Simulation for diffuser at upstream of ESS

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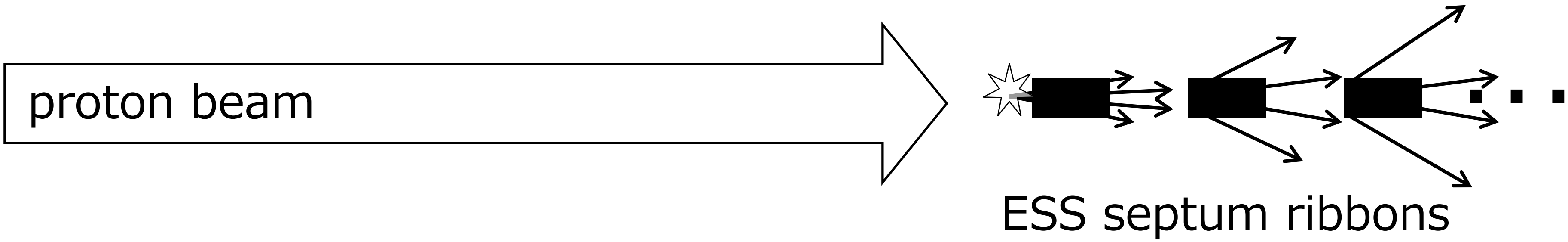
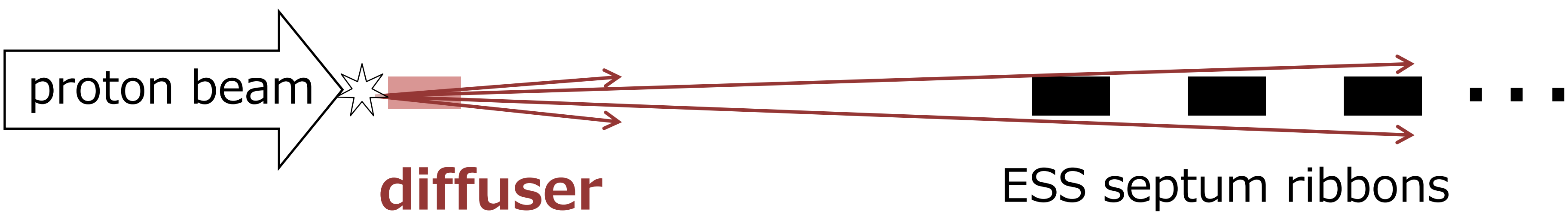
Diffuser concept

large scattering angle → large beam loss



small scattering angle → small beam loss



Multiple scattering with Coulomb potential

Protons traversing matter are deflected by the Coulomb field of nuclei (Multiple scattering)

$$\Theta_{\mathrm{rms}} \approx \frac{19.2\ \mathrm{MeV}}{\beta c p}\sqrt{\frac{x}{X_0}}$$

x/X_0 : thickness of the scattering medium measured in Radiation Length

Material	Z	X_0 [mm]
Be	4	352
C	6	193
TI	22	36
W	74	3.5

with x/X_0 = 0.1,
Θ_{rms} ~ 19.2/(30.9 x 10^3) x sqrt(0.1) = 0.2 [mrad]
(30.9 GeV proton)

To Suppress Nuclear Collision

Protons traversing matter are also scattered by the nuclear collisions, which causes large angle scatterings

It is desirable for the diffuser to have small x/λ_T
(λ_T : Nuclear Collision Length)
for small nuclear collision cross section

Material	Z	A	X_0 [mm]	λ_T [cm]
Be	4	9	353	29.9
C	6	12	193	26.8
TI	22	48	36	17.4
W	74	184	3.5	5.7

