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AN e-p FACILITY FOR EUROPE - WEAK INTERACTIONS IN e-p PHYSICS -

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Abstract

We first present the recent development on an e-p collider in Europe occuring in the last year. Then a review of physics motivations for an e-p ring is discussed and developed with the latest work presented at the meeting on "Study for an e-p Facility for Europe" held at Hamburg on April 2-3, 1979.

1. Introduction

Although the kind of physics which can be investigated with very large e-p rings has always been qualified as "very interesting" and although such possibilities have been extensively studied, it seems that an e-p ring project has remained up to now less successful than colliding e^-e^+ and (p-p, or $\bar{p}$-p) machines. The sorts of physics which can be examined is different for the two types of colliding beams and Europe has definitively chosen the e^+e^- machine, but e-p colliding machine suffers from a bad prejudice : it is always considered as a "complementary" machine and as such is considered by laboratories which have already either electron or proton machines as the "second best project". It is why I shall not begin this talk by the list of e-p ring proposals. You can do it yourself, knowing the existing electron and proton machines, since the e-p ring list is identical since every laboratory has proposed to add respectively a proton or an electron ring. My intention is to restrict myself to the recent European developments concerning an e-p facility.

Electron-proton colliders have been seriously studied in Europe since 1972. The successive study groups have been the following :

1972 - DESY First Report[1] followed by a seminar in Hamburg in October 1973[2].

1976 - Study group at the Rutherford Laboratory[3] and at CERN[4].

1977 - 1978 - C.H. Llewellyn-Smith and B.H. Wiik[5] discussed extensively the physics of e-p colliders and at that time there where three possibilities to realize a large electron-proton colliding-beam :

- Upgrade ISR by superconducting magnets to an energy of 140 GeV and add an electron machine of 12 GeV (Center of mass energy squared, s = 6720 GeV^2).
- Add a 25 GeV electron machine to the 400 GeV proton storage ring studied at CERN (s = 40000 GeV^2).
- Add a superconducting proton ring to PETRA (s = 20000 GeV^2).

The results of a working group set up by ECFA held at Milton House, Stevenson, to study the feasibility of colliding electrons with protons of the SPS was presented in the famous "CHEEP Report"[6]

Obviously the acceptation of the $\bar{p}$-p project which places Europe at the front in the search for the intermediate bosons has more or less killed the proposals made on e-p ring using the present set of proton machines at CERN. Since then it has become obvious that in Europe the LEP has priority and thus it is not a question to discuss this point when we think about e-p rings. At the same level one can mention the project Isabelle and the energy doubler at Fermilab in USA. Because of the success of all these projects the question of e-p machine in the world and in Europe in particular was slowing down. But if the CERN has its future defined, it is not yet the case at DESY. The main project under consideration for e-p ring there, was PROPER using superconducting storage ring for proton in the tunnel of PETRA which could allow a polarized electron beam of about 20 GeV colliding with protons of about 300 GeV.

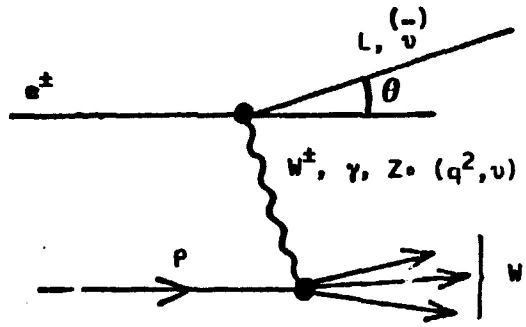
At the end of 1978, ECFA and DESY asked to consider both this possibility and the collision of ring SPS protons with electrons from LEP in an e-p working group. Under the direction of U. Amaldi different working groups were created. The time available between the establishment of these working group and the final meeting held in Hamburg the 2nd and 3th April 1979 was very short, none the less a new step was advanced in the e-p domain. The main conclusions[7] concerning the machine itself was that the construction of a superconducting magnet ring with a field around 5 Tessla is possible. Technical problems of mass production seem about to be solved. We would like to note that such a conclusion is not surprising if we consider the effort currently spent on the FNAL doubler and Isabelle !

The conclusions for the physics possibilities confirm the interest for an e-p machine in studying the strong interaction and the unique possibility for new phenomena in the field of weak interactions. As a matter of comment, I did not find people at the Hamburg meeting very excited : I think that we were a new sample of physicists, left from the large assembly which is working for LEP with somewhat divided interests, physicists from DESY for example were not prepared to defend too strongly an e-p ring with conflicting e^+e^- ideas to upgrade beams. Neverless ECFA and DESY decided to further pursue the study on an e-p facility for Europe. The two main directions of research presently followed are first the PROPER study, and second a study for a new ring of 1 km radius to be constructed on the underground site of DESY, in which colliding particle energy will reach 30 to 40 GeV for electrons and 800-1000 GeV for protons. The results of this new preliminary study should be given at the end of 1979 and will be discussed in the middle of 1980. There stands the development story of e-p ring facility in Europe.

There has been progress on some technical points and calculations concerning the feasibility of e-p experiments since the "CHEEP Report" and the following part of this talk will be devoted to these physics ideas. I should remark that lots of ideas and numbers are still the same and thus what follows is a summary of present e-p "lore" to which I shall add the last developments from the Hamburg meeting. Since the "Cheep Report"[6] and the "e-p Facility for Europe"[8] are both available, many details can be found these.

2. Kinematics

We define the variables of the following Feymann graph :



E_e energy of the electron

E_p energy of the proton

E_L energy of the lepton

s (total energy)^2 $\qquad s = 4\,E_e\,E_p + m_p^2$

Q^2 four momentum of the current $\qquad Q^2 = -q^2 = 4\,E_e\,E_L\,\sin^2\frac{\theta}{2}$

W effective mass of the final hadronic system $\qquad W^2 = 2\,m_p\,\nu + m_p^2 - Q^2$

$$\nu = \frac{p.q}{m_p} = \frac{E_p}{2\,E_e}\left|Q^2 + 2\,E_p\,(E_e - E_L)\right|\frac{1}{m_p}$$

$$\nu_{max} = 2\,E_e\,E_p\,/\,m_p$$

Scaling variables : $\quad x = \dfrac{Q^2}{2\,m_p\,\nu} \qquad y = \dfrac{\nu}{\nu_{max}}$

A 20 GeV electron and 270 GeV proton machine gives the following parameters :

s = 21601 GeV^2	Q^2 max = 21600 GeV^2/c^2
W_{max} = 147 GeV	ν max = 10800 GeV

We must emphasize the tremendous increase for the Q^2 variable. Although the very large Q^2 values at large x do not represent much of the total cross section, reasonable event numbers can still be obtained with $x \simeq 0.2$ and a value of Q^2 of 2000 GeV^2/c.

Figure 1 shows the two variables q^2 and W in the x, y plane.

