The Superheated Target for Astrophysics Research

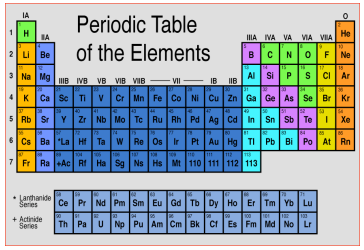
or "Low energy measurements of the $^{12}C(\alpha,\gamma)^{16}O$ reaction with a bubble chamber"

Claudio Ugalde, for the **STAR** collaboration.

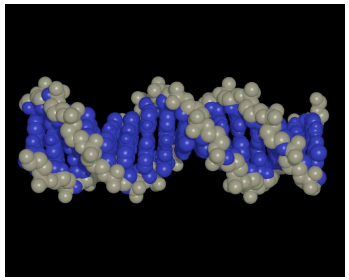
Argonne, Duke, Chicago, Chapel Hill, Fermilab, Illinois

$^{12}C(\alpha,\gamma)^{16}O$ Reaction

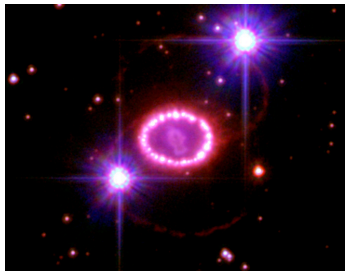
Key reaction for nucleosynthesis in massive stars



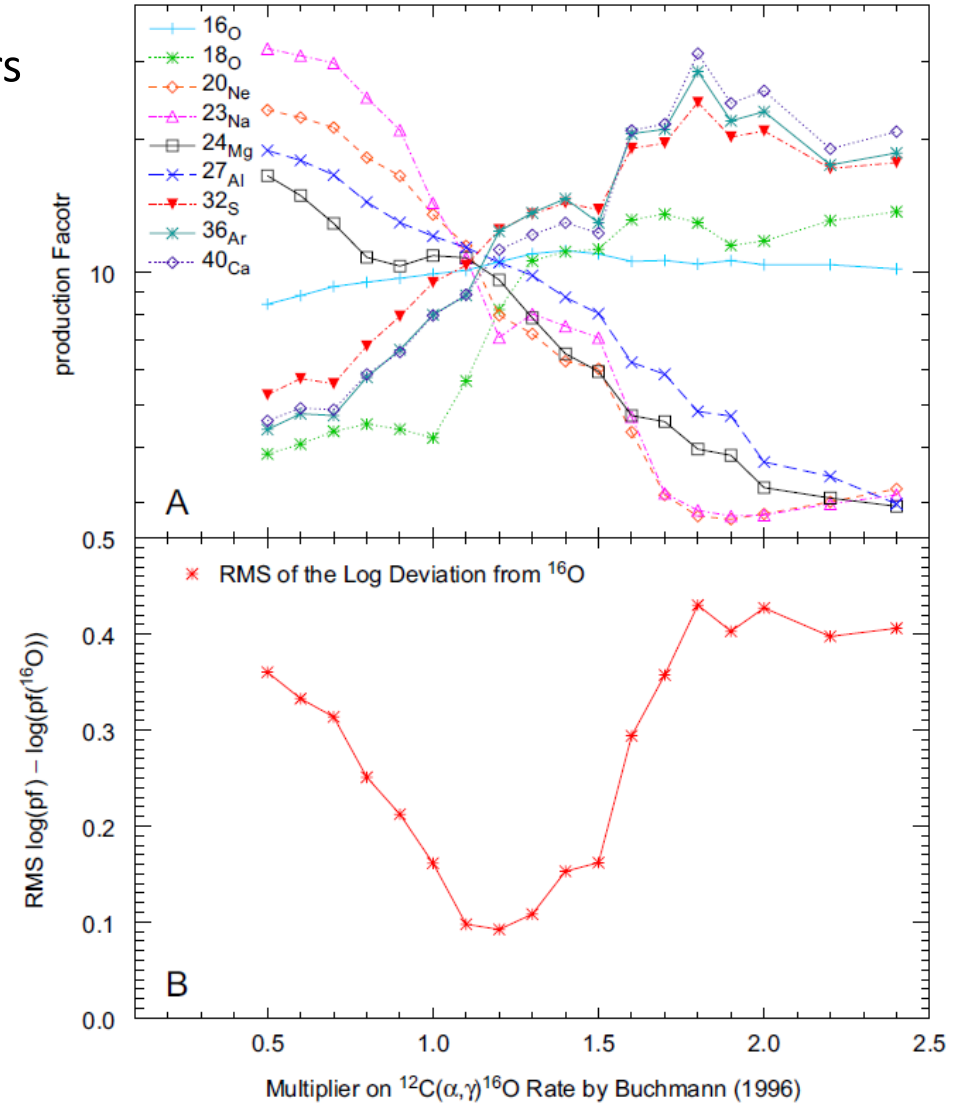
Affects the synthesis of most of the elements of the periodic table



