MASTER**EXPERIMENTAL HALL DESIGN CONSIDERATIONS**

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EXPERIMENTAL HALL DESIGN CONSIDERATIONS

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ABSTRACT

General requirements for experimental halls at the Fermilab Collider are set forth, and specific designs for two halls are presented, one for the Detector Group's large "W detector" and the other for several smaller setups and for ep experiments. We survey the physics which cannot be studied with the W detector, and recommend that the second area incorporate a transposed geometry to allow small angle experiments. Our most important recommendations are (1) that the halls have good access and the possibility of changing entire setups during short shutdowns, (2) that both equal energy ($\bar{p}p$) and unequal energy (pp , ep) experiments be accommodated (3) that construction take place during the superconducting ring installation, (4) that the halls incorporate assembly areas in which detectors can be built and serviced during machine operation and (5) that detailed design, including radiation safety calculations and muon background measurements, begin immediately.

We address some basic questions concerning the nature of the experimental halls needed for colliding beam experiments at Fermilab. General requirements and design considerations are dealt with first, followed by our specific proposals for the layout of actual halls.

A. General Considerations

We consider the following questions:

1. What is the optimum number and location of experimental halls?
2. When should these halls be constructed?
3. Is the added expense of attached assembly areas warranted, and where can they be located to allow occupancy during accelerator operation?
4. Should the halls be asymmetric or symmetric (e.g., for unequal energy pp or for one-ring $\bar{p}p$)?
5. Are halls of the "open area" type, as proposed for ISABELLE and PEP, appropriate at Fermilab?

Our recommendations are based on estimates of the probable lifetime of the Fermilab colliding beam facility, expected funding levels (and rough cost estimates), and operational requirements.

We expect that pp collisions at Fermilab will be available for experiments three to five years before ISABELLE becomes operational, and that programs making use of stored antiproton and electron beams will gradually supplant proton-proton operation as ISABELLE pp experiments become competitive. Both the 2 TeV $\bar{p}p$ program and the ep colliding beam facility will provide unique research opportunities for the following period of at least

five years. Thus, the experimental halls will be required to house several rather different types of detectors at various times. These halls should therefore be of a general design to accommodate unequal-energy proton beams, equal energy (single ring) $\bar{p}p$ collisions, and very asymmetric ep experiments. They should also provide for the installation and removal of complete detector systems without an extended shutdown of the accelerators.

Since much of the assembly, debugging, and upgrading of the installed detectors will have to be accomplished during numerous short access periods when the accelerators are off, fast and efficient access to the experimental halls is of prime importance. In addition to access facilities for large equipment, (e.g., a 5-m diameter, 10-m long solenoid coil), there should also be minor entrances for both people and equipment. Crane coverage of the underground hall also seems very important for efficient operation. Detectors themselves should be of a modular construction as much as possible to minimize the size of access ways.

Radiation protection must be adequate to protect detectors from high tunnel backgrounds, and provision will have to be made for shielding around the beam pipes on both sides of intersection regions, without blocking tunnel traffic. Radiation shielding for personnel must provide adequate protection in the event of a worst case accident (e.g., complete dumping of both beams in the experimental hall), while still allowing experimenters free access to nearby experimental control areas. Substantial cost savings are possible by reducing the thickness of earth shielding on top of the halls from the usual 4.5 m to as little as 1.5 m, while at the same time denying personnel access

to potentially high dose areas.

Further economies may be realized by attention to sensible engineering considerations in the design of experiments. For example, large roof spans in more than one direction will be very expensive, and major penetrations of structural walls by large openings should be avoided where possible. We have assumed that a total budget of \$4 to \$5 million will be available for the construction of all the colliding beam experimental halls.

In light of these considerations, we have reached the following conclusions:

1. Number and Locations of Experimental Halls

In order to provide the opportunity for the simultaneous operation of as many experiments as possible, we believe that three experimental halls should be constructed if at all possible. It seems likely that two of these could be at either end of a "transposed" sector, in which the main ring lies below the energy doubler. A third region, which might make use of the "kissing" scheme to achieve collisions, would probably not be operational as soon as the first two intersections. During the course of the summer study serious consideration has been given to colliding beam experiments at B0, C0, and E0, although practical considerations may limit actual usage to only two of these three straight sections.¹ In light of this, and despite our preference for three experimental areas, we consider the construction of only two halls, which can then be somewhat more versatile than if the available funds had to be divided three ways. As a working hypothesis we assume that one hall (e. g., at B0) will be devoted to the large general purpose "W-

detector", and the other to several smaller experiments which can operate simultaneously. These experiments will presumably undergo fairly rapid turnover, and will concentrate on physics which is not well studied by the W detector.

