Primary spectrum and mass composition of cosmic rays in PeV region

O.B. Shchegolev for PRISMA collaboration

PRISMA-LHAASO consists of the collaborators from INR, IHEP, HNU, TU and SCU

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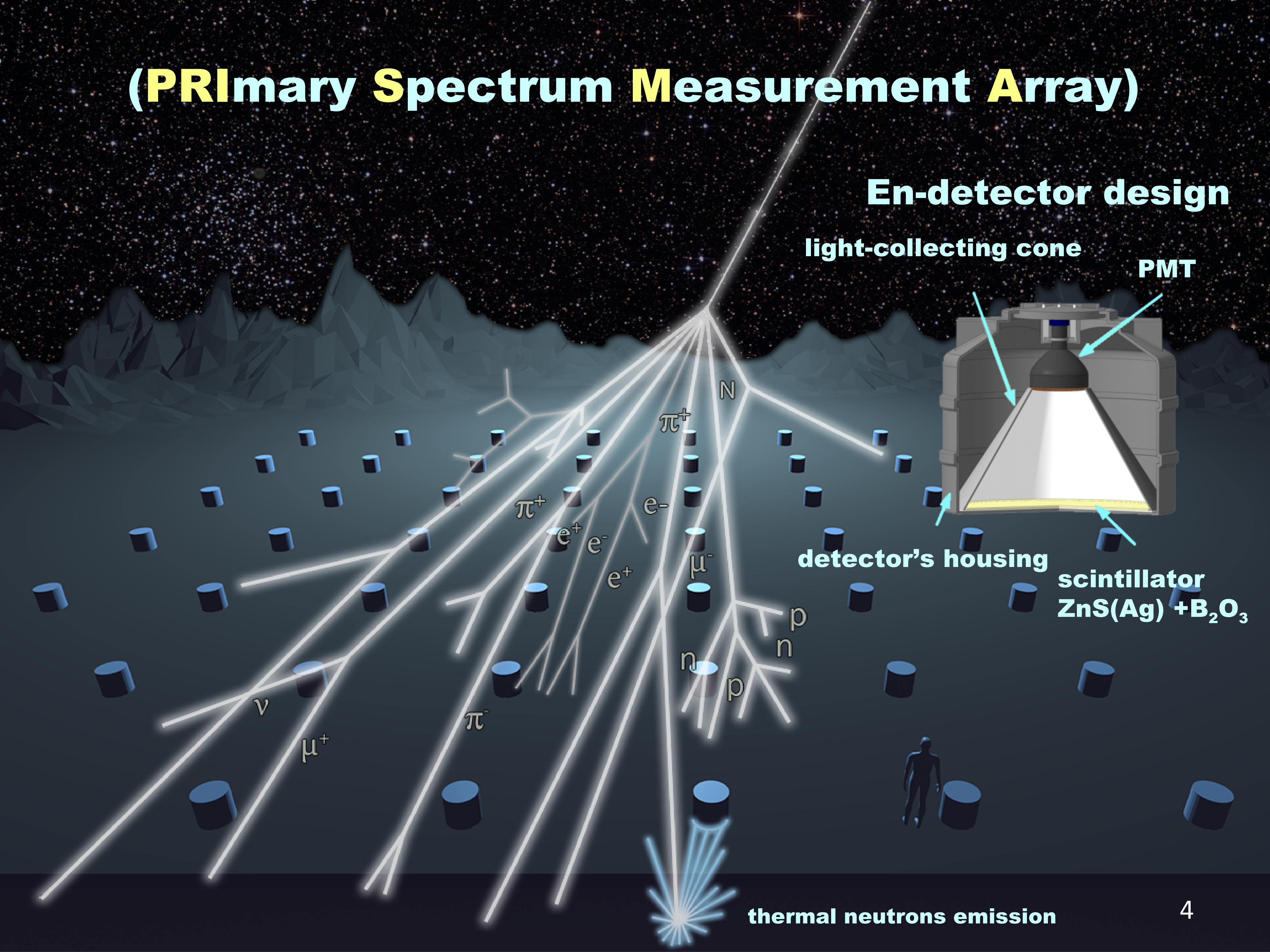
WASDHA2018

Outline

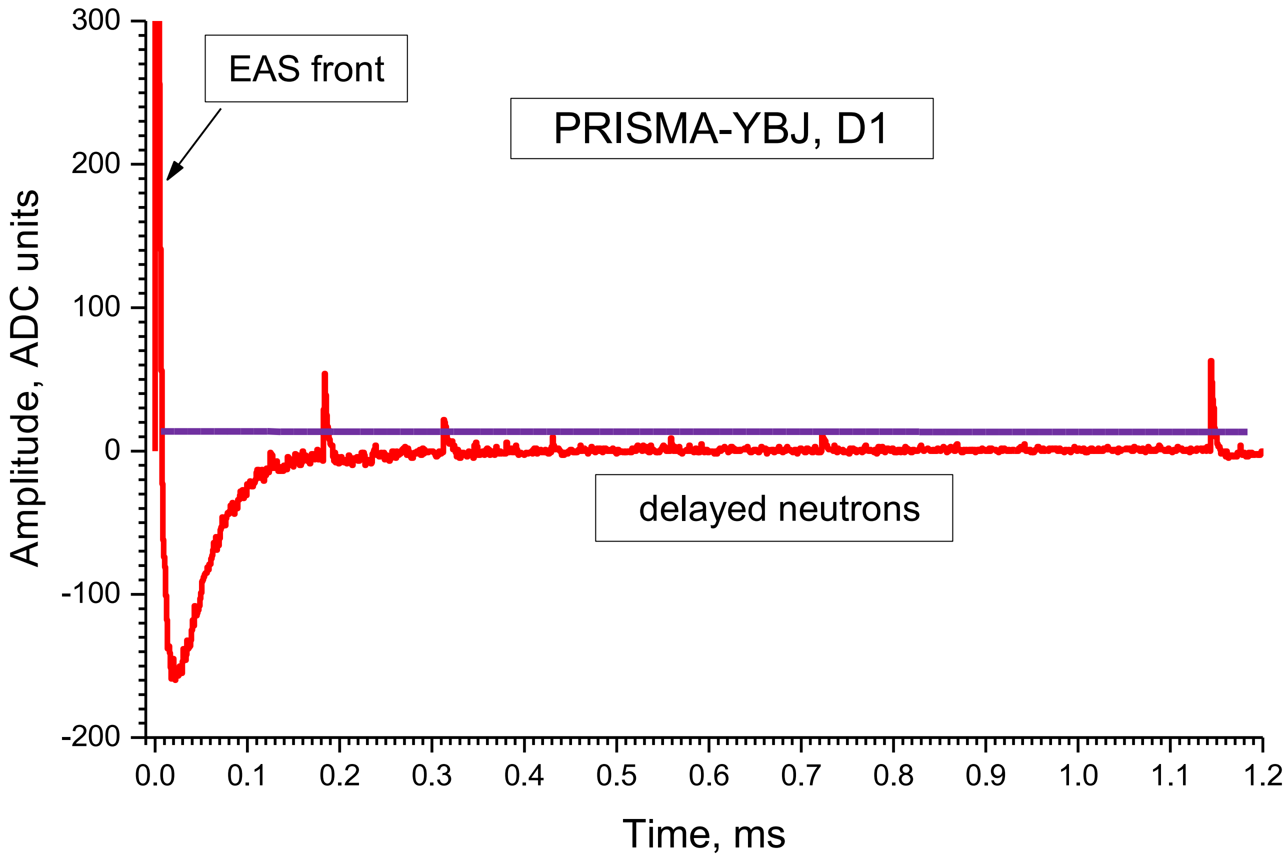
- PRISMA-LHAASO project and prototype
- Results obtained with prototypes and simulations
- Conclusions and future plans

