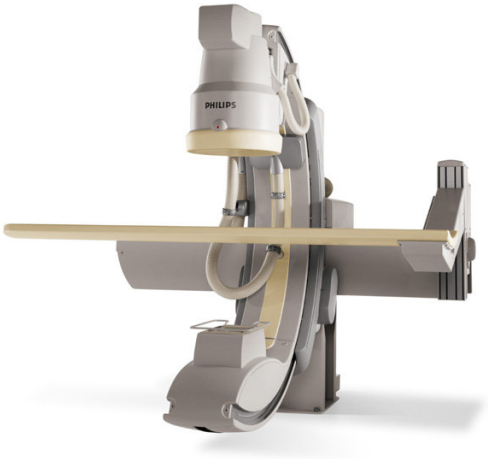
Image Quality assessment in digital X-ray detection systems

AAPM 2004
Summer School

Pittsburgh PA
29 July – 1 August

31-07-2004 Tom Bruijns / Dick Stueve Philips Medical Systems

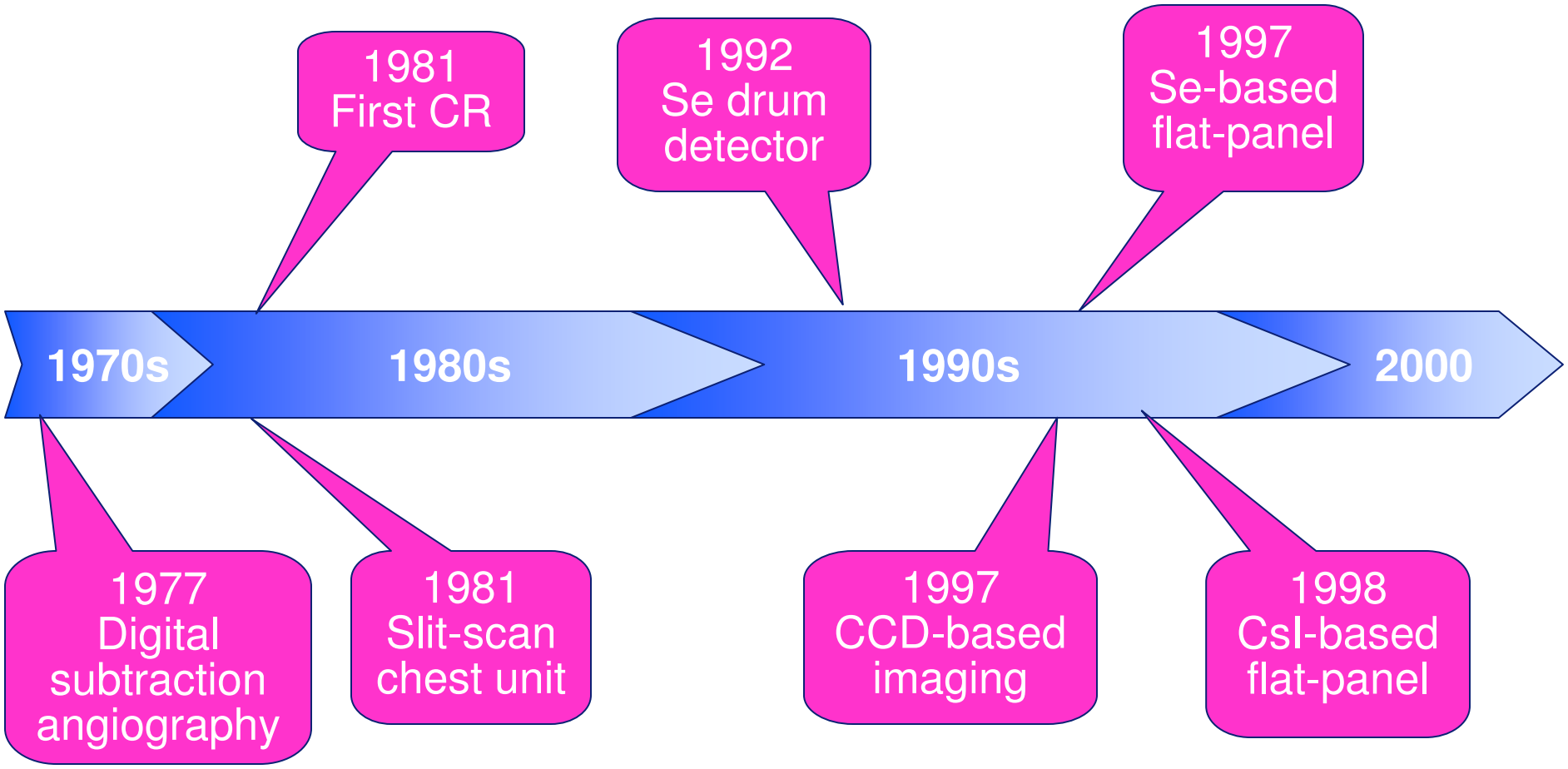


Outline

- Introduction
- Technologies in Rad and RF
- Performance Characteristics
- IQ assessment
- IQ design: a system approach
- Summary

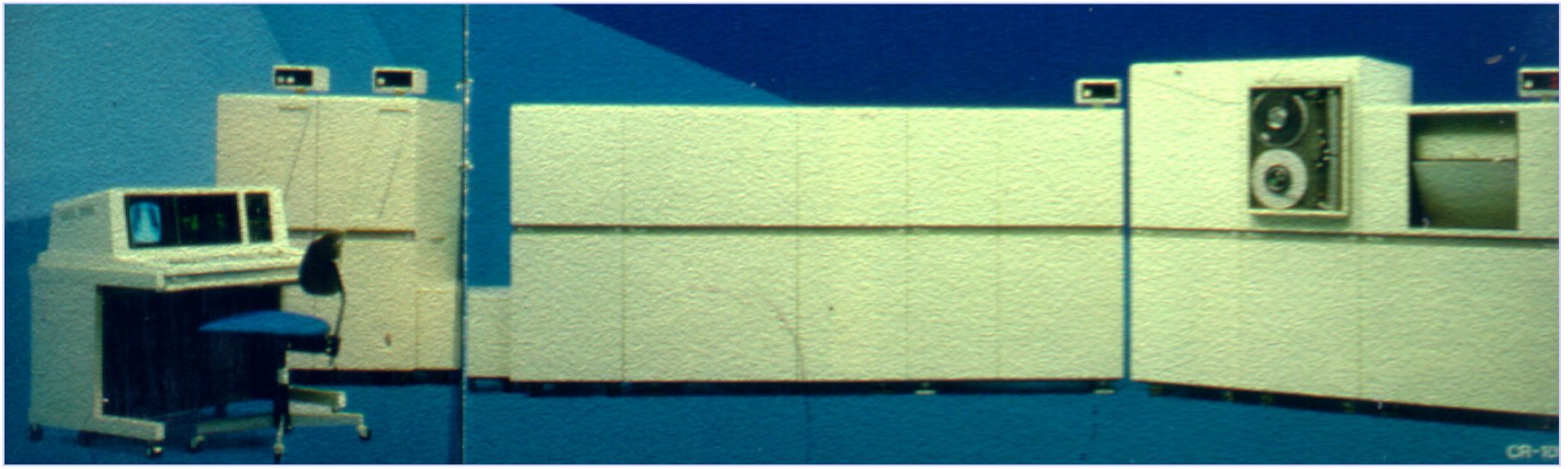
- *Evening session QC tools*
  19:00-21:00

