Fibre Array Design for CLOUD Inner Detector

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LiquidO Scintillation Technology

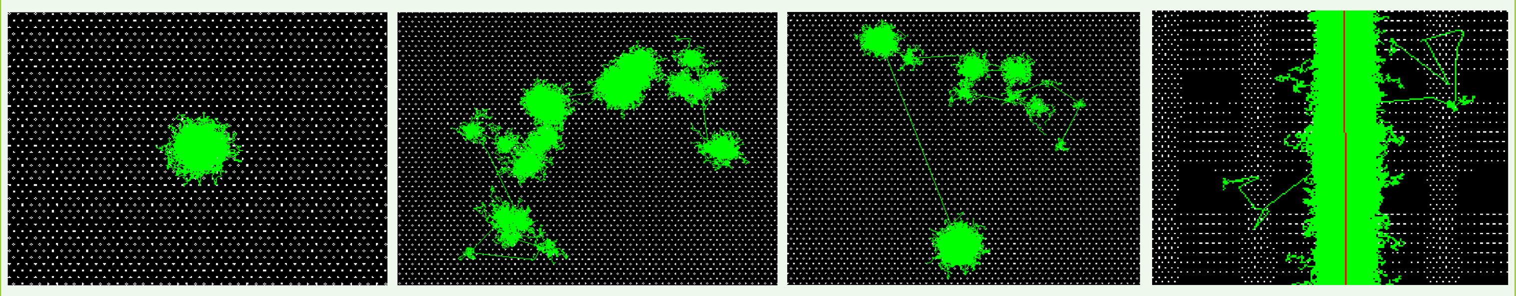
Short scattering length and long absorption length.

⇒ Photons are confined and collected close to their creation point,

⇒ High-resolution imaging,

⇒ Particle ID from event topology.

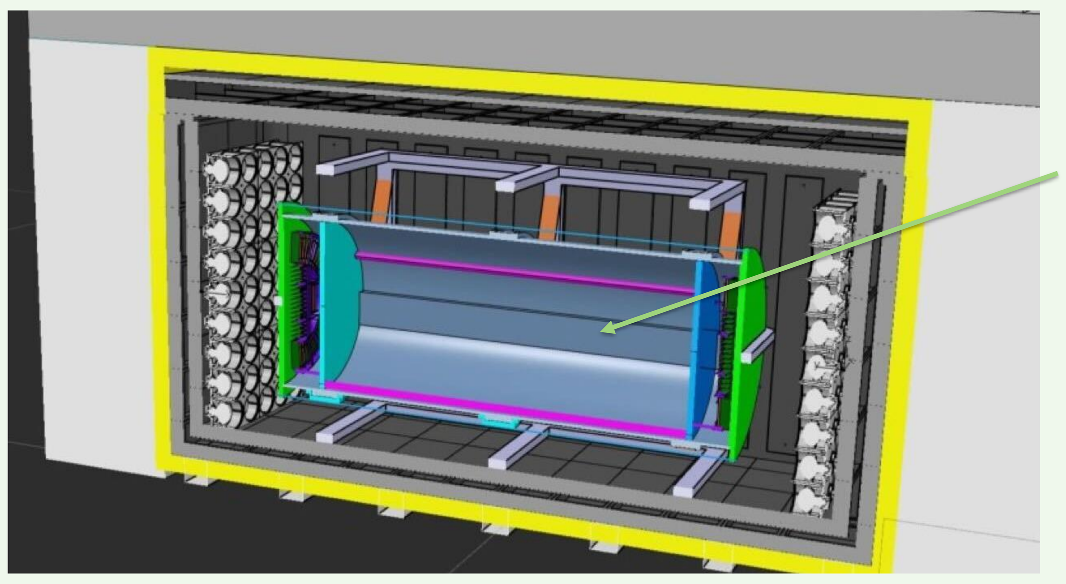
Geant4 simulation of particle signals in a Liquid-O detector



Electron | Positron | Gamma | Muon

CLOUD - Chooz LiquidO Ultra-near Detector

CLOUD is a future **5-10 ton** ultra-near reactor neutrino detector (**~30 m from reactor**). It will be surface level with an **overburden ~3 m w.e**. and is expected to see **~10,000 IBD interactions per day**.

