HERO

"High Energy Rays Observatory"

New Astroparticle Missom

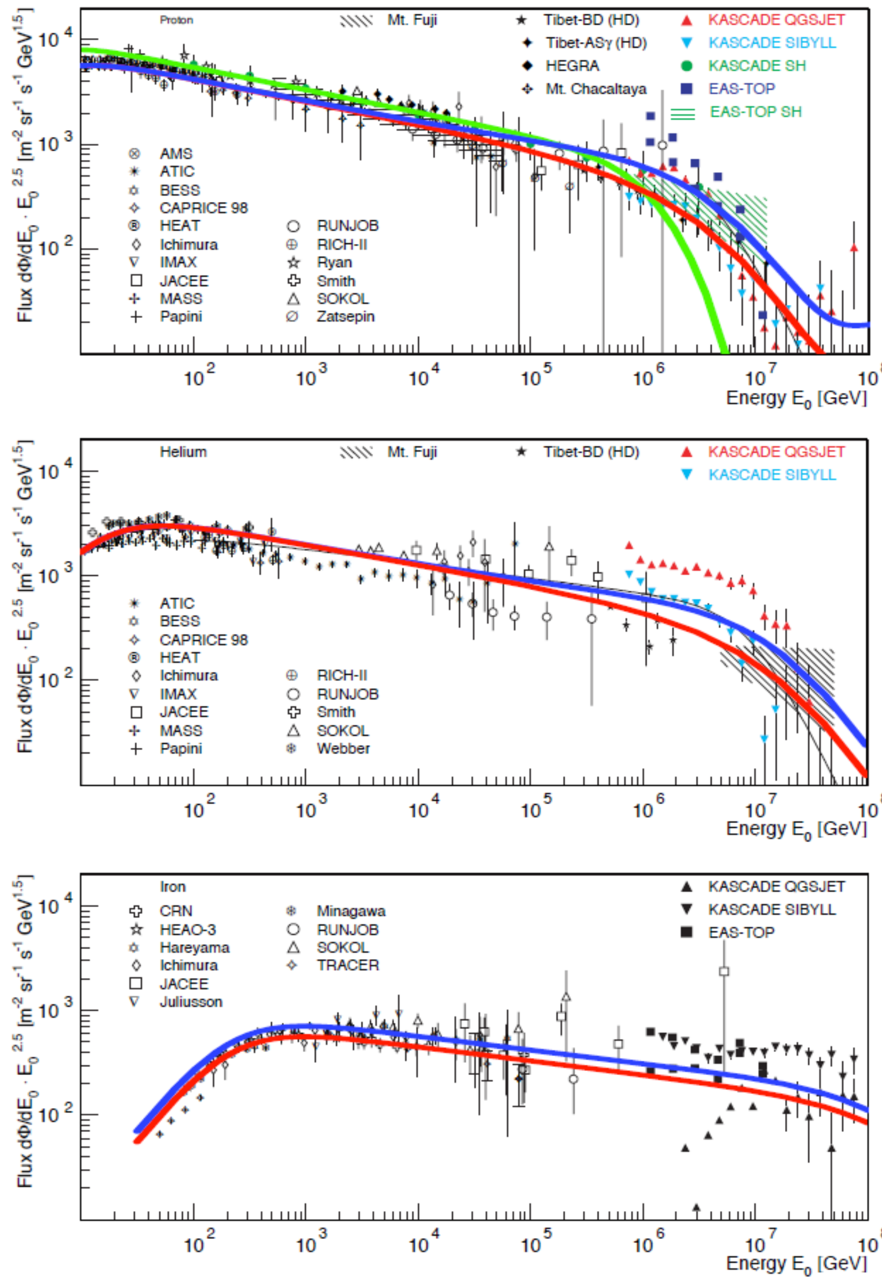
Dmitry Podorozhny for the HERO collaboration

NextGAPES-2019 22.06.2019

some history

Primary CR Experiments above 10^{12} eV/par. 1964- 2015

- Proton (4 satellites) – 60' SINP/Russia
- CRN (Space station) – 80', US
- Mubee (balloon) - 80' SINP/ Russia
- SOKOL (2 satellites) -80' SINP/ Russia
- TIC (balloon) - 1994, SINP/ Russia
- JACEE (balloons) - 90', US, Japan.....
- RUNJOB (balloons) - 80' -90', SINP/Russia, Japan
- AMS 1 (Space Shuttle) -1998 Intern. Collaboration
- ATIC (balloon) - 2001, 2004, 2008 US, SINP/Russia,...
- TRACER (balloon) – 2003, 2006 US
- BESS (balloon) - 2004 US, Germany, Japan,...
- CREAM (balloon) - 2005, 2008 US, Korea Russia…
- PAMELA (satelite) - 2006 Italy, Russia,Sweden, Germany

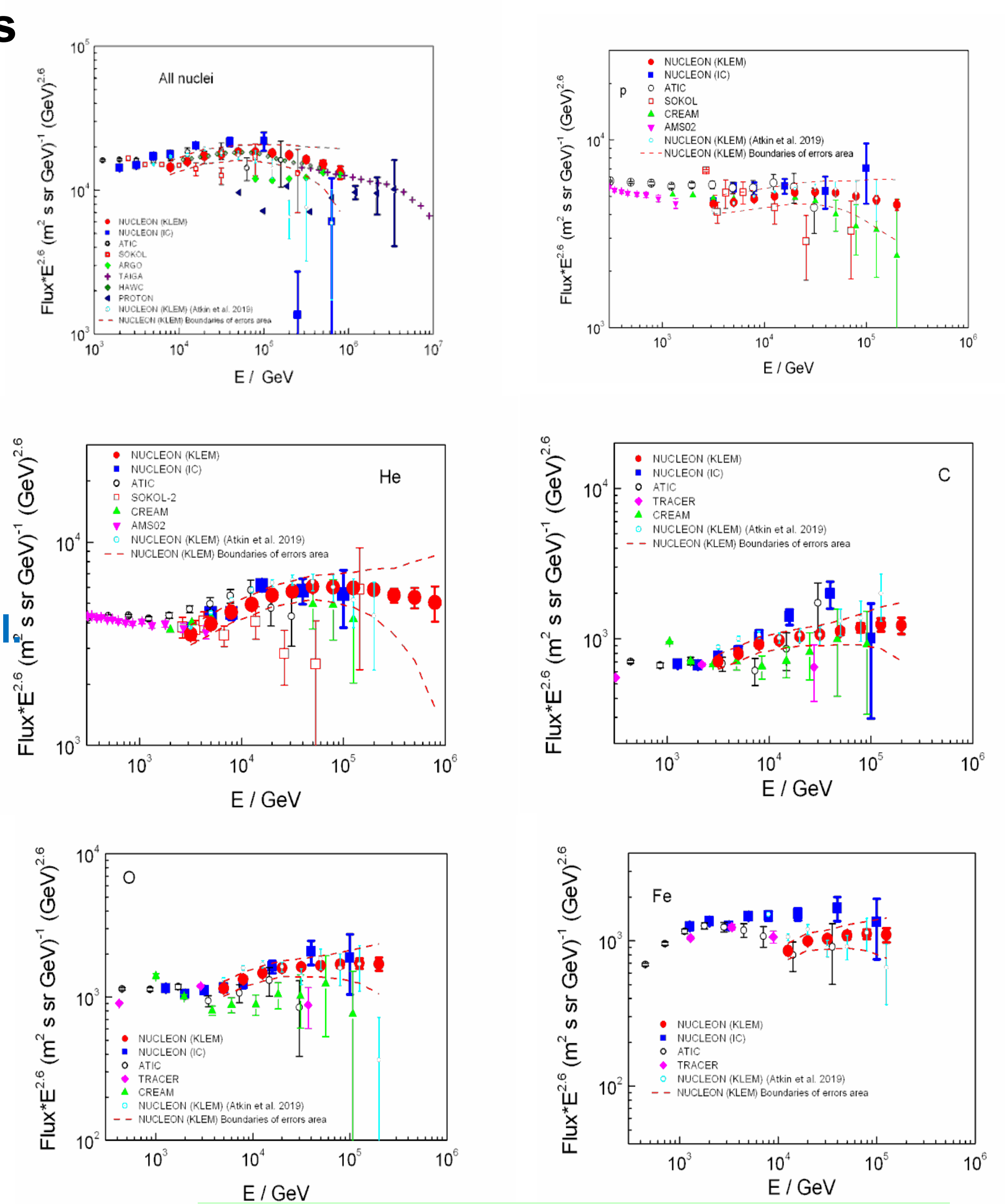


A. De Rújula NuclearPhysics B (Proc.Suppl.) 165 (2007) 93-102

Primary CR Experiments above *10^{12} eV/par.* *after 2015*

- •AMS 2 (ISS) -2011 Int. Col.
- •NUCLEON (satelite) - 2014 Russia
- •CALET (ISS) -2015 Japan, Italy…
- •DAMPE (satelite) - 2015 China
- •ISS-CREAM (ISS) - 2017 US, Int. Col.

