Algoritmi di ricostruzione tomografica in applicazioni di tomosintesi per imaging medico

Nico Lanconelli
Dipartimento di Fisica
Alma Mater Studiorum – Università di Bologna

Contents

- Image ⇔ sinogram
- Analytic methods: Filtered Back-Projection (FBP)
- Iterative methods: outline
- Iterative vs analytic methods
- Reconstruction in Breast Tomosynthesis
- Reconstruction in ECORAD

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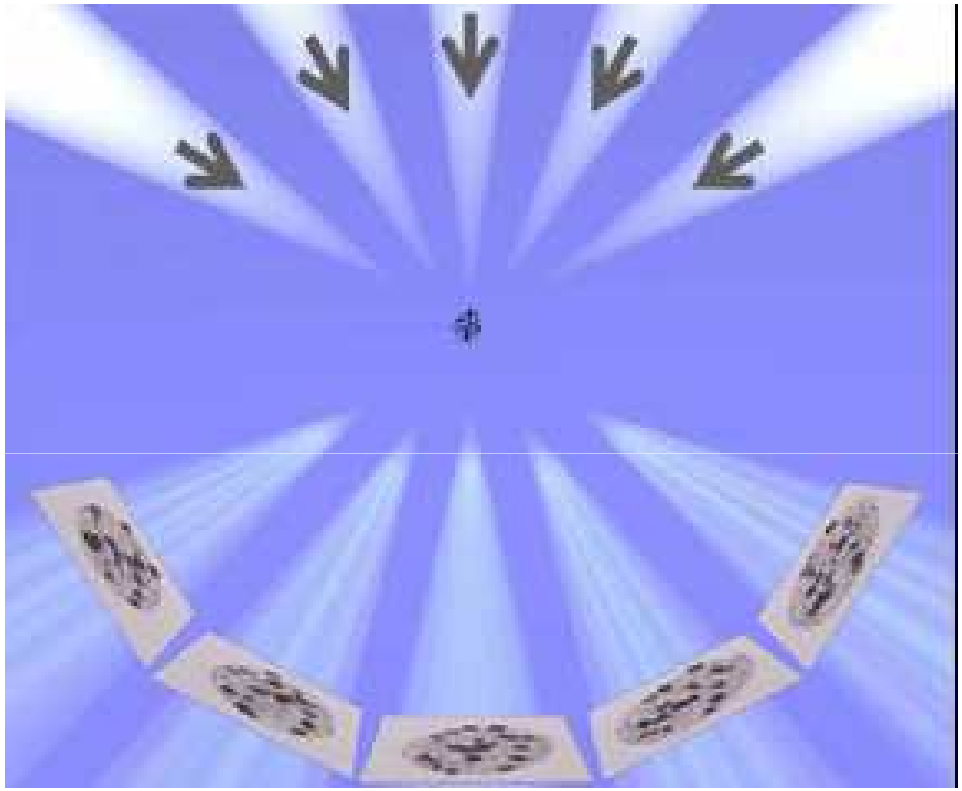
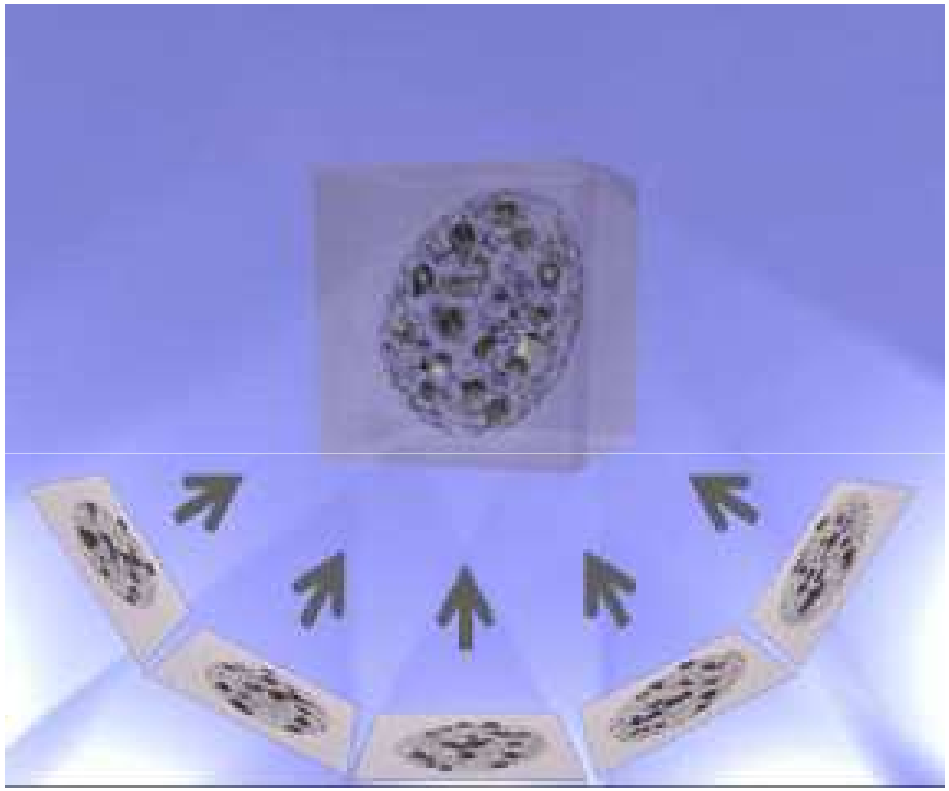
Image reconstruction

