Argonne Effective Mass Spectrometer Facility[+*]

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The facility consists of a large aperture magnet surrounded by magnetostrictive wire spark chambers and associated equipment. It was designed and built as a collaborative effort of two Argonne groups[1] and is shown in Fig. 1.

The beam supplied to the facility is unseparated with maximum momentum 6 GeV/c. A six-counter hodoscope at the first focus tagged the momentum to ± 0.2% and four threshold Cerenkov counters identified the beam particles as fast (π, μ, e), K or proton. A maximum of 200,000 beam particles per 0.7-sec spill passed through the apparatus, with special gating to avoid extra beam tracks.

Two liquid hydrogen targets (8" and 20" long, 2" diameter) were mounted on moveable carts along with associated counters and/or spark chambers. This allowed a rapid changeover of experiments.

The magnet is one of three SCM-105 magnets at the ZGS. The gap was opened to 26 inches, giving a central field of 11.4 kG for 1 MW of power and a 40-inch effective length. A 40-counter hodoscope at the magnet exit was used in the trigger to count the number of charged particles traversing the magnet.

The spark chambers were constructed by epoxying flattened 4 mil aluminum wire onto 1 mil Mylar having 1 mil aluminum foil backing for even distribution of the high voltage pulse. The wire spacing ranged from 40/inch (K 1, 2, 3) to 20/inch (K0, 4). Each spark chamber had two Mylar sandwiches glued onto a G-10 fiberglass-epoxy frame, and a total thickness of about 0.0018 radiation lengths (including the neon gas). For the chambers inside the magnet, the Mylar sheets and wires were continued on out the rear of the magnet to a low field region for readout. The magnetostrictive readout lines of all chambers

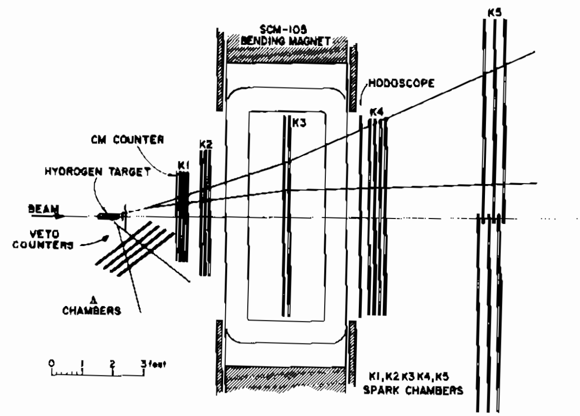

Fig. 1 Plan view of the Effective Mass Spectrometer as used with a neutral trigger to study $\pi^- p \to K^0\Lambda$.

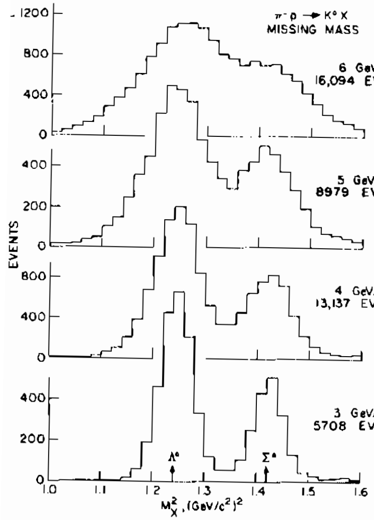

Fig. 2 Missing mass distribution showing Λ-Σ^0 separation.

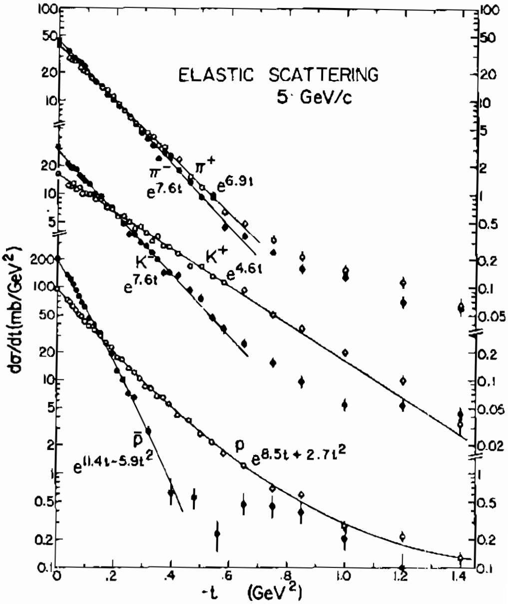

Fig. 3 Differential cross sections for the elastic scattering of $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$ off protons at 5 GeV/c; similar data were also obtained at 3, 3.65 and 6 GeV/c.

close to the magnet were placed in massive iron shields (3/4 to 2 inches thick).

