







INTERACTIONS OF PARTICLES WITH MATTER SIMULATION

Agnieszka Obłąkowska-Mucha
Faculty of Physics and Applied Computer Science
AGH-UST Kraków

HOW TO DETERMINE THE OUTCOME OF AN EXPERIMENT

- When you flip a coin you get  OR .
- But after a many experiments you obtain about 50%  and 50% of .
- It was easy to calculate since the probability of each outcome is $1/2$.
- How can you predict an outcome if you have 10^{23} coins with 10^{12} options? You cannot...
- The only option is to use Monte Carlo methods.
- MC methods are a set of computational algorithms on **repeated random sampling** to obtain numerical results for solving problems that are deterministic in principle.
- The desired calculation is typically a sum of a discrete distribution or integral of a continuous distribution and is intractable to calculate. The calculation may be intractable for many reasons, such as the large number of random variables, the stochastic nature of the domain, noise in the observations, the lack of observations, and more.
- MC methods were first used in Manhattan project.

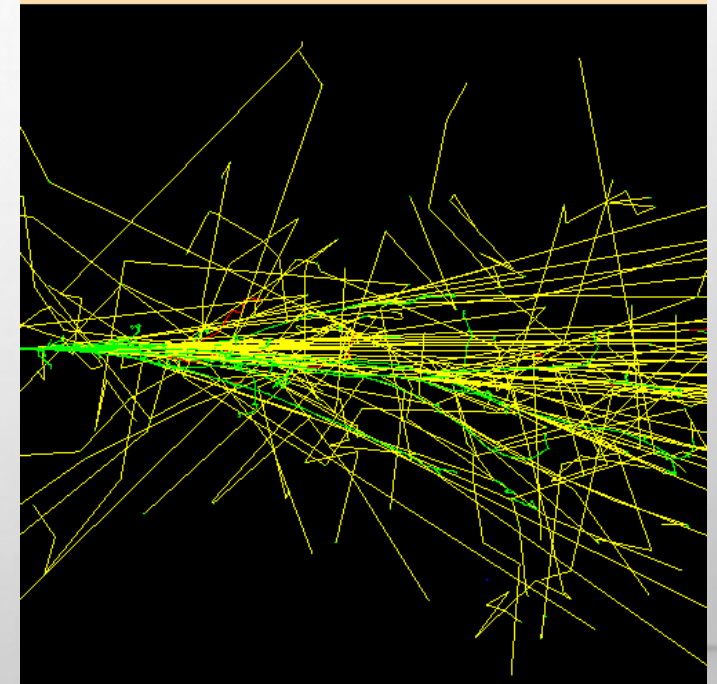
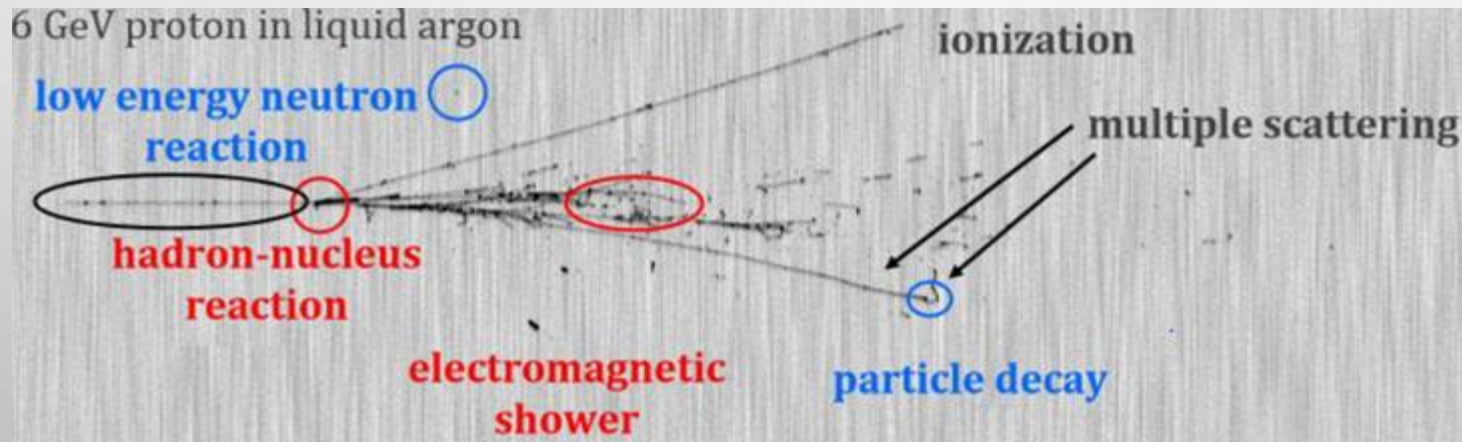


