Shielding the DØ Upgrade Muon Detector

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Abstract

Shielding material will reduce the background flux in the D0 Upgrade muon detector. A factor of 100× reduction in the energy deposition can be achieved in the EF B and C-layers. A factor of 5× to 20× reduction can be achieved in the CF and EF A-layer. The present status, plans and issues regarding shielding the DØ muon upgrade detector are described.

Introduction

The upgrade of the DØ muon system will include the addition of shielding material. This shielding will block non-muon background particles which originate from the three largest hotspots[1]. The main source is scattered proton and antiproton fragments which interact with both the exit of calorimeter, producing a background in the central and forward muon A-layer, and the beampipe and low beta quad, producing a showers in the forward B and C-layers. The accelerator produces halo which comes from the tunnel; however, this is small compared to the contribution from interactions after shielding was installed in the tunnel during Run 1B [2]. Shielding these background sources is important. For it will reduce the occupancy of the detectors. This decreases the fake trigger and track probability and increases the detector lifetime by reducing aging. It also provides insurance against the unpredictable effects of large background fluxes.

This note describes the shielding plan to the extent that it is presently developed. First, the basic shield is described. A discussion of some unresolved issues is presented in the next section. Following a short summary, the cost estimate for the present scheme is presented in an appendix.

Shielding Material (cm)	B-layer Iarocci Tubes	B-layer Scint. Counter	C-layer Iarocci Tubes	C-layer Scint. Counter
like Run 1	1	1	1	1
25 Fe + 5 CH	0.052	0.075	0.16	0.065
39 Fe + 5 CH	0.037	0.029	0.11	0.021
39 Cu + 5 CH	0.018	0.019	0.076	0.034
34 Fe + 10 CH	0.019	0.030	0.052	0.037
39 Fe + 15 CH	0.007	0.025	0.013	0.018

Table 1: Reduction in energy deposition for various shielding configurations.

Description of the Basic Shield Design

The main feature of the shield is a thick iron and polyethylene case surrounding the beampipe and low beta quadrupole magnet. This is shown in Figure 1 extending from the calorimeter to the accelerator tunnel. The case is $\sim$ 67 inches wide on the outside and has a hole $\sim$ 20 to 25 inches wide on the inside for the accelerator equipment. Additional polyethylene shielding is located on the endcap cryostat to provide protection for the central A-layer[3].

Iron is conventionally used as a hadron and electromagnetic absorber because it has reasonably short interaction length (16.8 cm) and radiation length (1.76 cm) and is relatively inexpensive. However, iron is almost transparent for low energy neutrons. Polyethylene is used as neutron absorber because it is rich in hydrogen, effective because it is a low mass nucleus. The appropriate thickness of the iron and polyethylene was determined by Monte Carlo simulation. A list of "source particles" was created from minimum-bias collisions in a GEANT Monte Carlo simulation of the DØ detector. This list was then used as input to a MARS Monte Carlo simulation of various shielding configurations. Figure 2 is the energy deposition from hadrons (upper) and electromagnetic showers (lower) in the shielded detector. A luminosity of 2×10^{32} cm^{-2}s^{-1} is assumed. This plot is best viewed in color. Table 1 shows a list of total energy deposition in B and C-layer upgrade detectors for five shielding configurations relative to the protection offered by the Run 1 design (no special shield). Table 2 shows the partial energy depositions from low energy neutrons, exitation, electromagnetic showers and charged hadrons. In the Run 1 design, 45% of the energy comes from easily suppressed electromagnetic showers. Increasing the thickness of the iron further reduces the energy deposition by providing more protection against hadronic showers. Copper is a somewhat more effective shielding material than iron but is more than twice as expensive. Increasing the thickness of the polyethylene reduces the total energy deposition by decreasing the contribution of low energy neutrons. Figure 3 is the energy deposition from hadrons (upper) and electromagnetic showers (lower) in the shielded detector. As in Figure 2, a luminosity of 2×10^{32} cm^{-2}s^{-1} is assumed. This plot is best viewed in color. The contrast with between Figure 2 and Figure 3 is striking. The bottom line is that the energy

Shielding Material (cm)	Low Energy Neutrons	d, t, α from exitation	Electromagnetic Showers	Charged Hadrons
like Run 1	0.11	0.23	0.45	0.21
25 Fe + 5 CH	0.40	0.31	0.037	0.25
39 Fe + 5 CH	0.42	0.29	0.008	0.28
39 Cu + 5 CH	0.31	0.33	0.10	0.26
34 Fe + 10 CH	0.23	0.49	0.053	0.23
39 Fe + 15 CH	0.18	0.44	0.002	0.38

Table 2: Partial energy deposition for various shielding configurations.

