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Performance evaluation of the KM-200 amplifier in a standard safeguards neutron well-counter

WP NDA, Action sheet 59

Pedersen B., Bogucarska T., Varasano G., Holzleitner L., Ianakiev K., Iliev M., Stave S.,Swinhoe M., De Baere P., Vaccaro S., Couland M.

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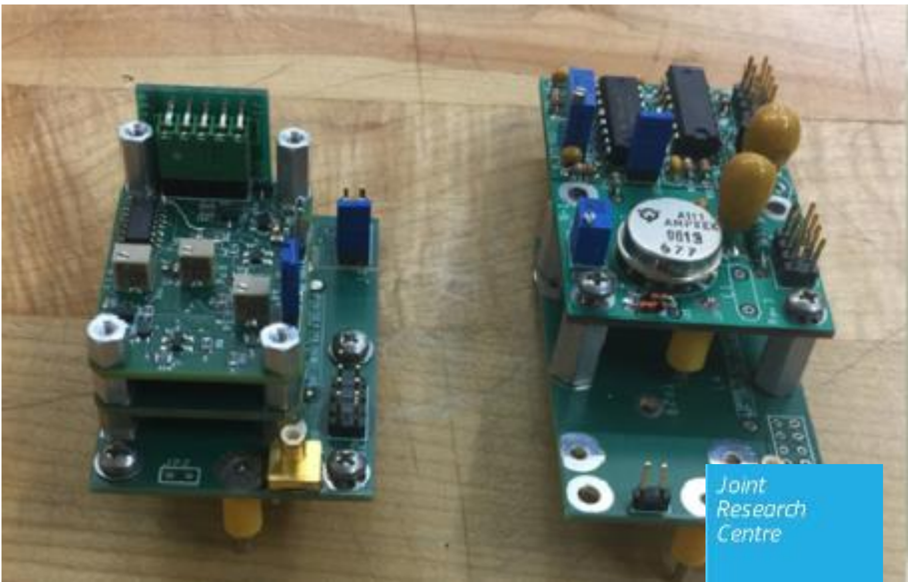

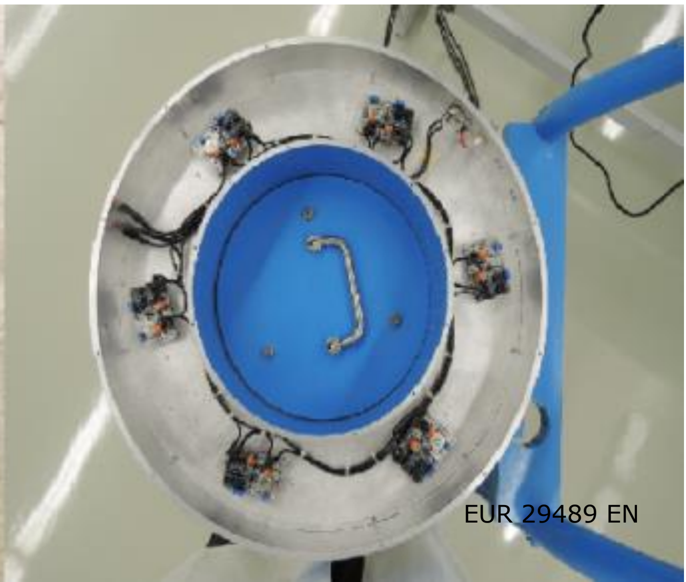

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Contents

Abstract

A novel amplifier circuit, named KM-200, suitable for 3He gas proportional counters for neutron detection was developed at LANL. The new circuit is proposed as a potential substitute for the standard Amptek A111 amplifier currently used in many neutron well-counters by Euratom and IAEA. It is expected that due to aging many such A111 units could need replacing in the coming years.

The purpose of the Action Sheet 59 of the Euratom-DoE collaboration is the field testing of the new KM-200 amplifier circuit. Under AS-59 a test campaign of the KM-200 at high count rate had previously been performed at the JRC PUNITA facility in Ispra.

The present report concerns the 2nd test campaign carried out jointly between LANL and JRC staff at the JRC laboratory in Karlsruhe. The intention was to test the compatibility of the KM-200 with a standard safeguards well-counter such as the AWCC, and to quantify the expected improvements of the new circuit in terms of the combined dead-time effect caused by the ^{3}He detector tubes and the amplifier.

The test campaign demonstrated that the KM-200 can indeed be directly accommodated in the EURATOM AWCC. Suitability was assessed by 1) evaluation of the KM-200 as a drop-in replacement for the original EURATOM safeguards system amplifiers, and 2) performance comparison of original vs KM-200 preamplifiers for normal and high rate measurements.

The results from the Karlsruhe test campaign are reported. Clearly the KM-200 is a versatile amplifier suitable for gas proportional counters, and a potential candidate for substitution of aging A111 units used in field. The test results however are not conclusive with respect to reducing the dead-time effect at high counting rates. Further work is proposed to complete these investigations.

1 Introduction

The present report concerns the testing and implementation of a novel amplifier circuit KM-200 developed at LANL. A measurement campaign took place at EUSECTRA-Karlsruhe jointly with G.II.7, G.II.6 and LANL. This campaign was carried out as part of the Action Sheet 59 between the United States Department of Energy (DOE) and the European Atomic Energy Community (EURATOM) for Cooperation on Improved Techniques for High Count Rate Nondestructive Assay Measurements.

On a wider scale the objective of the KM-200 testing is to prepare for a potential need to substitute the aging Amptek A111 amplifier circuits which are in use in numerous NDA instruments operated by Euratom and IAEA. The KM-200 is a potential candidate being plug-compatible with the A111.

Also as part of AS 59 the KM-200 had been tested thoroughly in an earlier joint campaign at the PUNITA facility of JRC ([1]). The PUNITA facility includes a pulsed neutron generator capable of producing 2×10^8 neutrons per second, and more importantly at a rate of up to 2×10^{11} neutrons per second during the short time interval of each pulse. Exposed to so high rates, any gas proportional counter will saturate during and shortly after the neutron pulse. The advantage of these tests was that simply observing the time of recovery of the combined amplifier and detector allowed quantifying the performance of the amplifier to high count rates. The results of these tests were presented at the ESARDA conference ([2]).

Following the tests at the PUNITA facility the decision was made to advance to testing of the KM-200 in the configuration of a standard safeguards well-counter. It is desirable to perform tests on a standard system used in international nuclear safeguards operations. The choice fell on the standard Active Well Coincidence Counter (AWCC) because of the detection system comprising 42 one-inch ^{3}He proportional detectors distributed on a total of six Amptek A111 amplifier circuits yielding a relatively high neutron detection efficiency. The test campaign included substituting the Amptek amplifiers with six plug-compatible units of the KM-200, and to compare count rate performance of the two amplifier circuits. The expectation was a lower dead-time effect in the KM-200 circuit and thus higher Singles and Doubles rates when measuring a spontaneous fission sources such as ^{252}Cf.

([1])K. Ianakiev (LANL), B. Pedersen (JRC-Ispra), Test Plan of the KM200 Electronics and the Dead-Time Losses Correction Method at the Joint Research Centre's (JRC's) Pulsed Neutron Interrogation Test Assembly (PUNITA) Facility, January 13, 2017

([2])Ianakiev, K., Iliev, M., Swinhoe, M., Pedersen, B., Varasano, G., Bogucarska, T., Holzleitner, L., De Baere, P., Vaccaro, S. and Couland, M., Field trial of KM-200 Electronics in the JRC PUNITA Facility, In: ESARDA, 16-18 May 2017, Düsseldorf, Germany, ESARDA 39th Annual Meeting - Symposium, 2017, ISBN 978-92-79-73861-6, ISSN 1831-9424, p. 708, JRC110771.

2 Methodology

2.1 The AWCC well-counter

The AWCC is a standard safeguards well-counter used by Euratom and IAEA inspectors for the assay of bulk fissile material samples. The AWCC counter used in these tests belongs to Euratom and is one of the early versions with symmetrical "zig-zag"wiring of high voltage to the anode wires as shown in Figure 1. The AWCC includes 42 ^{3}He detector tubes in 2 rings, 6 amplifier circuits, 7 tubes per amplifier wired in segments (Figure 1). In total, three amplifiers are connected to 3 tubes of the inner ring and 4 tubes of the outer ring, and three amplifiers are connected to 4 tubes of the inner ring and 3 tubes of the outer ring. A view of the internals of the high and low-voltage compartments of the junction box is presented in Figure 2.

Figure 1. Schematic of HV wiring in the AWCC.

