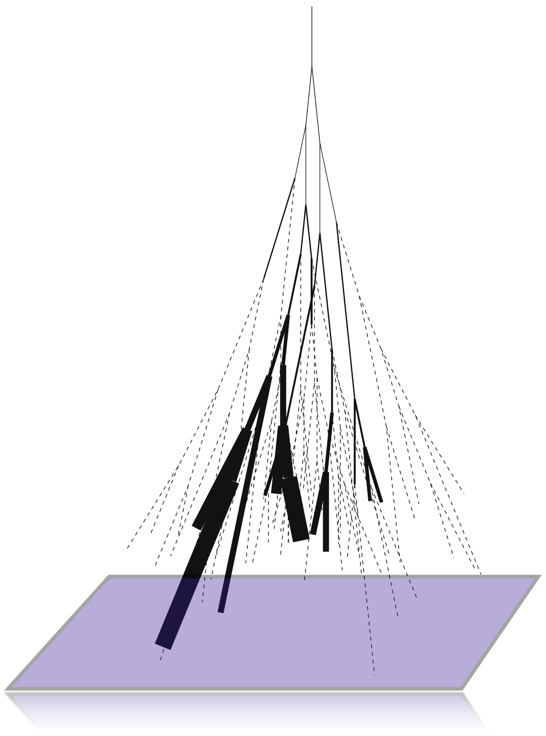
Attaching weight

De-thinning method (P. Billion, AUGER group)



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Introduction

What are Ultra High Energy Cosmic Rays (UHECRs)?

Cosmic rays elementary particles, nuclei, and electro-magnetic radiation of extra-terrestrial origin.

Ultra-high energy cosmic rays?

- cosmic rays with energies above ~10^{18}eV

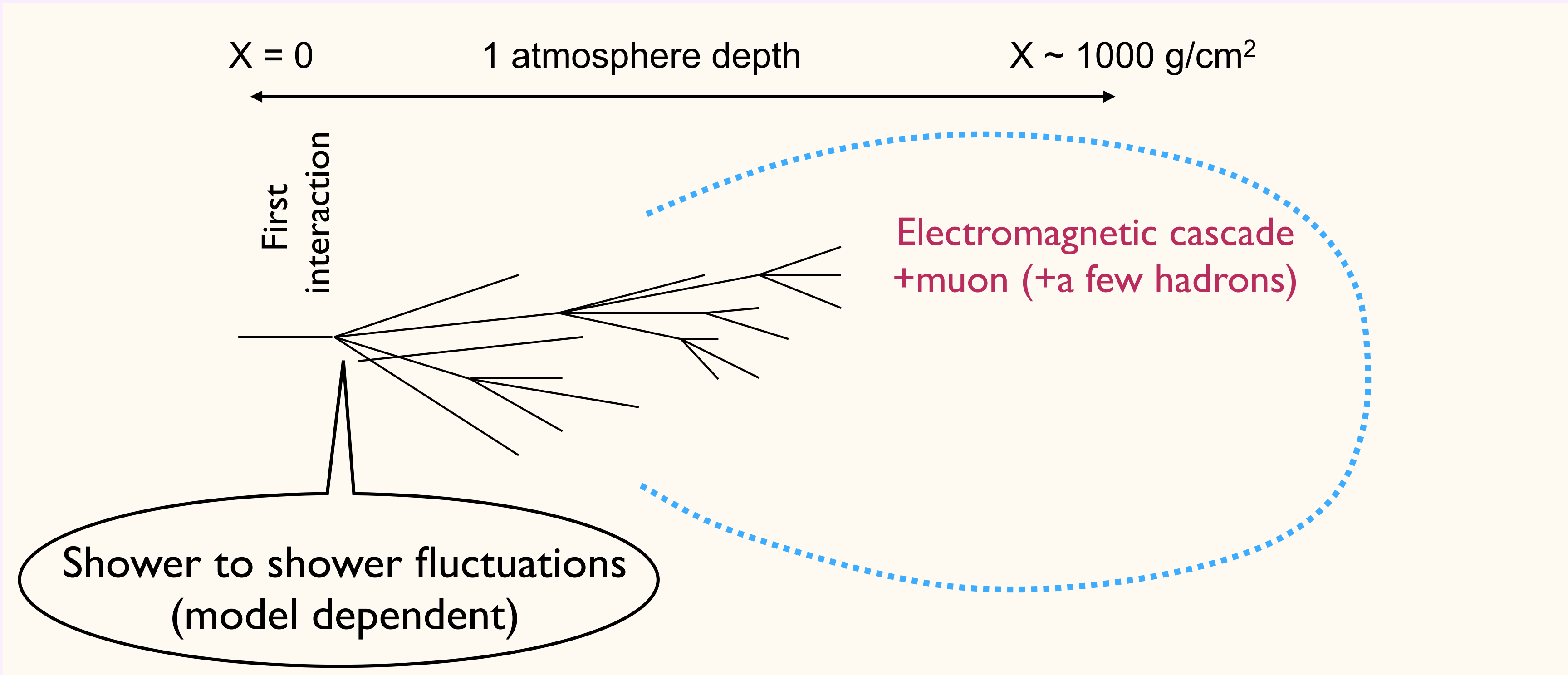
The Mystery of Ultra-High Energy Cosmic Rays

