Overview of the Outer Muon System

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Correlated Muon Backgrounds

- Spallation Neutrons
  - Primarily of concern when the muon is not detected
    - Want to increase detectable volume for muons which hit the rock outside of the primary detector
  - From CHOOZ, ~10% background
    - Doubled target volume and additional neutron attenuation in mineral oil buffer reduce this as a concern for the Double Chooz far detector
  - Near detector will have much higher rate
    - Muon rate is x50 but signal rate is only x10
- Muon Induced Radioactive Isotopes
  - Primarily concerned with ^{9}Li, ^{11}Li, ^{8}He
  - Evidence that these are related to high-energy “showering” muons
    - Want to detect a large dE/dx or high multiplicity for a muon which crosses the target volume
  - Implies that absolute rates are not significantly different between near and far detectors
    - Primarily a concern for the far detector

Goals for Outer Muon System

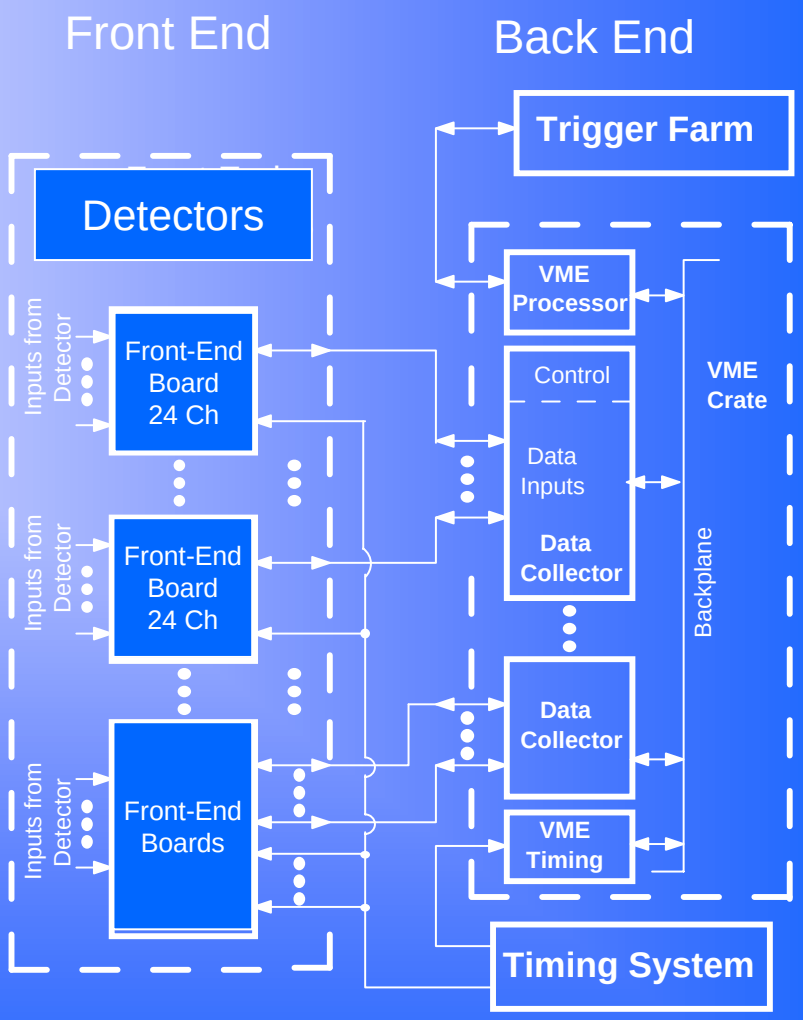
- Near Detector
  - Reduce untagged correlated neutron background to ~1%
    - 7 x 10^{-5} Hz or ~6 ev/day
  - Large area coverage with >99% efficiency
- Far Detector
  - Determine track entry point
  - Sensitivity to showering/multiplicity
  - Need small granularity and fast response
- Additional
  - Cross-check efficiency of Inner Veto System
  - Need some 3 dimensional tracking

Detector Technology

- Wire Proportional Chambers with Ar/CO_2 gas
- Effective single layer efficiency of 97%
- A coincidence of 2/3 has 99.7% efficiency and reduces singles backgrounds

