



BeamScan

A Particle-Beam Material Classifier — From Recycling to Heritage Science

Los Topos Cósmicos · Instituto San Francisco de Asís
Santa Rosa de Calamuchita, Córdoba, Argentina 

BL4S 2026 · Project Briefing for Teachers

What is BeamScan?

The Idea

Shoot a beam of particles (protons, pions, electrons) through a thin slab of material.

Measure how much the beam spreads out — Multiple Coulomb Scattering (MCS).

Different materials scatter differently → each gets a unique "fingerprint."

● **Non-destructive:** the sample is untouched.

Two Real-World Applications

Recycling

Detect PVC contamination in mixed plastic waste — a critical quality-control problem for cooperatives in Córdoba.

Heritage Science

Classify geological materials in Comechingón *morteros* — 2,000-year-old stone tools that cannot be destroyed for analysis.

The Physics — Multiple Coulomb Scattering

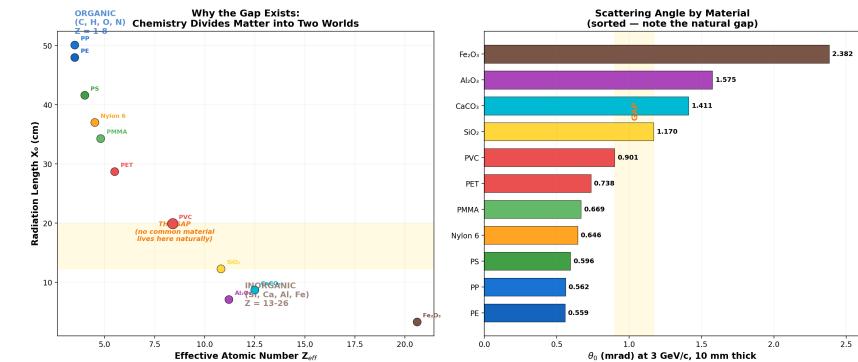
When a fast particle passes through matter, it bounces off atomic nuclei many times.

Heavier atoms (higher Z) → more scattering → wider beam spread.

The Highland formula gives the expected spread:

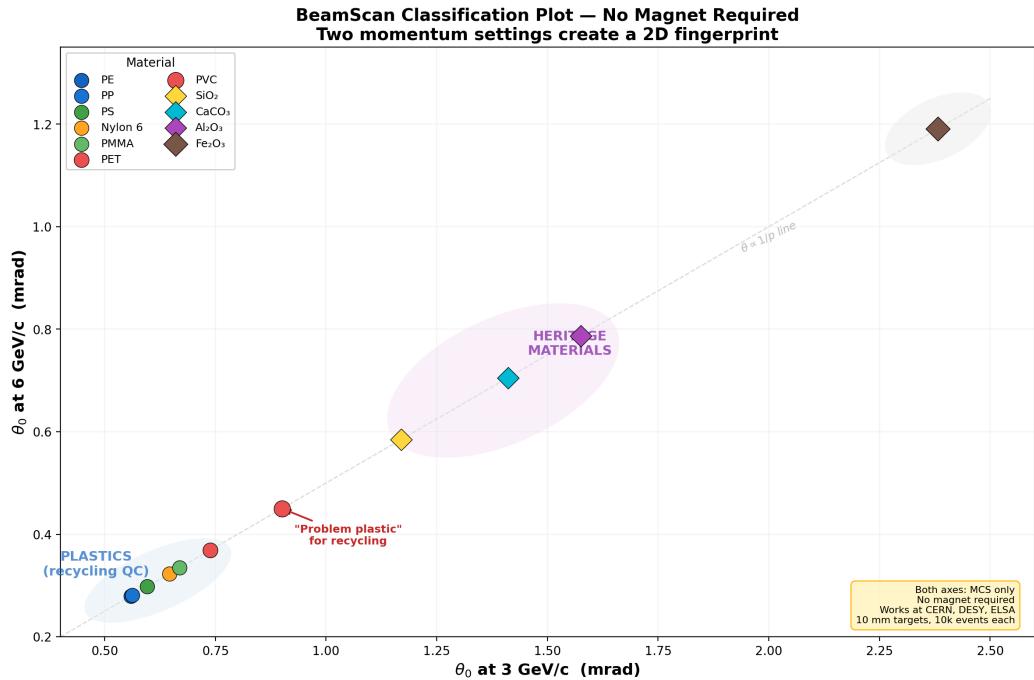
$$\theta_0 = \frac{13.6 \text{ MeV}}{p\beta c} \sqrt{\frac{x}{X_0}} \left[1 + 0.038 \ln \frac{x}{X_0} \right]$$

Where: x = thickness, X_0 = radiation length (material property), p = momentum.



The natural gap between plastics (C,H,O) and minerals (Si,Ca,Al,Fe) is the scientific result.

