Calculations of biological protection for Au-Au collisions

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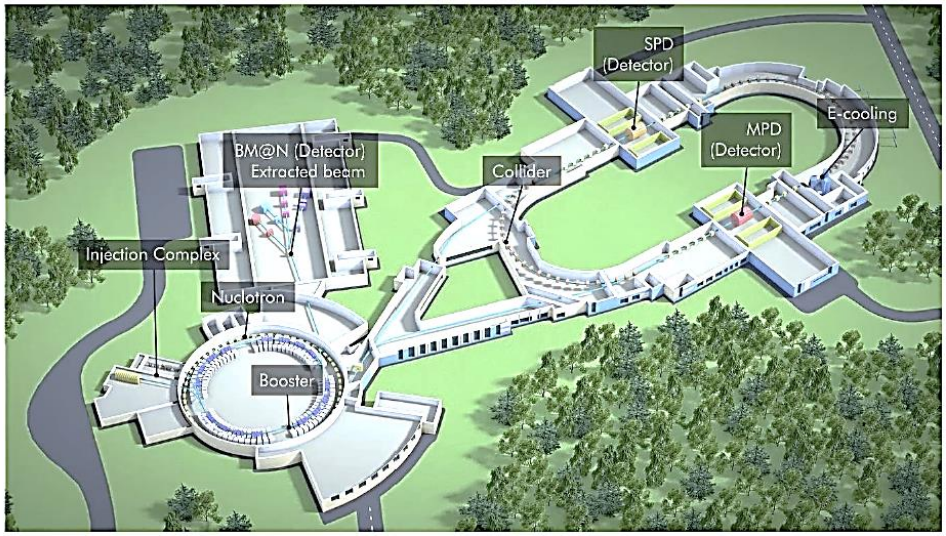
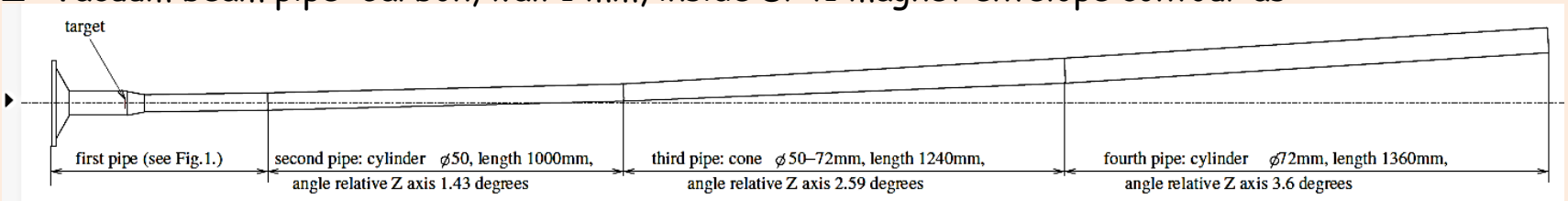
BM@N: heavy ion energy 1 - 4.5 GeV/n, beams: p to Au, Intensity ~few 10^6 /s (Au)



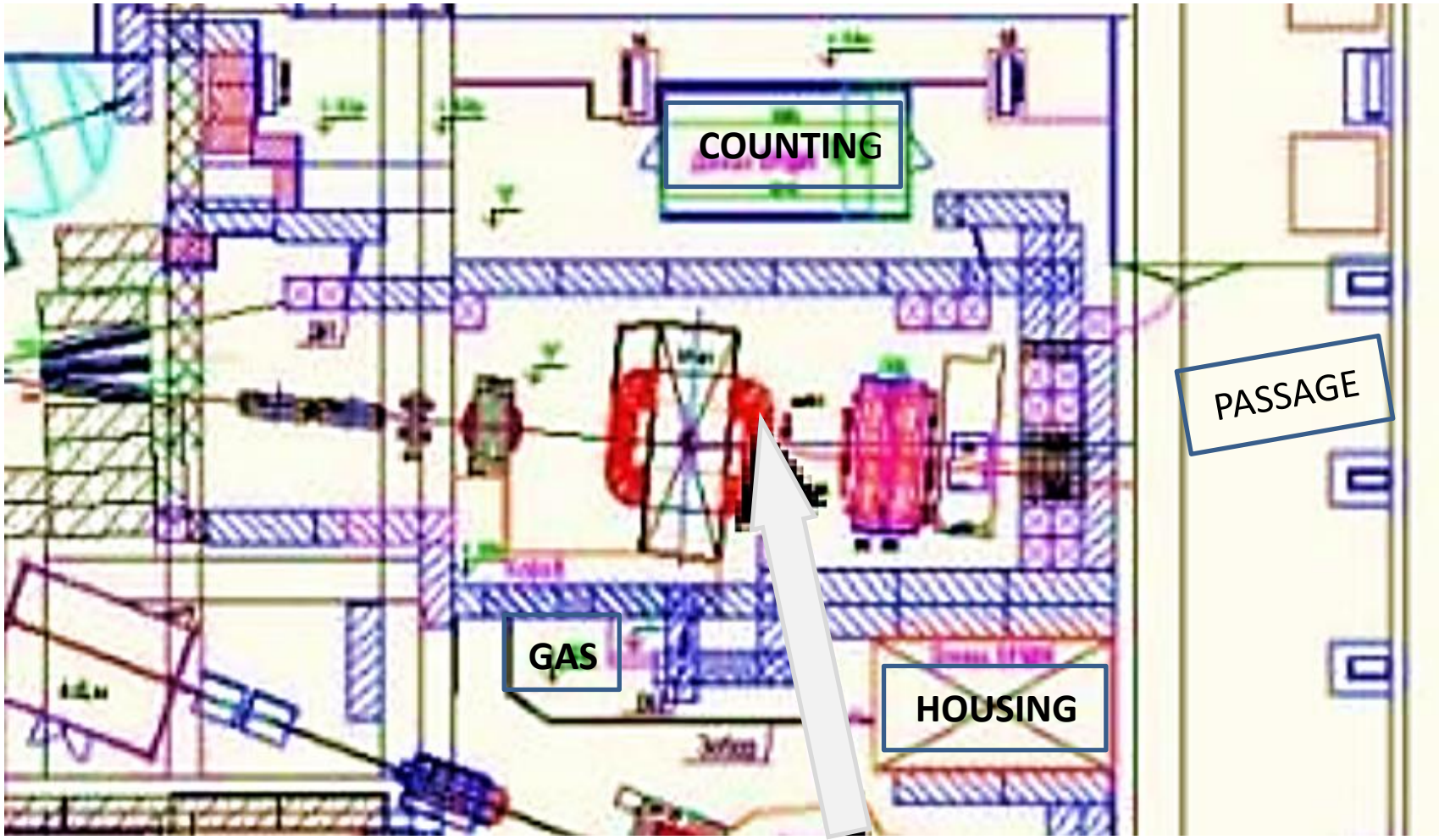
Task definition

- To perform equivalent dose rate calculations in the experimental area of the BM@N using particle physics MonteCarlo simulation package FLUKA
- To calculate the equivalent dose rate in μSv/h in the areas where personnel are located during the experiment (COUNTING and HOUSING rooms), as well as in the areas of short-term presence of personnel (GAS) and personnel passage (PASSAGE) at different beam intensities.

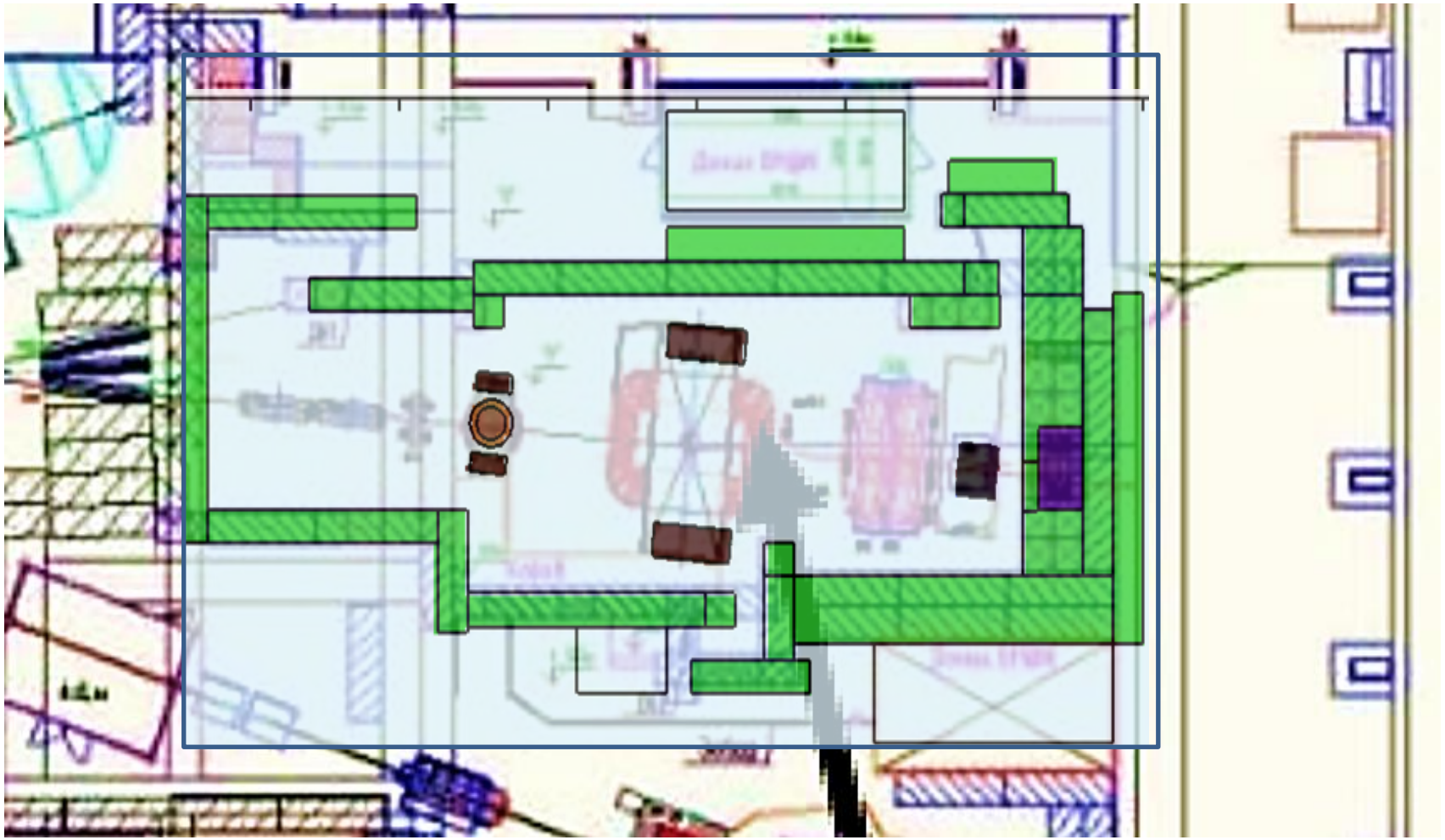
- Beam: Au 4.5 AGeV, Gaussian, $\sigma_x = \sigma_y = 3.5$ mm (on the target), intensity $2 \cdot 10^6$ ions/sec (also $1 \cdot 10^6$ and $5 \cdot 10^5$)
- Target: Au, cylider, radius 15 mm, length 1.06 mm
- Beamstop: Steel-15, cube 1.6x2.45x1.1 m^3 , behind near half of meter layer of concrete
- Vacuum beam pipe: Carbon, wall 1 mm, inside SP41 magnet envelope contour as:

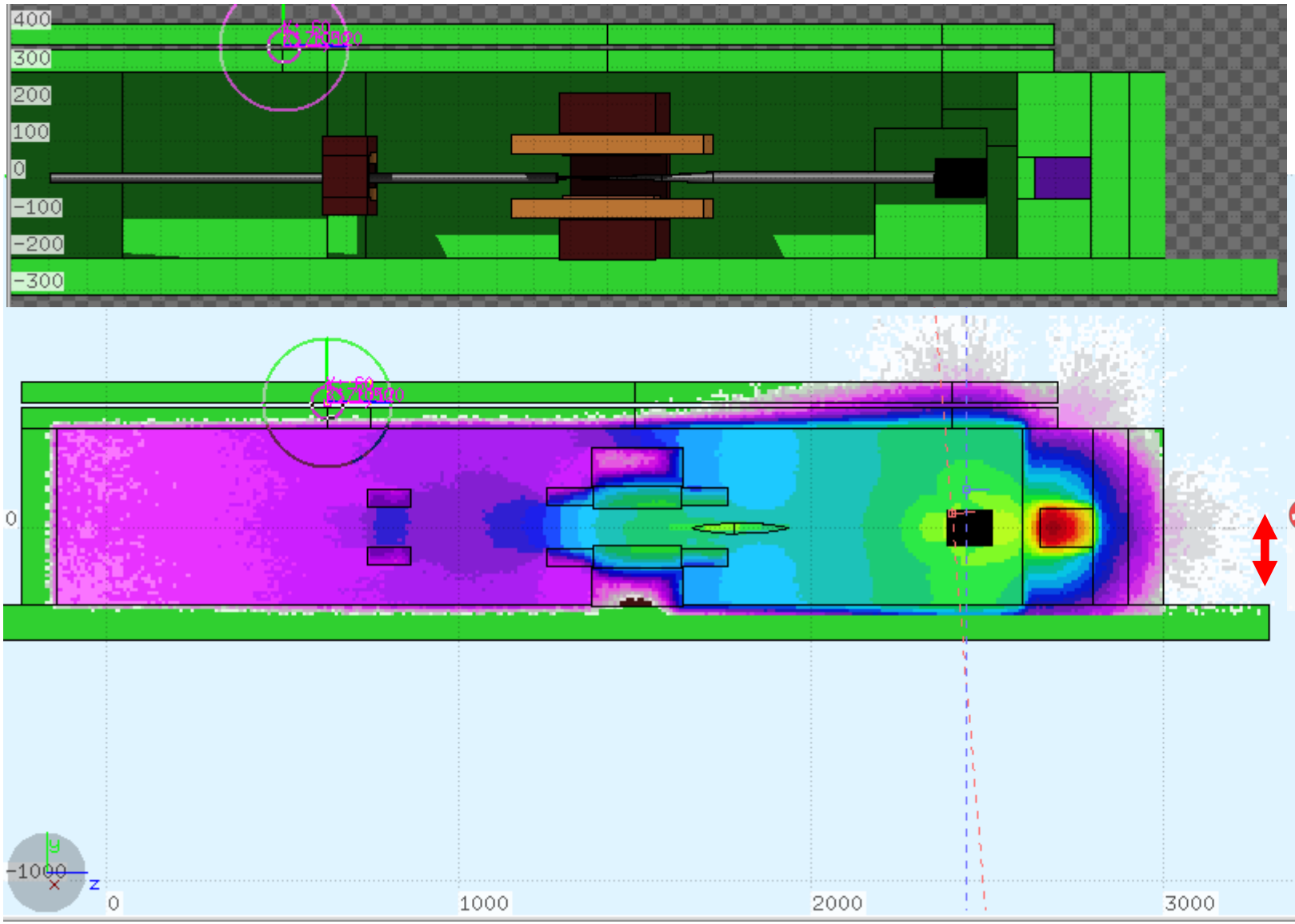


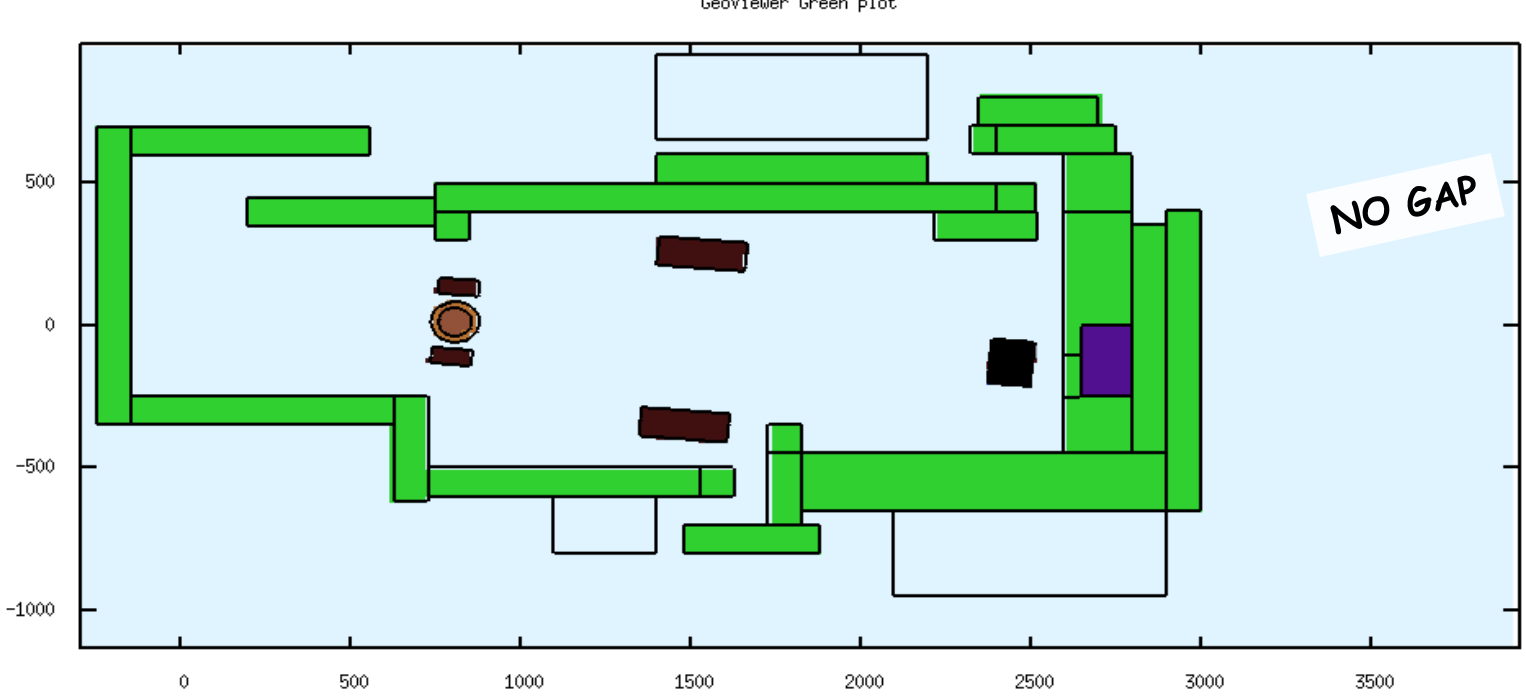
- Magnets: analyzing SP41 and bending SP57
- ZDC: layers from Pb (16 mm) and scintillator (4mm) with the inclusion of 20 mm steel plates for screed, hole 15x15 cm in the center.
- Staff houses with thin steel walls
- Main protection - concrete walls of various thicknesses, 5 m high, in the configuration implemented in the experimental zone, with concrete roof, 1.2 m high

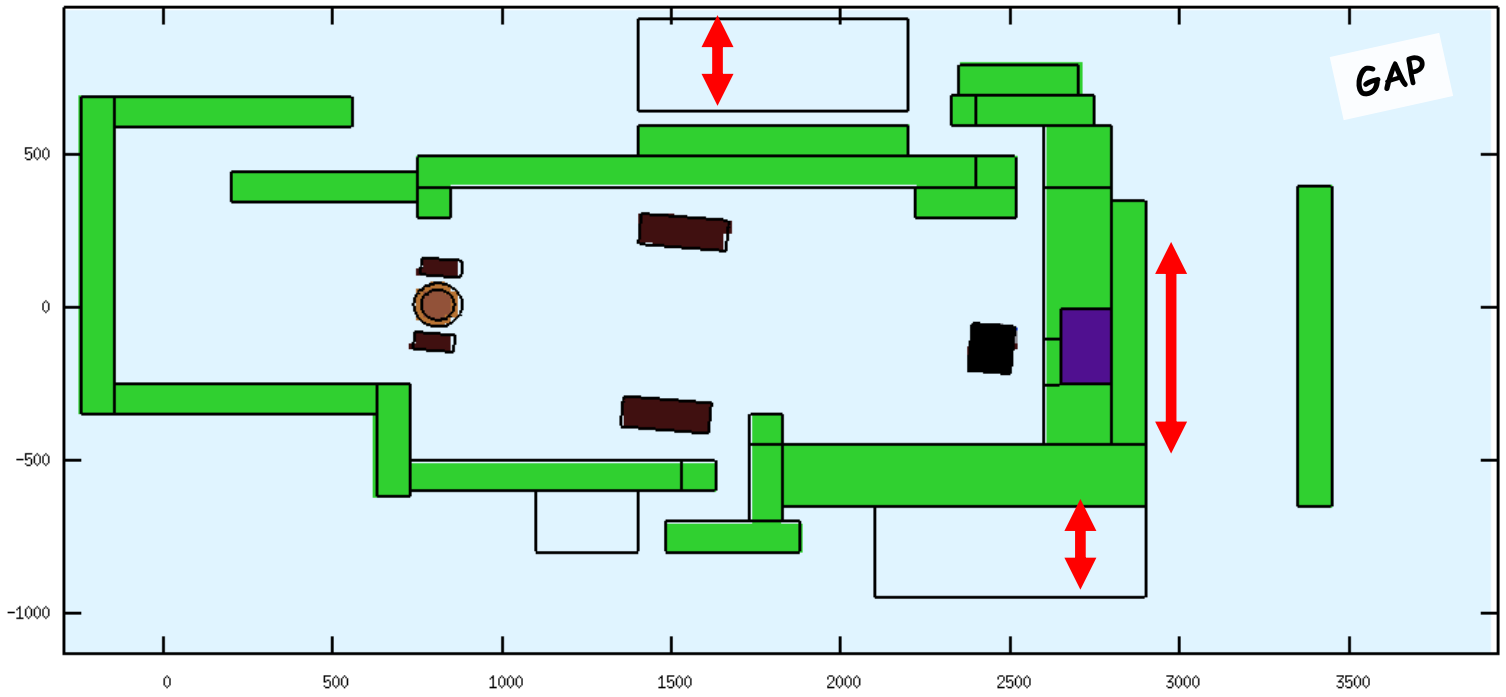

COUNTING
PASSAGE
GAS
HOUSING

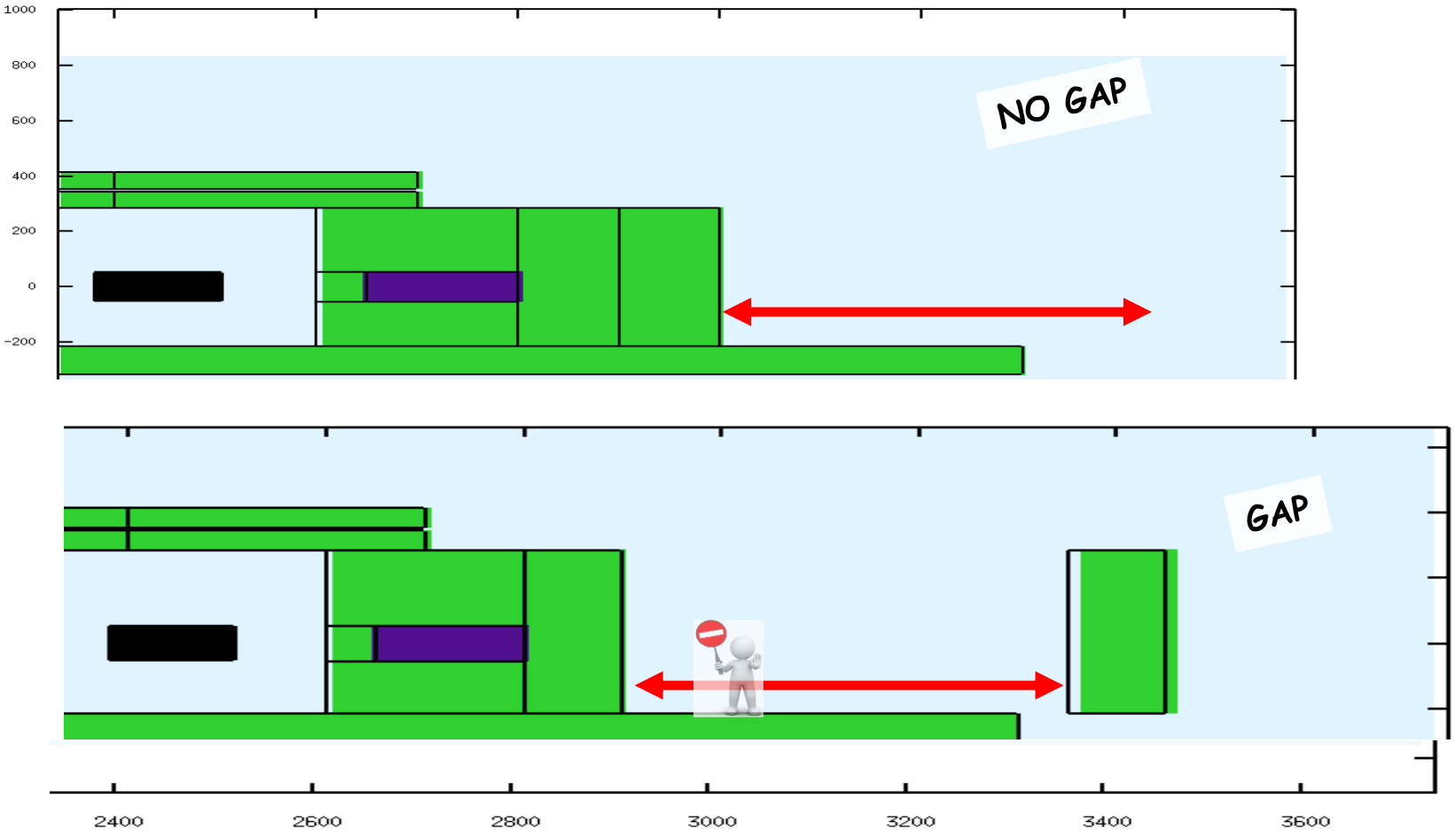
Geometry for FLUKA




400
300
200
100
0
-100
-200
-300
Left
1
0.1
0.01
0.001
0.0001
1e-05
1e-06
0
-1000
0
1000
2000
3000
y
x
z


Geoviewer Green plot
500
0
-500
-1000
0
500
1000
1500
2000
2500
3000
3500
NO GAP


500
0
-500
-1000
0
500
1000
1500
2000
2500
3000
3500
GAP


1000
800
600
400
200
0
-200
NO GAP
GAP
2400
2600
2800
3000
3200
3400
3600

Calculation details

- The calculations were performed on the HybriLIT computer farm, for this the basic packages were specially installed (thanks to Maxim Zuev for the installation)
- RQMD was used as external event generator for FLUKA.
- Statistics - about 150000 primary particles
- Performance - about
  100 primary particles per hour