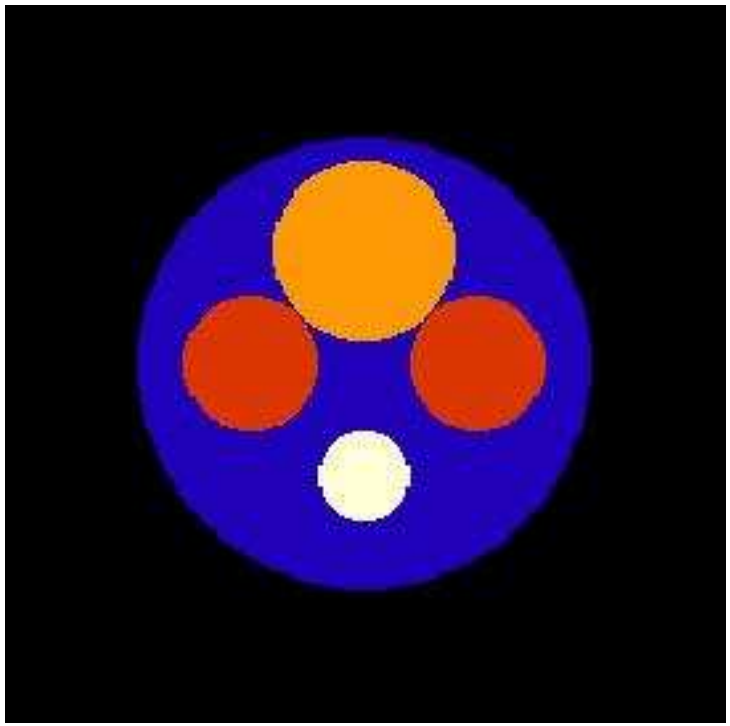
3D object ⇒
set of 2D projections

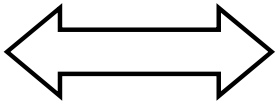
2D projections ⇒
3D reconstruction

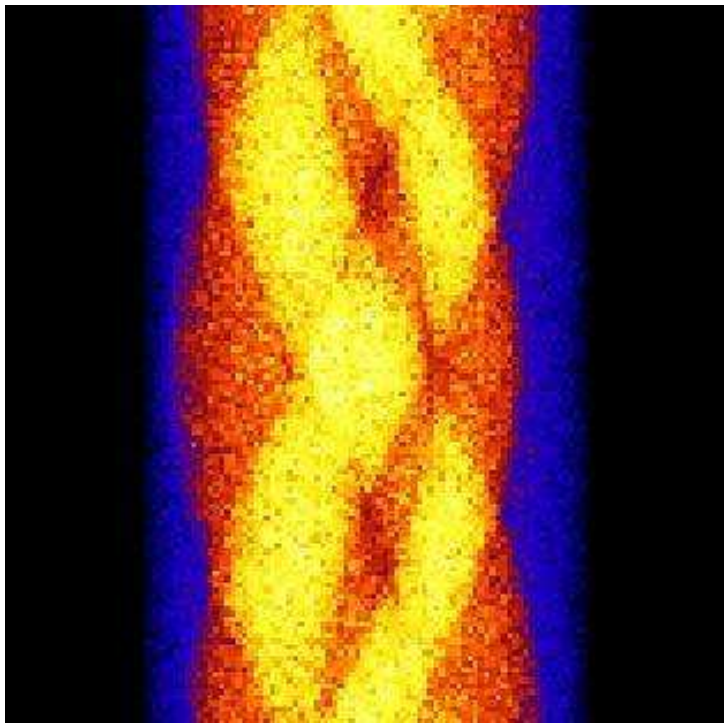




From image to sinogram



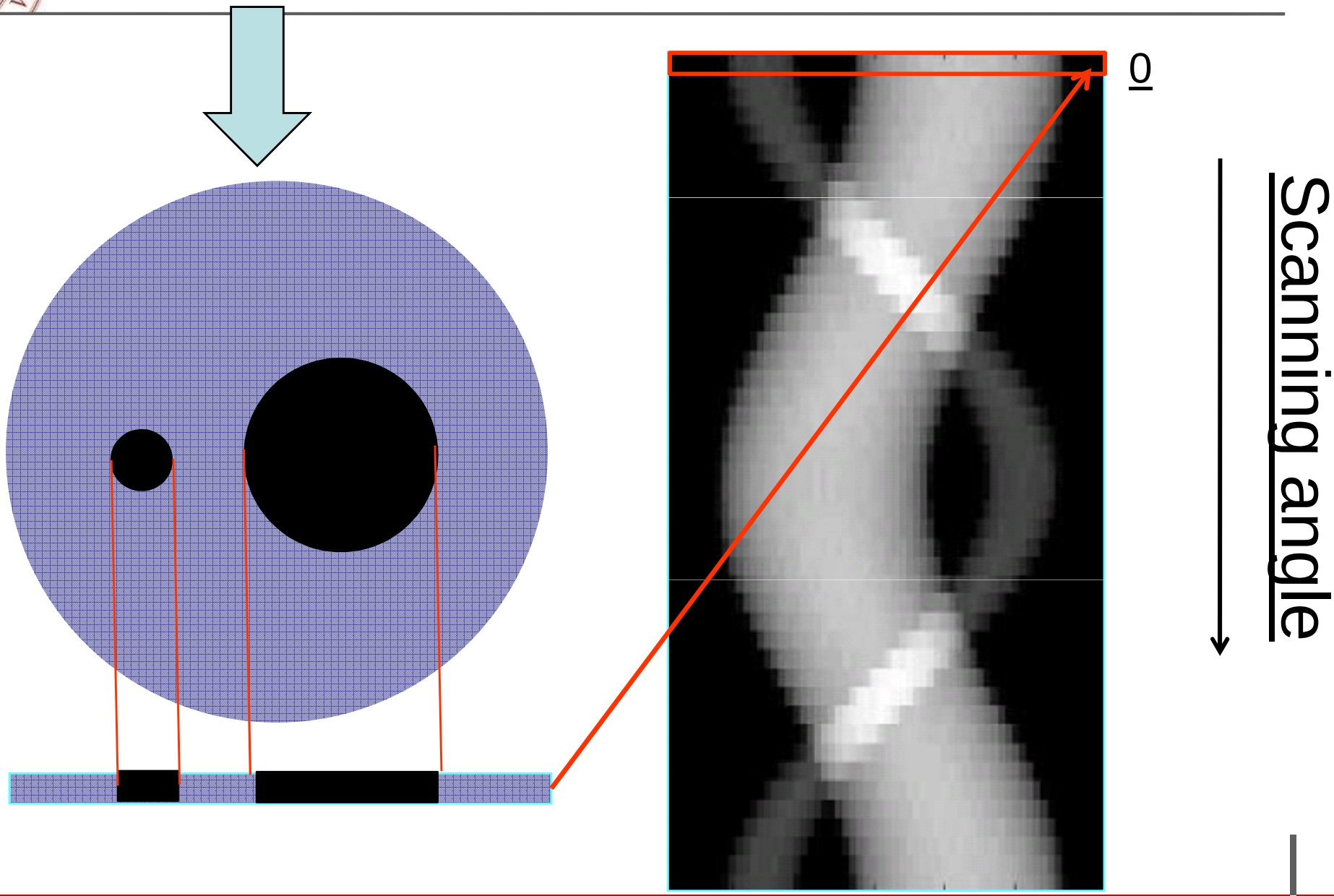




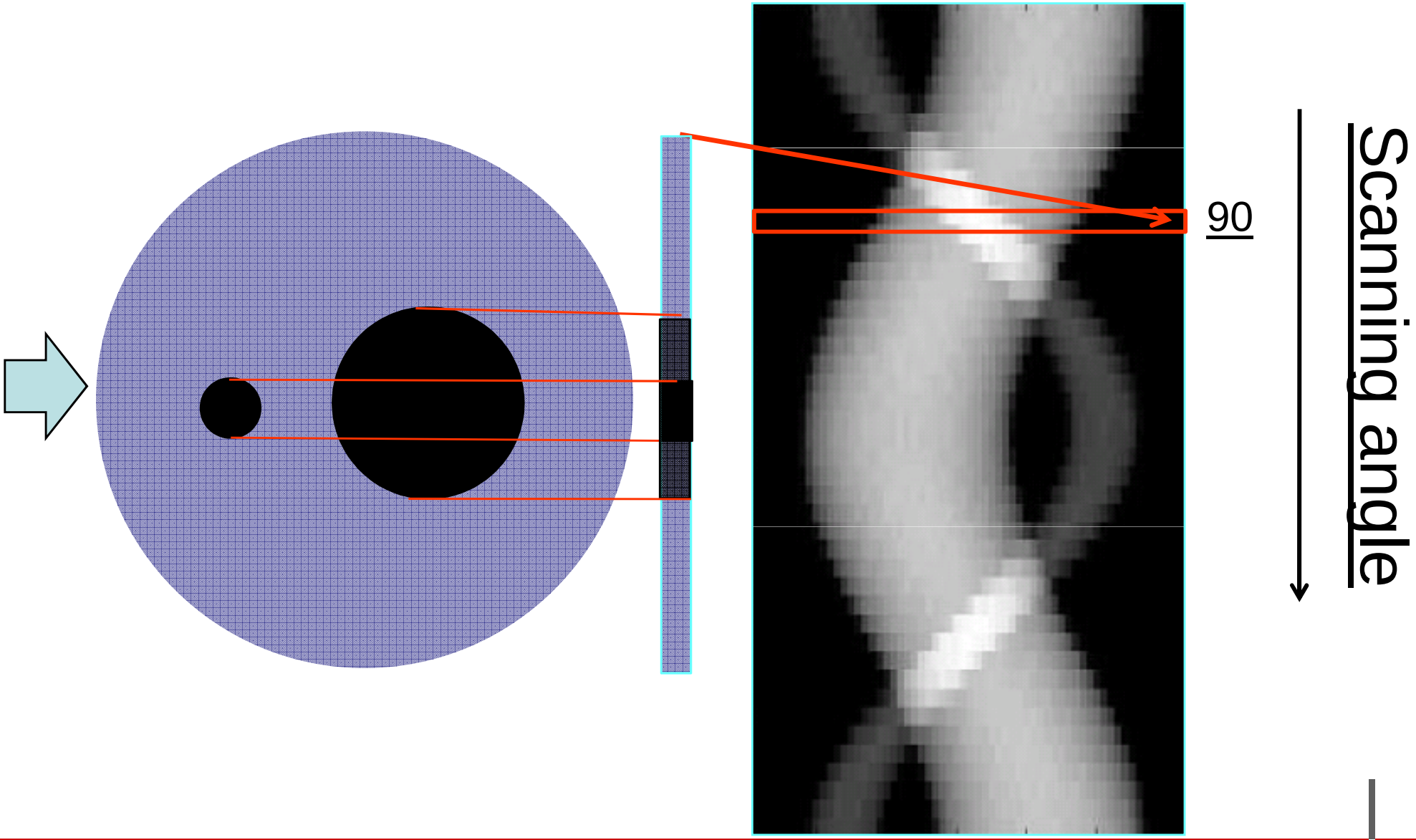
True image

Sinogram

Sinogram formation



Sinogram formation



Sinogram formation

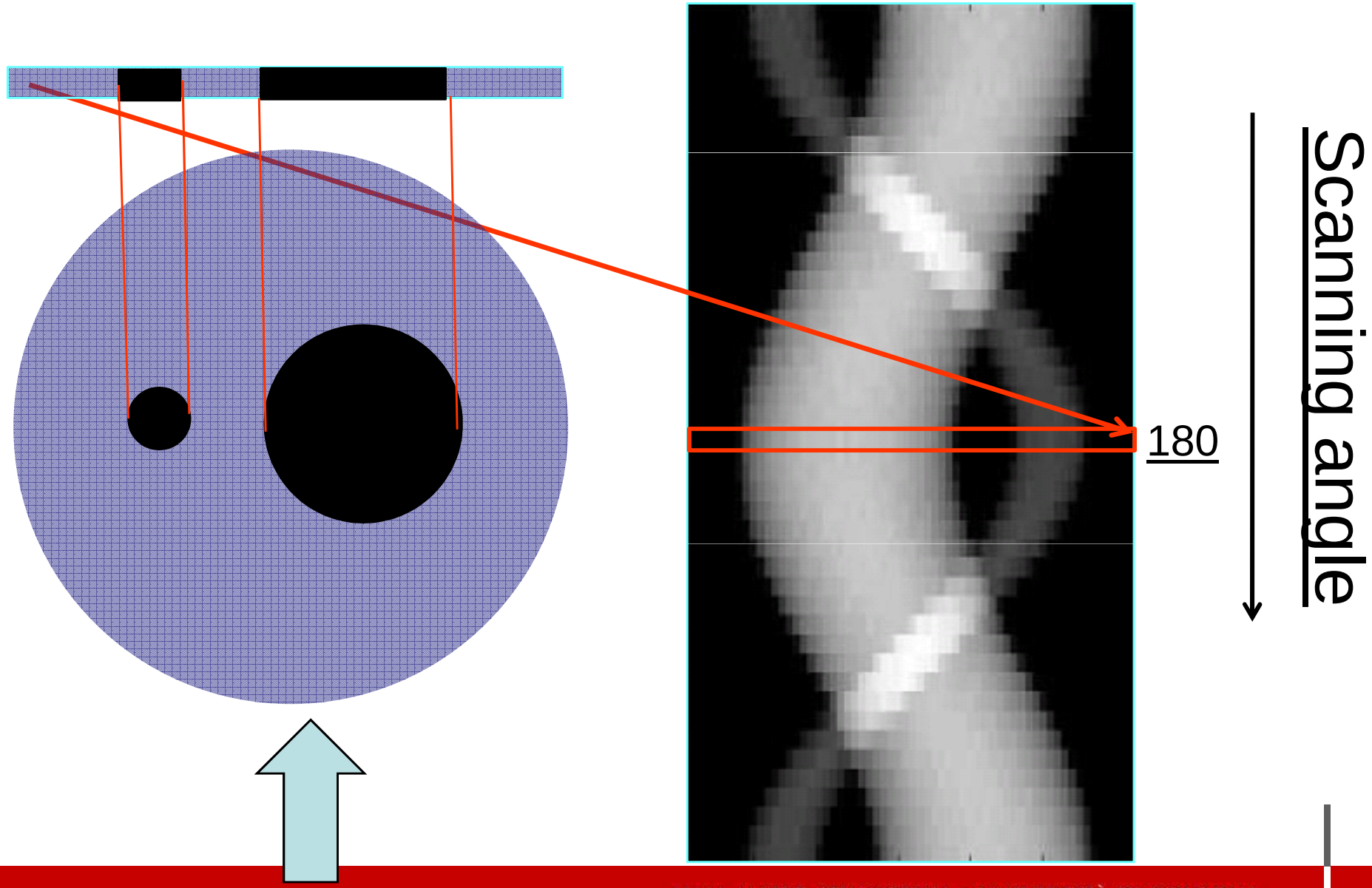
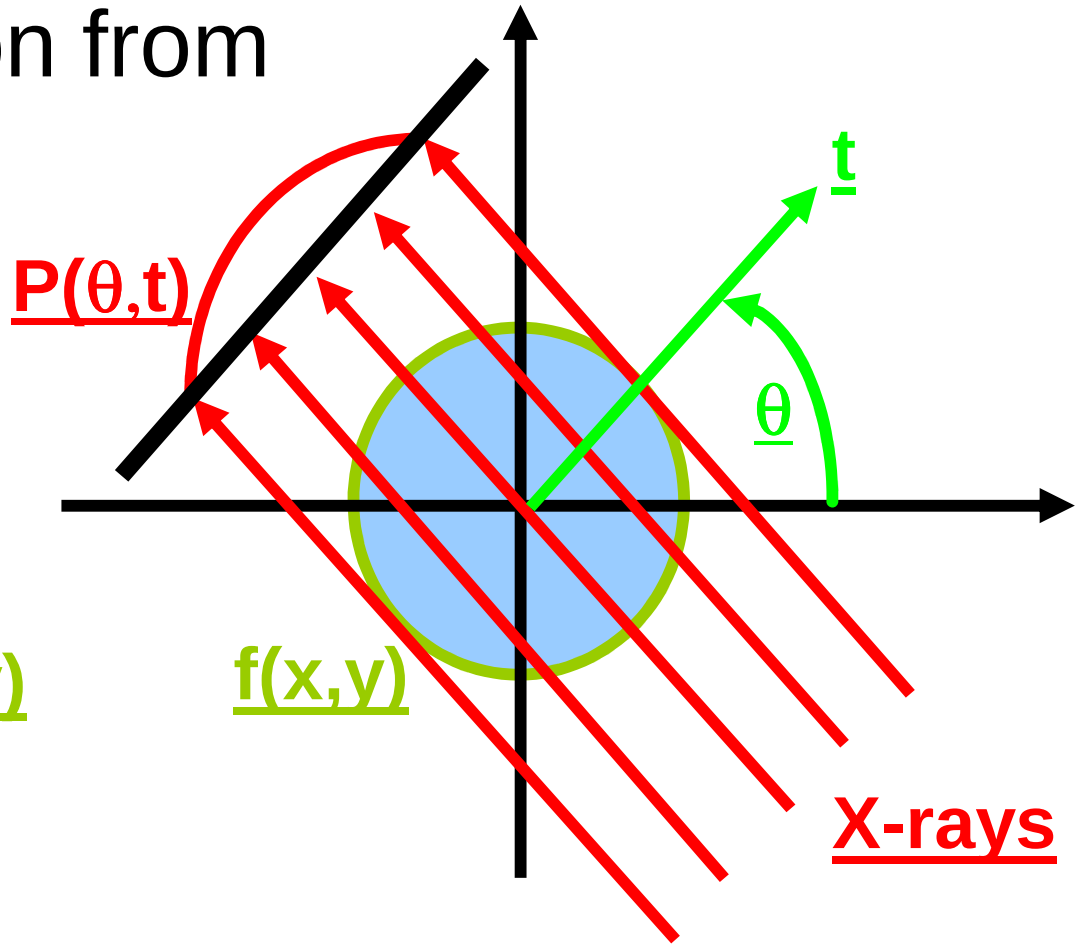


Image reconstruction principle

Computed tomography (CT):
Image reconstruction from projections



P(θ,t) ⇨ f(x,y)

f(x,y)

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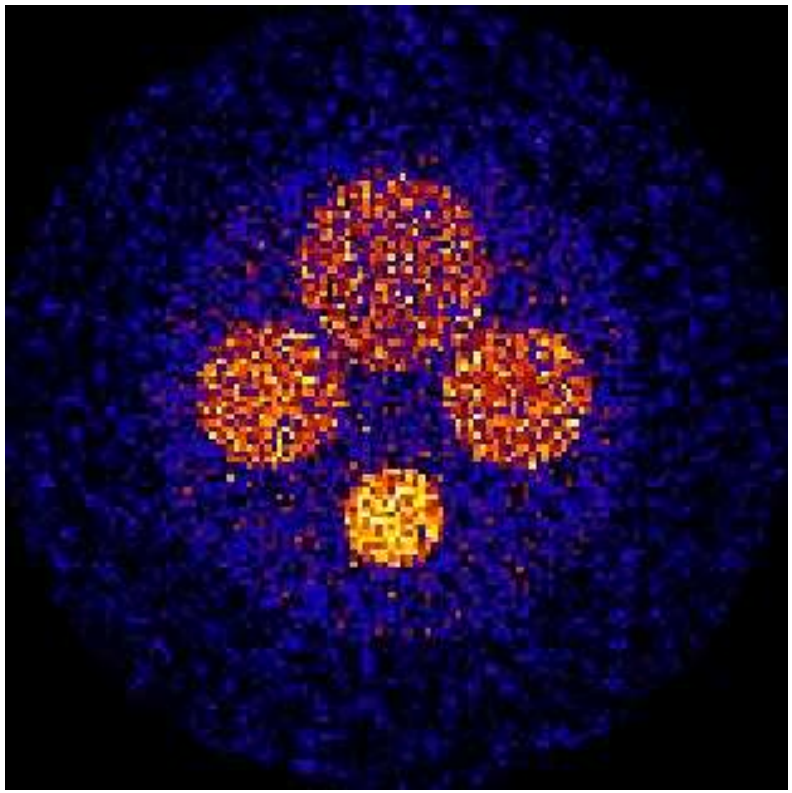
FBP: outline

