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Investigation of "Dead Layer" in the Natural Diamond Detectors by Low Energy Cut-off Measurements

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Scope of the Talk

- Introduction
- Motivation
- Experimental
- Simple modeling of "dead layer" in NDD
- Conclusion and Outlook

Introduction

Natural diamond detectors (NDDs) are of great interest, mostly due to their ability to serve as energy spectrometers even for low energy ions. This issue was demonstrated in our talk given at the 1st NoRHDia on study of spectrometric properties of the NDDs under heavy ion irradiation in the energy range 1-20MeV.

Based on these measurements and results of simple TRIM and RBS modeling of energy loss of ions penetrating through NDD, we report in this talk, in particular, some preliminary estimates of the value of “dead layer” in the NDD

Motivation

A dead layer in every detector:

- Determines a low energy limit for any applications
- Imposes an limitation on the ultimate energy resolution of a NDD, especially for heavy ions
- Must be taken into account in some precise ion energy measurements

Experimental

Detectors & electronics

- Made of type IIa diamonds (2mm, 250μm)with use of standard selection/treatment procedure
- Deposited very thin electrical contact of gold ~20μg/cm^2 thick (NDD#1) or carbon 10μg/cm^2 thick (NDD#2)
- Commercial electronics for nuclear spectroscopy

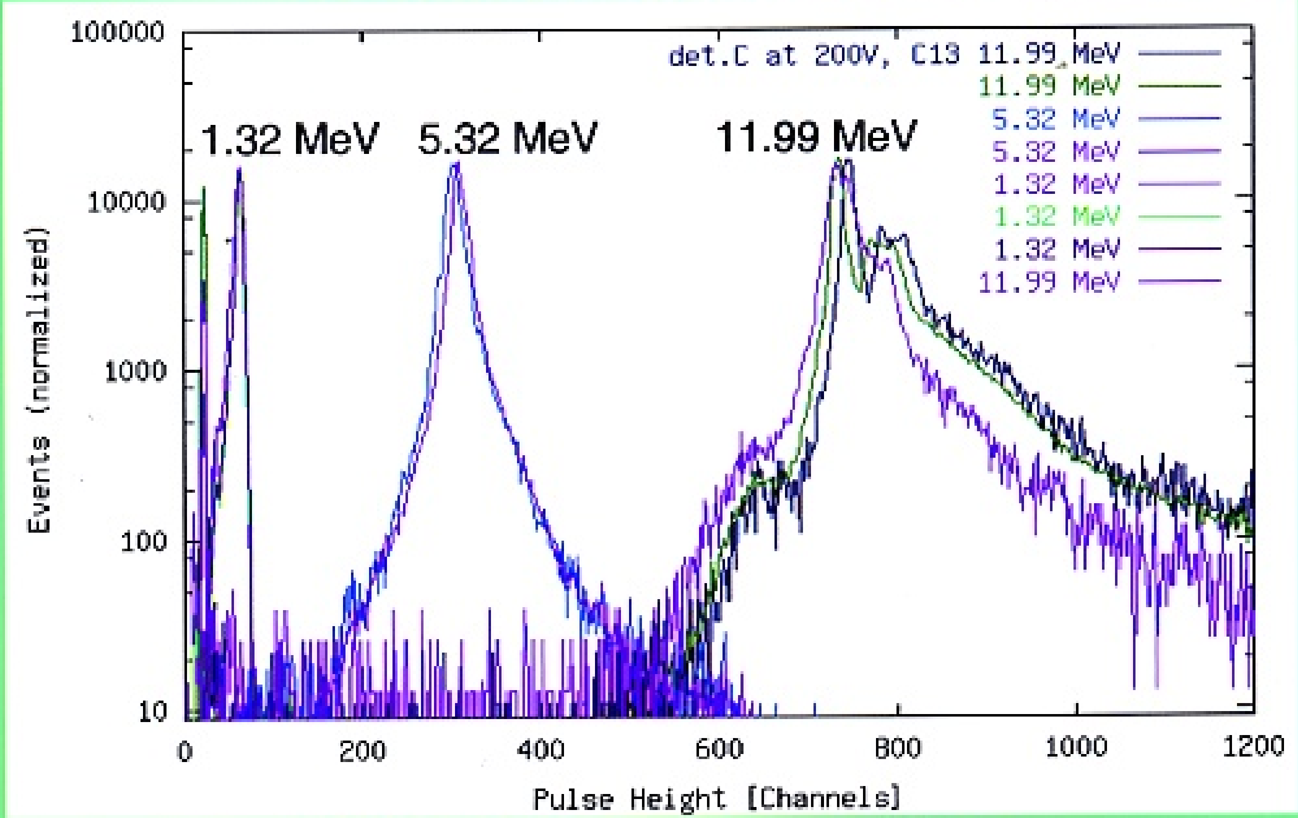
Irradiation conditions & detector performance

