Physics Presentations of this Tutorial

Geant4 PHENIICS & IN2P3 Tutorial,
16 – 20 May 2022,
Orsay

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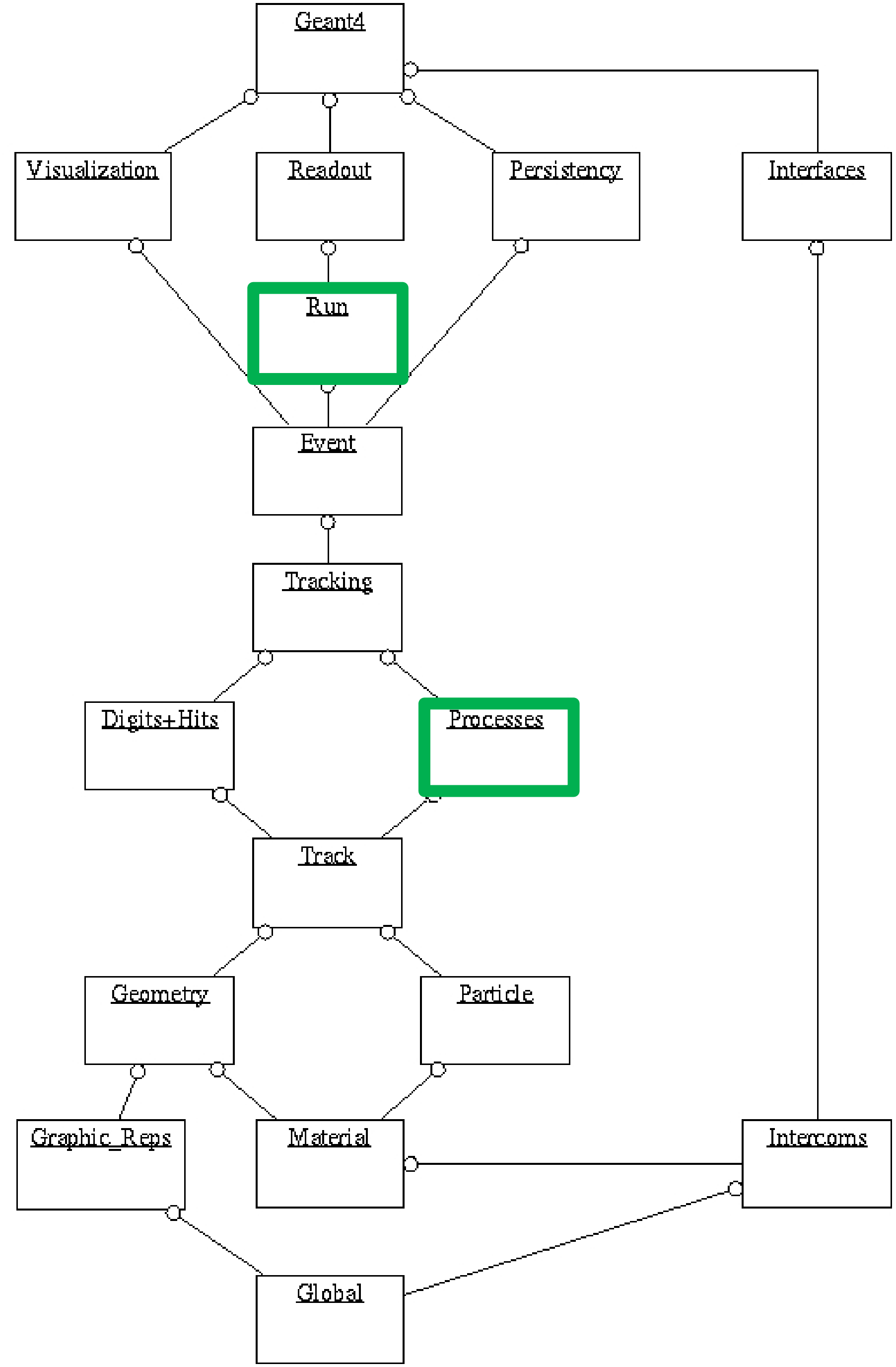
Where will we look in the toolkit ?

