

INVESTIGATE EXOTIC HIGH-ENERGY PHYSICS SCENARIOS IN AIR SHOWERS WITH CORSIKA 8

Internship M2/Mag3

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Internship done at KIT in Karlsruhe (100% remote) from May
2020 to September 2020 included.

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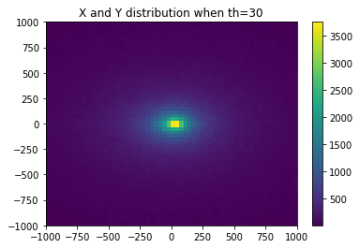
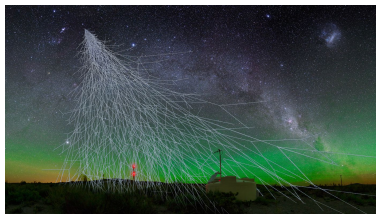
- 1 High energy boson cascade
- 2 CORSIKA8 Simulations
 - "In" parameters
 - "Out" parameters
- 3 Standard simulations
 - Own research
 - Focus on X_{max}
 - Focus on the muon production
- 4 Boson cascade simulation
- 5 Conclusion

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The physics of high scattering boson cascade

Air shower : Cosmic ray entering the atmosphere yielding to a multitude of scattered particles decaying more and more.



- Cosmic rays reach $1e14$ to $1e19$ eV
LHC is $1e13$ eV as a comparison
- Bad side : Not controled
- Use CORSIKA to simulate showers
- Air shower is a tool to test "higgsplosion" theory

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"In" parameters

- Particle type : Hadron (lighter than ${}^{56}_{26}\text{Fe}$)

PERIODIC TABLE OF THE ELEMENTS

The periodic table is color-coded by groups:

- Non-metal: Grey
- Metal: Green
- Noble gas: Blue
- Alkali metal: Orange
- Metalloid: Light Green
- Lanthanide: Purple
- Alkaline earth metal: Red
- Halogen: Cyan
- Actinide: Pink
- Transition metal: Yellow

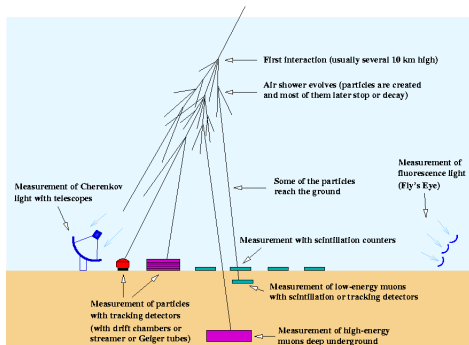
Elements **H** (Hydrogen) and **Fe** (Iron) are highlighted with red boxes.

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	57-71	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	89-103	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv	Ts	Og

- Energy (1e14-1e19eV)
- Angle (0=zenit)
- Physical model of computation (Sybill)

"Out" parameters

Measuring cosmic-ray and gamma-ray air showers



(c) 1999 IC. Baezler

- Study the evolution of the shower across the air (X_{max})
- Study the particle hitting the ground. (more precise but part is lost) particle type, energy, position

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Standard air showers simulations

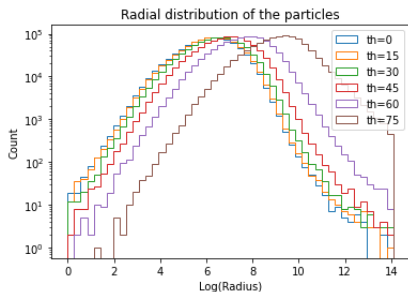
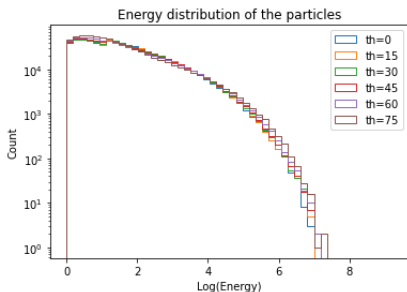
Goal of this section:

- Setting a ground
- Verify the transition CORSIKA 7 to 8

Own research

Looking for any original result

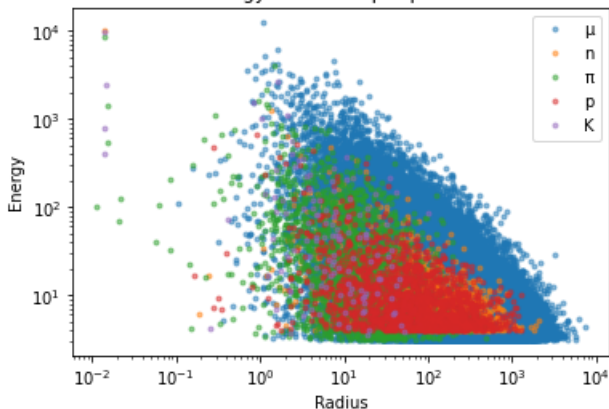
Looking for a way to deduce the "in" parameters by only looking at the ground.