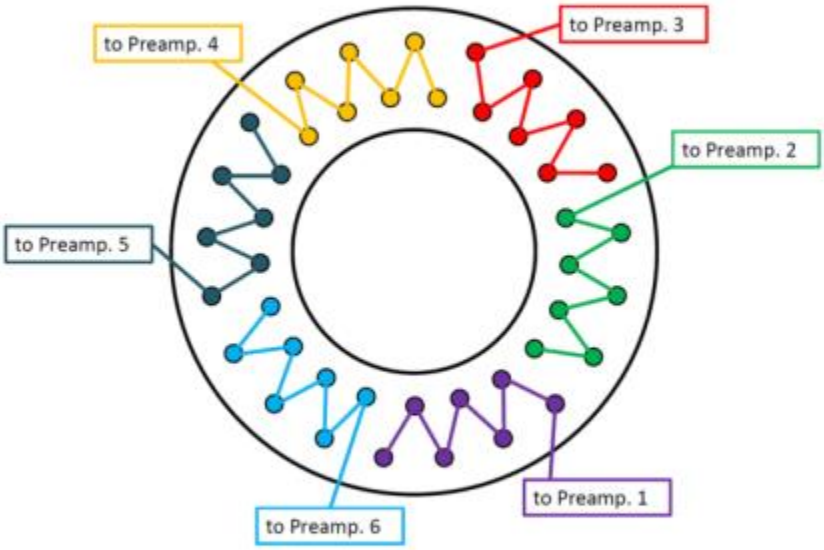


Figure 2. Left: Top view of the AWCC electronics compartment with the external lid removed; Right picture: HV compartment showing wiring to ^{3}He tube anode wires and decoupling capacitors to amplifier inputs. Left picture: LV compartment with the six Amptek A111 circuits mounted, digital pulse outputs daisy-chained.

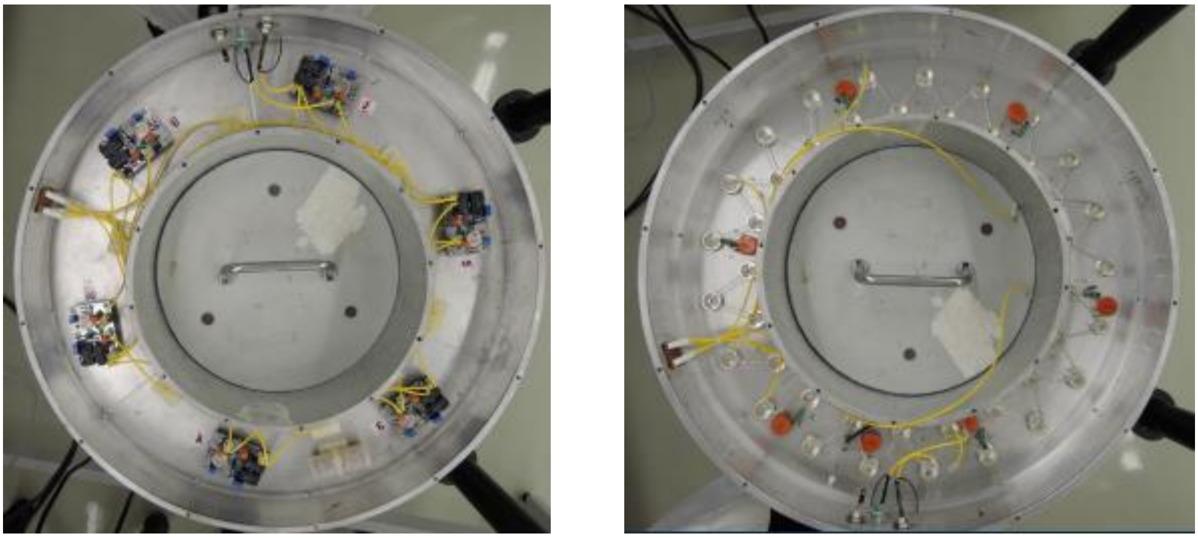
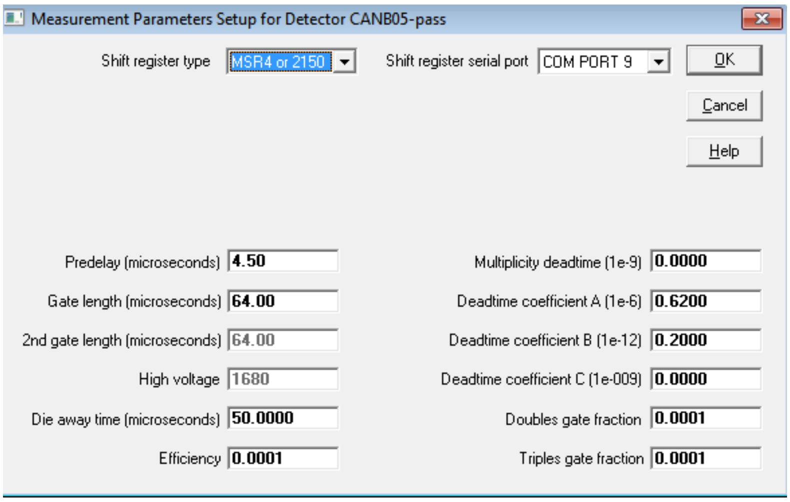


Table 1. Typical assay parameters of AWCC counters

Type	Serial No.	Various Parameters of AWCC counters							Source	Weight (kg)	Cavity / Dewar size	
		HV (V)	a (*10E-6)	b (*10E-12)	k	gate with (µs)	die away (µs)	Efficiency (%)			High mm	Ø mm
Jomar Active Well JCC51 (fast)	10923199 (Canb-01)	1680	0.589	0.277		64			no	130	352	220
Jomar Active Well JCC51 (thermal)	8601802 (Canb-05)	1680	0.62	0.2	2.166	64		34.25	no	130	352	220

The INCC measurement parameters pre-set during the acquisition of the measurement data are shown in Figure 3.

Figure 3. The INCC measurements parameters pre-set during intercomparision of the A111 & the KM-200.



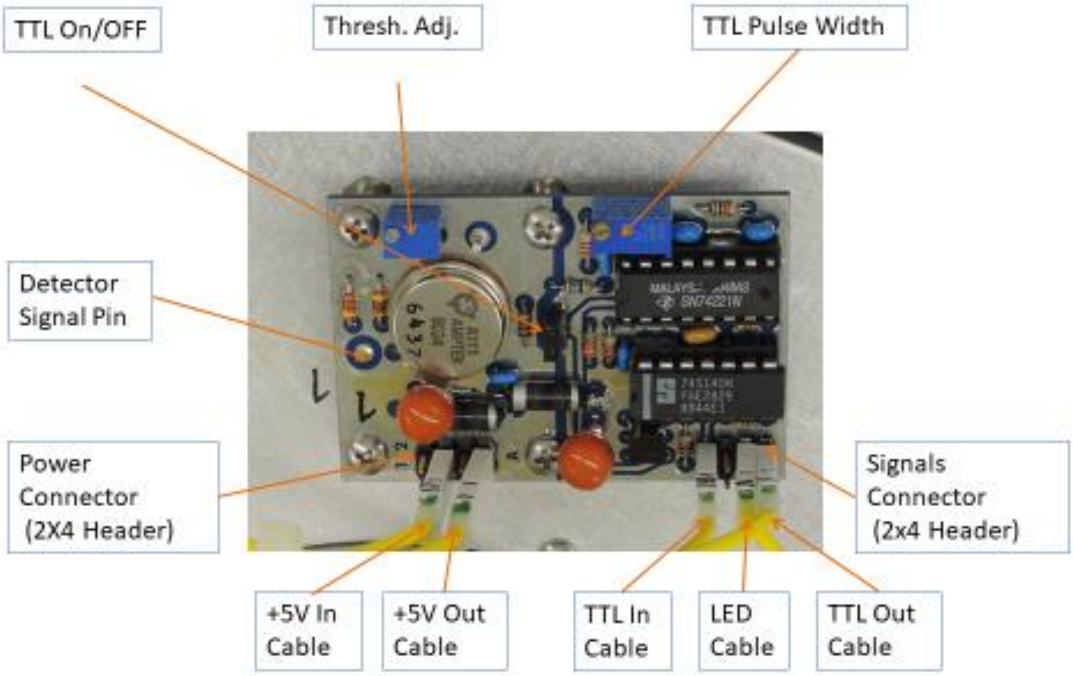
2.2 KM-200 electronics

The overall description of KM-200 electronics functionality and performance can be found in ([3]). Here we present in more details the KM-200 electronics set as a drop-in replacement of A-111 based JAB-01 board with emphasis on the connectors and controls of the two designs.

The JAB-01 board, shown as reference on Figure 4 has two 2X4 header connectors (power and signals) and three controls (threshold, pulse width adjust and TTL signal ON/OFF).

