1. Status of the MAGIC Gamma-ray Observatory

Brief Overview of MAGIC

August 2004 - data taking

2. Novel Photosensor Development at UC Davis

Daniel Ferenc, UC Davis

1. MAGIC Gamma-ray Observatory

Daniel Ferenc (UC Davis) for MAGIC

MAGIC-1 is now operational and is taking physics data

MAGIC Colaborators:

IFAE Barcelona,
UAB Barcelona,
Humboldt U. Berlin,
UC Davis,
U. Lodz,
UC Madrid,
MPI München,
INFN / U. Padova,
U. Potchefstrom,
INFN / U. Siena, Tuorla Observatory,
INFN / U. Udine,
U. Würzburg,
Yerevan Physics Inst.,
ETH Zürich

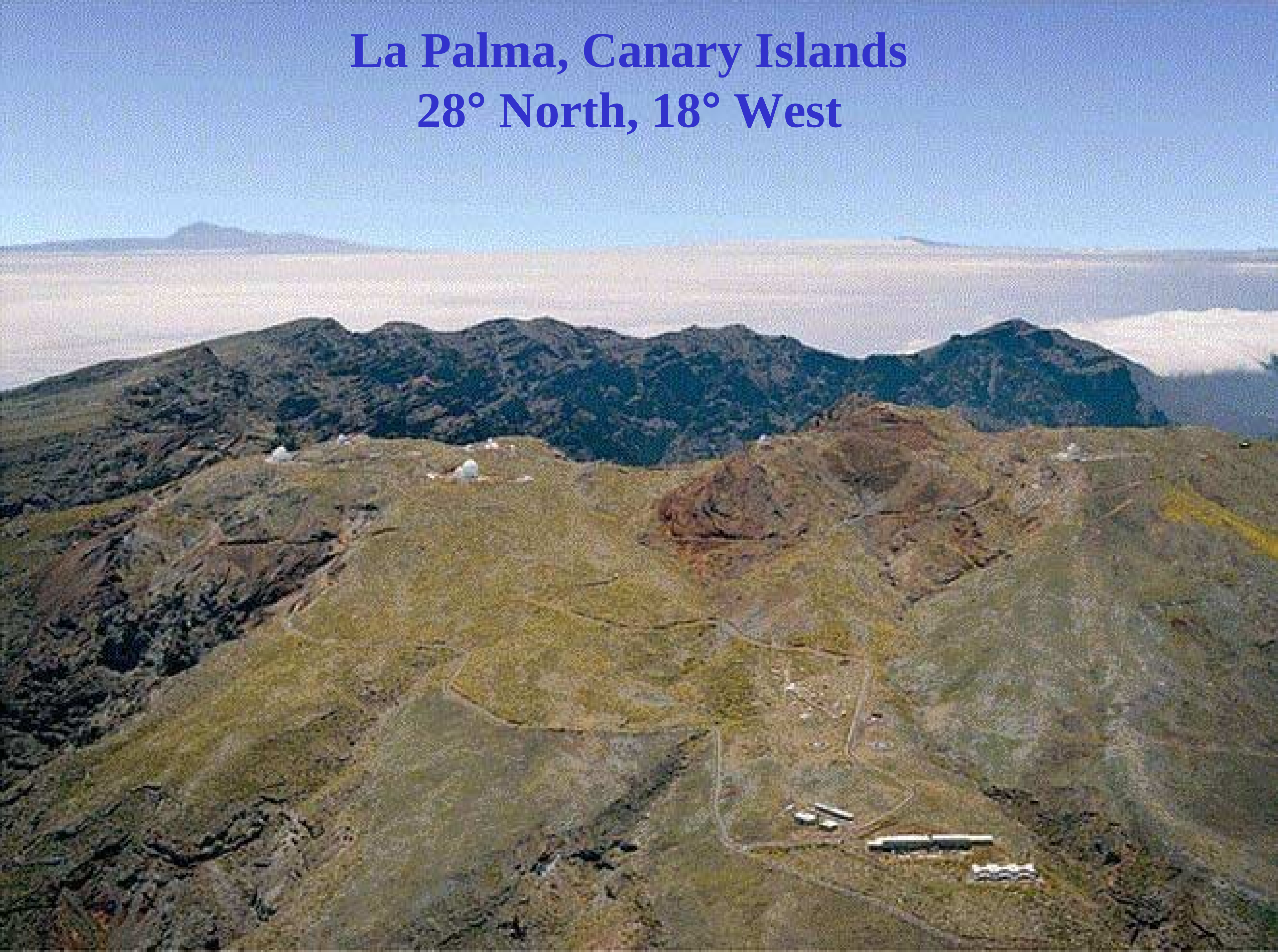
Daniel Ferenc

Eckart Lorenz (became a UCD Adjunct Faculty)

Daniel Kranich (Feodor Lynen Fellow)

Alvin Laille (Graduate Student)

University of California Davis


La Palma, Canary Islands
28° North, 18° West

What Happened to HEGRA?

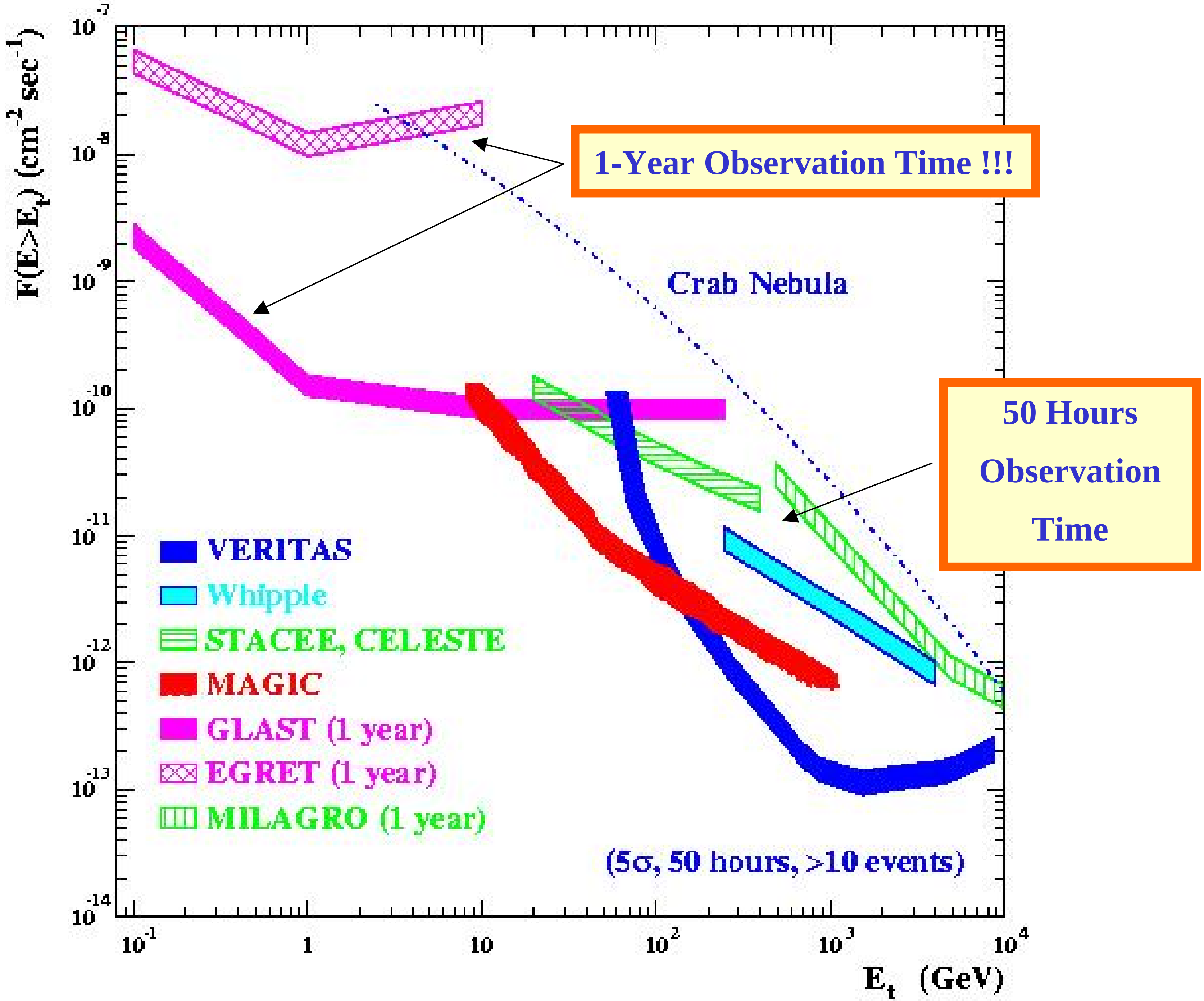
2 telescopes → Los Alamos, MILAGRO

3 telescopes → Croatia

New project:

CROATEA

(Cosmic Ray Observatory at the Eastern Adriatic)



F(E>E_t) (cm^-2 sec^-1)
10^-7
10^-8
10^-9
10^-10
10^-11
10^-12
10^-13
10^-14
10^-1
1
10
10^2
10^3
10^4
E_t (GeV)
1-Year Observation Time !!!
Crab Nebula
50 Hours Observation Time
VERITAS
Whipple
STACEE, CELESTE
MAGIC
GLAST (1 year)
EGRET (1 year)
MILAGRO (1 year)
(5σ, 50 hours, >10 events)

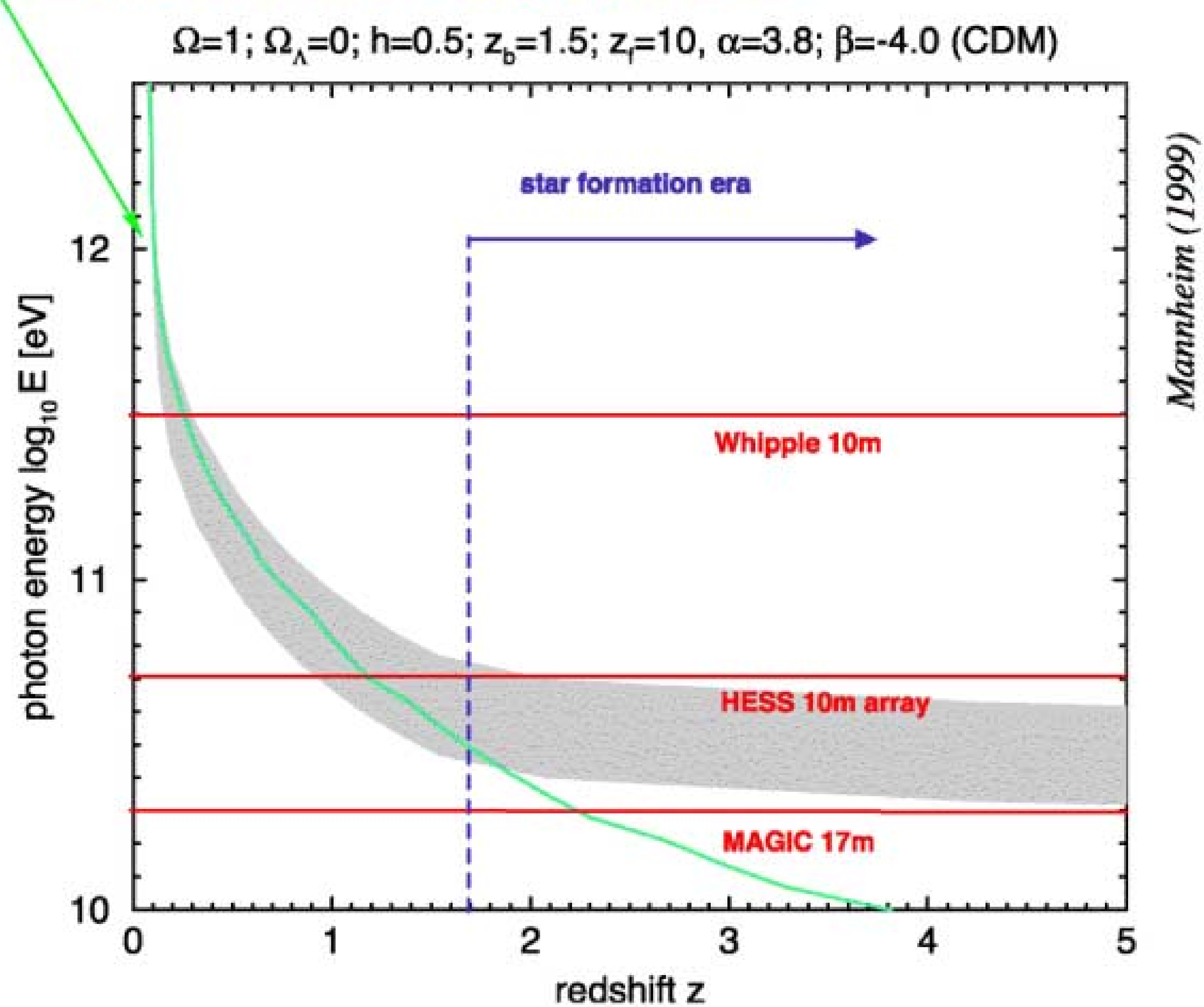
MOTIVATION:

1. **High Sensitivity for the very important energy interval 10 GeV < E < 100 GeV**

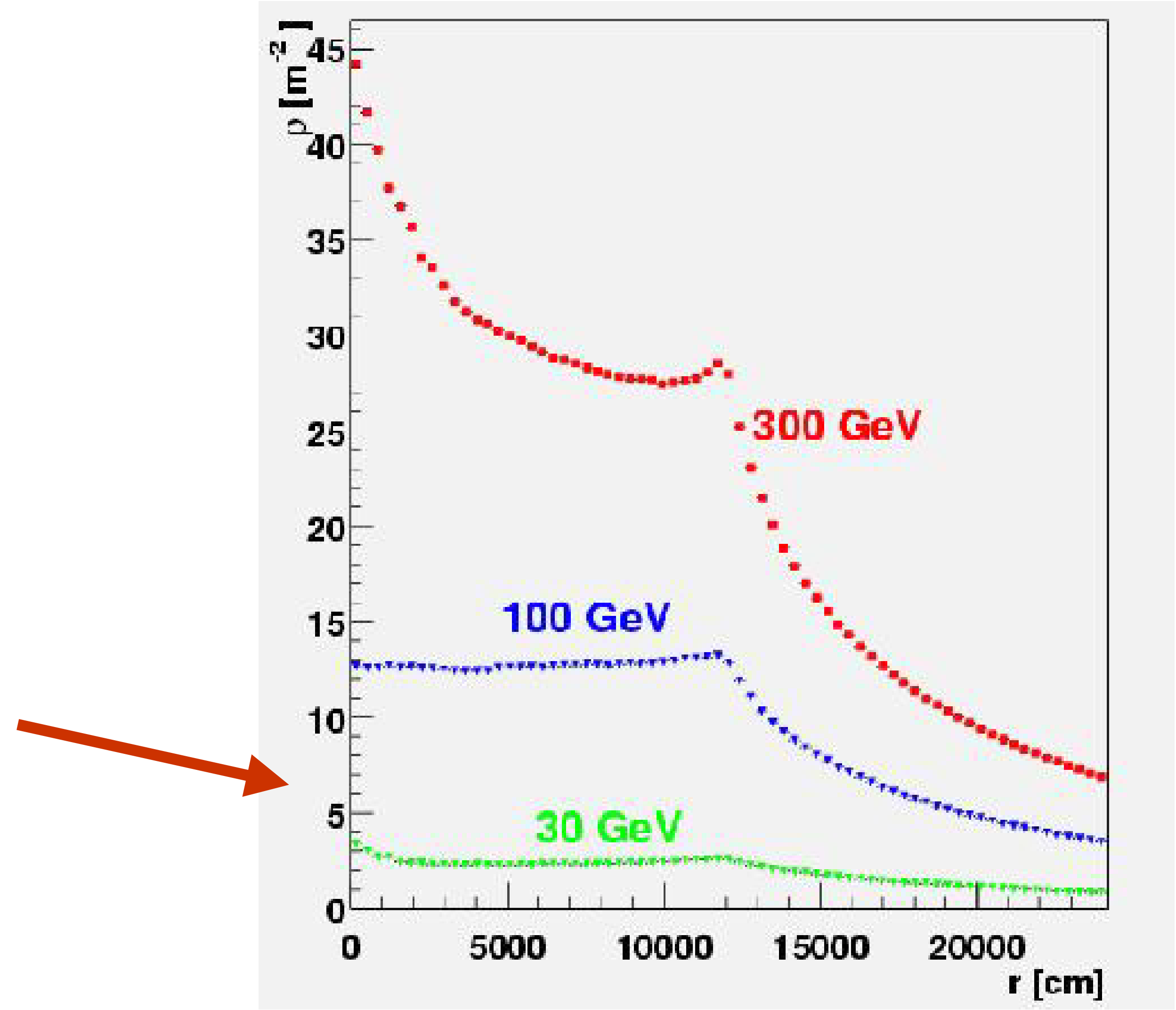
- **The “extinction” interval for many sources that have been observed at low energies (EGRET) and invisible at high energies (ground-based IACTs)**
- **Extended gamma-ray horizon at low energies:**
  - **- AGN studies per se, and**
  - **- IR background studies**

2. **Counterparts of Gamma Ray Bursts at higher energies & Transients in general (like AGNs, Mkn 421, Mkn501)**

Current IACTs can see only up to z~0.1



Cherenkov Photon Density at Low Energies



Fight for every Cherenkov photon

EFFICIENT PHOTON COLLECTION

- Very large collection (mirror) area
- High mirror reflectivity
- Efficient light concentration into PMTs