PRISMA-LHAASO project and prototype

(PRImary Spectrum Measurement Array)



Response of en-detector to EAS

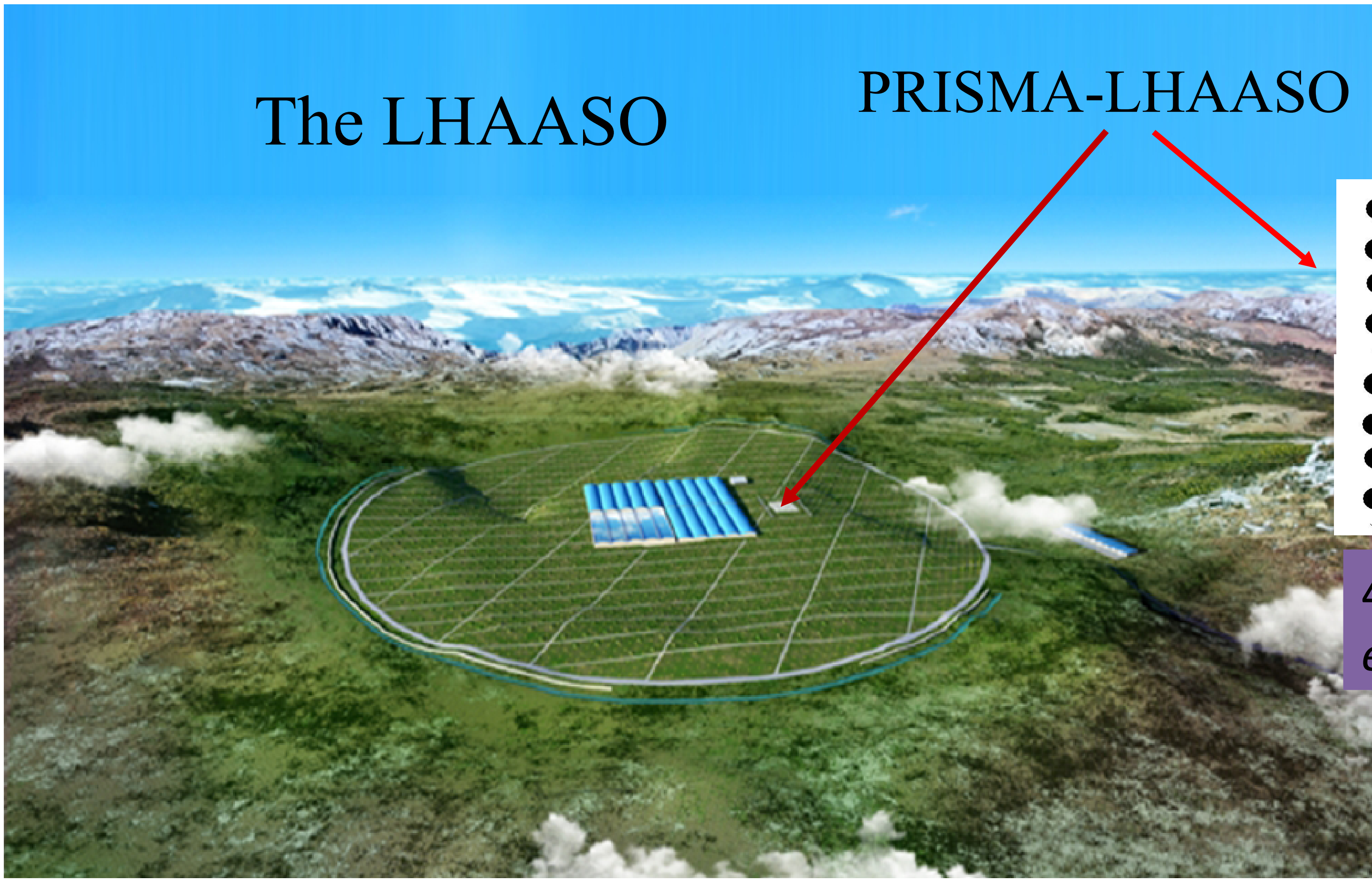


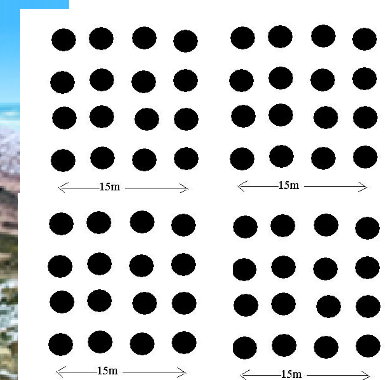
Electromagnetic component is recorded with ZnS(Ag) scintillator, during the first microsecond from coincidence.

After ~100 microsecond delayed neutrons are recorded.

Neutrons are produced by high energy EAS hadrons in the soil under detector, thermolized there and then captured by B^{10} or Li^{6}.

The last year LHAASO array construction was started at 4400 m (PRC, Sichuan prov., Mnt. Haizi)



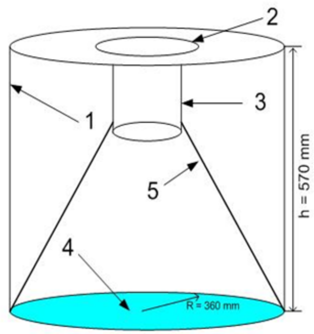


4 Clusters of 16 *en-detectors*

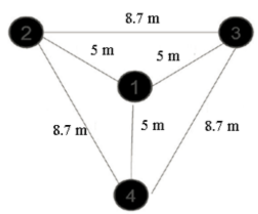
PRISMA-YBJ - the prototype at 4300 m a.s.l.