([3])M. Iliev, K.Ianakiev, M., Swinhoe, KM-200 Front-End Electronics for Thermal Neutron Detectors, INMM 57th Annual Meeting, 2016-07-24/2016-07-28 (Atlanta, Georgia, United States)

Figure 4. Amptek A-111 based JAB-01 Board connected to the AWCC coincidence counter cables.

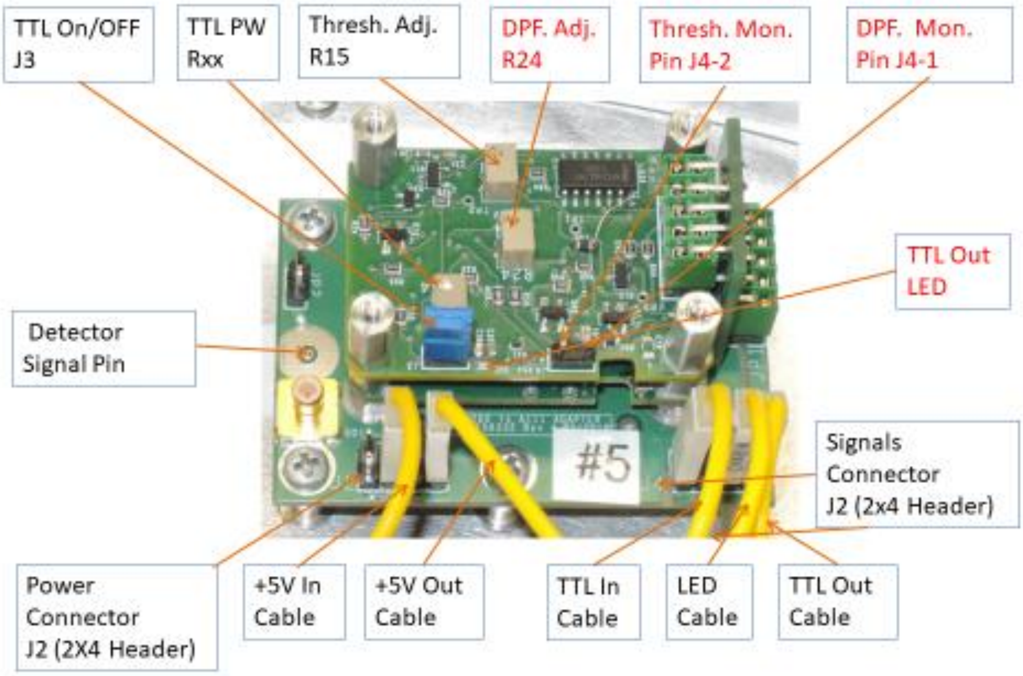


Source: M.C. Browne, K. Ianakiev, M.Iliev Detailed test plan for KM-200 electronics evaluation in the Active Well Coincidence Counter (AWCC), 2018

The KM-200 drop-in replacement set shown on Figure 5 has an adapter board with the same outline and connections as the JAB-01 board but one additional control for adjustment of the Double Pulsing Filter (DPF) and two pins for monitoring of threshold and DPF settings. It is worth to mention that these new controls and functionality are not available in commercially available designs as the A-111 and the PDT-10A.

Figure 5 shows the new additional setting for double pulse filtering (DPF) as well as two monitor pins for the threshold (THR) and DPF settings available in the KM-200 (labelled red). The THR and DPF monitor pins allow quick control and setting of these very important parameters of the amplifier at the time of installation in the AWCC counter.

Figure 5. The KM-200 Amplifier connectors and controls. The connectors and controls that are same as A-111 board are marked in black. The additional controls: Double Pulsing Filter (DPF Adj.), threshold Monitor and DPF Monitor are marked in red.



Source: M.C. Browne, K. Ianakiev, M.Iliev Detailed test plan for KM-200 electronics evaluation in the Active Well Coincidence Counter (AWCC), 2018

KM200 Controls and Indicators:

(a) Threshold Adjust. Sets the discriminator DC threshold voltage via a ten-turn potentiometer (designated as R15) located at the far side of the board. The minimal threshold setting is when the potentiometer is turned to its counter-clockwise limit.

(b) Double Pulsing Filter Adjust. Sets the level of double pulsing rejection via a ten-turn potentiometer (designated as R24) located in the middle of the board. The DPF rejection is disabled when the potentiometer is turned to its counter-clockwise limit.

(c) TTL Pulse Width Adjust. Adjusts the width of TTL pulse via a ten-turn potentiometer (designated as R34) located behind the TTL ON/OFF jumper. The range is from 50ns to 500ns. The minimum pulse width is when the potentiometer is turned to its counter-clockwise limit.

(d) Threshold Adjust Indicator Pin. Provide DC voltage proportional to the discriminator threshold setting. Left pin of JP2. Minimal threshold setting corresponds to about 0.09V.

(e) Threshold Adjust Indicator Pin. Provides DC voltage proportional to the discriminator threshold setting at the left pin of jumper JP2. Minimal threshold setting corresponds to about 0.09V.

(f) ON board LED indicator for TTL pulse. Mirrors the functionality of LED indicator outside the counter for diagnostic purposes.

The technology was implemented in the earlier PUNITA field trial to obtain data at different configurations of number of ^{3}He tubes per amplifier without disassembling the detectors/electronics modules from the PUNITA facility, and thus maximizing operational availability.

2.3 Initial setup and testing at LANL

2.3.1. Switching the load and amplifier mounting configurations

The campaign included investigation of side-by-side performance, functionality and user-friendliness for replacement and adjustments of both units (the KM-200 and the A111).

The technology was implemented in the AWCC field trial to test at increased count rates and consequently increased dead-time effects, and load per amplifier with the available sources in the laboratory. In order to conduct a real side-by-side comparison test both the KM-200 and A111 were mounted on adapter boards with capability for switching between detector configurations. Figure 6 shows the amplifiers mounting configuration.

Figure 6. Side-by-side comparison of KM-200 (left) and A111 (right) on JAB-01 adapter boards.

Source: M.C. Browne, K. Ianakiev, Detailed test plan for KM-200 electronics evaluation in the Active Well Coincidence Counter (AWCC), 2018

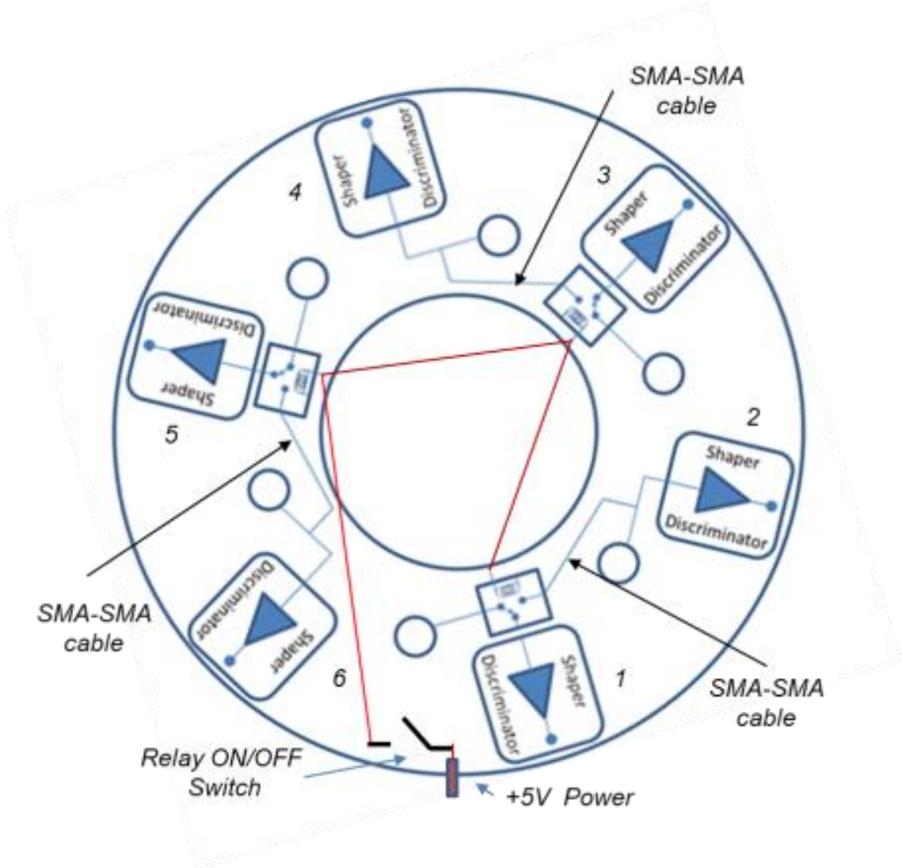
For the purpose of increasing (doubling) the count rate per amplifier a particular switching circuit was implemented in the AWCC counter allowing more flexible test options with the neutron sources available in the lab. The diagramme of the switching circuit is shown in Figure 7. The amplifiers have same position designation as for the A111 shown on Figure 1. The shaper/discriminator used are located on the KM-200 or A111 amplifiers boards which are mounted on the JAB-01 adapter boards that carry the switching relays and SMA connectors for switching of detectors signals.

