# Polarization Profile Issue for the Fixed Target Experiment

Itaru Nakagawa

RIKEN

# Run15 STAR Fixed Target Beam Condition

From Run15 fixed target pilot run

- $\beta^*$ of the beam = 10m
- The transverse beam size is ~300μm at the location of fixed target (2m away from IP)
- The fixed target experiment was carried out at 7mm away from the target.
- This corresponds to 23$\sigma$ of the beam intensity profile.

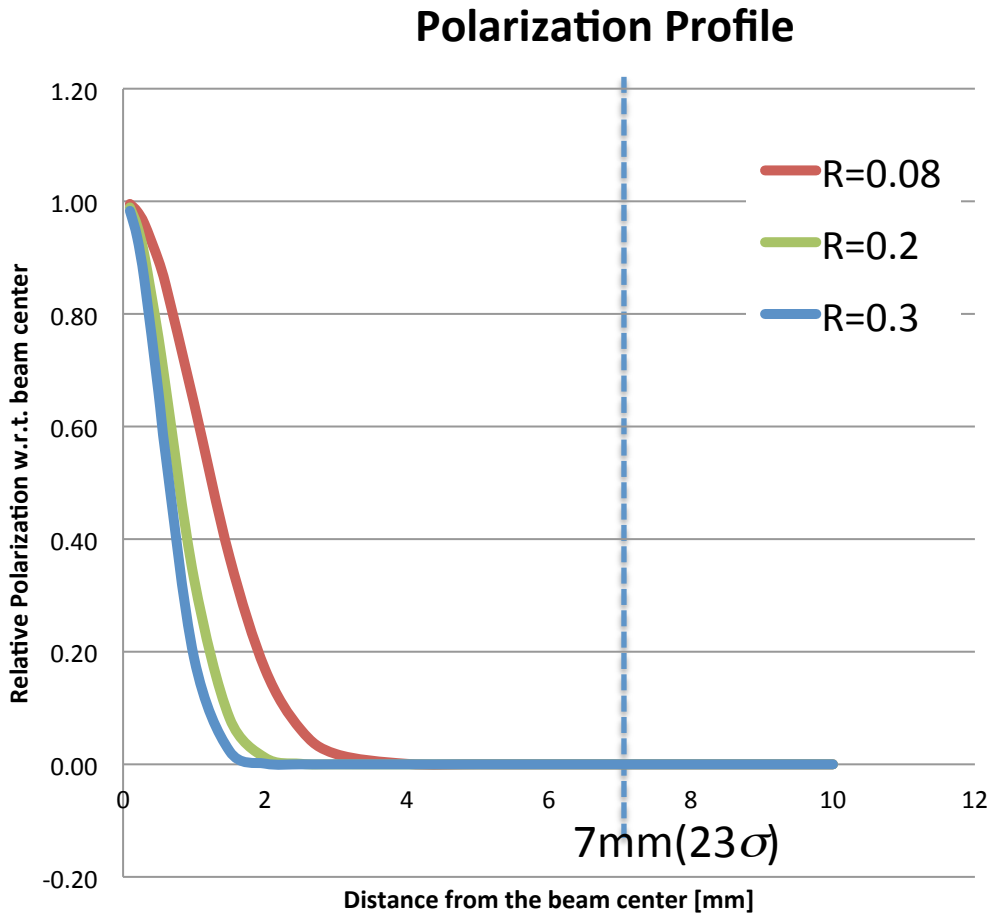
# Observed Polarization Profiles from Past Runs

data source : cnipol webpage

| $R = \left(\frac{\sigma_I}{\sigma_P}\right)^2$ | 100 GeV | | 250 GeV | |
|---|---|---|---|---|
| | Horizontal | Vertical | Horizontal | Vertical |
| Run 9 | 0.073 | 0.075 | 0.37 | |
| | 0.056 | 0.117 | 0.32 | 0.39 |
| Run12 | 0.097 | 0.122 | 0.17 | 0.21 |
| | 0.091 | 0.11 | 0.14 | 0.07 |
| | 0.24 | 0.088 | 0.12 | 0.15 |
| | 0.10 | 0.20 | 0.15 | 0.06 |
| Run13 | | | 0.17 | 0.21 |
| | | | 0.14 | 0.07 |
| | | | 0.12 | 0.15 |
| | | | 0.15 | 0.06 |

R values are larger at 250 GeV which indicates smaller $\sigma_p$ from smaller $\sigma_I$ than 100GeV. Let's wildly assume R=0.2 and R=0.08 as typical polarization profile for 250GeV and 100GeV, respectively.