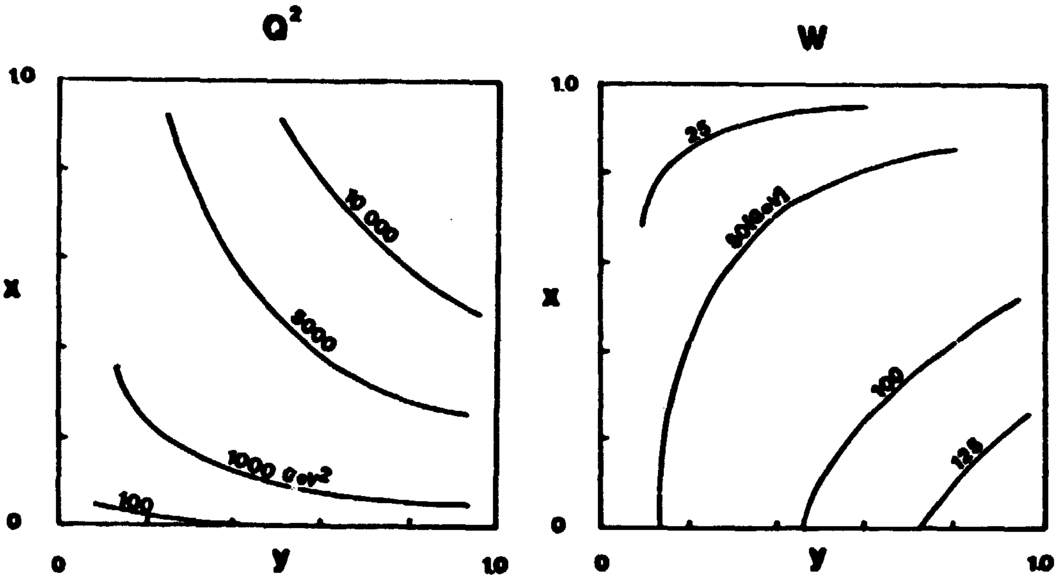
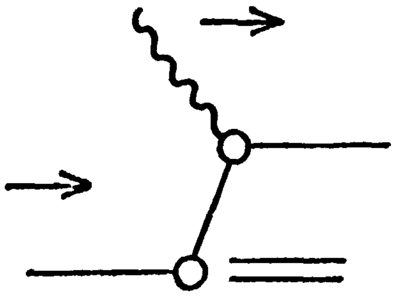


FIG. 1 : Q^2 and W curves for E_e = 20 GeV, E_p = 270 GeV.

The outgoing lepton kinematics is given by momentum and energy conservation. If we want see what to expect for the hadrons directions and momenta we need a model.



The most commonly used is the quark parton model. With this model the kinematics gives only the angle of the current jet θ_j and assumes that the angle of the proton jet is equal to zero. This gives us a kind of "3 particle" direction system which shows a priori that the detection of events should not be too difficult. The average direction of the hadron jet is not sufficient to understand the kinematics of all hadrons. The "dressing" of the quark is also model dependent. Presently the best program which includes this question has been constructed by A.L. Grant [9]. Different hypotheses used for the final quark "dressing" can change the population density of hadrons but the overall angles θ_j and θ_p remain the same. These angles and momentum of the lepton, the hadron jet and the proton jet are shown in figure 2.

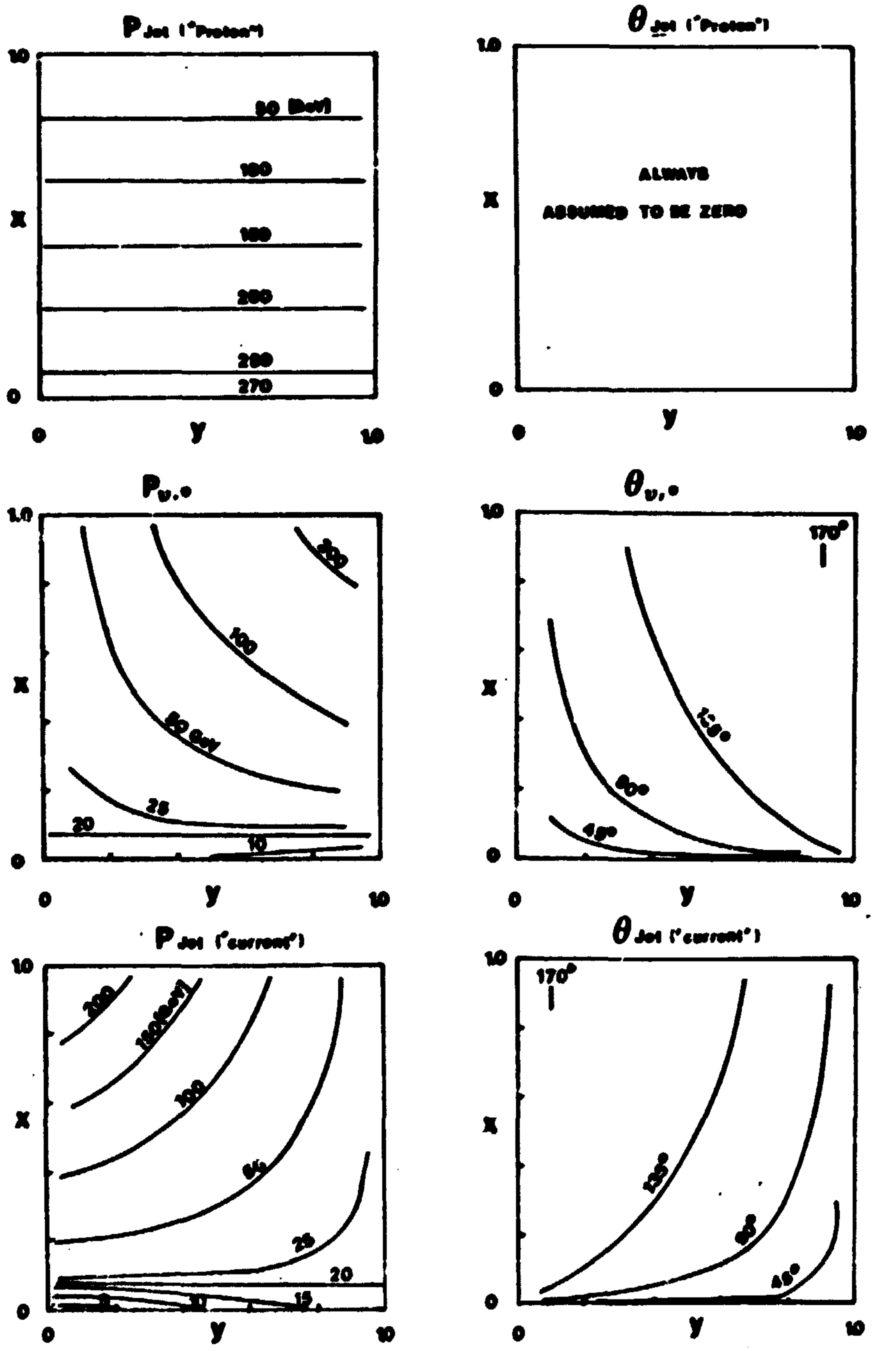


FIG. 2 : Angle and momentum of the lepton, the hadron jet, and the proton jet (E_e = 20 GeV, E_p = 270 GeV).

3. Rates

The rates of neutral current and charged current events have been calculated in the CHEEP Report for $E_e = 25$ GeV and $E_p = 270$ GeV

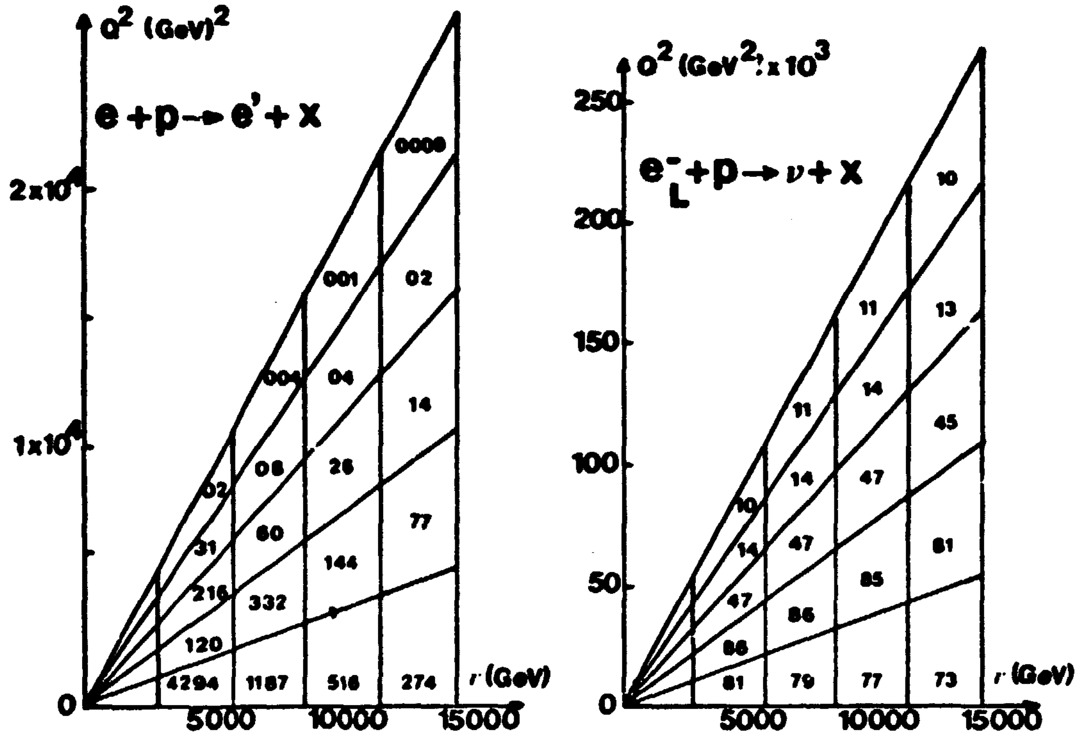


FIG. 3 : Calculated rates for charged and neutral currents from the CHEEP Report (p.104 and p.101).

