



Workshop RENAFAE:
Projetos para o Futuro da Física de Altas Energia no Brasil
12 à 14 de Julho de 2021



Instituto de Ciência e Tecnologia
Universidade Federal de Alfenas | Campus Poços de Caldas



ArapucaSim: Desenvolvimento e Validação da Simulação em Geant4 da X-ARAPUCA

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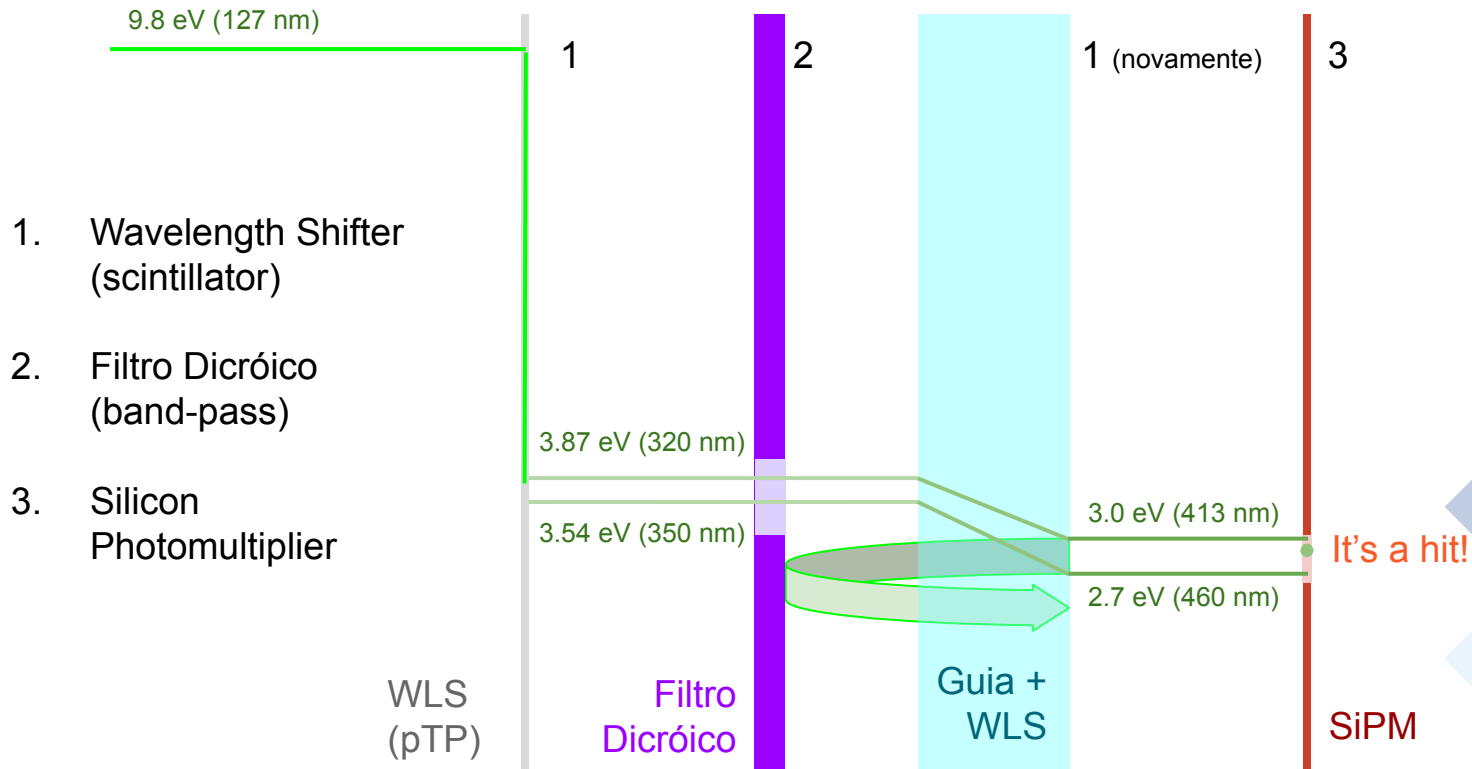
anibal.bezerra@unifal-mg.edu.br