4 detectors since 01.2013 till 01.2017

En-detector design

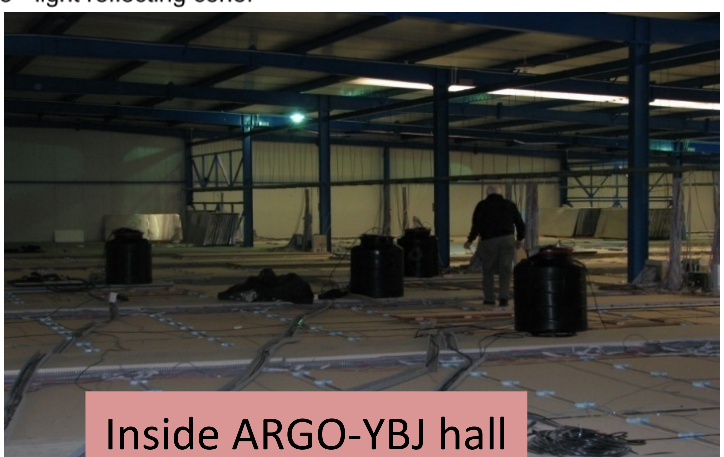


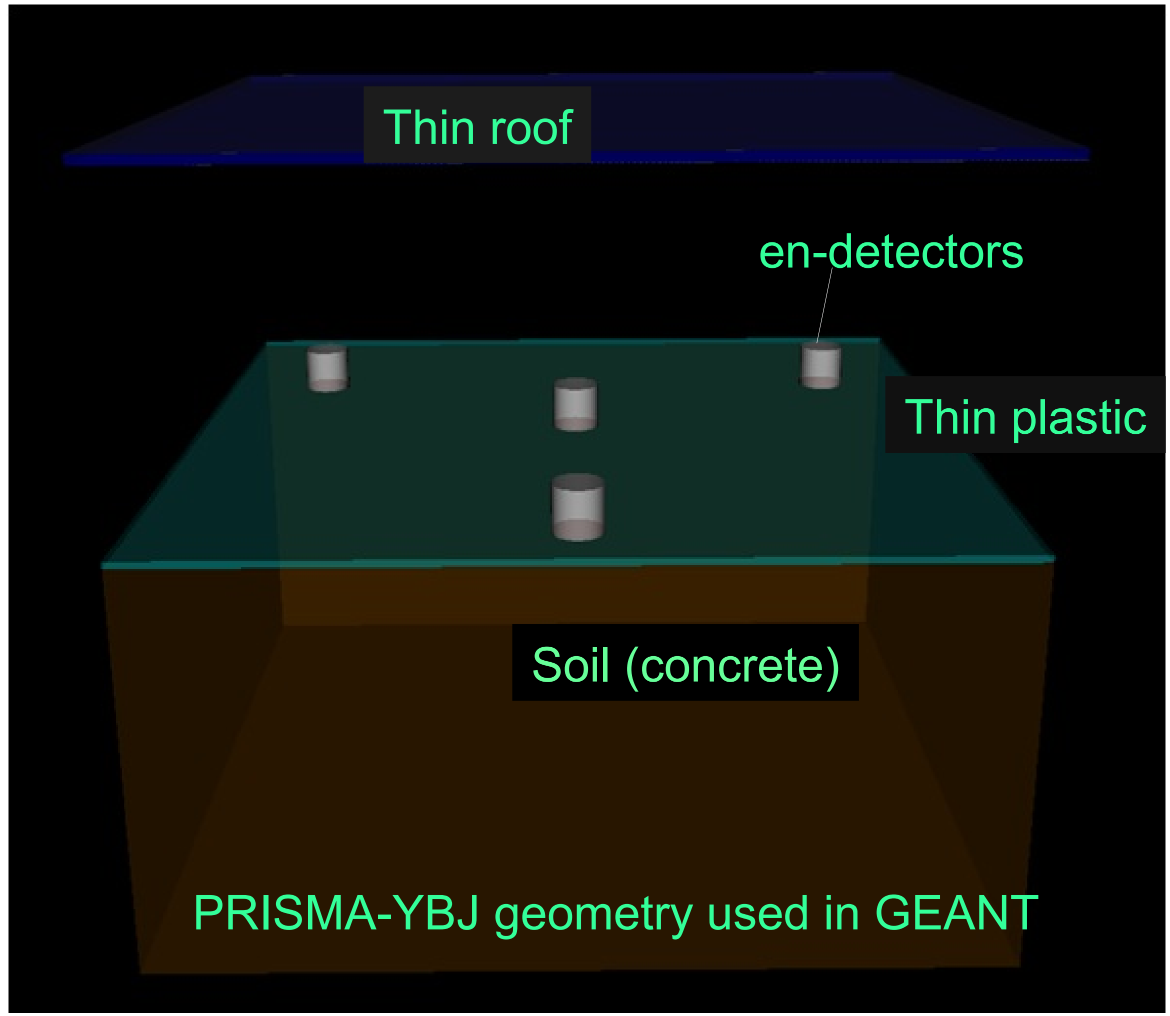
PRISMA-YBJ array



1 – PE water tank;
2 – PE lid;
3 – FEU-200 PMT ;
4 - ZnS(Ag)+^{6}LiF scintillator;
5 - light reflecting cone.

S=0.36 m^2
ε≈20%





Mass composition problem yesterday

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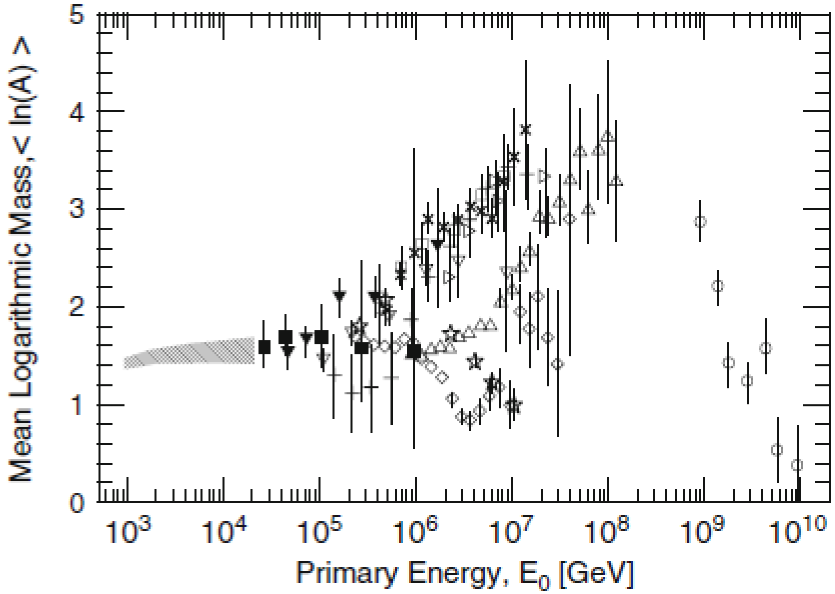
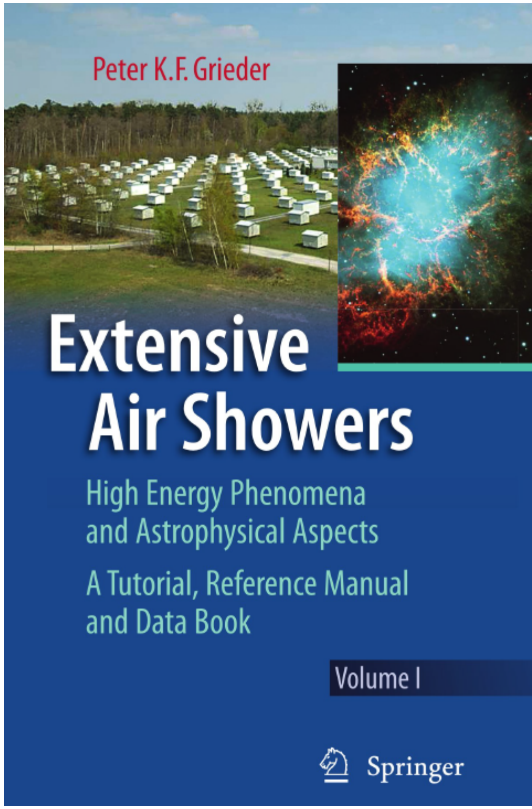
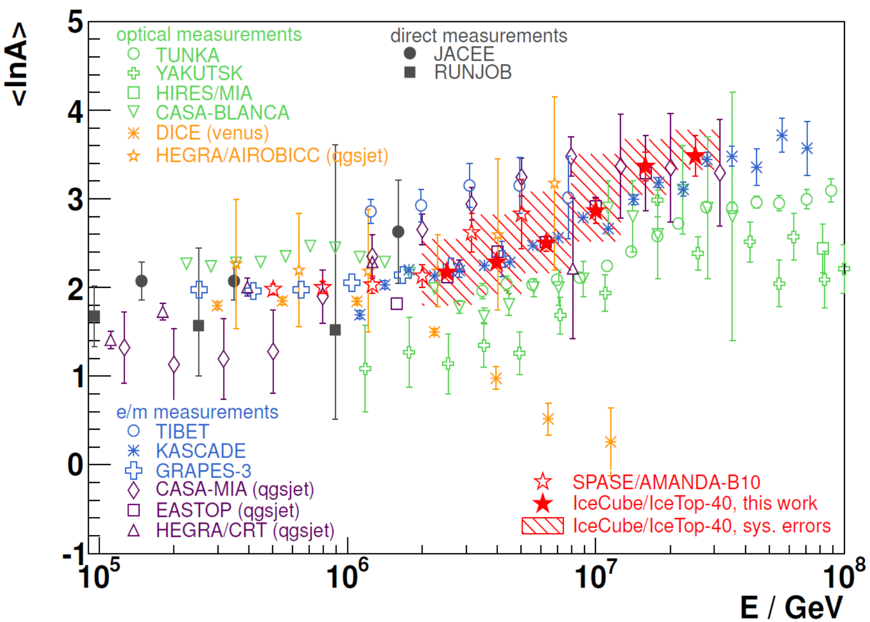


