Your First Input and beyond

FLUKA Beginner's Course

Before starting: FLUKA Manual

in *continuous* development (as the program)!

More a User Guide than a Reference Manual

(only a short summary about physics)

FM.pdf

update of the published CERN yellow report

ToC, cross-references, and citations are active links

analytical index at the end

ASCII

fluka2011.manual (no figures)

Tk interface accessible through FLAIR or

from command line **`/usr/local/bin/fm`**

(HTML version is available on FLUKA website)

Before starting: FLUKA Manual

Short description of FLUKA

program and its capabilities, implemented physics models, installation...

User guide

- detailed description of input options
- available particles and materials
- combinatorial geometry
- low-energy neutrons library
- how to write/compile/link user routines
- ....and much more!

REMEMBER!

The first place to look at when puzzled!

...and the very best friend of a beginner user!

FLUKA and FLAIR

FLUKA users can....

- prepare their own input with a text editor
- use their own tools for plotting results
- submit jobs by command line

FLAIR (Fluka Advanced InteRface) can be used as well

- It helps the users with the aforementioned tasks (see FLAIR lecture)

You can choose your favorite way...

...but a good user should be able to go both ways!

Structure of the input file

General definitions

Beam definition
Materials: definition and assignment
Random number initialization
Start/Stop of simulation

This lecture

Physics settings

Defaults
Physical processes
Transport thresholds
Low energy neutrons
Induced radioactivity

This lecture and many others

Geometry

Geometry lecture

Output settings

Estimators / scoring cards

Scoring lecture

FLUKA input file commands

Commands aka cards, aka options, aka directives, aka definitions

One keyword (command), 6 floating point numbers (WHATs), one string (SDUM)

Example of a FLUKA command (text editor style)

```
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+...
BEAM          1.E+04        0.0         0.0         0.0         0.0        0.0PROTON
*keyword    momentum mom.spread  diverg.    X-width    Y-width  ignored particle
*             WHAT(1)    WHAT(2)    WHAT(3)    WHAT(4)    WHAT(5)    WHAT(6)  SDUM
```

- Command keywords MUST be uppercase, numbers MUST have the decimal point
- Some commands require more than one “card“
- Some special commands (like **TITLE** and **OPEN**) are/may be followed by a text line
- With few exceptions, the order of commands is irrelevant
- Most commands can be repeated several times
- Repeated command can add themselves or override previous commands
- A line with a * character in column 1 is a comment
- Text after an exclamation mark (!) is ignored (does not work within the geometry)
- Almost all the WHAT() have a default value
- Commands can be issued in fixed or free format

Fixed vs free format [1/2]

Fixed format:

```
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+...
BEAM           1.E+04   0.0D+00        0.0        0.0        0.0        0.0PROTON
*keyword    momentum mom.spread  diverg.   X-width   Y-width  ignored particle
*             WHAT(1)   WHAT(2)   WHAT(3)   WHAT(4)   WHAT(5)   WHAT(6)  SDUM
```

- The “traditional“ FLUKA format is (A8, 2X, 6E10.0, A8)

  Numbers: 9 digits at most can be used!
- All WHAT fields are in floating point format, *even integers*

  They must always be written with the decimal point
- Exponential notation numbers (e.g. 1.234E+5), must be right aligned
- Double precision format (e.g. 1.234D+5) is allowed
- Blank numerical fields are read as 0.0

  In most cases (*not all!*) such values are ignored and the corresponding default values are used
- Blank lines NOT ALLOWED in geometry declaration (tolerated elsewhere)
- FLAIR takes care of all the alignment problems for you

Fixed vs free format [2/2]

Free format:

- Free format can be made *locally* available issuing option FREE (without any parameter), until the option FIXED restores the fixed format; the opposite can be done either
- Option GLOBAL provides free format also for the geometry input
- In free format input, the different fields are separated by blanks and/or separators (usually commas). *All fields must be present* or at least represented by two successive separators
- Character fields (command name, SDUM) must be input without quotes

```
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+...
BEAM , 1.234567890E+04 , 0.0 , 0.0 , 0.0 , 0.0 , 0.0 , PROTON
*
*keyword    momentum mom.spread  diverg.   X-width   Y-width   weight particle
*            WHAT(1)   WHAT(2)   WHAT(3)   WHAT(4)   WHAT(5)   WHAT(6)  SDUM
```

Temporarily switching to FREE format is particularly helpful when more than 10 digits are required for precision reasons !!!

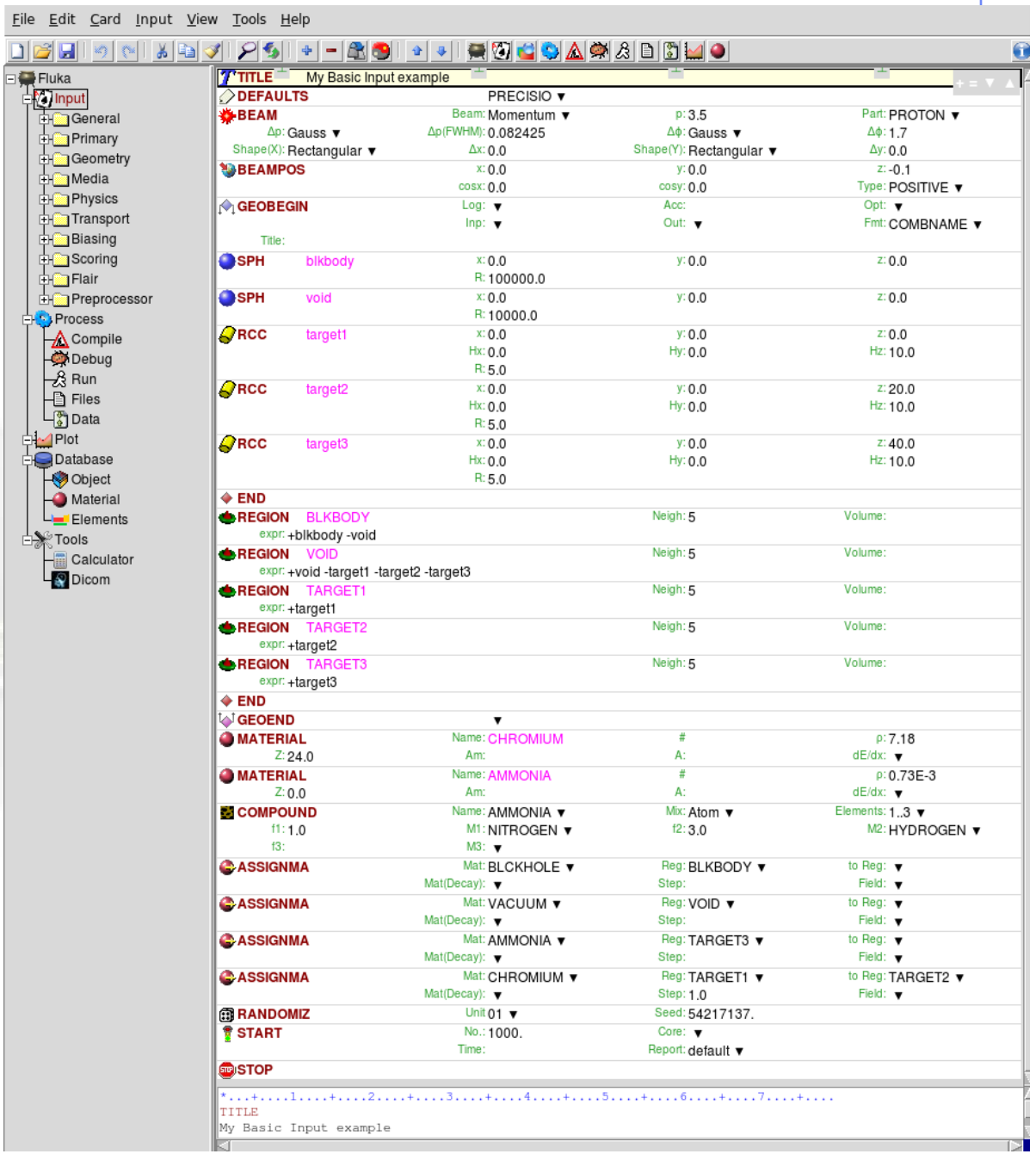
Names instead of numbers

- FLUKA also allows to use keywords (names) - 8 characters maximum length - instead of numbers inside FLUKA commands
- Examples later (for instance materials, or geometrical region, can be inserted using their name instead of numbers)
- This *helps* the user, improving the *readability* of the input FLUKA file, and is again managed by the FLAIR graphical interface

A basic input

```
TITLE
My Basic Input example
* Set the defaults for precision simulations
DEFAULTS                                                              PRECISIO
* Define the beam characteristics
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAM             3.5 -0.082425      -1.7       0.0       0.0          PROTON
* Define the beam position
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAMPOS          0.0       0.0      -0.1       0.0       0.0
*
GEOBEGIN                                                              COMBNAME
    0    0
* Black body
SPH blkbody    0.0 0.0 0.0 100000.0
* Void sphere
SPH void       0.0 0.0 0.0 10000.0
* Cylindrical target
RCC target1    0.0 0.0  0.0 0.0 0.0 10.0 5.0
RCC target2    0.0 0.0 20.0 0.0 0.0 10.0 5.0
RCC target3    0.0 0.0 40.0 0.0 0.0 10.0 5.0
END
* Black hole
BLKBODY      5 +blkbody -void
* Void around
VOID         5 +void -target1 -target2 -target3
* Target
TARGET1      5 +target1
TARGET2      5 +target2
TARGET3      5 +target3
END
GEOEND
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
MATERIAL        24.0               7.18                               CHROMIUM
MATERIAL         0.0            0.73E-3                               AMMONIA
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
COMPOUND         1.0  NITROGEN       3.0  HYDROGEN                    AMMONIA
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
ASSIGNMA    BLCKHOLE   BLKBODY
ASSIGNMA      VACUUM      VOID
ASSIGNMA     AMMONIA   TARGET3
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..*
ASSIGNMA    CHROMIUM   TARGET1   TARGET2       1.0

* Set the random number seed
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
RANDOMIZ         1.0 54217137.
*
* Set the number of primary histories to be simulated in the run
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
START          1000.
STOP
```

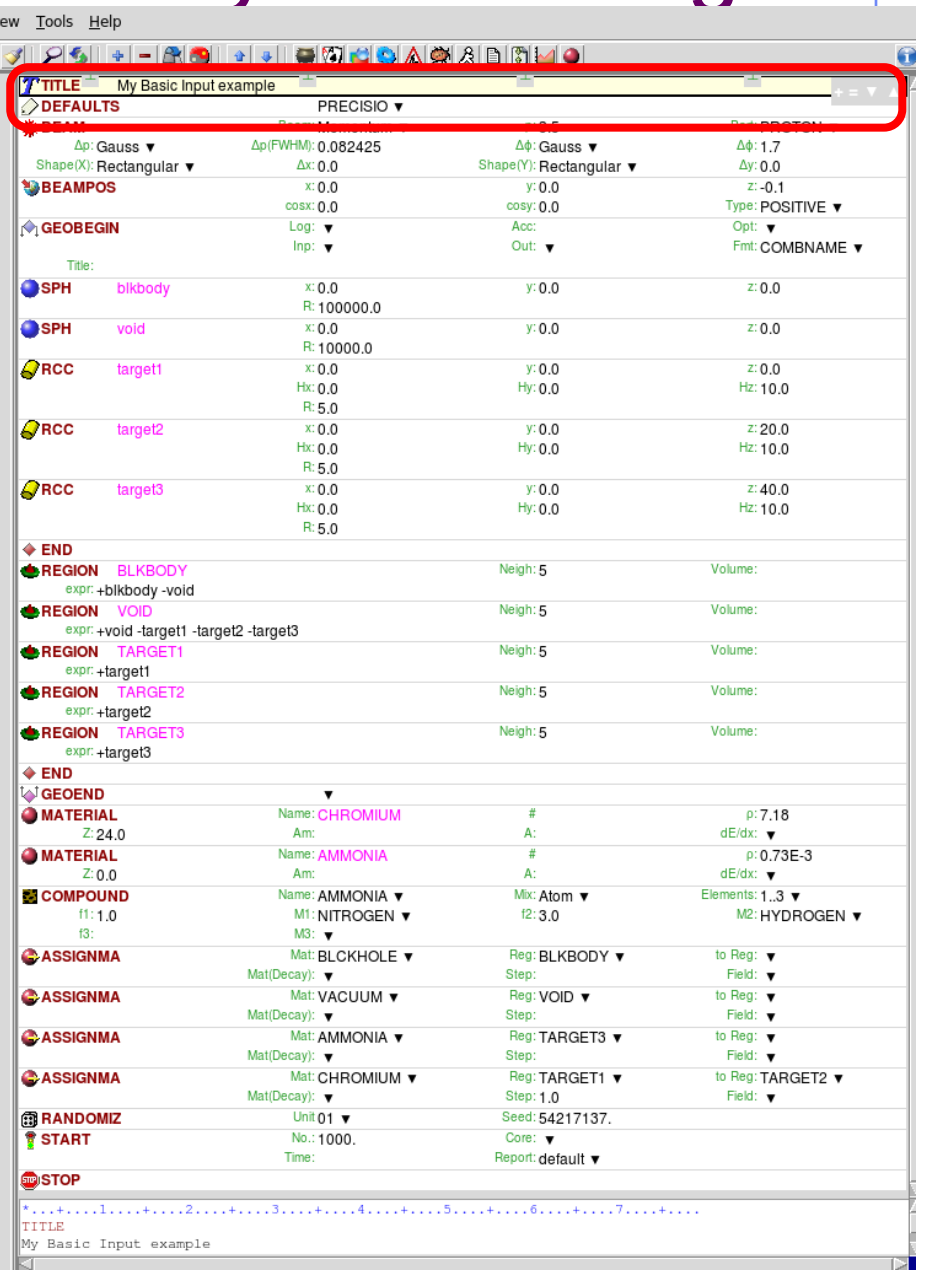
A basic input



A basic input card by card

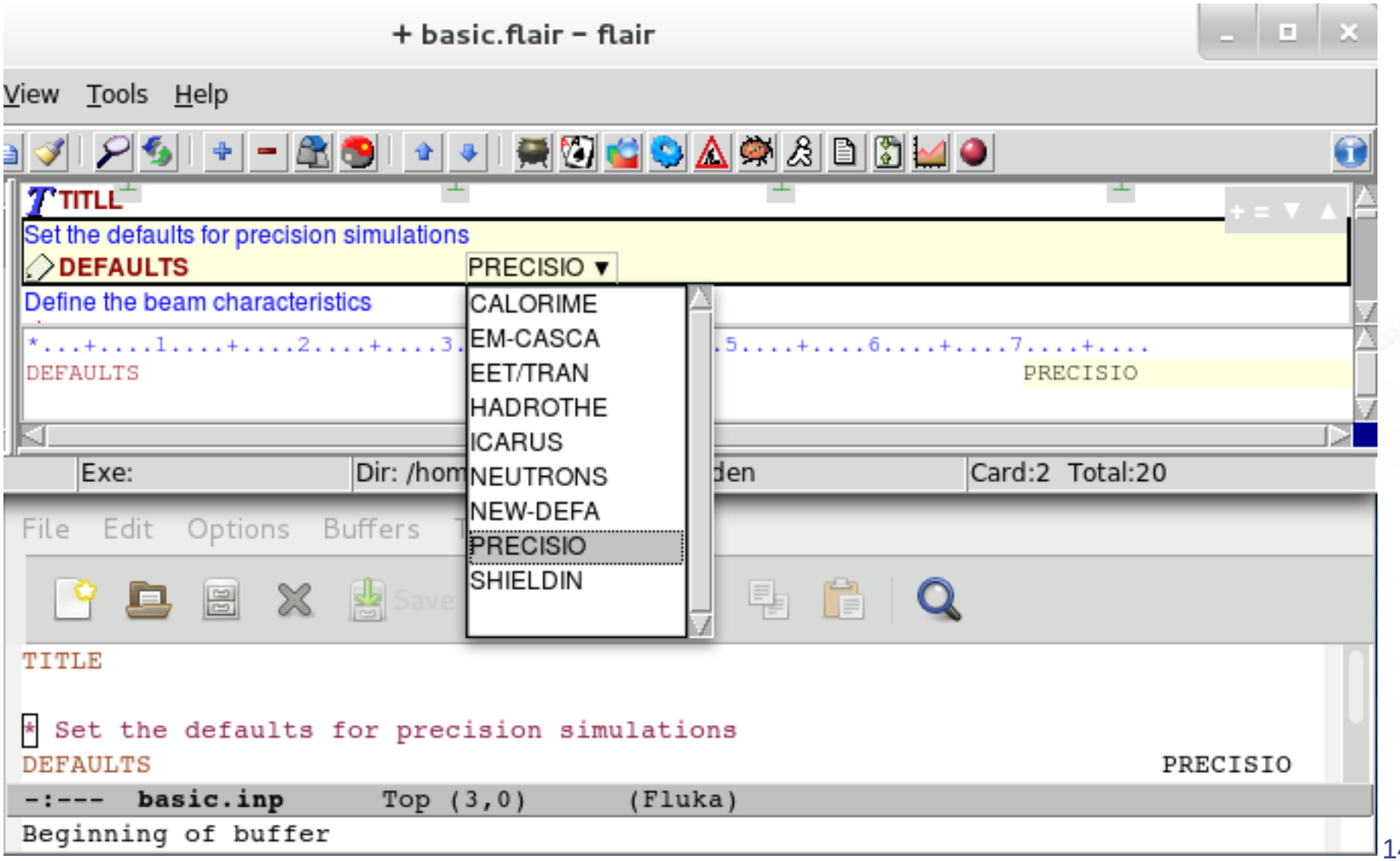
A basic input: step 1: Physics settings

```
TITLE
My Basic Input example
* Set the defaults for precision simulations
DEFAULTS                                                          PRECISIO
* Define the beam characteristics
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAM             3.5 -0.082425       -1.7        0.0        0.0          PROTON
* Define the beam position
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAMPOS          0.0         0.0       -0.1        0.0        0.0
*
GEOBEGIN                                                          COMBNAME
    0    0
* Black body
SPH blkbody    0.0 0.0 0.0 100000.0
* Void sphere
SPH void       0.0 0.0 0.0 10000.0
* Cylindrical target
RCC target1    0.0 0.0  0.0 0.0 0.0 10.0 5.0
RCC target2    0.0 0.0 20.0 0.0 0.0 10.0 5.0
RCC target3    0.0 0.0 40.0 0.0 0.0 10.0 5.0
END
* Black hole
BLKBODY      5 +blkbody -void
* Void around
VOID         5 +void -target1 -target2 -target3
* Target
TARGET1      5 +target1
TARGET2      5 +target2
TARGET3      5 +target3
END
GEOEND
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
MATERIAL         24.0                7.18                          CHROMIUM
MATERIAL          0.0             0.73E-3                          AMMONIA
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
COMPOUND          1.0  NITROGEN       3.0  HYDROGEN                 AMMONIA
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
ASSIGNMA    BLCKHOLE    BLKBODY
ASSIGNMA      VACUUM      VOID
ASSIGNMA     AMMONIA    TARGET3
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..*
ASSIGNMA    CHROMIUM    TARGET1    TARGET2       1.0

* Set the random number seed
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
RANDOMIZ         1.0 54217137.
*
* Set the number of primary histories to be simulated in the run
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
START          1000.
STOP
```



Physics settings: **DEFAULTS**

Select predefined physics settings (e.g. transport thresholds)



Physics settings: **DEFAULTS**

Select predefined physics settings (e.g. transport thresholds)

- **CALORIME** : calorimeter simulations
- **EM-CASCA** : pure EM cascades
- **EET/TRAN** : Energy Transformer or transmutation calculations
- **HADROTHE** : hadrotherapy calculations
- **ICARUS** : studies related to the ICARUS experiment
- **NEW-DEFA** : minimal set of generic defaults (default of **DEFAULTS**)
- **PRECISIO** : precision simulations (**recommended**)

avoid NEUTRONS and SHIELDIN

Physics settings: **DEFAULTS: PRECISIO**

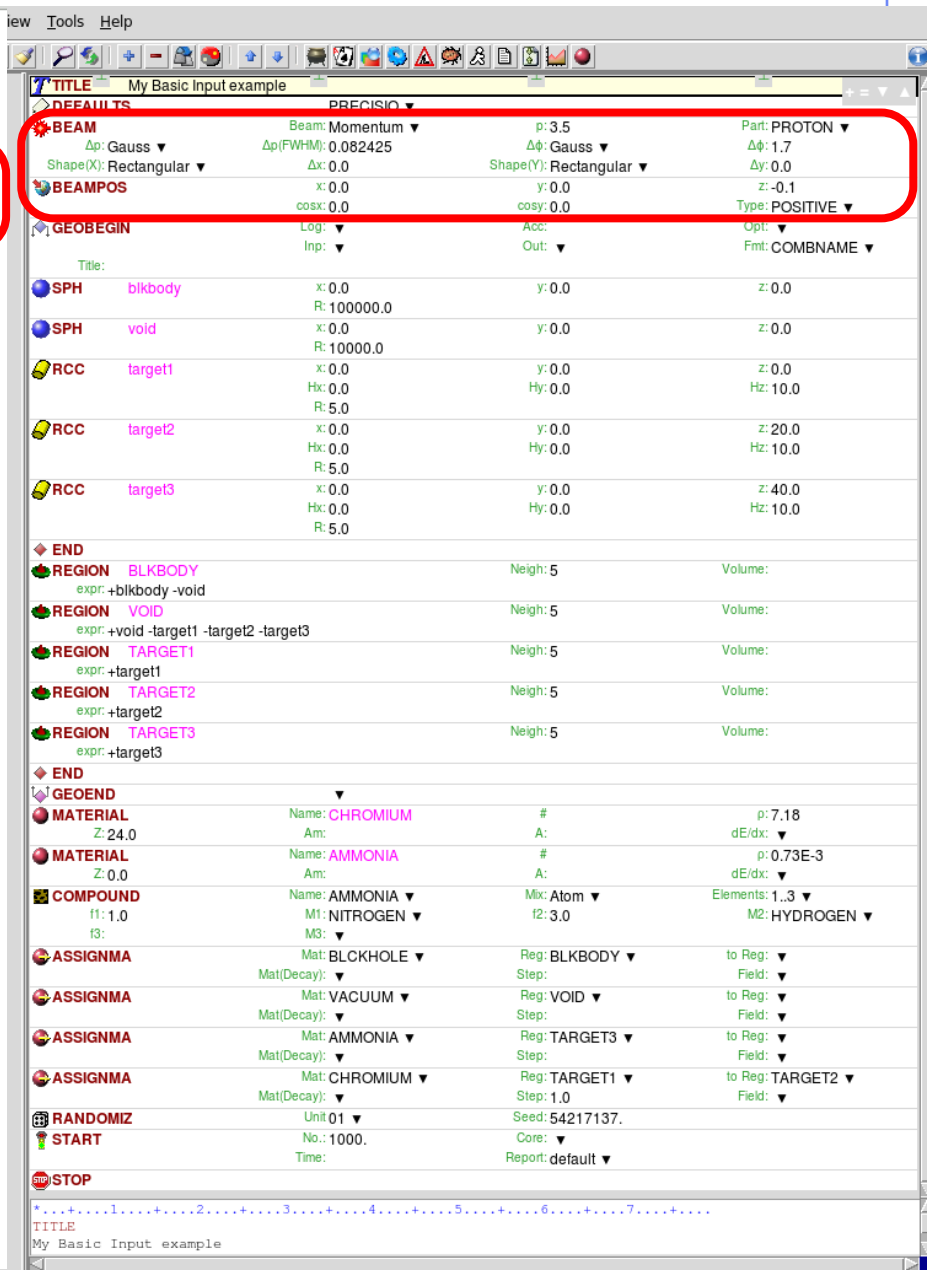
- EM transport on (**EMF** on), threshold set by **EMFCUT** (default: *100keV* for e^-/e^+ and *33keV* for γ)
- Inelastic form factor correction to Compton scattering on (**EMFRAY** on)
- Detailed photoelectric edge treatment and fluorescence photons activated
- Low energy neutron transport on (**LOW-NEUT** on), threshold 20 MeV, with fully analogue absorption
- All transport threshold = 100keV, but neutrons (10^{-5} eV) and neutrinos (0, but they are discarded)
- Multiple Scattering threshold at minimum allowed energy, for both primary and secondary charged particles
- Delta rays production on, threshold 100keV (**DELTARAY**)
- Restricted ionization energy loss fluctuations for all particles (**IONFLUCT**)
- Tabulation ratio for hadron/muon dp/dx set at 1.04, fraction of the kinetic energy to be lost in a step set at 0.05, number of dp/dx tabulation points set at 80 (**DELTARAY, EMFFIX, FLUKAFIX**)
- e+e- pair production and bremsstrahlung by heavy particles on (**PAIRBREM**)

  Pair threshold =2 m_e , bremsstrahlung threshold = 300keV
- Muon photonuclear interactions on (**MUPHOTON**)

```
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+
DEFAULTS                                                        PRECISIO
```

A basic input: step 2: Beam

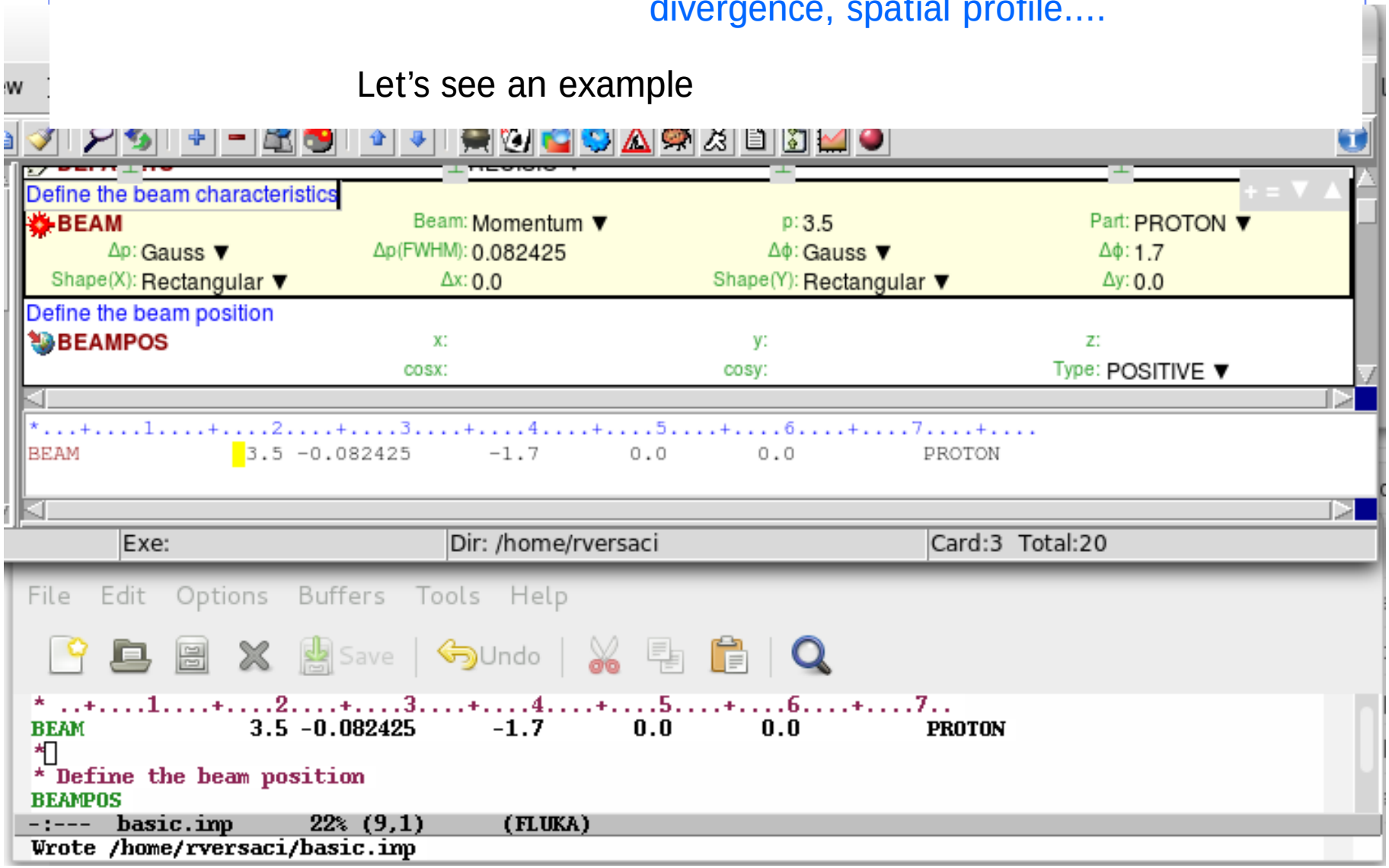
```
TITLE
My Basic Input example
* Set the defaults for precision simulations
DEFAULTS                                                          PRECISIO
* Define the beam characteristics
*    +....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAM             3.5 -0.082425       -1.7        0.0        0.0          PROTON
* Define the beam position
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAMPOS          0.0         0.0       -0.1        0.0        0.0
*
GEOBEGIN                                                          COMBNAME
    0    0
* Black body
SPH blkbody    0.0 0.0 0.0 100000.0
* Void sphere
SPH void       0.0 0.0 0.0 10000.0
* Cylindrical target
RCC target1    0.0 0.0  0.0 0.0 0.0 10.0 5.0
RCC target2    0.0 0.0 20.0 0.0 0.0 10.0 5.0
RCC target3    0.0 0.0 40.0 0.0 0.0 10.0 5.0
END
* Black hole
BLKBODY      5 +blkbody -void
* Void around
VOID         5 +void -target1 -target2 -target3
* Target
TARGET1      5 +target1
TARGET2      5 +target2
TARGET3      5 +target3
END
GEOEND
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
MATERIAL         24.0                7.18                          CHROMIUM
MATERIAL          0.0             0.73E-3                          AMMONIA
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
COMPOUND          1.0  NITROGEN       3.0  HYDROGEN                 AMMONIA
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
ASSIGNMA    BLCKHOLE    BLKBODY
ASSIGNMA      VACUUM      VOID
ASSIGNMA     AMMONIA    TARGET3
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..*
ASSIGNMA    CHROMIUM    TARGET1    TARGET2        1.0

* Set the random number seed
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
RANDOMIZ         1.0 54217137.
*
* Set the number of primary histories to be simulated in the run
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
START          1000.
STOP
```



