US-Japan Advanced Science
And Technology Symposium
Japan Side Industry Talk

An example of Technical Innovation Cascade

Dynamic Tracking Radiation Therapy System

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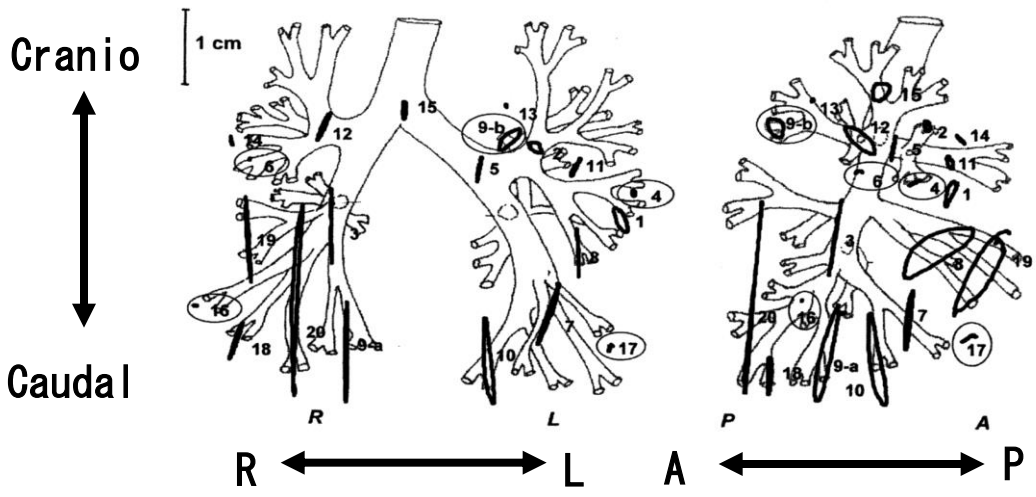
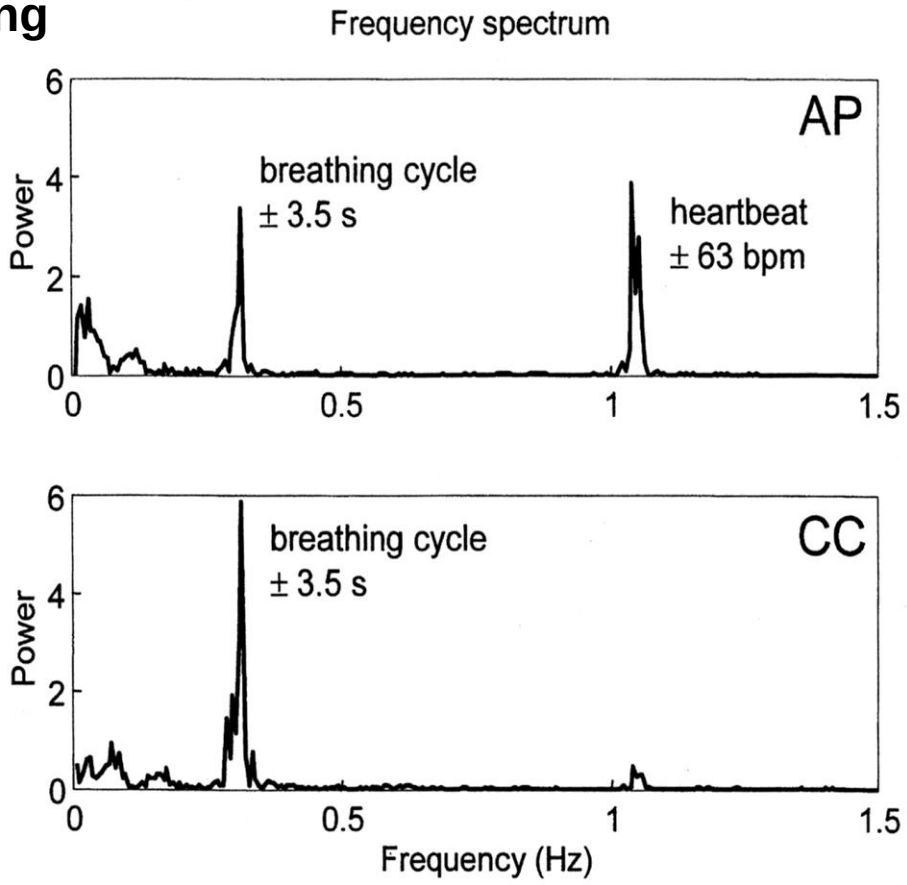
1. At the start

Started at the simple desire by medical doctors.

- **All external and internal movement of the human organ**
- **Any motion seriously affects the uncertainty of the radiation therapy**
- **Only the brain area can be fixed mechanically via the skull**
- **Most obvious motion is caused by breathing and heartbeat.**

Observed motion around lung area.

