The methods of uncertainty estimation for the large-scale anisotropy measurement in the PAMELA experiment

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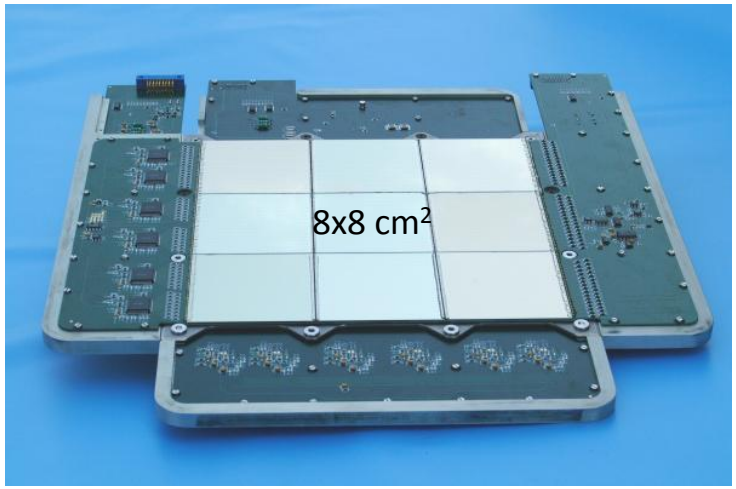
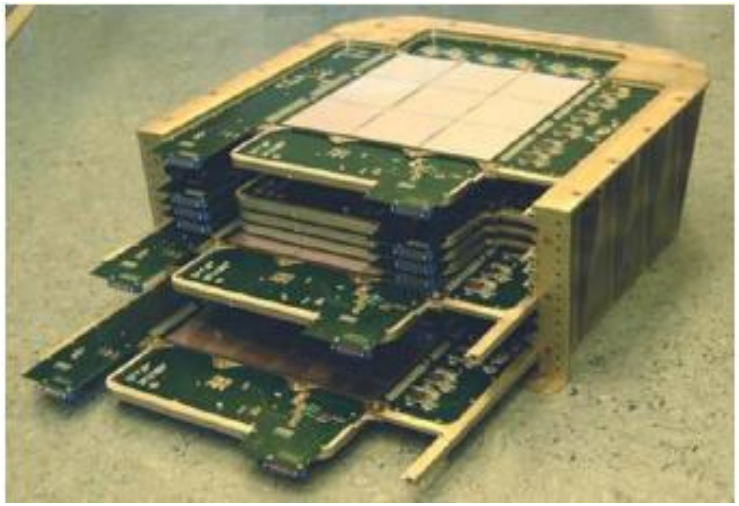
The schematic overview of the PAMELA