HIGH PHOTON DETECTION EFFICIENCY

- Quantum Efficiency
- Wide Spectral Coverage

The name of the game:

Fight for every Cherenkov ph

EFFICIENT PHOTON COLLECTIO

- **Very large**
  (mi
- **ty**
- **Eff**
  concen into PMTs

HOTON ETECTION EFFICIENCY

- **Quantum Efficiency**
- **Spectral Coverage**

MAGIC – based on numerous innovations

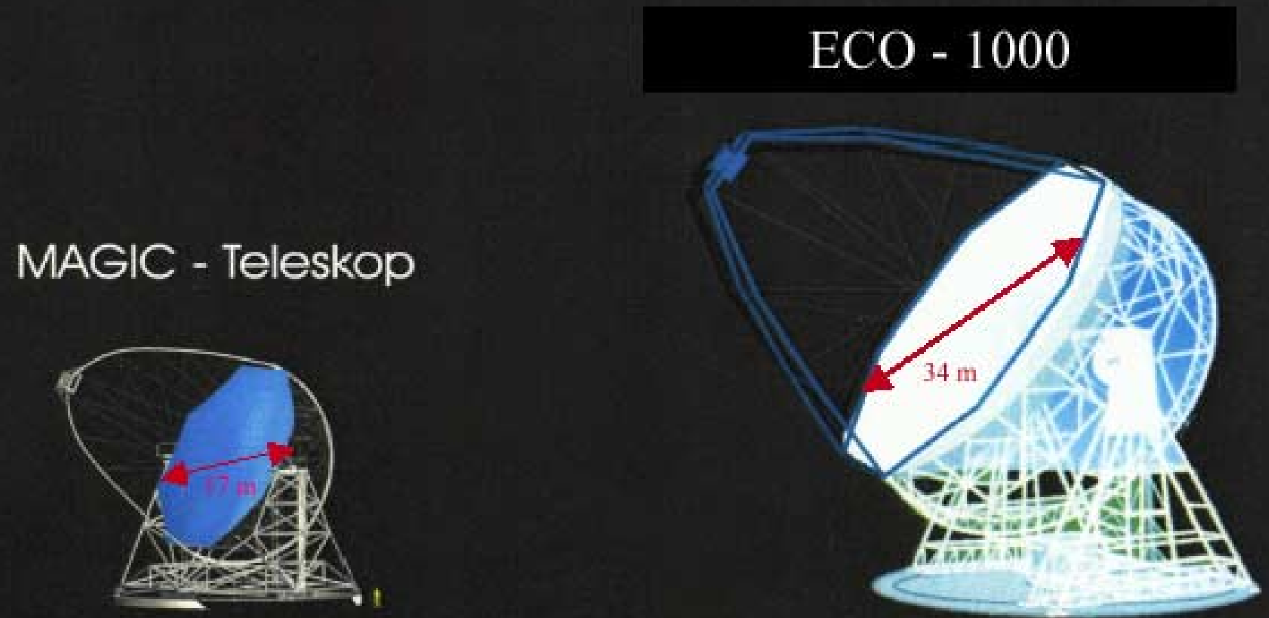
The MAGIC Observatory

MAGIC-1 Telescope is now ~fully operational!
→ currently the largest ACT in the World

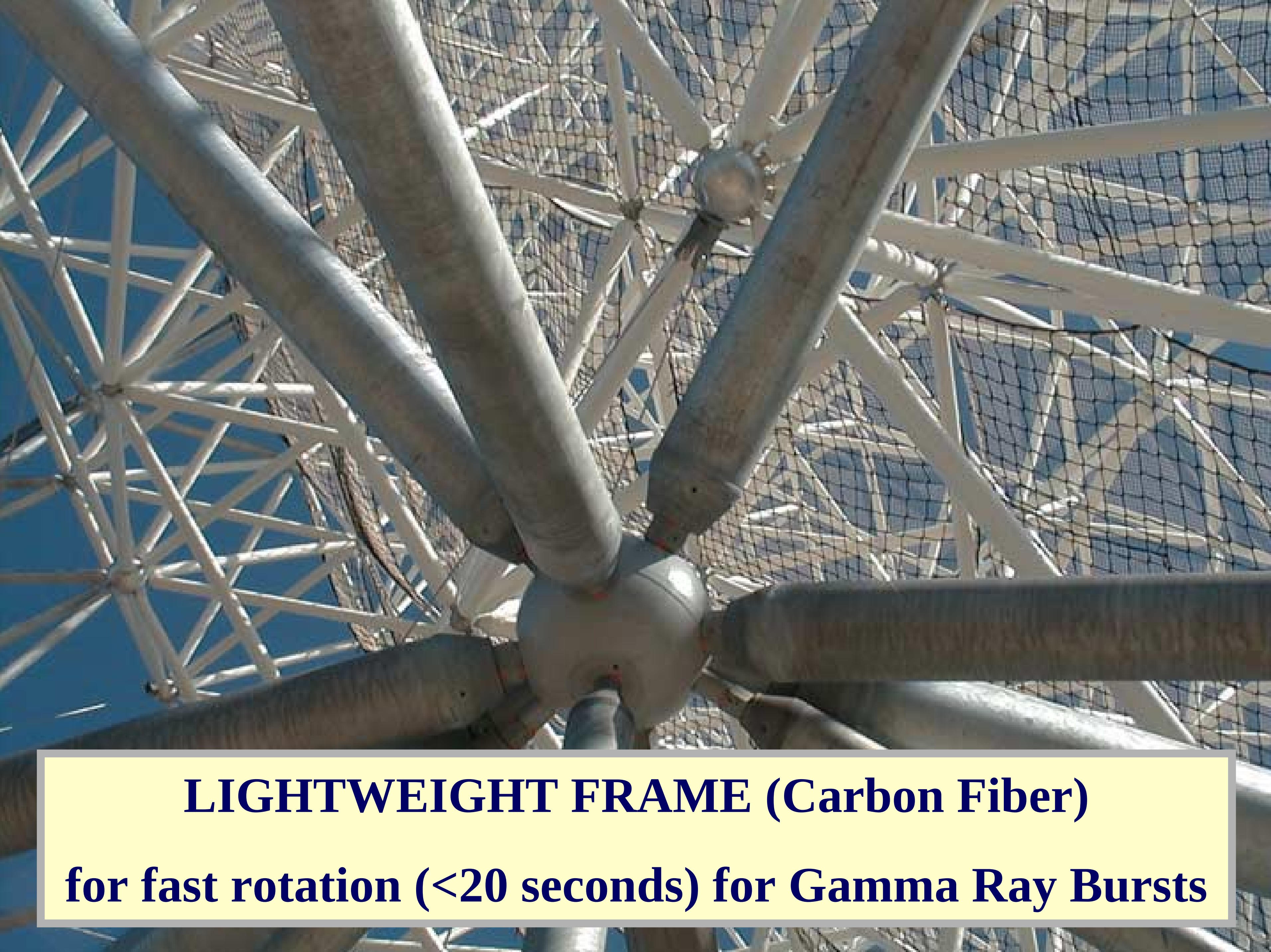
- **Mirror area = 234 m^2 (diameter = 17 m)**
- **Field of view = 3.5 º**
- **The Effective gamma-ray detection area >10^4 m^2**
- **Current trigger threshold estimated ~ 50 GeV**

- **MAGIC-2 is under construction (independent or stereoscopic mode together with MAGIC-1)**
- **A 1000 m^2 telescope ECO-1000 has been studied**

STUDY OF A 1000 m² CHERENKOV TELESCOPE



MAGIC is based on several key innovations



LIGHTWEIGHT FRAME (Carbon Fiber)

for fast rotation (<20 seconds) for Gamma Ray Bursts

SUPER-EFFICIENT CAMERA

A METHOD TO INCREAS E THE QE:COAT WINDOW WITH A LAQUER LOADED WITH WLS AND USING A FAST EVAPORATING SOLVENT -> FORMS FROSTED WINDOW SURFACE LAYER

◆ Simple way of producing a scattering layer

- Increase the quantity of Paraloid B-72 by a factor 2-3
- Dip the PMT 2-3 times (waiting 5 min.)

→ Milky layer easy to be removed

The camera

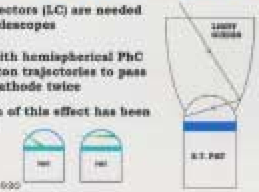
- Matrix of 577 PMTs
  - Two sections:
    - Inner part: 0.1⁰ PMTs
    - Outer part: 0.2⁰ PMTs

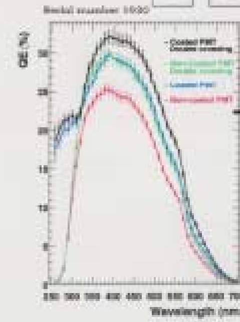
Plate of Winston cones ⇒ Active camera area ~100%

CAMERA

4- INCREASE IN THE QE BY ALLOWING LIGHT TO CROSS THE PhC TWICE IN A HEMISPHERICAL PMT

- Light Collectors (LC) are needed in IACT telescopes
- LC+PMT with hemispherical PhC allows photon trajectories to pass the photocathode twice
- Estimation of this effect has been measured



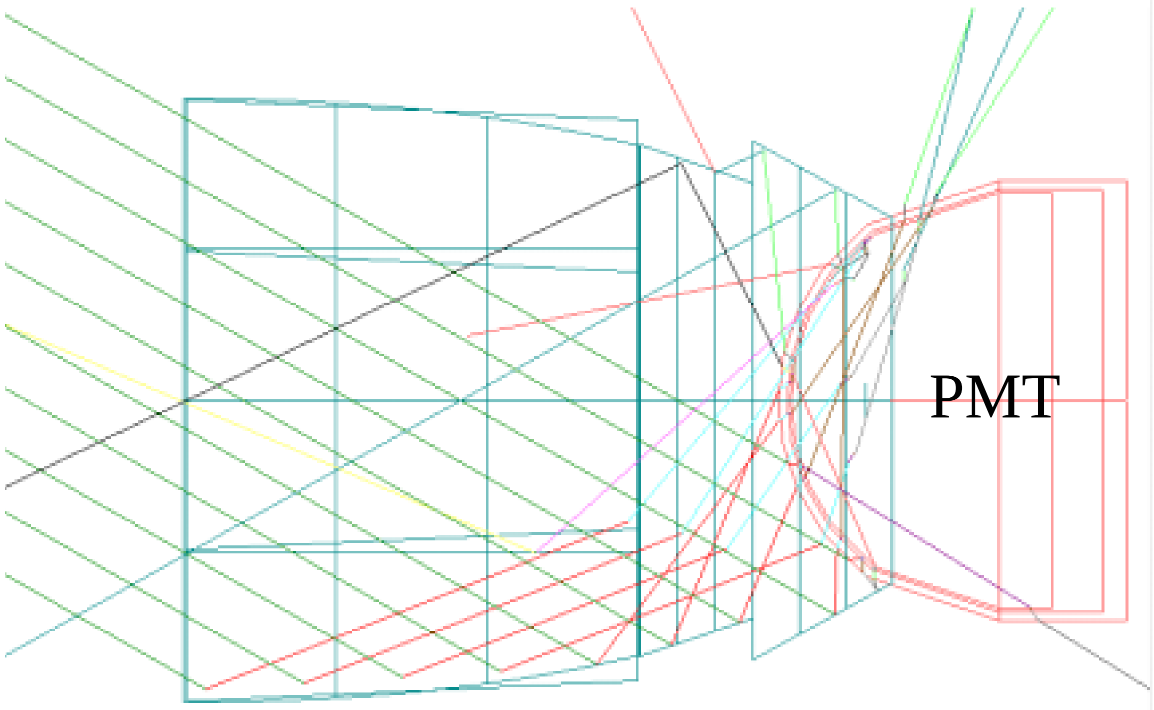


Double cross coated PMT...

at 400 nm

$$\frac{QE^{Double\_cross}_{Coated}}{QE} \approx 1.30$$

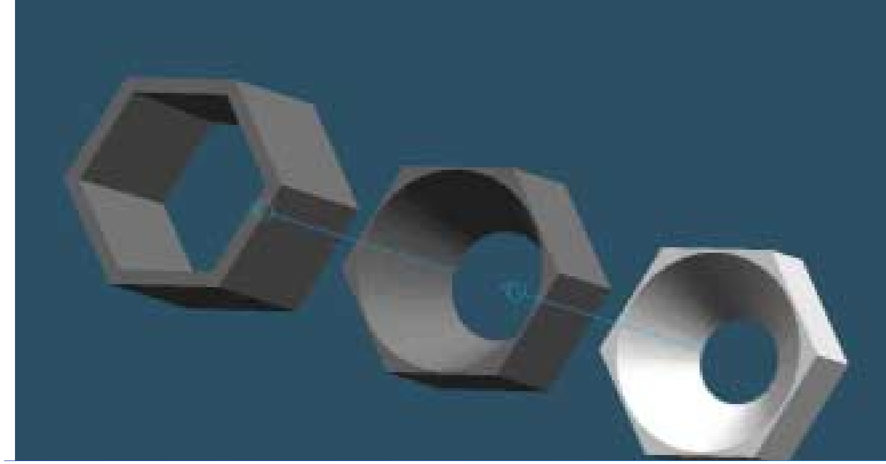
Maximizing Double-Hits in a PMT

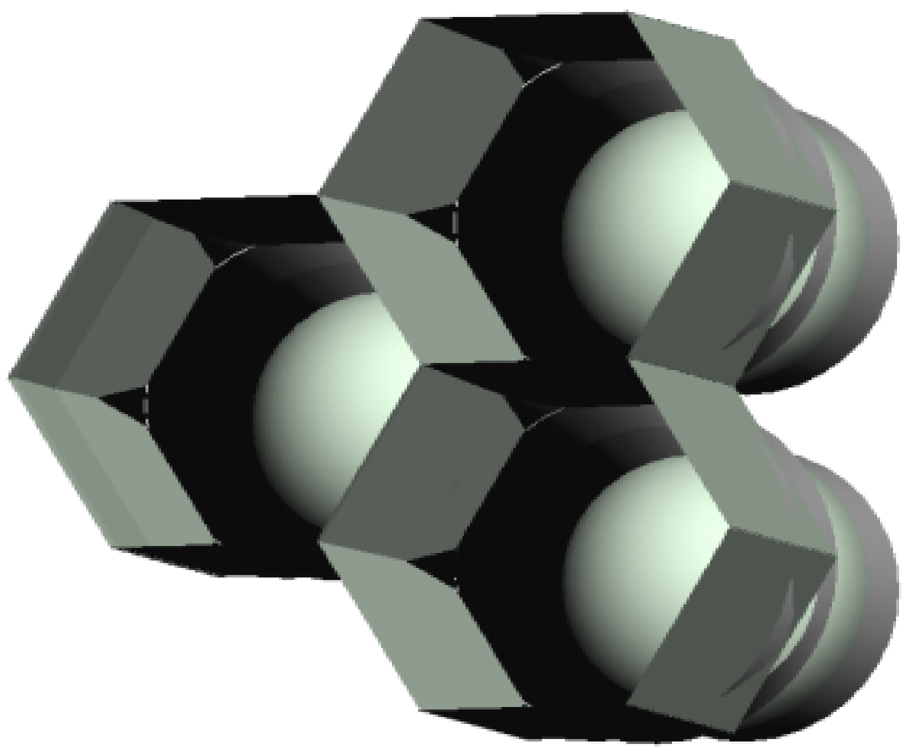


Not yet optimized for the milky PMT coating

➔

Significant additional improvements to come

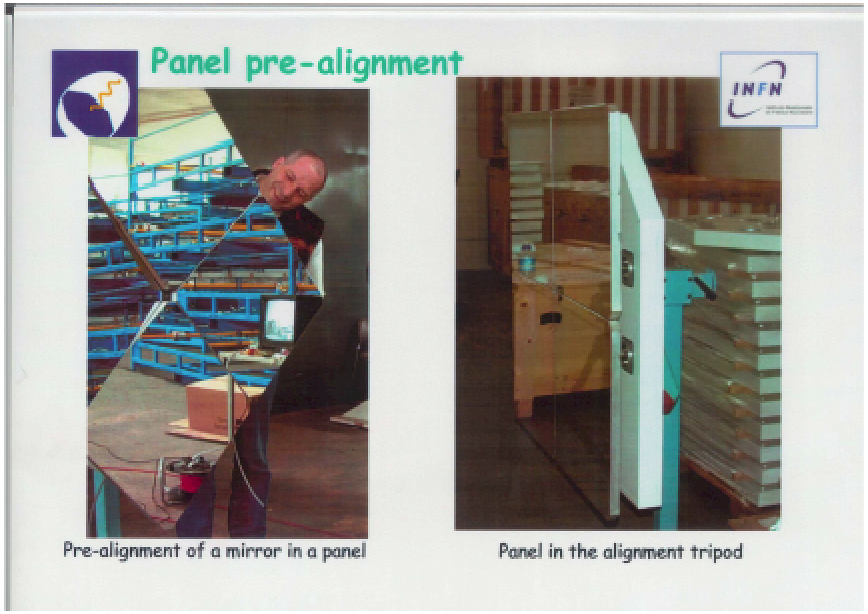


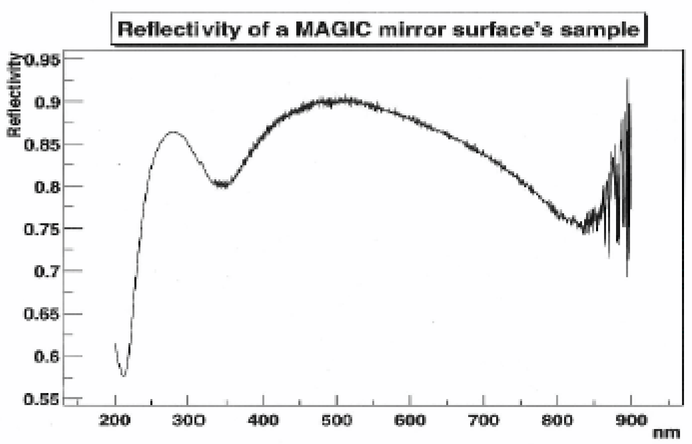


Gain: Wiston cone + Laquer coating
cone lined with 3M dielectric foil + laquer coating
cone lined with aluminised Mylar + laquer coating
plain PMT, diaphragm 22 mm
<- LIMIT ANGULAR ACCEPTANCE ->
RELATIVE GAIN/cos θ, NORMALIZED TO 0° INCIDENCE OF PLAIN PMT
ANGLE OF INCIDENCE
3
2,5
2
1,5
1
0,5
0
-60
-40
-20
0
20
40
60

