SNO-STR-93-008

BLOCKING THE β's in the ^{16}N SOURCE

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1 Introduction

The decision will have to be made as to whether or not it is desirable to block out the β's from the ^{16}N source, but first it must be determined to what extent the Cerenkov radiation from the β decays can be attenuated. The D_2O option is used for the calculations, assuming 1 inch ID acrylic pipe with a 1/4 inch thick wall. The detector response is calculated for both a clear and blackened acrylic tube. The bottom line is that a blackened tube very effectively blocks out the 4.27 MeV β and there is very little distortion of the 6.13 MeV γ from the 10.4 MeV β . There are many figures and one table in this report so for those of you who just want the final result, I refer you to the final figure which shows.

a) Detector response to a 'pure' 6.13 MeV γ .

b) Detector response to ^{16}N with a blackened acrylic tube

c) Detector response to ^{16}N with a clear acrylic tube

2 Results Assuming a Black Pipe

A simple EGS4 program is used for the calculation instead of using the full blown detector MC. The number of Cerenkov photons is calculated at each step EGS4 takes, then scaled down to the the number of PMT's predicted by the Queens MC, which is then given a Poissonian variation. The regions 1) smaller than the inner radius of the acrylic tube, 2) between the acrylic radii and 3) outside the acrylic are taken to be D_2O , acrylic and H_2O respectively. 100K events are generated uniformly in the D_2O for the 6.13 MeV γ and each of the β's. Table I shows the number of events generating Cerenkov light in each of the three regions for each of the three radiations. The last line in the table shows the number of events that have an electron in the H_2O region.

So while the 4.27 MeV β has 3311 electrons leaking out of the acrylic, only 1325 will generate Cerenkov radiation, out of the 100k generated.

2.1 6.13 MeV γ Outside Pipe

Fig 1 overlays the PMT response to a 'pure' 6.13 MeV γ with those that escape the acrylic pipe. While some events occur at low NPMT, the overall 6.13 MeV shape remains virtually undistorted.

2.2 4.24 MeV β Outside Pipe

In Fig 2 the 98431, 6.13 MeV γ events are compared with the 1325, 4.27 MeV β events that make Cerenkov light outside the acrylic. The combination of the low fraction of 4.27 MeV β that escape (3.3%) and the small amount of Cerenkov light they generate results in no distortion of the 6.13 MeV γ spectrum as shown in Fig 3 where the convolution of the two is compared with the 6.13 MeV γ alone.

2.3 10.4 MeV β Outside Pipe

Fig 4 shows the detector response from the Cerenkov radiation generated in each of the three regions individually as well as the sum. The relative amplitude of the 10.4 MeV β is 0.38 that of of the 6.13 MeV γ . Fig 5 overlays the 10.4 MeV β spectrum, weighted by 0.38 with that of the 6.13 MeV γ outside the acrylic. The simple sum of these two (as opposed to the convolution required for the 4.27 MeV β) is shown in Fig 6 in overlay with an undistorted 6.13 MeV γ . There is some distortion of the 6.13 MeV spectral shape below the lower half point but above that there is no discernible distortion and the peak position remains unaffected.

3 Results with a Clear Pipe

The detector response of the 4.27 MeV β from all three regions now has to be convolved with the 6.13 MeV. The γ and 4.27 MeV β are shown in Fig 7 along with their convolution. This is now added to the 10.4 MeV β spectrum weighted by 0.38. (Fig 8)

4 Conclusion

The comparison of 'pure' 6.13 MeV γ with that of a clear pipe and a blackened pipe is shown in Fig 9. The blackened pipe leaves the 6.13 MeV spectral shape virtually undistorted above the low 1/2 point, with the 4.27 MeV β all but totally eliminated.. The 10.4 MeV β causes some distortion below the lower 1/2 point, but any correction is of second order compared to the spectral response with a clear pipe.

Thus the option exists for eliminating the β's from the ^{16}N source to the extent that there is virtually no distortion of the 6.13 MeV energy spectrum above 40 PMT and only a second order distortion above 30 PMT.

TABLE I

Number of Events Generating Cerenkov Light

100k Events Generated

Region	Number of Events		
	4.27 β	10.4 β	6.13 γ
D_2O	91812	95918	4046
Acrylic	21622	60531	5470
H_2O	1325	32859	98431

