# 3D CT

HELICAL CT

MULTIDETECTOR CT

CONE BEAM CT

3D RADON SPACE

REFERENCES

COMPUTED TOMOGRAPHY..., 3rd EDITION
WILLI KALENDER

COMPUTED TOMOGRAPHY..., 2nd EDITION
JIANG HSIEH

BASED ON NOTES FROM
ADAM WANG

# HELICAL CT

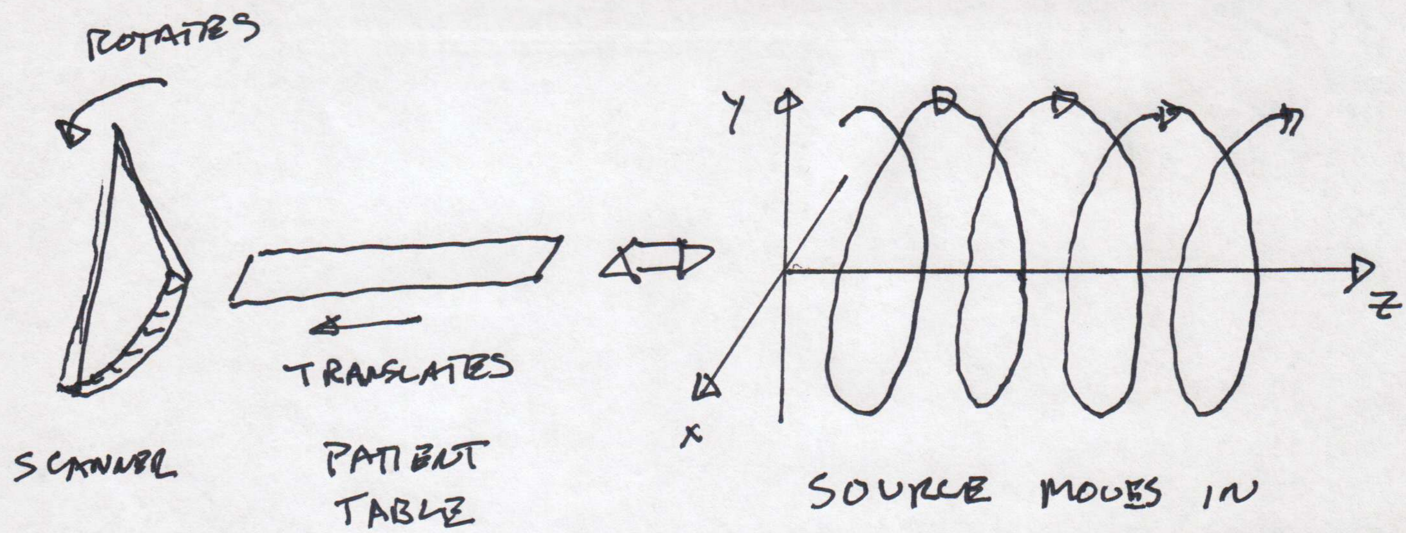
PROBLEM WITH VOLUME IMAGING WITH CONVENTIONAL CT IS MOTION

FOR EACH SLICE

- PATIENT ACCELERATED / DECCELERATED TO NEW POSITION
- IF TOO FAST, ORGANS CONTINUE TO MOVE
- LIMITS COVERAGE / SCAN TIME
- TUBE ON ONLY 50% OF TIME: INEFFICIENT

HELICAL CT

- SCAN CONTINUOUSLY AS PATIENT MOVES THROUGH SCANNER




SOURCE MOVES IN A HELIX AROUND PATIENT

## ADVANTAGES

CONTINUOUS MOTION (SCANNER AND PATIENT)

