# Upgrades of the Pierre Auger Fluorescence detector

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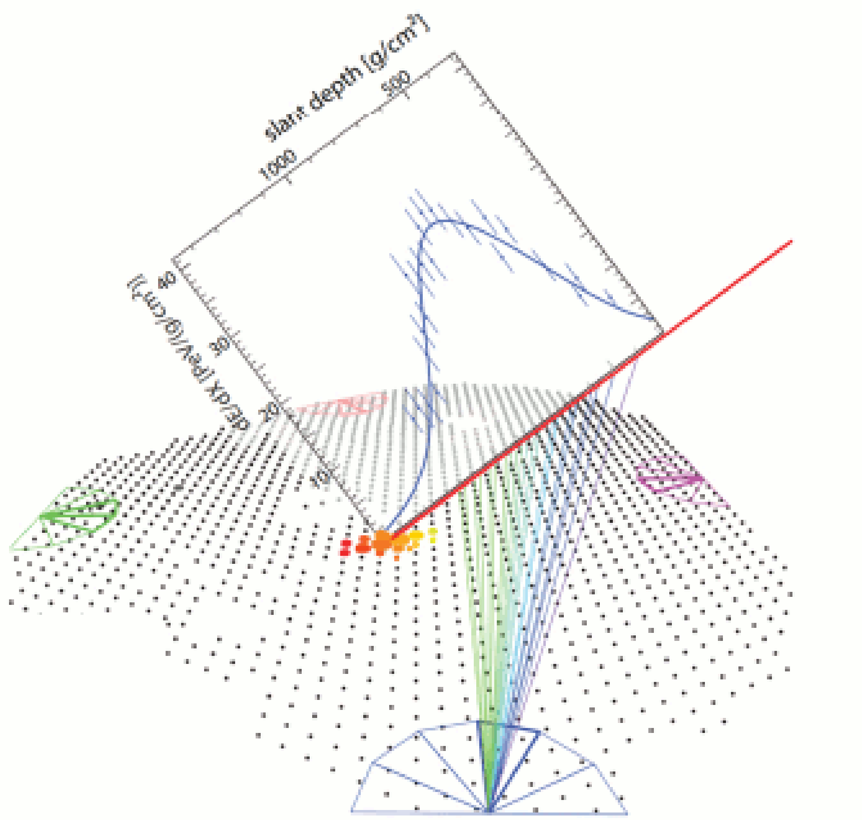
or

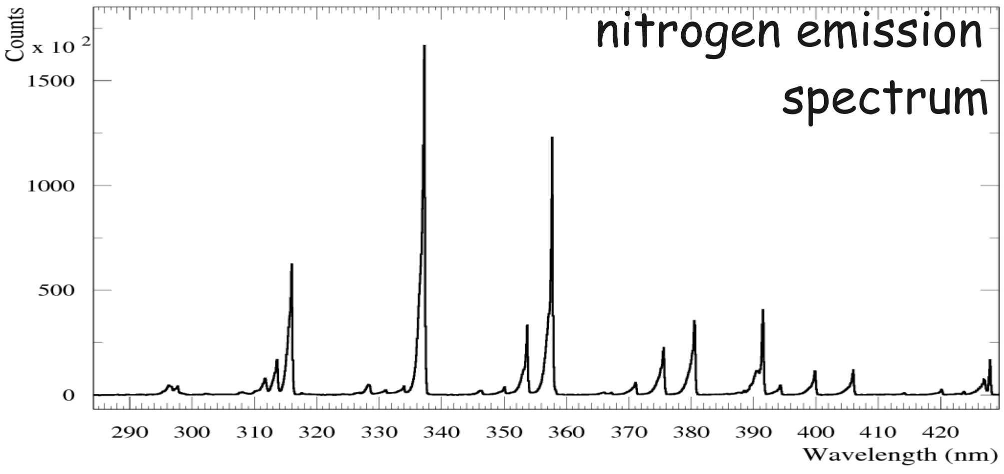
How to increase the detection statistics?

# Fluorescence technique




+ mature technique
+ isotropic emission
+ direct observation of Xmax

- weak emission in near UV range
- disturbed by parasitic light, weather, etc.
  => low duty cycle



# FD uptime

Current requirements:
1. Sun more than 18 deg below the horizon (astronomical twilight)
2. Illuminated fraction of the moon less than 70% at UTC midnight
3. The moon longer than 3 hours below the horizon