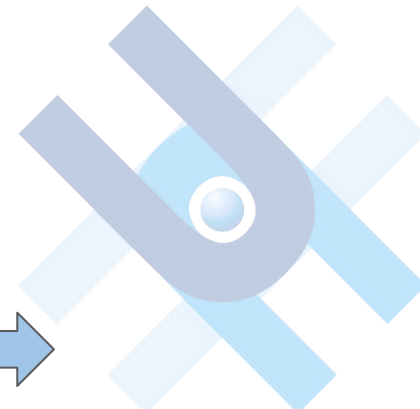
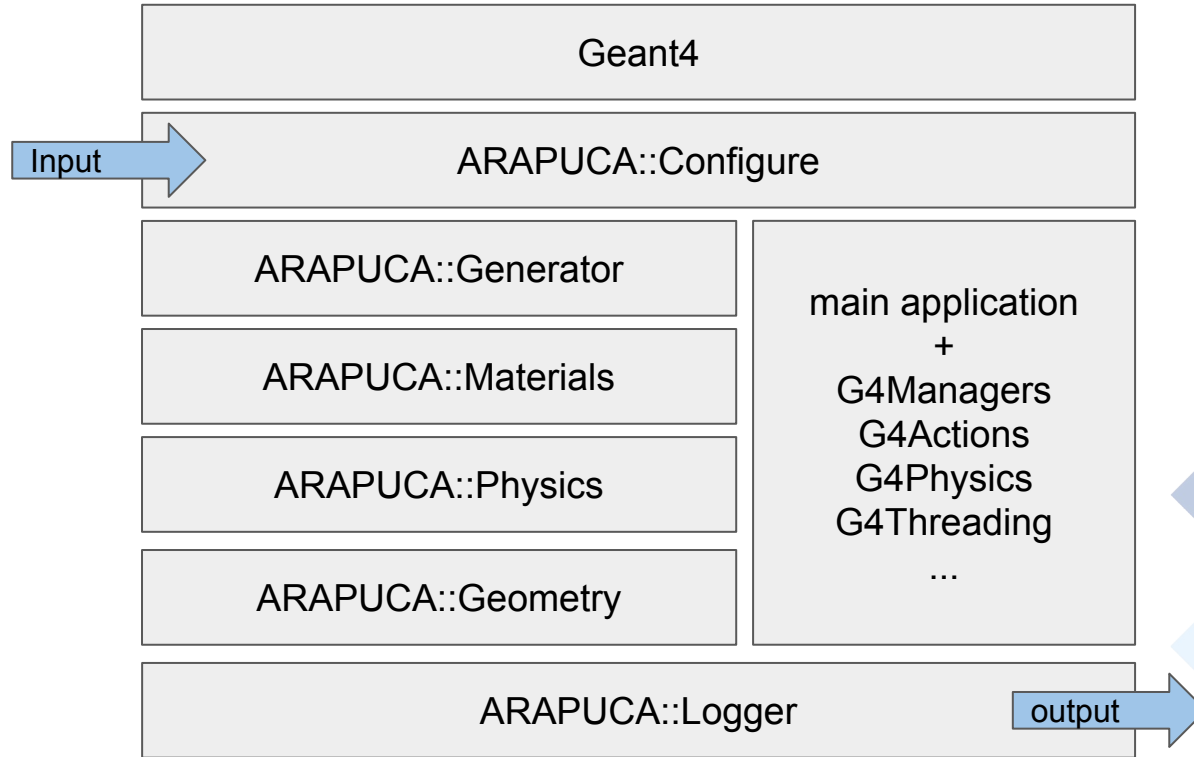
DEEP UNDERGROUND
NEUTRINO EXPERIMENT

