USING THE FD TELESCOPES TO DETECT THE MICROWAVE RADIATION PRODUCED BY ATMOSPHERIC SHOWERS

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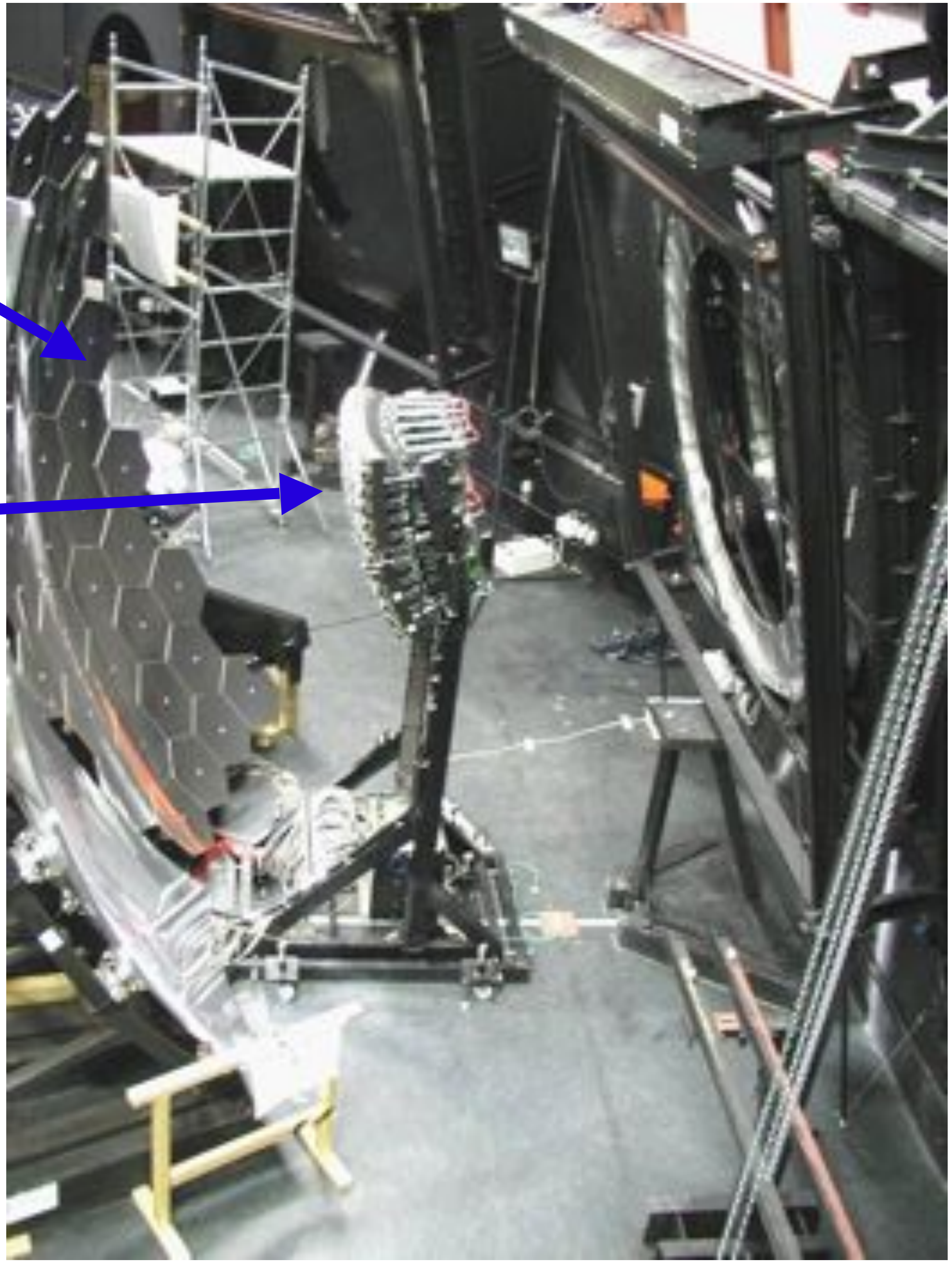
INFN Roma
And
INFN LNGS

Coimbra, September 2010

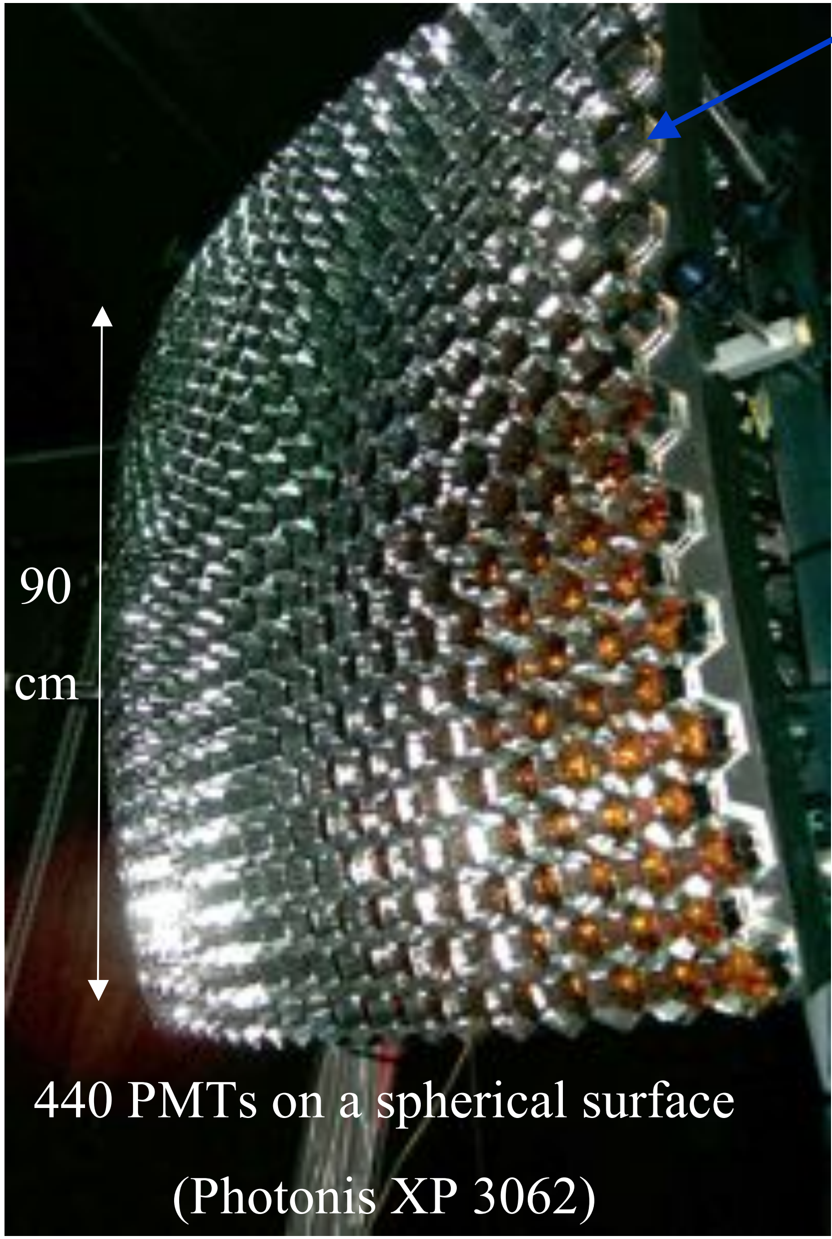
FD Telescope

- Spherical mirror with radius of curvature of 3.4 m
- Camera of pmt placed on a spherical focal surface with a FOV ~ 30°x30°

