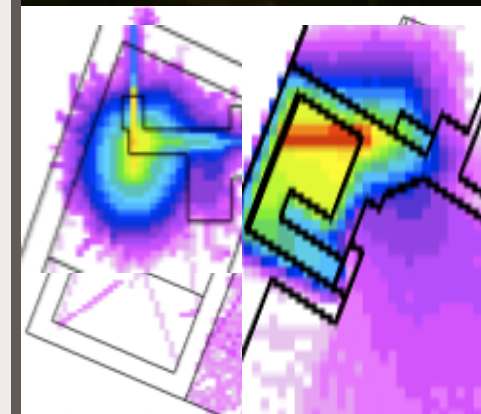


TWO STEP METHOD FOR SHIELDING SIMULATION

2nd Fluka Advanced Course and Workshop TRIUMF

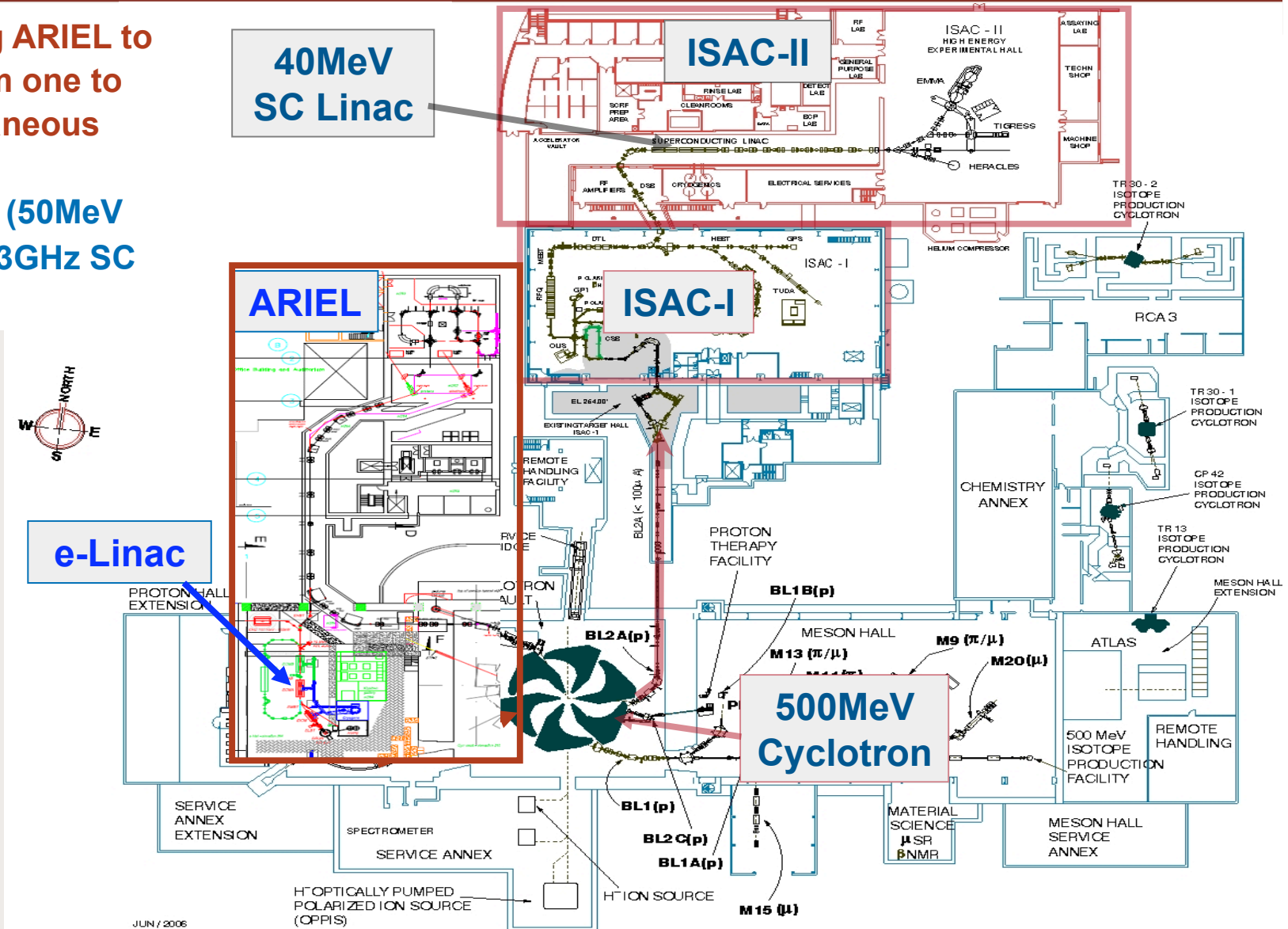
September 17, 2012

Aurelia Laxdal TRIUMF



- Introduction:
 - Present
 - Future: adding **Advanced Rare Isotope Laboratory (ARIEL)**
- **ARIEL** target stations:
 - **p+** target station: **100 μ A at 500MeV**
 - **e-** target station: 10mA at 50MeV
- Proton target station overview & adjacent areas
- Standard simulation to determine the necessary shielding for the **Laser Ion Source (LIS)** setup
- Alternative solutions:
 - use a **Two-Step method**
- File manipulation for the Two-Step method
- Results
- Conclusions

- Now adding ARIEL to increase from one to three simultaneous beams
- Add e-Linac (50MeV 10mA cw - 1.3GHz SC linac)



