An Accurate, but Novel Application of the Relative Flow Technique, Using a Moveable Aperture Source of Gas Atoms to Measure Elastic Electron Scattering Differential Cross Sections.

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- Basic electron scattering
  - -Experimental setup
  - -Basic scattering equation
- Variations employed in our experiment
  - -Moveable, collimated gas source
  - -Thin aperture gas source
- Relative flow technique
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  - -Experimental verification of principle
  - -Flow rate measurements
- Differential cross sections for Ethylene (C_2H_4)
  - -Incident energies of 2eV, 5eV, 10eV, 20eV, 30eV
- Conclusions

Basic Layout

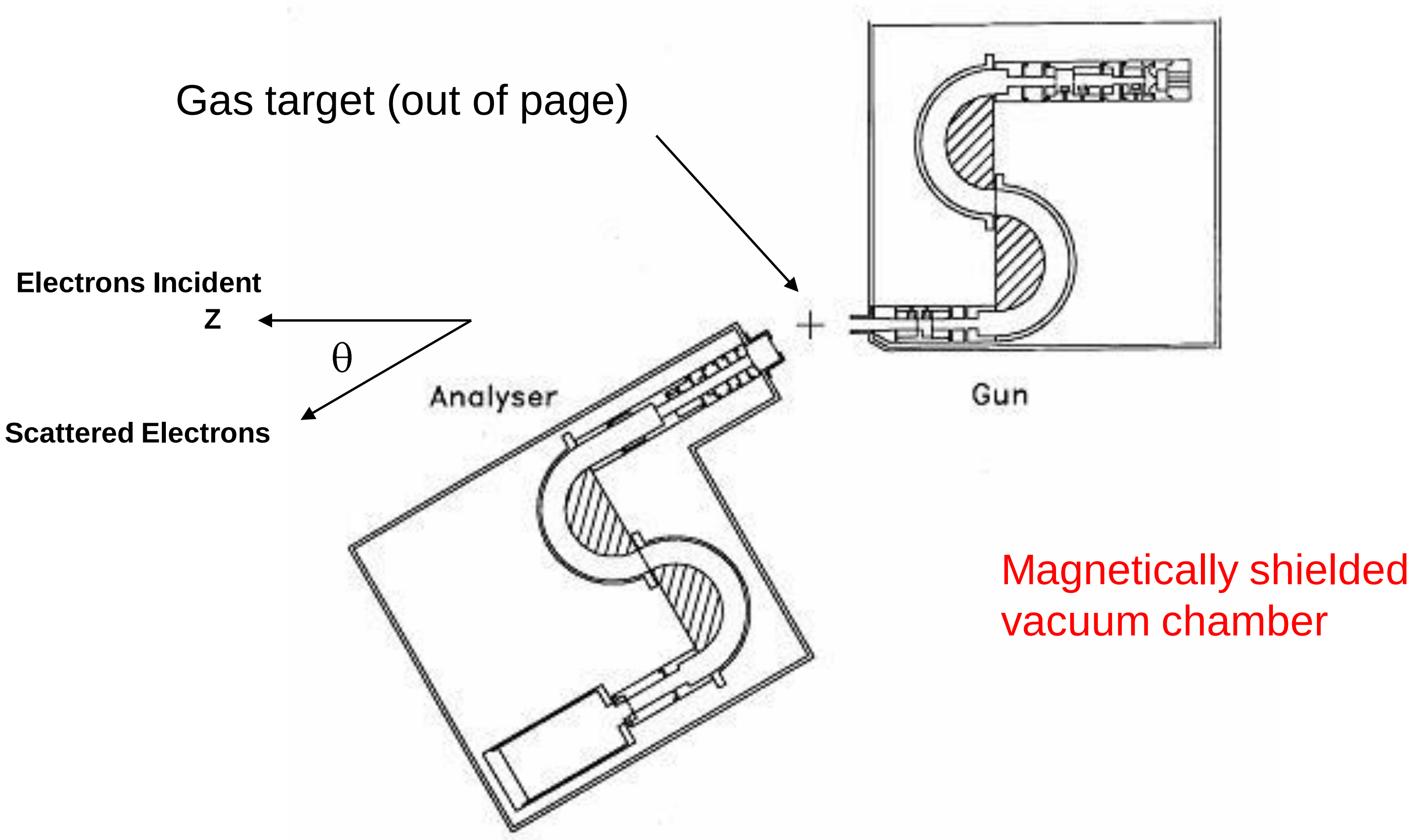
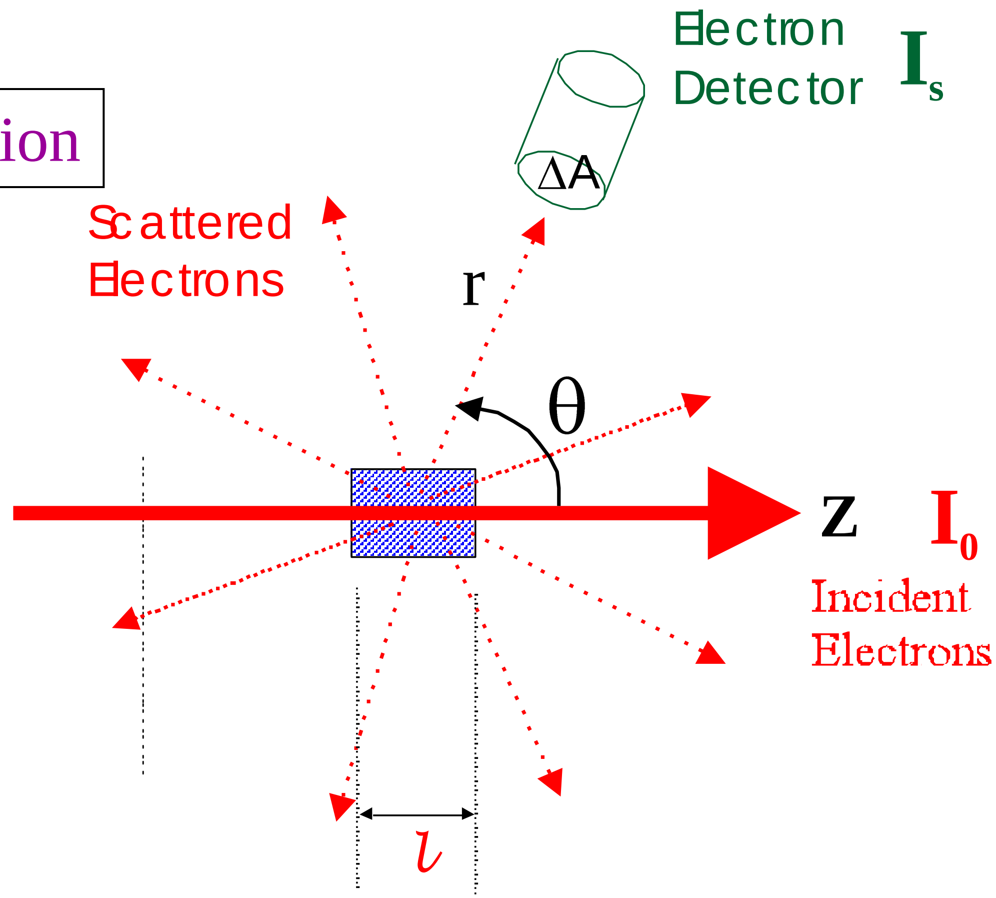