Number of Events with Electrons			
H_2O	3311	38518	99809

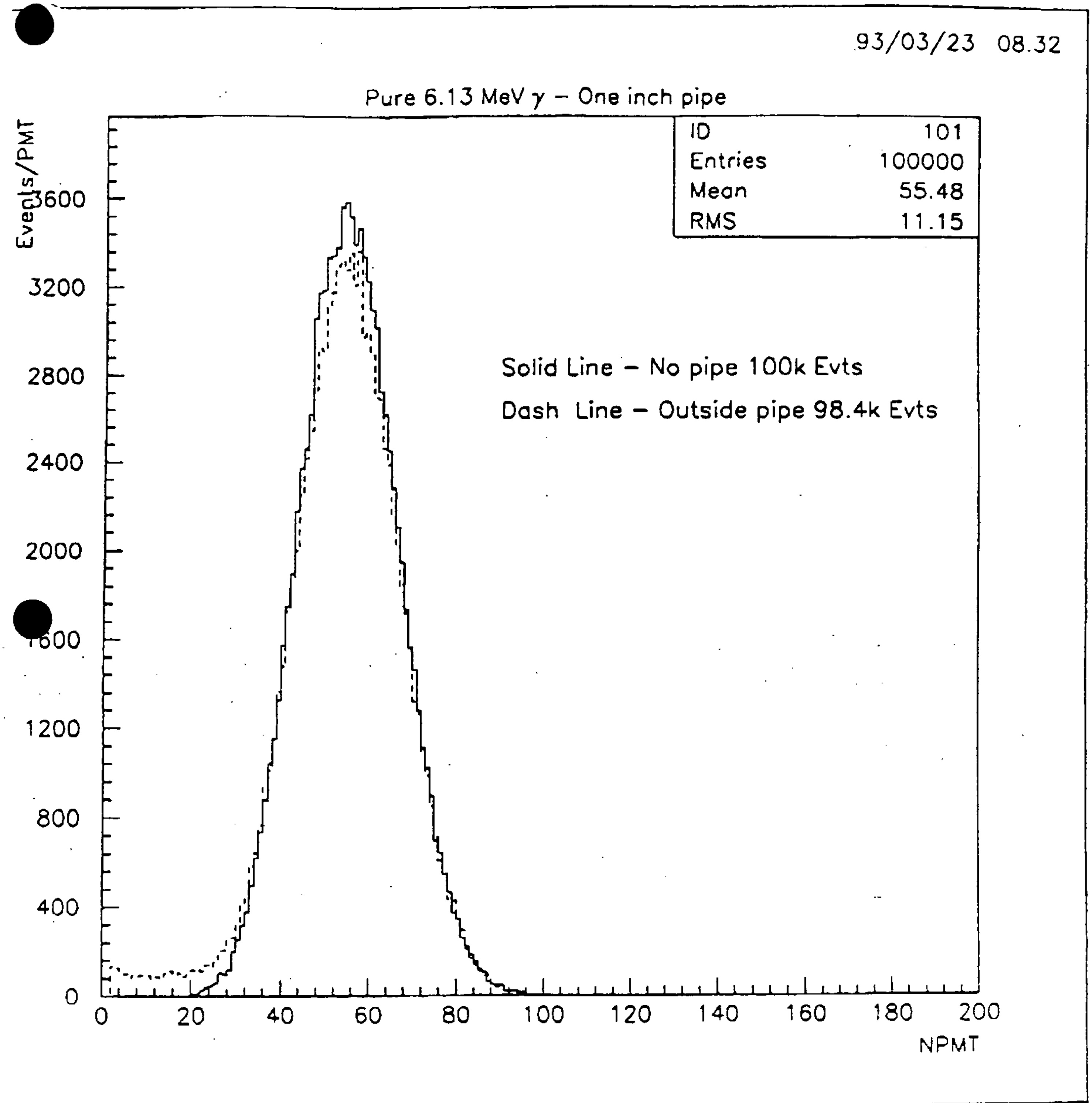

93/03/23 08.32
Pure 6.13 MeV γ – One inch pipe
ID 101
Entries 100000
Mean 55.48
RMS 11.15
Solid Line – No pipe 100k Evts
Dash Line – Outside pipe 98.4k Evts
Events/PMT
0
400
800
1200
1600
2000
2400
2800
3200
3600
0
20
40
60
80
100
120
140
160
180
200
NPMT

