PRIMARY COSMIC RAY ENERGY SPECTRUM ABOVE THE KNEE MEASURED WITH PRISMA-32 ARRAY

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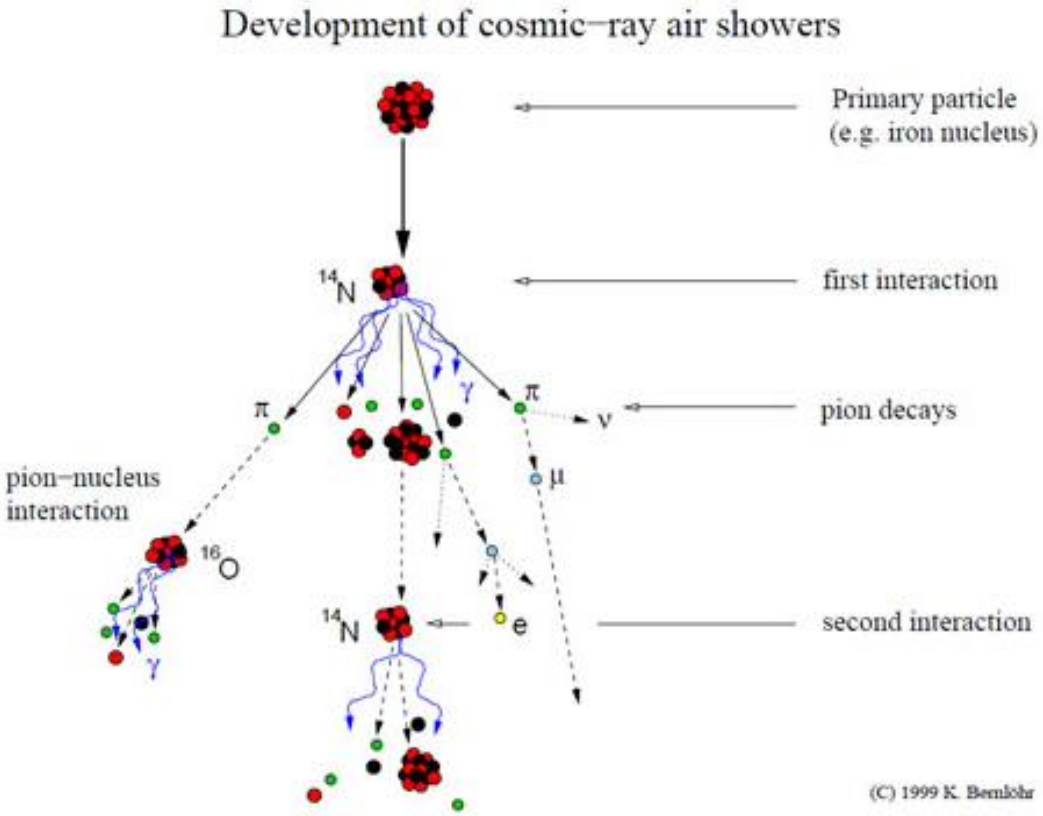
Outline