1. Projection of original data (sinogram)
2. Transformation of data into Fourier Domain
3. Filtering of data in Fourier space
4. Transformation of data back into Spatial Domain (inverse Fourier transform)
5. Backprojection

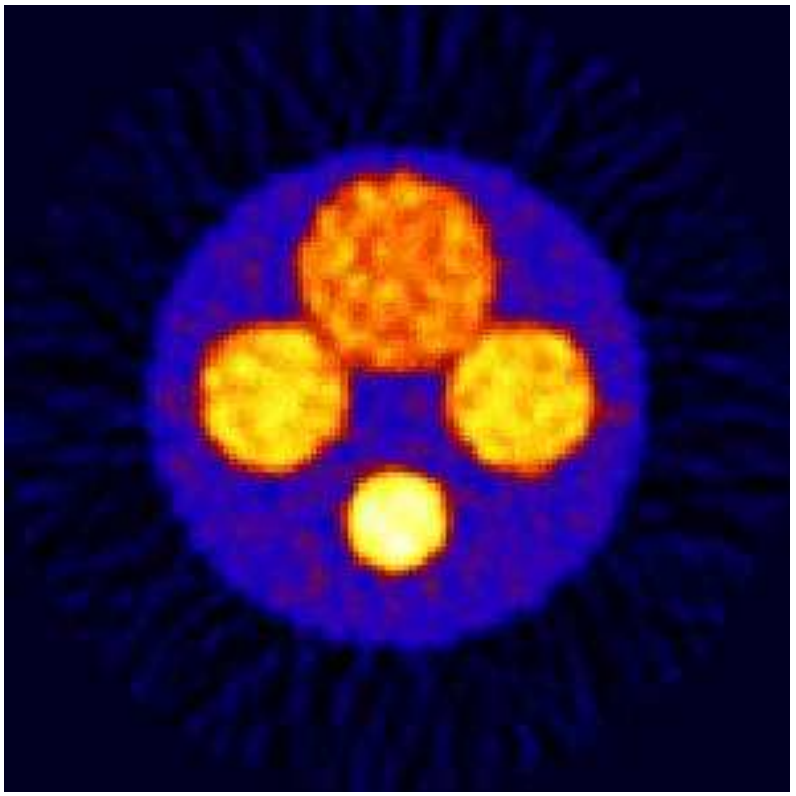
Filtering: why?

- Intrinsinc effect of FBP of amplifying low-frequency signals
- Inherent noise in the data due to the random nature of radioactivity
- Smooth out the statistical noise
- Filtering in Fourier space is less time-consuming than in real space

Data filtering

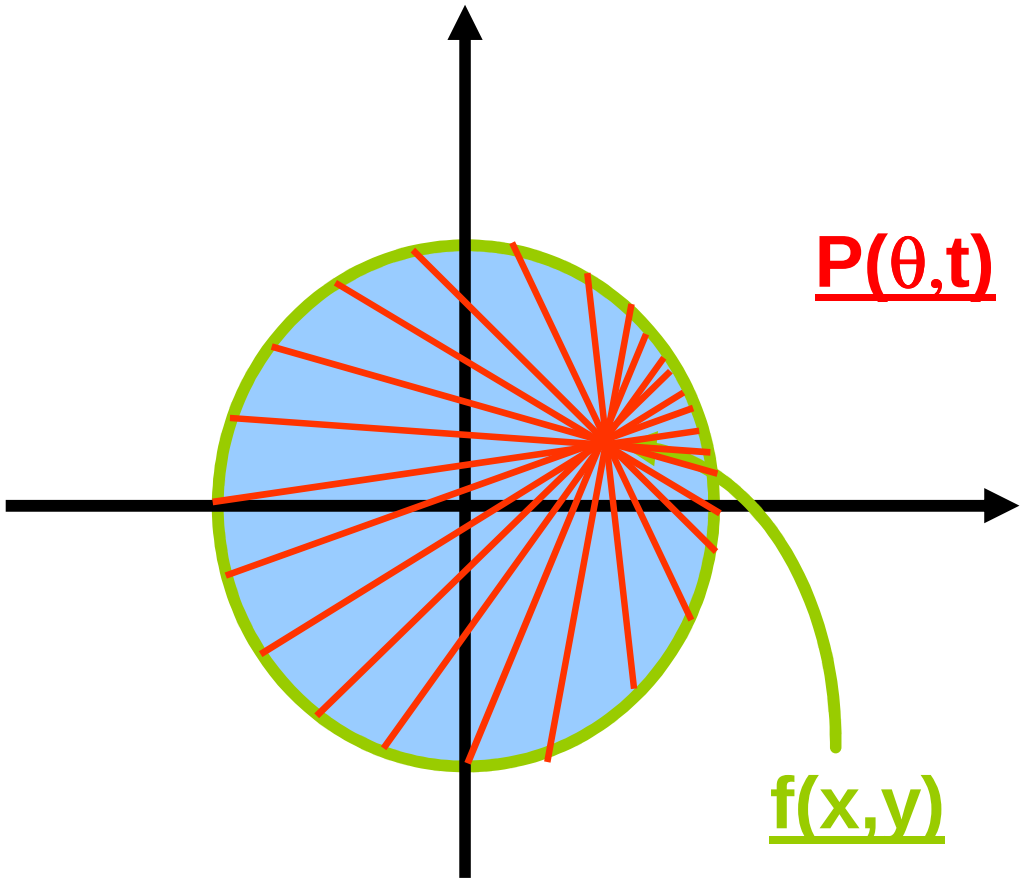


Non- filtered



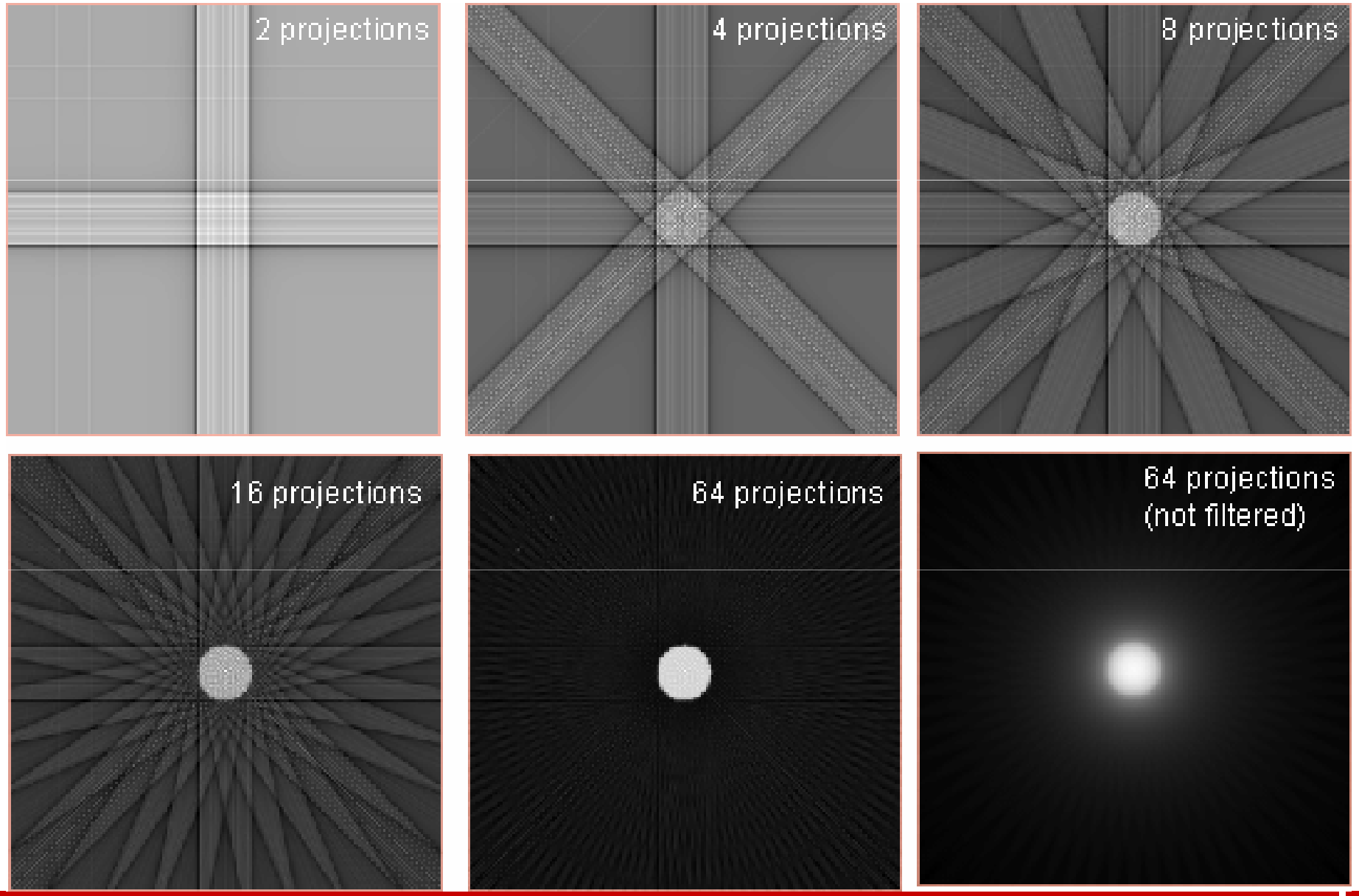
Filtered

Backprojection



f(x,y) is calculated by means of all the projections **P(θ,t)** which cross the point (x,y)

