

Direct hole-ice simulations with Upgrade-like geometry: Stronger bubble column and more photons

IceCube Calibration Call 2018-11-09

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<https://github.com/fiedl/hole-ice-study/issues/117>
<https://github.com/fiedl/hole-ice-study/issues/118>
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Erlangen Centre for Astroparticle Physics

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Resources

Scripts and plots for this talk:

<https://github.com/fiedl/hole-ice-study/issues/117>

YouTube video with Steamshovel visualization:

<https://youtu.be/Wiu8CpVQn14>

Thesis (2018-09-05) with more info on direct hole-ice simulation:

<https://github.com/fiedl/hole-ice-latex>

Previous talks:

<https://github.com/fiedl/hole-ice-talk/releases>

LATEX version of these presentation slides:

<https://github.com/fiedl/hole-ice-talk>

Simulation scenario

For each angle polar and azimuthal angle, shoot photons onto the DOM, possibly propagate through the bubble column, and count hits.

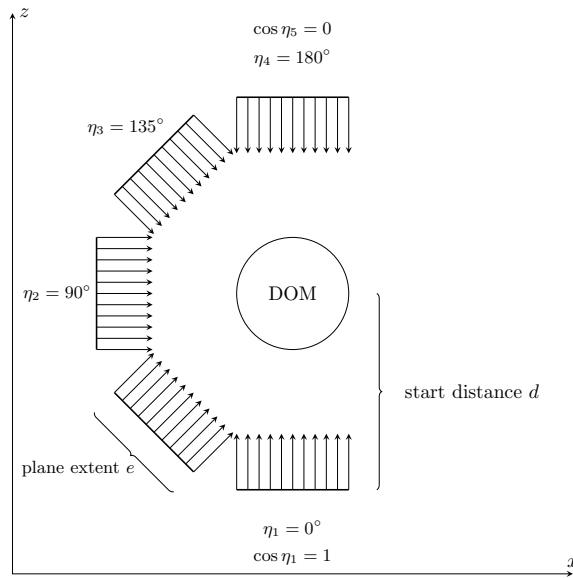


Figure: View from the side. Shooting photons from different polar angles.

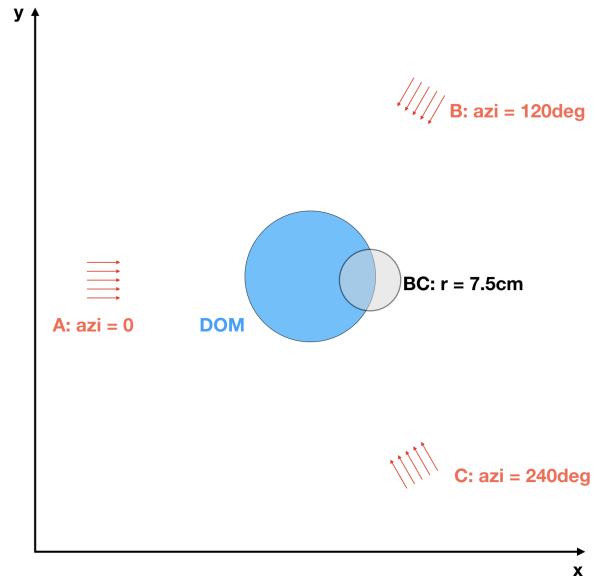
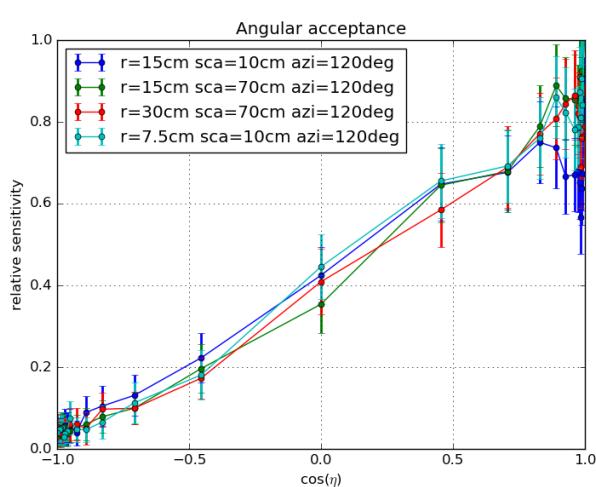


Figure: View from above. Shooting photons from different azimuthal angles.