To Suppress Nuclear Collision

x/λ_T of each material with $x/X_0 = 0.1$

Material	Z	A	x [mm]	X_0 [mm]	x/X_0	x/λ_T
Be	4	9	35	353	0.1	0.120
C	6	12	19	193	0.1	0.071
TI	22	48	4	36	0.1	0.023
W	74	184	0.4	3.5	0.1	0.007

multiple-scattering angles are same

Larger Z material has smaller x/λ_T

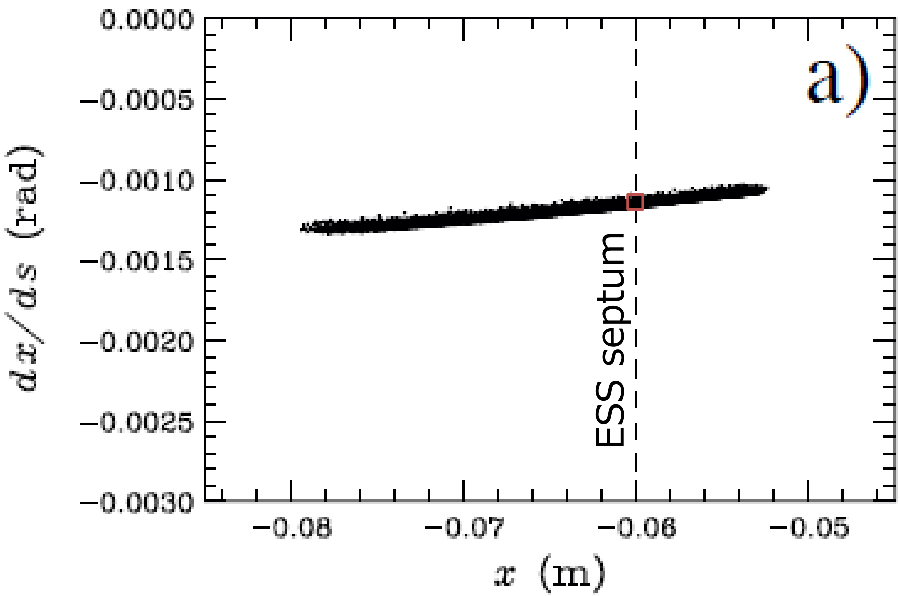
Simulation by MARS

