Simulating light collection

Paloma Díaz

GENP, Dpto. Física de Partículas, Universidade de Santiago de Compostela

What we want to do?

- Use geant4 and ROOT for simulate light propagation in a crystal

1st

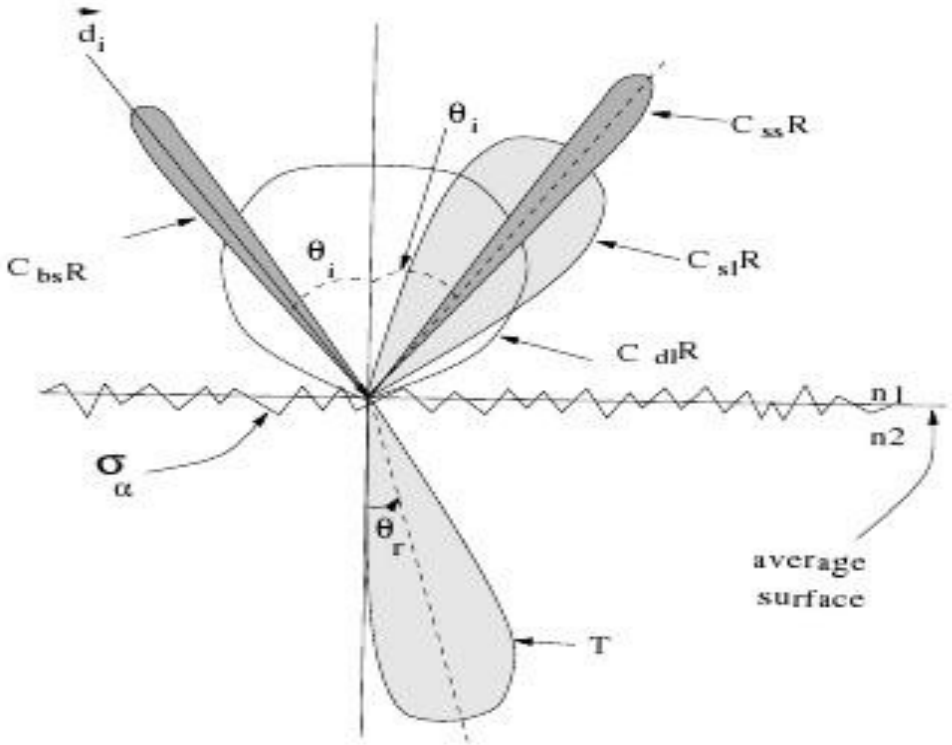
For understand completly how the program works → A box is going to be used for first tests

2nd

Check a real crystal

Unified model in Geant4

- Specular Spike ➡ Photon reflected like in a perfect mirror about the average surface norma
- Lambertian reflection ➡ Photon will be reflected with a lambertian distribution
- Backscatter ➡ Photon reflected back into the direction the photon come
- Specular Lobe ➡ Specular reflection based on the micro-facet orientation



Sigmaalpha: defines te standard deviation of the distribution of the micro-facets orientation

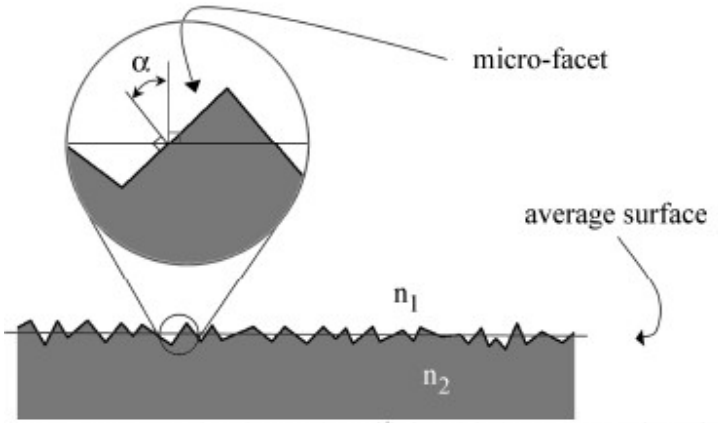
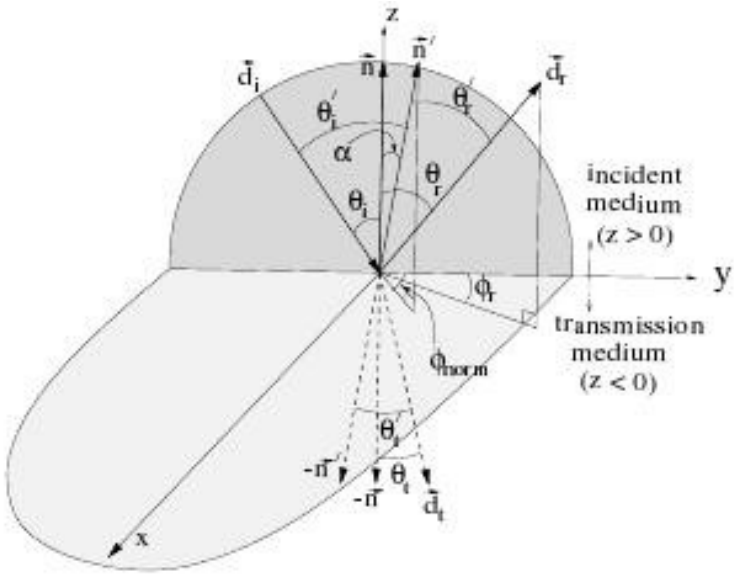


Fig. 3. For a ground surface in the *unified* model, the parameter *sigmaalpha* defines the standard deviation of the Gaussian distribution of micro-facets around the average surface normal.

Unified model in Geant4



- $\vec{d_i}$ - the direction vector of the incident photon,
- $\vec{d_r}$ - the direction vector of the reflected photon,
- $\vec{d_t}$ - the direction vector of the refracted photon,
- θ_i - the angle of incidence relative to the average normal,
- θ_r - the angle of reflection with respect to the average normal,
- θ_t - the angle of refraction with respect to the average normal,
- ϕ_r - the angle between the projection of the reflected or refracted photon onto the average surface and the plane of incidence,
- $\vec{n'}$ - the normal of a particular micro-facet,
- α - the angle between a given micro-facet and the mean surface,
- ϕ_{norm} - the angle between the projection of the micro–facet normal onto the average surface and the plane of incidence,
- θ_i' - the angle of incidence relative to the micro–facet normal,
- θ_r' - the angle of reflection with respect to the micro–facet normal,
- θ_t' - the angle of refraction with respect to the micro–facet normal.

Unified model in Geant4

Surface type and finish

- dielectric_dielectric: *polished, polishedfrontpainted, polishedbackpainted, ground, goundfrontpainted, groundbackpainted*
- dielectric_metal: *polished, ground*

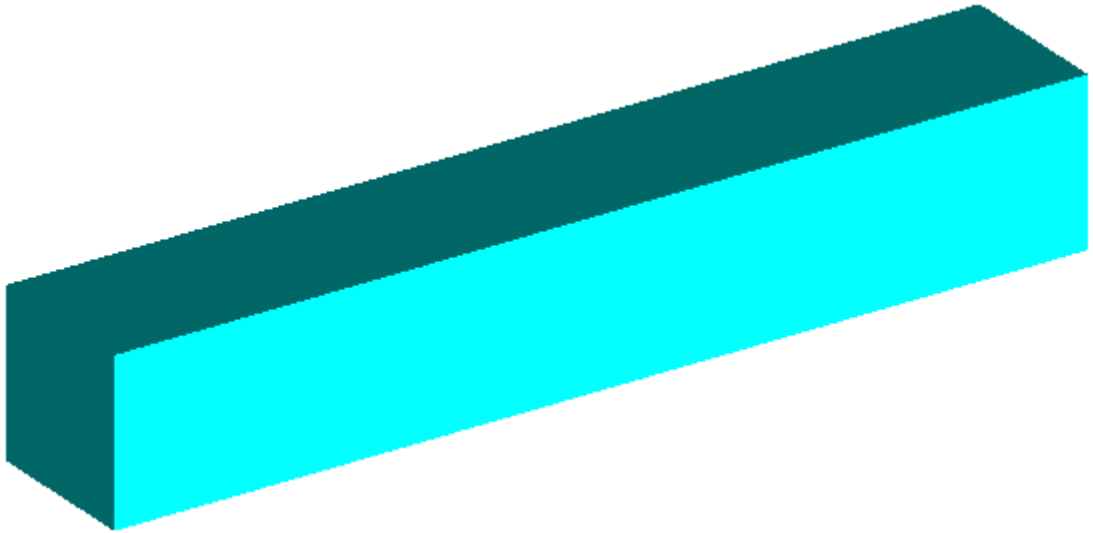
Reflectivity of the reflector attached to the material

