μCAP Magnet and Detector Geometry

1. Introduction

In this note we study the **final** choice of the μSR detector position based on GMU simulations. The details of the studies are given in an associated worksheet. Please study this note carefully and critically. After we all agree on its conclusions we will freeze the detector geometry and order the support and detector components. Speak now or…..

2. Procedure

We study two basic geometries:

- far: magnet between ePC2 and eSC, requiring a larger radial gap between these two detectors (fig.4)
- close: magnet wrapped around hydrogen pressure vessel (fig.5)

In the sequence of MC runs we compared the change in electron detection efficiency and scattering in different geometries.
Caveats:

- The physical detector resolution was ignored, i.e. the MC trajectory coordinates were used directly. Because physics effects dominate over detector granularity this should be a small correction.
- More subtle effects due to the generation of secondaries and associated correlations (e.g. two simultaneous hits in the eSC will confuse the z resolution, backscattering etc.) are not investigated.

10 k incident muons were generated for each run. For a summary of run conditions see *sheet data*.
The electron selection cuts are

cut1: mustop in TPC |x|<7.5cm, |y|<6cm, |z|<15cm
cut5: 10 ns time cut first hit epc1/epc2
cut6: 10 ns time cut first hit epc2/eSC, >1MeV energy deposition in eSC
cut7: cos (vector epc1->epc2 hit, vector epc2->eSC hit) >0.9

Coincidences defined between first hits only.
The efficiency is defined as events passing cut6/cut1. The effect of scattering is quantified by calculating the impact parameter (vector of closest approach) between mustop and reconstructed mustop. Its absolute projections on the x and z axis are given.

3. Main conclusions and discussion

For details see work *sheet data* and *figures*.
Magnet criteria:

1. efficiency close/far=1.05
   Small effect. Efficiency somewhat dependent on optimal ESC length, but not very critical.
2. impact para close/far=1.08
   Noticable, but relatively small. The bottomline here is that as long as we have a 4mm vessel wall it dominates all scattering (Should be confirmed by Steve with real data). Without wall the close magnet would be a significant scattering source (ratio=1.4).
3. According to Bernhard's calcs the far magnet provides a 5 times more uniform field than the close one. The dominant variation in the fiducial volume is Bz which changes by 5G .

magnet	B_x field	B_y field	B_z field
small coil	0 ± 1 gauss	0 ± 0.25 gauss	69 ± 5 gauss
large coil	0 ± 0.05 gauss	0 ± 0.02 gauss	70 + 0.5 - 1.4 gauss

4. The stray field at the PM's probably would be much smaller for the close magnet. Bernhard? For the far magnet we can handle the situation by somewhat extending the length of the light guides.
5. The close magnet is smaller and easier to build and cool. It has to be inserted in the close space between hydrogen vessel and ePC1. Reliable cooling has to be guaranteed. Feedthrough notches have to be drilled into the stainless and Al end flanges of the pressure vessel. This has to be approved and done by PSI (Claude).

Other conclusions:

1. 1 cm of Al support structure behind the ESC does not affect the present results. However, as we have not studied correlation, backscattering etc we should provide a reasonable thin support of the detector slabs.
2. A 1 cm passive absorber together with a 1 MeV energy threshold in eSC implies an effective energy cut for Michel electrons of ~10MeV and reduces the impact para by 5%. The price is a 12% efficiency loss and again the effect of correlations and backscattering (should be compared with measurements using active thick scintillator (Steve)).

My opinion:
Magnet criteria 1 and 2 have been investigated in this note. Further detailed studies of systematics associated with secondaries is difficult, probably the magnet is not too relevant for this. Criteria 3, field homogeneity, is believed not to be too important, but we have not really proven that. The technical criteria 4,5 should be finally assessed by Berkeley and PSI. If that's ok, let's go for the closer, small magnet.

