Monte Carlo Method and Codes for Transporting Particle and Rays

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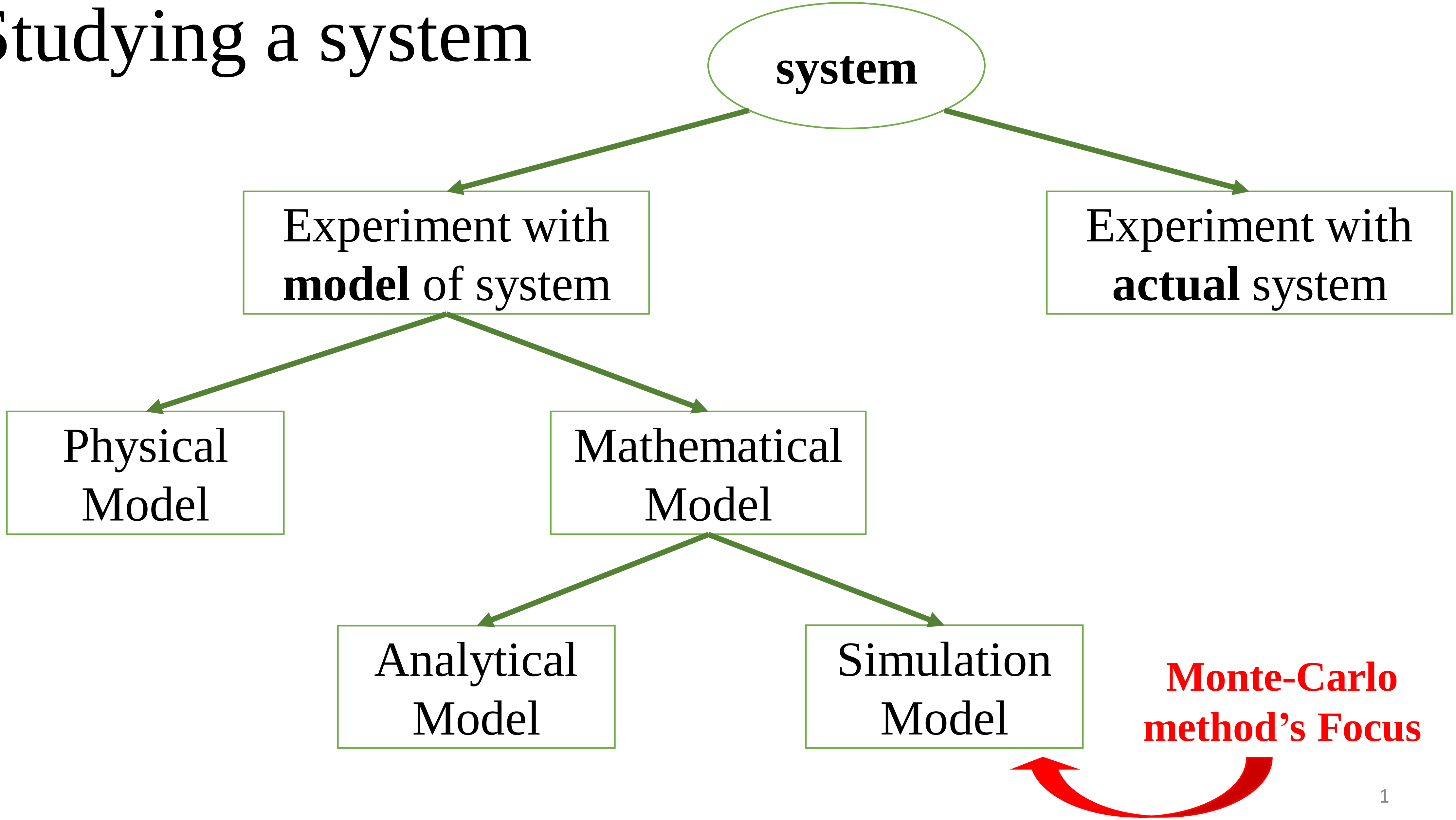
Outline

- Studying a system
- Monte-Carlo method
- Monte-Carlo Simulation
- Continuity Equation
- Transport Equation
- Monte-Carlo codes
    - Application
    - Mechanism
    - Tallies
    - Specification

Studying a system



Monte-Carlo: Terminology

Monte Carlo is the name of a city at the south of France.

