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Physics with high intensity polarized protons

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There are four clear experiments that will be pursued with polarized protons at the AGS, which are tied to previous surprising results with the polarized beam at Argonne and with unpolarized beams at several accelerators.

1] Spin-spin correlations for proton-proton elastic scattering at large angles. At Argonne, spin parallel scattering to large angles was observed to be four times more prevalent than spin-antiparallel scattering. This experiment, already proposed, can use 10^{11} protons/pulse to reach the transverse momenta of 2.4 GeV/c. They are limited to 10^{11} by the beam's depolarization effect on their target. A large aperture experiment (see appendix) could reach the kinematic limit of $p_\perp$ = 3.4 GeV/c.

2] Parity violation. An unexpectedly large parity violation was seen at 6 GeV/c, and parity violation at lower energy has considerably lower limits. It is possible that the effect is energy-dependent. A longitudinally polarized proton beam is required (this may require a different extraction channel to eliminate transverse polarization), and intensity $\approx 10^{11}$ to do total cross section experiments. It is also interesting to look for parity violation in inclusive production of particles at large angles (muons), which requires intensities $> 10^{12}$.

3] Inclusive asymmetries. Large asymmetries for pion production were seen at Argonne and, after a target subtraction, at CERN. Higher intensity would allow these to be pursued to higher transverse momentum. In general, however, interesting initial experiments can be done with $<10^{10}$ polarized protons/pulse. (See Appendix.)

4] Spin transfer experiments. The D parameter measures the degree to which the proton polarization is transfered to outgoing particles (inclusive or exclusive). Inclusively produced hyperons are very polarized at high transverse momentum and it is attractive to test the spin transfer to them. Beams of 10^{11} and 10^{12} have been used at Fermilab to reach very high $p_\perp$. Initial experiments at the AGS would use beams of 10^8, reaching only moderate $p_\perp$. If large effects are seen, a dedicated experiment would be required to use 10^{12}.

A number of intriguing ideas were put forward at the recent Spin Symposium. Most require longitudinal polarization which can be accomplished by using a half a Siberian snake (Sidewinder species). There were a number of predictions for two-spin aysmmetries (A_{LL}), looking at $\mu^+\mu^-$, direct-γ's, ρ's, etc. from QCD calculations. These experiments may be quite interesting. Due to the limitations of polarized targets they would have a proton intensity of 10^{11}.

John Ralson of Argonne argued that wiggles seen in pp large angle cross sections as a function of s, after removing the dominant s^{-10} behavior, may come from a QCD phase. If so, he predicts 20% asymmetries which oscillate in s in single spin large angle Drell-Yan muon production. High intensity ($\geq 10^{11}$) would be needed for such an experiment.

Neal Craigie of Trieste presented an argument that polarized proton beams can be seen as polarized gluon beams in colliders in the central region where gluon-gluon reactions should dominate, and suggested tests of supersymmetric QCD with A_{LL} measurements.

The strongest arguments for pushing the intensity of polarized protons are:

1] with 10^{13} polarized proton per pulse, the unpolarized and polarized experiments can run simultaneously, and

2] also with 10^{13}, the polarized luminosity of a collider would be the same as the unpolarized luminosity. A lot has been written on the uses of polarized protons in a collider to study QCD and to distinguish rare weak interaction effects--see, for example, the ISA summer study of 1981, Volume 2, p. 600 and the contribution (G. Bunce et al.) to the Snowmass DPF workshop, 1982.

Appendix

Here we present event rates in the region of the kinematic limit for several experiments with 25 GeV/c incident protons. The experiments are elastic proton-proton scattering and inclusive pion production for p-p, each near 90° in the center of mass or at 15° in the laboratory. Two experimental arrangements, proposal 642 (J. Russ) and E748 (A. Krisch) are used to give upper and lower limits on the solid angle acceptance. Also, two targets are considered: a 6 inch long hydrogen target (following proposal 642) and the E748 polarized proton target. The intention is to show what physics is or isn't accessible with high intensity polarized protons.

Elastic Proton-Proton Scattering (90°)

Apparatus	$\Delta\Phi/2\pi$	Δt	Target	Events/10^{12} protons	Events/hour*
P642	.15	23	6" H_2	1	1200
P642	.15	23	PPT	1/4	30
E748	.008	1	PPT	1/1600	3/40

* This uses 10^{12}/pulse for the hydrogen target and 10^{11}/pulse for the PPT

Conclusions: both single-spin and double-spin (i.e. PPT) exclusive experiments at the kinematic limit are accessible with a large aperture apparatus. Note that the events for P642 are collected over a much wider range (Δt) than for E748. At 25 GeV/c, this corresponds to $p\perp = 2.77$ GeV/c to 3.36 GeV/c.

Notes: $d\sigma/dt = 6 \times 10^{-37}$ $cm^2(GeV/c)^{-2}$ (see P642), $N_o\ \ell\rho = 1.5 \times 10^{23}$ cm^{-2} for the PPT; $= 6 \times 10^{23}$ cm^{-2} for 6" H_2.

Inclusive Pion Production (90°)

Apparatus	$\Delta\phi/2\pi$	$\Delta p\perp$	Target	Events/10^{12}	Events/hour*
P642	.08**	2.67-3.34	6" H_2	420	5×10^5
P642	.08	2.67-3.34	PPT	105	1.2×10^4

* 10^{12}/pulse for H_2 target; 10^{11}/pulse for PPT.

** This is half the exclusive case because we assume only one arm will be used.

Conclusion: single and double-spin inclusive experiements are also accessible. For pion production, 10^{12}/pulse polarized protons are not needed. However, other single particle production would be lower.

Notes: $E \frac{d^3\sigma}{dp^3} = 60\ e^{-6p\perp}$ mb/GeV^2 (U. Becker et al., PRL 38, 140 (1977).

$$\Delta\sigma = \Delta\Omega dp \left(\frac{d\sigma}{dp d\Omega}\right)_{lab}$$

$$\Delta\sigma = d\Omega dp \frac{p^2_{lab}}{E_{lab}} \left(E \frac{d^3\sigma}{dp^3}\right) \quad , \ p = p\perp/\sin\theta$$

$$\Delta\sigma = \frac{d\Omega}{\sin^2\theta_{lab}} 60 \int_{2.67}^{3.36} e^{-6p\perp}\ p\perp\ dp\perp$$

$$\Delta\Omega = d\ \cos\theta d\phi = \sin\theta\ d\theta d\phi$$

$$\Delta\Omega = .012$$

$$\Delta\sigma = \frac{.012}{.067} 60 \times .64 \times 10^{-7}\ \text{mb} = 1.4 \times 10^{-6}\ \text{mb}$$

$$\text{Events}/10^{12} = (1.4 \times 10^{-6} \times 10^{-27}\ \text{cm}^2) \times 10^{12} \times (6 \times 10^{23}\text{cm}^{-2})$$

$$N_o \ell\rho = 6 \times 10^{23}\ \text{cm}^{-2} \text{ for } 6\text{" } H_2$$

$$\text{Events}/10^{12} = 420.$$