Previous talk (2018-10-19)

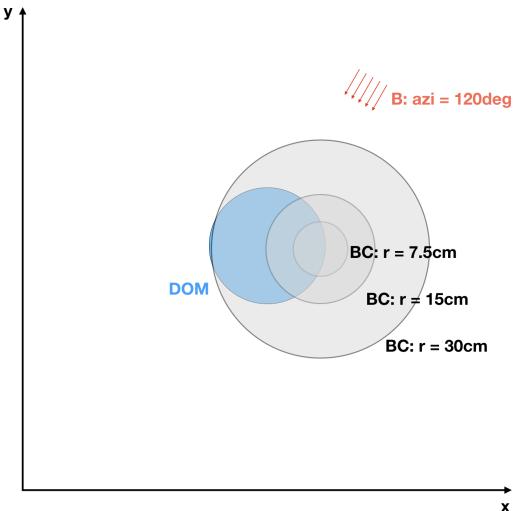
<https://github.com/fiedl/hole-ice-talk/releases/download/v1.4/2018-10-19.Direct.hole.ice.simulations.with.Upgrade-like.geometry.Blot.Fiedlschuster.pdf>



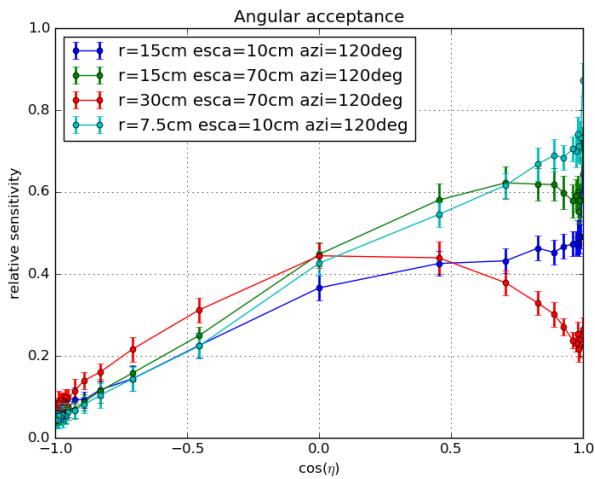
Configuration: Starting distance 3 m, plane-wave extent 3 m, bulk-ice geometric scattering length 130 cm.

Comparing different bubble columns for the same direction of incoming photons.

- In preparation of the last call, we had some misunderstanding regarding the values of the geometric vs. effective scattering length of the hole ice.
- For weak hole as (e.g. geometric $\lambda_{\text{sca}} = 10 \text{ cm}$), as shown in the last call, the angular-acceptance curves do not look that different for different hole-ice radii.



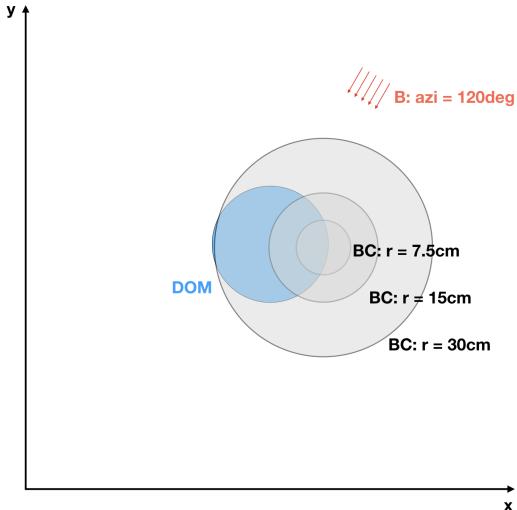
New simulation results



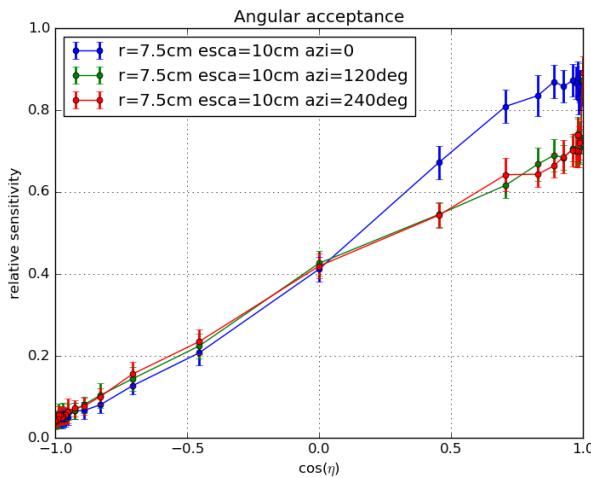
Configuration: Starting distance 3 m, plane-wave extent 3 m, bulk-ice geometric scattering length 130 cm.

