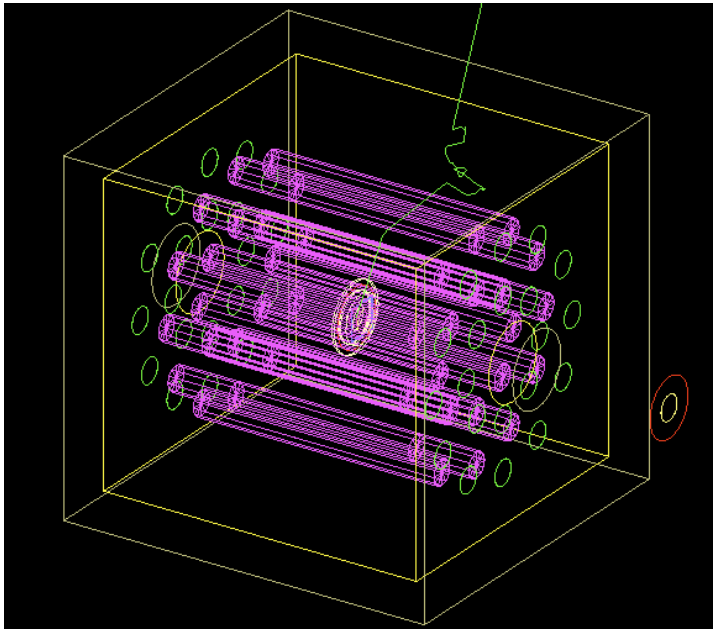
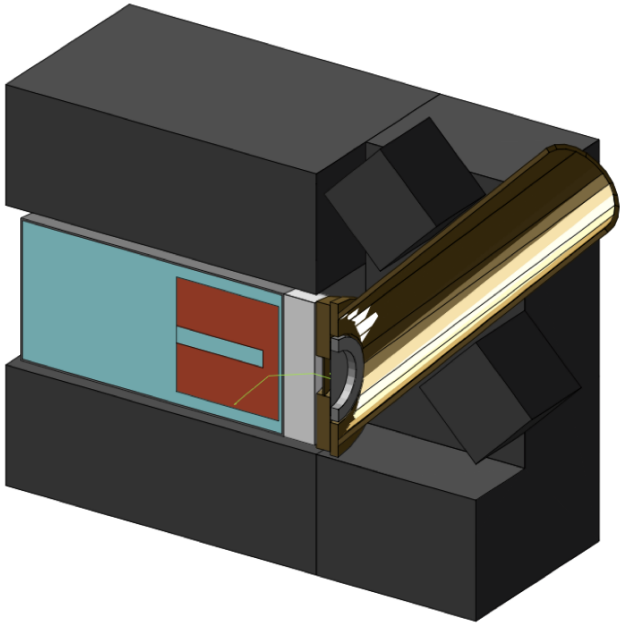
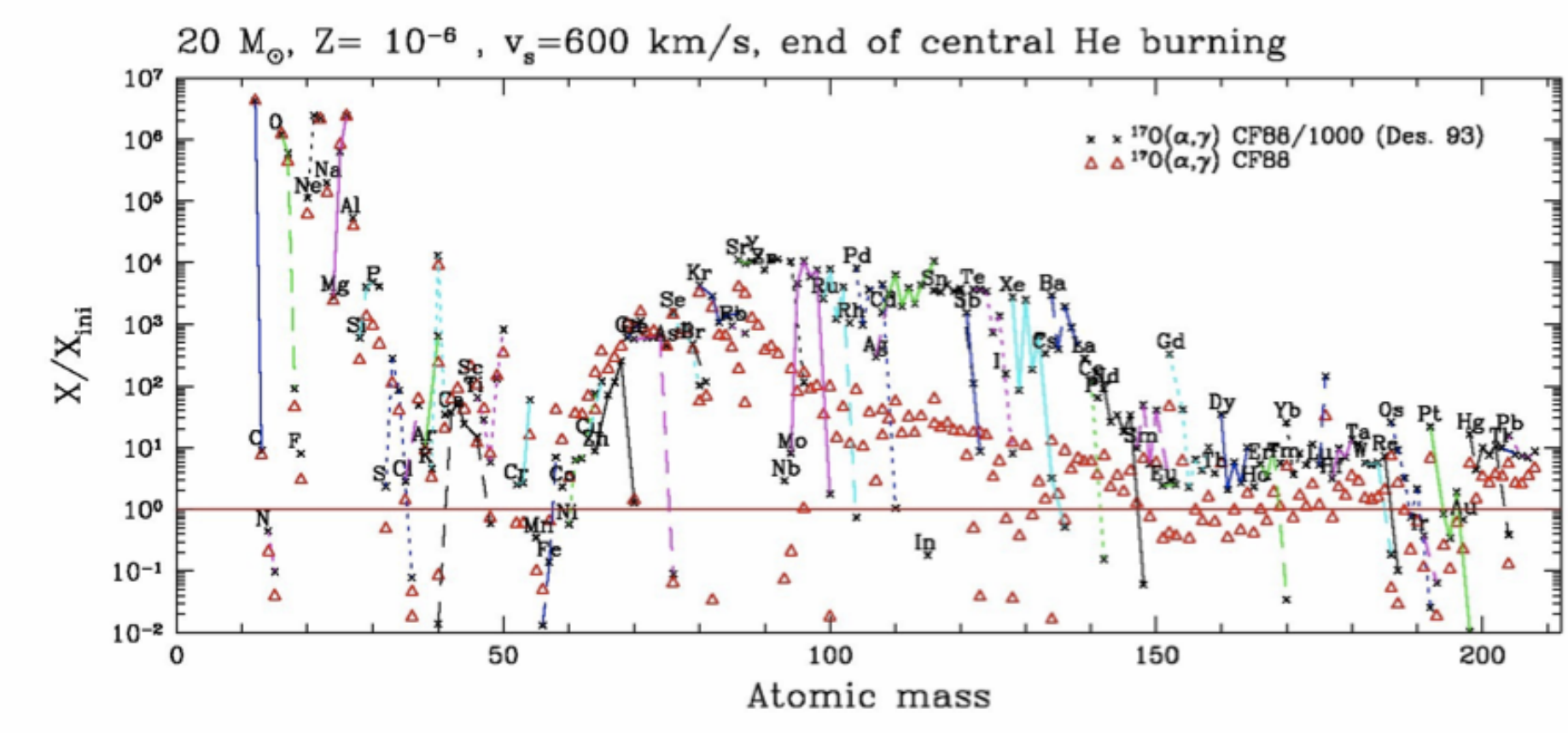
Determination of the stellar reaction rates of $^{17}O(\alpha, n)^{20}Ne$ and $^{17}O(\alpha, \gamma)^{21}Ne$





Andreas Best

Is ^{16}O a neutron poison (in the weak s process)?



Pignatari et al.