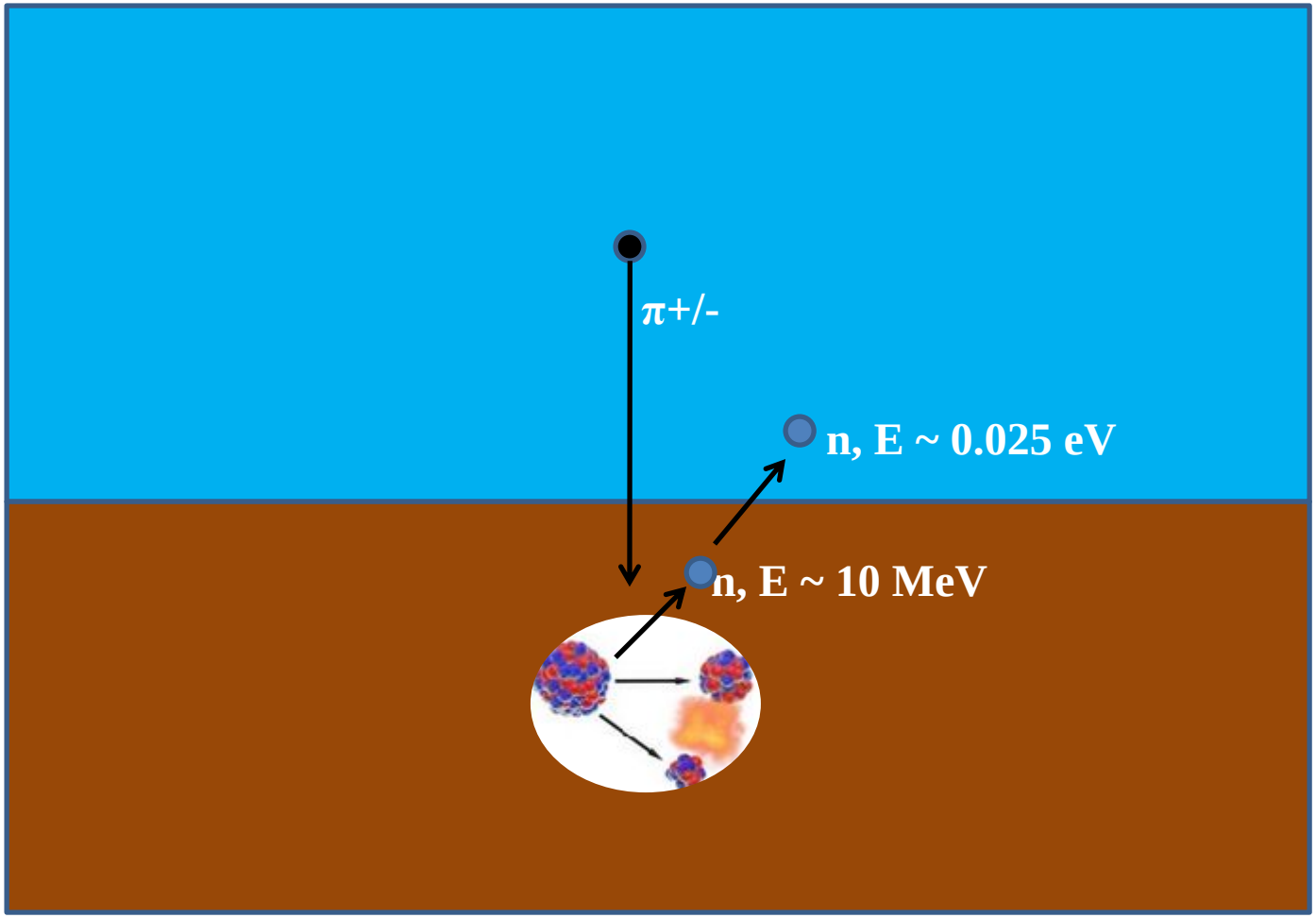
- PRISMA project (PRImary Spectrum Measurement Array)
- Results obtained with PRISMA-32 prototype
- Conclusion

EAS is a nuclear cascade in the atmosphere



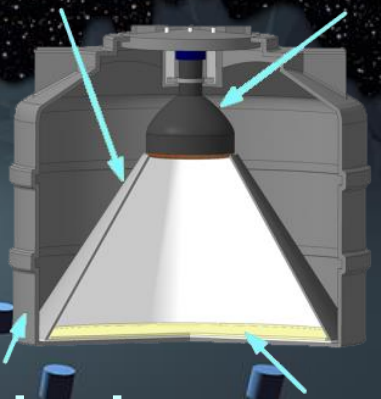
Hadrons are the “skeleton” of the Extensive Air Shower and the capability of hadrons measurement is important feature for EAS hybrid detection and analysis

Thermal neutrons in EAS



(PRImary Spectrum Measurement Array)

