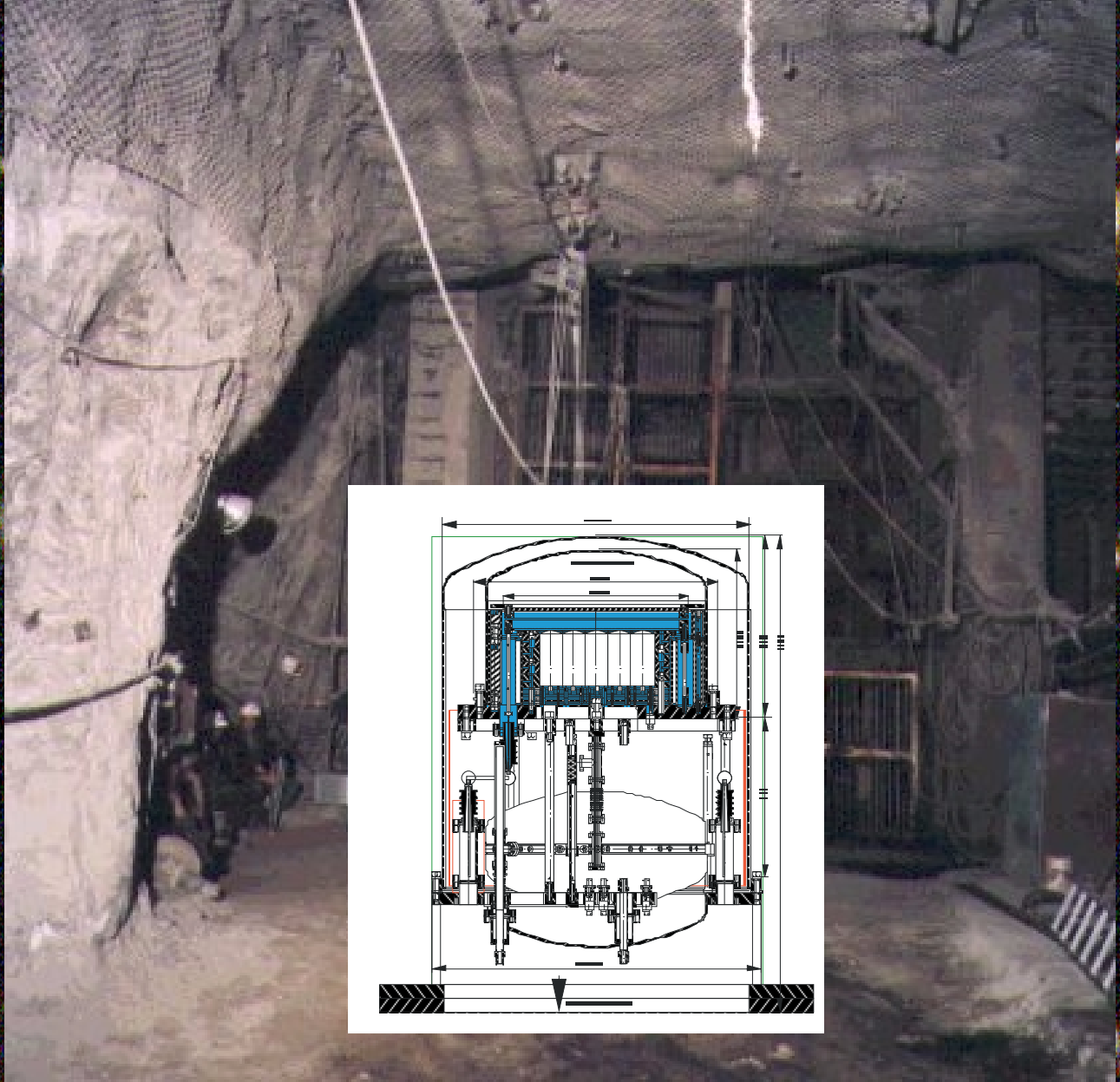
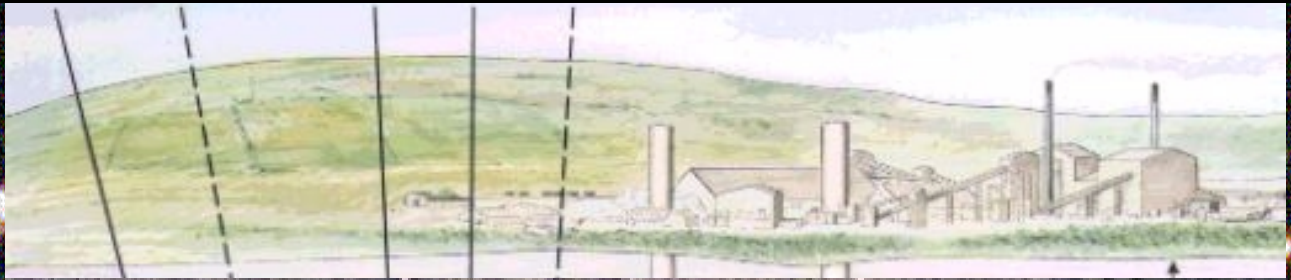