Heavy ion interaction models in FLUKA

E > 5 GeV/n

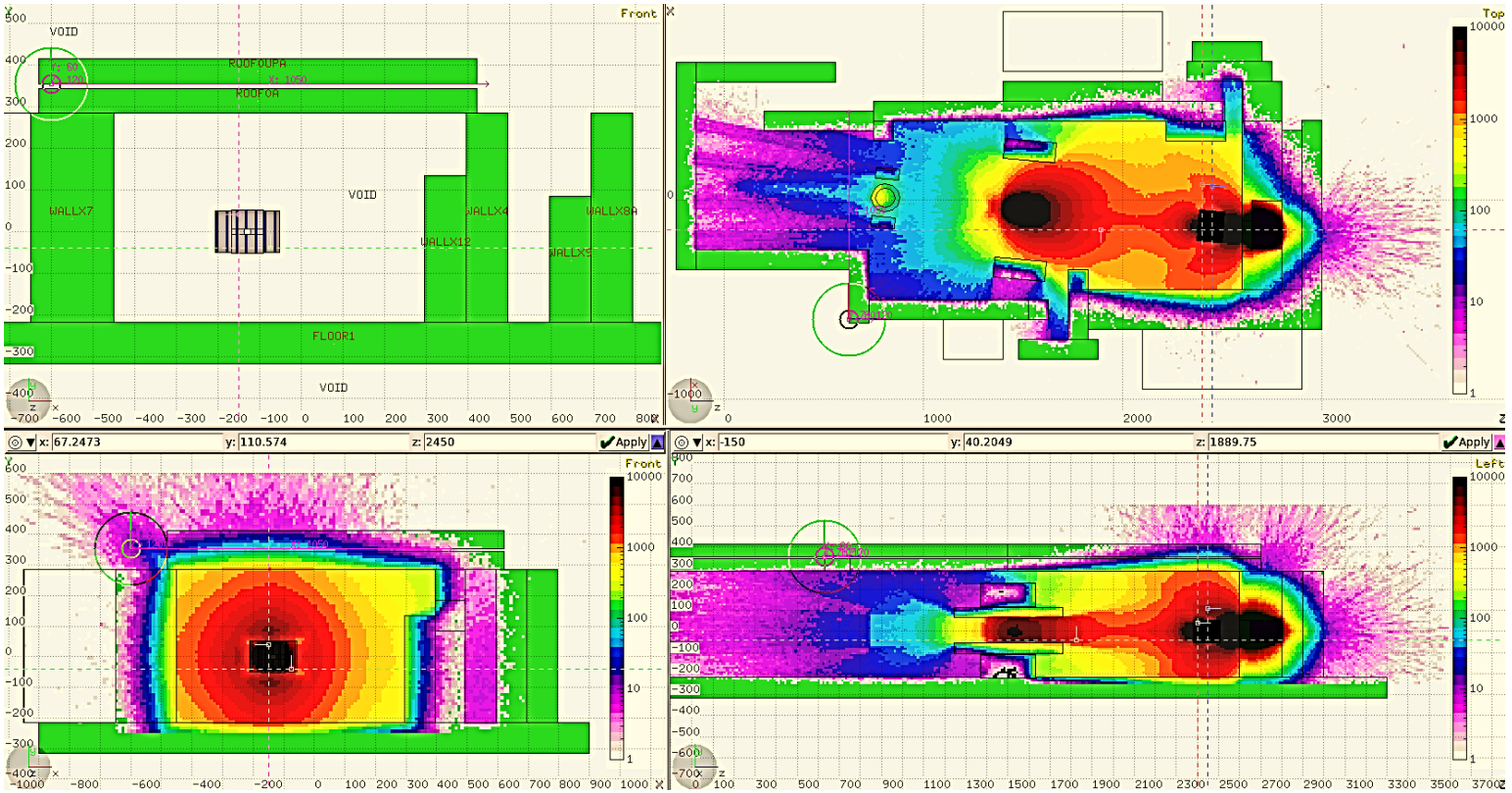
Dual Parton Model (DPM)
DPMJET-III (original code by R.Engel, J.Ranft and S.Roesler, FLUKA-implementation by T.Empl *et al.*)

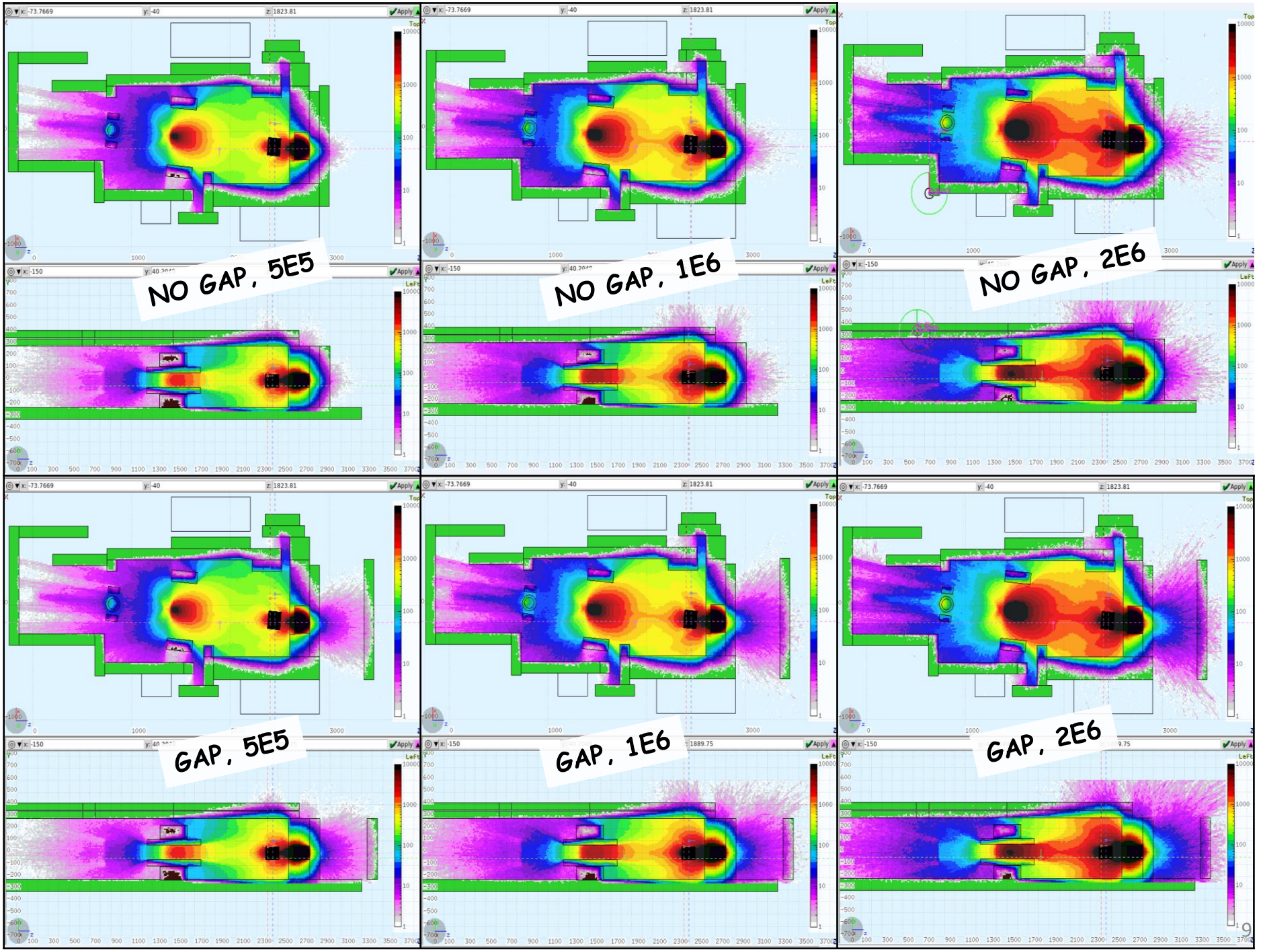
~0.1 GeV/n < E < 5 GeV/n

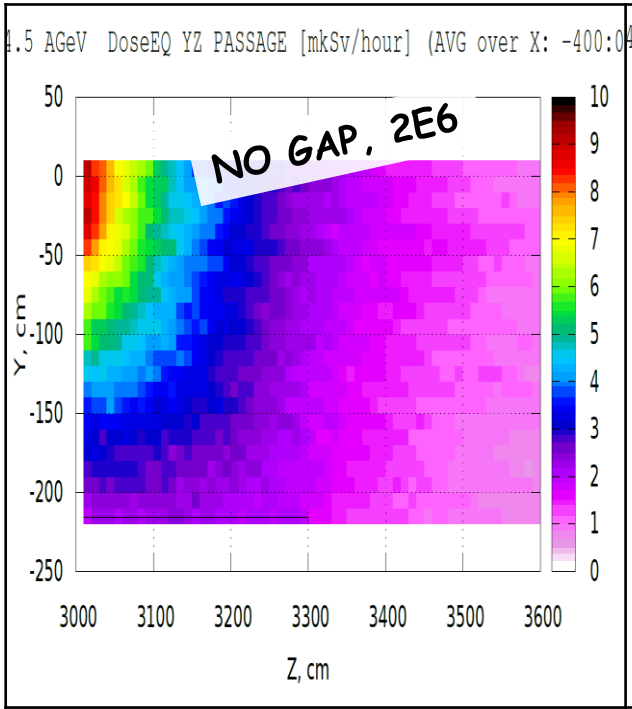
Relativistic Quantum Molecular Dynamics Model (RQMD)
RQMD-2.4 (original code by H.Sorge *et al.*, FLUKA-implementation by A.Ferrari *et al.*)

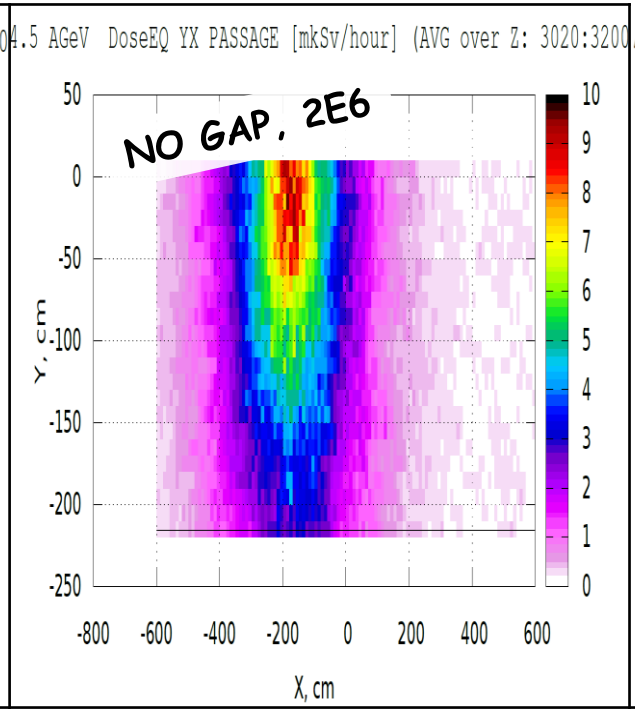
E < ~0.1 GeV/n

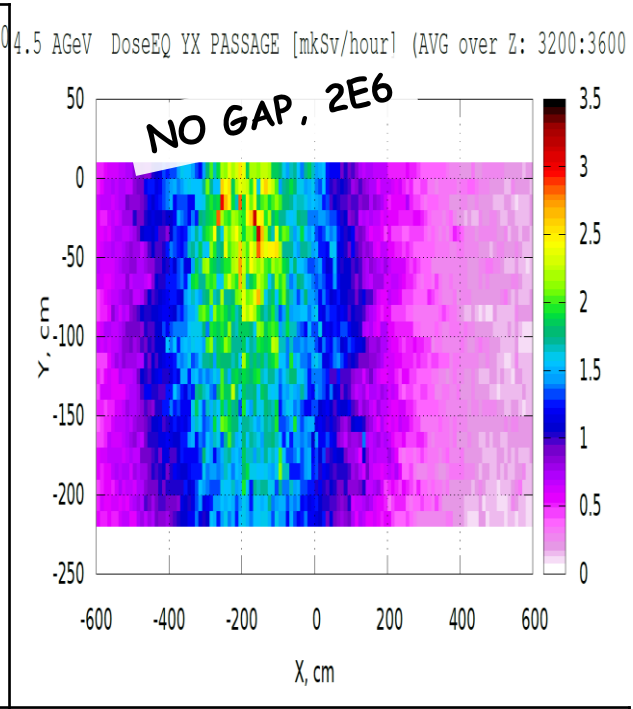
Boltzmann Master Equation (BME) theory
BME (original code by E.Gadioli *et al.*, FLUKA-implementation by F.Cerutti *et al.*)