Magnet position worksheet

Considerations

We consider two options. Magnet around hydrogen vessel or between ePC2 and eSC.
The resulting scintillator dimensions and PM face requirements are listed below.

option	r(mm)	l/2(mm)	diam/16	w(mm) exact	area(cm2)	vol(cm3)
far	414	520	162.577	161.535	8.077	8399.809
close	357	445	140.194	139.294	6.965	6198.605
ratio	1.160	1.169	1.160	1.160	1.160	1.355
choice?	360	445	141.372	140.465	7.023	6250.694
	inch	r(mm)				
tube	1.5	19.05			11.401	
	2	25.4			20.268	

MC studies far distance

First we study the situation for the magnet at the far position.

run	cond	inc file	magnet (Cu) r(cm)	th(cm)	scint r(cm)	l/2(cm)	absorber (Al) r(cm)	th(cm)	ratio events with cut/mu in tpc: cut1 mu in tpc	cut5 ePC1/2 coinc	cut6 ePC2/eSC	cut7 scattering ePC2/eSC	impact para rms x (cm)	rms z (cm)
500	far	inc500	37	0.3	41.5	44.5			6943	0.773	0.682	0.642	1.000	1.055
501	far		37	0.3	41.5	52			6994	0.764	0.710	0.674	1.027	1.055
502	far		no magnet		41.5	52			6970	0.762	0.746	0.718	1.041	1.071
503	far		no magnet	no wall	41.5	52			6841	0.781	0.765	0.751	0.621	0.633
504	far		magnet	no wall	41.5	52			6937	0.788	0.740	0.716	0.586	0.624
505	far		magnet	0.3	41.5	52	42.5	1	7048	0.764	0.712	0.674	1.006	1.016
506	far		magnet	0.3	41.5	52	39.5	1	6977	0.766	0.619	0.593	0.967	0.982

cuts		
internal info	cut $1 nh1>0.and.abs(gve(1))<7.5.and.abs(gve(2))<6..and.abs(gve(3))<15	mu stop in tpc cut
	cut $5 $1.and.nh7>0.and.nh6>0.and.abs(hit6(4,1)-hit7(4,1))<10..and.hit7(5,1)>.0	10 ns time cut first hit pc1/pc2
	cut $6 $1.and.nh8>0.and.nh7>0.and.abs(hit7(4,1)-hit8(4,1))<10..and.hit8(5,1)>.0	10 ns time cut first hit pc2/epc
	cut $7 sinner.f(3)>0.90	scattering between ePC2 and eSC < 0.1 = 6 deg

Conclusions

1. lengthening eSC gives gain 1.040
2. magnet/no magnet very small difference in scattering, difference in efficiency 1.051
3. target wall makes all the difference for scattering, see also figure 1, less for efficiency 1.026
4. magnet makes no difference, even for good (no wall) situation
5. external support cyclinder no difference, compare 501/505
6. degrader of 1cm Al before ESC, scattering better by 1.062 efficiency reduced l 0.873 see fig.3,4

MC studies close distance

Finally we study the situation for the magnet at the close position.

									ratio events with cut/mu in tpc					
									cut1	cut5	cut6	cut7	impact para	
run	**cond**	**inc file**	**magnet (Cu)**		**scint**		**absorber (Al)**		**mu in**	**ePC1/2**	**ePC2/eSC**	**scattering**	**rms x**	**rms z**
			r(cm)	**th(cm)**	**r(cm)**	**l/2(cm)**	**r(cm)**	**th(cm)**	**tpc**	**coinc**		**ePC2/eSC**	**(cm)**	**(cm)**
600	far	inc600	16	0.15	36	44			7042	0.759	0.746	0.715	1.109	1.142
602	far		no magnet		36	44			7024	0.772	0.758	0.734	1.036	1.058
603	far		no magnet	no wall	36	44			6953	0.786	0.772	0.757	0.629	0.636
604	far		16	no wall	36	44			6998	0.781	0.766	0.748	0.866	0.920
605	far		16	0.15	36	44	37	1	6938	0.759	0.748	0.720	1.095	1.151
606	far		16	0.15	36	44	34	1	6987	0.763	0.661	0.622	1.029	1.079

