CERN

Investigating the secondary electron energy spectrum

Eric Wulff

Acknowledgements: Thanks to Giovanni Iadarola for helpful discussions and input.

Outline

Introduction

- A new feature has been implemented[1] in PyECLOUD to ensure that true secondary electrons cannot have higher energies than the impacting electron that gave rise to them.

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Introduction

- A new feature has been implemented[1] in PyECLOUD to ensure that true secondary electrons cannot have higher energies than the impacting electron that gave rise to them.
- We will study the effect of this new feature on simulation results and compare with previous simulations

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Short recap: elastic and true secondary

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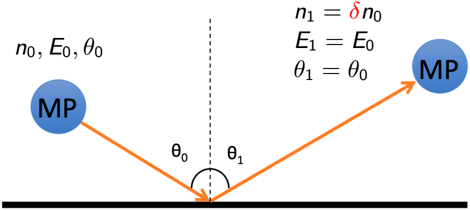
Elastic

Emitted energy equals impacting energy.



Short recap: elastic and true secondary

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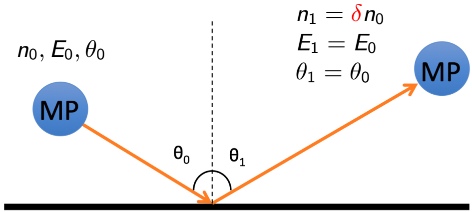
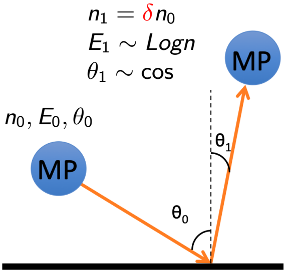

n_0, E_0, θ_0

$n_1 = \delta n_0$
$E_1 = E_0$
$\theta_1 = \theta_0$

True secondary

Emitted energies follow a lognormal distribution.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$E_1 \sim Logn$
$\theta_1 \sim \cos$

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Short recap: elastic and true secondary

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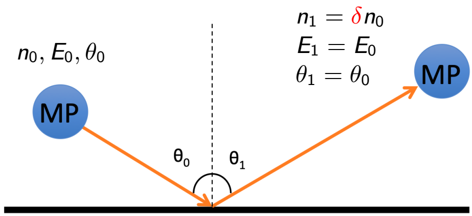
Emitted energy equals impacting energy.

True secondary

Emitted energies follow a lognormal distribution.
We will focus on the true secondaries in these slides.



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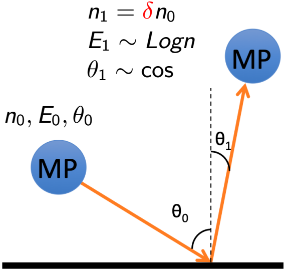

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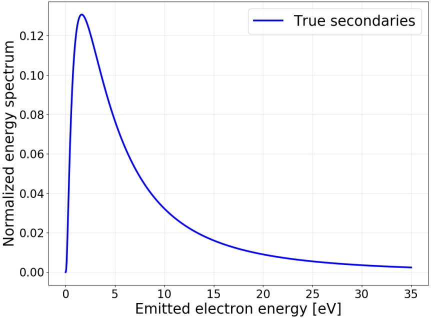
The models

The default model

$$\frac{dn_{true}}{dE} = \frac{1}{E\sigma_{true}\sqrt{2\pi}}\ e^{-\frac{(\ln(E)-\mu_{true})^2}{2\sigma_{true}^2}}$$

- The energy of emitted true secondary MPs are independent of their impacting energy
- The energies are drawn from a lognormal distribution cut at 35 eV



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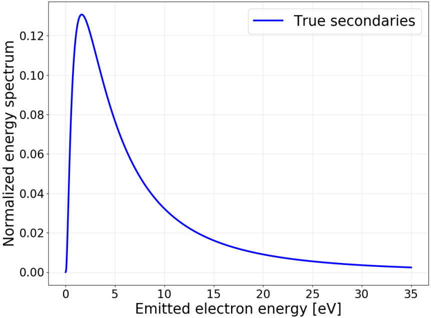
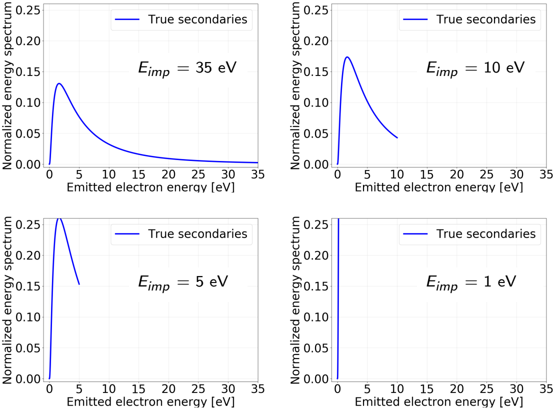