As shown in the Figure 7 block diagram, the A111 adapter boards (#5, #3 and #1) have switching relays while boards (#6, #4 and #2) have the SMA connector directly connected to the detector signal pin. The new adapter boards have the same connections to the existing cables harnesses plus the following additional connections for detector signal switching:

— SMA connectors of neighbouring #5,#6; #3,#4; and #1,#2 are connected with SMA-SMA coaxial cable

— The relay control line (designated red) connecting the relays control pins via a magnetic controlled switch inside the junction box to the +5V power supply.

Figure 7. AWCC amplifier layout and switching relay interconnection diagramme.



Source: M.C. Browne, K. Ianakiev, M.Iliev Detailed test plan for KM-200 electronics evaluation in the Active Well Coincidence Counter (AWCC), 2018

2.3.2. Initial experimental results taken with LANL AWCC Counter.

In order to test the functionality some KM-200 amplifiers circuits of each type were installed on a LANL AWCC counter prior to the campaign at JRC, and plateau characteristics with/without relay were recorded as shown on Figure 8 and Figure 9. Figure 8 presents the slope of the plateaus without shift (KM-200 can accept a wide range of input capacitance without a change in gain). The count-rate shift at the plateau region (about 1%) is due to dead-time (DT) losses. Figure 9 demonstrates the slope with the relay ON plateau shifts right due to the higher capacitance of two clusters of tubes. The HV or gain may need to be re-adjusted to do both measurements on the plateau.

Figure 8. Counting plateaus of KM-200 #4-#5 and #5-#6 with relay ON/OFF.

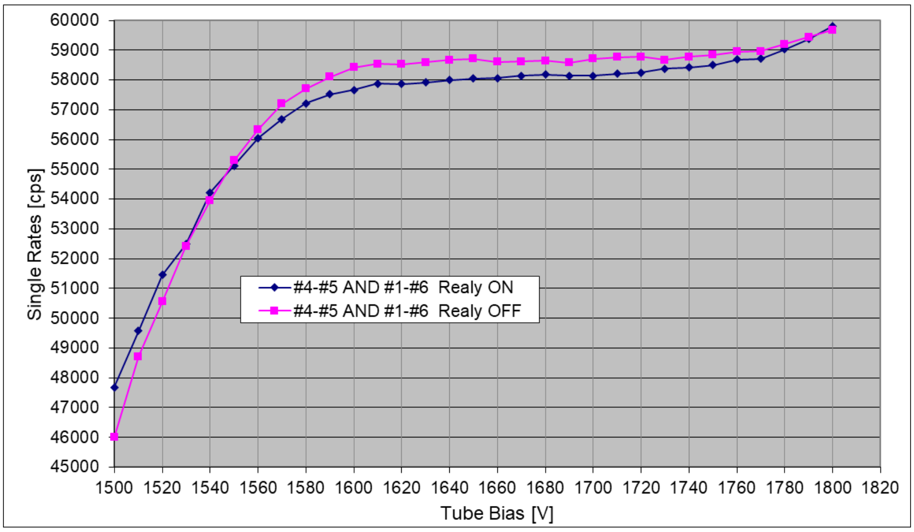
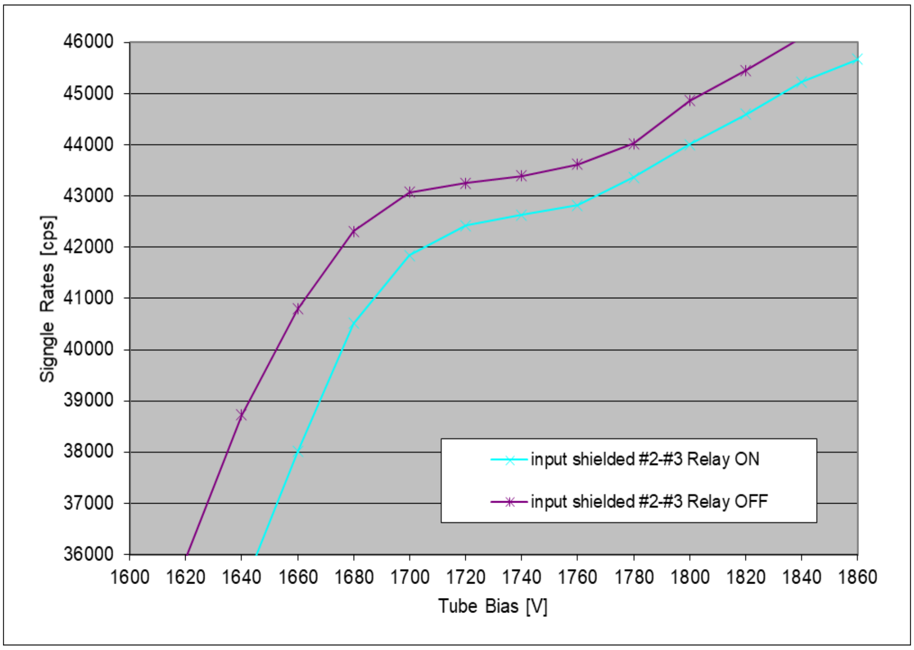


Figure 9. Counting plateaus of A111 #5 and #6 with relay ON/OFF.



Source: M.C. Browne, K. Ianakiev, M.Iliev Detailed test plan for KM-200 electronics evaluation in the Active Well Coincidence Counter (AWCC), 2018

Based on the measured 1% DT losses in two amplifiers caused by an increase of 28000 cps, in count rate for two amplifiers, we can estimate about 4% DT losses for the whole counter at 10^6 n/s emission from the strongest available ^{252}Cf source at JRC in Karlsruhe. These data, and already known DT losses of the A111 electronics, were taken into account when planning the necessary measurement time for the tests ([4]).

([4]) M. C. Browne, K.Ianakiev, M. Iliev, Detailed test plan for KM-200 electronics evaluation in the Active Well Coincidence Counter (AWCC), 2018

3 The KM-200 amplifier test results

3.1 Installation of KM-200 amplifiers

LANL manufactured eight KM-200 amplifier circuits for the present test campaign. The KM-200 circuits were mounted on the A111 adapter boards.

Figures 10a, 10b, 10c show the mounting sequence. KM-200 in the AWCC, each step is listed below:

— Insert the detector pin and align the holes of adapter board and mounting standoffs.

— Install the 4-40 mounting screws with retaining washers.

— Install the cables and connects in the same place as the original A111 boards.

Note that the KM-200 is mounted asymmetrically in order to be compatible with the connectors used in different counters and therefore is mounted using only three screws.

When mounted, an initial visual check was performed. After power to the counter was applied, the verification of the LEDs blinking due to background neutrons on the KM-200 preamplifiers and AWCC counter.

JRC staff were able to install the KM-200 amplifiers with LANL observation according to the installation sequence shown on Figure 10.

Figure 10. KM-200 installation procedure

a b c

Source: M.C. Browne, K. Ianakiev, Detailed test plan for KM-200 electronics evaluation in the Active Well Coincidence Counter (AWCC), 2018

3.2 KM-200 setup procedure

3.2.1 Introduction

The setup of typical ^{3}He electronics like the A111, PDT-10A, PDT-110A, etc. is based on adjustment of amplifier sensitivity (A111 and PD-10A, PDT-11A have gain adjustment, KM-200 has discriminator threshold adjustment). These are used to set the beginning of the plateau (the knee) of counting characteristic at desired HV bias voltage. There are two typical steps for making a set of electronics operate at the same desired bias voltage: a) initial setting of a single amplifier sensitivity, and b) gain (sensitivity) matching of the rest of amplifiers in the neutron counting system. Because the A111 and other commercial amplifiers, have a threshold adjustment control potentiometer but not an indication for its settings, the gain matching step is usually done by using radioactive source and iterative procedure for matching the slope of plateaus on every amplifier. The gain matching using radioactive source is tedious and time consuming procedure in the lab. Troubleshooting and replacement of defective amplifier in the field is even more challenging.

The KM-200 can be adjusted using the same procedure as commercial amps, but it also offers options for less time consuming gain matching and an option for reducing double pulsing.

Step 1: The first step in sensitivity adjustment (which is the same for the KM-200 and for the other common ^{3}He amplifiers) is to iteratively take several high voltage plateaus with different amplifier gain/sensitivity settings until the desired high voltage operating point is achieved (i.e. 1680V is 40 volts above the plateau knee).

