Laser Nuclear Reactions at High Temperatures

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Nuclear Physics at High Temperatures

This is a nuclear regime which is best carried out using lasers - opportunities at Livermore, RAL, XFEL and ELI Bucharest

At present there is no laser induced reaction which cannot be done better using conventional accelerators –

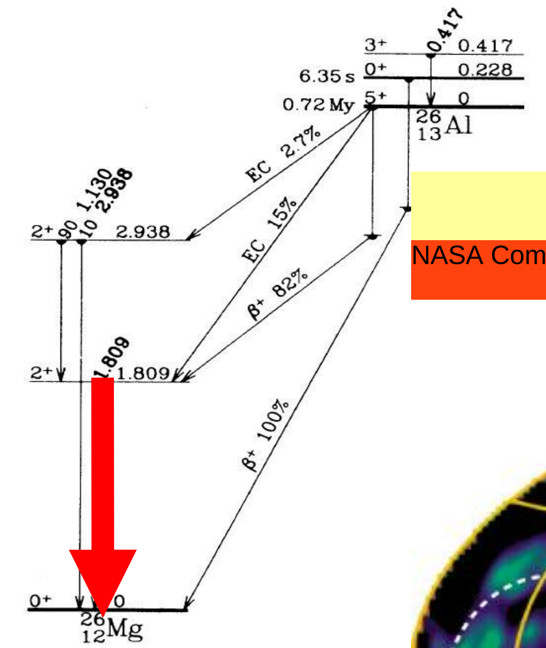
at high temperatures this could be very different (stellar conditions)