THE MIRROR

COMPOSED OF 940 ELEMENT
ALL ALUMINIUM CONSTRUCTION
MANY DIFFERENT RADII (PARABOLIC PROFILE)

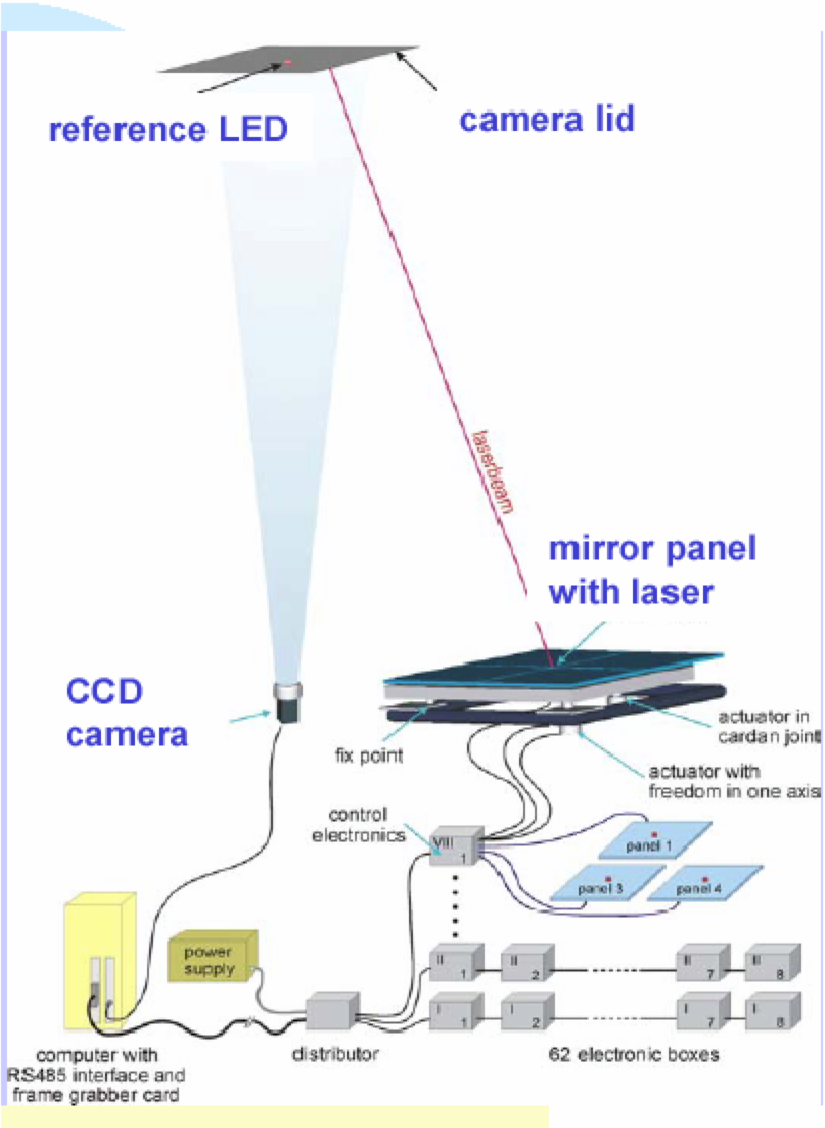




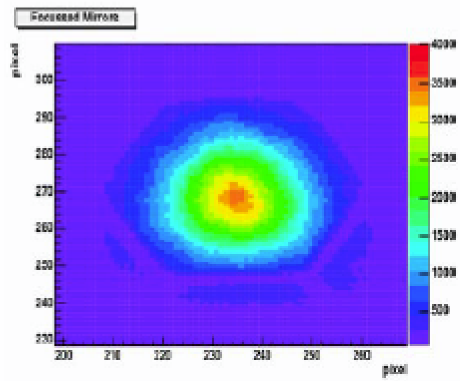
Mirrors quartz coated

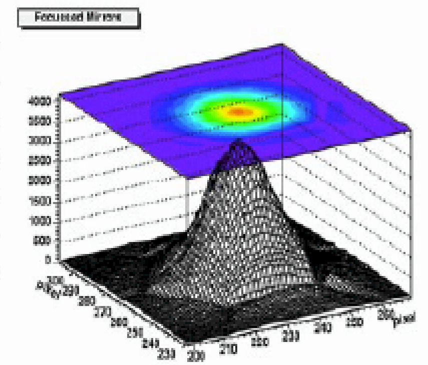
THE ACTIVE MIRROR CONTROL

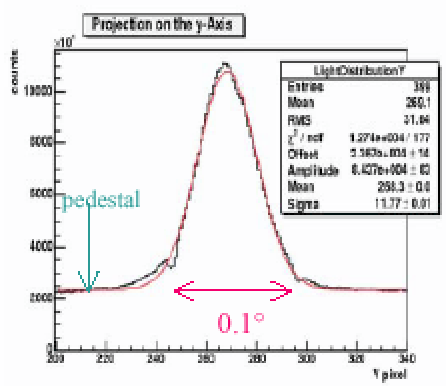
COUNTERACTS SOME SMALL DEFORMATIONS OF MIRROR SUPPORT FRAME



EXAMPLE OF MIRROR FOCUSSED TO A LIGHT SOURCE 1000mtr AWAY



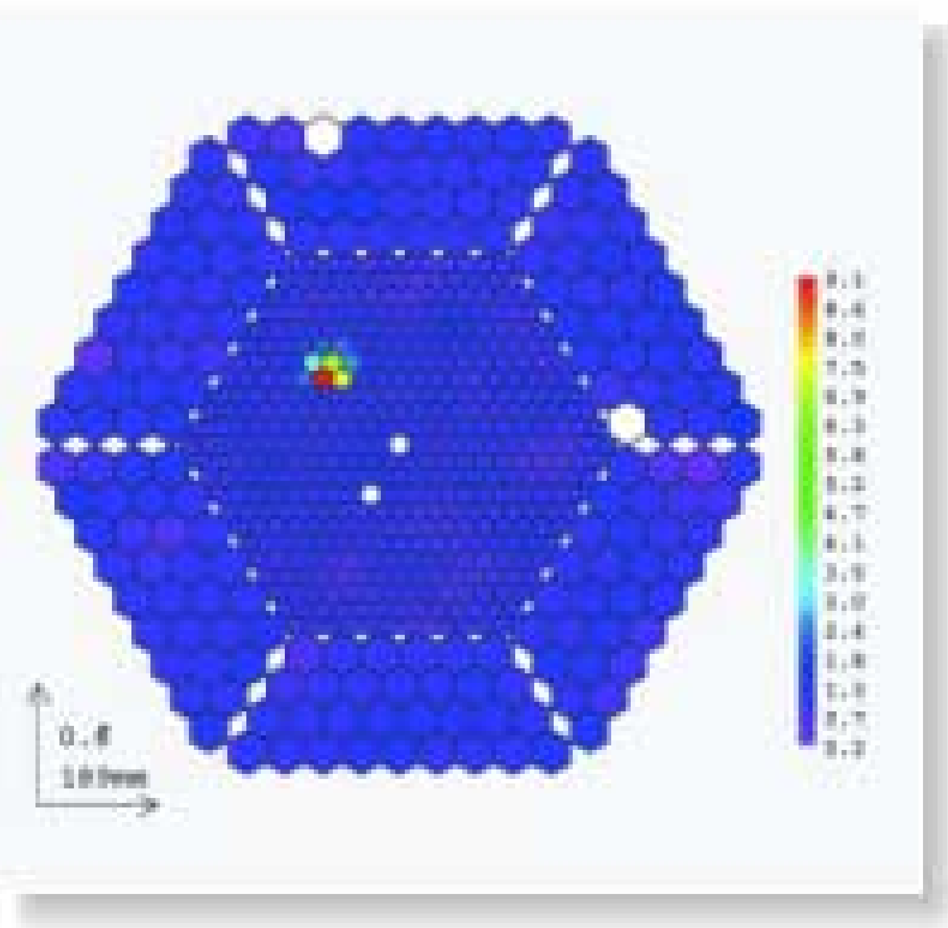


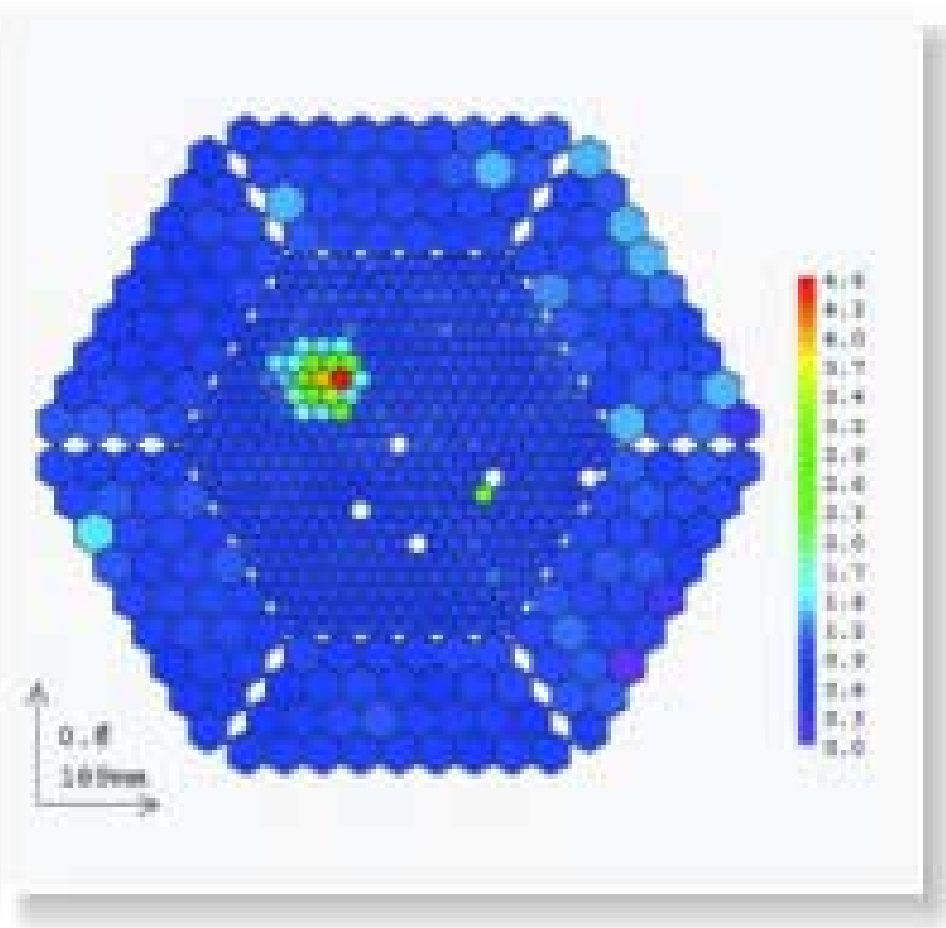


PSR 0.3° AFTER MANUAL ADJUSTMENT (0.025° POSSIBLE) WILL DEGRADE DURING RUNS IF NOT FREQUENTLY READJUSTED

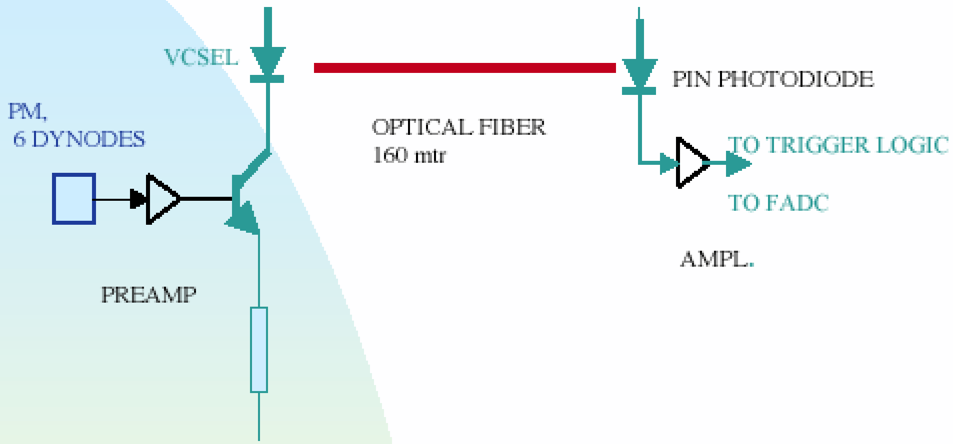
MAGIC
by night

MIORROR CONTROL – Focusing a star

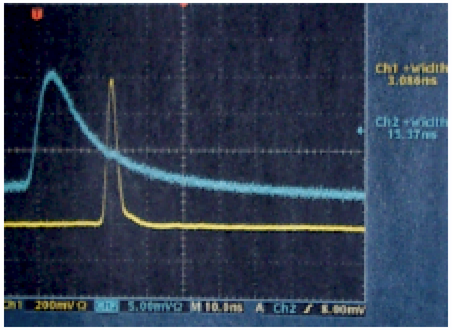




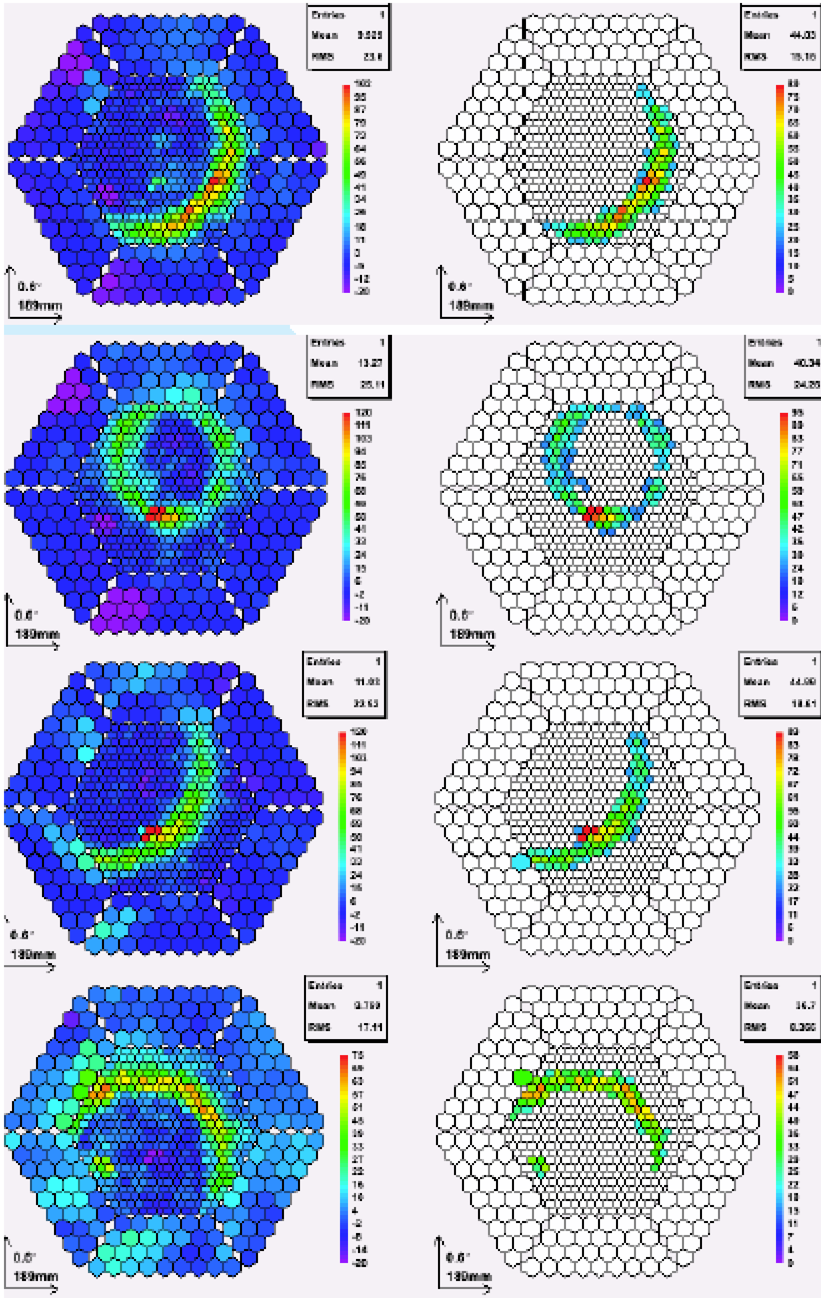
FAST PM SIGNAL TRANSMISSION BY OPTICAL FIBER SYSTEM WORKING IN ANALOG MODE



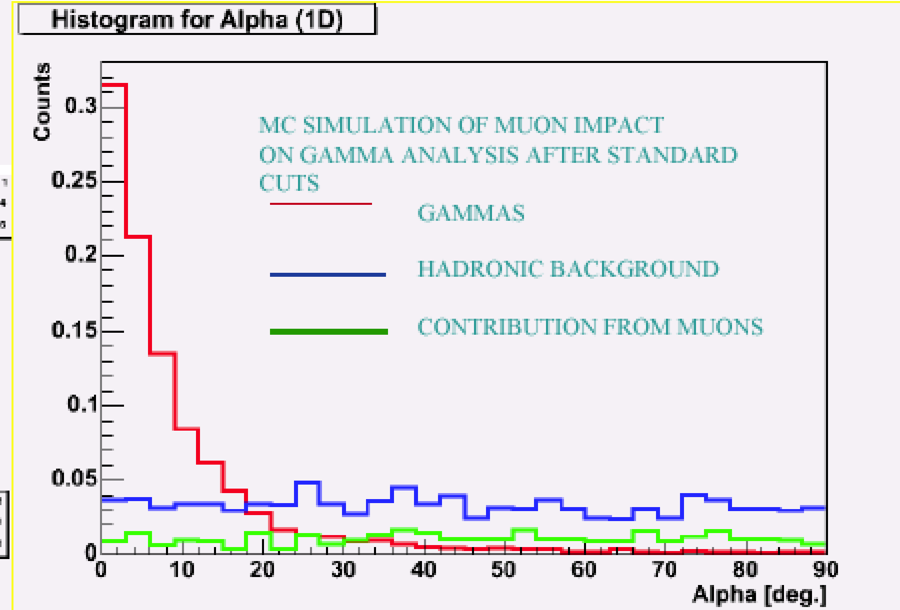
Input pulse ≈ 2.5 nsec
Output pulse at optical fiber system, 160mtr
Output pulse after RG 58C cable, 156 mtr



