ISCRA 2019

Goals and tasks of ISCRA-2019

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Introduction

In the last years, the number of various conferences, symposiums and workshops is increasing very sharply.

And correspondingly, is increasing the number of participants, number of talks, number of discussed problems and tasks.

As a result: total time for talks is increasing

time for each talk is decreasing

time for discussions is decreasing

Primary General Goal of ISCRA

To stop and to turn this tendency.

For that, it is necessary.

- To decrease the number of directions (topics)
- To decrease the number of talks
- To decrease total time for talks
- To increase time for discussions

Of course, it was very difficult to fulfill these requirements, but we tried.

Difficulties at ICRA-2019 organization

- The choice of topics (different opinions, firstly – three, then four, and at last - five).
- We did not limit the number of talks if they corresponded to announced topics.
- We try to keep the rule: one person – one oral talk.

  Three exceptions were made for participants with very long way (Mexico, USA, Yakutia).
- We keep the rule, that 15 min is minimal time for talk and questions.

Conveners and discussions

To organize fruitful discussions, good conveners are required.

I would like on behalf of the Program and Organizing Committees to express our thanks to ISCRA 2019 conveners

Hans Dembinski

Andrea Chiavassa

Igor Lokhtin

MartinTluczykont

Juan Garzon

for the big and productive work in forming of Symposium Program. And we hope for their active participation in discussions during Symposium.

About Symposium Program

5 topics

1. EAS muon component and muon puzzle.
2. Energy spectrum and mass composition around and above the knee (direct and EAS measurements).
3. Nucleus-nucleus interactions at high energies (models and experiments).
4. TeV-PeV gamma rays.
5. Muon telescopes, muon hodoscopes and muonography.

The four of them are basic (fundamental) researches.

The fifth represents applied researches.

I would like to give some comments about these topics.

1. EAS muon component and muon puzzle

Historically, the words ‘muon’ and ‘puzzle’ were as synonyms beginning from muon discovery.

These puzzles:

1. What is muon if it is not a quant of strong interactions?
2. What is difference between muon and electron except the mass?
3. Does exist anomaly interaction of muon compared to electron?
4. Do exist so-called ‘prompt muons’, which give an excess of muons at highest energies of their energy spectrum?
5. Now….

Today muon puzzle is a growing with energy excess of muon bundles in EAS

This excess was observed in various experiments, but it was difficult to compare their results:

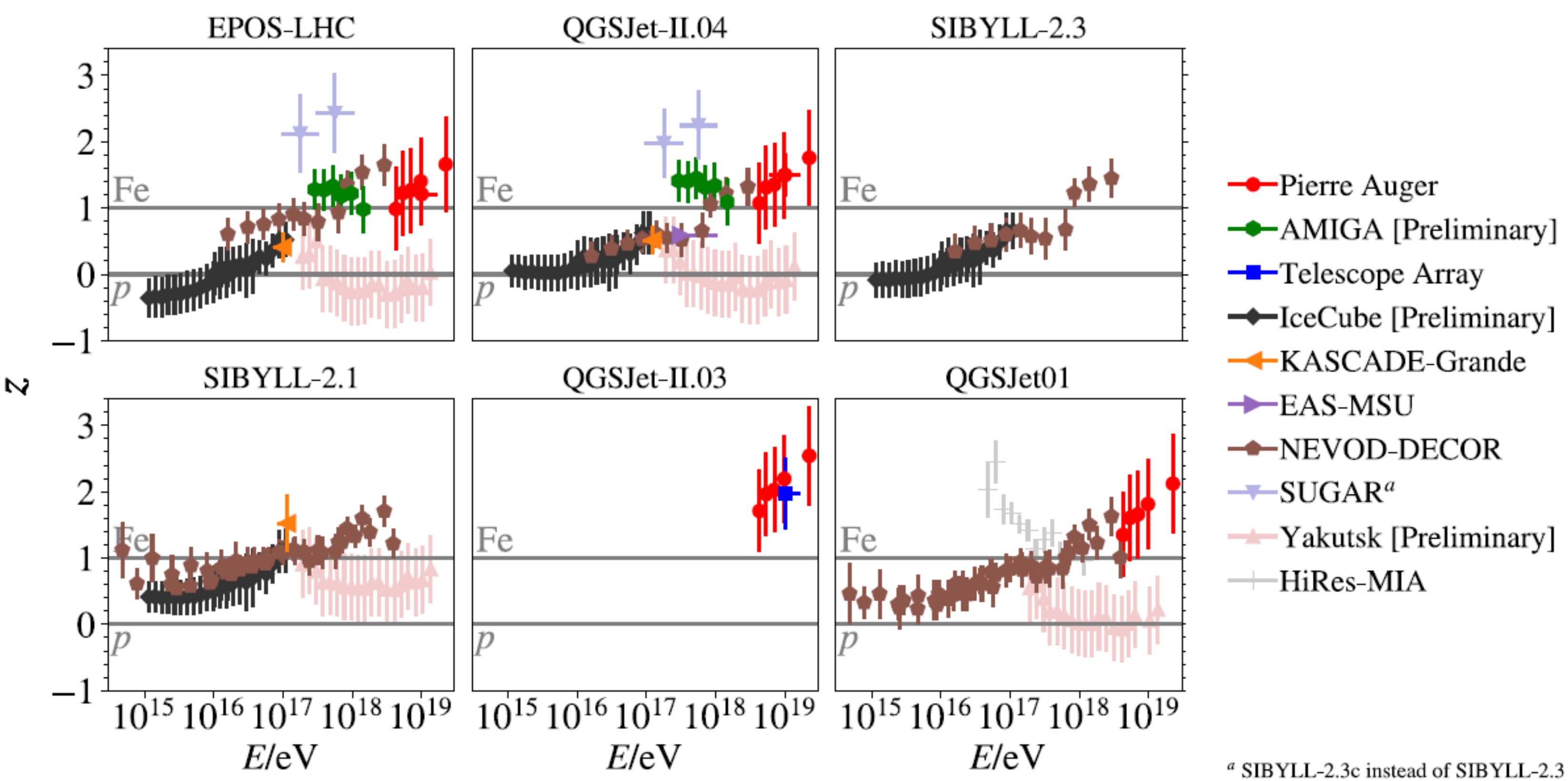
- Different measured values: number of muons, multiplicity, muon density…
- Different intervals of energies and zenith angles
- Different models in comparison with predictions of which muon excess was determined
- Different CR energy spectrum and composition which were used in simulations.

