蘭州大學
LANZHOU UNIVERSITY

Scoring example

23rd FLUKA Beginner's Course
Lanzhou University
Lanzhou, China

June 2–7, 2024

Exercise: USRBIN

- Start from the solution of Geometry_exercise (either copy your `.inp` and .flair files and rename them to `example_score`, or download/copy the file `Geometry_exercise/geometry_solution.inp` and rename it):

```
mkdir example_scoring
cp Geometry_exercise/geometry_solution.inp example_score/ex_Score.inp
cd example_scoring
```

- Open in FLAIR or with your preferred editor
- Add USRBIN scoring to:
  1) score Energy on a CYLINDRICAL GRID (R, Φ, Z covering the target and surroundings: $0 < r < 10$ cm, $-5 < z < 15$ cm, with cells having $\Delta r = \Delta z = 1$ mm, $\Delta\Phi = 2\pi$, Output unit = 40 BIN
  2) score Neutron Fluence on the same grid, Output unit = 41 BIN
  3) score Charged Hadron Fluence on the same grid, Output unit = 42 BIN
- Run 5 cycles, 1000 primaries each

Exercise: USRBIN

1) Add USRBIN to score ENERGY on a CYLINDRICAL GRID (R, Φ, Z) covering the target and the surroundings: $0 < r < 10$ cm, $-5 < z < 15$ cm, with cells having $\Delta r = \Delta z = 1$ mm, $\Delta\Phi = 2\pi$

```
* Energy deposition [GeV/cm^3]
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7...
USRBIN           11.     ENERGY       -40.       10.0                 15.0TargEne
USRBIN           0.0                  -5.0       100.                 200. &
```

- This is an R-Φ-Z binning (WHAT(1) = 11.), scoring energy density (generalized particle ENERGY, or FLUKA PID 208), writing unformatted output to unit 40, spanning $0 < R < 10$ cm in 100 bins, $0 < \Phi < 2\pi$ in 1 bin (default), $-5 < Z < 15$ cm in 200 bins.

Exercise: USRBIN

2) Add USRBIN to score Neutron Fluence on the same grid as before:

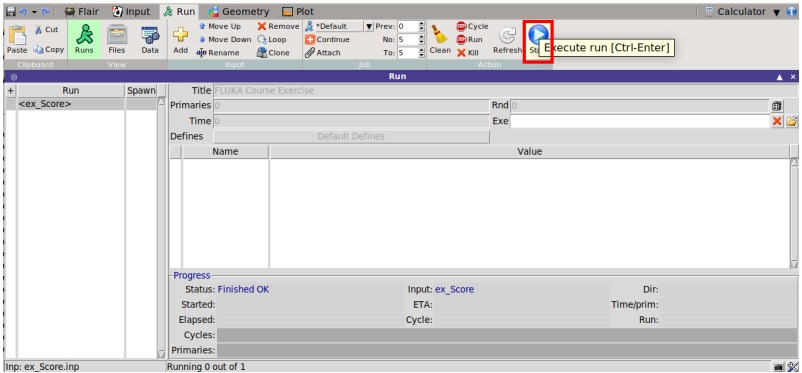
```
* Neutron fluence [1/cm^2]
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7...
USRBIN           11.    NEUTRON       -41.       10.0                 15.0TargNeu
USRBIN           0.0                  -5.0       100.                 200. &
```

- This is an R-Φ-Z binning (WHAT(1) = 11.), scoring neutron fluence (particle NEUTRON, or FLUKA PID 8), writing unformatted output to unit 41, spanning $0 < R < 10$ cm in 100 bins, $0 < \Phi < 2\pi$ in 1 bin (default), $-5 < Z < 15$ cm in 200 bins.

3) Add USRBIN to score Charged Hadron Fluence (HAD-CHAR) on the same grid as before, writing to output unit = 42 BIN.
   - You can use the Clone button in FLAIR to clone the previous scorer, then modify Unit: and Part: accordingly
   - Or simply the copy the two lines in your favorite text editor...