The PAMELA calorimeter

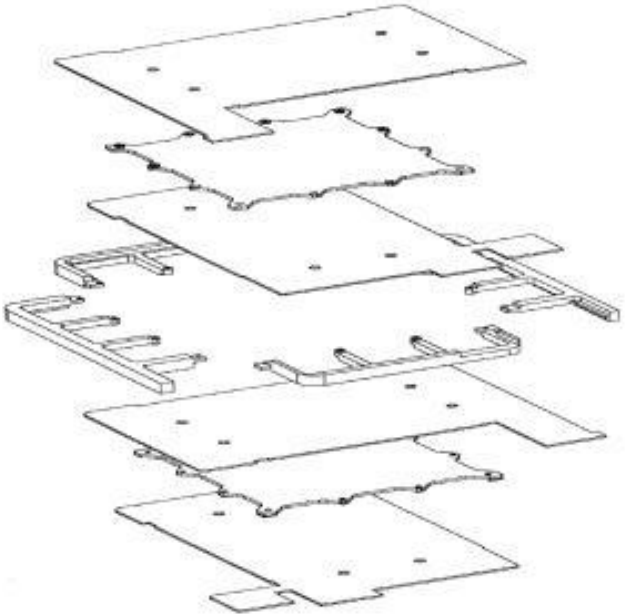




The total depth is 16 X_0

The total sensitive area is 24x24 cm^2
22 layers of tungsten

44 layers of silicon detectors
The strip number in layer is 96

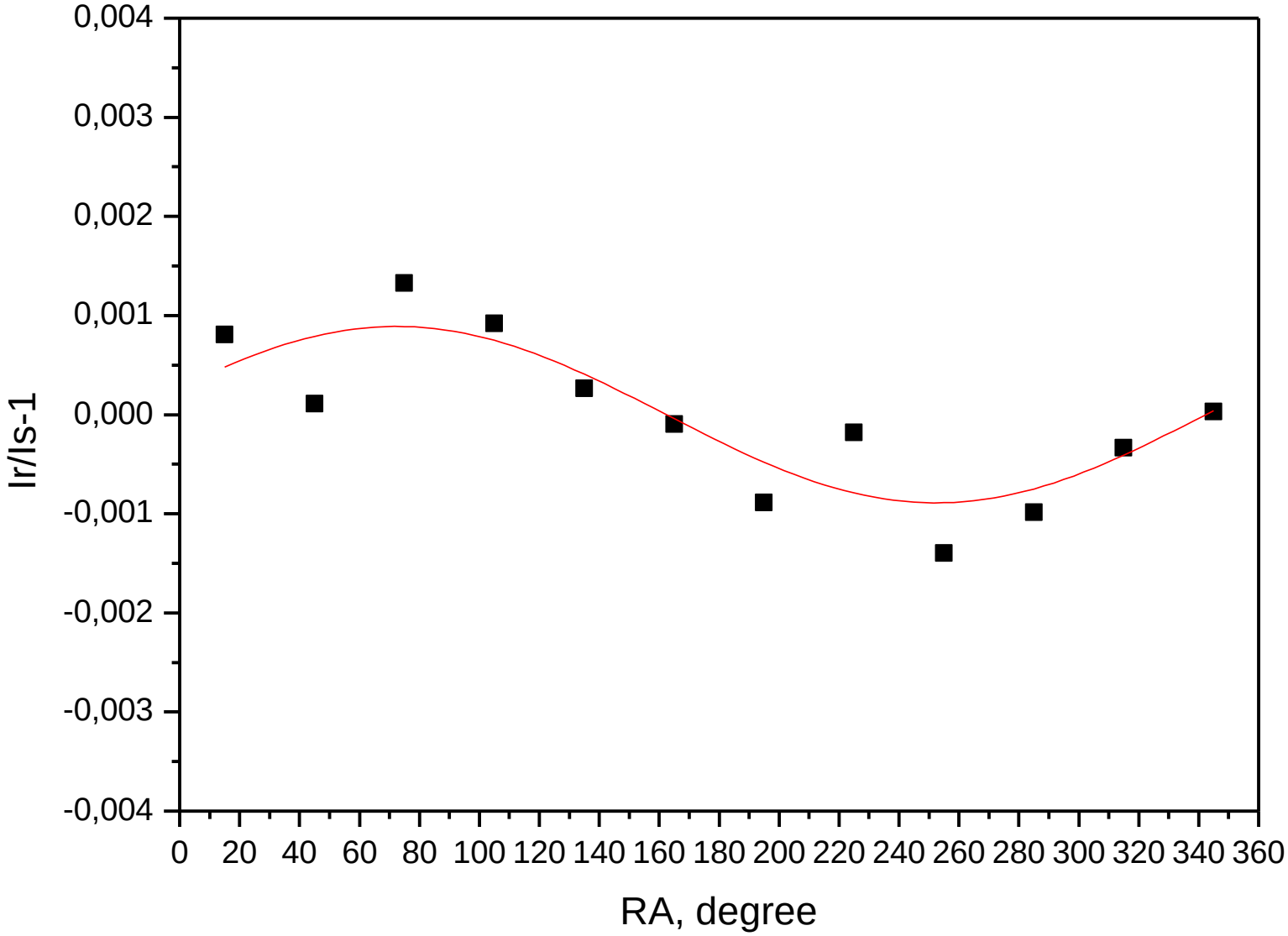


- The large scale anisotropy was studied with the PAMELA calorimeter for cosmic ray protons and helium in the energy range 1-20 TeV/nuc

