Measurement of $^{19}F(\gamma,\alpha)^{15}N$ with a bubble chamber and a bremsstrahlung beam

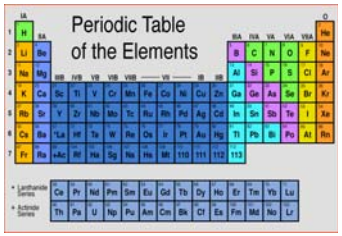
Superheated Target for Astrophysics Research (STAR)

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

Argonne, UChicago, JLab, Fermilab, Chapel Hill

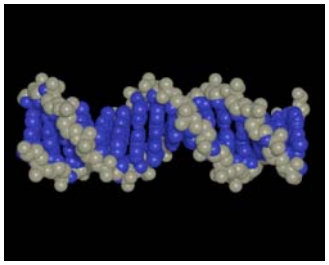
$^{12}C(\alpha,\gamma)^{16}O$ Reaction

Key reaction for nucleosynthesis in massive stars, progenitors of Type Ia SN, WD ages.

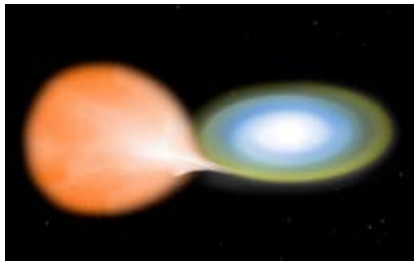


Affects the synthesis of most of the elements of the periodic table

Determines whether for a given initial mass, a star will become a black hole or a neutron star



Sets the C to O ratio in the universe



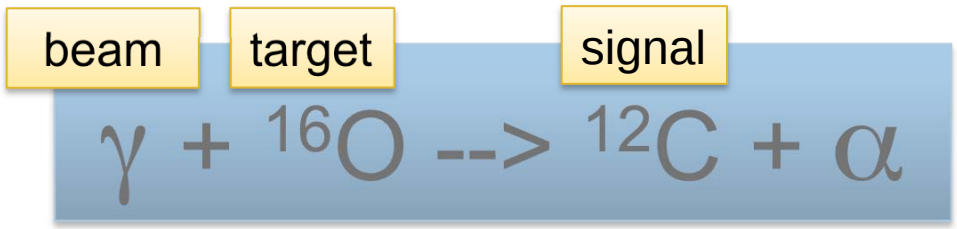
The variation of the C/O ratio in the progenitor might be a cause of the variation of SNIa brightness

Determines the minimum mass a star requires to become a core collapse supernova

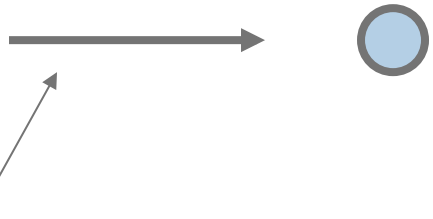
Affects the constraints on the age of stellar populations from White Dwarfs

However, $\sigma \sim 1 \times 10^{-17}$ barns at astrophysical temperatures.

New approach:
Inverse reaction + Bubble chamber + Bremsstrahlung



- Extra gain (x100) by measuring time inverse reaction
- The target density up to x10^6 higher than conventional targets.
- Superheated water will nucleate from α and ^{12}C recoils
- The detector is insensitive to γ-rays (at least 1 part in 10^{11})
- Prototype tested at HIγS



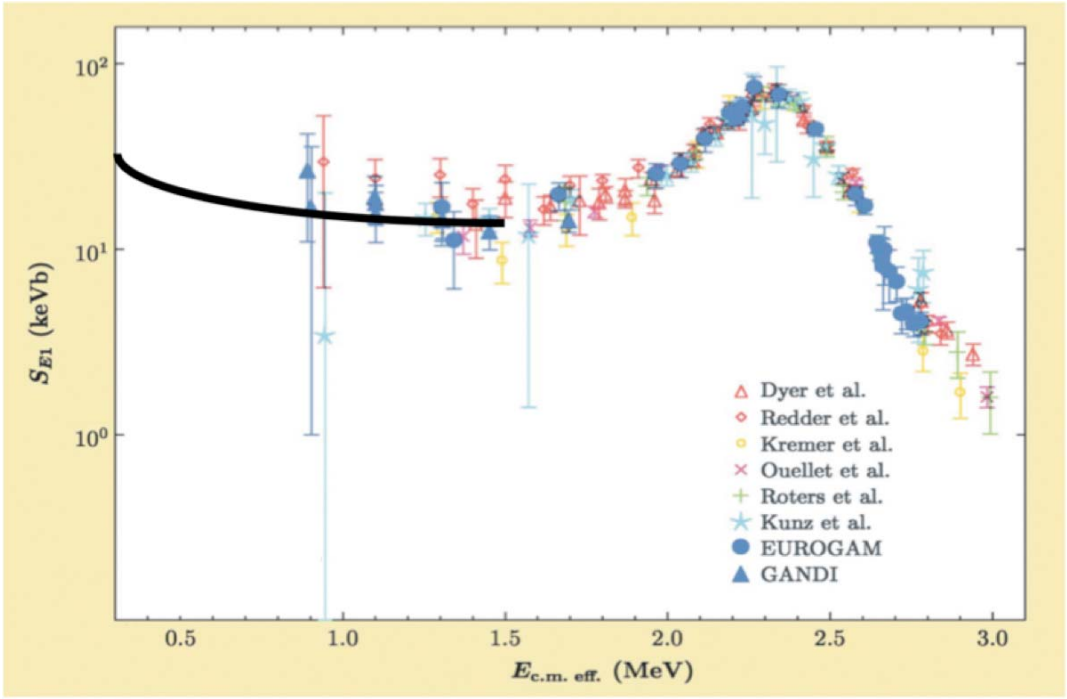
Monochromatic γ beam from HIγS
~ $10^{7\text{-}8}$ γ/s
Bremsstrahlung from JLab ~ $10^{10\text{-}12}$ γ/s