- MeV energy range - beam line of the VERA Tandem accelerator, Vienna : ions: ^{13}C, ^{197}Au, at 1 - 20 MeV
- KeV energy range –beam line of the Lebedev instititute Electroststic accelerator: Ions ^{1}H, ^{4}He, ^{14}N, ^{20}Ne

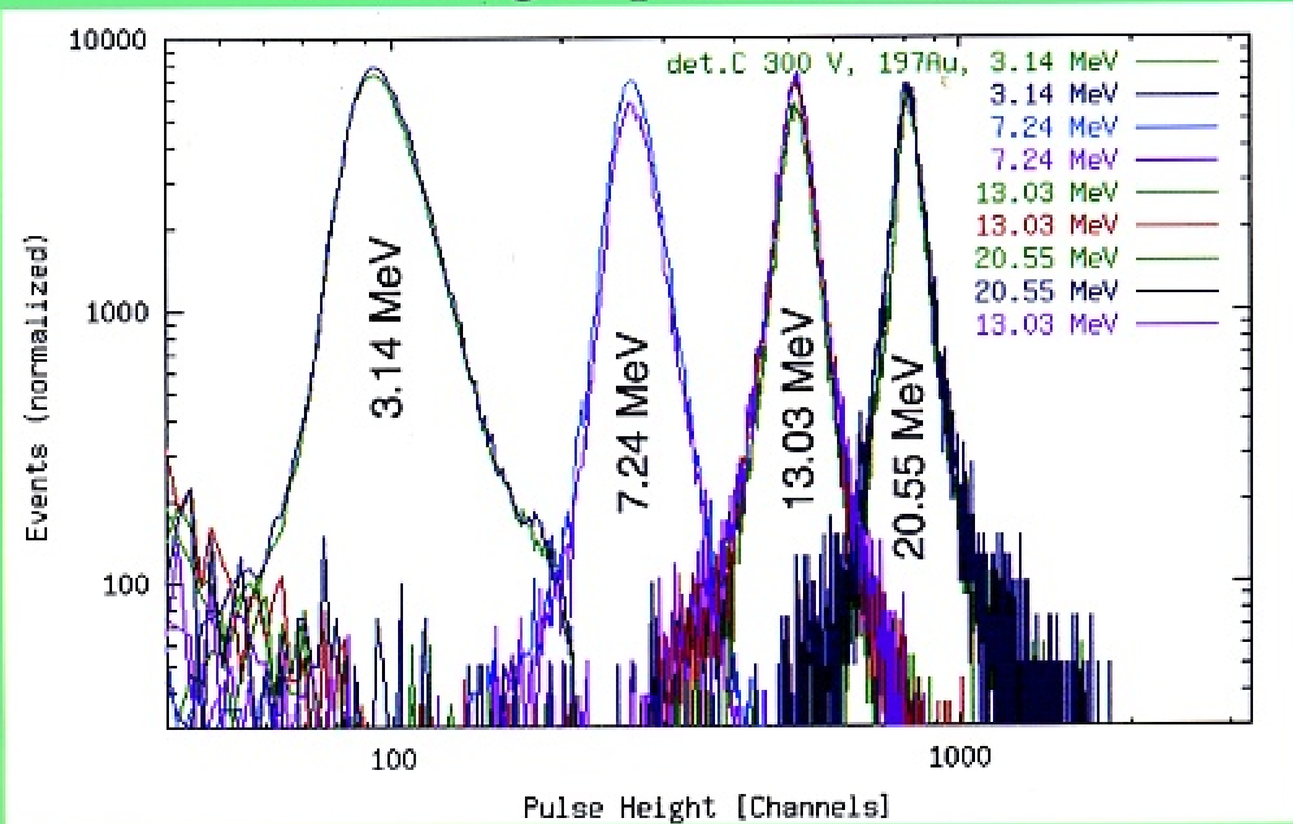
Measurements

- Detector performance was described at the last talk
- Results of the PH measurements- at the next slide

