Do Spectrometer Design Proposal

The Northwestern High Energy Physics Group

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Introduction

The purpose of this proposal is to offer two specific contributions.

1. The overall D_o detector design architecture. We will outline the reasoning which underlies the particular geometry we have chosen and consider it to be the one which best exploits the opportunity afforded by D_o. We believe that it is presumptive to attempt to provide serious designs for all of the major subsystems of the spectrometer. We anticipate a merging of several collaborations and parties who have interest in D_o once the optimum overall design architecture is selected by Fermilab. The detailed subsystem design can only proceed when more specific goals, time schedules, space limitations and overall cost constraints are established.

2. One very specific subsystem which we propose to construct is a pair of E.M. shower detectors to operate in the forward regions (1°-15°). We have a number of solid and innovative ideas to put forth. We have construction, operation and analysis experience obtained in the M1 beam line to draw upon. The scope of the proposed commitment is reasonably well matched to our Northwestern resources.

Spectrometer Design

The advent of TEV I will provide a CM energy of 2 TeV $\sim$45 times greater than that available in the fixed target program and $\sim$3 times greater than the SPS Colliding System. With three circulating $\bar{p}$ bunches we can look forward to an interaction rate $\sim$few x10^4/sec. This is approximately one order of magnitude below the interaction rates which have been sustained in those fixed target experiments featuring large aperature spectrometers. Such a valuable resource deserves full utilization - 4π detection. In fact, the totality is of greater value than the sum of the constituent systems - dynamical constraints (e.g. $p_\perp$ balance) accrue.

We defer for the present a discussion of physics goals and motivations. The task of designing a 4π detector geometry is more akin to that presented by a bubble chamber complex than to that normally encountered in fixed target physics.

For the purpose of our discussion we distinguish 3 regions of acceptance (polar angle defined) the beam hole region ($0-1^\circ$), the forward region ($1-15^\circ$), the central region ($15-90^\circ$).

($0-1^\circ$)

Most of the reaction energy flow goes down the pipe. Several proposals discuss this region in detail. A relatively modest goal is to squeeze the uncertainty in missing $p_\perp$ to the barest minimum. A more ambitious goal is to measure the longitudinal energy flow to sufficient accuracy as to facilitate a useful constraint on the amount of energy that is released in the central collision process. In considering such a prospect there are a number of grave concerns. Some form of staggered calorimetry must by employed and one must evaluate energy losses in cracks. Forward neutrino losses are a

second concern. Compatibility with beam elements including low β quadrapoles, are also to be considered. Presumably, one will be loathe to sacrifice luminosity particularly in the early stages of operation. Some real hard performance data obtained from simulation tests carried out with a low flux proton beam and a fixed target would be useful if not imperative, before commiting to luminosity sacrifice.

In any event, none of the ideas we are presenting in this proposal preclude the execution of beam line energy detection to the ultimately achievable sensitivity. We do not vie for that responsibility.

At this juncture, before considering the $(1\text{-}15^{o})$ and $(15\text{-}90^{o})$ regions we must make a decision - magnetic tracking around the collision region vs. nonmagnetic spectrometer. In the absence of a central magnetic detector, one proceeds with EM shower detectors and calorimetry plus muon detection. The obvious advantages of this choice are: It is more compact and cheaper, magnet power consumption is avoided and the decay path for the production of uninteresting leptons from π,K,Λ ... decay is reduced to the barest minimum.

The advantages of magnetic tracking are: Momentum tracking is inherently of higher resolution than calorimetry. Of course calorimetry is essential for neutrals - n, $\bar{n}$, k^{o},π^{o} excluded It is one thing to require calorimetric information for (10-20)% of the total energy flow, it is far cruder to be totally dependent on it. Charge sign is identified. This is particularly valuable for $e^{\pm}$. One can study same sign, opposite sign correlations and other correlations such as charge vs rapidity (e.g. $W^{\pm}$ production is expected to correlate with $p(\bar{p})$ direction). Electron-hadron separation is $\sim$10 times improved with momentum information available.

The advantages of the nonmagnetic system are less than dramatic if one considers the situation further. It is not really prudent to collapse the detector system to the "iron ball" limit. The segmentation of the EM shower system and the inner hadronic calorimetry layers, the quality of energy flow direction determination, overlap problems etc. strongly suggest leaving some void surrounding the beam pipe in the collision region. Furthermore, some kind of inner tracking system is advisable in order to pin down the event vertex and locate an accidental vertex if any.