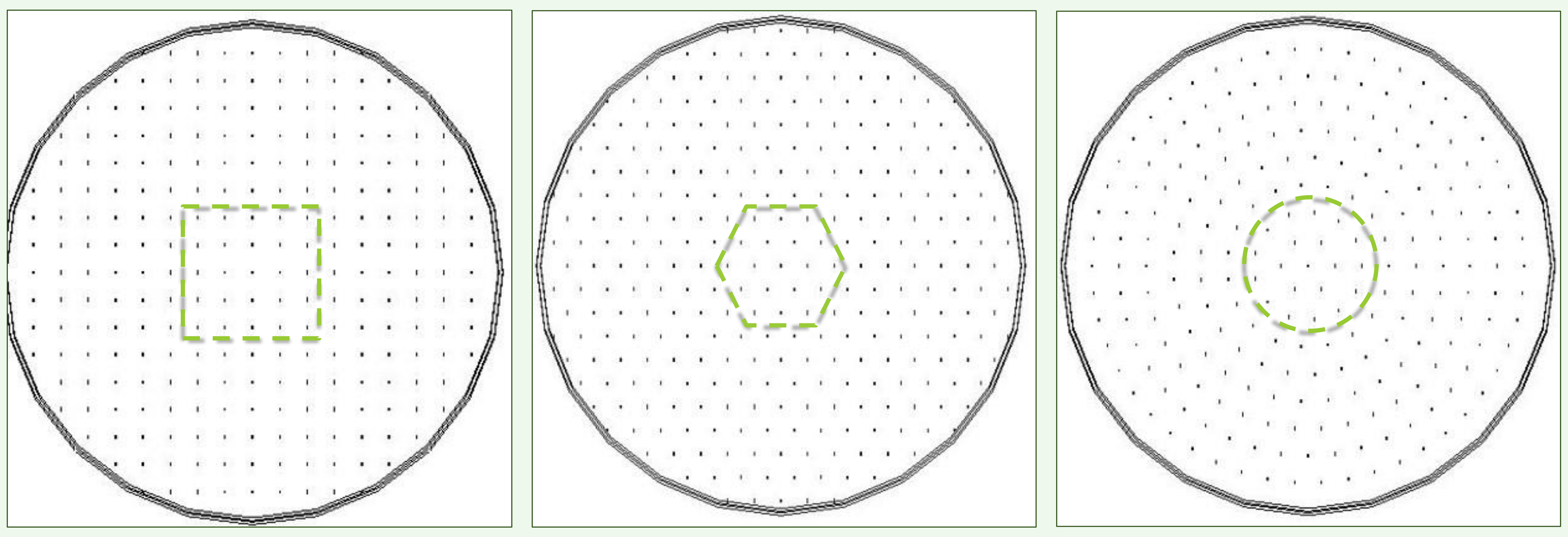


Data collection due to start in 2025/26.

Inner detector: LiquidO scintillator with an **array of WLS fibres.**

~10 000 fibres are read out by SiPMs at both ends of the detector.

Z-Parallel Fibre Array Geometries



Square Array Shape | Hexagon Array Shape | Circle Array Shape

Simplest case - parallel fibres are arranged in a 2D array shape.

The **Hexagon Array Shape** is the preferred option here as it is homogeneous, isotropic in 3 directions and produces the most uniform local fibre density.

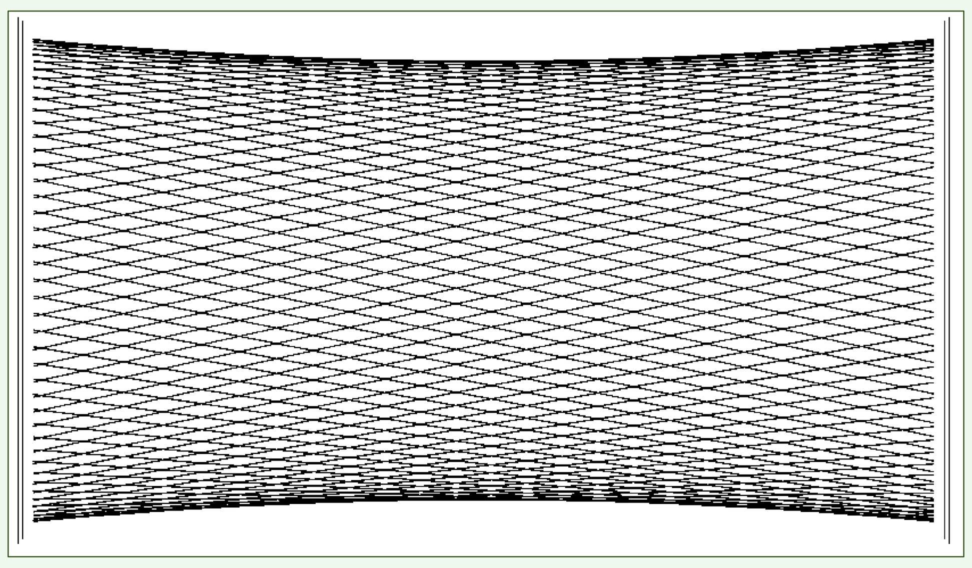
Position reconstruction:

- **x & y resolution ~ few mm,** determined from the fibre hit pattern (ie. which fibres see signal);
- **z resolution ~ 1 cm** determined from the time difference in readout at the two ends of the fibre.

