Neutron and gamma-ray spectrometry

Testing and characterization of BGO scintillation gamma-ray detectors

by

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Outline

- Aim of the work and tasks to do
- Experimental setup
- Data acquisition and analysis
- Results and discussion
- Conclusion

Aim of the work

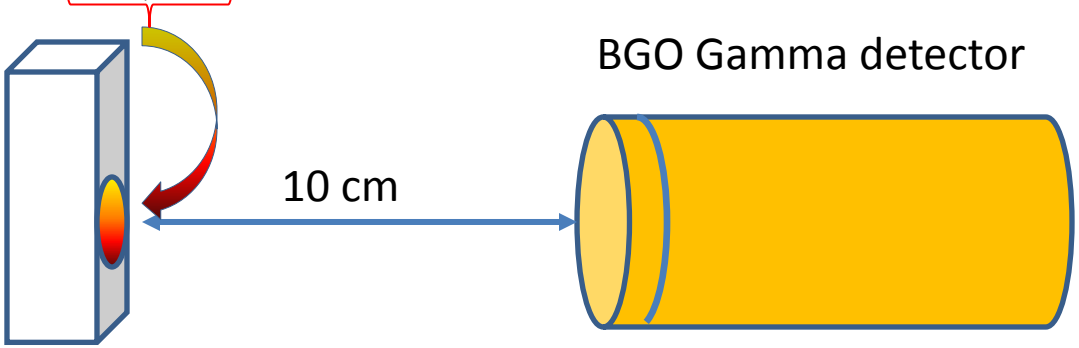
- The aim of this work was to test and characterize 24 BGO gamma-ray detectors, using calibration "point"- type sources (^{60}Co and ^{137}Cs).

Tasks to do

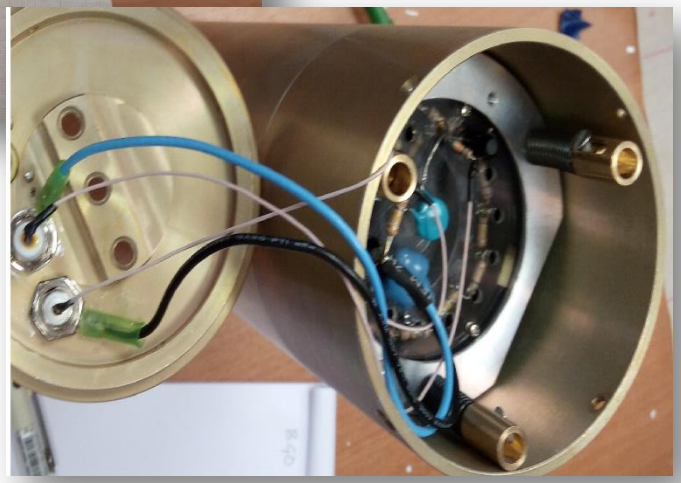
- ✓ Setting the geometry of the experiment.
- ✓ Finding the optimal HV for BGO photomultiplier, changing the HV from 800V to 1450V with a step of 50V.
- ✓ Determining the energy resolution of all 24 BGO gamma-ray detectors.

Experimental setup

Source: $^{60}Co, ^{137}Cs$

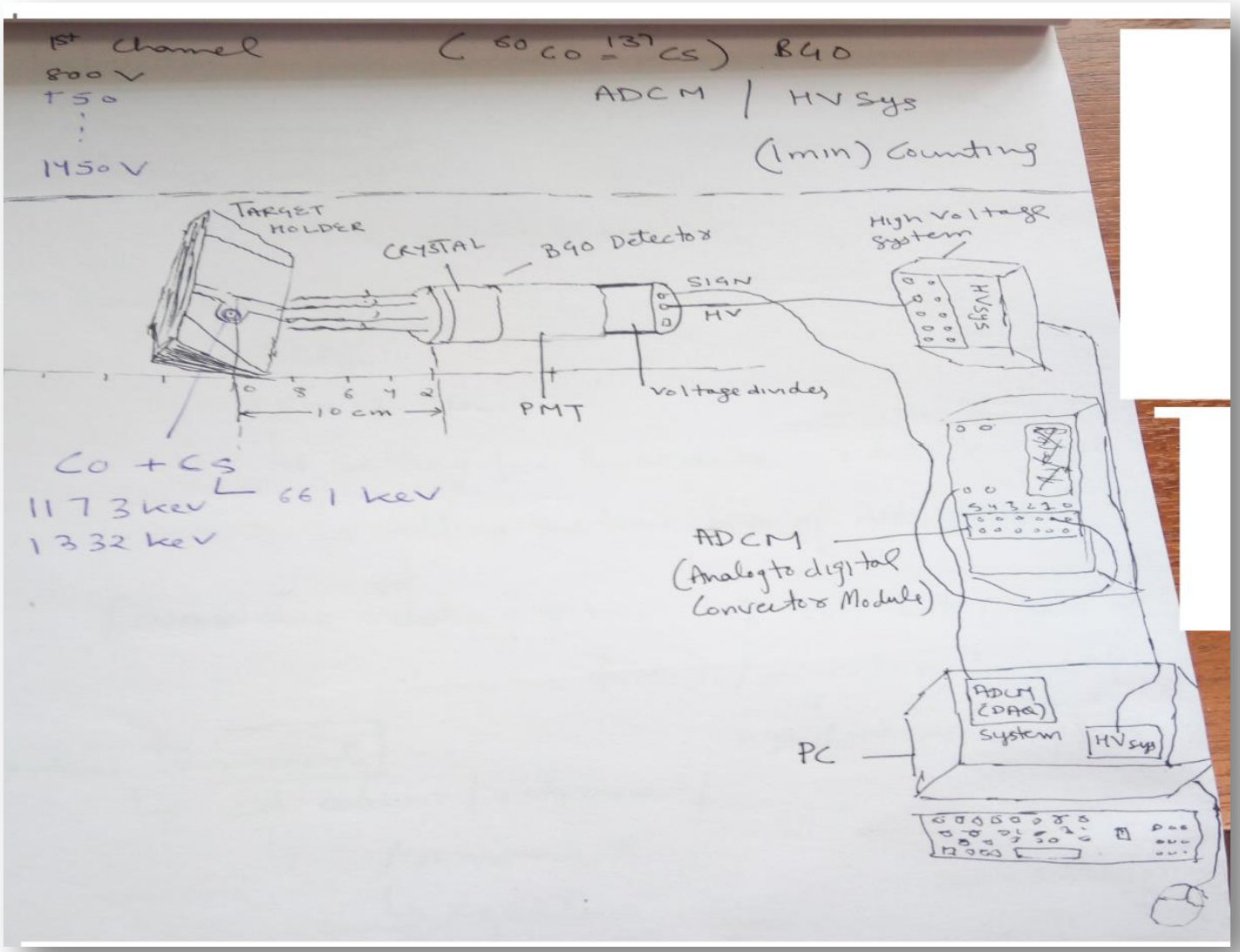


Voltage Divider



HV Power supply and Data acquisition system

Cont…


1st Channel
800 V
+50
1450 V
(60Co - 137Cs) BGO
ADCM / HV Sys
(1min) Counting
TARGET HOLDER
CRYSTAL
BGO Detector
SIGN
HV
High Voltage System
HVSys
Voltage divider
PMT
10 cm
Co + Cs
1173 keV
1332 keV
661 keV
ADCM
(Analog to digital Convertor Module)
PC
ADCM (DAQ) System
HV Sys

Data acquisition and analysis

ADCM is the compact and universal Digital Pulse Processing system for nuclear physics experiments.

