Starting with the GOSIA code

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Outline

- What is the GOSIA code ?
- How does it work ?
- GOSIA's input

GOSIA

- GOSIA is a Rochester – Warsaw semiclassical coupled-channel Coulomb excitation least-squares search code.

- Developed in early eighties by **T. Czosnyka, D. Cline, C.Y.Wu** and continuously upgraded to fulfill requirements of new experiments.

- Used extensively for Coulomb excitation studies of a wide range of nuclei.

- Typical use of GOSIA:
  - Fitting of the matrix elements to the experimental data.
  - Simulation of the experiments:

    - to predict which γ - ray will be observed
    - to check to what extent the observation will depend on individual matrix elements.

GOSIA code - Mozilla Firefox

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http://www.slcj.uw.edu.pl/en/81.html

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HIL GOSIA code

HIL MENU

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GOSIA code

- Standard version of the GOSIA code (revised in December 2009): GOSIA
- Version of the GOSIA code handling simultaneously projectile and target excitation: GOSIA2

to compile it on a Linux machine: f77 gosia_20080630.f -o gosia -fno-automatic

GOSIA webpage

GOSIA User Group webpage is maintained by Doug Cline from the University of Rochester. The website is designed to provide the potential user with the information and codes to facilitate use of the GOSIA suite of codes for Coulomb excitation studies. Gosia source codes, sample inputs and outputs, the User Manual, reports, newsletters, as well as links to resources of potential use to the members of the Gosia Users Group are provided. In addition a Gosia Forum has been implemented to facilitate discussion between individual members as well as between the Steering Committee and Users Group members.

GOSIA User's Manual

GOSIA User's Manual (version April 2008)   ← User's manual

GOSIA mailing list

We maintain a mailing list. All GOSIA users are welcome to subscribe. Please follow the instructions.

GOSIA Workshop '08

The first GOSIA Workshop took place at HIL Warsaw, 8-10 April 2008. During the first day of the workshop presentations were concentrated on recent achievements in Coulex analysis. On the second day a GOSIA hands-on training was organised, while the last day provided an opportunity to discuss future plans and possible developments of the Coulex analysis software.
GOSIA Workshop website

Done

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GOSIA: Coulomb Excitation Codes
Web site of the GOSIA User Group

| Home | Coulex News | Downloads | Forum | Facilities | Resources | Users Group | Publications | Links |

Tomasz
Czosnyka
1952 - 2006

UNIVERSITY of
ROCHESTER

UNIVERSITAS
VARSOVIENSIS

New developments

See Coulex News for descriptions of the new Gosia GUI, Gosia User Manual, the Gosia Wiki, and Gosia User Forum

The wealth of Coulomb excitation data collected using present day experimental technique allows model independent determination of most E2 and E3 matrix elements connecting low-lying collective nuclear levels populated by electromagnetic excitation. A semiclassical coupled-channel Coulomb excitation least-squares search code, GOSIA, has been developed to analyze the large sets of experimental data required to unambiguously determine the many electromagnetic matrix elements involved in heavy-ion induced Coulomb excitation. Up to 999 electromagnetic matrix elements, coupling up to 100 levels, can be fitted to reproduce simultaneously several thousand data from up to 50 independent experiments. Fast semi-analytic approximation of the coupled-channels system of differential equations describing electromagnetic excitation is used to achieve computational speed required for such a task. Evaluation of rotational invariants using the measured E2 matrix elements derived using GOSIA determines the intrinsic frame quadrupole shape parameters for low-lying states. The completeness and extent of such electromagnetic structure information adds a new dimension to the study of collectivity in nuclei.