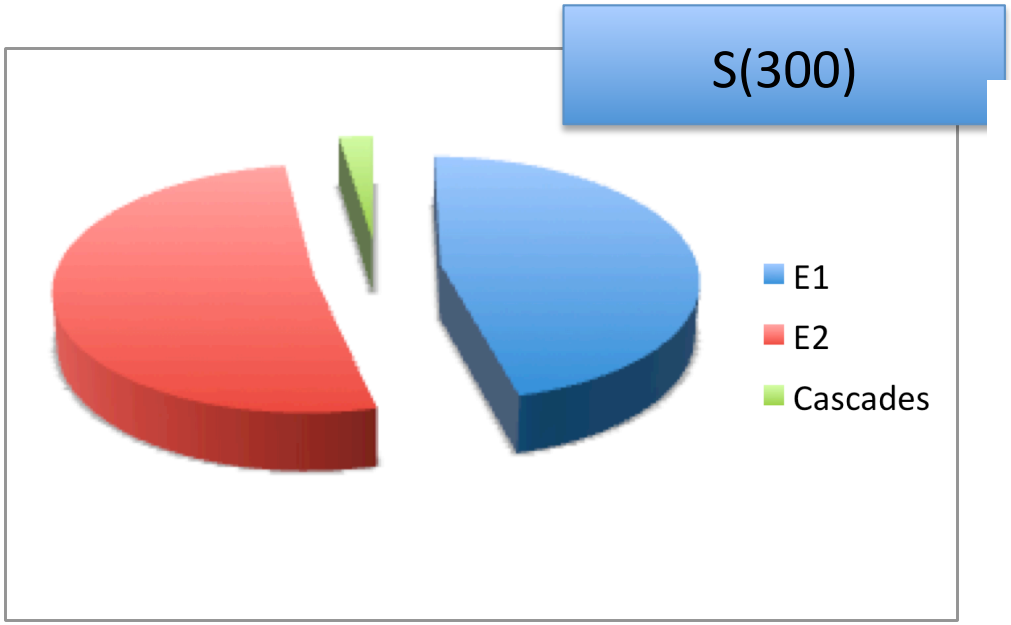
Sets the C to O ratio in the universe



Determines the minimum mass a star requires to become a supernova



S. Woosley, A. Heger, Phys. Rep. 442 (2007) 269



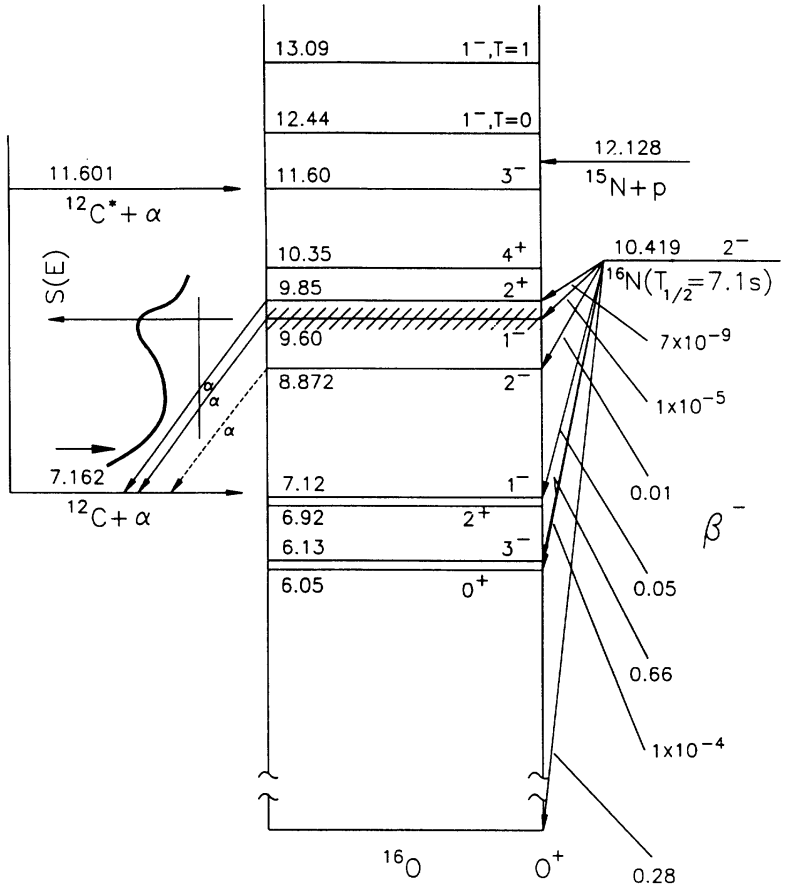