-How are UHECRs accelerated to such extreme energies?

-Where do UHECRs come from?

-What is the composition of the UHECRs?

Particles generate from air shower simulation



How to simulate an EAS ?

Follow the particles and their fate

Main effect of initial fluctuations :
Global translation of em. Cascade
Modulation of muon rate

Air shower simulation

COSMOS : Hybrid with sub-shower library (Kasher et al)

MOCCA : Split algorithm, thinning, Pascal (Hillas)

AIRES : transcript of MOCCA to Fortran (Scout)

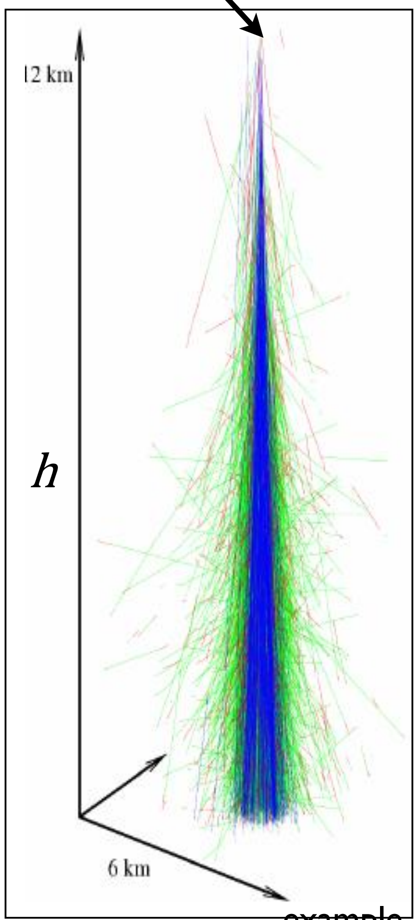
SENECA : Hybrid with cascade equations (Drescher et al)

...

Probabilities (transport, interactions):

Decision by random numbers

→ Monte Carlo method



Particle for Interaction

The probability P_{int} to traverse a layer with thickness χ without interaction is

$$P_{int}(\chi) = \frac{1}{\lambda_{int}} e^{-\chi/\lambda_{int}}$$

The individually traversed matter thickness χ is $\chi = -\ln(RNDM) \cdot \lambda_{int}$

with random number $0 < RNDM < 1$

The mean free path λ_{int} is given by $\lambda_{int} = \frac{\sum_{i=1} n_i A_i}{\sum_{i=1} n_i \sigma_{i_{int}}}$

with A_i = **atomic weight of component i**

and σ_{int} = **(energy dependent) cross-section of component i**

The atomic fractions n_i (volume) of air are adopted to

N_2	0.7848	(78.084%)
O_2	0.2105	(20.948%)
Ar	0.0047	(0.934%)