Refractive indices for the two materials

Probabilities for each of the four surface reflection types (must add up 1)

Sigmaalpha for the case of lobe reflection

First tests results



- Type: dielectric_dielectric
- Finish: testing all
- Particles: optical photons in the (0,0,0)
- Direction: random

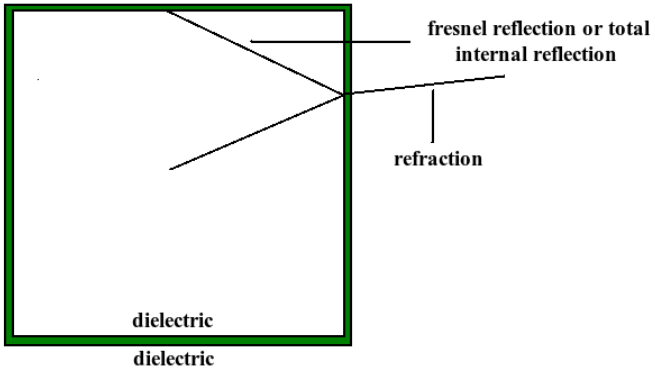
How is the behaviour of each finish surface??

- Polished: *fresnel reflection, total internal reflection and fresnel refraction*
- PolishedFrontPainted: *spike reflection and absorption*
- PolishedBackPainted: *spike reflection, lobe reflection, backscatter, lambertian reflection, fresnel refraction and absorption*
- Ground: *spike reflection, lobe reflection, backscatter, lambertian reflection and fresnel refraction*
- GroundFrontPainted: *lambertian reflection and absorption*
- GroundBackPainted: *spike reflection, lobe reflection, backscatter, lambertian reflection, fresnel refraction and absorption*

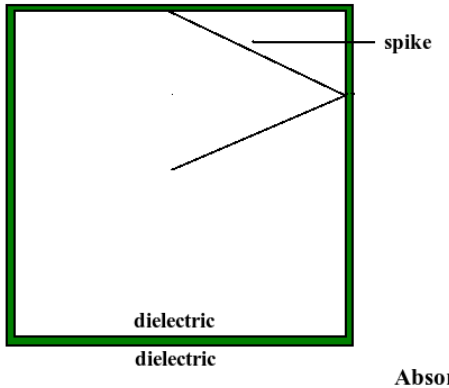
First tests results

How is the finish surface??