ADCM16- LTC
- One PCI slot
- 16 channels
- 14-bit 100Mhz

➢3 modes
- ❖Time-driven
- ❖Single channel
- ❖Double coincidence

ADCM-16

16/32/48-channel digitizers, in the form of one or several PCI-E cards.

Sampling frequency **100 MHz**

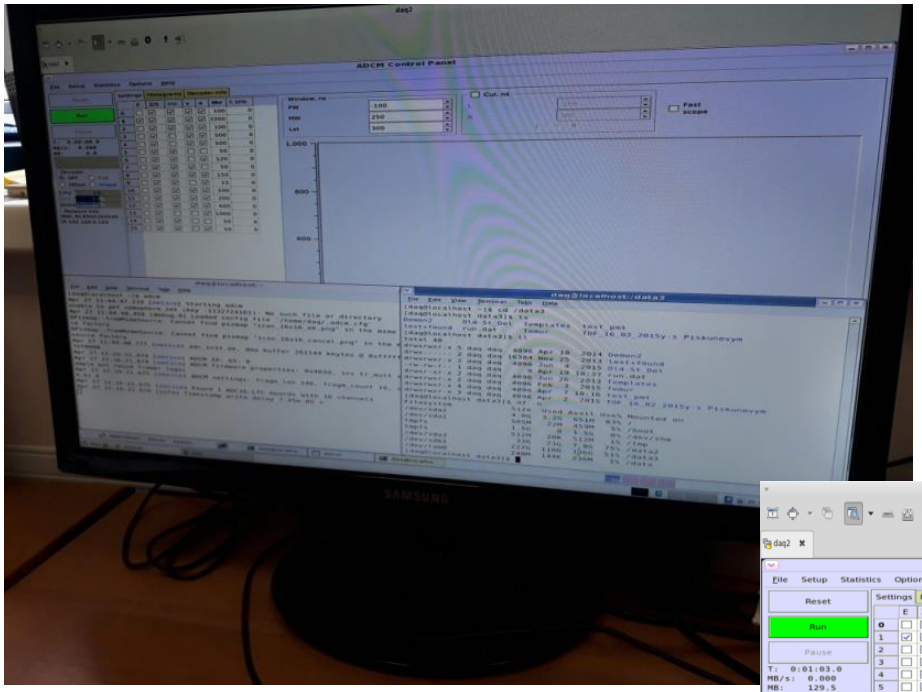
The digitized signals are transmitted via the PCI-E bus in the computer's memory, where all the data processing and storage takes place.

Maximum load of the system is ~ 10^5 events per second

http://afi.jinr.ru/ADCM

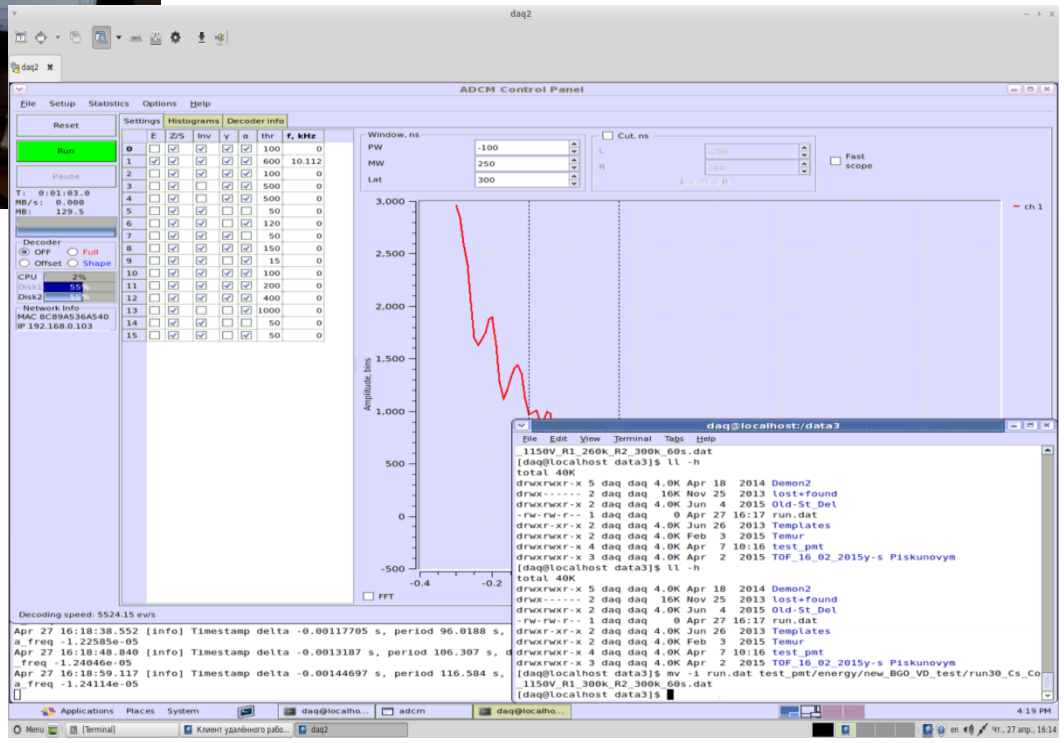
http://afi.jinr.ru/ADCM16-LTC

Cont.

