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INTERSECTING STORAGE ACCELERATOR NOTES

A Scheme for Absolute Calibration of ISABELLE Luminosity

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A Scheme for Absolute Calibration of ISABELLE Luminosity

P. Gobbi and J.L. Rosen

A tractable scheme for calibrating the ISABELLE luminosity is of some interest. It is essential for the measurement of total cross sections. Admittedly, a good deal of the conjectured physics concerns studies of reaction distribution and will not depend critically on the absolute normalization of the various partial reaction cross sections. Nevertheless, orderly bookkeeping, if nothing else, would be served by a luminosity measurement.

We would like a simple reaction channel, easily identifiable, with reasonable rate and one which can be reliably predicted on the basis of precise measurement at lower energies. By this we mean the data can be extracted from conventional secondary beam measurements with fixed targets.

The choice of reaction channel seems to narrow down to an electromagnetic reaction produced in the Coulomb field of the colliding particles.

We believe that the most commendable reaction is:

$$p + p \rightarrow p + \Delta^+ \rightarrow \begin{Bmatrix} n + \pi^+ \\ p + \pi^0 \end{Bmatrix} \quad (1236)$$

Let us consider the longitudinal momentum kick (q_0) required for this reaction:

$$q_0 = \frac{M^{*2} - M^2}{2p_1} \approx 3 \text{ kev/c}$$

where p_1 is the momentum of proton (1) in the rest frame of proton (2)
and

$$M^* = \Delta \text{ mass}$$

$$M = \text{nucleon mass}$$

It is interesting to note the range of impact parameters that are relevant to the Coulomb dissociation process:

$$r_0 \approx 0.7 \text{ \AA} = 0.7 \times 10^{-8} \text{ cm} !!$$

Since the relevant impact parameters are typically $> 10^4$ times larger than the proton size we can, to excellent approximation, regard the protons as point like.

Further, the proton magnetic field produced by the magnetic dipole moment falls off more rapidly than the Coulomb field and can also be neglected. It could be accurately included as one of several niggling corrections.

Following Primakoff and others, (a good recent paper on Coulomb production which contains extensive reference is G. Faldt, et. al., Nuclear Physics B41 (1972)), we can write an expression for the cross section of reaction (1) in terms of the cross section for the well studied reaction:

$$\gamma + p \rightarrow \Delta^+ \rightarrow \left\{ \begin{matrix} n^+ & \pi^+ \\ p^+ & \pi^0 \end{matrix} \right\} \quad (2)$$

The low energy photoproduction cross section is dominantly but not exclusively Δ^+ production. Other partial waves are present. In greater generality we can directly relate

$$(1)' \quad \gamma_c + p \rightarrow n + \pi^+$$

and

$$(2)' \quad \gamma(\text{real}) + p \rightarrow n + \pi^+ \quad (\text{photoproduction})$$

The Coulomb photon γ_c is off the mass shell by a completely negligible amount.

In effect the two processes are related by a Lorentz transformation and multiplicative kinematical factors.

We emphasize: The accuracy of the prediction of (1)' should be limited only by the accuracy of the measurement of (2)'. An accuracy of 1% seems achievable.

For present orientation purposes, it is convenient to use the approximation wherein pure Δ^+ production is assumed. Then

$$\frac{d\sigma}{dq^2} (p+p \rightarrow p + \Delta^+) = 16\pi\alpha \left(\frac{M^*}{M^{*2} - M^2} \right)^3 \Gamma(\Delta^+ \rightarrow p + \gamma) \frac{q_t^2}{(q_t^2 + q_o^2)^2}$$

$$\text{where } q^2 = q^2 + q_o^2$$

and q_t = transverse momentum transfer

$$\Gamma(\Delta^+ \rightarrow p + \gamma) \approx 0.6 \text{ MeV (experiment)}$$

$$\sigma(\text{effect}) = \int_{q_o^2}^{q^2} \frac{d\sigma}{dq^2} dq^2$$

$$= 16\pi\alpha \left(\frac{M^*}{M^{*2} - M^2} \right)^2 \Gamma(\Delta^+ \rightarrow p + \gamma) \left\{ \ln \left(\frac{q}{q_o} \right)^2 + \left(\frac{q_o}{q} \right)^2 \right\}$$

If the upper limit of integration is chosen to be $\approx 30 \text{ MeV}/c$

$$\sigma \approx 10 \mu\text{b}$$

Given a luminosity of say $10^{31}/\text{cm}^2 \text{ sec}$ a comfortable rate of $100 \Delta^+/\text{sec}$ results.