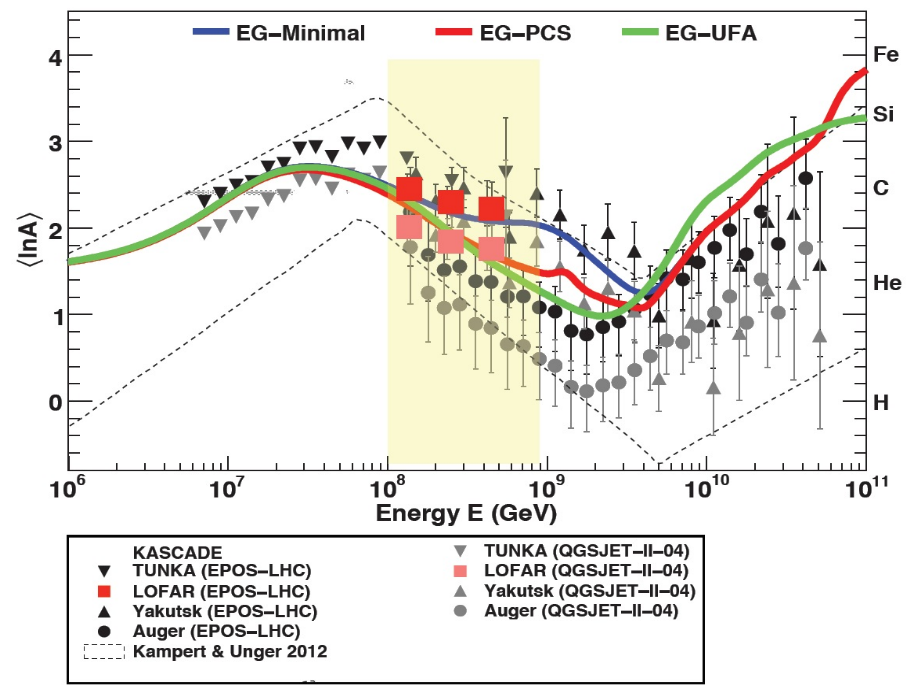
Fig. 11.48 Mean logarithmic mass, $\langle \ln(A) \rangle$, measured by the BASJE-MAS array as a function of primary energy, × (Ogio et al., 2004), compared with the results of other experiments. Balloon-borne detectors: ▼ JACEE (Asakimori et al., 1995, 1998); ■ RUNJOB (Apanasenko et al., 2001). Ground based detector systems: + CASA-MIA (Glasmacher et al., 1999b, d); □ KASCADE (hadrons) (Engler et al., 1999); ▽ HEGRA-CRT (Bernlöhr et al., 1998); △ KASCADE (electrons) (Ulrich et al., 2001); ◇ CASA-BLANCA (Fowler et al., 2001); ⋆ DICE (Swordy and Kieda, 2000); ○ Fly's Eye (Bird et al., 1993); ▷ Chacaltaya Cherenkov detector (Shirasaki et al., 2001). The hatched region represents the results of other direct observations compiled by Linsley (1983) (after Ogio et al., 2004)



Mass composition problem today



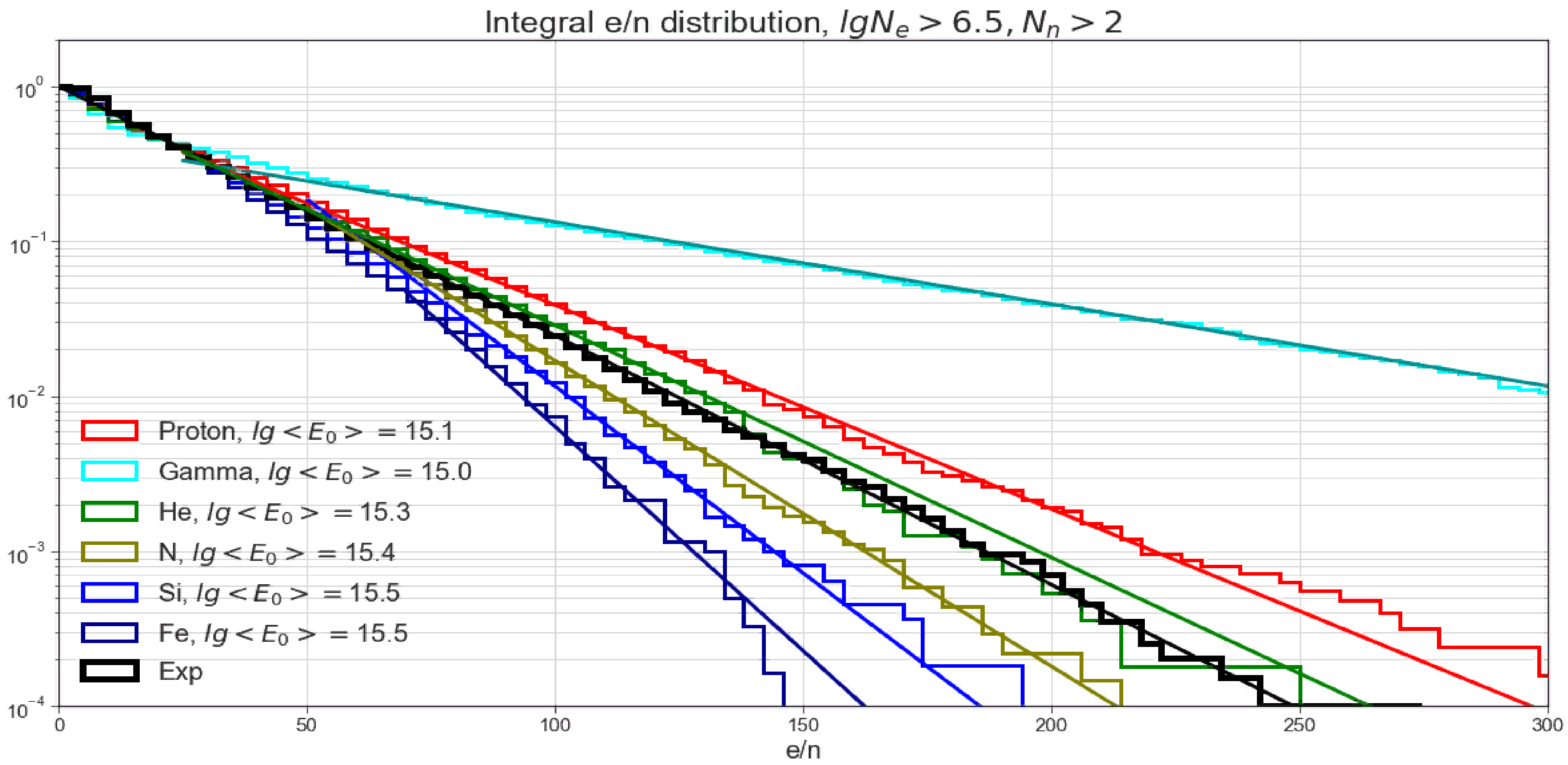
Published by IceCube collaboration, arXiv:1601.06670 [astro-ph.HE]