Comparing different bubble columns for the same direction of incoming photons.

- Effective scattering length $\lambda_e = \frac{\lambda_{\text{sca}}}{(1-\langle \cos \theta \rangle)}$, $\langle \cos \theta \rangle = 0.94$, $\lambda_{\text{sca}} = 0.06 \lambda_e$
- For stronger hole ice (e.g. $\lambda_e = 10$ cm, i.e. $\lambda_{\text{sca}} = 0.6$ cm), the hole-ice radius does matter. ✓
- For a stronger or larger bubble column, the hole-ice effect for lower angles should increase. ✓



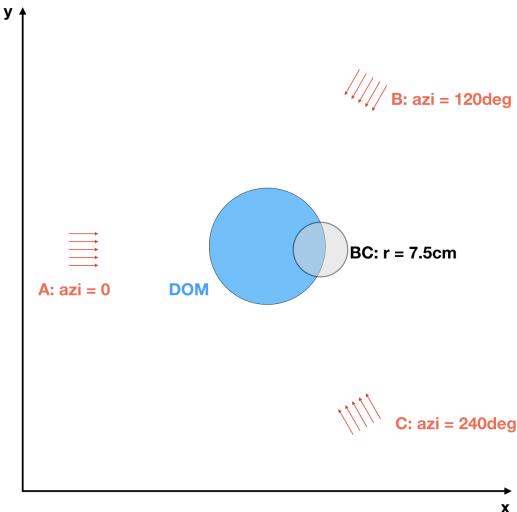
New simulation results: Different azimuthal directions



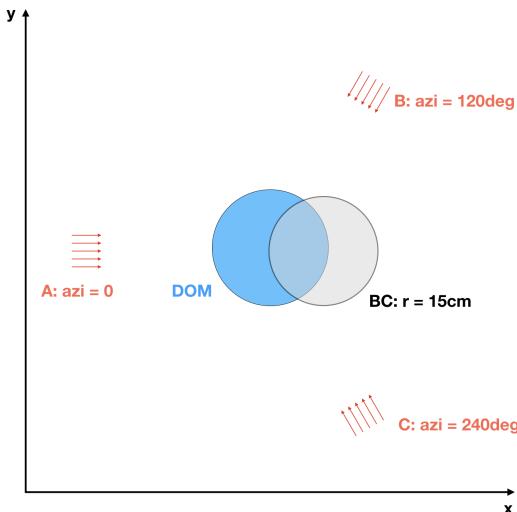
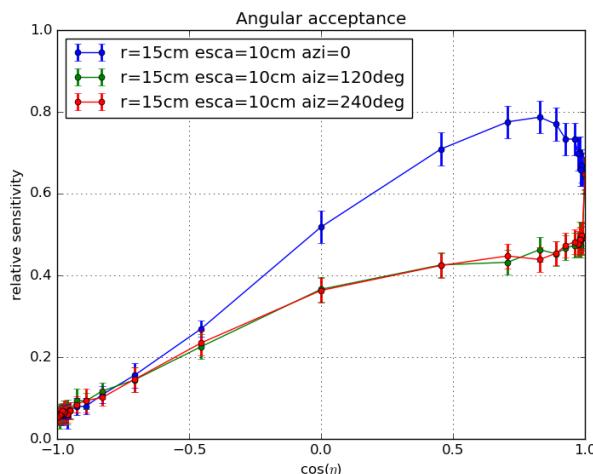
Total photon hit count: 118441 / 1e7

Configuration: Starting distance 3 m, plane-wave extent 3 m, bubble-column geometric scattering length 10 cm, bulk-ice geometric scattering length 130 cm.

- For lower polar angles ($\cos \eta \approx 1$), less photons should arrive from azimuths B and C as from azimuth A as the DOM's PMTs look downwards and photons from B and C are more likely to cross the bubble-column cylinder. ✓
- From azimuths B and C, the same number of photons should arrive due to the symmetry of the scenario (right image). ✓



