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Hadron Spectroscopy at RHIC and KAON

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ABSTRACT

A description is given of the physics opportunities at RHIC regarding quark-gluon spectroscopy. The basic idea is to isolate with appropriate triggers the sub-processes pomeron + pomeron → hadrons and $\gamma^* + \gamma^* \to$ hadrons with the net effective mass of hadrons in the range of 1.0 to 10.0 GeV, in order to study the hadronic states composed of u, d, c, b and gluons. The double-pomeron interactions are expected to produce glueballs and hybrids preferentially, while the two-offshell-photon initial states should couple predominantly to quarkonia and multiquark states. Of particular interest is the possibility of carrying out a CP-violation study in the B decays.

The KAON facility, proposed for TRIUMF, Vancouver, Canada, is an intense hadron factory with a proton flux some 25 times higher than that available at the BNL AGS with the Booster. Therefore, a general purpose hadron spectrometer will be able to tackle the problem of studying gluonic and multiquark degrees of freedom in strangeonia.

1. *Hadron Physics at RHIC*

In this section is described a conceptual design for carrying out a study of quark-gluon spectroscopy at the BNL Relativistic Heavy Ion Collider (RHIC)[1].

The idea is derived from a double-pomeron exchange trigger which was successfully implemented in R807 (an ISR experiment at CERN)[2]. The resulting $\pi^+\pi^-$ (see Fig.1) and K^+K^- spectra provided key ingredients in the study of $J^{PC} = 0^{++}$ states[3] with masses around 1.0 GeV.

For the trigger to succeed, it is necessary that for $p \times p$ the recoiling beam particles come off at a very small angle, $\theta < 2$ mr. At RHIC energies this corresponds to installing a set of four 'Roman pots,' two on each side up and down, 10 m away from the intersection region. Precision 5x5 cm mini-drift chambers and scintillation counters will be installed in each Roman pot to detect and trigger on the scattered beam particles. The intersection region will be instrumented with a 4π-detector consisting of cylindrical drift chambers, ring-imaging Cerenkov counter and lead-scintillator barrel counters, all within a 5.4m-long solenoid magnet with a 3.6 m coil diameter, patterned after the Mark III[4] and the ARGUS apparatus.

It was shown in R807 that imposition of momentum balance in the direction perpendicular to that of the beam particles results in pure exclusive events, as follows:

$$pp \to p\,(\pi^+\pi^-)\,p$$
$$pp \to p\,(K^+K^-)\,p$$

where the systems shown in parentheses indicate the particles detected in the central detector. In the proposed RHIC experiment, the central detector will be optimized for charged as well as neutral particles with momenta up to 3 GeV/c, so that the following reactions can be studied:

$$pp \to p\,(\eta\eta)\,p$$
$$pp \to p\,(\omega\omega)\,p$$
$$pp \to p\,(\phi\phi)\,p$$
$$pp \to p\,(\eta\pi\pi)\,p$$
$$pp \to p\,(\omega\pi\pi)\,p$$
$$pp \to p\,(K\bar{K}\pi)\,p$$
$$pp \to p\,(p\bar{p}\pi)\,p$$

where the parentheses indicate again the central system.