Main categories and directories involved:

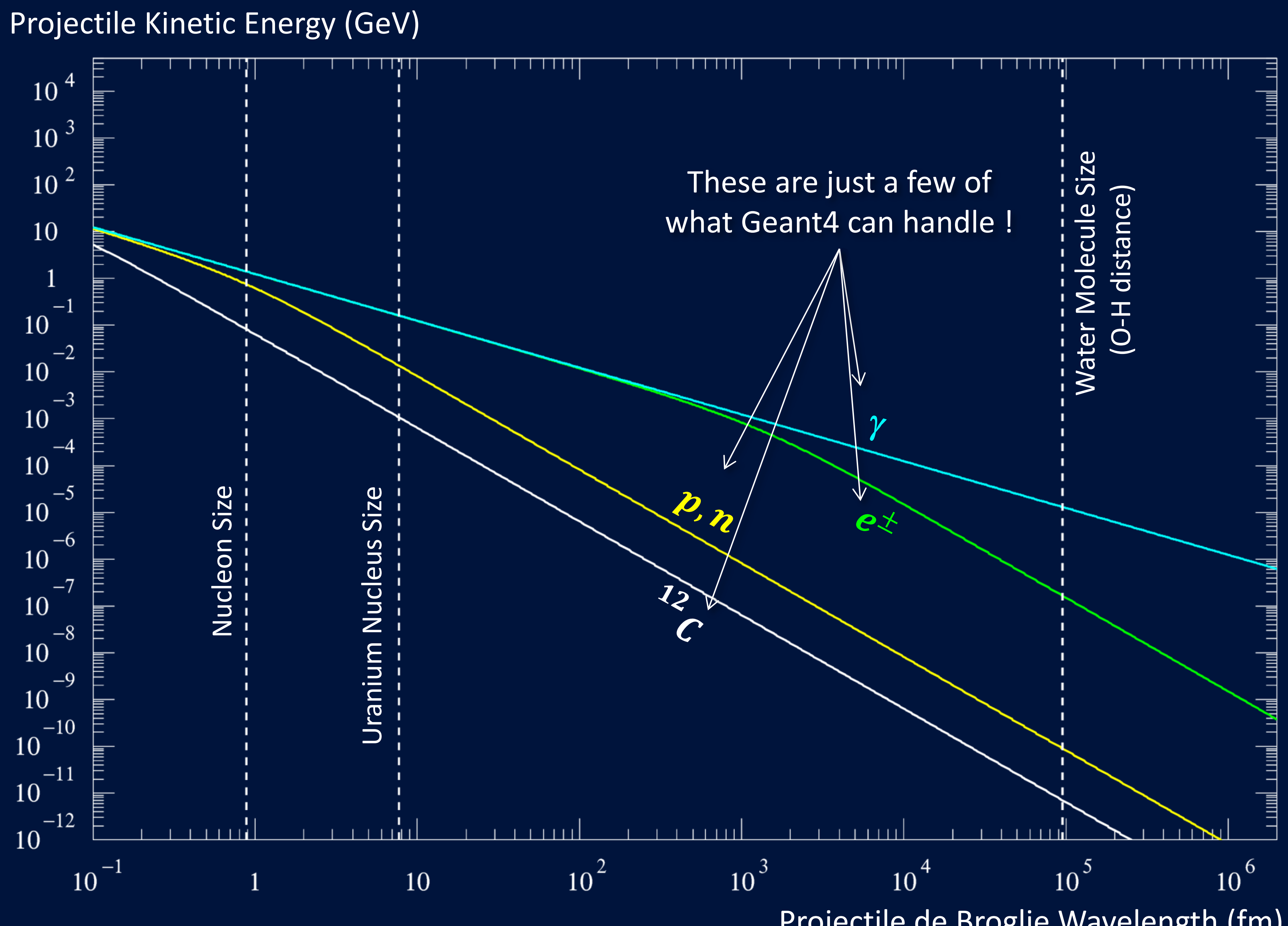
- Processes:
  - geant4/source/processes
- Run
  - geant4/source/run



