Geant4 Application to Low Background Experiments Underground and in Space

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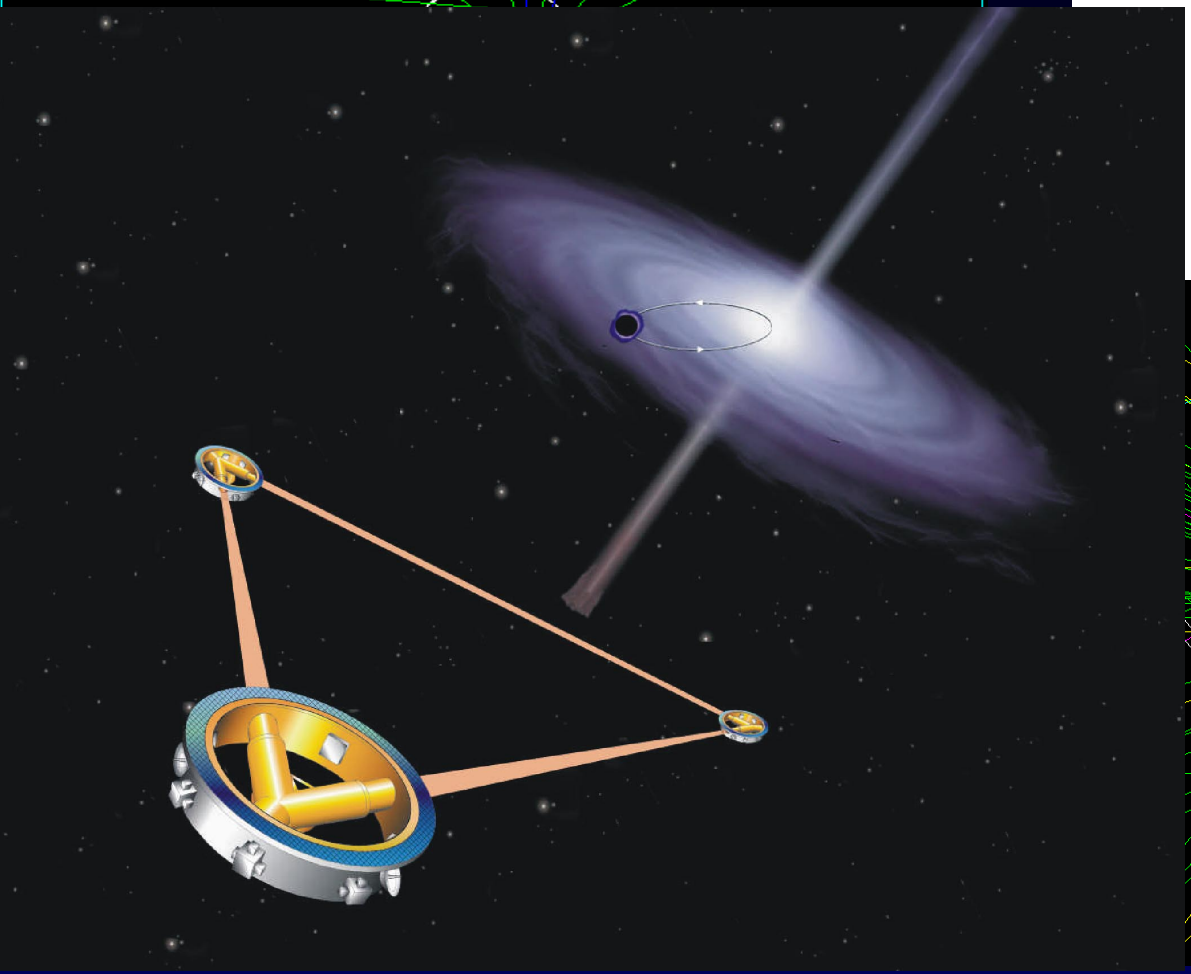
Why GEANT 4?

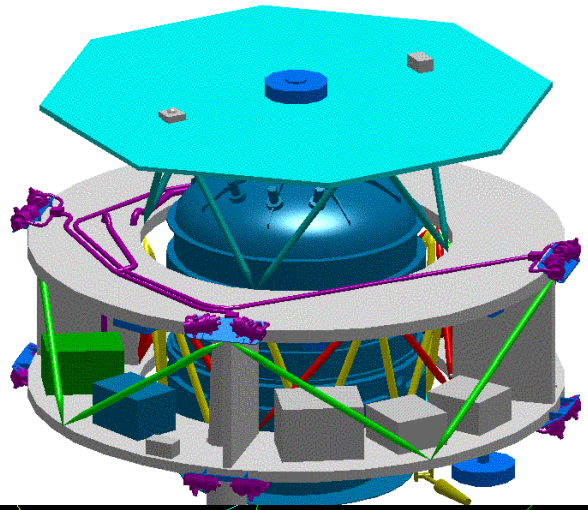
- Geant4 (over other MC codes) includes low energy electromagnetic physics and neutron transport with single event output (without variance reduction) which is crucial to understanding expected Dark Matter type interactions and backgrounds

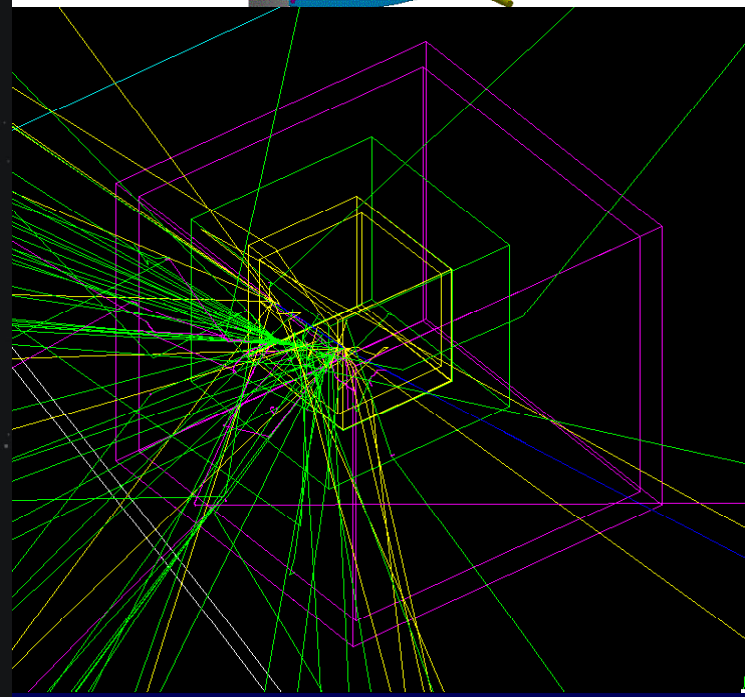
- Recent advances in Dark Matter detectors necessitate enhanced simulation techniques in order to understand the full physics reach

- The LISA spacecraft charging rate is also reliant on the full physics models and low energy electromagnetic implementations available within Geant4

