Magnetic Field Stripping of H^- - Theories

- T. Khoe – unpublished
- J.R. Hiskes – unpublished (1962)
- L.R. Scherk – Canadian Journal of Physics, vol. 57, p. 558 (1979):

$$\tau = 4mz_T / [S_0 N^2 \eta (1+p)^2 (1 - 1/2k_0 z_T)] \times \exp (4k_0 z_T / 3)$$

Several ways to parameterize this formula. The simplest and most commonly used one is the 2-parameter version:

$$\tau = a/E \times \exp (b/E)$$

where the electric field E is the Lorentz-transform of the magnetic field B:

$$E\,(\mathrm{MV/cm}) = 3.197\, p\,(\mathrm{GeV/c})\, B\,(\mathrm{Tesla})$$

"Rule of thumb:" $p \times B \leq$ 6-7 GeV/c × KG

Magnetic Field Stripping - Measurements

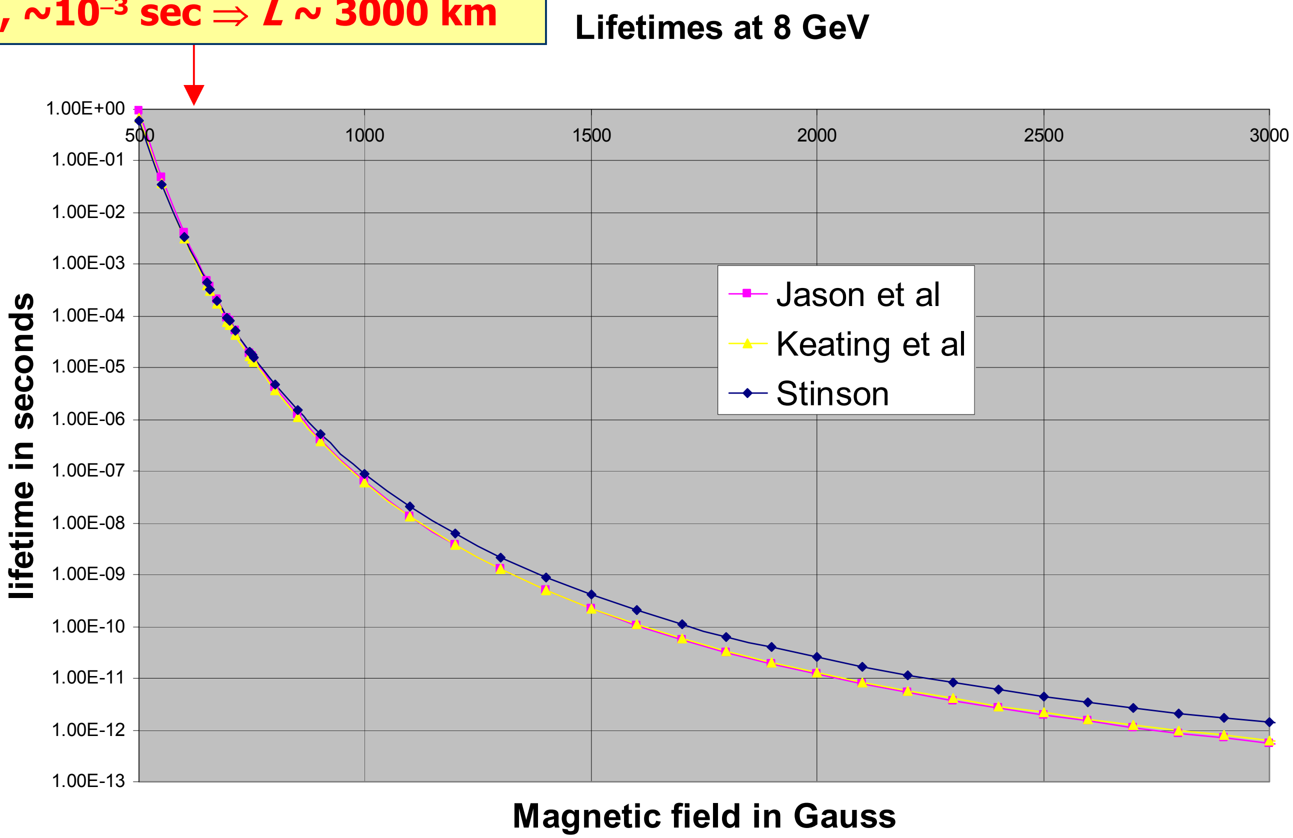
	a (10^{-14} s-MV/cm)	b (MV/cm)
◆ Khuri (1956)		
◆ Darewych (1963)		
◆ Kaplan et al. (1963) D-, 20 MeV, 2.4 MV/cm	1.05 (compared to Hiskes' theory)	49.25
◆ Cahill et al. (1966) H-, 48 Mev	A factor of 3 difference between Hiskes and measurement	
◆ Stinson et al. (1969) H-, 50 MeV, 1.867-2.140 MV/cm	7.96	42.56
◆ Jason et al. (1981) H-, 800 MeV, 1.87-7.02 MV/cm	2.47(±4%)	44.94(±0.25%)
◆ Keating et al. (1998) H-, 800 MeV	3.073	44.14

