Optical Surface Support in GeGeDe

Adding surface physics to GDML geometry builders

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What Was Added This Session

GeGeDe Python API `geom.surfaces.OpticalSurface`, `BorderSurface`, `SkinSurface` now emit correct GDML `<opticalsurface>`, `<bordersurface>`, `<skinsurface>` nodes

Geant4 energy-unit fix GDML `<matrix>` values are read as bare MeV (Geant4 internal units), not eV; all property-table energies in `optical.py` now use the correct scale (e.g. `1.77e-6` for 1.77 eV / 700 nm)

Dispersive glass RINDEX prism material now has a 7-point wavelength-dependent table ($n = 1.570$ at 700 nm $\rightarrow$ 1.655 at 400 nm, Abbe $V_d \approx 26$) so colours separate visibly in simulation

Water optical properties RINDEX (Sellmeier), ABSLENGTH (50–70 m peak), RAYLEIGH (λ^4 scaling) representative of SK-quality ultra-pure water

Full Geant4 sim app (g4app/) GPS primary generator, `G4OpticalPhysics`, PMT hit collection via `G4OpBoundaryProcess::Detection`, CSV output (`hits.csv`, `trajectories.csv`), Python visualisers

How to Add Optical Properties in a GeGeDe Builder

Material properties

```
# Energies in MeV (= eV × 1e-6) Geant4 GDML internal unit
geom.matter.Molecule("Glass", ...,
    properties = [
        ("RINDEX", [(1.771e-6, 1.570),   # 700 nm red
                    (3.100e-6, 1.655)]),  # 400 nm violet
    ])
geom.matter.Molecule("Water", ...,
    properties = [
        ("RINDEX",    [(1.77e-6, 1.331), (4.14e-6, 1.353)]),
        ("ABSLENGTH", [(1.77e-6, 1e3),   (3.10e-6, 7e4)]),  # mm
        ("RAYLEIGH",  [(1.77e-6, 7.5e5), (4.14e-6, 3e3)]),  # mm
    ])
```

Surfaces

```
geom.surfaces.OpticalSurface("pmt_surface",
    model="unified", finish="polished", type="dielectric_metal", value=1.0,
```

The optical/ Example: What It Models

Geometry (all volumes share the world origin)

Volume	Material	Size
world_vol	stainless steel	1 m cube
air_vol	ultra-pure water	90 cm cub
prism_vol	dense flint glass	30×20×2
pmt_vol	PMT window glass	R=5 cm h

- 384 PMTs: 8×8 grid on each of 6 faces, 10 cm pitch
- Sensitive detector wired via GDML `<auxiliary auxtype="SensDet"/>`

Surfaces

Steel reflector (BorderSurface)

- REFLECTIVITY 90 % (red) → 85 % (UV)

PMT photocathode (SkinSurface)

- REFLECTIVITY = 0 (fully absorbing)
- EFFICIENCY 5 % (red), 25 % (blue), 8 % (UV)
- Geant4 sets status Detection and kills track when photon passes QE roll

Build / run one-liner:

```
uv run gegede -o optical_prism.gdml op
./g4app/build/optical_g4 macros/run.ma
```

Run 1: PMT Hits Isotropic Spectrum

Macro (macros/run.mac)

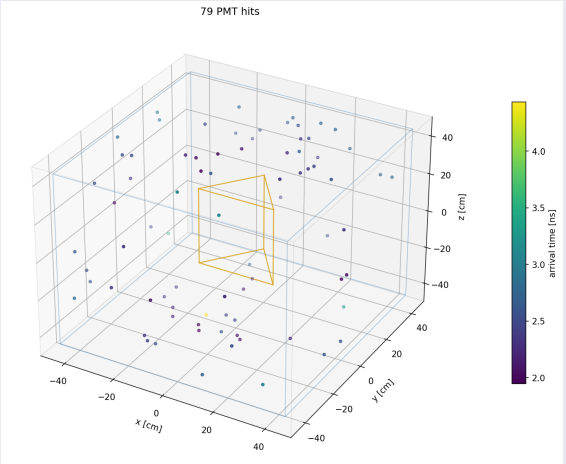
```
/gps/particle opticalphoton
/gps/pos/centre 0 0 0 cm
/gps/ang/type   iso

/gps/ene/type      Lin
/gps/ene/min  1.77 eV   # 700 nm
/gps/ene/max  4.14 eV   # 300 nm
/gps/ene/gradient  0
/gps/ene/intercept 1

/run/beamOn 1000
```

1000 isotropic photons from the centre; no trajectory storage. Output: `hits.csv` (~80 detections, ~8 %

Result



Run 2: Trajectories - Isotropic Spectrum

Macro (macros/run_traj.mac)

```
/tracking/storeTrajectory 1

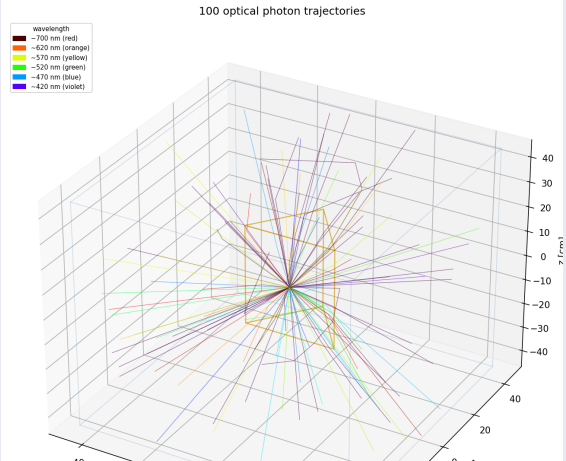
/gps/particle opticalphoton
/gps/pos/centre 0 0 0 cm
/gps/ang/type   iso

/gps/ene/type      Lin
/gps/ene/min  1.77 eV
/gps/ene/max  4.14 eV
/gps/ene/gradient  0
/gps/ene/intercept 1

/run/beamOn 50
```

50 photons; every step point recorded.

Result



Run 3: Dark Side Of The Moon - Dispersion Demo

Macro (macros/dsotm.mac)

```
# 7 equal-intensity GPS sources; same
# position/direction, one per colour.
/gps/source/add 1
/gps/particle   opticalphoton
/gps/pos/centre -35 8 0 cm
/gps/ang/type   beam1d
/gps/ang/sigma_r 0 deg
/gps/direction  1 0 0
/gps/ene/type   Mono
/gps/ene/mono   1.771 eV   # red 7(
# ... repeated for 2.000 2.138 2.3
#     2.530 2.755 3.100 eV
/tracking/storeTrajectory 1
/run/beamOn 700
```

Result

