

# HEP - Cosmic Frontier and Material Science

## 18<sup>th</sup> Geant4 Collaboration Meeting

A. Dotti ; Seville ; 21<sup>st</sup> September 2013

Contributing Material: L. Pandola, D. Brandt, D. Wriqth, J. Singal

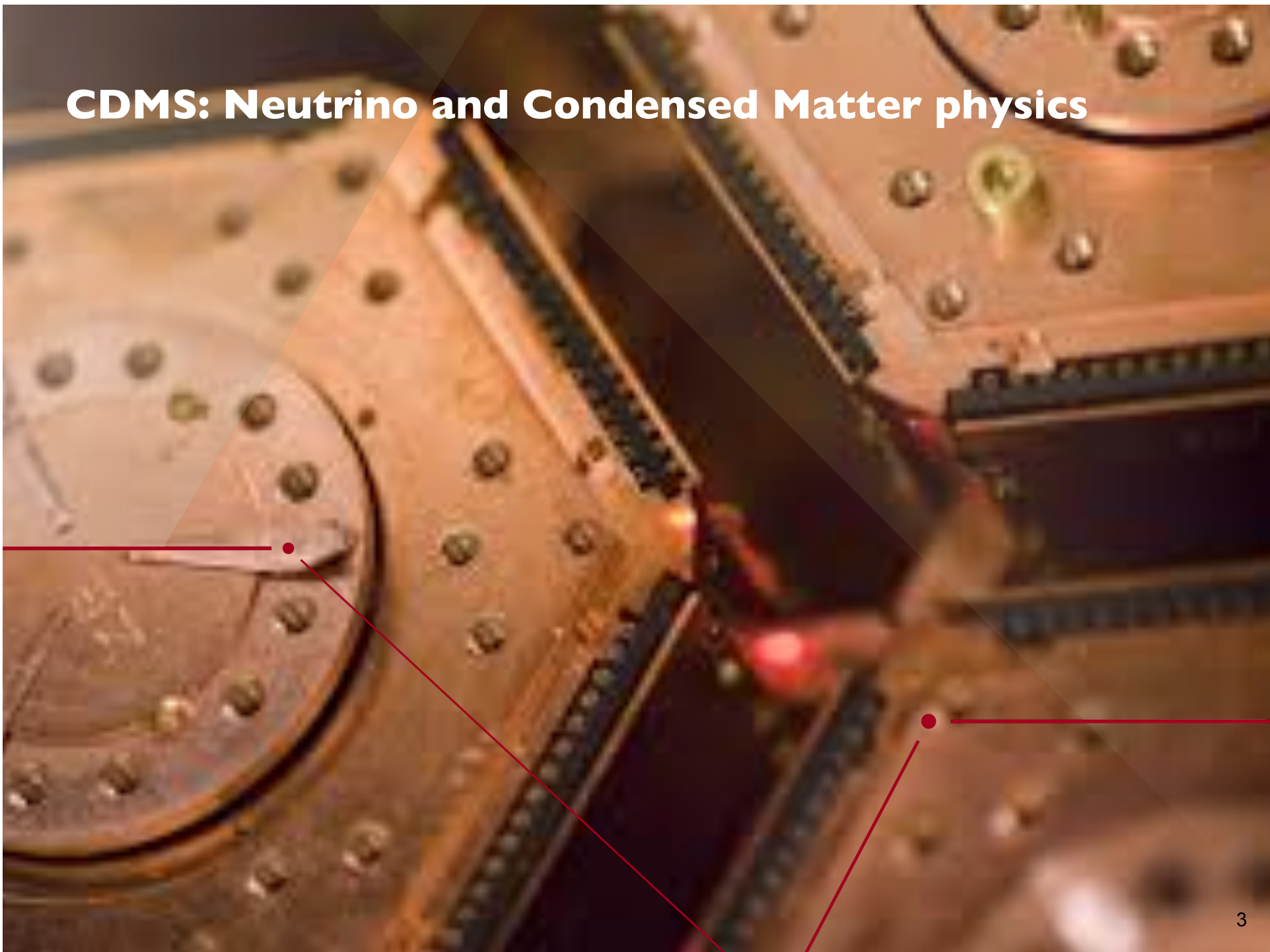


## Note

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- Only main updates shown here
- Will not discuss about supported experiments/activities using G4 with no major updates: Fermi/GLAST, EXO

