Energy Deposition on the Roman pot window of the pp2pp/STAR experiment.

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This is a summary of the energy deposition simulation on the steel window of the Roman pot of the pp2pp/STAR experiment.

1. Simulation Details

The simulation software used is "MCNPX" with the newest version 2.6.c (at the time of writing). In the simulation, a proton beam of 100 GeV is bombarded with normal incidence onto the center of a steel window of a Roman pot with a cross-section of 5 cm (in x-direction) × 10 cm (in y-direction) and the thickness in the beam (z) direction is t = 0.03048 cm (12 mils).

One version of the input file is as shown below.

```
Roman Pot (pp2pp)
c
10 1 -7.8 -10   imp:n,p,h,/,z=1
c
11 0 10 -11     imp:n,p,h,/,z=1
c
999 0 11        imp:n,p,h,/,z=0

  10 rpp -2.5 2.5 -5. 5.  0. 0.03048
  11 rpp -3.0 3.0 -6. 6.  -1. 1.

mode n p h / z
c
c Steel
```

```
c
m1 6000 -.0003                              $ .0003 carbon
     7014 -.0009963 7015 -.0000037          $ .001 nitrogen
     14000 -.0075                           $ .0075 silicon
     15031 -.00045                          $ .00045 phosphorous
     16032 -.0003                           $ .0003 sulpher
     24050 -.00862 24052 -.16752            $ chromium
     24053 -.0191 24054 -.00476             $ .20 chromium
     25055 -.02                             $ .02 manganese
     26054 -.03785619 26056 -.5962025   $ iron
     26057 -.01424486 26058 -.002146485  $ .65045 iron
     28058 -.0814176 28060 -.0314736     $ nickel
     28061 -.0014256                        $ nickel
     28062 -.0043896 28064 -.0012936     $ .12 nickel
mx1:p 6012  j j 14028 18j
mx1:h 6012  j j 14028 18j
c
c
sdef par=9 erg=100000 dir=1 vec=0 0 1 x=D1 y=D2 z=-0.1
c
SP1 -41  0.131869922522  0. $ sigma = 0.056 cm => FWHM = 2 sqrt(2 ln 2)sigma
SP2 -41  0.101257261936  0. $ sigma = 0.043 cm => FWHM = 2 sqrt(2 ln 2)sigma
c
F6:n  10
F16:h  10
F26:p  10
c
e0 1000 10000 20000 30000 40000 50000 60000 70000 80000 90000 100000
c
nps 10000000
c
phys:n 100001
c
c phys:p 100001 2j -1 => analog  1 => biased
c
phys:p 100001  2j -1
c
phys:h 100001
phys:z 100001
phys:/ 100001
c
print
prdmp 2j 1
c
tmesh
rmesh3 total
CORA3 -2.5 100i  2.5
CORB3 -5.0 100i  5.0
CORC3  0.0  0.03048
endmd
```

As shown in the above input file, the beam is assumed to have a Gaussian distribution in x and y with σ's of 0.056 cm and 0.043 cm respectively. The above input file also includes the detailed composition of steel, which is what the author has typically used for steel. Photo-nuclear reactions are switched on.

2. Results

The simulation results are shown in the mesh tally plots over the cross-section of the steel window. The colored contours shown in the figures below have the unit of MeV/cm^3 per incident proton. The energy depositions are averaged over the entire thickness of the steel window (0.03048 cm).

For the mesh tally plots as in both Figure 1and Figure 2 below, only protons, neutrons and photons are transported in the MCNPX simulation. The maximum energy deposition is 1.3×10^3 MeV/cm^3 per incident proton in the center of the window. In Figure 3, π^0 and $\pi^\pm$ are also transported in the MCNPX simulation. This gives rise to a higher maximum energy of 2.1×10^3 MeV/cm^3 per proton in the center of the window.