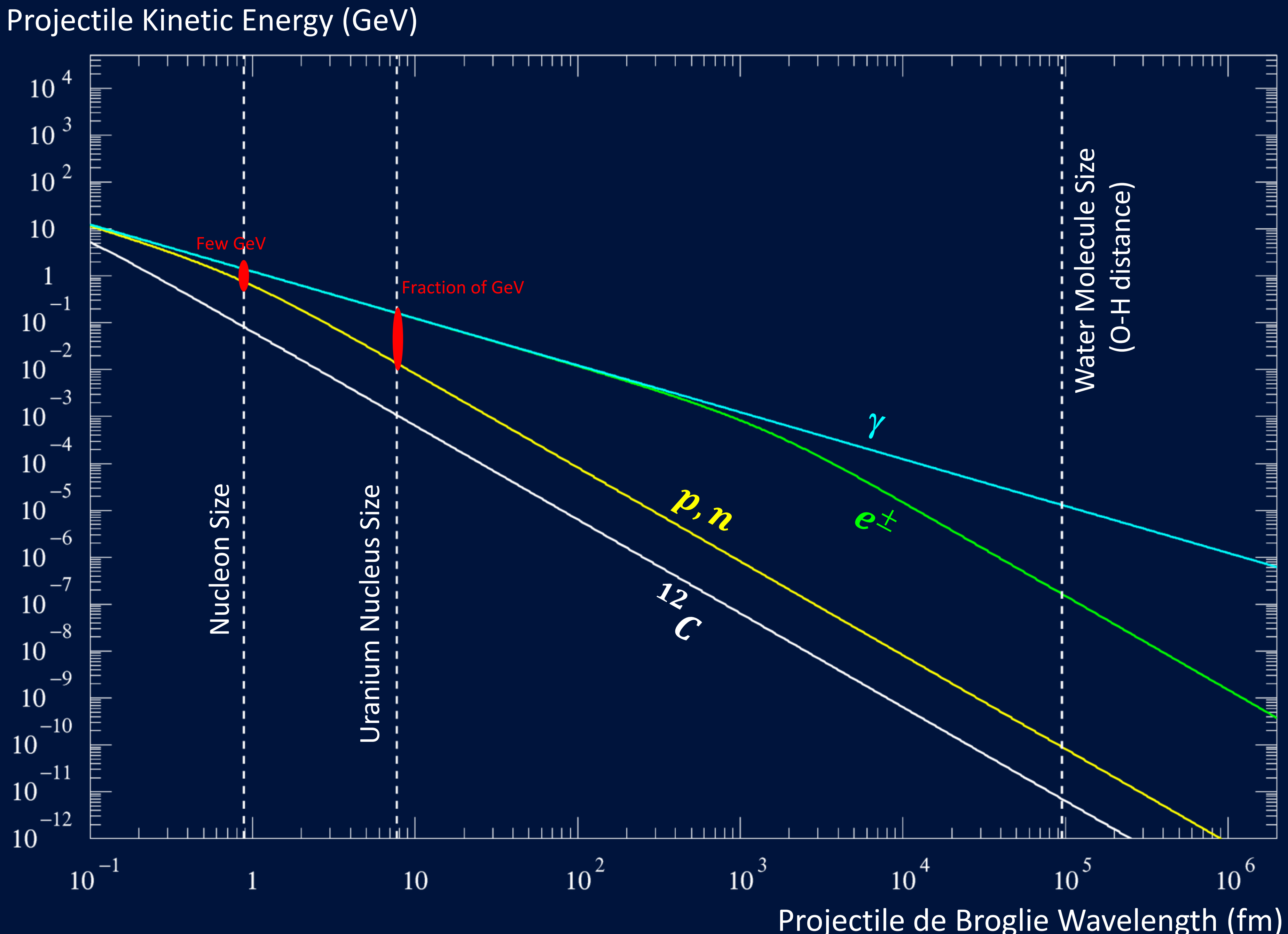
Overview of physics presentations

- In the “Geant4 : introduction” tutorial, session IV:
  - This introduction
  - Two presentations:
    - Physics list
    - Physics overview, processes and cuts
  - Which are focused on technical aspects
    - But with some real physics overview

- Actual physics content of Geant4 in discussed in the “Geant4 : perfectionnement” tutorial:
  - “Standard” EM physics
  - Low Energy EM physics
  - Hadronic physics
    - The big catalogue of it



Projectile Kinetic Energy (GeV)
10^4
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
Nucleon Size
Uranium Nucleus Size
Water Molecule Size
(O-H distance)
These are just a few of
what Geant4 can handle !
γ
$e^{\pm}$
p, n
^{12}C
10^{-1}
1
10
10^2
10^3
10^4
10^5
10^6
Projectile de Broglie Wavelength (fm)



