Document Title The PSD correction as function of PSD selection and D1E

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Abstract

This document describes the determination of the acceptance probabilities of photons as function of D1 energy deposit and applied Pulse Shape Discriminator (PSD) selection.

Document references

- Data selections and related normalisations, J.W. den Herder and R. van Dijk, 21-FEB-1992, COM-RP-ROL-DRG-016
- PSF normalisations: the PSD correction, R. van Dijk, 15-NOV-92, COM-RP-ROL-DRG-035

1. Introduction

As described in documents COM-RP-ROL-DRG-016 and COM-RP-ROL-DRG-035, the PSD distribution for calibration data deviates significantly at low D1 energies from the Gaussian shape it has at higher D1 energies (Fig. 1). Spectral analysis revealed that the high PSD events at low D1 energy deposits are ‘normal’ source photons with a badly determined PSD value (calibration data with a TOF selection of 110-130 may be considered neutron free).
A selection on PSD therefore rejects a certain fraction of normal events. This fraction depends both on *D1 energy deposit* as well as *PSD selection*, and will be larger for lower D1 energies and narrower PSD selections.
To account for this loss of good events, the Point Spread Functions (PSFs) need to be modified based on the D1 energy distribution of the assumed spectrum as well as the PSD selection on the data. This step requirs knowledge of the acceptance probability of photons as function of D1 energy deposit and PSD selection.

In COM-RP-ROL-DRG-016 the acceptance probability of events with a D1 energy deposit E_{D1} subject to a PSD selection [0.0,110.0] was determined in a few steps. Firstly, PSD distributions were created in small E_{D1} ranges. Secondly, for each E_{D1} range the ratio of the total number of counts in the PSD intervals [0.0,110.0] and [0.0,256.0] were determined. These ratios, which denote the desired acceptance probabilities in the E_{D1} ranges, were fitted as function of E_{D1}. The acceptance probabilities determined this way are presently being used in RES and SIM.

This report extends the work done in COM-RP-ROL-DRG-016 to all possible PSD selections (with some restrictions, see section 3.2). This is accomplished by *fitting* the PSD distributions mentioned in step 2 above. Section 2 describes the analysis and data used, while section 3 shows some results. The implementation in the COMPASS system is described in section 4.