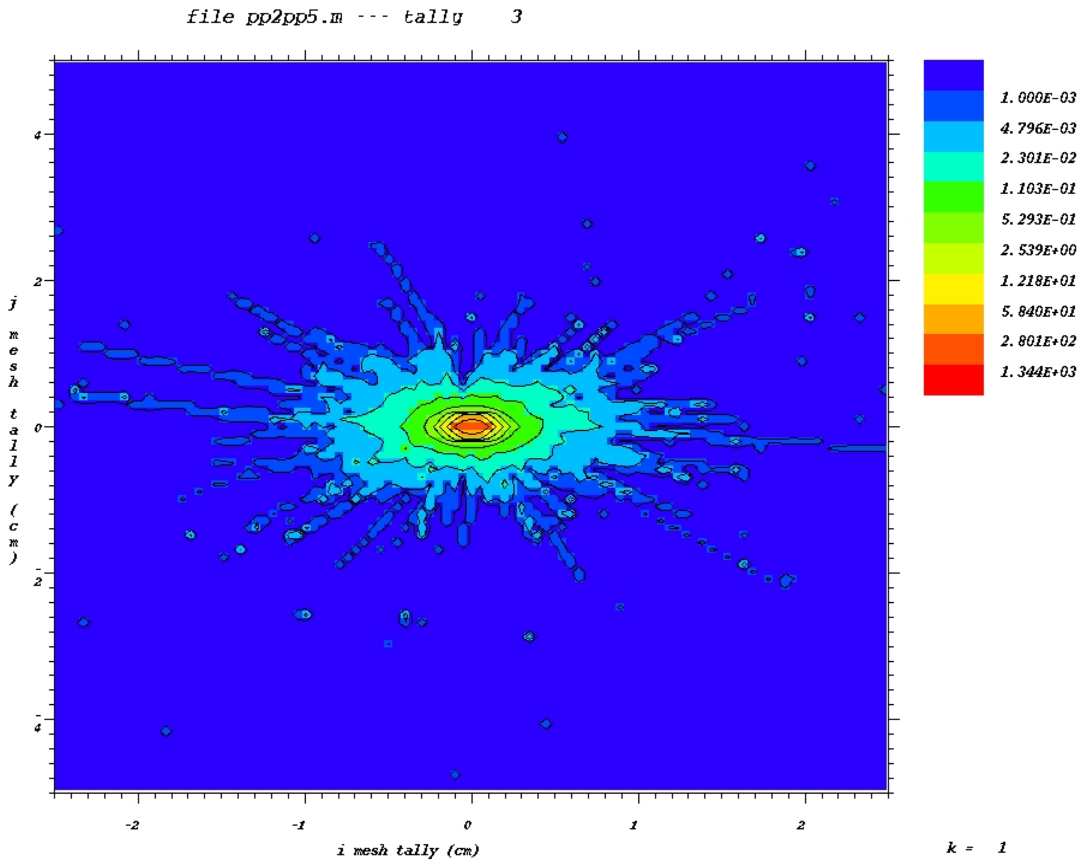

Figure 1: Mesh tally of energy depositions with 100 divisions in both x and y directions.

