GRUPO DE FISICA MEDICA
DEPARTAMENTO DE FISICA

V UNIANDES DETECTOR SCHOOL

13-15 December 2021

UNIVERSIDAD NACIONAL DE COLOMBIA
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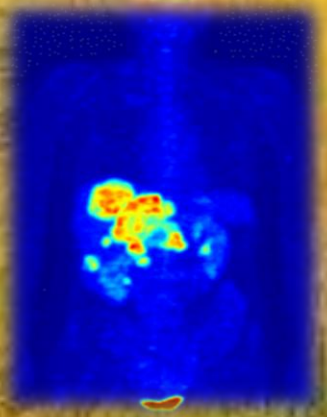
DEPARTAMENTO DE FÍSICA
GRUPO DE FÍSICA MÉDICA

PARTICLE DETECTORS IN MEDICINE



Hector Castro

Cryomag and Medical Physics Groups
Physics Department
National University of Colombia

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PARTICLE & RADIATION DETECTORS

technology transfer

FROM HIGH ENERGY PHYSICS TO MEDICINE

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FROM HEP TO MEDICINE

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CERN

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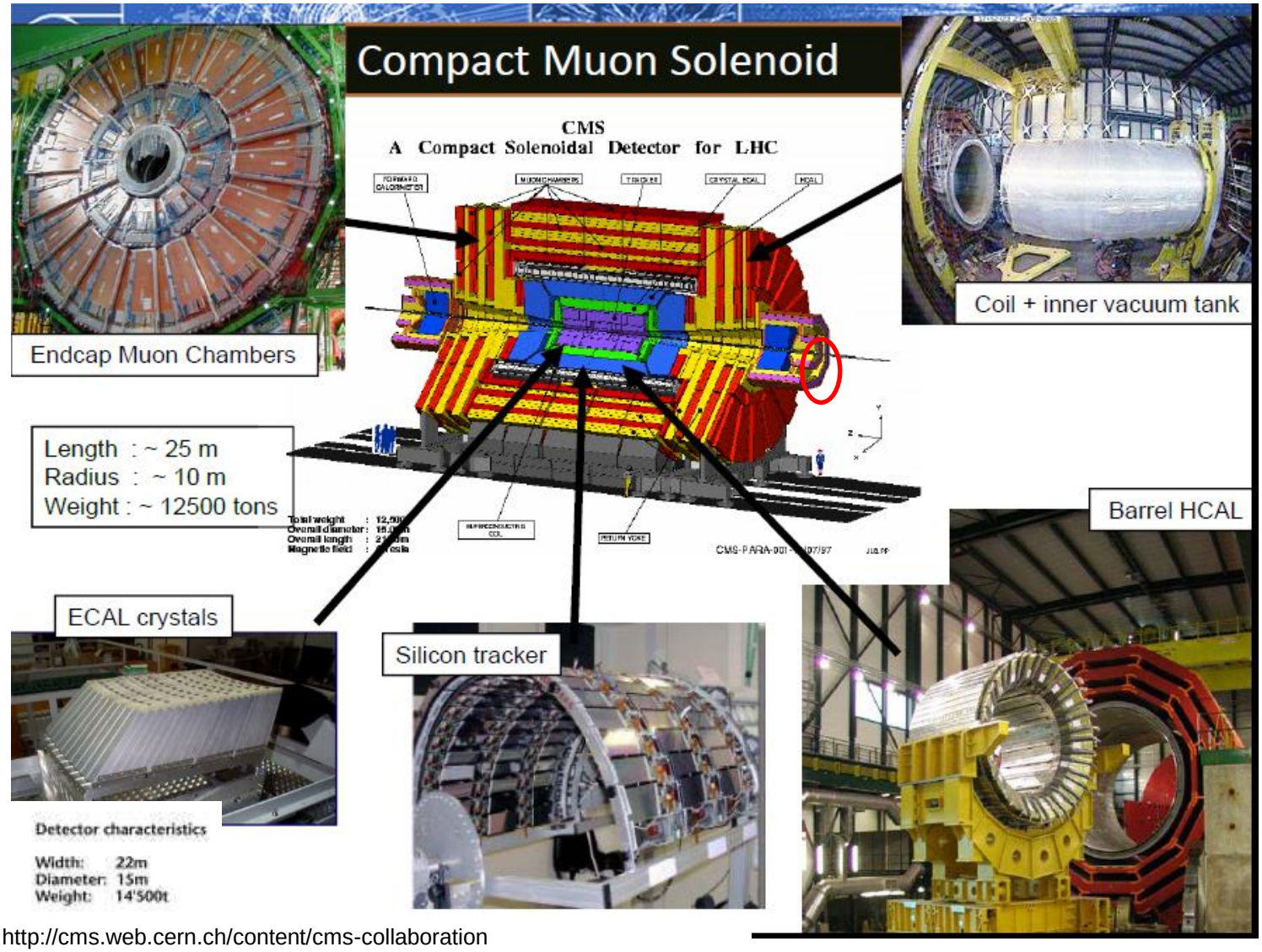
FROM HEP TO MEDICINE



Taken from: web: http://cms.web.cern.ch/content/cms-collaboration

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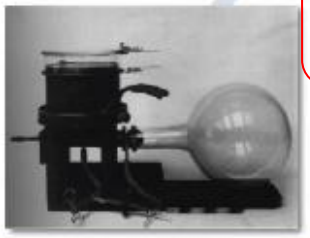
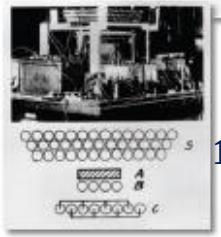
HISTORICAL REVIEW

1895 Radiographic film



1900 Cloud chambers/ Geiger Müller Ionization chamber



1930 Films/ Emulsions

1940 Scintillator counter

1950 Bubble/ spark/ wire Chambers

1960 Semiconductor detectors

Starting shot of Nuclear Medicine imaging devices

Second World War. Fantastic boost to electronics systems

Encapsulation allows to produce more compact and complex systems.

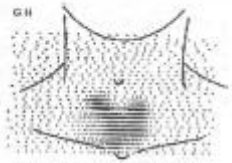
Technology drivers

1990 micropattern gas detectors

HISTORICAL REVIEW

DETECTORS IN NUCLEAR MEDICINE

Manual mapping with Geiger counters



1951: Benedict Cassen invents first automatic scanner (scintillator counter attached to a plotter)

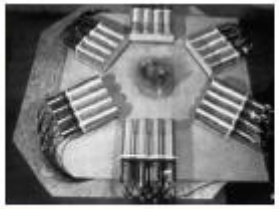
1952: Hal Anger invents gamma camera

1953: Birth of Positron Imaging (Gordon Brownell)

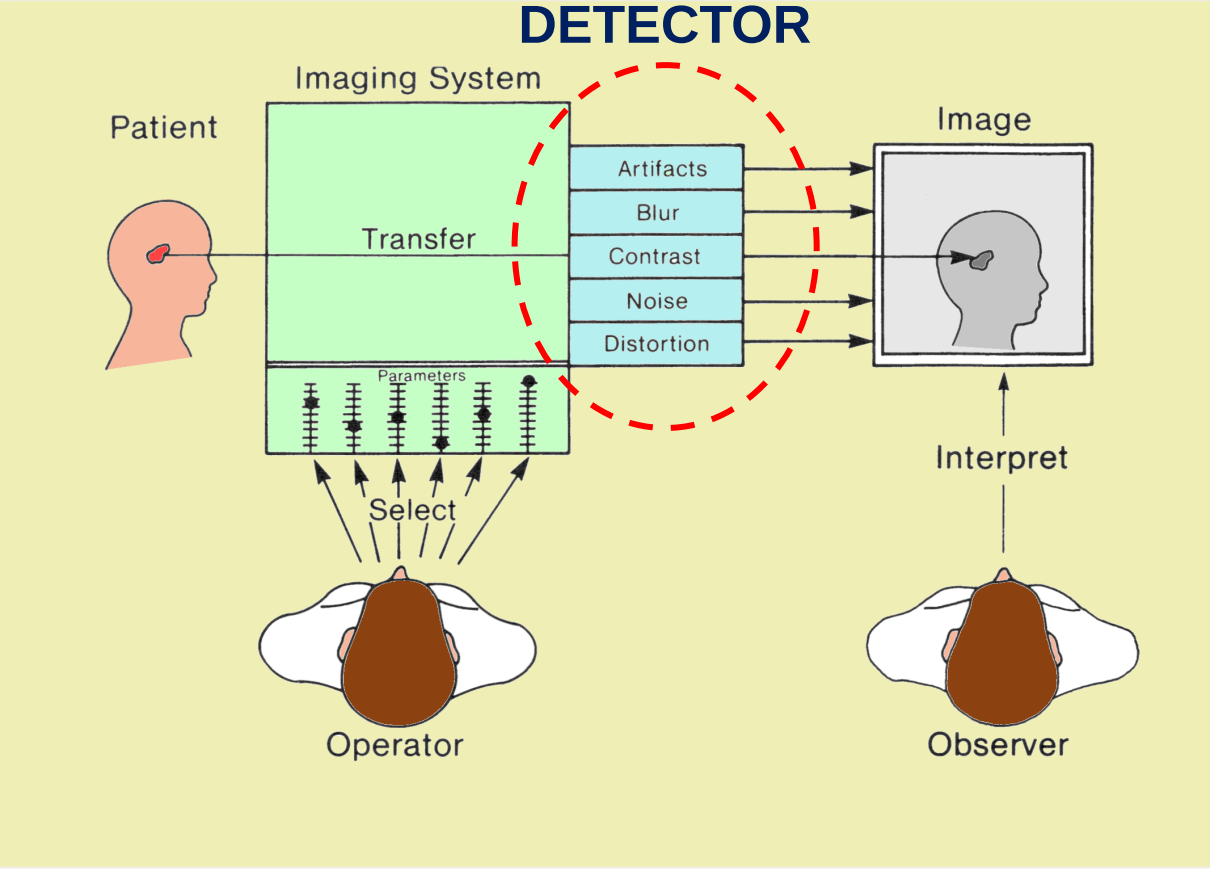
1959: Beginning of emission CT (D. Kuhl)

1974: First PET camera for human studies

(M. Phelps, E. Hoffman, T. Pogossian)



FORMATION OF DIAGNOSTIC IMAGES

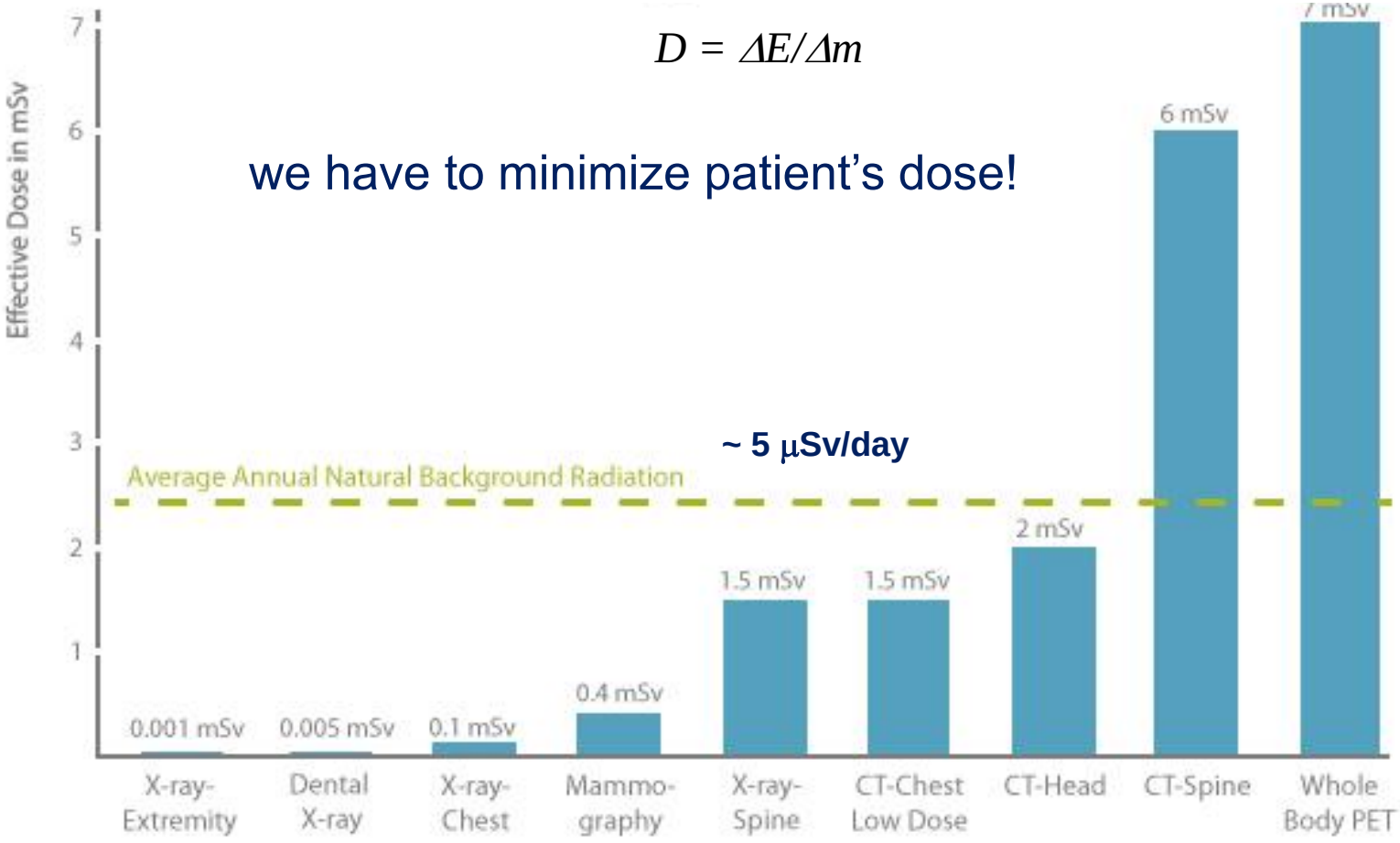


RADIATION DOSE

DOSES IN TYPICAL MEDICAL EXAMINATIONS

$$D = \Delta E / \Delta m$$

we have to minimize patient's dose!



All information from radiologyinfo.org except "Whole Body PET" (Source: Radiation Exposure of Patients Undergoing Whole-Body Dual-Modality 18F-FDG PET/CT Examinations, Brix G et al., JNM, 46:4, 4/2005) and "Average Annual Background Radiation" (Source: http://www.iaea.org/Publications/Factsheets/English/radlife.html)

HOW TO REDUCE PATIENT'S DOSE?

- First of all the physician has to **justify** the exam
- Minimize scattered radiation (Rayleigh and Compton dispersions)
- **Use high efficiency low noise detectors**
- Improve DAQ fast and low noise electronics
- Improve Image reconstruction algorithms
- Follow safe and efficient protocols during medical practices
- Improve Physician's capability to read images (radiologist)

DETECTORS IN MEDICAL APPLICATIONS

RADIO-PROTECTION

- **DOSIMETRY:** Ionization chamber, Geiger-Muller, film, TLD, OSL, SC

DIAGNOSTIC IMAGES

ANATHOMIC

- **RADIOLOGY**: Film, semiconductor, gaseous
- **CT**: gas (Ar), scintillators, semiconductor

FUNCTIONAL

- **GAMMAGRAPHY**: Scintillators
- **PET:** Scintillators
- **SPECT:** Scintillators

THERAPEUTIC TREATMENTS

- **RADIOTHERAPY:** Ionization chamber, photodiodes,SC
- **IODOTHERAPY:** Ionization chamber, SC

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MEDICAL APPLICATIONS

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MEDICAL IMAGING - RADIOLOGY

- **Conventional XR:** mammography, fluoroscopy, oral/dental, etc.
- **CT**

NUCLEAR MEDICINE

- **Gammagraphy**
- **SPECT**
- **PET**

RADIOTHERAPY

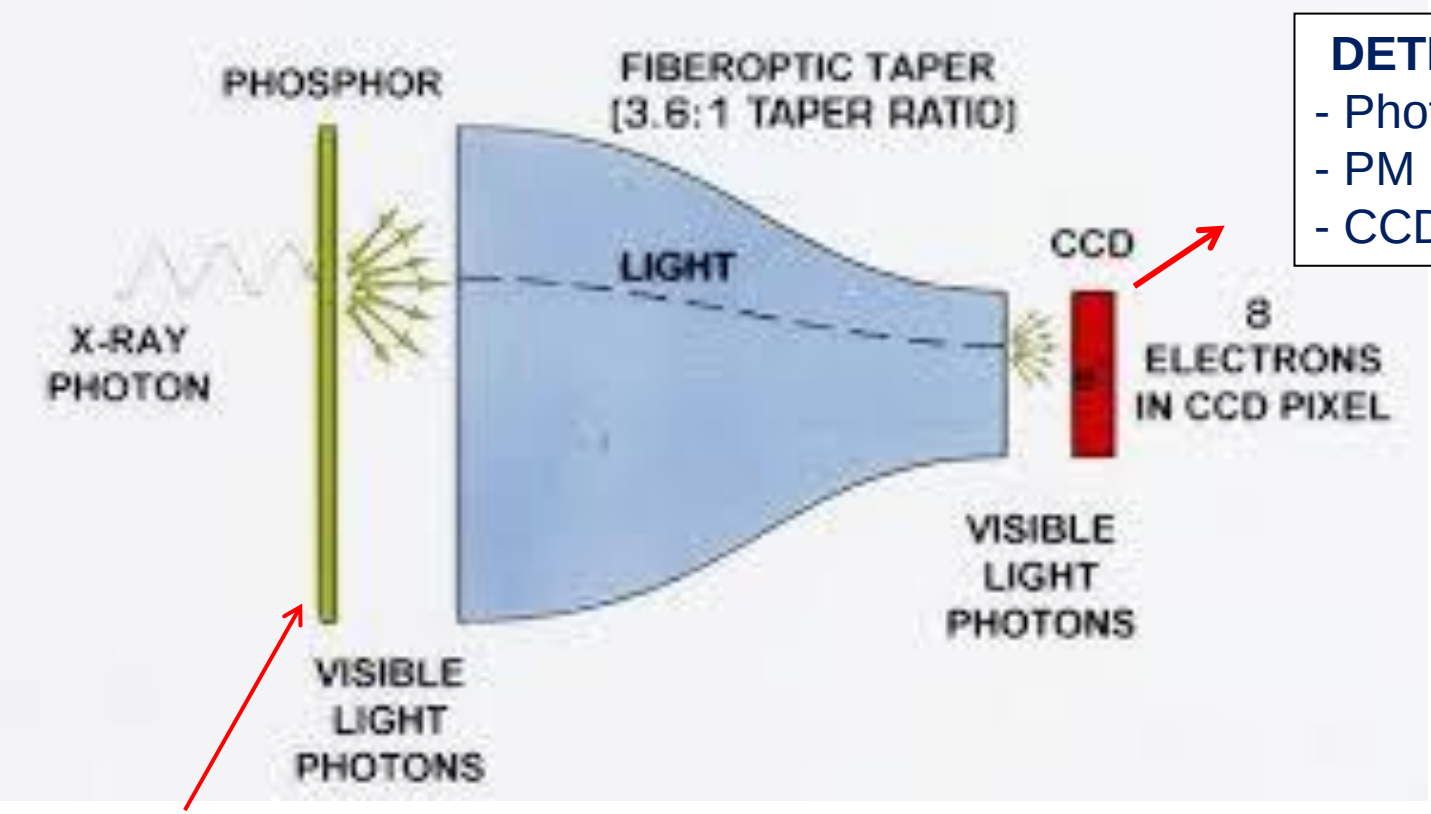
- **Braquitherapy: Ir, Cs**
- **Teletherapy: XR, e, Co (γ)**
- **Hadrontherapy: p, C^{+}**