CONTINUOUS DATA COLLECTION

100% BEAM UTILIZATION

RECONSTRUCT ARBITRARY SLICE POSITIONS

## CHALLENGES

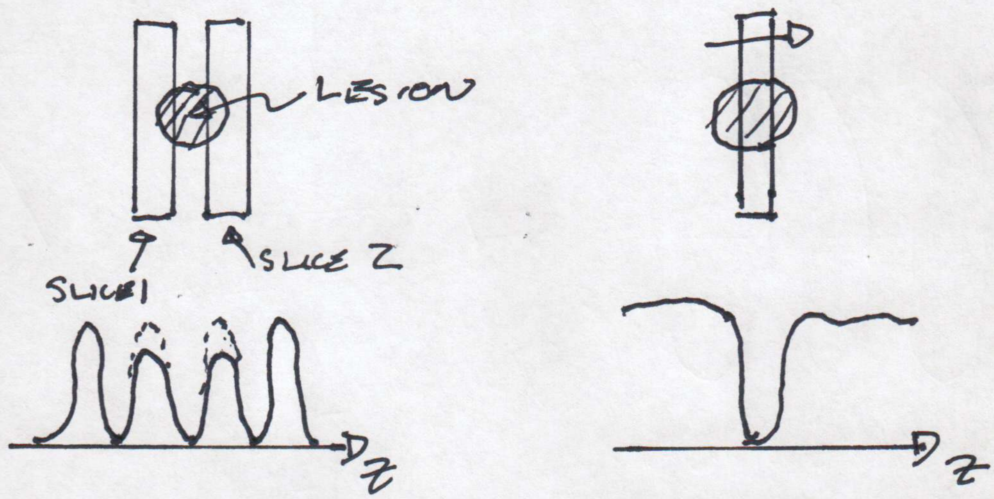
POWER, DATA CONNECTIONS

SLIP RINGS

50 KW POWER

~1 GBIT/S DATA (MULTIDECTOR)

