GOSIA hands-on sessions

- ^{74}Zn projectile excitation
- E=275 MeV, I=10^{6} pps
- ^{196}Pt target, 1 mg/cm^{2}
- GALILEO (25 HPGe), 22 cm from the target
- ANNULAR Si DETECTOR, forward angles: 20-60^{o} LAB
- OP,GDET
- OP,INTI → count rates for ^{74}Zn, gamma efficiency will be introduced
- OP,MINI → gamma yields will be provided

GOSIA installation

LINUX:

> f77 gosia.f -o gosia -fno-automatic

> gfortran gosia.f -o gosia

MAC:

> ifort gosia.f -o gosia

(you can use linux approach)

GOSIA input structure

1. OP,FILE – header files (TAPEs)

2. OP,TITL

3. OP,GOSI (with fit) - OP,COUL (without fit)

- LEVE

- ME

- EXPT

- CONT

END,

4. OP,YIEL

5. OP,RAW

6. OP,INTG/INTI

7. OP,MINI

8. OP,ERRO

9. OP,POIN

10. OP,STAR

11. OP,THEO

12. OP, MAP

13. OP, REST

14. OP,GDET

15. OP,SIXJ

GOSIA input structure

1. OP,FILE – header files (TAPEs)

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3. OP,GOSI (with fit) - OP,COUL (without fit)

- LEVE

- ME

- EXPT

- CONT

END,

4. OP,YIEL

5. OP,RAW

6. OP,INTG/INTI

7. OP,MINI

8. OP,ERRO

9. OP,POIN

10. OP,STAR

11. OP,THEO

12. OP, MAP

13. OP, REST

14. OP,GDET

15. OP,SIXJ

OP,FILE

22 3 1

mini.out

9 3 1

gdet.f9

8 3 1

gdet.f8

12 3 1

matrix.me

3 3 1

yield.f3

4 3 1

corr.f4

7 3 1

map.f7

14 3 1

sixj.14

0 0 0

GOSIA options use/create files

TAPE

GAMMA DETECTORS

OP,GDET

```
OP,FILE
22 3 1
gdet.out
9 3 1
gdet.f9
8 3 1
gdet.f8
0 0 0
OP,TITL
Gamma detectors
OP,GDET
-1
0.5 3.5 7.8 12.5
0 0 0 0 0 0 0
OP,EXIT
```

22 – output name

GDET output file – parameters needed to reproduce γ energy dependence of the gamma detector solid angle attenuation coeff. Q_k

GDET output file – absorption coeff. needed to reproduce the detector efficiency, created if NPD is **negative** – related to “raw” spectra defined in OP,RAW

End of OP,FILE

Title

OP,GDET input options

OP,GDET

```
OP,GDET
-2
0.5  3.8  7.8  22     !det1
0 0 0 0 0 0 0
0.5  3.8  8.8  22     !det2
0 0 0 0 0 0
OP,EXIT
```

OP,GDET

```
OP,GDET
-2
0.5  3.8  7.8  22     !det1
0 0 0 0 0 0 0
0.5  3.8  8.8  22     !det2
0 0 0 0 0 0
OP,EXIT
```

NPD – number of physically different gamma detectors in use for all experiments defined in EXPT

OP,GDET

```
OP,GDET
-2
0.5  3.8  7.8  22     !det1
0 0 0 0 0 0 0
0.5  3.8  8.8  22     !det2
0 0 0 0 0 0
OP,EXIT
```

The radius of the inactive core

OP,GDET

```
OP,GDET
-2
0.5  3.8  7.8  22     !det1
0 0 0 0 0 0 0
0.5  3.8  8.8  22     !det2
0 0 0 0 0 0
OP,EXIT
```

The radius of the active core

OP,GDET

```
OP,GDET
-2
0.5  3.8  7.8  22     !det1
0 0 0 0 0 0 0
0.5  3.8  8.8  22     !det2
0 0 0 0 0 0
OP,EXIT
```

The length of a crystal [cm]

OP,GDET

```
OP,GDET
-2
0.5  3.8  7.8  22     !det1
0 0 0 0 0 0 0
0.5  3.8  8.8  22     !det2
0 0 0 0 0 0
OP,EXIT
```

The distance from the target [cm]

OP,GDET

```
OP,GDET
-2
0.5  3.8  7.8  22     !det1
0 0 0 0 0 0 0
0.5  3.8  8.8  22     !det2
0 0 0 0 0 0
OP,EXIT
```

NPD – number of physically different gamma detectors in use for all experiments defined in EXPT

The distance from the target [cm]

The length of a crystal [cm]

The radius of the active core

The radius of the inactive core

GOSIA INPUT

GOSIA

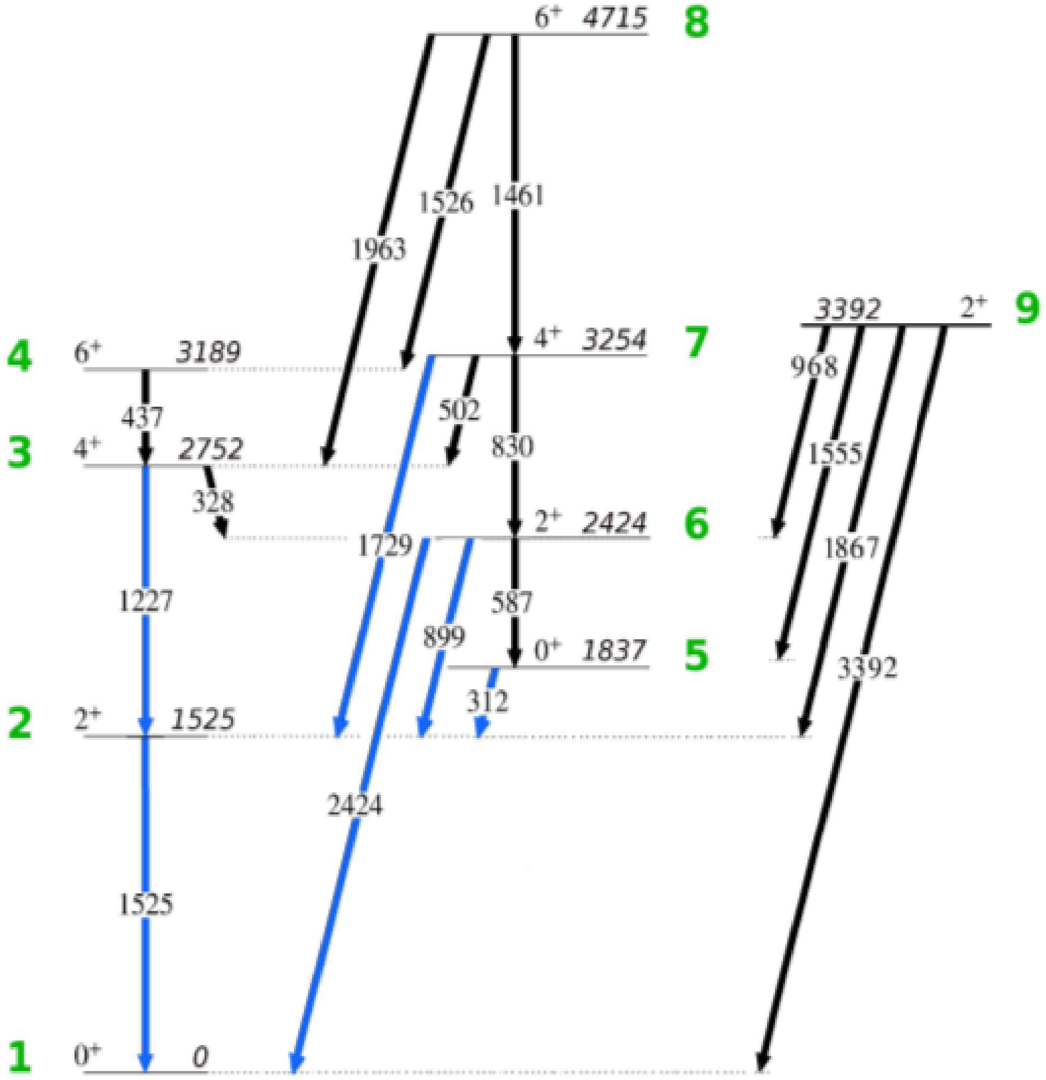
```
OP,FILE
    22 3 1
    star.out
    0 0 0
OP,TITL
    OP,STAR output test
OP,GOSI
    LEVE
        1,1,0,0.0
        2,1,2,1.500
        3,1,4,2.700
        0,0,0,0
    ME
        2 0 0 0 0
        1  2 0.1   1.0  -1.0
        2  2 0.1   1.0  -1.0
        2  3 0.1   1.0  -1.0
        0 0 0 0 0
    EXPT
        1 20 42
        -79 197 100 100  3 1 1 -170 172 0 1
    CONT
        INR,
        INT,1.
        1,1000
        LCK,
        0 0
        WRN,3.
        PRT,
        0 0
END,

OP,STAR
OP,EXIT
```

OP,STAR

Command to calculate Coulomb excitation amplitudes and probabilities (not the gamma-ray yields)

OP,GOSI – level scheme

LEVE
1 1 0 0.0
2 1 2 1.525
3 1 4 2.752
.
.
.
0 0 0 0

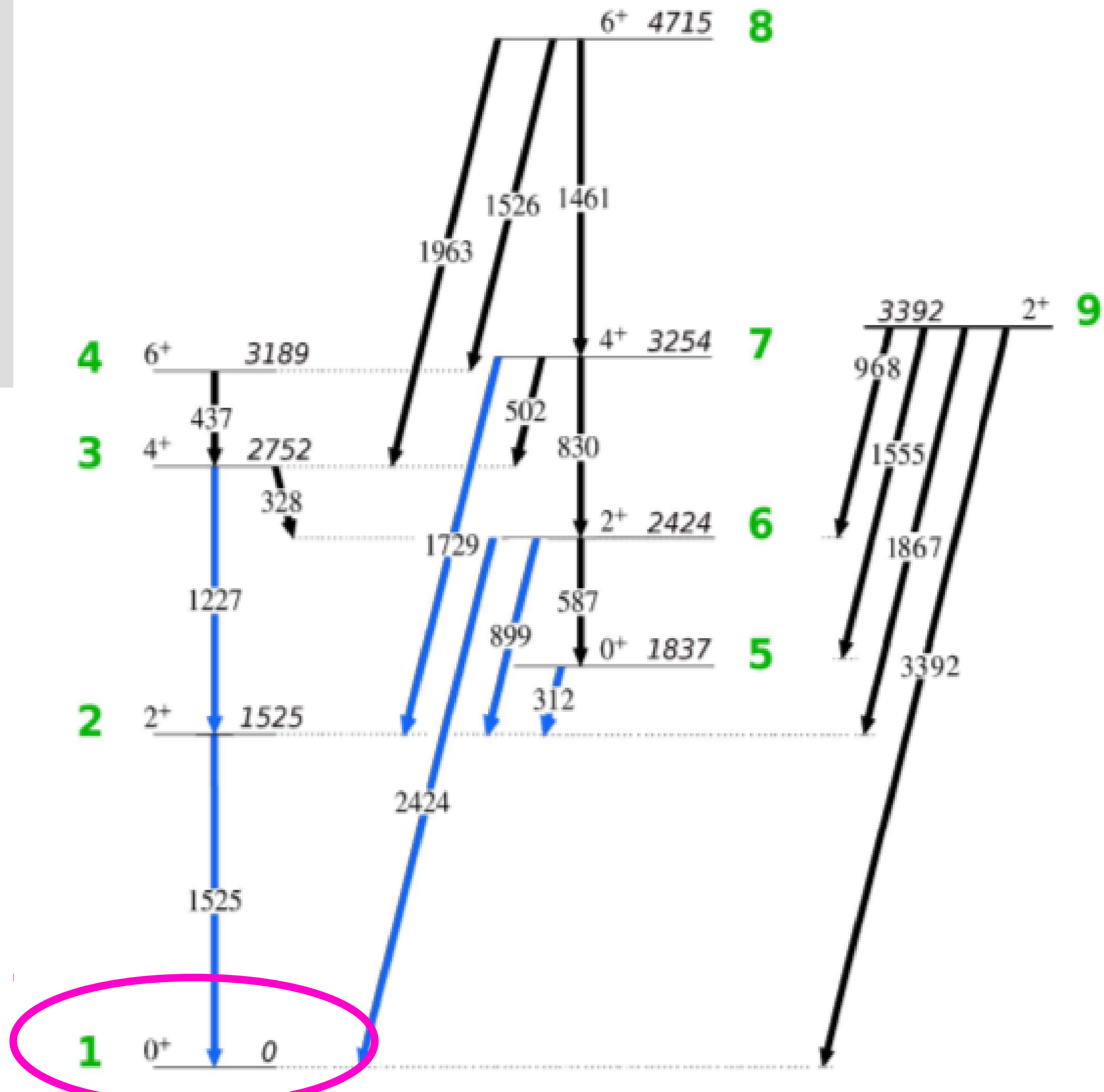


1 = GROUND STATE

OP,GOSI – level scheme

```
LEVE
1  1  0  0.0
2  1  2  1.525
3  1  4  2.752
.
.
.
0  0  0  0
```