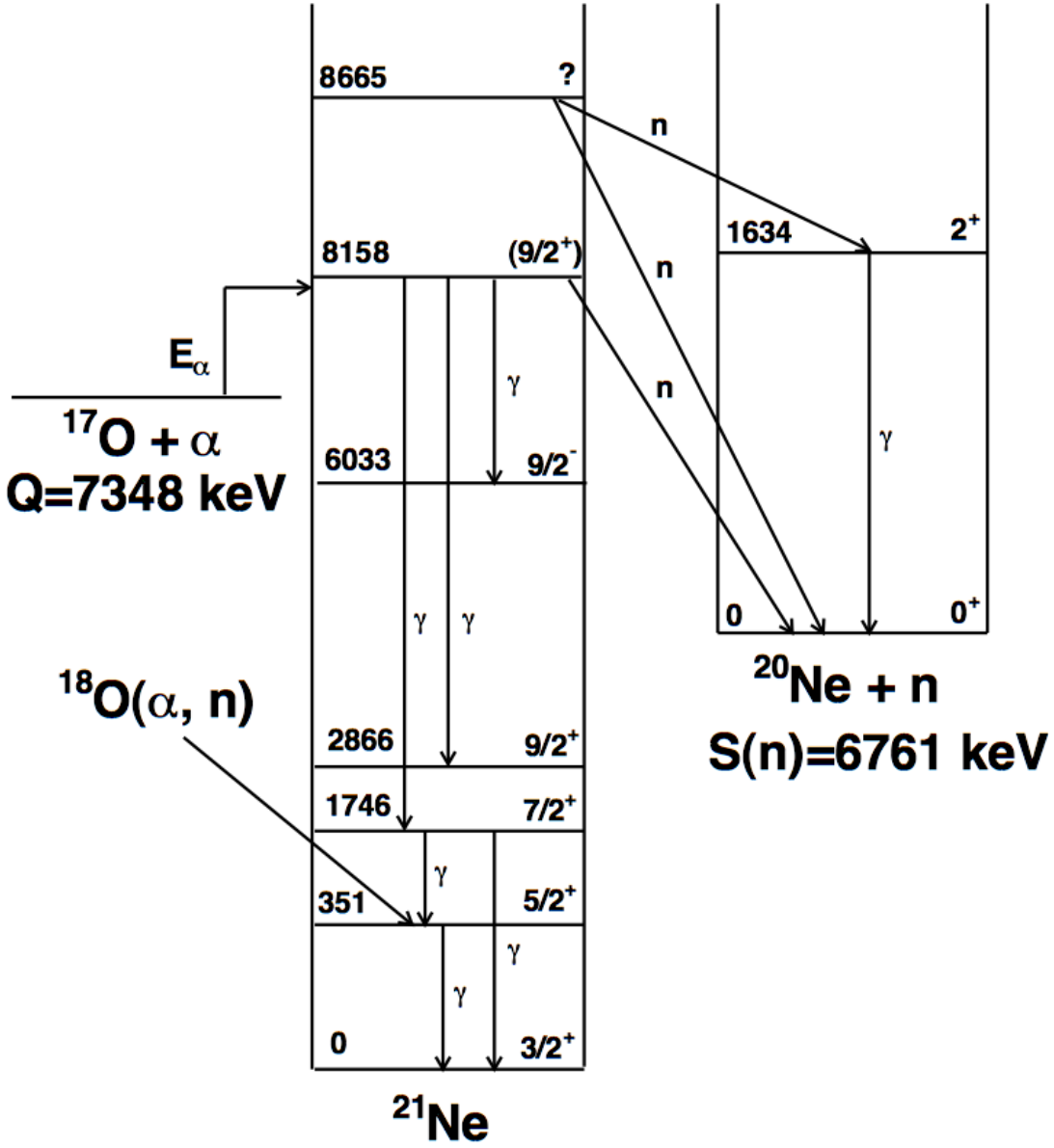
- Unknown ratio of reaction rates $\frac{^{17}O(\alpha,n)^{20}Ne}{^{17}O(\alpha,\gamma)^{21}Ne}$
- Theoretical calculation gets a 3 orders of magnitude smaller ratio
- Large effect on final abundances

Current situation

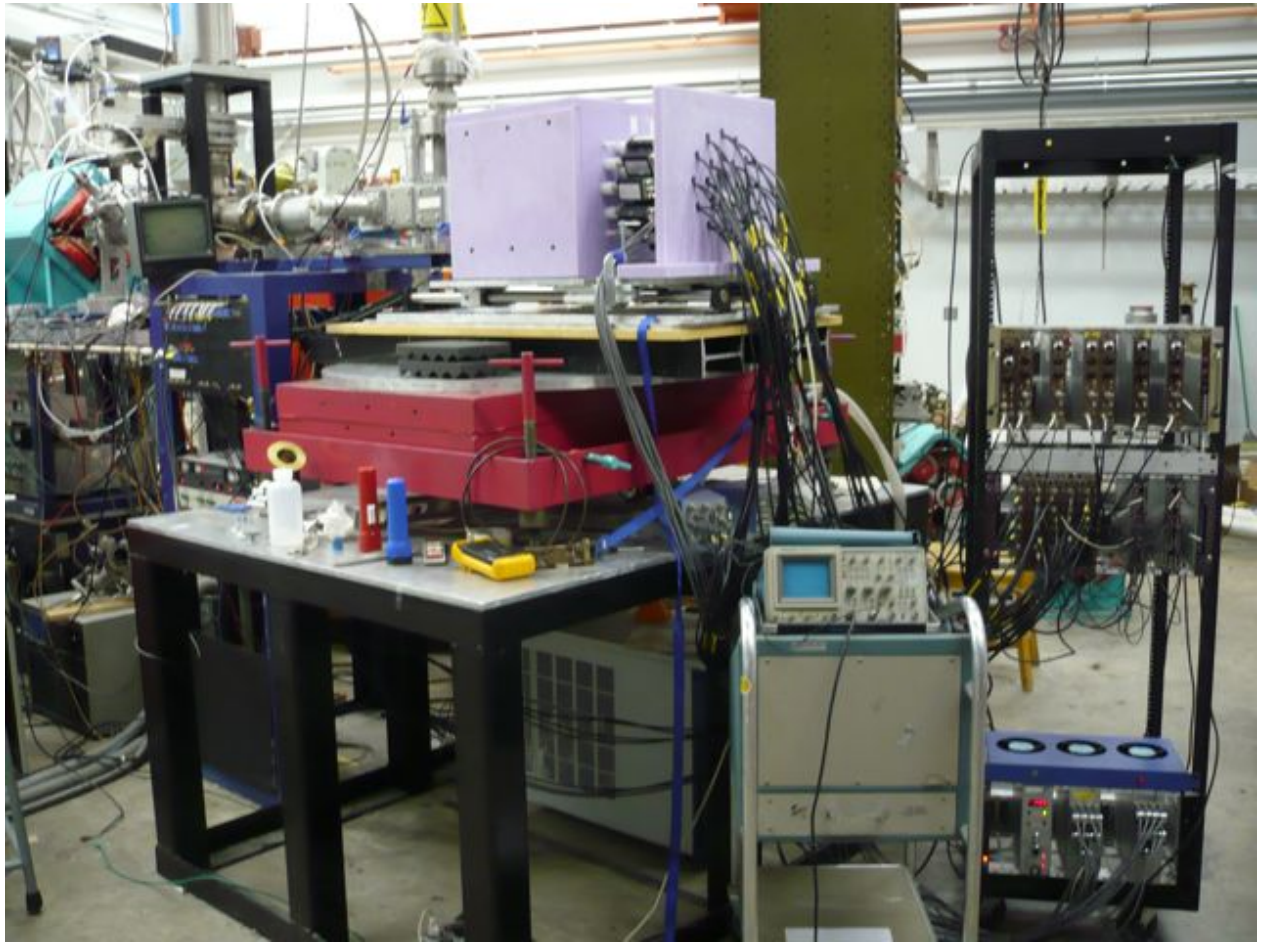
- No experimental data on $^{17}O(\alpha,\gamma)$
- Previous (α, n) experiment analized some dubious resonances
- Target 50% ^{17}O, 29% ^{18}O
- Unknown $^{17}O(\alpha, n_1)$ channel $\Rightarrow$ uncertain efficiency

