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DECEMBER 15, 2014

Study of beta delayed particle emission from ^{21}Mg

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AARHUS UNIVERSITY
ON BEHALF OF IS507 COLLABORATION

VERSITET UNI

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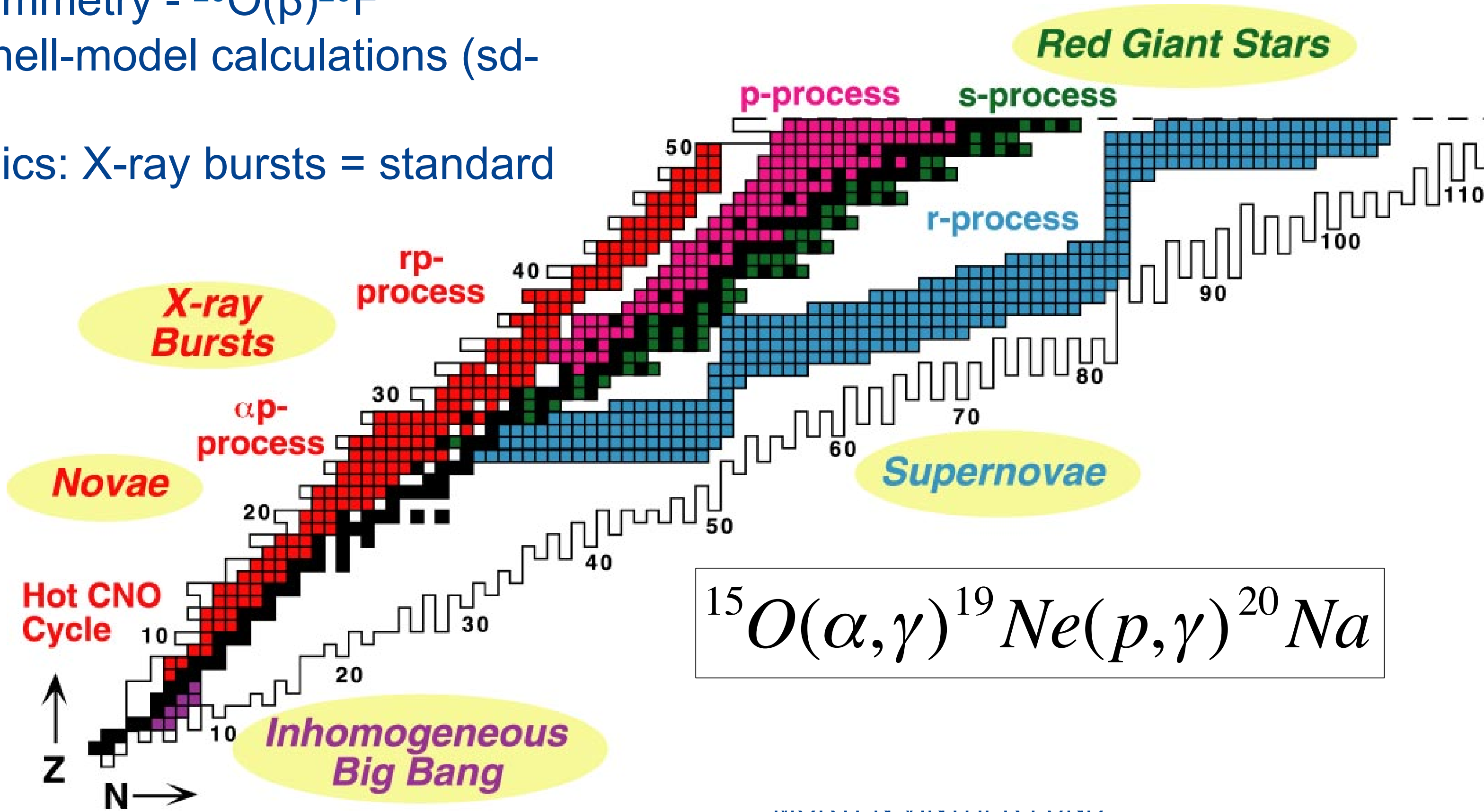
MOTIVATION ^{20}MG

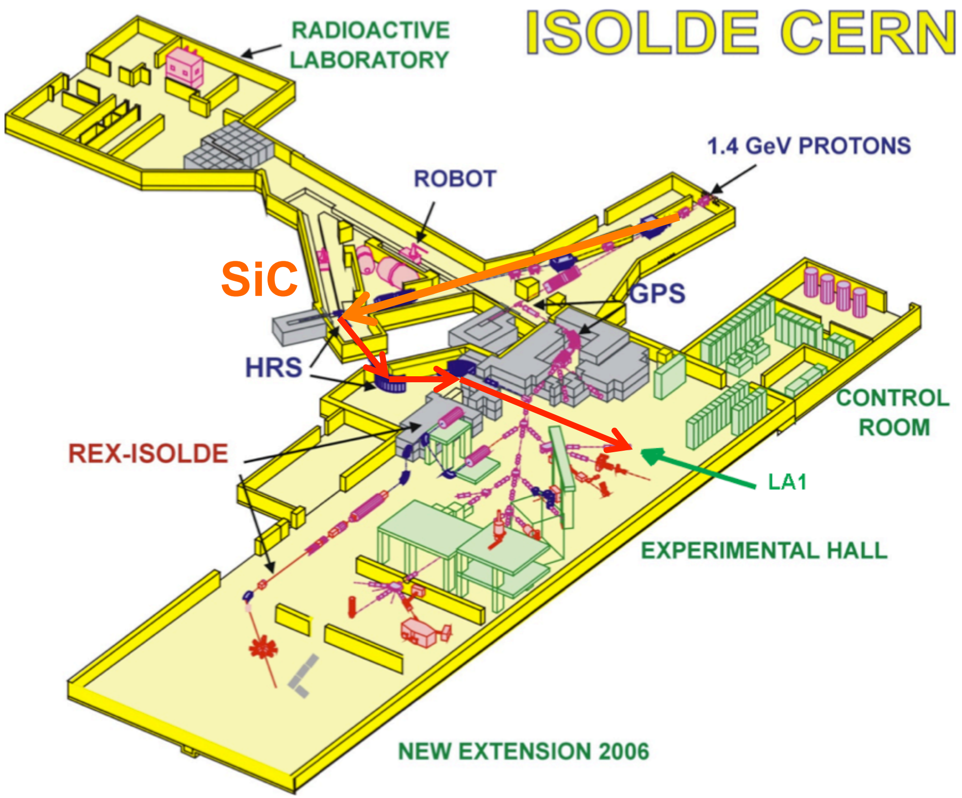
Threefold motivation:

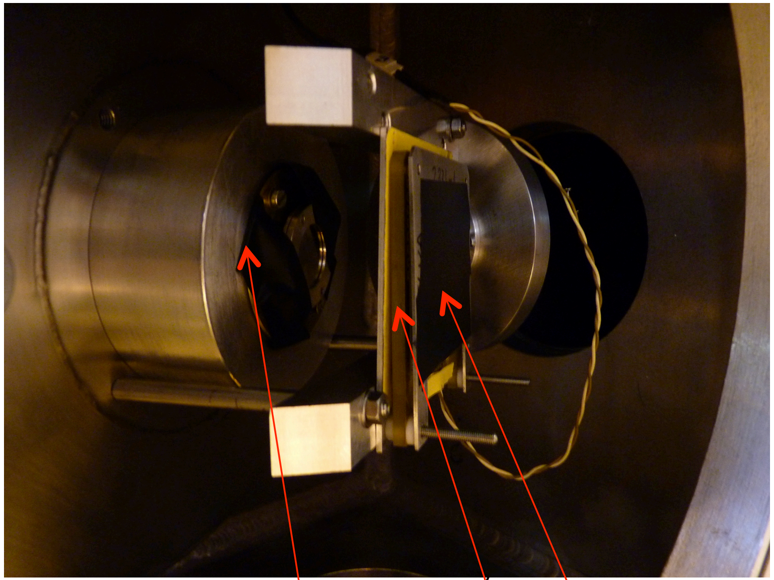
1. Mirror asymmetry - $^{20}O(\beta)^{20}F$
2. Modern shell-model calculations (sd-shell)
3. Astrophysics: X-ray bursts = standard candles

