High-Resolution Cherenkov Telescopes for the Observation of High-Energy Gamma Rays

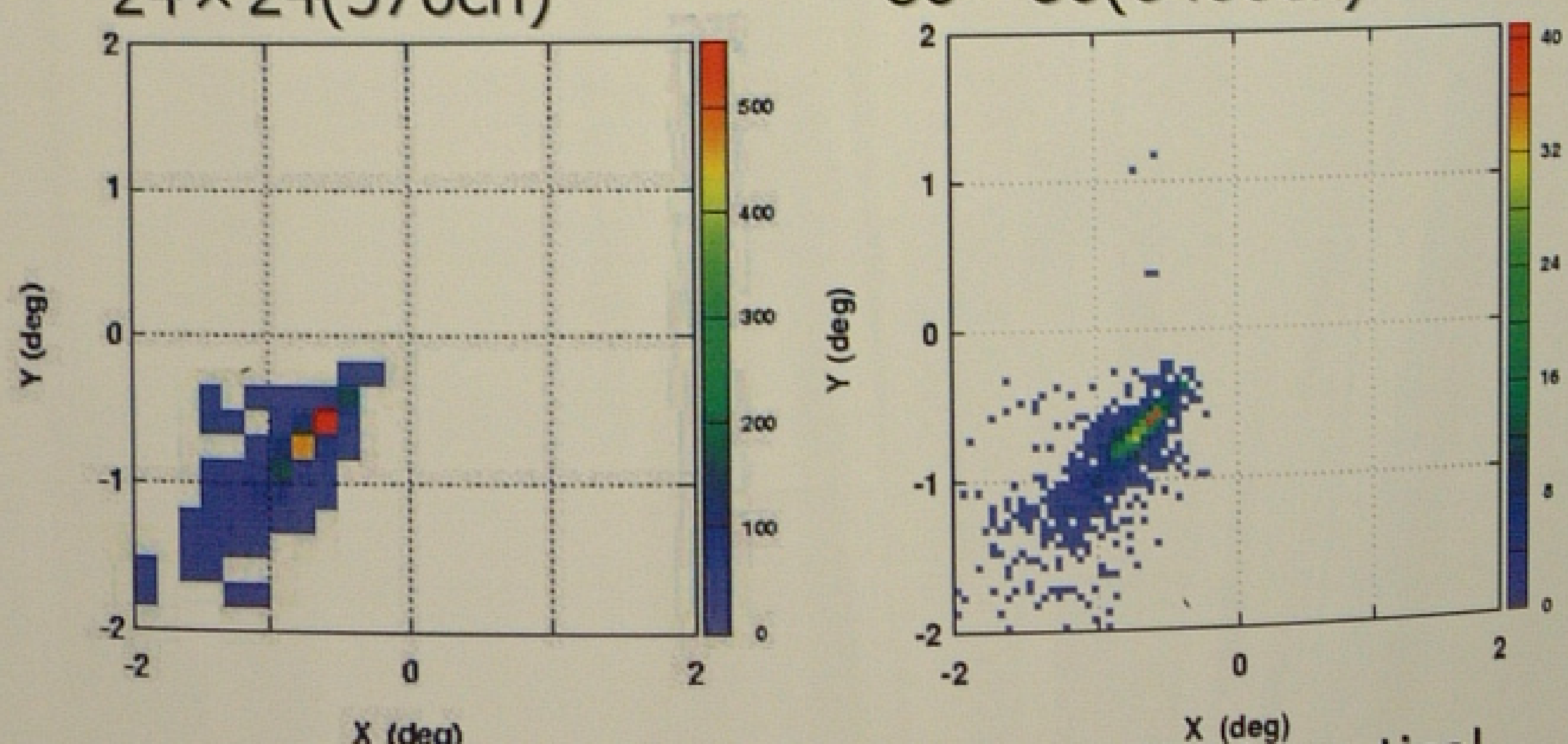
F. Kajino, T. Wasio, Tada, T. Oda, E. Choi, S. Hayashi, M.Sakata, Y. Yamamoto

Department of Physics
Konan University

F. Kajino

Image by using high resolution camera

24 × 24(576ch) 80 × 80(6400ch)



γ -ray, 1 TeV, vertical
4300m a.s.l.

