Overview of Geant4 Examples

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Geant4 Tutorial

Bordeaux

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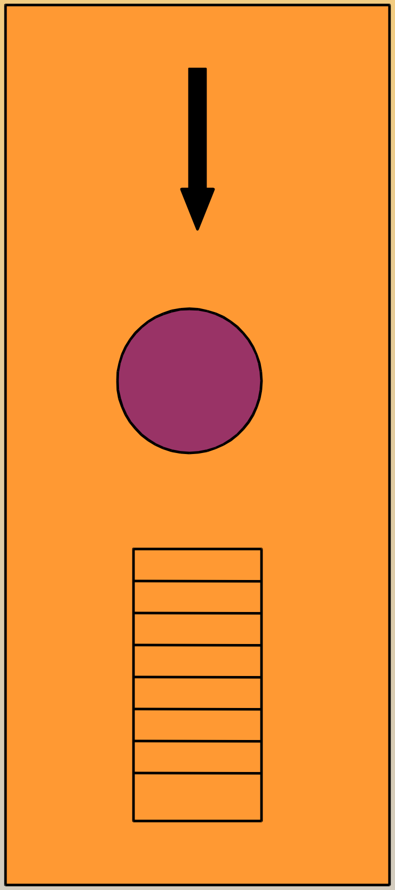
Types of Examples

- Novice
  - Simple: trivial detector with non-interacting particles
  - Detailed: complex detector with full physics
- Extended
  - Testing and validation
  - Demonstrating Geant4 tools
  - Extending Geant4
- Advanced
  - Practical applications
  - Examples from outside HEP (space, medical, etc)

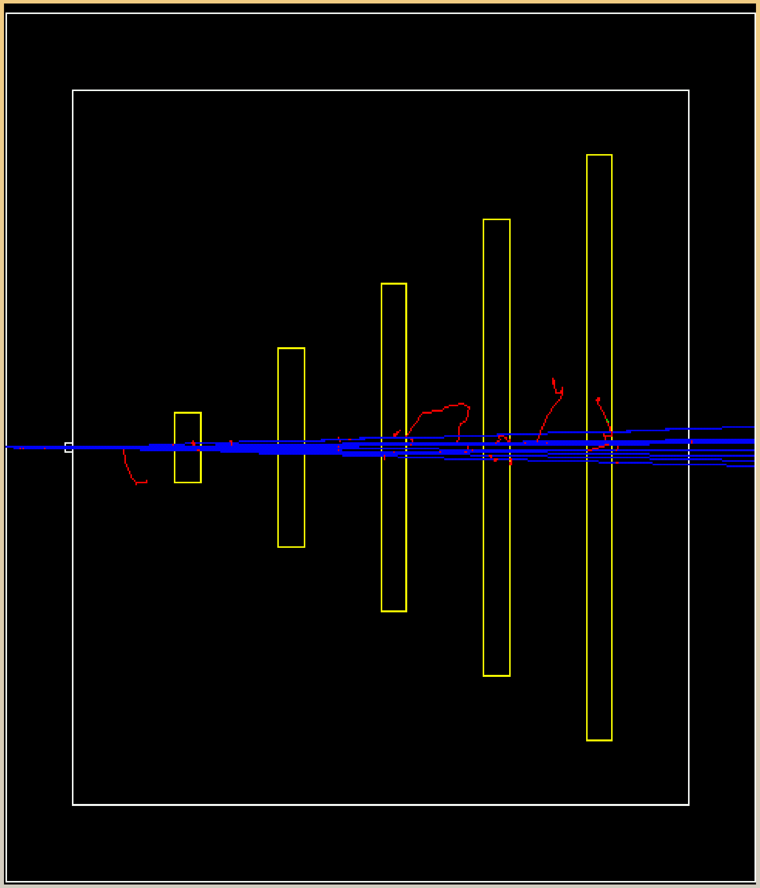
Novice Example N01

- Fixed geometry: Ar gas mother volume with Al cylinder and Pb block with Al slices
- Incident particle is a geantino – no physics interactions
- No magnetic field and only the transportation process is enabled
- Hard coded batch job and verbosity