The number of events per day are in bins of dx dy = 0.04. For the charged current one assumes scaling and a point-like coupling. For the neutral current the rates are evaluated for one photon exchange assuming scaling. For a luminosity of 10^{32} cm^{-2} sec^{-1} one sees that we can expect ~ 1000 events a day for charged currents. We know that the propagator effect with a mass M_W of 63 GeV could decrease this rate by an order of magnitude. It is interesting to note the large number of neutral current events produced at low q^2 (207014 in the smaller q^2 bin). This implies that very good electron identification is necessary to avoid contamination of the charged current event sample by misidentified electrons from neutral current events.

4. Physics Motivation

The physics interests for an e-p machine have been extensively discussed by all the previous working groups. We shall restrict the topics to weak interactions. As a matter of fact even if the results are connected to strong interactions (e.g. jet structure) they are generated by charged or neutral intermediate bozons and we shall go through the list of possible mechanisms connected with these interactions.

4.1 $W^{\pm}$, Z°, Higgs Boson Production

The production of $W^{\pm}$ and Z° can be estimated in terms of $\sigma(\nu + p \rightarrow \mu + W + X)$ and $\sigma(\nu + p \rightarrow \nu + W + X)$ for which numerical calculations have been done[5]. The cross sections turn out to be very small and the order of $\simeq 10^{-38}$ cm^2 leading to $\simeq 1$ event per day, at an energy of 20 x 280 GeV. Although the detection of events given by the W (single lepton at large angle with a large momentum imbalance) or the Z° ($Z^{\circ} \rightarrow e^+ + e^-$ or $\mu^+ + \mu^-$) is very clean, an e-p machine is not competitive for reason of rates with a $\bar{p}$ p machine (cross-section $\simeq 10^{-33}$ cm^2) or with LEP (cross-section $\simeq 10^{-31}$ cm^2 at the Z° pic).

The production of higgs bosons coupled to the fermions and gauge bosons via intermediate vector bosons has been calculated by J. Ellis, M.K. Gaillard and D.V. Nanapoulos. At a total energy squared of ~ 20000 GeV^2 the ratio $\sigma(e^- p \rightarrow \nu H X) / \sigma(e^- p \rightarrow \nu X)$ is $\simeq 10^{-4}$. The observation of the higgs boson production with a so small ratio will be very difficult. The difficulty should be the same in a pp or $\bar{p}p$ machine.

4.2 New Leptons

If heavy neutral and charged leptons exist, coupled to electrons by known weak current i.e. : $g_{e_L E^{\circ}} = g_{e\nu}$ the rates of production for s $\gg M_{E^{\circ}}$ are quite important [5,6,10]. The only parameter left is the mass of the new lepton. As an example for a mass $M_L \sim 35$ GeV one can obtain 100 events per day[10] at s $\simeq$ 20000 GeV^2.

The second good feature in favor of the detection of there heavy leptons are their spectacular signatures for instance :

$E^{\circ} \rightarrow e^- +$ hadrons		3 jet events
	$e^- + \mu^+ + \nu_\mu$	two leptons
	$e^- + e^+ + \nu_e$	
$E^- \rightarrow e^- +$ hadrons		3 jet events
	$e^- + e^+ + e^-$	3 leptons with which
	$e^- + \mu^+ + \mu^-$	one can obtain M_{E^-}

Such events will lead to events with three-jet structure[5] which will surely be seen by experimentalists. These spectacular events should be detectable even at a rate of $\simeq 1$ per day, thus one could look for new leptons as heavy as 100 GeV. In this area an e-p machine is extremely attractive and in very good position to compete with LEP. One should mention that for this type of research one needs the highest energy (s) and one can claim that the solution LEP*SPS i.e. 100*400 GeV is preferable. The knowledge of the coupling of these new leptons could be achieved by looking at their production via polarized beams, thus completing beautifully their study.

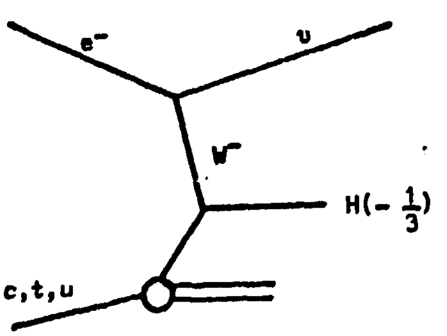
4.3 New Quarks

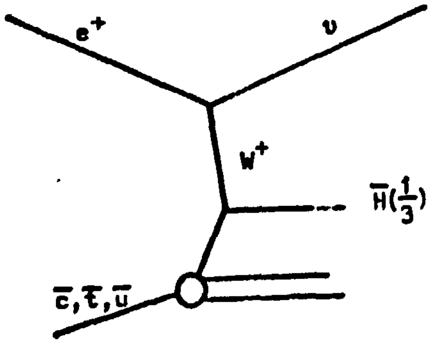
If one assumes the series of quark continues

u	c	t	G	...
d	s	b	H	...

with a W_{max} available of $\simeq$ 150 GeV, a good way to look for new quark production is via the charged current since we produce one single new flavor thus gaining an advantage in kinematics over processes which require quark-antiquark production.

On the other hand we lose because of the weak coupling (compared for example to the electromagnetic one for neutral current) and the mixing angle will surely be small. Nevertheless to illustrate the possibilities let's consider[11] the "H" (the lighter) quark of a new set $\binom{G}{H}$, coupled to the present quarks, it might be produced as follows :





Two features of such a new quark with very large mass will appear:

1) Jet of fragments will have a largely displaced angle (Figure 4) if we measure x, and y for large mass quark then the θ_j will be pushed forward. The scale of this effect is

$$\frac{M_q^2}{4\, E_e\, E_p\, y}$$

and is very large for masses of 50 GeV.