COMMON DETECTORS USED IN MEDICINE

- **RADIOGRAPHIC FILM**
- **P:** Photostimulable Phosphor (Computed Radiography)
- **IONIZATION CHAMBER**
- **G-M: GEIGER MULLER COUNTER**
- **TLD** :Thermoluminiscent Dosimeter
- **OSL**: Optically Stimulated Luminiscence Dosimeter
- **PD**: Photodiodes
- **CCD**: Charge Coupled Device
- **TFT** : Thin Film Transistor
- **SC**: Semiconductor (Si, Ge, GaAr)
- **FPD**: Flat Pannel Detector
- **Scintillators:** (NaI, BGO, LuYaP, etc)
- **MOSFET**: Methal Oxyde Semiconductor Transistor

COMPUTED RADIOGRAPHY

Intermediate conversion of XR to visible light



DETECTION
- Photodiodes
- PM array
- CCD camera

Photostimulable Phosphor

PHOTOSTIMULABLE PHOSPHOR PLATES

RADIOGRAPHY

PHOSPHOR PLATES

SCANER / DIGITIZER

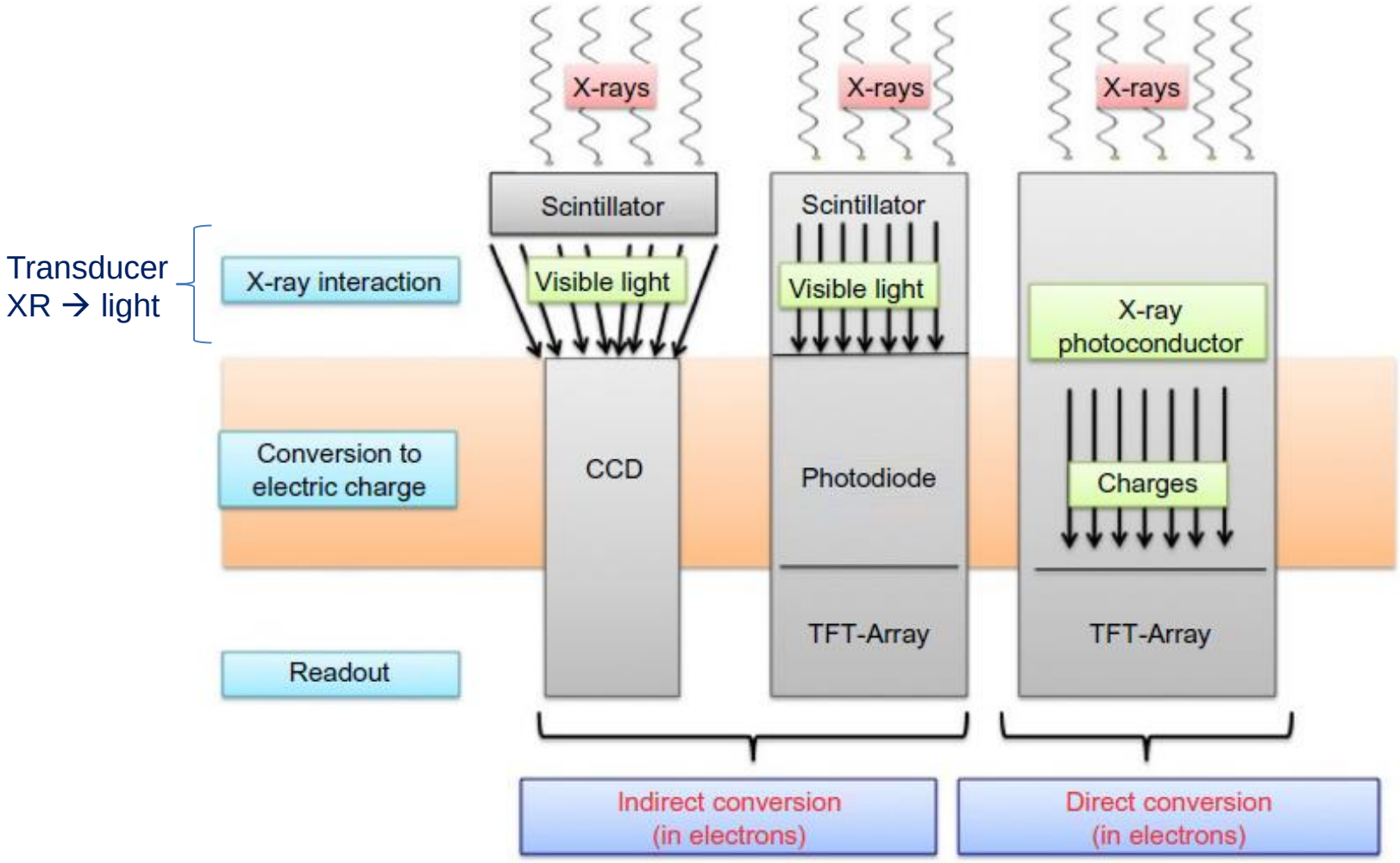
DIGITAL RADIOGRAPHY - DR

Direct detection of XR and image formation

DETECTORS

- PHOTODIODES
- SCINTILLATORS
- PHOTOTRANSISTORS (MOSFET, CMOS)
- CCD
- TFT

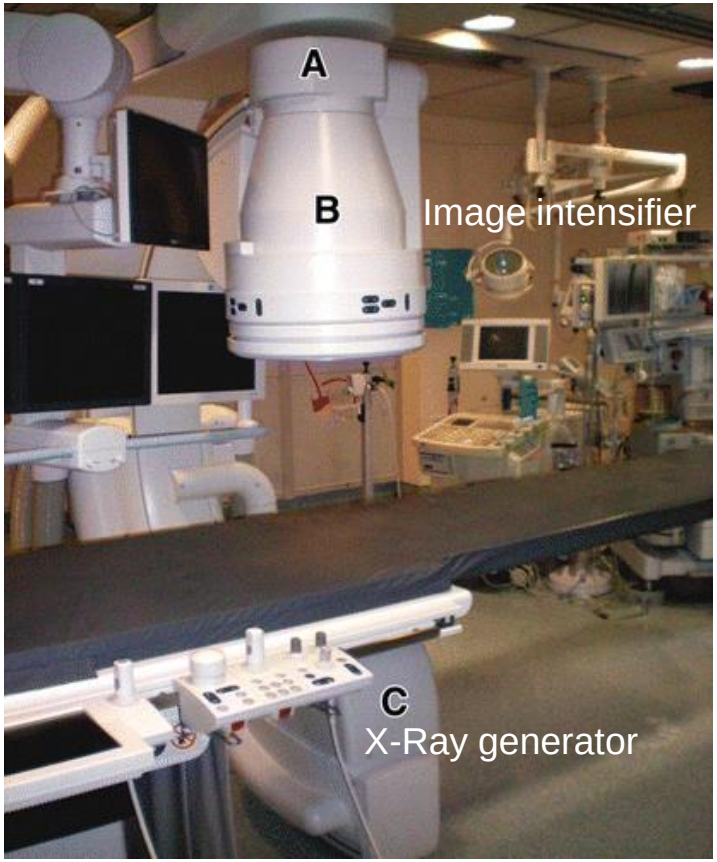
OVERVIEW OF DIGITAL DETECTORS

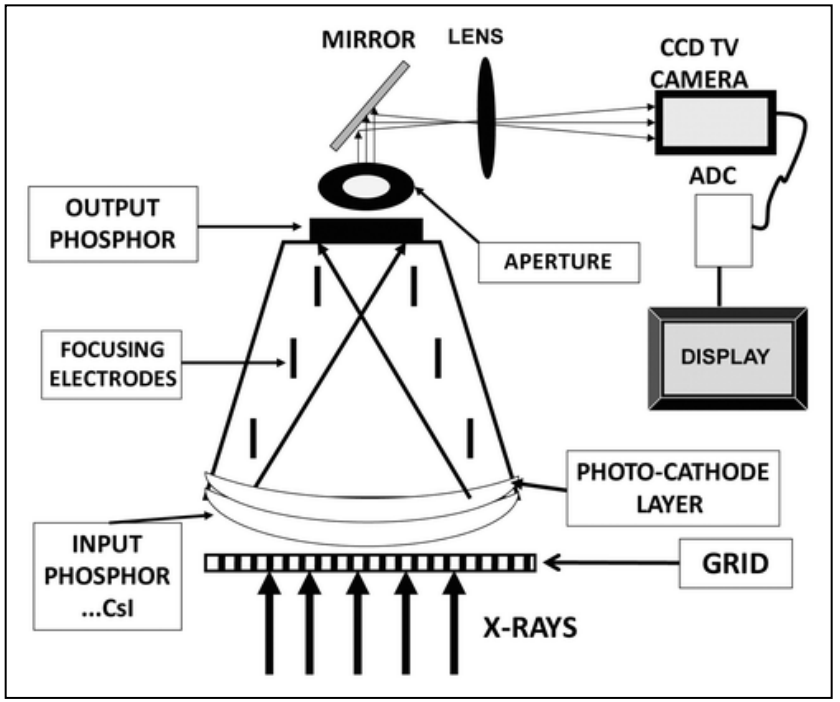


FLUOROSCOPY

CONVENTIONAL C-ARC INTENSIFIER

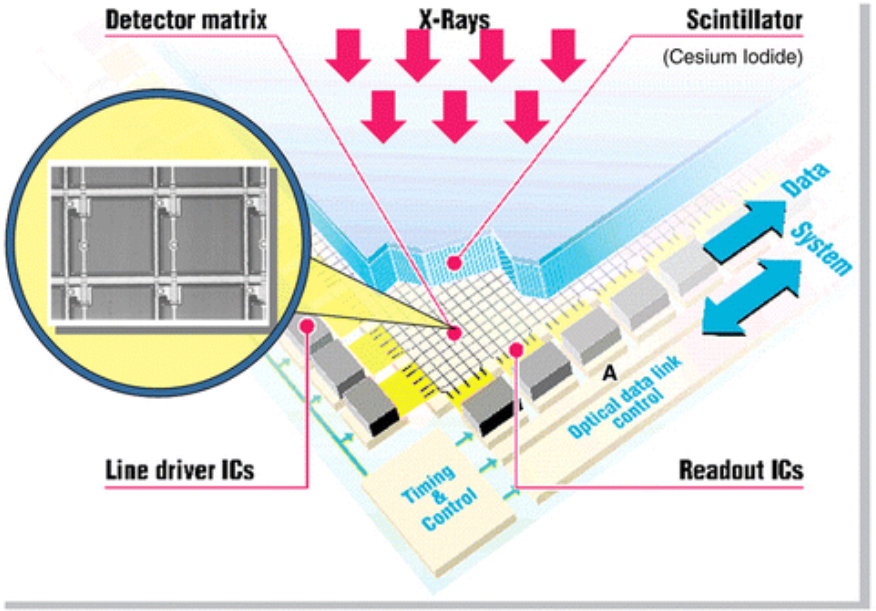
Conversion: RX → Light
B - Image intensifier
A - Reading by CCD camera





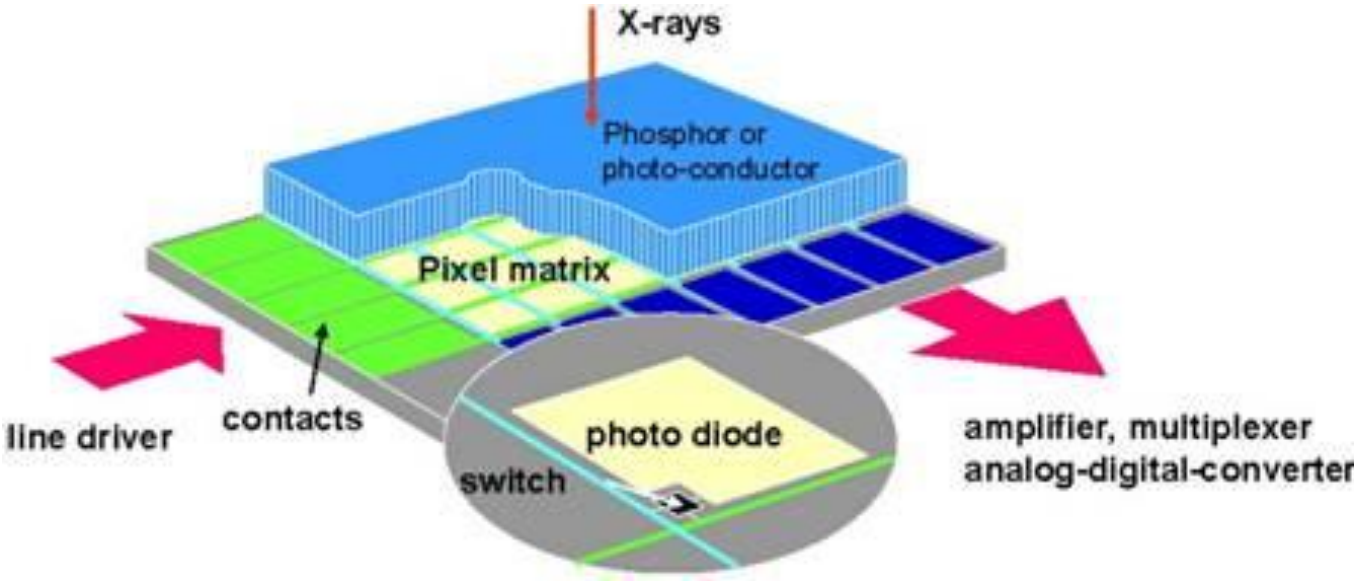
FLAT PANEL DETECTOR

SCINTILLATORS (CeI) + PHOTODIODES



FPD fluoroscopy systems represent more modern **solid-state detector** arrays used as image receptor. FPD receptors have a number of advantages over **image intensifier** fluoroscopy systems including better stability, lower patient radiation doses, and wider dynamic ranges.

FLAT PANEL DETECTOR



A FPD system consists of a large-area plate composed of amorphous silicon. Onto this plate a rectangular array of light-sensitive photodiodes is formed. X-rays are absorbed by a layer of thallium-activated cesium iodide phosphor CsI(Tl) deposited onto the photodiodes. The photodiodes detect the light emitted by the phosphor and create an electrical charge signal that is stored on each cell.