Overview Digital Technologies



Neitzel

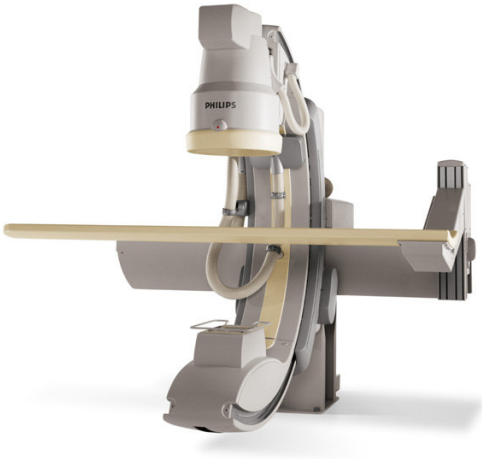
Overview Digital Technologies



CR in 1983

~ 10-20x reduction in size and price

CR in 2004

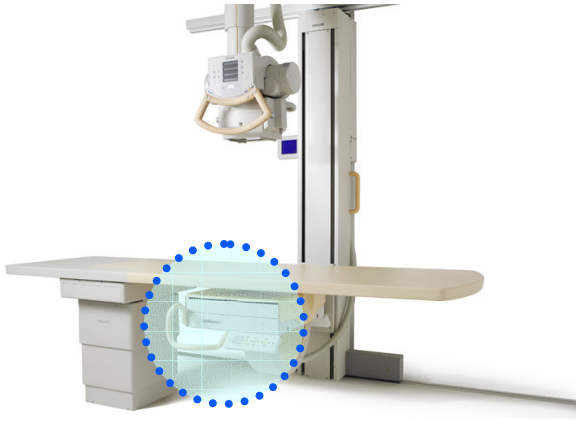


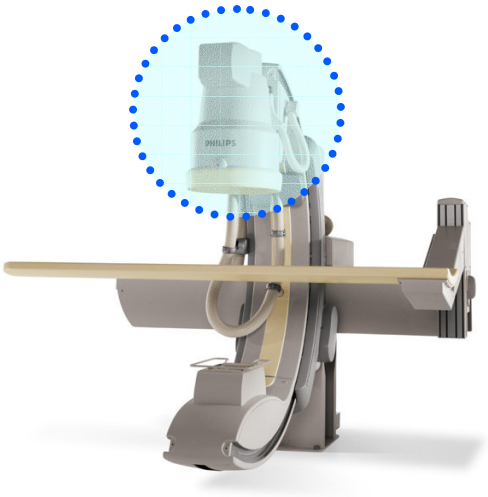
Product range overview
Digital Technologies

Rad systems:
- Thoravision (selenium drum)
- Computed Radiography
- Flat Detector technology

RF systems
- IITV technology (CCD based)
- *Flat detector to come*

CV systems
- IITV technology (CCD based)
- Flat Detector technology





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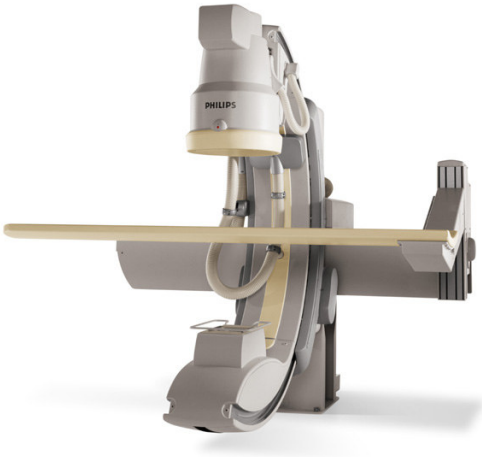

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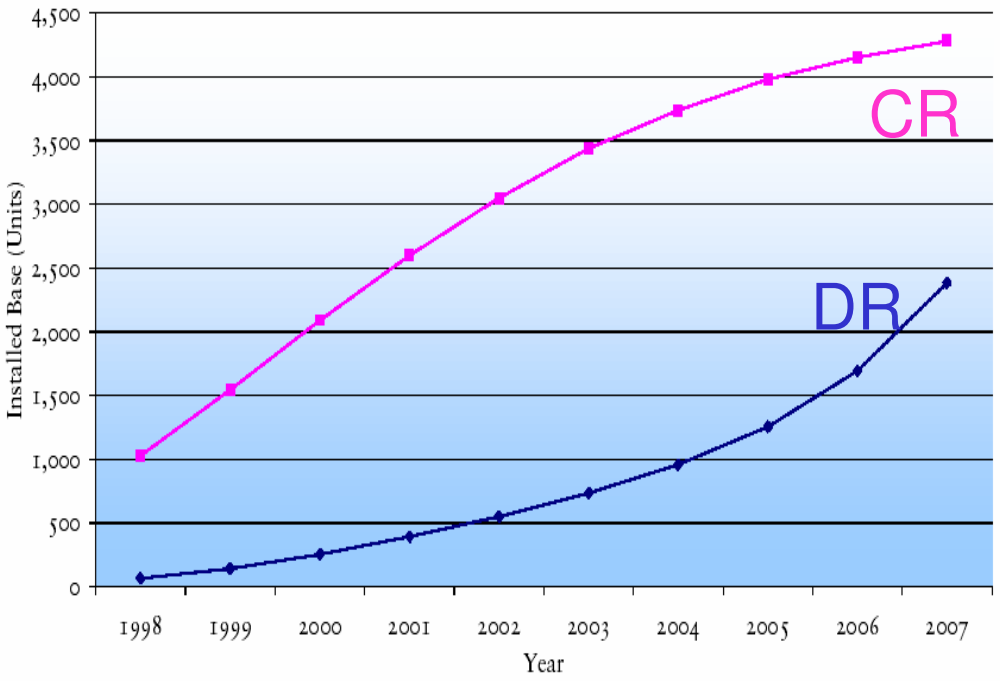
Flat Detector technology in Digital Radiography

CR and DR



Frost & Sullivan

CR :

- DQE will increase
- Line scan

CR will coexist next to DR for many years

Trixell *Moirans France*

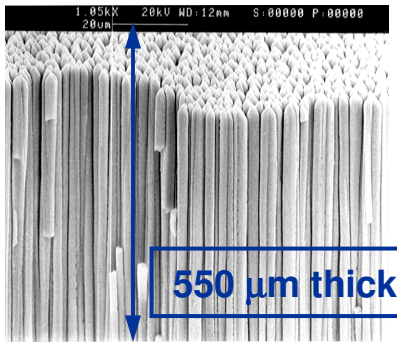
European Consortium

Thales, Philips, Siemens

Products

Static & Dynamic Flat x-ray Detectors (FD)

Flat Detector Technology



Scintillator (CsI)