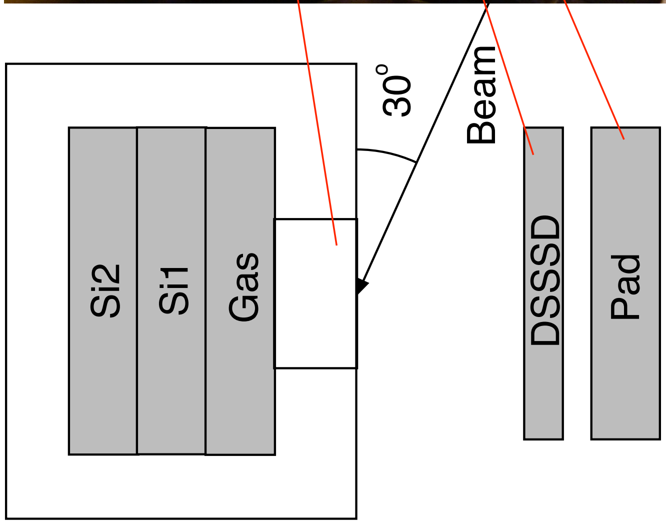


$$^{15}O(\alpha,\gamma)^{19}Ne(p,\gamma)^{20}Na$$

EXPERIMENT IS507



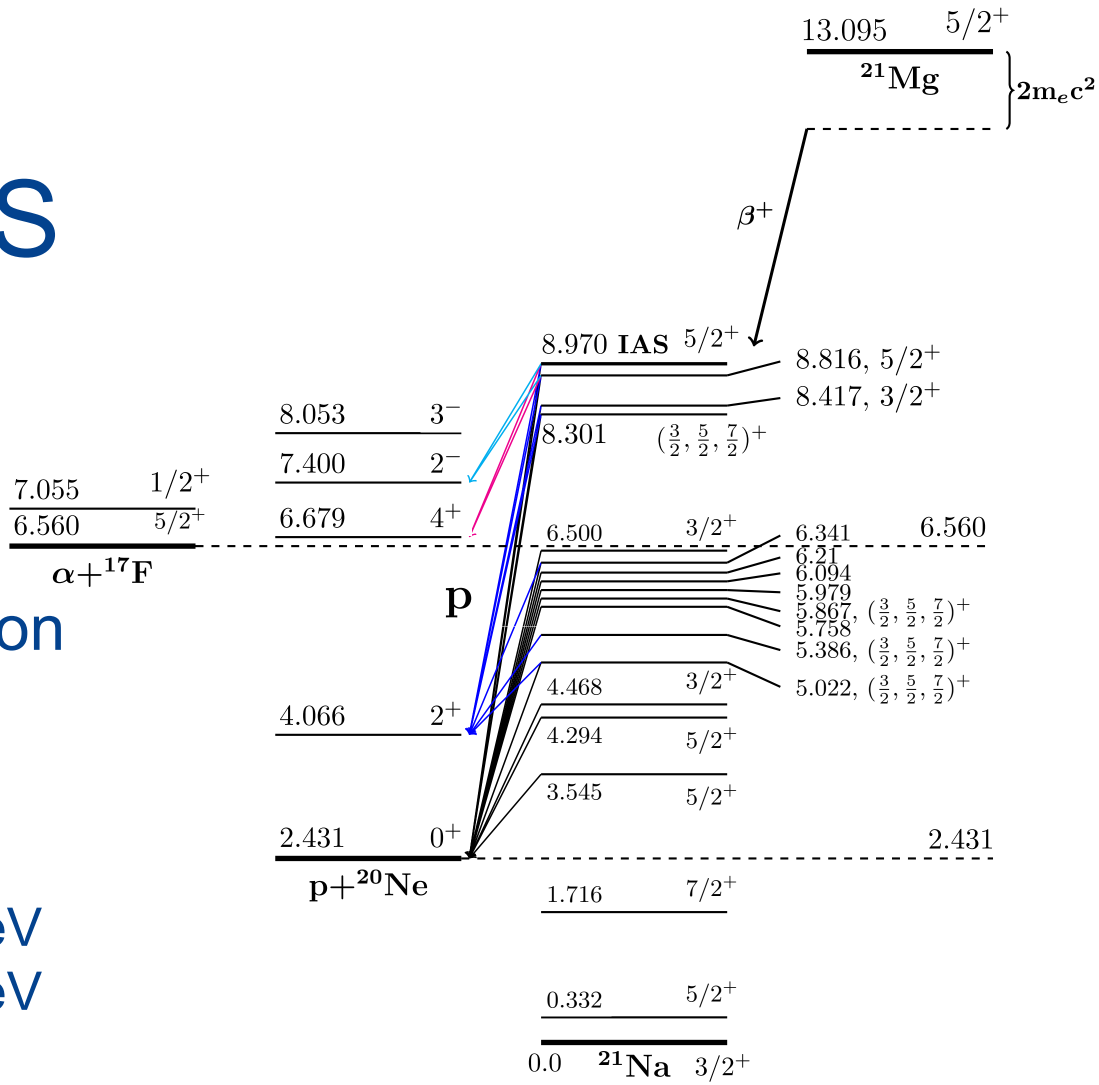




^{21}MG BETA DECAY

^{21}MG – STATUS

- ^{21}Mg is a well known proton emitter
- Used for proton calibration
- Delayed alpha emission energetically allowed:
  - Q_a(8816 keV) = 2256 keV
  - Q_a(8970 keV) = 2410 keV



Sextro et al. (1973)

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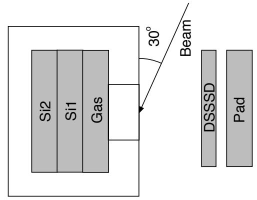
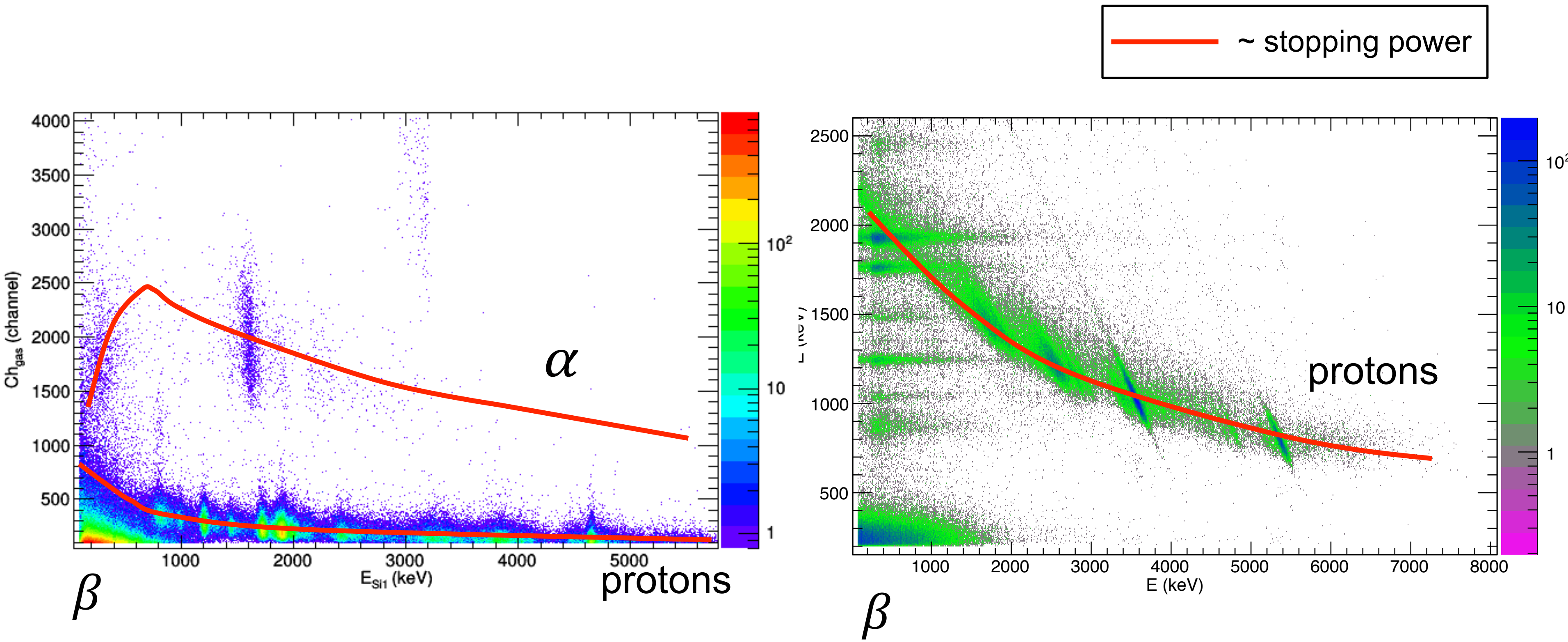


$$^{21}Mg \rightarrow \beta + {}^{21}Na \rightarrow p + {}^{20}Ne \rightarrow \alpha + {}^{16}O$$
$$\downarrow$$
$$^{17}F + \alpha$$