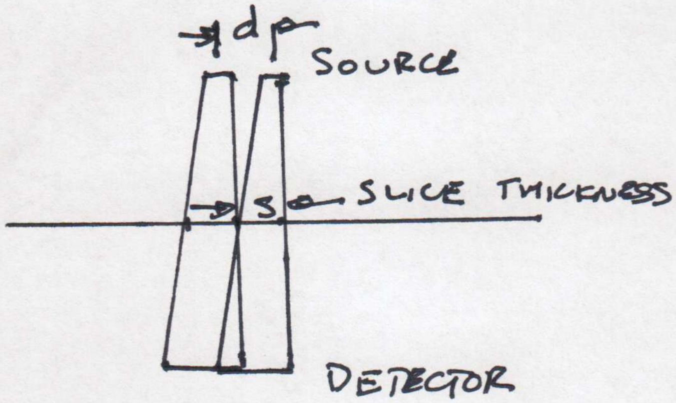
## IMPROVED LESION CONSPICUITY




FIXED SLICES ⇒ PARTIAL VOLUME

ARBITRARY SLICES ⇒ MAXIMUM CONTRAST

# HELICAL CT PITCH




d – DISTANCE FOR 360° ROTATION

S – SLICE THICKNESS AT ISOCENTER

PITCH IS

$$h = \frac{d}{S} = \frac{vt}{S}$$

TYPICAL IS $h = 1.5$

HIGHER PITCH GIVES

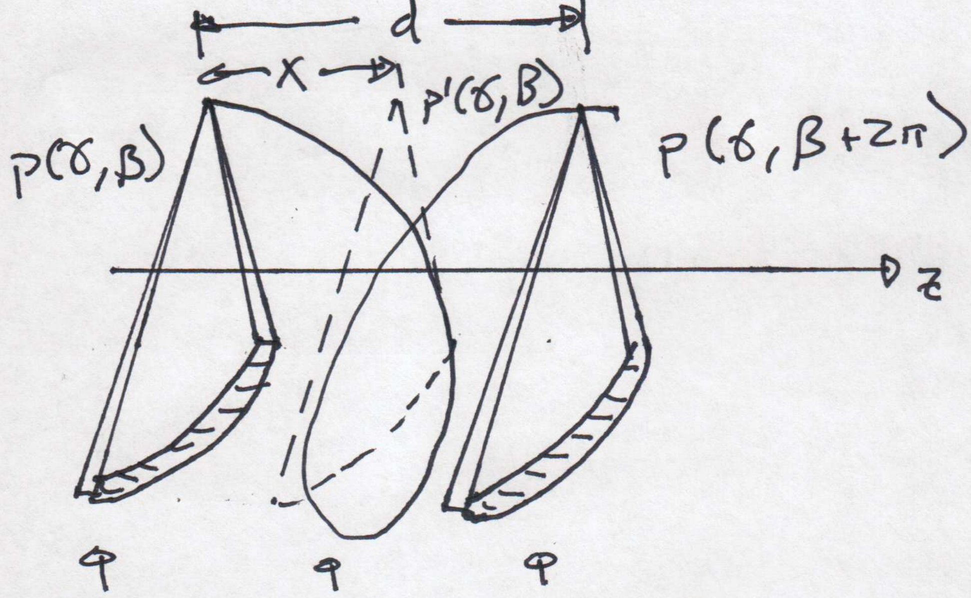
- FASTER VOLUME COVERAGE
- MORE IMAGE ARTIFACTS

# HELICAL CT RECON

USE 360° OF DATA

INTERPOLATE TO A PLANE $0 < x < d$

USE FAN BEAM RECONSTRUCTION ON INTERPOLATED DATA



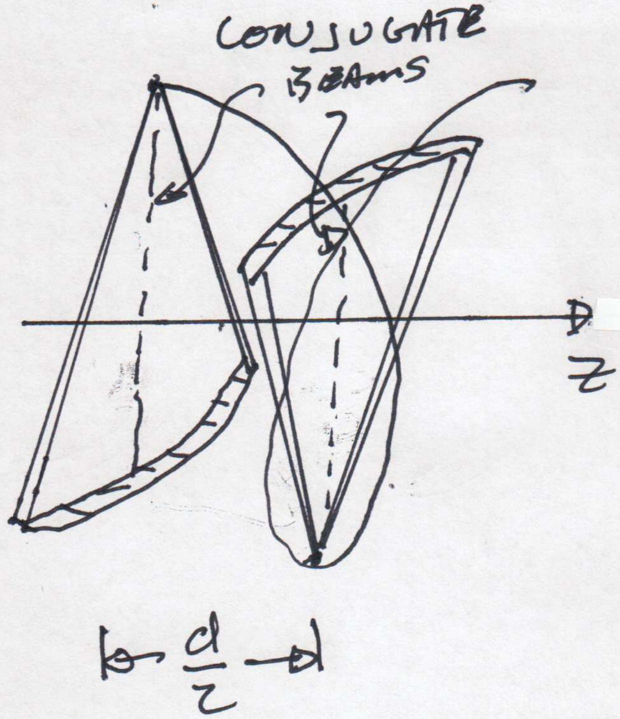

$$p'(\gamma, \beta) = \frac{d-x}{d} p(\gamma, \beta) + \frac{x}{d} p(\gamma, \beta + 2\pi)$$

WORKS REASONABLY WELL, LOSE RESOLUTION IN Z. BETTER INTERPOLATION HELPS.

ARTIFACTS DUE TO SEPARATION IN TIME AND DISTANCE BETWEEN $p(\gamma, \beta)$, $p(\gamma, \beta+2\pi)$