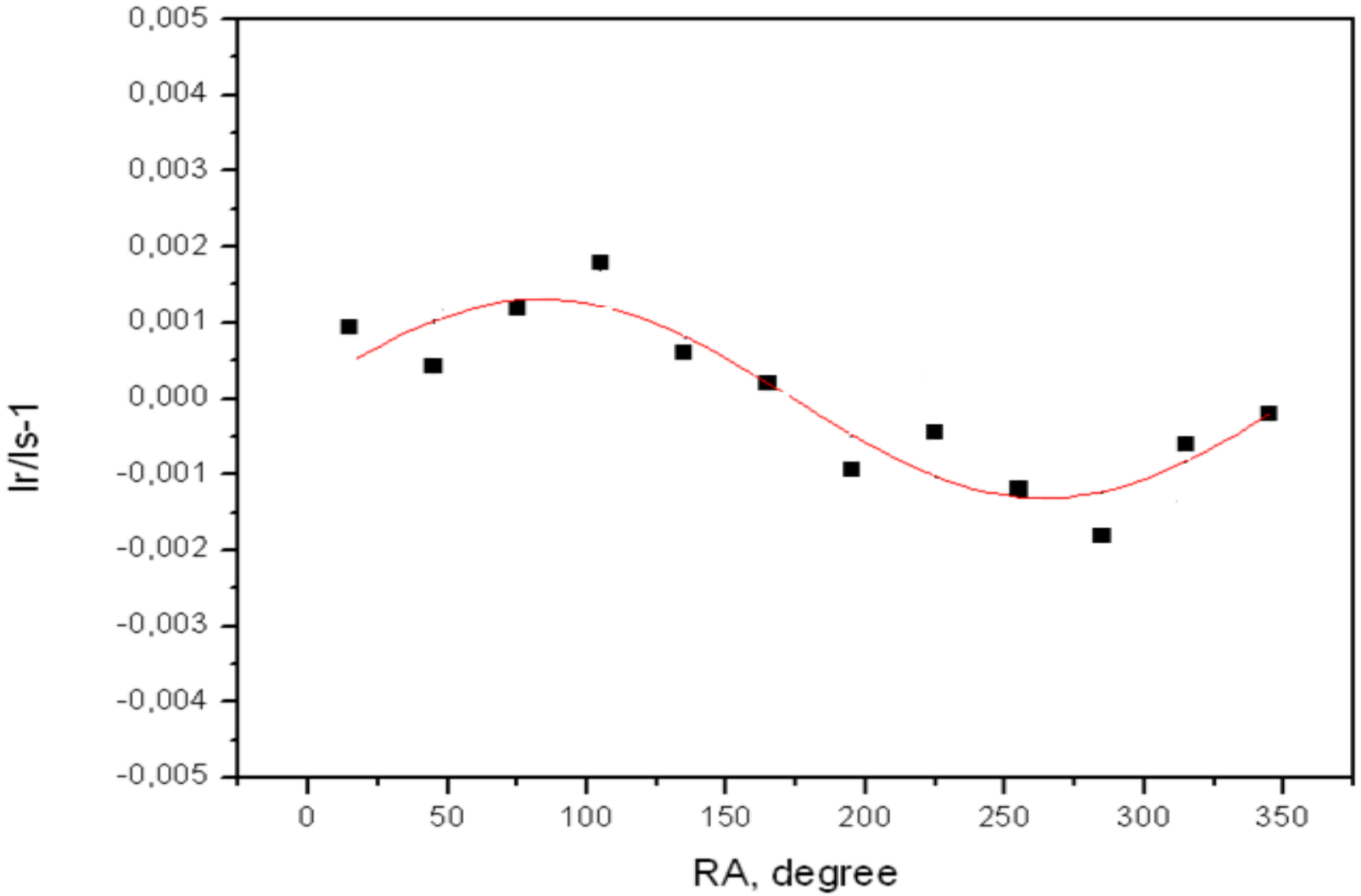
- The aperture of the calorimeter did not allow to collect enough events for direct measurements of anisotropy but with the integration technique and large number of correlated measurements we were able to obtain within some boards the dipole characteristics to fit our data

- Here we discuss the two methods to obtain such boards for amplitude and phase of the dipole

The firs method is fit of the experimental dots by dipole function



The dipole was simulated with the same amount of events to get the coefficient of determination and estimate the statistical fluctuations



