State of the hole-ice simulation

ECAP-IceCube Meeting 2019-03-14

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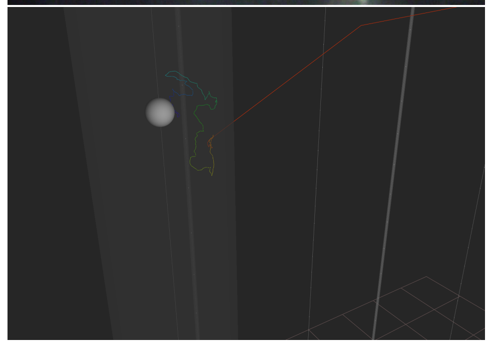
Overview: Goal and Context

Origin — **Diploma thesis** (2018-09) implementing direct photon propagation through hole ice in clsim in order to study hole-ice effects and improve understanding of low-energy systematics.
`https://github.com/fiedl/hole-ice-study`

Goal — **Bring** the new simulation **into** the icecube-simulation **framework** such that other icecubers can use it.

Context — **Service work** for the icecube collaboration in the beginning of my time as PhD student with icecube at ECAP/Erlangen.

Time frame — about 6 months



Source: Top: Rongen: The 2018 Sweden Camera run — light at the end of the ice, 2018. Bottom: https://github.com/fiedl/hole-ice-study/issues/107

Overview: Work to be done

- ✓ Compile IceSim V06-01-01 with Python 3
- ⇒ Port hole-ice code to clsim of icecube-simulation V06-01-01
- ☐ Provide example scripts for Python 3
- ☐ Implement missing features
- ☐ Merge hole-ice code into clsim trunk

✓ = done   ⇒ = work in progress   ☐ = still to do

✓ Compile IceSim V06-01-01 with Python 3

- In Stockholm (2018-09), the icecube software group requested the hole-ice example scripts to be provided in Python 3 (rather than Python 2 or Ruby) in order to push the migration to Python 3 forward.
- The current icecube documentation on how to install the framework on macOS still assumes Python 2: `http://software.icecube.wisc.edu/documentation/projects/cmake/supported_platforms/osx.html`

✓ Using Vagrant, a virtual-machine wrapper, I've documented a clean, reproducible way to install icecube-simulation V06-01-01 on macOS Sierra, which I use locally.

✓ Found a couple of issues and provided patches.

☐ Still need to talk to the software group. Maybe they want to link or import the install documentation.

☐ I would love to run this on Travis-CI. But this would expose the build logs (no credentials) to the public. Need to check with software group whether this would be ok.

Documented at: `https://github.com/fiedl/hole-ice-install`

⇒ Port hole-ice code to clsim of icecube-simulation V06-01-01

- The original study was based on the icecube-simulation framework V05-00-07 from 2016.
- From the V05-00-07 (2016) to V06-01-01 (2019), there are 93 commits in clsim. A lot has changed.
- There are two separate repositories for original clsim, in addition to the hole-ice fork, which need to be kept in sync. For my work, I have forked Claudio's repository on github. But now, Claudio's github repository is behind the current work in the SVN repository.
  `http://code.icecube.wisc.edu/svn/projects/clsim`
  `https://github.com/claudiok/clsim`
  `https://github.com/fiedl/clsim`

✓ Find common interface to sync the repositories: `git-svn`

⇒ Coordinating with the clsim maintainer, Claudio Kopper: The repositories need to be synced before the code can be ported to avoid conflicts later.

