http://www.geant4.org

Detector Simulations

Geant4 Physics

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U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Reminder from first day

A detector simulation program requires at least the following three components:

- Geometry description module: to describe the experimental setup in terms of shapes, materials, relative positioning
- Physics modules: to cover all particles, energies and interaction types of interest
- Primary definition/generation: to describe what are the properties (species, 4-momenta) of the first particles that "appear" in the setup (can be provided by an external tool, e.g. a *generator* -PYTHIA, HERWIG,...- for HEP)

A system (user-hooks) to interact with the simulation and extract the physics quantities must be provided (e.g. scorers that record energy deposits in specified regions)

Alternative, useful components:

- Analysis tools to create histograms and store data in files
- Visualization drivers (to display geometry and possibily tracks and doses)
- System integration tools: MPI interfaces to submit jobs on clusters, scripting/macro systems

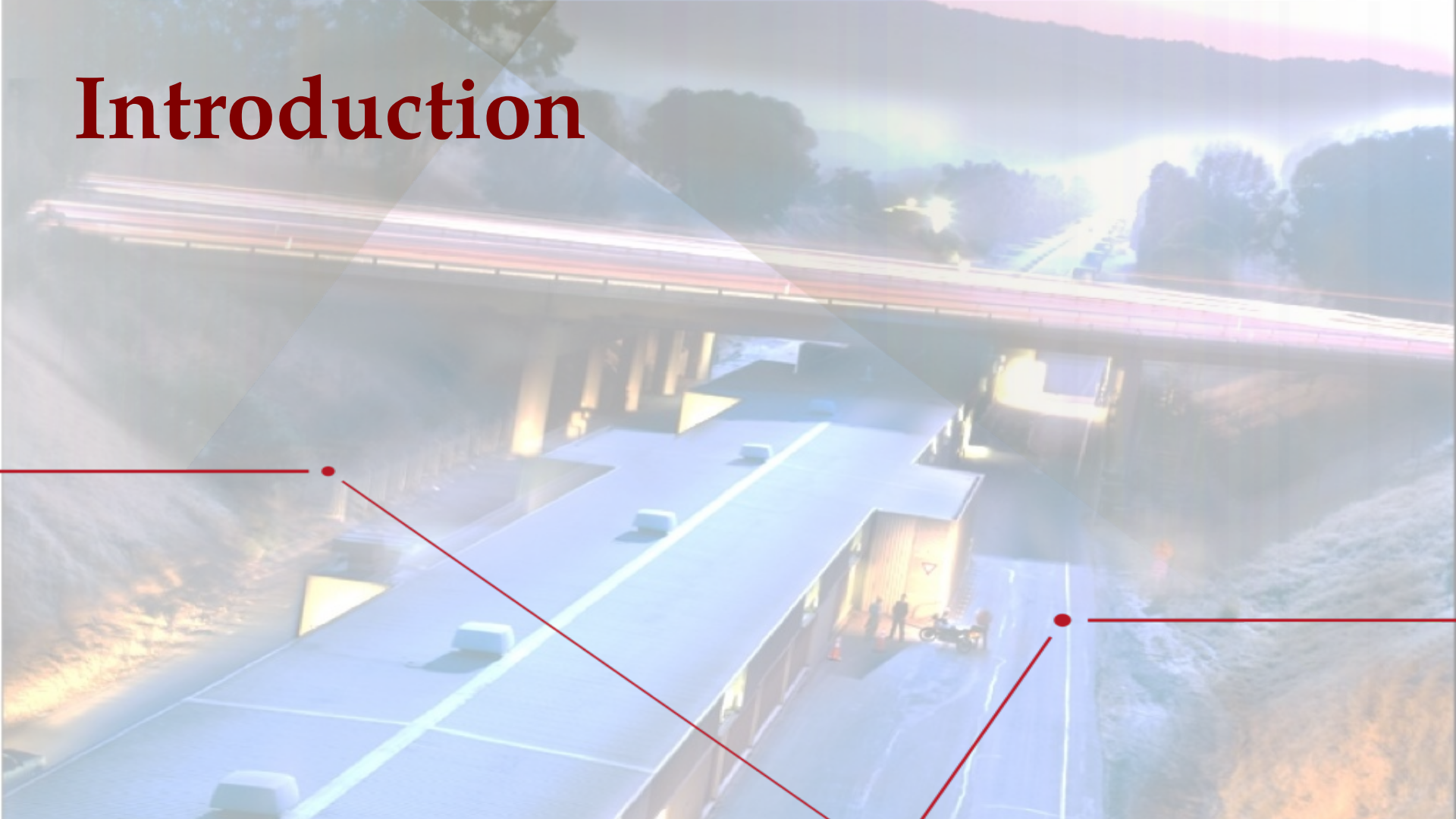
Overview

Part 4: Geant4 Physics

- Electromagnetic Phsyics
- Hadronic Physics
- Tracking Cuts
- Physics Lists

Part 4

Introduction



Geant4 Physics

Geant4 provides a wide variety of physics components for use in simulation

Physics components are coded as processes

- a process is a class which tells a particle how to interact
- Geant4 provides many of these
- users may write their own, but must be derived from a Geant4 process

Processes are classified as

- electromagnetic, hadronic, decay, parameterized or transportation

Geant4 Physics: Electromagnetic

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standard – complete set of processes covering charged particles and gammas

- energy range 1 keV to ~PeV

Low energy – specialized routines for e-, g, charged hadrons

- more atomic shell structure details
- some processes valid down to 250 eV or below
- others not valid above a few GeV

Optical photon – only for long wavelength photons (x-rays, UV, visible)

- processes for reflection/refraction, absorption, wavelength shifting, Rayleigh scattering

Geant4 Physics: Hadronic

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pure hadronic (0 - ~TeV)
- elastic
- inelastic
- capture
- fission

radioactive decay
- at rest and in-flight

photo-nuclear (~10 MeV – ~TeV)

lepto-nuclear (~10 MeV - ~TeV)
- e+, e- induced nuclear reactions
- muon induced nuclear reactions

Geant4 Physics: Decay, Parameterized and Transportation

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decay processes include

- weak decay (leptonic, semi-leptonic decays, radioactive decay of nuclei)
- electromagnetic decay (p0 , S0 , etc.)
- strong decays not included here (they are part of hadronic models)

parameterized process

- electromagnetic showers propagated according to parameters averaged over many events
- faster than detailed shower simulation

transportation

- only one process which is responsible for moving the particle through the geometry

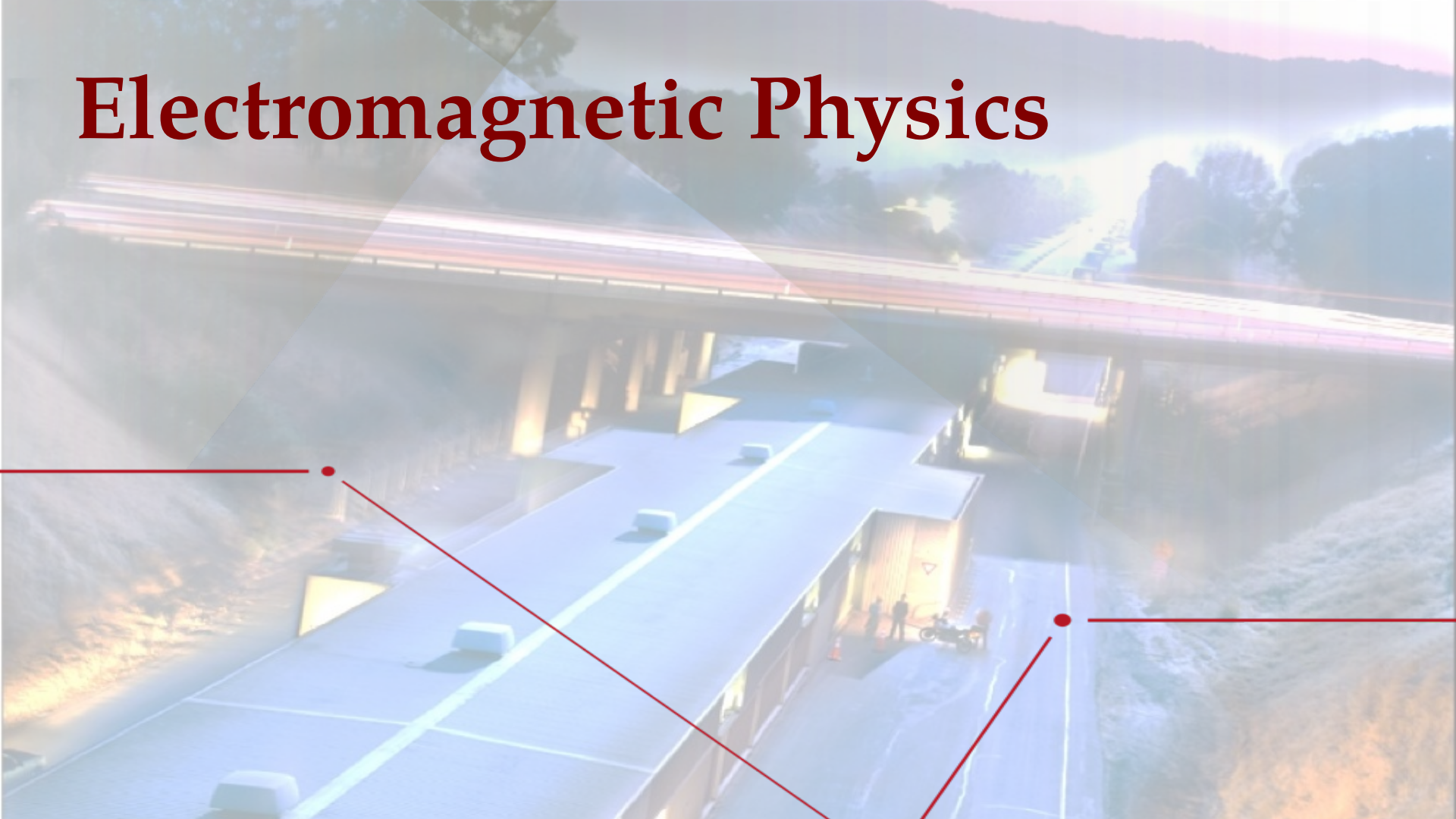
Physics Processes

All the work of particle decays and interactions is done by processes
A process does two things:

- decides when and where an interaction will occur
  - method: GetPhysicalInteractionLength()
  - this requires a cross section or decay lifetime
  - for the transportation process, the distance to the nearest object along the track is required

- generates the final state of the interaction (changes momentum, generates secondaries, etc.)
  - method: DoIt()
  - this requires a model of the physics

Electromagnetic Physics



Geant4 Electromagnetic Packages

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- Standard
  - γ, e± up to 100 TeV
  - hadrons up to 100 TeV
  - ions up to 100 TeV
- Muons
  - up to 1 PeV
  - energy loss propagator
- X-rays
  - X-ray and optical photon production proc.
- High-energy
  - processes at high energy (E>10GeV)
  - physics for exotic particles
- Polarisation
  - simulation of polarized beams
- Optical
  - optical photon interactions
- Low-energy
  - Livermore library γ, e- from 10 eV up to 1 GeV
  - Livermore library based polarized processes
  - PENELOPE code rewrite , γ, e- , e+ from 100 eV up to 1 GeV (2008 version)
  - hadrons and ions up to 1 GeV
  - atomic de-excitation (fluorescence + Auger)
- Geant4-DNA
  - microdosimetry models for radiobiology (Geant4-DNA project) from 0.025 eV to 10 MeV
- Adjoint
  - New sub-library for reverse Monte Carlo simulation from the detector of interest back to source of radiation
- Utils
  - general EM interfaces

