AMADEUS

User's Manual

Purpose of the programme

AMADEUS (**a** **mag**net and **deg**rader **u**tility for **s**caling) is designed for performing quick calculations related to the deflection of high-energetic heavy ions in magnetic spectrometers, to the slowing down and to nuclear reactions in layers of matter, and to relativistic kinematical transformations.

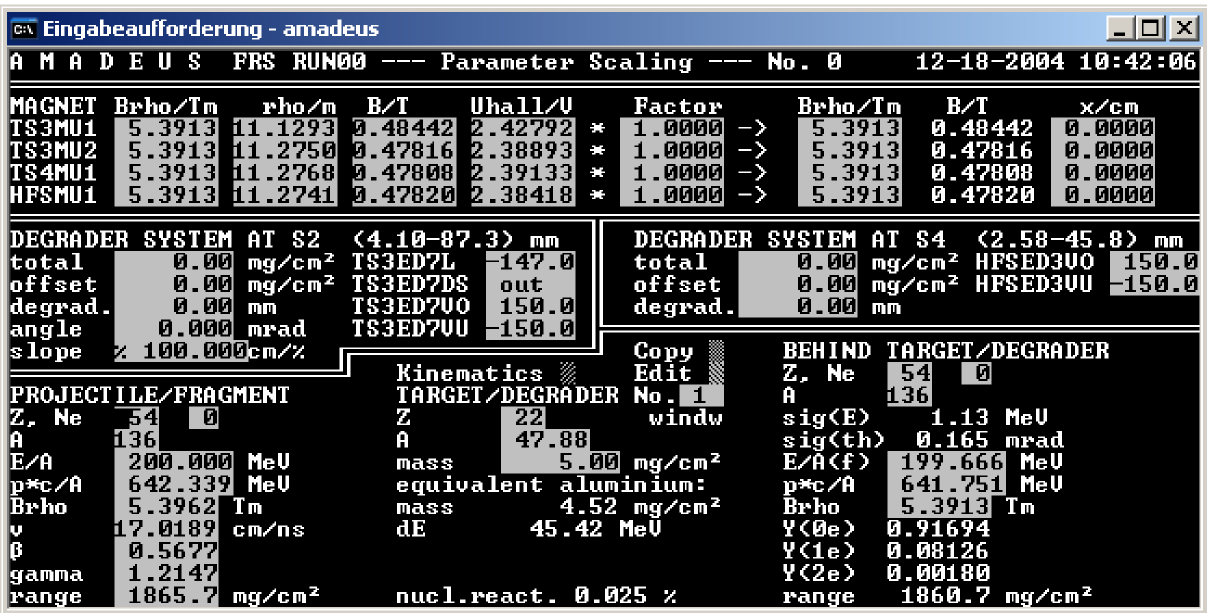
Validity range

The validity of the models used for the calculations is tested in the energy range between 50 A MeV and 1.5 A GeV. The agreement of calculated energy-loss and range values with measured data is in the order of 1%. This means that AMADEUS reproduces the measured data in this energy range with about the same accuracy as the ATIMA programme. The same is true for the calculation of charge-state distributions (Th. Brohm, PhD thesis) in comparison with the CHARGE programme. AMADEUS is limited to three charge states. This is sufficient for most applications at the fragment separator of GSI.

Starting the programme

The programme runs on WINDOWS. The necessary files can be downloaded from the following WEB page: http://www-w2k.gsi.de/charms/software.htm.

When AMADEUS is started, the following DOS window will appear:



Input and output

The fields with inverted colours are accessible for input. Those numbers, which will be re-calculated, are immediately erased. In this way it is transparent in which ‘direction’ the calculation takes place and furthermore the numbers which appear on the screen never contradict each other.

Chemical elements can be entered by the nuclear-charge number or by the element symbol.

The mouse is not supported. The fields can be chosen by the keyboard. The TABS key jumps to the next number field.

A new calculation is initiated by the ENTER key.

The INSERT key may be used to transfer numbers from one field to another. Pressing the INSERT key the first time copies the actual number into the internal memory, pressing the INSERT key the second time drops this number into the corresponding field.

By pressing the ENTER key when the cursor is on the COPY button of the menu, a copy of the actual panel is produced in the file FRSTOOLS\AMADEUS\AMADEUS.TXT.