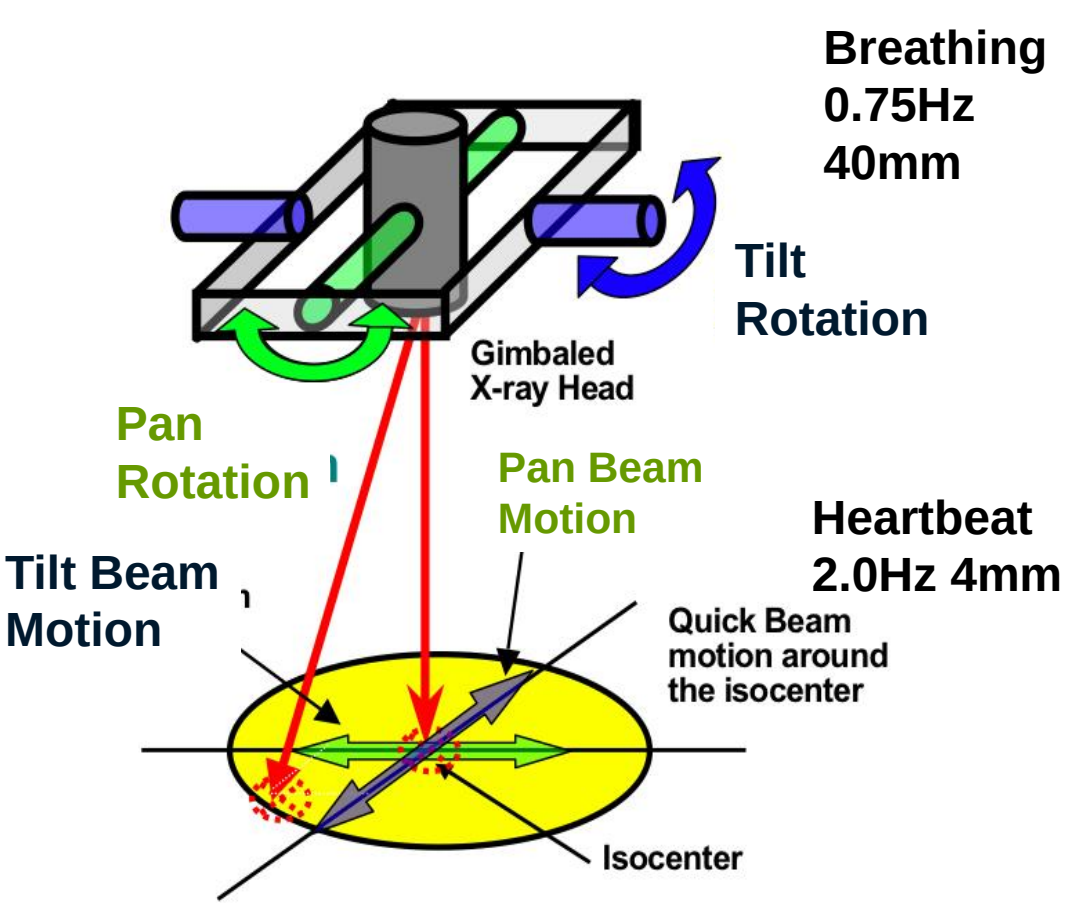




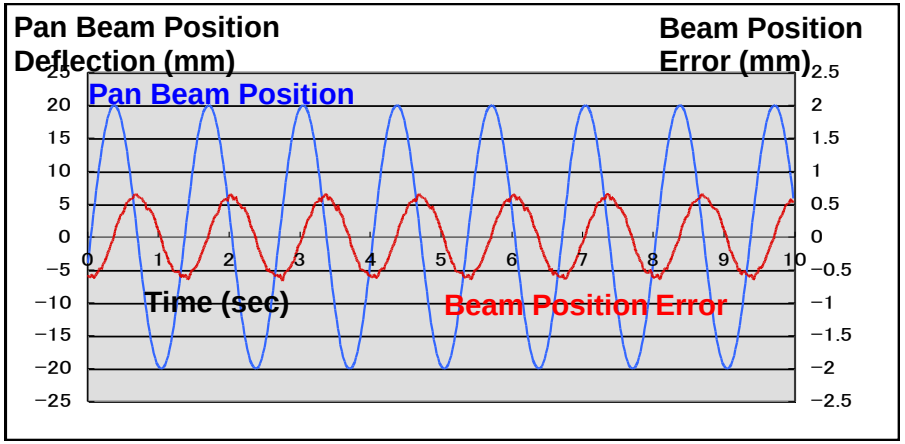
2. Engineering approach

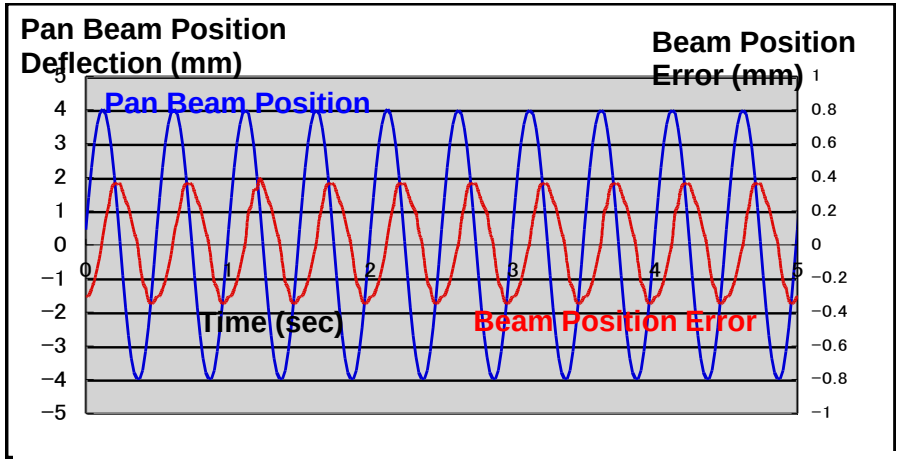
Engineers provided rough schetch of the solution.

Gimbaled X-ray Head Concept



Mechanical Tracking Capability

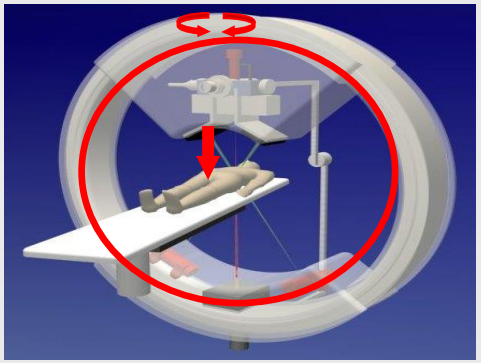




2. Engineering approach

Engineers integrated a set of total solution.

Isocentric motion

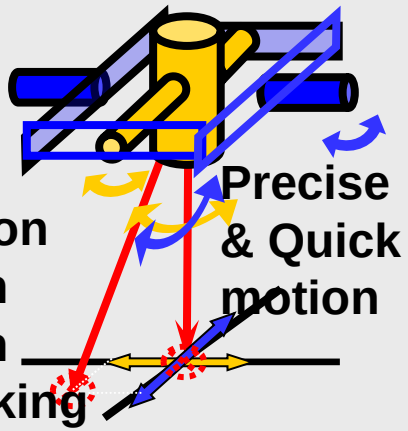


Port selection

Quasi-nonisocentric motion

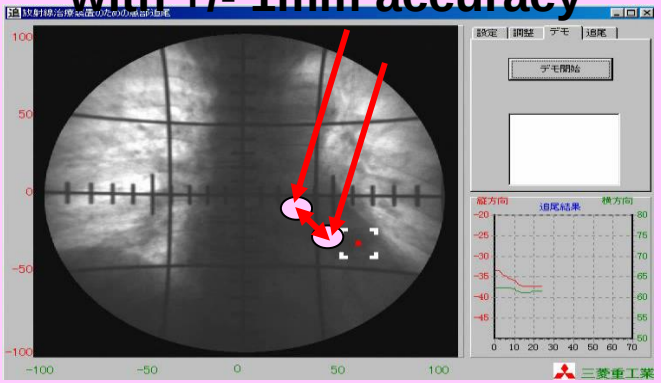
Non-isocentric motion

(1)Compensation of mechanical deformation
(2) Setup error correction without couch motion
(3) Real time motion tracking