H_2O bubble chamber

Astrophysical S-factor for $^{12}C(\alpha,\gamma)^{16}O$

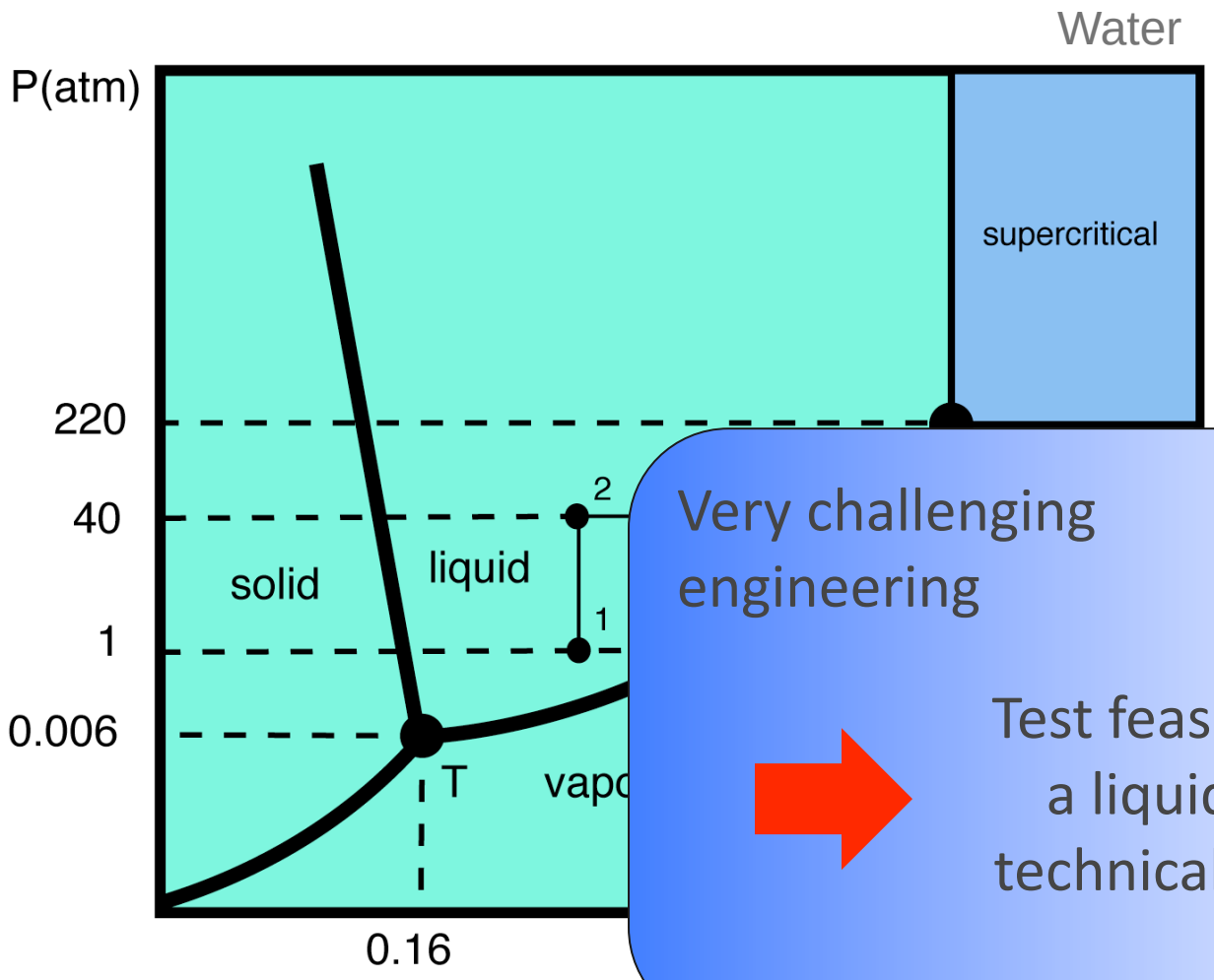
$$S = E\sigma e^{(2\pi\eta)}$$

Stellar helium burning at E=300 keV



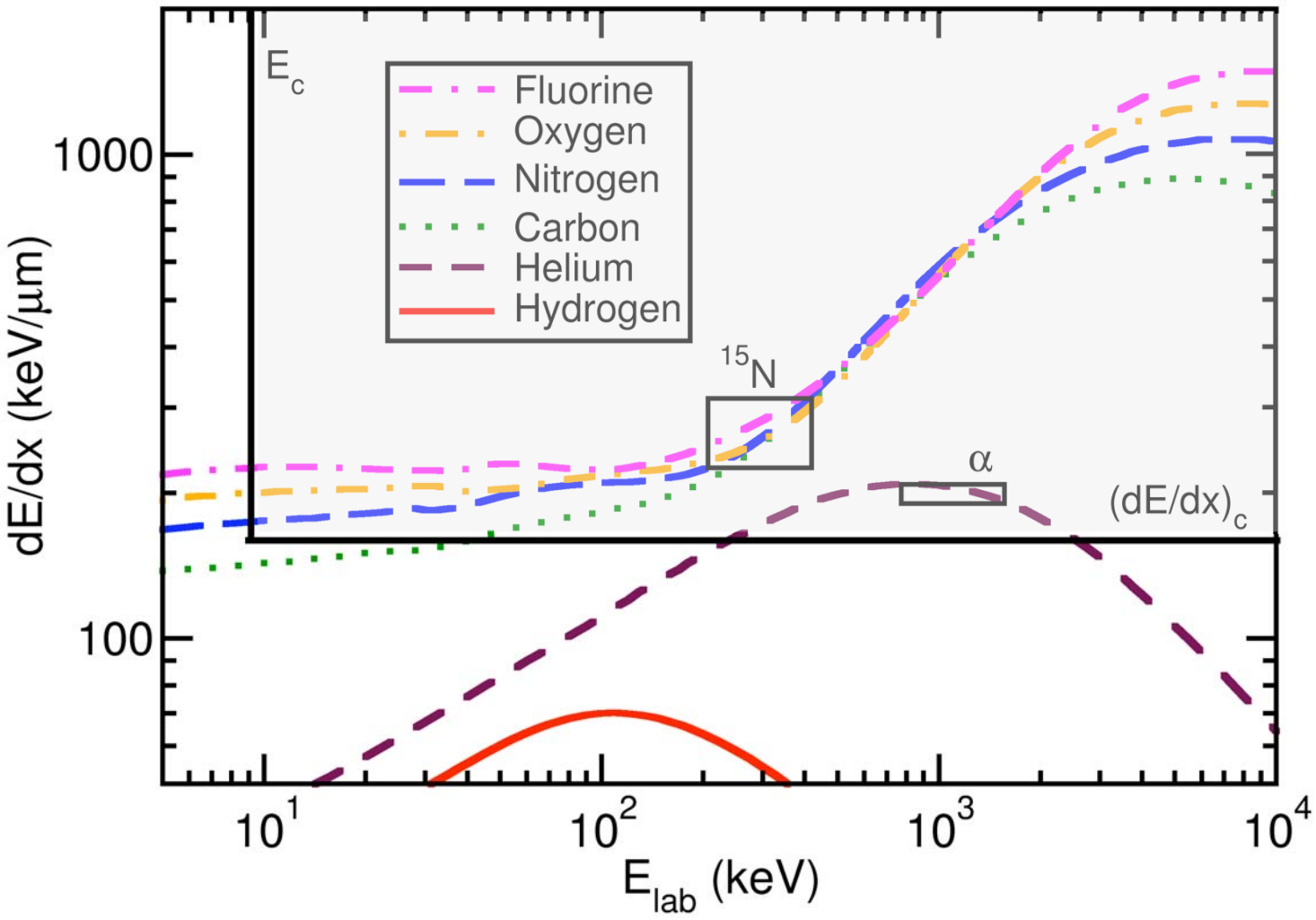
Author	S(300keV) (keV-b)
Buchmann (2005)	102-198
Caughlan and Fowler (1988)	120-220
Hammer (2005)	162+-39

