

LECTURE 18

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POSITRON EMISSION TOMOGRAPHY (PET)

BASIC PHYSICS

PROTECTIONS

PRACTICAL ISSUES, CALIBRATION

BACKPROJECTION

EXAMPLES

CHAPTER 9 FROM PRINCE + LINICIS

POSITRON EMISSION TOMOGRAPHY

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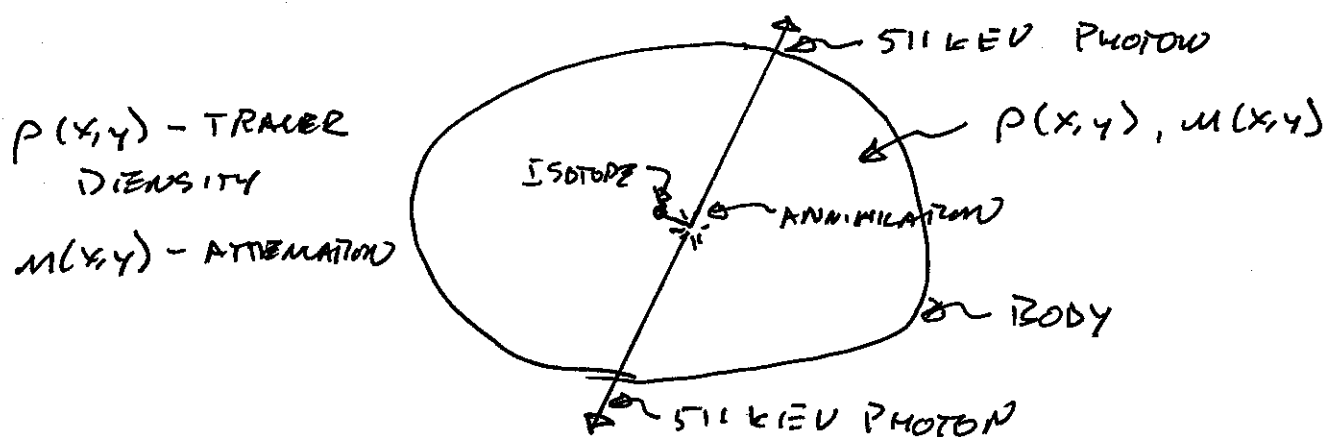
INJECT A TRACER WITH A RADIOACTIVE ISOTOPE