UNDERGROUND PROJECT – Overview and Goals



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Underground Project - Overview

- Brief Introduction to Dark Matter Detectors
- Aims of the Project
- Simulation Stages
- Zeplin III – Geometry
- Physics Processes
- Simulation Output
- Analysis
- Conclusions

Dark Matter Detectors

Direct dark matter detectors search for elastic nuclear recoil scattering signals from suspected WIMP interactions

The recoiling nucleus target produces a signal in the form of scintillation and ionisation. However the signal rate is extremely low (<0.1 events/kg/day)

It is important to be able to discriminate between the large levels of background ($\sim 10^6$ evts/day) and this extremely low signal

The majority of the background comes from gamma rays from local radioactivity

Background also comes from secondary nuclear products such as neutrons and gammas from alpha interactions

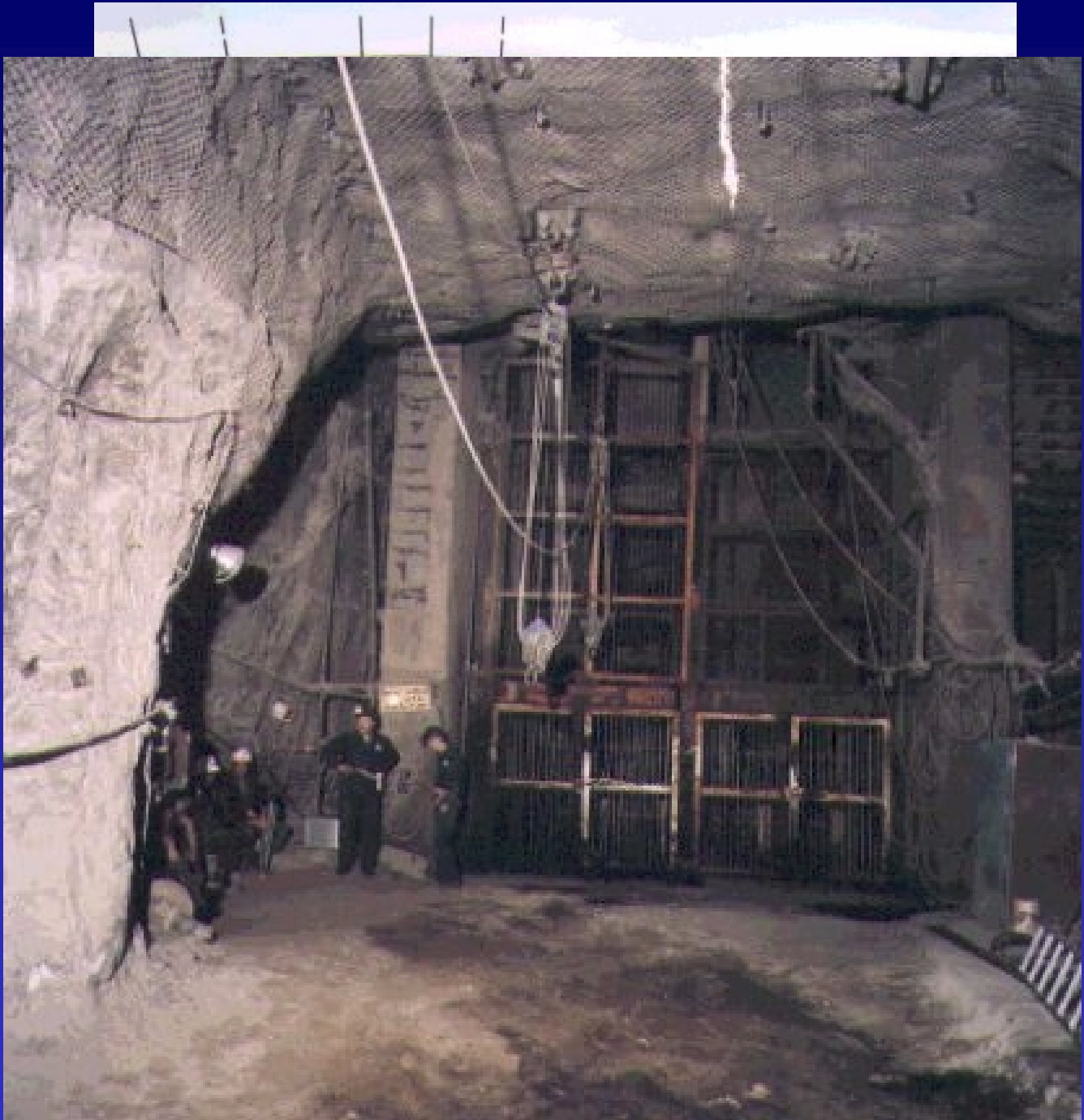
Rare background processes, detector systematics and inhomogeneities may ultimately lead to mis-interpretation of the output.