POLISHED

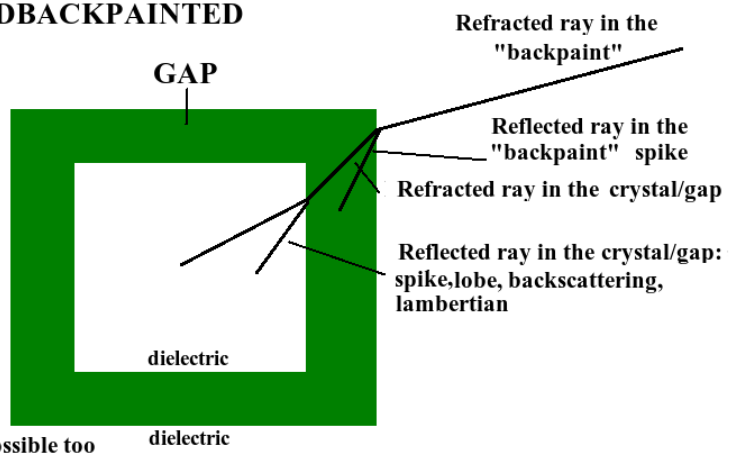


POLISHEDFRONTPAINTED



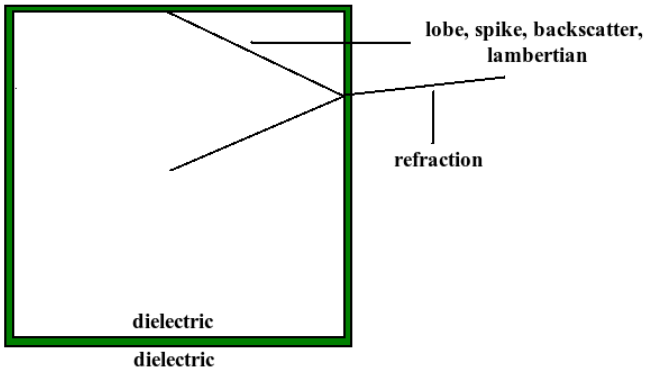
Absorption is possible too

POLISHEDBACKPAINTED

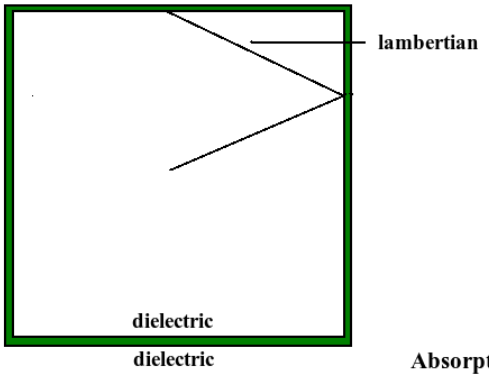


Absorption is possible too

GROUND

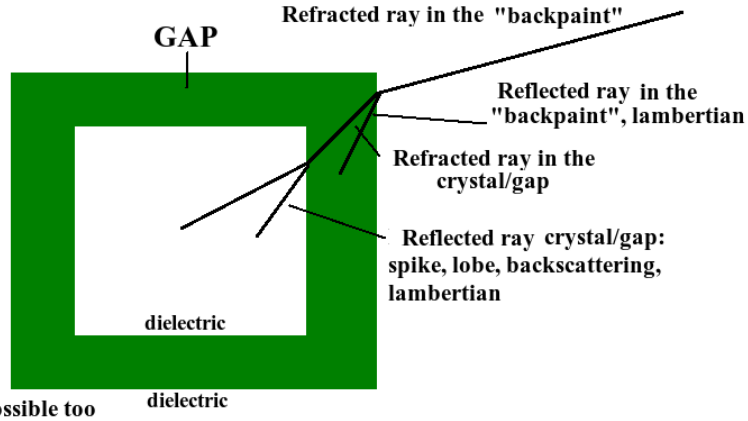


GROUNDFRONTPAINTED



Absorption is possible too

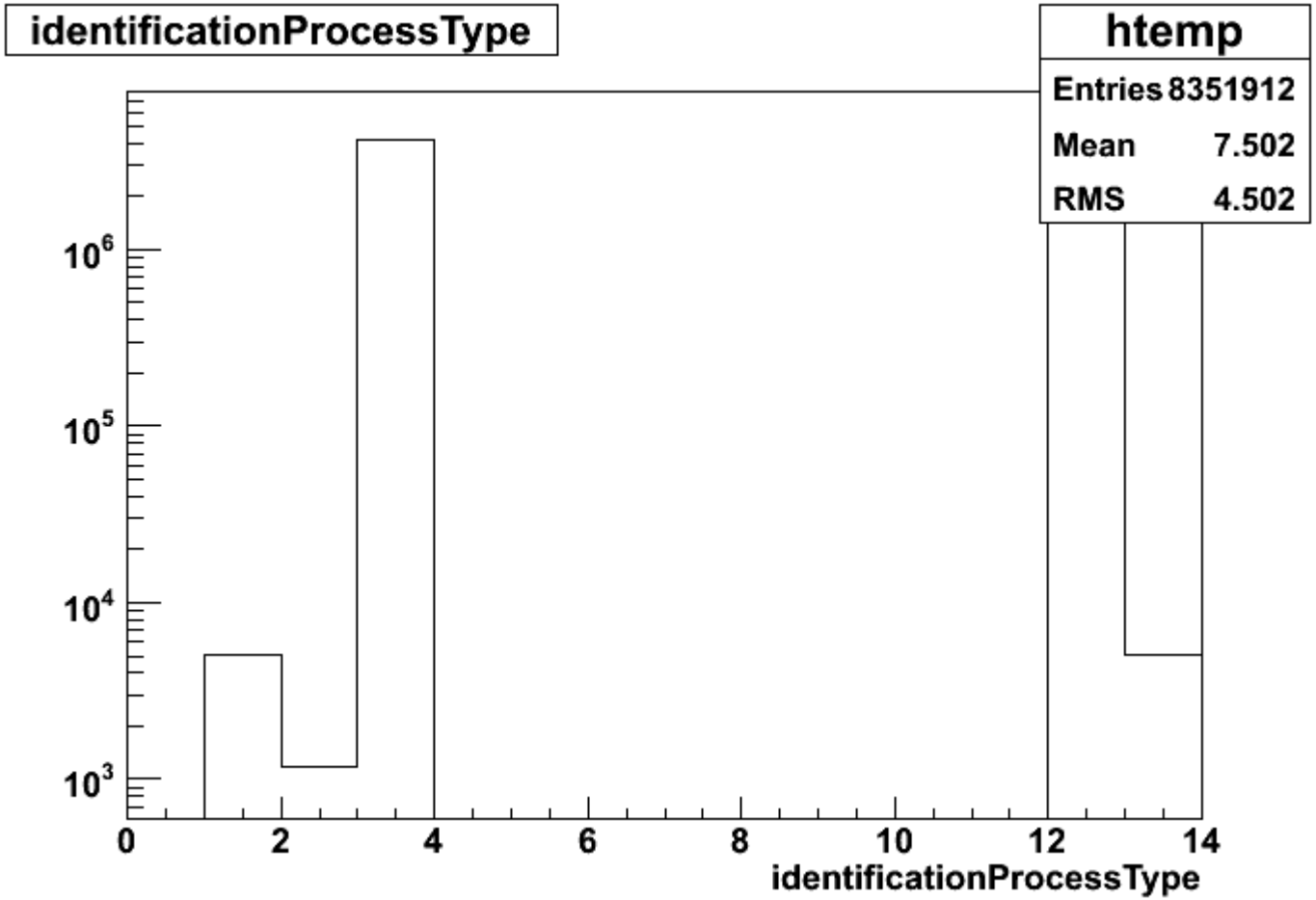
GROUNDBACKPAINTED



Absorption is possible too

First tests results: example polished surface

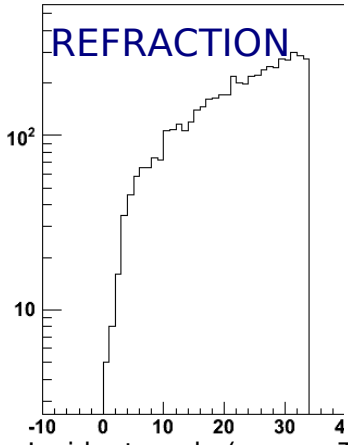
POSSIBLE PROCESSES FOR A POLISHED SURFACE

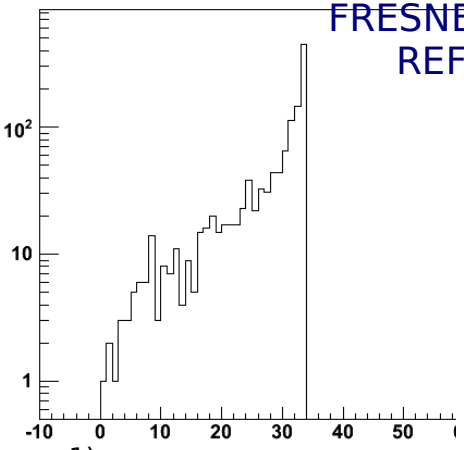


- Refractions: 5078
- Fresnel reflections: 1185
- Total internal reflections: 4167232

- 0: Undefined
- 1: Fresnel refraction
- 2: Fresnel reflection
- 3: Total internal reflection
- 4: Lambertian reflection
- 5: Lobe reflection
- 6: Spike reflection
- 7: Backscattering
- 8: Absorption
- 9: Detection
- 10: Not at boundary
- 11: Same Material
- 12: Step to Small
- 13: No rindex
- 14: Unknown

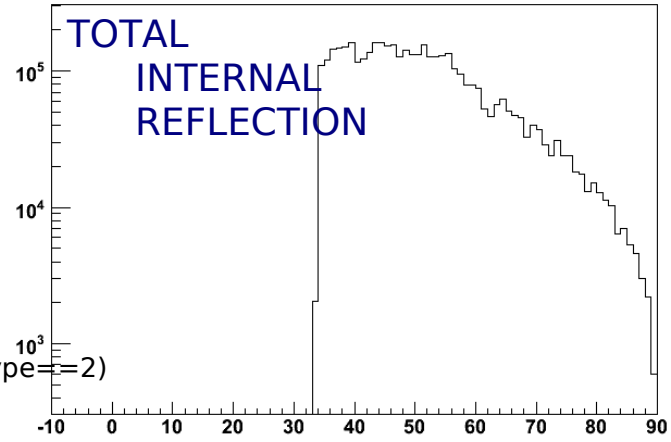
First tests results: example polished surface



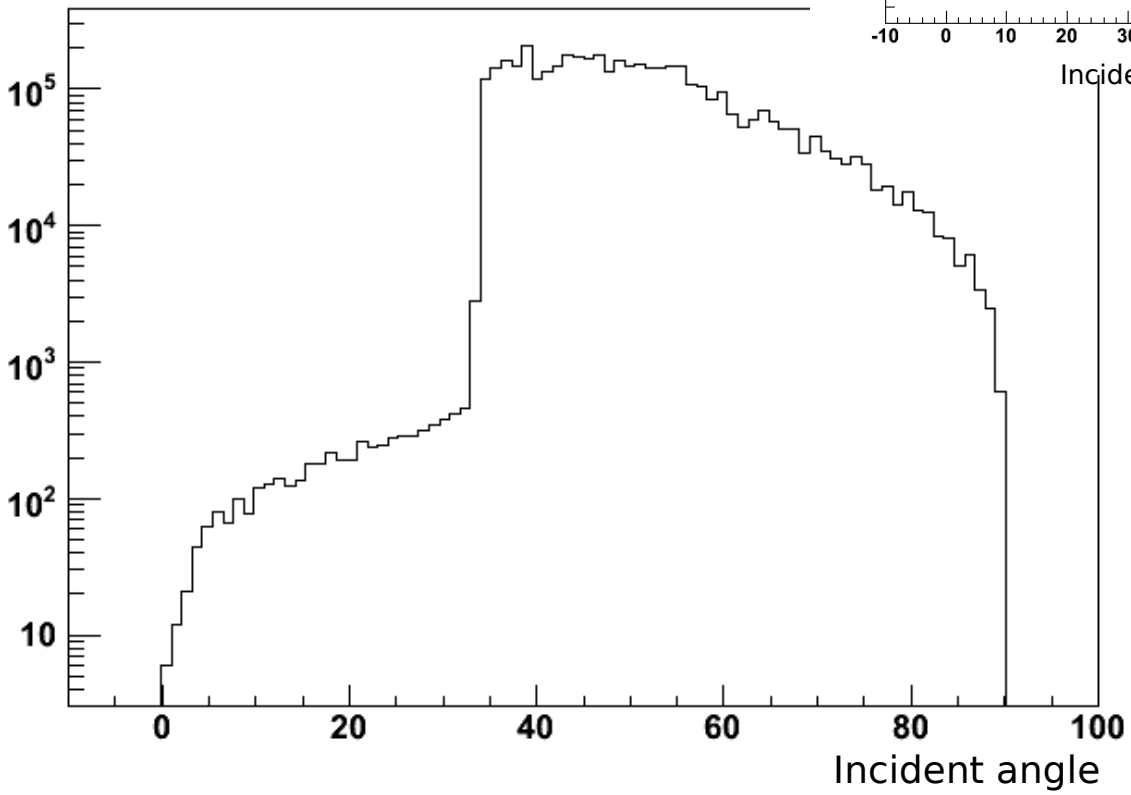


Incident angle (processType==1)

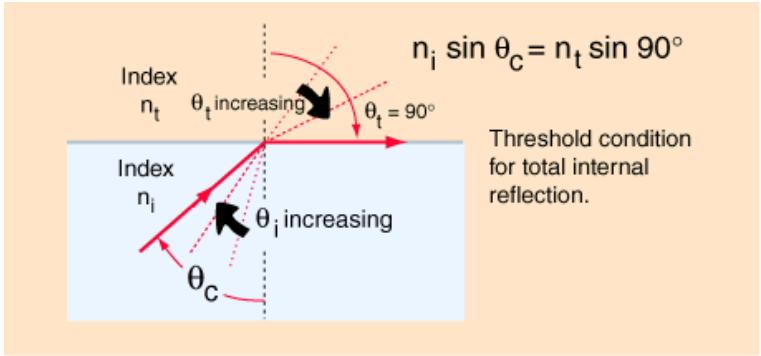
Incident angle (processType==2)



Incident angle (processType==3)