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CCD DETECTOR

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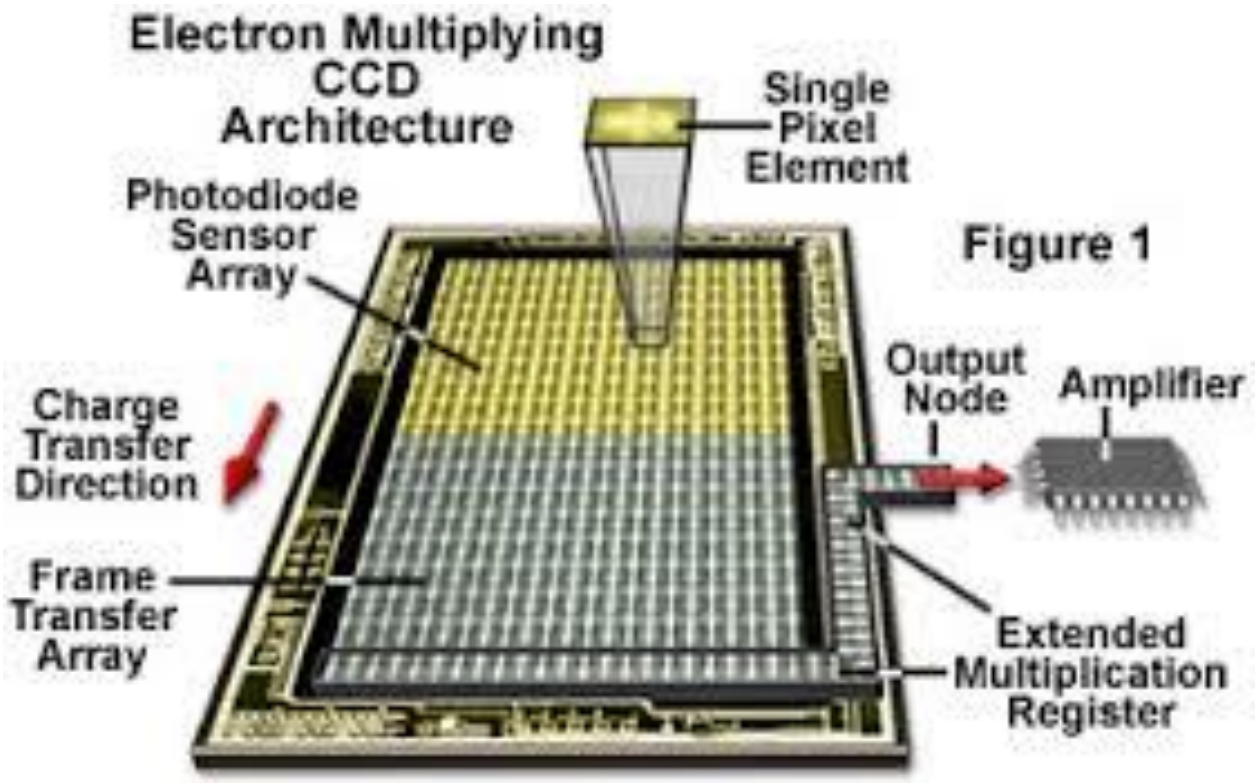
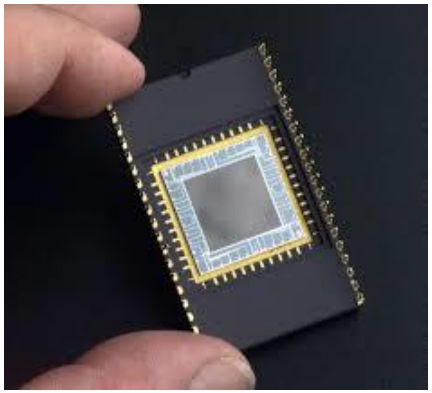
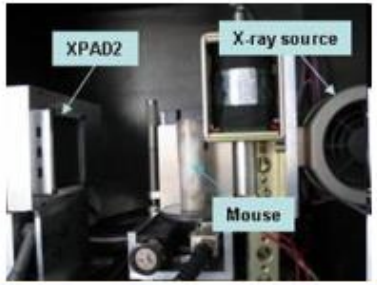


CCD
Charge
Coupled
Device



XPAD HYBRIDE PIXEL DETECTOR

The first XPAD detectors



Hybrid Pixel project

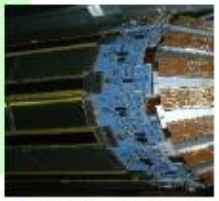
Atlas:50x400um pixels

XPAD 2: 330um² pixels 65x65mm

1991 1998 2001

1996 1999 2006

Delphi:
World first on
collider for charged particules



XPAD 1 :first hybrid pixel detector for xray applications

XPAD 3 :130um² pixel

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XPAD HYBRIDE PIXEL DETECTOR

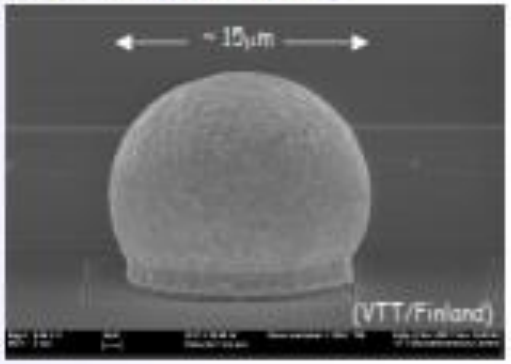
Hybrid Pixel Detectors

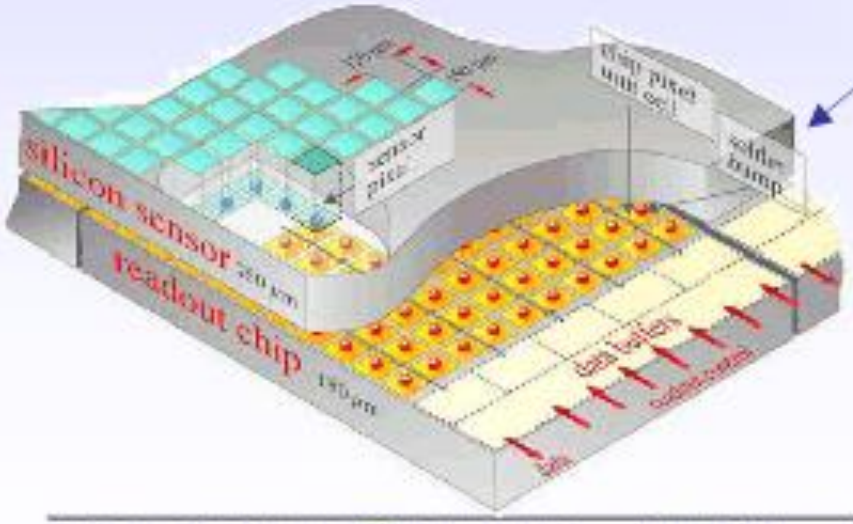
CERN Globe is a 3 million times bigger bump!

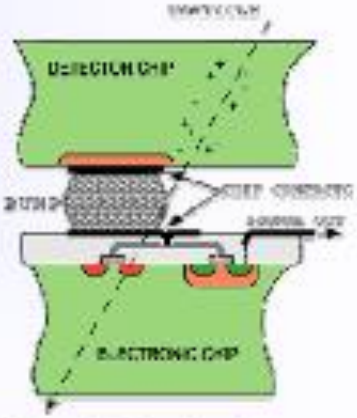
2b - Tracking with Solid State Detectors

- **HAPS – Hybrid Active Pixel Sensors**
  - segment silicon to diode matrix with high granularity (⇒ true 2D, no reconstruction ambiguity)
  - readout electronic with same geometry (every cell connected to its own processing electronics)
  - connection by "bump bonding"
  - requires sophisticated readout architecture
  - Hybrid pixel detectors will be used in LHC experiments: ATLAS, ALICE, CMS and LHCb

Solder Bump: Pb-Sn



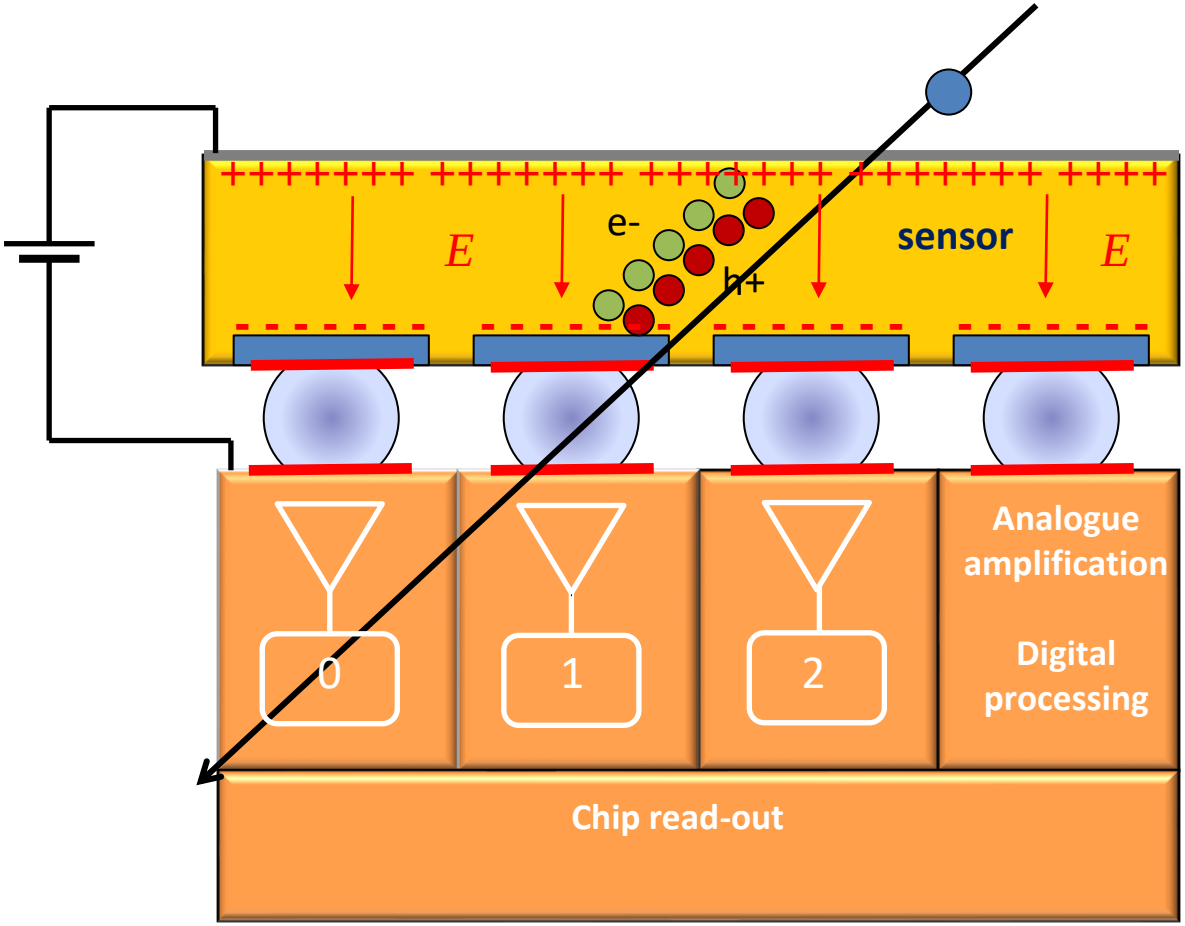


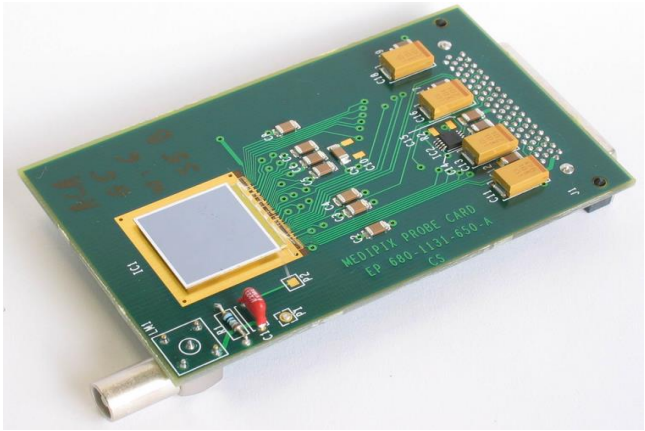


Flip-chip technique

CERN Academic Training Programme 2004/2005

MEDIPIX HIBRIDE PIXEL DETECTOR





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TLD DOSIMETER

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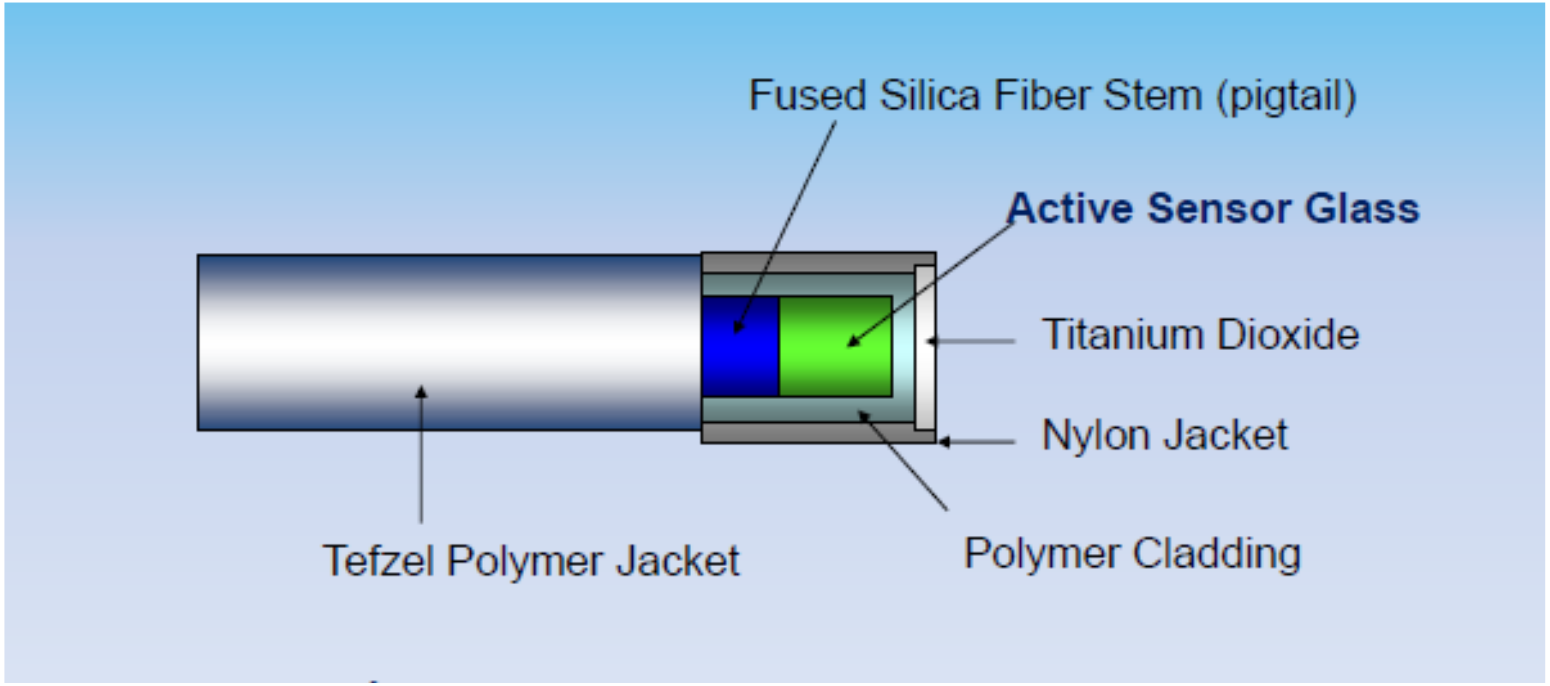
THERMO-LUMINISCENT DOSIMETERS (TLD)

TLD crystals absorb and store the energy relased by radiation and convert it to light when heated during reading process

OSL DOSIMETER

OPTICALLY STIMULATED LUMINISCENCE (OSL)



OSL crystals work in similar way to TDL, but instead of heating they are stimulated with laser light during reading process

DETECTORS IN MEDICAL APPLICATIONS

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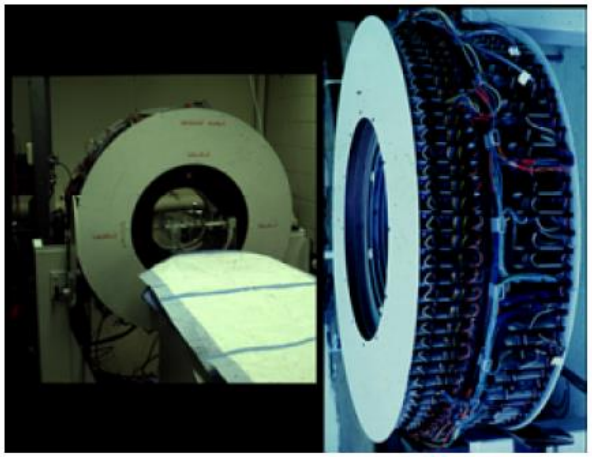
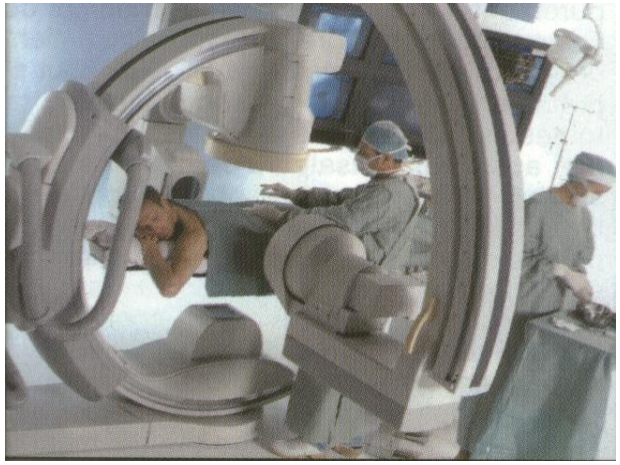
MEDICAL APPLICATIONS

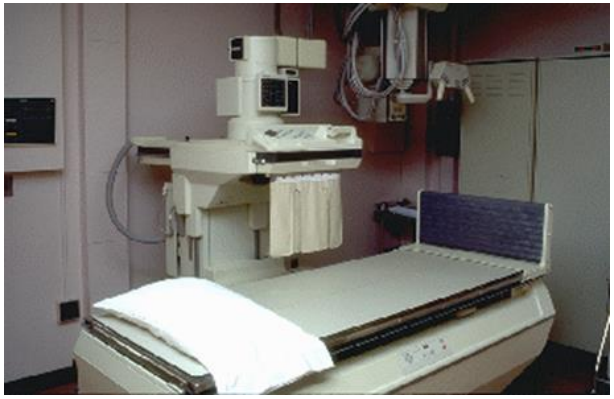


Computed Tomography

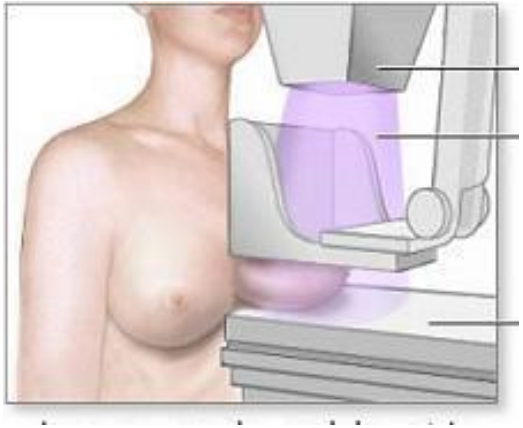


FLUOROSCOPY

ORAL RADIOLOGY



CONVENTIONAL XR



MAMMOGRAPHY

HADRONTHERAPY

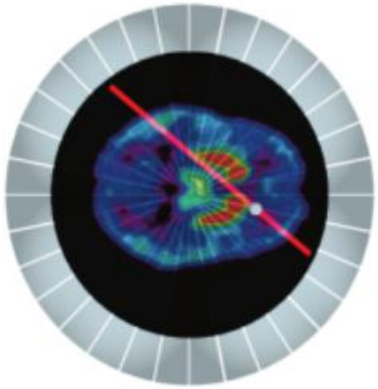
MEDICAL APPLICATIONS

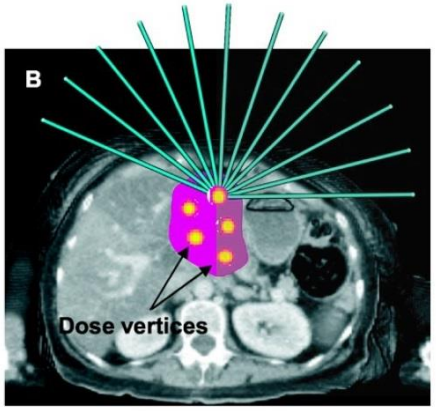
Environmental Dosimetry

Positron Emission Tomography

Radiotherapy

Personal Dosimetry





RADIOLOGICAL PROTECTION

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PERSONAL DOSIMETRY

MONITORING AND CONTROL OF EXPOSICION AT WORK

MODALITIES OF DOSIMETRY

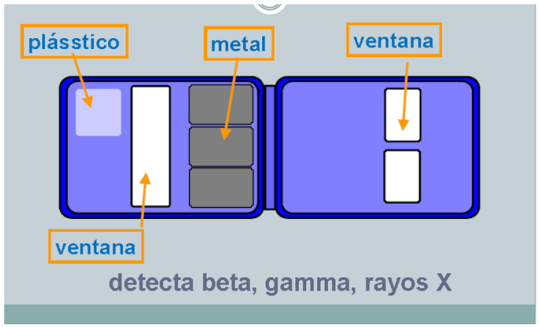
Direct (inmediate)