Beam definition: **BEAM**

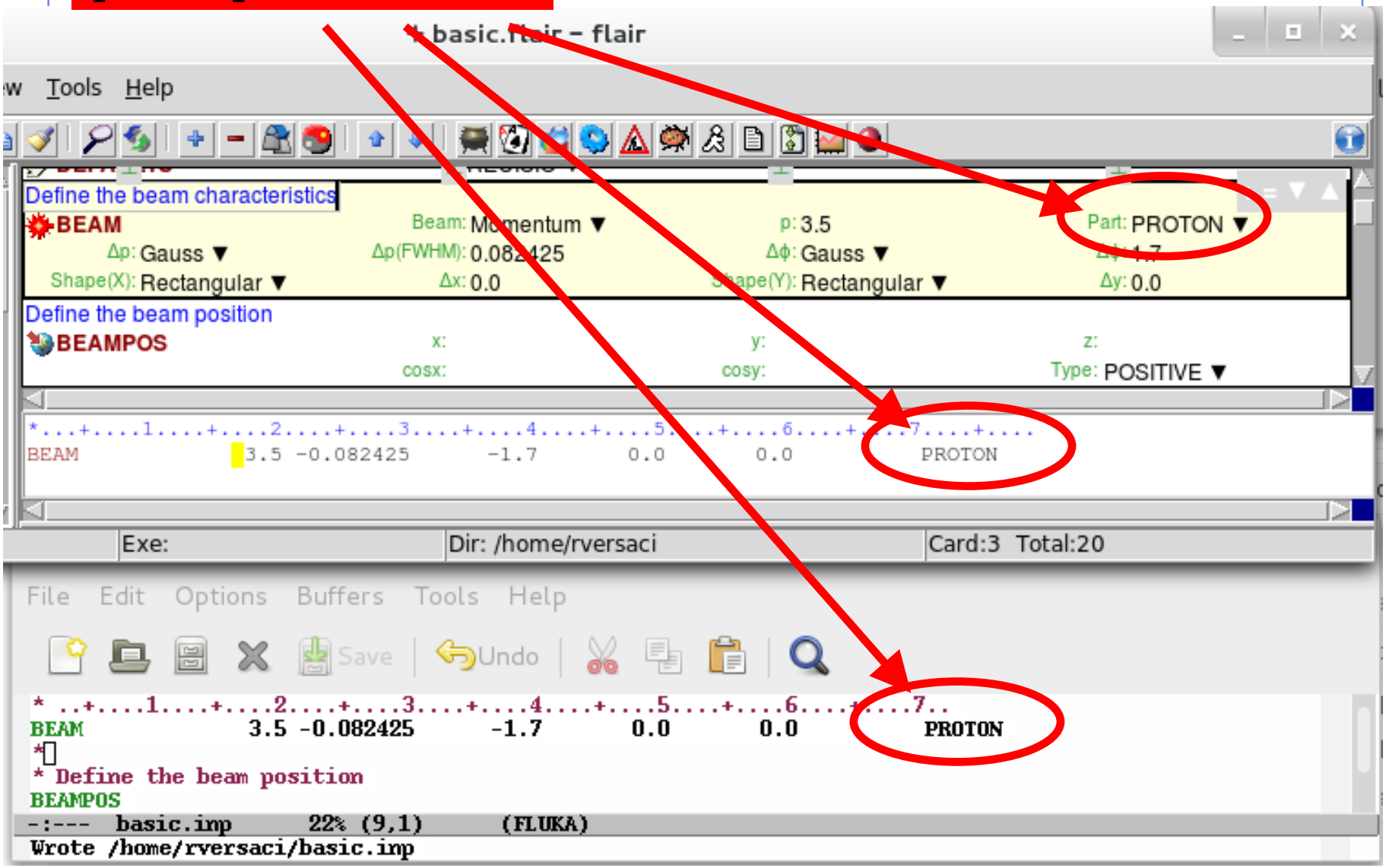
Defines beam characteristics: type of particle, energy or momentum, divergence, spatial profile....

Let's see an example



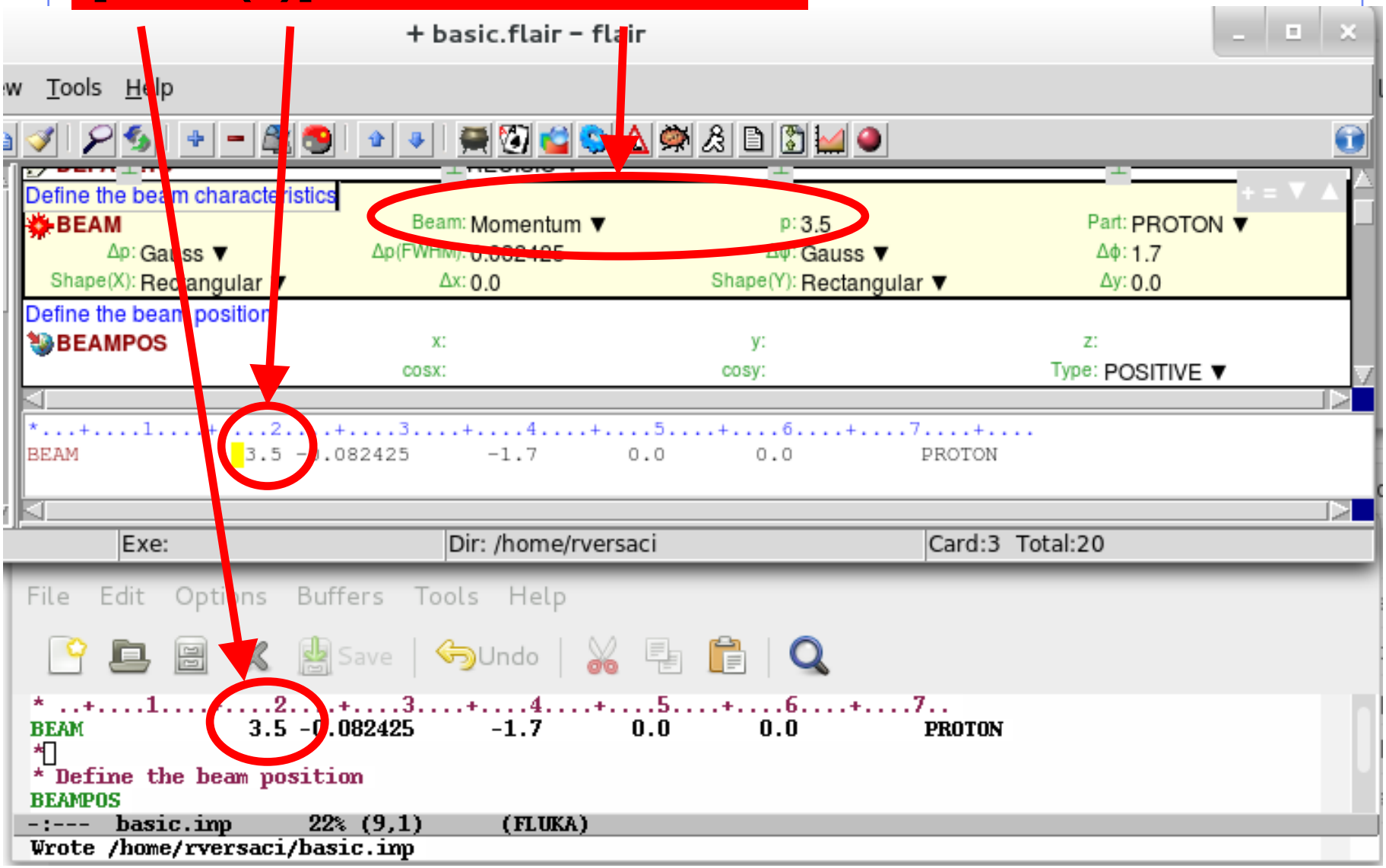
Beam definition: **BEAM**

[SDUM]: Proton beam



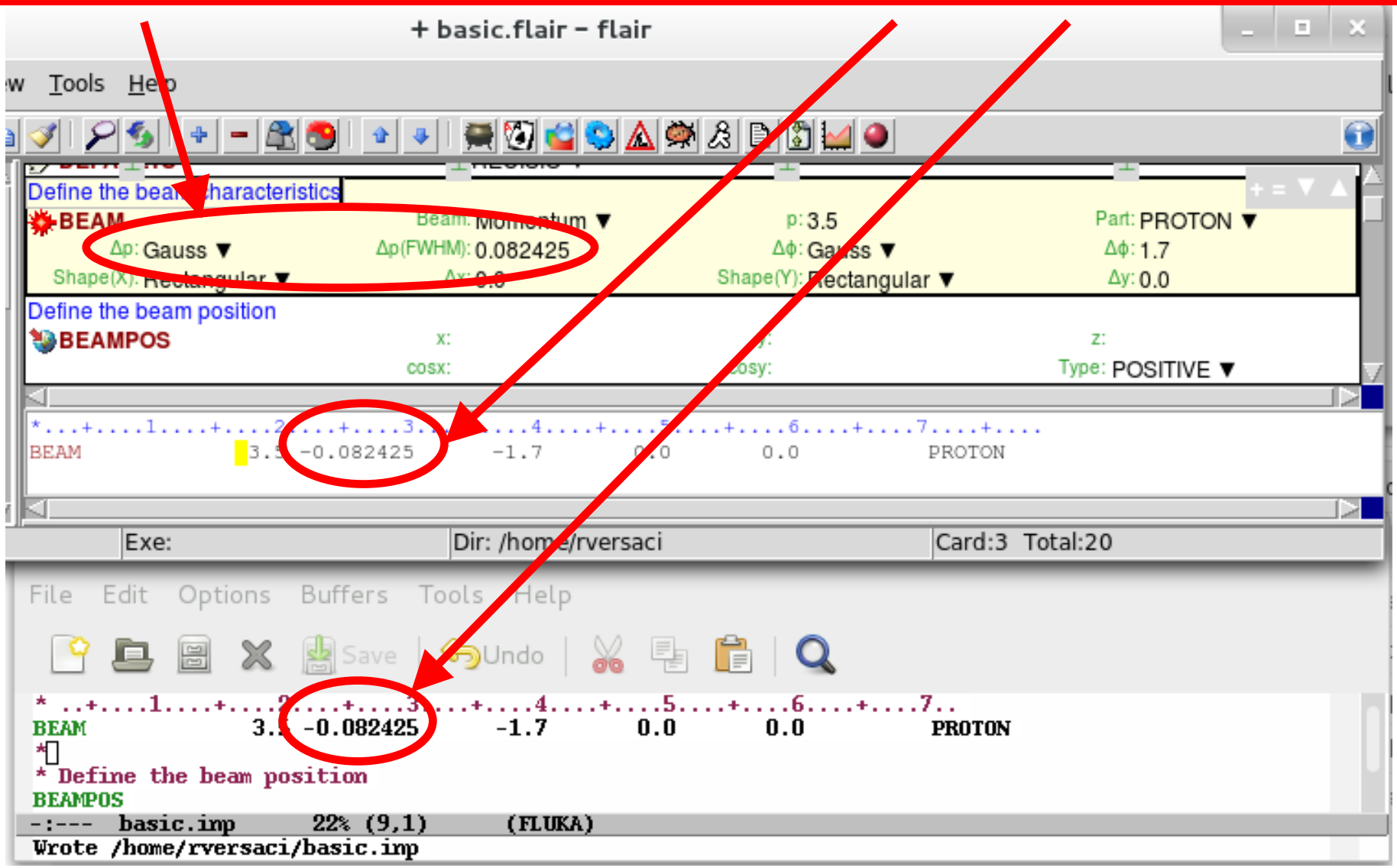
Beam definition: **BEAM**

[WHAT(1)]: 3.5 GeV/c momentum



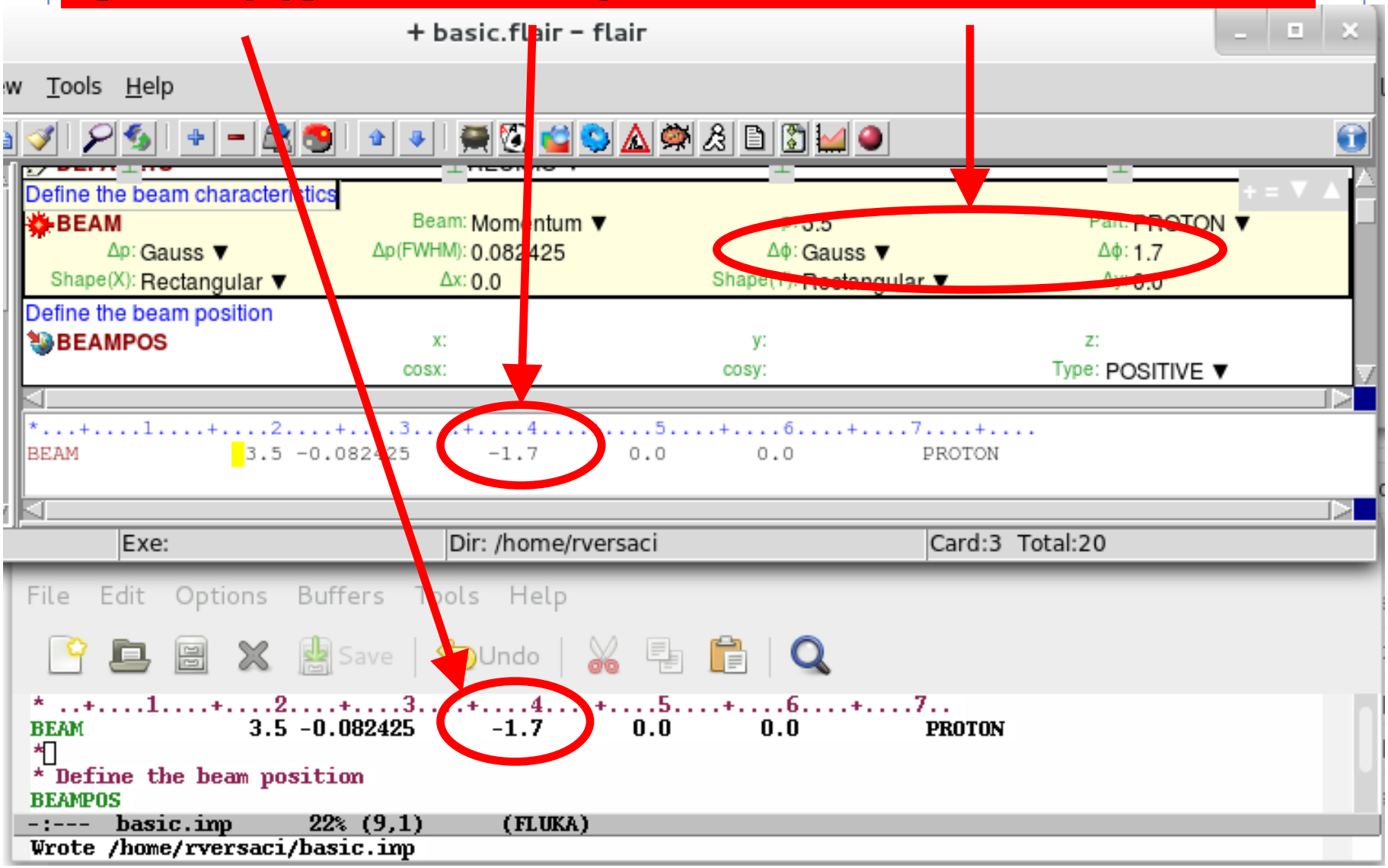
Beam definition: **BEAM**

[WHAT(2)]: Gaussian momentum distribution 0.082425 GeV/c FWHM



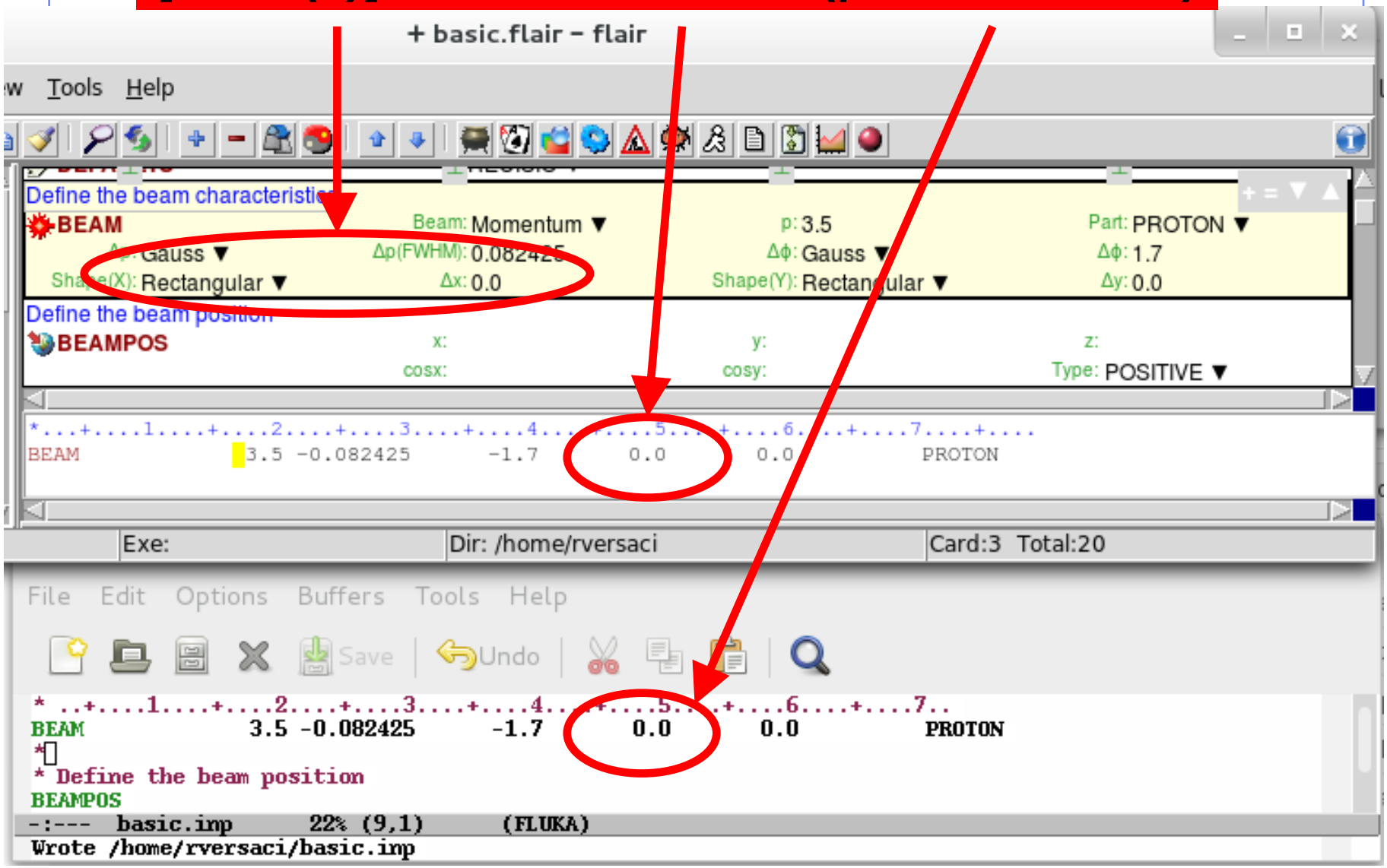
Beam definition: **BEAM**

[WHAT(3)]: Gaussian angular distribution 1.7 mrad FWHM



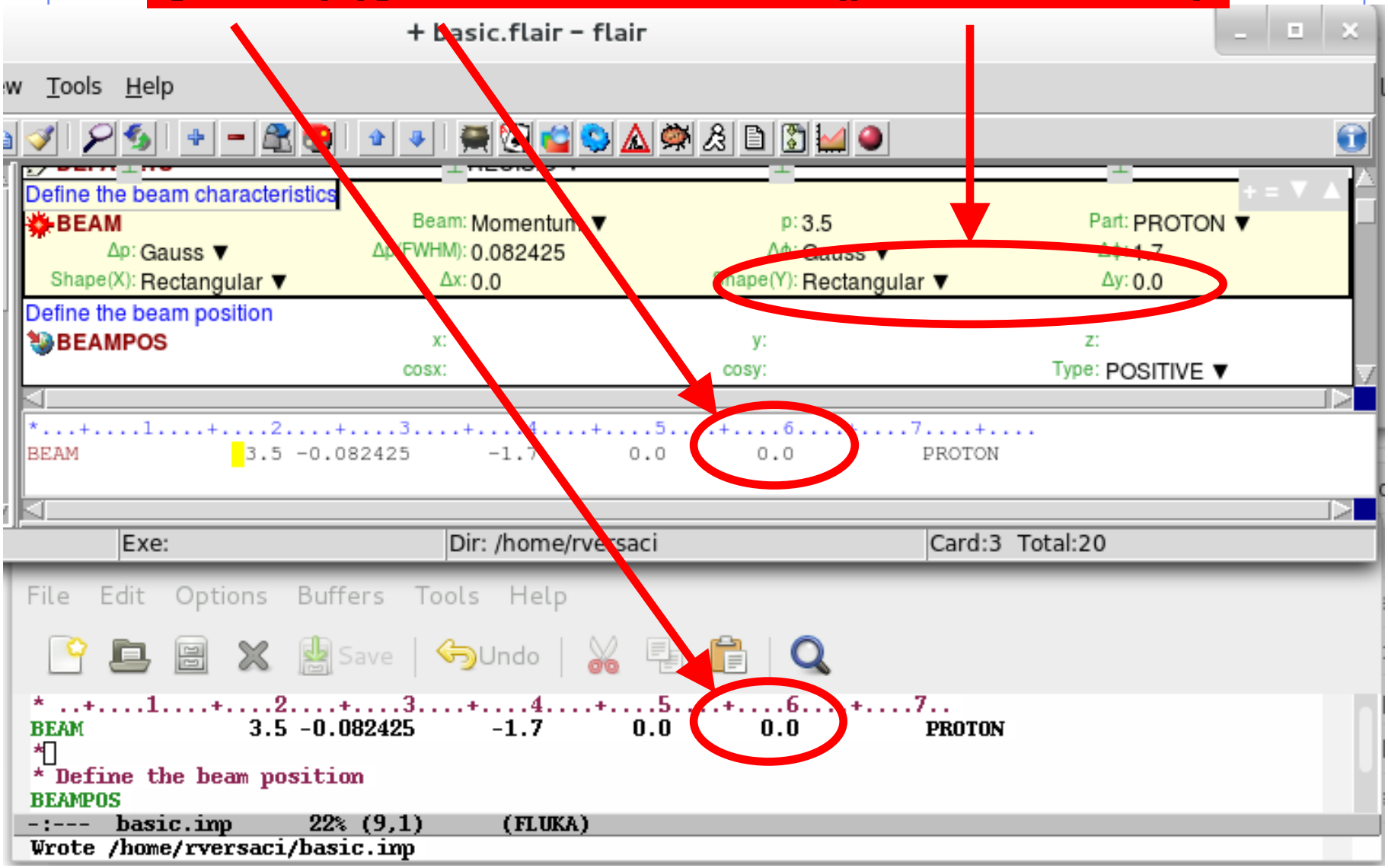
Beam definition: **BEAM**

[WHAT(4)]: No beam width in X (point-like source)



Beam definition: **BEAM**

[WHAT(5)]: No beam width in Y (point-like source)

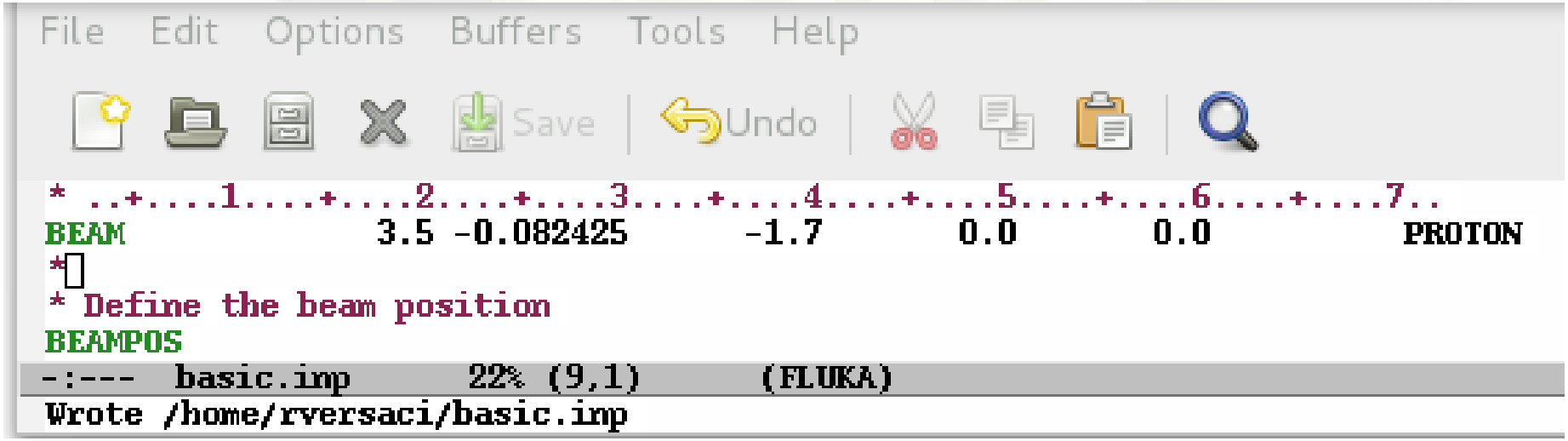


Beam definition: **BEAM**

defines beam characteristics:

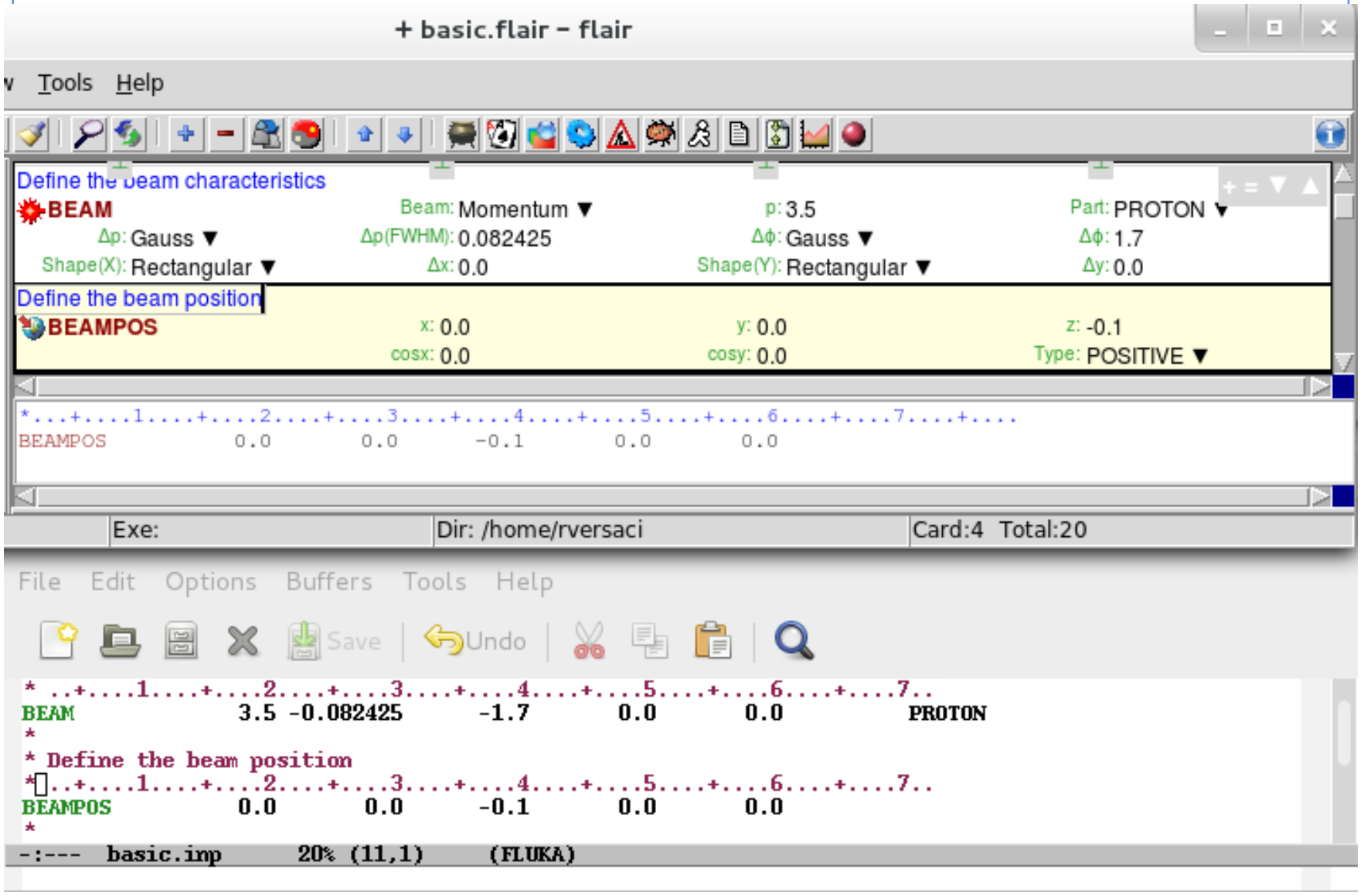
type of particle, energy, divergence, spatial profile....

- [SDUM] proton beam
- [WHAT(1)] 3.5 GeV/c momentum
- [WHAT(2)] Gaussian momentum distribution 0.082425 GeV/c FWHM
- [WHAT(3)] Gaussian angular distribution 1.7 mrad FWHM
- [WHAT(4)] No beam width in X (point-like source)
- [WHAT(5)] No beam width in Y (point-like source)



Beam definition: **BEAMPOS**

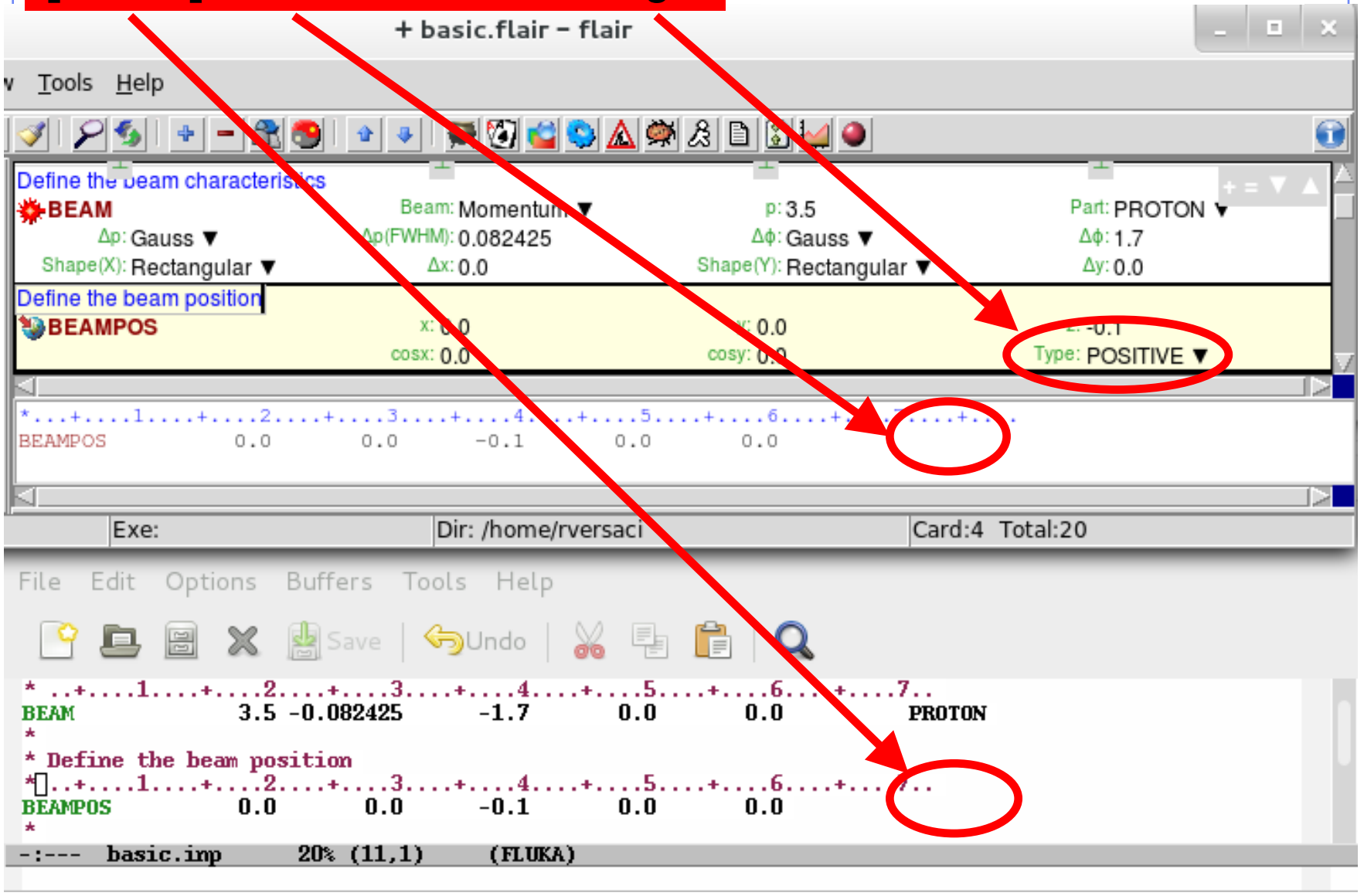
Defines beam position and direction



Beam definition: **BEAMPOS**

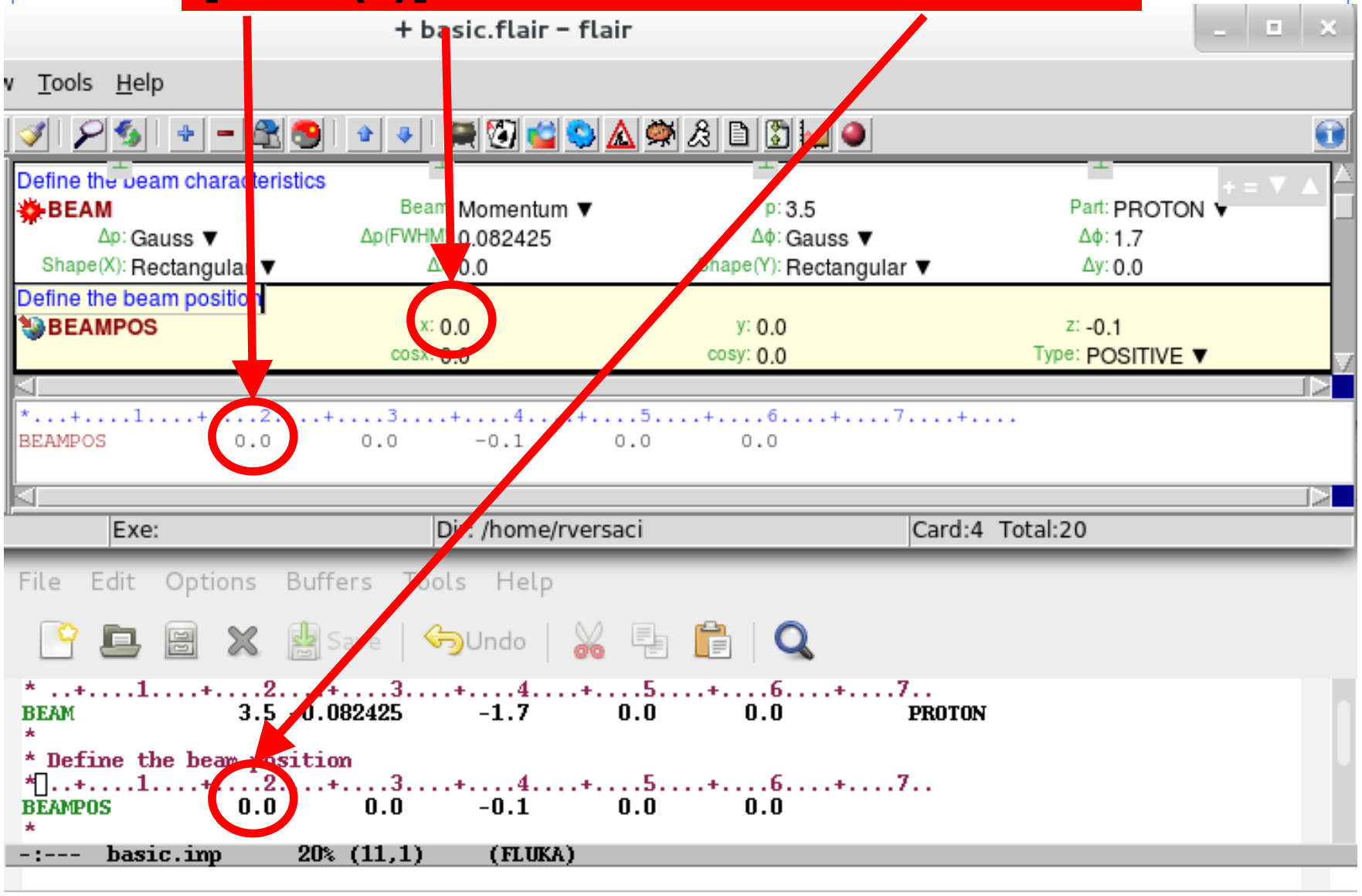
[SDUM]: beam direction along Z

By default toward positive Z



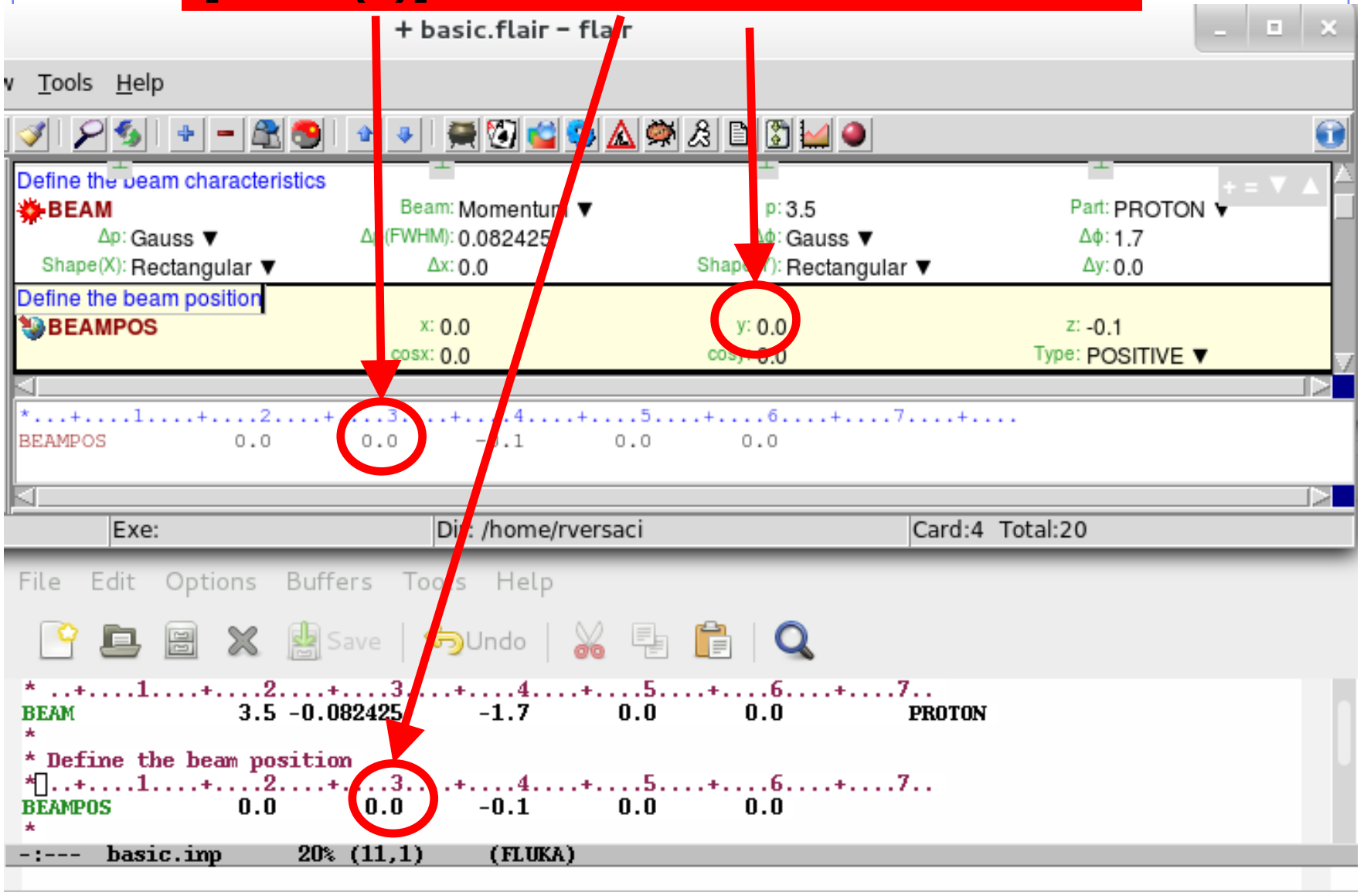
Beam definition: **BEAMPOS**

[WHAT(1)]: X coordinate of the beam center



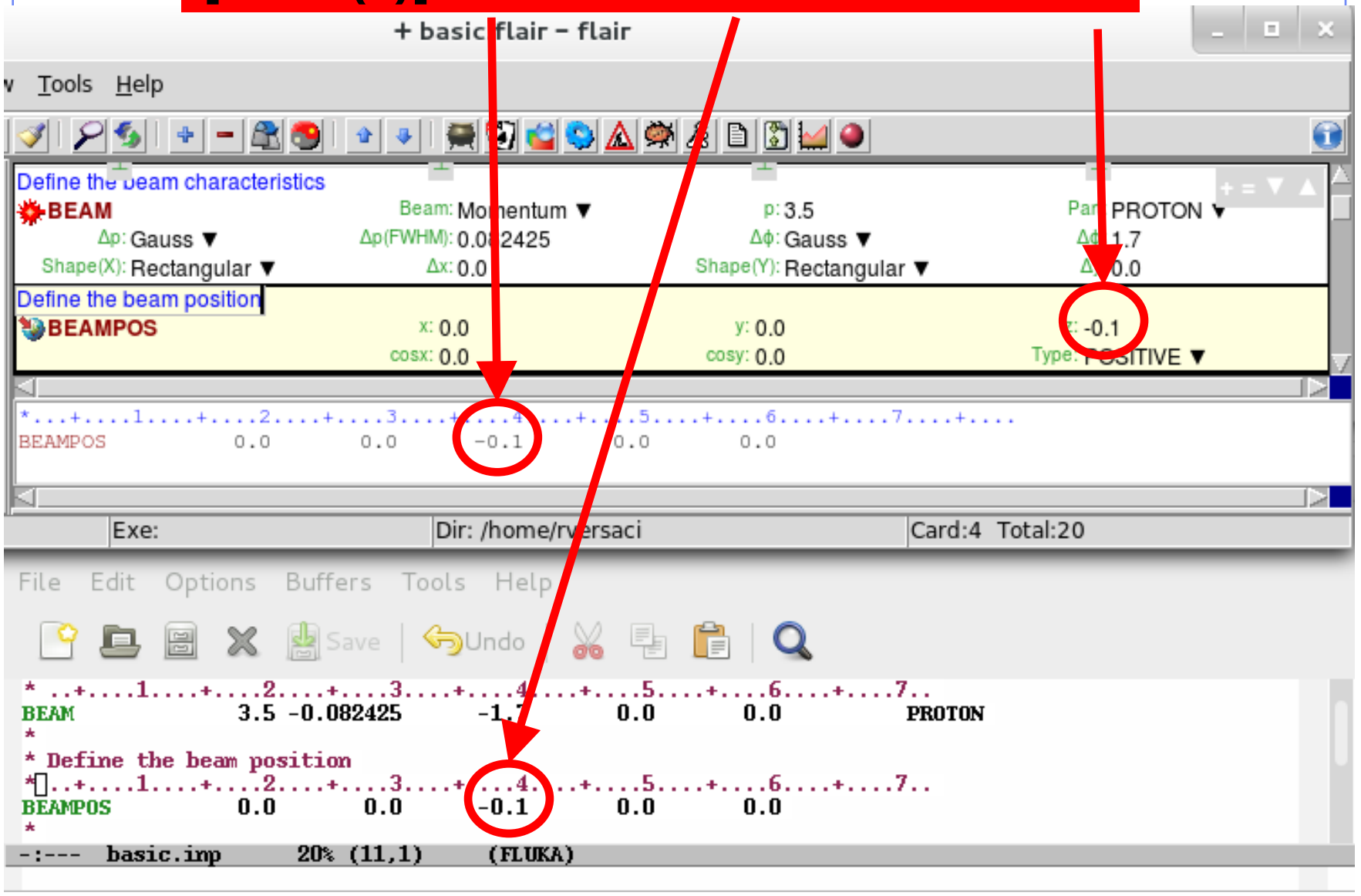
Beam definition: **BEAMPOS**

[WHAT(2)]: Y coordinate of the beam center



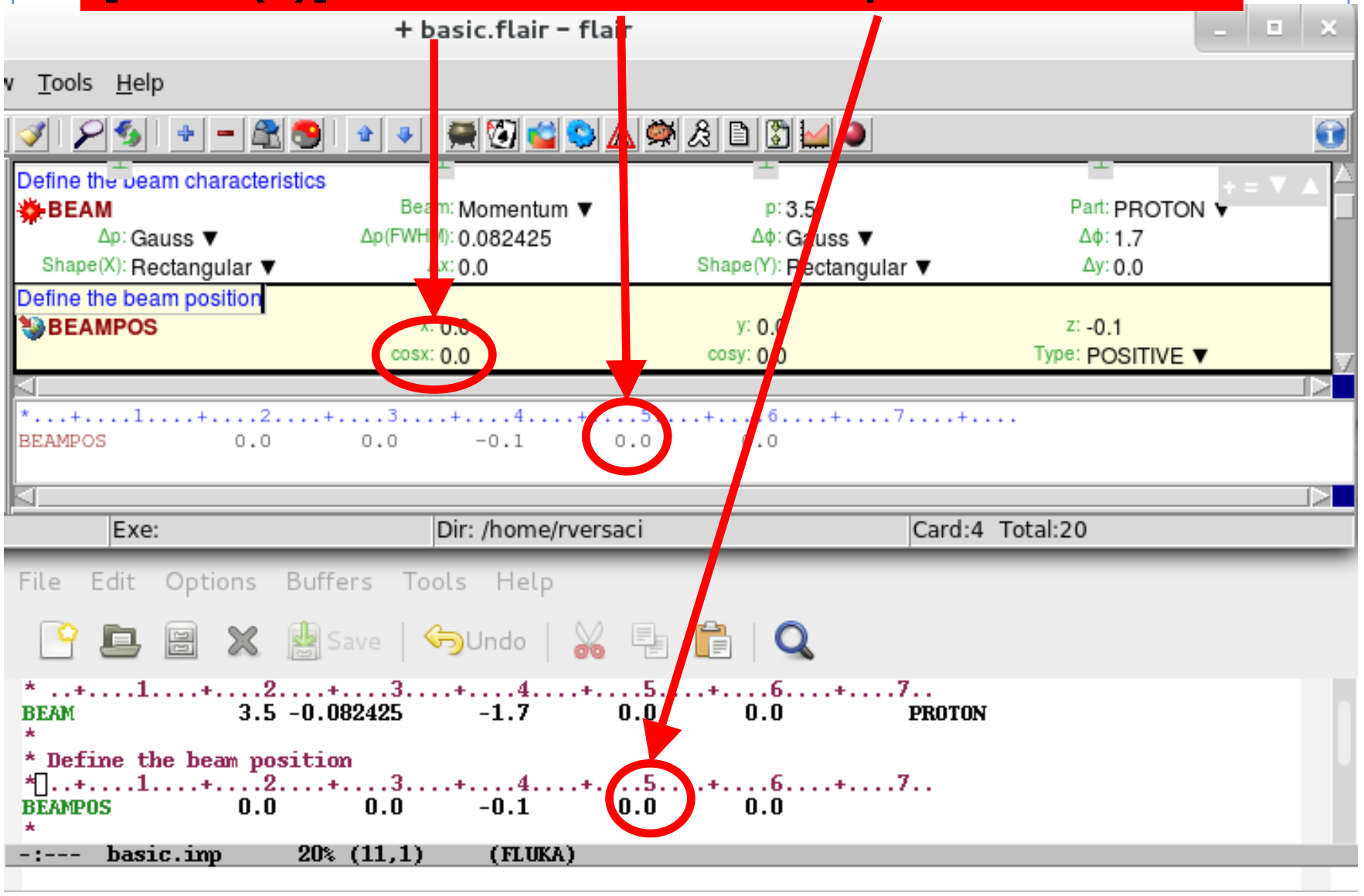
Beam definition: **BEAMPOS**

[WHAT(3)]: Z coordinate of the beam center



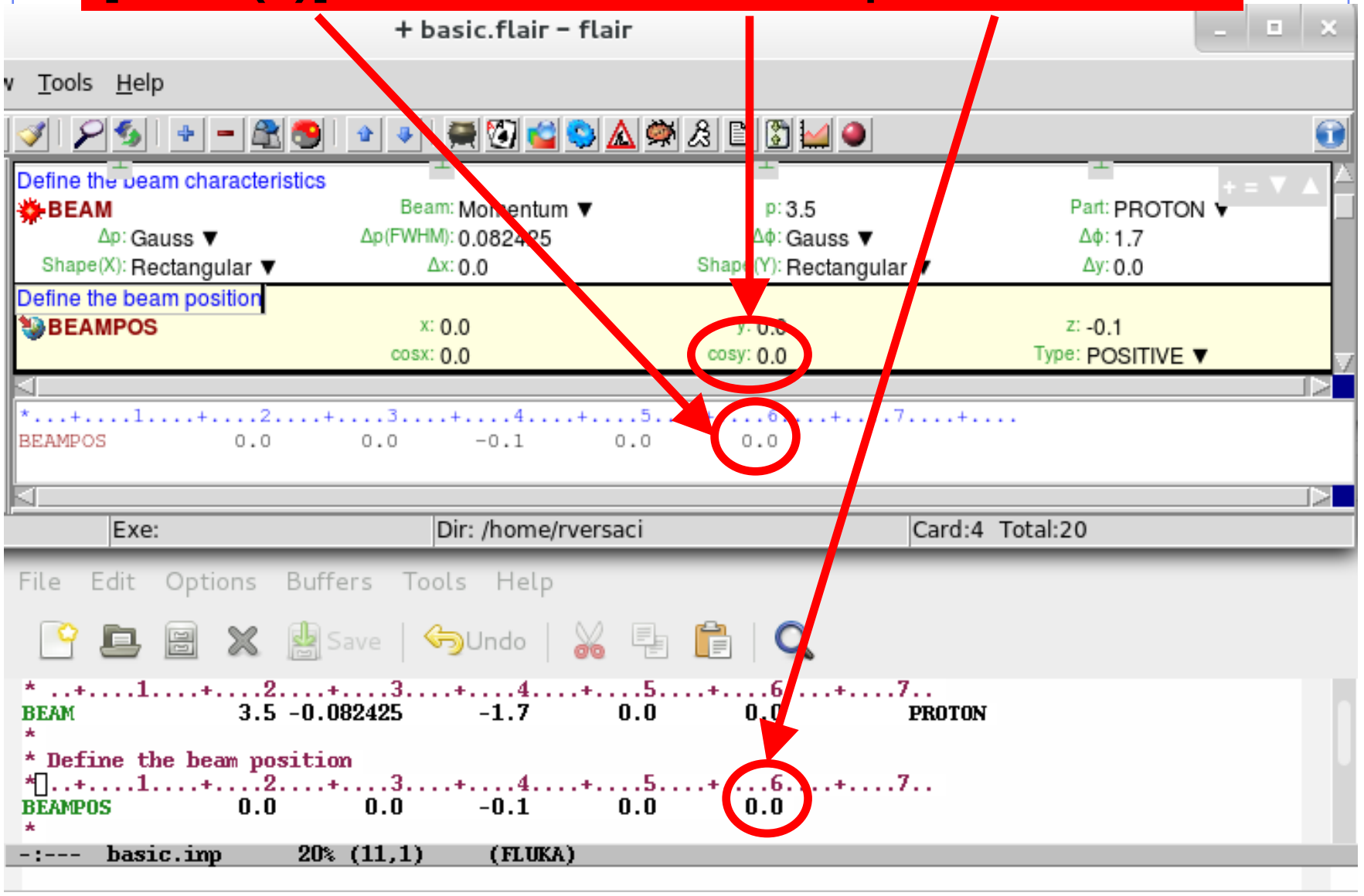
Beam definition: **BEAMPOS**

[WHAT(4)]: direction cosine with respect to the X axis



Beam definition: **BEAMPOS**

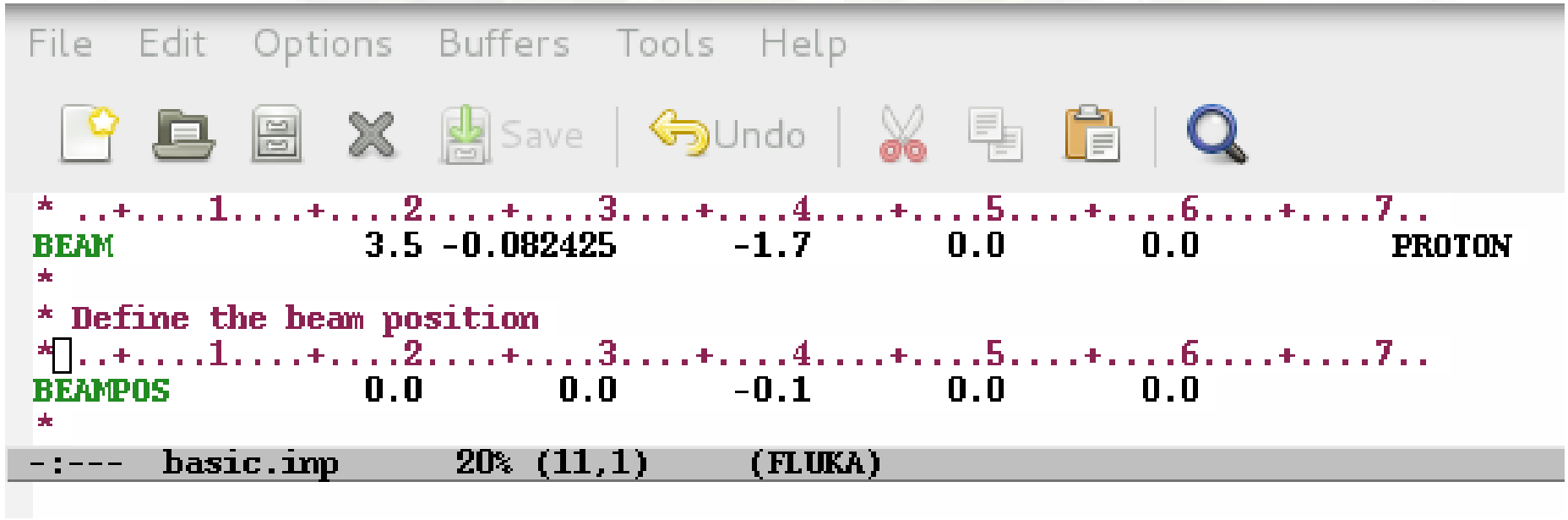
[WHAT(5)]: direction cosine with respect to the Y axis



