Contribution to: '79 INS Symposium on Particle Physics in GeV Region - Present Status and Future Prospects, November 21-23, 1979, Tokyo, Japan.

BNL-27324

HADRON SPECTROSCOPY IN THE BROOKHAVEN MULTIPARTICLE SPECTROMETER

CONF-791174--4

K.J. Foley
Brookhaven National Laboratory*

The Brookhaven Multiparticle Spectrometer is a large aperture magnetic spectrometer operated as a user facility at the Alternating Gradient Synchrotron (AGS). The magnet is shown in Fig. 1. The gap height is 1.2 meters and the pole area is 1.8 m x 4.6 m; all of the magnetic return yoke is on one side, leading to a very open structure: a "C" magnet with three 8" diameter stainless steel posts on the open side to support the weight and the magnetic forces. The spectrometer was designed with the use of magnetostrictive-readout spark chambers in mind. Consequently, the top pole is slotted so that readout lines can be located above the top pole in a region of low field. In order to facilitate the use of beams from different target stations at the AGS, the magnet is installed on ground steel plates with high pressure oil-bearings and can be rotated through an angle of 30° about a pivot near the upstream end.

A plan view of the MPS Spectrometer is shown in Fig. 2. The main downstream detectors inside the magnet consist of modules of magnetostrictive spark chambers. One type of module is inserted through the slots in the top pole and consists of four gaps, XUVX, where the X gaps have vertical wires and the U and V gaps have wires at ± 15° from the vertical. The second type of module, YY, has horizontal wires and is inserted from the open side of the magnet. All readouts are in a region of low magnetic field. In any one gap, the wires are parallel and both sides are read out, with a maximum of 16 sparks encoded on each readout. Eight XUVX modules and eight

* This research was supported by the U.S. Department of Energy under Contract No. DE-AC02-76CH00016.

DISCLAIMER

YY modules are available. Several proportional chambers (TPX's) plus scintillation counter hodoscopes and Cerenkov counters can be used for trigger purposes. Beyond the magnet, large magnetostrictive chambers, a pair of Cerenkov counter hodoscopes, and a large scintillation counter hodoscope complete the downstream system. In usual operation, the changes from experiment to experiment consist of rearranging the positioning of the detectors, though several experiments have used special purpose devices interspersed with the spark chambers. The target region is much more dependent on the particular experiment. There are two spark chamber systems available. One consists of 8 cylindrical spark chambers surrounding the target coaxial with the beam. In any one gap, one side has wires parallel to the axis and the other side is wound in a 45° helix. Stereo readout is achieved by reversing the helix angle on alternate gaps. Readout is via magnetostrictive wands positioned in a low field region behind the magnet end plate. The second target region is made up of planar spark chamber modules with capacitive readout. Finally, in several experiments involving reactions with recoil neutrons, a scintillation counter box served to veto events with recoil charged particles (and γ rays, if appropriate).

During the beam spill, information from the spark chambers, PWC's, etc. is collected by a data handler with a large buffer memory. In between AGS pulses, the data is written onto magnetic tape and, in parallel, a sample of the data is sent to a PDP10 computer at the BNL On-Line Data Facility for monitoring and analysis.

Two beams are available to the MPS: the Medium Energy Separated Beam (MESB) and the High Energy Unseparated Beam (HEUB). The former provides partially separated K mesons up to $\sim$ 6 GeV/c and antiprotons up to the momentum limit of 9 GeV/c, while the latter has an upper limit of $\lesssim$ 25 GeV/c.

In order to avoid serious biases at small production angles, the whole area of the chambers is active (one should also note that "beam region" is a function of incident momentum so the deadening of just a small area would be a very difficult problem). Because of the 2 μsec memory time of the spark chambers, most experiments limit the incident flux to $\lesssim 3 \times 10^5$/pulse. Since computer budgets are limited, one would not want to write more than 20 or so events per pulse; consequently, tight triggers are in order. Over the years many sophisticated triggers have been developed at the MPS. A good example is "RAM" trigger device,[1] designed and built at BNL using custom LSI integrated circuits. A "RAM" module consists of a two million bit memory arranged as a three-dimensional (128 x 128 x 128) lookup table. With this device, three detector planes can be used to select events with charged particles in a given range of angle and momentum, even in the presence of other particles. The information from the RAM is available $\sim$ 200 nsec after the input data, leaving time to trigger the spark chambers. During normal operation the memory load is checked, in between AGS pulses, against files stored at the PDP10 computer; the failure rate is extremely low and is due mainly to power dips. The RAM trigger typically produces an improvement of more than a factor of ten in trigger rates, while causing little or no bias in the data.

MPS Experiments

The MPS Facility has been in operation since late 1974 with 11 experiments completed to date and 2 more experiments approved. Data have been published from 6 experiments, with the other 5 in various stages of analysis.

I will discuss each MPS experiment briefly, following the sequence in which they were run.

1. Exp. 654 (BRANDEIS UNIVERSITY, BNL, CITY COLLEGE OF NEW YORK, CARNEGIE-MELLON UNIVERSITY, UNIVERSITY OF CINCINNATI, UNIVERSITY OF MASSACHUSETTS, UNIVERSITY OF PENNSYLVANIA, SOUTHEASTERN MASSACHUSETTS UNIVERSITY, SYRACUSE UNIVERSITY)

This collaboration searched for the η_c in a formation experiment using the MESB. The reactions sought were:

$$\bar{p}p \rightarrow \eta_c \rightarrow \begin{matrix} K^o + X \\ \Lambda^o + X \end{matrix} .$$

Three overlapping incident momenta near 4 GeV/c permitted a search in the mass region 2.99 to 3.14 GeV. The data have been published.[2] Briefly, upper limits were set on the above reactions; typically $\sigma B < 2\ \mu b$ for $\Gamma(\eta_c) = 5$ MeV.