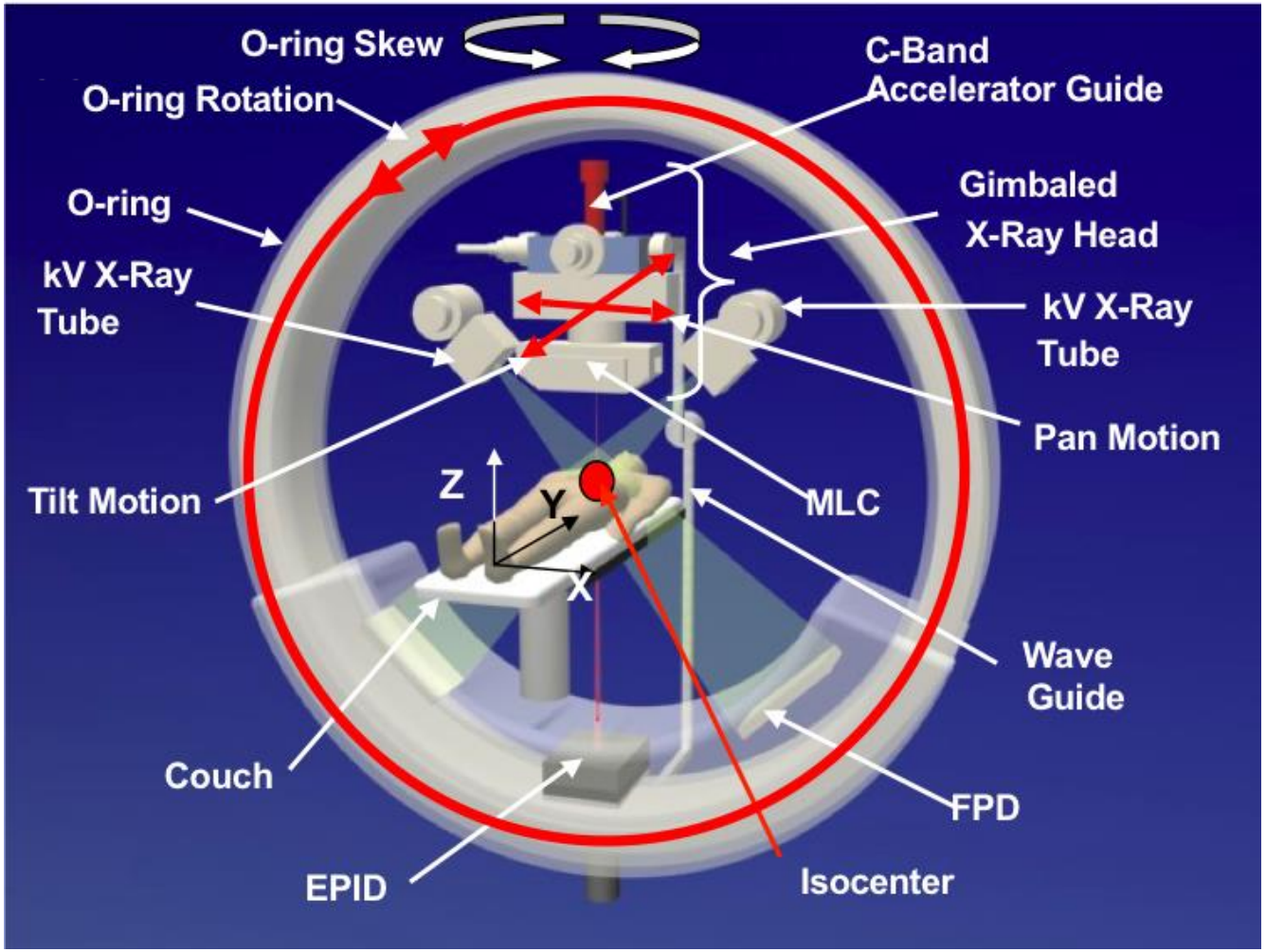
> Precise aiming +/- 0.1mm
> Setup error correction without couch motion

> Real time organ motion tracking and shooting 0.5Hz 40mm stroke with +/- 1mm accuracy



3. MDs' and Engineers' Dream

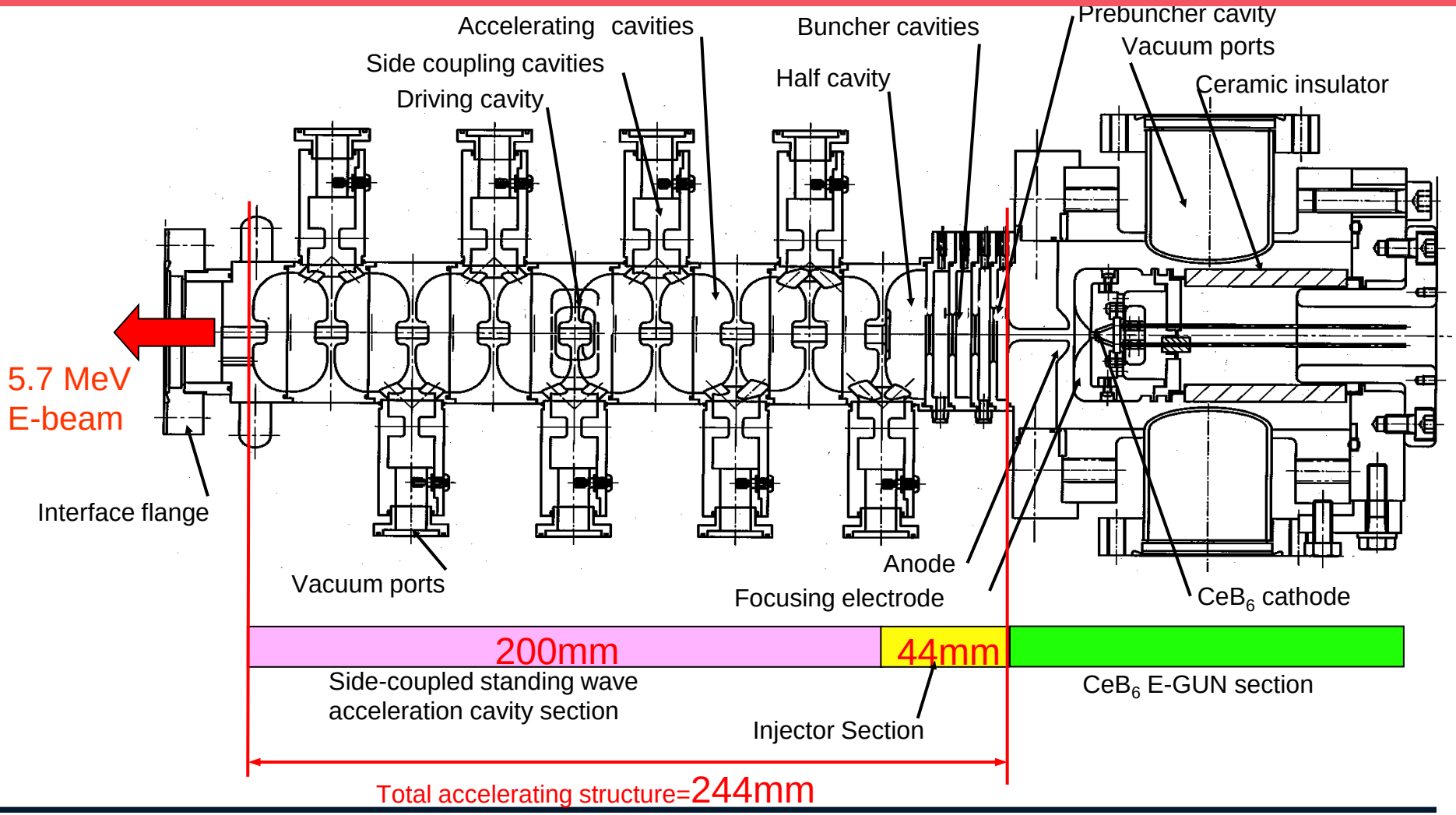
Engineers and MD's dreamt an ideal system.