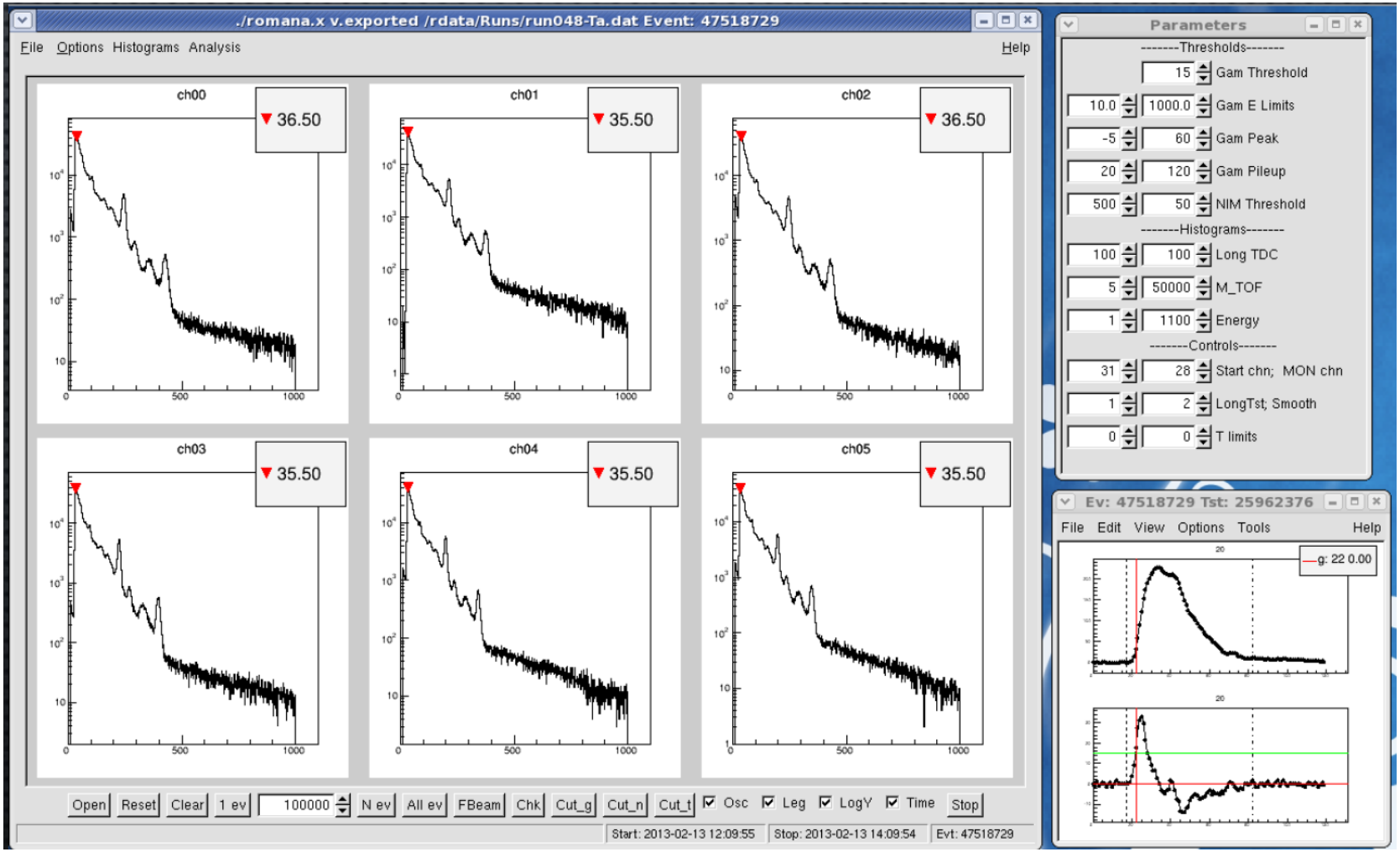


In the experiment process

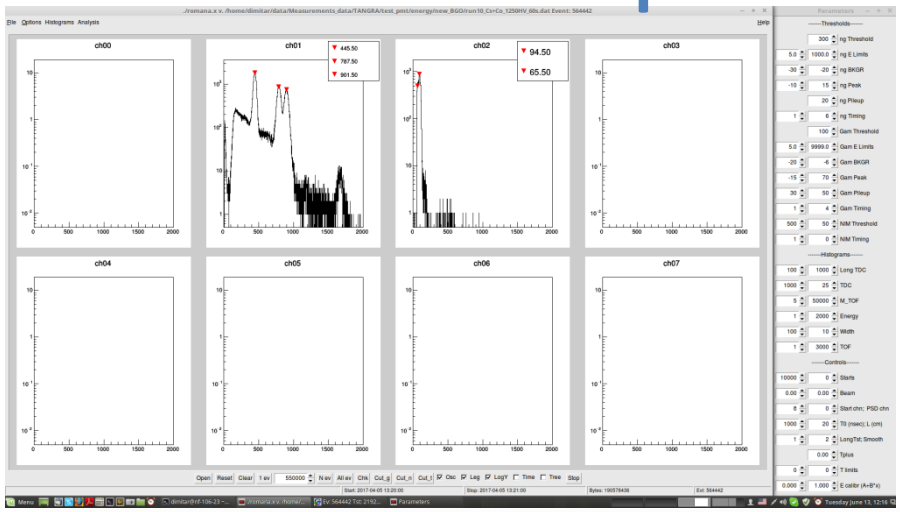
- voltage increment in each step = 50 V
- At each voltage, the amplitude spectrum was obtained
- Each measurement was saved on the server daq@159.96.105.92 hard disk in the folder **indata/test_pmt/energy/newBGO_VD_test/save** for off-line analysis by **ROMANA software**

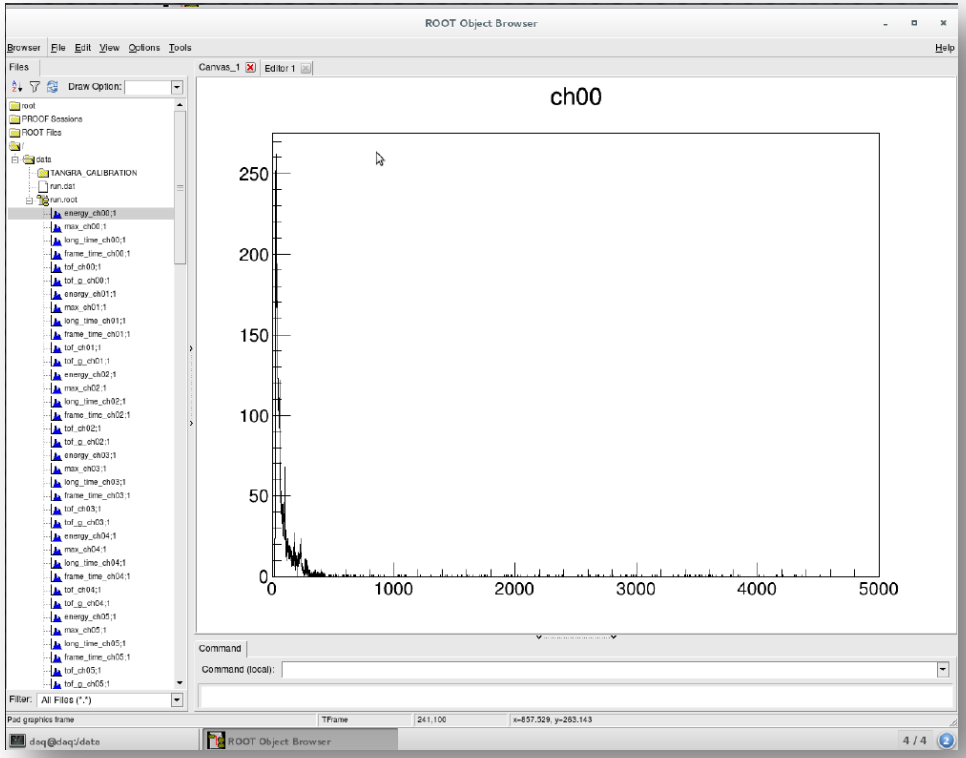


ROMANA Software



ROOT script for peak fitting





emacs@nf-106-23 (on nf-106-23)