Novice Example N02

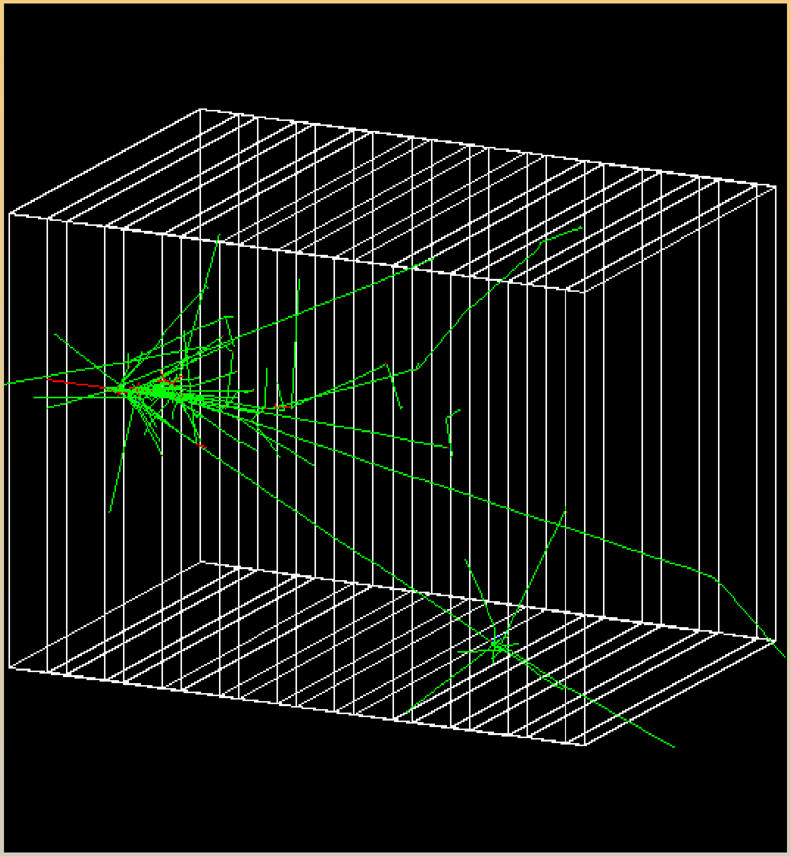
- Pb target, Xe gas chambers (parameterized volumes)
- All EM processes + decay included for γ, charged leptons and charged hadrons
- Detector response
  - trajectories and chamber hit collections may be stored
- Visualization of detector and event
- Command interface introduced
  - can change target, chamber materials, magnetic field, incident particle type, momentum, etc. at run time



Novice Example N03

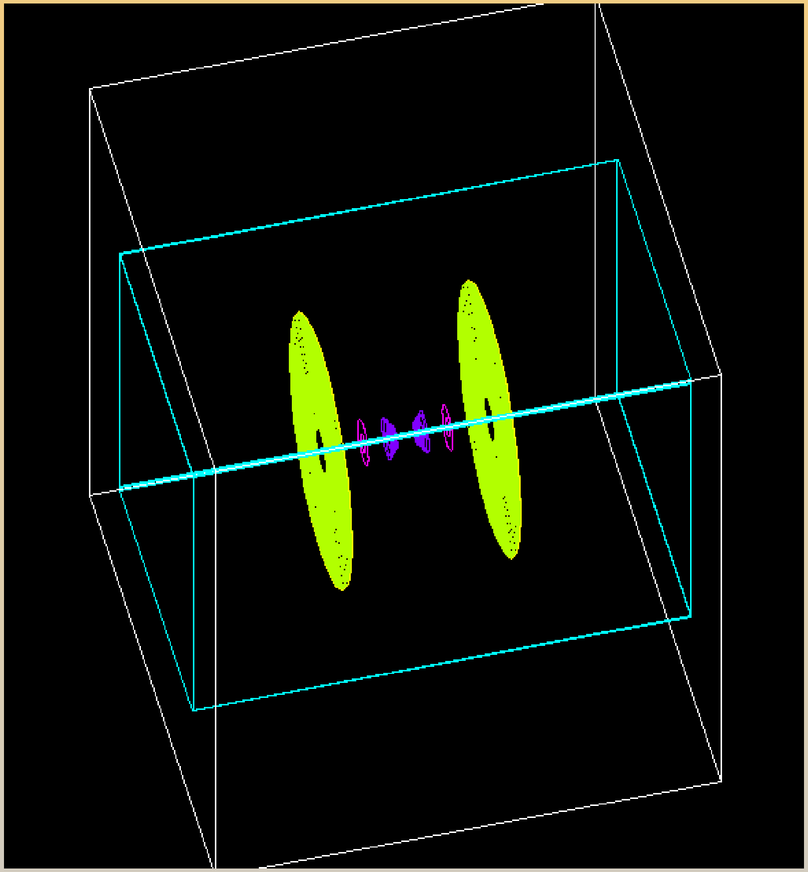
- Sampling calorimeter with layers of Pb absorber and liquid Ar detection gaps (replicas)
- Exhaustive material definitions
- Command interface
- Randomization of incident beam