# Expected Polarization at 7mm




Normalized Polarization Profile

$$\frac{P}{P_{Max}} = \left(\frac{I}{I_{Max}}\right)^R$$

where

$$\frac{I}{I_{Max}} = \exp\left(-\frac{x^2}{2\sigma_I^2}\right)$$

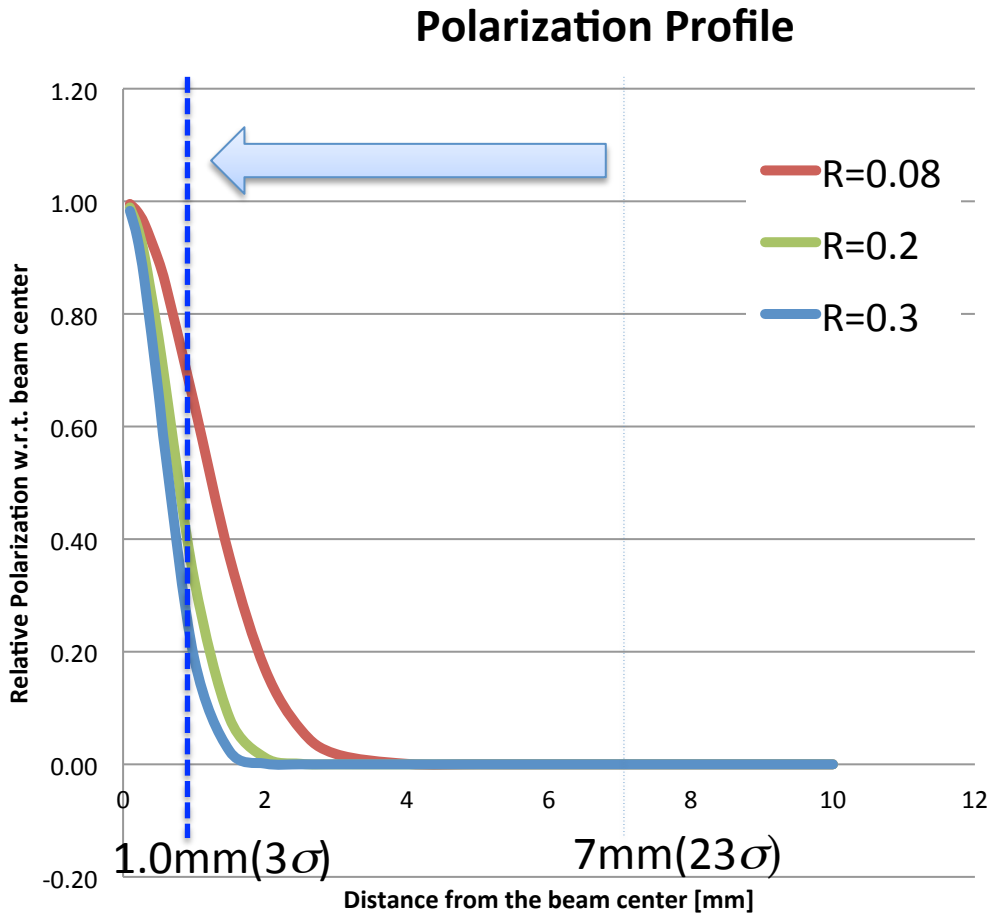
$$\sigma_I = 300\mu m$$

Expected polarizations were calculated for 0.08 and 0.2 as typical profile for 100GeV and 250GeV. Nevertheless regardless of beam energy, the polarization is nearly zero at 7mm away from the center.

# Interim Summary

- It is unfeasible to expect decent polarization for the 250GeV proton beam under the existing fixed target operating condition, i.e. distance between the beam center and the target of about 7mm (23$\sigma$).
- This is an unique issue for the polarized proton beam and not the case for unpolarized beam.

