



**POLARIS**

# **A Study of Polysiloxane Based Plastic Scintillator for High Energy Electron Beam Profiling**

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## **Introduction**

Traditional plastic scintillators are made of PVT or polystyrene. Which are widely used because they are fast and easy to handle. However, prolonged exposure to ionizing radiation can damage their carbon-based structure, leading to yellowing, micro-cracks, and a gradual loss of light output which limits their long-term use in intense beam environments.

On the other hand, Polysiloxane scintillators can be a strong alternative as their Si–O–Si backbone provides improved radiation tolerance, mechanical flexibility, and greater resistance to humidity and temperature variations. Some previous studies show that suitable formulations can remain stable in high doses. Unlike rigid plastics, polysiloxanes are elastomeric and allow thin and adaptable detector geometries.

Despite these advantages, thin polysiloxane sheets have not been systematically studied for profiling high-energy (1–6 GeV) electron beams, where detector thickness must be minimized to suppress shower effects. We aim to test their light yield, stability and thickness dependence under electron beam exposure and compare them with conventional plastics.

## Why do we want to go to DESY

We want to seize this opportunity because it offers something we cannot access anywhere else: the opportunity to test our ideas in a real accelerator environment. Seeing beam interactions and detector behavior firsthand would allow us to move beyond theory and understand how physics truly works under practical constraints.

DESY represents precision, collaboration, and world-class research. Being part of that environment would challenge us, refine our thinking, and help us grow not just as students, but as future scientists.

We don't want to just study advanced physics — we want to experience it where it actually happens.

### Research Question

Can a thin (3 mm) polysiloxane scintillator act as a practical DESY beam-profile screen compared to EJ-200?

## Methodology

### Formulation

We will fabricate our scintillator using the well-established room-temperature vulcanization (RTV) method, following the formulation optimized by Quaranta et al. (2013) [2] and Carturan et al. (2025) [3].

According to those papers our polysiloxane contains 22 mol% diphenyl groups, 2 wt% PPO, and 0.05 wt% Lumogen Violet for achieving 50% light yield of EJ-212 (5,000 photons/MeV).

For detailed Components, Fluorophores (Dyes) and Fabrication Steps see [Appendix 0.1](#).

## Optimal Thickness Selection:

Based on analytical calculations (see [Appendix0.2](#) for details), we selected **3 mm** thickness for our scintillator sheet because:

Parameter	Value	Benefits
Energy Deposition	0.6 MeV per electron	Sufficient for strong signal
Photon per electron	3,000	50% more than 2 mm
Radiation length fraction	0.0075 (0.75% of $X_0$ )	Shower negligible [6]
Integrated SNR (pessimistic)	6,000	Above imaging requirements
Per pixel SNR (realistic)	~12	With appropriate magnification

Why 3 mm? It maximizes signal while keeping shower effects fully suppressed.

## Measurements

### Beam Parameters

We will use DESY's 1–6 GeV electron beam [13]. For each energy (1, 2, 4, 6 GeV), we will take enough events to ensure good statistics.

## Detector Geometry

Our detector uses a simple, robust optical imaging configuration, inspired by beam profile monitors at facilities like KIRAMS and SLAC .