^{21}MG – ΔE-E DATA



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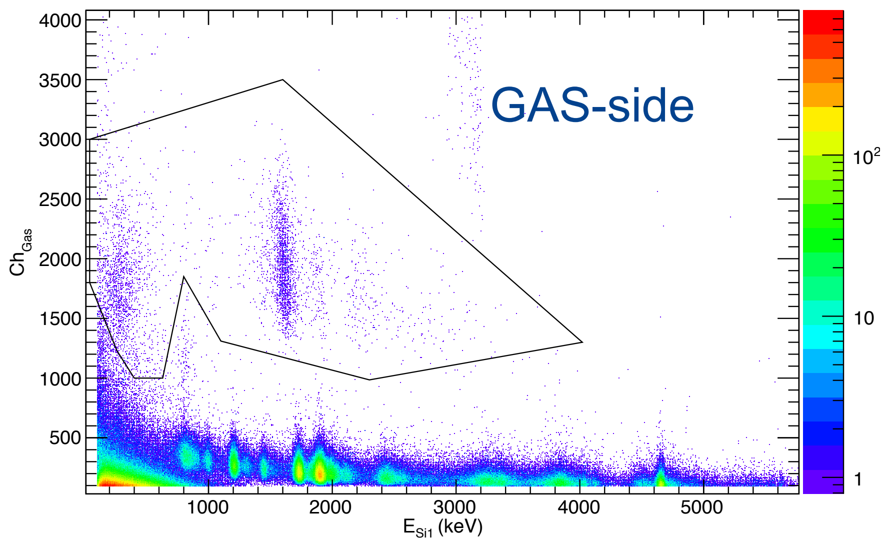
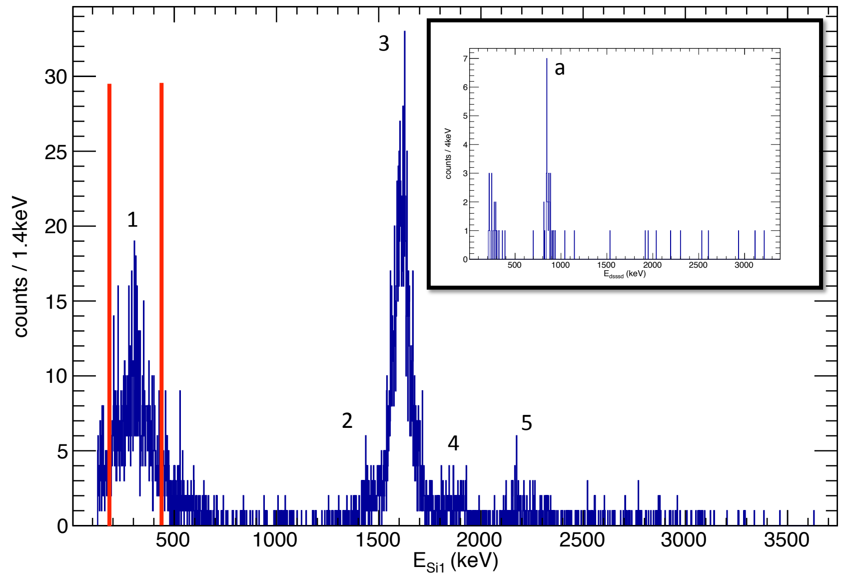
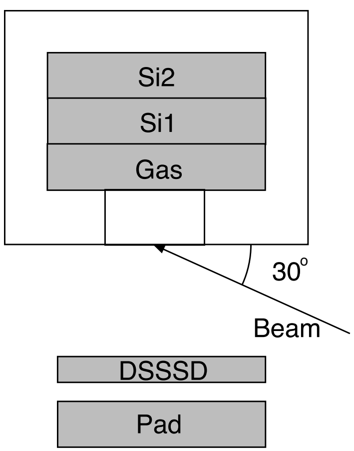
^{21}MG – ALPHA’S







<u>Decay modes observed:</u>

- 4 βα (nr. 2, 3, 4, and 5)
- 1 βpα (nr. 1)

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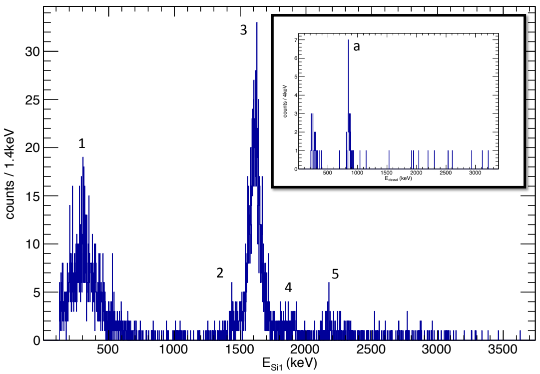
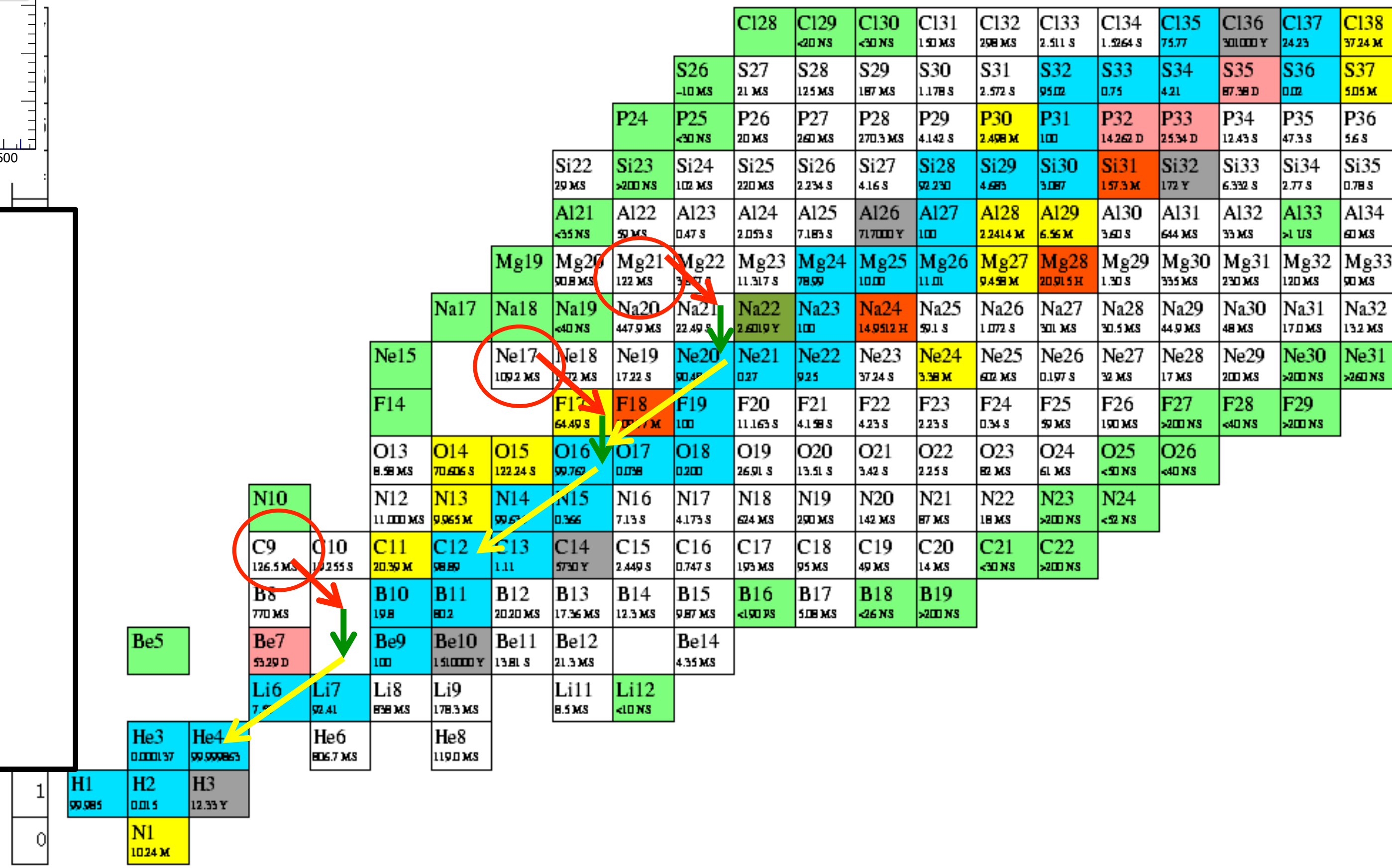
$$^{21}Mg \to \beta + {}^{21}Na \to p + {}^{20}Ne \to \alpha + {}^{16}O$$