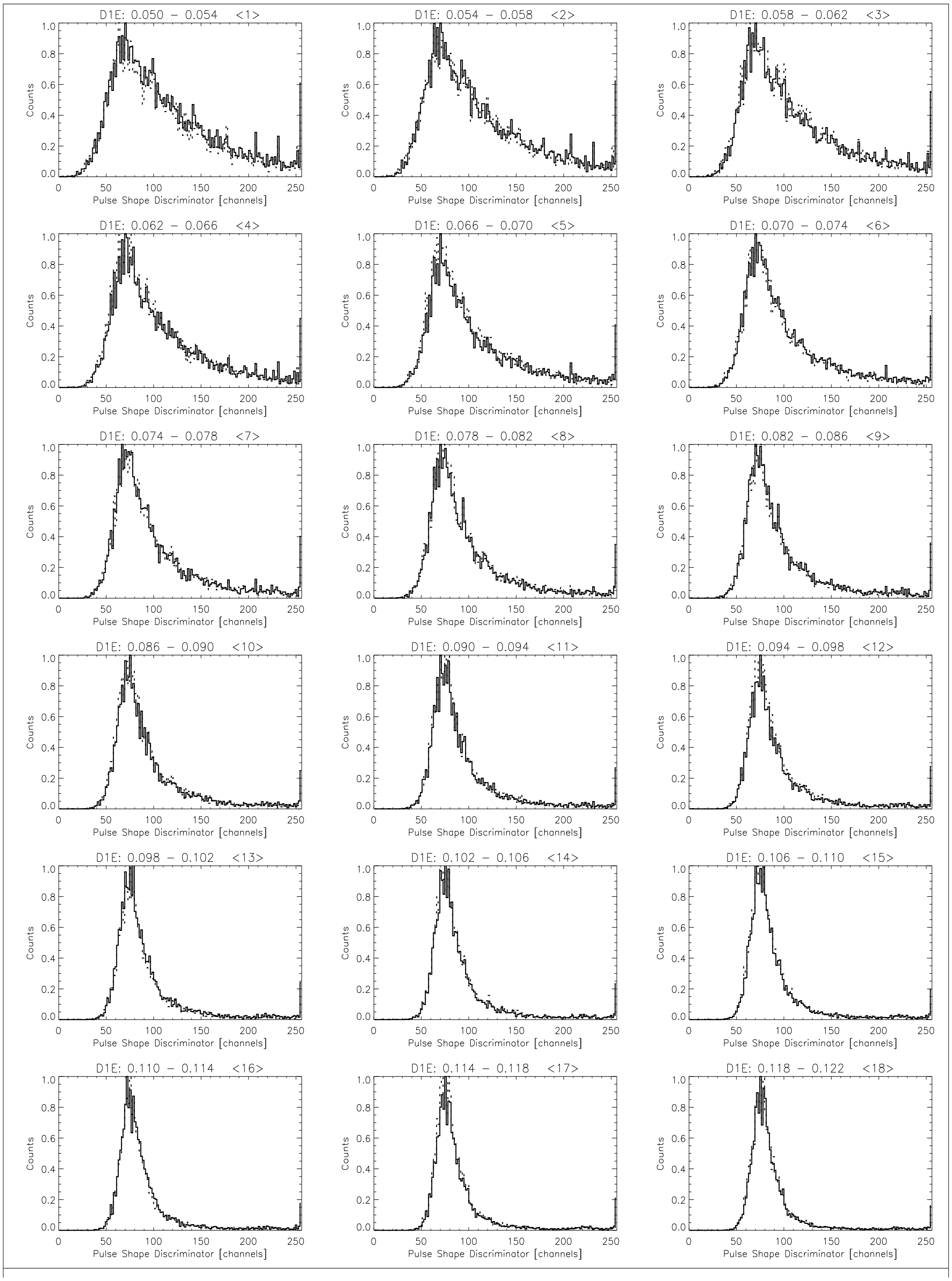

Fig. 1. Normalised PSD distributions for calibration data for the sources Na24-1,2,3 (solid line) and Mn54 (dots). Applied selections: 110<TOF<130, no veto.

2. Analysis

For the analysis, I used all available data of the telescope PSF calibrations for the following sources:

Table 1: Overview of calibration data used

Group	Source	Analysis sets	Line energies [MeV]
1	Na 24-1,2,3	3101..	1.37, 2.75
2	Mn 54	3104..	0.835
3	Na22-1,2	3105..	0.511, 1.275

All of the REM datasets were processed using IFCDDP to generate CP1/2 coefficients. Hereby ROL-CPP-10324 (MAIN status) was used for the PSD corrections. Finally EVPRNN was run to create EVP datasets from the REM and CP1/2 datasets. The relevant dataset identifiers can be found in tables 2, 3 and 4.

The large number of photons (~9.500.000) allowed creation of PSD distributions in small ranges of D1 energy deposit (2 keV). Such distributions were made for each of the groups mentioned in Table 1. Fig. 1 shows the normalised PSD distributions of groups 1 and 2 for D1 energy deposits less than 122 keV with a width of 4 keV (group 3, not shown here, gives similar distributions). This figure shows that for small enough D1 energy deposit windows, the PSD distribution is independent of source energy and zenith angle. It thus confirms that the D1 energy deposit is probably the *only* parameter that is of influence on the PSD distributions.

2.1 The fit function

Several fit functions were used to try to fit the data. Most of these functions, like the log normal and the gaussian, can fit the PSD distributions only at the high D1 energies. Therefore I composed a function which can fit the PSD distributions at all D1 energies. This so called *PSD function* has the additional advantage that the fits made at high D1 energies are better than those made with the above mentioned functions.
The PSD function, consisting of a *threshold function* times a *Gaussian*, has the following form:

$$F(x) = \begin{cases} a_3 \exp\left(-\frac{1}{2}\left(\left(\frac{x-a_1}{a_2}\right)^2 + a_4(x-a_1)^2 + a_5(x-a_1)\right)\right) & \text{for } x < a_1 \\ \text{and} & \\ a_3 \exp\left(-\frac{1}{2}\left(a_4(x-a_1)^2 + a_5(x-a_1)\right)\right) & \text{for } x > a_1 \end{cases}$$

where x denotes PSD value [channels].
The *threshold function* itself consists of a left flank of a Gaussian below $x = a_1$ (with amplitude 1,

Table 2: All available calibration data for sources Na24-1,2,3 in analysis sets 3101... Total number of events ~3.400.000. The dataset MPE-REM-11446 could not be transferred from IBM to SUN.