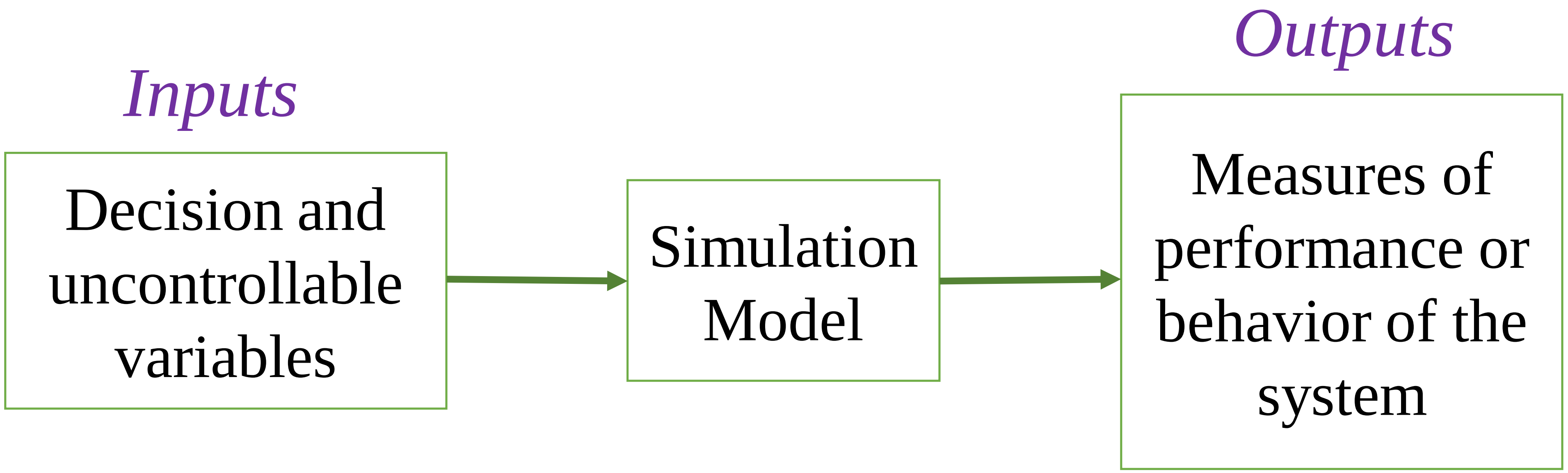
Monte-Carlo (MC) method

The Monte Carlo method: is a numerical method for statistical simulation which utilizes sequences of random numbers to perform the simulation

Monte-Carlo simulations

- MC simulation is a versatile tool to analyze and evaluate complex measurements.
- Constructing a model of a system.
- Experimenting with the model to draw inferences of the system’s behavior
- Using random numbers and probability algebra for modelling stochastic and deterministic phenomenon.

Monte-Carlo simulation (continued)



Monte-Carlo Method & Simulation applications

- Monte Carlo method has been used for solving a lot of mathematical and physical problems and equations:
  - PDE’s (linear and nonlinear)
  - Integrals
  - Schrodinger equations
  - Neural networks
  - etc.
- Monte Carlo Simulation is using for various stochastic phenomenon like:
  - Particles and photons transports
  - Economics
  - Fluid dynamics
  - etc.

Continuity Equation

- The Continuity equation is the basis of Transport equation where is a kind of conservation equation:

Change the number of particles=Production Rate – Annihilation Rate

$$\frac{d}{dt}\int_V n(r,\hat{\Omega},E,t)dV = \int_V S(r,\hat{\Omega},E,t)dV - \int_V \Sigma_t(r,E)\phi(r,\hat{\Omega},E,t)dV$$

$$-\int_V J(r,\hat{\Omega},E,t).\mathrm{n}\,dV$$

- Fick's Law

$$J(r,\hat{\Omega},E,t) = -D\nabla\phi(r,\hat{\Omega},E,t)$$

Transport Equation

- The transport equation is a conservation equation:

Time Dependence **Streaming** **Absorption** **External source**

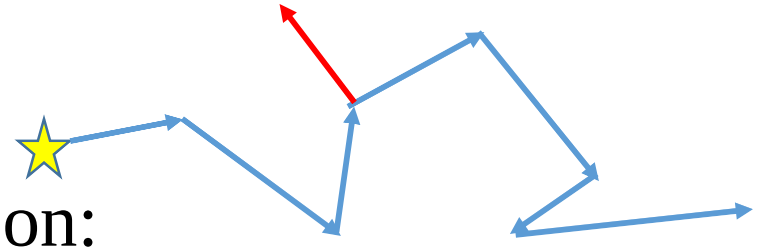
$$\underbrace{\frac{1}{v}\frac{\partial}{\partial t}\phi\left(r,\hat{\Omega},E,t\right)}_{\text{Time Dependence}}+\underbrace{\hat{\Omega}.\nabla\phi\left(r,\hat{\Omega},E,t\right)}_{\text{Streaming}}+\underbrace{\Sigma_t\left(r,E\right)\phi\left(r,\hat{\Omega},E,t\right)}_{\text{Absorption}}=\underbrace{S\left(r,\hat{\Omega},E,t\right)}_{\text{External source}}+$$

$$\underbrace{\int_{4\pi}d\hat{\Omega}\int_0^\infty dE'\Sigma_s\left(E'\to E,\hat{\Omega}'\to\hat{\Omega}\right)\phi\left(r,\hat{\Omega},E,t\right)}_{\text{Elastic scattering}}$$

Elastic scattering

Solving Transport Equation by MC

- Monte carlo method solves transport equation for each point for one particle at each calculation.



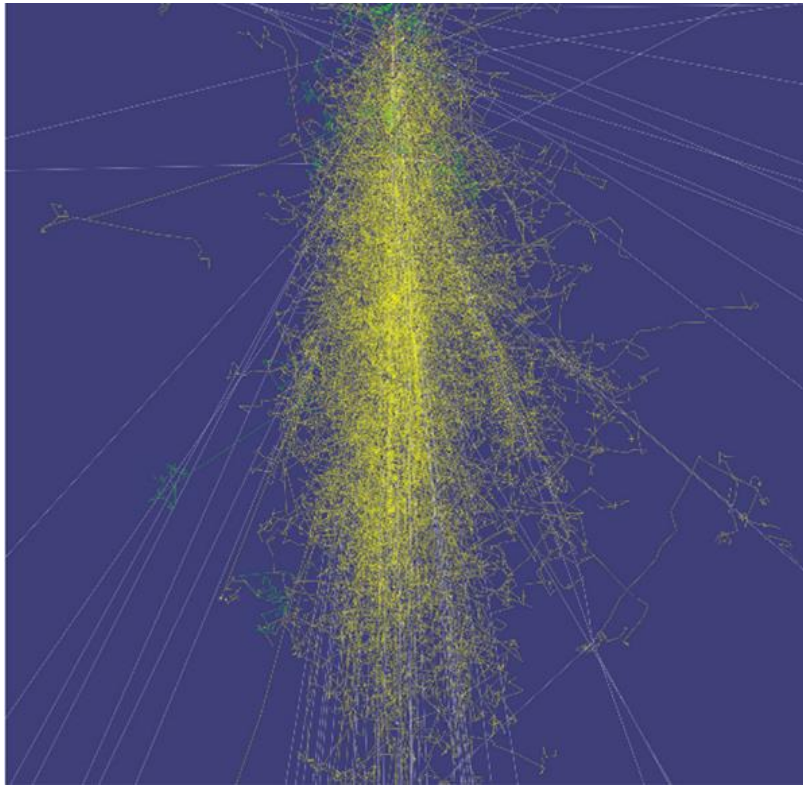
- Solving randomly on:
  - Position
  - Angular dist.
  - Energy
    - Discrete
    - Continues
  - Time
- Sampling methods:
  - Marcov chain
  - Metropolis
  - Metropolis-Hastings

Monte-Carlo codes

- There are several Monte-carlo codes have been being implementing and developing such as:
- MCNP developed by Los Alamos National Lab.
- FLUKA developed by INFN & CERN group
- GEANT4 developed by CERN
- PENELOPE developed by NEA
- EGSnrc developed by National Research Council Canada
- Etc.

