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Technical Design Report for the DØ forward trigger scintillation counters

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1 Introduction

The goal of the DØ Upgrade [1] is to exploit the physics potential to be presented by the Main Injector and Tevatron Collider during Run II. An integrated luminosity of 2 fb^{-1} is expected with instantaneous luminosity of up to $2 \cdot 10^{32} cm^{-2} s^{-1}$ accompanied by a reduction in a bunch spacing. This factor of 10 increase in integrated luminosity over Run I will provide an opportunity for significant improvements sweeping the wide range of physics studied at DØ during Run I.

Capability to identify and trigger on muons is one of the key features necessary to exploit these possibilties. Since studies of the aging of WAMUS chambers (the "EF" PDTs) reveal that these chambers will not survive Run II [2], a new design for the forward muon system has been developed. It is called FAMUS - Forward Angle MUon System.

The physics motivations for going to the highest luminosities are studies of low-cross-section, high-p_T processes, such as top and W/Z, and search for new phenomena. It was shown [3] that $|\eta|$ coverage out to ~ 2 is important for high p_T physics. The Run II DØ muon system features full coverage for $|\eta| \lesssim 2$.

The proposed layout of the forward ($1.0 < |\eta| < 2.0$) muon system is presented in Fig. 1. It consists of the following major parts:

- 3 layers of mini-drift tubes (MDT) for muon track reconstruction;
- 3 layers of scintillation counters for triggering on events with muons;
- Shielding around the beam pipe from calorimeter to the accelerator tunnel to reduce trigger rates, fake tracks reconstruction and aging of detectors [4, 5, 6, 7, 8].

There will be three planes (A,B,C) of scintillation counters on each side of the detector (see Fig. 1), A - closest to interaction region, then B and C is the most distant from the detector center. Counters are arranged in $R - \phi$ geometry to match central fiber detector (CFT) trigger segmentation. The muon trigger will combine track candidates from the CFT with information in the muon system. The effective η range of this trigger is defined by where CFT trigger ends, *i.e.* at $|\eta| \sim 1.7$. Studies of Run II trigger rates [9, 10] show that combined muon/CFT trigger will be unprescaled for high-p_T single muons ($p_T > 6$ GeV/c) and low-p_T dimuons ($p_T > 3$ GeV/c). The muon trigger in $1.7 < |\eta| < 2.0$ region will be provided by scintillation counters and MDTs. MDTs will be used to confirm triggers based on CFT and scintillation counters also.

Advantage of scintillation trigger counters is their ability to count substantially less background hits than other types of detectors [11, 12, 13]. Decrease of the gate width from 100 ns to 20 ns reduces the number of background hits per plane by ten times (keeping 100% efficiency of muon detection). The *mip* energy deposition in 1/2" plastic is 2.5 MeV. Setting detection threshold at 0.5 MeV will reduce counting rate due to neutrons by a factor of 3 [13]. Scintillation counters are substantially less sensitive to backgrounds than gas detectors.

The remainder of this document is organized as follows: Section 2 describes the pixel counter design. The performance of prototype counters is discussed in Section 3. The high voltage system and electronics are reviewed in Section 4. Installation, monitoring and commissioning of counters is described in Section 5. Section 6 presents assembly, commissioning

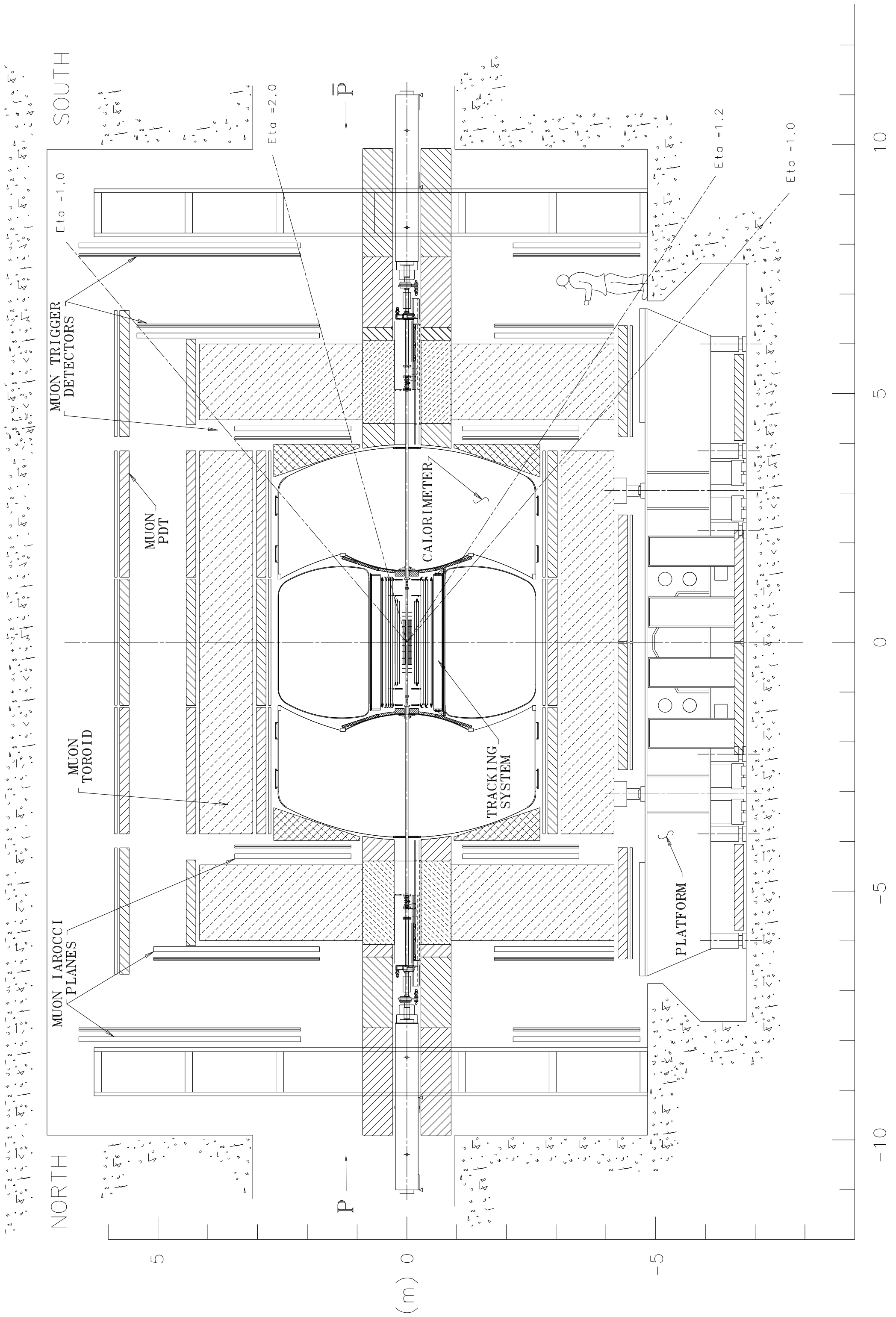


Figure 1: Side view of the DØ upgrade detector including various elements of the muon system upgrade.

and institutional responsibilities plan. Budget requirements and time schedule are listed in Section 7.

2 FAMUS trigger scintillation counters

2.1 System layout

The design of A-plane of scintillation counters is shown in Fig. 2. The ϕ segmentation is 4.5^o and matches CFT trigger sectors. Eta segmentation of the first nine rows of counters is 0.12 and for the last three it is 0.07. The selected segmentation was optimized to keep total number of counters per octant (1/8 plane) at 96, cover FAMUS η region, match with MDT sensitive area and minimize counters sizes at small eta. The maximum counter size in proposed design (C-plane, outer counters) is 95 cm, so the number of photoelectrons and time resolution are reasonable (see Section 3).

Each plane of counters is divided into 8 octants with 96 counters per octant in order to reduce size of mechanical units during production and testing: C-plane size is $12 \times 10\ m^2$. Each octant is assembled and tested separately, then moved to DØ for assembly into planes. Each plane of counters is mounted in the DØ detector with support at the top of the frame and is movable along beam line in order to get access to MDT planes.

B and C planes have geometry similar to A layer but limited in some places by the DØ collision hall sizes: floor and ceiling.

2.2 Counters design

The counter design was optimized to provide good time resolution and uniformity for background rejection, high efficiency of muon detection and reasonable cost for production of almost five thousand counters. The selected design is shown in Fig. 3. It consists of 1/2" Bicron 404A scintillator plate (Bicron, USA) cut to trapezoidal shape with two Kumarin 30 WLS bars (Dzerzhinsk, Russia) for light collection. The bars are 4.2 mm thick and 1/2" wide. They are installed along two sides of the counter and bended at 45^o to collect light on 1" phototube. Parameters of scintillator and WLS are presented in Table 1.

Table 1: Characteristics of scintillating materials.