12 de Julho 2021

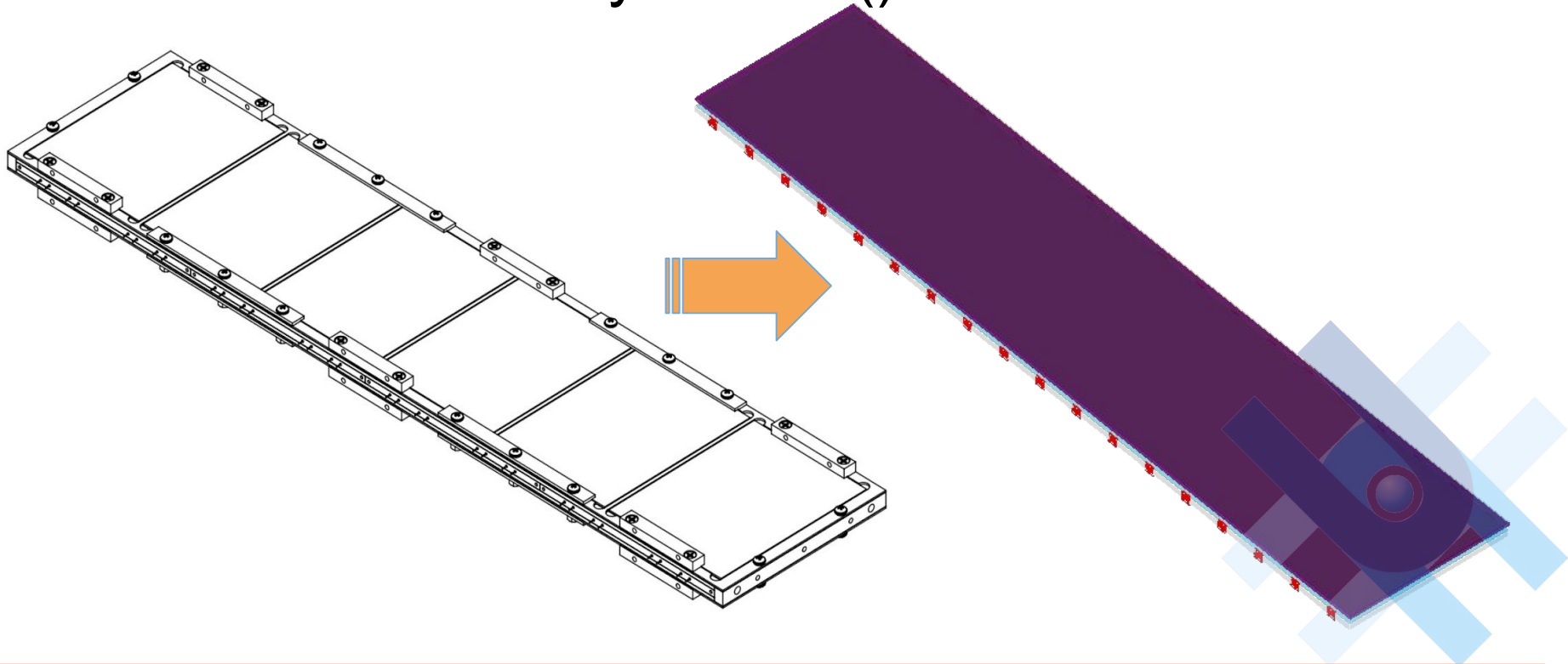
X-ARAPUCA Model



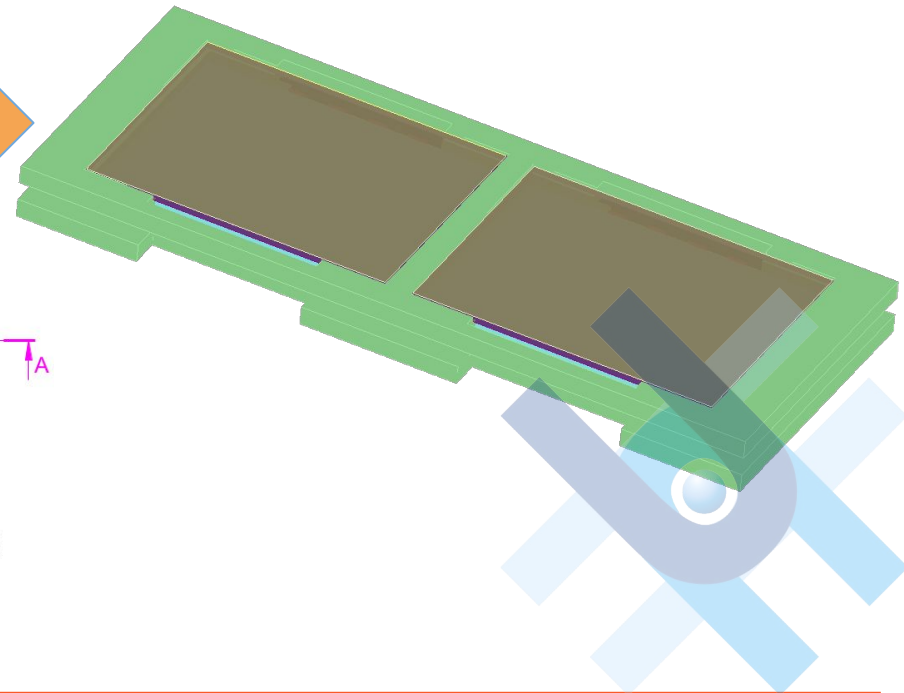
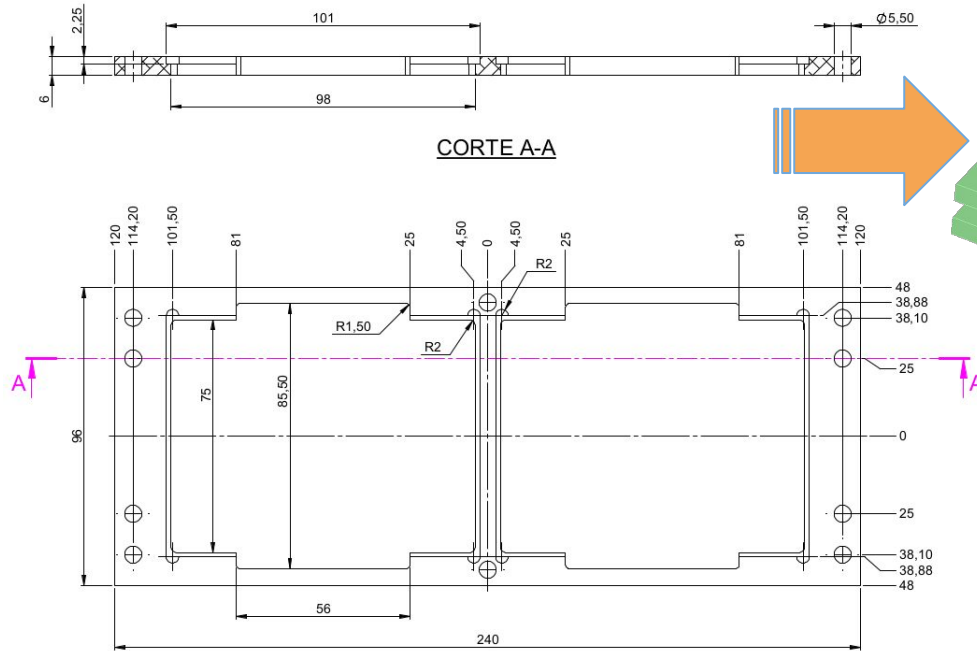
Software Architecture



