Extended (element) configurations upgrade

version 9.2.106

Aim:

Main task of analysis of the recent ^{82}Se experiment is to get production cross sections. Transmission through Transfer Hall and S800 BeamLine of beams with large emittances (X',Y',DP/P) was not study in details, and in analysis of the previous ^{76}Ge experiment 100%-transmission was assumed.

In order to obtain cross sections, it is necessary to perform
• detail analysis of transmission
• optics reconstruction to obtain A,Z,Q with good resolution

Therefore.. Above of all, LISE++ extended configurations should be constructed, which allows to estimate transmission.

***This analysis is based on the latest LISE++ development*:**

*** Utilities for Extended Configurations**
*** SLITS (Angular acceptance, Aperture, Slits)**
*** Beam emittance modes (1&2D-shapes)**
* Use of Apertures in MC calculations
* Benchmarks for Angular Acceptances

Extended (element) configurations upgrade

version 9.2.106

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NSCL Ion Optics Segments; Software

Transmission can be estimated with codes
MOCADI or LISE++ (in Monte Carlo mode with extended configurations)

Segment	beam pipe diameter	multipoles
A1900	8”	yes
Transfer hall	4”	no
S800BeamLine	7”	no

Software	Max.Order	multipoles use
COSY	5	yes
Transport	2	no
LISE++		
calculation (based on TRANSPORT)	2	no
use	5	yes

NSCL configurations in LISE++

version 9.2.106

Segmented configurations:	*Number of blocks*	*Start*	*Stop*	*Optics order*	*Source maps*
A1900_2010.lcn	4	z15	z105	1	
A1900_segmented_COSY.lcn	4	z15	z105	5	link
Extended configurations:					
A1900_extended_COSY.lcn*	73	z15	z106	5	link
A1900_extended_COSY_only_Quads.lcn	73	z15	z106	5	link
A1900_extended_LISE.lcn	73	z15	z106	2	
A1900_I190_extended_LISE.lcn	113	z15	i190	2	link
A1900_S800BL_extended_LISE.lcn	157	z15	i250	2	
S800BL_extended_LISE.lcn	48	i190	i250	2	link
Final extended configuration (version 9.2.107):					
A1900_extended_COSY_S800BL_LISE.lcn*	73	z15	i250	5-2	

**- includes sextupoles and octupoles for A1900*

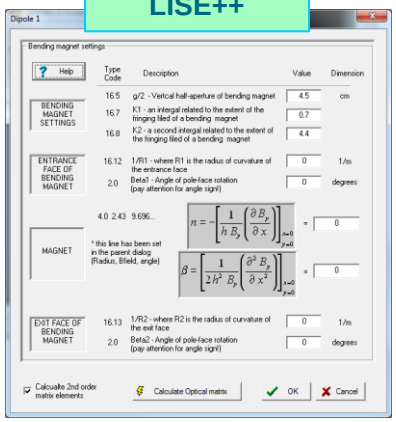
- *Extended_LISE versions (based on TRANSPORT calculations) have been created with use of TRANSPORT files obtained from J.Stetson,T.Ginter & D.Bazin*
- *Extended _ & Segmented_COSY versions (based on COSY maps) have been created with use of COSY files obtained from M.Portillo*

Dipole: different codes calculations

Transport source

```
0
1. 0.1 10. 0.1 10. 0. 0. 0.89939 ;
17. ;
16. 5.0  4.5  ; 16. 7.0  0.7  ; 16. 8.0   4.40 ;
2.0  0. ;
4. 2.43 9.69625 0. ;
2.0  0. ;
13. 24.;
SENTINEL
```