Fig 1

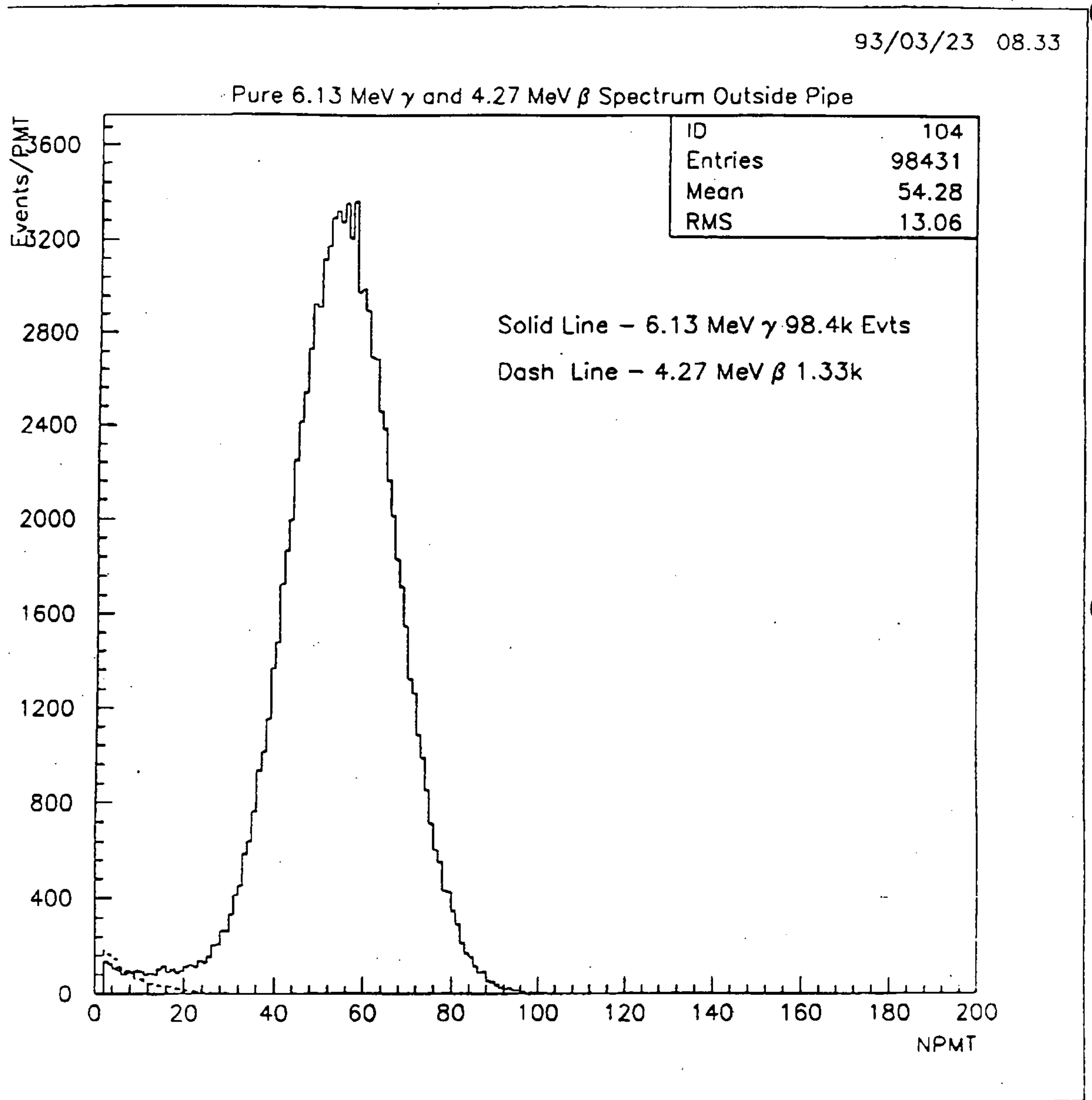

93/03/23 08.33
Pure 6.13 MeV γ and 4.27 MeV β Spectrum Outside Pipe
ID 104
Entries 98431
Mean 54.28
RMS 13.06
Solid Line – 6.13 MeV γ 98.4k Evts
Dash Line – 4.27 MeV β 1.33k
Events/PMT
NPMT
0
400
800
1200
1600
2000
2400
2800
3200
3600
0
20
40
60
80
100
120
140
160
180
200