- All EM processes + decay, with separate production cuts for γ, e+, e- (use for shower studies)
- Detector response: E deposit, track length in absorber and gap
- Visualization tutorial
- Random number seed handling



Novice Example N04

- Simplified collider detector
  - all kinds of volume definitions
- Magnetic field
- PYTHIA primary event generator
  - Higgs decay by Z0, lepton pairs
- Full set of EM + hadronic processes
  - should use updated hadronic physics lists
- Event filtering by using stacking mechanism

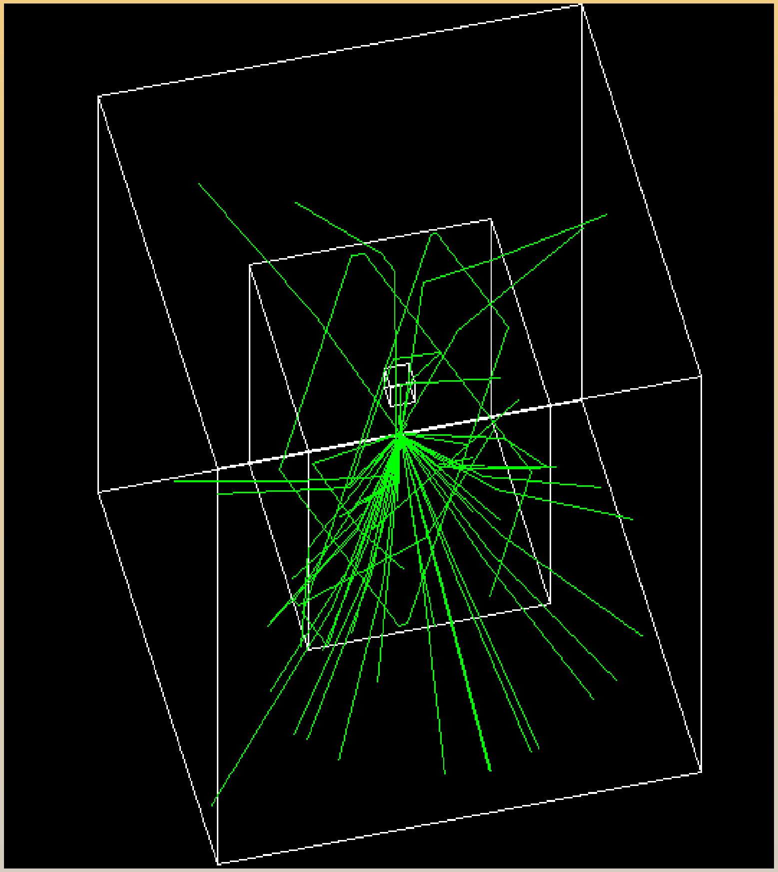


Novice Example N05

- Fast simulation with parameterized showers
  - EM showers (derived from G4VFastSimulationModel)
  - Pion showers (for illustration only – not used)
- EM physics only
  - Use of G4FastSimulationManagerProcess
- Simplified collider detector geometry
  - Drift chamber
  - EM, hadronic calorimeter
  - Ghost volume