Published by Jörg R. Hörandel et al., arXiv:1705.04233 [astro-ph.HE]

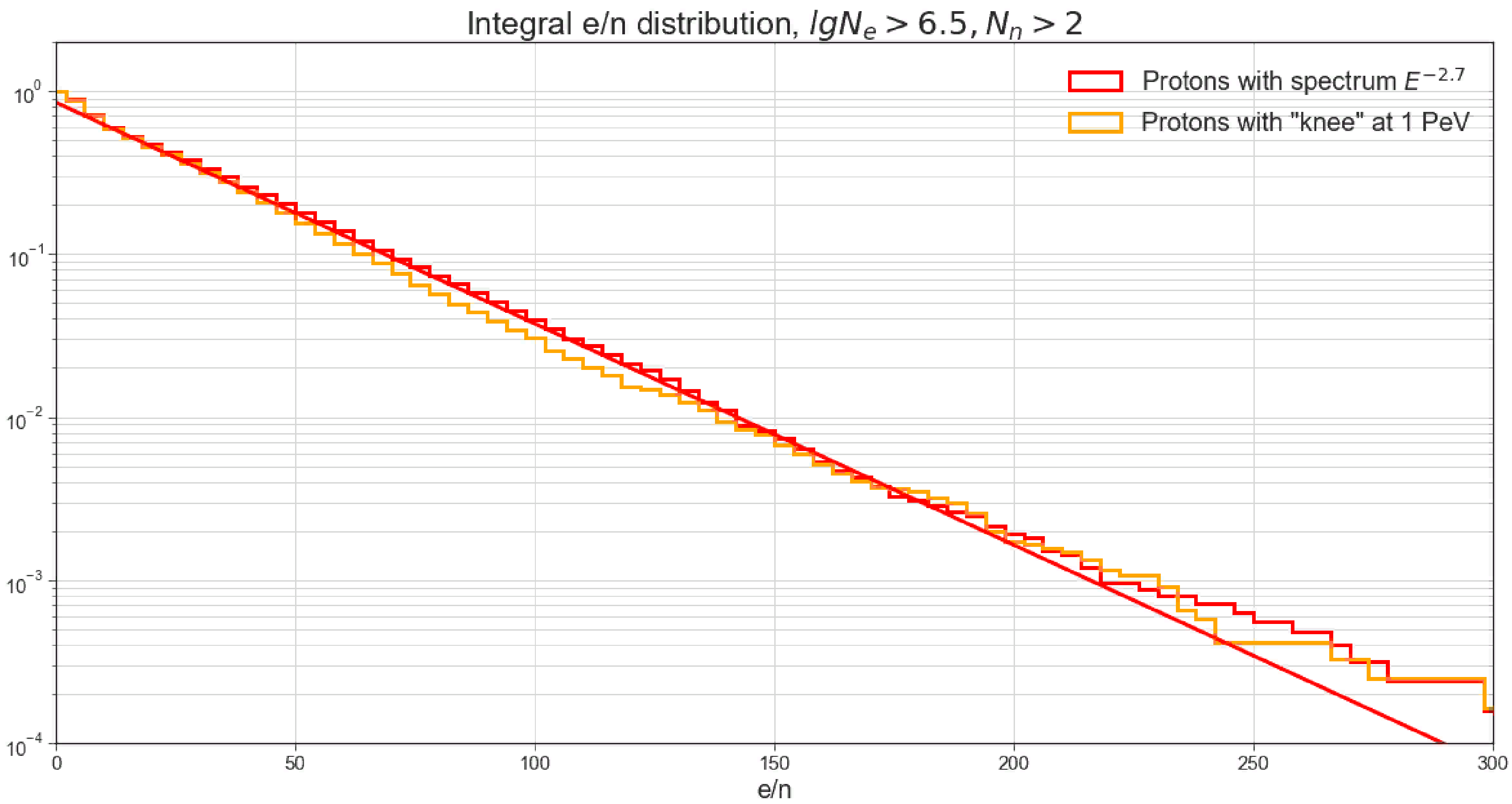
Results obtained with prototype and simulations