Gamma and Electron Transport

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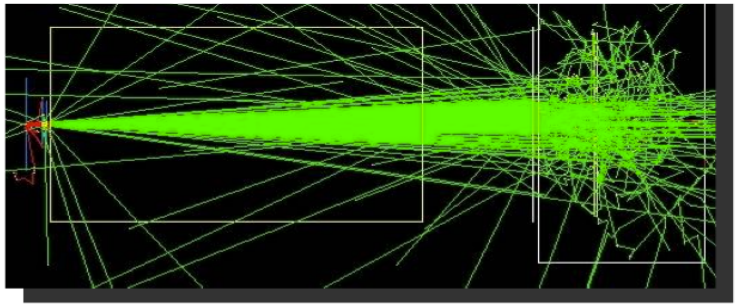
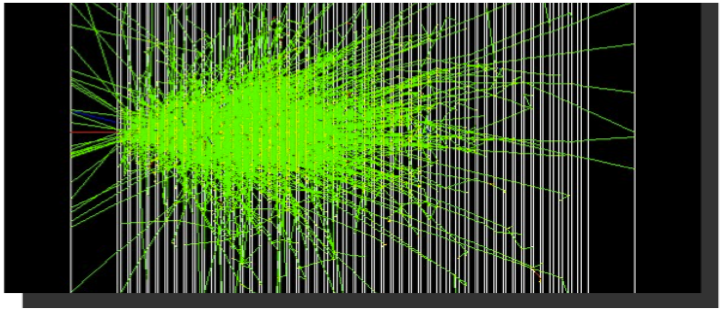
- Photon processes
  - γ conversion into e+e- pair
  - Compton scattering
  - Photoelectric effect
  - Rayleigh scattering
  - *Gamma-nuclear interaction in hadronic sub-package*
- Electron and positron processes
  - Ionisation
  - Coulomb scattering
  - Bremsstrahlung
  - Positron annihilation
  - *Nuclear interaction in hadronic sub-package*
- Suitable for HEP & many other Geant4 applications with electron and gamma beams





Low Energy EM Models

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- Extend the coverage of Geant4 electromagnetic interactions with matter
  - for photons, electrons, positrons and ions
  - down to very low energies (sub-keV scale)

- Possible domains of applications
  - Space science
  - Medical physics
  - Underground physics
  - Microdosimetry for radiobiology and microelectronics
  - …

- Choices of physics models include
  - Livermore : electrons and photons [250 eV – 1 GeV]
  - Penelope : electrons, positrons and photons [100 eV – 1 GeV]
  - Microdosimetry models
    - Geant4-DNA project: [eV – ~ few 100 MeV]
    - MicroElec for Silicon : [eV – 1 GeV/u]

Livermore EM Models

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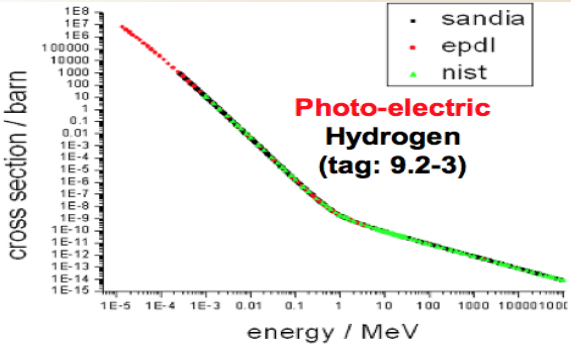
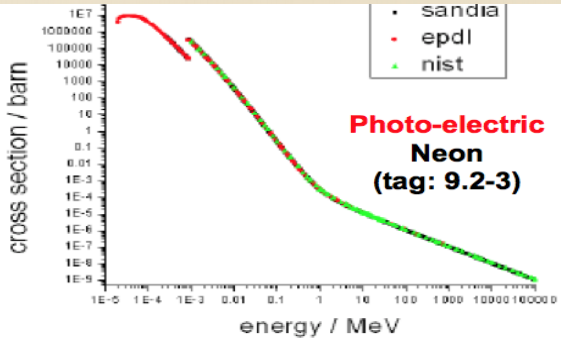
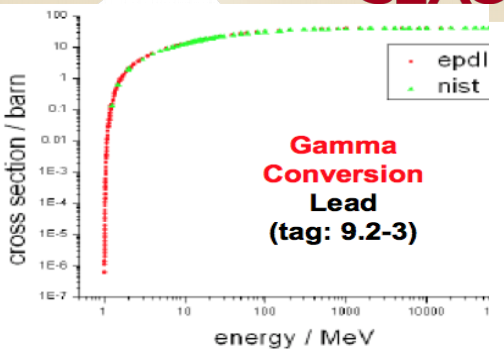
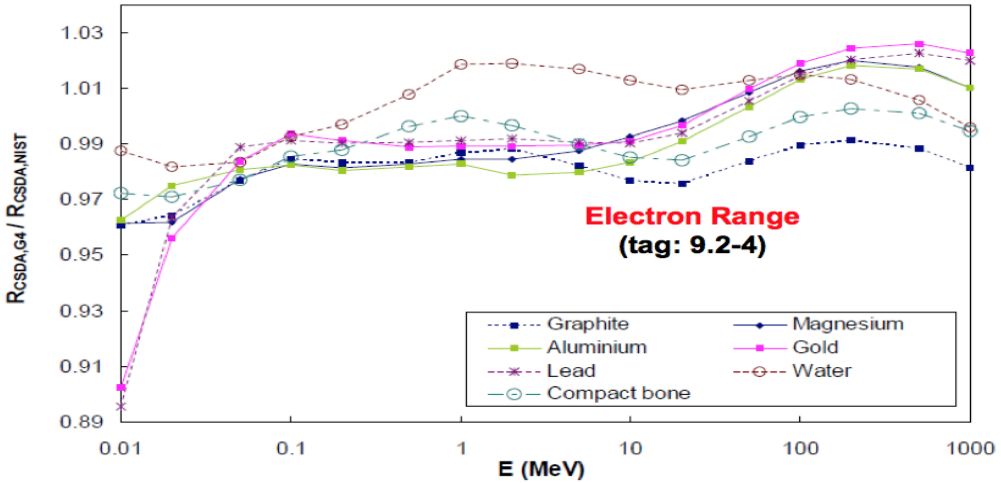
- Full set of models for electrons and gammas
- Based on publicly available evaluated data tables from the Livermore data library
  - EADL : Evaluated Atomic Data Library
  - EEDL : Evaluated Electrons Data Library
  - EPDL97 : Evaluated Photons Data Library
  - Mixture of experiments and theories
  - Binding energies: Scofield
- Data tables are interpolated by Livermore model classes to compute
  - Total cross sections: photoelectric, Compton, Rayleigh, pair production, Bremsstrahlung
  - Shell integrated cross sections: photo-electric, ionization
  - Energy spectra: secondary e- processes
- Validity range (recommended) : 250 eV - 100 GeV
  - Processes can be used down to 100 eV, with a reduced accuracy
  - In principle, down to ~10 eV
- Included elements from Z=1 to Z=100
  - Include atomic effects (fluorescence, Auger)
  - Atomic relaxation : Z > 5 (EADL transition data)
- Naming scheme: G4LivermoreXXXModel (eg. G4LivermoreComptonModel)

Livermore Models: Validation









Polarized Livermore Models

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- Describe in detail the kinematics of polarized photon interactions
- Based on the Livermore database
- Possible applications of such developments
  - design of space missions for the detection of polarized photons
- Naming scheme: G4LivermorePolarizedXXXModel
  - eg. G4LivermorePolarizedComptonModel
- More in the following publications

Nucl. Instrum. Meth. A 566 (2006) 590-597 (Photoelectric)
Nucl. Instrum. Meth. A 512 (2003) 619-630 (Compton and Rayleigh)
Nucl.Instrum. Meth. A 452 (2000) 298-305 (Pair production)

Available Livermore Models

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Physics Process	Process Class	Model Class	Low Energy Limit	High Energy Limit
Gammas				
Compton	G4ComptonScattering	G4LivermoreComptonModel	250 eV (kill)	100 GeV
Polarized Compton	G4ComptonScattering	G4LivermorePolarizedComptonModel	250 eV (kill)	100 GeV
Rayleigh	G4RayleighScattering	G4LivermoreRayleighModel	10 eV (kill)	100 GeV
Polarized Rayleigh	G4RayleighScattering	G4LivermorePolarizedRayleighModel	250 eV (kill)	100 GeV
Conversion	G4GammaConversion	G4LivermoreGammaConversionModel	1.022 MeV	100 GeV
Polarized Conversion	G4GammaConversion	G4LivermorePolarizedGammaConversionModel	1.022 MeV	100 GeV
Photo-electric	G4PhotoElectricEffect	G4LivermorePhotoElectricModel	~ few eV	100 GeV
Polarized Photo-electric	G4PhotoElectricEffect	G4LivermorePolarizedPhotoElectricModel	10 eV	100 GeV
Electrons				
Ionization	G4eIonisation	G4LivermoreIonisationModel	100 eV	100 GeV
Bremsstrahlung	G4eBremsstrahlung	G4LivermoreBremsstrahlungModel	10 eV	100 GeV

Penelope EM Models

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- Geant4 includes the low-energy models for electrons, positrons and photons from the Monte Carlo code PENELOPE (PENetration and Energy LOss of Positrons and Electrons) version 2008
  Nucl. Instrum. Meth. B 207 (2003) 107-123

- Physics models
  - Specifically developped by the group of F. Salvat et al.
  - Great care dedicated to the low-energy description
    - Atomic effects, fluorescence, Doppler broadening...

- Mixed approach: analytical, parameterized & database-driven
  - Applicability energy range: 100 eV – 1 GeV

- Also include positrons
  - Not described by Livemore models

- G4PenelopeXXXModel (e.g. G4PenelopeComptonModel)

Available Penelope Models

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Physics Process	Process Class	Model Class	Low Energy Limit	High Energy Limit
Gammas				
Compton	G4ComptonScattering	G4PenelopeComptonModel	100 eV	1 GeV
Rayleigh	G4RayleighScattering	G4PenelopeRayleighModel	100 eV	1 GeV
Conversion	G4GammaConversion	G4PenelopeGammaConversionModel	1.022 MeV	1 GeV
Photo-electric	G4PhotoElectricEffect	G4PenelopePhotoElectricModel	100 eV	1 GeV
Electrons/Positrons				
Ionization	G4eIonisation	G4PenelopeIonisationModel	100 eV	1 GeV
Bremsstrahlung	G4eBremsstrahlung	G4PenelopeBremsstrahlungModel	100 eV	1 GeV
Positrons				
Annihilation	G4eplusAnnihilation	G4PenelopeAnnihilationModel	100 eV	1 GeV

Geant4 for Micro-dosimetry in Radiobiology

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- History
  - initiated in 2001 by Petteri Nieminen (European Space Agency / ESTEC) in the framework of the « Geant4-DNA » project

- Objective : adapt the general purpose Geant4 Monte Carlo toolkit for the simulation of interactions of radiation with biological systems at the cellular and DNA level (« microdosimetry for radiobiology »)

- A full multidisciplinary activity of the Geant4 low energy electromagnetic Physics working group, involving physicists, theoreticians, biophysicists…

- Applications :
  - Radiobiology, radiotherapy and hadrontherapy
    - eg. early prediction of direct & non-direct DNA strand breaks from ionising radiation
  - Radioprotection for human exploration of Solar system

- Dedicated web site & publications : http://geant4-dna.org

How can Geant4-DNA model early DNA damage ?