=> theoretical uptime 21%

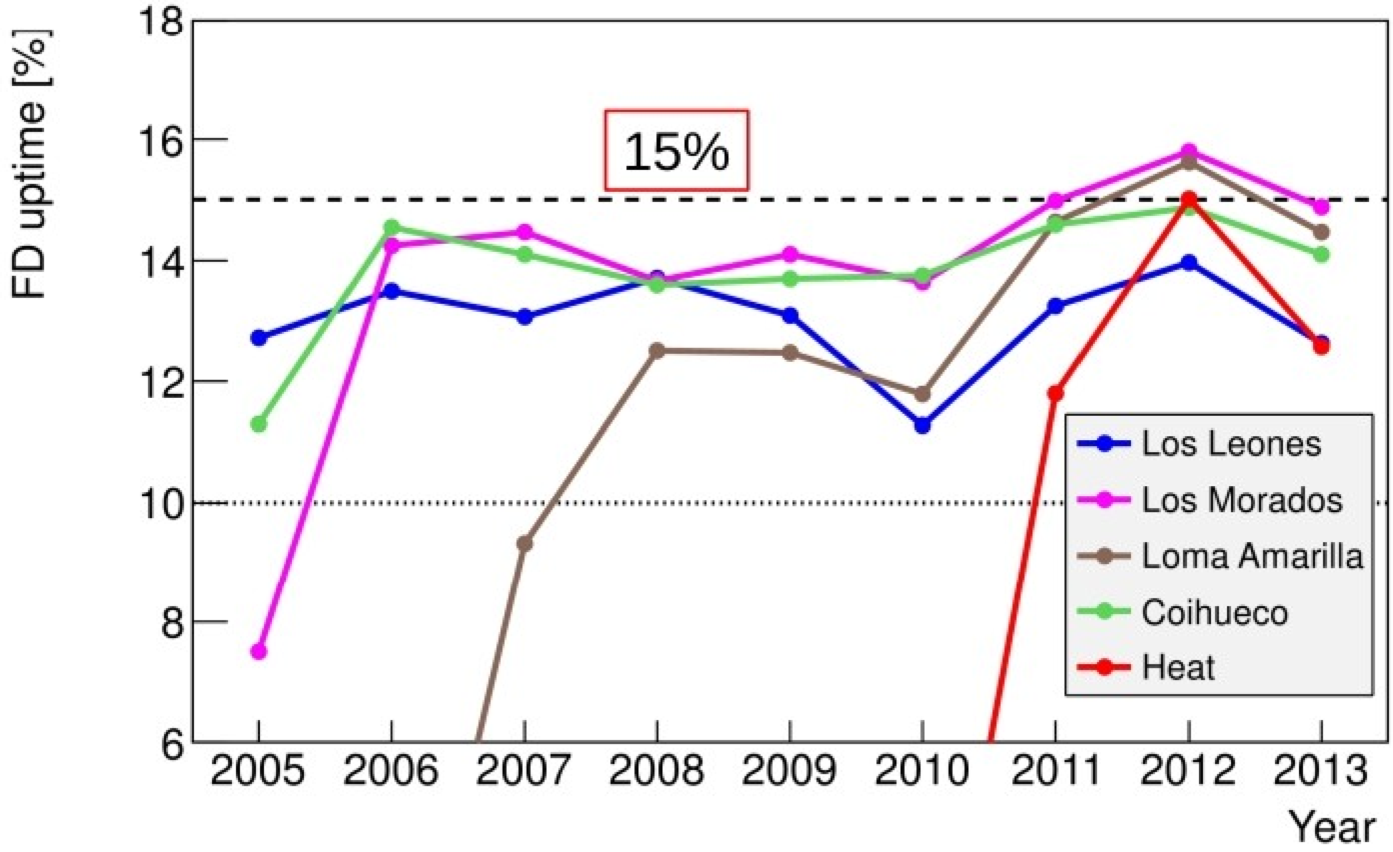
scattered moonlight !0% => 19%
weather conditions, hardware problems, etc. => further reduction

Can we relax 1.-3. in order to increase the detection efficiency at highest energies?



*M. Boháčová 29. 11. 2013*

# FD uptime




no quality cuts or bad periods considered

# FD uptime increase

Uptime increase estimate:

- Relaxing cuts on the variances: about 21%
- Relaxing all cuts on the moon: 31%
- Measurement during the astronomical twilight: 37%

(i.e. the sun lies between 12 and 18 degrees below the horizon)

In the most extreme case up to 40%

- no hardware changes needed

# laboratory tests in Karlsruhe

- light tight box
- LEDs for simulating the night sky brightness
- integrating sphere
- old FD PMTs

- changing applied high voltage
  - aging, linearity
  - performance

- Anode current recommended by the manufacturer < 10 μA
- maximum anode current allowed 200 μA

- goal: determine running conditions to meet the requirements

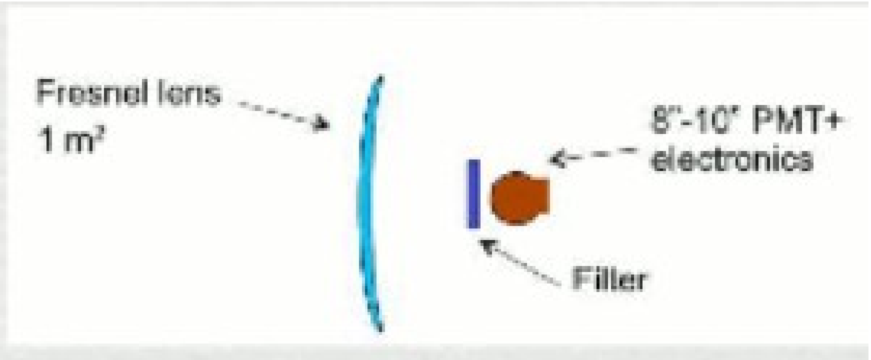
# FAST

## Fluorescence Array Single-pixel Telescopes

University of Chicago project

Basic idea:

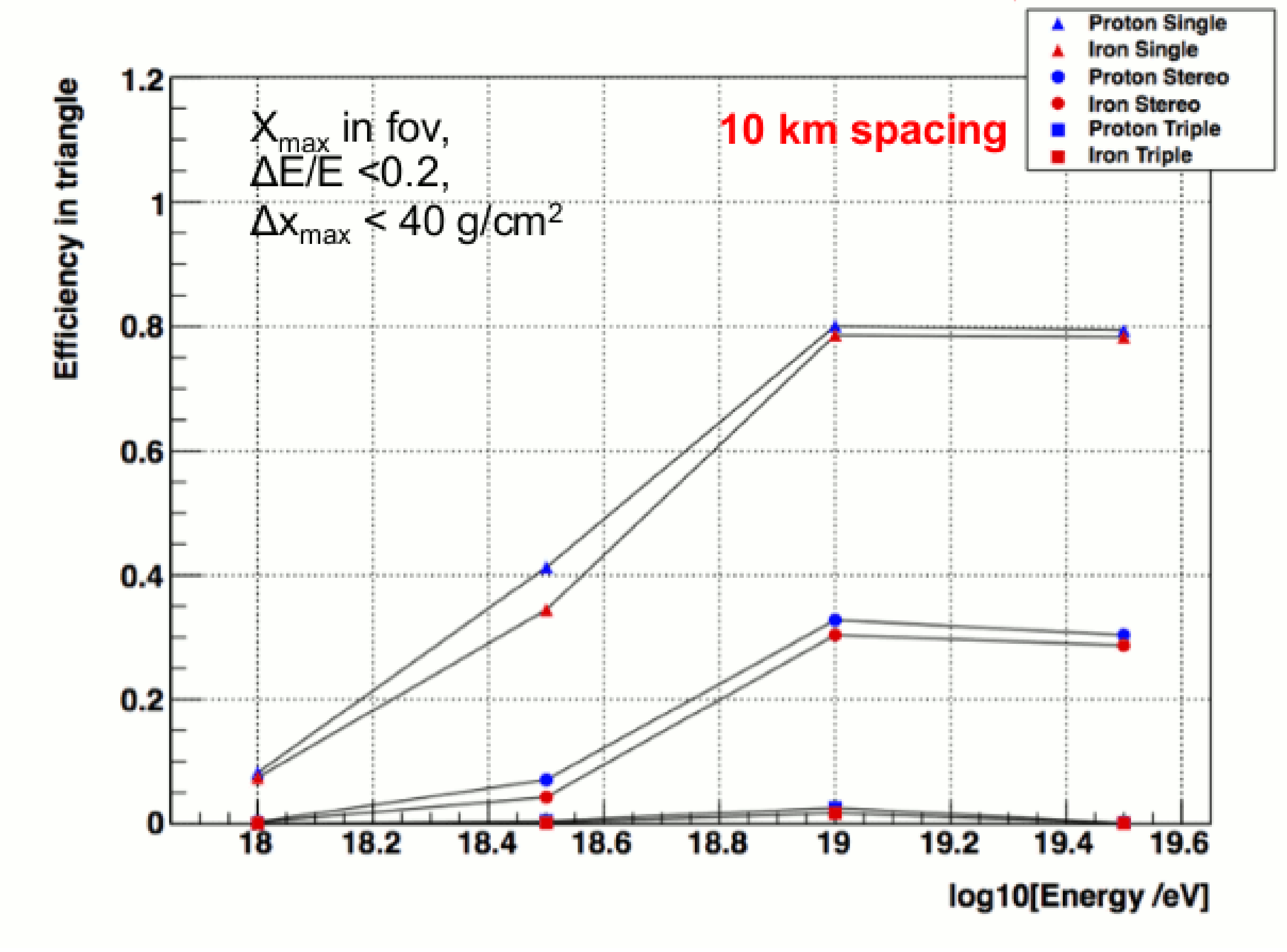
- if geometry is provided by another method
- low cost FD with few pixels
- covering large area in a regular grid
- fully efficient only at high energies




- large Fresnel lens ~1m$^2$
- large PMT ~ 10 inch
- four PMTs form a telescope
- 12 telescopes (360°) form a station
- regular grid with 10 to 20 km spacing