Analysis set	External run nr.	MPE-REM-	ROL-EVP-	number of events
310102	491	10481	11262	207766
	492	10485	11265	201603
	493	10495	11266	102669
310104	484	10504	11267	263170
	485	11445	11268	263628
	486	11446		
	487	11447	11269	174661
310107	497	11456	11270	7249
	498	11457	11271	189313
	499	11458	11272	191750
	500	11459	11273	184455
	501	11460	11274	181046
310109	508	11506	11275	142785
	509	11498	11276	168761
	510	11500	11277	166818
310112	513	11507	11278	150524
	514	11508	11279	147788
310116	518	11467	11280	68960
	551	11518	11281	149520
	552	11519	11282	159163
310119	570	11523	11283	148
	571	11522	11284	178524
	572	11521	11285	111324

mean a_1 and sigma a_2) and equals 1 above $x = a_1$. The other 3 coefficients (a_3, a_4 and a_5) describe the *Gaussian*. The combination of these 2 functions can describe all of the shapes shown in Fig. 1. Note that if the Gaussian of this PSD function is expressed in the normal terms of amplitude, mean and width, the fit procedure does not converge at low D1 energies. The reason for this is that, because of the additional threshold function, the mean shifts unconstrained to lower (and negative) PSD values while increasing the width and amplitude. This is different for the PSD function shown above because of the connection with a_1.

Table 3: All available calibration data for source Mn54 in analysis sets 3104... Total number of events ~2.000.000.

Analysis set	External run nr.	MPE-REM-	ROL-EVP-	number of events
310402	1250	12082	11300	106742
	1251	12083	11301	115103
	1252	12084	11302	103045
	1253	12085	11303	16435
310404	1259	12714	11304	82084
	1260	12715	11305	45801
	1261	12716	11306	63200
	1262	12717	11307	105669
	1263	12718	11308	103796
	1264	12719	11309	43519
310406	1274	12740	11311	98100
	1275	12743	11312	99529
	1276	12742	11313	102728
310408	1278	12756	11314	117901
	1279	12757	11315	117288
	1280	12758	11316	117404
	1281	12759	11317	117607
310410	1290	12780	11318	110958
	1291	12781	11319	110322
	1292	12782	11320	110456
	1293	12783	11321	110496

Table 4: All available calibration data for sources Na22-1,2 in analysis sets 3105... Total number of events ~4.100.000. The datasets MPE-REM-12787 and MPE-REM-12943 could not be transferred from IBM to SUN.

Analysis set	External run nr.	MPE-REM-	ROL-EVP-	number of events
310502	1299	11886	11335	231335
	1300	12738	11336	233459
310503	1301	11887	11337	168824
	1302	11888	11338	133256
310506	1306	12787		
	1307	12788	11339	57372
310507	1308	12789	11340	154203
	1309	12790	11341	192030
	1310	12791	11342	59608
310509	1313	11912	11343	151663
	1314	11913	11344	151084
310510	1315	11983	11345	95840
	1316	11927	11346	56718
310513	1321	12888	11347	185526
	1322	12889	11348	236961
	1323	12886	11349	98058
310515	1326	12885	11350	204232
	1327	12940	11351	246444
	1328	12941	11352	95976
310516	1329	12942	11353	246994
	1330	12943		
	1331	12944	11354	50296
310519	1334	12881	11355	153402
	1335	12880	11356	123007
310520	1336	12874	11357	155255
	1337	12875	11358	134119
310522	1295	12904	11359	116816
	1296	12906	11360	83741
310525	1405	11971	11361	139571
	1406	11972	11362	105188