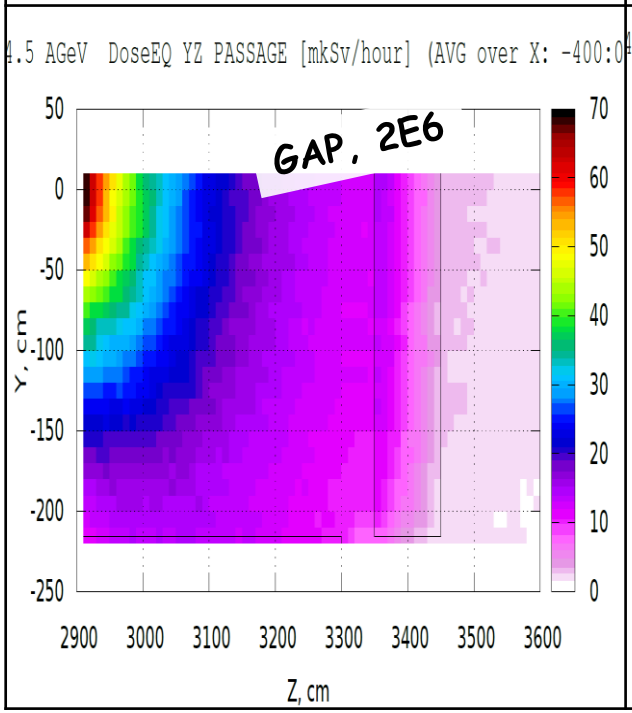



NO GAP, 5E5
NO GAP, 1E6
NO GAP, 2E6
GAP, 5E5
GAP, 1E6
GAP, 2E6


4.5 AGeV DoseEQ YZ PASSAGE [mkSv/hour] (AVG over X: -400:0
NO GAP, 2E6
Y, cm
Z, cm


4.5 AGeV DoseEQ YX PASSAGE [mkSv/hour] (AVG over Z: 3020:3200
NO GAP, 2E6
Y, cm
X, cm


4.5 AGeV DoseEQ YX PASSAGE [mkSv/hour] (AVG over Z: 3200:3600
NO GAP, 2E6
Y, cm
X, cm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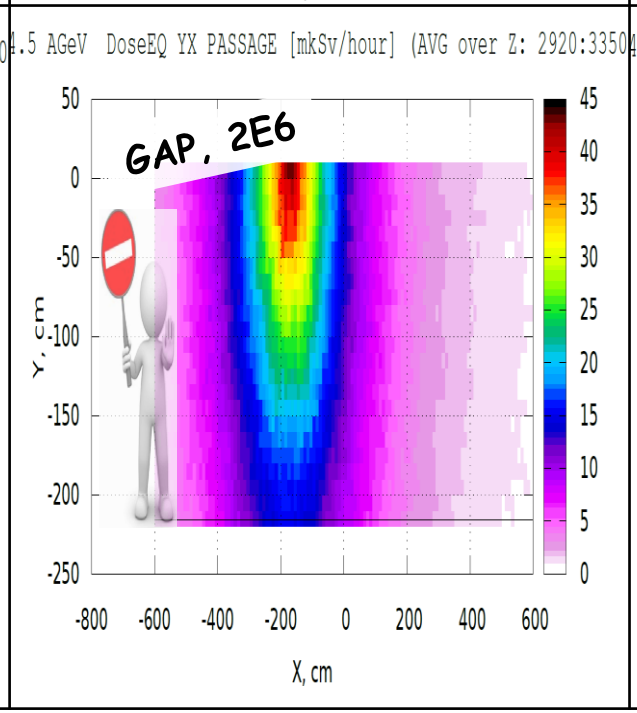
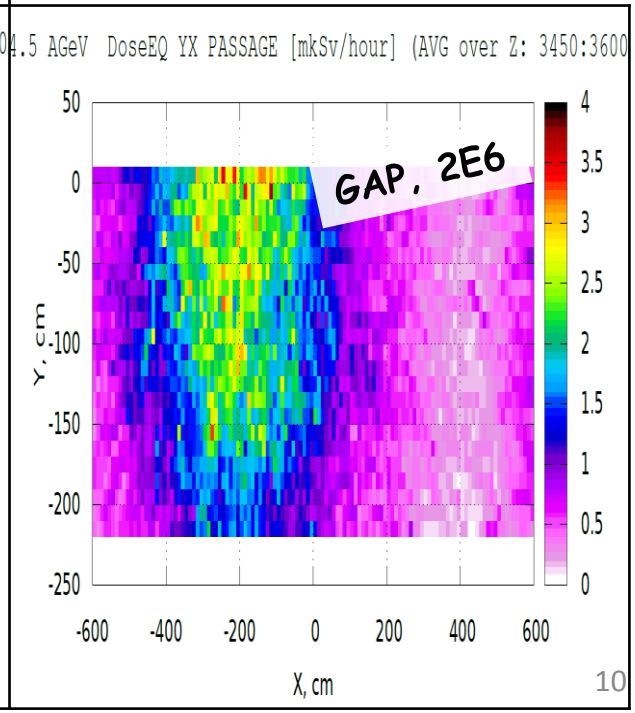
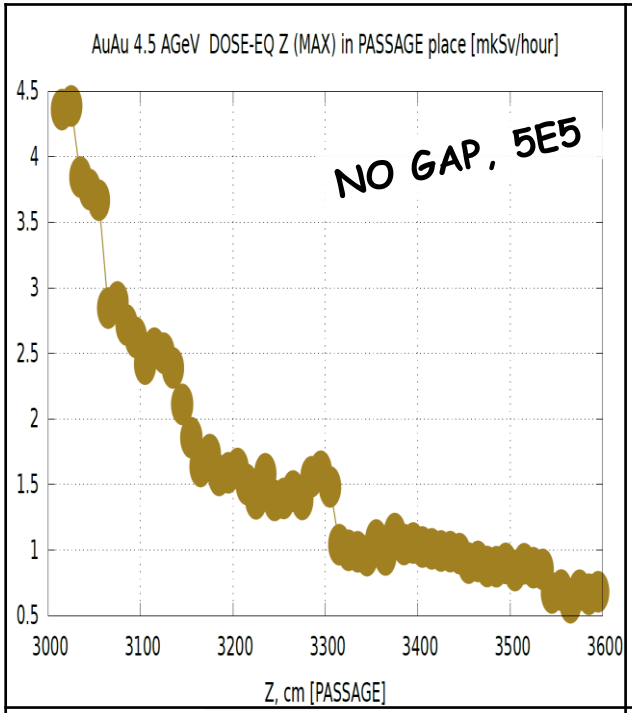
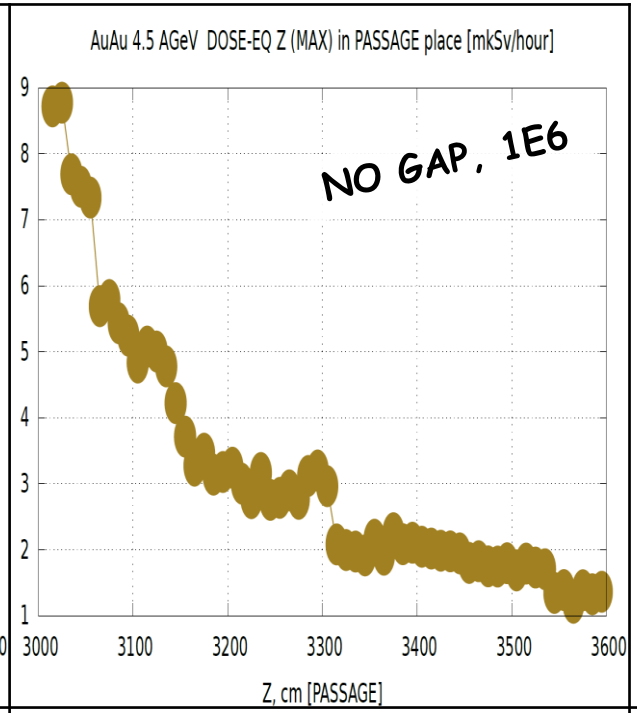
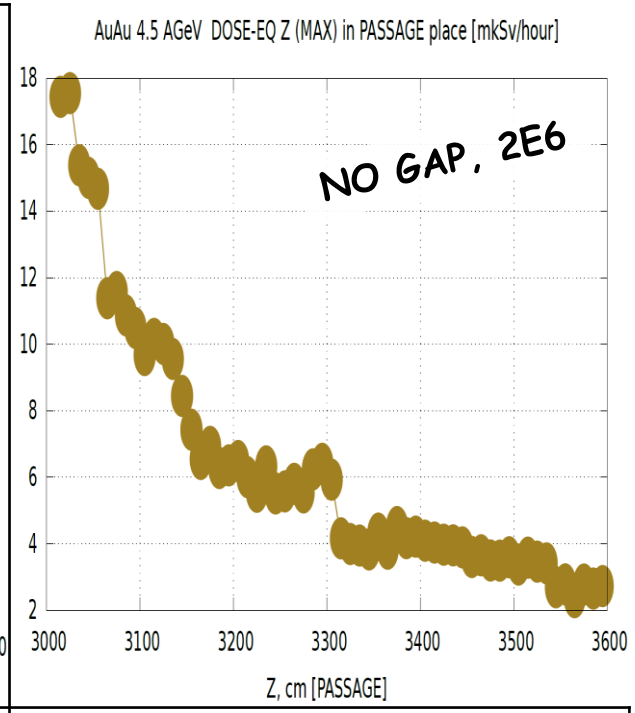
GAP, 2E6
Y, cm
Z, cm

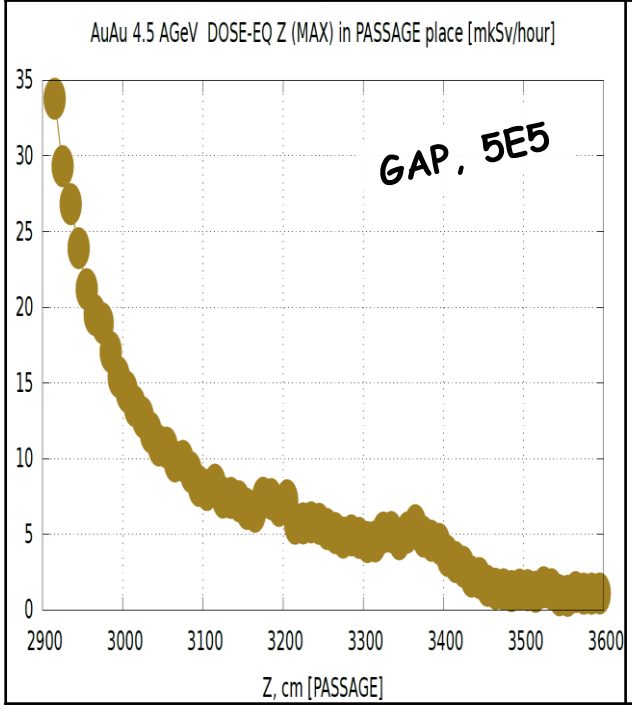

4.5 AGeV DoseEQ YX PASSAGE [mkSv/hour] (AVG over Z: 2920:3350
GAP, 2E6
Y, cm
X, cm

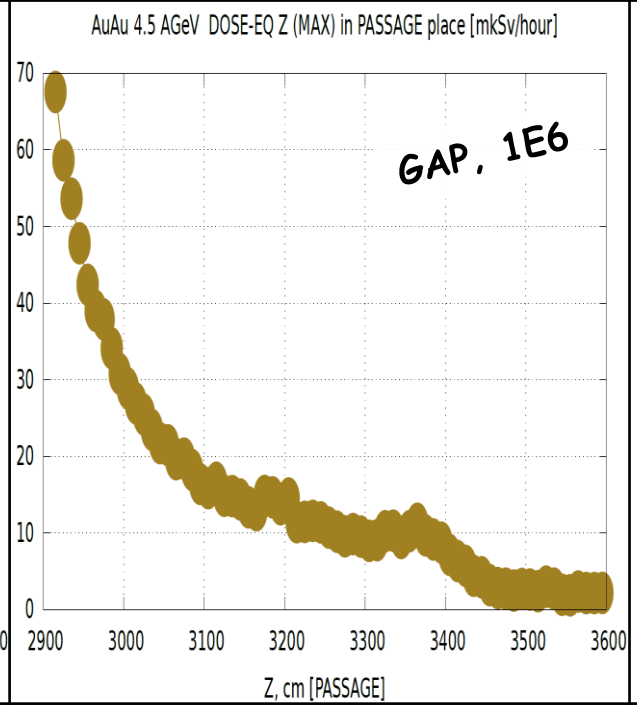

4.5 AGeV DoseEQ YX PASSAGE [mkSv/hour] (AVG over Z: 3450:3600
GAP, 2E6
Y, cm
X, cm

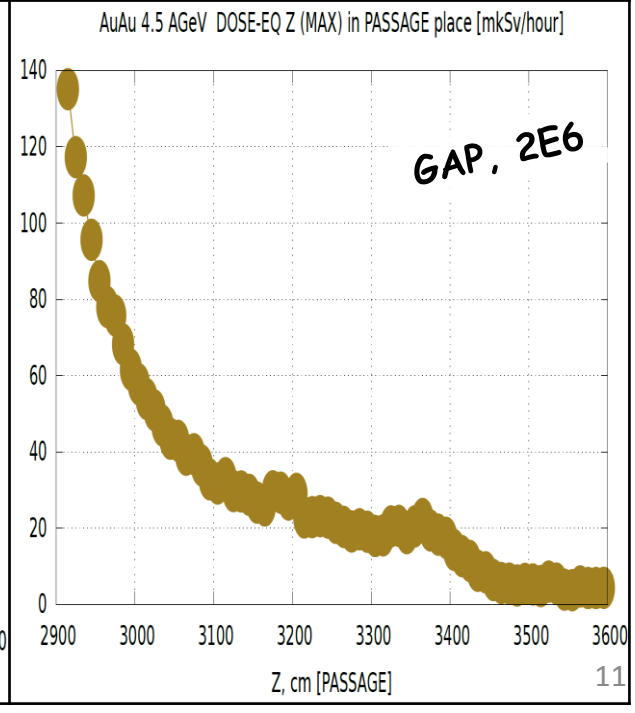

AuAu 4.5 AGeV DOSE-EQ Z (MAX) in PASSAGE place [mkSv/hour]
NO GAP, 5E5
Z, cm [PASSAGE]

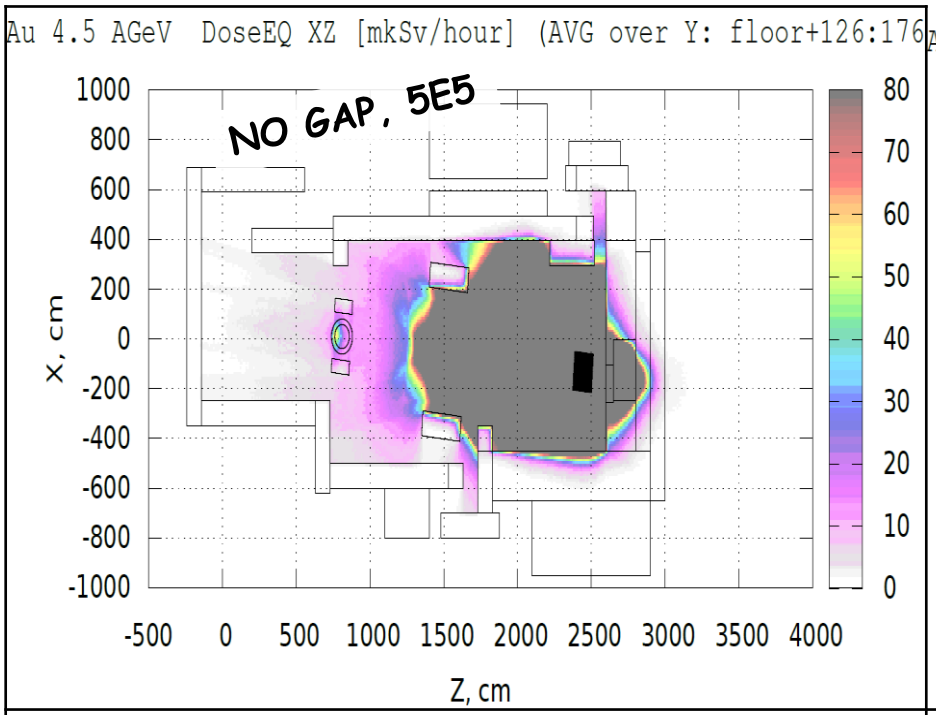

AuAu 4.5 AGeV DOSE-EQ Z (MAX) in PASSAGE place [mkSv/hour]
NO GAP, 1E6
Z, cm [PASSAGE]