# CDMS: Neutrino and Condensed Matter physics

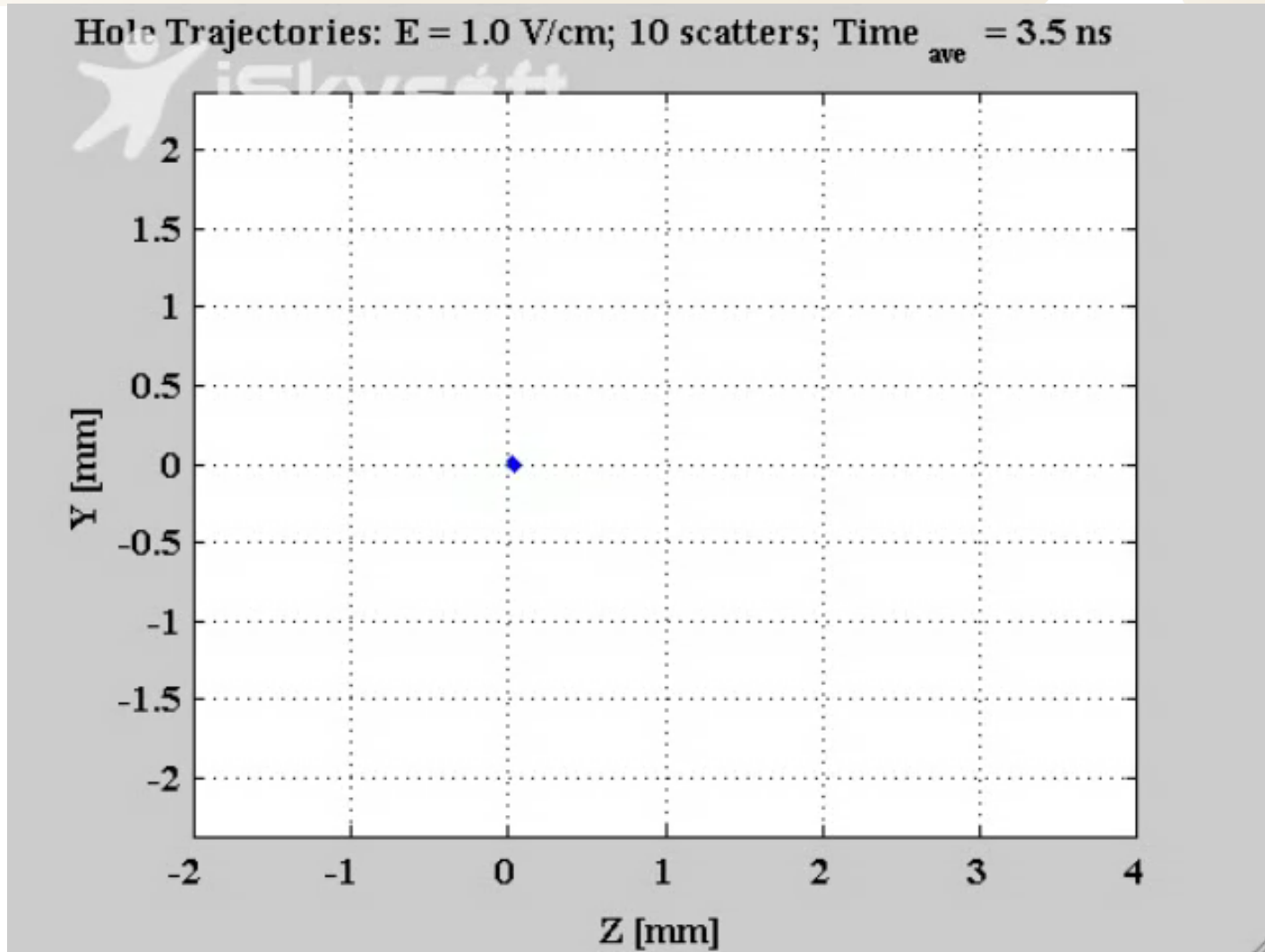


# Simulation of crystals

- CDMS requirement:
  - Simulation of **phonons** in ultra-cold crystals (example available):  
isotope scattering and mode mixing ; anharmonic down conversion ; reflection processes implemented
  - Simulation of **drifting carriers in conduction bands**
    - Oblique propagation implemented ; Luke Scattering under testing ; Intervalley scattering to be implemented
- Implemented description of crystals in G4
  - Possibility to open to new physics use cases(e.g. channeling in crystals for beam transport simulations)