3. Results

Fits have been made to the sum of the data listed in Table 1 in 2 keV D1 energy intervals from 30 up to 830 keV, and in 4 keV intervals from 830 up to 1630 keV. Figs. 2 and 3 show some PSD distributions and their fits. To display a wider range of D1 energies, the fits shown here were made for 4 keV wide D1 energy intervals from 50 to 122 and from 1050 to 1122 keV. Note that the overflow channel at PSD value 255 is kept out of the fit range.
Fig. 4 shows for 4 of the 5 parameters of the fit function their dependence on D1 energy (a_3 is just a scaling parameter and is not shown). All parameters show a smooth behaviour below D1 energies of ~200 keV, while above this energy the parameter values start varying wildly. The reason for this is that the mean of the Gaussian of the fit function does not differ significantly from a_1 at higher energies. Nevertheless, the fits at these higher energies are of good quality and the parameter values can be used as described in section 4.
The fit parameters are used to reconstruct PSD distributions as a function of D1 energy. For a given PSD selection [PSDL,PSDH] and an event with D1 energy deposit E_{D1}, we can calculate the integrals of the fit function for the intervals [PSDL,PSDH] and [0,256]. The ratio of these integrals is the acceptance probability of the event.

3.1 Comparison with previous results

Fig. 5. shows the acceptance probabilities obtained with the results from this report together with the results previously shown in COM-RP-ROL-DRG-016. Although the overall shapes are similar, the empirical points lie somewhat below the analytical curve, especially at higher D1 energies.

This discrepancy can be explained as follows. The emperical PSD distribution contains, besides the component which is accurately described by the PSD function at all D1 energies, a low and roughly constant level of a few counts per bin. This distribution extends even beyond PSD values of 256.0, as is clear from the overflow channel. In the emperical derivation, these counts contribute to the sum of the PSD distribution in the interval [0,256] thus lowering the acceptance probability (the overflow channel itself was excluded from the summation). To check whether this distribution is indeed the cause for the discrepancy, I included another fit parameter in the fit function to describe the constant level. The acceptance probabilities calculated using this extended fit function are indeed very similar to the emperically derived ones. The nature of the events causing this distribution is unknown. We do not believe, however, that they are normally scattered photons.

> **Since we are not sure of the true nature of the events causing the constant level, I did not include the fit component describing this constant level in the fit function actually used.**

Another factor playing a role, is the presence in some of the higher D1 energy windows of a bin around PSD = 80 containing several more counts than to be expected from a Gaussian distribution. This bin cannot be fitted accurately by the PSD function resulting in a slightly different distribution during the reconstruction from the fit parameters. The influence of this discrepancy, however, is almost negligible.

3.2 The ‘Forbidden Interval’

Since I fitted the PSD distributions up to 1630 keV, nothing is known about the acceptance probabili-