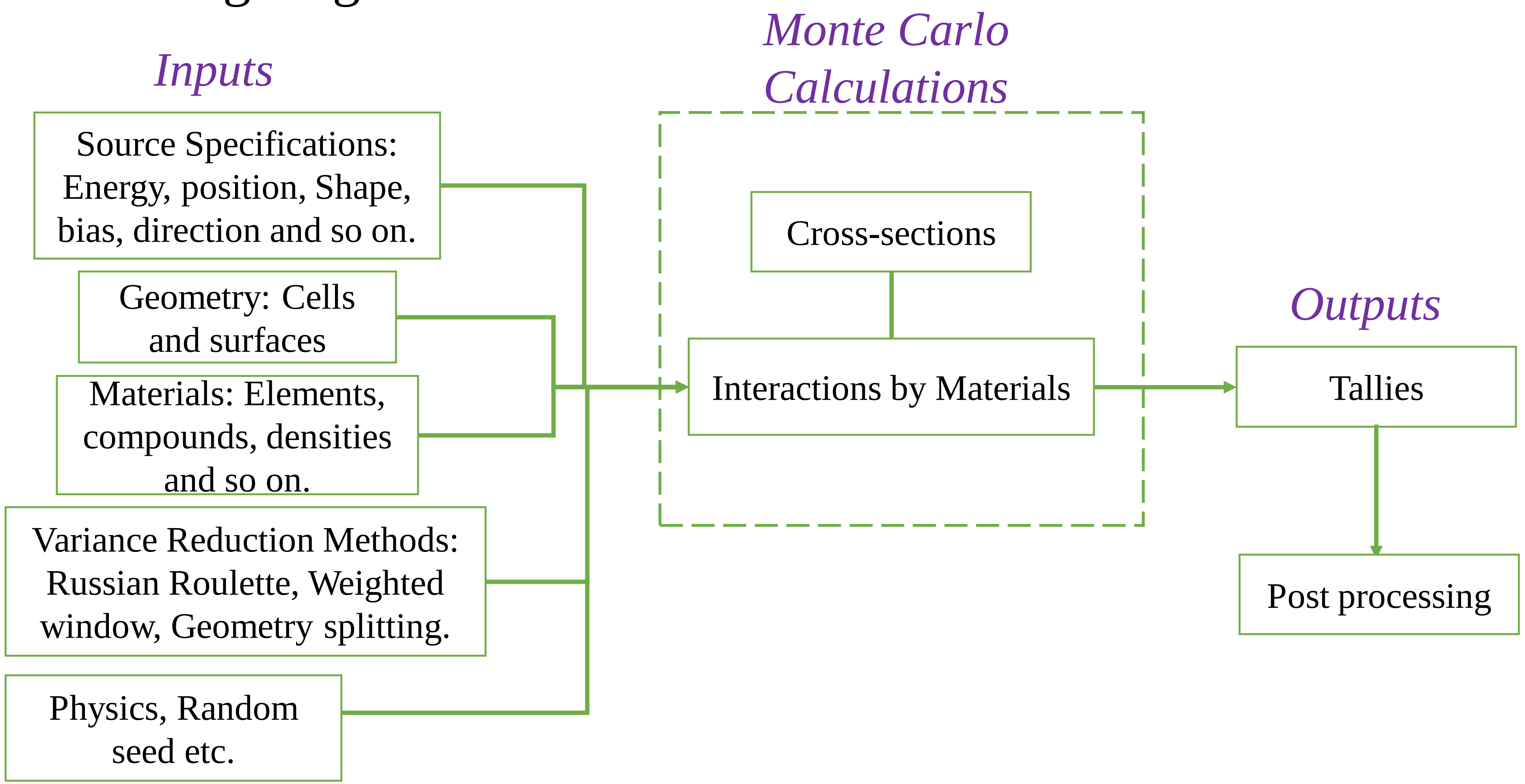
Monte-Carlo codes: Applications

- The area of using MC codes:
  - Particle physics
  - Health physics
  - Detection and calorimetry
  - Accelerators
  - Applied Radiation
  - Medical Radiation
  - Industrial application
  - Environmental rad. App.



Monte-Carlo codes: Mechanism

- Working diagram:



Monte-Carlo codes: Tallies

- Monte Carlo simulation outputs named tallies.
- Outputs can be:
  - Particle’s Flux (Flounce): surface and/or volumetric
  - Particles' current
  - Particle’s Products (Secondary Particle)
  - Energy deposition
  - Calorimetry (Detectors)
  - Dose (Eq. Dose, Absorbed dose, Dose rate etc.)
  - Electrical charges
  - Detector Pulse height
  - Etc.