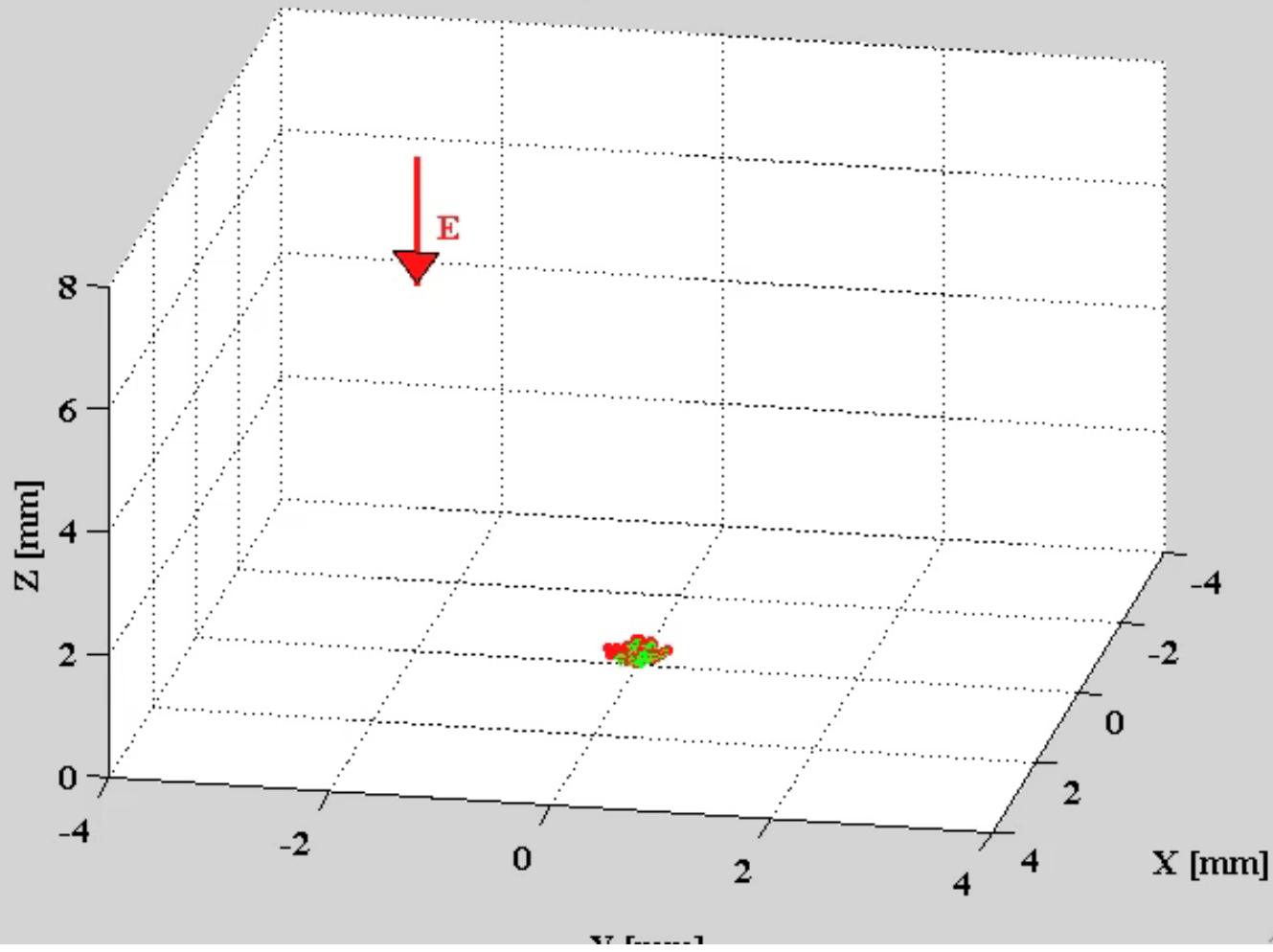


# Holes / Phonons simulation



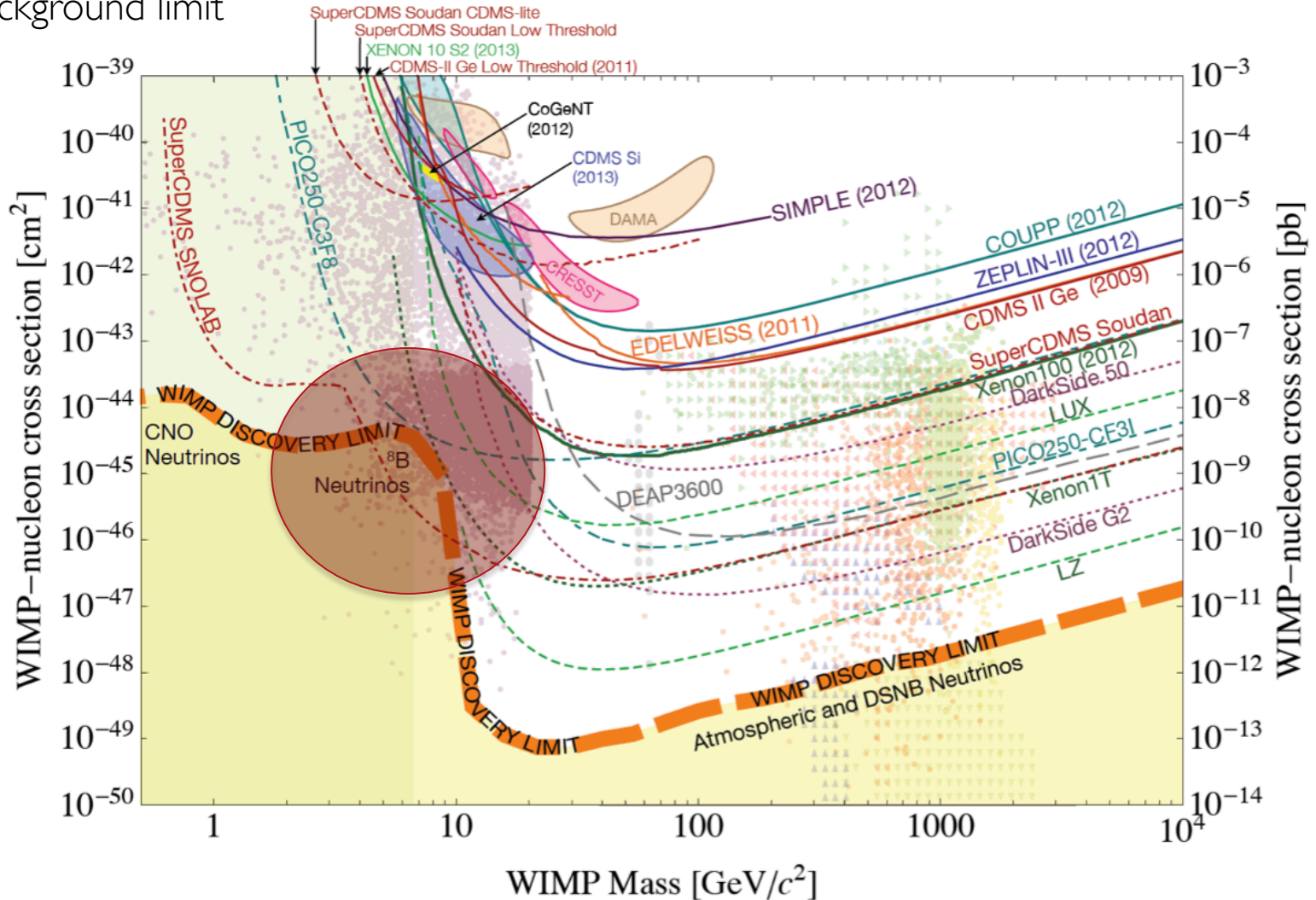
# Electrons in crystals

Electrons:  $E = 1.0 \text{ V/cm}$ ; 20 scatters;  $T_{\text{ave}} = 