Delayed (retarded)

DETECTORS

- Film
- Semiconductor
- TLD
- OSL

FILM PERSONAL DOSIMETER



SEMICONDUCTOR

TLD & OSL

ENVIRONMENTAL DOSIMETRY

MONITORING AND CONTROL OF EXPOSICION IN WORKING AREAS

GEIGER - MULLER

DETECTORS

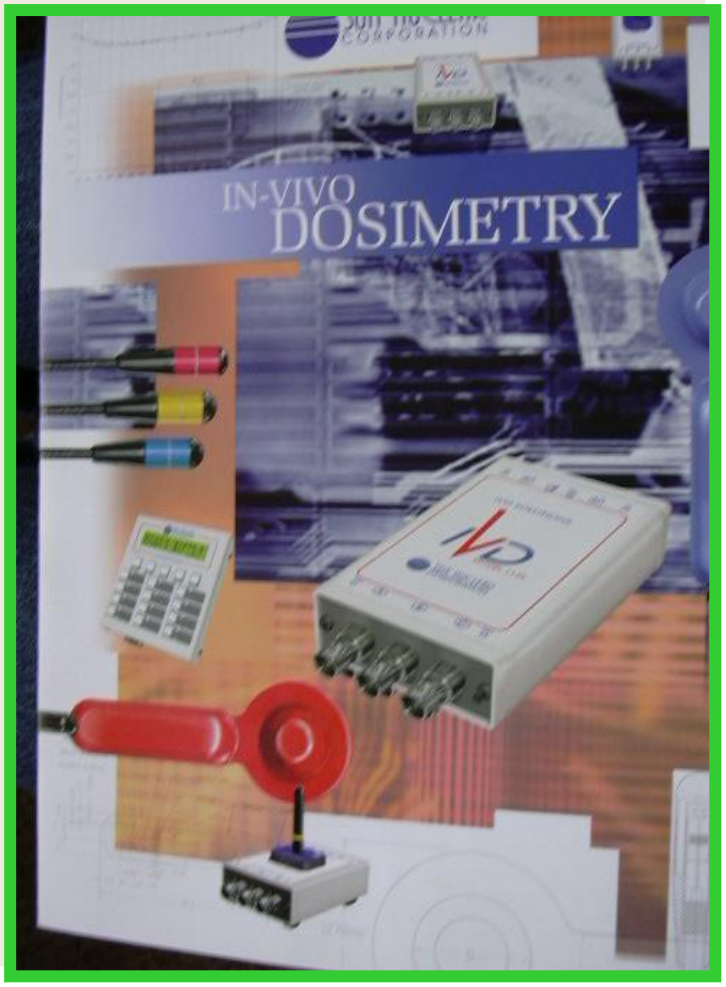
- Gas
- TLD
- OSL

TYPE OF AREA	CLOVER COLOR	OTHER DISTINCTIONS IN THE CLOVER
Monitored area	Grey	• Radial points on the ends: danger of extreme radiation • Dotted field around the clover: danger due to contamination • Both sings: danger from extreme contamination and radiation
Controlled area	Green	
Limited stay area	Yellow	
Forbbiden access area	Red	

CLASSIFICATION OF AREAS

SEMICONDUCTORS

COMERCIAL SEMICONDUCTOR DOSIMETERS



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MEDICAL IMAGING

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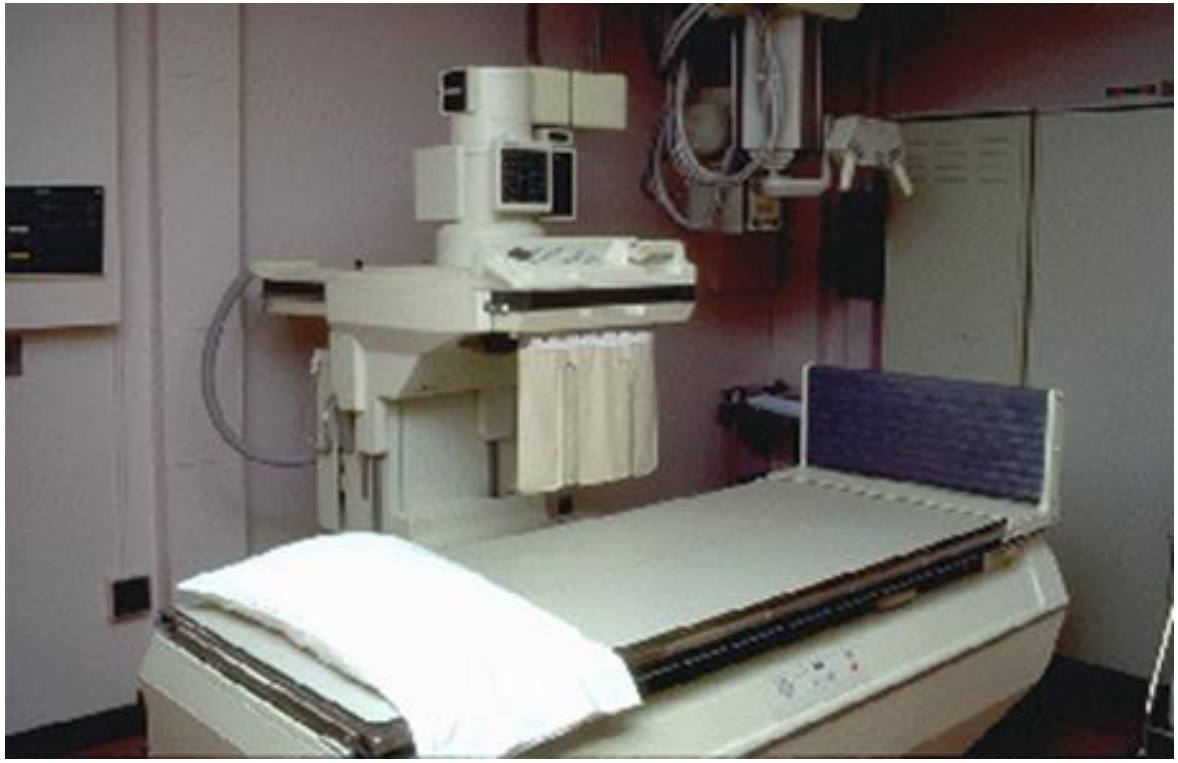
CONVENTIONAL RADIOLOGY

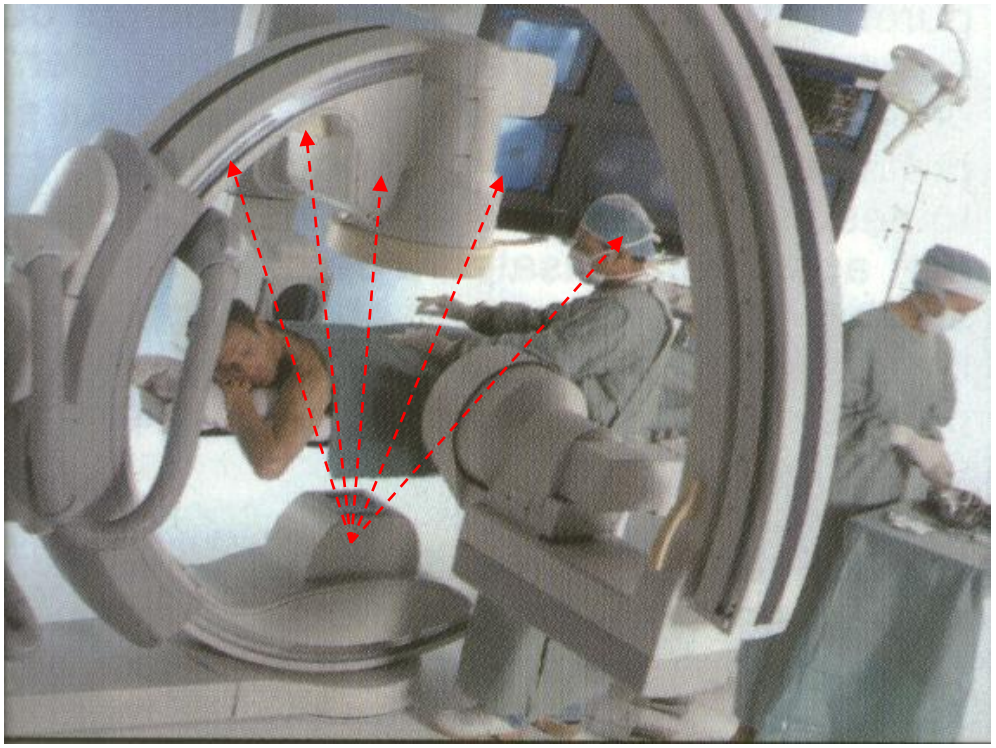


DETECTORS

- Film
- Flat Pannel Detectors:
- Direct: a-Se, CCD, CMOS
- Indirect: a-Si + photodetector
- Phosfor Plate + photodetector
- Photostimulable phosphor

INTERVENTIONAL RADIOLOGY

FLUOROSCOPY - REAL TIME IMAGING

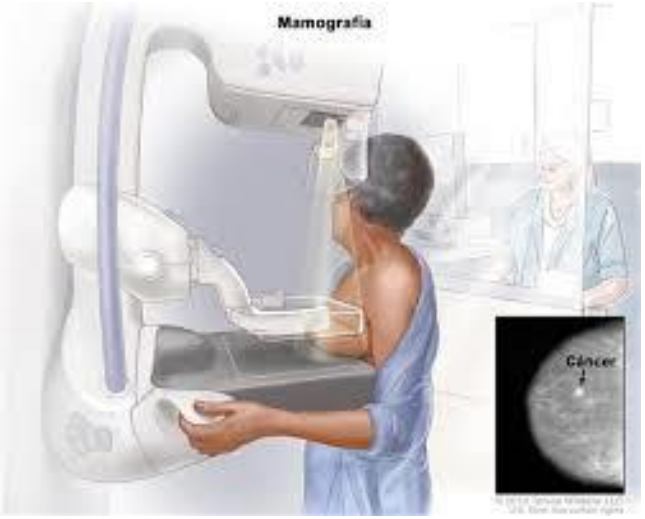


DETECTORS

- Image intensifier
- Flat Pannel Detectors:
- Direct: a-Se, CCD, CMOS
- Indirect: -Si + photodetector

"C –arc": Mobile C-arm system for full surgical and minimally-invasive procedures

MAMMOGRAPHY



DETECTORS

- Film (analog)
- Phosphor Flat Pannel
- Phosphor - CCD
- Photostimulable phosphor
- Se Flat pannel

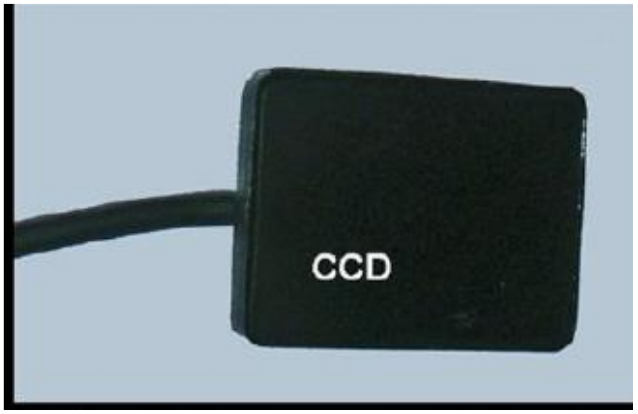
ORAL RADIOLOGY

PERIAPICAL

Integrated Panoramic X-Rays

PARTICLE DETECTORS IN MEDICINE

INTRAORAL RADIOLOGY



INDIRECT DETECTORS

- **Photografic film**
- **PSP** (Photostimulable storage phosphor)

DIRECT DETECTORS

- **CCD** (Charge Coupled Device - array)
- **CMOS** (Complementary Metal Oxyde – transistor array)
- **TFT** (Thin Film Transistor array)

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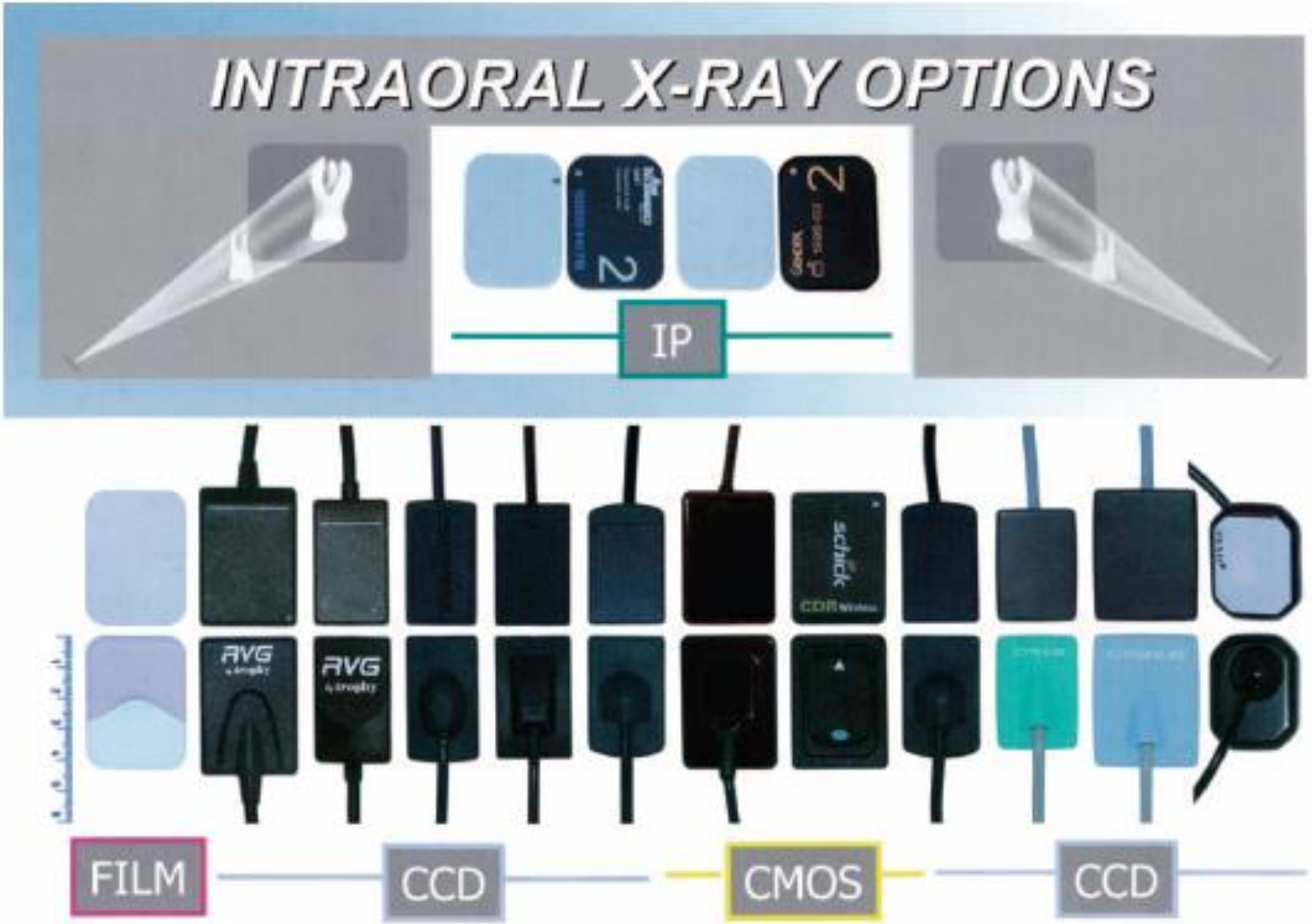
INTRAORAL RADIOLOGY



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PHOTOGRAFIC FILM DIGITIZER

DETECTORS

- CCD
- TFT

During a full mouth series, Smart Plates can be scanned in any order and the results are automatically arranged in their precise locations.