Backprojection



From projections to image

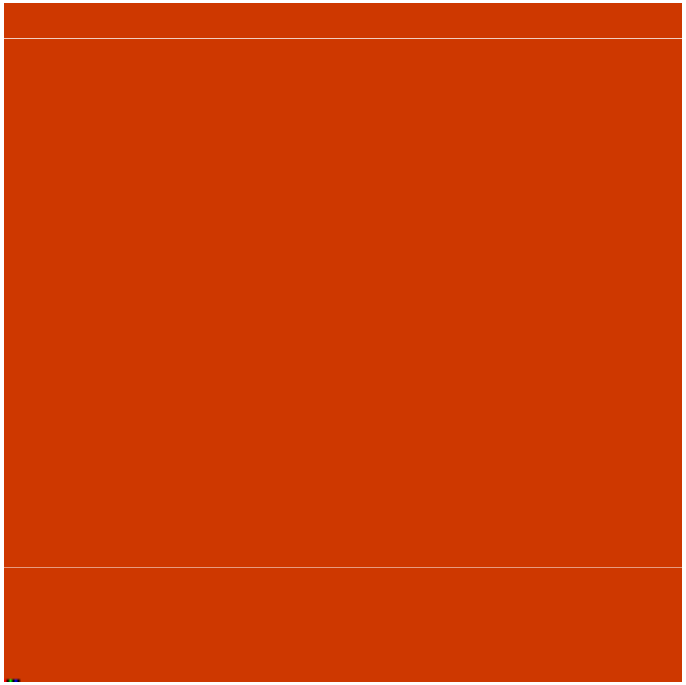


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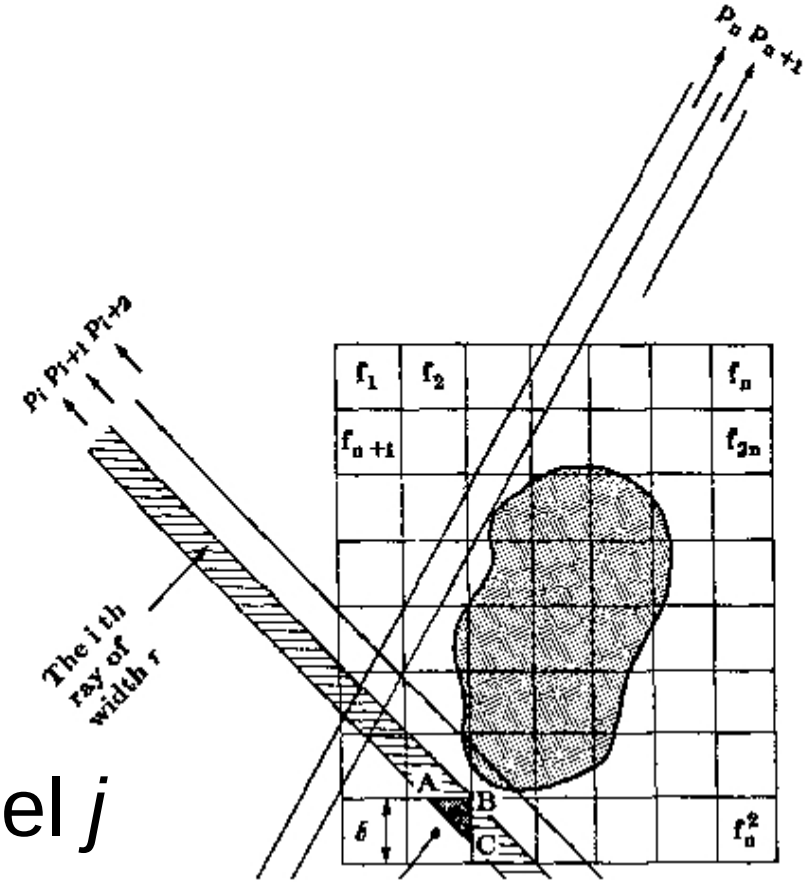
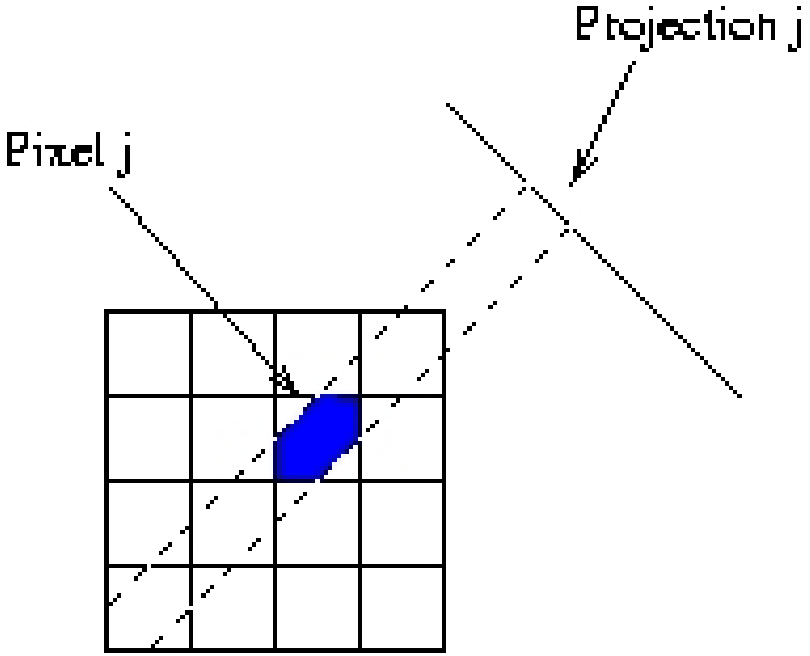
Image and projection representation

$$p_i = \sum_{j=1}^{N} w_{ij} f_j \quad i = 1,2,\ldots,M$$



- p_i : ray-sum (line integral)
- w_{ij}: weighting factor
- f_j: attenuation (activity) of pixel j
- M: # of rays
- N: # of pixel

Weighting factor



The weighting factors w_{ij} could simply be equal to the ratio of the two areas

Or:

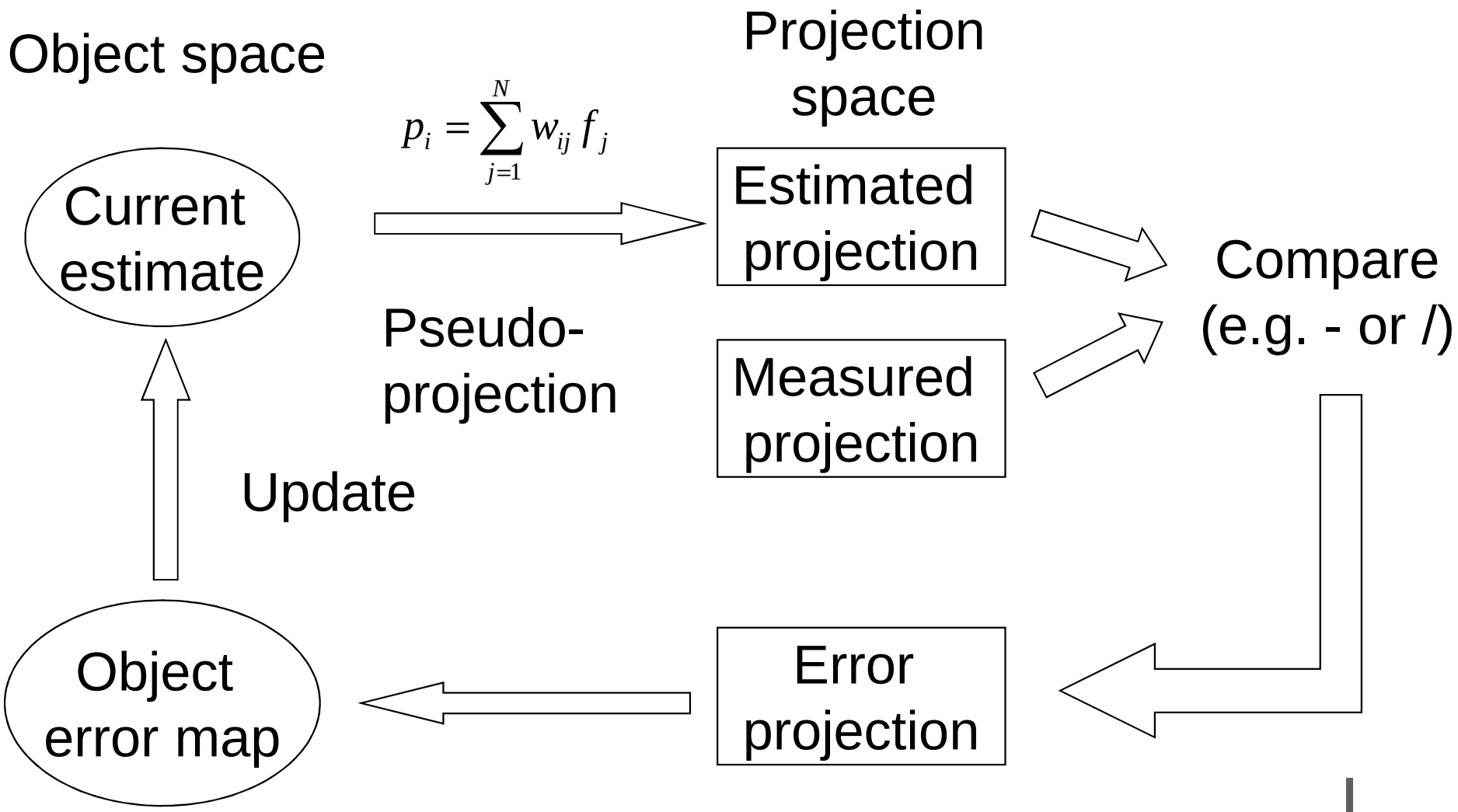
- Incorporate in w_{ij} the physics of the detection process
- Effects (e.g. scatter) can be included by known models or MonteCarlo simulations, or …

Problem formulation

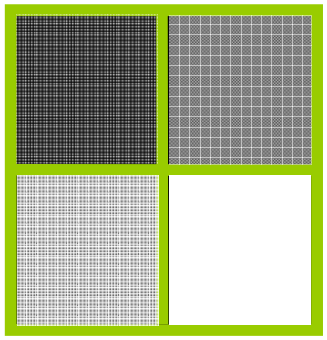
- The image reconstruction task consists in **estimating *f*** from the previous equation. If *M* and *N* are small, we could use matrix theory methods to invert the system of equations
- Unfortunately, in practice, this is NOT possible for the following reasons:
  - *M* and *N* are very large
  - noise is present in measured data.

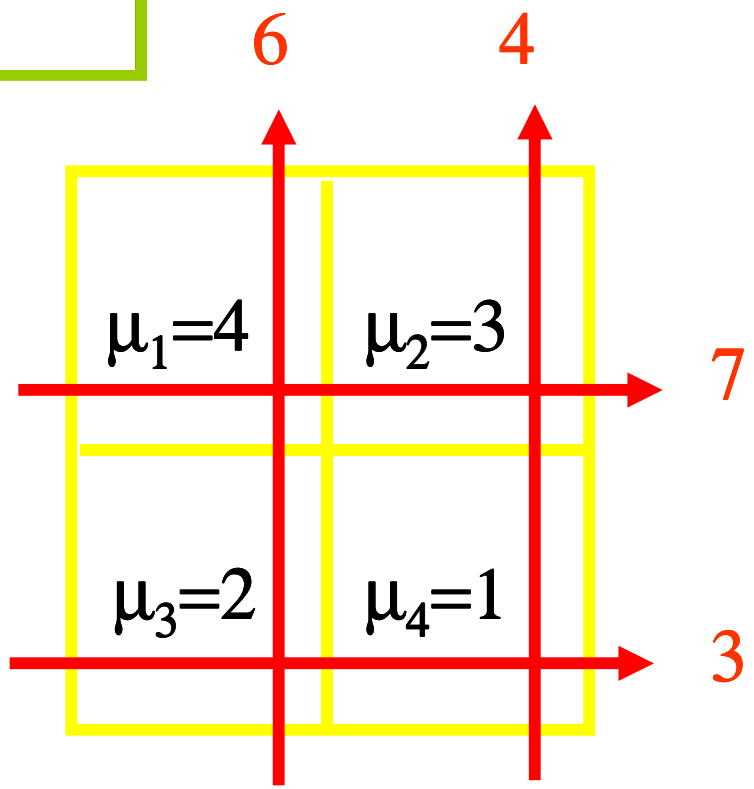
$$p_i = \sum_{j=1}^{N} w_{ij} f_j$$

Iterative reconstruction



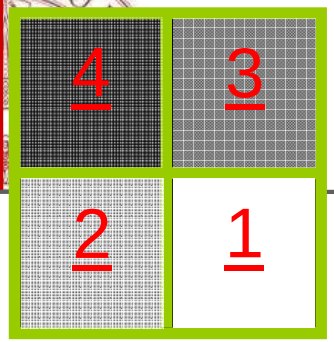
Reconstruction idea

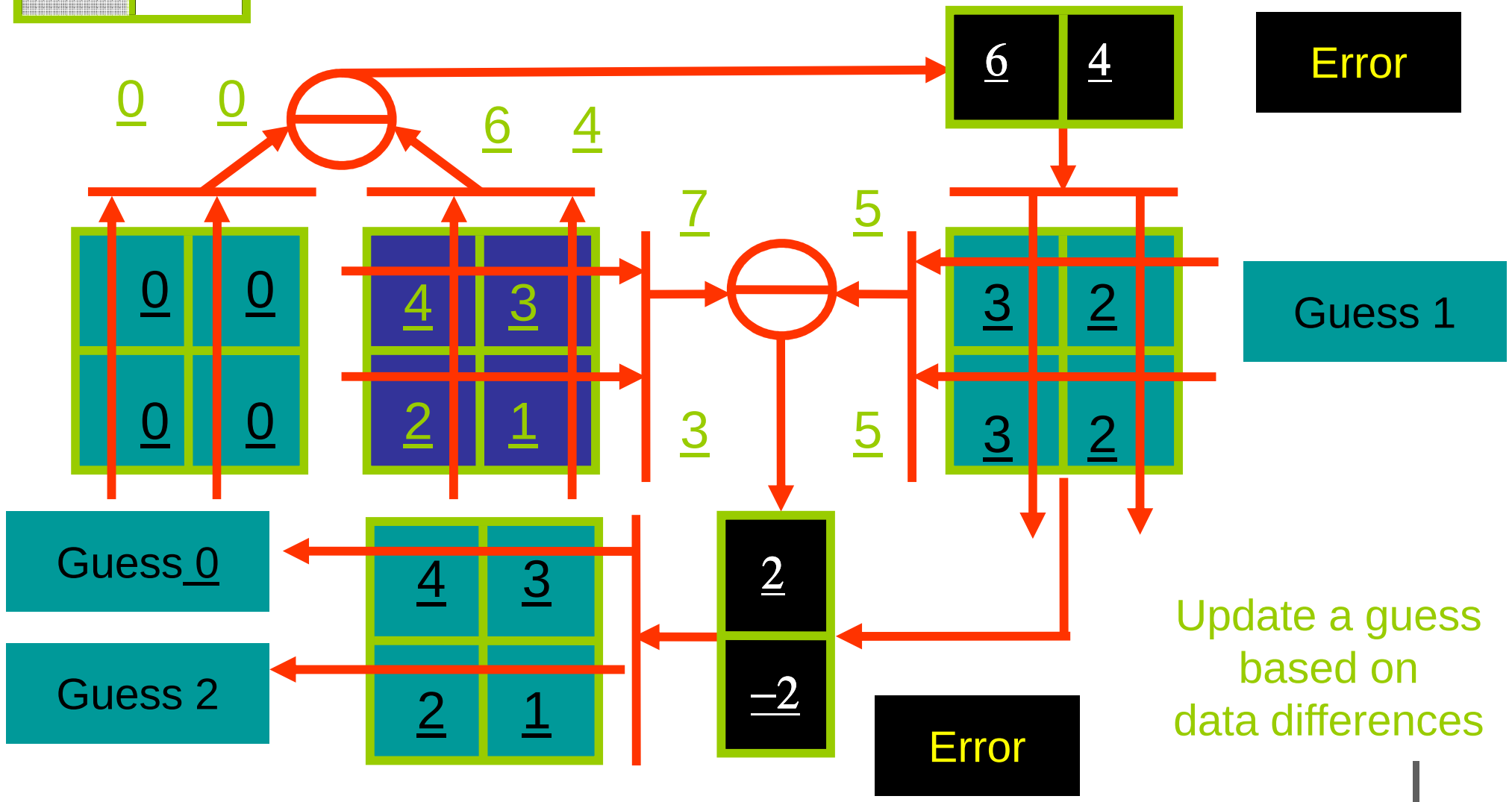




$$\begin{cases} p_1 = \mu_1 + \mu_2 = 7 \\ p_2 = \mu_3 + \mu_4 = 3 \\ p_3 = \mu_1 + \mu_3 = 6 \\ p_4 = \mu_2 + \mu_4 = 4 \end{cases}$$

ART


4
3
2
1


6 4
Error
0 0
6 4
7
5
0 0
0 0
4 3
2 1
3 2
3 2
Guess 1
3
5
Guess 0
Guess 2
4 3
2 1
2
–2
Error
Update a guess based on data differences

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Iterative vs. Analytic reconstruction

Advantages of analytic reconstruction (FBP):

- Very often much faster
- Sometimes simpler
- Very predictable, linear, behavior easier to understand.

