The Light Amplifier Concept

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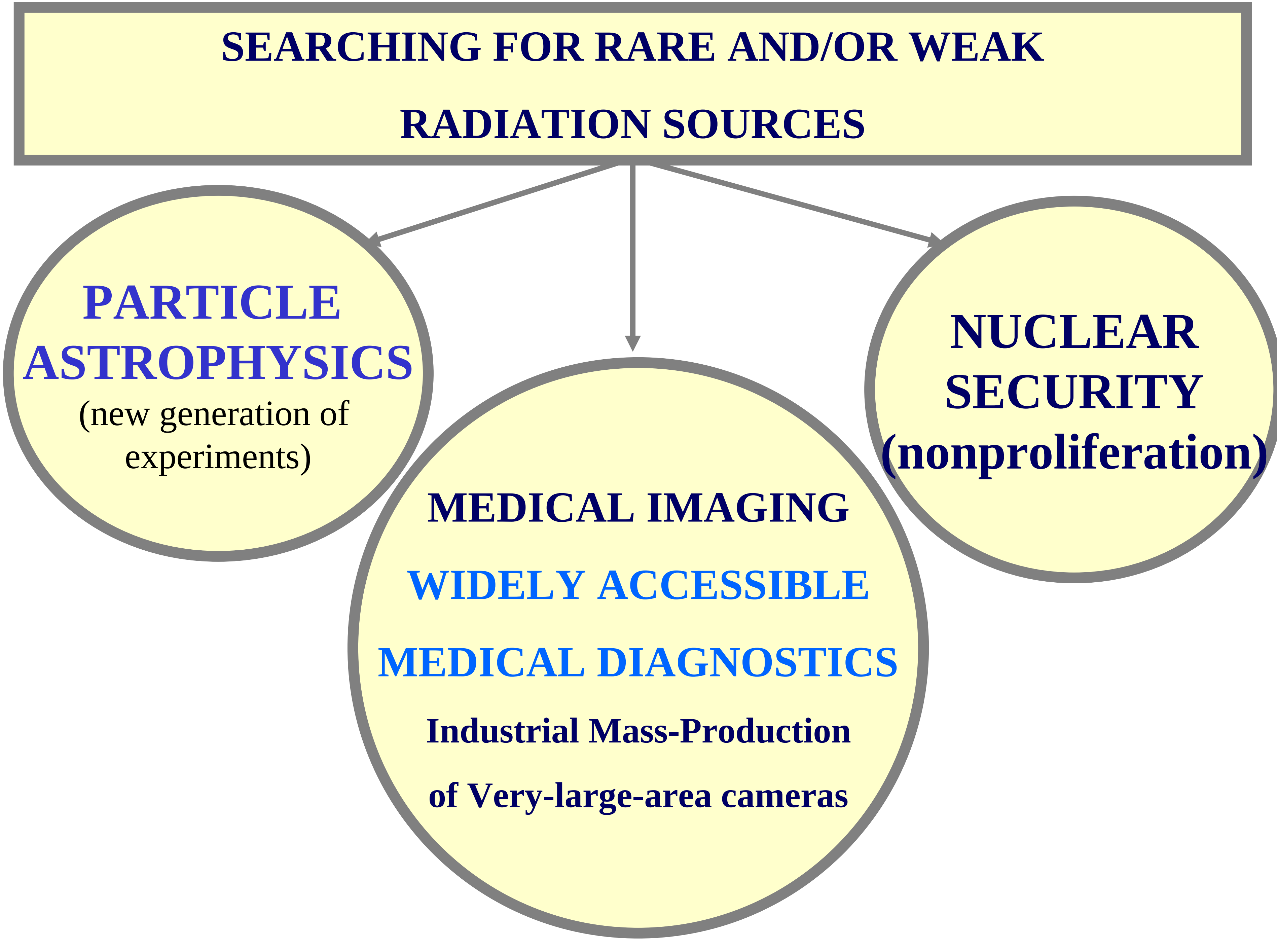
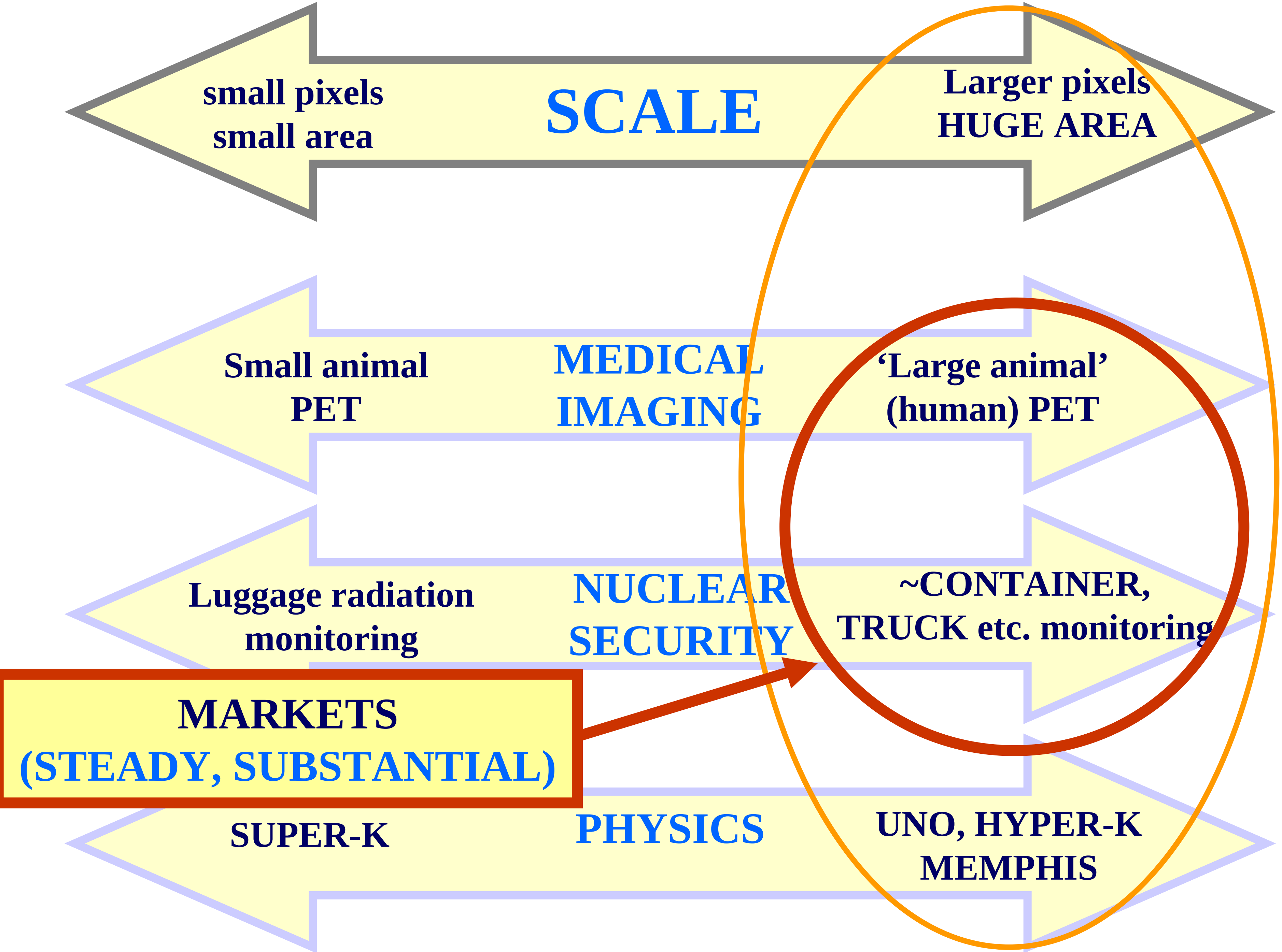
Future particle astrophysics projects to study very rare phenomena

- Proton Decay
- Neutrino Physics
- Neutrino Astrophysics
- Gamma-ray Astronomy
  (low detection threshold & wide acceptance angle)
- Ultra-high energy cosmic rays (>10^{19} eV)
- Neutrinoless Double Beta Decay
- WIMP Searches


SEARCHING FOR RARE AND/OR WEAK
RADIATION SOURCES
PARTICLE
ASTROPHYSICS
(new generation of
experiments)
NUCLEAR
SECURITY
(nonproliferation)
MEDICAL IMAGING
WIDELY ACCESSIBLE
MEDICAL DIAGNOSTICS
Industrial Mass-Production
of Very-large-area cameras


small pixels
small area
SCALE
Larger pixels
HUGE AREA
Small animal
PET
MEDICAL
IMAGING
'Large animal'
(human) PET
Luggage radiation
monitoring
NUCLEAR
SECURITY
~CONTAINER,
TRUCK etc. monitoring
MARKETS
(STEADY, SUBSTANTIAL)
SUPER-K
PHYSICS
UNO, HYPER-K
MEMPHIS

OUR GOAL

A new Technology for

Industrial Mass-Production

of large photosensor areas,

based on modified existing technologies

(e.g. the assembly of modern, plasma and field-emission flat-panel TV screens; low production cost ~$1000 per sq. meter)

+ 'REAL' (non-physics) MARKETS,

Several Unconventional Photosensors

- **Flat-Panel *ReFerence* Camera Concept (Patented)**
- ***Light Amplifier* - general concept**
  - **ReFerence panels → scintillator (fiber) readout**
  - **QUASAR or SMART PMT in a modified configuration**

+ Geiger-mode APDs

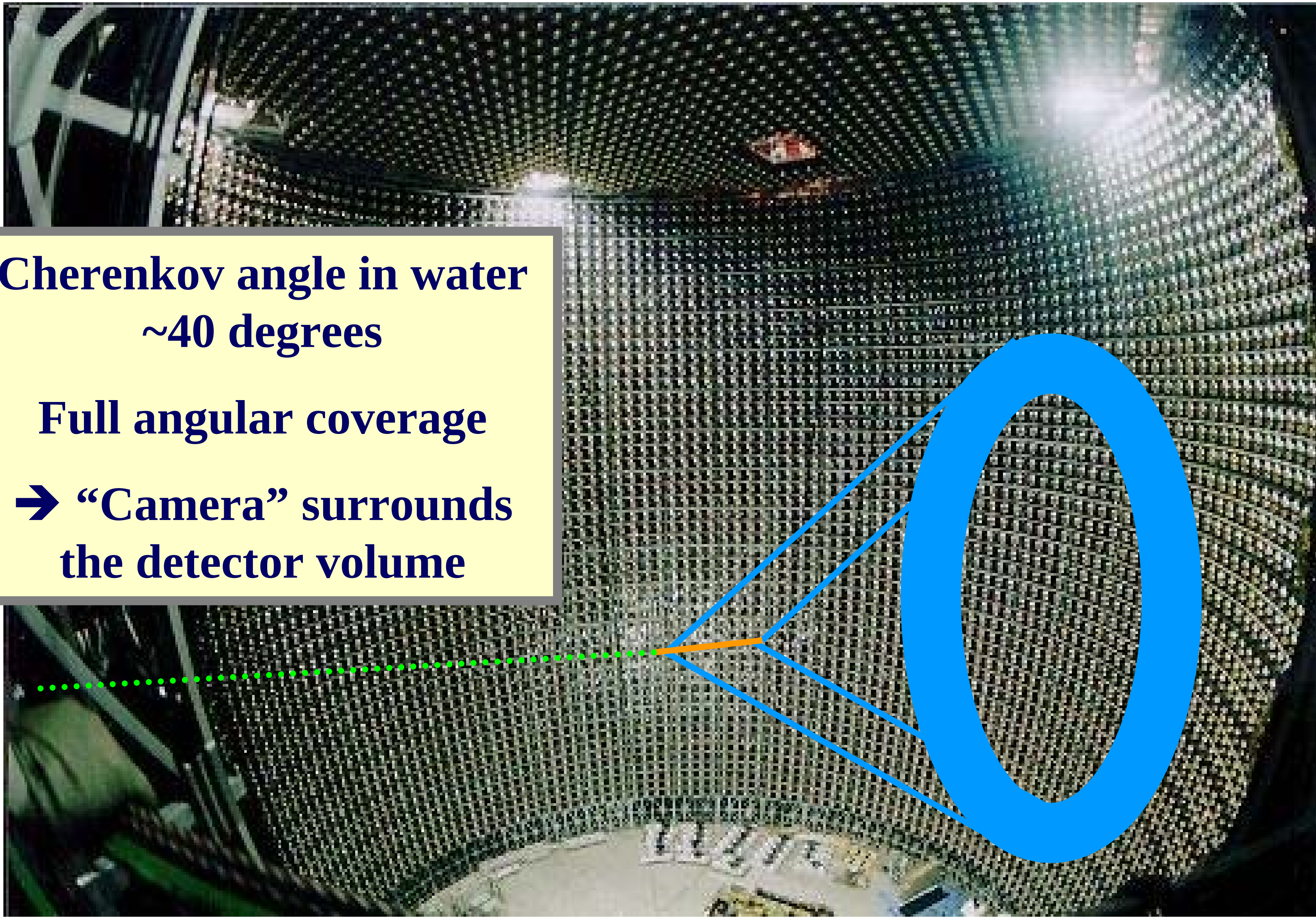
- ***"SIMPLE"* Space Imaging Camera Concept for EUSO, OWL, but also ground-based applications (Patented)**

