Opticks Integration with CRAB Prototype

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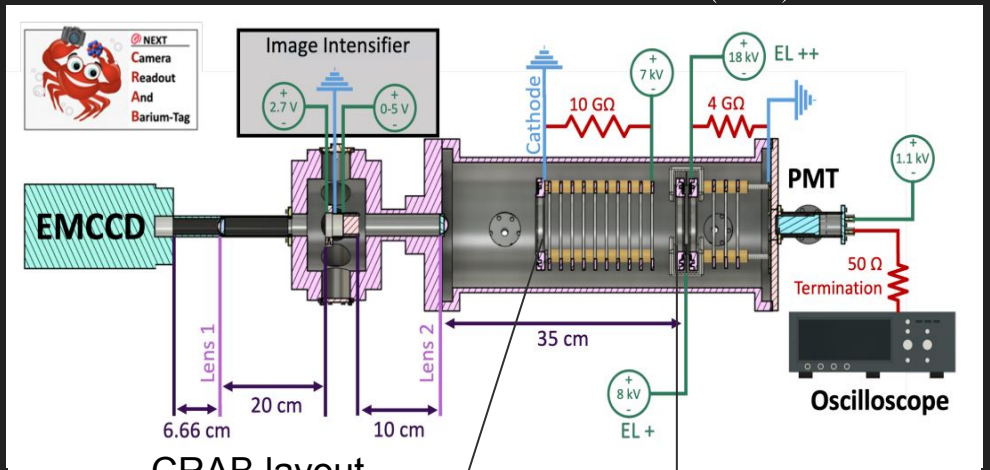
Outline

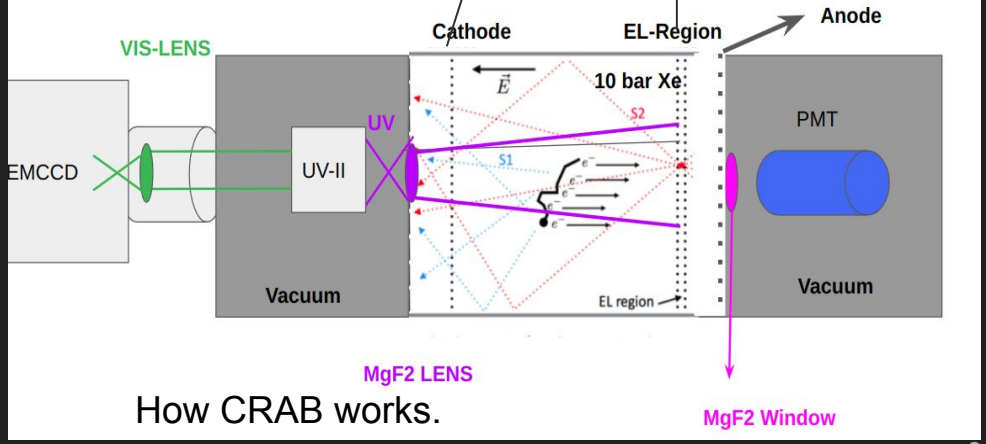
- CRAB0 detector
- Opticks
- Opticks and GEANT4 Comparison.
  - Visual,Performance and Hits
- Conclusion

- Camera Readout and Barium Tagging (CRAB)
  - Motivated by
    - The improving topological identification of charged particles in high-pressure xenon TPCs like NEXT.
    - Reducing Background with Barium Tagging.
- Optical TPC
  - Active Region
    - Length: 19.61 cm
    - Field Ring Diameter: 8.6 cm
    - Mesh diameter: 7.2 cm
    - EL-Gap: 7 mm
- 2 Viewports
  - MgF2 Lens (UV Sensitive) (LENS2)
    - VUV Image Intensifier
    - Visible Lens (LENS 1)
    - EMCCD
  - MgF2 Window
    - UV Sensitive PMT
- Constructed at UTA.