2. Construction Schedule

Since the construction of experimental halls seems likely to require a two to four month shutdown of the accelerators, it is important to build all the enclosures during the period when the energy doubler is being installed. The actual accelerator downtime required must be determined from a detailed engineering study; it can be significantly shortened by doing as much work as possible during normal machine operation. Despite possible funding restrictions and the logistical problem of installing experimental halls and the superconducting ring at the same time, we recommend that the construction be undertaken at the earliest possible date.² This will allow experiments to be assembled and installed in time to make full use of the colliding beams as soon as collisions are achieved. An interesting practical consideration is whether both halls will be put out as one construction bid package. This would have cost advantages but would probably increase the risk of construction delays.

3. Assembly Areas

The Fermilab colliding beam program will operate under the constraint of having to share the accelerator facility with a demanding schedule of fixed-target operation. Thus the experimental halls will be inaccessible for long periods of time when they are not actually in use for colliding-beam

experiments. This situation is quite different from that at facilities such as the ISR or ISABELLE, and seems to demand special consideration. This is certainly true for the complex W-detector designs currently under consideration, which are likely to benefit enormously from extensive attention during periods of fixed-target operation. We believe that it is highly desirable (and feasible) to be able to move an entire experimental setup from the interaction hall into an adjacent shielded assembly area in a period of a few days.³ In the case of the massive W detector (~ 4000 tons), this may well require the assembly area to be at the same elevation as the interaction hall, which will present a serious radiation shielding problem.

Personnel in the assembly hall must be protected from radiation resulting from worst case accidents (e.g., dumping of the stacked, 1-TeV energy-doubler beam), both for neutrons (beam dump in the interaction hall) and for muons (beam dump upstream in the energy doubler). Detailed estimates made at this summer study⁴ indicate that both problems are manageable, however, experimental measurements and more refined calculations are clearly called for if costs are to be kept to a minimum. The massive (~ 5 -m thick concrete), movable hadron shield wall between the interaction hall and the assembly area can then be made as thin as possible, and the seriousness of the muon problem in an assembly area outside the ring enclosure can be evaluated with confidence. Since the muon problem appears to be much less severe for an assembly area located inside the rings,^{4, 5} we have chosen this more difficult configuration for our detailed designs, even though it may require relocation of service

buildings, roads, and cooling ponds.

4. Symmetric versus Asymmetric Halls

As discussed above, the long projected lifetime of the facility and its probable use for both equal-energy (e. g., one-ring $\bar{p}p$) and unequal-energy (e. g., pp , ep) colliding beams, argues strongly for versatile, general-purpose halls. In any case, we found that an experimental area designed for 250 GeV $\times$ 1000 GeV pp collisions could also be used for most equal-energy experiments without further expansion.

5. Open Areas

An open area, as described in the ISABELLE and PEP proposals and in the 1976 Fermilab Summer Study, consists of a large concrete pad with a pit under the interaction region. Side and top shielding is provided by standard concrete shield blocks. Substantial savings over the cost of closed areas, such as the ones proposed here, can be realized if the required shield blocks are already on hand. In this case, the cost per cubic meter of enclosed volume may be as low as 25% of that for a closed hall. As at ISABELLE and PEP, we find this type of construction to be unsuitable for major experimental facilities, although "nook-and-cranny" experiments may be reasonably well accommodated. The use of standard size shield blocks severely limits the size and shape of the enclosure, and major accesses will require much rigging time. The principle utility of open areas is to reserve an intersection region for future development, making them much more attractive at totally new facilities like PEP and ISABELLE than at Fermilab.