The mean transverse radius of the calorimetric iron is

≈ Void radius (or magnetic tracking radius)
+0.5m (for shower detection)
+1m (assuming Calorimeter Fe ~ 1.5m thick)

The cost presumably scales as the cube of this quantity. A void radius would be $\lesssim$ 0.5m while a "reasonable" magnetic tracking system could be provided within 1m radius.

Conclusion: A 4π detector requires $>10^3$ ton's of Fe; therefore we might as well provide it with coils and develop an interior magnetic field.

Having opted for a magnetic field, we believe that it would be exceedingly unwise to choose a longitudinal field. The D_o area would replicate the C.D.F. A transverse field provides a complementary choice. See figure 1 for a comparison of the longitudinal and transverse options.

Figure 2 illustrates an extremely large (and appropriate) window frame dipole magnet. Such a magnet will cost several millions of dollars. The field is vertical in deference to the minibypass system. The minibypass deflects the main ring beam pipe to a distance of 2

meters above the Tevatron beam. In the position shown, the main ring passes through regions of calorimetry i.e., coarse detector systems which are not severely compromised by the intrusion. The dipole field in this region should be relatively weak. A portion of the Fe yoke-calorimeter surrounding the beam pipe will be replaced with a non magnetic matrix of Al and Pb so as to provide a non magnetic enviroment. It should not prove to be excessivly difficult to reduce the residual field in the pipe to the level of a hundred gauss.

The UA1 magnet system which is of comparable size has a field direction parallel to the ground. This makes possible access to the detector interior by a relatively simple horizontal split of the two symmetric detector halves. The vertical field we have chosen in deference to the minibypass does not permit this. The coils cannot be split. We propose to make the upper pole face modular and in sections which can be handled by a crane. The saddle coil construction gives access thru the magnet ends. The UA1 system does not employ saddle coils. It may be argued that the construction of properly vacuum impregnated saddle coils of this size is prohibitively painful. We have some thoughts to be described later on which may ameliorate the pain.

We opt for Cu coils and a power ~2 MW. We anticipate that the magnet will be fully powered with a 25% duty factor. The Cu is perfectly good (if expensive) calorimetric material.

The window frame magnet has four attractive features

1. Accessibility at the ends.

2. The forward detection regime (1-15°) will be carried outside the magnet. The magnetic field deflection will be tracked over a large distance (5m) and the shower detector segmentation will be more effective.

3. If nature should surprise us with some new long lived charged particle we will have a large window to study it with.

4. The ambient flux of low energy radiation in the magnet cavity should be reduced. This should be beneficial to the central tracking system.

Figure 3 shows schematically the disposition of the major detector systems.

1,2,3 - Drift chamber tracking chambers.

4,5 - Internal EM Shower detectors.

6 - Forward shower detectors.

7,8,9 - Fe based calorimetry.