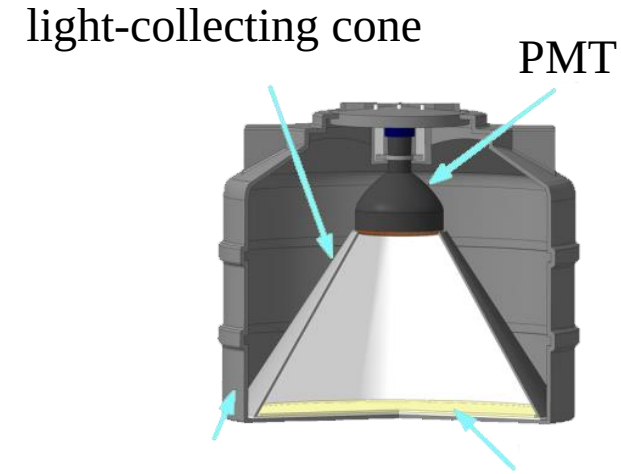
En-detector design



thermal neutrons emission

Electron-neutron detector

En-detector design



The first en-detector in Multic array, BNO INR RAS, Carpet array building, 2005.

En-detector of PRISMA-32 in Scientific&Educational Center NEVOD, MEPhI

En-detector is capable to:

- **measure electromagnetic component due to ZnS(Ag) scintillator**
- **measure number of delayed thermal neutrons produced by high energy hadrons of EAS core**