ARAPUCA::Geometry::DUNE()



ARAPUCA::Geometry::SBND()

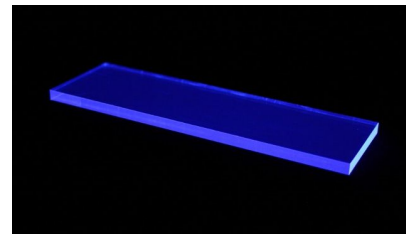


ARAPUCA::Materials

- The objective is to build the logical materials that makes up the ARAPUCA and validate them individually.
- Ana Amélia Machado and Ettore Segreto act as liaison between the collaborators and the companies (Opto, Eljen, Glass to Power).
- Started this work in Oct 2020, planning to have it conclude by Sept 2021 (presenting results at LIDINE21).

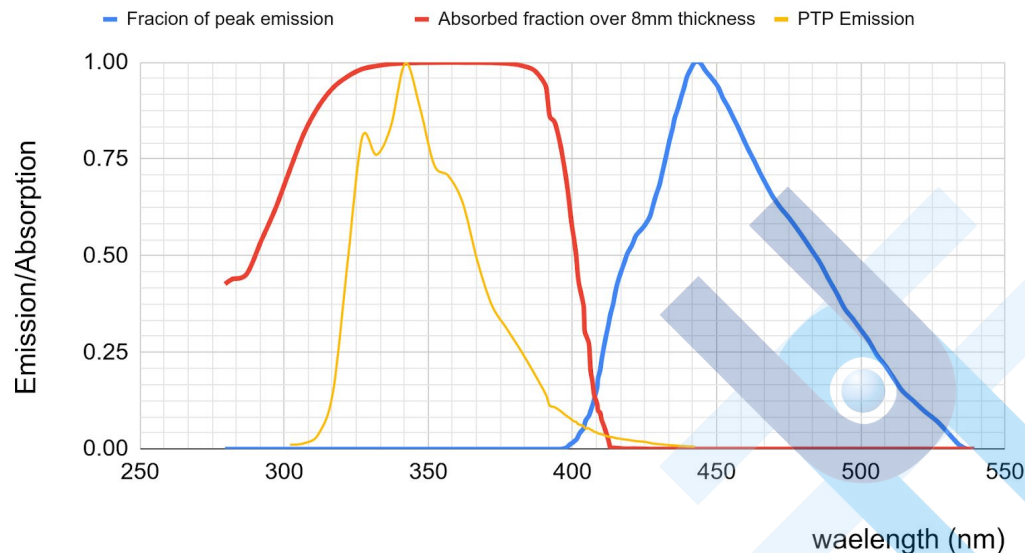


ARAPUCA::Materials::EJ286()

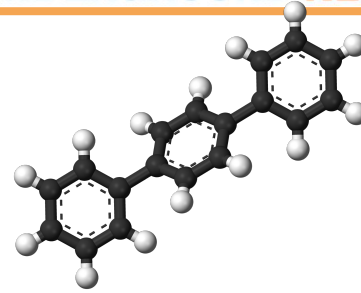


- Light guide with commercial WLS.
- Simulation needed an information that is an actual trading secret.
- With authorization from company, we used the **ArapucaSim** to simulate their public data in order to find the secret value.
- This process raised a question about how accurate is Geant4's scintillation simulation (spoiler alert: it is biased).