Seed: every integer number I with 1 ≤ I ≤ 900 000 000 starts an independent random number sequence

Particle for Decay

The probability P_D to traverse a path ℓ without decay is

$$P_D(\ell) = \frac{1}{\ell_D} e^{-\ell/\ell_D}$$

The individually traversed path length ℓ is $\ell = -\ln(\mathrm{RNDM}) \cdot \ell_D$

with random number $0 < \mathrm{RNDM} < 1$

The mean free path ℓ_D is given by $\ell_D = c \cdot \tau \cdot \gamma \cdot \beta$

with

- c = **vacuum speed of light,**
- τ = **particle life time at rest,**
- γ = **particle Lorentz factor and**
- β = **particle velocity in units of c**

Thinning method vs. Full M.C (no-thinning)

What is the problem from no-thinning?
-Not enough disk space, Save CPU time

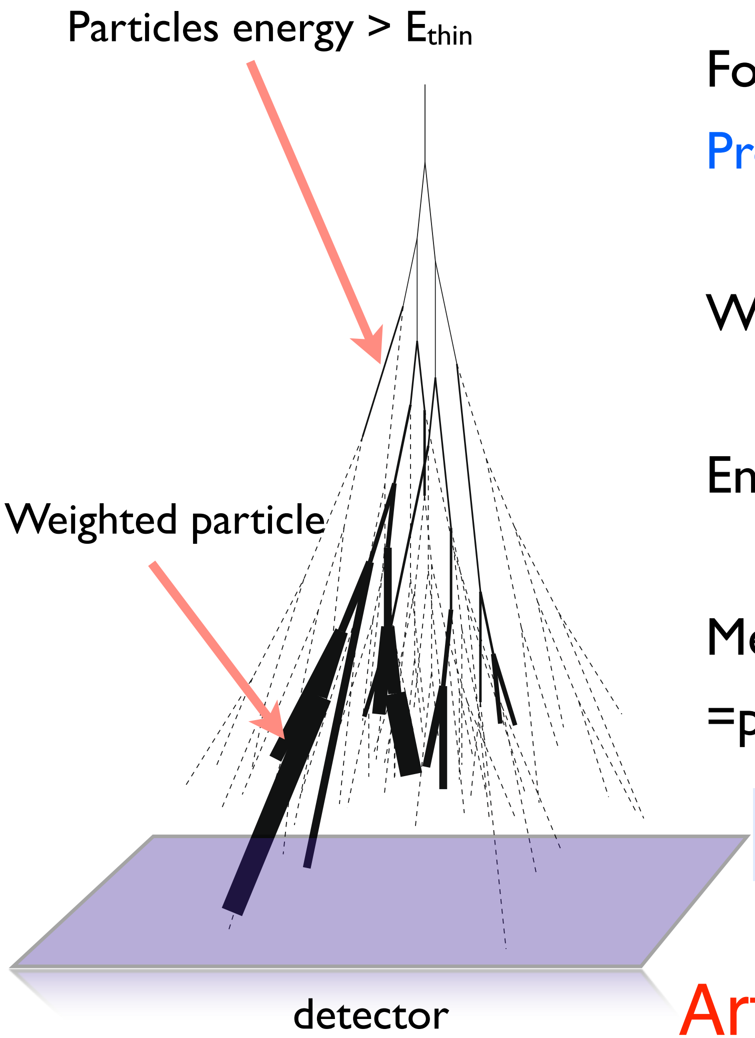
Why we need a thinning in the air shower simulations?
-we can't be tracked the created particles, only selected ones

How can we solve from this problem?
-Random sampling from particle energy
weight to selected particles

