Jefferson Lab Bubble Chamber Experiment Update and Future Plans

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

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Collaboration

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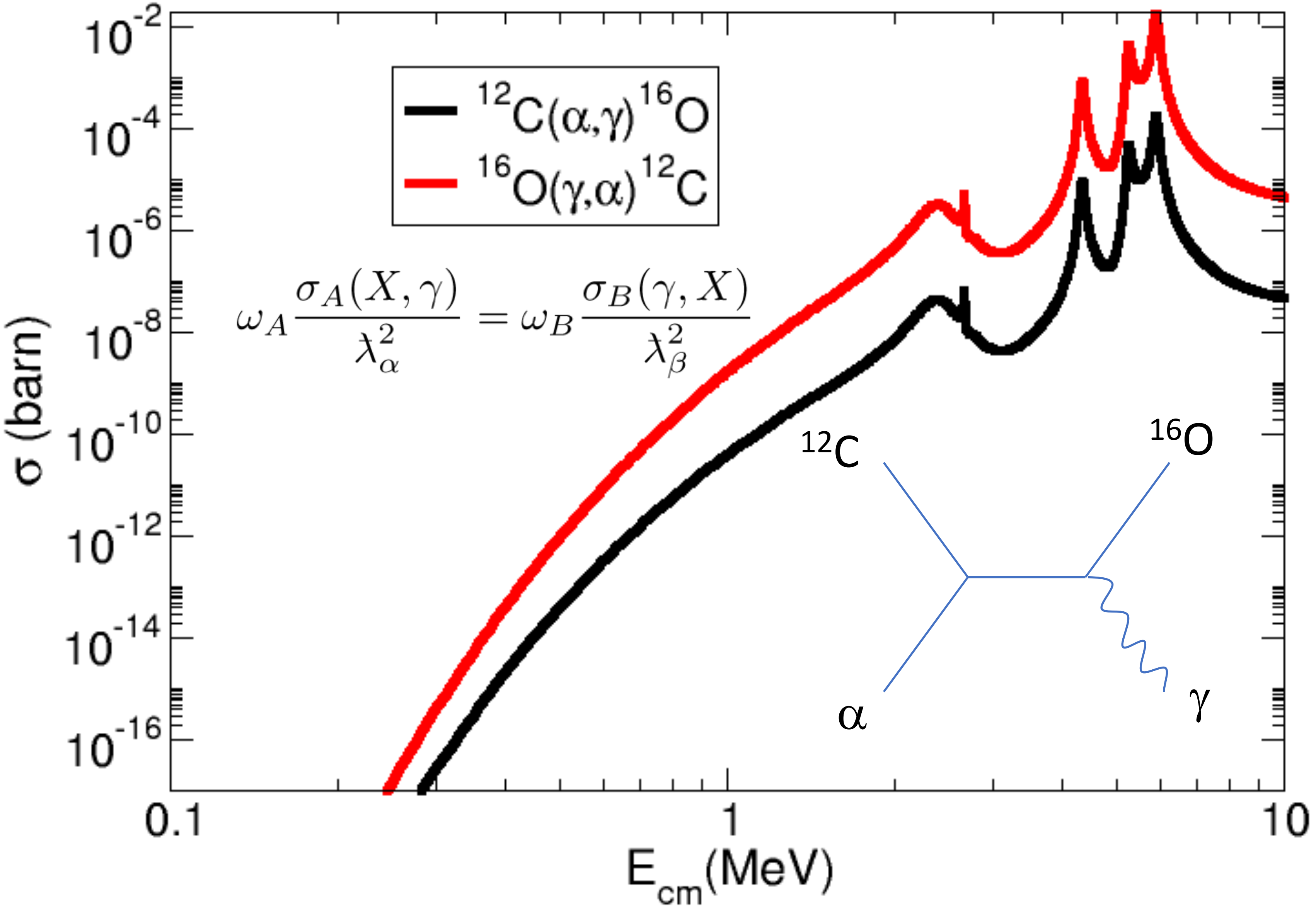
Time reversal symmetry: x100 gain in cross section



Our approach:
Inverse reaction + Bubble chamber + γ ray beam

beam | target | signal

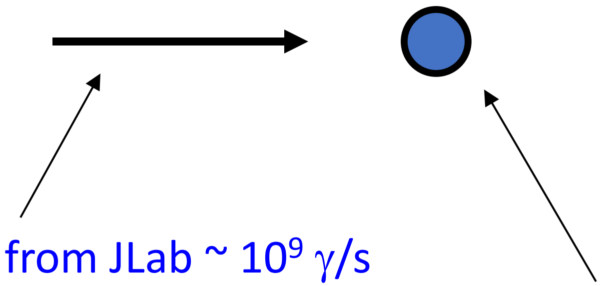
$$\gamma + {}^{16}O \dashrightarrow {}^{12}C + \alpha$$

•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})

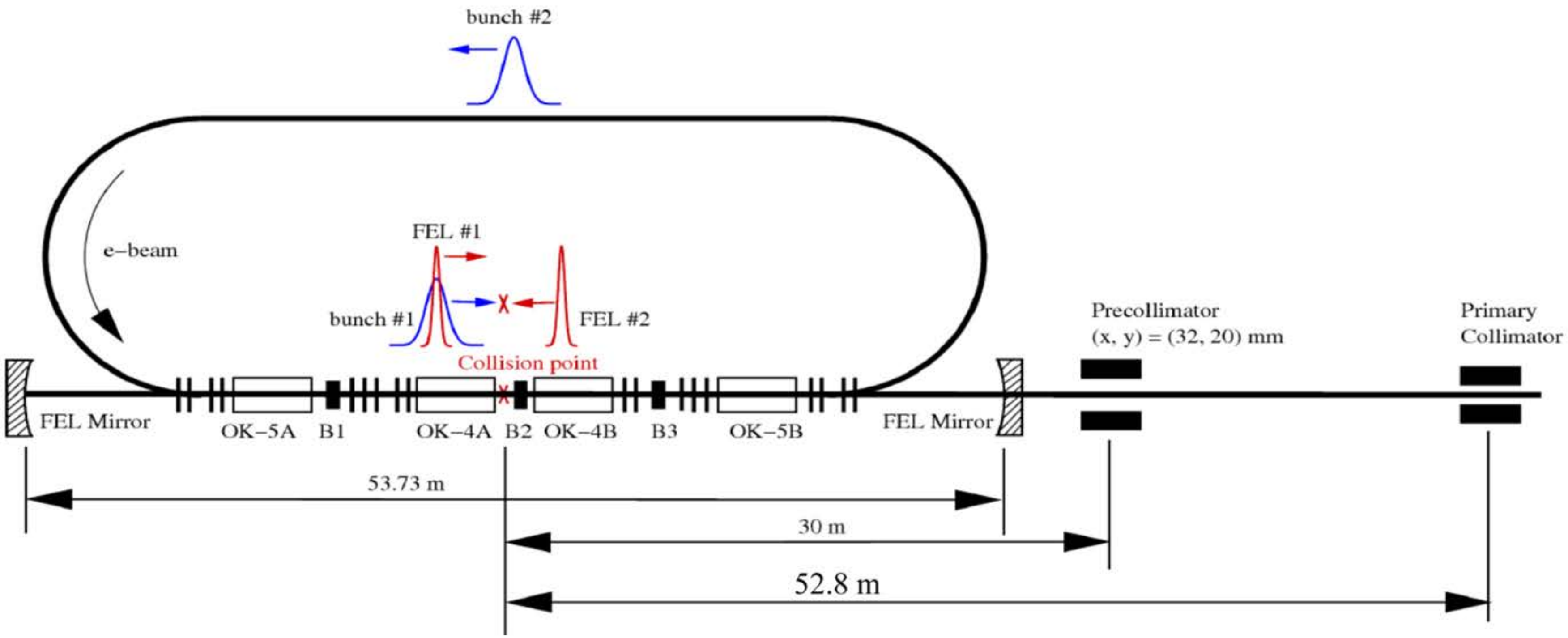


Bremsstrahlung from JLab ~ 10^9 γ/s (top 250 keV)