Dark Matter Detectors

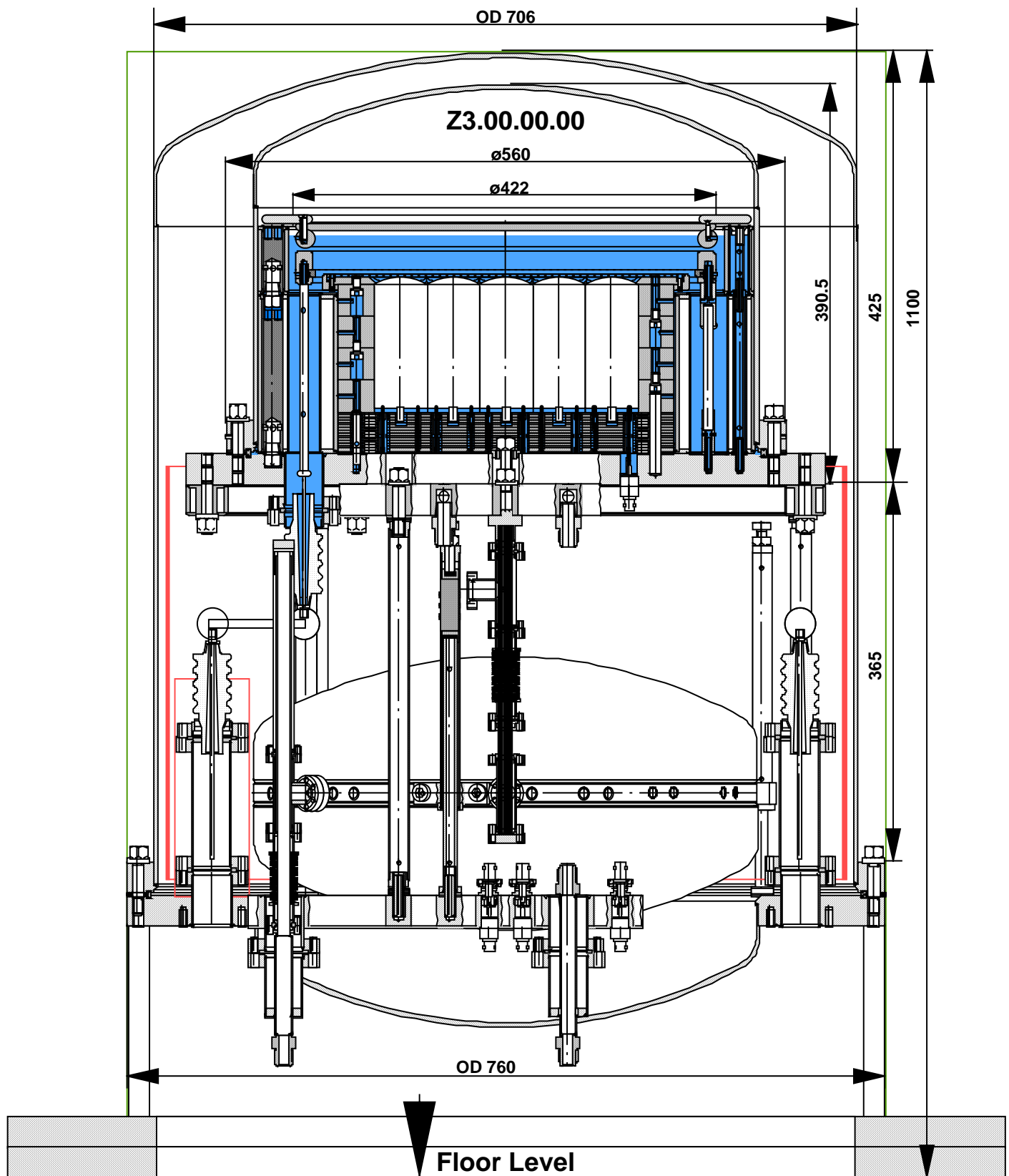
Therefore dark matter detectors require the following constraints:

- Very Low Background →
 - Go Underground +
 - Fabricate from low radioactivity materials
- Low Threshold Energy →
 - High Sensitivity/Signal output
- Clear Discrimination →
 - Dominant backgrounds are γ -rays
 - Dark Matter candidate signals Should look like Nuclear Recoils
- Understanding Systematics →
 - Any measured signal may be caused by rare vagaries of the detector system
- Identifying unknown/irreducible backgrounds →
 - Photonuclear neutrons
 - Multiple low energy γ -interactions
 - ... etc...

The Boulby Mine Facility

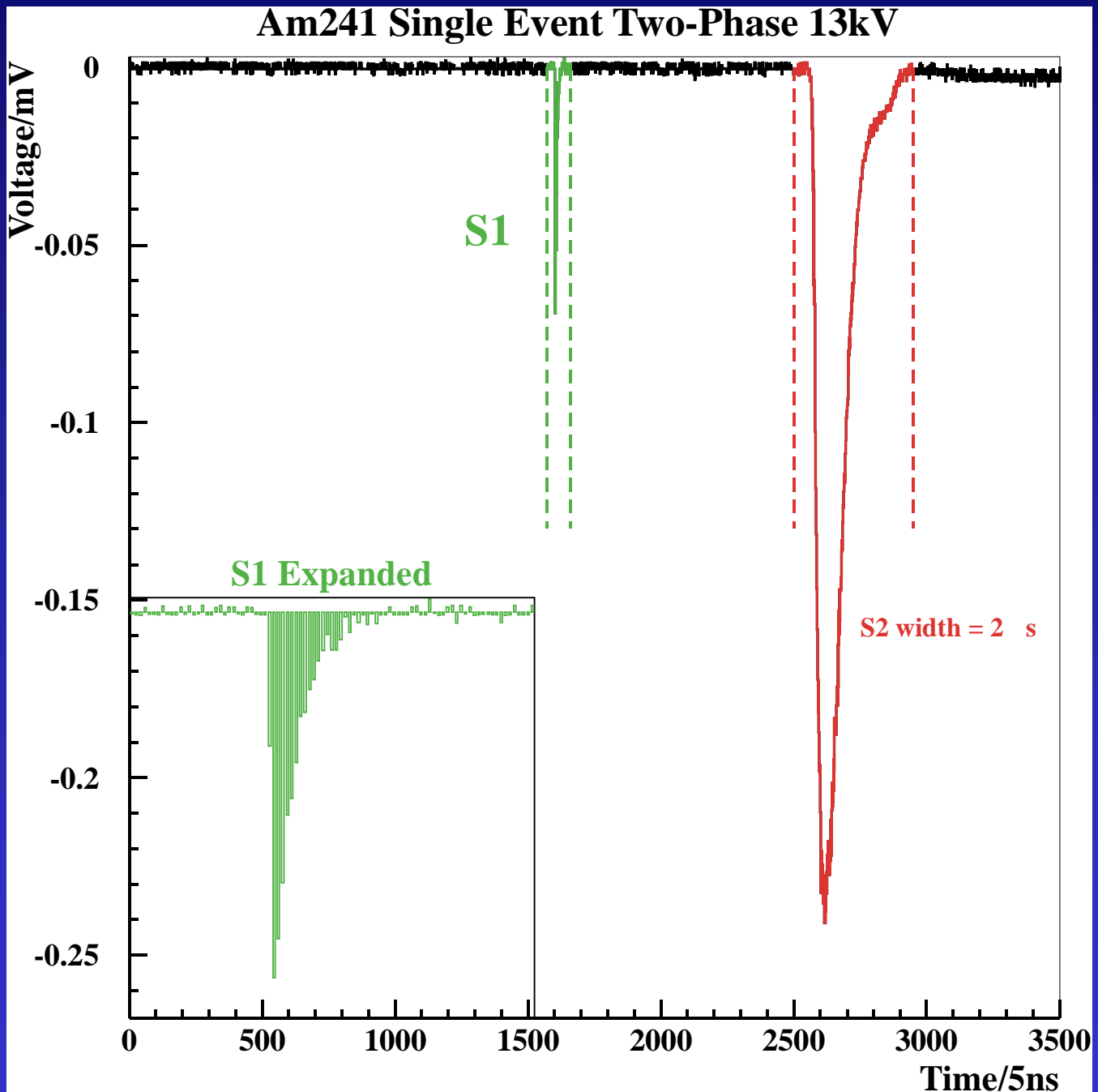


ZEPLIN III



Electroluminescence Signals

By running at an electric field of 13kV electron separation, extraction and then luminescence in the gas phase can be clearly seen:



Project Aims

- **To simulate the complete underground environment from cosmic rays to cavern via the 1.1km of rock between the surface and the underground detector;**
- **Reproduce background contribution from cosmic rays, local environment and construction materials and provide realistic events within the detector volume;**