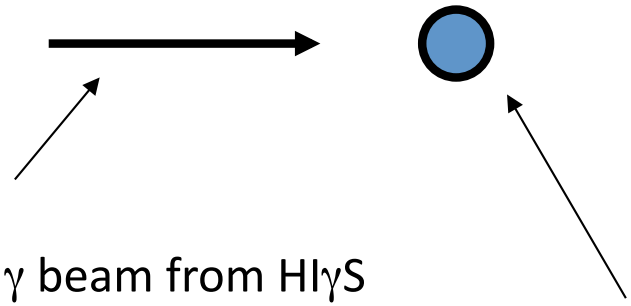


FIG. 1. Partial energy-level diagram for ^{16}O (adapted from [4]).

Bubble chamber at HIγS

beam | target | bubbles

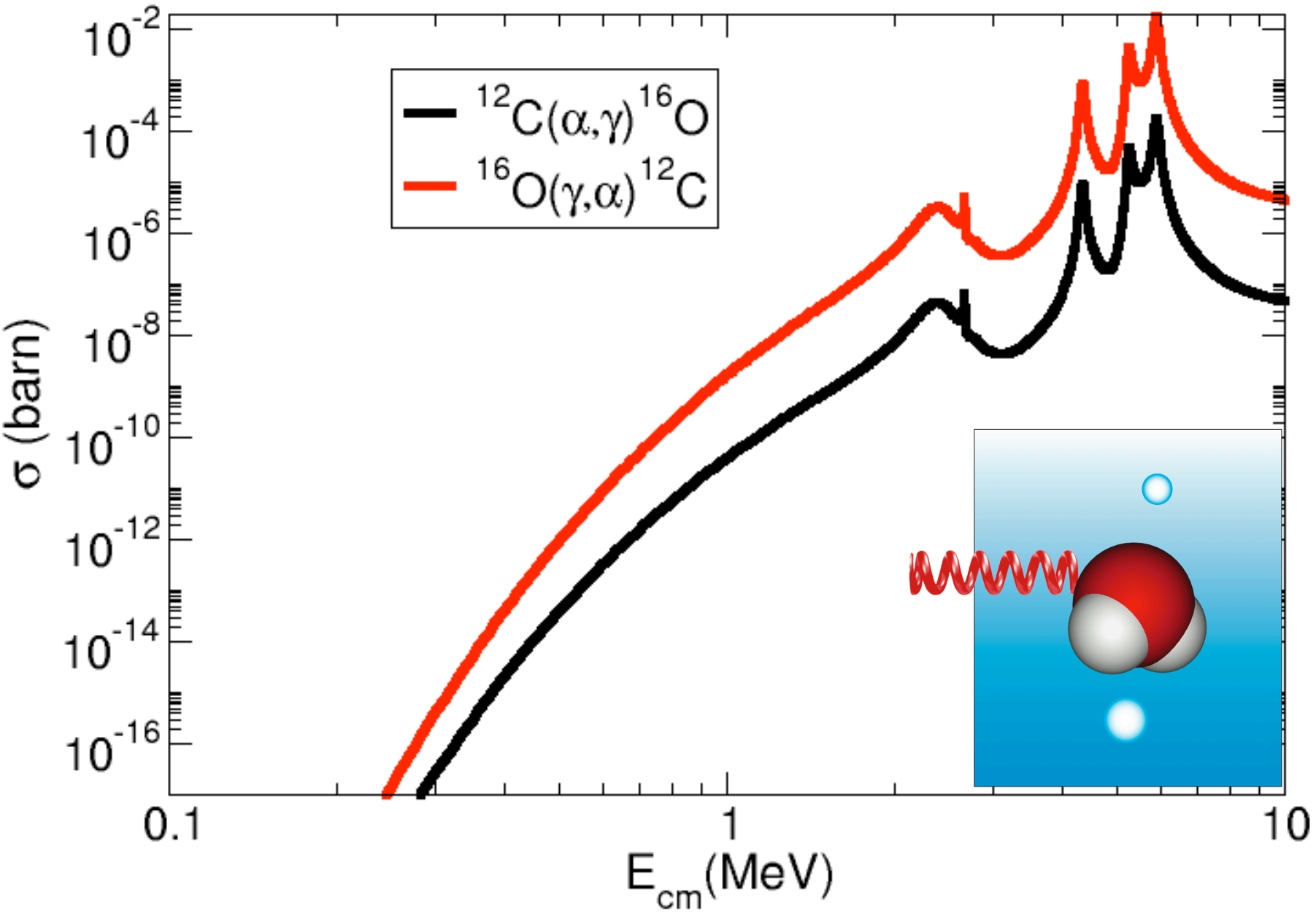
$\gamma + {}^{16}O \rightarrow {}^{12}C + \alpha$