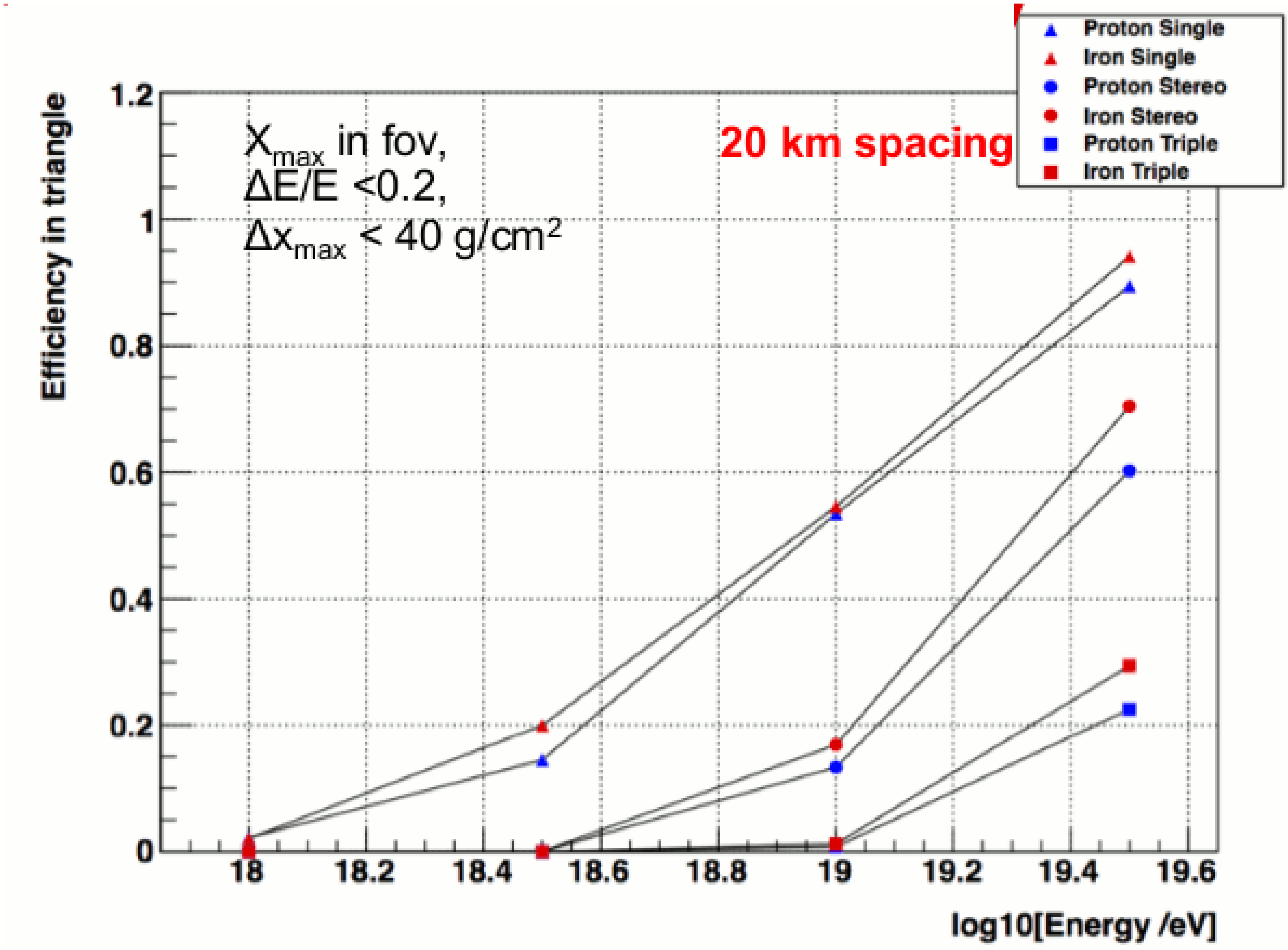
# FAST

## reconstruction efficiency

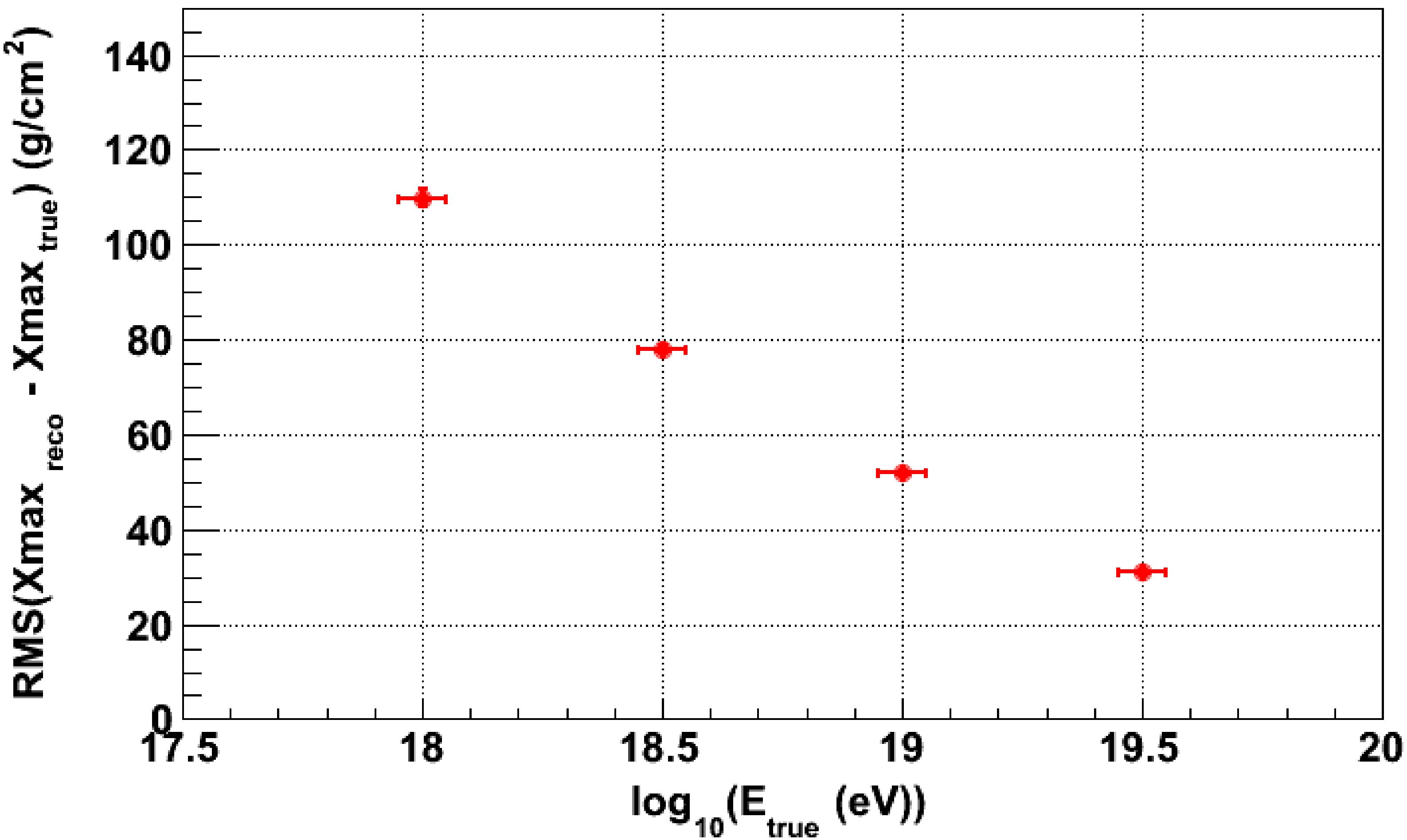


# FAST

## reconstruction efficiency



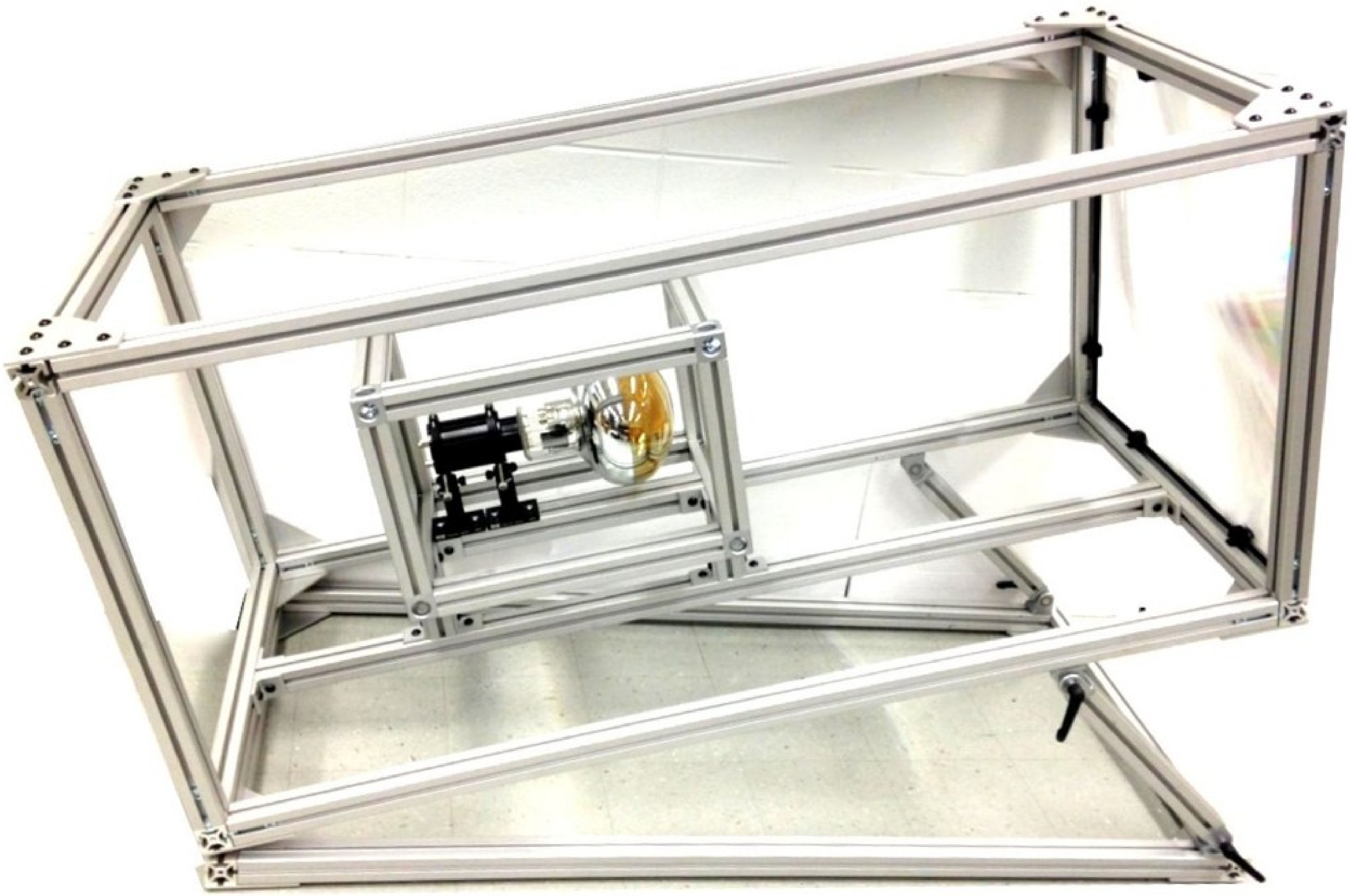