The momentum transfer squared from initial to final protons is given by

$$-t \simeq (p\alpha)^2 \simeq q^2 \simeq 0.025\ (\mathrm{GeV}/c)^2$$

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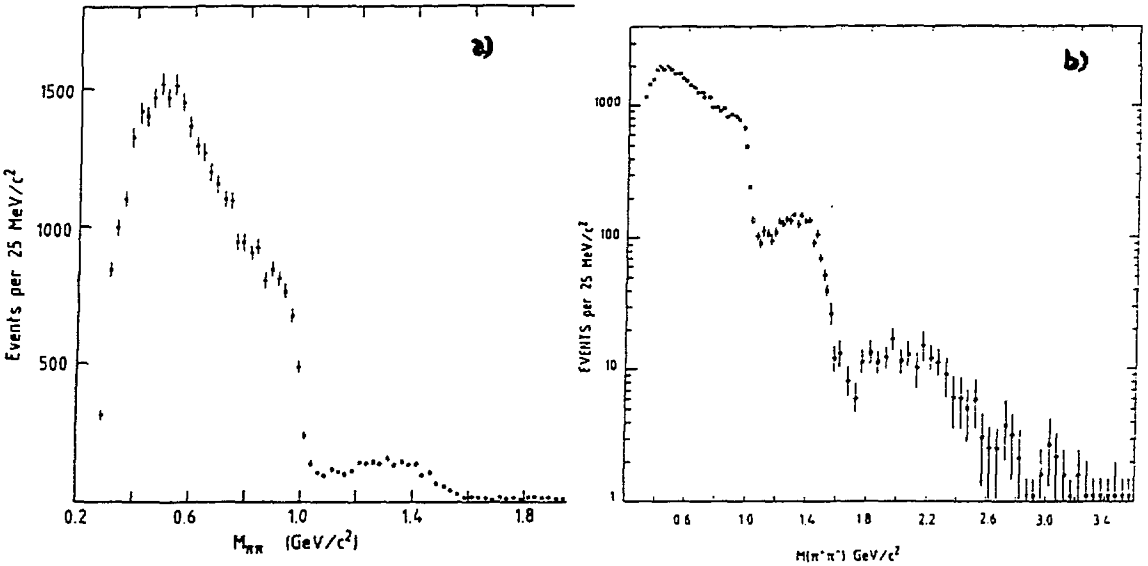

Figure 1: $\pi^+\pi^-$ spectra for $pp \rightarrow p(\pi^+\pi^-)p$ at $\sqrt{s} = 63$ GeV. (a) Raw $M(\pi^+\pi^-)$ spectrum. (b) Acceptance-corrected spectrum on log scale.

where $p = 250$ GeV/c is the momentum of the initial proton and $\alpha \sim 2$ mr is the scattering angle of the proton in the laboratory and $q \simeq 0.5$ GeV/c is the momentum of the final proton perpendicular to the beam. Since the slope of t distributions is expected to be around 10 GeV^{-2} at the top end of RHIC energy^5, the value $-t$ is sufficiently small to guarantee a pomeron exchange, and a double pomeron exchange reaction will result if both the final protons come off with $-t \leq 0.025$ (GeV/c)^2. In this case the central rapidity region corresponds in effect to the reaction

$$\mathbf{PP} \rightarrow \text{hadrons}$$

where **P** stands for a pomeron and the $\sqrt{s}$ for this subprocess ranges from 1.0 to 3.0 GeV. The upper limit on the $\sqrt{s}$ is not an inherent limitation; for a study of the states with $c(b)$ quarks, it should be extended to 5.0(10.0) GeV.

Let M denote the invariant mass of the total hadronic system, i.e. the $\sqrt{s}$ for the process given above. Then,

$$M^2 \simeq \epsilon_1\epsilon_2(2p)^2 + t_1 + t_2 - 2\mathbf{q}_1 \cdot \mathbf{q}_2$$

where subscripts 1 and 2 denote final deflected beam particles and $1 - x$ stands for the Feynman x variables^6. Replacing $-t$ by q^2, one obtains

$$M^2 \sim \epsilon_1\epsilon_2(2p)^2 - (\mathbf{q}_1 + \mathbf{q}_2)^2$$

From this one sees that

$$\epsilon_1 \sim \epsilon_2 \sim \frac{M}{2p} \simeq 4 \times 10^{-3}$$

for $M = 2$ GeV and $p = 250$ GeV/c.

According to S. Y. Lee (BNL), one can choose an insertion mode in which the angular dispersion of the beam can be held to as low as 1.0 mr at 10 m from the intersection. At this point, the deflected particles may range from 10 mm to 40 mm measured from the beam center. This corresponds to q in the range of 0.25 GeV/c to 1.0 GeV/c for a proton beam at 250 GeV/c. Within the Roman pots there will be a set of four drift-chamber modules and two scintillation counters, each with an active area measuring 50x50 mm.