Own research

Parameters distribution depending on the particle type

Energy vs Radius per particle



- Used Log scale to spread out the bundle
- Looking for any kind of emerging phenomenon
- Energy Threshold
(Chosen by CORSIKA team)

Own research

Parameters distribution depending on the particle type

Energy vs Radius per particle with an angle of 0

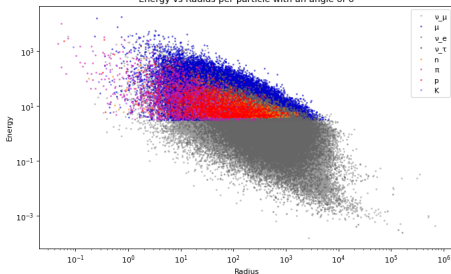


Figure: $\theta=0$

Energy vs Radius per particle with an angle of 45

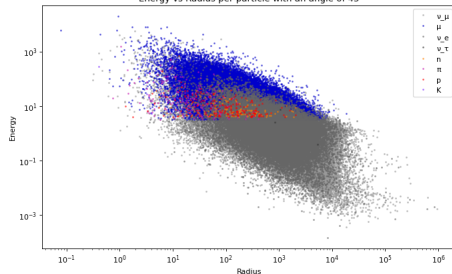


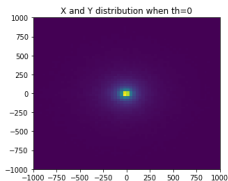
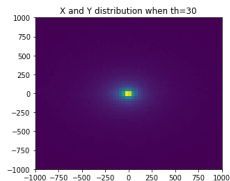
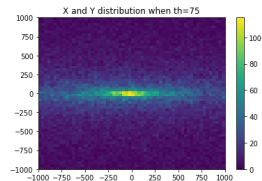
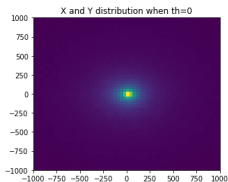
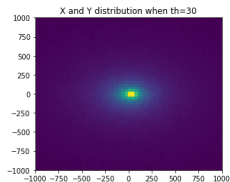
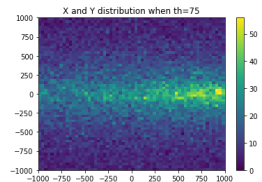
Figure: $\theta=45$

Wider angle \Rightarrow Longer travel in the atmosphere

Less n, p, K, π

Constant ν, μ

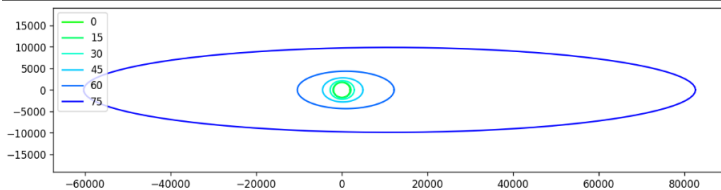
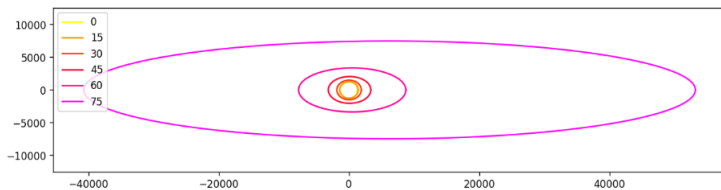
Spatial distribution of the particles

(a) $\theta = 0$ (b) $\theta = 30$ (c) $\theta = 75$ (a) $\theta = 0$ (b) $\theta = 30$ (c) $\theta = 75$

Top : Proton | Bottom : Iron

Spatial distribution of the particles

Parameters of the ellipse are such that 90% of the particles are in.