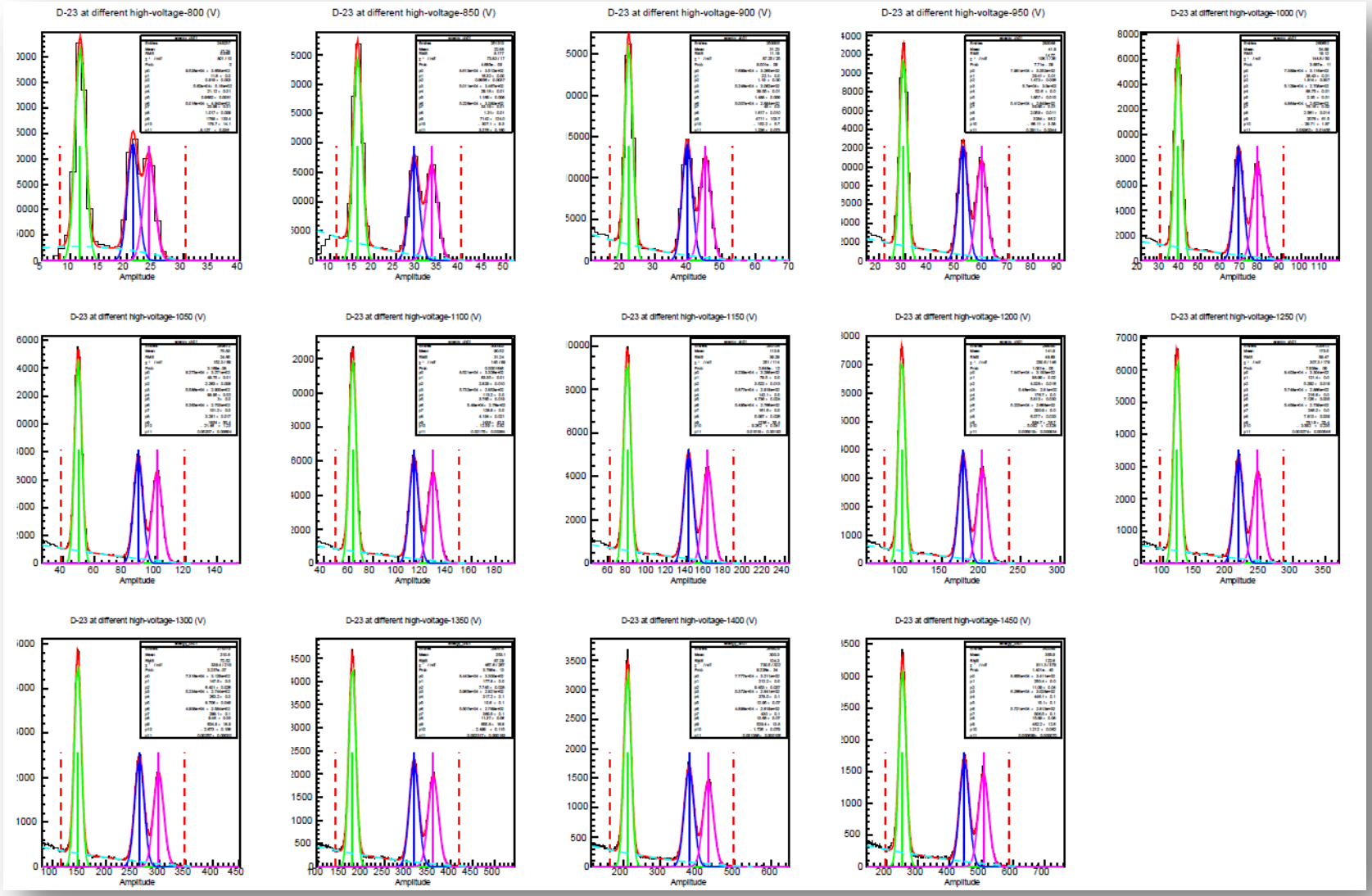
File Edit Options Buffers Tools C++ Help

Save Undo

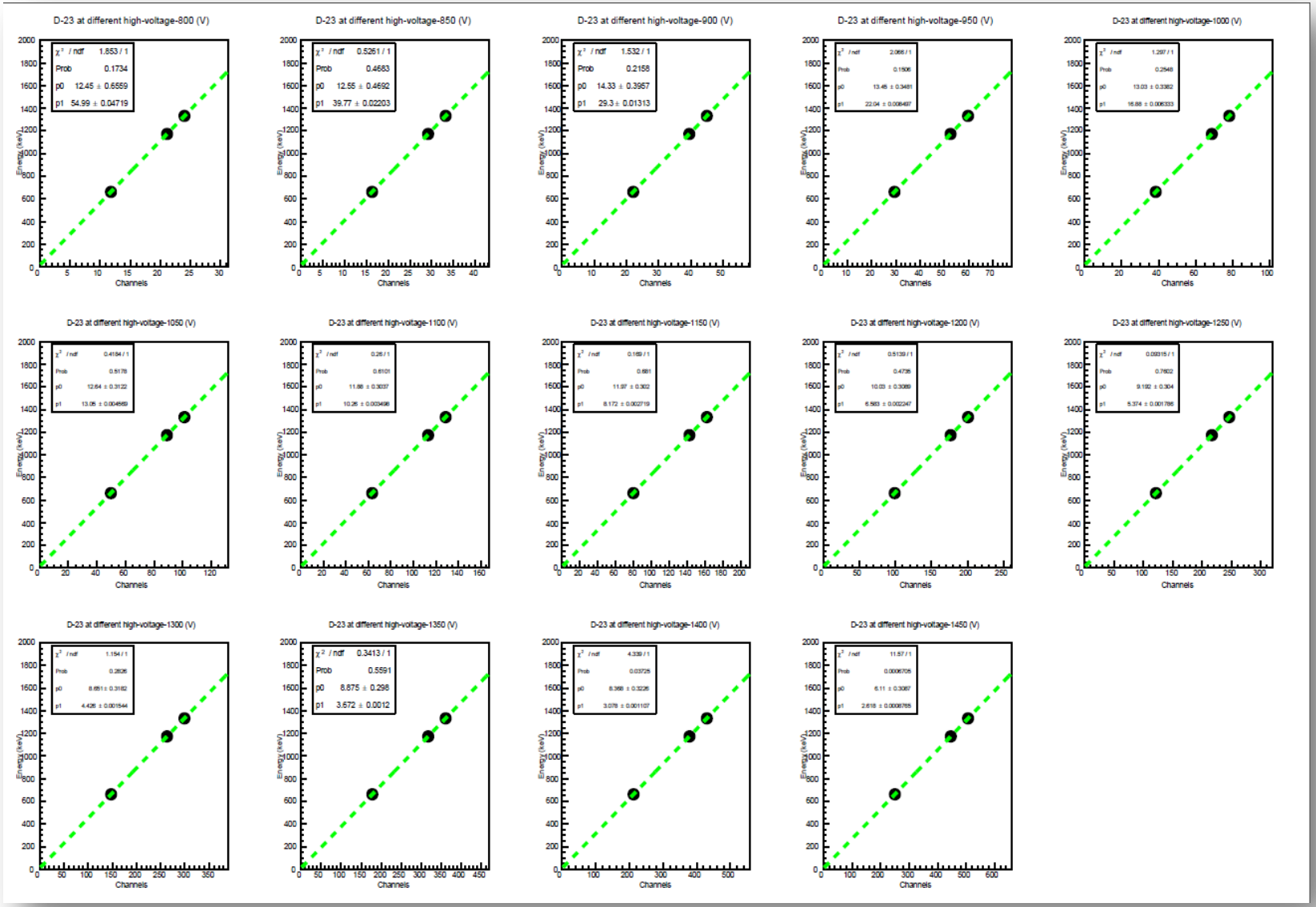
```
#include <TCanvas.h>
#include "TMath.h"
#include <TFile.h>
#include <TH1.h>
#include <TF1.h>
#include <TLegend.h>
#include <TSpectrum.h>
#include <TGraphErrors.h>
#include <TMultiGraph.h>
#include <TPaveStats.h>
#include <TStyle.h>
#include <TText.h>
#include <TVirtualFitter.h>

TCanvas *cc1 = new TCanvas("cc1","cc1");
TText *Tt = new TText();

const int NFILE = 4;
const int NPEAK = 4;
const int MAXGAM = 22;

char txt1_name[200];
char txt2_name[200];
char txt3_name[200];
char prn_name[200];
char open_name[200];
char close_name[200];

FILE *fp1;

const char*  NAME[NFILE];
const char*  NAME_area[NPEAK];
const char*  NAME_resolution[NPEAK];

double Ch_D_F_P[MAXGAM][NFILE][NPEAK];
double Ch_err_D_F_P[MAXGAM][NFILE][NPEAK];

TF1 *fit1gpol1;
TF1 *fit1gpol2;
TF1 *fit1gpol3;
TF1 *fit1gpol4;

TF1 *fit2gpol1;
TF1 *fit2gpol2;
TF1 *fit2gpol3;
TF1 *fit2gpol4;

TF1 *fit4gpol1;
TF1 *fit4gpol2;
TF1 *fit4gpol3;
TF1 *fit4gpol4;

TF1 *onegaus;
TF1 *pol0;
```