2. Exp. 557 (BRANDEIS UNIVERSITY, BNL, CITY COLLEGE OF NEW YORK, UNIVERSITY OF MASSACHUSETTS, UNIVERSITY OF PENNSYLVANIA)

This experiment was a study of K^*'s produced in the reaction

$$K^- p \rightarrow K^- \pi^+ n$$

using the MESB at 6 GeV/c. The capacitive-chamber target region system was used in this experiment, with a water Cerenkov counter[3] to detect slow pions. The results[4] showed a clear $K^*(1420)$ and $K^*(1780)$; analysis of the decay distribution shows bumps at 1780 MeV in the 5th and 6th moments indicating that spin of the $K^*(1780)$ is ≥ 3, in agreement with other experiments.

3. Exp. 594 (BNL, CITY COLLEGE OF NEW YORK)

The reaction studied was

$$K^- p \rightarrow K^o_S \pi^+ \pi^- n$$

at an incident momentum of 6 GeV/c. The purpose of the experiment was a search for K^* resonances in the $K^o_S \pi^+ \pi^-$ channel. Note that all spin-parity combinations are allowed and that diffractive backgrounds are suppressed because the reaction involves charge-exchange. A partial wave analysis has been performed[5] with the results shown in Fig. 3. Clear signals are seen for the $K^*(1430)$ ($J^P = 2^+$) the $Q_2(1400)$ (1^+) and the $K^*(1800)$ (3^-). In addition, strong evidence is found for a new resonance at ∿ 1500 MeV decaying into $K^*(890)\pi$ with $J^P = 1^-$.

4. Exp. 601 (BRANDEIS UNIVERSITY, UNIVERSITY OF CINCINNATI, SYRACUSE UNIVERSITY)

Antiproton annihilation was studied in the reactions

$$\bar{p}p \rightarrow K^o_s + X$$
$$\rightarrow \Lambda + X$$
$$\rightarrow \bar{\Lambda} + X$$

using the MESB at 3 GeV/c. Data have been published[6] on differential cross sections for many exclusive final states, along with polarization measurements for $\bar{\Lambda}$'s. A search was also carried out for s-channel production of the η_c.

5. Exp. 596 (CARNEGIE-MELLON UNIVERSITY, SOUTHEASTERN MASSACHUSETTS UNIVERSITY)

This was a systematic study of time reversal invariance in $\bar{p}p$ and πp reactions using the MESB at 6 GeV/c. The results have been published.[7] Briefly, line reversal works for the two line reversed pairs:

$$\bar{p}p \rightarrow \pi^+\pi^- \quad , \quad \pi^-p \rightarrow p\pi^-$$

and

$$p\bar{p} \rightarrow \pi^-\rho^- \quad , \quad \pi^-p \rightarrow \rho^-p$$

but is not correct for the pair

$$\bar{p}p \rightarrow \pi^-\pi^+ \quad , \quad \pi^+p \rightarrow p\pi^+ .$$

6. Exp. 679 (BNL, CITY COLLEGE OF NEW YORK)

This was the first experiment in the HEUB. The reaction studied was:

$$\pi^- p \to K^+ K^- K^+ K^- n$$

at an incident momentum of 23 GeV/c. The trigger included the 2 million bit RAM trigger and a large Cerenkov counter hodoscope to select kaons in the momentum range 4 to 12 GeV/c. One purpose of the experiment was to study the $\phi\phi n$ final state. Approximately 100 events were found[8] corresponding to a cross section of $\approx$ 25 nb; this was the first observation of double ϕ production. The $\phi\phi$ effective mass spectrum is shown in Fig. 4. The data peak at $\sim$ 2.35 GeV with very few events at high mass. An upper limit of $\approx$ 2 nb was placed on η_c production in the reaction

$$\pi^- p \to \eta_c n, \quad \eta_c \to (\phi\phi)$$

Another feature of the experiment was a test of the OZI rule in $\phi\phi$ production. The rule was found[9] to suppress "forbidden" reactions very weakly, if at all, when compared to the strong effects seen in decay processes.

7. Exp. 688 (BRANDEIS UNIVERSITY, BNL, UNIVERSITY OF CINCINNATI, SYRACUSE UNIVERSITY)

This was a charm search, using the presence of a prompt muon as a trigger. The reaction studied was

$$\pi^- p \to \mu + \text{Vee} + X .$$

For this experiment a copper absorber was placed in the downstream region of the MPS, with spark chambers in front of and behind the absorber to permit the tracking of muons. The present limit for associated charm production is[10] $\sigma B < 100$ nb. Data from a muon pair trigger are also being analyzed.

8. Exp. 686 (BRANDEIS UNIVERSITY, BNL, UNIVERSITY OF PENNSYLVANIA, SUNY at STONY BROOK, SYRACUSE UNIVERSITY)

In this experiment a prompt electron was used as an indication of charm production. The reaction was $\pi^- p \to e^- + X$ at a momentum of 17 GeV/c. Electrons were selected with a pair of transition-radiation detectors and a large shower detector. The aim is to reconstruct the recoil particle and search for charm production in an effective mass-missing mass distribution. The analysis is proceeding with an estimated final yield of one event for 5 nb of associated charm production. Another trigger yielded extensive data on e^+e^- pair production.

9. Exp. 716 (BNL, CARNEGIE-MELLON UNIVERSITY, SOUTHEASTERN MASSACHUSETTS UNIVERSITY)

The main part of this experiment was a search for baryonium production in the reaction $\pi^+ p \to \Delta^{++}_{(forward)} (\bar{p}p)$, $\Delta^{++} \to (p\pi^+)$

at 10 GeV/c. Events were triggered on a fast forward proton using the RAM trigger and the Cerenkov counter hodoscope. About half of the data has been analyzed. The $\bar{p}p$ effective mass spectrum[11] shows no significant narrow peaks with a number of events[12] about equal to that of the earlier ($\pi^- p$) experiment at the CERN Omega[13] (combined 9 and 12 GeV data) which showed narrow peaks at 2020 and 2200 GeV. The analysis is proceeding.