Diagram of our electron spectrometer

The Differential Cross Section

$$d\sigma/d\Omega\ (\theta)$$

n



Schematics of Experimental Setup

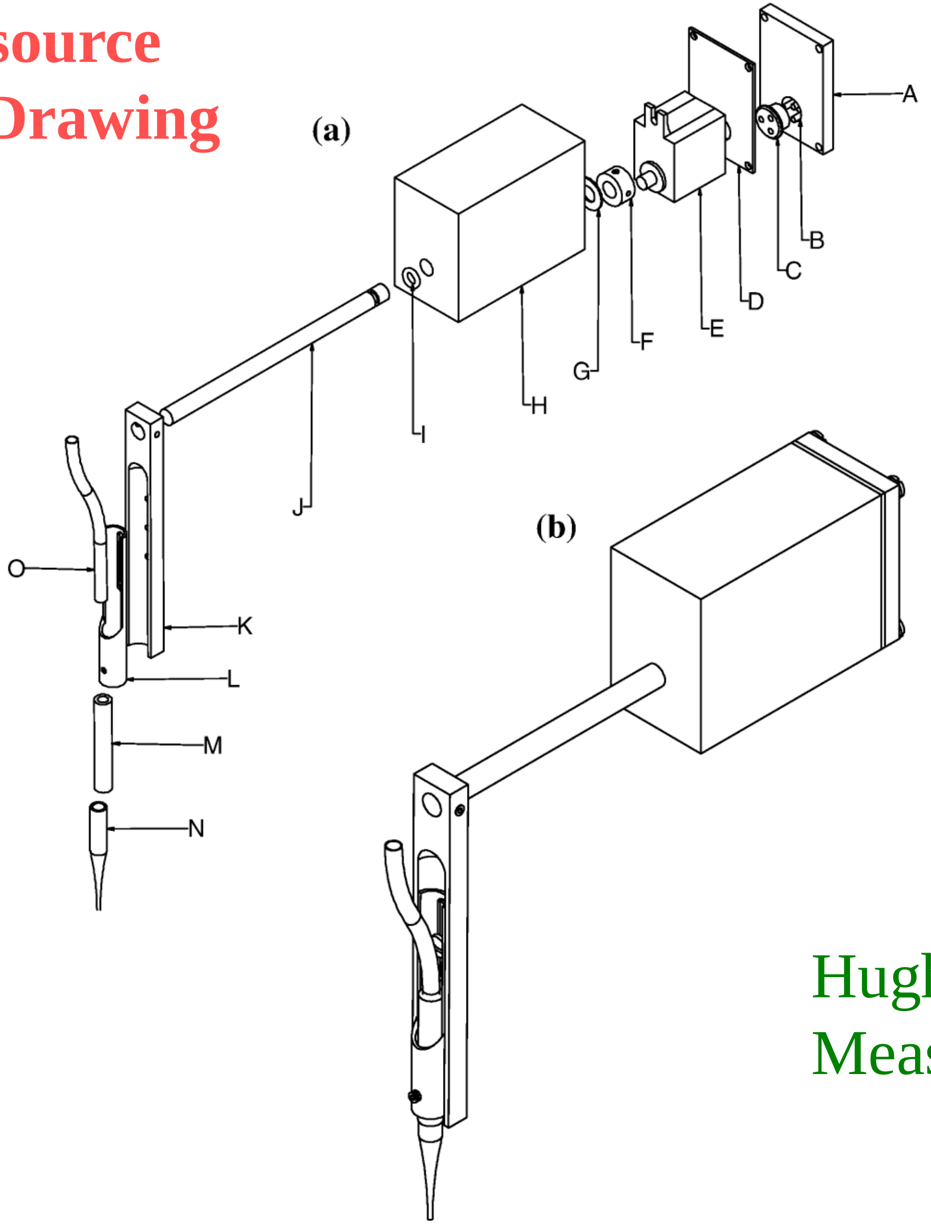
$$\Delta\Omega = \frac{\Delta A}{r^2}$$

$$I_S = I_0 \ n \ l \ \frac{d\sigma}{d\Omega} \ \Delta\Omega$$

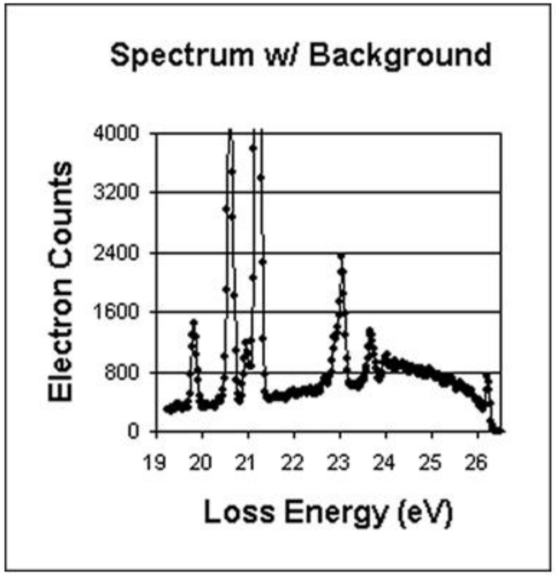
Units: I_o (s^{-1}), I_s (s^{-1}), n (cm^{-3}), l (cm)

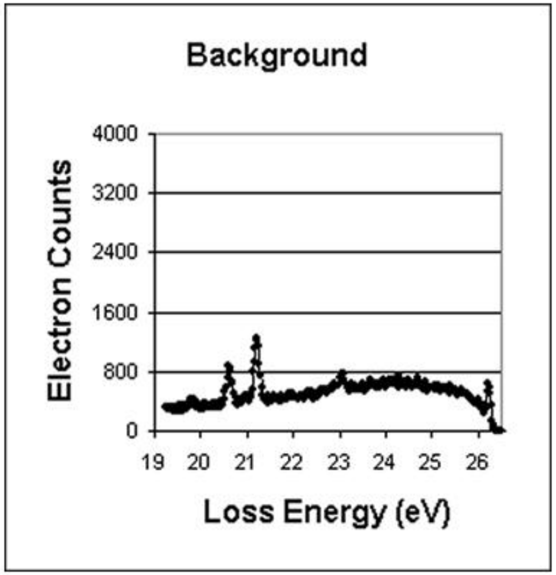
$d\sigma/d\Omega\ (\theta)$ (cm^2/sr)

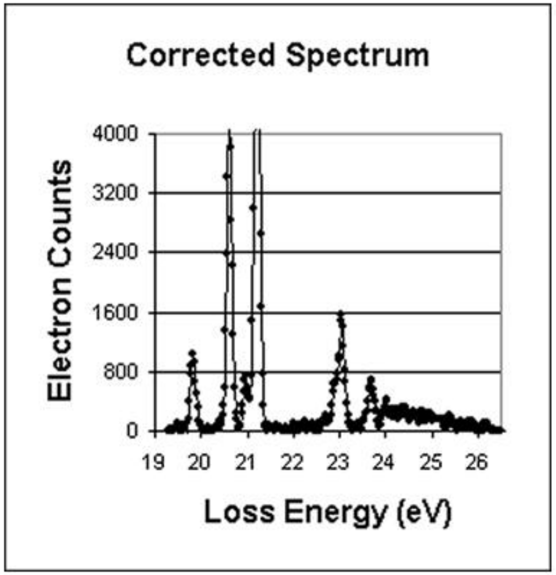
Moveable source Assembly Drawing

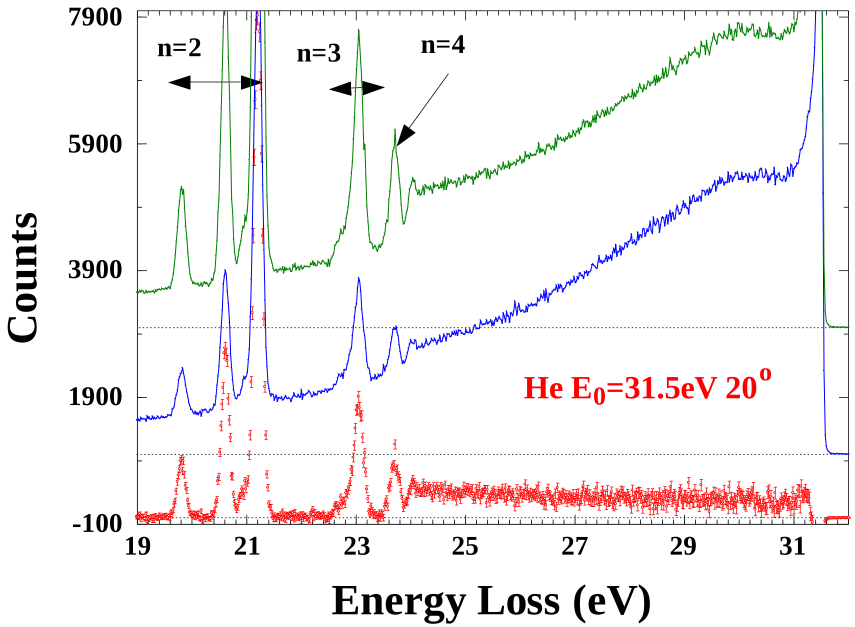


Hughes *et al*. 2003
Meas. Sci. & Tech.









Helium
Schow et al. 2005, CSUF.

Relative Flow Method

Flow standard gas (He)

Measure scattered signal

Flow gas X with the same gas distribution

Determine DCS for X:

$$DCS_X(E_0,\theta) = DCS_{He}(E_0,\theta)\frac{RFR_{He}\;\; Is_X}{RFR_X\;\; Is_{He}}\sqrt{\frac{M_{He}}{M_X}}$$