SIMULATION WITH MONTE CARLO METHODS

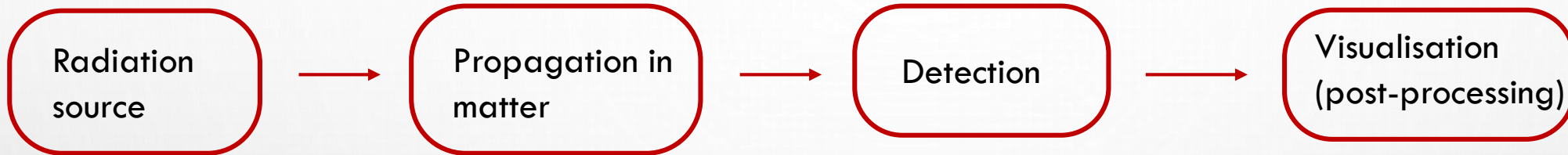
- Monte Carlo simulation refers to drawing a sample with complex computational simulation.
- Multiple samples are collected and used to approximate the desired quantity.
- Given the law of large numbers from statistics, the more random trials that are performed, the more accurate the approximated quantity will become.
- By generating enough samples, we can achieve any desired level of accuracy we like. The main issue is: how do we efficiently generate samples from a probability distribution, particularly in high dimensions?
- According to the central limit theorem, the distribution of the samples will form a Normal distribution, the mean of which can be taken as the approximated quantity and the variance used to provide a confidence interval for the quantity.

WHAT NEEDS TO BE SIMULATED

- Production of radiation from the source (type of particles, energy spectrum, physics model).
- Particle transport (energy deposition in the target material **averaged** over a track length of interest).
- Deposited energy and other dosimetry parameters (dose, ..)
- Nice if distributions are clearly visualidated.
- Results: estimators



HOW TO SIMULATE AN EXPERIMENT WITH RADIATION

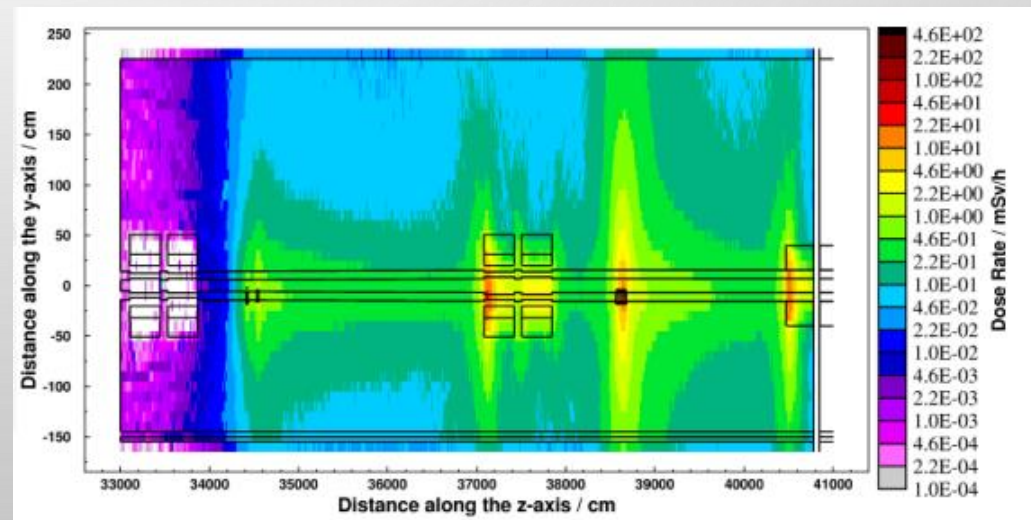


Type,
energy spectrum, activity,
shape, angular distribution,
Window,
HEP – collisions:
model of particle production

Bethe-Bloch formula,
Delta-ray production,
Non-ionising energy loss
Models for elastic and
hadron-nucleon collision
Low-energy neutrons
...