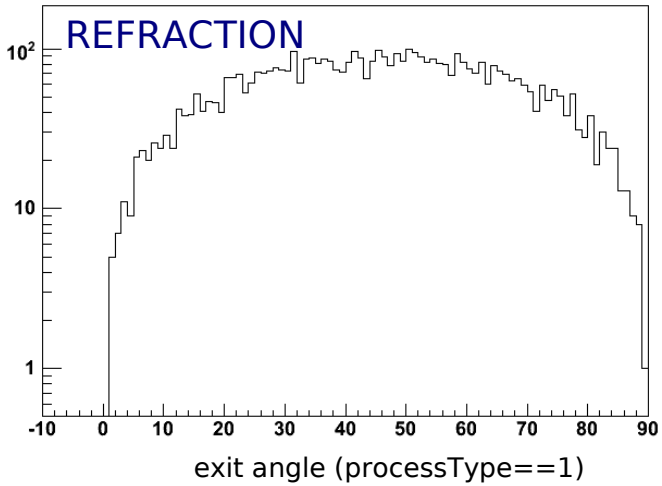


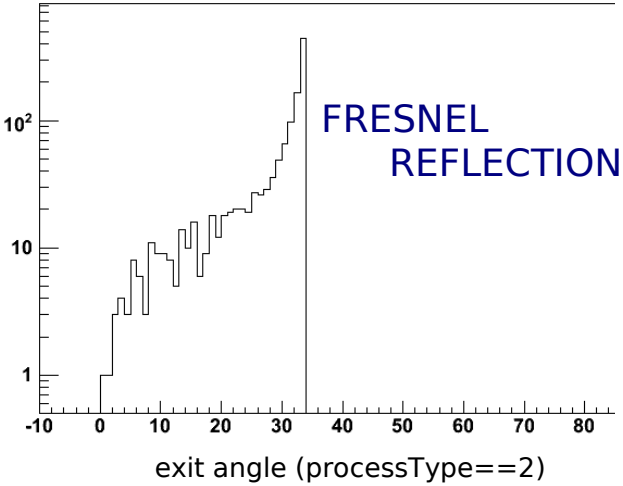
To understand these figure we need to know the critical angle

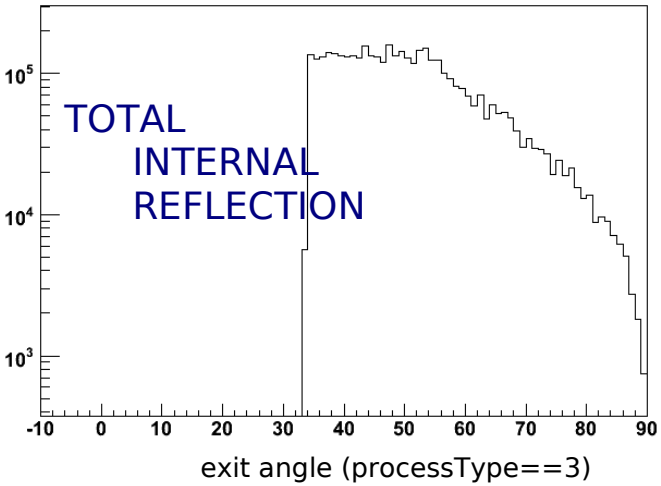


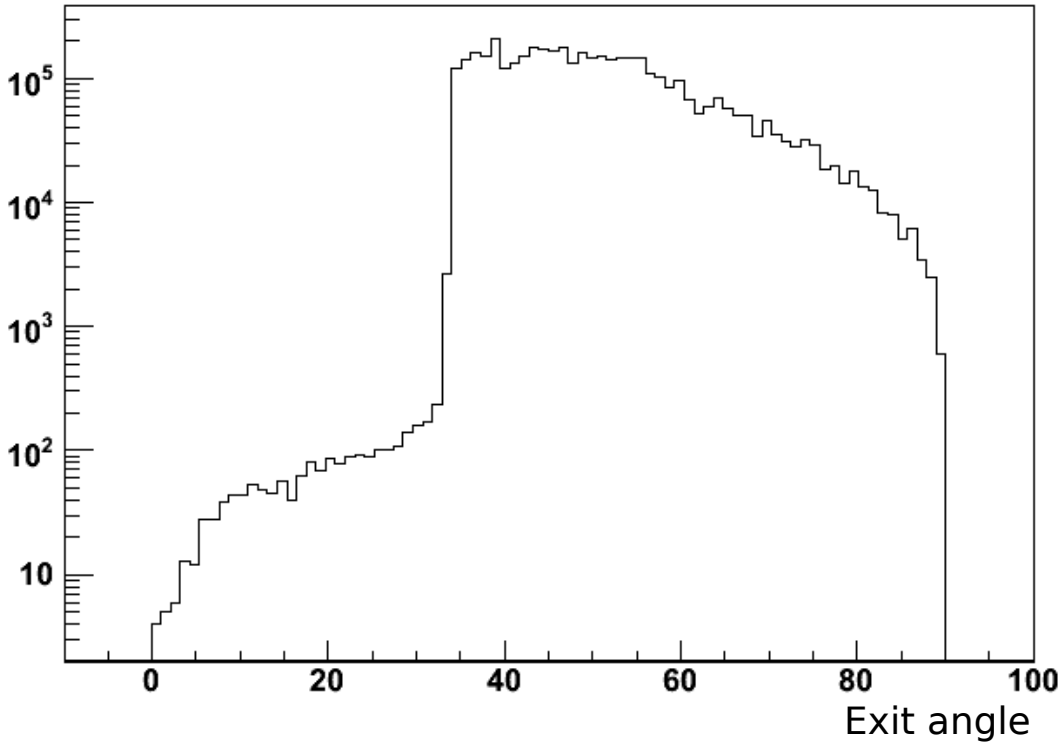
Critical angle = 34º

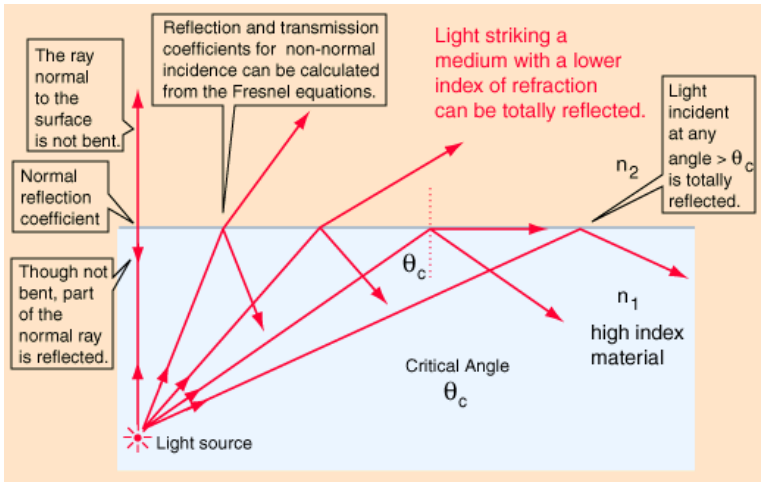
First tests results: example polished surface