B. Detailed Design of Experimental Halls

In addition to consideration of the general requirements outlined above, we have made a survey of proposals for colliding beam experiments at Fermilab, ISABELLE, and PEP, in order to determine the range of hall dimensions required by typical experiments. The results are summarized in Tables I and II, and in Figure 1. The survey suggests that closed halls cost $\$(200 \pm 50)/\text{m}^3$ of enclosed volume, similar to recent experience in the Proton Area at Fermilab. Ultimately, we found it most useful to configure one hall (hereafter the "W Hall") specifically for the massive solenoidal W detector being designed concurrently at this summer study.⁶ Close collaboration between the Detector Group and the Experimental Halls Group then led to the serious consideration of many practical details of assembly, installation, and servicing of the detector, and culminated in the design presented below. It is likely that any other massive detector would require a hall with similar characteristics.

The second hall (hereafter the "X Hall") has been specifically designed to house experiments which cannot be effectively performed by the large detector in the W Hall. These include the small angle experiments listed in Tables I, II, and III, as well as $\bar{p}p$ and ep experiments. While it seems very likely that the most important $\bar{p}p$ experiments can be performed quite satisfactorily with the same apparatus used for pp experiments (in particular, the W detector), the detectors for ep experiments will undoubtedly be of a unique design. The X Hall has been designed to house these experiments, including special ep squeezer magnets and quadrupoles, although detailed ep interaction configurations have not yet been worked out.

Table I

SUMMARY OF FERMILAB DETECTORS FOR COLLIDING BEAM FACILITY

Nature	Reference	Length (m)	Width (m)	Height (m)	Approx. Weight (tons)	Magnet Type	Particle Identification and Instrumentation	$\sqrt{WH}$ (m)
Proposal 491 (pp) (MR/ED)	Ankenbrandt I-107 (76-SS)	3.0	6.0	6.0	400	none	h, e calorimetry + drift	6
478 (pp/SSR)	Appel I-223 (76-SS)	10.0	7.0	7.0	1000	Iron toroids	h, e calorimetry, PWC, drift, transition	7
492/493 (pp)	Cline I-309/I-463 (76-SS)	5.0	5.0	4.0	1000	Magnetized iron	leptons, μ , e	4.5
480 (ep-SSR)	Mo I-391/I-437 (76-SS)	4.5	4.5	2.8	30	S. C. half toroid	μ , e	3.5
Detectors Proposed								
High P_T	Ankenbrandt I-517 (76-SS)	3.0	4.1	8.0	300	Solenoid	μ , e hadrons, drift chamber, transition	5.7
New Particle Search updated version	Ayres I-527 (76-SS) Ayres Ref. 10 (77-SS)	----- C0 Hall ----- (0, +10)	(0, 10)	6.0	150 200	Dipole SCM-105	hadrons hadrons, e, needs pit, remove spectrometer wall	- 7.7
Muon	Frish I-549 (76-SS)	3.2	2.8	2.8	128	Solenoid	μ + Drift	2.8
Hadron	Jones I-563 (76-SS)	46	4	4	480	none	PWC, scintillators, calorim.	4
Coulomb	Kalbfleisch I-567 (76-SS)	Detectors in accelerator vacuum pipe.						
Lepton	Singer I-573 (76-SS)	10	10	10	1500	Solenoid, mag. iron	e, μ , h, + drift	10
Multiparticle	Loken I-583 (76-SS)	12	12	12	2000	Solenoid	h, μ , + drift	12
C0	Olsen II-455 (76-SS)	3.5	5.0	5.0	25	S. C. solenoid	1.5m pit, circular C, γ , μ , + drift chambers	5
W-Detector I	Atac Ref. 6 (77-SS)	12	10	10	3800	S. C. solenoid	e, μ , h calorimetry transition, drift, LA shower	10
W-Detector II	Atac Ref. 6 (77-SS)	13	8.5	9	5500	Dipole	e, μ , h calorimetry, transition, drift, LA shower	9
W-Detector III	Atac Ref. 6 (77-SS)	16	12	12	11700	Toroid	calorimetry, PWC, μ	12
W-Detector IV	Atac Ref. 6 (77-SS)	14	9.2	9.2	4000	Convent. solenoid	μ , e, h calorimetry, transition, drift	9.2
Others: Z^0	Cline I-513 (76-SS)	4.0	1.5	3.0	200	Magnetized iron	μ only, inside tunnel, drift, scintillator	2.1