Scintillator

$^{6}Li + n = {}^{4}He + {}^{3}H + 4.8$ MeV

The crossection for thermal neutrons of ^{6}Li = 946 barn

White powder laminated on the white sheets of paper

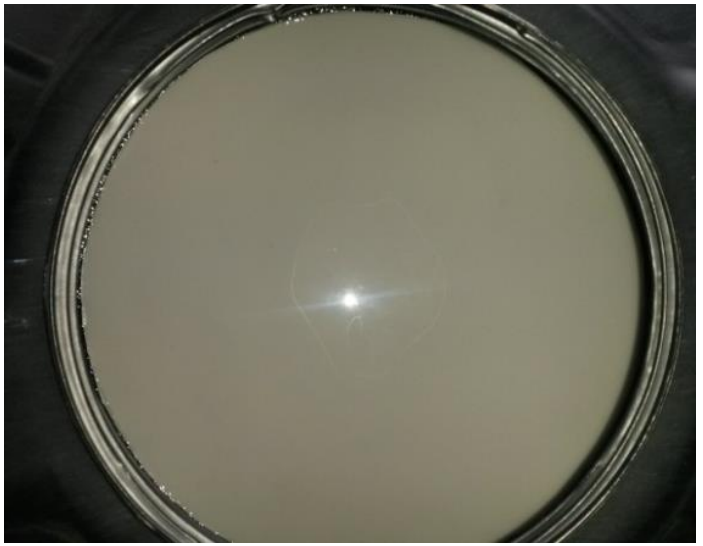
$ZnS(Ag)+{}^{6}LiF$

Li is enriched with ^{6}Li up to 90%

Density is 30 mg/cm^2 , neutron capture efficiency ~ 20%

$^{10}B + n = {}^{4}He + {}^{7}Li + 2.3$ МэВ

The crossection for thermal netrons of ^{10}B = 3880 barn



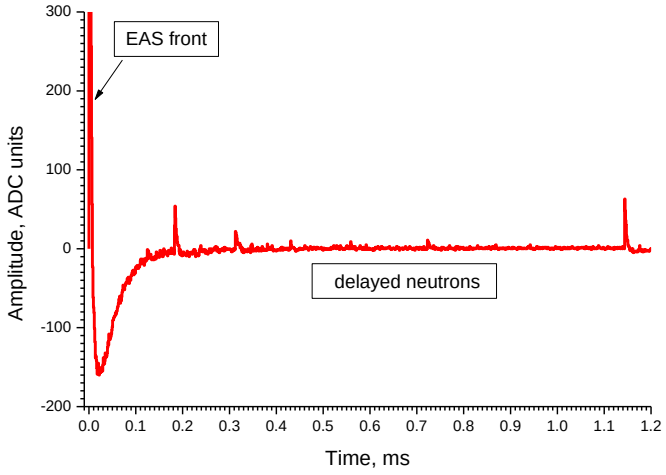
White powder in silicon compound

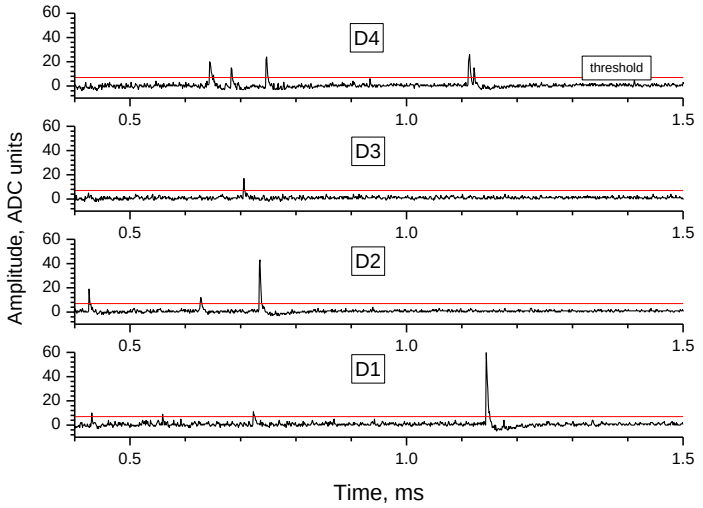
$ZnS(Ag)+ B_2O_3$

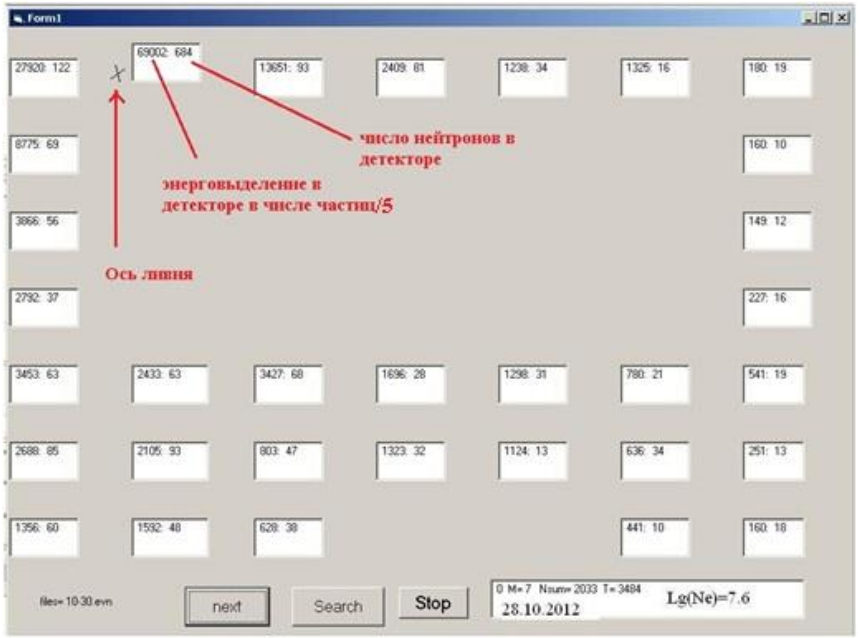
Natural B contains 20% of the ^{10}B isotope