The same experimental setup can be applied to heavy-ion collisions, e.g. those involving gold. M. Rhodes-Brown (BNL) points out that in the extreme low-momentum-transfer region the photon-photon interactions become competitive with the double-pomeron production,

$$\sigma \sim (Z\alpha)^4 \sim 0.1$$

for $Au \times Au$ at 100 GeV/u. The heavy ions of RHIC thus provide an opportunity for a study of two offshell-photon interactions,

$$\gamma^*\gamma^* \rightarrow \text{hadrons}$$

where $\sqrt{s}$ for this subprocess is in the range 1.0–3.0 GeV. Note that the photons involved are highly offshell indeed; the $-t$ corresponding to the photon is given by

$$t \simeq q^2 \sim (p \times 1\ mr)^2 \simeq 20\,(\mathrm{GeV}/c)^2$$

where $p = 197 \times 100$ GeV/c and 1 mr is the allowed angular dispersion of the beam.

The coherent production of hadrons by the two-photon process involves extremely sharp $-t$ distributions. According to A. Skuja and D. H. White[7], the slope of the $-t$ distributions is 700 GeV^{-2} for $Au \times Au$ at 100 GeV/u, indicating that the beams simply pass through undeflected in the region where the cross section is appreciable. The energy loss is also extremely small,

$$\epsilon_1 \sim \epsilon_2 \sim \frac{M}{2p} \simeq 5 \times 10^{-5}$$

for $M = 2$ GeV and $p = 197 \times 100$ GeV/c. It is seen that this loss factor is well within the allowed beam dispersion of RHIC.

It therefore follows that a proper $\gamma^*\gamma^*$ trigger calls for something other than the Roman pots, i.e. it has to rely on a veto on the deflected beam, by a set of four lead-scintillation sandwich barrel counters located at 10 m and 40 m away from the intersection point. A barrel counter consists of six truncated wedge detectors with widths 5 cm and 20 cm and 50 cm long. Its design is identical to that of the EM calorimeter in the central detector, as described in the next section. Note that each barrel counter covers radial distances down to 5 cm radius from the beam line. With this setup, one can span the deflection angles from 1.25 mr to 5 mr.

It is necessary, in addition, to veto on the diffractive dissociation of the beam. For this purpose, the end iron-plates of the magnet will be cut out at 100 cm radius, and a hadron calorimeter will be installed, which consists of 30 iron-scintillation sandwiches, designed to veto hadrons above 10 GeV/c. Additional material on the calorimeter is given in the next section.

The quark-gluon spectroscopy is a study of hadrons with mass in the range between 1.0 and 3.0 GeV, if the constituent quarks are comprised only of u, d and s. The initial state of the double-pomeron production is in reality a flavorless and colorless gluonic bundle. It follows therefore that the final state should be rich in gluonic excitations, i.e. glueballs and hybrids. In contrast, two offshell photons couple preferentially to charged quarks, e.g. $u\bar{u}$ or $c\bar{c}$ if the energy is high enough, leading to the production of quarkonia and multiquark states.

What quantum numbers are allowed for the initial state? Assuming a pomeron to be a $J^{PC} = 0^{++}$ state, one can expect for the double-pomeron initial state $I^G = 0^+$ and $J^{PC} = 0^{++}, 2^{++}, 4^{++}$, *etc.* For the two-offshell-photon initial state, one may expect $I^G = 0^+, 1^-$ and $J^{PC} = (0,1,2,3,4,..)^{++}, (0,1,2,3,4,..)^{-+}$. It should be noted that $J^{PC} = (1,3,5,..)^{-+}$ is exotic and cannot couple to quarkonia. Observation of such a state would imply an exotic multiquark state. Study of J/ψ radiative decays proved to be a prolific source of information for hadronic states. One can perform a similar study at RHIC by examining the hadronic system recoiling off a single photon.