VERY LOW FAILURE RATE AFTER ≈ 1 YEAR
VERY LOW CROSSTALK, NO PICKUP
LARGE DYNAMIC RANGE (>60 db)
SOME NONLINEARITY
SOME GAIN SHIFT AND MODE HOPPING
NEEDED TO SELECT VCSELS



MUON ARC IMAGES

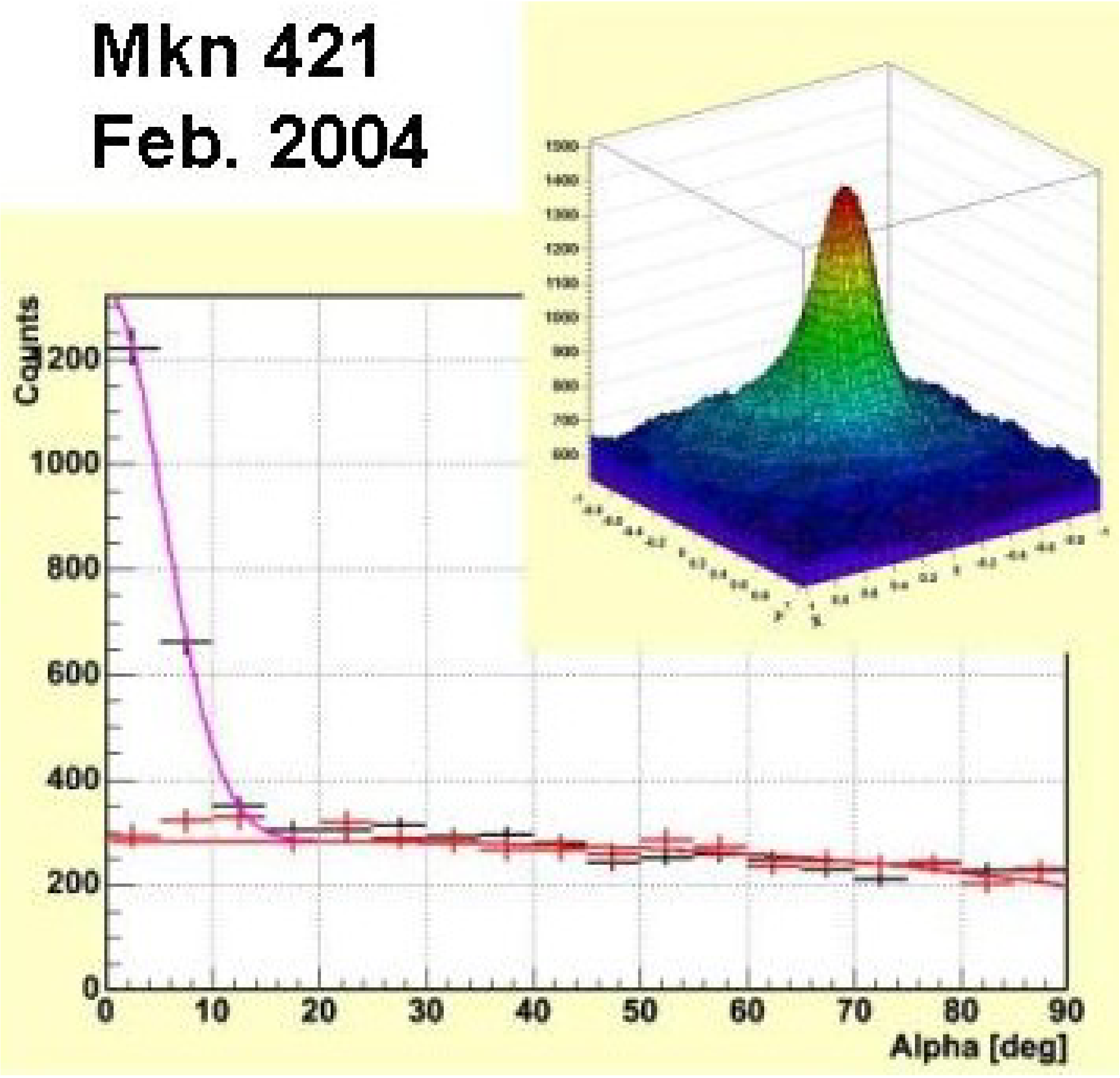


- TELESCOPE FOCUSSED TO 10 km,->ARCS BLURRED
- THE MAGIC TRIGGER SUPPRESSES FULL MUON RINGS (EX. CLOSE TO THRESHOLD)
- HIGH ‘TAIL’ CUT SUPPRESSES BACKGROUND
- LIGHT YIELD FROM MUON ARCS AGREES WITHIN 10% WITH OTHER METHODS (F-FACTOR ANALYSIS OF LIGHT PULSER SIGNAL)
- FROM MC SIMULATION: RESIDUAL MUON BG ONLY A FRACTION OF HADRONIC BG.
- IMPORTANT: MUONS DO NOT PEAK AT SMALL ALPHA AND DO NOT FAKE A SOURCE

MAGIC Inauguration – October 10, 2003

Photo: Prof. Winston Ko

Technical runs and fine tuning - until summer 2004



Summary high energy analysis Mkn421

Very preliminary

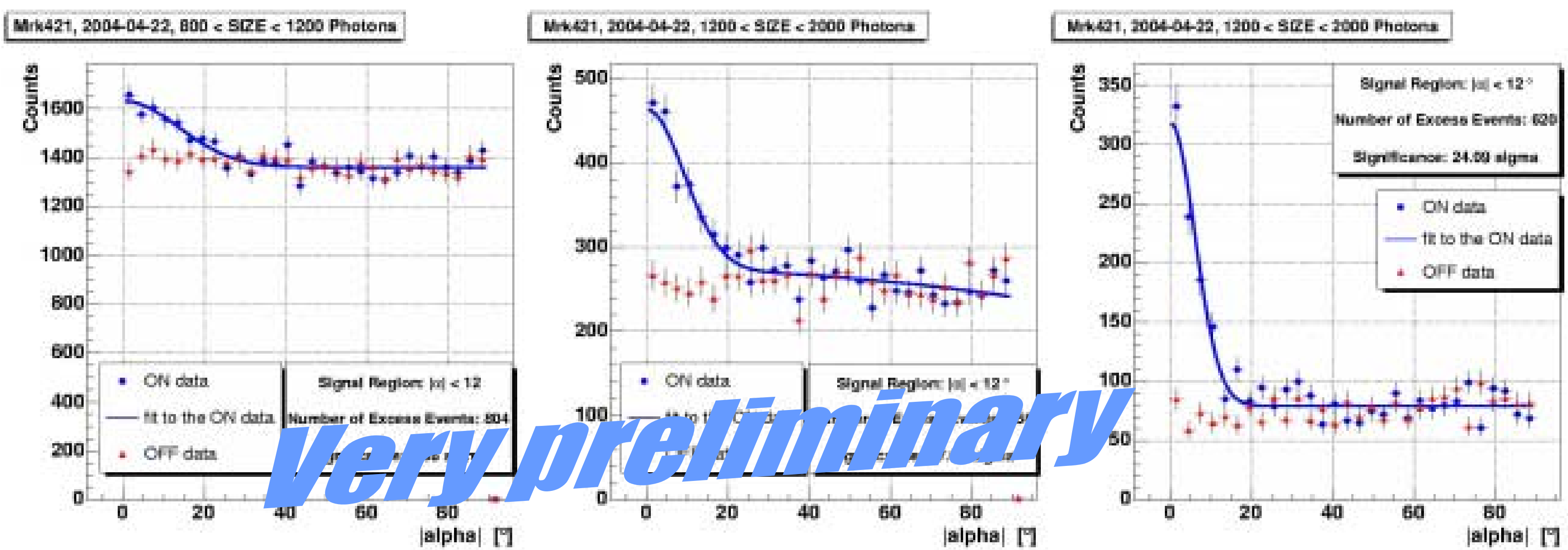
night	selection (size)	ontime (min)	Nexc	Rate (/min)
15 / 02	> 2000	104	1572	15.1
20 / 04	> 2000	68	1665	24.0
21 / 04	> 2000	167	2242	13.4
22 / 04	> 2000	150	2022	13.5

Note: systematic effects may still be present in the analysis

Mkn421 April ’04
energy dependence

Analysis in slices of the parameter size; in (red): most probable energy

800 - 1200 photons (75 GeV) | 1200 – 2000 photons (102 GeV) | 2000 - 4000 photons (160 GeV)



SUMMER 2004 – DATA TAKING

(close to the design performance)

August 2004 Data Taking

Crab, 252 min

3EG1727+04, 213 min

1ES1426, 18 min

3EG2033+41, 395 min

Mrk501, 26 min

3c66A, 536 min

…

VERY PRELIMINARY

VERY PRELIMINARY

SUMMARY

• MAGIC (PHASE I) COMPLETED, NOW RUNNING ≈ 50% OF TIME ON PHYSICS WITH REACH 80% ‘OBSERVATION TIME’ END OF YEAR

•CURRENT THRESHOLD AROUND 60-80 GEV, WILL REACH 30 GEV NOT BEFORE A YEAR FROM NOW

•NEW TECHNOLOGIES WORKING (ONLY THE USUAL STARTUP PROBLEMS)

•RUN-IN OF THE ULTRALARGE TELESCOPE MORE COMPLEX THAN ANTICIPATED

•MAGIC II: CONSTRUCTION HAS BEEN STARTED, READY 2006 (GLAST LAUNCH)
BASICALLY A MAGIC I CLONE WITH MINOR IMPROVEMENTS

•LONGTERM ACTIVITY: USE OF HIGH QE PHOTOSENSORS
-> LOWERING THRESHOLD BY ≈ 2 IN ENERGY

•LONGTERM VISION/PLANS: ADD ECO 1000 (THR.:5-10 GeV) IACT
ADD WIDEANGLE IACT (TECHNICALLY DEMANDING)

Development of Novel Photosensors at UC Davis

Daniel Ferenc

Eckart Lorenz (became Adjunct Faculty at UC Davis)

Daniel Kranich (Feodor Lynen Fellow)

Alvin Laille (Graduate Student)

University of California Davis

Future projects aiming to study very rarely occurring phenomena

- **Proton decay, Neutrino Physics and Astrophysics**

  UNO, HYPER-K, Kilometer-Cube, also Nestor, Nemo, Antares, etc.

- **Gamma-ray Astronomy – a study of faint and/or variable sources requires telescopes with**

  low detection threshold & wide acceptance angle

- **Ultrahigh-energy cosmic rays (>10^19 eV)**

  Auger, EUSO, OWL,…

- **Double beta decay**

New Experiments need sensitivity for very rare phenomena

↓

Very Large Volumes/Areas

↓

"Natural" **Transparent** Media (Water, Atmosphere, Ice)

No other choice than

↓

PHOTOSENSORS

<u>Irreducibly Large</u>
Illuminated Area

↓

Photosensors with

- **Very strong <u>internal information concentration</u>**

  → Vacuum

- **More efficient photocathodes**
- **Industrial Mass-Production at a very low cost**