The Unbeatable Reality of Mr. Liouville

Cherenkov angle in water ~40 degrees

Full angular coverage

➔ "Camera" surrounds the detector volume



Irreducibly Large Illuminated Area

↓

strong <u>internal</u> signal concentration

Vacuum

(photon → photoelectron ➔ 'no more Liouville')

Semiconductor Photosensors

→ developed very successfully

(but pixel sizes and areas - too small)

Vacuum Photosensors

(suitable for large-area applications, strong area reduction) did not develop significantly since mid-1960s

Why?

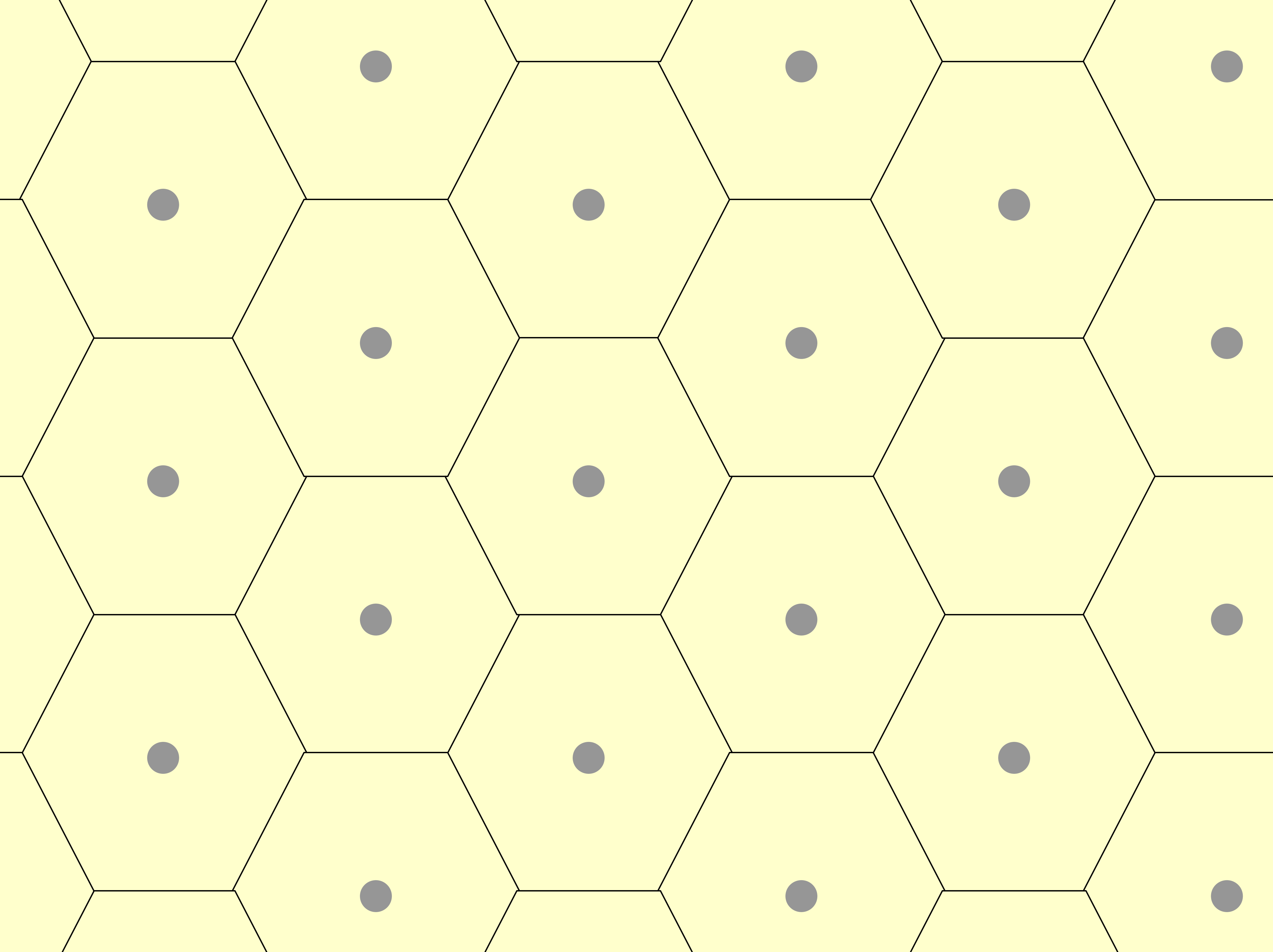
Because of the Vacuum?