To 2020 it'll be information about abundant CR up to 10^{15} eV.



Grebenyuk et al Advances in Space Research 2019

The main astroparticle objectives:

- The chemical composition of cosmic rays with an elemental resolution of the charges in the region of the "Christiansen-Kulikov CR knee" (energy 1-100PeV);

- A precise determination of the composition of CR in the energy range from several TeV to 1PeV (high statistics and energy resolution);

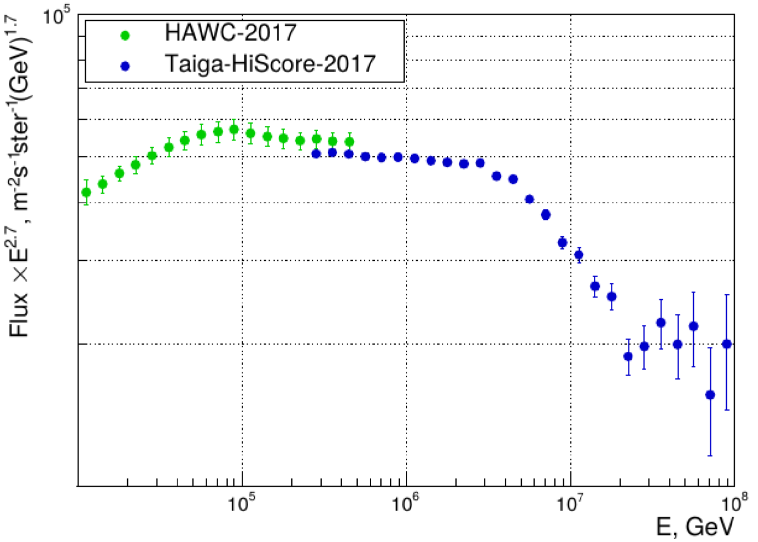
- Investigation of the electron spectrum from hundreds of GeV to ???

- The gamma-ray and electron spectra in a wide energy range with an ultrahigh energy resolution (monoenergetic lines → dark matter);

-Composition of heavy nuclei behind the peak of iron (superheavy exotic nuclei - ???)

- The study of the anisotropy of cosmic rays

What is necessary to do for next step?



CR Particle Flows (m^2 sr year)

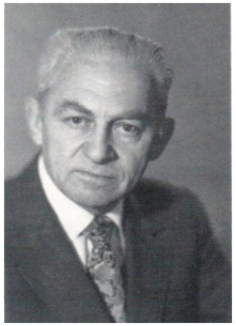
(>E)	10^{14}	10^{15}	10^{16}	10^{17}
	3200	56	0.7	0.0054

For 10^{15} - 10^{16} eV range exploring it's necessary at least 50 par. >10^{16} eV

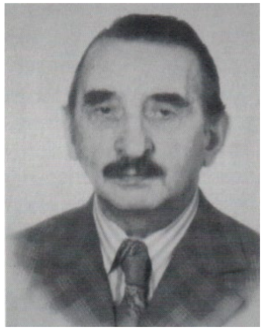
It is necessary to increase at least 100 times the exposure factor

Effective exposure factor must be ~120 m^2 cr year

1957



N.L.Grigorov



I.D.Rapoport

V.S.Murzin

For the CR study in a wide range of energies and charges, there is no alternation to the ionization calorimeter

The basic orbital device limitation – weight

Modern Russian carrier rocket launch a vehicle of ~17 tons (Orbit ~500 km)

That means 12.5 tons for scientific equipment

For IC not more then 10 tons

Promising super heavy rocket – 30 or just 70 tons for scientific equipment !!!

HERO
"High Energy Rays Observatory"
Heavy Calorimeter in Space

supported by the Russian Academy of Sciences and included in the Russian Federal Space Program

Main Requirements:

- Effective exposure factor >120 m^2 sr year
- Energy resolution
  - for Protons at 10^{15}-10^{16} eV < 30%
  - at 10^{12}-10^{15} eV < 20%
  - for Nuclei at 10^{12}-10^{16} eV < 15-20%
  - for Leptons at 3*10^{11}-10^{13} eV < 1%
- Charge resolution < 0.2 ch. u. for all Nuclei at all energy range

The main requirement for the HERO device technology is reliability.

Only proven techniques. The bulk is the NUCLEON experiment technique

Technology:

energy spectrometer - Ionization Calorimeter

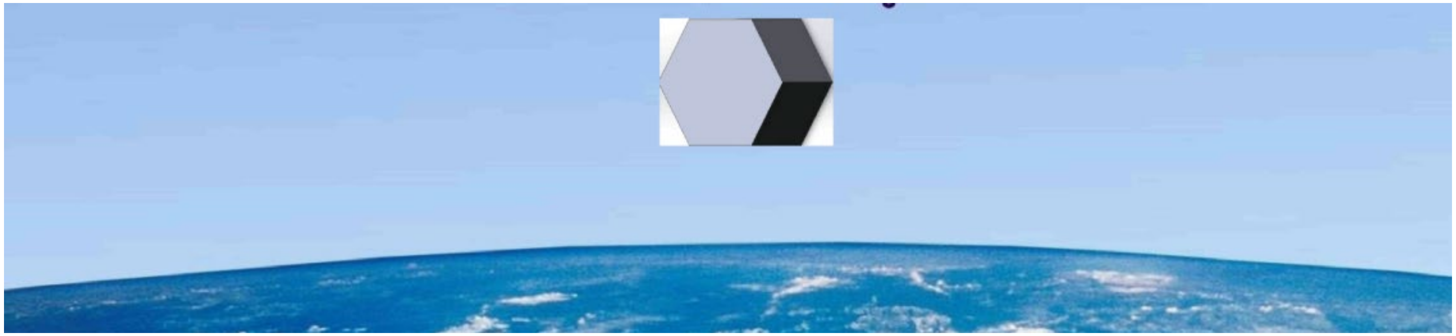
charge detector - Multilayer Silicone Matrix

IC substance.
optimal - a combination of a very heavy (tungsten) and very light (polystyrene) to optimize development electromagnetic and hadronic cascades

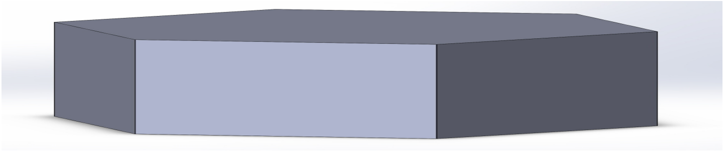
IC optimization

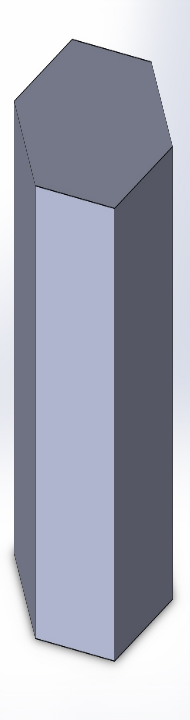
shape

After wild simulations the most optimal shape – 3D IC of a prism form placed lateral surface to the Earth