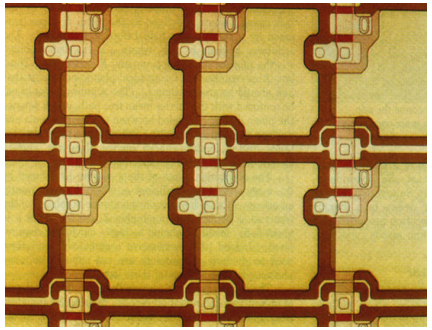
a-Si Sensor Matrix

Amplifiers

Address Lines

A/D-Converter

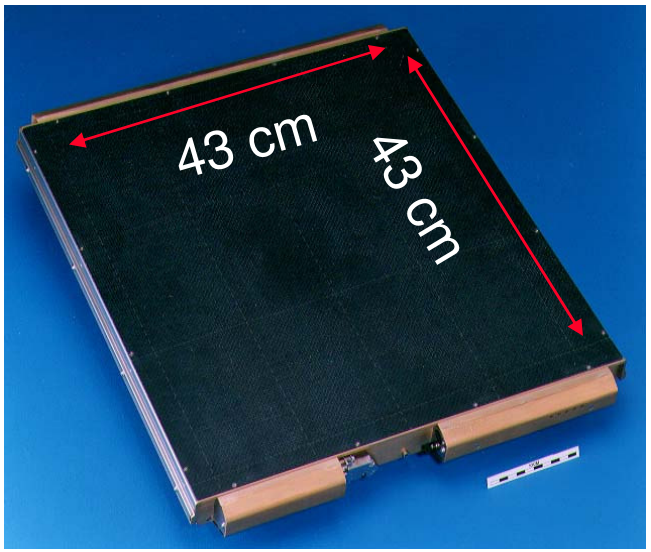
Glass Plate



43 cm x 43 cm static
18 cm x 18 cm dynamic
30 cm x 40 cm dynamic

Large area (43 cm x 43 cm) 9 Mpixel Flat Detector

- For radiographic applications
- Cesium Iodide scintillator (600 µm)
- Amorphous silicon photodiode array
- Array size: 43 cm x 43 cm
- Pixel size: 143 µm
- Bit depth:14 bits
- Image matrix: 3k x 3k
- Low noise electronics
- High sensitivity

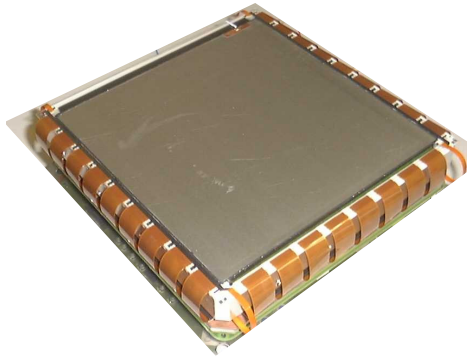


5 Mpixel Dynamic Flat Detector

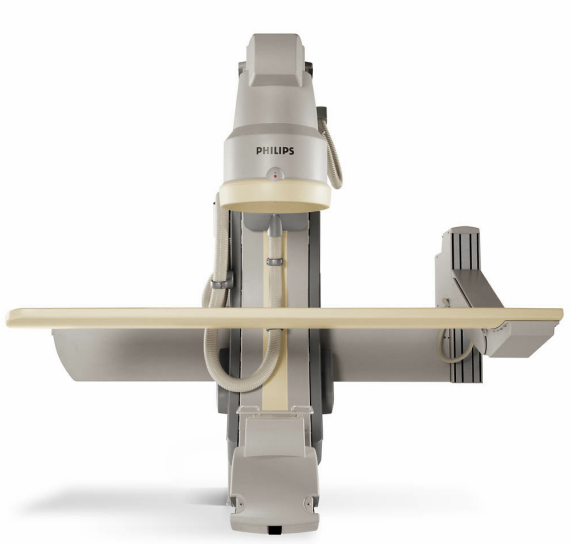
- For vascular (and RF) applications
- Cesium Iodide scintillator (550 µm)
- Amorphous silicon photodiode array
- Array size: 30 cm x 40 cm
- Pixel size: 154 µm
- Bit depth:14 bits
- Image matrix: 2.5 k x 2 k
- Low noise electronics
- High sensitivity

1 Mpixel Dynamic Flat Detector

- For cardio and vascular applications
- Cesium Iodide scintillator (550 µm)
- Amorphous silicon photodiode array
- Array size: 18 cm x 18 cm
- Pixel size: 184 µm
- Bit depth:14 bits
- Image matrix: 1 k x 1 k
- Low noise electronics
- High sensitivity



CCD based IITV technology for RF applications



CCD based IITV technology for RF applications

- Used for dynamic applications
- II: Cesium Iodide scintillator
- II size: 38 cm diameter
- Up to 5 zoom fields
- CCD Pixel size: 12,8 µm
- CCD Full well capacity: 170 ke^-
- CCD read out noise 40 e^-
- Bit depth:12 bits
- Image matrix: 1024^2

FD technology versus CCD based IITV technology for RF applications

+ No vignetting & no distorsion for FD
+ High resolution + coverage
+ High DQE for FD
+ Flat
- Price level high for FD

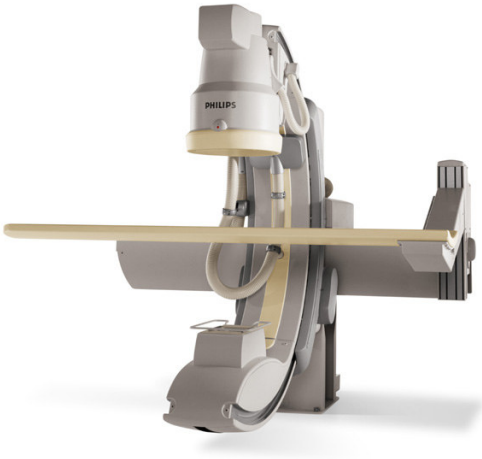


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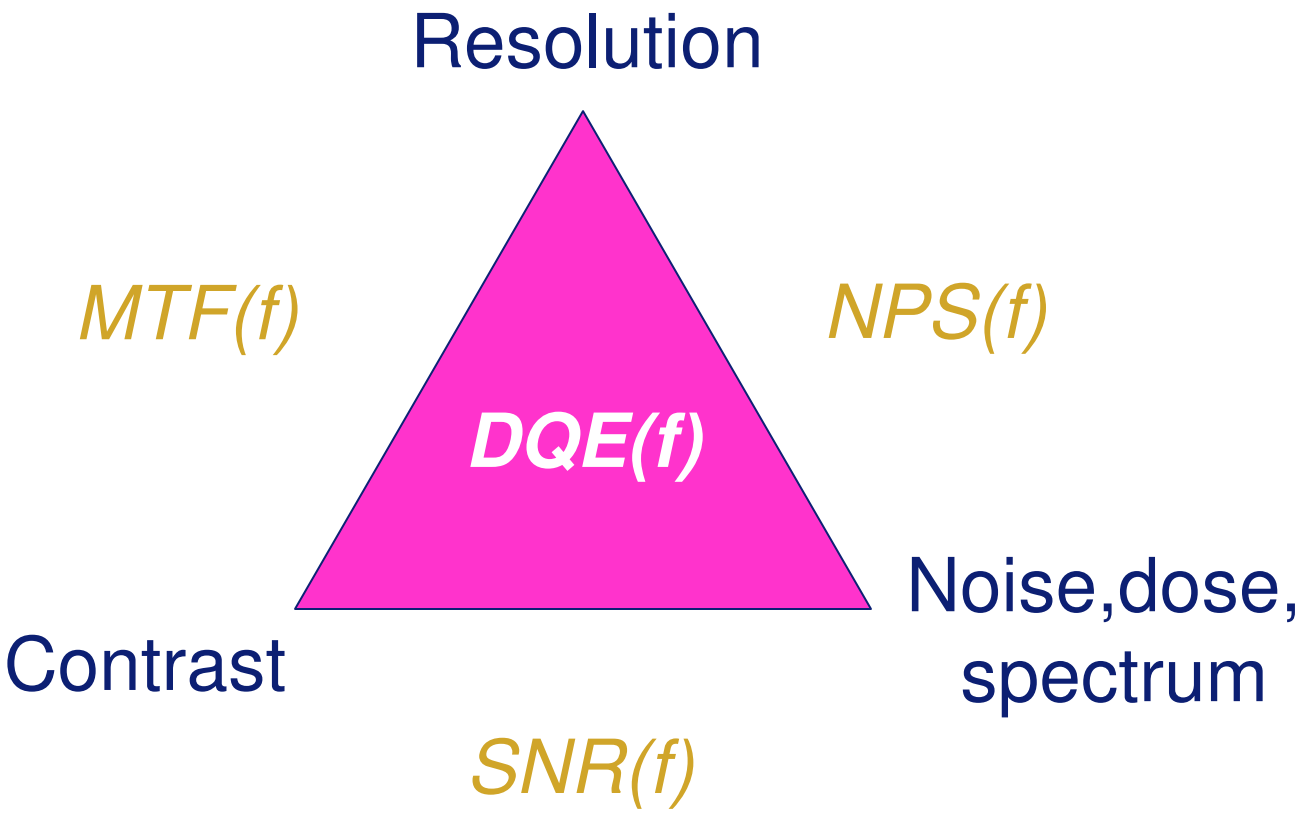
Image Quality Triangle