PANORAMIC AND 3D DENTAL IMAGES

DETECTORS

CCD
TFT
CMOS

Panoramic Modality	
Sensor technology	CCD - Optical fibre sensor
Gray scale	16384 (14 bits)

3D Modality	
Technology	Digital Volumetric Tomography (DVT)
Sensor technology	CMOS sensor with optical fibre

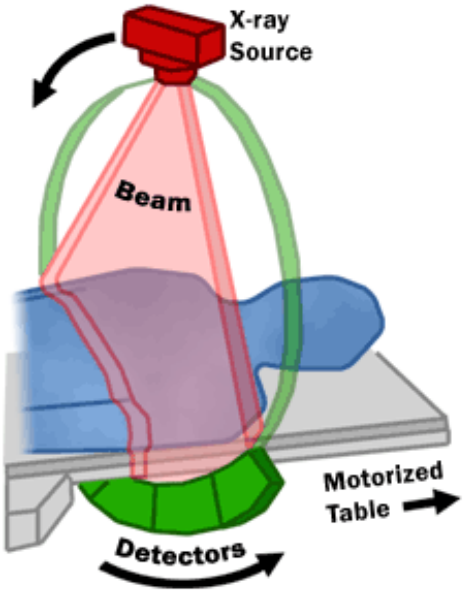
COMERCIAL DETECTORS

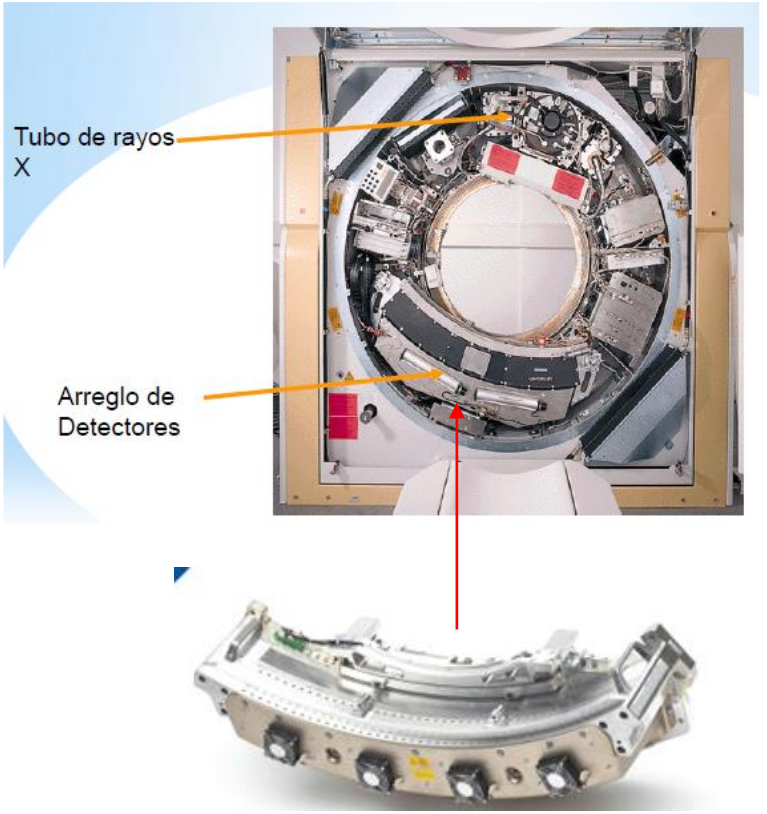
Table I. Detector specifications provided by manufacturers

Detector	*Pixel size (μm)*	*Technology*	*Software*
CDR	40 × 40	CMOS	CDR for DICOM Windows 3.0.1
CDR Wireless	40 × 40	CMOS	CDR for DICOM Windows 3.0.1
CygnusRay MPS	22 × 22	CCD	CygnusMedia 3.0
Dexis	40 × 40	CCD	DEXIS Software 3.01
Dixi 2 v3	19 × 19	CCD	Dimaxis Pro 3.1.3
DSX 730 - USB	21 × 21	CCD	Owandy/Julie RV2000
DSX 730 - Évolution	21 × 21	CCD	Owandy/Julie RV2000
Sigma	39 × 39	CCD	CliniView 5.1
Sidexis	39 × 39	CCD	Sirona Sidexis XG
RVG-ui	19.5 × 19.5	CCD	Trophy Windows 5.05
RVG 6000	18.5 × 18.5	CMOS	Kodak Windows 6.0.1
RVG 5000	18.5 × 18.5	CMOS	Kodak Windows 6.0.1
ViperRay ™	22.5 × 22.5	CCD	Vipersoft 4.0
Visualix HDI	22 × 22	CCD	VixWin 2000
Visiodent RSV	22 × 22	CCD	RSV Imaging XP
DenOptix	Scan Pitch	PIP	VixWin 2000
ScanX	Scan Pitch	PIP	EagleSoft 9.10
InSight	NA	Silver halide	NA

COMPUTED TOMOGRAPHY - CT

COMPUTED TOMOGRAPHY-CT





DETECTORS

- Gaseous (Xe, Ar): I y II generation
- Semiconductors and scintillators : III y IV generation
- Multiple detector array (semiconductors & scintillators) III y IV generations

COMPUTED TOMOGRAPHY

1974:

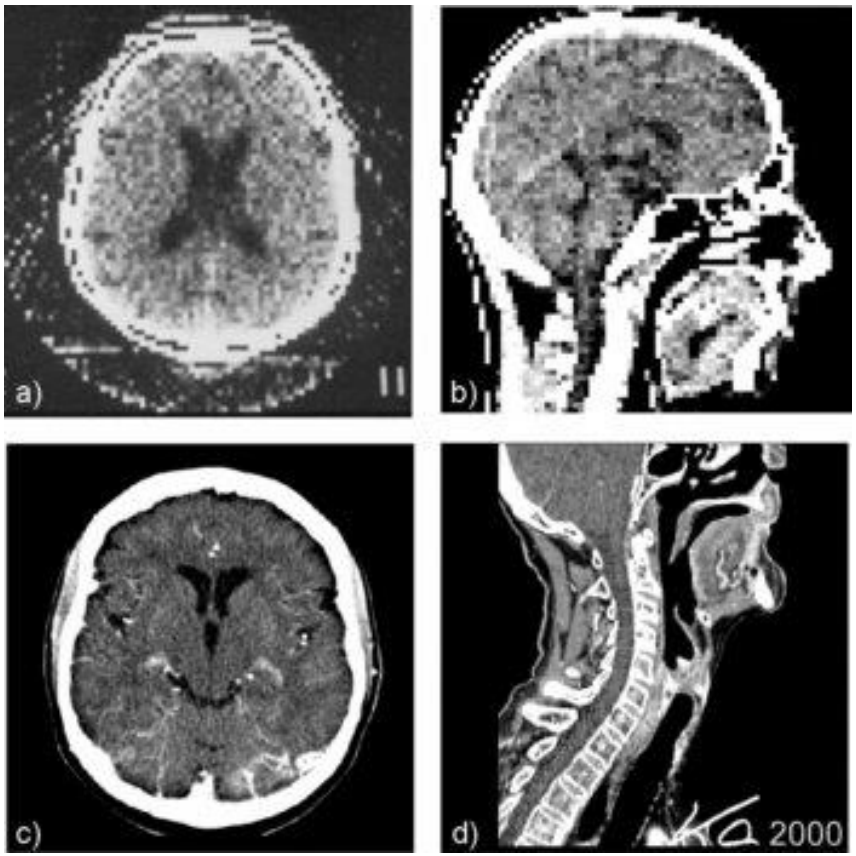
80 x 80 pixels

slices of 13 mm spacing

2000:

1024 x 1024 pixels

spiral scanning



From: W.A. Kalender, CT, 2000, MCD Verlag

SCINTILLATORS FOR CT

Among the preferred scintillator compositions in the present generation of CT scanners there are ceramic scintillators that employ at least one of the oxides of **lutetium, yttrium, and gadolinium** as matrix materials

Scintillator	Density (g/cm^3)	Thickness[a] to stop 99 % (mm)	Relative Light Output[b]	Emission band maximum (nm)	Primary decay time (μs)	Afterglow (% at 3 ms)
$CdWO_4$	7.9	2.6	1	495	2, 15	<0.1
$Gd_2O_3:Eu^{+3}$	7.55	2.6	-	610	-	-
$(Y,Gd)_2O_3:Eu$	5.9	6.1	1.52	610	1000	5
$Gd_2O_2S:Pr,Ce,F$	7.34	2.9	1.8	520	2.4	<0.1
$Gd_2O_2S:Tb(Ce)$	7.34	2.9	1.8	550	600	0.6
$La_2HfO_7:Ti$	7.9	2.8	0.45	475	10	-
$Gd_3Ga_5O_{12}:Cr,Ce$	7.09	4.5	1.38	730	150	<0.1

[a]Thickness to absorb 99% of x-ray photons generated by tungsten anode x-ray tube at 140 kVp.

[b]Relative light output measured using silicon photodiode, under 140 kVp tungsten anode XRT excitation.

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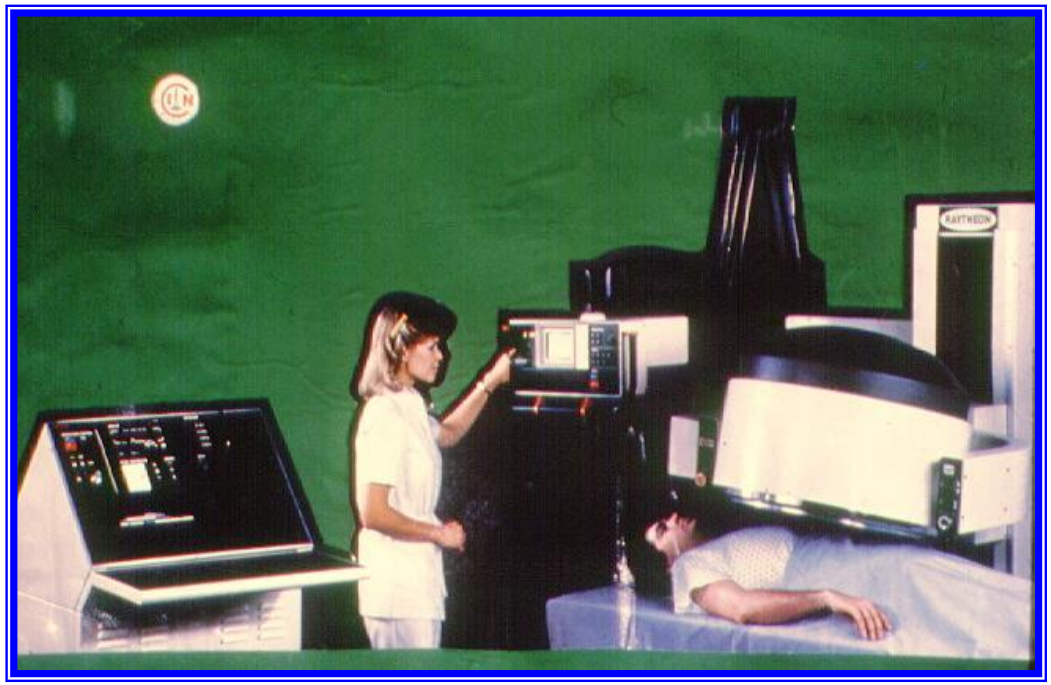
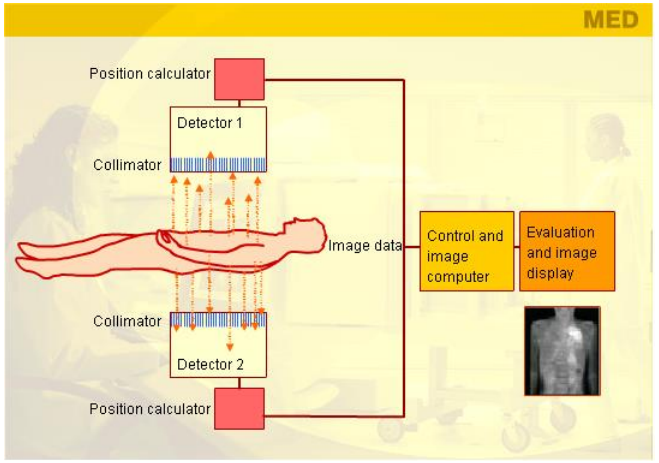
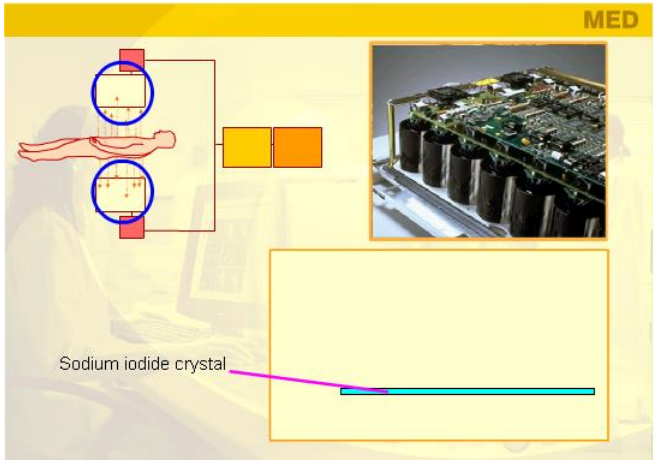
GAMMAGRAPHY

GAMMACAMERA = ANGER CAMERA







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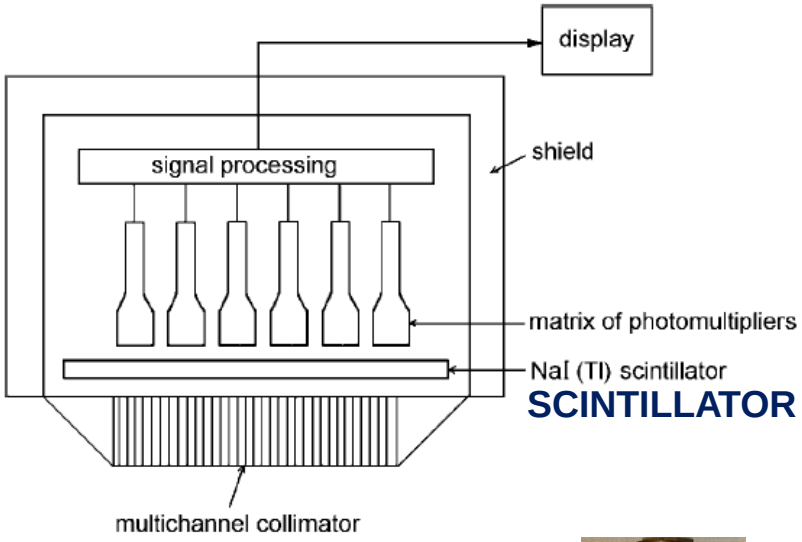
GAMMAGRAPHY