0.007 \mu\text{s}$ ;  $v_d = -29.5 \text{ km/s}$



# Neutrino interactions: motivation

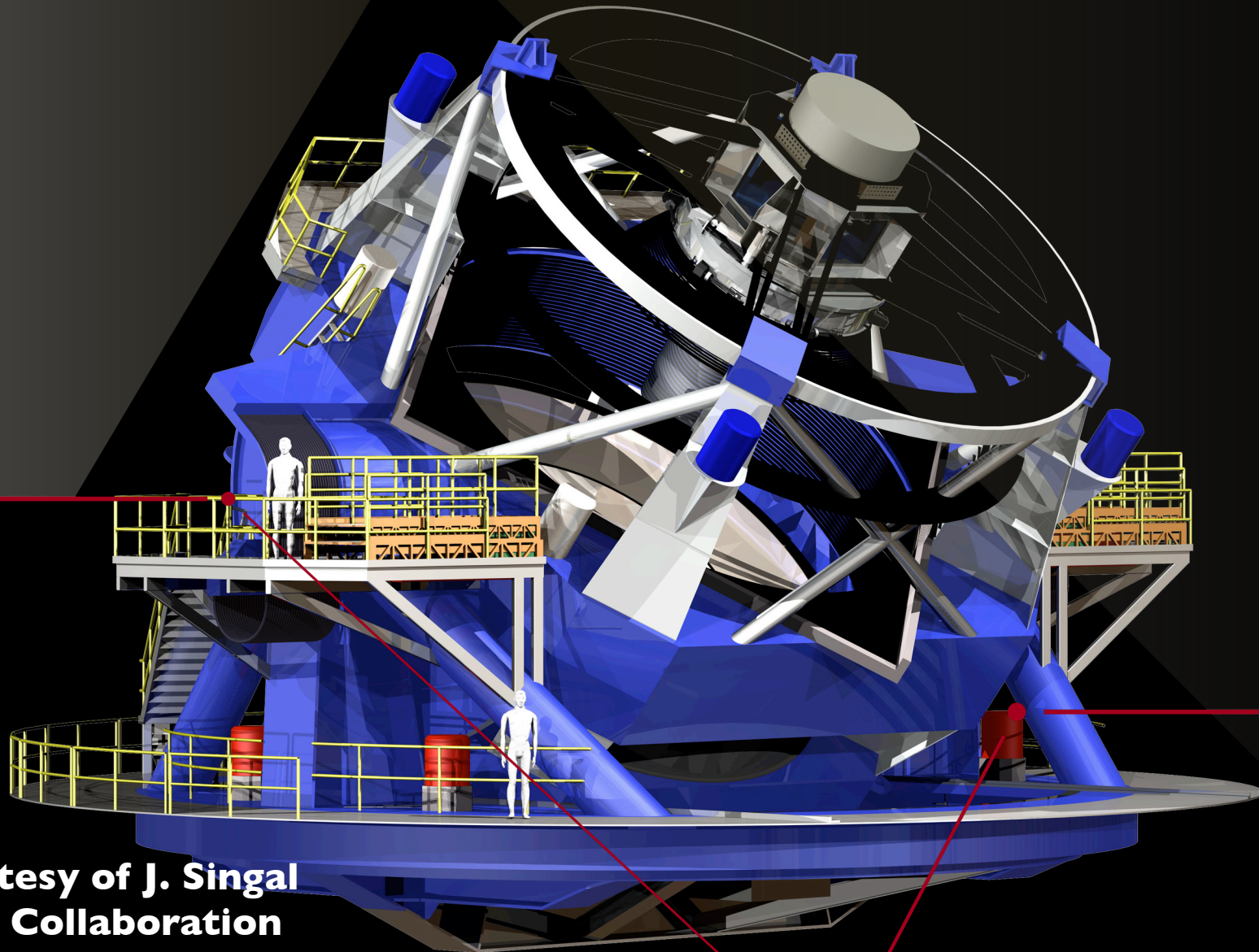
Expected performances for SuperCDMS to reach neutrino background limit



