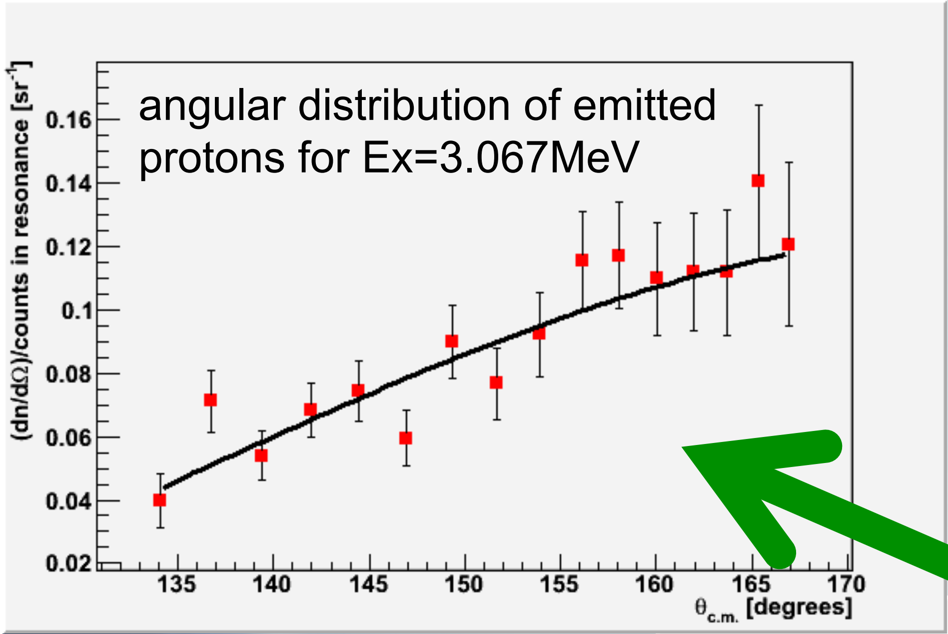
YLSA - silicon strip detector array

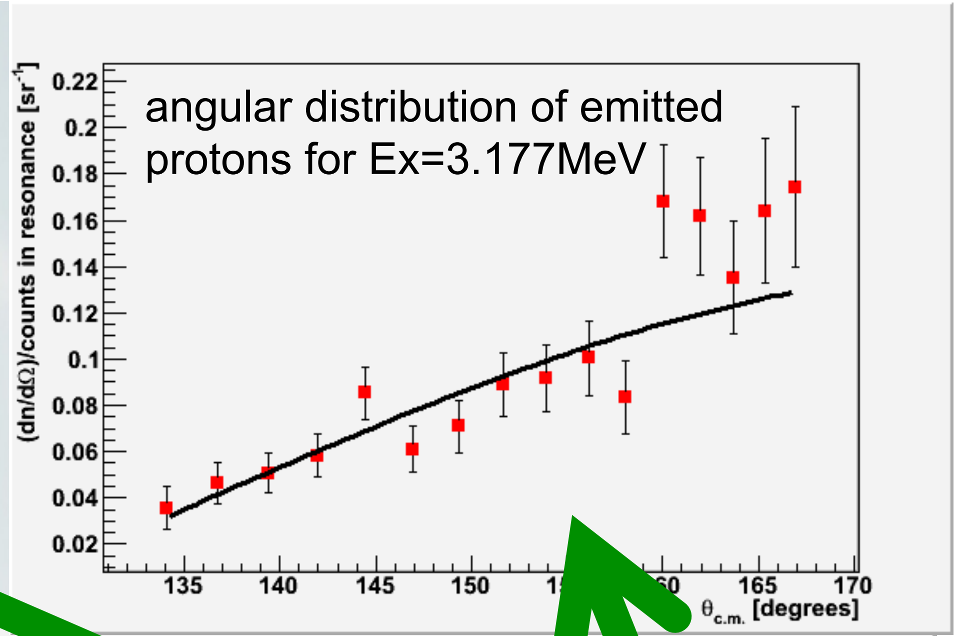
Efficiency calculations:
Monte Carlo
D.Visser, Yale