Electrical Design

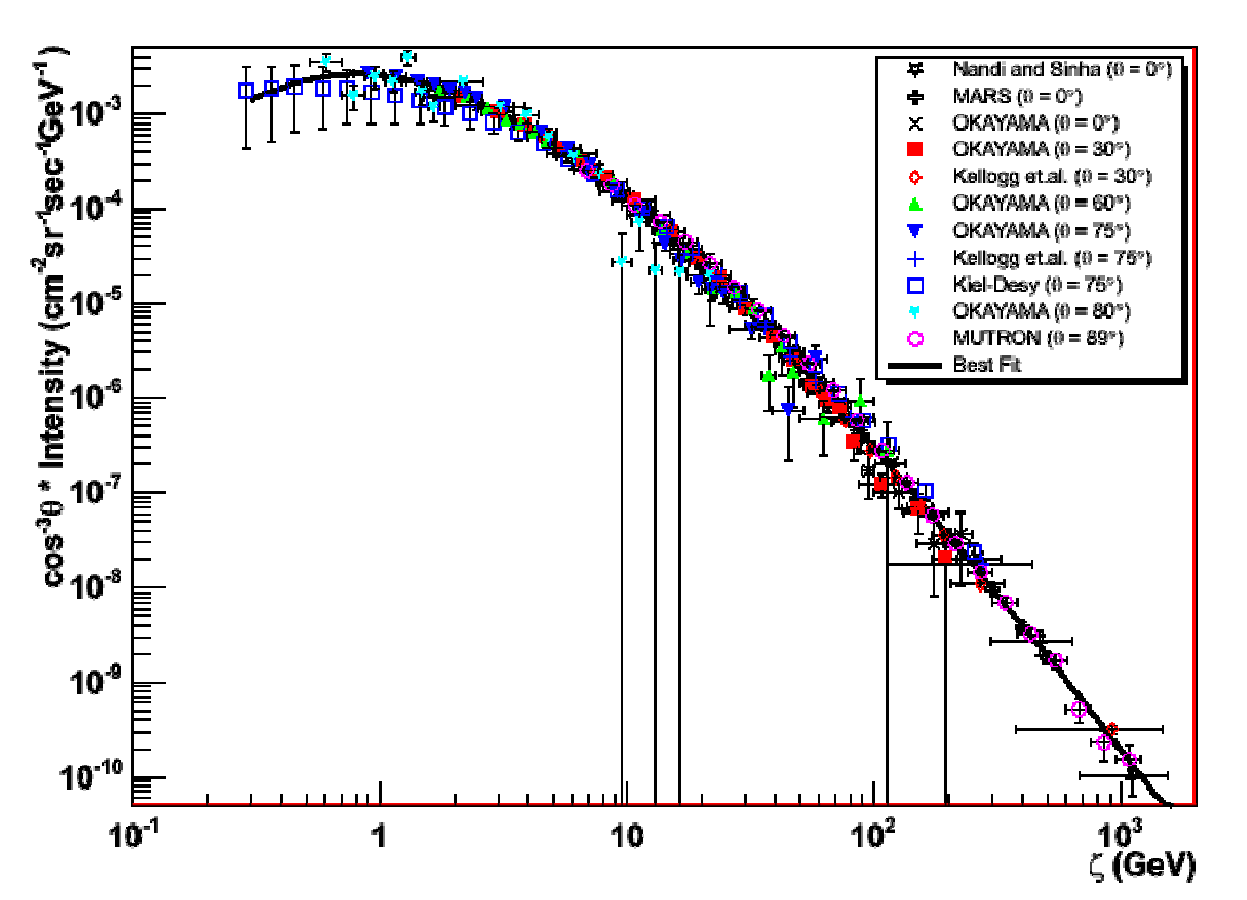
- System Block Diagram
  - Assumptions for Architecture:
    - Low Overall Trigger Rate
    - 100% Live Time (Low Trigger Rate)
    - Self-Trigger (Noise, CR)
  - Events are Tagged with Timestamps at Front End to Allow Processing Latency
  - Timestamps used for Event Reconstruction
- Front End
  - Amplifier/Discriminator made from discrete components
  - FPGA does timestamping and data processing
  - Can Self-Trigger, or Use External Trigger
  - One board for each module (24 detector channels)
  - Each data word = 24bit timestamp + 24 discriminator states



Simulation to Determine Coverage

- Use FLUKA to propagate muons from surface to near laboratory
- Record muon and neutron rates at various detector positions
- Save events in which at least one neutron entered the scintillator from outside

