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Study of the μ Background in CKM the Beam at the Fermilab Main Injector

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I) Introduction

This is the study of the muon rate in the K^+ separated beam near the CKM experiment, using the Geant MonteCarlo simulations. The design of the RF separated Beam is described in [1]. It was modified in order to use avalaible Fermilab magnets. The beamline layout was shown in the 1st figure of[2], and was described as a 3 stages beam, including a collection stage, a separation stage both common to CKM-CP/T, followed by a dipole switch and transport stage to each separate experiment. Here too, as in [2] we assume the C-Band(5.8)GHz cavities, 2 cavities for separation RF1, RF2 and a third cavity for recombination RF3 with a 25GeV Beam, as in [1]. The study will use the π^+ component of the beam (1/3 of the beam) which is the main source of μ's background. We will compare to the results in [2] and check how adding concrete walls and various pieces of shielding and choosing different beam stopper materials affects the μ background.

II Geant simulations

The model used in Geant has been described in some details in ref [2], here we have added

- concrete walls are made as a tube of concrete 93cm thick, with inner aperture 177cm and outer aperture 270cm

- a beam stopper shield made as a tube of concrete 50cm thick, with an inner aperture of 110cm and an outer aperture of 160cm the all length of the beam stopper. It leaves a layer of air of 15cm around the beam stopper.

- concrete shielding made as a tube of concrete 50cm thick, with inner aperture 35cm and outer aperture 85 cm, they are located around the quadrupoles with half length 508.5 cm, before and after the beam stopper. This leaves a layer of air of about 14 cm around the quads.

- A shielding of concrete at the entrance of the detector is made of two pieces. a)A trapezoid, asymmetric located away in x from the detector aperture (considered at most the size of BQ5)but covering in y and with Δz= 2m .b)A tube of concrete around the detector aperture, 50cm thick with inner aperture 44.7cm and outer aperture 94.7cm and with Δz= 2m

In Figure 1 the beam layout is shown with the shieldings The same 1GeV energy threshold was taken as in [2], a 14mm wide beam stopper was used. We used the Fnalu Batch facility which runs on AIX(IBM-unix) machines this allowed to gain more than a factor 2 in speed, namely more than 400000 events are generated in $\simeq$4hrs (instead of 200000 events). The whole study used 52 hours of CPU time.

III)The sources of muon background

- a)One of the important source of muon background comes from the interaction of the π^+ in the Beam Stopper. In Figure 2, such an event is shown. The particles created are then decaying or interacting farther away, after the beam stopper.

- b) another source of background are interactions in the RF magnets and quads located before the beam stopper and decays.

The radius of the production vertex of those muons is reported versus z in Figure 3for the muons in the halo and in the wings of the beam. This figure represents and event simulated by geant with a layout with "vacuum" walls and no shielding but with a beam stopper of Tungsten.

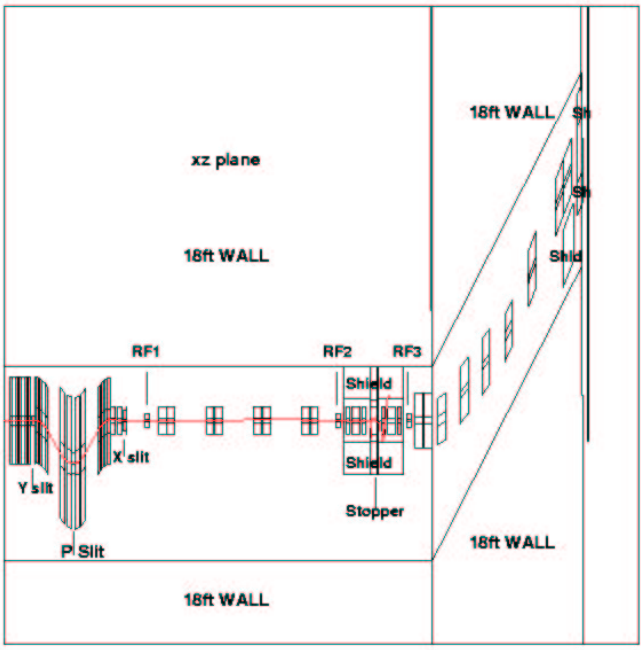

Figure 1: Beam Layout with the Concrete wall and shieldings

Tungsten has been chosen instead of iron. Both material have a similar dE/dx (iron has even slightly higher one), but the density of tungsten is bigger than twice the iron density, therefore the particle absorption is twice the absorption in iron. We will add concrete walls around the beam setup. We will then add various shieldings to absorb the background from various sources, e.g. around the beam stopper and to the quads next to it and close to the detector. We will generate 400000 π events in each channel using Geant and extrapolate our results to 1M generated π events to compare to [2] The background results are reported in Table 1 below for a concrete wall 1m thick, up to the beam stopper.