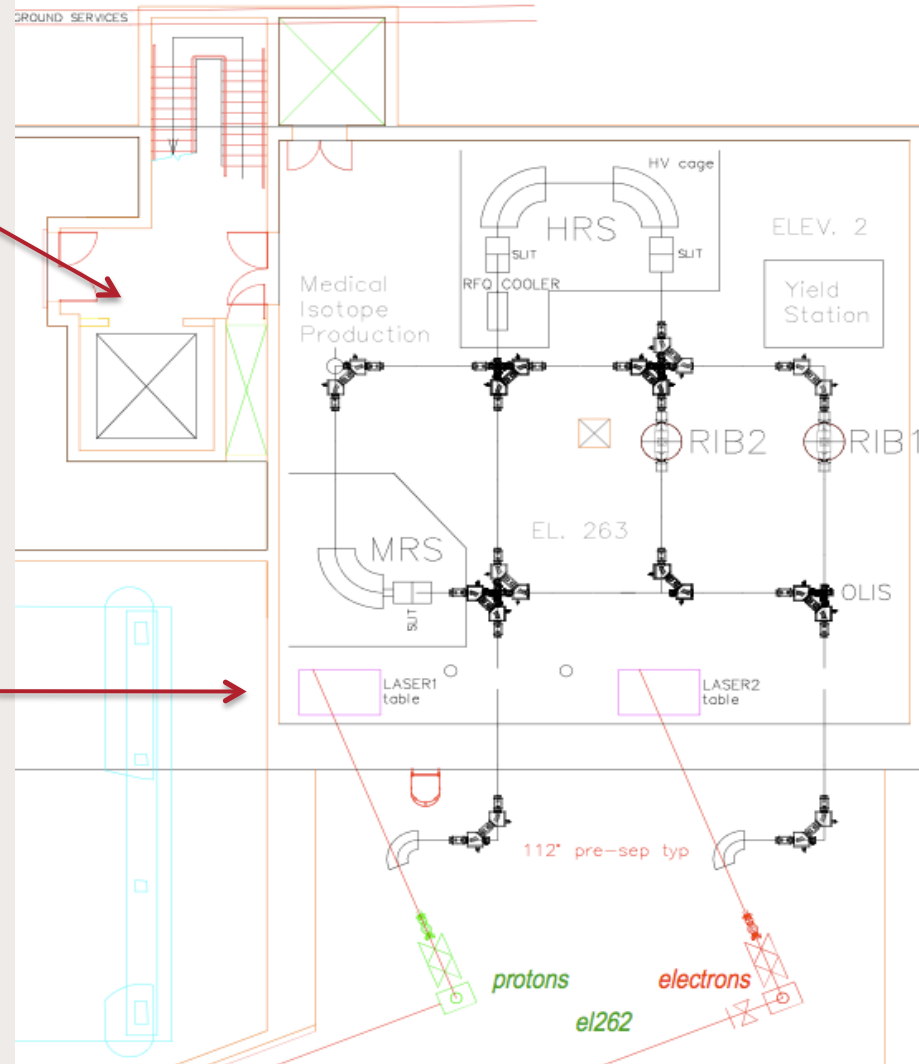
ARIEL target stations

Low
Occupancy
Area

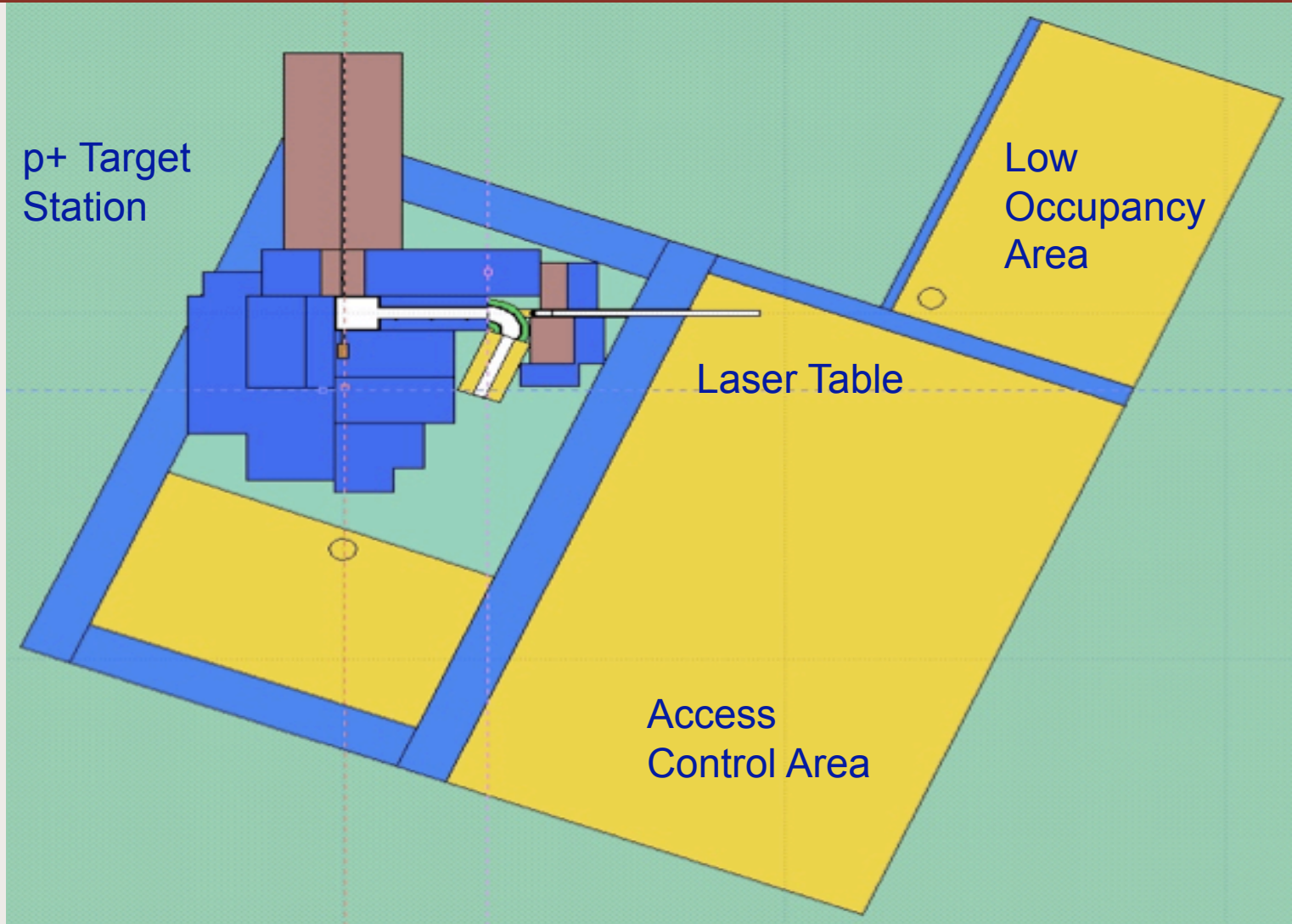
Access
Control Area

Laser Tables

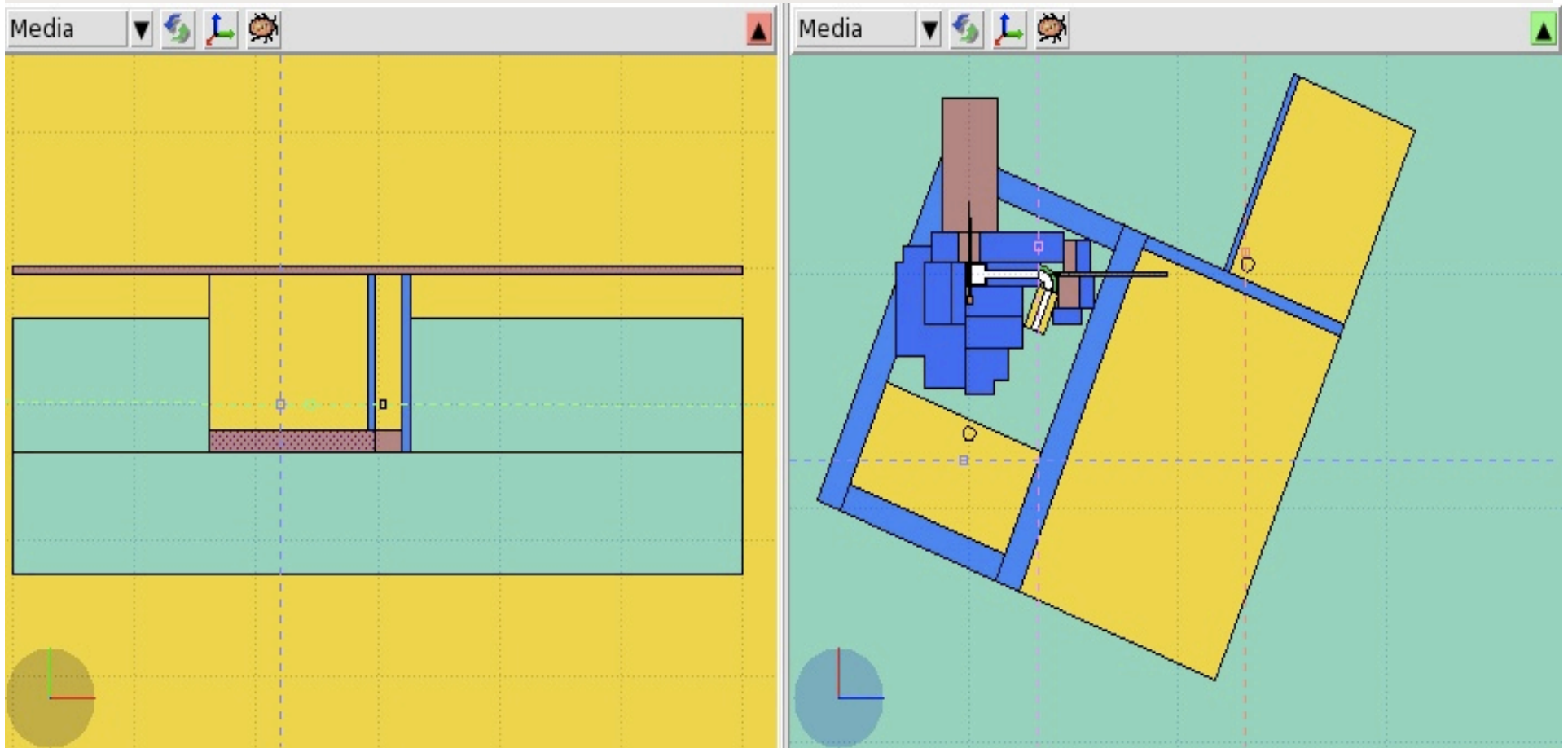
Target
Stations



Proton Station & LIS beam pipe - top view



Elevator & Stairs Locations



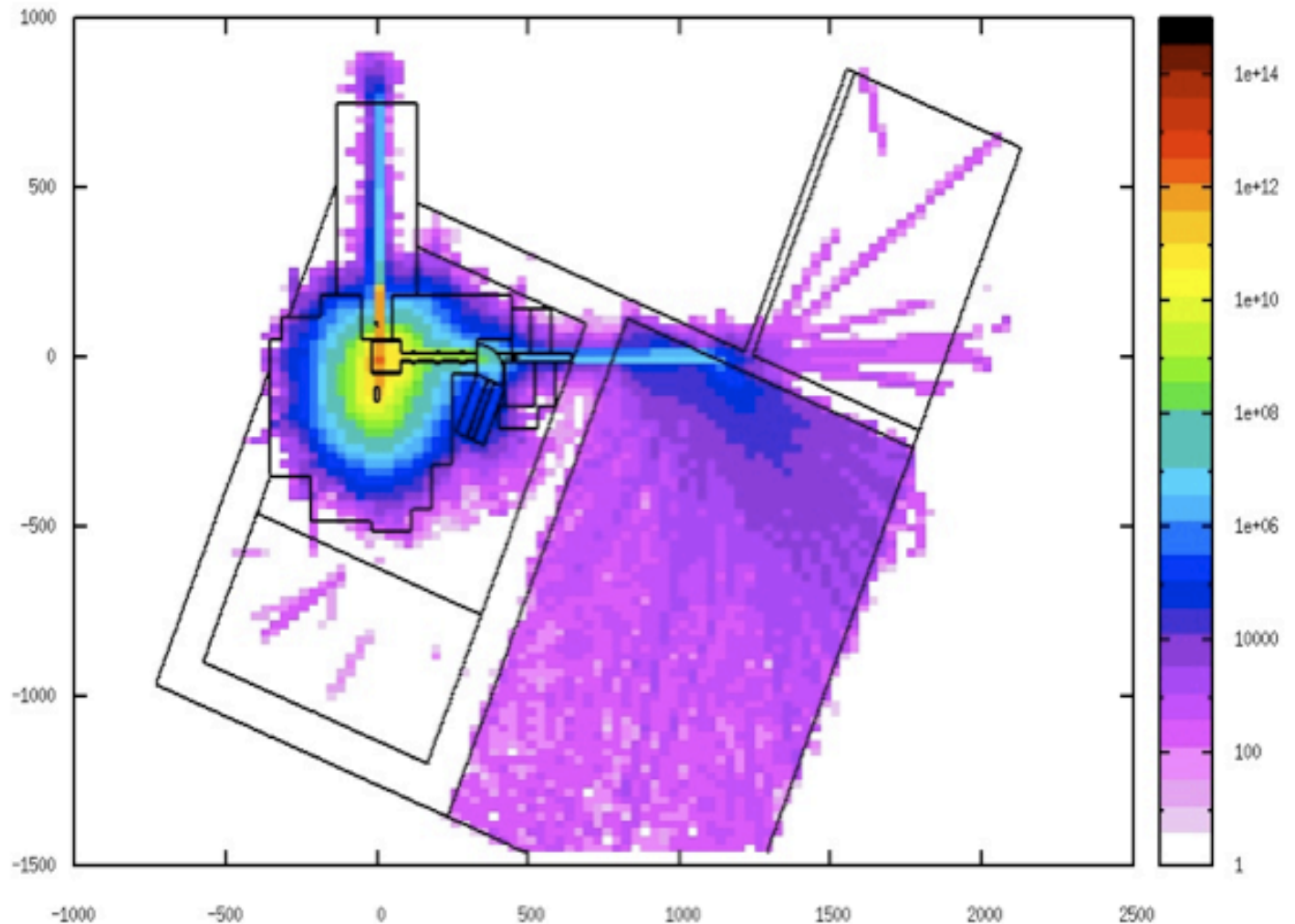
Results: B2 level

- TRIUMF's limit for Low Occupancy Area: $10\mu\text{Sv/hr}$

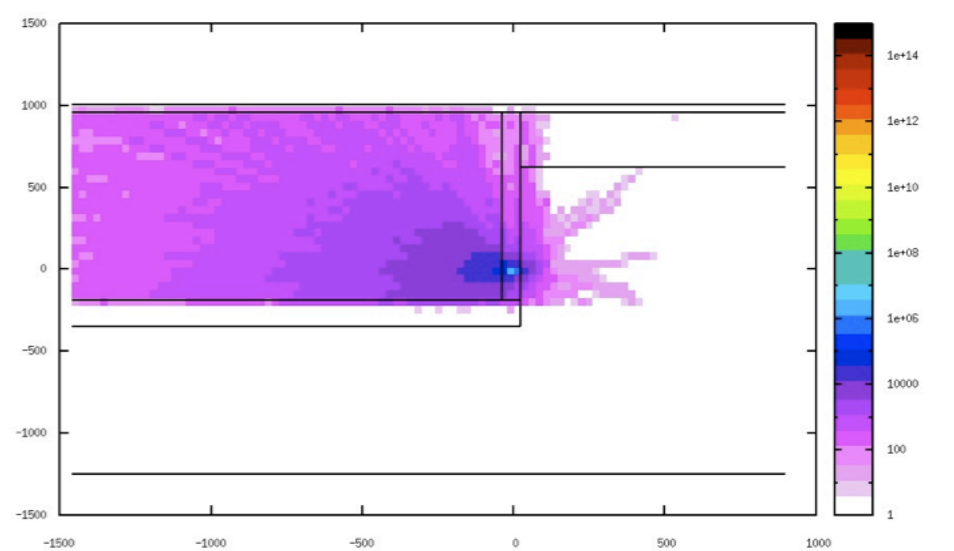