Spatial distribution of the particles

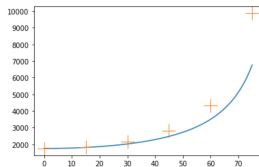
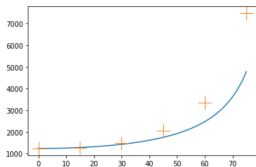
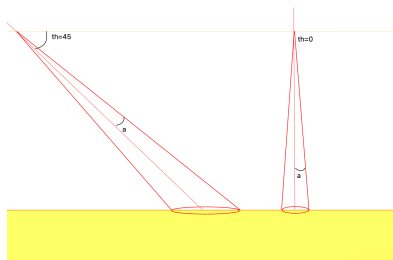


Figure: Expected ellipse width¹ (blue line) versus actual ellipse width (Orange crosses). Proton showers on the left, iron shower on the right

¹Same result for length, but data were lost

What is X_{max}

Study of the shower before impact

- Time-dependent evolution (no)
- Altitude dependence (no)
- Interaction Depth g.cm^{-2} (yes)

$$X = \int \rho dr$$

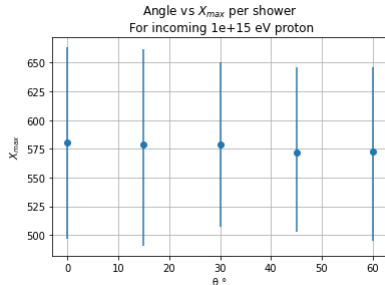
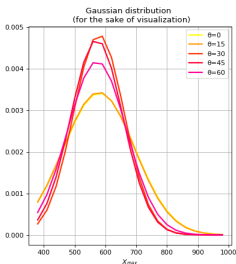
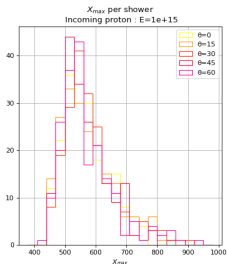
Starts at 0 when outside the atmosphere, and grows as the altitude goes down.

One important parameter² : X_{max} .

²The value of X when the amount of muon produced is at the maximum

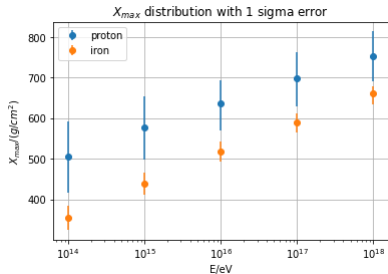
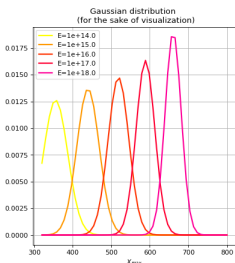
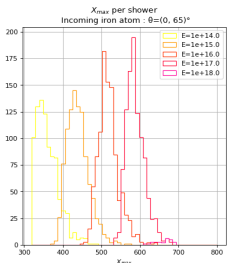
How X_{max} evolves depending on the input parameters

Angle



How X_{max} evolves depending on the input parameters

Energy

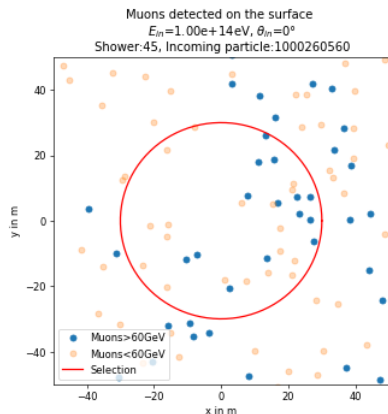
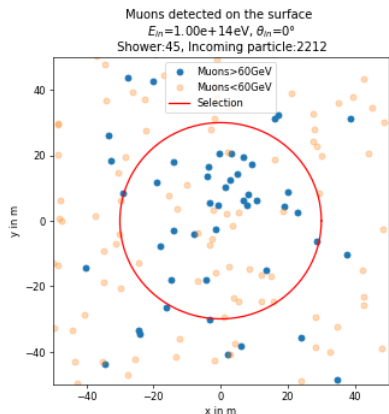