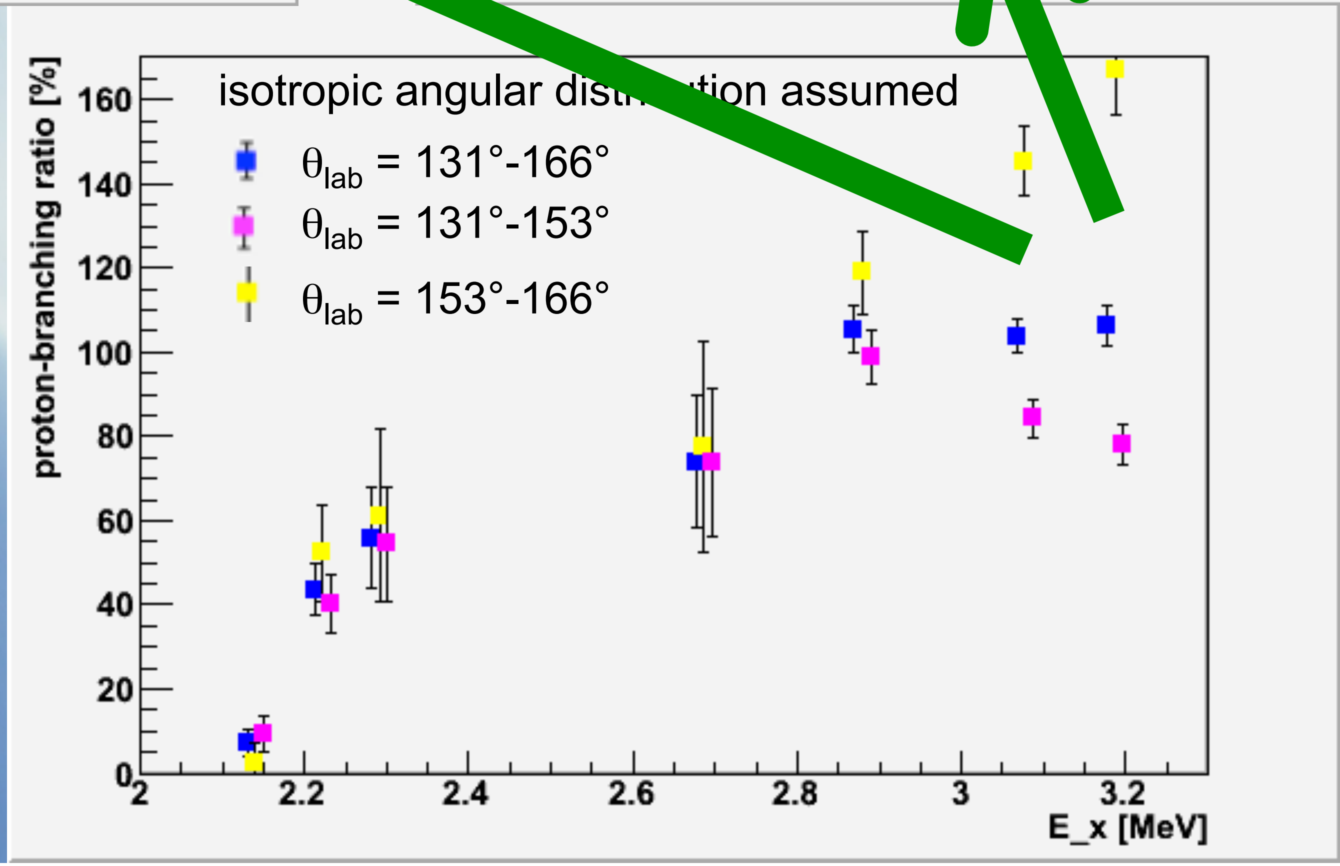


^{32}Cl proton threshold
S_p= 1.578 MeV





proton emission -- angular distribution



^{32}Cl proton threshold
S_p= 1.578 MeV

Conclusions

- levels in ^{32}Cl remeasured
- new level discovered
- our understanding of the properties of the levels in ^{32}Cl has been greatly improved
- currently evaluating impact on reaction rate:

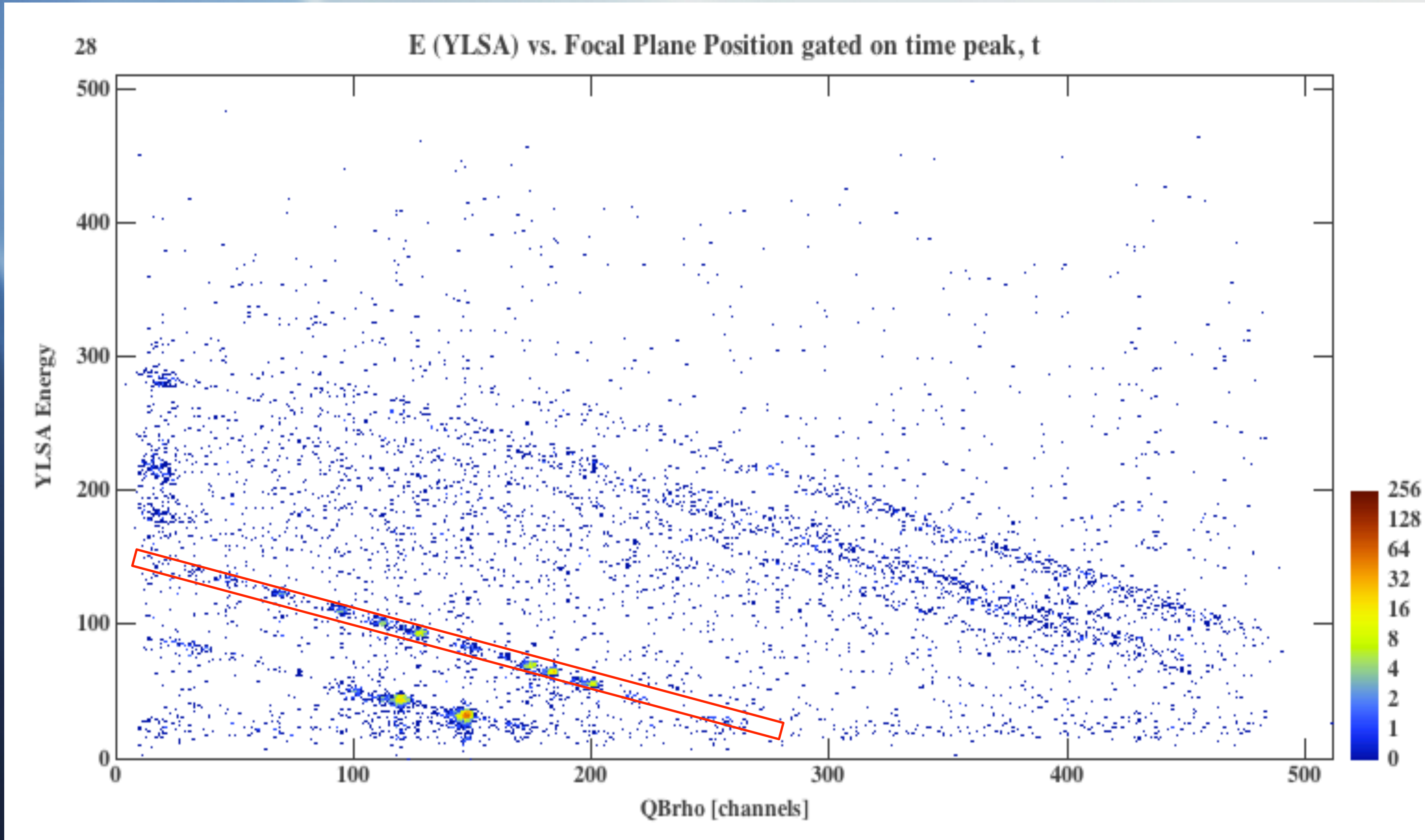
  widths of the 2.2 MeV state dominate

  uncertainty in reaction rate

  $\Gamma p \sim \Gamma\gamma$, but estimates $\Gamma p \sim 200x\ \Gamma\gamma$

  Are estimates of the gamma or proton widths wrong?
- Spins
- new mass value for ^{16}F ?

Thank you!