^{21}MG – ALPHA SPECTRUM





βpα-decay mode:

- Only seen in ^{9}C and ^{17}Ne before

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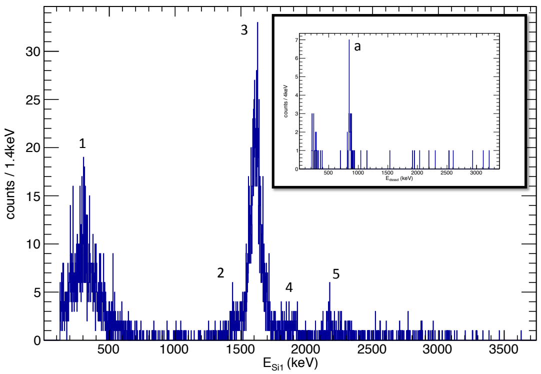
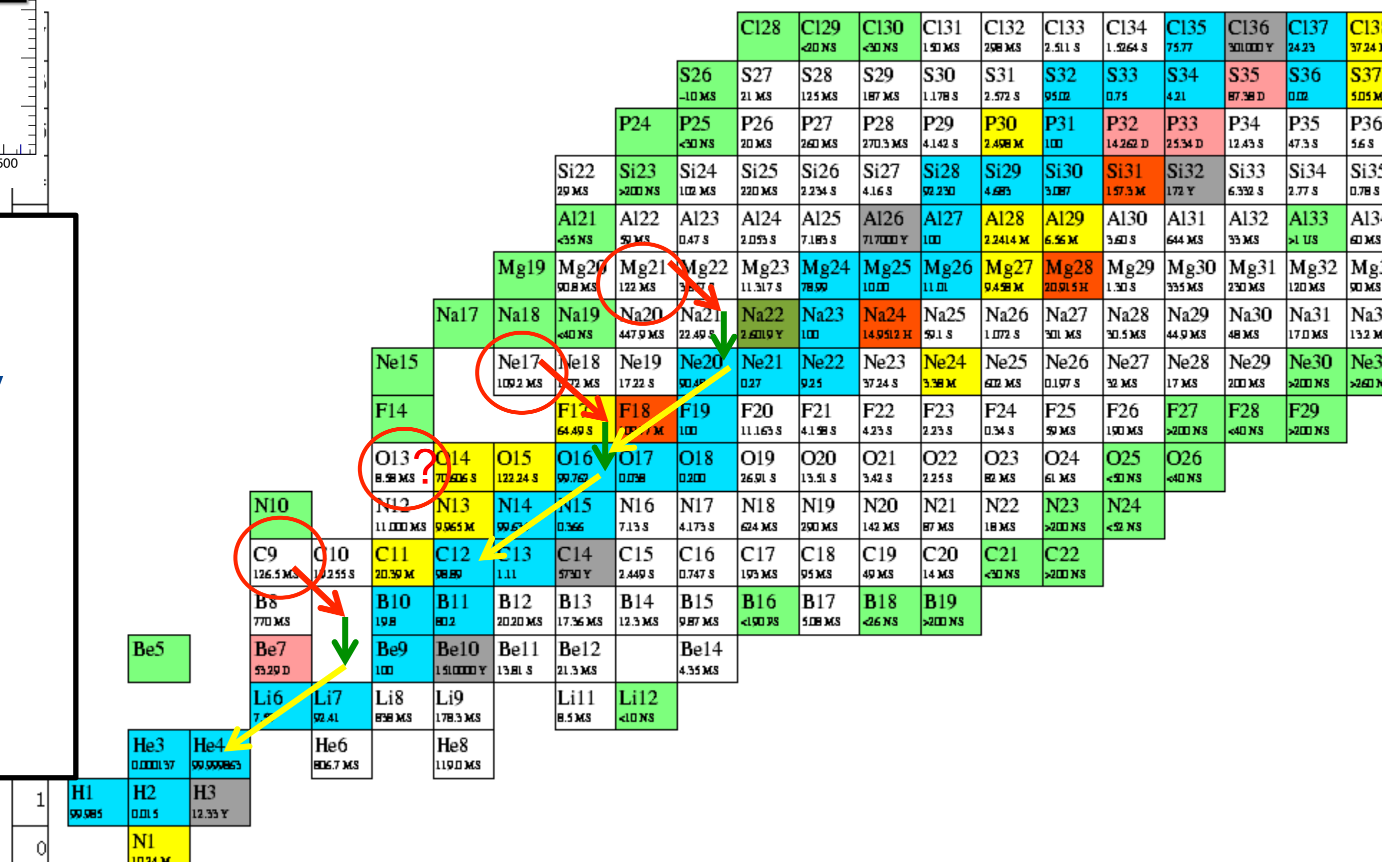


βpα-decay mode:

- Only seen in ^{9}C and ^{17}Ne before
- Known to be energetically possible in ^{13}O also – not observed in β-decay



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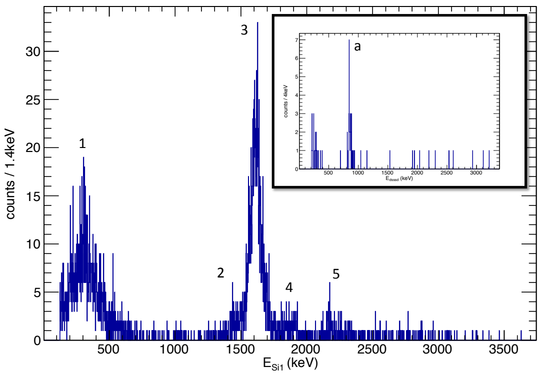
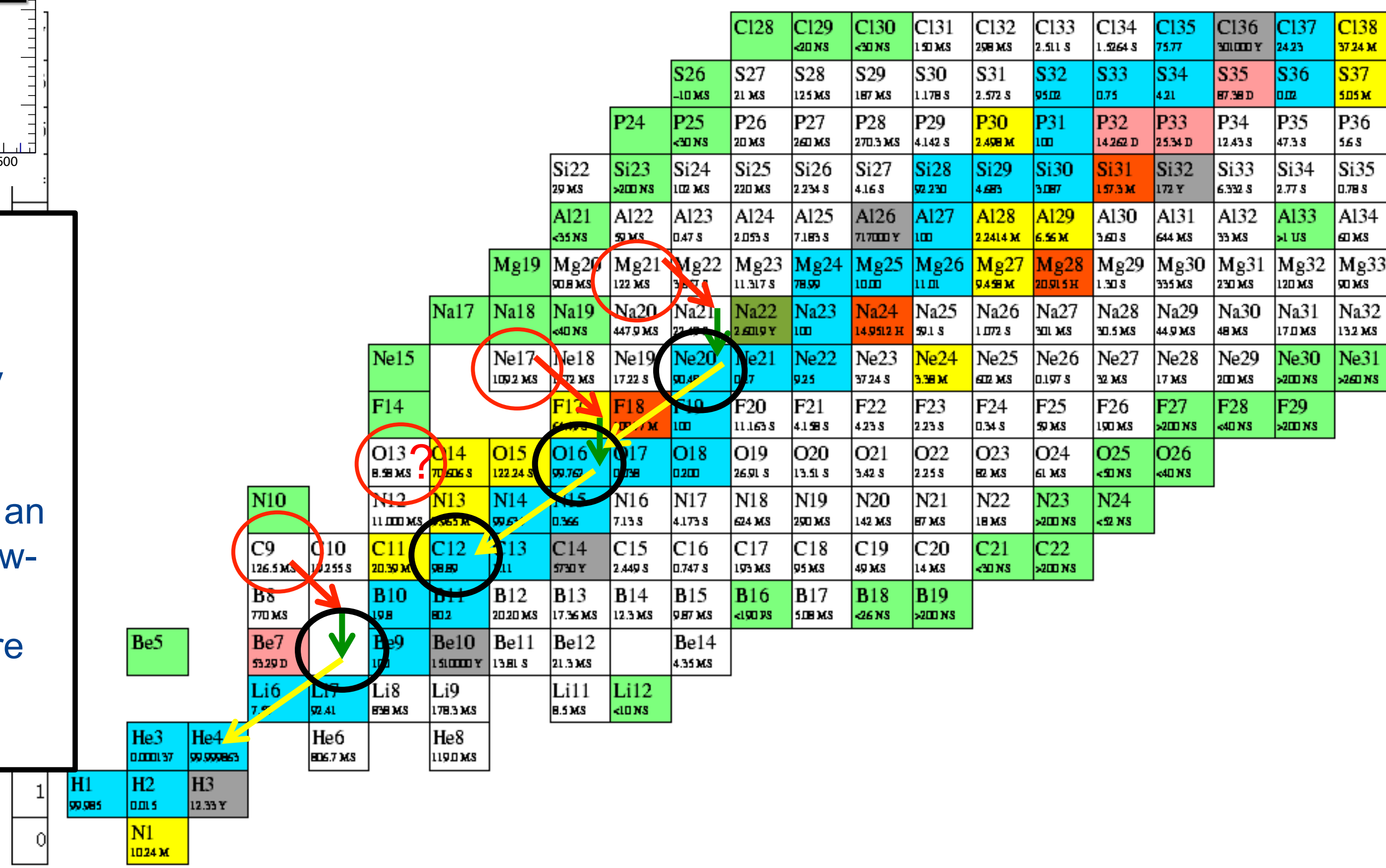
^{21}MG – ALPHA SPECTRUM