-:**- mac_Background.C Top L18 (C++/l Abbrev)

Amplitude spectra for D-23 at different high voltage



Channel-Energy calibration of D-23 at different high voltages



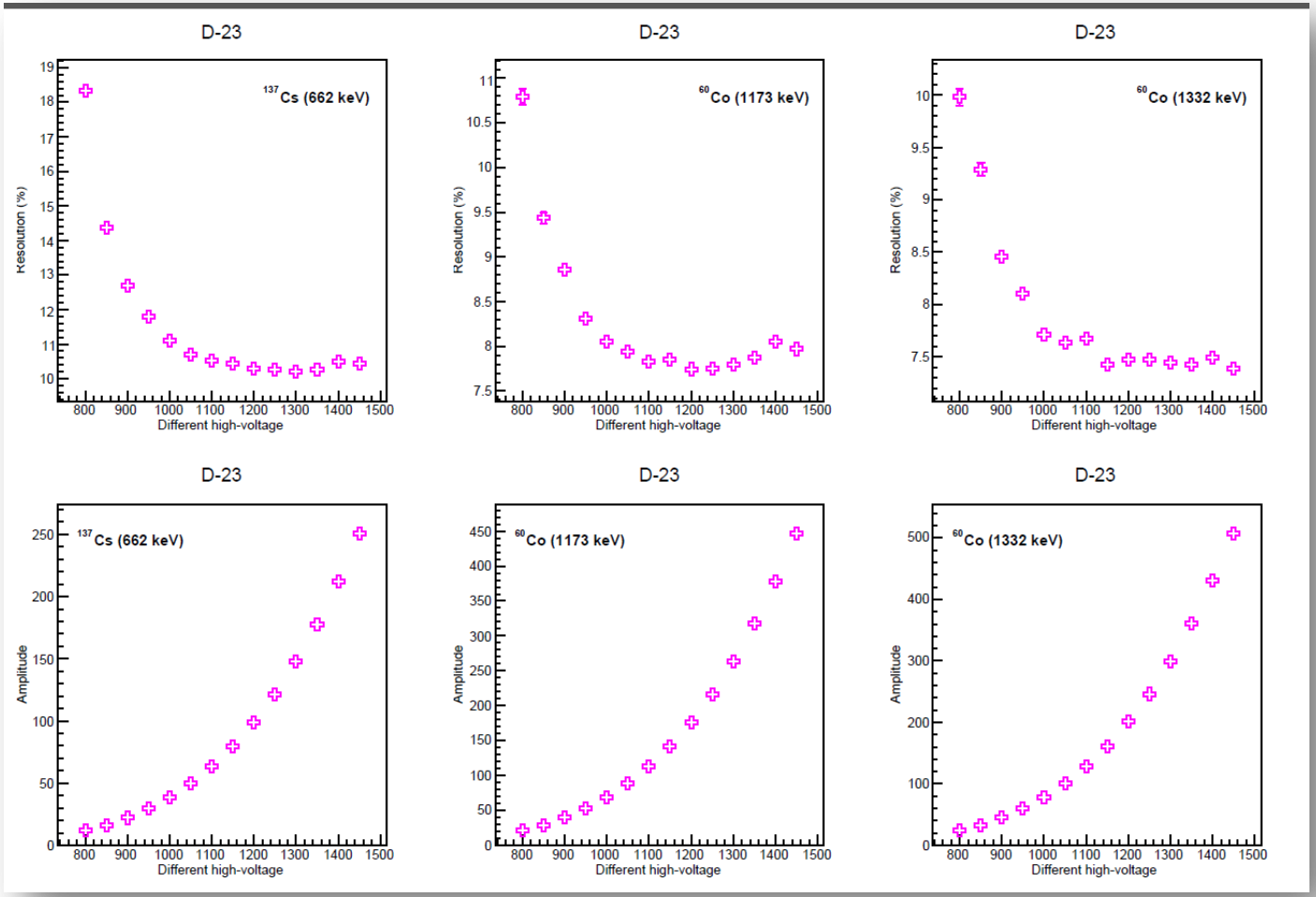
Results and discussions

- The energy resolution is obtained at FWHM of a single photo peak using this equation:
- $R = \frac{FWHM}{E_0} X\ 100\%$
- R is energy resolution.
- E_0 is related energy.