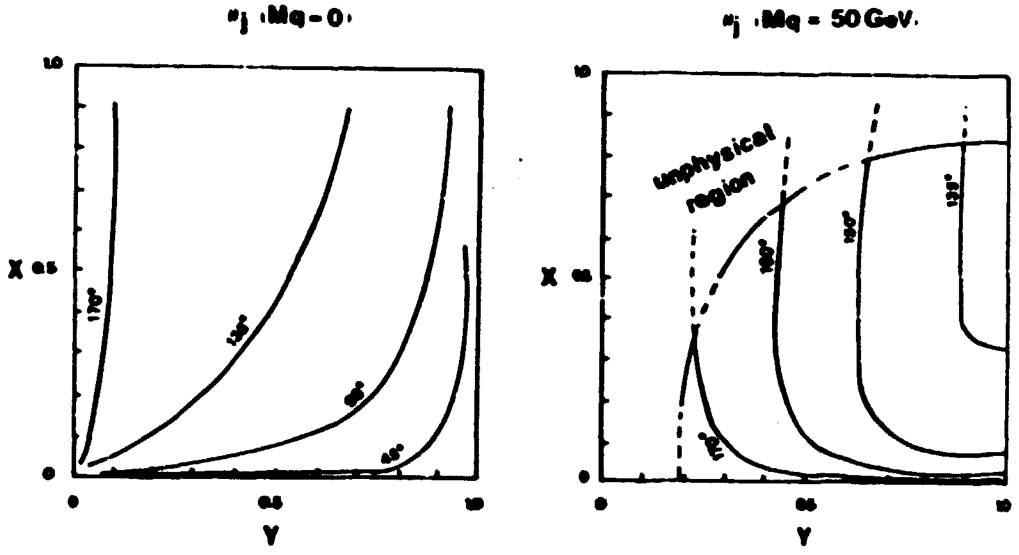
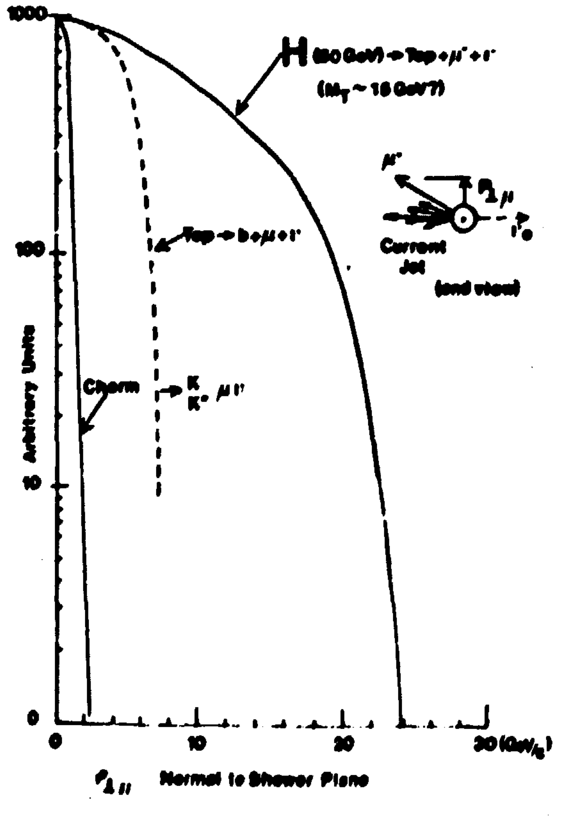


FIG. 4 : Jet angle for a 50 GeV quark production.

2) In a semi-leptonic decay of such quark one can expect to see large $P_\perp$ muons : if we assume it is coupled to the top quark for example:

$$H\left(-\frac{1}{3}\right) \qquad T^{+}\left(\frac{2}{3}\right) + \mu^{-} + \nu$$

50 GeV   15 GeV



The $P_\perp$ normal to the jet $- \nu_e$ plane is < 7 GeV >.

Figure 5 shows what is expected from charm and top decays for comparison.

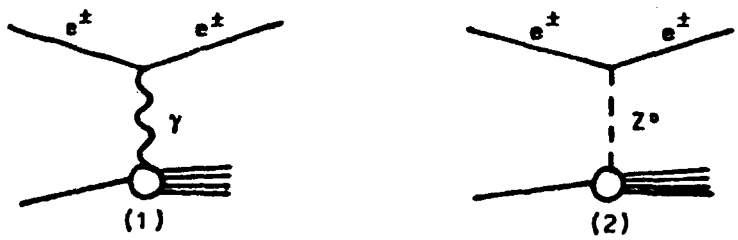
The muon $P_\perp$'s are quite large. Further more this $P_\perp$ distribution can be compared to the $P_\perp$ distribution for μ from e^+ and e^- running since electromagnetic μ's at large $P_\perp$ will be similar for $e^\pm$.

FIG. 5 : $P_\perp$ of muon decay of H quark.

The absolute rate of production is unknown. The clear signature of events and the mass region accessible (~ 150 GeV) gives a good position for an e-p machine in the quark search.

4.4 Neutral Currents

An e-p machine is a perfect tool to continue the study of the classical neutral current graphs :



The deep inelastic study (graph 1) started with the well known success at SLAC with an averaged Q^2 of ~ 10 GeV^2/c^2. The new Q^2 range (~ 5000 GeV^2/c^2) of an e-p machine would allow further search into the structure of the proton from 10^{-14} cm to 10^{-16} cm. The numbers do not need much comment. But at these energies the contribution of the second graph becomes important and we can also learn about neutral weak currents.

4.4.1 Study of structure functions and the jets

Progress have been made on the detection of neutral current events[11] and results were presented at the Hamburg meeting in April 1979. The event rates in the scaling hypothesis have already been presented. The influence of the electron scattering angle and energy measurement errors for the detectors which were studied in that workshop are presented in Figure 6.

The following precisions :σ_θ = 10 mrad and $\sigma_E = 0.1\sqrt{E}$ (E in GeV), are currently obtained with the detector proposed by this group. This precision allows a very good measurement of structure functions. One study of the measurement of $R = \sigma_l/\sigma_T$ which is important for the formalism of the structure function and for QCD theory has shown that by taking data at two different energies, as necessary, and for an integrated luminosity of 5.10^{37} cm^{-2} good measurement for R can be achieved for y > 0.5. This relative error is presented on Figure 7.

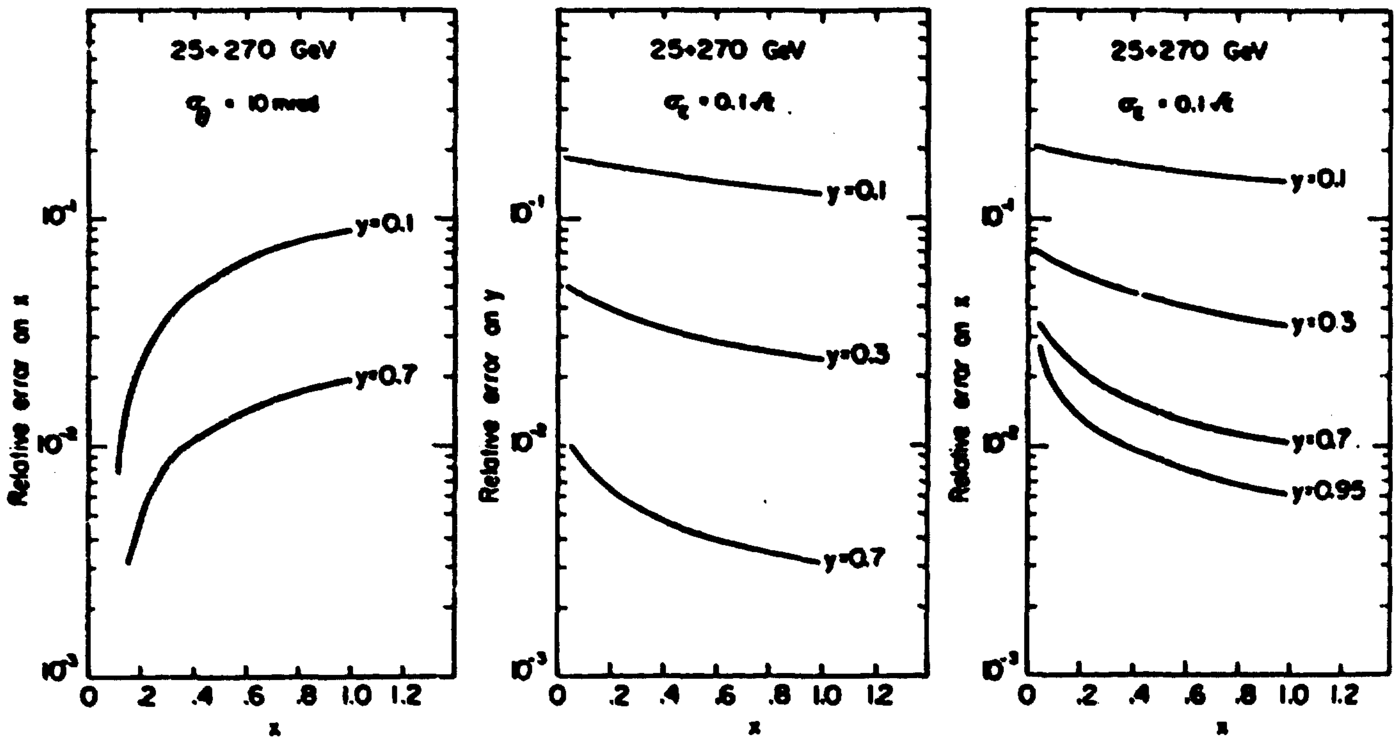


FIG. 6 : Relative error on x and y in neutral current events from P.G. Innocenti[12].