Level INDEX

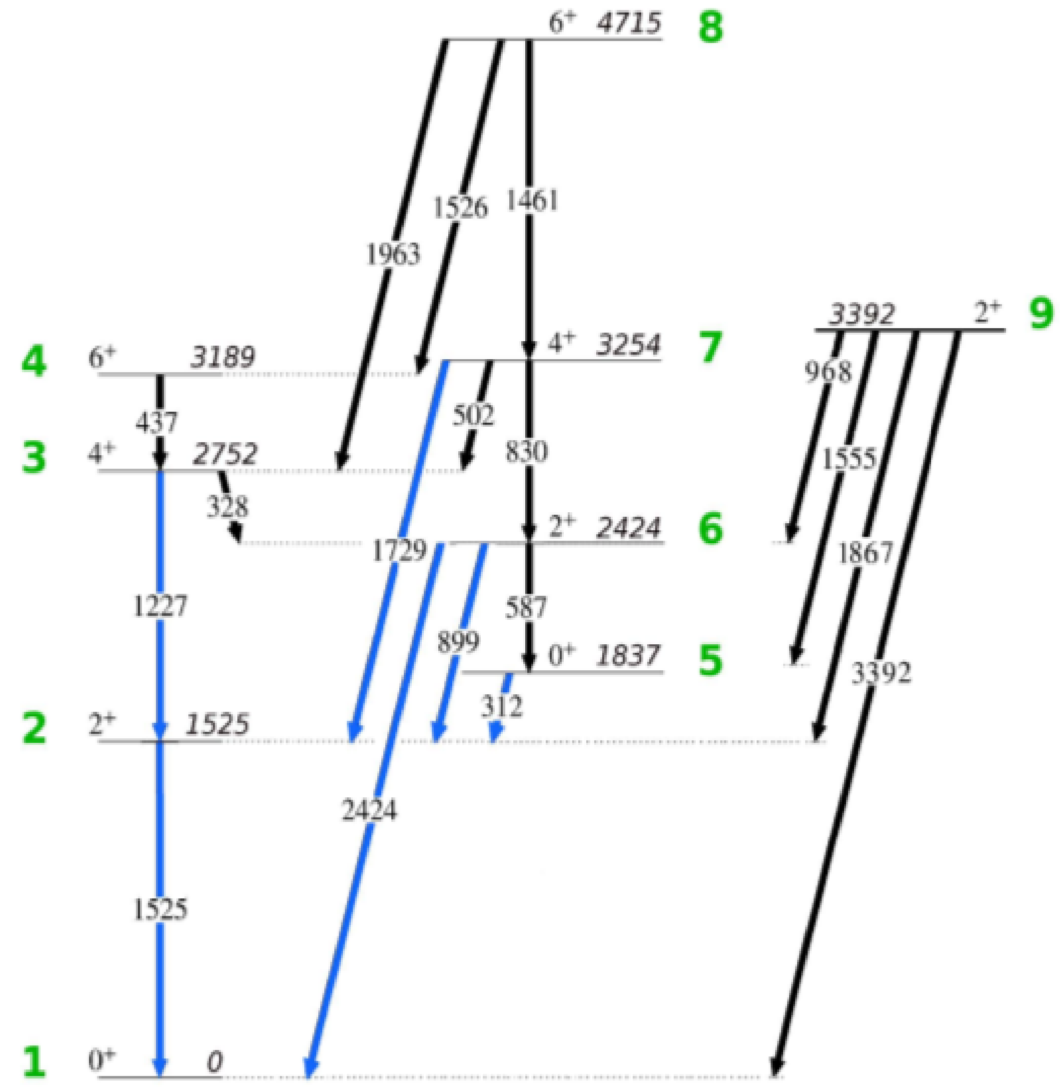


1 = GROUND STATE

OP,GOSI – level scheme

```
LEVE
1  1  0  0.0
2  1  2  1.525
3  1  4  2.752
.
.
.
0  0  0  0
```

Parity



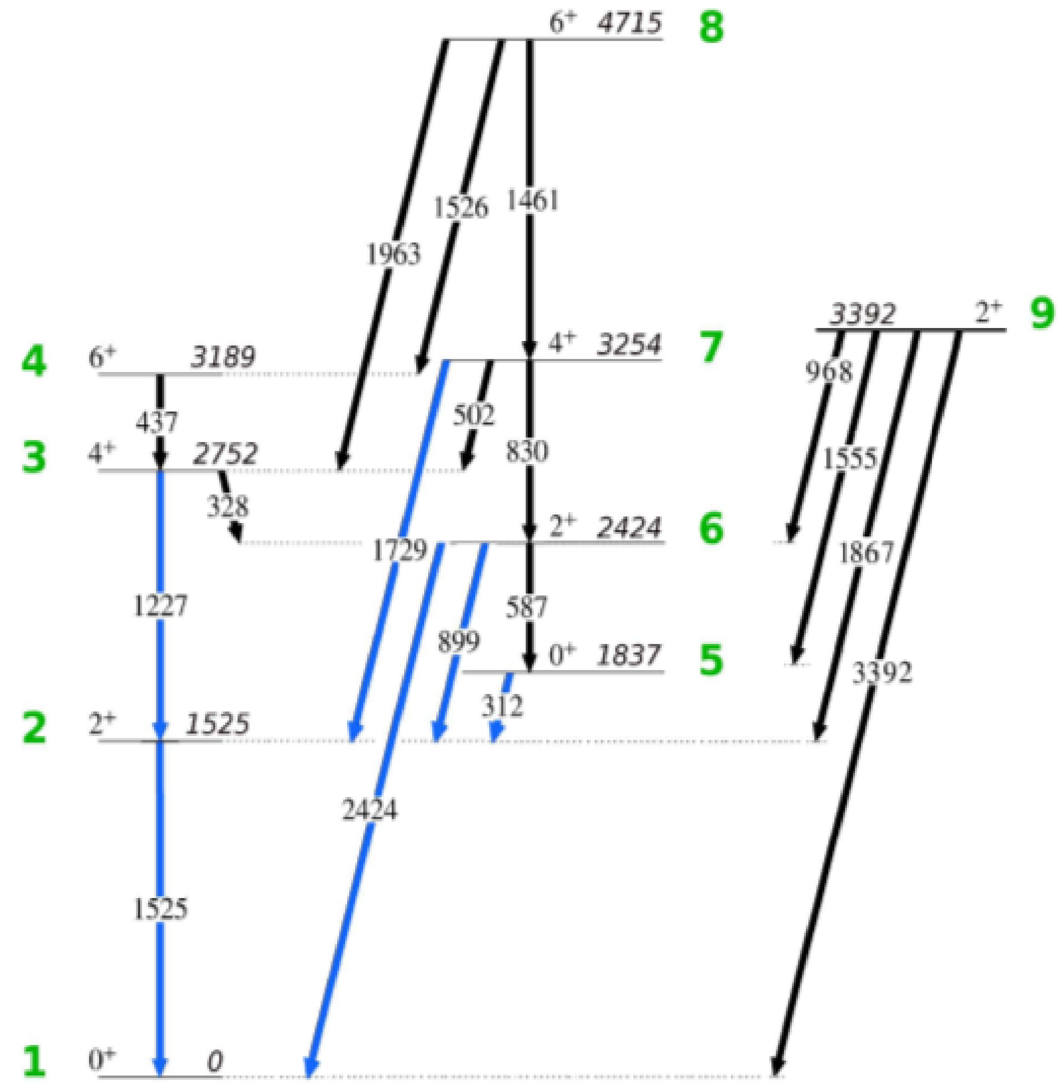
1 = GROUND STATE

OP,GOSI – level scheme

```
LEVE
1  1  0  0.0
2  1  2  1.525
3  1  4  2.752
.
.
.
0  0  0  0
```

SPIN

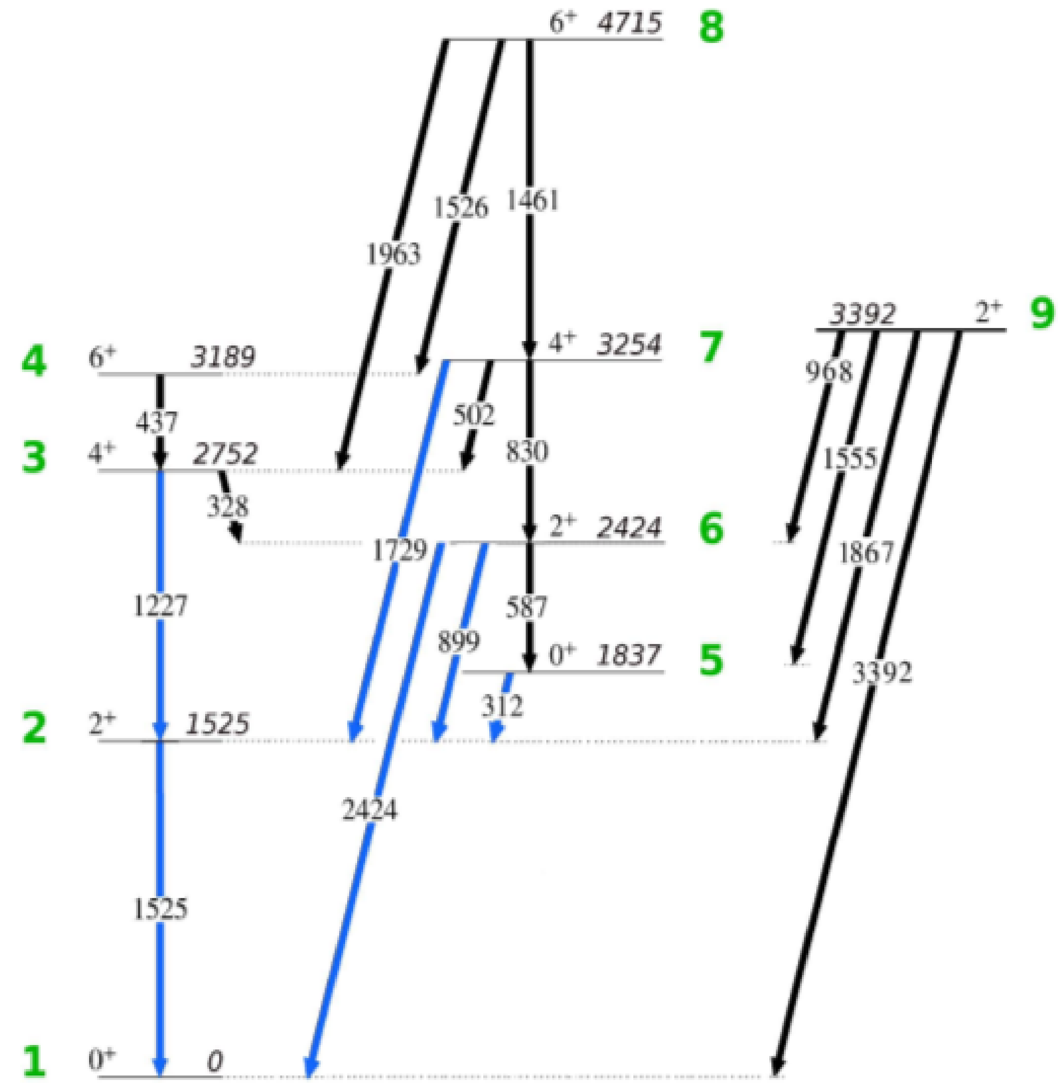
1 = GROUND STATE



OP,GOSI – level scheme

LEVE
1 1 0 0.0
2 1 2 1.525
3 1 4 2.752
.
.
.
0 0 0 0

E [MeV]



1 = GROUND STATE

OP,GOSI – level scheme

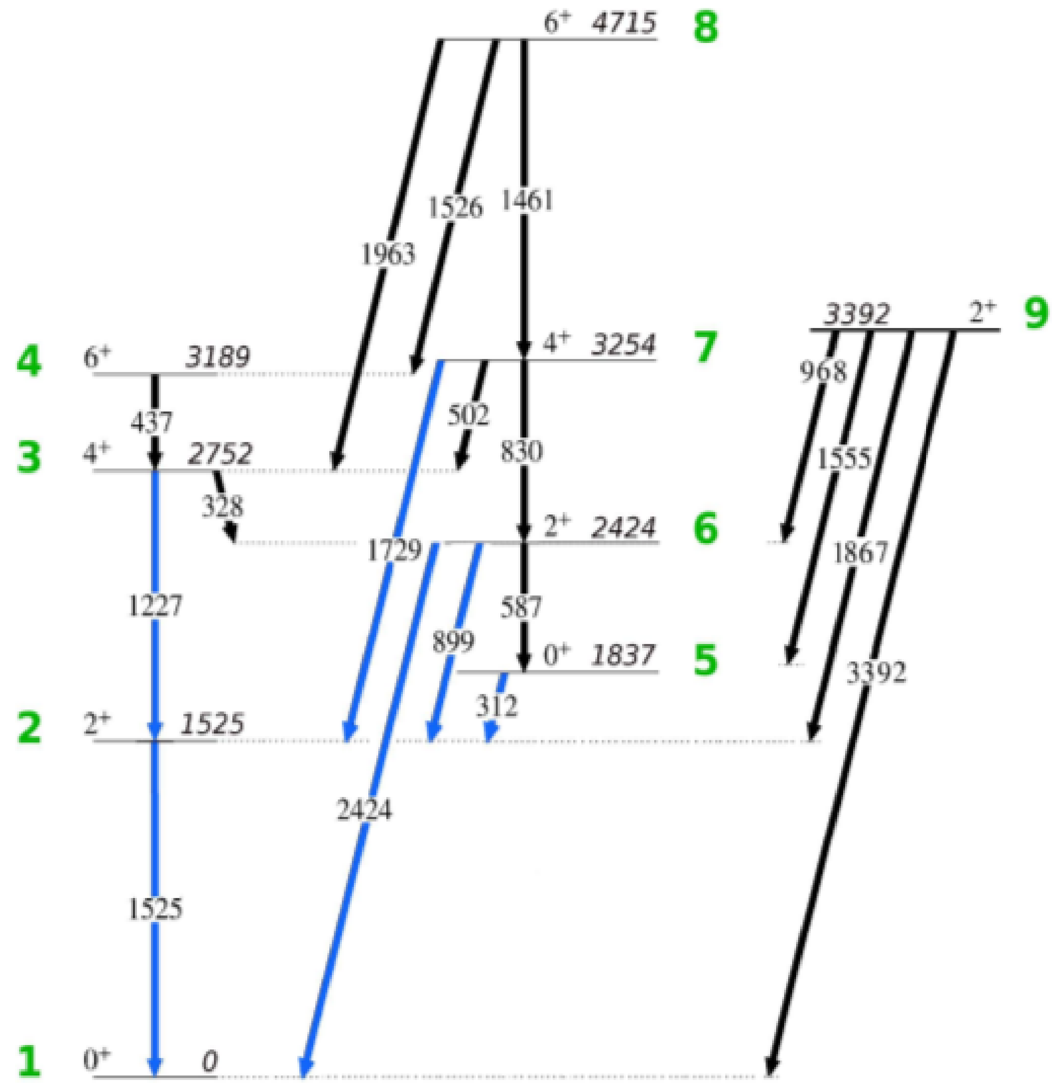
```
LEVE
1  1  0  0.0
2  1  2  1.525
3  1  4  2.752
.
.
.
0  0  0  0
```