Substructure

The programme consists of several independent routines, represented by four separate panels, which are divided by double lines.

Scaling of magnets

The upper panel allows for scaling of the dipole magnets of the FRS. The part on the left side of the “Factor” may serve to memorize a reference setting. The values of Brho and Uhall multiplied by the specified factor appear on the right side.

The right-most column serves to centre the beam. If the beam appears with a certain deviation behind the first, second, third or fourth dipole, the measured deviation may be entered into the corresponding field. The appropriate scaling factors, needed for centring the beam appear in the column “Factor”.

Degrader at S2

This routine calculates the settings of the step motors of the degrader unit installed at the intermediate image plane of the FRS, which correspond to a specific thickness and a specific slope. It can also be used to determine thickness and slope of the degrader unit for a given setting of the step motors. The thicknesses are given for an aluminium layer.

The number fields have the following meanings:
mass Σ total thickness of all layers at S2 in mg/cm^2

offset thickness of layers at the intermediate image plane which are present in addition to the degrader system (e.g. a scintillator plate for the ToF detector)
d thickness of the degrader system in mm
angle slope of the degrader system
slope inverse relative slope of the degrader system given in cm/%
TS3ED7L setting of the step motor TS3ED7L (ladder of plates with different thicknesses)
TS3ED7DS setting of the step motor TS3ED7DS (angle of wedge-shaped disks)
TS3ED7VO setting of the step motor TS3ED7VO (position of upper wedge)
TS3ED7VU setting of the step motor TS3ED7VU (position of lower wedge)

If the desired setting is not possible, the programme answers with "none".

Degrader at S4

This routine calculates the settings of the step motors of the degrader unit installed behind the FRS, which correspond to a specific thickness. It can also be used to determine the thickness of the degrader unit for a given setting of the step motors. The thicknesses are given for an aluminium layer.

The number fields have the following meanings:
mass Σ total thickness of all layers at S4 in mg/cm^2
offset thickness of layers at the final image plane which are present in addition to the degrader system (e.g. vacuum window of the FRS, sections of air, detectors etc.)
HFSED3VO setting of the step motor HFSED3VO (position of upper wedge)
HFSED3VU setting of the step motor HFSED3VU (position of lower wedge)

If the desired setting is not possible, the programme answers with "none".

Atomic and nuclear interactions of an ion beam with matter

The lower panel allows calculating atomic and nuclear interactions of an ion beam in a layer of matter.

The incoming beam is specified in the *left column* ("PROJECTILE/FRAGMENT")
Z nuclear charge of the ion
Ne number of electrons carried by the ion (0 to 2)
A mass number of the ion
E/A energy per mass unit of the ion
p·c/A momentum times velocity of light per mass unit
Brho magnetic rigidity
v velocity
β v/c
gamma Lorentz parameter (relativistic mass / rest mass)
range range of the ion in the layer given in the central column

The *central column* ("TARGET/DEGRADER") specifies the layer of matter. A list up to 20 layers can be entered after choosing the corresponding layer number of in a specific menu, which is accessible by the "EDIT" option (see below). Specific layers can be 'activated' or ‘de-activated’. The sequence of the layers can be changed by modifying the layer numbers in the EDIT menu. The “LIST” option prints a list of the layers and of the energies and energy-loss values behind the different layers.

The layers are specified by:

No.	number of the layer (1 to 20)
Z	nuclear charge of the layer nuclei (atomic number or element symbol)
A	mass number of the layer nuclei
mass	thickness of the layer in mg/cm^2

The following quantities related to the layer are calculated and listed:

equivalent aluminium	the thickness of a layer of aluminium causing the same energy loss as the specified layer
ΔE	energy loss
achrom.	slope corresponding to an achromatic shape
monochr.	slope corresponding to a monochromatic shape
nucl.react.	fraction of the ions undergoing nuclear reactions [a]

or (if a specific nuclear-reaction channel is chosen in the right column):

conversion rate per proj.	number of produced fragments per projectile
sigma	production cross section of the specified fragment

The *right column* lists the properties of the ions behind the layer. It may be chosen identical or different in nuclear composition to the incoming beam.