# Beam Position to secure finite polarization

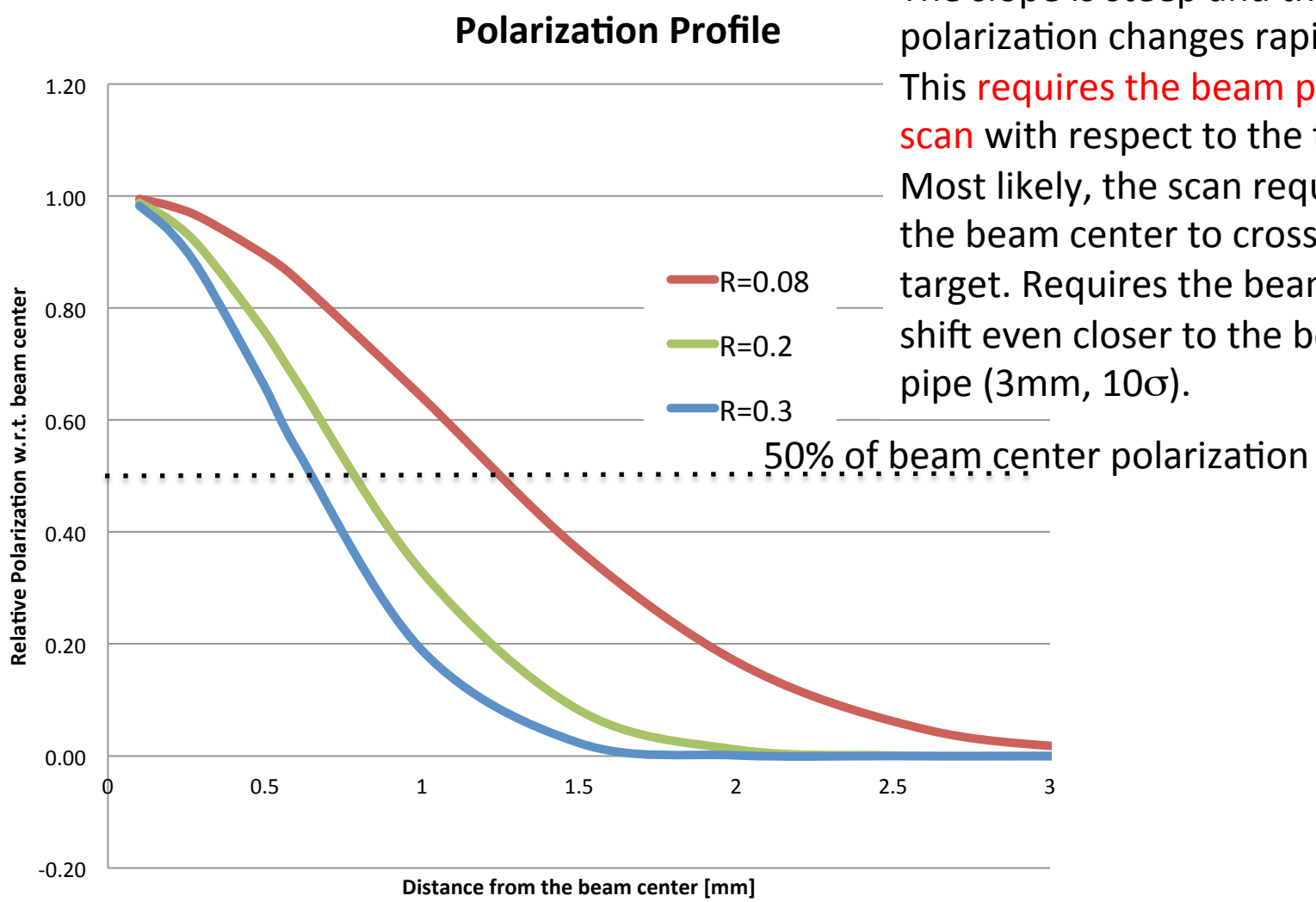



- The only way to run the experiment with finite polarization is to shift the beam center closer to the fixed target.
- As can be seen from the graph, the beam has to be significantly close to the target in order to secure reasonable polarization.