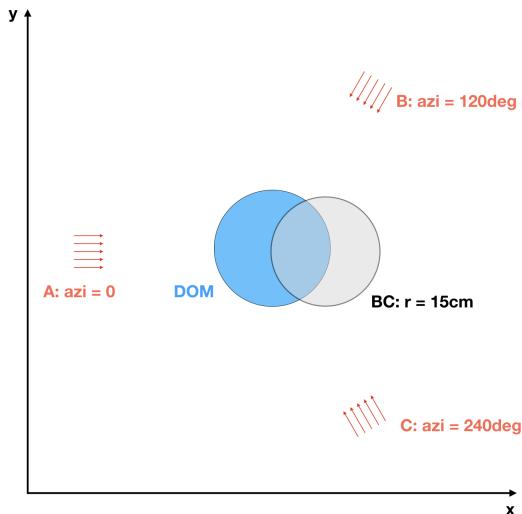
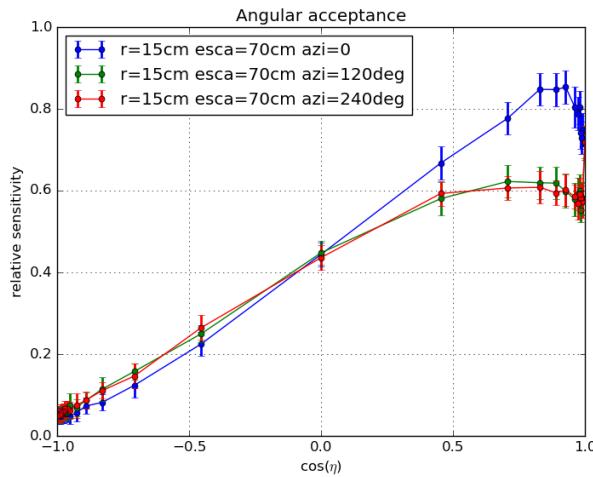
New simulation results: Different azimuthal directions



Configuration: Starting distance 3 m, plane-wave extent 3 m, bubble-column geometric scattering length 10 cm, bulk-ice geometric scattering length 130 cm.

- For a larger bubble column with same scattering length, the effect should increase. ✓
- For photons coming from below, the blue curve should see a stronger effect as well. ✓

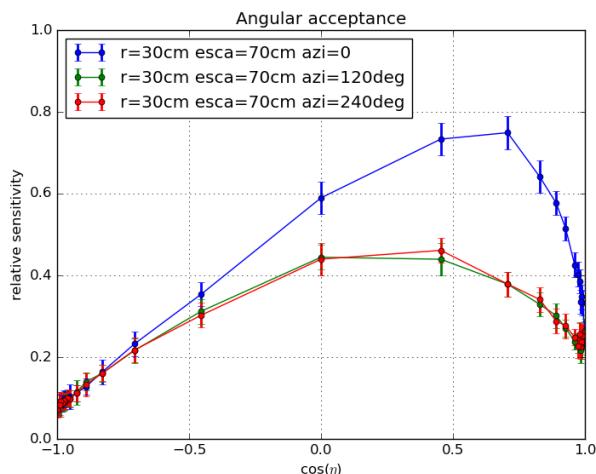
New simulation results: Different azimuthal directions



Configuration: Starting distance 3 m, plane-wave extent 3 m, bubble-column geometric scattering length 70 cm, bulk-ice geometric scattering length 130 cm.

- For a larger scattering length (weaker bubble column), the effect should decrease. ✓

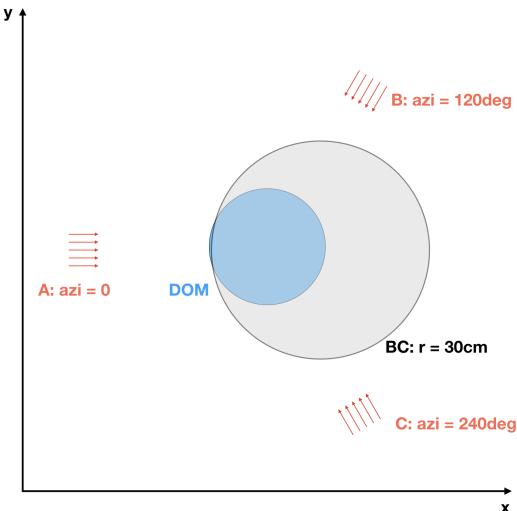
New simulation results: Different azimuthal directions



Total photon hit count: 72595 / 1e7

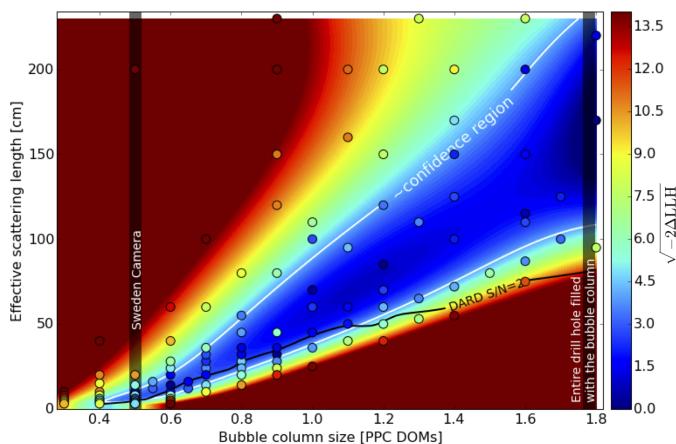
Configuration: Starting distance 3 m, plane-wave extent 3 m, bubble-column geometric scattering length 70 cm, bulk-ice geometric scattering length 130 cm.