FDG (FLUORODEOXYGLUCOSE) MOST COMMON

ISOTOPE DECAYS PRODUCING POSITRON

POSITRON ANNIHILATES WITH ELECTRON PRODUCING

TWO 511 KEV PHOTONS AT $\pm 180^\circ$

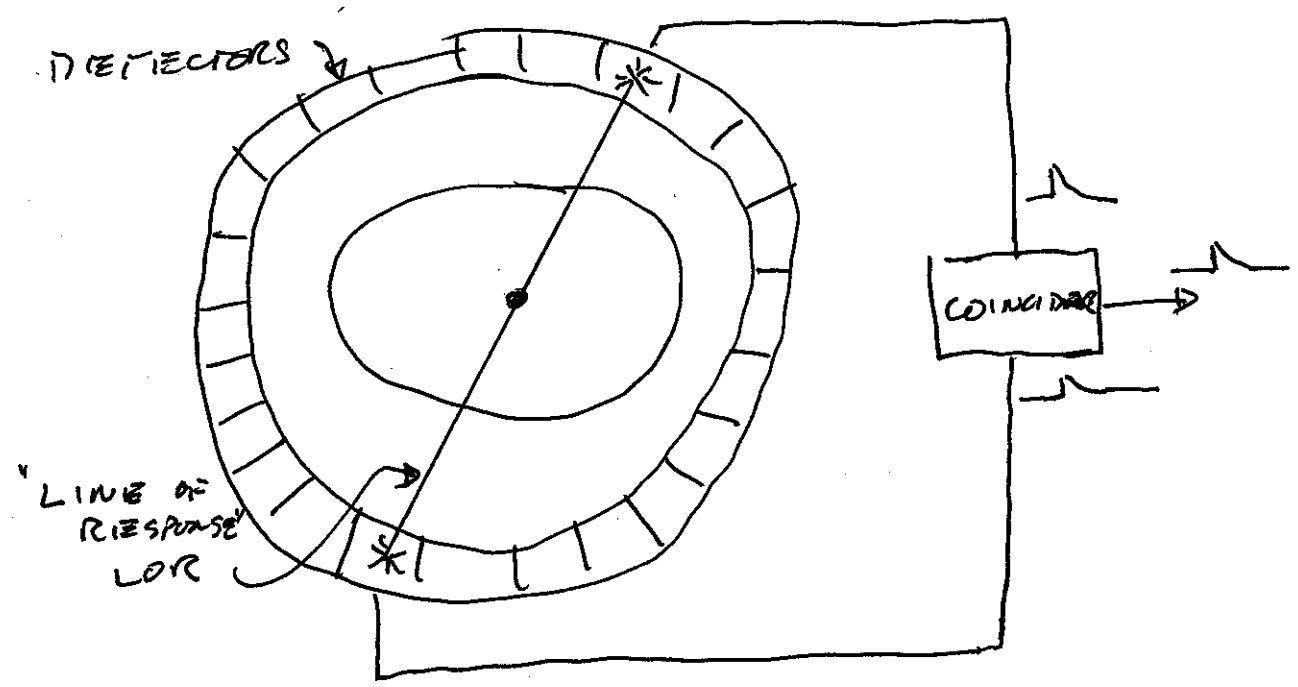


HOW DO YOU MAKE AN IMAGE OF $\rho(x,y)$?

CONVERT THE PROBLEM INTO A PROJECTION

RECONSTRUCTION PROBLEM.

SURROUND BODY WITH RING OF DETECTORS



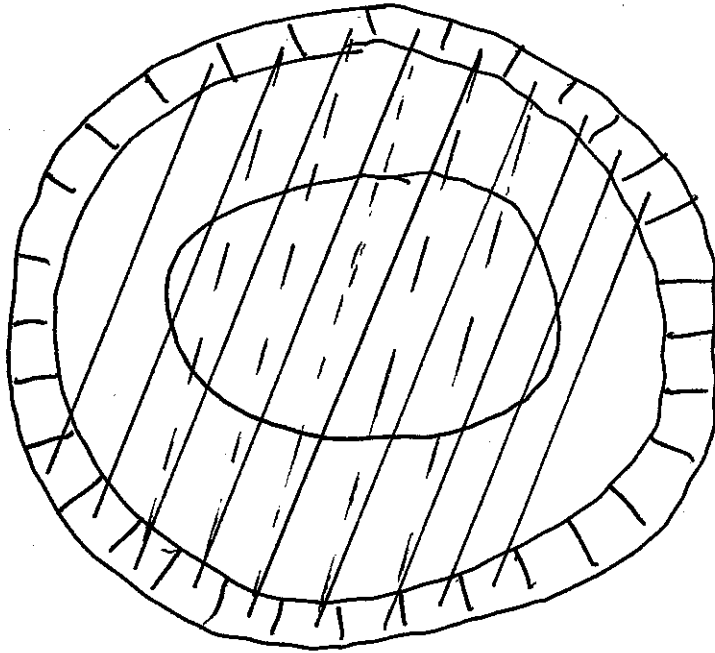
IF TWO EVENTS ARE DETECTED IN A 5-15 NS WINDOW, WE KNOW THERE WAS AN EVENT ALONG THE LINE CONNECTING THEM

THIS IS THE "LINE OF RESPONSE", OR LOR

MANY POSSIBLE LOR'S!

WE CAN GROUP LOR'S TO FORM PROJECTIONS

(4)