PHYSICAL STAGE
step-by-step modelling of **physical interactions** of incoming & secondary ionising radiation with biological medium (liquid water)

- Excited **water molecules**
- Ionised **water molecules**
- **Solvated electrons**

PHYSICO-CHEMICAL/CHEMICAL STAGE
- **Radical** species production
- Diffusion
- Mutual chemical interactions

GEOMETRICAL MODELS
DNA strands, chromatin fibres, chromosomes, whole cell nucleus, cells…
for the prediction of damage resulting from direct and indirect hits

DIRECT DNA DAMAGE

INDIRECT DNA DAMAGE

t=0 $t=10^{-15}s$ $t=10^{-6}s$

Overview of physics models for liquid water

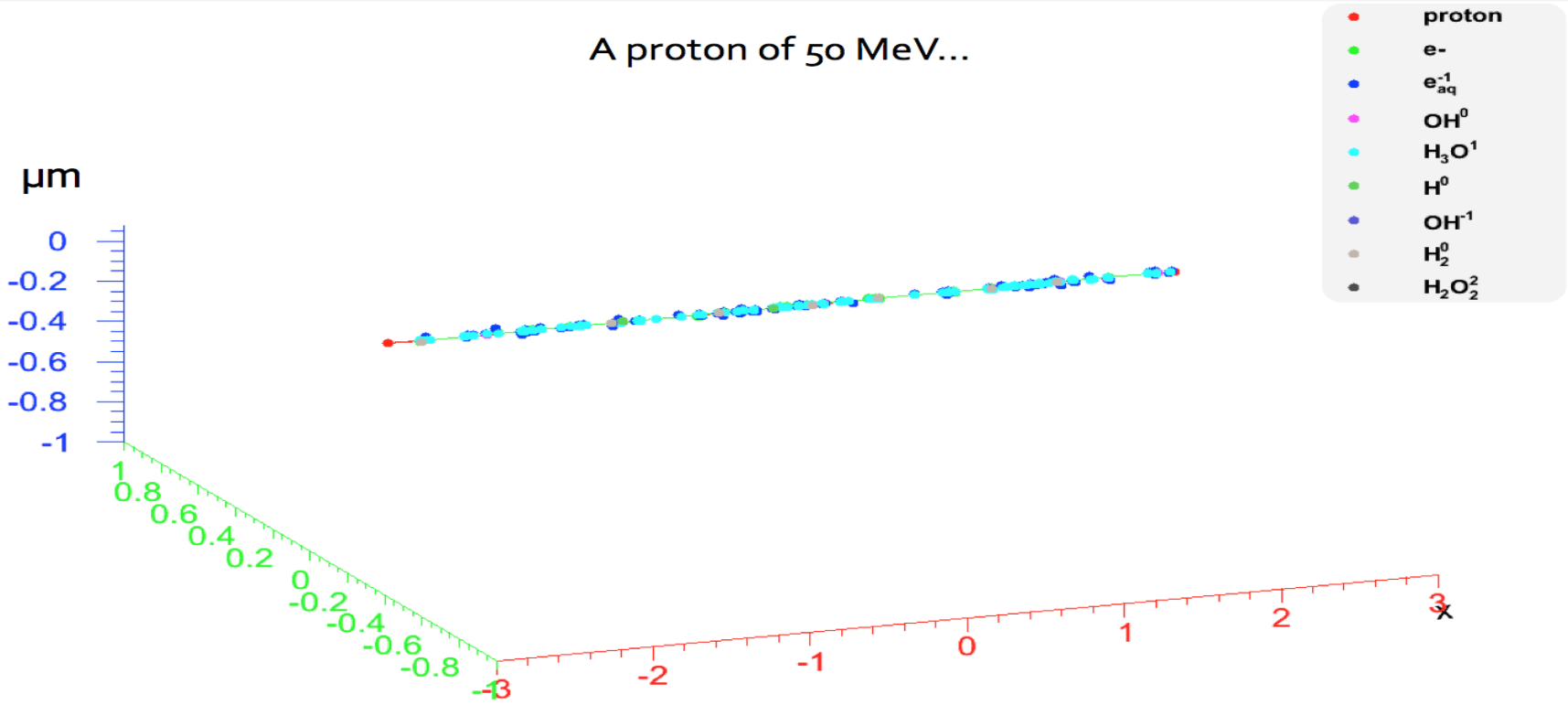
- **Electrons**
  - **Elastic scattering**
    - Screened Rutherford and Brenner-Zaider below 200 eV
    - Partial wave framework model, 3 contributions to the interaction potential
  - **Ionisation**
    - 5 levels for H_2O
    - Dielectric formalism & FBA using Heller optical data up to 1 MeV, and low energy corrections
  - **Excitation (*)**
    - 5 levels for H_2O
    - Dielectric formalism & FBA using Heller optical data and semi-empirical low energy corrections
  - **Vibrational excitation (*)**
    - Michaud *et al.* xs measurements in amorphous ice
    - Factor 2 to account for phase effect
  - **Dissociative attachment (*)**
    - Melton *et al.* xs measurements

(*) only available in Geant4-DNA

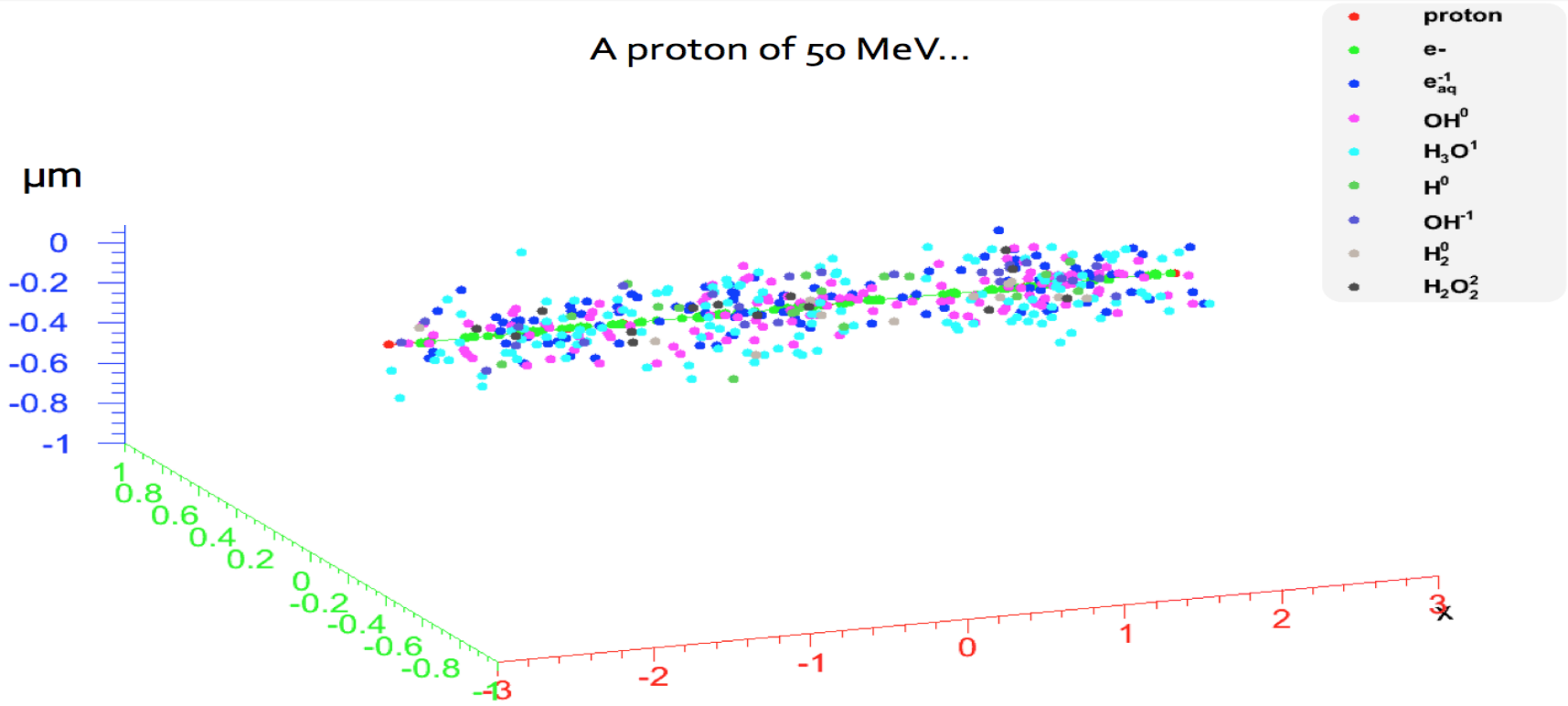
See Med. Phys. 37 (2010) 4692-4708 (link) and Appl. Radiat. Isot. 69 (2011) 220-226 (link)

- **Protons & H**
  - **Excitation (*)**
    - Miller & Green speed scaling of e^- excitation at low energies and Born and Bethe theories above 500 keV
  - **Ionisation**
    - Rudd semi-empirical approach by Dingfelder *et al.* and Born and Bethe theories & dielectric formalism above 500 keV (relativistic + Fermi density)
  - **Charge change (*)**
    - Analytical parametrizations by Dingfelder *et al.*
- **He^0, He^+, He^{2+}**
  - **Excitation (*) and ionisation**
    - Speed and effective charge scaling from protons by Dingfelder *et al.*
  - **Charge change (*)**
    - Semi-empirical models from Dingfelder *et al.*
- **Li, Be, B, C, N, O, Si, Fe**
  - **Ionisation**
    - Speed scaling and global effective charge by Booth and Grant
- **Photons**
  - from EM « standard » and « low energy »
    - Default: « Livermore »

Situation at 1 picosecond

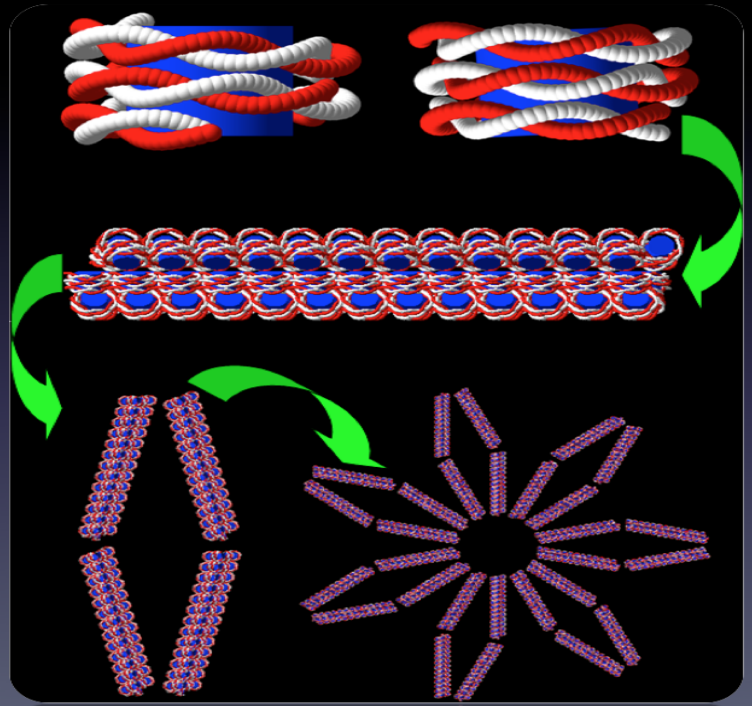


Situation at 1 microsecond



« dnageometry » advanced example

Morgane Dos Santos PhD thesis (link)



Nucleosome

- 200 bp / nucleosome
- DNA diameter = 2.16 nm
- Histone = cylinder of 6.5 nm in diameter and 5.7 nm in height