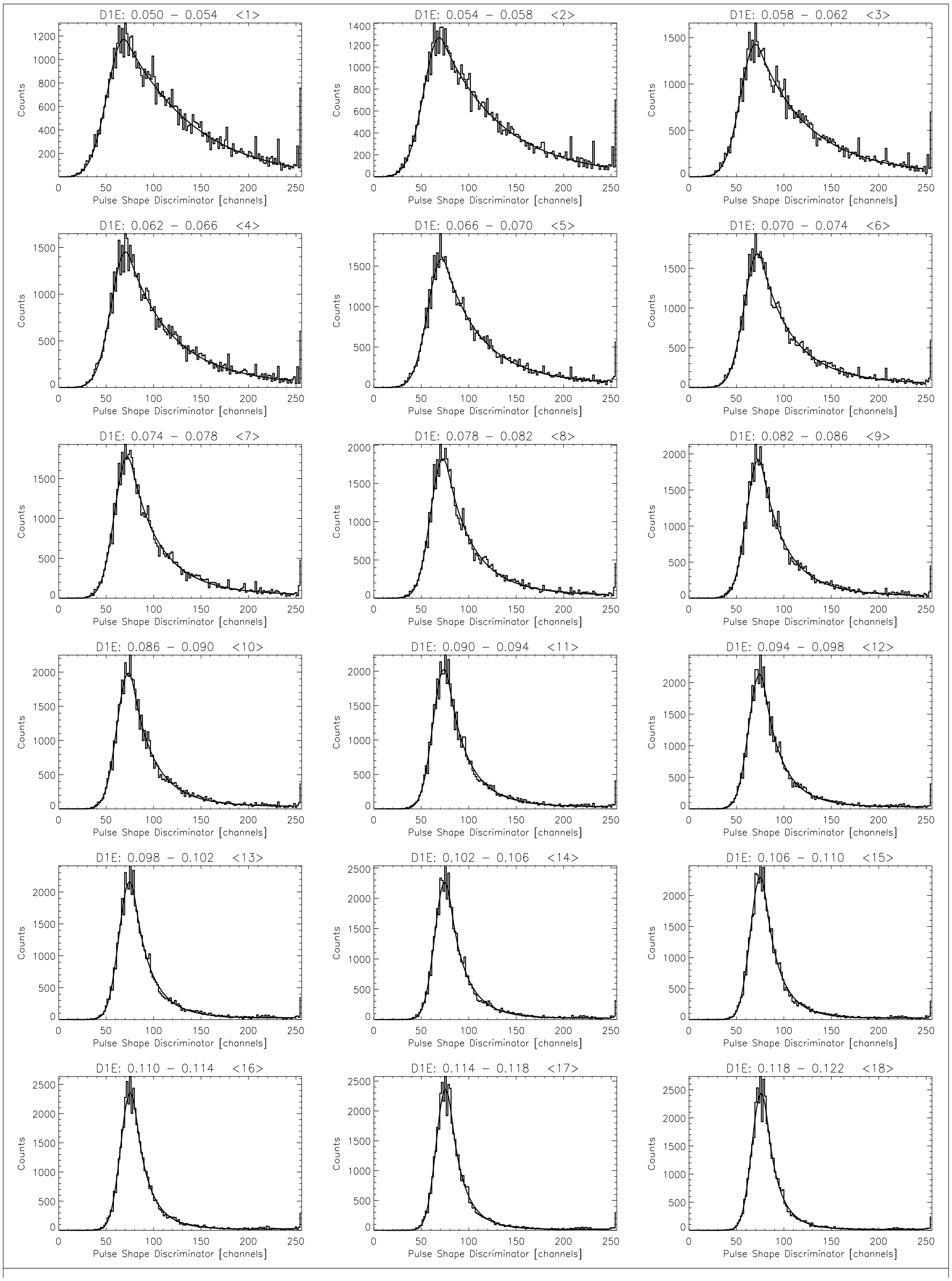

Fig. 2. PSD distributions and fits using the PSD function. The data consist of the sum of the data mentioned in Table 1. D1 energy ranges from 0.050 to 0.122 MeV, step 4 keV.