Material	Decay time, ns	Peak emission, nm	Attenuation length, m
Bicron 404A scintillator	2.0	408	1.7
Kumarin 30 WLS	2.7	460	1.4

Green extended phototube 115M from MELZ (Moscow, Russia) is used for light detection (Table 2). The tube has average quantum efficiency of 15% at 500 nm and gain around 10^6. The phototube base optimized for high gain, high time resolution operation is presented in Fig.4. The mechanical design of the counter with sizes $338 \times 216\ mm^2$ is presented in Fig. 5. The scintillator and WLS bars are wrapped into Tyvek material (for better light collection)

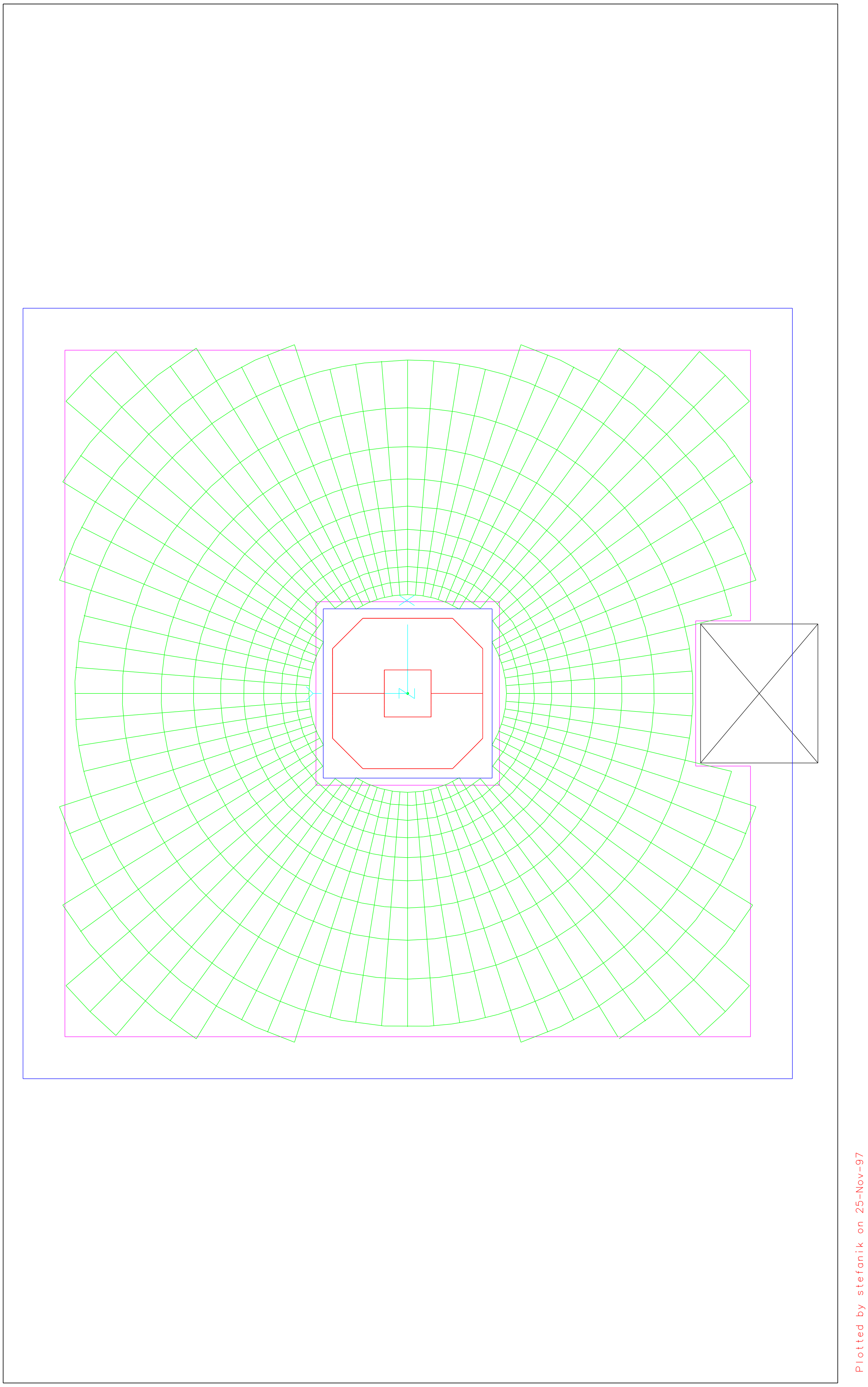


Figure 2: Layout of the scintillation counters plane of A-layer.

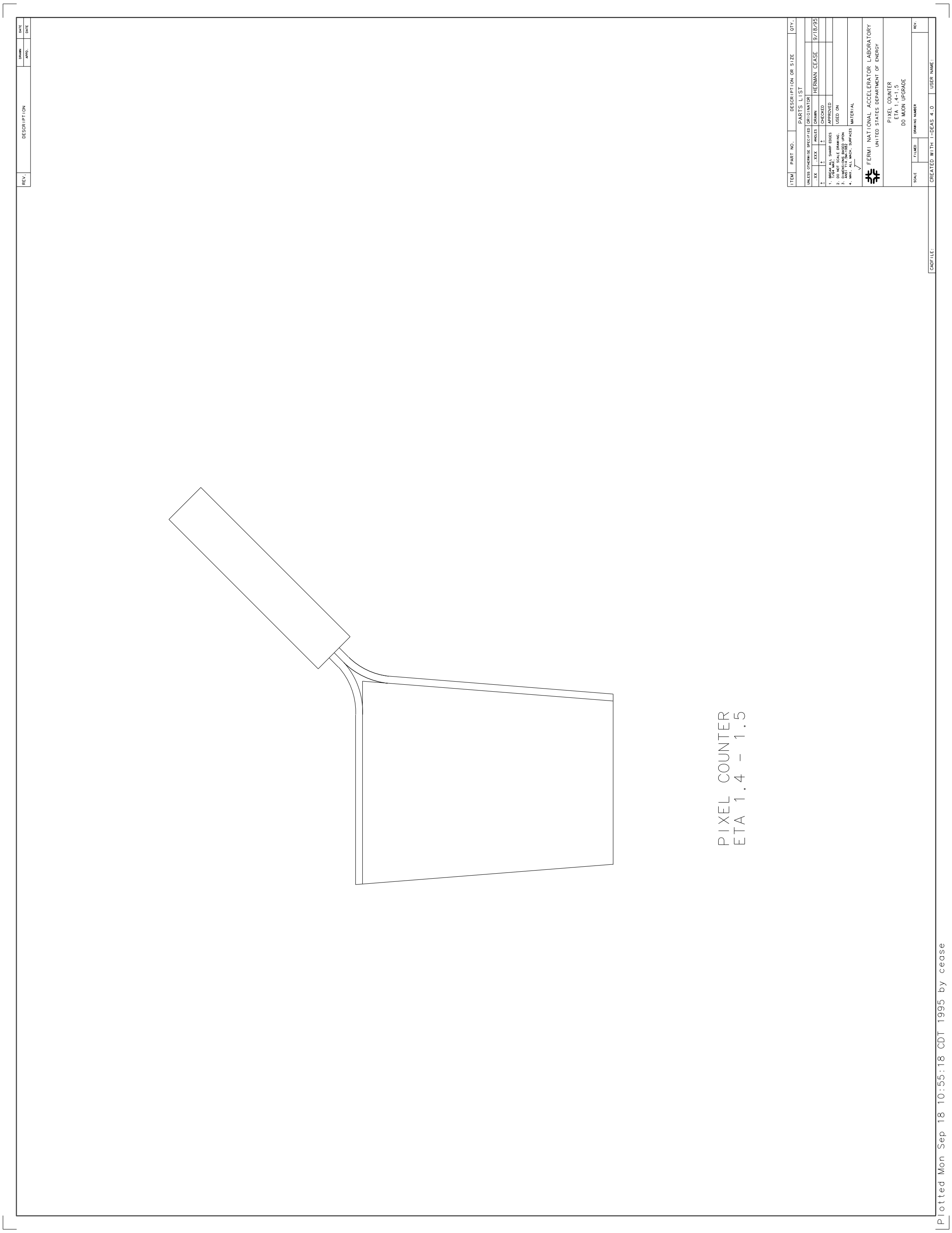
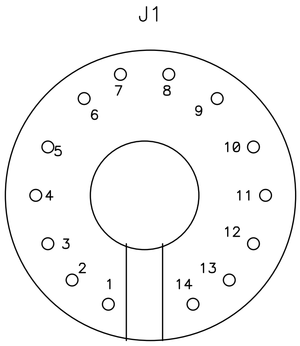


Figure 3: Design of the scintillation counter.