Level INDEX

Parity

SPIN

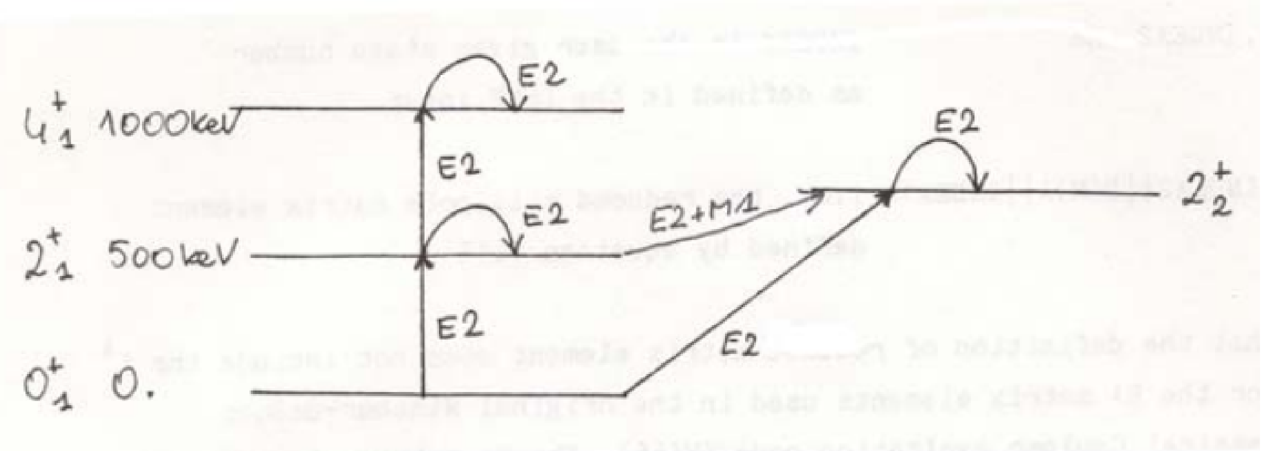
E [MeV]



1 = GROUND STATE

OP,GOSI – matrix elements

```
ME
2 0 0 0 0
  1  2 0.20   0.0001  1.5
  2  6 0.08   -1.5     1.5
  .
  .
7 0 0 0 0
  2 6 1.01   -2.      2.
  .
  .
0 0 0 0 0
```

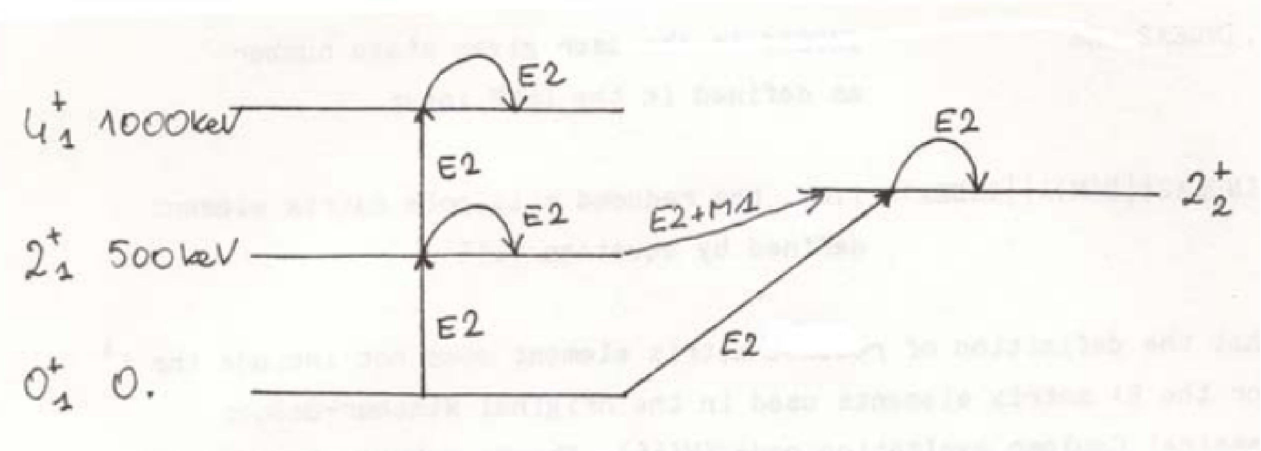


OP,GOSI – matrix elements

```
ME
2 0 0 0 0
  1  2 0.20   0.0001  1.5
  2  6 0.08   -1.5     1.5
  .
  .
7 0 0 0 0
  2 6 1.01   -2.      2.
  .
  .
0 0 0 0 0
```

< INDEX1 || E(M)λ || INDEX2 >

INDEX1 and INDEX2 are given in increasing order (start with INDEX1)



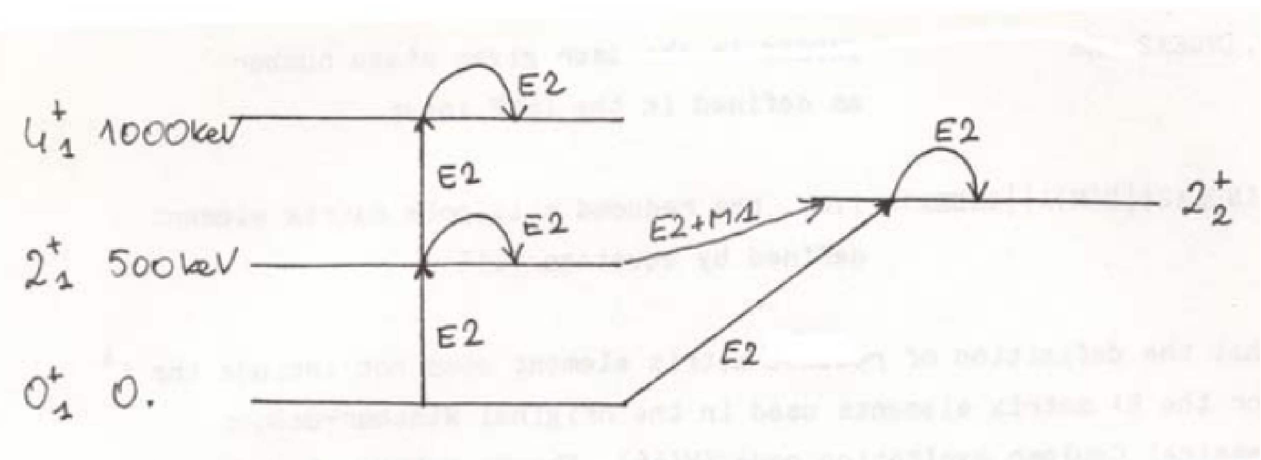
OP,GOSI – matrix elements

```
ME
2 0 0 0 0
  1  2 0.20   0.0001  1.5
  2  6 0.08   -1.5     1.5
  .
  .
7 0 0 0 0
  2 6 1.01   -2.        2.
  .
  .
0 0 0 0 0
```

Multipolarity E(M)λ:
1 E1
2 E2
3 E3
..
7 M1
8 M2

< INDEX1 || E(M)λ || INDEX2 >

INDEX1 and INDEX2 are given in increasing order (start with INDEX1)



OP,GOSI – matrix elements

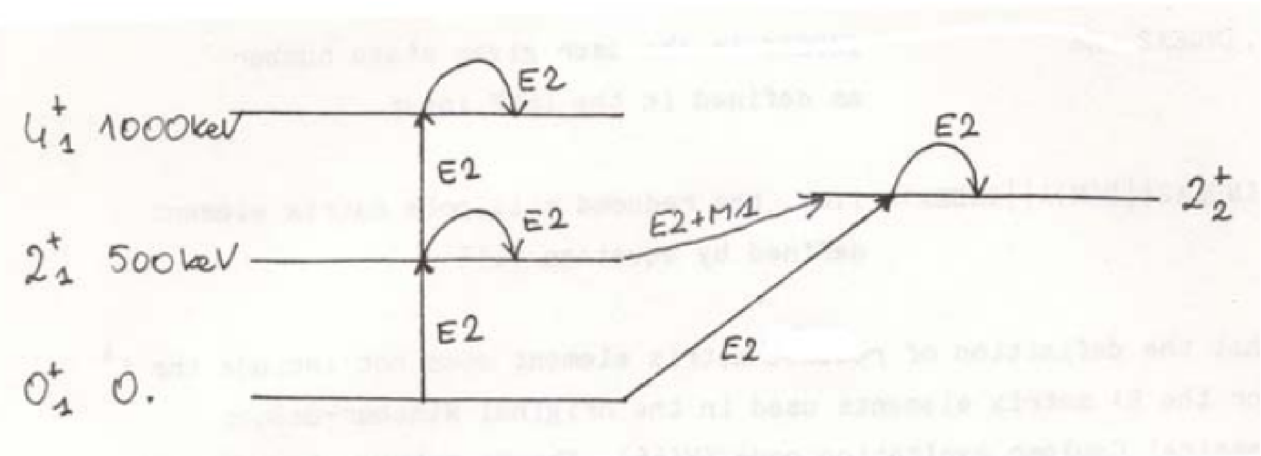
```
ME
2 0 0 0 0
  1  2 0.20   0.0001  1.5
  2  6 0.08   -1.5     1.5
  .
  .
7 0 0 0 0
  2 6 1.01   -2.       2.
  .
  .
0 0 0 0 0
```

INDEX1

Multipolarity E(M)λ:
1 E1
2 E2
3 E3
..
7 M1
8 M2

< INDEX1 || E(M)λ || INDEX2 >

INDEX1 and INDEX2 are given in increasing order (start with INDEX1)



OP,GOSI – matrix elements

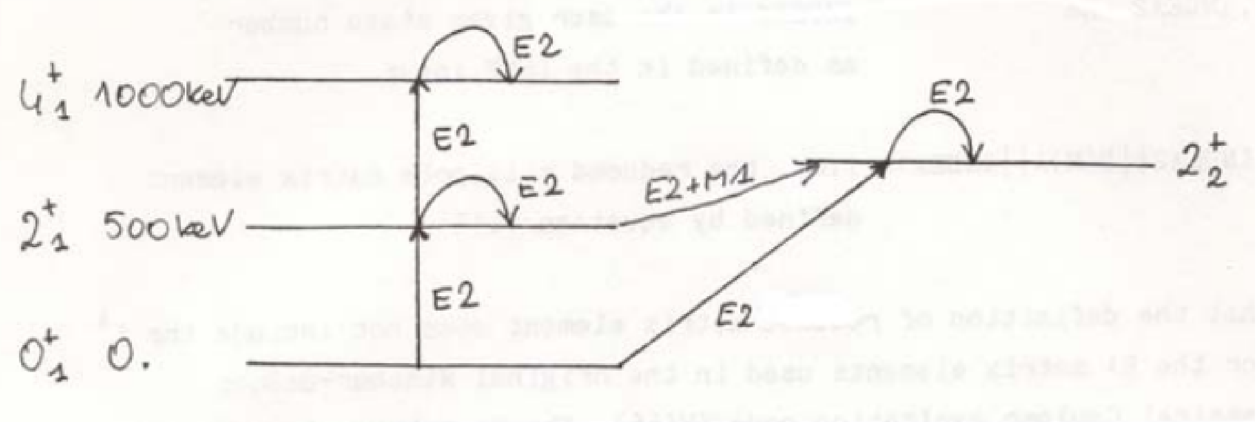
```
ME
2 0 0 0 0
  1  2 0.20   0.0001  1.5
  2  6 0.08   -1.5     1.5
  .
  .
7 0 0 0 0
  2 6 1.01   -2.       2.
  .
  .
0 0 0 0 0
```

INDEX2

Multipolarity E(M)λ:
1 E1
2 E2
3 E3
..
7 M1
8 M2

< INDEX1 || E(M)λ || INDEX2 >

INDEX1 and INDEX2 are given in increasing order (start with INDEX1)



OP,GOSI – matrix elements

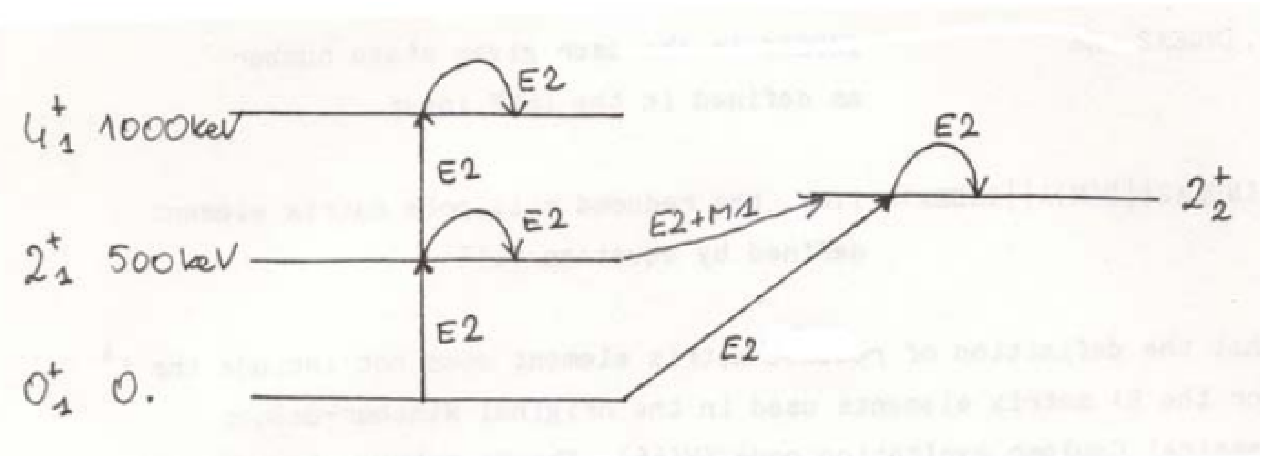
```
ME
2 0 0 0 0
  1  2 0.20   0.0001  1.5
  2  6 0.08   -1.5     1.5
  .
  .
7 0 0 0 0
  2 6 1.01   -2.       2.
  .
  .
0 0 0 0 0
```

ME

Multipolarity E(M)λ:
1 E1
2 E2
3 E3
..
7 M1
8 M2

< INDEX1 || E(M)λ || INDEX2 >

INDEX1 and INDEX2 are given in increasing order (start with INDEX1)