10. Exp. 682 (BRANDEIS UNIVERSITY, BNL, CITY COLLEGE OF NEW YORK, UNIVERSITY OF MASSACHUSETTS, UNIVERSITY OF PENNSYLVANIA)

The main reaction studied was

$$\pi^- p \to (p\pi^-)_f \, \bar{p}p$$

at 12 and 16 GeV/c in a search for baryonium. The trigger used the RAM system with two large Cerenkov counter hodoscopes to separate fast forward protons from pions and kaons. The analysis is in progress. A clear sample of 4c events has been obtained at 16 GeV/c and a final sensitivity of approximately 4 events/nb is expected; this will be about twice the sensitivity of the experiment of Benkheiri et al.[13] This should be a definitive experiment on the production of baryonium.

11. Exp. 673 (BRANDEIS UNIVERSITY, BNL, UNIVERSITY OF CINCINNATI, FLORIDA STATE UNIV., SOUTHEASTERN MASSACHUSETTS UNIV.)

This was a study of Ξ^* production in K^-p reactions at 5 GeV/c. Two types of triggers were employed: one used a stopping K^+ detector to signal the production of S = -2 states and the other selected forward protons which, at this energy, come mainly from the decay of forward Λ^o's. The analysis is just starting, but the on-line data showed plentiful forward Λ^o production, and the $\Lambda^o\pi^-$ spectrum contained a clear Ξ^-.

There are two experiments approved, but still to be run at the Multiparticle Spectrometer:

A. Exp. 705 (BNL, TUFTS UNIVERSITY, VANDERBILT UNIVERSITY)

This is an experiment to study the reaction

$$\pi^- p \rightarrow K_S^o K_S^o + X$$
$$\rightarrow \Lambda\Lambda + X$$

at 20 GeV/c. A sensitivity of 100 ev/nb is expected.

B. Exp. 698 (UNIVERSITY OF MASSACHUSETTS)

This will be the first use of a polarized target in the MPS. The target, a spin-refrigerator system, has been tested at BNL and has achieved proton polarization as high as 80%.[14] The experiment will study s-channel and t-channel production of hyperons in a low momentum K^- beam.

FUTURE PLANS: MPS II

At the moment, the maximum beam rate in the MPS is limited to ≈ 3 x 10^5/pulse because of the 2 μsec memory time of the spark chambers. Since the next generation of experiments must surely include very sensitive "charm" and "exotic" studies, we have started a program to replace the spark chambers with narrow-cell drift chambers. The drift distance will be 1/8" (≈ 3 mm) giving a drift time of ≈ 60 nsec and an expected overall resolution of better than 200 μm. We are currently constructing planar modules for use in the downstream system. Each module has five gaps, XXX'YY' with "U,V" cathode readouts at ± 30° to give stereo information. This configuration was chosen after Monte Carlo studies of the reconstruction of tracks bending in a magnetic field; briefly, measurements with offset wires, X' and Y' are needed to resolve the left-right ambiguity, while the third "X" gap is needed since the bending in the magnetic field complicates the tracking from module to module. In most cases, analysis of the data in a single module will remove the L-R ambiguity and give point + slope plus a 3D point. This extensive information will simplify (and speed up!) the pattern recognition.

The MPS II drift chambers will employ three custom integrated circuits: an amplifier, a discriminator and a digital "delay-line, digitizer". The amplifier and discriminators are relatively conventional in approach and the specifications are given in Table I. The "delay-line, digitizer" uses a new principle for drift chamber readout. A simplified layout is shown in Fig. 5. Each channel consists of a 256 bit shift register capable of an effective clock speed of 250 MHz. During normal operation, data from each channel is shifted continuously through a shift register in 4 nsec "buckets". If the trigger devices indicate a good event, the clock is stopped, one microsecond after the arrival of the incident beam particle. At this point, a time record of each wire resides in the end region of the shift register, automatically digitized in 4 nsec steps. During the readout cycle just this part of the shift register (in the case of MPS II this will be the last 32 bits) is read out using the logic shown schematically in Fig. 5. Thus a single circuit occupying one quarter of an IC has provided a 1 μsec delay plus time digitization. This approach will lead to inexpensive chamber readout with total cost, after initial engineering, of $\lesssim$ \$10/channel for large quantities.

At the moment, three modules are being constructed, with enough IC's for readout on order. Following a successful test in the spring of 1980 the construction of six more modules will complete the downstream region. Meanwhile, studies of target region detectors are proceeding in order to achieve a solid angle coverage close to 4π.

REFERENCES

1. E.D. Platner, A. Etkin, K.J. Foley, J.H. Goldman, W.A. Love, T.W. Morris, S. Ozaki, A.C. Saulys, C.D. Wheeler, E.H. Willen, S.J. Lindenbaum, J.R. Bensinger, M.A. Kramer. Nucl. Instr. and Methods 140, 549-552 (1977).

2. J.R. Bensinger, S.M. Jacobs, L.E. Kirsch, S.C. Moore, P.E. Schmidt, S.U. Chung, K.J. Foley, W.A. Love, W.J. Miller, T.W. Morris, S. Ozaki, E.D. Platner, S.D. Protopopescu, A.C. Saulys, E.H. Willen, S.J. Lindenbaum, R.M. Edelstein, D.R. Green, H. Halpern, J.S. Russ, N.A. Stein, D.M. Weintraub, R. Endorf, B.T. Meadows, A. Etkin, M.A. Kramer, U. Mallik, J. Button-Shafer, M. Singer, W. Selove, Z. Bar Yam, J.P. Dowd, H. Gittleson, W. Kern, J.J. Russell, A. Fainberg, P.S. Gauthier, M. Goldberg, N. Horwitz, I.R. Linscott, D.P. Weygand. Nucl. Phys. B119, 77-84 (1977).