$$Xe^{136} -> Ba^{+2} + 2e + 2\nu(0\nu)$$

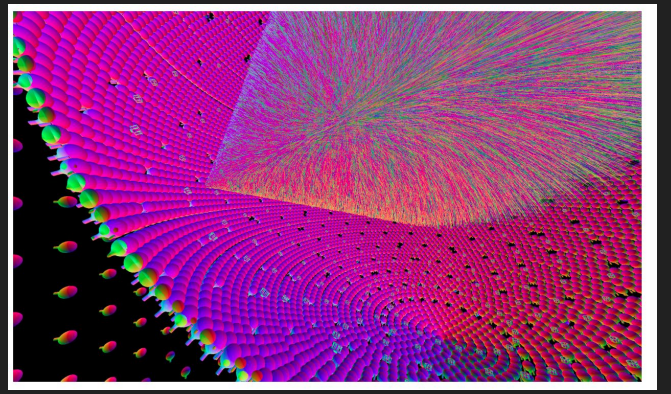


CRAB layout.



How CRAB works.

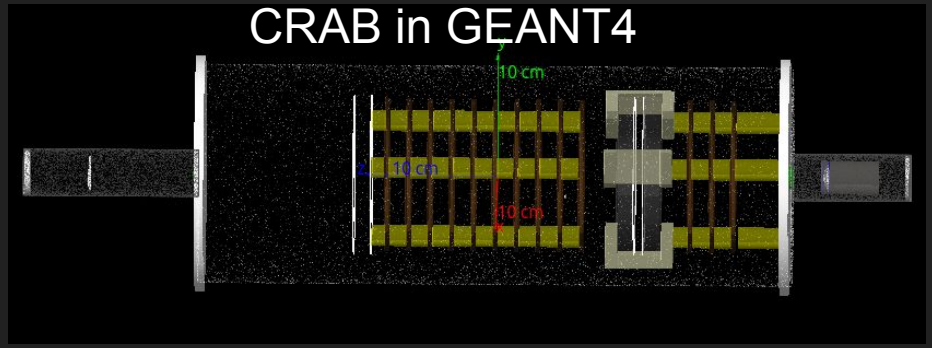
About Opticks

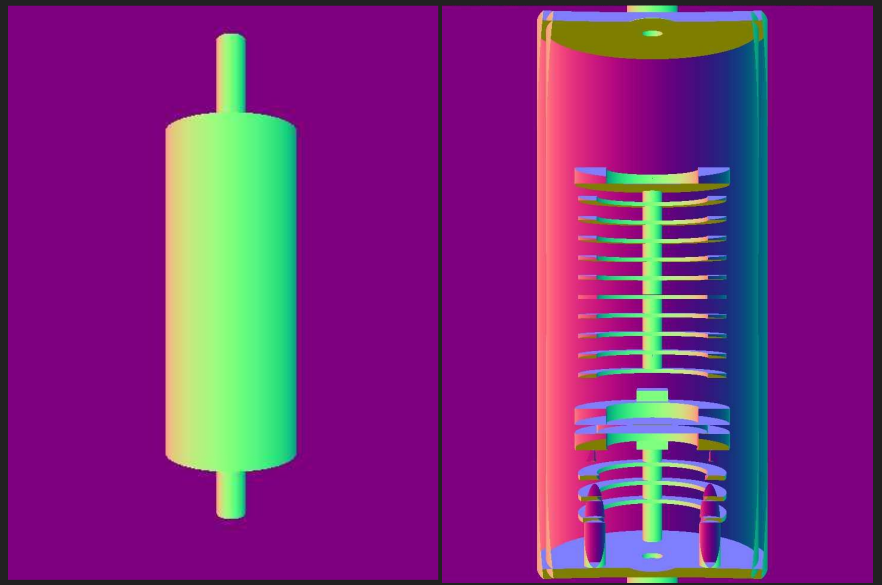


- GPU based photon simulation tool
  - Ray Tracing
- Actively developed by Simon Blyth (JUNO)
  - https://bitbucket.org/simoncblyth/opticks
  - https://indico.jlab.org/event/459/contributions/11811/
- Works with NVIDIA GPUs that support CUDA (11.5 tested) and NVIDIA Optix (7.5 tested)
- 1000x photon simulation speeds over GEANT4 (11.1.1 tested)
- Hybrid Workflow
  - GEANT4 geometry is translated to NVIDIA Optix 7.5
    - CSG Geometry
      - Surfaces + Optical Material Properties are imported from GEANT4
  - GEANT4 simulates primary particles
  - Photons simulated by Opticks as rays
    - Scintillation and Cherenkov processes
    - Optical physics processes are implemented in CUDA
      - scattering, absorption, scintillator reemission and boundary processes.