QTY	PART	#
1	PHOTOMULT. BASE	J1
1	BNC, ISOLATED GND	J2
1	SHV	J3
1	47nf, CERAMIC, 630VMAX	C1
1	22nf, CERAMIC, 630VMAX	C2
2	10nf, CERAMIC, 630VMAX	C3,4
1	2.4M, 1/4W, 5%	R1
1	1.8M, 1/4W, 5%	R2
1	1.3M, 1/4W, 5%	R3
10	820K, 1/4W, 5%	R4–13
1	100, 1/4W, 5%	R14
1	100K, 1/4W, 5%	R15
1	20K,1/4W,5%	R16

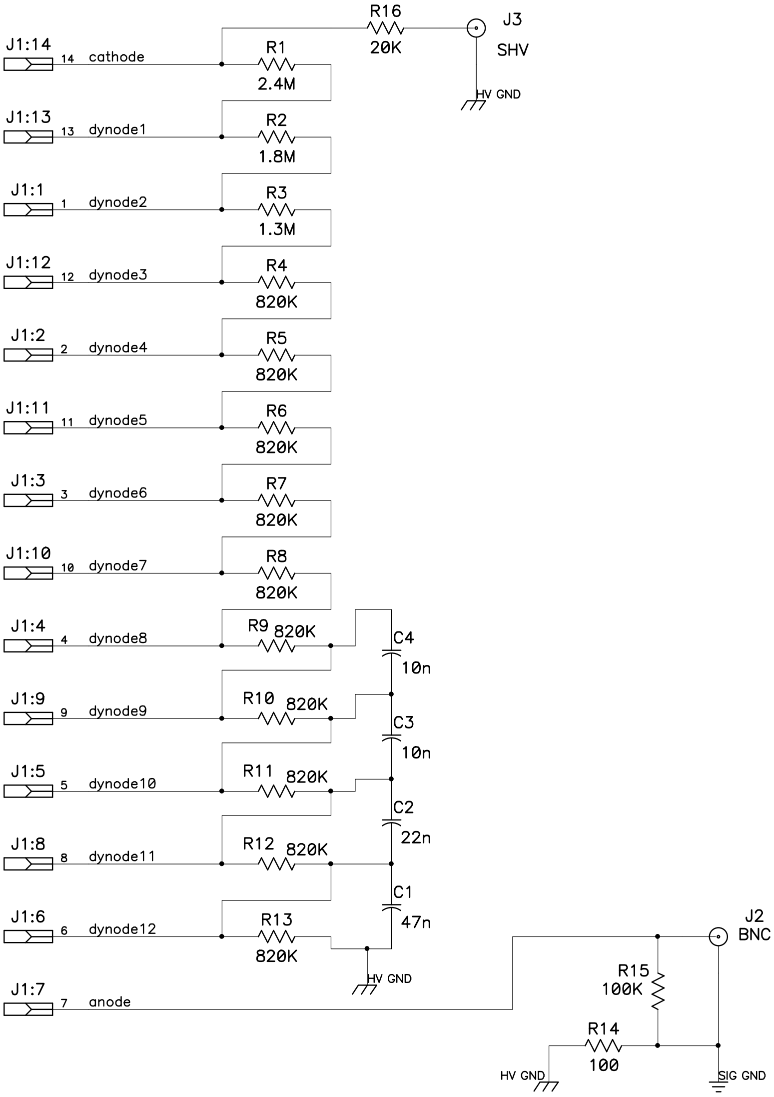


Figure 4: Phototube base.

and black paper (for light tightness). The wrapped counter is than placed into 1 mm thick aluminum container with stainless steel part for connection of phototube assembly.

Table 2: 115M phototube characteristics.

Diameter of photocathode, mm	20
Quantum efficiency at 500 nm, %	$15^{+5}_{-2.5}$
Non-uniformity of response of photocathode, %	< 10
Operating voltage for anode sensitivity of 100 A/Lm, kV	1.8 ± 0.2
Gain at operating voltage with anode sensitivity of 100 A/Lm	$2 \cdot 10^6$
Rise time, ns	3

Phototube is placed into magnetic shield made of soft steel and mu-metal and attached to the counter by threaded connection. Passive base is mounted at the end of the phototube. Each counter has two connectors: SHV to supply high voltage to the tube base and BNC for connection of signal cable.

Large number of prototype counters [14] have been built in order to optimize design, select materials with optimal properties and reduce cost of production. In Table 3, for example, results of studies of polishing plastic sides where WLS bars attached are presented. Unpolished surface directly after milling machine provides better properties and costs less than well polished surface.

Table 3: Polished vs unpolished scintillator side surface studies for 46×32 cm^2 counter.

Counter sides	Number of *phe*	Non-uniformity, %
Polished	92	9
Unpolished	102	5

The use of high light yield, transparent and fast scintillator and WLS materials provide time resolution below 1 ns, uniformity of 10% and 60 photoelectrons from *mip* signal even for largest counters. The above parameters provide high efficiency of muon detection and good rejection of backgrounds.

2.3 Assembly and mounting scheme

All scintillation counters will be produced and tested at IHEP, then shipped to Fermilab for mounting into octants. Each of 48 octants of FAMUS scintillation counters will be assembled and all counters are tested at Lab F. With all counters mounted, high voltage signal cables connected and calibration system installed octants will be delivered to the DØ assembly building for survey, assembly into planes and installation into detector.

In order to get access to A and B layers of MDT detectors ("covered" by trigger counters, see Fig. 1) the trigger counters planes will have movable supports at the top. Access to C

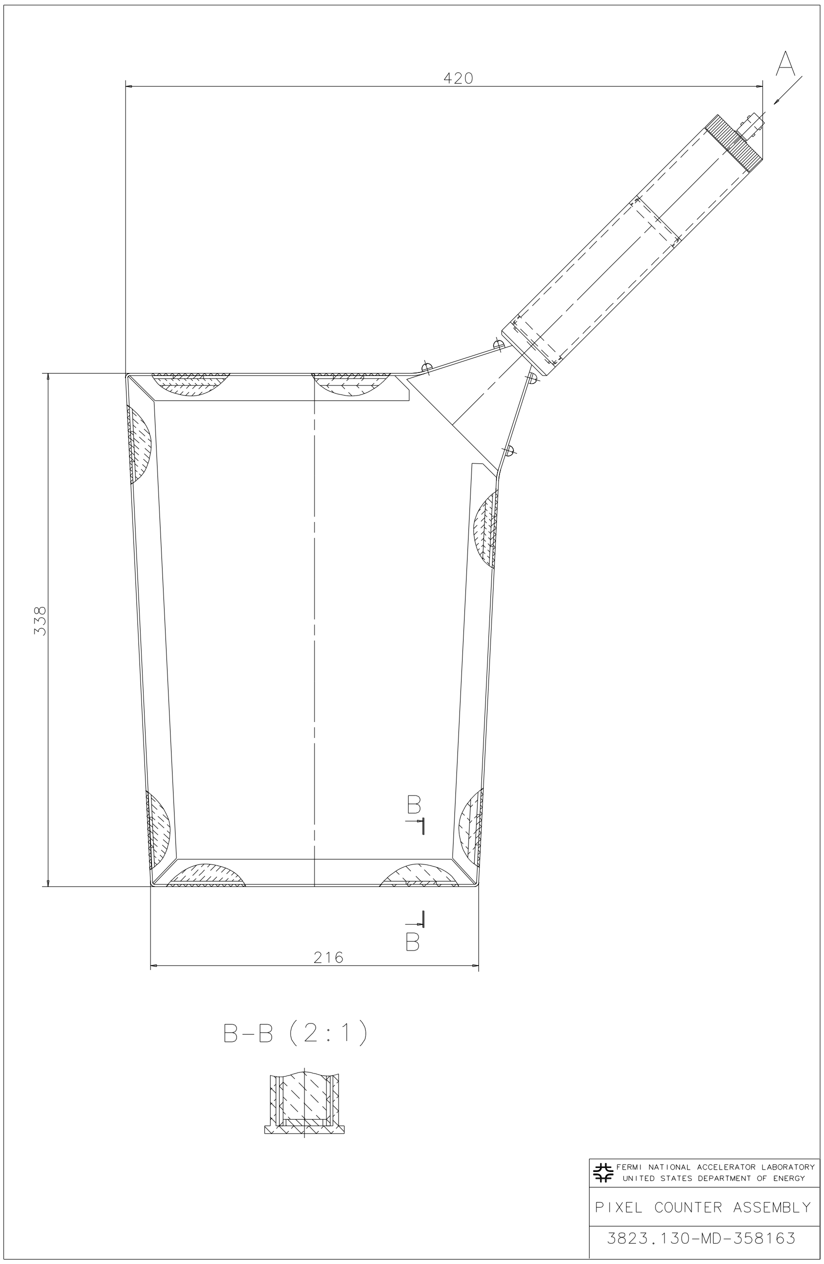


Figure 5: Mechanical design of the scintillation counter.

layer MDTs will be done from truss side, so no movable support for C counters plane is required. We will discuss installation accuracy and access requirements in Section 6.

3 Prototype counters performance

3.1 Efficiency and time resolution

Counters performance has been investigated at Fermilab 125 GeV/c test beam. At Fig. 6 the dependence of counter efficiency and time resolution vs high voltage is presented for counters of 3 different sizes: “large” - 60×106 cm^2, “typical” - 24×34 cm^2 and “small” - 17×24 cm^2. Detection threshold for these measurements has been set at 10 mV. Time resolution achieved is 0.5-1.0 ns. This value is consistent with limitations of time resolution by vertex position, interaction time and different time of flight between interaction point and scintillation counter in the DØ detector. Detection efficiency on plato is 99.9 % and limited by the beam telescope.