Motivation

- ^{26}Al in the astrophysical context using a gamma camera

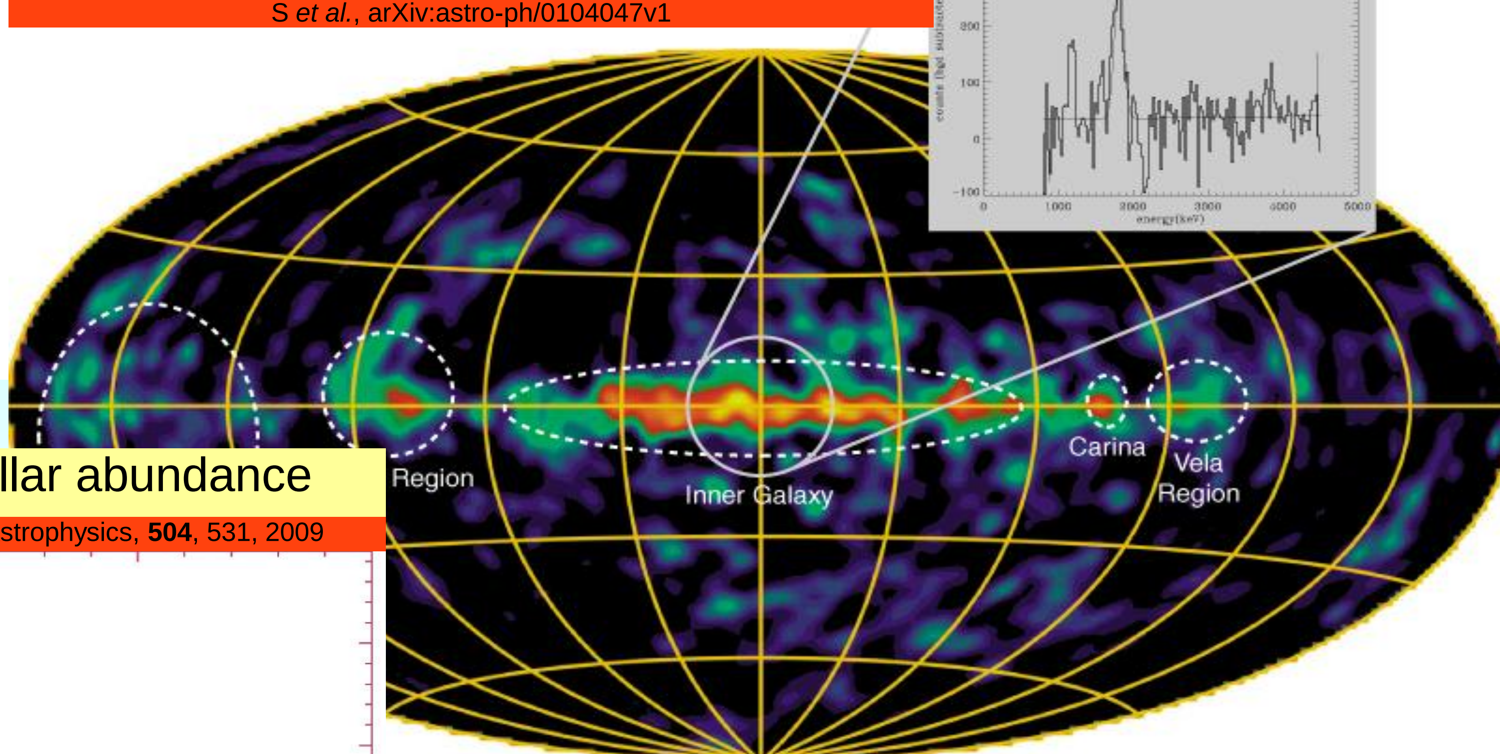
Level scheme

Skelton R *et. al.*, Phys.Rev. C**35**(1),45,1987



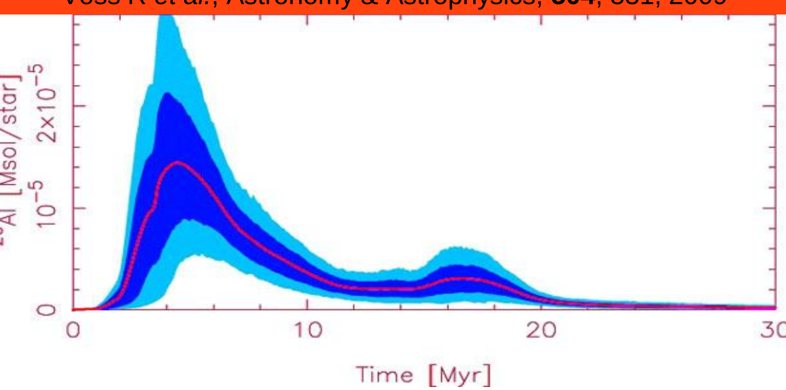
Interstellar abundance

NASA Compton Gamma Ray observatory (COMPTEL) 1991-2000 & Plüschke S *et al.*, arXiv:astro-ph/0104047v1