- Uncertainty for the amplitude is ±0,3 10^-3
- Uncertainty for the phase is ± 10 degree

the coefficient of determination (from simulation):

$$R^2 = 0,89 \pm 0,07$$

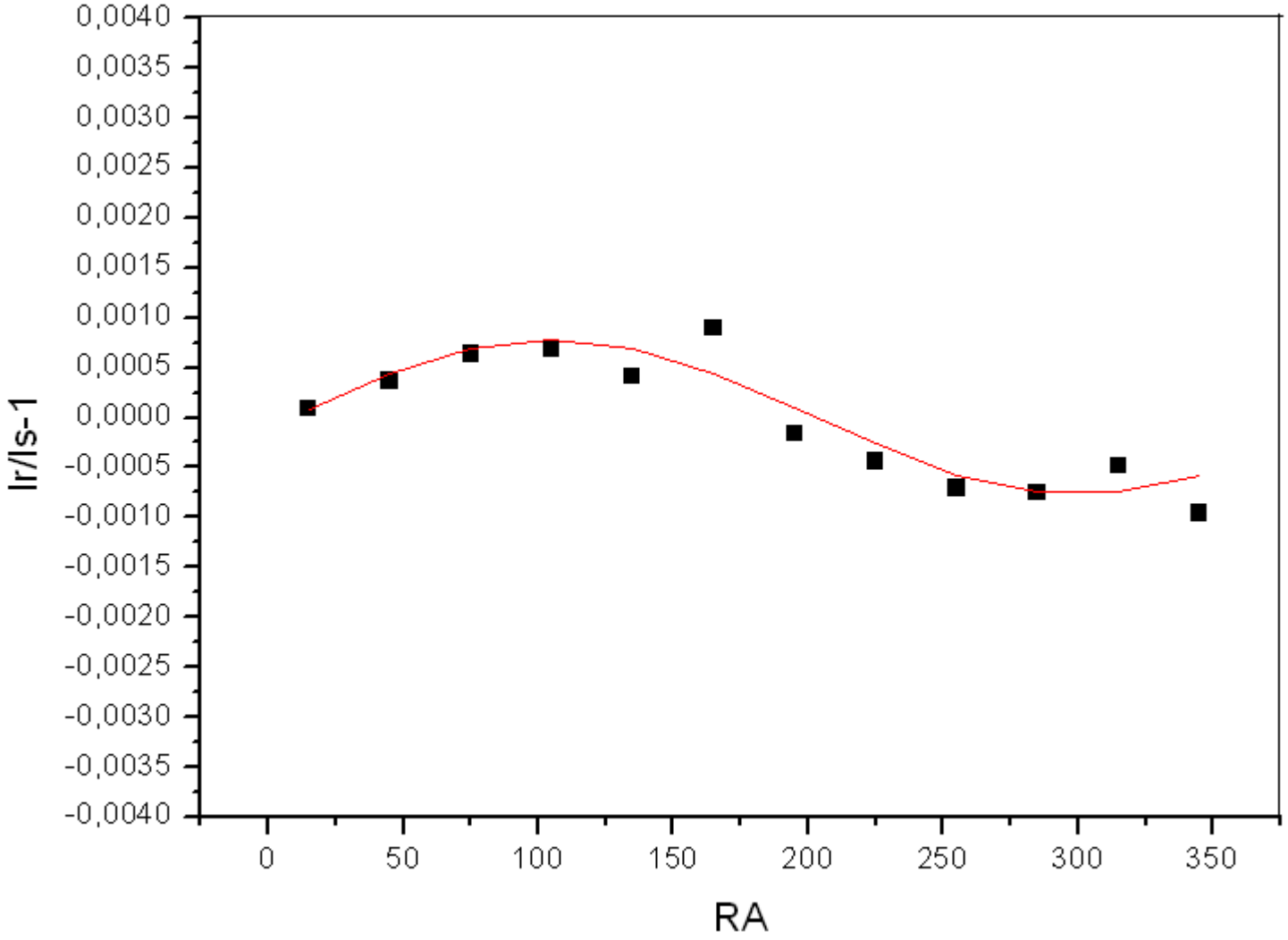
While in the experiment we have 0,88 that is in the good agreement with the numerical test

The second method is “the bootsrtap”