Visual Comparison

- We have integrated Opticks into our GEANT4 simulation package.
- Visual comparison of GEANT4 geometry to Opticks looks identical.
- Some of the G4 Solids are not compatible with opticks yet they are most likely be included in the near future.
  - G4ExctrudedSolid
  - G4TessellatedSolid

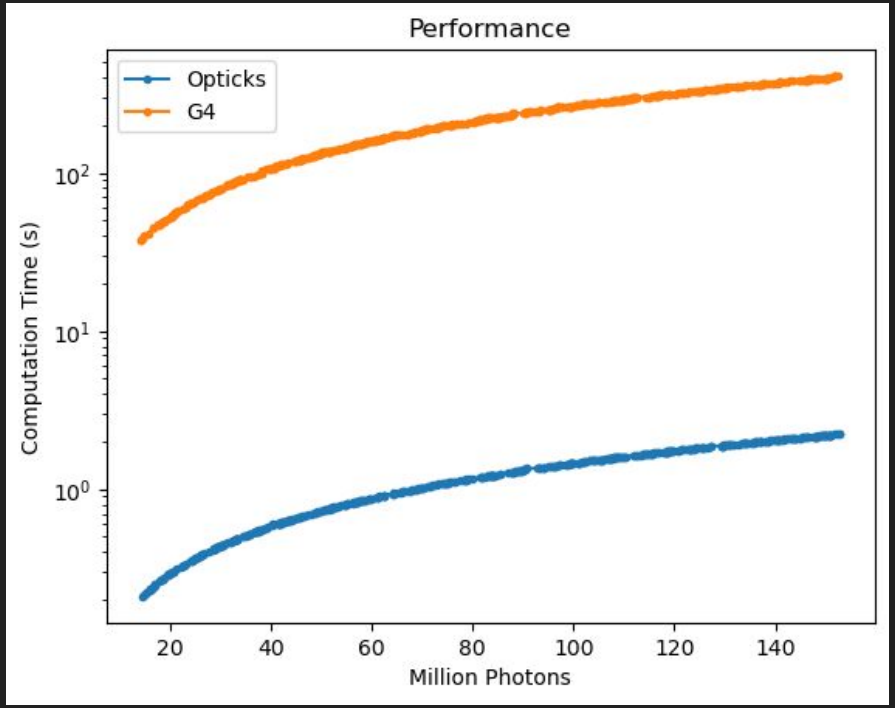




CRAB in Opticks

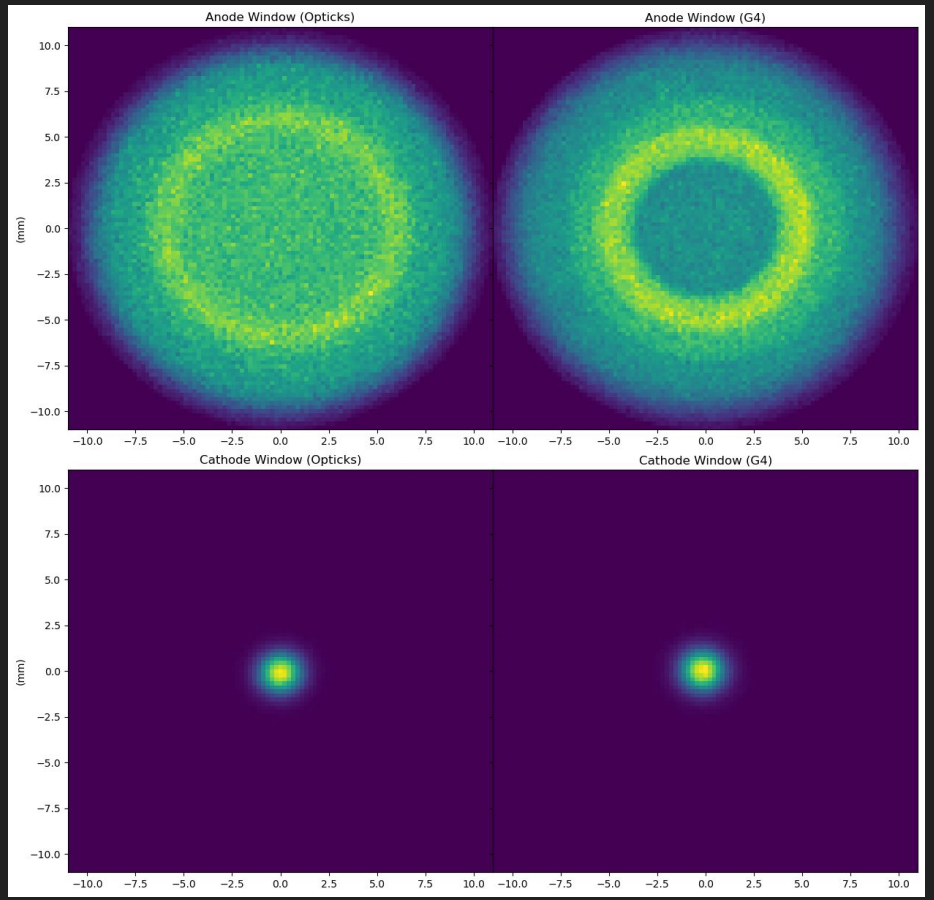
Performance Comparison

- GEANT4 vs Opticks Photon propagation simulation completion times
  - CPU (I9-13900k) (Single Core)
  - GPU (RTX-4090)
- Simulated 14 M to 153 M Photons
- 183x speed over CPU is observed.



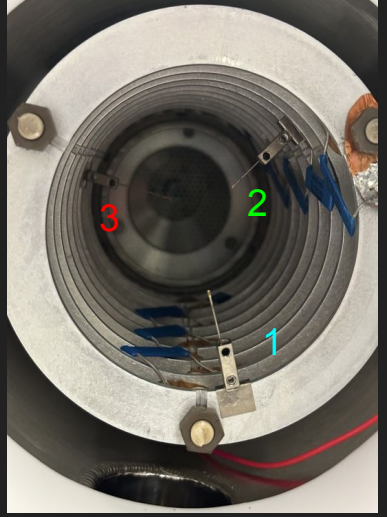
Hits Comparison

- 5.4 MeV alphas are simulated in the middle of the detector at 10 bar under uniform electric field.