The time resolution for particles passing center of “typical” counter for thresholds 5, 10 and 25 mV is shown at Fig. 7. With working point at 1.8 kV and 10 mV threshold we will have high efficiency of muon detection and time resolution below 1 ns.

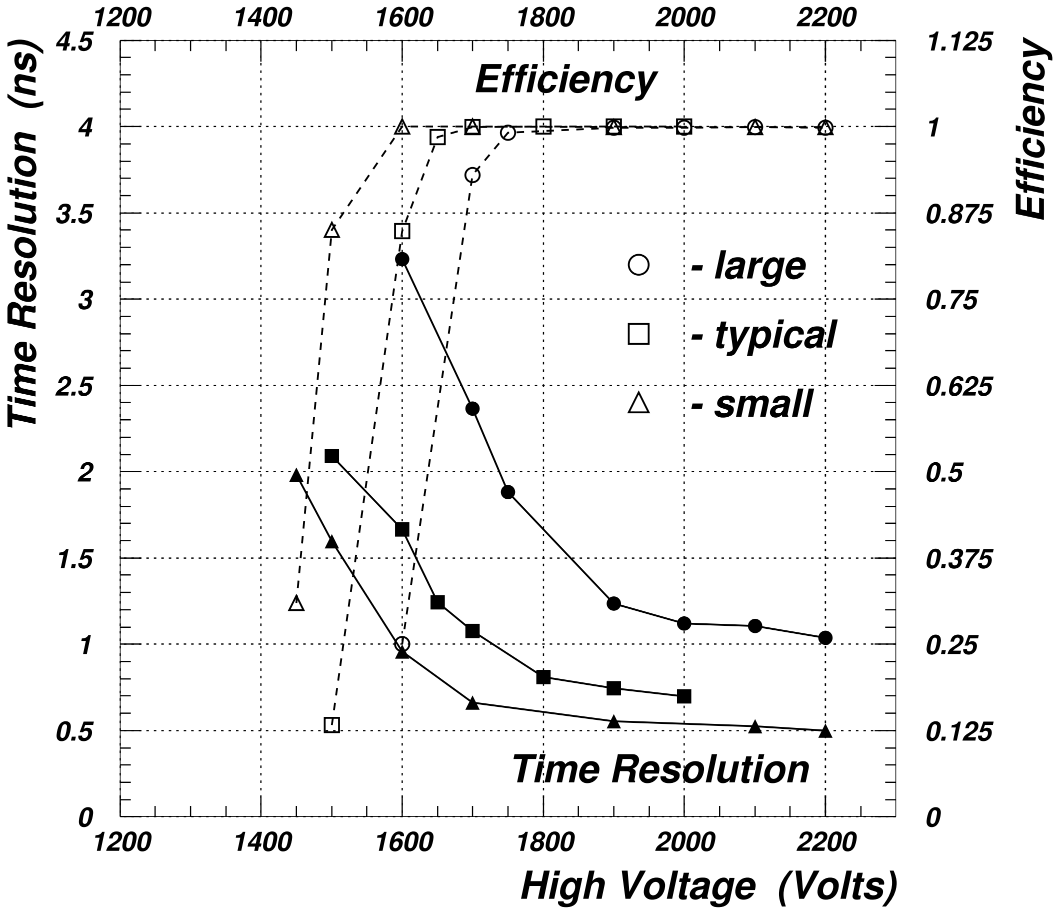


Figure 6: Time resolution and detection efficiency of scintillation counters.

In order to make efficient energy deposition cut number of photoelectrons should be large to reduce statistical fluctuations and non-uniformity should be reasonably low. Non-unformity was measured by irradiating counters in different points by Sr^{90} radioactive source and cross checked by cosmic ray studies. For all counters sizes measured rms non-uniformity is less than 10 %.

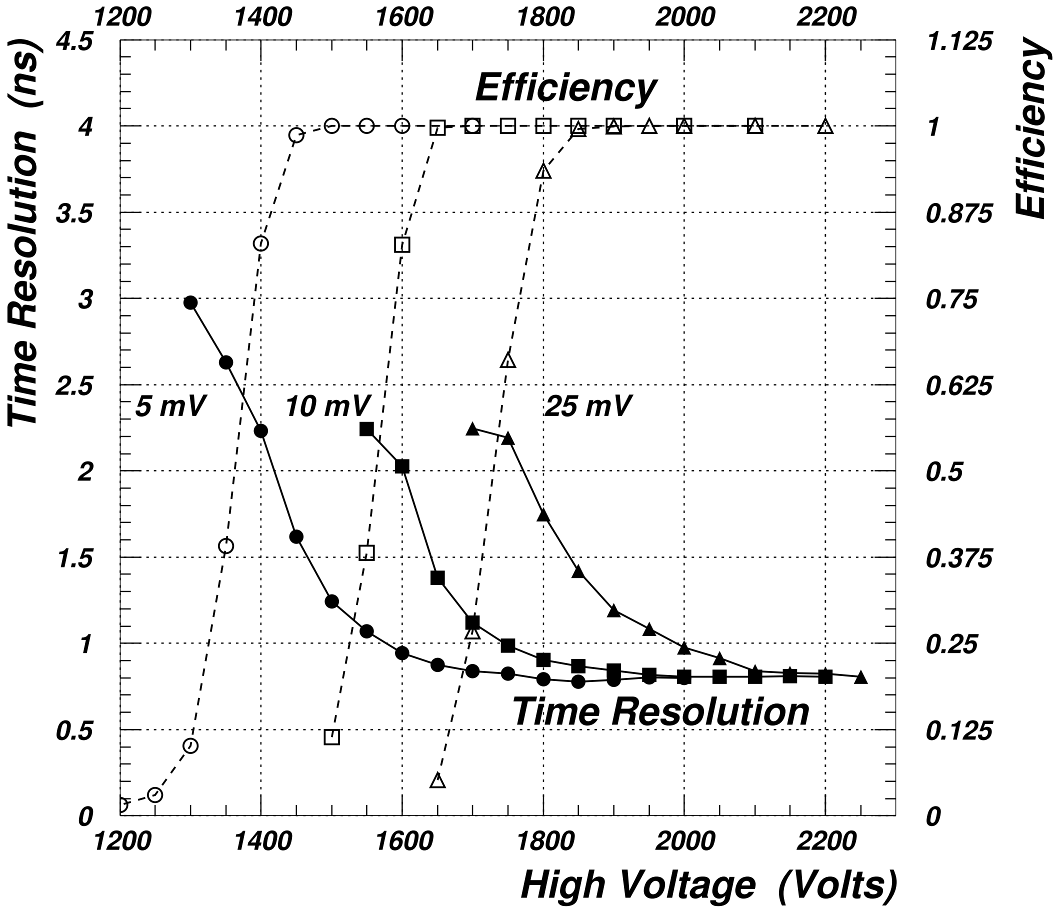


Figure 7: Time resolution and detection efficiency of "typical" counter for different detection thresholds.

In Table 4 average number of photoelectrons detected for cosmic ray muons passing counter perpendicular to its surface is presented. Calibration of ADC scale in number of photoelectrons has been done by LED producing single photoelectron pulses. The number of photoelectrons is large and amplitude distributions is mainly determined by Landau fluctuations. On Fig. 8 typical amplitude distribution for $106 \times 60\ cm^2$ counter irradiated at Fermilab test beam is presented.

We have demonstrated that proposed counter design satisfies all major requirements for the DØ upgrade. Now we turn to specific studies performed to ensure reliable long term operation of the detector.

Table 4: Average number of photoelectrons.