EJ286



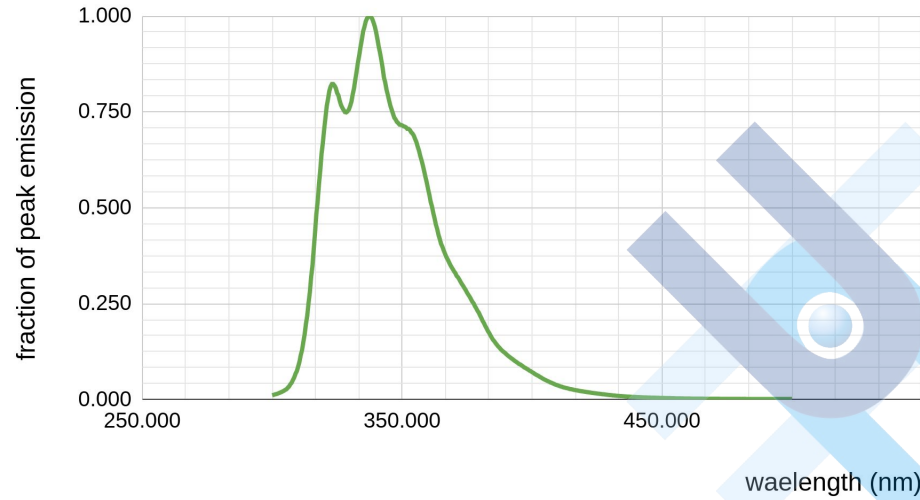
ARAPUCA::Materials::pTP()



p-Terphenyl

- p-Terphenyl is used to shift LAr VUV light to UV/Violet light
- Using G4WLS, we observed a spectral distortion in the MC.
- This is where **ARAPUCA::Physics** as born

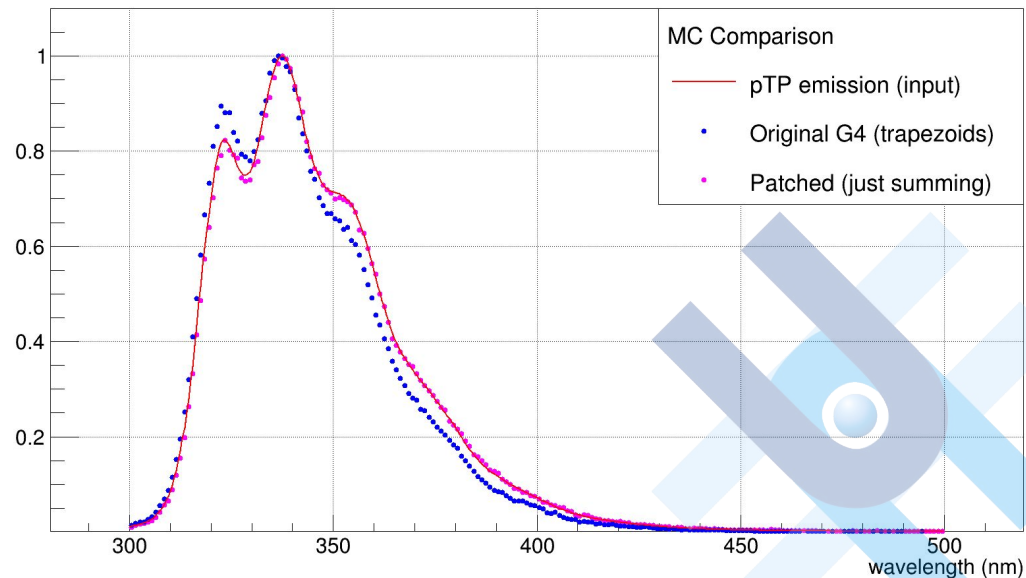
pTerphenyl (PTP) emission



ARAPUCA::Physics::Scintillation

- The G4WLS class have a couple of issues that may add up to 10~15% systematic deviation from the desired spectrum.
- Developed **ARAPUCA::Physics::Scintillation** which not only correct this bias but is also a bit faster.
- I hope this correction becomes public in the near future. I just recently communicated both the problem and the correction to the Geant4 collaboration.