Beam definition: **BEAMPOS**

defines beam position and momentum

- [SDUM] blank, therefore beam towards positive Z
- [WHAT(1)] X coordinate of the beam center
- [WHAT(2)] Y coordinate of the beam center
- [WHAT(3)] Z coordinate of the beam center
- [WHAT(4)] Direction cosine with respect to the X axis
- [WHAT(5)] Direction cosine with respect to the Y axis



A basic input: step 3: Geometry

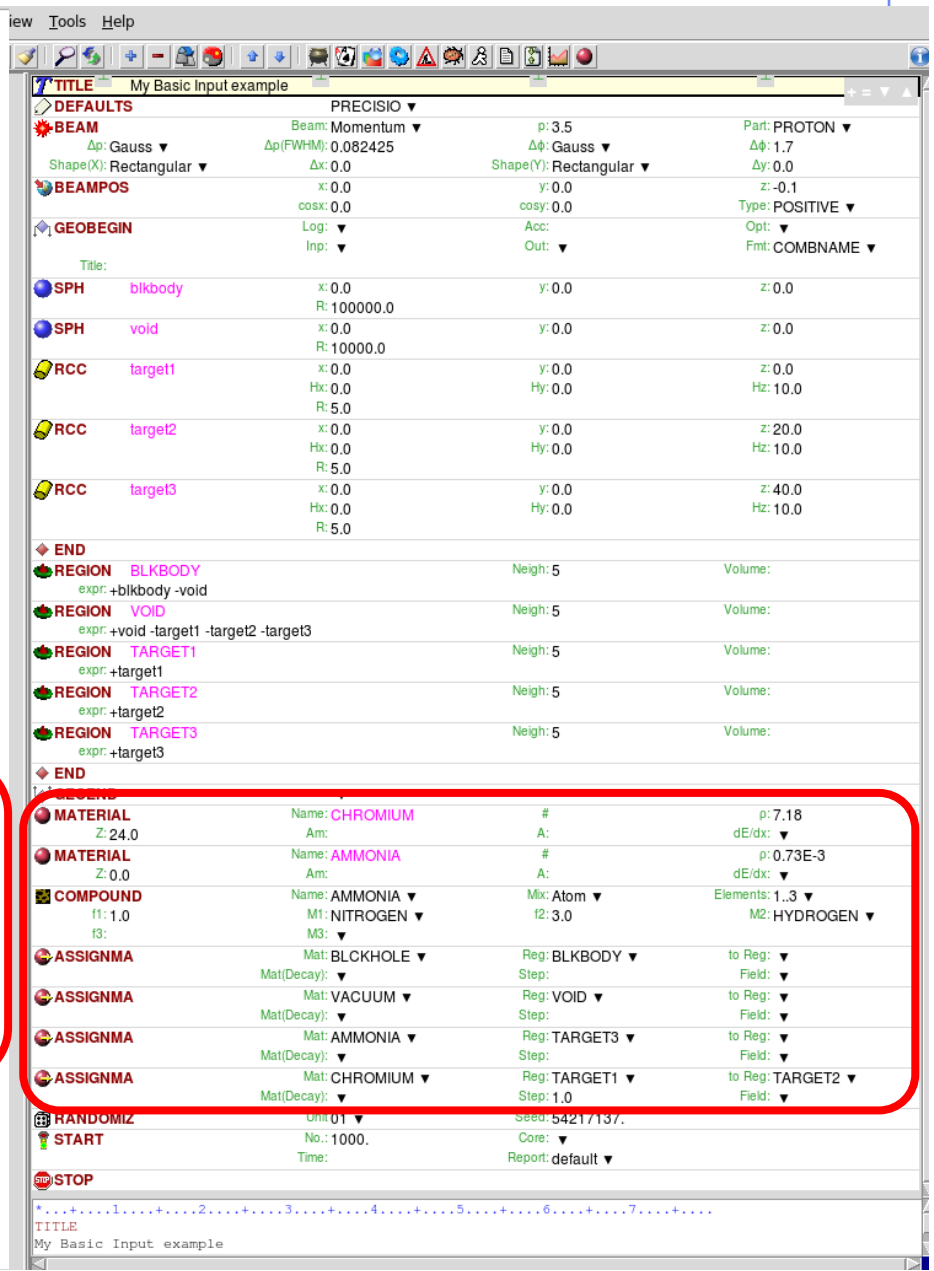
```
TITLE
My Basic Input example
* Set the defaults for precision simulations
DEFAULTS                                                              PRECISIO
* Define the beam characteristics
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAM             3.5 -0.082425      -1.7       0.0       0.0          PROTON
* Define the beam position
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAMPOS          0.0       0.0      -0.1       0.0       0.0
*
GEOBEGIN                                                              COMBNAME
    0    0
* Black body
SPH blkbody    0.0 0.0 0.0 100000.0
* Void sphere
SPH void       0.0 0.0 0.0 10000.0
* Cylindrical target
RCC target1    0.0 0.0  0.0 0.0 0.0 10.0 5.0
RCC target2    0.0 0.0 20.0 0.0 0.0 10.0 5.0
RCC target3    0.0 0.0 40.0 0.0 0.0 10.0 5.0
END
* Black hole
BLKBODY      5 +blkbody -void
* Void around
VOID         5 +void -target1 -target2 -target3
* Target
TARGET1      5 +target1
TARGET2      5 +target2
TARGET3      5 +target3
END
GEOEND
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
MATERIAL         24.0              7.18                               CHROMIUM
MATERIAL          0.0            0.73E-3                              AMMONIA
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
COMPOUND
*
* ..+....1
ASSIGNMA
ASSIGNMA
ASSIGNMA
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..*
ASSIGNMA    CHROMIUM    TARGET1    TARGET2       1.0

* Set the random number seed
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
RANDOMIZ         1.0 54217137.
*
* Set the number of primary histories to be simulated in the run
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
START          1000.
STOP
```

Geometry definition: please, wait for the Geometry lecture

but notice the structure

A basic input: step 4: Materials

```
TITLE
My Basic Input example
* Set the defaults for precision simulations
DEFAULTS                                                              PRECISIO
* Define the beam characteristics
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAM             3.5 -0.082425      -1.7       0.0       0.0          PROTON
* Define the beam position
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAMPOS          0.0       0.0      -0.1       0.0       0.0
*
GEOBEGIN                                                              COMBNAME
    0    0
* Black body
SPH blkbody    0.0 0.0 0.0 100000.0
* Void sphere
SPH void       0.0 0.0 0.0 10000.0
* Cylindrical target
RCC target1    0.0 0.0  0.0 0.0 0.0 10.0 5.0
RCC target2    0.0 0.0 20.0 0.0 0.0 10.0 5.0
RCC target3    0.0 0.0 40.0 0.0 0.0 10.0 5.0
END
* Black hole
BLKBODY      5 +blkbody -void
* Void around
VOID         5 +void -target1 -target2 -target3
* Target
TARGET1      5 +target1
TARGET2      5 +target2
TARGET3      5 +target3
END
GEOEND
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
MATERIAL         24.0              7.18                               CHROMIUM
MATERIAL          0.0           0.73E-3                               AMMONIA
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
COMPOUND          1.0  NITROGEN       3.0  HYDROGEN                   AMMONIA
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
ASSIGNMA    BLCKHOLE    BLKBODY
ASSIGNMA      VACUUM      VOID
ASSIGNMA     AMMONIA    TARGET3
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..*
ASSIGNMA    CHROMIUM    TARGET1    TARGET2       1.0

* Set the random number seed
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
RANDOMIZ         1.0 54217137.
*
* Set the number of primary histories to be simulated in the run
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
START          1000.
STOP
```



Materials

FLUKA handles:

- elemental materials (by default natural composition, the user can set a specific isotope, *being aware of low energy neutron cross sections availability)
- compounds (chemical molecules, alloys, mixtures...)

Each material is uniquely identified by an index/name

FLUKA has a set of predefined materials

Users can both use/modify* these and define their own ones*

Basic cards:

MATERIAL	material declaration
COMPOUND	compound definition (a **MATERIAL** card is mandatory for a compound declaration)
ASSIGNMA	material assignment to regions of geometry

Predefined materials

In FLUKA 2 special materials +23 natural elements of most common use, e.g. Oxygen, Carbon, Iron... (check them out in the manual, Chap. 5), are predefined

The first two are very important:

- **BLCKHOLE** (mat #1): material with infinite absorbance;
- **VACUUM** (mat #2)

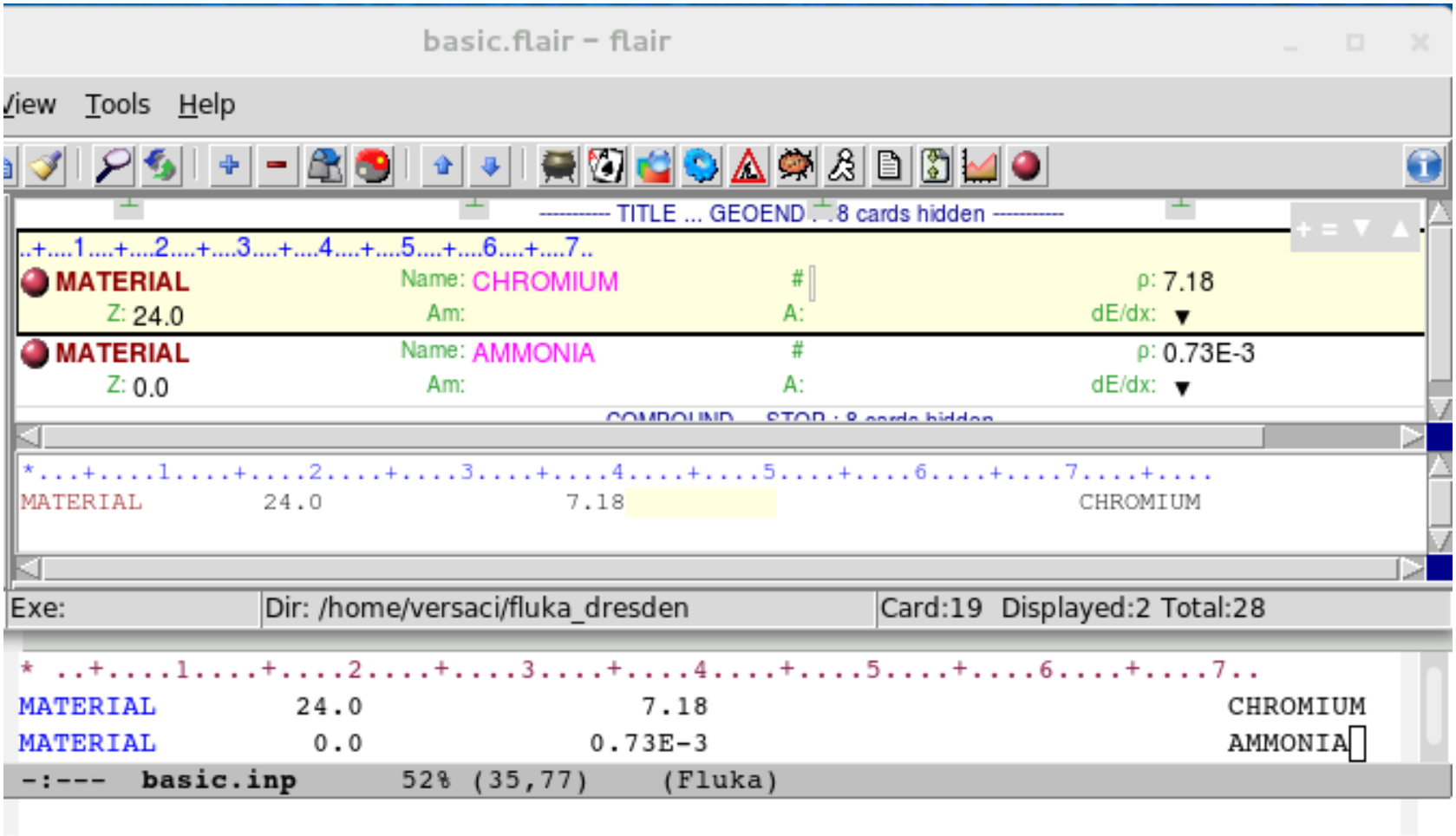
12 compound materials with the composition suggested by ICRU are predefined as well (again, check the manual!)

All predefined materials can be used WITHOUT explicit **MATERIAL** / **COMPOUND** cards

WARNING: user defined **MATERIAL** cards OVERRIDE PREDEFINED materials having the same name

Material definition: **MATERIAL**

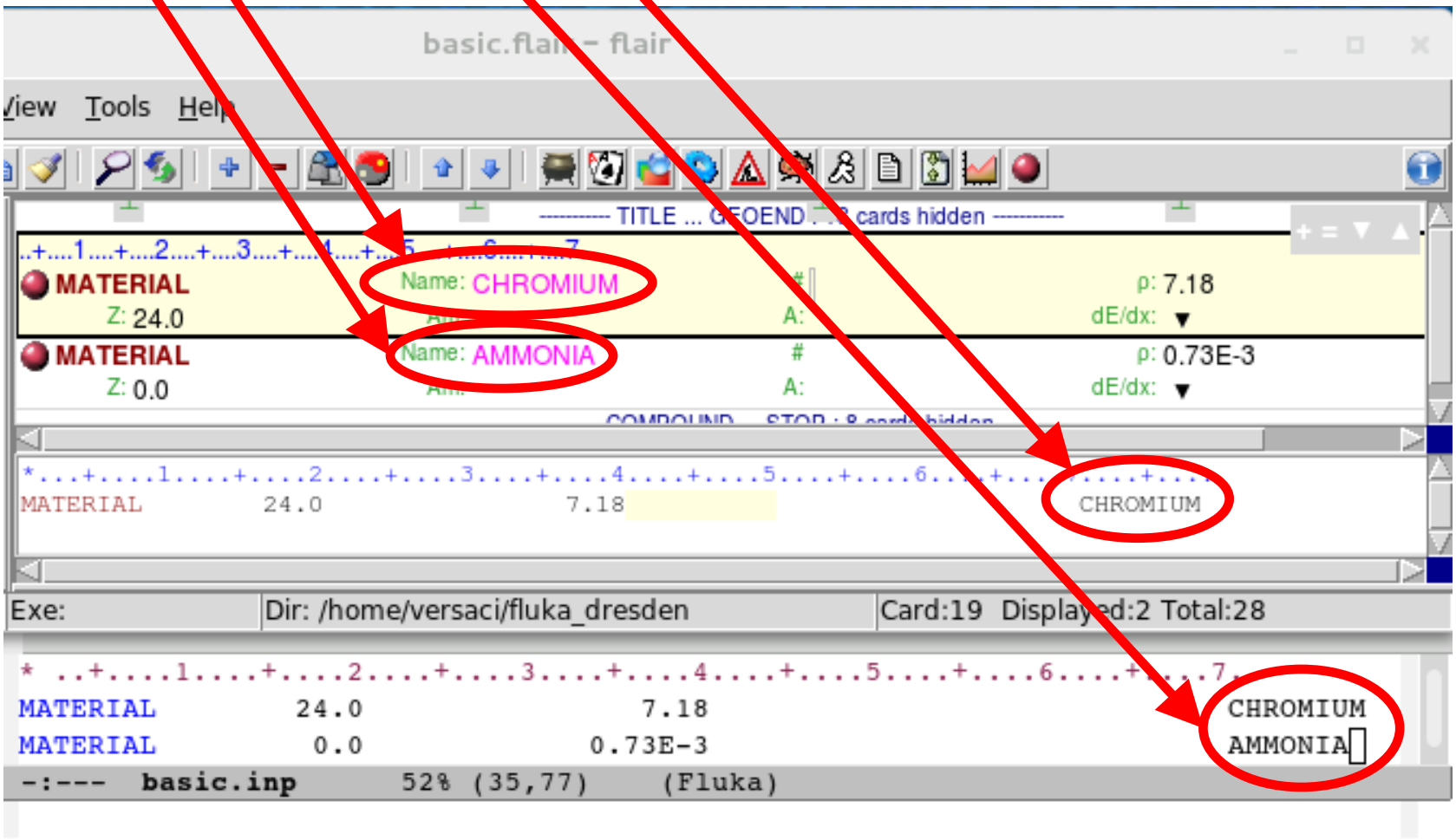
Defines a new material or override a previous one



Material definition: **MATERIAL**

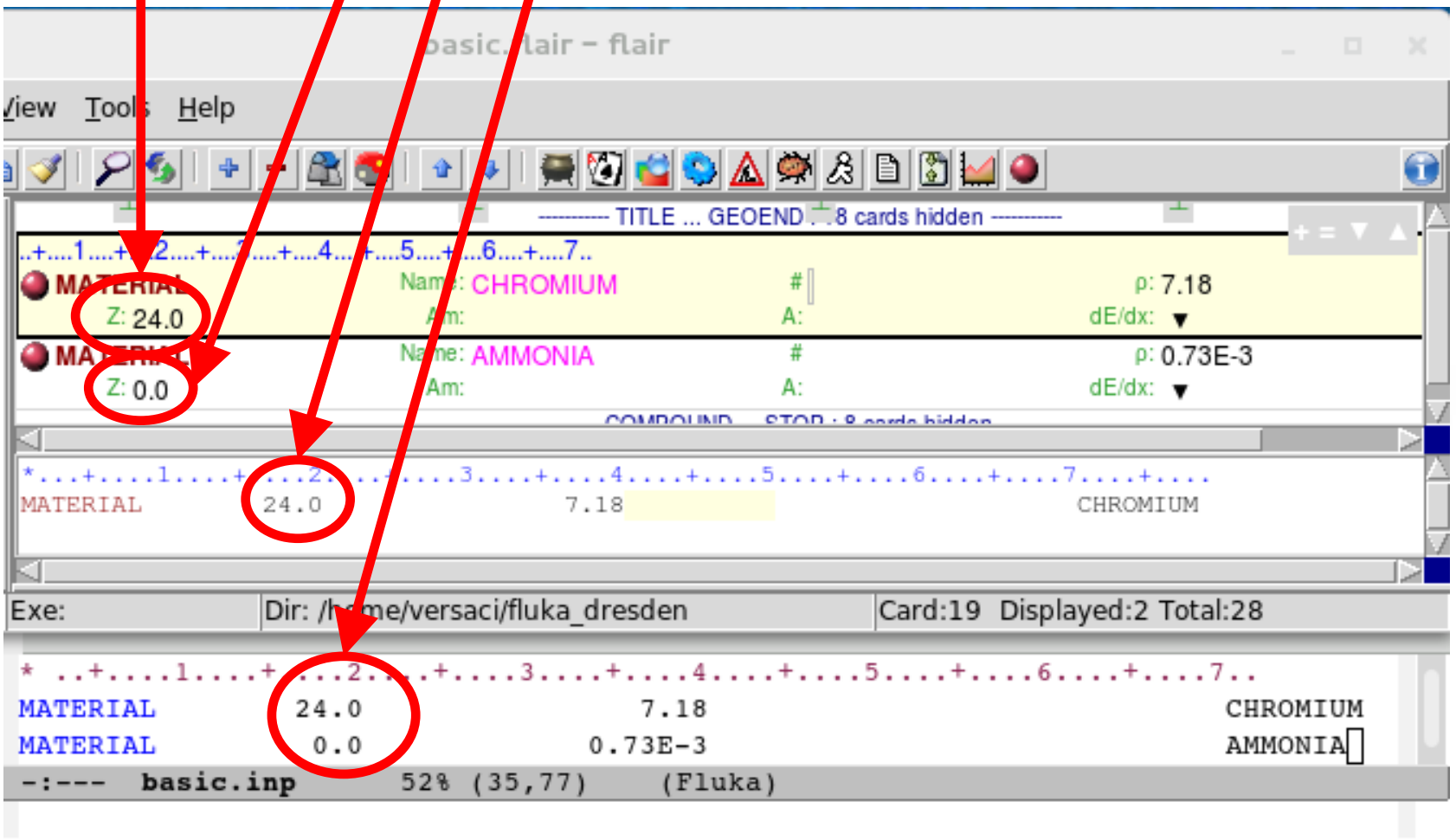
[SDUM]: material name

Chemical elements names should correspond to an entry in the LOW-ENERGY neutrons database (see manual section 10.4 & neutrons lecture)



Material definition: **MATERIAL**

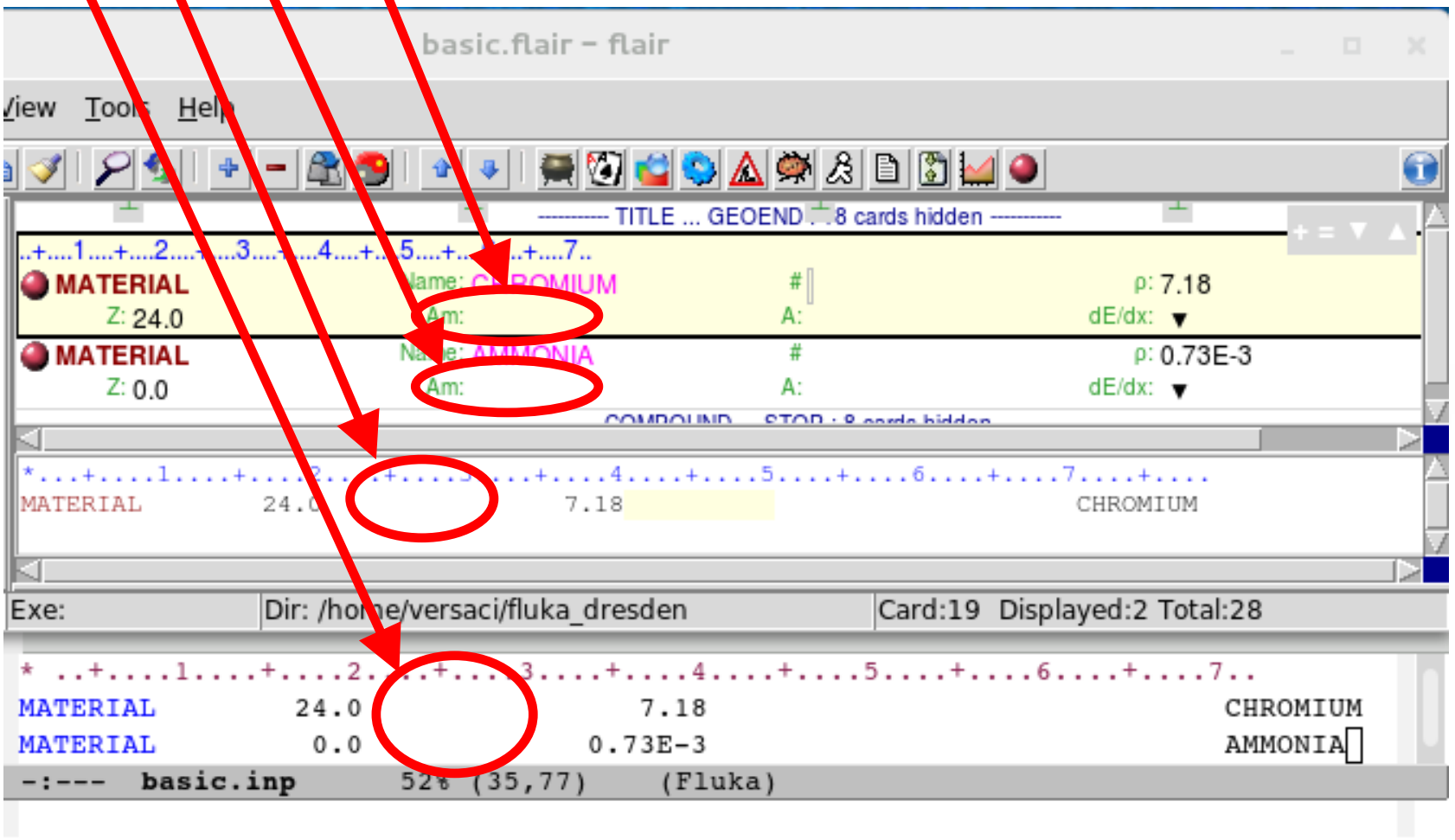
[WHAT(1)]: atomic number Z



Material definition: **MATERIAL**

[WHAT(2)]: atomic weight

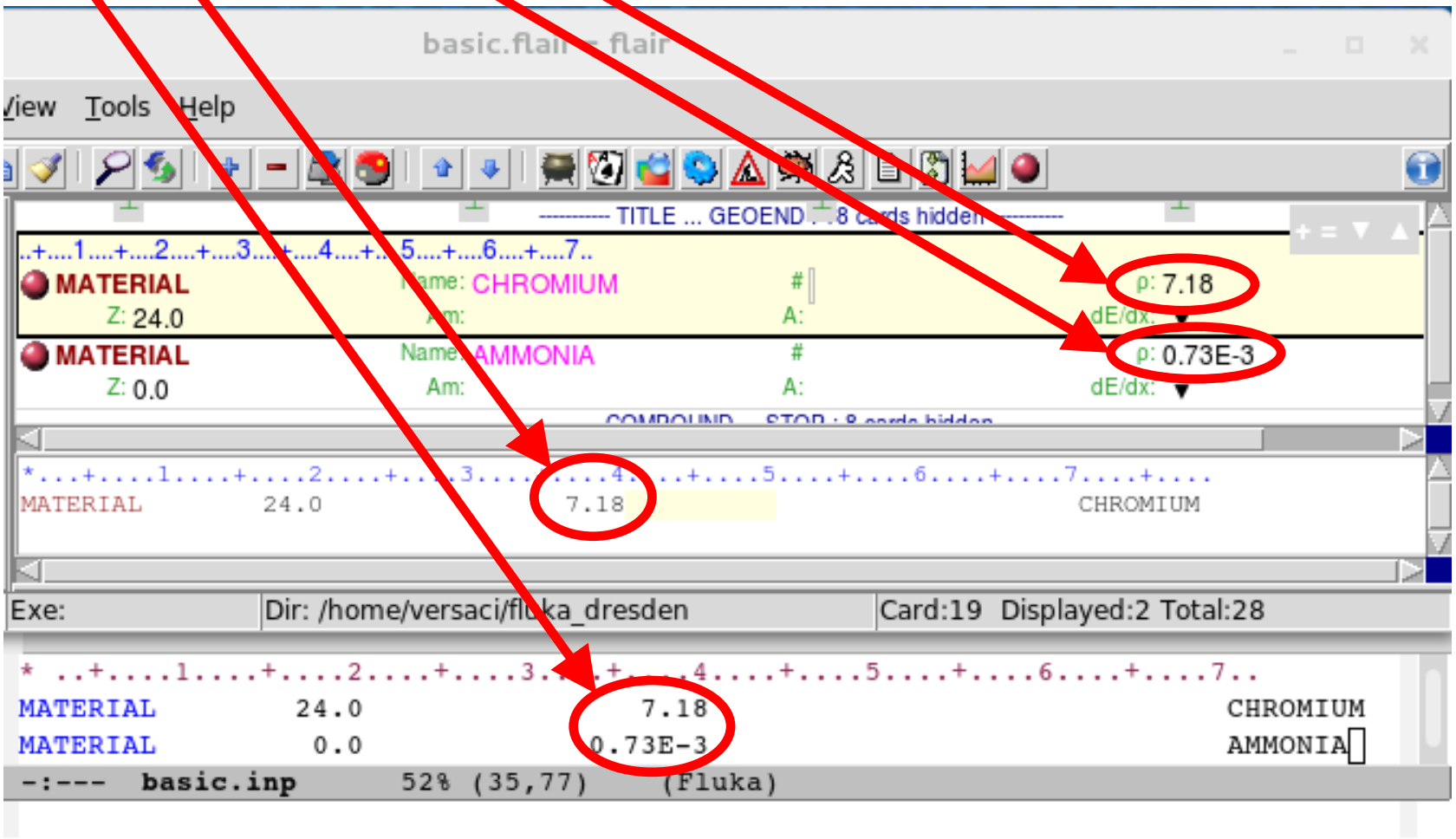
Calculated by the code using its internal database: **leave it empty**