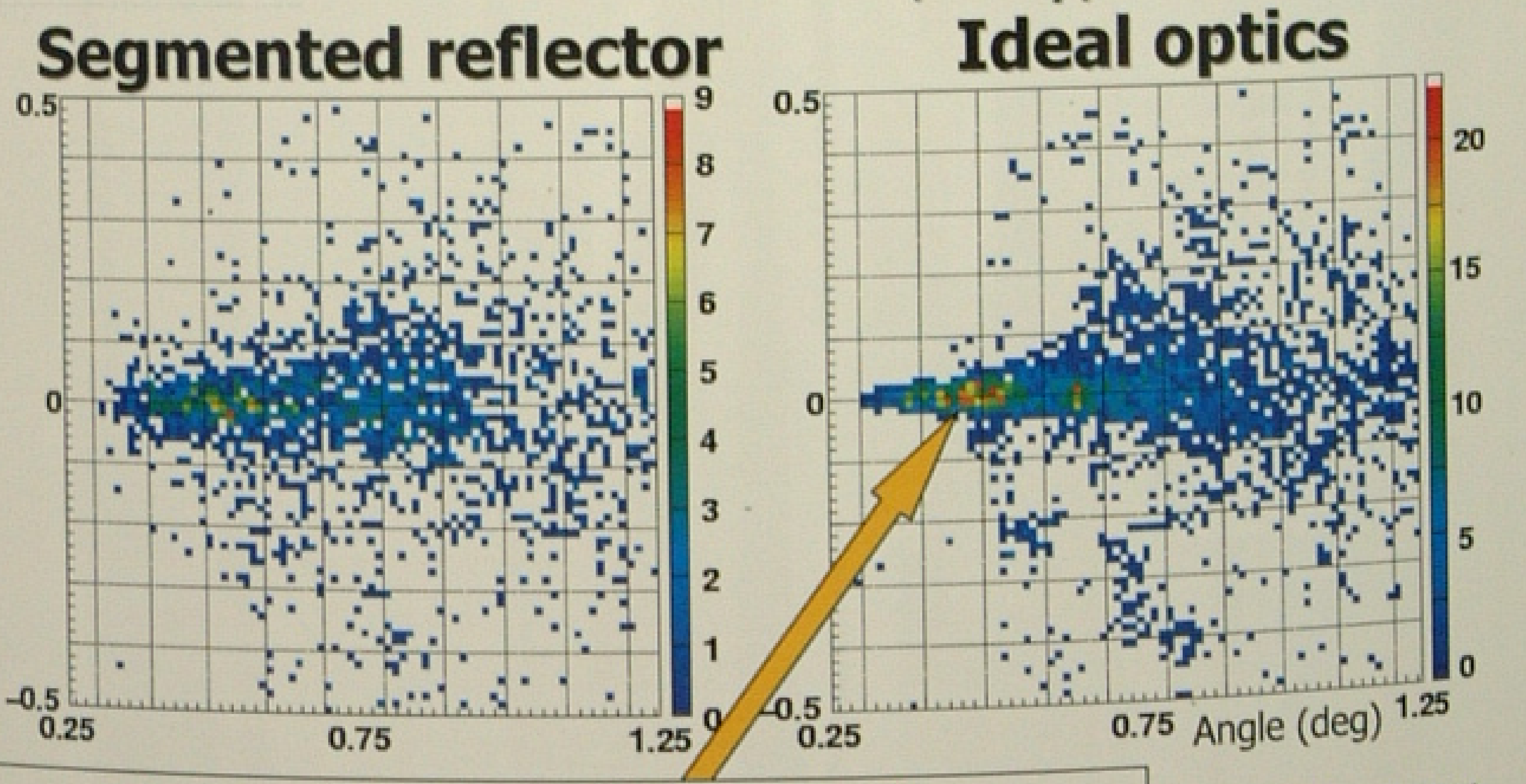
abstract

Resolution of the telescope optics and the camera used for recent Cherenkov telescopes is usually limited to be only about 0.1 degree. Therefore, small size images caused by low energy gamma rays are difficult to detect by such system. In this paper we tried to use ideal telescope which has no aberration and high resolution camera with very fine pixels to detect the images of the Cherenkov light generated by high energy gamma rays.

As a result we found that the threshold energy decreased significantly and the angular resolution was improved. Such high resolution telescopes with 10m diameter at high altitude of about 4000m will be useful to observe the energy region at around a few 10 GeV.

Difference of the Images by the Optics

γ-ray, 1TeV, 4300m



Fuzzy image at the center of the air shower become small
⇒ Decrease of energy threshold

320 × 320ch
pixel-size =0.0125°

What is High-Resolution Cherenkov Telescopes ?

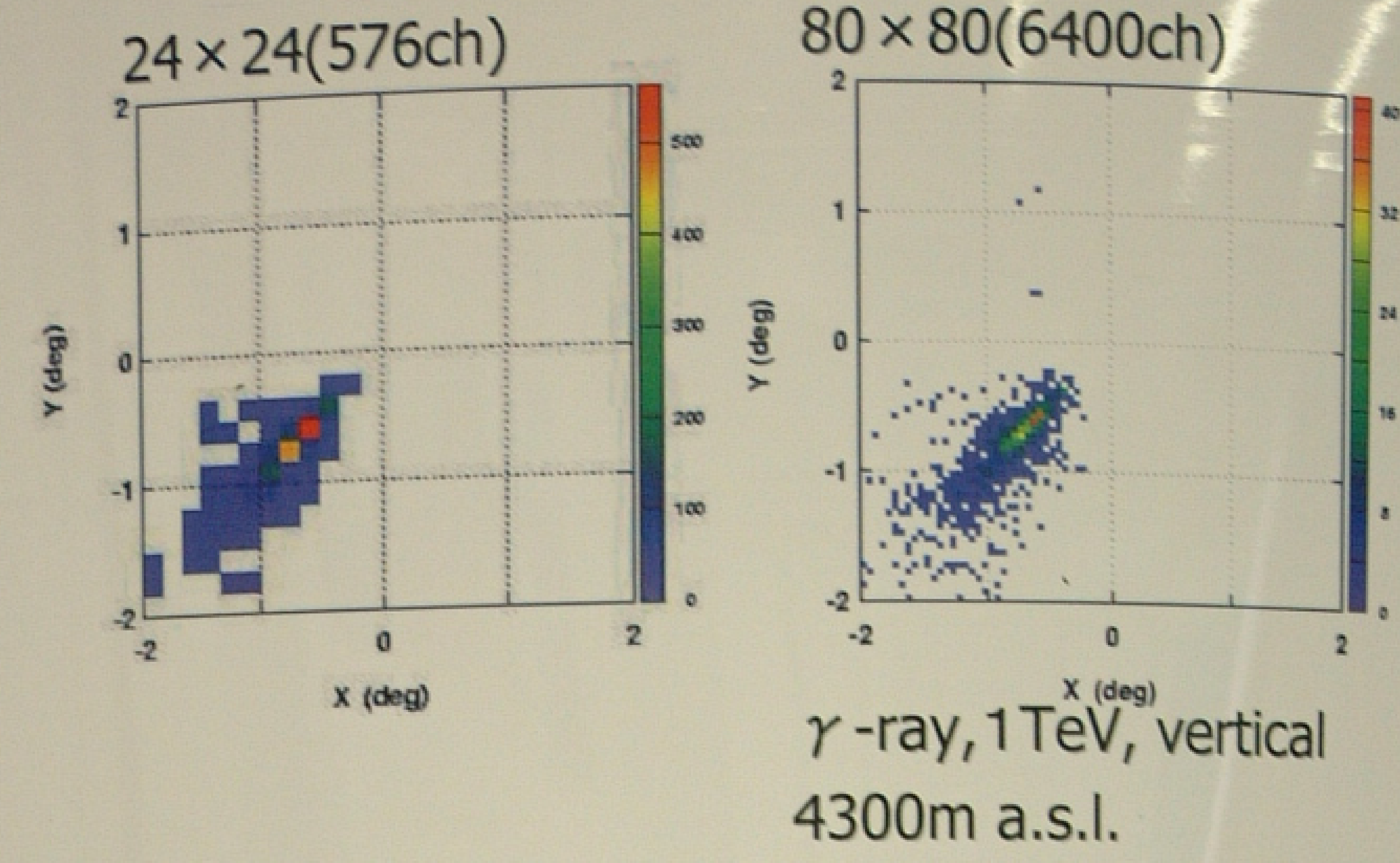
- **Ideal Optics**
  No optical aberration
- **High Resolution Camera**
  Large number of pixels