LISE++



COSY

```
DI 3.094   45.0  0.045     0 0   0 0 ;
```

LISE++

```
Block: "Dipole 1"    Matrices: "LOCAL"
                                                    transport format [cm-mrad]
                        * TRANSFORM 1 *
  1 [X]:    +7.0711e-01  +2.1878e-01   0            0            0            +9.0620e-01
  2 [T]:    -2.2854e+00  +7.0711e-01   0            0            0            +7.0711e+00
  3 [Y]:     0            0           +1.0160e+00  +2.4300e-01   0            0
  4 [F]:     0            0           +1.3270e-01  +1.0160e+00   0            0
  5 [L]:    -7.0711e-01  -9.0620e-02   0            0           +1.0000e+00  -2.4223e-01
  6 [D]:     0            0           0            0            0            +1.0000e+00
-------------------------------------------------------------------------------------------
                        * TRANSFORM 2 *
  1   1:    -8.0803e-04
  1   2:    +5.0000e-04  +3.2039e-05
  1   3:     0            0           -4.7353e-04
  1   4:     0            0           -3.9568e-04  -1.4074e-04
  1   5:     0            0            0            0            0
  1   6:    +5.0000e-03  +6.4078e-04   0            0            0            -7.7349e-03
-------------------------------------------------------------------------------------------
  2   1:     0
  2   2:     0           -3.5355e-04
  2   3:     0            0           -3.6949e-03
  2   4:     0            0           -2.3272e-05  -3.5355e-04
  2   5:     0            0            0            0            0
  2   6:    +2.2854e-02   0            0            0            0            -7.0711e-02
-------------------------------------------------------------------------------------------
  3   1:     0
  3   2:     0            0
  3   3:    +4.6543e-05  -7.7943e-04   0
  3   4:    +7.0711e-04  +9.0620e-05   0            0
  3   5:     0            0            0            0            0
  3   6:     0            0           +1.5944e-05  +2.4223e-04   0            0
-------------------------------------------------------------------------------------------
  4   1:     0
  4   2:     0            0
  4   3:    -7.3837e-03  -9.9797e-04   0
  4   4:    -1.7484e-03  +5.6133e-04   0            0
  4   5:     0            0            0            0            0
  4   6:     0            0           +1.0495e-06  +1.5944e-05   0            0
-------------------------------------------------------------------------------------------
  5   1:     0
  5   2:     0            0
  5   3:     0            0           -1.1427e-03
  5   4:     0            0            0            0
  5   5:     0            0            0            0            0
  5   6:     0            0            0            0            0            0
```

COSY

```
Block: "Dipole 1"    Matrices: "LOCAL"
                                                    transport format [cm-mrad]
                        * TRANSFORM 1 *
  1 [X]:    +7.0711e-01  +2.1878e-01   0            0            0            +9.0621e-01
  2 [T]:    -2.2854e+00  +7.0711e-01   0            0            0            +7.0711e+00
  3 [Y]:     0            0           +1.0000e+00  +2.4300e-01   0            0
  4 [F]:     0            0            0           +1.0000e+00   0            0
  5 [L]:    -7.0711e-01  -9.0620e-02   0            0           +1.0000e+00  -2.4223e-01
  6 [D]:     0            0           0            0            0            +1.0000e+00
-------------------------------------------------------------------------------------------
                        * TRANSFORM 2 *
  1   1:    -8.0802e-04
  1   2:    +5.0000e-04  +3.2039e-05
  1   3:     0            0            0
  1   4:     0            0            0           -4.5311e-05
  1   5:     0            0            0            0            0
  1   6:    +5.0000e-03  +6.4079e-04   0            0            0            -7.7350e-03
-------------------------------------------------------------------------------------------
  2   1:     0
  2   2:     0           -3.5355e-04
  2   3:     0            0            0
  2   4:     0            0            0           -3.5355e-04
  2   5:     0            0            0            0            0
  2   6:    +2.2854e-02   0            0            0            0            -7.0711e-02
-------------------------------------------------------------------------------------------
  3   1:     0
  3   2:     0            0
  3   3:     0            0            0
  3   4:    +7.0711e-04  +9.0621e-05   0            0
  3   5:     0            0            0            0            0
  3   6:     0            0            0           +2.4223e-04   0            0
-------------------------------------------------------------------------------------------
  4   1:     0
  4   2:     0            0
  4   3:     0            0            0
  4   4:     0            0            0            0
  4   5:     0            0            0            0            0
  4   6:     0            0            0            0            0            0
-------------------------------------------------------------------------------------------
  5   1:     0
  5   2:     0           -1.0939e-04
  5   3:     0            0            0
  5   4:     0            0            0           -1.0939e-04
  5   5:     0            0            0            0            0
  5   6:     0           -9.0621e-04   0            0            0            0
```