Conclusions

		eff	scat
1	eff close/far (600/501)	1.050	1.08
2	magnet/no magnet difference in eff	0.98	1.07
3	target wall effect	0.965	1.762
4	magnet effect for good (no wall) situation	0.992	1.376
5	external support cyclinder no difference	1.004	0.992
6	degrader of 1cm Al before ESC	0.887	0.945

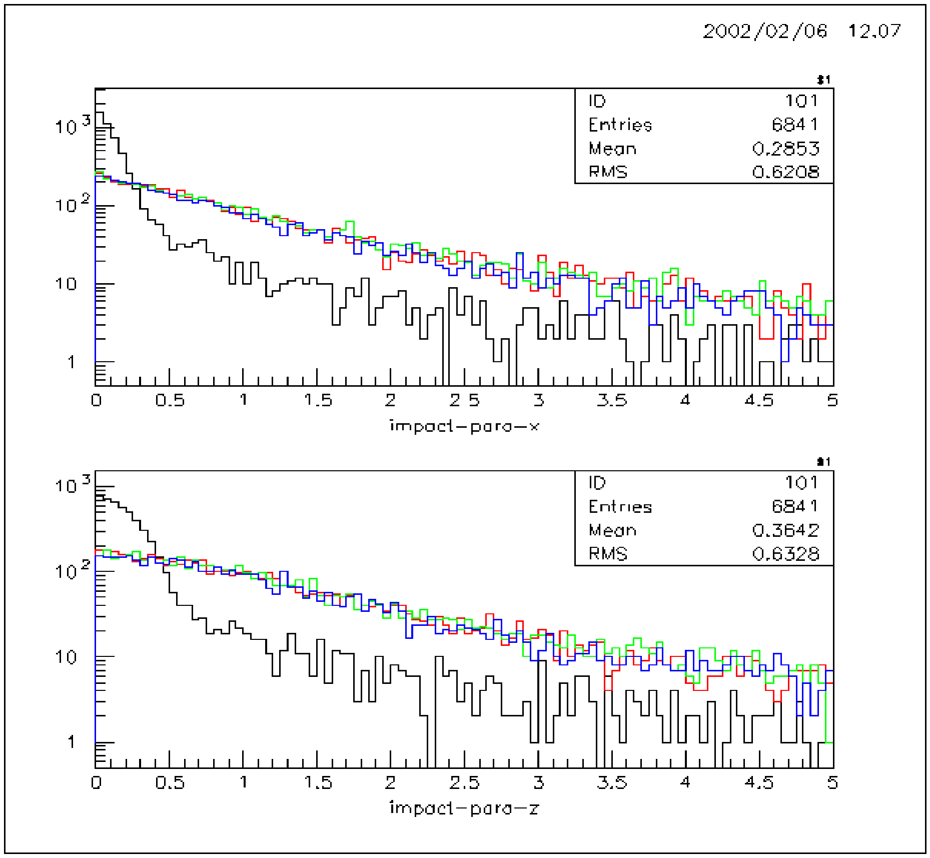