Deposited energy,
fluence

GEOMETRY



FLUKA – LABORATORIUM II

Wyznaczenie zasięgu protonów i elektronów w różnych materiałach

1. Obserwacja różnic w oddziaływaniach protonów i elektronów (BEAMPART, ALL-PART, ENERGY, EM-ENERGY, DOSE),
2. Wyznaczenie zasięgu i porównanie z wartościami tablicowymi,
3. Sprawdzenia prawa skalowania.

SPRAWOZDANIE

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1. Obserwacja różnic w oddziaływaniach protonów i elektronów (BEAMPART, ALL-PART, ENERGY, EM-ENERGY, DOSE),

BEAMPART - gęstość oddziaływań nieelastycznych TYLKO cząstek pierwotnych ,

ALL-PART - gęstość oddziaływań nieelastycznych wszystkich cząstek,

ENERGY - całkowita zdeponowana energia (bardziej ściśle: gęstość energii, [GeV/cm³])

EM-ENERGY - energia promieniowania elektromagnetycznego (elektrony, fotony), [GeV/cm³]

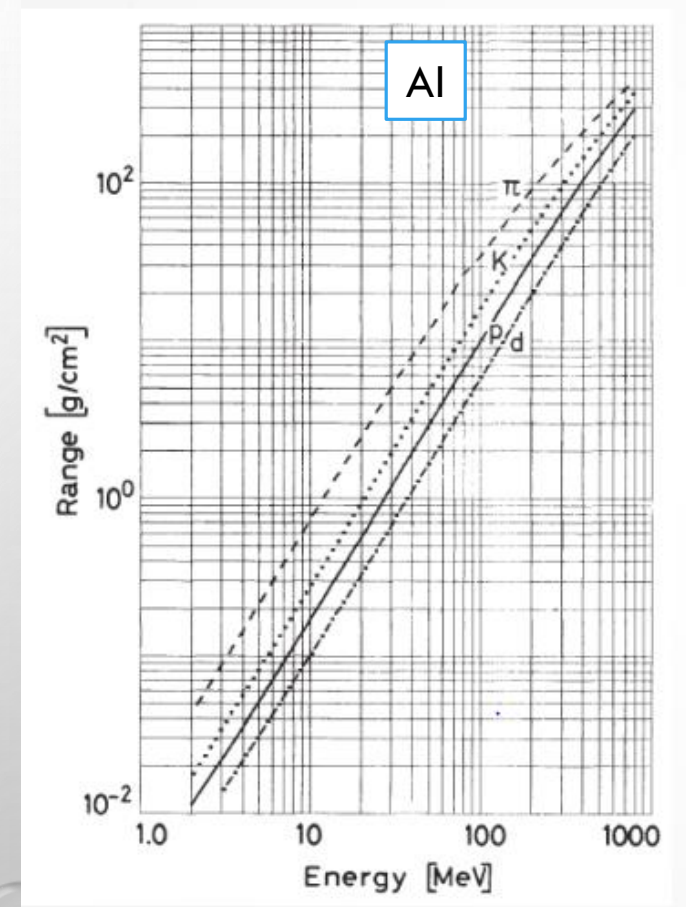
DOSE - dawka promieniowania, [GeV/g], aby wynik był w [Gy]=[GeV/g]x1.602e-7

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Wyznaczenie zasięgu protonów i elektronów w różnych materiałach

2. Wyznaczenie zasięgu i porównanie z wartościami tablicowymi,

| Material | Z | A | X_0 [g/cm ²] | X_0 [cm] | E_c [MeV] |
|-----------|-----|-------|----------------------------|------------|-------------|
| Hydrogen | 1 | 1.01 | 61.3 | 731 000 | 350 |
| Helium | 2 | 4.00 | 94 | 530 000 | 250 |
| Lithium | 3 | 6.94 | 83 | 156 | 180 |
| Carbon | 6 | 12.01 | 43 | 18.8 | 90 |
| Nitrogen | 7 | 14.01 | 38 | 30 500 | 85 |
| Oxygen | 8 | 16.00 | 34 | 24 000 | 75 |
| Aluminium | 13 | 26.98 | 24 | 8.9 | 40 |
| Silicon | 14 | 28.09 | 22 | 9.4 | 39 |
| Iron | 26 | 55.85 | 13.9 | 1.76 | 20.7 |