28
E (YLSA) vs. Focal Plane Position gated on time peak, t
YLSA Energy
QBrho [channels]
0
100
200
300
400
500
256
128
64
32
16
8
4
2
1
0

PHYSICAL REVIEW C VOLUME 50, NUMBER 2 AUGUST 1994

Reaction rate for $^{31}S(p,\gamma)^{32}Cl$ and its influence on the SiP cycle in hot stellar hydrogen burning

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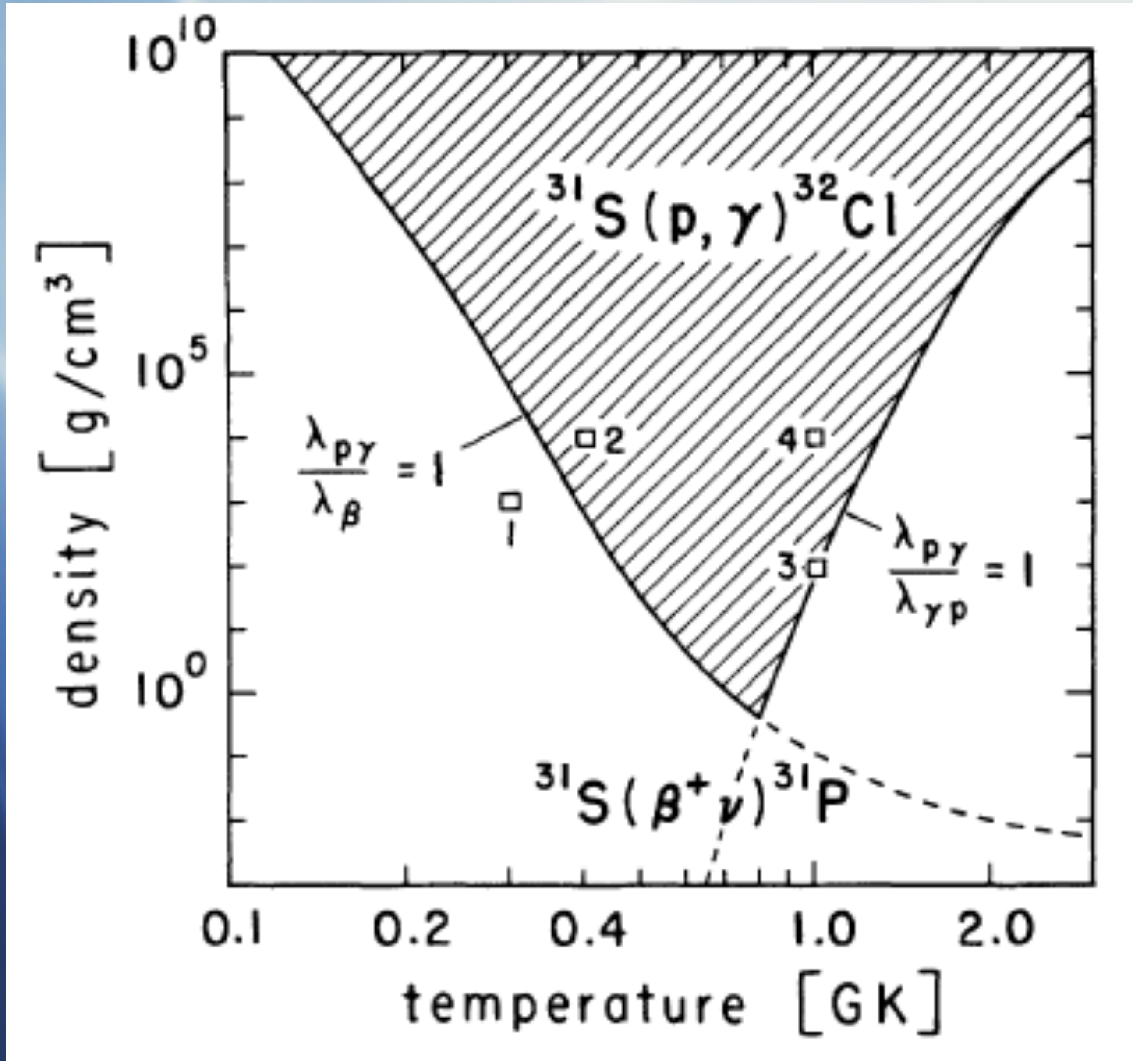