## Neutrino interactions: status

- **Discussion started** for inclusion of processes:
  - SLAC/TRIUMF contacted GENIE authors: G4-GENIE interface could be developed
  - KISTI expressed interest in developing novel models
- Requires coordination with activities on biasing

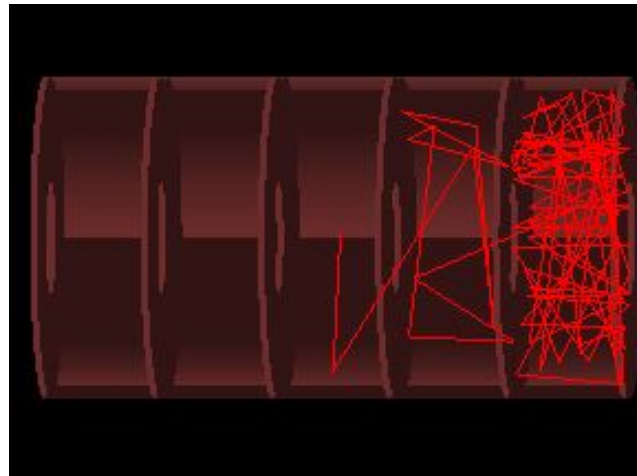
# LSST: Novel use of Geant4



Courtesy of J. Singal  
LSST Collaboration

# Vacuum Transport

- Vacuum transport in the molecular flow regime involves **repeated adsorption and reemission at surfaces**
- Each reemission event has a random component to the direction, necessitating a **Monte Carlo treatment** for simulation
- Geant4 is a natural solution for handling Monte Carlo in **complex geometries**



Details:

“Geant4 Applications for Modeling Molecular Transport in Complex Vacuum Geometries.” J.Singal, J. Langton, R. Schindler, Int J Mod Sim Sci Comp, in press (arXiv:1302.2963)

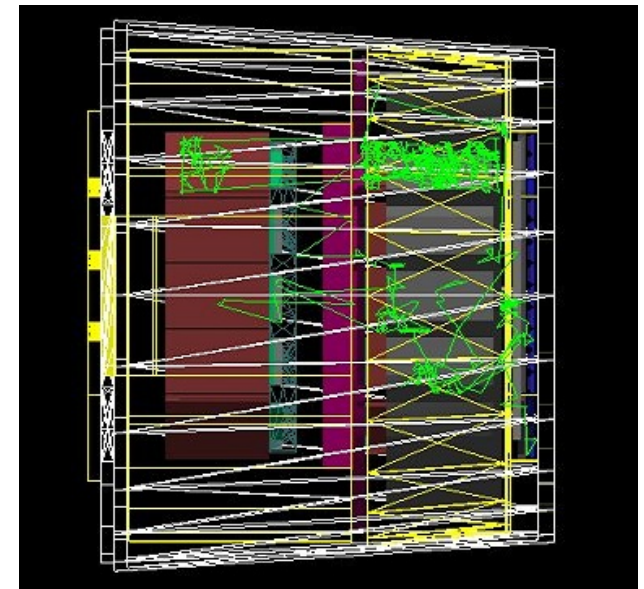
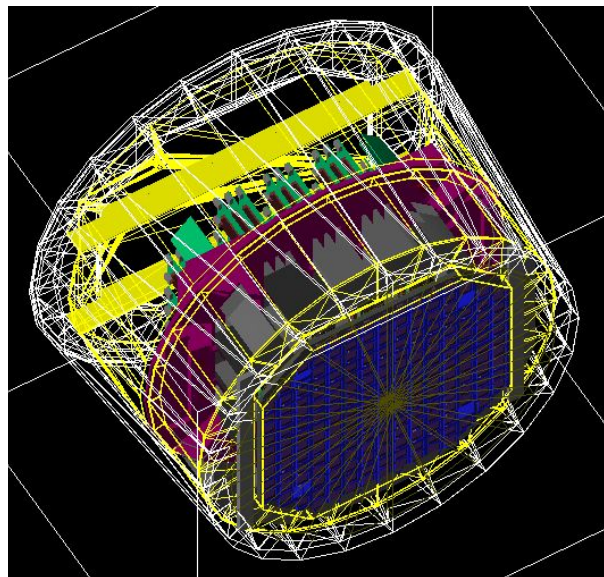
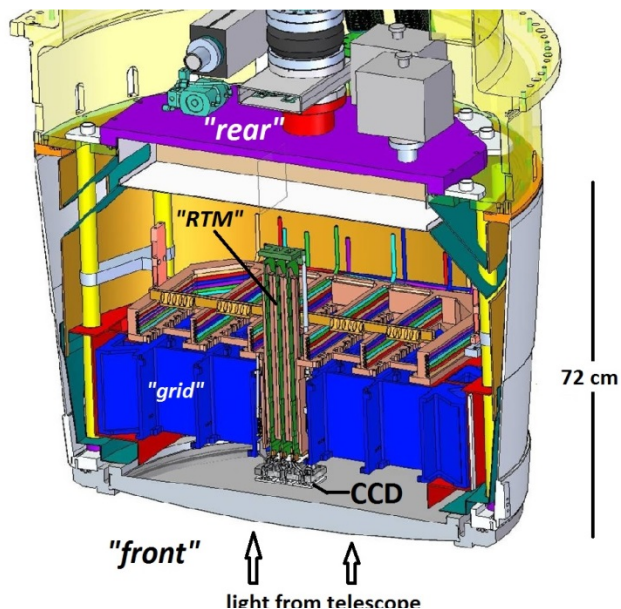
Application source: <http://sourceforge.net/projects/geant4vacmod>



