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pp elastic analyzing power from 318 to 800 MeV

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The maximum value of the analyzing power A for pp elastic scattering has been measured at 17° lab as a function of energy from 318 to 800 MeV. No unexpected energy dependent structure is observed at the 0.5% level.

[NUCLEAR REACTIONS ^{1}H$(p,p)^1$H, $E = 318-800$ MeV, measured A at $\theta_{\rm lab} = 17°$.]

The observation of energy dependent structure in proton-proton scattering has generated much interest recently. Significant structure has been observed in the medium energy range in measurements of $\Delta\sigma_T$,[1–7] $\Delta\sigma_L$,[7–13] A_{NN},[14] and A_{LL}.[15,16] The most recent data, including preliminary LAMPF data, are shown in Ref. 17.

A variety of interpretations have appeared in the literature. Partial wave analyses[18,19] indicate that this structure is associated with a resonancelike behavior in the $^1D_2$ and $^3F_3$ waves. This has led to the suggestion[10,17–19] that dibaryon resonances may be responsible. Others[20,21] are of the opinion that no resonances or exotic phenomena are needed to explain the results.

While there is little agreement on the origin of the structure, it is generally agreed that more energy dependent data are required. During the summer of 1980 the LAMPF accelerator ran at a variety of energies from 318 to 800 MeV. At each energy, the analyzing powers of the beam line polarimeters were measured. Since these polarimeters are essentially detectors of pp elastic scattering, and since their analyzing powers differ by a few percent from pp elastic, it was possible to extract the pp analyzing powers from these calibrations.

The quench ratio method of calibration has been described before, both in principle[22] and as it applies to LAMPF.[23] The method uses the atomic physics of the ion source to measure the beam polarization.

The LAMPF beam line polarimeters have also been described before.[23,24] In principle, they consist of four pairs of detectors (left, right, up, down) set to detect pp elastic scattering from CH_2 targets. By measuring the scattering asymmetry e for the polarimeters in a beam whose polarization P is known from the quench measurement, we extract the analyzing power $A = e/P$.

The polarimeters are set a fixed lab angle of 17.0° with an angular acceptance of $\pm 1.1°$ in the primary arm. (The conjugate detectors are designed so that they do not limit the acceptance of elastics.) It is known[25–29] that from below 300 to above 800 MeV the pp elastic analyzing power has a broad maximum near 17° lab. Within the angular range 17 $\pm$ 1°, the analyzing power varies by less than about 0.5% from the maximum value at each energy. The measurements reported here are strictly the average over this angular range, but within the uncertainties of these data, the measurement is of the maximum analyzing power at each energy.

A few percent of the events detected by the polarimeter are from ^{12}C$(p,2p)$ quasielastic scattering. Since these have about half the analyzing power of pp free,[24] a small correction is required to extract the elastic analyzing power from that of the polarimeters. This correction factor has been precisely measured[23,25] for the LAMPF *EP* polarimeter at three energies, as plotted in Fig. 1. In addition, since the conjugate detector geometry for the *LB* polarimeter gives twice the quasifree acceptance of the *EP* polarimeter, then the correction factor $A_{EL}/A_{EP} \simeq A_{EP}/A_{LB}$, where A_{EL}, A_{EP}, and A_{LB} are the analyzing powers for the elastic, the *EP*, and the *LB* polarimeters. These estimates are also plotted on Fig. 1, together with the correction factor actually used (solid line). We estimate the uncertainty in this correction factor to be $\pm 0.3\%$.

Systematic errors in the polarimeters are discussed in Refs. 23 and 24. With exceptionally large

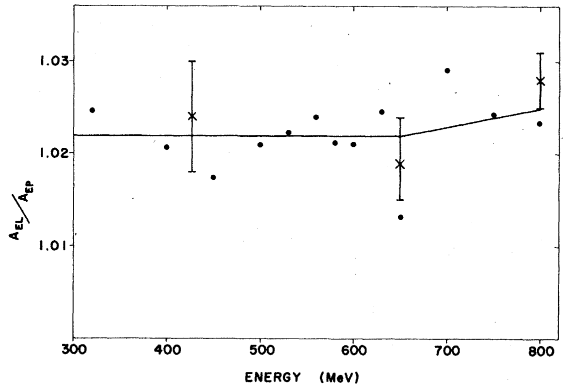

FIG. 1. Correction factor A_{EL}/A_{EP} as a function of energy. Crosses are from direct measurements, dots are estimated from A_{EP}/A_{LB}, and the line is the correction factor actually used.

beam spots (>1 cm rms) or high beam currents ($\gtrsim 10$ nA), the polarimeters are known to have analyzing powers 1 or 2% low. Under the conditions of these calibrations, however, the systematic errors are believed to be less than 0.3%. At some of the energies, three other polarimeters were cross calibrated at the same time as the measurements reported here. Data are smooth and consistent.[30–32]

Quench calibrations of the beam polarization have been performed at LAMPF about 25 times over four years with a wide variety of accelerator and ion source tunes. Apart from two occasions when preliminary results came out about 2% low, all calibrations have been internally consistent typically to $\pm 0.4\%$. This internal consistency is given as the point to point uncertainty in Table I.