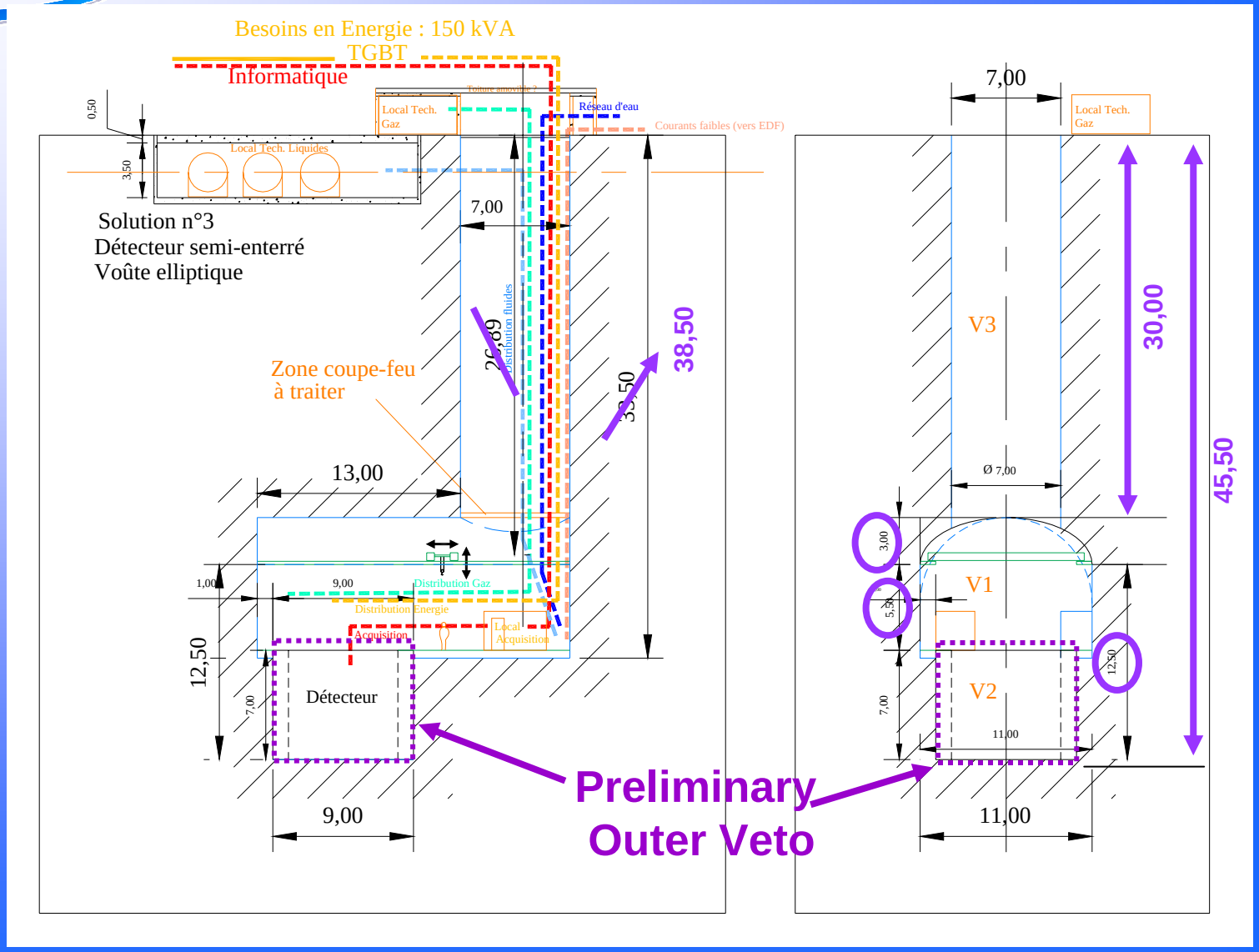
Surface Muon Distribution



For more info:
hep-ph/0604145

$$I(p_\mu,\theta) = \cos^3(\theta) I_\nu(p_\mu \cos\theta)$$

Near Lab Definition

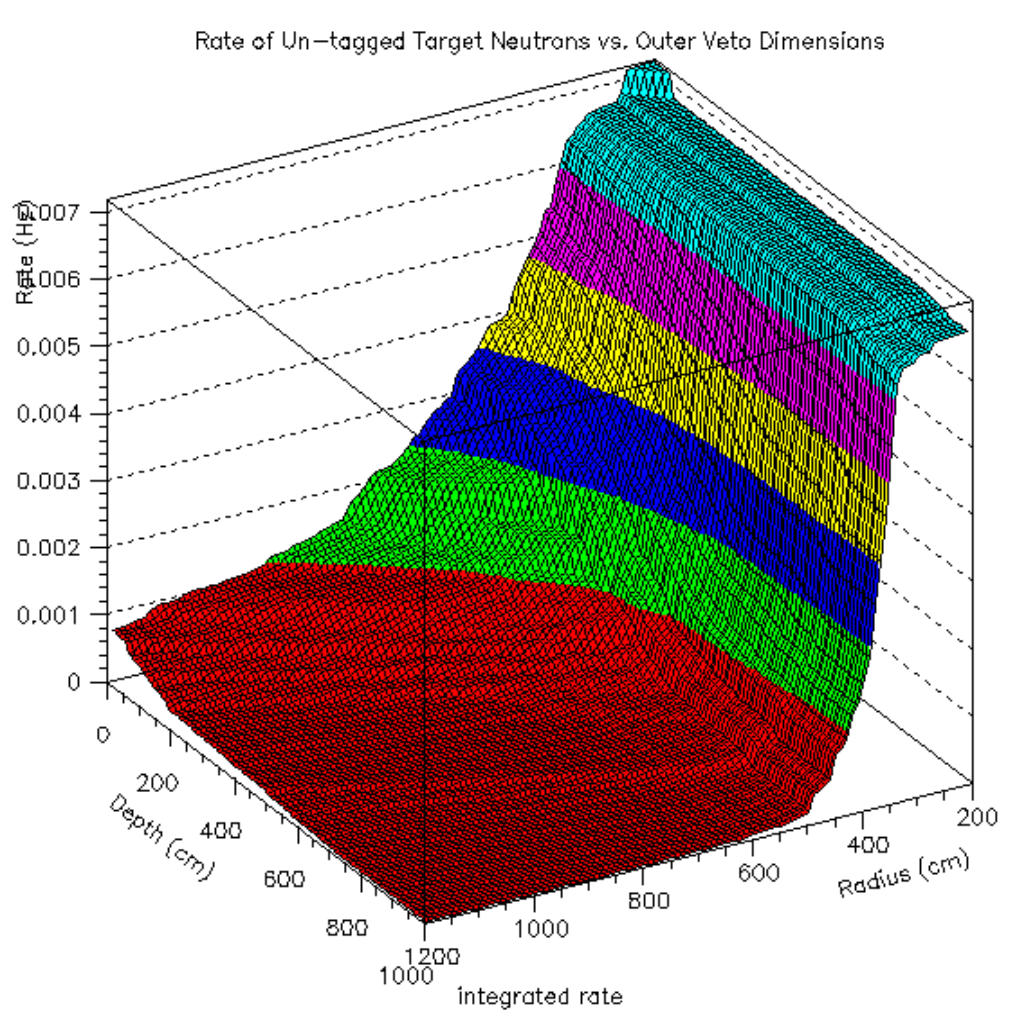


Some Basic Rates

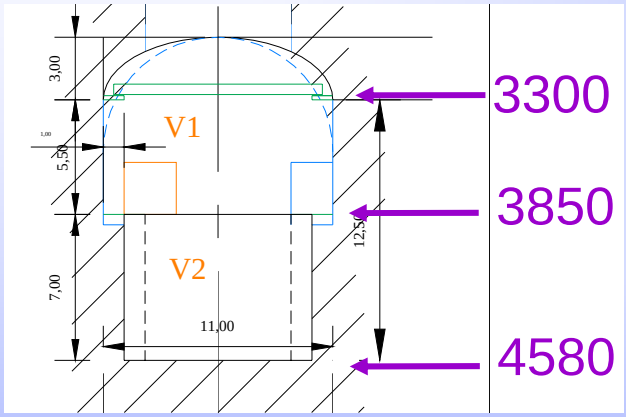
Detected Muon Rates	
Outer Veto	848 Hz
Inner Veto	658 Hz
Target + GC	314 Hz
Rate of Neutrons Entering Target + GC	
