AngCorr.C for γ-γ angular correlation analysis

1 Introduction

The AngCorr.C ROOT macro is intended for the analysis of γ–γ angular correlations in nuclear spectroscopy and for the extraction of δ mixing ratios of electromagnetic transitions. The calculations are based on the formalism developed by K.S. Krane and R.M. Steffen in *Phys. Rev. C* **2**, *724 (1970)* [DOI: https://doi.org/10.1103/PhysRevC.2.724].

Experimental angular correlation data are fitted directly with the theoretical angular correlation function

$$W(\theta_{\gamma\gamma}) = A_0 \left[1 + A_{22}(\delta) Q_2 P_2(\cos\theta_{\gamma\gamma}) + A_{44}(\delta) Q_4 P_4(\cos\theta_{\gamma\gamma})\right]$$

where A_0 is an overall normalization factor and A_{22} and A_{44} are the angular correlation coefficients, which depend on the δ mixing ratios of the transitions involved in the cascade. The coefficients Q_2 and Q_4 account for finite detector geometry effects, P_n are Legendre polynomials, and $\theta_{\gamma\gamma}$ is the relative angle between the two emitted gamma rays.

N.B.: In this macro, angular correlation data are directly fitted using the theoretical angular correlation function expressed as a function of the mixing ratio δ. The coefficients A_{22} and A_{44} are not treated as free fit parameters, but are computed at each step from the chosen cascade configuration and the corresponding value of δ. As a consequence, the extraction of the mixing ratio is performed through a direct χ^2 minimization with respect to δ, rather than through an intermediate fit of the angular correlation coefficients.

2 Minimal Usage

First, start an interactive ROOT session and load the macro: open ROOT with `root -l` and load the macro using `.L AngCorr.C`. Once the macro is loaded, define the gamma cascade to be analyzed with

`SetGammaCascade(J1, J2, J3, L1f, L2f, L1s, L2s, delta1, delta2)`.

Here `J1`, `J2` and `J3` are the spins of the nuclear levels involved in the cascade, given in sequence from the initial to the final state. The parameters `L1f` and `L2f` specify the multipolarities of the first gamma transition, while `L1s` and `L2s` refer to the multipolarities of the second gamma transition. The quantities `delta1` and `delta2` are the corresponding mixing ratios. By default, the code uses the Q_n coefficients corresponding to the FIPPS detector at ILL in single-crystal mode. If needed, the Q_n coefficients can be set explicitly using

`SetQvalues(Q2, Q4)`.

The mixing ratio of interest is then extracted using

`GetDelta(datafile.txt, whichdelta [1|2], arctan [0|1], logy [0|1])`.

The input file `datafile.txt` must contain the experimental angular correlation data arranged in three columns with $\cos\theta_{\gamma\gamma}$, $W(\theta_{\gamma\gamma})$, and the associated uncertainty σ_W. The parameter `whichdelta` selects which mixing ratio is varied in the χ^2 minimization (1 for δ_1, 2 for δ_2), while the other is kept fixed. The option `arctan` plots χ^2 as a function of δ (0) or $\arctan(\delta)$ (1, default). The option `logy` selects a linear (0) or logarithmic (1, default) scale for the χ^2 axis. If the default scanning range $\delta \in [-50, 50]$ or step size (0.01) for the mixing ratio is not appropriate, both can be modified using

`SetDeltaRange(delta_min, delta_max, delta_step)`

2.1 Usage example

This example considers a $2^+ \rightarrow 2^+ \rightarrow 0^+$ cascade, consisting of a mixed M1+E2 (γ_1) transition followed by a pure E2 (γ_2) transition. Of course, you may set any initial value for the mixing ratio that you wish to minimize.

```
$ root -l
root [0] .L AngCorr.C
root [1] SetGammaCascade(2, 2, 0, 1, 2, 2, 2, 0, 0)
root [2] GetDelta("angcorr_1382_614.txt", 1)

########################################
Fit parameters (chi2 global minimum):
A0  = 0.501822
A22 = 0.150149
A44 = 0.299961
########################################
DELTA = -3.355 (+0.295, -0.355)
CHI2 = 5.84376, NDOF = 20
P-VALUE = 0.999093
########################################
DELTA = 0.165 (+0.035, -0.035)
CHI2 = 130.397, NDOF = 20
P-VALUE = 3.28363e-18
########################################
```

The input text file `angcorr_1382_614.txt` is organized in three columns as follows:

```
 0.84805    0.53486     0.02368
 0.81915    0.52548     0.02343
 0.70711    0.46897     0.01523
 0.68200    0.47038     0.01549
 0.52992    0.47182     0.02413
 0.51504    0.46795     0.02324
 0.24192    0.51204     0.02307
 0.20791    0.49466     0.02252
 0.01745    0.51236     0.01613
-0.01745    0.50681     0.01599
-0.20791    0.50604     0.02288
-0.24192    0.49193     0.02253
-0.51504    0.42884     0.02104
-0.52992    0.45997     0.02207
-0.68200    0.45670     0.01542
-0.70711    0.46927     0.01590
-0.81915    0.49983     0.02309
-0.84805    0.52332     0.02362
-0.94552    0.63540     0.02583
-0.97437    0.67563     0.02040
-1.00000    0.68074     0.02668
```