# LSST Vessel

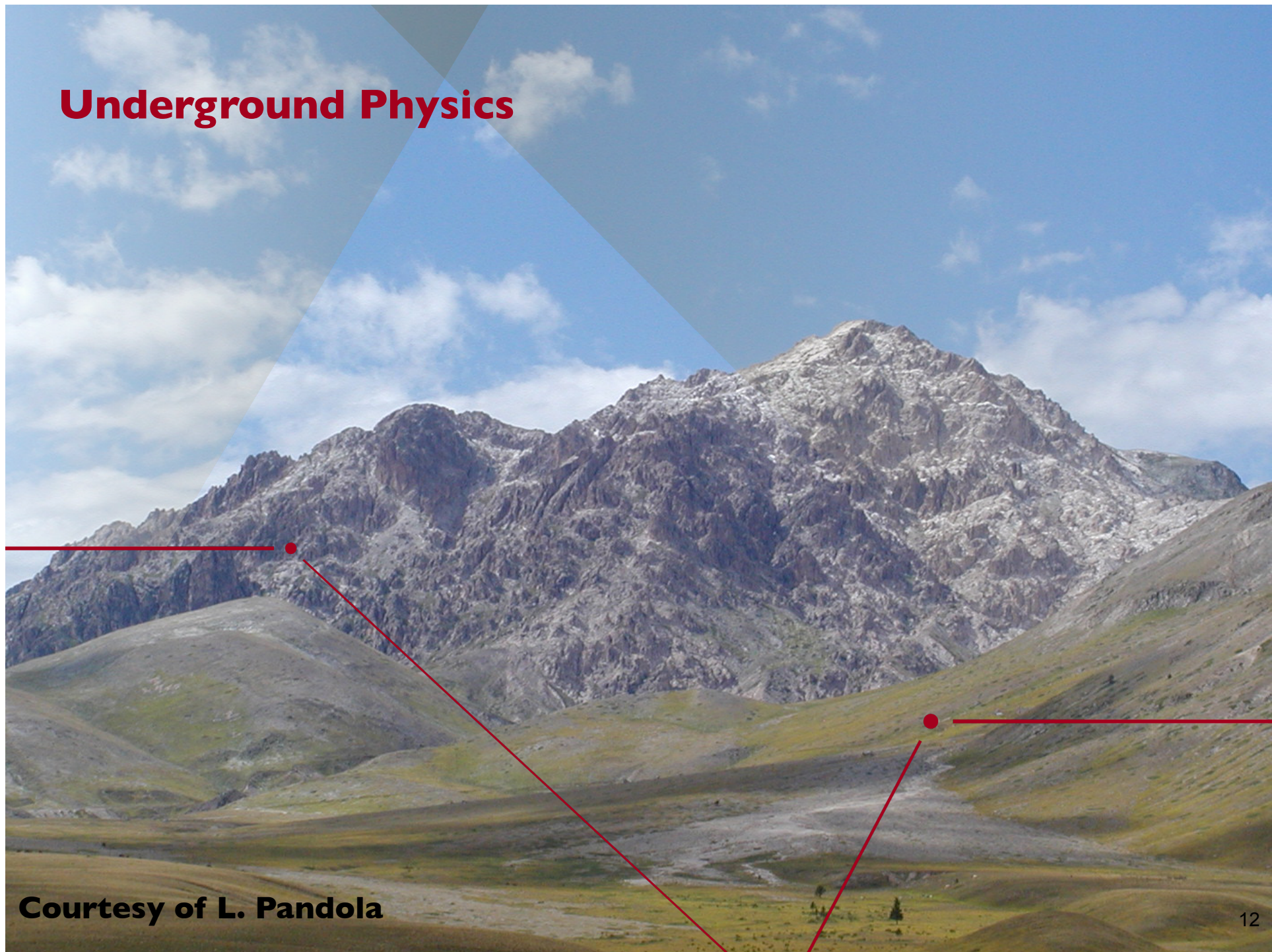
- Outputs can be e.g. **probability for reaching a certain region versus exiting** through a pump port
- Technique verified with relatively simple test geometries and comparison with results in literature (see arXiv:1302.2963)
- Results for complex geometry (LSST Camera Cryostat) already informing design choices for shrouds, pump diameters, etc.
- Future extension may incorporate **temperature-dependent** sticking probabilities