Development of Other Vacuum Devices

~1960

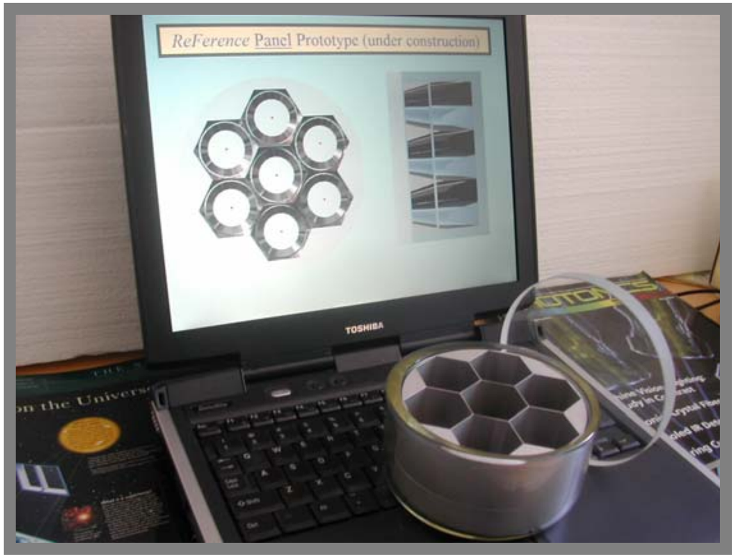
~2000

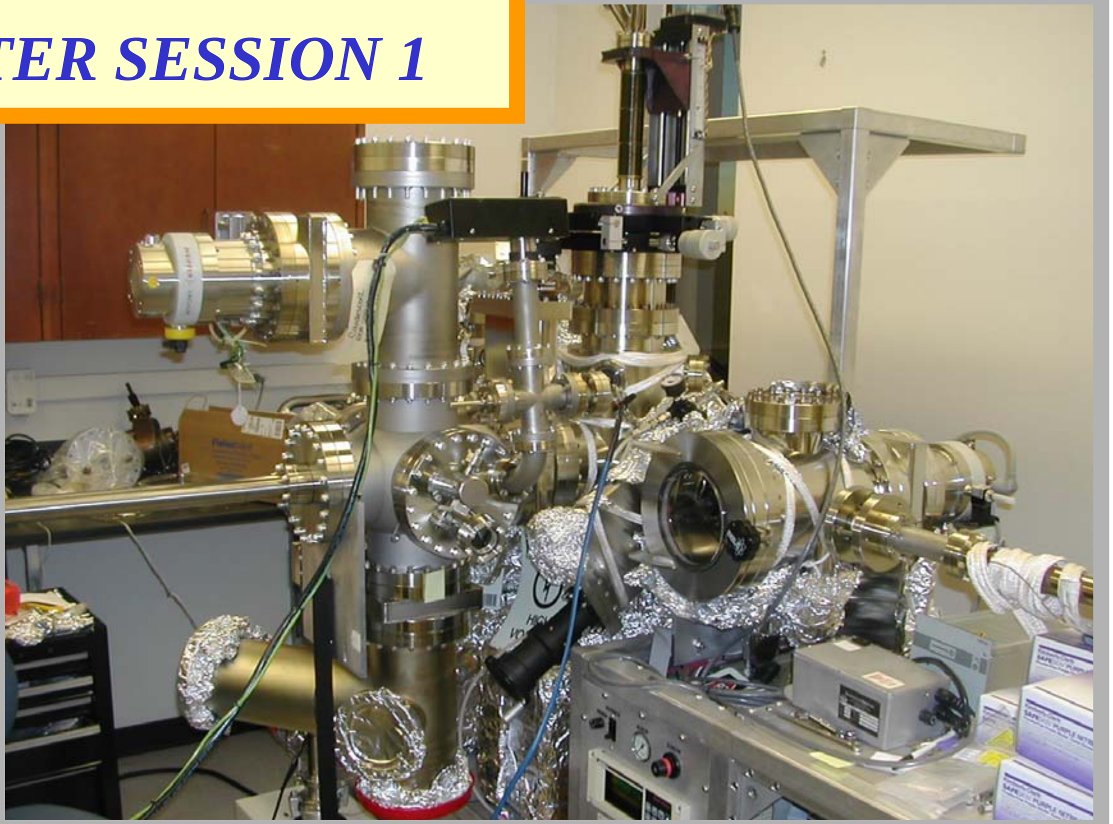
Production Cost: < $1,000 per m^2



7-pixel 5-inch ReFerence Flat-Panel Prototype

POSTER SESSION 1



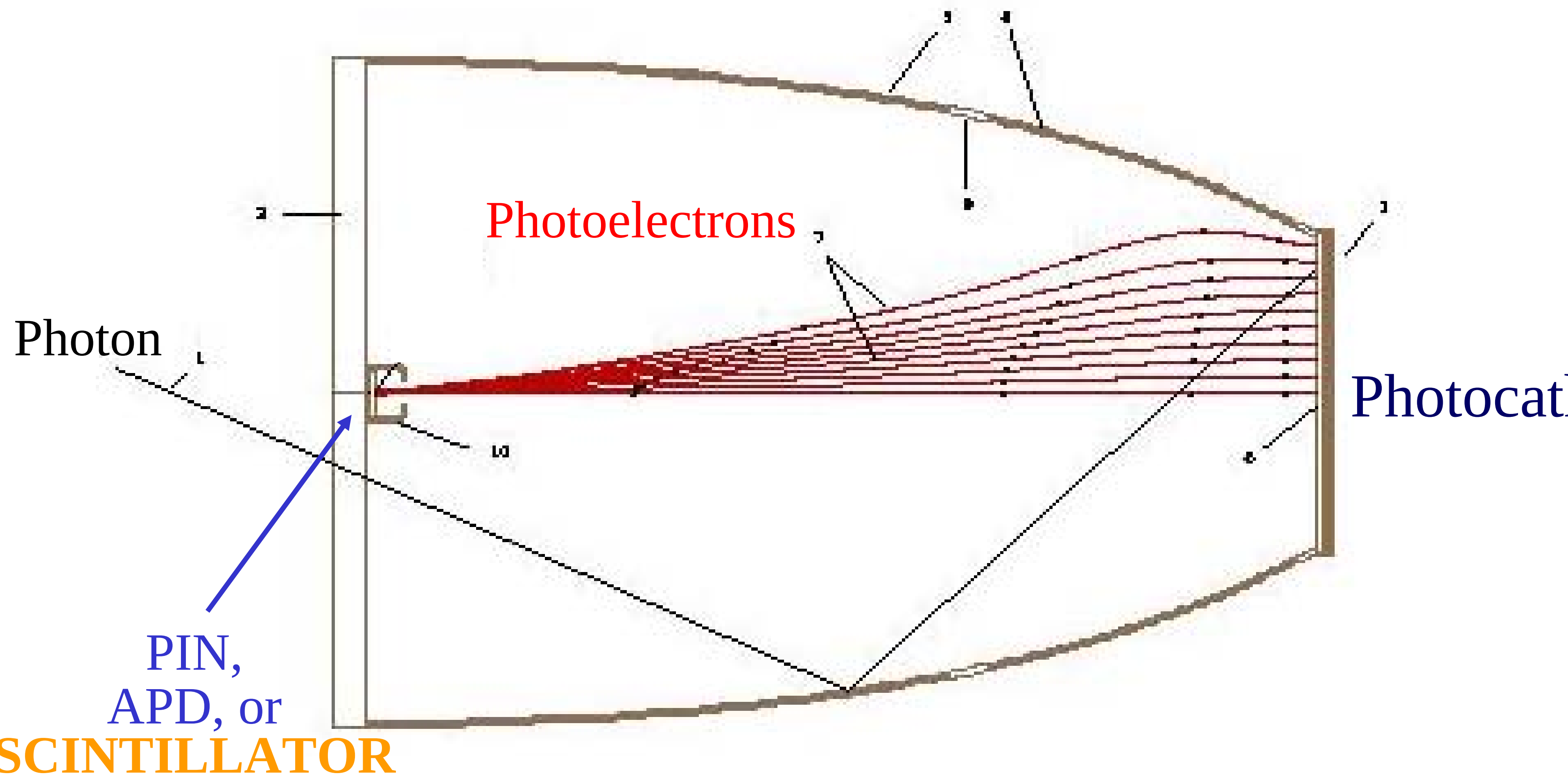


UHV Transfer System :

- **Photocathode deposition**
- **Indium/Au/Cr deposition**
- **Vacuum sealing**

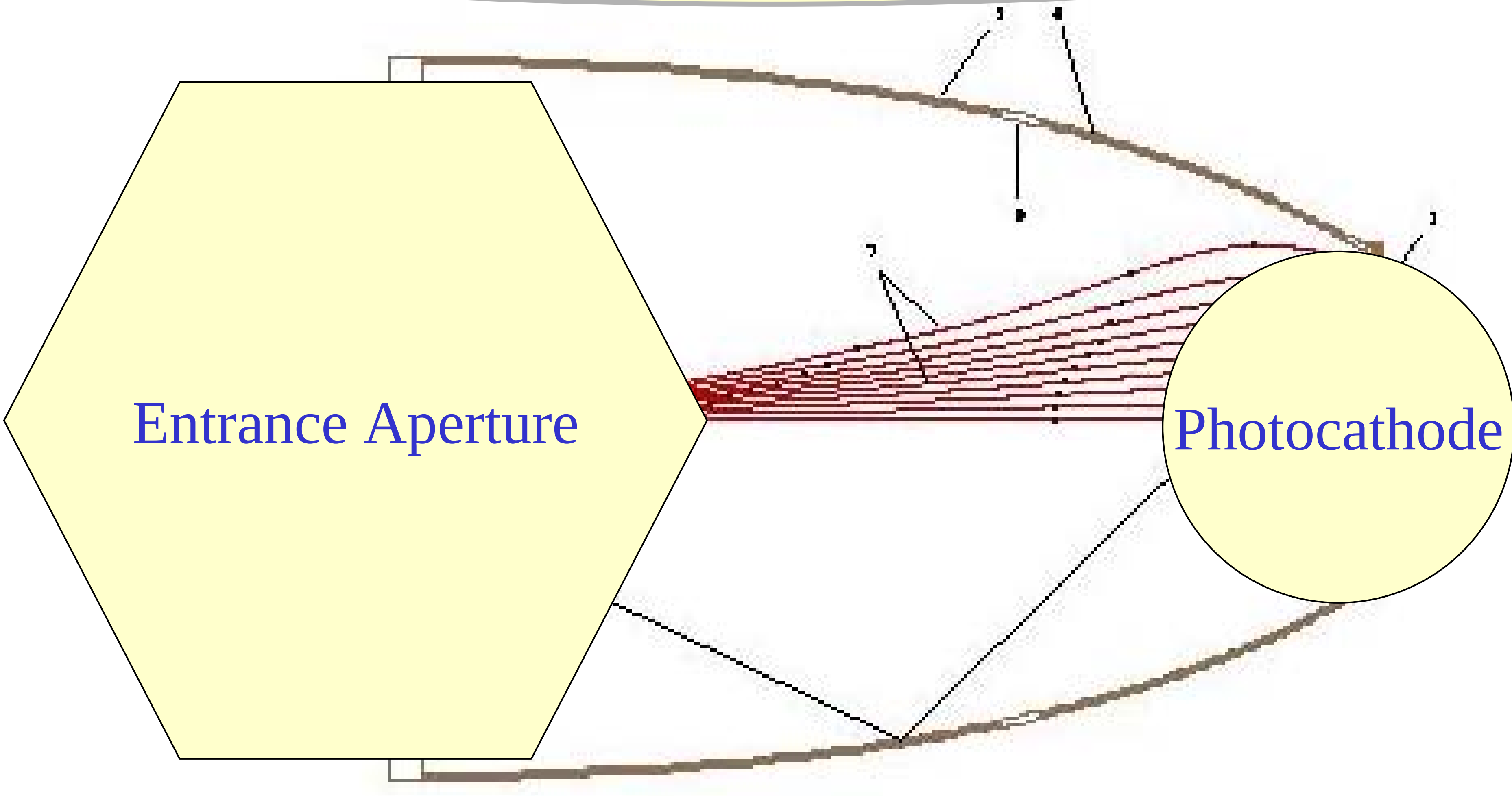
Ideal Light Concentrator

(takes the maximum of Liouville!)

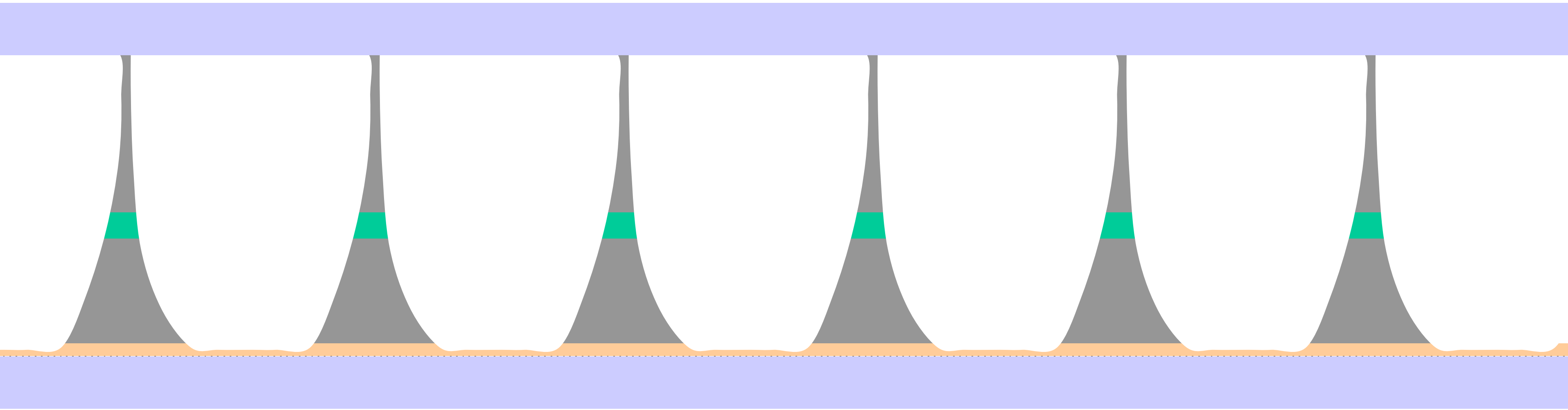


Optimal Electron Lens

Very Important: Hexagonal Packing

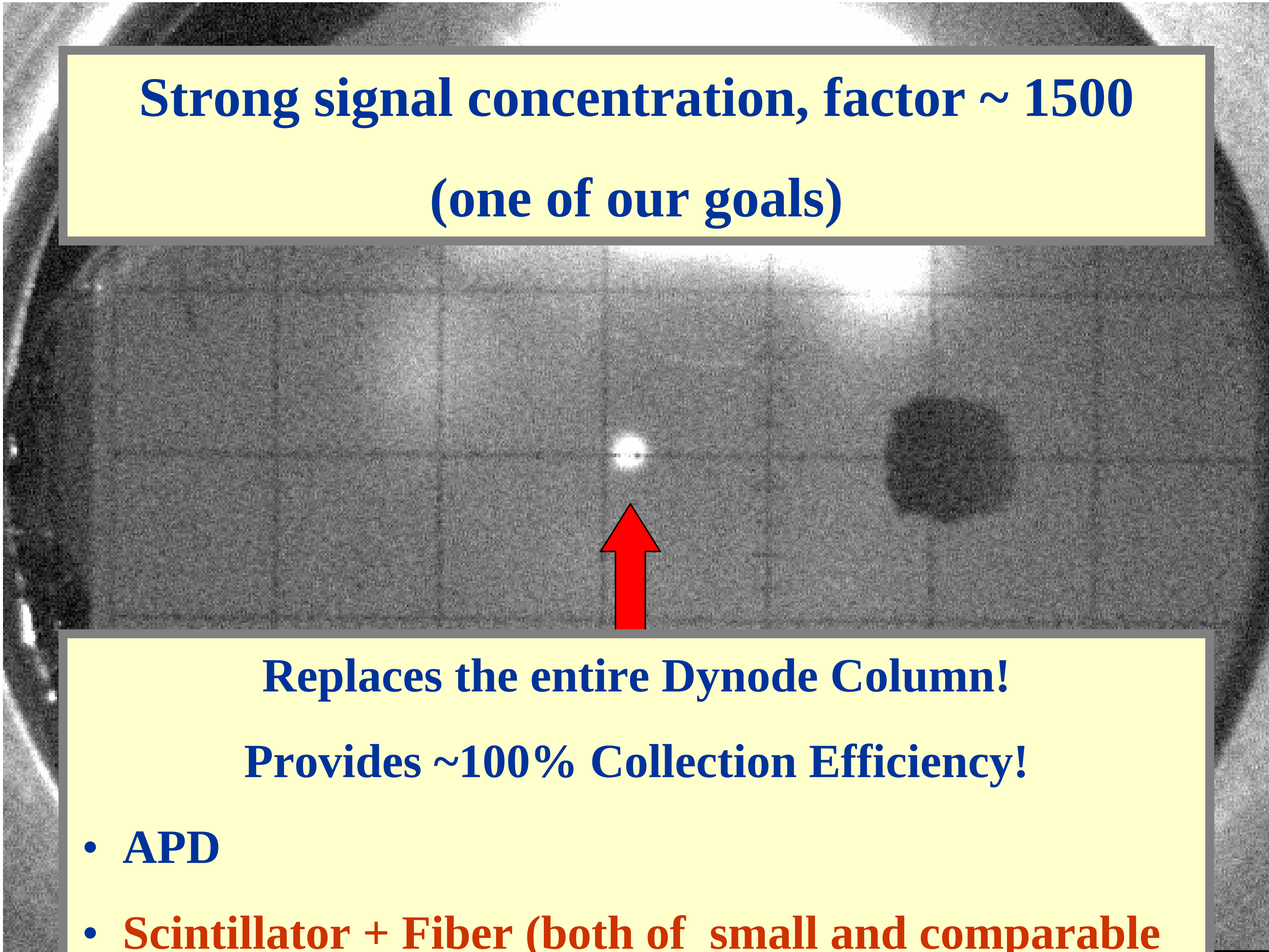


Flat-Panel Honeycomb Sandwich Camera Construction



Industrial Production (no glass blowing etc.)