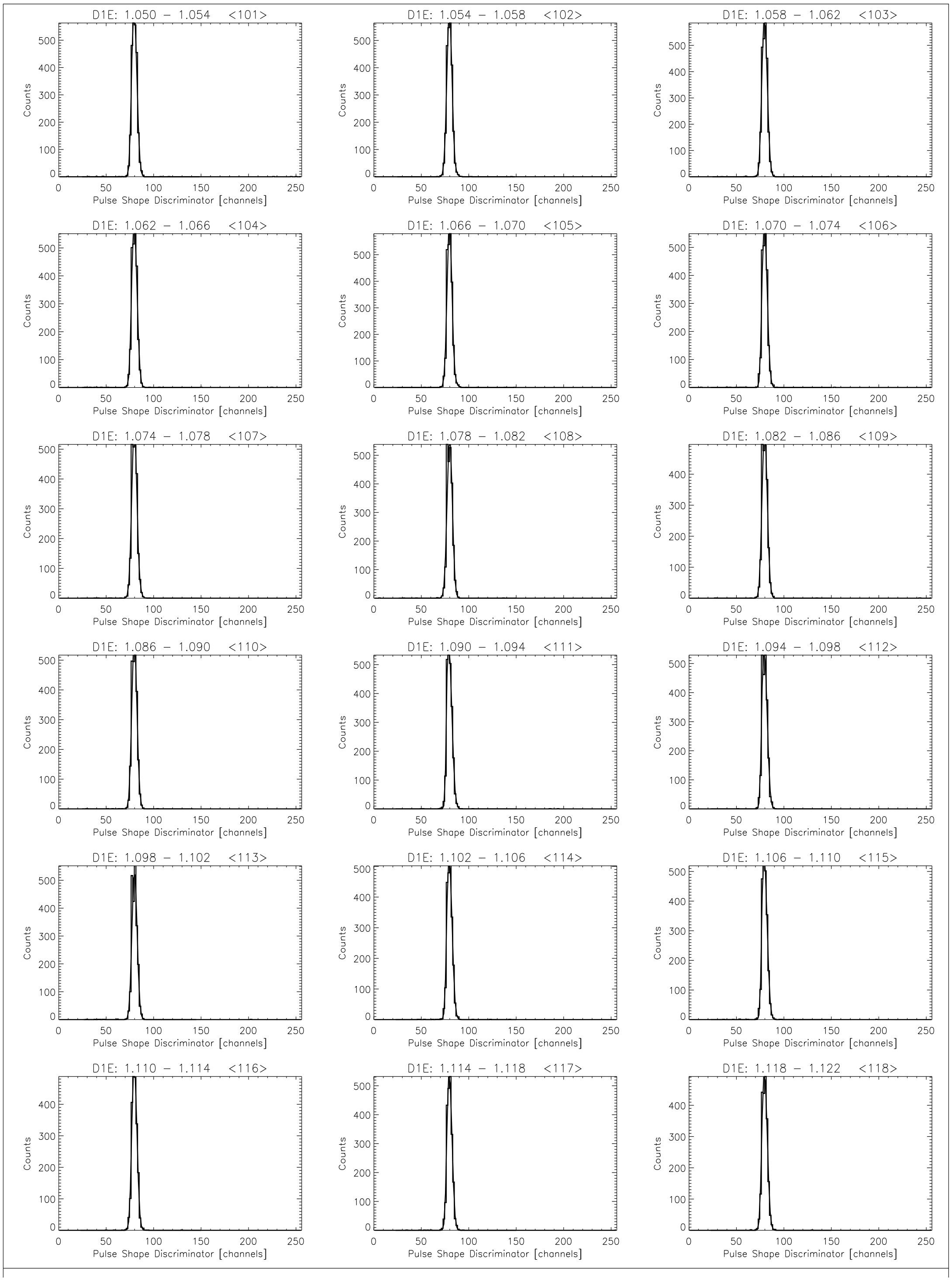

Fig. 3. PSD distributions and fits using the PSD function. The data consist of the sum of the data mentioned in Table 1. D1 energy ranges from 1.050 to 1.122 MeV, step 4 keV.