Total	0.340 Hz
Excluding Target Muon	0.104 Hz
Excluding Inner Veto	0.007 Hz
Excluding Outer Veto	0.001 Hz

Detailed Configuration Study

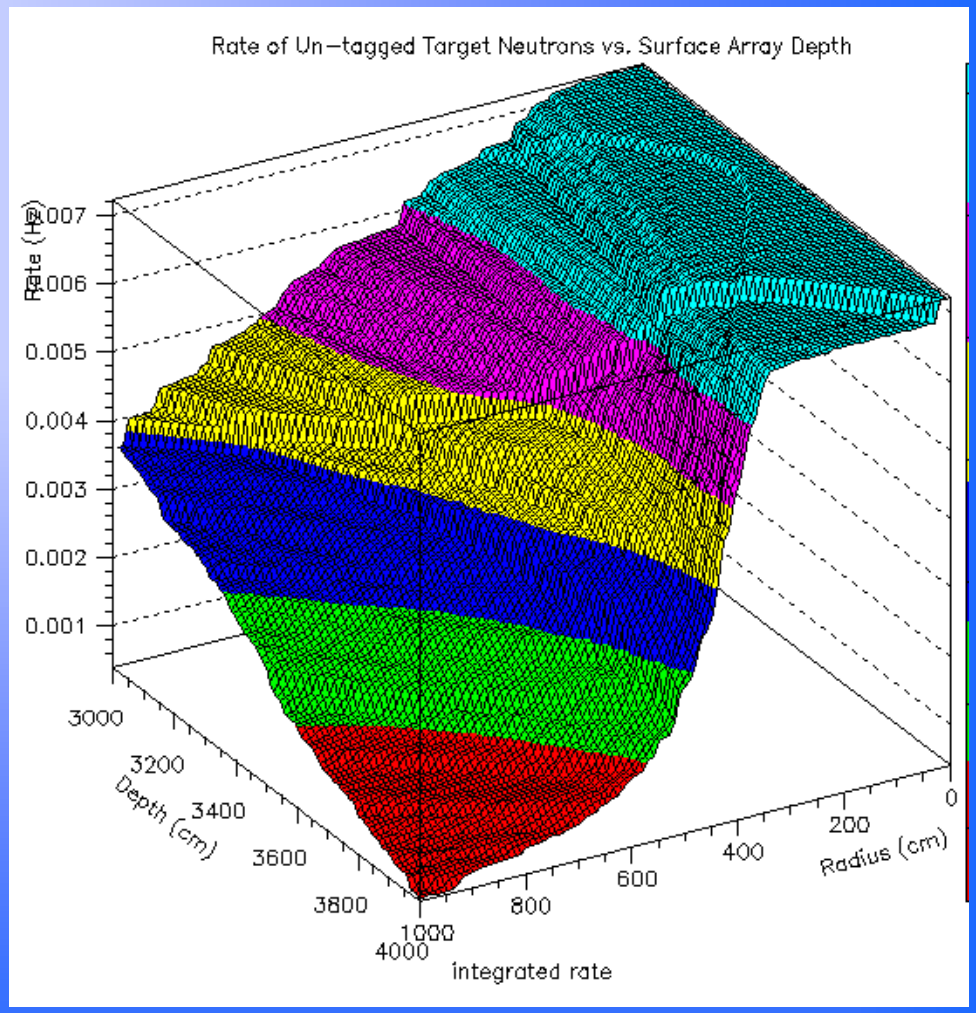
Untagged Neutron Rates for Various Detector Configurations	
Simulated cylinder (4.5m radius and 8m depth)	0.001 Hz
Top and Sides (5.2m radius and 5.2m depth)	0.0005 Hz
Top Only (7m radius)	0.0022 Hz