2. Central Detector at RHIC

The central detector consists of a neutral and charged particle detection device with a 4π coverage, all housed in a moderate-size solenoid magnet with an inner radius of 155 cm and 540 cm long outside. The magnet uses Al coils inside the yoke producing a field strength of 0.5 T. It is designed to identify up to a dozen particles with momenta in the range 0.05–2.50 GeV/c, for a study of meson systems with mass 1.0–3.0 GeV. The central detector is thus given the name QGS, for Quark-Gluon Spectrometer (see Fig.2).

The QGS consists of a drift-chamber module surrounding the beam pipe, followed by a ring-imaging Cerenkov counter (RICH), a time-of-flight (TOF) hodoscope and a lead-scintillation sandwich EM calorimeter, all within the magnet coil. Each end of the magnet is instrumented with a hadron calorimeter. These items are described briefly below.

The drift-chamber module is 3.2 m long along the beam; it starts at a radius of 5 cm and extends to 75 cm. The size of drift cells (5 mm) is dictated by the time interval of 225ns between bunch crossings. The whole module is divided into 9 layers, each containing two axial sense wires and two stereo wires at angles from 40 mr to 80 mr. In all there will be some 9100 sense wires. The rms error on the transverse momentum is estimated to be

$$\frac{\delta p_\perp}{p_\perp} = 1.5\%\, p_\perp\,(\ \mathrm{GeV/c})$$

assuming a measurement accuracy of 200 μm and a field of 0.5 T. The angular resolution is, from multiple scattering,

$$\delta\theta = \frac{1.3\ \mathrm{mr}}{p_\perp\,(\ \mathrm{GeV/c})}$$

The particle identification is provided by the dE/dx measurement. Assuming an average of 36 measurements per track, the resolution is expected to be 15% FWHM. This provides a 3σ π/K separation up to about 0.6 GeV/c.

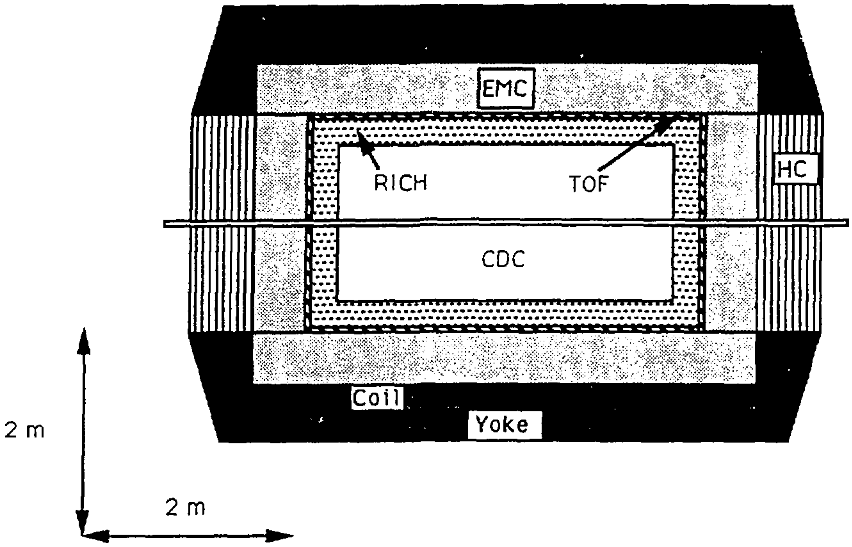

Figure 2: The Central detector: Quark-Gluon Spectrometer (QGS). The major components consist of a central drift-chamber module (CDC), a ring-imaging Cerenkov counter (RICH), a time-of-flight hodoscope (TOF), an electromagnetic calorimeter (EMC), and a hadron calorimeter (HC).