We have tried to simulate to examine the validity of the high-resolution Cherenkov telescopes for the observation of high-energy gamma rays.

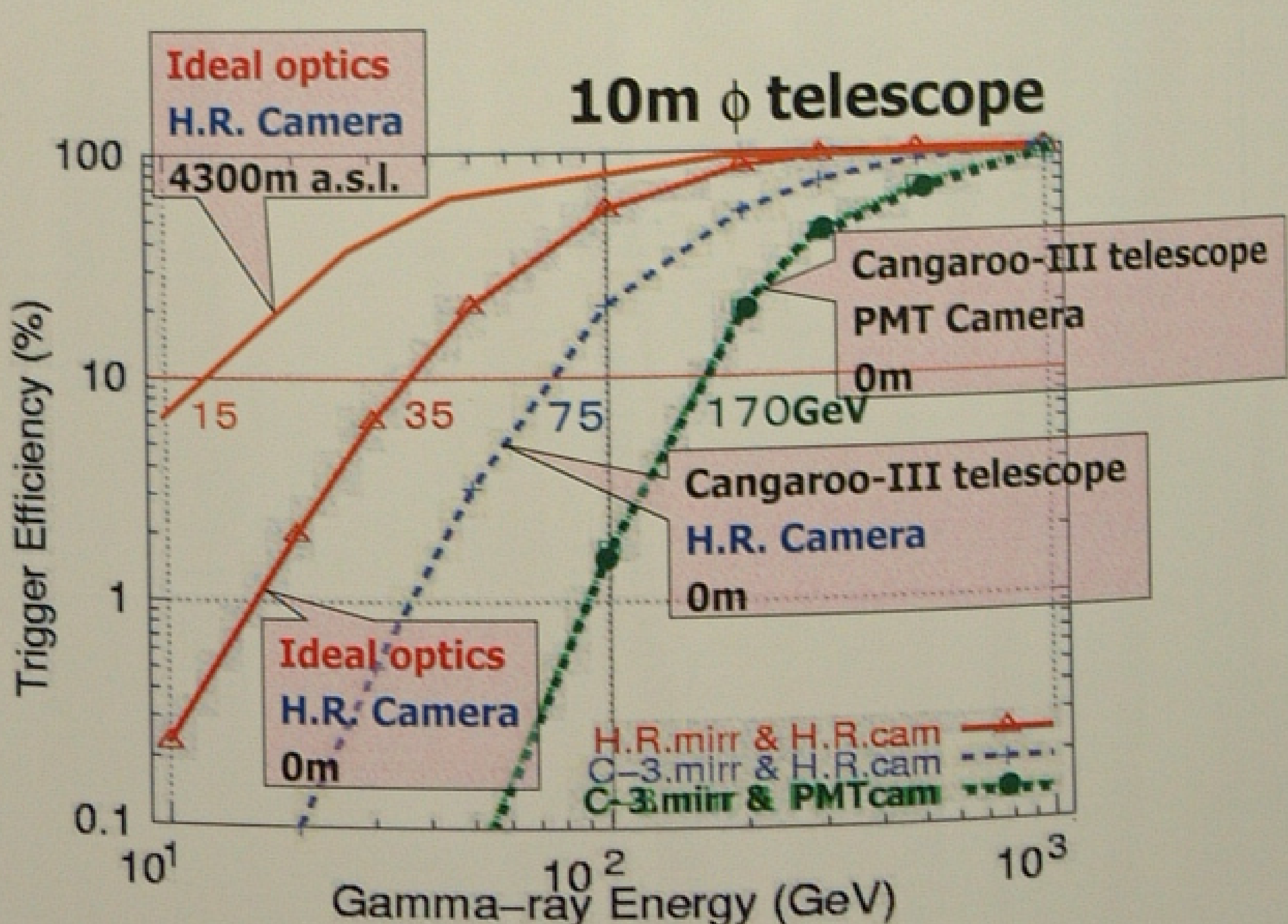
Simulation method to estimate observation efficiency