Intrinsic Mechanical Stability, Low Buoyancy,..



Strong signal concentration, factor ~ 1500

(one of our goals)

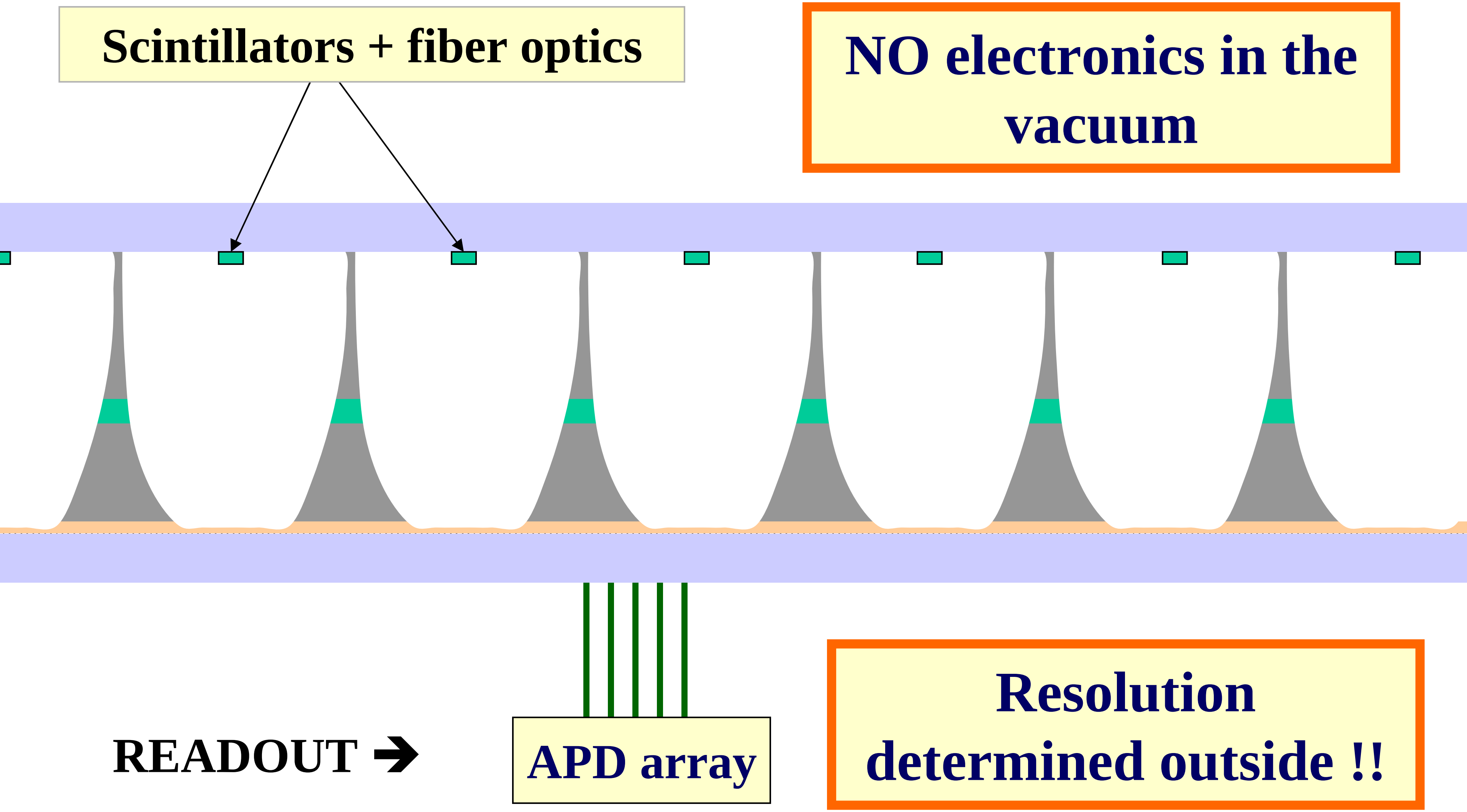
Replaces the entire Dynode Column!

Provides ~100% Collection Efficiency!

- **APD**
- **Scintillator + Fiber (both of small and comparable diameter → good coupling efficiency)**

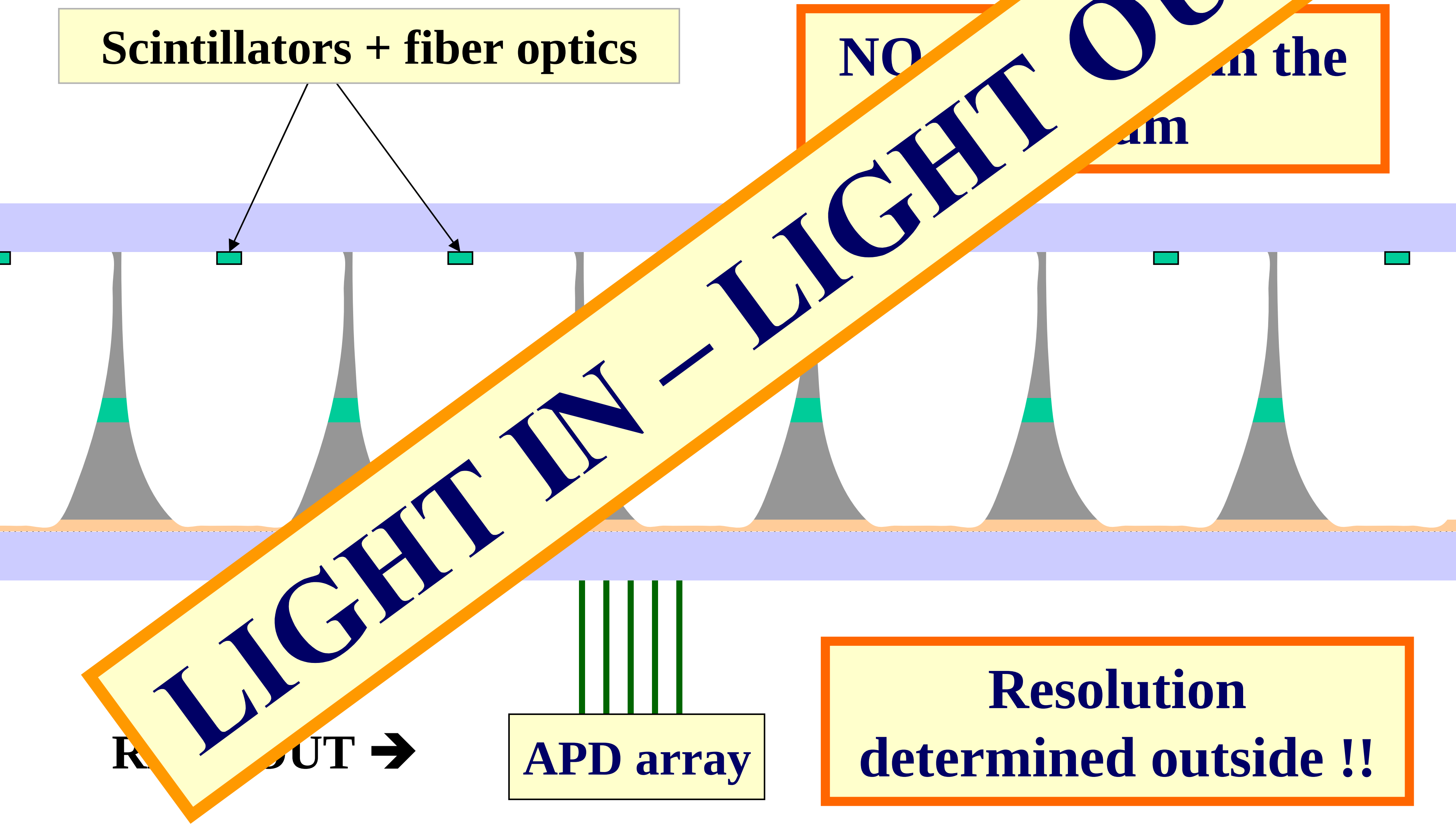
Light Amplifier Concept

NO electronics in the vacuum

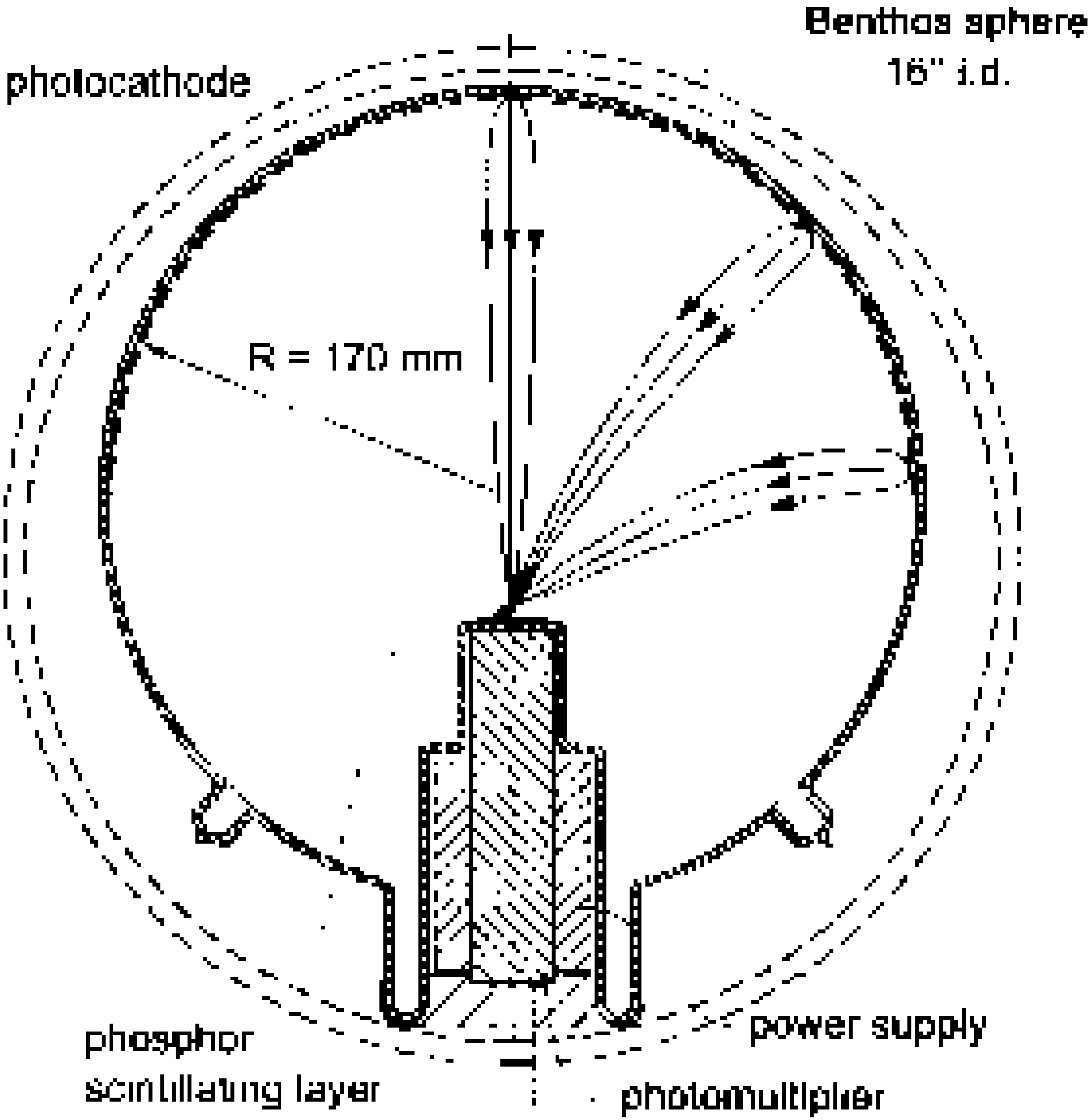


Resolution determined outside !!