Fig 2

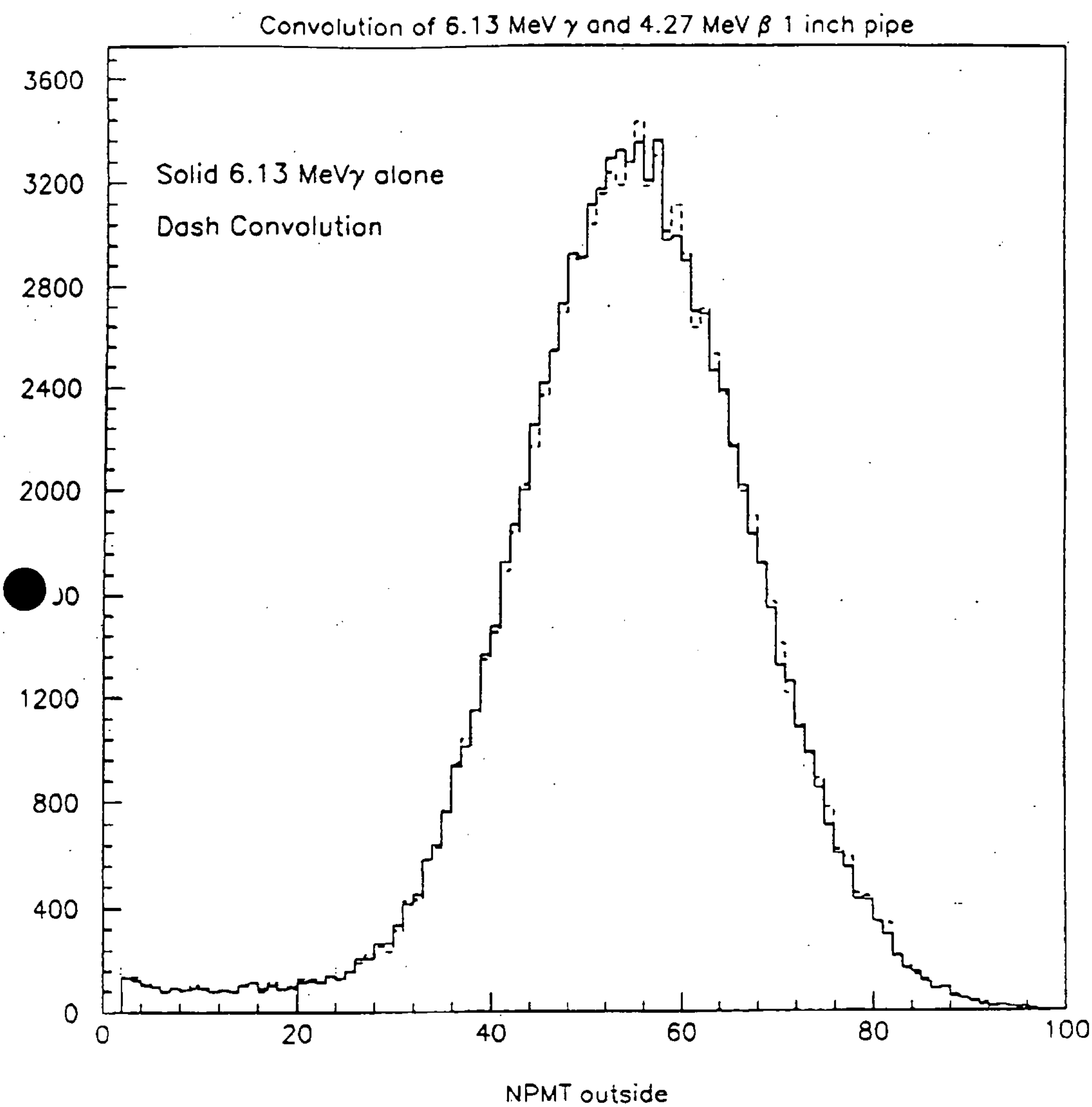
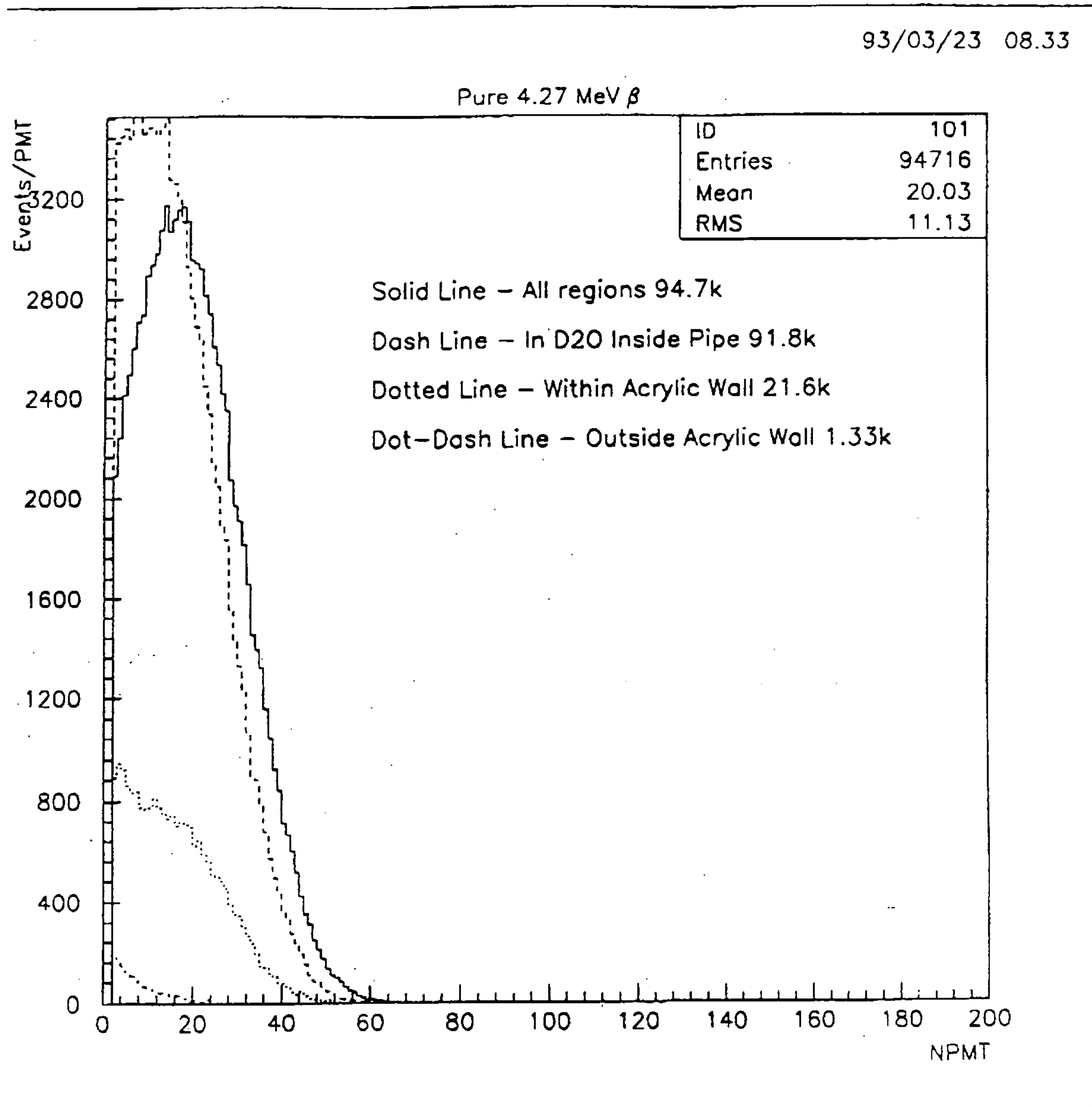

Convolution of 6.13 MeV γ and 4.27 MeV β 1 inch pipe
Solid 6.13 MeVγ alone
Dash Convolution
3600
3200
2800
2400
2000
1200
800
400
0
0
20
40
60
80
100
NPMT outside

Fig. 3



93/03/23 08.33
Pure 4.27 MeV β
ID 101
Entries 94716
Mean 20.03
RMS 11.13
Solid Line – All regions 94.7k
Dash Line – In D2O Inside Pipe 91.8k
Dotted Line – Within Acrylic Wall 21.6k
Dot–Dash Line – Outside Acrylic Wall 1.33k
Events/PMT
0
400
800
1200
1600
2000
2400
2800
3200
0
20
40
60
80
100
120
140
160
180
200
NPMT

