LOW AND MEDIUM (∿ 30 GeV/c) P_t PHYSICS AT ISABELLE*

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I would first like to point out that if you do forward angle physics at ISABELLE you are not necessarily doing low P_t physics. For example, if a 400 GeV/c proton is scattered by ∿ 5°, P_t is ∿ 30 GeV/c. Thus even small angle physics at ISABELLE represents a mixture of very low to medium (∿ 30 GeV/c) P_t; a general discussion of low P_t physics (and some related topics) is given in ISABELLE - PROCEEDINGS of the 1981 Summer Workshop.[1,2]

Let us now consider some Forward Angle Physics that can ONLY be done at ISABELLE.

I. p-p Total Cross Section
II. Real Part of the p-p Elastic Forward Scattering Amplitude
III. p-p Differential Elastic Scattering Cross Section

Obviously the $\bar{p}$-p colliders at CERN and Fermilab can do I, II and III only for $\bar{p}$-p, σ_{total}(p-p) and the real part of forward scattering amplitude can be measured with L ≉ $10^{29}cm^{-2}sec^{-1}$ (see Fig. 1 for a summary of the present situation). Since the $\bar{p}$-p colliders

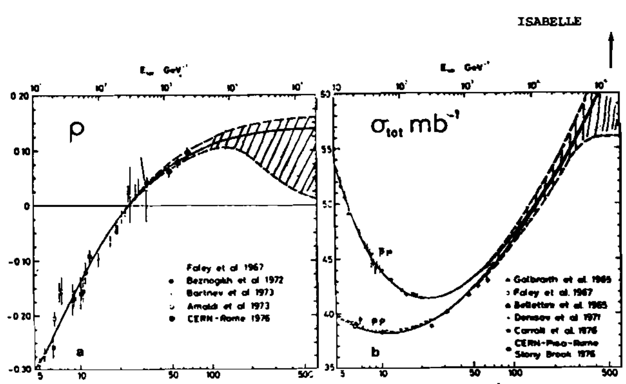

Fig. 1 (a) A compilation of ρ-values for p-p scattering as a function of $\sqrt{s}$. ρ is the ratio of the real to the imaginary part of the forward scattering amplitude (assuming spin independence). (b) Total cross sections for p-p and $\bar{p}$-p. The full curves are the results of a fit performed simultaneously on σ_{tot} and ρ. The shaded areas represent the one standard deviation region for ρ and the cross sections. The boundaries of these regions were obtained by changing the high energy behavior of the cross sections in such a way that the χ^2 of the fit was increased by one.

are expected to obtain L = 10^{29}-$10^{30}cm^{2}sec^{-1}$, they can do the $\bar{p}$-p equivalents of these and a comparison can be made to check the behavior of these two with their $\bar{p}$-p equivalents and in particular make sure there are no surprises. Assuming spin independence, one can use the crystal-ball aspect of the forward dispersion relations to predict the behavior of the total cross sections to much higher energies, check the Pomeranchuk theorem, etc.

In the case of III (p-p differential cross section, see Fig. 2), the higher luminosity of

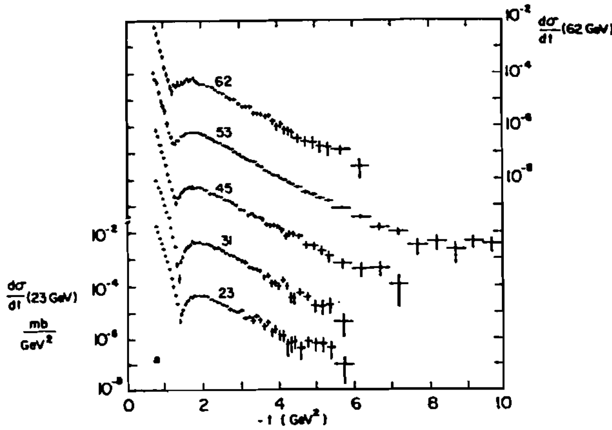

Fig. 2 Differential cross section dσ/dt for p-p elastic scattering at ISR energies.

ISABELLE will allow one to probe higher t than the p-p equivalent in the CERN and Fermilab colliders. For example, the first dip in elastic scattering should be seen with the $\bar{p}$-p colliders as well as at ISABELLE, and this may be possible for a second dip. However, ISABELLE's luminosity is required to study elastic scattering more thoroughly. The dip-bump structure in the elastic scattering should be measurable with luminosities of a few times 10^{30}, however for t > 5 GeV, one would need L > $10^{31}cm^{-2}sec^{-1}$.