- Hits on both windows compared between Opticks and GEANT4
- No difference on the Camera side(Cathode Window) but there is some difference on the PMT Side (Anode Window).
    - Currently not sure about the reason but looking into it.

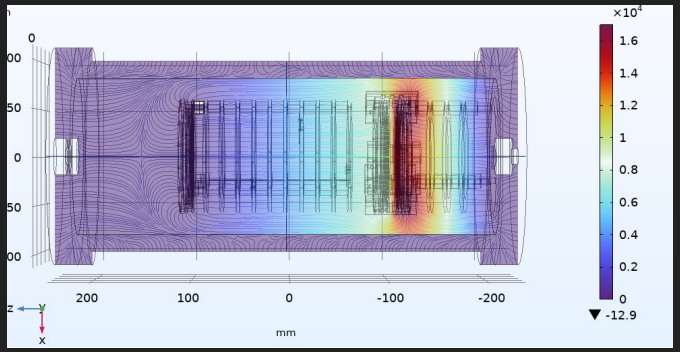


CRAB-0 Diffusion Setup

- Currently I am working on transverse diffusion study in high pressure xenon.
- 3 Pb-210 sources placed in the field cage at varying distances from the EL-region
  - 4cm , 10cm , and 14cm
- We have simulated detector behaviour by combining various tools
  - COMSOL for electrical fields
  - Garfield++ for electron drift.
  - Magboltz for gas properties such as diffusion
  - NEST for predicting light/charge yields at interaction vertices.
  - GEANT4 for common geometry and simulate primaries
  - Opticks for photon propagation.