OP,GOSI – matrix elements

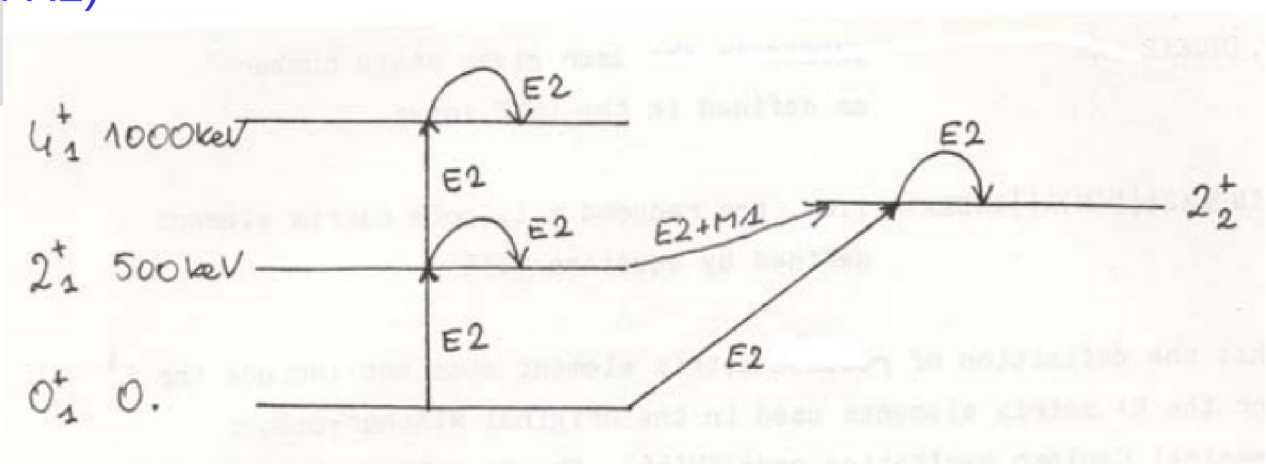
```
ME
2 0 0 0 0
  1  2 0.20   0.0001  1.5
  2  6 0.08   -1.5     1.5
  .
  .
7 0 0 0 0
  2 6 1.01   -2.      2.
  .
  .
0 0 0 0 0
```

Limits for ME (R1 and R2)

Multipolarity E(M)λ:
1 E1
2 E2
3 E3
..
7 M1
8 M2

< INDEX1 || E(M)λ || INDEX2 >

INDEX1 and INDEX2 are given in increasing order (start with INDEX1)



OP,GOSI – matrix elements

```
ME
2 0 0 0 0
  1  2 0.20   0.0001  1.5
  2  6 0.08   -1.5     1.5
  .
  .
7 0 0 0 0
  2 6 1.01   -2.       2.
  .
  .
0 0 0 0 0
```

Limits for ME (R1 and R2)

ME

INDEX2

INDEX1

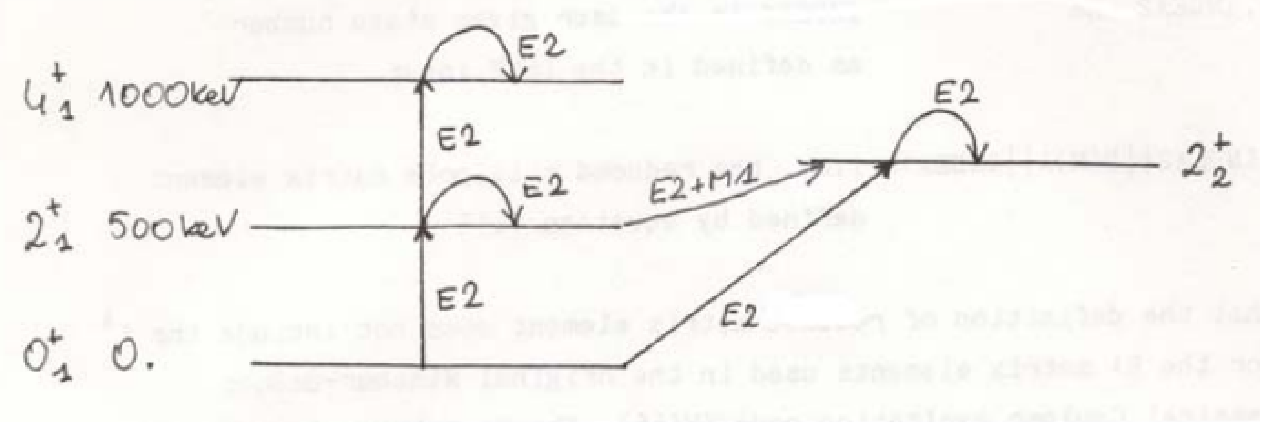
Multipolarity E(M)λ:
1 E1
2 E2
3 E3
..
7 M1
8 M2

< INDEX1 || E(M)λ || INDEX2 > **[eb]**

INDEX1 and INDEX2 are given in increasing order (start with INDEX1)

If "-" used before INDEX2 → COUPLING

2 -6 0.08 1 2



MATRIX ELEMENTS

We need a set of ME to start with

levels.inp

```
1  1  0  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

```
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
(...)
7                                              <- M1
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
```

We need a set of ME to start with

levels.inp

```
1  1  0  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 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
   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
```

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

OP,THEO

- generates the ME from rotational model
- generates only the matrix specified in the ME input and writes them to the output file
- For **in-band or equal-K** interband transitions only one intrinsic moment for a given multipolarity - **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.

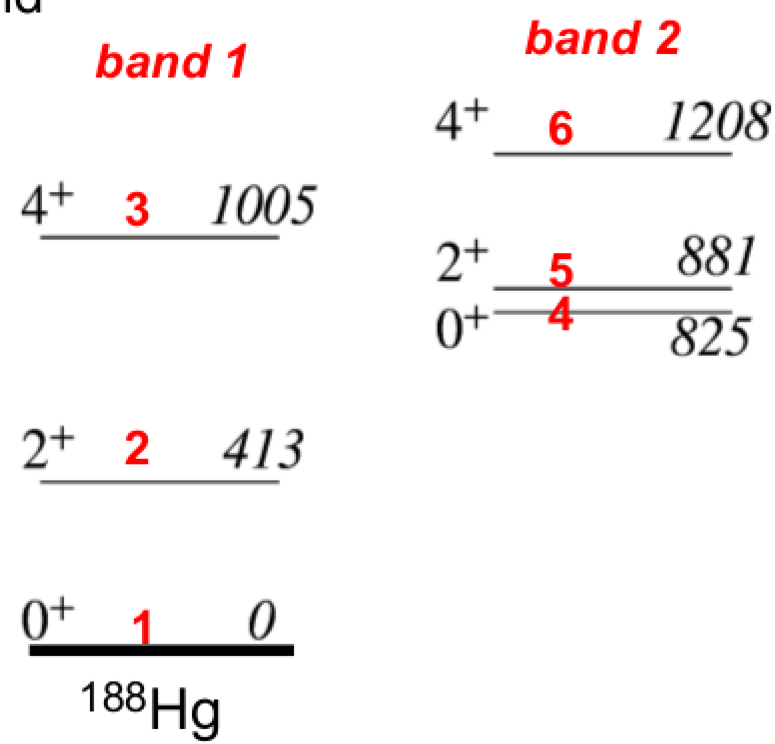
OP,THEO

OP,THEO	
2	Two bands
0,3	K of the gsb, # of levels
1,2,3	Level list for the gsb
2,3	K of the gamma band, # of levels
4,5,6	Level list for the gamma band
2	Multipolarity E2
1,1	In-band, gsb
1,0,0	Q1, two zeros irrelevant
1,2	Interband E2
1,1,0	Q1,Q2- Mikhailov formula, none of the K's=1/2, so Q3 irrelevant
2,2	In-band, gamma band
1,0,0	In-band Q1, Q2 and Q3 irrelevant
0,0	Ends E2 loop
7	M1 loop
1,2	Interband M1
1,1,0	Q1 and Q2 for Mikhailov formula
2,2	In-band M1
1,0,0	Q1 for in-band transitions
0,0	Ends M1 loop
0	Ends multipolarity loop and OP, THEO input

OP,THEO for ^{188}Hg (example)

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

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



Courtesy: K. Wrzosek-Lipska

EXPERIMENT

OP,GOSI: EXPT

EXPT

NEXP Z1 A1

+/-Z2 A2 Ep +/-θ_{proj} Mc Ma IAX φ1 φ2 IKIN LN

EXPT

2 20 42

-79 197 167 122 3 1 1 -170 172 0 1

-82 208 167 122 3 1 1 -170 172 0 2

^{42}Ca beam on ^{197}Au and ^{208}Pb targets

OP,GOSI: EXPT

Number of experiments

EXPT

NEXP Z1 A1

+/-Z2 A2 Ep +/-θ_{proj} Mc Ma IAX φ1 φ2 IKIN LN

EXPT

2 20 42

-79 197 167 122 3 1 1 -170 172 0 1

-82 208 167 122 3 1 1 -170 172 0 2

^{42}Ca beam on ^{197}Au and ^{208}Pb targets

OP,GOSI: EXPT

Charge and mass number of investigated nucleus

EXPT

NEXP Z1 A1

+/-Z2 A2 Ep +/-θ_{proj} Mc Ma IAX φ1 φ2 IKIN LN

EXPT

2 20 42

-79 197 167 122 3 1 1 -170 172 0 1

-82 208 167 122 3 1 1 -170 172 0 2

^{42}Ca beam on ^{197}Au and ^{208}Pb targets

OP,GOSI: EXPT

EXPT

NEXP Z1 A1

+/-Z2 A2 Ep +/-θ_{proj} Mc Ma IAX φ1 φ2 IKIN LN

Charge and mass number of uninvestigated nucleus:
"+" target excitation
"-" beam excitation

EXPT

2 20 42

-79 197 167 122 3 1 1 -170 172 0 1

-82 208 167 122 3 1 1 -170 172 0 2

^{42}Ca beam on ^{197}Au and ^{208}Pb targets

OP,GOSI: EXPT

EXPT

NEXP Z1 A1

+/-Z2 A2 Ep +/-θ_{proj} Mc Ma IAX φ1 φ2 IKIN LN

Mean value of
beam energy [MeV]

EXPT

2 20 42

-79 197 167 122 3 1 1 -170 172 0 1

-82 208 167 122 3 1 1 -170 172 0 2

^{42}Ca beam on ^{197}Au and ^{208}Pb targets

OP,GOSI: EXPT

EXPT

NEXP Z1 A1

+/-Z2 A2 Ep +/-θ_{proj} Mc Ma IAX φ1 φ2 IKIN LN

Mean value of scattering angle:
"+" projectile
"-" recoil

EXPT

2 20 42

-79 197 167 122 3 1 1 -170 172 0 1

-82 208 167 122 3 1 1 -170 172 0 2

^{42}Ca beam on ^{197}Au and ^{208}Pb targets

OP,GOSI: EXPT

Controls of magnetic substates

EXPT

NEXP Z1 A1

+/-Z2 A2 Ep +/-θ_{proj} Mc Ma IAX φ1 φ2 IKIN LN

EXPT

2 20 42

-79 197 167 122 3 1 1 -170 172 0 1

-82 208 167 122 3 1 1 -170 172 0 2

^{42}Ca beam on ^{197}Au and ^{208}Pb targets

OP,GOSI: EXPT

EXPT

NEXP Z1 A1

+/-Z2 A2 Ep +/-θ_{proj} Mc Ma IAX φ1 φ2 IKIN LN

Axial symmetry flag
0 – yes
1 – no

EXPT

2 20 42

-79 197 167 122 3 1 1 -170 172 0 1

-82 208 167 122 3 1 1 -170 172 0 2

^{42}Ca beam on ^{197}Au and ^{208}Pb targets

OP,GOSI: EXPT

EXPT

NEXP Z1 A1

+/-Z2 A2 Ep +/-θ_{proj} Mc Ma IAX φ1 φ2 IKIN LN

Min and max
φ angle

EXPT

2 20 42

-79 197 167 122 3 1 1 -170 172 0 1

-82 208 167 122 3 1 1 -170 172 0 2

^{42}Ca beam on
^{197}Au and ^{208}Pb targets

OP,GOSI: EXPT

EXPT

NEXP Z1 A1

+/-Z2 A2 Ep +/-θ_{proj} Mc Ma IAX φ1 φ2 IKIN LN

Kinematic flag:
0 - backward θ_{CM}
1 - forward θ_{CM}

EXPT

2 20 42

-79 197 167 122 3 1 1 -170 172 0 1

-82 208 167 122 3 1 1 -170 172 0 2

^{42}Ca beam on ^{197}Au and ^{208}Pb targets

OP,GOSI: EXPT

Normalization flag

EXPT

NEXP Z1 A1

+/-Z2 A2 Ep +/-θ_{proj} Mc Ma IAX φ1 φ2 IKIN LN

EXPT

2 20 42

-79 197 167 122 3 1 1 -170 172 0 1

-82 208 167 122 3 1 1 -170 172 0 2

^{42}Ca beam on ^{197}Au and ^{208}Pb targets

OP,GOSI: EXPT

Number of experiments

Charge and mass number of investigated nucleus

Controls of magnetic substates

Normalization flag

EXPT

NEXP Z1 A1

+/-Z2 A2 Ep +/-θ_{proj} Mc Ma IAX φ1 φ2 IKIN LN

Charge and mass number of uninvestigated nucleus:
"+" target excitation
"-" beam excitation

Mean value of beam energy [MeV]

Mean value of scattering angle:
"+" projectile
"-" recoil

Axial symmetry flag
0 – yes
1 – no

Min and max **φ** angle

Kinematic flag:
0 - backward θ_{CM}
1 - forward θ_{CM}

EXPT

2 20 42

-79 197 167 122 3 1 1 -170 172 0 1

-82 208 167 122 3 1 1 -170 172 0 2

^{42}Ca beam on ^{197}Au and ^{208}Pb targets

OP,YIEL

```
OP,YIEL
0
5 2
0.1 0.3 0.5 1.0 1.5
1
0.000829  2.41E-5  5.60E-6  1.143E-6  0.000269
2
0.01175   0.0001328  2.06E-5  2.59E-6  8.94E-5
5 5
1  2  3  4  5
25  55  85   130  172
40  75  270 325  59
1  2  3  4  5
25  55  85   130  172
40  75  270 325  59
2 1
1                                        !EXP1
0.001
1
1                                        !EXP2
0.001
1
3
```

OP,YIEL

```
OP,YIEL
0
5 2
0.1 0.3 0.5 1.0 1.5
1
0.000829  2.41E-5  5.60E-6  1.143E-6  0.000269
2
0.01175   0.0001328  2.06E-5  2.59E-6  8.94E-5
5 5
1  2  3  4  5
25  55  85   130  172
40  75  270 325  59
1  2  3  4  5
25  55  85   130  172
40  75  270 325  59
2 1
1                                        !EXP1
0.001
1
1                                        !EXP2
0.001
1
3
```

Electron conversion coefficients (BRICC)

number of energies and multi-polarities
Energy points [MeV]
Mult. 1
Coeff. for each energy point
Mult. 2
Coeff. for each energy point

OP,YIEL