Exercise: USRBIN

Run the input file by clicking the button in the "Run"-menu of FLAIR:

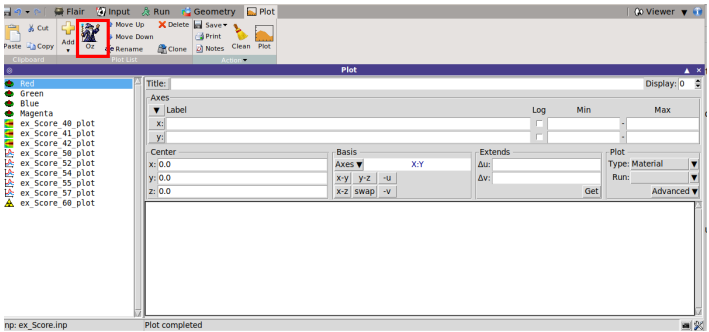


Or execute FLUKA on the commandline:

```
$FLUPRO/flutil/rfluka  -e  $FLUPRO/flukahp  -N0 -M5  ./ex_Score
```

Exercise: USRBIN - Plotting of the data

Plots can be created in the "Plot" menu - add new plots or clone from existing ones:



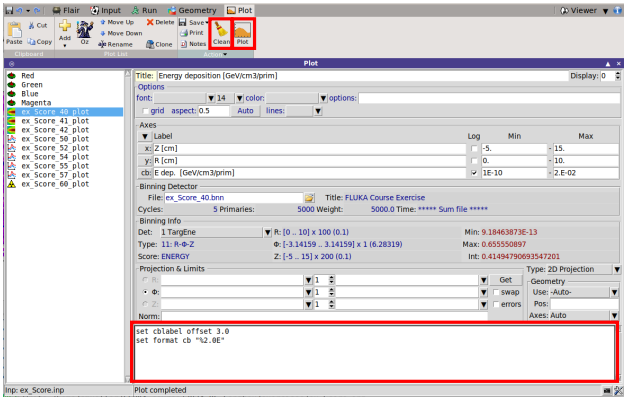
- The "Wizard" button scans the input and creates automatically a plot for each processed unit
- Set a unique filename for each plot
  - This filename will be used for auxiliary files that the plot needs

Plot types:

- Geometry — For geometry plots
- USRBIN — For plotting the output of USRBIN
- USR-1D — To plot single differential quantities from USRBDX, USRTRACK, USRCOLL, USRYIELD
- USR-2D — To plot double differential distributions from USRBDX
- RESNUCLE — To plot 1d or 2d distributions from RESNUCLEi
- USERDUMP — To plot the output of USERDUMP
  Useful for visualizing source distribution

Exercise: USRBIN - Plotting of the data

FLAIR uses **GNUPLOT** to create the plots:

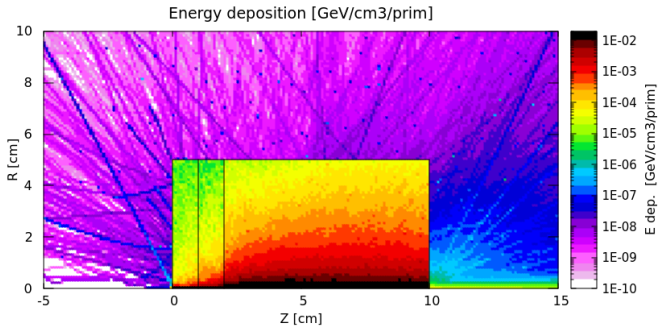


- For all plots one can specify: Title + options, filename, axis labels, legends, Gnuplot commands
- The button (Ctrl-Enter) will generate all the necessary files (if they don't exist yet) and produce the plot
- The button will remove al files generated by FLAIR during plotting (useful when the plot name was changed)

- Additional GNUPLOT commands can be specified in the white field, e.g.:
  - Change colorband label offset
  - Change format of colorband (cb) palette values to "%2.0E"