The overall concept was published in IJROBP Vol.66 Number 1 Sept. 2006 By Kamino *et al*

4. Enabler innovative technology comes

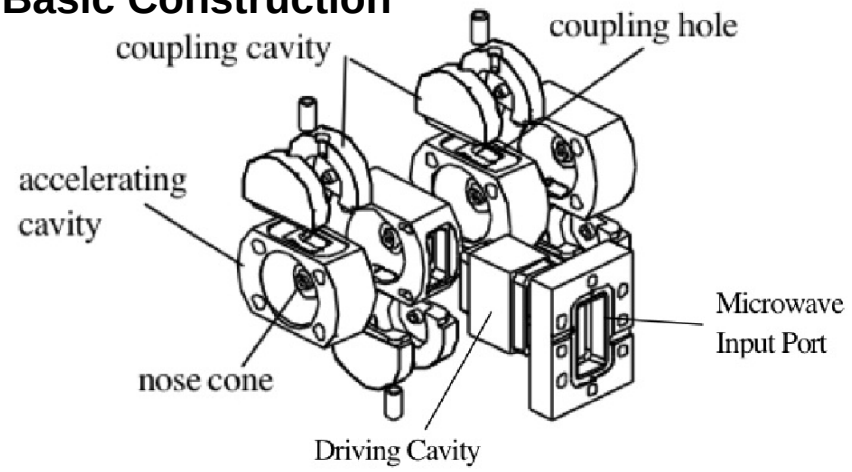
The key innovative technology gives reality.
(Ultra small and light weight C-band LINAC co-dev.with KEK)

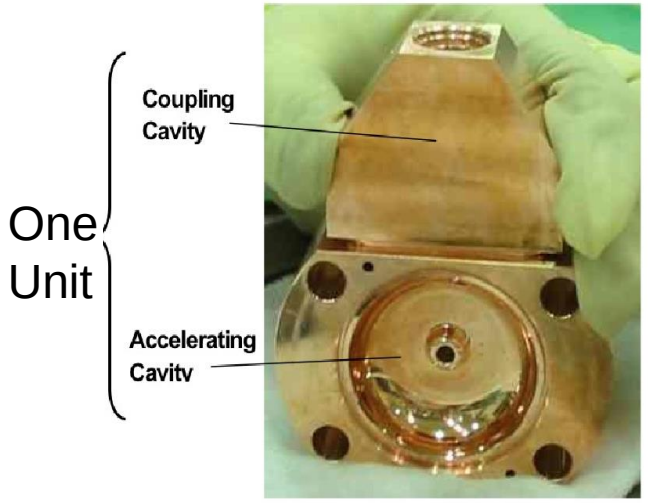


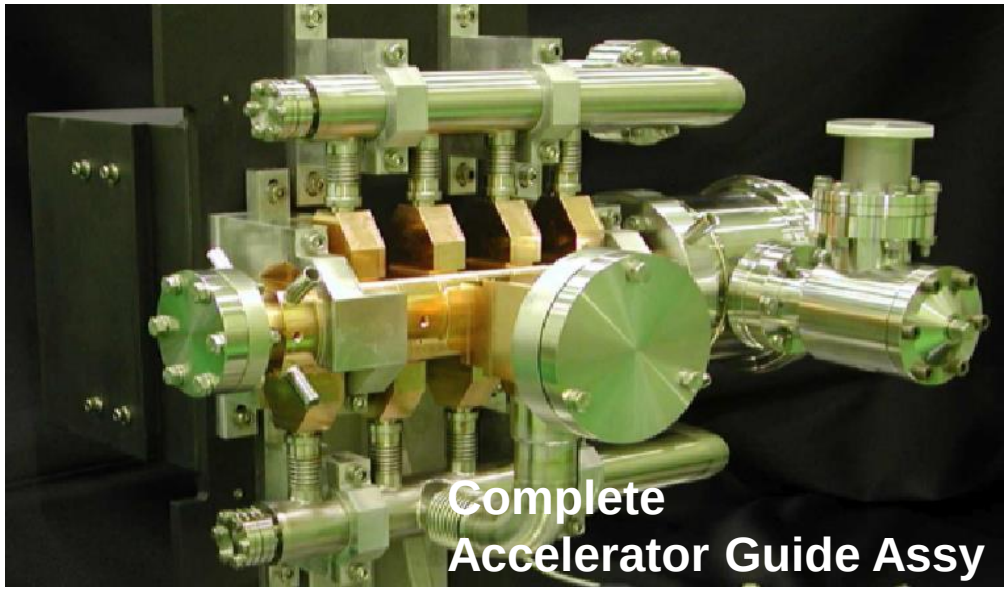
5. Technology taking shape

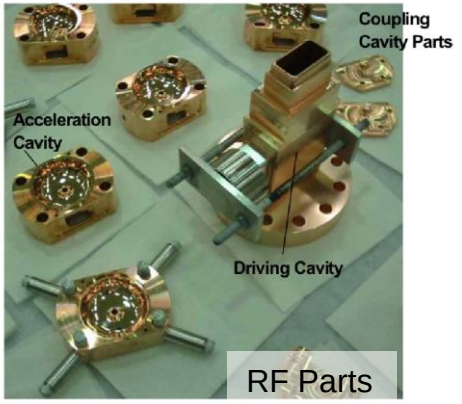
The advanced LINAC took shape.