Chromatin fiber

- 90 nucleosomes / fiber
- 7 nucleosomes / turn
- D = 31 nm
- L = 161 nm

Chromatin fiber loop

- 4 fibers / loop assembled in a diamond shape
- 7 loops to form a "flower"*

* W. Friedland et al, Rad. Res 59 (2003), 401-410

A new way to describe geometries in Geant4-DNA

- PDB : Protein Data Bank
  http://www.rcsb.org/pdb/
  - 3D structure of molecules
  - Proteins
  - Nucleic acids
- Description of DNA molecules
  - 1FZX.pdb
    - Dodecamer
    - 12 DNA base pairs
    - (2,8 x 2,3 x 4,01 nm³)
  - 1ZBB.pdb
    - Tetranucleosome
    - 2 nucloosomes : 347 pairs of bases
    - (9,5 x 15,0 x 25,1 nm³)

```
HEADER    STRUCTURAL PROTEIN/DNA                  08-APR-05   1ZBB
TITLE     STRUCTURE OF THE 4_601_167 TETRANUCLEOSOME
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ATOM      1  O5'  DA I   1      70.094  16.969 123.433  0.50238.00      O
ATOM      2  C5'  DA I   1      70.682  18.216 123.054  0.50238.00      C
ATOM      3  C4'  DA I   1      69.655  19.289 122.776  0.50238.00      C
...
TER   14223      DT J 347
...
HELIX    1   1 GLY A   44  SER A   57  1                                14
HELIX    2   2 ARG A   63  ASP A   77  1                                15
...
SHEET    1   A 2 ARG A  83  PHE A  84  0
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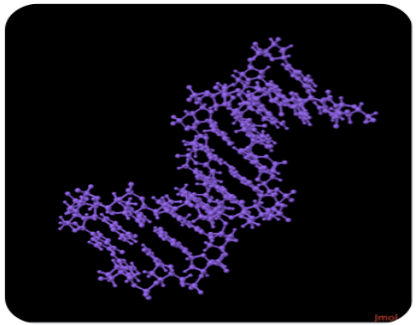

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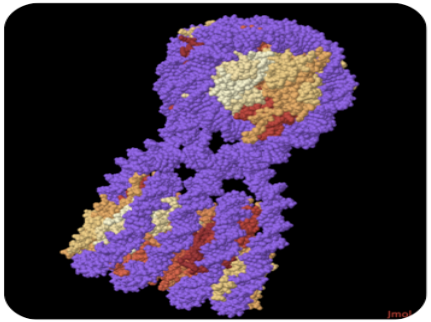
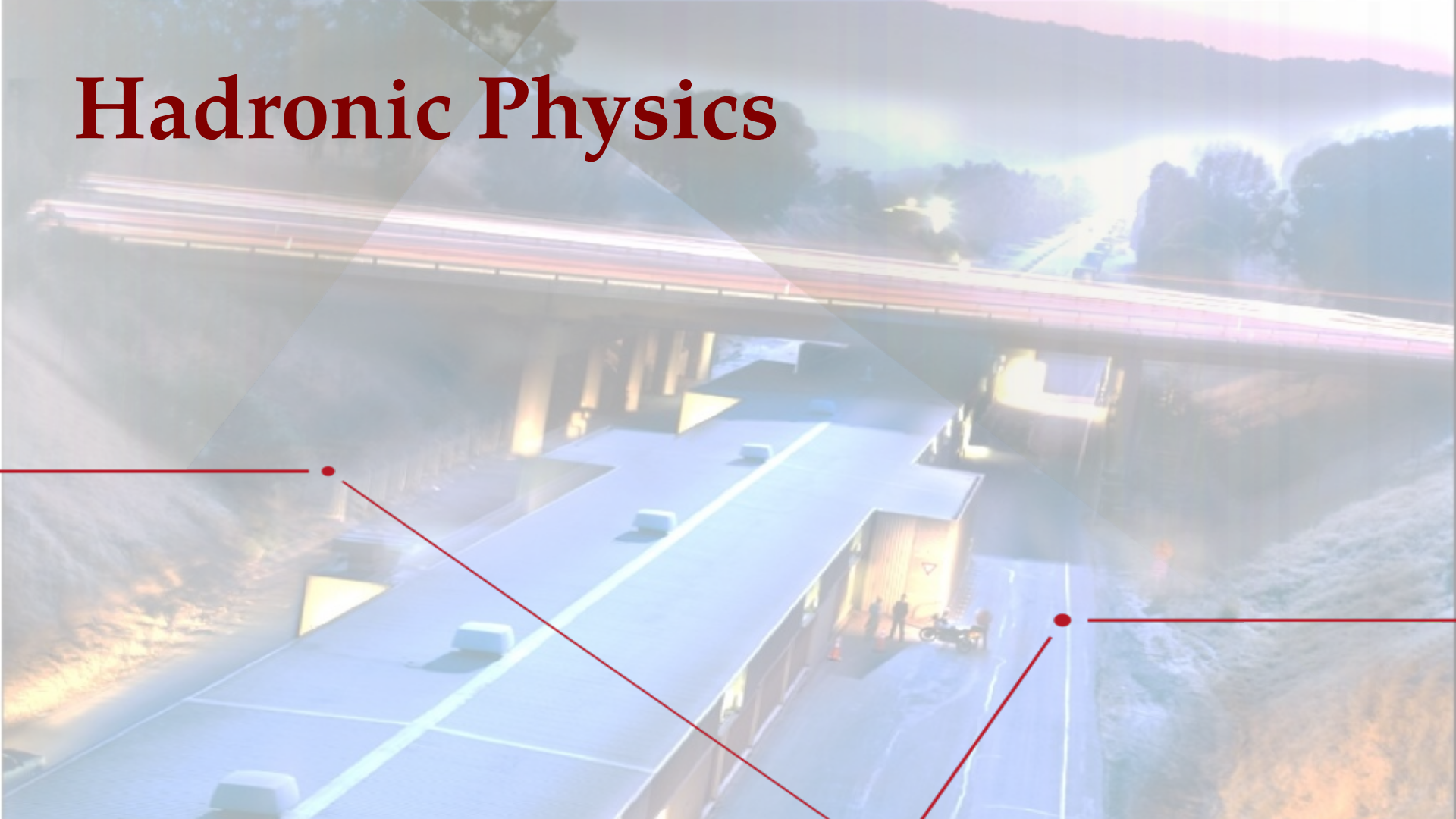


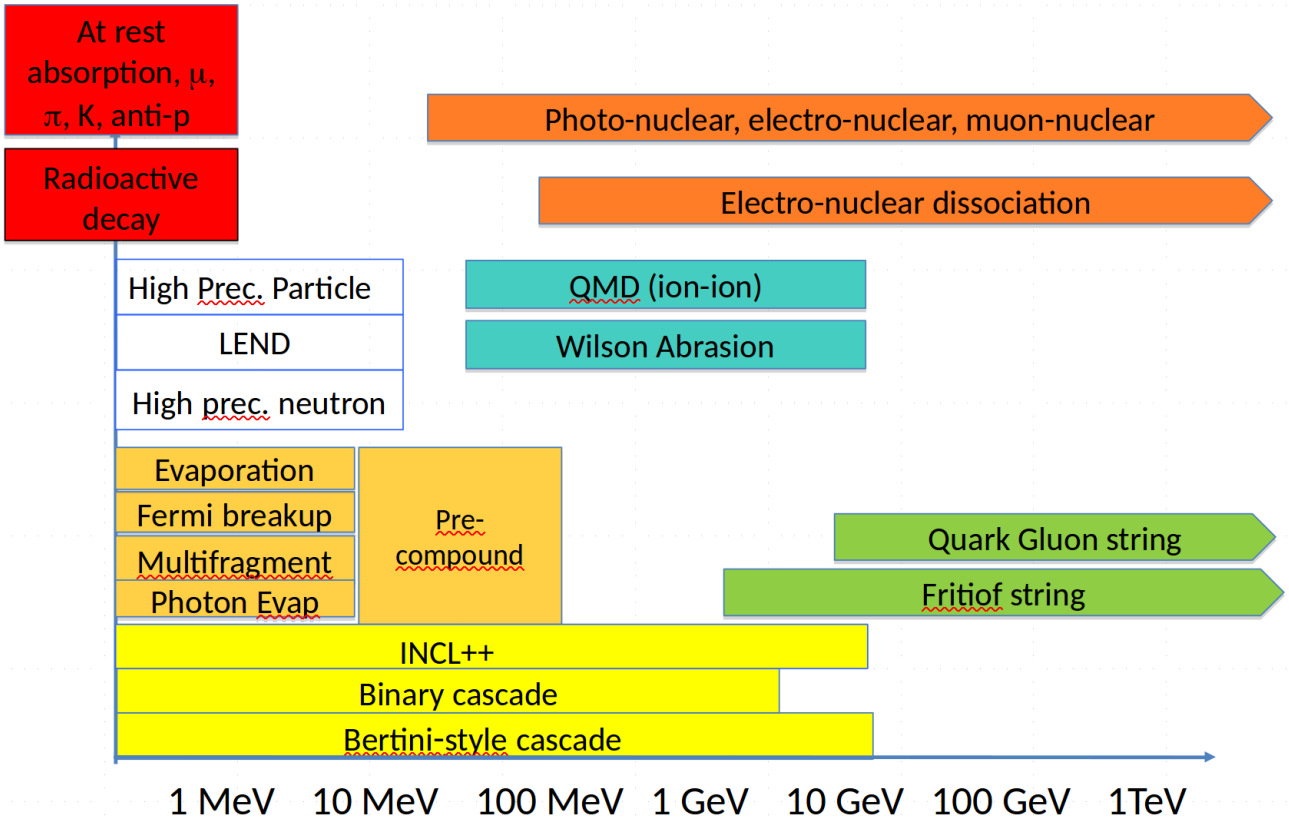
1ZBB.pdb

Trung Pham PhD thesis (soon)

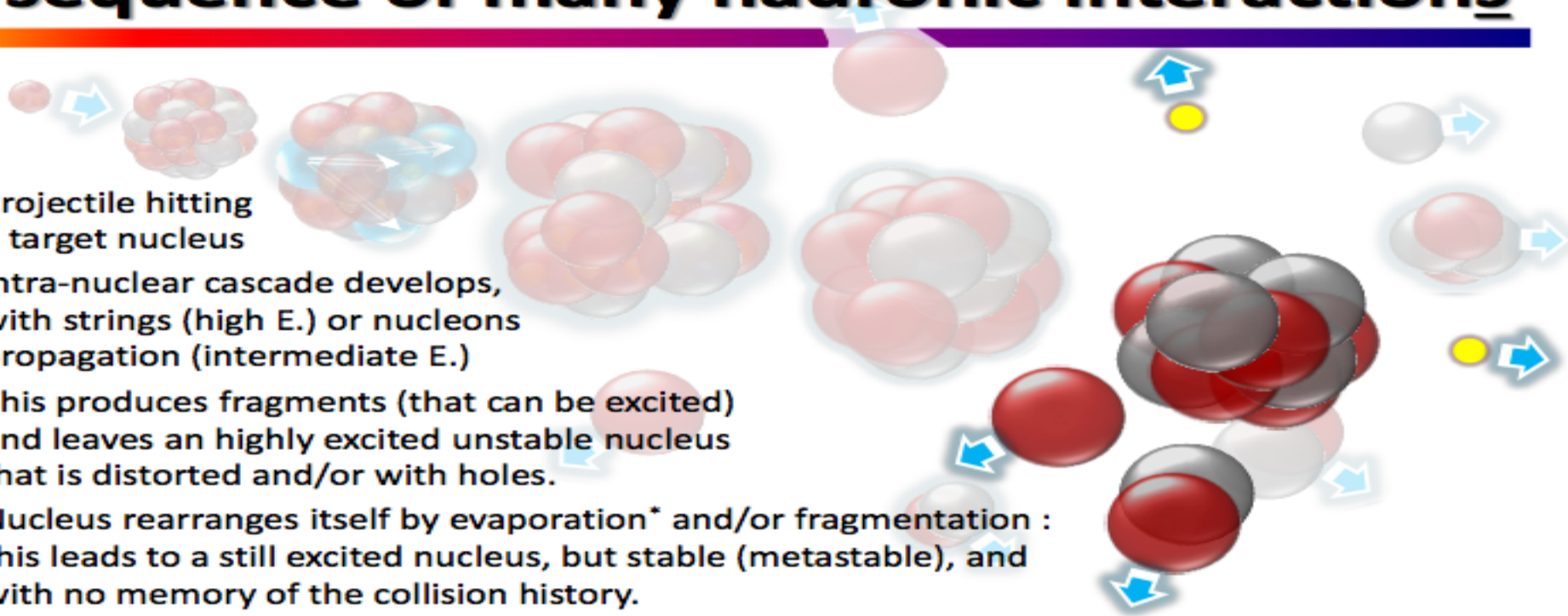
Hadronic Physics



Partial Hadronic Catalog



One hadronic collision = sequence of many hadronic interactions



Projectile hitting a target nucleus

Intra-nuclear cascade develops, with strings (high E.) or nucleons propagation (intermediate E.)

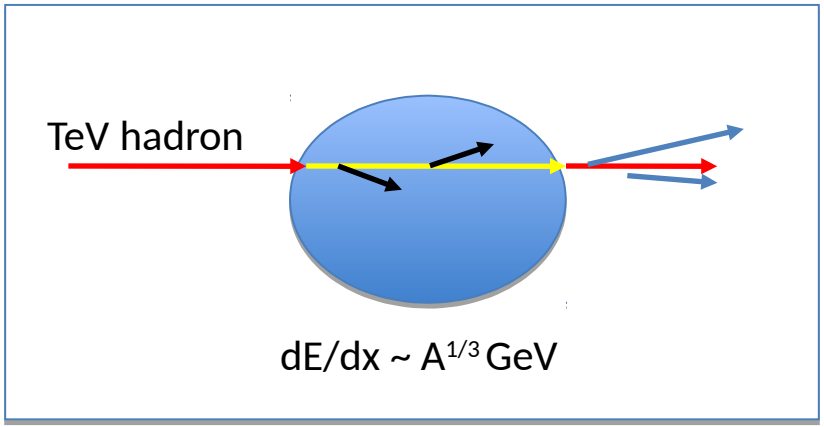
This produces fragments (that can be excited) and leaves an highly excited unstable nucleus that is distorted and/or with holes.

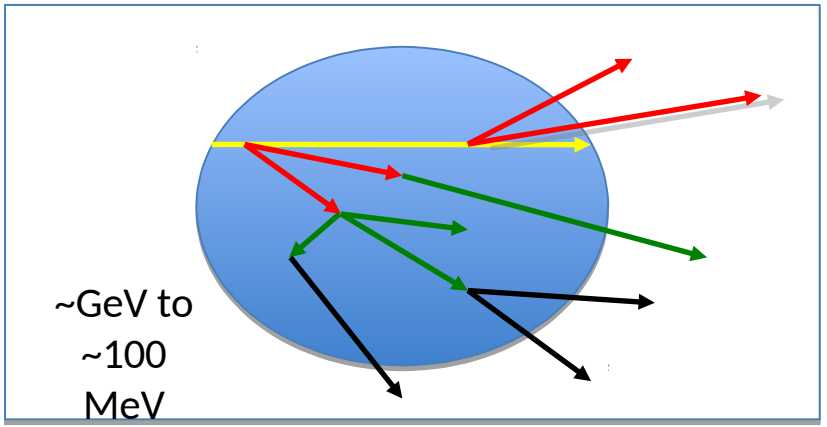
Nucleus rearranges itself by evaporation* and/or fragmentation : this leads to a still excited nucleus, but stable (metastable), and with no memory of the collision history.

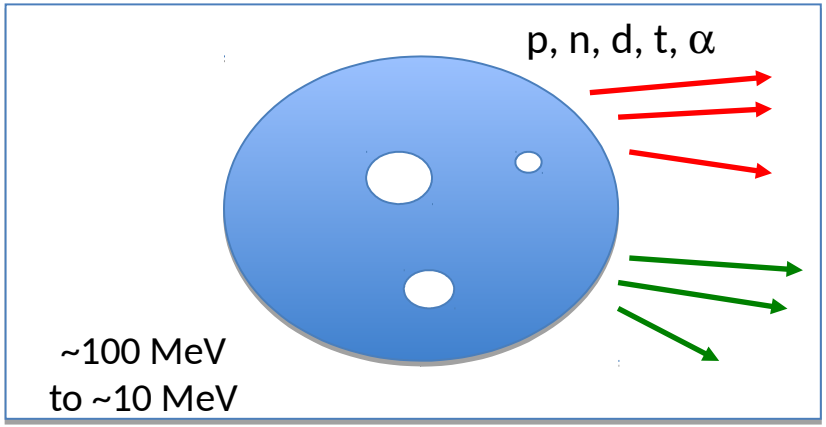
The nucleus undergoes final de-excitation by evaporation* or fission and ends-up in its ground state. In case of fission, further de-excitation of fragments may occur.

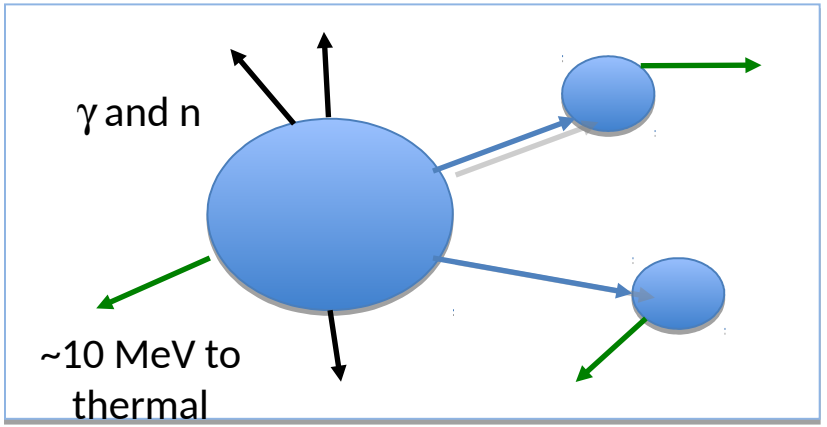
(*) **Evaporation** = de-excitation by emission of light nuclei $\in$ {n, p, d, t, 3He, α} or photon

Schematic view of hadronic interaction









Precompound Models

G4PrecompoundModel is used for **nucleon-nucleus interactions at low energy** and as a nuclear de-excitation model within higher-energy codes

- valid for incident p, n from 0 to 170 MeV
- takes a nucleus from a highly excited set of particle-hole states down to equilibrium energy by emitting p, n, d, t, ^{3}He and γ
- once equilibrium is reached, four sub-models are called to take care of nuclear evaporation and break-up
  - these 4 models not currently callable by users

De-excitation Models

Four sub-models typically used to de-excite a remnant nucleus

- Fermi break-up
- photon evaporation
- multi-fragmentation
- fission

De-excitation Details

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Fermi break-up

- remnant nucleus is destroyed – nothing left but p, n, t, a
- valid only for A < 17 and high excitation energies

Fission

- splits excited nucleus and emits fission fragments + n
- valid only for A > 65

Multi-fragmentation

- statistical breakup model with propagation of fragments in Coulomb field
- for excitation energies E/A > 3 MeV

Photo-evaporation

- Lower (nuclear) excitation energy is reduced via emission of gammas
- Finally brings nucleus to ground state

Intra-nuclear Cascade Models

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Typical intra-nuclear cascade energies are inconvenient

- too high for nuclear physics treatments