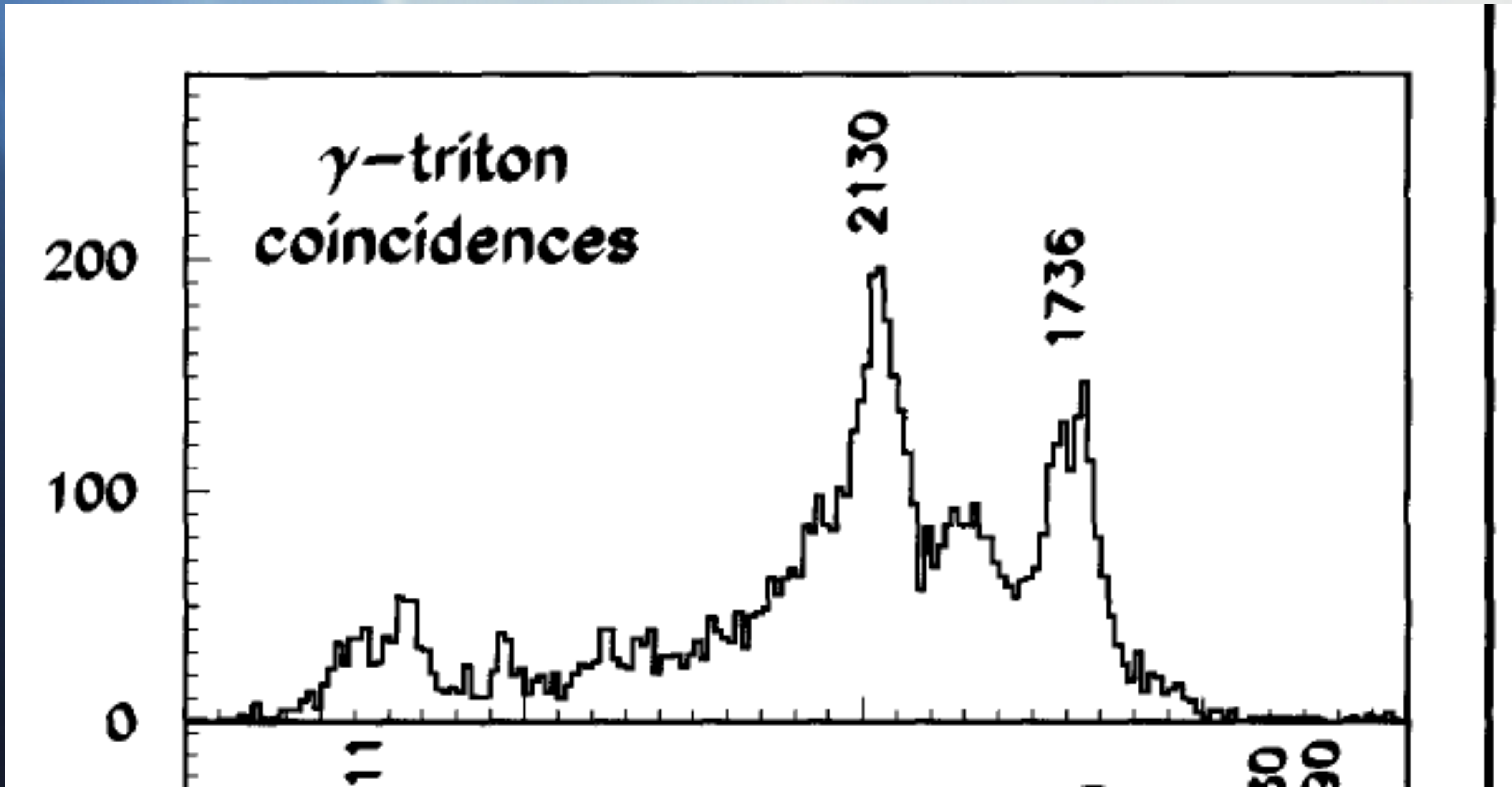

γ−triton
coincidences
2130
1736
200
100
0