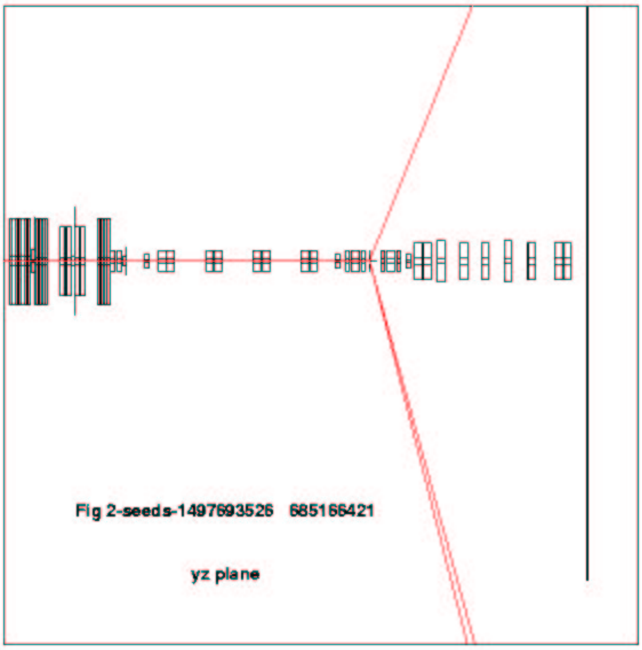

Figure 2: π^+ Interacting in the Beam Stopper

The first column in Table 1 compares directly to the numbers in ref [2], however we have a beam stopper of tungsten instead of the Iron used there and therefore, expect a smaller background since more particles are absorbed by the tungsten. One notices that the walls and the shielding decreases the μ background in the halo and wings. The shielding around the beam stopper seems to decrease the μ background in the beam, whereas the shield before the detector seems to increase it, whereas the combination of both shieldings in the detector region and in the stopper region devreases it. We describe

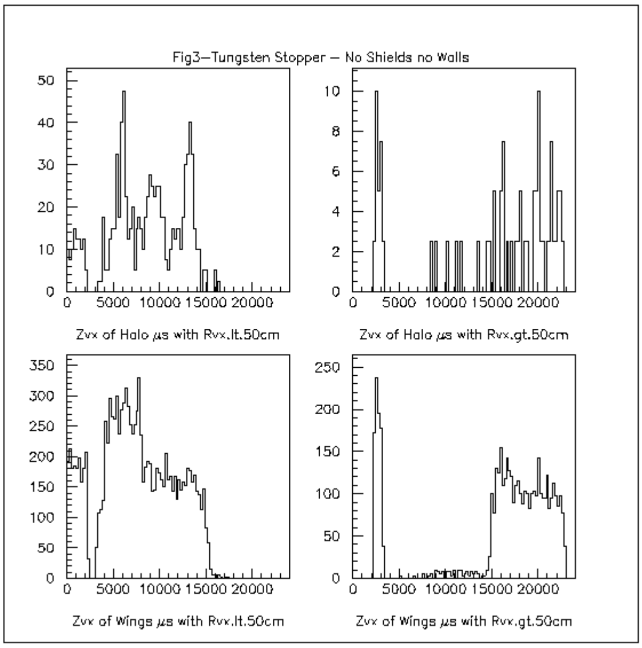

Figure 3: π^+ event with Vacuum walls and no Shielding

below, in some detail the concrete wall and the various shieldings.

A concrete wall: is a 1 meter thick wall around the beam line (1.7m from the beam center)

Stopper Shield :

- a) a beam stopper shield 50cm thick (concrete brick) around the 288cm beam stopper
- b) a concrete shield before and after the beam stopper to stop the particles having interacted at or before the beam stopper

1Million π^+	no shield Vac. wall Fe stper	no shield Vac. wall W stper	no shield Conc. wall W stopper	Stp_shield Conc. wall(*) W stopper	Det_shield Conc. wall(*) W stopper	Both shields Conc. wall(*) W stopper
Beam	68	70	63	48	75	55
Halo	1201	1075	778	668	708	673
Wings	19510	15910	12510	8138	11558	6943

Table 1: The μ background for Fe and W beam stopper, and when concrete walls and shielding are added.The columns marked with a (*) have been extrapolated from 400000 simulated events

- c) the concrete wall described above

Detector Shield:

- a) a beam stopper as above (50cm thick of concrete 288cm long)
- b) a concrete 2m thick shield at the level of BQ5 next to the bending of the beam to CKM+a 2m thick 50cm wide concrete shield around the detector aperture between BQ5 and the Detector
- c)the concrete wall described above.

Both Shields: includes both Stopper shield and Detector Shield.

There is a background previous to the beam stopper and the shielding before the beam stopper takes care of part of it.