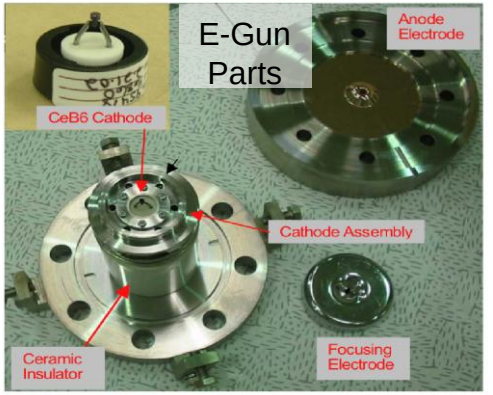
Basic Construction





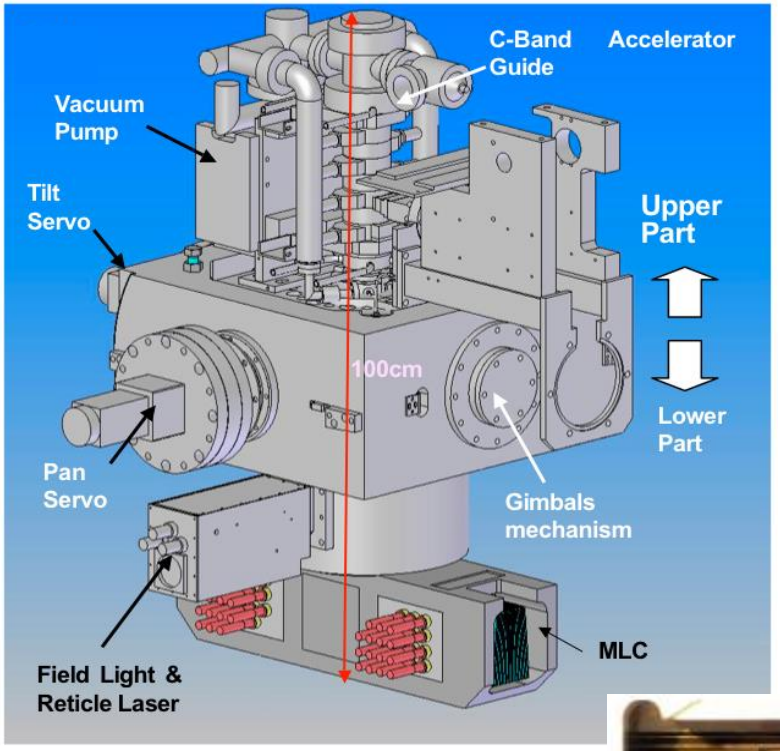


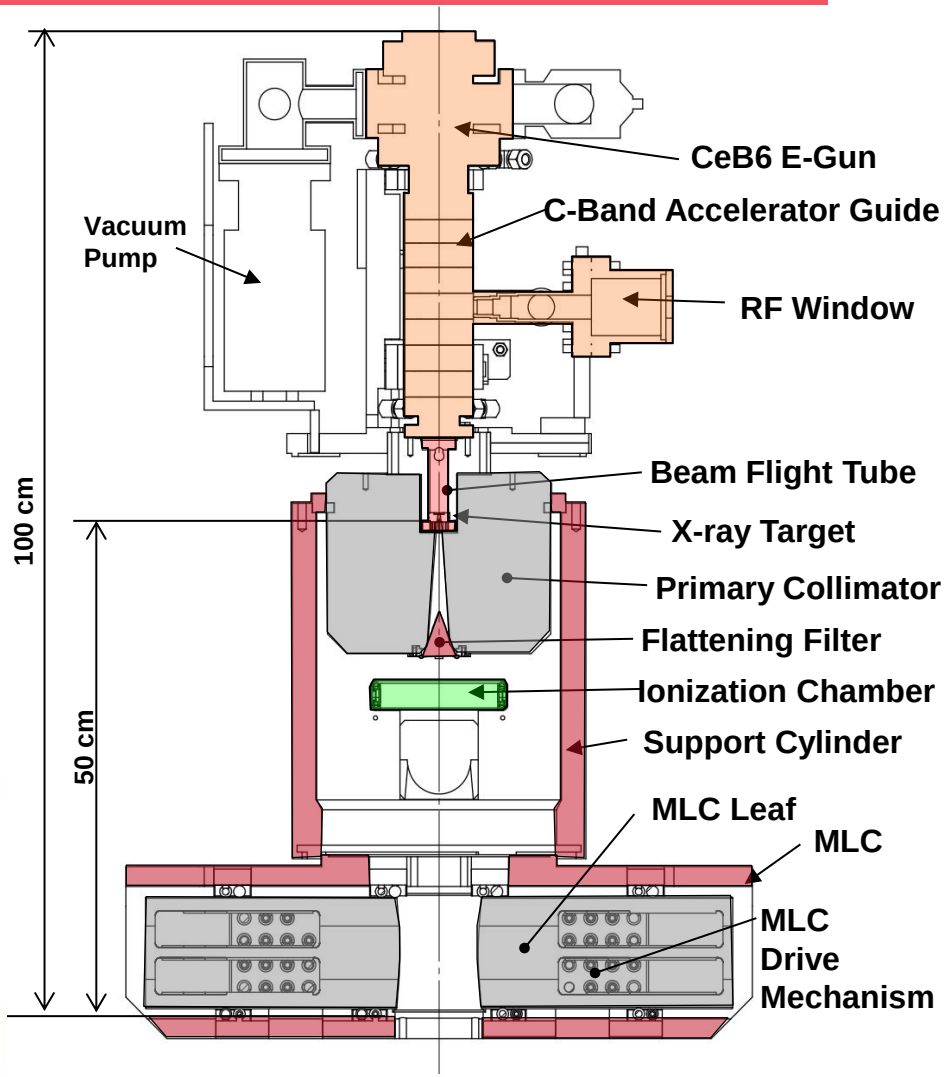




6. Dream system taking shape

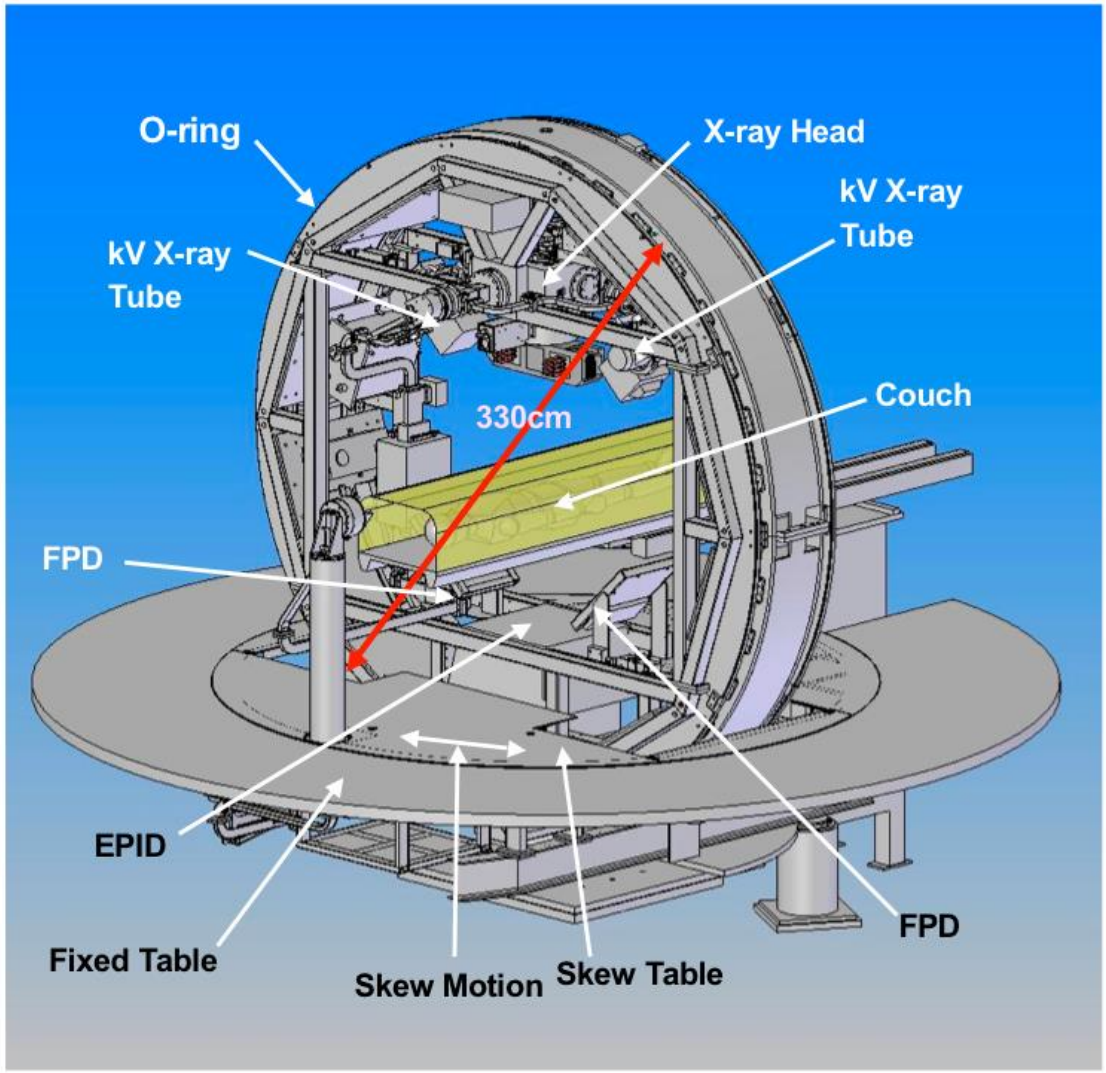
The system are integrated. (Gimbaled X-ray Head)