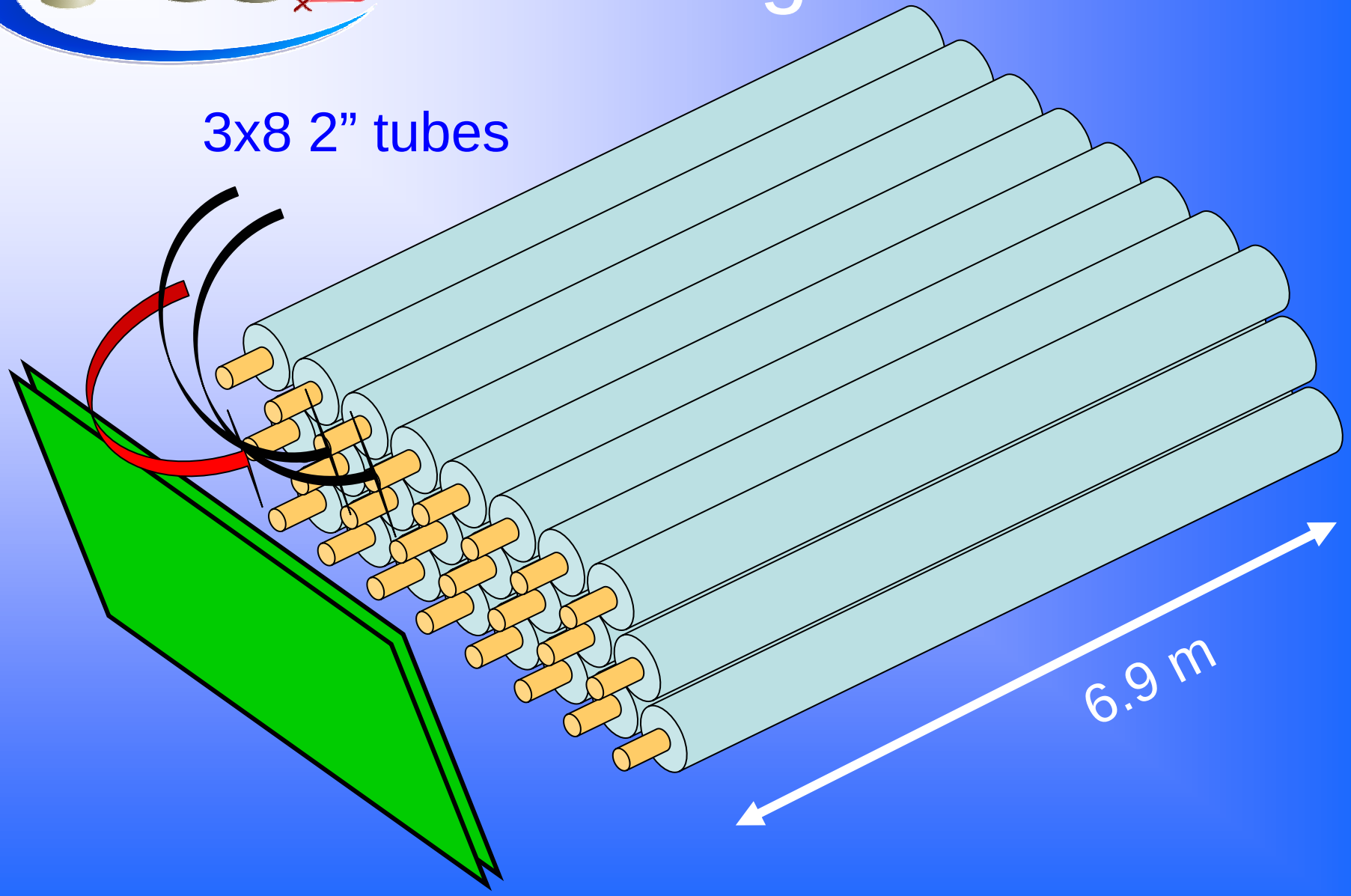
Position in Laboratory



Untagged Neutron Rates for Various Heights of a 7m Detector	
Nominal 1m above (3750)	0.0022 Hz
Top of Detector (3850)	0.0016 Hz
Top of Crane (3300)	0.004 Hz

