Aristotle University of Thessaloniki

Physics Department

Exercise 1

Spectrum analysis on ^{55}Fe using ROOT

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Contents

Introduction

In the exercise below, we analyze a gas detector spectrum obtained by irradiation with 5.9 keV X-rays from a ^{55}Fe source. Due to electronic noise, the escape peak at $\sim$2.7 keV is partially masked. A multi-Gaussian fit with linear background is performed to extract and quantify the relative peak intensities.

Key points

- **Source**: ^{55}Fe emits characteristic X-rays at 5.9 keV (85%) and 6.5 keV (15%)
- **Escape Peak**: Argon K-shell escape reduces energy by $\sim$ 3.2 keV, forming a peak at $\sim$ 2.7 keV
- **Method**: Fit includes 3 Gaussians + linear background
- **Goal**: Determine the intensity ratio between the 5.9 keV and escape peaks

Complete ROOT Script

Listing 1: Complete ROOT script for ^{55}Fe spectrum analysis

```
// analyze_55Fe.C
// ROOT script for 55Fe spectrum analysis

void analyze_55Fe() {
    // 1. Create histogram
    TH1F *spc4 = new TH1F("spc4", "55Fe Spectrum;Channel;Counts", 1024, 0, 1024);

    // 2. Read data file
    FILE *fp4 = fopen("QMO_5310.TXT", "r");
    if (!fp4) {
        std::cerr << "Error: Cannot open file!" << std::endl;
        return;
    }

    char line[80];
    int chnl, entr, nn;
    while (fgets(line, 80, fp4)) {
        sscanf(line, "%d,%d %d", &chnl, &entr, &nn);
        spc4->SetBinContent(chnl, entr);
    }
    fclose(fp4);

    // 3. Define fit function (3 Gaussians + linear background)
    TF1 *fitFunc = new TF1("fitFunc",
        "[0]*exp(-0.5*((x-[1])/[2])^2) + "  // 5.9 keV peak
        "[3]*exp(-0.5*((x-[4])/[5])^2) + "  // 6.5 keV peak
        "[6]*exp(-0.5*((x-[7])/[8])^2) + "  // Escape peak (~2.7 keV)
        "[9] + [10]*x",                     // Linear background
        0, 1024);

    // 4. Initial parameters (adjust based on your data)
    fitFunc->SetParameters(
        1120, 220, 30,    // 5.9 keV peak (amplitude, mean, sigma)
        350, 430, 100,     // 6.5 keV peak
        5850, 180, 20,     // Escape peak
        -3, 0.1           // Background (constant + slope)
    );

    // 5. Perform the fit
    spc4->Fit("fitFunc", "R");  // "R" for fit range

    // 6. Plot results
```

```
    TCanvas *c2 = new TCanvas("c2", "55Fe Fit Results",
        1000, 800);
    spc4->Draw();
    fitFunc->Draw("same");

    // Draw individual components
    TF1 *g1 = new TF1("g1", "gaus", 0, 1024);
    g1->SetParameters(fitFunc->GetParameter(0), fitFunc->
        GetParameter(1), fitFunc->GetParameter(2));
    g1->SetLineColor(kRed);
    g1->Draw("same");

    TF1 *g2 = new TF1("g2", "gaus", 0, 1024);
    g2->SetParameters(fitFunc->GetParameter(3), fitFunc->
        GetParameter(4), fitFunc->GetParameter(5));
    g2->SetLineColor(kBlue);
    g2->Draw("same");

    TF1 *g3 = new TF1("g3", "gaus", 0, 1024);
    g3->SetParameters(fitFunc->GetParameter(6), fitFunc->
        GetParameter(7), fitFunc->GetParameter(8));
    g3->SetLineColor(kGreen);
    g3->Draw("same");

    // 7. Calculate peak ratios
    double area_59keV = g1->Integral(g1->GetParameter(1)-3*
        g1->GetParameter(2),
                                g1->GetParameter(1)+3*g1->
                                    GetParameter(2));
    double area_escape = g3->Integral(g3->GetParameter(1)-3*
        g3->GetParameter(2),
                                g3->GetParameter(1)+3*g3->
                                    GetParameter(2));

    std::cout << "\nResults:\n";
    std::cout << "5.9 keV peak area: " << area_59keV << "\n"
        ;
    std::cout << "Escape peak area: " << area_escape << "\n"
        ;
    std::cout << "Ratio (5.9keV/Escape): " << area_59keV/
        area_escape << "\n";

    // 8. Save results
    c2->SaveAs("55Fe_fit_results.png");
}
```

Step 1: Histogram creation

```
// 1. Create histogram
TH1F *spc4 = new TH1F("spc4", "55Fe Spectrum;Channel;Counts"
    , 1024, 0, 1024);
```

Explanation: Creates a 1D histogram (`TH1F`) with:

- 1024 bins (channels) from 0 to 1024
- Title "55Fe Spectrum"; x-axis "Channel"; y-axis "Counts"
- `spc4` is the pointer to the histogram object

Step 2: Data loading

```
// 2. Read data file
FILE *fp4 = fopen("QMO_5310.TXT", "r");
// Read and parse lines, fill histogram
```

Data from the detector is read from a '.TXT' file line-by-line and each entry is loaded into the histogram.