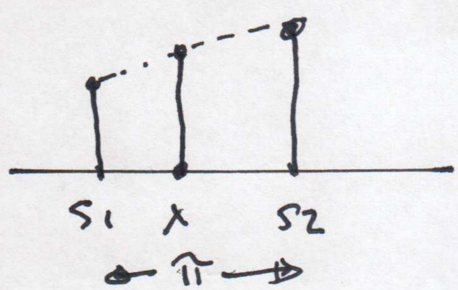
ALTERNATIVE IS TO ONLY USE 180° OF DATA, AND CONJUGATE BEAMS

PROBLEM IS THAT CONJUGATE BEAMS SEE SLIGHTLY DIFFERENT OBJECT DUE TO BEAM DIVERGENCE

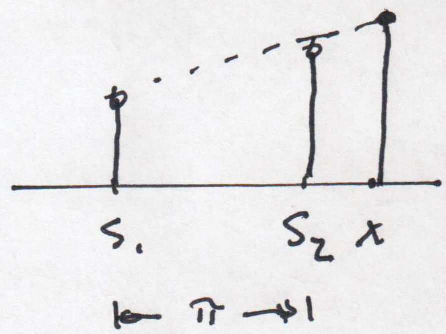



INTERPOLATE TO SOME FIXED X

SINCE WE NEED π + FAN ANGLE SOME OF THE DATA WILL BE EXTRAPOLATED



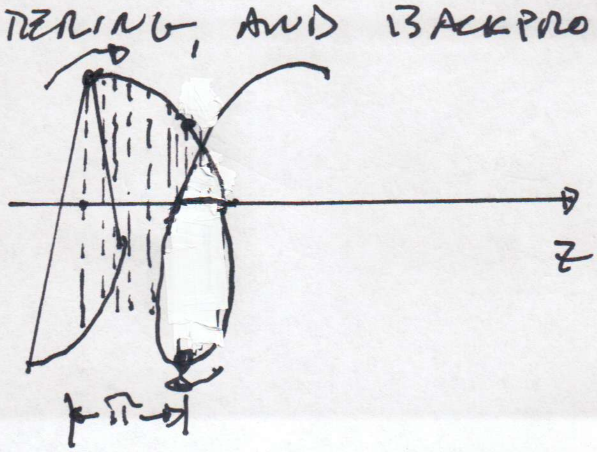

INTERPOLATED




EXTRAPOLATED

## REBINNING

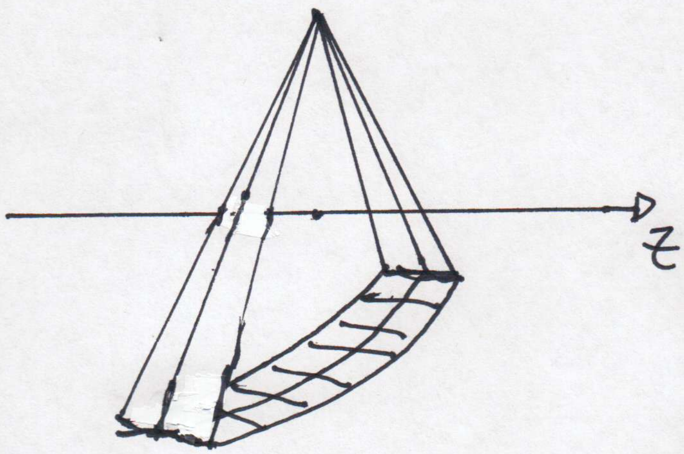
ANOTHER OPTION IS TO DO REBINNING FIRST, AND THEN MULTIPLE OPTIONS FOR INTERPOLATION, FILTERING, AND BACKPROJECTION



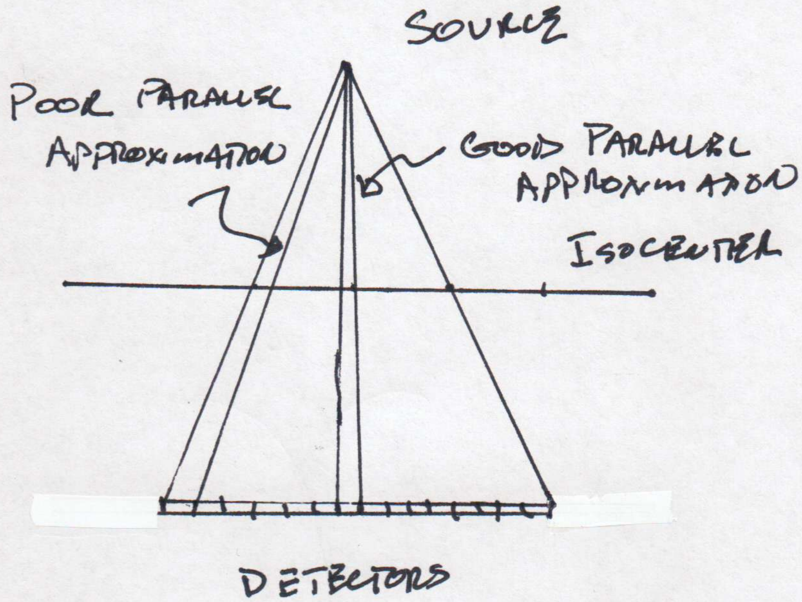

PARALLEL BEAM DATA WITH SOURCE ON HELIX

# MULTISLICE CT

TO IMAGE FASTER, AND USE MORE OF THE SOURCE PHOTONS, ADDITIONAL ROWS OF DETECTORS WERE ADDED




ORIGINALLY THIS WAS 2, 4, 8, OR 16. RECONSTRUCTED AS PARALLEL. DETECTOR ~1mm, ANGLE SMALL!