- COLLECT EVENTS
- SORT INTO PARALLEL PROJECTIONS
- BACKPROJECT

COLLECT TWO SETS

OPPOSING DETECTORS

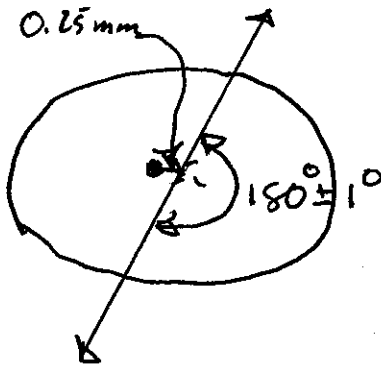
OPPOSING BUT 1 DETECTOR

INTERLACING DOUBLES LOR SPACING

DETECTOR SPACING IS 23mm

WITH INTERLACING IS 11.5mm

RESOLUTION



LIMITS ARE

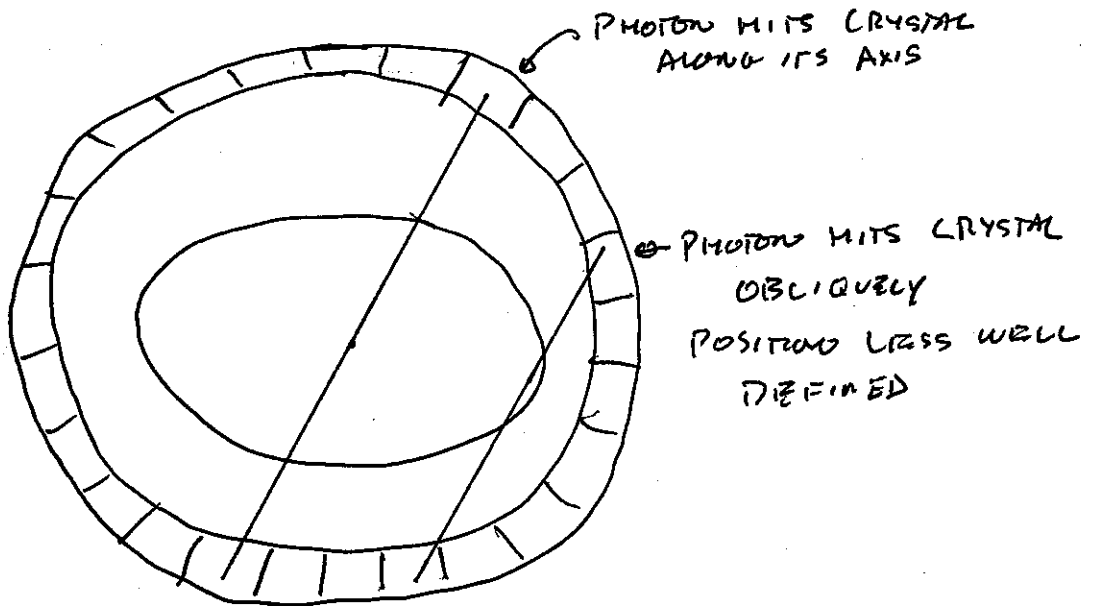
POSITION RANGE $\sim 0.25 \text{ mm}$

POSITION MOMENTUM $\sim 180^\circ \pm 1^\circ$

LOR SPACING $\sim 1.5 \text{ mm}$

DETECTOR FWHM $\sim 3 \text{ mm}$ CENTER OF FOV

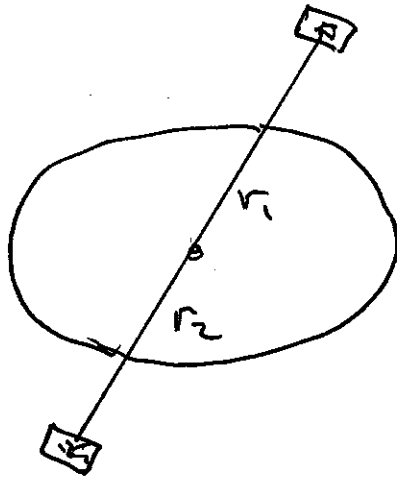
$\sim 5 \text{ mm}$ EDGE OF FOV



ATTENUATION

6

WE WANT TO RECONSTRUCT $\rho(x,y)$, BUT
ATTENUATION WILL CAUSE EVENTS TO BE LOST



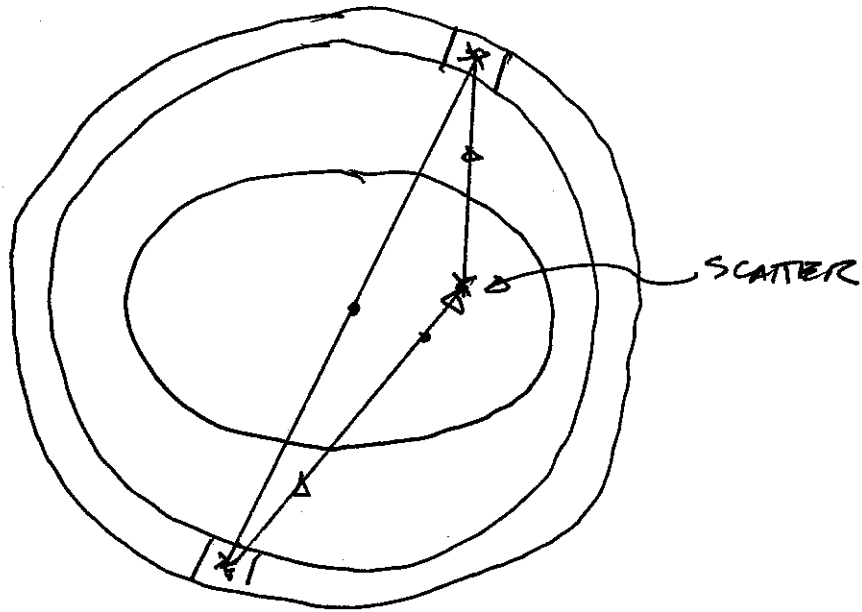
WE LOSE EVENT IF EITHER PHOTON IS ATTENUATED,
THE PROBABILITY BOTH PHOTONS SURVIVE IS