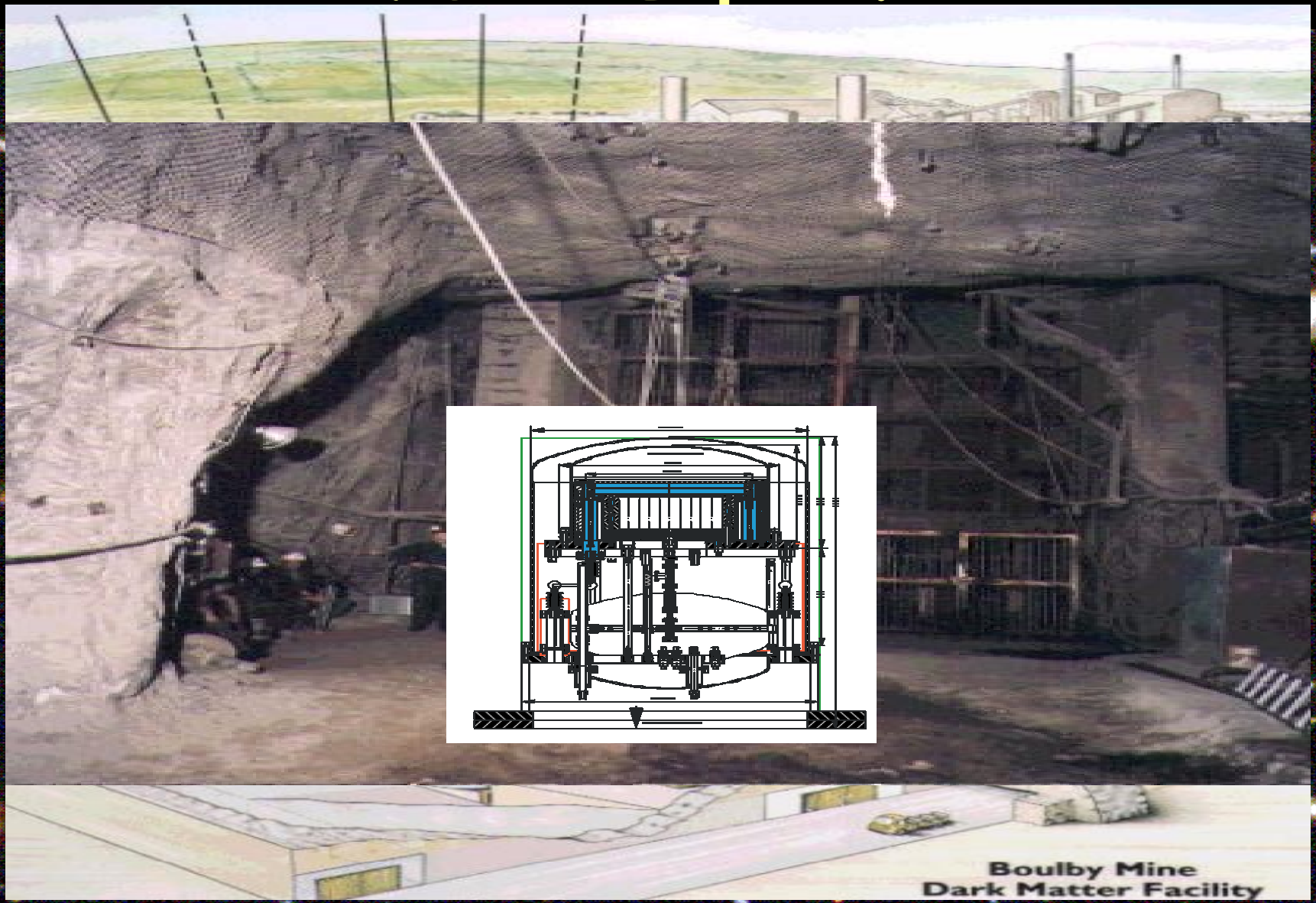
Geant4 Simulation of Test-Mass Charging in the LISA Mission







UKDMC Experiment



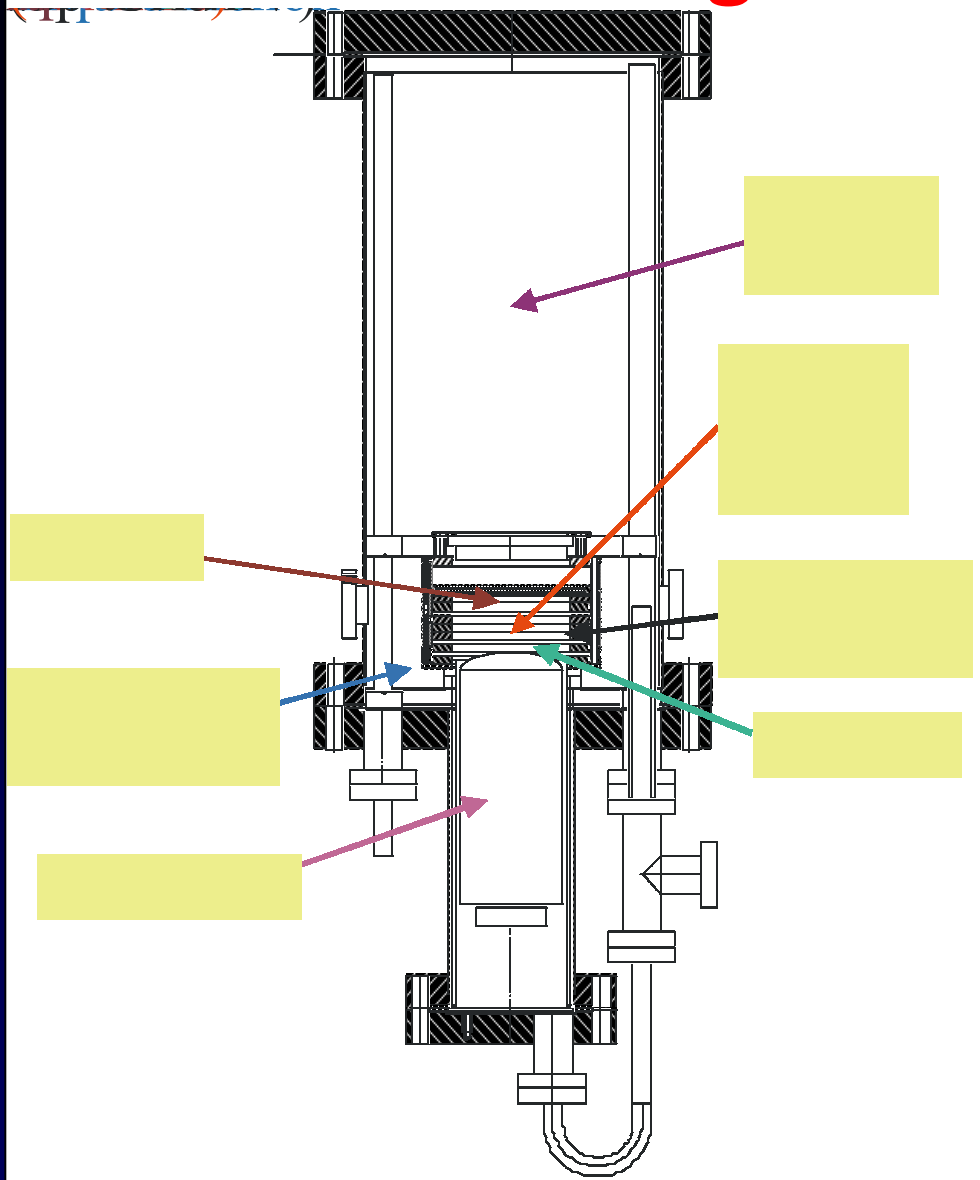
The DMX advanced example

- The Underground Physics work presented here is released with the general Geant4 distribution as an advanced example.