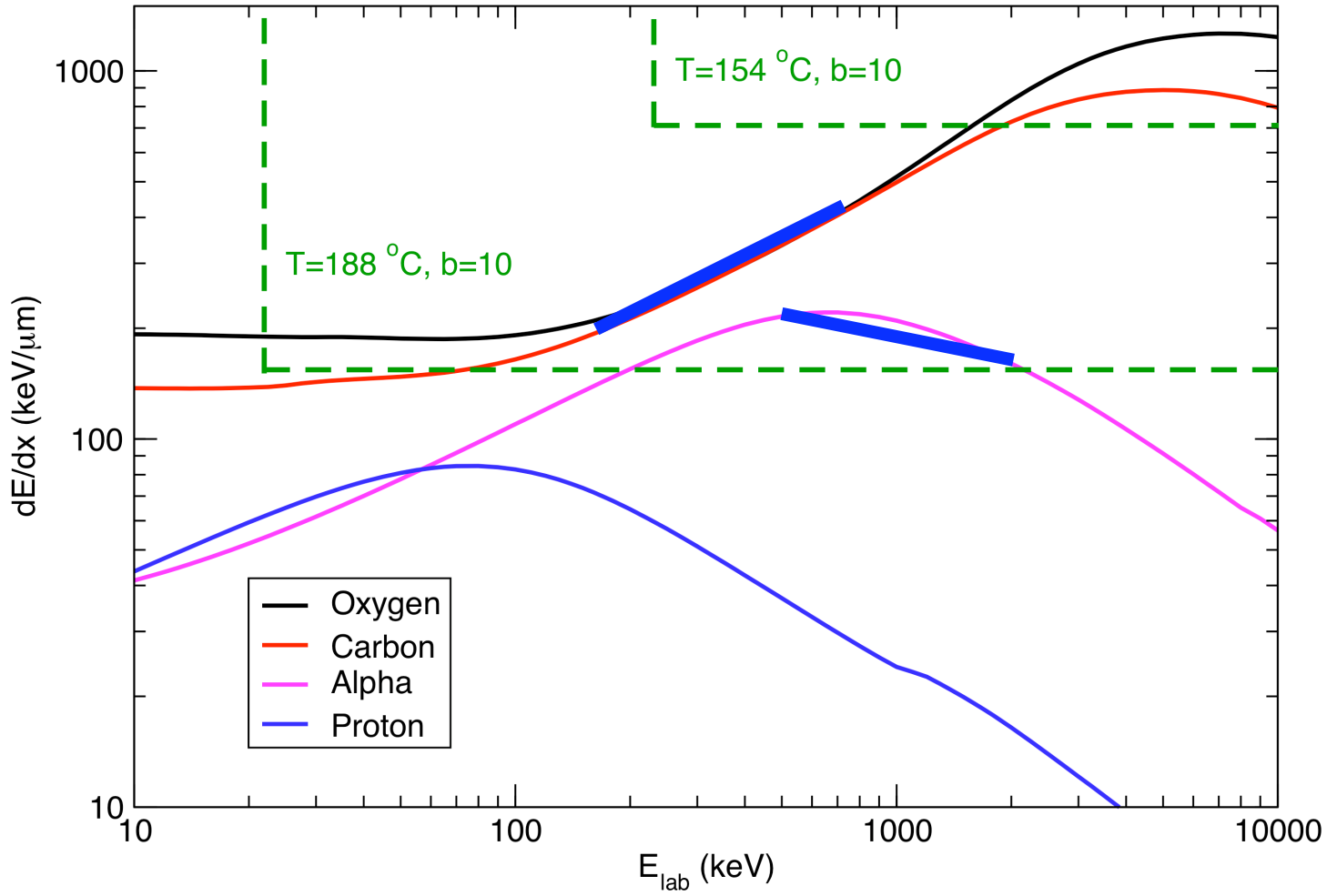
Monochromatic γ beam from HIγS
~ 10^7 γ/s