$$P(\text{PHOTON 1}) \cdot P(\text{PHOTON 2}) \\ = \left[e^{-\int_{r_1} \mu(x,y) ds} \right] \left[e^{-\int_{r_2} \mu(x,y) ds} \right] = e^{-\int_{r_1/r_2} \mu(x,y) ds}$$

ONLY A FUNCTION OF TOTAL PATH LENGTH,
NOT SOURCE LOCATION.

SCATTERING

(7)



SCATTERED PHOTONS ALSO PRODUCE COINCIDENCE

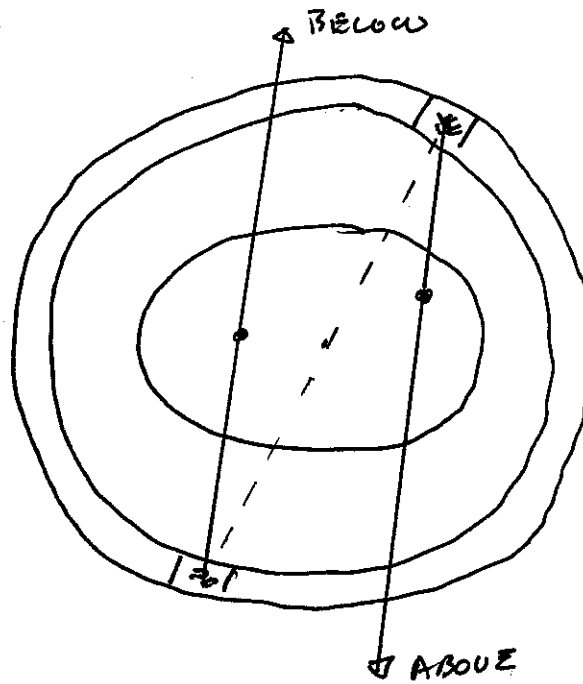
ENERGY SENSITIVE DETECTION ($\pm 10\%$) REDUCE

LARGE ANGLE EVENTS

FUNCTION OF SUBJECT.

ACCIDENTALS (RANDOMS)

(8)



TWO COINCIDENT EVENTS LOOK LIKE A SINGLE EVENT.

RATE AT DETECTOR i IS R_i

GIVEN AN EVENT AT i , THERE ARE

$$\uparrow R_j$$

AT DETECTOR j , WHERE τ IS COINCIDENCE WINDOW (5-15ns)

TOTAL RATE IS

$$R_c = 2\tau R_i R_j$$

WHERE THE FACTOR OF 2 IS BECAUSE EITHER DETECTOR
COULD BE FIRST

QUADRATIC IN DOSE!