- **Record energy deposition in the active volume and produce detector-like output via ray-tracing and digitisation;**

This project is a precursor to an advanced underground example that will be included in the December release

Simulation Stages

1. High energy muons and neutrinos inputted at the surface;
1. Muons tracked through the rock into the underground cavern – an average chemical composition of the rock should be adequate;
- ;
- ’ Reproduce local environment impinging on the detector

Additional contributions to detector background will come from the radioactive isotope composition of the construction materials – both internally and externally of the detector system – RDM;

Store energy deposition in veto to remove higher energy gamma events;

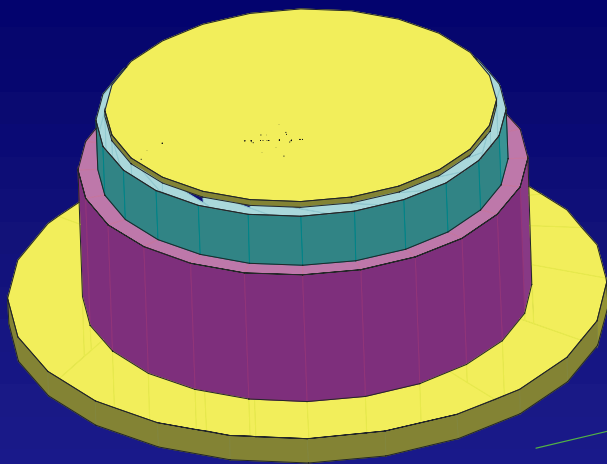
Transport is then required through the detector geometry into the active volume of liquid xenon;

The energy deposition in this volume is converted into scintillation photons;