- E_γ : 10 GeV～ 1 TeV
- Vertical injection
- Observation altitude: 0m, 4300m
- **Trigger condition** :
  Total number of pixels : 576ch
  Number of pixels having at least 17 p.e. should be larger than 3

Image by using high resolution camera

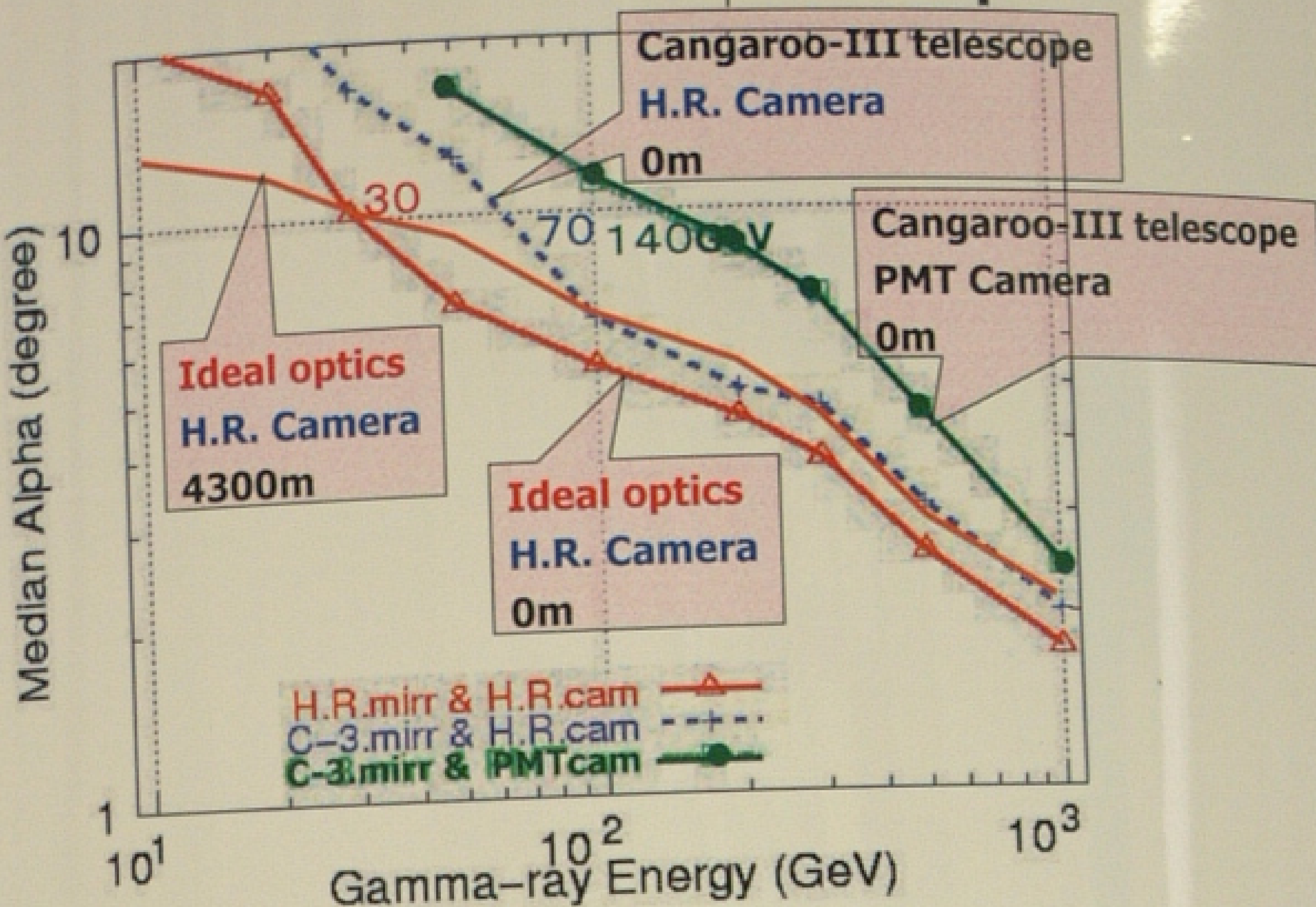


Observation Efficiency



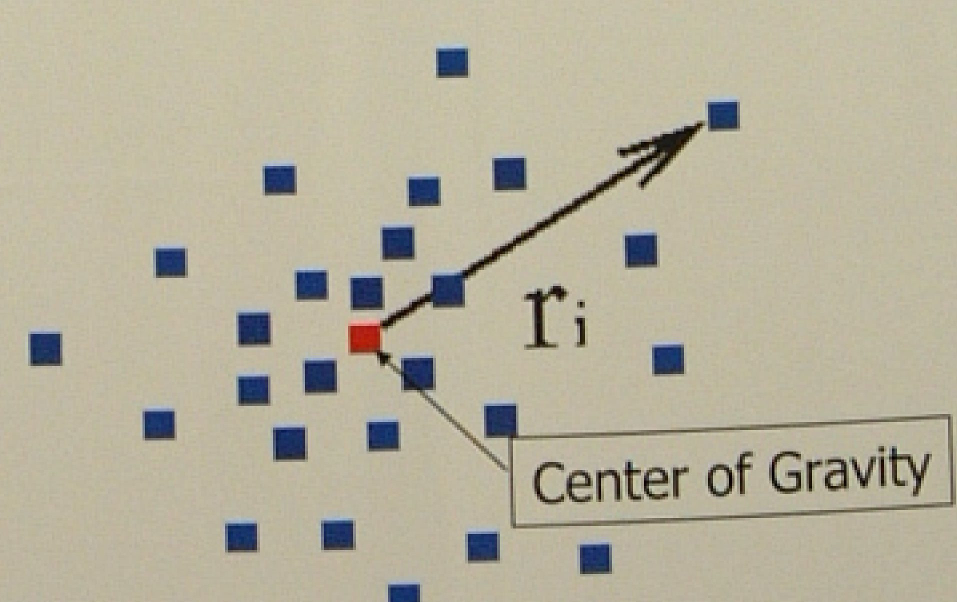