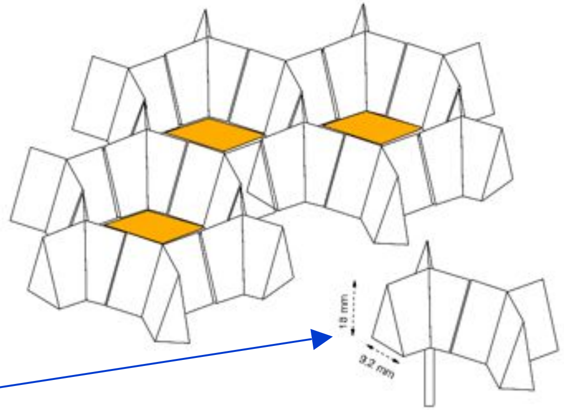


B. Dawson [Pierre Auger Collaboration], Proc. 30th ICRC, Mérida, (2007) #0976, arXiv:astro-ph/0706.1105.

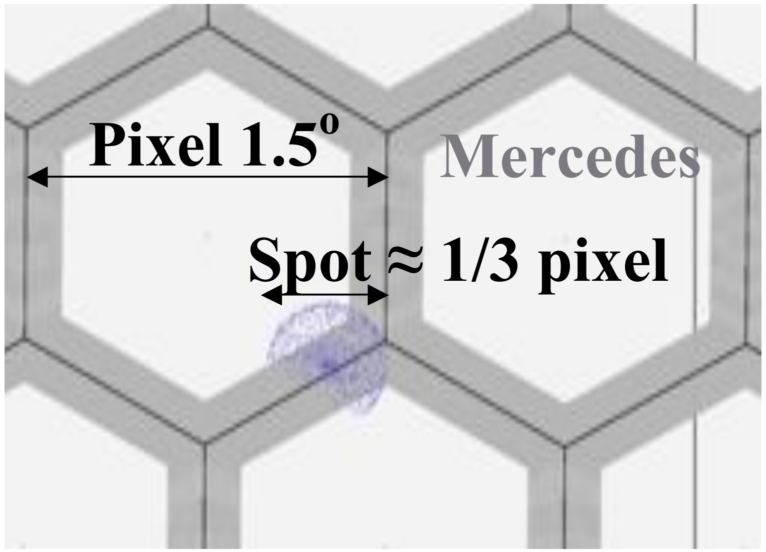
FD camera



light collectors to recover border inefficiencies



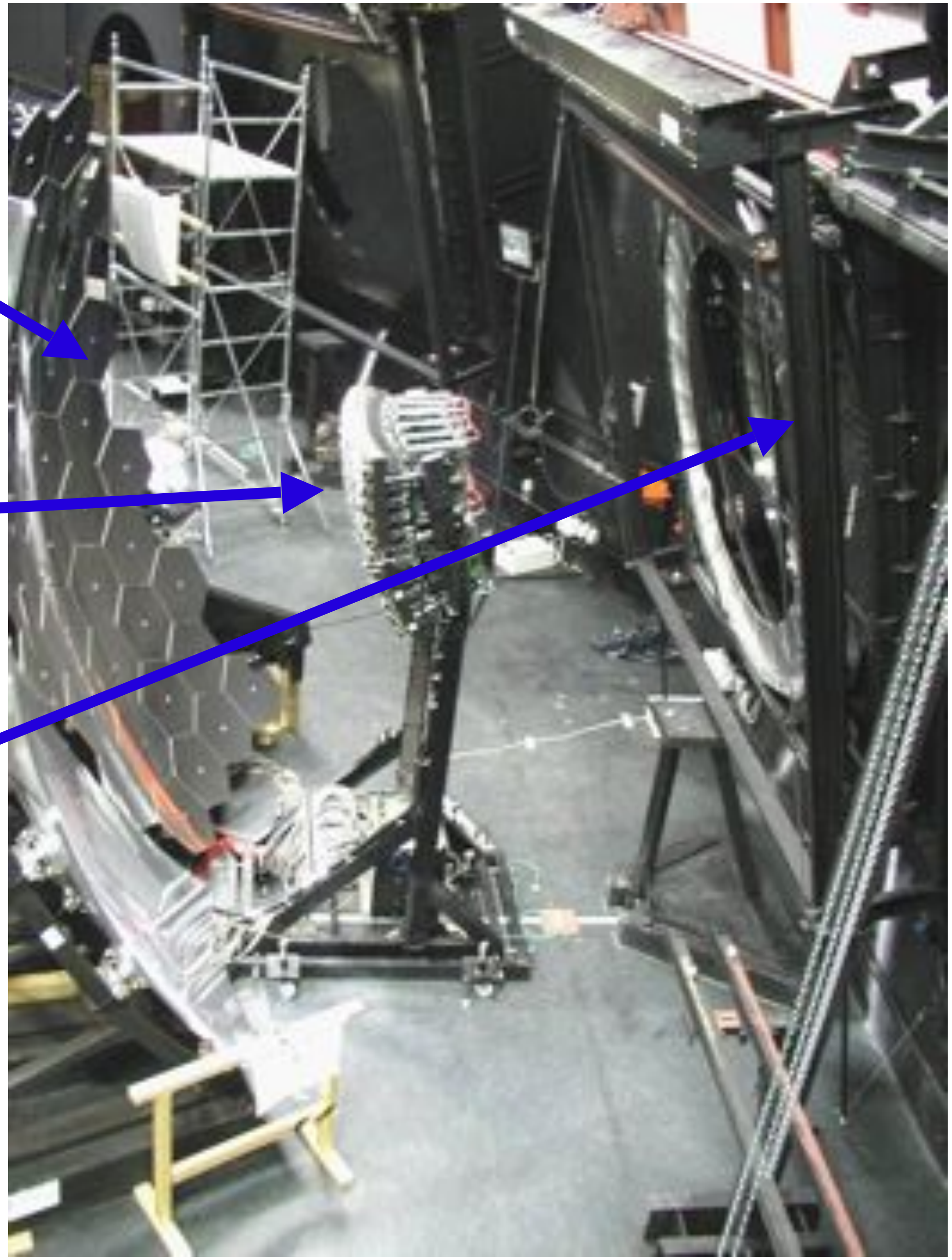
"mercedes star" with aluminized mylar reflecting walls



→ Auger FD: 10560 PMTs

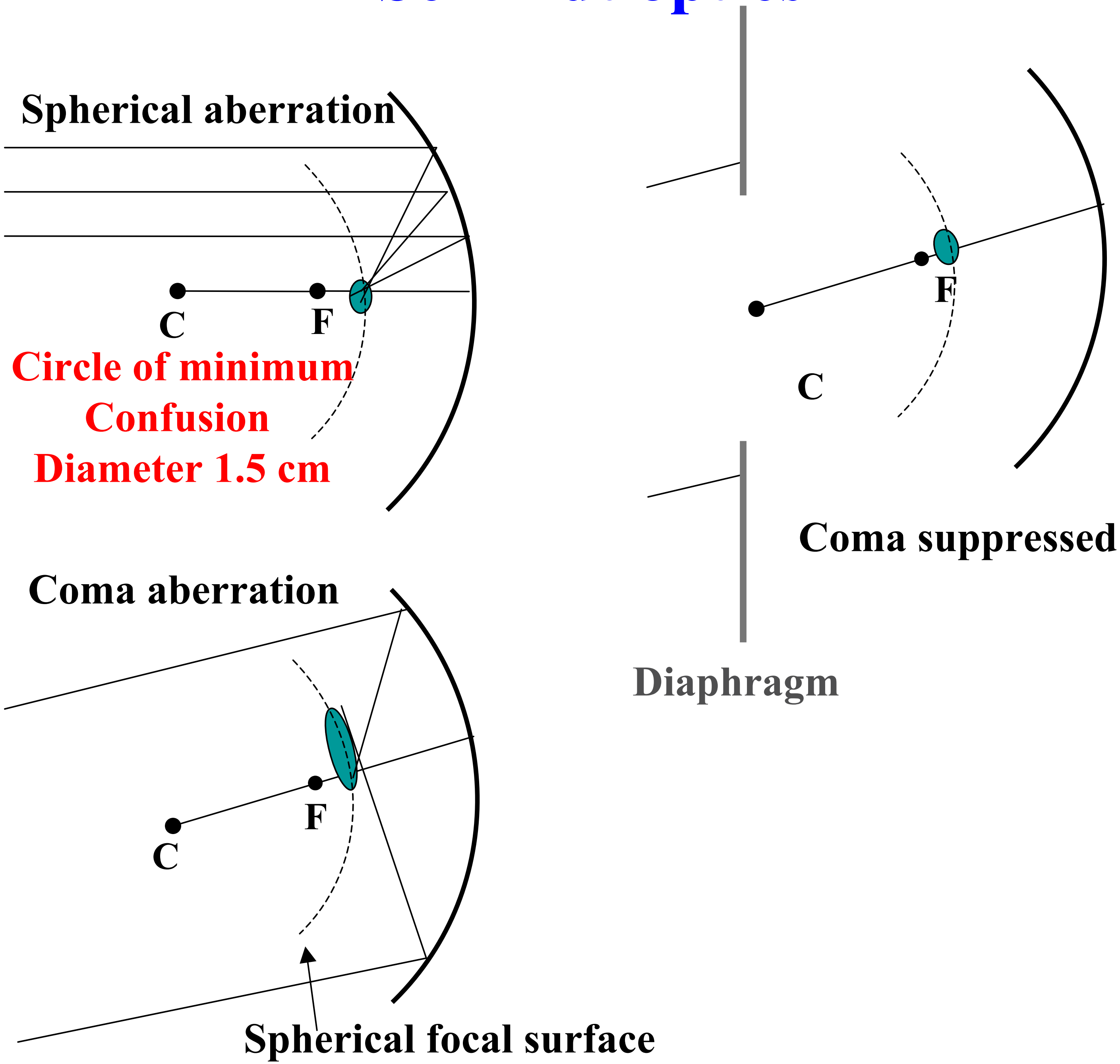
FD Telescope

- Spherical mirror with radius of curvature of 3.4 m
- Camera of pmt placed on a spherical focal surface with a FOV ~ 30°x30°
- Diaphragm with diameter of 2.2 m