Oxygen bubble chamber

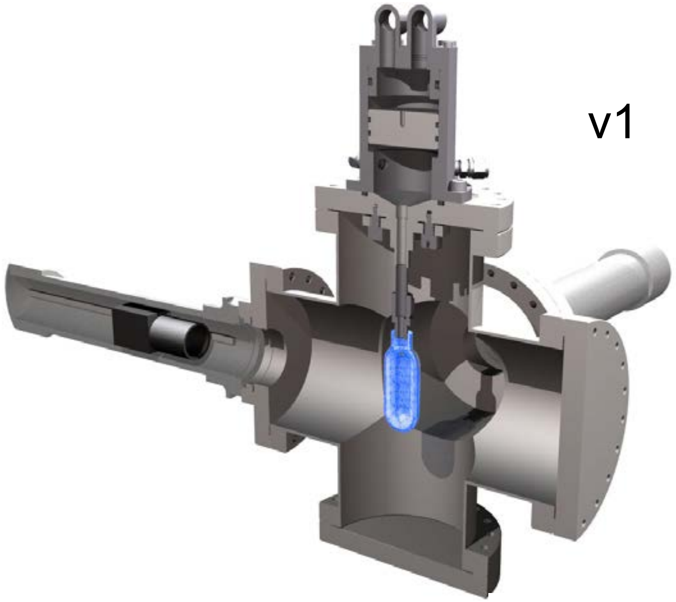
2010-2013 experiments at HIγS

HIγS Photon Beam

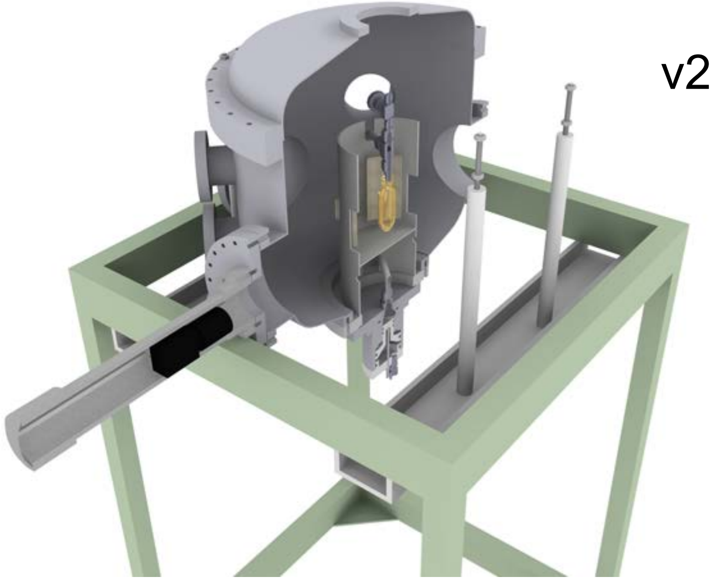


Liquids tested

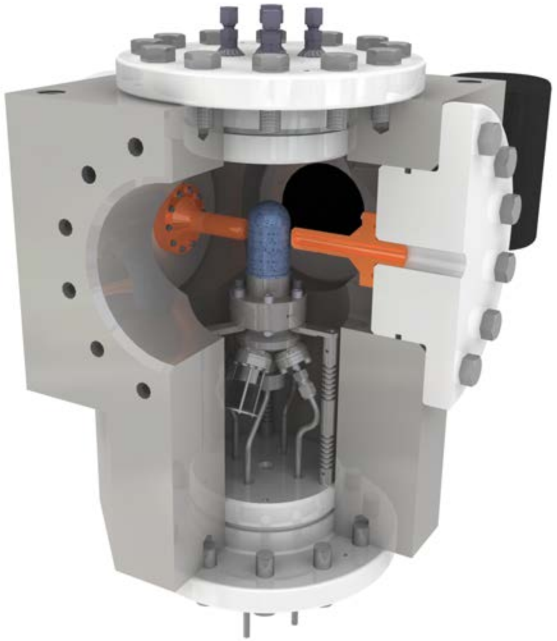
- CH_2FCF_3
- C_4F_{10}
- H_2O
- N_2O
- CO_2