Muon puzzle in 2018

Hans Dembinski proposed a simple parameter for comparison of various experimental data and different models.

Step 1: Convert all measurements to z-scale $z = \dfrac{\ln N_{\mu}^{\text{det}} - \ln N_{\mu,p}^{\text{det}}}{\ln N_{\mu,\text{Fe}}^{\text{det}} - \ln N_{\mu,p}^{\text{det}}}$

corrects simple biases; $z_p = 0$ and $z_{Fe} = 1$



[a] SIBYLL-2.3c instead of SIBYLL-2.3

Hans Dembinski | MPIK Heidelberg, Germany 7

- We will discuss: What to do? How explain the excess? etc.

2. Energy spectrum and mass composition around and above the knee (direct and EAS measurements)

EAS study – the only possibility to get information about energy spectrum and composition of primary cosmic rays and their interactions at energies higher~ 10^{15} eV.

In principle, two approaches for analysis of measured EAS parameters are possible:

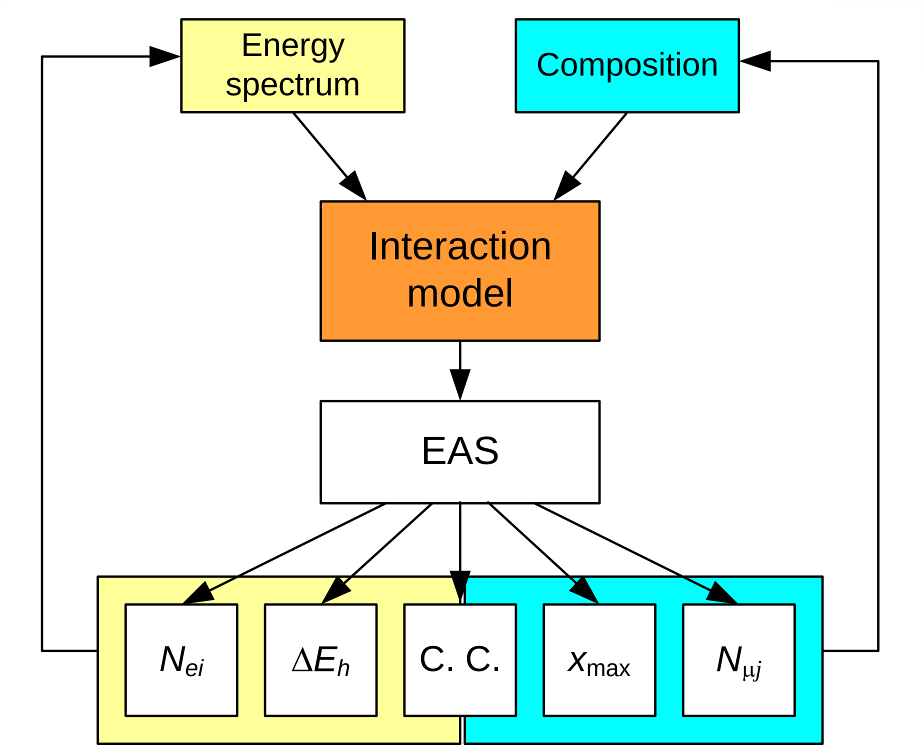
Approach	Energy spectrum and composition	Interaction model
Cosmo-physical	Unknown	Known
Nuclear-physical	Known	Unknown

As result, observed changes in measured EAS parameters are explained:

In C-Phys approach by changes of PCR parameters,

In N-Phys approach by changes of interaction model.