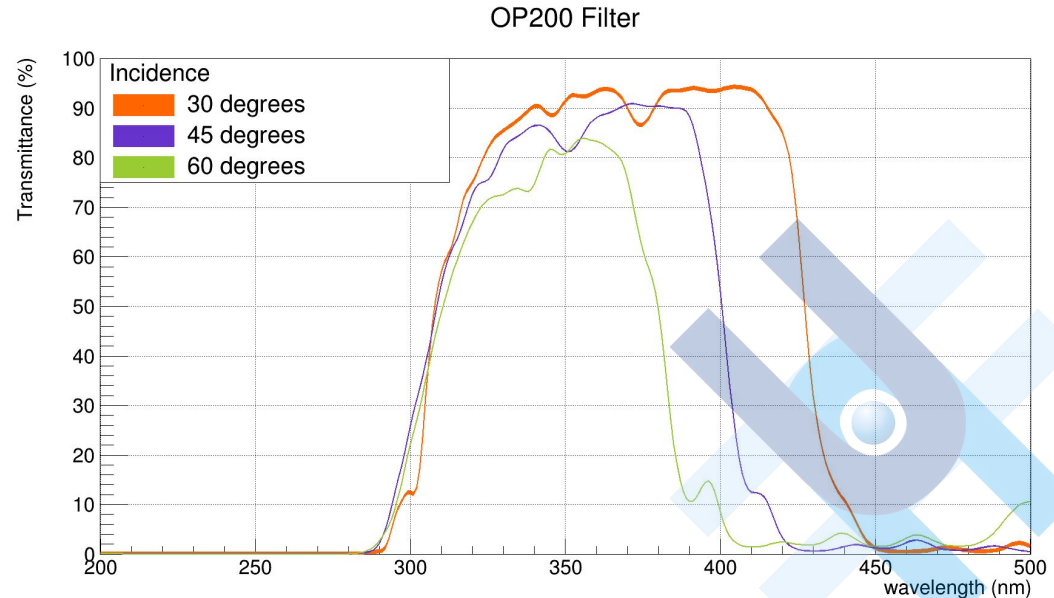
Algorithm Comparisson



ARAPUCA::Physics::DichroicFilter

- Again, the Dichroic filter simulation given by Geant4 has a few technical issues.
- Developed **ARAPUCA::Physics::DichroicFilter** which is in the process of being validated.
- This class and others will also be made available publicly at:

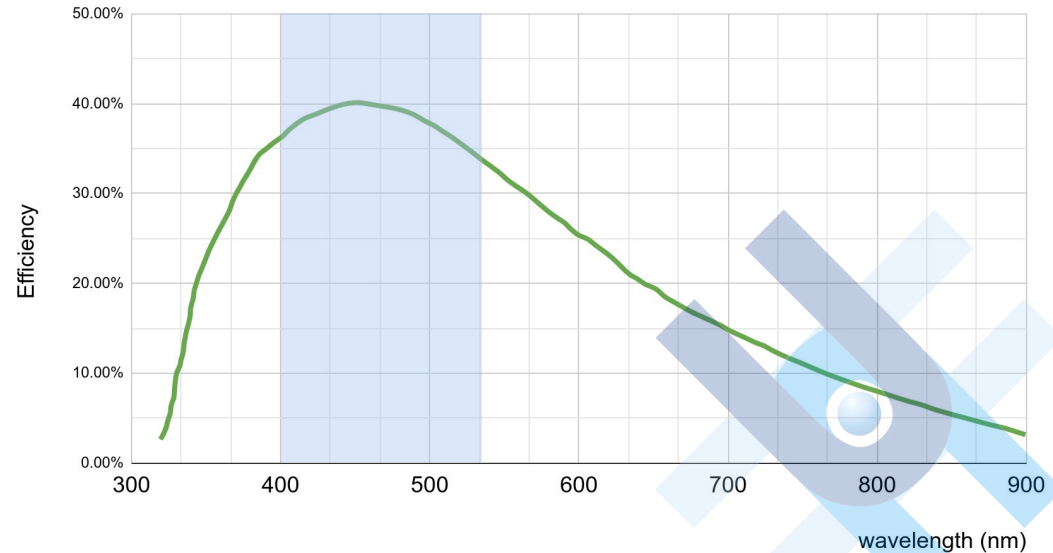
<https://github.com/gustavogx>



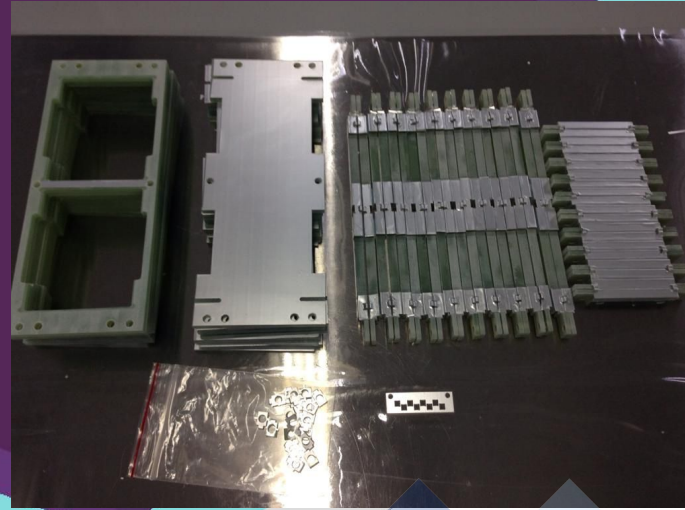
ARAPUCA::Materials::Hamamatsu()

- The last active components are the SiPM's.
- It uses standard G4 classes, with the complete material description managed by the **ARAPUCA::Materials** library.
- Hits are generated by the SiPM's and handled by the **ARAPUCA::Logger**.