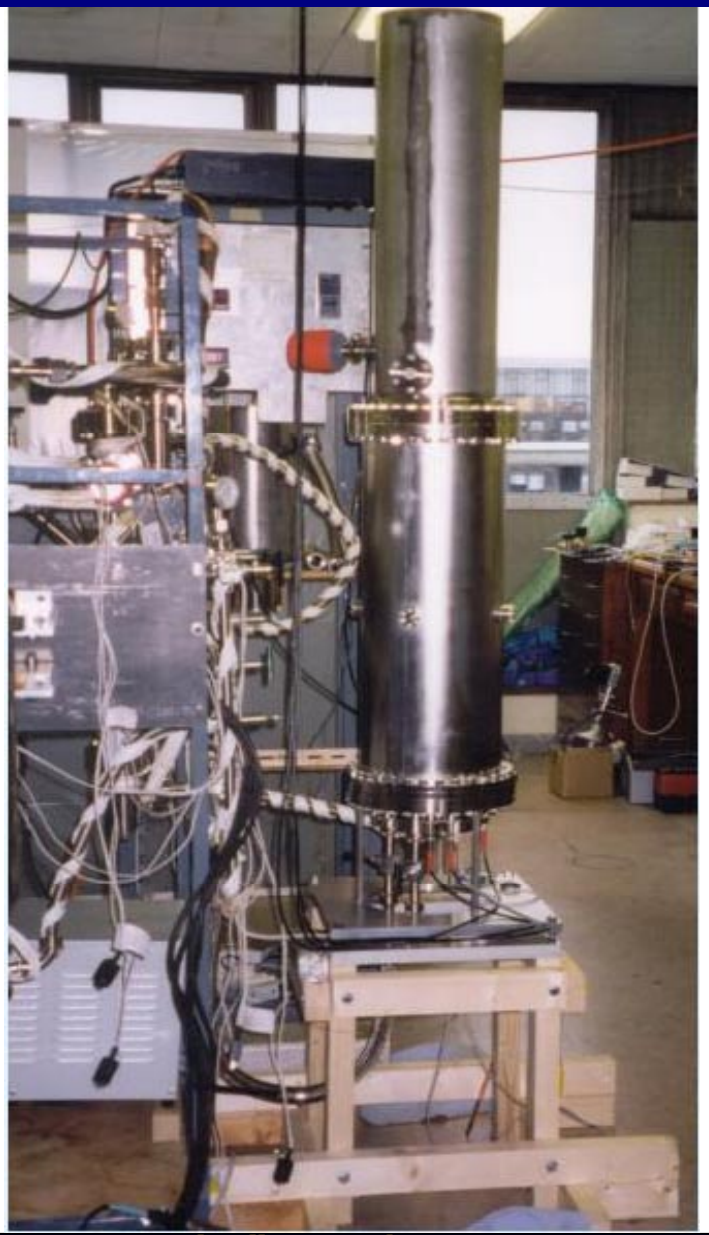
- DMX demonstrates a Dark Matter type experiment with a scintillator target (LXe), low energy physics interactions, ray tracing of scintillation of photons and time constants introduced to demonstrate discrimination

- In addition AIDA is implemented producing hbook files and run-time histograms saved to postscript format