Z (inches)	Minimum $\|\eta\|$	Maximum $\|\eta\|$
160	1.9	2.2
240	2.3	2.6
365	2.7	2.7

Table 3: Pseudorapidity edge of a square with side 70 inches long at various Z locations corresponding approximately to the A, B, and C-layers of the forward muon detector.

deposition from proton and antiproton remnants is reduced by approximately a factor of 50 with a shield comprised of 39 cm (15 inches) of iron and 15 cm (6 inches) of polyethylene.

Additional studies indicated that an additional 3.2 inches of iron located on the inner core of the shield at the location from the exit of the toroid to the front of the low beta quadrupole magnet increased the shielding another factor of $2\times$ to a total of $\sim 100\times$.

The shield necessacarily occupies space at high pseudorapidity. To put a hole in it thick enough for a detector destroys the shield's effectiveness[4]-[5]. Table 3 indicates the minimum and maximum pseudorapidity covered by a square with side of length 70 inches (approximate size of the SAMUS magnet hole) at Z locations corresponding approximately to the A, B and C-layers of the forward muon system.

Discussion of Remaining Issues

We have some issues remaining before we can specify the final design of the shield. They are mainly details of the shielding which are tied up with engineering concerns. We are working to optimize the shielding in such a way that the concerns are met. The issues are listed below.

- Dimensions of the different materials in the EF A-layer shield.

- Do we need the SAMUS collimator? We would like to use the tungsten in the the EF A-layer shielding. In that case we would probably fill the SAMUS collimator hole with iron.
- Shielding from the calorimeter to the tunnel must provide a way to roll (in $\hat{z}$) both the calorimeter and the EF muon toroid magnet for access to the A-layer and central tracking detectors.
- How much modification of the SAMUS magnet will be required?
- Access must be available to the low beta quadrupole magnet and accelerator components with the shield. This should include a provision for replacing the low beta quad if necessary.
- We have space available for more material at Z greater than $\sim$ 800 centimeters. Is an increase in the thickness of the shield worthwhile in this region. Is a one meter thick concrete wall located between 800 and 900 cm worthwhile?
- How much beam halo will come from the accelerator?
- Is there a presently overlooked source which is the largest background contributer when the known hotspots are suppressed by a factor of 100 times?

Summary and Conclusion

The upgrade of the DØ muon system will include the addition of shielding material. This shielding will reduce the occupancy of the detectors, the fake trigger and track probability, and reduce aging by supressing the main background sources by approximately a factor of 100X in the EF B and C-layers. We have a good start on developing the design. A polyethylene do-nut will provide a factor of $\sim 5\times$ rate reduction in the CF A-layer. Additional shielding, to be installed closer to the beampipe, will provide background reduction for the EF A-layer counters and some additional factor for the CF A-layer.

Appendix: Cost Estimates

The following is the cost estimate for the shielding.

Item	Description	Unit	#	$ Cost per Unit	Cost	Contingency (%)	Contingency Cost	Total Cost
1	Iron Slab + Plate	lb	225000	0.35	78750	10	7875	86625
2	Polyethelene	ea	110	225	24750	10	2475	27225

	Sheet 1" thick							
3	Machining Iron	lot	1	157500	157500	20	31500	189000
4	Cutting Poly	lot	1	24750	24750	20	4950	29700
5	Bearings + Gizmos	lot	1	30000	30000	20	6000	36000
Total					315750	17	52800	368550

References

[1] H. T. Diehl, "Aggressive Shielding Strategies for the Muon Upgrade", DØNote 2713, September 1995.

[2] J. M. Butler *et al.*, "Reduction of Tevatron and Main Ring Induced Backgrounds in the DØ Detector", DØNote 2559, July 1995.