Projectile Kinetic Energy (GeV)
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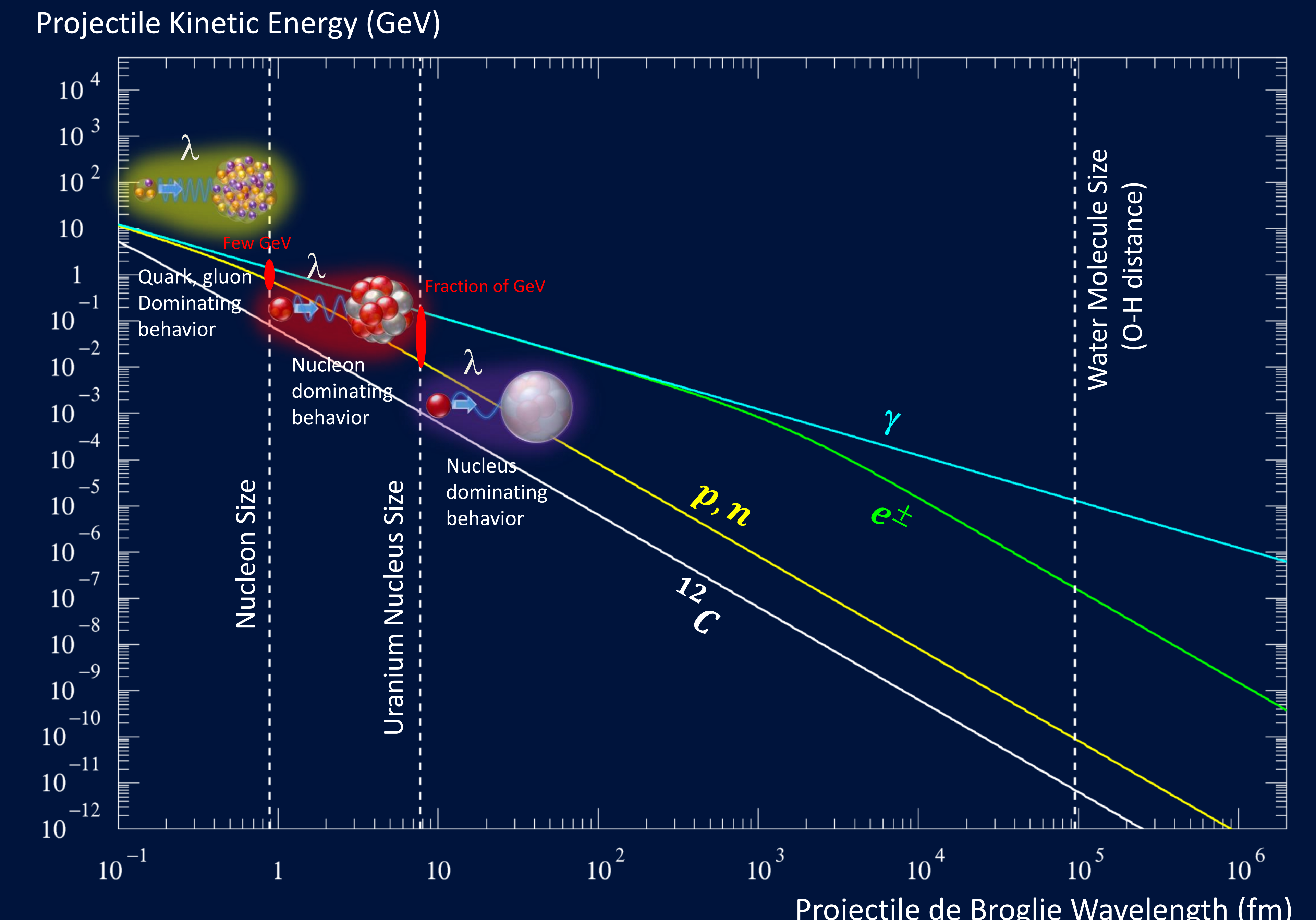
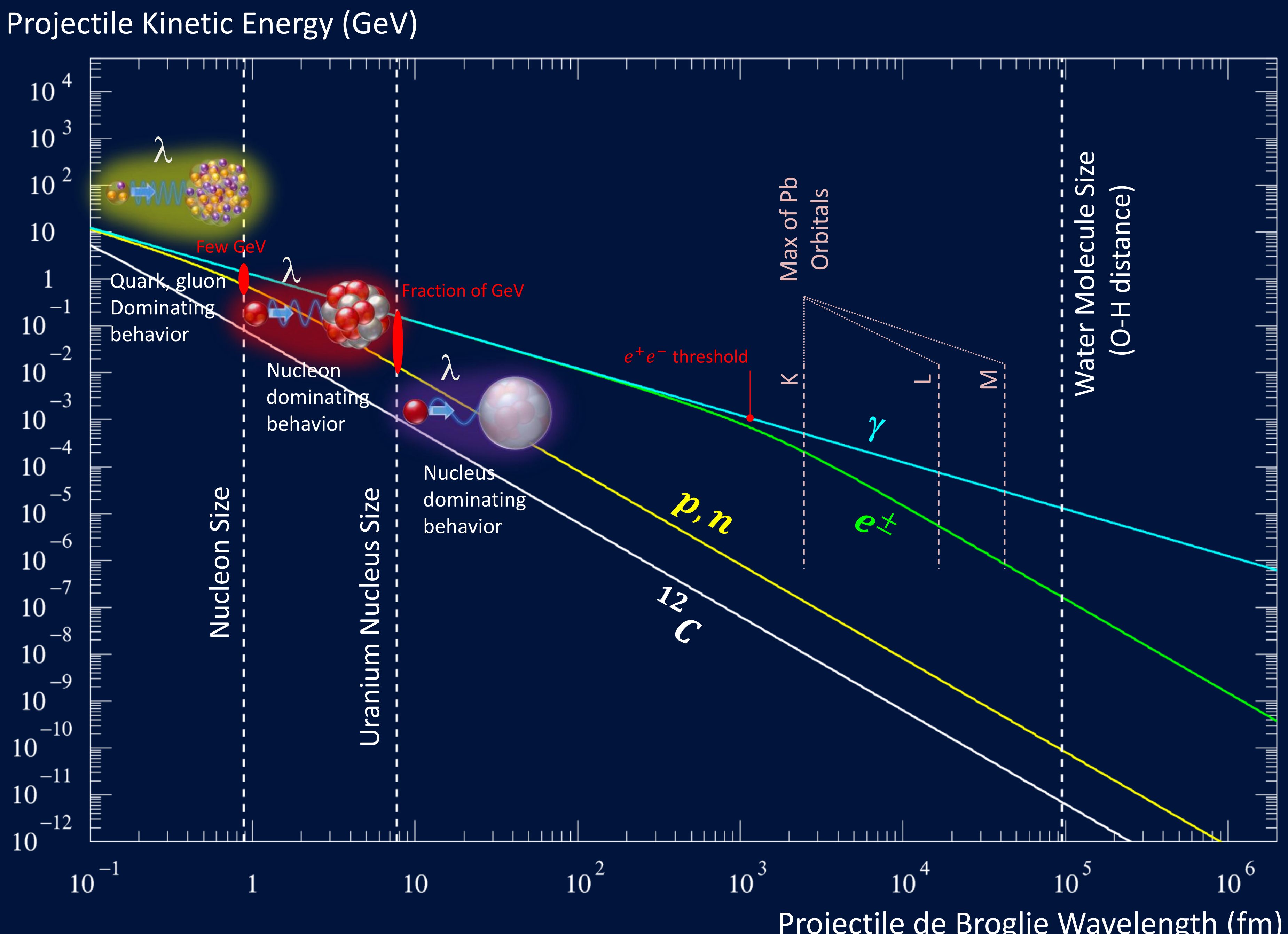
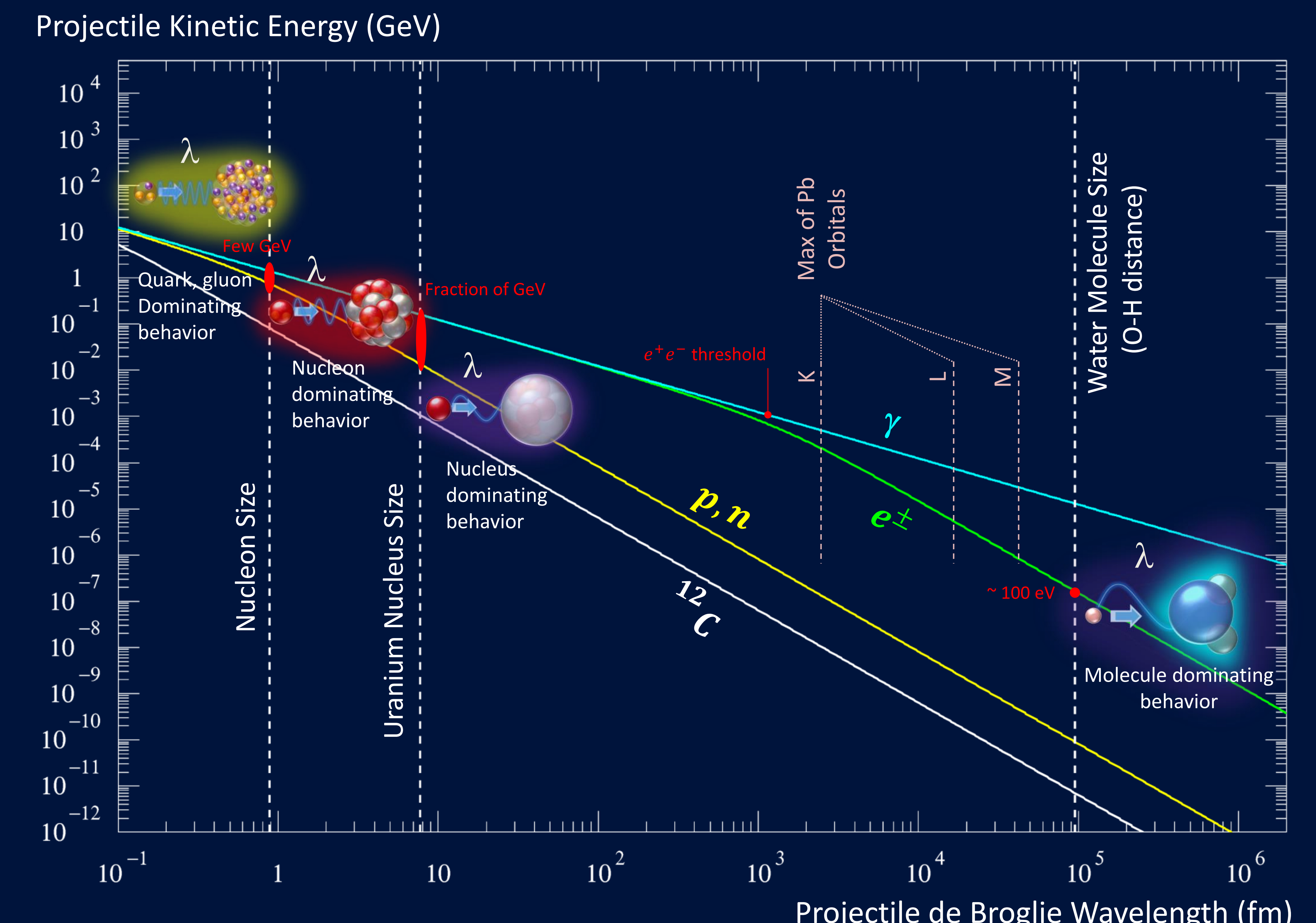
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
Few GeV
Fraction of GeV
Nucleon Size
Uranium Nucleus Size
Water Molecule Size
(O-H distance)
γ
$e^{\pm}$
p, n
^{12}C
10^{-1}
1
10
10^2
10^3
10^4
10^5
10^6
Projectile de Broglie Wavelength (fm)