H_2O bubble chamber

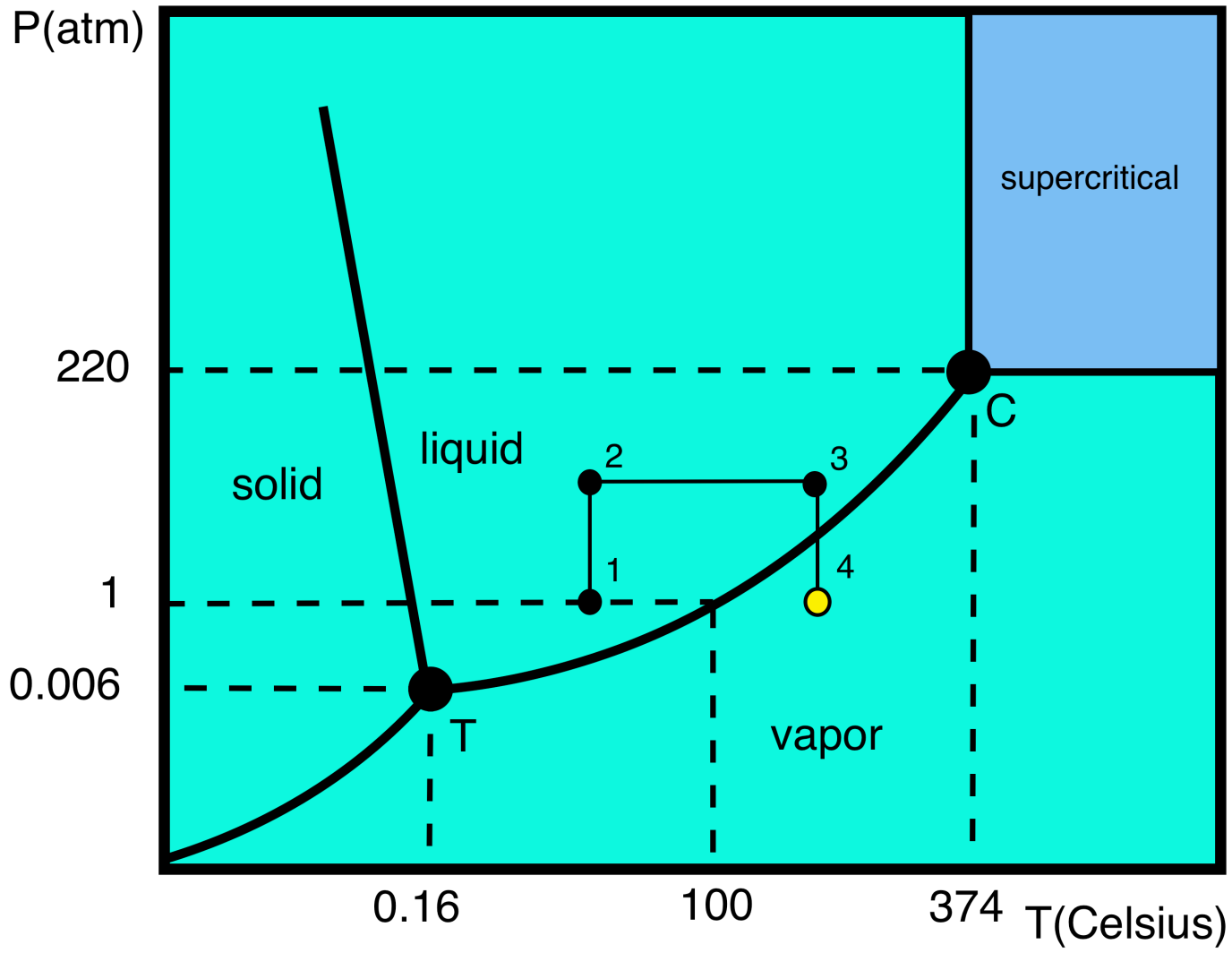
- The target density is 1000-10000x higher than gas targets.
- Superheated water will nucleate from α and ^{12}C recoils
- The detector is insensitive to γ-rays.
- Isotopically pure water is needed.
- Prototype tested at HIγS