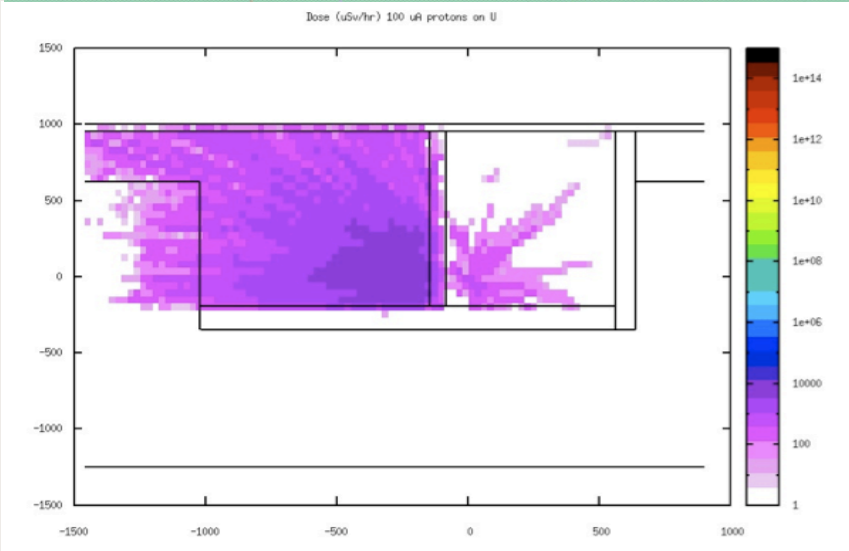
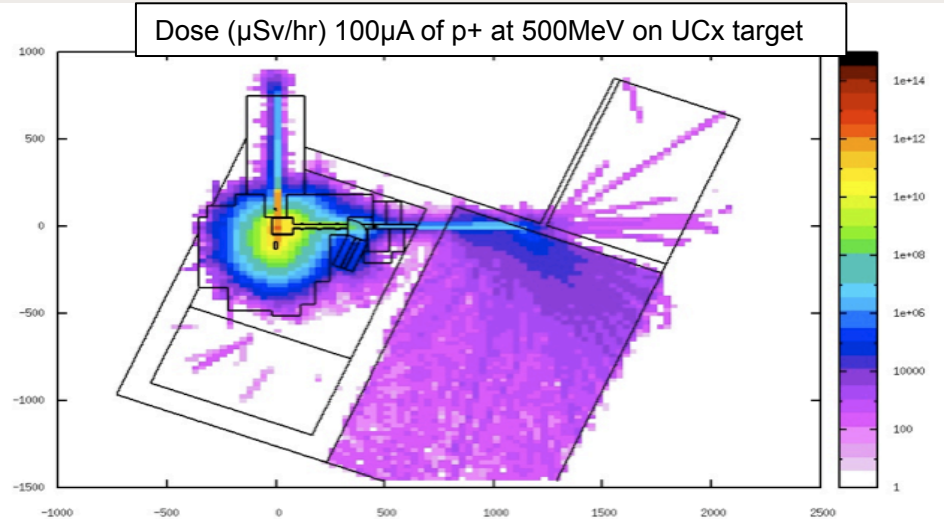
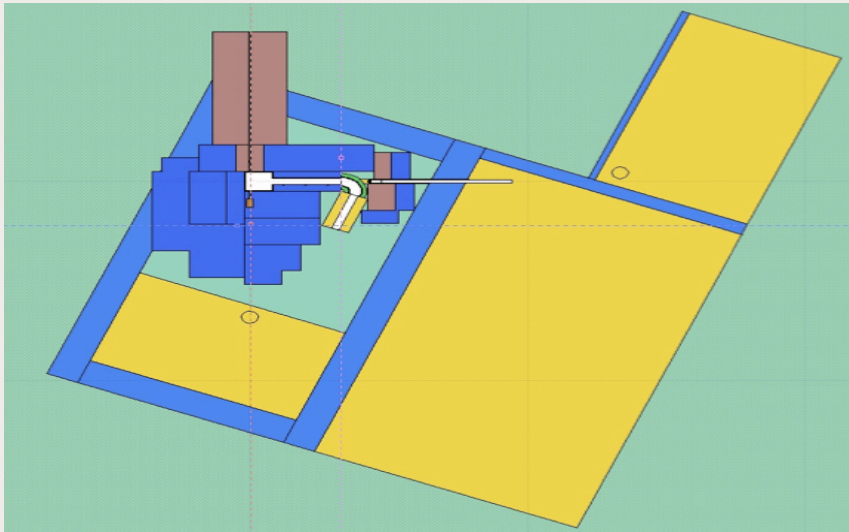
- Recommendations: additional localized shielding to the north of the LIS table to allow occupancy during beam operation

MAZE

Dose ($\mu\text{Sv/hr}$) 100 μA of p^+ at 500MeV on UCx target



Results: summary

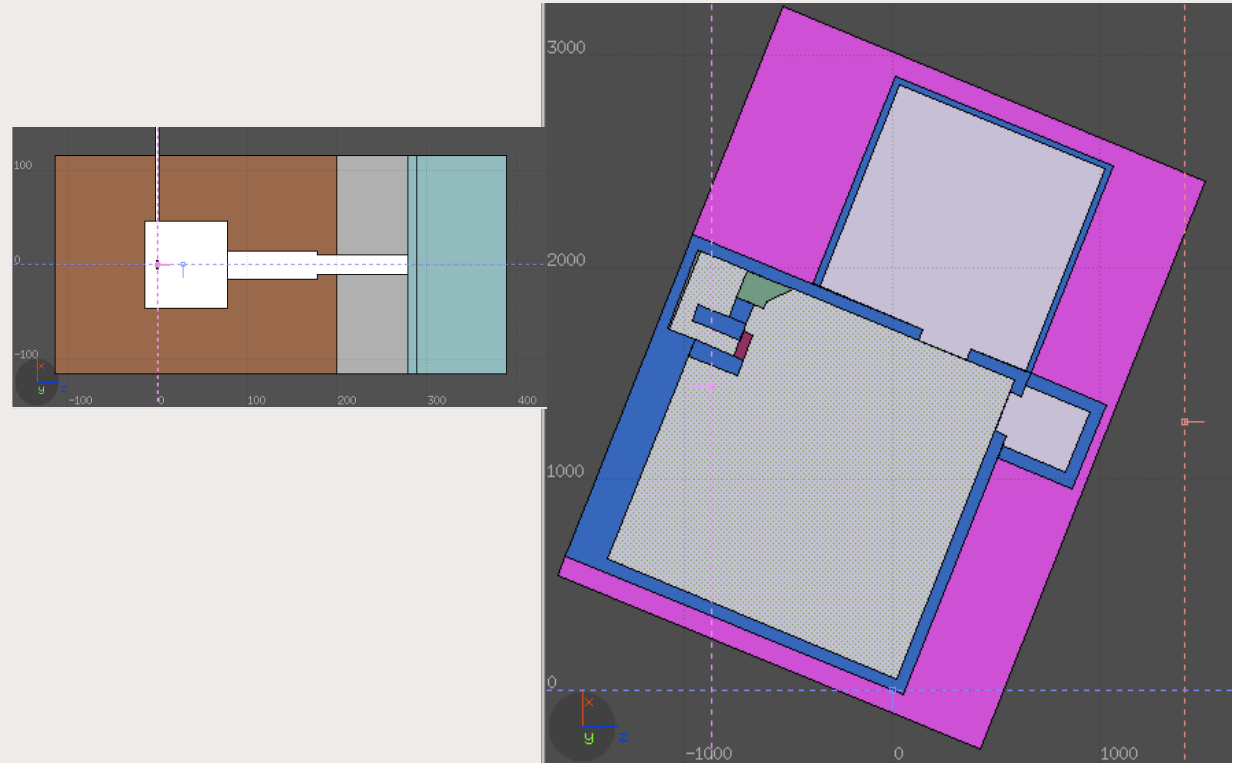
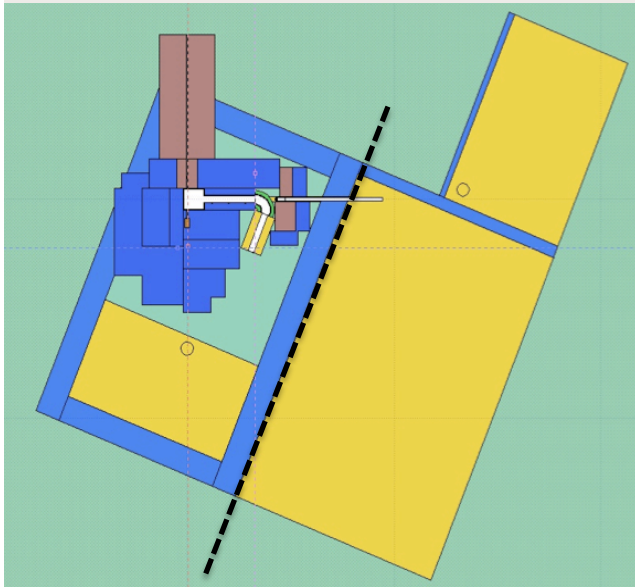