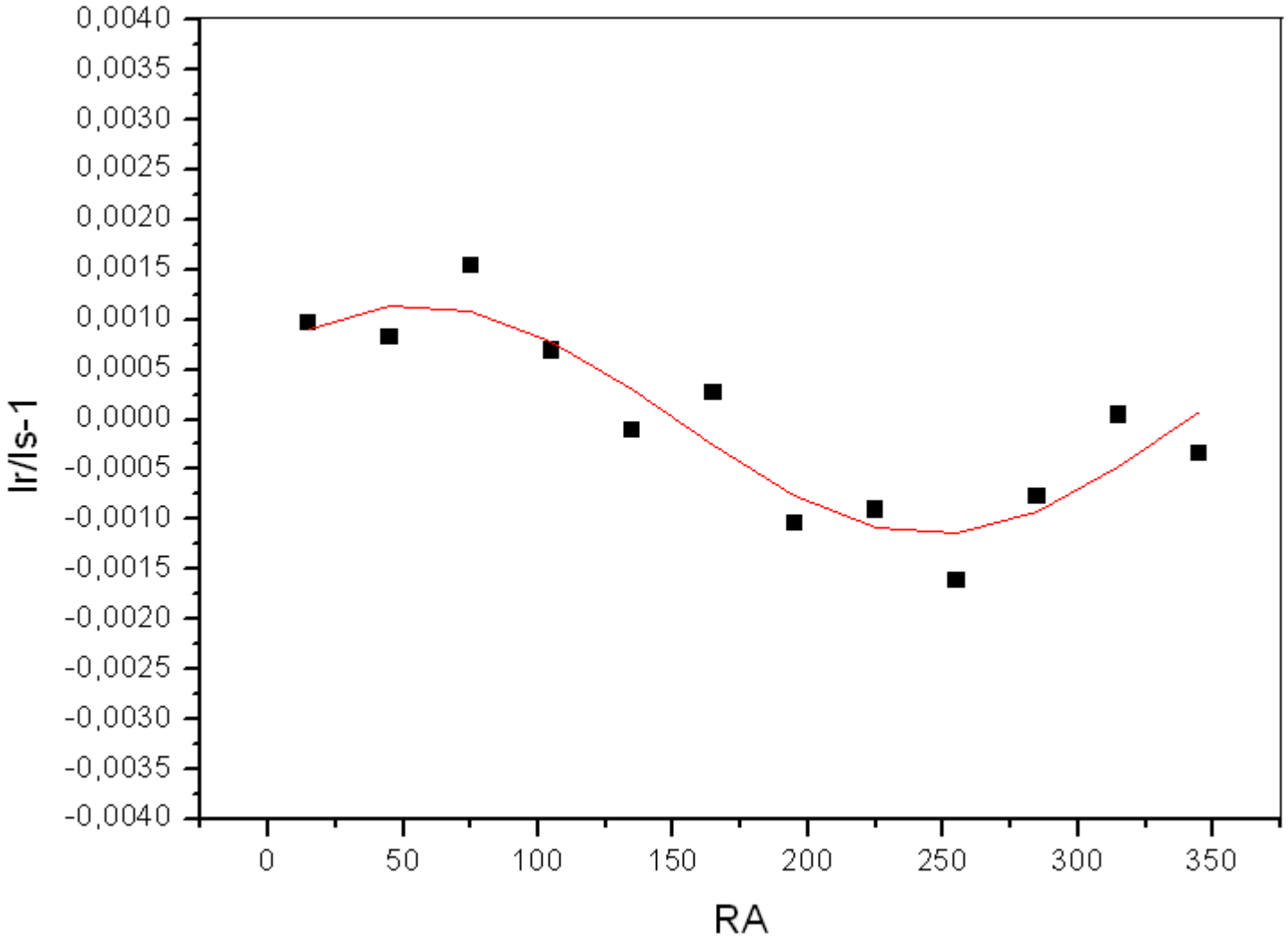
[1] Efron, B 1979, Rietz Lecture, Ann. Statistics, 7, 1
[2] P. Barbe, P. Bertail, The Weighted Bootstrap, Springer, New York, 1995.
[3] Efron, B 1982, The Bootsrap, Jacknife, and Other Resampling Plans, Philadelphia SIAM

The method is based on the process of the simulation of many data sets directly from the real experimental set. The simulated data sets are used to estimate the statistical fluctuations of the investigated phenomenon.