Table II
SPECIFICATIONS OF EXPERIMENTAL AREAS

Design	Power MW	Approx. Cost	Pit Size (mxm) W x L x Ht x D* (m) (m) (m) (m)	Crane (tons)	Whole area + alcove W x L x Ht x D* (m) (m) (m) (m)
Fermilab I-603 (76 SS)	?	\$0.3M (\$55/m ³)	7 x 20 x 7 x 3½	none	(60 in tunnel) 20 x 40 x 7 x 1
Tevatron Prop.	?	\$1.5M	12 x 12 x 7 x 3	30	14 x 40 x 4 x 2
Proposal 491	?	\$0.3M	13 x 10 x 5 x 4	30	13 x 10 x 5 x 4
ISABELLE '77 Table II Pit 1	?	\$.9M (\$260/m ³)	8 x 72 x 6 x 1.75	10	+ alcove, 6 m wide
5	?	\$1.10M (\$175/m ³)	36 x 16 x 11 x 3	10	+ alcove, 6 m wide
7/11	?	\$1.2M ea. (\$145/m ³)	16 x 36 x 15 x 5	40	+ alcove, 6 m wide
2 open areas	?	\$.4M ea. (\$40/m ³)	54 x 36 x open x 3	none	+ alcove, 6 m wide
PEP 2 (1976 report)	3	\$1.1M (\$200/m ³)	24 x 20 x 10 x 4	30	+ alcove (one end) 7 x 20 x 5 x 2
4	3	\$1.0M (\$230/m ²)	12 x 40 x 9 x 4	30	--
6 (open)	3	\$0.26M (\$40/m ³)	20 x 40 x open x 4	none	--
8	3	\$1.5M (\$150/m ³)	30 x 20 x 15 x 6	30	7 x 20 x 5 x 2
10 (open)	-	--	7 x 20 x 5 x 2	open	--
12	3	\$1.1M (\$200/m ³)	24 x 20 x 10 x 4	30	7 x 20 x 5 x 2

* D = depth of pit.

Table III: A survey of detector dimensions for experiments which cannot be performed by the large detector in the W Hall.

Experiment	Length (m)	Width (m)	Height (m)	Weight (tons)	Comments	Reference
Total cross section	30	1	1	-	like Pisa/Stony Brook (plus foward scattering amplitude)	8, 11
Elastic scattering: Coulomb interference $0.02 < -t < 5 \text{ GeV}^2$	- 20	- 1	- 1	- -	special high- β st. section	12, 13 14
Particle spectra	40 180 10	3 4 10	3 - 6	200 - 200	pseudo rapidity, energy inclusive small $p_{\perp}$ inclusive large $p_{\perp}$	8 15 10
Multiplicity	30	1	1	-	like Pisa/Stony Brook	8, 11
Correlations	46	4	4	480	charged and neutral particles; pseudo rapidity, energy	8
Diffractional excitation	20	1	1	-	low mass, low multiplicity	14
Particle searches	10	10	6	200	quarks or other stable objects	10, 16

Fig. 1 Scatter plot of experimental hall dimensions for colliding beam experiments proposed for the Fermilab Collider. The data for the plot are given in Table I.

1. The W Hall

Figure 2 shows the hall which we have designed to house the Detector Group's W detector, a 12 m long, 10 m diameter solenoid (outside dimensions, including calorimetry), weighing about 4000 tons.⁶ The device requires the floor of the 20-m-long by 12-m-wide interaction hall to be 5.75 m below beam elevation, and the pit in the associated assembly area is at the same elevation. (To cut excavation costs, a minimum of undercarriage gear has been assumed.) The 5-m-thick concrete shield-block wall separating the interaction hall from the assembly area can be unstacked by the assembly-area crane to permit moving the detector on rails between the two areas; the entire moving operation is expected to require a machine shutdown of a few days.

The assembly area has been made large enough to permit final construction of the detector, including insertion of the core detector into the outer yoke and calorimeters, and to allow for storage of the shield-wall blocks. The 30 ton assembly-area crane is used for shield wall stacking, detector construction, and for moving equipment to and from a drop area which is serviced by a vehicle ramp to grade level. (An alternative scheme would be to increase the building height and bring equipment in at grade level.) The shield wall between the two areas contains a 2-m wide fast access way within a cast-in-place section at one end, in addition to the stackable shield block section. Stairways and elevators provide for personnel access to both areas.