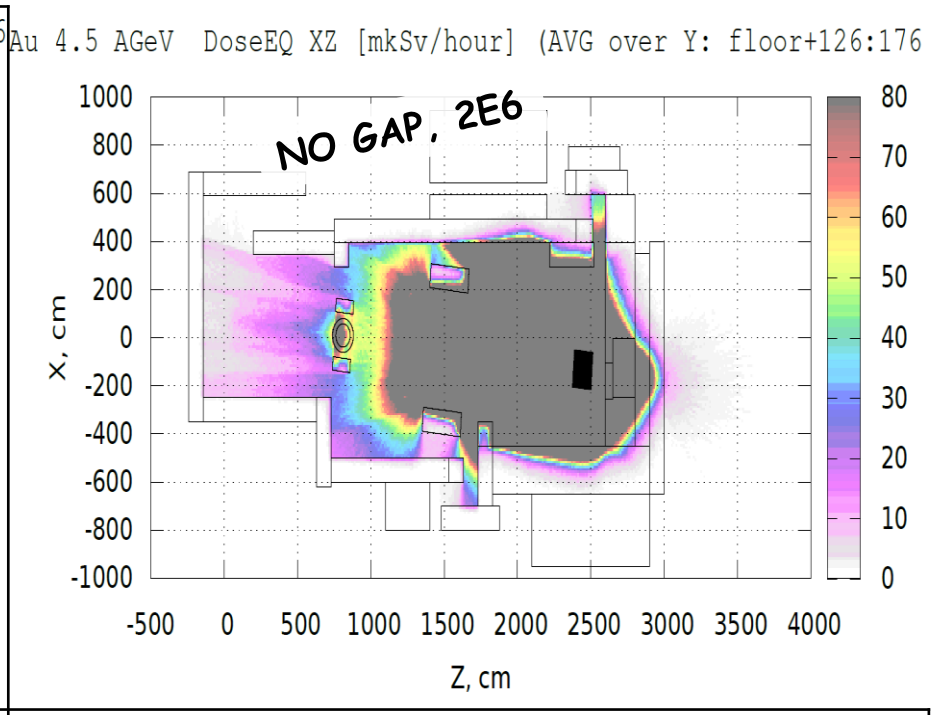

AuAu 4.5 AGeV DOSE-EQ Z (MAX) in PASSAGE place [mkSv/hour]
NO GAP, 2E6
Z, cm [PASSAGE]

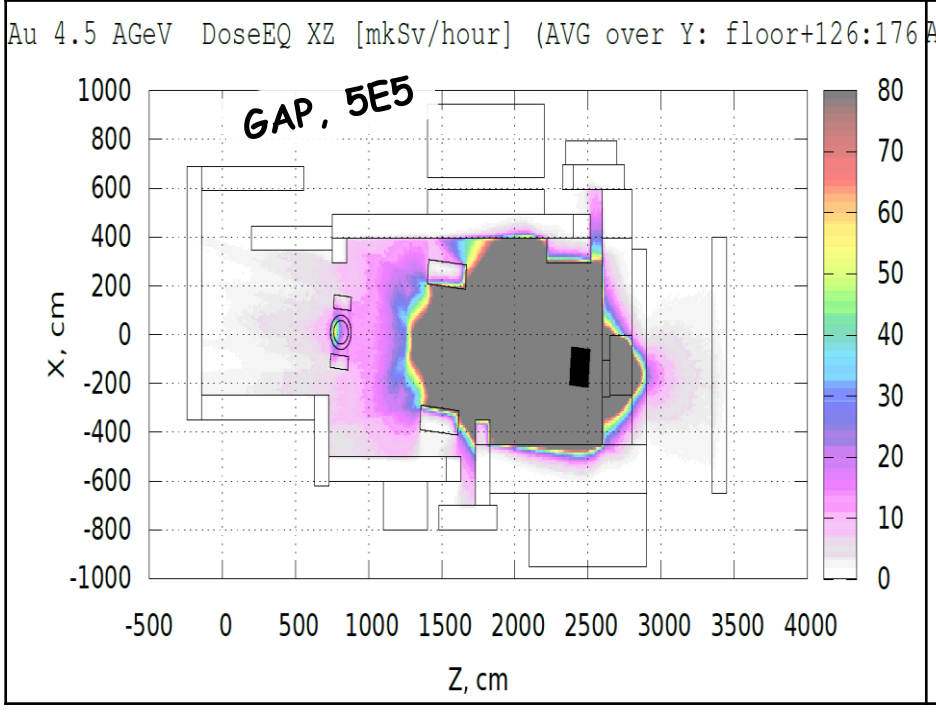

AuAu 4.5 AGeV DOSE-EQ Z (MAX) in PASSAGE place [mkSv/hour]
GAP, 5E5
Z, cm [PASSAGE]

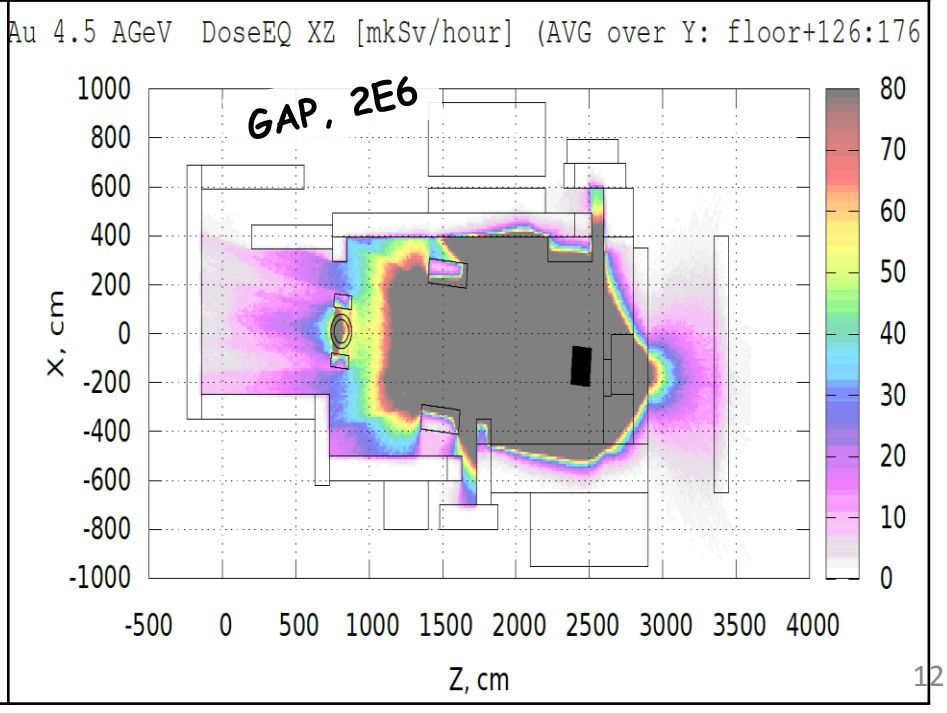

AuAu 4.5 AGeV DOSE-EQ Z (MAX) in PASSAGE place [mkSv/hour]
GAP, 1E6
Z, cm [PASSAGE]

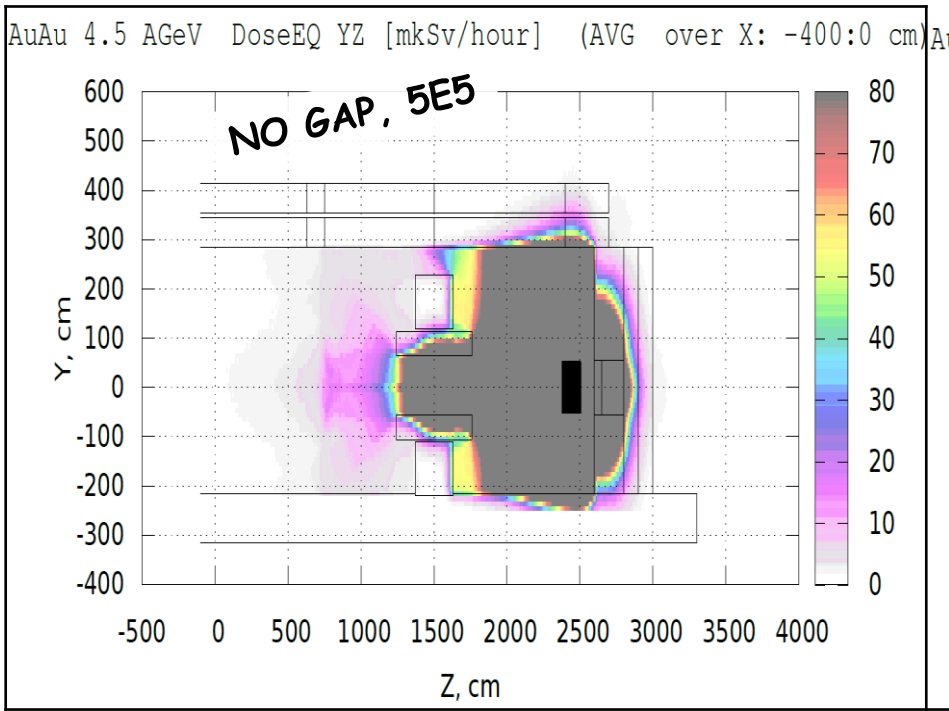

AuAu 4.5 AGeV DOSE-EQ Z (MAX) in PASSAGE place [mkSv/hour]
GAP, 2E6
Z, cm [PASSAGE]


Au 4.5 AGeV DoseEQ XZ [mkSv/hour] (AVG over Y: floor+126:176
NO GAP, 5E5
X, cm
Z, cm


Au 4.5 AGeV DoseEQ XZ [mkSv/hour] (AVG over Y: floor+126:176
NO GAP, 2E6
X, cm
Z, cm


Au 4.5 AGeV DoseEQ XZ [mkSv/hour] (AVG over Y: floor+126:176
GAP, 5E5
X, cm
Z, cm