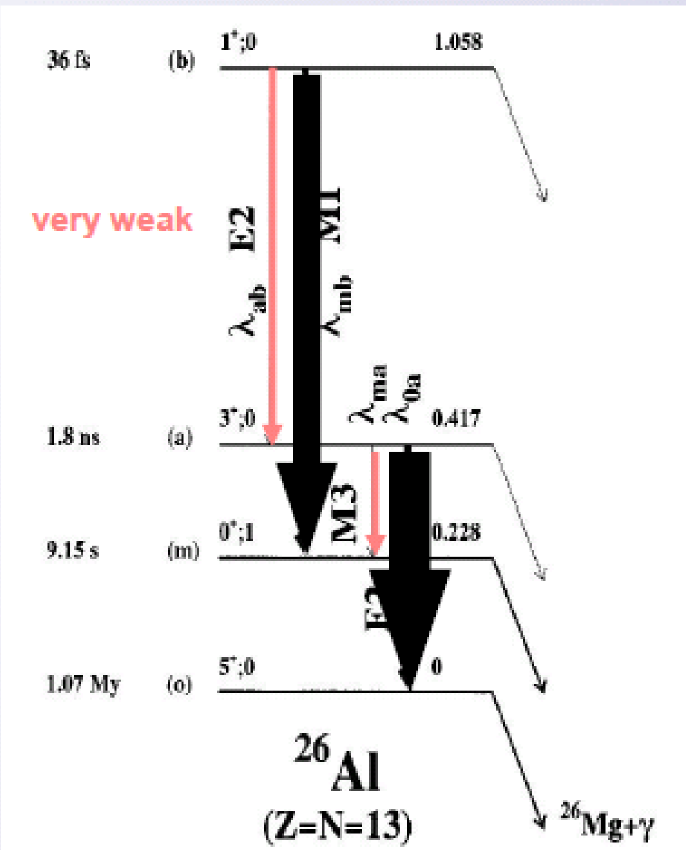
Evolution of stellar abundance

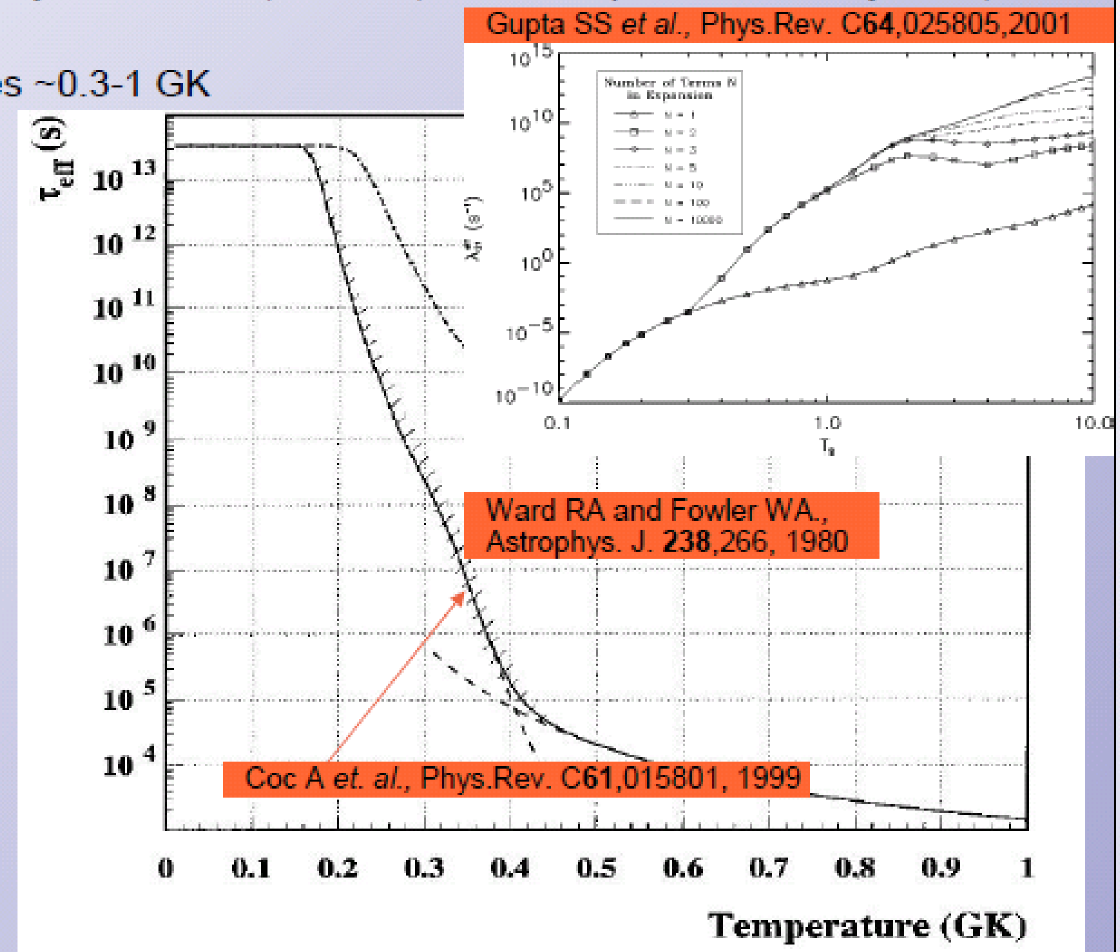
Voss R *et al.*, Astronomy & Astrophysics, **504**, 531, 2009



Motivation

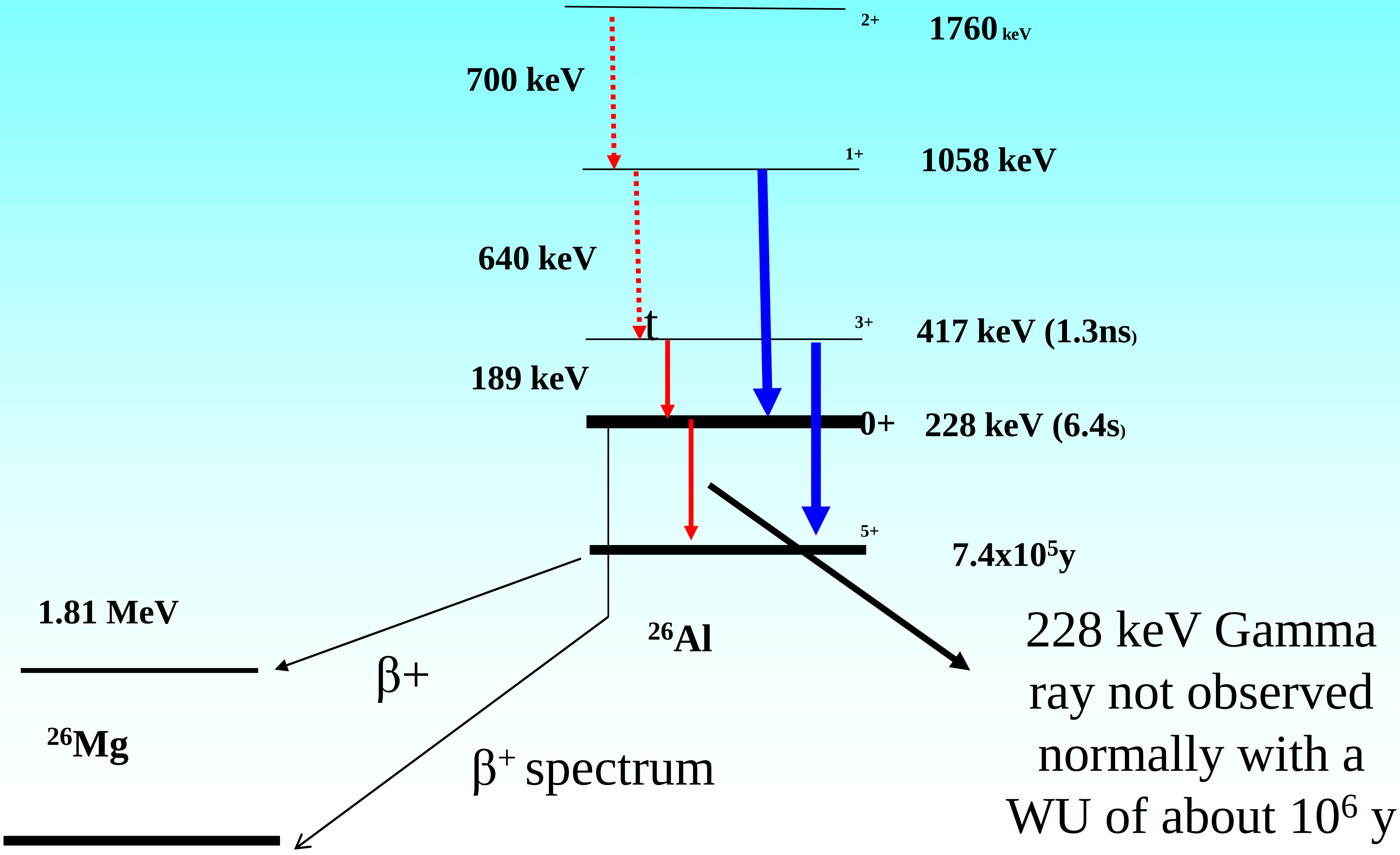
- Theories of production and decay of ^{26}Al in stars
  - $\tau_{eff}(^{26}Al_{(g.s.)})$ predicted to reduce by 10^9 within temperature between 0.15-0.4 GK
    - based on branching ratios from shell model calculations for low electron densities Coc A, Porquet M-G and Nowacki F, Phys. Rev. C **61**, 015801,1999 & Gupta SS and Meyer BS, Phys Rev C **64**,025805, 2001
    - Very complex interplay of states ~0.3-1 GK