Problem: An impacting MP with energy $E_{imp} < 35$ eV can give rise to secondaries with $E > E_{imp}$

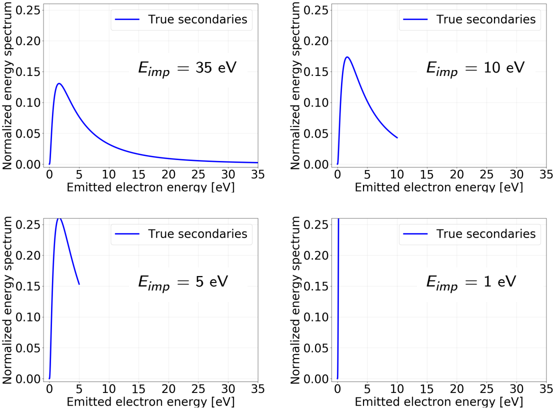
The new model

- Emission energies are still drawn from the same lognormal distribution
- The distribution is now cut at the impacting energy of the MP
- This ensures that we do not emit MPs with higher energies than the impacting MP



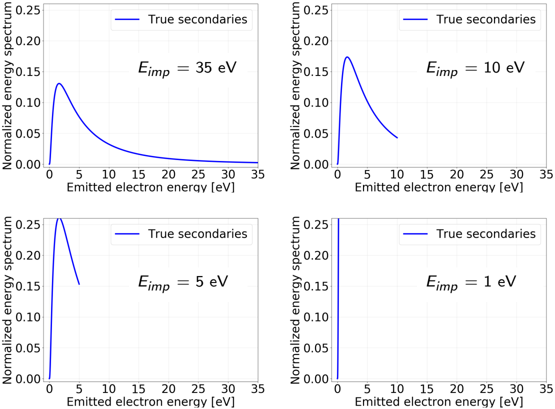
The new model

- Note that energy conservation can still be broken in single events due to rescaling and splitting of MPs.
- This happens only very rarely and averaged over many events energy is still conserved.



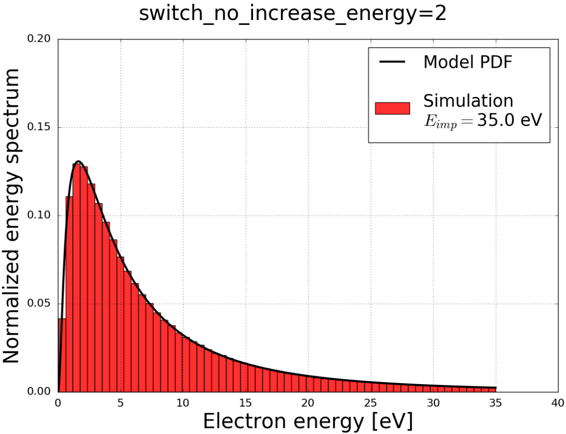
The new model

- Also note that PyECLOUD uses a variable, `E_th`, which specifies the maximum energy a true secondary MP is allowed to be generated with. This variable is still used in the new model.
- Typically, including in the following, `E_th` is set to 35 eV.



The new model

- The energy distribution of secondary electrons from simulation is shown in the histogram to the right
- The black curve is the usual lognormal distribution used in PyECLOUD cut at the impacting energy and then renormalised



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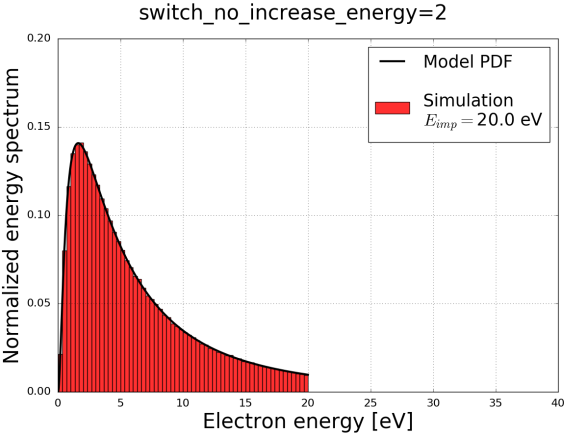