3. J. Button-Shafer, H.W. Churchill, R.L. Lichti, D.H. Novack. Nucl. Instr. and Methods 137, 29-40 (1976).

4. S.U. Chung, A. Etkin, V. Flaminio, K.J. Foley, J.H. Goldman, J. Kopp, W.A. Love, D.N. Michael, T.W. Morris, S. Ozaki, E.D. Platner, S.D. Protopopescu, A.C. Saulys, C.D. Wheeler, E.H. Willen, J.R. Bensinger, S.M. Jacobs, S.J. Lindenbaum, I.J. Kim, M.A. Kramer, J. Button-Shafer, S. Dhar, R. Lichti, W. Selove. Phys. Rev. Letts. 40, 355-358 (1978).

5. A. Etkin, K.J. Foley, J.H. Goldman, R.S. Longacre, W.A. Love, T.W. Morris, S. Ozaki, E.D. Platner, A.C. Saulys, C.D. Wheeler, E.H. Willen, S.J. Lindenbaum, M.A. Kramer, U. Mallik. "Measurement and Partial Wave Analysis of the Reaction $K^-p \rightarrow K_S^o\pi^+\pi^-n$ at 6 GeV/c". Submitted to Phys. Rev. D.

6. S.M. Jacobs, L.E. Kirsch, S.C. Moore, P.E. Schmidt, T. Davis, B.T. Meadows, A. Fainberg, M. Goldberg, I.R. Linscott, G.C. Moneti, D.P. Weygand. Phys. Rev. D17, 1187-1196 (1978).

7. N.A. Stein, R.M. Edelstein, D.R. Green, H.J. Halpern, E.J. Makuchowski, J.S. Russ, D.M. Weintraub, Z. Bar-Yam, J.P. Dowd, W. Kern, J.J. Russell, N. Sharfman, M.N. Singer. Phys. Rev. Letts. 39, 378-381 (1977); Phys. Rev. Letts. 39, 1243-1246 (1977); Phys. Rev. Letts. 40, 681-684 (1978).

8. A. Etkin, K.J. Foley, J.H. Goldman, W.A. Love, T.W. Morris, S. Ozaki, E.D. Platner, A.C. Saulys, C.D. Wheeler, E.H. Willen, S.J. Lindenbaum, M.A. Kramer, U. Mallik. Phys. Rev. Letts. 40, 422-425 (1978).

9. A. Etkin, K.J. Foley, J.H. Goldman, W.A. Love, T.W. Morris, S. Ozaki, E.D. Platner, A.C. Saulys, C.D. Wheeler, E.H. Willen, S.J. Lindenbaum, M.A. Kramer, U. Mallik. Phys. Rev. Letts. 41, 784-787 (1978).

10. D.P. Weygand. Thesis. Syracuse University (1979).

11. A.S. Carroll, G. Bunce, R.M. Bionta, R.M. Edelstein, D.R. Green, E.J. Makuchowski, S.P. Morrissey, J.S. Russ, N. Sharfman, R.B. Sutton, J.J. Russell. Report to Montreal Meeting, Division of Particles and Fields, American Physical Society (1979).

12. Because of the isospin coupling factors, the reaction $\pi^+ p \to \Delta^{++}(\bar{p}p)$ is expected to have a larger cross section than the reaction $\pi^- p \to \Delta^o(\bar{p}p)$; Δ exchange would give an enhancement factor of 9/4 and proton exchange a factor of 9. The observed cross section seems to be between these two extremes.

13. P. Benkheiri, J. Boucrot, B. Bouquet, P. Briandet, B. D'Almagne, C. Dang Vu, B. Eisenstein, A. Ferrer, P. Fleury, B. Grossetête, G. Irwin, A. Jacholkowski, A. Lahellec, H. Nguyen, P. Petroff, F. Richard, P. Rivet, G. DeRosny, P. Roudeau, A. Rouge, M. Rumpf, J. Six, J.M. Thénard, D. Treille, A. Volte, D. Yaffé, T.P. Yiou, H. Yoshida. Phys. Letts. 68B, 483-488 (1977).

14. J. Button-Shafer, "The U. Mass. Spin Refrigerator and Strange-Particle Physics with the Brookhaven Multiparticle Spectrometer". Talk presented at the III International Symposium on High Energy Physics with Polarized Beams and Polarized Targets, Argonne National Laboratory, October 1978.

TABLE 1

Amplifier Specifications

Output dynamic range = 1000 to 1 with 5% linearity

Input = true differential

Z_{in} common mode = 50Ω max.

Input protection = 4.5 x 10^{-4} joules for no permanent damage, 100 pfd at 3 KV discharge

Transfer impedence = 12 ± 10% mV/μA per lot

Gain stability = 0.1%/°C

Temperature range = 0°C to 50°C

Linearity = 5% max. with external 8 ns integration time for a 3V peak signal into 1K load

Equivalent input current noise = 0.25 μA RMS with external 8 ns integration time constant

Z_{out} = 50Ω max.

Rise and fall time = 4.4 ns max. for 10% to 90%, 0.25V output

Overshot = 10% max.

Overload recovery = 40 nsec for 100 μA 30 ns wide input pulse

Propagation delay = 10 nsec max.

Propagation delay variation between channels on a chip = ± 1.5 nsec max.

Discriminator Specifications

Discriminator time slewing = < 4 ns for 2X-20X threshold

Hysteresis = 6 mv

Threshold = 0 to 500 mv

Threshold match = ± 5 mv

Crosstalk between channels = > 40 db down

Output = low: 1.5 volt; high: 3.5 volt; 3 ns risetime

FIGURE CAPTIONS

Fig. 1 The MPS magnet

Fig. 2 The spectrometer layout. This particular experiment used just a veto box in the target region.

Fig. 3 Results of a Partial Wave Analysis of the reaction $K^- p \rightarrow K^0_s \pi^+ \pi^- n$. The solid lines are fits allowing resonances in the 1^+, 1^-, 2^+ and 3^- waves. For more details see Reference 5.

Fig. 4 The $\phi\phi$ effective mass spectrum, corrected for acceptance.

Fig. 5 A simplified schematic of the delay-line, digitizer circuit.

