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SDC
SOLENOIDAL DETECTOR NOTES

SOURCE CALIBRATION ACCURACY

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01 Introduction

Sources have previously been used to calibrate scintillator calorimeters and will also be used in SDC[1] . This note presents the results of an EGS4 study of the sensitivity of the source calibration to the type and location of the source, the impact of a magnetic field on calibration, and the degree to which the measured signal represents the illuminated tile. The study is a continuation of calculations and measurements performed at the SSC lab and previously reported at calorimeter meetings.

The EGS geometry consists of 36 cylindrical layers, each consisting of 4 mm lead, 4 mm scintillator, and 2 mm air. Each scintillator layer is divided into two pieces for the purpose of EGS scoring; a 10.8×10.8 cm tile centered on $y = 0$ and $z = 0$, and the remainder.

Two different photon energies have been used, 0.8 MeV and 122 keV. These approximately correspond to the photons emitted by ^{54}Mn and ^{57}Co, which have been selected because they are pure gamma sources—they have no β decays. A pure gamma source may have less sensitivity to magnetic fields and to ionization losses in the tile wrapping and other stray material. The sources were placed at $y = 0$ and $z = 0$, at a radius (x) ranging from 0 to 1.3 mm from the surface of eighteenth scintillator layer.

02 RESULTS

Table 1 summarizes the distribution of energy between the illuminated tile (*i.e.*, layer 18, $|y| < 5.4$ cm, $|z| < 5.4$ cm), the other tiles in the tower, and the scintillator in other towers. With the 0.8 MeV source, only 45% of the energy deposited in scintillator is deposited in the desired tile (Fig. 1). Note that the quantity actually measured is the energy in the tower, not in the individual tile. The low energy gamma gives a substantially cleaner signal, in that the energy deposited in the tower is confined to the desired tile only. Although the attenuation length for a 122 keV gamma is substantially longer in iron than in lead (Table 2), the division of energy will be nearly clean in the hadron calorimeter, due to the greater plate thickness.

The energy deposited in the tile per decay is approximately ten times lower with the 122 keV gamma than with the 0.8 MeV gamma; approximately 0.002 MeV per decay versus 0.020 MeV per decay. For a PMT gain of 6000 and assuming 3 photoelectons per MeV deposited in the tile (corresponding to 250 p.e./incident-GeV), the corresponding PMT currents are 0.2 nA/mCi and 2.0 nA/mCi.

The sensitivity of the signal to source location is summarized in Fig. 2. With the 0.8 MeV photon, the measured signal (the tower sum) is less sensitive than the desired signal (the tile energy), approximately 5%/mm vs 10%/mm. The tile signal with the 122 keV gamma is even more sensitive to location, approximately 10% in 0.6 mm. (The tower signal is identical). The reduced sensitivity of the 0.8 MeV gamma may be due to rescattering from the lead into the scintillator. The solid line in Fig. 2 is the tile signal from the 122 kev source with no other scintillator or lead in the calculation. The agreement with the complete calculation indicates the absence of rescattering with the low energy gamma.

These results are comparable to those found at the SSCL. Note that this sensitivity would be reduced by running the source through the center of the tile perpendicular to its face. The source tube would then represent a projective hole in each tile.

The dependence of the tile signal on the magnitude of the solenoidal field is shown in Fig. 3. For the low fields expected in the barrel, the change in the energy deposited in the tile is 7%/kG. The study has not been done for the fields expected in the endcap or for the lower energy gamma. The light yield of the scintillator itself has a dependence on the magnetic field that must be also considered during calibration[2] .

Table 1. Fraction of energy deposited in scintillator that is deposited in the desired tile, the other tiles in the tower, and elsewhere, for 0.8 MeV and 122 keV gamma sources. The source is 0.3 mm from the tile surface.

Gamma Energy	Fraction of Energy in		
(MeV)	Tile	Rest of Tower	Elsewhere
0.8	0.40	0.43	0.17
0.122	0.90	0.00	0.10

Table 2. Absorption length (cm) for 0.8 MeV and 122 keV gammas. (Absorption length is distance to reduce number of photons to e^{-1} of initial number).

Gamma Energy (Mev)	Lead	Iron	Polystyrene
0.8	1.5	6.8	24
0.122	0.03	0.63	20

03 Summary

The relatively low energy gamma emitted by ^{57}Co is energetic enough to penetrate a scintillator tile but not a lead layer. As a consequence, the measured signal corresponds almost entirely to the tile being calibrated. In contrast, only half of the signal from ^{54}Mn is from the tile. ^{57}Co is an attractive candidate for use as a calibration source. It does have the disadvantages of low energy yield

per decay, requiring a hotter source to achieve the same current, and a relatively short half life, 9 months. To use it as part of a system that calibrates each tile to 1%, the radial distance of the source must be defined to less than $100\mu m$. The magnetic field strength must also be known and its effect on the scintillator understood.