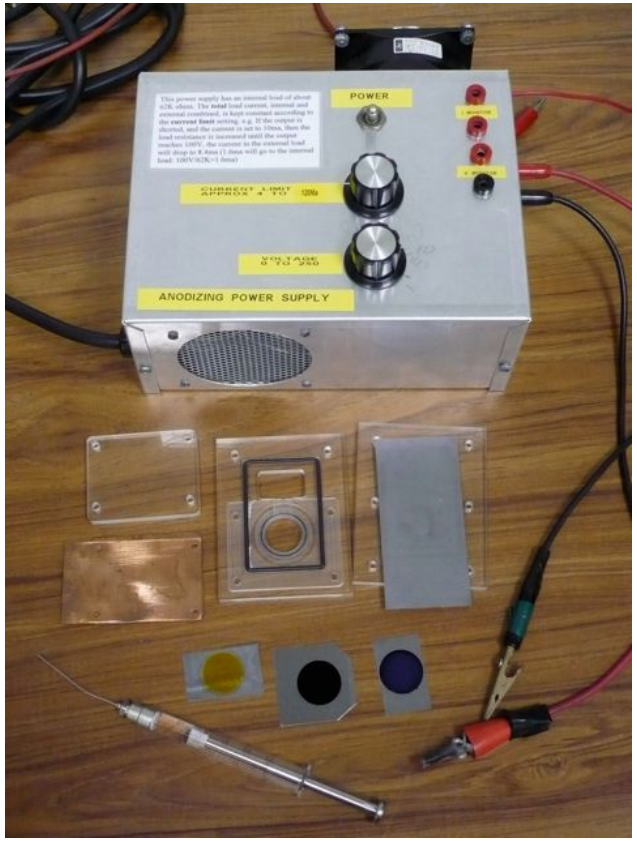
Our experiments

- Remeasured $^{17}O(\alpha, n)^{20}Ne$
  - High efficiency PE moderated ^{3}He detector
  - Detailed GEANT4 simulation and efficiency measurements
  - Used highly enriched ^{17}O ($> 90\%$) for target production
  - $Q = 587\,\mathrm{keV}$, two neutron groups for $E_\alpha > 1293\,\mathrm{keV}$
  - Determined $^{17}O(\alpha, n_1)$ branching $\Rightarrow$ neutron energy $\Rightarrow$ efficiency
- Measured $^{17}O(\alpha, \gamma)^{21}Ne$
  - Scan with lead shielded HPGe detector
  - 1st excited state in ^{21}Ne populated by $^{18}O(\alpha, n_1)^{21}Ne$ as well: measured with enriched ^{18}O


8665
?
n
8158
(9/2+)
n
n
Eα
17O + α
Q=7348 keV
γ
6033
9/2-
γ
γ
18O(α, n)
2866
9/2+
1746
7/2+
γ
351
5/2+
γ
γ
0
3/2+
21Ne
1634
2+
γ
0
0+
20Ne + n
S(n)=6761 keV