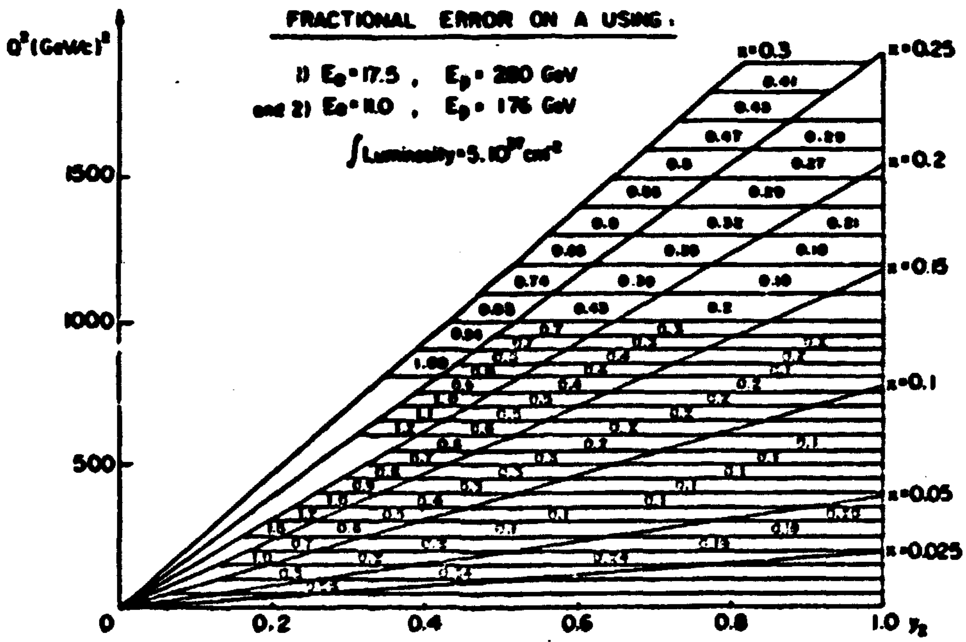


FIG. 7 : Fractional error on A[12)]

One defines $A=2xF_1(q^2,x)/F_2(q^2,x)$ and $R= \frac{1}{A}(4\frac{M_p^2x^2}{Q^2})+1)-1$

The current jet in the case of neutral current is well defined since the electron is well detected and the angle θ_j of the jet is deduced from the angle θ_L. This is an advantage over charged current events when the et angle is measured and used to determine the angle of the missing neutrino. The particles of the jet are well separated from the electron and the proton jet in most of the x,y plane. The conclusion is that if particle identification can be done efficiently the study of the current jet is done easily in an e-p machine.

4.4.2 Study of Neutral Weak Current[10,6)]: interference term

Beyond the one photon exchange contribution the cross second will have 3 contributions :

$$\sigma = \sigma_\gamma + \sigma_{int} + \sigma_{weak}$$

At sufficiently high Q^2 i.e. $Q^2 > 3000\ GeV^2/c^2$ one can expect to be able to see effect of the interference term and then to test hypothesis for the neutral weak current. The comparison of the cross-section for this interference term between the week interaction and the electromagnetic cross-sections is shown in figure 8.

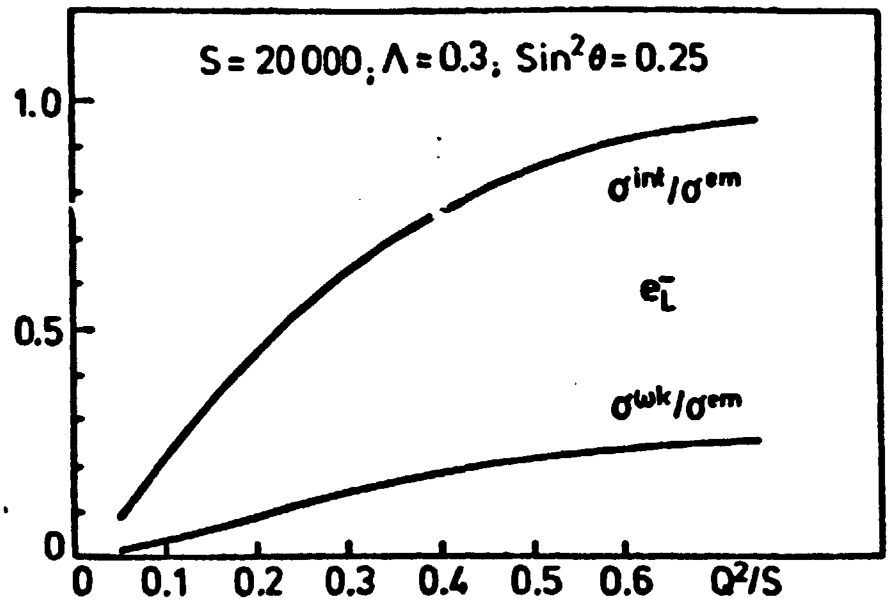


FIG. 8 : Comparison of σ/σ_{em} for e_L^- beam at 20 x 250 GeV[10)]

The nature of the weak current is studied by looking at the different cross-section for the different helicities of the lepton : e_L^-, e_R^-, e_L^+, e_R^+ as indicated in figure 9 calculated in the frame of the Weinberg-Salam model.

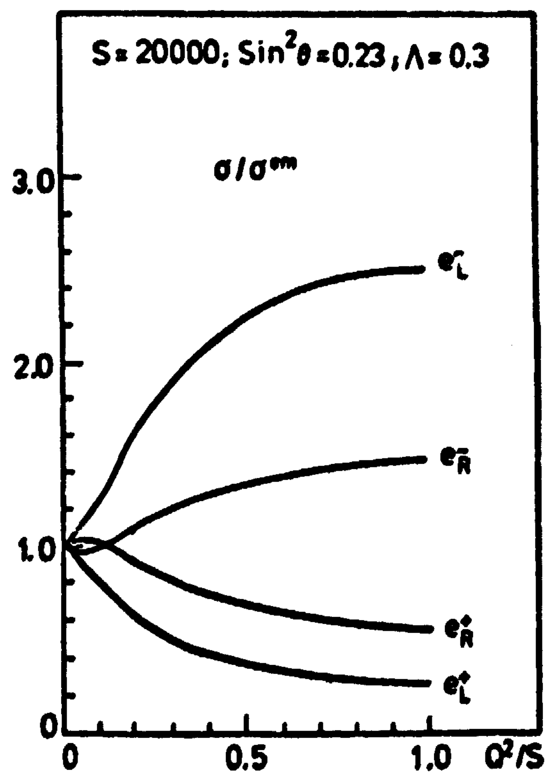


FIG. 9 : Comparison of σ/σ_{em} for different helicity lepton beams at 20 x 250 GeV[10)].

One can define an asymmetry parameter $A = \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R}$ and by this means test of the different parameter of a particular model or the validity of different models. The sensitivity to $\sin^2\theta_W$ and the mass of the Z° in the case of the Weinberg model illustrates such a possibility and has been calculated by R.J. Cashmore[10].