REFERENCES

1. V. Barnes, *et al*, "Calibration of scintillating calorimeters", Proceedings of the ICC, Oct. 1990.
2. J. Mainusch, *et al*, "Influence of Magnetic Fields on the Response of a Uranium Scintillator Sampling Calorimeter", DESY 91–027, April 1991.

FIGURE CAPTIONS

1. Energy deposited in each layer of a tower by a 0.8 MeV γ source at layer 18.
2. Energy deposited by a ^{54}Mn source (0.8 MeV γ) in the full EM tower (squares) and in a single tile in that tower (diamond), and by a ^{57}Co source (122 keV γ) in a single tile (cross-diamond), as a function of the radial distance between the tile surface and the point source. All cases are normalized to the 0 mm case. With the ^{57}Co source, the tile and full tower signals are identical. The solid curve is the ^{57}Co calculation with a single tile only—no lead or additional scintillator. Curves are to guide the eye.
3. Energy deposited by a ^{54}Mn source in the illuminated tile as a function of the applied solenoidal field. The two points at small field represent the difference between no applied field and a very small applied field; the effect is almost certainly computational.

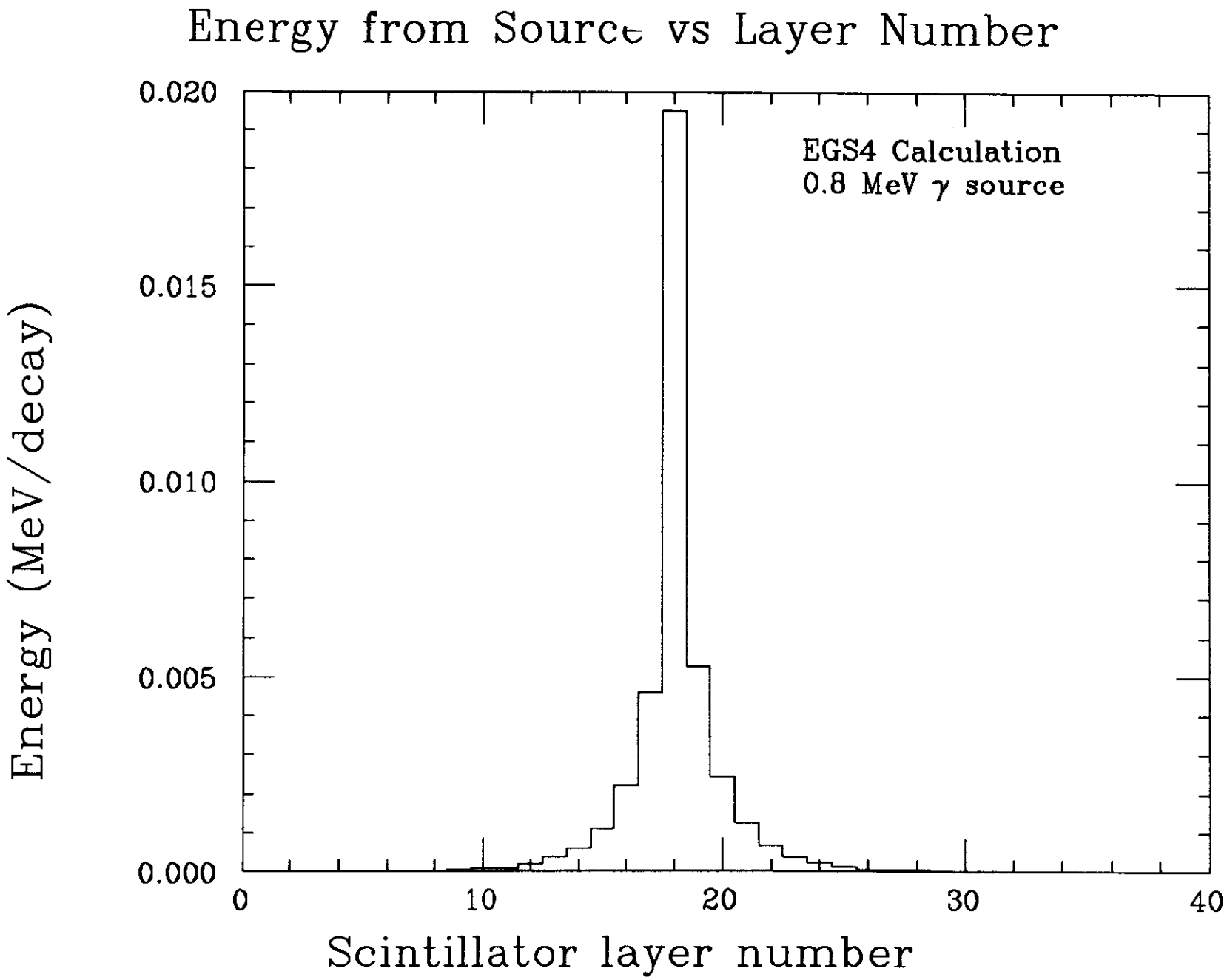
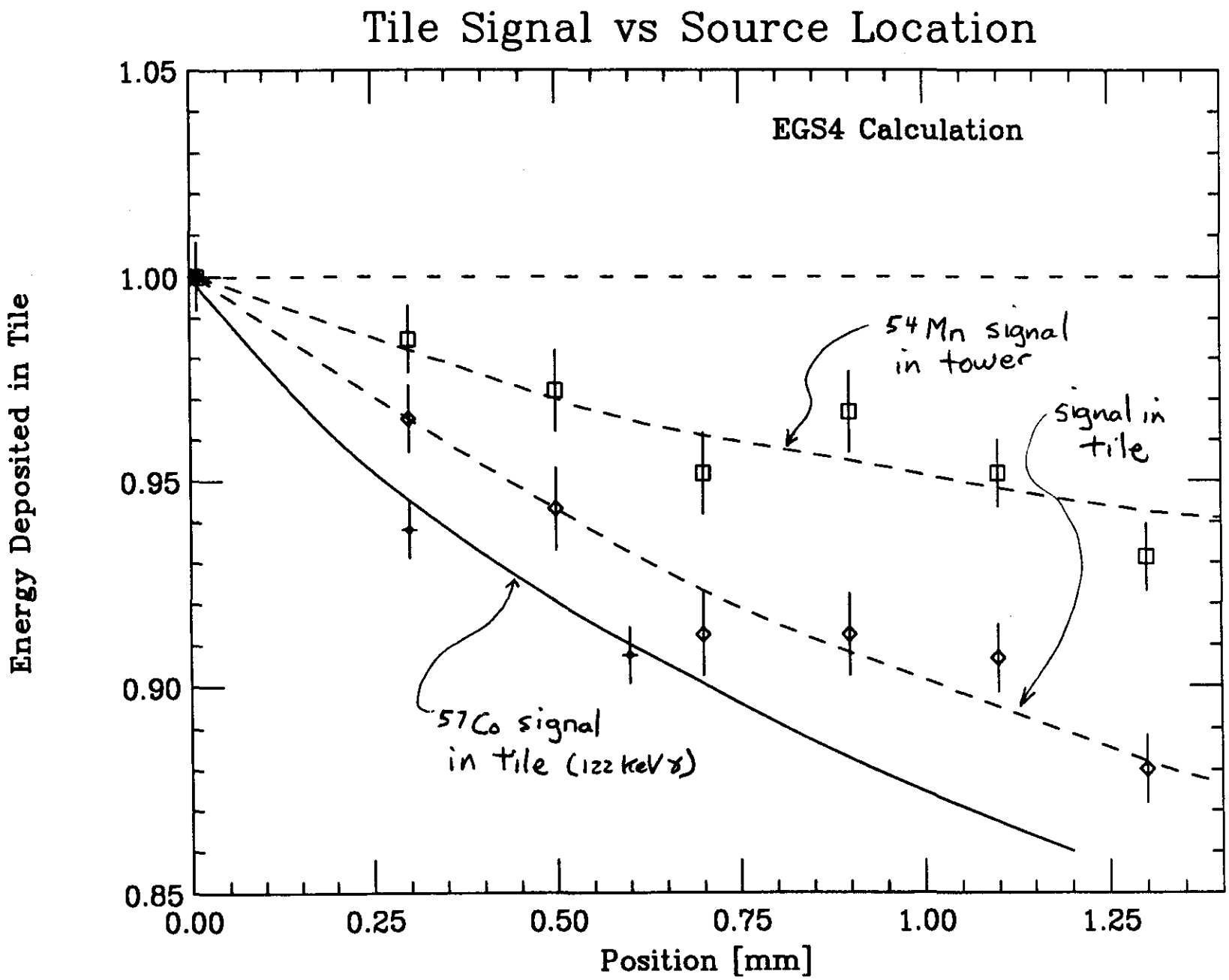