Cosmo-physical approach



In favor of this approach evident the results of p-p-interaction investigations at LHC, in which no evidences of deviations from SM were observed.

Arguments in favor of Nuclear-physical approach

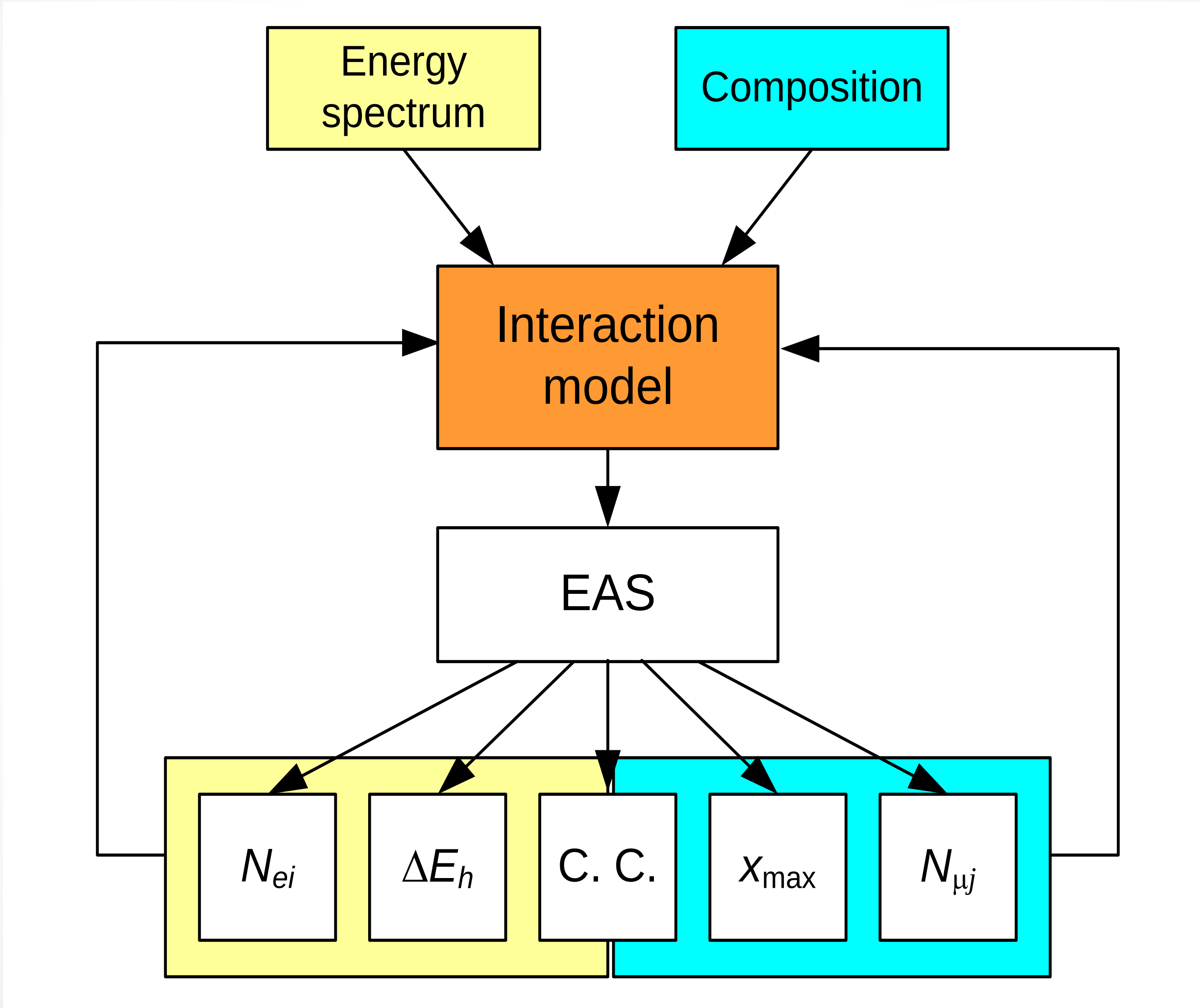
But PCR consist mainly of nuclei which interact with nuclei of the atmosphere.

Particles	Z	<A>	Energy per nucleon	Energy per nucleus
Protons	1	1	92 %	42 %
α-particles	2	4	7 %	21 %
Light nuclei	3-5	10	0.15 %	1 %
Medium nuclei	6-10	15	0.5 %	18 %
Heavy nuclei	≥ 11	32	0.15 %	18 %

In the favor of this approach evident numerous experimental data obtained in CR investigations (alignment, penetrating cascades, Centauros, large transferred momenta, etc.)