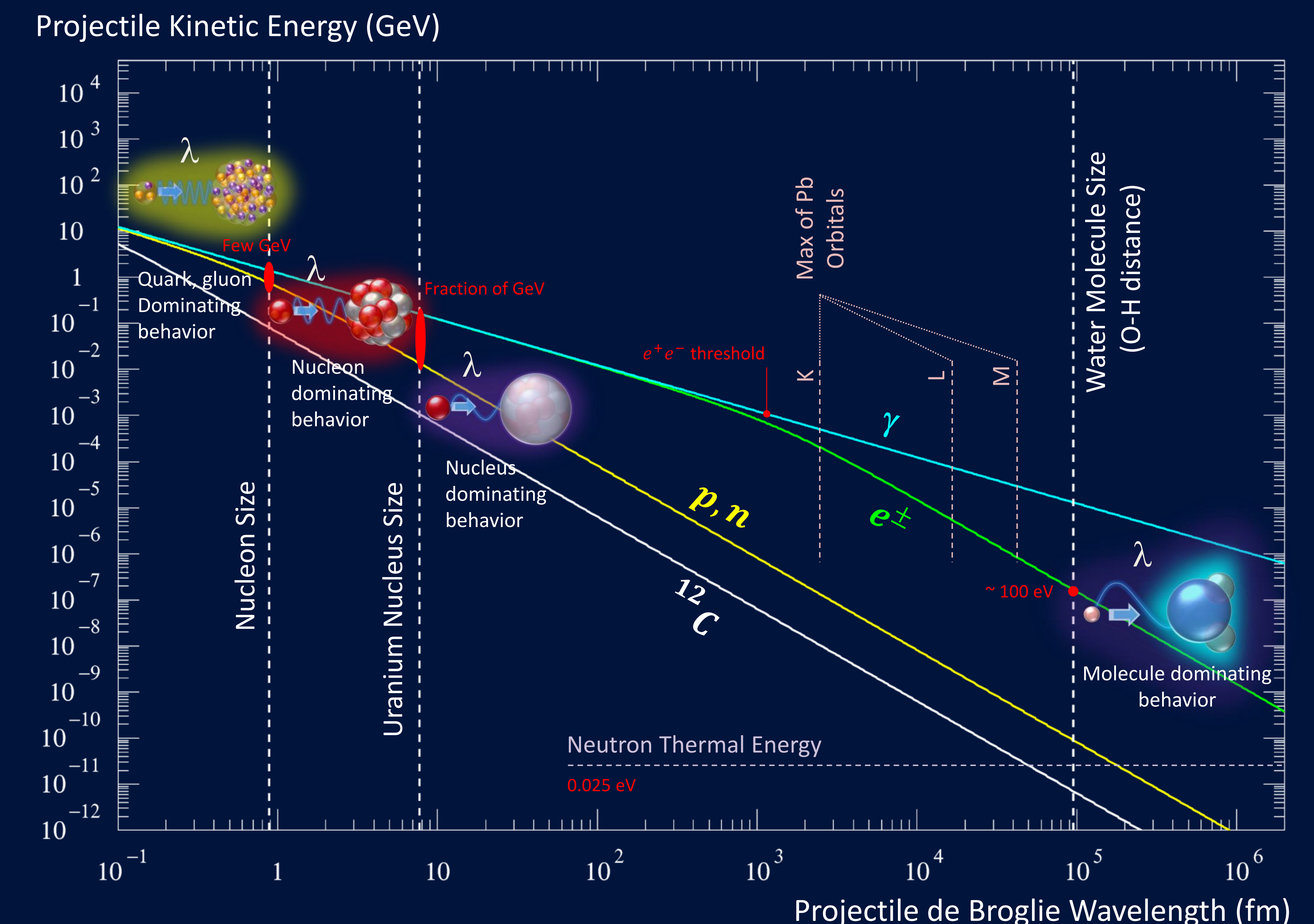


Projectile Kinetic Energy (GeV)
Projectile de Broglie Wavelength (fm)
Few GeV
Fraction of GeV
λ
Quark, gluon Dominating behavior
Nucleon dominating behavior
Nucleus dominating behavior
Nucleon Size
Uranium Nucleus Size
Water Molecule Size (O-H distance)
γ
e±
p, n
12C