- too low for QCD

Must use Monte Carlo techniques to propagate hadrons within the target nucleus in order to produce a final state

- "Monte Carlo within a Monte Carlo"
- one of the first applications of Monte Carlo methods to nuclear interactions
- time-consuming

Bertini-style Cascade Model

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A classical (non-quantum mechanical) cascade

- average solution of a particle traveling through a medium (Boltzmann equation)
- no scattering matrix calculated
- can be traced back to some of the earliest codes (1960s)

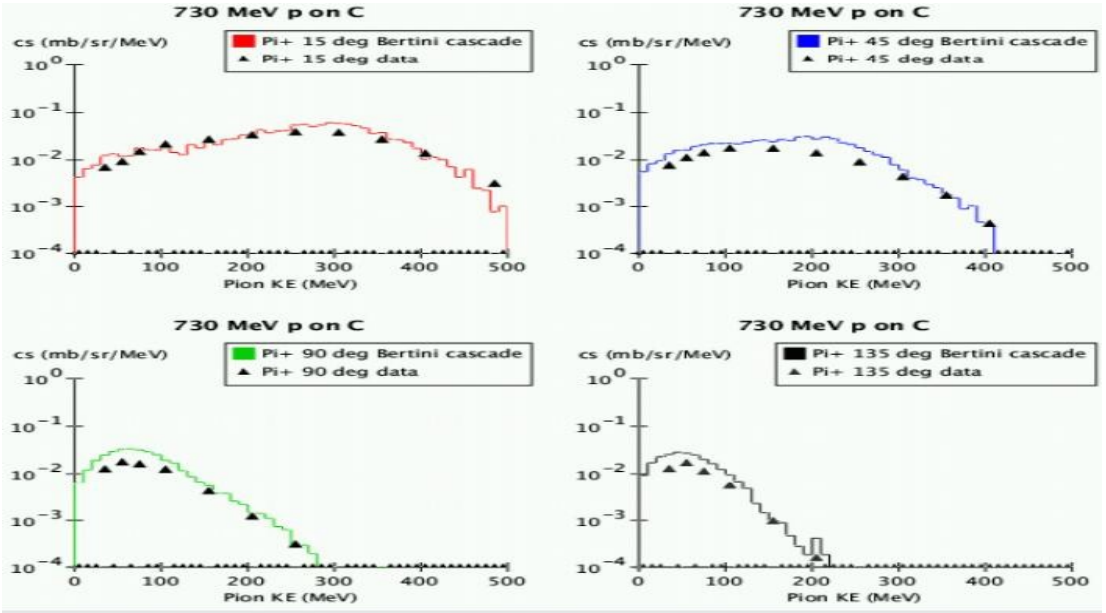
Core code:

- elementary particle collisions with individual protons and neutrons: free space cross sections used to generate secondaries
- cascade in nuclear medium
- pre-equilibrium and equilibrium decay of residual nucleus
- target nucleus built of three concentric shells

Using the Bertini Cascade

In Geant4 the Bertini cascade is used for p, n, π^+, π^-, K^+, K^-, K^0_L, K^0_S, Λ, Σ^0, Σ^+, Σ^-, Ξ^0, Ξ^-, Ω^-

- valid for incident energies of 0 – 10 GeV
- can also be used for gammas



Binary Cascade Model

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Modeling sequence similar to Bertini, except

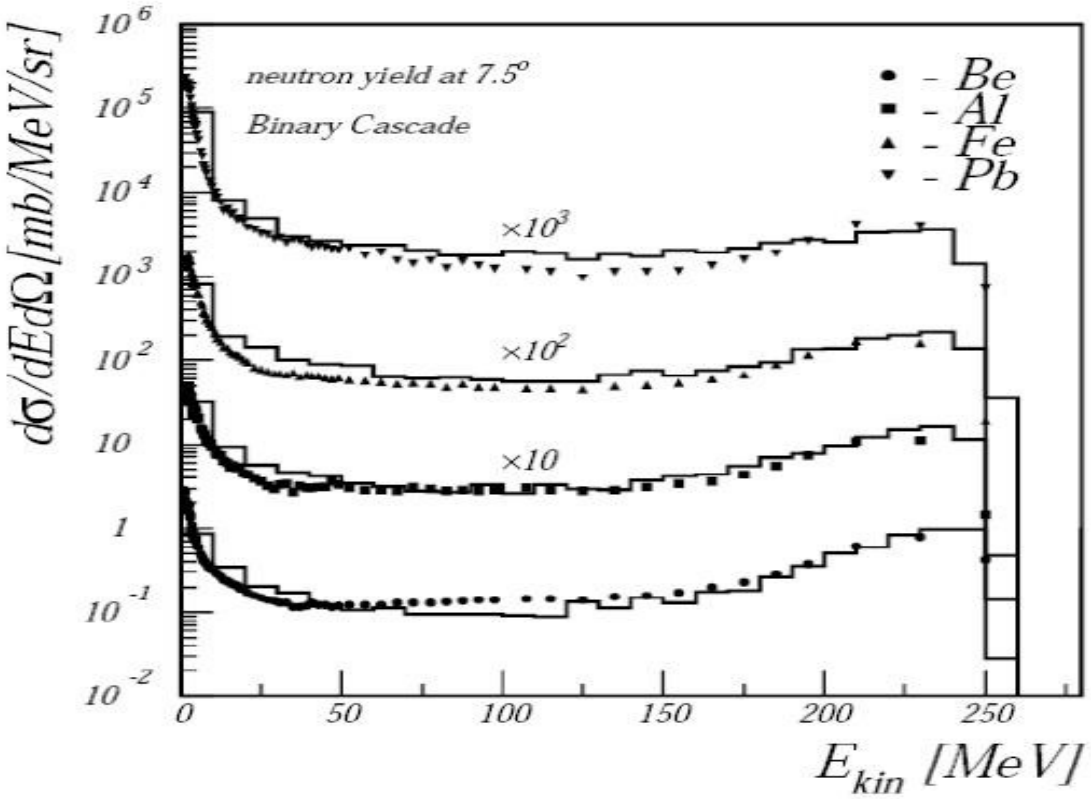
- it's a time-dependent model
- hadron-nucleon collisions handled by forming resonances which then decay according to their quantum numbers
- particles follow curved trajectories in smooth nuclear potential

Binary cascade is currently used for incident p, n and valid for incident:

- from 0 to 10 GeV valid for incident p,n
- from 0 to 1.3 GeV for incident π

A variant of the model, G4BinaryLightIonReaction, is valid for incident ions up to A = 12 (or higher if target has A < 12)

Validation of Binary Cascade: 256 MeV protons



INCL++ Cascade Model

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Model elements

- time-dependent model
- smooth Woods-Saxon or harmonic oscillator potential
- particles travel in straight lines through potential
- delta resonance formation and decay (like Binary cascade)

Valid for incident p, n and π, d, t, ^{3}He, α from 150 MeV to 10 GeV

- also works for projectiles up to A = 12
- targets must be 11 < A < 239
- ablation model (ABLA) can be used to de-excite nucleus

Used successfully in spallation studies

- also expected to be good in medical applications

Validation of INCL++ Model

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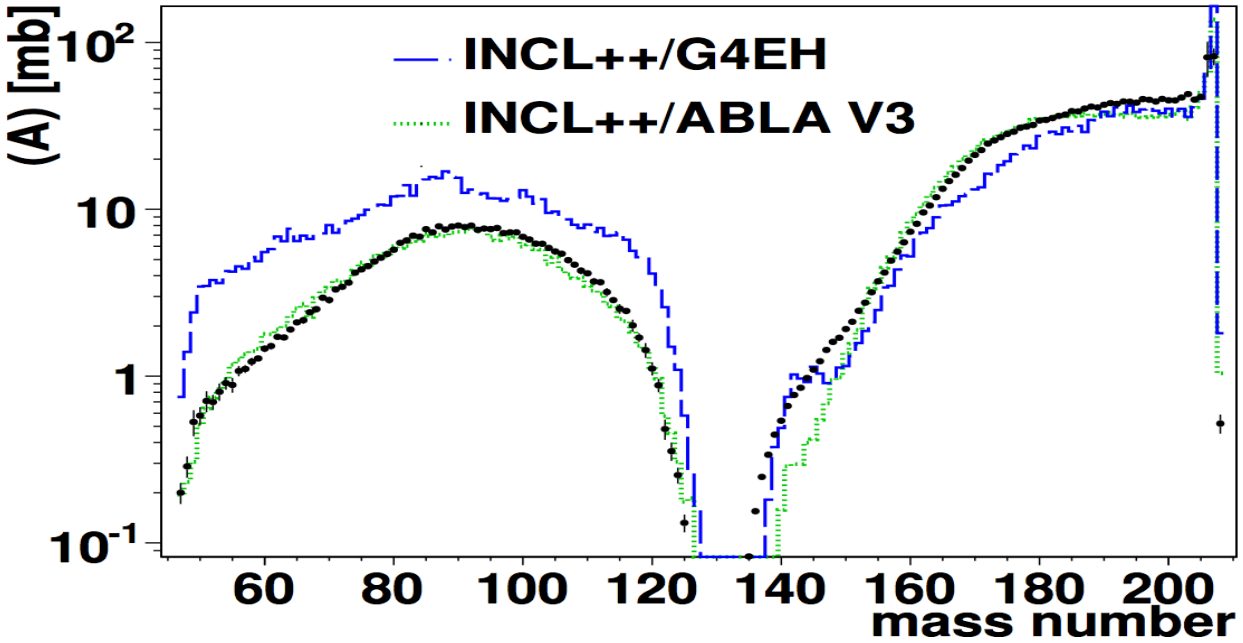
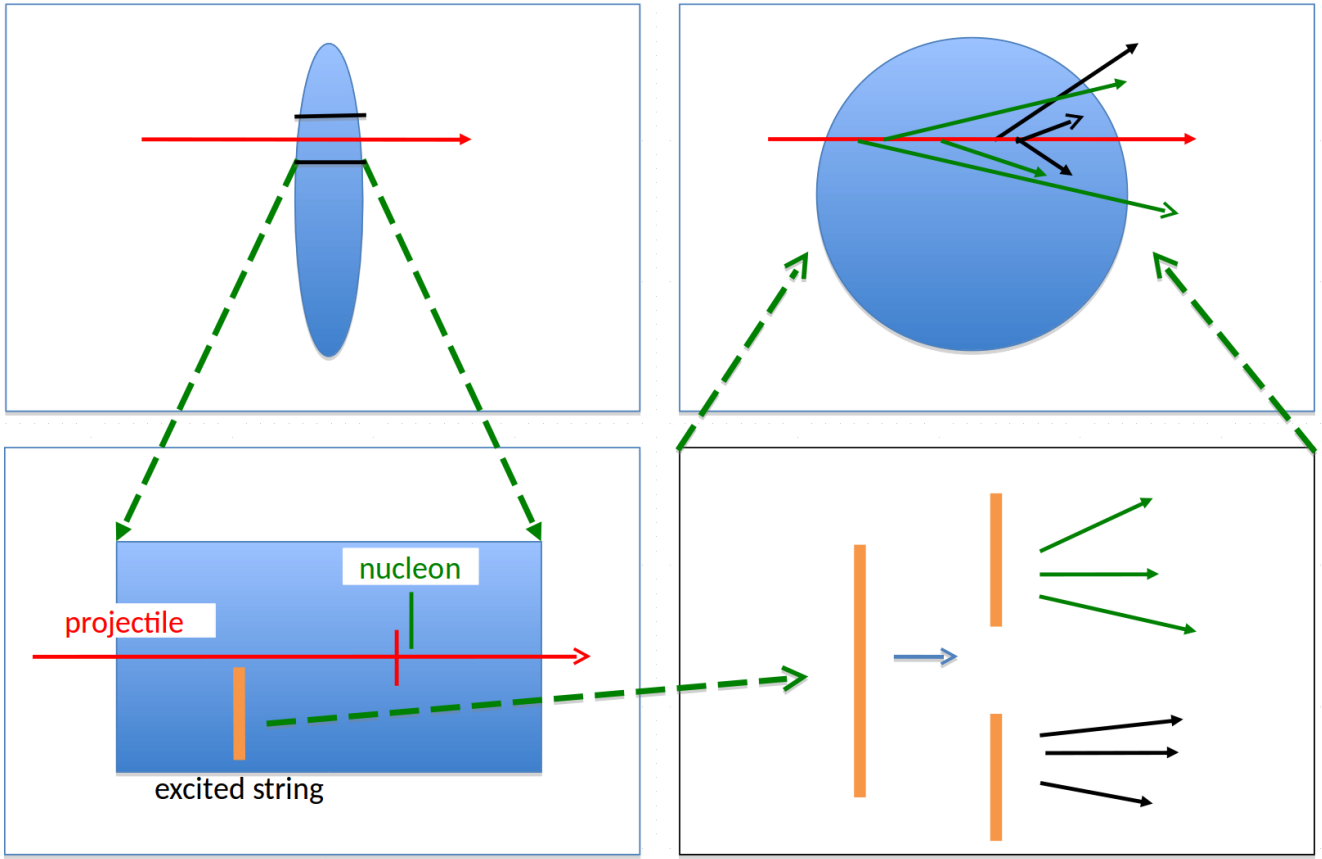
Spallation residues from p + ^{208}Pb



High Energy Interactions



How the String Model Works (FTF Model)

Lorentz contraction turns nucleus into pancake

All nucleons within 1 fm of path of incident hadron are possible targets

Excited nucleons along path collide with neighbors

- n + n → nΔ, NN, ΔΔ, NΔ, …
- essentially a quark-level cascade in vicinity of path → Reggeon cascade

All hadrons treated as QCD strings

- projectile is quark-antiquark pair or quark-diquark pair
- target nucleons are quark-diquark pairs

How the String Model Works (FTF Model)

Hadron excitation is represented by stretched string

- string is set of QCD color lines connecting the quarks

When string is stretched beyond a certain point it breaks

- replaced by two shorter strings with newly created quarks, anti-quarks on each side of the break

High energy strings then decay into hadrons according to fragmentation functions

- fragmentation functions are theoretical distributions fitted to experiment

Resulting hadrons can then interact with nucleus in a traditional cascade

Two QCD String Models Available

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Fritiof (FTF) valid for

- p, n, π, K, Λ, Σ, Ω from 3 GeV to ~TeV
- anti-proton, anti-neutron, anti-hyperons at all energies
- anti-d, anti-t, anti-^{3}He, anti-α with momenta between 150 MeV/nucleon and 2 GeV/nucleon

Quark-Gluon String (QGS) valid for

- p, n, π, K from 15 GeV to ~TeV

- Both models handle:
  - building 3-D model of nucleus from individual nucleons
  - splitting nucleons into quarks and di-quarks
  - formation and excitation of QCD strings
  - string fragmentation and hadronization

There is more….

Hadronic Elastic scattering: Barashenkov-Glauber-Gribov approach

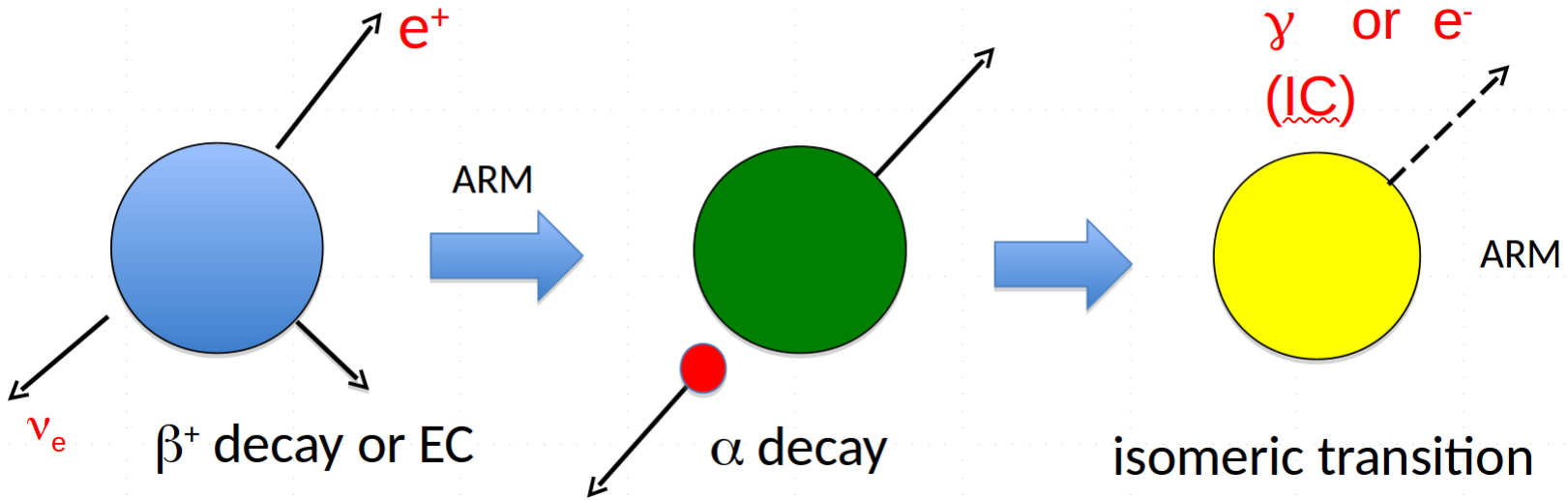
Low Energy neutrons (E<20MeV): treated w/ data-driven models, international data-base (ENDF-VII.B)

Capture of negatively charged particles from nuclei: treated w/ Bertini modle

Gamma and Lepto-nuclear: mediated w/ virtual photon exchange, again via Bertini model (converting γ to π^0)

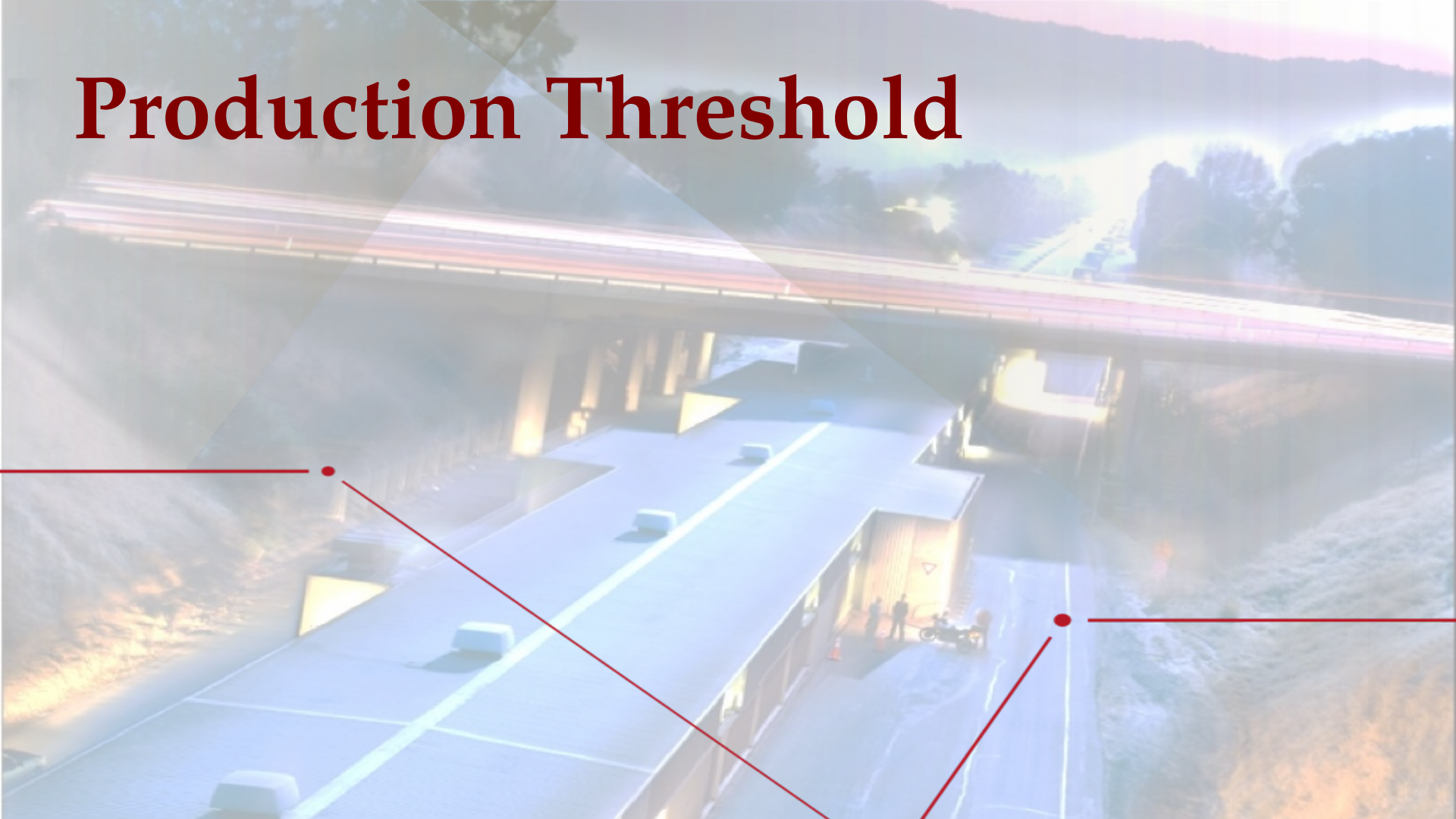
Radioactive Decay

Radioactive Decay Chain



EC: electron capture
IC: internal conversion
ARM: atomic relaxation model

Production Threshold



Threshold for Secondary Production

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Every simulation developer must answer the question: how low can you go?

- at what energy do I stop tracking particles?

This is a balancing act:

- need to go low enough to get the physics you're interested in
- can't go too low because some processes have infrared divergence causing CPU to skyrocket

The traditional Monte Carlo solution is to impose an absolute cutoff in energy

- particles are stopped when this energy is reached
- remaining energy is dumped at that point

Threshold for Secondary Production

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But, such a cut may cause imprecise stopping location and deposition of energy

- There is also a particle dependence
- range of a 10 keV γ in Si is a few cm
- range of a 10 keV e^- in Si is a few microns

And a material dependence

- suppose you have a detector made of alternating sheets of Pb and plastic scintillator
- if the cutoff is OK for Pb it will likely be wrong for the scintillator which does the actual energy measurement

Threshold for Secondary Production

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Geant4 solution: impose a production threshold

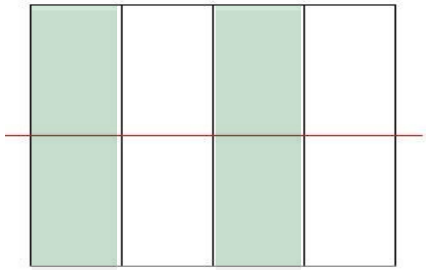
- this threshold is a **distance**, not an energy
- default = 0.7 mm
- the primary particle loses energy by producing secondary electrons or gammas
- if primary no longer has enough energy to produce secondaries which travel at least 0.7 mm, two things happen:
  - discrete energy loss ceases (no more secondaries produced)
  - the primary is tracked down to zero energy using continuous energy loss

Stopping location is therefore correct

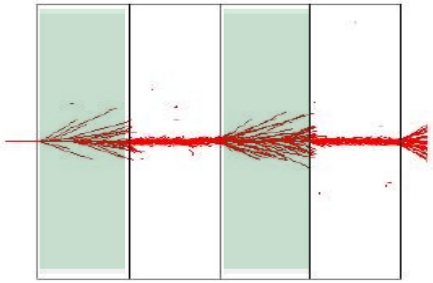
Only one value of production threshold distance is needed for all materials because it corresponds to different energies depending on material

Production Threshold vs. Energy Cut
Example: 500 MeV p in LAr-Pb Sampling Calorimeter

Geant3 (and others)

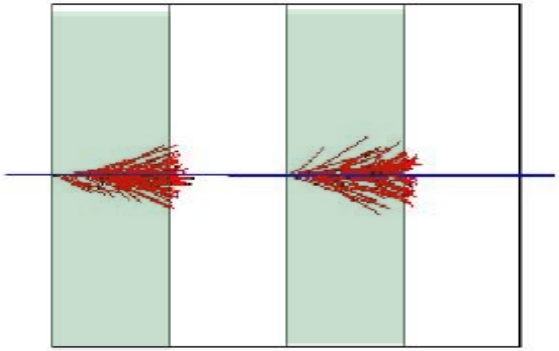


Cut = 2 MeV



Cut = 450 keV

Geant4



Production range = 10.5 mm

Physics Lists

What is a Physics List?

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A class which collects all the particles, physics processes and production thresholds needed for your application

It tells the run manager how and when to invoke physics

It is a very flexible way to build a physics environment

- user can pick the particles he wants
- user can pick the physics to assign to each particle
-

But, user must have a good understanding of the physics required

- omission of particles or physics could cause errors or poor simulation

Why Do We Need a Physics List?

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Physics is physics – shouldn't Geant4 provide, as a default, a complete set of physics processes that everyone can use?

No:

- there are many different physics models and approximations
  - very much the case for hadronic physics
  - but also true for electromagnetic physics
  -
- computation speed is an issue
  - a user may want a less-detailed, but faster approximation

- no application requires all the physics and particles that Geant4 has to offer
  - e.g., most medical applications do not want multi-GeV physics