$^{12}C(\alpha,\gamma)^{16}O$
$^{16}O(\gamma,\alpha)^{12}C$
σ (barn)
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
10^{-12}
10^{-14}
10^{-16}
0.1
1
10
E_{cm}(MeV)

Nucleation thresholds (Water)



Recipe for the preparation of superheated water.



Experiment 1 **R134a** **$^{19}F(\gamma,\alpha)^{15}N$** **E$\gamma$=8-10 MeV** **Low beam intensity** **Proof of principle**	**Experiment 2** **Water** **$^{16}O(\gamma,\alpha)^{12}C$** **E$\gamma$=9-10 MeV** **Low beam intensity** **Engineering test**
Experiment 3 C_4F_{10} $^{19}F(\gamma,\alpha)^{15}N$ Eγ=4.5 MeV Full beam intensity Backgrounds	Experiment 4 Water $^{16}O(\gamma,\alpha)^{12}C$ Eγ=8.1 MeV Full beam intensity Production run

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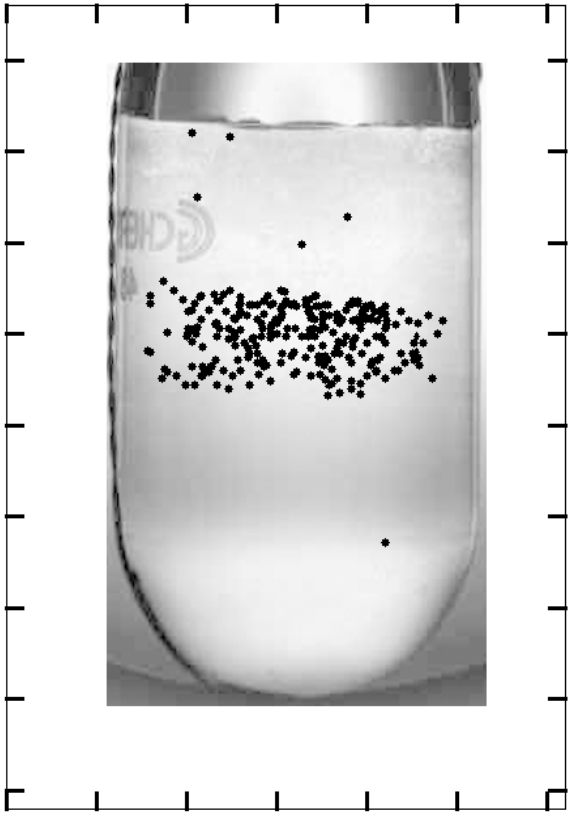
Proof of principle: as predicted, photodisintegration does induce nucleation

To keep the bubble chamber count rate at 0.1Hz levels, the beam intensity had to be reduced from $1x10^7$ to $5x10^3$ γ/s.