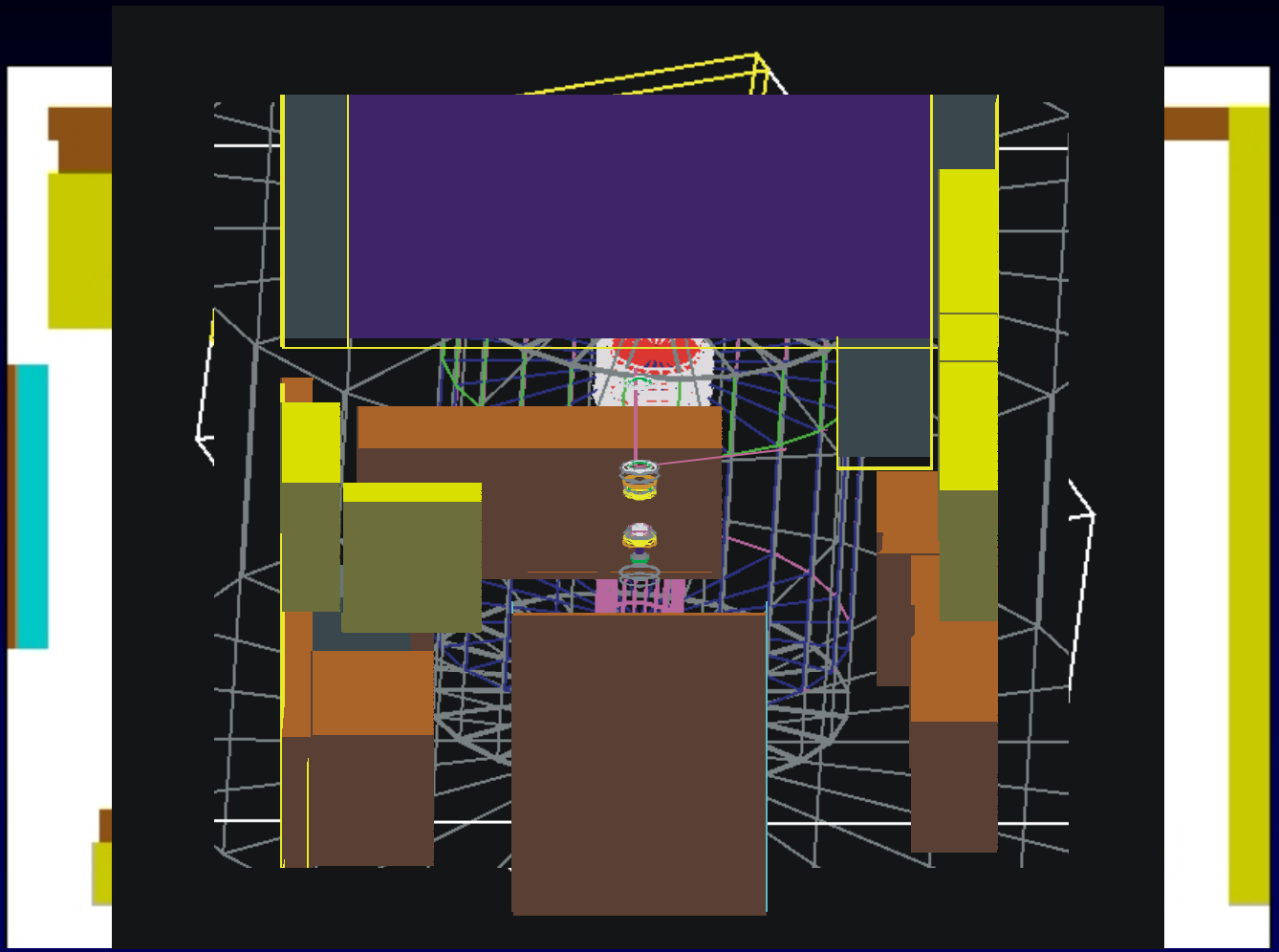
Detector Design



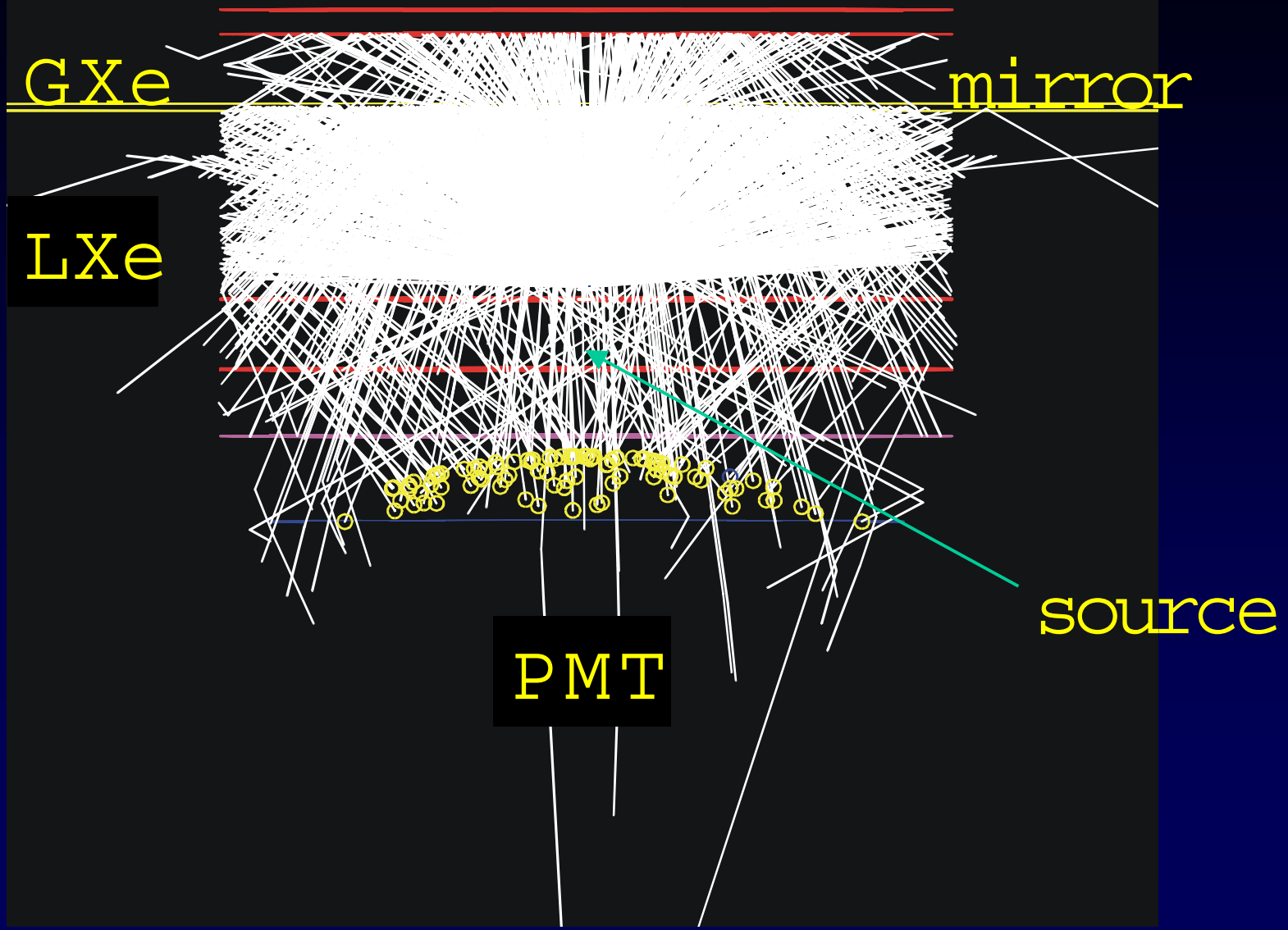
Full construction:



Laboratory Geometry Implementation



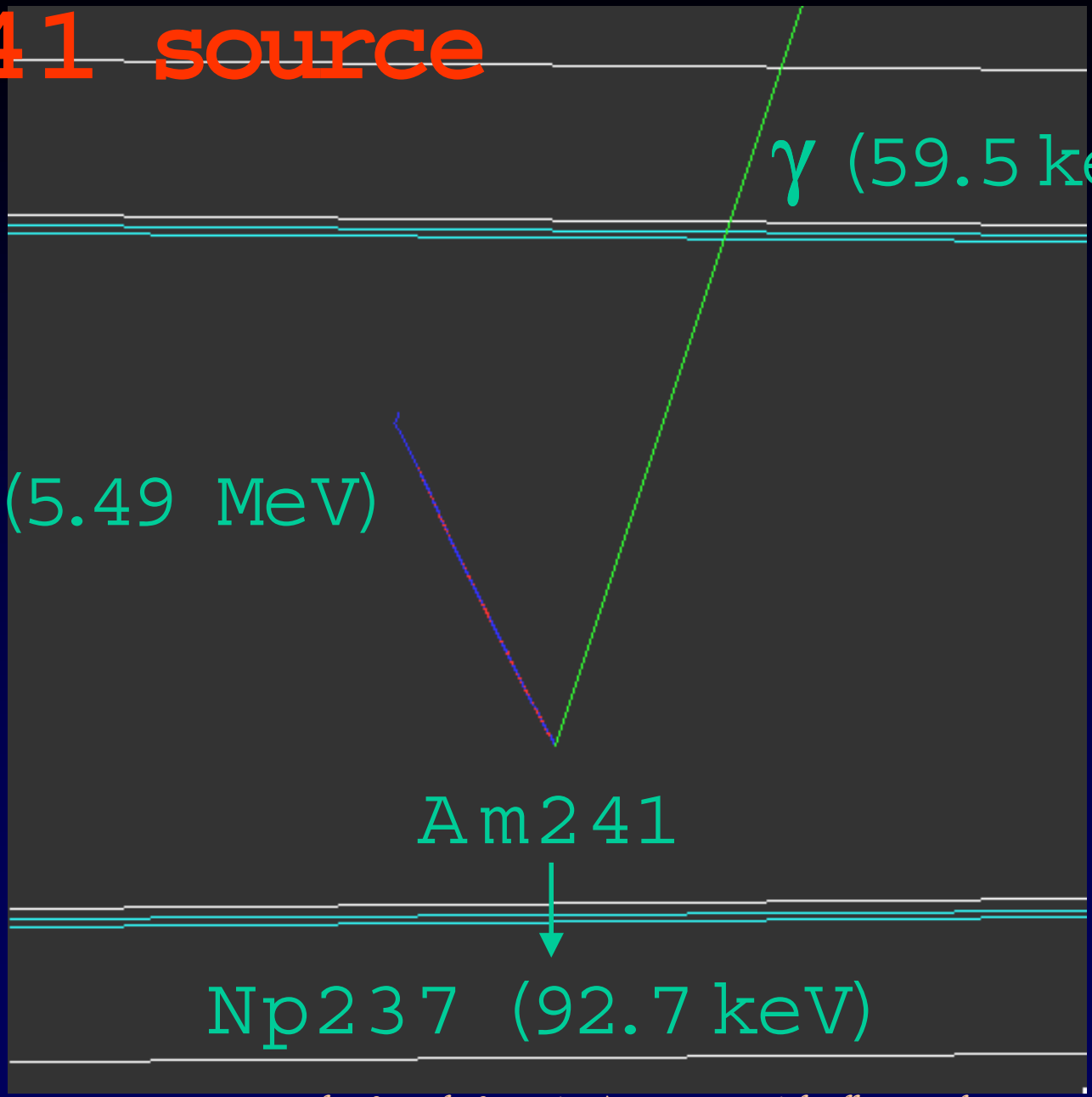
Ray Tracing



PhysicsList

transportation	user cuts: step, time
optical	"selective" scintillation
electromagnetic	low energy models
hadronic	neutronHP models
decay	radioactive decay
analysis	→ AIDA and ANAPHE