# FAST
# Xmax resolution




30 $g/cm^2$ @$10^{19.5}$ eV (Auger FD 25 $g/cm^2$[i])

# FAST

## prototype



# FAST

## prototype testing plans

- assemble the UV filter and Winston cone
- tests in Colorado facility using laser
- proposal to test at TA site with laser, electron beam and real showers and compare to TA

# FAMOUS

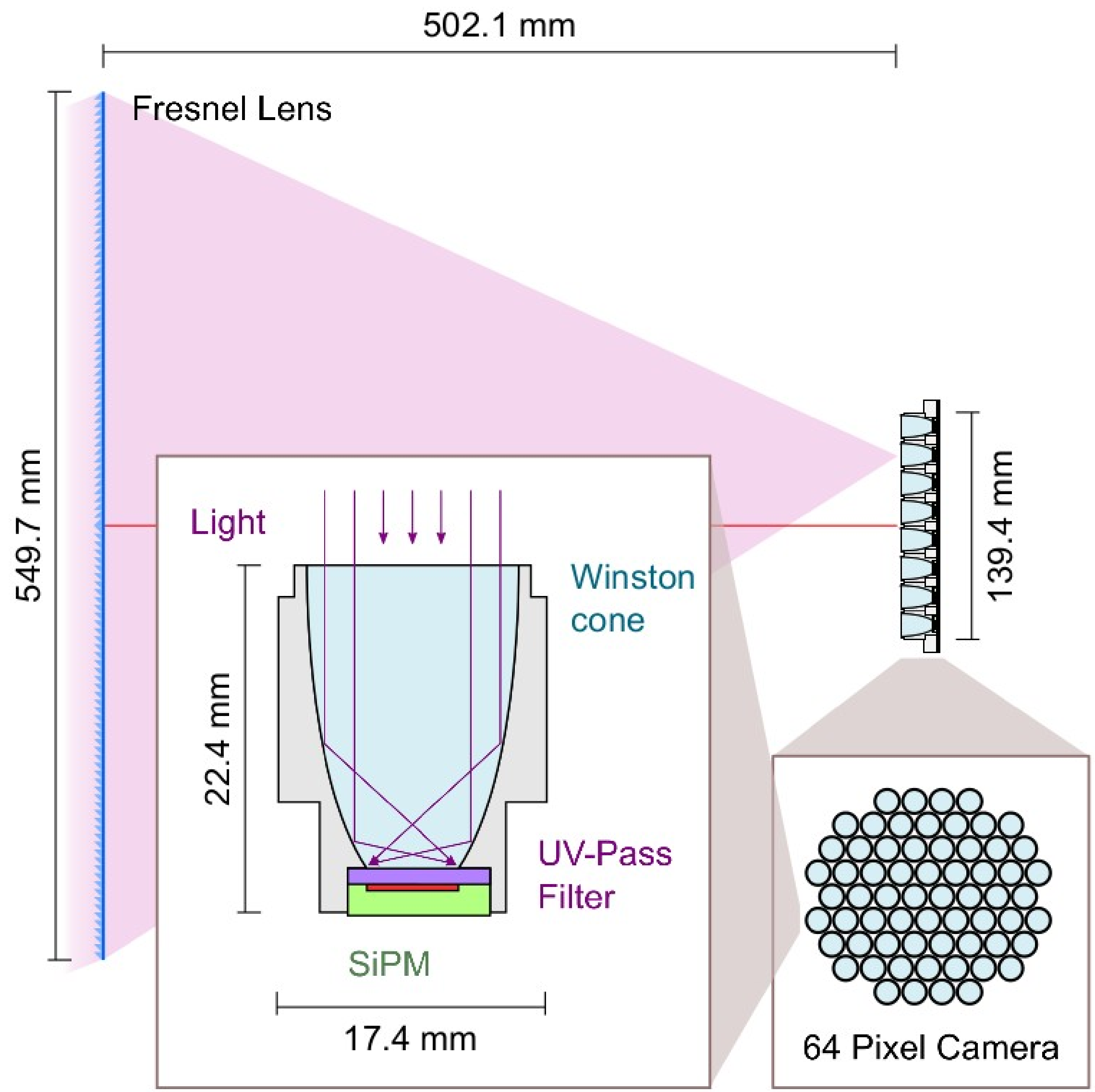
**F**irst **A**uger **M**ulti-pixel-photon-counter-camera for the **O**bservation of **U**ltra-high-energy-cosmic-ray air **S**howers