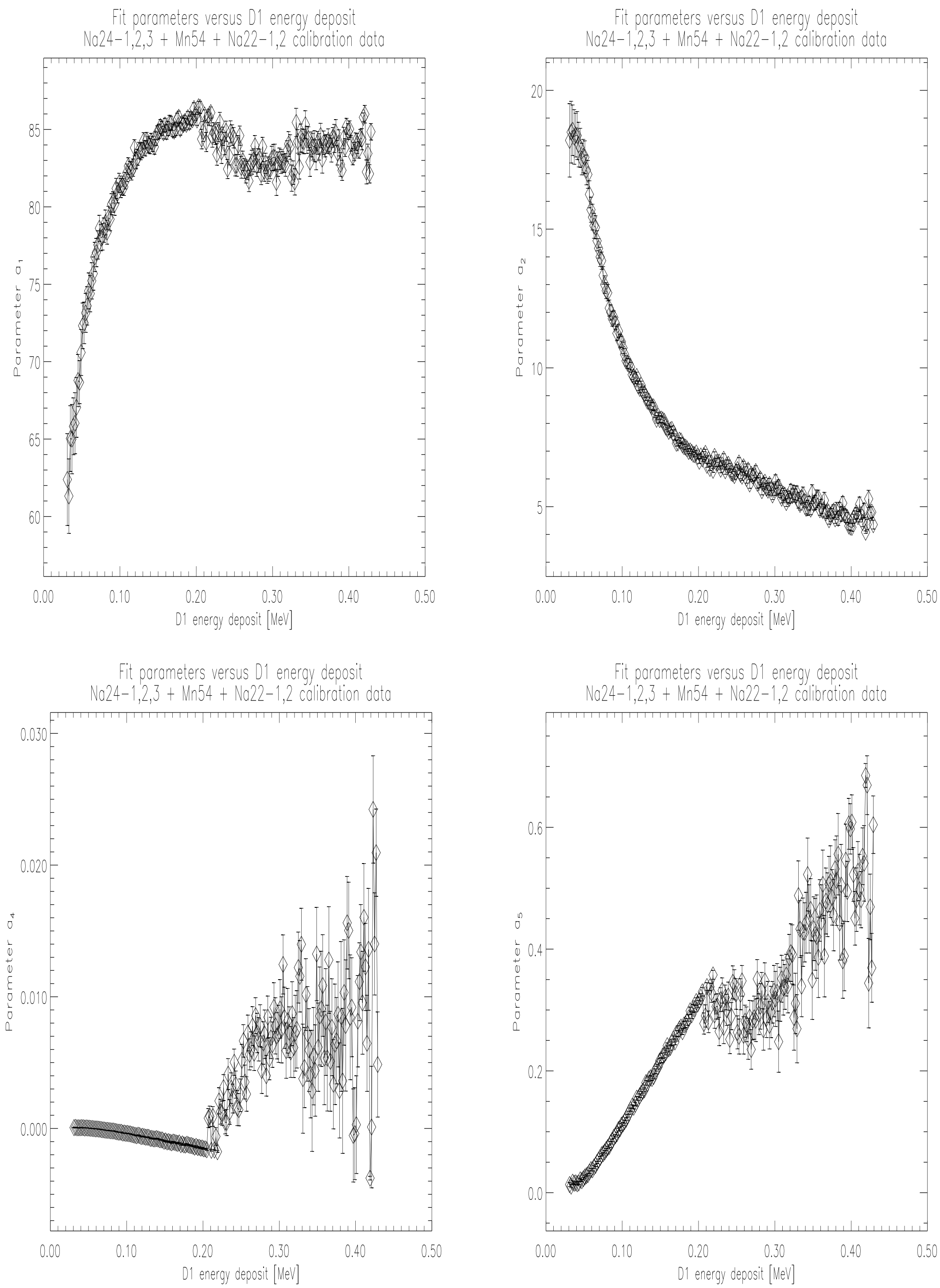

Fig. 4. The fit parameters a_1, a_2, a_4 and a_5 for D1 energies from 30 up to 430 keV, width 2 keV. Parameter a_3 is just a scaling parameter and is not shown here.