B. Dawson [Pierre Auger Collaboration], Proc. 30th ICRC, Mérida, (2007) #0976, arXiv:astro-ph/0706.1105.

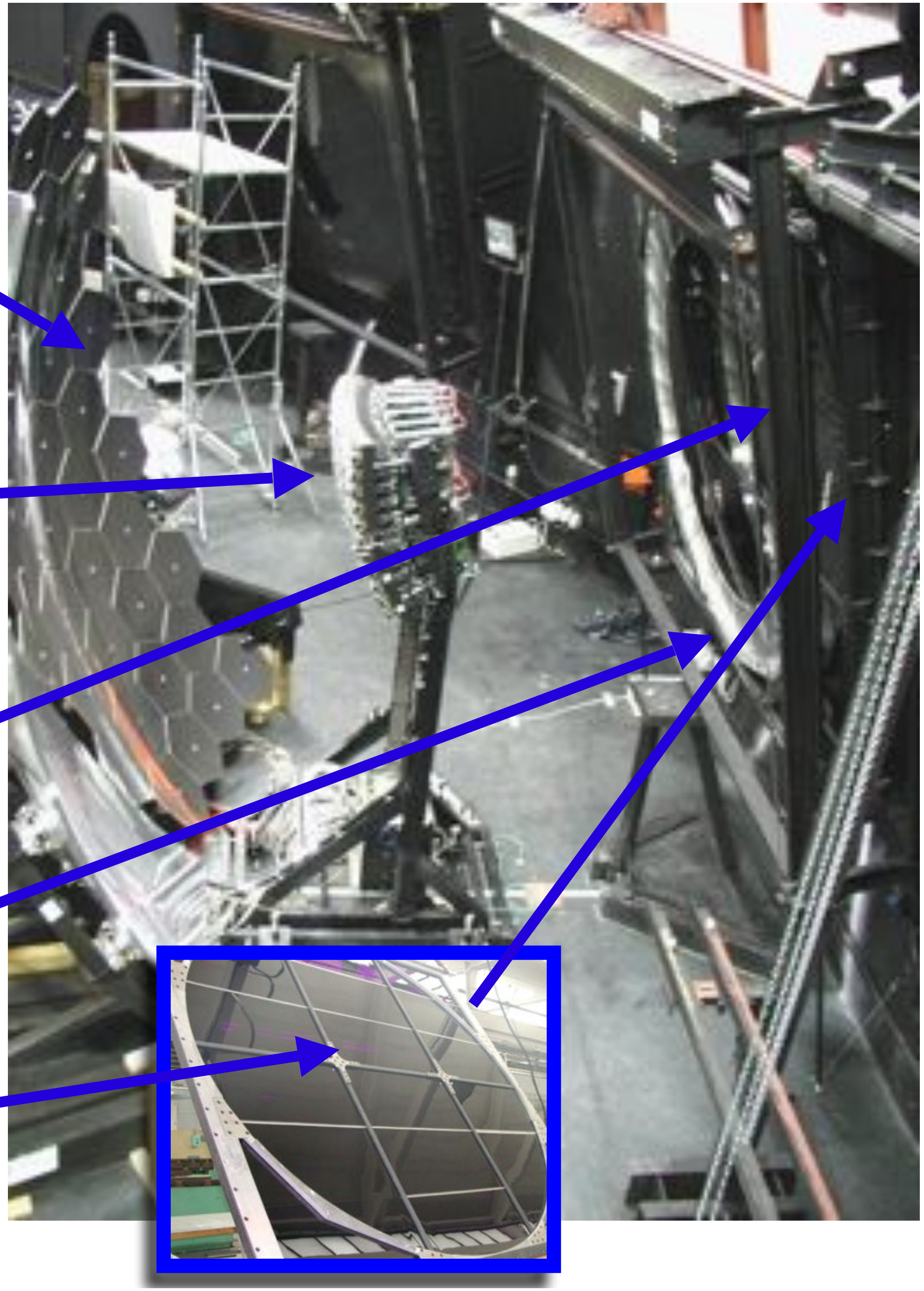
Schmidt optics



FD Telescope

- Spherical mirror with radius of curvature of 3.4 m
- Camera of pmt placed on a spherical focal surface with a FOV ~ 30°x30°
- Diaphragm with diameter of 2.2 m
- Corrector ring to increase the aperture

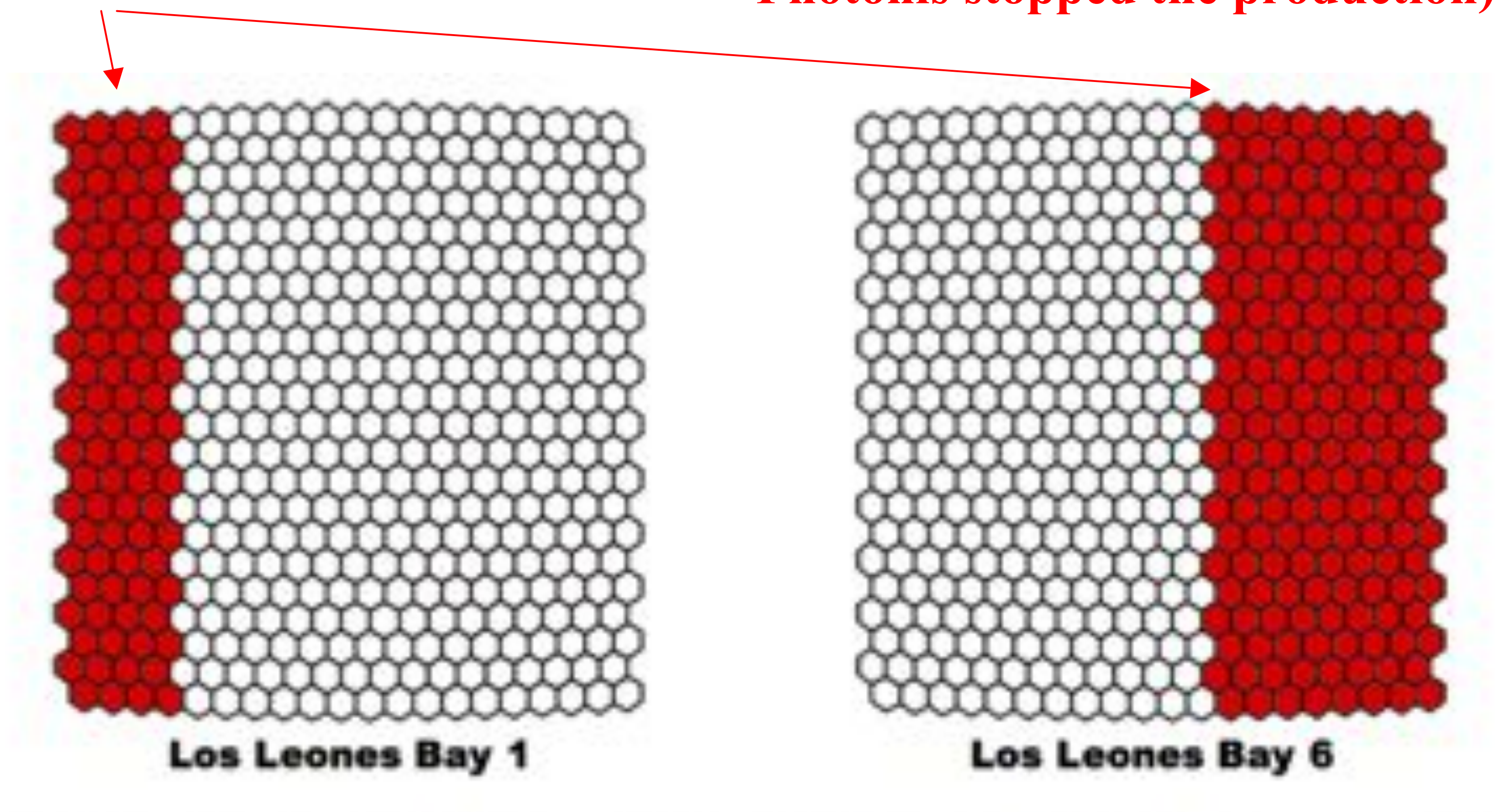
+ UV optical filter



B. Dawson [Pierre Auger Collaboration], Proc. 30th ICRC, Mérida, (2007) #0976, arXiv:astro-ph/0706.1105.

FDWAVE

Pixels without photomultipliers (removed to be installed in HEAT -
- Photonis stopped the production)

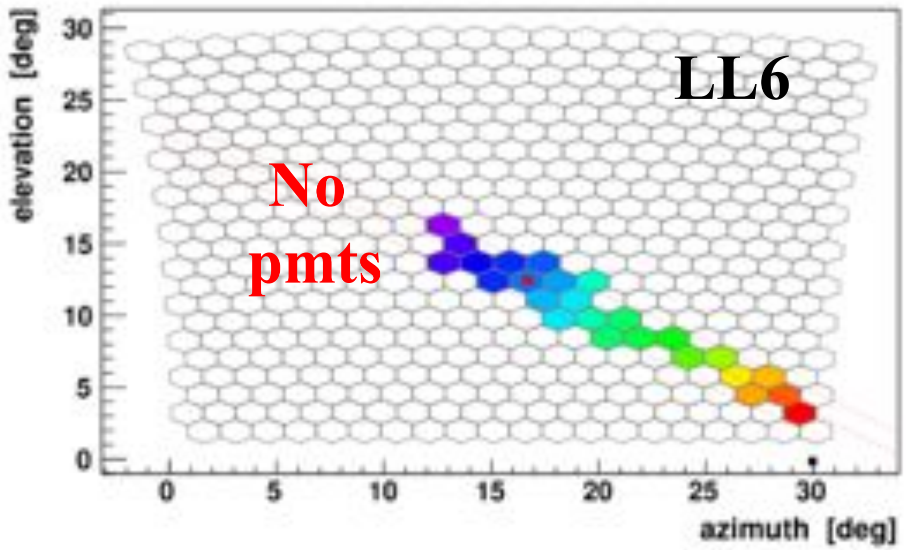


220 pixels available (not considering the columns adjacent to pmts)

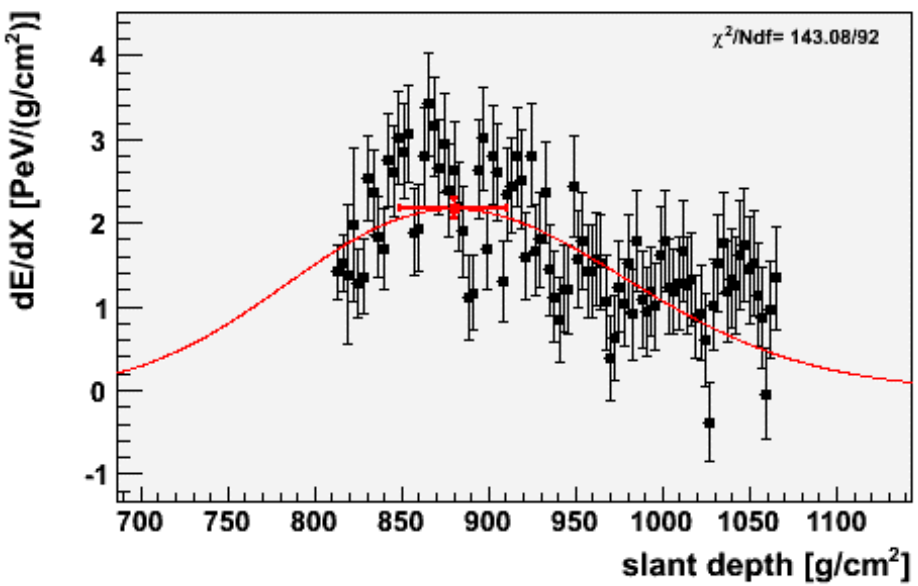
<u>Use LL1 & LL6 to detect microwave radiation equipping the empty pixels with microwave radio receivers</u>

FDWAVE

Use the standard FD trigger and readout the radio receivers every FD shower candidate



Use the profile reconstructed with pmts to estimate the energy deposit seen by radio receivers

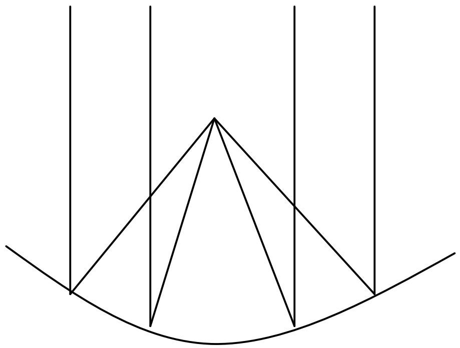


Optics

<u>Reflector</u>

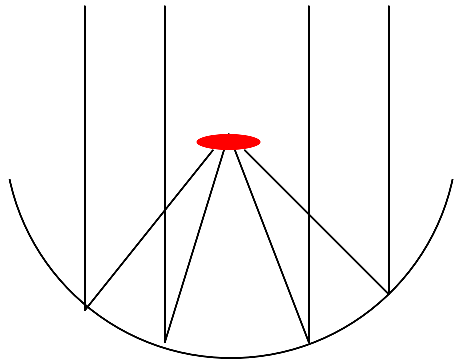
LL mirrors are produced with aluminium --> good reflectivity

Parabolic
microwave telescope



in the focus all rays
have the same phase!