Am241 source



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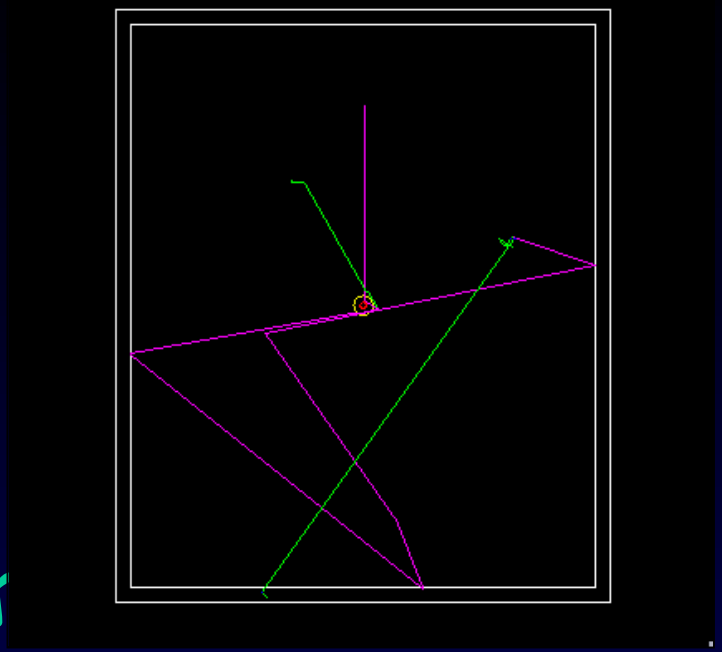

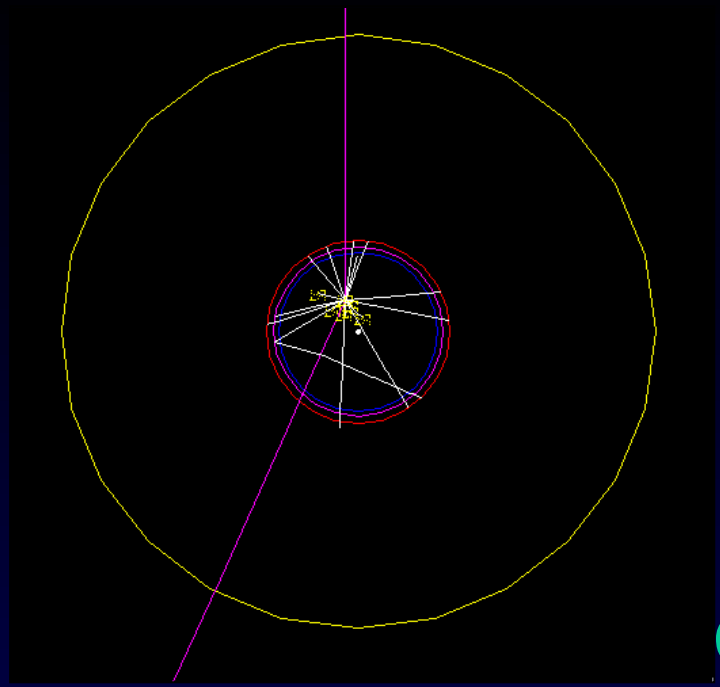

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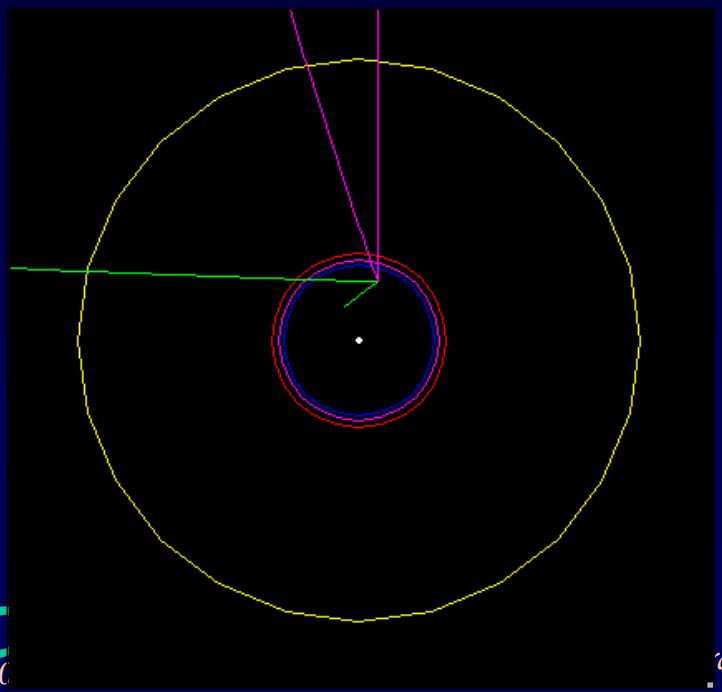