In the last years, to them the muon puzzle added, for explanation of which new processes of muon generation are required.

Nuclear-physical approach



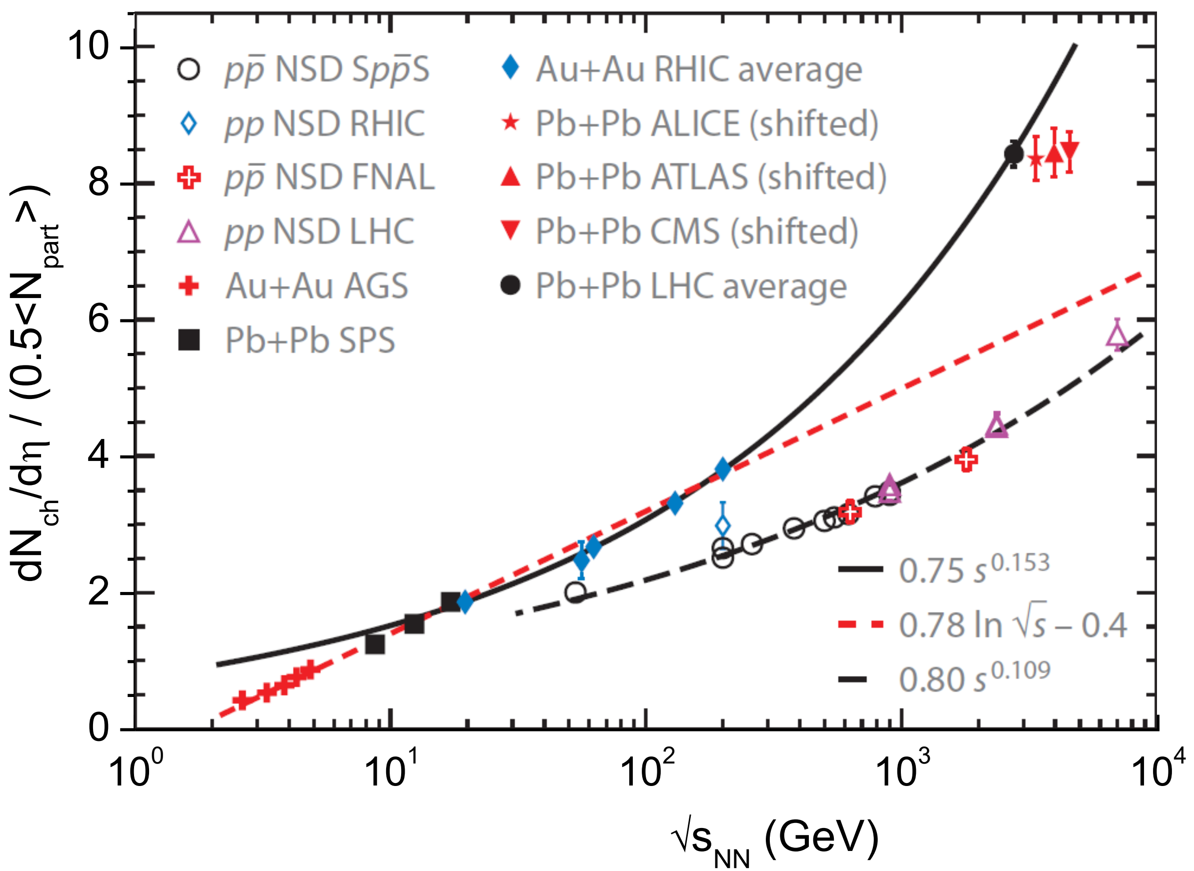
3. Nucleus-nucleus interactions at high energies (models and experiments).

Nucleus-Nucleus interactions do not like both theorists and experimentalists due to their complexity. Theorists – due to the practical absence of pure particle physics, which has good mathematical description, and require various statistical, hydrodynamical and thermodynamical approaches.

The experimentalists – due to very large multiplicity of particles after interaction and big difficulties in their parameter measurements, especially in forward region which is important for cosmic ray experiments.