The RICH detector envisaged here is patterned closely after the conceptual design worked out by B. Ratcliff[8]. It extends from a radius of 75 cm to 100 cm and is 370 cm long on the outside. The front segment consists of a 1cm-thick liquid Freon (C_6F_{14}) with an index of refraction $n = 1.277$, so that a relativistic particle produces Cerenkov light of 17 cm radius at the end of a 13 cm drift region. It is then followed by a 4.4cm-thick photon-conversion region containing C_2H_6 and TMAE (Tetrakis Dimethyl Amino Ethylene). The readout is accomplished by a system of 2950 10x10 cm electronic pads. The drift time is about 25 μs, which implies that this RICH counter is not a trigger device. The offline π/K separation is impressive, starting at 0.03 GeV/c and extending to 3 GeV/c.

The TOF system is located at a radius of 100 cm and is 3.8 m long. It consists of 128 5x5 cm scintillation counters, each viewed by two photomultipliers. The resolution is conservatively estimated to be 250 ps, providing a 3σ π/K separation from 0.08 GeV/c to 0.6 GeV/c. Thus it can be used as an independent check of both the drift-chamber module and the RICH counter. It can also be used as a component in the charged particle triggers.

The EM calorimeter covers radii from 105 cm to 155 cm and is 480 cm long outside. It consists of 3200 10x10 cm towers, each with 84 layers of 6 mm lead-scintillation sandwiches (1 mm of lead and 5 mm of plastic scintillator) for a total of $15X_0$ and viewed by a photomultiplier through a wave-length shifter. A similar device was used by ARGUS[9]. The energy resolution is expected to be

$$\frac{\delta E}{E} = \frac{7\%}{\sqrt{E(\text{ GeV})}}$$

for the photon energy from 0.07 GeV to 3.0 GeV. This device can be used to detect $\pi^0 \to \gamma\gamma$, $\eta \to \gamma\gamma$ and $\omega \to \pi^0\gamma$.

The end caps of the magnet have cutouts with radius 100 cm, and two hadron calorimeters with the active areas at radii from 5 cm to 100 cm will be installed in this space. The calorimeter consists of 30 iron-scintillation sandwiches. Both the iron plate and the plastic scintillator are 1 cm thick, and the periphery of the scintillator is edged with a wave-length shifter, which is read out by a photomultiplier. It is estimated that the energy resolution is

$$\frac{\delta E}{E} = \frac{60\%}{\sqrt{E(\text{ GeV})}}$$

so that a 10 GeV/c particle can be measured with an accuracy of about 20%. For the $Au \times Au$ run, the two hadron calorimeters will be used to veto on any particle with energy greater than 10 GeV/c. It is expected that about 90% of all the diffractive dissociation events can thus be eliminated at the trigger level.

3. Triggers at RHIC

The trigger for **PP** interactions relies on a set of four scintillation counters within the Roman pots. For $p \times p$ runs, two triggers are possible with the Roman pots, 'up-up' and 'down-down.' This means that both of the counters above (below) the beam line at either side of the intersection region are triggered for 'up-up' ('down-down'). The triggers will be augmented with signals from the QGS, utilizing among others the hits in the EM calorimeter. Each hit above the minimum energy threshold, but below the maximum allowed energy, e.g. 10 GeV, is treated with equal weight; a fast microprocessor sums up independently the x, y and z projections of the location of the hit with respect to the midpoint of the intersection region. The trigger requires that the three sums are within a small preset range. This algorithm ensures that an event with a large missing energy in any direction will be eliminated, on the average. Note also that this technique treats charged and neutral particles on an equal footing.

For $Au \times Au$ runs, instead of the Roman pots, the trigger relies primarily on signals from the QGS to pick out two-photon events, accompanied by vetos at two end-cap hadron calorimeters and the four lead-scintillation barrel counters located 10 m and 40 m away from the intersection region. The vetoes guard against the small-angle beam deflections and the diffractive dissociation of the beams.

A Monte Carlo study is planned to assess the efficacy of the x-, y- and z-projection methods described above in selecting production of low-mass hadrons in the central region.