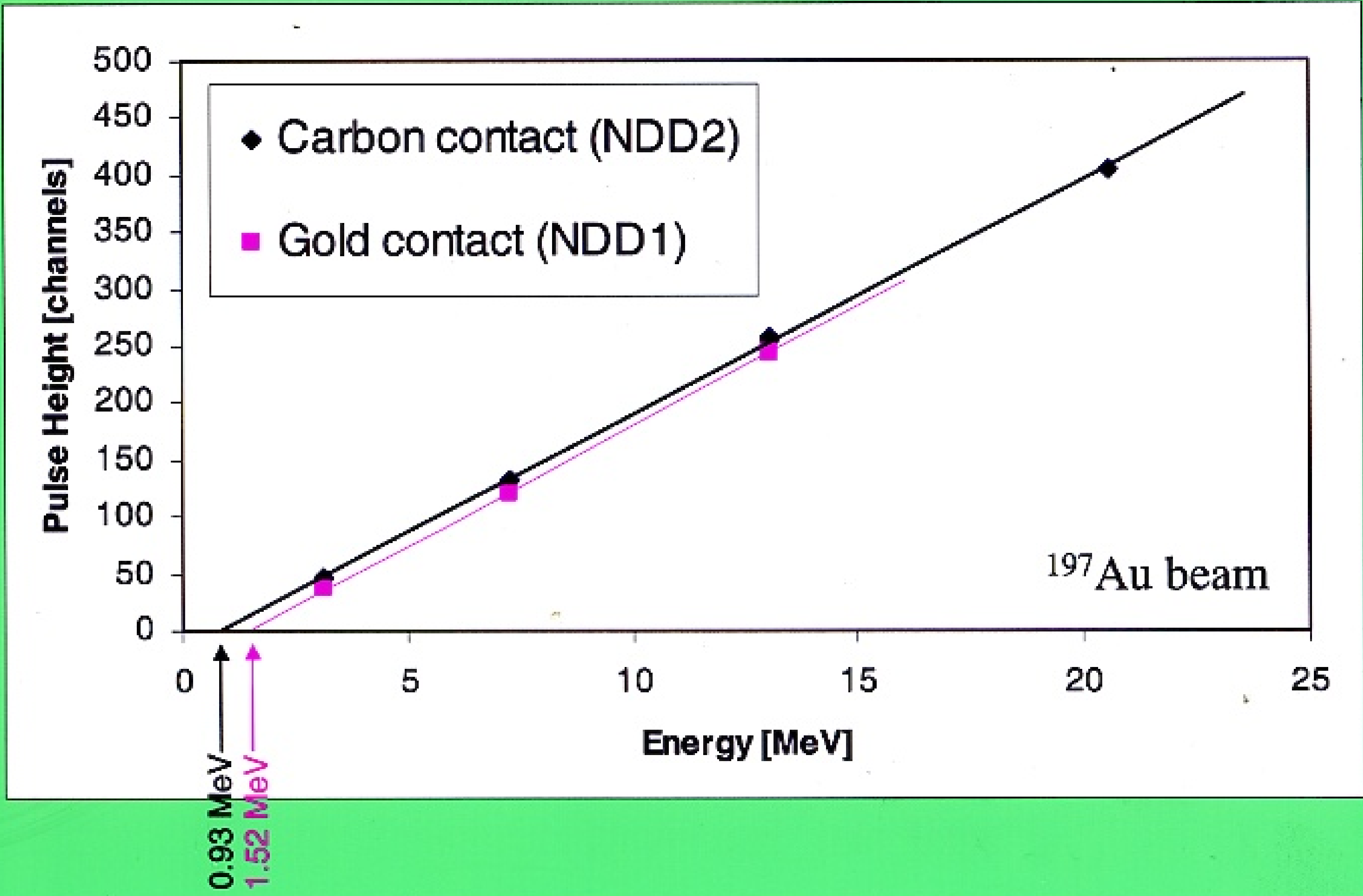
Pulse height spectra of ^{13}C



Pulse height spectra of ^{197}Au



Energy calibration and cut-off for two different NDDs



Cut-off Energies in MeV Range

NDD2 (C-contacts)

Ion	Mass	Cut-off energy
Au	197	0.928 MeV
^{13}C	13	0.409 MeV

NDD1 (Au-contacts)

Ion	Mass	Cut-off energy
Au	197	1.520 MeV
^{13}C	13	0.550 MeV

Table 1

Experimental values of cut-of Energies at the Lower Energy (10 KeV - 800 keV) Range