  < 5% of PMTs per square meter

Development of Other Vacuum Devices

~1960

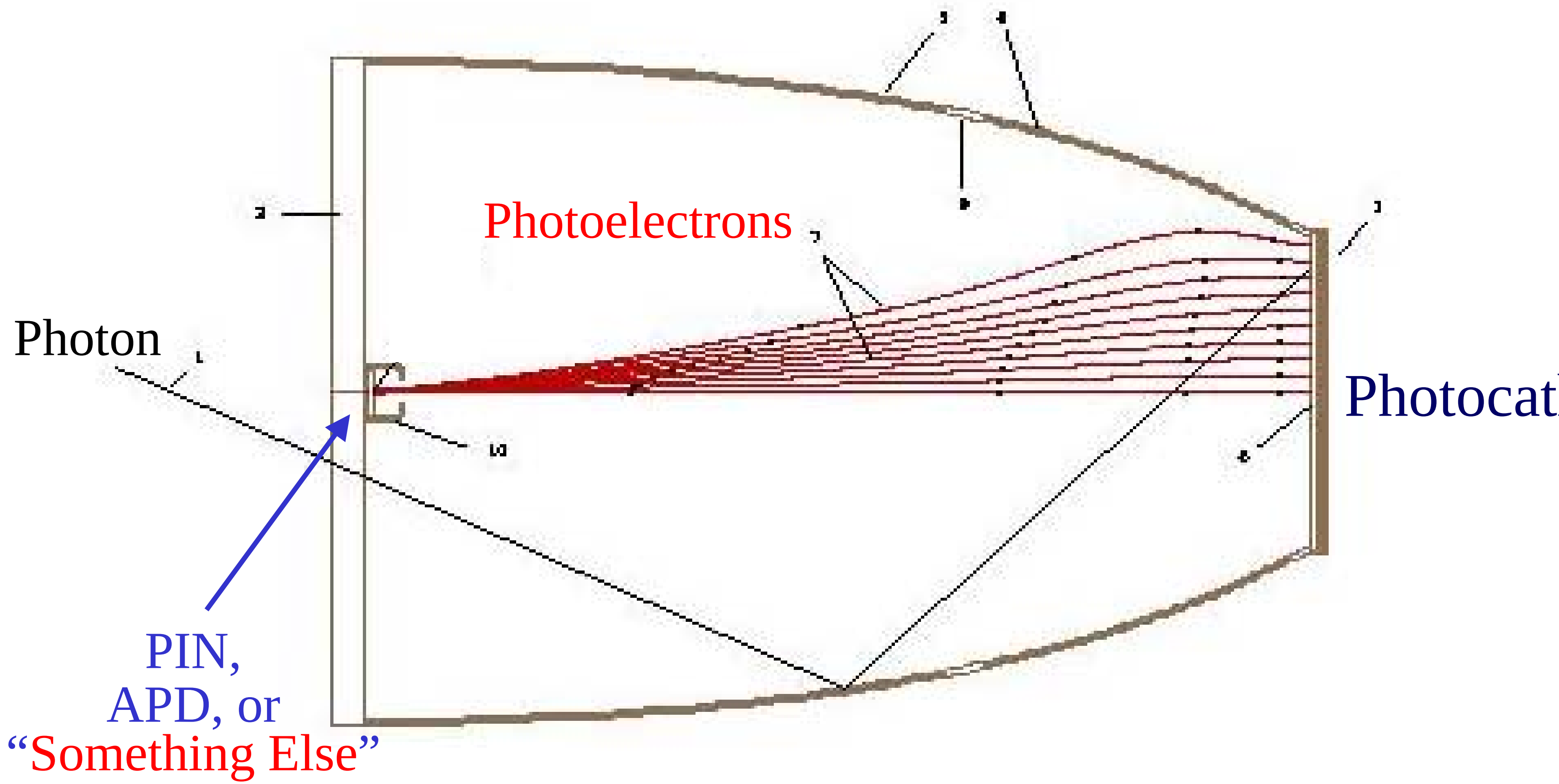
~2000

Flat-Panel Camera Configuration →

provided by the *ReFerence* Photosensor Concept

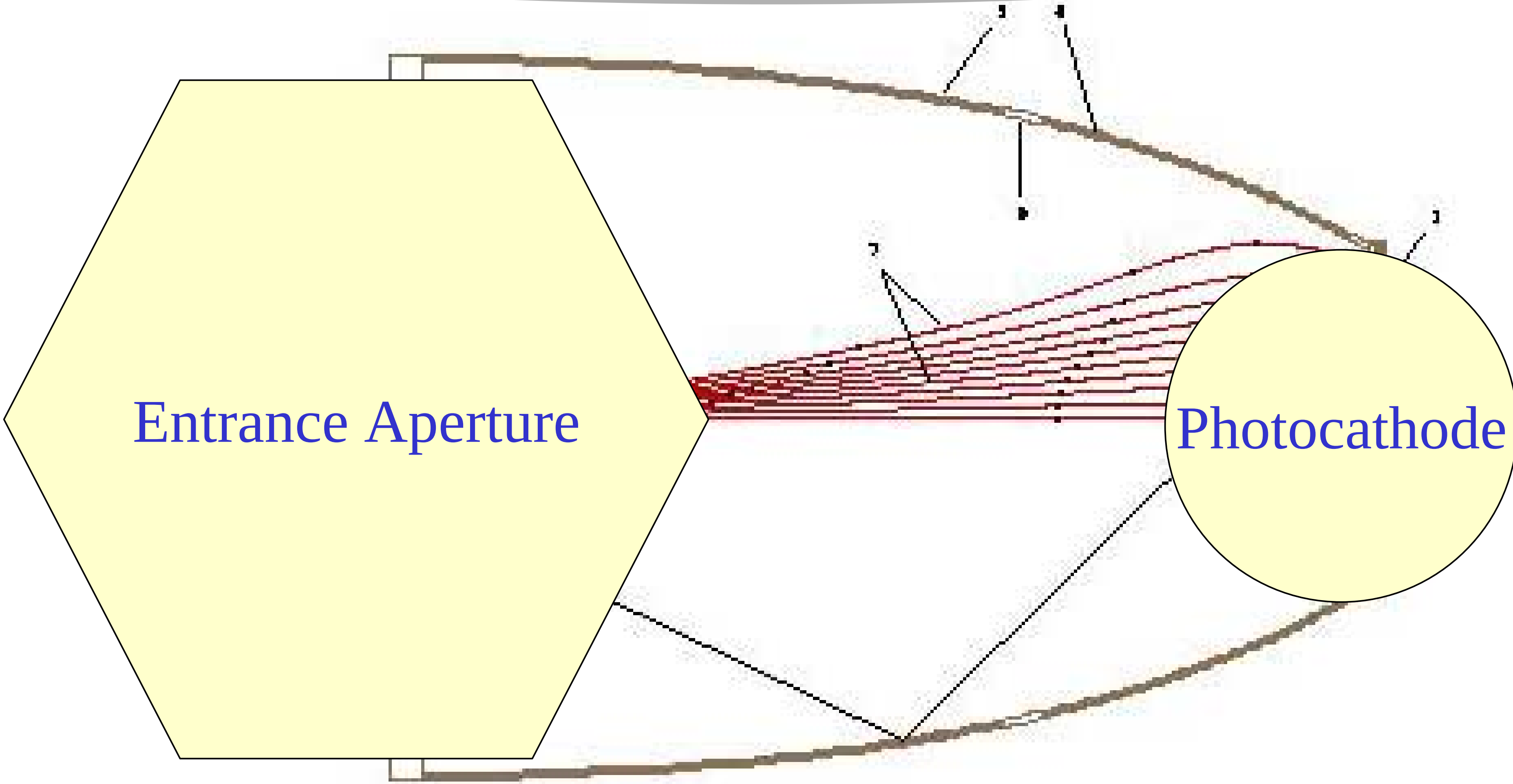
Ideal Light Concentrator

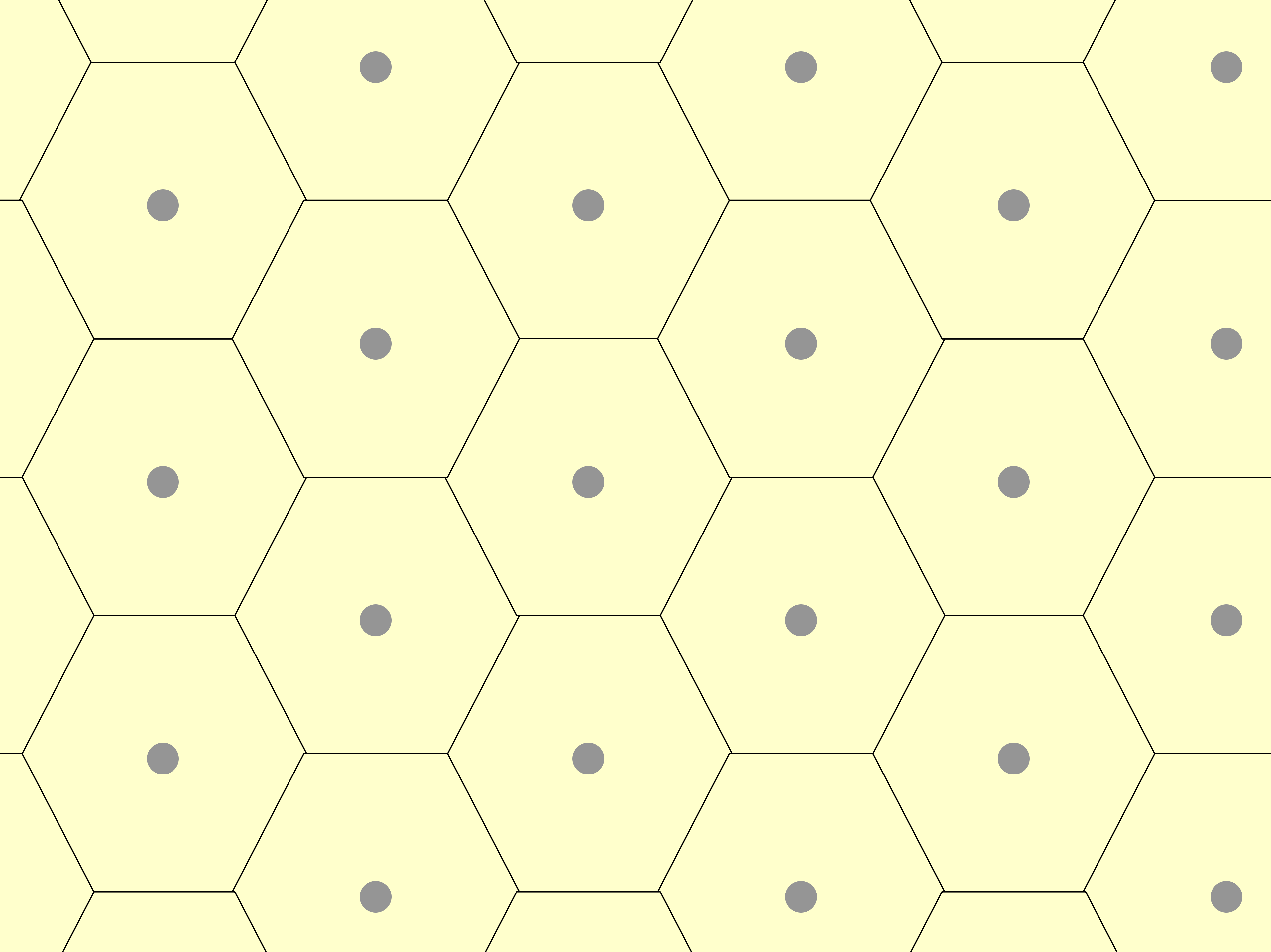
(takes the maximum of Liouville!)



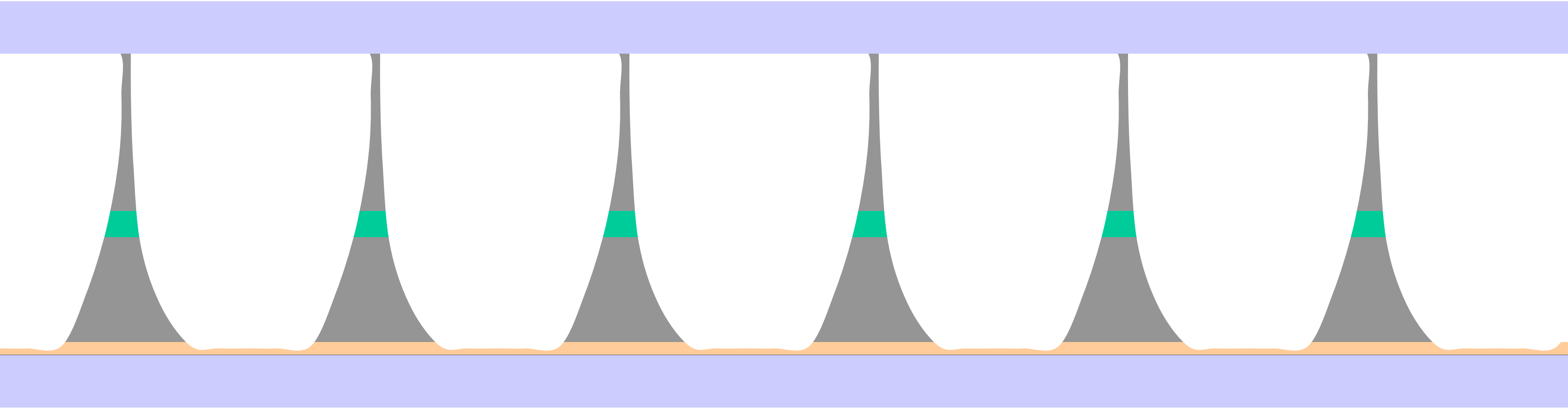
Optimal Electron Lens

Very Important: Hexagonal Packing





Flat-Panel Honeycomb Sandwich Camera Construction



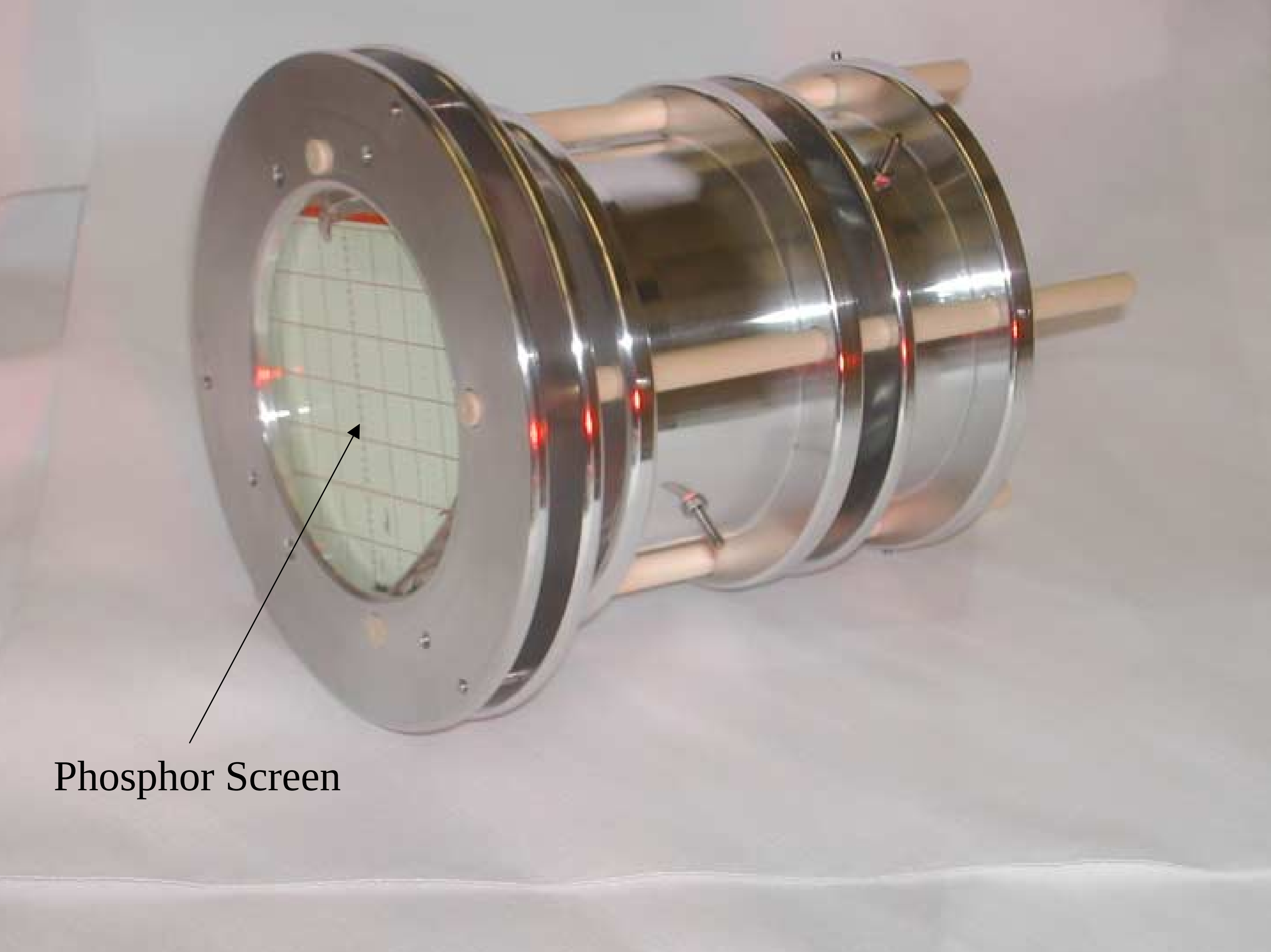
Industrial Production (no glass blowing etc.)

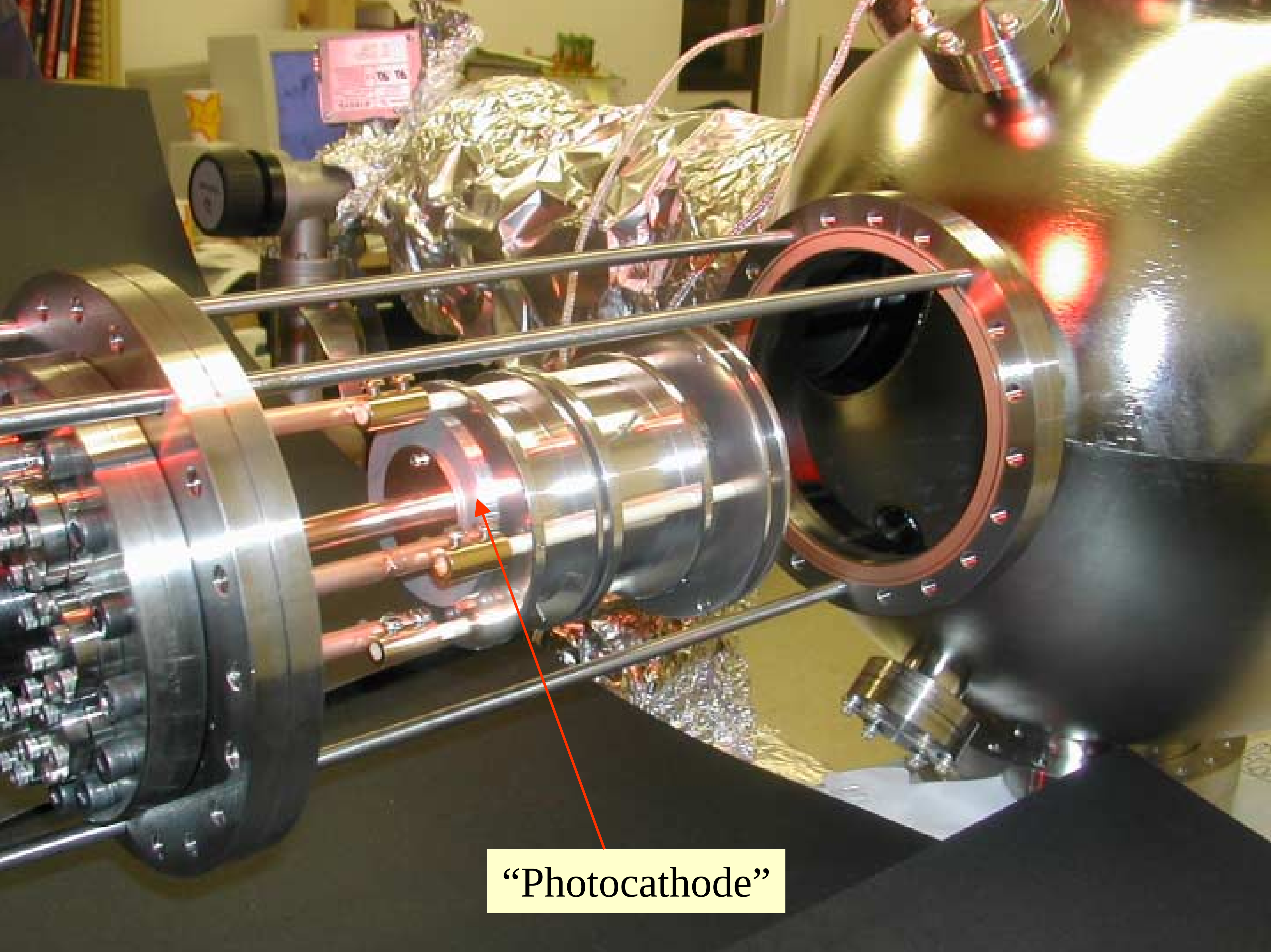
Intrinsic Mechanical Stability, Low Buoyancy,..