Au 4.5 AGeV DoseEQ XZ [mkSv/hour] (AVG over Y: floor+126:176
GAP, 2E6
X, cm
Z, cm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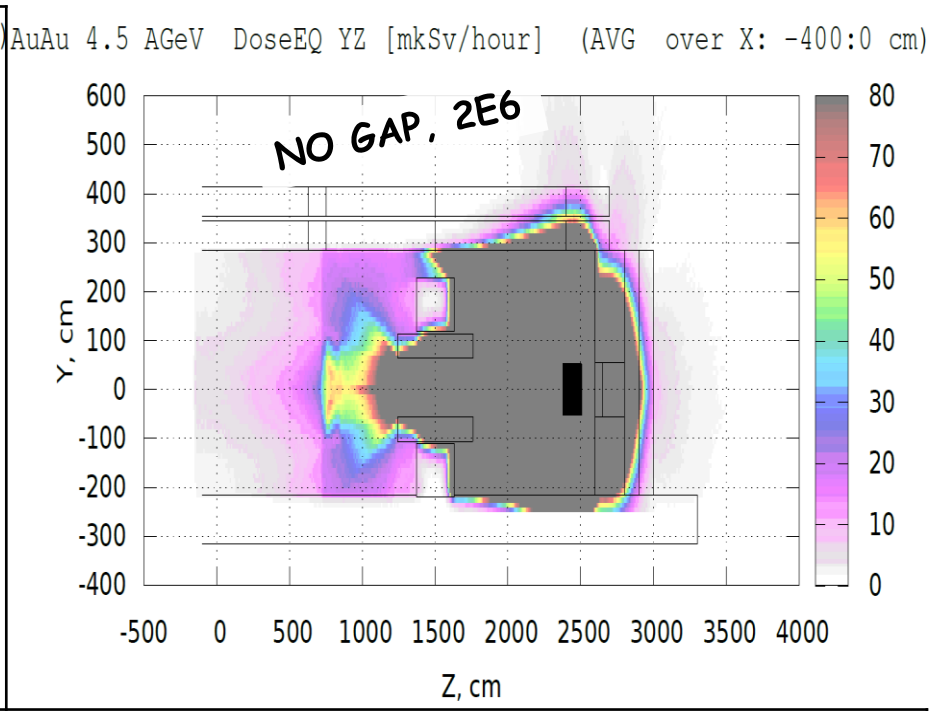
NO GAP, 5E5
Y, cm
Z, cm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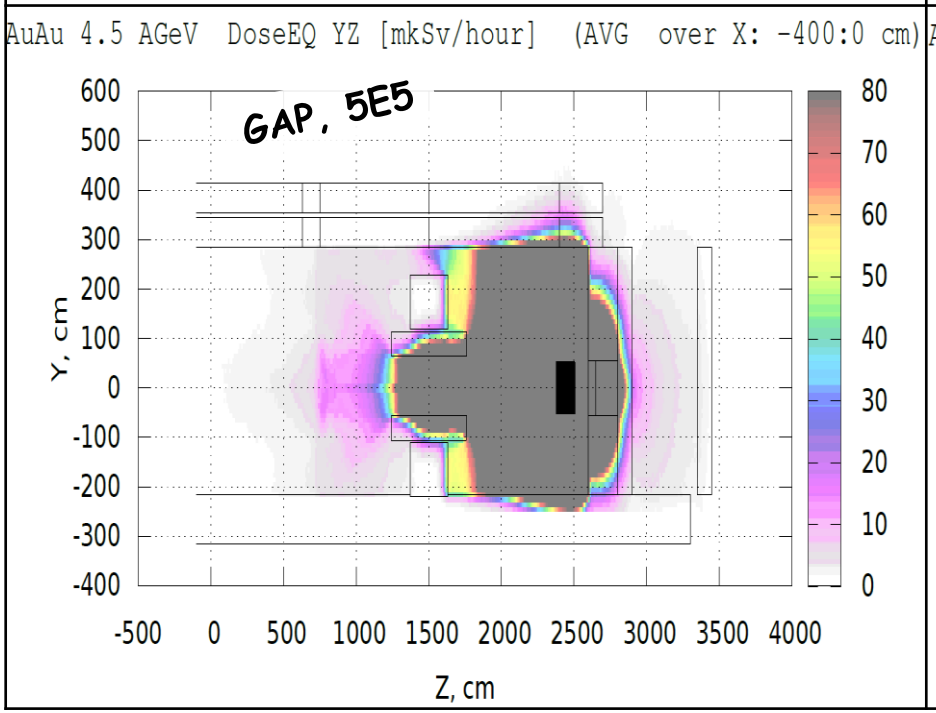
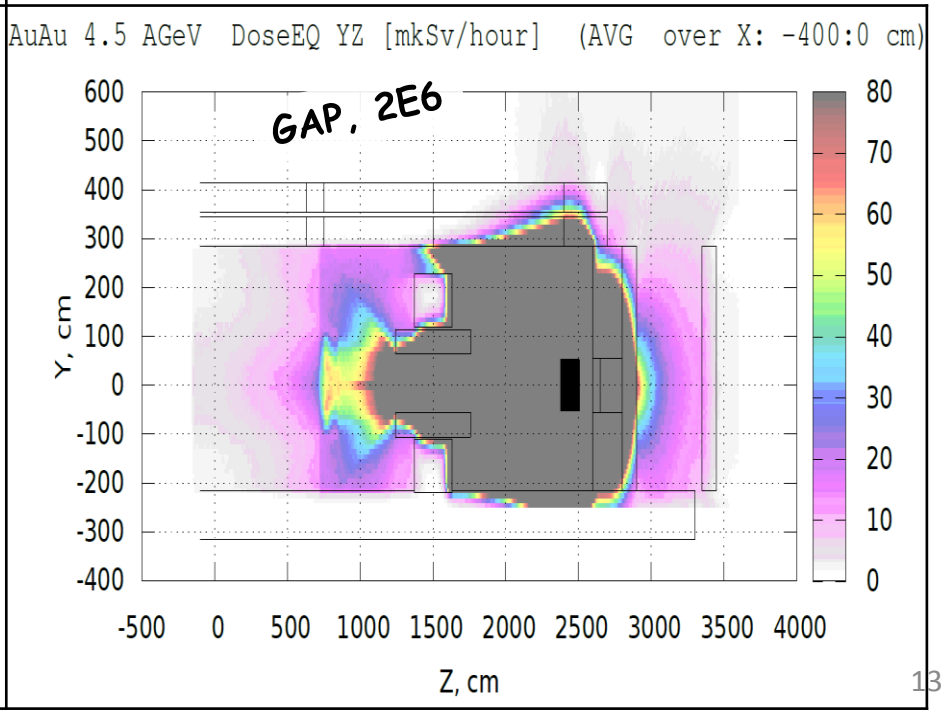
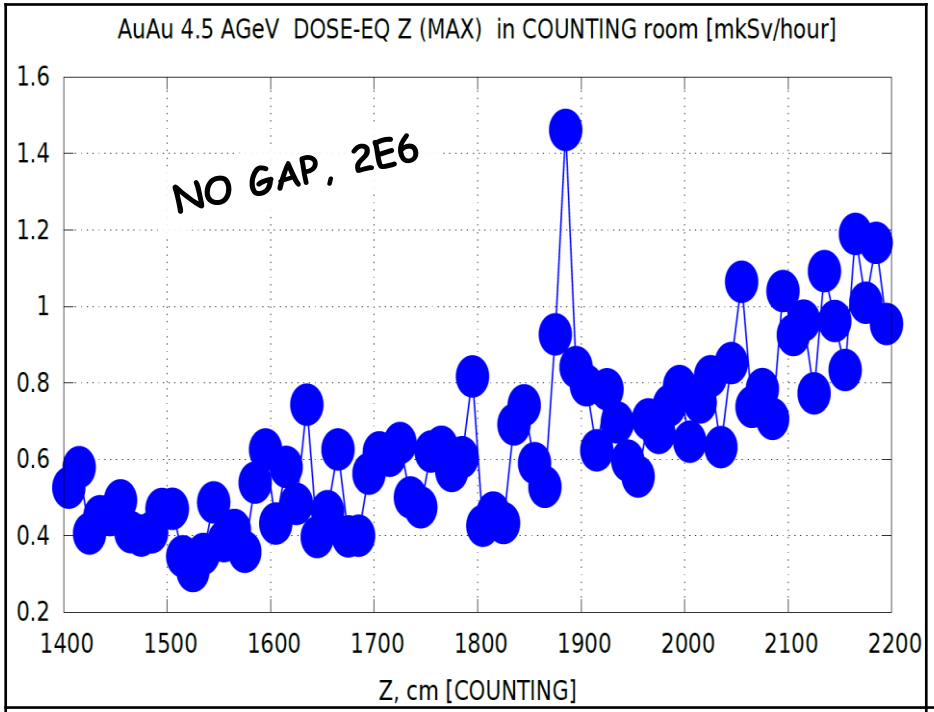
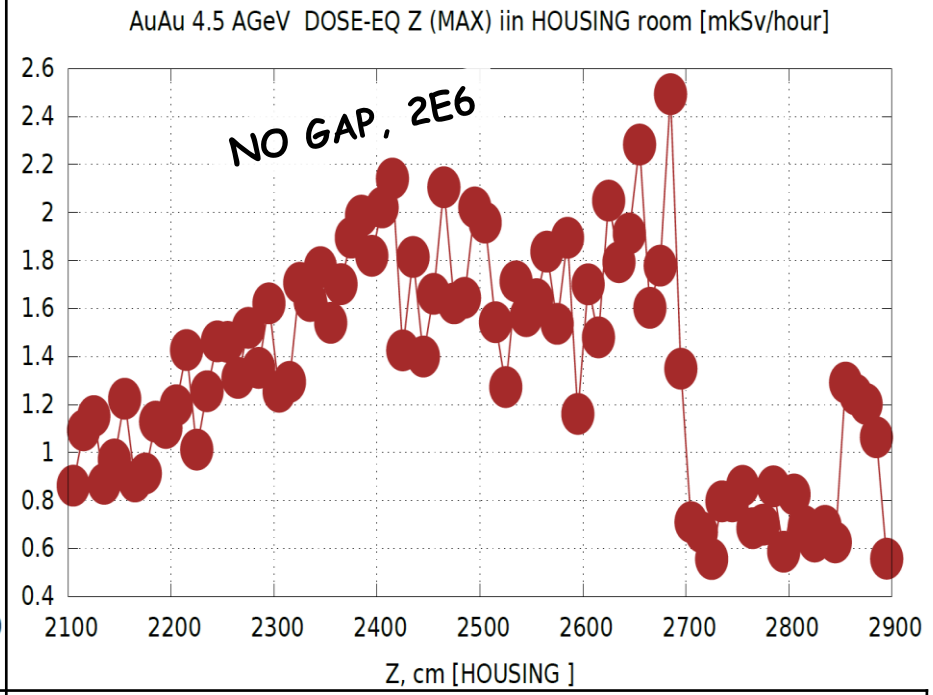
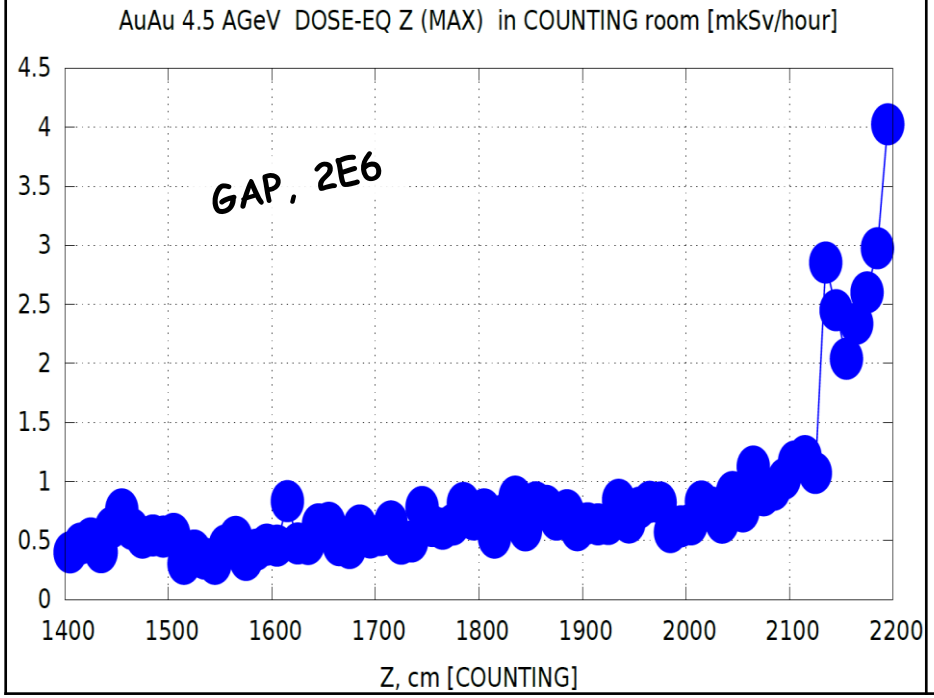
Y, cm
Z, cm

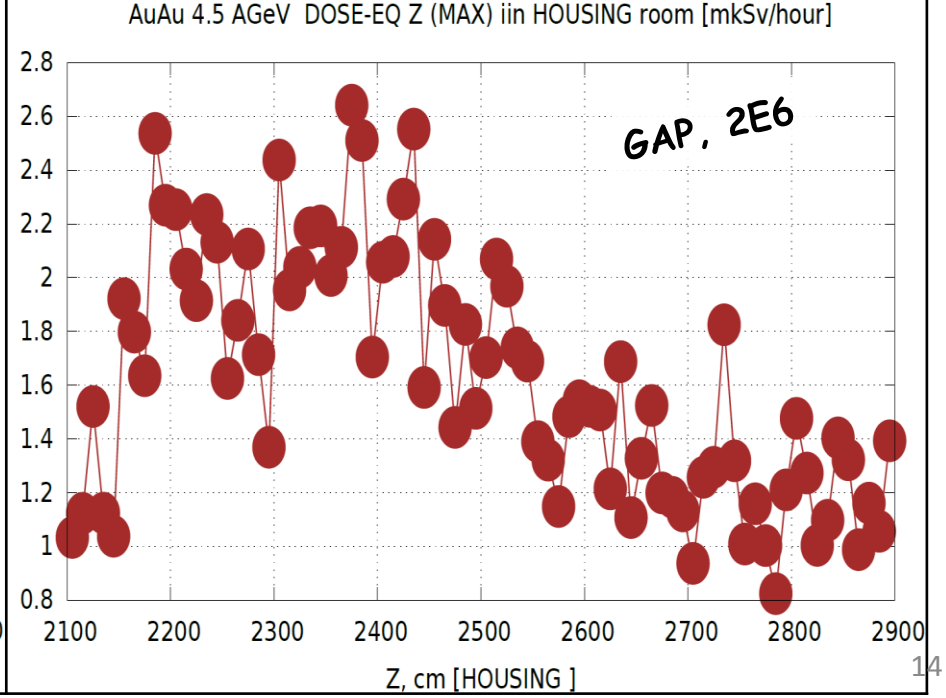

AuAu 4.5 AGeV DoseEQ YZ [mkSv/hour] (AVG over X: -400:0 cm)
GAP, 5E5
Y, cm
Z, cm

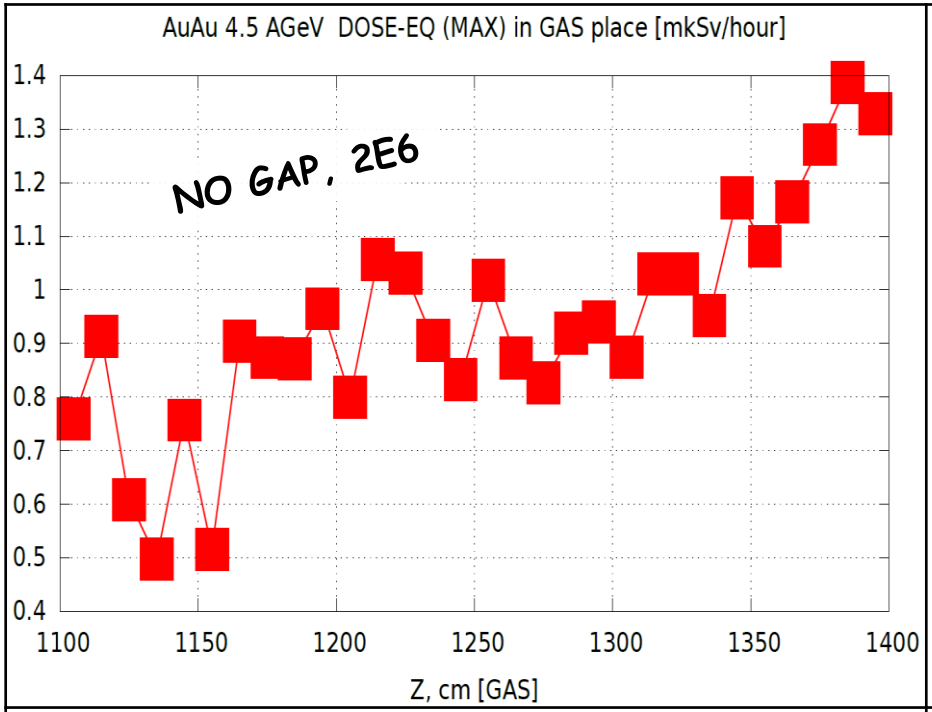

AuAu 4.5 AGeV DoseEQ YZ [mkSv/hour] (AVG over X: -400:0 cm)
GAP, 2E6
Y, cm
Z, cm

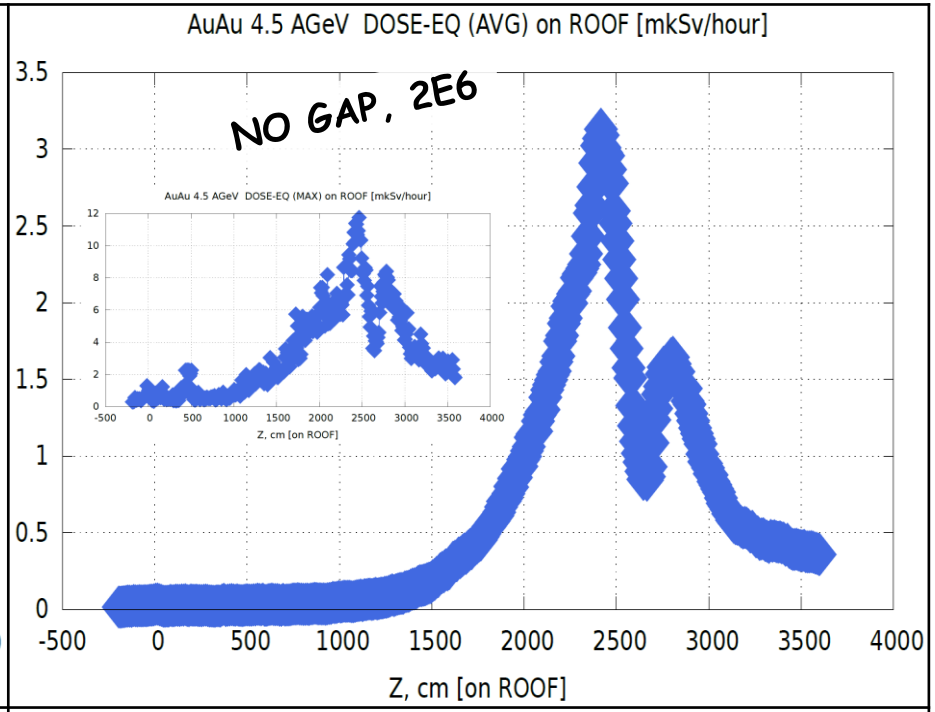

AuAu 4.5 AGeV DOSE-EQ Z (MAX) in COUNTING room [mkSv/hour]
NO GAP, 2E6
Z, cm [COUNTING]