The possibility of systematic error in the quench calibrations was considered in detail in Ref. 23. It was concluded that an uncertainty of $^{+1}_{-0.5}\%$ should be added (in quadrature) to cover possible systematic errors in the method. While it is possible that systematic errors might be a function of energy, the smoothness of the data (Fig. 2) shows that at worst this would be a slowly varying function. Our best estimate of systematic error is that the $^{+1}_{-0.5}\%$ uncertainty in the quench method should be combined with the $\pm 0.3\%$ uncertainty in the correction A_{EL}/A_{EP} (Fig. 1) and applied to all data equally. Since all data taken with the LAMPF polarized beam are normalized (more or less directly) to the quench calibrations, this normalization uncertainty is common to all such data. The uncertainty in the LAMPF beam energy was discussed in Ref. 23 and is believed to be $\pm 0.5\%$.

The data are listed in Table I and shown in comparison with selected data from other laboratories in Fig. 2. The selection criteria are discussed in Ref. 33. Much of the early (pre-1972) data have been omitted on the grounds that their absolute normalization is too uncertain. Except for the overall normalization ($^{+1}_{-0.5}1\%$), the present data are independent of previously reported measurements from LAMPF.[23,25,34] Also shown in Fig. 2 is a recent phase-shift fit (*SM*81) from Arndt.[19] It

TABLE I. Analyzing power A_{LB} and A_{EP} for *LB* and *EP* polarimeters and A_{EL} for *pp* elastic at 17.0° lab.

Energy MeV	A_{LB}	A_{EP}	A_{EL}	ΔA_{EL}	$\theta_{c.m.}$
318	0.406	0.416	0.425	0.005	36.6
398	0.440	0.449	0.459	0.004	37.2
447	0.461	0.469	0.479	0.003	37.6
496	0.479	0.489	0.500	0.002	37.9
530	0.493	0.504	0.515	0.002	38.2
547	0.503	0.515	0.526	0.002	38.3
581	0.521	0.532	0.544	0.002	38.6
597	0.525	0.536	0.548	0.002	38.7
630	0.531	0.544	0.556	0.002	38.9
647	0.531	0.542	0.554	0.002	39.0
699	0.517	0.530	0.542	0.002	39.4
750	0.496	0.508	0.520	0.002	39.8
800	0.473	0.484	0.496	0.002	40.1

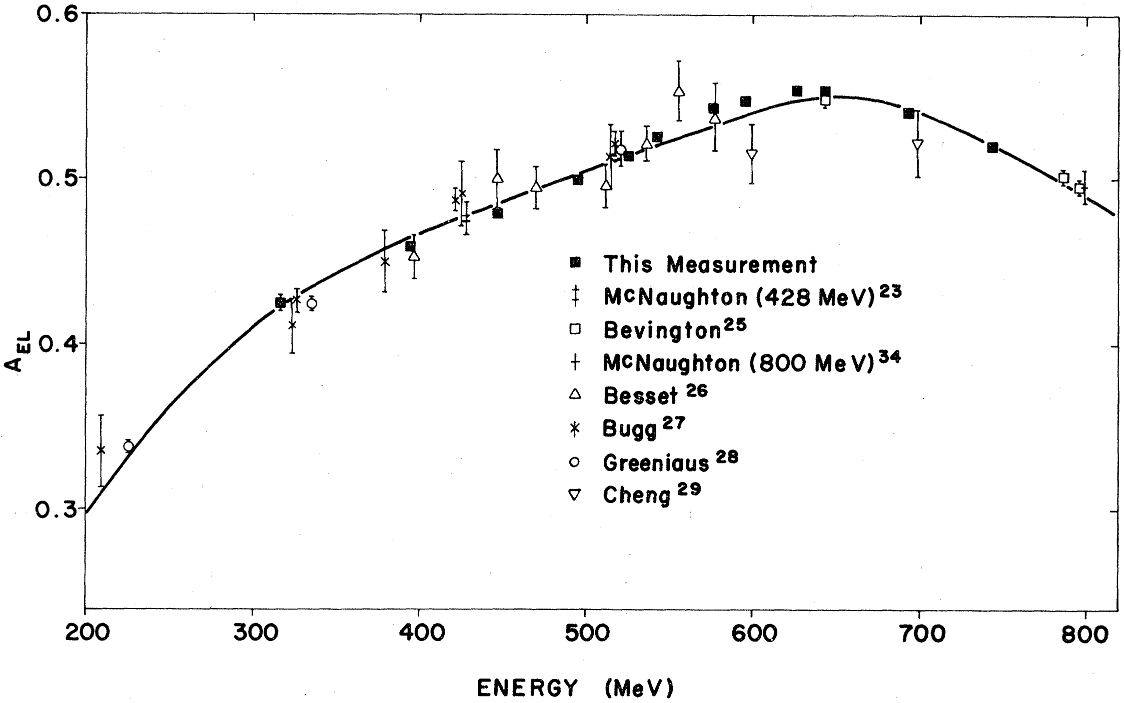

FIG. 2. Analyzing power for *pp* elastic near 17° lab as a function of beam energy. The curve is Arndt's phase shift fit *SM*81 (Ref. 19).

is apparent from the large χ^2 that the very small uncertainties on the present data are significantly constraining the phase-shift solutions.

Apart from the broad peak near 650 MeV, no structure is observed in the energy dependence of the *pp* elastic analyzing power at the 0.5% level. This is not unexpected since the $^1D_2$ partial wave (with structure near 600 MeV) does not contribute to the product of analyzing power and cross section while the structure in the $^3F_3$ wave is closer to 800 MeV, which is the maximum measured here. However, the data from 400 to 500 MeV and from 550 to 630 MeV do differ significantly from Arndt's curve.

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