quasi-monochromatic γ-ray beams in nuclear astrophysics

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Quasi-monochromatic and polarized γ-ray beams

- **excellent tool** for indirect approaches:
  - γ-ray strength functions for heavy nuclei
  - parities of particular states
  - ground state radiation widths $\Gamma_{\gamma,0}$
- **limited** for total (X,γ) capture cross sections and resonance strengths from reverse (γ,X) reactions:
  - capture: proportional to $\sum_i$ (X,γ_i)
  - photodisintegration: proportional to $\sum_j$ (γ_0,X_j)

  knowledge of γ-ray branchings from other sources!
- **very limited** for stellar rates of (γ,X) reactions:
  - laboratory: target is in ground state
  - stellar: thermal equilibrium, excited states dominate!

(X,γ) from reverse (γ,X) ?

- dominating ground state branching:
  - $^{12}C(\alpha,\gamma)^{16}O$: the „Holy Grail“ of nuclear astrophysics (N.B.: no success at HIγS)
  - $^{2}H(\alpha,\gamma)^{6}Li$: big-bang nucleosynthesis
  - triple-alpha: 2^{+} contribution at high temperatures (also interesting: 2-body vs. 3-body break-up)
  - almost no (p,γ) or (n,γ) for stable (γ,X) targets

- ground state branching known from elsewhere:
  - many further candidates for experiments
  - $^{3}H(\alpha,\gamma)^{7}Li$ („first-day experiment“ at ELI-NP)
  - but do we really need the (γ,X) data in these cases?

Some candidates (from ELI-NP presentations)

- $^{24}Mg(\gamma,\alpha)^{20}Ne$:
  Direct data (Schmalbrock/Koelle) show that most of the resonances in $^{20}Ne(\alpha,\gamma)^{24}Mg$ decay via the first 2^+ in ^{24}Mg
  0^+ states are not accessible in (γ,α)
  - what can we learn from (γ,α) data?

- $^{22}Ne(\gamma,\alpha)^{18}O$:
  Low-lying (α,γ) resonances have been measured by $\gamma\gamma$-coincidences; the direct ground state branching is small (Dababneh). The lowest resonance has most likely $J^\pi = 0^+$ (Mohr).
  - what can we learn from (γ,α) data?

Some candidates (from ELI-NP presentations)

- $^{21}Ne(\gamma,\alpha)^{17}O$:
  Direct data show that the lowest observed resonance in (α,γ) has no ground state branching (Best)
  \- what can we learn from (γ,α) data?

- $^{19}F(\gamma,p)^{18}O$, $^{19}F(\gamma,\alpha)^{15}N$:
  ^{19}F has low-lying states at 110 and 197 keV. Only very few resonances have strong ground state branches (Wilmes).
  \- what can we learn from (γ,α) data?

Some candidates (from ELI-NP presentations)

- (γ,α) or (γ,p) for A ≈ 75-100 for p-process:
  In this mass region total (α,γ) capture cross sections have been measured from the yield of the $2^+ \to 0^+$(gs) transition in the residual nucleus. The measured (γ,α) or (γ,p) cross section can be used to constrain the γ-ray strength function, but will be only a very minor part of the total (α,γ) or (p,γ) cross section.
  - what can we learn from (γ,α) or (γ,p) data?

Thank you very much for your attention!