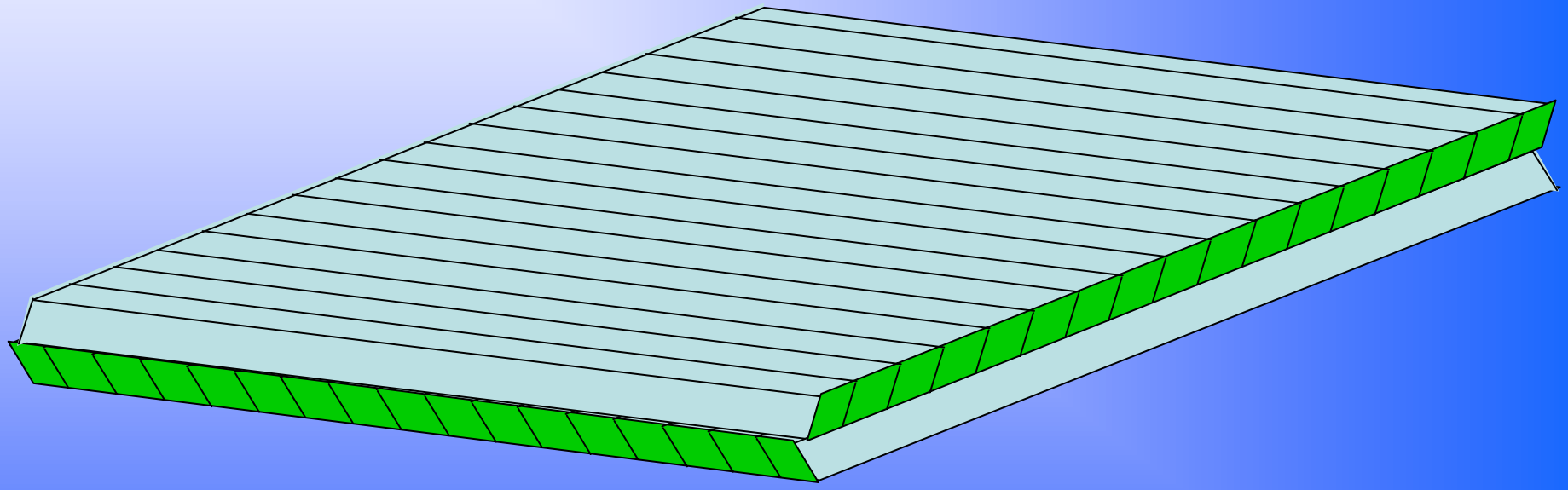


A Single Module



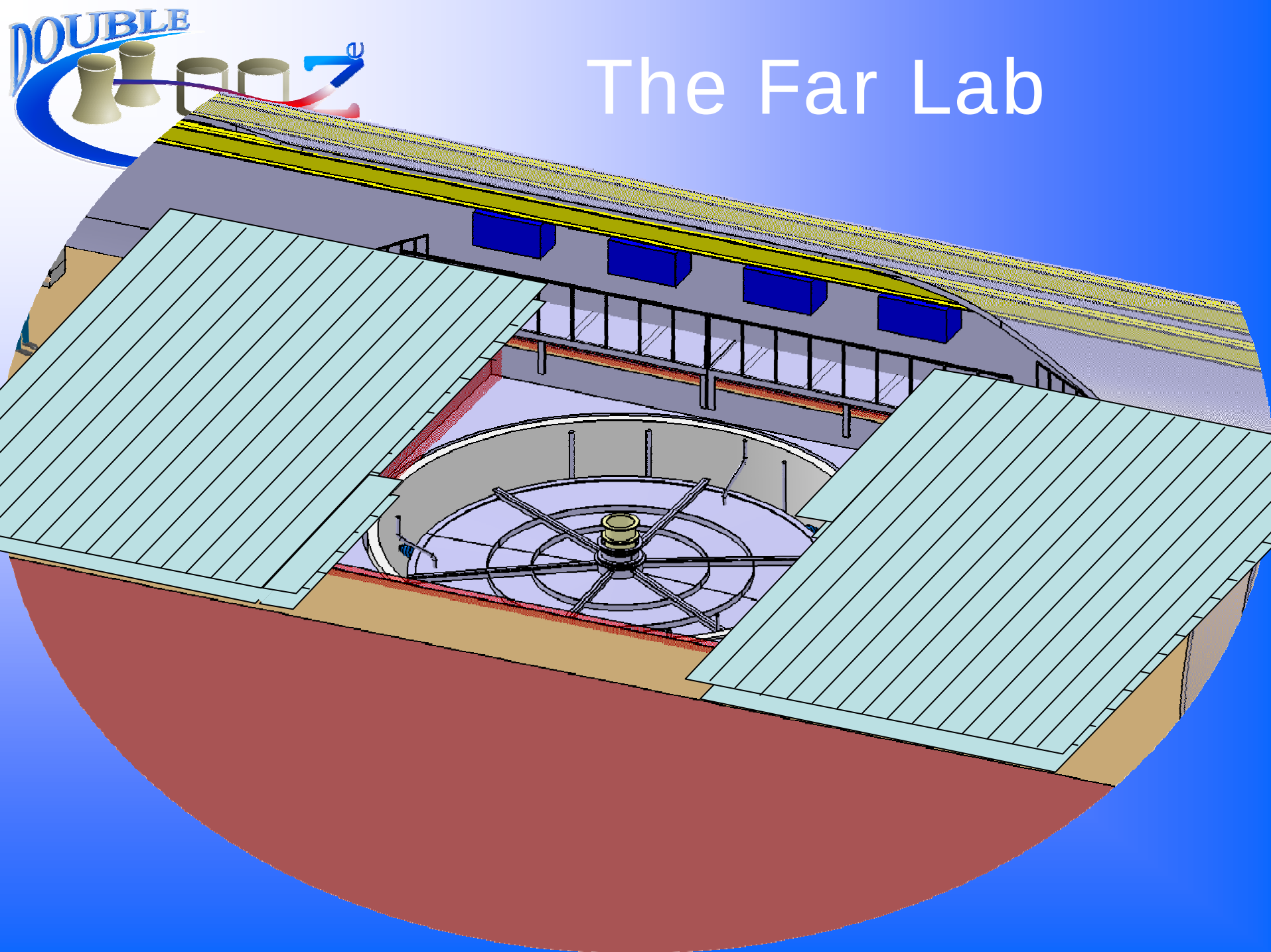
A Panel