Fig. 4

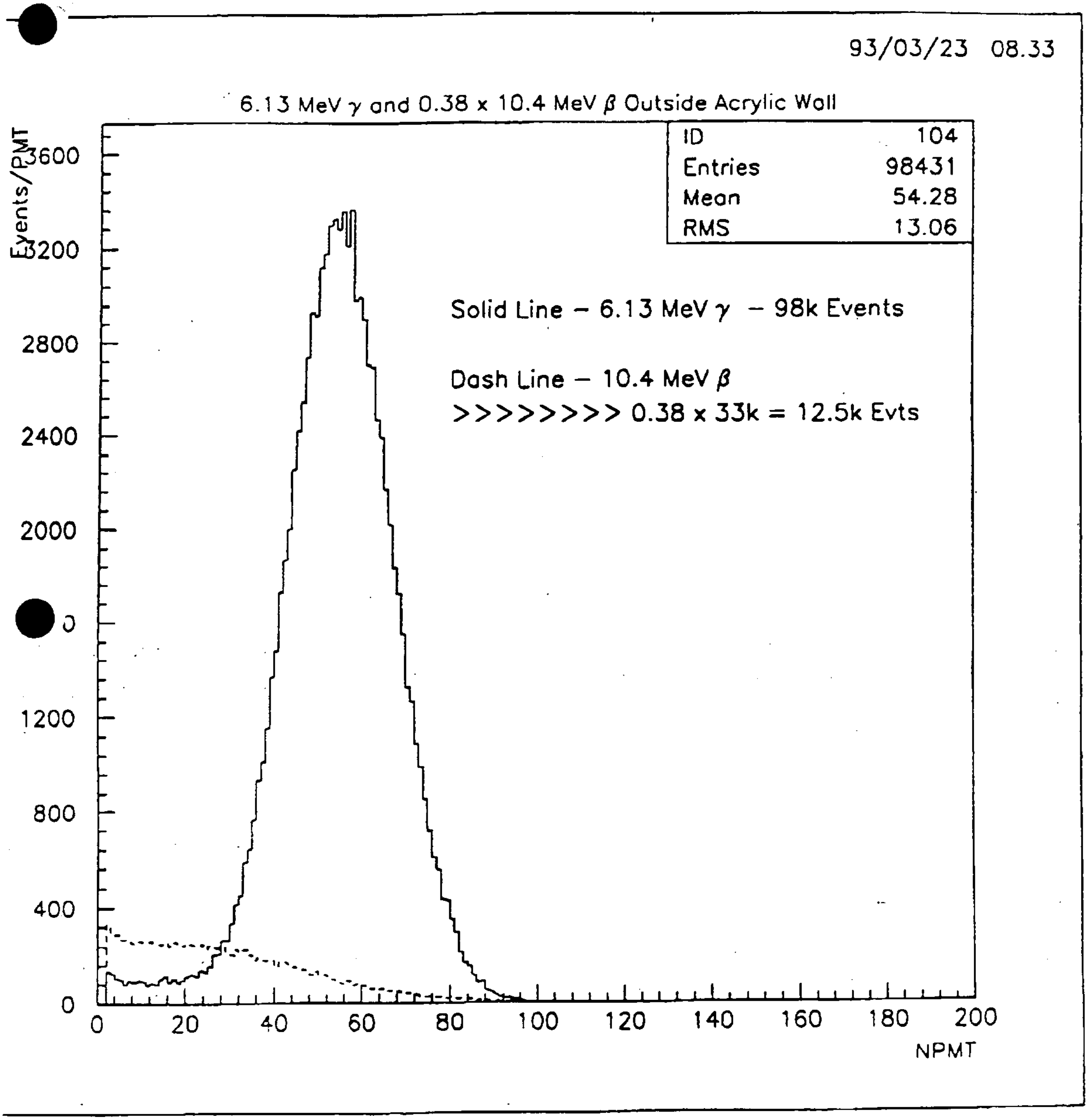

93/03/23 08.33
6.13 MeV γ and 0.38 x 10.4 MeV β Outside Acrylic Wall
ID 104
Entries 98431
Mean 54.28
RMS 13.06
Solid Line – 6.13 MeV γ – 98k Events
Dash Line – 10.4 MeV β
>>>>>>>>> 0.38 x 33k = 12.5k Evts
Events/PMT
NPMT
0
400
800
1200
2000
2400
2800
3200
3600
20
40
60
80
100
120
140
160
180
200