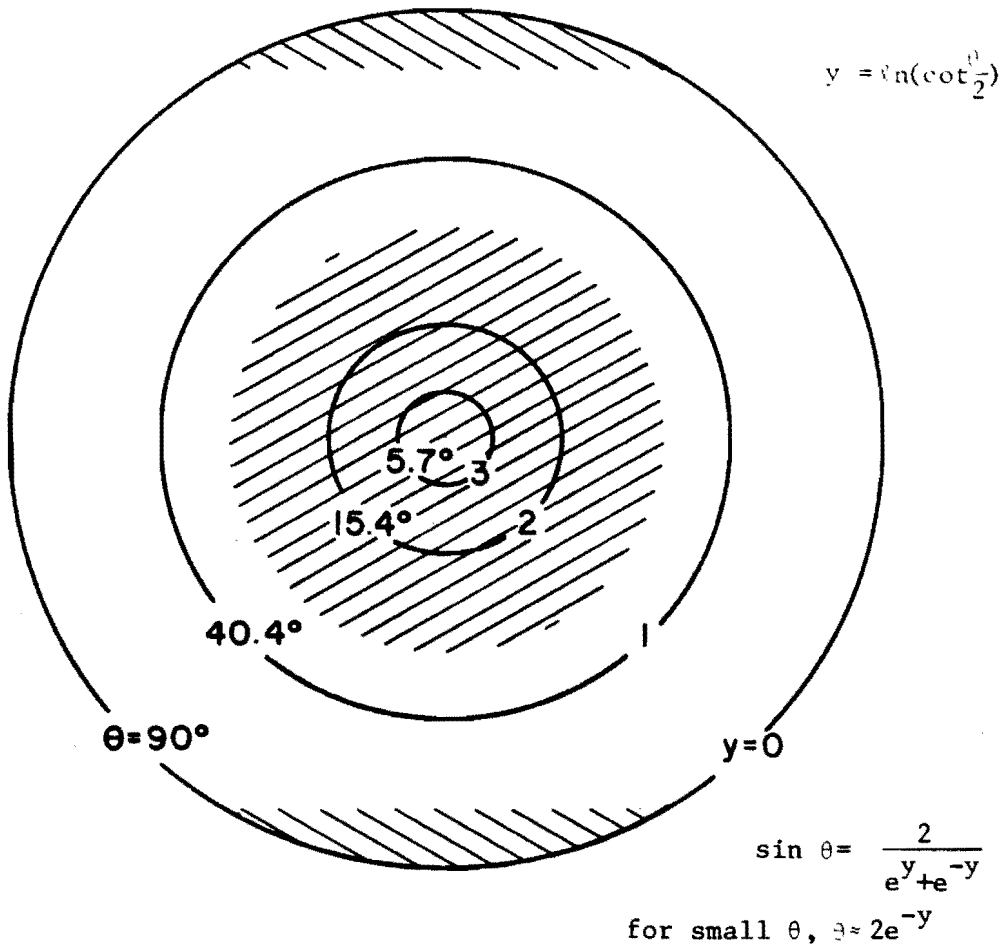

Figure 1. Hemisphere projection of the polar angle plot. Zero degrees corresponds to the beam pipe direction. Circles of constant pseudorapidity (y) are indicated. The half width at half maximum of the central rapidity plateau is predicted to correspond to $y \approx 5$ for TEV I. This is for general inclusive production. For $W^{\pm}$ production the half width at half maximum is $y \approx 2$. The central shaded region indicates the end cap regime of the C.D.F. ($\theta < 30^0$) where the magnetic tracking is very weak or nonexistant. The oppositely cross hatched areas correspond to the analogously weak tracking regions for a transverse field spectrometer such as UA1.