Superheating of liquids



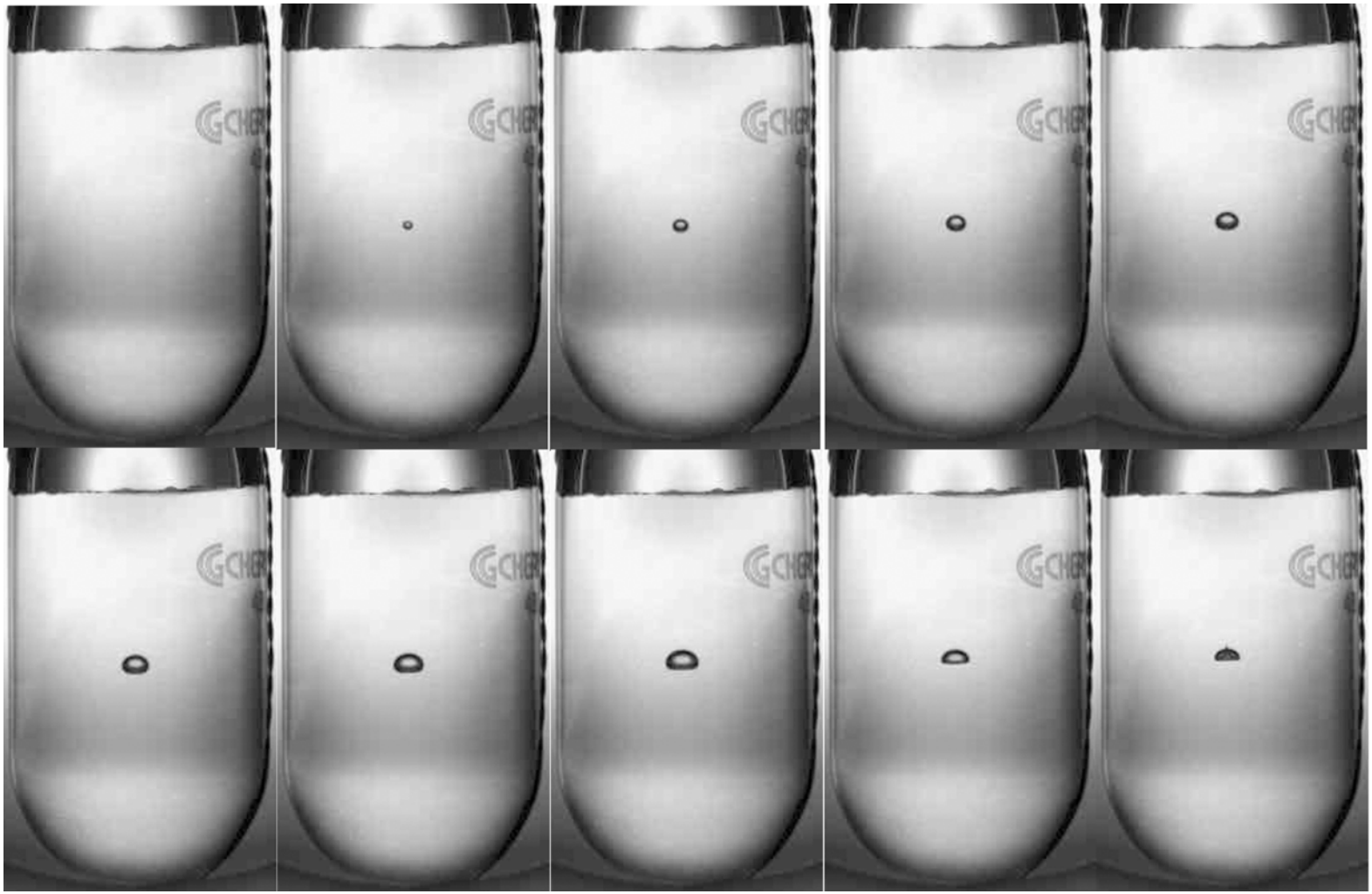
Very challenging engineering

Test feasibility with a liquid requiring technical simplicity (C_4F_{10})