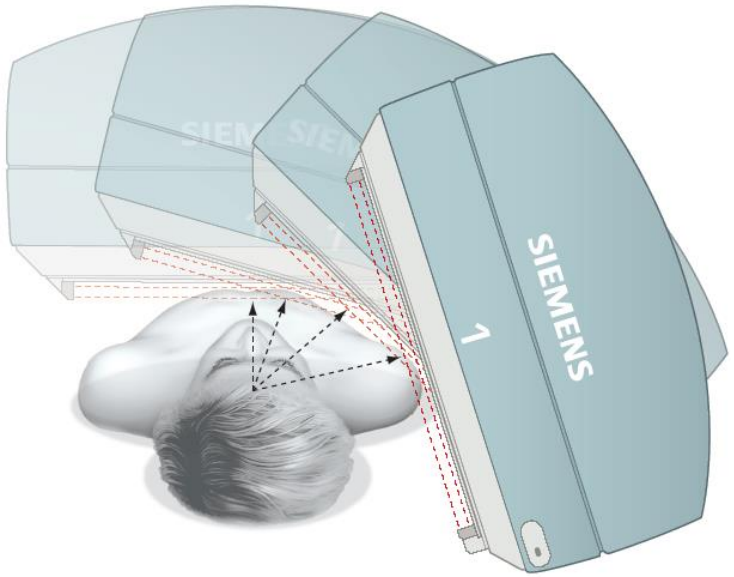
SCINTILLATORS



SCINTILLATOR

PHOTOMULTIPLIER TUBE

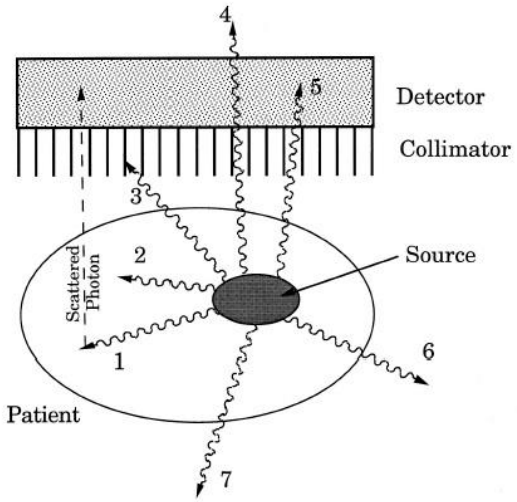
GAMMAGRAPHY

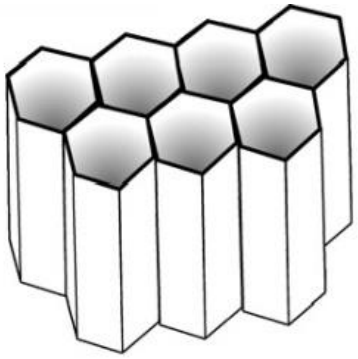


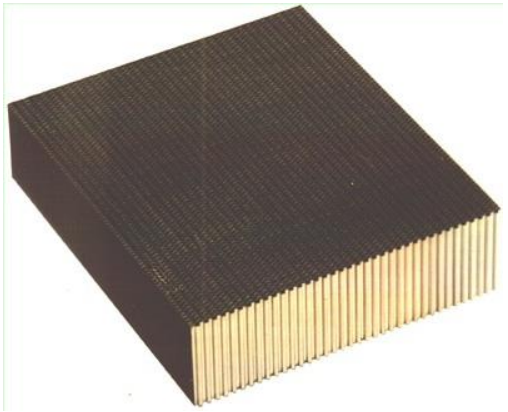
Autocontour whole body image

SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHY - SPECT

COLLIMATORS

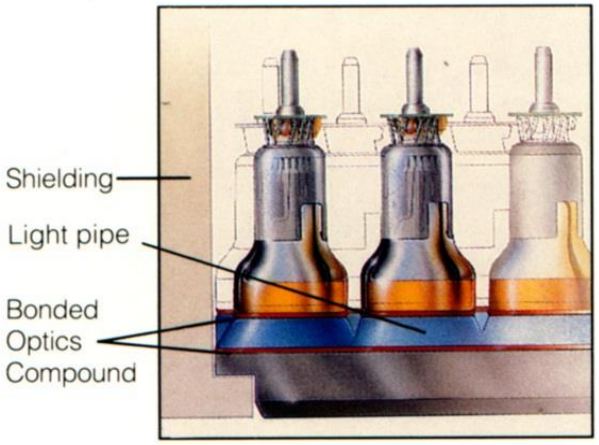


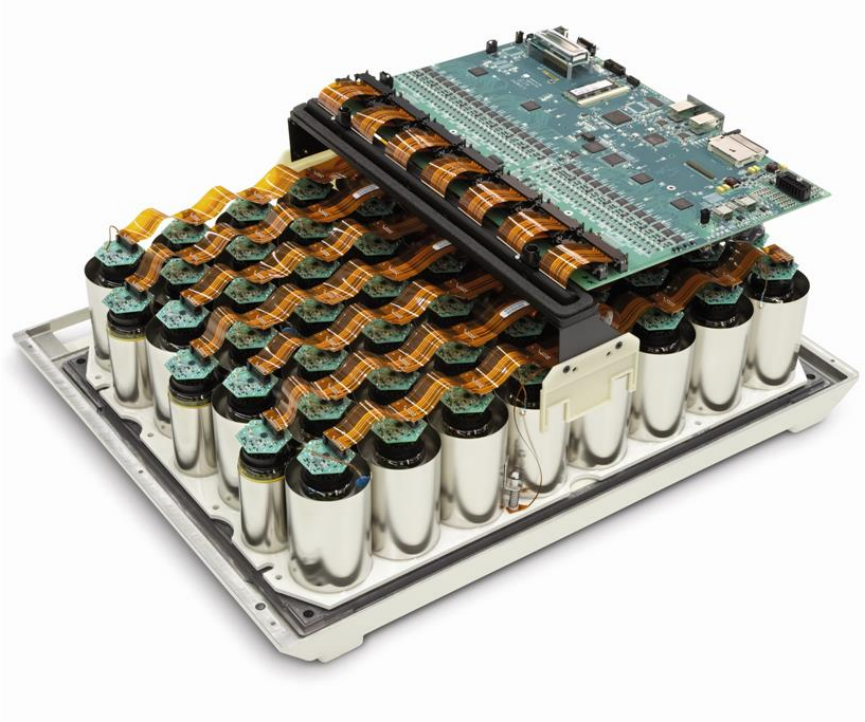




Pattern of gamma events reaching the cristal Is comparable to one side (planar) view of activity within the patient. Only events whose paths are parallel to the exagonal holes pass throgouth the collimator

LIGHT PIPE AND PHOTOMULTIPLIER ARRAY





Preamplifier uses **ASIC**
Application Specific Integrated Circuit

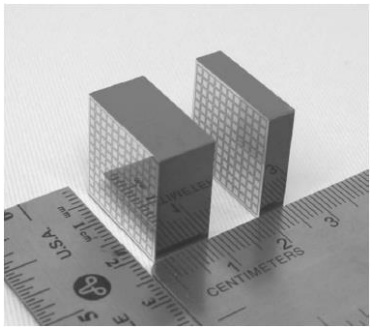
SCINTILLATION CRYSTALS

	Na(Tl)	CsI(Tl)	CsI(Na)
Z_{eff}	3.67	54	54
Density (g/cm^3)	50	4.51	4.51
Decay time (ns)	230	1,000	630
Photon yield (keV)	38	45 52[a]	39
Refraction index	1.85	1.8	1.84
Hygroscopic	Yes	Slightly	yes
Peak emission (nm)	415	540	420

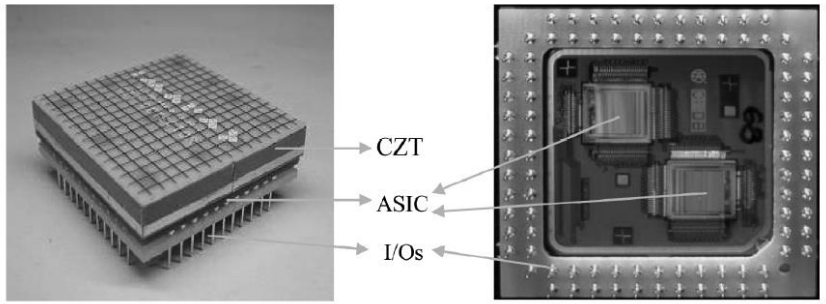
From: Basic Science of Nuclear Medicine

PIXELATED SCITILLATOR ARRAY

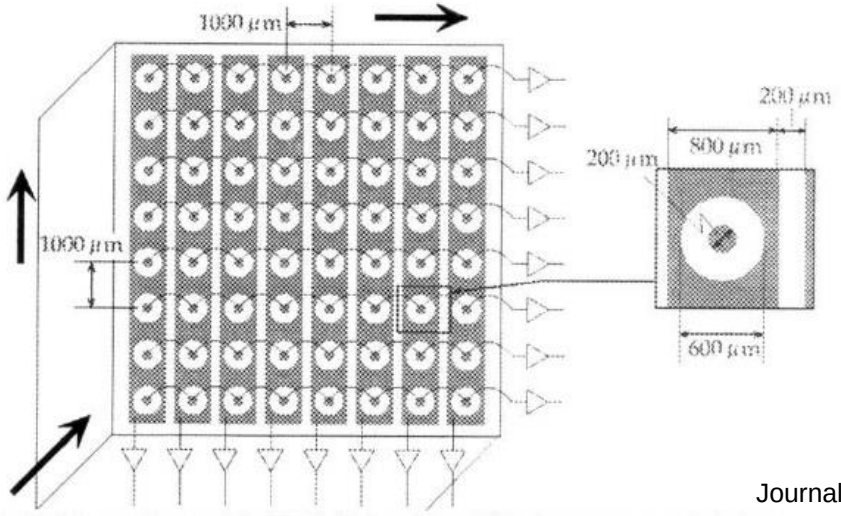
(Cadmium Zinc Telurium)



20x20x10 mm3
20x20x5 mm3

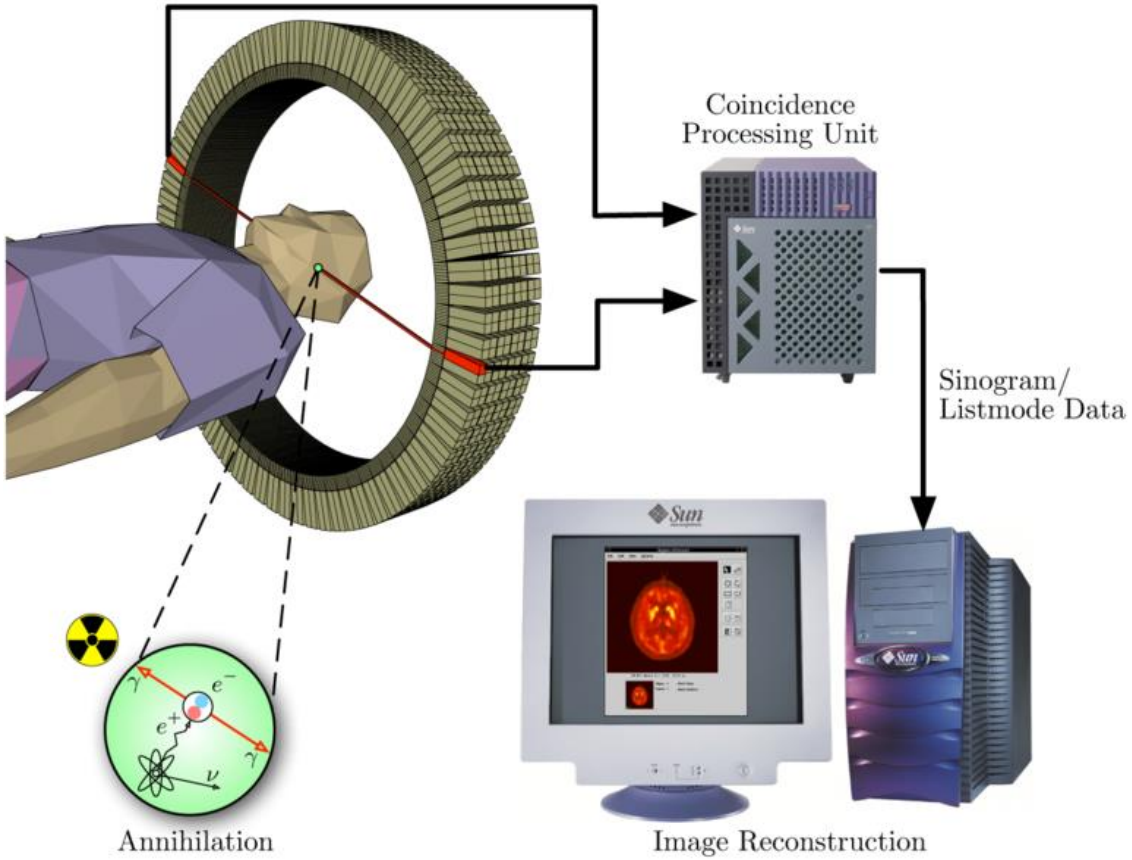


CZT module

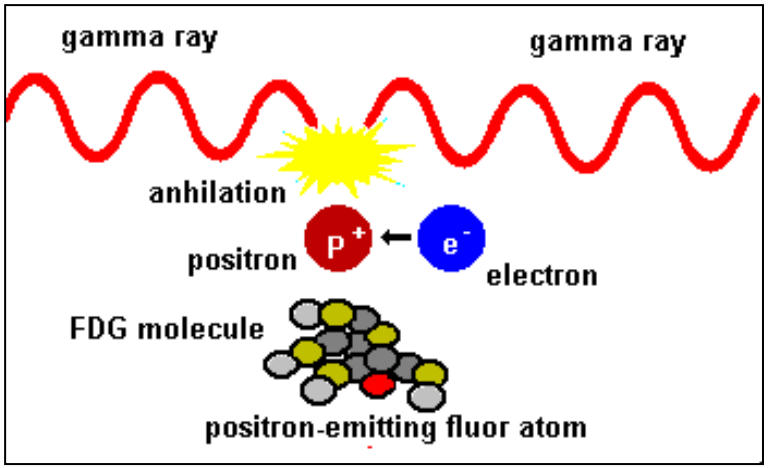


Journal of Applied Physics 103,014903 (2008)

POSITRON EMISSION TOMOGRAPHY (PET)

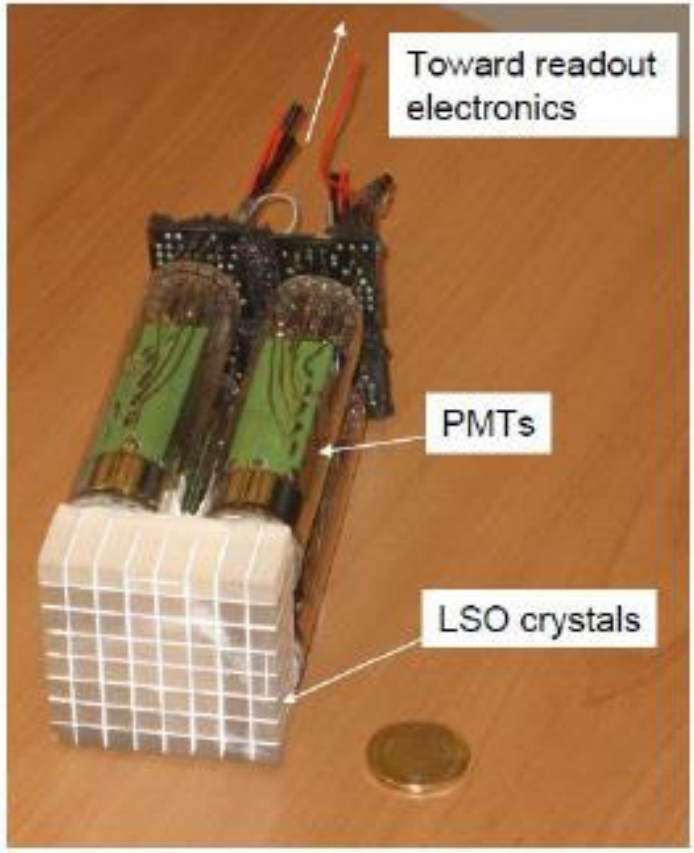


PET

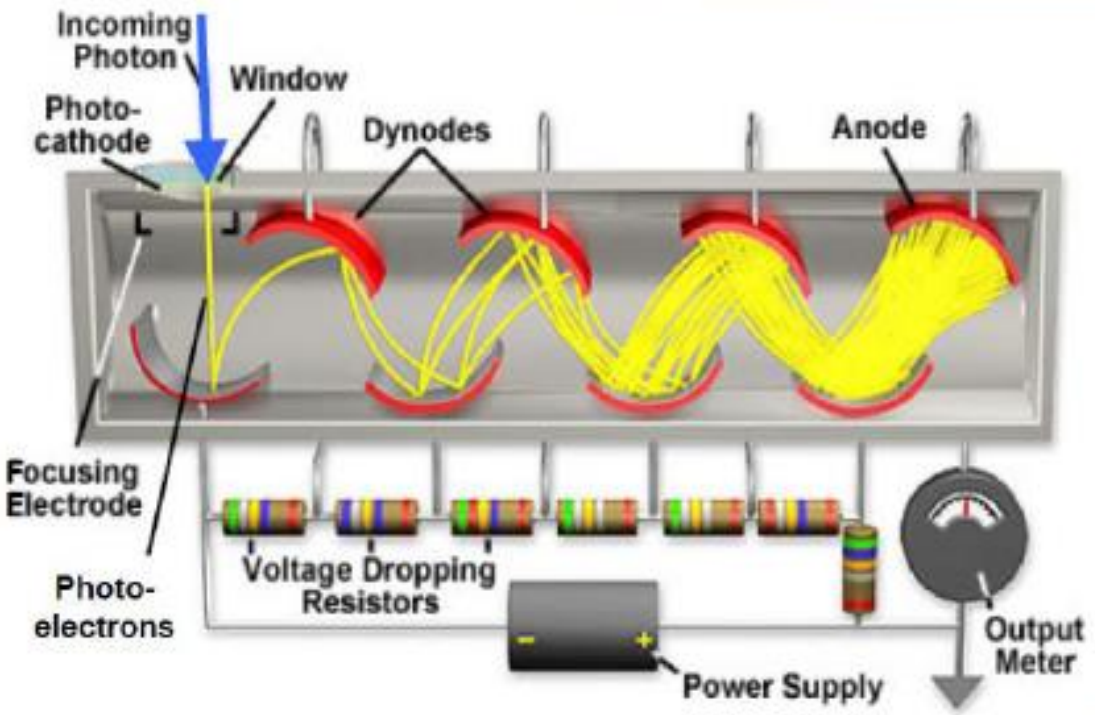


Scintillating crystal and photomultiplier

SCINTILLATORS + PM ARRAY FOR PET



PHOTOMULTIPLIER TUBE

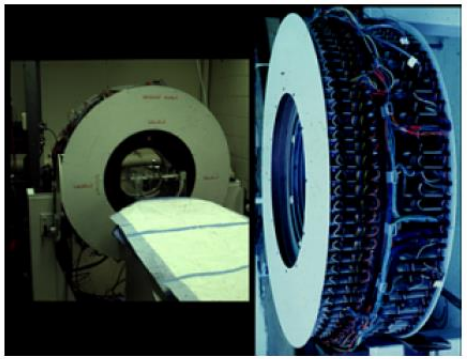


BEGININGS OF PET

1er prototype build: Gordon Brownell, 1952
Physics Research Laboratory, Massachusetts General Hospital 2 NaI scintillators

PC-II PET, 1976, Physics Research Laboratory, Massachusetts General Hospital, 2 banks of NaI scintillators

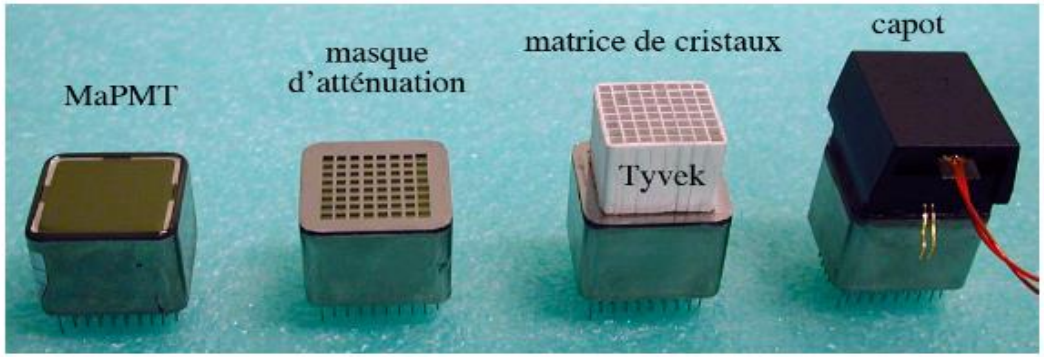
Figure 15: A commercial version of PC-II; The Cyclotron Corporation Positron Camera Model 4200.