v1

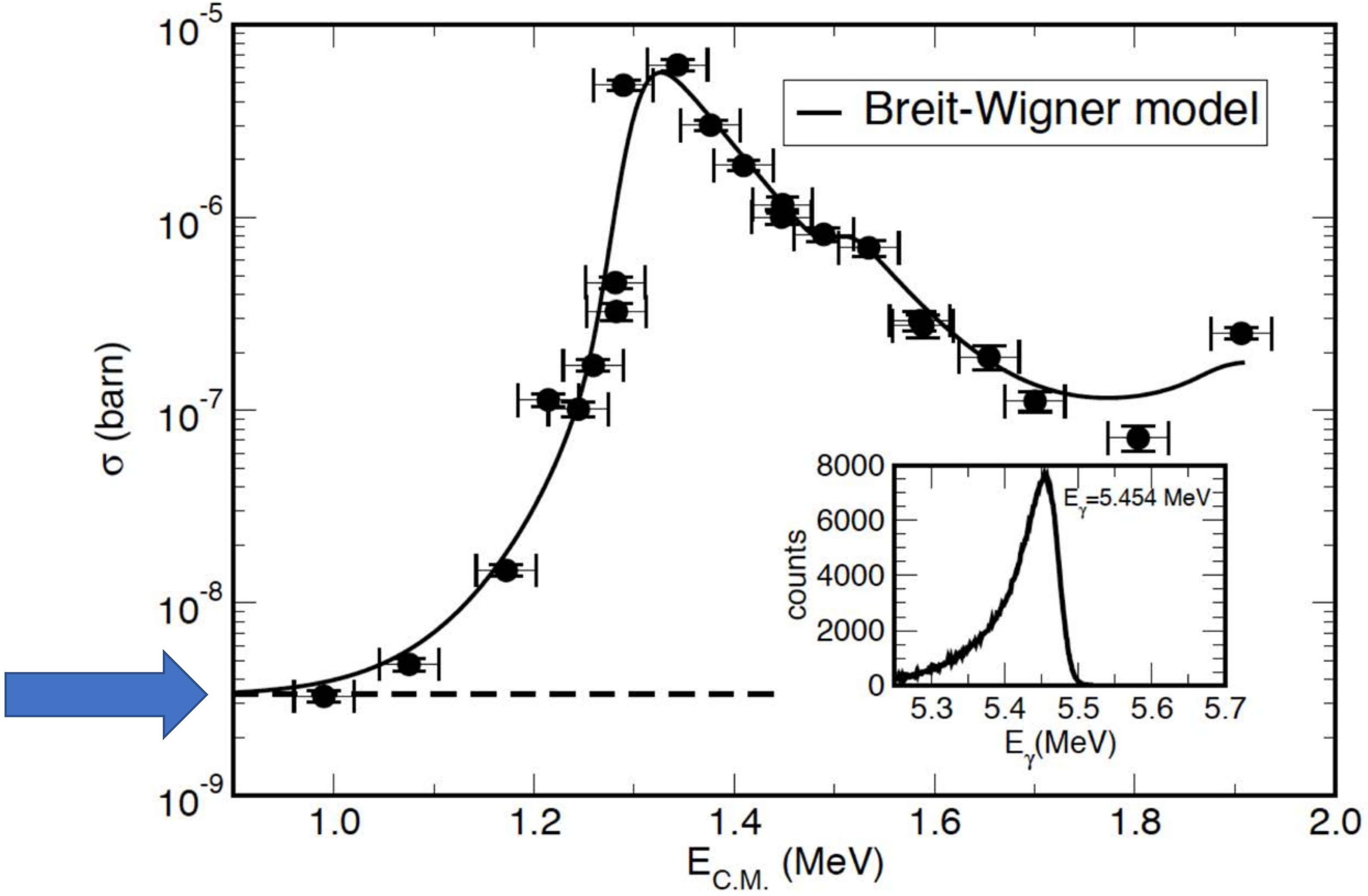


v2



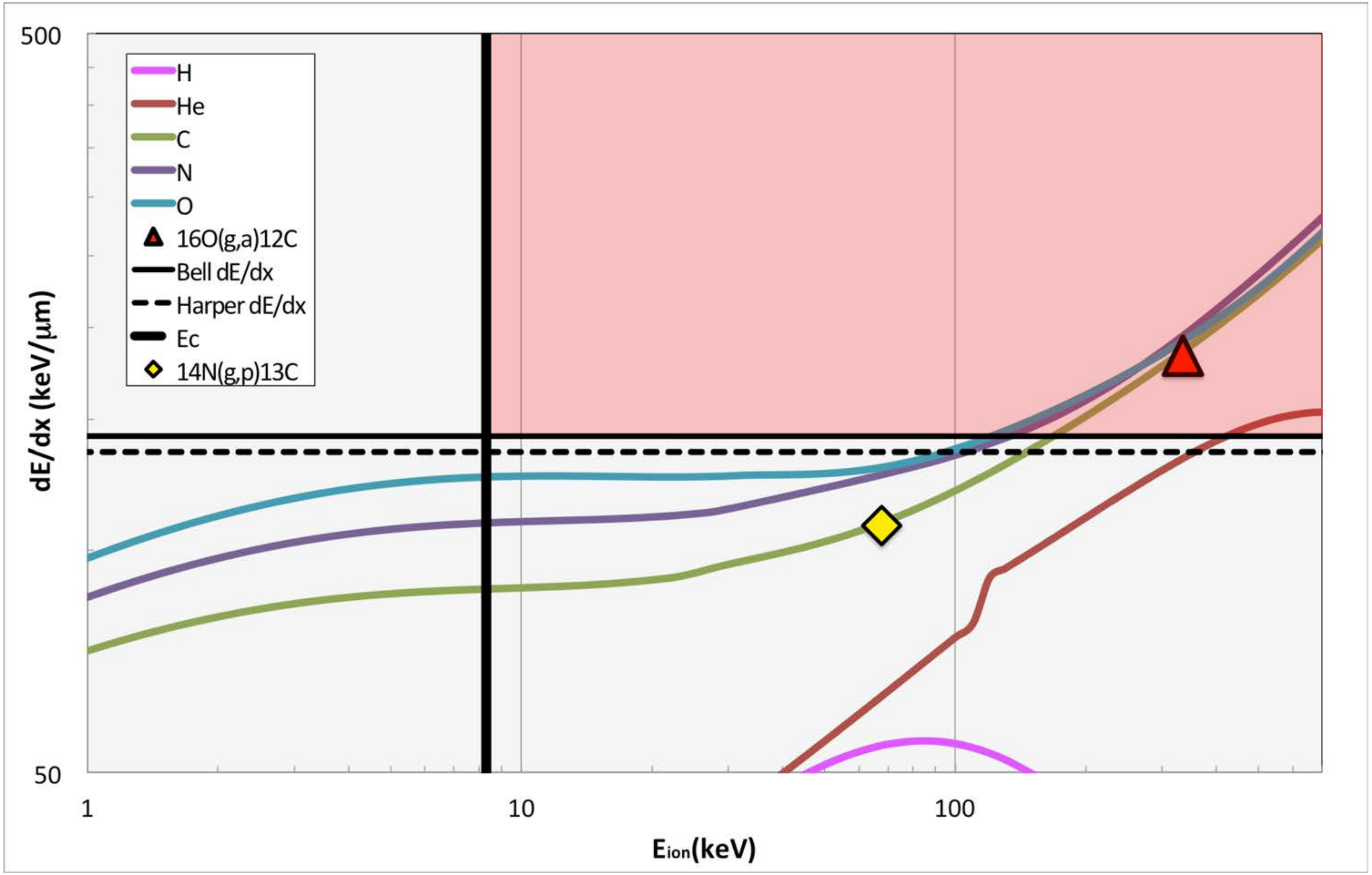
v3

$^{19}F(\gamma,\alpha)^{15}N$

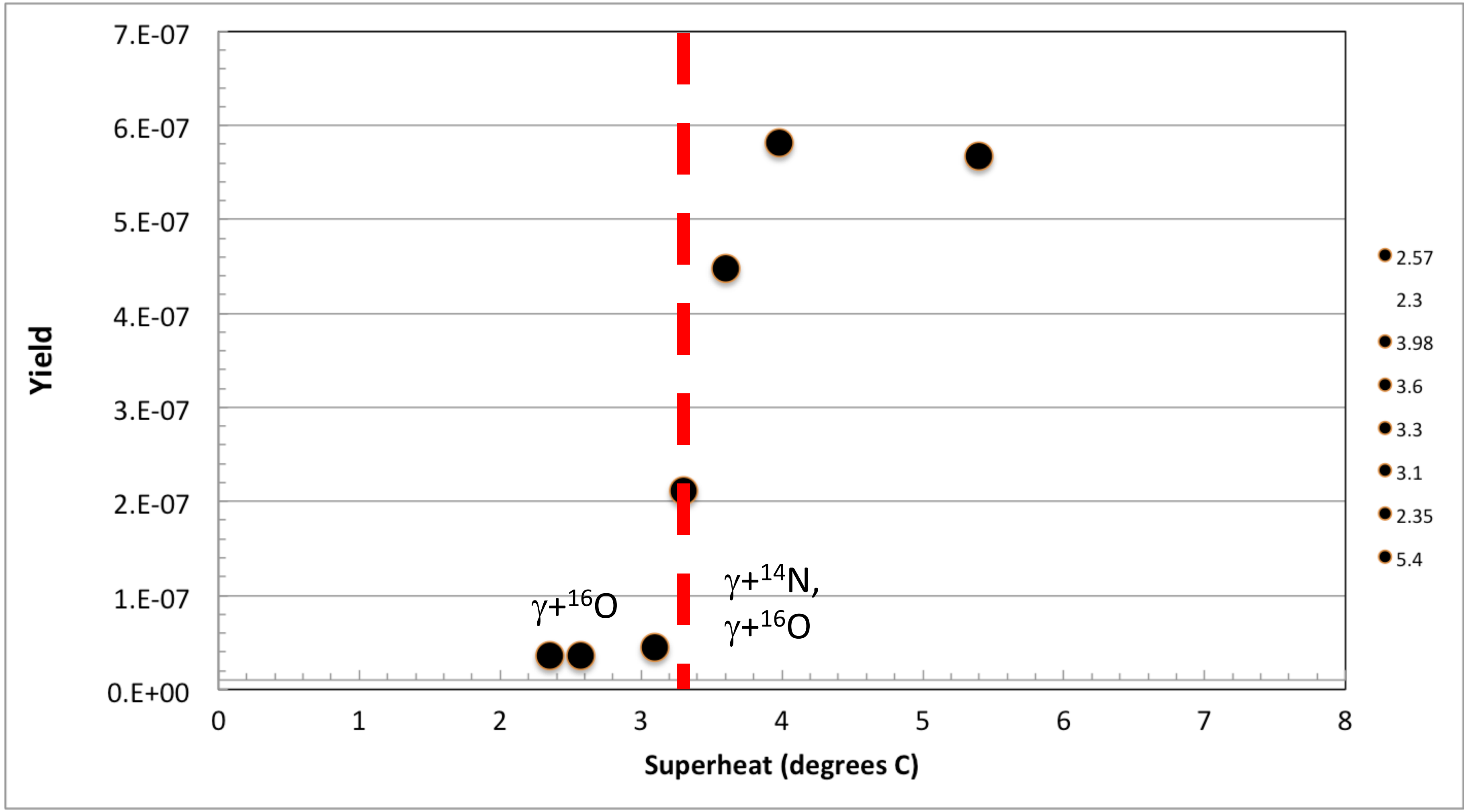


Bremsstrahlung