This Gosia users website is designed to provide the potential user with the information and codes to facilitate use of the GOSIA suite of codes for Coulomb excitation studies. The above links provide access to a library of Gosia source codes, sample inputs and outputs, the User Manual, reports, newsletters, as well as links to resources of potential use to the members of the Gosia Users Group. Registration to the Gosia Users Group is available via the above link to the User Group webpage.
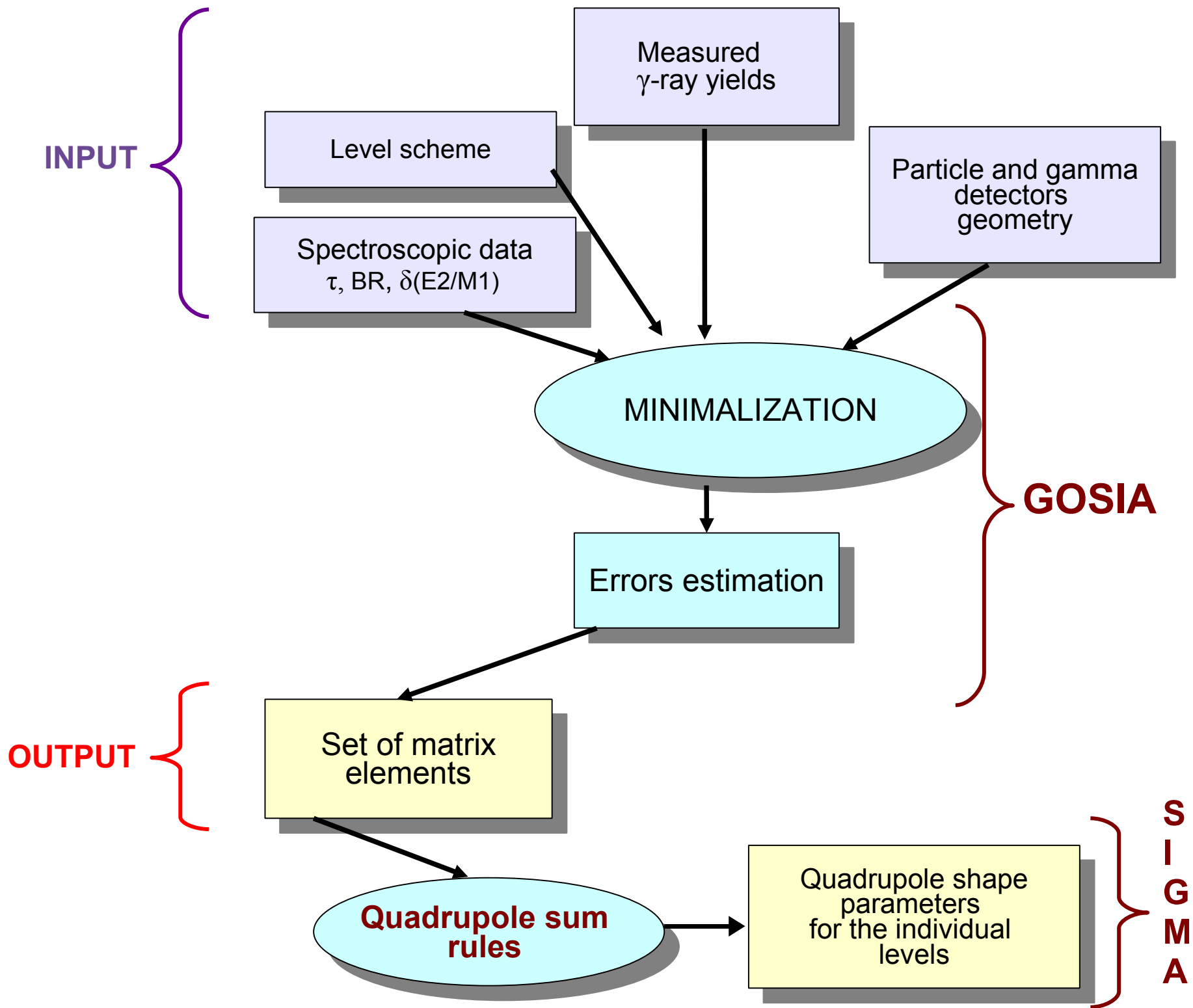
Rochester Coulex Homepage   Gosia Wiki   Warsaw
Coulex Homepage

Mozilla Firefox

How does GOSIA work?

