Predicting Efficiency of INDet Detectors

Monte Carlo simulations have been created using NCrystal & Geant4 to accurately determine the efficiency of different geometries, thus maximising the potential of manufactured devices. A variety of improvements will feed back into the NCrystal framework.

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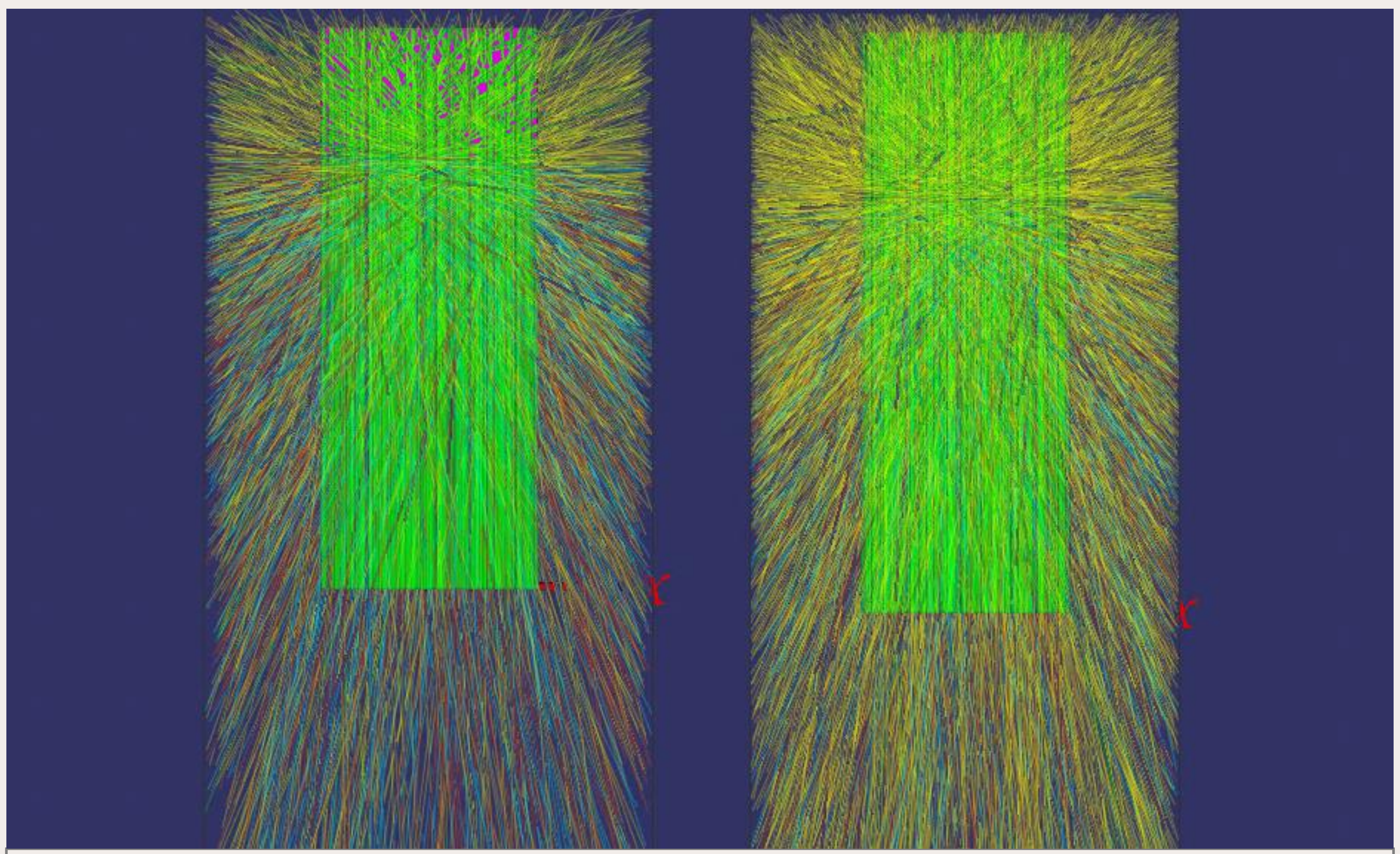


An increase in neutron interaction can be seen between a planar (left) detector and an INDet device (right, with 4 µm holes and 8 µm spacing)

ABSTRACT

NCrystal [1], a C++ library, improves low-energy neutron accuracy within Geant4 [2]. Here, it was used to enhance simulations of innovative boron-coated solid-state detectors containing an etched surface. The boron layer allows for a capture reaction producing charged particles which can be detected in the silicon.