☐ Rebase the hole-ice changes onto the V06-01-01 release

☐ Make sure everything is still running

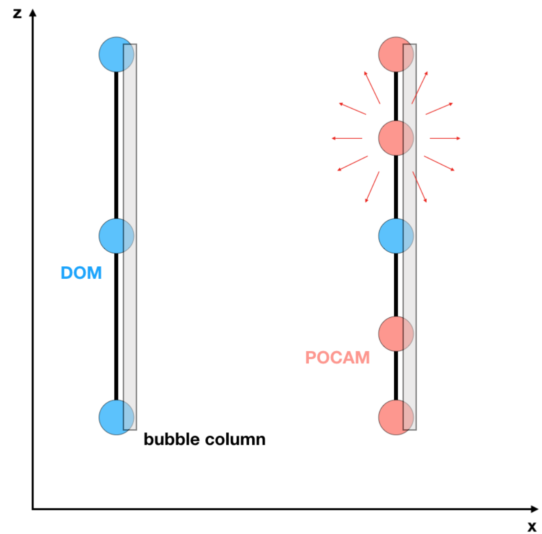
☐ Make sure there are no conflicts with other attempt on cable shadows

☐ Provide example scripts for Python 3

- The example scripts of the original hole-ice study are written in Ruby: `https://github.com/fiedl/hole-ice-study`
- Icecubers prefer Python instead.

⇒ Together with the calibration group and the POCAM group in Munich, I'm working on a series of hole-ice simulations to study proposed geometries for the icecube upgrade.

☐ The scripts will be migrated to Python 3, documented, and provided as example scripts for the collaboration.



Example scripts will be at: `https://github.com/fiedl/hole-ice-scripts`

Source: `https://github.com/fiedl/hole-ice-talk/releases/tag/v1.5`

☐ Implement missing features

Ice tilt Re-implementing ice tilt will be relatively easy after the hole-ice code is ported.

Direct detection Direct detection has already been implemented during the original study. But we need a switch to turn it on and off.

Anisotropy Instead of re-implementing the old ice-anisotropy model, I'd like to coordinate with Martin Rongen and Dima. Maybe it is possible to implement the new anisotropy model discussed in the previous calibration calls.
`https://drive.google.com/file/d/1TyqDQgHXSKuHBUC0gLo4xz9RKvxk5dGV/view`

☐ Merge hole-ice code into clsim trunk

- When everything works as expected:

☐ Port hole-ice code to work with svn trunk of the icecube-simulation framework

☐ Create a feature branch based on the clsim trunk on the svn

☐ Coordinate with the clsim maintainer, Claudio Kopper, to get it merged into the clsim trunk

Thanks for your attention!

Any input you might have is welcome:

`https://github.com/fiedl/hole-ice-study/issues`

Slack: `@fiedl`

Video illustration of a simple example:
`https://youtu.be/BhJ6F3B-I1s`

Backup Slides

Martin's wish list

Feature	Possible	Done	In progress	Will be done by me
Separate hole-ice positions for each string	✓	✓		
Nested cylinders: Bubble column and outer column	✓	✓		
Cable shadows using cylinder parts	✓	✓		
Absolute scattering and absorption lengths in hole ice	✓	✓		
Direct detection	✓		✓	yes
Bring tilt and anisotropy back	✓			yes
Gradient of scattering length in bubble column	✓			no
DOM oversizing	?			?

See also: List of issues on github: `https://github.com/fiedl/hole-ice-study/issues`

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.

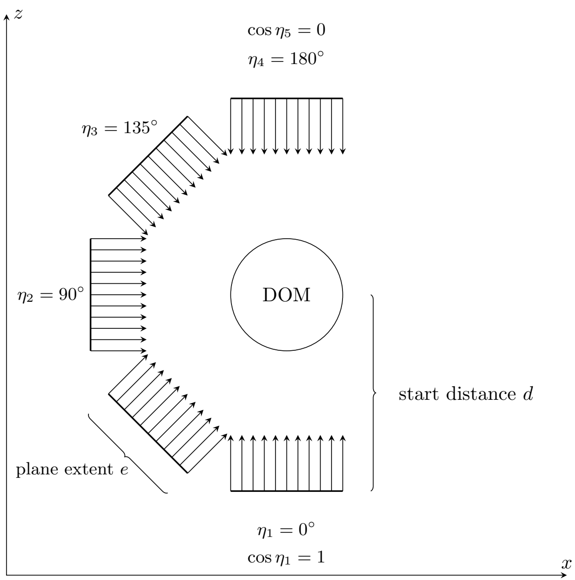


Figure: View from the side. Shooting photons from different polar angles.