Goal

De-thinning

Thin method algorithm & Weight



For particles with $E_i < E_{thin}$

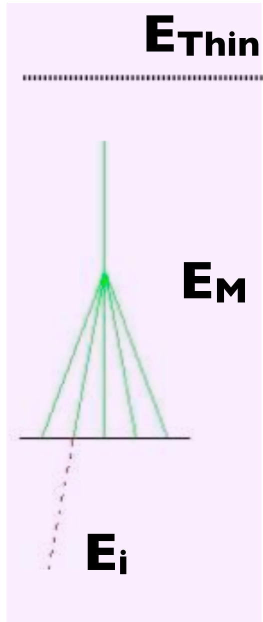
Probability of particle to be kept

$$P_i = E_i / E_M$$

Weight attached to particle

$$W_i = 1 / P_i$$

Energy Conservation : ($E_M = E_i * W_i$)



Meaning of Weight!

=particle resembles W_i particles of its kind

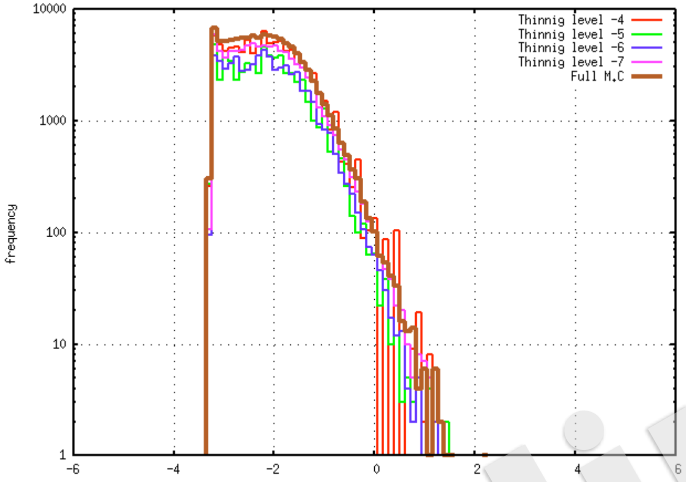
Weights are inherited : $W_i' = W_i * W_M$

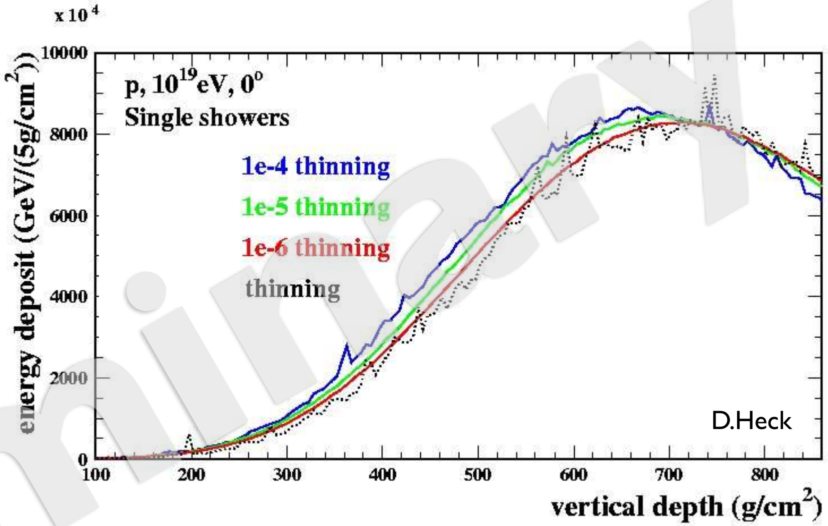
Artificial fluctuations due to weights

Quality of Simulation

ε controls **quality** of thinning

Gamma energy distribution at the entire ground





Log energy (GeV)