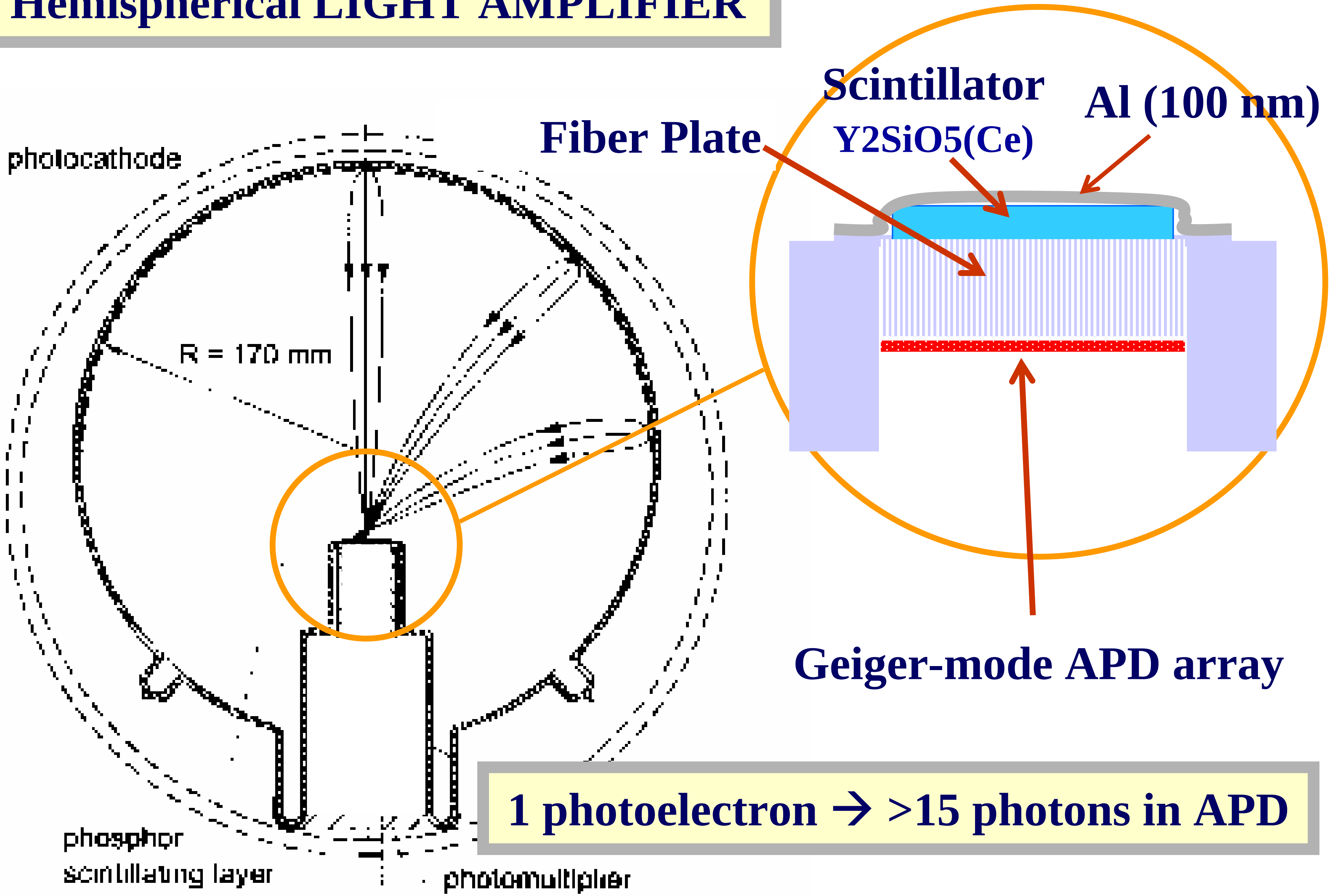
Light Amplifier Concept



SMART PMT, QUASAR



Hemispherical LIGHT AMPLIFIER



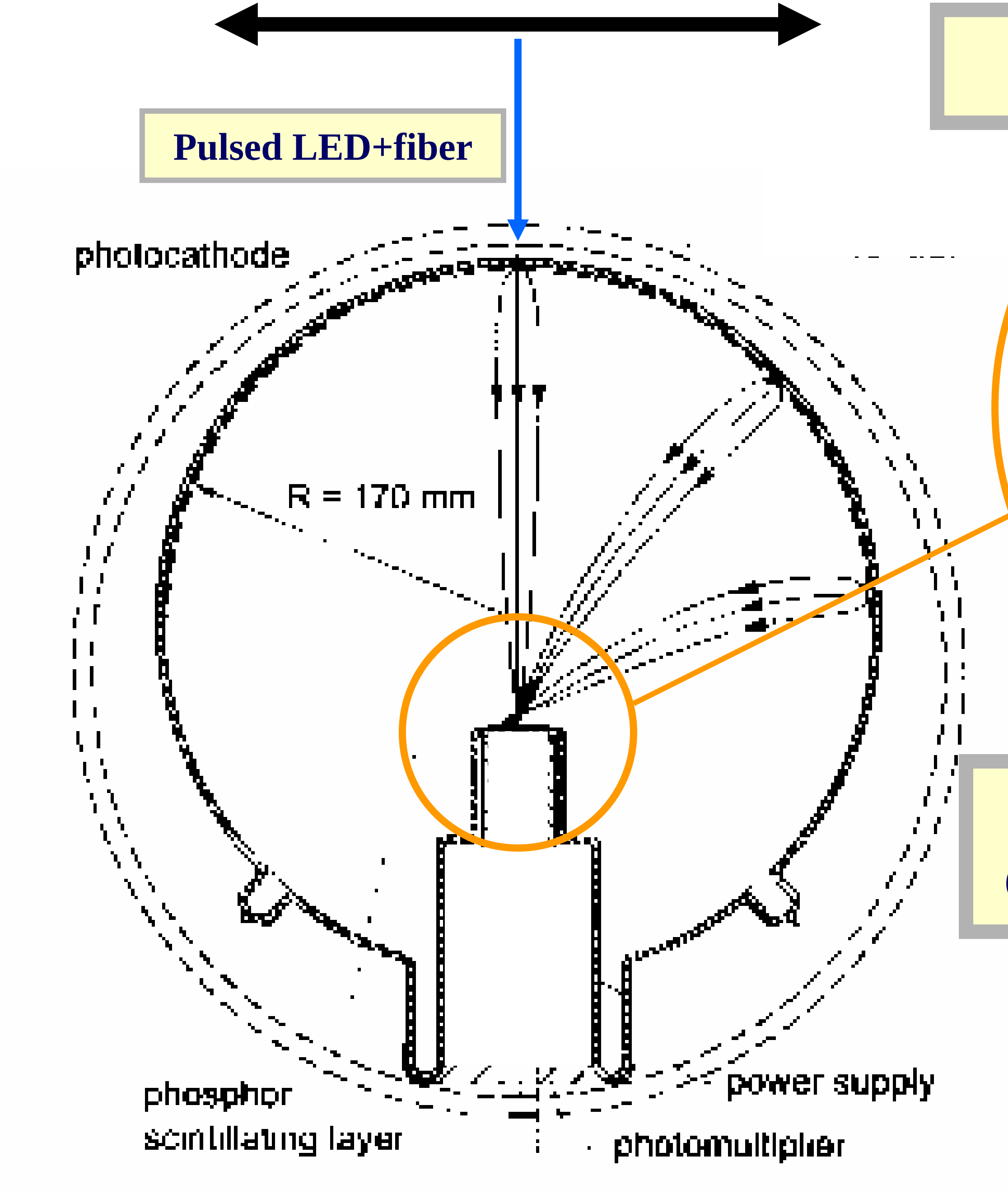
1 photoelectron → >15 photons in APD

SMART PMT, QUASAR

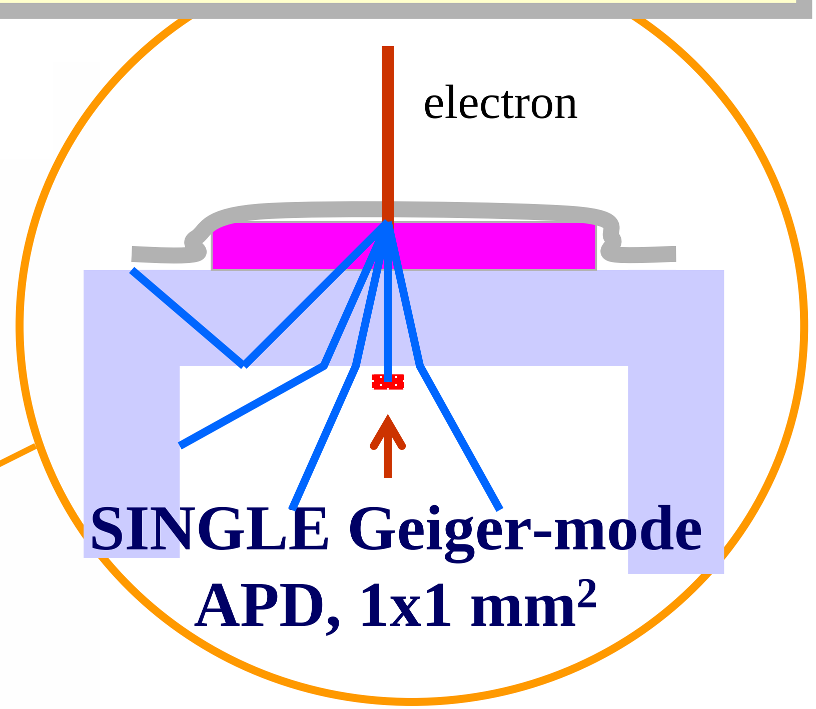
CODORNIU
Reserva
BRUT
ANNA DE CODORNIU
CODORNIU