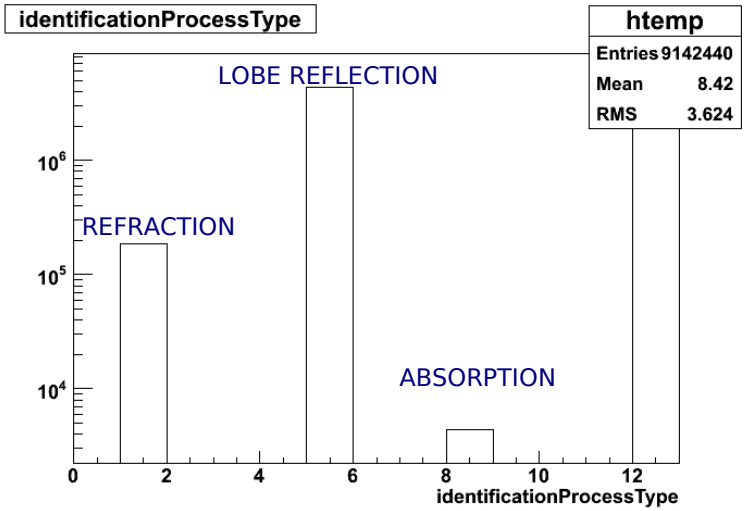


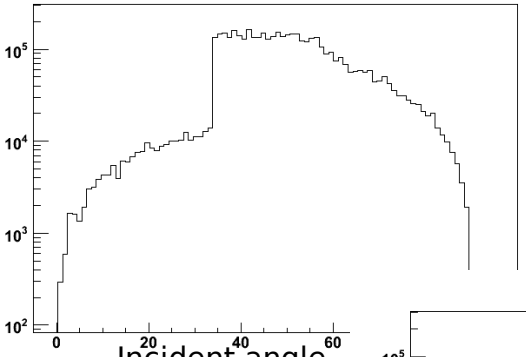


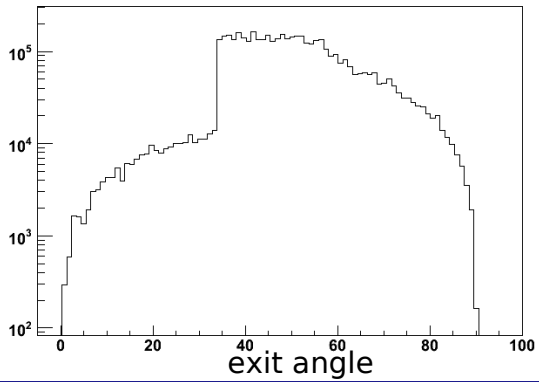


First tests results: comparison

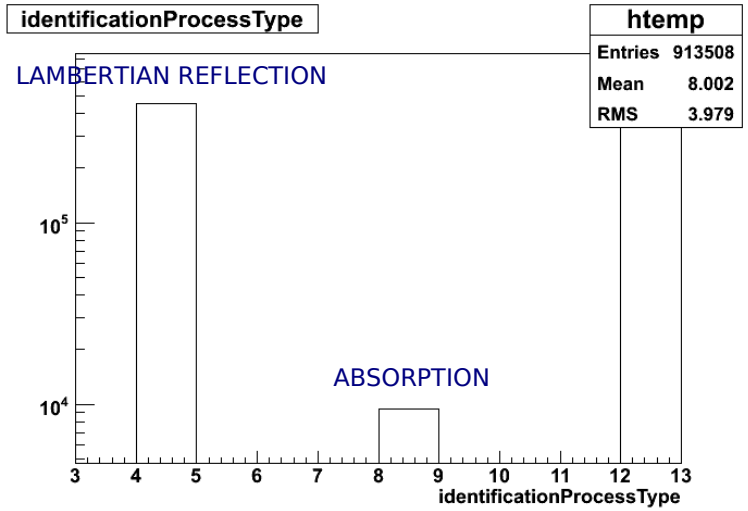
POLISHEDBACKPAINTED

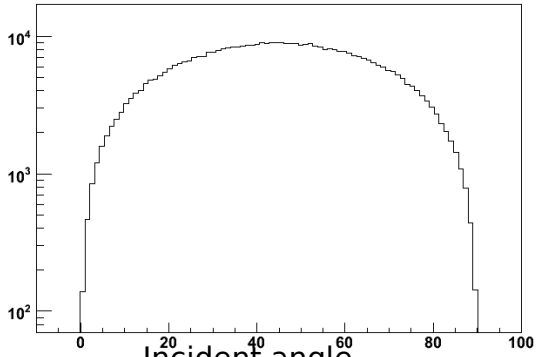


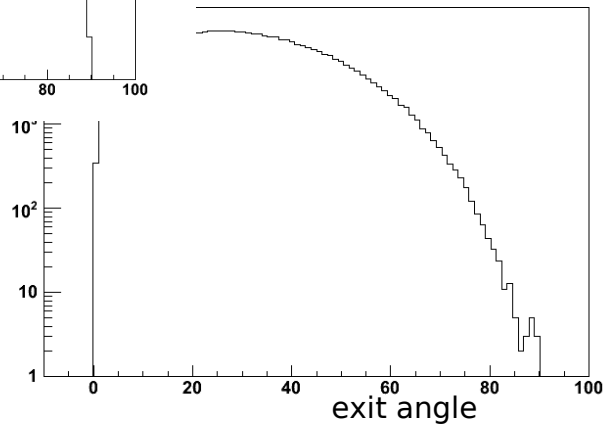




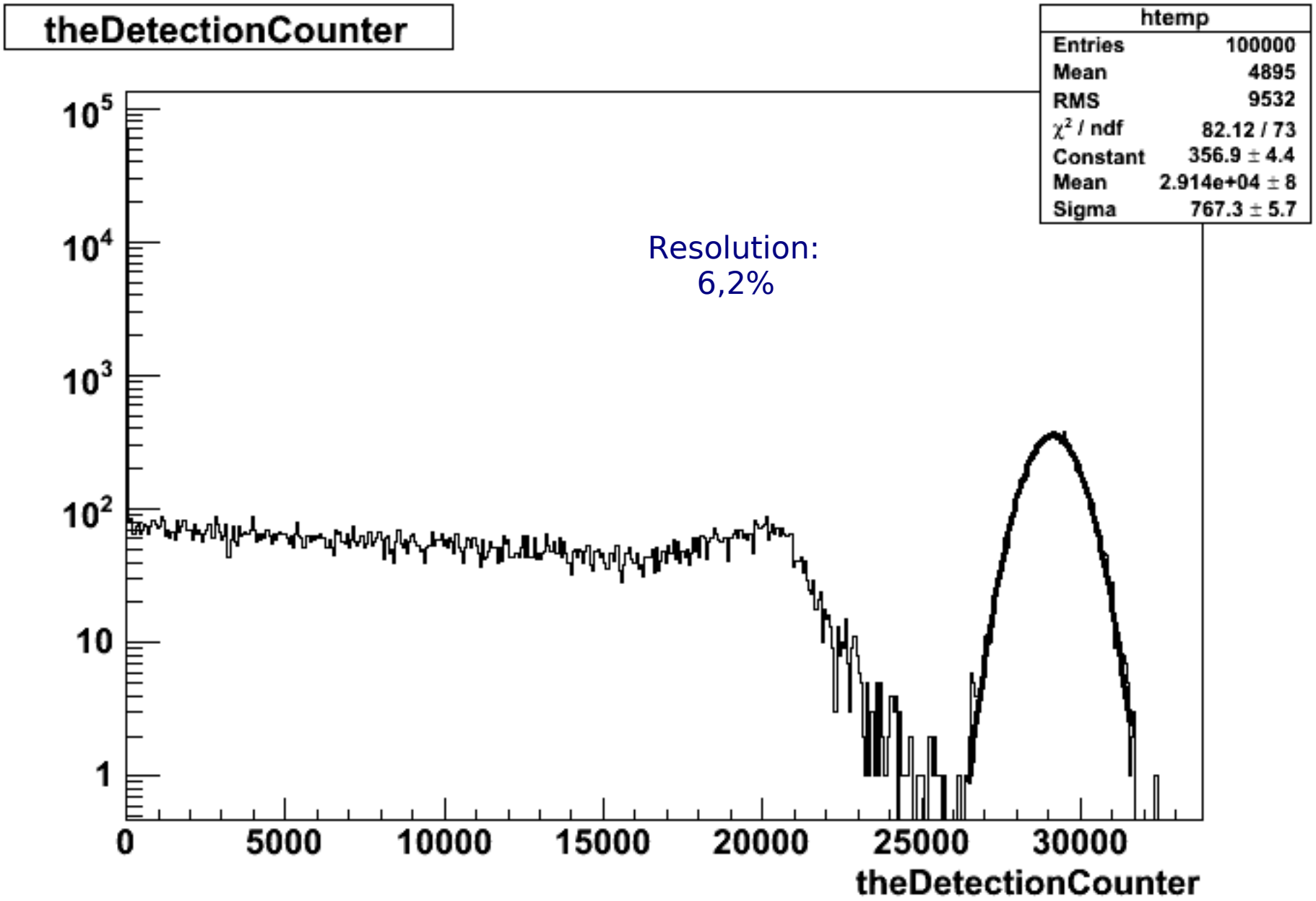
GROUNDFRONTPAINTED







Obtaining an spectra



Obtaining an spectra: comparison

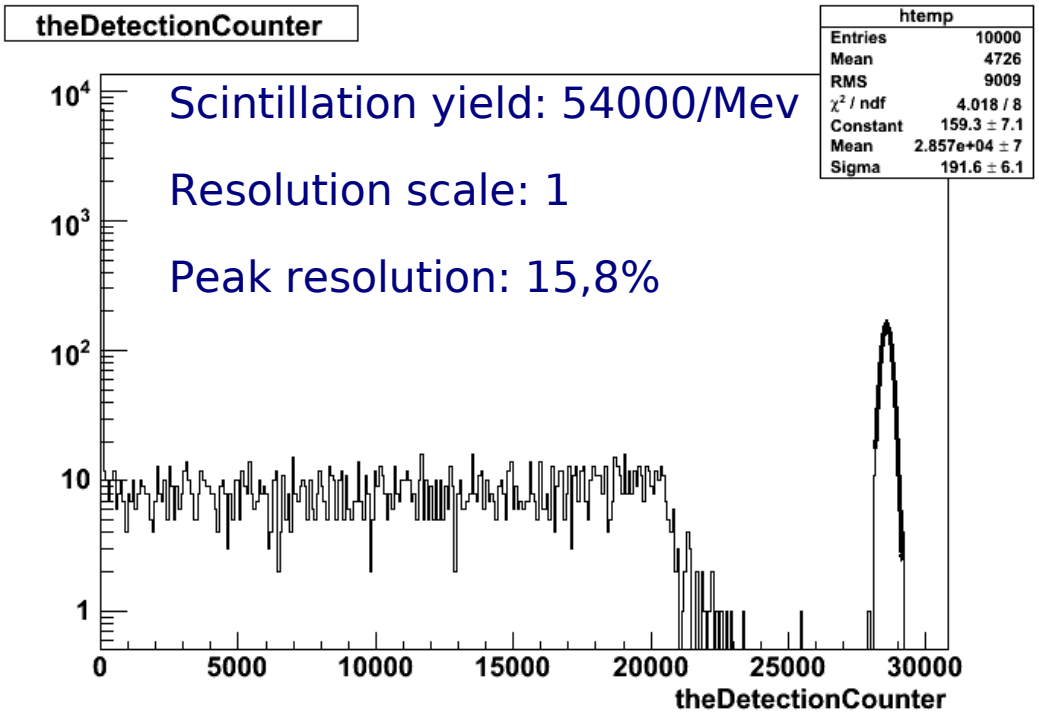
