Gaussian Laser Source Implementation in Chroma for Environmental Test Stand

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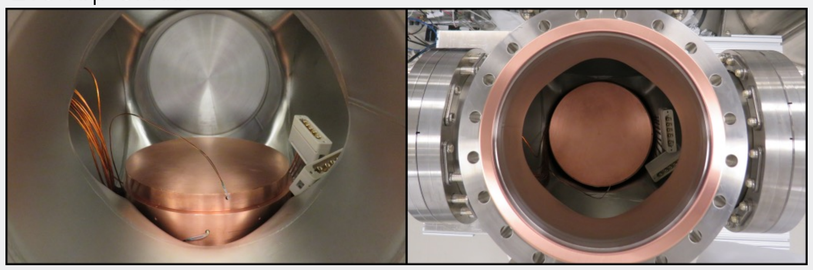
Intro

- nEXO is proposed 5 tonne Liquid Xenon detector enriched with 90% Xe^{136} to search for neutrinoless beta decay [1]
- The detector will be lined with staves of 10x10cm^2 integrated Silicon Photomultiplier (SiPM) tiles to detect 175 nm scintillation light from excited Xe [1]
- SiPMs are solid state detectors that provide fast response time with single-photon sensitivity [2]
- The Environmental Test Stand (ETS) is being developed to perform precision testing on the SiPM tiles in a controlled environment [3]
- SiPMs have non-trivial optical surfaces which makes it hard to predict photon transport
- Chroma is a GPU-based optics simulation software that will be used to better understand photon scattering in the ETS setup

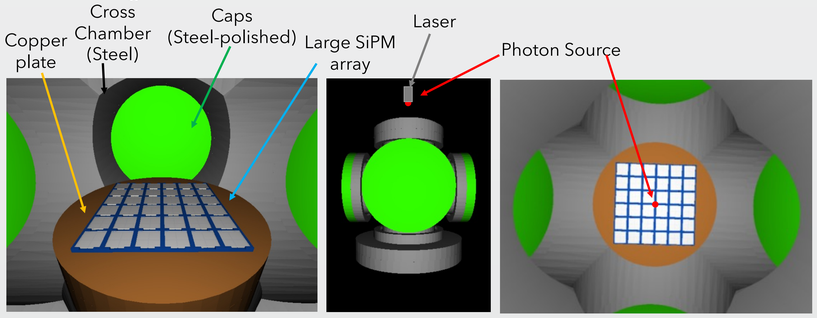
Experimental Setup

ETS Top Cross:



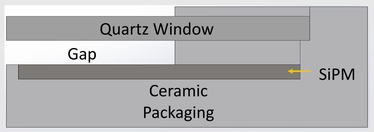
** Pictures taken by Lucas Darroch*

Renderings in Chroma:



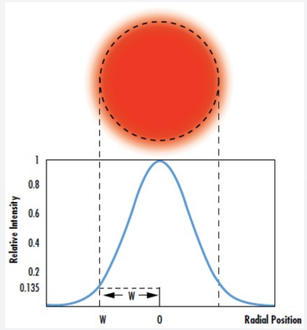
(Inside Side View) *(Outside Side View)* *(Inside Top View)*

- The SiPMs used are the Hamamatsu VUV4 SiPMs
- Cross-section of single SiPM *(right)*



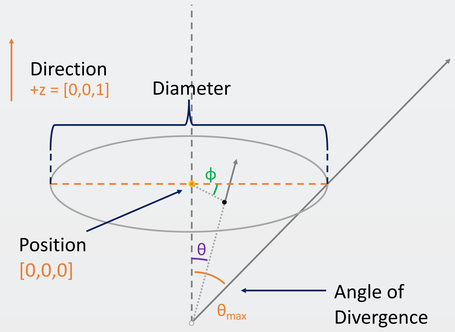
Gaussian Laser

- A Gaussian Laser will be used in the ETS setup
- Max intensity at the center and decreases exponentially with radius
- Beam size (2W in diagram [4]) corresponds to where the intensity drops by factor of $1/e^2$