The etched surface increases the apparent thickness of converter seen by the neutrons, without impacting the distance the charged particles must travel through. A mathematical approach can reveal an expected number of converted neutrons but cannot easily consider the stopping power of the converter and passivation layer to determine true efficiency.

To best simulate the thousands of sub-structures on a single pixel detector, NCrystal has been merged with Geant4v11.0-02, creating 'NCrysta11'.

Geant4 + NCrystal

Geant4 evolved from a *FORTRAN*-based code focused on high-energy physics. Over time, interactions have become more accurate at low energy, but are unreliable when simulating thermal neutrons.

NCrystal overcomes this by 'hijacking' the physics events and utilizing experimental data for a range of common materials such as silicon and boron carbide.

Sub-structures

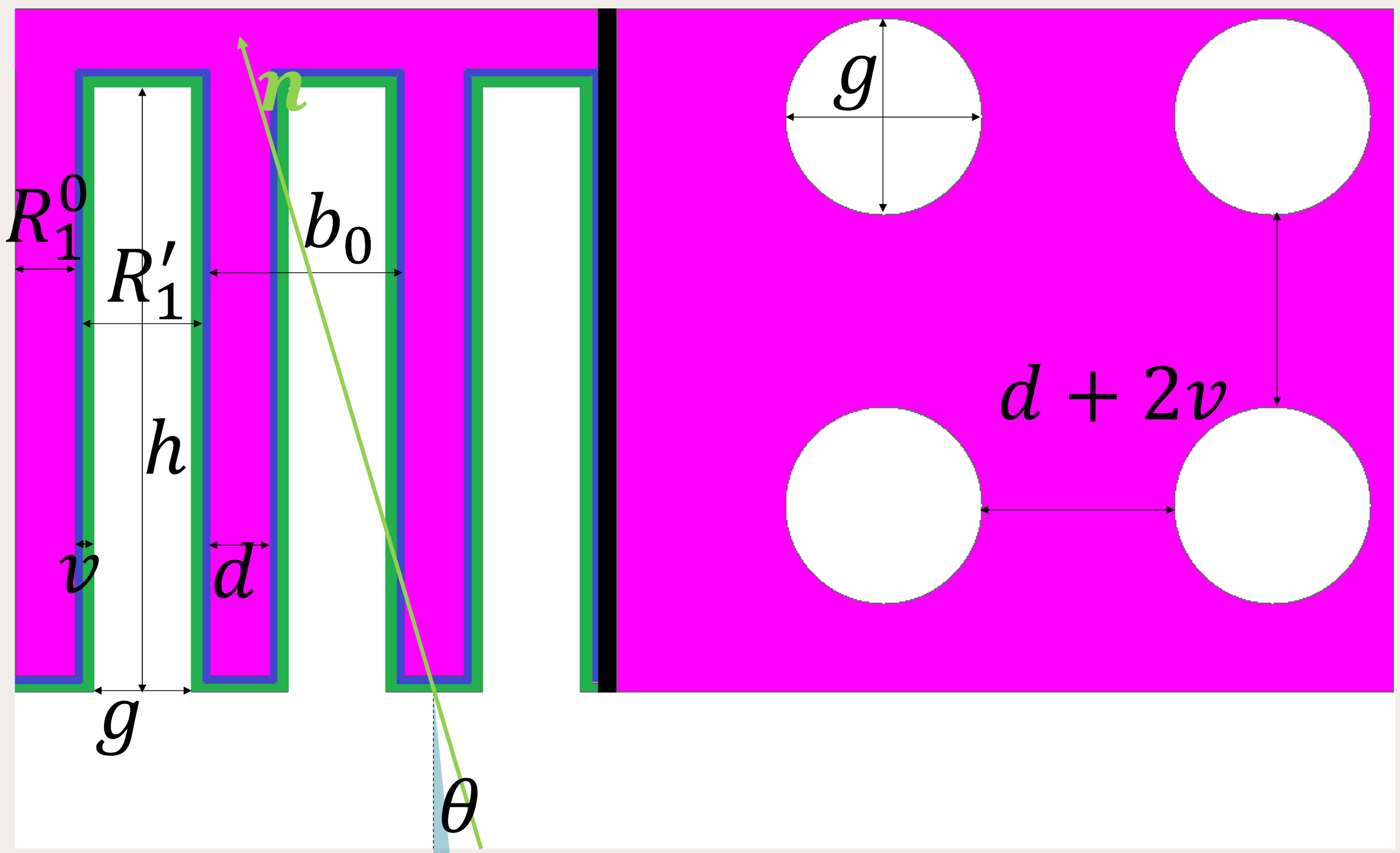
Each created volume requires computational resources, so parameterization was used to 'make once, copy many' to minimize running time.