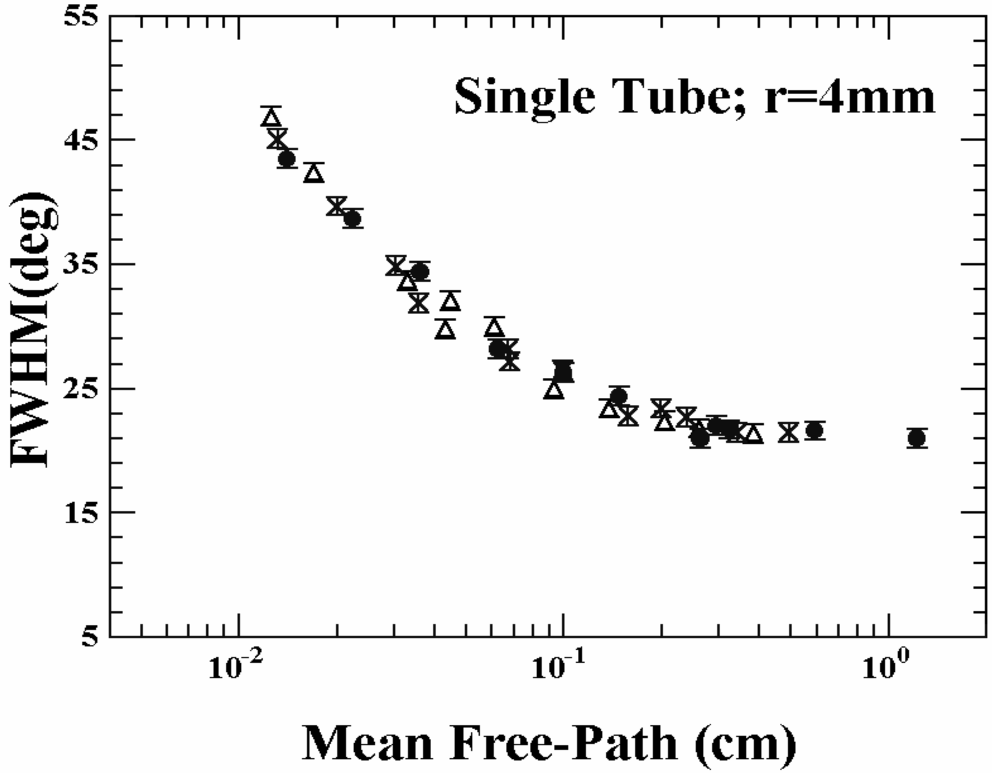
Mean Free Path Issue

$$\lambda = \frac{1}{\sqrt{2}\pi n \delta^2}$$

δ is the Gas Kinetic Molecular Diameter

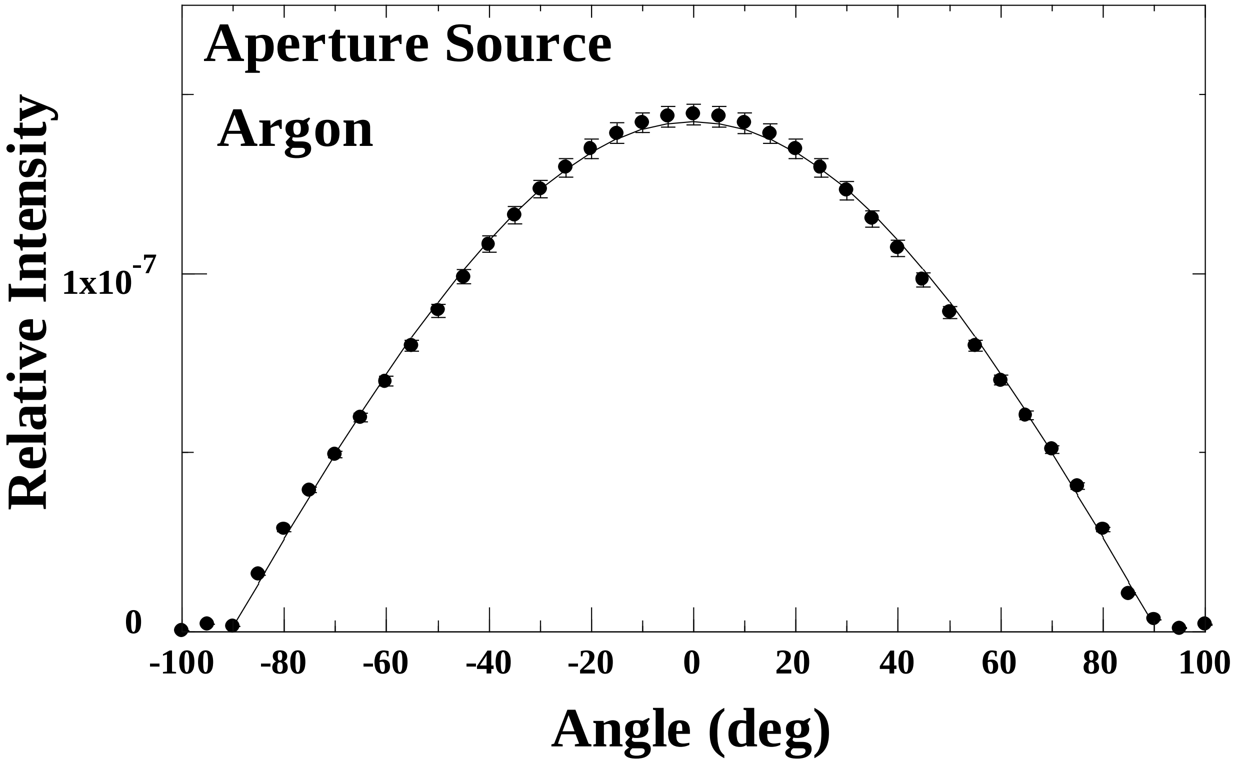
- Olander and Kruger (1970) – Angular profile (FWHM) of gases for tubes dependent on the mean-free path.
- Rugamas et al. (2000) Experimental evidence

Profiles vs. Mean-Free Path



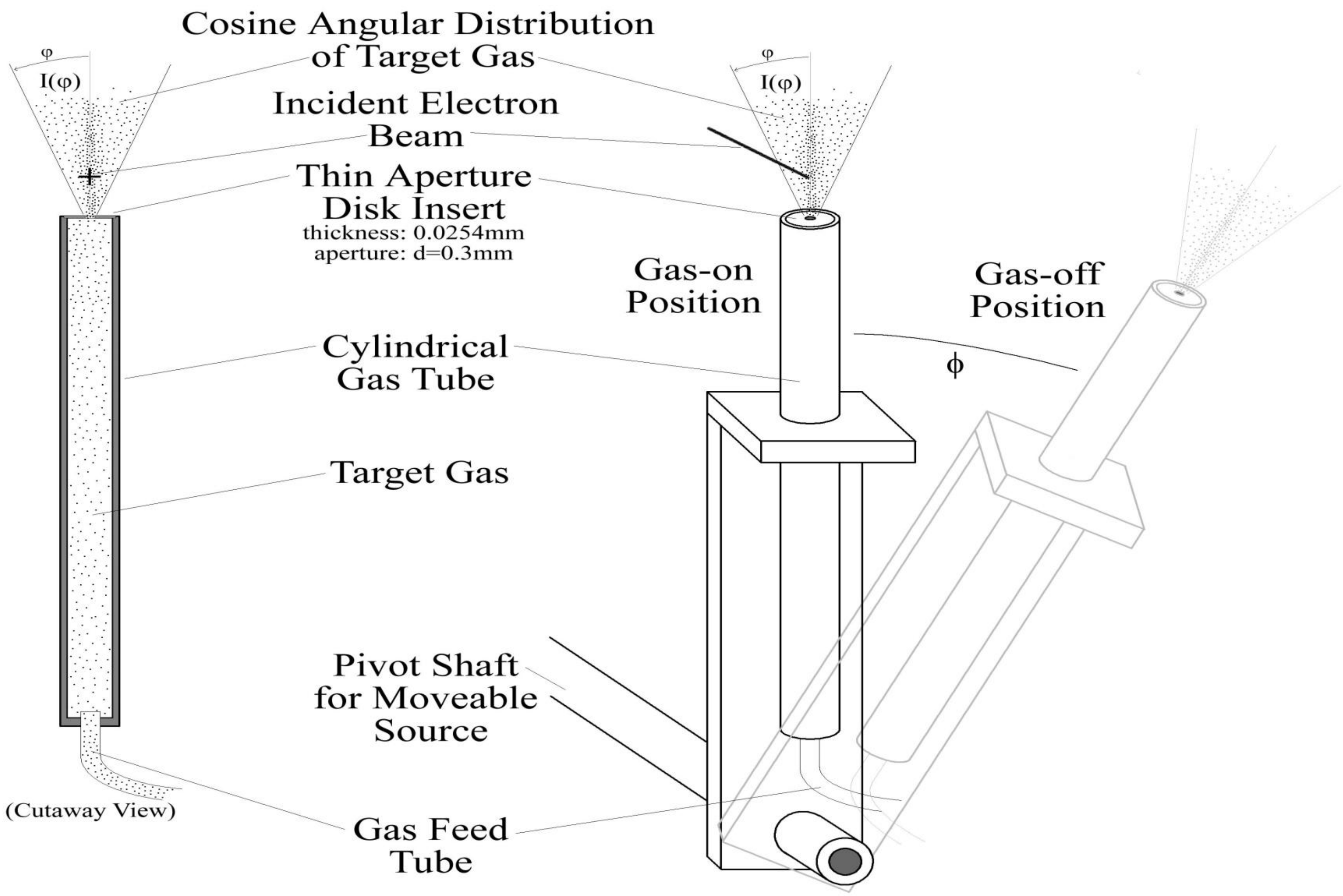
Rugamas et al. (2000)