Density is 50 mg/cm^2 , neutron capture efficiency ~ 20%

EAS thermal neutron measurements



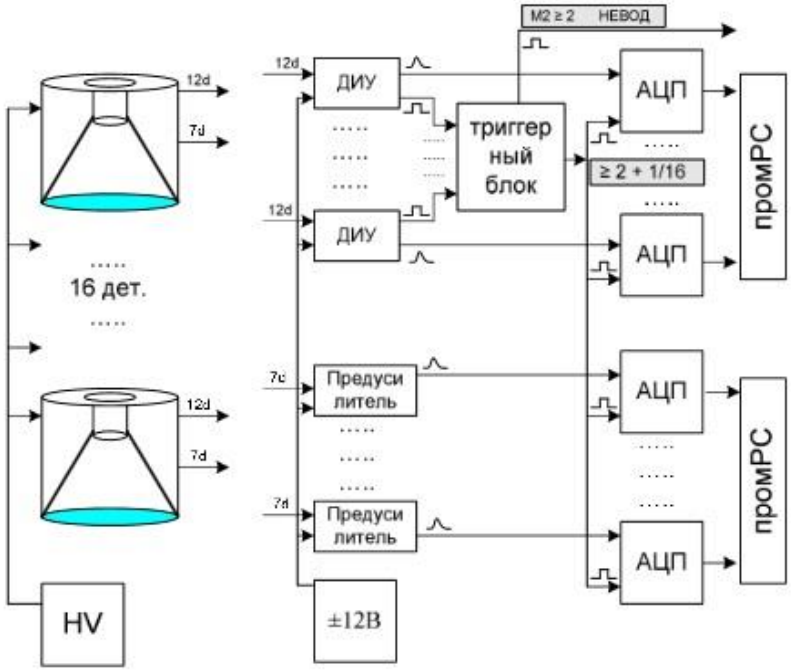


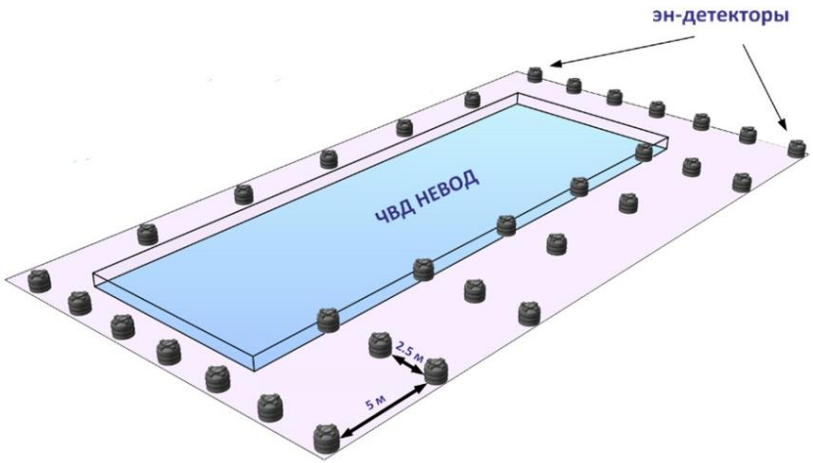


The pulse is digitized during 20 ms after coincidence of 2 or more detectors

The first pulse corresponds to electromagnetic component and delayed pulses correspond to thermalized evaporative neutrons produced by the shower hadronic core