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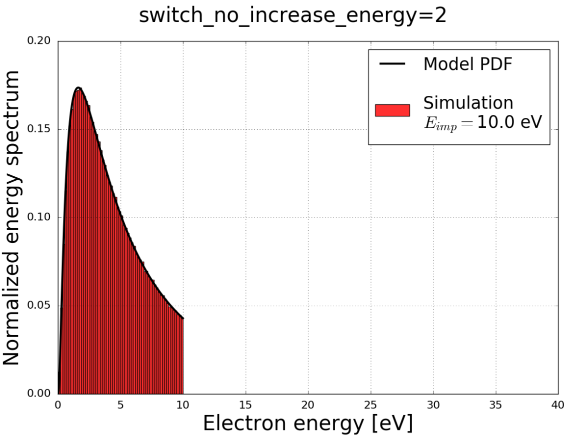

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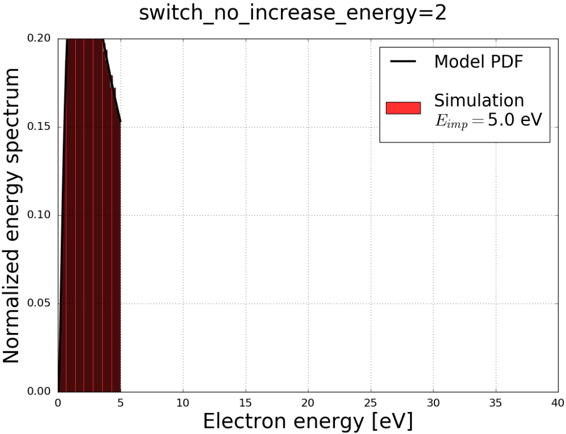
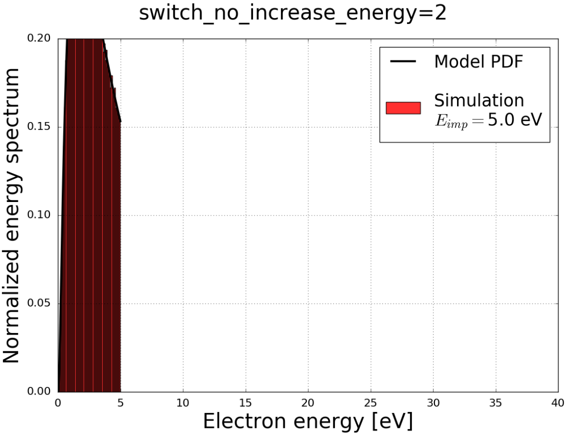


The new model

- Let's now zoom in to get a better look



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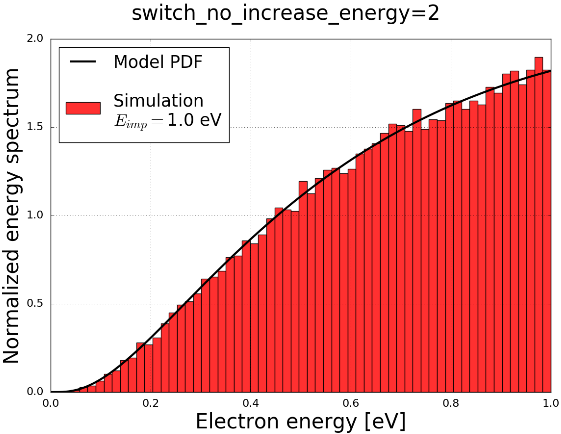

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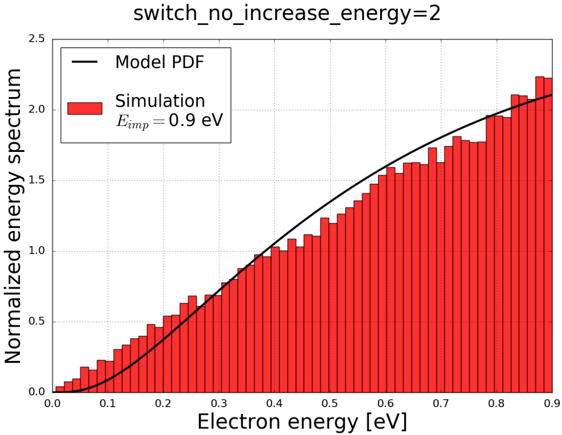
- To reduce computational cost, energies are generated from a linear distribution when $E_{imp} < 1$ eV



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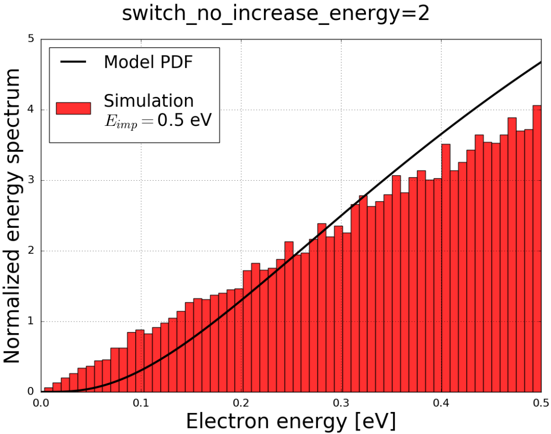