fig.1 black without walls (#503), others 500-502

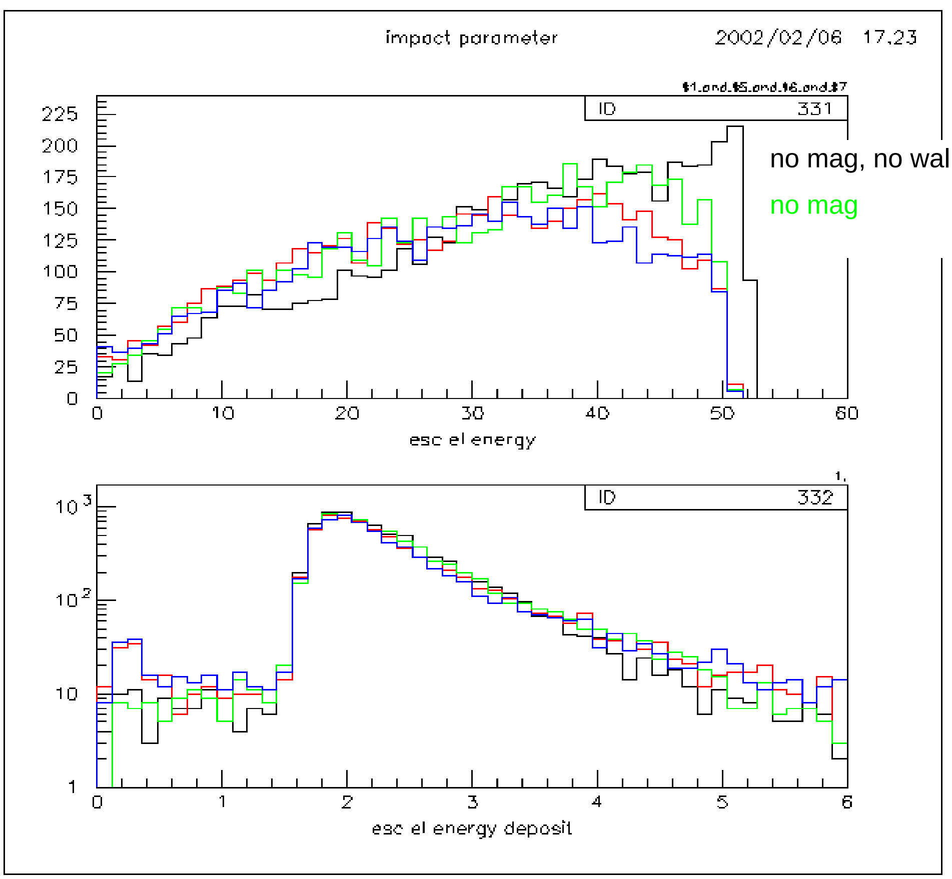

fig. 2 energy and energy deposition in ESC

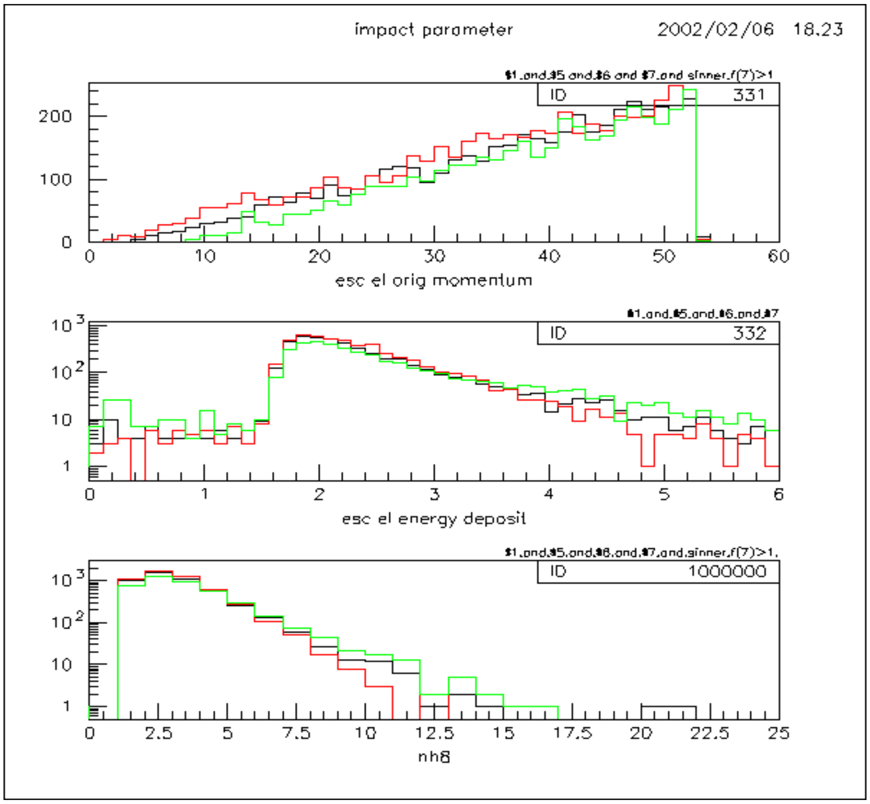

fig.3 run 503,501,506. Effect of passive absorber is shown. Last row is hit multiplicity in ESC with total energy deposition >1MeV.