Exercise: USRBIN → The result

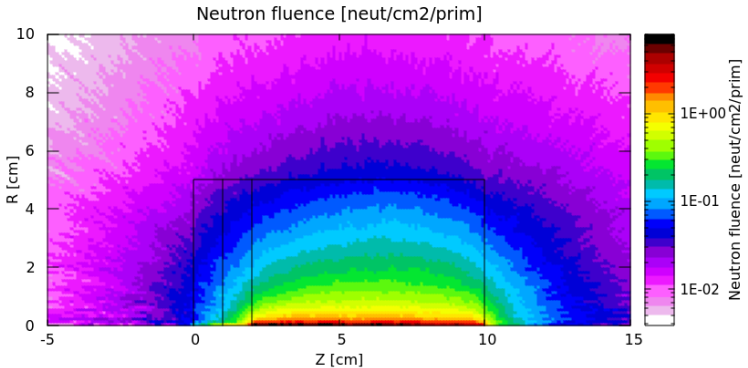
WHAT(2) = ENERGY: Energy deposition from a 3.5 GeV proton beam hitting at [0., 0., 0.] directed alona z. Results are normalized to **GeV/cm^3 per primary**



This plot is a 2D projection of a 3D structure → the result is averaged over the 3rd coordinate. Projection limits can be set in FLAIR.

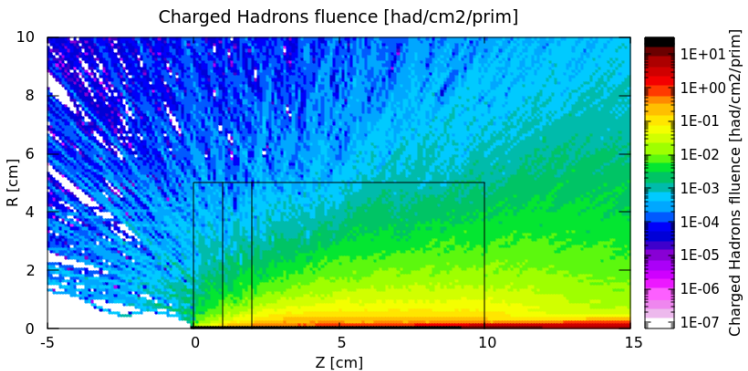
Exercise: USRBIN → The result

Same for WHAT(2) = NEUTRON: Neutron fluence from a 3.5 GeV proton beam hitting at [0., 0., 0.] directed along z. Results are normalized to **neutrons/cm^2 per primary**



Exercise: USRBIN → The result

Same for WHAT(2) = HAD-CHAR: Charged hadron fluence from a 3.5 GeV proton beam hitting at [0., 0., 0.] directed along z. Results are normalized to **charged hadrons/cm^2 per primary**



Exercise: USRBDX

1) Score CHARGED HADRONS at the outer surface of the lead segment (from TARGS3 to INAIR). WHAT(1)=99 means: fluence scoring, one-way only, logarithmic intervals in energy from 1 MeV to 10 MeV in 40 ntervals, and *one angular interval (default).* WHAT(6) is a normalization factor: setting it equal to the surface area provides results normalized to cm^{-2} (unit of fluence) GeV^{-1} sr^{-1} per primary particle. Write the output to unformatted unit 50:

```
*  charged hadron fluence exiting lead target
USRBDX          99.   HAD-CHAR      -50.     TARGS3      INAIR     329.87Sp3ChH
USRBDX          10.      0.001       40.                                  &
```

charged hadron fluence exiting lead target

USRBDX

Type: Φ1,LogE,LinΩ ▾ | Reg: TARGS3 ▾ | Unit: 50 BIN ▾ | Name: Sp3ChH

Part: HAD-CHAR ▾ | Emin: 0.001 | to Reg: INAIR ▾ | Area: 329.87

Ωmin: | Emax: 10. | Ebins: 40.

Ωmax: | Ωbins:

Repeat the same between TARGS1 and TARGS2, and between TARGS2 and TARGS3 (take care to use the correct normalization factor!).