17 modules cover a 6.9m x 6.9m area

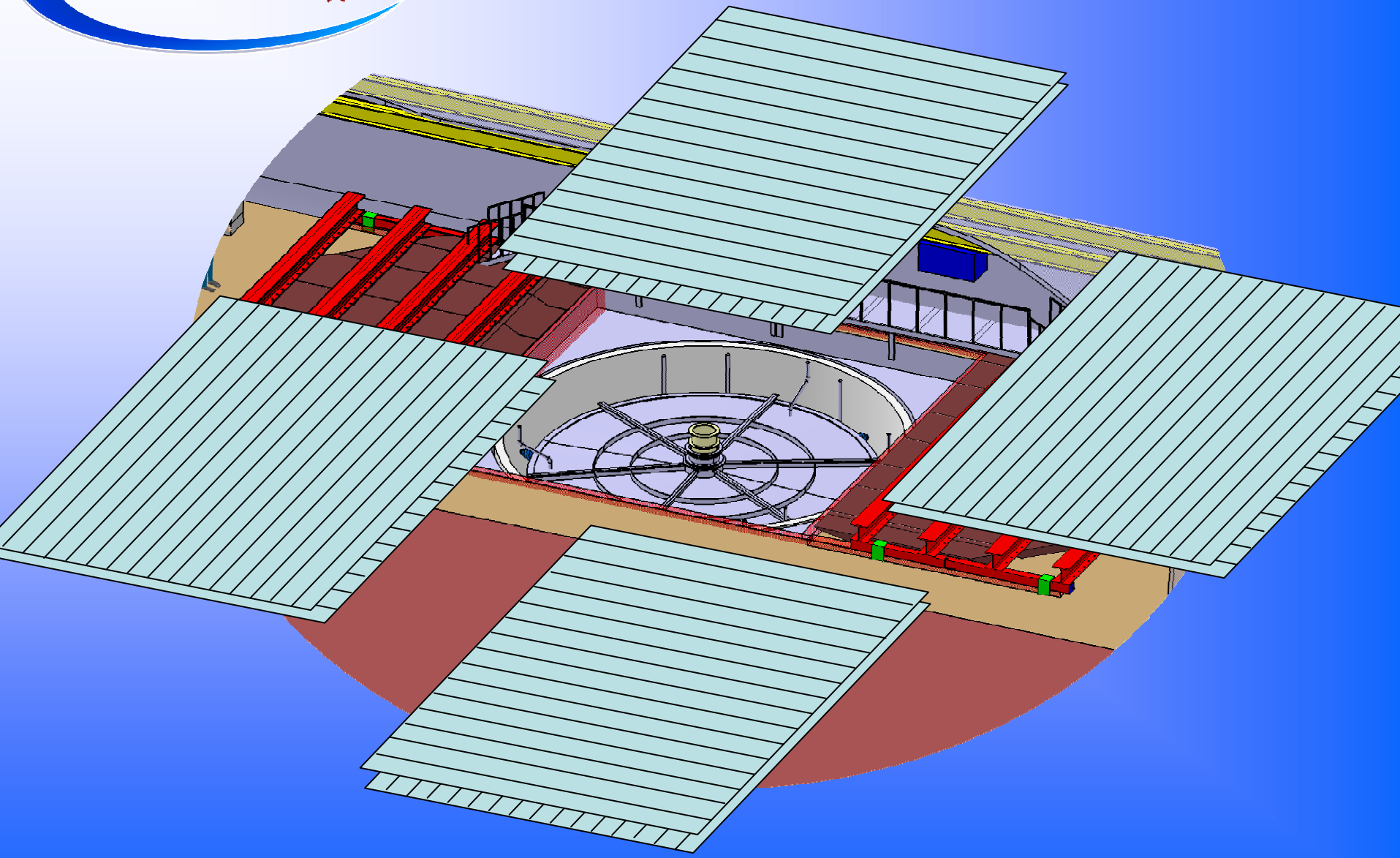


2 layers define a Panel
(34 total modules)