Material definition: **MATERIAL**

[WHAT(3)]: density [g/cm³]

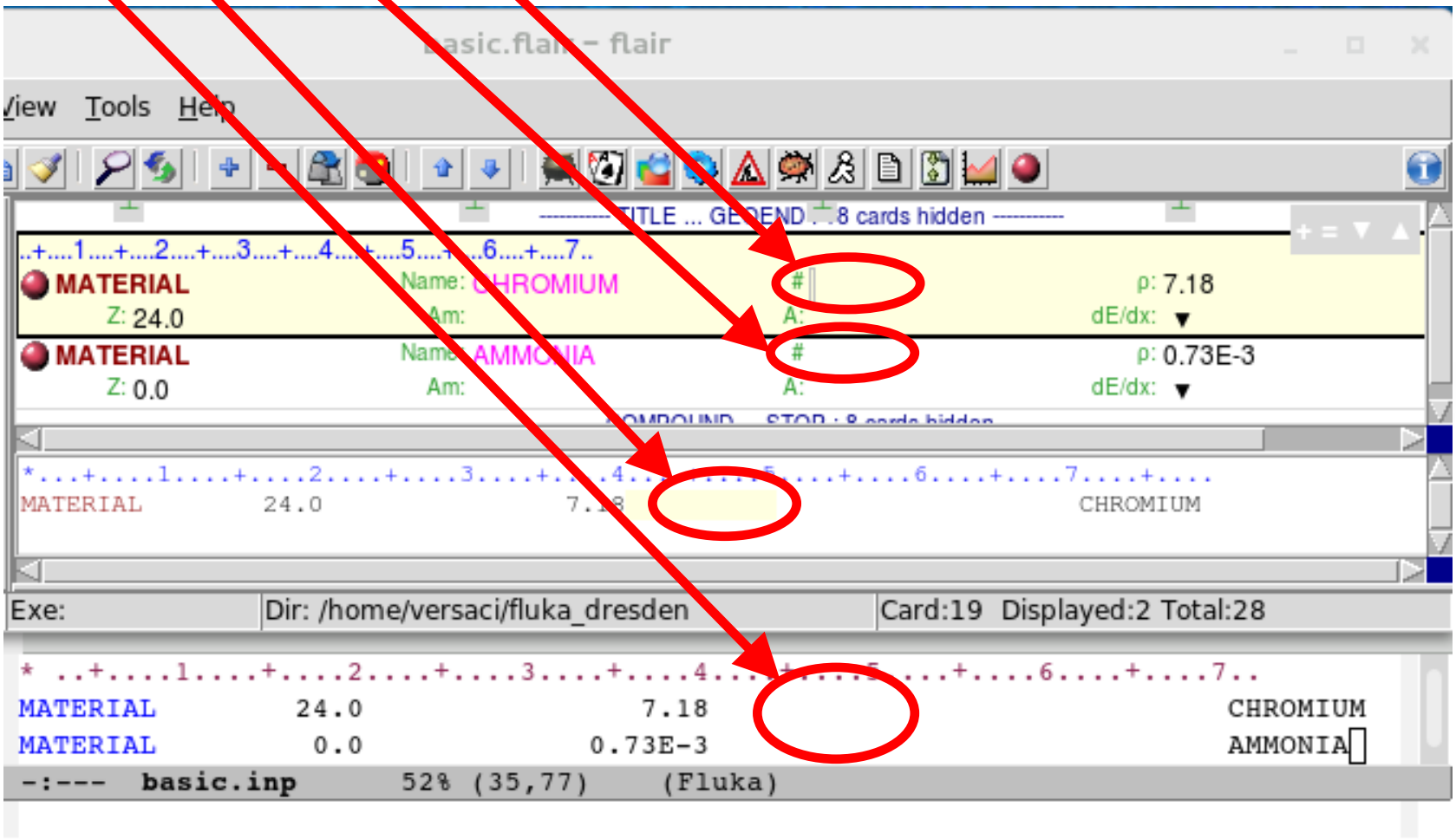
If ρ < 0.01 assumed to be a gas



Material definition: **MATERIAL**

[WHAT(4)]: material number

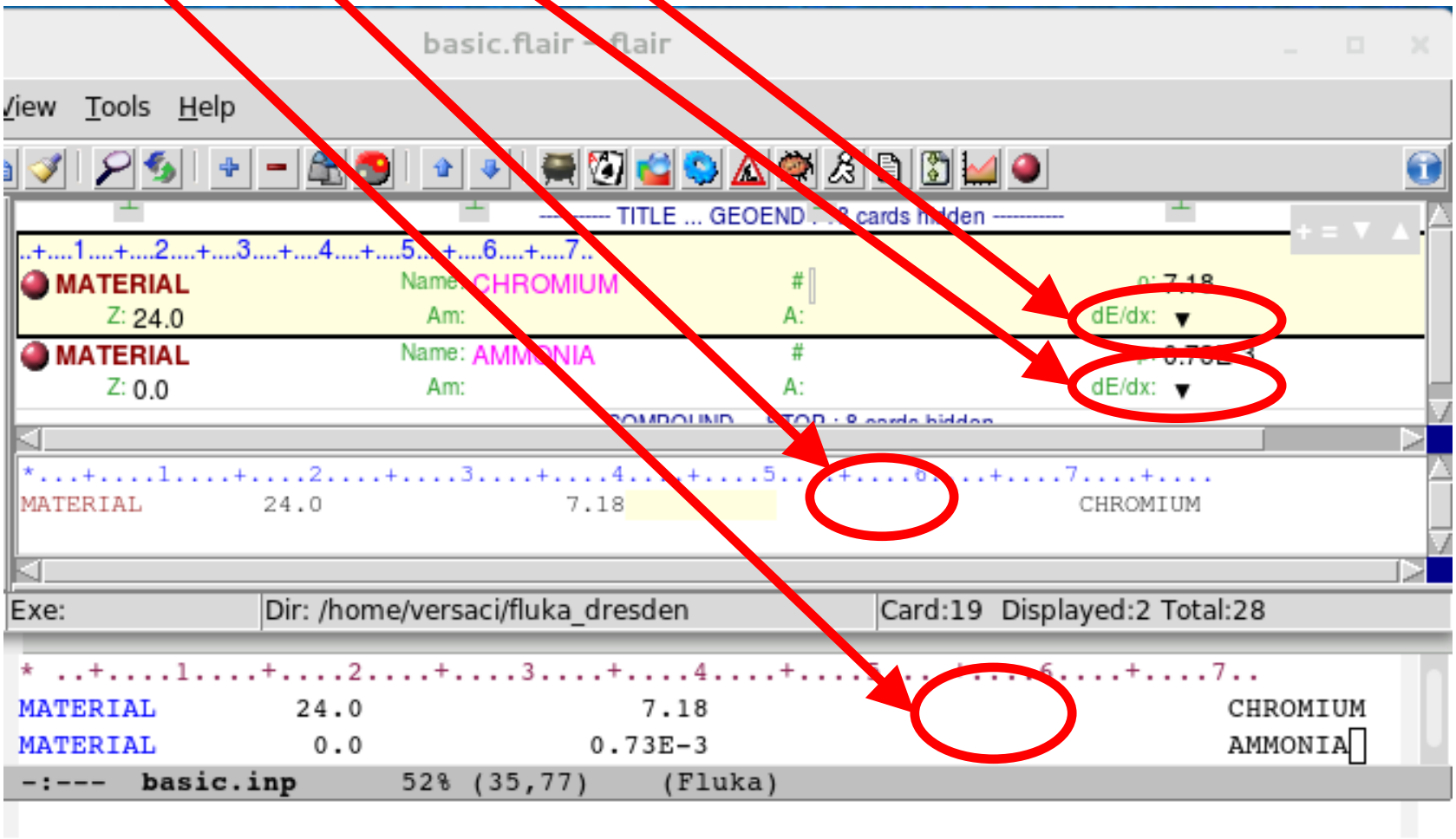
Available for backward compatibility:
leave it empty



Material definition: **MATERIAL**

[WHAT(5)]: alternate material to be used for dE/dx

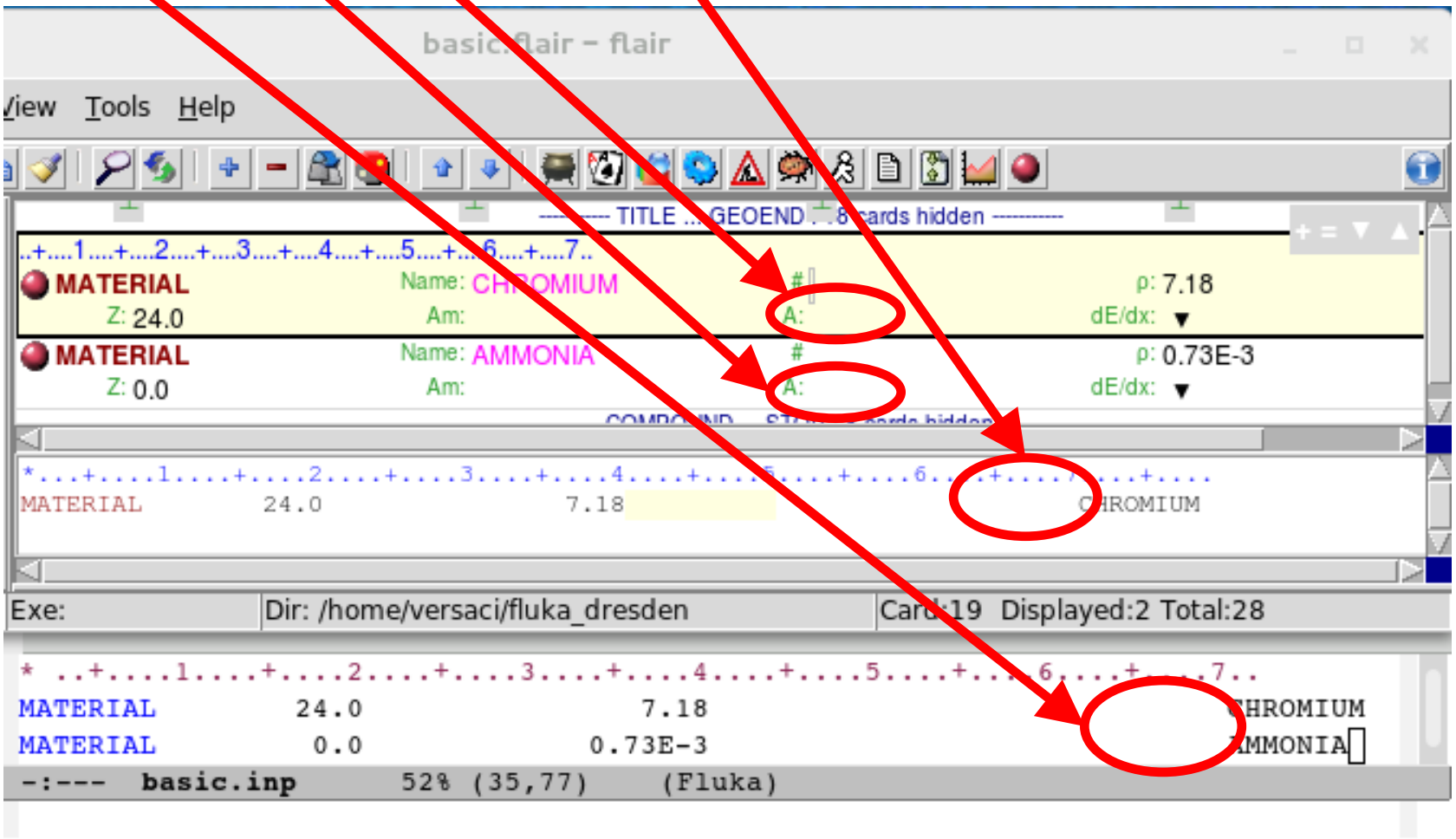
normally empty



Material definition: **MATERIAL**

[WHAT(6)]: mass number A

normally empty
unless a specific isotope is desired



Material definition: **MATERIAL**

Defines a new material or override a previous one

- [SDUM] material name
- [WHAT(1)] atomic number Z
- [WHAT(2)] atomic weight (**leave it empty**)
- [WHAT(3)] density [g/cm^3]
- [WHAT(4)] material number (**leave it empty**)
- [WHAT(5)] alternate material to be used for dE/dx (**normally empty**)
- [WHAT(6)] mass number A (**leave it empty unless you want a specific isotope**)

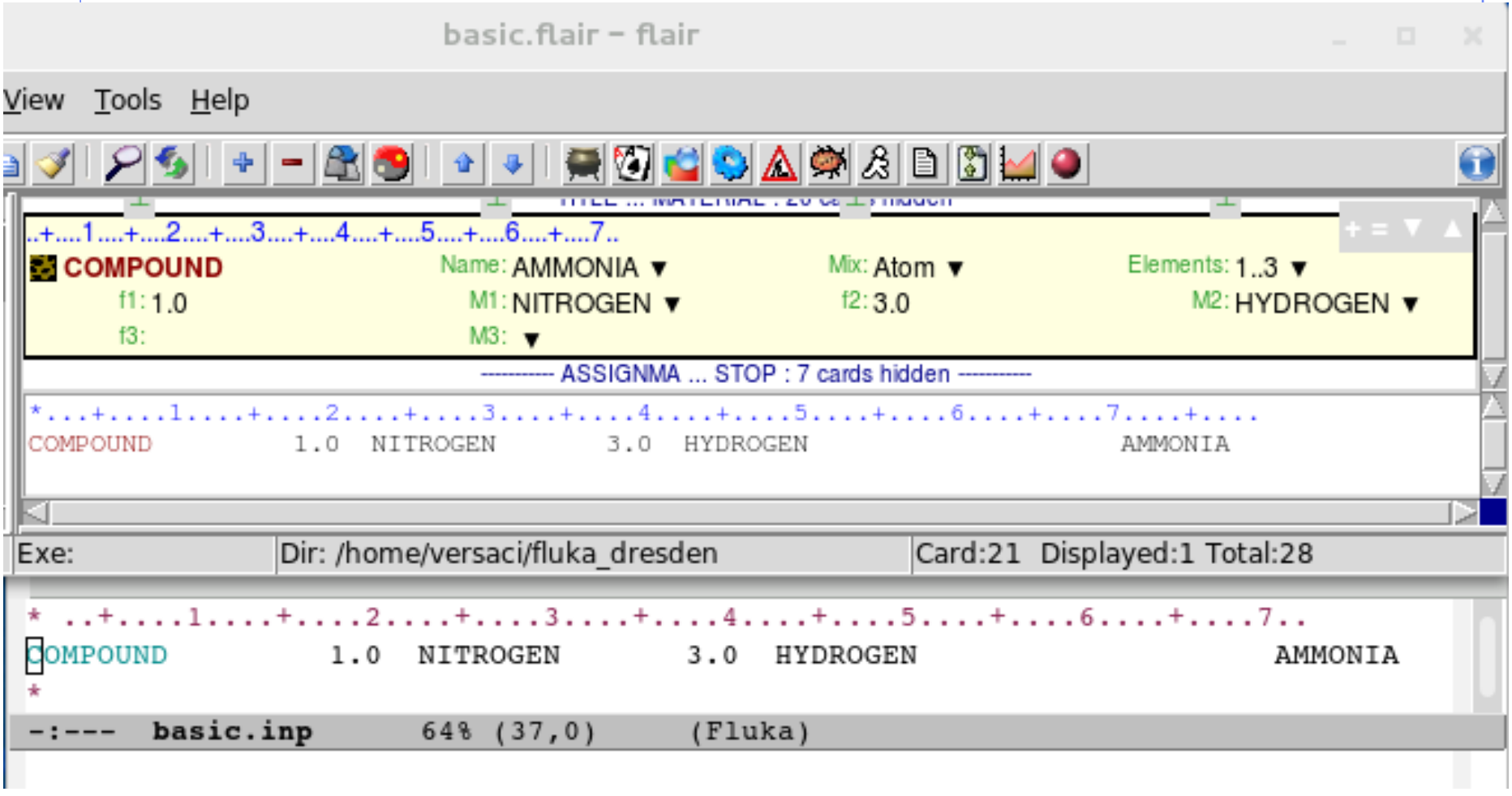
```
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
MATERIAL         24.0                 7.18                          CHROMIUM
MATERIAL          0.0               0.73E-3                          AMMONIA
-:---  basic.inp      52% (35,77)    (Fluka)
```

Material definition: **COMPOUND**

Defines a new compound

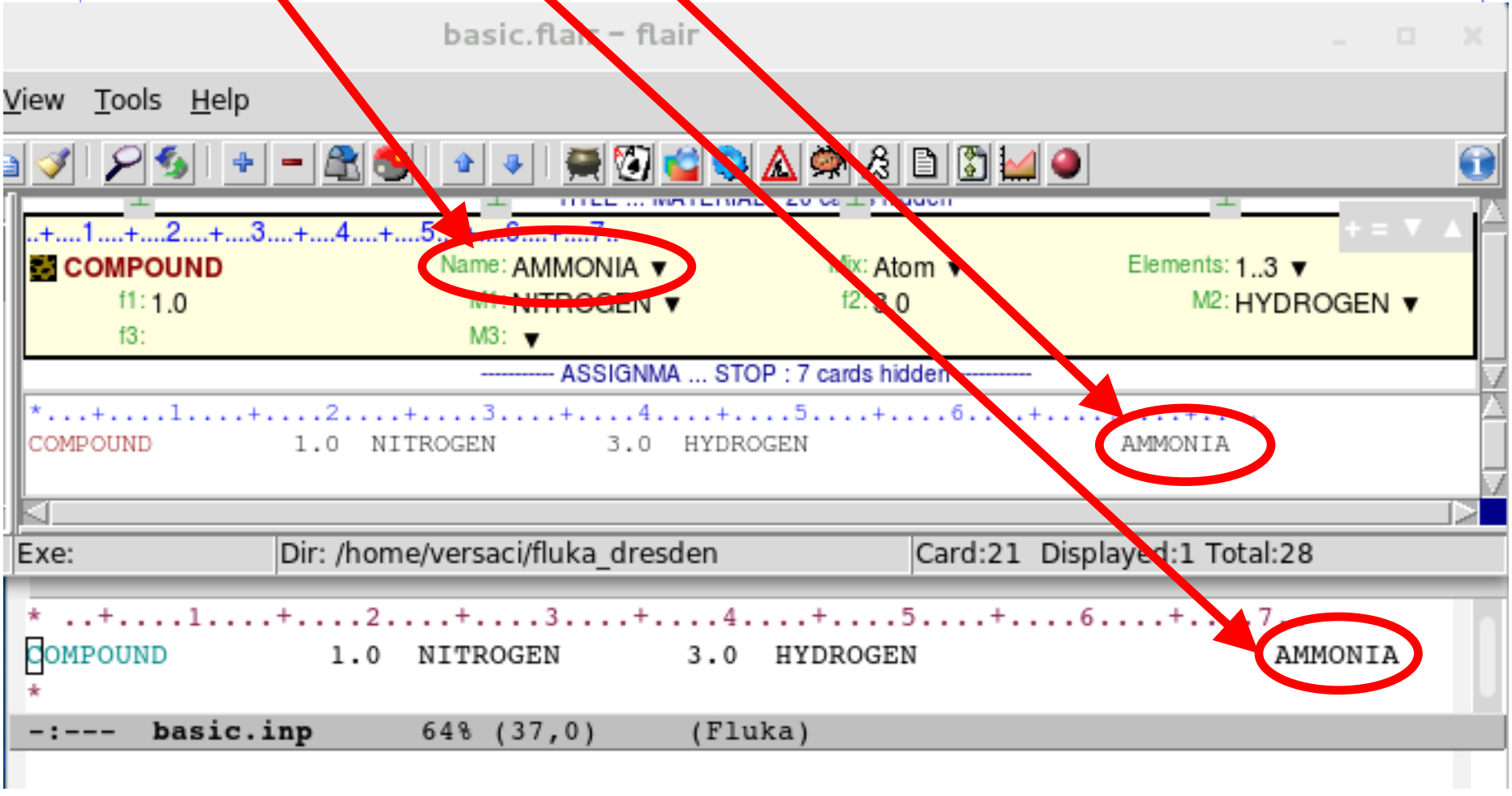
Each **COMPOUND** card must be associated to a **MATERIAL** card

More **COMPOUND** card can be used to define a compound



Material definition: **COMPOUND**

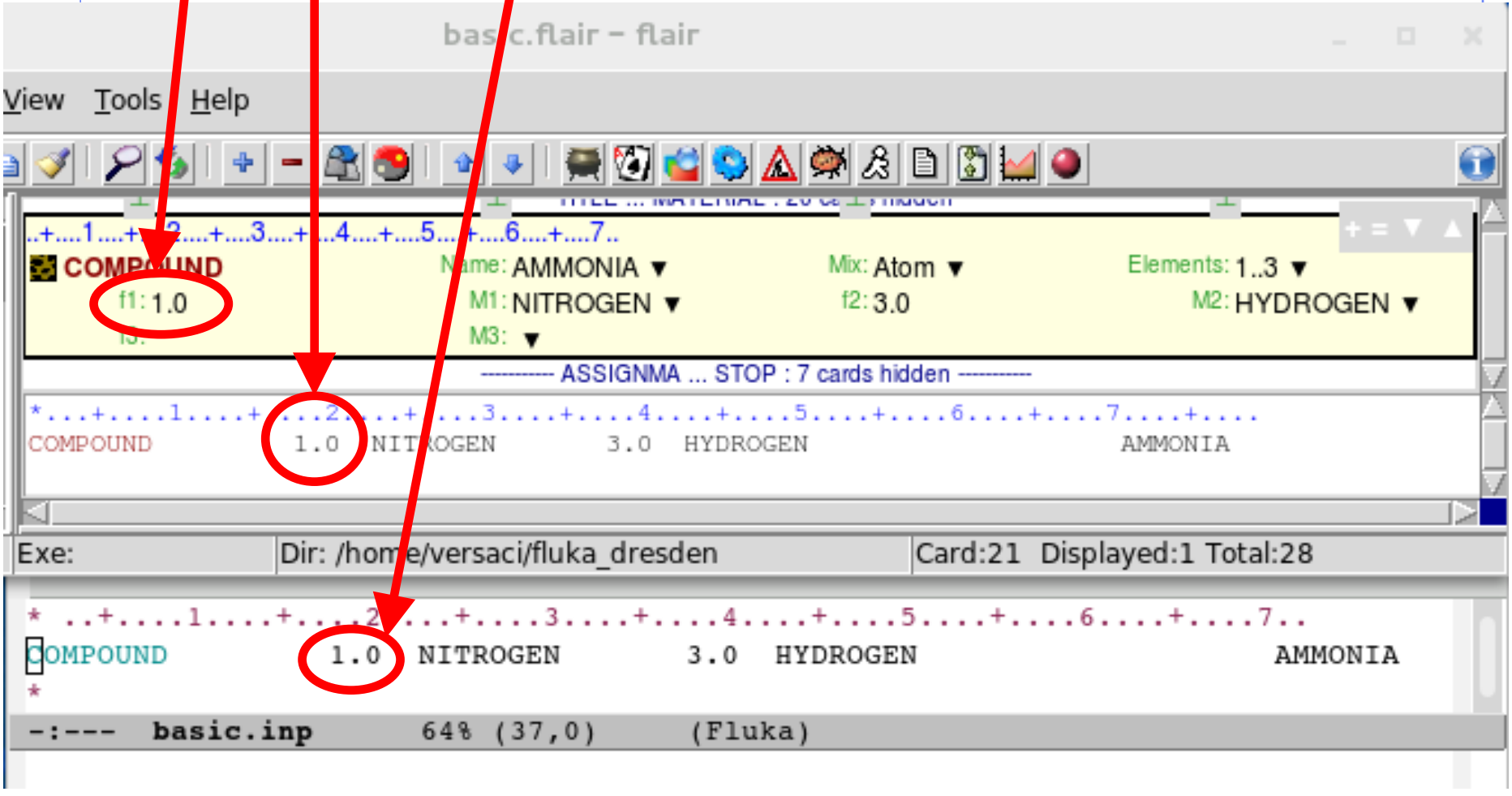
[SDUM]: compound name



Material definition: **COMPOUND**

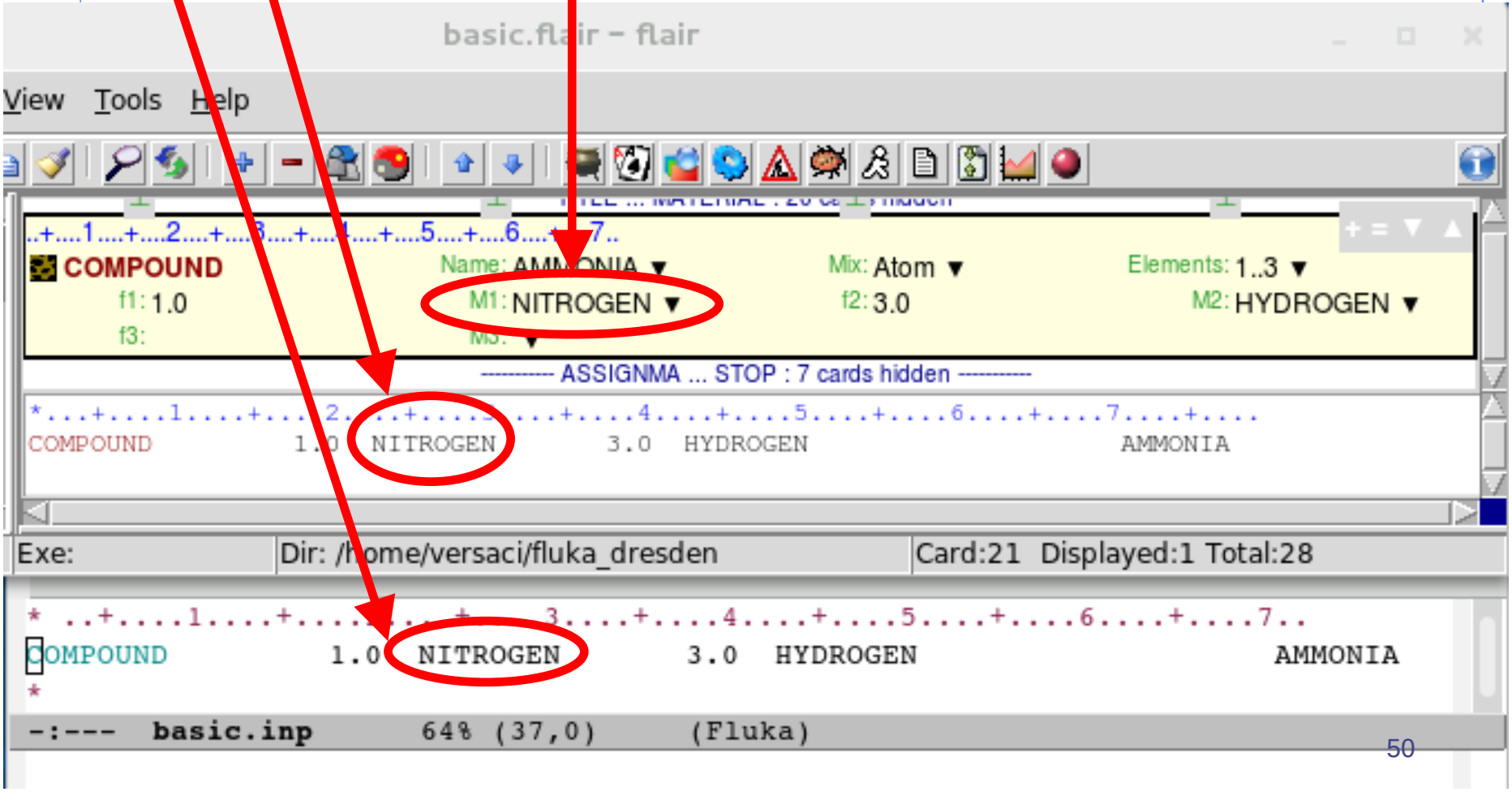
[WHAT(1)]: amount of the first component