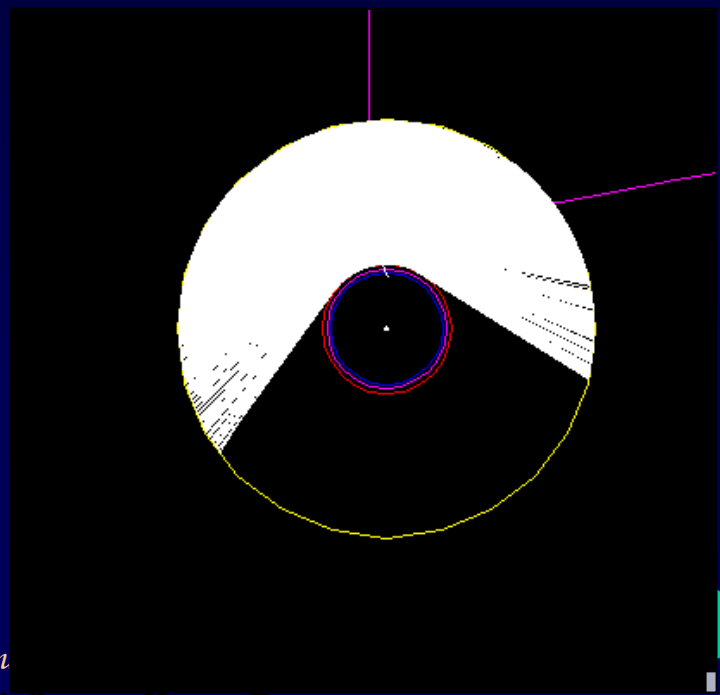

inelc

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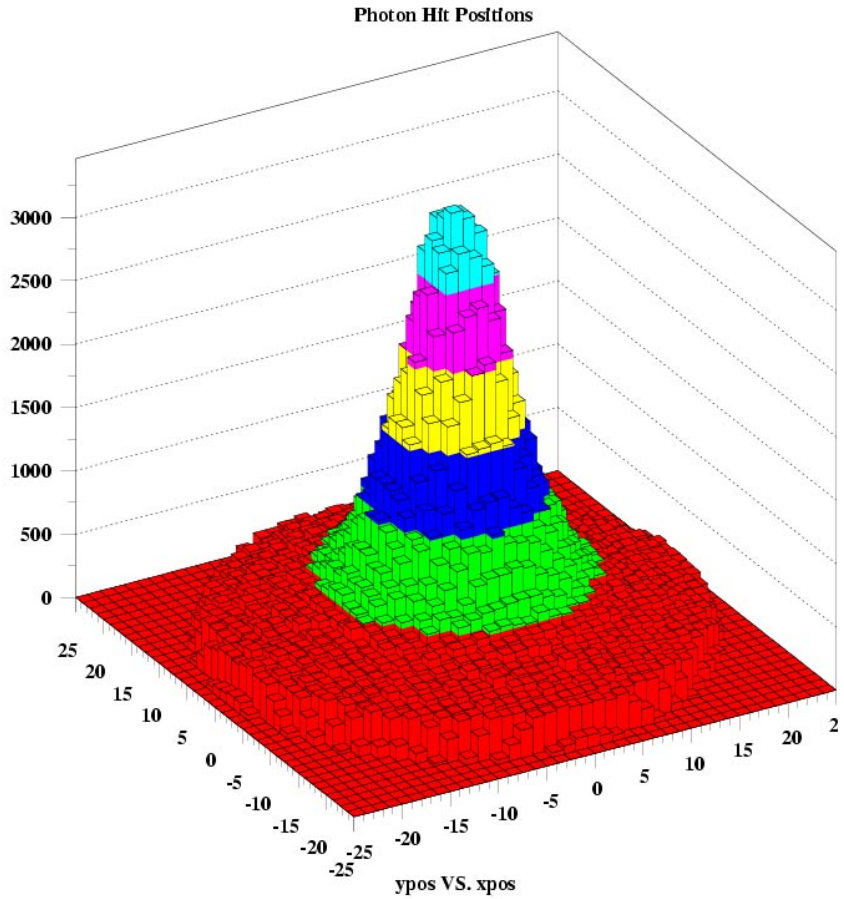
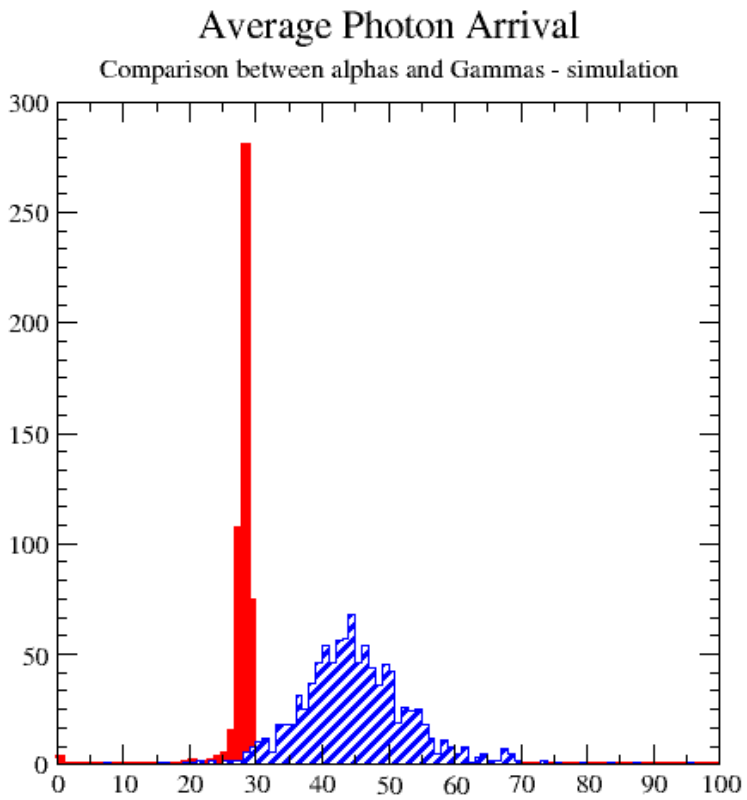
AIDA Implementation

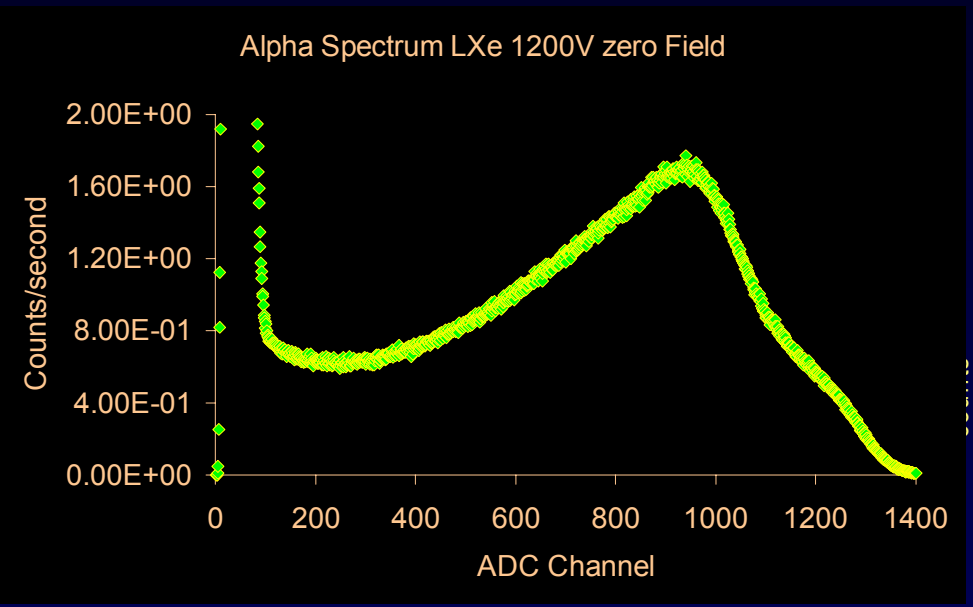
- Has been carried out and released in Geant4.4.1 advanced examples
- Relatively straightforward
- Installation and update scripts make it particularly simple – automated GRID running… (!)
- Interactive histograms produced at the end of the run and saved in postscript
- Currently HBOOK output format