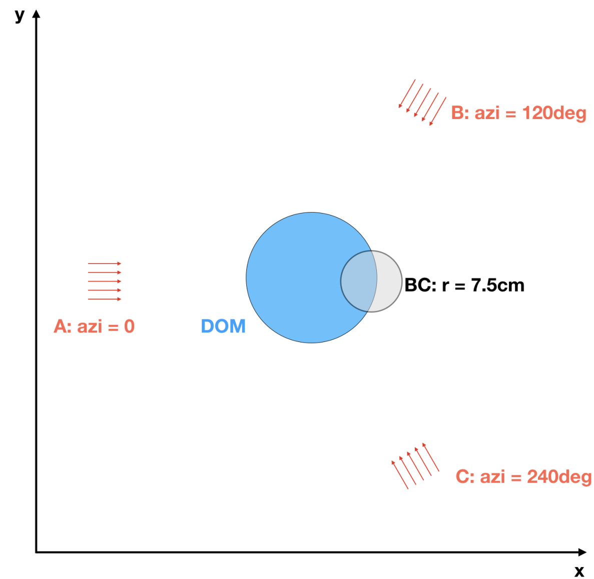
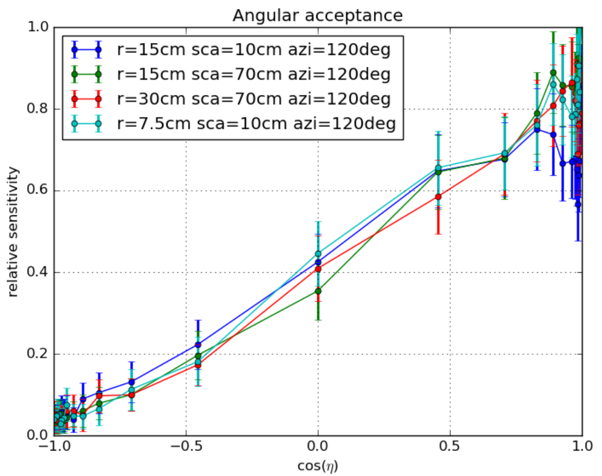
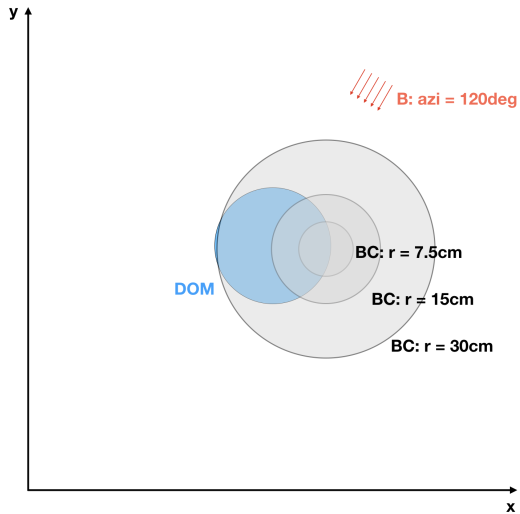


Figure: View from above. Shooting photons from different azimuthal angles.