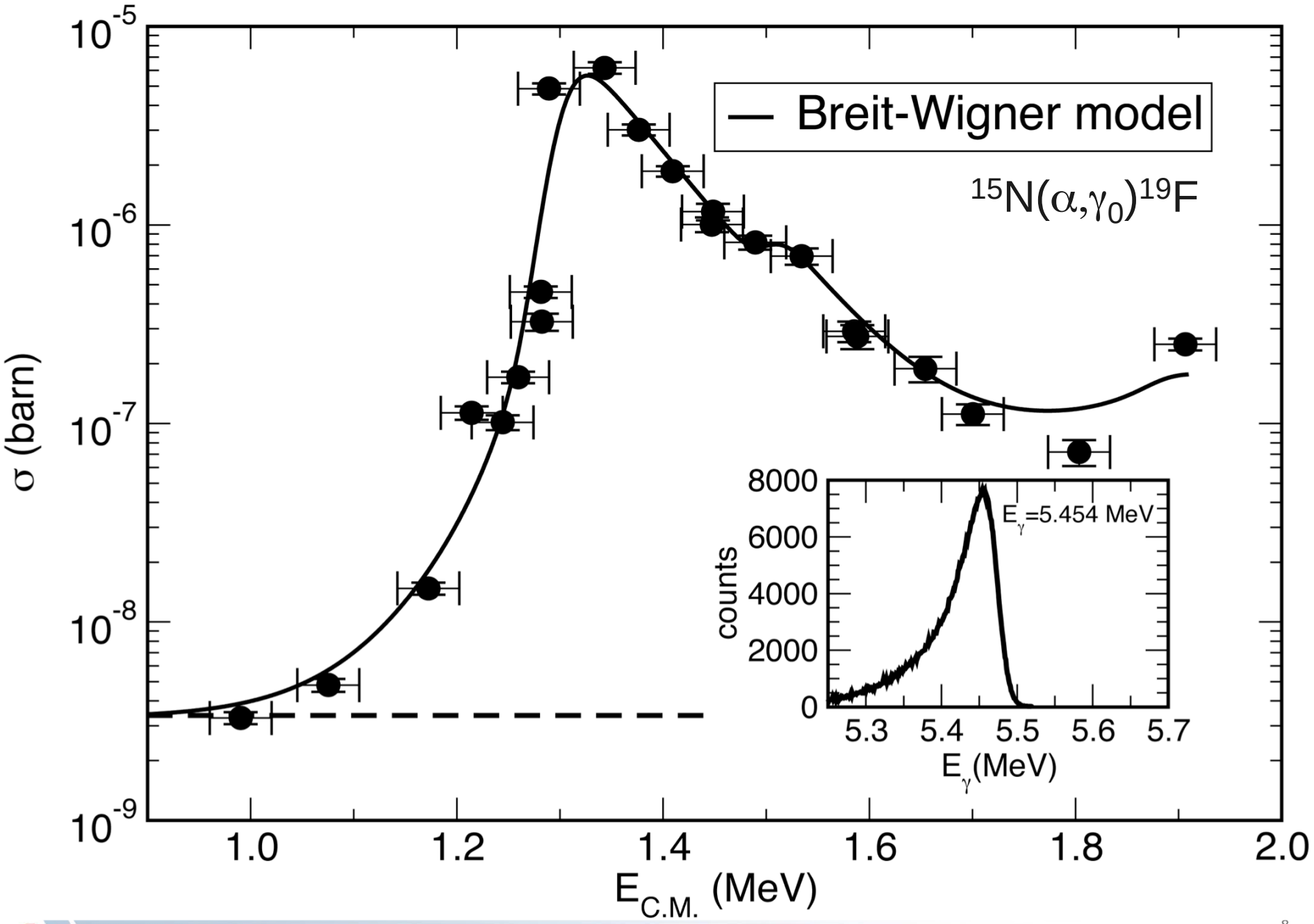


C_4F_{10}

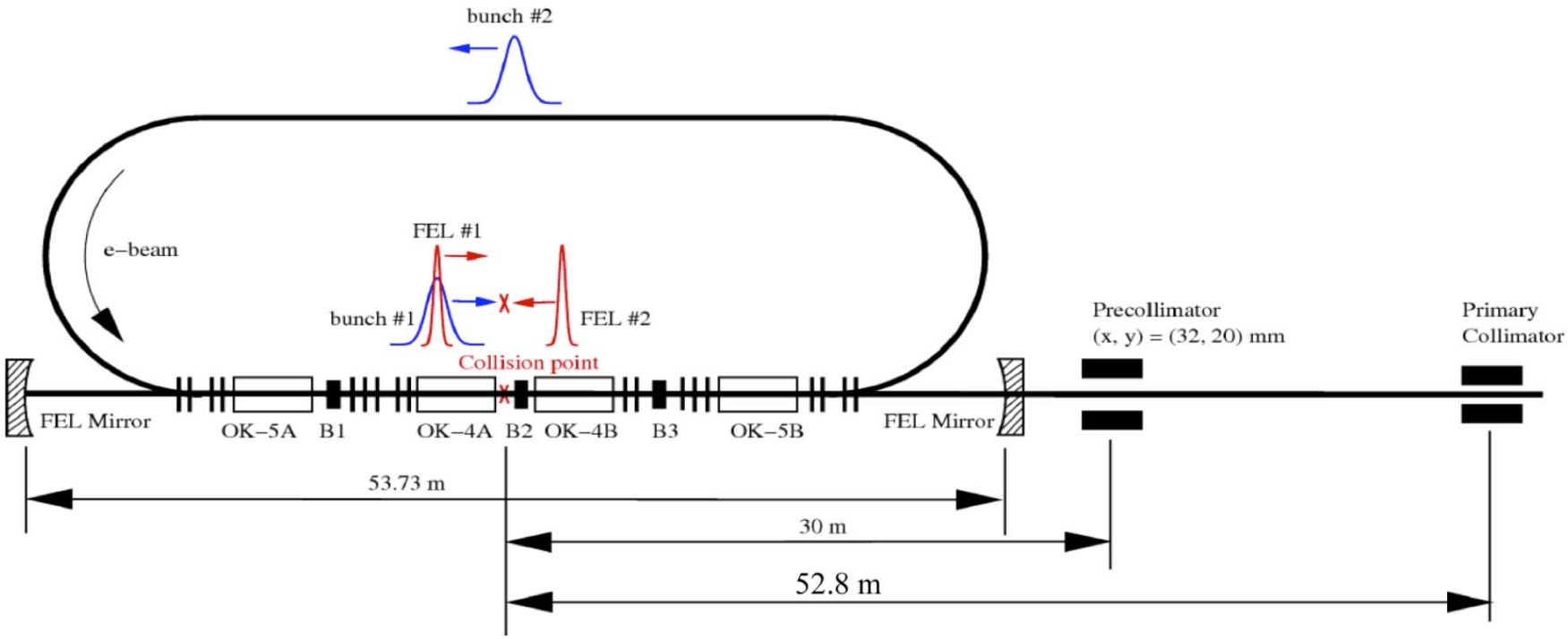
Acceptance window size is tunable by varying P and T (amount of superheat)



$\Delta t = 10$ ms


Breit-Wigner model
$^{15}N(\alpha,\gamma_0)^{19}F$
σ (barn)
$E_{C.M.}$ (MeV)
counts
E_γ=5.454 MeV
E_γ(MeV)

HIγS Photon Beam



E (electron) ~ 500 MeV
+
2 x10^{-10} torr vacuum

Strong bremsstrahlung background component

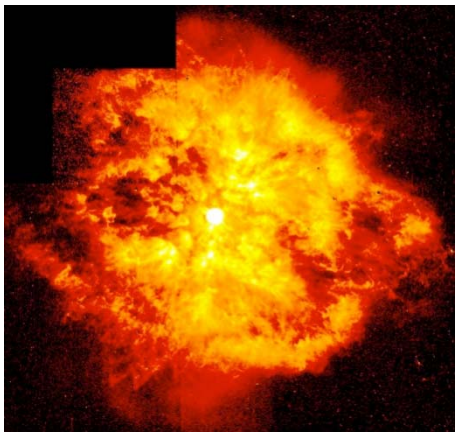
Fluorine nucleosynthesis

Possible scenarios:
a) Neutrino spallation in core collapse SN
b) He intershell in asymptotic giant branch stars
c) Core He burning in some massive (Wolf-Rayet) stars