Gas Distribution of a Thin Aperture Source



Rugamas et al. (2000) CSUF

Thin-Aperture Moveable Gas Source



Transformation of Basic Scattering Equation

$$I_s = I_o\, n\, l\, \frac{d\sigma}{d\Omega}\, \Delta\Omega$$

Basic scattering amplitude from theory

Flow rate

$$\dot{N} = n\, A\, v$$

$$n = \frac{\dot{N}}{A\, v}$$

$$n = \frac{\dot{N}\sqrt{m}}{A\sqrt{3\, k\, T}}$$

$$\alpha = \frac{1}{A\sqrt{3\, k\, T}}$$

$$n = \alpha\, \dot{N}\sqrt{m}$$

RMS velocity

$$\frac{1}{2}\, m\, v^2 = \frac{3}{2}\, k\, T$$

$$v = \sqrt{\frac{3\, k\, T}{m}}$$

Ideal Gas Law

$$P\, V = N\, k\, T$$

$$\dot{P} = \frac{d}{dt}\left(\frac{N\, k\, T}{V}\right)$$

$$\dot{P} = \frac{k}{V}\left(N\, \dot{T} + \dot{N}\, T\right)$$

$$\dot{P} = \frac{k\, T}{V}\, \dot{N}$$

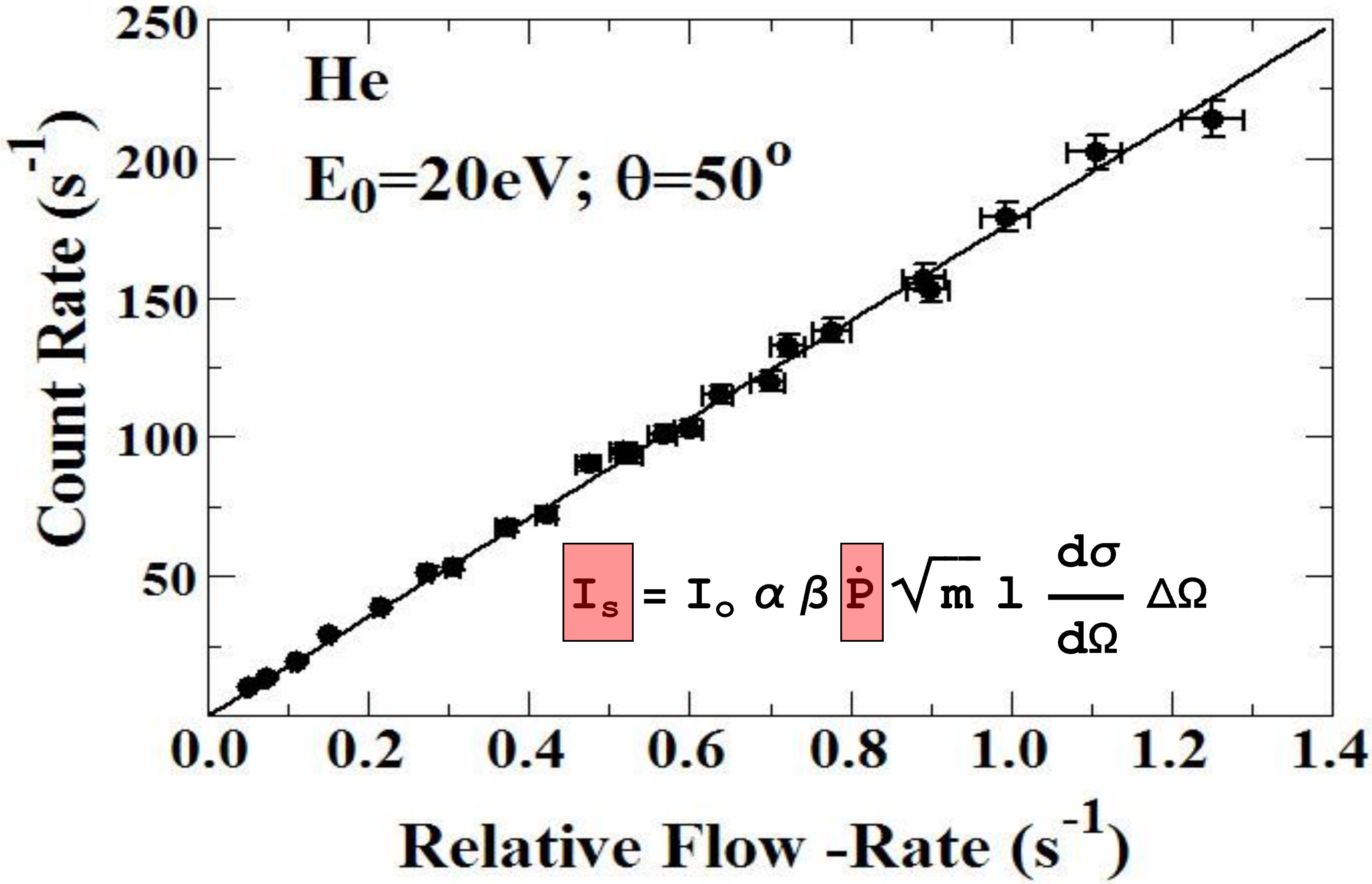
$$\beta = \frac{V}{k\, T}$$

$$\dot{N} = \beta\, \dot{P}$$

$$I_s = I_o\, \alpha\, \beta\, \dot{P}\sqrt{m}\, l\, \frac{d\sigma}{d\Omega}\, \Delta\Omega$$

New scattering equation

Experimental Verification



Differential Cross Section of Gas X

$$\frac{I_s^x = I_o^x \,\alpha_x\, \beta_x\, \dot{P}_x \sqrt{m_x}\; l_x \frac{d\sigma_x}{d\Omega} \Delta\Omega_x}{I_s^{He} = I_o^{He}\, \alpha_{He}\, \beta_{He}\, \dot{P}_{He} \sqrt{m_{He}}\; l_{He} \frac{d\sigma_{He}}{d\Omega} \Delta\Omega_{He}}$$

$l_x = l_{He}$ Same distribution of gas

$\alpha_x = \alpha_{He}$ Same aperture

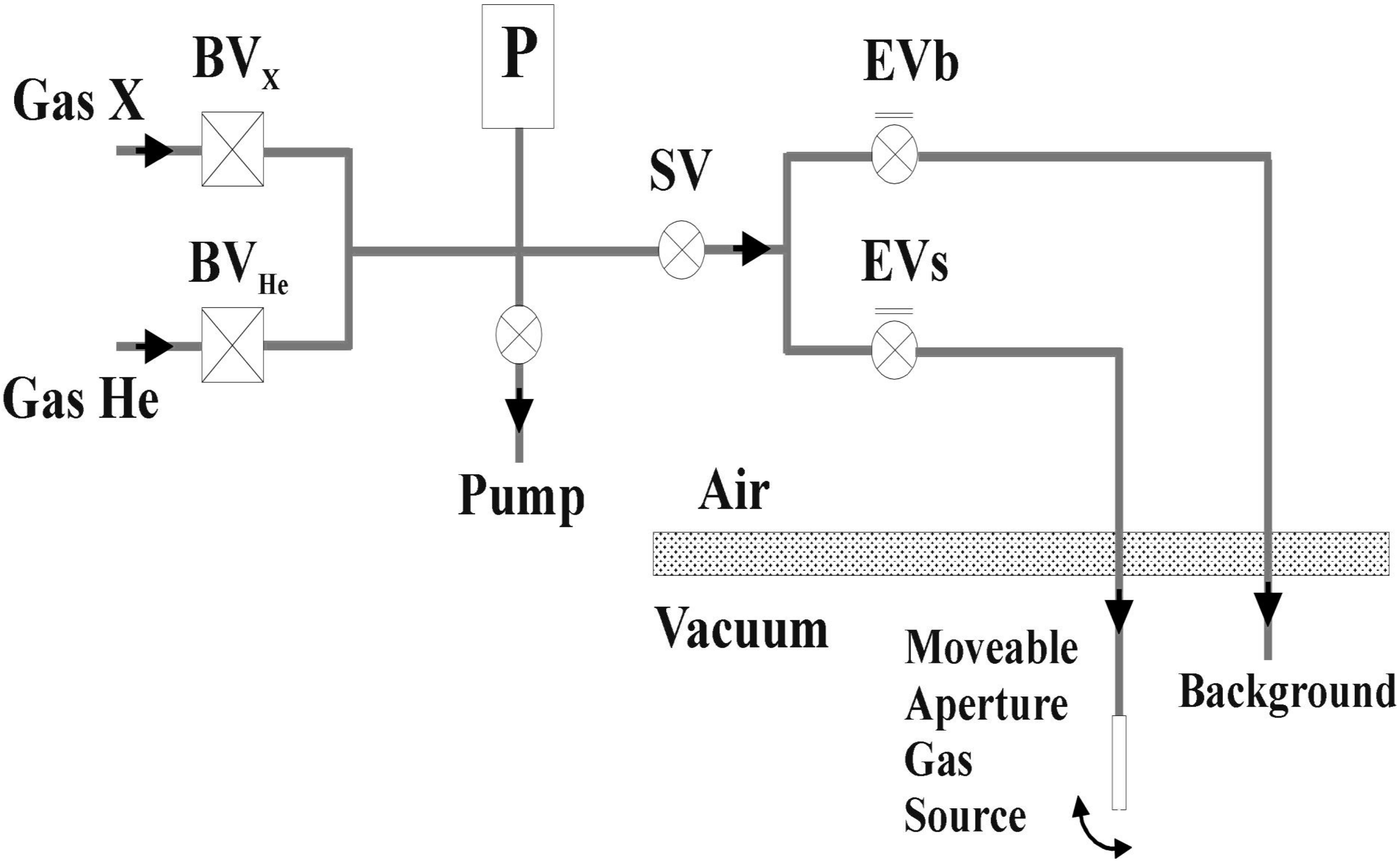
$\Delta\Omega_x = \Delta\Omega_{He}$ Same detector

$\beta_x = \beta_{He}$ Same system

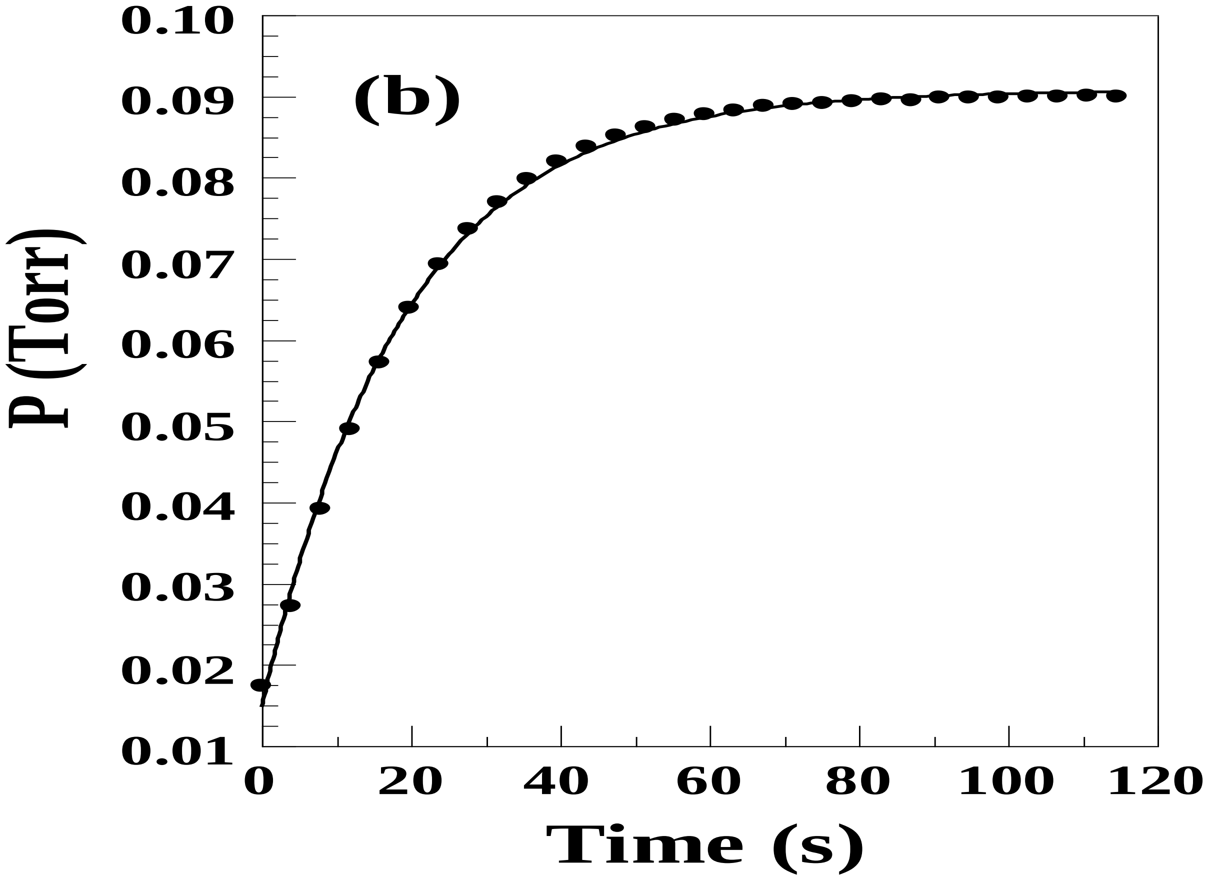
$$\frac{I_s^x = I_o^x \, \dot{P}_x \sqrt{m_x} \frac{d\sigma_x}{d\Omega}}{I_s^{He} = I_o^{He} \, \dot{P}_{He} \sqrt{m_{He}} \frac{d\sigma_{He}}{d\Omega}}$$