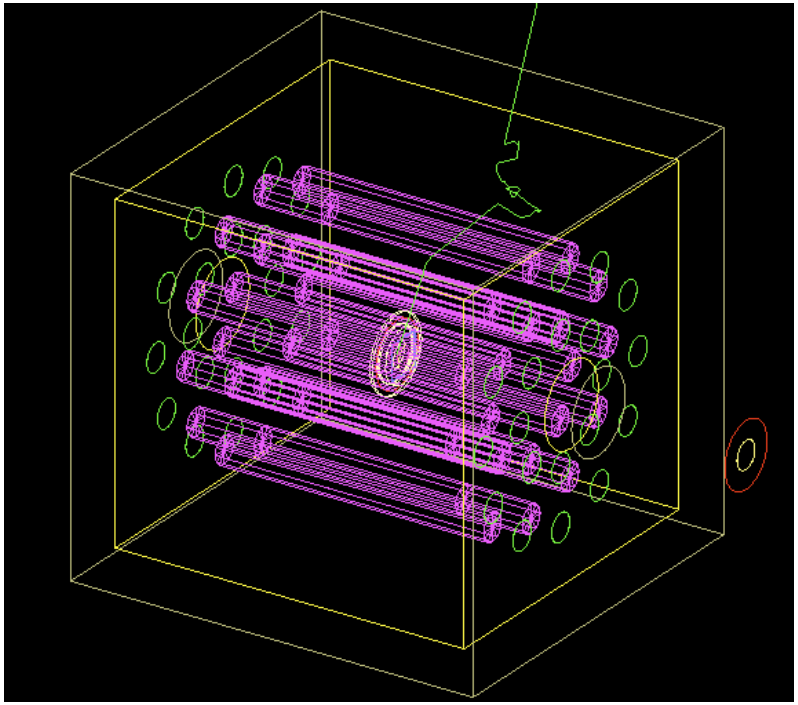
$^{17}O(\alpha, n)$ setup

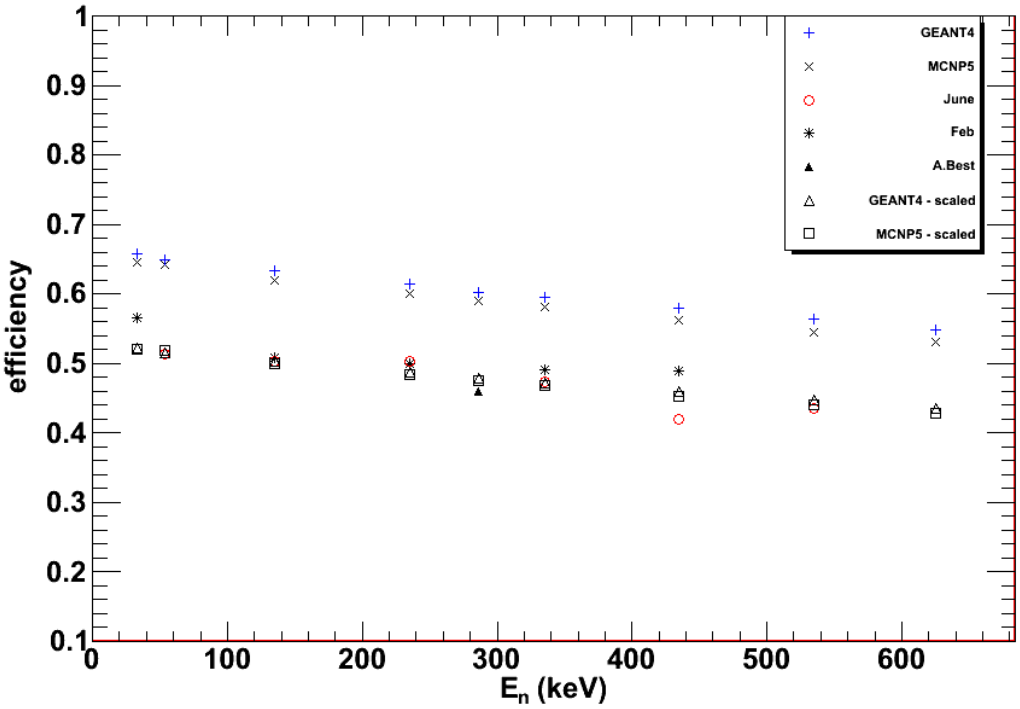




- Polyethylene moderated, 20 ^{3}He counters in two rings (8 + 12)
- Anodized Ta_2O_5 targets using 90.1% enriched ^{17}O water

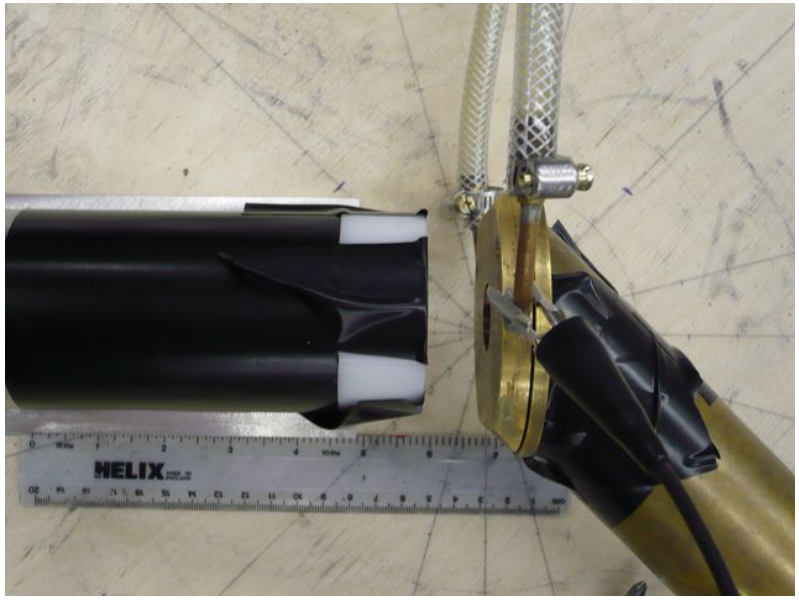
Neutron detector efficiency determination

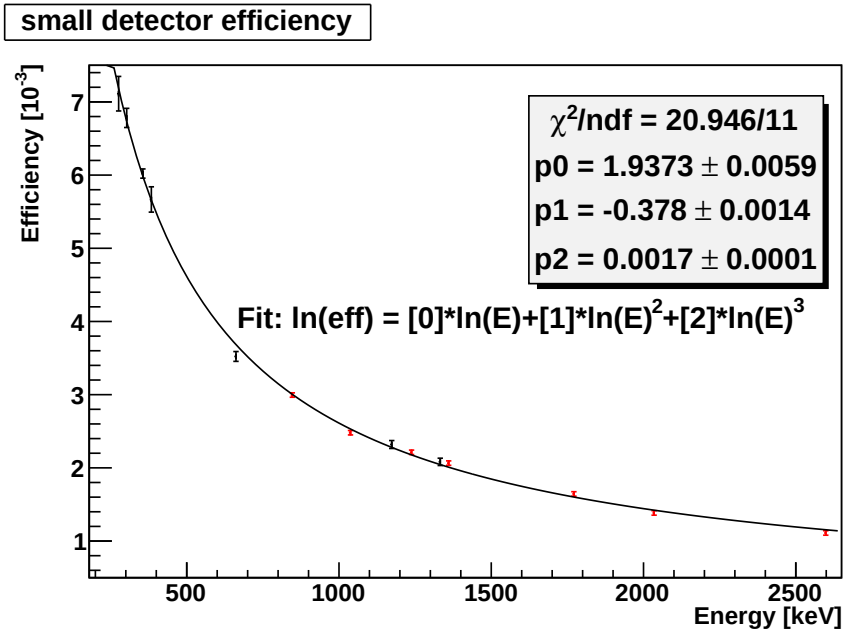




- Efficiency simulations with GEANT4 and MCNP
- Measurements between 50 keV and 600 keV via ^{51}V(p,n)
- Limited information about neutron energy using inner/outer ring