Neitzel, Malmö 2004

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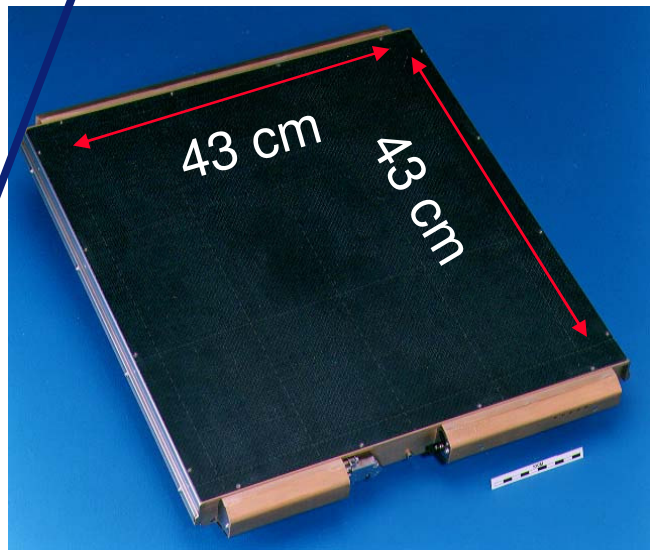
- Low noise electronics
- High X-ray sensitivity

Low noise



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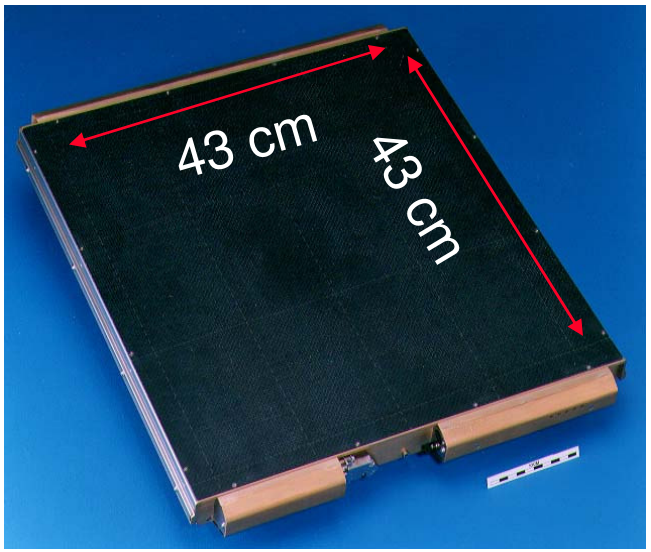
- High sensitivity

Resolution
(and Coverage)



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Low Noise

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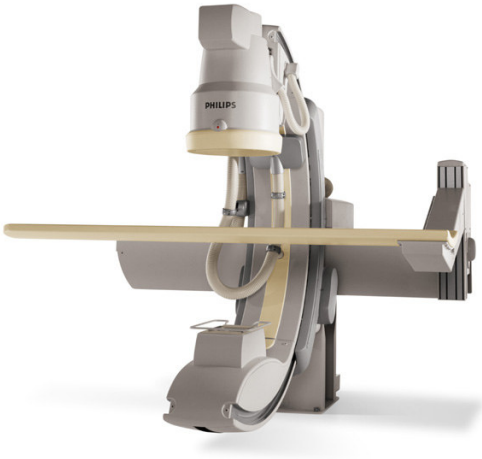

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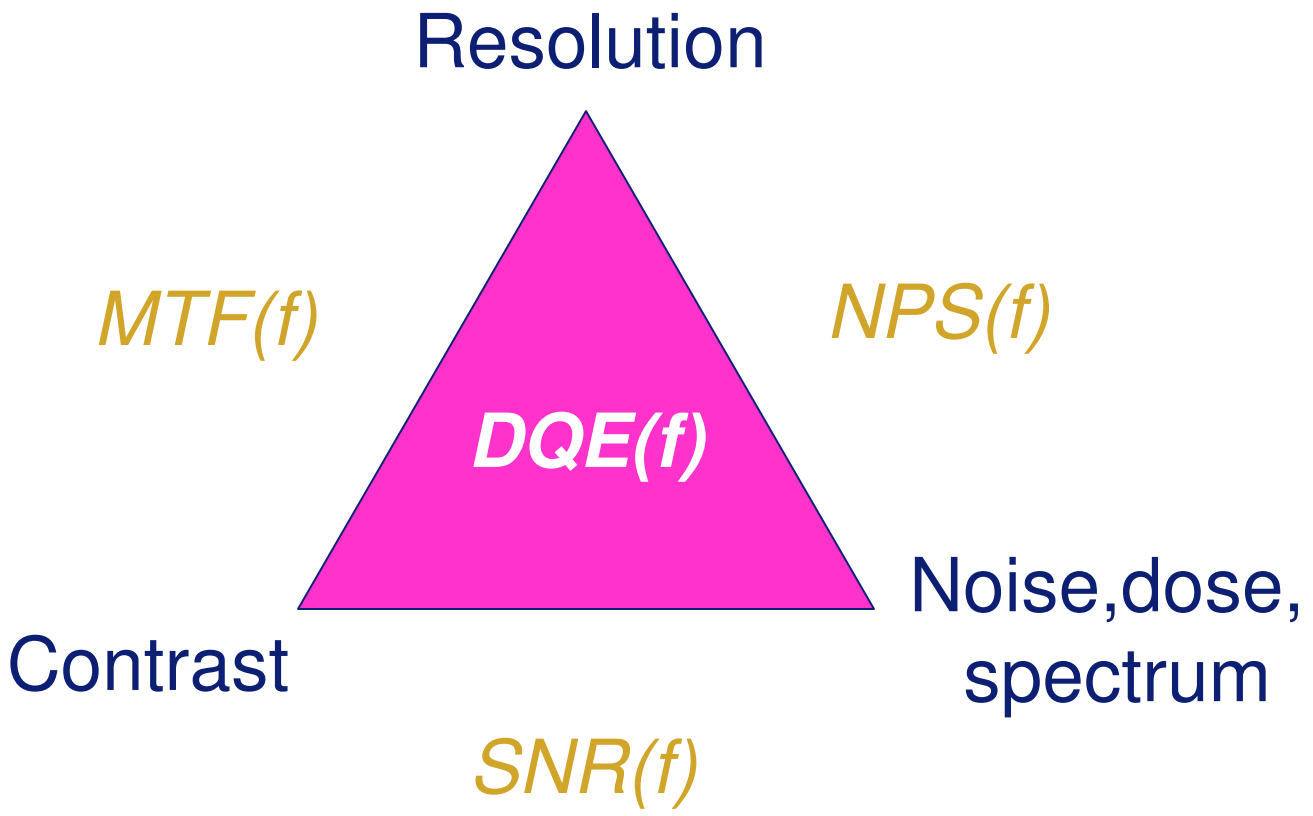