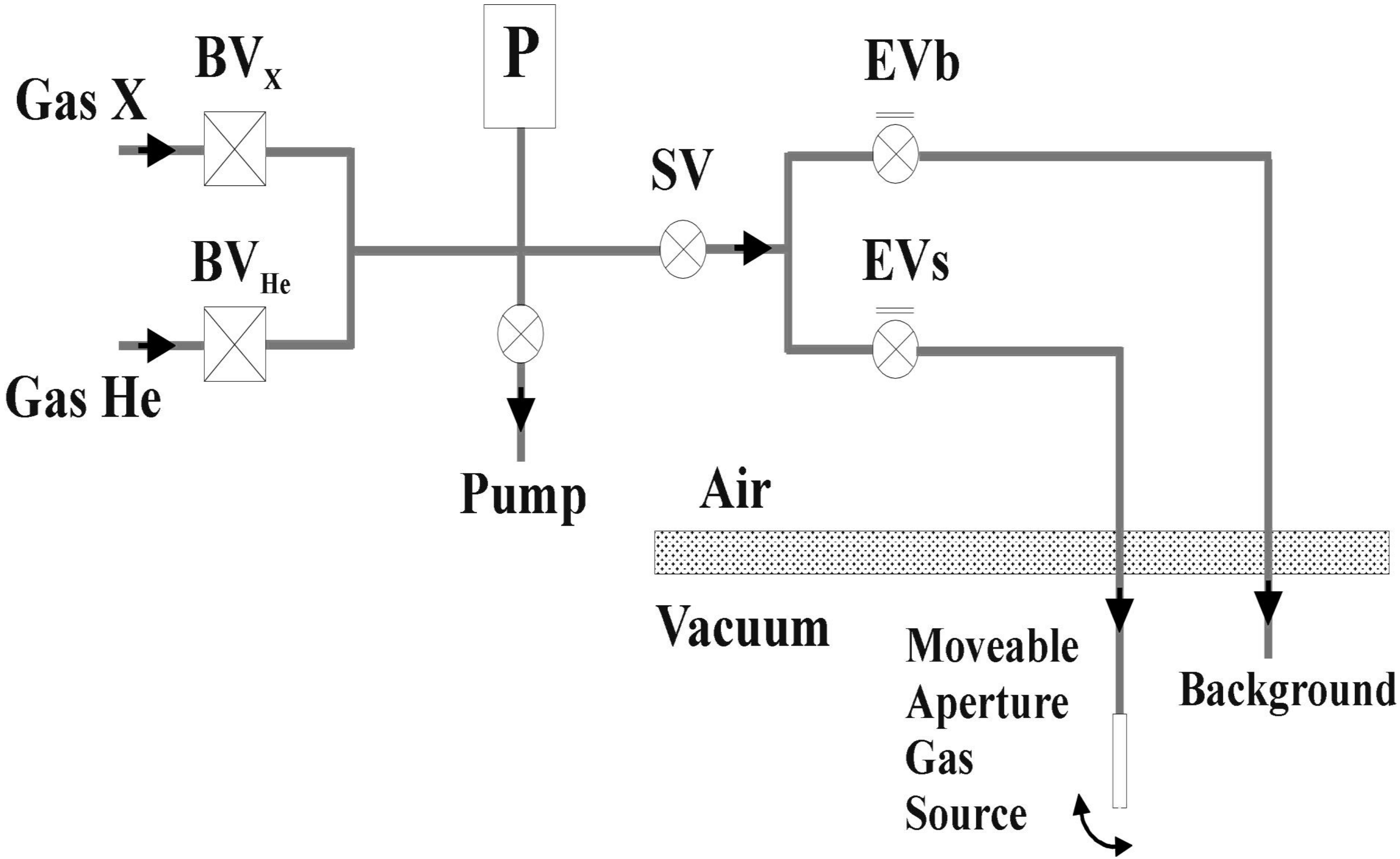
$$DCS_x (E_o, \theta) = \frac{I_s^x \; I_o^{He} \; \dot{P}_{He} \sqrt{m_{He}}}{I_s^{He} \; I_o^x \; \dot{P}_x \sqrt{m_x}} DCS_{He} (E_o, \theta)$$