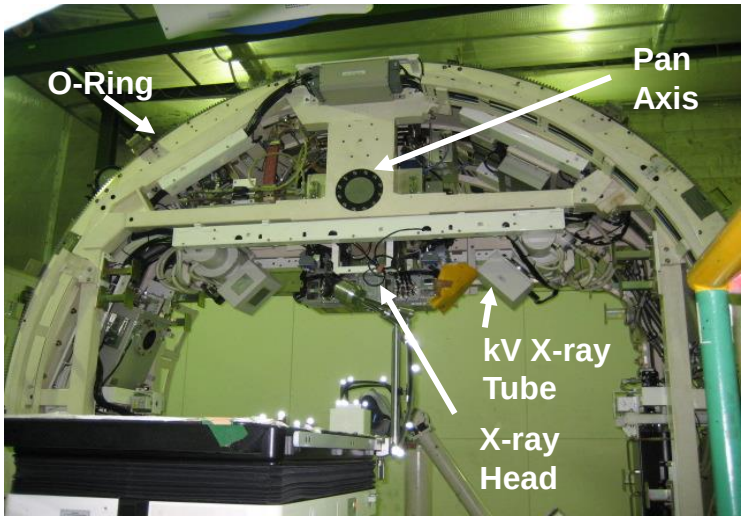


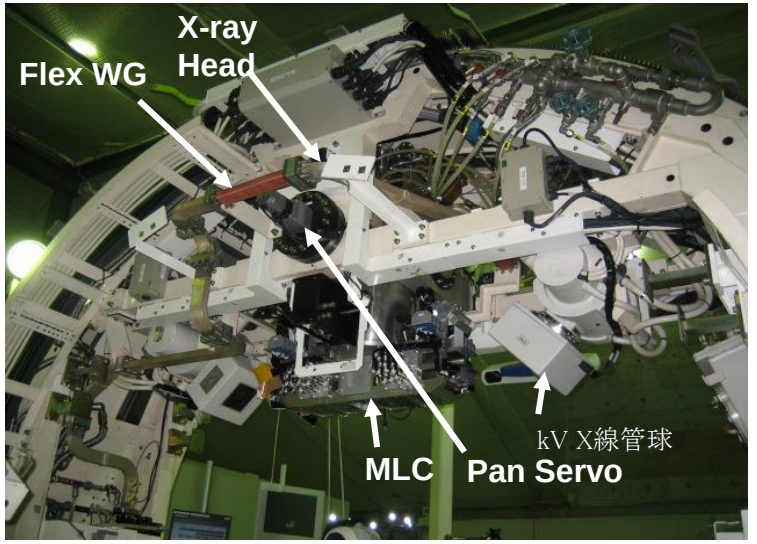


6. Dream system taking shape

The system is integrated. (Complete system)

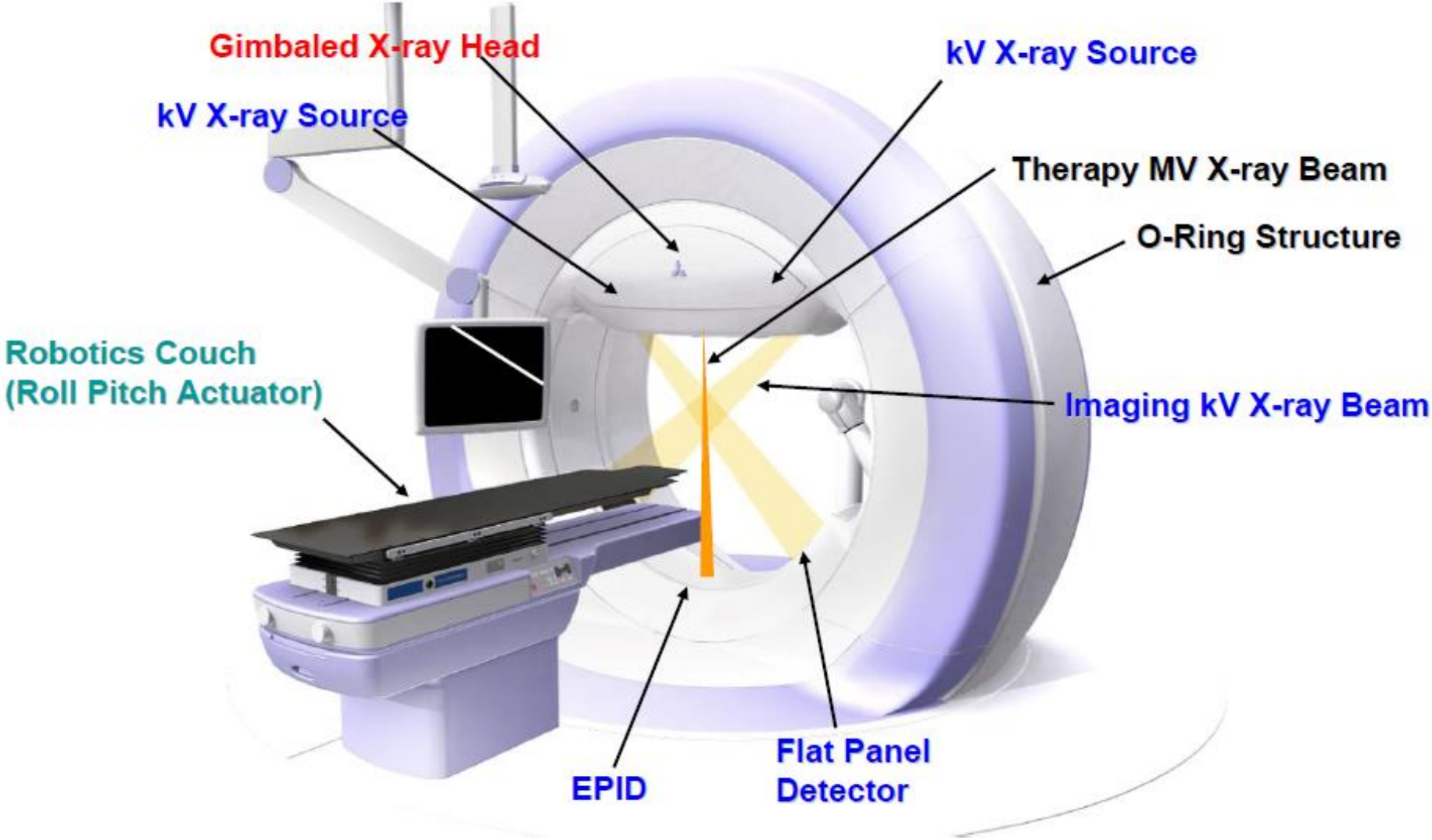






6. Dream system taking shape

The system is refined to the real clinical equipment.