```
OP,YIEL
0
5 2
0.1 0.3 0.5 1.0 1.5
1
0.000829  2.41E-5  5.60E-6  1.143E-6  0.000269
2
0.01175   0.0001328  2.06E-5  2.59E-6  8.94E-5
5 5
1  2  3  4  5
25  55  85   130  172
40  75  270 325  59
1  2  3  4  5
25  55  85   130  172
40  75  270 325  59
2 1
1                                 !EXP1
0.001
1
1                                 !EXP2
0.001
1
3
```

Total number of gamma detectors for each exp
Numbers of gamma det. in GDET, exp 1 (here 5)
Θ, exp 1
Φ, exp 1
Numbers of gamma det. in GDET, exp 2 (here 5)
Θ, exp 2
Φ, exp 2

OP,YIEL

```
OP,YIEL
0
5 2
0.1 0.3 0.5 1.0 1.5
1
0.000829  2.41E-5  5.60E-6  1.143E-6  0.000269
2
0.01175   0.0001328  2.06E-5  2.59E-6  8.94E-5
5 5
1  2  3  4  5
25  55  85   130  172
40  75  270 325  59
1  2  3  4  5
25  55  85   130  172
40  75  270 325  59
2 1
1                                   !EXP1
0.001
1
1                                   !EXP2
0.001
1
3
```

NORMALIZATION transition (only for printout) ← "2 1"

OP,YIEL

```
OP,YIEL
0
5 2
0.1 0.3 0.5 1.0 1.5
1
0.000829  2.41E-5  5.60E-6  1.143E-6  0.000269
2
0.01175   0.0001328  2.06E-5  2.59E-6  8.94E-5
5 5
1  2  3  4  5
25  55  85   130  172
40  75  270 325  59
1  2  3  4  5
25  55  85   130  172
40  75  270 325  59
2 1
1                                   !EXP1
0.001
1
1                                   !EXP2
0.001
1
3
```

Number of data sets for exp. 1
Upper limits for all gamma det in exp 1
Relative normalization factors for each det. In exp 1

OP,YIEL

```
OP,YIEL
0
5 2
0.1 0.3 0.5 1.0 1.5
1
0.000829  2.41E-5  5.60E-6  1.143E-6  0.000269
2
0.01175   0.0001328  2.06E-5  2.59E-6  8.94E-5
5 5
1  2  3  4  5
25  55  85   130  172
40  75  270 325  59
1  2  3  4  5
25  55  85   130  172
40  75  270 325  59
2 1
1                                   !EXP1
0.001
1
1                                   !EXP2
0.001
1
3
```

NTAP (0 for OP,POIN, OP,STAR, 3 if OP,CORR after integration is used, 4 if OP,MINI and ERRO is used)

OP,YIEL

```
OP,YIEL
0
5 2
0.1 0.3 0.5 1.0 1.5
1
0.000829  2.41E-5  5.60E-6  1.143E-6  0.000269
2
0.01175   0.0001328  2.06E-5  2.59E-6  8.94E-5
5 5
1  2  3  4  5
25  55  85   130  172
40  75  270 325  59
1  2  3  4  5
25  55  85   130  172
40  75  270 325  59
2 1
1                              !EXP1
0.001
1
1                              !EXP2
0.001
1
3
```

Electron conversion coefficients (BRICC)

number of energies and multi-polarities
Energy points [MeV]
Mult. 1
Coeff. for each energy point
Mult. 2
Coeff. for each energy point

Total number of gamma detectors for each exp
Numbers of gamma det. in GDET, exp 1 (here 5)
Θ, exp 1
Φ, exp 1
Numbers of gamma det. in GDET, exp 2 (here 5)
Θ, exp 2
Φ, exp 2

NORMALIZATION transition (only for printout)

Number of data sets for exp. 1
Upper limits for all gamma det in exp 1
Relative normalization factors for each det. In exp 1

NTAP (0 for OP,POIN, OP,STAR, 3 if OP,CORR after integration is used, 4 if OP,MINI and ERRO is used)

OP,YIEL

```
2      1.0
       4 5 4 2    0.007  0.003
       5 1 5 2    0.34   0.02
2      1.0
       2      1.19  0.04
       3      4.45  0.10
1      1.0
       6 2   -0.18      0.02
1      1.0
       2  2  2    -0.25  0.051
```

Number and weight of known branching ratios:
Transition 1 (I2, I1), Transition 2 (I2, I1), BR, ΔBR

OP,YIEL

```
2     1.0
      4 5 4 2   0.007  0.003
      5 1 5 2   0.34   0.02
2     1.0
      2    1.19  0.04
      3    4.45  0.10
1     1.0
      6 2  -0.18      0.02
1     1.0
      2  2  2   -0.25  0.051
```

Number and weight of known mean lifetimes [ps]
Level index, τ, Δτ

OP,YIEL

```
2     1.0
      4 5 4 2    0.007  0.003
      5 1 5 2    0.34   0.02
2     1.0
      2     1.19  0.04
      3     4.45  0.10
1     1.0
      6 2  -0.18      0.02
1     1.0
      2  2  2    -0.25  0.051
```

Number and weight of of known δ(E2/M1) mixing
Transition, δ, Δδ

OP,YIEL

```
2    1.0
     4 5 4 2   0.007  0.003
     5 1 5 2   0.34   0.02
2    1.0
     2     1.19  0.04
     3     4.45  0.10
1    1.0
     6 2  -0.18     0.02
1    1.0
     2  2  2    -0.25  0.051
```

Number and weight of of known matrix elements
multipolarity, I1, I2, ME, ΔME

OP,YIEL

```
2     1.0
      4 5 4 2   0.007  0.003
      5 1 5 2   0.34   0.02
2     1.0
      2     1.19  0.04
      3     4.45  0.10
1     1.0
      6 2  -0.18     0.02
1     1.0
      2  2  2   -0.25  0.051
```

Number and weight of known branching ratios:
Transition 1 (I2, I1), Transition 2 (I2, I1), BR, ΔBR

Number and weight of known mean lifetimes [ps]
Level index, τ, Δτ

Number and weight of of known δ(E2/M1) mixing
Transition, δ, Δδ

Number and weight of of known matrix elements
multipolarity, I1, I2, ME, ΔME

```
0 0
0 0      in case nothing is known
0 0      about the investigated nucleus
0 0
```

YIELDS:
SIMULATIONS and ANALYSIS

YIELD definition

POINT

- **<u>One</u>** energy (E)
- **<u>One</u>** angle (Θ)

as defined in EXPT

use **OP,POIN**

INTEGRATED

- Energy **<u>range</u>**

  $(E_{min}-E_{max})$
- Angular **<u>range</u>**

  $(\Theta_{min},\varphi_{min})-(\Theta_{max},\varphi_{max})$

  as defined in **OP,INTG / INTI**

↓

Matrix elements values, excitation probability

TAPE 3 / 4 (experimental yields)

1	**1**	**20**	**42**	**167**	**3**	**1.0**
5	2	88	10			
3	2	500	20			
2	1	11000	100			

IEXP – exp. Number – the same order as in EXPT and OP,YIEL

TAPE 3 / 4 (experimental yields)

1	**1**	**20**	**42**	**167**	**3**	**1.0**
5	2	88	10			
3	2	500	20			
2	1	11000	100			

TAPE 3 / 4 (experimental yields)

1	**1**	**20**	**42**	**167**	**3**	**1.0**
5	2	88	10			
3	2	500	20			
2	1	11000	100			

NG – number of data sets for exp. IEXP (NDST in OP,YIEL)

TAPE 3 / 4 (experimental yields)

1 1 20 42 167 3 1.0

5 2 88 10

3 2 500 20

2 1 11000 100

ZP – proj. charge number

TAPE 3 / 4 (experimental yields)

1	**1**	**20**	**42**	**167**	**3**	**1.0**
5	2	88	10			
3	2	500	20			
2	1	11000	100			

AP – proj. mass number

TAPE 3 / 4 (experimental yields)

1	**1**	**20**	**42**	**167**	**3**	**1.0**
5	2	88	10			
3	2	500	20			
2	1	11000	100			

EP – proj. bombarding energy [MeV]

TAPE 3 / 4 (experimental yields)

1 1 20 42 167 3 1.0

5 2 88 10

3 2 500 20

2 1 11000 100

ND - of γ-rays for the specific IEXP and data set

TAPE 3 / 4 (experimental yields)

1	**1**	**20**	**42**	**167**	**3**	**1.0**
5	2	88	10			
3	2	500	20			
2	1	11000	100			

WT - Weight

TAPE 3 / 4 (experimental yields)

Ii – initial level index

1	1	20	42	167	3	1.0
5	**2**	**88**	**10**			
3	2	500	20			
2	1	11000	100			

TAPE 3 / 4 (experimental yields)

If – final
level index

1	1	20	42	167	3	1.0
5	**2**	**88**	**10**			
3	2	500	20			
2	1	11000	100			

TAPE 3 / 4 (experimental yields)

Y – γ-ray yield

1	1	20	42	167	3	1.0
5	**2**	**88**	**10**			
3	2	500	20			
2	1	11000	100			

TAPE 3 / 4 (experimental yields)

ΔY – absolute error of γ-ray yield

1	1	20	42	167	3	1.0
5	**2**	**88**	**10**			
3	2	500	20			
2	1	11000	100			

IEXP – exp. Number – the same order as in EXPT andOp,YIEL

TAPE 3 / 4 (experimental yields)

1	**1**	**20**	**42**	**167**	**3**	**1.0**
5	2	88	10			
3	2	500	20			
2	1	11000	100			

NG – number of data sets for exp. IEXP (NDST in OP,YIEL)

ZP – proj. charge number

AP – proj. mass number

EP – proj. bombarding energy [MeV]

ND - of γ-rays for the specific IEXP and data set

WT - Weight

Ii – initial level index

If – final level index

Y – γ-ray yield

ΔY – absolute error of γ-ray yield

1	1	20	42	167	3	1.0
5	**2**	**88**	**10**			
3	2	500	20			
2	1	11000	100			

OP,POIN

- **NTAP = 0** in OP,YIEL
- This option evaluates the point gamma yield in the laboratory frame for the Ii→If transition for **one energy** and **one particle scattering angle** given in **EXPT**

$$Y^{Point}(I \rightarrow I_f) = \sin(\theta_p) \int_{\phi_p} \frac{d^2\sigma(I \rightarrow I_f)}{d\Omega_\gamma d\Omega_p} d\phi_p$$

- includes the **Rutherford cross section**, the sin(Θ) term, integration over the projectile φ scattering angle, the deorientation effect and gamma-detector attenuation coefficients (from OP,GDET)
- Calculates the yield for one system – defined as one **θ-E** point
- We use OP,POIN after OP,YIEL

1 – "real" calculations →