The locations of the utility buildings and counting room facilities (at grade level) shown in Figure 2 have not been optimized, and it may be necessary to provide a hardstand for Porta-Kamps and other experimental support equipment in addition to the buildings shown. The assembly area itself will

Fig. 2 Plan and elevation views of the W Hall. All distances given on the figure are in meters. The numbered features are (1) the W detector outline, (2) the tunnel traffic bypass, (3) the hadron shield wall, and the fast access way which penetrates it, (4) the stair access to the assembly pit, (5) the assembly area pit, (6) the road access to the assembly area, and (7) outline of the straight-section tunnel.

be usable for some of the detector's electronics during colliding beam operations, but this equipment would have to be removed when the detector is moved out of the interaction hall. The size of the assembly area shown is the absolute minimum required for building of the detector, and in practice it may be desirable to make it somewhat larger should funding be available.

No enlargement of the long straight section enclosure outside the interaction hall has been shown in Figure 2, since the present squeezer magnet design appears to fit in the existing tunnel. Provision has been made for tunnel traffic to move past the installed detector, utilizing a movable bridge over the pit area.

Fermilab Architectural Services has provided a cost and construction time estimate for the hall shown in Figure 2. With adequate advance preparation and working two shifts a day, the hall could be completed during an accelerator shutdown of about 72 days. The total cost of the hall, including utilities, would be about \$1.8 million. Details are given in Table IV.

We have considered an interesting alternate scheme for the assembly area, in which the entire detector is raised out of the tunnel using a super-sized elevator. This design trades excavation costs for an expensive elevator; one variation is shown in Figure 3. The elevator lifts the 4000 ton load about 18 m to the above-grade detector-assembly hall, and a 2000 ton concrete shield is moved in under the detector to provide radiation shielding and support. Alternately, the shielding could ride on the elevator. The plan has the advantage of fast and convenient access, although adding a large, automatically movable shielding door to the scheme of Figure 2 would

Table IV. Estimates of cost and accelerator shutdown time required for the W Hall configuration shown in Figure 2.

I. <u>Cost Estimate (in thousands of dollars)</u>		
Interaction hall		370
Power, LCW, Road, Utilities		210
Service buildings		90
Assembly area: underground		350
Assembly area: surface building		80
30 ton crane		80
Landscaping		20
Overtime for double shift work		100
	Subtotal	<u>\$1300</u>
EDIA (10%)		130
Contingency (10%)		130
Escalation (15%)		240
	Total	<u>\$1800</u>
II. <u>Time schedule for excavation, break-in and close-up of Main Ring tunnel (1 shift/day, 5 days/week):</u>		
Excavation and break-in		40 days
Base pad and support piling installation		10 days
Wall forming		25 days
Roof		30 days
Backfill		20 days
	Total shutdown time	<u>125 days</u>
	2 shifts/day, 5 days/week	72 days
	3 shifts/day, 5 days/week	60 days
	3 shifts/day, 6 days/week	50 days

W HALL: ELEVATOR SCHEME

Fig. 3 Sketch of the elevator scheme for moving the W detector to an assembly area above the interaction hall. The numbered features are (1) the detector outline, (2) the elevator support pistons, shown not telescoping (the actual number and size of pistons needed is not known), (3) the assembly area, and (4) the movable hadron shield and support block.

produce the same access speed. While the elevator scheme may ultimately prove to be more costly than that of Figure 2, we feel that it should be studied in more detail before a final design is adopted.

2. The X Hall

a. Physics Considerations

The large solenoidal W detector under study by the Detector Group⁶ is configured to study large angle events particularly well. Large transverse momentum phenomena, direct lepton production, as yet undiscovered particles which decay leptonically or semileptonically (Higgs bosons, heavy vector mesons, $W^{\pm}$ and Z^0 particles) and jets will all be sought or investigated with this large, general purpose apparatus. It will be the most expensive, most highly instrumented colliding beam detector at Fermilab and therefore will be used during most of the time available for colliding beam research. There are, however, many other experiments for which the W detector is not well suited. Examples are the determination of the total cross section, elastic scattering differential cross section, particle spectra and correlations, and diffractive excitation. The size and shape of the experimental hall required for these experiments is quite different than for the large angle detector, and we have designed the X Hall specifically to accommodate them.

Some physics topics for which a dedicated apparatus is better suited than the W detector are listed in Table III. Experiments designed to study these topics have been discussed elsewhere in these proceedings⁷ and in the proceedings of previous Fermilab and ISABELLE studies. What emerges from a consideration of these experiments together with those which can be

performed with the W detector is the possibility of a rich and flexible experimental program.