Median of Alpha Distribution

10m ϕ telescope



Definition of the Spread of the image

$$R_{r.m.s.} = \sqrt{\frac{\Sigma r_i^{\,2}}{n}}$$



17 p.e. should be larger than 3

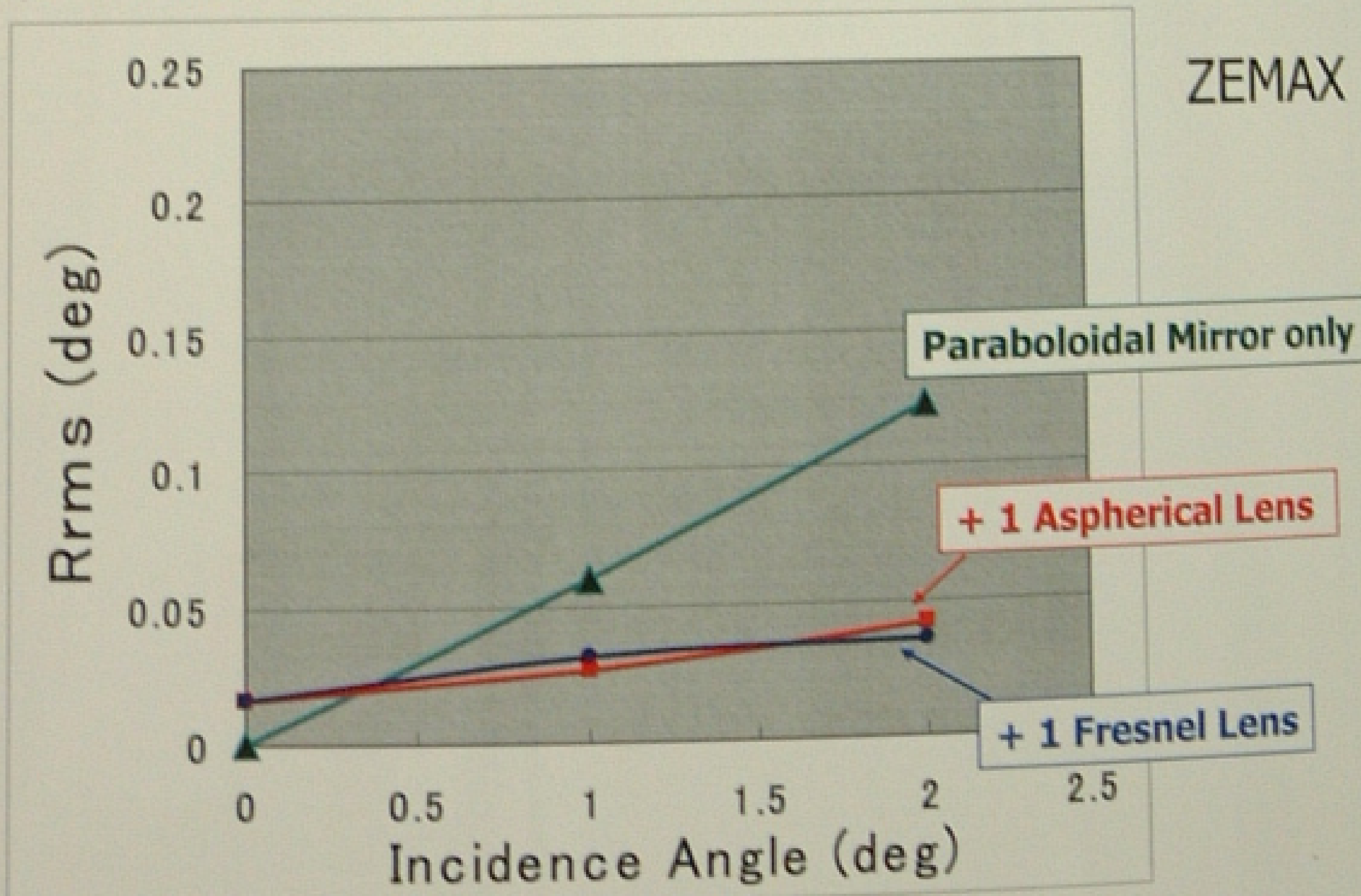
Results of Simulation

Using 10m Φ telescope
At 4300m a.s.l.

Ideal Optics
+ High Resolution Camera

High energy gamma rays from 20 to 100 GeV can be observable .