Spherical
FD



spherical
aberration

A Schmidt-Camera for Radio Waves

February 1953

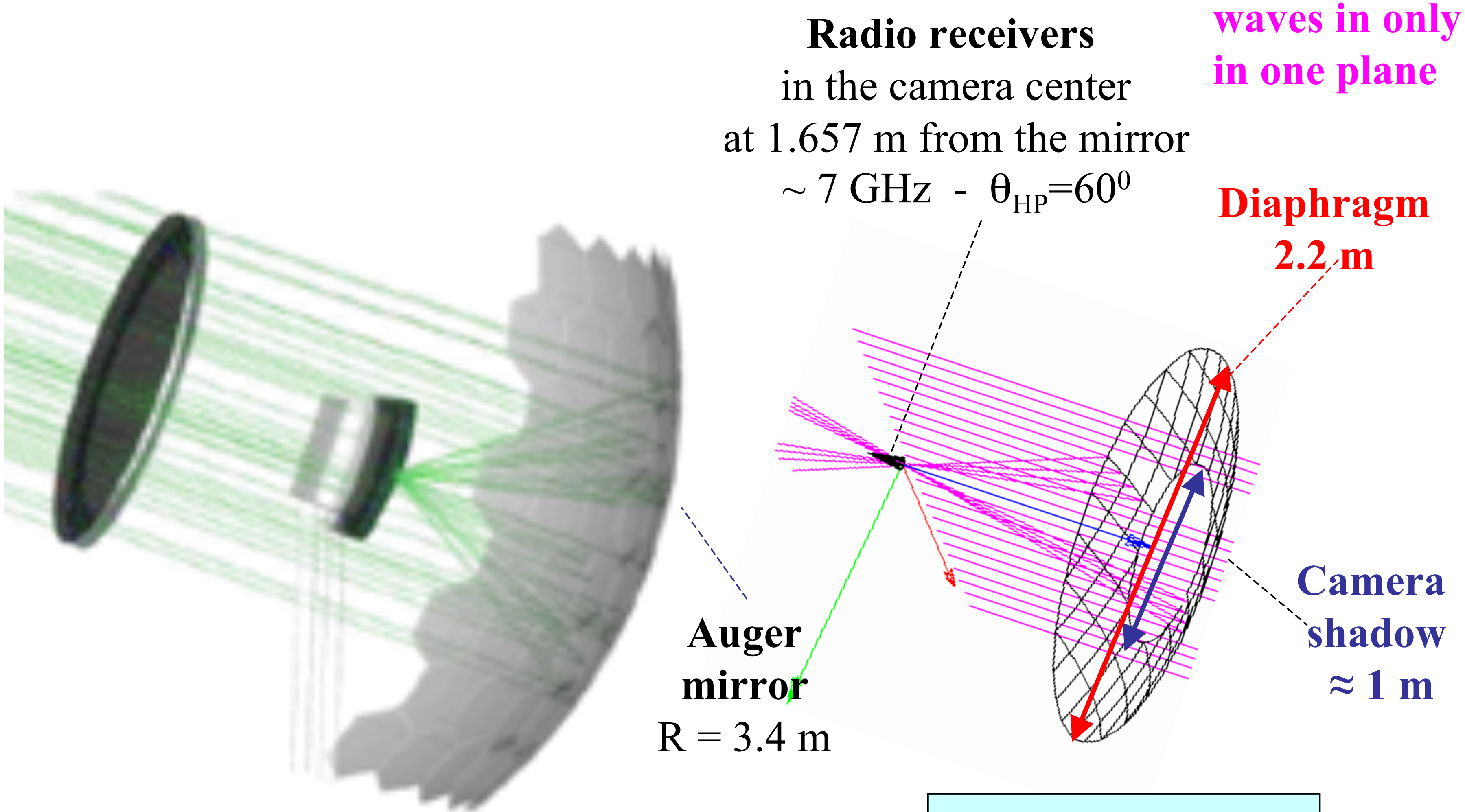
JAAKKO TUOMINEN.

BUT:

the parabolic dish is not suitable for track imaging purposes
because of the strong aberrations for inclined rays

$\Rightarrow$ <u>the best reflector is spherical !!!</u>

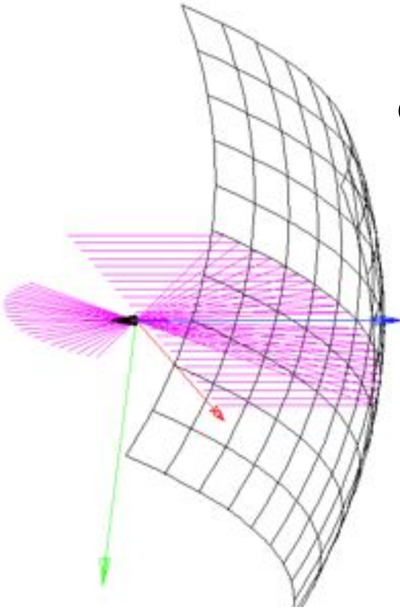
FD optics simulation

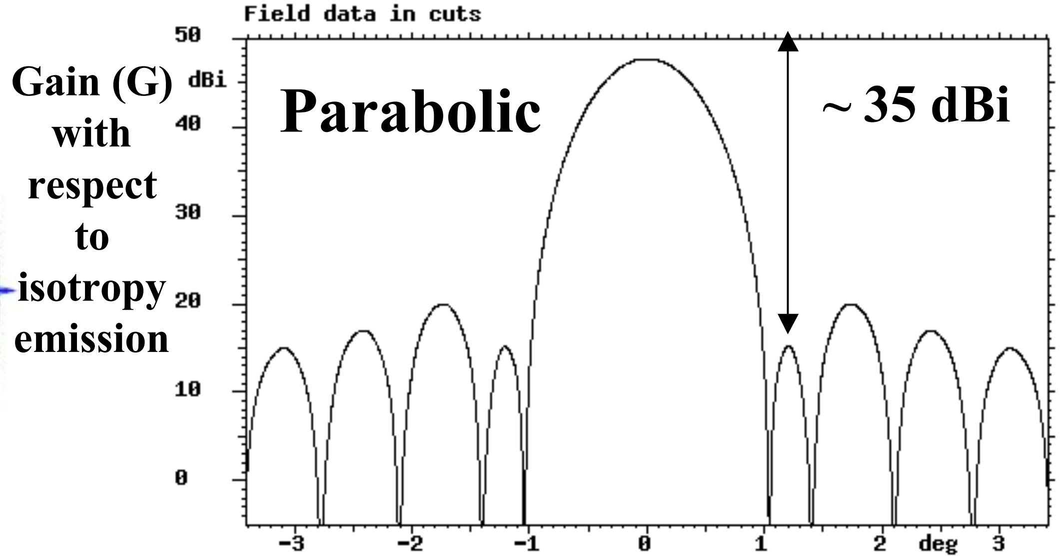


GRASP

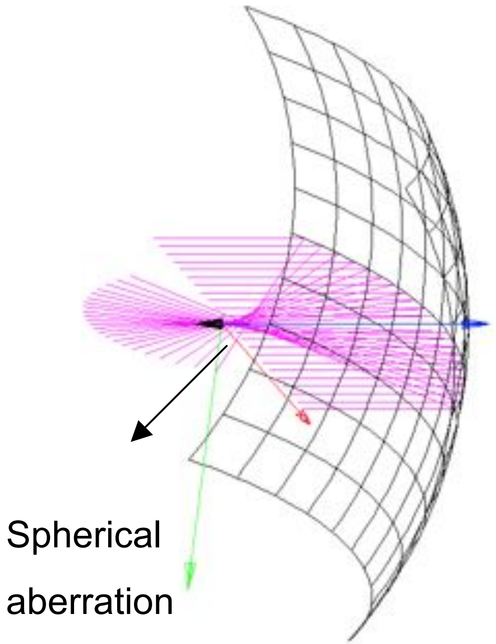
www.ticra.com

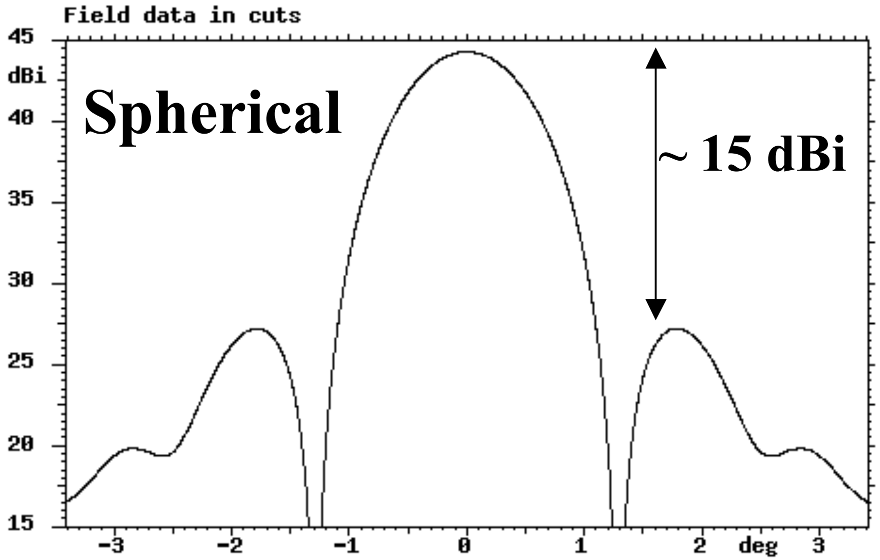
Simulation without Diaphragm and Camera shadow