MPS MAGNET

Weight	650 tons
Gap	6' wide x 4' high x 15' long
Central Field	10kG
Coils	14 pancakes, 11 turns ea.
Power	10,000 A @ 240V
Cooling Water	400 GPM @ 20°C rise
Downward Force at Midplane	550 tons (magnet powered)
Support	4 hydrostatic bearings, 30" dia. on steel plates
Rotation	± 15°, pivot 18" inside upstream end

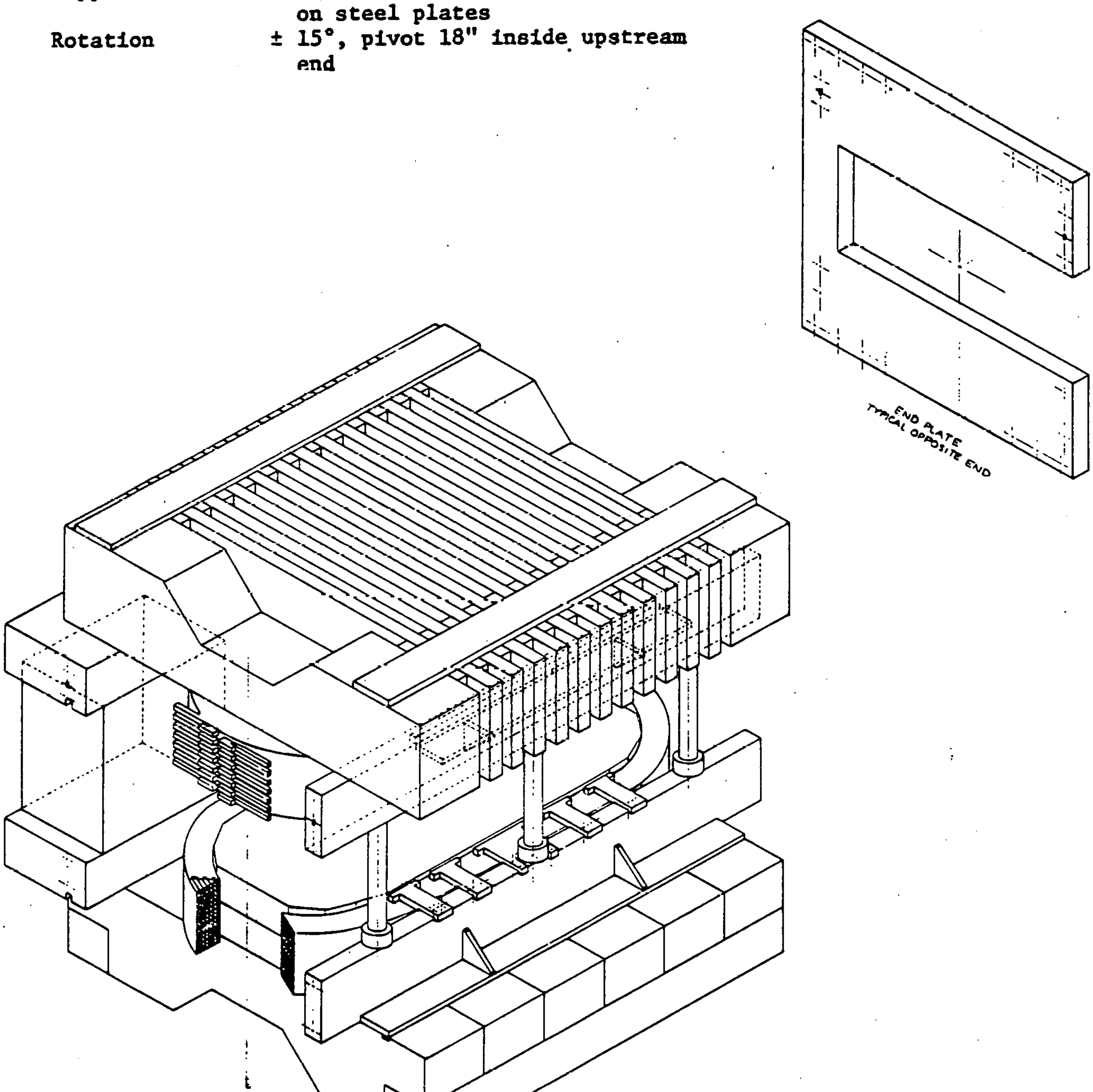
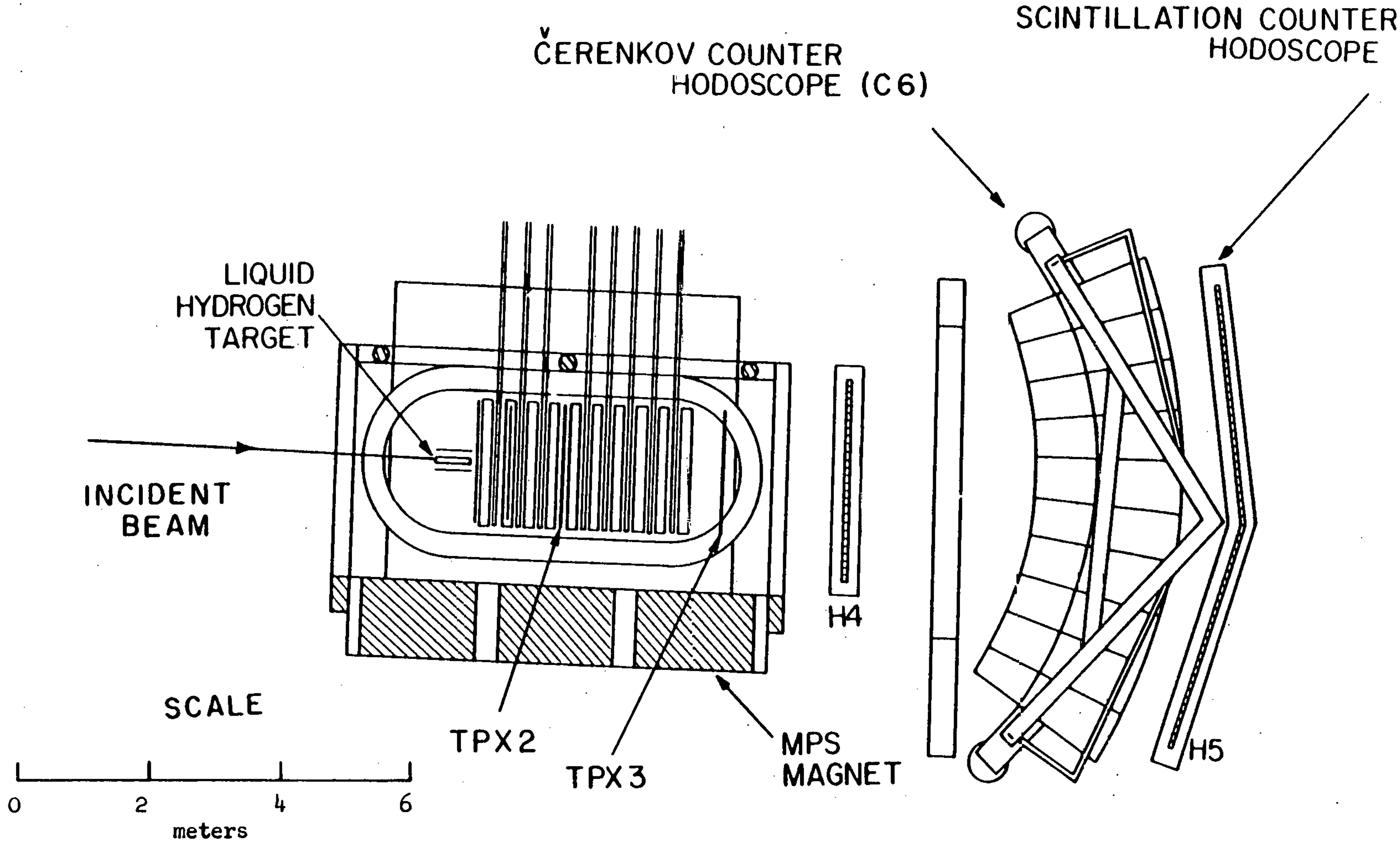