Step 3: Fit function definition

```
// 3. Define fit function (3 Gaussians + linear background)
TF1 *fitFunc = new TF1("fitFunc",
    "[0]*exp(-0.5*((x-[1])/[2])^2) + "
    "[3]*exp(-0.5*((x-[4])/[5])^2) + "
    "[6]*exp(-0.5*((x-[7])/[8])^2) + "
    "[9] + [10]*x",
    0, 1024);
```

The fit function consists of 3 Gaussians and a linear background model.

Step 4: Initial parameters

```
// 4. Initial parameters
fitFunc->SetParameters(
    1120, 220, 30,     // 5.9 keV
    350, 430, 100,      // 6.5 keV
    5850, 180, 20,      // Escape
    -3, 0.1            // Background
);
```

Estimated initial values for peak amplitudes, means and widths, based on expected peak locations.

Step 5: Fit

```
// 5. Perform the fit
spc4->Fit("fitFunc", "R");
```

Performs the fit using the specified function over the full histogram range.

Step 6: Plot

```
// 6. Plot results
TCanvas *c2 = new TCanvas("c2", "55Fe Fit Results", 1000,
    800);
spc4->Draw();
fitFunc->Draw("same");
```

The total fit and each component Gaussian are drawn on a ROOT canvas.

Step 7: Peak ratio

```
// 7. Calculate peak ratios
double area_59keV = g1->Integral(...);
double area_escape = g3->Integral(...);
double ratio = area_59keV / area_escape;
```

Using numerical integration over $\mu \pm 3\sigma$, the area under each peak is computed and their ratio is calculated.

Results

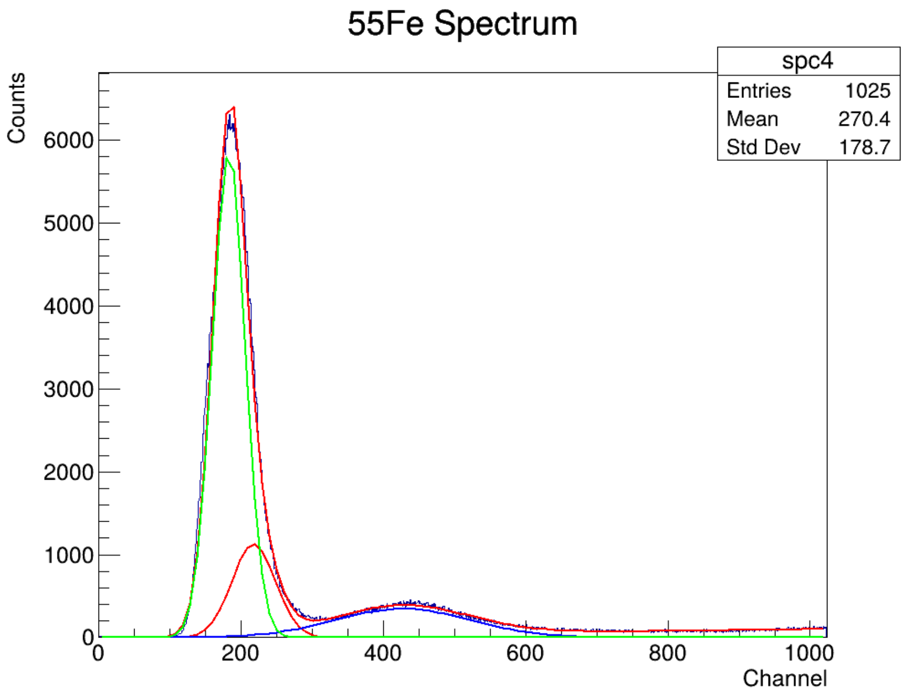

Figure 1: Fit results for the ^{55}Fe spectrum showing the three Gaussian components (red: 5.9 keV, blue: 6.5 keV, green: escape peak) and linear background.

The peak areas computed from the fitted Gaussians are:

- **5.9 keV peak area:** 87,295.7
- **Escape peak area:** 344,669

The ratio of the main 5.9 keV peak to the escape peak is:

$$\text{Ratio}_{5.9\text{ keV}/\text{Escape}} = \boxed{0.253}$$

This ratio characterizes the detector's response to the 5.9 keV X-rays versus the argon escape events, as visualized in Fig. 1.