N_2O thresholds, Superheat = 3.3 ^{O}C, Eγ=8.5 MeV

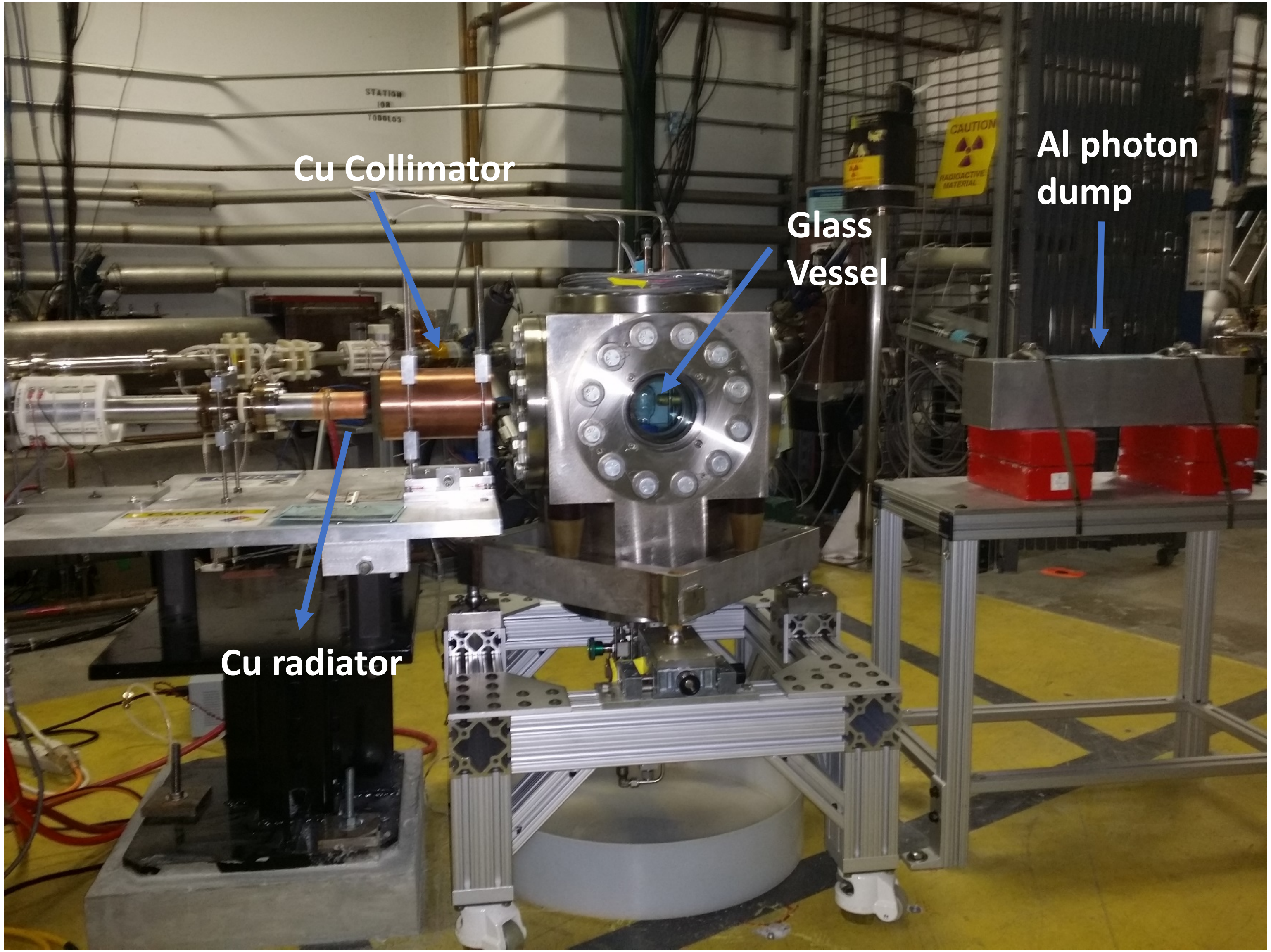


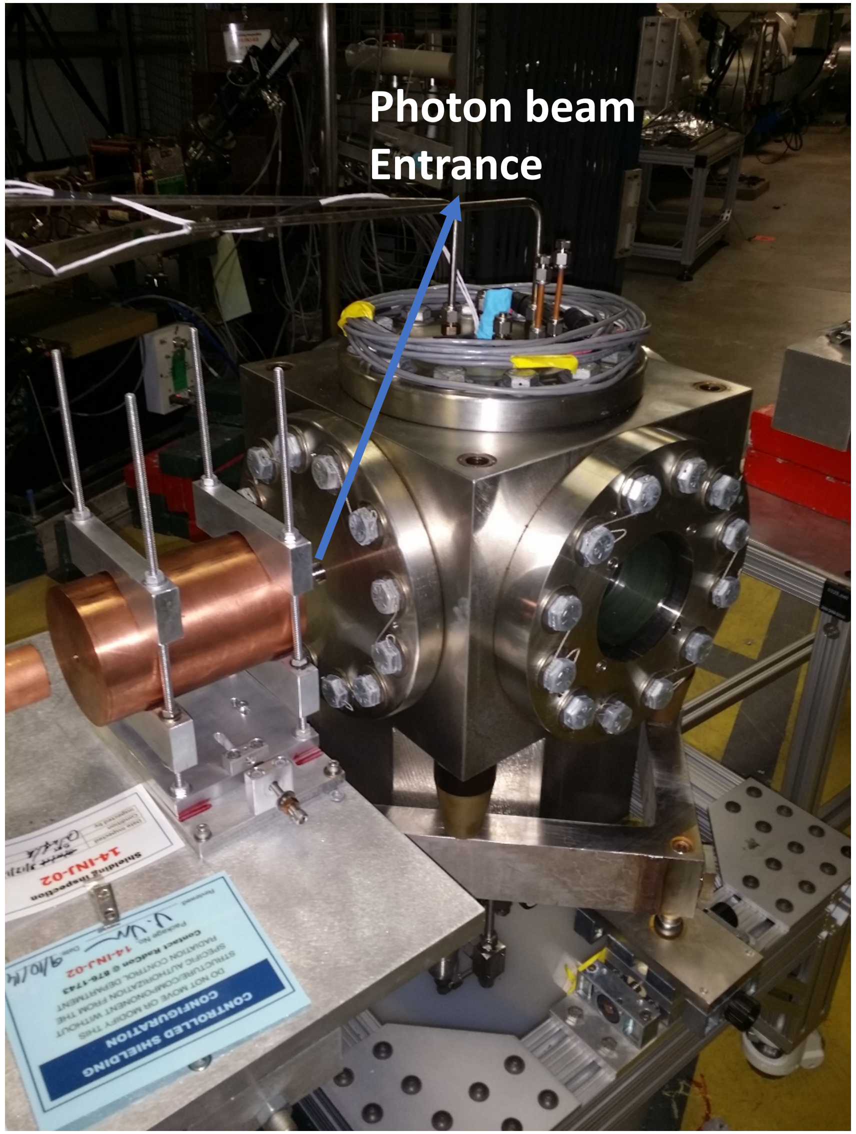
N_2O efficiency curve, HIγS April 2013. $E\gamma$ = 9.7MeV