PRISMA-32

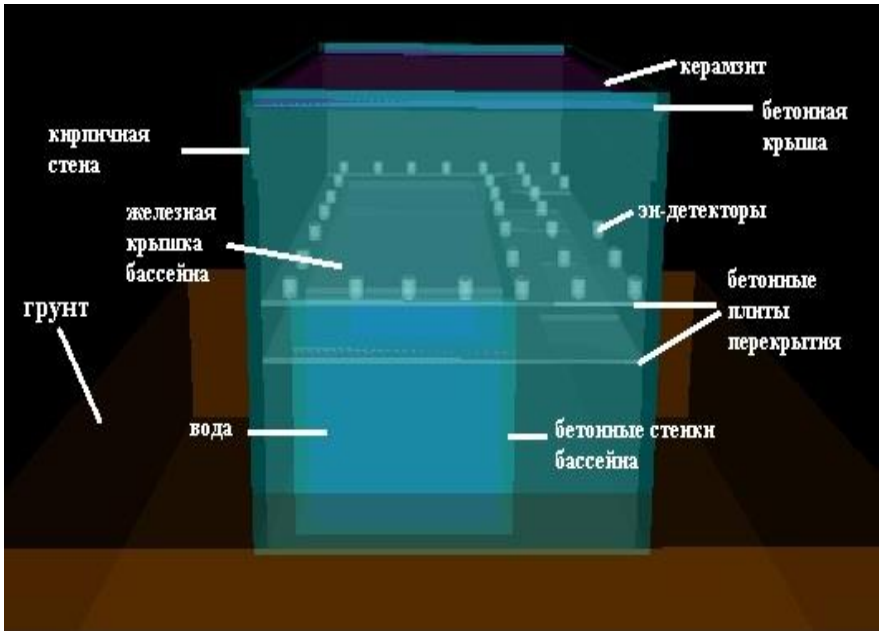




PRISMA-32 consists of two clusters of 16 detectors installed around the water pool of NEVOD.

The array works since 2012 up to now

Simulations

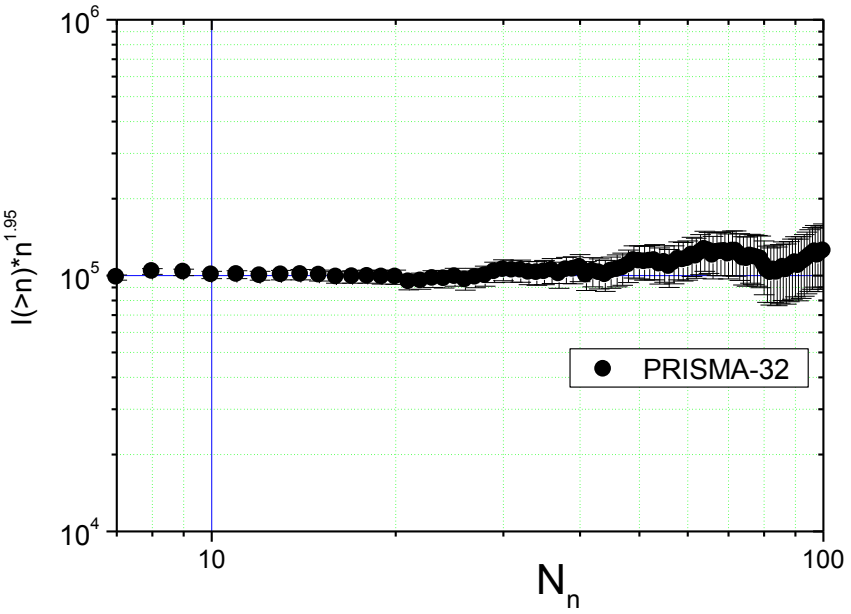


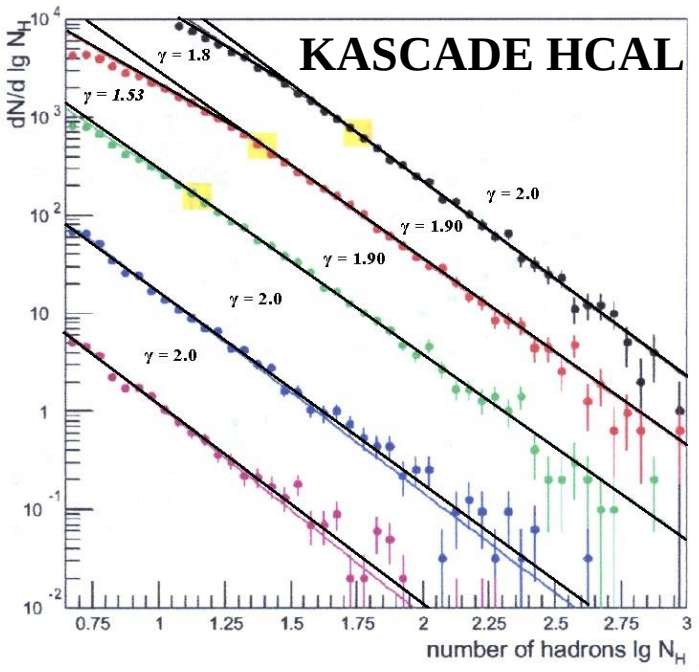
Simulations were performed with CORSIKA7.56 and GEANT4.10 packages.