Amount definition in few slides



Material definition: **COMPOUND**

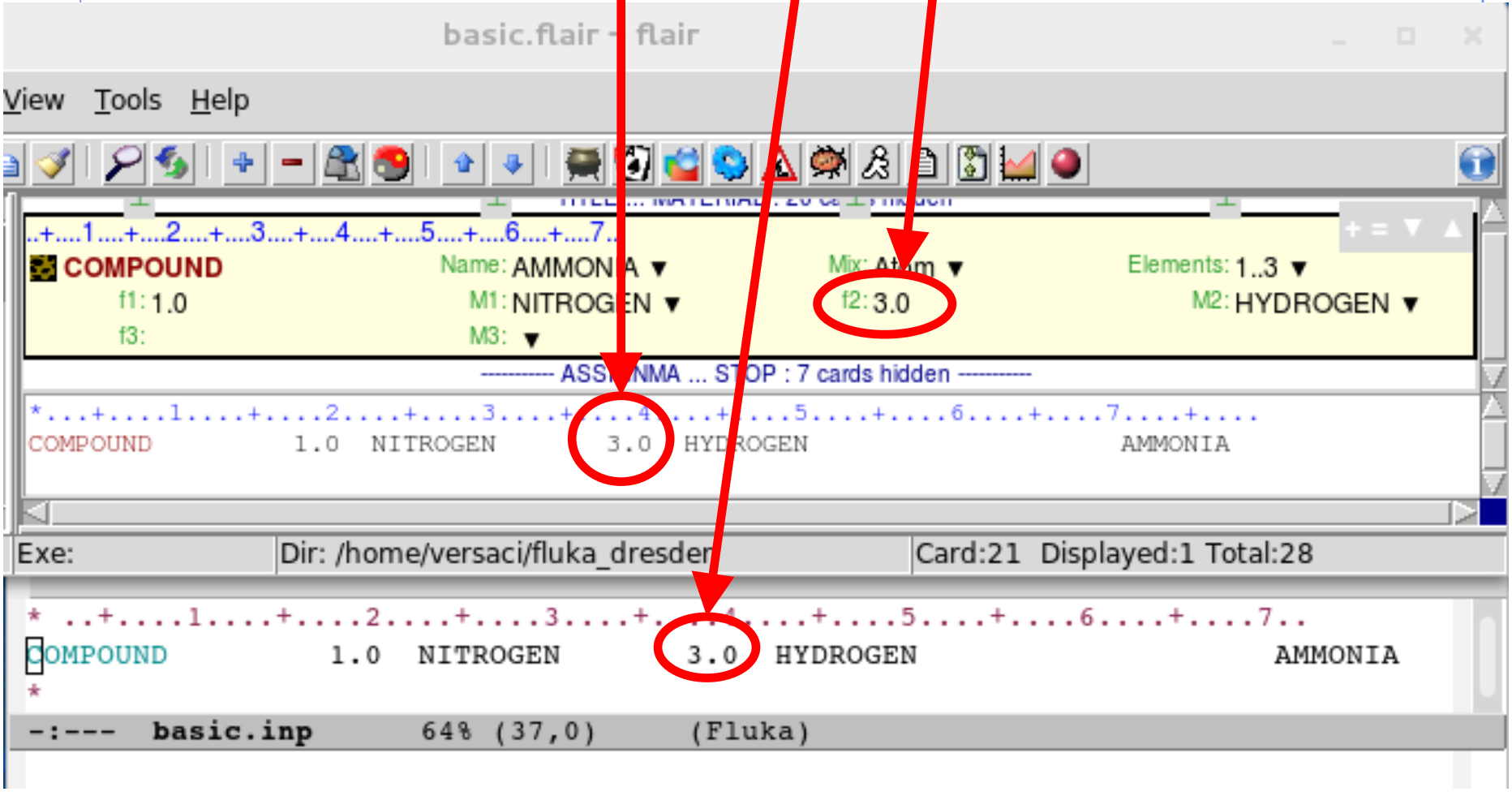
[WHAT(2)]: first component material



Material definition: **COMPOUND**

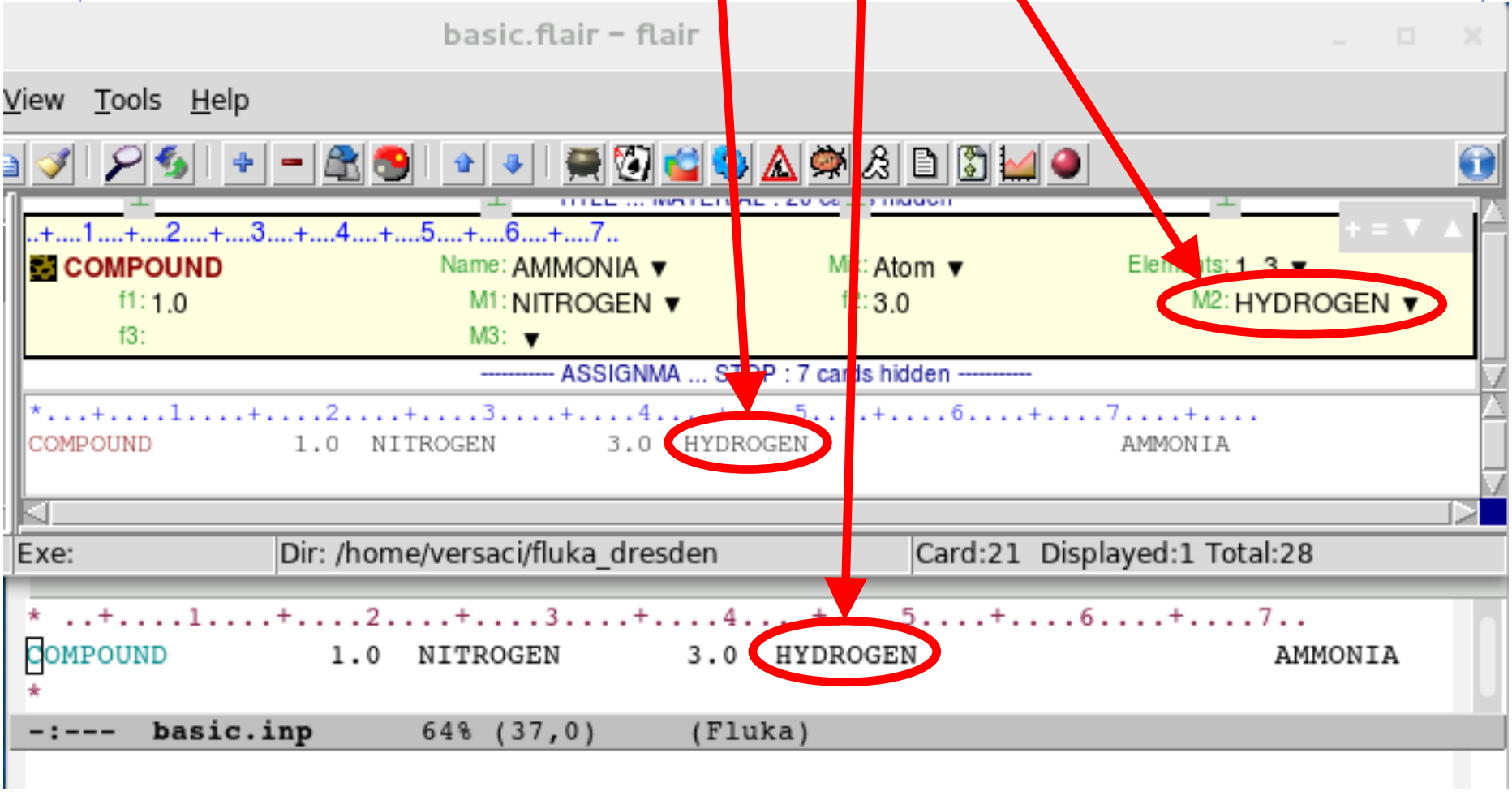
[WHAT(3)]: amount of the second component

Amount definition in few slides



Material definition: **COMPOUND**

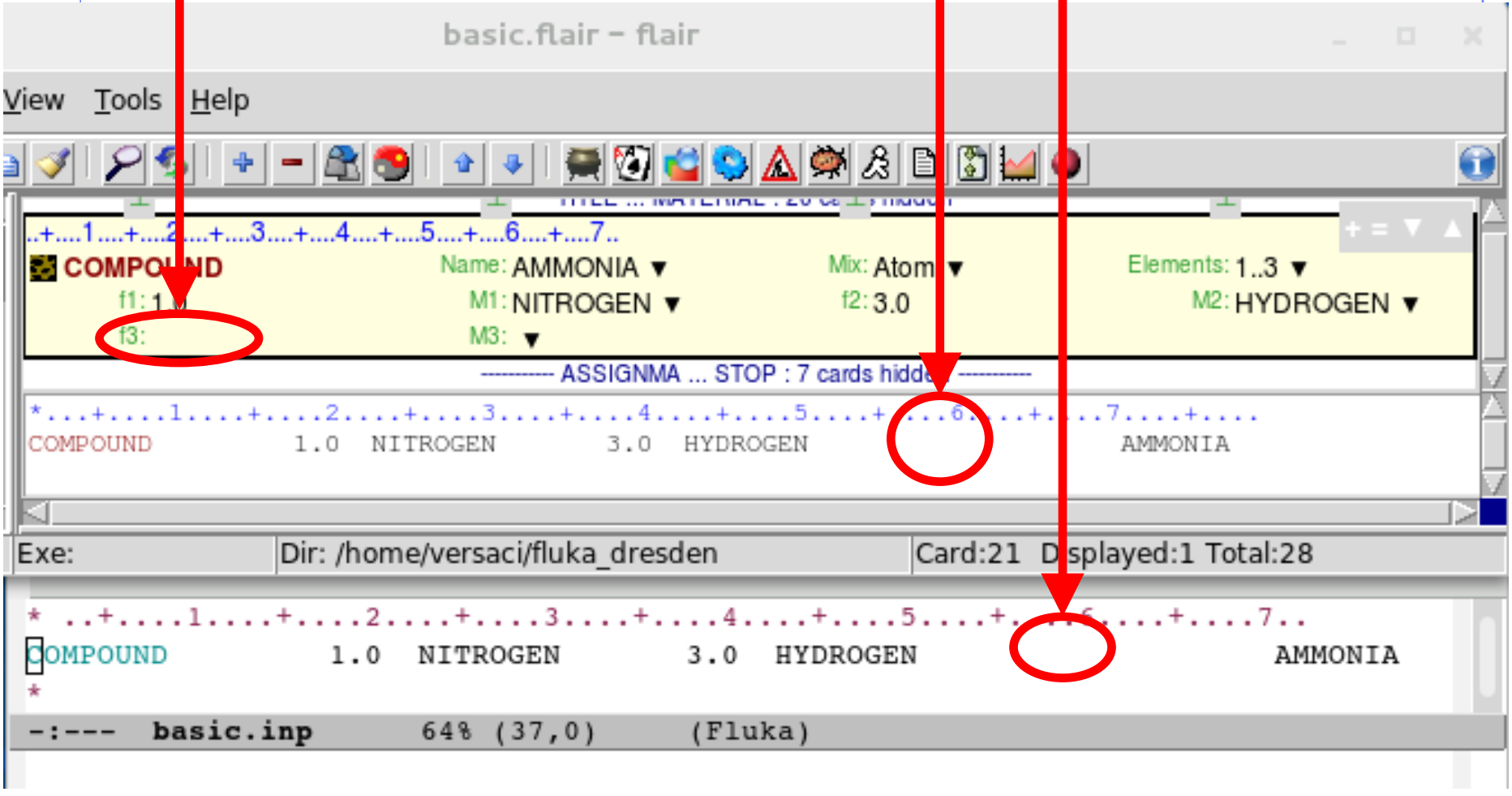
[WHAT(4)]: second component material



Material definition: **COMPOUND**

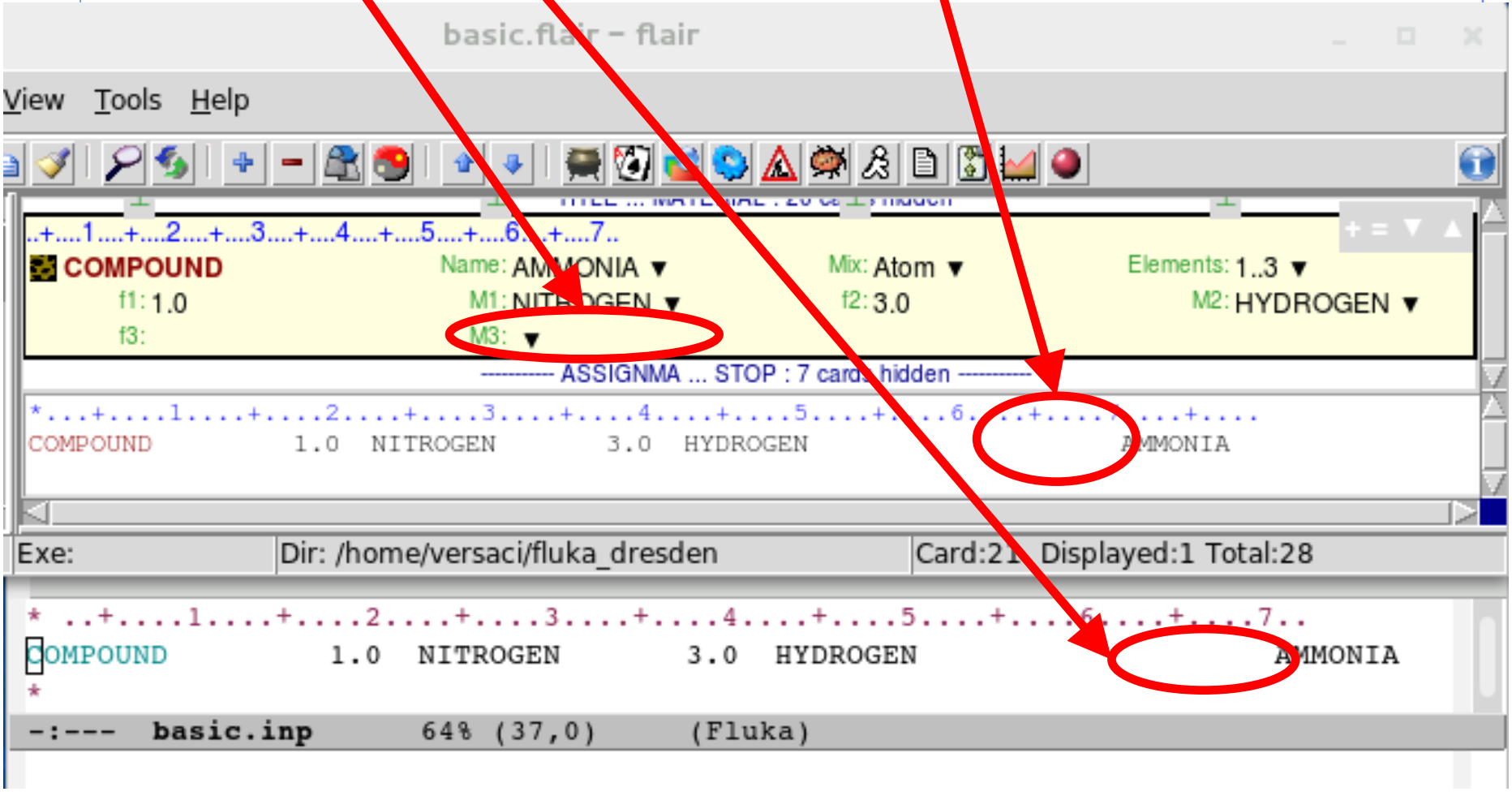
[WHAT(5)]: amount of the third component

Amount definition in few slides



Material definition: **COMPOUND**

[WHAT(6)]: third component material



Material definition: **COMPOUND**

Defines a new compound

Each **COMPOUND** card must be associated to a **MATERIAL** card

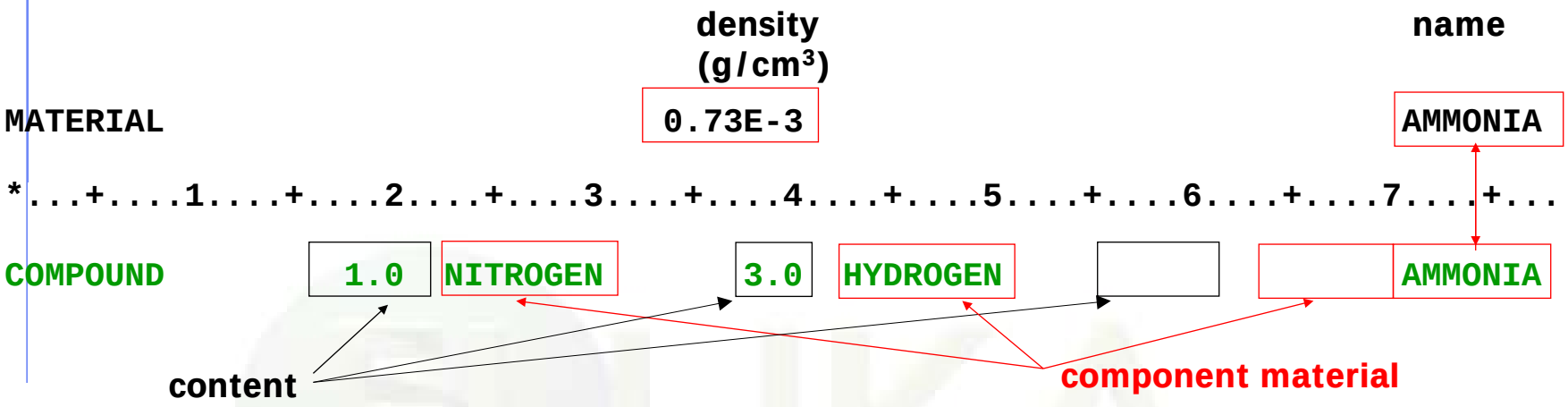
More **COMPOUND** card can be used to define a compound

- [SDUM] compound name
- [WHAT(1)] amount of the first component
- [WHAT(2)] first component material
- [WHAT(3)] amount of the second component
- [WHAT(4)] second component material
- [WHAT(5)] amount of the third component
- [WHAT(6)] third component material

How to define the “amount”?

```
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
COMPOUND          1.0   NITROGEN        3.0   HYDROGEN                    AMMONIA
*
```

Material definition: **COMPOUND**



content > 0	component material > 0	⟹ **ATOM content**
content < 0	component material > 0	⟹ **MASS content**
content < 0	component material < 0	⟹ **VOLUME content**

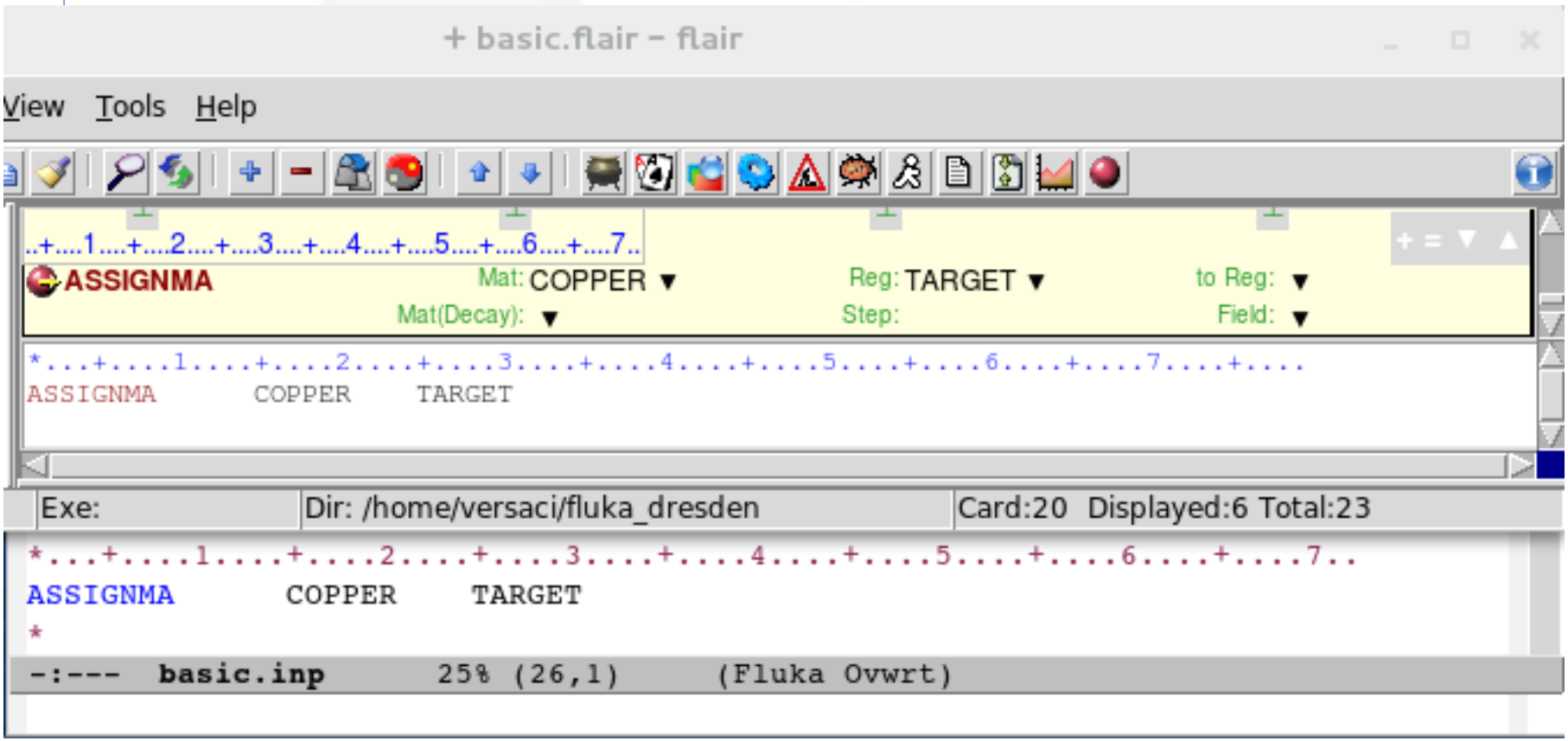
Names can be preceded by a minus sign!