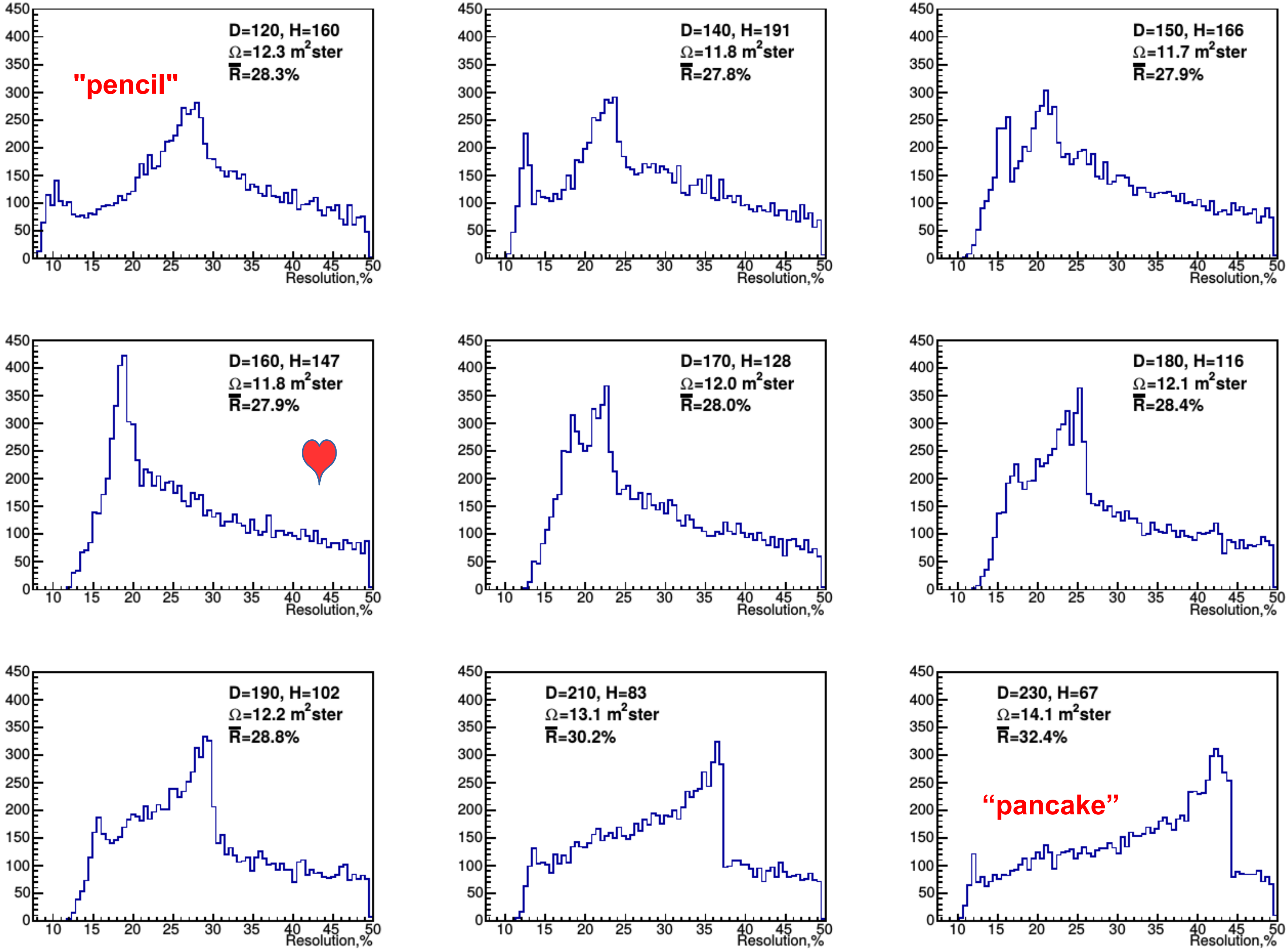


two limiting forms of the prism: “pancake“, "pencil"

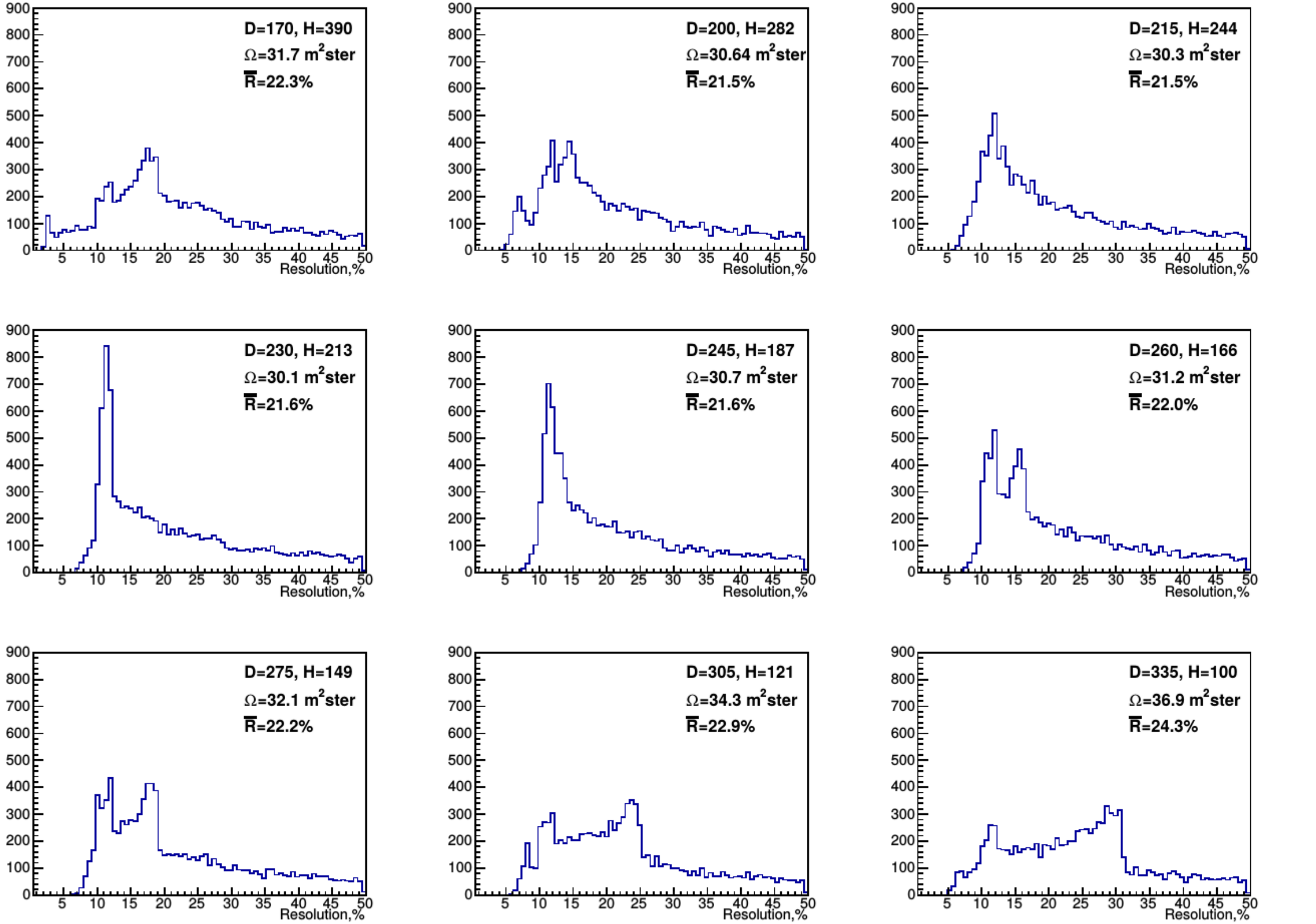




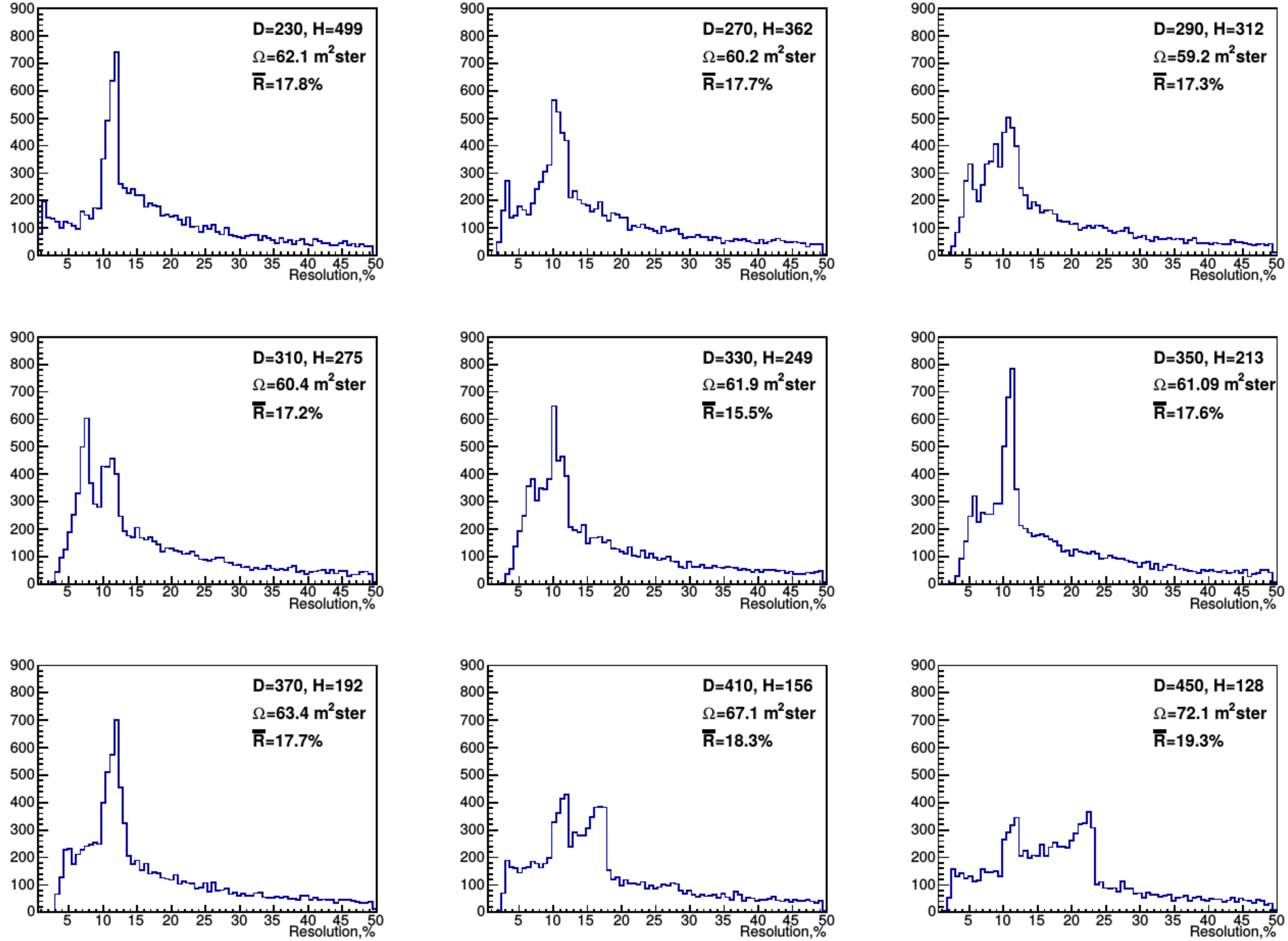
Monte Carlo Energy Resolution Simulations of 3D IC weighing 10 tons. Protons Orbit 500 km. Mean resolution <30%