Step 2: The KM-200 allows the user to apply a double pulsing filter (DPF) if the plateaus taken in the sensitivity adjustment step are degraded due to double pulsing. This degradation is often expressed by an excessive slope at the plateau. The DPF adjustment procedure and plots of the DPF's effect on plateaus can be found in section 3.2.4

Step 3: Gain matching is a particularly tedious operation for multi-detector systems. It involves matching the plateau characteristics of all the amplifiers to the one that was adjusted in step one. KM200 offers a very quick way to do this using a digital multi meter (DMM) to measure a monitoring pin voltage output proportional to the gain setting. This gain matching procedure is described in section 3.2.2.

Step 4: Alternatively, a LANL designed hand held charge calibrator can be used for extracting the sensitivity setting of the amplifier adjusted in step one and replicating it in the rest of the amplifiers in the system regardless if they are the KM-200 or other common ^{3}He amplifiers. This procedure is described in section 3.2.3.

3.2.2 Threshold setup using KM-200 monitor pins and DMM

This procedure assumes that the detector system to be calibrated is a coincidence counter like AWCC or INCC that normally uses Amptek A111 amplifiers. However the procedure can be generalized for most multi-detector systems. Figure 11 shows the setup for this procedure:

- Install all KM200 amplifiers in the counter using adapter board.
- Choose one channel to perform "step 1" described in the section 3.2.1.
- Disable the DPF by turning potentiometer R24 counter clockwise by 10 turns.
- Perform "step 1" on the chosen channel (iteratively find the desired plateau position) using potentiometer R15 to vary the sensitivity.
- If the plateau slope is more than 2%/100V perform DPF adjustment described in section 3.2.4 on the selected channel.

- Using DMM measure the voltage between ground and the Threshold Monitoring Pin (left pin on J4). Record this value as it is the sensitivity setting for the calibrated channel.
- For each of the remaining channels, connect the DMM between ground and the Threshold Monitoring Pin and adjust R15 of the respective amplifier until the voltage at the Threshold Monitoring Pin is matched to the previously recorded value.

Figure 11. Setup for discriminator threshold adjustment. The ground lid (black) of DMM is connected to the BNC connector solder lug. The signal lid of DMM is connected to Threshold Adj. indicator pin (J4-2)

3.2.3 Threshold setup and gain adjustment using LANL Universal Charge Calibrator.

The Universal Charge Calibrator offers a capability for fast precise setting of sensitivity of whole amplifier (shaper and discriminator) to a charge signal injected in the input. It is applicable for gain matching for KM-200 as well as other commercial amplifiers such as A-111 or PDT-10. The detailed principle of operation summary and viewgraphs of the charge calibrator are shown in Annex 1. A subset is shown on Figure 12.

3.2.3.1 Initial adjustment and sensitivity sampling

Initial adjustment and sensitivity sampling refer to Figure 12 and Annex 1:

- Choose one amplifier and one 3He detector from the set of amplifiers that need to be calibrated.
- Perform "step 1" described in the section 3.2.1 on the chosen amplifier using the chosen detector (i.e. adjust the sensitivity until the high voltage plateau is at the desirable position).
- Sample the adjusted sensitivity of the calibrated amplifier by performing the following steps:
  - Connect the input of the amplifier with previously adjusted sensitivity to the charge calibrator charge output (the charge injection head). Figure 4 shows the connection for an A111 based amplifier, however the LANL charge calibrator allows PDTs and KM200s to be connected too.
  - Connect power to the amplifier.
  - Connect the counting output signal of the amplifier to the charge calibrator input called TTL IN.
  - Turn ON the amplifier and charge calibrator power
  - Observe the Zero Indicator on the charge calibrator (the needle indicator with centre equilibrium position).
  - If the zero indicator needle is to the left of centre, turn the threshold adjust potentiometer (refer Appendix 1) clockwise (CW) to set the dial in the middle of the scale.
  - If the zero indicator needle is to the right of centre, turn the threshold adjust potentiometer (refer to Appendix 1) counter clockwise (CCW) to set the dial in the middle of the scale
  - When the zero indicator needle is positioned in the middle, the charge calibrator is set to inject the same charge as the sensitivity threshold of the calibrated amplifier. This setting can be used to adjust the remaining amplifiers.
- Secure the charge calibrator setting by locking the threshold adjust potentiometer.

3.2.3.2 Procedure for threshold setting (gain matching) of the remaining amplifiers.

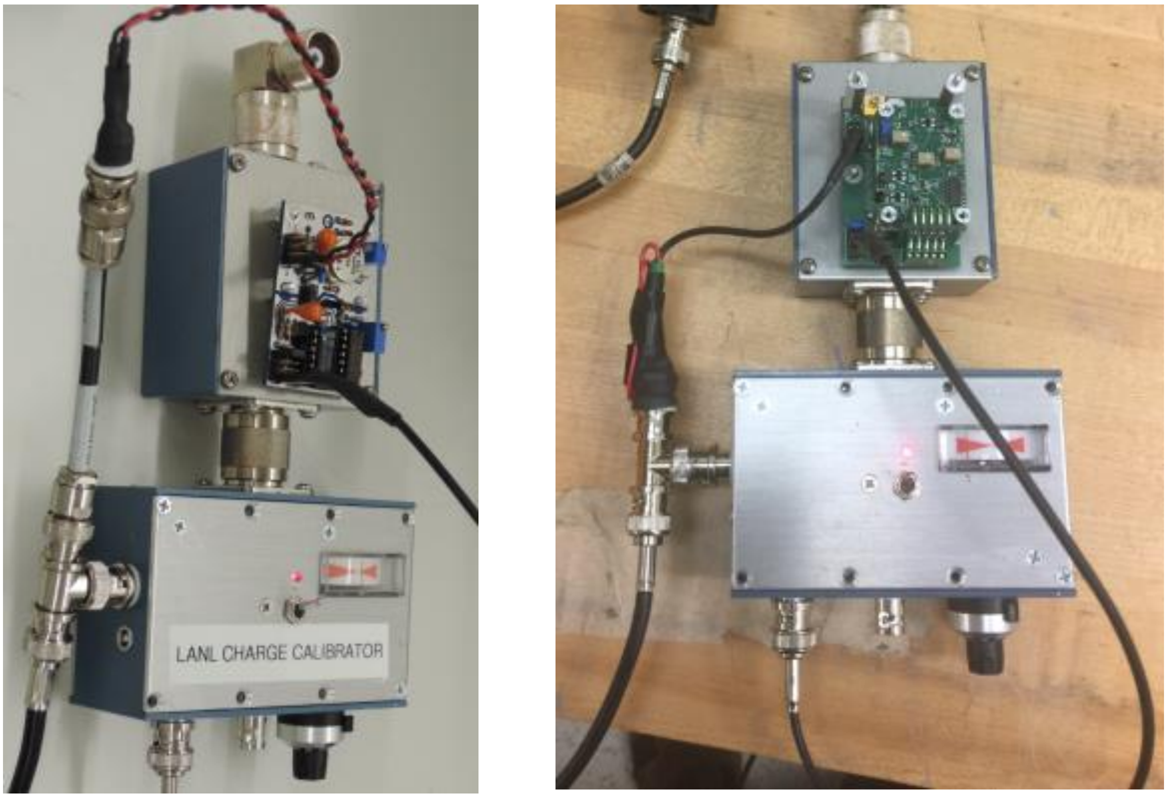
This procedure allows is intended to set the thresholds of all amplifiers to the same value as the one calibrated in 3.2.3.1:

- Connect the input of the next amplifier that is to be gain matched to the charge calibrator charge output (the charge injection head).
- Connect power to the amplifier.
- Connect the counting output signal of the amplifier to the charge calibrator input called TTL IN.
- Turn ON the amplifier and charge calibrator power
- Observe the Zero Indicator on the charge calibrator (the needle indicator with centre equilibrium position).
- Turn the threshold or gain adjustment potentiometer on the amplifier until the charge calibrator zero indicating needle is position in the middle. The specific

direction of potentiometer rotation depends on the type of amplifier; therefore the user has to try both CW and CCW.

- Once zero indication is achieved, the gain/threshold of the amplifier is matched to the gain/threshold of the calibrated amplifier
- Repeat the steps in 3.2.3.2 for all amplifiers that have to be gain matched.

Figure 12. Left: LANL Charge calibrator with A-111 amplifier (left) and KM200 amplifier (right)**.**



3.2.4 Double Pulse Filter Setting

The effect of the KM-200's Double Pulse Filter (DPF) on the counting characteristics of the amplifier is explained in ([3]). The implementation of double pulsing filter is effective for counters using slow tubes with CO_2 gas admix. The DPF adjustment is based on taking of multiple plateaus at different setting of DPF potentiometer R24. The DPF rejects the parasitic double pulsing events. These events cause excessive slope in high voltage counting characteristic that obscures the normally flat high voltage plateau. Applying DPF can flatten the plateau. However, excessive DPF can reject normal neutron events. The effect of that rejection will show up as a shift the knee of the high voltage characteristic to the right. The plateaus on Figure 14 taken with INVS counter demonstrated that effect. DPF rejection shouldn't be increased if the knee is beginning to be affected.