Material definition: **ASSIGNMA**

Assign a material to one (or more) region in the geometry
(for the region definition see the geometry lecture or the manual)

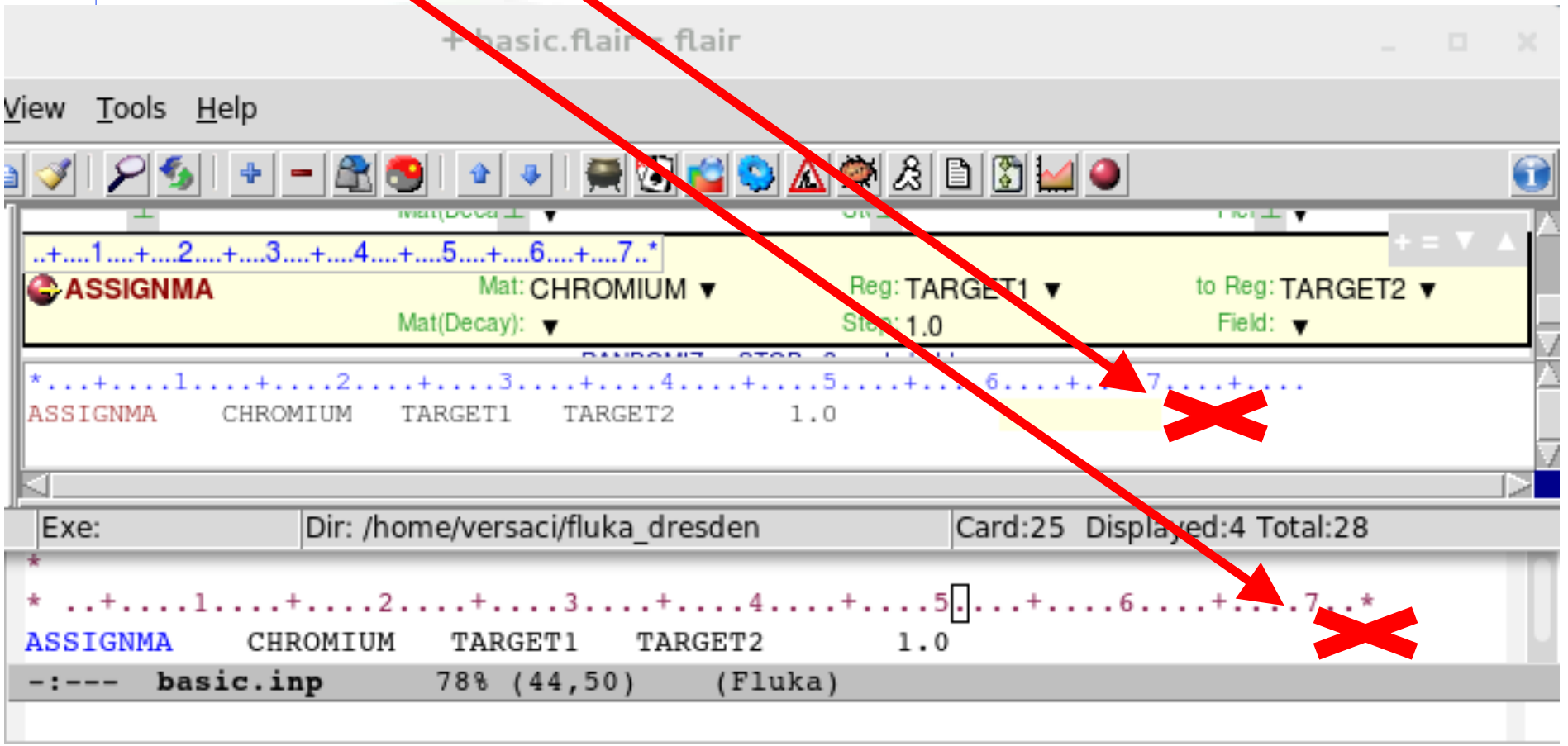
The assigned material could be

either a single element material or a compound



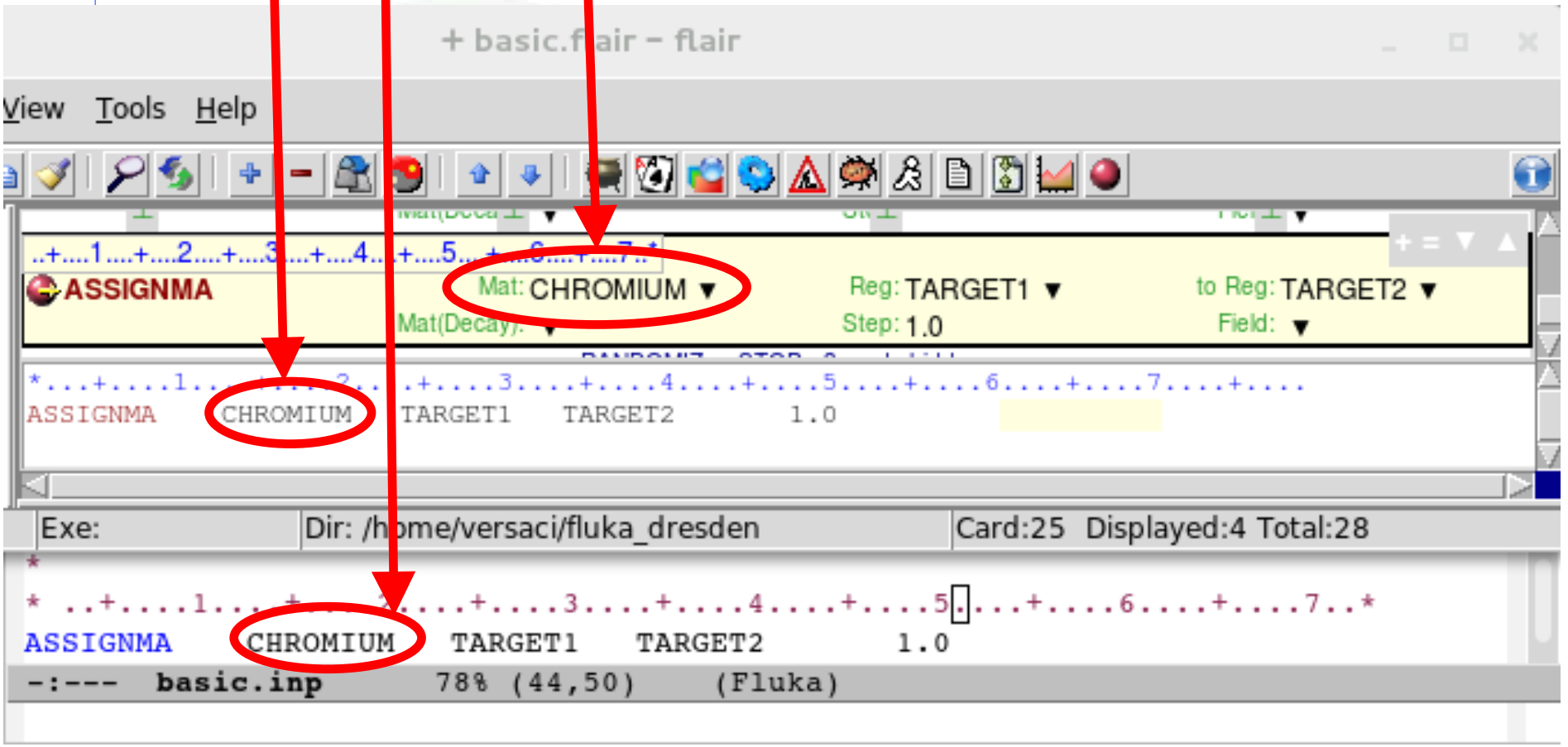
Material definition: **ASSIGNMA**

[SDUM]: not used



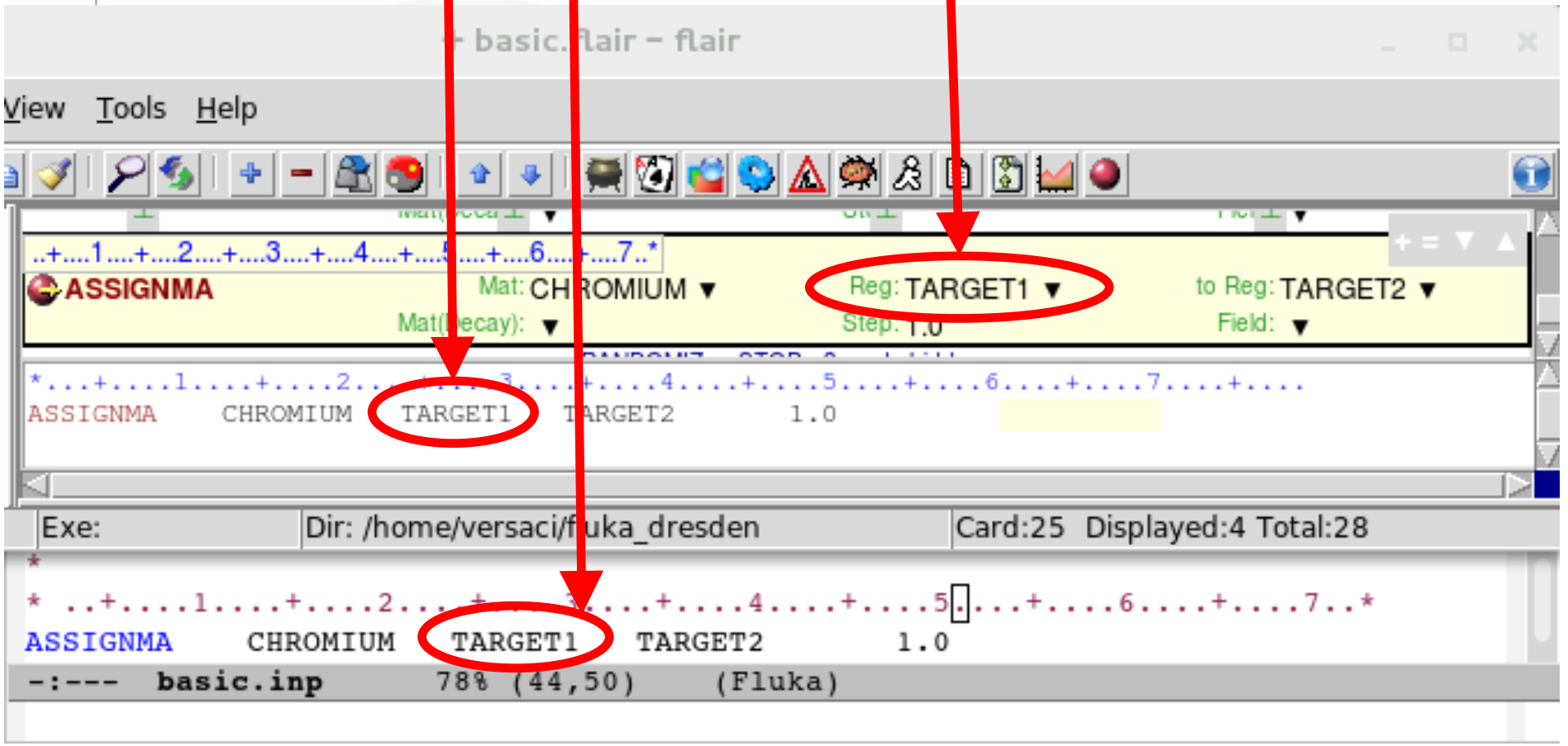
Material definition: **ASSIGNMA**

[WHAT(1)]: material to be assigned



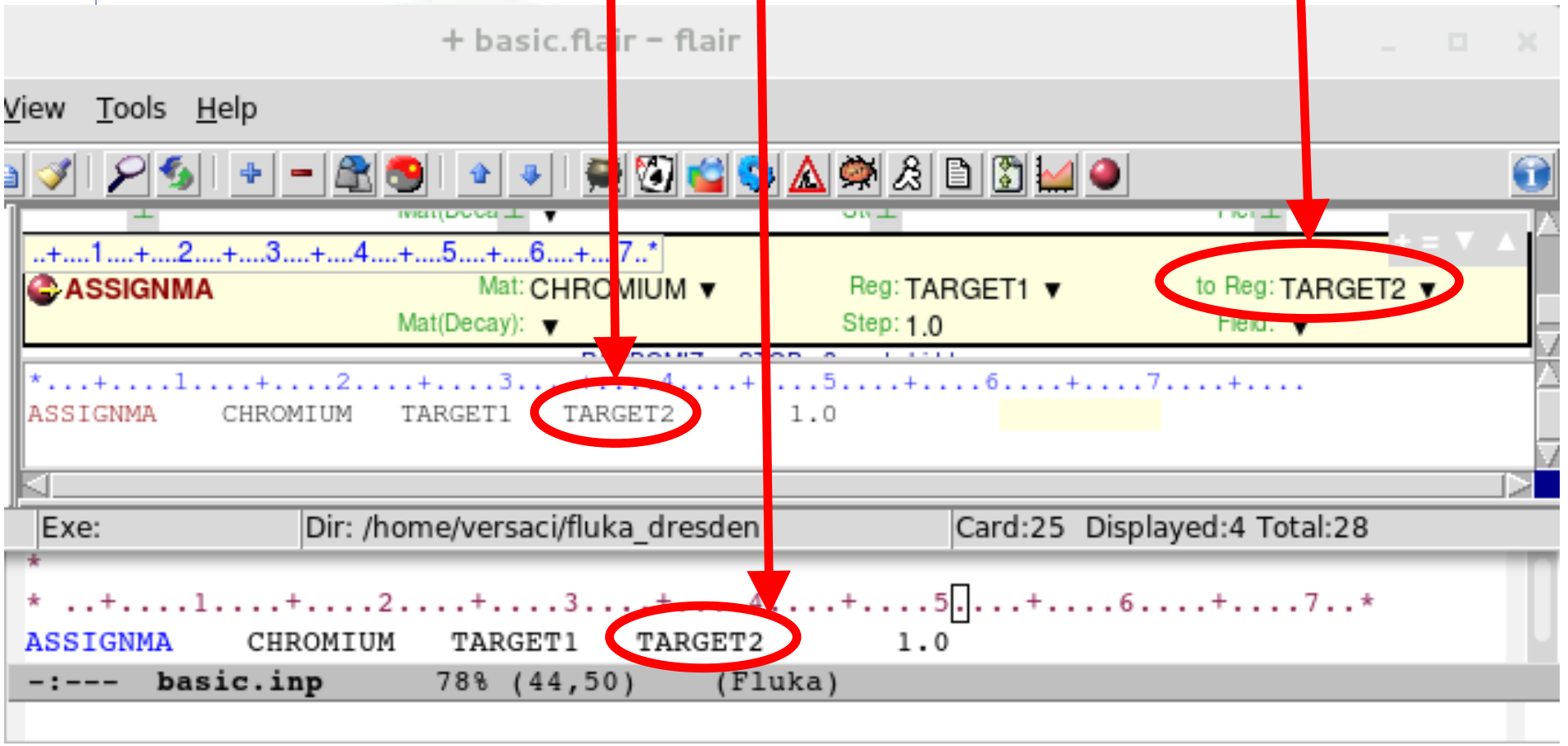
Material definition: **ASSIGNMA**

[WHAT(2)]: first region to be “filled” with the material



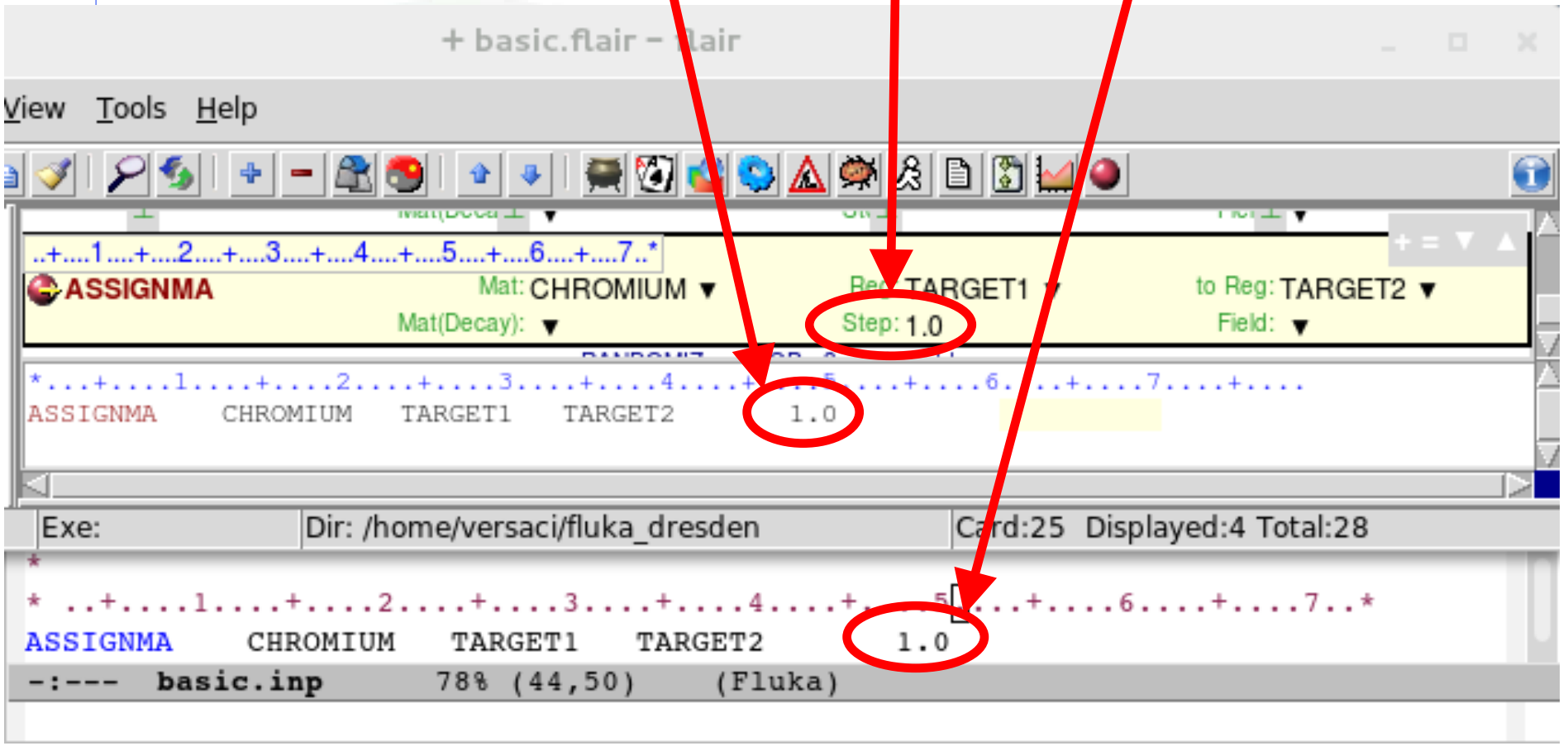
Material definition: **ASSIGNMA**

[WHAT(3)]: last region to be “filled” with the material



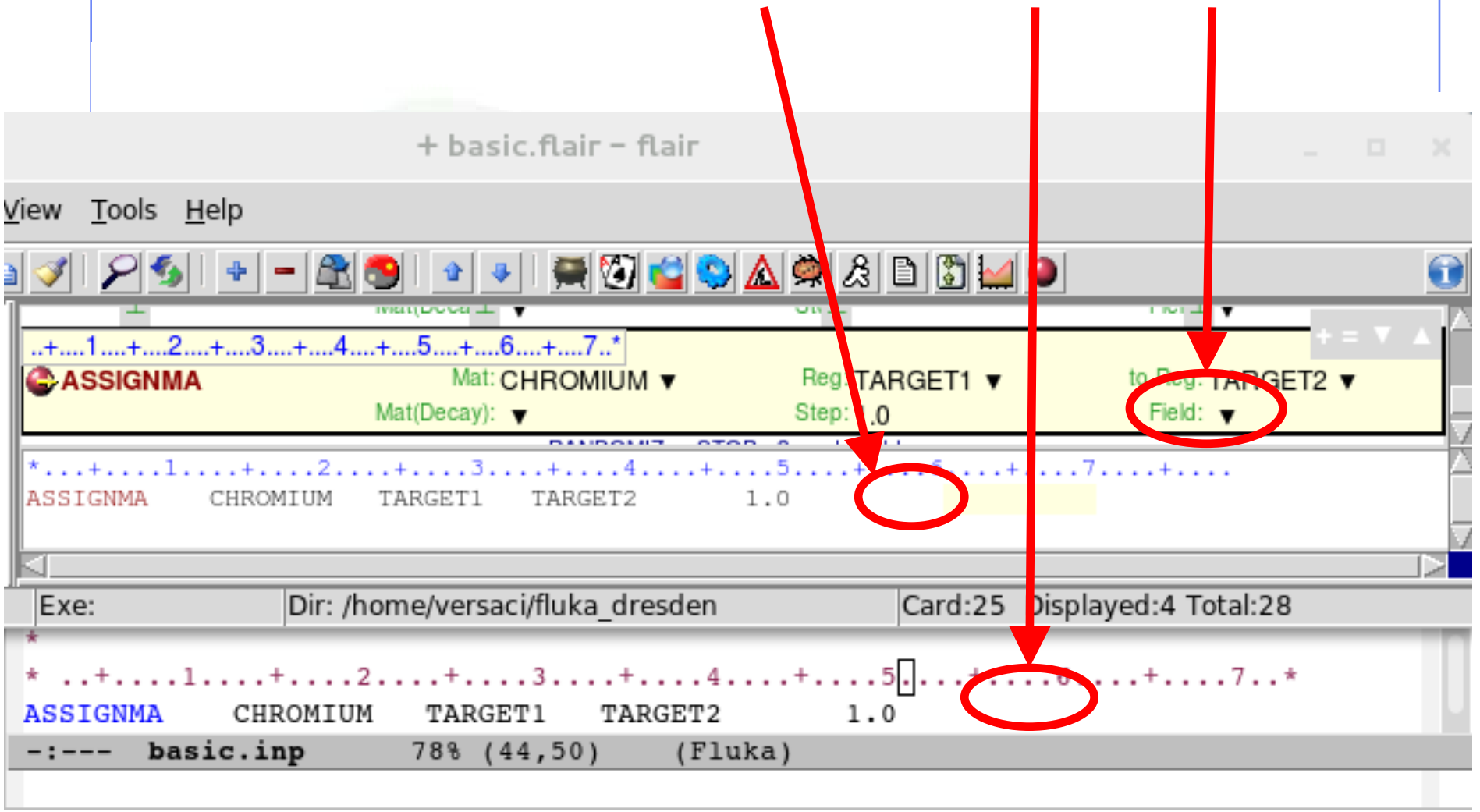
Material definition: **ASSIGNMA**

[WHAT(4)]: step to span region-to-be-filled range



Material definition: **ASSIGNMA**

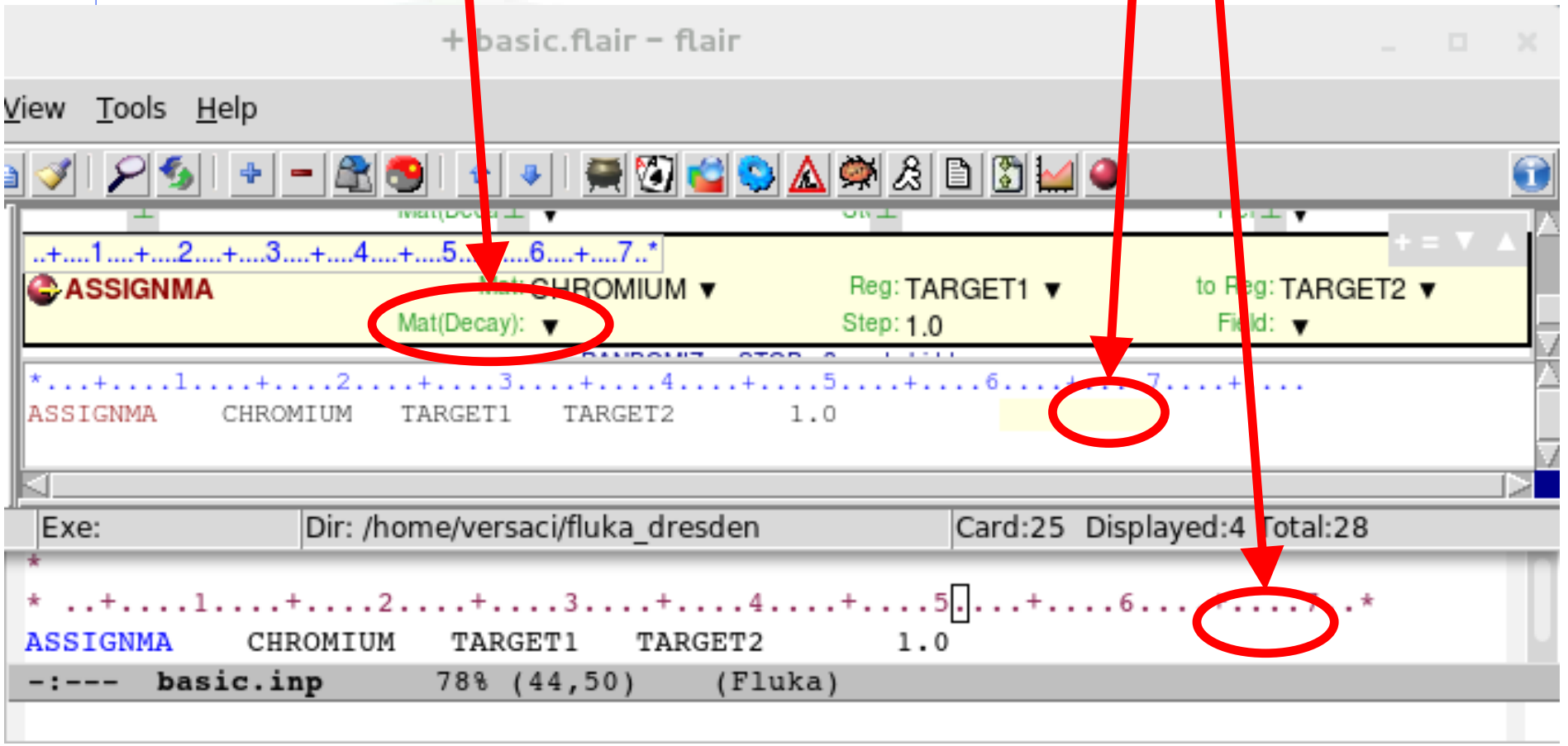
[WHAT(5)]: activate magnetic field in the concerned regions



Material definition: **ASSIGNMA**

[WHAT(6)]: assign another material for radioactive decay products transport

As of now, only **BLCKHOLE** and **VACUUM** supported



A basic input: step 5: Random Seed, **START**, and **STOP**

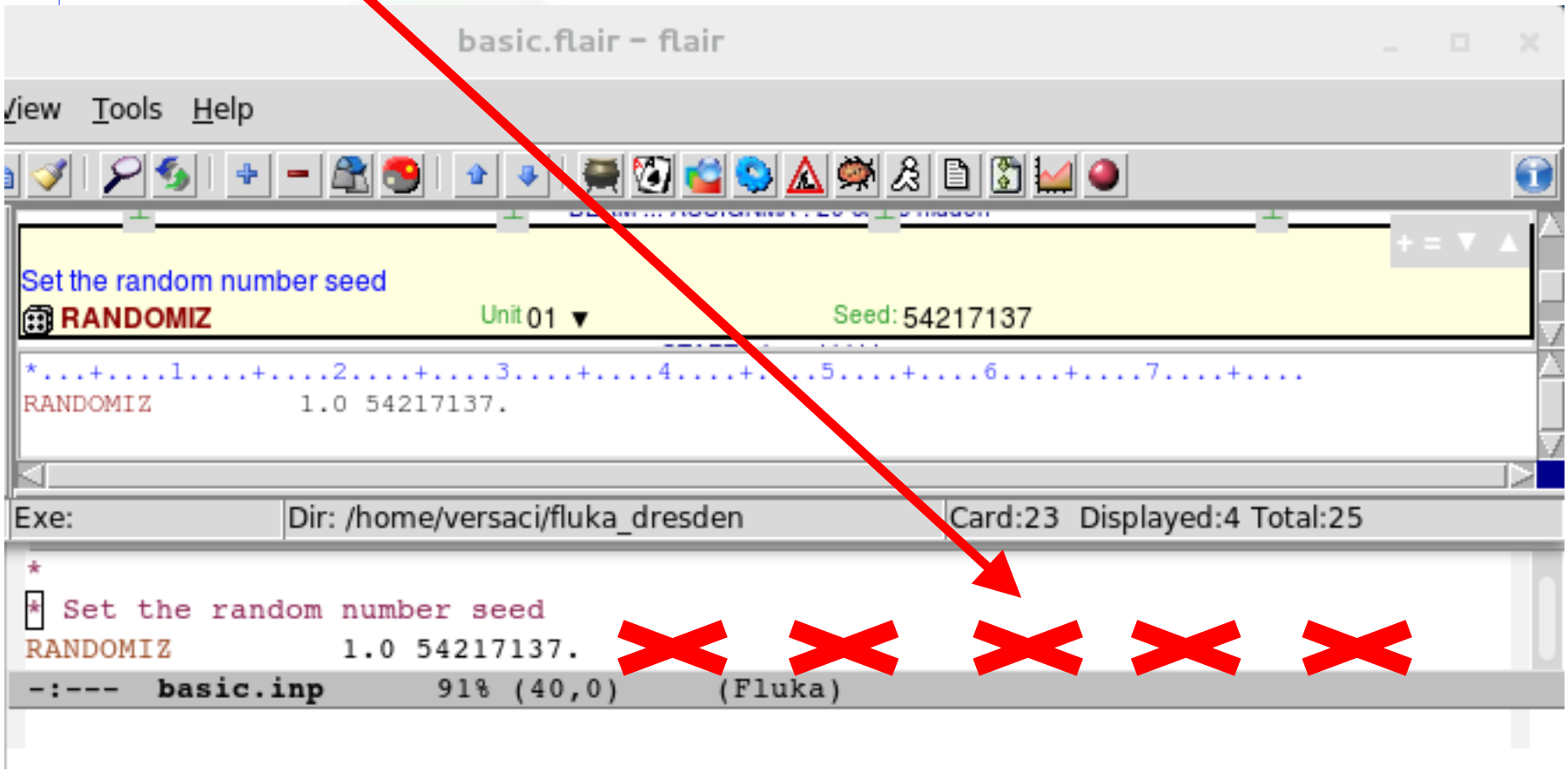
```
TITL
My B
* Se
DEFA
* Define the beam characteristics
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAM          3.5 -0.082425      -1.7       0.0       0.0          PROTON
* Define the beam position
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAMPOS         0.0       0.0      -0.1       0.0       0.0
*
GEOBEGIN                                                          COMBNAME
    0    0
* Black body
SPH blkbody    0.0 0.0 0.0 100000.0
* Void sphere
SPH void       0.0 0.0 0.0 10000.0
* Cylindrical target
RCC target1    0.0 0.0  0.0 0.0 0.0 10.0 5.0
RCC target2    0.0 0.0 20.0 0.0 0.0 10.0 5.0
RCC target3    0.0 0.0 40.0 0.0 0.0 10.0 5.0
END
* Black hole
BLKBODY      5 +blkbody -void
* Void around
VOID         5 +void -target1 -target2 -target3
* Target
TARGET1      5 +target1
TARGET2      5 +target2
TARGET3      5 +target3
END
GEOEND
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
MATERIAL        24.0               7.18                           CHROMIUM
MATERIAL         0.0            0.73E-3                           AMMONIA
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
COMPOUND         1.0  NITROGEN       3.0  HYDROGEN                AMMONIA
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
ASSIGNMA    BLCKHOLE   BLKBODY
ASSIGNMA      VACUUM      VOID
ASSIGNMA     AMMONIA   TARGET3
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..*
ASSIGNMA    CHROMIUM   TARGET1   TARGET2       1.0

* Set the random number seed
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
RANDOMIZ         1.0 54217137.
*
* Set the number of primary histories to be simulated in the run
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
START          1000.
STOP
```