Neitzel, Malmö 2004

Detective Quantum Efficiency

$$\mathrm{DQE}(f) = G^2 \cdot \frac{\mathrm{MTF}^2(f) \cdot X}{\mathrm{NPS}(f) \cdot q},$$

The detective quantum efficiency (DQE) is considered to be the fundamental performance parameter of digital X-ray detectors.

But

There are many ways to come to many different answers

Detective Quantum Efficiency

Working group FD (DR)
IEC standard 62220-1

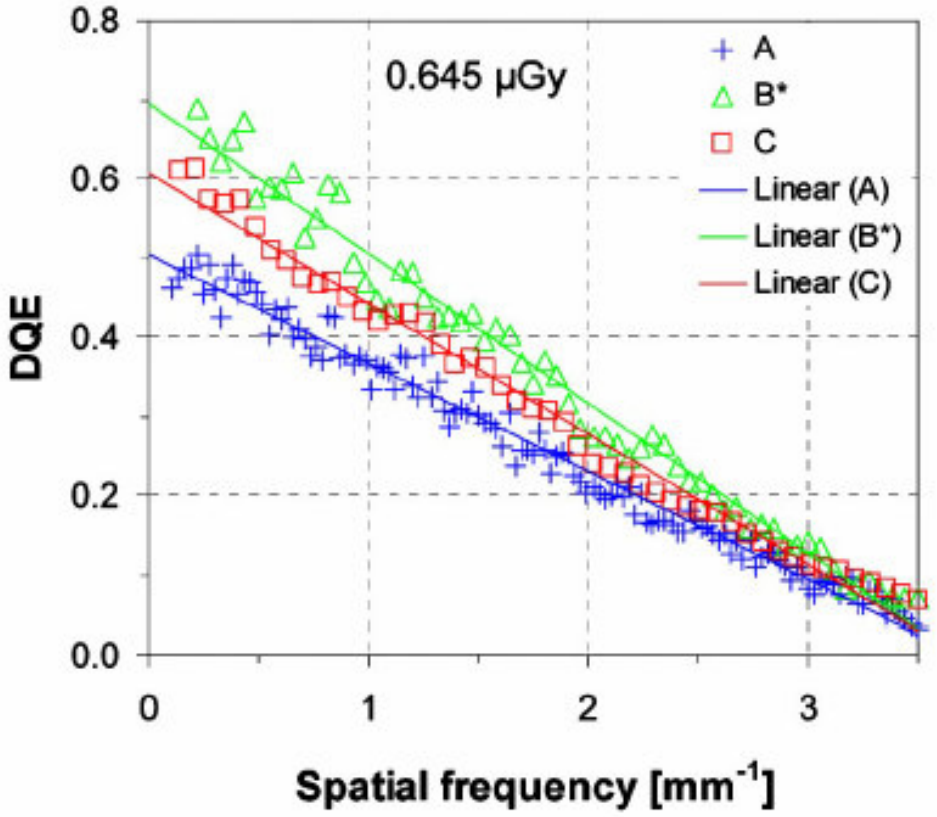
Detective Quantum Efficiency