3.2.4.1 Measurement setup

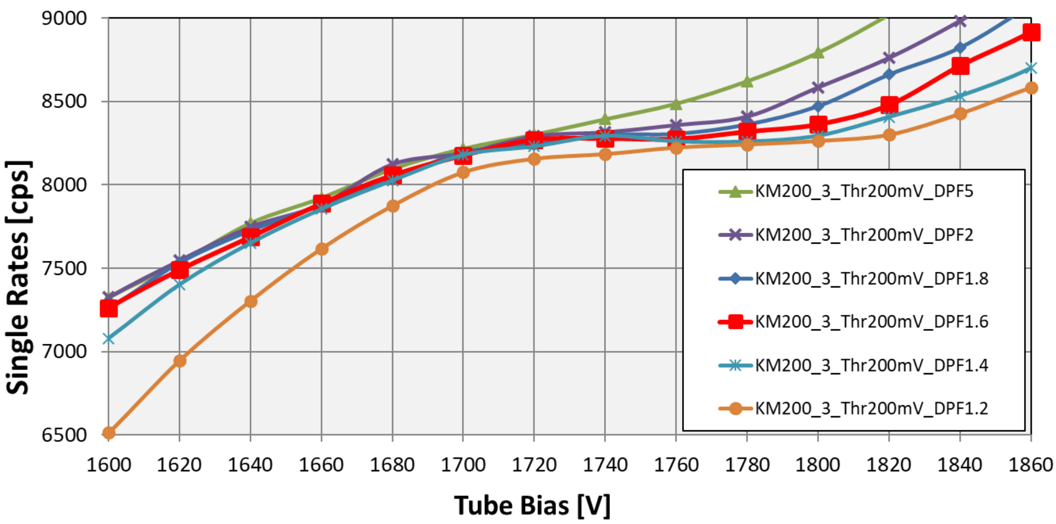
The measurement setup refers to Figure 13

- Measurement equipment:
  - The KM-200 amplifier installed in a coincidence counter (INVIS counter)
  - Digital Multi Meter (DMM)
  - Pulse Train Recorder PTR-32
  - 1X0.2mm flat screw driver.

Figure 13. Setup for Double Pause rejection adjustment. The ground lid (black) of DMM is connected to the BNC connector solder lug. The signal lid of DMM is connected to DPF indicator pin (J4-1)

- Set amplifier threshold as described in section 3.2.2
- Turn R24 counter clockwise 10 full revolutions. When the DMM is connected between J4-21and grown, it should read 4.5V. This corresponds to disabled DPF.
- Build a family of high voltage counting distribution curves like the one shown on figure 6 by changing the DPF settings (through potentiometer R24) from 4.5V (disabled DPF) on J4-1 to about 1.5V (Strongest DPF).
- From the curves select DPF value that provide flattest region without affecting the knee of the plateau.
- Select HV set point on the plateau and take Time Interval Histogram (TIH) data using a list mode pulse recorder like PTR32 to verify the level of double pulsing.
- It is possible that the amplifier shaper is too fast for the 3He detector under test, and the DPF cannot eliminate all double pulsing.

Figure 14. The KM200 Plateaus with 200 mV threshold settings taken at different values of DPF. The DPF=1.6V provides flat region (the plot in red colour)



3.3 Intercomparision of KM-200 and A111

3.3.1 Sources

The intercomparision was done using the ^{252}Cf sources M5-028 and J4-240 with neutron emissions of 2.45·10^{4} s^{-1}, 9.18·10^{5}s^{-1} respectively, and an ^{241}AmLi source with neutron yield of 6.5·10^{4} s^{-1} (Table 2).

Table 2. Characteristics of the neutron sources used in the test campaign

Source description	**Isotope**	**Reference date (certificate)**	**Activity at certificate, Bq**	**Neutr.Yield at certificate (s^{-1})**	**Activity, (Bq) on 5/06/2018**	**Neutr.Yield (s^{-1}) on 5/06/2018**
M5-028	^{252}Cf	15/04/2015	4.81E+05	5.59E+04	2.11E+05	2.45E+04
J4-240	^{252}Cf	15/07/2012	3.70E+07	4.30E+06	7.91E+06	9.18E+05
Sorg Am-Li AN-HP N008	^{241}Am	29/09/1993	4.44E+10	6.50E+04	4.26E+10	6.50E+04

3.3.2 Implementation of the setup procedure

Following the setup procedure described in the section 3.2, six of KM-200 amplifier circuits were tested in the AWCC counter. The bipolar shaped amplifier pulse of KM-200 allows a simple adjustment of the gain trimmer, threshold and pulse pileup rejection. These values were pre-set by the LANL experts and the further adjustments were performed in Euratom laboratory during the training provided within framework of the measurement campaign.

The setup parameters used for the testing and intercomaprision of KM-200 and A111 are shown in Table 3.

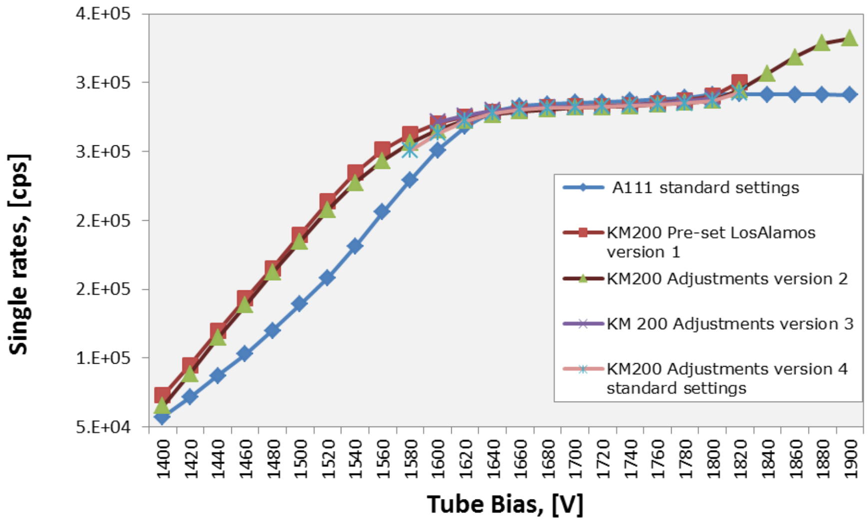
Table 3. Setup parameters used for the testing and intercomparision of KM-200 and A111.

Pre-set LANLversion 1						
Parameters	**KM200 -1**	**KM200-2**	**KM200-3**	**KM200-4**	**KM200-5**	**KM200-6**
Threshold, mV	197	217	219	180	218	197
DPF, V	1.689	1.682	1.604	1.584	1.607	1.685
Adjustments version 2						
Parameters	**KM200 -1**	**KM200-2**	**KM200-3**	**KM200-4**	**KM200-5**	**KM200-6**
Threshold, mV	220	220	220	220	220	220
DPF, V	1.8	1.8	1.8	1.8	1.8	1.8
Adjustments version 3						
Parameters	**KM200 -1**	**KM200-2**	**KM200-3**	**KM200-4**	**KM200-5**	**KM200-6**
Threshold, mV	220	220	220	220	220	220
DPF, V	2.0	2.0	2.0	2.0	2.0	2.0
Adjustments version 4 Standard settings						
Parameters	**KM200 -1**	**KM200-2**	**KM200-3**	**KM200-4**	**KM200-5**	**KM200-6**
Threshold, mV	220	220	220	220	220	220
DPF, V	1.6	1.6	1.6	1.6	1.6	1.6
Standard settings	**A111-1**	**A111-2**	**A111-3**	**A111-4**	**A111-5**	**A111-6**
Measured charge	0.56	0.56	0.57	0.56	0.59	0.58

The individual plateau curves for the A111 and the KM-200 amplifiers were measured using the ^{252}Cf source with neutron emission rate of $9.18 \cdot 10^5$ s^{-1}. The KM-200 threshold and DPF adjustments were compared with the A111 standard settings.

The set measurement parameters were: HV bias range 1400 – 1900 V; 20V increments; measurement time 10 s. The measurement data were plotted after each HV adjustment. Gain adjustments were made if the plateaus knee differed by more than 20V. The analysed data is presented in Figure 15.