E/n ratio distribution method

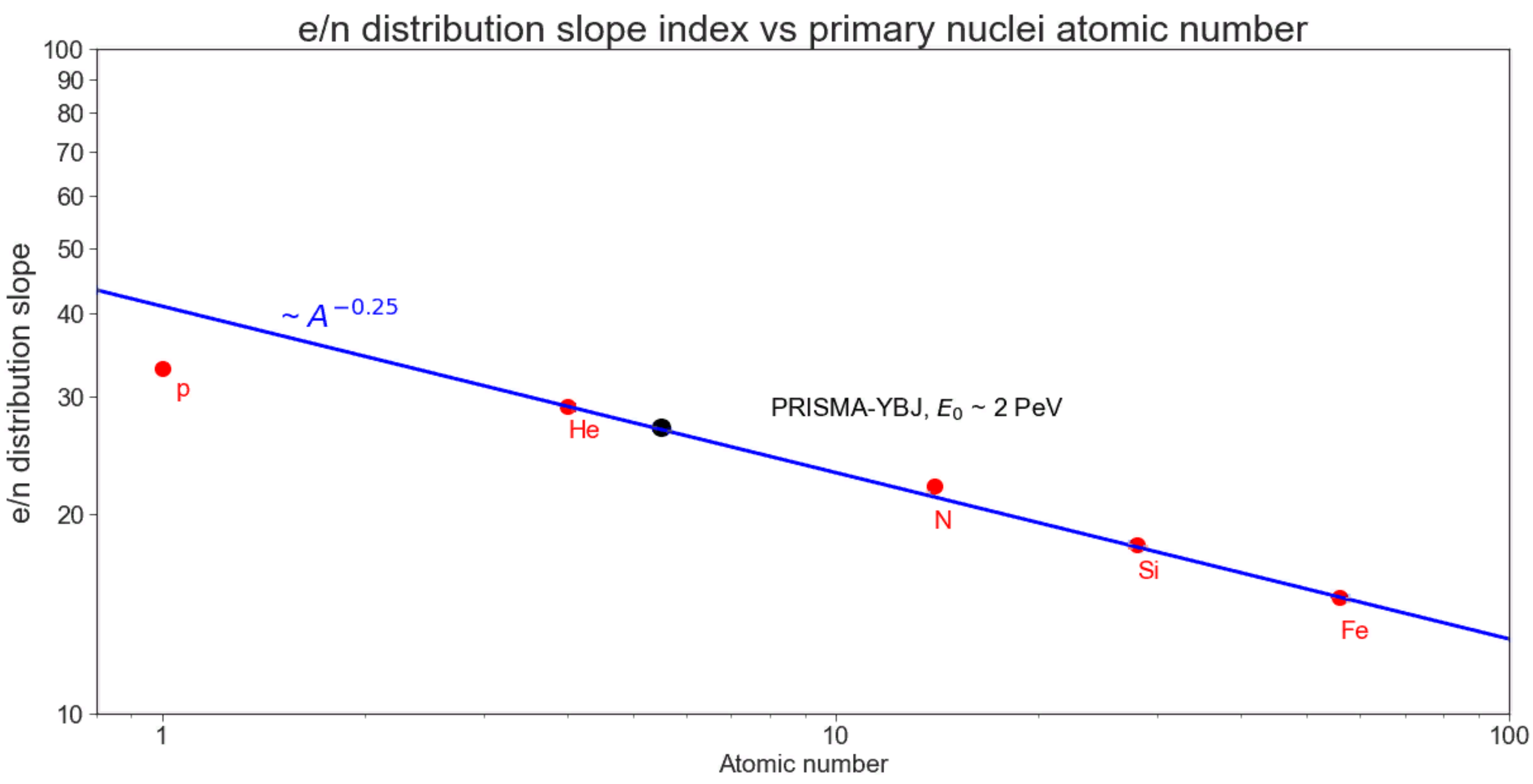


Electron/neutron ratio distributions have different slopes for different primary nuclei. The same feature has electron/muon ratio. We use integral distributions because of small statistics and can estimate mass composistion on the base of average primary energy

E/n ratio method is independent from primary energy spectrum



Electron/neutron ratio distribution slope vs primary nuclei atomic number



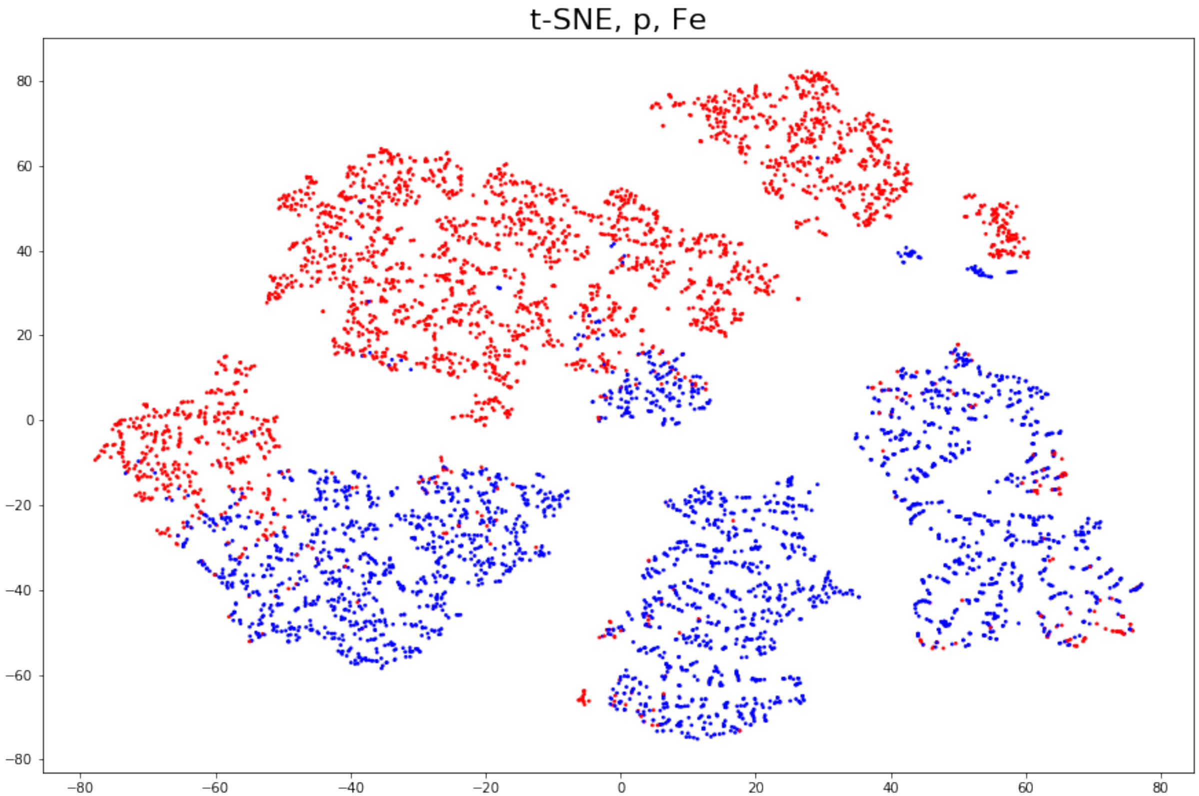
e/n ratio distribution slope dependence on atomic mass number could be explained with superposition principle