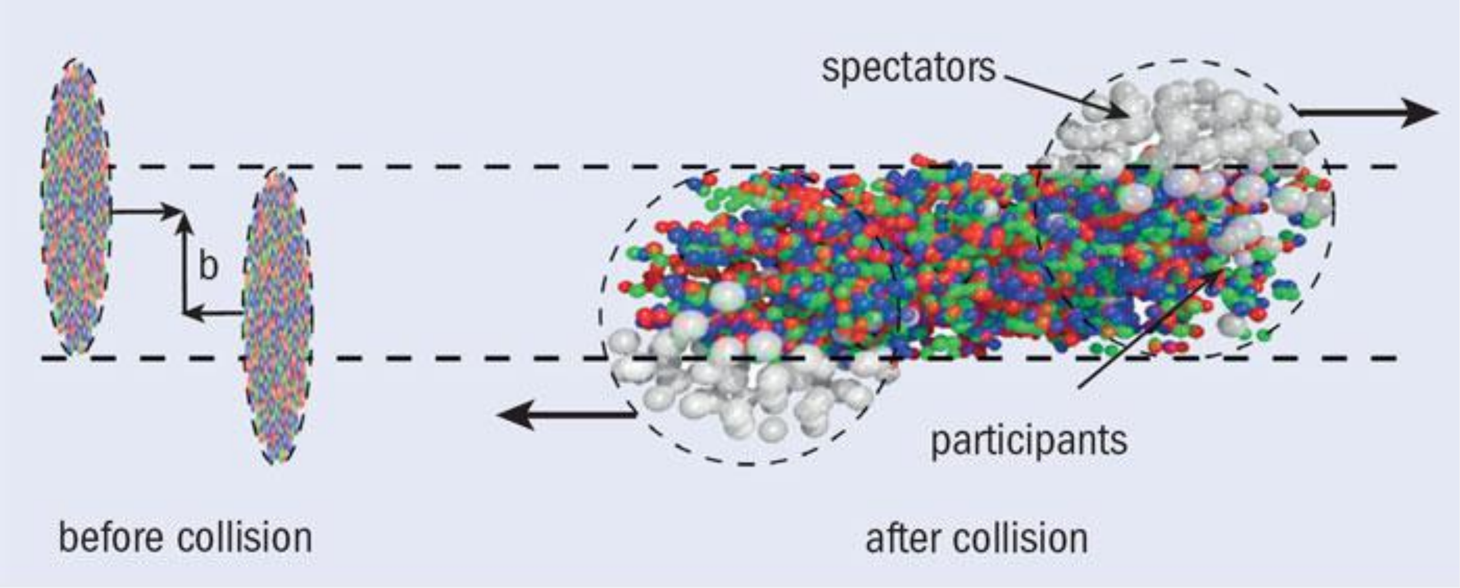
Since It is recognized, that in physics of interactions the last word belongs to accelerator results let’s see LHC results.

Nucleus-nucleus interactions at LHC



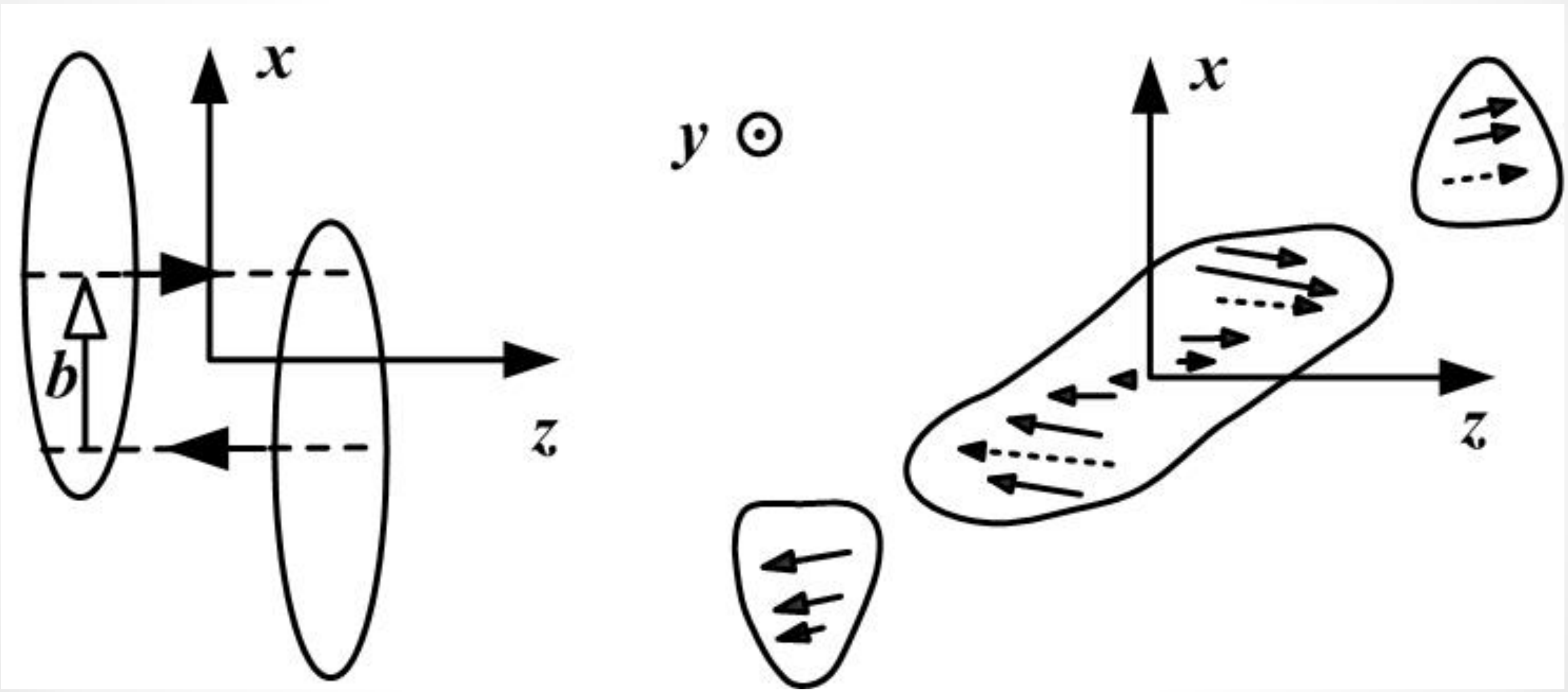
Possible nucleus-nucleus interaction model