The production and decay of ^{26}Al in a hot photon bath using a laser driven $^{26}Mg(p,n)^{26}Al$

Partial Level Diagram for ^{26}Al



The decay scheme of ^{26}Al

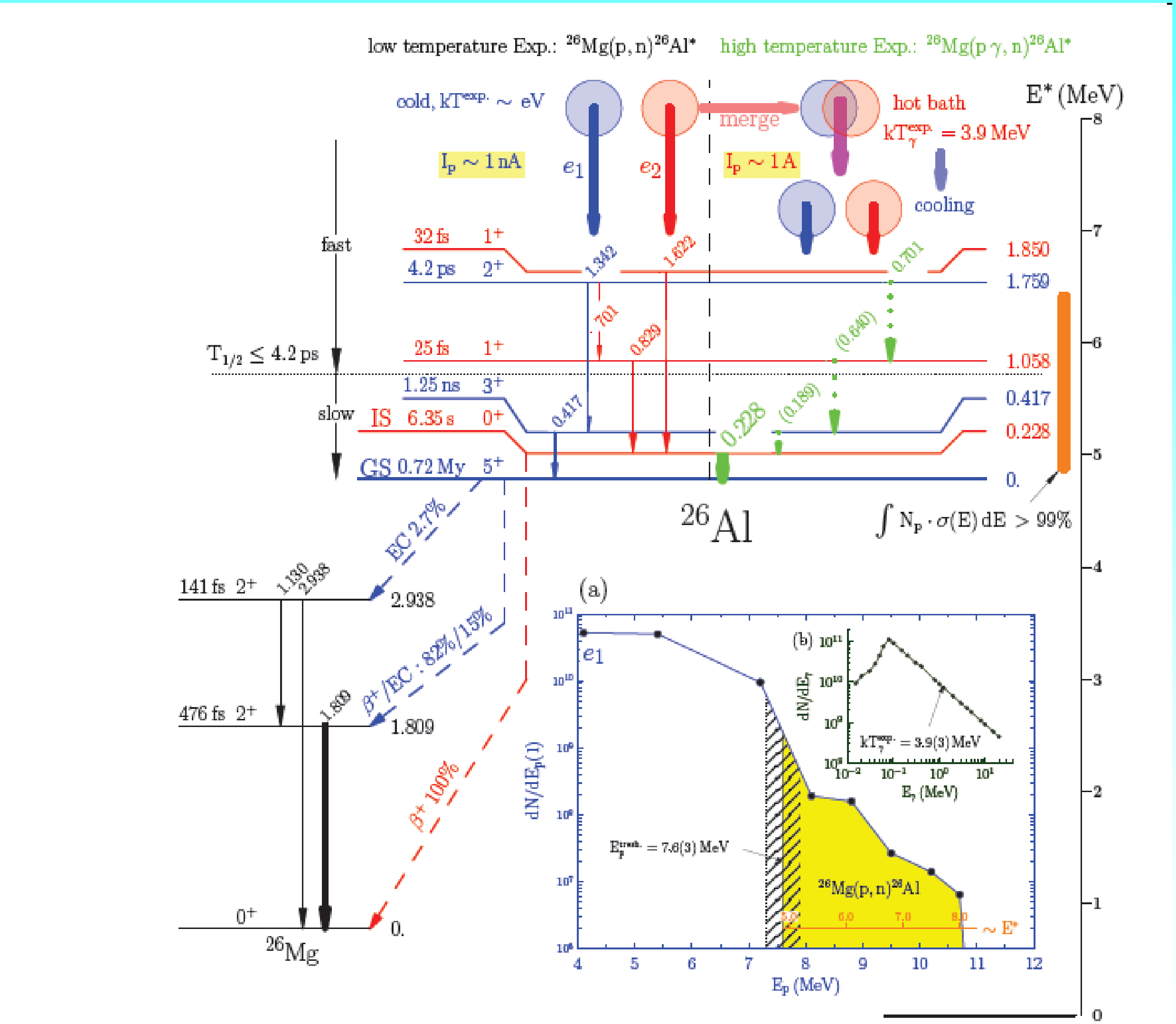
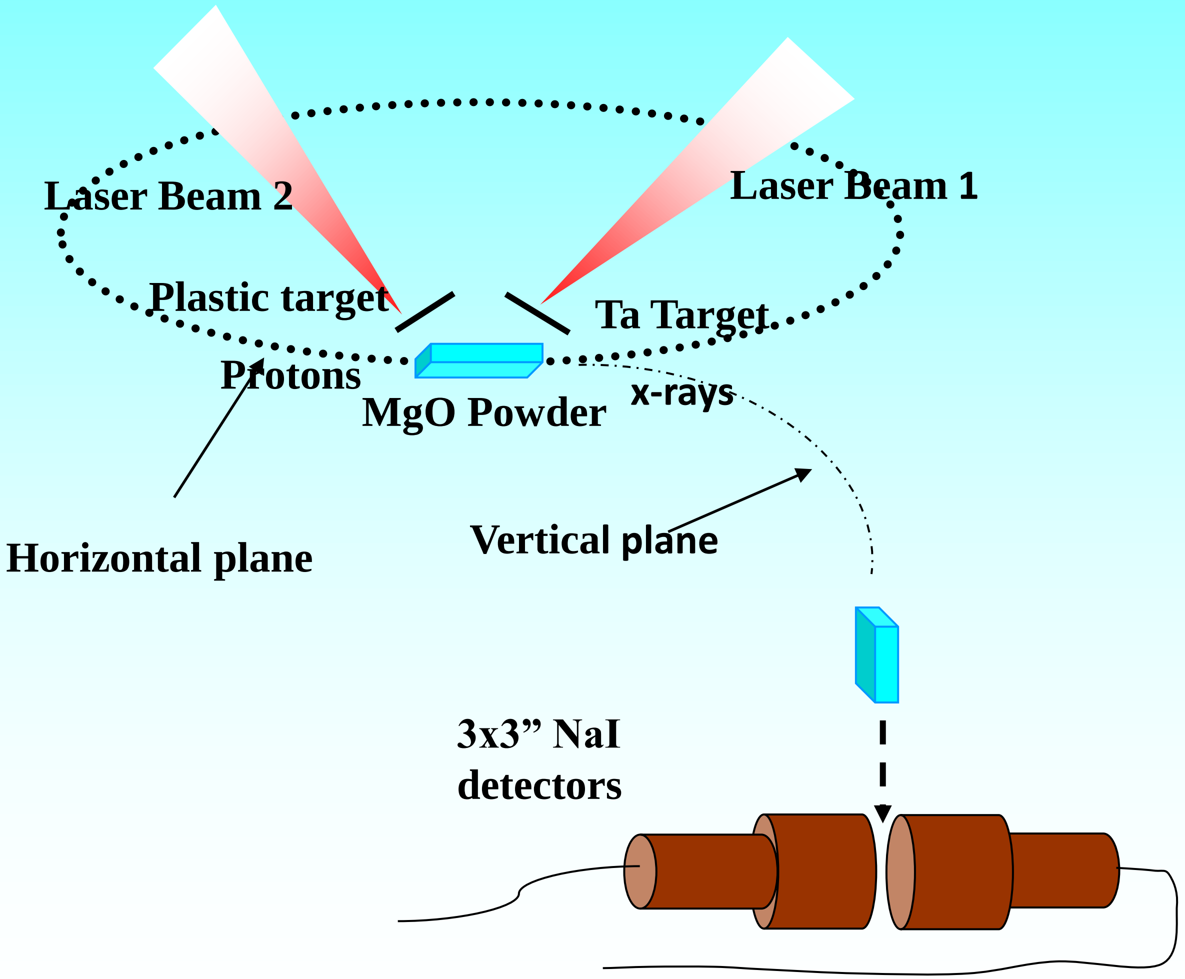