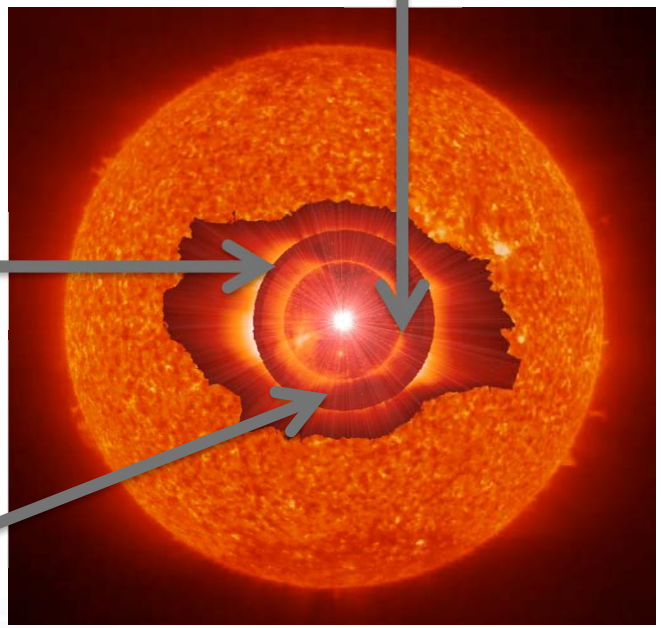
T = 0.2-0.35 GK

For AGB and WR scenarios,
$^{14}N(\alpha,\gamma)^{18}F(\beta\nu)^{18}O(p,\alpha)^{15}N(\alpha,\gamma)^{19}F$

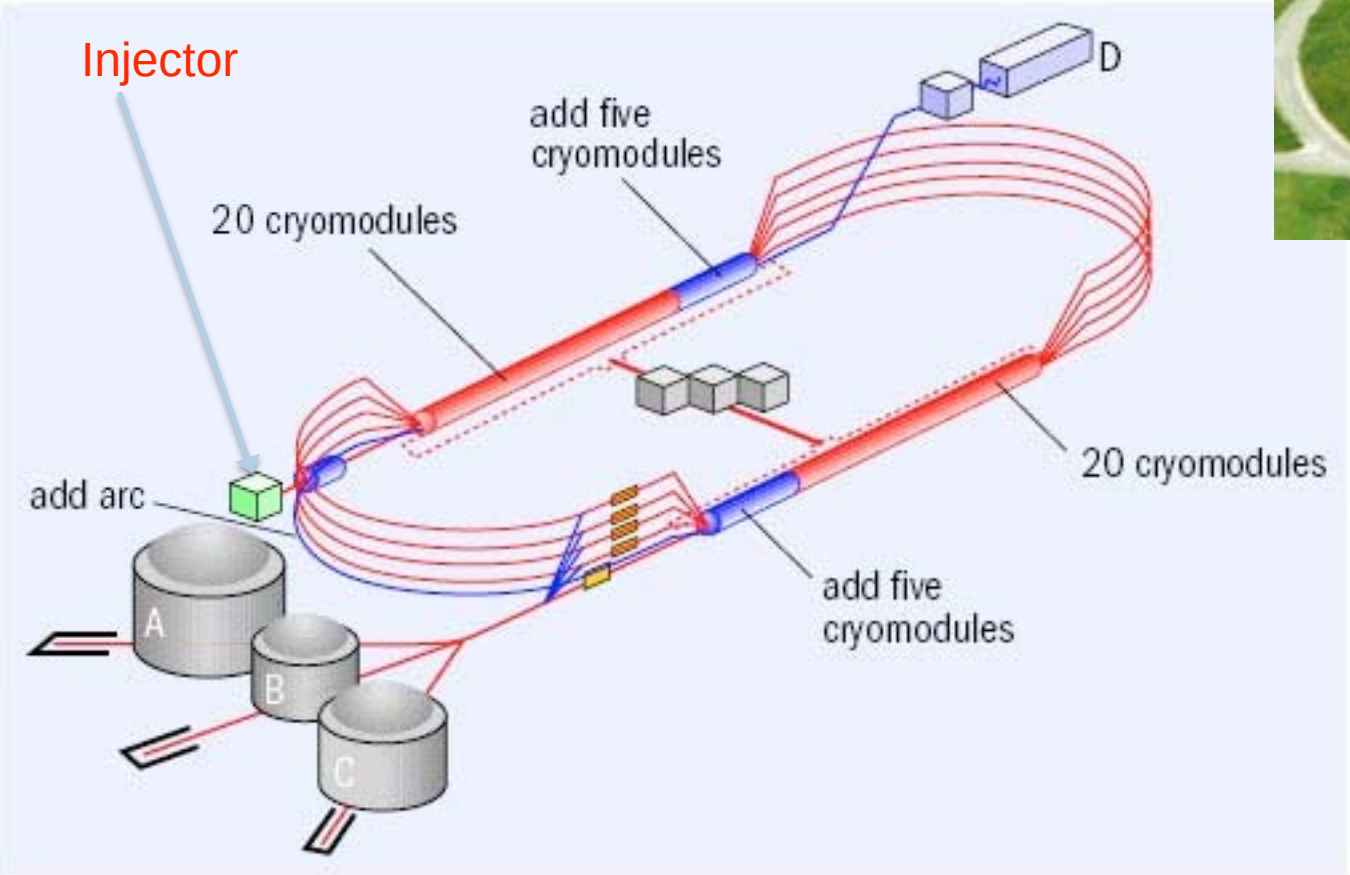
$^{15}N(\alpha,\gamma)^{19}F$ still uncertain at stellar temperatures