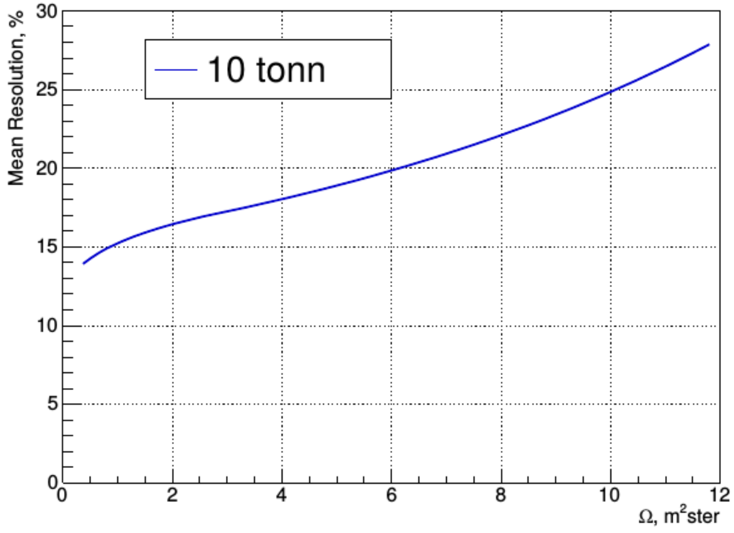
Monte Carlo Energy Resolution Simulations of 3D IC weighing 30 tons. Protons Orbit 500 km. Mean resolution <30%

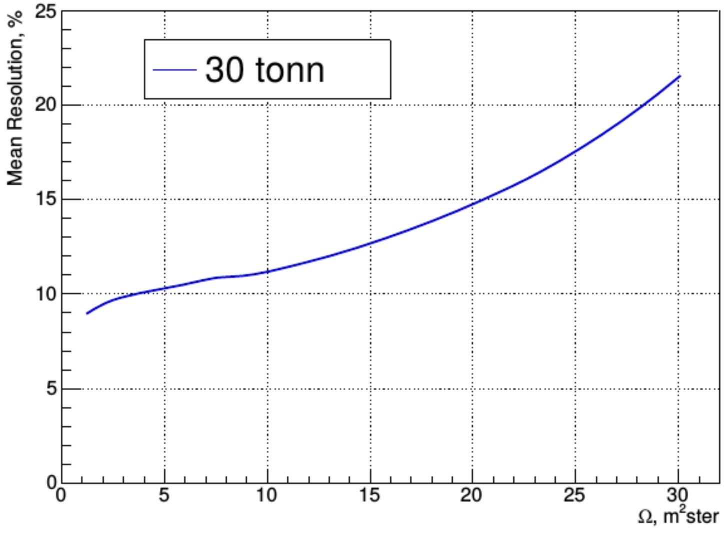


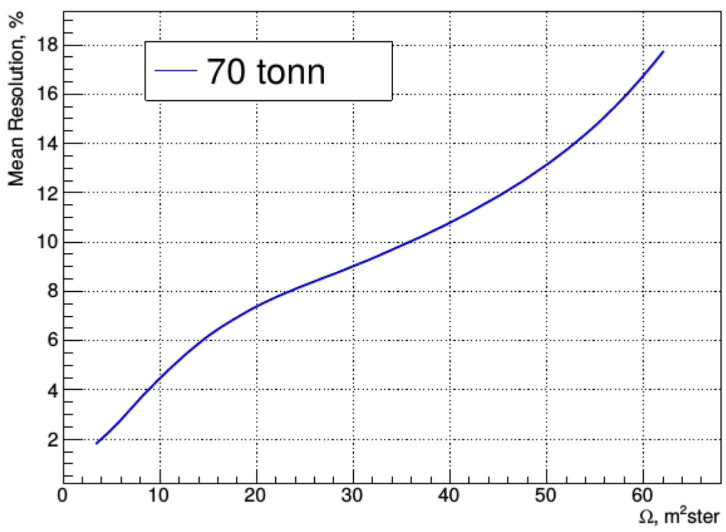
Monte Carlo Energy Resolution Simulations of 3D IC weighing 70 tons. Protons Orbit 500 km. Mean resolution <30%



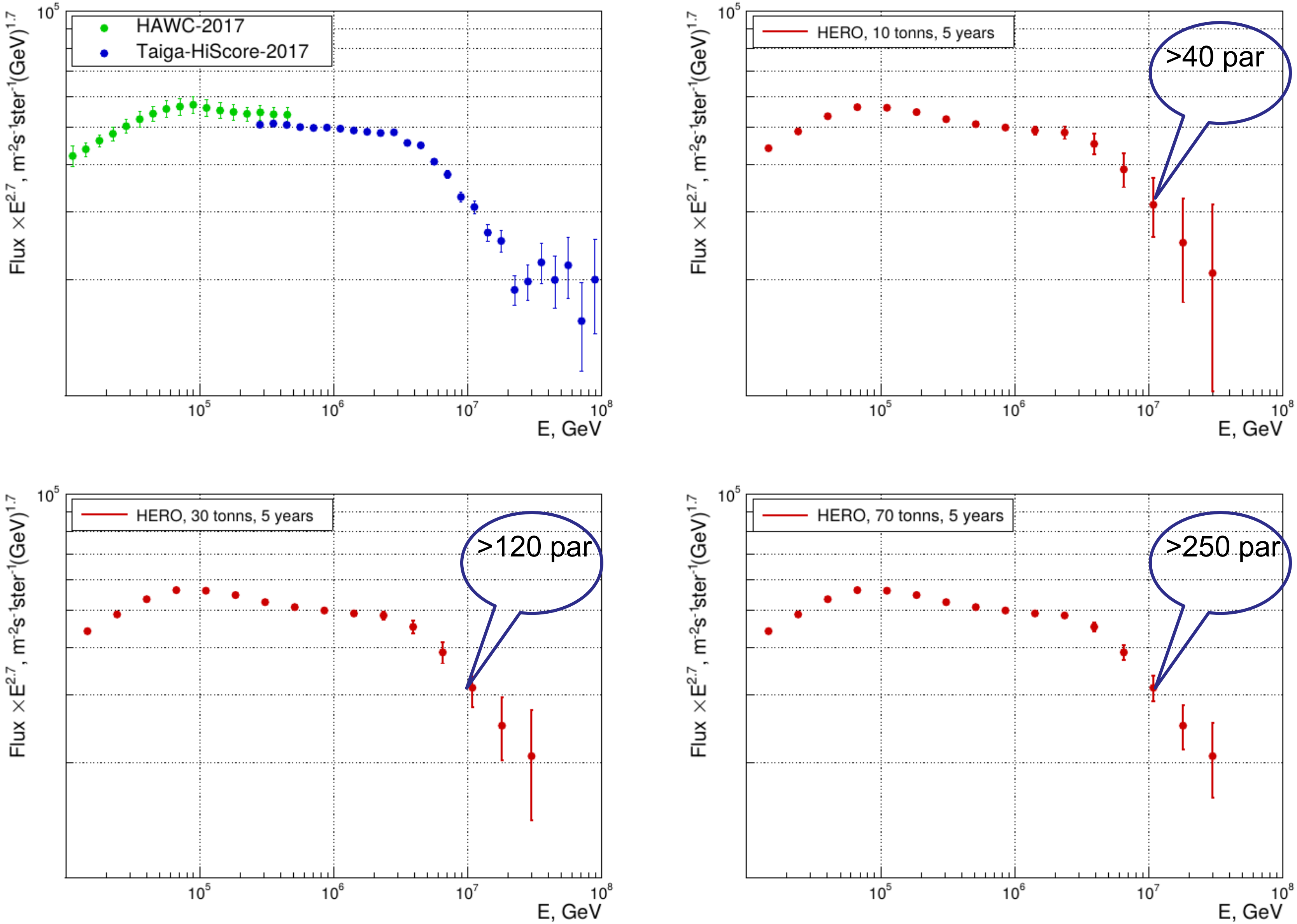
Dependence of the energy resolution of the calorimeter on the effective geometric factor of the spectrometer