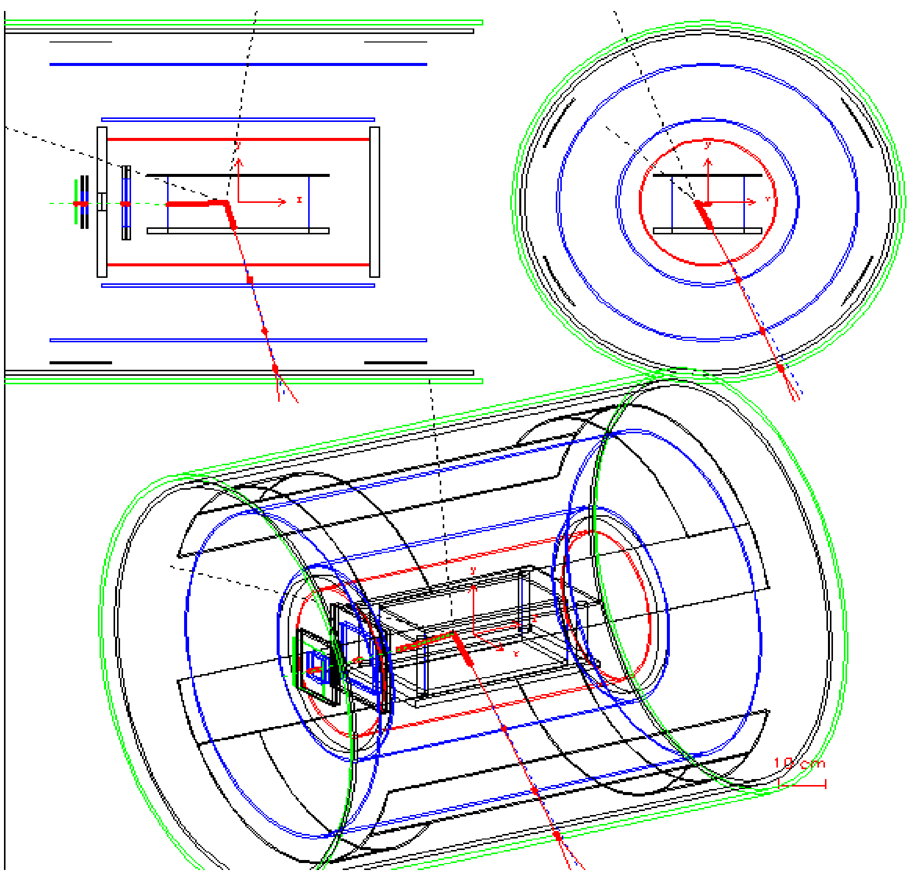

fig.4 geometry for run 506, far

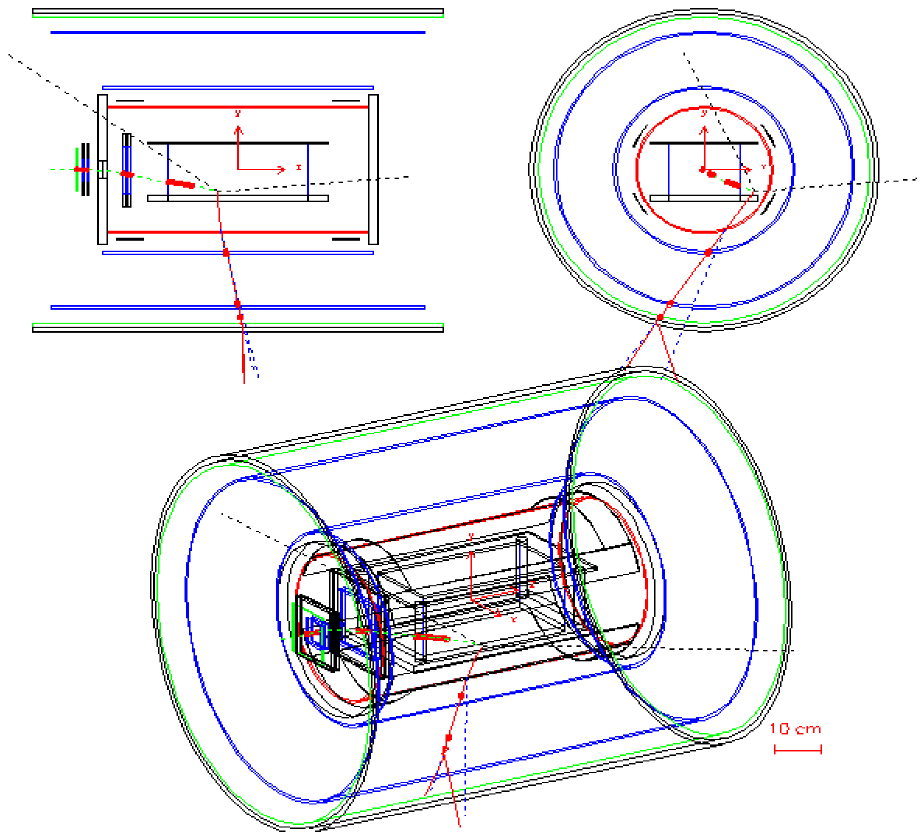

fig.5 geometry for run 605, close

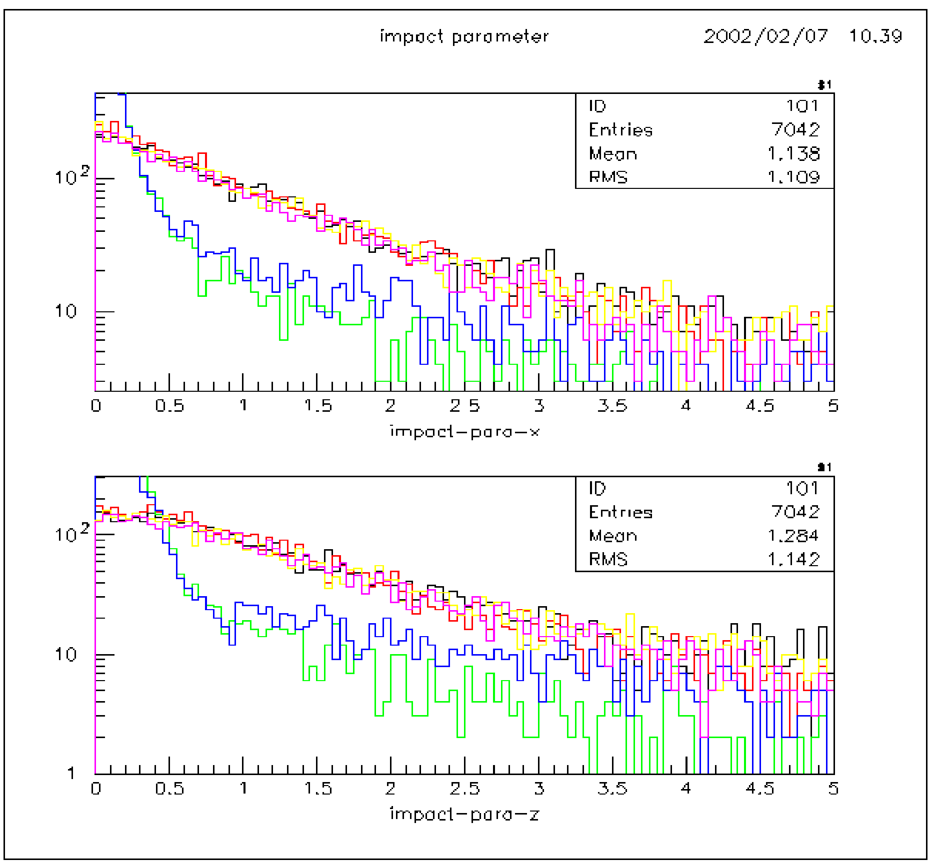

fig. 6 impact para for run 60x series, again vessel wall is dominating

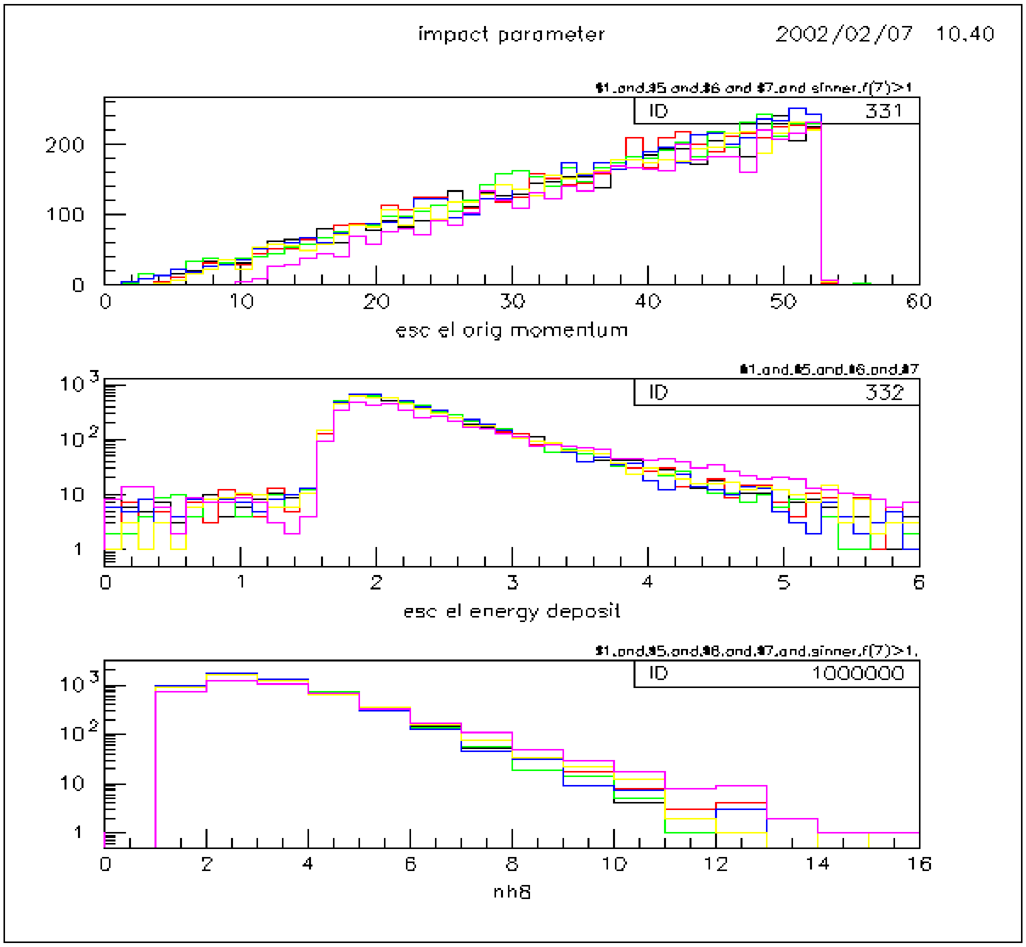