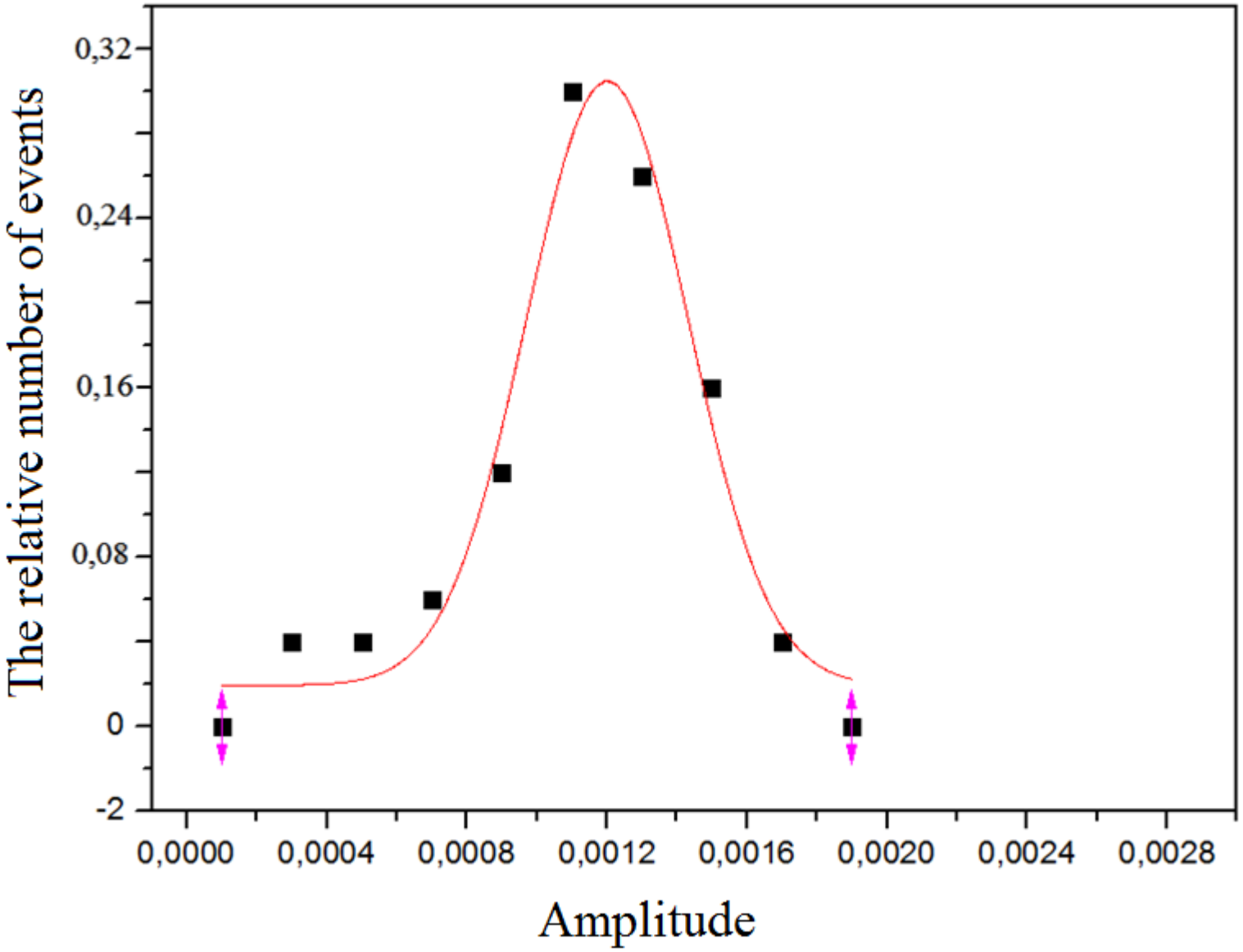
The example of the simulated dipole



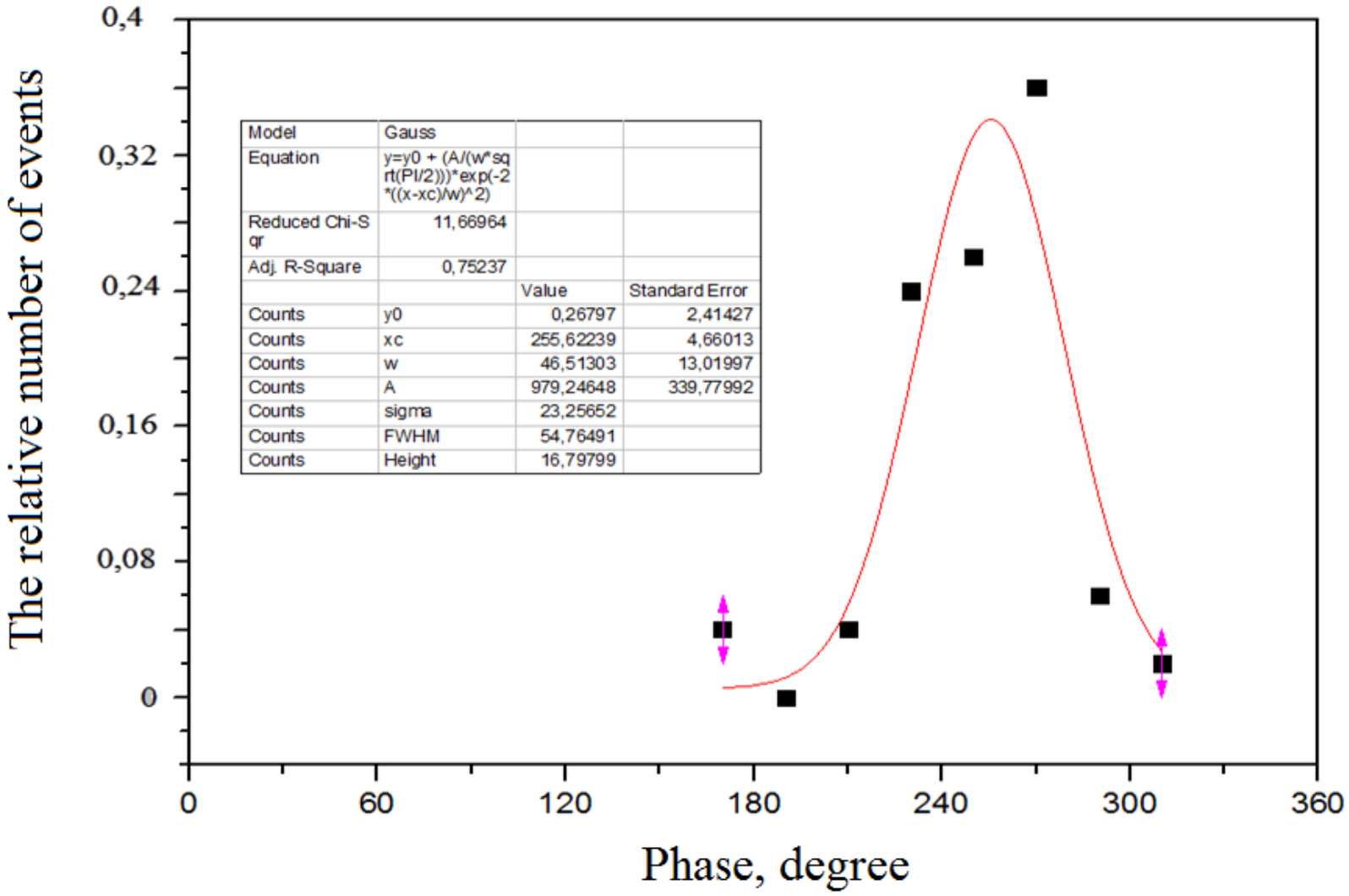
The example of the simulated dipole



The distribution for the amplitude



The distribution for the phase



Model	Gauss		
Equation	y=y0 + (A/(w*sqrt(PI/2)))*exp(-2*((x-xc)/w)^2)		
Reduced Chi-Sqr	11,66964		
Adj. R-Square	0,75237		
		Value	Standard Error
Counts	y0	0,26797	2,41427
Counts	xc	255,62239	4,66013
Counts	w	46,51303	13,01997
Counts	A	979,24648	339,77992
Counts	sigma	23,25652	
Counts	FWHM	54,76491	
Counts	Height	16,79799	

- Uncertainty for the amplitude is ±0,3 10^-3
- Uncertainty for the phase is 20 degree

Conclusion

- Two methods give the similar uncertainties for the amplitude and phase of the dipole

We can use to calculation proton flux F obtained by PAMELA calorimeter:

$\int_{1000\ \text{GeV}}^{20000\ \text{GeV}} F\,dE$ ≈0,064 $m^{-2}\,s^{-1}\,sr^{-1}$

So, the total number of protons N_p *registered by PAMELA calorimeter within period 2006-2014*

N_p=0,064*100000000*0.5*0,0021*100≈600000