Focus on the muon production

Study of the shower on the ground

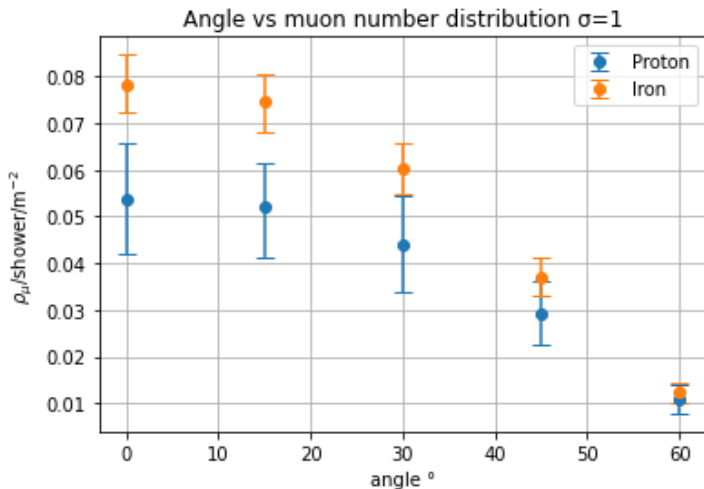
The amount of muon per shower : good indicator to compare standard showers and high boson scattering theory showers.
Introduction of the Muon Bundle.

The Muon Bundle

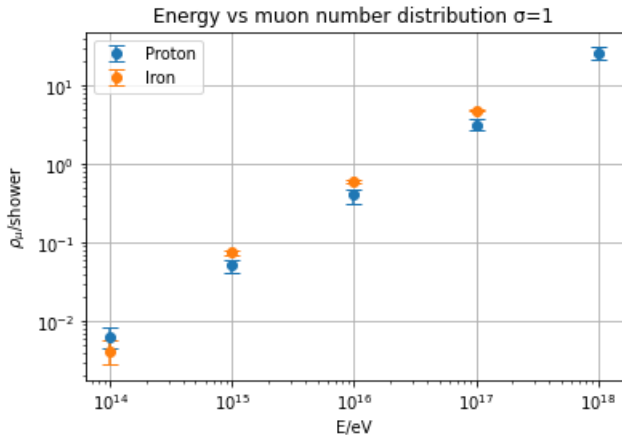


Two examples of muon bundle selection.
Threshold : $E_\mu > 60\text{GeV}$, Radius < 30m

Angle dependency



Energy dependency

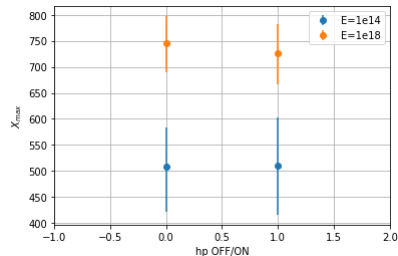
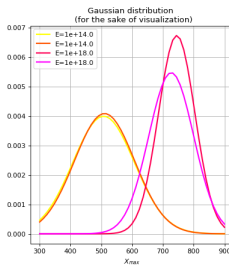
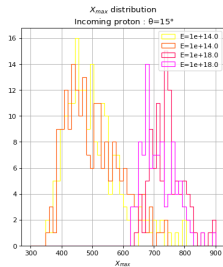


- Linear behavior
- No Iron data at $E=1e18eV$
- Small inaccuracy at $E=1e14eV$

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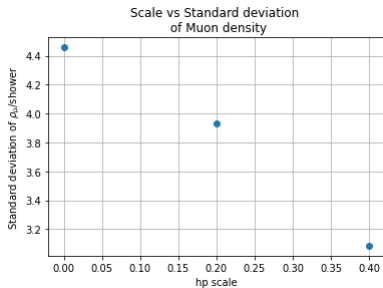
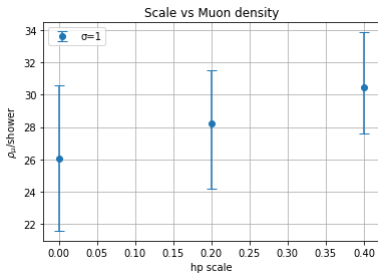
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High scattering boson cascade simulation



High scattering boson cascade simulation

Muon Bundle



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Conclusion

The cosmic rays showers studies are a very important field of particle physics that one must not neglect.

I did not have the time to compare my result properly with experimental data.

This internship showed me a new way to study particle physics that I had never considered before.

Bad side : Remote. (SSH problems, communication problems)

Thank you for your attention.