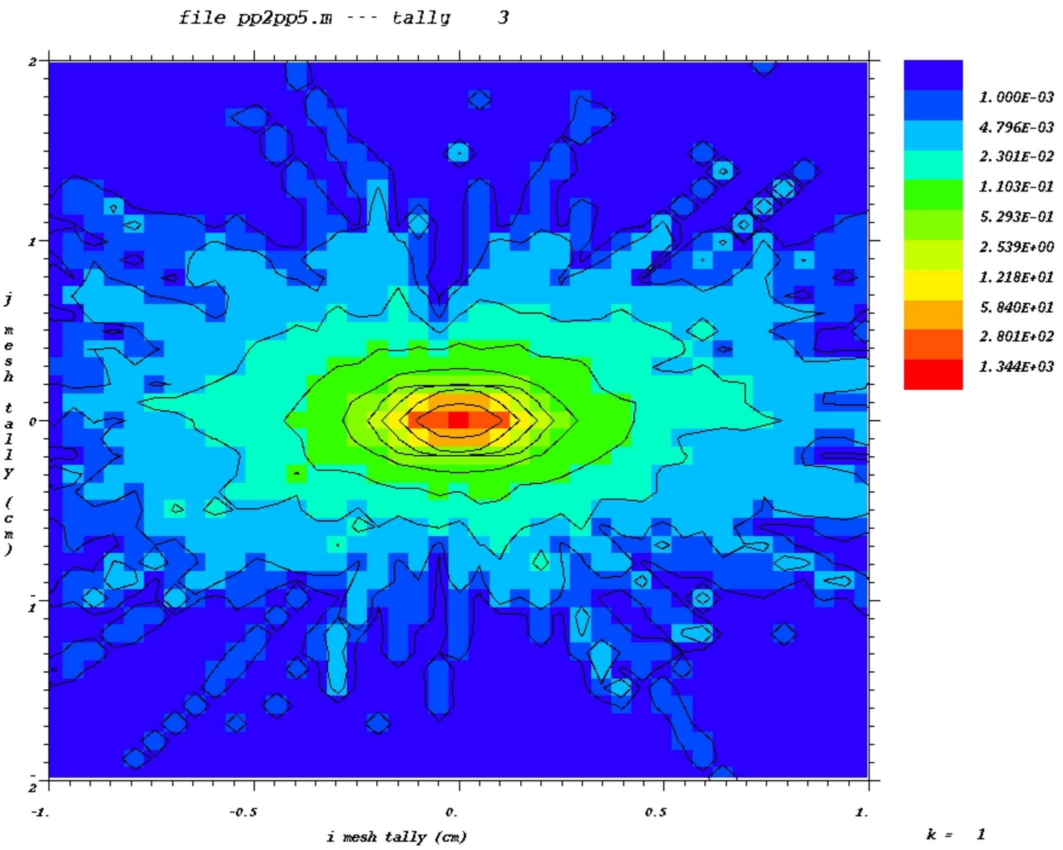

Figure 2: Same as Figure 1 but zoomed-in in the middle of the steel window.