The following quantities specify the ions behind the layer:

Z	nuclear charge of the layer nuclei (atomic number or element symbol)
A	mass number of the ion
E/A	energy per mass unit of the ion
p·c/A	momentum times velocity of light per mass unit
Brho	magnetic rigidity

The following properties of the ion beam behind the layer are calculated:

sig(E)	energy straggling in the layer
sig(th)	angular straggling in the layer
Y(0e)	fraction of fully stripped ions [b]
Y(1e)	fraction of ions with one electron [b]
Y(2e)	fraction of ions with two electrons [b]
range	residual range of the ion after the layer

[a] Based on the estimation of the total nuclear interaction cross section in C. J. Benesh, B. C. Cook, J. P. Vary, Phys. Rev. C 40 (1989) 1198

[b] Based on the three-stage model derived by Th. Brohm, PhD thesis, TH Darmstadt, 1994

The EDIT menu

```
Eingabeaufforderung - amadeus
A M A D E U S   FRS RUN00 --- Parameter Scaling --- No. 1      12-18-2004 14:30:16

  List of layers (press 'ENTER' to continue)     Help ?     Load from dataset «
  (↓'D'elete, 'I'nsert, 'R'epeat supported)                 Write to dataset  »
  No. Z      mg/cm²  in(1)/out(0) comment       g/cm²          mm
   1 22        5.00       1          windw   4.520000       0.011
   2 22       10.00       1          SEETR   4.520000       0.022
   3 22       18.00       1          windw   4.520000       0.040
   4  1      100.00       1          H2trg   0.000084   11940.298
   5 22       18.00       1          windw   4.520000       0.040
   6 22       36.00       1          strip   4.520000       0.080
   7 13      721.30       0          SC21    2.698000       2.673
   8 13       60.00       1          PPAC    2.698000       0.222
   9 22       46.00       1          Strip   4.520000       0.102
  10 13      165.00       1          MW41    2.698000       0.612
  11 22       90.20       1          windw   4.520000       0.200
  12  7       50.00       1          air     0.001165     429.185
  13 22       23.00       1          strip   4.520000       0.051
  14 18      100.00       1          MUS1    0.001662     601.685
  15 22       23.00       1          strio   4.520000       0.051
  16 18      100.00       1          MUS2    0.001662     601.685
  17 13      565.00       1          SC3m*   2.698000       2.094
  18 22       23.00       1          strip   4.520000       0.051
  19 18      180.00       0          MUS3    0.001662    1083.032
  20 13       23.00       0          strip   2.698000       0.085
```

The EDIT menu is selected by the EDIT button of the main menu. It allows entering the properties of up to 20 layers (sequence, chemical nature, thickness, comment). Each layer can be inserted or taken out of the beam. The sequence of layers can be changed by modifying the layer numbers. If the specific weight of the material is known to the programme, the thickness may be specified also in mm. For gases, AMADEUS assumes “normal” conditions (1 atmosphere and 20^{0}C). (In the above example the length of the liquid H_2 target is listed wrongly, because the density of gaseous hydrogen is assumed.)

The HELP button gives access to additional information on composite material.

When the ENTER key is pressed, AMADEUS proceeds to the LIST option.