γ-ray beam @ 8.7 - 10.0 MeV

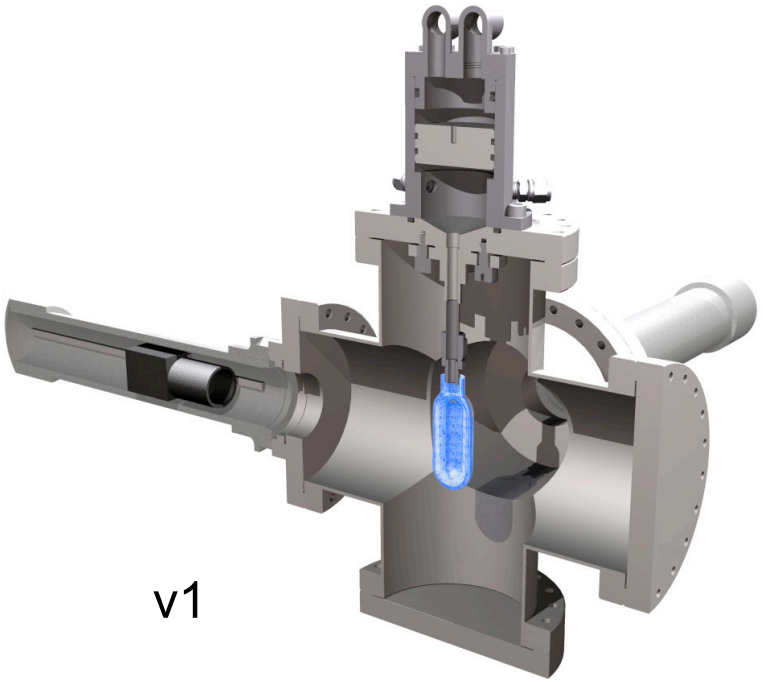
Counted for ~1 hr per data point

Experiment performed in two 12 hour sessions



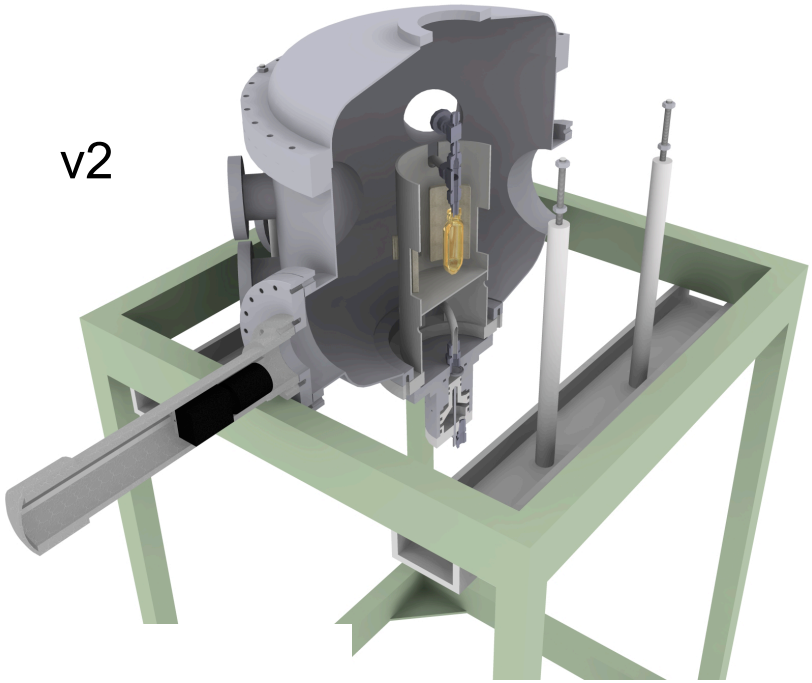
- **Event distribution from 1 hour of beam.**
- **2% of events appear outside the beam region.**
- **No surface nucleation problems!**