MAI
BRUT
CODORNIU

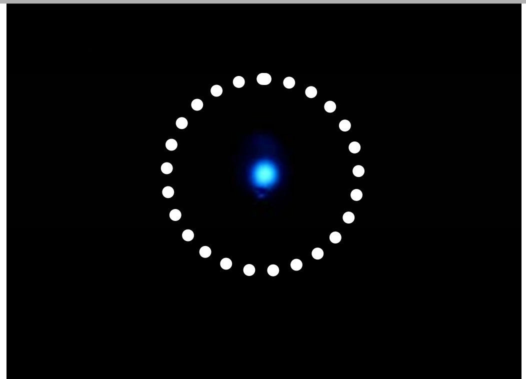
CURRENT SETUP



SMART PMT, QUASAR



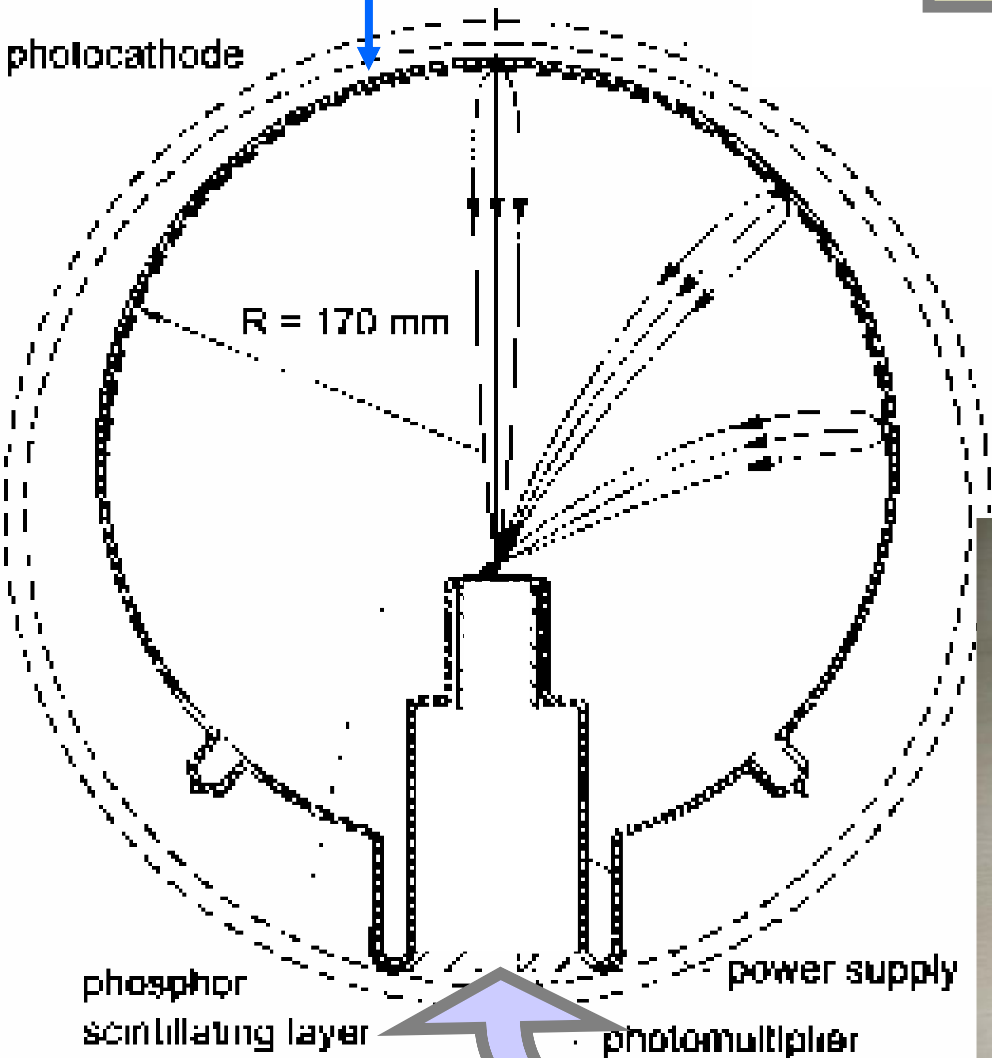
No face-plate → low light Collection Efficiency ~1:150