βpα-decay mode:

- Only seen in ^{9}C and ^{17}Ne before
- Known to be energetically possible in ^{13}O also – not observed in β-decay
- Systematics: βp-decay to an alpha-conjugate nuclei, low-mass
- Alpha-conjugates are more stable hence making S_p(i*alpha+p) and S_α low



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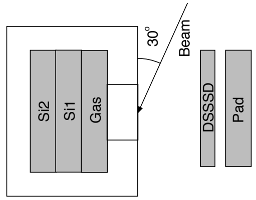

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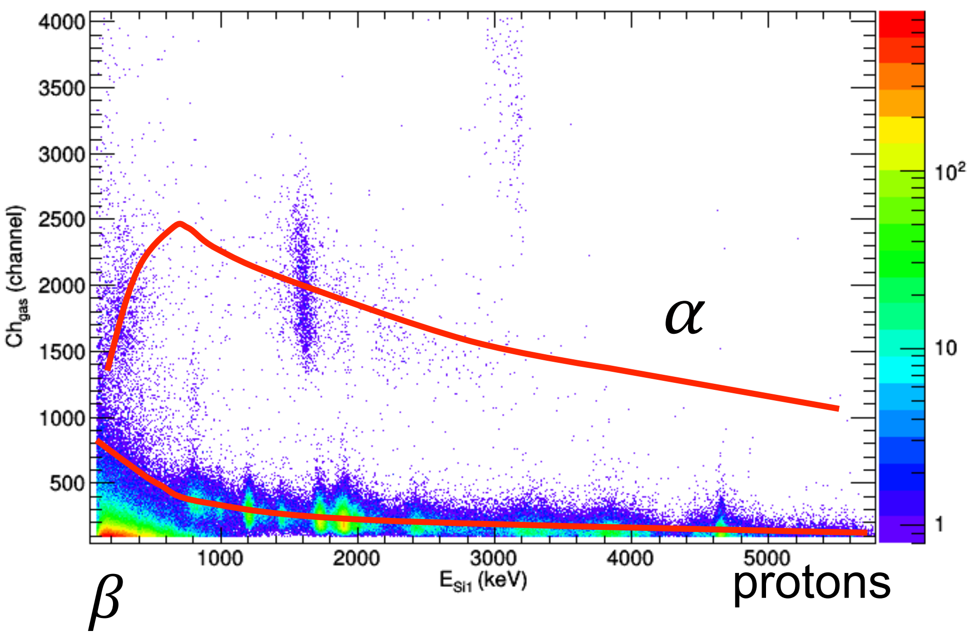
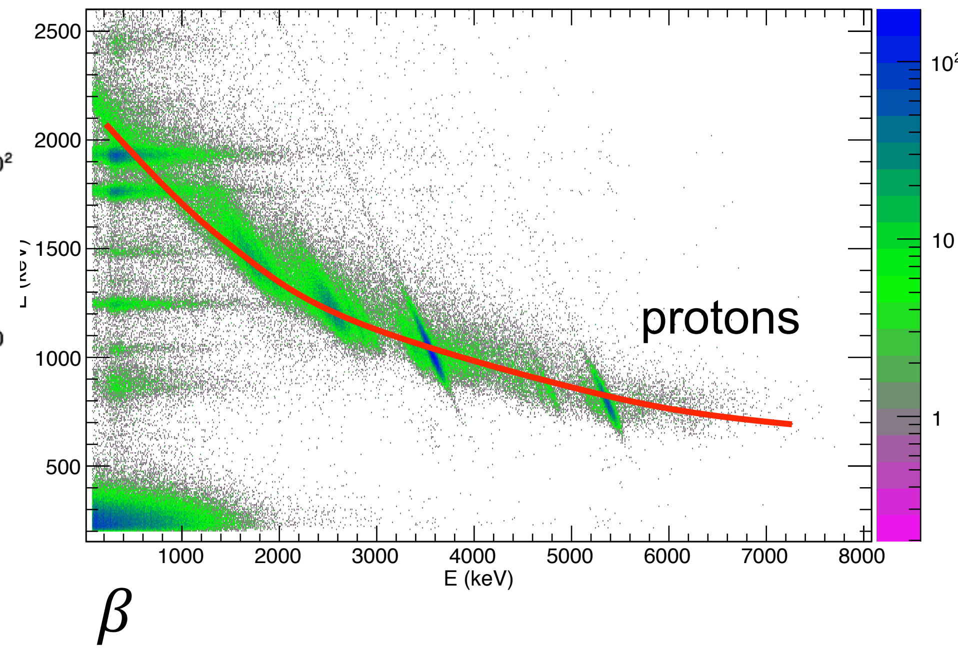
$$^{17}F + \alpha$$

^{21}MG – ΔE-E DATA

~ stopping power





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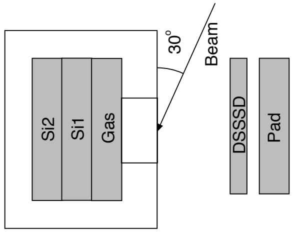

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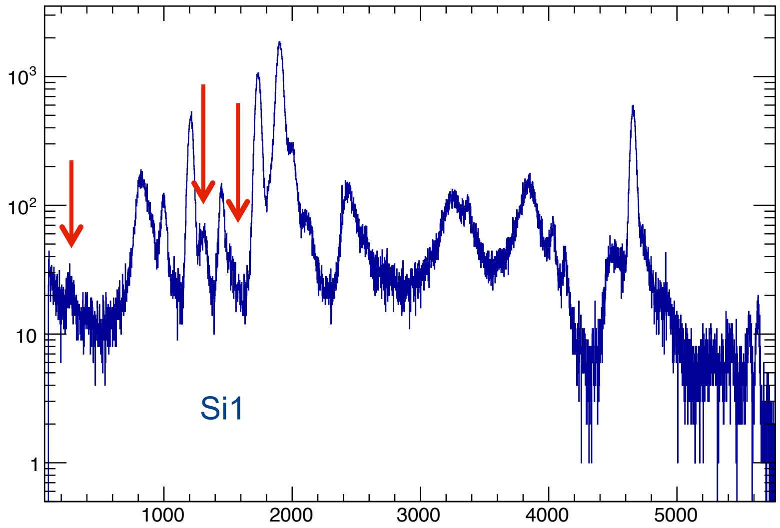
$$^{20}Ne + p$$

^{21}MG – PROTON SPECTRUM



Q_p = 394 (5) keV : ^{21}Na(4468) ➔ ^{20}Ne(1633) + p

Q_p = 1416 (6) keV : ^{21}Na(8827) ➔ ^{20}Ne(4968) + p

Q_p = 1626 (17) keV : ^{21}Na(8303) ➔ ^{20}Ne(4247) + p

$S_p(^{21}Na)$ = 2431keV

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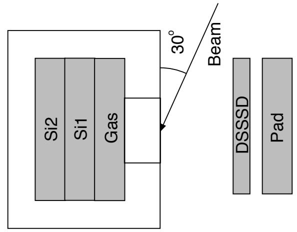