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



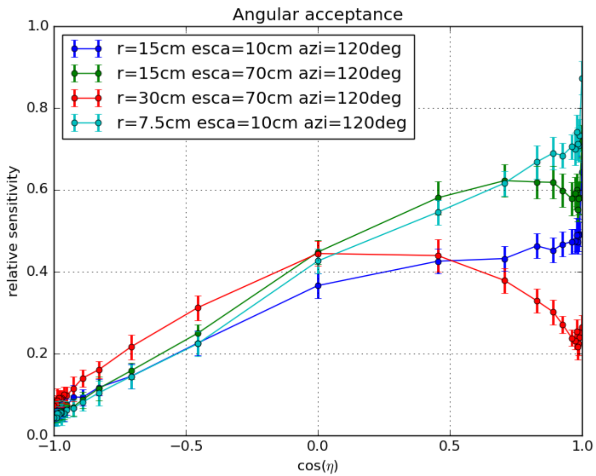


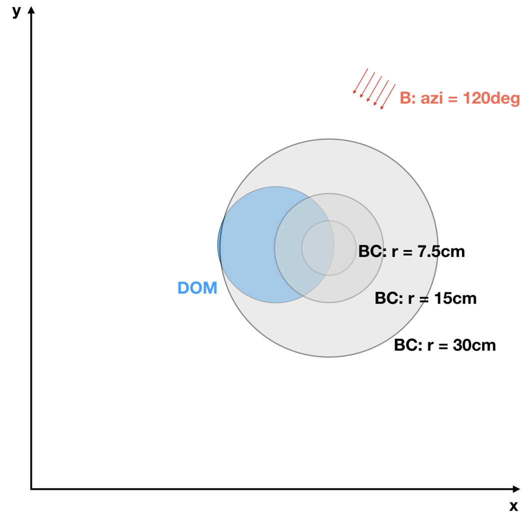
Configuration: Starting distance 3 m, plane-wave extent 3 m, bulk-ice geometric scattering length 130 cm.

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 $\lambda_{sca} = 10\,\text{cm}$), as shown in the last call, the angular-acceptance curves do not look that different for different hole-ice radii.

New simulation results



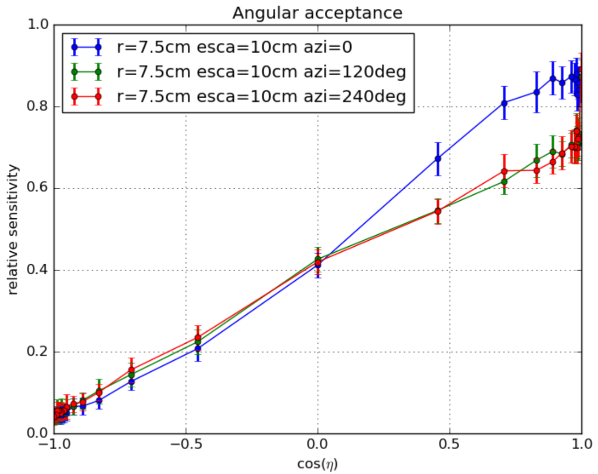


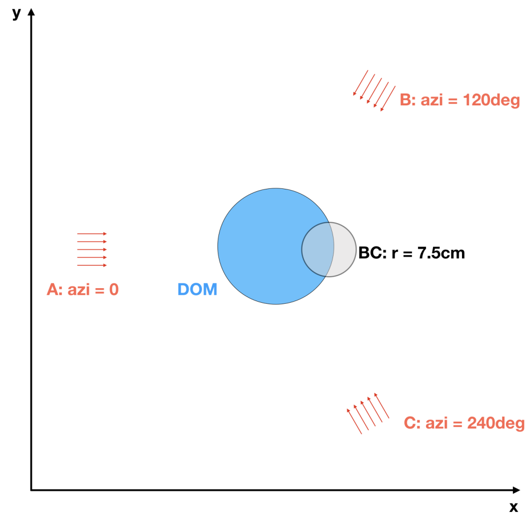
Configuration: Starting distance 3 m, plane-wave extent 3 m, bulk-ice geometric scattering length 130 cm.