[3] H. T. Diehl *et al.*, "Test of a Polyethylene Shield for the Central Muon A-layer Upgrade", DØNote 2685, August 1995.

[4] V. Sirotenko, "Shielding for D0 Detector: The First Look", DØNote 2512, March 1995.

[5] N. V. Mokhov and V. Sirotenko, "Possible Minimal Solutions for D0 Detector Shielding Based on GCALOR and MARS13 Simulations", DØNote 2601, July 1995.

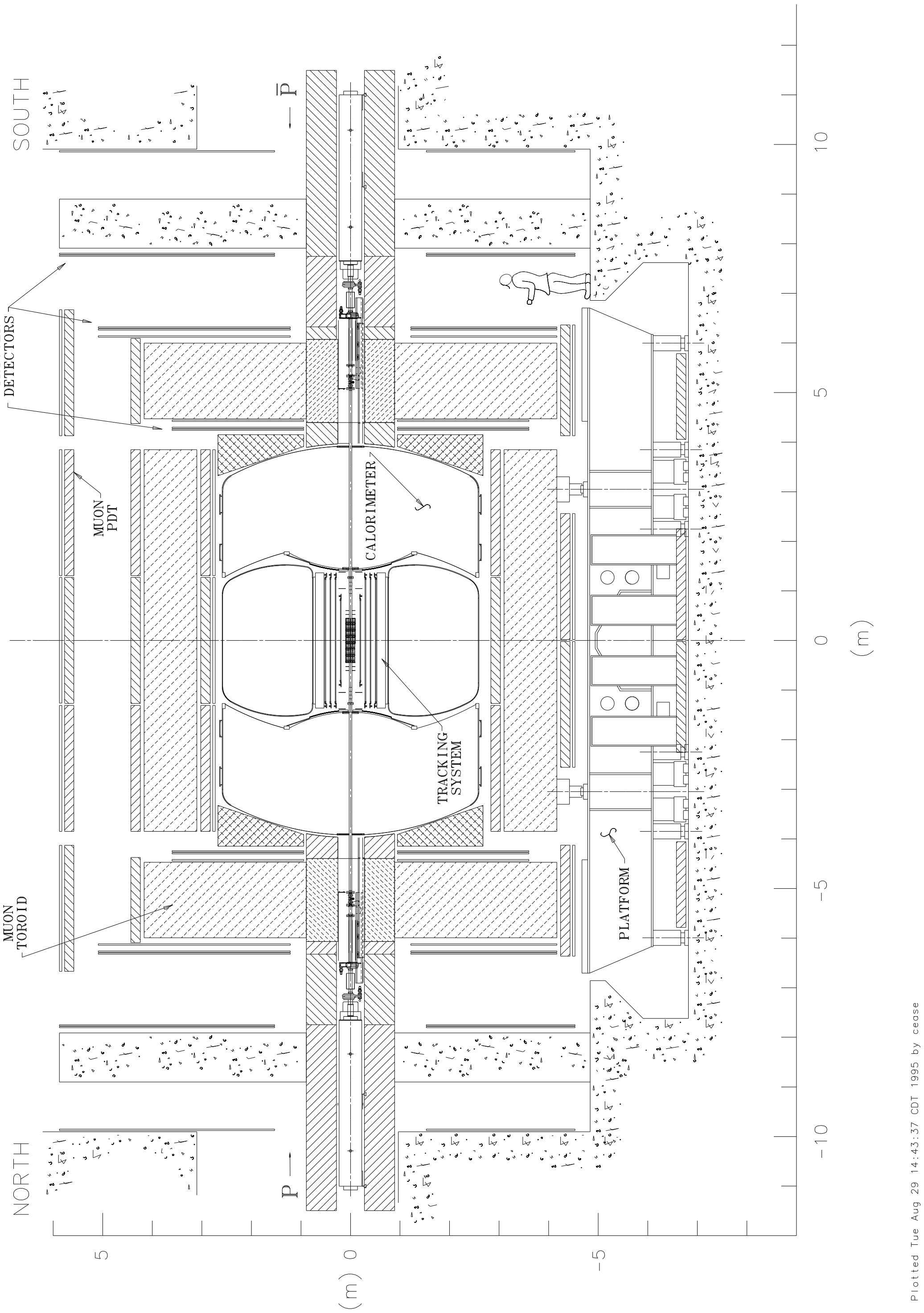

Figure 1: Shown is a hypothetical side view of the DØ upgrade detector including options for large scale shielding being considered.