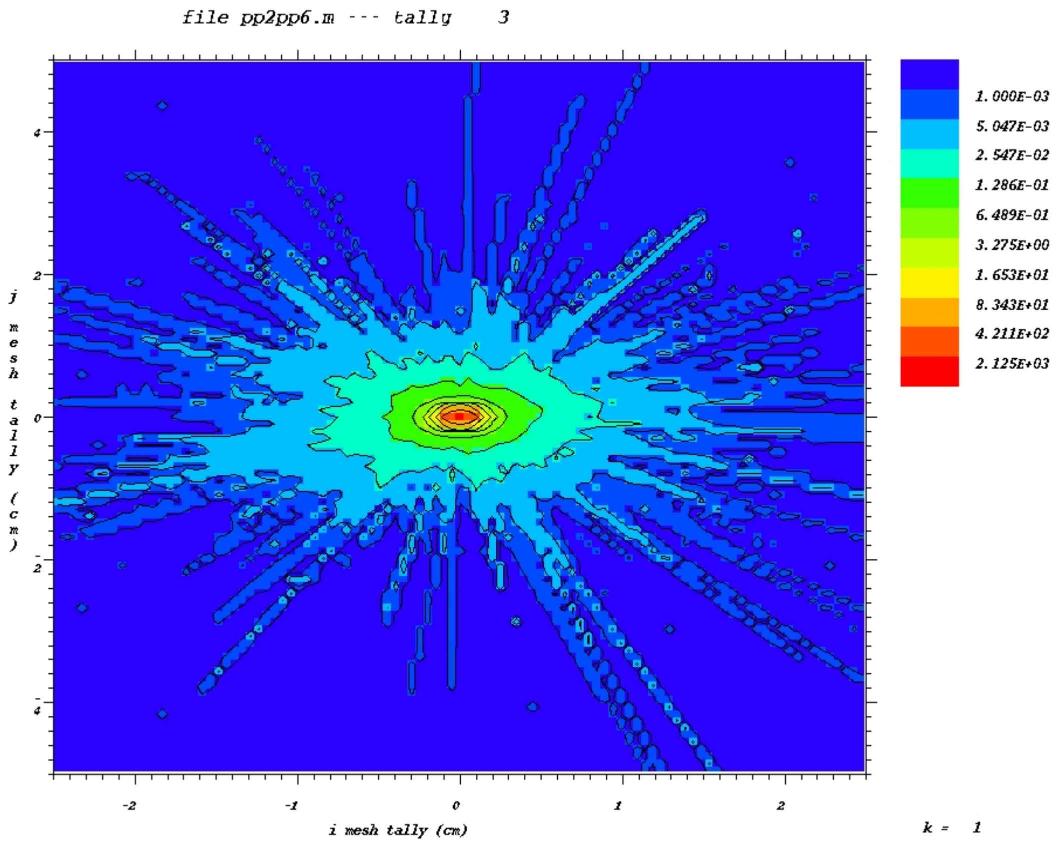

Figure 3: Same as Figure 1 but π^0 and $\pi^\pm$ are added in the MCNPX simulation.

3. Comparison with the old calculation

From the note with the subject title "Sample Calculations Relevant to Roman Pot Protection" written by A.J. Stevens on Feb. 12, 2001, the effective energy deposition determined was 2.7 MeV/g-cm^{-2}. With this number, a density of 7.8 g/cm^3 and a window thickness of t = 0.03048 cm, the energy deposited would be about 2.7 × 7.8 × t = 0.642 MeV.

The energy density would be 0.642/(t × A_{xy}) = 21.1/$A_{\mathbf{xy}}$ MeV/cm^3, where $A_{\mathbf{xy}}$ is the cross-section (the interaction area between the beam and the surface) considered. If I take $A_{\mathbf{xy}}$ to be $6\sigma_{\mathbf{x}}\sigma_{\mathbf{y}}$ (~95% of the beam), ie., $A_{\mathbf{xy}}$ = 6×0.056 × 0.043 cm^2, the energy density would be about 1.46 GeV/cm^3.

This number obviously depends on what the "interaction area" is but the energy density result is in the same order of magnitude as the present result shown here.

4. Comparison between MCNPX and MARS

MARS version 15.05 has been used to find the same energy deposition peaks in the same geometry. In fact, in this simulation, the same MCNPX geometry has been used as an input to the MARS program. The energy deposition densities as a function of grid sizes are shown in Table 1 and Table 2. As the grid areas become smaller, it has becoming increasingly difficult to gather enough statistics and a lot of computational time has been spent in the last couple points. The last point in each simulation has the largest uncertainty.

Grid (cm^2)	0.05×0.1	0.02×0.025	0.016×0.01	0.008×0.005
Energy Density (GeV/cm^3)	2.50	2.67	2.69	2.93

Table 1: Energy deposition densities on the Roman pot window by the MCNPX simulation.

Grid (cm^2)	0.05×0.1	0.025×0.05	0.02×0.025	0.016×0.01	0.008×0.005	0.004×0.0025	0.002×0.00125
Energy Density (GeV/cm^3)	0.554	0.930	1.12	1.17	1.20	1.24	1.31

Table 2: Energy deposition densities on the Roman pot window by the MARS simulation.

The MCNPX and MARS energy density seem to settle down at different grid areas. For the maximum energy deposition densities, the MCNPX results seem to be slightly more than a factor of 2 over the MARS results. From the MCNPX experts, their data file for electron stops at 1 GeV and the same cross-section at 1 GeV is probably used for higher energies. This might be one reason for the difference between these two simulation packages.