Basic idea:

- low cost
- compact
- easily deployable

RWTH Aachen
University project

# FAMOUS



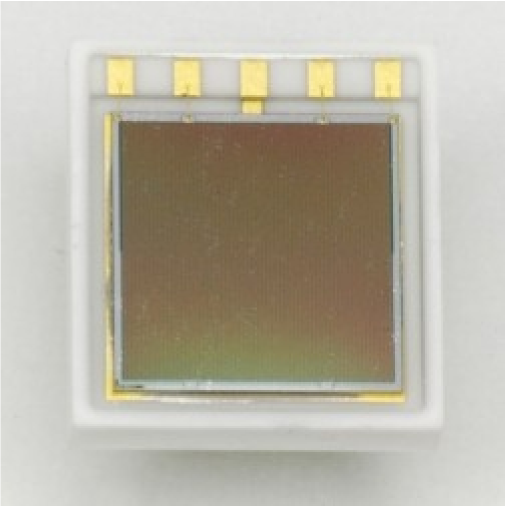

Large Fresnel lens as refractor
Pixel = Light funnel (Winston cone) + four 3 × 3 mm2 SiPMs (Hamamatsu S10985-100C)
1.5 ° field of view per pixel
12 ° field of view in total

Transmission efficiency of the Fresnel lens ≈ 70 %
Transmission efficiency of the system w/o SiPMs ≈ 55 % (comparable to Auger FD w/o PMTs)

# SiPM

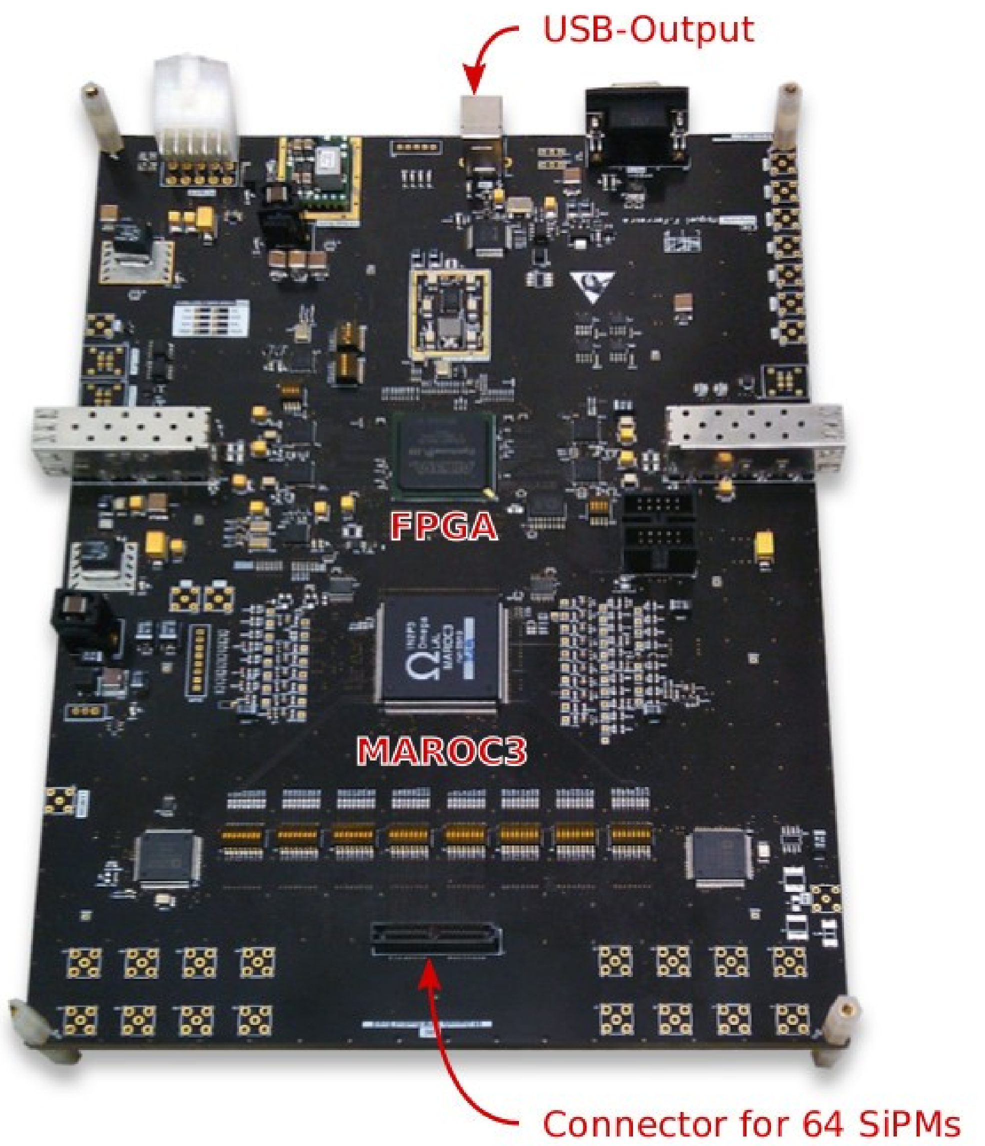
- matrix of Geiger-mode avalanche photodiodes (GAPD)
- each giving a standard signal – 1 photon equivalent (1 p.e.)
- sum of all fired GAPDs presents the SiPM signal
- up to 1000 GAPDs on one SiPM => defines the dynamic range of SiPM