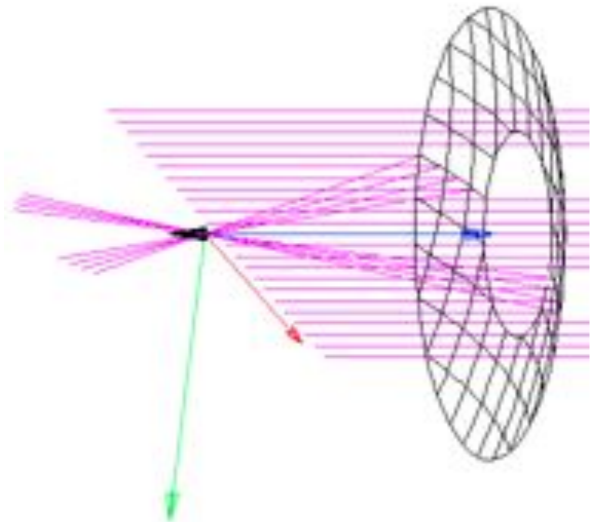
Parabolic it's better than spherical



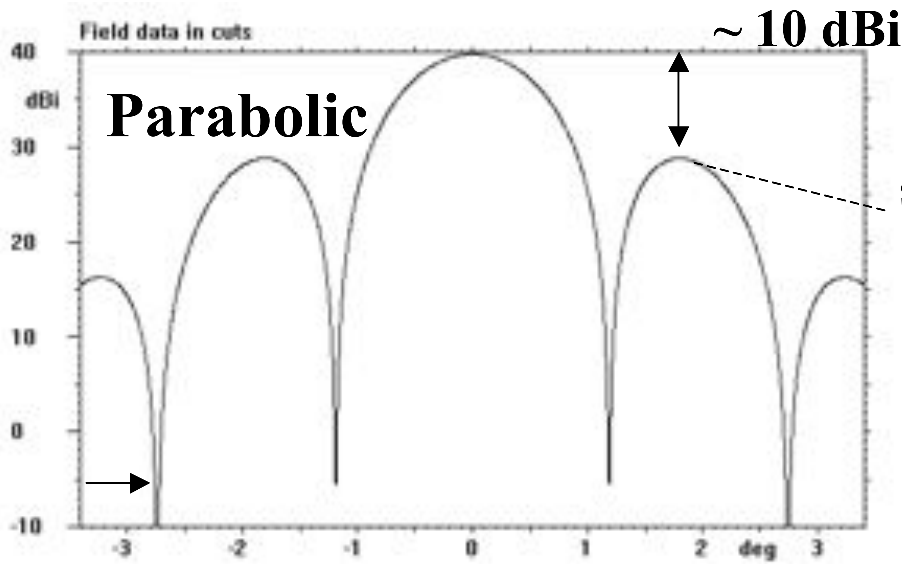


viewing angle

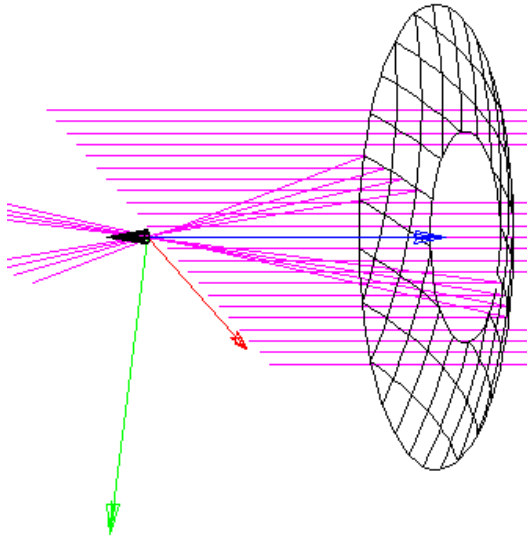
Simulation with Diaphragm and Camera shadow

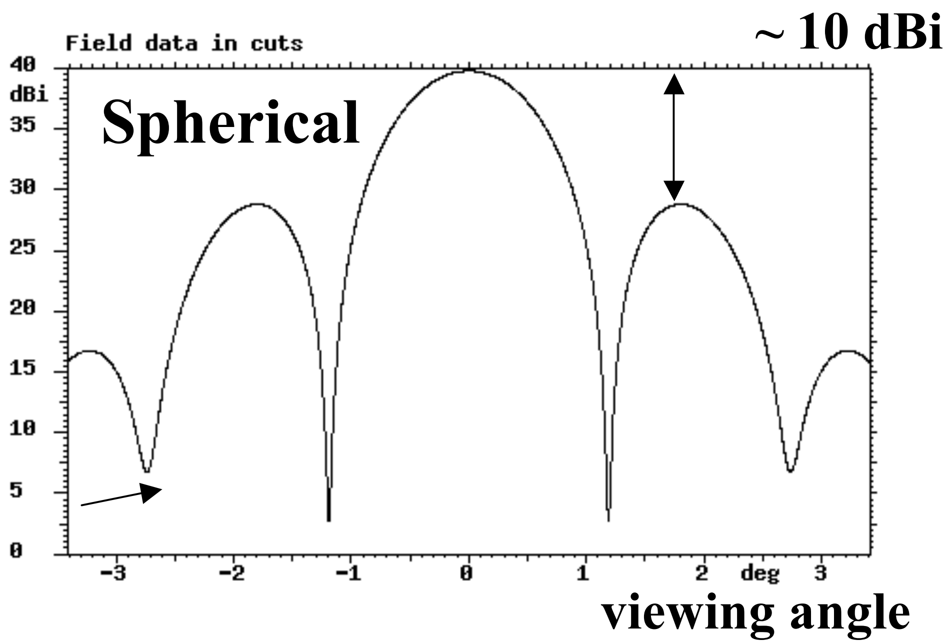


Gain (G) with respect to isotropy emission

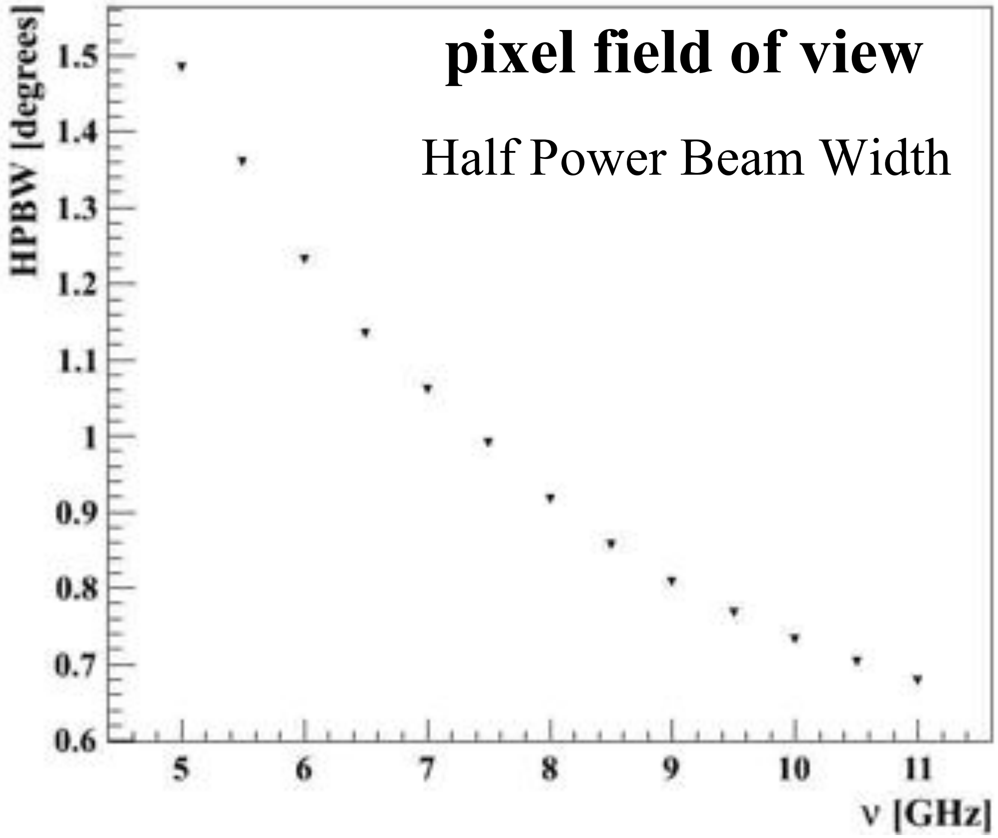


secondary lobes due mainly to camera shadow





Optimal Wavelenght

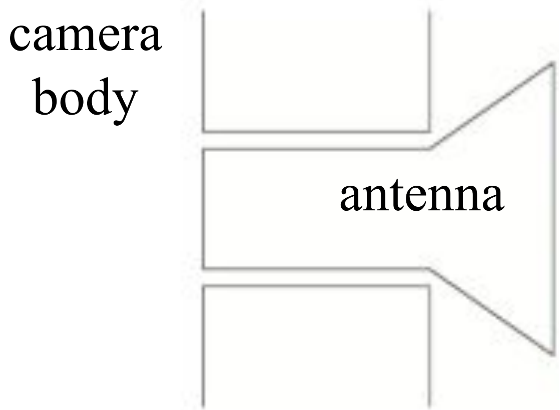


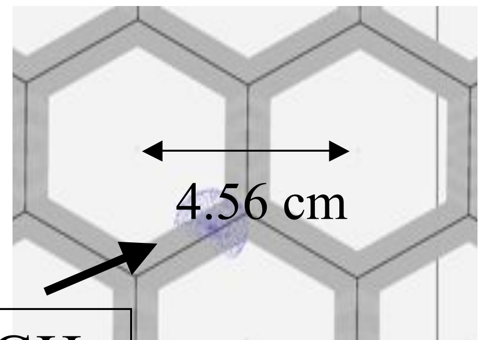
optimal ν

1.5^0: 5 GHz

⇔ 6 cm

inserting antenna
in camera holes
⇒ <u>lower limit on ν</u>





> 6.6 GHz

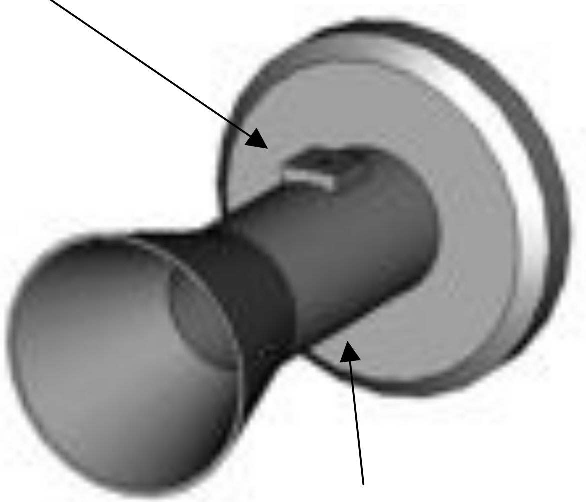
Antenna

Conical Horn in the frequency range [9-11] GHz

(0.7^0-0.8^0)