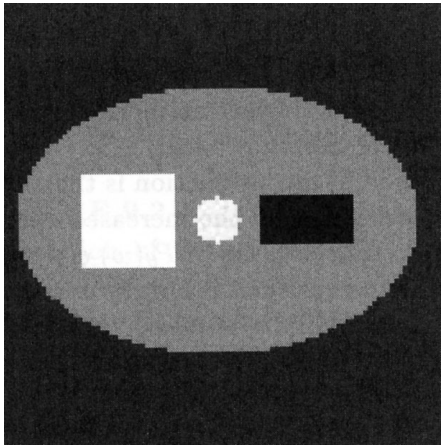
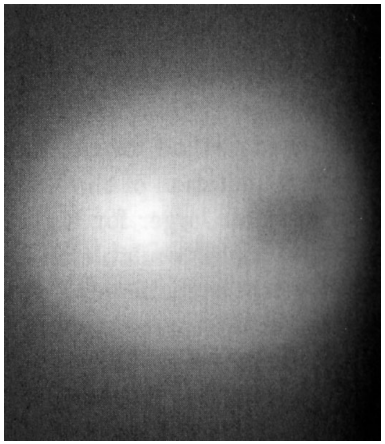
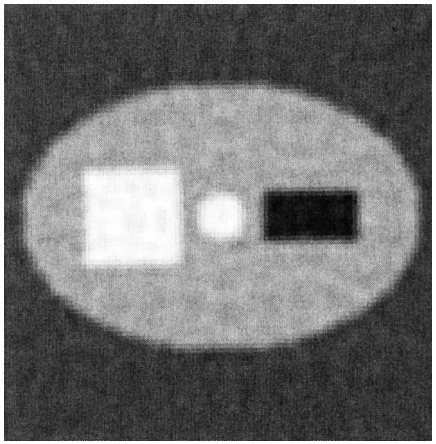
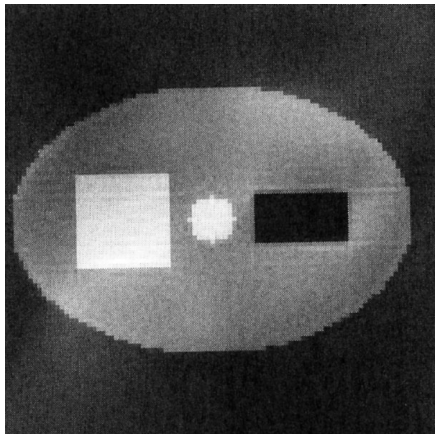
Iterative vs. Analytic reconstruction

Advantages of discrete reconstruction:

- Accurate models of the image formation process can be incorporated ⇒ quantitative image reconstruction, noise reduction
- Very flexible to adapt to different imaging geometries
- Well-designed for non-standard ring geometries
- Non-negativity constraints can be used

Comparison

Phantom BP FBP ART

Reconstruction of phantom with different reconstruction methods using 90 projections

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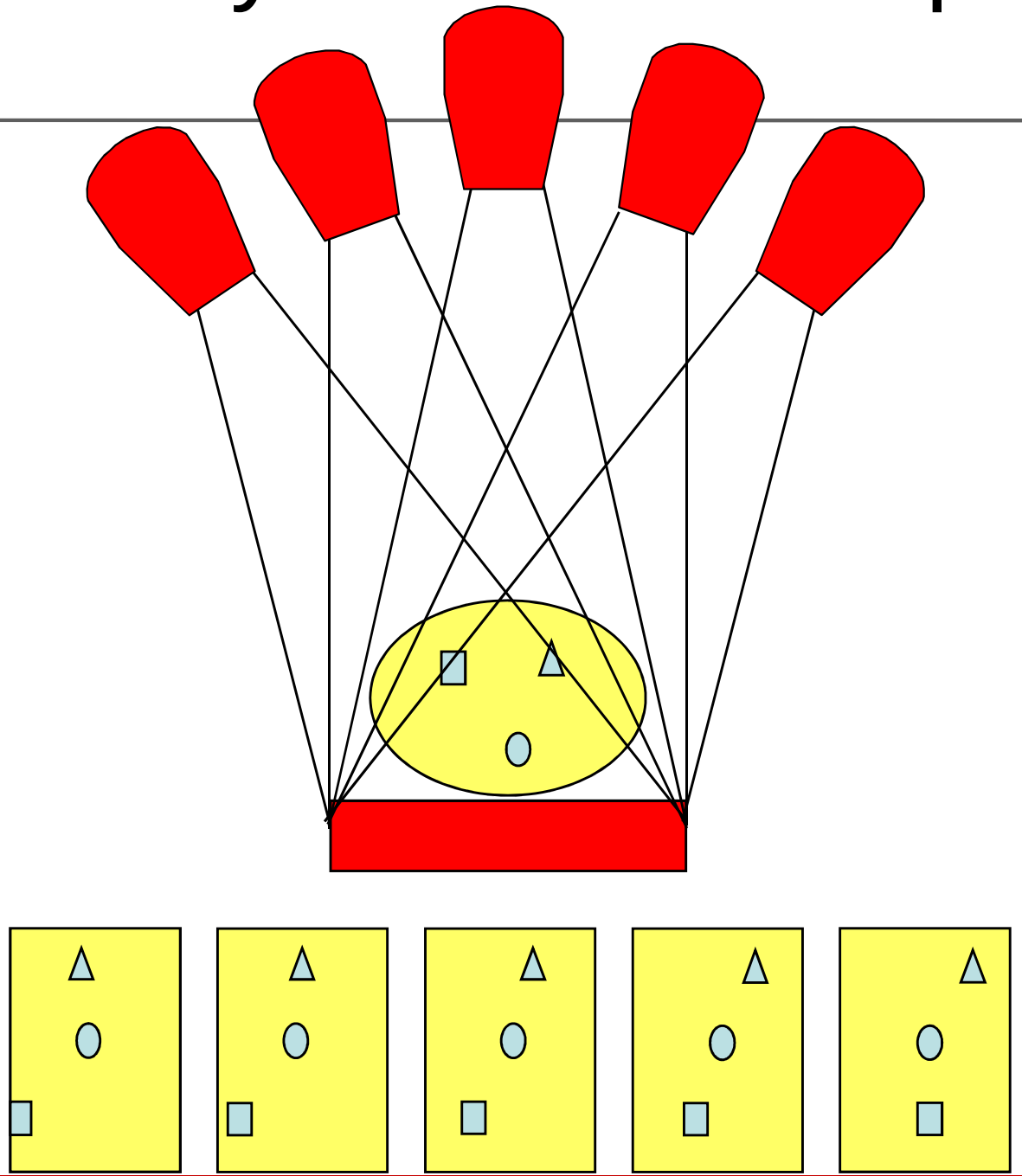
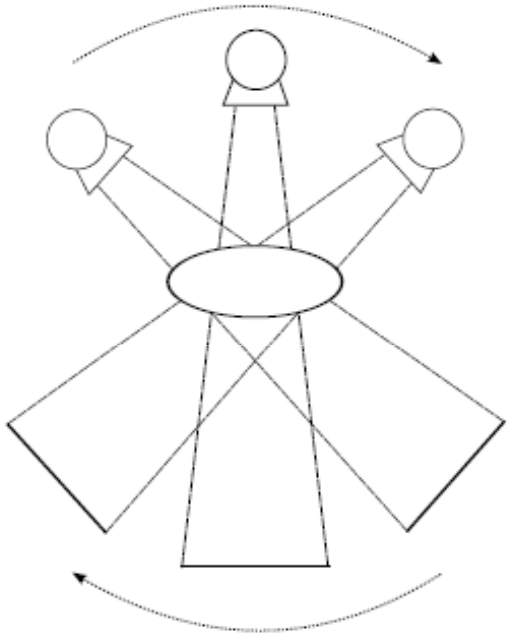
Tomosynthesis Concept

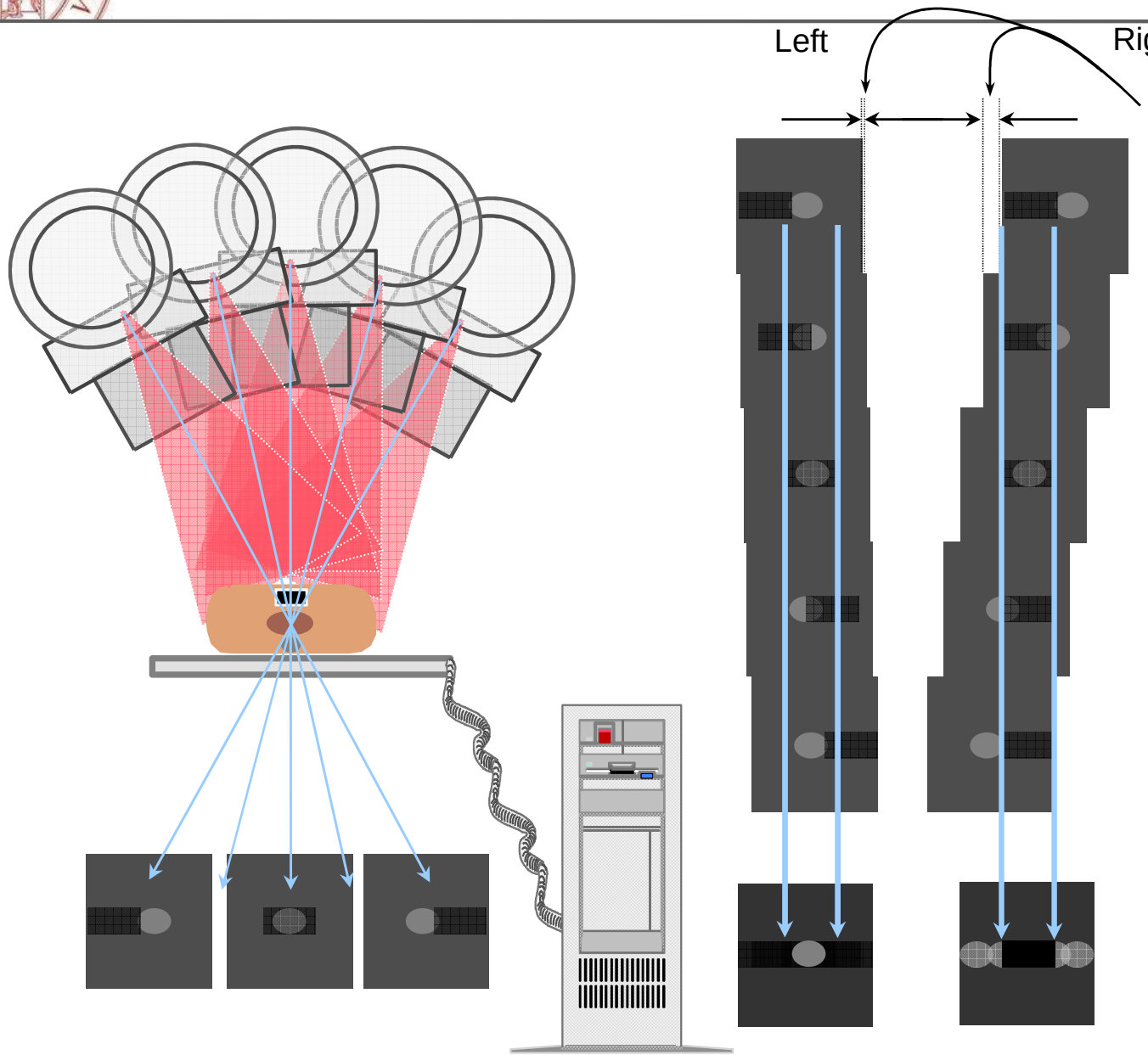


The first prototype

- Geometry:
  - C-arm
  - Angular range: ± 18°
- Detector:
  - a-Se Flat panel
  - 85 um pixel size
  - 24 cm × 30 cm
- X-ray tube:
  - W anode
  - Rh and Ag filter