Initial Beam Condition

Horizontal

x : uniform with 1.0 mm full width

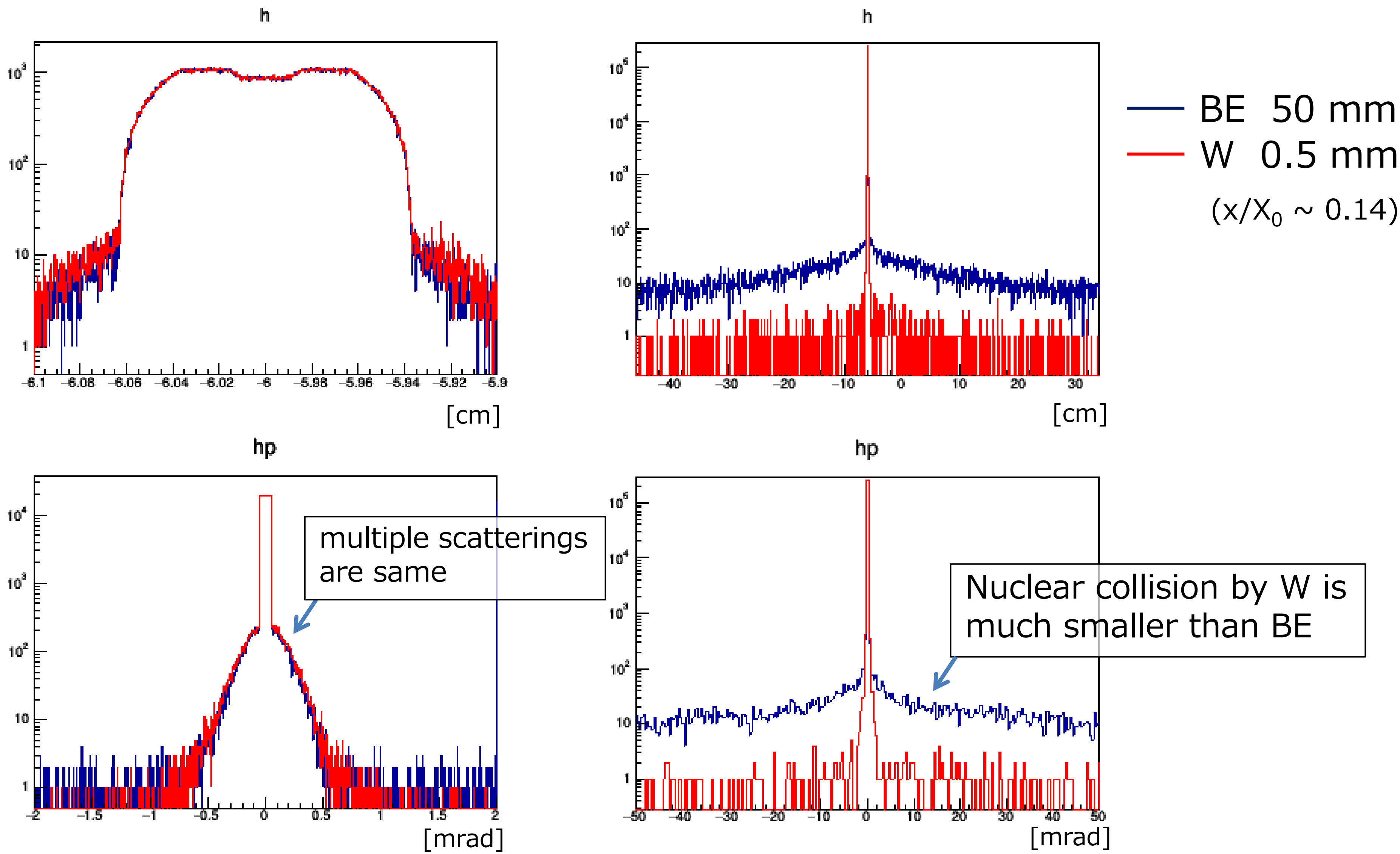
x′ : uniform with 0.1 mrad full width



Horizontal phase space distribution at the ESS1 entrance by tracking simulation (with dynamic bump)

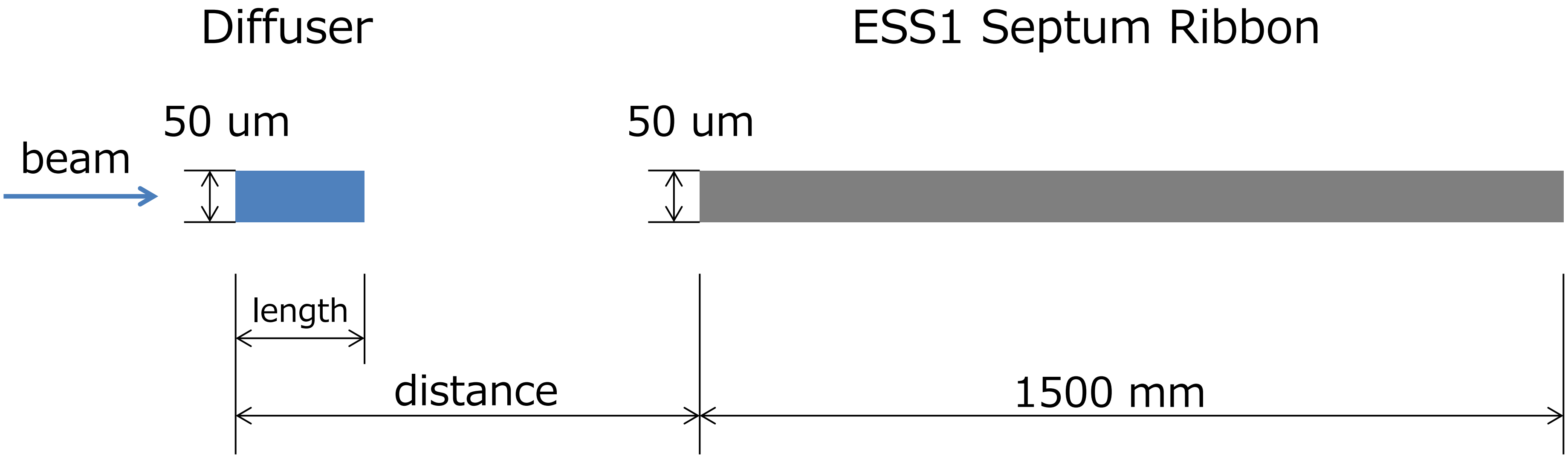
Comparison between W and BE with same x/X_0