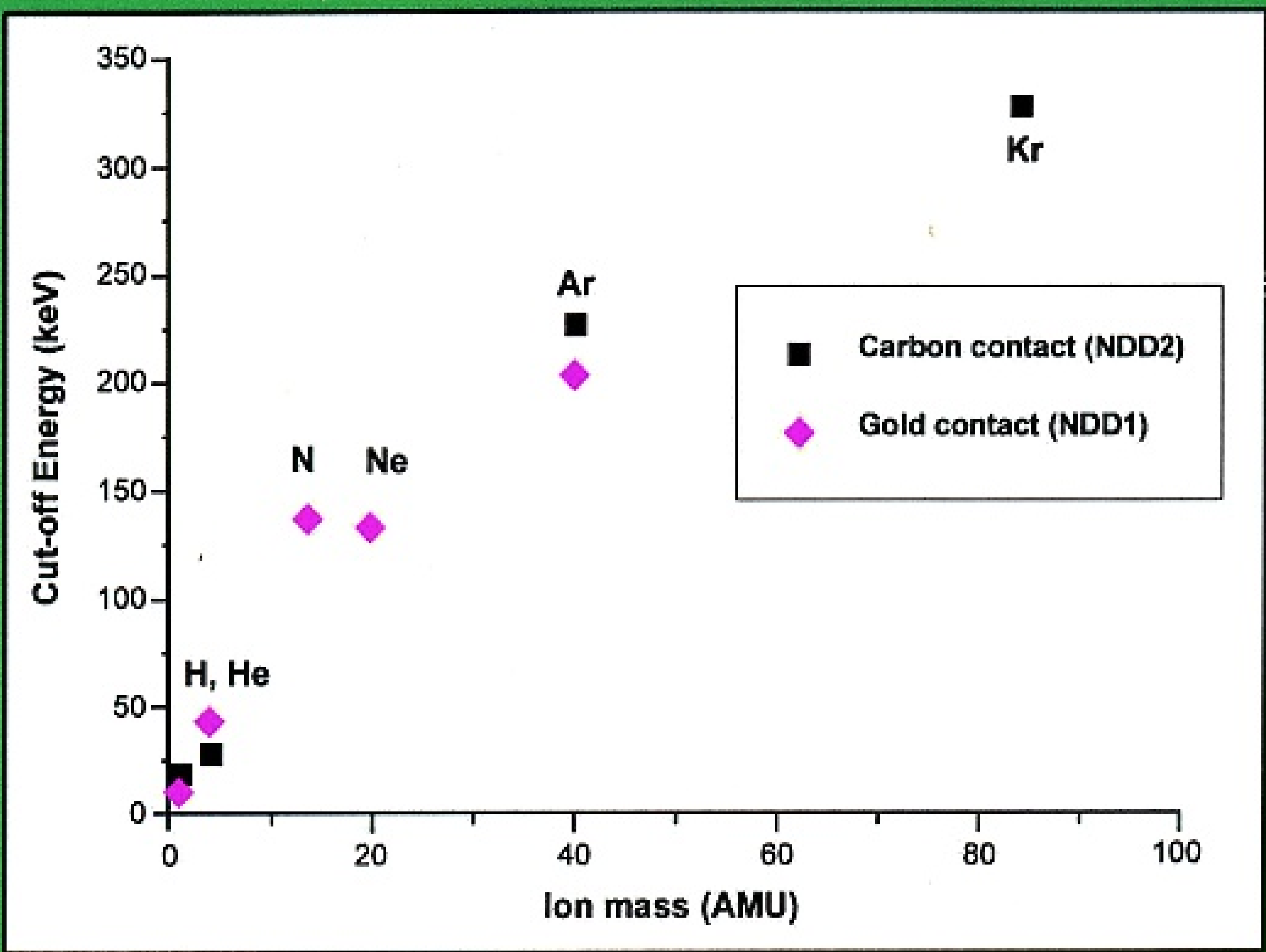
NDD2

Ion	Mass	Cut-off energy
H	1	13.8 keV
He	4	42.82 keV
N	14	137.07 keV
Ne	20	133.16 keV
Ar	40	202.5 keV

NDD1

Ion	Mass	Cut-off energy
H	1	17.4 keV
He	4	28.02 keV
Ar	40	225.19 keV
Kr	84	322.68 keV

Cut-of Energies at the Lower Energy (10 KeV - 800 keV) Range



Simple model to estimate a "dead layer"

Definition

"Dead layer" in a diamond detector, is commonly defined as the detector front layer in which energy loss of projectile does not contribute to the charge carrier motion, and therefore can' be measured

The value of the low energy cut-off, $E_{cut-off}$ is approximately expressed as:

$$E_{cut-off} \approx E_{dead} \qquad (1)$$

E_{dead} - ion energy depcsited in the "dead layer

Dead layer includes the contact layer + the surface low EF region + effective surface recombination layer

Approach

We used TRIM and RBS program to obtain the energy loss of different ions in both detectors. These calculated energy loss were plotted then vs projectile energy and theoretical values of energy cut-offs were found via extrapolation in Exel and compared with experimental cut-off energy values

Extrapolated Cut–off Energies for NDD1 (Au-contacts)

Ion	Dead layer (A)	Extrapolated cut-off (keV)	Experimental value of cut-off (keV)
^{13}C	1200 1600 **2200** 2400	320.807 408.848 **537.460** 577.315	550.893