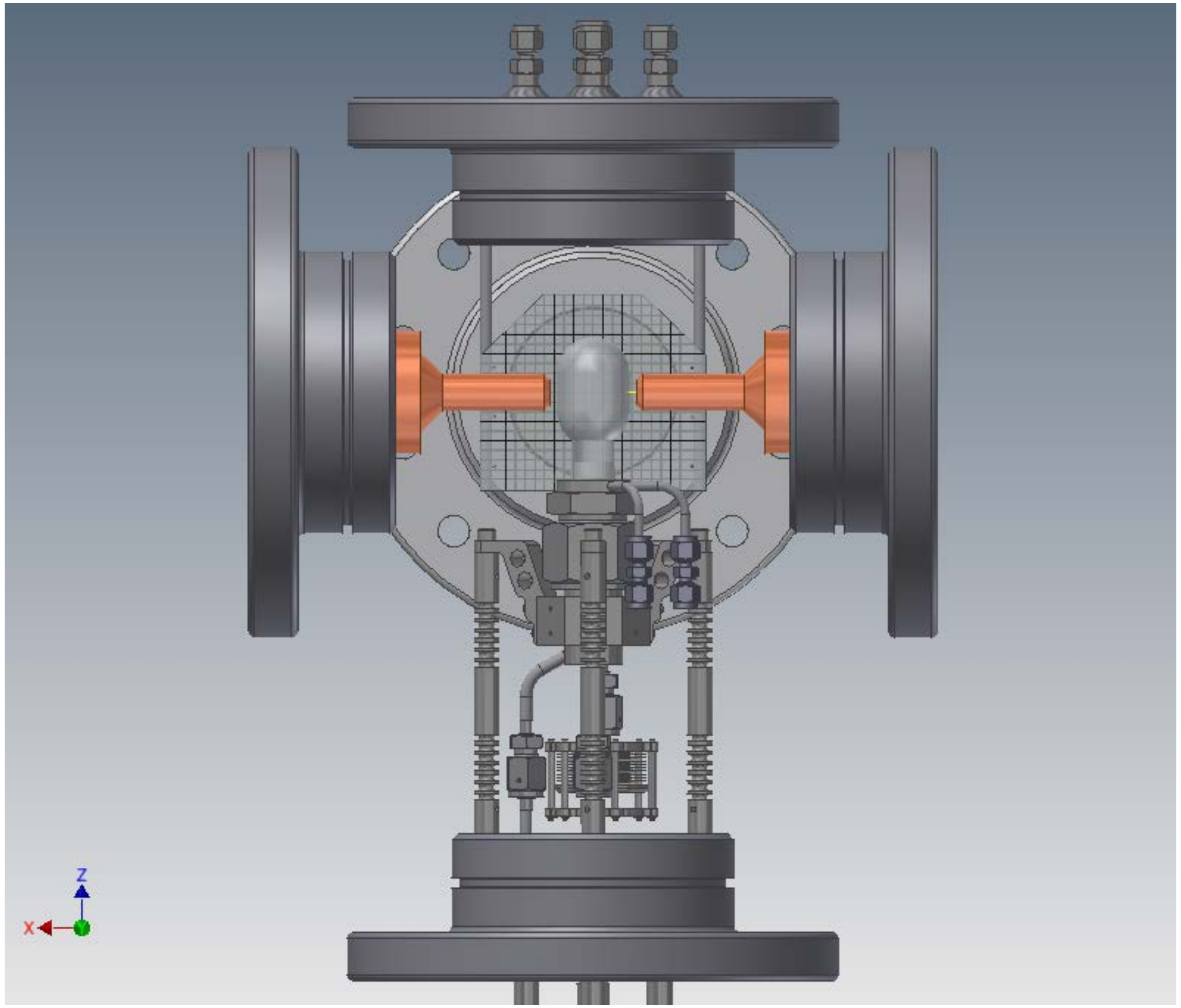
September 2015 experiments at JLab

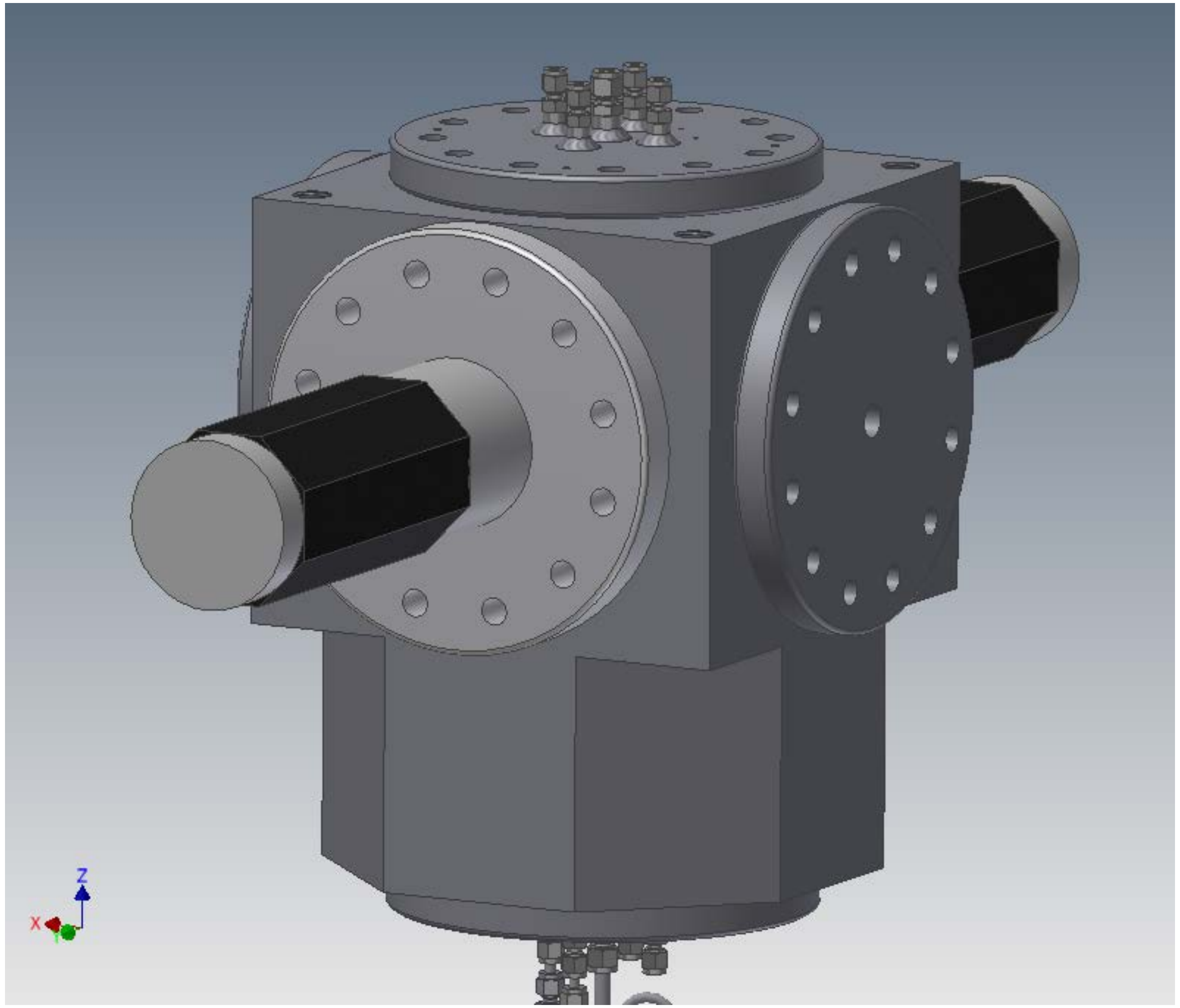
Experimental Set-Up for the N_2O Bubble Chamber





Mechanical Design of the Bubble Chamber





Fluids in the Glass Vessel

Active Fluid :

- Molecular content of target ions should be maximized
- Transparent liquid is a convenient choice for using optical imaging techniques to detect the bubble events

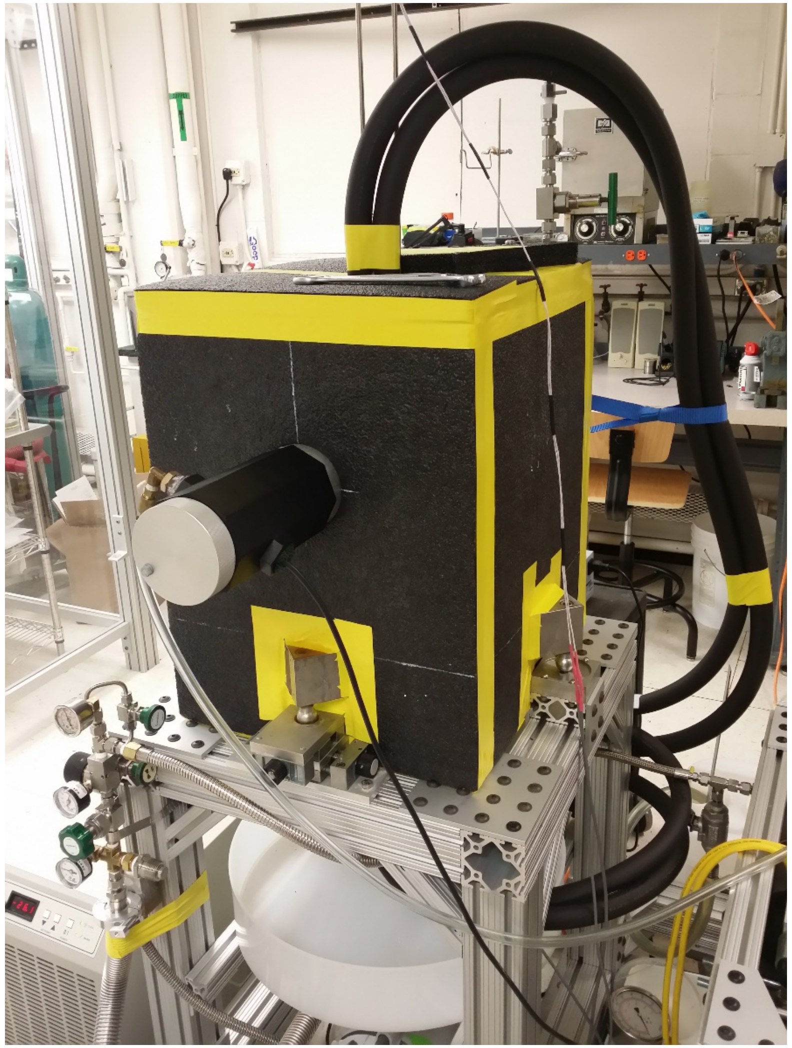
Buffer Fluid :

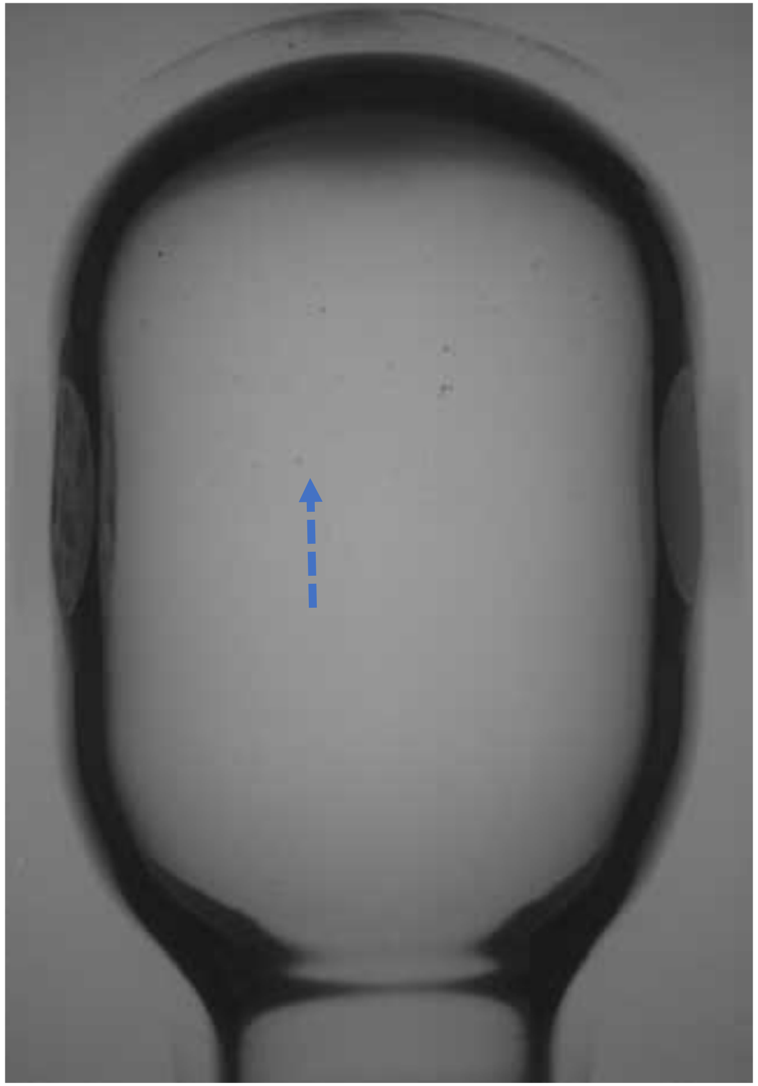
- It must be immiscible with active fluid to form a meniscus
- Solubility between active fluid and buffer fluid must be very low
- It should not become superheated in the pressure/temperature range chosen for the experiment

The active fluid should be kept clean and must only come in contact with smooth surfaces. Therefore it is only allowed to come in contact with the glass pressure vessel or the buffer fluid which provides a smooth interface for the transmission of pressure changes from the hydraulic system.