Alternative Solution

1. General method

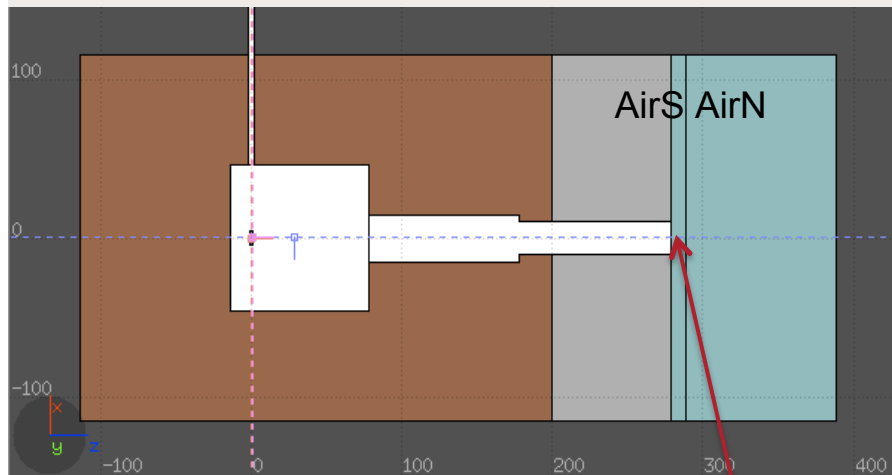
REPLACE

2. Two-Step method



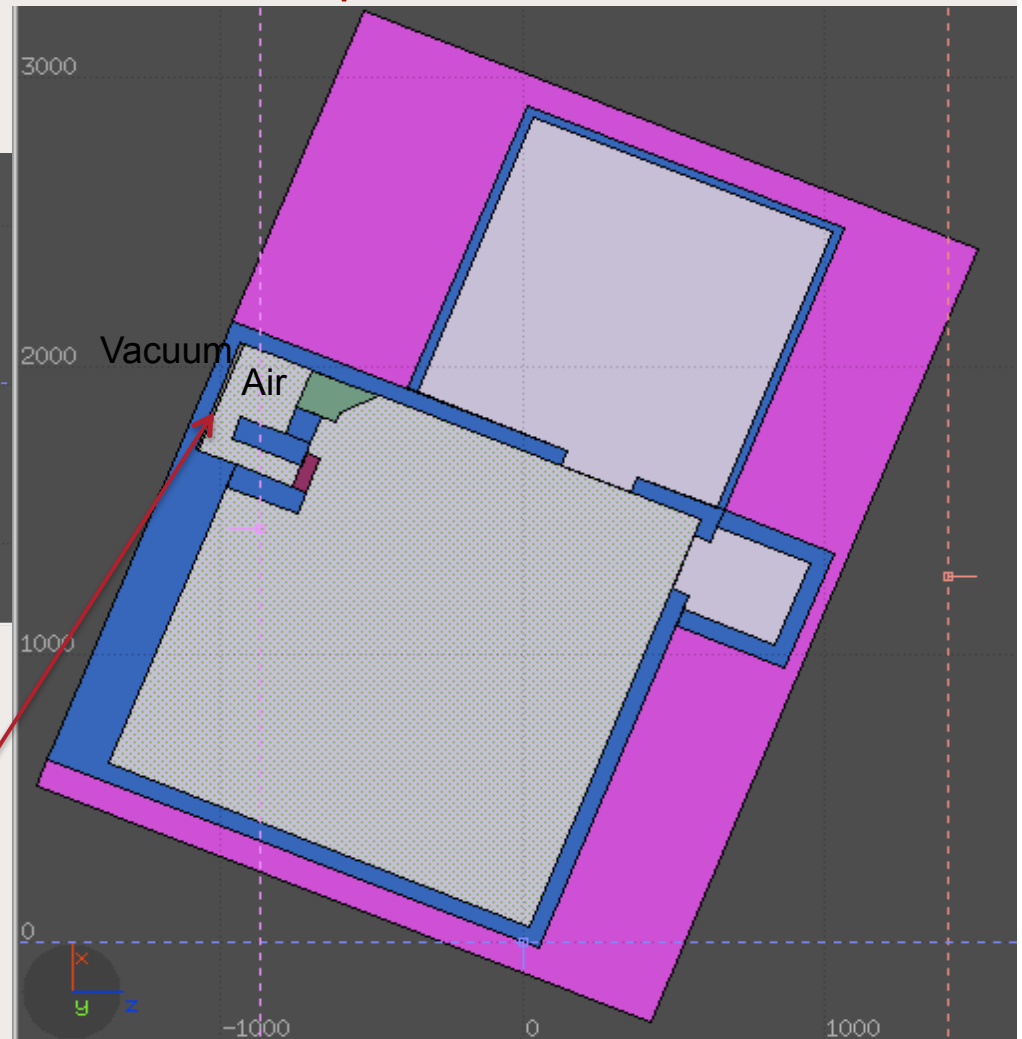
Two-Step Method

First Step



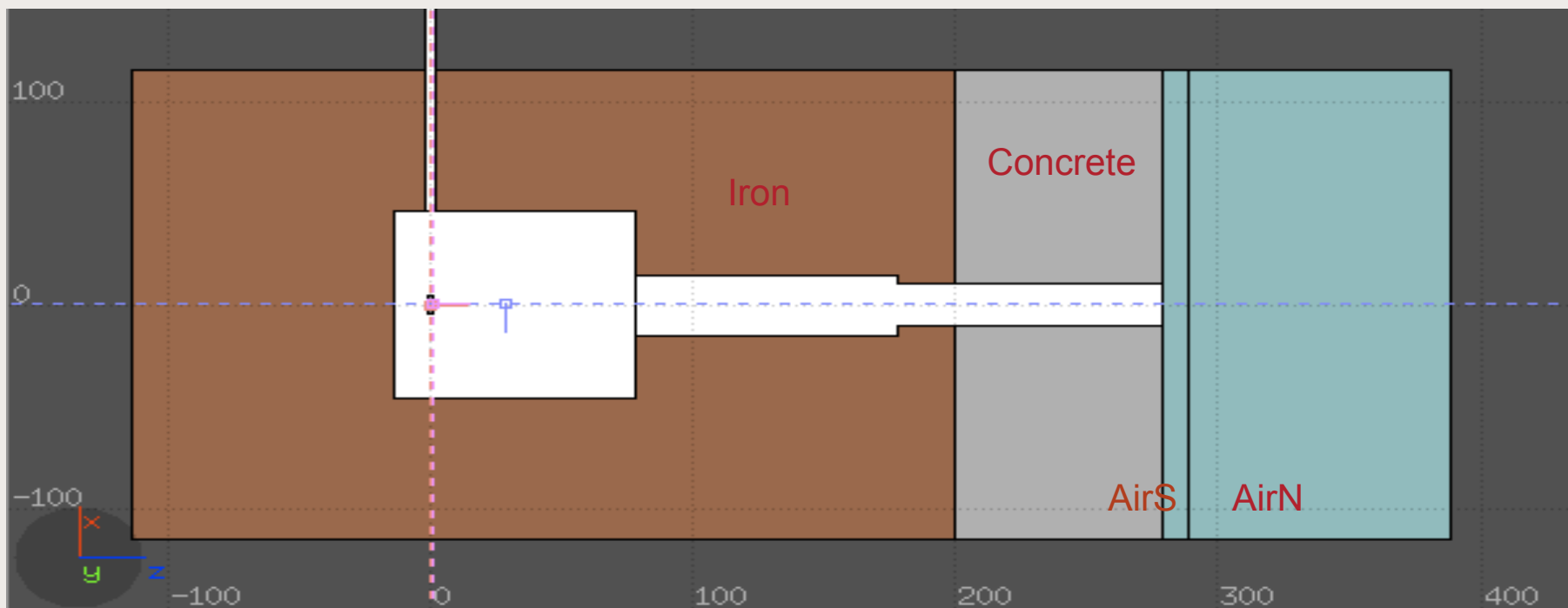
- **First Step:** score the hadrons crossing the **Air Regions**: position, angle, energy & weight;
- **Second Step:** input them from the **Vacuum Region**

Second Step



First Step – How?

1. Scoring: **USERDUMP** card
2. Do a coordinate transformation
3. Compile: Use & Modify **mgdraw.f** user routine of the first file
4. Concatenate the data files after the Run(s) -> output first step -> input second step
5. Check the results: the output and the data file



First Step - USERDUMP card

1. Scoring: USERDUMP card

USERDUMP

Type: Dump ▼

Unit: ▼

File: Dump

What: Complete ▼

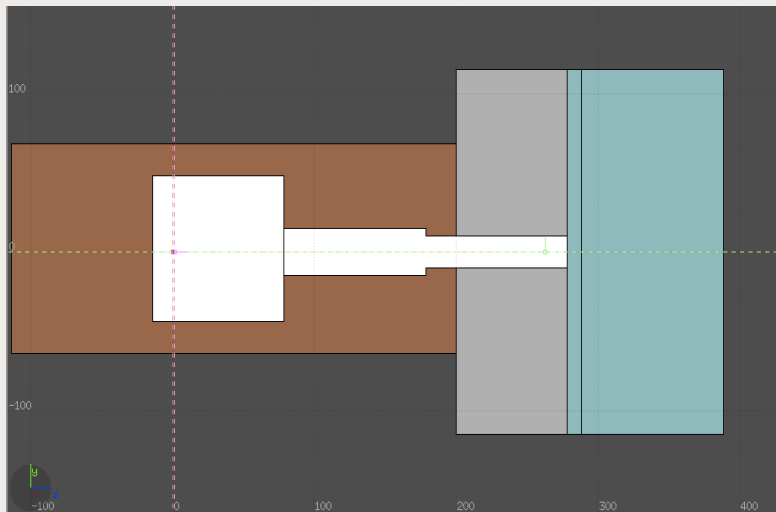
Score: Local Losses ▼

Dump: ▼

- Defines a phase space file to be written.

First Step - coordinate transformation

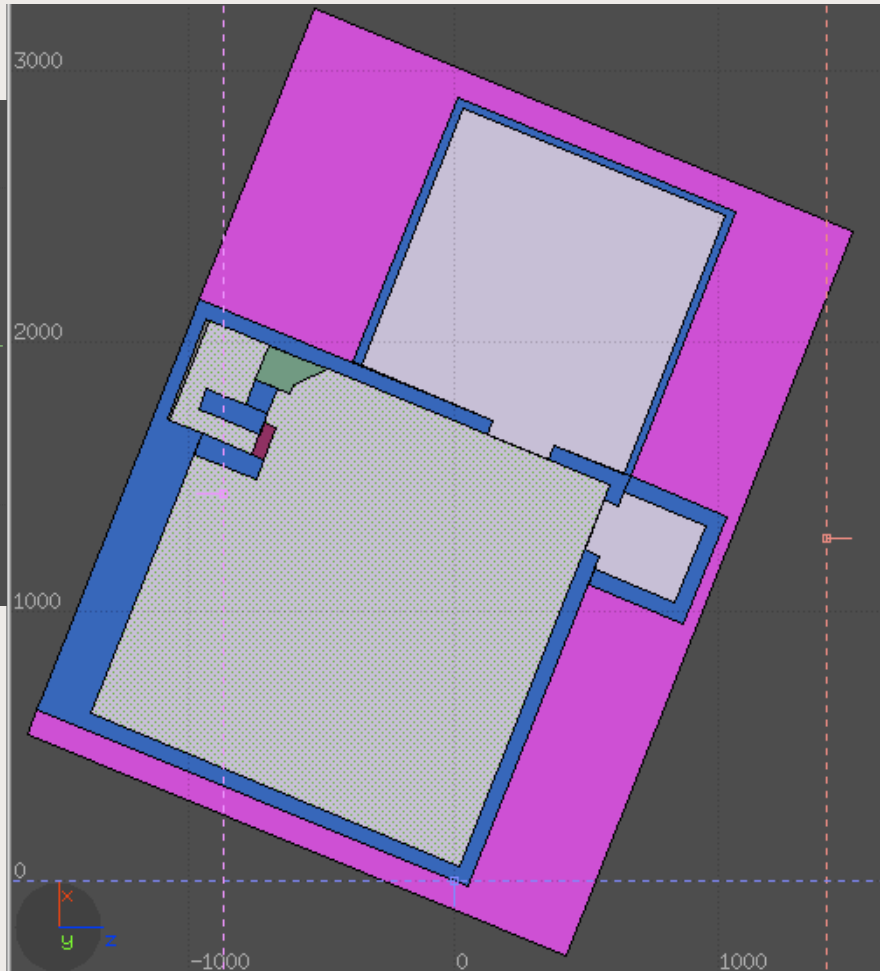
2. Coordinate transformation



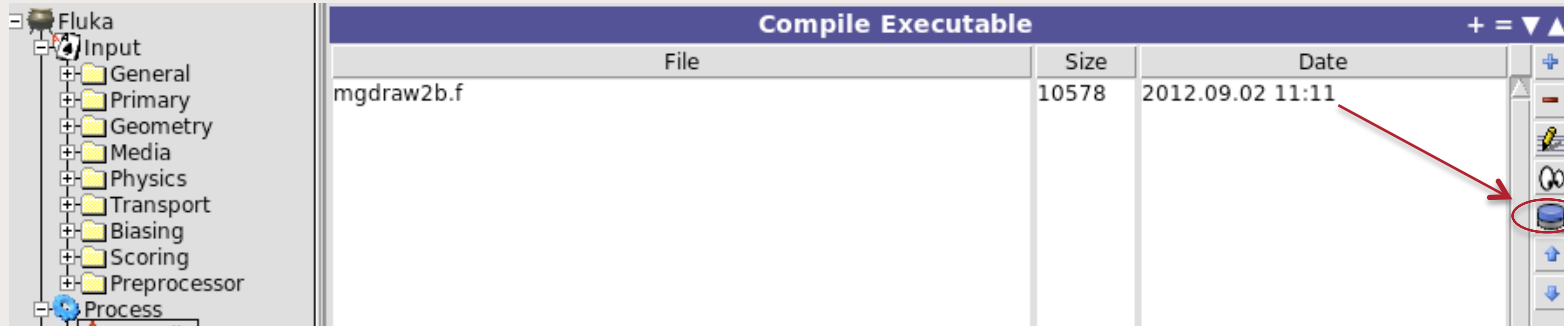
In FORTRAN:

$XSCO = XSCO + 1859.11$

$ZSCO = ZSCO - 1093.78$



First Step - mgdraw.f user routine



```

*
ENTRY BXDRAW ( ICODE, MREG, NEWREG, XSCO, YSCO, ZSCO)
IF(.NOT. LFCOPE)THEN
  LFCOPE=.TRUE.
  OPEN (UNIT=47, FILE="srcNEUT", STATUS='UNKNOWN')
END IF
* Write in event file the position of the particle crossing the boundary
* its direction cosines,its energy and weight.
CALL GEOR2N ( MREG, MREGNAM, IERR1 )
CALL GEOR2N ( NEWREG, NREGNAM, IERR2 )
IF(MREGNAM .EQ. "AirS" .AND. NREGNAM .EQ. "AirN" .AND.
& (JTRACK .EQ. 1 .OR.JTRACK .EQ. 8 .OR.JTRACK .EQ. 13 .OR.
& JTRACK .EQ. 14 .OR.JTRACK .EQ. 23))THEN
* Shift the x and z coordinates for the new geometry:
  XSCO=XSCO+1859.11
  ZSCO=ZSCO-1656.43
  WRITE (47,*)JTRACK,XSCO,YSCO,ZSCO,CXTRCK,CYTRCK,CZTRCK,
& ETRACK-AM(JTRACK),WTTRACK
END IF
* 100 FORMAT(8(E10.4,1X))
RETURN
*
*-----*
  
```

- 1 - proton
- 8 - neutron
- 13 - pion+
- 14 - pion-
- 23 - pion-zero

coordinate transformation

First Step – Checking the Results

FirstA-001_fort.56	56	310	2012.08.31 20:59
FirstA-001_fort.54	54	2326	2012.08.31 20:59
ranFirstA-001	-file-	1651	2012.08.30 19:08
FirstA-001_out	FLUKA out	171082	2012.08.31 20:59
FirstA-001_srcNEUT	-file-	20446	2012.08.31 20:59
FirstA-002_out	FLUKA out	170593	2012.08.31 22:25
FirstA-002_fort.54	54	2326	2012.08.31 22:25
FirstA-002_srcNEUT	-file-	23668	2012.08.31 22:25
FirstA-002_fort.55	55	64238	2012.08.31 22:25
ranFirstA-002	-file-	1651	2012.08.31 20:59

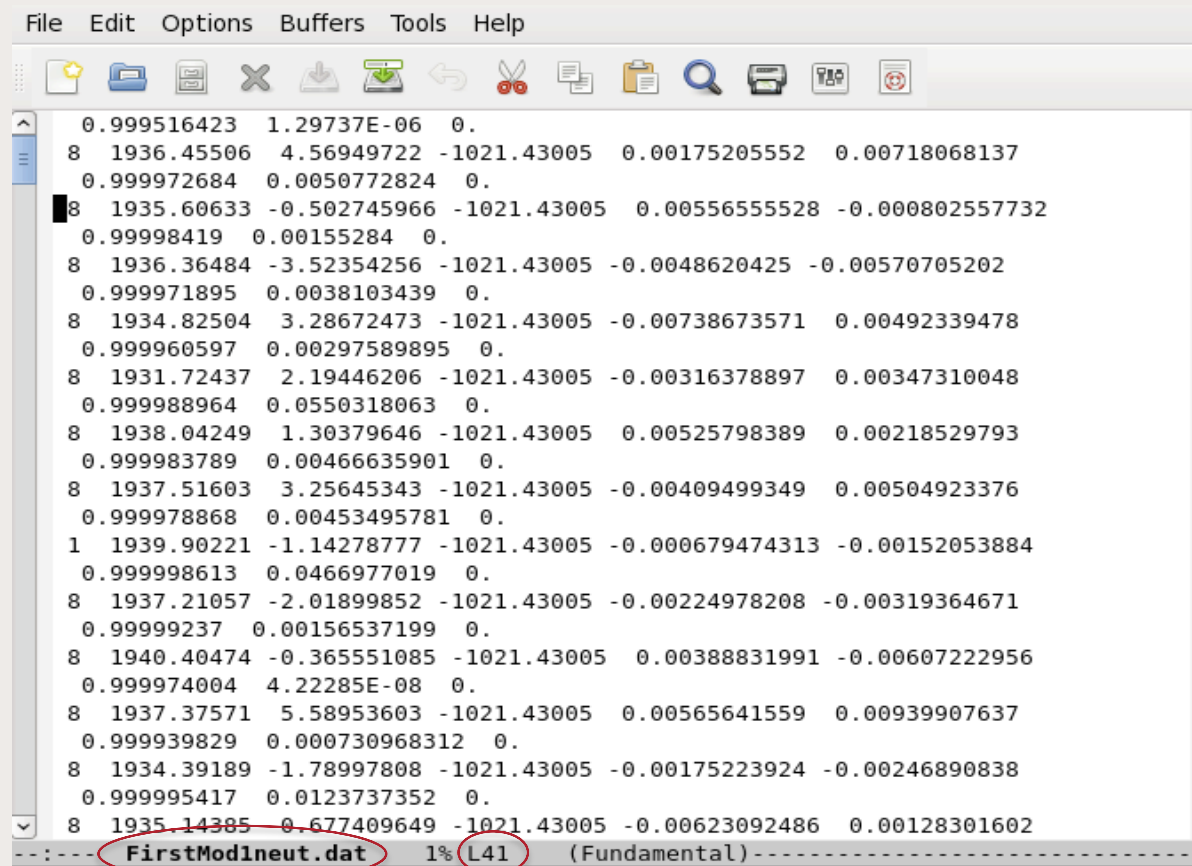
```

8  1940.82207 -0.58650769 -1021.43005  0.00829271167 -0.00133180802
0.999964728  0.00266983597  0.
1  1940.0558 -1.81006416 -1021.43005  0.00306237128 -0.00273399738
0.999991574  0.0132999552  0.
8  1925.94277  0.851876395 -1021.43005 -0.812045381 -0.250975075  0.526871722
0.00120935  0.
8  1932.36131  0.0597017901 -1021.43005 -0.00705415101 -0.000174097706
--:--- FirstJ-002_srcNEUT 23% L96 (Fundamental)-----
    
```

First Step – The Output File

- Concatenate the data files:

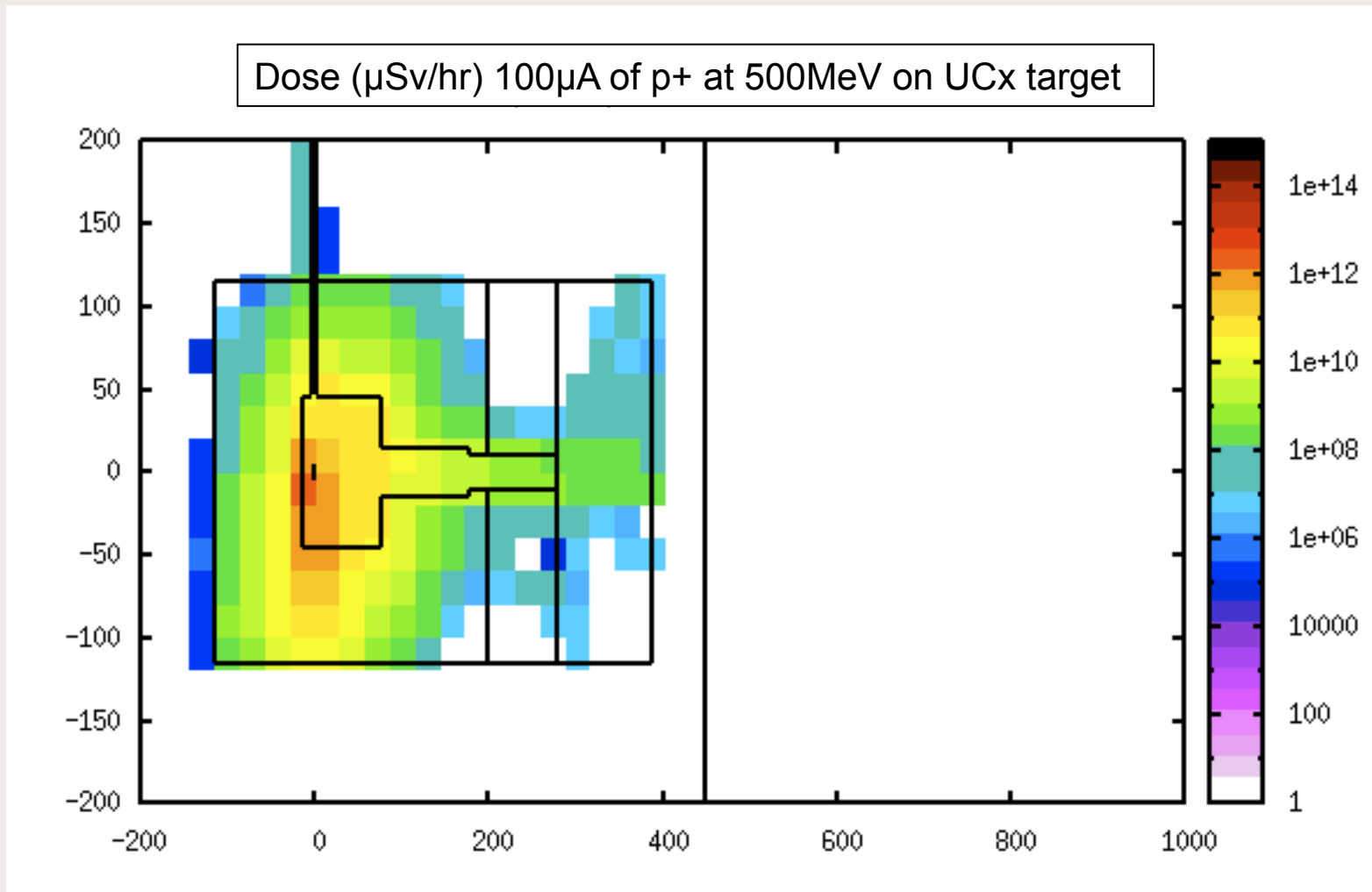
```
>cat *srcNEUT FirstMod1neut.dat
```



```
File Edit Options Buffers Tools Help
0.999516423 1.29737E-06 0.
8 1936.45506 4.56949722 -1021.43005 0.00175205552 0.00718068137
0.999972684 0.0050772824 0.
8 1935.60633 -0.502745966 -1021.43005 0.00556555528 -0.000802557732
0.99998419 0.00155284 0.
8 1936.36484 -3.52354256 -1021.43005 -0.0048620425 -0.00570705202
0.999971895 0.0038103439 0.
8 1934.82504 3.28672473 -1021.43005 -0.00738673571 0.00492339478
0.999960597 0.00297589895 0.
8 1931.72437 2.19446206 -1021.43005 -0.00316378897 0.00347310048
0.999988964 0.0550318063 0.
8 1938.04249 1.30379646 -1021.43005 0.00525798389 0.00218529793
0.999983789 0.00466635901 0.
8 1937.51603 3.25645343 -1021.43005 -0.00409499349 0.00504923376
0.999978868 0.00453495781 0.
1 1939.90221 -1.14278777 -1021.43005 -0.000679474313 -0.00152053884
0.999998613 0.0466977019 0.
8 1937.21057 -2.01899852 -1021.43005 -0.00224978208 -0.00319364671
0.99999237 0.00156537199 0.
8 1940.40474 -0.365551085 -1021.43005 0.00388831991 -0.00607222956
0.999974004 4.22285E-08 0.
8 1937.37571 5.58953603 -1021.43005 0.00565641559 0.00939907637
0.999939829 0.000730968312 0.
8 1934.39189 -1.78997808 -1021.43005 -0.00175223924 -0.00246890838
0.999995417 0.0123737352 0.
8 1935.14385 0.677409649 -1021.43005 -0.00623092486 0.00128301602
----- FirstMod1neut.dat 1% L41 (Fundamental) -----
```