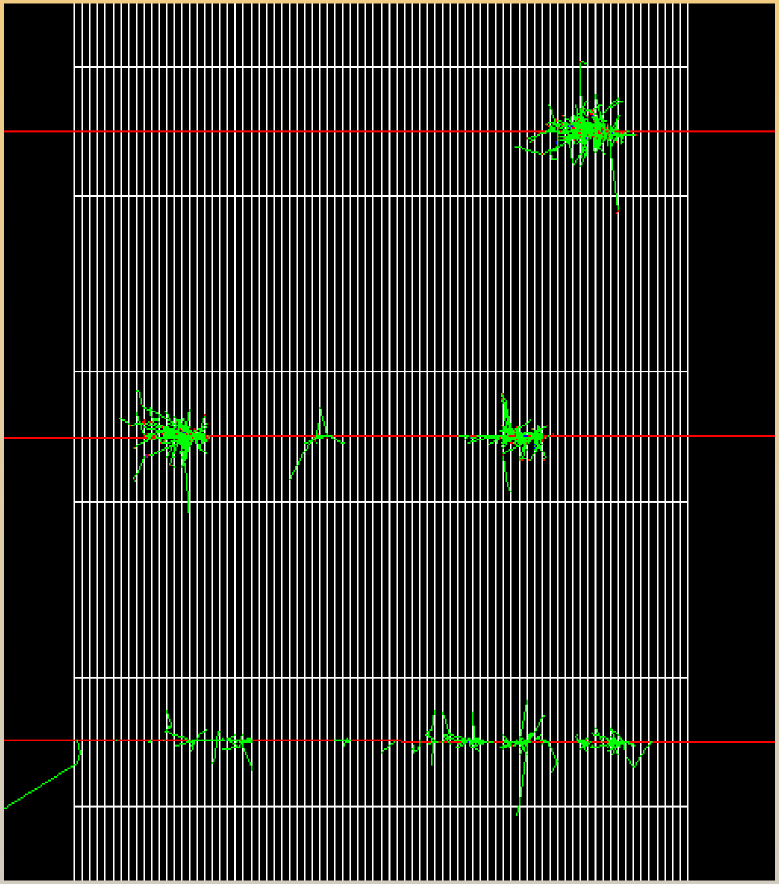
Novice Example N06

- Water Cerenkov detector with air “bubble”
- Materials
  - specification of optical properties
  - specification of scintillation spectra
- Physics
  - optical processes
  - generation of Cerenkov radiation, energy loss collected to produce scintillation



Novice Example N07

- 3 simplified sandwich calorimeters (Pb, Al, Ar)
- Run-based (as opposed to event-based) hit accumulation
- Changing geometries without re-building world
- Setting different secondary production cuts for each calorimeter using G4Region



Extended Examples

- Testing and validation of processes and tracking
  - Electromagnetic (TestEm1 – TestEm10)
  - Field (field01 – field03)
  - Geometry (olap)
- Demonstration of Geant4 tools
  - Analysis,eventgenerator, g3tog4, persistency
  - Biasing (B01-B03)
- Extensions of Geant4
  - GDML
  - Medical (DICOM files)
  - Parallel computing (ParN02, ParN04)

Advanced Examples

- HEP detectors

  CMS hadron calorimeter test beam, ATLAS Forward Liquid Ar Calorimeter, LHCb Rich test beam