Two plots are generated as output:

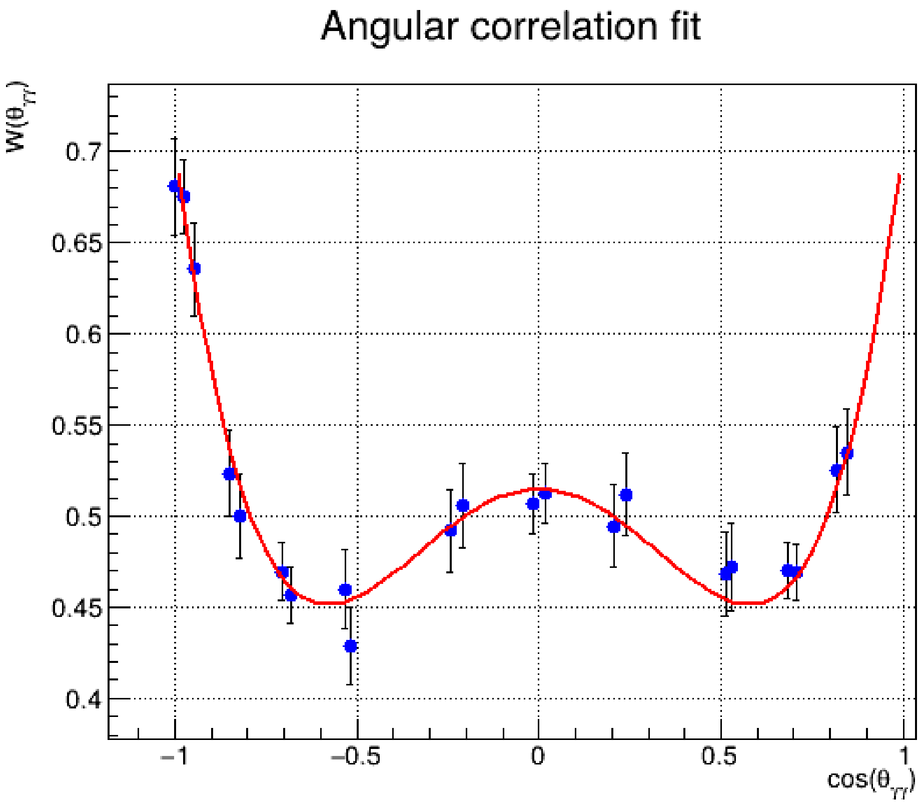

Figure 1: Angular correlation fit of experimental data.

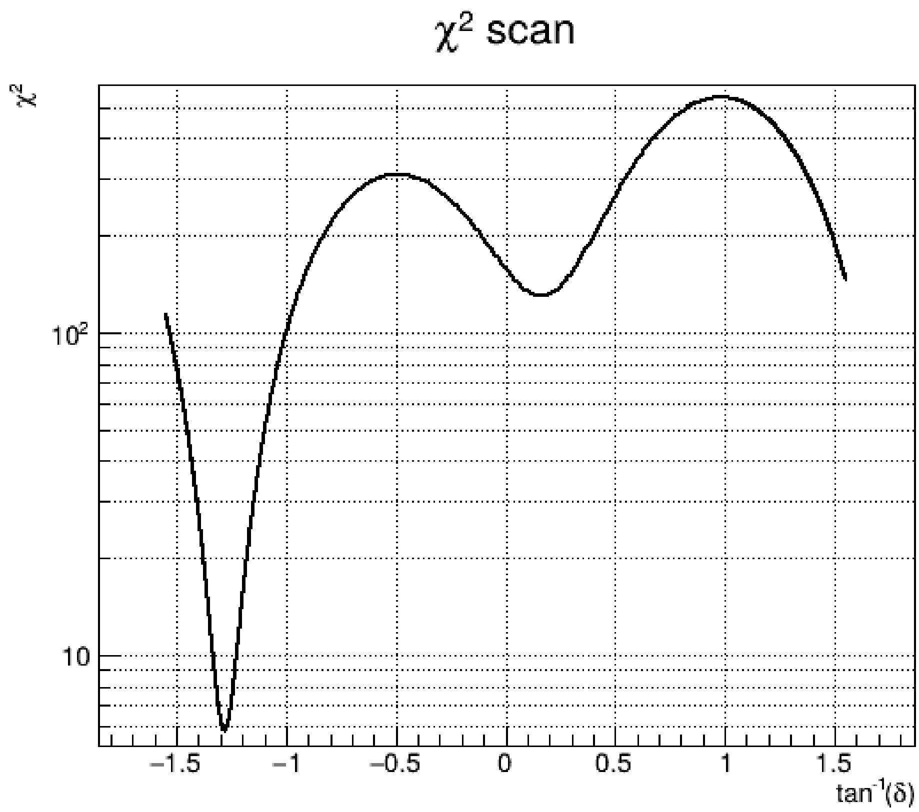

Figure 2: χ^2 scan as a function of the mixing ratio δ.