Exercise: USRBDX

2) Score CHARGED HADRONS at the surface between 2nd and 3rd section, but in 3 angular bins:

```
*  double-differential charged hadron fluence entering lead target
USRBDX            99.   HAD-CHAR      -54.     TARGS2     TARGS3    78.5398Sp2ChHA
USRBDX            10.     0.001       40.                                 3. &
```

double-differential charged hadron fluence entering lead target

USRBDX

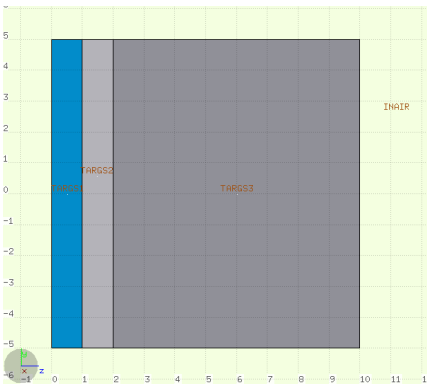
Type: Φ1,LogE,LinΩ ▾ | Reg: TARGS2 ▾ | Unit: 54 BIN ▾ | Name: Sp2ChHA

Part: HAD-CHAR ▾ | Emin: 0.001 | to Reg: TARGS3 ▾ | Area: 78.5398

Ωmin: | Emax: 10. | Ebins: 40.

Ωmax: | Ωbins: 3.

Exercise: USRBDX - Normalization



R_{TARG} = 5 cm

Z_{TARGS1} = Z_{TARGS2} = 1 cm

Z_{TARGS1} = 8 cm

Area between TARGS2 and TARGS3:

πR_{TARG}^2 = **78.5398 cm²**

Area between TARGS3 and INAIR:

$\pi R_{TARG} Z_{TARGS3} + \pi R_{TARG}^2$ = **329.87 cm²**

Exercise: USRBDX - Results

The result shows the evolution of charged hadron spectra at the different surfaces. post-processed results are normalized to GeV^{-1} cm^{-2} per primary (only if surface area is explicitely given).

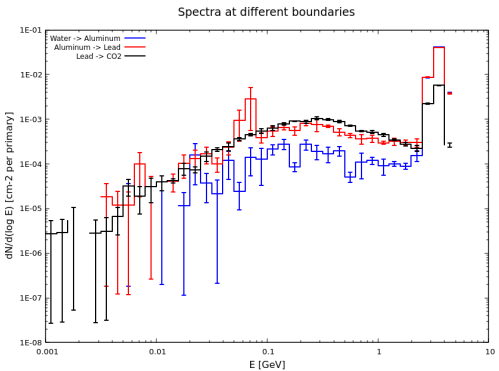
From post-processing, we get **single** differential spectra since we asked for one angular bin only

- **Lethargy plots** are used to display spectra where the energy extends over may orders of magnitude

$$y = \frac{dn}{d(logE)} = E\frac{dN}{dE}$$

Value: <X>*Y

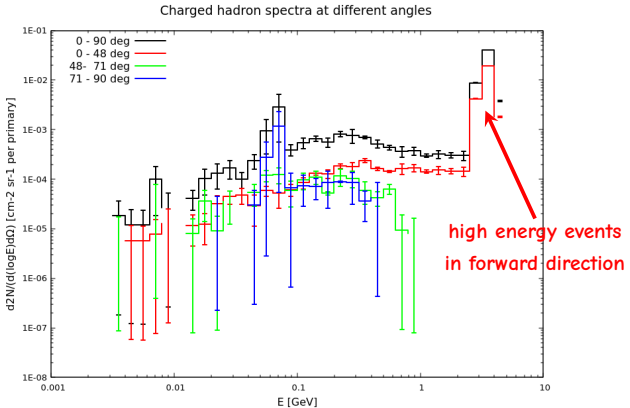
- In this way, the area of each bin is proportional to the corresponding integral flux, giving an immediate feeling which energy bin or region contributes more or less particles.