Fig. 5

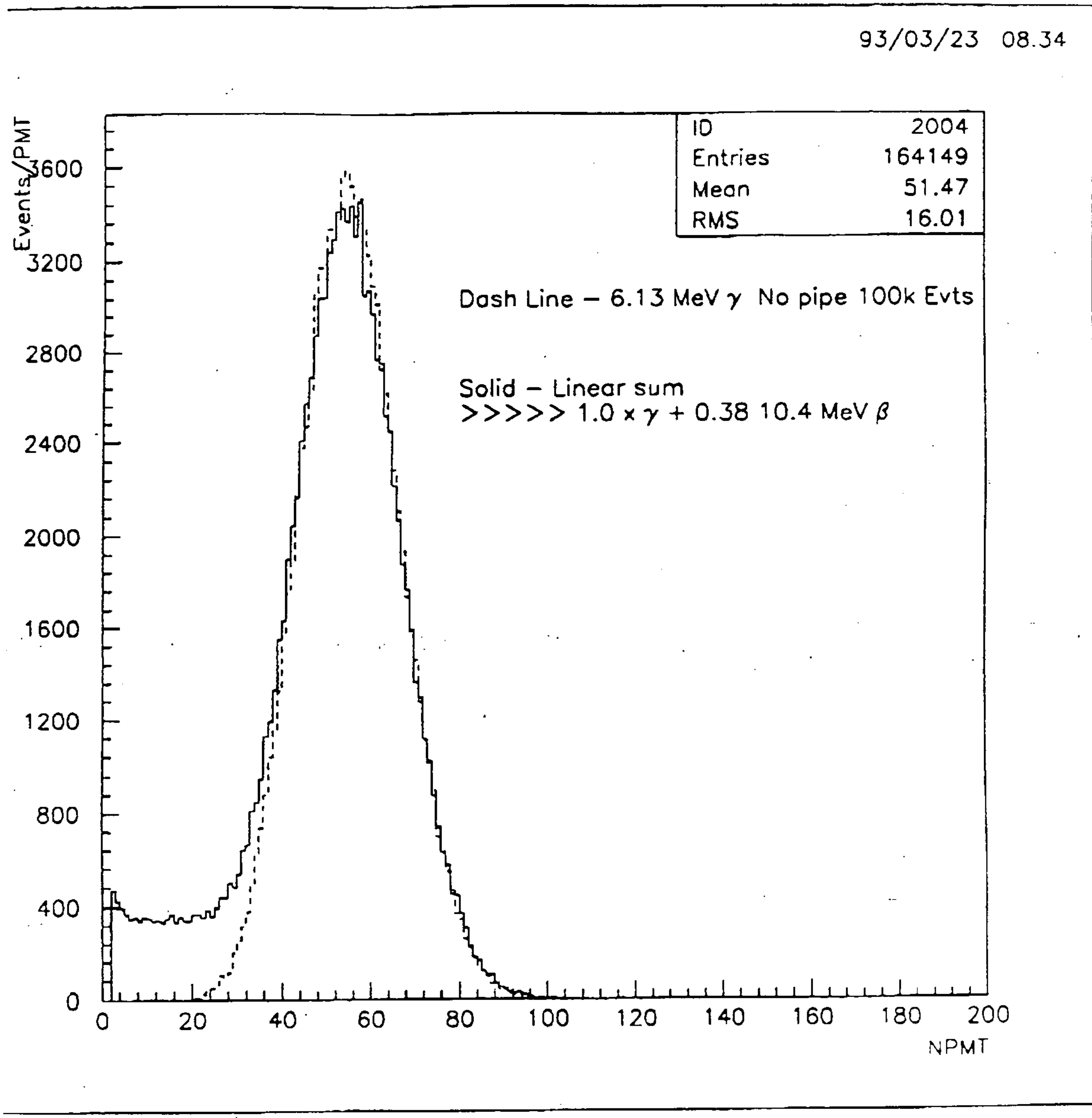

93/03/23 08.34
ID 2004
Entries 164149
Mean 51.47
RMS 16.01
Events/PMT
Dash Line – 6.13 MeV γ No pipe 100k Evts
Solid – Linear sum
>>>>> 1.0 x γ + 0.38 10.4 MeV β
NPMT
0
400
800
1200
1600
2000
2400
2800
3200
3600
0
20
40
60
80
100
120
140
160
180
200