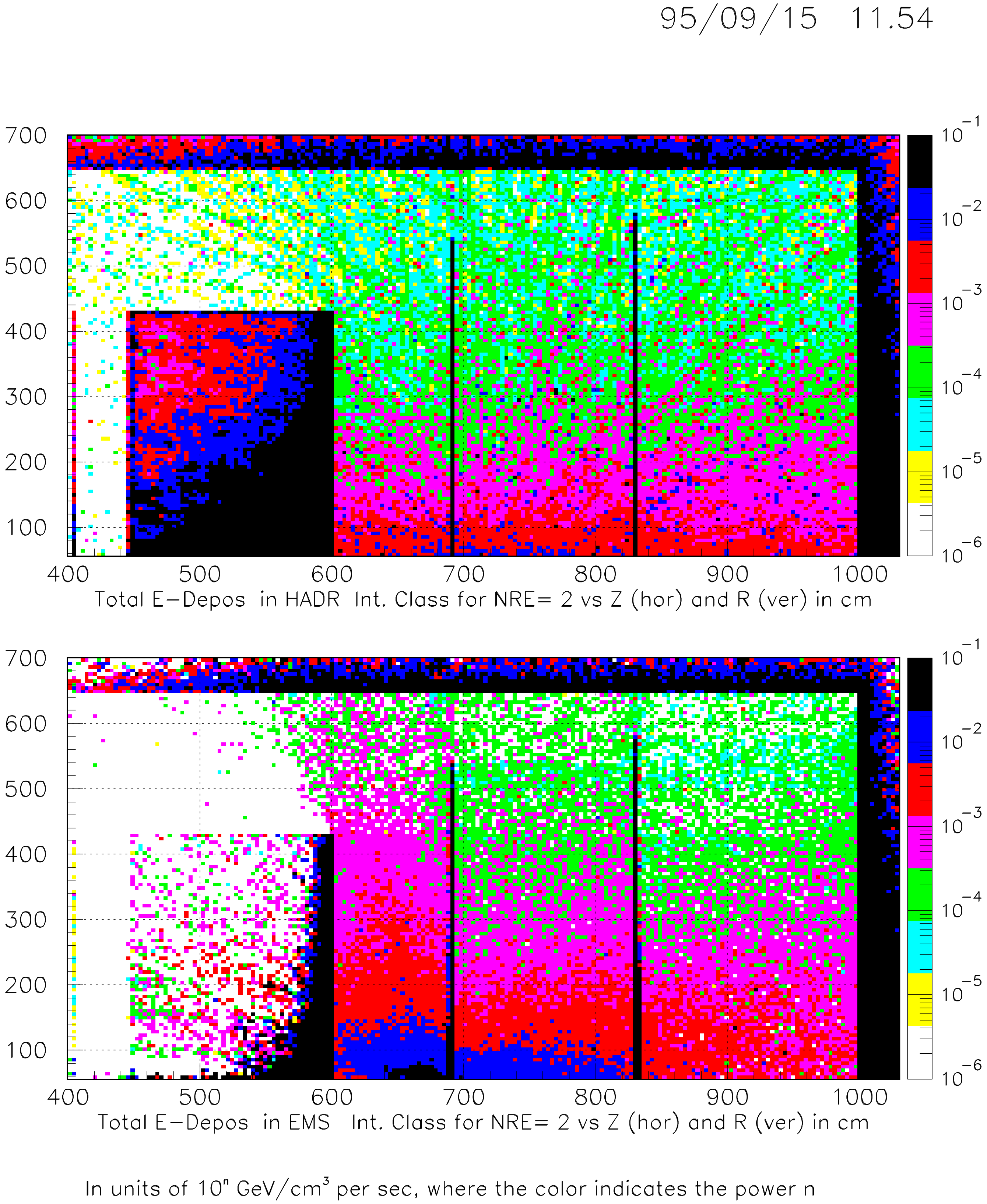

Figure 2: This is the energy deposition from hadrons (upper) and electromagnetic showers (lower) in the unshielded detector. A luminosity of 2×10^{32} cm^{-2}s-1 is assumed. This plot is best viewed in color.

