Fermilab

Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

Effort, Summer of 2020

J.A. Johnstone

Monthly Group Meeting

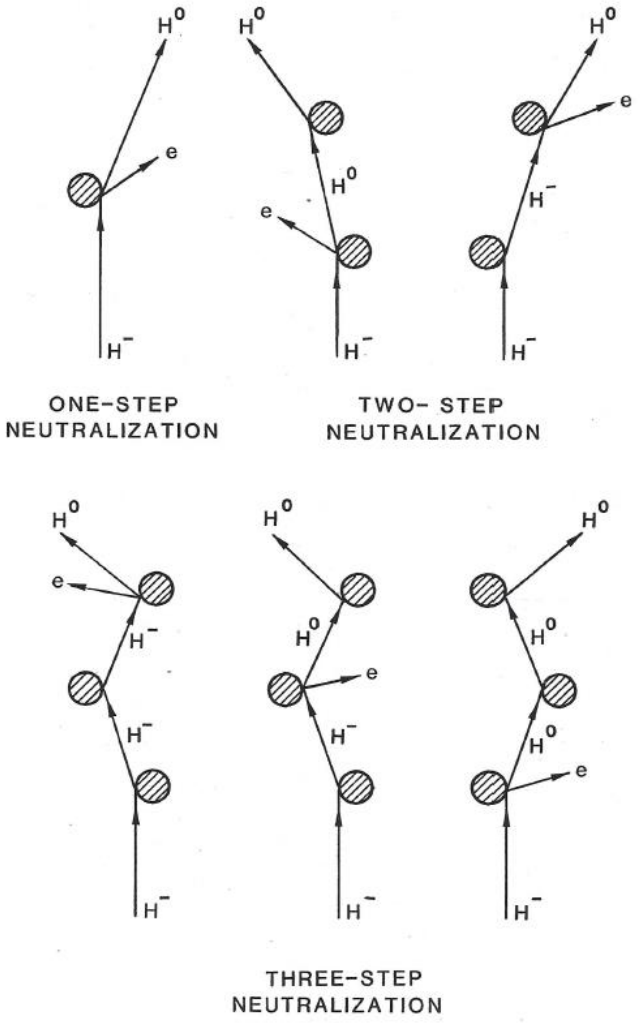
5th August 2020

- Last Month & Current:
  - Much time devoted to mentoring (with Jeff & Carol) AD CCI & SULI interns:
    - 1/3-Integer extraction from DR at 800 MeV;
    - Analytic β-bump expressions for localized amplitude manipulation in rings, and;
    - Design of an imaginary γt model basis cell for the RCS.
  - H species angular distributions from stripping foils with (attempt) to sum infinite multiple scattering series.
- Coming Month(s):
  - Assist Dave in determining H^0 angular distributions stripped in magnetic fields as functions of excited state populations & magnetic field profiles.
    - Non-trivial problem that can't be addressed in either MAD-X or MARS:
      - MAD-X doesn't do particle interactions & doesn't track neutrals, and;
      - MARS is a nuclear/particle tracking code – not atomic.

Atomic processes, for which Fermi has zero expertise. Perhaps atomic group at, say, Los Alamos could be consulted ??

H species angular distributions from stripping foils

Examples of multi-step neutralization



• evolution of H species fractions with foil thickness:

$$\frac{dH^-}{dx} = -\sigma_{-0}\, H^- \quad ; \quad \frac{dH^0}{dx} = +\sigma_{-0}\, H^- - \sigma_{0+}\, H^0$$

$$H^0(x) = \frac{\sigma_{-0}}{\sigma_{-0} - \sigma_{0+}} \left(e^{-\sigma_{0+}x} - e^{-\sigma_{-0}x} \right)$$

$$H^-(x) = e^{-\sigma_{-0}x} \quad ; \quad H^+(x) = \frac{1}{\sigma_{-0} - \sigma_{0+}} \left(\sigma_{-0}[\, 1 - e^{-\sigma_{0+}x}\,] - \sigma_{0+}[\, 1 - e^{-\sigma_{-0}x}\,] \right)$$

- *H* species angular distributions as infinite coupled multiple-scattering equations:

$$\frac{dH^-(\theta, x)}{dx} = -(\sigma_{-0} + \sigma_{--})\, H^-(\theta, x) + \int d\Omega' \frac{d\sigma_{--}}{d\Omega'} H^-(\theta'', x)$$

$$\frac{dH^0(\theta, x)}{dx} = -(\sigma_{0+} + \sigma_{00})\, H^0(\theta, x) + \int d\Omega' \frac{d\sigma_{-0}}{d\Omega'} H^-(\theta'', x) + \int d\Omega' \frac{d\sigma_{00}}{d\Omega'} H^0(\theta'', x)$$

Example of multiple scattering contributions to beam divergence – 200 MeV Booster protons.

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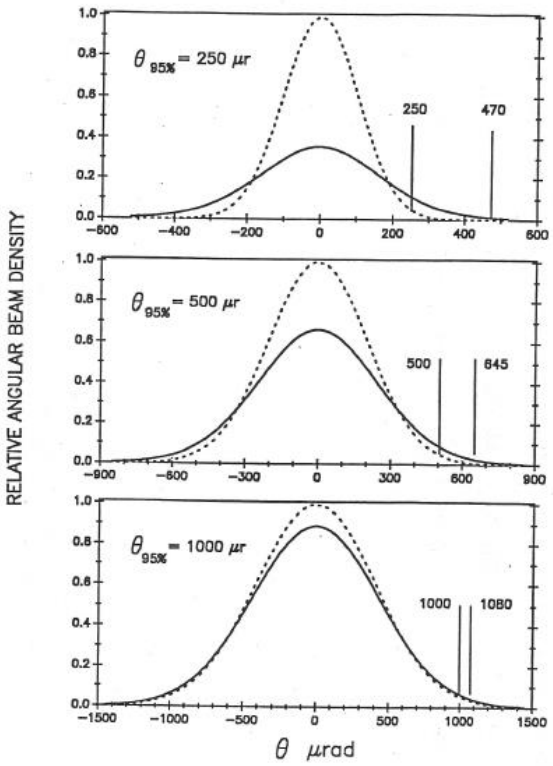
DIVERGENCE GROWTH AT 200 MeV VIA MULTIPLE PROTON SCATTERING
IN THE 200 $\mu gm/cm^2$ CARBON FOIL – 11 PASSES



- A PROTON SCATTERS 16 TIMES ON AVERAGE DURING EACH PASS.
- THE CURVES† DEMONSTRATE THE RESULTING INCREASE IN THE HALF-ANGLE WHICH CONTAINS 95% OF THE BEAM FOR VARIOUS INITIAL BEAM CONFIGURATIONS.

† J.A. Johnstone, ANL, unpublished, 1988.