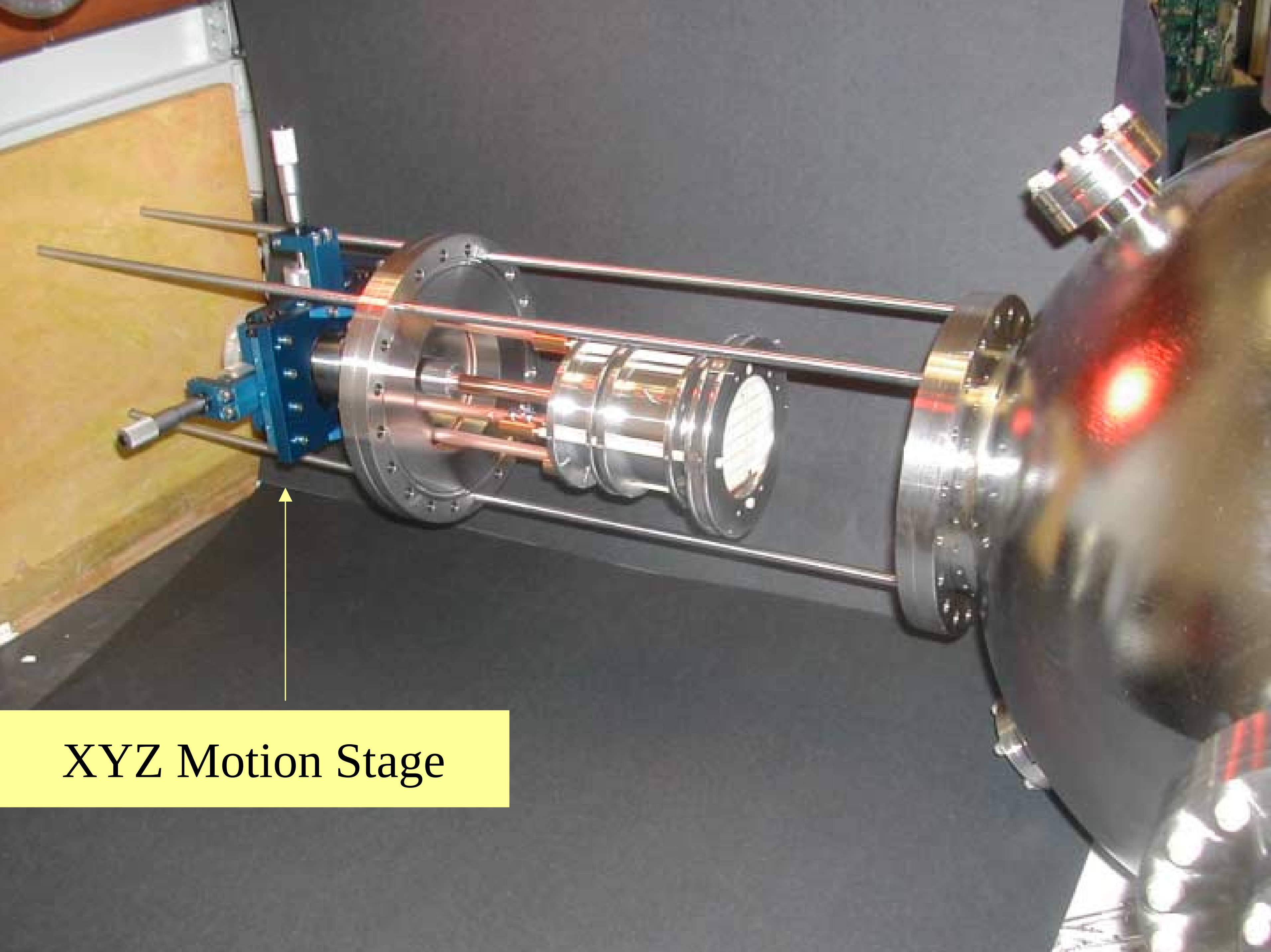
3rd ReFerence Prototype (tested)

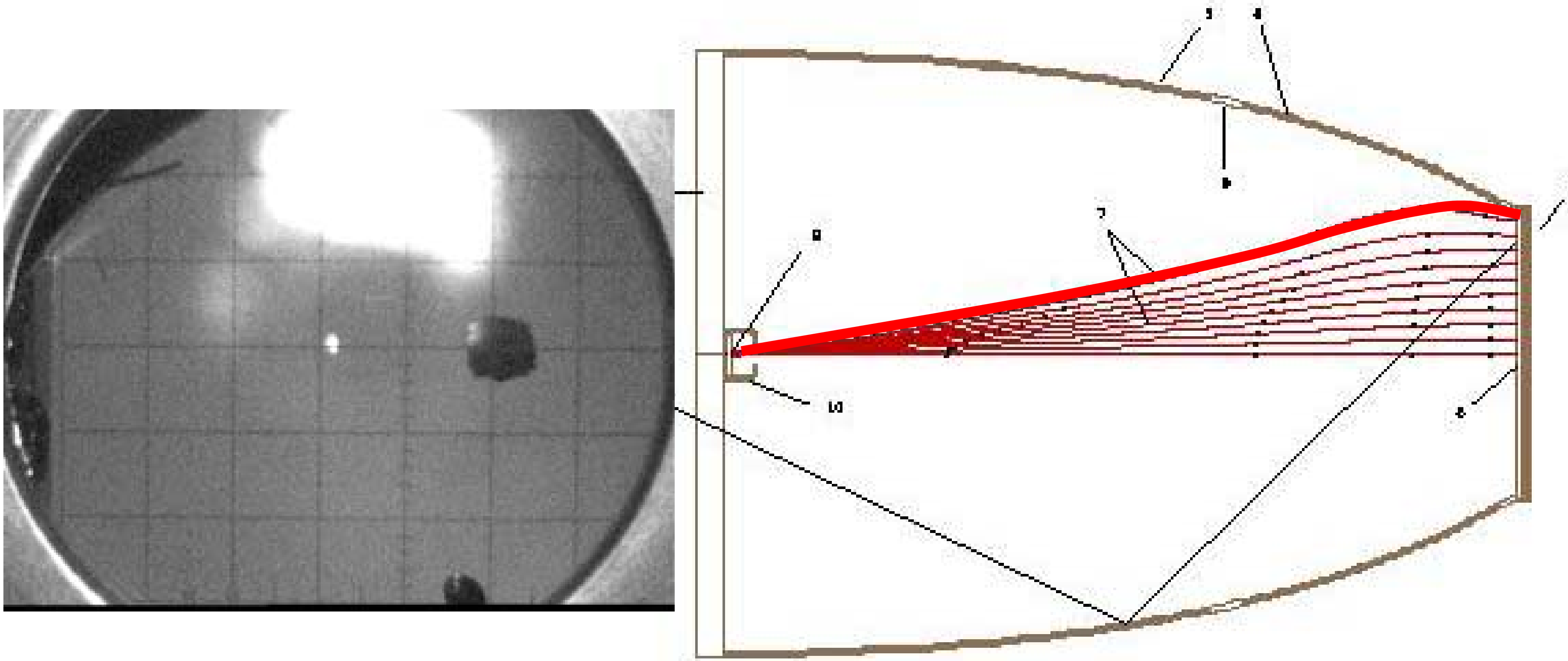
3” diameter, single pixel

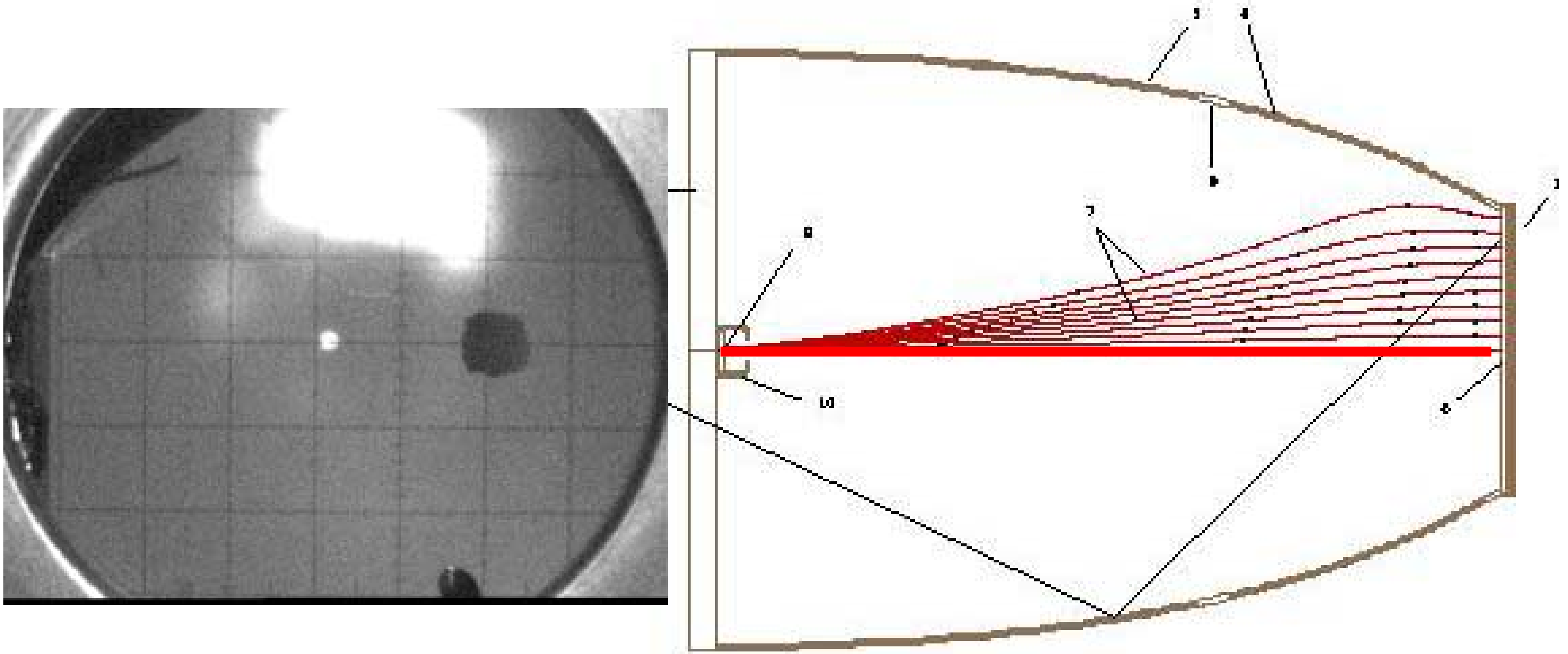
(successfully tested – see below)


Phosphor Screen


"Photocathode"


XYZ Motion Stage





Strong signal concentration, factor ~ 1500

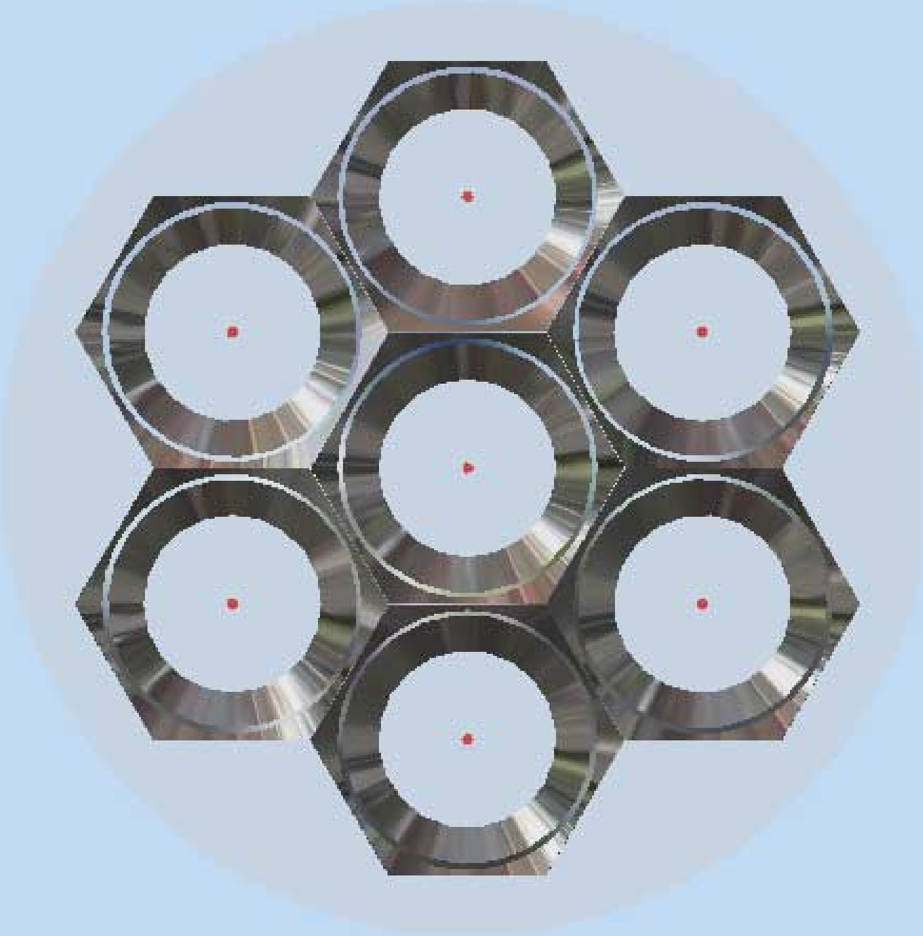
(one of our goals)

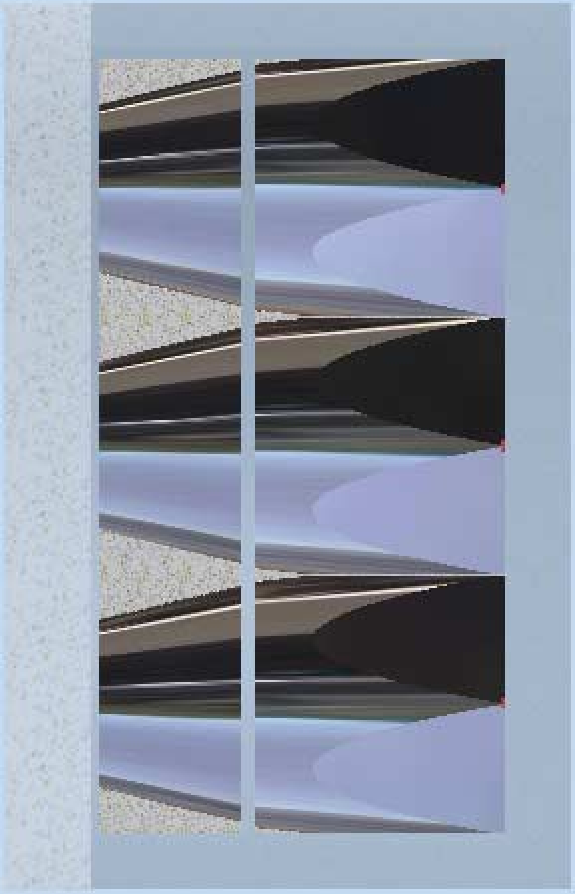
Replaces the entire Dynode Column!

Provides 100% Collection Efficiency!