The LIST option

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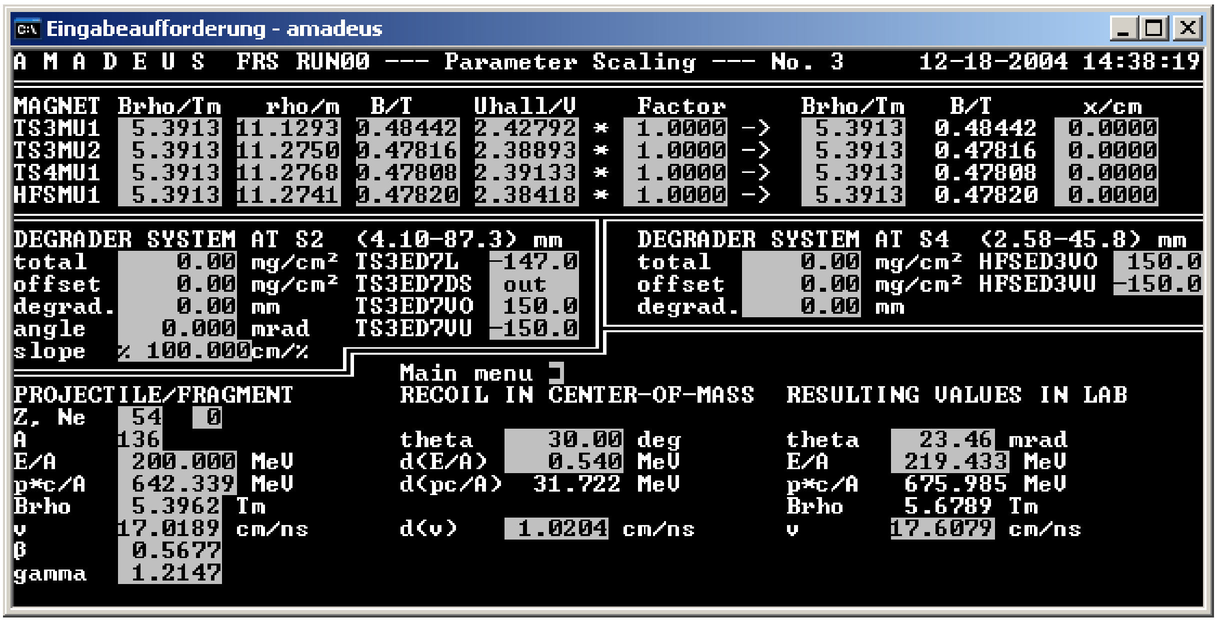
Eingabeaufforderung - amadeus
A M A D E U S   FRS RUN00 --- Parameter Scaling --- No. 1      12-18-2004 14:34:30

Values for the projectile: Z= 54 , A= 136 (Ranges correspond to layers!)