Projectile Kinetic Energy (GeV)
Projectile de Broglie Wavelength (fm)
Few GeV
Fraction of GeV
Quark, gluon
Dominating
behavior
Nucleon
dominating
behavior
Nucleus
dominating
behavior
Nucleon Size
Uranium Nucleus Size
Water Molecule Size
(O-H distance)
Max of Pb
Orbitals
K
L
M
e^+e^- threshold
γ
$e^\pm$
p, n
^{12}C
λ
λ
λ

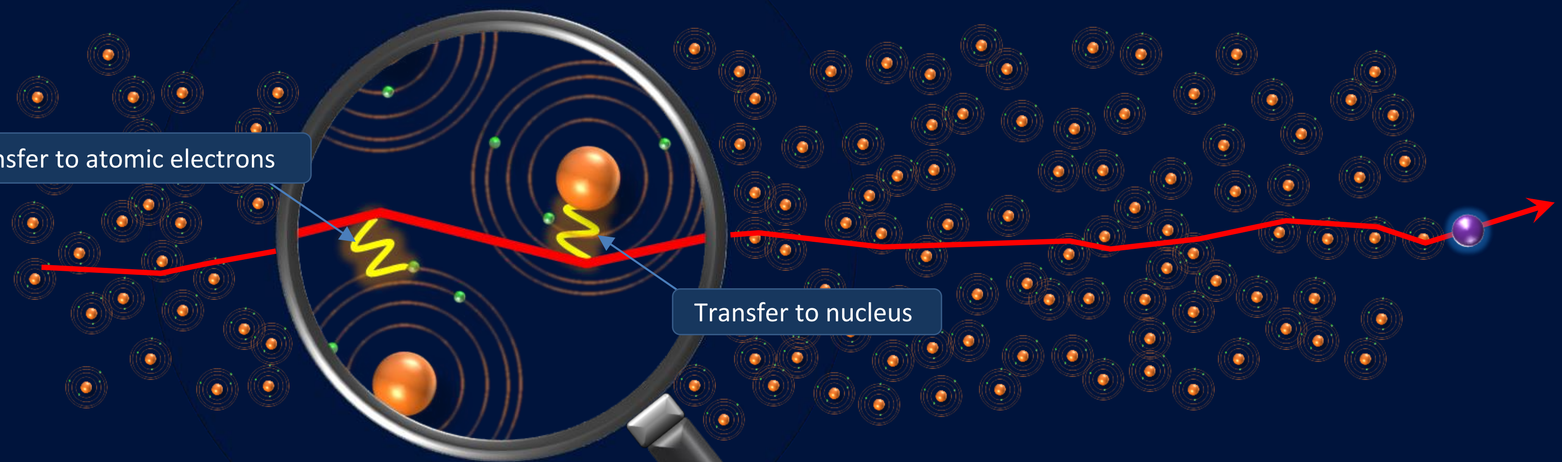

Projectile Kinetic Energy (GeV)
Projectile de Broglie Wavelength (fm)
Nucleon Size
Uranium Nucleus Size
Max of Pb Orbitals
K
L
M
Water Molecule Size (O-H distance)
Few GeV
Fraction of GeV
Quark, gluon Dominating behavior
Nucleon dominating behavior
Nucleus dominating behavior
Molecule dominating behavior
e^+e^- threshold
~ 100 eV
γ
$e^{\pm}$
p, n
^{12}C
λ



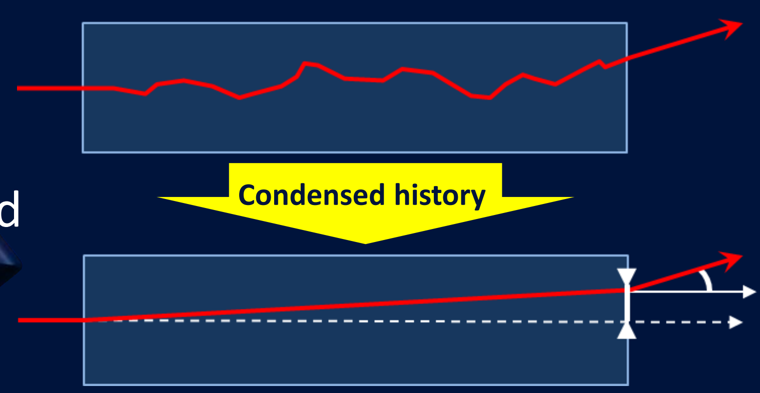
Projectile Kinetic Energy (GeV)
Projectile de Broglie Wavelength (fm)
λ
Few GeV
Quark, gluon Dominating behavior
Fraction of GeV
Nucleon dominating behavior
Nucleus dominating behavior
Nucleon Size
Uranium Nucleus Size
Max of Pb Orbitals
K
L
M
e^+e^- threshold
γ
p, n
$e^{\pm}$
^{12}C
Water Molecule Size (O-H distance)
~ 100 eV
Molecule dominating behavior
Neutron Thermal Energy
0.025 eV