Back
NI-IMAQdx Basics
What do you want to do?
Connect my camera
Configure my device
Set my remote image options
DAQmx
Example

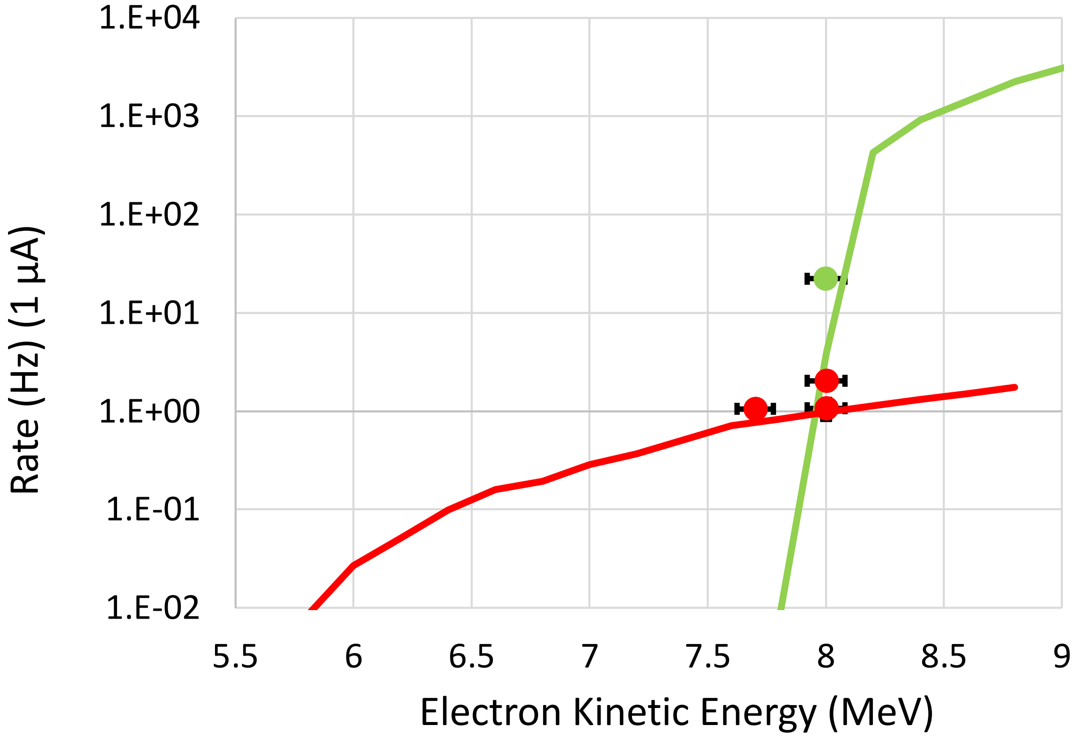
Bubble Formation and Data Acquisition

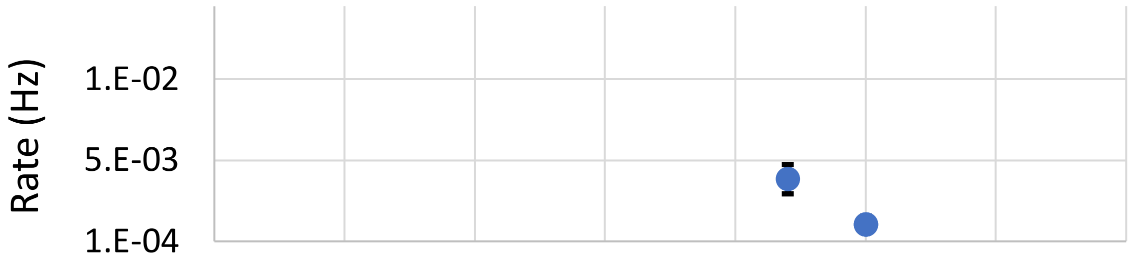




First Half of the Experiment

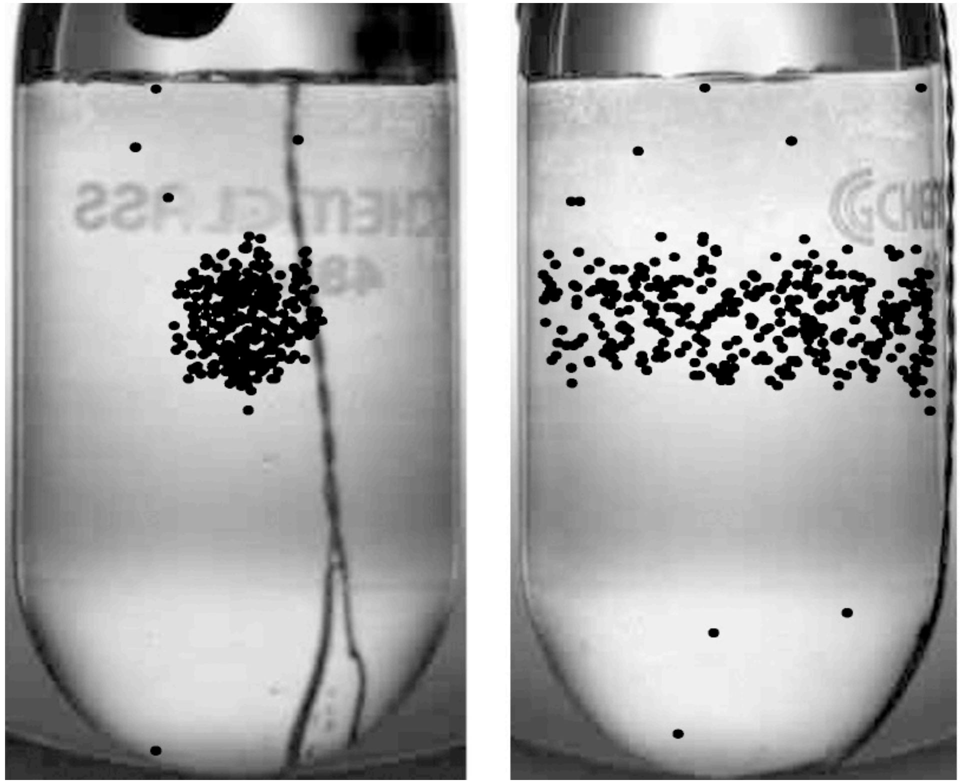
Energy Measured (MeV)	Superheat Pressure (psi)	Superheat Temperature (°C)	Beam Current (µA)
7.7	325	-8	0.4
8	325	-8	0.4
8	325	-8	0.04
8	310	-8	0.035



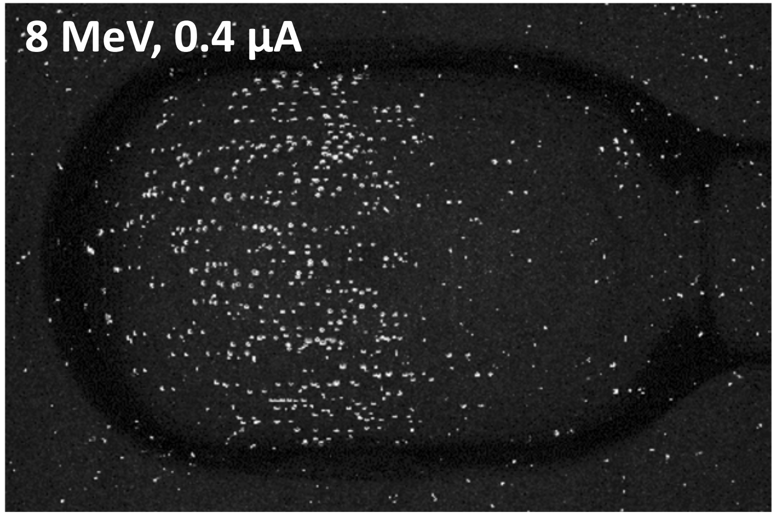


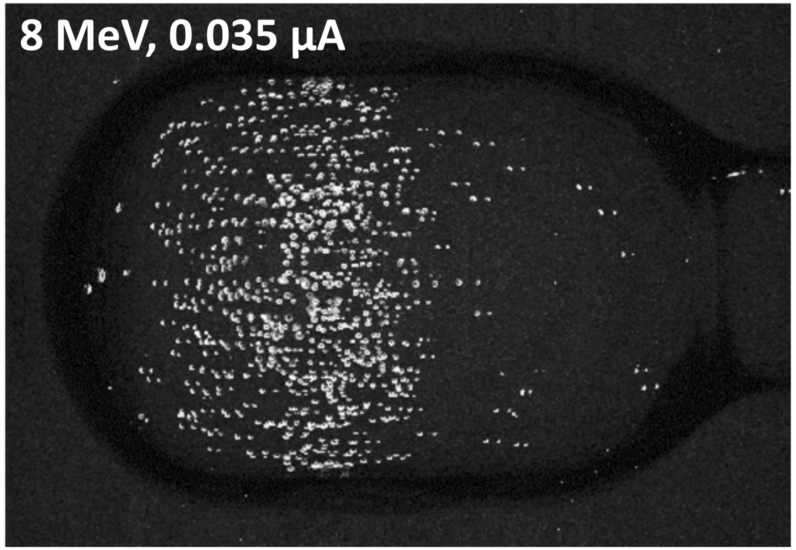
Bubble Distribution

HIγS Data



JLab Data





Experimental aspects that had to be improved

- At high beam currents (10 μA), we observed camera scintillation events
- During the last few days, beam induced background became very high throughout the volume of the bubble chamber: particulates from chemical reactions with Hg induced nucleation.
- Beam position was ambiguous.
- Mercury droplets on the glass vessel started forming