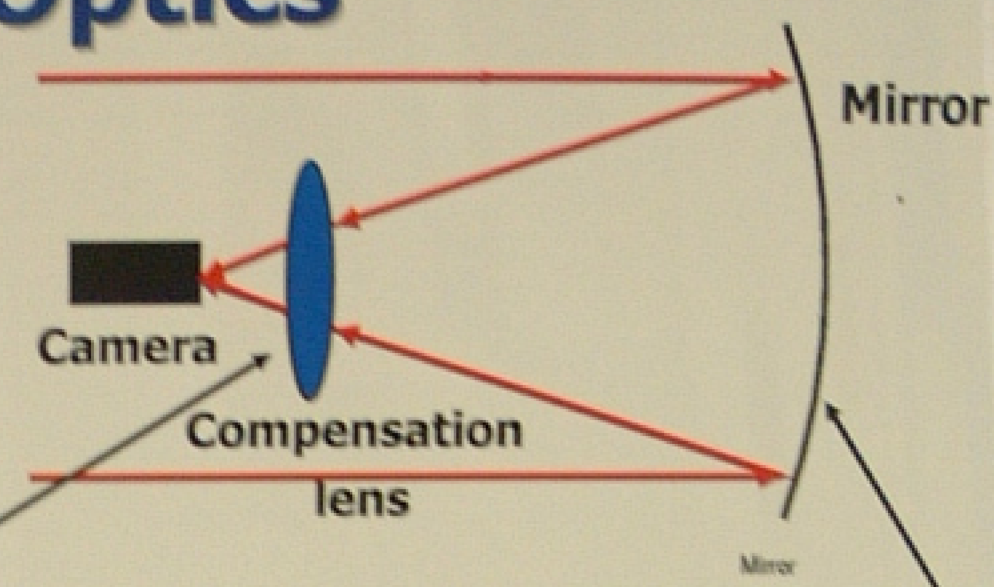
Image Spread
(Paraboloidal Mirror, F/1.0)



Rrms : root mean square of the image spread

Results of Optical Design

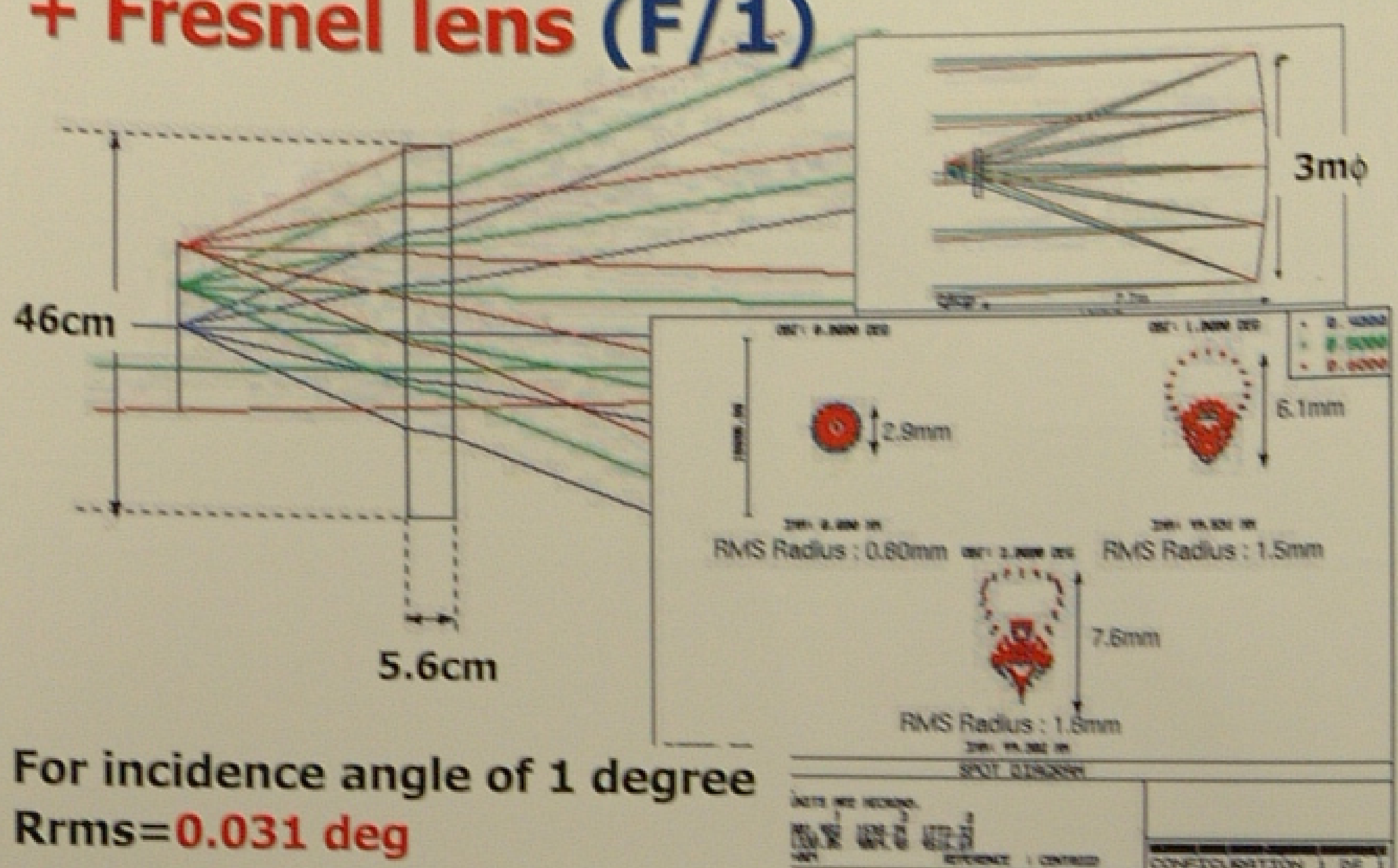
Design Work to Approach the Ideal Optics