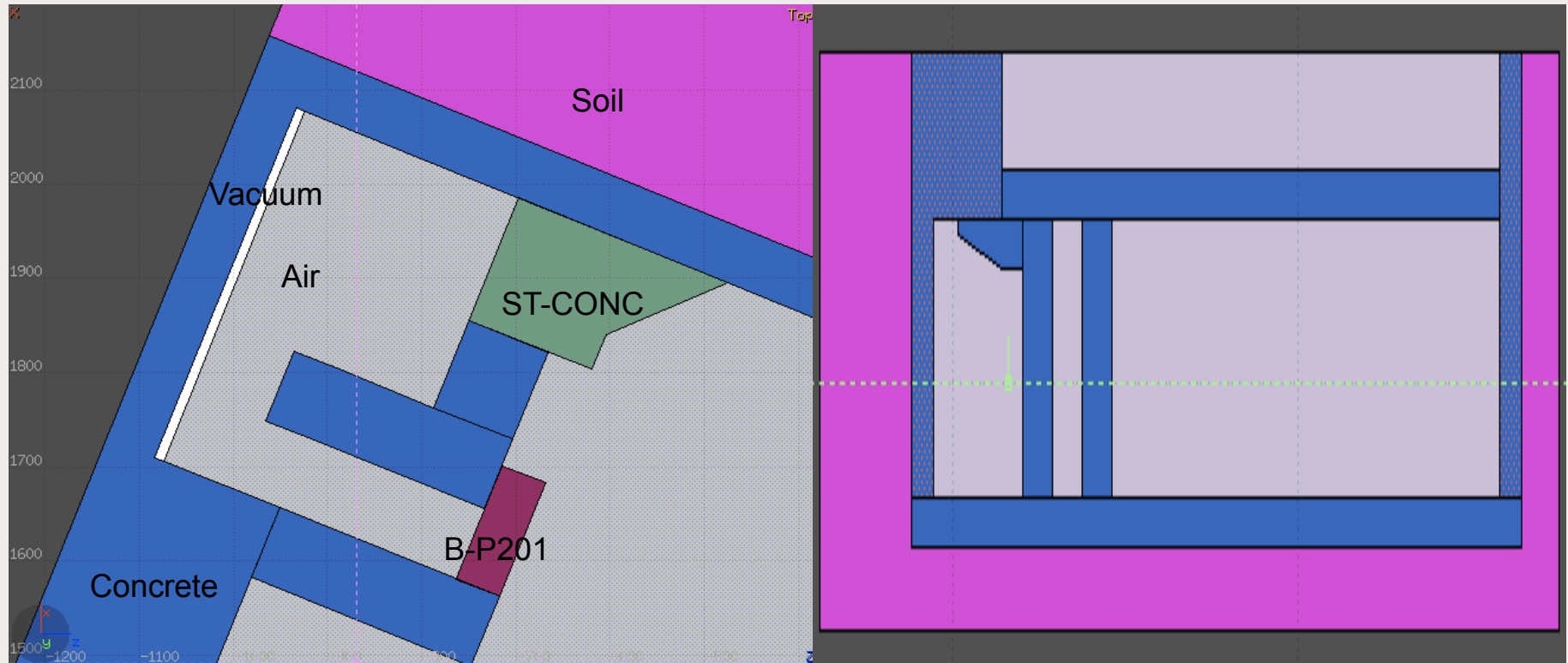
Output First Step -> Input Second Step

First Step – Results/USERBIN Plot



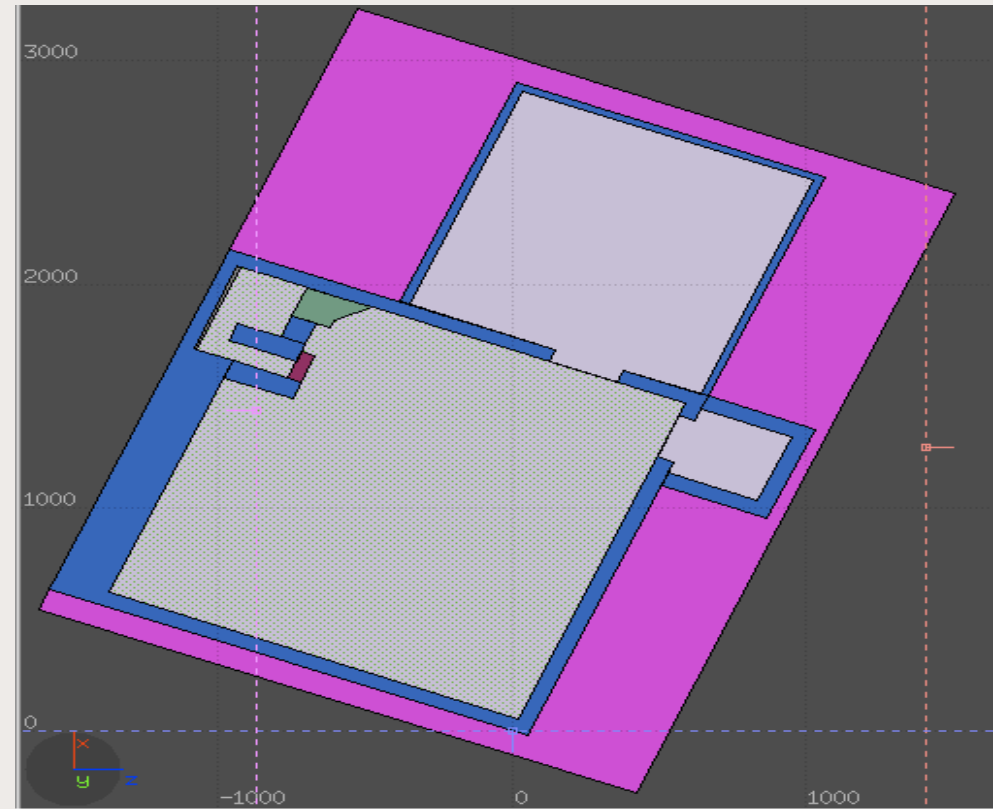
Second Step - Maze

Second Step: input/launch the hadrons from the Vacuum Region



Second Step – How?

1. In **Primary**: SOURCE card + BEAM card
2. In **Compile**:
 - Use & Modify `source.f` user routine -> `source2b.f`
 - Use `soevsv.f` user routine
3. Check the results
4. Normalize accordingly



Second Step – Primary

In **Primary**: SOURCE card + BEAM card

Fluka

- Input
- + General
- + **Primary**
- + Geometry
- + Media
- + Physics
- + Transport
- + Biasing
- + Scoring
- + Preprocessor
- Process
- Plot
- Red

----- TITLE ... DCYSCORE : 48 cards hidden -----

Neutron source read in via source.f

SOURCE	#1:	#2:	#3:
sdum:	#4:	#5:	#6:

..+...1...+...2...+...3...+...4...+...5...+...6...+...7...