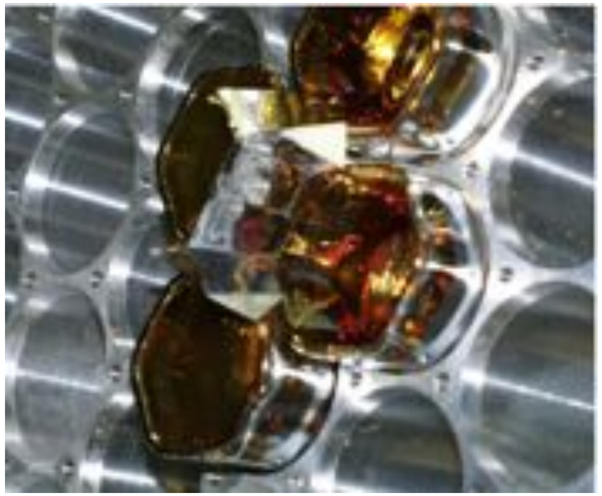
support
(can be removed)

connector for
output signal
(can be put in
another position)



circular aperture
∅ 42 mm
(<a)

waveguide
∅ 24.5 mm
(<b)



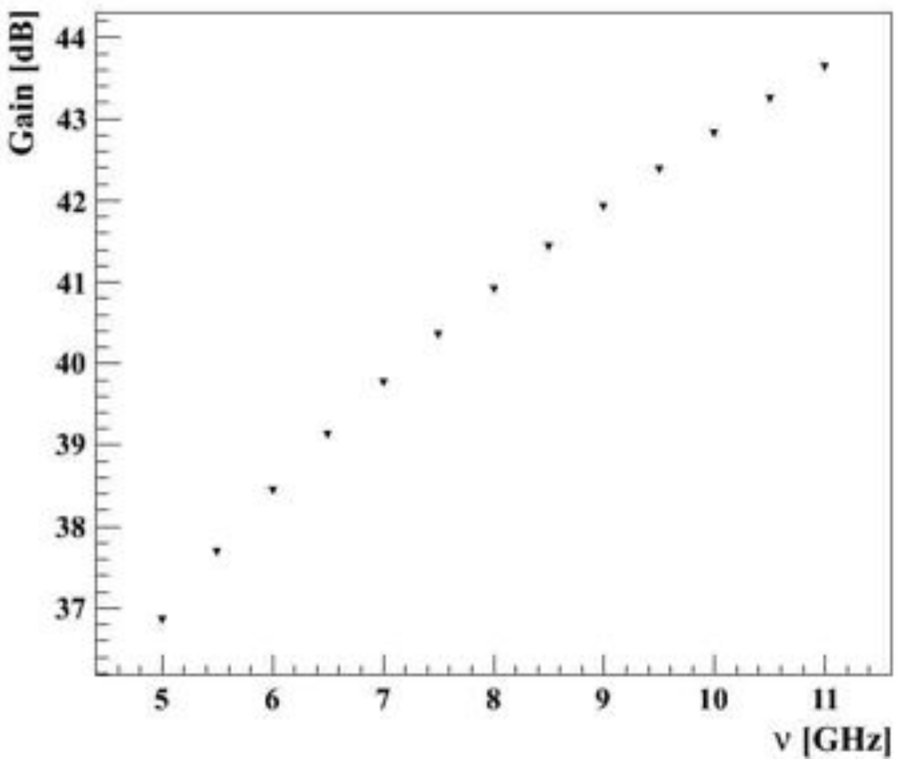
camera holes b=38 mm

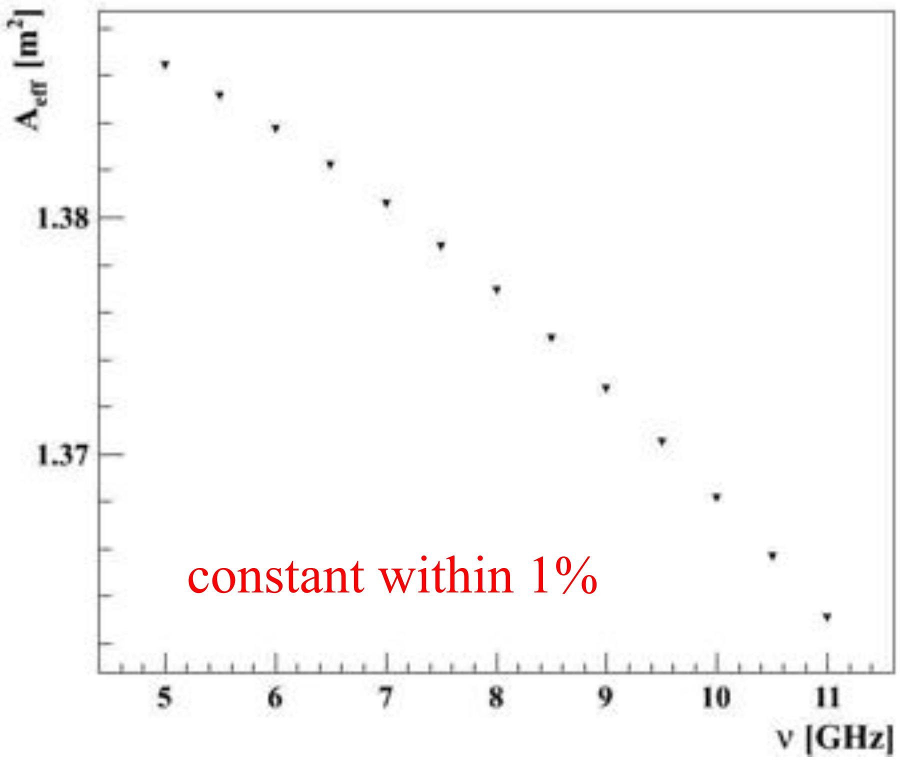
maximum aperture a=45.6 mm

Contacts with SATIMO experts to lower the frequency

Telescope Aperture

aperture from Gain $$A_{eff} = \frac{\lambda^2 G}{4\pi}$$





efficiency factor $$A_{eff} = \eta\left[\pi\left(\frac{D}{2}\right)^2 - 0.85\right]$$ $\eta \approx 50\%$

Signal / Background

Expected flux density

P.W.Gorham et al.,
Phys.Rew. D78, 032007 (2008)

$$I \approx \left(\frac{E[EeV]}{0.34}\right)^{\alpha} \frac{1}{R[km]^2}\; 3\cdot 10^{-22}\, \frac{W}{m^2 Hz}$$

α: 1÷2

Background

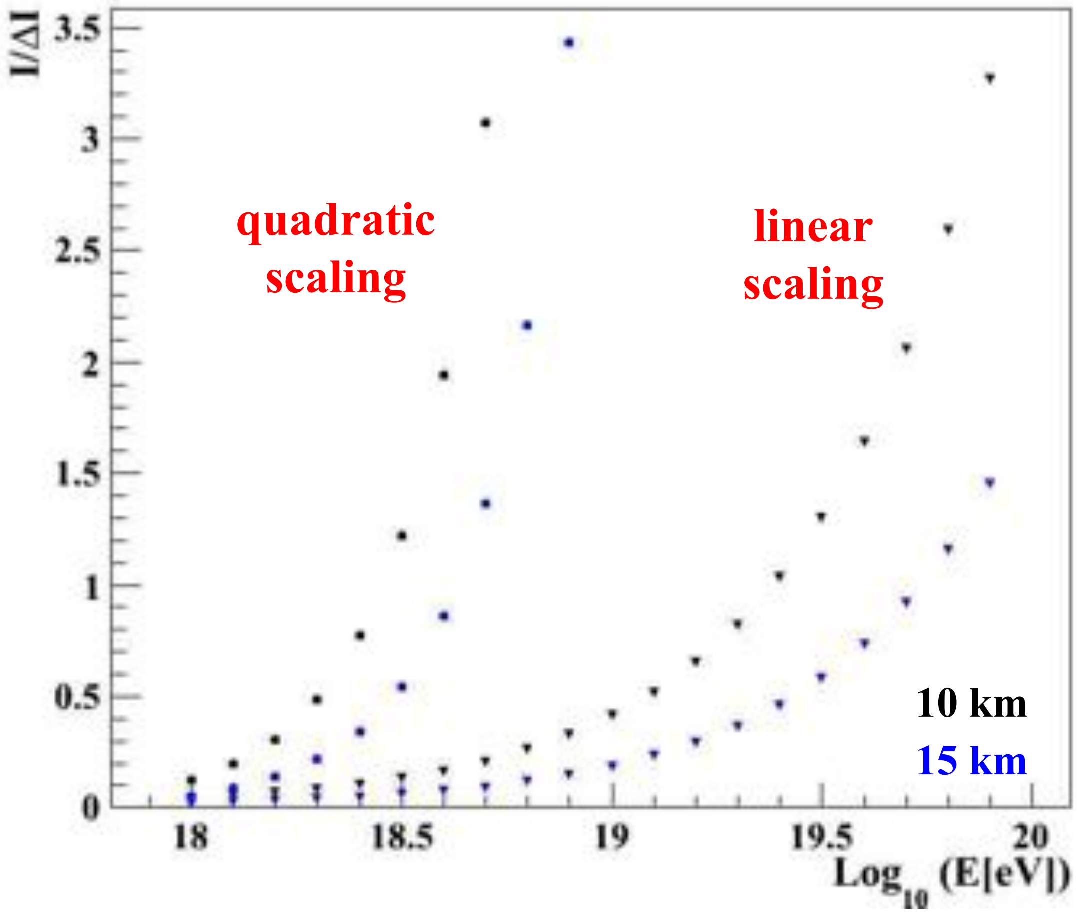
$$\Delta I \;=\; \frac{k\,T}{A_{eff}\sqrt{\Delta t\;\Delta f}} \sim 0{,}8\cdot 10^{-22}\,\frac{W}{m^2 Hz}$$