Measuring the Flow Rate

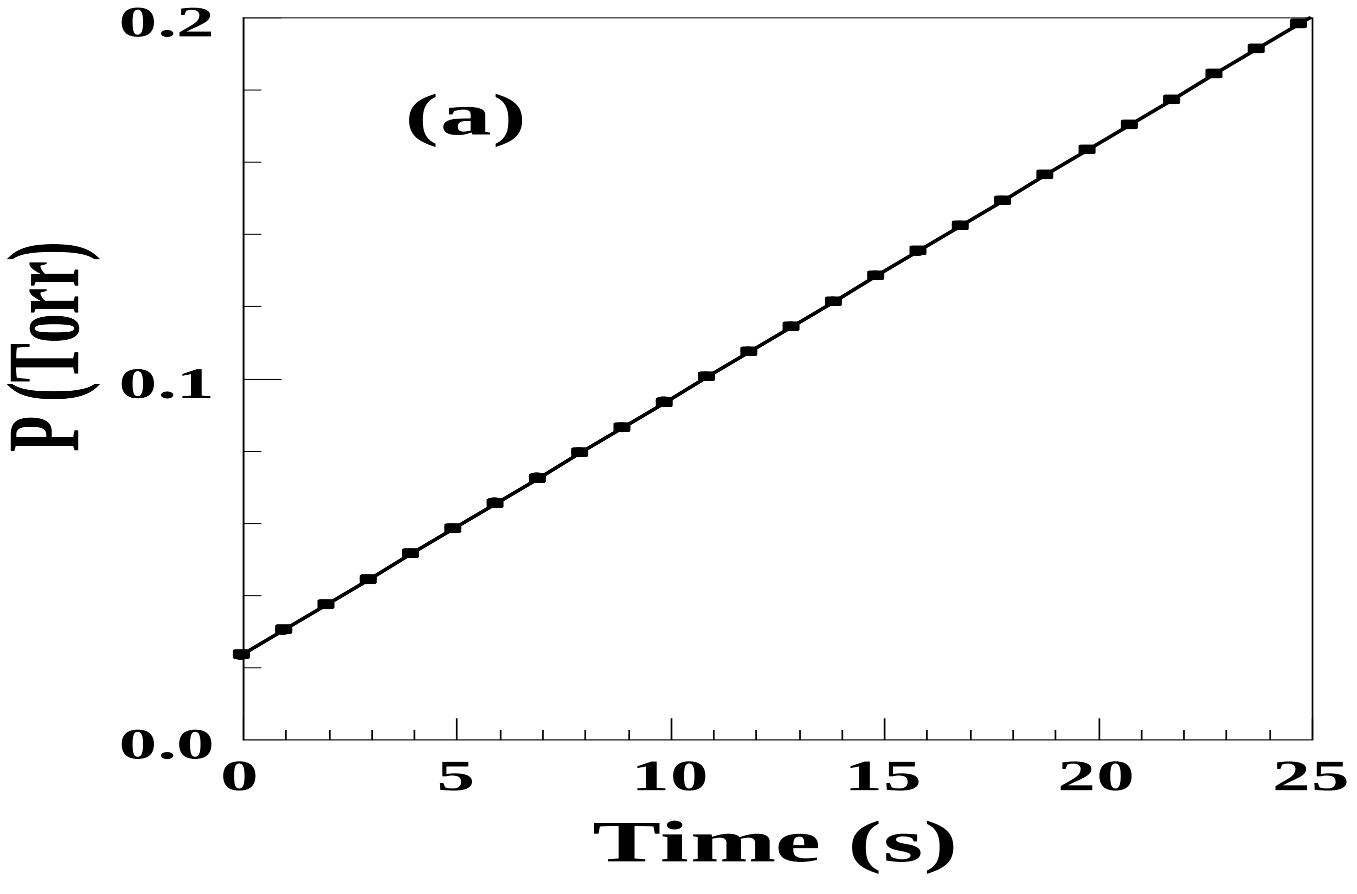


Stabilization Through Aperture P measurements

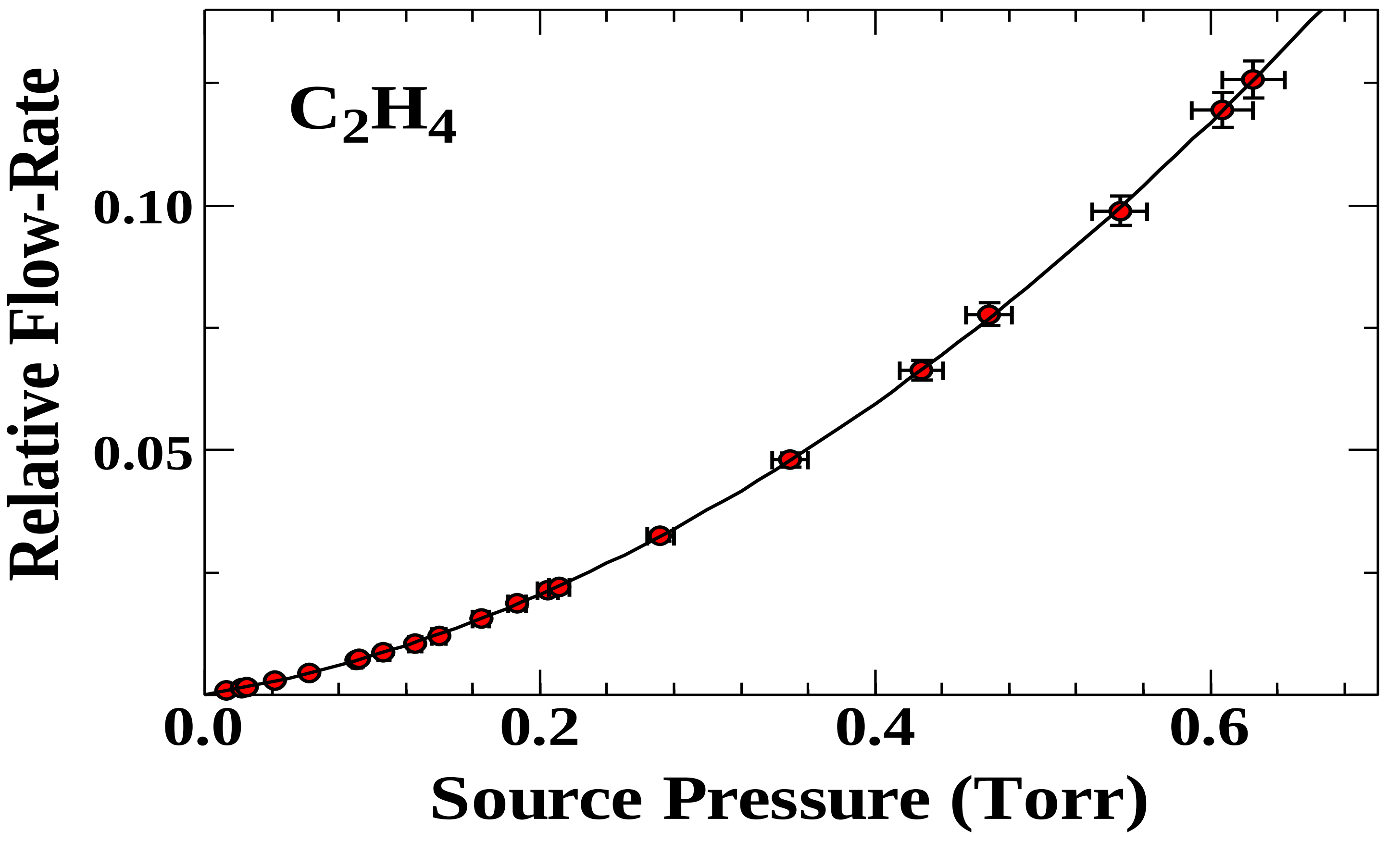



P
BV$_X$
Gas X
BV$_{He}$
Gas He
SV
EVb
EVs
Pump
Air
Vacuum
Moveable
Aperture
Gas
Source
Background

Filling of Evacuated Volume
dP/dt measurements



dP/dt vs. P



C2H4
Relative Flow-Rate
0.10
0.05
0.0
0.2
0.4
0.6
Source Pressure (Torr)

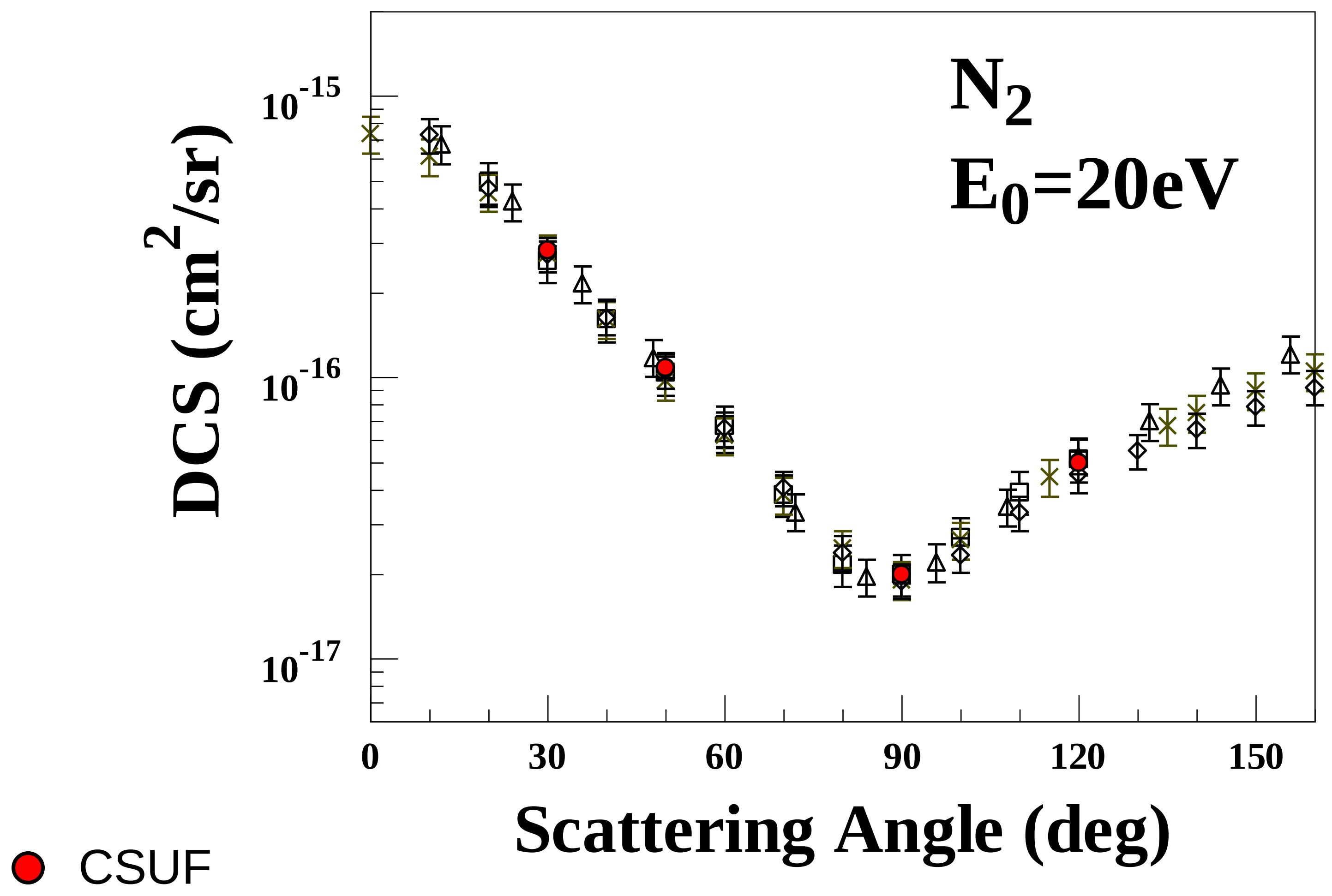
Initial Tests with a Known Gas - N_2

DCSs available:

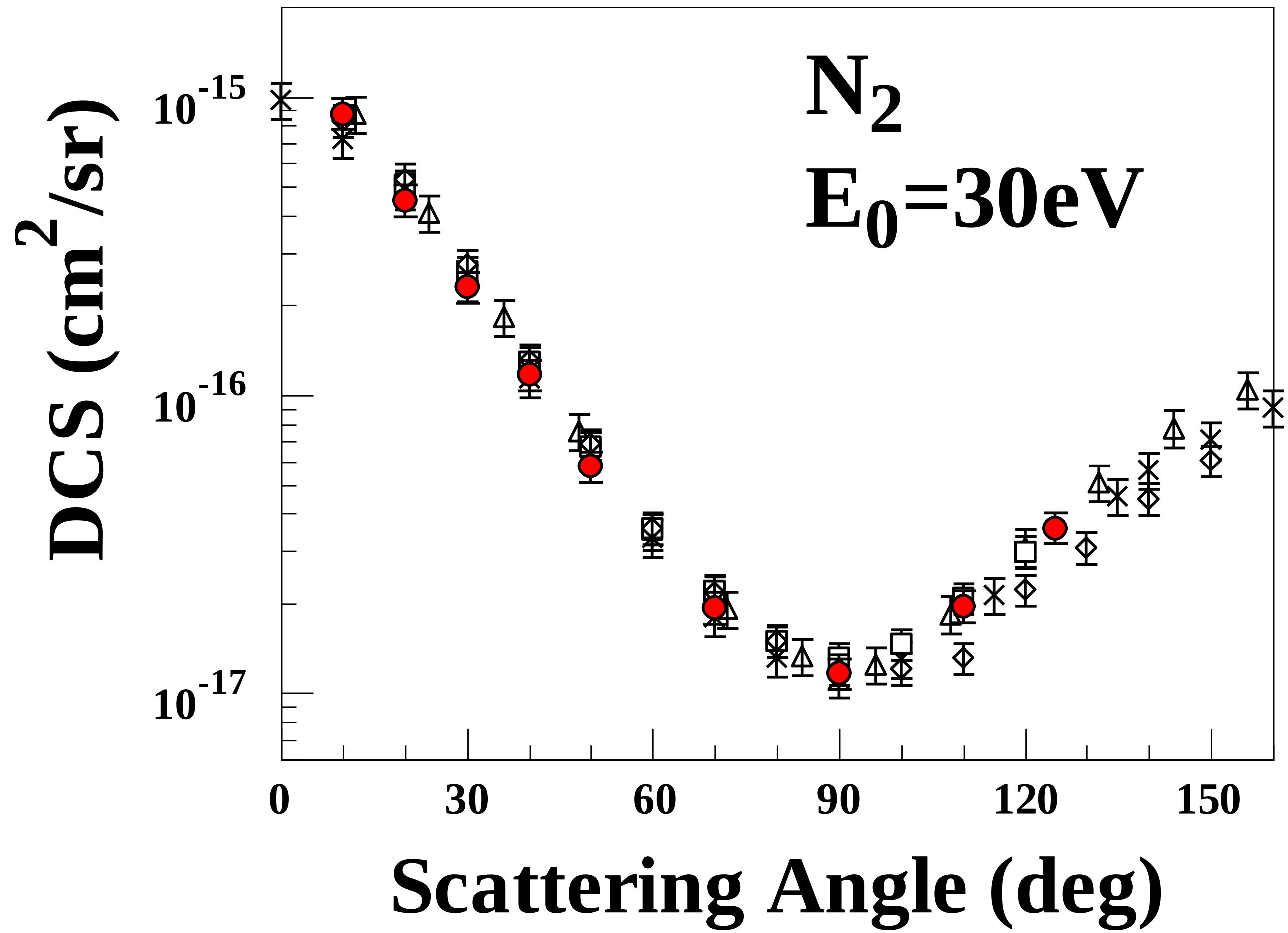
× Srivastava et al., JPL, CA
Δ Shyn and Carignan, Ann Arbor, MI