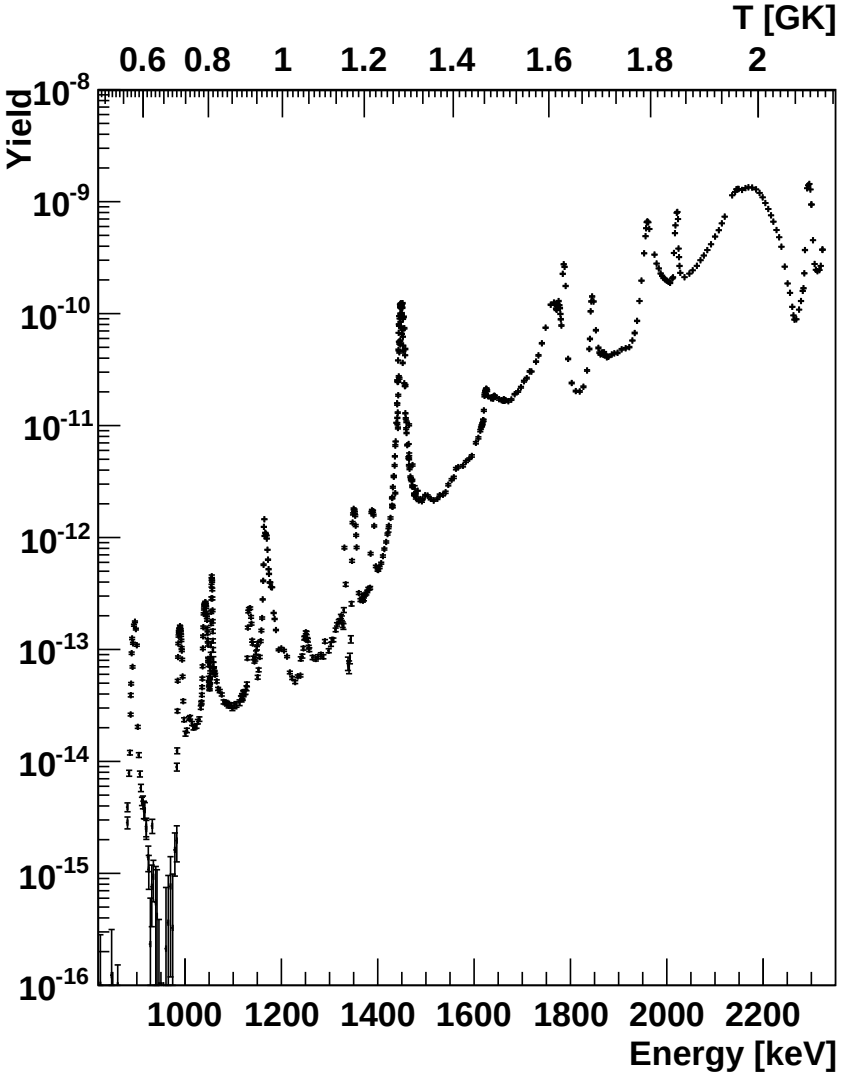
$^{17}O(\alpha, n_1)^{20}Ne$ setup

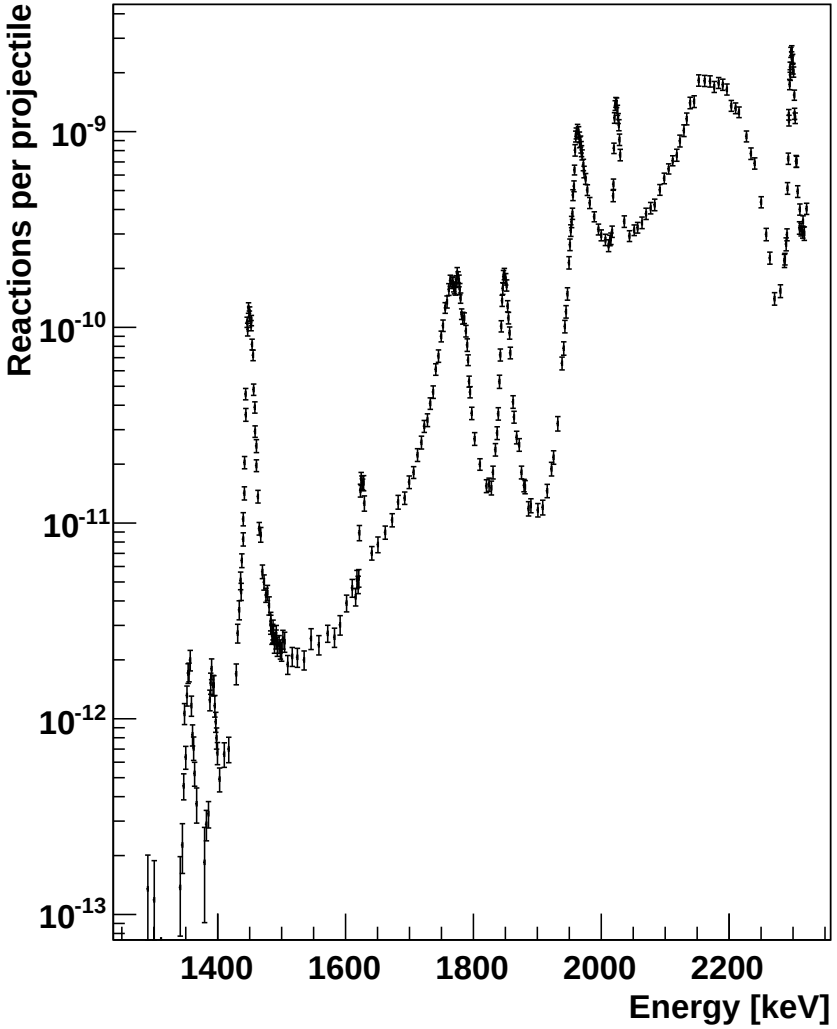




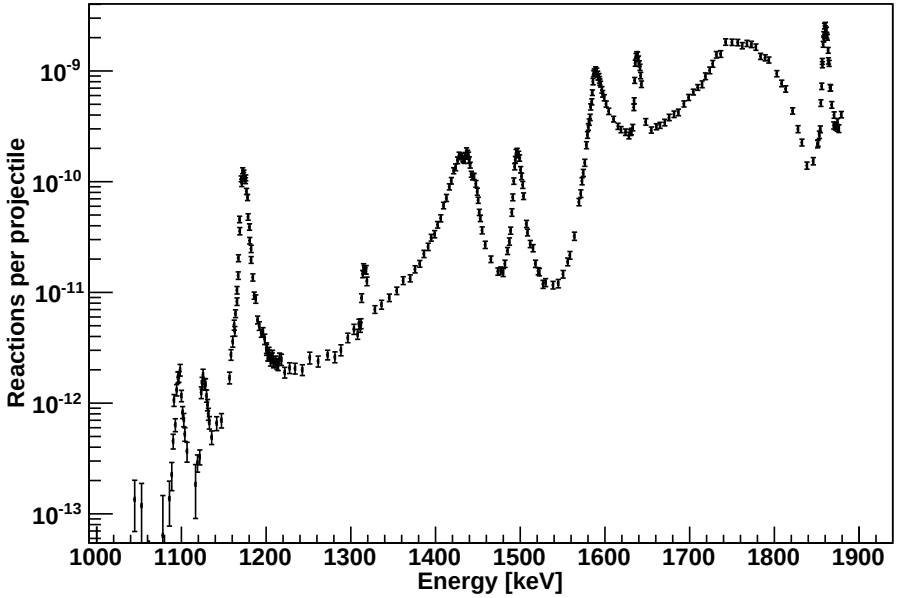
- Ta_2O_5 target at 45 deg, $\approx$ 20% efficiency HPGe detector
- Polyethylene disk in front of detector to scatter neutrons
- Looking for 1634 keV transition in Ne^{20}