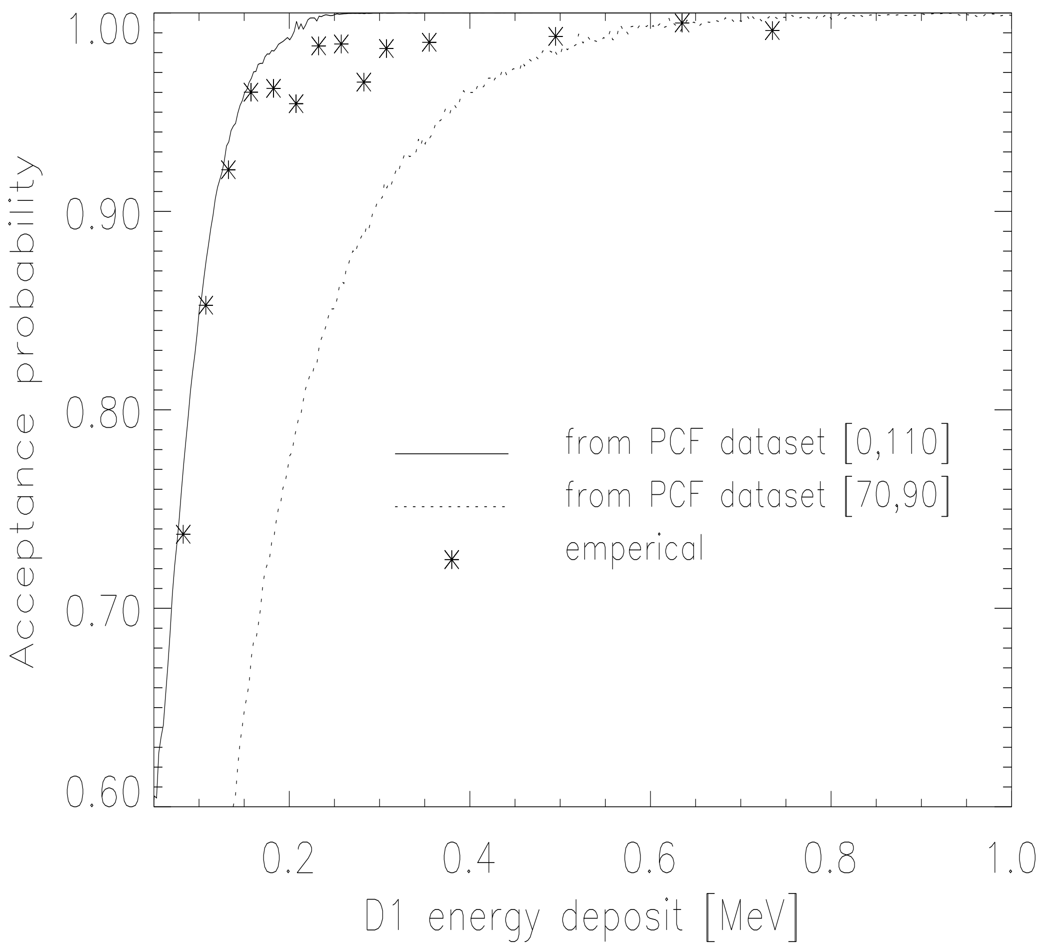

Fig. 5. Acceptance probabilities as a function of D1 energy deposit. The asterisks denote the emperically derived acceptance probabilities as described in COM-RP-ROL-DRG-016 for Boron data with a PSD selection of [0,110]. The solid line shows the acceptance probabilities for the same PSD selection [0,110] from the subroutine PPCFRD in library IFCPCF01 with ROL-PCF-5 as input dataset. For comparison the acceptance probabilities as a result of a [70,90] PSD selection are also plotted (dotted line).

ties above this energy. We do know, however, that the PSD distributions above this energy are Gaussians with a fairly small width, for which all counts are between PSD values 70 and 90. For a PSD selection which encloses this interval the acceptance probability above 1630 keV is therefore equal to 1. If one of the boundaries of the PSD selection is inside this interval, however, the acceptance probability above 1630 keV cannot be determined. Because of the above, neither of the two boundaries of the PSD selection is allowed to lie within the interval [70,90] (the ‘Forbidden Interval’).

4. Implementation

To make the information described in this report available to COMPASS, I created the library IFCPCF01. This library contains two subroutines which are of interest to the user:

- PSDINI(TPAR,PSDL,PSDH,PRLU,ERLU,RETGP,RETNO)
- PSDPRB(PRLU,ERLU,ENERG,ACCP,RETGP,RETNO)

PSDINI reads the fit parameters contained in the PCF dataset, calculates the acceptance probabilities for the PSD selection [PSDL,PSDH] at the D1 energies for which the fit parameters were derived, and finally interpolates these acceptance probabilities on a finer and equidistant D1 energy grid. If only one PCF dataset is used (as will generally be the case), and if the PSD selection does not change, this subroutine needs to be called only once, *before* a call to PSDPRB is made.

PSDPRB returns the acceptance probability ACCP for an event with D1 energy ENERG [MeV]. This acceptance probability is a number between 0 and 1 denoting the chance of the event having assigned a PSD value in the interval [PSDL,PSDH]. The user can then use his favorite random number generator to decide whether or not he accepts the event. Note that before a call to PSDPRB can be made, the acceptance probabilities have to be initialised by a call to PSDINI.

4.1 Available PCF datasets

The following PCF dataset is available for use with the above mentioned subroutines PSDINI and PSDPRB:

ROL-PCF-5

It contains fit parameters for 2 keV D1 energy intervals from 30 up to 830 keV and for 4 keV intervals from 830 up to 1630 keV. The fit function used is the function described in section 2.1 of this report, which was fitted to the sum of the data from Table 1.