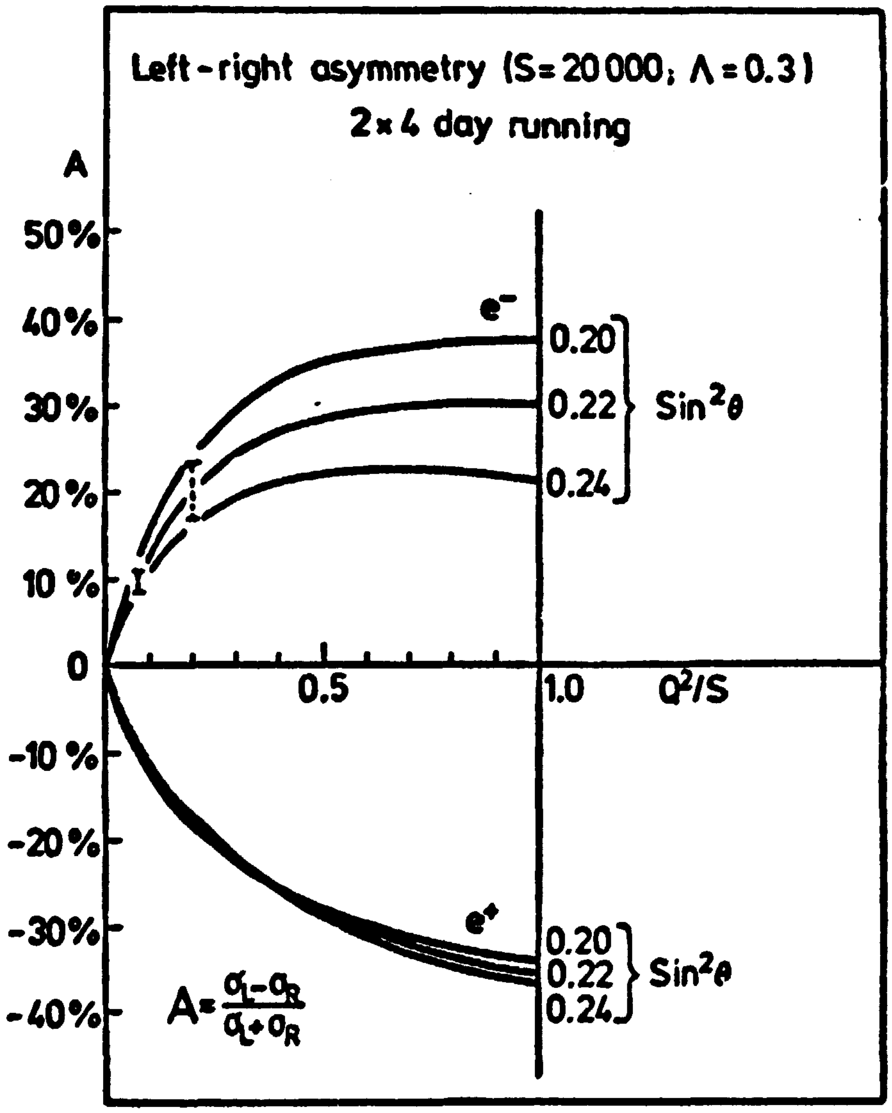


FIG. 10 : Sensitivity to $\sin^2\theta_W$. The variation of $A = \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R}$ with Q^2 as a function of $\sin^2\theta$ for e^- and e^+ beams. Hypotetical data points are included for 2x4 day experiments[10]. One obtains $\Delta(\sin^2\theta_W) \leq 0.01$. One should mention that results from present neutrino data begin to approach this precision.

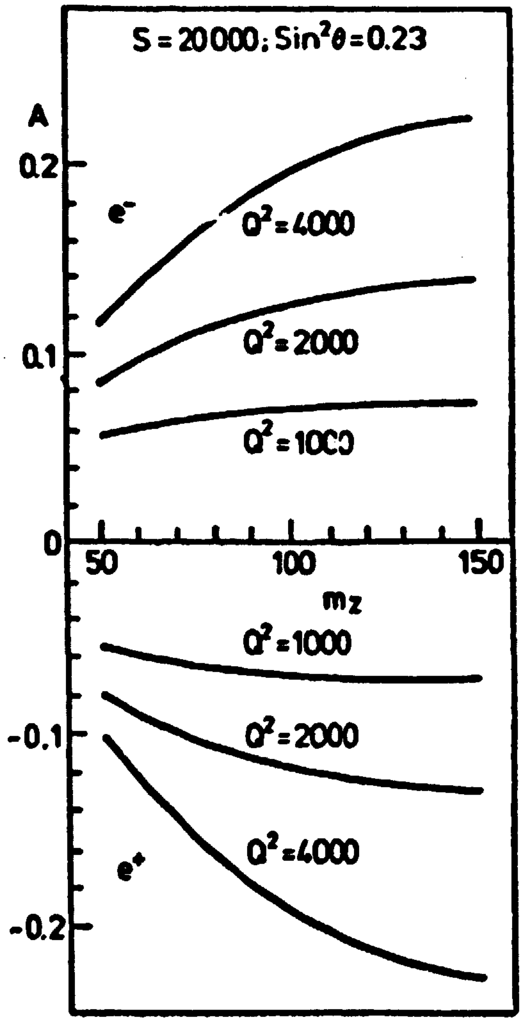


FIG. 11 : Sensivity to $M_{Z°}$

Variation of A at different Q^2 as a function of the mass of the $Z°(m_Z)$[10].

One should mention that it is necessary to reach high Q^2 (> 4000 GeV^2/c^2) to obtain a sensitivity of ~ 5-10 GeV.

This should be a wonderful result but $\bar{p}$ p experiments should get the answer before any e-p machine !

If one considers only the charge symmetry $\dfrac{\sigma(e^-)-\sigma(e^+)}{\sigma(e^-)+\sigma(e^+)}$ the sensitivity to $M_{Z°}$ will be of the order of 10 GeV, but there is no sensitivity with this measurement to the Weinberg angle.

More generally these asymmetries are probes to differentiate various classes of models[6]. Some of these examples shown earlier by John Ellis[6] are given on the figure 12.

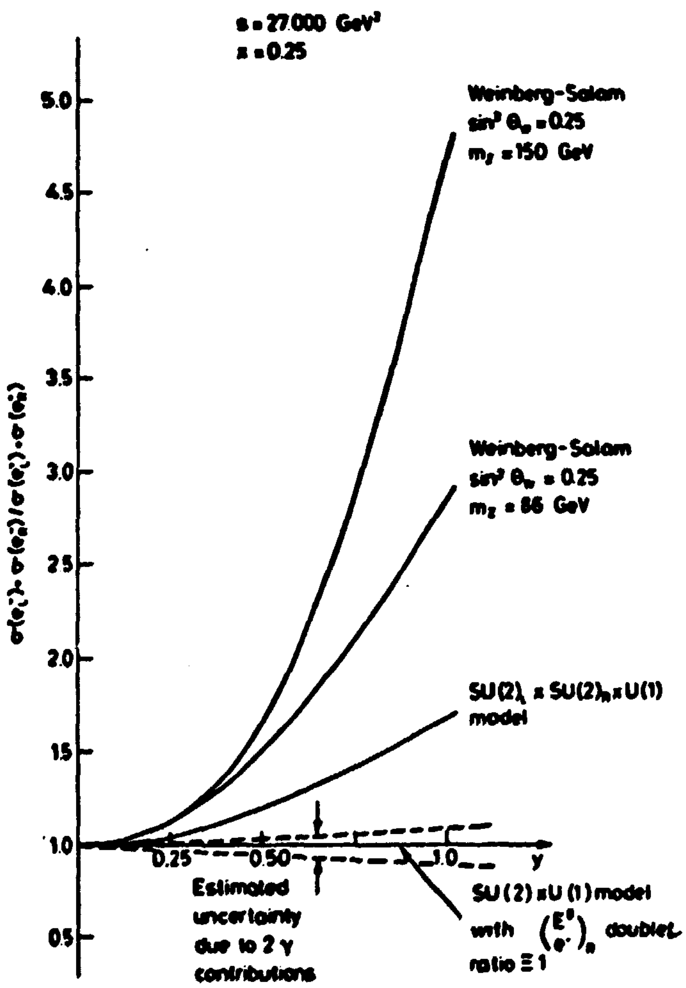
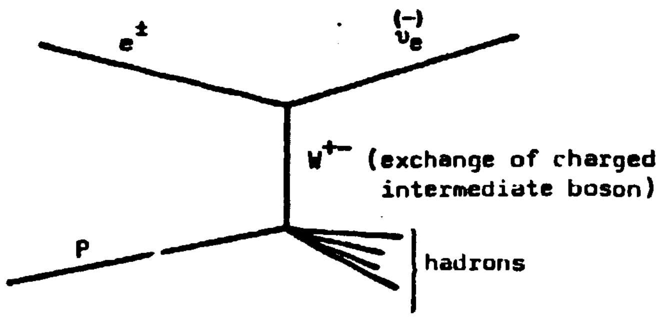


FIG. 12 : $\sigma(e^-)/\sigma(e^+)$ for different weak interaction models, J. Ellis, CHEEP Report[6], p. 54.