(α, n) and (α, n_1) yield



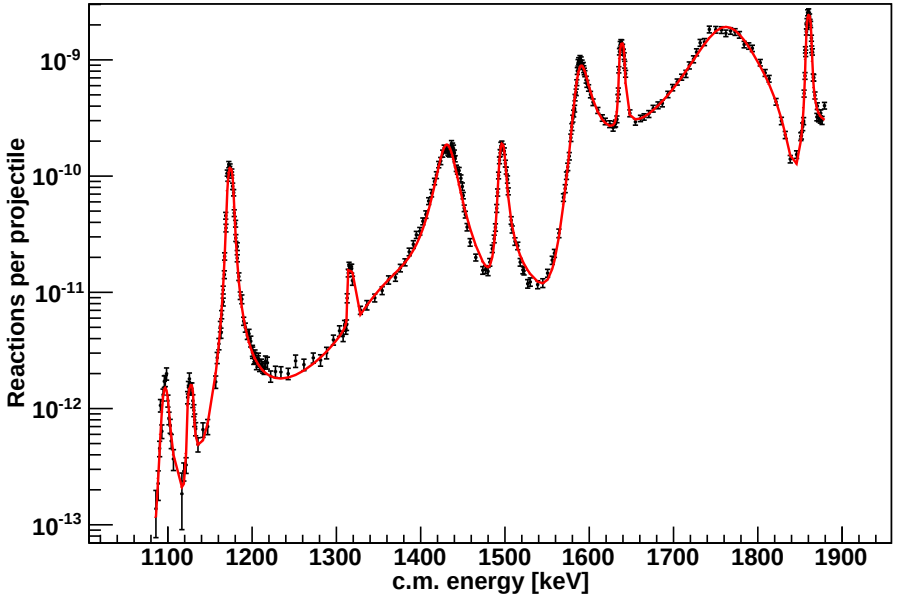


Azure



- Multi-channel R-Matrix code
- Fortran version released to public last year
- Translated into C++ by Ethan
- Implemented target integration routine

Azure



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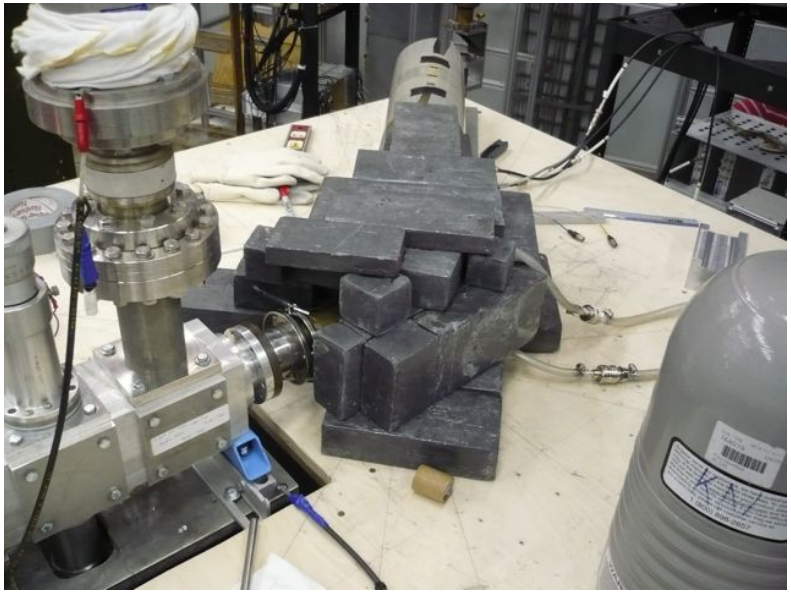
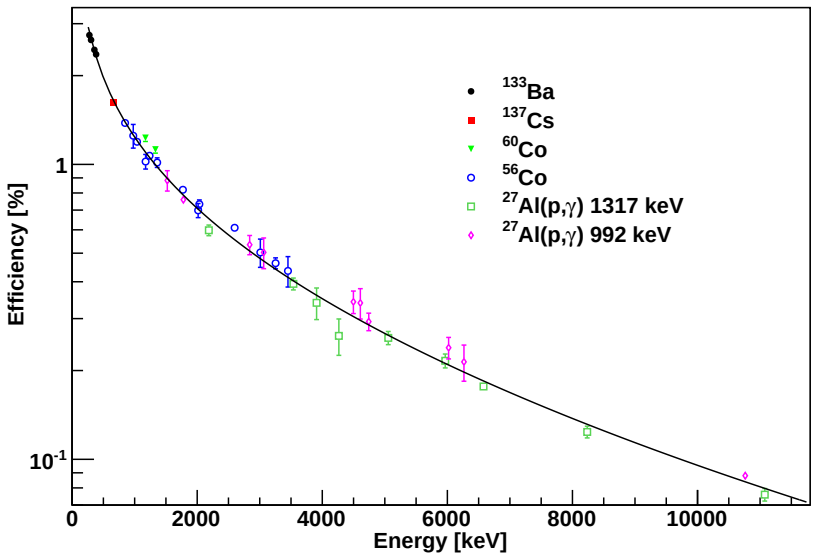
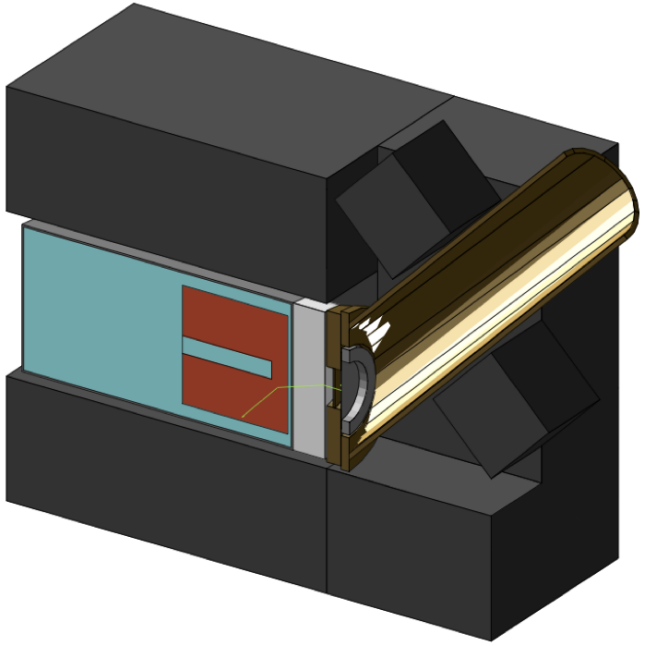
$^{17}O(\alpha,\gamma)^{21}Ne$ setup



- Prominent transition at 351 keV (^{238}U line there)
- Contribution from $^{18}O(\alpha, n_1)^{21}Ne$
- Lead castle, larger (≈55%) HPGe