Below, in Table 2 we show the values obtained before extrapolation with some more detail about the z position and radius around the beam of the vertex point were those muons have been produced.(see also Fig. 2)

In hist 55-56-57 the vertex at which the muons was created is located within 50cm of the beam center, whereas it is between 51cm-300cm of the beam center in hist 65-66-67. The histograms shown in Figure 3 have been reported for the case no shielding-no walls.

400K π^+	no shield Vac. wall W stopper	no shield 1m Conc.wall W stopper	Stp_shield 1m Conc. wall W stopper	Det_shield 1m Conc. wall W stopper	Both shield 1m Conc. wall W stopper
Beam rvtx<50cm 50< $rvtx$ <300	 28 0	 23 2	 18 1	 26 3	 21 1
Halo Region $rvtx$ <50cm 50< $rvtx$ <300	 374 56	 287 24	 258 9	 262 21	 262 7
Wings rvtx<50cm 50< $rvtx$ <300	 4551 1813	 3570 1434	 3097 158	 3406 1217	 2777 145

Table 2: The muon Background

IV) Study of the background with different thickness and length of the wall

We will compare the muon background for various wall thickness and length. Above we considered a concrete wall 1m thick(which correspond to 2GeV energy loss of the μ). We will increase the wall thickness to 18feets ($\simeq 550cm$) covering also the beam-stopper region, RF3 and the quads up to the bendind magnet. Then we will extend the 18 feet thickness wall over the ckm region and up to the detector. The compared number of muons in the beam, halo and wings region are reported in Table 3.

One notices that increasing the wall thickness lower the number of background μ both in the beam halo and wings. There is a very slight increase in the beam μ which might be partly a statistical fluctuation but can be consistant with an increase of material in the detector. It does improve however with the standard shielding added cutting mostly with the events produced in the wings, which originate at the beam stopper . This can be shown in Figure 4 which shows the evolution of Figure 3. For a 30Mhz beam, if we assume

1M. π^+	no shield Conc. wall 1m Wall	no shield Conc. wall 18ft Wall	no shield Conc. wall 18ft wall to CKM	Shield Conc. wall 18ft wall to CKM
Beam	63	59	80	70
Halo	778	620	558	517
Wings	12510	7785	1165	853

Table 3: The effect of the concrete wall on the μ Background

that it is composed of 1/3 π's and 2/3 K's, the number of μ's produced by the π component (the biggest source of μ's)in the halo(outside beam within $\pm$100cm from the beam center)it is at most $<$ 3 mrem/hour whereas in the wings (distance from the center of the beam greater than $\pm$100cm) it is at most 0.43 mrem/hour, in the region [dx,dy]= [-190:-130,-120:-100] and less than half of it everywhere else in the case of both a 18ft concrete wall to the CKM detector and the shielding, a dose of 0.25mrem/hour is condidered to be safe for an office space.(the mrem/h is defined as $8\mu/cm^2sec$).

V)Conclusion

The beam stopper is an important source of μ Background. Other μ background events comes from the interaction in quads and decay the charged secondary particles beeing " channeled in the quads and dipoles. The choice of a tungsten beam stopper improves the μ background. Two kinds of shielding are used, one in the beam stopper region and one in the Detector region. The concrete wall is extremely important and we can see that an 18ft concrete wall in the CKM region can make quite a difference.

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References

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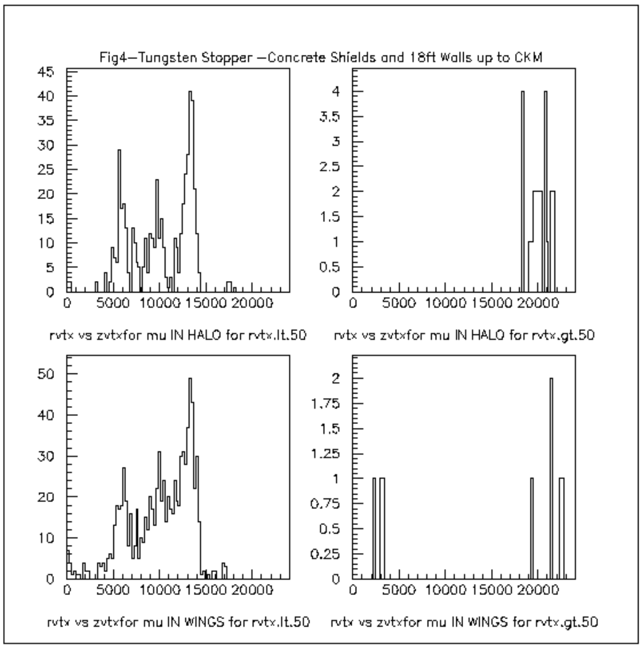

Figure 4: π^+ event with 18ft concrete walls and shieldings around the stopper and before the detector