Fig. 6

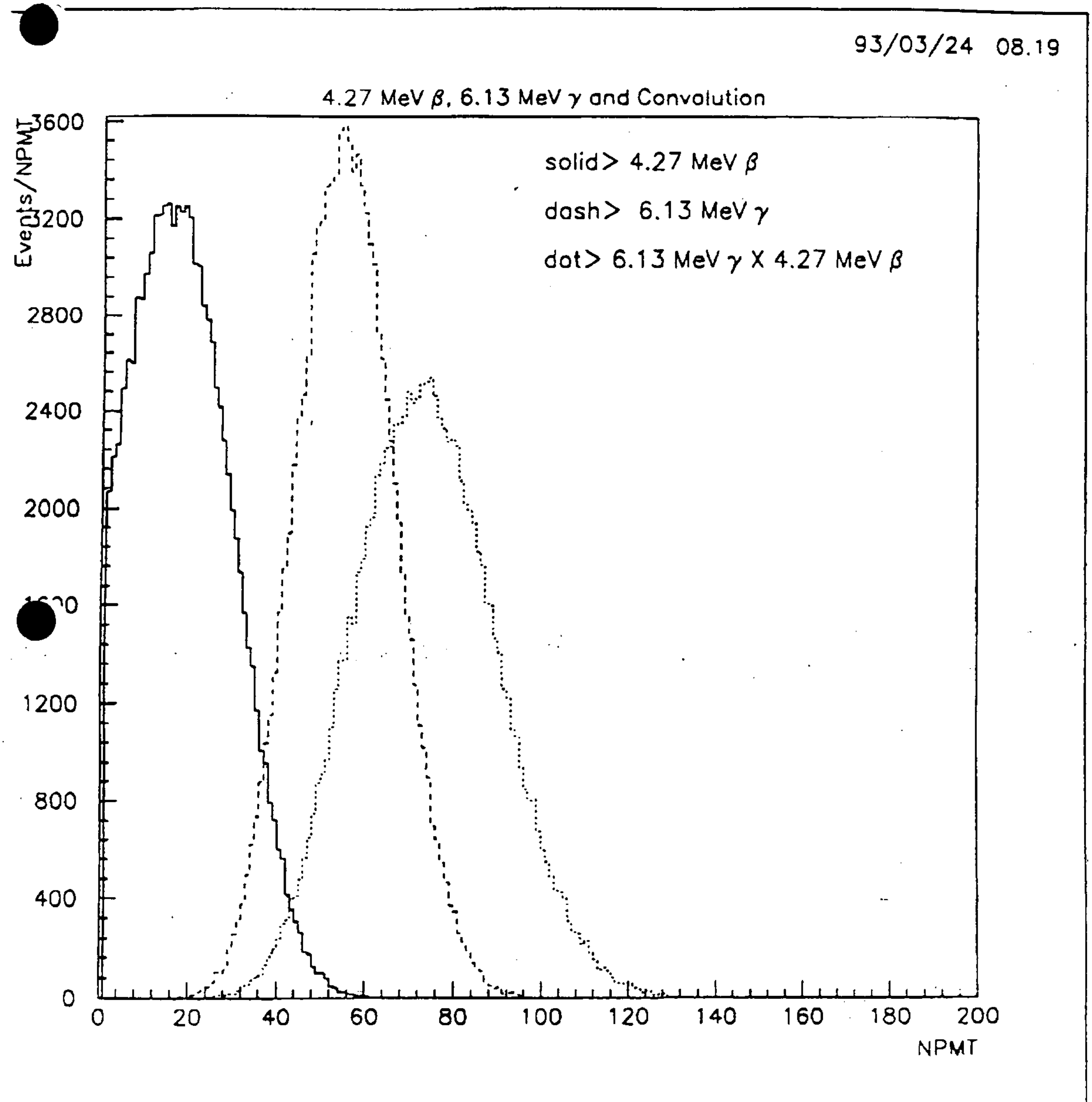

93/03/24 08.19
4.27 MeV β, 6.13 MeV γ and Convolution
solid> 4.27 MeV β
dash> 6.13 MeV γ
dot> 6.13 MeV γ X 4.27 MeV β
Events/NPMT
NPMT
0
400
800
1200
2000
2400
2800
3200
3600
0
20
40
60
80
100
120
140
160
180
200