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3. Sprawdzenia prawa skalowania:

Obserwacje pokazały, że dla niskich energii wielkość: $R_t \rho / \sqrt{A}$ jest stała (z dokładnością ok. 15%)

Prawo Bragga-Kleemanna:

A- ciężar atomowy

$$\frac{R_{t,1}}{R_{t,2}} \approx \frac{\rho_2}{\rho_1} \sqrt{\frac{A_1}{A_2}}$$

zasięg

$$R_t = \int_0^{E_{ki}} \frac{dE_k}{(-dE/d\chi)}$$

stopping power

$$-\frac{dE}{d\chi} = \frac{1}{\rho} \frac{dE}{dx}$$

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Wyznaczenie zasięgu protonów i elektronów w różnych materiałach

SPRAWOZDANIE:

1. Proszę wybrać rozkład pokazujący różnice w propagacji elektronów i protonów w materii.
2. Dla protonów lub elektronów dla 3-5 energii wyznaczyć zasięg w jednym materiale, pokazać na rozkładzie 1D.
3. Dla protonów o jednej wybranej energii w kilku materiałach (3-5) sprawdzić prawo skalowania.

Jeśli zdalna praca z FLUKĄ jest bardzo uciążliwa proszę wykonać mniejszą liczbę symulacji.

Mean Range and Energy Loss in Lead, Copper, Aluminum, and Carbon

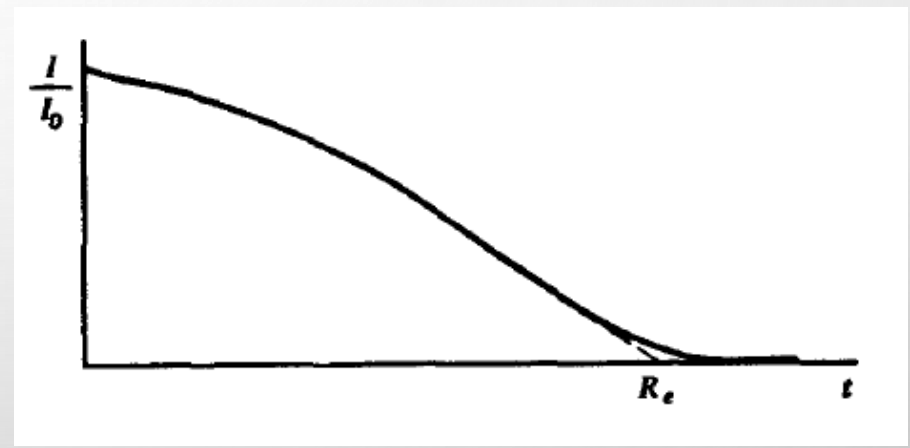
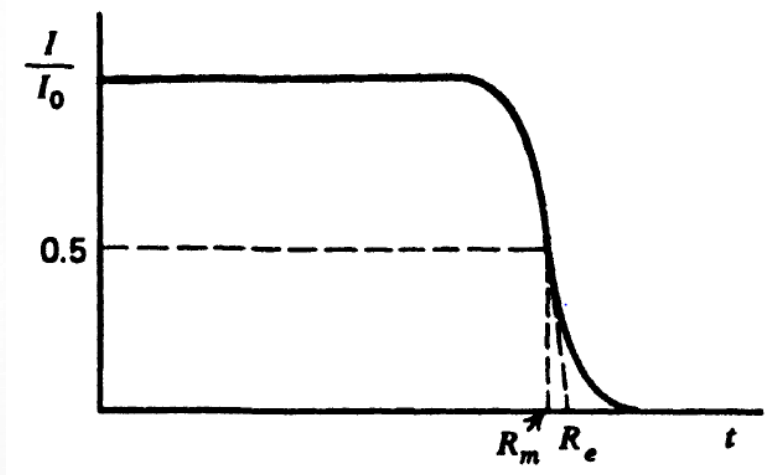
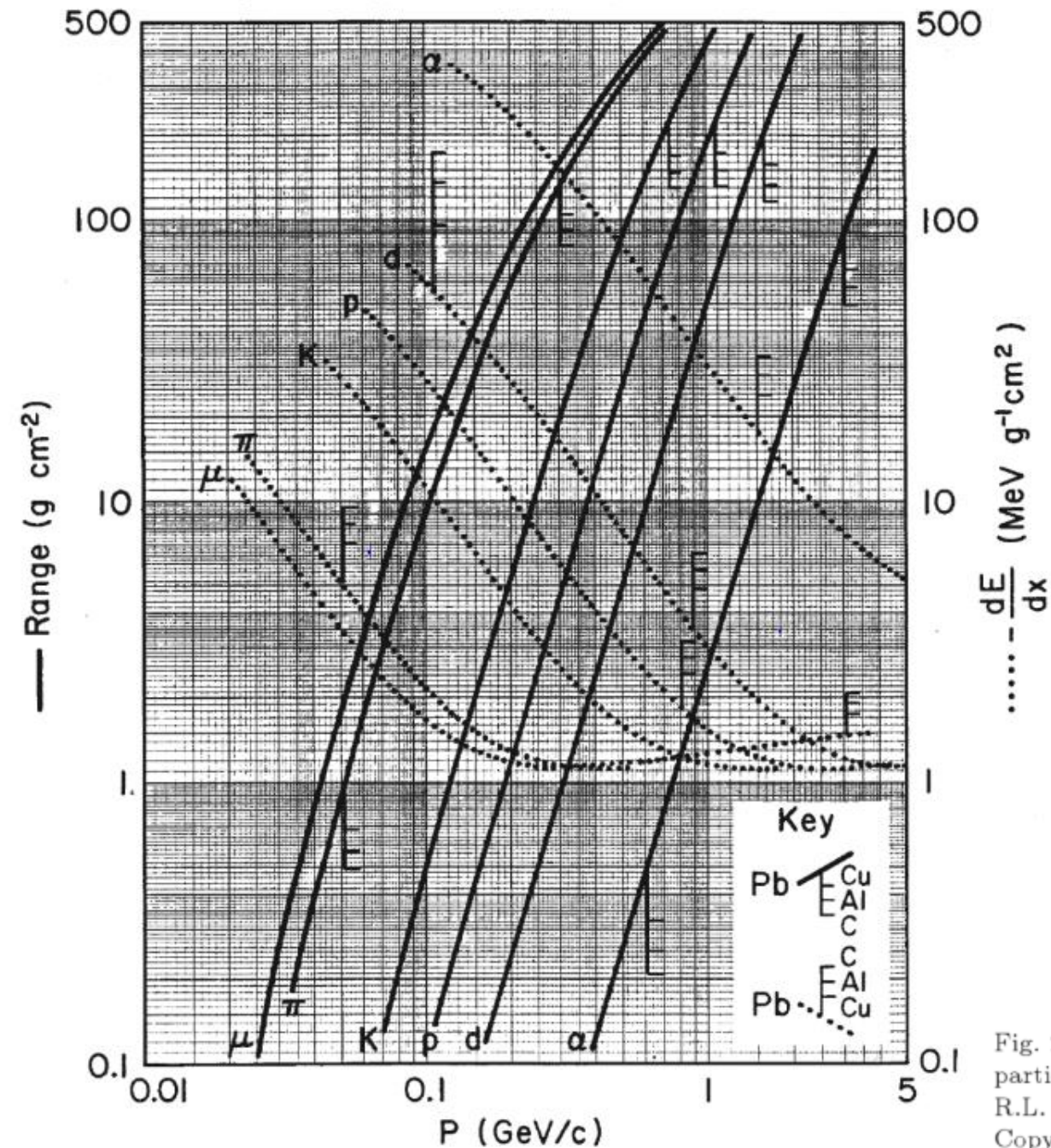


Fig. 2.16 Mean range in g cm^{-2} and stopping power in $\text{MeV g}^{-1}\text{cm}^2$ from Eq. (2.1) for various particles in Pb, with scaling to Cu, Al and C (adapted and republished with permission from Kelly, R.L. et al., Particle Data Group, Review of Particle Physics, *Rev. of Mod. Phys.* **52**, S1 (1980); Copyright (1980) by the American Physical Society).