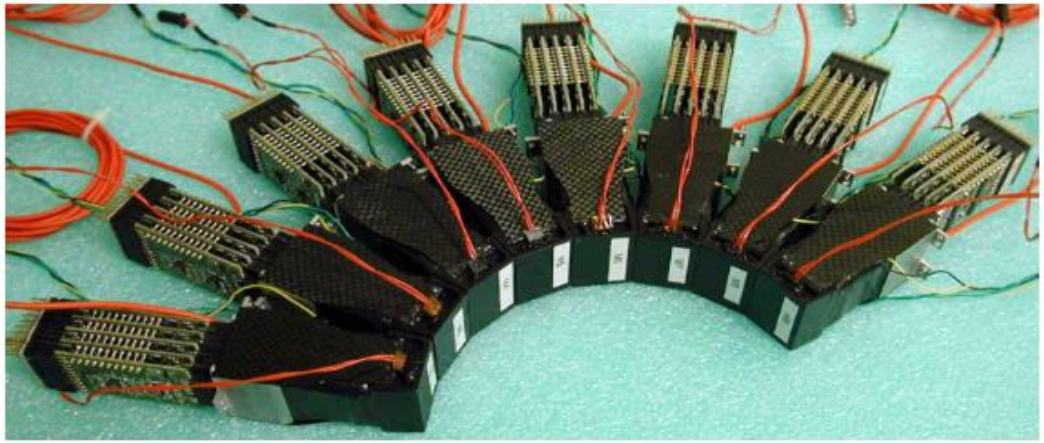


PCR-I PET, 1985, Ring Detector structure
Brownell et al. Physics Research Laboratory, Massachusetts General Hospital
Cilindro de centelladores con pequenos fotomultiplicadores

SMALL ANIMAL PET

SCINTILLATOR DETECTORS FOR A SMALL ANIMAL PET–CT PROTOTYPE





phoswich detector assembly – Université Aix-Marseille, France

SCINTILLATORS FOR PET

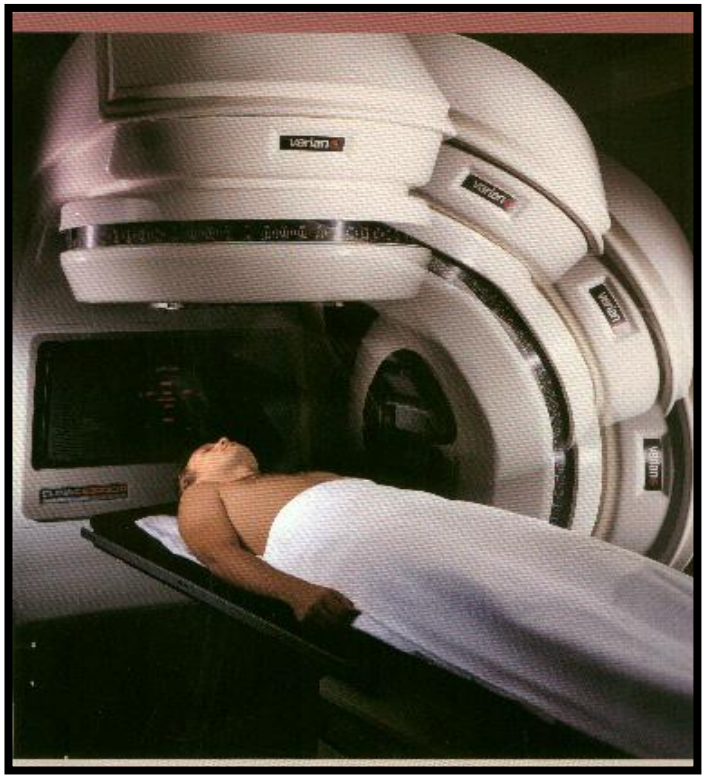
CERN

erimed
www.cern.ch/cerimed/

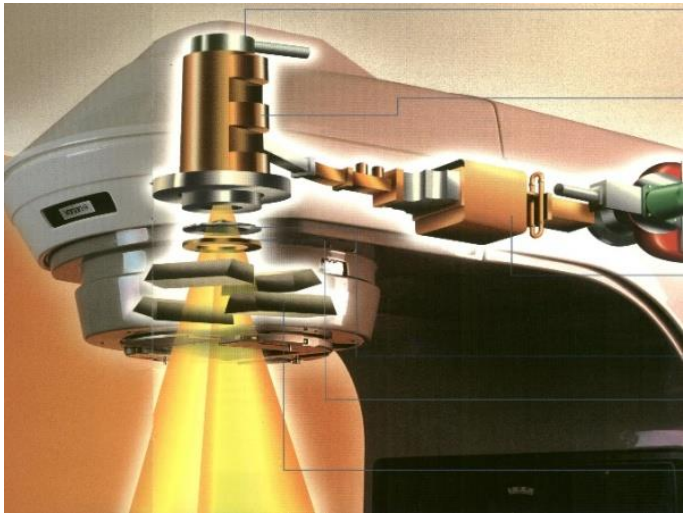
Scintillators for PET

	1962	1977	1995	1999	2001
	NaI	BGO	GSO:Ce	LSO:Ce	LuAP:Ce
Density (g/cm³)	3.67	7.13	6.71	7.40	8.34
Atomic number	51	75	59	66	65
Photofraction	0.17	0.35	0.25	0.32	0.30
Decay time (ns)	230	300	30-60	35-45	17
Light output (hv/MeV)	43000	8200	12500	27000	11400
Peak emission (nm)	415	480	430	420	365
Refraction index	1.85	2.15	1.85	1.82	1.97

TELETHERAPY



CLINICAL e- ACCELERATOR

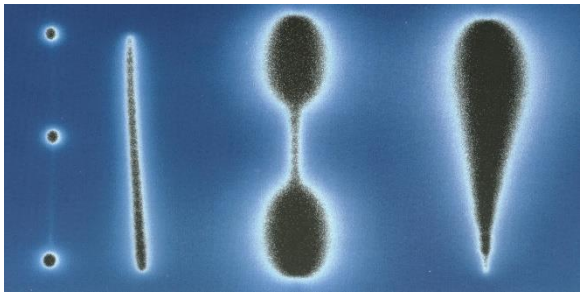


DETECTORS

- Ionization chamber
- Diode array
- EPID (Electronic Portal Imaging Device)

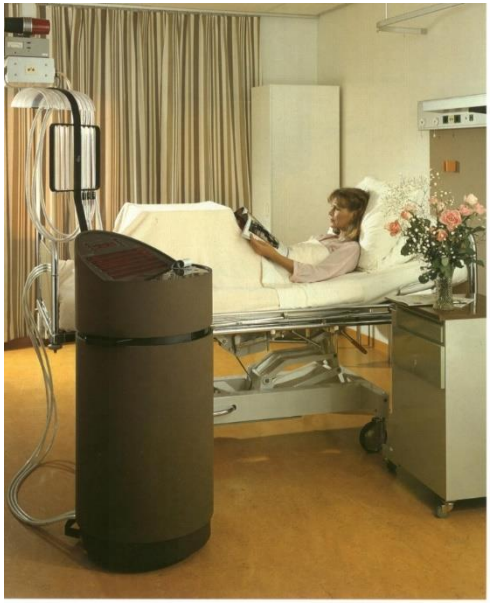
RADIOTHERAPY

BRAQUITHERAPY

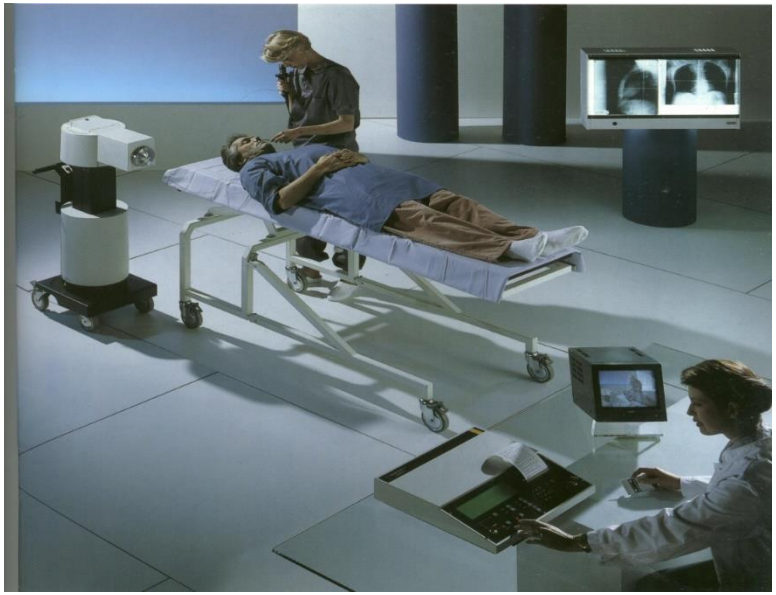


Ir 192

Ir 131



Cs137



DETECTORS

- Ionization chamber
- G-M counter
- Personal dosimeters

HADRONTHERAPY

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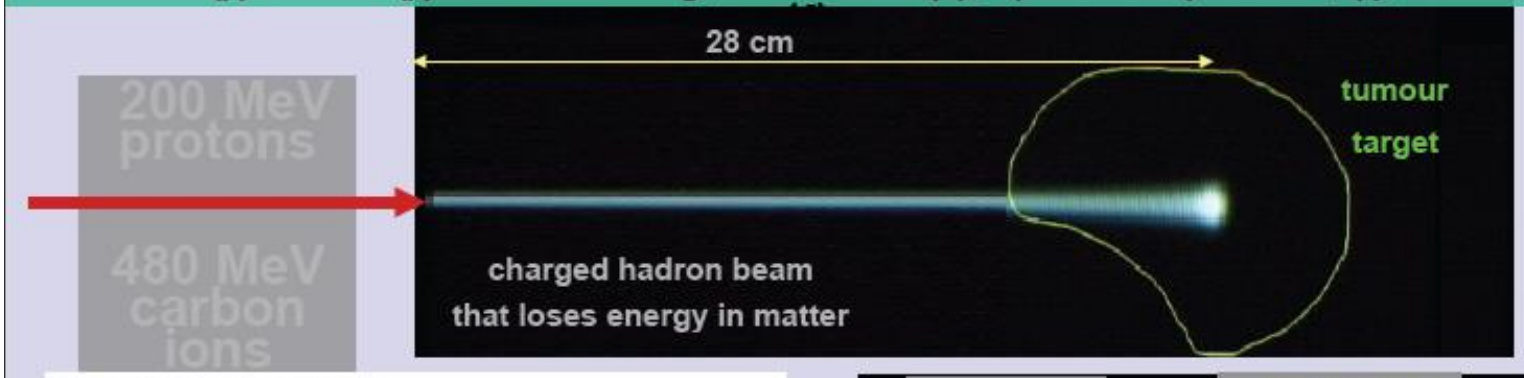
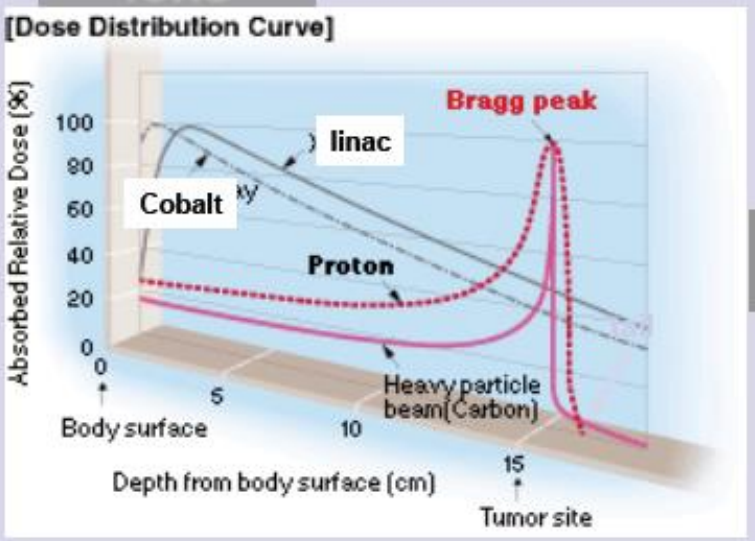
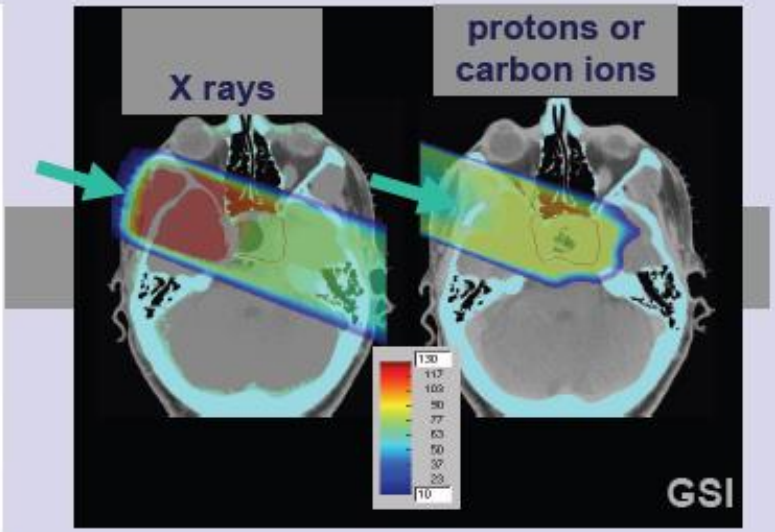
Hadron Therapy

Loma Linda(p)-US; PSI(p)- CH; Heidelberg, Pavia-CNAO (C), Lyon-Etoile (all C ions, p), Medastron







PARTICLE DETECTORS IN MEDICINE

CERN

Cyclotron solution for protons by IBA - Belgium

Five companies c

If proton accelerato
no radiotherap

ENLIGHT

DETECTORS

- Ionization chamber
- CMOS trasistor array
- Transducers + gas detectors
- SC detectors

RESEARCH ON NEW DETECTORS

CERN PROJECTS

- RD51
- CERIMED

NEW DETECTORS

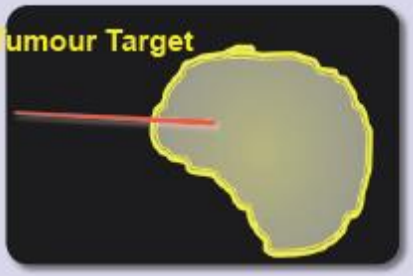
- GEM (gas)
- MEDIPIX (SC)
- X-PAD

PARTICLE DETECTORS IN MEDICINE

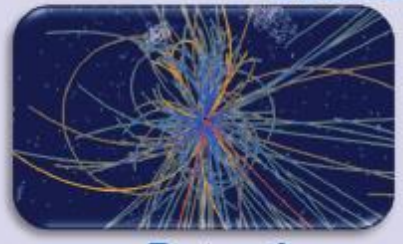
SINERGY HEP ⇔ MEDICINE

High Energy Physics Technologies

Accelerating particle beams



Particle Therapy



Detecting particles

Medical imaging

Large scale computing (Grid)

Grid computing for medical data management and analysis

NEW TECHNOLOGIES

The future Healthcare Mission

erimed
www.cern.ch/cerimed/

We need to capture enough information from each individual person to:

- Prevent disease or diagnose it at its earliest stage
- Understand disease parameters, such as aggressiveness or metastatic potential
- Optimize delivery of therapy based on the patient's current biologic system
- Instantaneously evaluate therapeutic effectiveness

Requires a "new generation" of imaging devices and bioengineering…

From HEP detectors to Medical Imaging

erimed
www.cern.ch/cerimed/

Requirements for HEP EM calorimetry

1. **Crystals** — Technology transfer
   - High density (> 6 g/cm^3)
   - Fast emission (< 100 ns), visible spectrum
   - Moderate to high light yield
   - High radiation resistance
2. **Photodetectors** — Technology transfer
   - Compact
   - High quantum efficiency and high gain
   - High stability
3. **Readout electronics** — Technology transfer
   - Fast shaping, low noise
   - Highly integrated
4. **Intelligent and parallel DAQ** — Technology transfer
   - Reduce dead time
5. **Software** — Technology transfer
   - Accurate Monte Carlo simulation
6. **General design** — Technology transfer
   - Compact integration of a large number of channels (> 10'000)

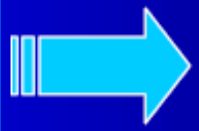
Requirements for Medical Imaging

1. **Crystals**
   - High density (> 7 g/cm^3)
   - Fast emission (< 100 ns), visible spectrum
   - High light yield
   - Moderate radiation resistance
2. **Photodetectors**
   - Compact
   - High quantum efficiency and high gain
   - High stability
3. **Readout electronics**
   - Fast shaping, low noise
   - Highly integrated
4. **Intelligent and parallel DAQ**
   - Reduce dead time
5. **Software**
   - Accurate Monte Carlo simulation
6. **General design**
   - Compact integration of a large number of channels (> 10'000)

The future of medical imaging

erimed
www.cern.ch/cerimed/

- Faster exams
- Movement correction
  - Breathing
  - Cardiac beating
  - Digestive bolus
- Dynamics
- Quantification
- True multimodality
- Reduce dose to patient



IMPROVE

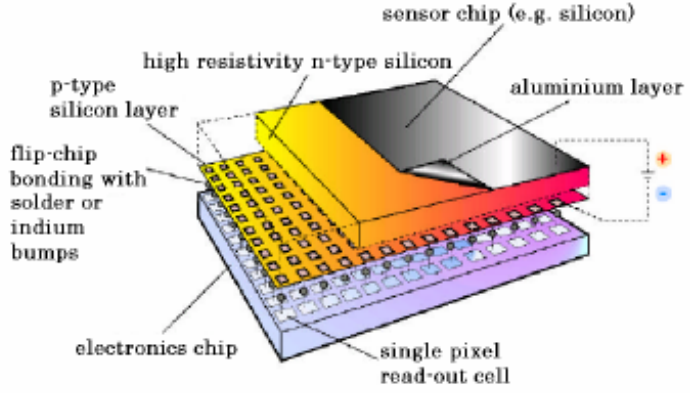
- Spatial resolution
- Timing resolution
- Sensitivity
- Signal/Noise ratio

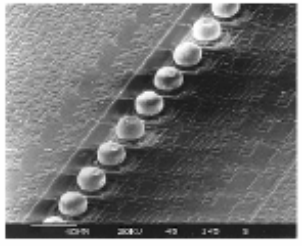
Hybrid pixel detector
Single photon counting