Collective interactions of many quarks and gluons during nucleus-nucleus collisions with production of blobs of quark-gluon plasma (matter) with large orbital momentum.



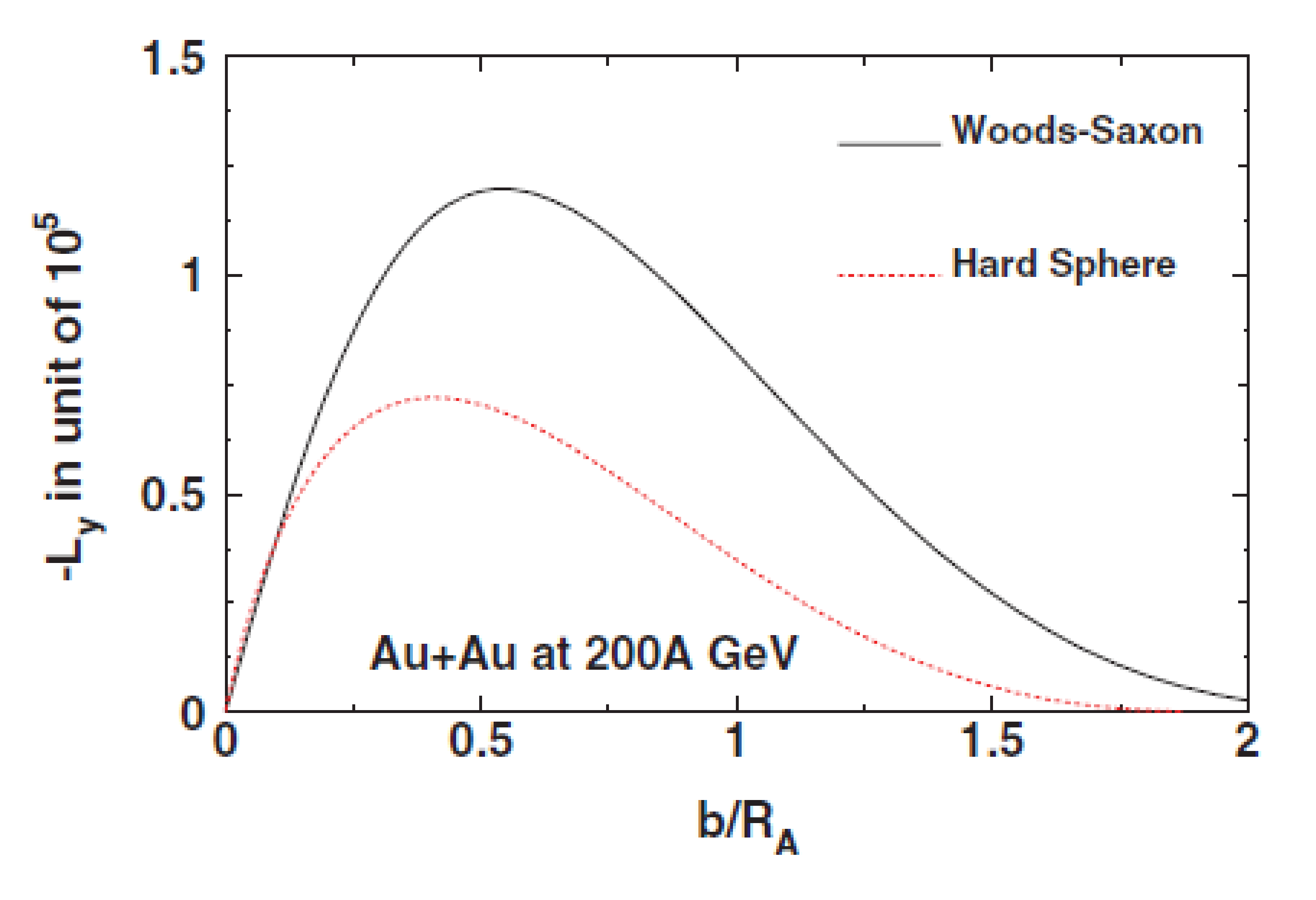
Orbital angular momentum in non-central ion-ion collisions

Zuo-Tang Liang and Xin-Nian Wang // PRL 94, 102301 (2005); 96, 039901 (2006)



The value of orbital angular momentum

Jian-Hua Gao et al., Phys. Rev. C 77 (2008) 044902



Total orbital angular momentum of the overlapping system in Au+Au collisions at the RHIC energy as a function of the impact parameter b.