Let us now consider Diffractive Dissociation. At the ISR, for $\sqrt{s}$ = 53 GeV, it has been determined that $\sigma_{diffractive}$ ∿ 10 mb; $\sigma_{elastic}$ ∿ 7 mb; $\sigma_{inelastic-non-diffractive}$ ∿ 23 mb, σ_{total} ≉ 40 mb. Hence $\sigma_{diffractive}$ is ≉ 1/4 σ_{total}. This order of magnitude relationship is also expected for ISABELLE.

$(d\sigma/dM)_{diffractive} \propto 1/M$, but there is an approximately maximum M for diffractive processes which is given by

$$M_{max}/\sqrt{s} ≉ 0.2\text{-}0.3.$$

At ISABELLE, $\sqrt{s}$ = 800. Thus M_{max} ≉ 160-240 GeV.

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Thus heavy objects can be formed diffractively. These objects can decay to naked heavy quark baryons such as Λ_t and naked heavy quark mesons.

Based on present data,[3] $\sigma_{\Lambda_c} \gtrsim 100\ \mu b$. Therefore a reasonable estimate for ISABELLE is

$$\sigma_{\Lambda_t} \gtrsim \sigma_{\Lambda_c} \times \left(\frac{\text{charmed quark mass}}{\text{top quark mass}}\right)^2 .$$

Since neither $t\bar{t}$ or naked top quark particles have been seen at PETRA, let us make the assumption that the top quark mass is $\gtrsim$ 20 GeV. Thus $\sigma_{\Lambda_t} \gtrsim 100 \times (1.5/20)^2\ \mu b \gtrsim .5\ \mu b$.

Experiments to detect Λ_t would require a lepton (prompt) trigger from the decaying associated meson (or anti-particle) and a charged hadronic decay mode of the Λ_t to be reconstructed. This requires a good tracking momentum resolution and particle identification spectrometer.

The process we would be looking at could be

$$p + p \rightarrow \Lambda_t + \bar{t}\ \text{(meson or baryon)}\ldots.*$$

$\Lambda_t \downarrow$ All hadronic decay 1%; $\bar{t} \downarrow$ electronic decay 10%

so the visible charged decay mode cross section for Λ_t with an electronic trigger is $\gtrsim$ 0.5 nanobarns.

Obviously even if one forgets background, the $\bar{p}$-p collider would have difficulty getting reasonable statistics on a cross section of this size. For 1 nb and $L = 10^{29}$-10^{30}, $\sigma L \sim 10^{-4}$-10^{-3} or in a 10^6 sec year (based on ISR experience) one would obtain $\sim$ 100-1000 events. However in general the effective acceptance in an experimental apparatus might be $\sim$ 1/10 so one would obtain only $\sim$ 10 to 100 events.

On the other hand, with ISABELLE having $L = 10^{32}$-10^{33}, for a one nanobarn cross section and effective acceptance $\sim$ 10% one would in a 10^6 sec. running year obtain 10,000 to 100,000 events.

Of course we have not yet addressed the question of could one build practical forward direction detectors which could stand the ISABELLE event rate. Secondly, even so could one clearly pick out a small cross section from the $\sim$ 50 mb inelastic cross section.

To answer these questions, I will draw upon my experience with the AGS. Question I - practical detectors for high rates?

First let us see what the event rate would be for the various machines.

$\bar{p}p$ colliders $L = 10^{29}$
event rate $50 \times 10^{-27} \times 10^{29} = 5{,}000\ \text{sec}^{-1}$
$L = 10^{30}$
event rate $50{,}000\ \text{sec}^{-1}$

ISABELLE $L = 10^{32}$
event rate $5 \times 10^6\ \text{sec}^{-1}$

ISABELLE $L = 10^{33}$
event rate $5 \times 10^7\ \text{sec}^{-1}$.

We have just successfully put MPS II[4] with a new, beyond previous state-of-the-art narrow drift space chamber system[5] into operation. It has also run its first physics experiment. It has handled several million incident beam particles per second and very cleanly reconstructed the exclusive channel $\pi^- p \rightarrow \phi\phi n$. The track memory time is $\sim$ 60 nanoseconds so that one could expect with $\sim$ 20% double ϕ events which we could eliminate by a trigger arrangement, to handle $\sim$ 2 million events per second. Thus since we have not taken advantage of possible future improvements and the usual bag of tricks one uses in actual future cases, we would expect that present MPS II technology would allow us to use $L = 10^{32}$ even in the extreme forward direction.

Question 2 - could one pick out a small cross section, say $\sim$ 1 nb visible, from the large inelastic background?