Figures 1 and 2 show the energy and angle distributions of the nucleon and pion produced by the decay of Coulomb excited Δ^+ . These distributions are Monte Carlo generated and include both the q dependent of the Primakoff formula and a P wave Breit Wigner distribution of Δ^+ masses.

The Primakoff formula predicts a peak cross section for $q^2 \rightarrow 2 q_0^2$. The yield is so peaked forward that for all intents and purposes it can be regarded as zero degree production. (The situation is reminiscent of transmission K_S^0 regeneration. The sharp angular yield of the regeneration process is completely beyond experimental resolution).

Note then the correlations which are manifest:

1. $E(\pi) + E(N) = \text{Energy of ring protons}$
2. The transverse momentum transfer $q_t = p_t(\pi) + p_t(N) \approx 0$
to good accuracy
3. The angle and energy distributions are strongly correlated,
vis. soft pions are emitted at wider angles.

Experimental Detection Scheme

A straightforward, detection scheme is illustrated in Figure 3. The pions with typical emission angles of 4 mrad and energies of 40 GeV are easily bent out of the beam and measured with wire detectors.

The neutrons are measured in a calorimeter some 50m downstream of the clash region. Energy resolution is relatively unimportant. We do require that the calorimeter be constructed of interlaced x and y hodoscope elements so that the detection coordinate of the neutron can be measured to ± 0.5 cm accuracy. This does not seem unreasonably difficult. The x and y dimensions of the calorimeter can be modest (~ 50 cm) since the neutron angles are in the range 0-4 mrad.

The events are treated as O C fits. The neutron energy is given as $E(\text{proton}) - E(\pi)$. The neutron transverse momentum is then given by the measured angle of emission.

$$\int p_t (\text{neutron}) \approx (150 \text{ GeV}) (0.1 \text{ mrad}) \approx 15 \text{ MeV/c}$$

The pion transverse momentum is measurable to better accuracy.

The $\vec{l}'$ distribution ($\vec{l}' = -\vec{q}^2$) will then show the characteristic sharp spike predicted.

This calibration effort requires reasonable but not trivial experimental gear. It will not play the role of an ISABELLE version of a Faraday cup, i.e., it is not to be considered a permanent parasitic installation. Instead, we imagine that the measurement will be carried out under modest luminosity conditions and the yield of charged particles in the vicinity of 90° to the intersecting beams will be calibrated absolutely.

Strong Interaction Background

The pp interaction rate is more than 3 orders of magnitude larger than the $10 \mu\text{b}$ of Coulomb Δ^+ production. The great bulk of these interactions will have large multiplicities and considerably different kinematics. Judiciously placed veto counters can suppress most of these interactions prior to recording. This has been our experience in coherent dissociation work at 23 GeV

experimentation at the AGS.

What is worthy of consideration, however, is the production of $n\pi^+$ via Pomeron exchange. (As a matter of fact, this is a process worth studying in its own right). Other dissociation channels, double diffractive dissociation and a host of other possibilities are also interesting to study. But we are taking the view in this note that physics is bad in that it represents background for the calibration study.

We are led to expect a cross section $\approx 100 \mu\text{b}$ for such diffraction dissociation production of $n + \pi^+$.

- (1) Most of this yield will have an effective mass higher than Δ^+ .
- (2) The t' distribution pattern is expected to be ~ 100 times more diffuse.
- (3) The angular distribution of the decay in the N^* rest frame is expected to be substantially different from the Δ^+ decay distribution. A $(1 + 3/2 \cos^2 \theta_{\text{cm}})$ distribution is imbedded in the distributions of Figures 1 and 2.

It could be argued that $p + p \rightarrow p + \Delta^+$ can occur via virtual ρ^0 exchange. The ρ^0 is often the surrogate for a photon. Further, this amplitude, even if small, could interfere with the Coulomb amplitude. The distribution could be examined for evidences of this. However, the presence of any ρ^0 exchange at ISABELLE energies would have to be considered an enormous surprise.

Emission Angle Distribution

Fig 2

Fig. 3