Place diffuser only for comparison (no ESS)
distribution at the 500 mm downstream of the ESS1 exit



Optimize of the length and distance

Configuration

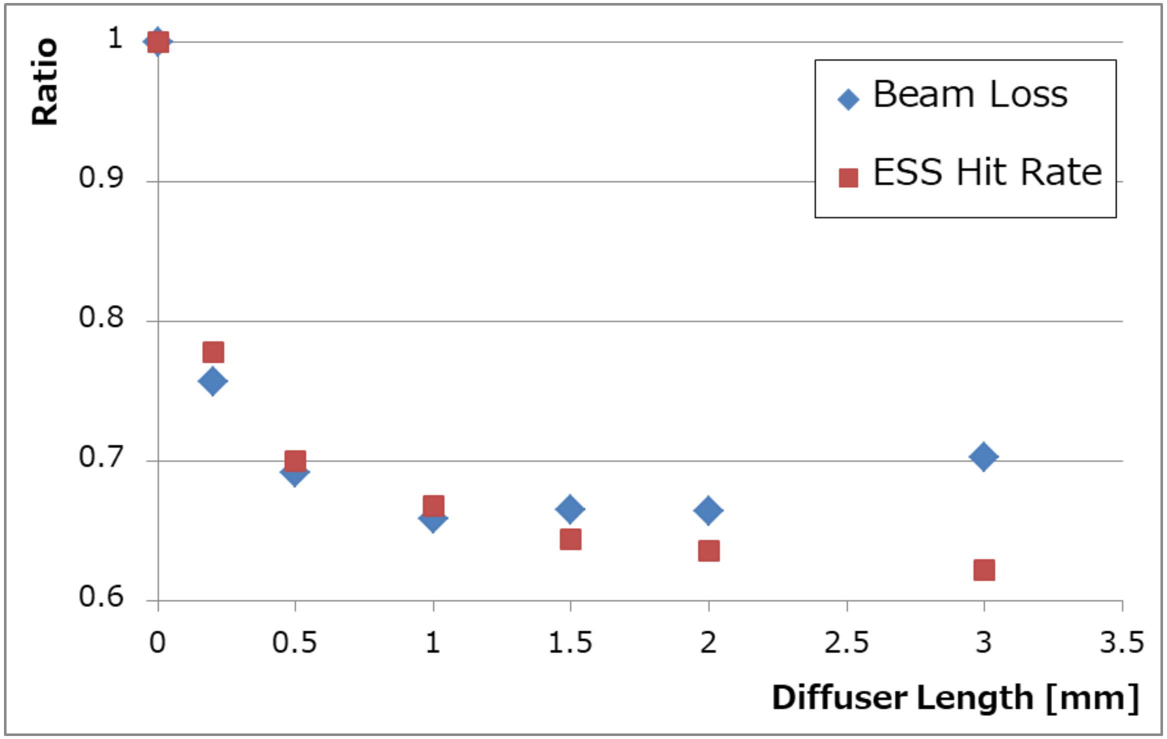


Material : W
Density : 19.3 g/cm^3

Material : W
Density : 6.43 g/cm^3
(1/3 of normal W)