Can the fibres be arranged such that z can be reconstructed from the fibre hit pattern?

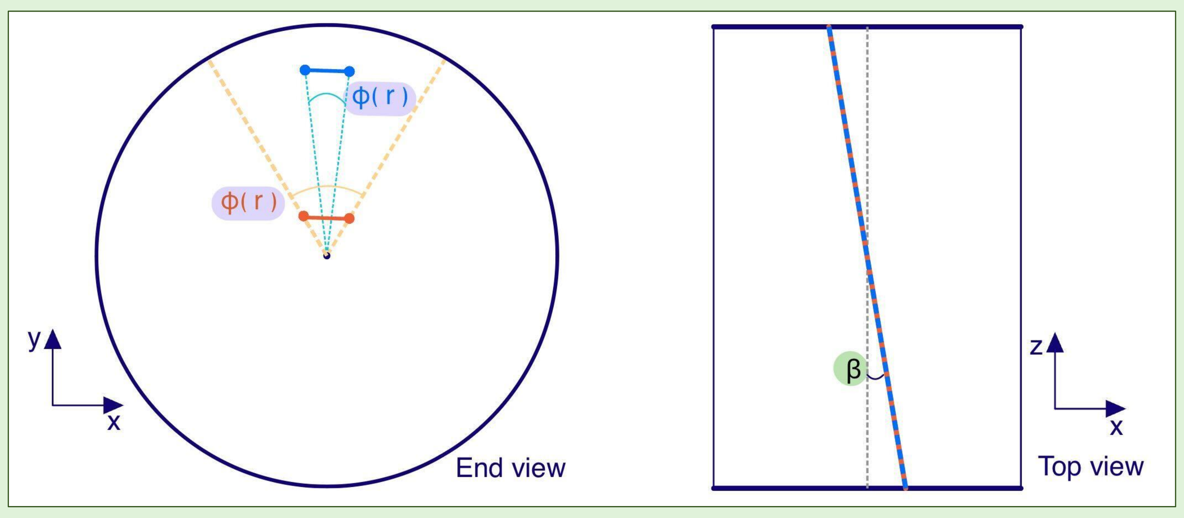
Rotated Shell Arrays

This family of fibre array geometries uses the circle array shape as a base. Fibre shells are twisted in alternating directions so adjacent shells are stereo.



Side view of a rotated shell fibre array.

Geometric Construction



ϕ - relative angle of shell ends.

β - angle of a fibre off the z-axis.

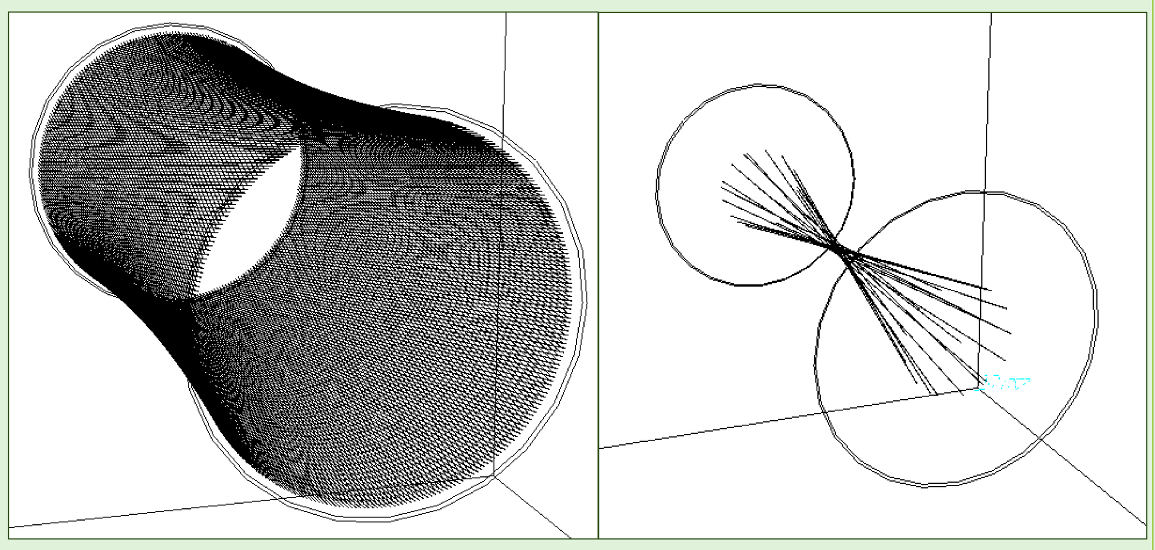
An ideal array would have a constant **β** angle throughout the fiducial volume of the detector.