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

- Effective scattering length $\lambda_{\text{e}} = \frac{\lambda_{\text{sca}}}{(1-\langle\cos\theta\rangle)}$, $\langle\cos\theta\rangle = 0.94$, $\lambda_{\text{sca}} = 0.06\,\lambda_{\text{e}}$
- For stronger hole ice (e.g. $\lambda_{\text{e}} = 10\,\text{cm}$, i.e. $\lambda_{\text{sca}} = 0.6\,\text{cm}$), 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



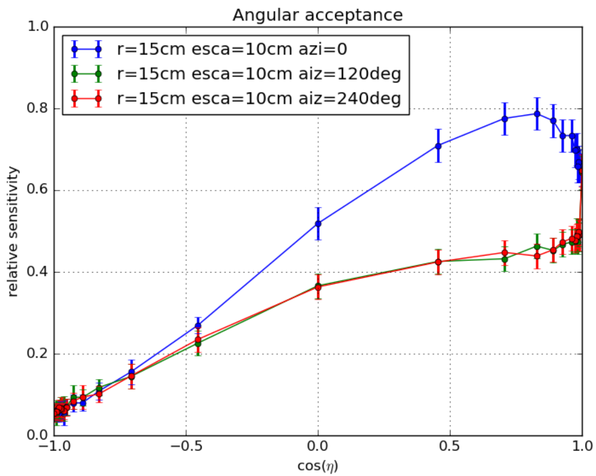


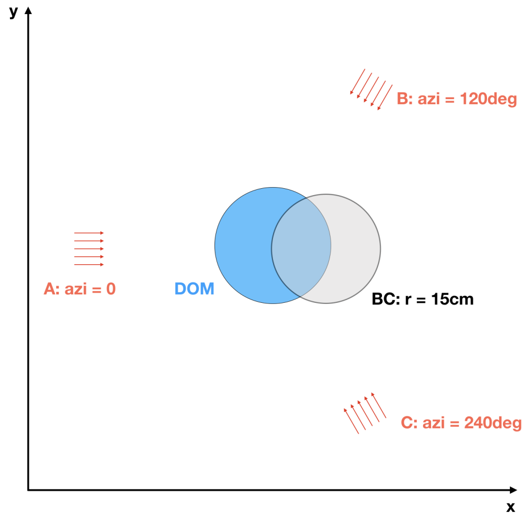
Total photon hit count: 118441 / 1e7

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



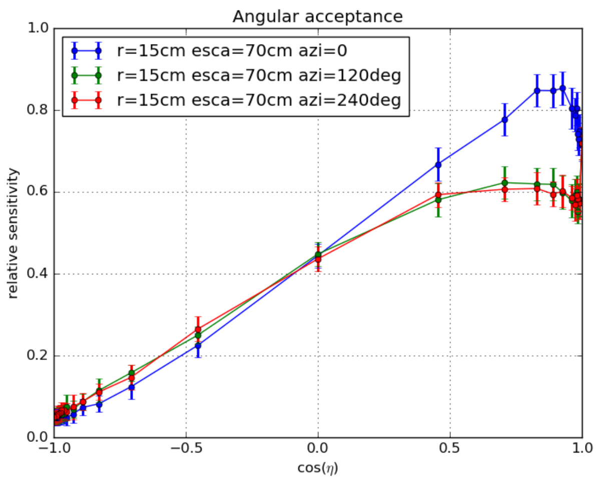


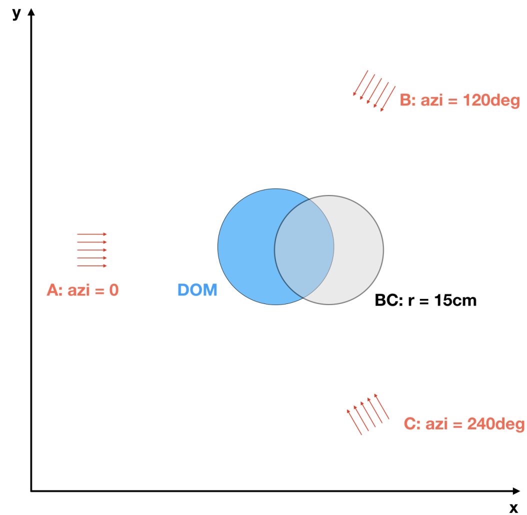
Total photon hit count: 94866 / 1e7

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 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