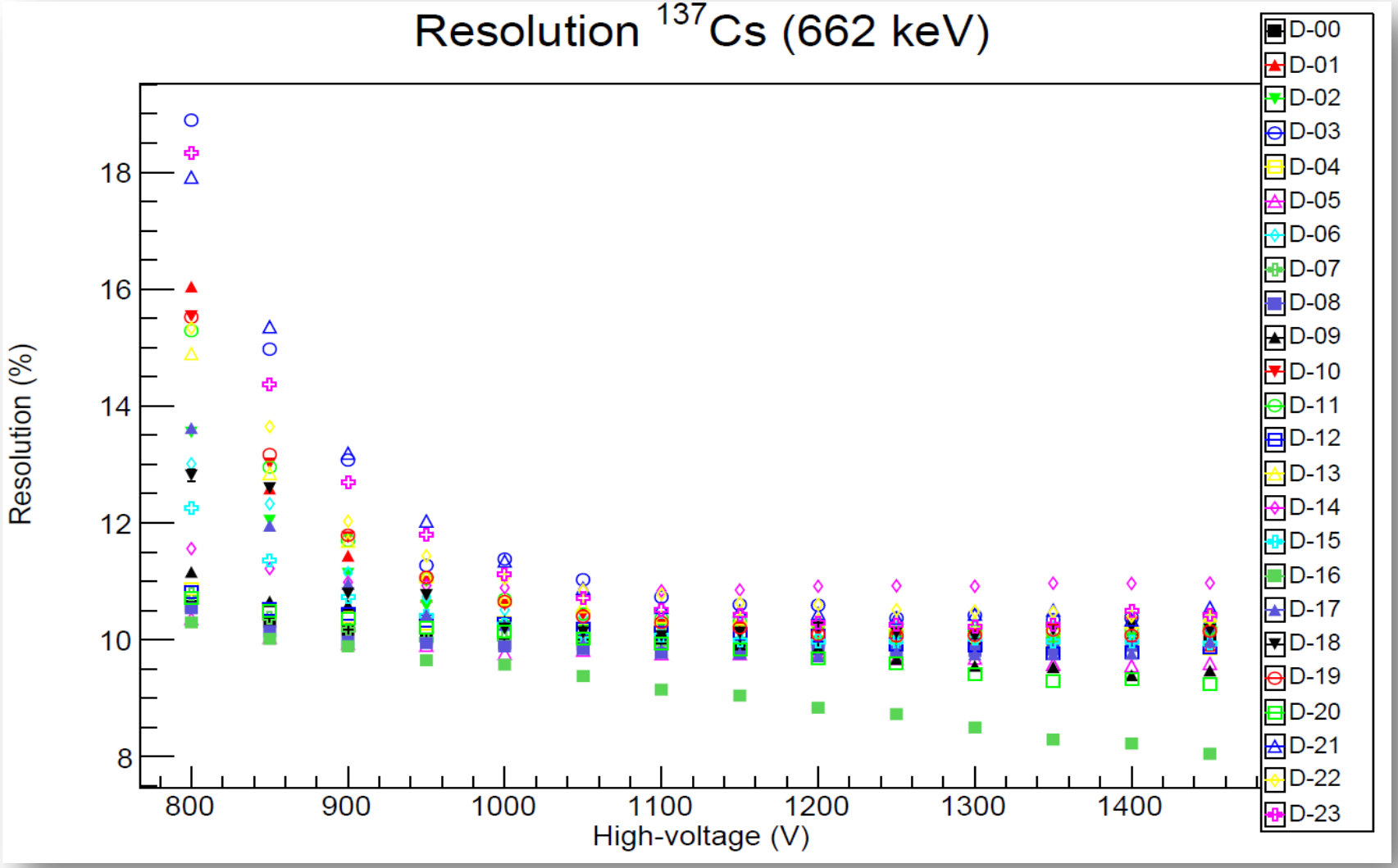
FWHM- Full-Width-At-Half-Maximum

Cont.

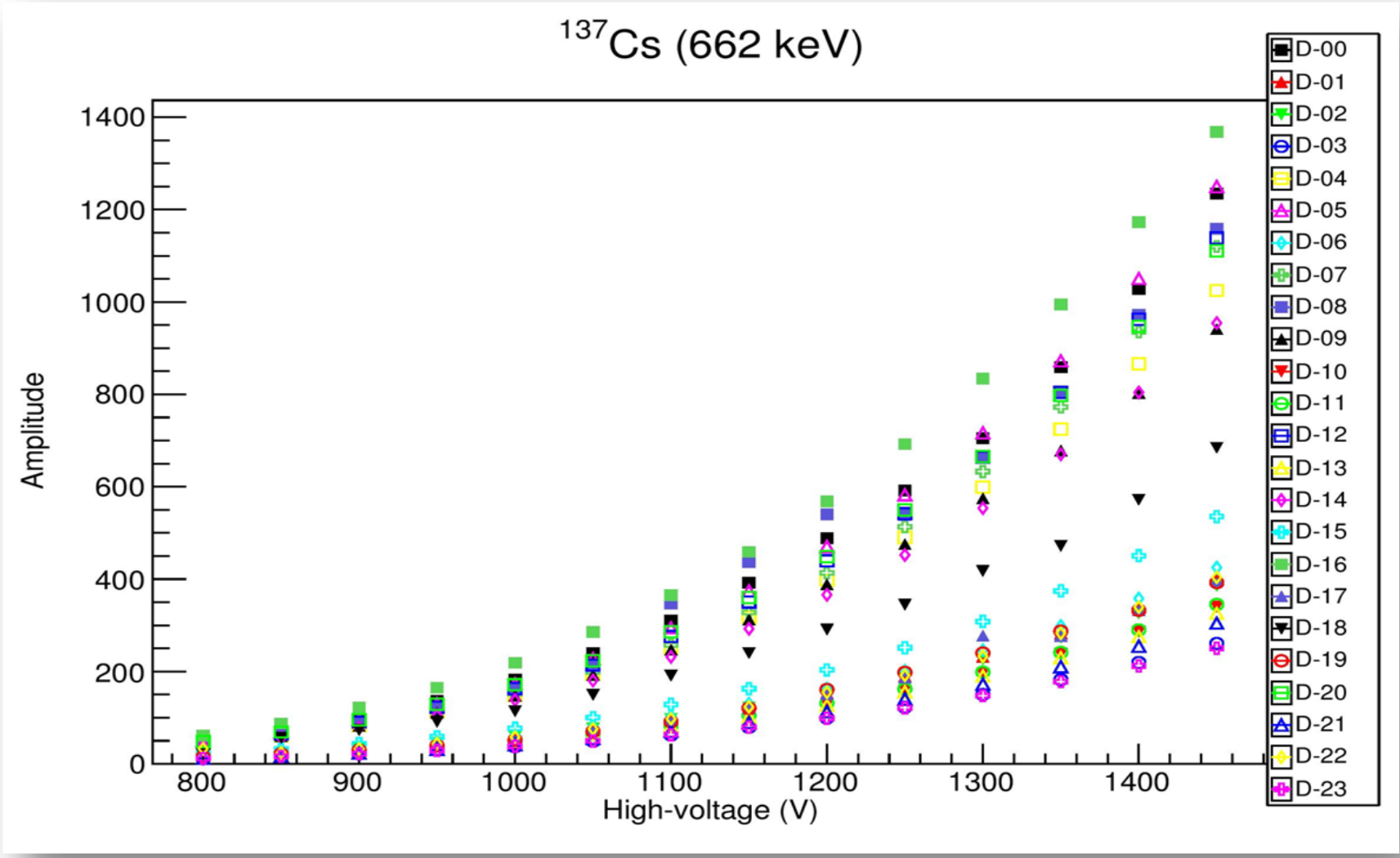
Resolution (%) and Amplitude as function of HV



Cont.