Comparison of Three Measurements

Experiment	Energy (MeV)	F (MV/cm)	a (10^{-14} s-MV/cm)	b (MV/cm)	Reference
Cahill et al.	48	2.4	N/A	N/A	[16] (1966)
Stinson et al.	50	1.867 – 2.140	7.96	42.56	[17] (1969)
Jason et al.	800	1.87 – 7.02	2.47	44.94	[18] (1981)
Keating et al.	800	1.87 – 7.02	3.073	44.14	[19] (1998)

Plot of Three Measurements

600 G, ~10^{-3} sec ⇒ *L* ~ 3000 km



Residual Gas Stripping of H^{-} – Theories

- Theoretical papers:
  - G.H. Gillespie (Feb 1977, Sept 1977, 1984) (use cross section σ)
  - B. Gervais et al. (1996) (use inverse mean free path λ^{-1}, which equals $N\sigma$)
  - P. Kurpick et al. (1998) (ditto)

- Born approximation for single- and double-electron detachment cross section:

$$\sigma(-, 0) + \sigma(-, +) = 8\pi\, a_0^2\, (\alpha^2/\beta^2) \sum_{n\neq 0} \sum_{m} [I_{nm} - J_{nm}(\beta^2) - K_{nm}(\beta^2)]$$

a_0 = Bohr radius

α = fine structure constant

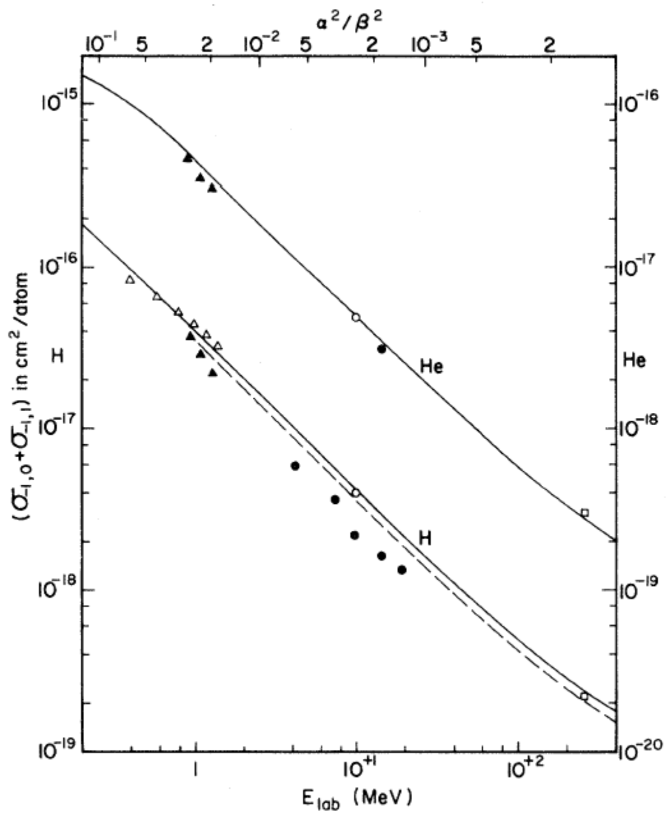
$\beta = v/c$

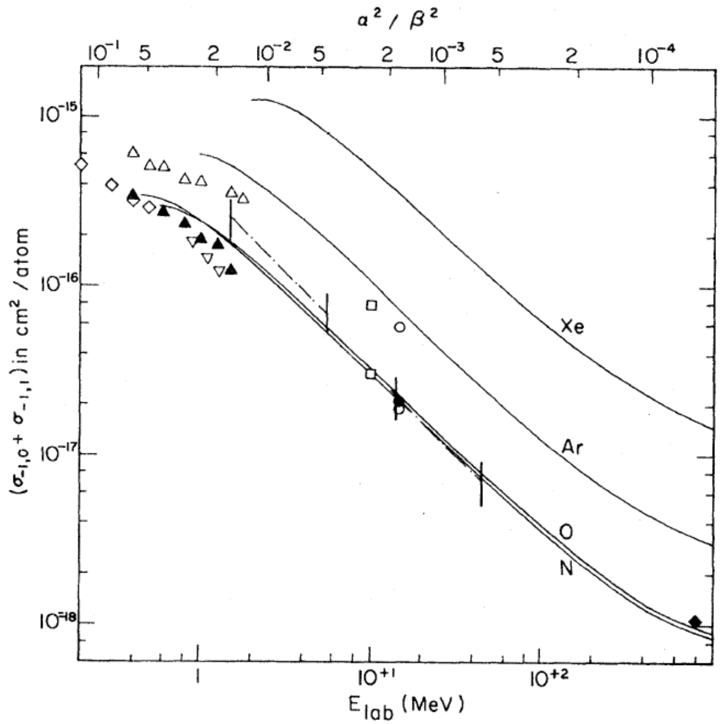
I_{nm} = collision strength summed over all final states (ion+target atom)