Figure 15. Plateau of KM-200 (adjustment values are shown in Table 3) compared with A111 standard settings



Based on these results optimum values of 1.6V for DPF and 1740V for HV could be recommended. The adjustments version 4 (Table 3) was considered the final standard settings of KM-200.

3.3.3 Multiplicity measurements

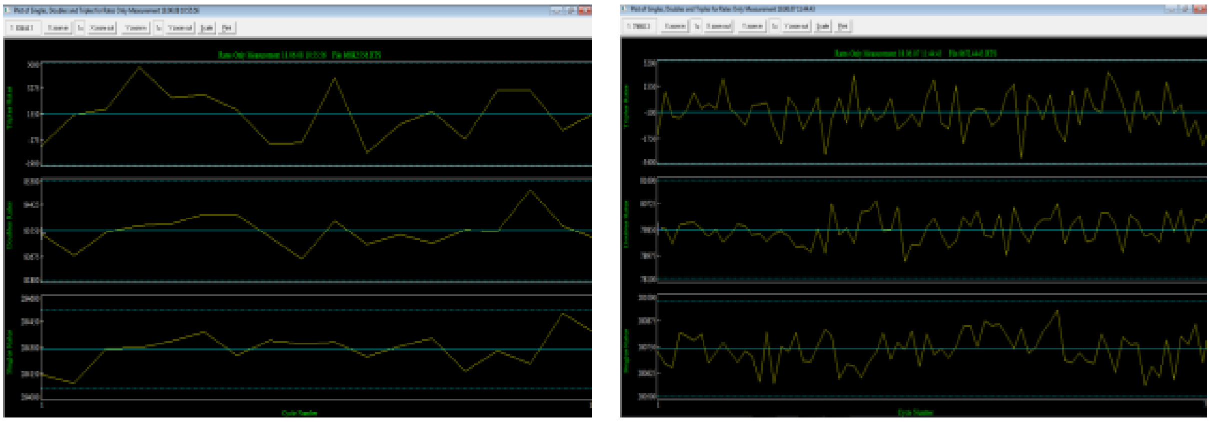
The multiplicity measurements of neutron sources were performed applying the standard settings in the KM-200 (Table 3 as adjustment version 4).

Figure 16 shows Singles, Doubles and Triples count rates as function of time under similar measurement conditions with either the KM-200 (right) or the A111(left) installed. These measurements were performed using the strongest ^{252}Cf source (J4-240).

The summary of intercomparison of the KM-200 and A111 preamps is presented in Table 4. The multiplicity measurements performed with the KM-200 and A111 amplifiers were executed under the final settings as presented in Table 3, (Adjustments version 4).

The intercomparison tests were performed using the ^{252}Cf and AmLi sources (listed in Table 2). The sources were placed in identical locations in the AWCC cavity. The high voltage 1680 V and low voltage 5 V were supplied by the JSR-12 analyser. The data were acquired using a JSR-15 shift register and the INCC software package. It was noted that the new JSR-15 injects noise into the amplifiers because of the internal DC/DC converter via the HV power supply line during multiplicity counting. For this reason the high and low voltages were supplied by a JSR-12 towards the end of the campaign.

Figure 16. Timeline of multiplicity counting (Singles, Doubles, Triples) A111 (left) and KM-200 (right)



Measurements were done with two different ^{252}Cf sources and one AmLi source, and combinations thereof (Table 4). Measured non dead-time corrected values of Singles, Doubles and Triples are reported for the different neutron source combinations, and repeated for the two amplifier configurations.

Sample measurement times were long, typically from 30 minutes to 16 hours in overnight measurements which is also reflected in the relatively low standard error on the measured multiplets.

The reported rates show equal performance of the two amplifier systems when dead-time effects are expected to be small. See for example the Doubles rates in the measurement of the small ^{252}Cf source (M5-028) of 2779 s^{-1} and 2754 s^{-1} for the KM-200 and the A111 configurations, respectively. For the strong ^{252}Cf source (J4-240) however the Doubles and Triples rates are quite different in the two amplifier configurations, with the KM-200 producing the lowest (non dead-time corrected) rates.

A change in Doubles/Singles ratio is an indication of dead-time effect as the Doubles are relatively more affected by dead-time than the Singles. When changing from the weak ^{252}Cf source (M5-028) to the strong ^{252}Cf source (J4-240), the ratio Doubles/Singles drops by 6% for the KM-200 configuration, whereas the drop is 0.4% for the A111 configuration.

The Doubles/Singles ratio of the weak ^{252}Cf source + the AmLi source is the same for the two amplifier configurations. This is not consistent with the findings from the measurement of the two ^{252}Cf sources alone.

In summary the measurements with the two ^{252}Cf sources and the AmLi source is not conclusive with respect to estimating the better dead-time performance of the two amplifier configurations. They appear to be relatively similar.

Table 4 also shows the measured background rates of Doubles and Triples to be zero within the error on the measurements. There is no evidence of neither double pulsing nor electrical disturbances on any of the two amplifiers. Had this been the case, the Doubles and Triples rates would typically show elevated rates. The Singles rate however shows a significant neutron room background presumably from the neutron sources stored nearby. Background measurements should be repeated with the external sources removed for the purpose of observing noise issues in the amplifiers.

Table 4. Intercomparison of multiplicity count rates of zero dead-time corrected signal multiplets using the standard settings of KM-200@ JSR12:1680kV, 5V and A111@ JSR12:1680kV, 5V .

		KM-200							A111						
Source Description	**Isotope**	**Singles (s^{-1})**	**Singles err. (s^{-1})**	**Doubles (s^{-1})**	**Doubles err. (s^{-1})**	**Triples (s^{-1})**	**Triples err. (s^{-1})**	**Meas. Time, s**	**Singles (s^{-1})**	**Singles err. (s^{-1})**	**Doubles (s^{-1})**	**Doubles err. (s^{-1})**	**Triples (s^{-1})**	**Triples err. (s^{-1})**	**Meas. Time,s**
J4-240	^{252}Cf	280739	9	79854	63	-82	124	7700	280978	8	81815	57	871	115	9700
M5-028	^{252}Cf	9190	1	2779	1	472	1	57600	9414	2	2754	4	479	3	2900
Sorg Am-Li AN-HP N008	^{241}Am	25977	4	-4	7	5	6	2000	26365	4	-2	7	1	6	1800
M5-028+Sorg Am-Li AN-HP N008	$^{252}Cf+^{241}Am$	35378	3	2804	7	433	7	5100	35822	2	2836	5	443	5	8300
Background		325.496	1.042	-0.063	0.214	0.005	0.018	300	52.576	0.229	0.006	0.019	0.001	0.001	1000

4 Conclusions

A measurement campaign was carried out at JRC in Karlsruhe to investigate the performance of the KM-200 amplifier with ^{3}He gas proportional counters. The measurements were done with a AWCC safeguards well-counter by comparison of performance in configurations using the standard Amptek A111 amplifier and the new KM-200. Measurements were done at different threshold settings of the KM-200 preamplifier. The corresponding "HV plateau" curve was plotted at each setting.

The fact that the KM-200 is plug-compatible with the A111 is a significant benefit considering the many aging detectors with A111 amplifiers currently in use by Euratom and IAEA: Also the adjustments of the KM-200 is relatively straightforward.

The measurements of different Cf sources and an AmLi neutron source did not yield conclusive results with respect to improved dead-time performance. The observed dead-time effect was similar for the two amplifier configurations (KM-200 and A111), and the small variations in Singles and Doubles rates were found to be inconsistent.

In addition, some measurement data were affected by noise in the amplifiers generated by noisy power supplies in the new JSR-15. Similar effects were observed at JRC in Ispra where a 3 stage RC filter on the JSR-15 HV supply was used to reduce the high frequency noise significantly in amplifier circuits of discrete components (such as the KM-200). The integrated circuit of the A111 appeared to be less disturbed by power supply noise.

The recommendation following the present campaign is that more specific measurements should be done to quantify the difference in dead-time effect caused by the two amplifiers.

At the time of this report, new ^{252}Cf sources with certified neutron emission has been acquired at JRC in Ispra. Currently neutron rates in the range of 5×10^4 to 1.2×10^7 s^{-1} can be achieved by combinations of these sources. The proposal is to transfer the AWCC to Ispra, and to use the new ^{252}Cf sources to experimentally determine dead-time values in the AWCC in the two amplifier configurations (A111 and KM-200).