4. B Physics at RHIC

One of the more fundamental questions confronting the Standard Model based on the group $SU(3) \otimes SU(2) \otimes U(1)$ is the problem of understanding the origin of the CP violation and of the existence of three generation of quarks and leptons. In a conventional parameterization of the Standard Model, the CP violation arises from a single non-zero phase in the Cabbibo-Maskawa-Kobayasi (CKM) matrix. The study of the CP violation therefore involves, among others, precision measurements of all the elements of the CKM matrix.

It is now an accepted norm that, in addition to the $K^0\bar{K}^0$ system, the CP-violation effects should occur substantially in the B decays, especially those involving B_s. There is therefore a tremendous push to start B physics at LEP and TEVATRON. In addition, asymmetric e^+e^- machines as B factories have been proposed at SLAC[10], KEK[11], Cornell[12] and CERN[13]. A proposal also exists to build a dedicated detector[14] for B physics at the SSC.

With several crucial additions and modifications to the QGS, one can contemplate carrying out B physics at RHIC. A possibility of B physics at RHIC has been previously investigated by N. Lockyer et al.[15]. In terms of certain key parameters, the QGS described above is essentially similar to the detector studied by them.

Of particular interest are the self-tagging B decays: $B^0 \to K^+\pi^-$ and $\bar{B}^0 \to K^-\pi^+$ The P_t of the B mesons at RHIC are typically about 4.4 GeV/c. About 90% of the decay tracks are contained within ±2 units of pseudo-rapidity, and the p_t of the $K^\pm$ ranges from 0.7 GeV/c to 7.0 GeV/c, in contrast to the typical 300-MeV/c track for the underlying events. As $c\tau = 350\ \mu m$ for the B mesons, it is necessary to measure vertices at an accuracy of 10 μm in order to be efficient in picking out B events from the background.

These considerations suggest that one needs to install a micro-vertex detector, e.g. the silicon drift chamber[16] with a position resolution in both x and y directions at 10 μm. It is envisioned that a three-layer barrel vertex detector will be fully instrumented for triggers, with a fast on-line processor called on to determine in real time the production and decay vertices. A B trigger may be that in which a decay vertex is separated by more than 30 μm from the production vertex.

At the highest luminosity for $p \times p$ at RHIC, there may be one to two interactions per bunch crossing, with the time separation between bunches expected to be 225 ns. The drift-chamber module has an average drift space of 5 mm and the maximum drift time of 50 to 100 ns depending on the type of gas mixture used. As the interaction diamond length is ±22 cm, multiple events from on a single bunch crossing can be resolved offline in principle as distinct clusters separated along the beam line. However, one may, for an extra margin of safety, decrease the drift space to 2.5 mm, increasing the total number of sense wires to 18200, and in addition use a gas mixture with a fast drift velocity of 100 μm/ns, thus reducing the maximum drift time to 25 ns.

In order to distinguish the mass of the B_d^0 from that of the B_s^0, a momentum resolution of the drift-chamber module better than that given in Section 2 may be necessary; one may then have to replace the conventional solenoid magnet with a superconducting one and increase the field strength from 0.5 T to 2.0 T, for a factor of four gain in the momentum resolution. As the $K^{\pm}$ momenta range up to 7.0 GeV/c, a second RICH counter will have to be added as well to handle momenta between 3.0 to 7.0 GeV/c; this necessitates increasing the radius of the solenoid magnet by 25 cm.

The RHIC machine may operate in a $p \times p$ mode with a luminosity of 10^{32} cm^{-2} sec^{-1} at 250 × 250 GeV. The estimated $B\bar{B}$ cross section at these energies is about 10 μb, and a run of 10^7 sec would produce roughly 10^{10} $B\bar{B}$ pairs. Assume that the fraction of $B_d^0\bar{B}_d^0$ pair production is 20% of that of the B as a whole; that the branching ratio for $B_d^0 \to K^+\pi^-$ is 10^{-5}; that the overall trigger and other efficiencies add up to 1%. Then from a sample of $10^{10} B\bar{B}$ events, a CP asymmetry of 20% could be observed at the level of 3σ effect.