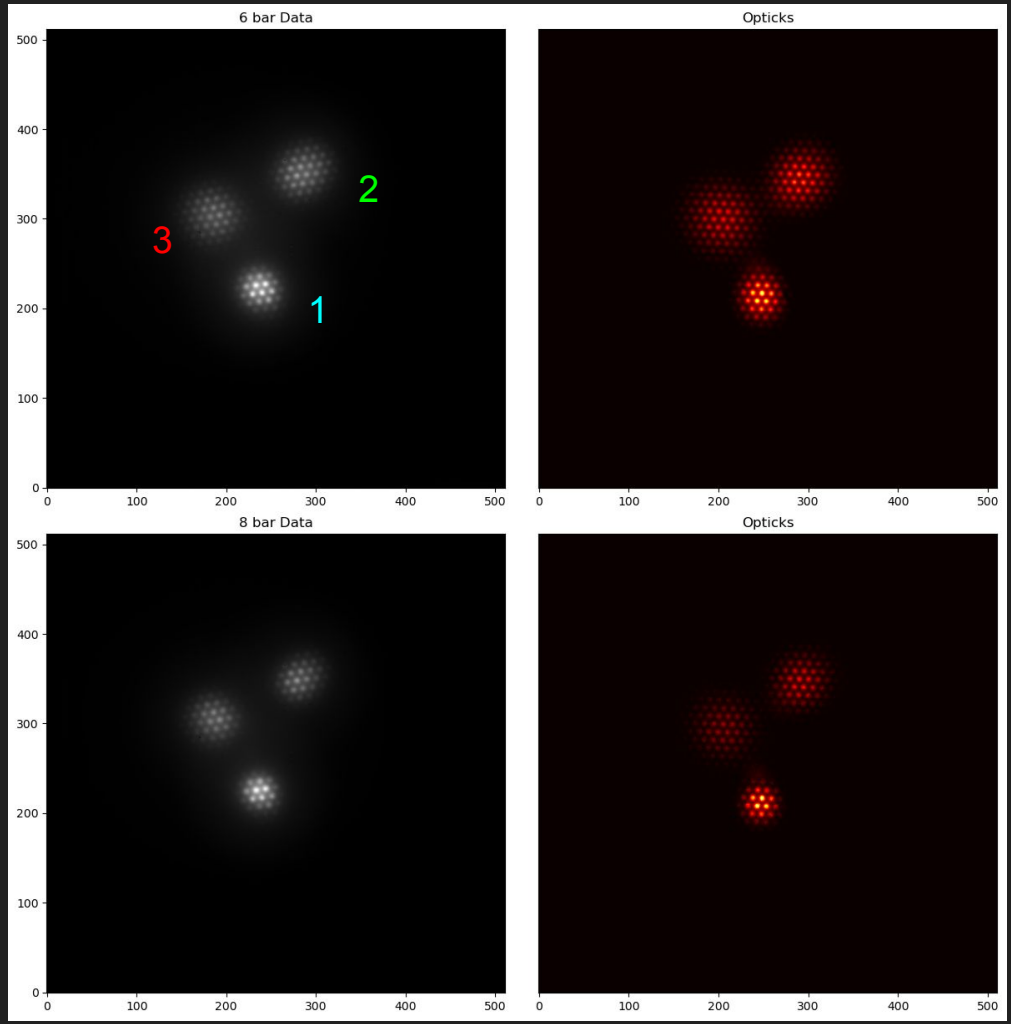
Position of the Sources



COMSOL, Francisco UTEP

Data and Simulation

- Images on the left are from the EMCCD (Gray Scale)
- Both data and simulation show hexagons.
- Data and simulations show similarities



Conclusion

- We have integrated Opticks into our GEANT4 based simulation package.
- Initial tests indicates Opticks speeds up photon propagation 183 times with our geometry.
- We are currently comparing opticks results to G4 and preliminary results are promising.

Thank you for listening!

Important Links

- Opticks Repo : https://bitbucket.org/simoncblyth/opticks
- Opticks form : https://groups.io/g/opticks
- Installation and Troubleshooting Guide
  - https://docs.google.com/document/d/1dEGLSMZWgbARayXikQR63GqEBl2TxBieSrb8njberlg/edit