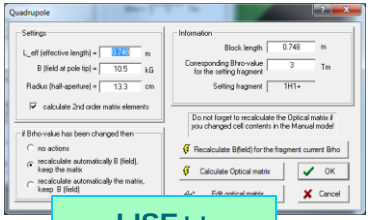
Quad + Dipole system: different codes calculations

Transport source

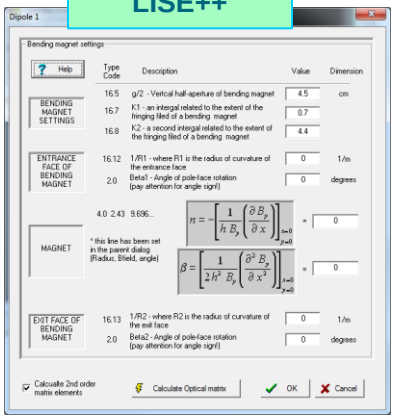
```
 0
 1. 0.1 10. 0.1 10. 0. 0. 0.89939 ;
 13. 4.;
 17. ;
 5. 0.748 10.5 13.3 /1TA/ ;
 13. 24.;
 16. 5.0  4.5  ; 16. 7.0  0.7  ; 16. 8.0  4.40 ;
 2.0  0. ;
 19. 24.;
 4. 2.43 9.69625 0. ;
 13. 24.;
 2.0  0. ;
 13. 24.;
 SENTINEL
```

Transport

```
*TRANSFORM 2*
 -3.07740   0.11737   0.00000   0.00000   0.00000   0.90619
-11.54554   0.11539   0.00000   0.00000   0.00000   7.07098
  0.00000   0.00000   7.90681   0.54101   0.00000   0.00000
  0.00000   0.00000  25.52349   1.87289   0.00000   0.00000
  1.12978  -0.07254   0.00000   0.00000   1.00000  -0.24222
  0.00000   0.00000   0.00000   0.00000   0.00000   1.00000
*2ND ORDER TRANSFORM*
 1 11  4.642E-03
 1 12 -7.589E-04   1 22  1.133E-05
 1 13  0.000E+00   1 23  0.000E+00   1 33 -1.255E-01
 1 14  0.000E+00   1 24  0.000E+00   1 34 -1.759E-02   1 44 -6.157E-04
 1 15  0.000E+00   1 25  0.000E+00   1 35  0.000E+00   1 45  0.000E+00   1 55  0.000E+00
 1 16  2.019E-02   1 26  1.868E-03   1 36  0.000E+00   1 46  0.000E+00   1 56  0.000E+00   1 66 -7.735E-03

 2 11 -8.165E-02
 2 12  3.759E-03   2 22 -4.327E-05
 2 13  0.000E+00   2 23  0.000E+00   2 33 -2.334E-01
 2 14  0.000E+00   2 24  0.000E+00   2 34 -3.376E-02   2 44 -1.226E-03
 2 15  0.000E+00   2 25  0.000E+00   2 35  0.000E+00   2 45  0.000E+00   2 55  0.000E+00
 2 16  7.308E-02   2 26  4.978E-03   2 36  0.000E+00   2 46  0.000E+00   2 56  0.000E+00   2 66 -7.071E-02

 3 11  0.000E+00
 3 12  0.000E+00   3 22  0.000E+00
 3 13 -6.393E-03   3 23  1.311E-03   3 33  0.000E+00
 3 14 -9.472E-04   3 24  1.073E-04   3 34  0.000E+00   3 44  0.000E+00
 3 15  0.000E+00   3 25  0.000E+00   3 35  0.000E+00   3 45  0.000E+00   3 55  0.000E+00
 3 16  0.000E+00   3 26  0.000E+00   3 36 -7.742E-02   3 46 -2.032E-03   3 56  0.000E+00   3 66  0.000E+00

 4 11  0.000E+00
 4 12  0.000E+00   4 22  0.000E+00
 4 13 -2.055E-01   4 23  9.648E-04   4 33  0.000E+00
 4 14 -1.561E-02   4 24  1.019E-04   4 34  0.000E+00   4 44  0.000E+00
 4 15  0.000E+00   4 25  0.000E+00   4 35  0.000E+00   4 45  0.000E+00   4 55  0.000E+00
 4 16  0.000E+00   4 26  0.000E+00   4 36 -1.296E-01   4 46  2.910E-03   4 56  0.000E+00   4 66  0.000E+00

 5 11 -2.886E-02
 5 12  1.602E-03   5 22 -3.714E-05
 5 13  0.000E+00   5 23  0.000E+00   5 33 -7.869E-02
 5 14  0.000E+00   5 24  0.000E+00   5 34 -1.162E-02   5 44 -4.415E-04
 5 15  0.000E+00   5 25  0.000E+00   5 35  0.000E+00   5 45  0.000E+00   5 55  0.000E+00
 5 16 -2.532E-04   5 26 -9.437E-04   5 36  0.000E+00   5 46  0.000E+00   5 56  0.000E+00   5 66  0.000E+00
```