```
OP,POIN
YFL YLIM

OP,POIN
1 0
```

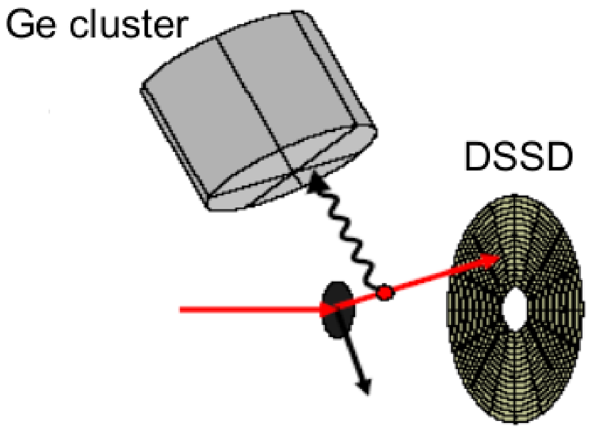
← If **IFL=1** – if the transition specified in TAPE3 normalized to norm. transition in OP,YIEL exceed it, it is treated like the experimental observable and stored on TAPE4

- We use REAL detectors with continuous dimensions

Why integration?

- REAL conditions - GOSIA calculates **yields** from ME to get **realistic comparison** with experimental data
- integration over **solid angle** of the particle detectors, **energy loss in the target,** full correction for the velocity of the deexciting nucleus and the **deorientation effect** is included
- the Rutherford scattering is integrated over the particle detectors and energy loss in the target – an absolute normalization.
- the '**GOSIA yield**' may be understood as a mean differential cross section multiplied by a target thickness (in mg/cm^2)

[Y] = [mb/sr] × [mg/cm^2]



OP,INTG

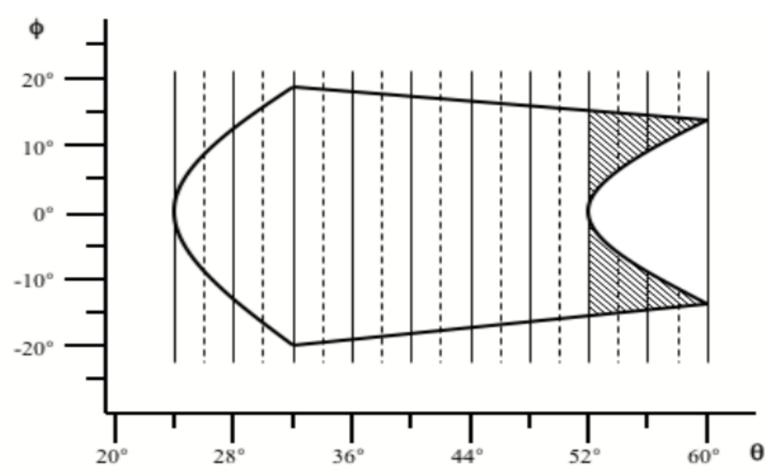
2 stages:
- γ yields integrated over azimuthal angle **φ** for each energy **E** and center-of-mass scattering angle **θ** meshpoint (stored as an external array). The calculation of the meshpoint yields is repeated for each experiment (**as declared in EXPT**)

- integrate over bombarding energy **E** and the range of scattering angles **θ** of the particle detectors which is performed by **interpolation** between the yields calculated at each **E-θ** meshpoint

(*axial sym., circular detectors option recommended)

OP,INTG
NE +/-NT E_{min} E_{max} θ_{min} θ_{max}
E_1 E_2 ... E_{NE}
+/-θ_1 +/-θ_2 ... +/-θ_{NE}
NFI
φ_1 φ_2 ...
NP
E_1 E_2 ... E_{NP}
$(dE/dx)_1$ $(dE/dx)_2$ … $(dE/dx)_{NP}$
NI_1 NI_2

CONT
SPL,1. - SPLINE
END,



OP,INTG

OP,INTG

NE **+/-NT** E_{min} E_{max} θ_{min} θ_{max}

Total number of E meshpoints

E_1 E_2 ... E_{NE}

$+/-\theta_1$ $+/-\theta_2$ ... $+/-\theta_{NE}$

NFI

φ_1 φ_2 ...

NP

E_1 E_2 ... E_{NP}

$(dE/dx)_1$ $(dE/dx)_2$ … $(dE/dx)_{NP}$

NI_1 NI_2

OP,INTG

OP,INTG

NE +/-NT E_{min} E_{max} θ_{min} θ_{max}

Total number of θ meshpoints ("-" when the (θ,φ) shape will be defined)

E_1 E_2 ... E_{NE}

$+/-\theta_1$ $+/-\theta_2$ ... $+/-\theta_{NE}$

NFI

φ_1 φ_2 ...

NP

E_1 E_2 ... E_{NP}

$(dE/dx)_1$ $(dE/dx)_2$ … $(dE/dx)_{NP}$

NI_1 NI_2

OP,INTG

OP,INTG

NE +/-NT E_{min} E_{max} θ_{min} θ_{max}

Integration limits: minimum and maximum bombarding E [MeV]

E_1 E_2 ... E_{NE}

+/-θ_1 +/-θ_2 ... +/-θ_{NE}

NFI

φ_1 φ_2 ...

NP

E_1 E_2 ... E_{NP}

$(dE/dx)_1$ $(dE/dx)_2$ … $(dE/dx)_{NP}$

NI_1 NI_2

OP,INTG

OP,INTG

NE   +/-NT E_{min} E_{max} θ_{min} θ_{max}

Integration limits: minimum and maximum LAB angle of detected particle (in degrees)

E_1 E_2 ... E_{NE}

$+/-\theta_1$ $+/-\theta_2$ ... $+/-\theta_{NE}$

NFI

φ_1 φ_2 ...

NP

E_1 E_2 ... E_{NP}

$(dE/dx)_1$ $(dE/dx)_2$ … $(dE/dx)_{NP}$

NI_1 NI_2

OP,INTG

OP,INTG

NE +/-NT E_{min} E_{max} θ_{min} θ_{max}

E_1 E_2 ... E_{NE}

Energy meshpoints (COULEX calculation performed for points)

+/-θ_1 +/-θ_2 ... +/-θ_{NE}

NFI

φ_1 φ_2 ...

NP

E_1 E_2 ... E_{NP}

$(dE/dx)_1$ $(dE/dx)_2$ … $(dE/dx)_{NP}$

NI_1 NI_2

OP,INTG

OP,INTG

NE +/-NT E_{min} E_{max} θ_{min} θ_{max}

E_1 E_2 ... E_{NE}

+/-θ_1 +/-θ_2 ... +/-θ_{NE}

Projectile scattering θ meshpoints (COULEX calculation performed for points)

NFI

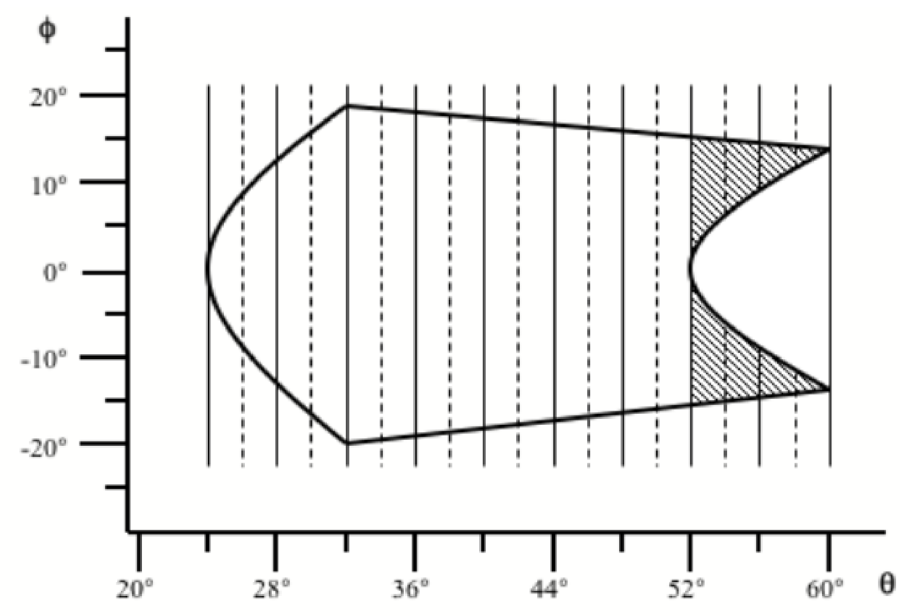
φ_1 φ_2 ...

NP

E_1 E_2 ... E_{NP}

$(dE/dx)_1$ $(dE/dx)_2$ … $(dE/dx)_{NP}$

NI_1 NI_2



OP,INTG

OP,INTG
NE +/-NT E_{min} E_{max} θ_{min} θ_{max}

E_1 E_2 ... E_{NE}

+/-θ_1 +/-θ_2 ... +/-θ_{NE}

NFI
Number of φ ranges for θ_i meshpoint - for $\theta(\varphi)$ dependence (repeat for each θ)

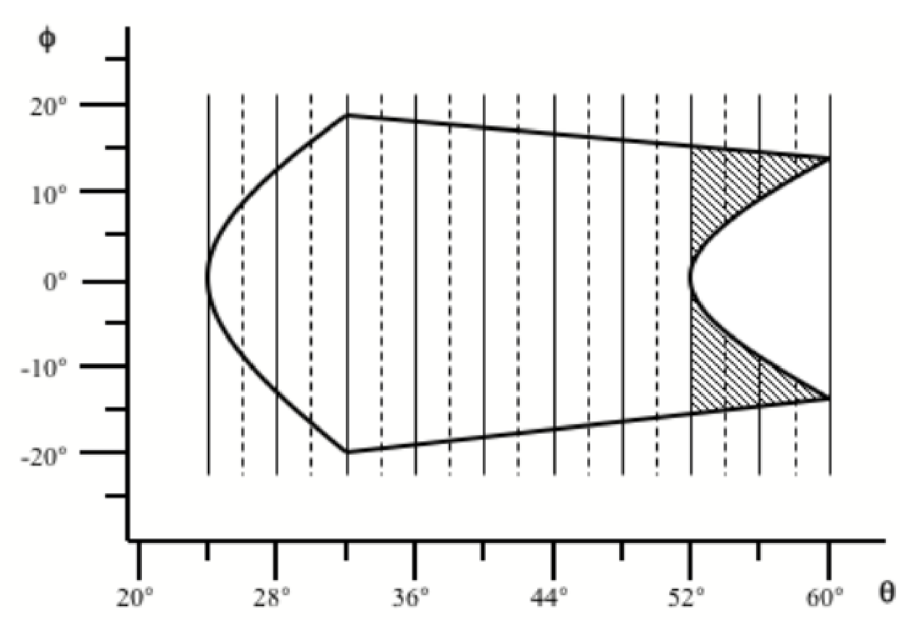
φ_1 φ_2 ...

NP

E_1 E_2 ... E_{NP}

$(dE/dx)_1$ $(dE/dx)_2$ … $(dE/dx)_{NP}$

NI_1 NI_2



OP,INTG

OP,INTG

NE +/-NT E_{min} E_{max} θ_{min} θ_{max}

E_1 E_2 ... E_{NE}

$+/-\theta_1$ $+/-\theta_2$ ... $+/-\theta_{NE}$

NFI

φ_1 φ_2 ...

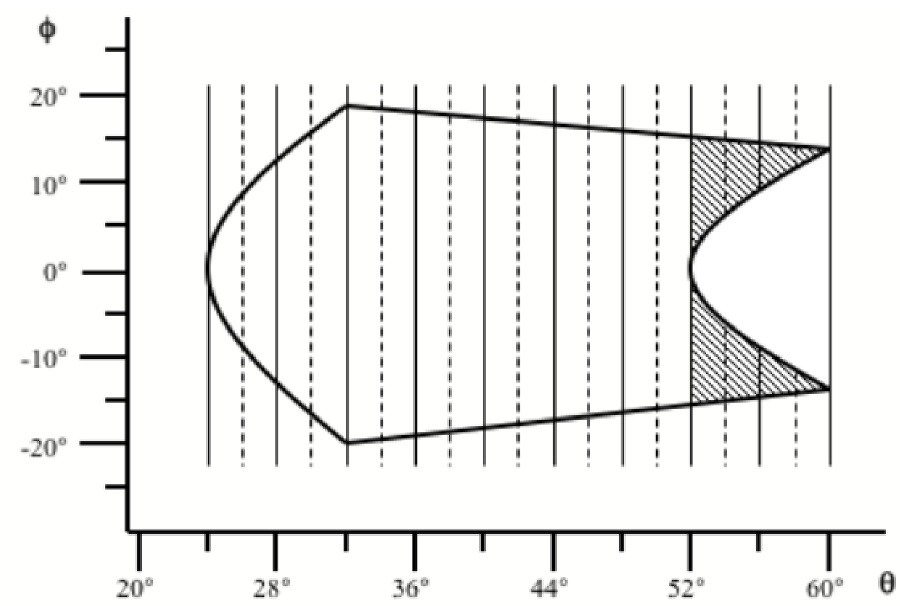
NFI pairs of φ for θ_i meshpoint (repeat for each θ_i)

NP

E_1 E_2 ... E_{NP}

$(dE/dx)_1$ $(dE/dx)_2$ … $(dE/dx)_{NP}$

NI_1 NI_2



OP,INTG

OP,INTG

NE +/-NT E_{min} E_{max} θ_{min} θ_{max}

E_1 E_2 ... E_{NE}

+/-θ_1 +/-θ_2 ... +/-θ_{NE}

NFI

φ_1 φ_2 ...

NP

Number of stopping power (3<NP<20). If NP=0, values are taken from prev. exp.

E_1 E_2 ... E_{NP}

$(dE/dx)_1$ $(dE/dx)_2$ … $(dE/dx)_{NP}$

NI_1 NI_2

OP,INTG

OP,INTG
NE +/-NT E_{min} E_{max} θ_{min} θ_{max}

E_1 E_2 ... E_{NE}

+/-θ_1 +/-θ_2 ... +/-θ_{NE}

NFI

φ_1 φ_2 ...

NP

E_1 E_2 ... E_{NP}
Energy meshpoints in [MeV] for the stopping powers
$(dE/dx)_1$ $(dE/dx)_2$ … $(dE/dx)_{NP}$

NI_1 NI_2

OP,INTG

OP,INTG
NE   +/-NT E_{min} E_{max} θ_{min} θ_{max}

E_1 E_2 ... E_{NE}

$+/-\theta_1$ $+/-\theta_2$ ... $+/-\theta_{NE}$

NFI

φ_1 φ_2 ...

NP

E_1 E_2 ... E_{NP}

$(dE/dx)_1$ $(dE/dx)_2$ … $(dE/dx)_{NP}$
Stopping powers in [MeV/(mg/cm^2)]
NI_1 NI_2

OP,INTG

OP,INTG

NE +/-NT E_{min} E_{max} θ_{min} θ_{max}

E_1 E_2 ... E_{NE}

$+/-\theta_1$ $+/-\theta_2$ ... $+/-\theta_{NE}$

NFI

φ_1 φ_2 ...

NP

E_1 E_2 ... E_{NP}

$(dE/dx)_1$ $(dE/dx)_2$ … $(dE/dx)_{NP}$

NI_1 NI_2

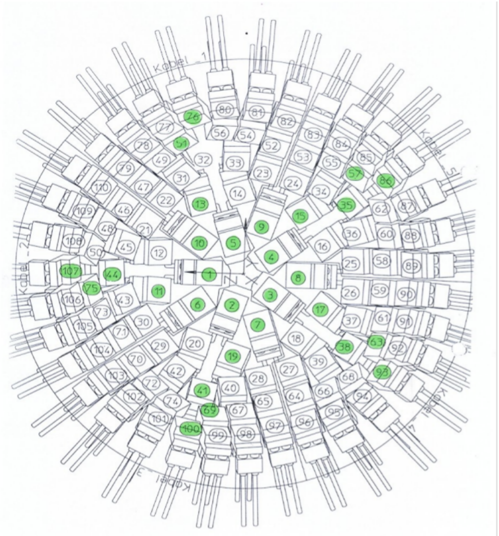
Number of subdivisions in E (NI1) and projectile scatt. angle (NI2) used during the integration. EVEN and less than 100 both.

OP,INTG – circular detector

Intensities **<u>for each Ge detector</u> – circular <u>particle detector</u> option (with PIN diodes)**

Calculate the Δφ at each subdivision of θ (**CONT CRD,#exp**)
Circular det. approximation for PiN diodes (**CONT PIN,#PIN**)

OP,INTG
NE +/-NT E_{min} E_{max} θ φ $θ_{1/2}$
E_1 E_2 ... E_{NE}



OP,INTG
7 3 146. 152. 123.9 242.32 4.4 ! PIN6
146 147 148 149 150 151 152
7 3 146. 152. 123.9 298.28 4.4 ! PIN62
146 147 148 149 150 151 152
7 3 140. 152. 123.9 226.27 4.4 ! PIN68
146 147 148 149 150 151 152
7 3 140. 152. 123.9 98.32 4.4 ! PIN75
146 147 148 149 150 151 152
...

CONT
SMR,
LCK,
0,0
INR,
SPL,1.
CRD,1.
1
PIN,1.
1,44
PRT,
4,0
2,0
13,0
14,0
16,0
5,1
12,0
18,1
0,0
END,

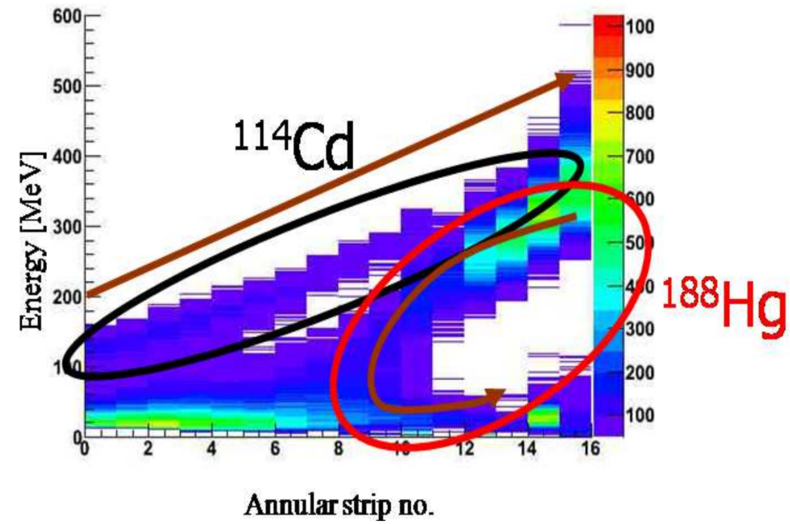
→ Pawel’s talk tomorrow!

OP,INTI

Developed to handle problems that occur for integration of systems involving inverse kinematics and when the **recoiling target nucleus is detected** (2 kinematic solution).

For each beam E and each angle the subroutine INVKIN calculates the appropriate value of kinematic flag and set it **automatically**

Θ angles <u>always</u> positive and correspond to laboratory scattering angles of the **<u>detected particle</u>**, that is, the angle of the scattered projectile if it is detected and the angle of the recoiling target nucleus if it is detected.



N. Bree, PhD thesis, KULeuven,

OP,INTI
NE +/-NT E_{min} E_{max} θ_{min} θ_{max}
E_1 E_2 ... E_{NE}
θ_1 θ_2 ... θ_{NE}
NFI
φ_1 φ_2 ...
NP
E_1 E_2 ... E_{NP}
$(dE/dx)_1$ $(dE/dx)_2$ … $(dE/dx)_{NP}$
NI_1 NI_2