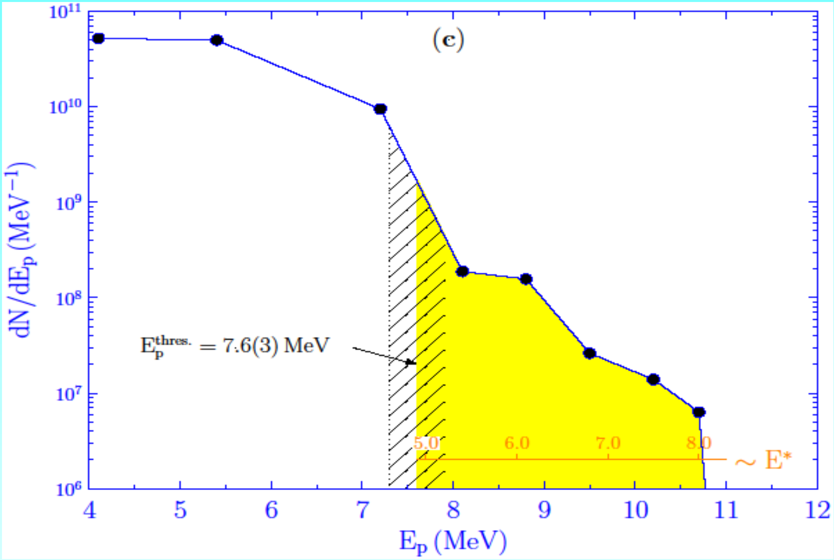
Figure 1

This is the two ensemble level diagram which must be used to determine thermal equilibrium

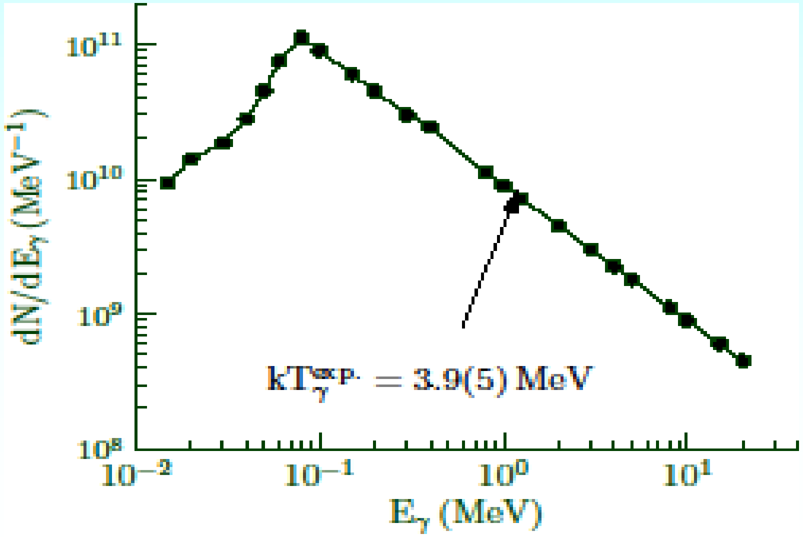
Experimental arrangements for simultaneous irradiation of target with protons and photon