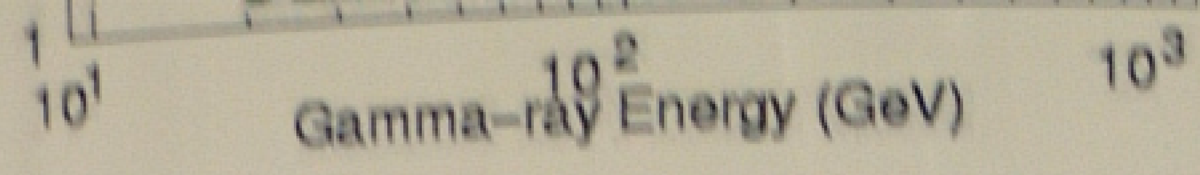
Aspherical lens (1～3) and/or Fresnel lens (1 or 2)	+	Paraboloid or Spherical

- Design software：ZEMAX (Version:XE)
- 11 types of optics are designed and evaluated

Paraboloidal Mirror + Fresnel lens (F/1)



For incidence angle of 1 degree
Rrms=0.031 deg



Definition of the Spread of the image

$$R_{r.m.s.} = \sqrt{\frac{\Sigma r_i^2}{n}}$$

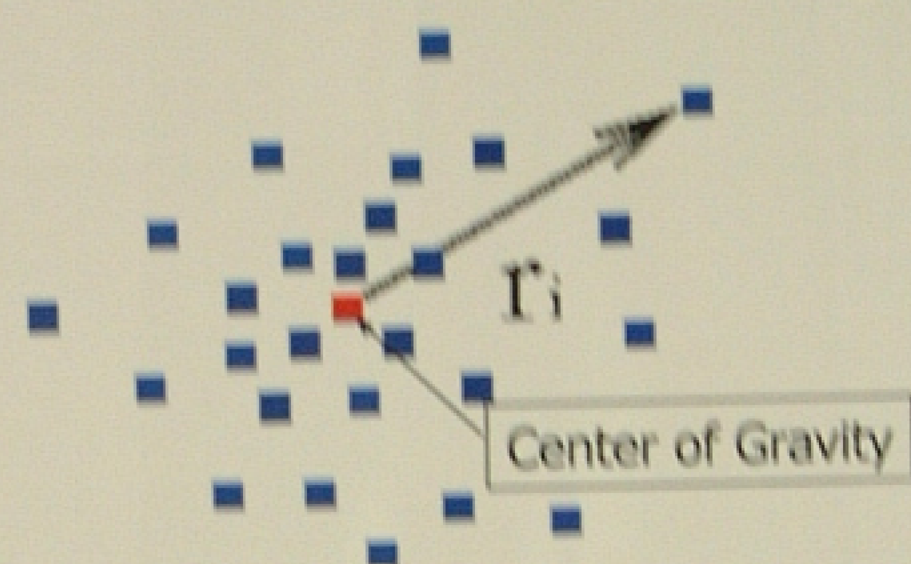
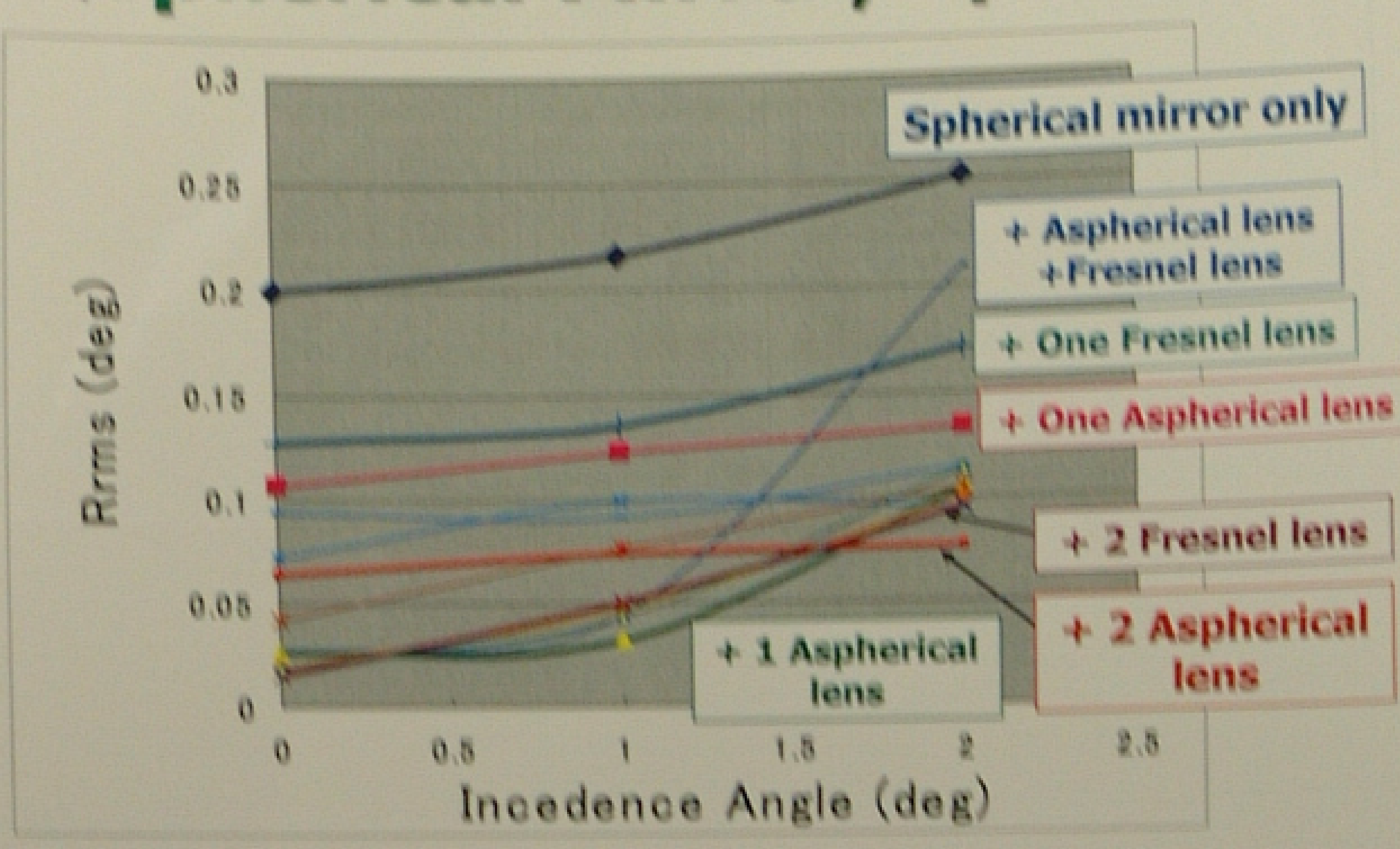
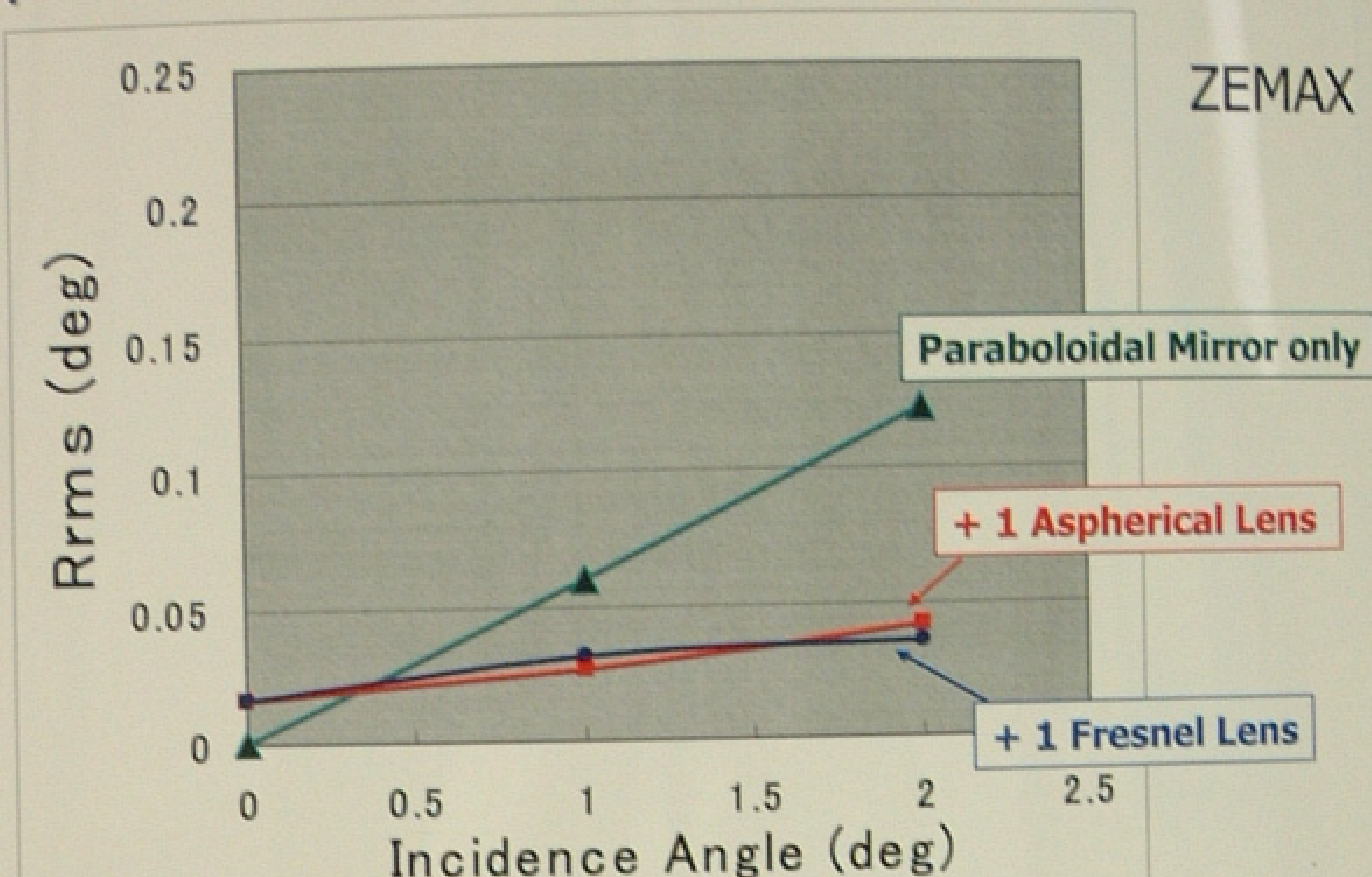


Image Spread (Spherical Mirror, F/1.0) ZEMAX



to 100 GeV can be observable.

Image Spread
(Paraboloidal Mirror, F/1.0)



Rrms : root mean square of the image spread

Results of Optical Design

For incidence angle of 1 degree

- **Paraboloidal mirror** (F/1.0)
  0.06° ⇒ 0.027°
  using an aspherical lens or a Fresnel lens
- **Spherical mirror** (F/1.0)
  0.22° ⇒ 0.031°
  using an aspherical lens

Image spread of 0.03° corresponds to roughly 18,000 pixels with 4° F.O.V.