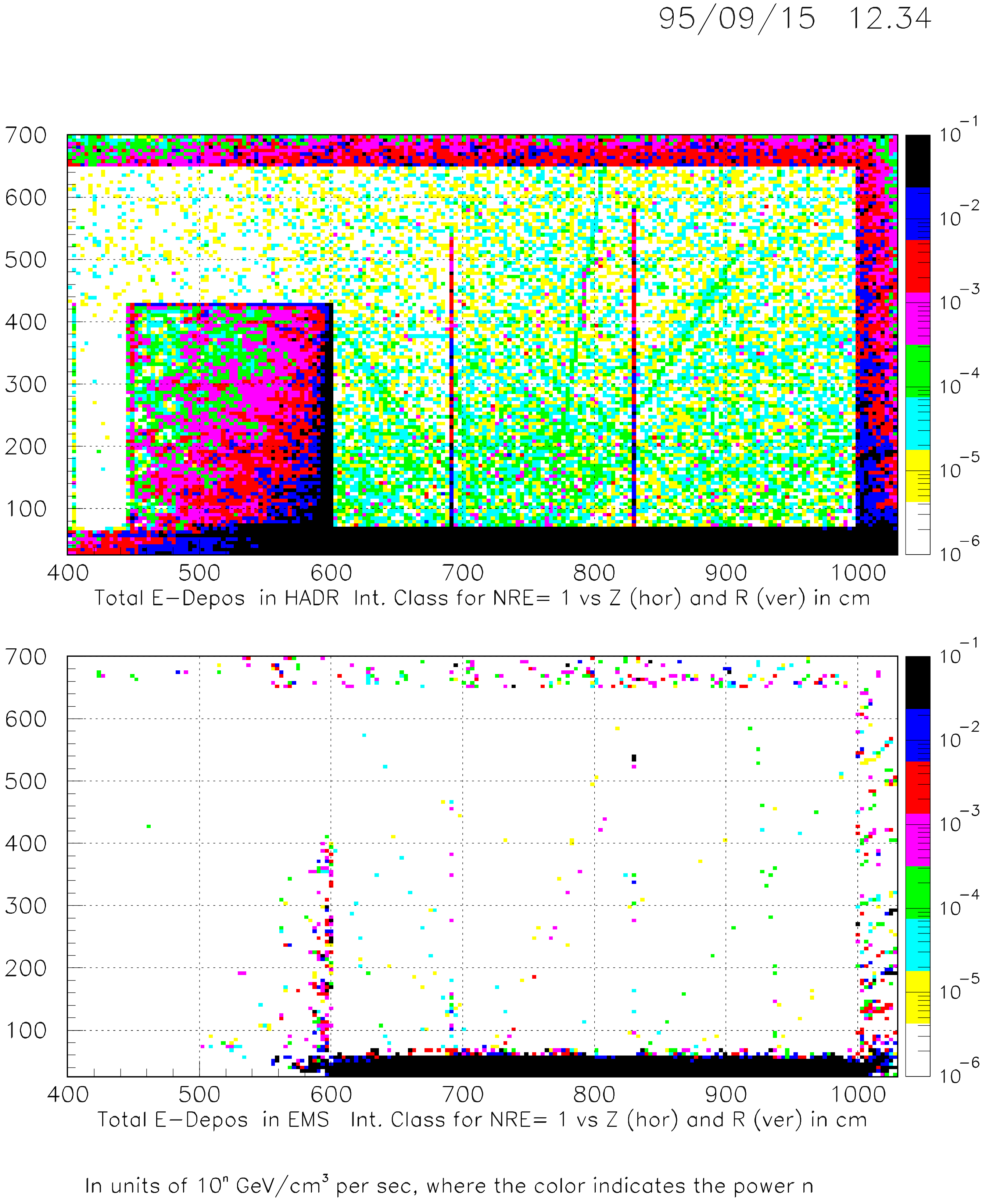

Figure 3: This is the energy deposition from hadrons (upper) and electromagnetic showers (lower) in the shielded detector. A luminosity of 2×10^{32} cm^{-2}s-1 is assumed. This plot is best viewed in color.