LISE++



Block: "Dipole 1" Matrices: "GLOBAL"

LISE calculations (9.2.106)

transport format [cm-mrad]

```
                    * TRANSFORM 1 *
 1 [X]:    -3.0773e+00  +1.1737e-01    0            0            0            +9.0618e-01
 2 [T]:    -1.1546e+01  +1.1537e-01    0            0            0            +7.0711e+00
 3 [Y]:     0            0           +7.9067e+00  +5.4100e-01    0            0
 4 [F]:     0            0           +2.5524e+01  +1.8729e+00    0            0
 5 [L]:    +1.1298e+00  -7.2536e-02    0            0           +1.0000e+00  -2.4223e-01
 6 [D]:     0            0           0            0            0            +1.0000e+00

                    * TRANSFORM 2 *
 1   1:    +4.6424e-03
 1   2:    -7.5093e-04  +1.1327e-05
 1   3:     0            0           -1.2478e-01
 1   4:     0            0           -1.7504e-02  -6.1311e-04
 1   5:     0            0           0            0            0
 1   6:    +2.0186e-02  +1.8680e-03   0            0            0            -7.7347e-03

 2   1:    -8.1655e-02
 2   2:    +3.7592e-03  -4.3266e-05
 2   3:     0            0           -2.3342e-01
 2   4:     0            0           -3.3763e-02  -1.2265e-03
 2   5:     0            0           0            0            0
 2   6:    +7.3081e-02  +4.9780e-03   0            0            0            -7.0711e-02

 3   1:     0
 3   2:     0            0
 3   3:    -6.3932e-03  +1.3106e-03   0
 3   4:    -9.4709e-04  +1.0729e-04   0            0
 3   5:     0            0           0            0            0
 3   6:     0            0          -7.7421e-02  -2.0317e-03   0            0

 4   1:     0
 4   2:     0            0
 4   3:    -2.0444e-01  +9.5348e-04   0
 4   4:    -1.5550e-02  +1.0133e-04   0            0
 4   5:     0            0           0            0            0
 4   6:     0            0          -1.3030e-01  +2.8763e-03   0            0

 5   1:     0
 5   2:     0            0
 5   3:     0            0           -3.8314e-03
 5   4:     0            0           -3.9572e-04  -1.0218e-05
 5   5:     0            0           0            0            0
 5   6:    -1.4025e-02  -6.2672e-04   0            0            0            0
```

Block: "Dipole 1" Matrices: "GLOBAL"