Counter size, cm^2	14×14	46×32	106×60
Average number of photoelectrons	184	115	61

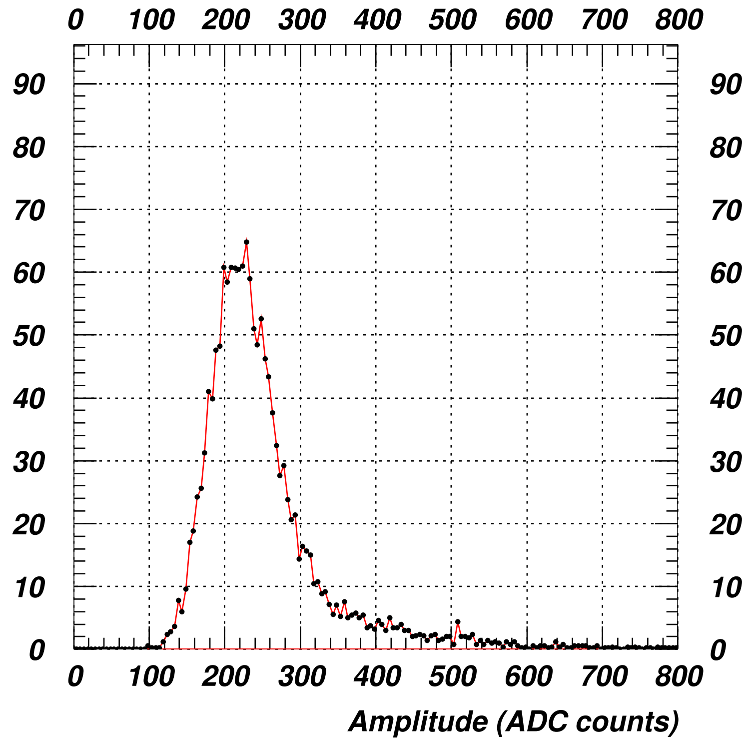


Figure 8: Amplitude spectrum for 106×60 cm^2 counter

3.2 Scintillator and WLS radiation aging

An important characteristic for detectors operating under heavy radiation is stability of their parameters during long run. An estimation of the total radiation dose during Run II (2 fb^{-1}) for the hottest region gives $\sim$ 1 krad for scintillation counters. Aging of scintillation counters under radiation depends mainly upon radiation hardness of scintillation materials. We performed detailed studies of scintillator and WLS under irradiation [15] to ensure reliable operation of counters over long term. The studies have been done using set of Cs^{137} radioactive sources producing close to uniform irradiation in the sample volume. On Fig. 9 Bicron 404A light output as a function of accumulated dose is shown. Clearly we are well below doses which cause scintillator damage.

On Fig. 10 the light output for pair of non-irradiated Bicron 404A scintillator and irradiated Kumarin 30 WLS bar is presented. While WLS demonstrate considerably faster radiation aging than scintillator, for Run II doses (< 1 krad) radiation damage is manageable.

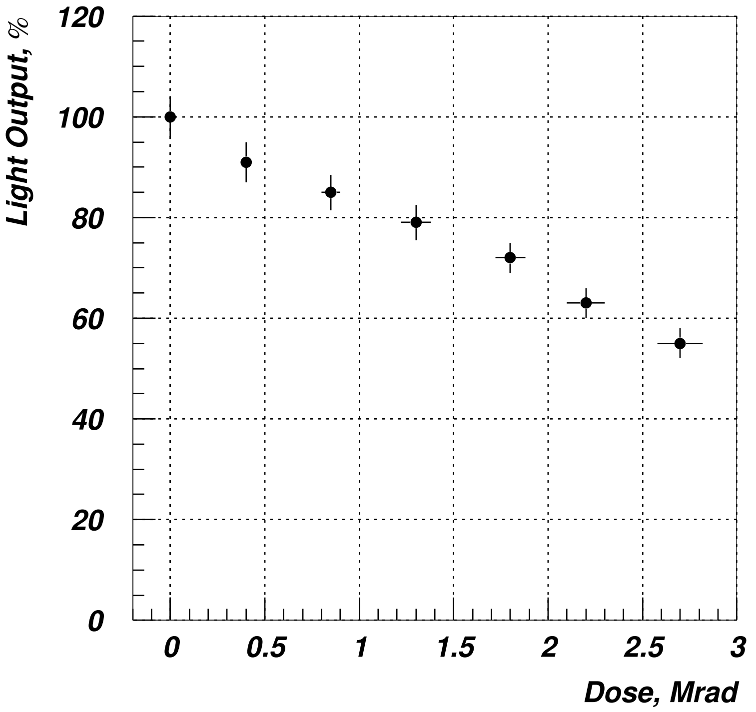


Figure 9: Bicron 404A scintillator light output vs accumulated dose.

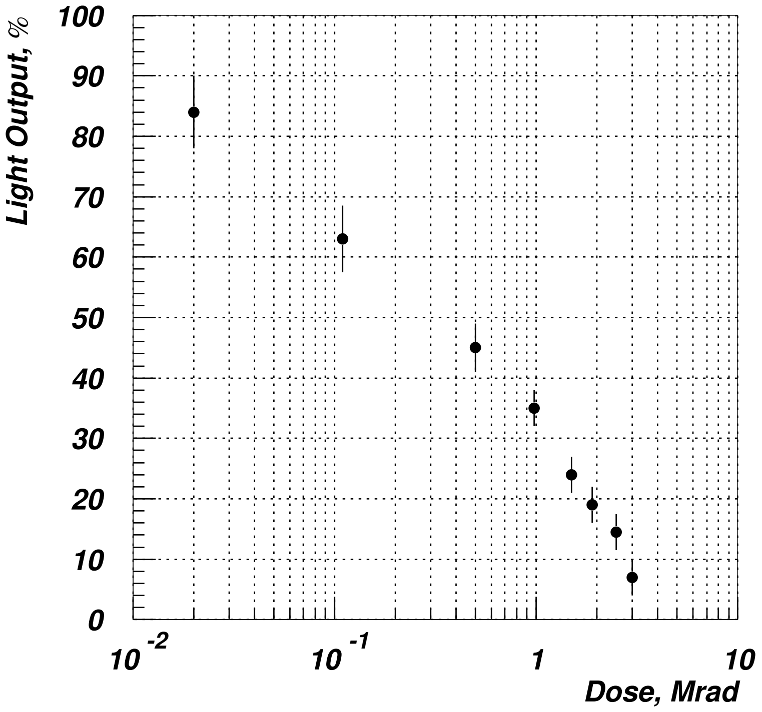


Figure 10: Light output for pair: non-irradiated Bicron 404A scintillator and irradiated Kumarin 30 WLS.

In order to study aging at closer to real conditions time scale and irradiation flux prototype counter with sizes 33×22 cm^2 was placed for 9 months in the DØ collision hall during fixed target run operation. The total accumulated neutron dose was 49 krad and gamma dose was 30 krad. The decrease of the signal before/after irradiation is small ($11 \pm 3\%$) and can be attributed to aging of scintillating material and/or changes in phototube gain. So, we expect to observe no significant radiation aging not only for 2 fb^{-1} of Run II, but for 20 fb^{-1} of TeV33.

3.3 Phototube magnetic shielding

The fringe magnetic field of the DØ superconducting solenoid and toroidal magnet reaches 350 G in the area where phototubes are situated [16]. In order to reduce magnetic field in the phototube area down to ~ 1 G necessary for normal operation special shielding made of 1.2 mm thick mu-metal and 3 or 6 mm thick soft steel tube has been designed (see Fig. 11). The soft steel flange mounted on counter case (see Fig. 5) serves as a part of the shield also. For the field perpendicular to the tube axis no reduction in output pulse has been observed up to 700 G. For the field parallel to the tube axis the reduction in pulse amplitude vs magnetic field is presented in Fig. 12. The effect of magnetic field on phototube signal is less than 10% up to 350 G for 48 mm external diameter shield. We will use 48 mm diameter shield for A-layer counters and 42 mm diameter shields for B and C layer counters where fringe field is below 200 G and effect of magnetic field on tube gain is less than 10%.

3.4 Phototubes aging

Phototubes gain decreases with time due to the interaction of accelerated electrons with surface of dinodes and anode. This aging is commonly represented in terms of accumulated anode charge [17]. Our estimations shows that the largest anode charge will be accumulated for the outer counters in A-layer. For integrated luminosity of 2 fb^{-1} the anode charge will be ~ 20 C. In Fig. 13 typical 115M phototube aging curve is presented. The drop of phototube gain is less then 5% for accumulated charge of 20 C. We will monitor phototubes gains using LED pulser and real muons (see Section 5), so any drop in gain could be compensated by adjusting threshold or operating voltage.

4 High voltage system, cabling and electronics

4.1 High voltage system

We plan to use parts from the existing DØ High Voltage (HV) system based on VME type modules [18]. For our base design we will use negative HV power supplies. In order to reduce the number of HV supplies we plan to connect 16 tubes with similar operating voltage to the same supply. Due to the large number of phototubes and relatively narrow operating voltage distribution it is not a problem to select large number of tubes with similar voltage. Typical current per base is 145 μA at 2.0 kV and we plan to use 3.5 kV 3.0 mA max output current supplies.

The total number of HV supplies and VME crates needed is presented in Table 5.