Centrifugal barrier

A blob of a globally polarized QGM with large orbital angular momentum can be considered as a usual resonance with a large centrifugal barrier

$$V(L) = L^2 / 2mr^2$$

which will be large for light quarks but much less for top-quarks.

Though in interacting nuclei top-quarks are absent, the suppression of decays into light quarks gives time for the appearence of heavy quarks.

Produced $t\bar{t}$-quarks will decay $t(\bar{t}) \to W^+(W^-) + b(\bar{b})$

In their turn *W*-bosons decay into leptons (~30%) and hadrons (~70%) and we can get muons and neutrinos with very high energies.

4. TeV – PeV gamma-rays

This energy region is interesting from various points of view, f.e. to search PeVatrons. But in the last years interest to gamma-rays with these energies is increasing after observations in IceCube neutrinos with energies more 100 TeV and even above PeV.

Probability to observe such neutrinos from π- and k-decays due to properties atmosphere is very small and more heavy and short-lived bosons are required (f.e. W-bosons)

Gamma-rays, neutrinos and muons

Therefore non-terrestrial origin of these neutrinos is in favor. But in the case if neutrinos are produced in π-decays anywhere in astrophysical objects gamma-rays from π°-decays must be observed.

So

To prove origin of PeV neutrinos

in astrophysical objects ↓ in Earth atmosphere

it is necessary to observe

gammas of corresponding energies muons with such energies.

5. Muon telescopes, muon hodoscopes and muonography

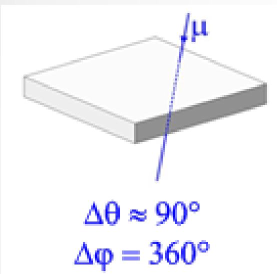
It is very well known that governments and funding agencies require practical application of scientific investigations.

From this point of view, muons are very good object. Muon flux and its variations depend on both PCR flux changes in heliosphere, caused by solar activity, and secondary particle (pions and muons) flux changes caused by various atmospherical processes.

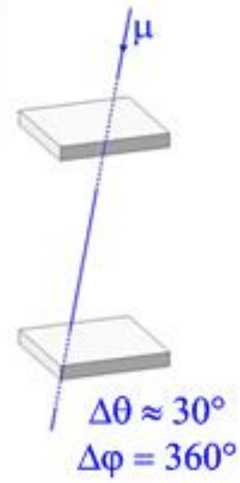
Therefore variations of muon flux (especially spatial and angular) can be used for monitoring and prediction of further development as of heliospheric (magnetospheric) so atmospheric disturbances.