15% IN 2D

30-50% IN 3D

L15

DEAD TIME / DETECTOR EFFICIENCY

9

AFTER EVENT THERE IS A RECOVERY TIME
1 - 10'S OF NS

IF THE RATE IS HIGH ENOUGH, DEAD MOST OF THE TIME
SATURATED

LIMITS DOSE

PET IMAGE RECONSTRUCTION

SYSTEM MODEL

DETECTED EVENTS ALONG r, θ

$$Y_{r,\theta} = Y \left[\eta^t P_m + \eta^r r + \eta^s s \right]$$

WHERE

$Y_{r,\theta}$ MEASURED
 P_m DESIRED

m - NUMBER OF SOURCE EVENTS

P - SOURCE ATTENUATION $e^{-\int \mu(x,y) ds}$

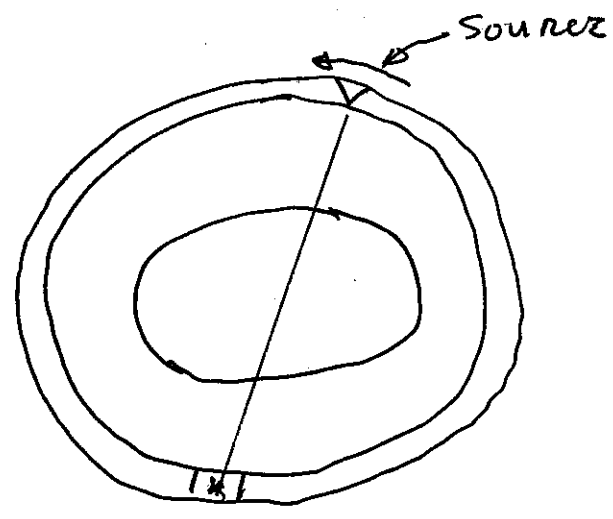
r - NUMBER OF RANDOM EVENTS

s - NUMBER OF SCATTERED EVENTS

η^t, η^r, η^s - DETECTOR EFFICIENCIES FOR TRUE,
RANDOM AND SCATTERED EVENTS

δ - DEAD TIME LOSS

ATTENUATION ESTIMATE



MEASURE USING:

BLANK SCAN $B_{r,\theta}$

TRANSMISSION SCAN $T_{r,\theta}$

DETECTOR SENSITIVITIES
(ONCE/DAY)

ATTENUATION OF SUBJECT
(ONCE/STUDY)

THEN

$$P_{r,\theta} = \frac{T_{r,\theta}}{B_{r,\theta}}$$

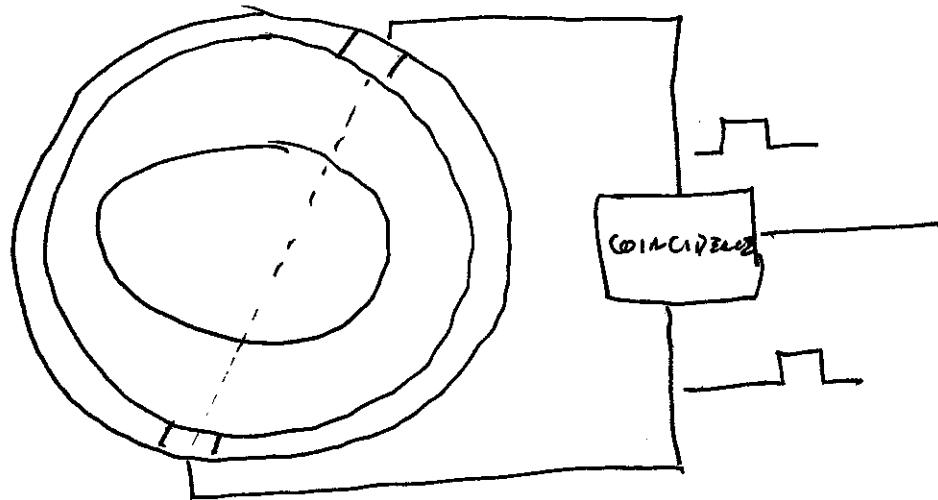
INCLUDES γ, η^t

ESTIMATE USING

CT SCAN (PET/CT SCANNER)

ACCIDENTAL ESTIMATE

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USE NON-OVERLAPPING COINCIDENCE WINDOWS

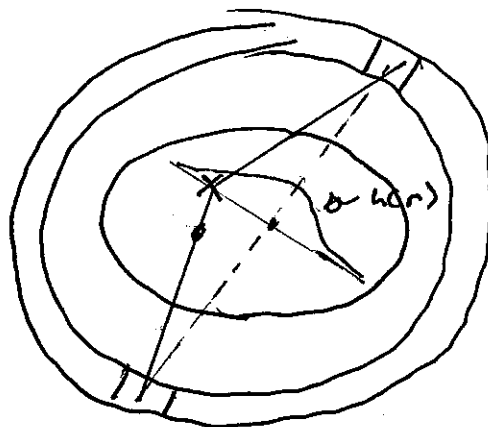
ACCIDENTALS ARE SAME!