```
OP,INTI                    !for axial sym. and circ. det.
8 9 226 240 133 168
226 228 230 232 234 236 238 240
133 135 140 145 150 155 160 165 168
8
226 228 230 232 234 236 238 240
12.2 12.17 12.13 12.10 12.05 12.00 11.90 11.80
20,20
```

OP,YIEL – yield correction

- Minimization of is usually performed using **corrected** yields
- Correction depends on the set of ME: GOSIA calculates the **point** yield (**Y_p**) and the **integrated** yield (**Y_I**) from the ME and gives the **correction factors CF** for each experimental yield (**OP,CORR** needed):

$$CF = \frac{Y_P}{Y_I} \longrightarrow Y^c_{exp} = Y_{exp} \cdot CF$$

After minimization the correction procedure should be repeated with a new set of ME (better fit, different correction) → until the solution is converged

- CF are calculated for **each** experimental yield

^{42}Ca on ^{197}Au

E_{av} = 167 MeV

Θ_{av} = 122°

EXPERIMENT 2 DETECTOR 1

NI	NF	YEXP	YCOR	COR.F
3	2	.112E+00	.113E+00	.101E+01
6	1	.380E-01	.374E-01	.984E+00
6	2	.106E+00	.102E+00	.966E+00
5	2	.854E+00	.822E+00	.962E+00
2	1	.124E+02	.120E+02	.969E+00

GOSIA AS A SIMULATION TOOL: YIELD ⇒ COUNT RATE

$$Counts = 10^{-27} \cdot \left[\frac{Q}{\hat{q}\, e}\right] \cdot \left[\frac{N_A}{A}\right] \cdot [\rho\, dx] \cdot Y^{INTG}(I \rightarrow I_f) \cdot \Delta\theta_p \cdot \varepsilon_p \cdot \varepsilon_\gamma \cdot \Delta\Omega_\gamma$$

Where:
Q – integrated beam charge [C]
q – the average charges state of the beam
e – the proton charge [1.602×10^{-19} C]
N_A – Avogadro number [6.022×10^{23} atoms/mol]
A – target mass number [g/mol]
ρdx – areal target thickness [g/cm^2]
Y^{INTG} ($I \rightarrow I_f$) OP,INTG or OP,INTI output in [mb/sr/rad]
$\Delta\theta_p$ – projectile scattering angle range [rad]
ε_p – particle detection efficiency per unit solid angle
ε_γ – gamma detection efficiency excluding the geometrical solid angle
$\Delta\Omega_\gamma$ – geometrical solid angle of the gamma-ray detector. Note that usually one only knows the product $\varepsilon_\gamma * \Delta\Omega_\gamma$

$$\textbf{Count Rate} = \frac{7.6 \times 10^{-6} \times yield \times current[pps] \times eff}{A_{target}}$$

OP,RAW

- This option needs energy-dependent efficiency calibration for each individual gamma detector (GREMLIN, EFFIT..)
- the first entry of **OP,GDET** should be **negative** to produce the **TAPE8**
- Need to declare which efficiency parametrization you need! (in **CONT**, flag **EFF**): 0-Gremlin, 1-Jaeri, 2-Fiteff, 3-Leuven, 4-Radware
- **Do not use if all gamma intensities are efficiency-corrected**

```
CONT
EFF,5
1,0
2,0
3,0
4,-1
5,0
END,
```

Input	Description
OP,RAW	
IEXP	number of experiments (according to the sequence in **EXPT**)
A1 A2 A3 A4 A5 A6 A7 A8	gamma det. Eff. Parametrization, det 1 (as in **OP,GDET**)
A1 A2 A3 A4 A5 A6 A7 A8	gamma det. Eff. Parametrization, det 2
…	**0 0 0 0 0 0 -50 0 – “flat” efficiency curve**
...	
A1 A2 A3 A4 A5 A6 A7 A8	
NC	number of CLUSERS
ID1	number of Ge detectors in cluster 1
I1 I2 … I(ID1)	index numbers of Ge detectors in the cluster
ID2	number of Ge detectors in cluster 2
I1 I2 … I(ID2)	index numbers of Ge detectors in the cluster
...	
…	
0	End of the input

COULEX ANALYSIS: MINIMISATION

OP,MINI
χ^2 function minimization

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

experimental yield

calculated yield

normalisation factor

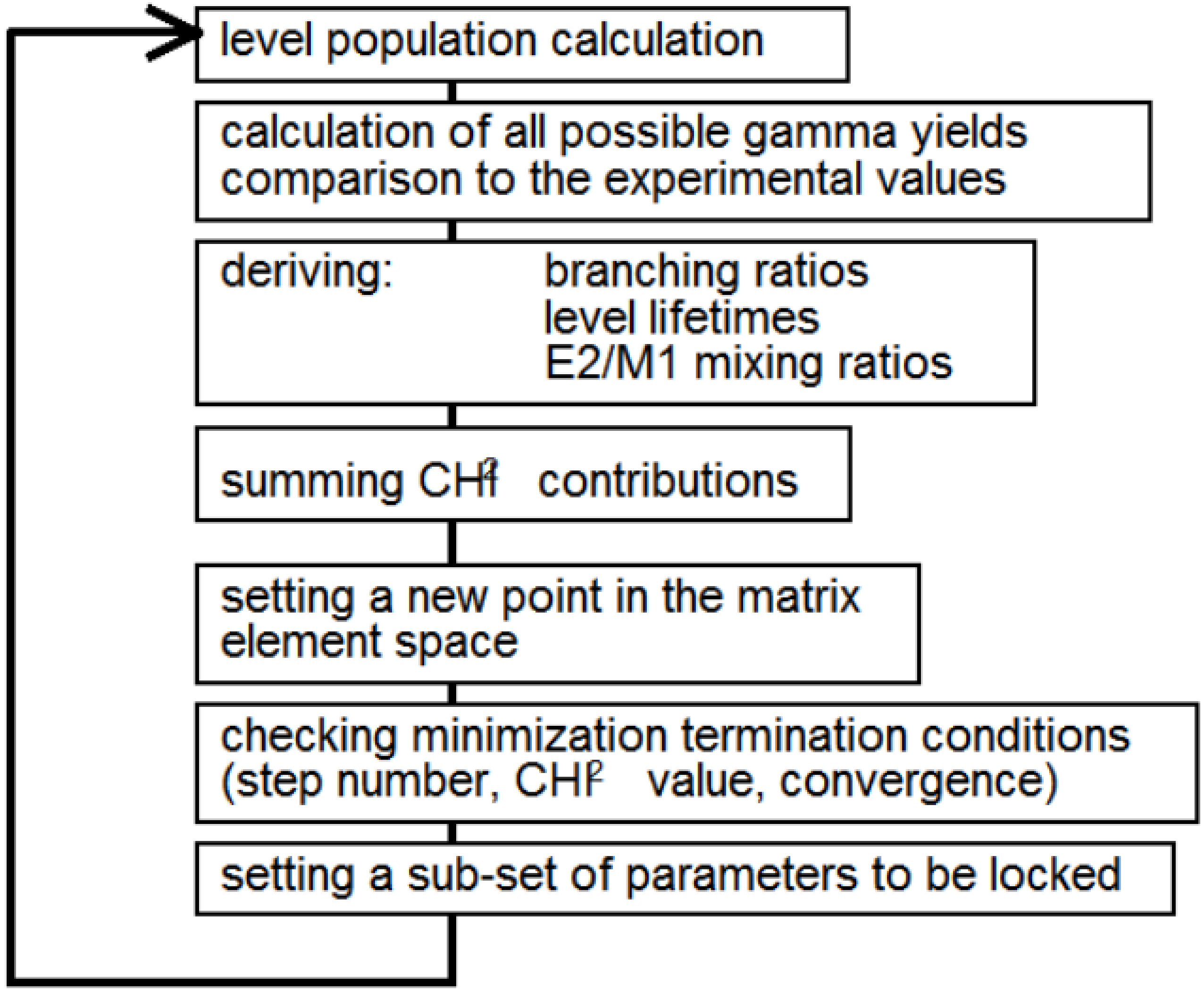
spectroscopic data point

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.

Remember to run **OP,MAP** before **OP,MINI**, each time you change something in ME (insert OP,MAP command directly after OP,YIEL). This option stores the **q-parameters** important for **reorientation effect** (effective strength, related to the magnetic sub-states coupling) on **TAPE7**

OP,MINI


level population calculation
calculation of all possible gamma yields
comparison to the experimental values
deriving:
branching ratios
level lifetimes
E2/M1 mixing ratios
summing CHI² contributions
setting a new point in the matrix
element space
checking minimization termination conditions
(step number, CHI² value, convergence)
setting a sub-set of parameters to be locked

OP,MINI

```
OP,MINI
IMODE   IPTL  CHILIM  CONV  TEST  LOCKF  NLOCK  IFBL  LOCKS  DLOCKS
```

```
OP,MINI
2100    20   0.0001   0.0001   1   1   1   1   1   0.0001
OP,EXIT
```

OP,MINI

IMODE (4 digits):
1-fast approximation, **2**-full COULEX formalism
0-simple steepest descent mini, **1**-gradient mini with gradient derivative mode
0-absolute changes in values of ME will be used to improve the fit, **1**-LOG values of ME used
0- absolute values of spectroscopic data will be used, **1**-LOG values of spectroscopic data

```
OP,MINI
IMODE   IPTL  CHILIM  CONV  TEST  LOCKF  NLOCK  IFBL  LOCKS  DLOCKS
```

```
OP,MINI
2100    20   0.0001   0.0001   1   1   1   1   1   0.0001
OP,EXIT
```

OP,MINI

```
OP,MINI
IMODE   IPTL  CHILIM  CONV  TEST  LOCKF  NLOCK  IFBL  LOCKS  DLOCKS
```

max number
of mini steps

```
OP,MINI
2100    20   0.0001   0.0001   1   1   1   1   1   0.0001
OP,EXIT
```

OP,MINI

```
OP,MINI
IMODE   IPTL  CHILIM  CONV  TEST  LOCKF  NLOCK  IFBL  LOCKS  DLOCKS
```

Stop criterion

```
OP,MINI
2100   20   0.0001   0.0001   1   1   1   1   1   0.0001
OP,EXIT
```

OP,MINI

OP,MINI
IMODE IPTL CHILIM CONV TEST LOCKF NLOCK IFBL LOCKS DLOCKS

convergence criterion
$|\overline{ME}_{n+1} - \overline{ME}_{n}| < CONV$

```
OP,MINI
2100   20   0.0001   0.0001   1   1   1   1   1   0.0001
OP,EXIT
```

OP,MINI

```
OP,MINI
IMODE   IPTL  CHILIM  CONV  TEST  LOCKF  NLOCK  IFBL  LOCKS  DLOCKS
```

TEST≤1 – recalculation of the internal correction coeff. between fast approx. and full mini.