Every scintillating material has a characteristic light yield, SCINTILLATIONYIELD, and an intrinsic resolution, RESOLUTIONSCALE, which generally broadens the statistical distribution of generated photons.

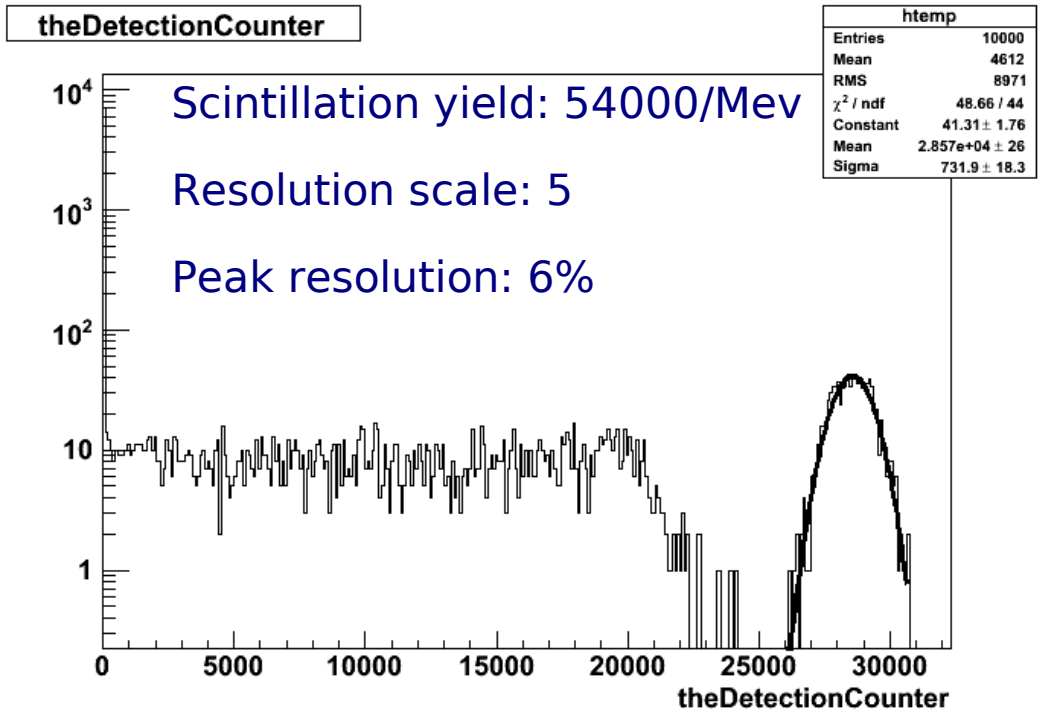
The actual number of emitted photons during a step fluctuates around the mean number of photons with a width given by ResolutionScale*sqrt(MeanNumberOfPhotons). The average light yield, MeanNumberOfPhotons, has a linear dependence on the local energy deposition.