- starts with **experimental conditions** - angle, energy and **matrix element set** between all relevant states.

- **GOSIA solves differential equations and calculates excitation probabilities to find the level population and γ-ray yields.**

- **Construct the standard χ^2 function built on the observed and calculated γ-ray yields.**

- Known spectroscopic data related to the matrix elements may also be taken into account.

- Experimental γ-ray yields are integrated over the θ_{scatt} and energy range of incident projectile.

- Includes effects influencing γ-ray yields: internal conversion, size of Ge, deorientation effect, γ-ray angular distribution.

$$\chi^2 = \frac{1}{p} \left\{ \sum_{i=1}^{N\exp} \sum_{j=1}^{N\det} \sum_{k=1}^{N\gamma} \left[\left(\frac{C_{ij} Y_k^{(T)} - Y_k^{(E)}}{\Delta Y_k^{(E)}} \right)^2 \right. \right.$$

$$\left. \left. + \sum_{i=1}^{Ns.d.} \left(\frac{d_i^{(T)} - d_i^{(E)}}{\Delta d_i^{(E)}} \right)^2 \right] \right\}$$

experimental yield

calculated yield

normalisation factor

spectroscopic data point
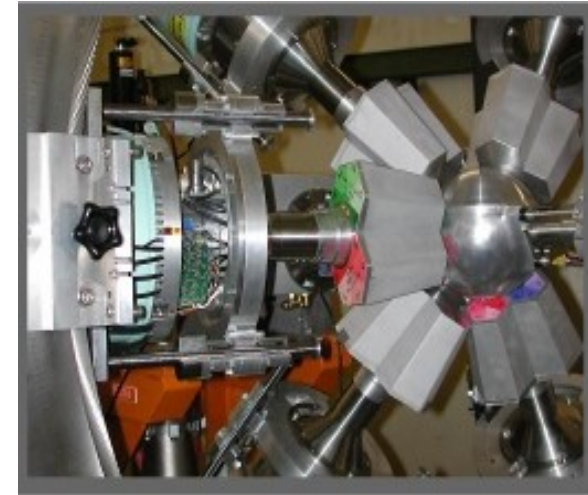
calculated magnitude

The fitting procedure is continued, until the convergence of the χ^2 is achieved and the set of matrix elements optimally reproduce the experimental data.
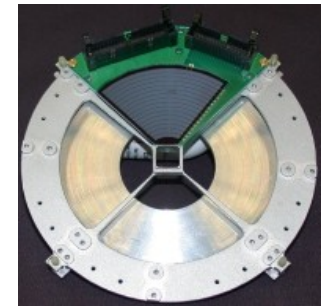
Schematic illustration of a typical Coulomb excitation setup.