Proton and Photon Spectra on target



Proton spectrum
16 ps pulse,
$5x10^{19}$ W/cm^2 20μ
plastic



Photon Spectrum
2 ps, 1mm Ta
target,
$5x10^{19}$W/cm^2

What we observe with only the laser induced proton beam interacting the target

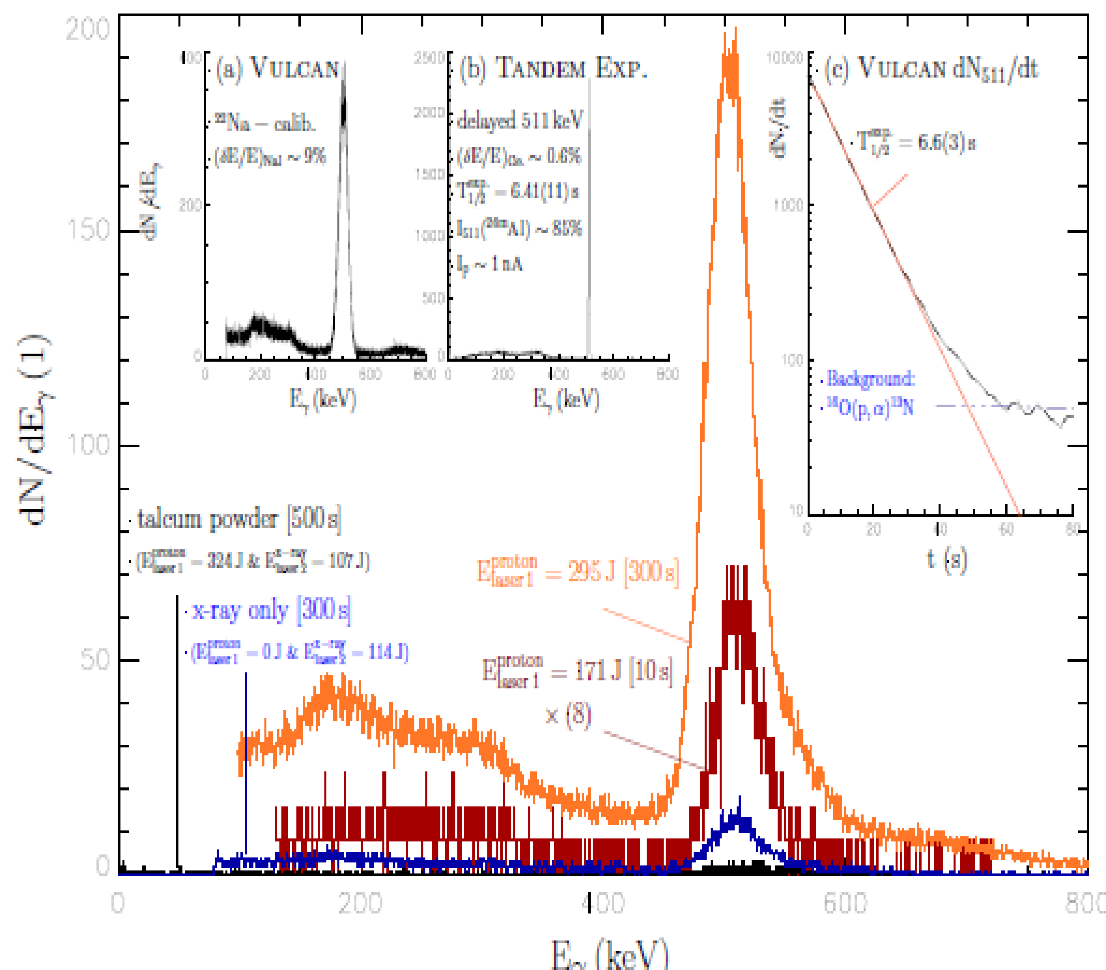
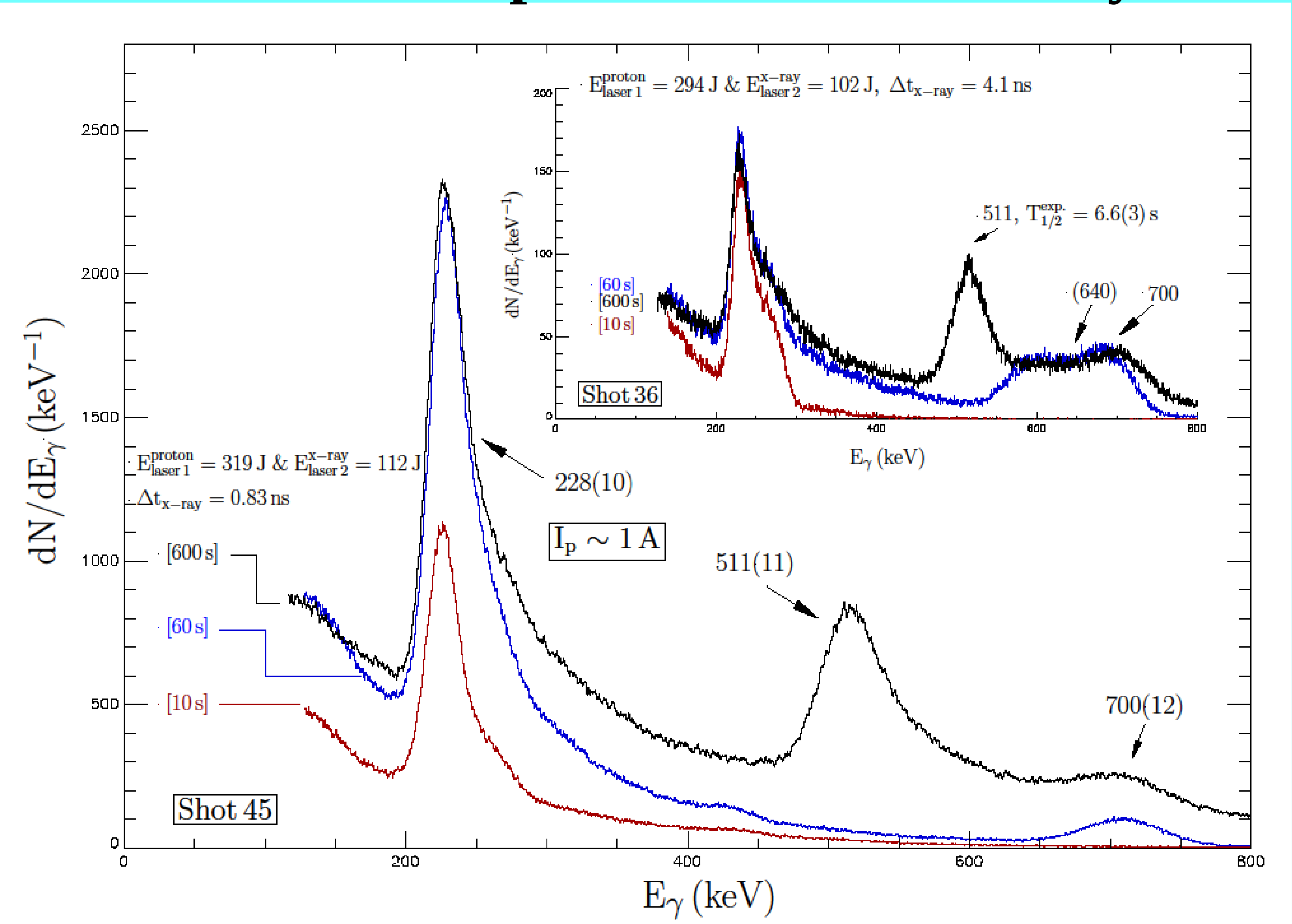