Count the beam loss (= the number of the protons outside the aperture,
aperture : $|x'| < 1.5$ mrad, $|x-60| < 60$ mm, $E > 29.9$ GeV)
and hit rate on ESS ribbons
with various length and distance of the diffuser

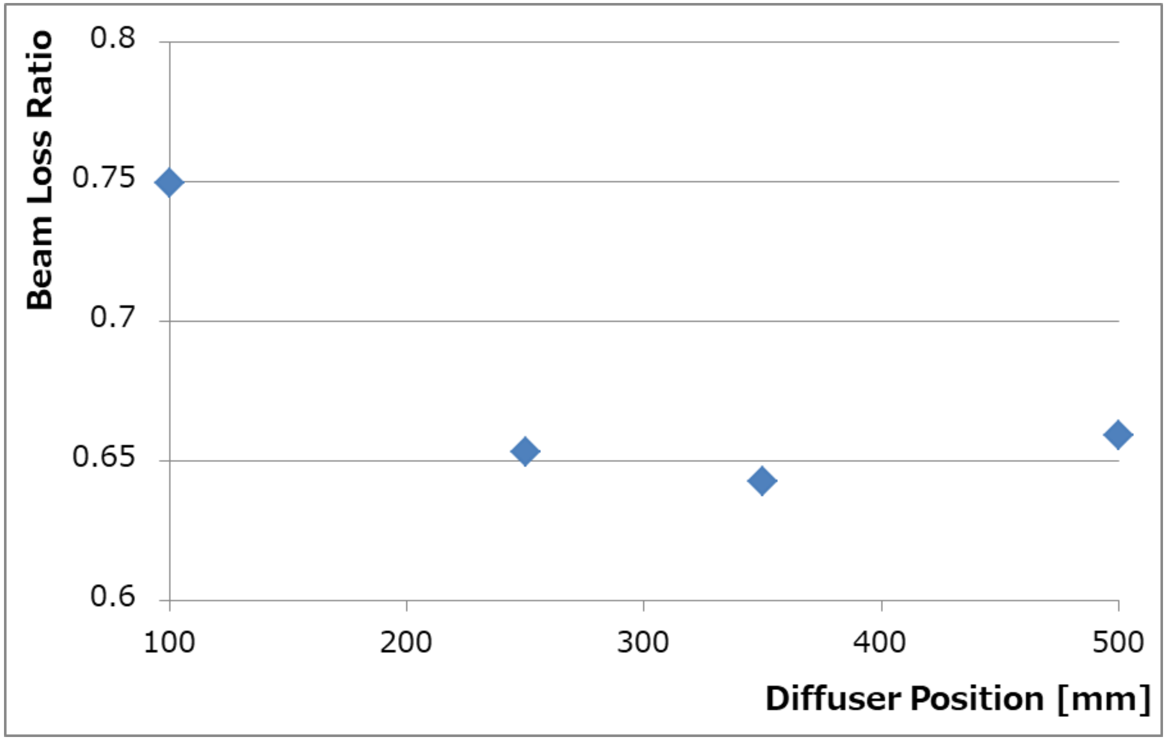
Diffuser Length Scan



The simulation results of the total beam losses and the hit rates on ESS septum ribbon with various diffuser lengths.
The distance between diffuser and ESS is 500 mm in this calculation.

The ESS hit rate become smaller with longer diffuser,
but the total beam loss has minimum value around
the diffuser length of 1 mm.

Diffuser Position Scan



The simulation results of the total beam losses with various diffuser positions.
The length of the diffuser is optimized individually for each diffuser position.

distance [mm]	length [mm]	loss ratio
-	-	1
500	0.5	0.68
250	1.0	0.65

Summary

- Material : Large Z material is better for the diffuser to suppress large angle nuclear scatterings. We choose tungsten for the calculation.

- Position and Length :
  500 mm distance with 0.5 mm length &
  250 mm distance with 1.0 mm length
  have almost same effect.
  Beam loss can be reduced by factor ~0.7 in both cases.