Main Concerns:

1. How close to be for reasonable polarization?
2. Do we have a good control polarization slope?

# Closer look near the beam center



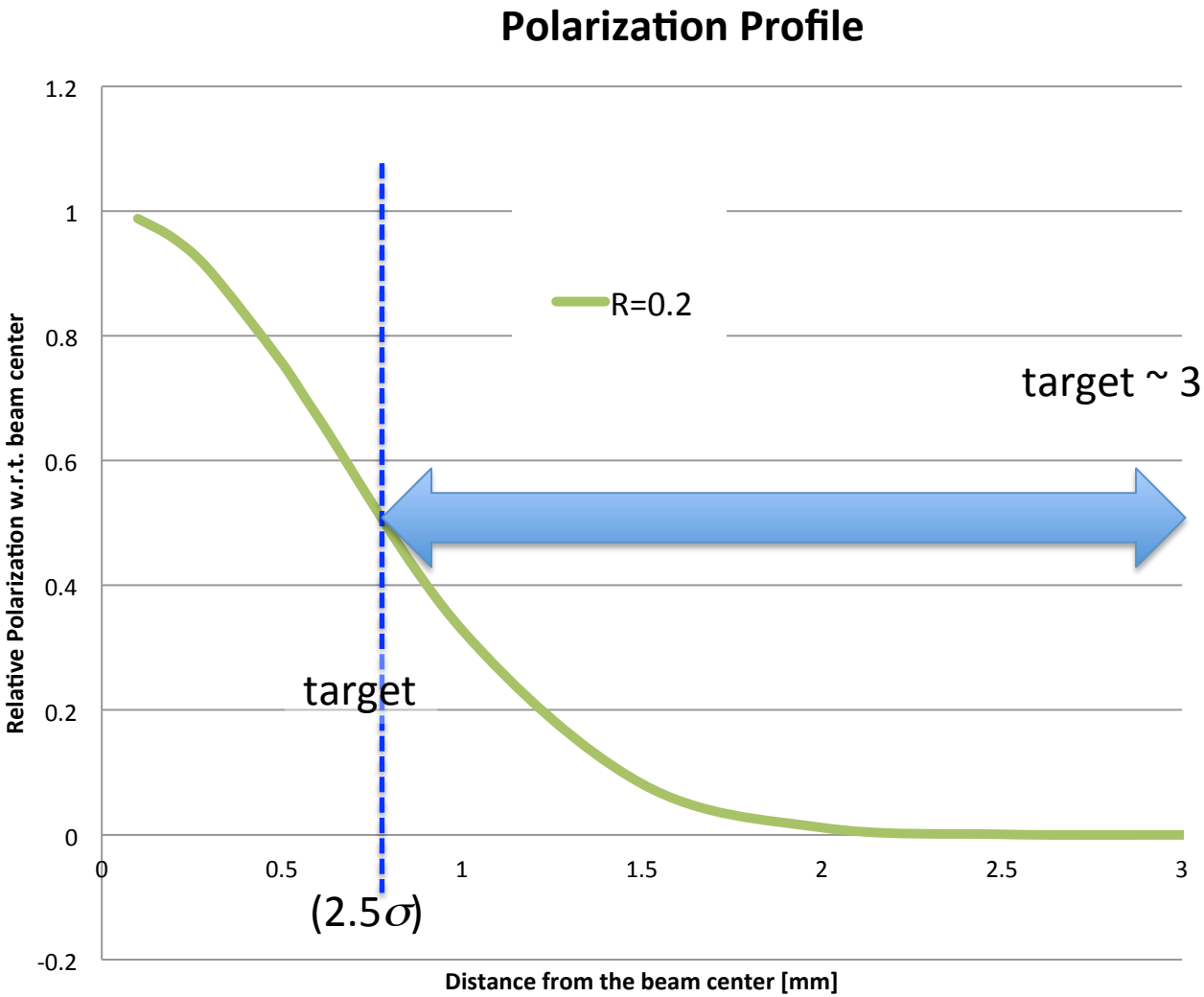

The slope is steep and the polarization changes rapidly. This requires the beam position scan with respect to the target. Most likely, the scan requires the beam center to cross the target. Requires the beam to shift even closer to the beam pipe (3mm, 10$\sigma$).