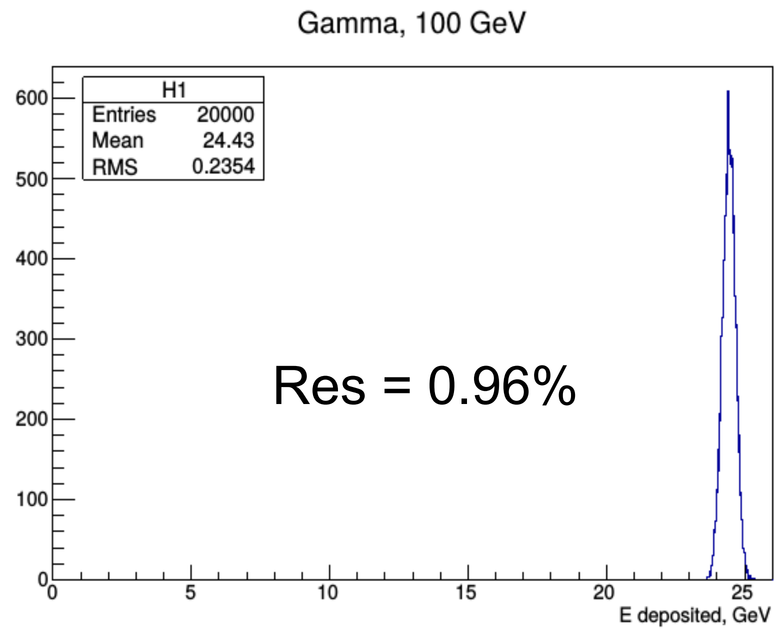


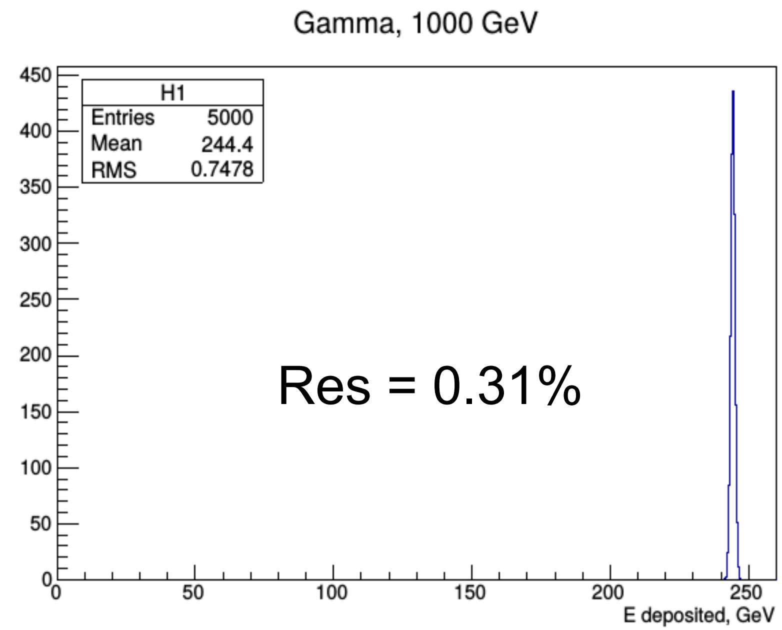


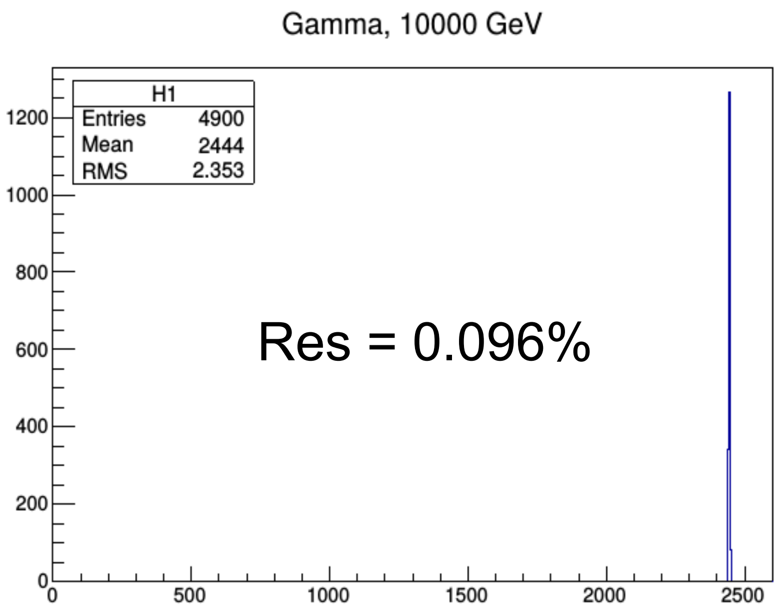
Expected statistics for different configurations of HERO calorimeter for 5 years operation