Figure 1



TPX2 & TPX3: Proportional Wire Chambers

Wires 2.5 mm apart, tied in groups of 5

Trigger resolution: 1.25 cm

--With 3 detectors, measure momentum

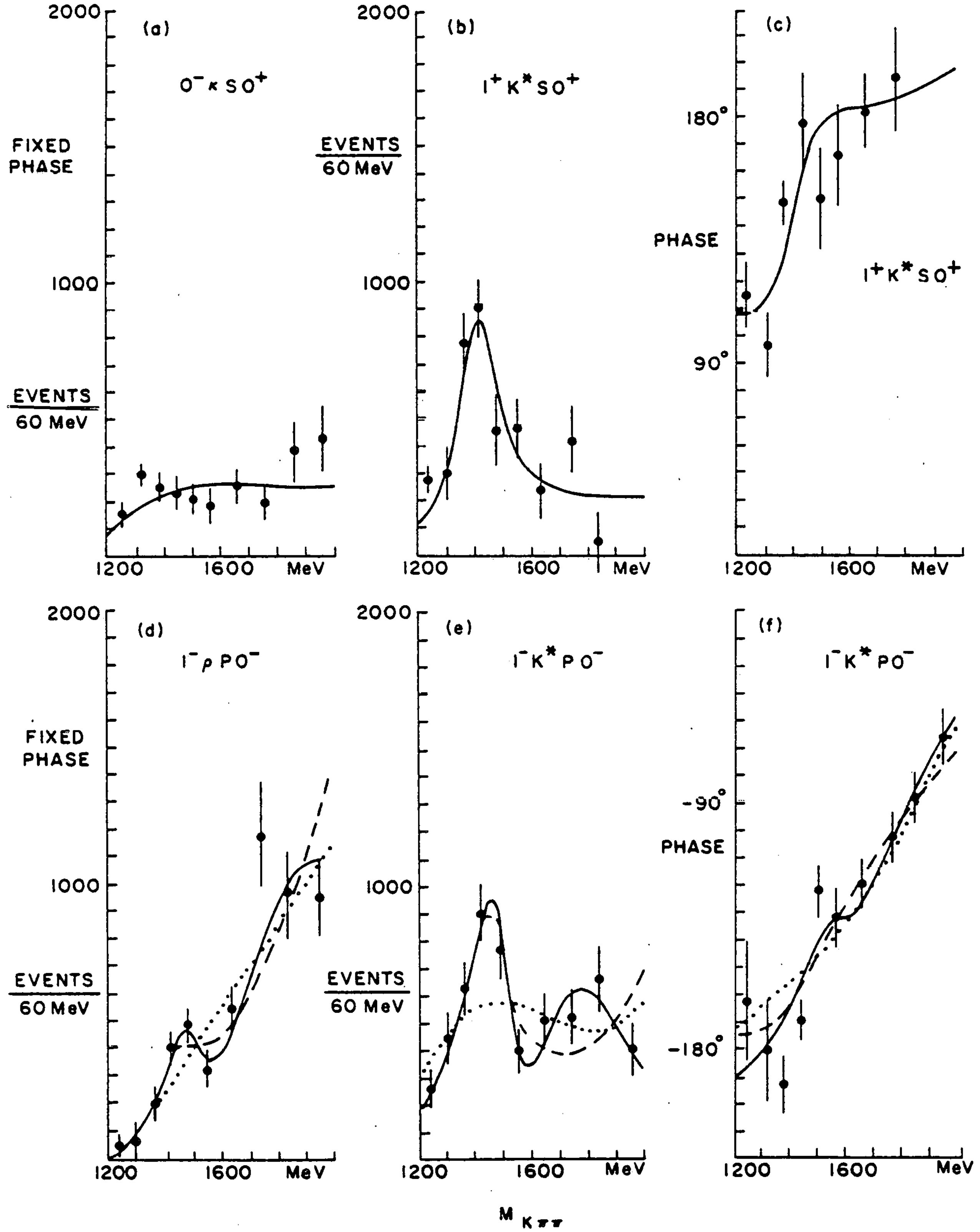
--With C6, identify K or P, reject PI

H5: Scintillation counters 6.25 cm wide

C6: Threshold Cherenkov counter

$\gamma = 20$

Figure 2



2000
(a)
0⁻ κ S 0⁺
FIXED
PHASE
1000
EVENTS
60 MeV
1200
1600
MeV
2000
(b)
1⁺ K* S 0⁺
EVENTS
60 MeV
1000
1200
1600
MeV
(c)
180°
PHASE
1⁺ K* S 0⁺
90°
1200
1600
MeV
2000
(d)
1⁻ ρ P 0⁻
FIXED
PHASE
1000
EVENTS
60 MeV
1200
1600
MeV
2000
(e)
1⁻ K* P 0⁻
1000
EVENTS
60 MeV
1200
1600
MeV
(f)
1⁻ K* P 0⁻
-90°
PHASE
-180°
1200
1600
MeV
M Kππ