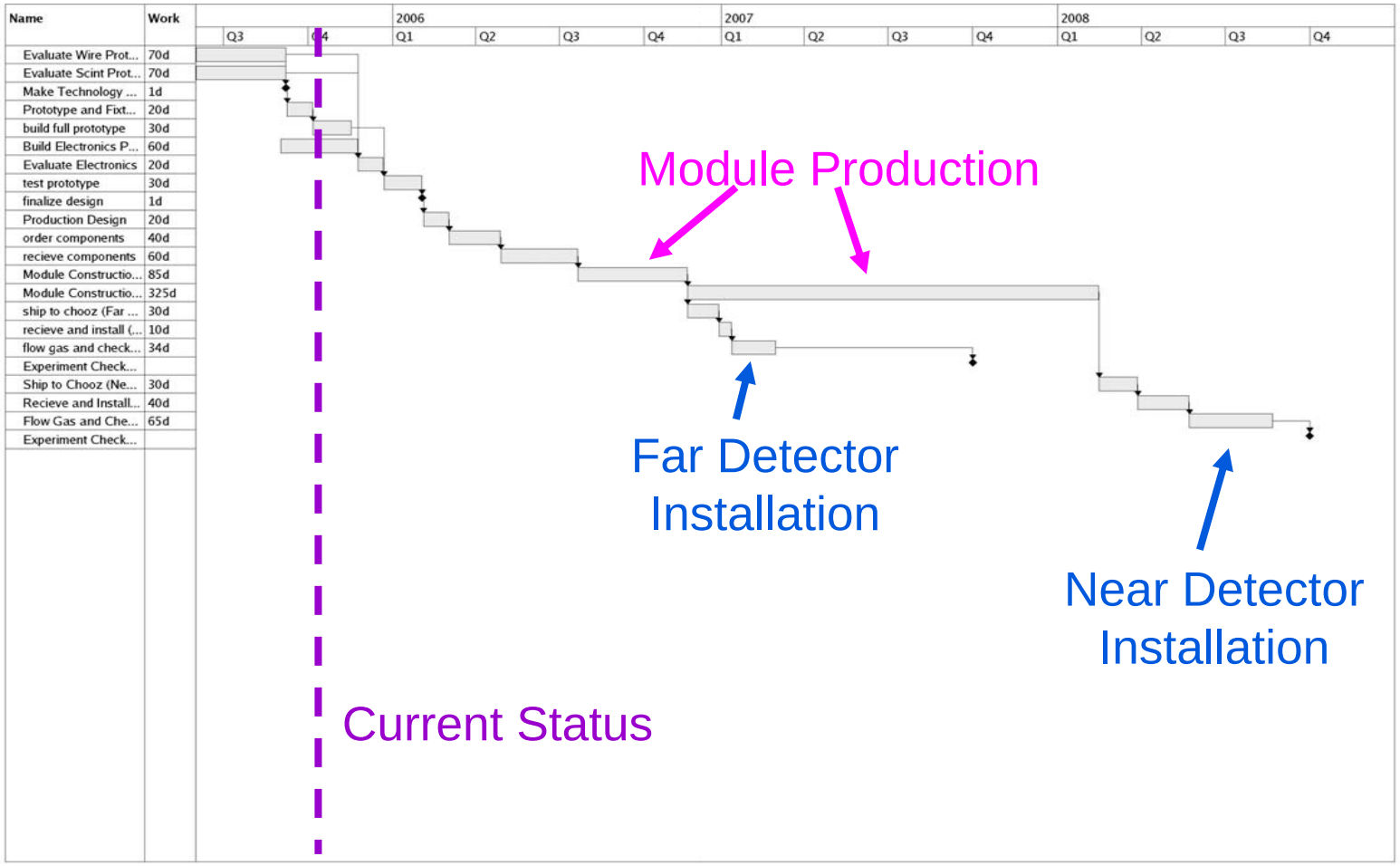
The Far Lab



The Near Lab



Production Schedule



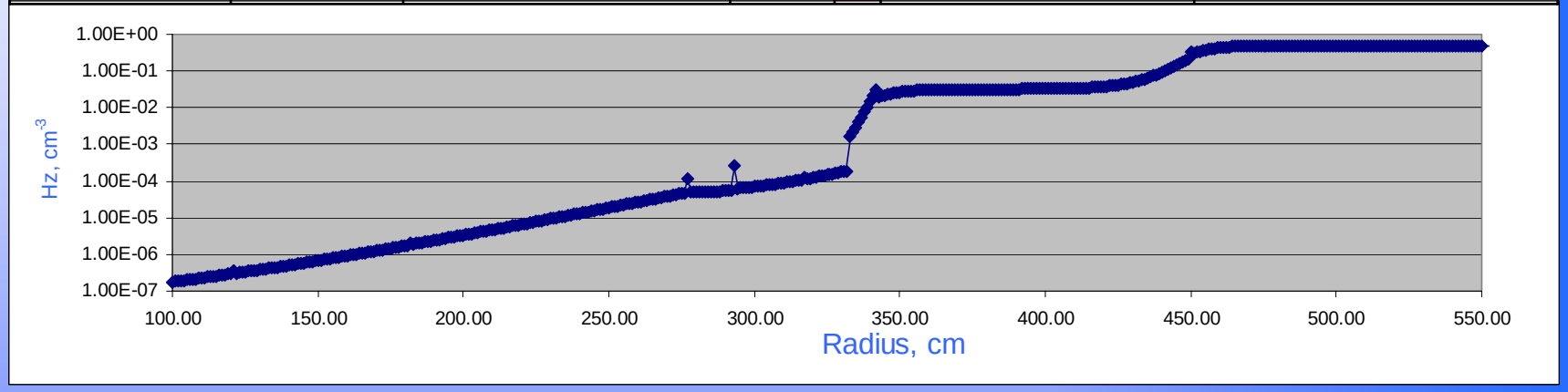
Summary

- Goals are achievable
  - Provides a factor 3-4 improvement over inner veto alone at near detector
  - Provides multiplicity and tracking at far detector
- Outer muon system was optimized for cost
  - $1.3M Mechanics, $1.0M Electronics
  - Other technologies are possible
- With top only construction, the outer muon system can be installed after the other systems, so the production schedule is not a significant constraint

Steel Shielding at Near Detector?

Steel?

Target	GC	Buffer	IV		Sand	Rock



Rate for R<180 cm:

With Steel: 1.74E+01 Hz

With no Steel: 1.63E+02 Hz