Energy Resolution for gamma quanta, IC of 3λ, 52 X_0



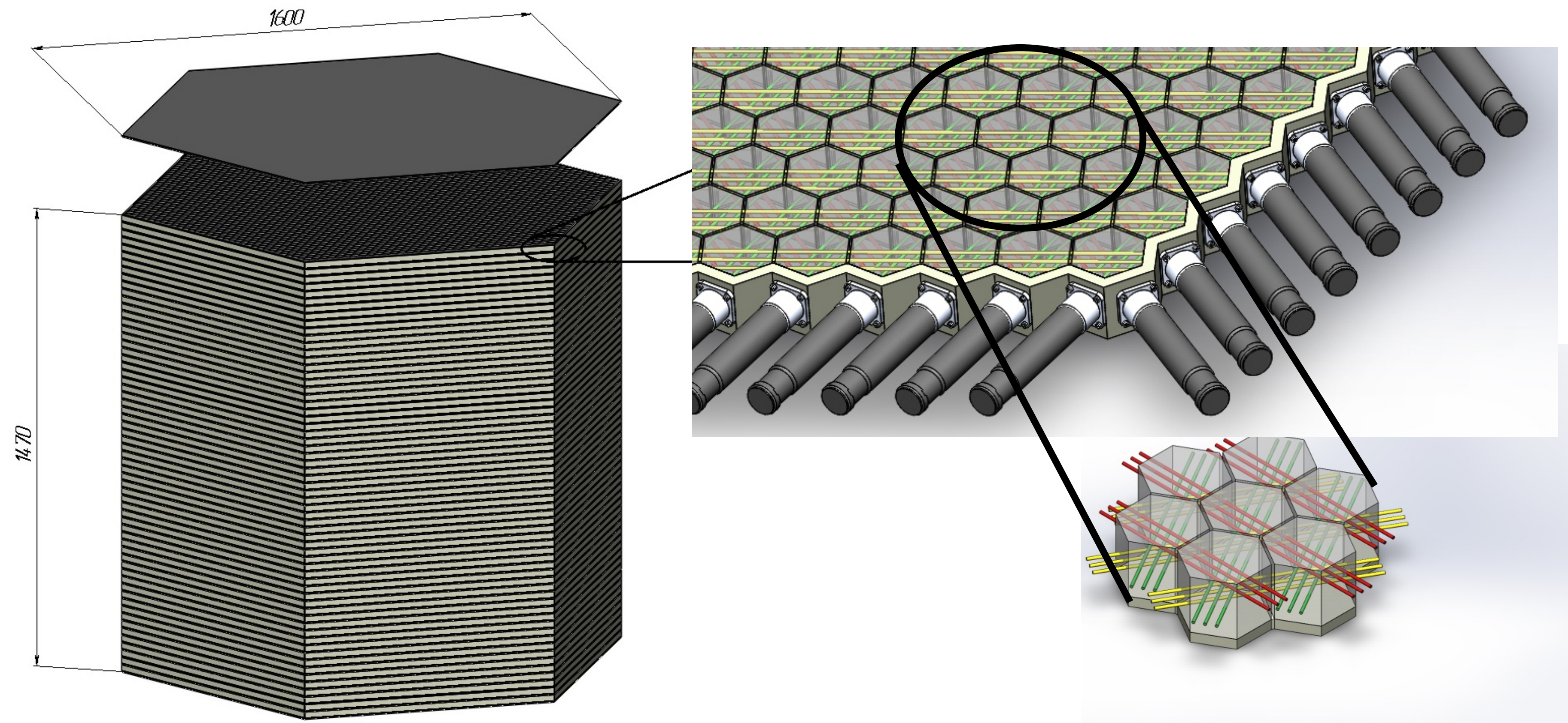




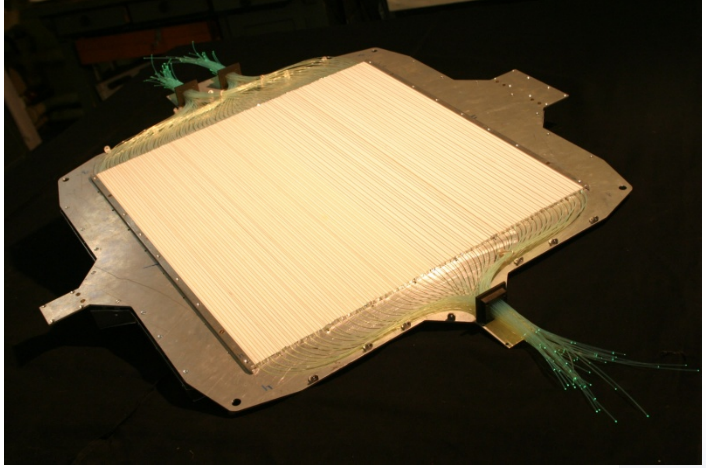
only physical fluctuations !

Preliminary Design of HERO

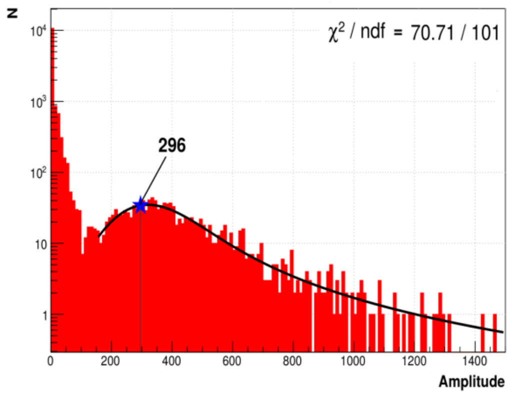
Ionization Calorimeter

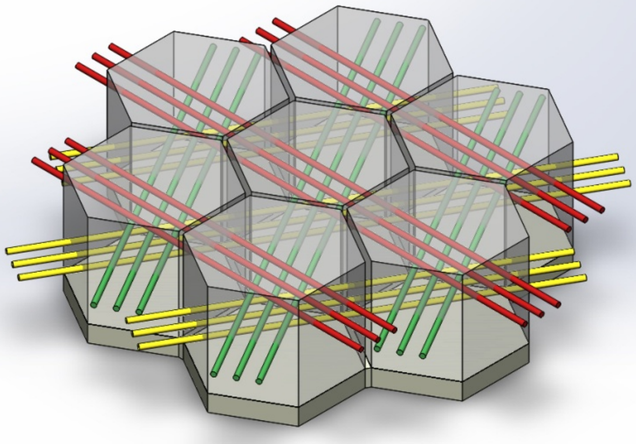


- Geometrical dimensions of IC: Diameter of circumscribed circle 1600 mm, height 1470 mm, Weight ~ 10 tons
- IR consists of 62 identical layers. Each layer is a hexagonal plane, 23,5 mm thick, with a polystyrene scintillator (ρ~1.0 g/cm3, h=20 mm) and a tungsten-copper-nickel alloy absorber (ρ~16/5 g/cm3, h=3,5 mm)
- Number of registration channels 6696.



NUCLEON scintillation counter. It use the same technology in HERO, but plastic is thicker in four times. It means resolution is also four times better. An additional feature of the HERO scintillator is the implantation of B10 nucleus into its composition.

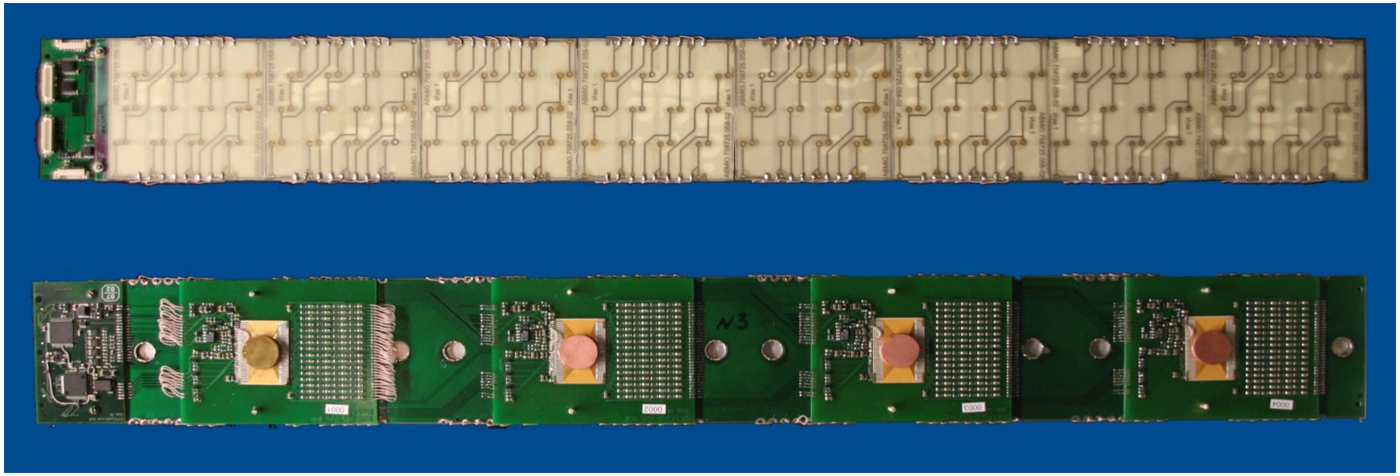




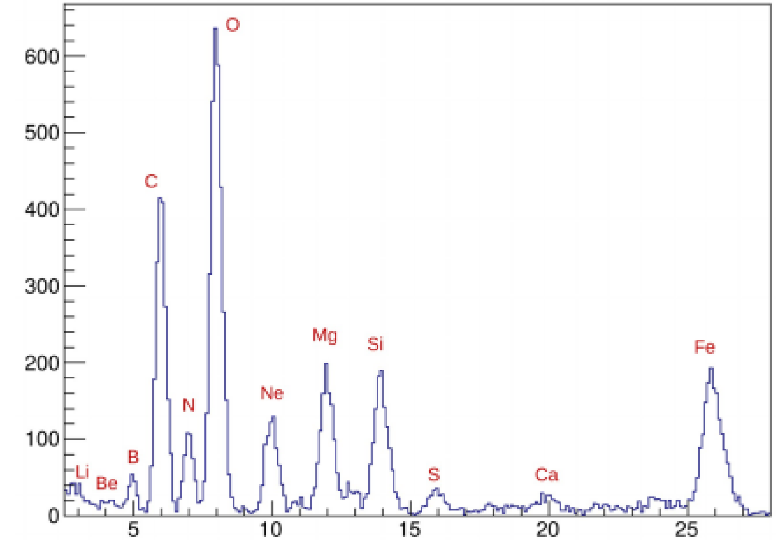
- Each scintillator layer consists of 4033 prisms (diameter of circumscribed circle 25 mm). The light signal is recorded by light-shifting fibers guides, which placed in three dimensions (X = 0 °, Y = 60 °, U = 120 °) towards PMT

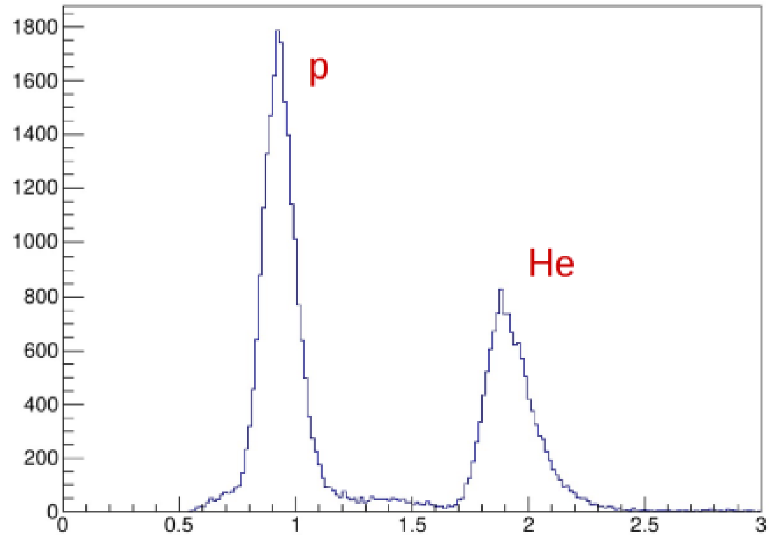
- Each PMT is additionally switched as a non-stop neutron counter. Thus, an additional tool for detecting energy and determination of lepton CR component appears in the HERO.