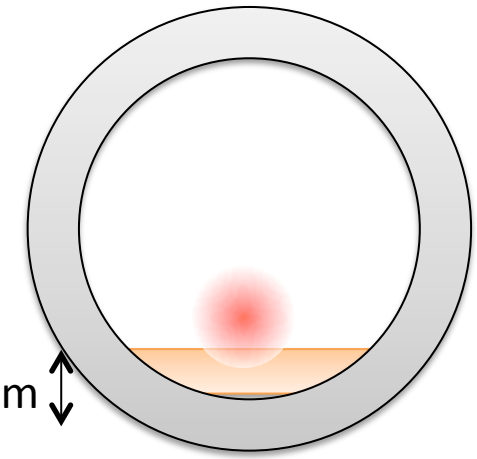
# Polarization Profile Table

| Distance [mm] | Sigma [σ] | Relative Beam Intensity | R=0.08 | R=0.2 | R=0.3 |
|---|---|---|---|---|---|
| 0.1 | 0.3 | 0.95 | 1.00 | 0.99 | 0.98 |
| 0.2 | 0.7 | 0.80 | 0.98 | 0.96 | 0.94 |
| 0.3 | 1.0 | 0.61 | 0.96 | 0.90 | 0.86 |
| 0.5 | 1.7 | 0.25 | 0.89 | 0.76 | 0.66 |
| 0.6 | 2.0 | 0.14 | 0.85 | 0.67 | 0.55 |
| 0.75 | 2.5 | 0.04 | 0.78 | 0.54 | 0.39 |
| 0.9 | 3.0 | 0.01 | 0.70 | 0.41 | 0.26 |
| 1 | 3.3 | 3.87E-03 | 0.64 | 0.33 | 0.19 |
| 1.2 | 4.0 | 3.35E-04 | 0.53 | 0.20 | 0.09 |
| 1.5 | 5.0 | 3.73E-06 | 0.37 | 0.08 | 0.02 |

Additional distance to the beam pipe -> + 3mm (10 sigma)