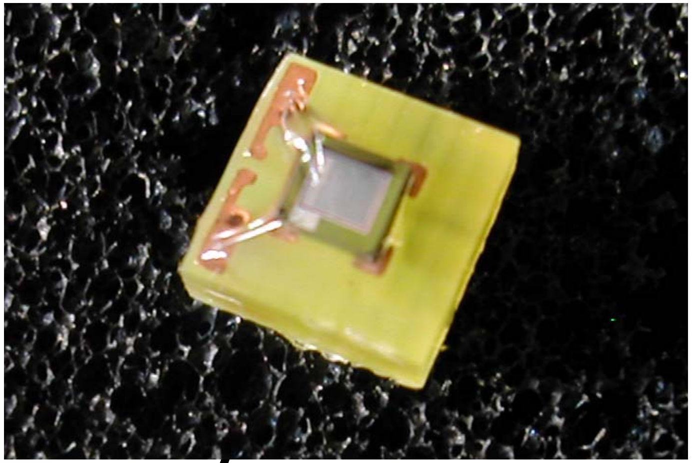


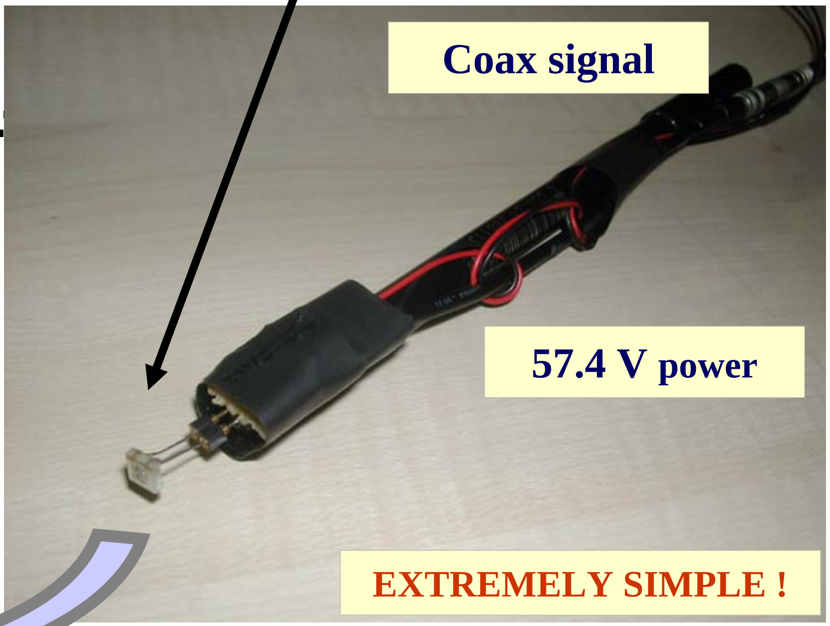
Geiger-mode APD

ZS-2 from Sadygov, MICRON

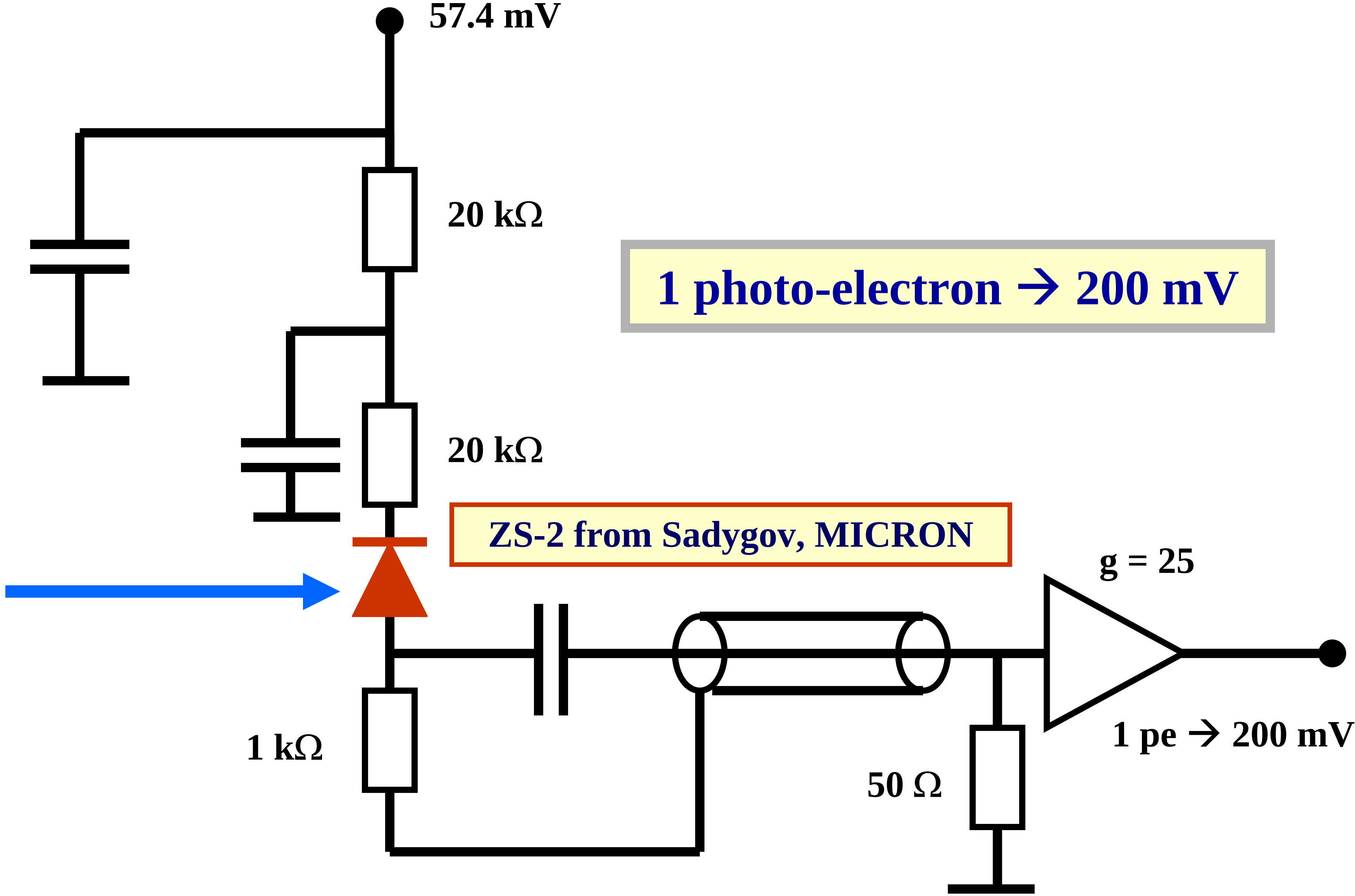
Pulsed LED+fiber





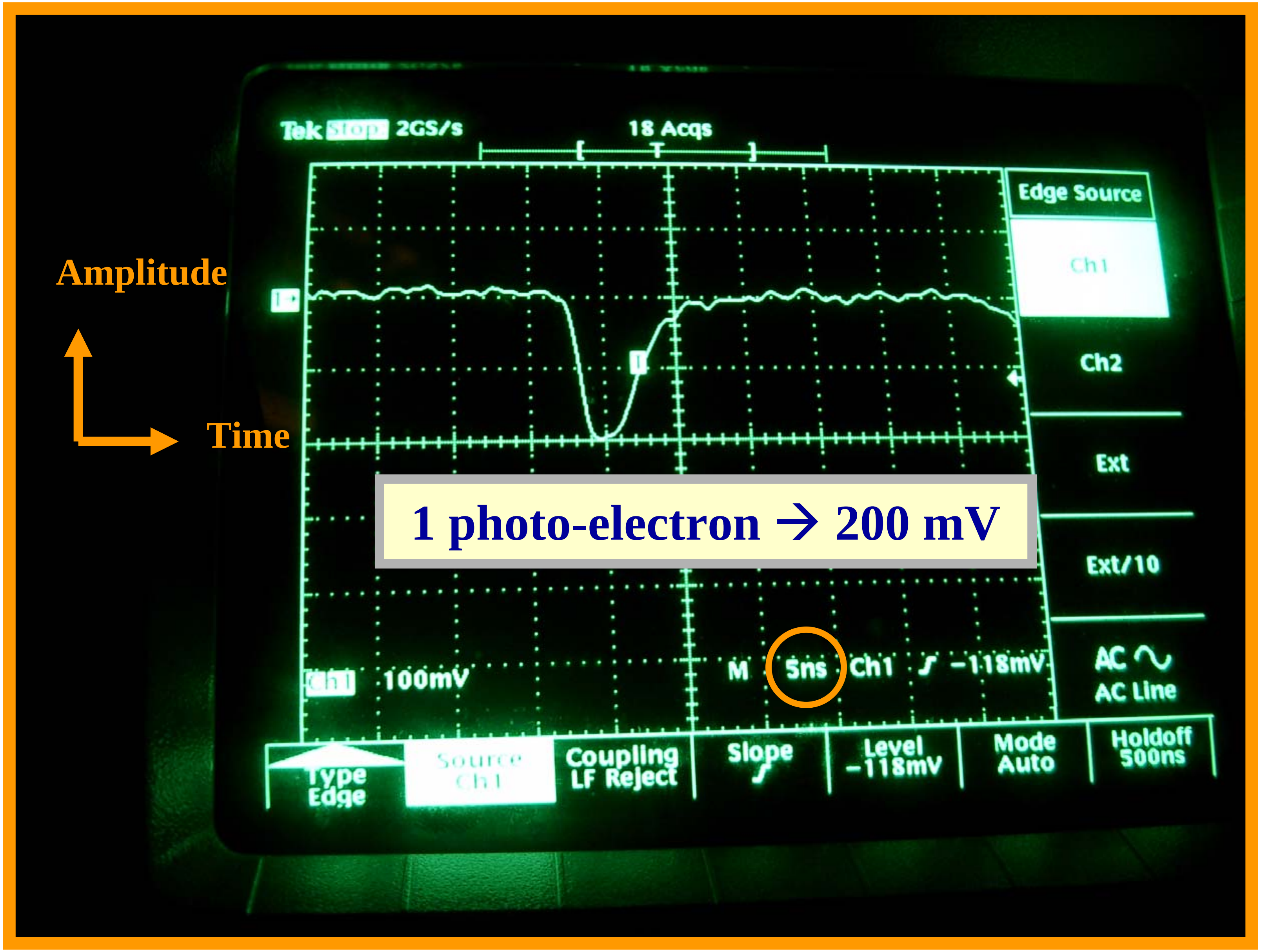


Very Simple Electronics



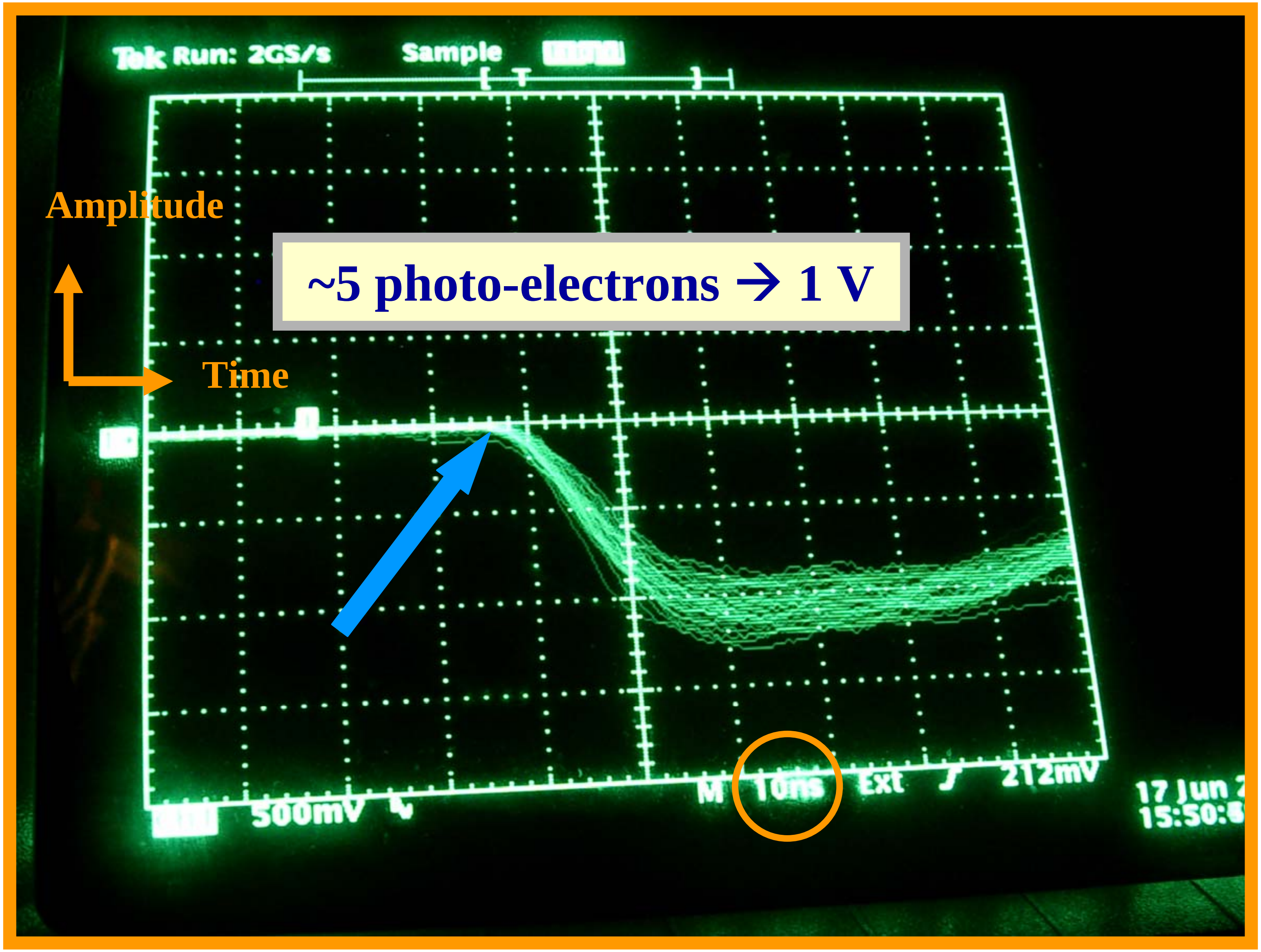
1 photo-electron → 200 mV

A Typical Single-Photon Signal in the Geiger-mode APD



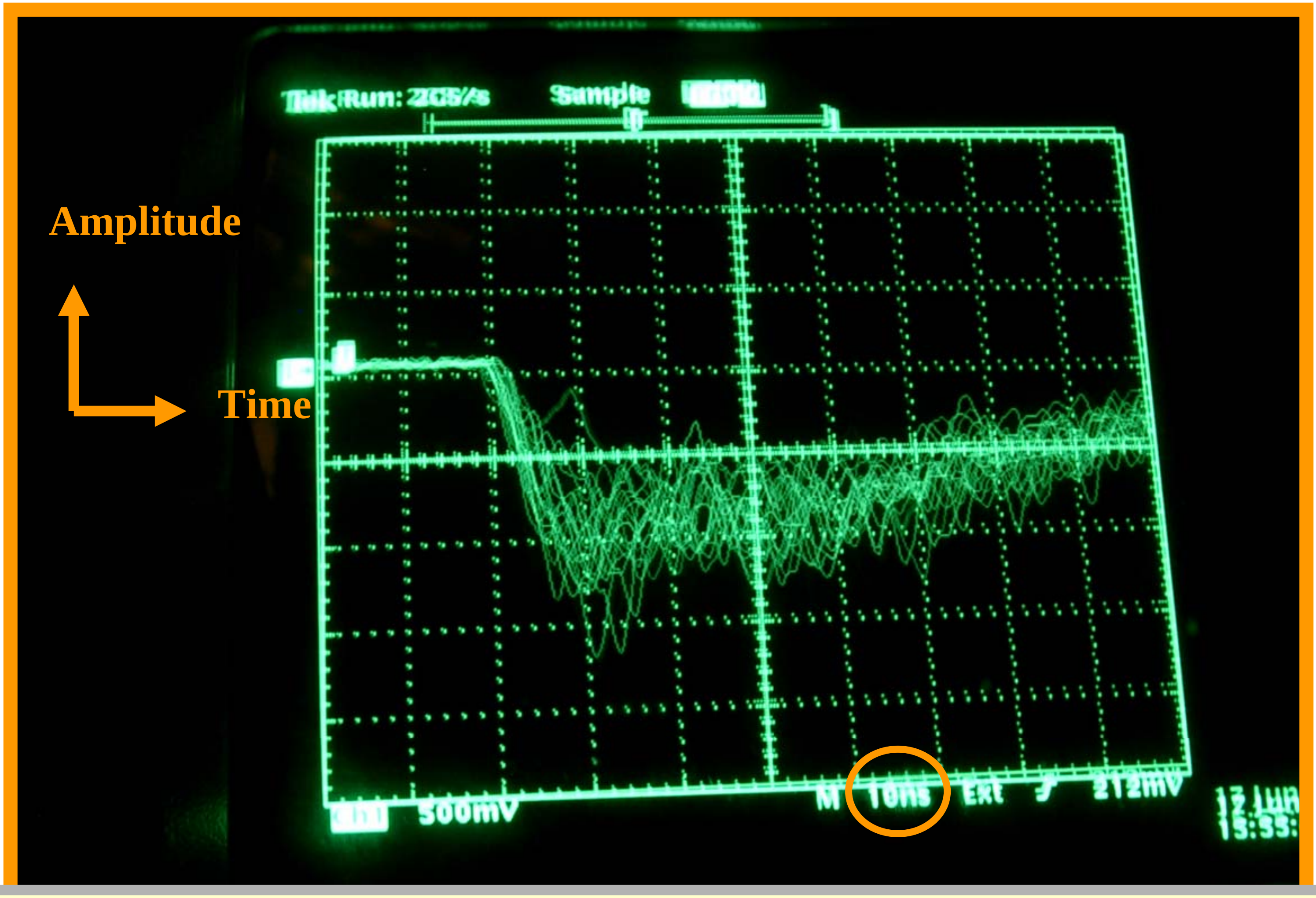
Superposition of many light pulses in the Geiger-mode APD

(signal integrated)

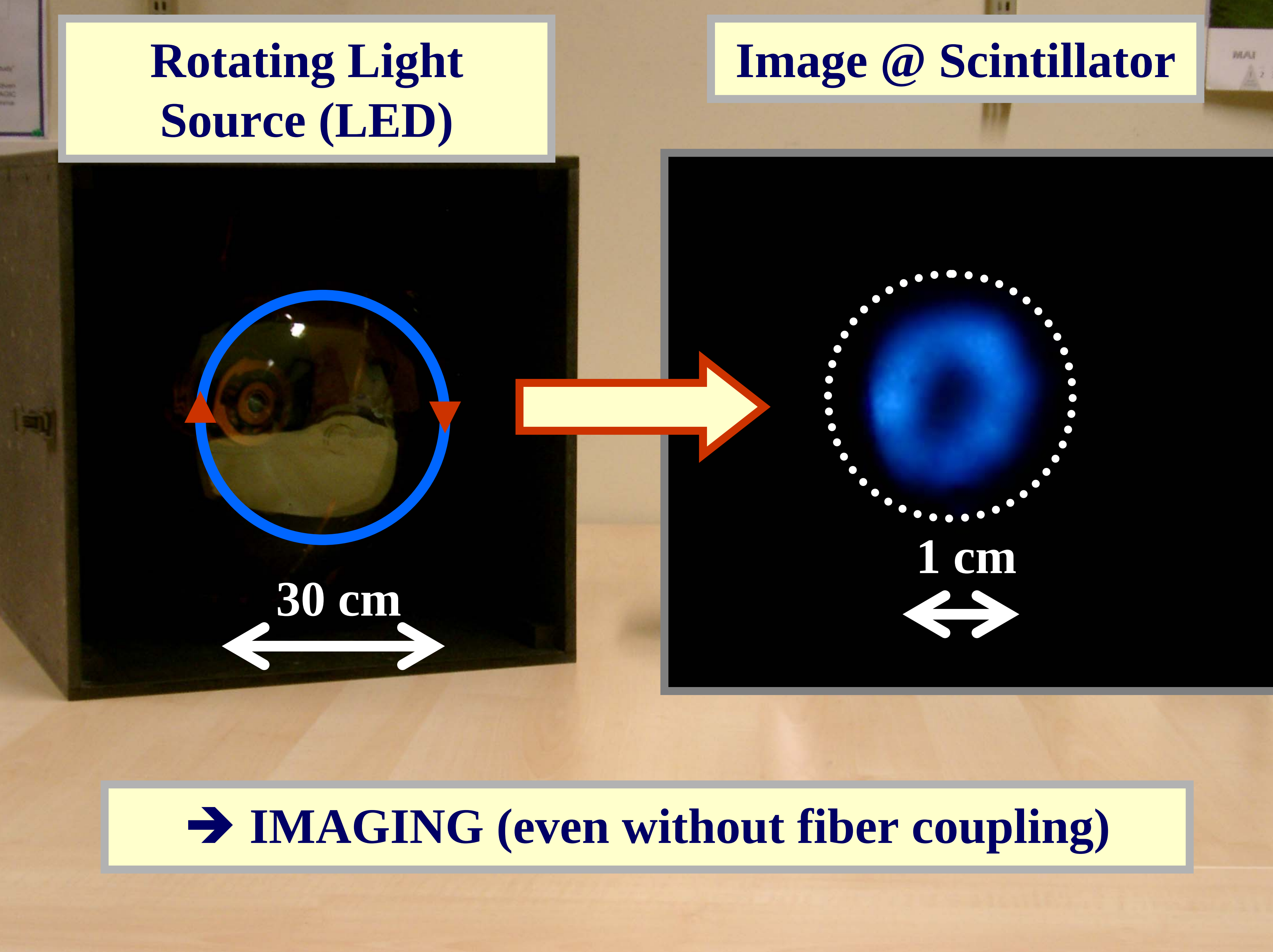


Superposition of many light pulses in the Geiger-mode APD

(full bandwidth)