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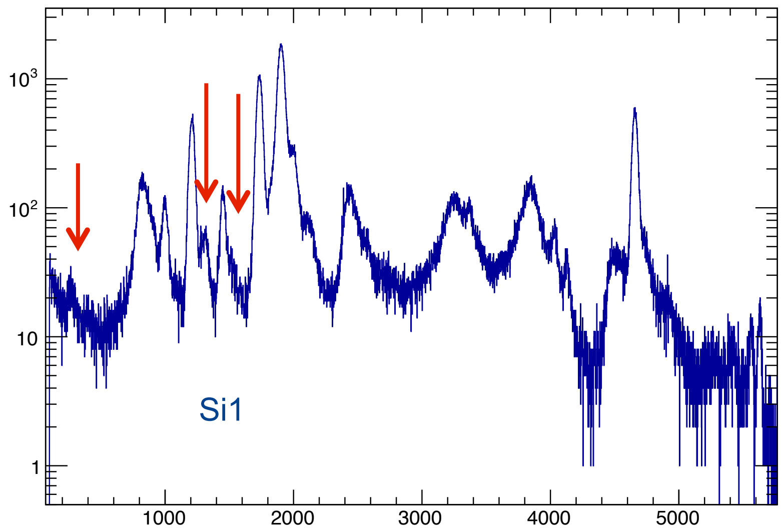

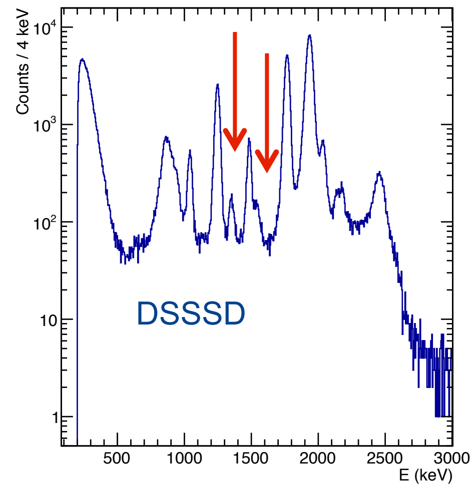

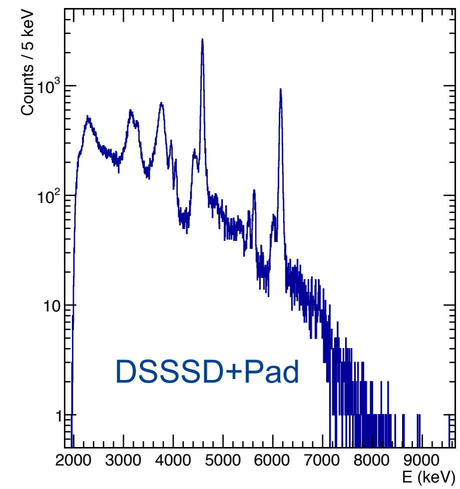

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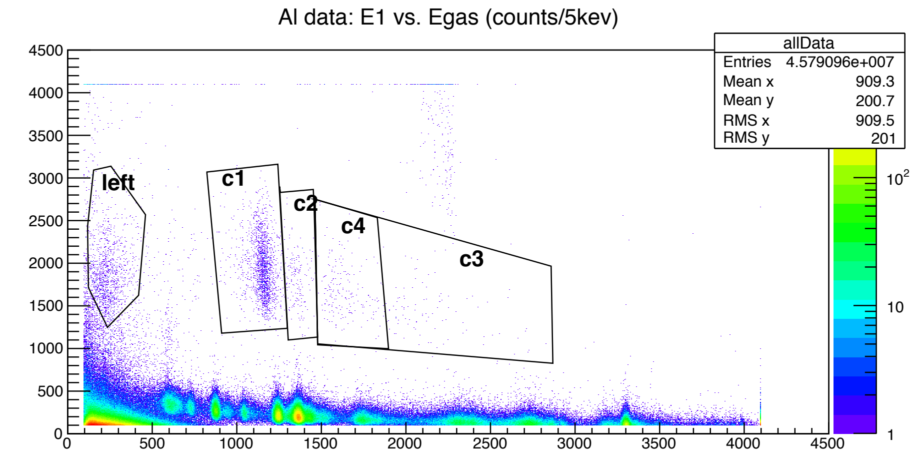
Courtesy of J. Halkjær

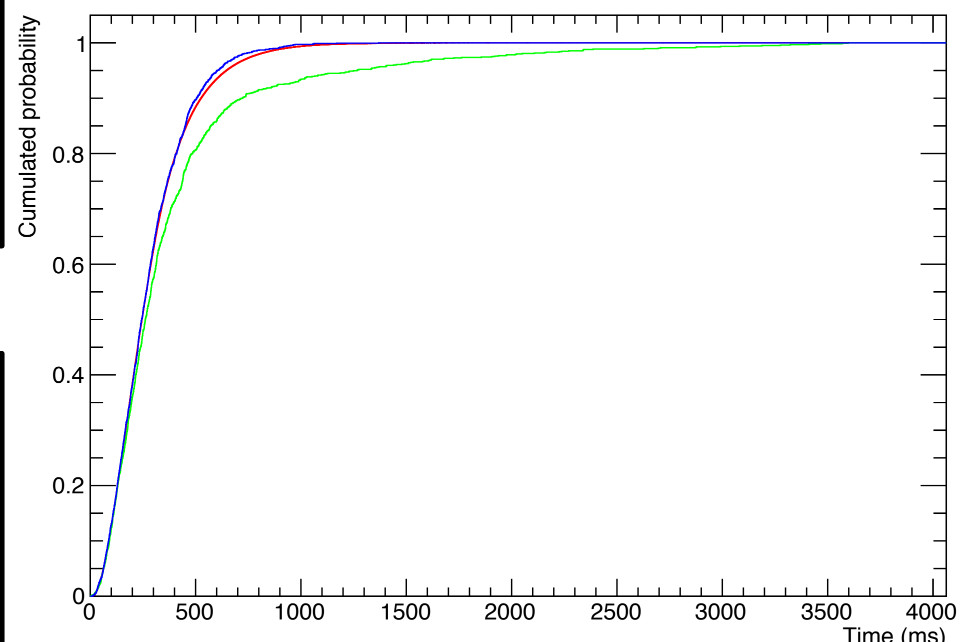
^{21}MG – TIME TEST

<u>Method:</u>

- Use 3 different statistical tests: Kolmogorov-Smirnov, Cramer-von Mises, and Anderson-Darling
- All quantify the vertical difference between the reference distribution and the distribution in question
- MC simulation to get confidence limits