T: **≈ 100 K + penalty factor (100 K?)**
staying within
FD building
(diaphragm, …)

Δt: 100 ns

Δf: 1 GHz **bandwidth**

Signal / Background

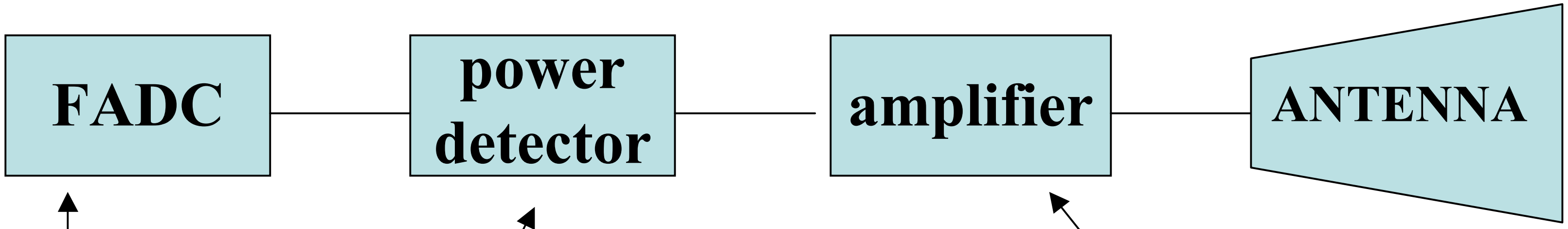


Rate in LL6 above $10^{18.5}$eV: 50 events/year

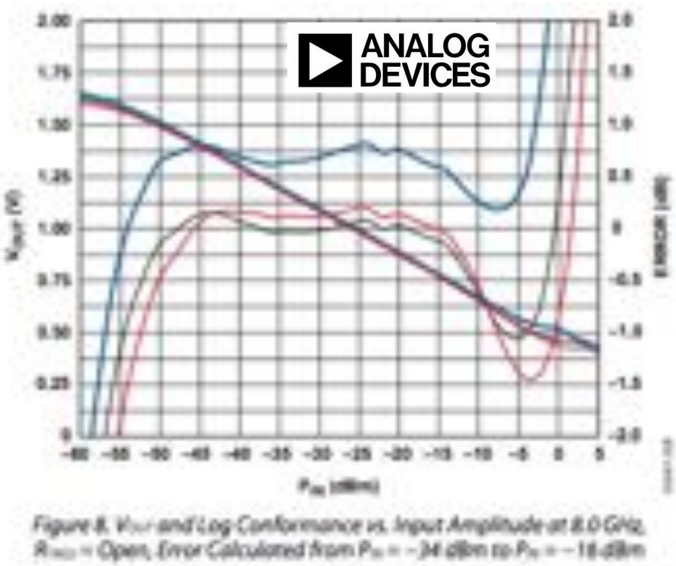
Possibility to increase I/ΔI: Δt > 100 ns

averaging over more showers and FADC traces

Elettronics & DAQ



Log-power detector AD8317
up to 10 GHz 55 dB dyn. range



typical signals very low
$I\,A_{eff}\,\Delta f \approx -90$ dBm (1 pW)

⇒ we need 50 dB amplification with low noise to match the power detector dynamic range

AMF-5F-07100840-08-13P MITEQ

7.1-8.4 GHz Gain 53 dB T_{noise} = 58.7 K

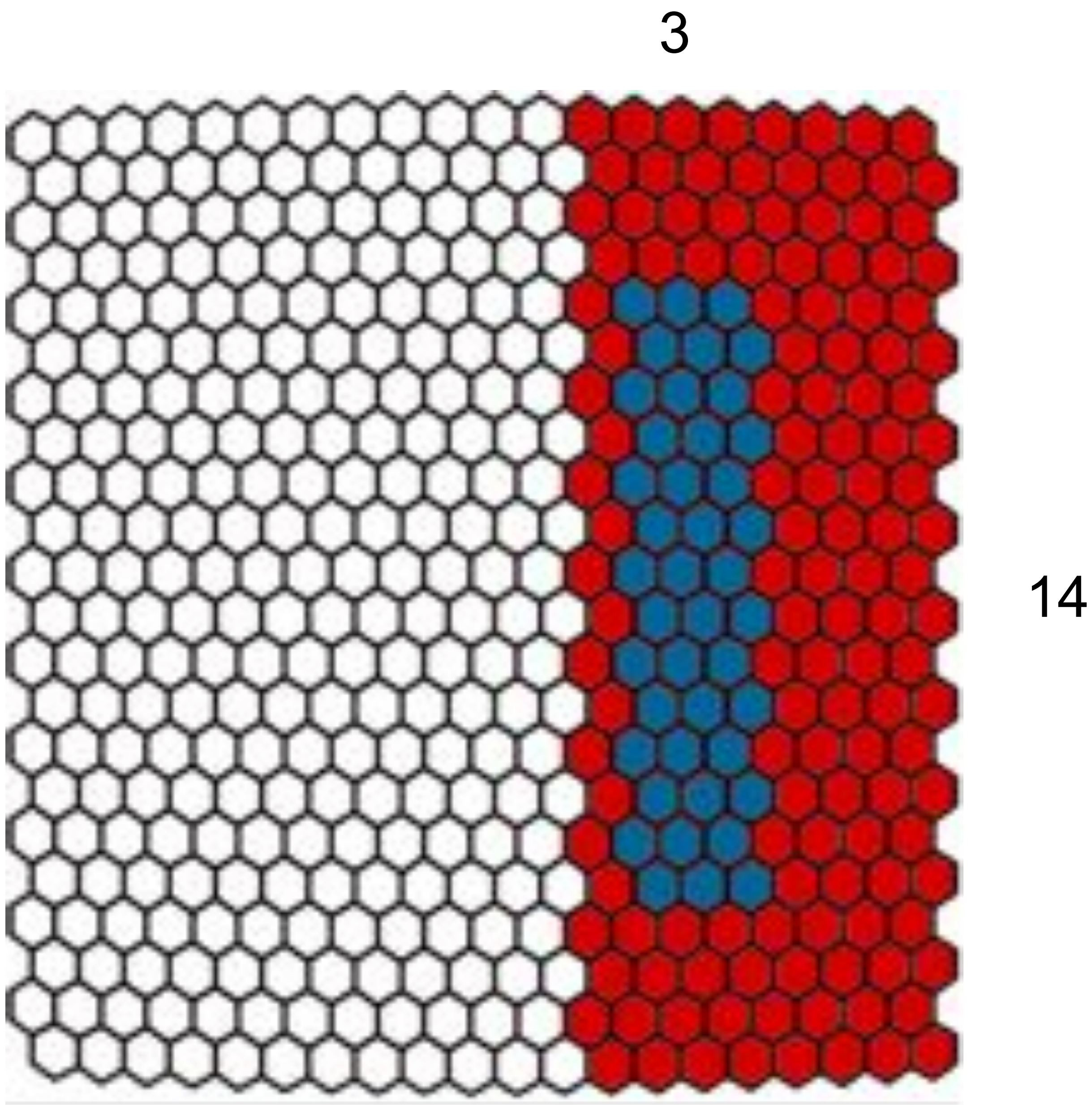
use the FD FADCs
→ a trigger signal is needed
→ radio signals will be available in a friendly style

CONCLUSIONS

- The possibility to detect the microwave emission from air shower using the FD telescope optic it’s under investigation.

- To detect different part of the same shower with different techinque (Fluor. and Microwave) it will be nice.