$J_{nm}(\beta^2)$, $K_{nm}(\beta^2)$ = low energy corrections

Residual Gas Stripping – Measurements

Energy dependence of total electron loss cross section for H⁻ incident on atoms





Residual Gas Stripping Lifetime

Total electron loss cross section for H^- (unit 10^{-18} cm^2)

Energy of H^- ion	H	N	O
400 MeV	0.2	–	–
1 GeV	–	1	1
8 GeV (scaled)	0.1	0.8	0.8

$$\tau = \frac{1}{\sum_i \frac{1}{\tau_i}}$$

$$\frac{1}{\tau_i} = n_i \sigma_i \beta c$$

$$L = \tau \beta c$$

Assuming 1×10^{-7} torr, 50% H_2 and 50% N_2 and O_2, the loss rate:

$1/L = 3.2 \times 10^{-7}$ m^{-1}

Summary of H^- Stripping Losses

Blackbody	$0.8 \times 10^{-6}\ m^{-1}$
Magnetic field	$0.3 \times 10^{-6}\ m^{-1}$
Residual gas	$0.3 \times 10^{-6}\ m^{-1}$
Total	$\mathbf{1.4 \times 10^{-6}\ m^{-1}}$

Transport beam line: ~ 1 km

Loss on the beam line: ~ 10^{-3}

H^- Beam intensity: $1 \times 10^{14}\ s^{-1}$

Loss rate: 1.4×10^{8} particles $m^{-1}s^{-1}$

@ 8 GeV: **~ 0.2 W/m**

Concern: Activation on bare beam pipe

Blackbody Radiation Stripping