Implementation in Chroma

- The laser is always initially located at the origin (0,0,0) then rotated and shifted after defining the direction vectors
- Randomly generate points on a disk (given position and diameter) and defined in cylindrical coordinates



Note: Parameters in orange can be varied

- Polarization of photons taken to be perpendicular to direction of propagation
- Rotations using rotation matrix in 3D
  - Note: When rotating, one axis is kept constant and thus a fraction of the vectors will be pointing in wrong direction. To account for this, the vectors are reflected in y-axis first

Next Steps

- An issue was found with how Chroma deals with incident photons and this issue is being fixed
- The optical properties for the test simulations are approximations and data found online, better data can be measured and fed into the SiPM model in Chroma and compared to ETS measurements

Simulation Results

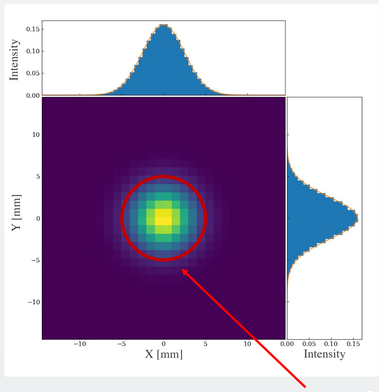
Test Parameters

Runs	**10**	Position	**(0,0,250)***
Photon Sources	**100**	Diameter	**10 mm**
Photons/Source	**10000**	Direction	**(0,0,-1)**
Wavelength	**193 nm**	Angle of Divergence	**0.000001 rad**

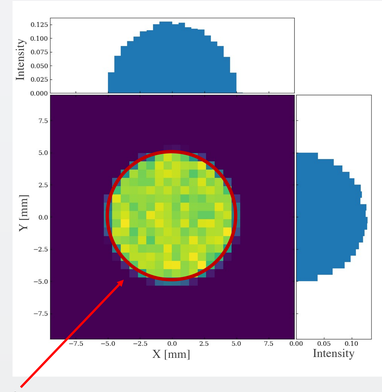
* The laser is centered with the ETS top cross and is slightly above the top CaF2 window

Comparison of Gaussian Laser and Pencil Beam Profiles

Gaussian Laser



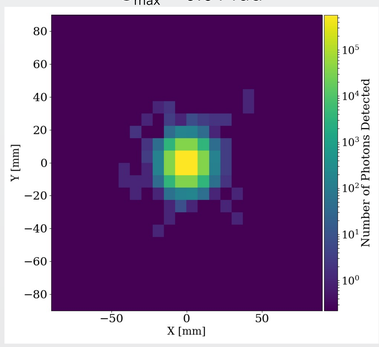
Pencil Beam



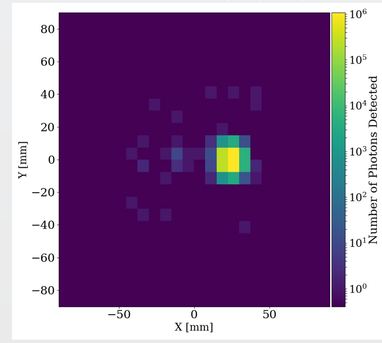
Laser Outlet

Changing Parameters of the Laser

Increased Angle of Divergence
Θ_{max} = 0.01 rad



Angled the Laser to Point in Direction d = (0.1,0,-1)



References

1. nEXO Collaboration, “nEXO pre-Conceptual Design Report”, Oct 2018.
2. L. Baudis, M. Galloway, A. Kish, C. Marentini, andJ. Wulf, “Characterization of Silicon Photomultipliers forLiquid Xenon Detectors,” Oct 2018.
3. Lucas Darroch, “Environment Test Stand”
4. https://www.edmundoptics.com/knowledge-center/application-notes/lasers/gaussian-beam-propagation/