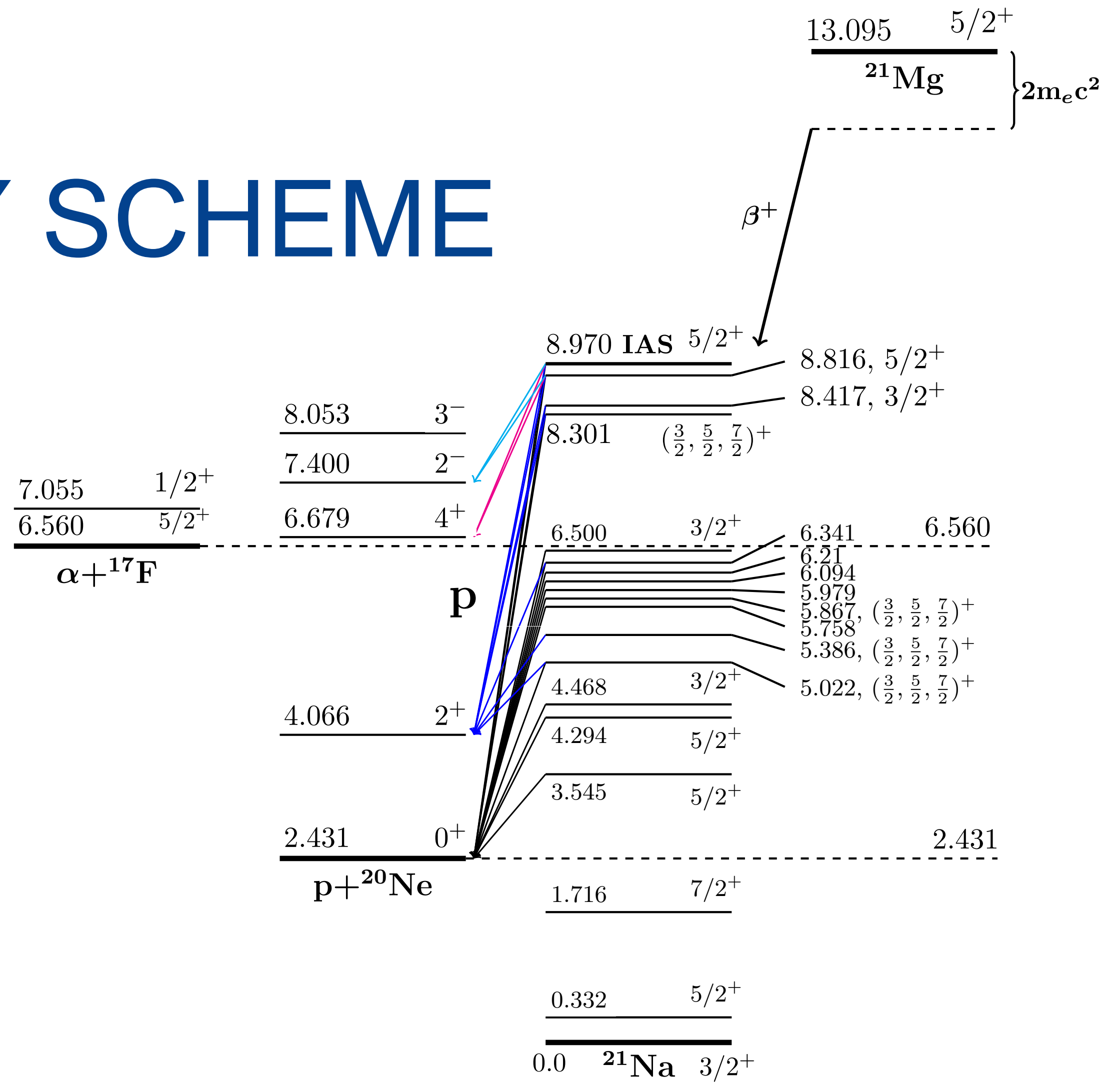


- Reference distribution from protons, excluding lowest energy
- Left region (1 of 3 tests positive to >5%, 2 of 3 <5%)
- Central region, c1, (positive all, >25% significance)



^{21}MG – DECAY SCHEME

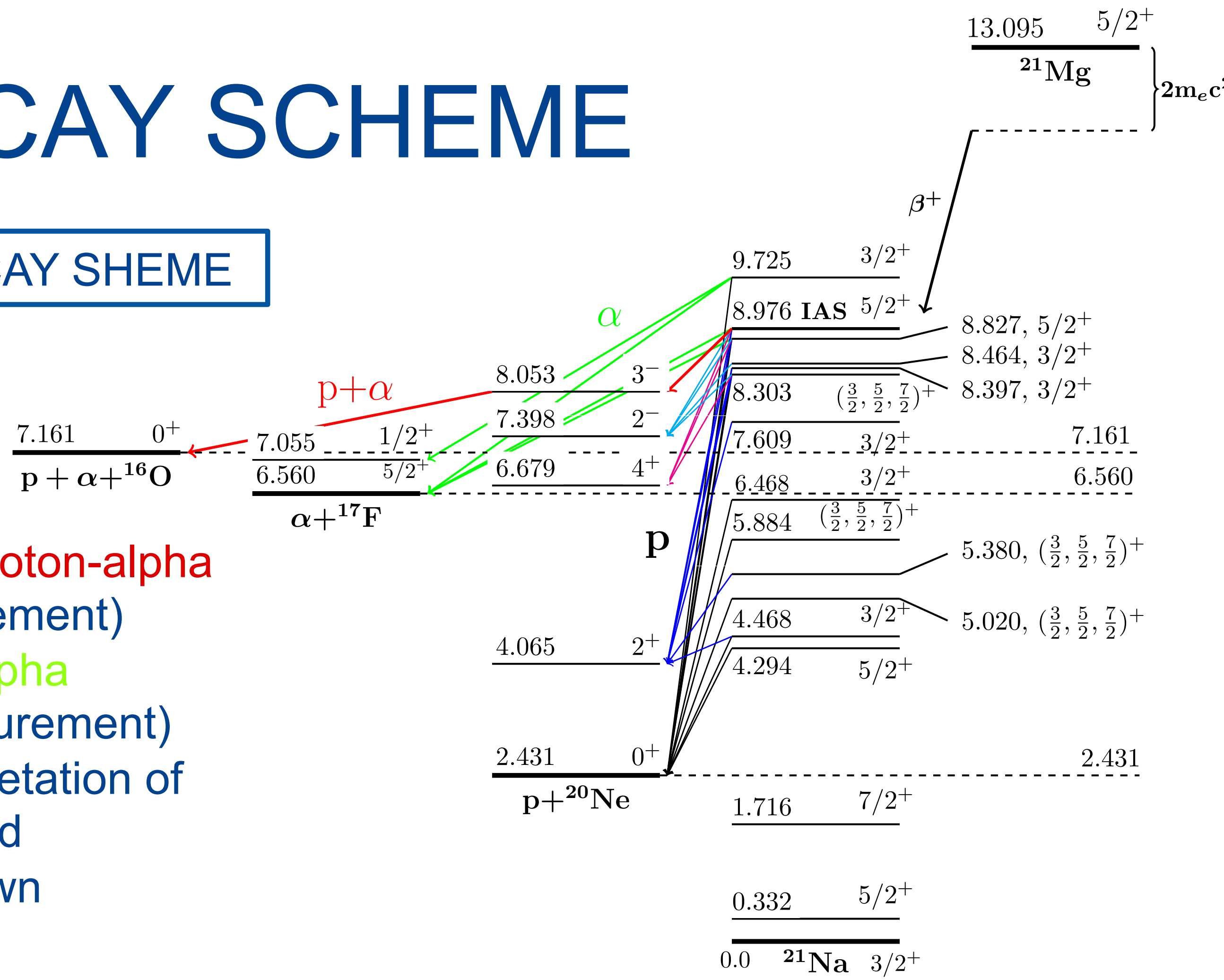
- Decay scheme mainly based on Sextro et al. from 1973 seem unlikely:
  - new ^{20}Ne(p,p) scattering experiments
  - Sextro et al. introduced new resonances not seen again
- New tentative interpretation based on:
  - new knowledge of resonance widths
  - new knowledge of J^P
  - energy considerations



^{21}MG - DECAY SCHEME

NEW TENTATIVE DECAY SHEME

- New beta-delayed proton-alpha branch (first measurement)
- New beta-delayed alpha branches (first measurement)
- New tentative interpretation of decay scheme – need gamma's to pin it down completely (future experiment@IDS)



Only showing beta fed resonances.

ON BEHALF OF THE IS507 COLLABORATION.

THANK YOU FOR YOUR ATTENTION!

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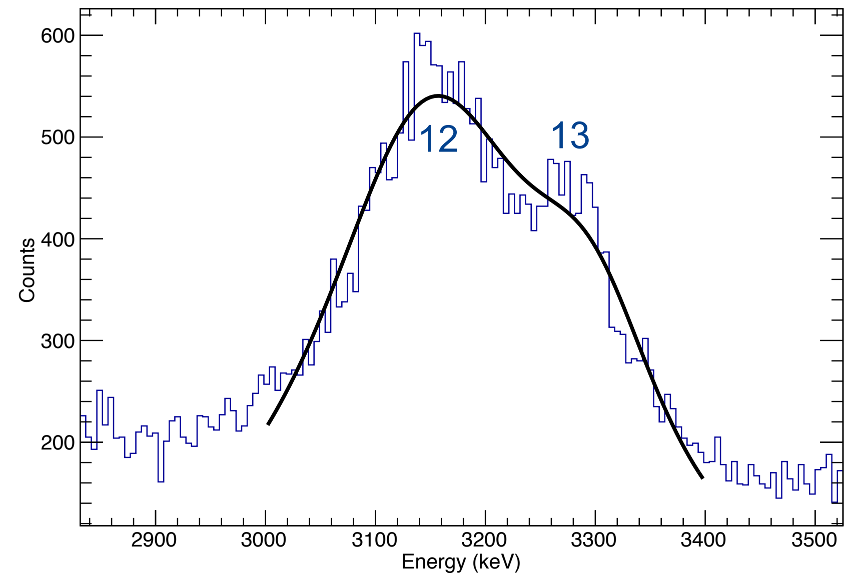
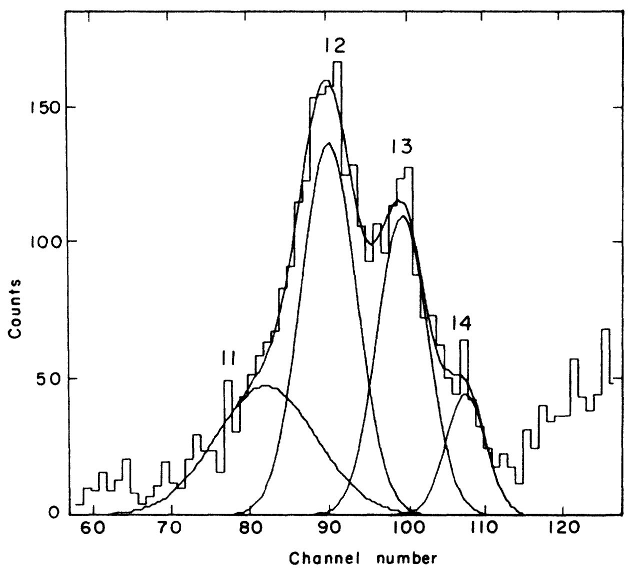
^{21}MG – DECAY SCHEME