^{197}Au	1200 **1600** 2200 2400	1230.698 **1529. 816** - -	1519.953

Table2

Extrapolated cut-off energies for NDD2 (C-contacts)

Ion	Dead layer (A)	Extrapolated cut-off (keV)	Exp. cut-off (keV)
H	200 400 1000	8.529 **13.705** 28.873	13.823
He	200 400 1000	14.520 23.146 **47.955**	42.820
C *	400 1600	126.353 **397.963**	409.007
N	200 400 1400 1600	26.287 42.985 **130.070** 150.314	137.071
Ne	200 400 1400 1600	25.813 42.407 **126.381** 146.305	133.167
Au *	200 400 1000	147.753 186.828 **964.550**	928. 477

* MeV energy range

Table 3

Estimated thickness of the "dead layer" for the NDDs with C and Au´contacts

Ion	Carbon contact layer	Gold contact layer
C	1600 A	2200A
Au	1000A	1600A

Conclusions and Outlook

- Cut-off energies for NDDs with contacts made of very thin gold and carbon have been measured for a variety of ions in the energy range of about 10keV -20 MeV

- Based on these measurements and simplified ion energy loss model as well, the thickness of an effective " dead layer" in the NDD with very thin carbon contacts is estimated to be around 1000 A , the value being comparable with that of best silicon detectors.

- Further study is needed to understand all these features more clearly

- In the near future, we plan to perform a comparative test of SC artificial and natural diamond detectors at the VERA- Lab Tandem Facility on a collaborative basis