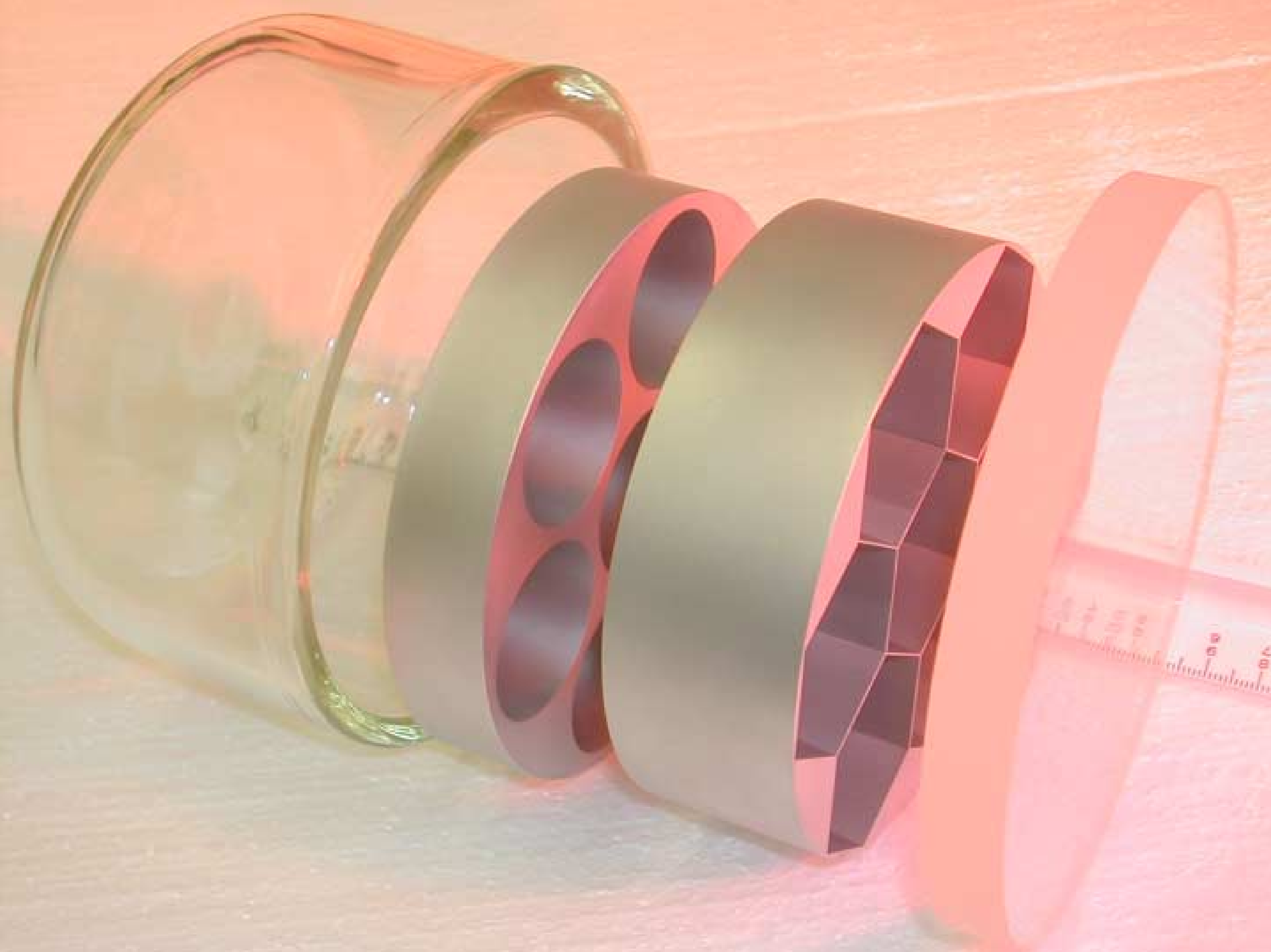
- **APD**
- **Scintillator + Fiber (both of small and comparable diameter – transmission efficiency)**

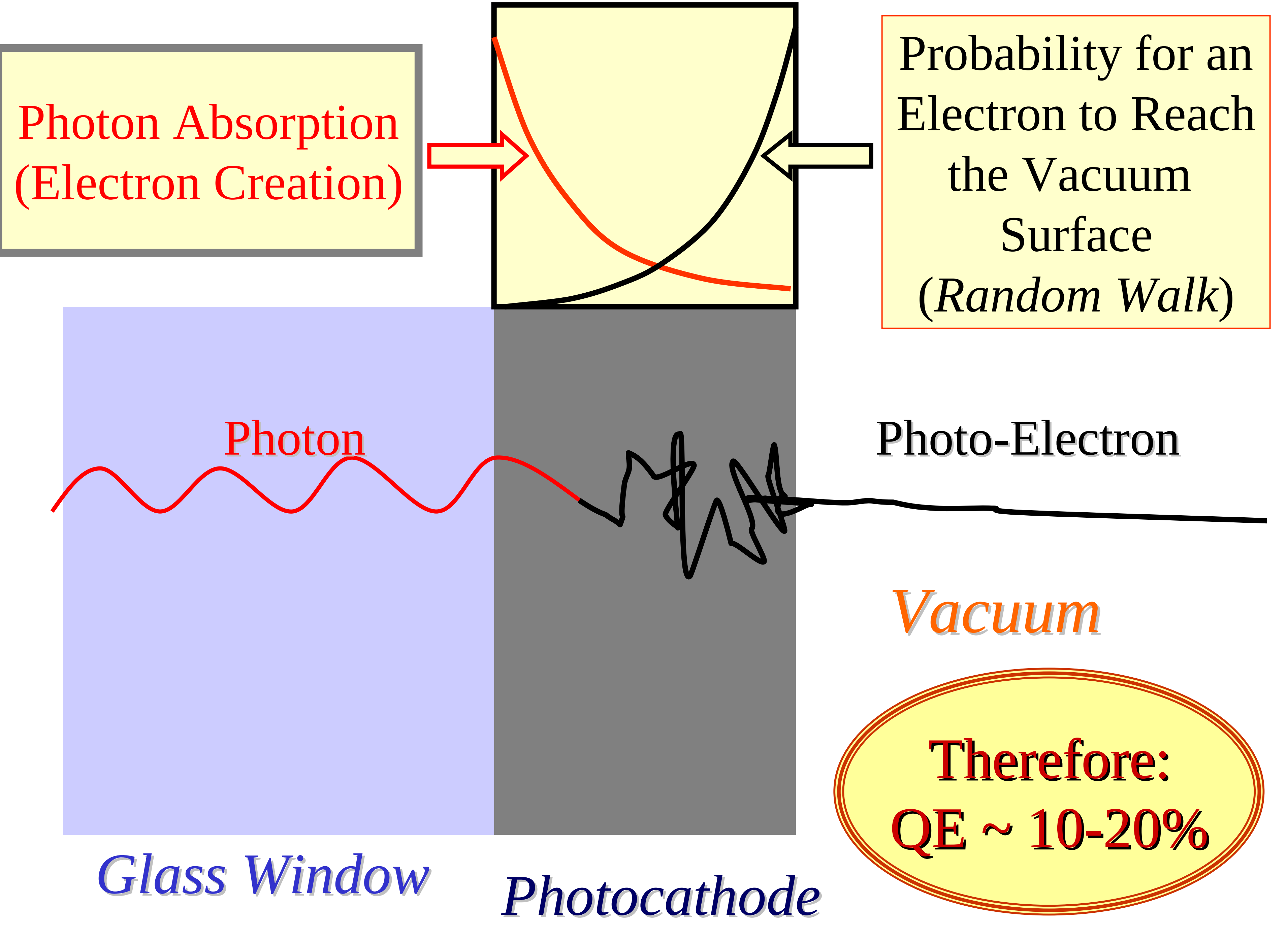
ReFerence Panel Prototype (under construction)

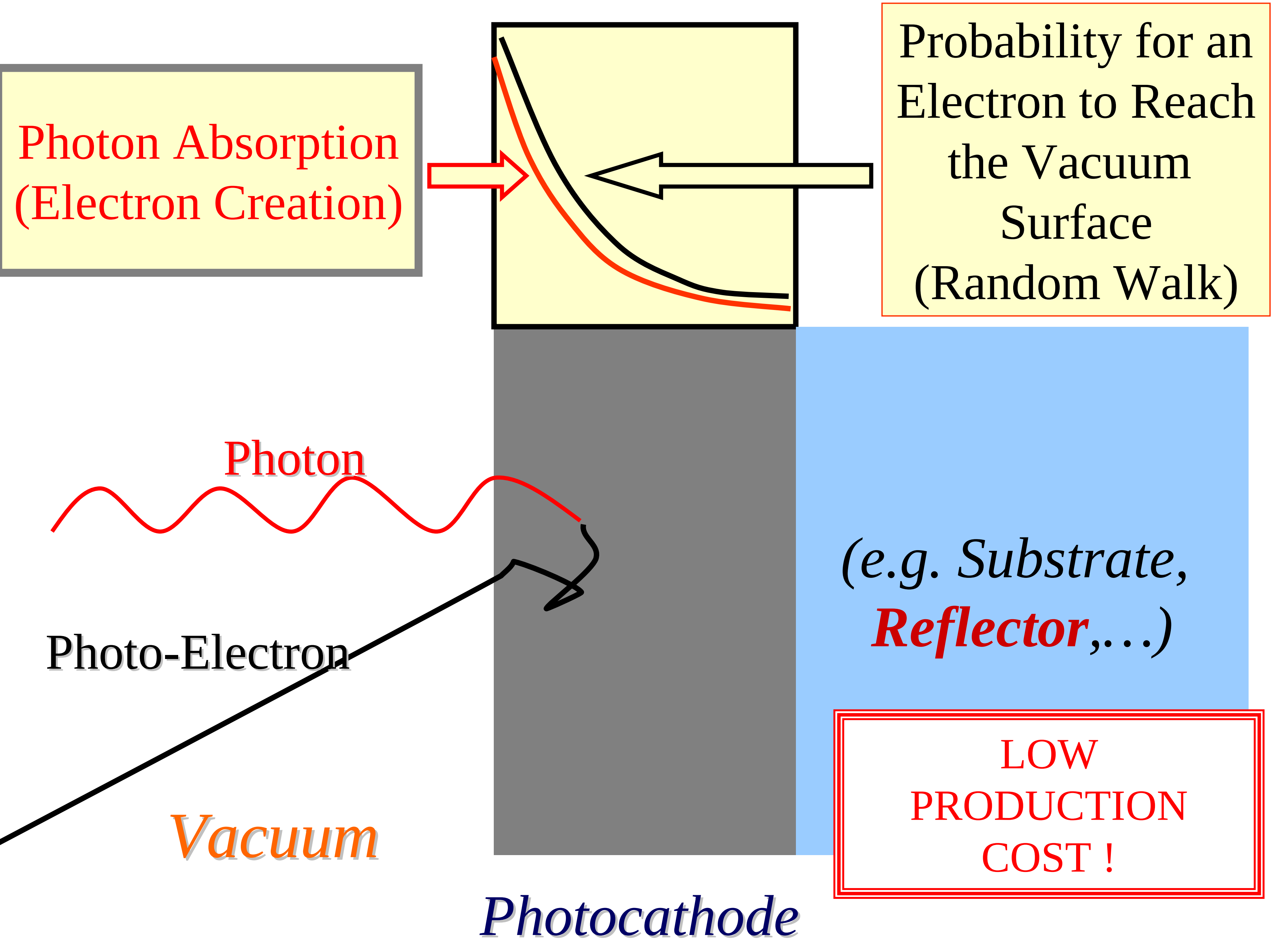


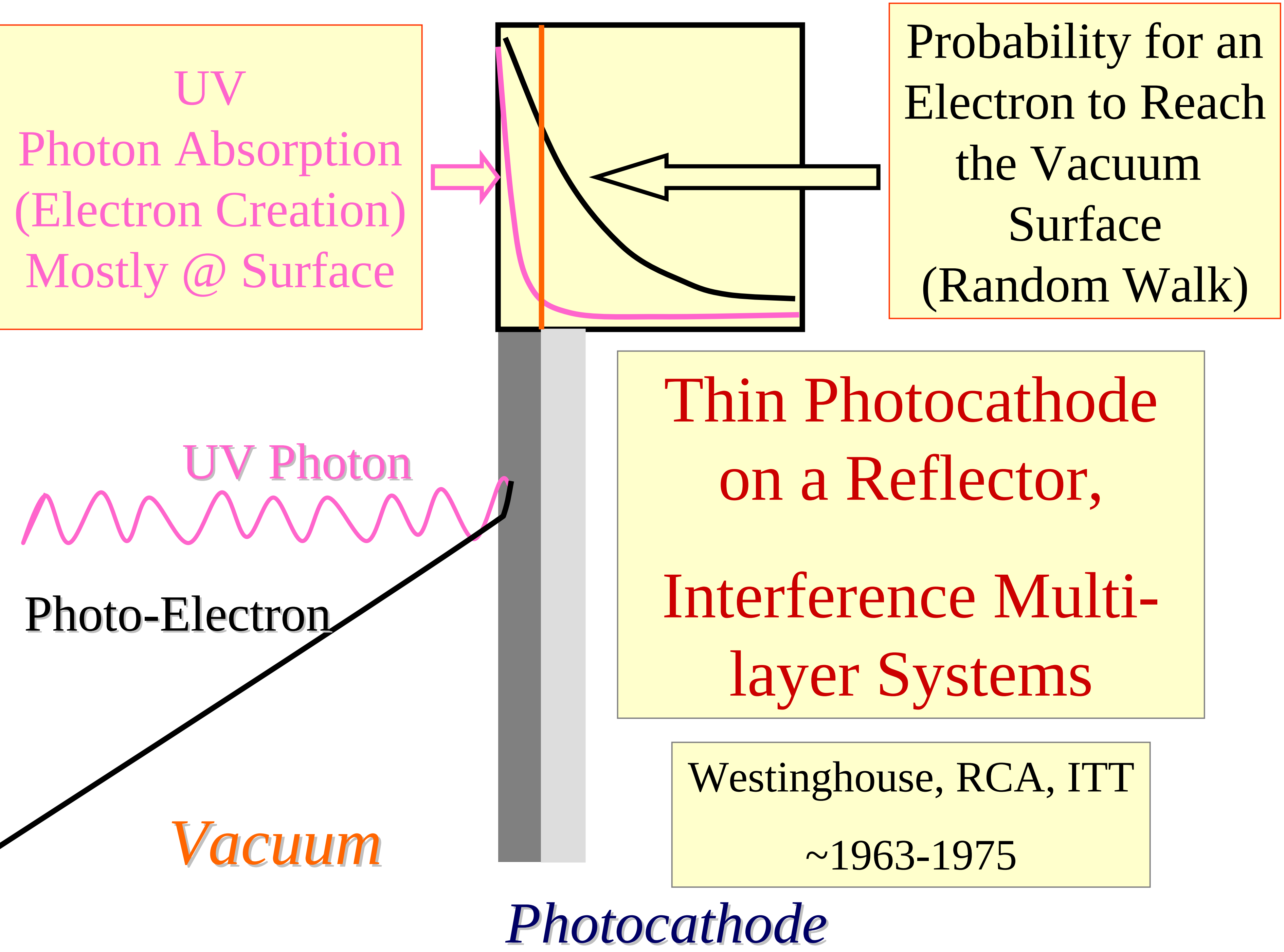



ReFerence Panel Prototype (under construction)
TOSHIBA

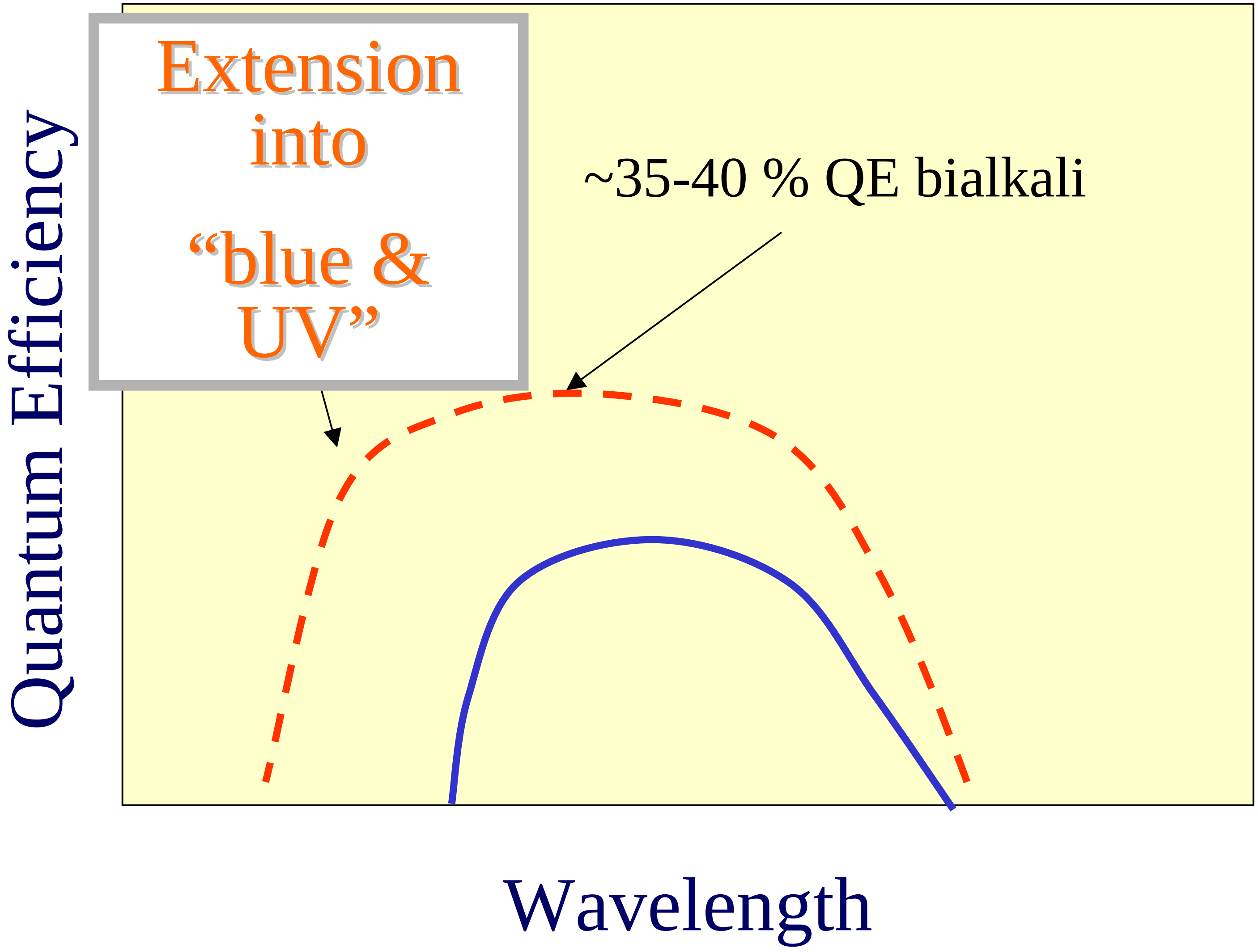



Photon Absorption
(Electron Creation)
Probability for an Electron to Reach the Vacuum Surface
(Random Walk)
Photon
Photo-Electron
Vacuum
Therefore:
QE ~ 10-20%
Glass Window
Photocathode