Hamamatsu S13360



ARAPUCA::Materials::Vikuiti()



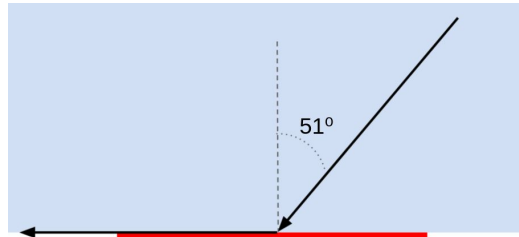
- Very efficient lambertian reflector provided by 3M.
- Vikuiti mask around WLS bar.
- Prevents photon absorption by internal walls.

What does the simulation tells us?

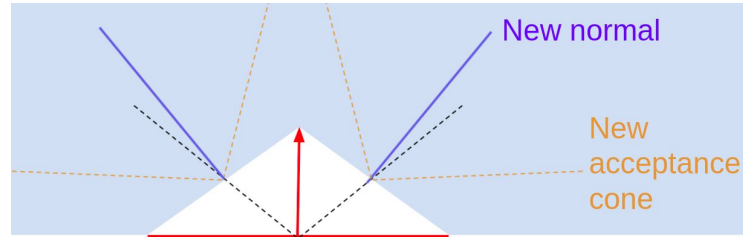
- Despite being in development, **ArapucaSim** has already been used for a few studies:
 - Effects of WLS bar geometry (un-trapping).
 - Effects of thermal contraction.
 - Optimization of EJ286 chemical concentration.
 - Comparison between different dichroic filters.
 - Determination of global efficiency to LAr VUV light.



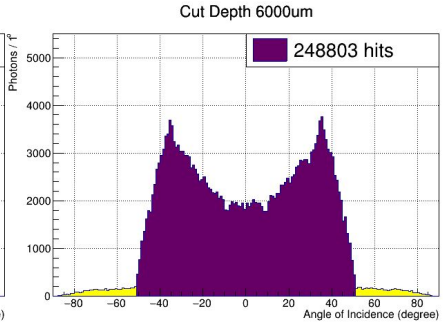
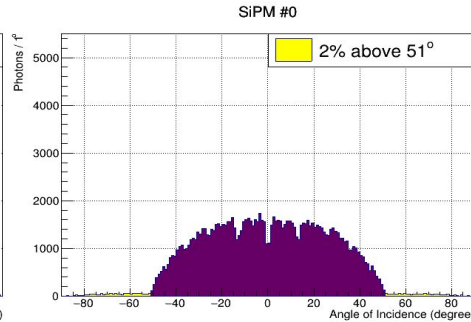
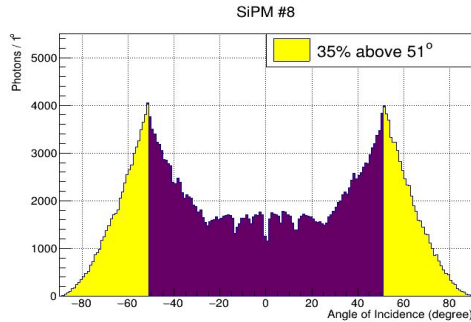
Untrapping



SiPM



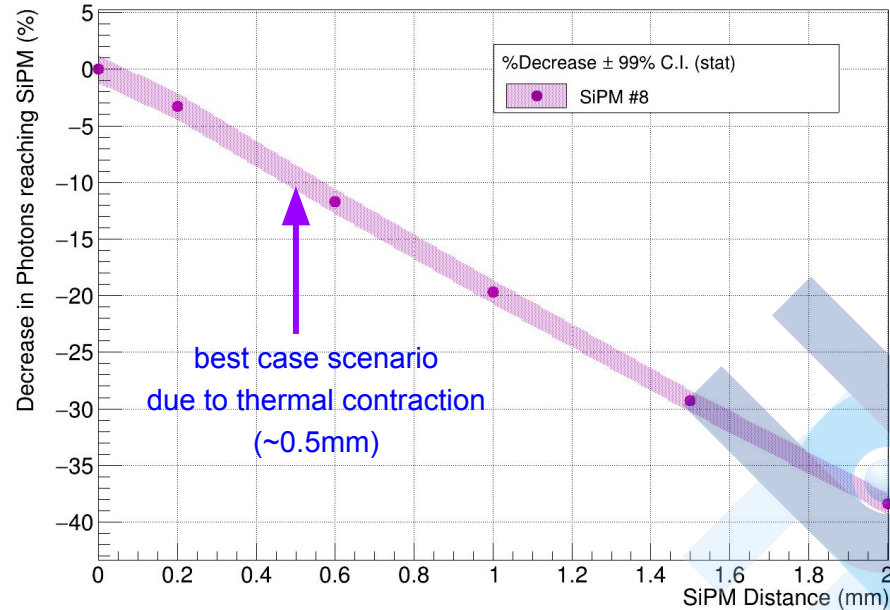
varying cut depth



6mm deep cut
2x untrapped
photons

Thermal expansion study

- Thermal contraction from room temperature to -90°C may impact the photon collection.