Constant β – Minimum r Issue

If β is kept constant, the fibre length, l_f, is also constant. Fibres only fit in shells with radius: $r > \frac{l_f \sin\beta}{2}$.

This produces cones of uninstrumented space at $r < r_{min}$. No fibres = No signal.

To instrument this space a **constant ϕ geometry must be used at small radii.**



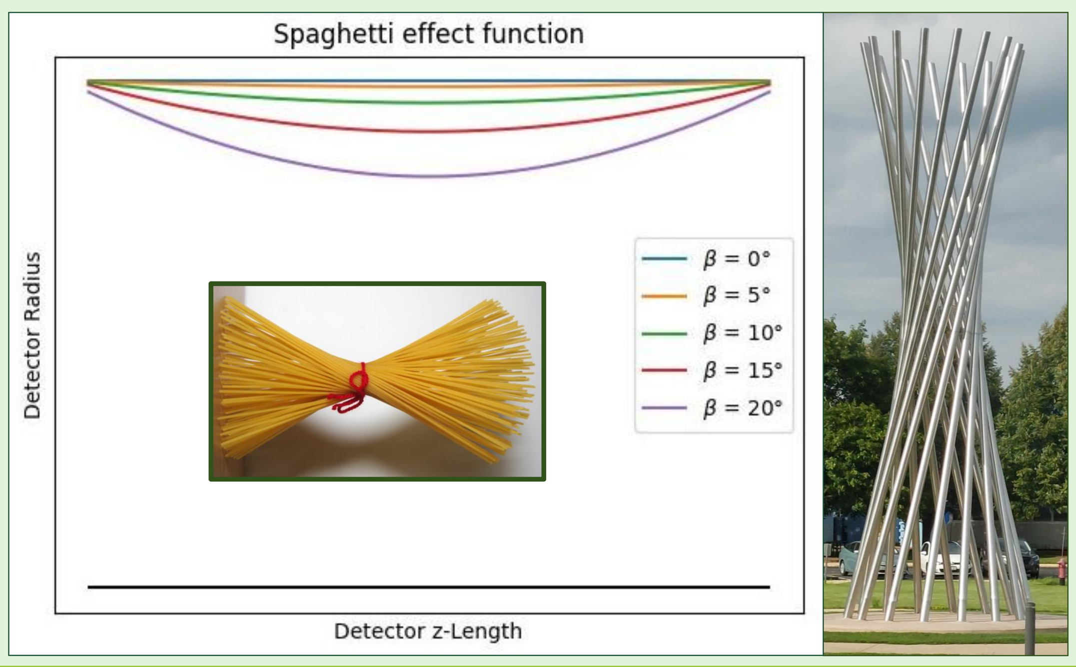
The two outermost and two innermost shells of fibres in a constant beta geometry. Cones of empty space occur at small r.

Spaghetti Effect

Twisting a shell of fibres causes the middle of the shell to 'pinch in'. The magnitude of this pinching effect depends on the shell's β angle, radius and length.

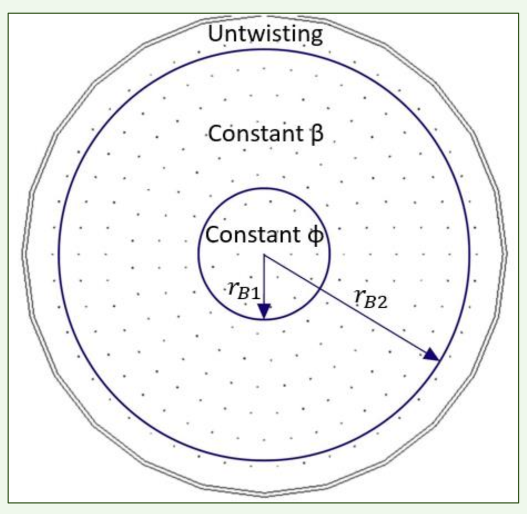
If the outermost shell is twisted, there is uninstrumented space around the edge of the detector. No fibres = No signal.

To instrument this space the **shells must be gradually untwisted at large radii.**



Hybrid Geometry

A full constant β geometry is not possible (due to the issues above). A hybrid geometry is therefore considered and optimised to maximise a constant β volume. A non-trivial calculation due to the four degrees of freedom: β angle, detector length, and two boundary radii.



Yes, but:

- The fiducial volume may need to be reduced,
- Issues arise for triggering and traditional reconstruction methods,
- The engineering complexity of the detector is increased.

Outlook

This poster only outlines a few of the considered fibre array geometries. Simulation will be used to optimise and ultimately decide which will be used for CLOUD.

European Innovation Council

CLOUD Collaboration
A fundamental physics extension of the AntiMatter-OTech innovation project detector

UK Research and Innovation