$$e \sim A\left(\frac{E_0}{A}\right)^{\alpha}, \alpha \approx 1.2$$

$$n \sim A\left(\frac{E_0}{A}\right)^{\beta}, \beta \approx 0.95$$

$$\frac{e}{n} \sim A^{0.95-1.2} = A^{-0.25}$$

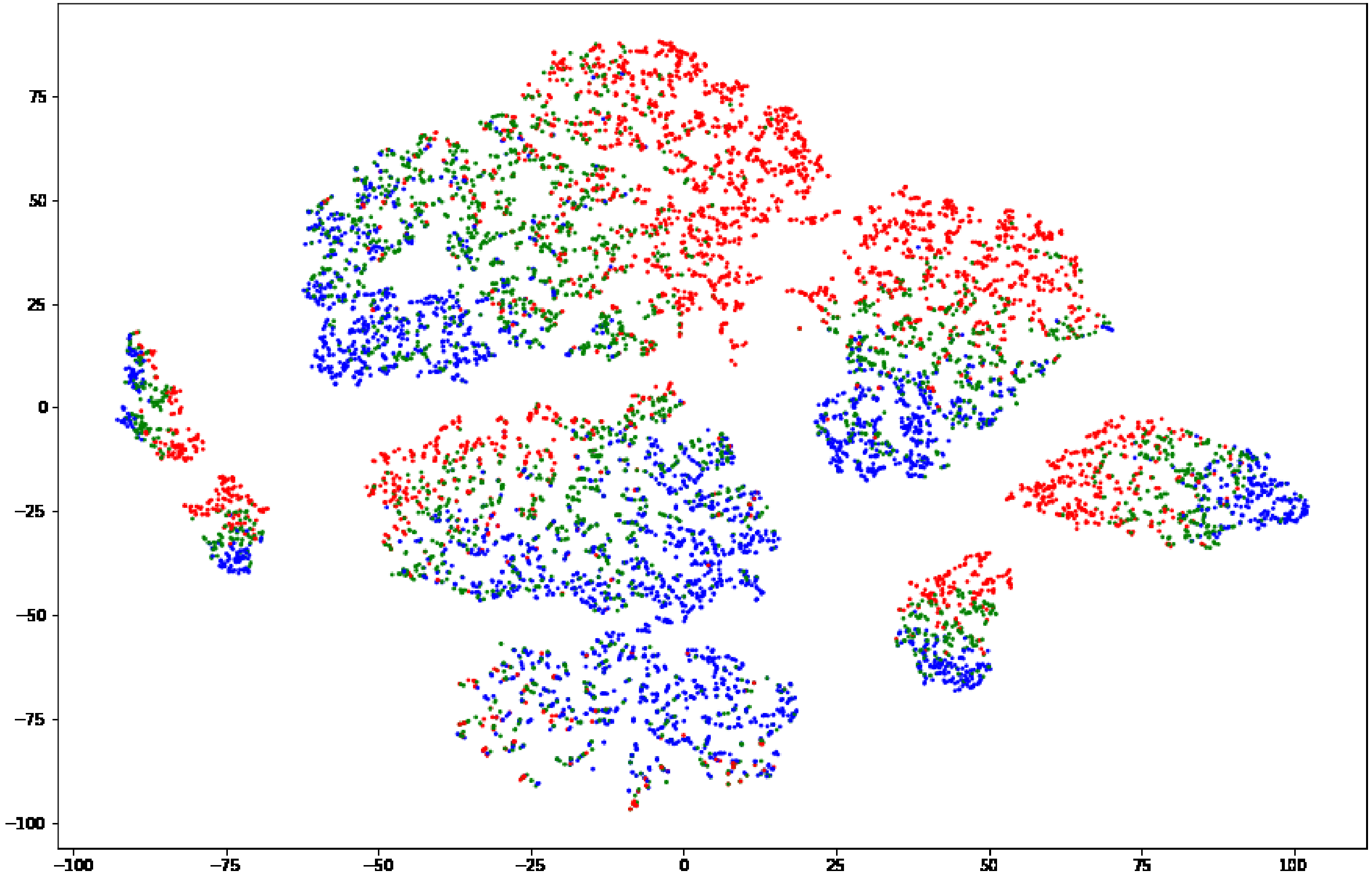
Mass composition research with PRISMA-LHAASO simulations (p/Fe)



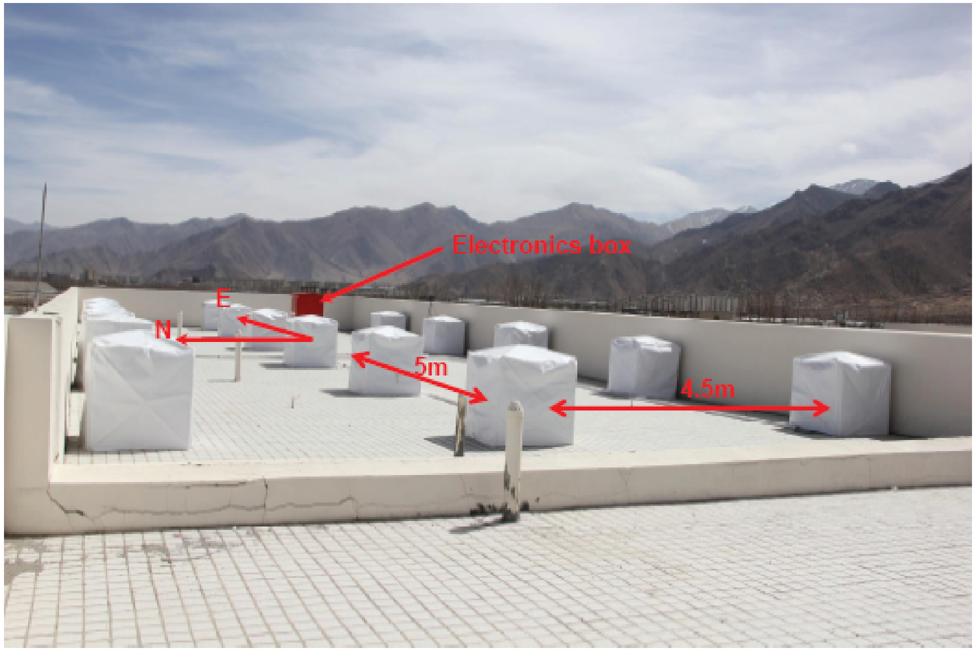
Simultaneous measurement of three components of EAS (electrons, muons, neutrons) promises mass composition estimation improvement.

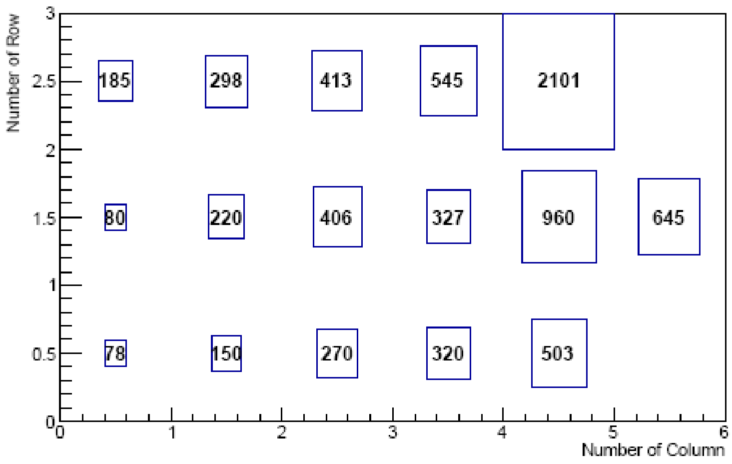
On the picture one can see t-SNE machine learning method applied to simulated data of PRISMA-LHAASO (electrons and neutrons) and one muon detector of LHAASO (we expect that at least one such detector will be put under the PRISMA-LHAASO array)