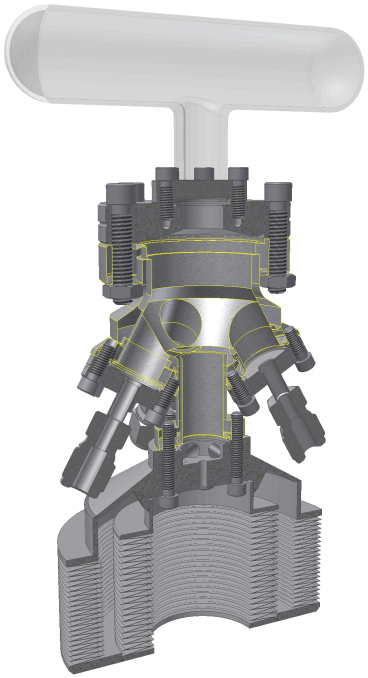
STAR



v1

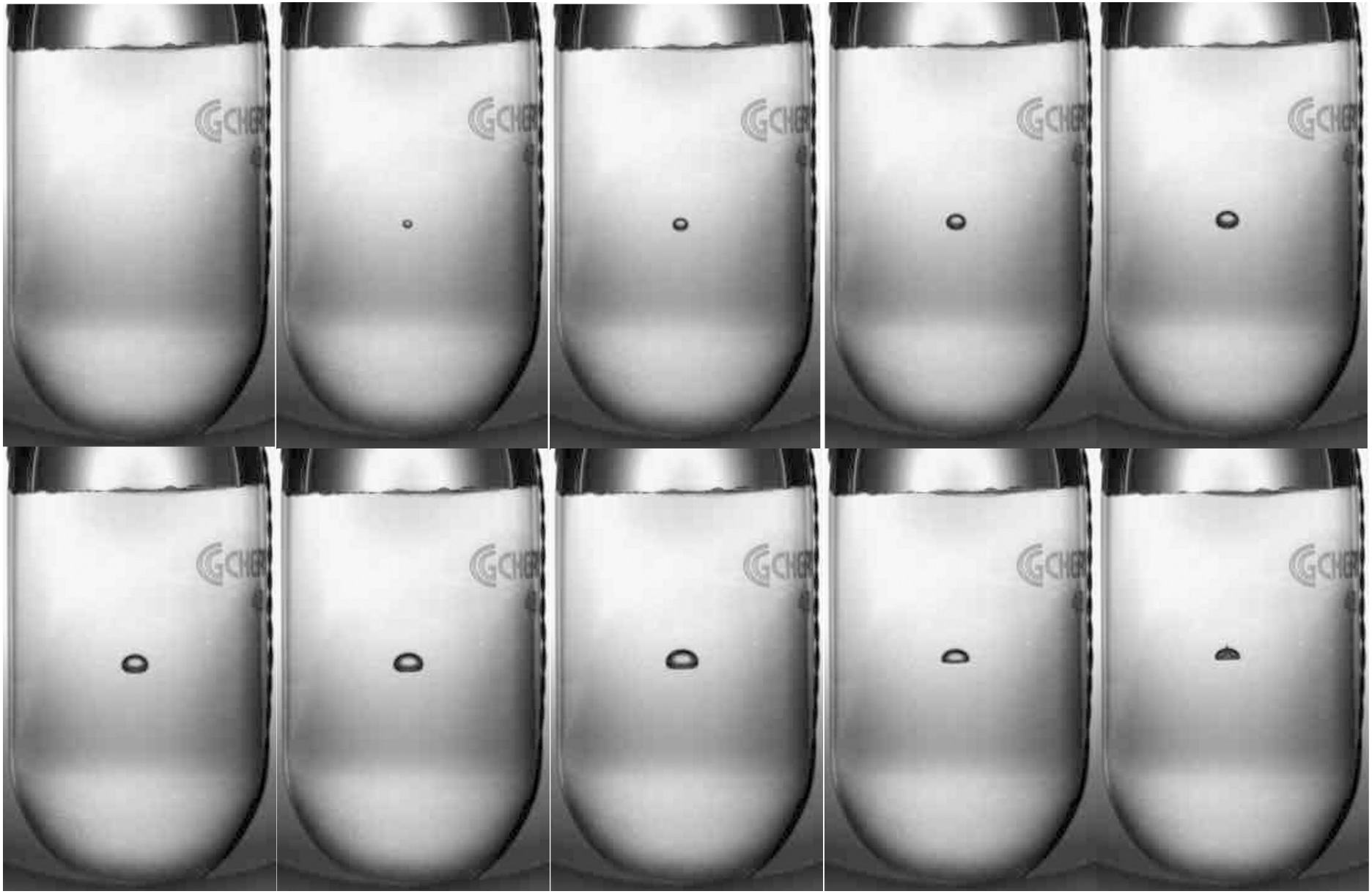
v2





v3

Thanks!



(By the way, STAR is an amazing neutron detector as well)