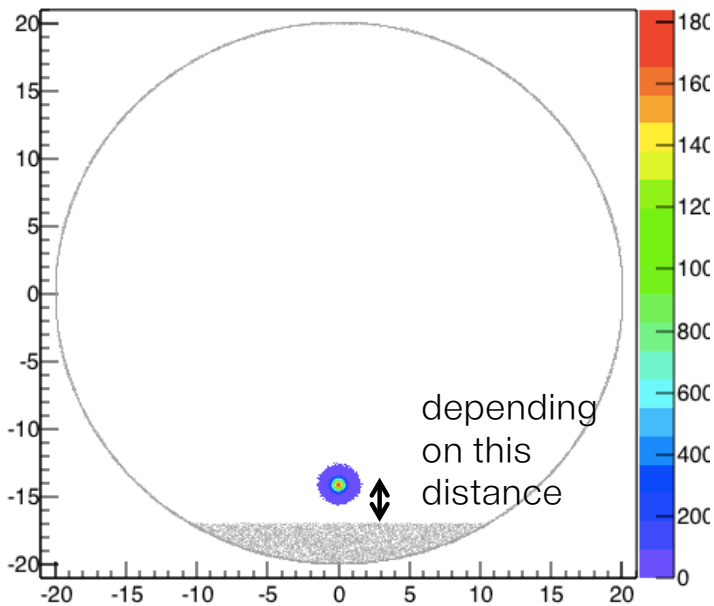
# Averaging over the pol. Profile

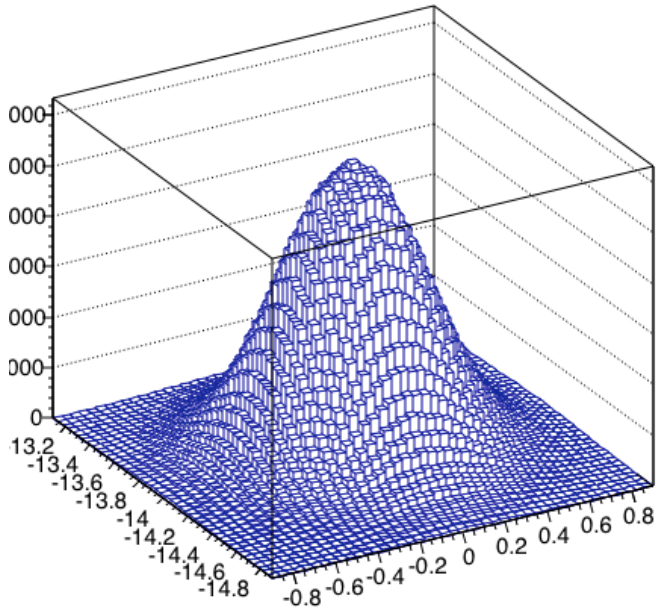



Need to integrate over wide profile region to calculate the average polarization. This will blow up the systematic error.

# Beam Loss by the Target



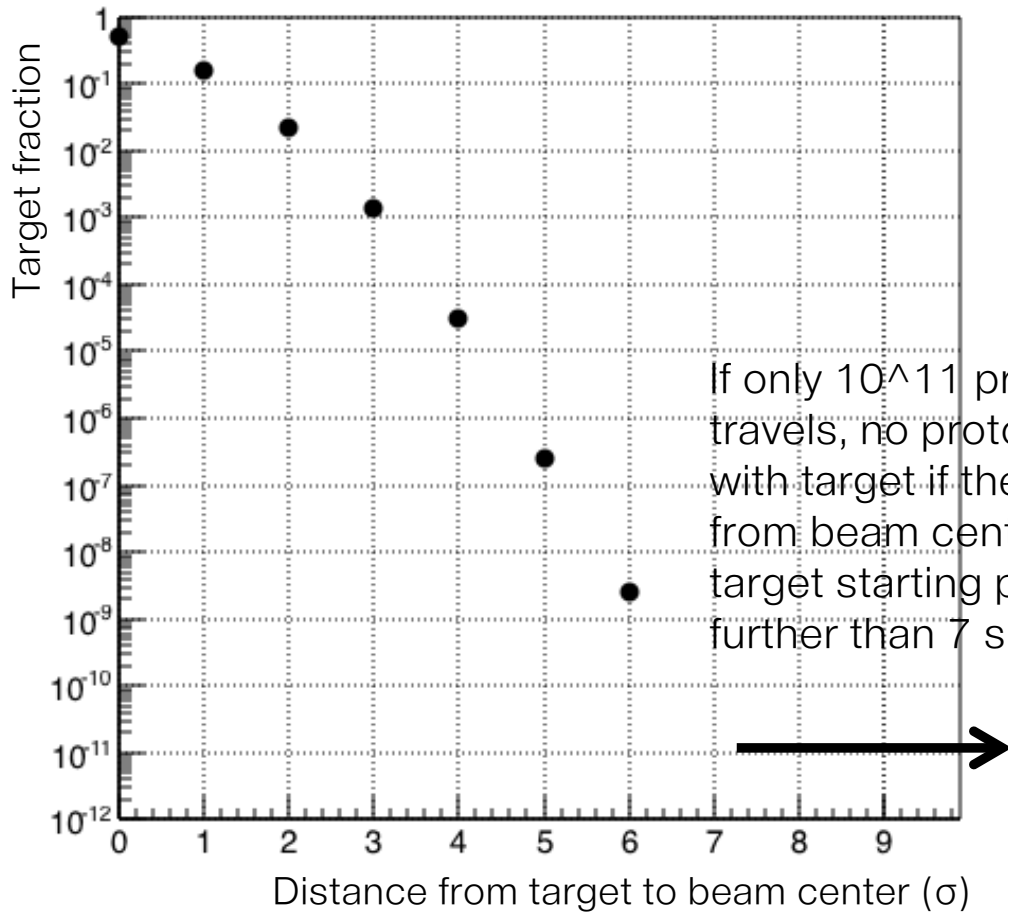



$10^{11}$ (x, y) positions are randomly picked.
→ "how much fraction of them passes through the target" is estimated depending on how many sigma target is far away from target.

σ = 0.3 mm is set for beam intensity profile.