+ low voltage operation < 100 V   (PMT ~ 1000V) at similar gain
+ photon detection efficiency up to 60%  (latest PMTs ~40%)
+ mass production will lower the cost significantly
+ insensitive to magnetic field
+- very small size (few millimeters)



- temperature dependent (thermal noise)
- optical crosstalk
- afterpulses

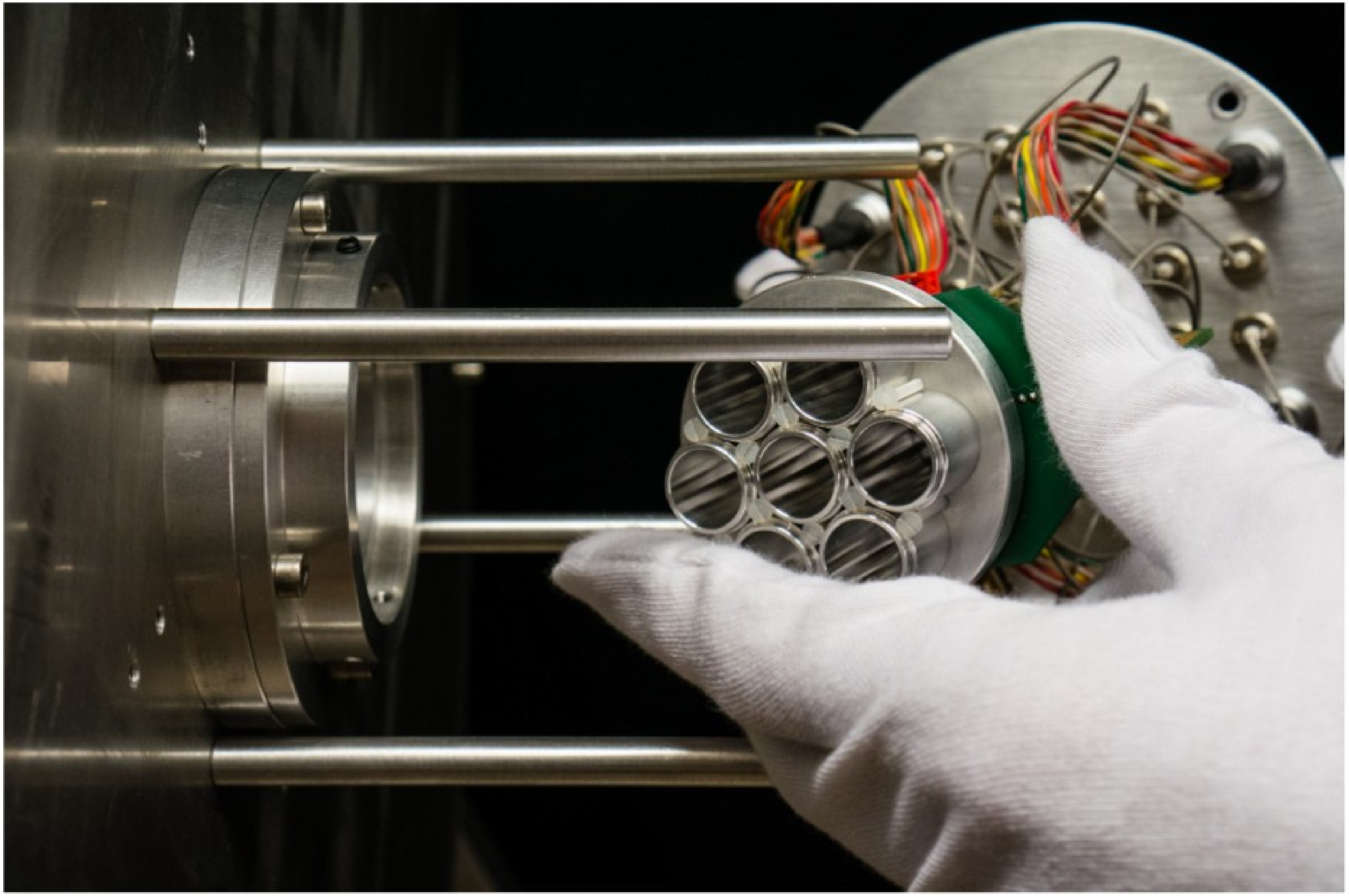
# FAMOUS
# readout electronics




- Based on MAROC3 chip
- 64 channels (2 discriminators each)

- ADC for digital readout
- Individual control of bias voltage for each pixel
- FPGA handles all digital functions including trigger
- USB output

# FAMOUS$^{SEVEN}$ prototype



# Conclusions

- new ideas using fluorescence technique were presented
- promising to increase detection efficiency at highest energies
- microwave detection does not prove viable (previous talk)

- keep looking for a new and better technique