7. Performance validated with phantoms

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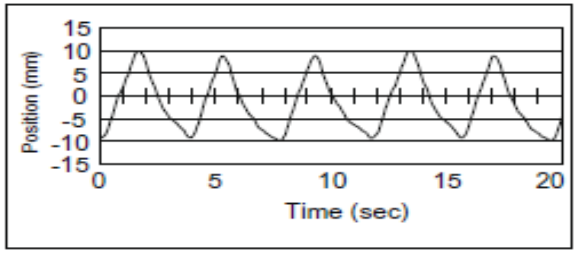
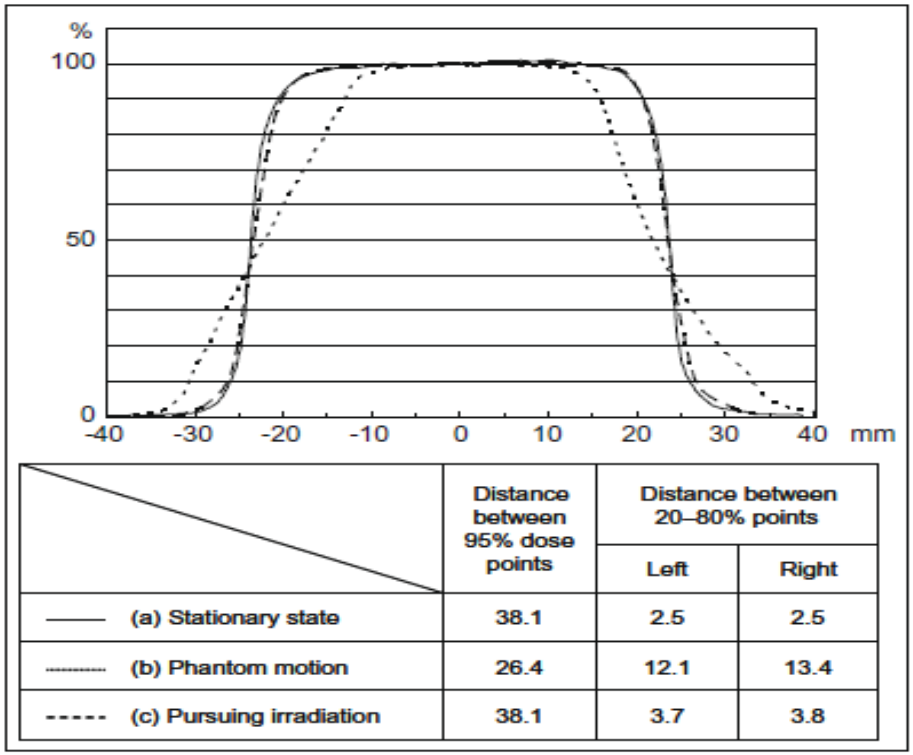
The performance was validated by MD's with phantoms

[3] linear reciprocal motion of a respiration-like wave

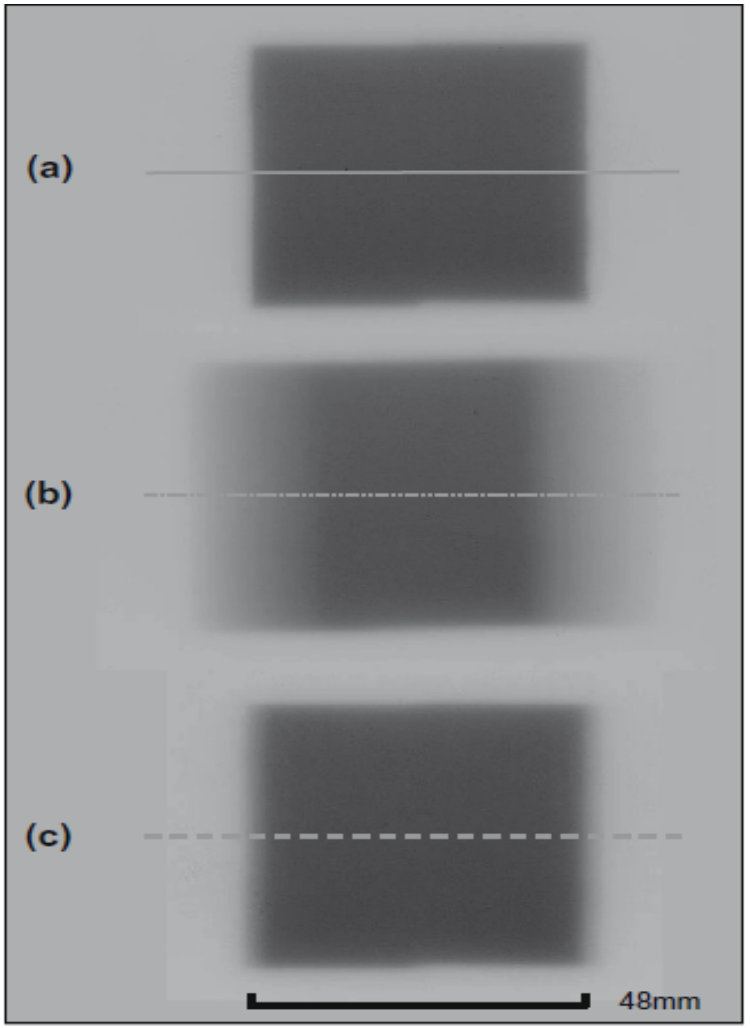
(48- × 48-mm field)





	Distance between 95% dose points	Distance between 20–80% points	
		Left	Right
—— (a) Stationary state	38.1	2.5	2.5
····· (b) Phantom motion	26.4	12.1	13.4
- - - - - (c) Pursuing irradiation	38.1	3.7	3.8

Takayama et al., Radiother. Oncol. (2009)



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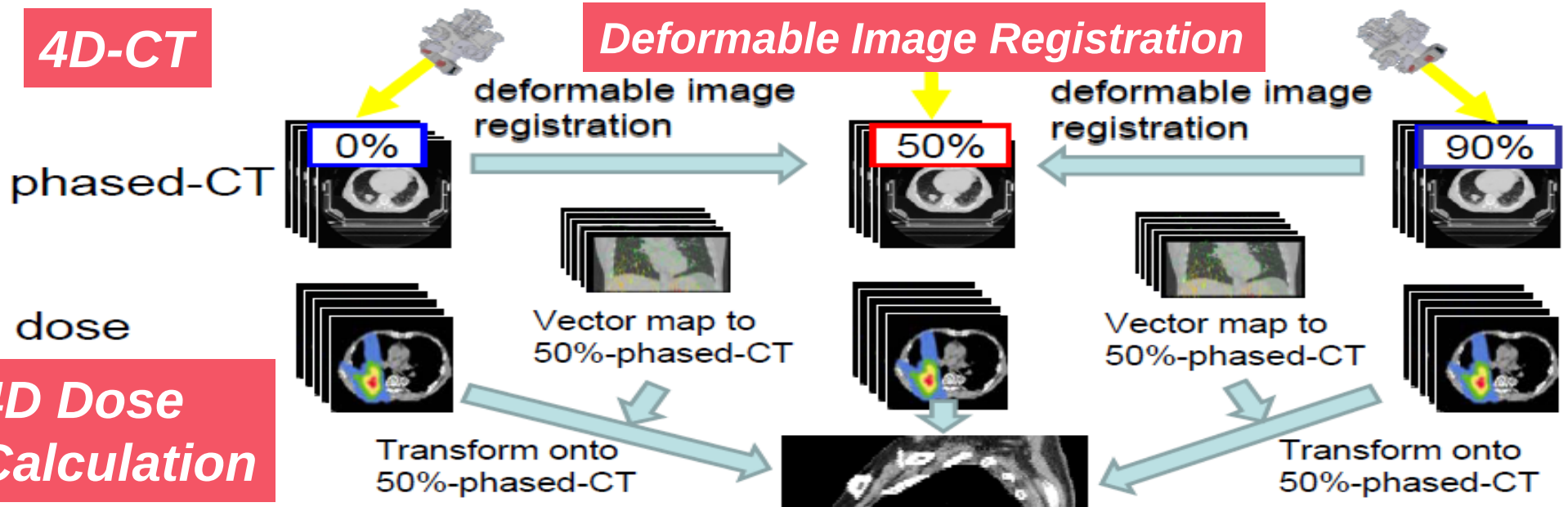
8. Innovation cascade triggered