***** BEAM SPECIFICATION *****

Still need Beam card for energy range of primaries when scoring

BEAM	Beam: Energy ▼	E: 0.5	Part: ▼
Δp: Flat ▼	Δp: 0.0	Δφ: Flat ▼	Δφ: 0.0
Shape(X): Rectangular ▼	Δx: 0.0	Shape(Y): Rectangular ▼	Δy: 0.0

BEAMPOS	x: 1950.0	y: 0.0	z: -870.0
	cosx: 0.0	cosy: 0.0	Type: POSITIVE ▼



----- ACCURACY ... STOP : 139 cards hidden -----

START	No.: 1.0E+04	Report: default ▼	Time:
--------------	--------------	-------------------	-------


Second Step – Compile (1)

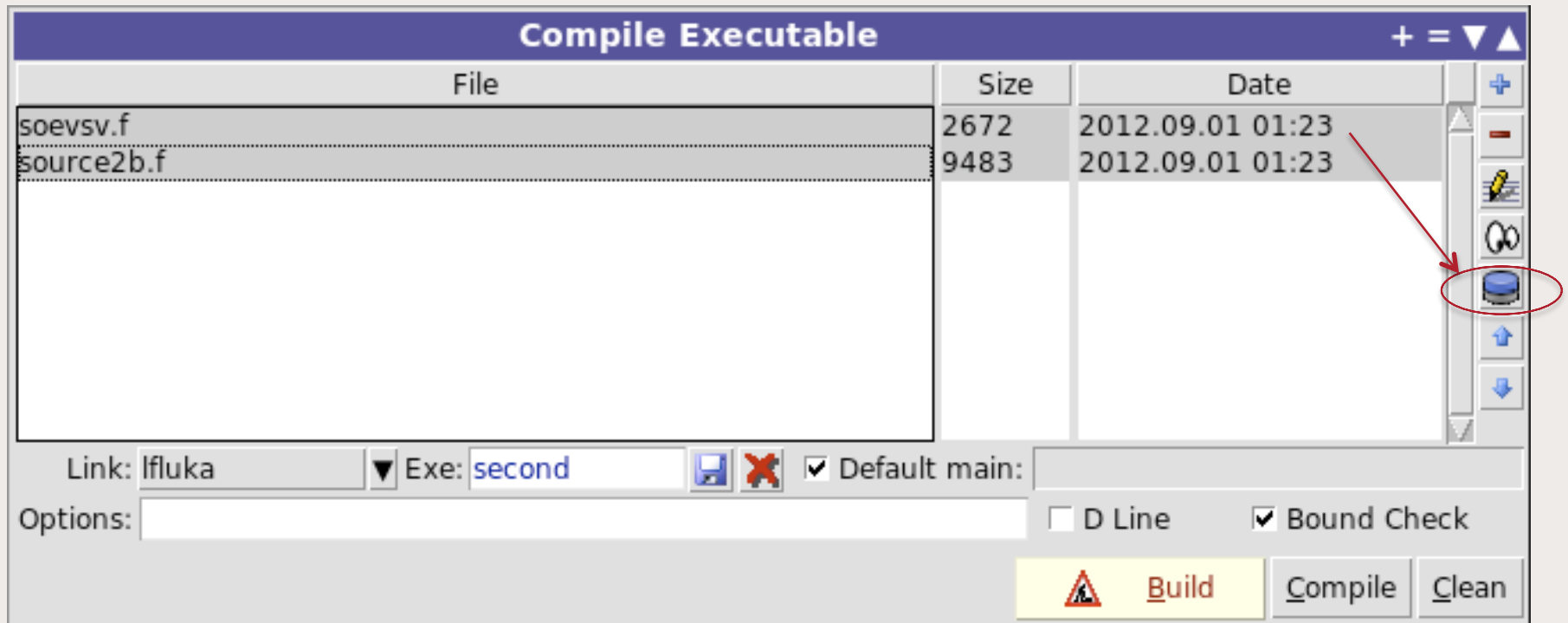
Compile Executable + = ▾ ▲

File	Size	Date
soevsv.f	2672	2012.09.01 01:23
source2b.f	9483	2012.09.01 01:23

Link: ▾ Exe:   Default main:

Options: D Line Bound Check

 **Build**



Second Step – Compile (2)

Use & Modify `source.f` user routine -> `source2b.f`

```

* +-----*
* | First call initializations:
* | IF ( LFIRST ) THEN
* | *** The following 3 cards are mandatory ***
* |     TKESUM = ZERZER
* |     LFIRST = .FALSE.
* |     LUSSRC = .TRUE.
* | *** User initialization ***
* |     WRITE(LUNOUT,*)
* |     WRITE(LUNOUT,'(a,132a)') ("*",i=1,132)
* |     WRITE(LUNOUT,*)
* |     WRITE(LUNOUT,*) "Source Collision file for ARIEL RIB B2 Level"
* |     OPEN(UNIT=41, file='./FirstModlneut.dat', status='old')
* |     WRITE(LUNOUT,*)
* |     WRITE(LUNOUT,*)
* |     DO i = 1,nlines
* |         READ(41,*,END=501) IZbeam, Xbpos(i), Ybpos(i), Zbpos(i),
* |         & Xbdir(i), Ybdir(i), Zbdir(i), Tener(i), Bweig(i)
* |         Jbeam(i) = IZbeam
* |     END DO
501 CONTINUE
* |     Nfile = I-1
* |     CLOSE(41)
* |     WRITE (LUNOUT,*) "Source file number of lines", Nfile
* |     WRITE(LUNOUT,'(a,132a)') ("*",i=1,132)
* |     XDUMMY = 101.D+00
* | END IF

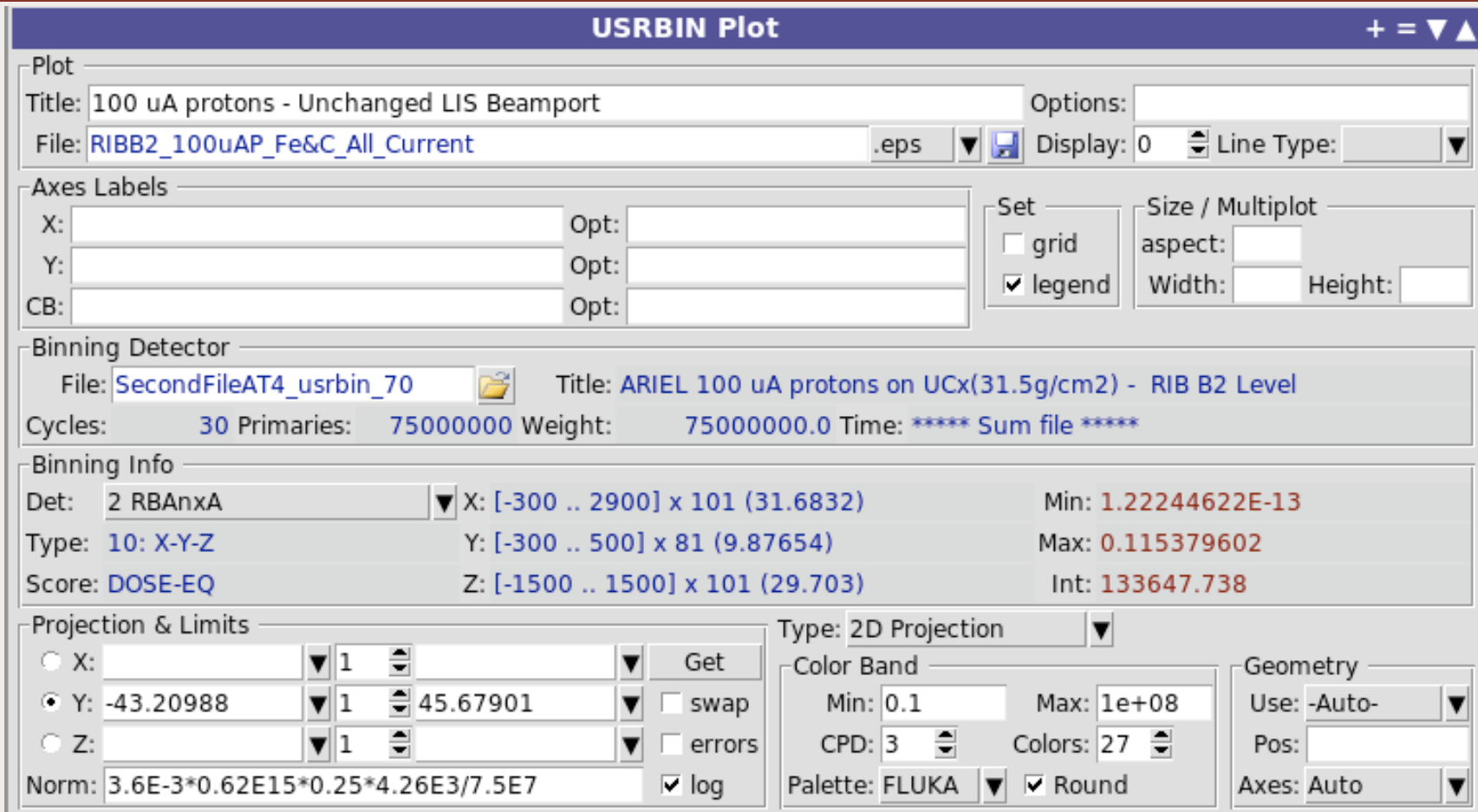
```

Second Step – Compile (3)

Use & Modify `source.f` user routine -> `source2b.f`

```
* Wt is the weight of the particle. Use no biasing in generating the  
* source file so that the particle weight should be one. Note for low  
* energy neutron the weight can be different than one.  
  WTFLK (NPFLKA) = Bweig(line)  
  WTFLK (NPFLKA) = 1.00+00  
  WEIPRI = WEIPRI + WTFLK (NPFLKA)  
→ IJBEAM = Jbeam(line)  
* Particle type (1=proton.....). Ijbeam is the type set by the BEAM  
* card. Here it is input as the appropriate particle.
```

Second Step – Normalization



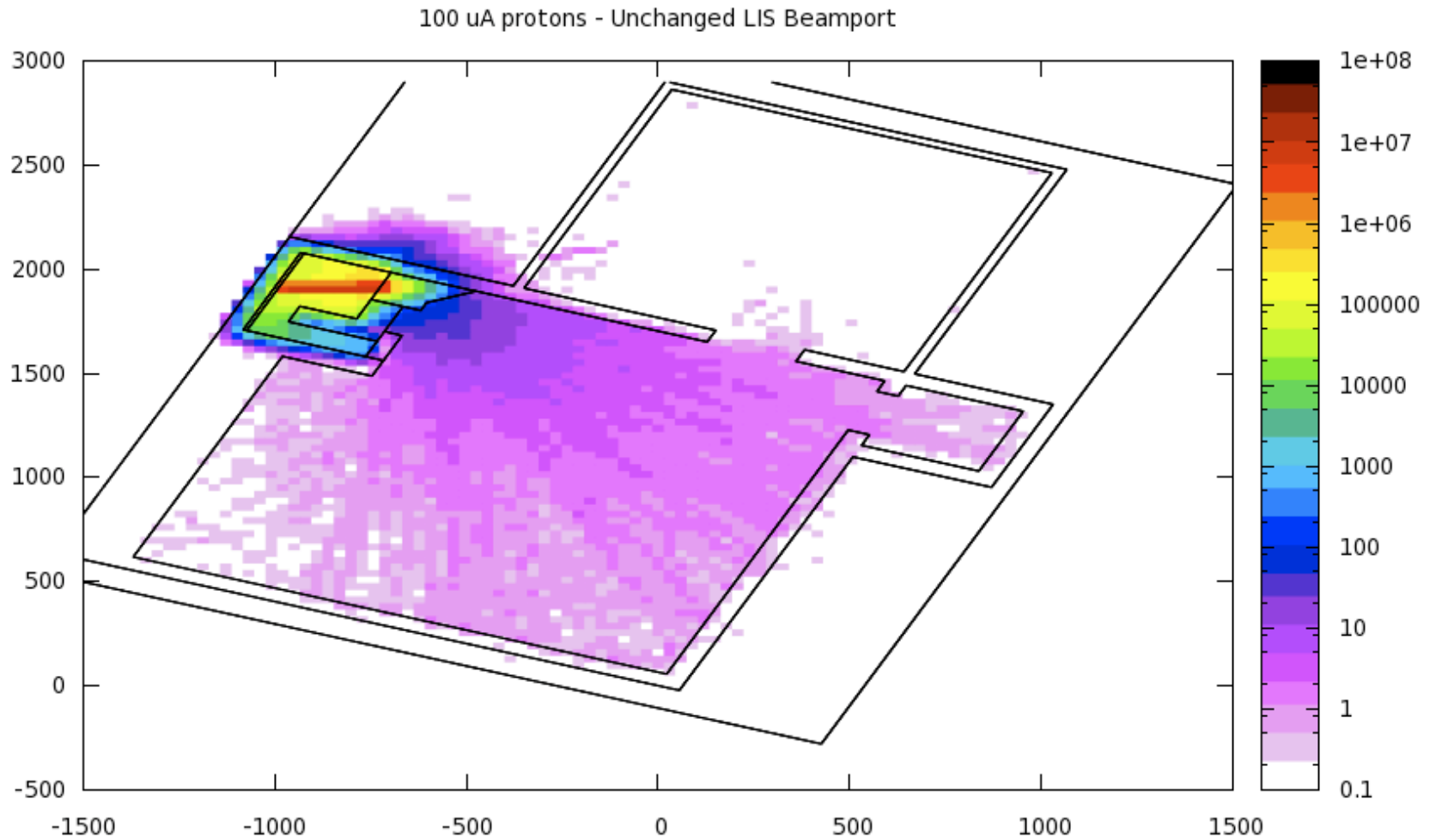
The screenshot shows the 'USRBIN Plot' window with the following settings:

- Plot:** Title: 100 uA protons - Unchanged LIS Beamport; File: RIBB2_100uAP_Fe&C_All_Current; Options: (empty); Display: 0; Line Type: (dropdown)
- Axes Labels:** X, Y, CB fields with Opt: (dropdown) for each.
- Binning Detector:** File: SecondFileAT4_usrbin_70; Title: ARIEL 100 uA protons on UCx(31.5g/cm2) - RIB B2 Level; Cycles: 30; Primaries: 75000000; Weight: 75000000.0; Time: *****; Sum file *****
- Binning Info:** Det: 2 RBAnxA; X: [-300 .. 2900] x 101 (31.6832); Y: [-300 .. 500] x 81 (9.87654); Z: [-1500 .. 1500] x 101 (29.703); Min: 1.22244622E-13; Max: 0.115379602; Int: 133647.738
- Projection & Limits:** Type: 2D Projection; X: 1; Y: -43.20988; Z: 1; Norm: 3.6E-3*0.62E15*0.25*4.26E3/7.5E7; log: checked
- Color Band:** Min: 0.1; Max: 1e+08; CPD: 3; Colors: 27; Palette: FLUKA; Round: checked
- Geometry:** Use: -Auto-; Pos: (empty); Axes: Auto

1st step normalization

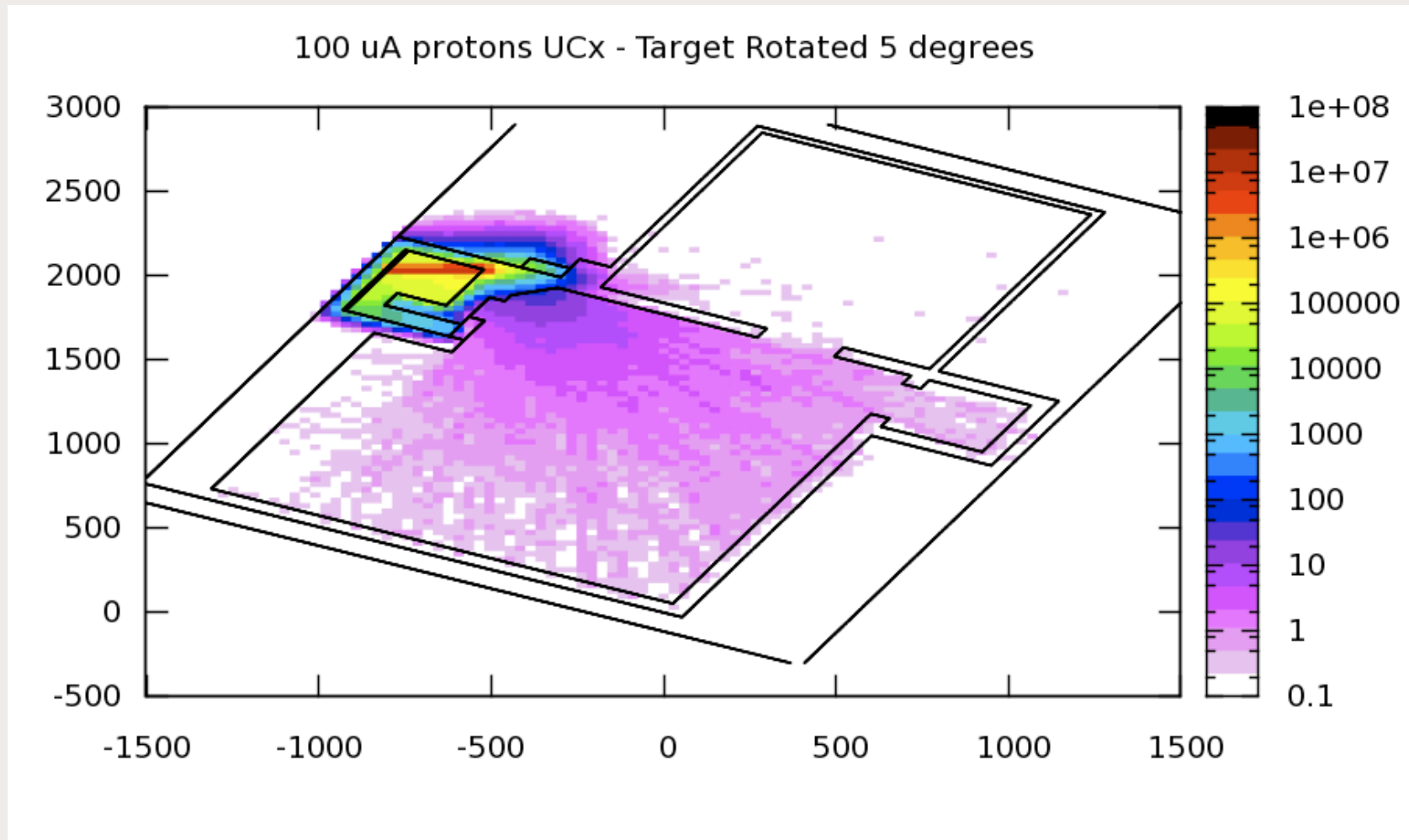
SCORING normalization: # of hadrons scored / # of primaries

Second Step – USRBIN for Normal Target

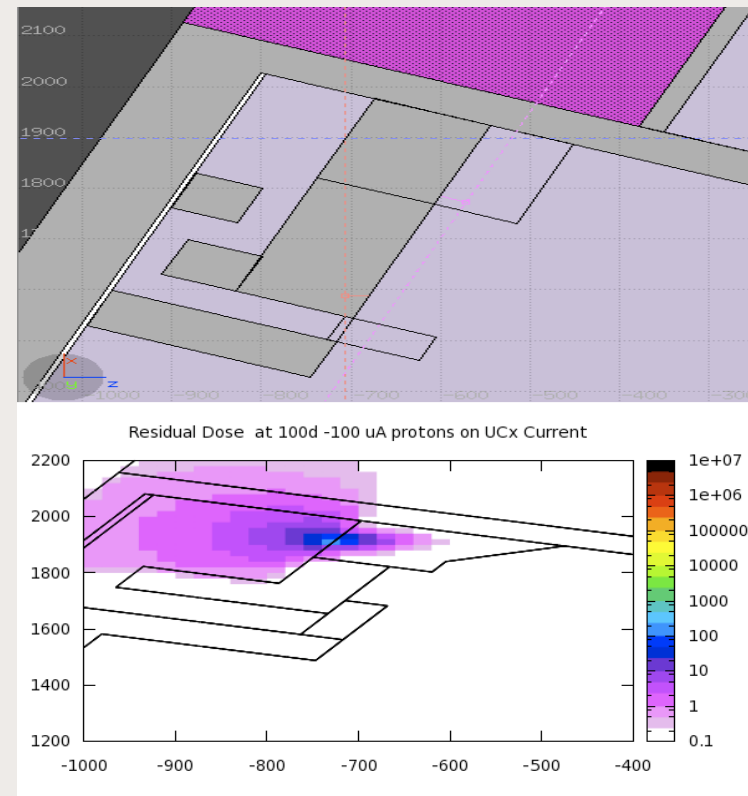
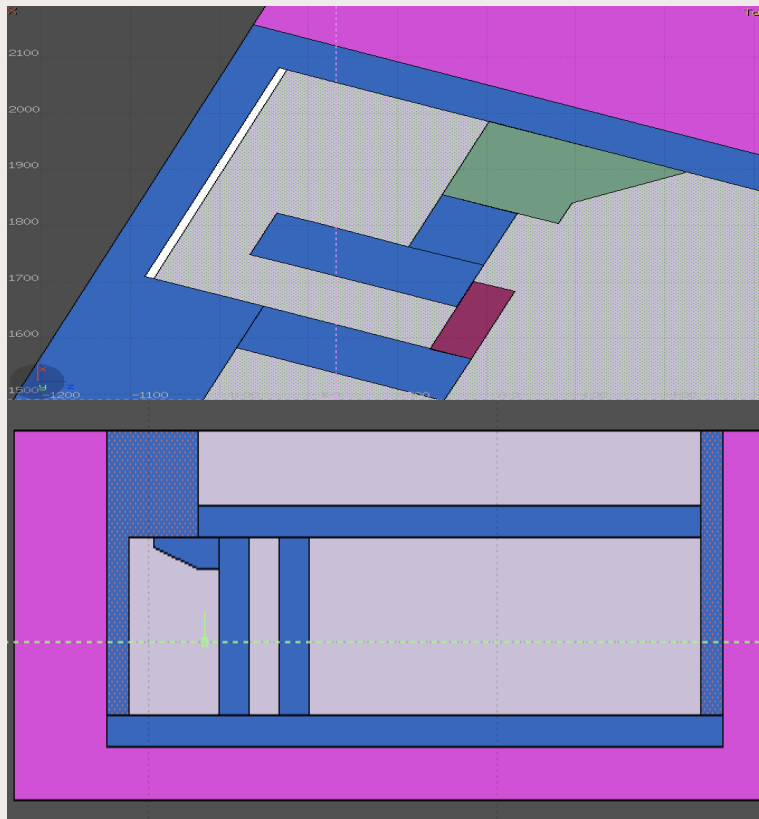


Second Step–USRBIN for 5 degrees Rotated Target

Used ROT-DEFI to rotate the target 5 degrees



- Saves CPU time
- Cannot Bias
- Flexibility in changing the geometry to achieve the optimal solution
- Flexibility in activation assessments



Thank you!

Merci

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TRIUMF: Alberta | British Columbia |
 Calgary | Carleton | Guelph | Manitoba |
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 Columbia | Queen's Regina | Saint Mary's |
 Simon Fraser | Toronto Victoria | Winnipeg
 | York