- For a larger bubble column, the effect should increase. ✓
- Less photons should arrive in total as the whole DOM is now shielded by the hole ice. ✓



Facit & questions

- The method is sensitive to the bubble-column position.
- The method is sensitive to the bubble-column radius or scattering length if the other is known.
- **Question:** Is there an independent method of determining bubble-column radius or scattering length in the Upgrade?



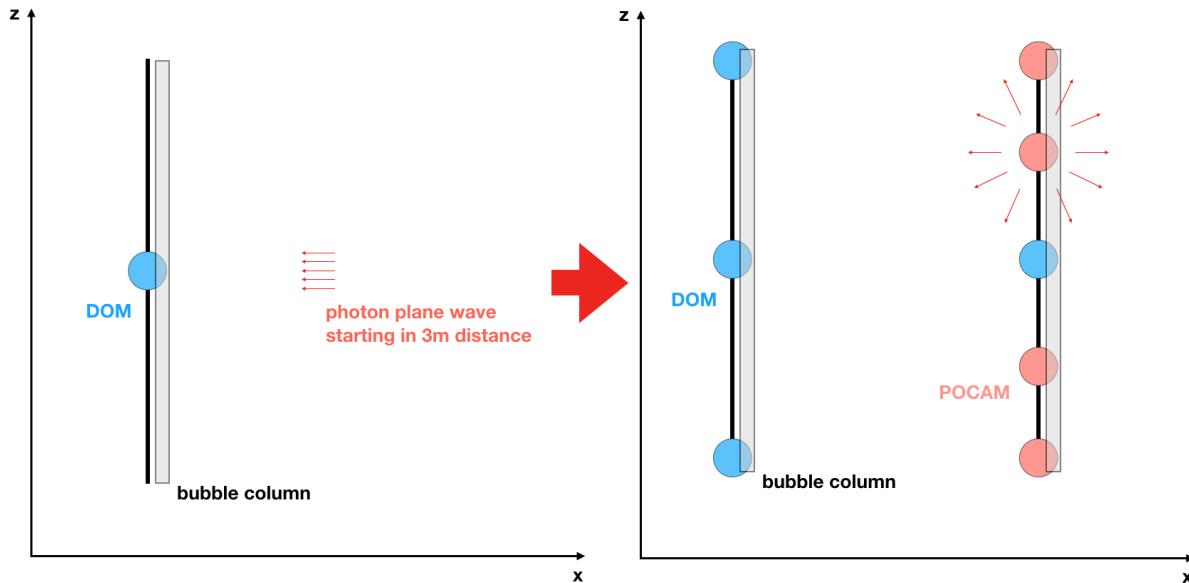
SpiceHD study using direct hole-ice propagation, fitting the size and scattering length of the bubble column and the position of the optical modules relative to the column. Source: Rongen. Status and future of SpiceHD and DARD, Calibration Workshop August 2017.



Swedish-camera images from 2018 still show a diffuse bubble column. Source: Resconi, Rongen, Krings. The Precision Optical CALibration Module for IceCube-Gen2: First Prototype. 2017.

Next step: More realistic simulation scenario

- New scenario: Still count hits at receiving DOM and check if sensitive to the bubble-column position and strength, but start photons from near POCAMs rather than from plane waves.
- **Question:** Is there a POCAM photon source in IceTray?
- **Question:** Where can I get the coordinates of the proposed POCAMs?



For a follow up on this, see <https://github.com/fiedl/hole-ice-study/issues/118>.

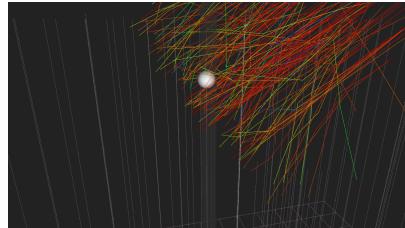
Thanks for your attention!

Any input you might have is welcome:

<https://github.com/fiedl/hole-ice-study/issues/117>

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Slack: @fiedl



YouTube video of the simulation:

<https://youtu.be/Wiu8CpVQn14>