Same seed, random number

Simulation Conditions

E0 : 10^{15}eV
Primary : Iron
Incident θ = 45°

Fluka&QGSJET-II

Follow all particles with $E_i > E_{thin}$

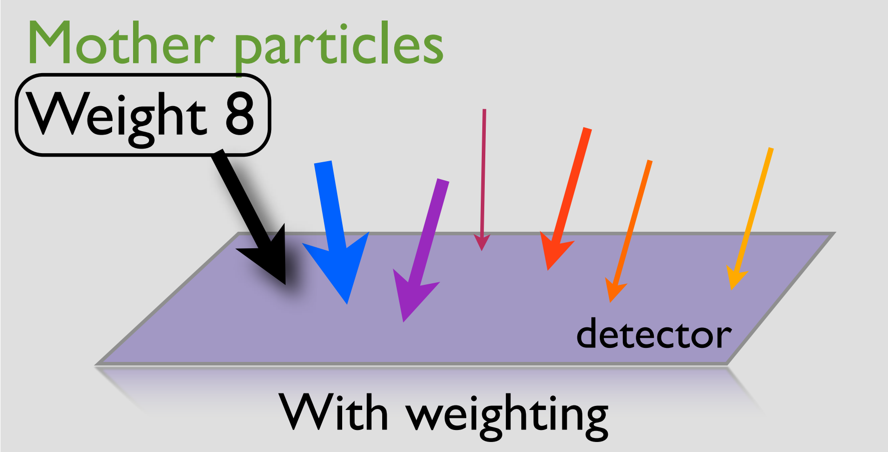
$E_{thin} = \varepsilon * E_0$, $\varepsilon \sim 10^{-4} \sim 10^{-7}$

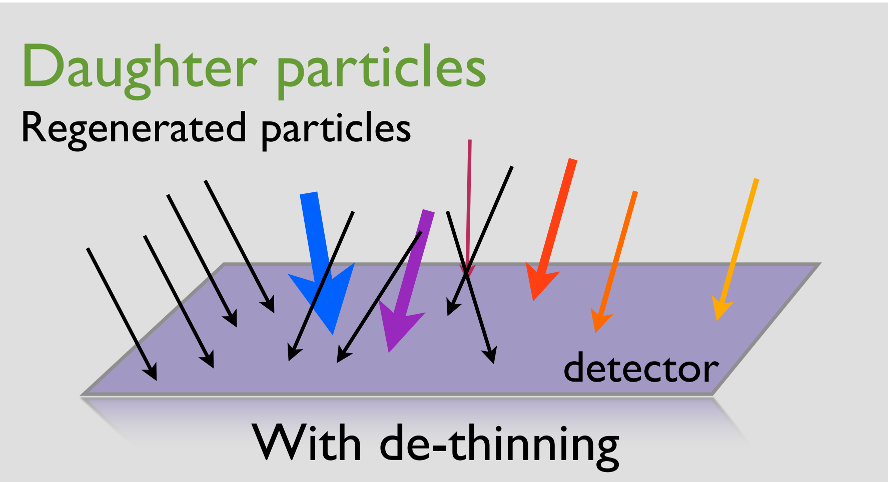
ε : thinning level

W_{max} (e,g) = ε* E_0/GeV

W_{max} (m,h) = 0.01* W_{max} (e,g)