3 methods for analysing 1 dataset

Differences +/- 15%

After using standard IEC 62220-1

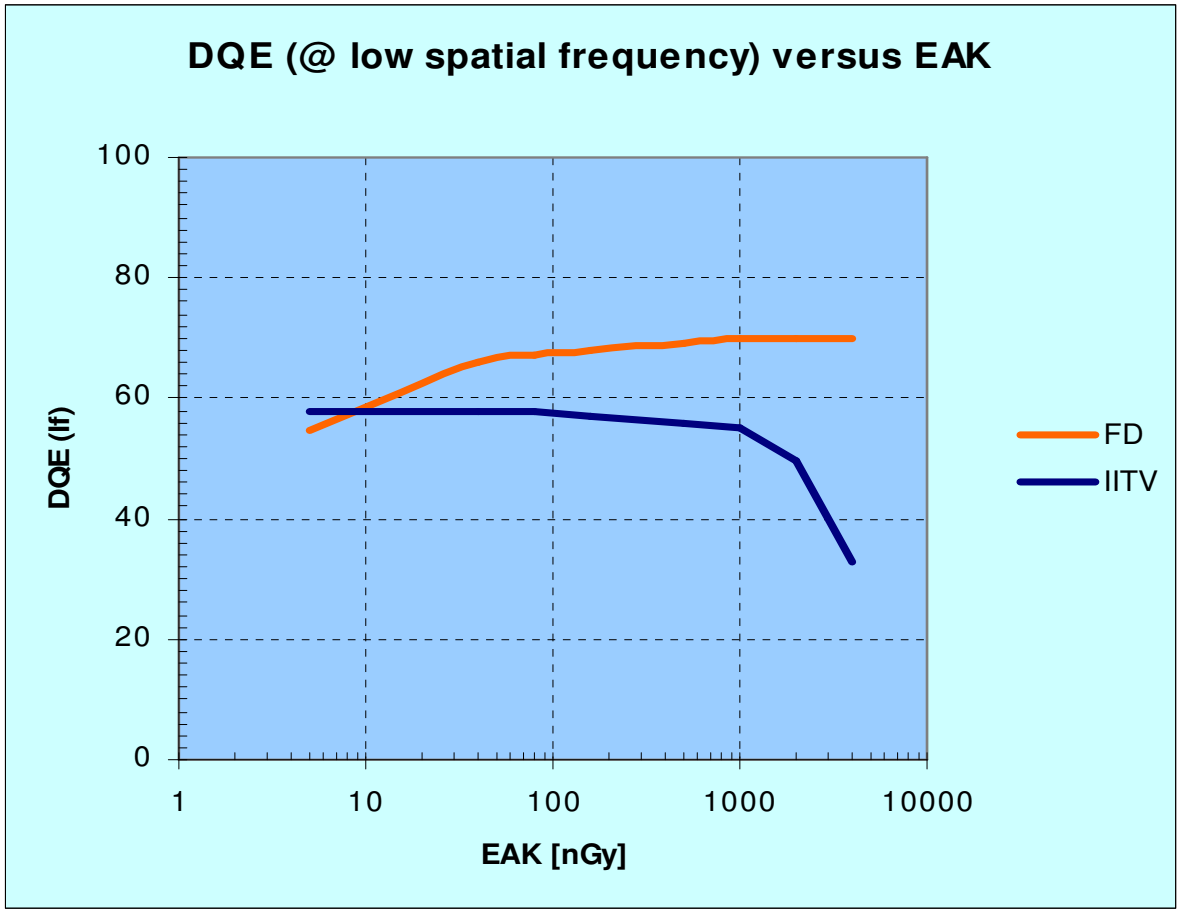
Differences +/- 5%



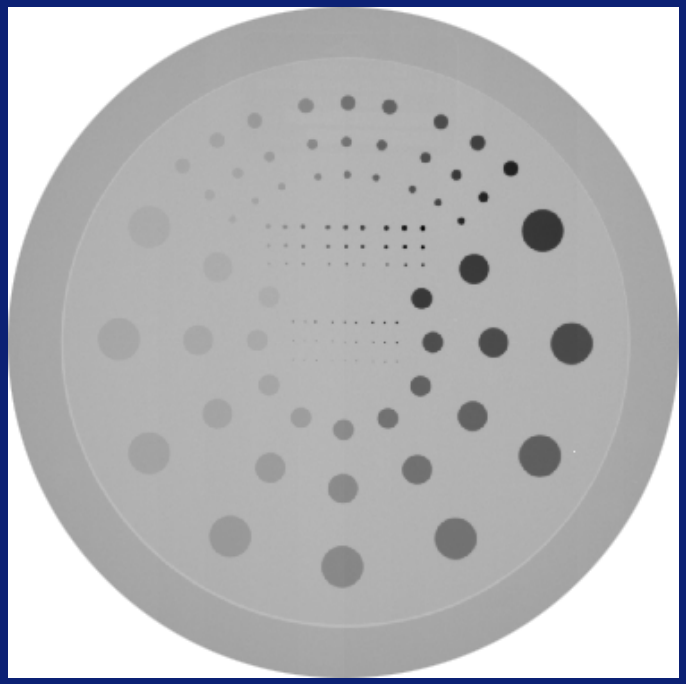
Neitzel, Günther-Kohfall, Borasi, Samei
Medical Physics August 2004

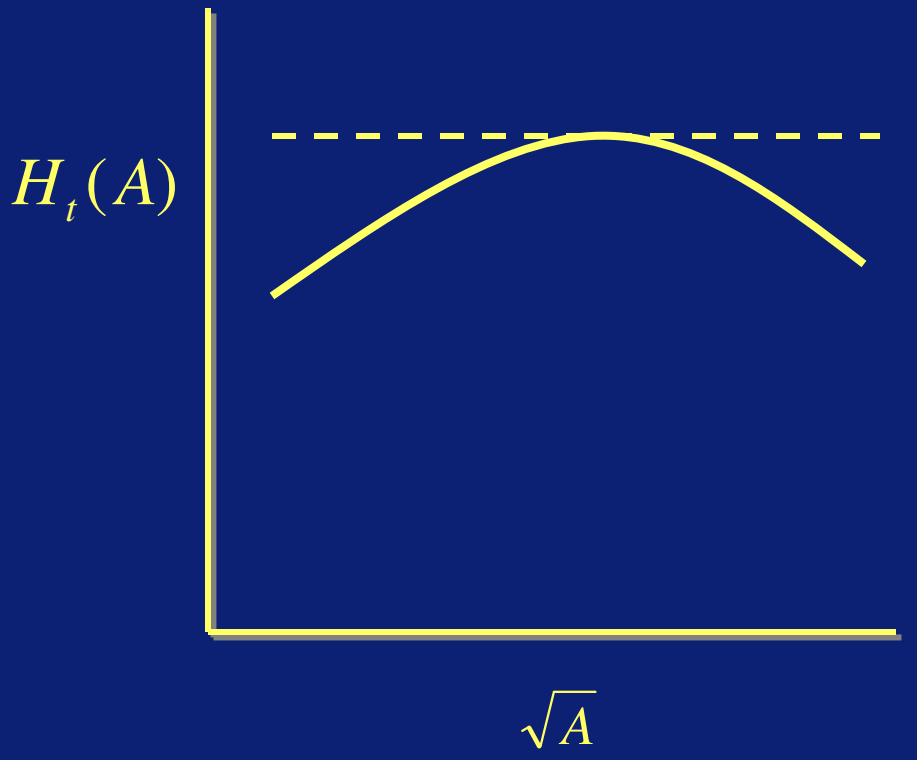
Linking DQE and observer tests

DQE versus EAK for dynamic 30x40 FD and IITV



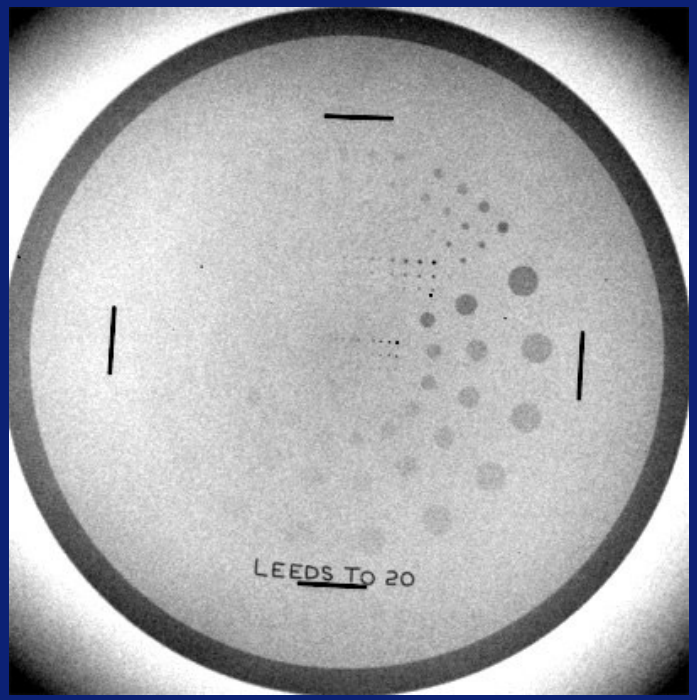
Observation tests (using Treshold Contrast Detail Detectability)