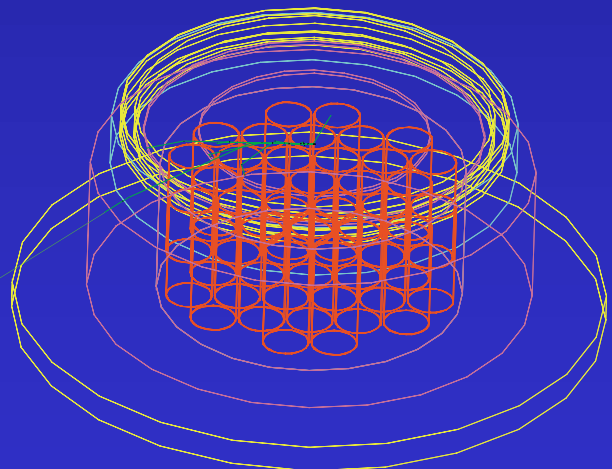
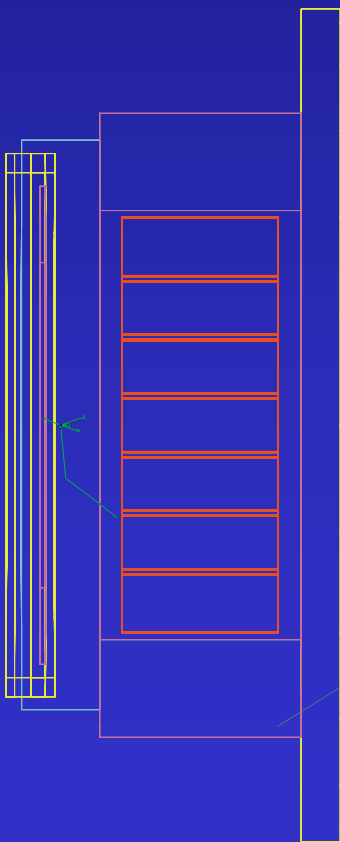
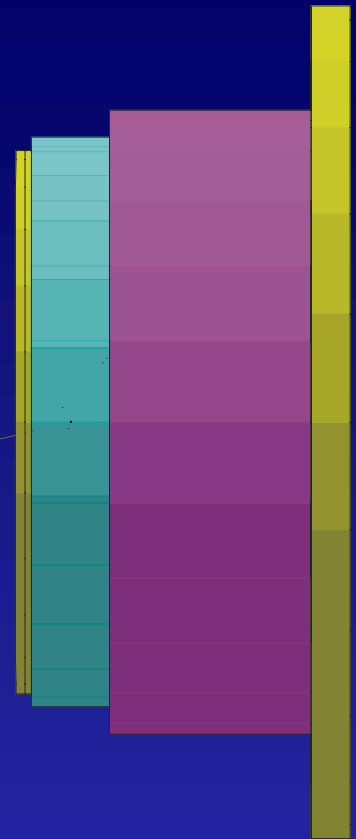
Ray tracing is applied to determine the number of photons reaching the PMT array;

DAQ type digitisation is then applied to the photon levels to include effects of Poisson statistics, Time Profile, Noise, Limited ADC Range etc.....

Geometry Set-up



Has already been partially implemented within Geant4



Geometry Set-up – Additions

An organic scintillator based veto should encapsulate the liquid xenon detector

The local cavern wall materials should be included (substantial ^{40}K contribution)

The rock between the surface and the detector environment – the mine facility is 1.1km deep with a water equivalent of 3.3km. However it is unclear what the true high energy spectrum is underground

Physics Processes

The physical processes required are:

- **Standard Electromagnetic**
- **Low Energy Electromagnetic**
 - Compton
 - Photoelectric,
 - Bremsstrahlung
 - Rayleigh
 - electromagnetic ionisation
 - Delta Rays
 - Heavy Ion Transport
- **High Energy Muon Tracking**
- **Radioactive Decay Module**
 - Implement radioactive composition of internal construction materials with forced M/C decay as well as real-time – requires implementation/definition of equilibrium conditions.

Analysis

Online:

The analysis should provide run-time histograms of energy deposition, deposition and multiplicity.

Offline:

Ntuple type output.

- True energy deposition
- Measured energy
- True position (x,y,z)
- Reconstructed position (primitive centroid of measured light)
- Veto energy deposition
- Veto position
- Multiplicity (for looking at each part of a multiple gamma interaction individually and combined)
- Time (with the RDM real-time-like output should be generated)
- Primary source particle-type
- Primary source particle energy.

Full record track for debugging purposes

User Interface

It would be useful for the user to carry out basic changes during run-time including:

- Active geometry set-up/dimension
- Location of source particle, type and energy
- Forced decay of isotopes
- Calibration/Characterisation of the ray-tracing and detector digitisation via internal mono-energetic source within the volume

Conclusions

It is hoped that this project will produce the first Geant4 based simulation of an underground experiment

Previously Dark Matter detectors have not been properly simulated

Await the end of the week for final conclusions.....