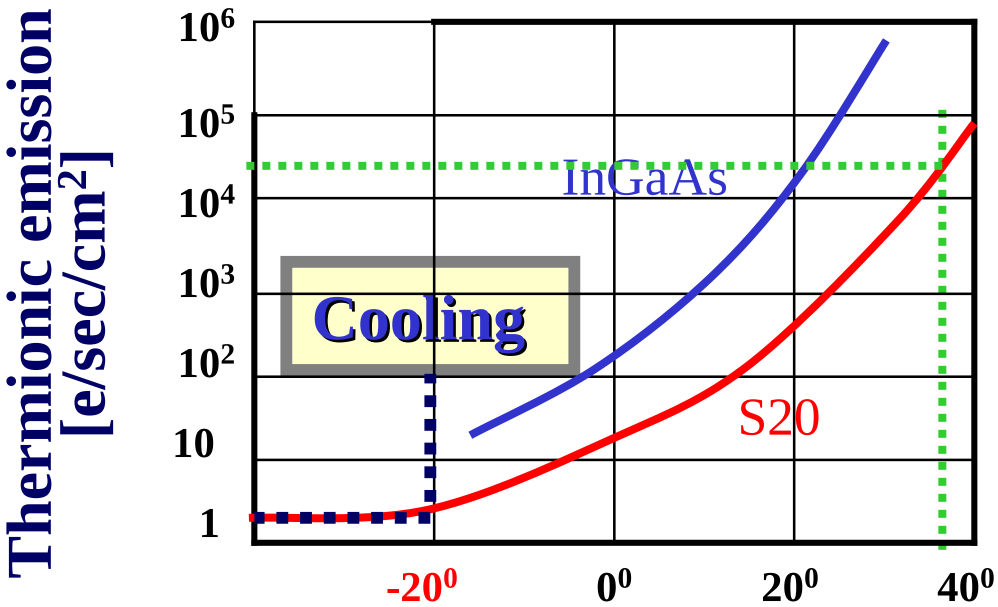

Photon Absorption
(Electron Creation)
Probability for an Electron to Reach the Vacuum Surface
(Random Walk)
Photon
Photo-Electron
(e.g. Substrate, Reflector,…)
LOW PRODUCTION COST !
Vacuum
Photocathode


UV
Photon Absorption
(Electron Creation)
Mostly @ Surface
Probability for an
Electron to Reach
the Vacuum
Surface
(Random Walk)
Thin Photocathode
on a Reflector,
Interference Multi-
layer Systems
UV Photon
Photo-Electron
Westinghouse, RCA, ITT
~1963-1975
Vacuum
Photocathode

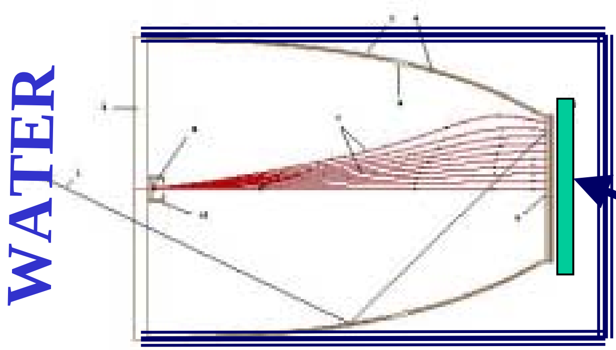
Reflection Mode vs. Transmission Mode



Photocathode Cooling - Diminished Dark Current

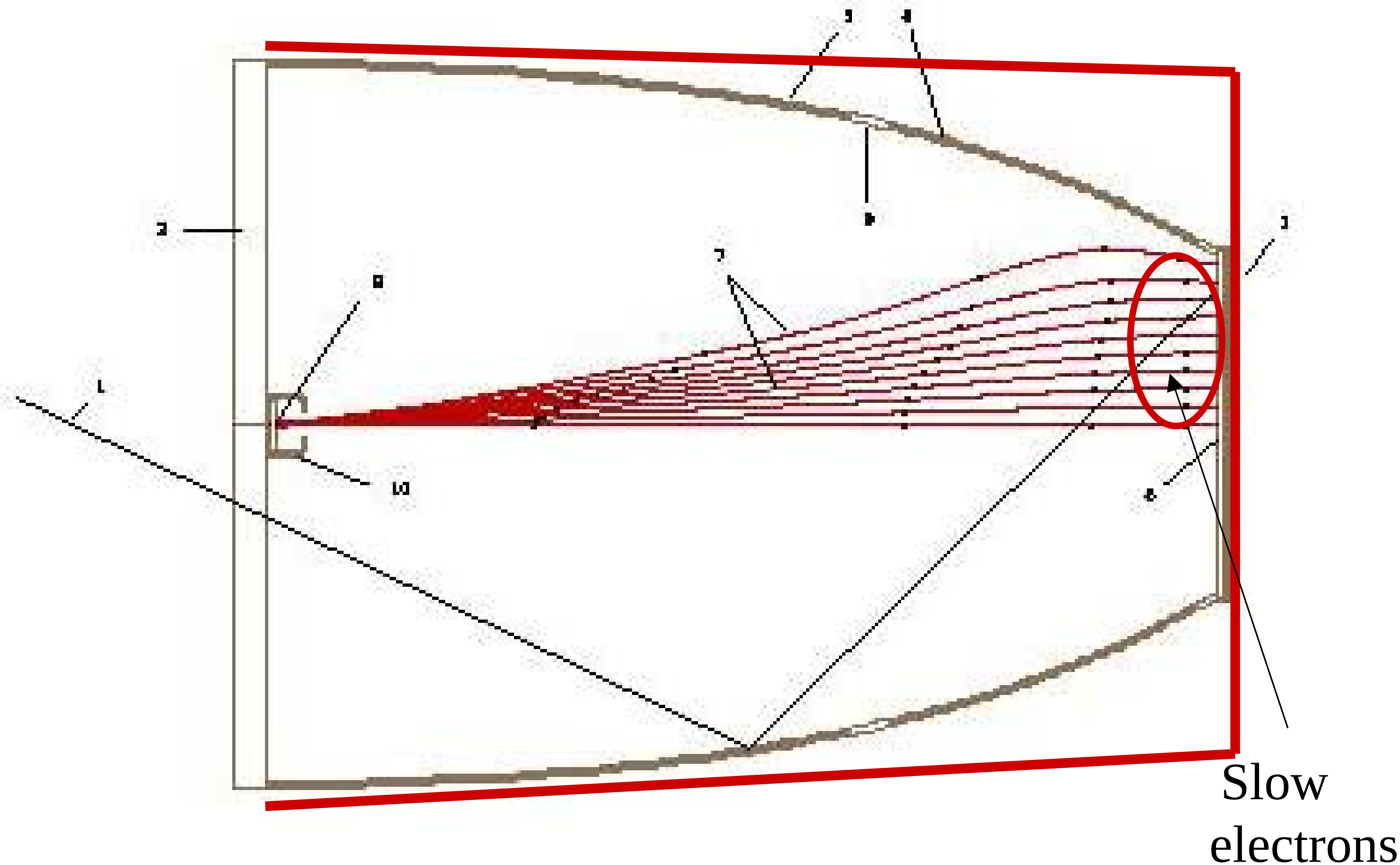


Carlsbad NM



Cooling (Peltier)

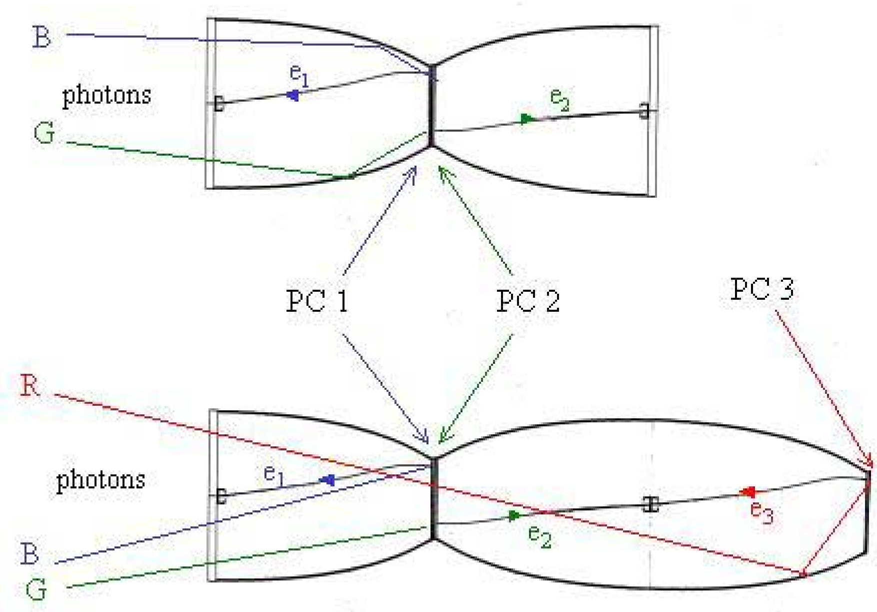
VERY EFFICIENT MAGNETIC SHIELDING

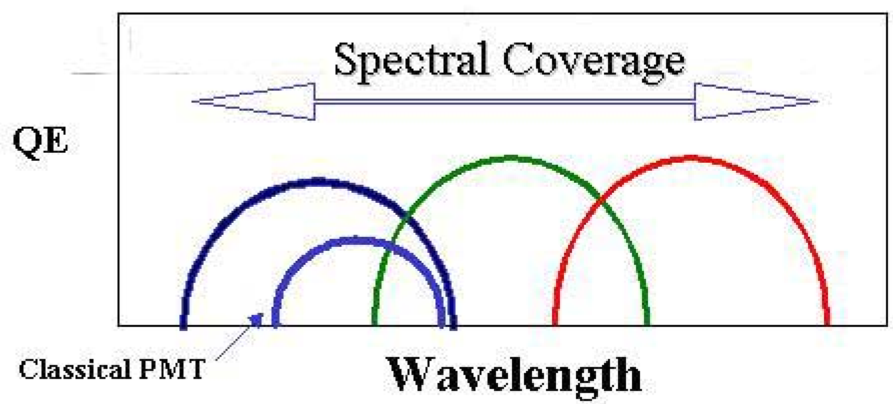


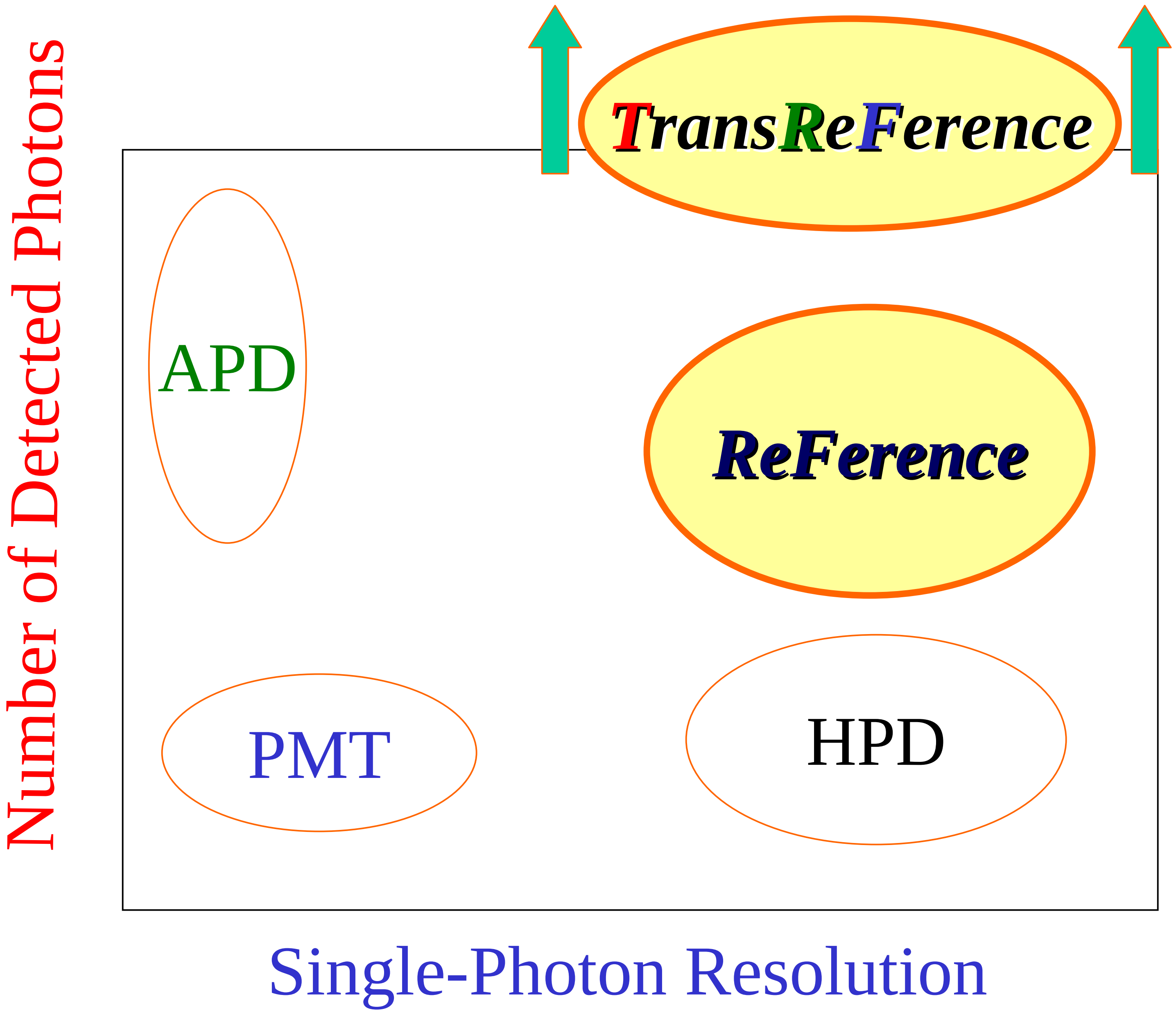
e.g. UNO with Magnetic Field (???)

TransReFerence

Single-Photon Color Sensitivity






TransReFerence
ReFerence
APD
PMT
HPD
Number of Detected Photons
Single-Photon Resolution

Resources @ UC Davis

- **Ideas, enthusiasm, physicists**
- **Running Projects**
- **Equipment (>$2M value)**

For Photocathode development:

Surface Science laboratory: AES, XPE, SIMS,…

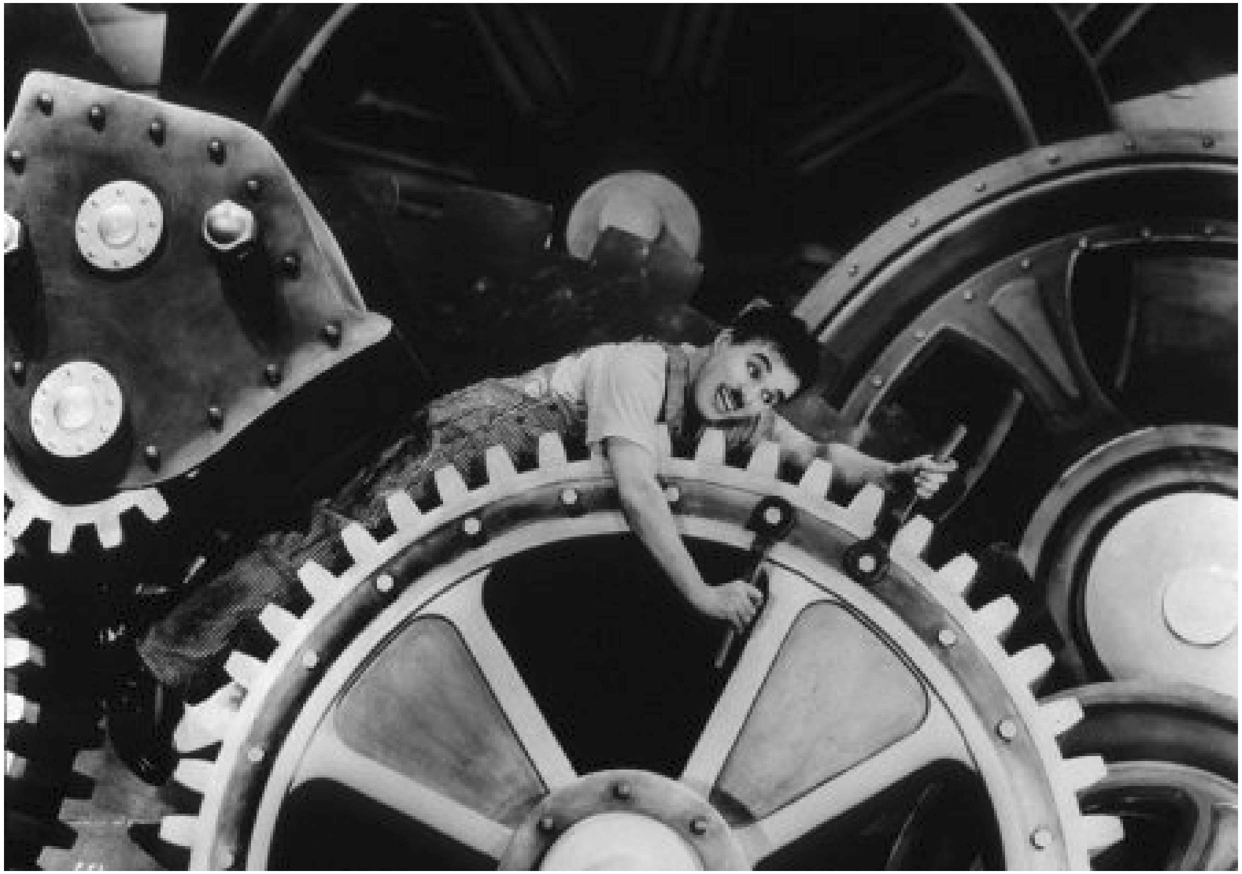
For Flat Panel <u>manufacturing</u>:

2 Flat Panel Sealing Devices (IR Laser Sealing)

Several Transfer UHV Systems !!!

Night Vision production machine

WHAT WE NEED:



➔ NEW PHYSICS