Energy from Source vs Layer Number
EGS4 Calculation
0.8 MeV γ source
Energy (MeV/decay)
0.020
0.015
0.010
0.005
0.000
0
10
20
30
40
Scintillator layer number

Fig. 1


Tile Signal vs Source Location
EGS4 Calculation
Energy Deposited in Tile
Position [mm]
1.05
1.00
0.95
0.90
0.85
0.00
0.25
0.50
0.75
1.00
1.25
54Mn signal in tower
signal in tile
57Co signal in tile (122 keV γ)

Fig

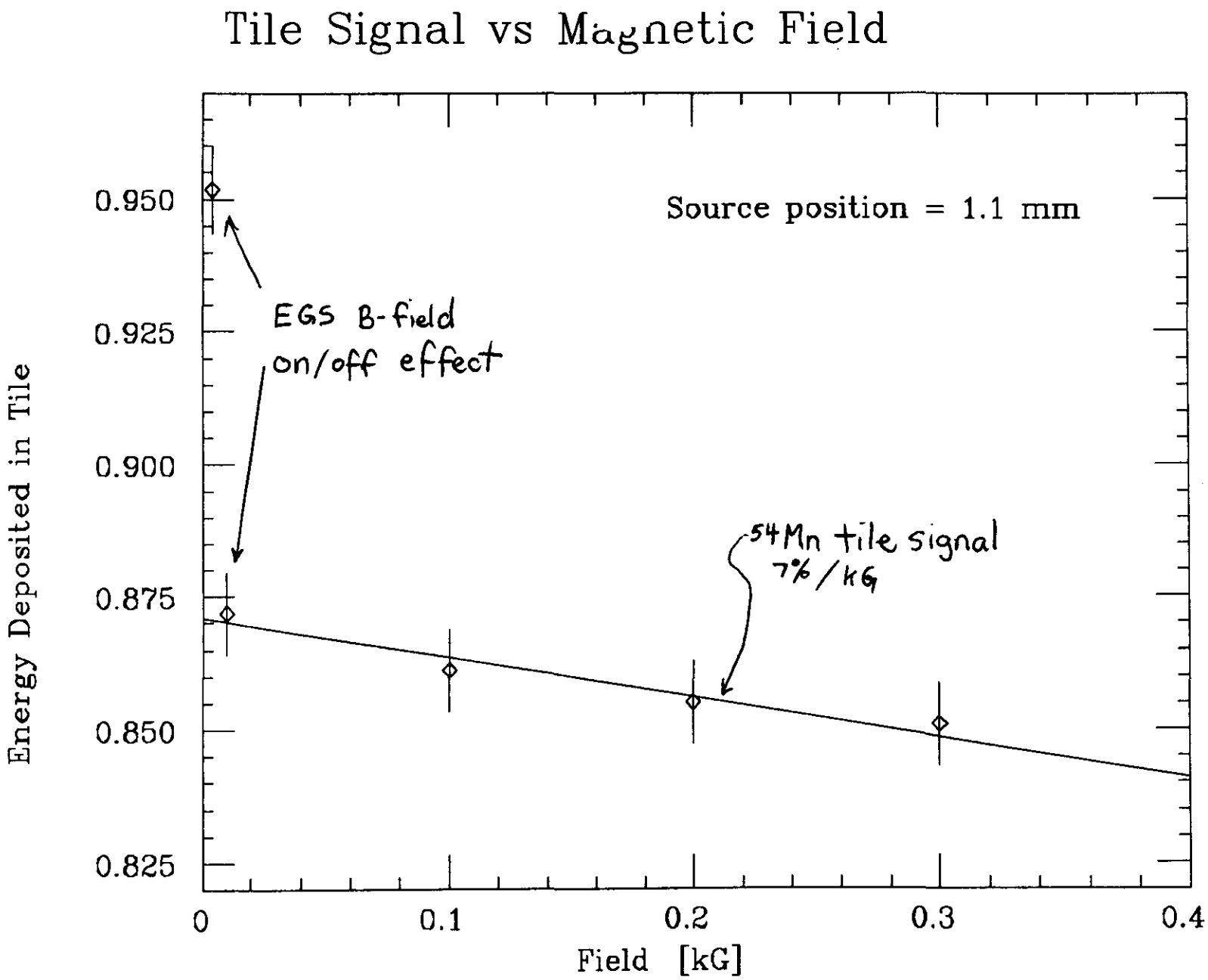

Tile Signal vs Magnetic Field
Source position = 1.1 mm
EGS B-field
on/off effect
54Mn tile signal
7%/kG
Energy Deposited in Tile
0.950
0.925
0.900
0.875
0.850
0.825
0
0.1
0.2
0.3
0.4
Field [kG]

Fig. 3