This exercise shows that the B physics at RHIC can be competitive with other machines.

5. Hadron Physics at KAON

The KAON facility[17], proposed for TRIUMF, Vancouver, Canada, is an intense hadron machine, capable of generating proton fluxes some 25 times higher than those available at the BNL AGS machine with the Booster. The KAON facility, therefore, affords an opportunity for carrying out the study of hadron spectroscopy at a level hitherto inaccessible with the current-generation machines.

At the present time, a number of experiments are underway or planned throughout the world, to study the ways in which the simple picture of quarkonia (states composed of a quark and an antiquark) of mesons fails. These simple pictures are thought to fail in two different directions: a meson can contain a valence gluon with the resultant increase in mass and with possible existence of J^{PC}-exotic quantum numbers, or it may be composed of two pairs of $q\bar{q}$; if each $q\bar{q}$ is a color singlet, the resulting multi-quark state may be thought of as a mesonic molecule, whereas if each $q\bar{q}$ pair is in color octet state, the state represents a fundamentally new kind of meson.

It is expected that such a study will be necessarily incomplete, as the current generation of machines cannot provide sufficient sample of strangeonia. In order to carry out the gluonic and multiquark degrees of freedom, an intense K^- secondary beam is necessary; the KAON facility has a plan to implement an RF separated beam capable of delivering the beam in the range of 5×10^6 per second. A modernized version the SLAC LASS detector is a logical choice for the spectrometer at which such a study can be carried out.

6. Hadron Spectrometer at KAON

The hadron Spectrometer envisioned for the KAON facility resembles the SLAC LASS detector, albeit modernized to take advantage of all the recent progress made in the detector developments.

A conceptual design for the spectrometer is shown in Fig.3, as sketched out by C. Amsler and K. Crowe[18]. The target region is contained within a solenoid magnet and is instrumented with drift chambers and CsI crystals, very similar to that of the CERN Crystal Barrel detector[19]. A dipole magnet is located downstream of the target for measurement of the forward-going charged particles. Further downstream is located a lead-glass detector for neutral-track measurements. Two sets of proportional chambers, a Cerenkov counter and a hodoscope counter are interspersed among the detectors as shown in Fig.3.

A solenoid magnet around the target has been shown by LASS to be a powerful device for measuring slow recoil tracks from the target. The success of the Crystal Barrel Detector argues for CsI blocks to be placed around the target for detection of low-energy photons. The GAMS experiments both at CERN and at Serpukhov demonstrated that an array of lead-glass blocks can be successfully used to trigger and measure fast forward-going photons. It is therefore natural that such a device be placed downstream of the dipole magnet as an integral part of the Hadron Spectrometer at KAON.

A detailed design has yet to begin; however, certain parameters are easy to be fixed at this time. The drift chambers can be made to have a space resolution of 100 μm. The energy resolution of the CsI crystals should be