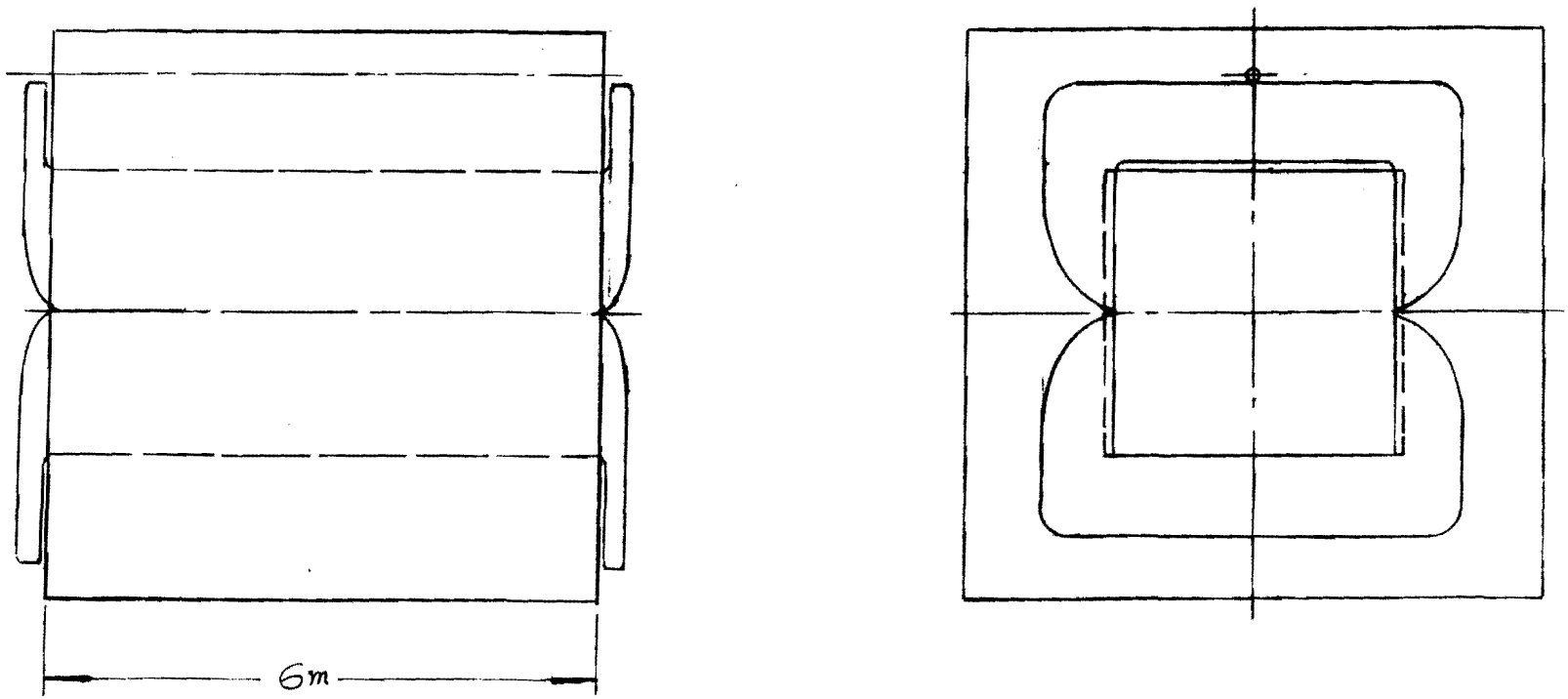

Figure 2

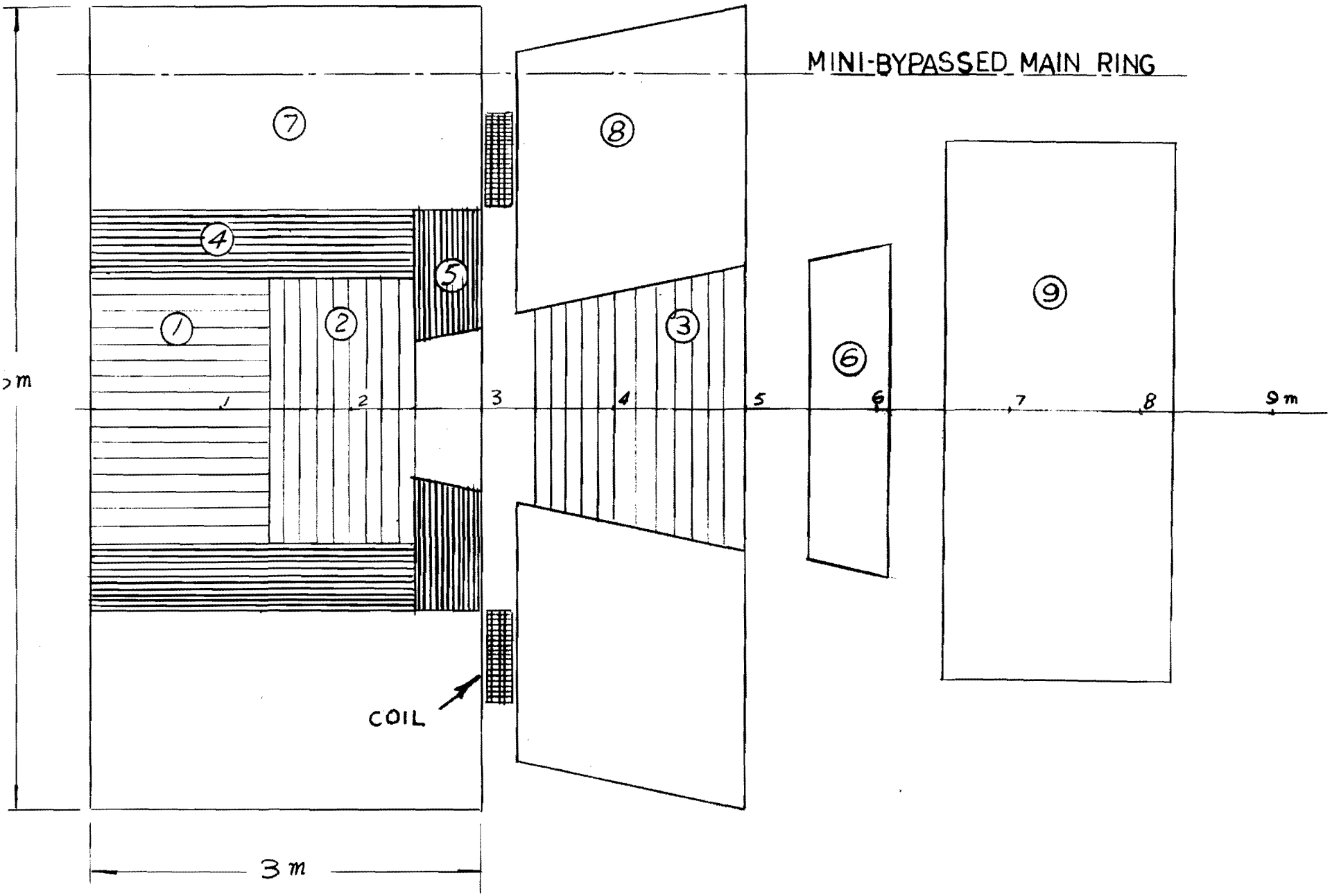

Figure 3