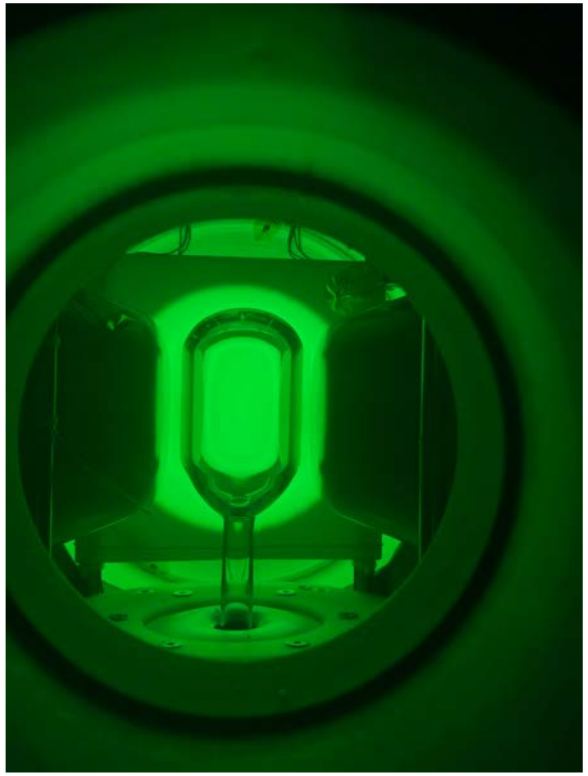
May 2018 experiments JLab

Improvements over previous generation bubble chamber

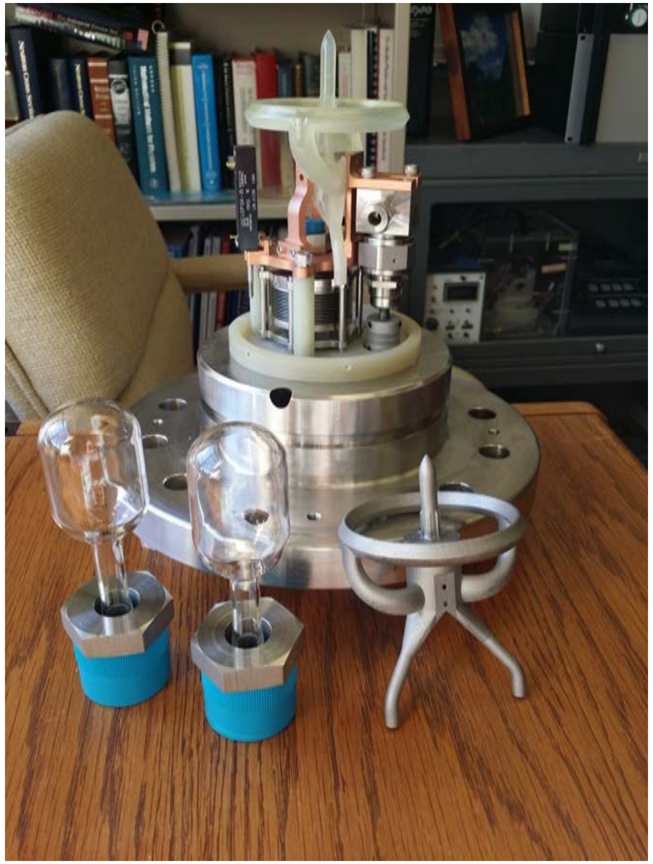
Switched from two-liquid bubble chamber to single fluid. This removed chemical interactions between superheated fluid and buffer fluid. Also removed accumulation of drops of buffer fluid (mercury) on glass wall.

Lead shielding of video camera from scattered γ-rays.

Improved system of beam collimators and determination of beam parameters (current, momentum, position).



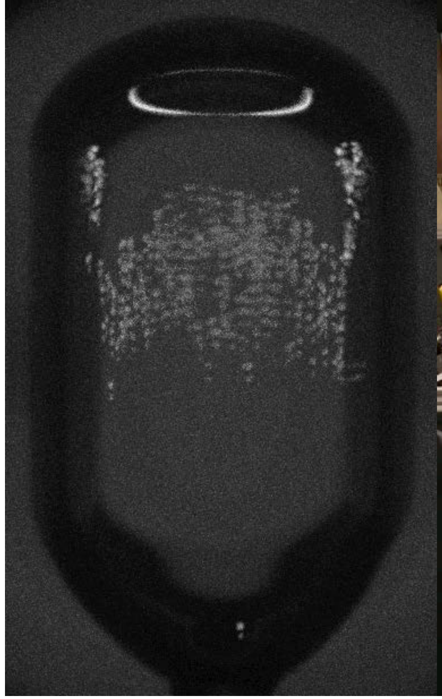
All were implemented successfully.