Different types of muon detectors

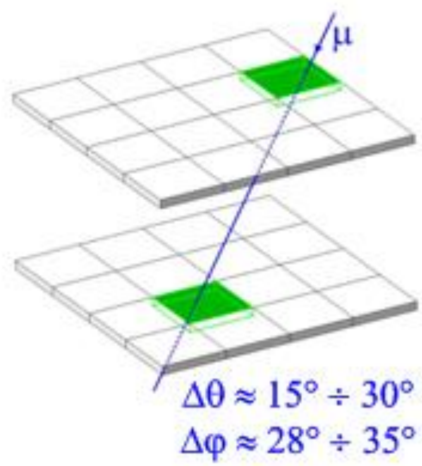
Muon detector



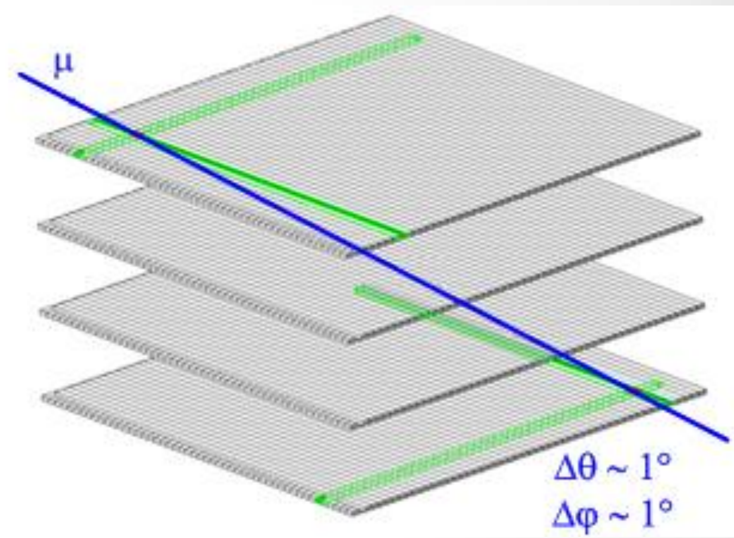
Muon telescope



Multidirectional muon telescope



Muon hodoscope

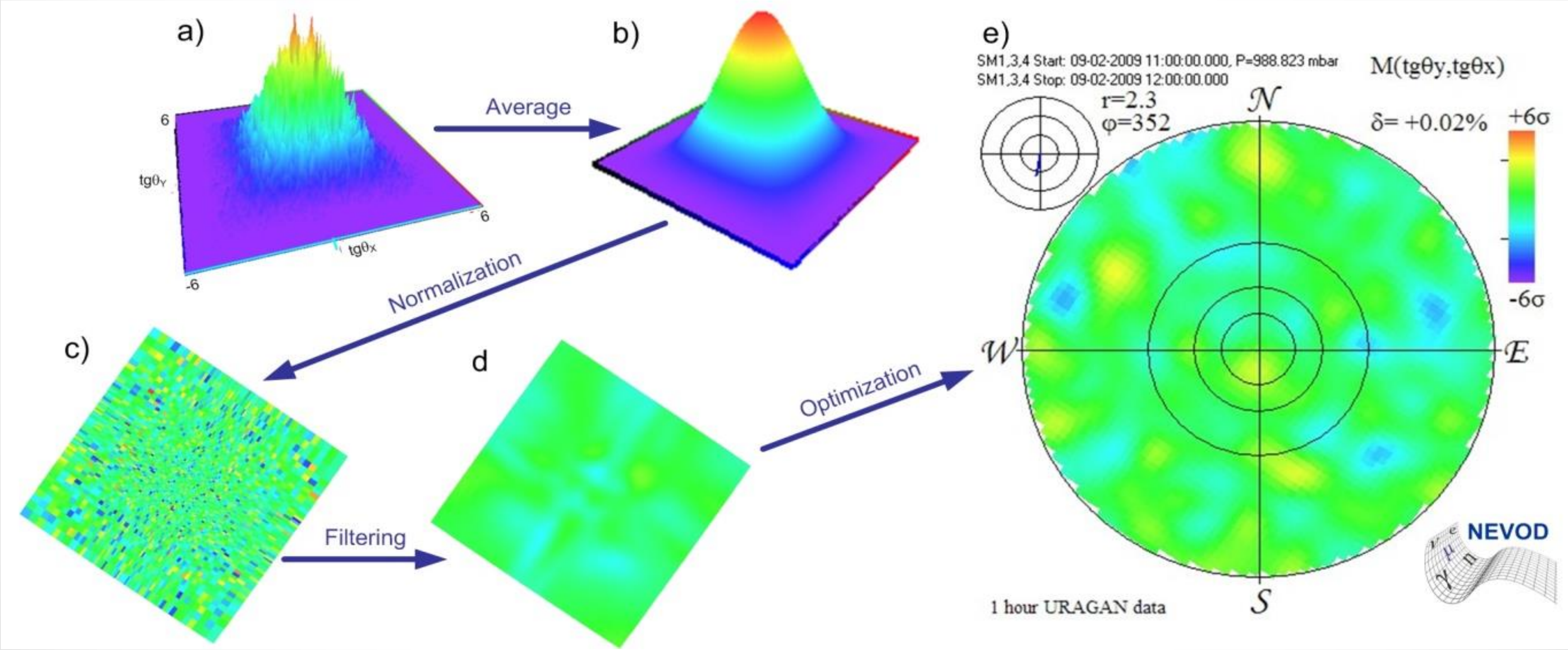


The main feature of muon hodocope is track reconstruction of each muon

A **hodoscope** from the Greek "hodos" for way or path, and "skopos" an observer

From muon matrix to muonography

To separate small deviation in muon flux from basic muon flux the muonography technique is used. To get a muonographs we do the following manipulations:



Color shows the deviation from the average in sigma

Such muonographs allow to study the time dynamics of two-dimensional muon flux variations. More detailed description of Muonography will be presented in the talk of Natalia Barbashina today afternoon.

Conclusion

- In my introductory talk I would like to pay your attention at necessity to develop the nuclear-physical approach to results of cosmic ray investigations.
- For 60 years after observation of the first change in EAS energy spectrum – the knee and then other various changes in it, no satisfactory and generally recognized their description in frame cosmo-physical approach was proposed.
- If the problem is connected with nucleus-nucleus interactions, the CR have serious advantages compared to colliders due to large primary momenta which provide very large energies of secondary particles and their separation that makes easier their measurements.

Thank you for your attention!