Note the individual photon structure and decay spectrum of the scintillator


Rotating Light Source (LED)
Image @ Scintillator
30 cm
1 cm
➔ IMAGING (even without fiber coupling)

CONCLUSIONS

Light Amplifier *:*

LIGHT IN-(VACUUM)-LIGHT OUT

- **CONCENTRATION (photoelectron focusing)**
- **AMPLIFICATION (photoelectron acceleration)**

ADVANTAGES :

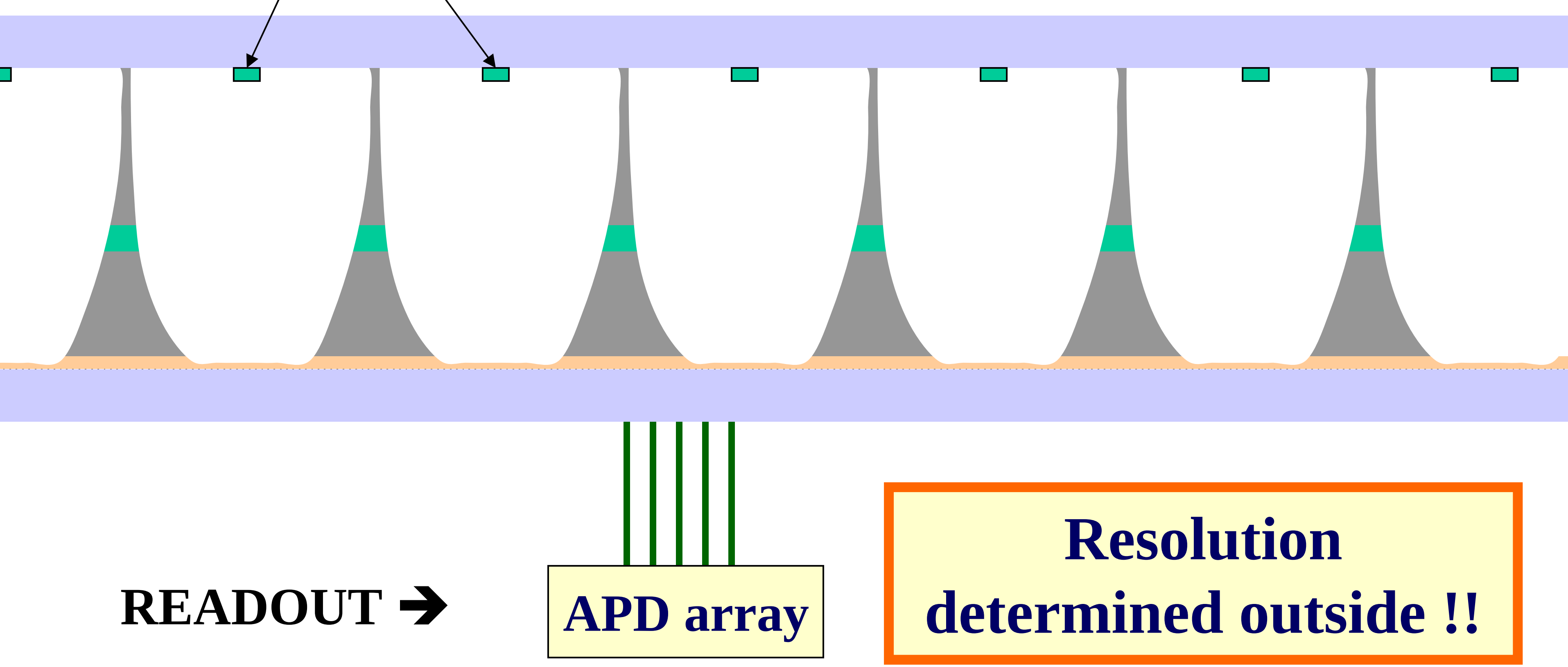
- **No electronic components in the vacuum**
- **Extreme Simplicity & Robustness**

→ Low cost, mass production

Tested - a QUASAR tube + a Geiger-mode APD

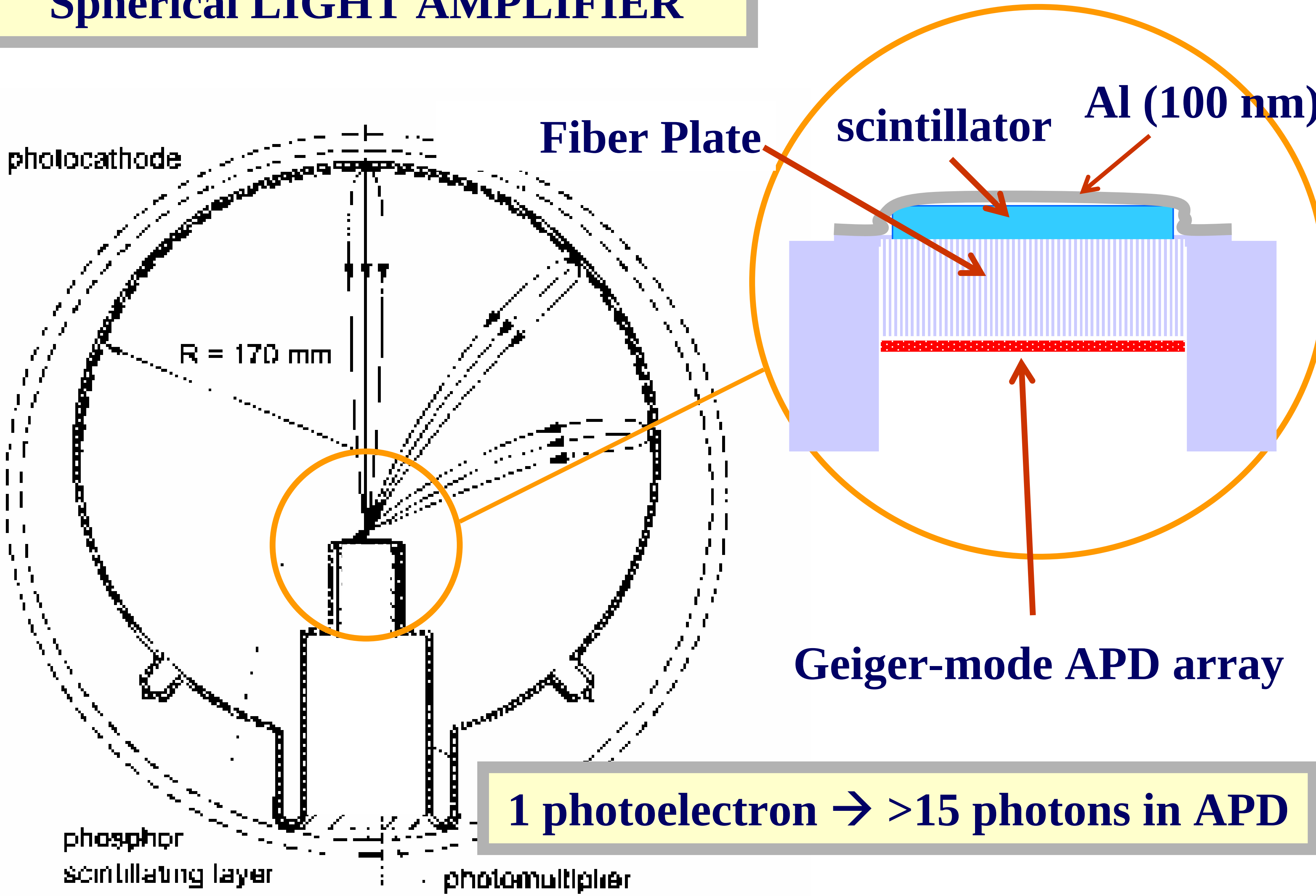
"Light Amplifier" Concept

NO electronics inside!!



Resolution determined outside !!

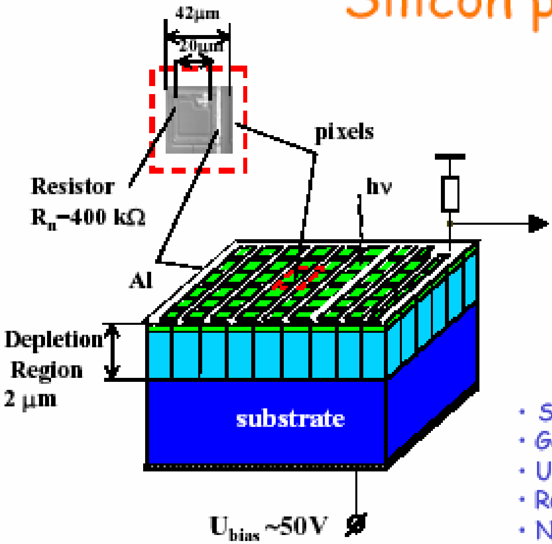
Spherical LIGHT AMPLIFIER

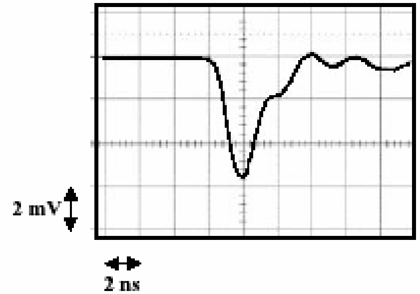


1 photoelectron → >15 photons in APD

SMART PMT, QUASAR

Silicon photomultiplier (SiPM)



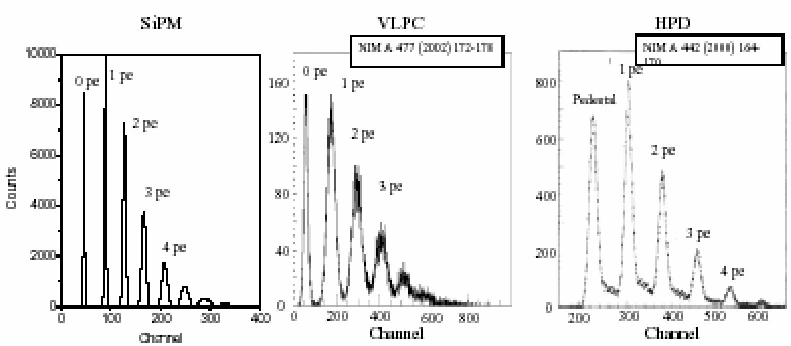


SiPM main features:

- Sensitive size 1x1mm^2 on chip 1.5x1.5 mm^2
- Gain $2 \cdot 10^6$
- U_{bias}~50V
- Recovery time ~ 100 ns/pixel
- Number of pixels: 576
- Nuclear counter effect: negligible (due to Geiger mode
- Insensitive to magnetic field
- Dynamic range ~10^3/mm^2

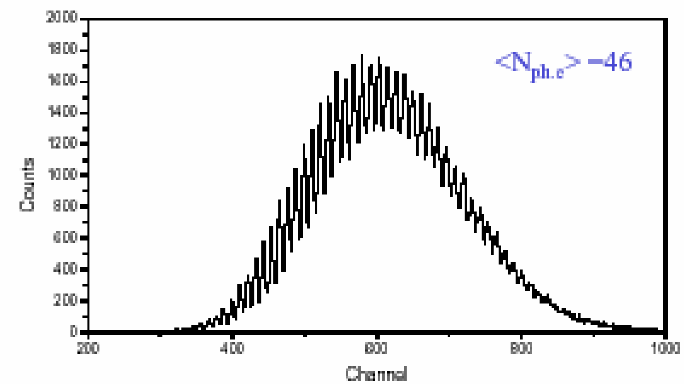
For further details see:
«Advanced study of SiPM»
http://www.slac.stanford.edu/pubs/icfa/fall01.html

Single photoelectron (single pixel) spectra



SiPM:
- excellent single photoelectron resolution
- low ENF expected

More about pixel signal resolution: tens of photoelectrons



- SiPM consists of a large number of pixel photoelectron counters with binary readout for each pixel, working as analogue device
- signal uniformity from pixel to pixel is quite good