Choosing a Physics List

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Which physics list you use is highly dependent on your use case

Before choosing, or building your own, familiarize yourself with the major physics processes available

- the process-model catalog is useful for this
- see Geant4 web page under User Support, item 11b

Geant4 provides several "production physics lists" which are routinely validated and updated with each release

- these should be considered only as starting points which you may need to validate or modify for your application

There are also many physics lists in the examples which you can copy

- these are often very specific to a given use case

Choosing a Physics List

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There are currently 19 packaged physics lists available

- but you will likely be interested in only a few, namely the “production” physics lists
- many physics lists are either developmental or customized in some way, and so not very useful to new users

6 reference physics lists:

- FTFP_BERT, FTFP_BERT_HP
- QGSP_BERT, QGSP_BERT_HP, QGSP_BIC
- QGSP_FTFP_BERT

Physics List Naming Convention

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The following acronyms refer to various hadronic options

- **QGS** -> Quark Gluon String model (>~20 GeV)
- **FTF** -> Fritiof string model (>~5 GeV)
- **BIC** -> Binary Cascade (<~ 10 GeV)
- **BERT** -> Bertini-style cascade (<~ 10 GeV)
- **HP** -> High Precision neutron model (< 20 MeV)
- **P** -> G4Precompund model used for de-excitation

EM options designated by

- no suffix : standard EM physics
- EMV suffix : older but faster EM processes
- other suffixes for other EM options

Production Physics Lists

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FTFP_BERT

- recommended by Geant4 for HEP
- contains all standard EM processes
- uses Bertini-style cascade for hadrons < 5 GeV
- uses FTF (Fritiof) model for high energies (> 4 GeV)

QGSP_BERT

- all standard EM processes
- Bertini-style cascade up to 9.9 GeV
- QGS model for high energies (> ~18 GeV)
- FTF in between

Production Physics Lists

SLAC

QGSP_BIC

- same as QGSP_BERT, but replaces Bertini cascade with Binary cascade and G4Precompound model
- recommended for use at energies below 200 MeV (many medical applications)

FTFP_BERT_HP

- same as FTFP_BERT, but with high precision neutron model used for neutrons below 20 MeV
- significantly slower than FTFP_BERT when full thermal cross sections used there's an option to turn this off
- for radiation protection and shielding applications

Other Physics Lists

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Shielding

- based on FTFP_BERT_HP with improved neutron cross sections from JENDL
- better ion interactions using QMD model
- currently used by SuperCDMS dark matter search

recommended for:

- shielding applications
- space physics
- HEP

Other Physics Lists (based on use-cases)

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If primary particle energy in your application is < 5 GeV (for example, clinical proton beam of 150 MeV)

- start with a physics list which includes BIC or BERT
- e.g. QGSP_BIC, QGSP_BERT, FTFP_BERT, etc.

If neutron transport is important

- start with physics list containing "HP"
- e.g. QGSP_BIC_HP, FTFP_BERT_HP, etc.

If you're interested in Bragg curve physics

- use a physics list ending in "EMV" or "EMX" or "EMY"
- e.g. QGSP_BIC_EMY

Choosing a Physics List

SLAC

Ultimately you must choose a physics list based on how well its component processes and models perform

- physics performance
- CPU performance

Geant4 provides validation (comparison to data) for most of its physics codes

- validation is a continuing task, performed at least as often as each release
- more validation tests added as time goes on

To access these comparisons, go to Geant4 website

- follow the chain: click on “Validation of Geant4” -> “Validation and testing” -> Validation Database: “FNAL_DB”

Geant 4