WR124, HST

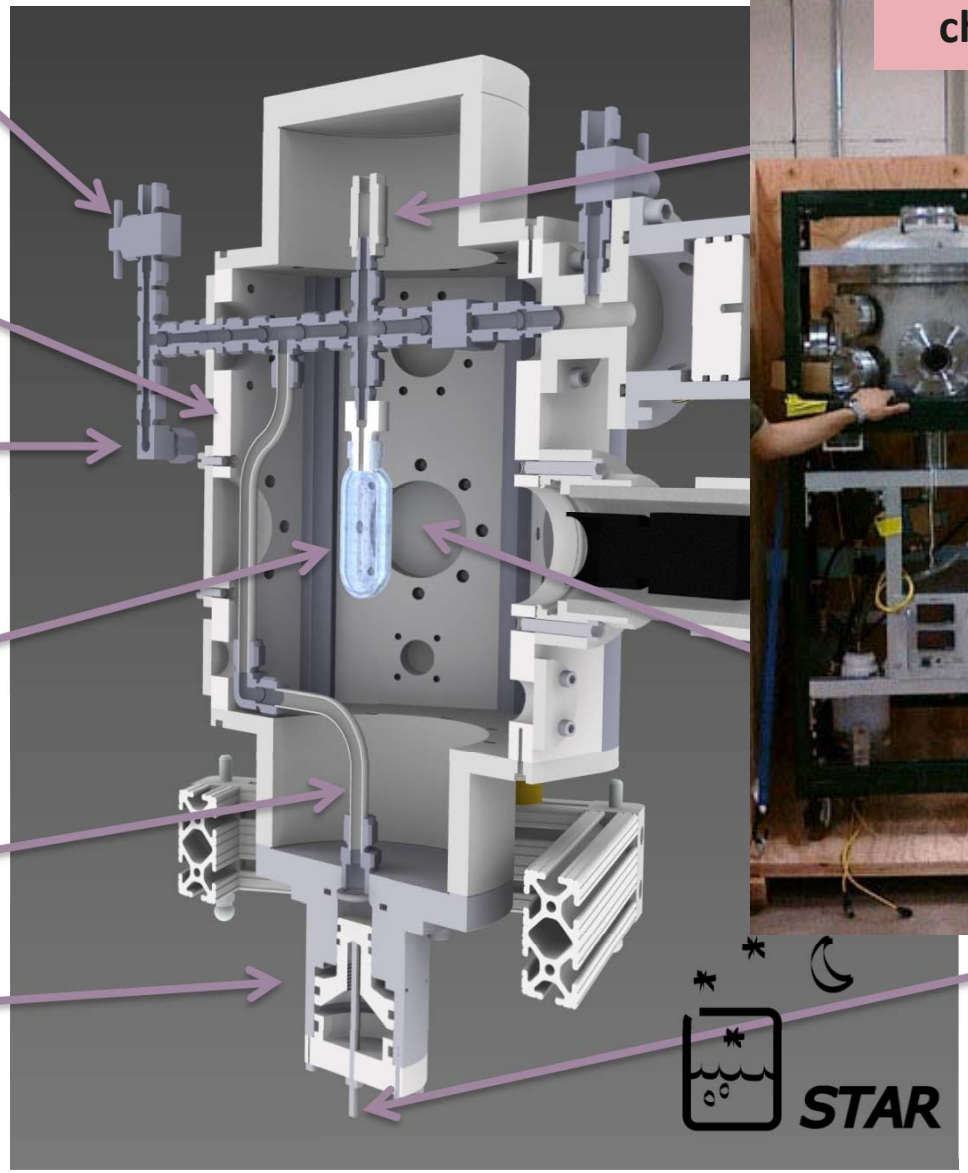


Bremsstrahlung beams at Jefferson Lab

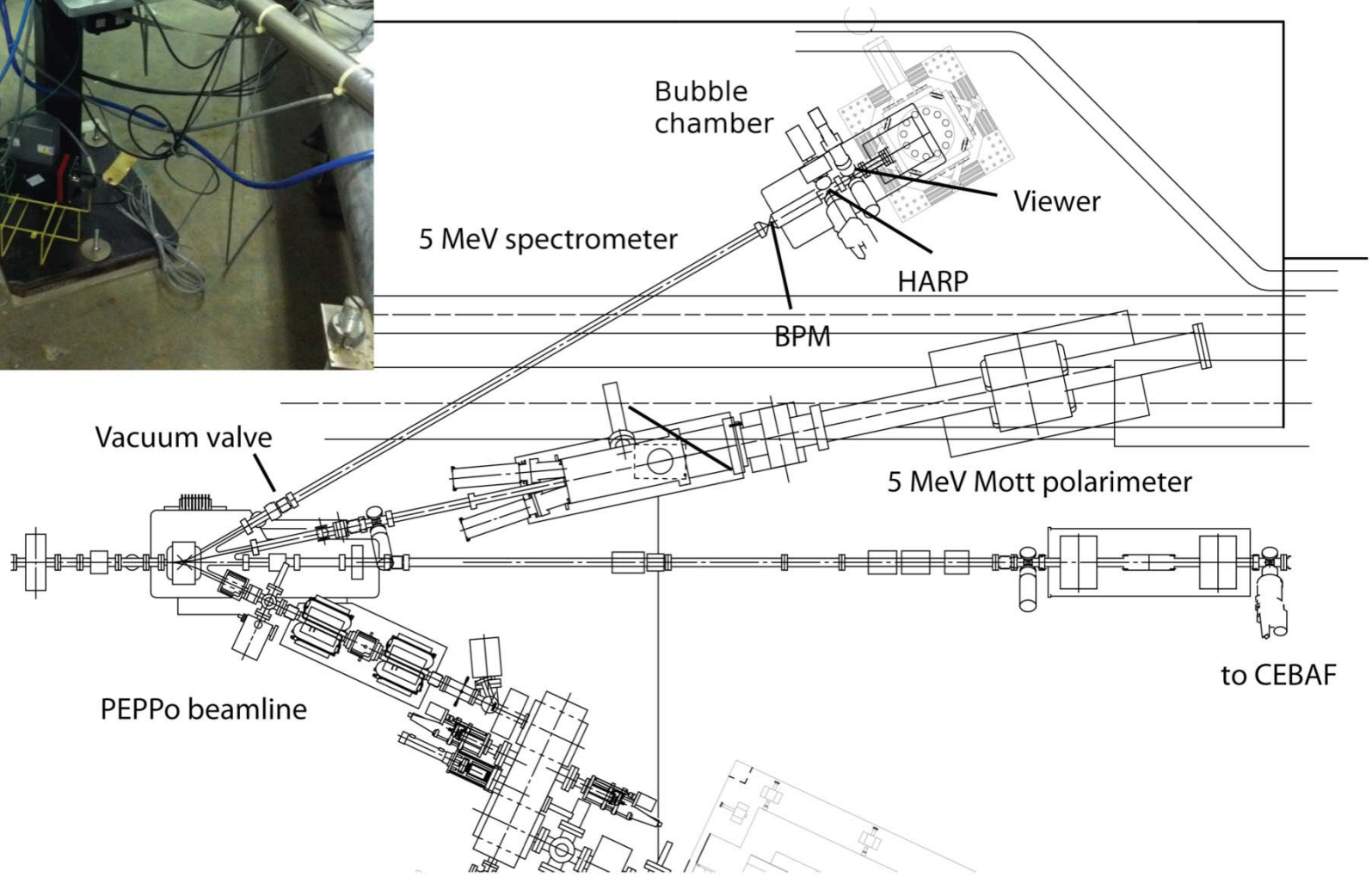


CEBAF 12 GeV

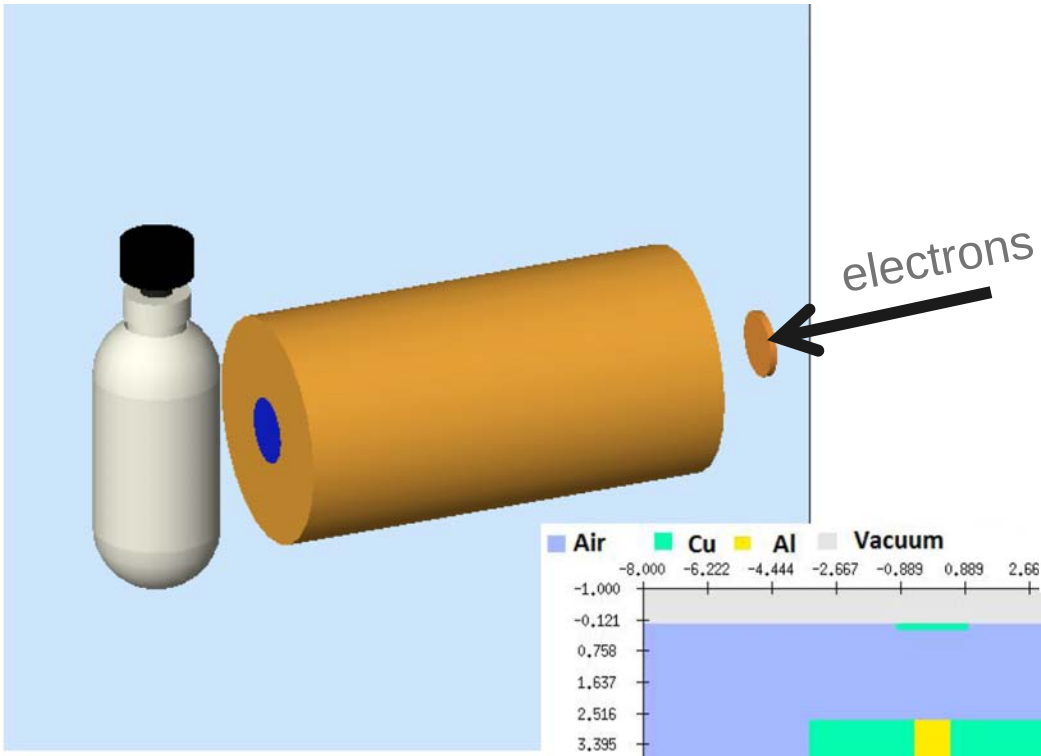
C_4F_{10} bubble chamber for JLab

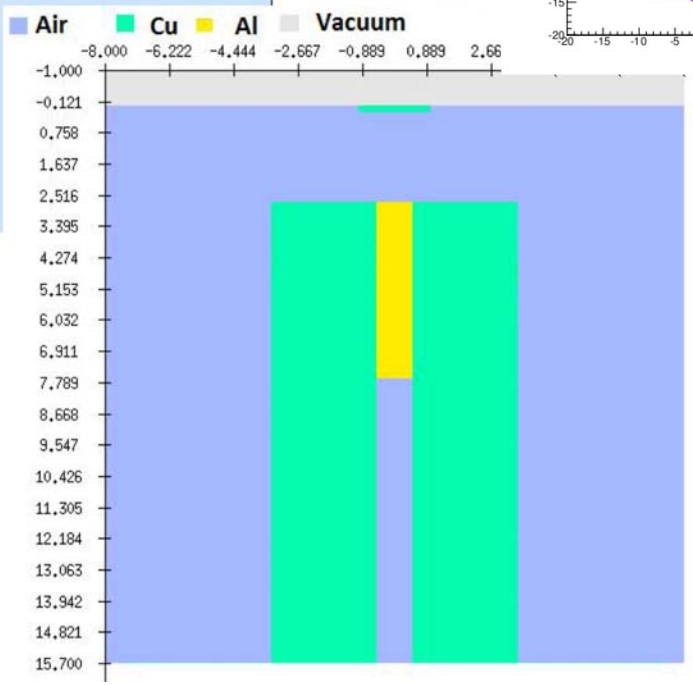


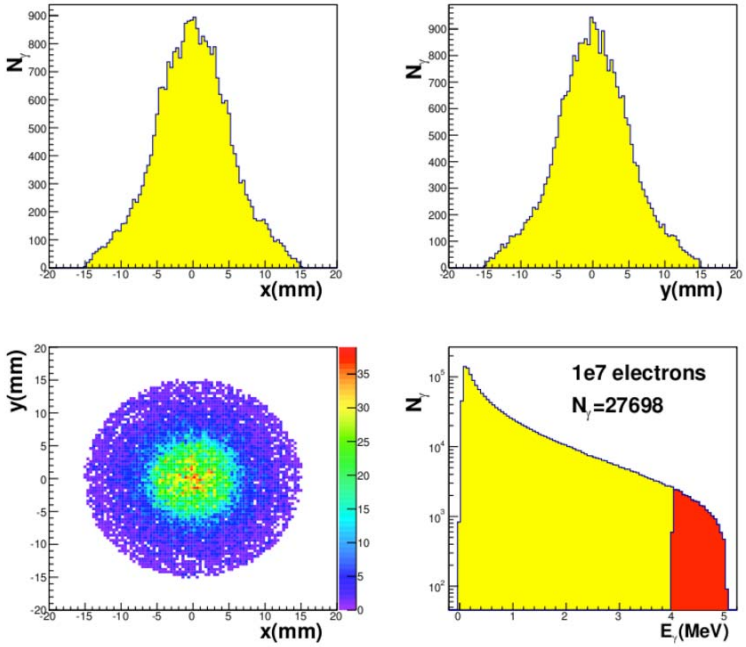
Courtesy of B. DiGiovine