De-thinning





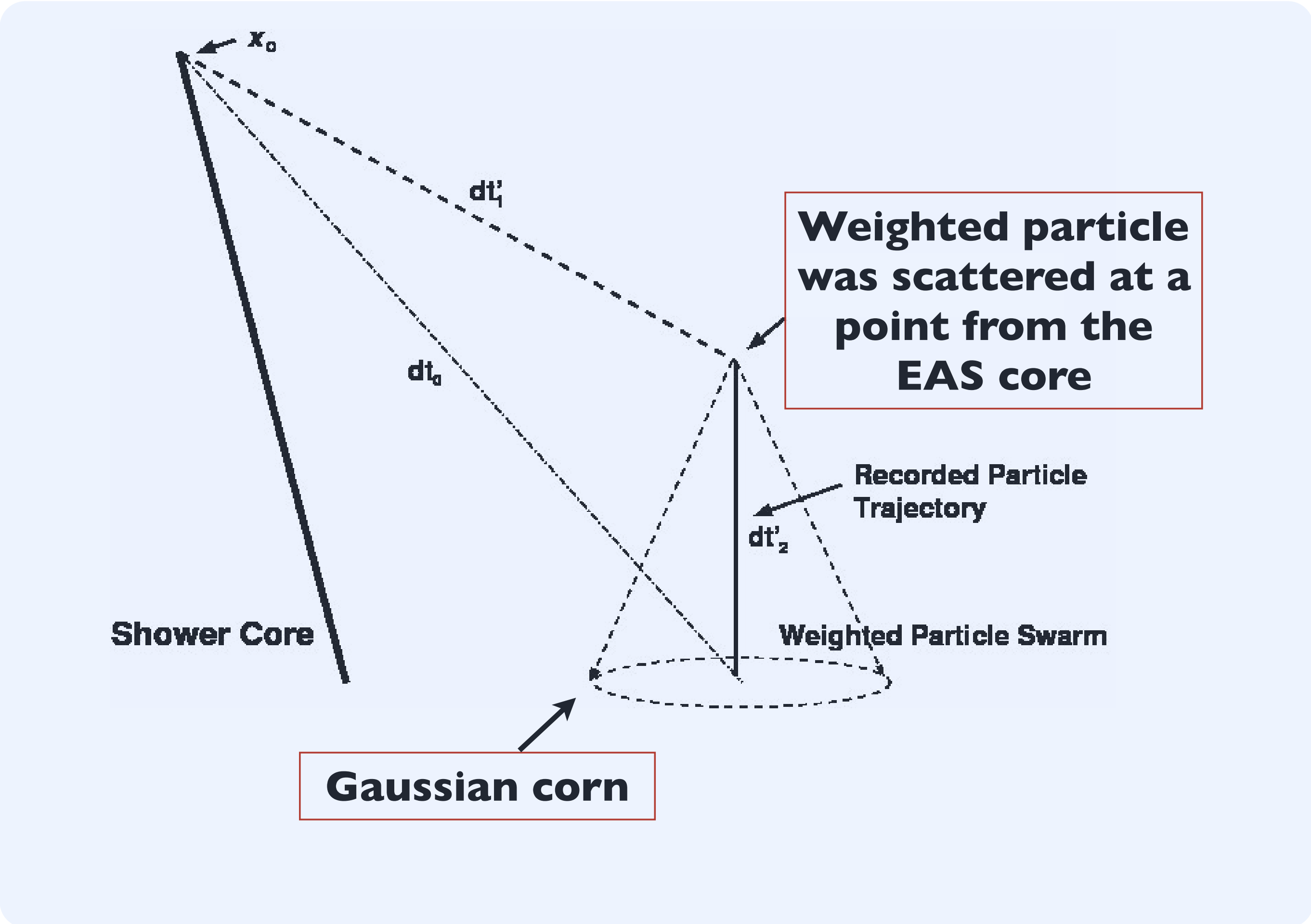
Recorded data

Particle energy
Momentum px, py, pz
Position x,y
Incident angle
Incident azimuth angle
Weight

De-thinning
(Keep small fluctuation)