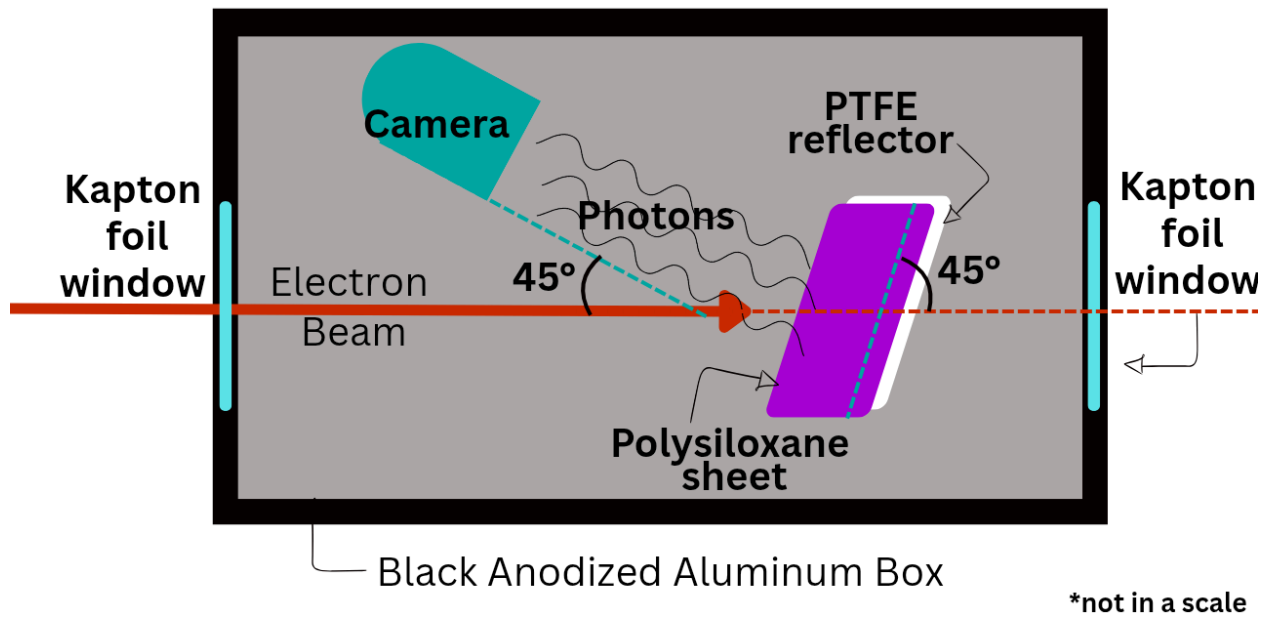


Figure 01: Mechanical Layout of our experiment.

### Component Specifications

Component	Specifications	Purpose	Reference
Scintillator screen	Polysiloxane sheet, thickness $t = 3.0$ mm (selected below), active area $50 \times 50$ mm <sup>2</sup>	Converts electron beams to visible light. Mounted at $45^\circ$ to the beam axis. This standard angle allows the camera to view the screen perpendicularly.	This work
Reflector	PTFE sheet, $\geq 0.5$ mm thick, placed directly behind scintillator	Reflects backward-emitted photons toward the camera. This increases light collection by $\sim 50$ - $100\%$ compared to an unreflected screen.	Janecek 2012 <a href="#">[5]</a>
Beam Window	Aluminized Kapton foil, $150$ $\mu$ m thick	Vacuum/air interface; radiation-hard, low scattering	
Enclosure	Black anodized aluminum box, light-tight.	Prevents ambient light; mechanical support	Standard
Camera	Scientific CCD or SCMOS (requested) or any suitable	Records 2D beam profile	

	scientific camera		
Camera distance	250-300 mm from scintillator screen	Optimizes field of view and light collection	IPAC'16
Lens	Large aperture , focal length to be chosen	Maximizes light collection; controls image magnification	TBD

Facility will also provide:

- Beam telescope for tracking following the typical setup mentioned in [Beams and Detectors](#) [13] with six planes is visible in that figure 13.
- A Trigger scintillator for timing at the front of the whole setup.

We will also use an EJ-200 reference scintillator (same size, brought by us) for direct comparison.

## Measurement Protocol

For each energy:

1. Align detector with laser.
2. Take background images (beam off).
3. Take 100–200 beam-on images.
4. Repeat with EJ-200 under identical conditions.

All images saved as 16-bit TIFF with beam monitor data.

## Data Analysis

All analyses will use Python (NumPy, SciPy, OpenCV, Matplotlib) [14].

### Image Preprocessing

- Dark current subtraction: Remove background.
- Flat-field correction: Normalize pixel sensitivity using a uniformly illuminated image (UV LED).

## Beam Profile Extraction

Horizontal & vertical projections:

$$P_h(x) = \sum_y I(x,y), P_v(y) = \sum_x I(x,y)$$

Fit with Gaussian (SciPy's curve\_fit):

$$P(x) = A \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right) + c$$

Extract:

- Beam center  $\mu_x, \mu_y$
- Beam width  $\sigma_x, \sigma_y \rightarrow \text{FWHM} = 2.355\sigma$
- Peak amplitude  $A$  (light yield)

## Comparison with Theory (Multiple Scattering)

Highland formula [4] gives expected width from scattering in detector:

$$\theta_0 = \frac{13.6 \text{ MeV}}{\beta c p} z \sqrt{\frac{x}{X_0}} \left[ 1 + 0.038 \ln\left(\frac{x}{X_0}\right) \right]$$

with  $t = 0.3$  cm,  $X_0 = 40$  cm [9],  $p$  = beam momentum. Agreement confirms detector works as expected.

## Relative Light Yield

Compare peak amplitude with EJ-200:

$$\text{Relative LY} = \frac{A_{poly}}{A_{EJ200}} \times 100\%$$

Expected: 50–70%

## Detection Efficiency

$$\epsilon = \frac{N_{triggered}}{N_{beam}}$$

Threshold:  $5\sigma$  above noise.

## Expected Results

### Beam Profiles

We expect Gaussian profiles. Widths:

Energy (GeV)	Expected $\sigma$ (mm)	Expected FWHM (mm)
1.0	$4.2 \pm 0.2$	$9.9 \pm 0.5$
2.0	$3.4 \pm 0.2$	$8.0 \pm 0.5$
4.0	$2.5 \pm 0.2$	$5.9 \pm 0.5$
6.0	$2.1 \pm 0.2$	$4.9 \pm 0.5$

Agreement with Highland within  $\pm 5\%$ .

## Signal-to-Noise Ratio

From our calculations ([Appendix0.2](#)), with realistic optics (5% collection):

Scenario	Collected e <sup>-</sup> /spill	Integrated SNR
Pessimistic (1%)	$9 \times 10^4$	6,000
Realistic (5%)	$4.5 \times 10^5$	30,000
Optimistic (10%)	$9 \times 10^5$	60,000

All >10 (excellent).