Accuracy & Precision

Precision improves as *n* increases, but accuracy is harder to confirm. Tests have been made with coated geometries utilizing pyramids [3] and other converter materials [4] that have helped ensure the INDet simulations are as close to expected performance as possible.

'NCrysta11'

Geant4 offers several improvements that will help users create more accurate, complicated geometries quicker and easier.

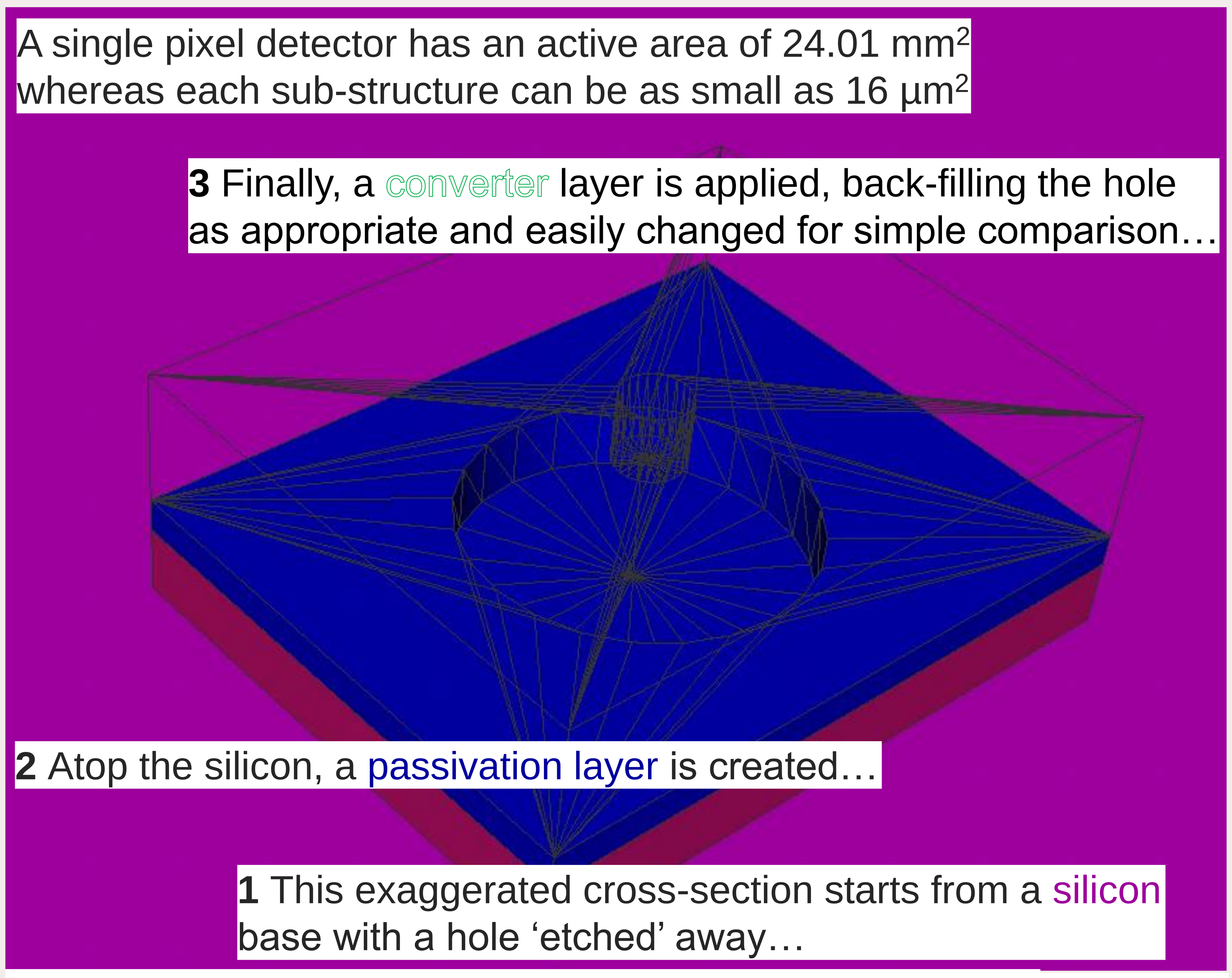


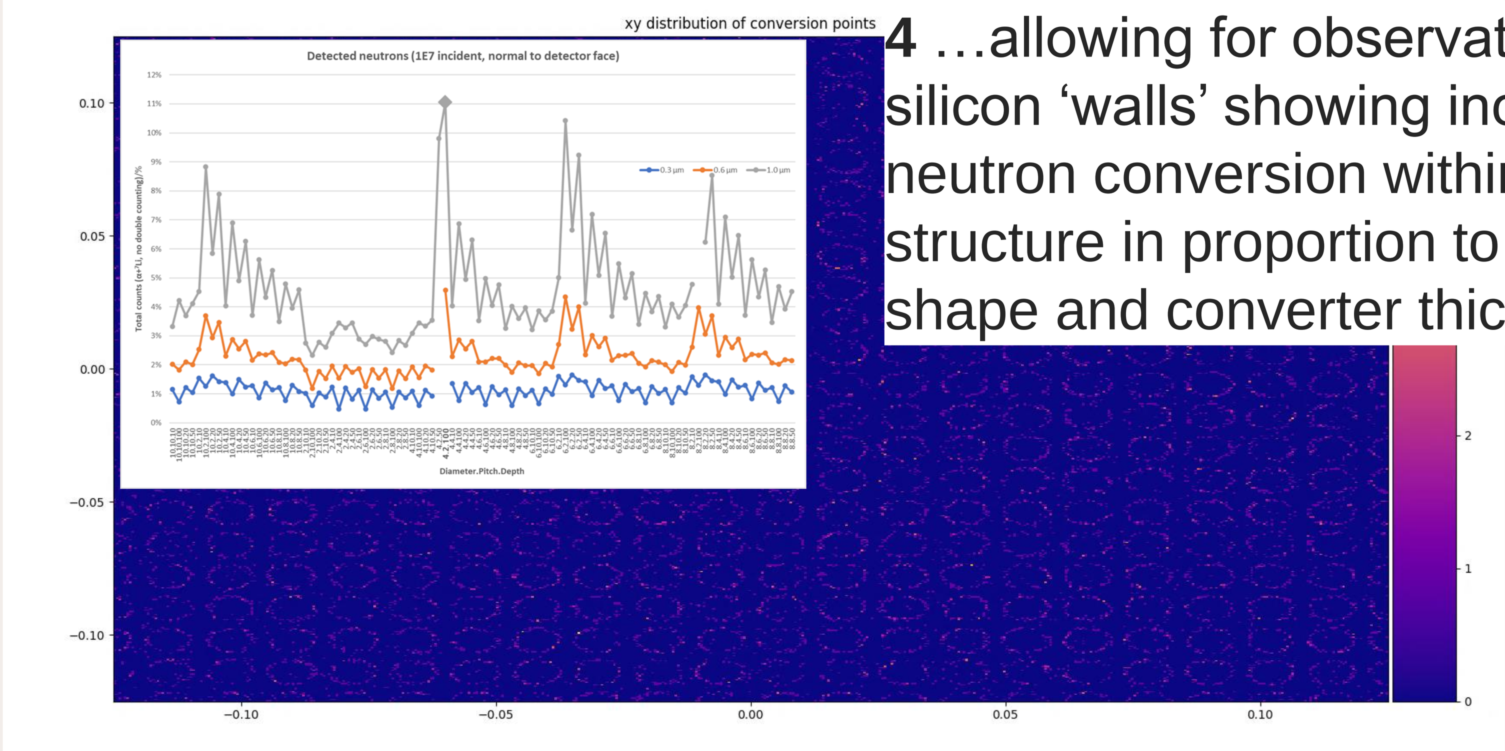
A geometric treatment is illustrated here for a simple hole geometry, but the solution is non-trivial…