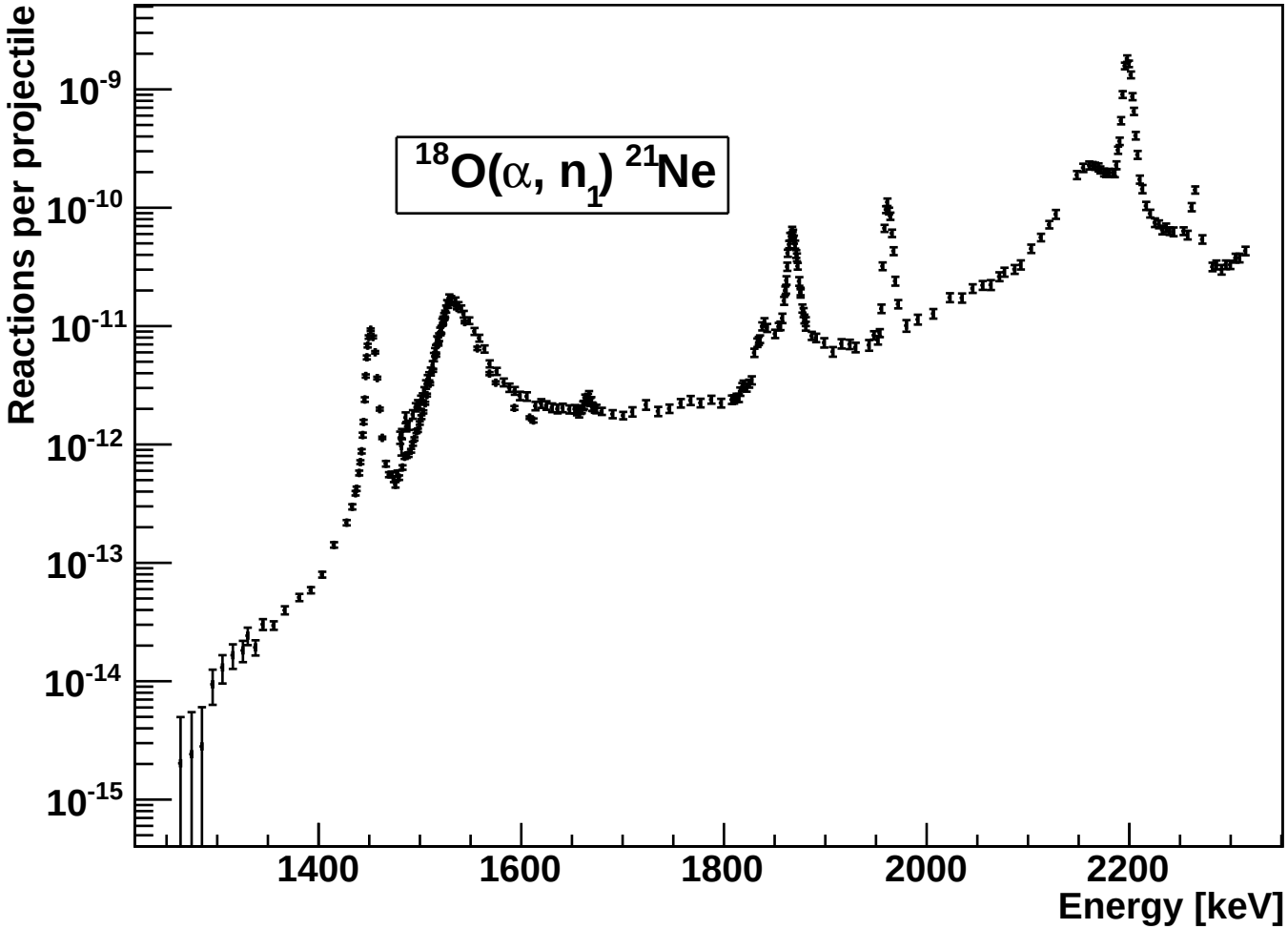
Efficiency



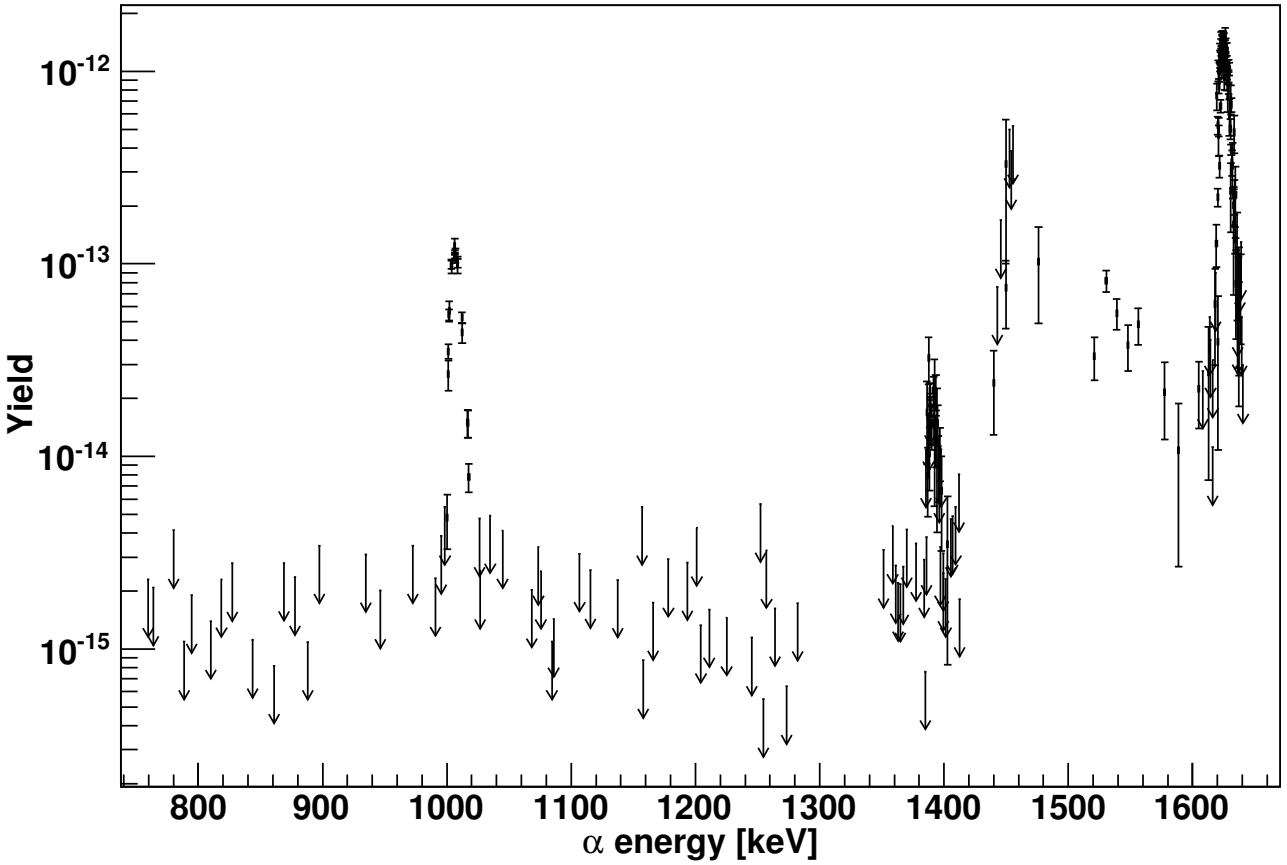


- Absolute measurements using calibrated sources, standard resonances (^{27}Al(p,γ))
- Relative efficiency data from ^{56}Co