CMOS *technology*

erimed
www.cern.ch/cerimed/

Hybrid Pixel Detector

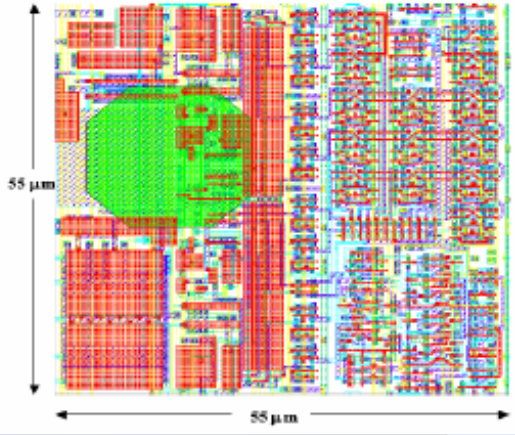




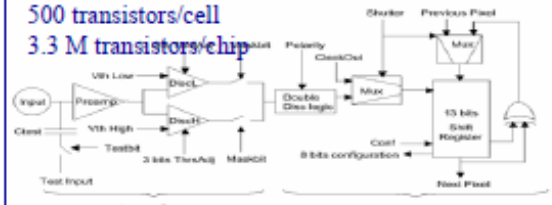
Bump-bonding: an industrial technology still posing yield problems

Medipix2 (55 µm pitch) 1 µm SACMOS
(M. Campbell et al.,1998)

Medipix2 Pixel Cell Layout

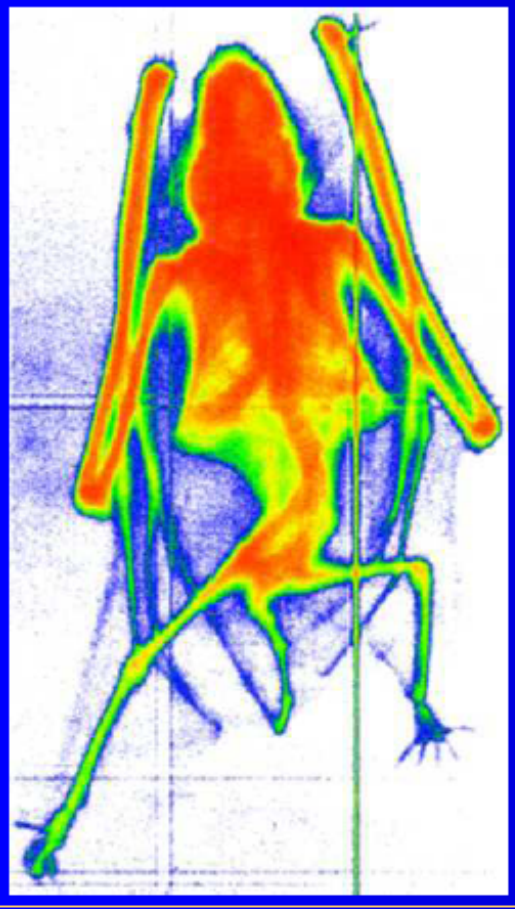


500 transistors/cell
3.3 M transistors/chip

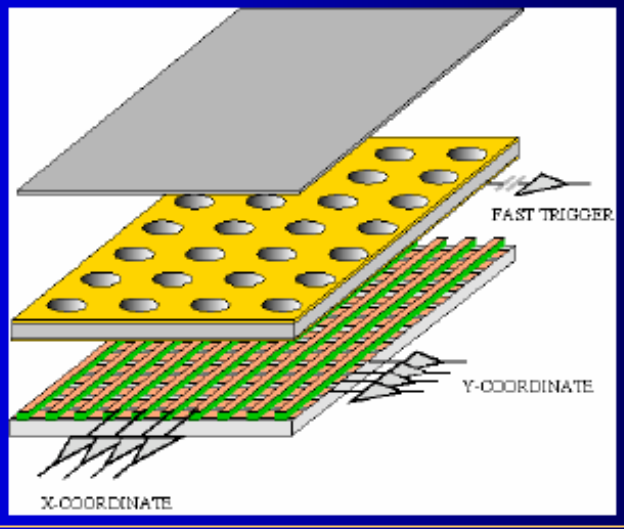


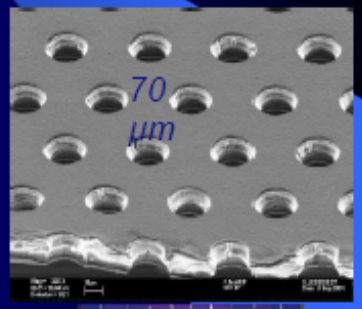
GEM Detector

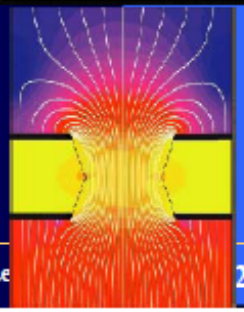
erimed
www.cern.ch/cerimed/



- Thin, metal-clad polymer foil, chemically pierced by a high density of holes (70-80 µm diameter).
- On application of a difference of potential between the two electrodes, electrons released by radiation in the gas on one side of the structure drift into the holes, multiply and transfer to a collection region.
- Cascading several foils results in high multiplication factors.







AVALANCHE PHOTOMULTIPLIER

Geiger mode APD (SiPM)

erimed
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GM-APD + $R_{quenching}$

Output signal is independent of number of photoelectrons (binary device)

n pixels

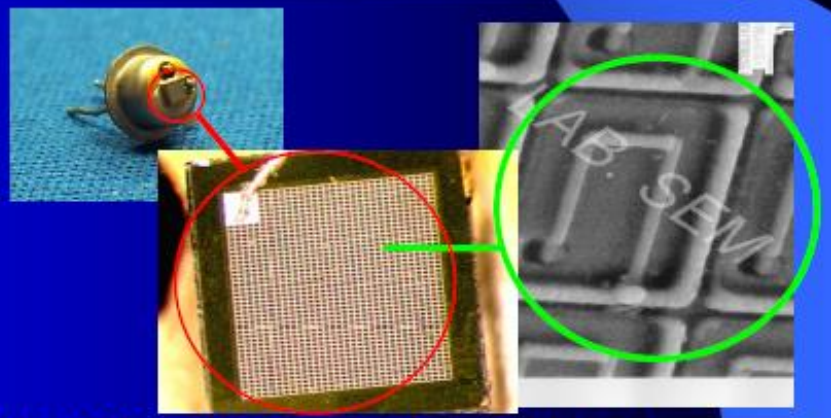
$-V_{bias}$ ($> V_{breakdown}$)

SiPM
- matrix of n pixels (~1000) in parallel
- each pixel: GM-APD + $R_{quenching}$

Output signal is the sum of the signals from all fired pixels (analogue device)

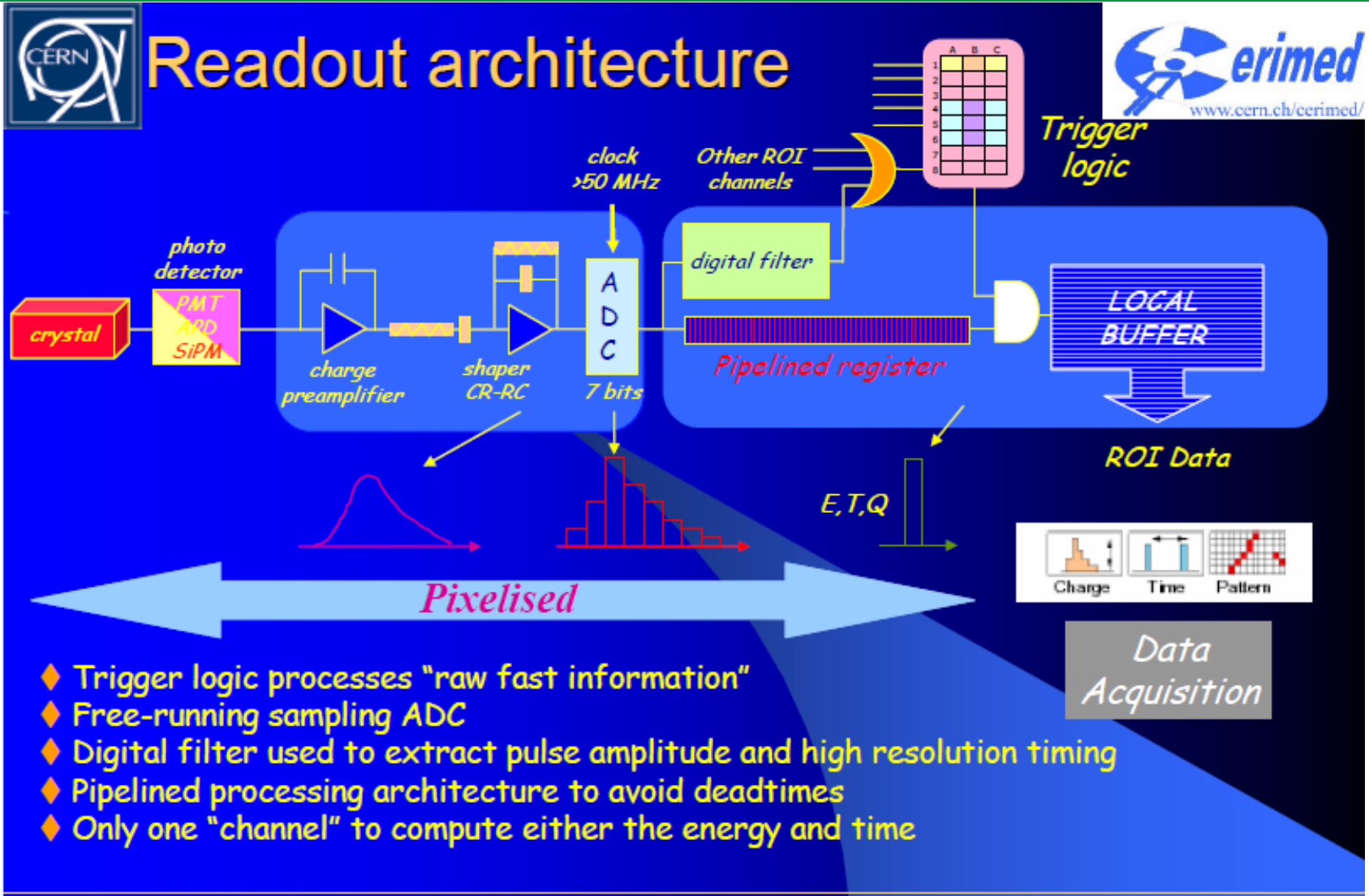
Result: high gain, low noise detector and proportional for $N_{photon} < N_{cells}$

- Excellent photon counting capability
- Fast response time (<1ns); small recovery time (~few ns)
- Noise (dark counts) limited to few photoelectron level
- Insensitivity to magnetic fields
- Compact and rugged



→ *Potential replacement for traditional vacuum-based PMT*

Readout architecture

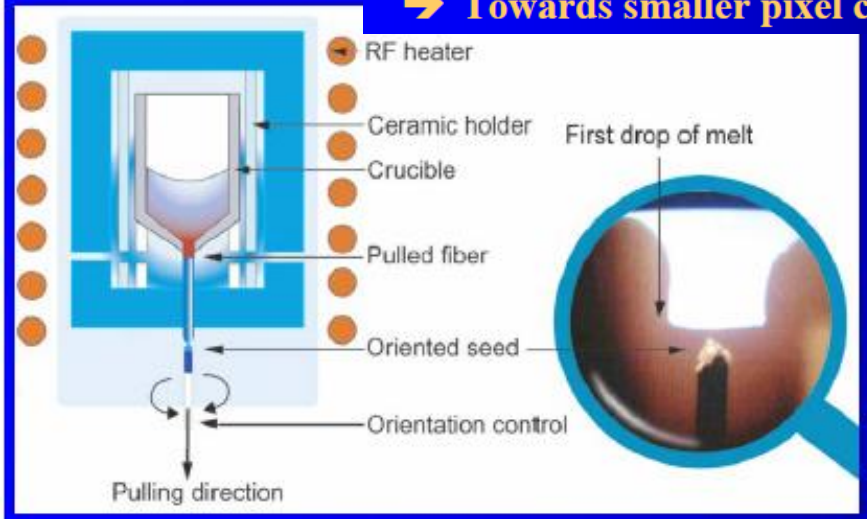


- Trigger logic processes "raw fast information"
- Free-running sampling ADC
- Digital filter used to extract pulse amplitude and high resolution timing
- Pipelined processing architecture to avoid deadtimes
- Only one "channel" to compute either the energy and time

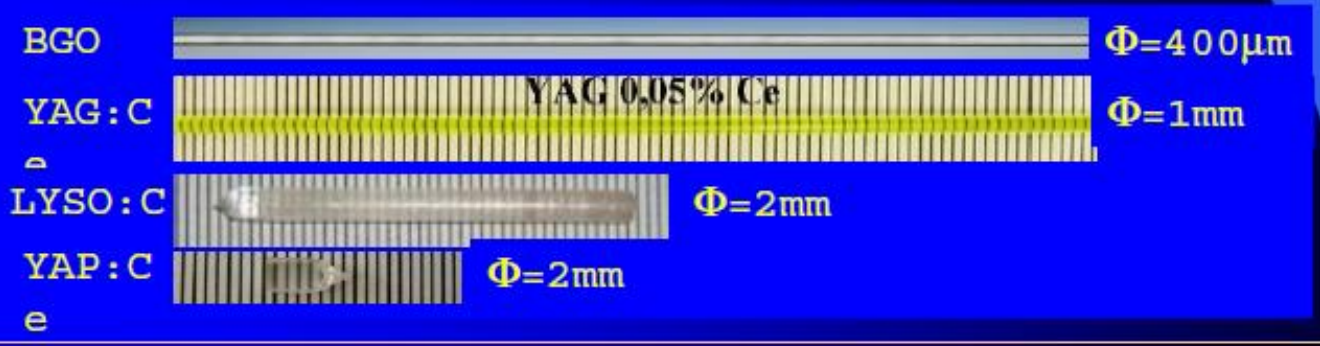
NEW SCINTILLATORS

Next generation of high spatial resolution small animal PET

➔ **Towards smaller pixel cross section**



Crucible and fiber



Can we do more?

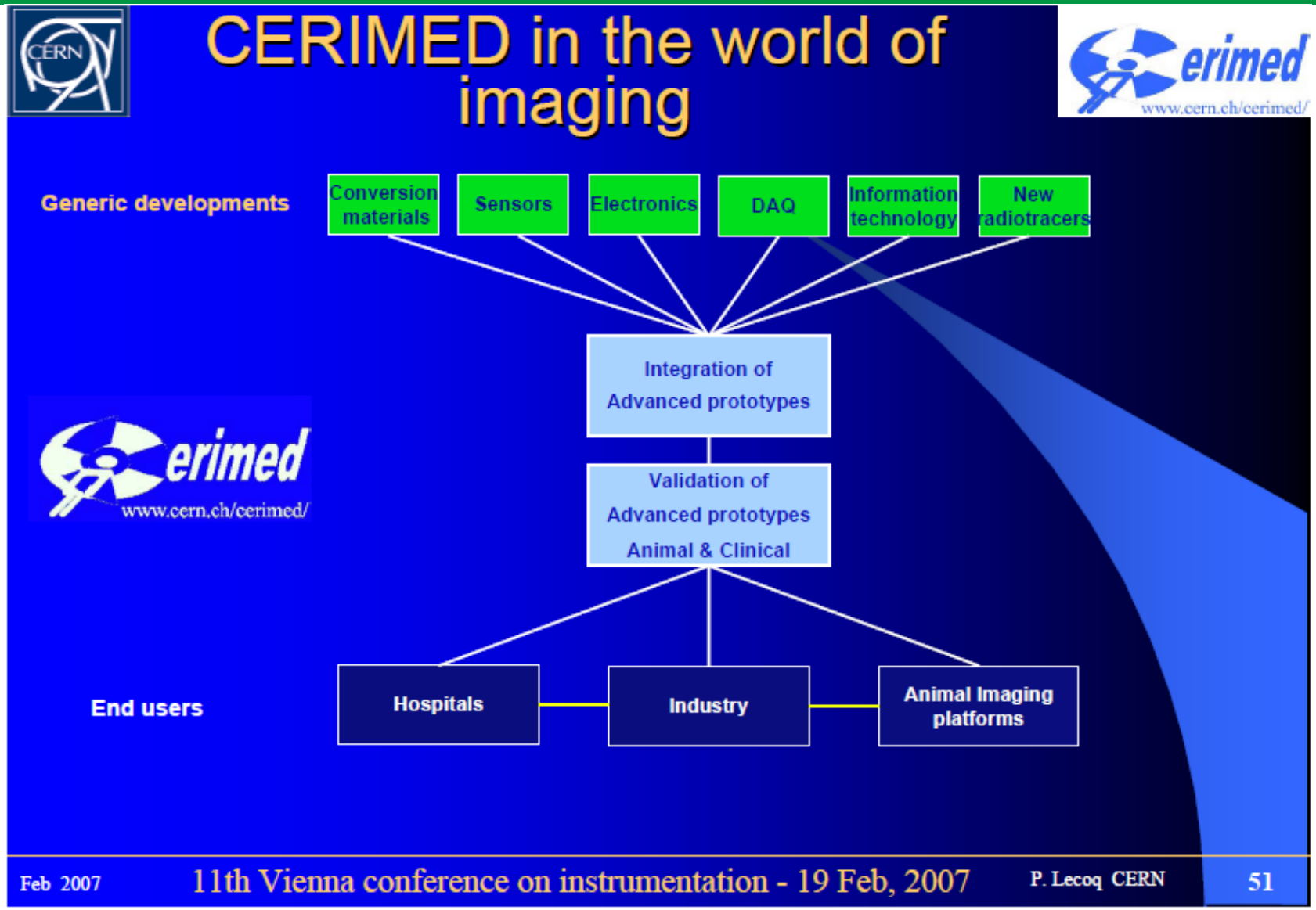
- Technology transfer from HEP to medicine is strongly encouraged

BUT

- CERN and HEP community main mission is to do particle physics, not medical imaging
- A stronger coordination is needed and must be further developed between physicists, the biomedical world and industry
- A bridge must be built to integrate innovative technologies developed in HEP and other fundamental disciplines, and to validate them in complex systems in a biomedical environment
- No structure exists at the European level for this mission

Cerimed (European Centre for Research in Medical Imaging) could be a solution

CERIMED COLLABORATION



THANKS