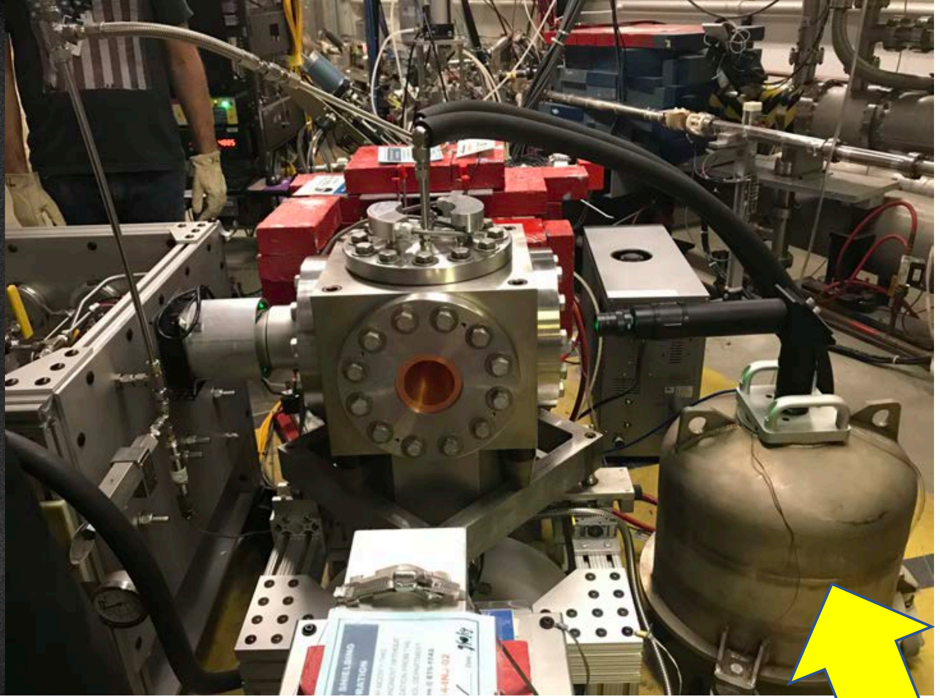


May 2018 Run
Jefferson Lab

C_3F_8

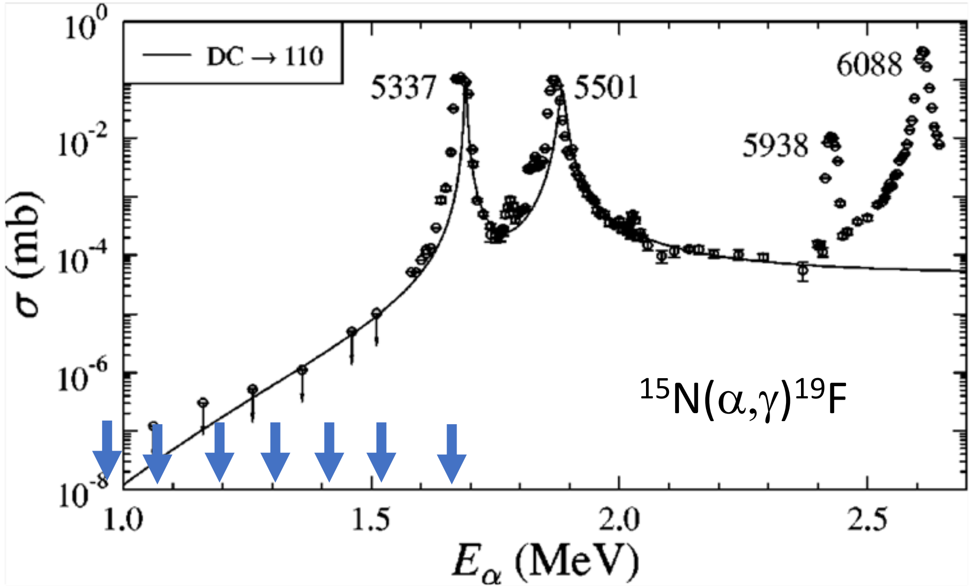
p ~ 5.5 MeV/c





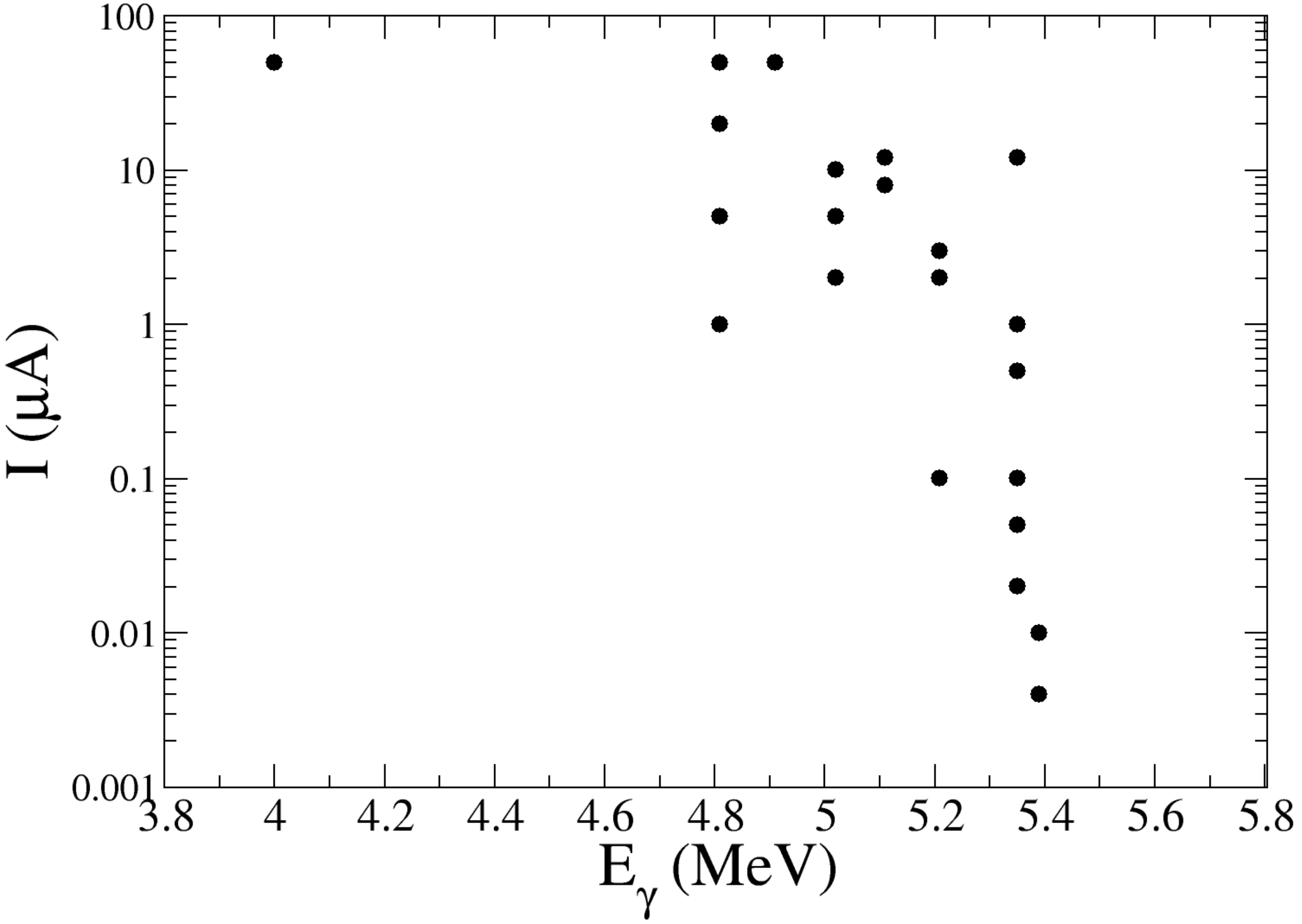
- Easier to work with than with N_2O (Temperature and Pressure)
- We have measured these cross sections for $^{19}F(\gamma,\alpha)^{15}N$ before. This allowed us to test cross section unfolding.

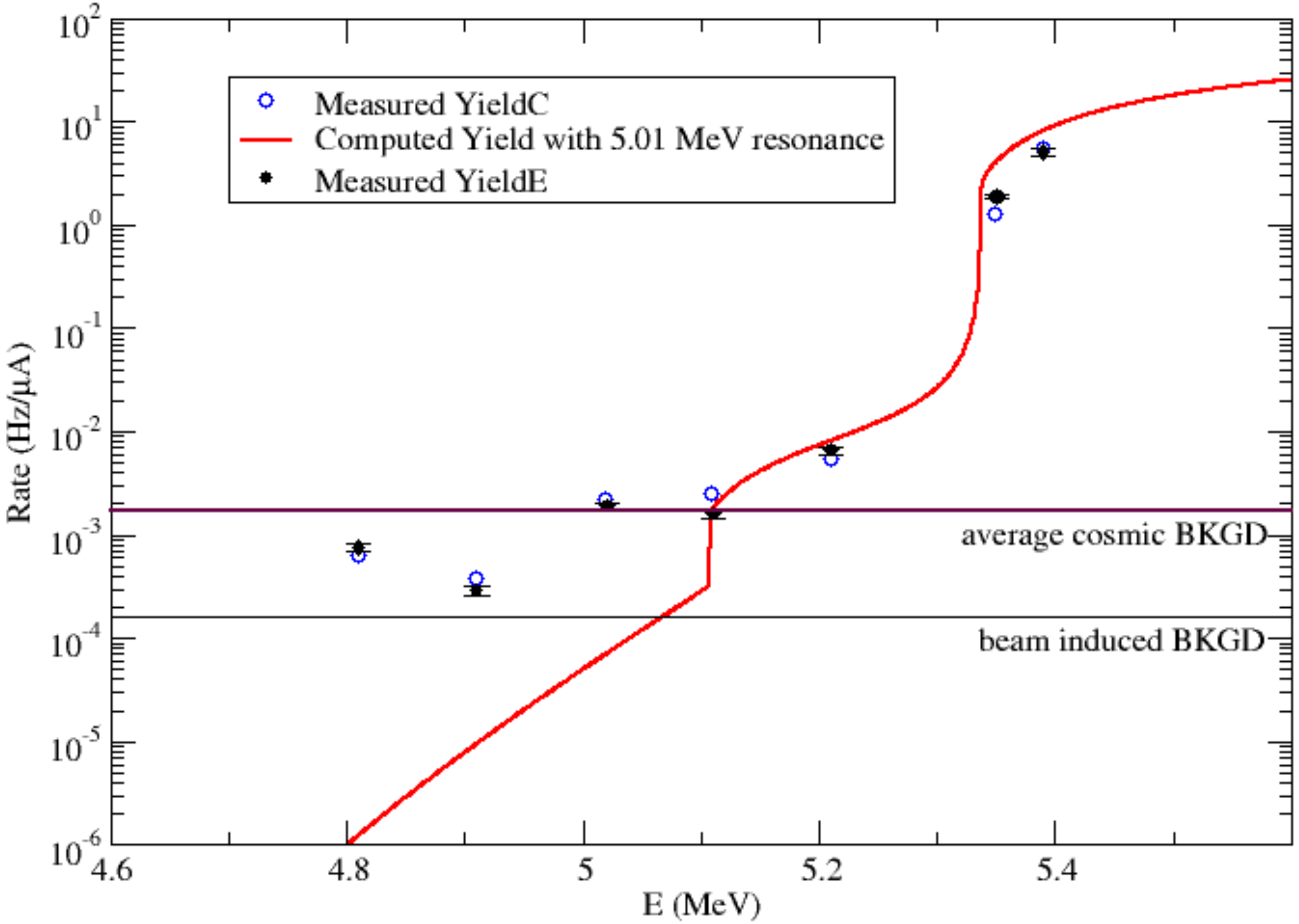
Wilmes et al. (2005)



Pb shielding of camera
Removed scintillation

Beam currents and intensities achieved





Measured YieldC
Computed Yield with 5.01 MeV resonance
Measured YieldE
average cosmic BKGD
beam induced BKGD
Rate (Hz/μA)
E (MeV)
10^2
10^1
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
4.6
4.8
5
5.2
5.4

Conclusions

- Single liquid bubble chamber commissioned successfully.
- Level of sensitivity of the technique improved from 3 nb down to 80 pb
- We will require a campaign that consists of two engineering runs and one production run:

  a) a C_3F_8 run for removal of the beam induced backgrounds,

  b) a N_2O run as the active detector with natural oxygen (commission oxygen single liquid device)

  c) production run with oxygen depleted of the heavy ^{17}O and ^{18}O isotopes