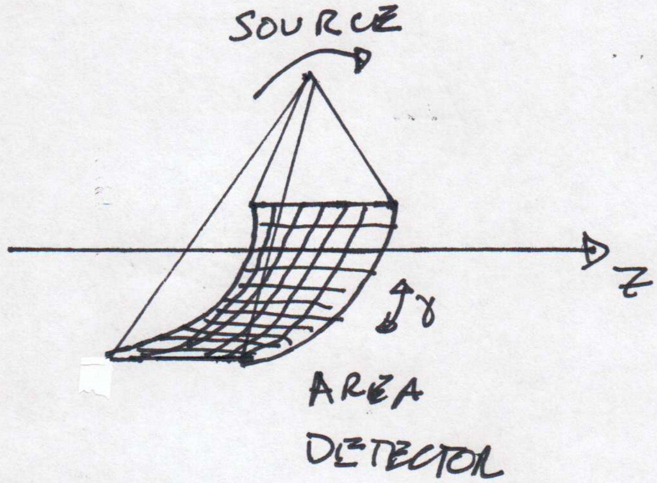



AS THE NUMBER OF DETECTORS INCREASE PARALLEL APPROXIMATION FAILS.

WITH ENOUGH DETECTORS (~320) WE CAN IMAGE AN ENTIRE ORGAN WITHOUT TRANSLATION

WHOLE HEART IN 0.5 s !

THIS CHANGES THE PROBLEM TO A CONE BEAM CT RECONSTRUCTION




NO TRANSLATION

WELL KNOWN APPROXIMATE RECONSTRUCTION

FDK : FELDCAMP - DAVIS - KRESS

NATURAL EXTENSION OF FAN BEAM FILTERED BACKPROJECTION

NOW TWO ANGLES TO CORRECT FOR, FAN ANGLE σ AND CONE BEAM ANGLE τ. RESULT IS PROJECTION WEIGHTING BY

$$\cos\gamma \cos\tau$$

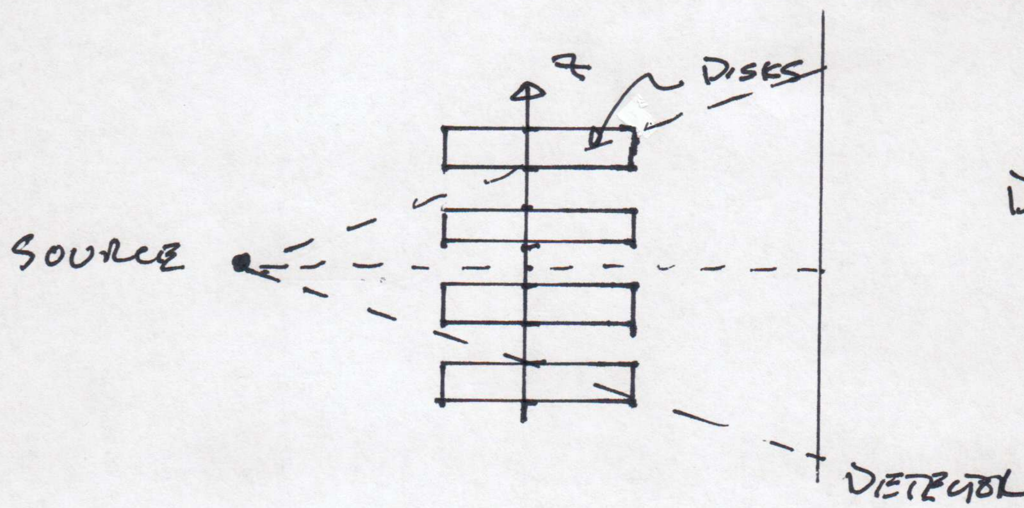
THEN BACKPROJECT IN 3D WEIGHTED BY $(D/d)^2$ WITH DEPTH, AGAIN DUE TO TWO ANGLES

REPEAT FOR ALL PROJECTIONS

WORKS WELL, SIMPLE, EXACT FOR $z=0$

FAILS AS YOU MOVE FURTHER OFF AXIS.

SOME OBJECTS ARE VERY DIFFICULT




DEFRISE PHANTOM

NO BEAMS PASS THROUGH GAPS OFF ISOCENTER

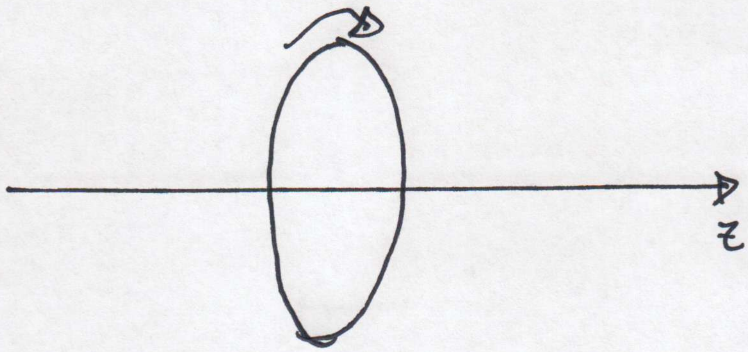
THE GAPS ARE NEVER RECONSTRUCTED PROPERLY

WHY IS THIS?