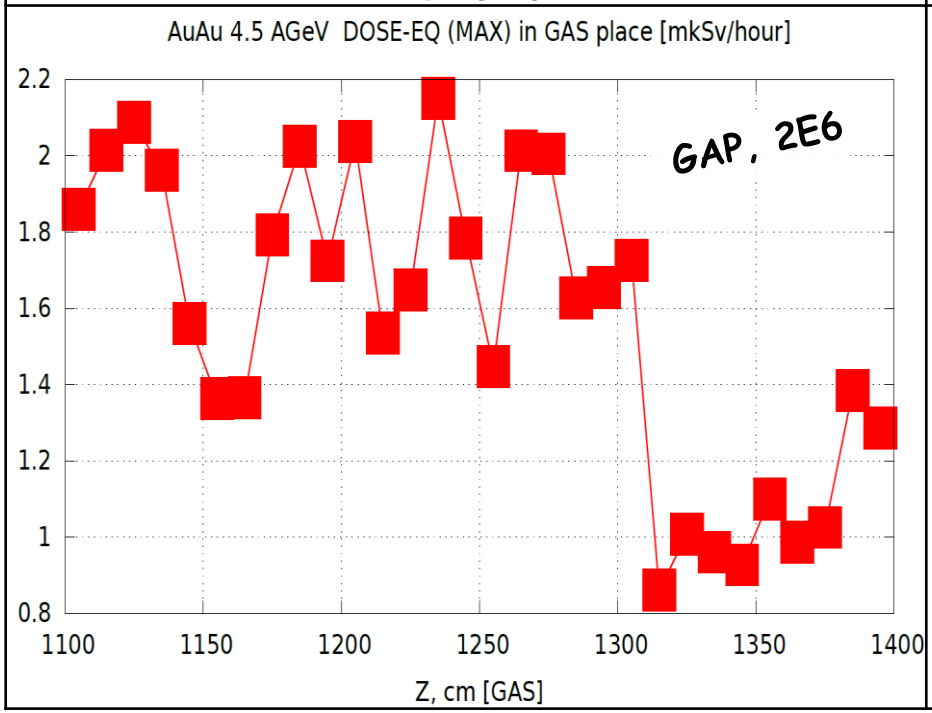

AuAu 4.5 AGeV DOSE-EQ Z (MAX) iin HOUSING room [mkSv/hour]
NO GAP, 2E6
Z, cm [HOUSING]

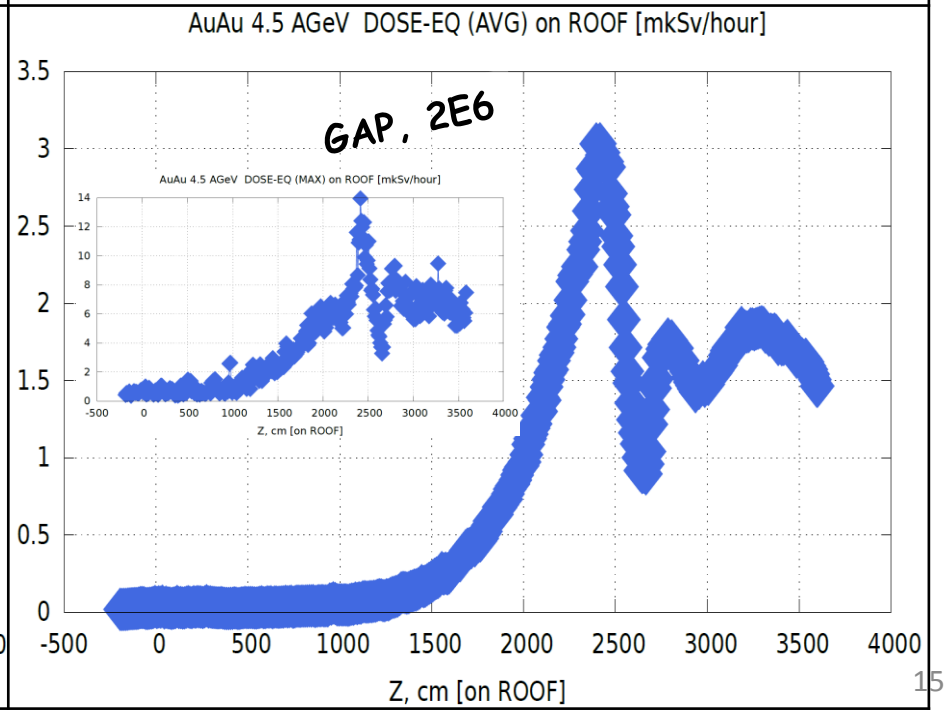

AuAu 4.5 AGeV DOSE-EQ Z (MAX) in COUNTING room [mkSv/hour]
GAP, 2E6
Z, cm [COUNTING]


AuAu 4.5 AGeV DOSE-EQ Z (MAX) iin HOUSING room [mkSv/hour]
GAP, 2E6
Z, cm [HOUSING]


AuAu 4.5 AGeV DOSE-EQ (MAX) in GAS place [mkSv/hour]
NO GAP, 2E6
Z, cm [GAS]

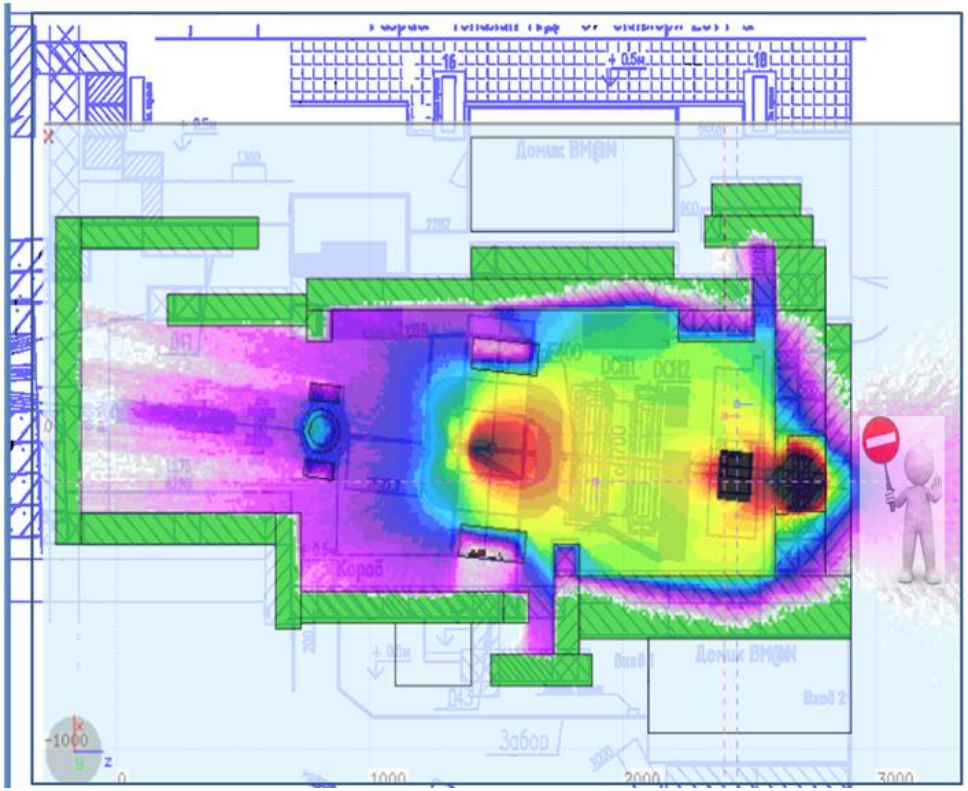

AuAu 4.5 AGeV DOSE-EQ (AVG) on ROOF [mkSv/hour]
NO GAP, 2E6
AuAu 4.5 AGeV DOSE-EQ (MAX) on ROOF [mkSv/hour]
Z, cm [on ROOF]


AuAu 4.5 AGeV DOSE-EQ (MAX) in GAS place [mkSv/hour]
GAP, 2E6
Z, cm [GAS]

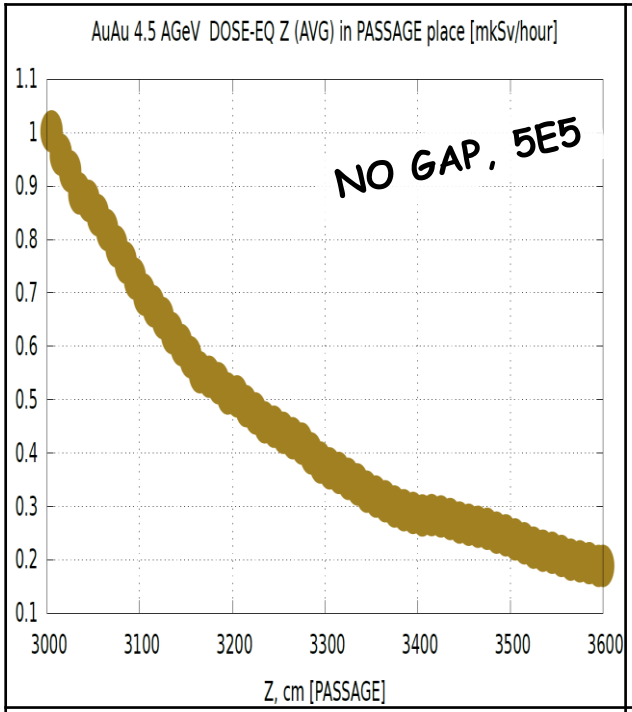

AuAu 4.5 AGeV DOSE-EQ (AVG) on ROOF [mkSv/hour]
GAP, 2E6
AuAu 4.5 AGeV DOSE-EQ (MAX) on ROOF [mkSv/hour]
Z, cm [on ROOF]

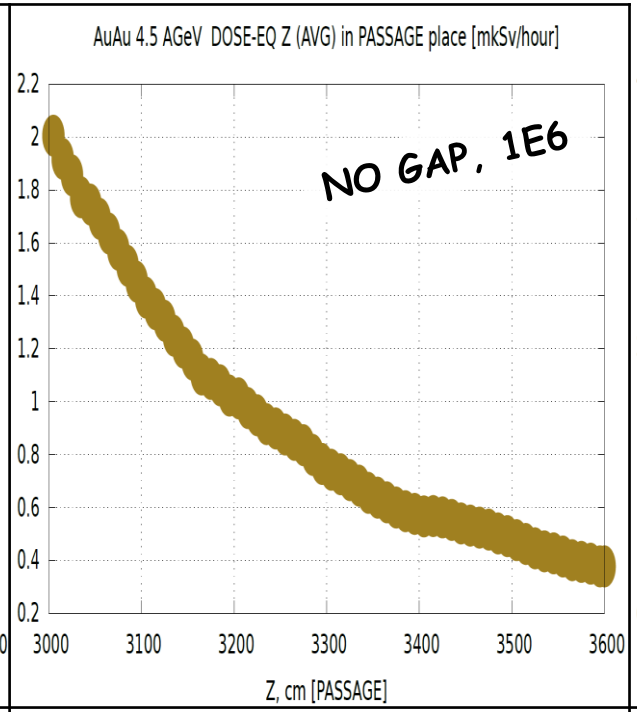
Conclusions

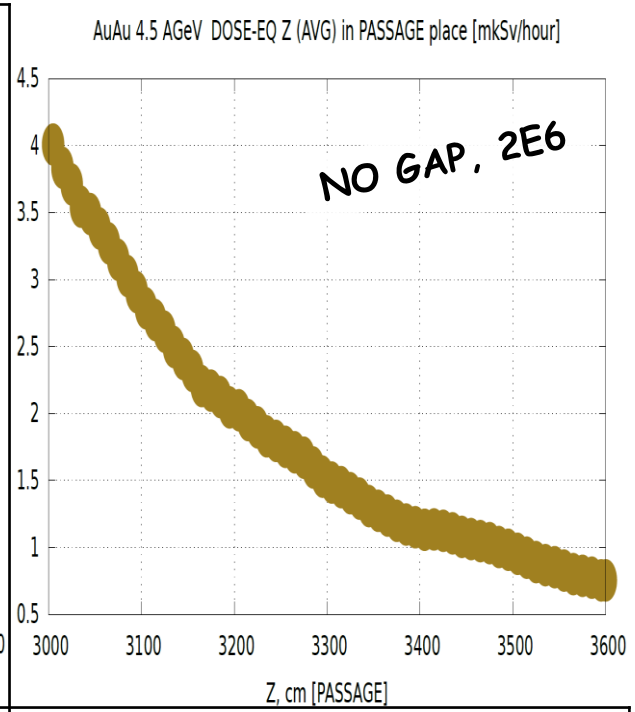
- The doze level inside the areas where personnel are located during the experiment (COUNTING and HOUSING), as well as in the areas of short-term presence of personnel (GAS), does not exceed allowed radiation level (6 μSv/h) for intensities up to $2 \cdot 10^6$ ions/sec
- For the passage area (PASSAGE) the final decisions have to be discussed