$$= \frac{1}{b_0} \sum_{j=0}^{\left\lfloor \frac{b_T}{b_0} \right\rfloor - 1} \Bigg(2(v+t)(T+h) \Bigg(j \Bigg(\tan^{-1} \frac{\left\lceil \frac{j+1}{2} \right\rceil d + \left\lceil \frac{j+1}{2} \right\rceil g + (j+1)(t+v)}{h} - \tan^{-1} \frac{\left\lfloor \frac{j}{2} \right\rfloor d + \left\lfloor \frac{j}{2} \right\rfloor g + (j+1)(t+v)}{h} \Bigg) + \frac{1}{2} \ln \frac{\left(\left\lceil \frac{j+1}{2} \right\rceil d + \left\lceil \frac{j+1}{2} \right\rceil g + (j+1)(t+v) \right)^2 + h^2}{\left(\left\lfloor \frac{j}{2} \right\rfloor d + \left\lfloor \frac{j}{2} \right\rfloor g + (j+1)(t+v) \right)^2 + h^2} \Bigg)$$

$$+ dT \Bigg(j \Bigg(\tan^{-1} \frac{\left\lceil \frac{j+1}{2} \right\rceil d + \left\lceil \frac{j+1}{2} \right\rceil g + (j+1)(t+v)}{h} - \tan^{-1} \frac{\left\lfloor \frac{j}{2} \right\rfloor d + \left\lfloor \frac{j}{2} \right\rfloor g + (j+1)(t+v)}{h} \Bigg) + \frac{1 + j - 2\left\lfloor \frac{j}{2} \right\rfloor}{2} \ln \frac{\left(\left\lceil \frac{j+1}{2} \right\rceil d + \left\lceil \frac{j+1}{2} \right\rceil g + (j+1)(t+v) \right)^2 + h^2}{\left(\left\lfloor \frac{j}{2} \right\rfloor d + \left\lfloor \frac{j}{2} \right\rfloor g + (j+1)(t+v) \right)^2 + h^2} \Bigg)$$

$$+ gT \Bigg(j \Bigg(\tan^{-1} \frac{\left\lceil \frac{j+1}{2} \right\rceil d + \left\lceil \frac{j+1}{2} \right\rceil g + (j+1)(t+v)}{h} - \tan^{-1} \frac{\left\lfloor \frac{j}{2} \right\rfloor d + \left\lfloor \frac{j}{2} \right\rfloor g + (j+1)(t+v)}{h} \Bigg) + \frac{1 - j + 2\left\lfloor \frac{j}{2} \right\rfloor}{2} \ln \frac{\left(\left\lceil \frac{j+1}{2} \right\rceil d + \left\lceil \frac{j+1}{2} \right\rceil g + (j+1)(t+v) \right)^2 + h^2}{\left(\left\lfloor \frac{j}{2} \right\rfloor d + \left\lfloor \frac{j}{2} \right\rfloor g + (j+1)(t+v) \right)^2 + h^2} \Bigg) \Bigg)$$





4 …allowing for observation of 3-D silicon 'walls' showing increased neutron conversion within each structure in proportion to structure shape and converter thickness

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