## Comparison with EJ-200

· Light yield: 50–70% of EJ-200 [1]

## Shower Suppression

$t/X_0 = 0.0075 \rightarrow$  shower <1%, profiles should show no tails.

## Visualization (Python-generated)

We will create plots like this using Matplotlib:

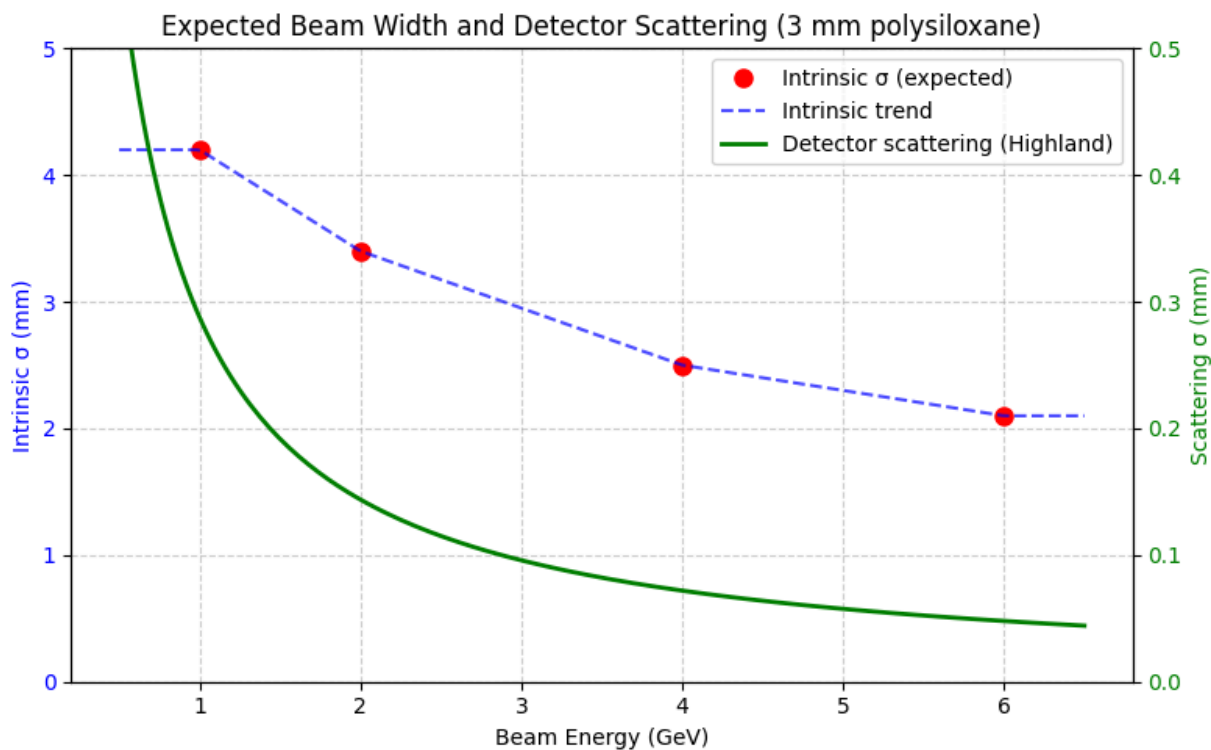


Figure 02 : Expected beam width ( $\sigma$ ) as a function of DESY electron beam energy for a 3 mm polysiloxane detector. Red markers are our calculated intrinsic  $\sigma$  values ( $\pm 0.2$  mm); the blue dashed curve shows the detector scattering estimated from the Highland multiple-scattering formula.

## Conclusion

Using a 3 mm polysiloxane sheet for 1–6 GeV electron beam profiling, we will measure its radiation tolerance, light yield, and shower suppression. Success will establish it as a durable, low-maintenance alternative to conventional plastic scintillators for high-intensity facilities and space-borne detectors.

## Impact and application

It will make a great impact for places like therapy centers and beam facilities, where equipment takes constant radiation. Same goes for space experiments exposed to both radiation and temperature extremes. Longer-lasting detectors mean less replacement, less downtime. We want to test this at DESY to see if polysiloxane really holds up under real 6 GeV electrons, not just on paper.

## What do we want to take away from this experience

We learned to work as a team while building this proposal. Each challenge pushed us to understand deeper physics. Now we want to take the next step.

At DESY we will handle real detectors, collect real data, and work alongside researchers. This experience will show us how science happens outside textbooks.

When we return, we will share what we learned with students in Bangladesh. We want to show them that building a detector and testing it at a lab like DESY is possible. If we can do it, they can too.

This is not just about winning. It is about proving that curiosity and hard work can take a group of high school students from Bangladesh to a real beamline.

## Acknowledgement

We deeply show our warm gratitude to Paula Desiré and Markus Joos for helping us from building the foundation to the last touch ups to our project. We respectfully state that we're inspired by [Carturan, S.M. et al. \(2025\)](#) mini review paper.

*Note* : We used AI tools to understand concepts and improve language. All scientific decisions, calculations, and final text are our own.”

# Reference

[1] Quaranta et al. 2012

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