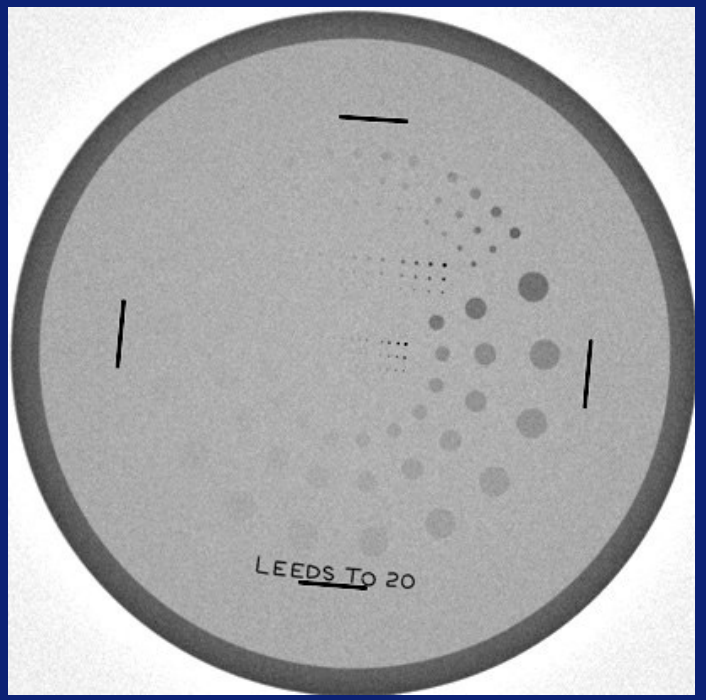




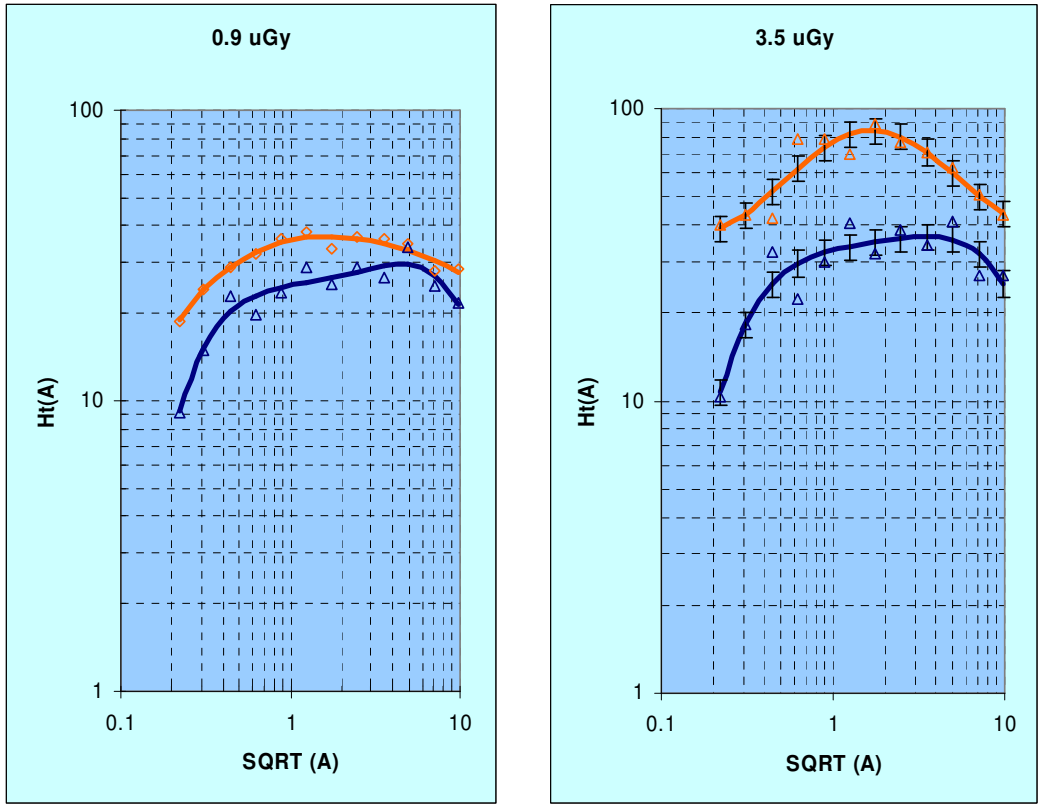
$$H_t(A) = \frac{1}{C_t(A) \times \sqrt{A}}$$

Observation tests IITV (L) and FD (R)