Figure 3a-f

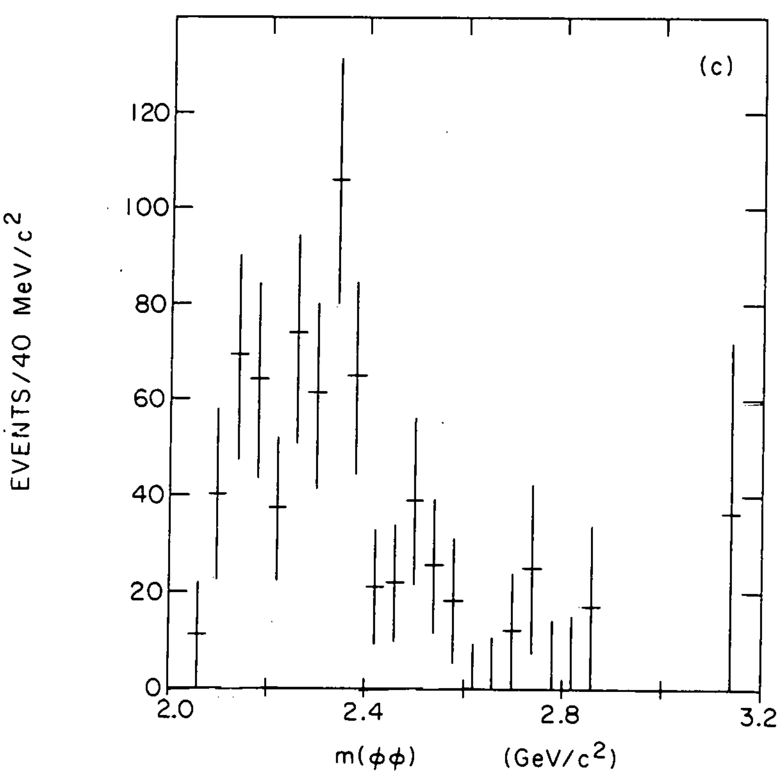


Figure 4

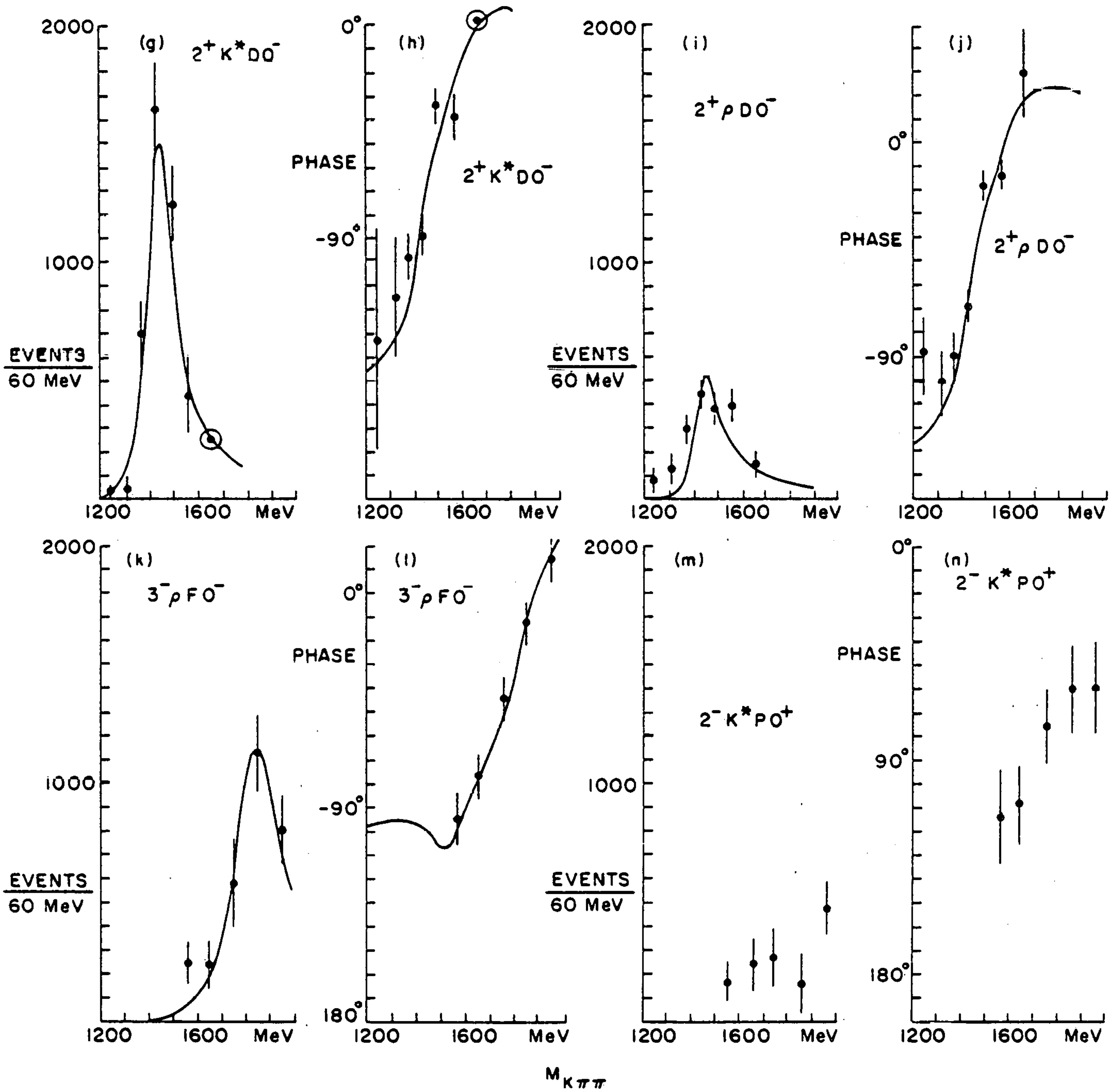

(g)
2+ K* DO-
2000
1000
EVENTS / 60 MeV
1200
1600
MeV
(h)
0°
PHASE
2+ K* DO-
-90°
(i)
2+ ρ DO-
(j)
0°
PHASE
2+ ρ DO-
-90°
(k)
3- ρ FO-
(l)
3- ρ FO-
-90°
180°
(m)
2- K* PO+
(n)
2- K* PO+
90°
180°
M Kππ

Figure 3g-n

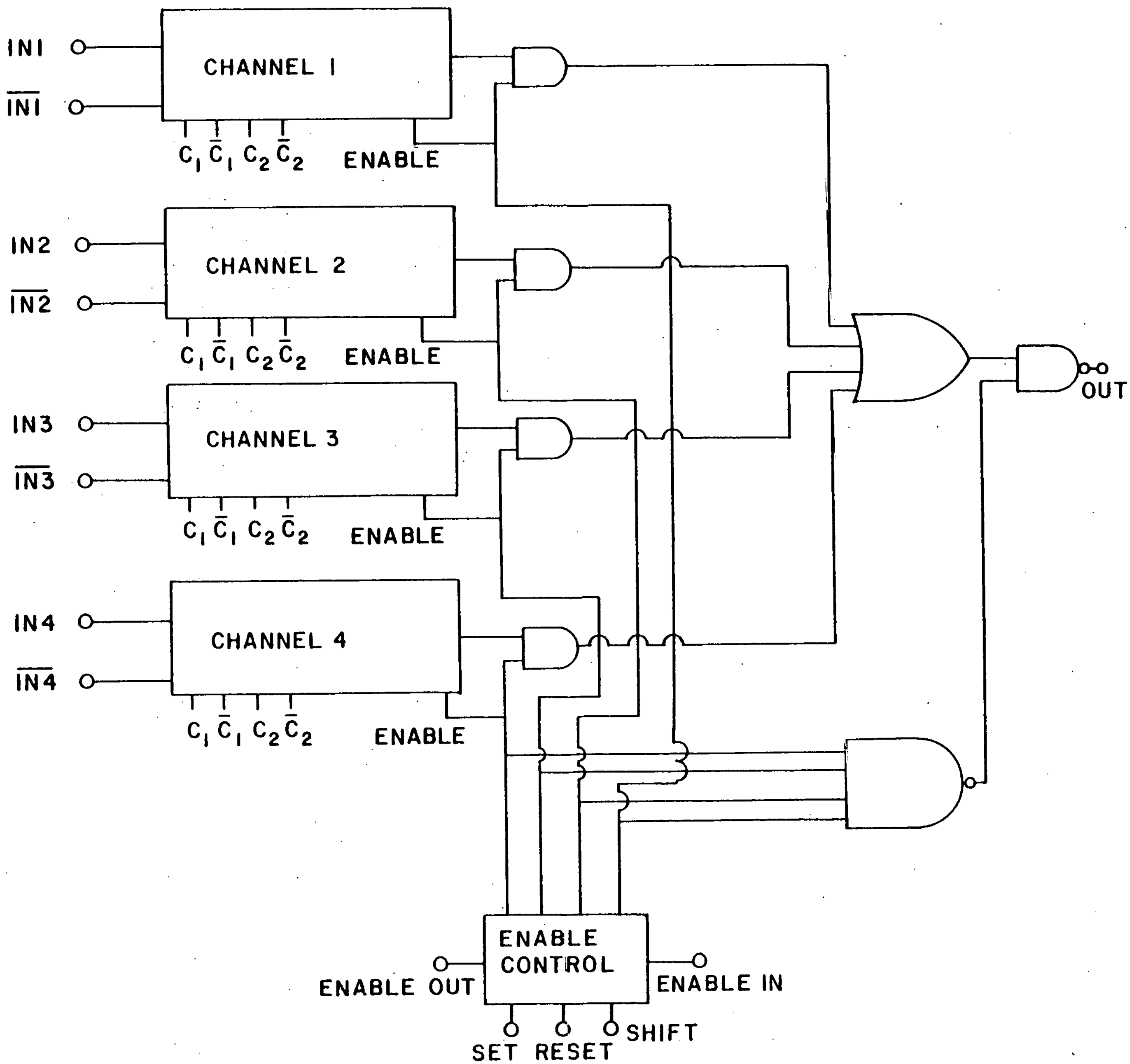

IN1
$\overline{IN1}$
CHANNEL 1
C_1 $\bar{C}_1$ C_2 $\bar{C}_2$
ENABLE
IN2
$\overline{IN2}$
CHANNEL 2
C_1 $\bar{C}_1$ C_2 $\bar{C}_2$
ENABLE
IN3
$\overline{IN3}$
CHANNEL 3
C_1 $\bar{C}_1$ C_2 $\bar{C}_2$
ENABLE
IN4
$\overline{IN4}$
CHANNEL 4
C_1 $\bar{C}_1$ C_2 $\bar{C}_2$
ENABLE
OUT
ENABLE CONTROL
ENABLE OUT
ENABLE IN
SET
RESET
SHIFT

Figure 5