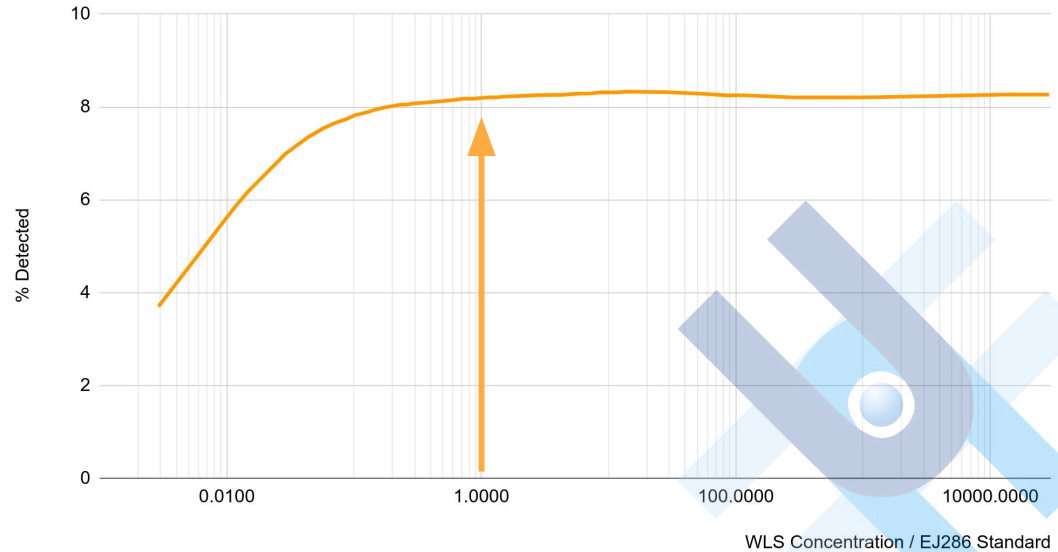


EJ286 concentration Study

- Simulation showed the the off-the-shelf EJ286 would already be at its optimal concentration.
- This result was just recently confirmed by Lab. Leptons in Campinas.

Fraction of IN-GOING* pTP photons detected

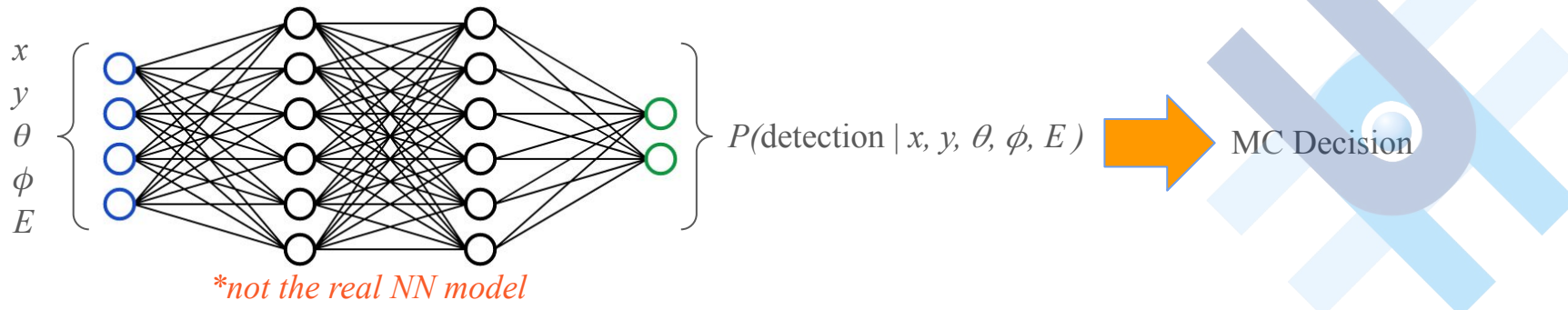
10M photons per point



What is in the future for ArapucaSim?

- The plan is to map the efficiency as a function of:
 - Position over the window (x,y)
 - Direction of incidence (θ,ϕ)
 - Photon energy (E)

and use a **neural network** to interpolate the map, giving us the probability of detecting a given photon.



In summary

- ArapucaSim is a full simulation of the X-ARAPUCA family of detectors, based upon Geant4 but with customized optical classes and materials manager.
- Its input/output system allows it simulation to runs silently, becoming a link in any simulation chain that other groups would envision.
- The current prediction for the ARAPUCA efficiency is just above 3%, which is already consistent with what we see in the lab, without the need for any fine tuning.

 www.youtube.com/c/GustavoValdivieso