Operating parameters for good multiple-track efficiency were optimized in the laboratory using a ^{106}Ru beta source together with permanent magnets to select and guide the 2-MeV electrons.[2] The spark chamber gas was recirculated through a purifier and bubbled through ethanol at -5° C and 2 psig. High voltage pulses of 7 kV and 60 nsec FWHM were followed by a pulsed clearing field of 200 V for 6 msec on top of an 80 V dc clearing field. Up to 50 triggers per 0.7-sec spill were recorded with a minimum dead time of 10 msec. The chamber sensitive time was about 1 μsec, and the high voltage pulse was applied 400 nsec after each event.

The K3 chambers had only one readout per gap (giving horizontal information); these chambers made an important contribution to the good momentum resolution of the system. All other chambers had two readouts giving horizontal and vertical information; the vertical information from the K1 and K2 chambers came from wires oriented $\pm 30^{\circ}$ from vertical (also used to resolve ambiguities). Chamber resolution was about $\pm$ 0.5 mm.

The counter and spark chamber information was read into an EMR-6050 computer via SAC electronics; up to four sparks per readout were digitized with 10 mil least count. The computer had 32 K of 24-bit word memory, 1.9 μsec cycle time, floating point hardware, priority interrupts, a CRT display, two fast tape units, and other peripherals. It not only logged the raw data onto tape, but also analyzed a sample of the events (typically 10 events in the 3 seconds available between beam spills) and displayed the results on the CRT.[3]

An essential feature of the spectrometer is its good resolution. Fig. 2 shows the Λ, Σ^0 missing mass separation for the reactions $\pi^- p \rightarrow K^0(\Lambda, \Sigma^0)$ with $K^0 \rightarrow \pi^+\pi^-$ being detected by the spectrometer. The separation is very clean at 3 GeV/c (rms width of $\pm$ 13 MeV); at 6 GeV/c the peaks have merged ($\pm$ 34 MeV), but the cross sections can still be unambiguously determined with a computer fit. The good effective mass resolution (typically $\pm$ 3 or 4 MeV with little dependence on energy) for two-particle systems coming through the spectrometer, combined with the capability for high statistics, make the spectrometer ideal for studying fine structure in $\pi^+\pi^-$, K^+K^-, π^+K^-, and $p\bar{p}$ mass spectra. A large Cerenkov counter[4] (not shown in Fig. 1) was recently placed behind the K5 chambers to aid in K^+K^- and $p\bar{p}$ studies.

The spectrometer first received beam in

May 1971, and data were collected for five experiments during the period August 1971 to April 1972. Several papers reporting results (mainly preliminary) from these experiments were presented to this conference:

1, 2) Wicklund et al.(No. 355 and 734), "Comparison of Particle-Antiparticle Elastic Scattering from 3 to 6 GeV/c." About 300,000 good events were obtained, mainly in the cross-over region, with some data out to $-t \approx 1.5$ GeV^2. Final results at 5 GeV/c are shown in Fig. 3 and have been submitted to Phys. Rev. Letters.

3) Ayres et al.(No. 735), "Structure in the $\pi^+\pi^-$ Mass Spectrum." Eventually more than 500,000 events are expected, including results from both π^+ and π^- incident on deuterium, allowing a detailed study of ρ-ω interference.

4) Ayres et al.(No. 736), "Meson Resonance Studies with K^+K^- and $\bar{p}p$ Spectra." The data will give information on $\pi^-p \rightarrow \phi n$, f-A_2 interference, etc., with 24,000 events at 6 GeV/c, as well as data at 4 and 5 GeV/c. About 8,000 $\bar{p}p$ events were obtained at 6 GeV/c.

5) Knasel et al.(No. 459), "Λ and Nucleon Resonance Production in pp Collisions at 6 GeV/c." About 1,000 Λ events were found in the data analyzed so far ($\sim$ 15% of total) as well as a large number of Δ events.

6) Yovanovitch et al.(No. 298), "Λ^0 Polarization in Semi-Inclusive π^-p Reactions from 3 to 6 GeV/c." Results are based on about 33,000 events.

7) Yovanovitch et al.(No. 299), "The Reactions $\pi^-p \rightarrow K^0\Lambda^0$ and $\pi^-p \rightarrow K^0\Sigma^0$ at 3, 4, 5 and 6 GeV/c." About 40,000 events were found in the region $-t \leq 0.7$ GeV^2; data on Y^* production as well will be analyzed.

8) Yovanovitch et al.(No. 300), "The Baryon Exchange Process $\pi^-p \rightarrow \Lambda^0K^0$ at 3, 4, 5 and 6 GeV/c." About 4,000 ΛK events were used to measure both $d\sigma/du$ and the Λ polarization.

The facility has a busy future ahead with seven proposed experiments waiting to be run. Fortunately, experiments can be run in a fast, efficient manner since the system is well understood and debugged, and these experiments represent less than a year of running.

References

+Invited talk given at the Parallel Session on Detectors and Instrumentation, XVI International Conference on High Energy Physics, Chicago, Sept. 1972.

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