DMX Analysis Output

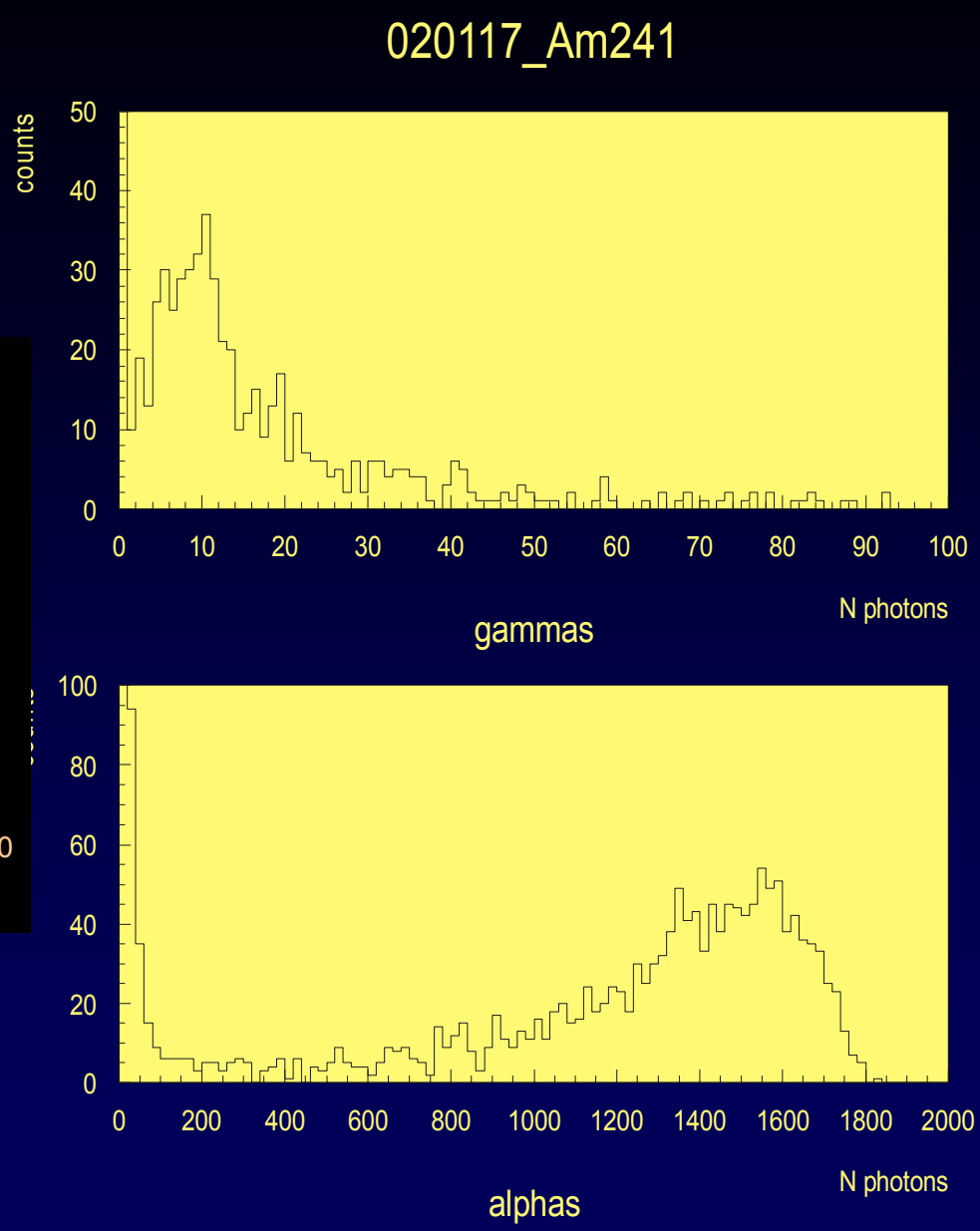




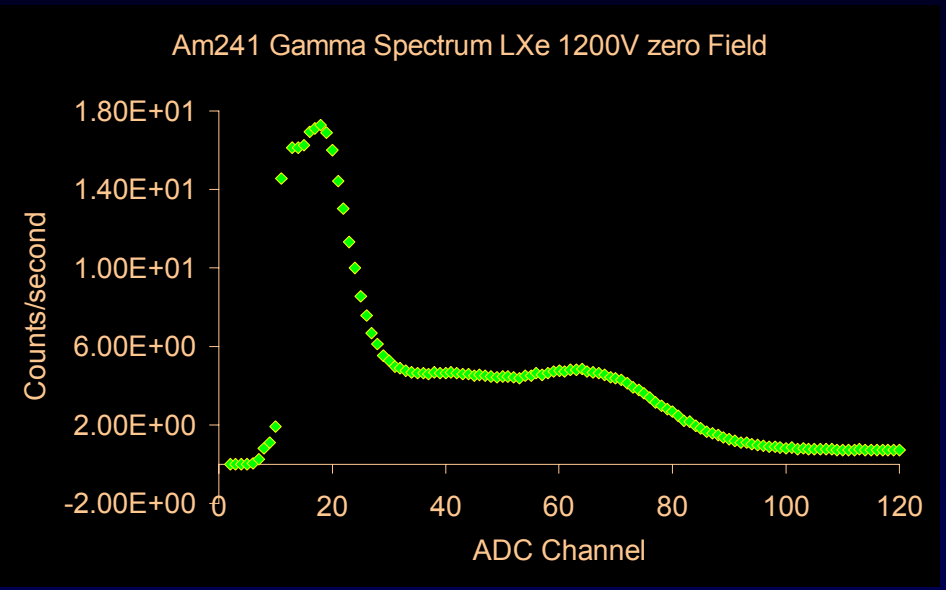
^{241}Am spectrum

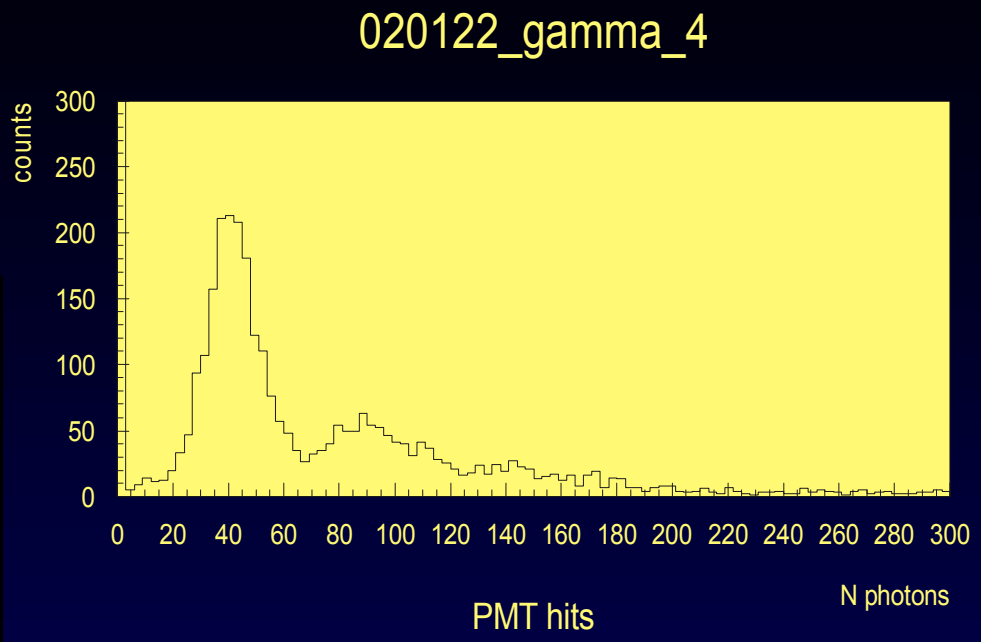


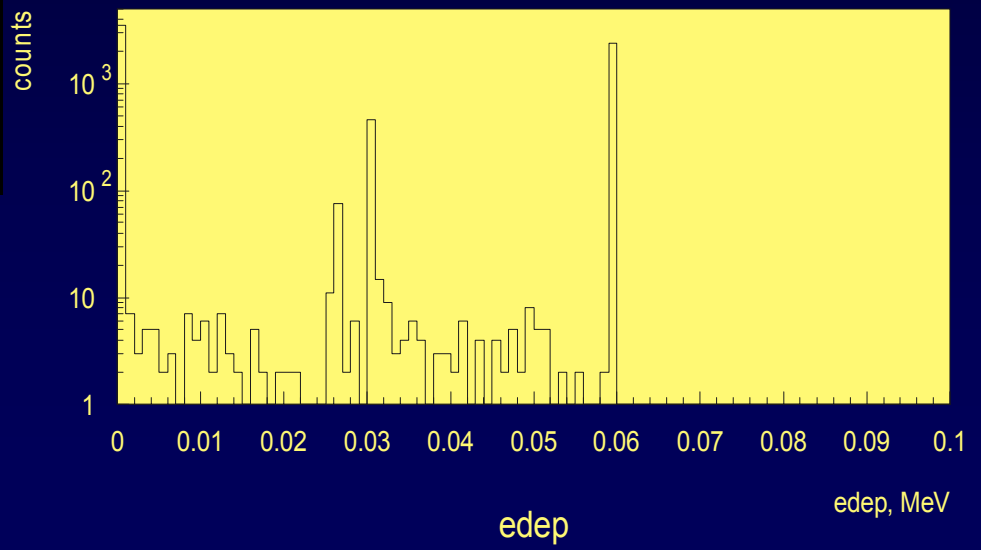
experimental



γ spectrum



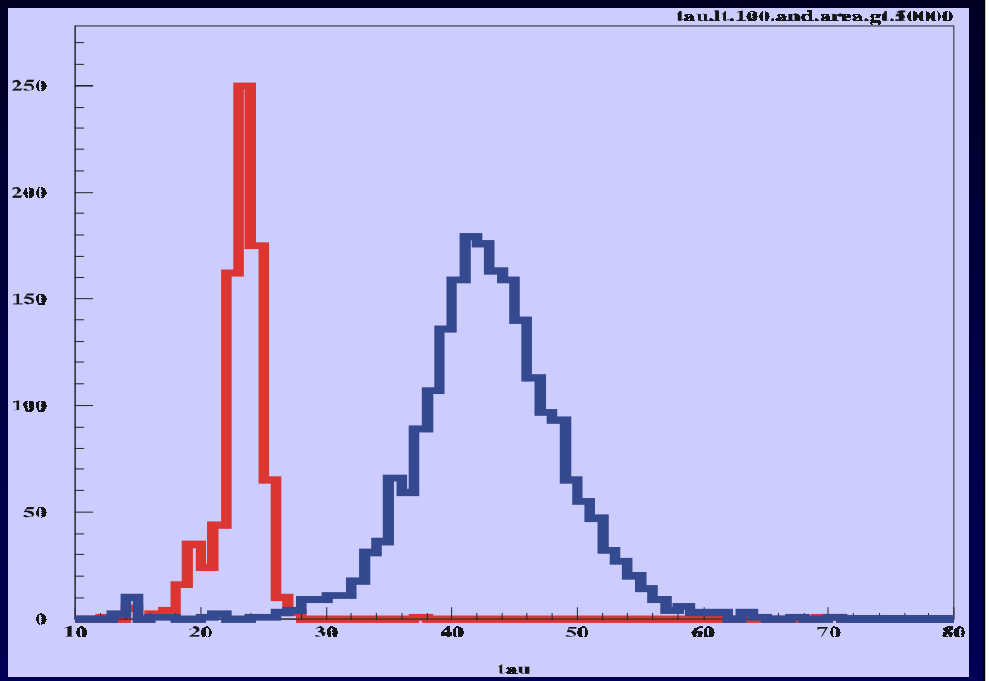




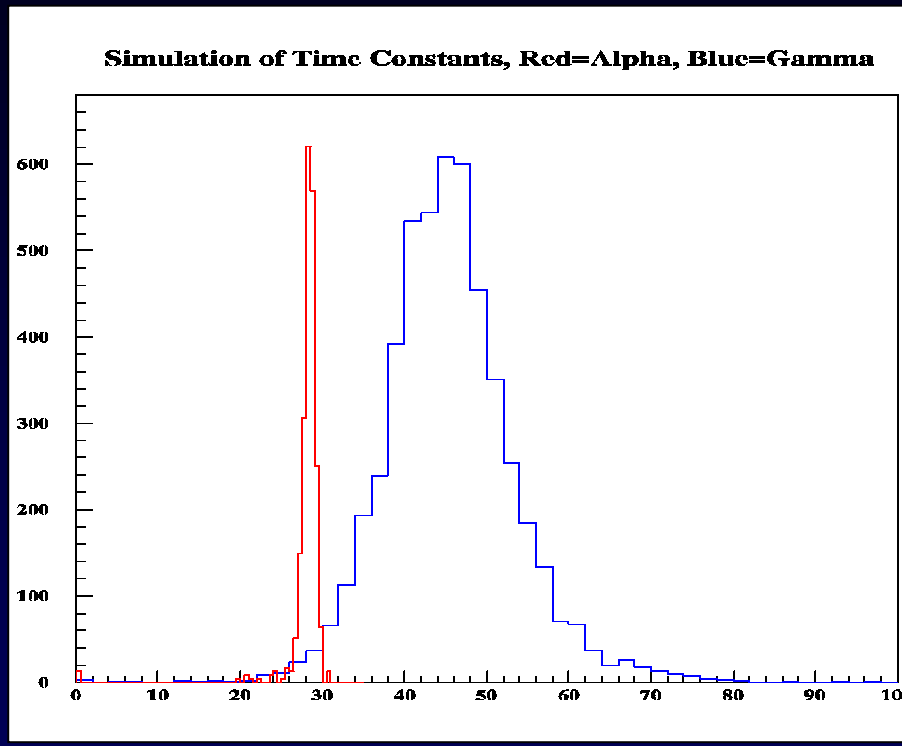
experimental

Time Constant Discrimination

Experimental Data



Geant4 Output



- Red Curve = Alphas
- Blue Curve = Gammas

Future Work

- Our future full-scale Dark Matter detector, ZEPLINIII, is in the process of being simulated complete with position sensitivity and Electroluminescence classes

- The LISA work is ongoing, particularly due to the sensitivity to hadronic models and the computation time required to produce statistically valid charging rates

- In the near-future pulse-shape fitting will be included into the simulation → allowing exactly the same analysis procedure for REAL data and SIMULATION during run-time

- In addition high precision simulations for both Space and Underground applications will require more sophisticated distributed resources/GRID-ification
  - → DIANE project & Top-C

Conclusions

- Geant4 has been used extensively to model Dark Matter prototype detectors and the LISA Gravitational Wave Spacecraft

- The simulation has given insight into energy deposition and is being currently used for neutron investigation

- Simulations for both LISA and Dark Matter have been run in a distributed environment with up to 130 nodes used simultaneously

- Interactive analysis is incorporated through the AIDA interfaces

- In the future parallelisation will become increasingly important