Ge cluster

DSSD

$\theta_{LAB} \approx 15^o - 52^o$
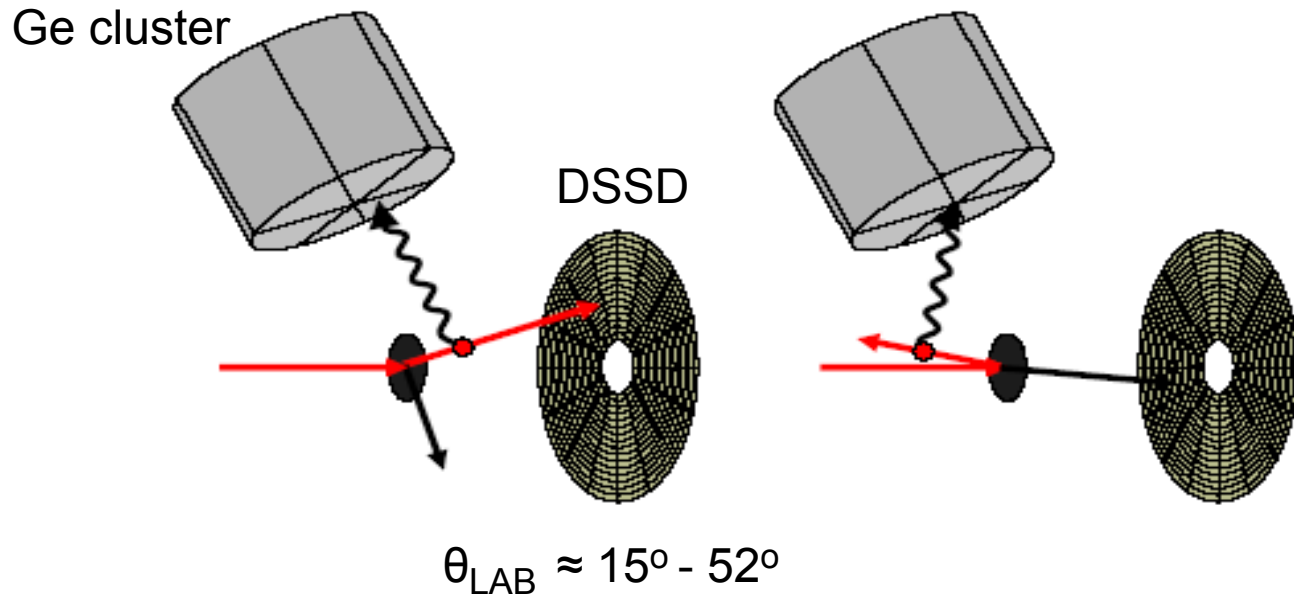
MINIBALL

DSSD

- $^{188}_{80}$**Hg** beam bombarding $^{107}_{47}$**Ag** target
- E_{beam} (535.8 MeV) < E_{safe} (θ_{scatt}=52°)

- **D**ouble-**s**ided **s**ilicon **d**etector **DSSD** placed at forward angles to cover a large range of $\theta_{CMscatt}$
- Recoil or projectile nuclei detected, identified by the energy deposited – kinematics of the scattering process reconstruction.

- Ge array MINIBALL (granuality: **8 x 3** x 6 = 144 segments)

8 clusters (θ, Φ) defined in GOSIA

GOSIA's INPUT

SECTIONS:

0. **header files** – additional files: experimental yields, fitted ME,...

1. **LEVE** – level scheme of the investigated nucleus

2. **ME** – set of matrix elements

3. **EXPT** – definition of the experimental condition for each of the experiments to be analyzed
($Z_{P/T}$, $A_{P/T}$, mean θ_{scatt} and $E_{bombarding}$)

4. **OP,YIEL** – calculation of the γ – ray yields following Coulomb excitation:

      i. first part: ICC, γ – ray detectors description (θ,Φ)

     ii. second part: additional informations required for fitting:
normalization constants, BR, τ, δ(E2/M1), known ME

5. **OP,RAW** – declaration of the efficiency curves of all Ge, summation over a set of γ detectors.

6. **OP,STAR** – calculate the Coulomb excitation amplitudes and cross sections

7. **OP,POIN** – to calculate the Coulomb excitation and deexcitation ***point*** γ – ray yields at **one** mean θ_{scatt} and **one** $E_{bombarding}$ (specified in EXPT)

8. **OP,INTG** – to integrate the deexcitation γ – ray yields over the θ_{scatt} and energy loss in the target. Produces ***integrated*** yields that are used for realistic comparison with experimental data.