Bubble
chamber
Viewer
5 MeV spectrometer
HARP
BPM
Vacuum valve
5 MeV Mott polarimeter
to CEBAF
PEPPo beamline

Bremsstrahlung radiator + collimator



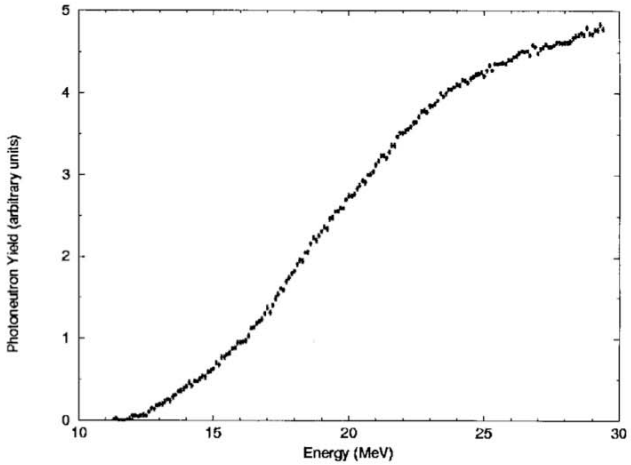




Geant 4.
Courtesy of A. El Alaoui

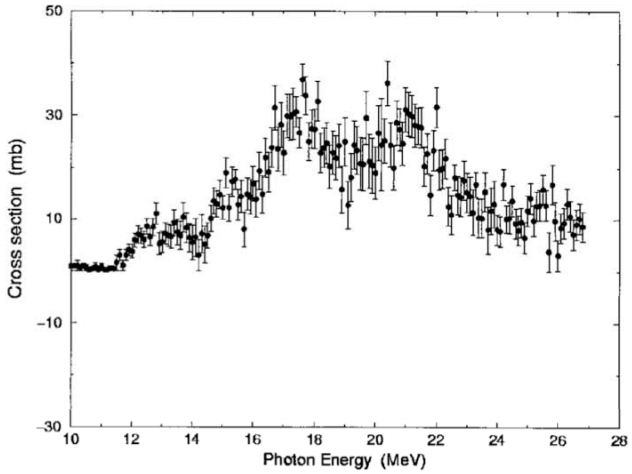
Bremsstrahlung unfolding – Penfold and Leiss