NO TRUE EVENTS

MEASURES δz^2

NOISY, SNR SIMILAR TO DATA

SCATTER ESTIMATE



PROBABILITY OF SCATTER IS DETERMINED BY PROBABILITY

OF SOMETHING TO SCATTER OFF OF

ENERGY SELECTIVITY LIMITS ANGLE

ESTIMATE BY CONVOLVING PROJECTION DATA WITH
KERNEL $h(\theta)$ IN 2D

INCORPORATE INTO SYSTEM MODEL IN 3D

L15

CORRECTED BACKPROJECTION DATA

SYSTEM MODEL

$$Y_{r,\theta} = \underbrace{\gamma \mathcal{N}^T P_{r,\theta} m}_{\text{MEASURED}} + \underbrace{\gamma \mathcal{N}^T r}_{\text{MEASURED DESIRED}} + \underbrace{\gamma \mathcal{N}^T s}_{\text{RANDOM, ESTIMATED}}$$

CORRECTED DATA

$$\hat{m}_{r,\theta} = \frac{1}{\gamma \mathcal{N}^T P_{r,\theta}} \left[Y_{r,\theta} - \gamma \mathcal{N}^T R - \gamma \mathcal{N}^T S \right]$$

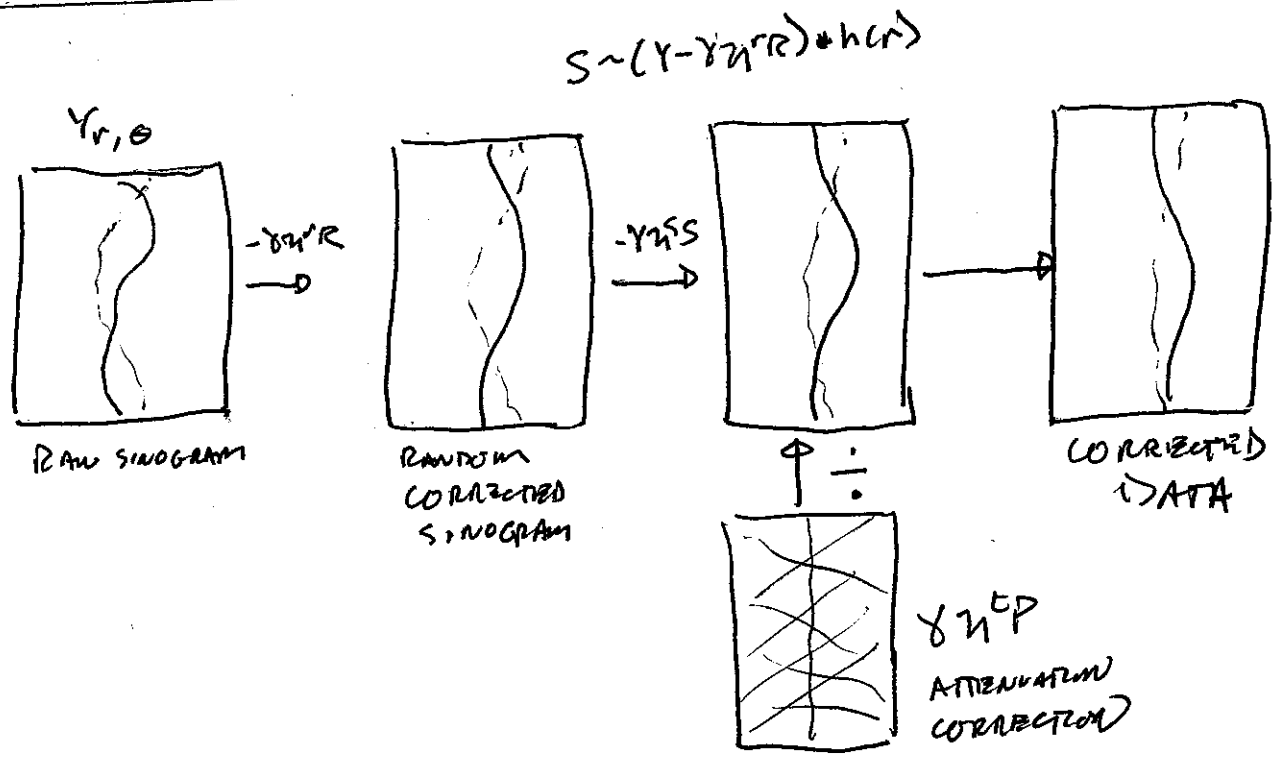
WHERE

$$R = E[r]$$

$$S = E[s]$$

$\hat{m}_{r,\theta}$ CAN BE BACKPROJECTED

BLOCK DIAGRAM



PROBLEMS

- CORRECTIONS ARE RANDOM, ADD NOISE
- DOESN'T EXPLOIT KNOWLEDGE OF SYSTEM
- IMAGE IS POSITIVE
- STATISTICS ARE POISSON
- PARTS OF IMAGE ARE ZERO

NEXT TIME, HOW CAN WE EXPLOIT THESE CHARACTERISTICS TO PRODUCE BETTER RECONSTRUCTIONS