```
OP,MINI
2100   20   0.0001   0.0001   1   1   1   1   1   0.0001
OP,EXIT
```

OP,MINI

```
OP,MINI
IMODE  IPTL  CHILIM  CONV  TEST  LOCKF  NLOCK  IFBL  LOCKS  DLOCKS
```

0 – mini will be terminated if CONV is fulfilled
1 – fix the NLOCK number of ME with the most significant derivative

```
OP,MINI
2100  20  0.0001  0.0001  1  1  1  1  1  0.0001
OP,EXIT
```

OP,MINI

```
OP,MINI
IMODE   IPTL  CHILIM  CONV  TEST  LOCKF  NLOCK  IFBL  LOCKS  DLOCKS
```

Number of ME to be locked if LOCKF=1 and CONV fulfilled

```
OP,MINI
2100    20   0.0001   0.0001   1   1   1   1   1   0.0001
OP,EXIT
```

OP,MINI

```
OP,MINI
IMODE   IPTL  CHILIM  CONV  TEST  LOCKF  NLOCK  IFBL  LOCKS  DLOCKS
```

IFBL: 0 – forward difference method, 1 – forward-backward method

```
OP,MINI
2100    20   0.0001   0.0001   1   1   1   1   1   0.0001
OP,EXIT
```

OP,MINI

1 – fixes all ME with absolute value of partial derivative is less than DLOCKS

OP,MINI
IMODE IPTL CHILIM CONV TEST LOCKF NLOCK IFBL LOCKS DLOCKS

The limit for LOCKS

```
OP,MINI
2100   20  0.0001  0.0001  1  1  1  1  1  0.0001
OP,EXIT
```

OP,MINI

IMODE (4 digits):
1-fast approximation, **2**-full COULEX formalism
0-simple steepest descent mini, **1**-gradient mini with gradient derivative mode
0-absolute changes in values of ME will be used to improve the fit, **1**-LOG values of ME used
0- absolute values of spectroscopic data will be used, **1**-LOG values of spectroscopic data

1 – fixes all ME with absolute value of partial derivative is less than DLOCKS

```
OP,MINI
IMODE   IPTL  CHILIM  CONV  TEST  LOCKF  NLOCK  IFBL  LOCKS  DLOCKS
```

The limit for LOCKS

max number of mini steps

convergence criterion
$|\overline{ME}_{n+1} - \overline{ME}_{n}| < CONV$

0 – forward difference method,
1 – forward-backward method

Stop criterion

TEST≤1 – recalculation of the internal correction coeff. between fast approx. and full mini.

Number of ME to be locked if LOCKF=1 and CONV fulfilled

0 – mini will be terminated if CONV is fulfilled
1 – fix the NLOCK number of ME with the most significant derivative

```
OP,MINI
2100    20   0.0001   0.0001   1   1   1   1   1   0.0001
OP,EXIT
```

COULEX ANALYSIS: ERROR CALCULATION

OP,ERRO

- for estimating the error bars to be assigned to the set of matrix elements corresponding to the minimum value of χ^2 (**CONT CRF,**), NTAP=4 (OP,YIEL)

OP,ERRO

- for estimating the error bars to be assigned to the set of matrix elements corresponding to the minimum value of χ^2 (**CONT CRF,**), NTAP=4 (OP,YIEL)

OP,ERRO
IDF MS MEND IREP IFC RMAX

OP,ERRO

- for estimating the error bars to be assigned to the set of matrix elements corresponding to the minimum value of χ^2 (**CONT CRF,**), NTAP=4 (OP,YIEL)

OP,ERRO
IDF MS MEND IREP IFC RMAX

- two separate stages:

1. the “diagonal“,or uncorrelated errors (calculated individually for each matrix element) and write them on TAPE15

2. the “overall“, or correlated errors (the total errors which are the widths of projections on each matrix element’s axis of the minimum at the $\chi^2 = \chi^2 + 1$ level). (**CONT SMR, for Sum Rules**). TAPE15 must be included as an input, TAPE3 will contain the output of OP,ERRO for program SIGMA (ATTENTION!!)

OP,ERRO

- for estimating the error bars to be assigned to the set of matrix elements corresponding to the minimum value of χ^2 (**CONT CRF,**), NTAP=4 (OP,YIEL)

Mode flag:
0 – diagonal
1 – correlated

OP,ERRO
IDF MS MEND IREP IFC RMAX

- two separate stages:

1. the “diagonal“,or uncorrelated errors (calculated individually for each matrix element) and write them on TAPE15

0

2. the “overall“, or correlated errors (the total errors which are the widths of projections on each matrix element’s axis of the minimum at the $\chi^2 = \chi^2 + 1$ level). (**CONT SMR, for Sum Rules**). TAPE15 must be included as an input, TAPE3 will contain the output of OP,ERRO for program SIGMA (ATTENTION!!)

1

OP,ERRO

- for estimating the error bars to be assigned to the set of matrix elements corresponding to the minimum value of χ^2 (**CONT CRF,**), NTAP=4 (OP,YIEL)

0 – all ME (excluding fixed ones)
-1 – for ranges of ME (introduced later on)

```
OP,ERRO
IDF   MS   MEND   IREP   IFC   RMAX
```

- two separate stages:

1. the “diagonal“,or uncorrelated errors (calculated individually for each matrix element) and write them on TAPE15

0 MS MEND

2. the “overall“, or correlated errors (the total errors which are the widths of projections on each matrix element’s axis of the minimum at the $\chi^2 = \chi^2 + 1$ level). (**CONT SMR, for Sum Rules**). TAPE15 must be included as an input, TAPE3 will contain the output of OP,ERRO for program SIGMA (ATTENTION!!)

1 MS MEND

OP,ERRO

- for estimating the error bars to be assigned to the set of matrix elements corresponding to the minimum value of χ^2 (**CONT CRF,**), NTAP=4 (OP,YIEL)

OP,ERRO
IDF MS MEND IREP IFC RMAX

Repetition flag
0 – a new calculation (always for diag. Err.)
1 – read from TAPE15 (for corr. err.)
2 – if Sum Rules TAPE3 was created

- two separate stages:

1. the “diagonal“,or uncorrelated errors (calculated individually for each matrix element) and write them on TAPE15

0 MS MEND 0

2. the “overall“, or correlated errors (the total errors which are the widths of projections on each matrix element’s axis of the minimum at the $\chi^2 = \chi^2 + 1$ level). (**CONT SMR, for Sum Rules**). TAPE15 must be included as an input, TAPE3 will contain the output of OP,ERRO for program SIGMA (ATTENTION!!)

1 MS MEND 1

OP,ERRO

- for estimating the error bars to be assigned to the set of matrix elements corresponding to the minimum value of χ^2 (**CONT CRF,**), NTAP=4 (OP,YIEL)

0 – correlation matrix used (recommended)
1 – correlation matrix not used

OP,ERRO
IDF MS MEND IREP IFC RMAX

- two separate stages:

1. the “diagonal“,or uncorrelated errors (calculated individually for each matrix element) and write them on TAPE15

0 MS MEND 0 0

2. the “overall“, or correlated errors (the total errors which are the widths of projections on each matrix element’s axis of the minimum at the $\chi^2 = \chi^2 + 1$ level). (**CONT SMR, for Sum Rules**). TAPE15 must be included as an input, TAPE3 will contain the output of OP,ERRO for program SIGMA (ATTENTION!!)

1 MS MEND 1 0

OP,ERRO

- for estimating the error bars to be assigned to the set of matrix elements corresponding to the minimum value of χ^2 (**CONT CRF,**), NTAP=4 (OP,YIEL)

```
OP,ERRO
IDF   MS   MEND   IREP   IFC   RMAX
```

The largest floating point number available on a given computer

- two separate stages:

1. the "diagonal",or uncorrelated errors (calculated individually for each matrix element) and write them on TAPE15

0   MS   MEND   0   0   RMAX

2. the "overall", or correlated errors (the total errors which are the widths of projections on each matrix element's axis of the minimum at the $\chi^2 = \chi^2 + 1$ level). (**CONT SMR, for Sum Rules**). TAPE15 must be included as an input, TAPE3 will contain the output of OP,ERRO for program SIGMA (ATTENTION!!)

1 MS   MEND   1   0   RMAX

OP,ERRO

- for estimating the error bars to be assigned to the set of matrix elements corresponding to the minimum value of χ^2 (**CONT CRF,**), NTAP=4 (OP,YIEL)

0 – all ME (excluding fixed ones)
-1 – for ranges of ME (introduced later on)

0 – correlation matrix used
1 – correlation matrix not used

Mode flag:
0 – diagonal
1 – correlated

OP,ERRO
IDF MS MEND IREP IFC RMAX

The largest floating point number available on a given computer

Repetition flag
0 – a new calculation (always for diag. Err.)
1 – read from TAPE15 (for corr. err.)
2 – if Sum Rules TAPE3 was created

- two separate stages:

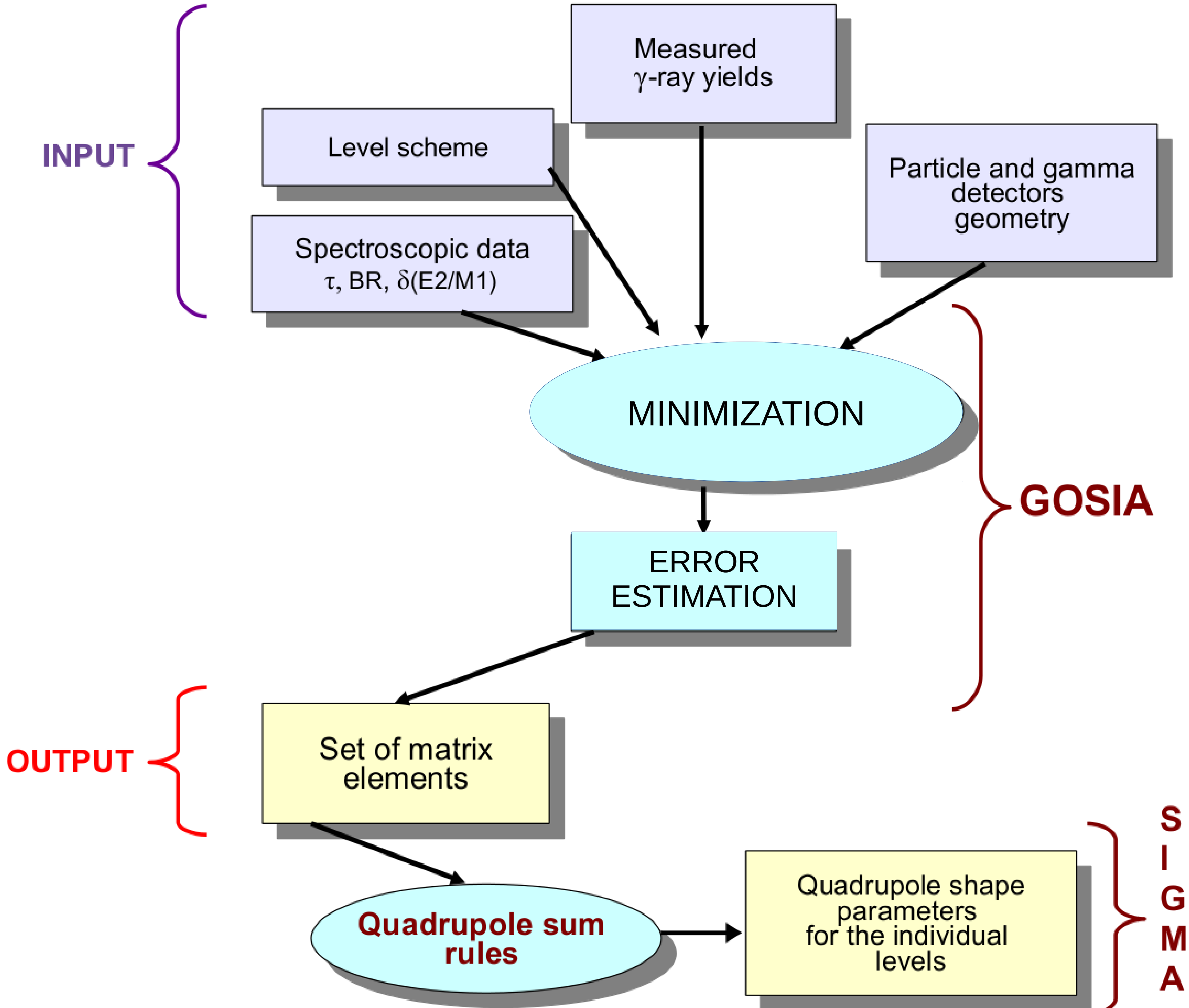
1. the "diagonal",or uncorrelated errors (calculated individually for each matrix element) and write them on TAPE15

0 MS MEND 0 0 RMAX

2. the "overall", or correlated errors (the total errors which are the widths of projections on each matrix element's axis of the minimum at the $\chi^2 = \chi^2 + 1$ level). (**CONT SMR, for Sum Rules**). TAPE15 must be included as an input, TAPE3 will contain the output of OP,ERRO for program SIGMA (ATTENTION!!)

1 MS MEND 1 0 RMAX

SIGMA


INPUT
Measured
γ-ray yields
Level scheme
Particle and gamma detectors geometry
Spectroscopic data
τ, BR, δ(E2/M1)
MINIMIZATION
GOSIA
ERROR ESTIMATION
OUTPUT
Set of matrix elements
Quadrupole sum rules
Quadrupole shape parameters for the individual levels
SIGMA

SIGMA

- Is a separate **fortran** program (you need to compile it like GOSIA)
- Very useful tool to **evaluate the Quadrupole Sum Rule Method**
- SIGMA uses the **output files from GOSIA** but can be also used separately (for expectation values estimation)
- Calculates the **shape invariants** and estimates their errors (if asked)
- Input is not complicated
- Output is full of information

SIGMA

- You must run OP,ERRO in GOSIA to get **TAPE3** (if CONT SMR, TAPE3 contains the output file for sum rules, IDF=1) and **TAPE15**
- You must run OP,SIXJ in GOSIA to calculate the table of 6j coefficients (output file **TAPE14**) (can be inserted anywhere in the input file, even as the only option)

SIGMA

- You must run OP,ERRO in GOSIA to get **TAPE3** (if CONT SMR, TAPE3 contains the output file for sum rules, IDF=1) and **TAPE15**
- You must run OP,SIXJ in GOSIA to calculate the table of 6j coefficients (output file **TAPE14**) (can be inserted anywhere in the input file, even as the only option)

sigma.inp

```
IL
NST
TAPE3.smr
TAPE15.err
TAPE14.tab
```

SIGMA

- You must run OP,ERRO in GOSIA to get **TAPE3** (if CONT SMR, TAPE3 contains the output file for sum rules, IDF=1) and **TAPE15**
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sigma.inp

```
IL
NST
TAPE3.smr
TAPE15.err
TAPE14.tab
```

IL: 1 – printout of the ME involved in evaluation of all shape invariants
0 – for the simpler output

SIGMA

- You must run OP,ERRO in GOSIA to get **TAPE3** (if CONT SMR, TAPE3 contains the output file for sum rules, IDF=1) and **TAPE15**
- You must run OP,SIXJ in GOSIA to calculate the table of 6j coefficients (output file **TAPE14**) (can be inserted anywhere in the input file, even as the only option)

sigma.inp

```
IL
NST
TAPE3.smr
TAPE15.err
TAPE14.tab
```

The mode of error calculations
-1 – no error estimation (SIGMA can be independent from GOSIA if you use this option)
0 – errors will be calculated only for Q2, three values of v(Q2) and four of cos3d for each state
99 – error will be calculated for each statistical moment (too long and complicated)

SIGMA

- You must run OP,ERRO in GOSIA to get **TAPE3** (if CONT SMR, TAPE3 contains the output file for sum rules, IDF=1) and **TAPE15**
- You must run OP,SIXJ in GOSIA to calculate the table of 6j coefficients (output file **TAPE14**) (can be inserted anywhere in the input file, even as the only option)

sigma.inp

```
IL
NST
TAPE3.smr
TAPE15.err
TAPE14.tab
```

1 – printout of the ME involved in evaluation of all shape invariants
0 – for the simpler output

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0 – errors will be calculated only for Q2, three values of v(Q2) and four of cos3d for each state
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```
0
0
TAPE3.smr
TAPE15.err
TAPE14.tab
```