Charge Measuring System

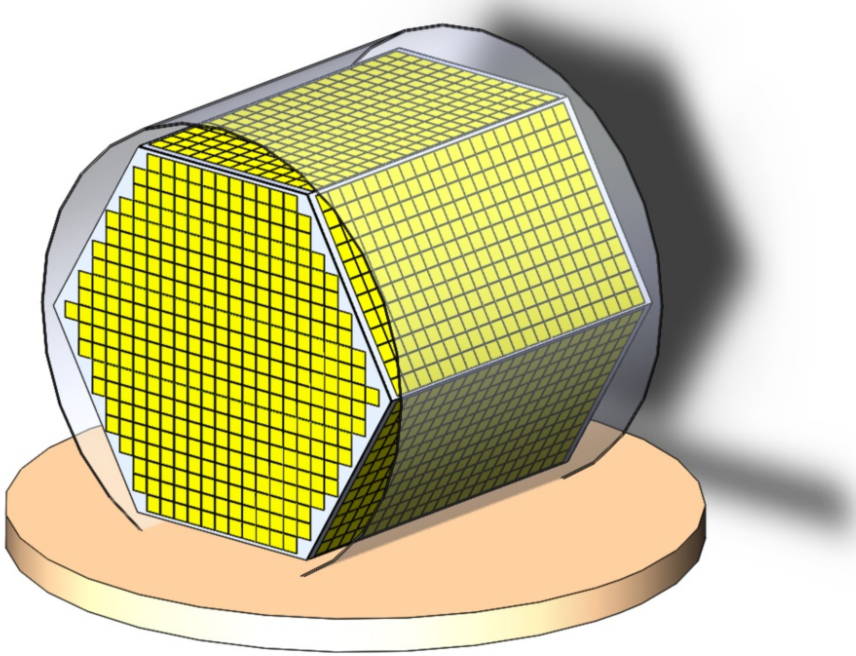


➢Leders construction is similar to NUCLEON one. Expected charge resolution is better then 0.2 ch. u. (Pads in HERO are three times less than in NUCLEON)





NUCLEON charge resolution ~0.2



- IC is surrounded on all sides by four-layer Silicone Matrixes. Matrixes consists of independent leders comprising from 3 to 16 detectors with dimensions of 100x100x0.5 mm3. Each detector is divided into 100 independent pads.

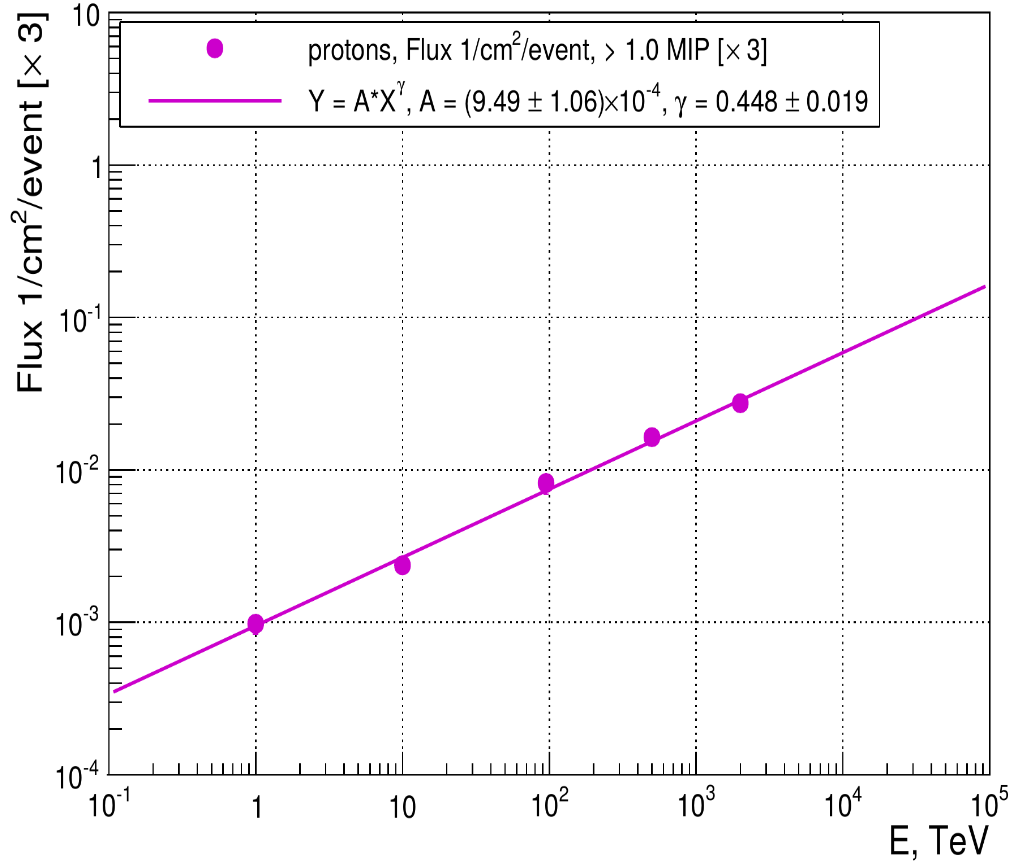
In total, HERO includes ~ 8000 detectors (8000×100 independent channels)

Backscatter Problem

A Monte-Carlo simulation (FLUKA code) was tested by comparing to the experimental results obtained in Sokol, ATIC and NUCLEON experiments.

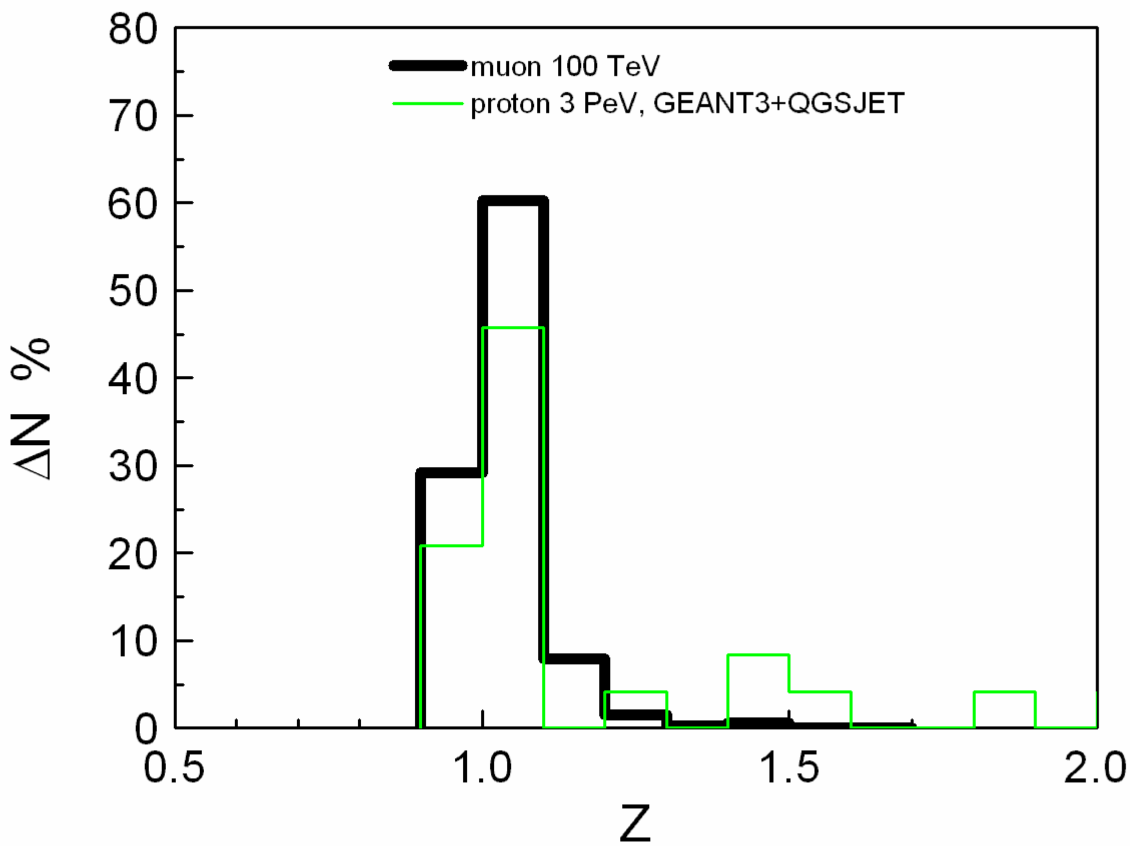
The experimental backscattering is twice larger than the simulation.

To evaluate the backscatter effect the simulation results were increased by three times to account for this systematic error.