Point-like interactions of charged particles → Condensed history

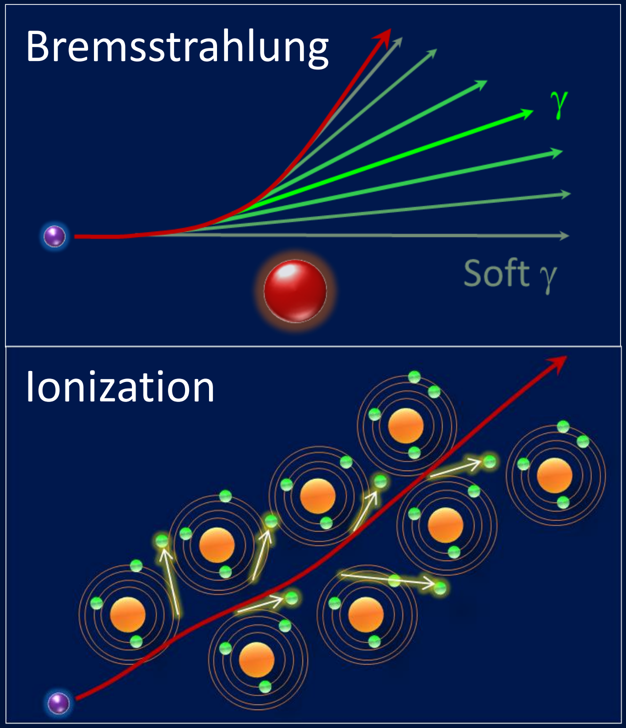
- In matter, interactions with low momentum transfer can occur MANY times
  - O(10^6 / mm) for multiple scattering, for example !



- Modeling a very low energy problem (eg : microdosimetry) requires to follow each of these interactions to be accurate
- **But unaffordable simulation at high energy !**
- Adopt a **"condensed history"** approach instead
  - Compute theoretical net effect of many interactions
  - Need to compute mean effect **and** fluctuations

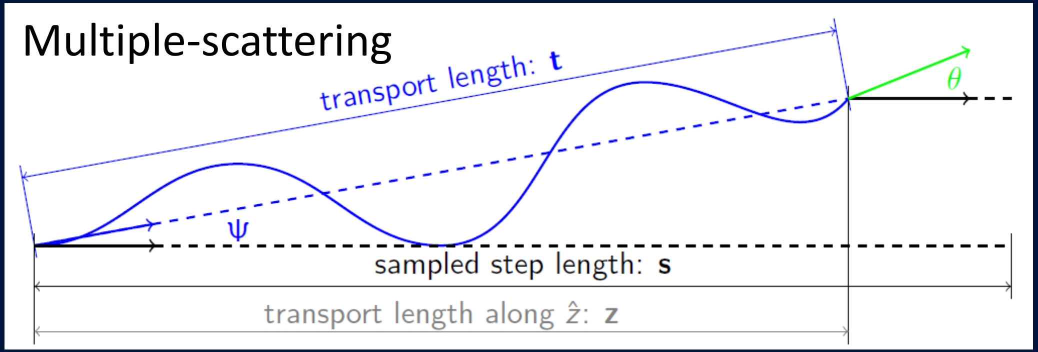


Condensed history : bremsstrahlung, ionization, multiple-scattering



- Infrared (quasi)divergence of bremsstrahlung (ionization) cross-section ⇒ **must define a production threshold**, the so-called "cut"
- Integrate production below cut
  - ⇒ "continuous energy loss"
  - local energy deposit
  - **Condensed history approach**
- Discrete production above cut value
  - Explicit production and tracking of γ or δ-ray

- Applies also to multiple scattering : effective deflection and lateral displacement after some travel distance t



Coping with complexity…

- Physics complexity is large:
  - Lots of particle types
  - Lots of different particle-matter interaction types
    - And which are totally different depending on energy

- In a physics code package, we have to decide of
  - how we model the point-like physics interactions
  - how we model the condensed history and under what conditions
  - how we make all these working together in consistent sets of models

- We resolve that thinking in term of "use cases":
  - Ie : what models suite is needed to cover specific physics needs
    - HEP, medical, space…
  - Use cases are determined by users : you !

- In most cases, you don't need to create/compose your physics list
  - But you only to select some pre-defined one
- And for that, you need to have some understanding of the Geant4 logic
  - Which is explained in the next two presentations