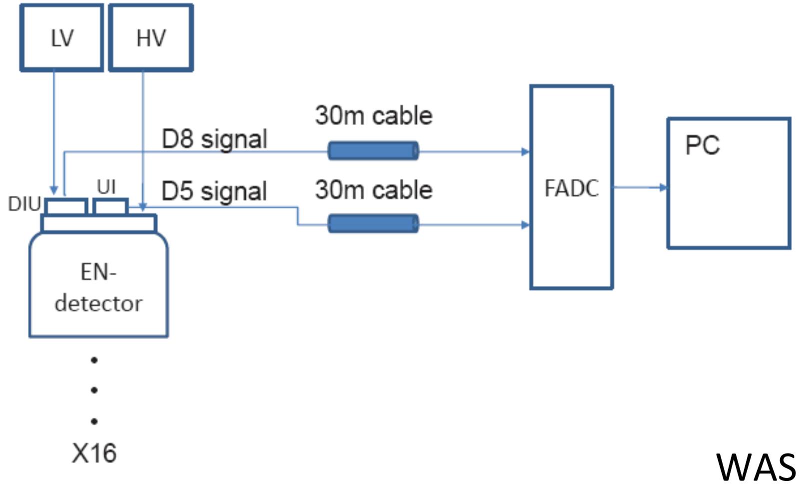
Mass composition research with PRISMA-LHAASO simulations (p, N, Fe)

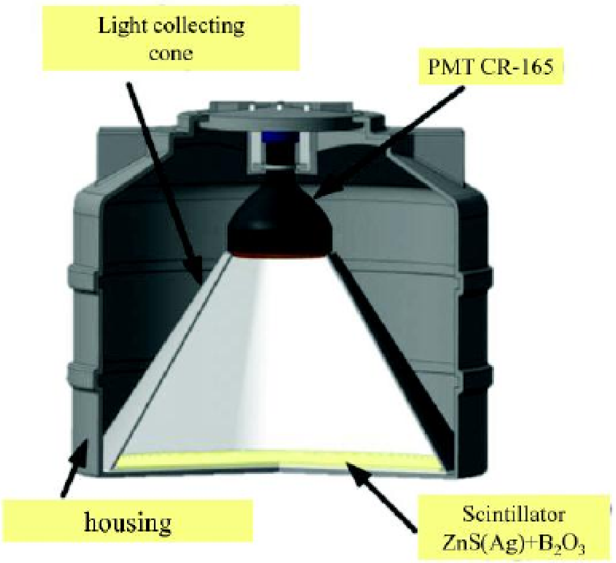


PRISMA-LHAASO first cluster (16 det.) test in Tibet University









Conclusions

- PRISMA-YBJ (prototype of 4 en-detectors) operated about 3.5 years in YBJ at 4300 m a.s.l.
- Our preliminary results show: mass composition of c.r. with average energy ~ $2*10^{15}$ is consistent with light composition (average mass number A is between Helium and Nitrogen)
- Electrons, muons and neutrons together can improve mass compositions measurements in region of $10^{15} – 10^{17}$ eV
- e/n ratio method promises high efficiency for gamma-ray showers selection
- PRISMA-LHAASO of 64 en-detectors is planned to install in LHAASO site in the end of this year

Thank you for attention!

Data acquisition and statistics for P-YBJ

Since 30.08.2013 until 02.03.2017

Event selection cuts:

R< 6 m

4-fold coincidence events for hit detectors deposit ε>10 mips

Number of triggers – 2.78*10^6

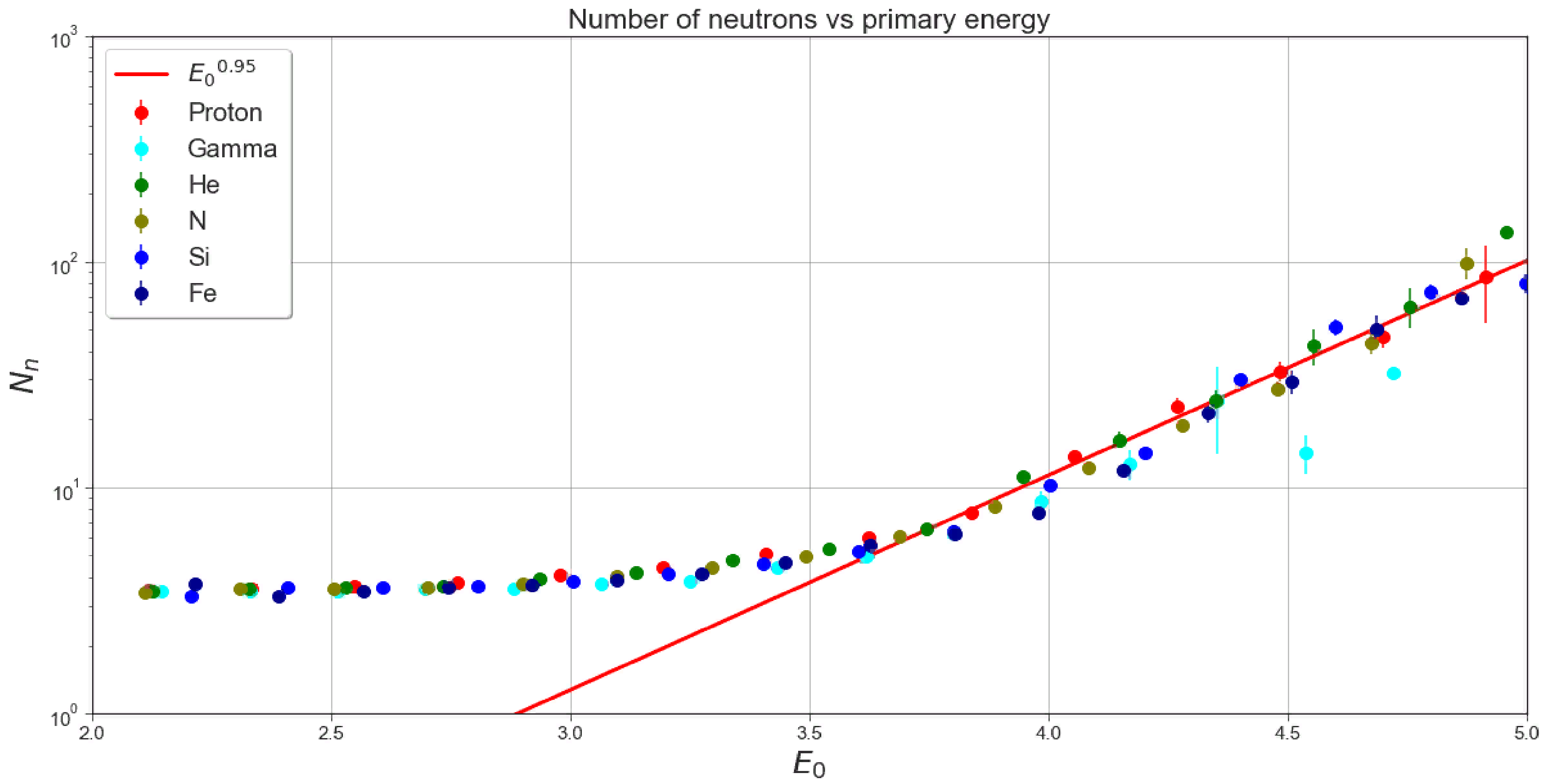
Number of selected events – 3.76*10^5

Time gate for neutrons - T=0.1 – 20 ms

Neutron recording efficiency ≈13%

All pulses are digitized with FADC and pulse shape discrimination applied

Number of neutrons vs primary energy



Total energy deposit vs primary energy