9. **OP,MINI** – execution of the least-squares fitting of matrix elements to the experimental data

```
OP,FILE
22,3,1
188hg107ag_px.out          ←——————— output
14,3,1
dum.14
15,3,1
dum.15
17,3,1
dum.17
18,3,1
dum.18
12,3,1
theo_min.me          ←——————— fitted matrix elements
9,3,1
miniball_gdet.f9     ←——————— Attenuation factor -  to reproduce experimental γ-ray angular
8,3,1                              distribution a finite size of Ge has to be taken into account.
miniball_gdet.f8     ←
3,3,1                              absorption coeff. to reproduce γ energy dependence
188hg107ag_px.yie    ←              of the detector efficiency
4,3,1
188hg107ag_px.cor
7,3,1                              experimental γ-ray yields not efficiency corrected
188hg107ag_px_mz.map
0,0,0
OP,TITL
Beam Excitation 188Hg, target 107Ag
OP,GOSI
LEVE
1,1,0,0
.
.
```

Beginning ...

```
OP,FILE
22,3,1
GDET.out
9,3,1
miniball_gdet.f9
8,3,1
miniball_gdet.f8
0,0,0
OP,TITL
GDET
OP,GDET
-23
0.05, 3.4, 7.8, 11.0 !1
0,0,0,0,0,0,0
0.05, 3.4, 7.8, 11.0 !2
0,0,0,0,0,0,0
0.05, 3.4, 7.8, 11.0 !3
0,0,0,0,0,0,0
.
.
.
0.05, 3.4, 7.8, 11.0 !22
0,0,0,0,0,0,0
0.05, 3.4, 7.8, 11.0 !23
0,0,0,0,0,0,0
OP,EXIT
```

OP,GDET – to create a files which contains the data needed to reproduce experimental γ – ray angular distribution (finite size of Ge and absorption mechanism have to be taken into account)

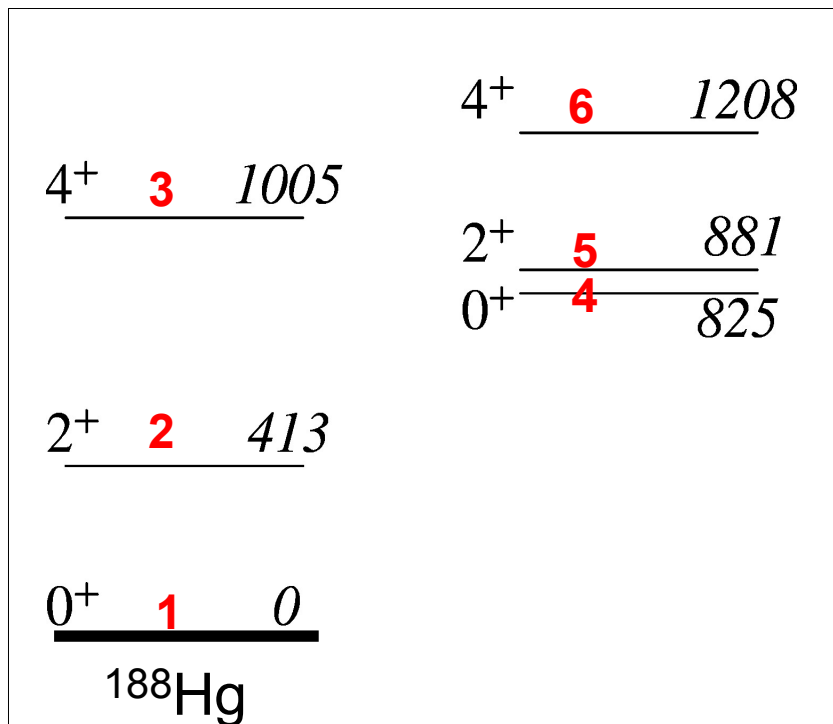Number of γ detectors (nr. of Miniball's clusters)

The distance from the taget

The length of crystal

The radius of active core

The radius of inactive core

Level scheme definition


```
LEVE
 1, 1, 0, 0.    !  nr, parity, spin, energy [MeV]
 2, 1, 2, 0.413
 .
 .
 .
 0, 0, 0, 0     !  input termination
```

megen

generation of matrix elements set

Apply γ transition selection rules to create a set of all possible matrix elements involved in excitation.

- This is easy but takes time and any error will corrupt the results of simulation!