Complex geometry: LSST camera cryostat





# Underground Physics



Courtesy of L. Pandola

# Underground Physics - I

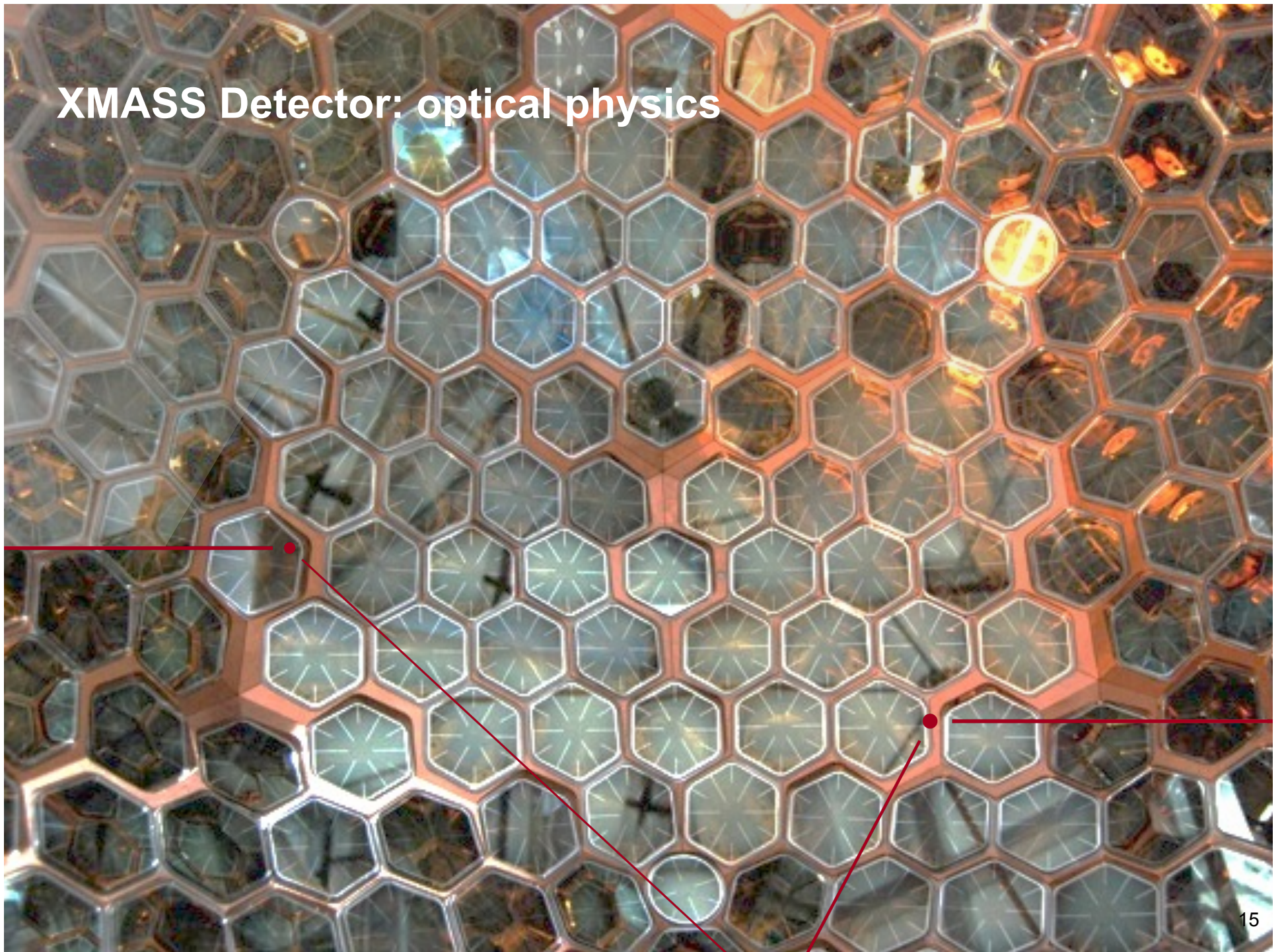
- Physics **items** and **requirements** are **very specific** of this community, with **small overlaps/** synergy with other Geant4 user communities
  - ... with some exceptions
- Difficult to find manpower in G4 to address requirements
- Usual **physics items** of **interest** for underground physics experiments
  - **Low energy** EM, low energy neutrons
  - **Cosmic ray** muons
  - Radioactive **isotopes**
    - Pretty much **improved** in the past couple of years
  - **Scintillation light** and **optical photon** propagation

## Underground Physics - 2

- Low-energy neutrons ( $< 20$  MeV), including elastic scattering, capture and inelastic interactions
  - Gamma rays from radiative captures
- Radioactive decay
  - Still need to improve the interface between RadioactiveDecay and AtomicDeexcitation
- Optical photons
  - Looks like the community is a good “customer” for these models: most experiments have simulation of the light response of detectors and are happy with them
- Low energy EM physics
  - Most experiments (e.g. Dark Matter) look for events in the 10 keV scale
- Showers induced by cosmic ray muons
  - Production of unstable isotopes and prompt neutrons in the showers