The BeamScan Atlas — 11 Materials, 2 Momenta



Key Results

- ✓ 7 plastics + 4 minerals fully separable
- ✓ PVC detection needs only ~50 events (seconds of beam time)
- ✓ Full atlas in under 1 hour
- ✓ No magnet required — works at CERN, DESY, ELSA
- ✓ Two momenta provide built-in consistency check (1/p scaling)

Geant4 validated: G4/Highland = **1.12 ± 0.03** across all light materials

Geant4 Validates Highland — And Reveals Nuclear Scattering

Material	3 GeV/c	6 GeV/c	Note
PET	1.097	1.090	Closest to Highland
PVC	1.101	1.108	
Nylon	1.105	1.113	
PMMA	1.112	1.111	
PP	1.120	1.122	
CaCO ₃	1.136	1.135	
SiO ₂	1.147	1.152	
Al ₂ O ₃	1.168	1.168	
Fe ₂ O ₃	1.397	1.493	⚠️ Nuclear scattering

What this means

Highland underestimates by a consistent 12% — because it only models electromagnetic scattering.

Geant4 adds nuclear elastic + inelastic scattering, which grows with Z.

Fe₂O₃ is the proof: iron nuclei (Z=26) have much larger hadronic cross-sections → 40–50% excess.

How It's Built — Technical Architecture

Student Input

Students write YAML request files: materials, momenta, thickness.
No code needed — just a text editor.

Highland CI

GitHub Actions runs Highland predictions in ~30 seconds.
Produces plots + CSV + PR comment.
Triggered automatically on PR.

Geant4 CI

Full Monte Carlo simulation.

Repository — 66 files, 100% open source

Directory	Contents	Who uses it
requests/	Student YAML files — material choices	 Students
requests/examples/	4 named examples (Lucía, Valentina, Tomás, Sofía)	 Students
analysis/	<code>highland_calculator.py</code> , <code>analyze_geant4.py</code>	 CI / Teachers
simulation/	Geant4 C++ (<code>beamscan.cc</code> , 6 source files)	 CI
scripts/	<code>validate_requests.py</code> , <code>generate_macros.py</code> , <code>pseudo_mc.py</code>	 CI
docs/	GitHub Pages site, Physics Deep Dive, Student Guide	 Everyone
results/	Committed predictions, plots, G4 comparison	 Everyone
.github/workflows/	2 CI pipelines (Highland + Geant4)	 CI
materials/	<code>materials.yaml</code> — 11 materials + Graphite fallback	 Reference
schemas/	<code>request.schema.json</code> — validates YAML structure	 CI

How Students Participate

Step	Action	Details
1	Choose Materials	Pick materials to study. <i>"I want to see if BeamScan can tell PVC apart from PE at 3 GeV."</i>
2	Write a YAML File	Copy a template, change materials, momenta, thickness. No programming — it's a structured text file.
3	Open a Pull Request	Push to a branch → open PR → GitHub Actions runs Highland predictions in 30 seconds.
4	Interpret Results	CI comments with plots + CSV. The student analyzes: <i>can these materials be distinguished? How many events are needed?</i>

 **Key:** Students never need to install Geant4, C++, or Python. Just a GitHub account and a text editor.

What a Student Request Looks Like

```
# valentina_pvc_detection.yaml
author: "Valentina García"
description: >
    Can BeamScan detect PVC contamination
    in a mixed plastic recycling stream?

materials:
- name: PE
  geant4_name: G4_POLYETHYLENE
  thickness_mm: 10
- name: PVC
  geant4_name: G4_POLYVINYL_CHLORIDE
  thickness_mm: 10

beam:
  particle: e-
  momenta_GeV: [3.0, 6.0]

num_events: 10000
```

What happens next

1. Student commits this file
2. Opens a Pull Request
3. CI validates the YAML
4. Highland runs in **30 seconds**
5. Bot comments with plots:
 - distributions.png
 - classification.png
 - predictions.csv
 - SUMMARY.md
6. **Student writes analysis** in their PR description

What's Missing — Next Steps

● Before Submission (March deadline)

- Video (1 min): required by BL4S — team intro + experiment explanation
- Cost estimate: target materials, shipping to facility
- Team photo + teacher signatures on application form

● Technical Hardening

- Schema caps: limit `num_events`, `moments_materials_per_request`

● Student Activities (can start now)

- Each student picks a research question → writes YAML → opens PR
- 4 named examples already exist: Valentina, Tomás, Lucía, Sofía
- Students write analysis in PR descriptions — builds proposal portfolio

● If Selected (summer/fall)

- Prepare physical target samples

Why This Proposal Stands Out

-  **Real Science** — Not a textbook repeat. Original classification method with validated predictions. The G4/Highland ratio analysis is genuinely publishable.
-  **Student-First Design** — Students participate without installing C++ or Geant4. YAML → PR → results in 30 seconds. The barrier to entry is a text editor.
-  **Social Impact** — Connects CERN physics to recycling cooperatives and indigenous heritage in Córdoba. Reviewers love proposals that matter beyond the lab.
-  **Facility-Agnostic** — Works at CERN T9, DESY, or ELSA. Adapts target list to safety rules. No magnet needed. Easy for BL4S organizers to schedule.
-  **Professional Infrastructure** — Public GitHub repo, CI/CD pipelines, automated



Ready to Explore

Website	los-topos-cosmicos.github.io/beam4school-proposal
Repository	github.com/los-topos-cosmicos/beam4school-proposal
Proposal	PROPOSAL .md
Contributing	CONTRIBUTING .md
Student Guide	docs/guides/STUDENT_GUIDE .md

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¡La física fundamental es para todos!