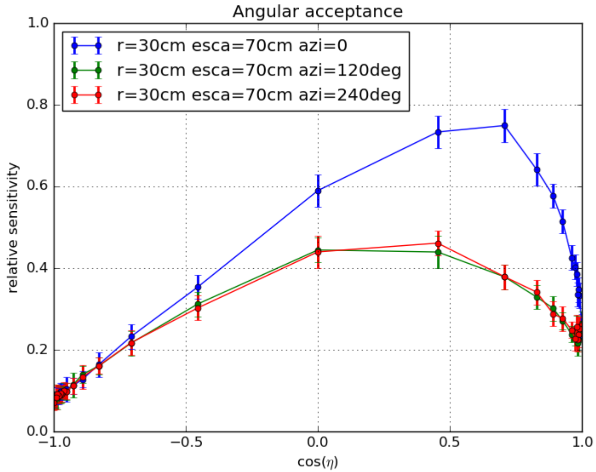


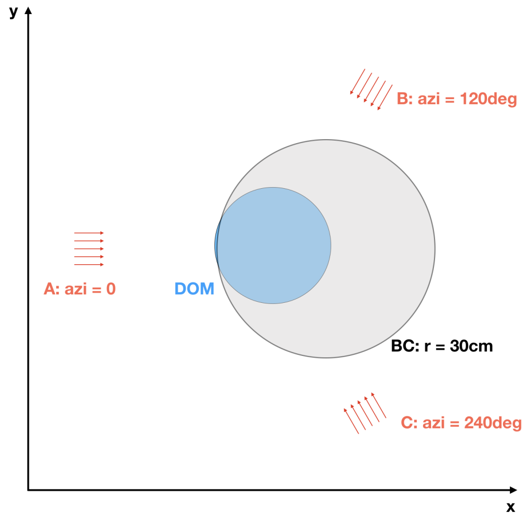
Total photon hit count: 108198 / 1e7

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 scattering length (weaker bubble column), the effect should decrease. ✓

New simulation results: Different azimuthal directions





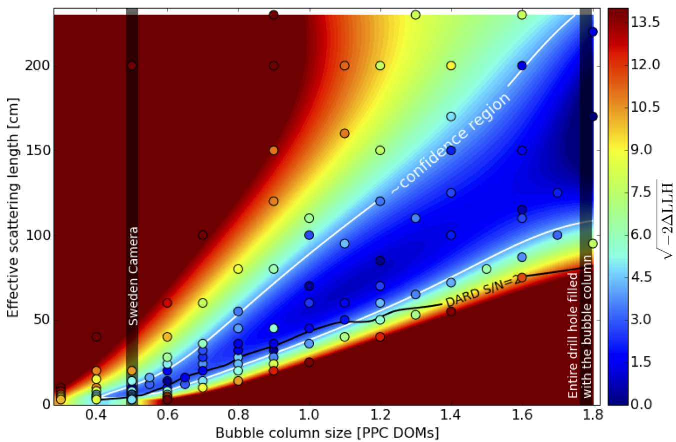
Total photon hit count: 72595 / 1e7

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?