- We need a background measurement in the FD building to estimate the system noise temperature.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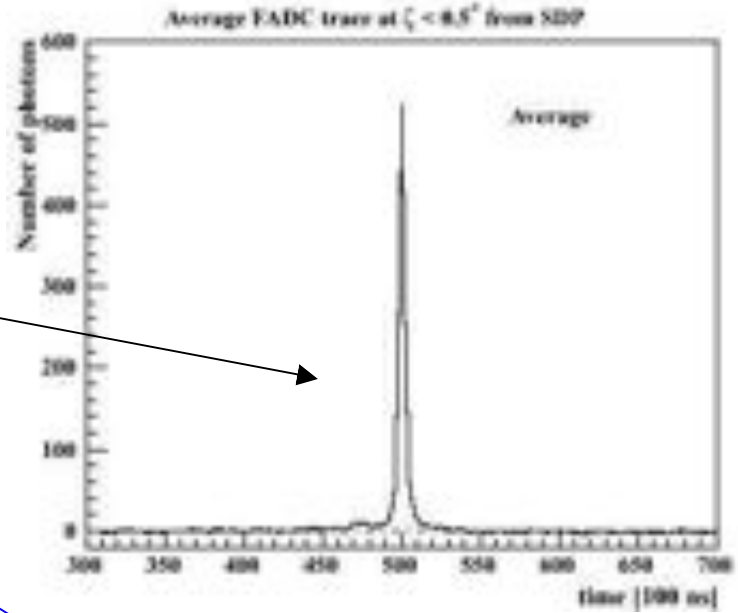
RECOVERING PMT PULSE

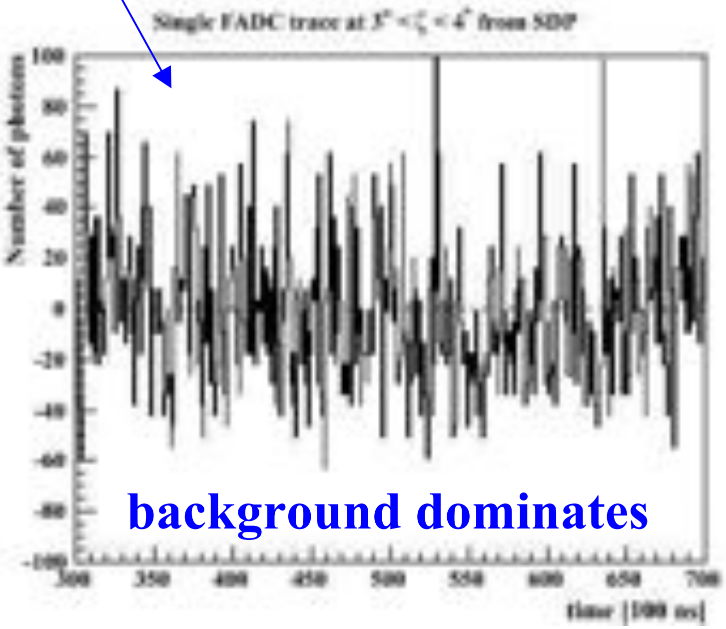
SHOWER DATA

pulse of pixels close to SDP

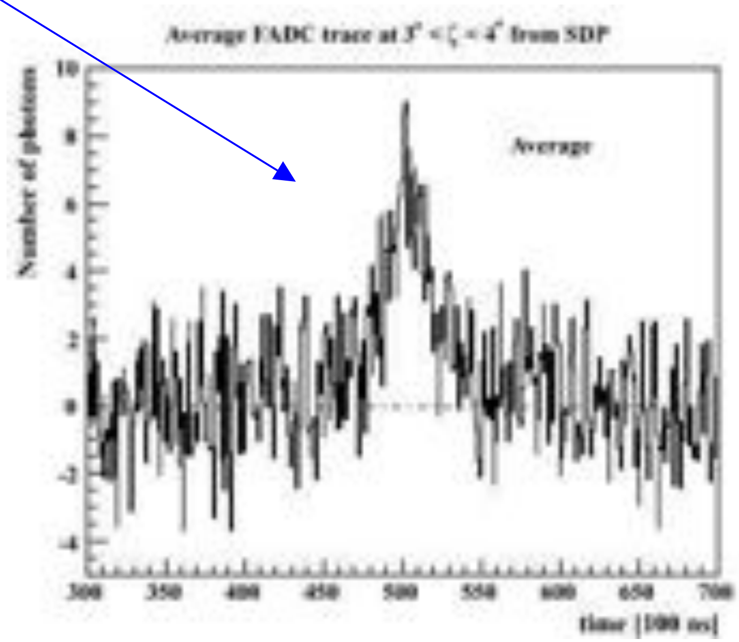


pulse of 1 pixel detecting the signal tail.

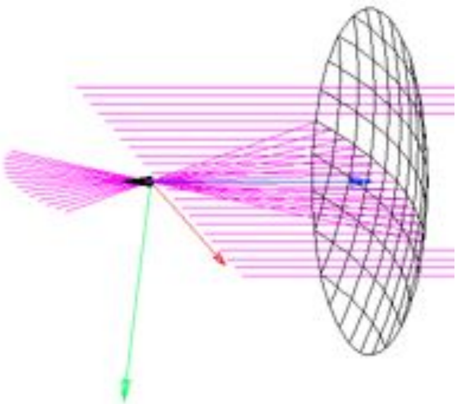
averaging over many events

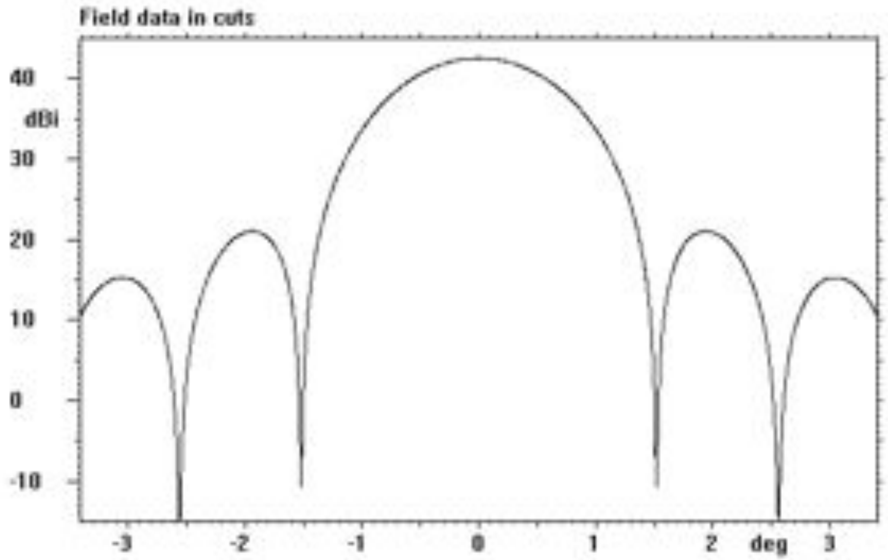


background dominates

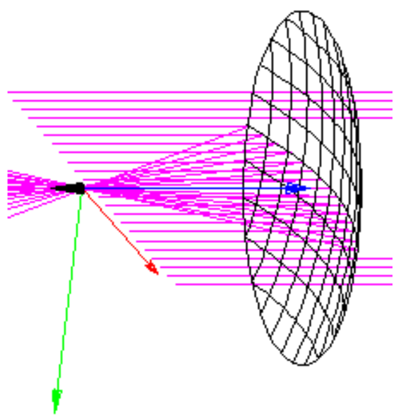


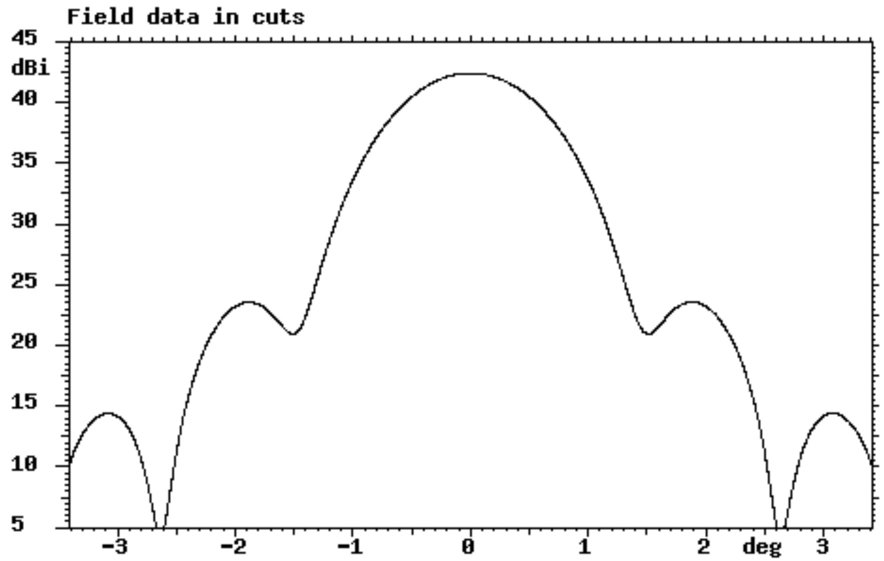
Parabolic Reflector with Diaphragm





Spherical Reflector with Diaphragm





Filter attenuation: as tempered glass??

(b) transfer test

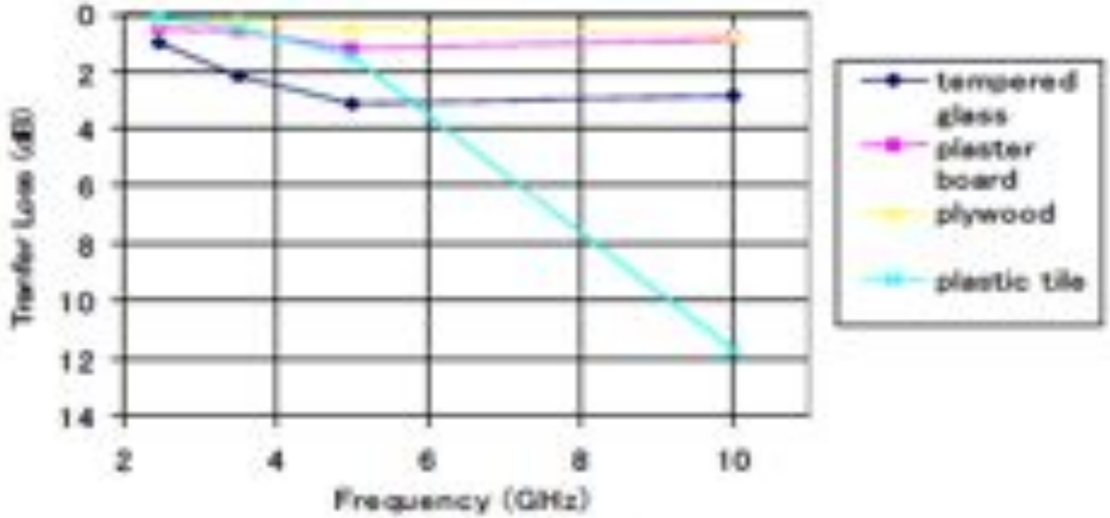


Fig.4 Transfer characteristics

Tempered Glass 3dB Transfert loss.

Experimental results of 2.45, 3.5, 5, and 10GHz radio propagation characteristics

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