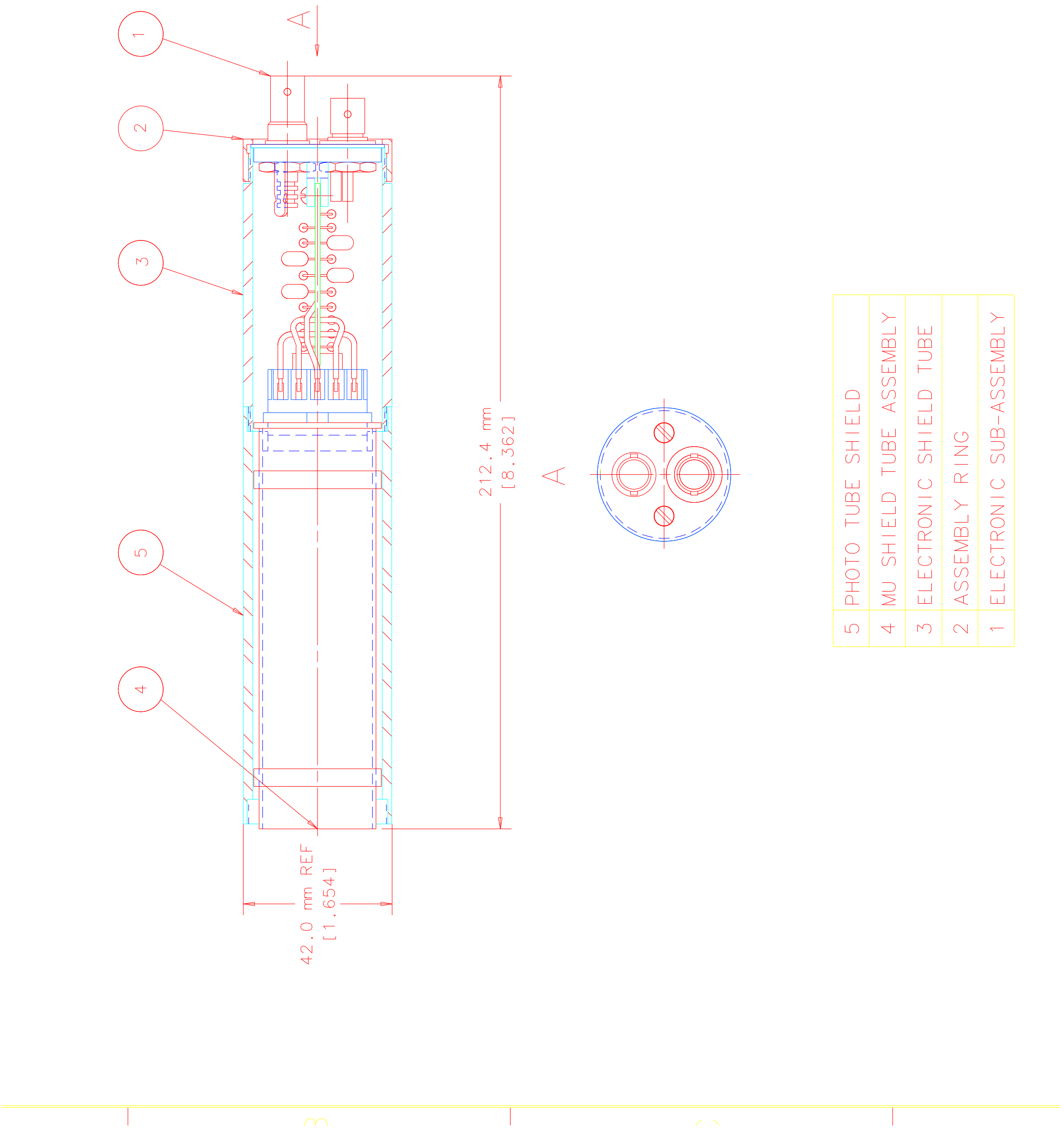


Figure 11: Assembly of base and 42 mm external diameter magnetic shield. For 48 mm diameter shield 120 mm long steel tube with 3 mm thick wall is mounted on top of the 42 mm shield.

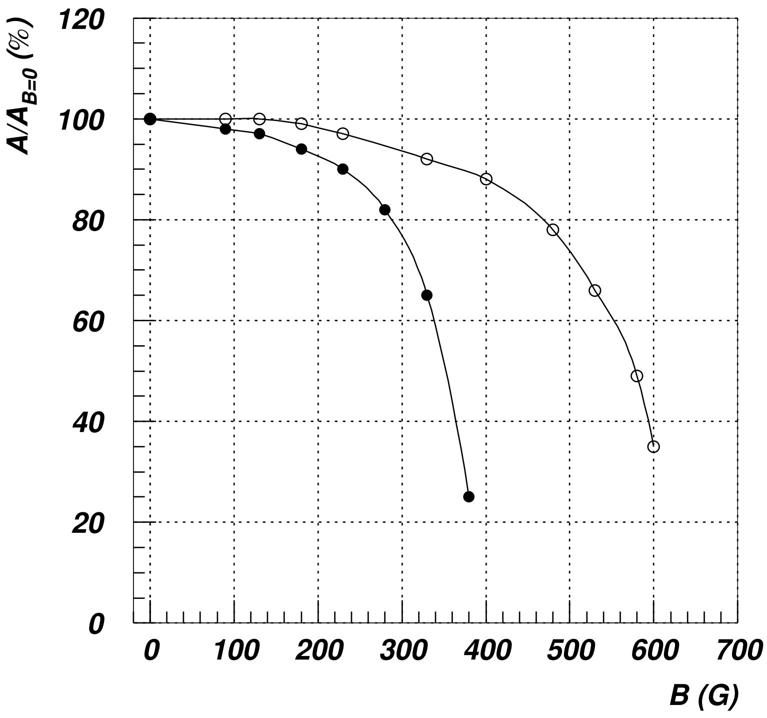


Figure 12: Relative gain change of 115M photomultiplier in magnetic field, parallel to the tube axis: solid circles - 3 mm soft steel (42 mm external diameter shield), empty circles - 6 mm soft steel (48 mm external diameter).

4.2 Cabling

Using red RG58 cables with SHV connectors outputs of HV power supplies will be connected to the fanouts situated nearby to VME crates. 8 wire cables will be used in order to supply HV to collision hall where $1 \to 16$ fanouts will be situated (See Fig. 14). From the fanouts situated in the collision hall close to counters planes RG58 cables with SHV connectors will deliver HV to each individual base. We plan to reuse from DØ Run I central tracking detector cables, VME crates and some fanouts.

Signal from each phototube via green RG58 cable around 10 m long will be sent to scintillator front end electronics, located in the collision hall [19]. Attenuation of signal in such cables is small and does not affect major counter characteristics (all Fermilab test beam studies have been performed with 12 m signal cables).

We plan to make, label, and test all signal and HV cables before their connections to counters. After octants are assembled two bundles of cables (HV and signal) will be used to connect counters to HV system and front-end electronics.

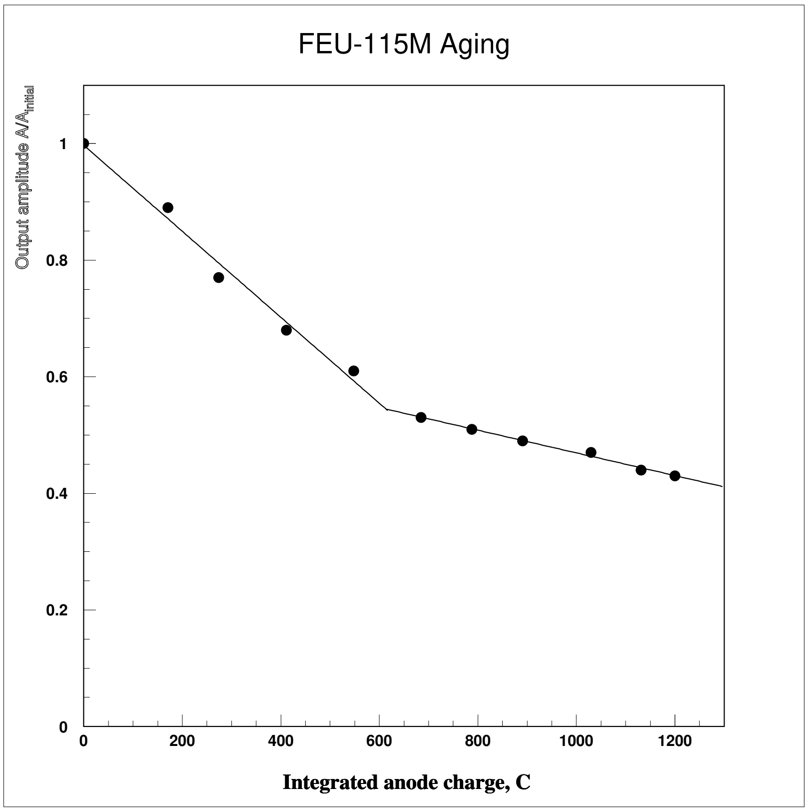


Figure 13: Phototube gain as a function of integrated anode charge.

Table 5: Trigger counters HV system.

Total number of counters	Number of HV supplies	Number of VME crates
4608	288	6

4.3 Electronics

Signals from phototubes via RG58 50 Ohm coaxial cables are delivered to inputs of 48 channels VME based Scintillator Front End (SFE) card [19]. Input connectors at SFE card are double LEMO. Input 1:1 transformers isolate SFE from DC type noises between phototubes and electronics modules situated around 10 m apart. The signals from counters after amplification are sent to 10-bit ADC (one ADC for 16 channels, multiplexed) and to discriminator with variable threshold (5-250 mV individual for each channel). Discriminated and gated signals are sent to Level 1 trigger system ("fired" counters) and to SFE TDC with 1.0 ns bin. After digitization amplitude and time information is sent to Level 2 trigger system and DØ DAQ.