If someone had asked me how to do this several years before the AGS was built (and finished about 1961), I obviously could not give an answer.

Nevertheless, even with MPS I we were able to very cleanly pick out an exclusive channel

$$\pi^- p \rightarrow \underset{\downarrow\atop K^+K^-}{\phi}\ \ \underset{\downarrow\atop K^+K^-}{\phi}\ \ n$$

with $\sim$ 5 nb visible cross section.[6] We have just redone this experiment with MPS II, obtained an order of magnitude more statistics, better resolution (by a factor $\sim$ 2) and an even cleaner result than with MPS I.[7] Many MPS I experiments were working deep in the so-called hadron machine dirt and cleanly picked out small cross section reactions.

It was physicist user pressure that demanded that we enable them to increase the obtainable event rate by an order of magnitude so that they could go down even further into the dirt.

Figure 3 shows results of part of the data of the first MPS II experiment - a search for glueballs, which

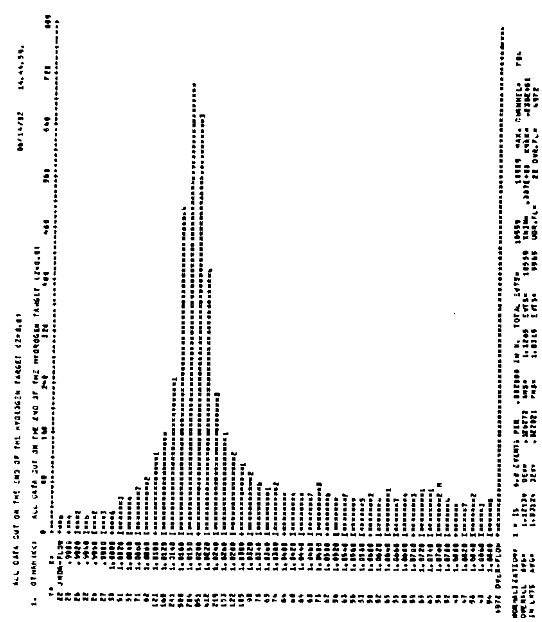

Fig. 3 Distribution of the effective mass of each K^+K^- pair for which the other pair lies in the mass band. This distribution was obtained from the partial sample of the data from the recent MPS II run on (22 GeV/c) $\pi^- p \rightarrow \phi\phi X$. The mass spectrum is plotted in 2 MeV bins. The huge peak at low mass is the $\phi\phi$ signal. The width of the peak is $\sim$ 1/2 that from a similar

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* I wish to thank Frank Paige for valuable discussions on these points.

Fig. 3 (Caption, continued) experiment with MPS I showing the superior resolution. If one cuts on the neutron mass the recoil neutron peak is very outstanding also furthermore the double ϕ peak stands $\sim$ 30 times above the ϕK^+K^-n reaction background.

has just been run. It looks at $\pi^- p \to \phi\ \phi\ X$, with $\phi \to K^+K^-$, $\phi \to K^+K^-$

which shows the $\phi\phi$ events in a clean peak. When we cut on recoiling neutrons, the ϕ peak is thirty times as high as the background. See Refs. 6 and 7 for detailed versions of this work which found two glueball candidates with all quantum numbers determined.

Who could have predicted this, and that one could pick out a 5 nb cross section from a 20 mb inelastic one.

Yet important and interesting planned research with MPS II (which incidentally, is a forward direction spectrometer) in this and other experiments is not yet generally limited by our ability to pick the desired events cleanly but rather is generally limited by lack of sufficient event rate, i.e., in collider terms not high enough luminosity.

These are the historical lessons we must not forget. Given enough event rate (i.e., luminosity) physicists are ingenious enough to use it well, and eventually plead for more. Therefore I believe that the high luminosity of ISABELLE will be very worthwhile.

A spectrometer which could be used for high luminosity experiments in ISABELLE has been described.[2]

I would also like to point out that while many physicists look at hadron accelerators as dirty machines, I and many others consider the variety of physics buried in the dirt both a great opportunity and a great challenge which allows generation after generation of important experiments to be done.

I have only cited a few specific examples. They are merely illustrative. References 1 and 2 discuss many other subjects including particle production mechanisms, correlations at low P_t, characteristics of multiparticle production, searches for quarks and other $Q \neq 1$ particles, one particle inclusive physics with particle identification, multiparticle event and jet behavior as a function $f(P_t, x, s)$, possible surprises, etc.

The best argument for ISABELLE physics in the forward direction or elsewhere cannot be made by present studies, but has been repeatedly made by history itself.

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