Download | User Forum | Gallery
Contact Us

Search Geant4

Home > Results & Publications > Testing and Validation

Testing and Validation

This webpage is under redesign. Some links are old and may be removed. Please be patient.

Physics Validation

This collection of links and resources covers the aspects of general interest for Geant4 physics validation.
The activities of this area are coordinated by the Physics Validation Task Force in the Testing and Quality Assurance Working Group.

Results and documents

- Validation DataBase: FNAL DB, or access to previous, no longer supported version of FNAL DB
- Electromagnetic physics: Results, publications, validation; HEP journals publications ; HEP conference proceedings ; HEP presentations
- Electromagnetic Validation repository
- Hadronic Validation Web Pages
- HEP experiments related notes documents and notes (in collaboration with LCG Physics Validation Project)

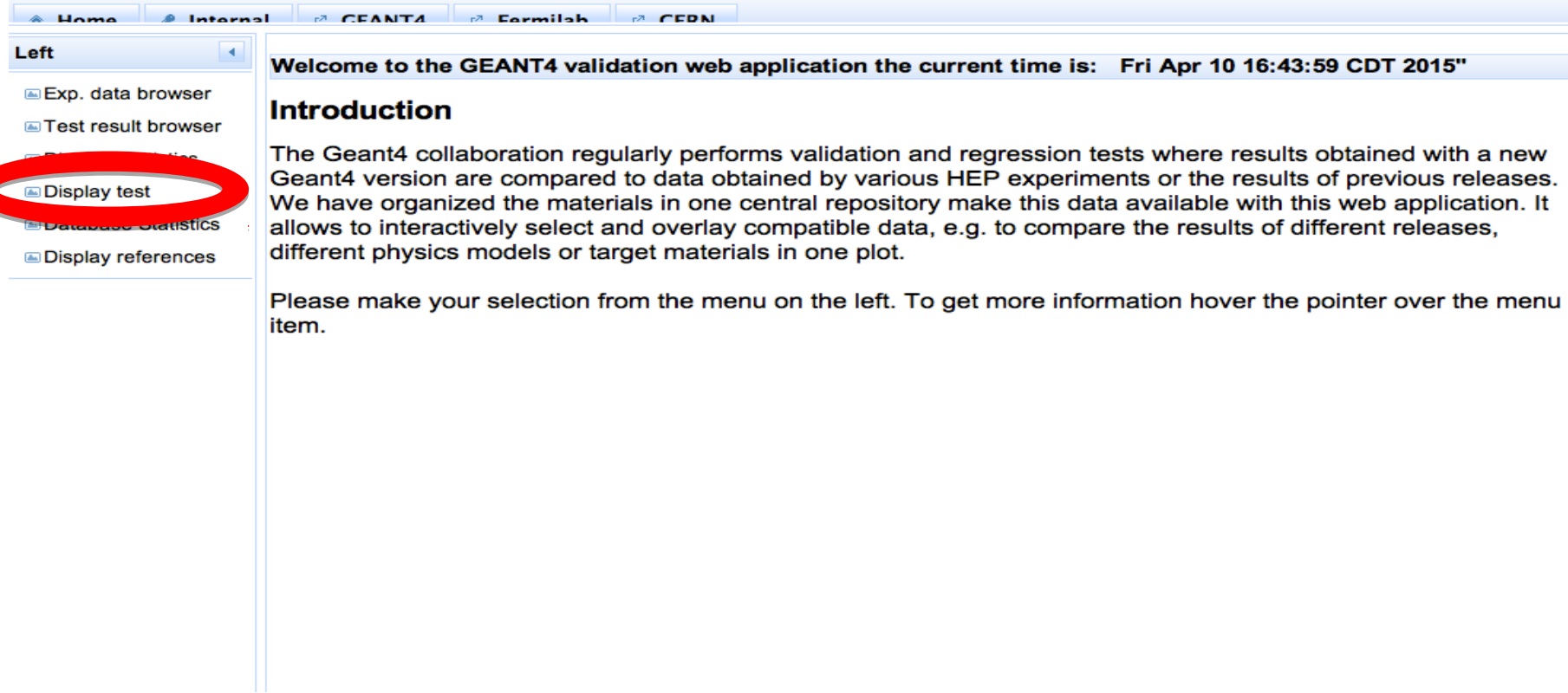
Technical documentation and resources

- The Geant4 testing system
- The Geant4 GRID-based testing system
- Validation Framework Design Proposal
- LCG Physics Validation Project (focus on LHC experiments)
- The task force twiki contains information on the current activities.

Computing Performance

This collection of links and resources covers the aspects of the monitoring of performances of the Geant4 code.
The activities of this area are coordinated by the Monitoring computing performance and benchmarking Task Force in the Testing and Quality Assurance Working Group.

Geant 4 validation web application



Geant 4 validation web application

Home | Internal | GEANT4 | Fermilab | CERN

Left

- Exp. data browser
- Test result browser
- Display Statistics
- Display test
- Database Statistics
- Display references

Name	Description	Working Group
ATLAS	shower characteristics of ATLAS Calorimeters	LHC-feedback
CMS	shower characteristics of CMS Calorimeters	LHC-feedback
atlasbar	Test of ALTAS barrel type em calorimeter, determines response, resolution, and CPU performance	electromagnetic
test37	Test against Sandia data, electron beam in semi-infinite media.	electromagnetic
test41	Comparison with MUSCAT experiment for multiple scattering validation	electromagnetic
Franz	Neutron-induced production of protons, deuterons and tritons by neutrons between 300-580 MeV	hadronic
Hadrlon	Test of Physics Lists (thick targets, ion beams)	hadronic
IAEA	IAEA Benchmark of Nuclear Spallation Models	hadronic
Testfragm	Test of hadronic generators (thin targets, ion beams)	hadronic
simplifiedCalo	Test of Shower shapes using selected simplified calorimeter setups.	hadronic
test19	High energy test, provides comparison with NA61 (31 GeV/c proton beam) and NA49 (158 GeV/c proton beam) data sets.	hadronic
test22	Testing of the FTF model and comparison with experimental data for a wide energy region	hadronic
test23	Physicslist label test	hadronic
	Test of hadronic generators of inelastic processes	hadronic
test35	Test of hadronic generators of inelastic processes, based on results of HARP collaboration, Experiment PS214 at CERN.	hadronic
	Test of hadronic generators of inelastic processes on thick targets.	hadronic
test47	Intermediate energy validation is done by comparing Monte Carlo predictions vs experimental data.	hadronic
test48	Stopping particle test Monte Carlo predictions are compared to experimental data.	hadronic
test75	Test of gamma-nuclear interactions	hadronic

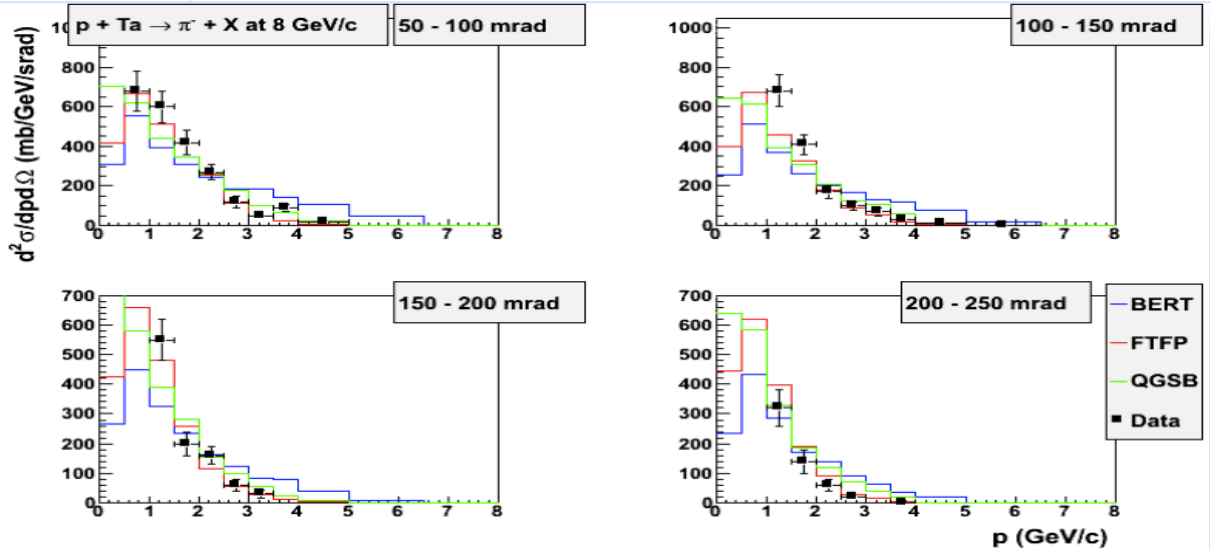
Geant 4 validation web application

Home | Internal | GEANT4 | Fermilab | CERN

Left

- Exp. data browser
- Test result browser
- Display Statistics
- Display test
- Database Statistics
- Display references

Name of the Test:	test35
Responsible:	V. Ivanchenko
Description:	Test of hadronic generators of inelastic processes, based on results of HARP collaboration, Experiment PS214 at CERN.



Required information specific to the selected test:

Geant4 Version:	geant4-09-06-ref-00

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