Much can be learned for example, from the behavior of the total cross section, the particle density in rapidity, and correlations in rapidity. The idea is to search for new phenomena which are manifested by a departure from the logarithmic energy dependence observed at Fermilab fixed-target and ISR energies. These can be studied with relatively small and inexpensive detectors dedicated to one or more of the specific topics listed in Table III. Although the total range of topics thus covered is broad and interesting, there remain areas of physics which cannot be investigated without a second major detector. In particular, a large aperture spectrometer with particle identification and good angular coverage over the complete solid angle is not included in Table III. Without it one might be unable to study fluctuations in rapidity or transverse momentum which correlate with quantum numbers (strangeness, baryon number), or to study high mass diffractive dissociation. The center-of-mass energy at the Fermilab Collider will be almost two orders of magnitude higher than at the ISR, and therefore large changes in the behavior of hadronic physics can be expected. For example, there may be a departure from constant density in rapidity or strong correlations in rapidity density. These would be observable in the experiments of Table III (see for example Jones⁸). As suggested by Jacob⁹, a sophisticated large-solid-angle hadron spectrometer should probably take lower priority at this time, and we do not attempt to accommodate such a device in the X Hall.

b. Small-Angle Kinematics

A major motivation governing the design of the X Hall is to allow the study of particles produced at small angles to the beam direction. It is desirable to understand the kinematics of these small-angle parameters in a systematic way in order to plan experiments and appraise alternatives.

Squeezer magnets, in either the "kissing" or "transposed" geometries, limit clear access to a region of ± 5 m to ± 8 m from the interaction point; perhaps 5 m is the furthest from the intersection that a particle could emerge and still be analyzed by a detector (e.g., a calorimeter). If the minimum distance to the beam orbit is taken to be 5 cm, the smallest laboratory angle explored would then be 10 mr. In the "transposed" geometry without squeezer magnets, a full ± 23 m of clear space is available, permitting the detection of particles which emerge from the beam pipe at ± 20 m. For a 5 cm beam clearance, laboratory angles θ of 2.5 mr are accessible in this scheme.

At least two kinematic parameters are of interest: the laboratory rapidity y (in the laboratory frame of the 250 GeV $\times$ 1000 GeV Collider) and the transverse momentum $p_{\perp}$, for different secondary particle momenta p and Lorentz factors γ . In this regime ($\gamma \gg 1$, $\theta \ll 1$ rad) it is useful to note that

$$y \approx \frac{1}{2} \ln [4 (\theta^2 + \gamma^{-2})^{-1}] .$$

In Figure 4 we have plotted y vs θ for values of γ of 50, 100, 250, 400, and 1000. It is apparent that at $\gamma = 1000$, for example, $y_{\max} = 7.6$, $y(2.5 \text{ mr}) = 6.6$, and $y(10 \text{ mr}) = 5.3$. On the other hand, for $\gamma = 100$,

Fig. 4 Plot of the relation between laboratory angle θ and laboratory rapidity y (for the 250 GeV x 1000 GeV Collider) for various values of secondary particle Lorentz factor γ and transverse momentum $p_{\perp}$ (in GeV/c). The rapidity cutoff corresponding to angular limit θ is obtained by reading up to the curve corresponding to the appropriate γ value. If the curves labeled γ are reinterpreted as secondary momentum (GeV/c), then the $p_{\perp}$ cutoff for a given angular limit and momentum may be obtained from the $p_{\perp}$ curve which intersects the appropriate γ curve at the desired value of θ .

$\gamma_{\text{max}} = 5.3$, $\gamma(2.5 \text{ mr}) \approx 5.3$, and $\gamma(10 \text{ mr}) \approx 5.0$.