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List of abbreviations and definitions

AWCC	Active Well Coincidence Counter
DPF	Double Pulsing Filtering
DT	Dead-time
THR	Threshold
DPF	Double Pulsing Filter
DMM	Digital Multi Meter
PTR	Pulse Train Recorder
TIH	Time Interval Histogram

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Annexes

Annex 1. Presentation of Kiril Ianakiev, Metodi Iliev, LANL Universal Charge Calibrator

Outline

- Principles of Charge Calibration for He-3 Electronics
- 2017 LANL charge calibrator
- Setup procedures for threshold measurement and gain matching

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Slide 2

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Classical Approach for Electronics Calibration (Gain Matching)

- ^{3}He tube and electronics;
  - Use radioactive source and neutron counter for taking plateau characteristics
  - Iterative procedure of stepwise change of threshold setting and taking plateau characteristics after each step
  - Very tedious, prone to human mistakes in the lab
- ^{235}U Fission Cambers and electronics
  - Use same setup as 3He tubes, but use only the count rate for each step to find the beginning of alpha distribution
  - More tedious because of lower efficiency
- None of them offer practical solution for in the field calibration without radioactive source.

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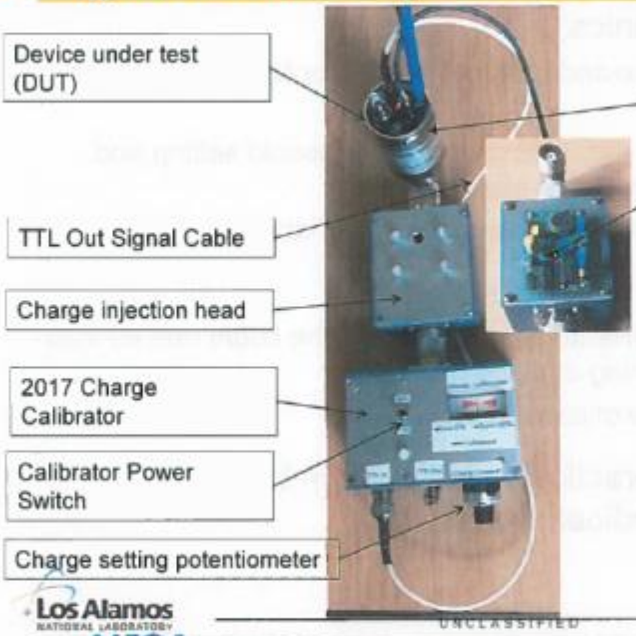
Slide 3

NNSA

Charge Injection Technique for Electronics Calibration (Gain Matching)

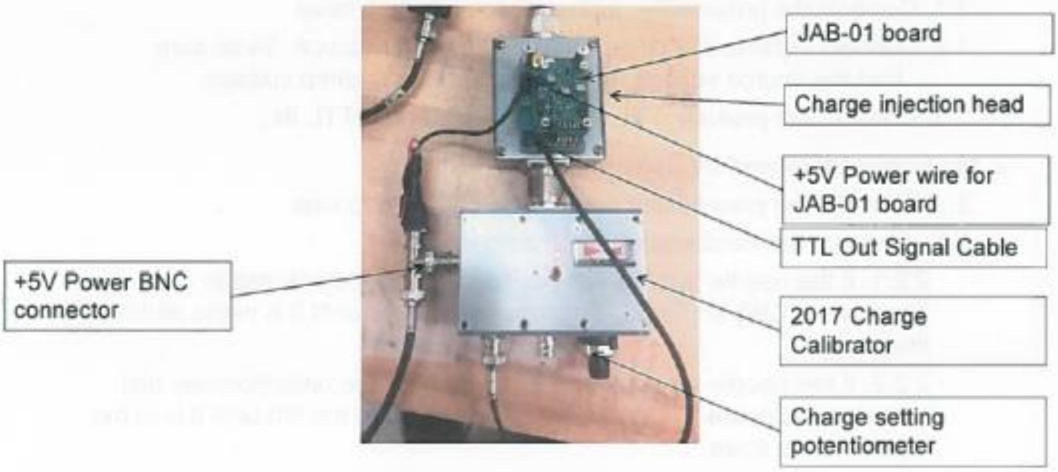
- Calibration with electronic charge injector (possible because of reproducible gain of Reuter Stokes He-3 tubes.
- The detector is replaced with electronic device injecting calibrated amount of charge with time distribution similar to the current pulse from He-3 detector
- The injected charge is controlled by precise potentiometer
- The preamp response to the injected charge (sensitivity below, equal or above the injected charge signal) is displayed on intuitive analog display.
- Provides capability for measuring of preamp sensitivity as well as gain matching

LANL 2017 Universal Charge Calibrator: Design Features Optimized for Fast Calibration

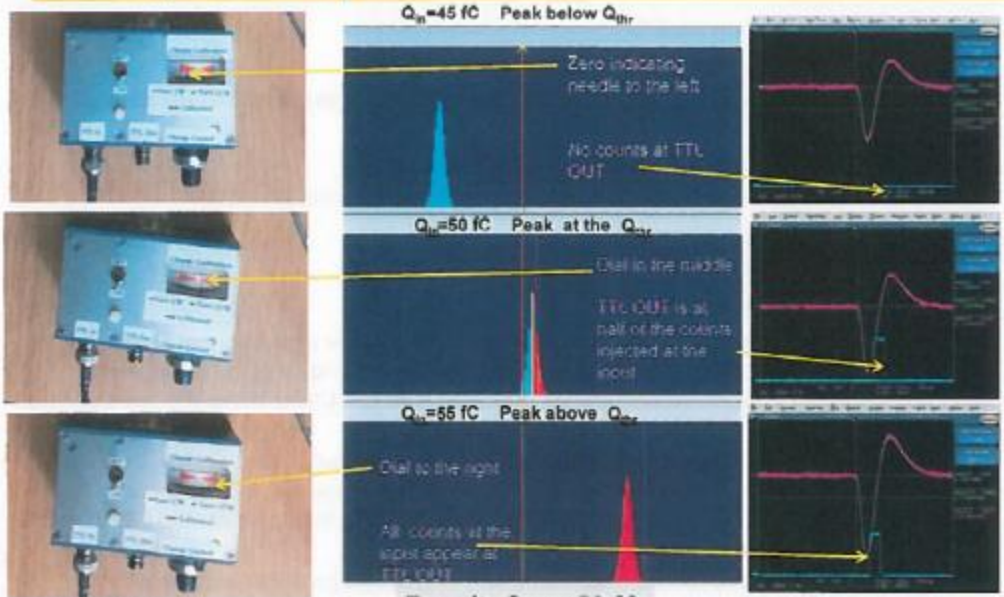


- Universal charge injecting head accepting, PDT, KM200, and Amptek A-111 DUTs
- Internal Li battery for 100 hours autonomous operation
- Simple connections with He-3 electronics
- Analog zero indicator for precise setting
- 1- 100 fC charge setting via 10 turn precision potentiometer
- Threshold setting in less than 10 sec

Calibration Setup for JAB-01 (Amptek Board)



LANL Charge Calibrator: Principle of Operation



Result: Q_{thr} = 50 fC

Setup Procedure for Measurement of Preamp Threshold Setting

1. Measurement setup (refer to slide 7)
   1.1. Connect the preamplifier to the charge injection head
   1.2. Connect preamplifier power output to a power source. Make sure that the source voltage match the specified preamp voltage
   1.3. Connect the preamp. TTL OUT to the calibrator TTL IN .
2. Measurement procedure (refer to slide 8)
   2.1. Turn ON the preamplifier and charge calibrator power
   2.2. Observe the needle position on zero indicator:
      2.2.1. If the needle is in the left position turn the potentiometer dial **clockwise (CW)** to move the needle to the right until it is in the middle of the scale.
      2.2.2. If the needle is in the right position turn the potentiometer dial **counterclockwise (CCW)** to move the needle to the left until it is in the middle of the scale.
   2.3. Record the setting of the potentiometer dial (scale 0 to 10.00) and use it for gain matching of other preamps.

Setup Procedure for Preamplifiers Gain Matching

1. Adjustment setup (refer to slide 7)
   1.1. Connect the preamplifier to the charge injection head
   1.2. Connect preamplifier power output to a power source. Make sure that the source voltage match the specified preamp voltage
   1.3. Connect the preamp. TTL OUT to the calibrator TTL IN .
   1.4. Insert a screwdriver in the slot of amplifiers gain setting potentiometer
2. Adjustment procedure (refer to slide 8)
   Turn ON the preamplifier and charge calibrator power
   2.2. Observe the needle position on zero indicator:
      2.2.1. If the needle is in the left position turn the amplifier's gain control potentiometer **clockwise (CW)** until the zero indicator needle is in the middle of the scale. **Note:** Some preamps might require rotating their gain control CCW to move the needle to the right.
      2.2.2. If the needle is in the right position turn the amplifier's gain control potentiometer **counterclockwise (CCW)** until the zero indicator needle is in the middle of the scale. **Note:** Some preamps might require rotating their gain control CW to move the needle to the left.

   Note: Some of the PDTs have unstable baseline of analog signal that will cause fluctuations of the dial .

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