The conclusion of the study of the properties of the weak neutral current using asymmetries shows clearly that the polarization of the beam is essential and that the question of the feasibility of such polarized beams in an e-p machine become important. Study of neutral current events shows the clear impact on structure function and weak neutral current in the large Q^2 range obtained with these machines.

4.5 Charged Current

The study of charged current events i.e. events characterised by the following graph :



is the continuation of neutrino physics in fixed target interactions ($\nu + p \rightarrow e^- + \ldots$ or $\bar{\nu} + p \rightarrow e^+ + \ldots$) where a $W^{\pm}$ is exchanged in the process. It means the sort of physics we are discussing at this conference but here most of the results are presented at an average Q^2 of 25 GeV^2/c^2 while with an e-p machine of the proposed energy the Q^2 will reach a tremendously larger value. The difficulty with these type of events in e-p is due to the evanescent neutrino, however progress on the method to extract these events has been made by the working group on "detectors for charged current events[11]"

What are the aspects specific to charged currents ?

4.5.1 Structure of weak charged current interaction

- The deviation from the four-fermion interaction is expected to be mainly due to the W propagator for $q^2 \geqslant 1000$ GeV^2, assuming the mass of the W is $\simeq 76$ GeV. This damping effect $P_W = m^2_W/(m^2_W + q^2)$ is shown in figure 13.

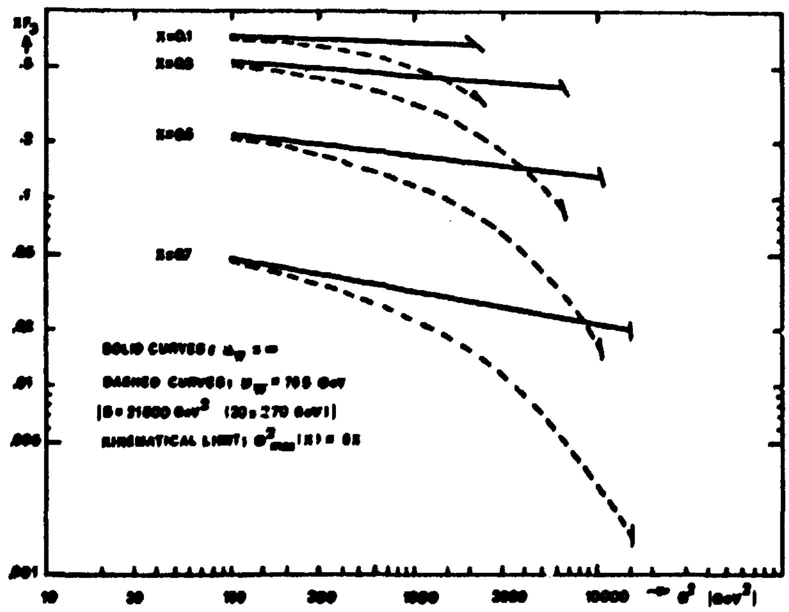


FIG. 13 : Buras-Gaemers Predictions[13] for $xF_3(x,Q^2)$ using CDHS[14] Data for Extrapolation of the Fit.

Such an effect, which can reach an order of magnitude, in the q^2 range available will allow a determination of the mass of the W or at least a limit on this mass, if it is larger than that expected by the Weinberg-Salam model. This effect is seen more concretely in the following figure[10].

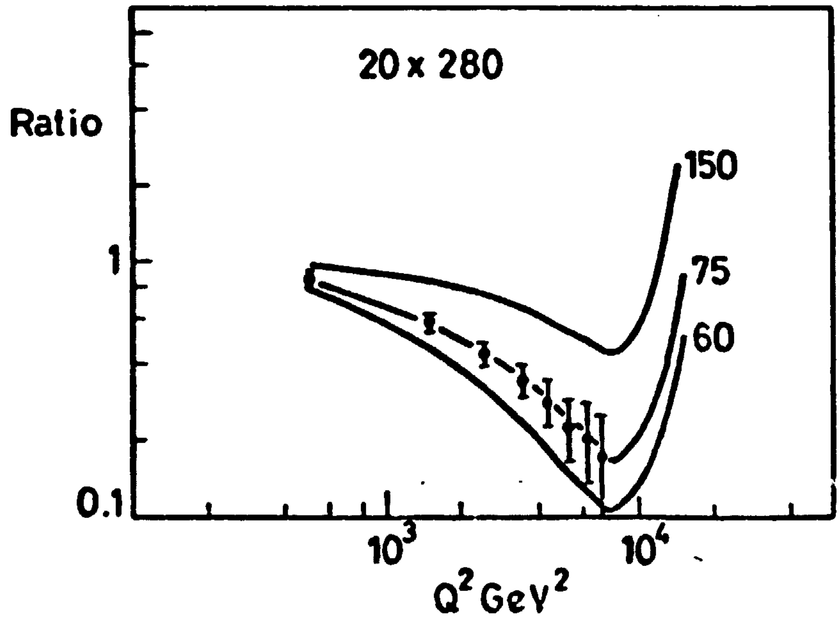


FIG. 14 : The effect of different W masses as a function of Q^2 for 20 x 280 GeV^2 collisions. (The cross-section is compared with that obtained when $m_W = \infty$). Hypothetical data points are included from a 4-day experiment (R.J. Cashmore[10]).

The accuracy obtained is of the order $\Delta(M_W) \sim$ 5-10 GeV at 20 x 280 GeV. The question of several W's is more subtle to disantangle and should be more easy with a machine of 100 x 400 GeV.

- More specific to the form of the charged current is the test on the pure V-A component of the space-time structure of weak interaction. The search for reactions

$$e^-_R + u \rightarrow \nu_e + d$$

$$e^+_L + d \rightarrow \bar{\nu}_e + u$$

which require V+A coupling will be of great interest. The difficulty of such an experiment is clear : one expects to find a small or zero effect within a large background. One such background source is the inefficiency of electron detection for neutral current events.

4.5.2 Structure of Nucleon and Fragmentation Functions

It is precisely on this topic that an e-p machine is far superior to e^+e^- or p-p machine. It offers a point like probe which accesses a very interesting (q^2,x) region and can thus extend the study of nucleon structure functions.

- The sea region at low x, and q^2 as large as 100 GeV^2.
- The large q^2 region for QCD tests (especially in the region before the propagator effect becomes too large).