# TUY'S CONDITION FOR EXACT RECONSTRUCTION

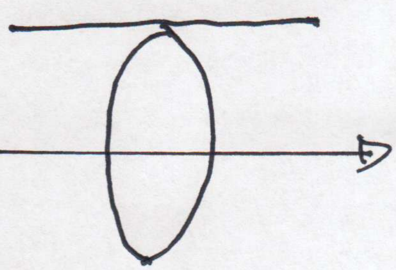
EVERY PLANE THROUGH THE OBJECT MUST INTERSECT THE SOURCE TRAJECTORY AT LEAST ONCE.

CIRCULAR TRAJECTORY FAILS

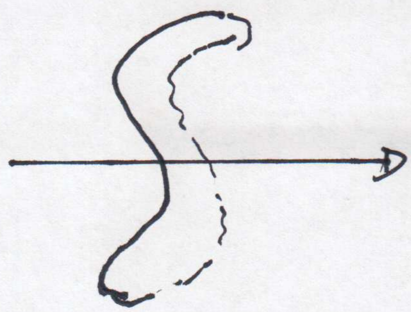



PLANES PARALLEL TO x-y AT $z \neq 0$ DON'T INTERSECT

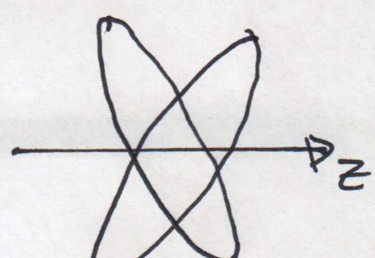
MANY OTHERS WORK



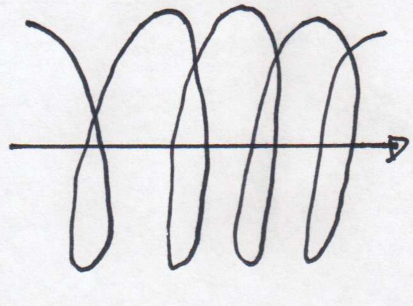
CIRCLE PLUS LINE



SADDLE




2 OBLIQUE CIRCLES

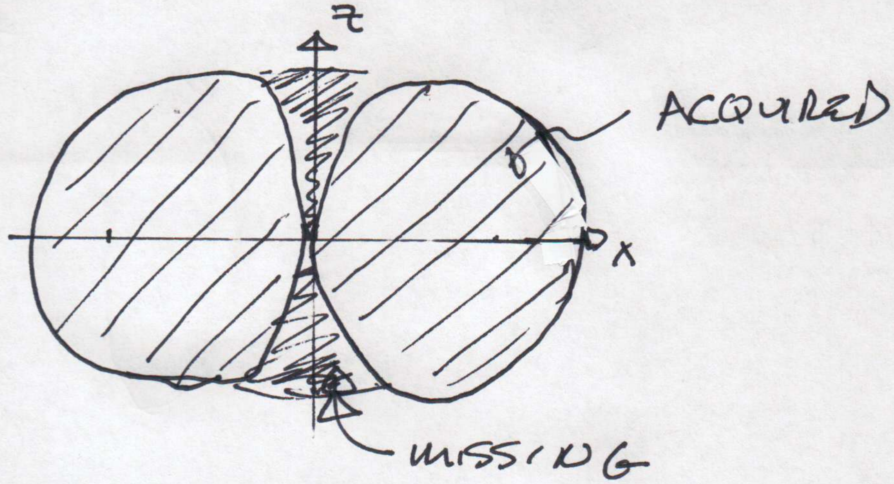


HELIX!