Similar to Full M.C

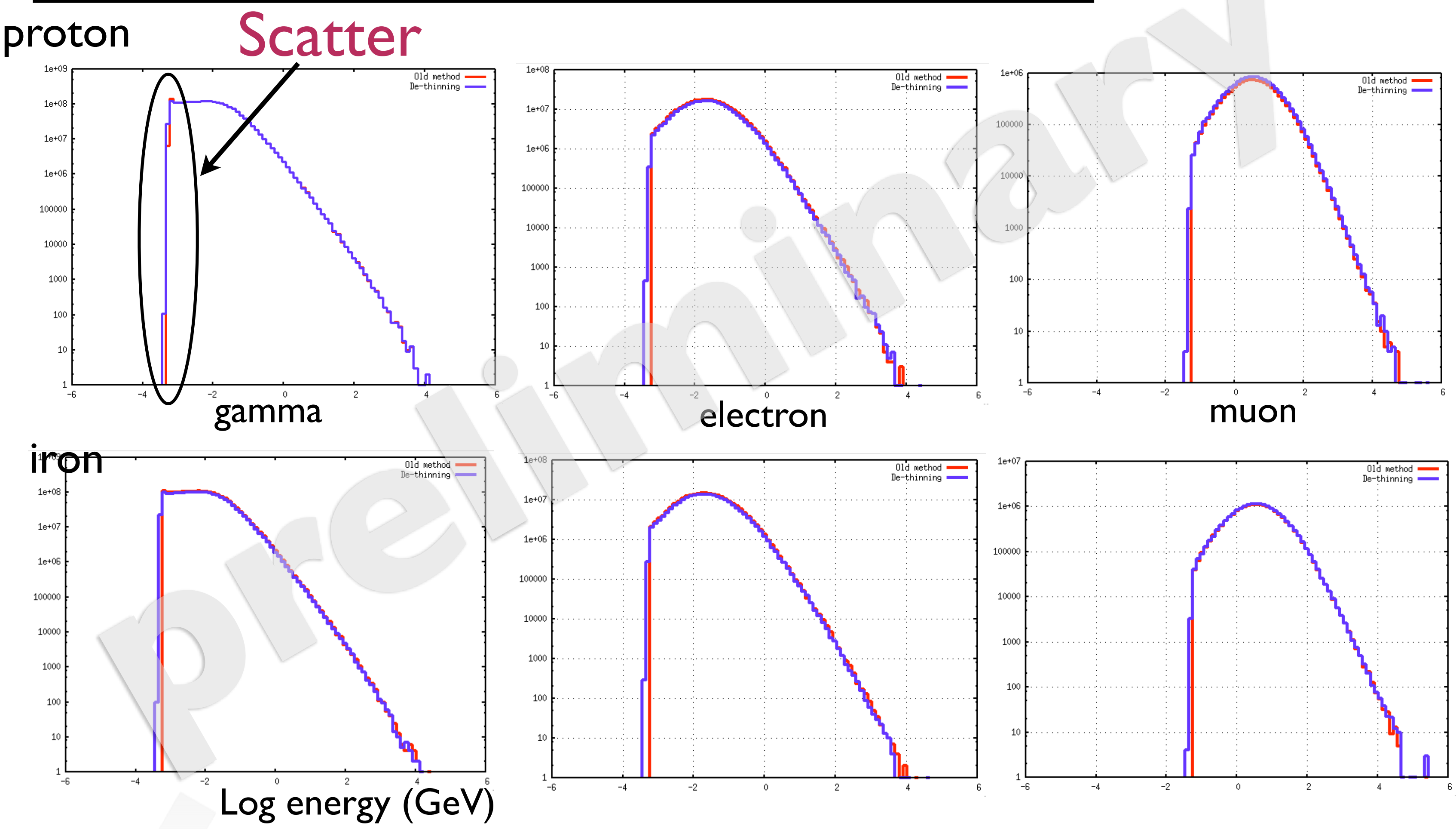
De-thinning : sprinkle the thinned particles



B.T. Stokes 2009 ICRC

De-thinning results

Ground particle spectra recovered based on "weights"



Conservation of energy : << 5%

Summary and Conclusions

particle thinning & weight limitation:

technique for M.C simulations at highest energies

$$w_{max}(e,g) = \varepsilon * E_0/GeV, \quad w_{max}(m,h) = w_{max}(e,g) / 100$$

But, discard produced particles

artificial fluctuations

attach weight to “surviving“ particles

De-thinning

Reference

- CORSIKA school : http://www-ik.fzk.de/corsika/corsika-school2008/participants.htm
- B.T. Stokes 2009 ICRC
- P. Billion 2009, AP 30, 270-285