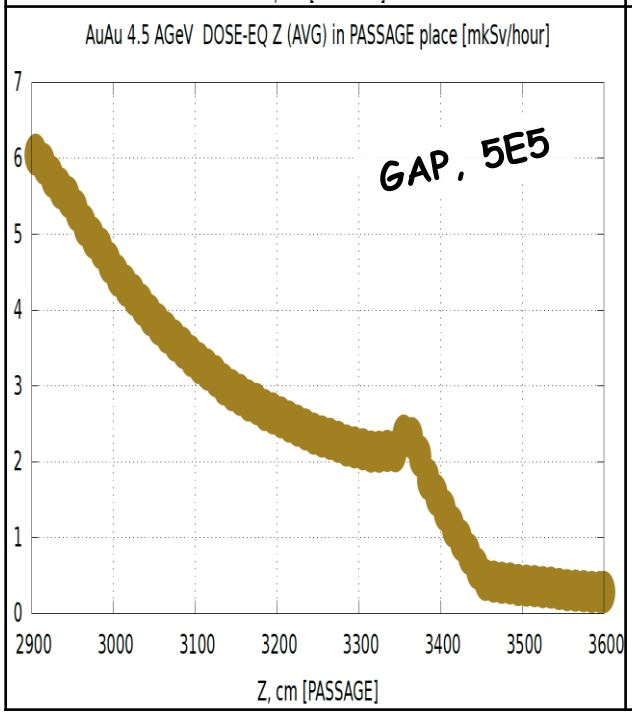


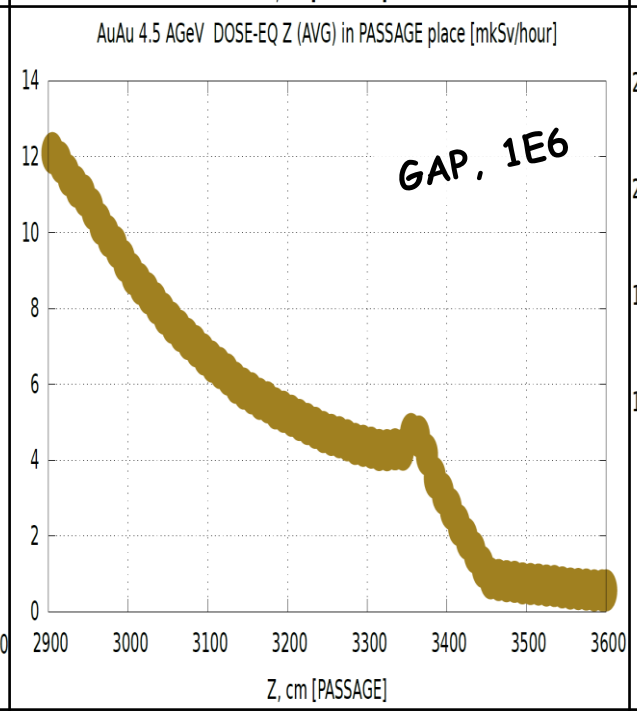
Backup slides

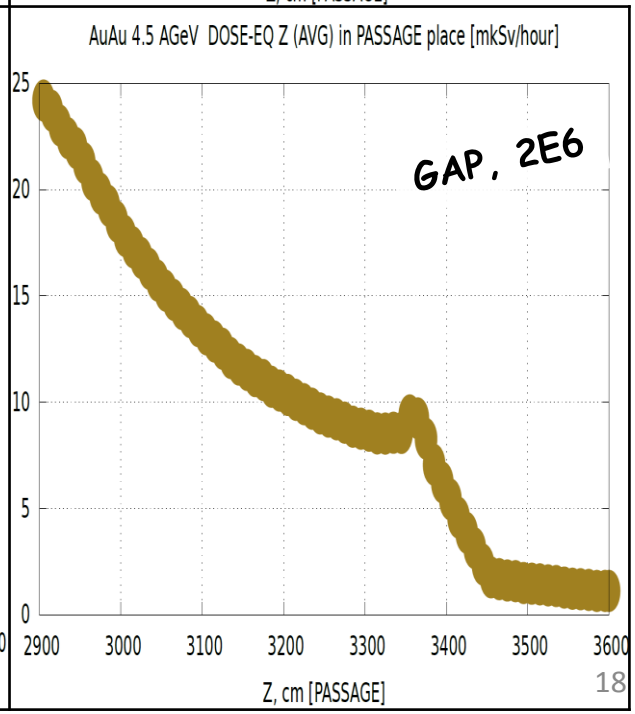

AuAu 4.5 AGeV DOSE-EQ Z (AVG) in PASSAGE place [mkSv/hour]
NO GAP, 5E5
Z, cm [PASSAGE]

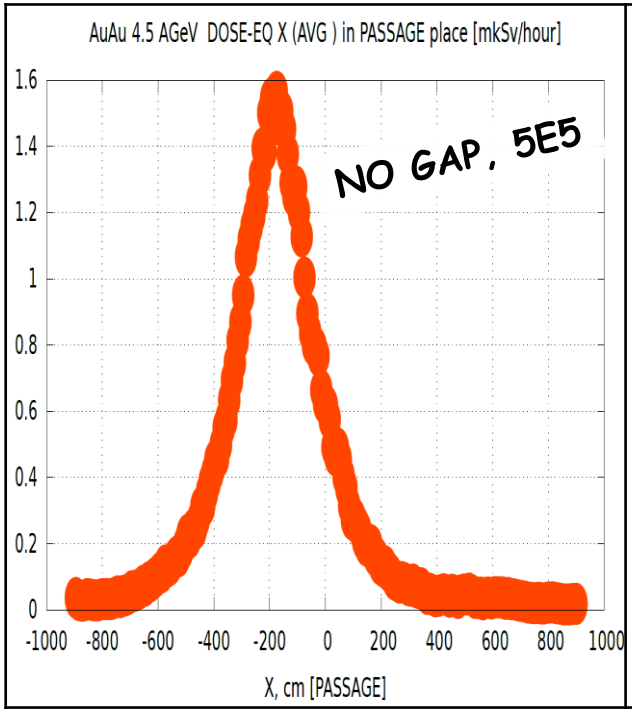

AuAu 4.5 AGeV DOSE-EQ Z (AVG) in PASSAGE place [mkSv/hour]
NO GAP, 1E6
Z, cm [PASSAGE]

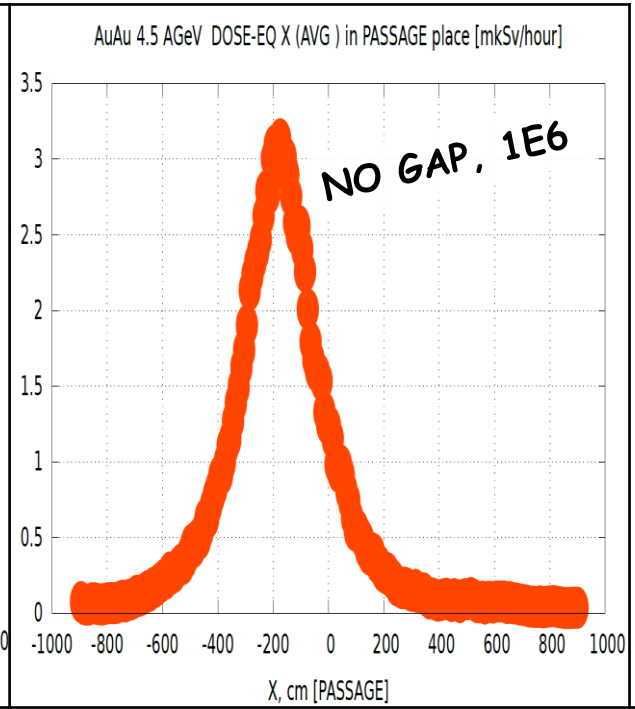

AuAu 4.5 AGeV DOSE-EQ Z (AVG) in PASSAGE place [mkSv/hour]
NO GAP, 2E6
Z, cm [PASSAGE]

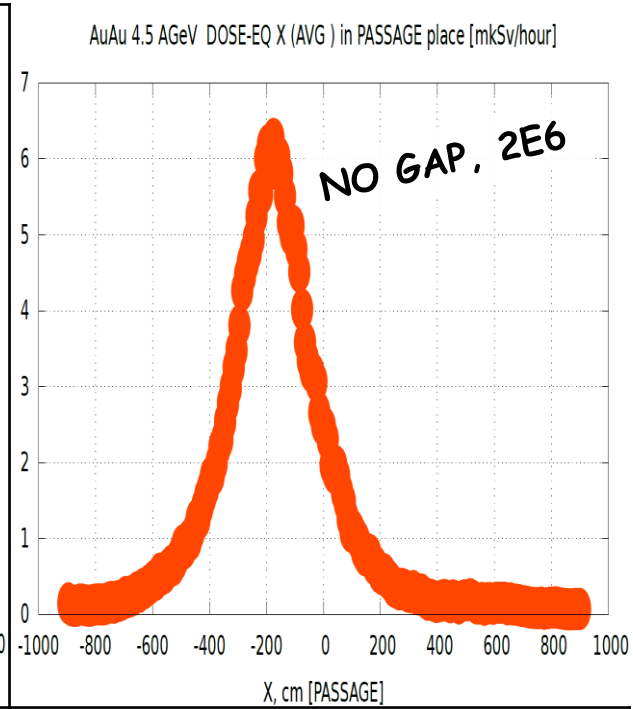

AuAu 4.5 AGeV DOSE-EQ Z (AVG) in PASSAGE place [mkSv/hour]
GAP, 5E5
Z, cm [PASSAGE]

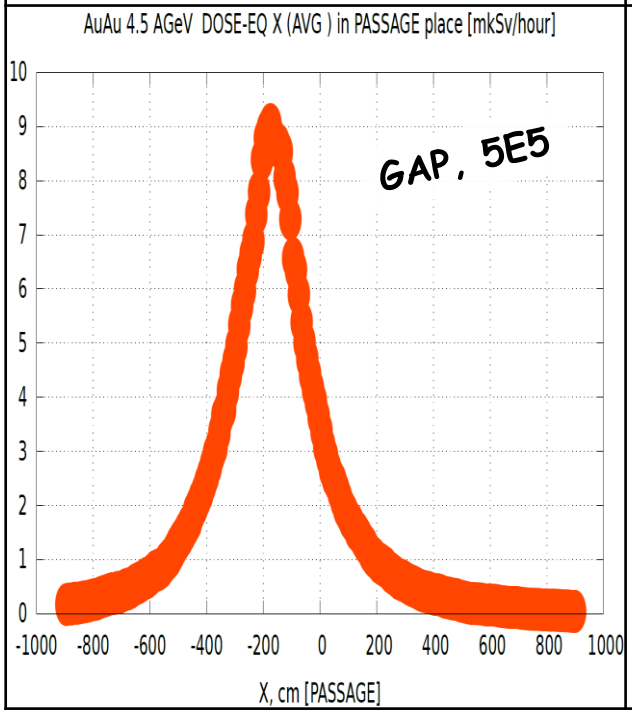

AuAu 4.5 AGeV DOSE-EQ Z (AVG) in PASSAGE place [mkSv/hour]
GAP, 1E6
Z, cm [PASSAGE]

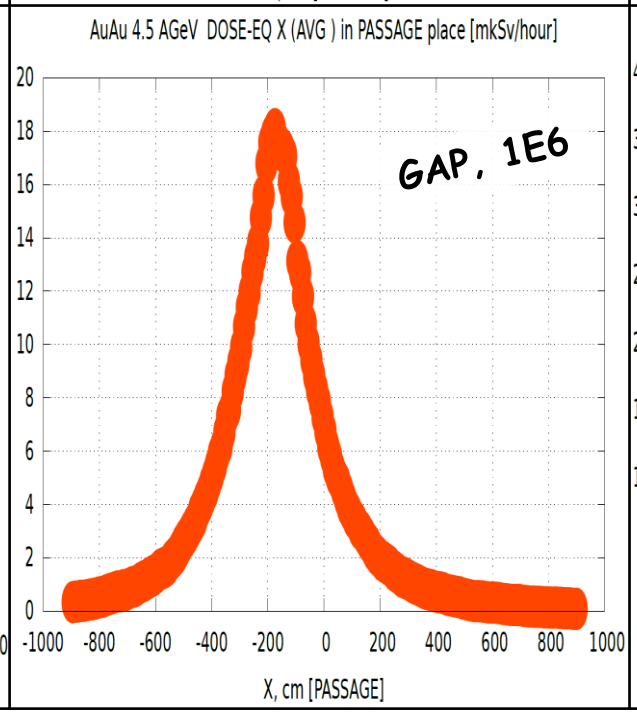

AuAu 4.5 AGeV DOSE-EQ Z (AVG) in PASSAGE place [mkSv/hour]
GAP, 2E6
Z, cm [PASSAGE]

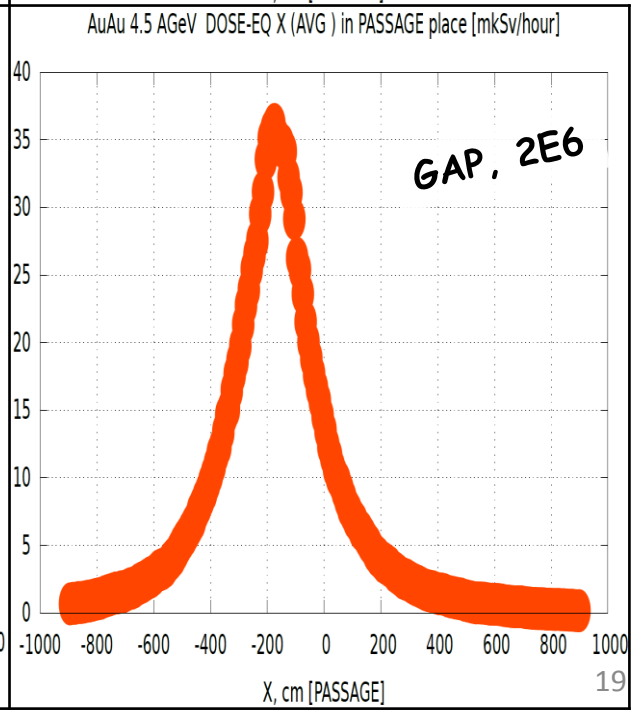

AuAu 4.5 AGeV DOSE-EQ X (AVG) in PASSAGE place [mkSv/hour]
NO GAP, 5E5
X, cm [PASSAGE]


AuAu 4.5 AGeV DOSE-EQ X (AVG) in PASSAGE place [mkSv/hour]
NO GAP, 1E6
X, cm [PASSAGE]


AuAu 4.5 AGeV DOSE-EQ X (AVG) in PASSAGE place [mkSv/hour]
NO GAP, 2E6
X, cm [PASSAGE]


AuAu 4.5 AGeV DOSE-EQ X (AVG) in PASSAGE place [mkSv/hour]
GAP, 5E5
X, cm [PASSAGE]


AuAu 4.5 AGeV DOSE-EQ X (AVG) in PASSAGE place [mkSv/hour]
GAP, 1E6
X, cm [PASSAGE]


AuAu 4.5 AGeV DOSE-EQ X (AVG) in PASSAGE place [mkSv/hour]
GAP, 2E6
X, cm [PASSAGE]