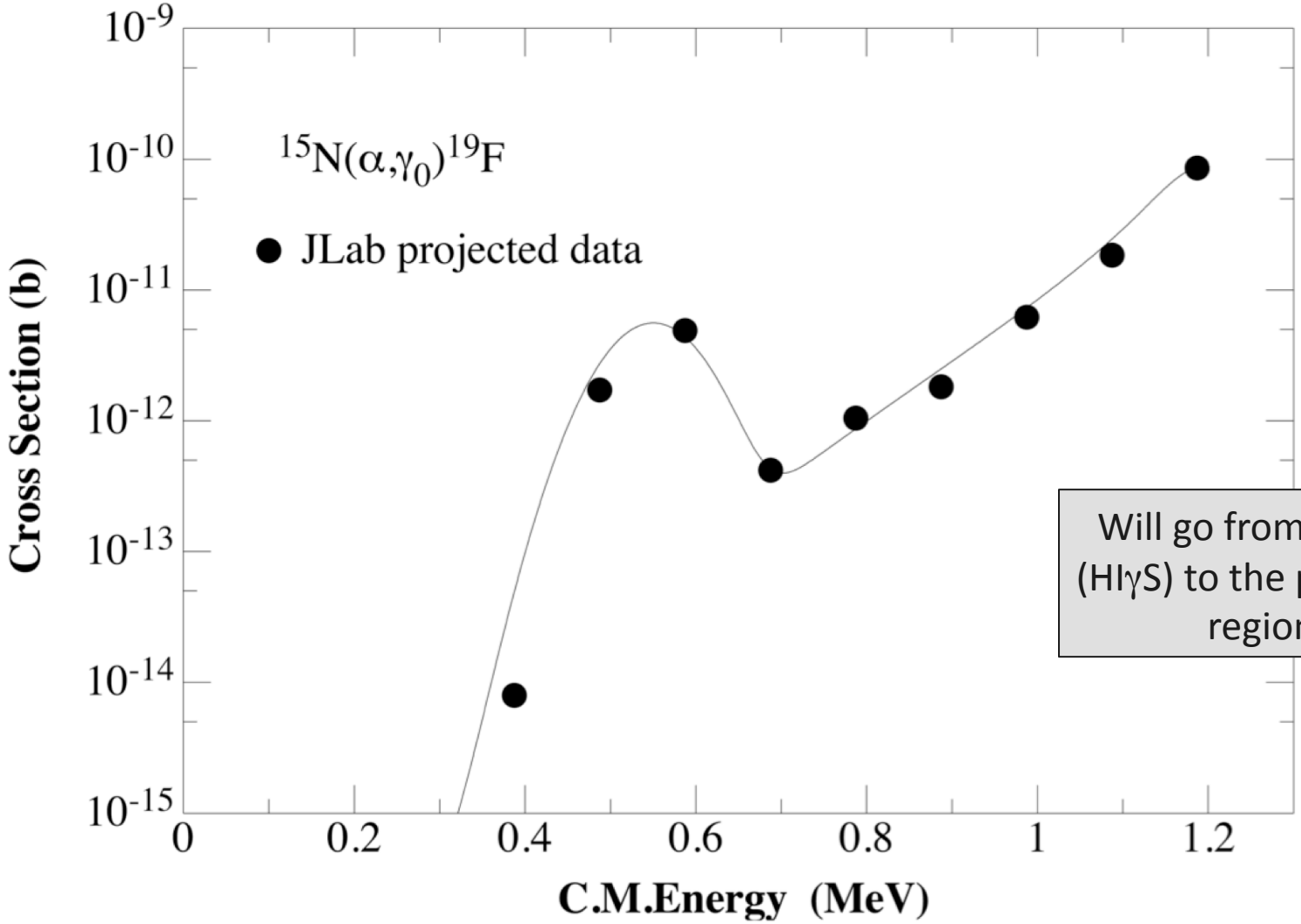
- $Y(E) = \int_{thr}^{E} N(E,k)\sigma(k)dk$
- $\sigma = \sum_{j=1}^{i} B_{ij} Y(E_j)$
- $\Delta\sum_{j=1}^{i} B_{ij} N\left(E_j, E_{i'} - \frac{\Delta}{2}\right) = \delta_{ii'}$



$^{34}S(\gamma,xn)$

Assafiri 1984





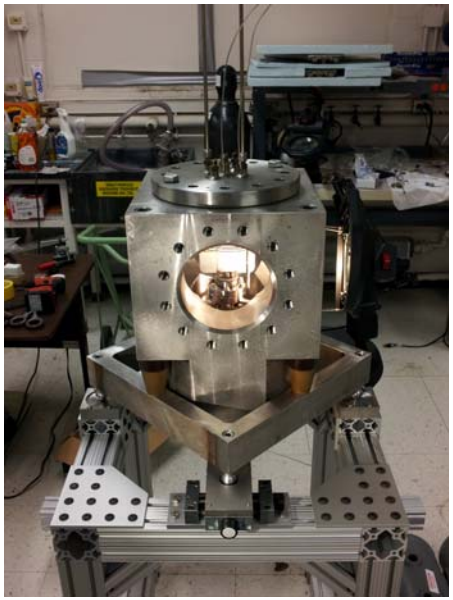
Will go from the nb (HIγS) to the pb (JLab) region

E(MeV)	IE(μAh)	events	error (stat)
****	*******	******	*******
4.35	400	54.7	7.3959
4.45	100	1363.5	36.926
4.55	1	3658.8	60.488
4.65	.2	3575.5	59.796
4.75	.1	2720.0	52.154
4.85	.1	3755.9	61.285
4.95	.05	2675.8	51.728
5.05	.02	1785.8	42.259
5.15	.02	3839.3	61.962
5.25	.005	3169.0	56.294

Summary

- We would test for the first time the bubble chamber in a bremsstrahlung beam
- We would obtain $^{15}N(\alpha,\gamma)^{19}F$ cross section data
- Background information would be obtained
- Would open the road towards a $^{12}C(\alpha,\gamma)^{16}O$ measurement

Our proposal requests 100 hours of injector beam time. These include time for commissioning, energy changes, and checkout time.



Water STAR