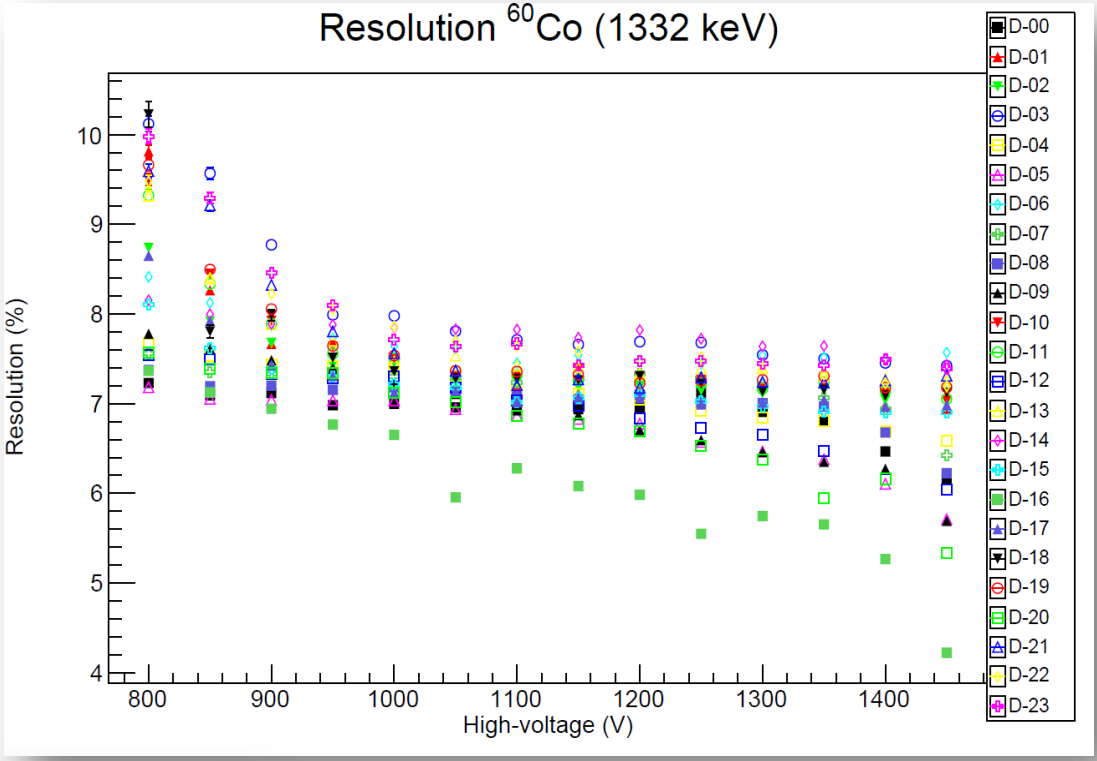

Resolution ^{137}Cs (662 keV)
Resolution (%)
High-voltage (V)
18
16
14
12
10
8
800
900
1000
1100
1200
1300
1400
D-00
D-01
D-02
D-03
D-04
D-05
D-06
D-07
D-08
D-09
D-10
D-11
D-12
D-13
D-14
D-15
D-16
D-17
D-18
D-19
D-20
D-21
D-22
D-23

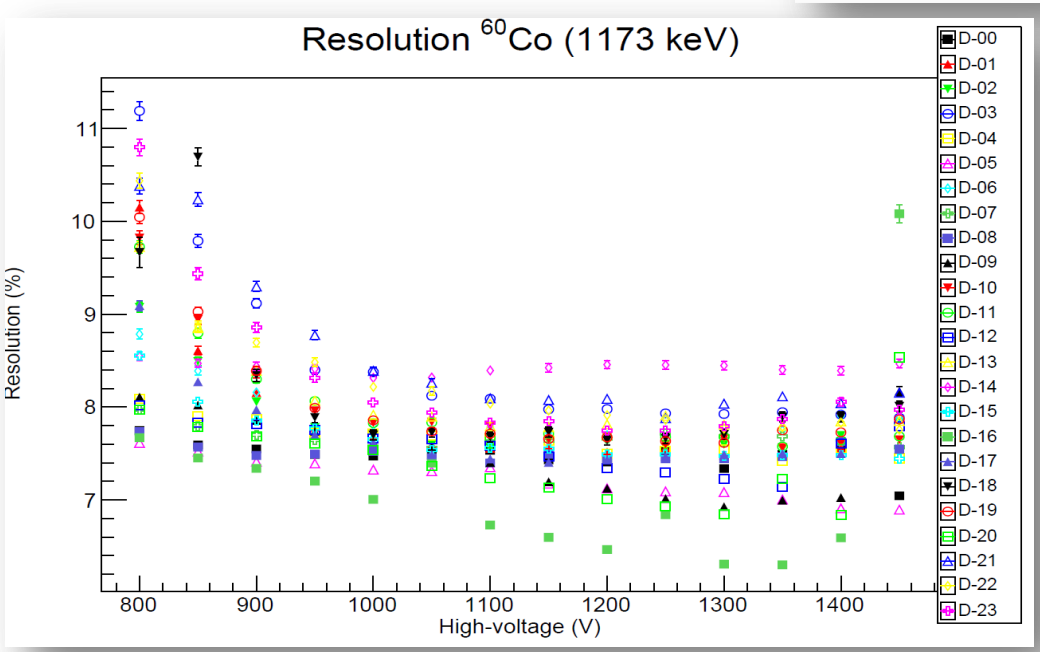
Cont.


^{137}Cs (662 keV)
Amplitude
High-voltage (V)
0
200
400
600
800
1000
1200
1400
800
900
1000
1100
1200
1300
1400
D-00
D-01
D-02
D-03
D-04
D-05
D-06
D-07
D-08
D-09
D-10
D-11
D-12
D-13
D-14
D-15
D-16
D-17
D-18
D-19
D-20
D-21
D-22
D-23

Cont.