□ Nickel et al., UC Riverside
◊ Gote and Ehrhardt, Kaiserslautern, GE

Molecular Nitrogen at 20eV



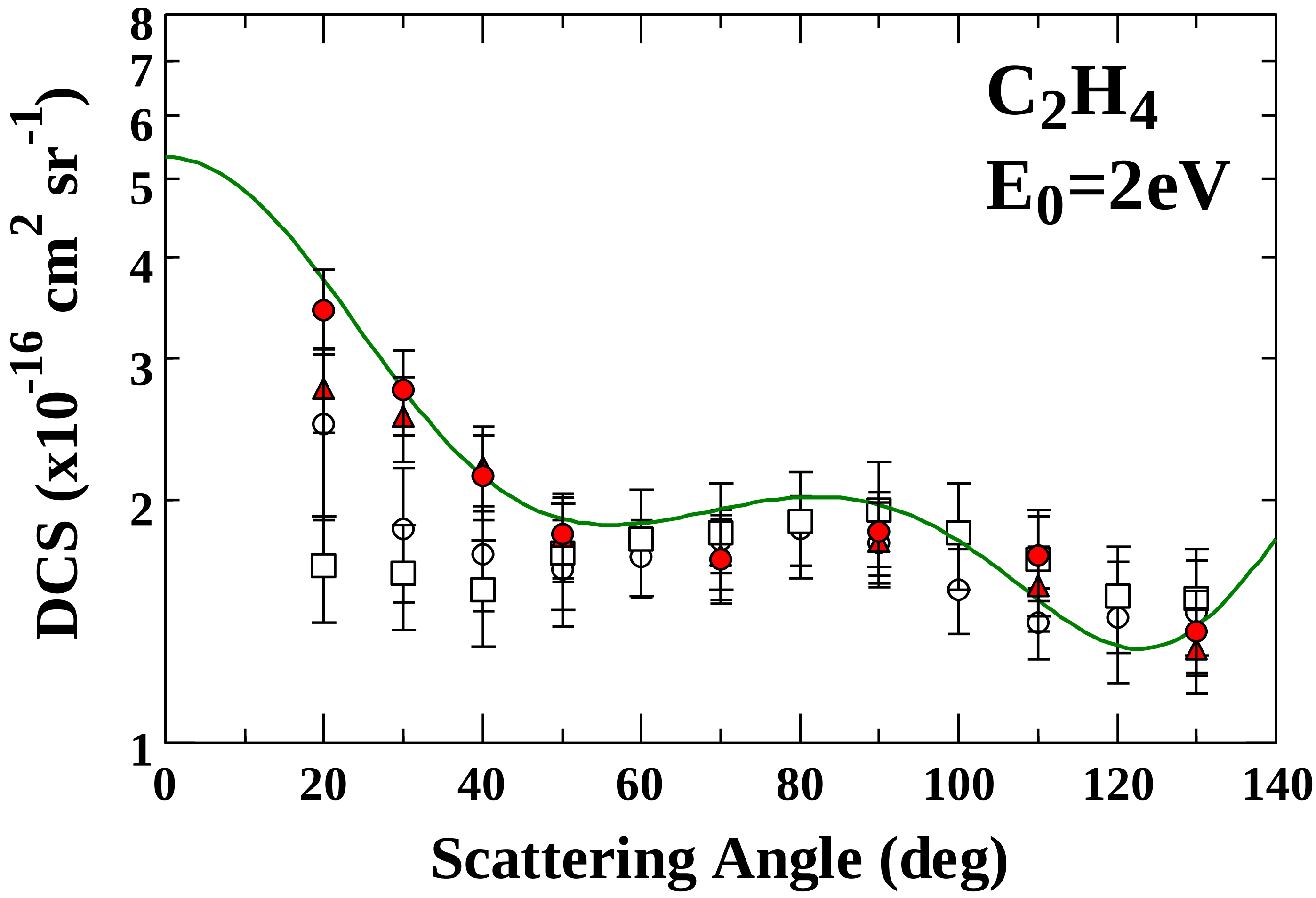
Molecular Nitrogen at 30eV



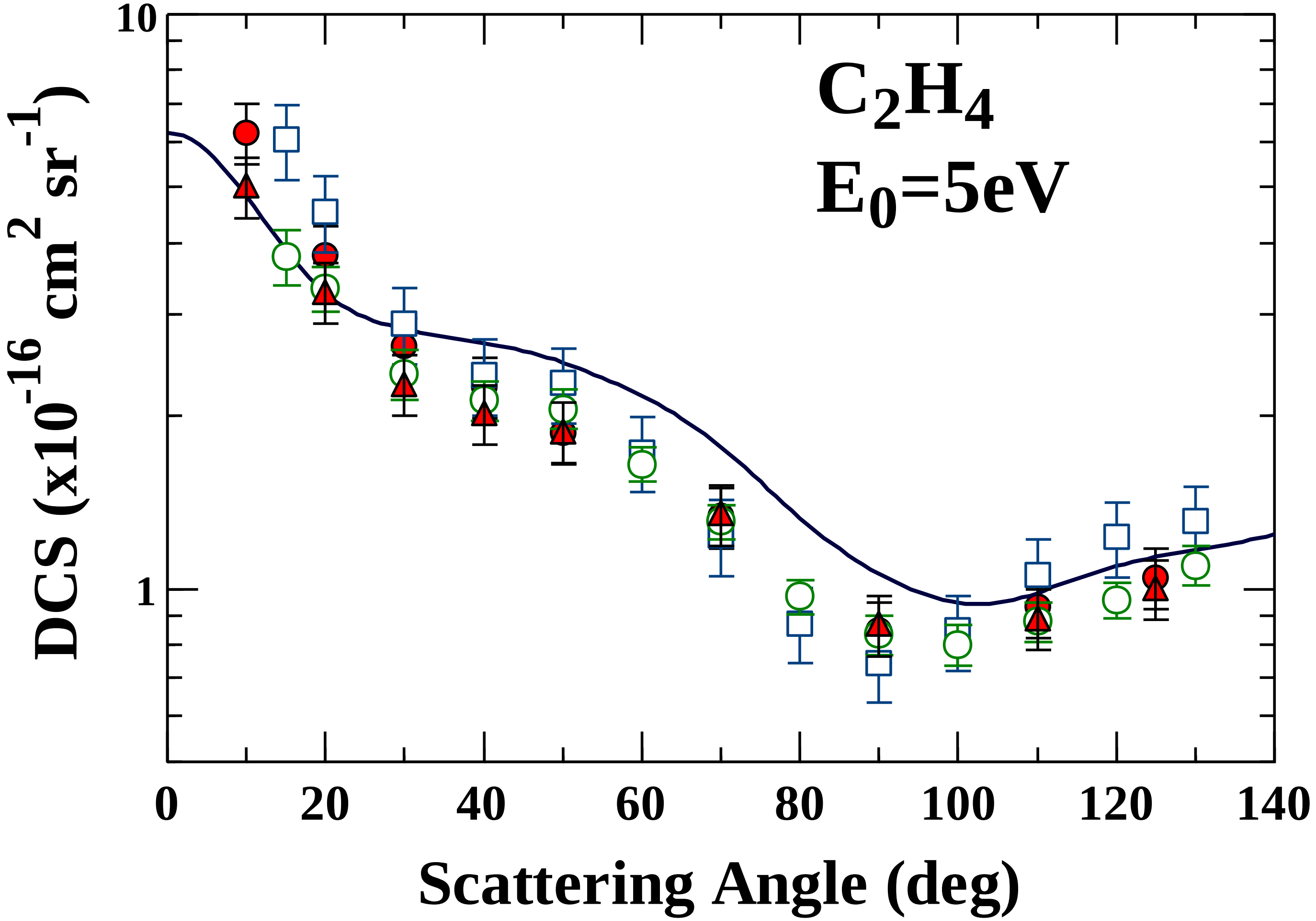
● CSUF

Final Results:

Differential Cross Sections:
Ethylene at
Incident energies of
2eV, 5eV, 10eV, 20eV, and 30eV



- CSUF ▲ CSUF 4-5 days later requiring a retune of spectrometer
- ANU Data Sophia U.
- Caltech Theory