Analysis levels:

- 0th order: Gaussian fit
- 1st order: detector response convoluted with a Breit-Wigner resonance lineshape
- 2nd order: includes also interference



Results:

- In general less proton branches are needed
- Levels only seen by Sextro et al. disappear
- The fitted B.W. widths in agreement with scattering results (when bigger than resolution)

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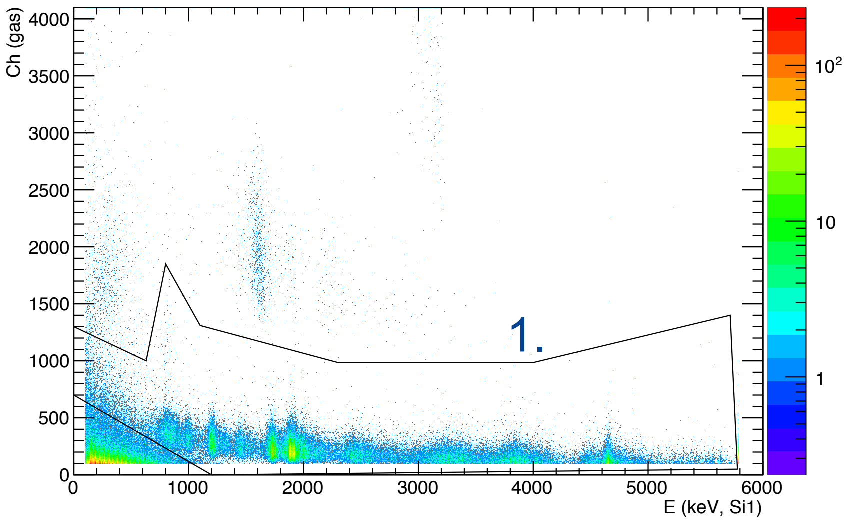
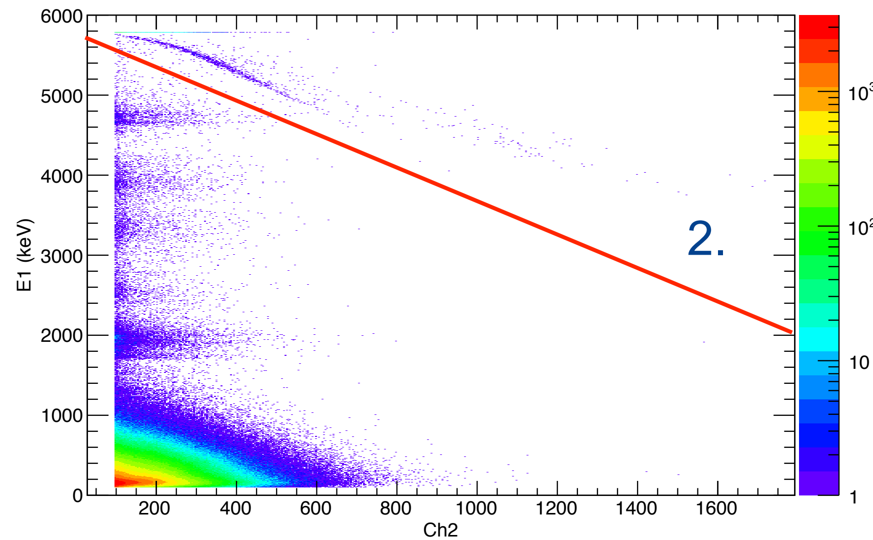
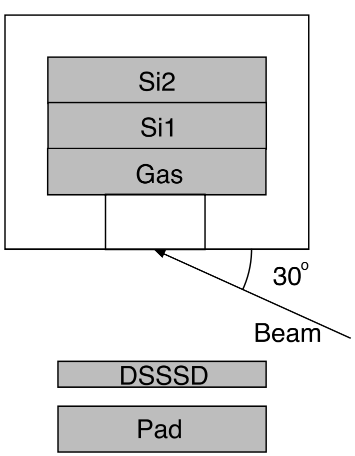
^{21}MG – PROTON SPECTRUM



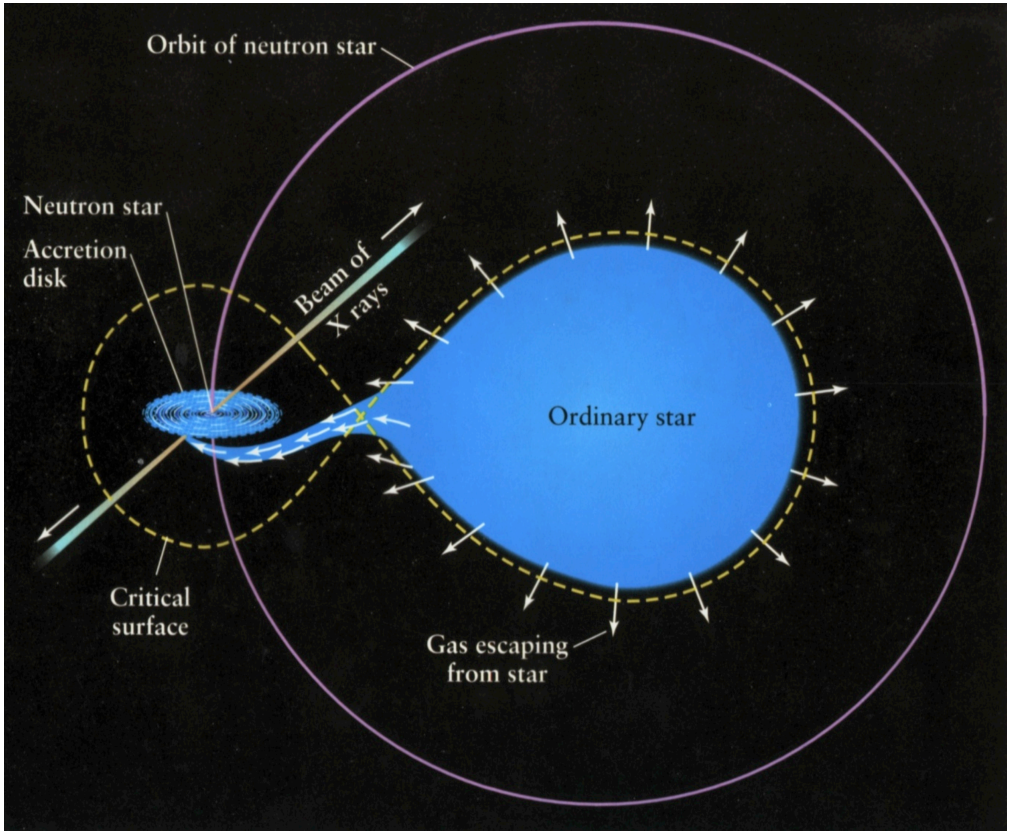




1. Remove alpha particles, beta's and recoils
2. Remove punch-through protons

TYPE 1 X-RAY BURST

- Binary star-system: neutron star + light pop. 2 star
- Transfer of material to the neutron star = X-ray emission due to high T
- Explosive H and He burning (HCNO and break-out to A>20)
- Burst time: seconds to minutes
- Time between bursts: hours to days



MOTIVATION II

- Break out sequence from the hot CNO cycle:

$$^{15}O(\alpha,\gamma)^{19}Ne(p,\gamma)^{20}Na$$

- Determination of Jπ for 2.645(6) MeV resonance: 1^+ or 3^+?
- Fed in beta decay of ^{20}Mg: allowed or second-forbidden?