- Neutron Shielding and Radiation Protection
- Medical

  brachytherapy, medical linac, hadron therapy

- Space applications

  gamma ray telescope, X-ray telescope, X-ray fluorescence

- Underground physics (liquid Xe dark matter detector)
- Cosmic rays

  air shower, cosmic ray charging

GDML Example

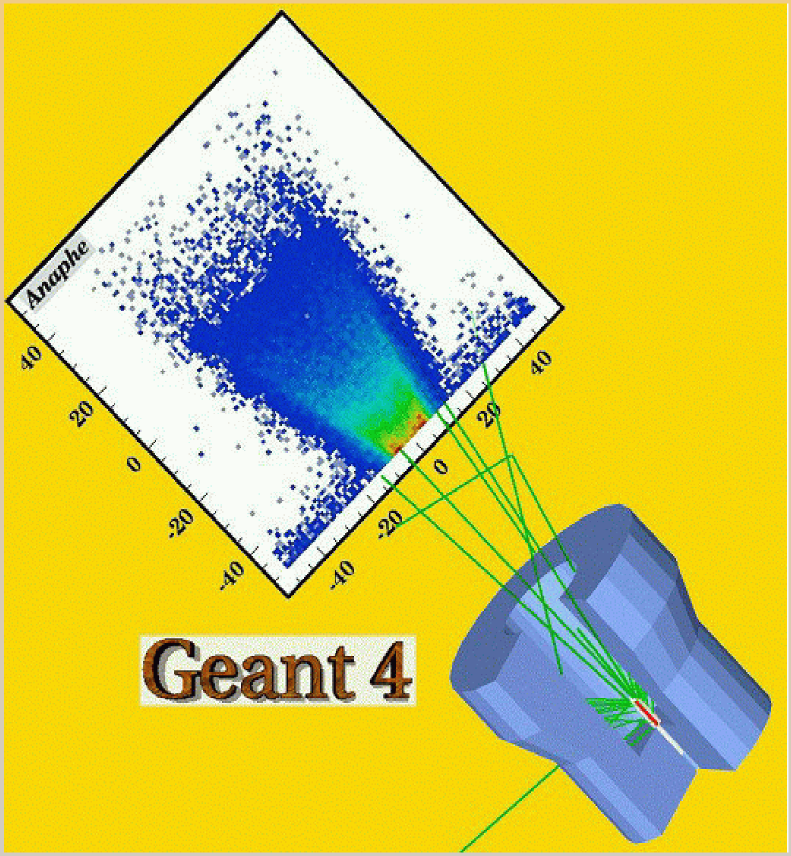
- Identical to example N03 (sampling calorimeter), except
  - GDML used for geometry description
- GDML schema supports:
  - Numerical expressions, constants, rotations, translations, units
  - Materials
  - CSG + boolean solids
  - Geometrical structure (volumes, placements)
- Uses Xerxes-C XML parser (linux only)
  - Installation instructions included in example

Neutron Shielding

- Physics:
  - Neutrons, with spectra from 43 and 68 MeV neutrons bombarding a ^{7}Li target, incident upon concrete and iron shielding
  - Energy dependent neutron flux measured behind shielding wall
  - Several hadronic models used
  - Checked-out hadronic physics lists
- Changeable shielding arrangement
- Geometric importance sampling
  - Example can be run with or without it

Brachytherapy Example

- Physics
  - Low energy EM processes for e-, γ
  - Standard EM for e^+
- Sensitive detector
  - “phantom” consisting of soft tissue
- Analysis
  - Energy deposition stored in n-tuple
  - Store primary particle energy spectra
  - 1D, 2D histograms of energy deposition



Medical Linac

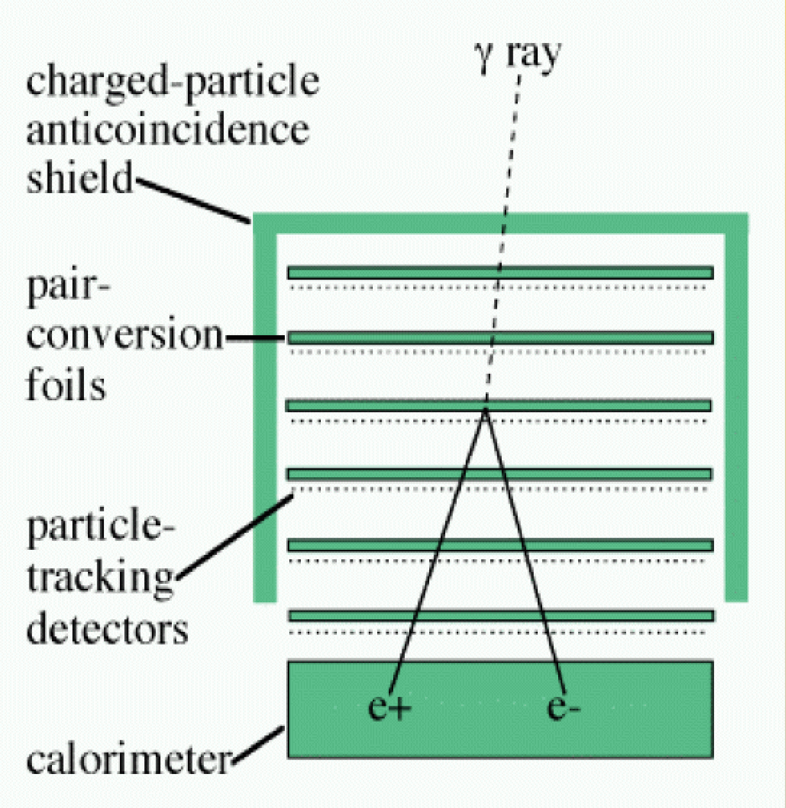
- Physics:
  - Low energy EM processes for electrons, gammas
  - Standard EM processes for positrons
- Linac beam
  - e- point source with Gaussian energy spread and radial intensity
- Geometry
  - collimators (primary, moveable secondary, jaws, multi-leaf)
  - flattening filter
  - ion chamber
  - water phantom
- Analysis
  - 1-D, 2-D histograms of energy distribution in phantom