Dashed lines are also plotted for $p_{\perp} = 0.1$, 0.4 , and 1.0 GeV/c ; for these the lines labeled γ should be reinterpreted as secondary particle momentum, p (GeV/c). Thus, at 10 mr and $p = 100 \text{ GeV/c}$, only $p_{\perp} \geq 1 \text{ GeV/c}$ may escape the beam pipe, whereas, at 2.5 mr , $p_{\perp} \geq 250 \text{ MeV/c}$ ($t = -0.0625 \text{ GeV}^2$) may be studied, and $p_{\perp} \geq 1 \text{ GeV/c}$ for $p = 400 \text{ GeV/c}$ is also accessible. It is therefore clear that the choice of a kissing geometry for the small-angle hall would severely limit the experiments which could be performed. Our design for the X Hall assumes a transposed geometry which could be operated without squeezer magnets at least part of the time. A quite different type of hall would be needed to accommodate experiments in a kissing geometry intersection.

c. Description of the X Hall

Figure 5 shows our design for the X Hall, which consists of an enlarged straight-section tunnel, 60 m long by 7 m wide by 5 m high, and a wide-angle hall similar to the internal target hall at C0. The center of the wide-angle room has been displaced in the direction of the Energy Doubler beam to accommodate experiments which take advantage of the unequal energies in pp operation.¹⁰ As in the W Hall, a 2-m -wide tunnel-traffic bypass has been provided.

The X-Hall design incorporates many of the access features of the W Hall, including a tunnel-level assembly area separated from the interaction hall by a 5-m -thick movable concrete-block shield wall. The pit area of the assembly hall is smaller, with much of the floor space located

Fig. 5 Plan and elevation views of the X Hall. All distances given on the figure are in meters. The numbered features are (1) the large-angle hall, (2) the pit-level assembly area, (3) the hadron shield wall and the fast access way which penetrates it, (4) the tunnel traffic bypass, (5) the grade-level assembly area, and (6) the road access to the assembly area.

near grade level, since the X-Hall detectors will be considerably more modular and less massive than the W-Hall apparatus. The concrete-block portion of the shield wall between the two areas is not as long as in the W Hall, and the cast-in-place part of the wall contains a 2-m-wide fast access way for small equipment.

The floor level in the large-angle hall is lower than in the tunnel enclosure, as required by many wide-angle experiments (e. g., to increase solid-angle acceptance). Since there is no crane coverage planned for the long tunnel enclosure, its floor level is extended under the crane for the large-angle hall.

The orientation of the grade-level part of the assembly area has been chosen to minimize the span of its 30 ton crane. An alternative position alongside the beam-level part of the assembly area would not require rerouting the existing road, however, and may prove to be more economical. This is only one of many detailed engineering questions which must be addressed before construction can begin.

There is probably some advantage to locating the X Hall at C0, thus making use of the existing internal-target experimental area, but we do not believe that this convenience should be weighted very heavily. The modifications to the C0 hall would be quite extensive, and include lowering the floor of the present hall in addition to enlarging the accelerator tunnel and constructing the assembly area. In the final analysis, the actual cost savings could be small compared to building at a different straight section which machine considerations favor.

We have not attempted to obtain cost and construction-time estimates for the X Hall in as much detail as for the W Hall. The enclosed volumes of the two halls are similar however, suggesting comparable costs and accelerator shutdowns required for construction.

C. Recommendations

1. All experimental halls should be completed well before the turnon of the superconducting ring, so that experiments can be ready to make use of collisions as soon as they are obtained. Detailed engineering studies should begin immediately, to determine the minimum length of the accelerator shutdown required for hall construction.

2. Two experimental halls should be built. If operation of a third collision region seems likely within a few years of turnon, then its hall should also be built during the superconducting ring construction period.

3. The decision as to which straight sections to use for experiments should be based primarily on machine considerations, and not heavily weighted by convenience factors such as the proximity of roads or the existence of the internal target hall at C0.

4. The incorporation of assembly areas, into which detectors can be moved during fixed-target operating periods, is highly recommended. The question of whether these areas can safely be located outside the rings, and the minimum thickness of the movable hadron shield, should be the subject of experimental investigation and detailed calculation in the very near future.

5. Halls should be able to accommodate experiments with both equal

energy (e.g., $\bar{p}p$) and unequal energy (e.g., pp and ep) collisions.

6. At least one hall should be designed to permit the study of small angle processes. This requires an enlarged tunnel cross section over at least the 50 m straight section length, and is not compatible with kissing geometry collision schemes.

7. The technique and cost of supporting the ~ 4000 ton W detector should be the subject of a detailed engineering study in the near future. The possibility of raising the W detector to an assembly area located above the ring enclosure should be evaluated in a detailed design study, to determine if it is competitive with schemes in which the detector is moved only horizontally.

8. The "open area" type of construction is not appropriate for the Fermilab Collider experimental halls.

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