BEAM		Beam: Momentum		p: 3.5		Part: PROTON	
	Δp: Gauss		Δp(FWHM): 0.082425		Δϕ: Gauss		Δϕ: 1.7
	Shape(X): Rectangular		Δx: 0.0		Shape(Y): Rectangular		Δy: 0.0
BEAMPOS		x: 0.0		y: 0.0		z: -0.1	
		cosx: 0.0		cosy: 0.0		Type: POSITIVE	
GEOBEGIN		Log:		Acc:		Opt:	
		Inp:		Out:		Fmt: COMBNAME	
	Title:						
SPH	blkbody	x: 0.0		y: 0.0		z: 0.0	
		R: 100000.0					
SPH	void	x: 0.0		y: 0.0		z: 0.0	
		R: 10000.0					
RCC	target1	x: 0.0		y: 0.0		z: 0.0	
		Hx: 0.0		Hy: 0.0		Hz: 10.0	
		R: 5.0					
RCC	target2	x: 0.0		y: 0.0		z: 20.0	
		Hx: 0.0		Hy: 0.0		Hz: 10.0	
		R: 5.0					
RCC	target3	x: 0.0		y: 0.0		z: 40.0	
		Hx: 0.0		Hy: 0.0		Hz: 10.0	
		R: 5.0					
END							
REGION	BLKBODY			Neigh: 5		Volume:	
	expr: +blkbody -void						
REGION	VOID			Neigh: 5		Volume:	
	expr: +void -target1 -target2 -target3						
REGION	TARGET1			Neigh: 5		Volume:	
	expr: +target1						
REGION	TARGET2			Neigh: 5		Volume:	
	expr: +target2						
REGION	TARGET3			Neigh: 5		Volume:	
	expr: +target3						
END							
GEOEND							
MATERIAL		Name: CHROMIUM		#		ρ: 7.18	
	Z: 24.0	Am:		A:		dE/dx:	
MATERIAL		Name: AMMONIA		#		ρ: 0.73E-3	
	Z: 0.0	Am:		A:		dE/dx:	
COMPOUND		Name: AMMONIA		Mix: Atom		Elements: 1..3	
	f1: 1.0	M1: NITROGEN		f2: 3.0		M2: HYDROGEN	
	f3:	M3:					
ASSIGNMA		Mat: BLCKHOLE		Reg: BLKBODY		to Reg:	
		Mat(Decay):		Step:		Field:	
ASSIGNMA		Mat: VACUUM		Reg: VOID		to Reg:	
		Mat(Decay):		Step:		Field:	
ASSIGNMA		Mat: AMMONIA		Reg: TARGET3		to Reg:	
		Mat(Decay):		Step:		Field:	
ASSIGNMA		Mat: CHROMIUM		Reg: TARGET1		to Reg: TARGET2	
RANDOMIZ		Unit 01		Seed: 54217137.			
START		No.: 1000.		Core:			
		Time:		Report: default			
STOP							

```
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+...
TITLE
My Basic Input example
```

Random seed initialization: **RANDOMIZ**

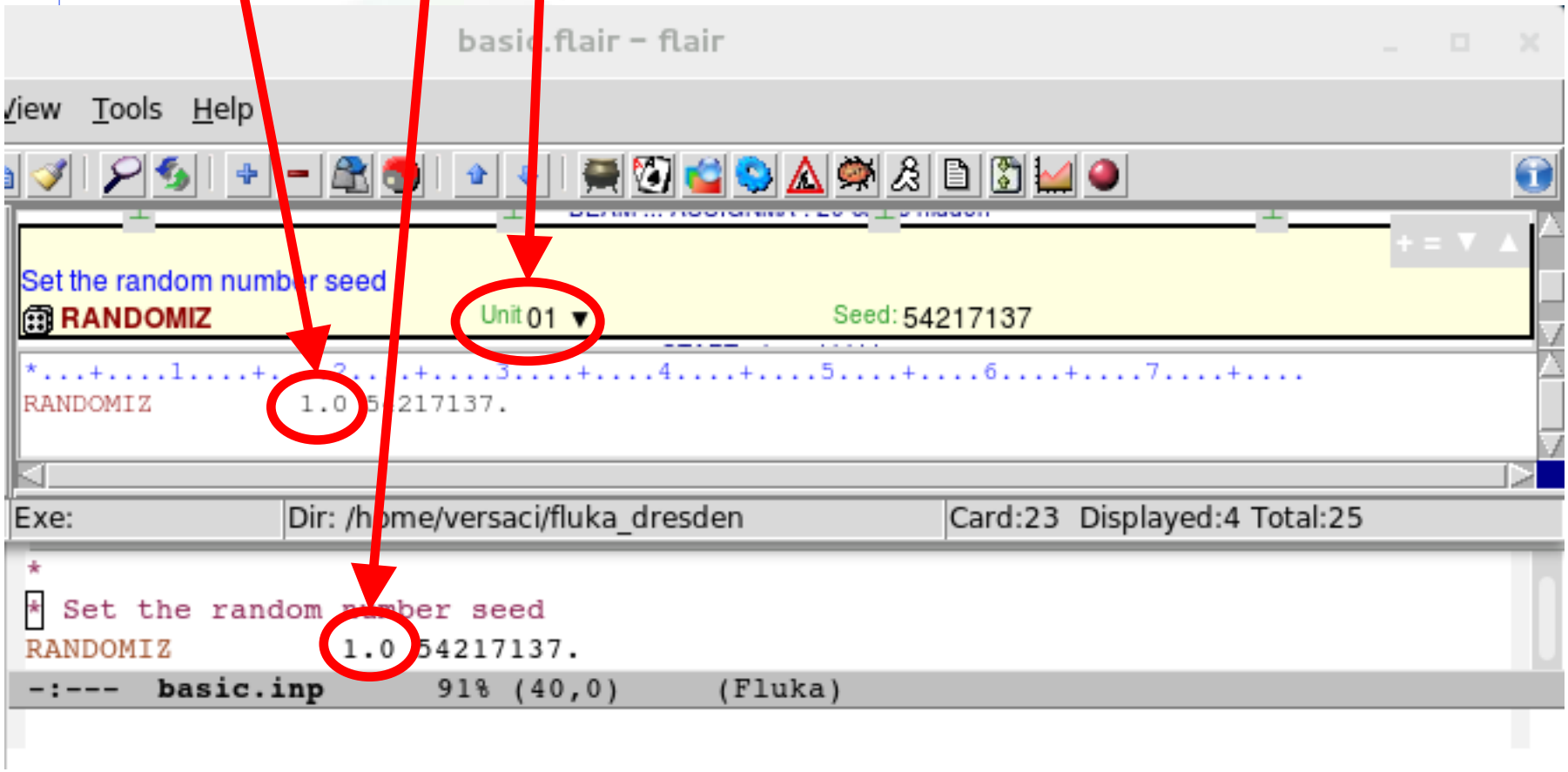
[SDUM]: not used
[WHAT(3-6)]: not used



Random seed initialization: **RANDOMIZ**

[WHAT(1)]: logical file unit where to read the seed

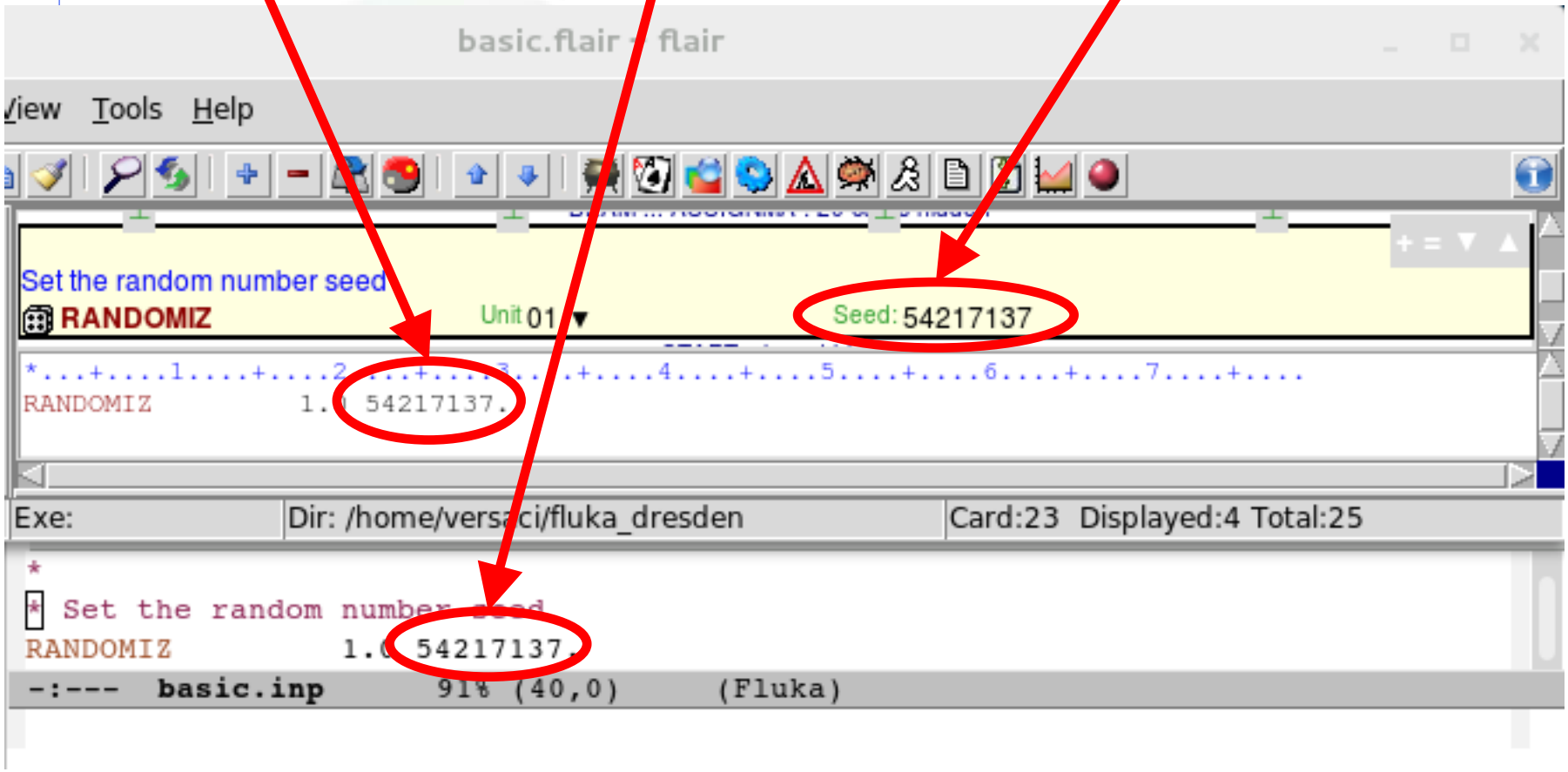
Do not touch! MUST be Unit 1



Random seed initialization: **RANDOMIZ**

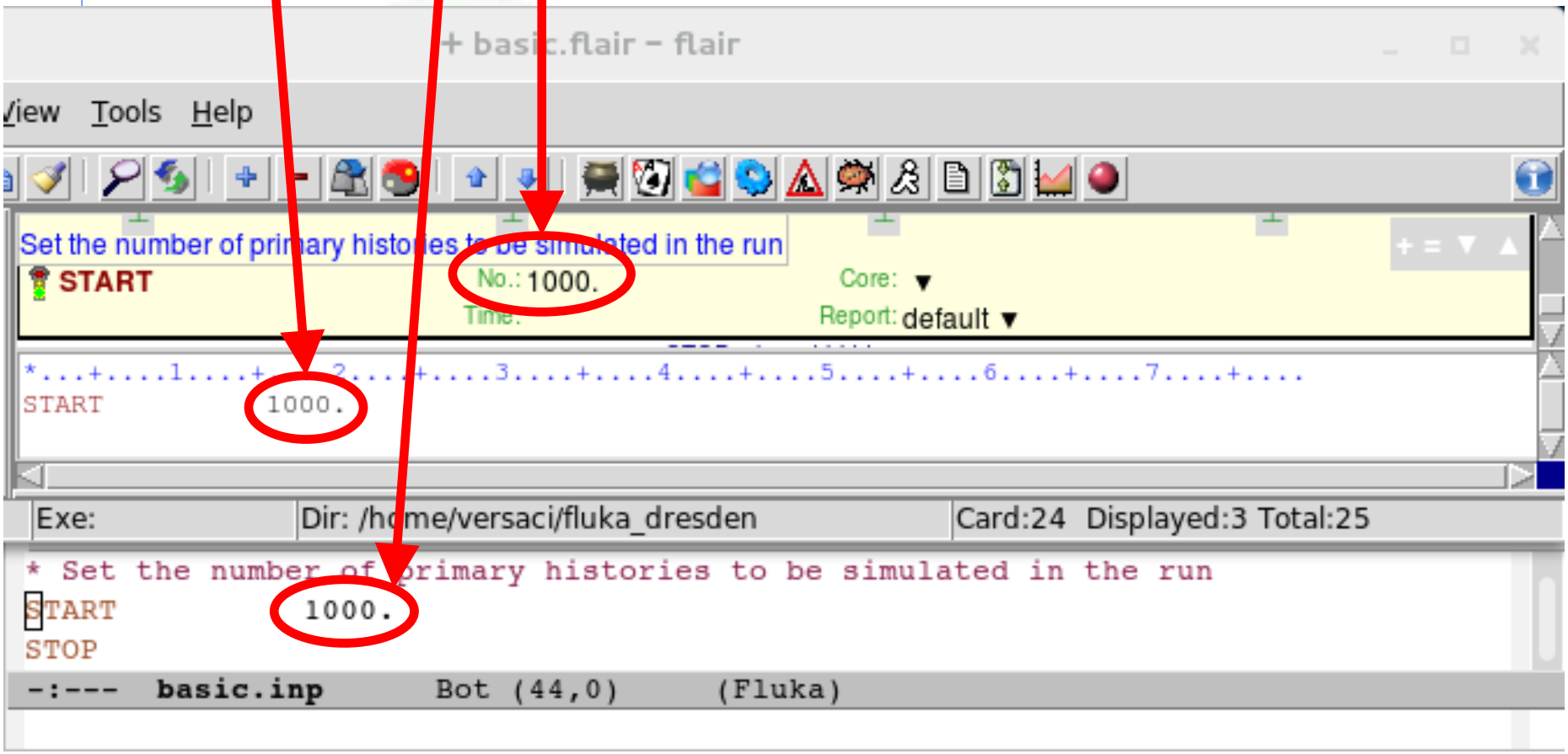
[WHAT(2)]: initialization of the random seed sequences

Different WHAT(2) lead to different sequences
allowing to run parallel jobs



Starting the simulation: **START**

[WHAT(1)]: number of primaries to be simulated



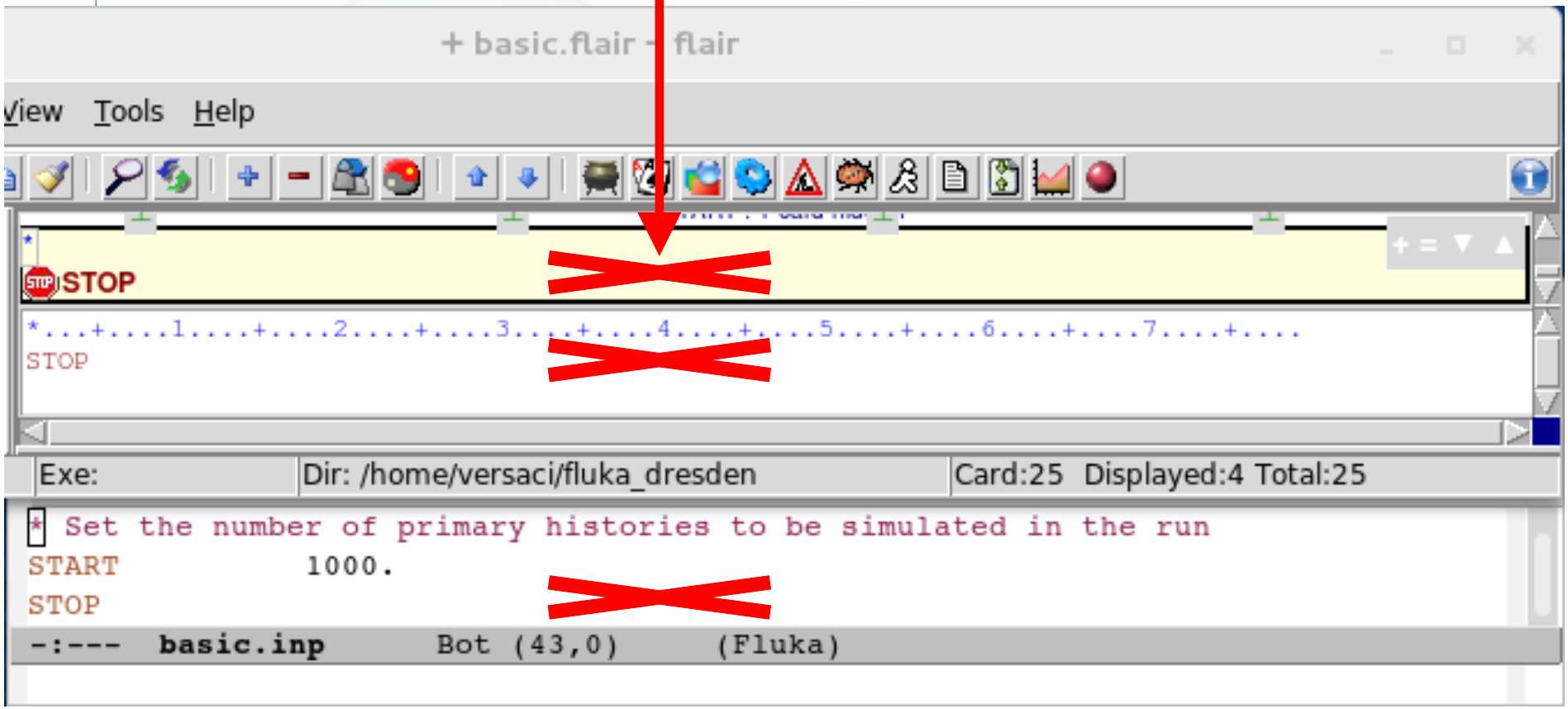
Stopping the program: **STOP**

[SDUM] & [WHAT(1-6)]: not used

Inserted before **START** stops input reading and de-activates all following cards

No particle transport is performed, useful for geometry debugging

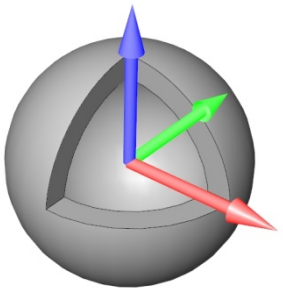
After **START**, its presence is optional and has no effect



Beyond a basic input

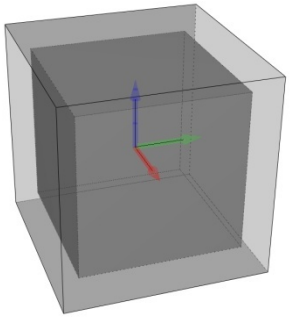
Special sources: 3D distributions

BEAMPOS card allows the user to define some 3D *spatial* distributions of source particles



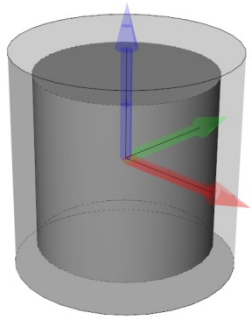
SDUM = SPHE-VOL:

defines a spatially extended source in a spherical shell



SDUM = CART-VOL:

defines a spatially extended source in a Cartesian shell with the sides parallel to the beam frame axes



SDUM = **CYLI-VOL**:

defines a spatially extended source in a cylindrical shell with the height parallel to the z-axis of the beam frame

SDUM = **FLOOD**:

defines a source distribution on a spherical surface, such as to produce a uniform and isotropic fluence within the sphere

Special sources: **SPECSOUR**

FLUKA allows the definitions of special sources for:

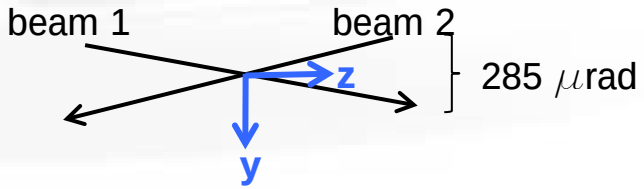
- two colliding beams
- galactic cosmic rays
- solar particles events

Various SDUM allow plenty of opportunities:

PPSOURCE, CROSSASY, CROSSSYM; GCR-IONF, GCR-SPEC, GCR-ALLF; SPE-SPEC, SPE-2003, SPE-2005

Example: LHC proton-proton collision

7 TeV/c, full crossing angle of 285 mrad in yz-plane



For all these special cases of source distributions, please, refer to the FLUKA manual!

FLUKA Preprocessor

- FLUKA supports preprocessing instructions like those used in C or C++
- This useful feature allows to keep different setups and configurations in a single input file, selecting the desired one when starting a run
- FLAIR supports this feature and allows to run different configurations in an easy way
- The **`#include`** directive can ease the handling of large input files

Conditional directives:

```
#define VARIABLE1
#undef VARIABLE2
#if VARIABLE1
#elif VARIABLE2
#else
#endif
```

Up to 10 nested levels of conditional statements (#if/#else/#endif) are supported

Include directive:

```
#include /home/geometries/target2.geom
```

FLUKA Preprocessor example

#define can be either commented out or undefined
e.g.: **#undef DUMP_COPPER**

```
#define DUMP_COPPER
*#define DUMP_CARBON
*
#if DUMP_COPPER
* Select copper as material for the dump
*...+....1....+....2....+....3....+....4....+....5....+....6
ASSIGNMA      COPPER  BEAMDUMP
#elif DUMP_CARBON
* Select carbon as material for the dump
ASSIGNMA      CARBON  BEAMDUMP
#else
* Use default material for the dump
ASSIGNMA        IRON  BEAMDUMP
#endif
```

Depending on the active define
(**DUMP_COPPER** or **DUMP_CARBON**)
different **ASSIGNMA** card are used

Spare

More Physics settings

Input card **PHYSICS**

Allows to override standard FLUKA defaults for some processes:

- activates coalescence (critical for calculation of residual nuclei)
- activates the new fragmentation model ("evaporation" of fragments up to A=24, critical for calculation of residual nuclei)
- activates PEANUT above 5 GeV
- activates electromagnetic dissociation of heavy ions
- activates charmed particle transport

Input card **PHOTONUC**

- activates photo-nuclear interactions
- activates muon pair production by photons

The use of the **LAM-BIAS** card (see Biasing lecture) coupled to the **PHOTONUC** card is recommended, in order to artificially *increase* the probability to have photonuclear reactions

Transport thresholds

Input card **PART-THR**

- Defines transport cut-offs for hadrons, muons, and neutrinos
- Setting done by particle type, overriding the selected **DEFAULTS**
- For **neutrons**, a <20.0 MeV cut-off is internally translated into the corresponding group energy; On a region basis, the neutron cut-off can be *increased* by the **LOW-BIAS** card (see Neutrons lecture)
- Charged particles (but electrons) are not stopped, but ranged out to rest in an approximate way (if the threshold is < 100 MeV)

Input card **EMFCUT**

For electron, positron, and photon, sets:

- Energy thresholds for production in the selected materials
- Transport cut-offs in the selected regions.
- Use **STRONGLY** recommended

Input card **DELTARAY**

- Activates delta ray production by muons and charged hadrons
- Sets energy threshold for their production

Low energy neutrons (E < 20.0 MeV)

FLUKA transports neutrons with energies lower than 20 MeV by means of a multi-group algorithm, based on 260 groups (See Neutrons lecture)

Input card **LOW-NEUT**

- Activates low-energy neutron transport
  (by default off only in EM-CASCA)
- Requests point-wise cross sections
  (only available for a few elements, see manual)

Input card **LOW-MAT**

- Sets the correspondence between FLUKA materials and low-energy neutron cross-sections
- By default, the link is between the FLUKA material and the first material of the same name present in the library. Therefore, the option is not needed in many cases

Heavy ions: beams and transport

Input card **HI-PROPE**

- When **BEAM**'s SDUM is **ISOTOPE**...

  ...specifies the isotope of a radioactive source

  ...requires a **RADDECAY** card

- When **BEAM**'s SDUM is **HEAVYION**...

  ...specifies the properties of an ion beam:

  in the **BEAM** card, the beam energy is given in GeV/nmu

  (**n**uclear **m**ass **u**nit, i.e. 1/12 of the ^{12}C nucleus mass)

  ^{2}H, ^{3}H, ^{3}He, and ^{4}He beams have dedicated SDUM in the **BEAM** card

Heavy ions: beams and transport

Input card **IONTRANS**

- Is not required when using an heavy ion beam **HEAVYION**
- Activates the ions transport
- Allows to limit it to a subset of light ions (A < 5)
- Switches between approximate and full transport

  ...(including nuclear interactions)
- Nucleus-nucleus interactions above 125 MeV/n

  ...can be performed only if the event generators

  DPMJET and RQMD are linked to the FLUKA executable
- Below 125 MeV/n...

  ...the BME event generator is already linked in the standard executable

Materials special cards

Input card **MAT-PROP**

Allows to provide extra information about materials
(e.g.: gas pressure, effective density, average ionization potential)

Input card **CORRFACT**

Allows to change material density for dE/dx and nuclear processes
on a region-by-region basis
(used in connection with voxel geometries derived from a CT scan)

Induced radioactivity

Input card **RADDECAY**

- Activates the simulation of the decay of generated radioactive nuclides
- Allows to set biasing for radioactive decay products

Input card **IRRPROFI**

- Defines an irradiation profile (i.e. irradiation time and intensity)

Input card **DCYTIMES**

- Defines the decay (cooling) time

Input card **DCYSCORE**

- Associates scoring detectors (radio-nuclides, fluence, dose) with different cooling times