Structure functions :

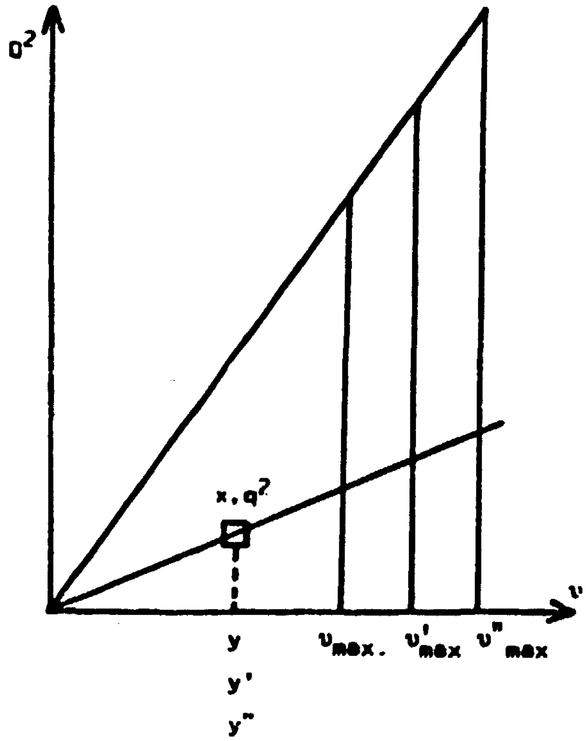
Assuming that we can detect events and measure q^2, ν (or x, y) we should notice that the study of the structure function is not completely the same as for the neutrino interactions on isoscalar target. In e-p interactions one has two types of processes :

where one measures separately u(x) and d(x). A priori these distributions are not equal and one should write the differential cross sections dependent upon 6 structure functions

$$\frac{d^2\sigma}{dxdy}(e^-p)\,\alpha\,(1-y)\,F_2(x,q^2) + y^2 \times F_1(x,q^2) + (y - \frac{y^2}{2}) \times F_3(x,q^2)$$

$$\frac{d^2\sigma}{dxdy}(e^+p)\,\alpha\,(1-y)\,F_2'(x,q^2) + y^2 \times F_1'(x,q^2) - (y - \frac{y^2}{2}) \times F_3'(x,q^2)$$

The main difference between a proton and an isoscalar target is clear : the sum of the two differential cross sections do not give $x\,F_3(x,q^2)$. Solving these equations and measuring the F_i and F_i' requires that one run at least 3 different energies for e^-p and e^+p.



This can best be illustrated if we consider an x, q^2 point (for either e^-p or e^+p), it corresponds to a specific value of ν(or y), however the same point for different energies of electron and proton (i.e. different values of ν_{max}) will correspond to different values of y thus yielding a set of solvable equations. Since the energy of the electron and the proton cannot change independently (Refer DESY report 78.02) one can propose respectively 17.5/280, 11/176, 6.3/100 which would give a good lever arm for ν and an order of magnitude larger for q^2 than we can expect to obtain for neutrinos at FNAL with the doubler. (These different running energies should be optimized after discussion with machine design group). Isoscalar target physics, however could be done if we accelerate deuterons (with an expected luminosity loss of a factor of 4). The development of this possibility will allow tests of charge symmetry $F_i^+(e^+p) = F_i^-(e^-p)$.

Fragmentation function :

The final hadronic state is kinematically more visible in e-p machine than in fixed target physics where both the target and current fragments are mixed together. If the identification of particles is possible, one can study the current jet and test the factorisation hypothesis at large q^2 over a large W range :

$$\frac{d\sigma}{dxdZ} \propto F(x,z,q^2) = q(x,q^2)\, D_q^h(z,q^2)$$

With the charged current we have the unique feature of knowing the flavor of the current quark, and thus we should have the possibility of separating the fragmentation functions coming from the valence and the sea together

$$(D_u^{\pi^+} = D_{\bar{d}}^{\pi^+} = D_d^{\pi^-} = D_{\bar{u}}^{\pi^-})$$

from those of the sea only

$$(D_u^{\pi^-} = D_{\bar{d}}^{\pi^-} = D_d^{\pi^+} = D_{\bar{u}}^{\pi^+})$$

which means a possible separation of non singlet and singlet contributions in fragmentation functions.

4.5.3 Techniques and Method

Detectors[11] have been optimized to study structure function of charged currents. Although the detection of all hadrons is a requirement that is desired for all experiments, in the specific case of charged currents it is a necessity because of the missing neutrino. In particular, the crutial point is the detection of the particles of the proton fragmentation region. Most of these are produced in the forward direction (direction following the proton) and are at very high energy.

The construction of the forward spectrometer has been studied. A more serious study of this problem needs a closer connection with the construction details of the machine. However we should note that the effect of the loss of these particle is minimized following the conceptual improvement found in a new method devised to study the charged current events which is described fully in the proceedings of the Hamburg meeting[15]. This technique was the greatest progress of this working group[11]. The conclusion of this study is summarized in the figure 15 which represent the error in the reconstructions of charged current events in the x and y scaling variables due to the two inevitable holes in the forward and backward directions.

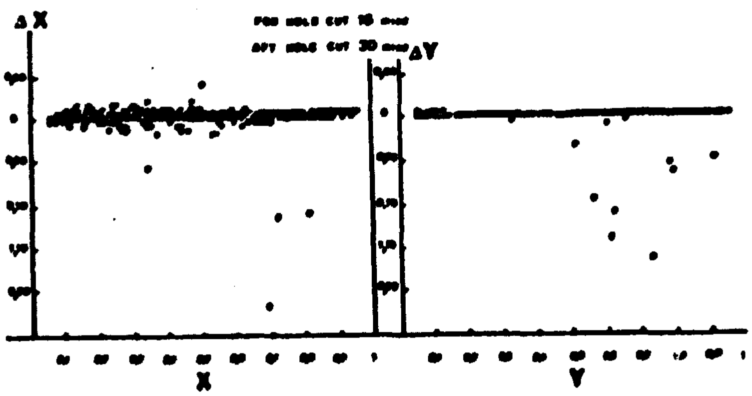


FIG. 15 : Error ΔX and ΔY between generated events in x, y plane and reconstructed event with particle non detected leaving the apparatus in a 15 mrad forward and a 30 mrad backward holes.

Figure 16 represents the final error we can expect on x and y with experimental precision obtained with one of the detectors studied[11].

Iron Calorimeter High Field

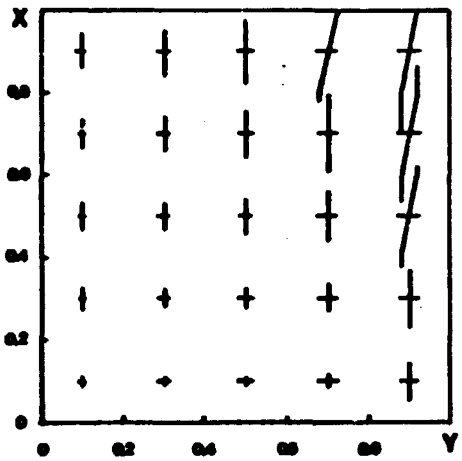


FIG. 16 : Measurement errors ΔX and ΔY presented over the x, y plane for one of the detector studied by the charged current working group[11].

In a way the conclusion on the charged current situation is even more interesting than for the neutral current, since charged current events give a better access to structure functions due to the flavour dependence effects, even if the experimental techniques appear to be slightly more difficult.

5. Conclusion

If one considers purely physics motivation we can see that an e-p ring is not the tool we need to study what is the present "excitation" of the physics community i.e. : the "long-sought-for" intermediate boson discovery. This situation is less strong for new lepton and quark hunting where it seems that e-p is as promising as the e^+e^-, $\bar{p}$ p proposals. But it is obvious that for the study of the structure of the nucleon - via neutral and charged currents - this machine is by far superior, even if without imagination we try to extrapolate, by an enormous factor, the physics we are doing now. But on the other hand this new range of physics where we are probing the proton at a distance of 10^{-16} cm could give us all kinds of surprises. It is because we can expect reality to be something quite different from what our painful workshops suggest, that we are not sure that one type of machine can be sufficient. We could miss a new big "turning-point" in physics. One should keep in mind for instance that e^+e^- rings had a rather sudden regain of interest after the discovery of the ψ. Thus an e-p machine is to be viewed as "complementary" to the others and one would prefer a <u>diversity</u> of tools available in our efforts to understand our world.

Technically the realization of an e-p ring in the years 1985-1986 is feasible and I think that an enormous excitment would take our physics community if such a thing happened. Today we are left with the financial questions and although it is not very "correct" to speak about finances I will finish my talk by saying that here lies the real key to our choice of machine.

I would like to acknowledge that I have borrowed heavily in the physics discussion from the following sources ; CHEEP Report, R.J. Cashmore and P.G. Innocenti and the working group on charged current from "e-p Facility for Europe".

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