COSY (GLOBAL after Quad+ Dipole)

no sextupoles

transport format [cm-mrad]

```
                    * TRANSFORM 1 *
 1 [X]:    -3.0775e+00  +1.1737e-01    0            0            0            +9.0621e-01
 2 [T]:    -1.1546e+01  +1.1538e-01    0            0            0            +7.0711e+00
 3 [Y]:     0            0           +7.8777e+00  +5.3951e-01    0            0
 4 [F]:     0            0           +2.4883e+01  +1.8311e+00    0            0
 5 [L]:    +1.1298e+00  -7.2540e-02    0            0           +1.0000e+00  -2.4223e-01
 6 [D]:     0            0           0            0            0            +1.0000e+00

                    * TRANSFORM 2 *
 1   1:    +4.6426e-03
 1   2:    -7.5093e-04  +1.1327e-05
 1   3:     0            0           -2.8055e-02
 1   4:     0            0           -4.1289e-03  -1.5192e-04
 1   5:     0            0           0            0            0
 1   6:    +2.0187e-02  +1.8681e-03   0            0            0            -7.7350e-03

 2   1:    -8.1655e-02
 2   2:    +3.7592e-03  -4.3266e-05
 2   3:     0            0           -2.1891e-01
 2   4:     0            0           -3.2217e-02  -1.1854e-03
 2   5:     0            0           0            0            0
 2   6:    +7.3081e-02  +4.9779e-03   0            0            0            -7.0711e-02

 3   1:     0
 3   2:     0            0
 3   3:    -2.8113e-02  +1.8049e-03   0
 3   4:    -2.0688e-03  +1.3282e-04   0            0
 3   5:     0            0           0            0            0
 3   6:     0            0          -7.7305e-02  -2.0299e-03   0            0

 4   1:     0
 4   2:     0            0
 4   3:     0            0           0
 4   4:     0            0           0            0
 4   5:     0            0           0            0            0
 4   6:     0            0          -3.0463e-01  -9.3062e-03   0            0

 5   1:    -2.8856e-02
 5   2:    +1.6019e-03  -3.7137e-05
 5   3:     0            0          -7.4199e-02
 5   4:     0            0          -1.1145e-02  -4.2875e-04
 5   5:     0            0           0            0            0
 5   6:    -2.5315e-04  -9.4374e-04   0            0            0            0
```

Block: "Dipole 1" Matrices: "GLOBAL"

COSY (Local Q +Local Dipole) => LISE multiplication

no sextupoles

transport format [cm-mrad]

```
                    * TRANSFORM 1 *
 1 [X]:    -3.0775e+00  +1.1737e-01    0            0            0            +9.0621e-01
 2 [T]:    -1.1546e+01  +1.1538e-01    0            0            0            +7.0711e+00
 3 [Y]:     0            0           +7.8776e+00  +5.3951e-01    0            0
 4 [F]:     0            0           +2.4883e+01  +1.8311e+00    0            0
 5 [L]:    +1.1298e+00  -7.2536e-02    0            0           +1.0000e+00  -2.4223e-01
 6 [D]:     0            0           0            0            0            +1.0000e+00

                    * TRANSFORM 2 *
 1   1:    +4.6426e-03
 1   2:    -7.5094e-04  +1.1327e-05
 1   3:     0            0           -2.8055e-02
 1   4:     0            0           -4.1289e-03  -1.5192e-04
 1   5:     0            0           0            0            0
 1   6:    +2.0187e-02  +1.8681e-03   0            0            0            -7.7350e-03

 2   1:    -8.1655e-02
 2   2:    +3.7592e-03  -4.3266e-05
 2   3:     0            0           -2.1891e-01
 2   4:     0            0           -3.2218e-02  -1.1854e-03
 2   5:     0            0           0            0            0
 2   6:    +7.3081e-02  +4.9780e-03   0            0            0            -7.0711e-02

 3   1:     0
 3   2:     0            0
 3   3:    -2.8114e-02  +1.8049e-03   0
 3   4:    -2.0688e-03  +1.3282e-04   0            0
 3   5:     0            0           0            0            0
 3   6:     0            0          -7.7304e-02  -2.0299e-03   0            0

 4   1:     0
 4   2:     0            0
 4   3:     0            0           0
 4   4:     0            0           0            0
 4   5:     0            0           0            0            0
 4   6:     0            0          -3.0463e-01  -9.3062e-03   0            0

 5   1:    -2.8856e-02
 5   2:    +1.6019e-03  -3.7137e-05
 5   3:     0            0          -7.4199e-02
 5   4:     0            0          -1.1144e-02  -4.2875e-04
 5   5:     0            0           0            0            0
 5   6:    -2.5304e-04  -9.4373e-04   0            0            0            0
```