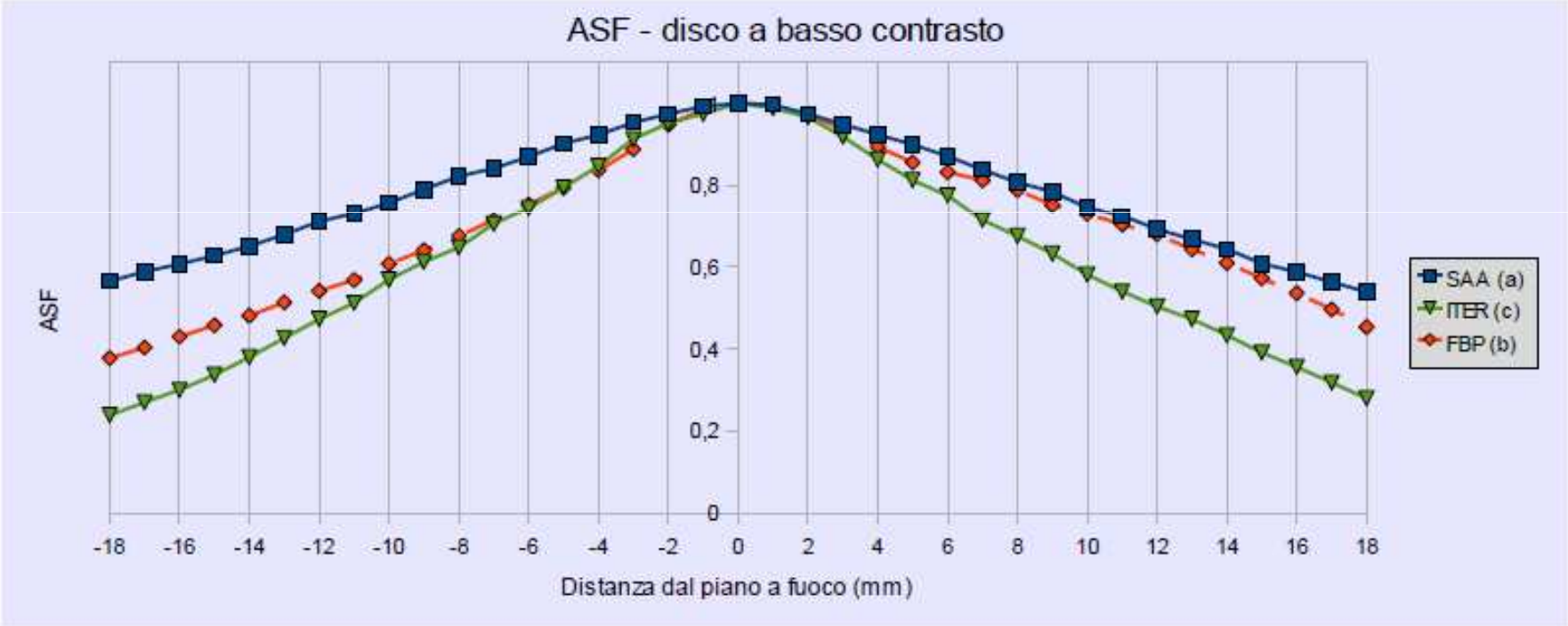


Digital Tomosynthesis



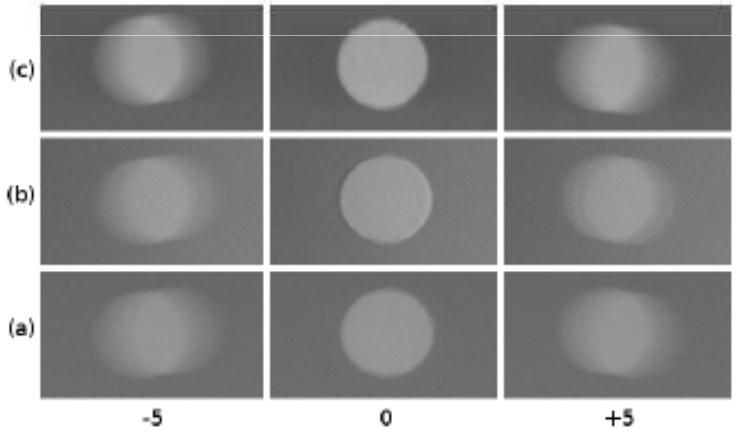
Shift images to select plane
Add to create tomogram