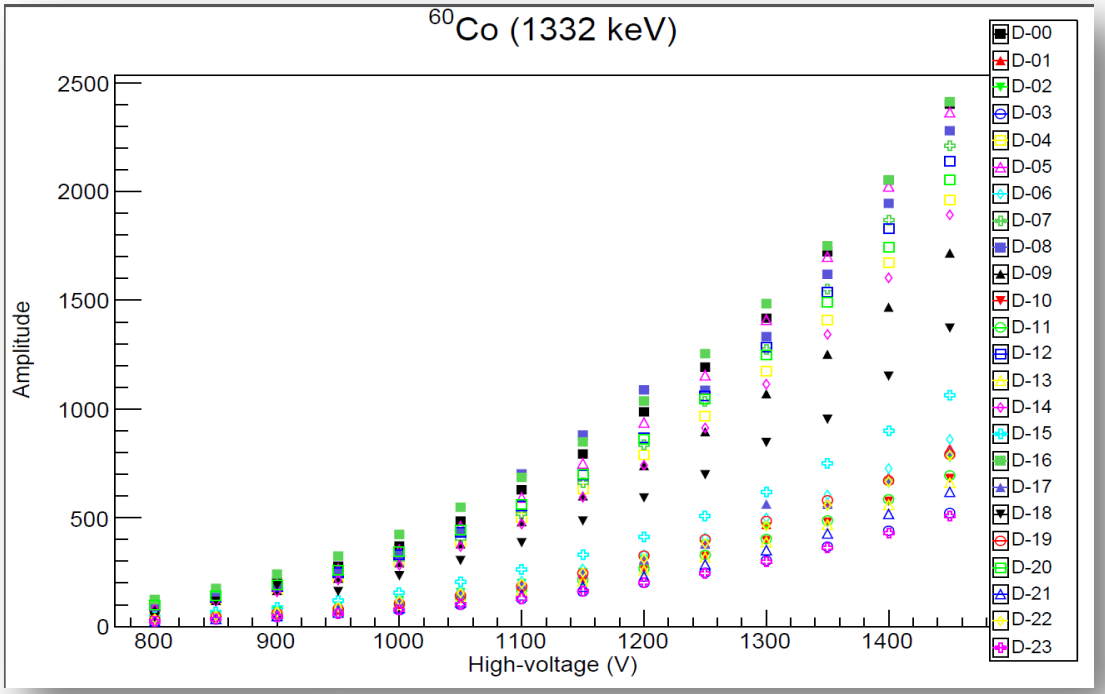
^{60}Co resolution

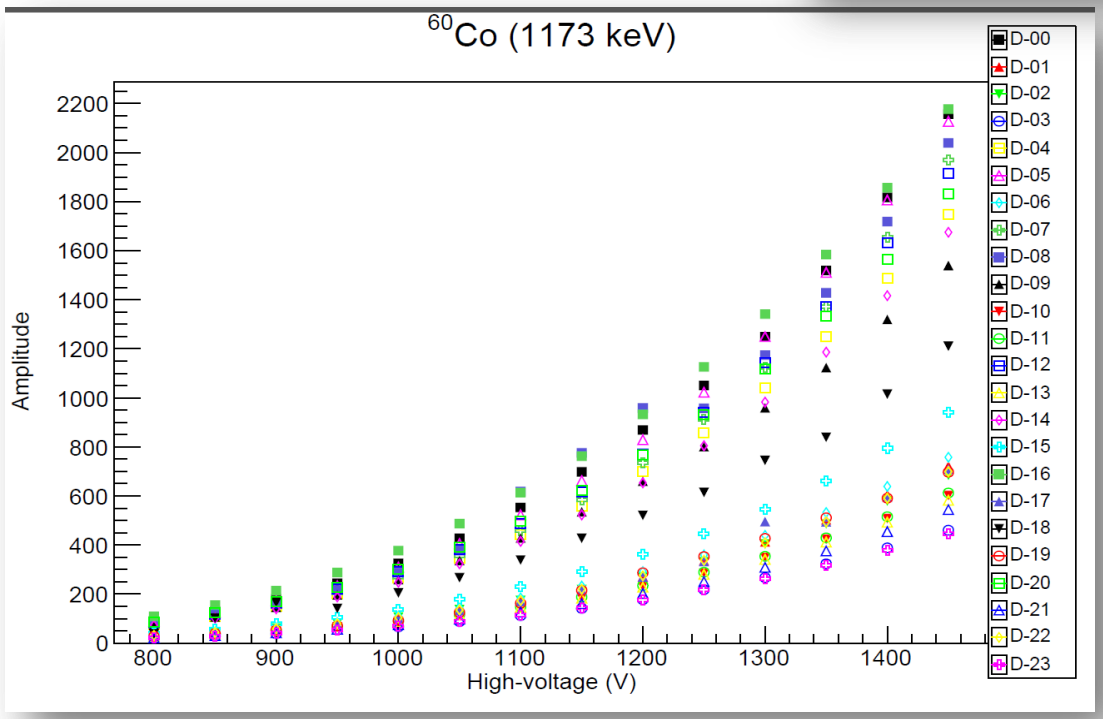




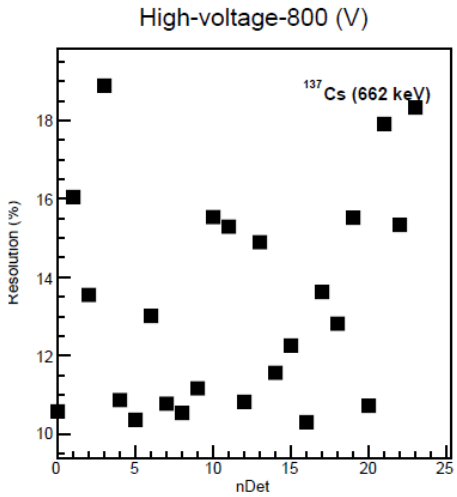
Cont.

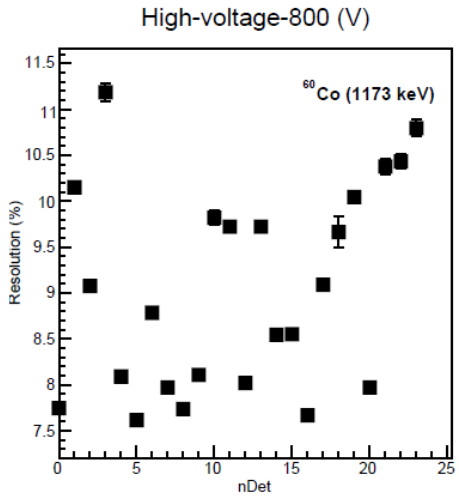
^{60}Co amplitude

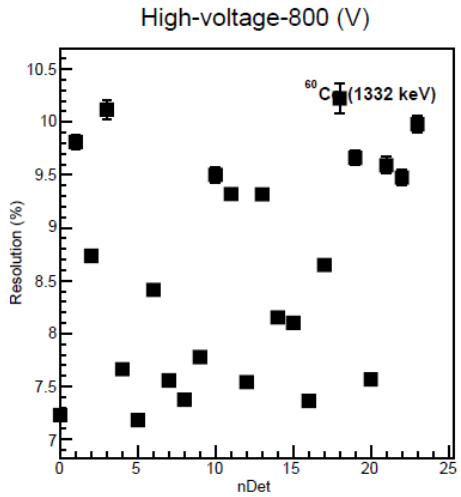


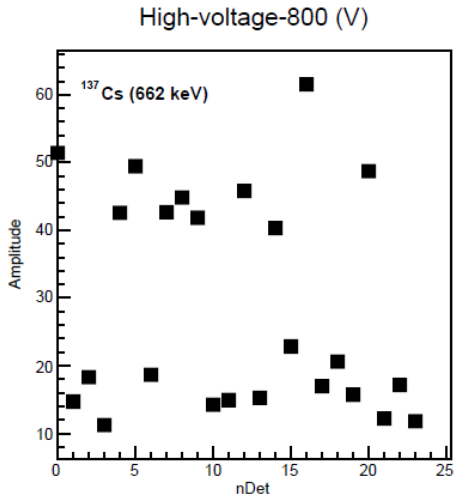


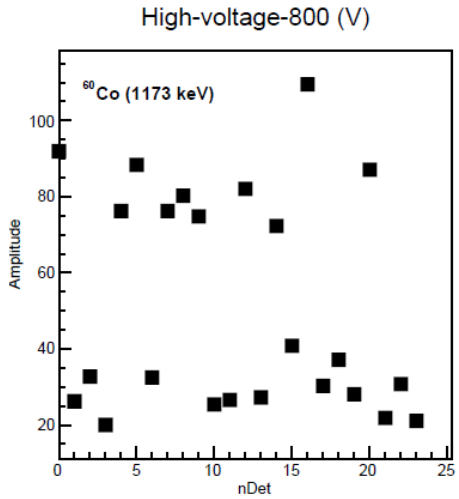
Cont.
Resolution & amplitude for nDet at 800V

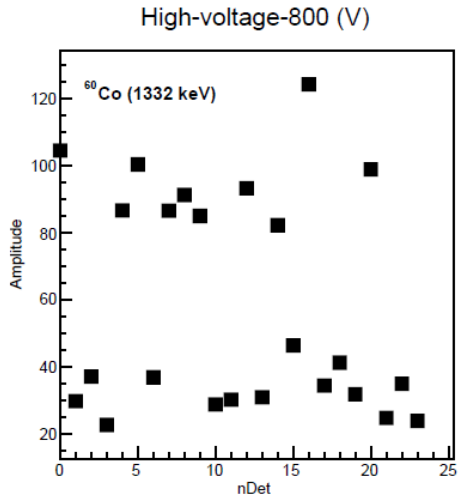












Conclusions

- 24 BGO gamma-ray detectors were tested and their energy resolution was determined using standard “point” calibration sources (^{137}Cs and ^{60}Co).
- For acquisition of the signals from BGO, a 32 channel computerized ADCM system was used.
- The digitized signals were analyzed by ROOT C++ software ROMANA.
- The photo-peak parameters were obtained by fitting Gaussian functions to the experimental data using ROOT C++ script.
- The obtained energy resolutions shows that the individual adjustment of the HV is needed for a single BGO gamma-ray detector.

Acknowledgement

- I would like to thank JINR for opening the invitation for us.
- DST, NRF and iThemba LABS for all the expenses of the trip.
- Many thanks goes to my project supervisor Dr. I.N Ruskov for endless assistence through this work.
- I also thank Mr. D. Grozdanov for technical assistence and result analysis.
- My S.A supervisors for allowing me to participate and gain such experience.
- Student practice 2017 group.

THANK YOU FOR YOUR ATTENTION!!