Benchmarks of configurations with different emittances

Please use links below to reach corresponding analysis

- **X & X'** (2D rectangle)
- **Y & Y'** (2D rectangle)
- **X' & dP** (2D rectangle)
- **Y' & dP** (2D rectangle)
- **X' & Y'** (independent 1D rectangles)
- **X',Y' & dP** (independent 1D rectangles)

Transmission results (1)

Initial emittance

X=Y=1mm,
X'=60mrad,
Y'=40mrad,
dp/p=2.5%

	configuration	order	from Target to A1900-FP (105)	from Target to i190 (rotate)	from Target to I-slits (214)	from Target to S800BL FP-slits	from A1900FP to S800BL FP	from Target to S800BL FP-slits with I-PPACs	from A1900FP to S800BL FP with I-PPACs
A1900_LISE	extended	1	**71.0%**	70.5%	61.9%	60.0%	84.5%	51.1%	72.0%
A1900_LISE	extended	2	**53.0%**	23.5%	21.1%	14.8%	27.9%	13.7%	25.8%
A1900_COSY	extended	1	**68.0%**						
A1900_COSY +S800BL_LISE	***extended***	***2***	***62.0%***	***54.0%***	***46.1%***	***35.0%***	***56.5%***	***31.3%***	***50.5%***
A1900_COSY +S800BL_LISE	extended	5	**66.0%**	51.0%	43.2%	32.0%	48.5%	28.5%	43.2%
A1900	segmented	1	**77.0%**						
A1900	segmented	Distribution	**91.0%**						

Transmission results (2)

Initial emittance

X=Y=1mm,
X'=60mrad,
Y'=40mrad,
dp/p=0.1%

	configuration	order	from Target to A1900-FP (105)	i190 (rotate)	S800BL FP-slits with I-PPACs	from A1900FP to S800BL FP with I-PPACs
A1900_LISE	extended	1	**89.4%**	88.4%	85.3%	95.4%
A1900_LISE	extended	2	**86.5%**	84.7%	81.0%	93.6%
A1900_COSY +S800BL_LISE	***extended***	***2***	***74.7%***	***63.6%***	***58.9%***	***78.8%***
A1900_COSY +S800BL_LISE	extended	5	**80.2%**	59.2%	55.5%	69.2%

Conclusion

• Extended configurations based on COSY and LISE-Transport optics calculations have been created for A1900 + TrasferHall + S800BeamLine lines.

•Analysis shows, that 2nd order corrections obtained with multipoles (6 or 8) and calculated by COSY are very important for high order optics of A1900.

• TransferHall and S800BL lines do not have multipoles (6 or 8), and therefore LISE-transport calculations can be used for second order optics.

• Based on previous two items, A1900_extended_COSY_S800BL_LISE.lcn configuration is recommended for qualitative transmission calculations

• Calculated Transmissions between A1900_FP_slits and S800_target_box are
for emittance X=Y=1mm, X'=60mrad, Y'=40mrad, dp/p=0.1% is about 80% (69-95%);
for emittance X=Y=1mm, X'=60mrad, Y'=40mrad, dp/p=2.5% is about 50% (26-72%);

• S800BL Momentum Acceptance with I-PPACs use is less than 4%

• Resolution of Momentum corrections with S800BL I-PPACS without optical reconstruction can not exceed 0.25% (StDev)

……. Will be updated

Outlooks

- Slits after block should be set in extended configurations to reproduce transmission lost according to MC calculations with bounds (apertures)

- Angular acceptances in A1900 segmented configurations should revised

- Real experimental fields should be used in extended configurations, and the following simulations should be compared with experimental results

- Momentum correction resolution @ S800BL I-PPACs should be obtained using experimental data with/without optical reconstruction

……. Will be updated