# XMASS Detector: optical physics

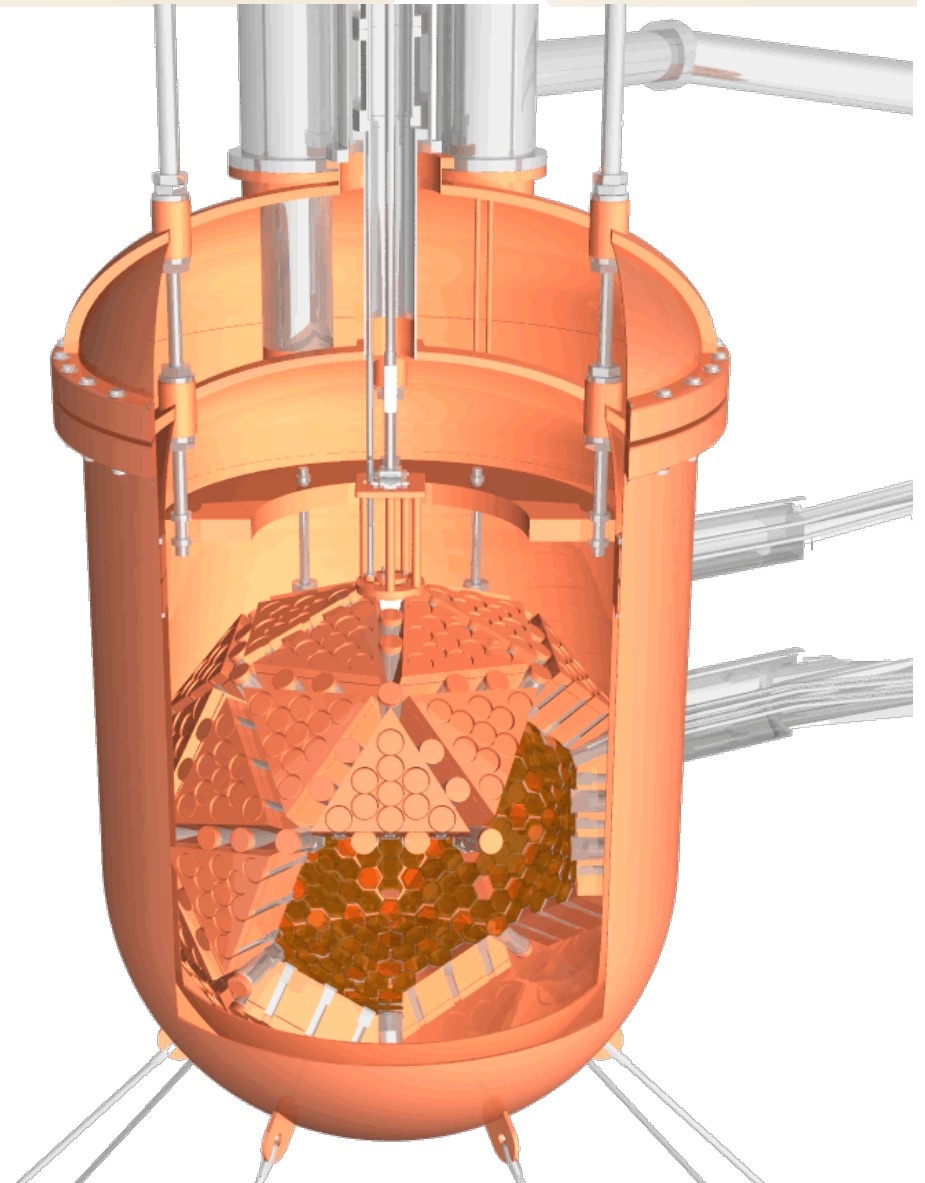
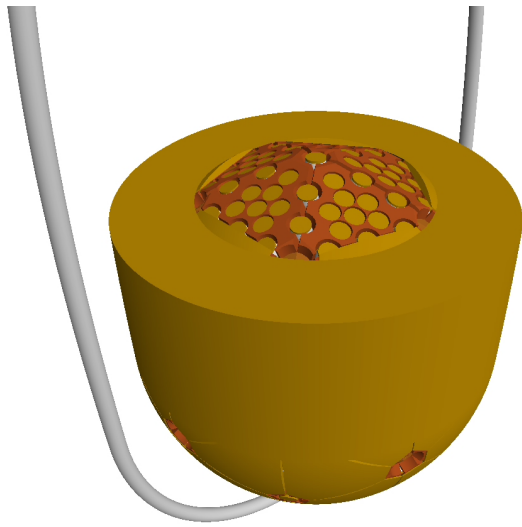




## Optical processes in layered mass geometry

SLAC

- Complex detector geometry implemented with layered mass geometry
- Optical processes have been updated for parallel worlds



# Conclusions

- Cosmic frontier / underground physics are using Geant4
- Specific needs developed by community
- Sharing of code is possible for common needs
  - e.g. Radioactive Decay, Low-Energy neutrons
- New interesting use cases:
  - Neutrino interactions (SuperCDMS G2 background)
  - Condensed matter physics (phonons in cryogenic temperature, channeling effect)
  - Vacuum vessel (LSST)