No. com.   Z   A  d/(mg/cm²)   DE/MeV  (E/A)/MeV  r/(mg/cm²)    r(Al)   v/(cm/ns)
 0                                        200.00              1687.93   17.01887
 1 windw  22  48       5.00      45.4     199.67    1860.68   1683.41   17.00830
 2 SEETR  22  48      10.00      90.9     199.00    1850.68   1674.36   16.98709
 3 windw  22  48      18.00     164.1     197.79    1832.68   1658.08   16.94864
 4 H2trg   1   1     100.00    2466.3     179.66     591.75   1419.62   16.34422
 5 windw  22  48      18.00     173.1     178.38    1551.11   1403.34   16.29981
 6 strip  22  48      36.00     348.3     175.82    1515.11   1370.77   16.20963
 8 PPAC   13  27      60.00     648.8     171.05    1310.77   1310.77   16.03859
 9 Strip  22  48      46.00     455.8     167.70    1402.79   1269.15   15.91598
10 MW41   13  27     165.00    1858.5     154.03    1104.15   1104.15   15.39368
11 windw  22  48      90.20     953.5     147.02    1130.22   1022.54   15.11072
12 air     7  14      50.00     684.5     141.99     840.59    965.28   14.90075
13 strip  22  48      23.00     252.2     140.14    1043.93    944.47   14.82190
14 MUS1   18  40     100.00    1119.0     131.91     944.33    854.03   14.46166
15 strio  22  48      23.00     263.2     129.97     920.97    833.23   14.37439
16 MUS2   18  40     100.00    1171.6     121.36     821.32    742.79   13.97320
17 SC3m*  13  27     565.00    9241.8      53.40     177.79    177.79    9.73775
18 strip  22  48      23.00     483.1      49.85     173.51    156.98    9.43361
```

The LIST option of AMADEUS gives a list of the layers, of the energy-loss values of the beam in these layers and of the energies behind the layers.

The KINEMATICS panel



The KINEMATICS panel is selected by the KINEMATICS button of the main menu. It allows calculating Lorentz transformations.

The left column specifies the properties of the ion in the laboratory frame before transformation.

The central column specifies the parameters of the transformation, formulated in the frame of the ion.

The right column lists the properties of the ion after transformation.

In the example given in the panel above, a ^{136}Xe ion moves initially in the laboratory frame with an energy of 200 A MeV. In the frame of this projectile, a reaction product (e.g. an evaporated neutron) is emitted with a velocity of 1.0204 cm/ns at an angle of 30 degrees with respect to the beam direction. The neutron is observed in the laboratory frame under an angle of 23.46 mrad with a longitudinal energy of 219.433 A MeV. Since the mass of the neutron is one mass unit, the longitudinal energy of the neutron is 219.433 MeV.

APPENDIX

The subroutines and data used in AMADEUS have been provided by

Th. Brohm: ionic charge-state distributions
H. Geissel: energy loss, energy-loss straggling, ion-optical parameters of the FRS
E. Hanelt: analytical approximation of the range relations
K. Sümmerer: fragmentation cross sections

H. Weckenmann and H. Folger: dimensions of the degrader systems

Additional information on the routines used in AMADEUS may be found in the following references:

"PROJECTILE FRAGMENTS ISOTOPIC SEPARATION: APPLICATION TO THE LISE SPECTROMETER AT GANIL".
J.-P. Dufour, R. Del Moral, H. Emmermann, F. Huber, D. Jean, C. Poinot, M. S. Pravikoff, A. Fleury, H. Delagrange, K.-H. Schmidt
Nucl. Instr. Methods A248 (1986) 267

„THE MOMENTUM-LOSS ACHROMAT – A NEW METHOD FOR THE ISOTOPICAL SEPARATION OF RELATIVISTIC HEAVY IONS"
K.-H. Schmidt, E. Hanelt, H. Geissel, G. Münzenberg, J.-P. Dufour,
Nucl. Instr. Meth. A 260 (1987) 287

„IONS PENETRATING THROUGH ION-OPTICAL SYSTEMS AND MATTER - NON-LIOUVILLIAN PHASE-SPACE MODELLING"
H. Geissel, T. Schwab, P. Armbruster, J.-P. Dufour, E. Hanelt, K.-H. Schmidt, B. Sherrill, G. Münzenberg,
Nucl. Instr. Meth. A 282 (1989) 247

„TARGET FRAGMENTATION OF Au AND Th BY 2.6 GeV PROTONS"
K. Sümmerer, W. Brüchle, D. J. Morrissey, M. Schädel, B. Szweryn, Y. Weifan,
Phys. Rev. C 42 (1990) 2546

J. Weckenmann, E. Hanelt, K.-H. Schmidt,
Report GSI-90-13, 1990, GSI Darmstadt

„TARGETS AND DEGRADERS FOR RELATIVISTIC HEAVY IONS AT GSI"
H. Folger, H. Geissel, W. Hartmann, J. Klemm, G. Münzenberg, D. Schardt, K.-H. Schmidt, W. Thalheimer,
Nucl. Instr. Meth. A 303 (1991) 24

„UNTERSUCHUNG ZUR PROJEKTILFRAGMENTATION RADIOAKTIVER SEKUNDÄRSTRAHLEN"
Th. Brohm
PhD thesis, TH Darmstadt, 1994

"THE GSI PROJECTILE FRAGMENT SEPARATOR (FRS) - A VERSATILE MAGNETIC SYSTEM FOR RELATIVISTIC HEAVY IONS"
H. Geissel, P. Armbruster, K.-H. Behr, A. Brünle, D. Burkhard, M. Chen, H. Folger, B. Franczak, H. Keller, O. Klepper, B. Langenbeck, F. Nickel, E. Pfeng, M. Pfützner, E. Roeckl, K. Rykaczewski, I. Schall, D. Schardt, C. Scheidenberger, K.-H. Schmidt, A. Schröter, T. Schwab, K. Sümmerer, M. Ziegler, A. Magel, H. Wollnik, J.-P. Dufour, Y. Fujita, D. J. Vieira, B. Sherril
Nucl. Instr. Meth. B 70 (1992) 286

„A METHOD FOR CALCULATING PHASE-SPACE DENSITIES IN ION-OPTICAL SYSTEMS"
E. Hanelt, K.-H. Schmidt
Nucl. Instr. Meth. A 321 (1992) 434

"MODIFIED EMPIRICAL PRAMETERIZATION OF FRAGMENTATION CROSS SECTIONS"
K. Sümmerer, B. Blank
Phys. Rev. C 61 (2000) 034607

"A FAST ALGORITHM FOR PRECISE ENERGY-LOSS CALCULATIONS OF HIGH-ENERGETIC HEAVY IONS"
J. Benlliure, E. Casarejos, D. Cortina-Gil, E. Hanelt, M. F. Ordonez, K.-H. Schmidt
http://www-w2k.gsi.de/charms/Preprints/EnergyLoss/paper.pdf