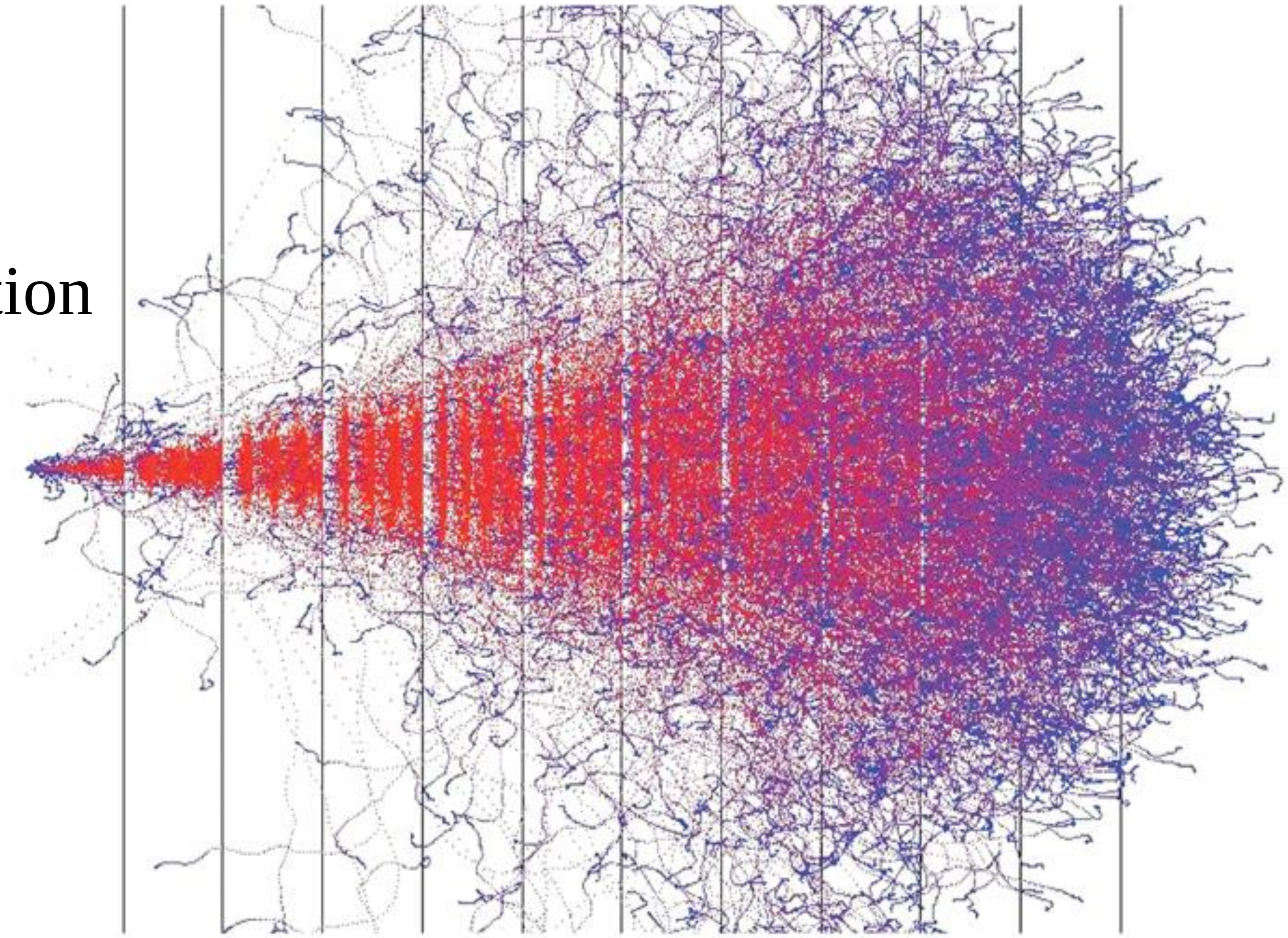
Monte-Carlo codes: Specifications

- They can transport particles and rays from thousandth of evs to hundreds of GeV.
- They transport heavy ions, particles, photons, electrons, kions, pions etc.
- Geometries can be entered by other auxiliary softwares like CAD, CATIA, 3DMAX and so on.
- Tallies can be visualized by other tools like tecplot, MATLAB, origion, Xming and so on.
- Outputs extracts in different formats.
- Simulation continues till reach minimum acceptable relative error.