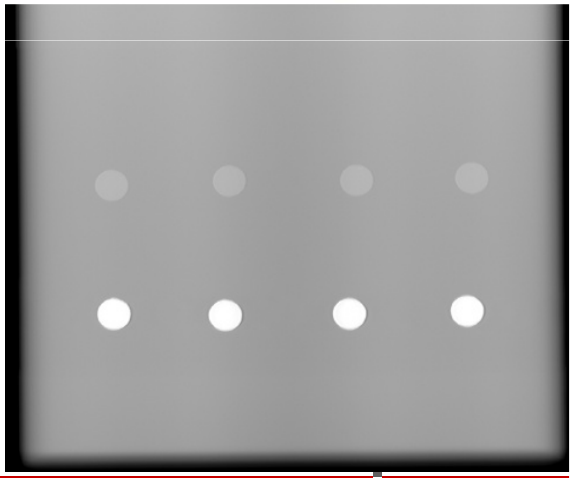
Results: phantoms



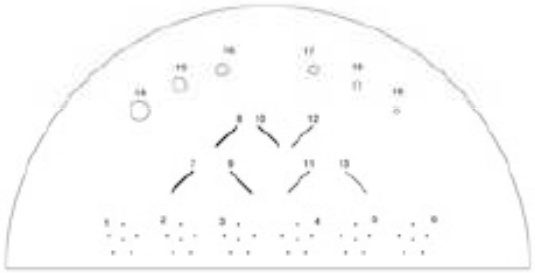
$$ASF(z) = \frac{CNR(z)}{CNR(z_0)}$$

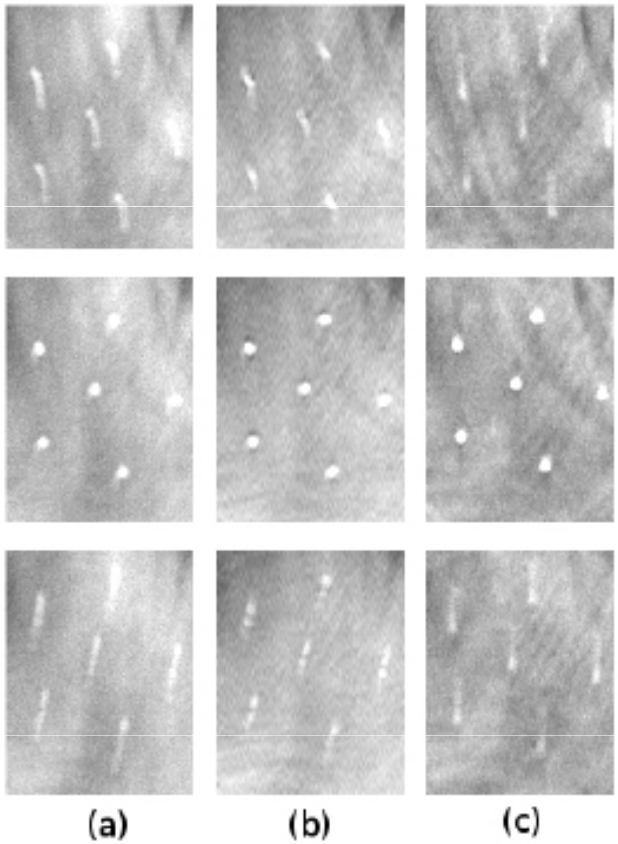
(a): SAA
(b): FBP
(c): Iterative

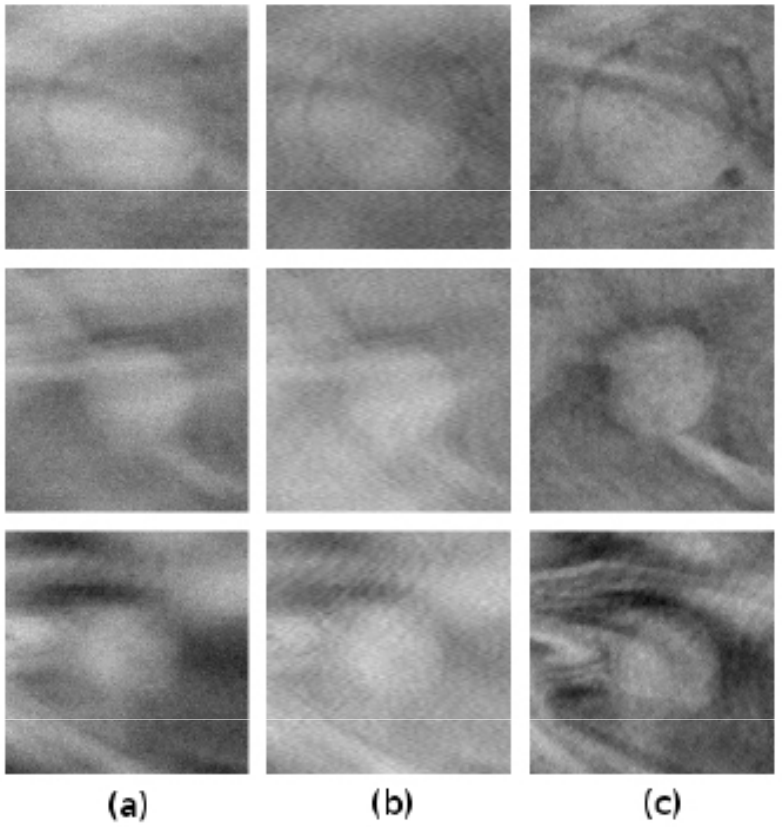




Results: phantoms







(a): SAA (b): FBP (c): Iterative

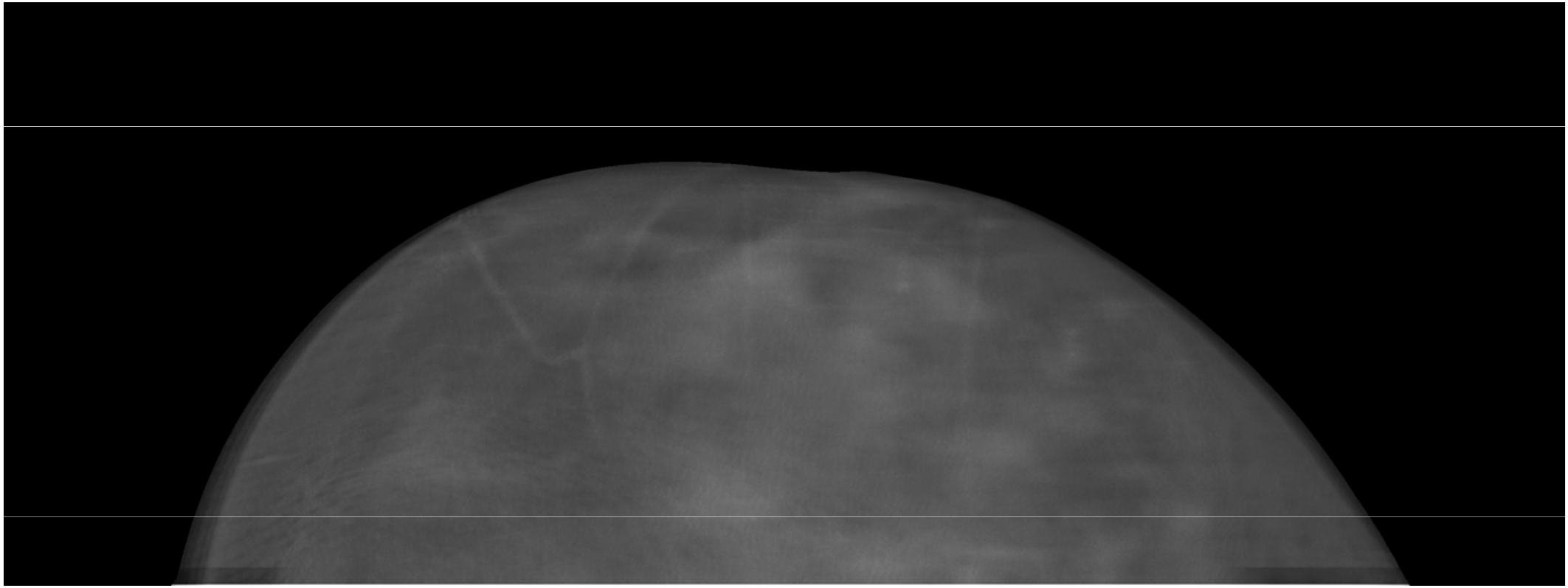


Image courtesy of IMS

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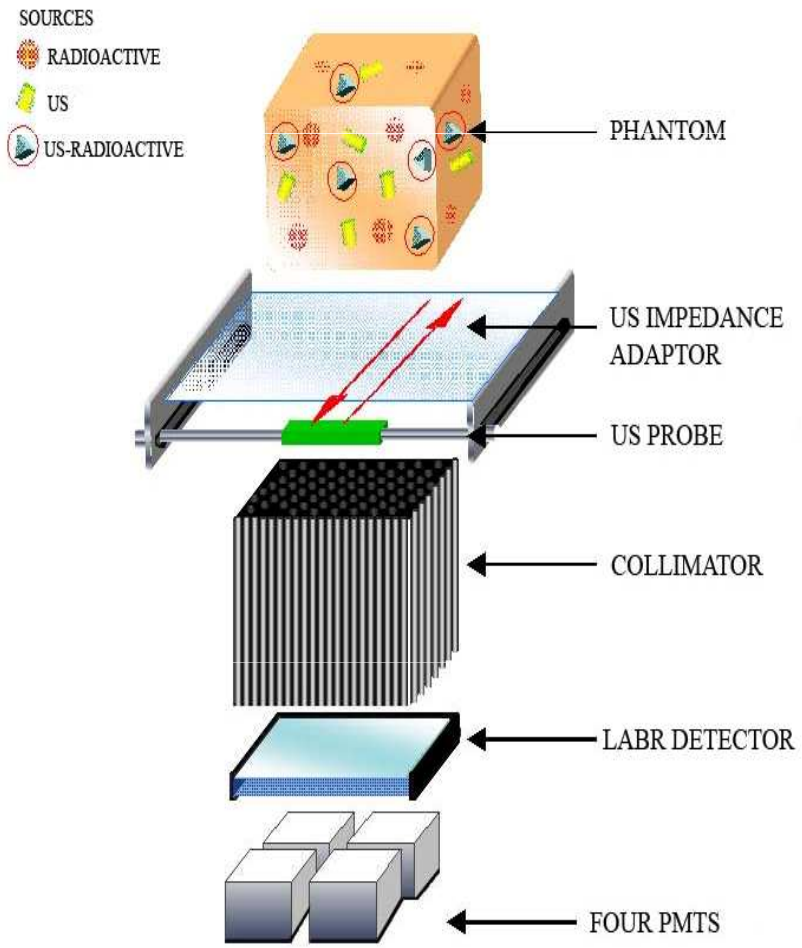
ECORAD

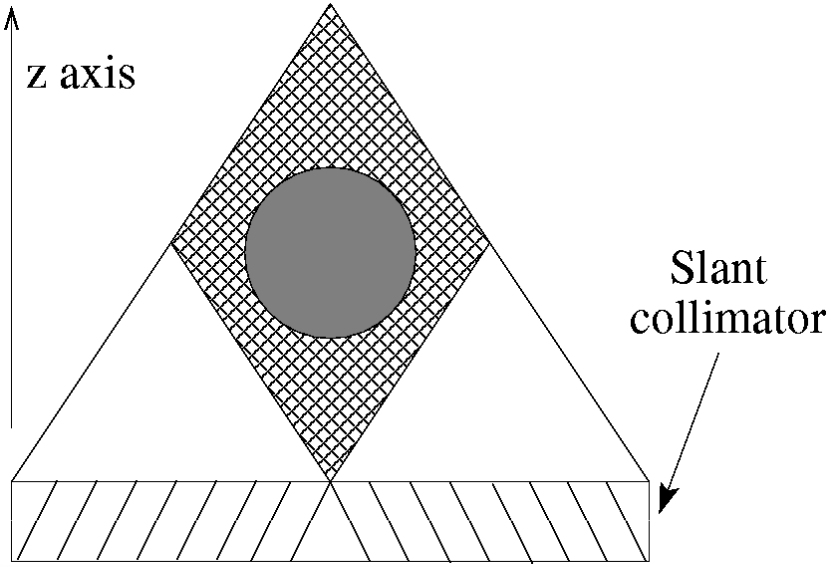
- Aim: to develop a dual compact camera for acquiring ultrasound and scintigraphic images (Rome I and III, Bologna, LNL)
- It will allow to get both morphological and functional information on the same device
- A volumetric image containing the fusion information will be provided to the user