QGSJETII-04 and FLUKA-2011 models were used in CORSIKA.

QGSP_BIC_HP model package was used in GEANT4.

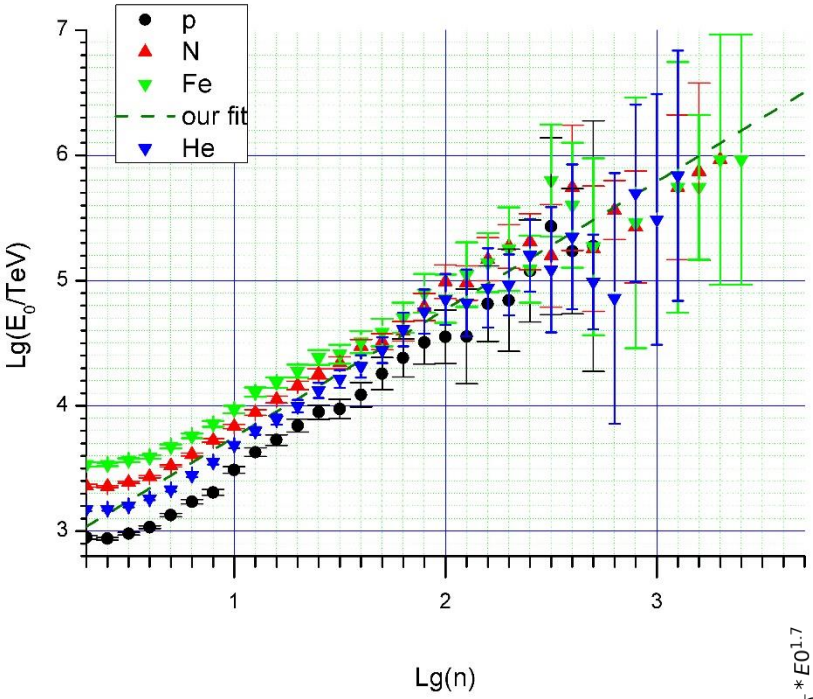
EAS neutron number spectrum





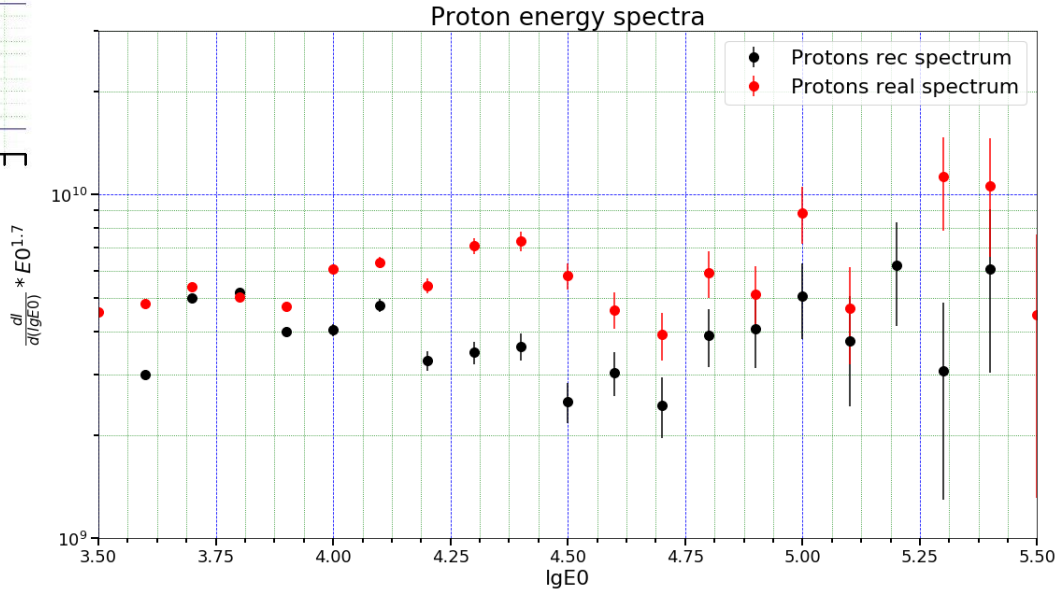
The spectral index of the neutron number spectrum measured with PRISMA-32 is 1.95+/-0.05. It is in agreement with hadron number spectrum measured by KASCADE