Example I

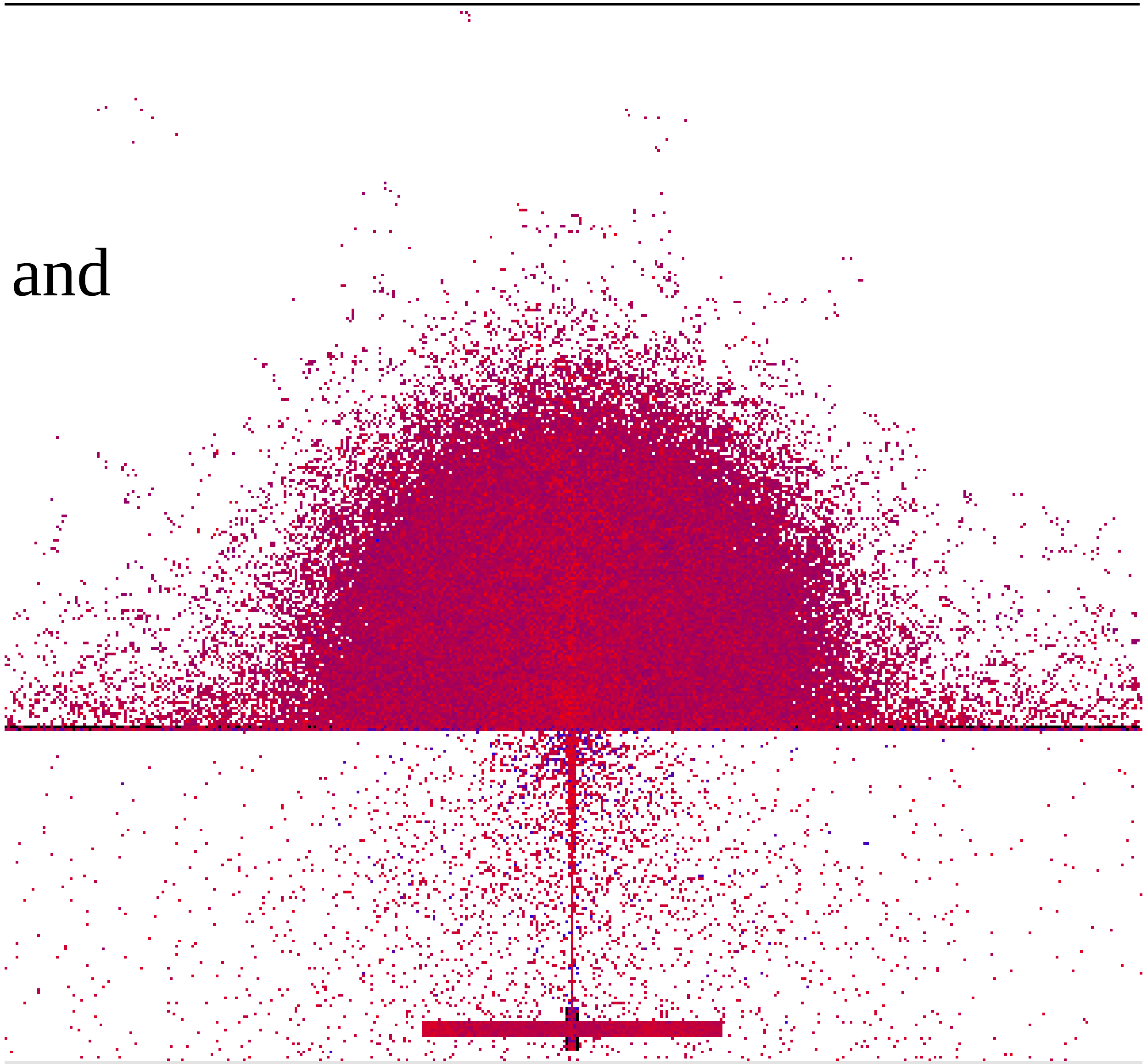
- Electron-photon interaction

    in matter using MC simulation



Example II

- A pencil beam scattering and backscattering



THANKS FOR YOUR ATTENTION :)