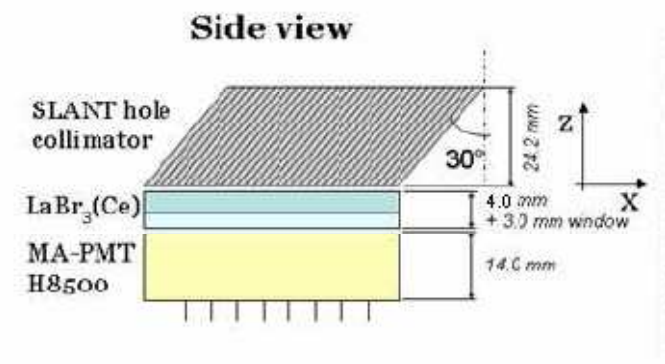
ECORAD



Collimator

Hole	Septa	Length	Angle
1.8 mm	0.2 mm	28 mm	30°



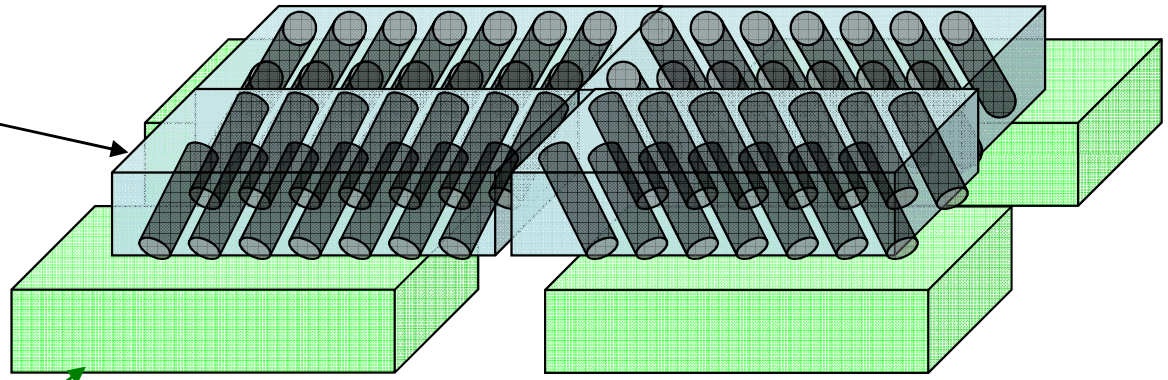


$LaBr_3$:Ce crystal

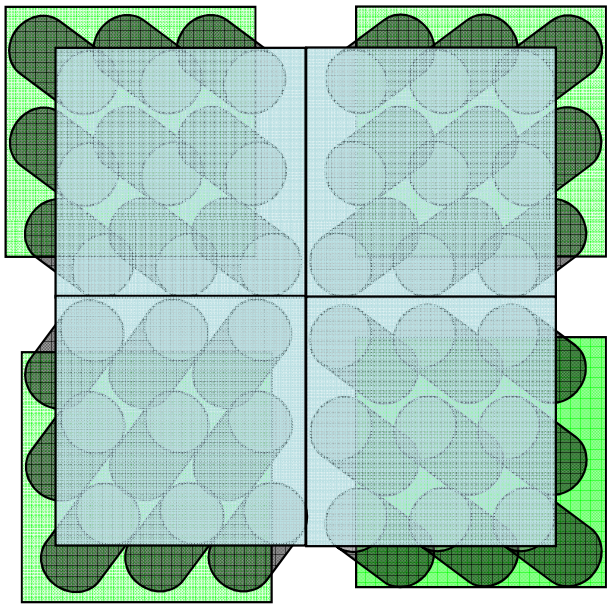
MAPMT H8500

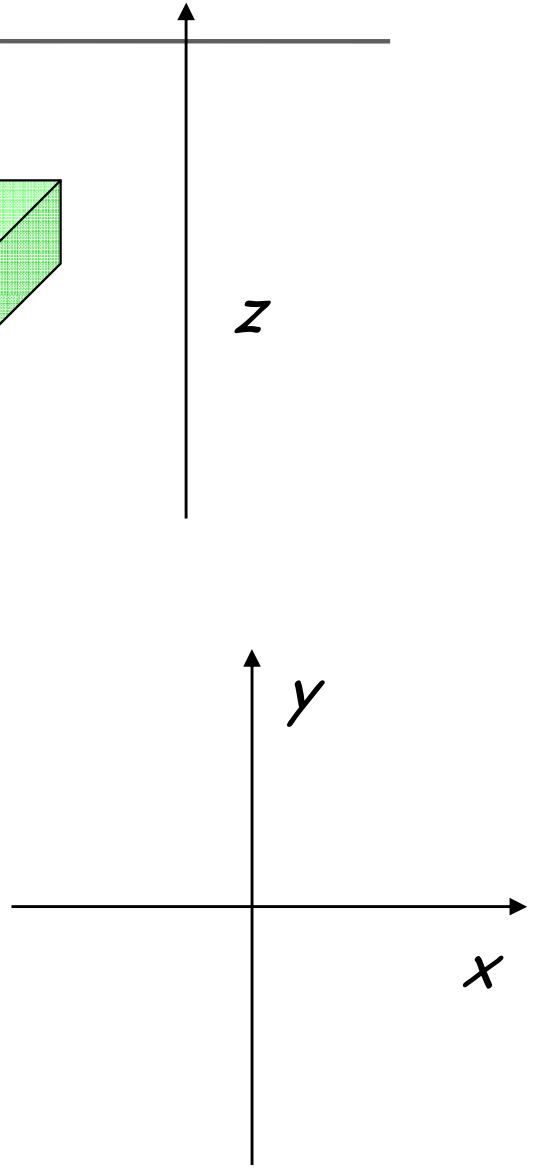
Sketch of the camera

Slant collimator

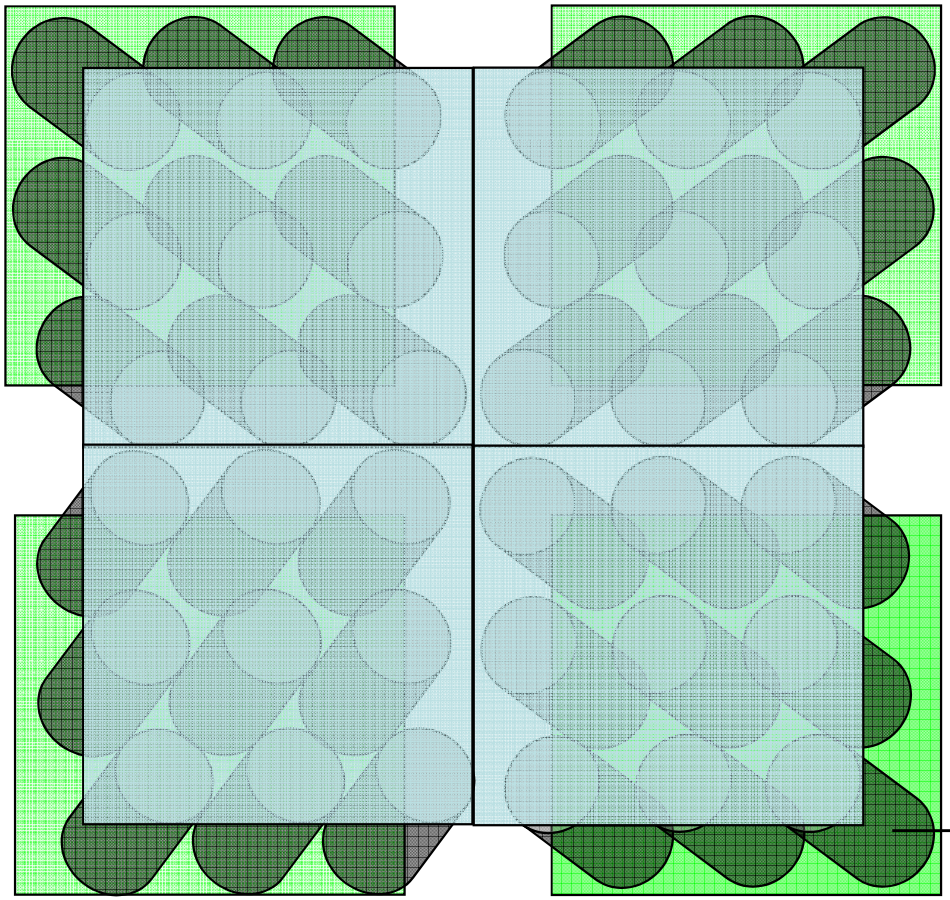


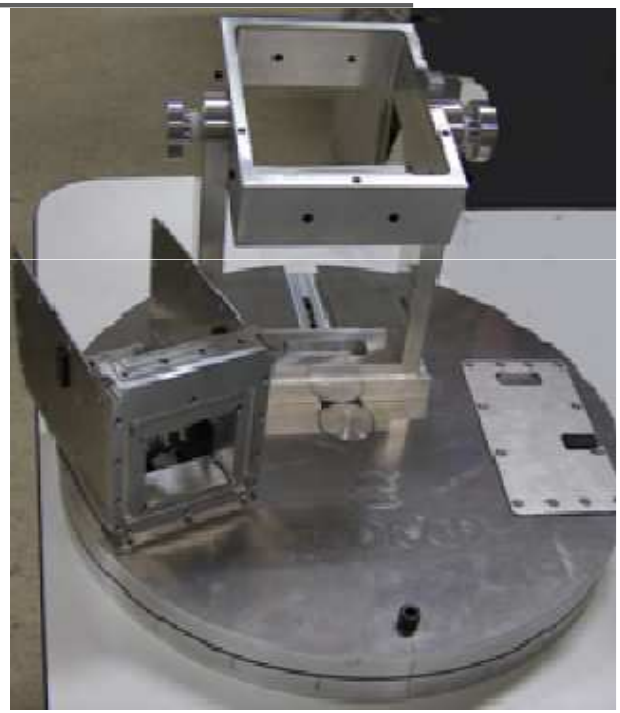
Crystal + PMT





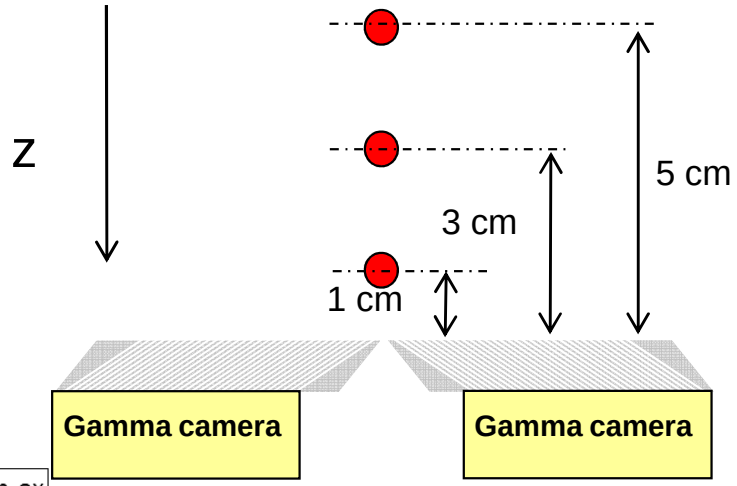
Rotating camera



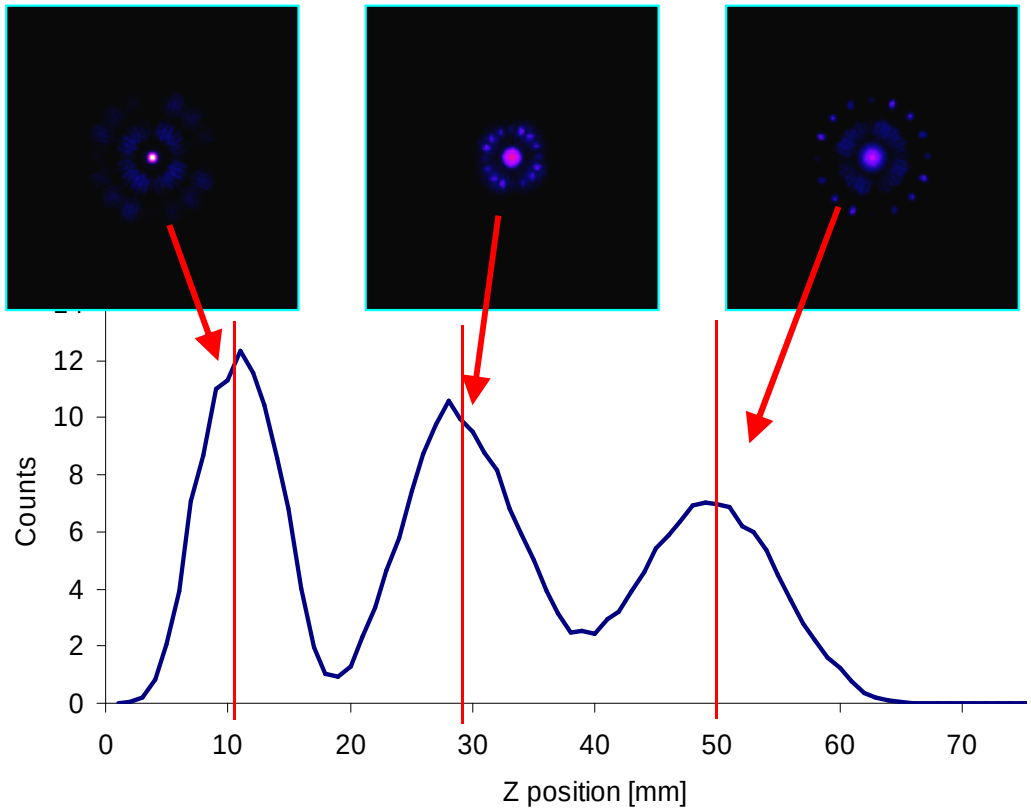


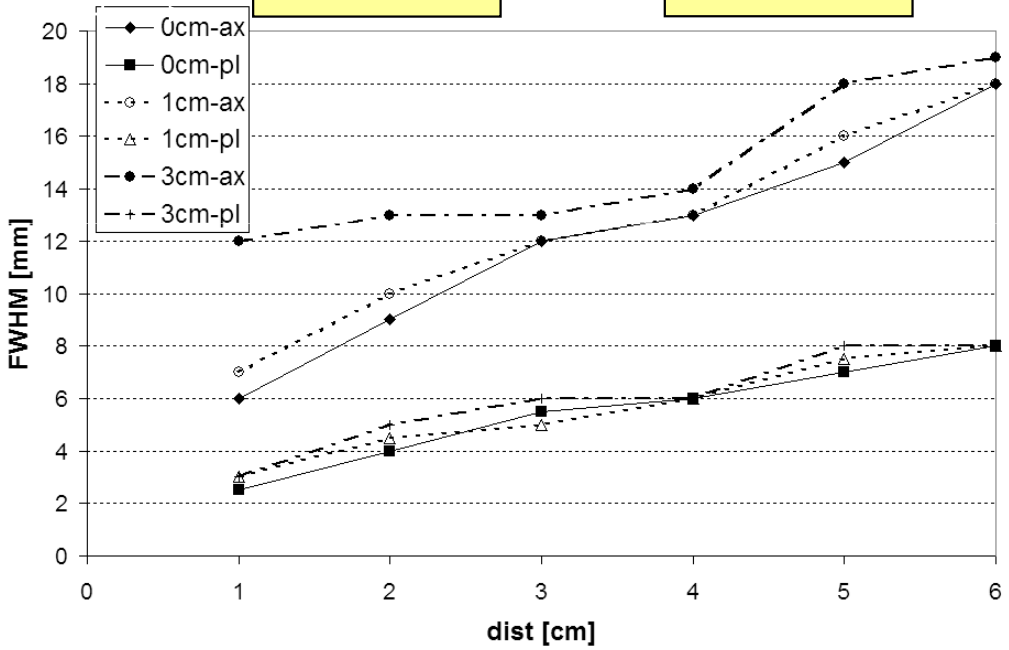
ECORAD

4 slant rotations - 10 min total imaging time



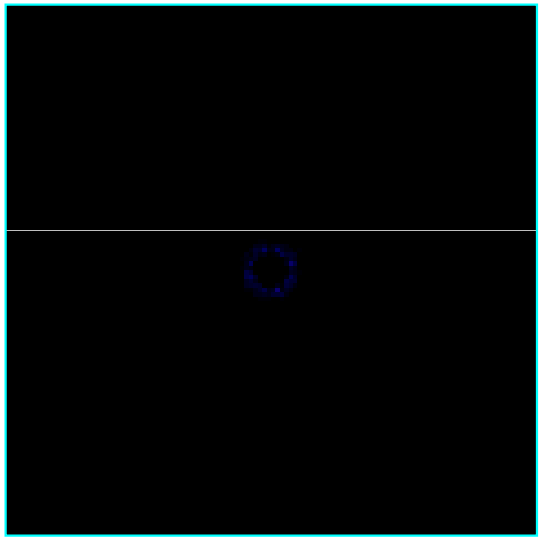
Reconstructed coronal slices:

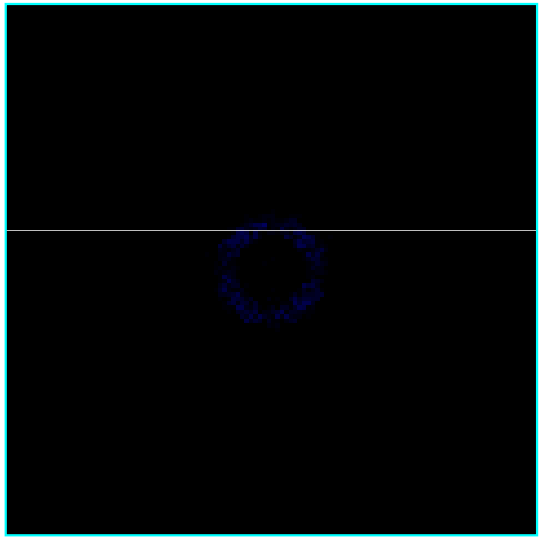




Point sources in air

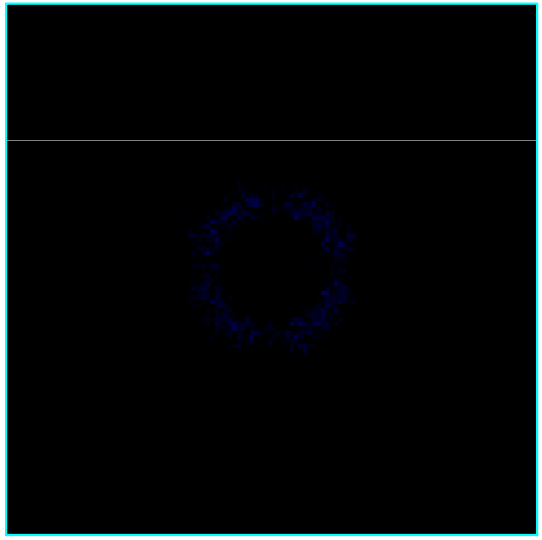
1 cm

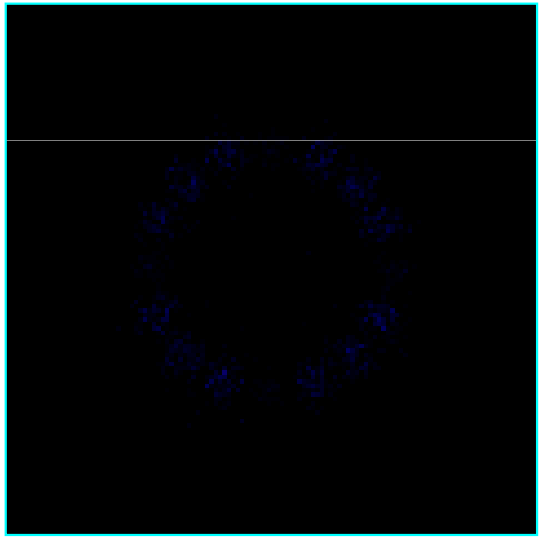




2 cm

3 cm





5 cm

Domande-guida

- Risultati recenti?
- Prospettive future e dove si prevedono gli sviluppi più interessanti?
- Competitori esterni al mondo della ricerca di fisica (industria, altri settori di ricerca...)?
- Cosa potrebbe permettere di migliorare la ricerca? (Formazione, personale e fondi, coordinamento e management,...)

Thank you!

Nico Lanconelli

Dipartimento di Fisica

nico.lanconelli@unibo.it

www.df.unibo.it/medphys