$^{18}O(\alpha, n_1)^{21}Ne$

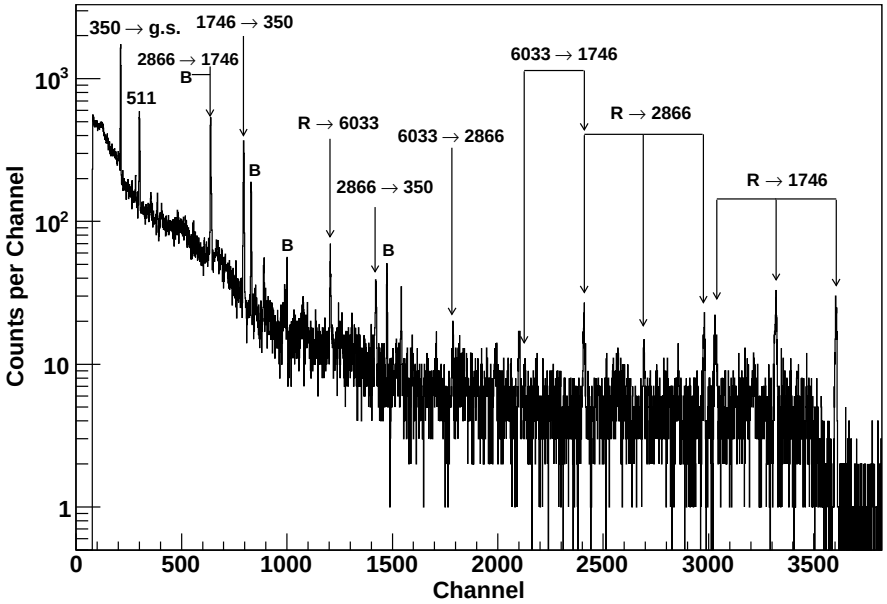


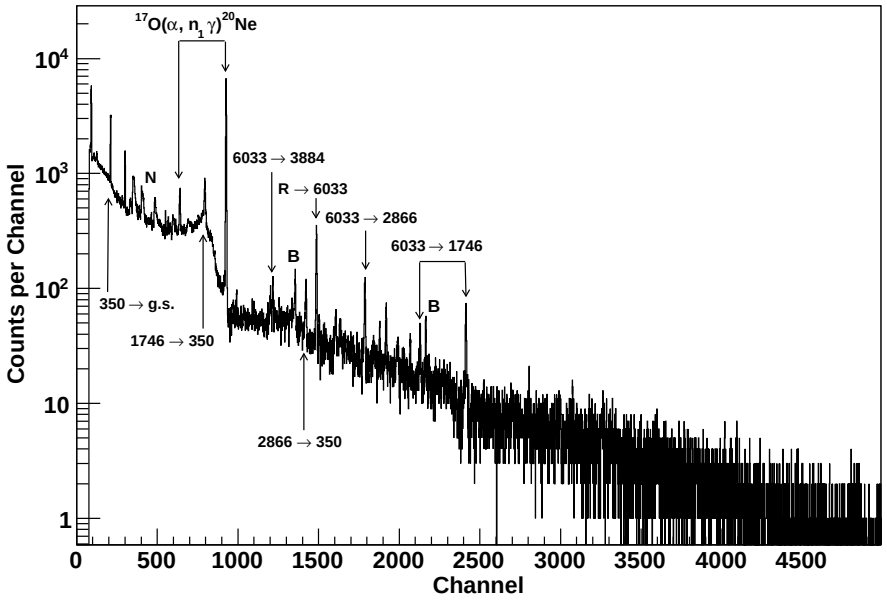
Excitation curve

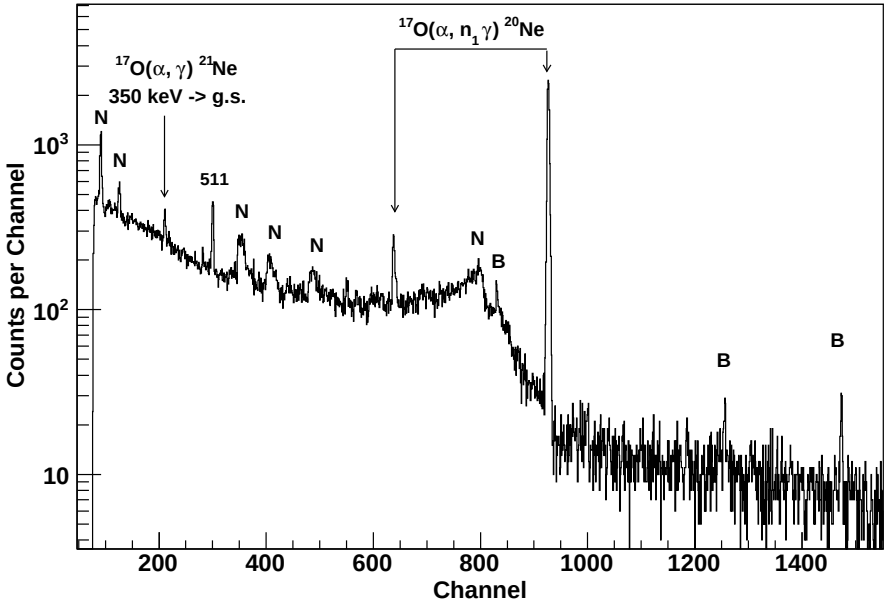


- Found three resonances at 998 keV, 1386 keV, 1620 keV
- 1450 keV yield due to $^{18}O(\alpha, n_1)^{21}Ne$ contribution

Branchings


350 → g.s.
1746 → 350
2866 → 1746
B
511
B
R → 6033
6033 → 2866
2866 → 350
B
B
6033 → 1746
R → 2866
R → 1746
Counts per Channel
Channel


17O(α, n1 γ)20Ne
N
6033 → 3884
R → 6033
6033 → 2866
6033 → 1746
B
B
350 → g.s.
1746 → 350
2866 → 350
Counts per Channel
Channel


17O(α, n1 γ) 20Ne
17O(α, γ) 21Ne
350 keV -> g.s.
N
N
511
N
N
N
N
B
B
B
Counts per Channel
Channel

Resonance strengths, γ vs. neutron channel (Denker)

- $\omega\gamma_\gamma(810\,\mathrm{keV}) = 5.6 \pm 0.6\,\mathrm{meV}$ n: 4.2 meV
- $\omega\gamma_\gamma(1122\,\mathrm{keV}) = 1.2 \pm 0.2\,\mathrm{meV}$ n: 39 meV
- $\omega\gamma_\gamma(1311\,\mathrm{keV}) = 105 \pm 11\,\mathrm{meV}$ n: 7.5 eV

Conclusion

- Completed $^{17}O(\alpha, n)^{20}Ne$ experiment
- Did initial $^{17}O(\alpha, \gamma)^{21}Ne$: stronger than expected!
- Possibly extend (α, γ) to lower energies using higher efficiency setup