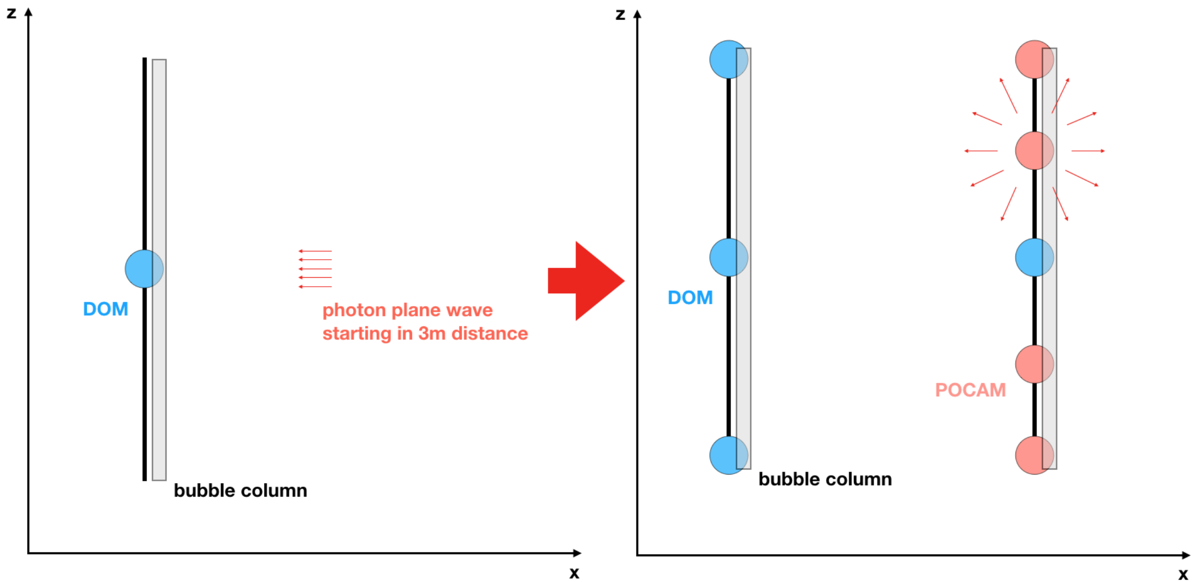


SpiceHD study using direct hole-ice propagation, fitting the size and scattering length of the bubble column and the position of the optical modules relative to the column. Source: Rongen. Status and future of SpiceHD and DARD, Calibration Workshop August 2017.

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?

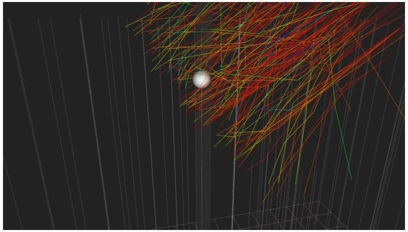


Thanks for your attention!

Any input you might have is welcome:

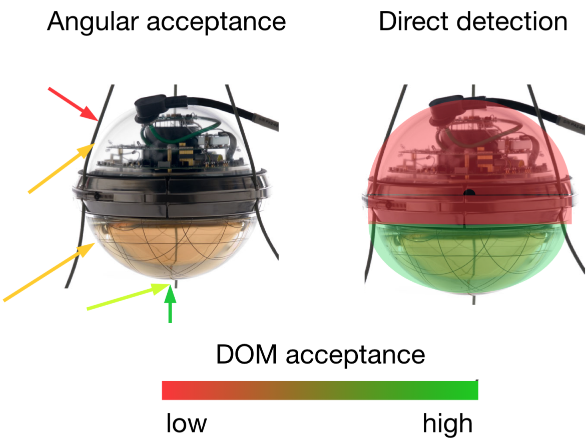
`https://github.com/fiedl/hole-ice-study/issues/117`
`https://github.com/fiedl/hole-ice-study/issues/118`

Slack: `@fiedl`



YouTube video of the simulation:
`https://youtu.be/Wiu8CpVQn14`

Direct detection



Source: Image: Martin Rongen, *Status and future of SpiceHD DARD*, 2017, Slide 17,
See also: `https://github.com/fiedl/hole-ice-study/issues/32`

- The DOM looks downwards by design
- Currently, the hit position is not used when determining DOM acceptance, just the photon direction when hitting the DOM (*DOM angular acceptance*)
- Direct detection: Accept all hits below the waist band, reject all others
- Direct detection is easy with clsim
  - Hit position is known and guaranteed to be on the DOM sphere
  - Idea: Accept hits depending on z of the hit position
  - Patch is a couple of lines: fiedl/clsim@96a2e3f
- Still work to be done:
  - Implement a switch for direct detection vs. DOM angular acceptance