fig.7 energies for run 60x series

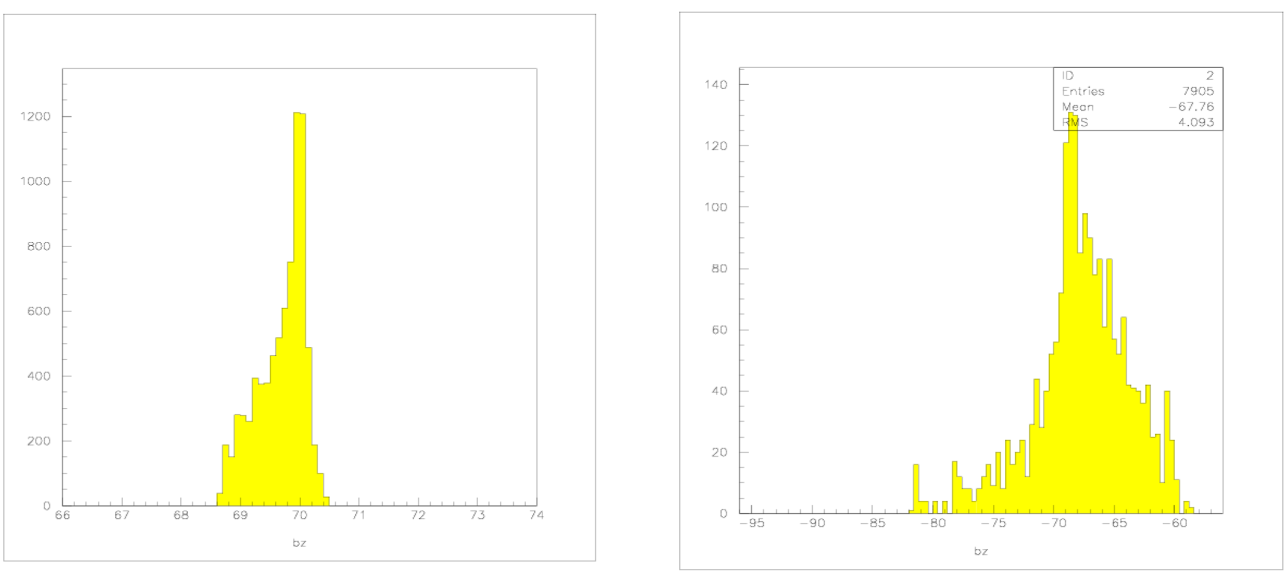

fig.8 Bz distribution over fiducial for far and close magnet option, respectively

Comparison of field variation of small and large magnet

small coil: placed around TPC pressure vessel , radius = 15 cm, length = 50 cm

large coil: placed around Sindrum 5 chamber , radius = 34 cm, length = 122 cm

x = horizontal
y = beam direction
z = vertical

given errors are kind of 2 sigma errors read from the B_i histogram plots.

magnet	B_x field	B_y field	B_z field
small coil	0 ± 1 gauss	0 ± 0.25 gauss	69 ± 5 gauss
large coil	0 ± 0.05 gauss	0 ± 0.02 gauss	70 + 0.5 - 1.4 gauss

given errors are FWHM errors read from the B_i histogram plots.

magnet	B_x field	B_y field	B_z field
small coil	0 ± 0.2 gauss	0 ± 0.05 gauss	69 ± 2 gauss
large coil	0 ± 0.05 gauss	0 ± 0.01 gauss	70 + 0.2 - 0.3 gauss