Detailed description of scintillation counters front-end electronics including specifications and prototype studies is presented in [19]. Electronics is designed not to limit overall detector

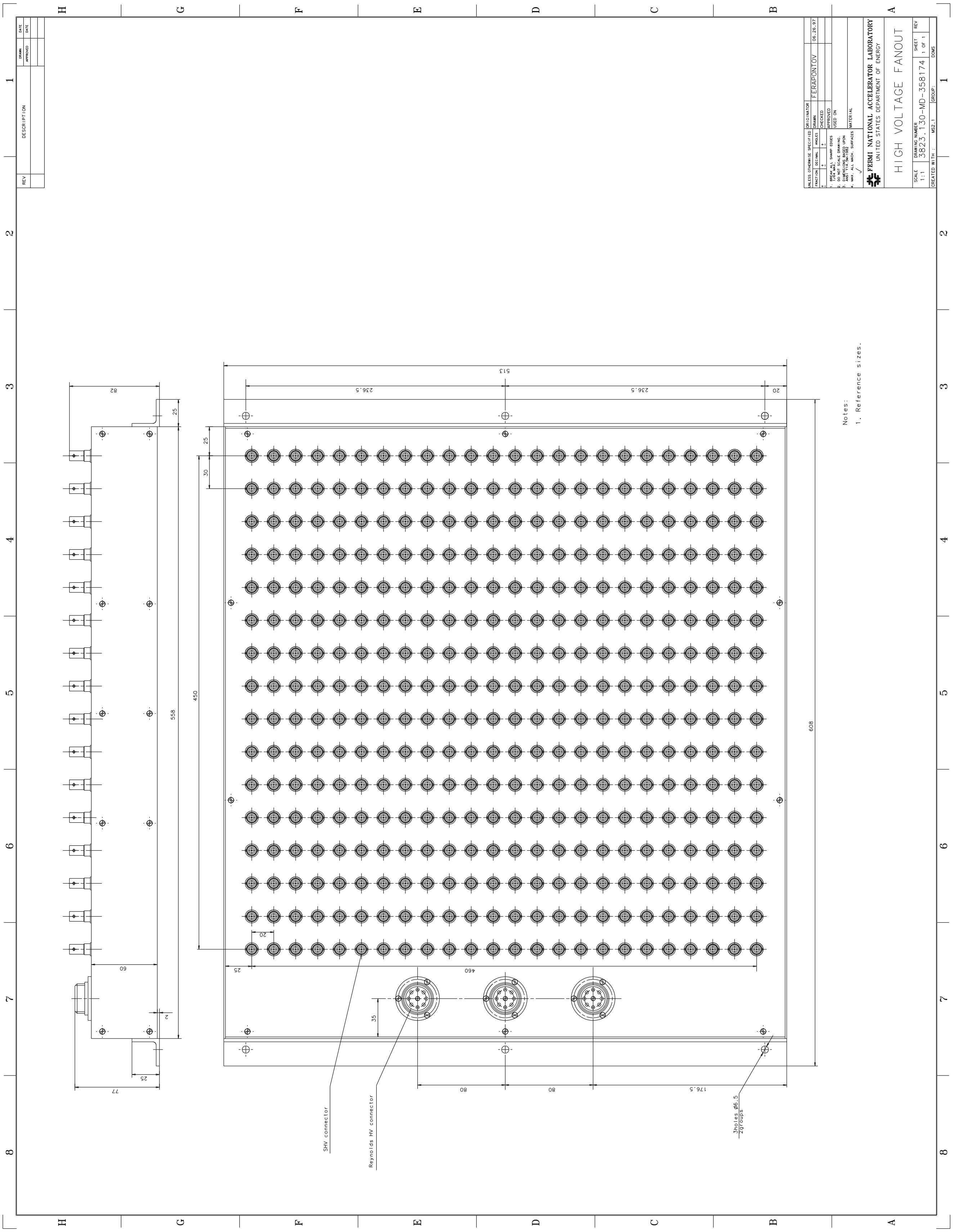


Figure 14: HV fanout.

performance and provide reliable tools for monitoring of counters operation.

5 Installation, monitoring and commissioning

5.1 Calibration and monitoring

The performance of FAMUS trigger counters will be monitored on a regular basis. Voltages and currents of the high voltage supplies will be checked in order to determine if any HV channel might have drifted. Calibration of various components of the electronics is accomplished by a precision pulser which injects charge at the front end of each amplifier. The pulse distribution system has been carefully designed to deliver equal pulses at each input.

For monitoring of phototubes gain and timing special LED based calibration system is being developed [20]. This system will illuminate each phototube with light pulse in amplitude and shape close to signal from muon. The light will be generated by LED and distributed to each counter by clear 1 mm diameter fiber. We will have single LED pulser module monitored by PIN diode per octant with light splitter to 96 individual counters. Optical connector will be mounted on each counter for connection of clear fiber. Counters timing and gain will be monitored by front-end electronics ADCs and TDCs.

Finally we will use muons produced in $p\bar{p}$ collisions to monitor/check counters operation including detection efficiency, phototube gain and time resolution. As it was shown in [3] luminosity of $2 \cdot 10^{32}$ $cm^{-2}s^{-1}$ provides unique possibility to collect large number of muons for calibration/monitoring purposes.

5.2 Alignment and survey requirements

Installation of scintillation counters into octants will be done with accuracy of 2 mm. This accuracy is 1% or less of the counters size. Special tooling balls will be mounted on each octant and location of counters grid will be measured with respect to these balls with accuracy less then 1 mm by optical survey.

After transportation of the assembled octants to the DØ building they will be assembled into planes and mounted into detector. The required mounting accuracy of the planes is 5 mm. After mounting each octant will be surveyed with accuracy of 1 mm and these data will be used for final trigger tables and off-line analysis.

After each magnet opening or/and pixel counters plane movement (to get access to MDT planes) tooling balls will be surveyed by optical methods with 1 mm accuracy. Our plan is to have plane movement system accurate to 1-2 mm, in this case opening/closing survey data will be used for cross checks only, but trigger tables and data for off-line analysis will stay the same over run duration.

5.3 Access issues

We anticipate the need to access all of the FAMUS scintillation counters and their components. Phototubes and bases are the parts we suspect will require occasional replacement, while counter cases and cables are highly reliable. The access to B and C layer counters will be provided by temporary trusses installed between B and C layers. Access to A-layer requires opening of muon toroid and installation of temporary trusses.

All other equipment for trigger scintillation counters in the collision hall including HV fanouts and VME crates with front-end electronics will be situated in permanent muon trusses and easily accessible.

5.4 On-line monitoring

We plan to develop a set of on-line programs for monitoring of scintillation counters operation during commissioning and data collection. Our plan is based on experience obtained during Run I in monitoring DØ muon system. The on-line software will consist of the following major parts:

- front-end electronics calibration and monitoring;
- LED calibration system operation and data analysis;
- data analysis during cosmic ray commissioning and collider operation;
- data bases for storage of counters parameters and calibration results.

In addition to the analysis of distributions obtained from scintillation counters, we will have special system, called CDAQ [18] to control and monitor slow changing parameters such as HV power supplies currents, voltages or maximum currents.

6 Assembly and commissioning

Scintillation counters, bases and shields will be manufactured at IHEP (Protvino), tested and shipped to Fermilab. The tests will include:

- check of mechanical dimensions;
- light leaks;
- response of counter to radioactive source in different points over counter surface.

The phototubes have been received at Fermilab already, tested and data entered into database. At Fermilab phototubes will be installed into counters and final assembly will be tested using radioactive source.

Octant frames will be manufactured at Fermilab and counters will be installed into frames at Lab F. After octant is assembled all 96 counters will be connected to the front-end electronics and tested with final cables in place using radioactive sources and cosmic rays. At this step operational voltage for groups of 16 tubes connected to a single HV power supply will be selected. After major tests octant survey (see Section 5) will be performed.

After octants are assembled and tested at Lab F they will be moved to the DØ assembly building for assembly into planes. Assembled planes will be installed into detector, connected to HV system and front-end electronics and surveyed.

When installation is finished counters will be tested using cosmic muons and final adjustment of operating HV and electronics thresholds will be performed.

Groups of physicists from collaborating institutes will supervise all steps of octants assembly and tests. Responsibilities of each group are specified in the Memoranda of Understanding between Collaborators and Fermilab.

IHEP group is responsible for counters design, production, participation in octants assembly and tests, on-line and off-line software developments. Prague group will design and manufacture fanouts and will be responsible for the HV system supervision. Northwestern University group is responsible for the calibration system. Fermilab group is responsible for the design of octants, their assembly, installation and survey. Nothern Illinois University group will take part in counters assembly, tests and software development. Fermilab performs overall supervision of the project.

7 Cost estimate and time schedule

Cost estimate for the trigger scintillation counters is presented in Table 6. It is based on quotes from manufacturers and experience with production of prototypes. Still, as in any new research project, there is level of uncertainty of funding needed, which we plan to cover by contingency.

Table 7 represents our time schedule for the project. The time schedule will be updated when we will get more experience with production, assembly and testing of the trigger scintillation counters.