$$\frac{\delta E}{E} = \frac{3\%}{\sqrt[4]{E(\,\mathrm{GeV})}}.$$

While for the lead-glass detector, one can expect

$$\frac{\delta E}{E} = \frac{5\%}{\sqrt{E(\,\mathrm{GeV})}}.$$

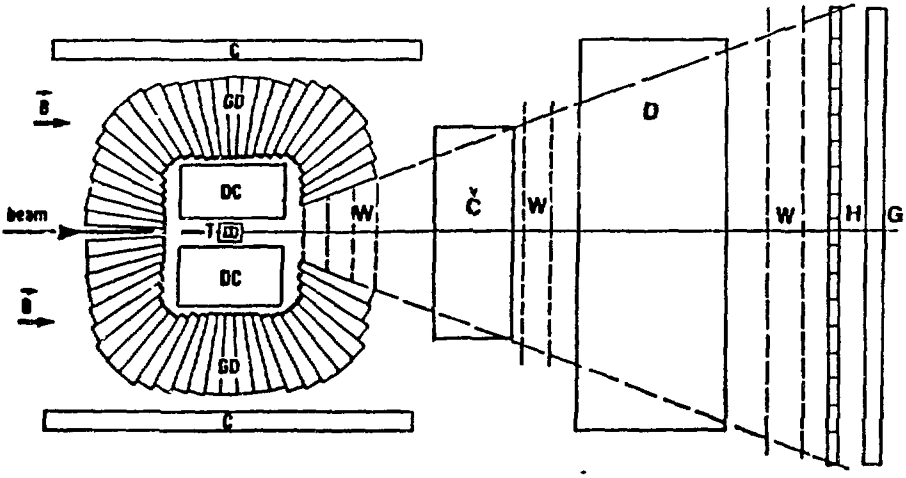

Figure 3: A possible layout of Hadron Spectrometer at KAON. Major elements are solenoid magnet (C), crystal barrel (GD), drift chambers (DC), proportional wire chambers (W), Cerenkov counter (Č), dipole magnet (D), hodoscope counter (H), and lead-glass detector (G).

Given the rapid progress with the powerful workstations, one can plan on taking data at the rate of up to one thousand events per second, and a run of a few months should provide at least a hundred-fold increase in statistics from those of LASS. A general long-range plan of hadron spectroscopy at KAON would call for a multi-year program with statistics exceeding 10^{10}; this is certainly not impossible in the late 1990s.

J. Comyn of TRIUMF and K. Crowe of LBL are organizing a group which will *propose to build a hadron spectrometer* at KAON; interested readers are invited to contact them for further informations.

7. Conclusions

In this note a brief description is given of an exciting opportunity to carry out hadron spectroscopy experiments at RHIC and KAON. Both machines are slated to be ready for physics in the latter half of 1990s. As such, both provide opportunities for further investigation into the outstanding problems in hadron physics, *in particular those that cannot easily be tackled with the machines currently available in the world.*

The key idea for RHIC is that by concentrating on the extreme double-peripheral region, the machine is used to produce hadronic systems at low $\sqrt{s}$ in the range 1.0–10.0 GeV.

The sub-processes responsible for the hadronic system in the central region may be expressed either as pomeron + pomeron → hadrons or as $\gamma^* + \gamma^* \to$ hadrons. The double-pomeron interactions are expected to produce glueballs and hybrids preferentially, while the two-offshell-photon initial states should couple predominantly to quarkonia and multiquark states. A whole gamut of J^{PC}-exotic mesons ($0^{+-}, 0^{--}, 1^{-+}, 2^{+-}, 3^{-+}, 4^{+-}, ..$) may be seen either directly in both types of interactions or in association with a single recoil photon in the final state. Another important distinction is that the hadronic system from a double-pomeron interaction has zero net flavor, whereas an $I^G = 1^-$ meson can couple readily to a two-photon initial state. The salient feature of this proposal lies in the fact that, for the first time, a study of the pomeron-pomeron interactions can be mounted with the same experimental setup as that of the photon-photon interactions.

In addition, the QGS with a micro-vertex detector and an expanded RICH counters can tackle the CP-violation effects in the B decays. The key element in this effort would have to be the capability to trigger on the B-decay vertices separated by more than 30 μm from the production vertex. The upgraded QGS may also serve as the apparatus for a study of χ_c and χ_b states.

The intense proton flux available at the KAON factory, Vancouver, Canada, affords an opportunity to carry out hadron spectroscopy with a statistical sensitivity unprecedented by the present day standards. Recent developments with hadron physics show that mesons in the mass range between 1.2 to 2.2 GeV are extremely complex, with many overlapping resonances from the $SU(3)$ family as well as exotic states with gluonic and multiquark degrees of freedom. A data sample in the range of 10^{10}, with good acceptance, should go a long way in settling many of the outstanding issues confronting hadron spectroscopy today.

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