Exercise: USRBDX - Results

Double-differential charged hadron spectra for 3 consecutive solid angle bins results are normalized to **GeV^{-1} sr^{-1} cm^{-2} per primary** (only if surface area is explicitely given)

From post-processing, we get **double** differential spectra,
since we asked for more than one angular bin,
but the angle-integrated spectrum is provided as well on top



Exercise: USRTRACK

1) Score the track-length of CHARGED HADRONS in TARGS3, with logarithmic binning in energy (WHAT(1)=-1) using 40 bins between 1 MeV and 10 GeV. Normalize with the region volume in order to have the results in GeV^{-1} cm^{-2} per primary particle. Write the output to unformatted unit 55:

```
*  charged hadron fluence in lead target
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7...
USRTRACK          -1.   HAD-CHAR      -55.     TARGS3    628.31        40.TrChH
USRTRACK          10.      0.001                                          &
```

charged hadron fluence in lead target

USRTRACK

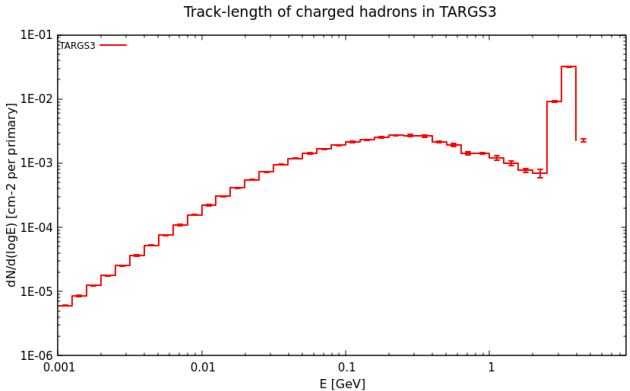
Type: LogE,Groupwise ▾ Reg: TARGS3 ▾ Unit: 55 BIN ▾ Name: TrChH

Part: HAD-CHAR ▾ Emin: 0.001 Emax: 10. Vol: 628.31 Bins: 40.

Remember: USRTRACK scores differential fluence in a region, USRBDX scores fluence or current on a surface, and USRBIN scores e.g. fluence in volumes and gives no differential information.

Exercise: USRTRACK - Result

Track-length based fluence of charged hadrons in region TARGS3, plotted as a lethargy plot:



Exercise: USRYIELD

1) Score plain double-differential yield (continuation card WHAT(6)=3) for pions, with the first quantity polar angle (degree) and second quantity kinetic energy (WHAT(1)=124), between TARGS3 and INAIR, between 0 and 180 degrees in 18 bins and between 0 and 10 GeV:

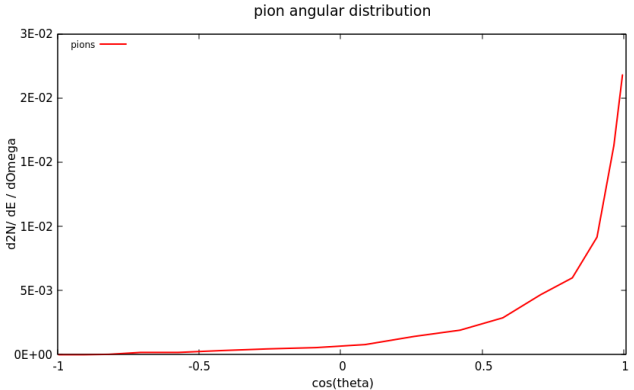
```
*  charged pion angular distribution exiting lead target
USRYIELD         124.    PIONS+-       -57.     TARGS3      INAIR          1.YieAng
USRYIELD         180.        0.0        18.         10.        0.0          3. &
```

Remember: Only one interval is possible for the second variable, but results are normalized as double-differential quantities (in this case, charged pions yield in GeV^{-1} sr^{-1} per primary).

Use WHAT(6) = 3 for plain double differential yield, DEFAULT is plain double-differential cross section!

USRYIELD - Result

Pion angular distribution:



Use **gnuplot** commands to plot with FLAIR:

```
set key top left
set format y "%2.0E"
set ylabel offset -1.

plot 'ex_Score_57_tab.lis' ind 0 us (cos(($1+$2)/2.0)):3 w lines lw 2 lc rgb 'red' t ' pions'
```

Plot completed

www.fluka.org