Comparison of simulation output

Simulation setup

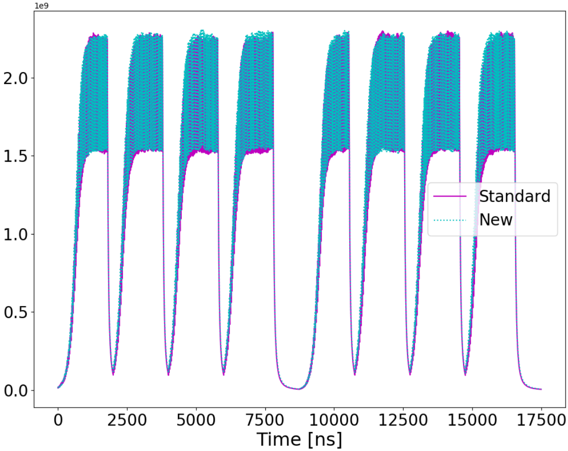
Simulations using `switch_no_increase_energy=0` and 2 were carried out with the following parameters.

- 450 GeV beam energy
- $2 \cdot 10^{11}$ protons/bunch
- SEY parameter $\delta_{max} = 2.0$
- Circular drift tube with 44 mm diameter

Electron cloud build-up

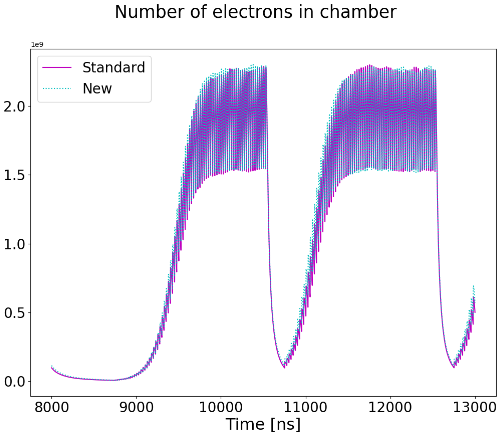
Electron cloud build-up

Practically no difference can be seen between the two models.



Electron cloud build-up

Zooming in on the second train, the results still look very similar.



Heat load

How does the produced heat load differ between the two models?

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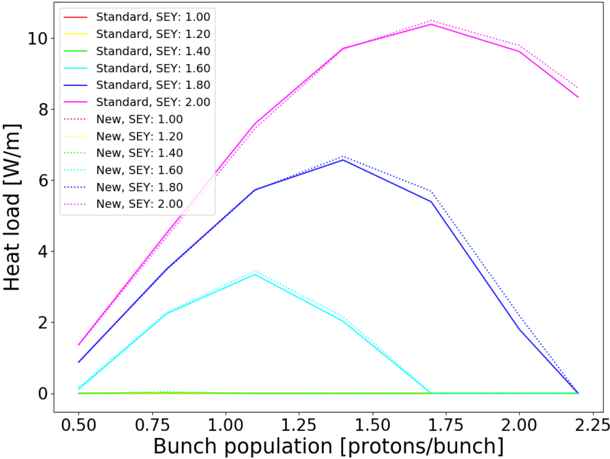
We see no or very small differences.



Electron current

Let's also have a look at the current impacting on the beam screen.

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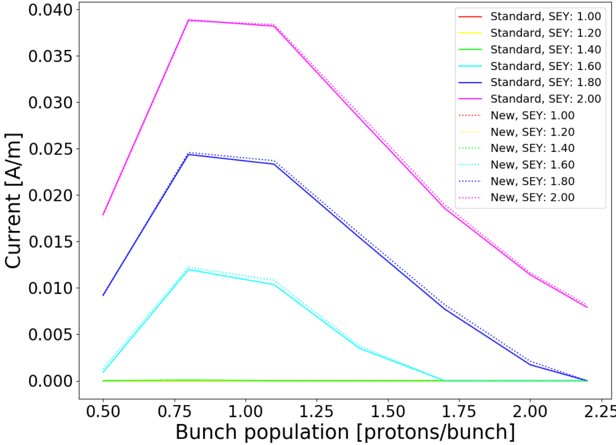
Again, no or very small differences.



Summary

- An option to generate true secondary electron energies in a new way has been implemented in PyECLOUD.
- This new option ensures that an MP cannot be emitted with higher energy than it impacted with.
- Switching the option on did not result in any significant changes in e-cloud build-up, heat load or electron current for the simulations performed in this study.

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