Energy spectrum reconstruction

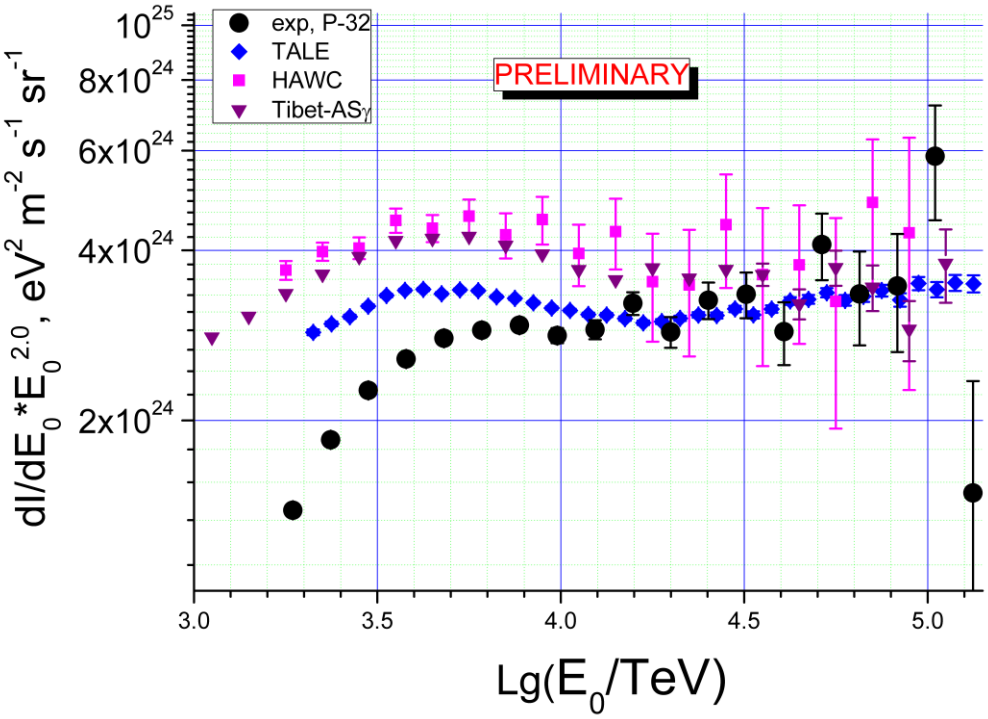


Average neutron number vs primary energy

Simulated proton spectrum reconstruction



Energy spectrum of primary cosmic rays measured with PRISMA-32 array



Primary energy was reconstructed from neutron number

Difference in spectra positions could be explained with systematic uncertainties of energy reconstruction (due to mass composition of CR or properties of the materials around array)

Conclusions

- PRISMA-32 is working continuously since 2012 for more than 7 years
- The thermal neutron number spectrum was measured and it is consistent with the hadron number spectrum measured by KASCADE
- The energy spectrum of primary cosmic rays was measured in range of 3-40 PeV. Unfortunately the reconstruction is strongly dependent on supposed primary mass composition.

Thank you for attention!