Table 6: Cost estimate for the Forward Trigger Detector

ITEM	**MATERIALS (M&S)**						
	Unit	**#**	**Unit Cost**	**M&S TOTAL**	**CONTINGENCY** %		**TOTAL Cost**
Engineering design				0	25	0	0
Scintillator	m^2	525	750	393,750	10	39,375	433,125
Wave-shifter Bars	ea	9677	7.50	72,576	20	14,515	87,091
Phototube System				556,416	13	74,995	631,411
Phototubes (1",MELZ)	ea	4838	50	241,920	10	24,192	266,112
Phototube Bases				120,960	10	12,096	133,056
Socket	ea	4838	5.50	26,611	10	2,661	29,272
High Voltage Connector	ea	4838	3	14,515	10	1,452	15,967
Signal BNC Connector	ea	4838	3.50	16,934	10	1,693	18,628

Continuation of Table 6

ITEM	MATERIALS (M&S)						
	Unit	**#**	**Unit Cost**	**M&S TOTAL**	**CONTINGENCY** %		**TOTAL Cost**
Resistors	ea	4838	13	62,899	10	6,290	69,189
Magnetic Shields				193,536	20	38,707	232,243
Soft Steel Shield	ea	4838	25	120,960	20	24,192	145,152
Mu-metal Shield	ea	4838	10	48,384	20	9,677	58,061
Assembly Parts	ea	9677	2.50	24,192	20	4,838	29,030
Counter Packing				145,960	20	29,192	175,152
Light Tight Coun. Pack.	ea	4838	25	120,960	20	24,192	145,152
Wrapping Materials	lot	1	15,000	15,000	20	3,000	18,000
Support Frames	lot	1	10,000	10,000	20	2,000	12,000
Mechanical Supports				192,000	20	38,400	230,400
Major Support Struc.	ea	48	1,100	52,800	20	10,560	63,360
Octants for Coun. Instal.	ea	48	2,900	139,200	20	27,840	167,040
Signal Cables				54,867	10	5,487	60,354
Coax RG58 Cables	ea	4838	4.75	22,982	10	2,298	25,281
BNC Connectors	ea	4838	2.63	12,725	10	1,272	13,997
Lemo Connectors	ea	4838	3.96	19,160	10	1,916	21,076
High Voltage System				118,528	20	23,706	142,234
Coax RG58 Cable	ea	4838	4.75	22,982	20	4,596	27,579
SHV Connectors	ea	9677	4.19	40,546	20	8,109	48,655
HV Fanout Box	ea	48	1,000	48,000	20	9,600	57,600
Other Parts	lot	1	7,000	7,000	20	1,400	8,400
Monitoring System				145,142	20	29,028	174,171
Light Pulsers	ea	48	1.915	91,920	20	18,384	110,304
Clear Fiber Light Guides	ea	4838	7.50	36,288	20	7,258	43,546
Optical Connectors	ea	4838	3.50	16,934	20	3,387	20,321
Testing & Shipping				30,000	23	7,000	37,000
Test Fixtures	lot	1	10,000	10,000	20	2,000	12,000
Shipping	lot	1	20,000	20,000	25	5,000	25,000
TOTAL				1,709,240	15	261,698	1,970,938

Table 7: Time Schedule for the Forward Trigger Detector

Task Name	Duration	Start	Finish
FORWARD TRIGGER DETECTOR	175.16w	8/1/96	2/24/00
FORWARD MUON UPGRADE TDR	0w	3/14/97	12/1/97
Develop Layout of the System	34w	8/1/96	4/10/97
FABRICATE COUNTERS	154.4w	8/1/96	9/15/99
Design Counters	17w	11/1/96	3/13/97
Design Calibration System	56w	11/1/96	12/18/97
Procure Scintillator	52w	9/16/96	10/1/97
Procure PMTs	32w	9/3/96	4/28/97
Procure WLS	18w	9/30/97	2/17/98
Procure PMT Base Parts FY96	18w	9/3/96	1/20/97
Procure PMT Base Parts FY97	24w	4/11/97	9/30/97
Procure Magnetic Shield Parts FY96	18w	9/3/96	1/20/97
Procure Magnetic Shield Parts FY97	24w	4/11/97	9/30/97
Procure Counter Case Materials FY97	24w	4/11/97	9/30/97
Procure Counter Case Materials FY98	24w	10/1/97	4/1/98
Machine Scintillator	52w	1/19/98	2/5/99
Machine Magnetic Shielding Parts	52w	1/19/98	2/5/99
Fabricate and Test PMT Bases	52w	4/15/97	5/1/98
Fabricate Counter Cases	59w	1/19/98	3/26/99
Assemble Counters	59w	2/16/98	4/23/99
BEGIN COUNTER ASSEMBLY	0w	2/16/98	2/16/98
ASSEMBLY OF 10% OF COUNTERS	0w	5/7/98	5/7/98
Test Counters	59w	3/16/98	5/21/99
Ship Counters to FNAL	59w	5/11/98	7/20/99
ALL MODULES AT FNAL	0w	7/20/99	7/20/99
Test Counters at FNAL	59w	7/8/98	9/15/99
FABRICATE COUNTER PLANES	171w	8/1/96	1/26/00
Procure HV Cables	26w	8/1/96	2/13/97
Procure RG58 Signal Cables	26w	8/1/96	2/13/97
Preliminary Octant and Octant Frame Design	30w	7/8/97	2/18/98
Preliminary Octant Frame Support Design	8w	2/19/98	4/15/98
SAFETY REVIEW	4w	4/16/98	5/13/98
Engineering Drawings for Prototype Octant	16w	2/19/98	6/11/98
Procure Materials for Prototype Octant	4w	5/14/98	6/11/98
Fabricate Prototype Octant	4w	6/12/98	7/10/98
Assemble and Evaluate Prototype Octant	10w	7/22/98	9/30/98

Continuation of Table 7

Task Name	Duration	Start	Finish
PROTOTYPE OCTANT ASSEMBLED	0w	9/30/98	9/30/98
Final Octant Assembly Design	36w	6/12/98	3/10/99
Procure Materials for Final Octants	8w	10/6/98	12/2/98
Fabricate Octant Frames	52w	12/3/98	1/5/00
Assemble Octants	52w	12/17/98	1/19/00
Connect HV Cables to Counters	52w	1/7/99	1/26/00
Connect RG58 Signal Cables	52w	1/7/99	1/26/00
ALL OCTANTS ASSEMBLED	0w	1/26/00	1/26/00
Test Assembled Counters	52w	1/7/99	1/26/00
Procure HV Distribution Boards	38w	10/1/97	7/10/98
Fabrication of Calibration System FY97	7w	9/10/97	10/28/97
Fabrication of Calibration System FY98	30w	3/5/98	10/5/98
Fabrication of Calibration System FY99	12w	10/6/98	1/13/99
INSTALLATION AND HOOKUPS	59w	12/3/98	2/24/00
Mount A-layer Octants Onto Supports	4w	5/6/99	6/4/99
Connection to Front-end Electronics	3w	5/20/99	6/11/99
Connection to HV System	3w	5/20/99	6/11/99
Survey of Pixel Planes	3w	5/20/99	6/11/99
A-LAYER PLANES READY	0w	6/11/99	6/11/99
Mount B-layer North Octants Onto Supports	2w	7/12/99	7/23/99
Connection to Front-end Electronics	1w	7/26/99	7/30/99
Connection to HV System	1w	7/26/99	7/30/99
Survey of Pixel Planes	1w	7/26/99	7/30/99
B-LAYER NORTH PLANE READY	0w	7/30/99	7/30/99
Mount C-layer Octants Onto Supports	4w	11/9/99	12/1/99
Connection to Front-end Electronics	3w	11/23/99	12/16/99
Connection to HV System	3w	11/23/99	12/16/99
Survey of Pixel Planes	3w	11/23/99	12/16/99
C-LAYER PLANES READY	0w	12/16/99	12/16/99
Mount B-layer South Octants Onto Supports	2w	1/27/00	2/9/00
Connection to Front-end Electronics	1w	2/10/00	2/16/00
Connection to HV System	1w	2/10/00	2/16/00
Survey of Pixel Planes	1w	2/10/00	2/16/00
B-LAYER SOUTH PLANE READY	0w	2/16/00	2/16/00
Cosmic Ray Commissioning	34w	6/11/99	2/24/00
COMMISSIONING COMPLETE	0w	2/24/00	2/24/00
SOFTWARE DEVELOPMENT	78w	5/11/98	12/3/99
On-line Software Development	78w	5/11/98	12/3/99
Creation of Databases	78w	5/11/98	12/3/99
Slow Control and Monitor Software	78w	5/11/98	12/3/99

8 Conclusions

We have well developed plan for construction, testing and commissioning of the DØ forward muon trigger detectors based on scintillation counters. Prototypes of final design have been extensively tested and satisfy all our requirements. Cost estimate is solid and based on quotes from manufacturers and experience with prototype production. Groups of physicists responsible for the project have been identified among DØ institutions. We see no major obstacles to finish the project on time for Run II.

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