Hadron Therapy

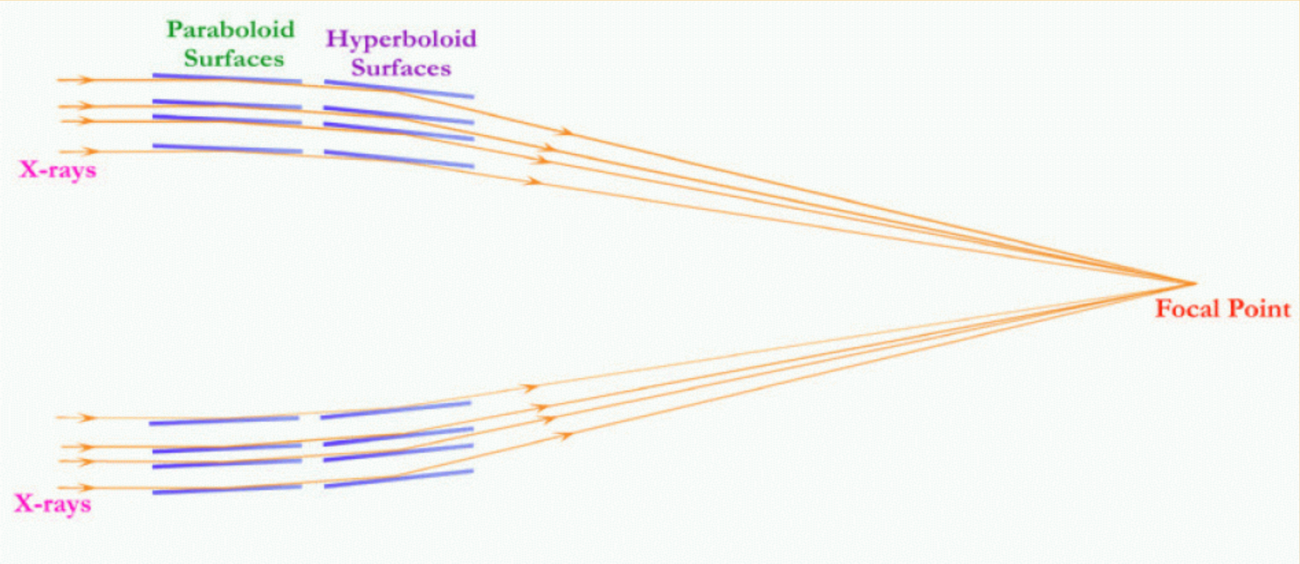
- Physics
  - user can choose low energy or standard EM processes for e+, e-, gamma, p, ions
  - hadronic processes, models for protons, ions
- Beamline elements
  - collimators, range shifters,
  - modulator wheel, monitor chambers
- Analysis
  - Energy deposition, Bragg curve stored in histograms
  - 3-D energy deposit in phantom store in n-tuples

Gamma Ray Space Telescope

- Use of messengers to change geometry interactively
- Modular physics list
- Particle generator with monochromatic or power law spectrum
- Readout geometry of Si tracker strips
- Hits collection stored in ascii file
- Simple digitization using hits collection to produce digi collections



X-ray Telescope (1)



Simple model of x-ray telescope to study proton damage

Geometry:

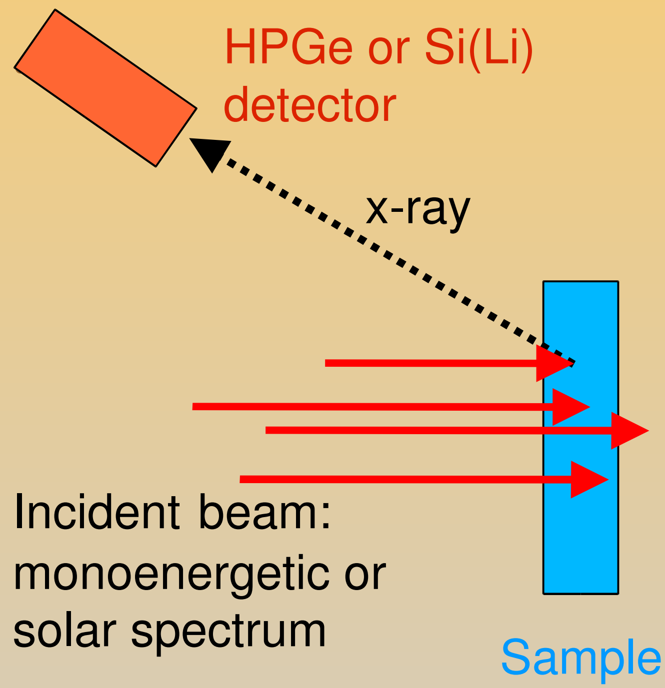
- single shell nickel-gold mirror
- two cones for paraboloid, two for hyperboloid section
- aluminum baffle
- main telescope: carbon fiber tube, aluminum end caps

X-ray Telescope (2)

- Main physics process is multiple scattering of protons from mirror surfaces
  - also e+, e-, gamma physics processes
- General particle source
  - many methods available to customize event generation
- Visualization of proton tracks
- AIDA interface for analysis
  - energy distribution histograms of photons reaching CCD detector

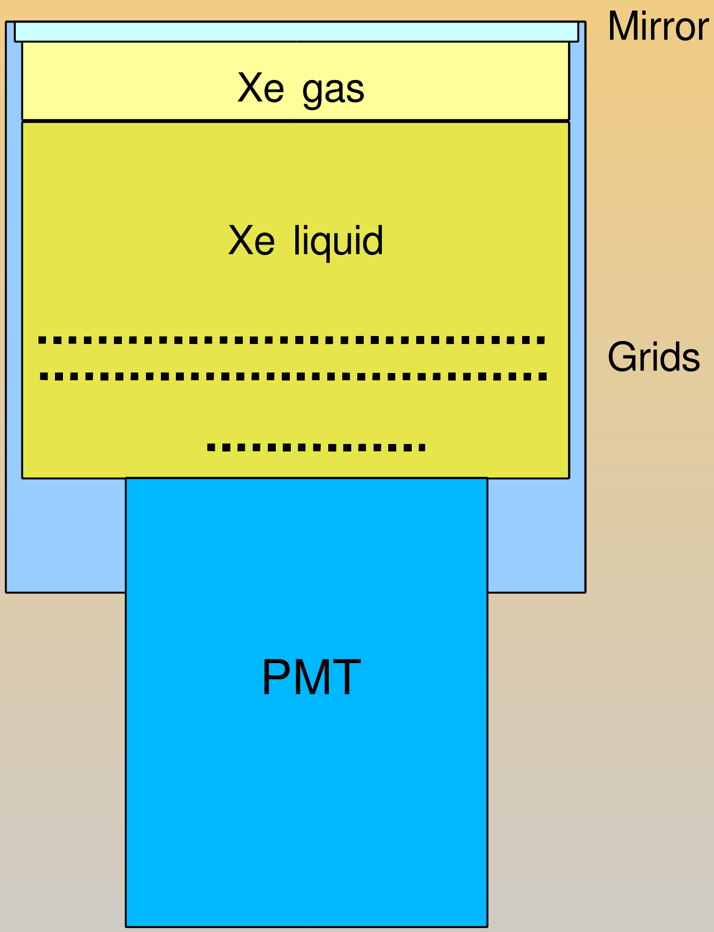
X-ray Fluorescence

- Realistic test beam simulation for measuring fluorescence emissions
- Uses tabulated detector response functions
- Incident particle can be photon, proton, alpha
- Several incident solar spectrum files available for use with particle gun
- Histogramming with AIDA



Underground Physics

- Realistic example of underground dark matter search experiment
- Detailed geometry, including optional file describing laboratory
- Physics
  - Low energy, standard EM
  - Optical processes
  - Radioactive decay
- General particle source
- Many macro files for various run conditions



Summary

- 7 novice examples
  - Users' Guide for Application Developers, Chapter 9.1
  - Code in geant4/examples/novice
- 15 advanced examples
  - Users' Guide for Application Developers, Chapter 9.2
  - Code in geant4/examples/advanced
- Many extended examples
  - Code in geant4/examples/extended