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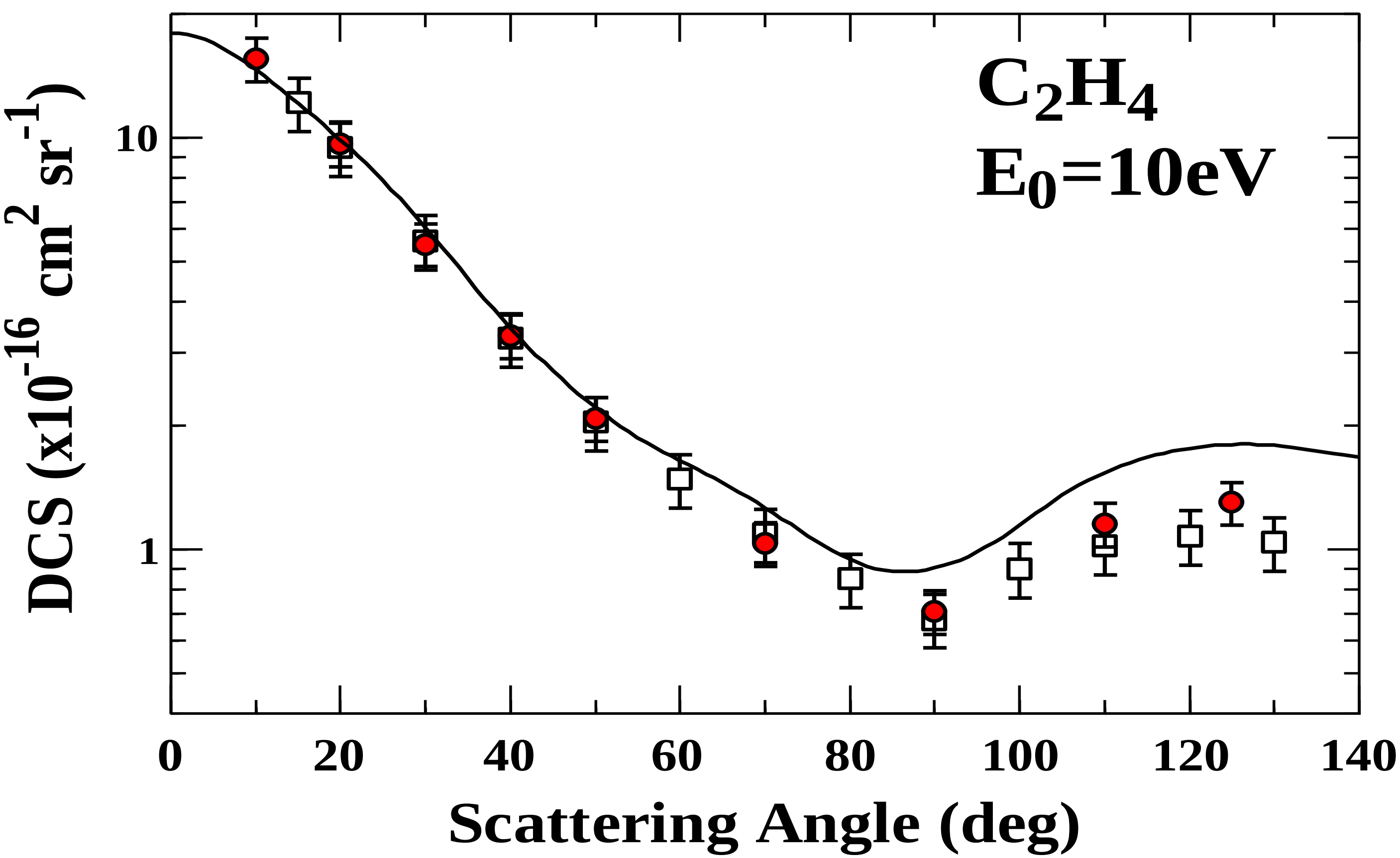

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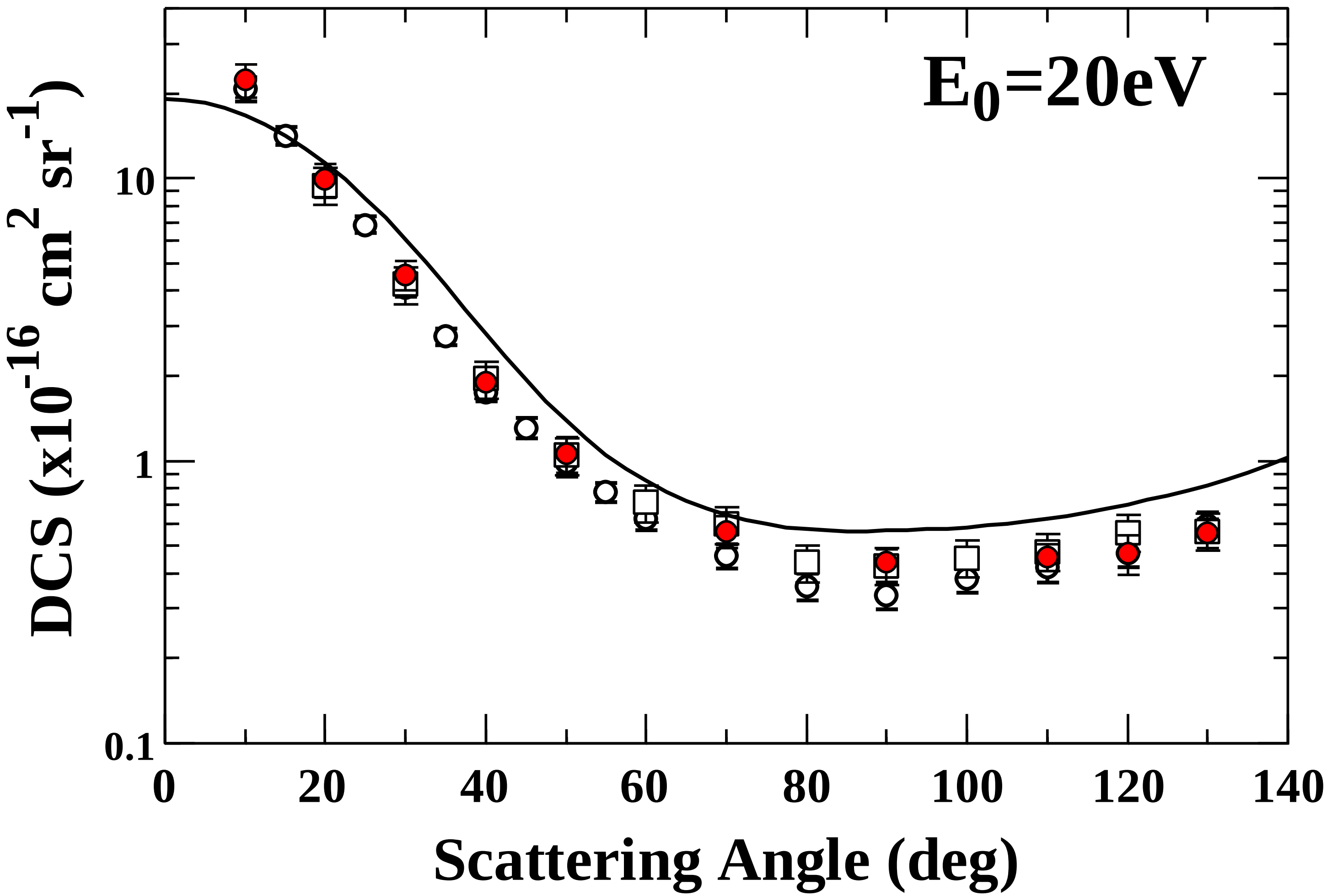

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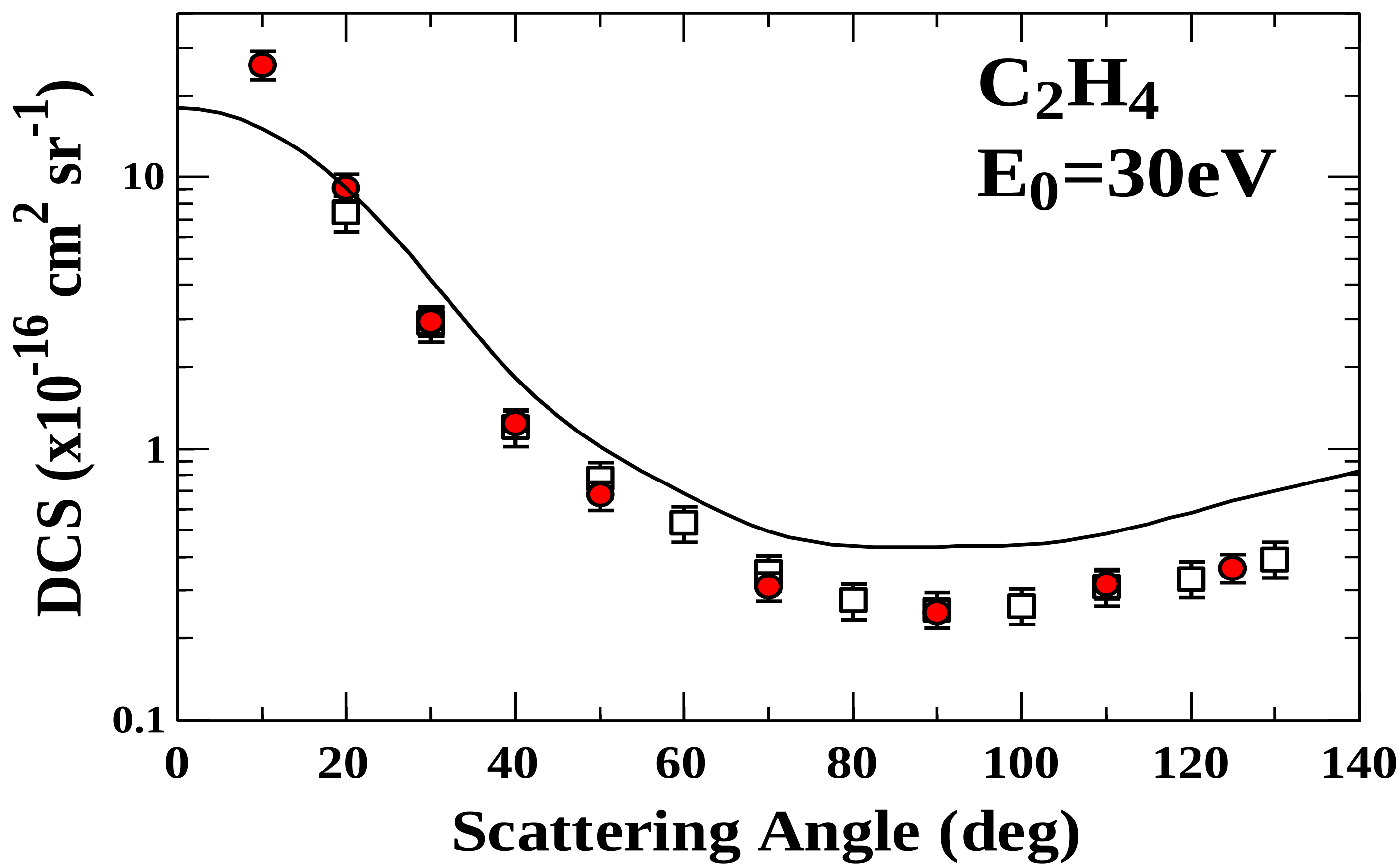

- CSUF
- ANU Data   Sophia U
- Caltech Theory

Conclusions

- C_2H_4 expts are on solid ground
- Our method clearly works
- Simple to apply
- Rapid and reliable
- Does not need to know δ for the target gas and can therefore be extended to molecules whose δ-values are unavailable

  e.g. CH_3OH, C_2H_5OH, C_3H_7OH, H_2O (?),

  Bio-molecules

Presently have extended technique to CH_3OH and C_2H_5OH

Poster R1.00099

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