Study made by Minho Kim

# Fraction of Beam hits the target




| Distance | Fraction |
|---|---|
| 0σ | 0.500002 |
| 1σ | 0.158657 |
| 2σ | 0.0227495 |
| 3σ | 0.00134888 |
| 4σ | 3.1485e-5 |
| 5σ | 2.45938e-7 |
| 6σ | 2.46761e-9 |
| 7σ | 0 |
| 8σ | 0 |
| 9σ | 0 |

# Survival fraction protons in the beam

The survival ratio $r_{suv}$ of protons in the beam can be formulated as follows:

$$r_{suv} = \left(1 - f_{tar} X_{rad}\right)^{N_{rev}}$$

$N_{rev}$ = 2.88 x $10^8$ : Number of revolutions after 1 hour
$f_{tar}$ = fraction of the beam goes thru the target per revolution
$X_{rad}$= Radiation length of the target

| | | Xrad | |
|---|---|---|---|
| sigma | Fraction of target | 0.001 | 0.01 |
| 0 | 0.500 | 0.000 | 0.000 |
| 1 | 0.159 | 0.000 | 0.000 |
| 2 | 0.227 | 0.000 | 0.000 |
| 3 | 0.00139 | 0.000 | 0.000 |
| 4 | 3.15E-05 | 0.000 | 0.000 |
| 5 | 2.46E-07 | 0.932 | 0.492 |
| 6 | 2.47E-09 | 0.999 | 0.993 |

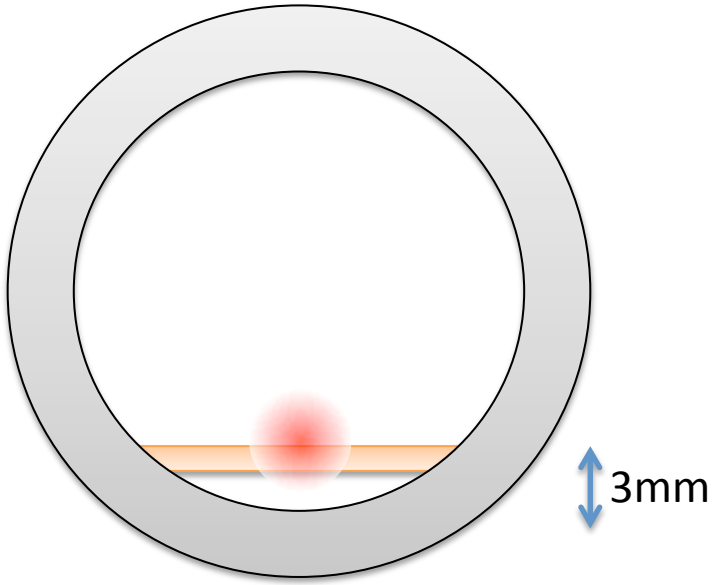
Beam is completely lost after 1h

Any beam distance below 5 sigma won't survive 1 hour store for the target radiation length > 0.1%.

# Conclusion (1)

- The polarization profile at the beam energy 250GeV requires the distance between the beam and target to be less than 2 to 2.5$\sigma$ to secure 50% pol of the beam center.
  - Still steep polarization slope requires full scan to be know the actual distance between the beam and the target.
  - Need to average over wide profile region if the target is plate type.
- The beam intensity profile requires the plate type target to be away more than 5$\sigma$ to survive the store for 1 hour.
- Thus there is no sweet spot which satisfies both polarization and the intensity profile.

# Wire Target




The only solution is the wire target to somewhat relieve the difficulties:

1. Beam intensity loss
2. Average polarization

However, still requires the scan to know the relative position to the target.

still requires the beam to shift the beam center 3mm ($10\sigma$) distance from the beam pipe. This is risky.

# Conclusion (2)

The only feasible get around solution

- Beam intensity loss
- Average over polarization profile

is to employ the wire target just as pC polarimeter.

However the wire target introduced following new difficulties

- Still requires beam position scan to 3mm (10$\sigma$) level with respect to the beam pipe, which is risky.
- Moving target in/out to the beam central orbit is the rather right way to reduce the radiation risk.
- Serious engineering work for the moving target system is required which is not feasible for Run17.