Checking how affect the resolution scale to the spectra

Box: 1x1x1 cm^3 10000 gammas with 662keV from a distance of 30mm of the box

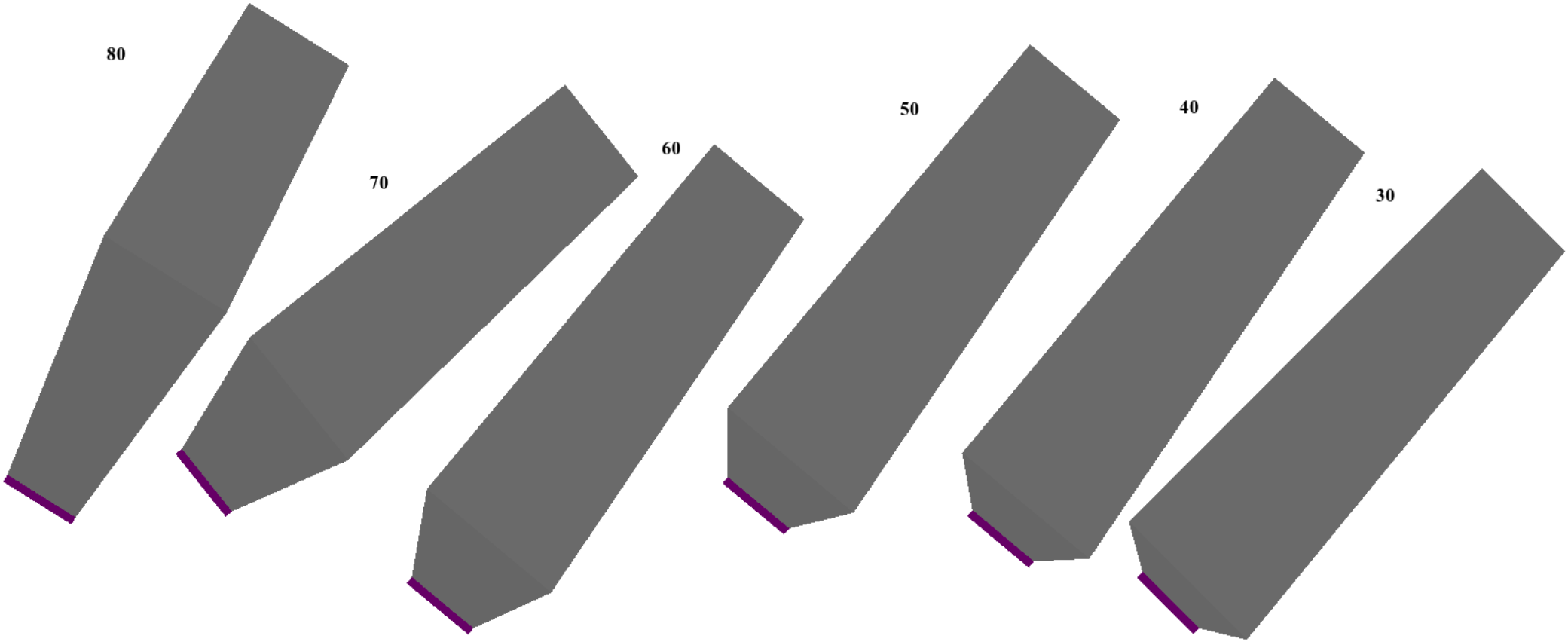
Crystal surface polishedBackPainted



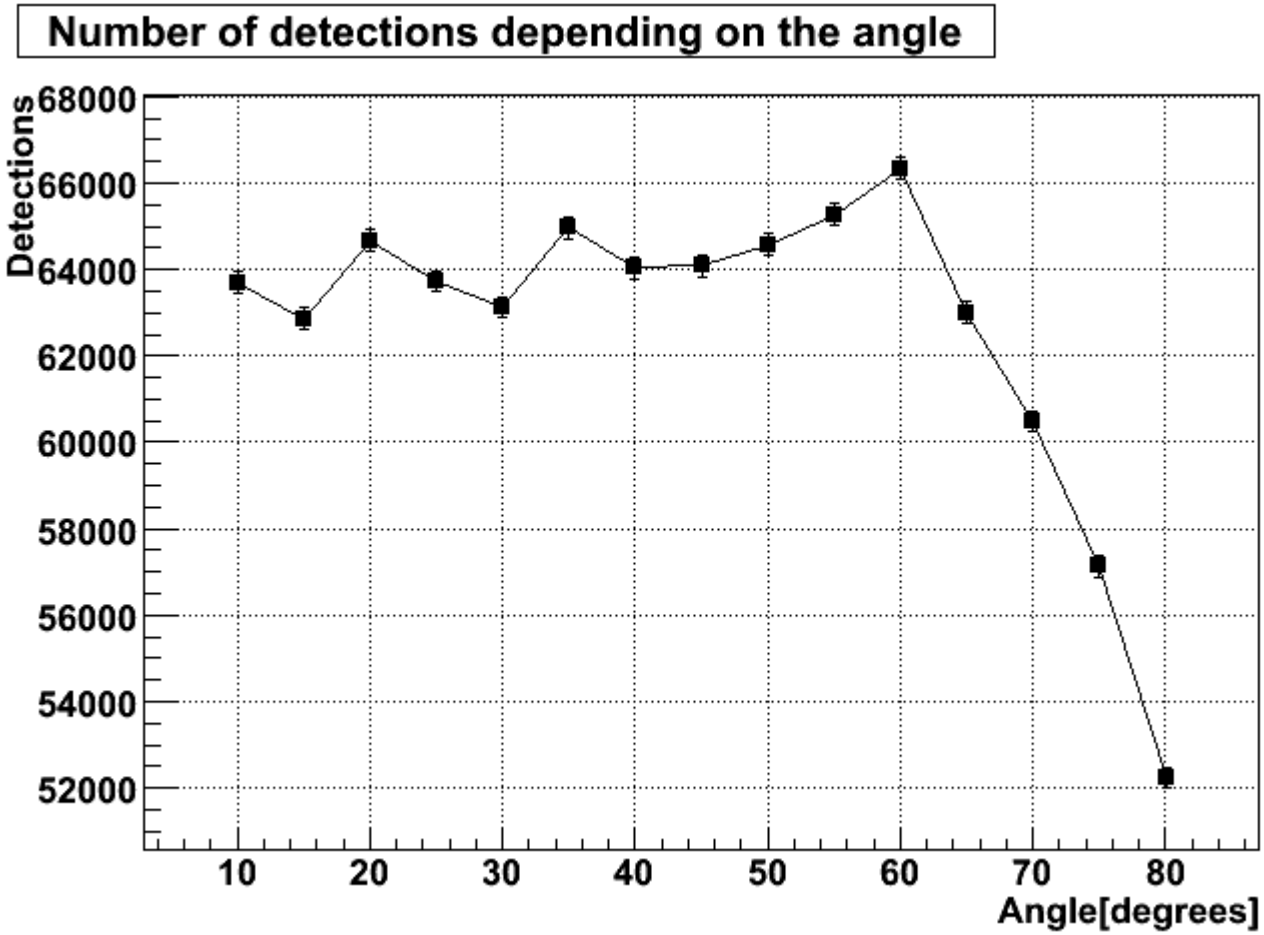


Detections depending on the angle

Check the light collection for the different angles of the protoZero

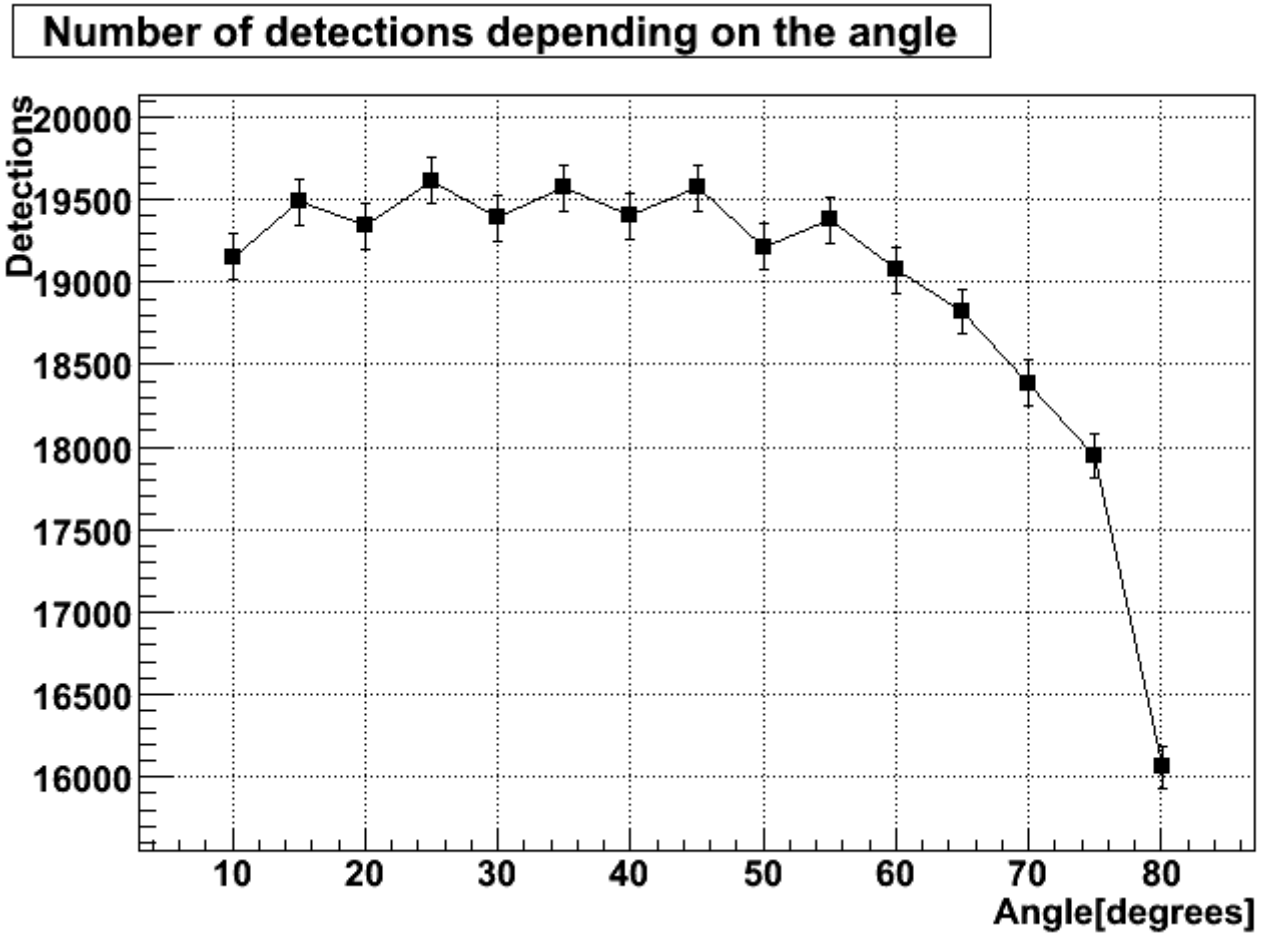


Number of detections depending on the angle



- Number of detections for a polishedbackpainted surface depending on the angle of the crystal
- There is a maximum in 60degrees and then the number of detections fall

Number of detections depending on the angle



- Number of detections for a groundfrontpainted surface depending on the angle of the crystal
- The number of detections fall after 55degrees