- megen - a simple code to do the job which uses data in **GOSIA** format.

megen

generation of matrix elements set

level number

parity

spin

level energy [MeV]

levels.inp

```
1,  1,  0.,  0.
2,  1,  2.,  0.413
3,  1,  4.,  1.005
4,  1,  0.,  0.825
5,  1,  2.,  0.881
6,  1,  4.,  1.208
0,0,0,0
```

megen input

input termination

megen
generation of matrix elements set

1
Create setup for this multipolarity (y/n)
n
2 ← **E2**
Create setup for this multipolarity (y/n)
y
Do you want them coupled ?
n
Please give limit value
-1.5 1.5
3
Create setup for this multipolarity (y/n)
n
(...) **M1**
7 ←
Create setup for this multipolarity (y/n)
y
Do you want them coupled ?
n
Please give limit value
-1 1
8
Create setup for this multipolarity (y/n)
n

megen output

```
          me.out

2 0  0  0  0    ◄──────── E2
     1   2  1   1.5  -1.5
     1   5  1   1.5  -1.5
     2   2  1   1.5  -1.5
     2   3  1   1.5  -1.5
     2   4  1   1.5  -1.5
     2   5  1   1.5  -1.5
     2   6  1   1.5  -1.5
     3   3  1   1.5  -1.5
     3   5  1   1.5  -1.5
```

initial level | final level | starting value (1) | low limit | high limit

```
     4   5  1   1.5  -1.5
     5   5  1   1.5  -1.5
     5   6  1   1.5  -1.5
     6   6  1   1.5  -1.5
7 0  0  0  0    ◄──────── M1
     2   2  1   1.0  -1.0
     2   5  1   1.0  -1.0
     3   3  1   1.0  -1.0
     3   6  1   1.0  -1.0
     5   5  1   1.0  -1.0
     6   6  1   1.0  -1.0
  0 0  0  0  0
```

How to get a starting value of matrix elements?

- Check the literature for published values
- Get all the available spectroscopic data (lifetimes, E2/M1 mixing ratios, branching ratios)
- Ask a theoretician

- Use **OP,THEO** to generate the rest from **rotational model**
- Do some fitting with spectroscopic data only

OP,THEO
generation of a starting point

From the GOSIA manual:

www.slcj.uw.edu.pl/en/gosia/2008manual.pdf

- OP, THEO generates only the matrix specified in the ME input and writes them to the (...) file.

- For in-band or equal-K interband transitions <u>only one</u> *(intrinsic moment for a given multipolarity)* marked Q1 is relevant. For non-equal K values generally two moments with the projections equal to the sum and difference of K's are required (Q1 and Q2), unless one of the K's is zero, when again only Q1 is needed.

- For the K-forbidden transitions a three parameter Mikhailov formula is used.

OP,THEO for ¹⁸⁸Hg

$$\langle KI_f \| \hat{M}(E2) \| KI_i \rangle = \sqrt{(2I_i + 1)} \langle I_i, K, 2, 0 \mid I_f K \rangle \sqrt{\frac{5}{16\pi}} e Q_0$$

OP,THEO

2   ← number of bands (2)

0,3   ← First band, K and number of states

1,2,3   ← band member indices

0,3   ← Second band, K and number of states

4,5,6

- - - - - -

2   ← Multipolarity E2

1,1   ← Bands 1 and 1 (in-band)

Q1,0,0   ← Moment Q1 of the rotational band

1,2

Q1,0,0

2,2

Q1,0,0

0,0   ← end of multipolarities loop

0   ← end of band-band input

band 1

band 2

4⁺   **6**   *1208*

4⁺   **3**   *1005*

2⁺   **5**   *881*

0⁺   **4**   *825*

2⁺   **2**   *413*

0⁺   **1**   *0*

¹⁸⁸Hg

Before minimisation ...

- Let's assume we have some best possible starting set of matrix elements.
- Using this matrix elements GOSIA calculates gamma ray yields.
- **What is the GOSIA yield ?**
- Point yield and integrated yield