Figure 3

Only the 6 sec 511 peak from the positrons is observed

What we observe when both the proton and photon beam are present simultaneously



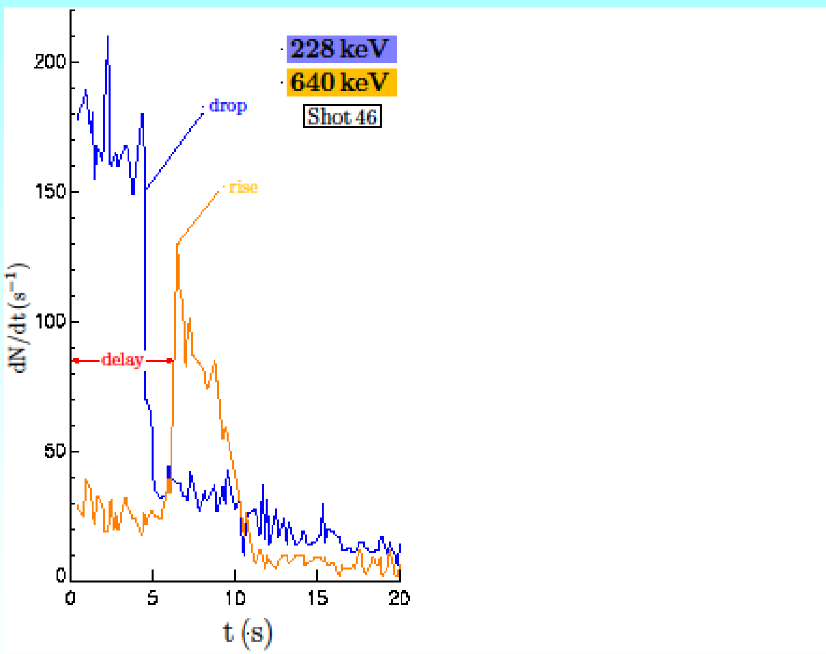
To begin with, only the 228 keV peak is visible and then 700, keV followed by 640, followed by 6 sec 511 peak

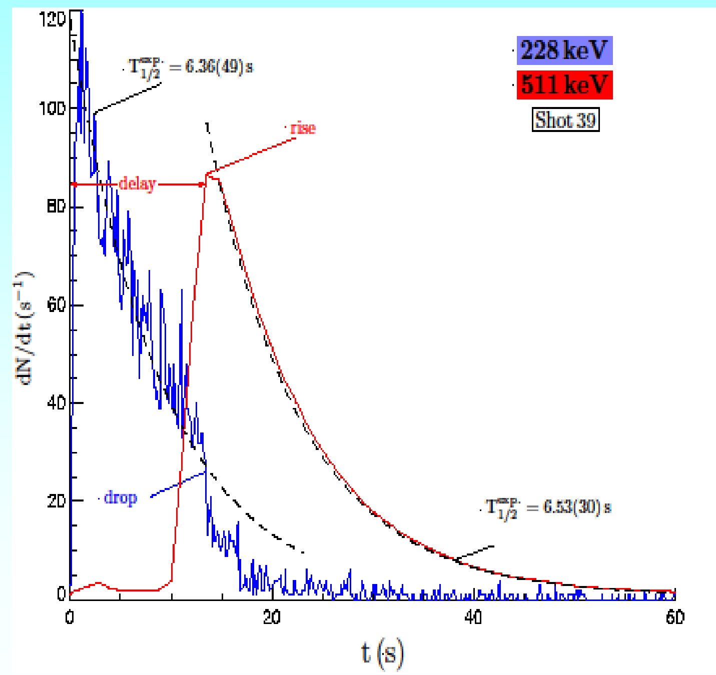
Time sequence of the decay of energy levels

1) Forbidden 228 kev gamma ray alone and then stops

2) followed by 700/640 keV

3) the 6 sec positron spectrum starts again when 228/700/640 stops (the delay before 511 starts can be almost 1 min)





The 228 keV counting rate as a function time suddenly stops at about 5 secs and the 640 keV CR suddenly rises for this shot

For this shot the 228 keV CR stops suddenly at about 18 s and the 511 keV starts

Observations

- The 228 keV gamma ray with a half life of about 10^6 years has an observed half life of seconds when both proton and photon pulses are present
- The photon flash switched off the beta decay branch and gamma rays from excited states which should have half lifes of ns decayed from excited state to state like a condensate
- When the 228 keV transition ceased, the beta decay switched back on when system cooled