Conclusions and goals

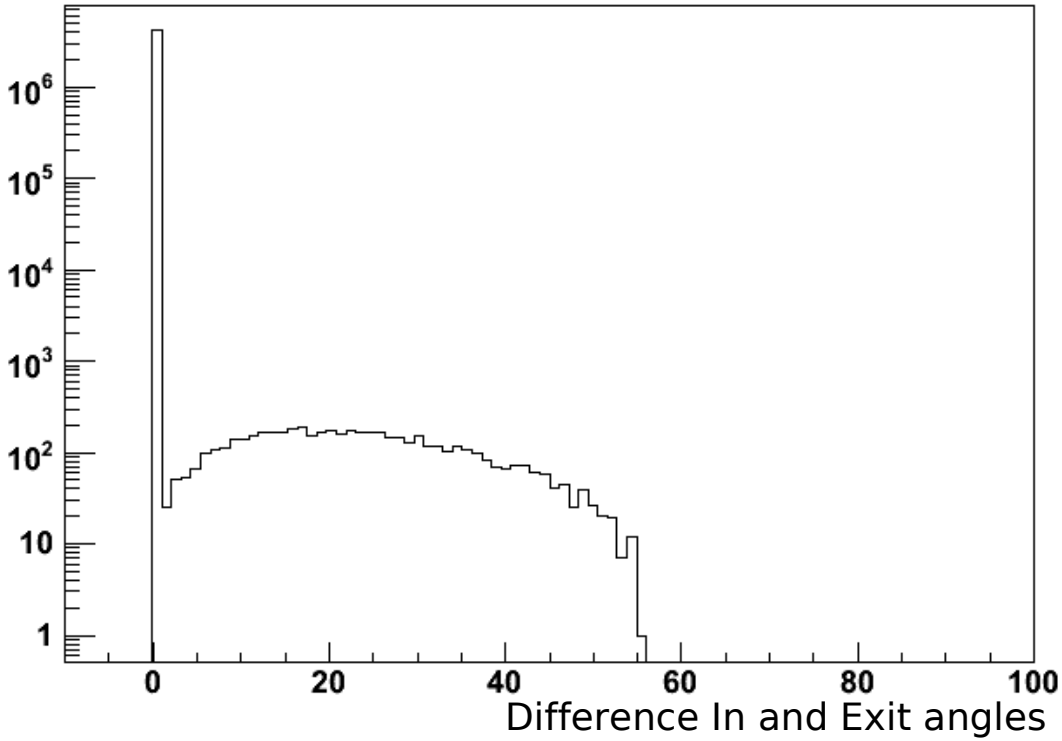
CONCLUSIONS

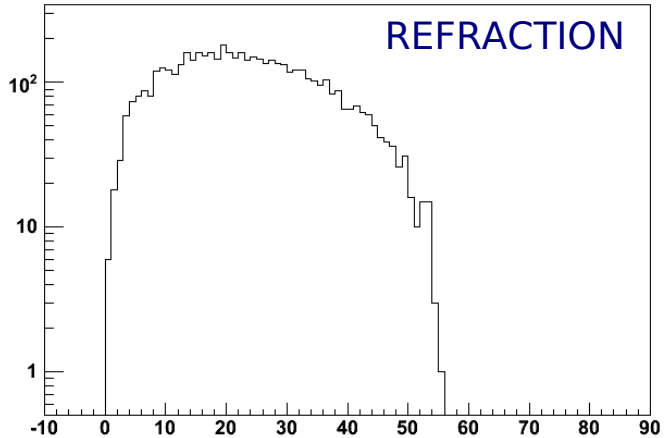
- We are able to understand the optical simulation included on geant4
- We reproduce spectra by collecting optical photons
- The effect of the light-guiding angle in the prototype is being studied

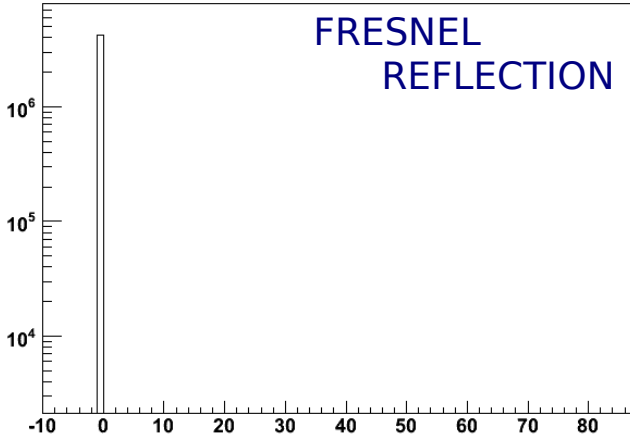
NEXT STEPS

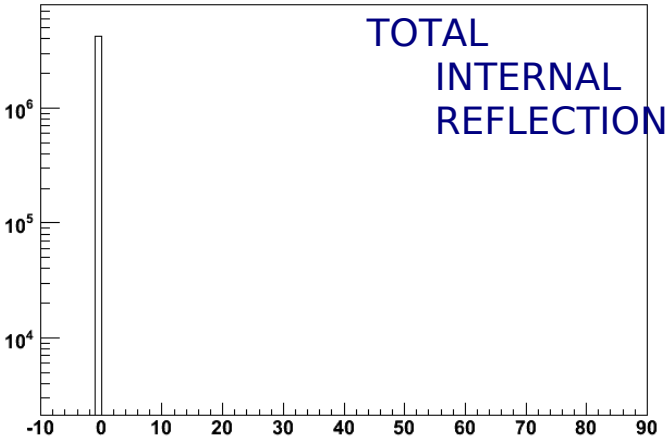
- Understand well the effect of the angle in the number of optical photons detected
- Fix all the optical parameters in geant4 to obtain the best results comparing with the real crystals

First tests results: example polished surface







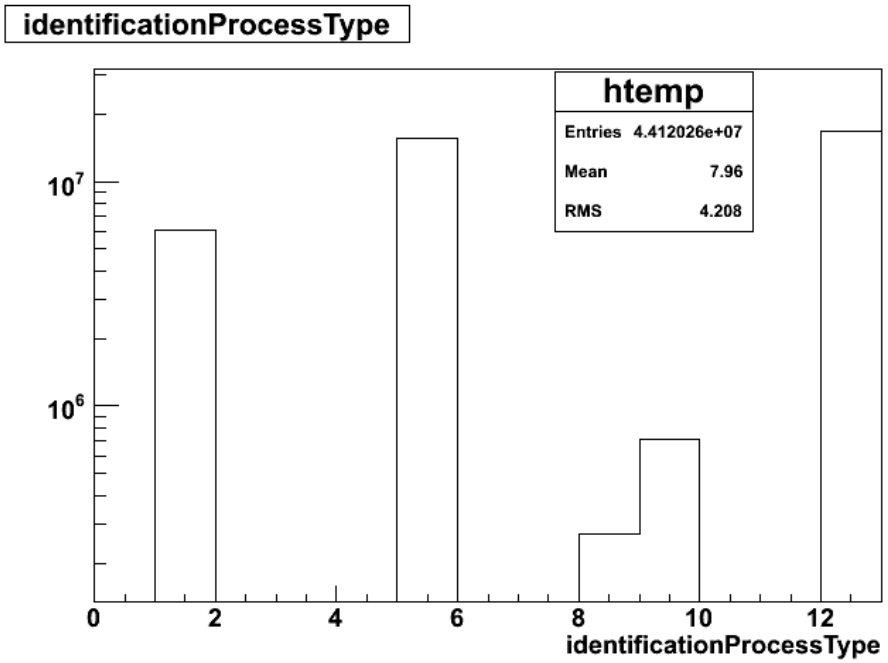


First tests results: comparison

polished

DETECTOR

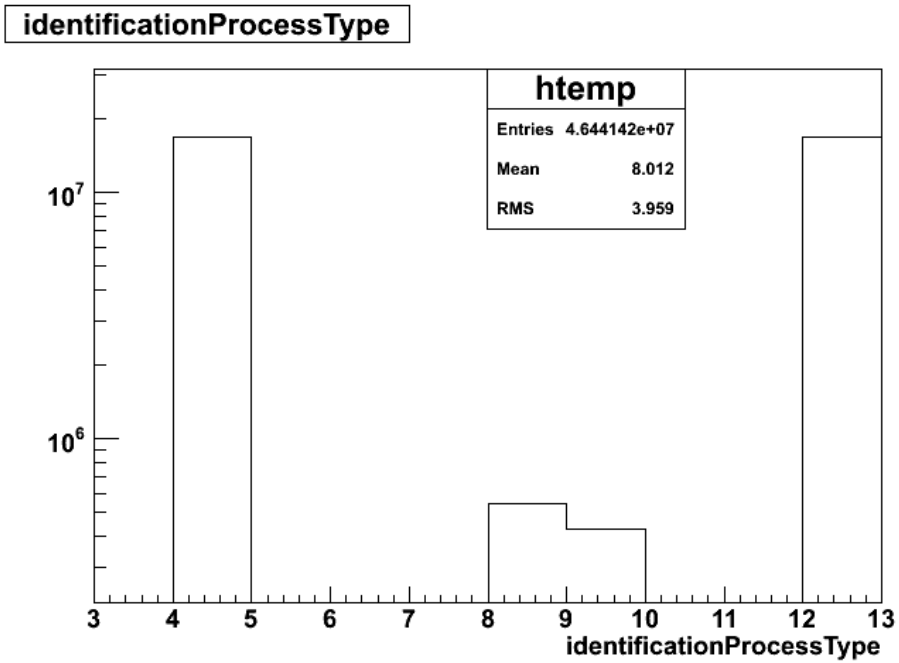
POLISHEDBACKPAINTED



- Refractions: 6026858
- Lobe reflections: 15533273
- Absorptions: 267644
- Detections: 709175

CRYSTAL

GROUNDFRONTPAINTED



- Lambertian reflections: 16777216
- Absorptions: 542579
- Detections: 428401