The energy dependence of the distortion signal, which could be simultaneously in a pad of CMS detector even at the end of the energy range this probability does not exceed 10%.

Using three or four layers reduces the backscatter effect by an order of magnitude.



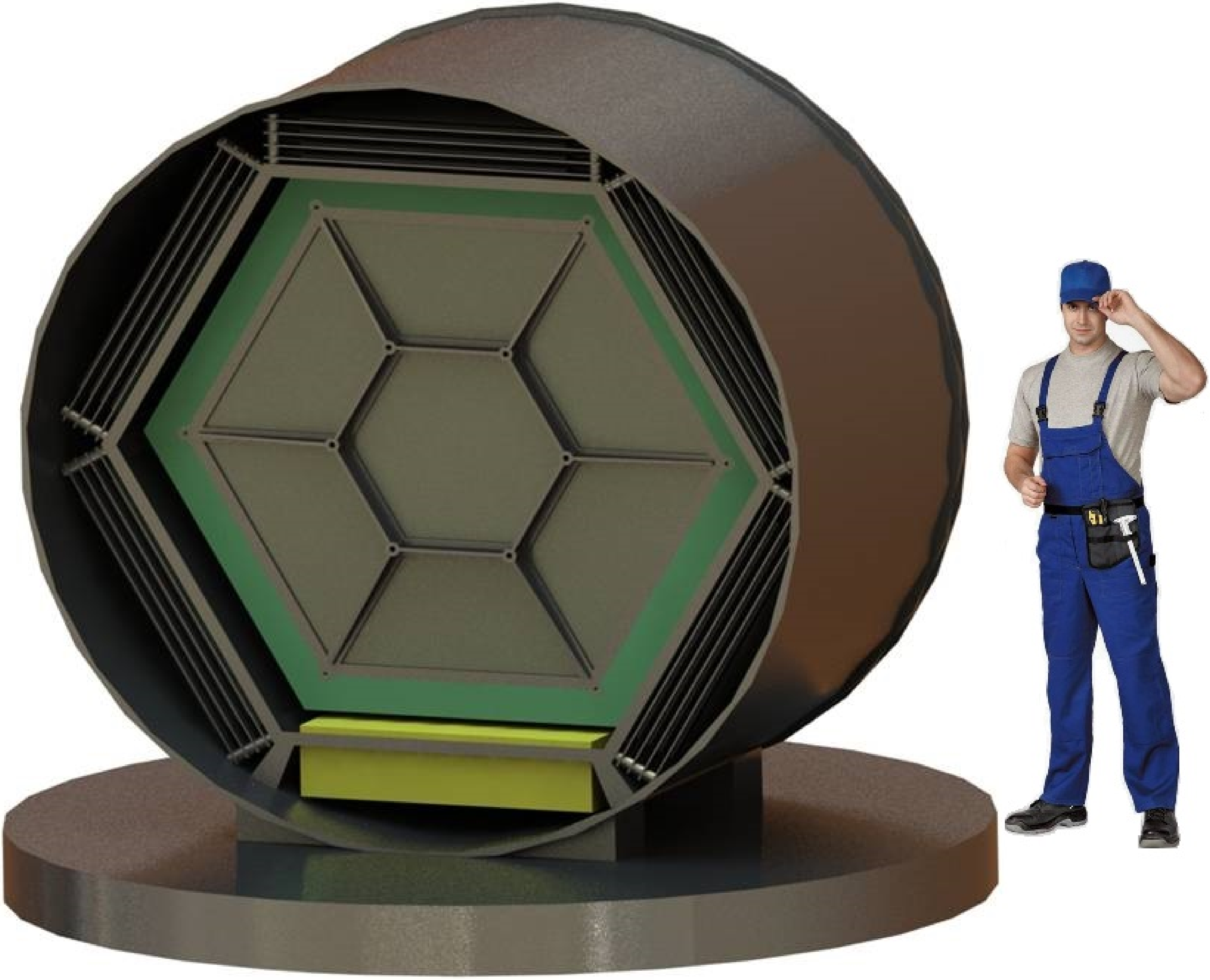
An alternative simulation was carried out using the GEANT code. The simulation was conducted at the energy of $3 \cdot 10^{15}$ eV, it gives an 8% probability that a proton will come out of the 0.5-1.5 charge range.

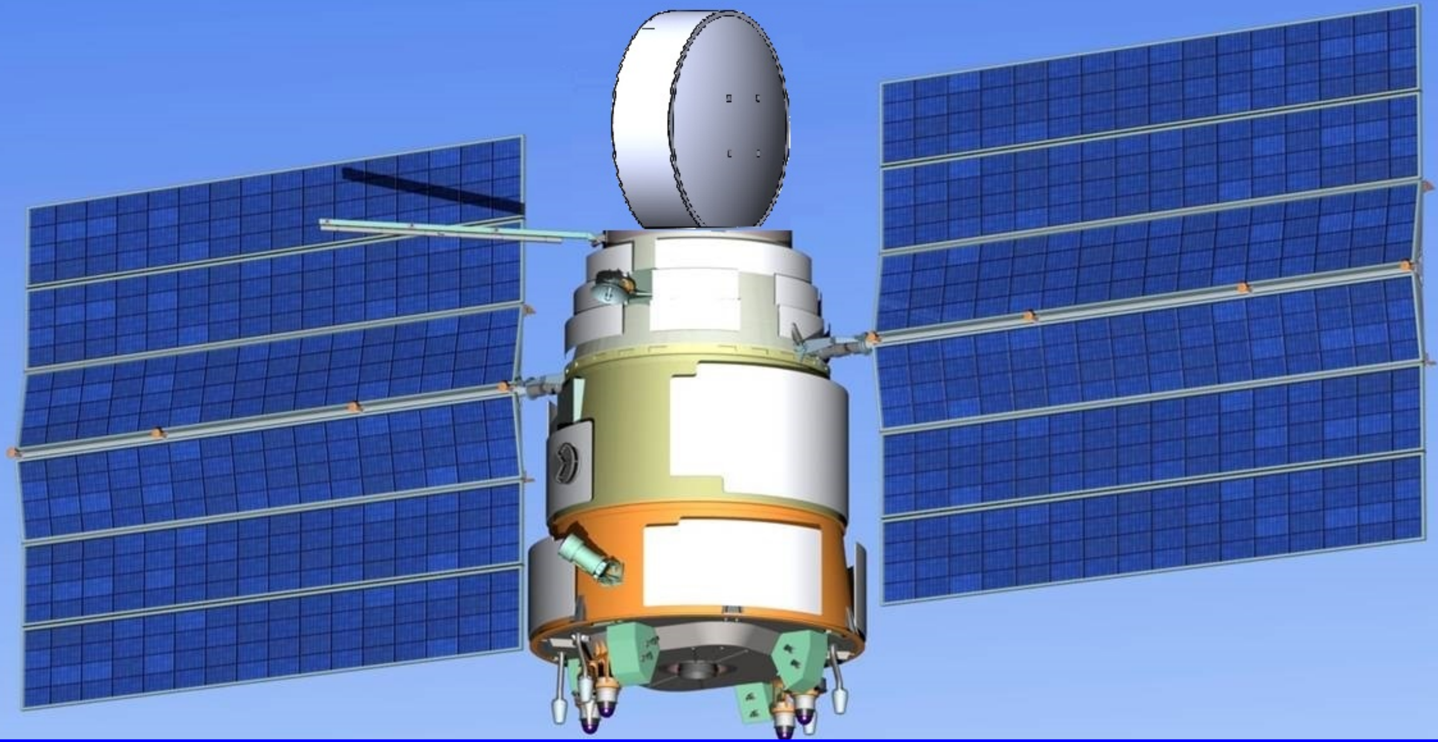
Current status

The **HERO** experiment is supported by the Russian Academy of Sciences and is included in the Russian Federal Space Program. The HERO will be in the R&D stage until 2019-2020. Starting from the year 2021 the project will shift into the construction stage. It is planned to be launched between 2025 and 2030.

Main characteristics of the 10 tonn HERO device

Effective Geometric Factor (m^2 sr)	Protons ~12 Nuclei ~15 γ and $e^{\pm}$ ~20
Energy Resolution (%)	Protons <30% Nuclei <15-20% γ and $e^{\pm}$ ~1%
Charge Resolution (charge units)	~0.2
Rejection Level	Protons to γ & e± - 10^{-6} γ to e± - 10^{-2}
HERO Weight (kg)	12500
Power Consumption (W)	4500
Dimensions	Smaller than a cylinder with ø 2.5 m and h = 2.5 m





Conclusion

The HERO effective exposure factor and its measuring accuracy provide the ability to solve several main problems of the astoparticle physics in the foreseeable future. These include the "CR knee" problem. The HERO experimental results will allow to make the detailed cosmic ray model up to 10^{16}

Thank you!