Fig. 7

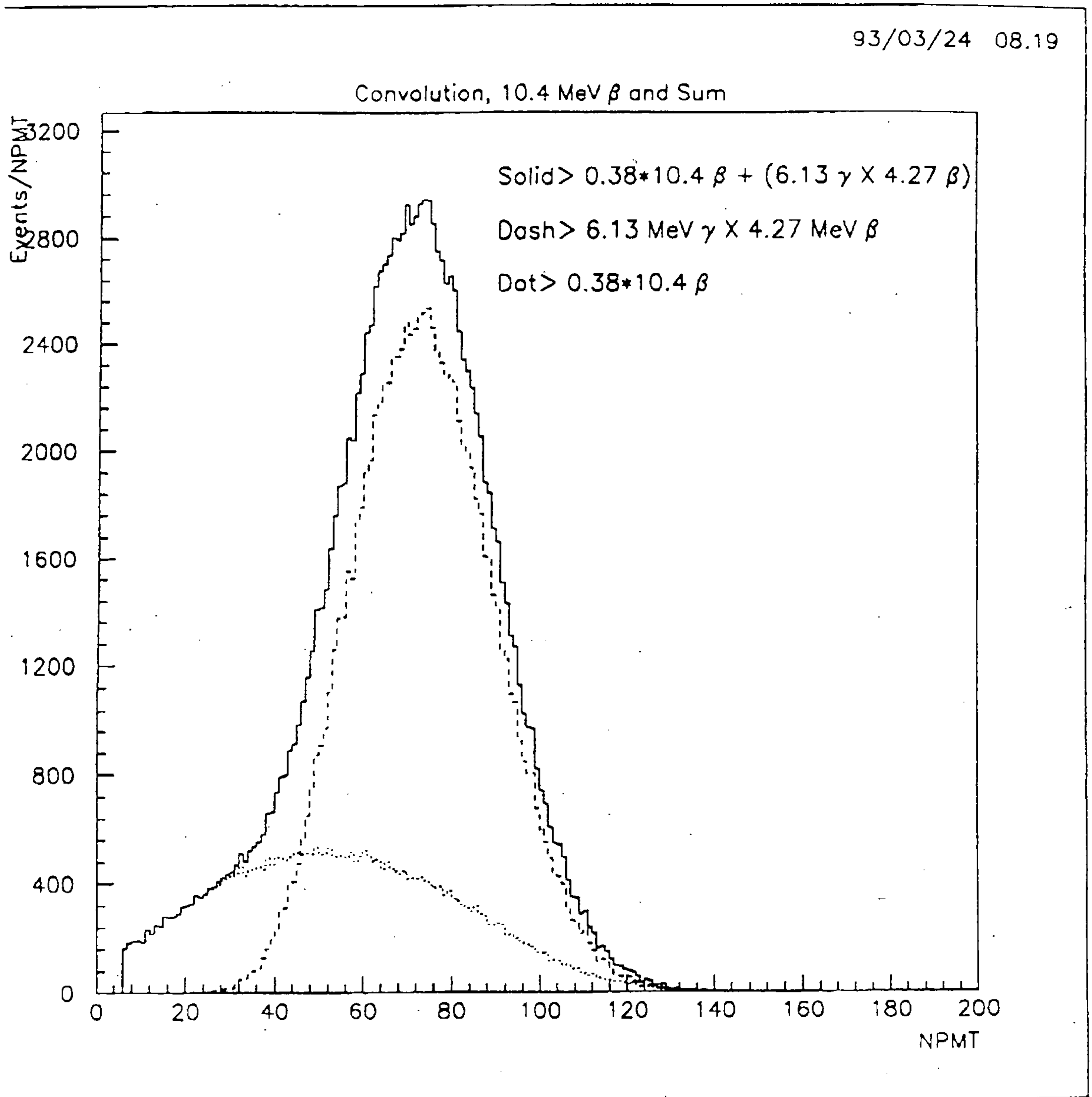

93/03/24 08.19
Convolution, 10.4 MeV β and Sum
Solid> 0.38*10.4 β + (6.13 γ X 4.27 β)
Dash> 6.13 MeV γ X 4.27 MeV β
Dot> 0.38*10.4 β
Events/NPMT
3200
2800
2400
2000
1600
1200
800
400
0
0
20
40
60
80
100
120
140
160
180
200
NPMT

Fig. 8

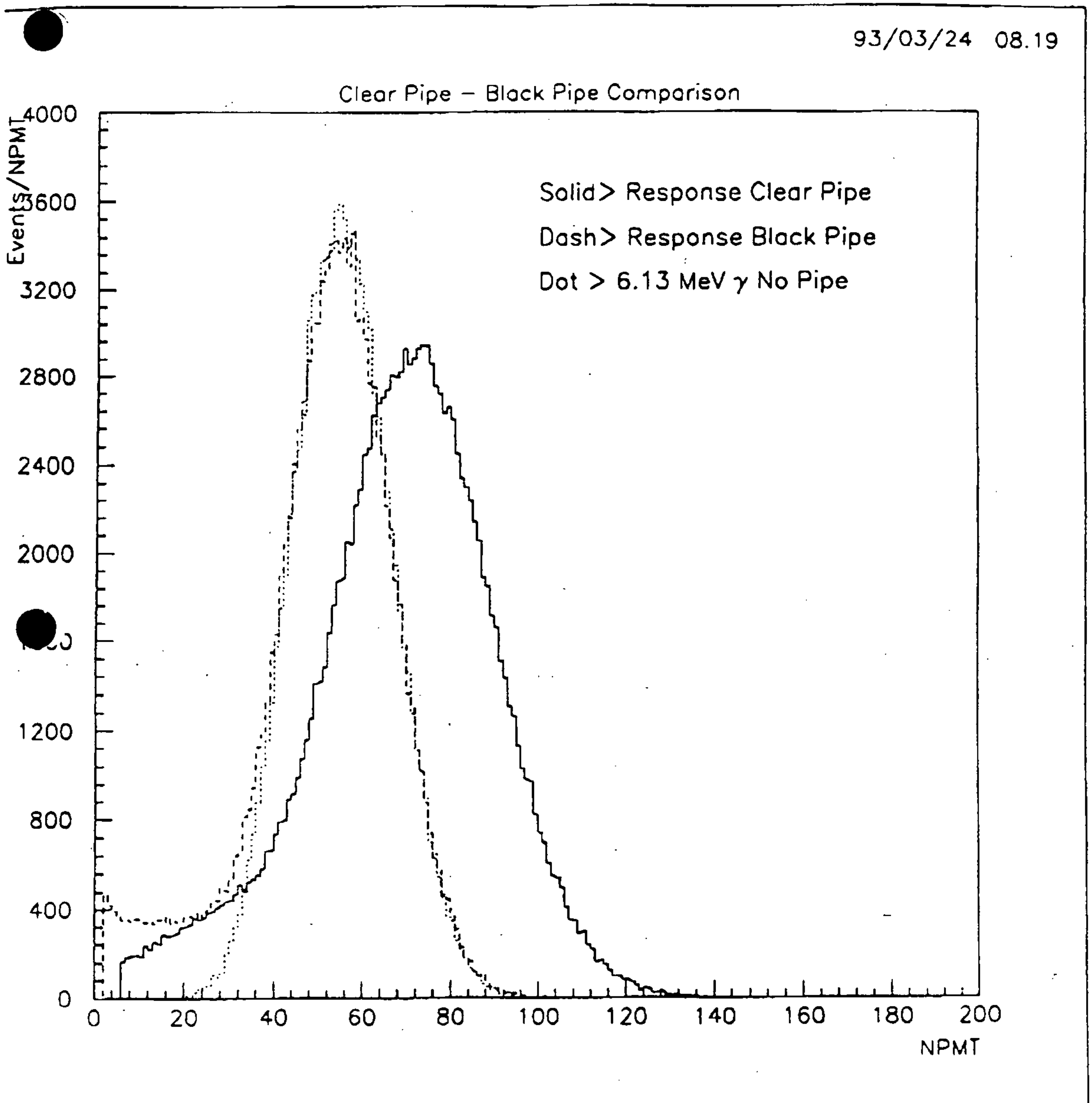

93/03/24 08.19
Clear Pipe – Black Pipe Comparison
Events/NPMT
Solid> Response Clear Pipe
Dash> Response Black Pipe
Dot > 6.13 MeV γ No Pipe
0
400
800
1200
2000
2400
2800
3200
3600
4000
0
20
40
60
80
100
120
140
160
180
200
NPMT

Fig. 9