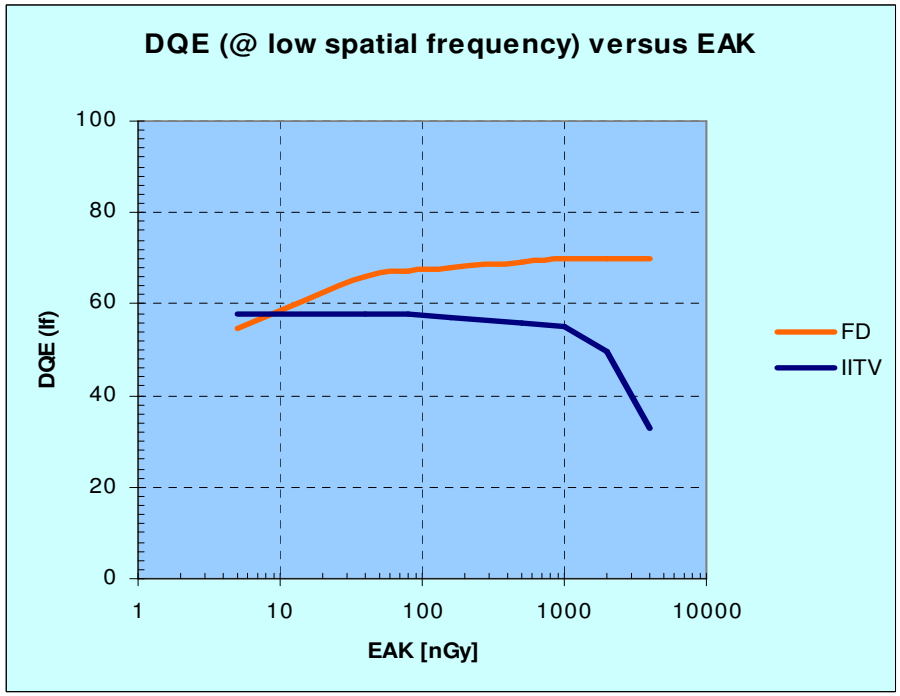


Observation tests IITV and FD

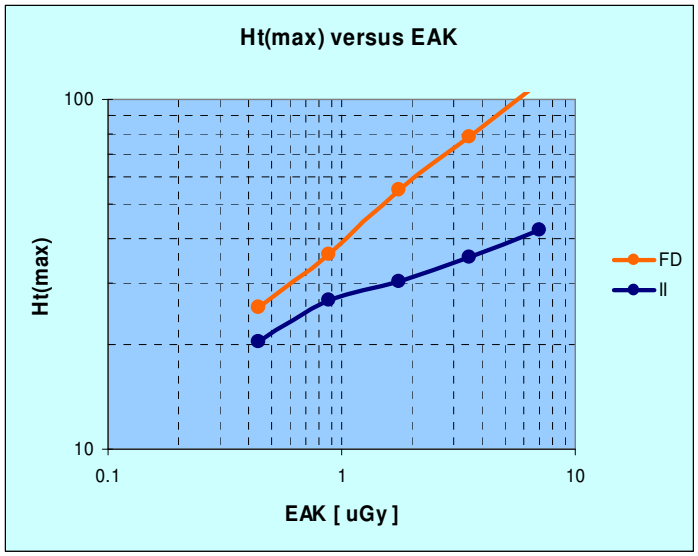


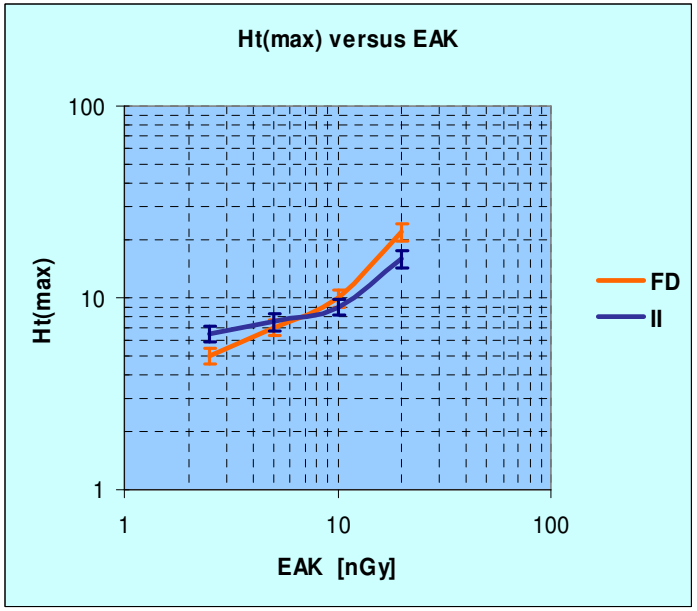
High dose

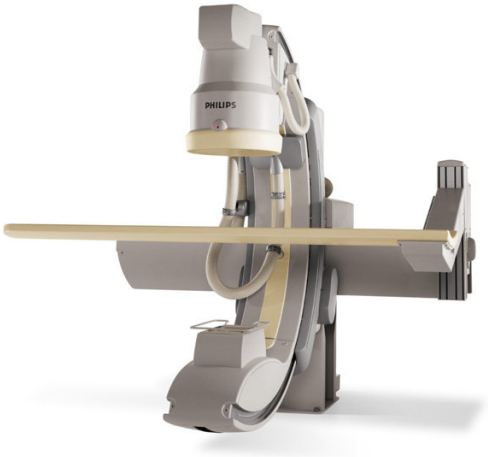
DQE versus EAK



TCDD versus EAK







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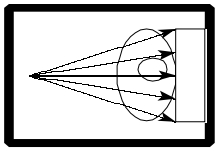
Rationale of Image Quality (IQ) Model *(Kroon)*

- IQ analysis of (non-)existing systems
  - system (de)composition for design process
  - comparison of present versus future systems
- Fast acquisition of IQ characteristics
  - optimization requires extensive data amount
  - simulation (seconds) versus experiment (hours-days)
- Various IQ related studies
  - design of test objects and methods

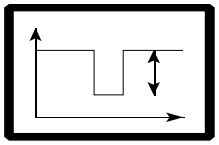
Objectives of Image Quality (IQ) Model

- Combines the IQ requirements of components into system level IQ specification
- All IQ main items are analyzed simultaneously, leading to a.o. DQE
- Permits tolerance and parameter studies
- Allows optimisation and prevents sub-optimisation
- Design of test objects & methods

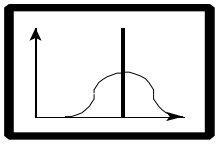
Image Quality Model Main Items



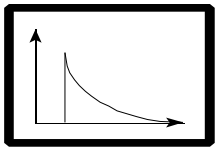
- X-radiation — spectrum, dose, AEC



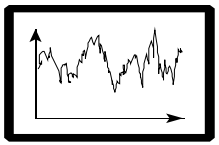
- Contrast — range and transfer



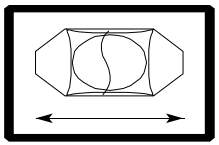
- Sharpness — MTF of stationary object



- Motion blur — MTF of moving object

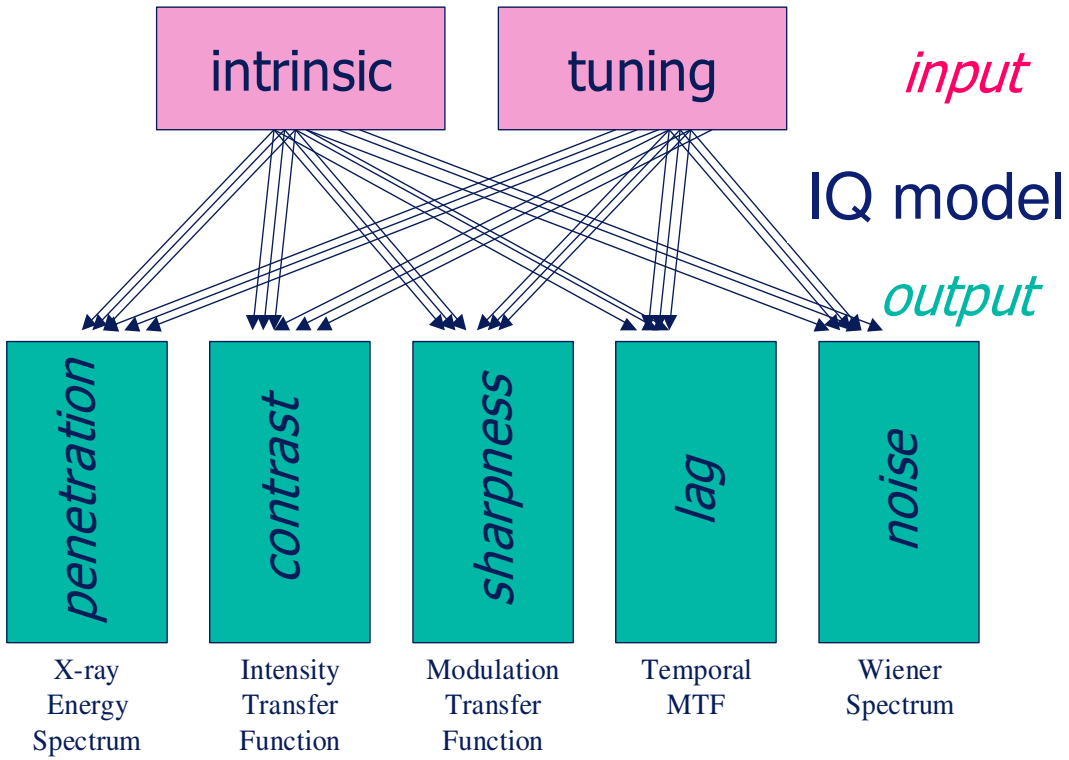


- Noise — dynamic & structure WS



- Mixed — geometrics & cosmetics

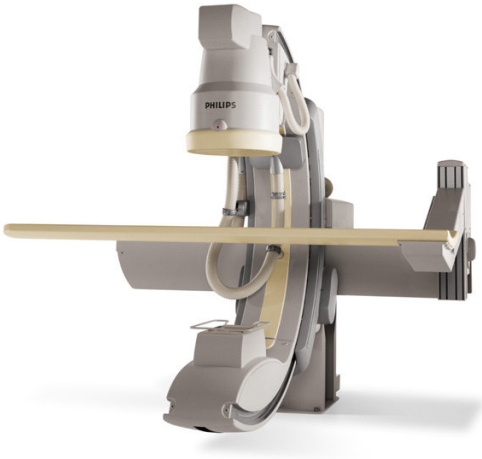
Input → Image Quality Model → Output



- Model input:
  - Components
  - Configuration
  - Tuning
- IQ model:
  - Architecture
  - IP functions
- Model output
  - IQ descriptors

Image Quality Model Implementation

- PC with LabVIEW ®
- Visual programming
- Clear hierarchy
- IQ analysis << 1 sec
- 350 program parts
- About 300 variables for settings, UI and system definition



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Summary

We discussed:

- Products FD and IITV and their proporties
- DQE and the present limitations
- DQE versus observation tests
- IQ modeling for fully optimized system IQ

- STRONG OR WEAK SYSTEM CHARACTER -

Thank you for your attention

See you this evening at our booth

for the session “QC tools”

Tom Bruijns
Dick Stueve