# CONE BEAM INCOMPLETENESS

A CIRCULAR TRAJECTORY DOESN'T ACQUIRE A FULL 3D RADON SPACE DATA SET

POINTS THAT ARE MEASURED FALL IN A TORUS



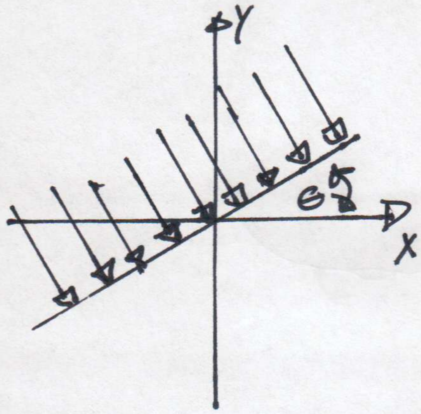

CIRCULAR CONE BEAM DATA CAN NEVER BE RECONSTRUCTED EXACTLY, DATA IS MISSING

THIS TURNS UP IN LOTS OF PROBLEMS, LIKE 3D ELECTRON MICROSCOPY

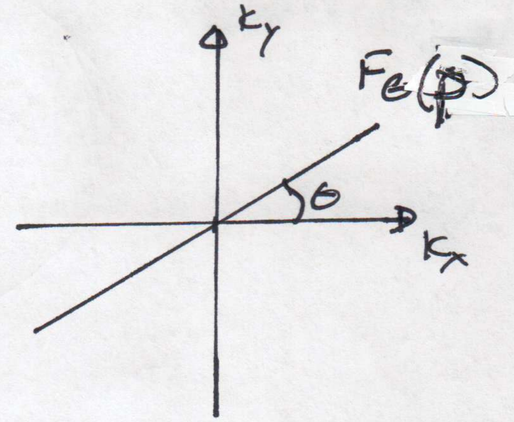
# 3D RADON SPACE

MORE ADVANCE / EXACT RECONSTRUCTIONS CONVERT TO 3D RADON SPACE FIRST, AND THEN RECONSTRUCT

IN 2D WE HAD THE CENTRAL SECTION THEOREM

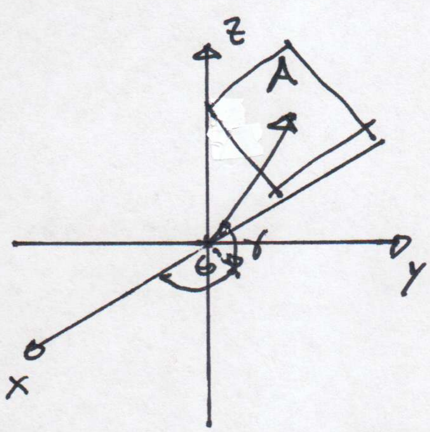



PROJECTIONS AT AN ANGLE θ

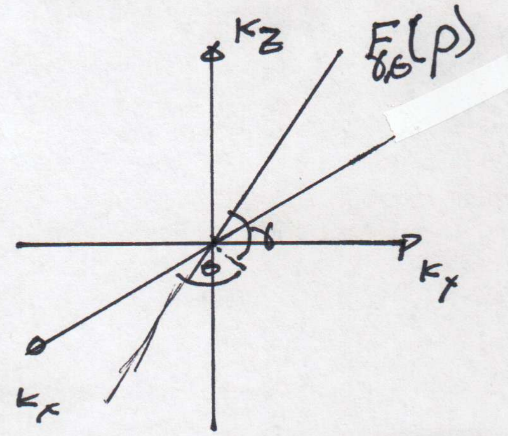



SAMPLE OF $F(k_x, k_y)$ ALONG DIAMETER AT ANGLE θ

IN 3D WE GET A SIMILAR RESULT




INTEGRALS OVER PLANES




SAMPLES OF $F(\underline{k})$ ALONG A DIAMETER

IF $P_{\gamma,\theta}(r)$ ARE PLANE INTEGRALS AT ANGLES $\gamma, \theta$, AND OFFSET $r$, THEN

$$P_{\gamma,\theta}(r) \overset{F.T.}{\Longleftrightarrow} F_{\gamma,\theta}(\rho)$$

GIVEN ALL PLANE INTEGRALS, WE CAN EXACTLY RECONSTRUCT THE OBJECT!

WE DON'T EVEN NEED THE LINE INTEGRALS!

THIS GETS BACK TO TUY'S CONDITION

- IF WE COVER ALL THE SAMPLES IN A SPHERE IN K-SPACE,
- WE HAVE PROJECTIONS FROM EVERY ANGLE
- IF SOME OF THOSE PROJECTIONS ARE MISSING, WE HAVE AN INCOMPLETE DATA SET, AND CAN'T RECONSTRUCT THE OBJECT EXACTLY.