MD's need the way for therapy planning.
(Innovation cascade triggered)

4D-CT

Deformable Image Registration



4D Dose Calculation

in-house 4D dose calculation system

- EGSnrc-based Monte Carlo
- dose calculation under geometrical condition at each phase
- no variance reduction technique
- fast computation by super computer
- DIR was performed using MIMmaestro

7 field Lung SBRT
14Gy * 4 fr
PTV margin
= ITV + 5 mm (ITV)
= Tracking ITV + 5 mm (DTT)

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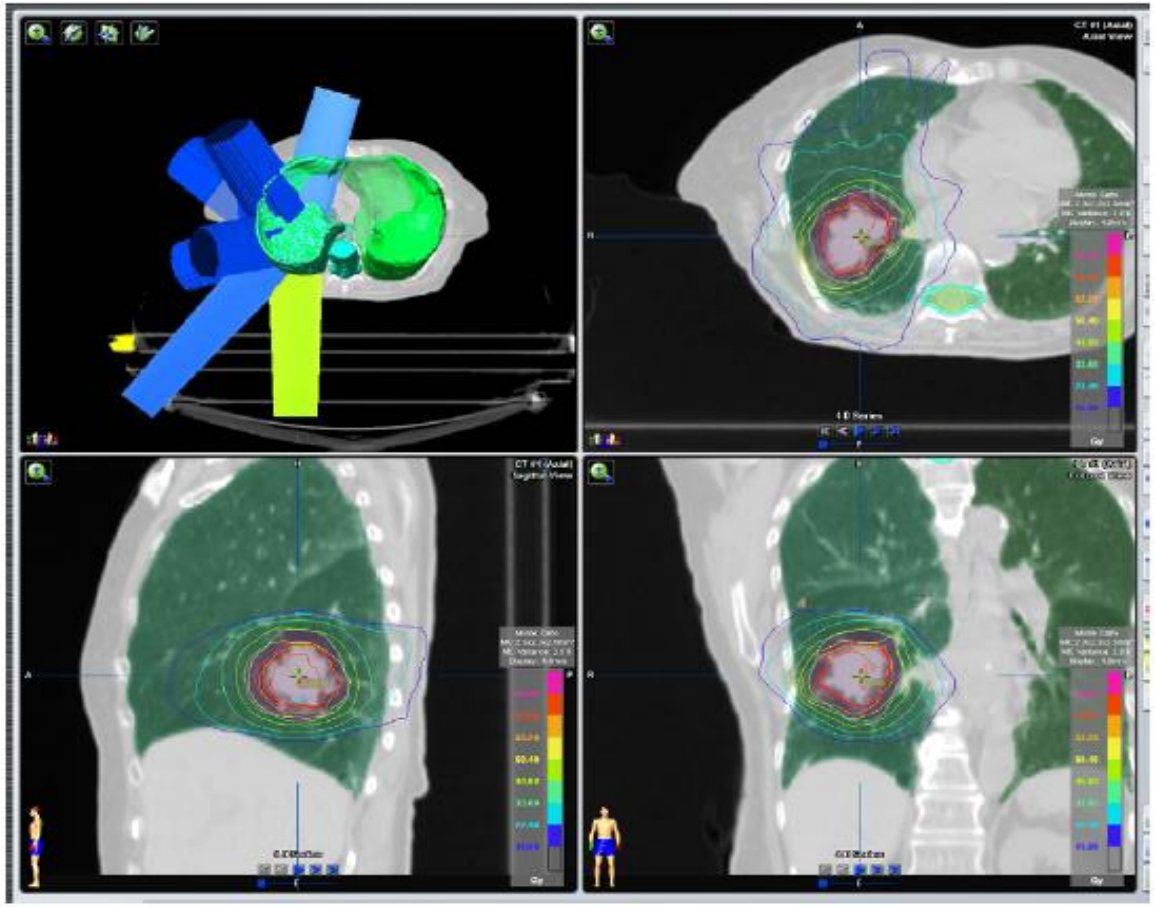
8. Innovation cascade triggered

MD's are developing many clinical technologies.



- Beam arrangement
  - Coplanar 3
  - Non-coplanar 4
- MLC fitting
  - PTV+5mm
- Energy
  - 6MV
- Prescription
  - 14Gy*4fr @IC

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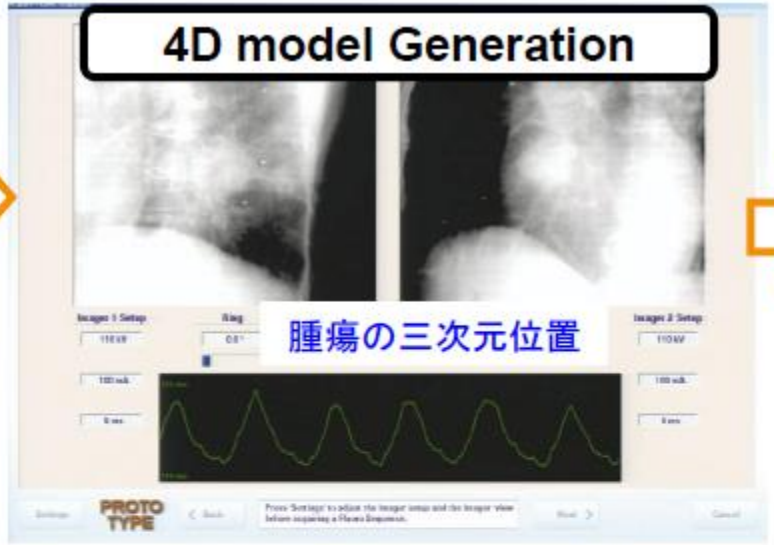
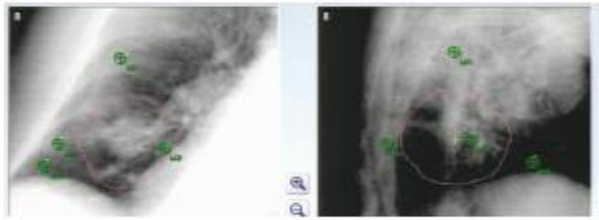
8. Innovation cascade triggered

Clinical Know-Hows are accumlated.

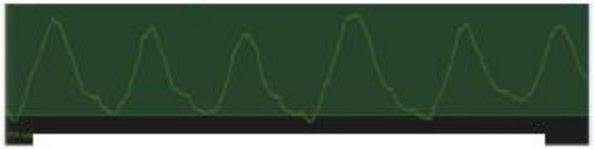
Patient Set Up



Dynamic Tracking Irradiation

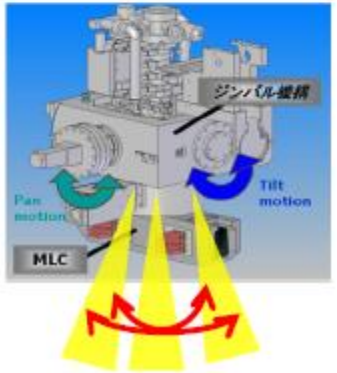


Tracking Confirmation with X-ray



Tracking Confirmation wit IR

Irradiation Verification



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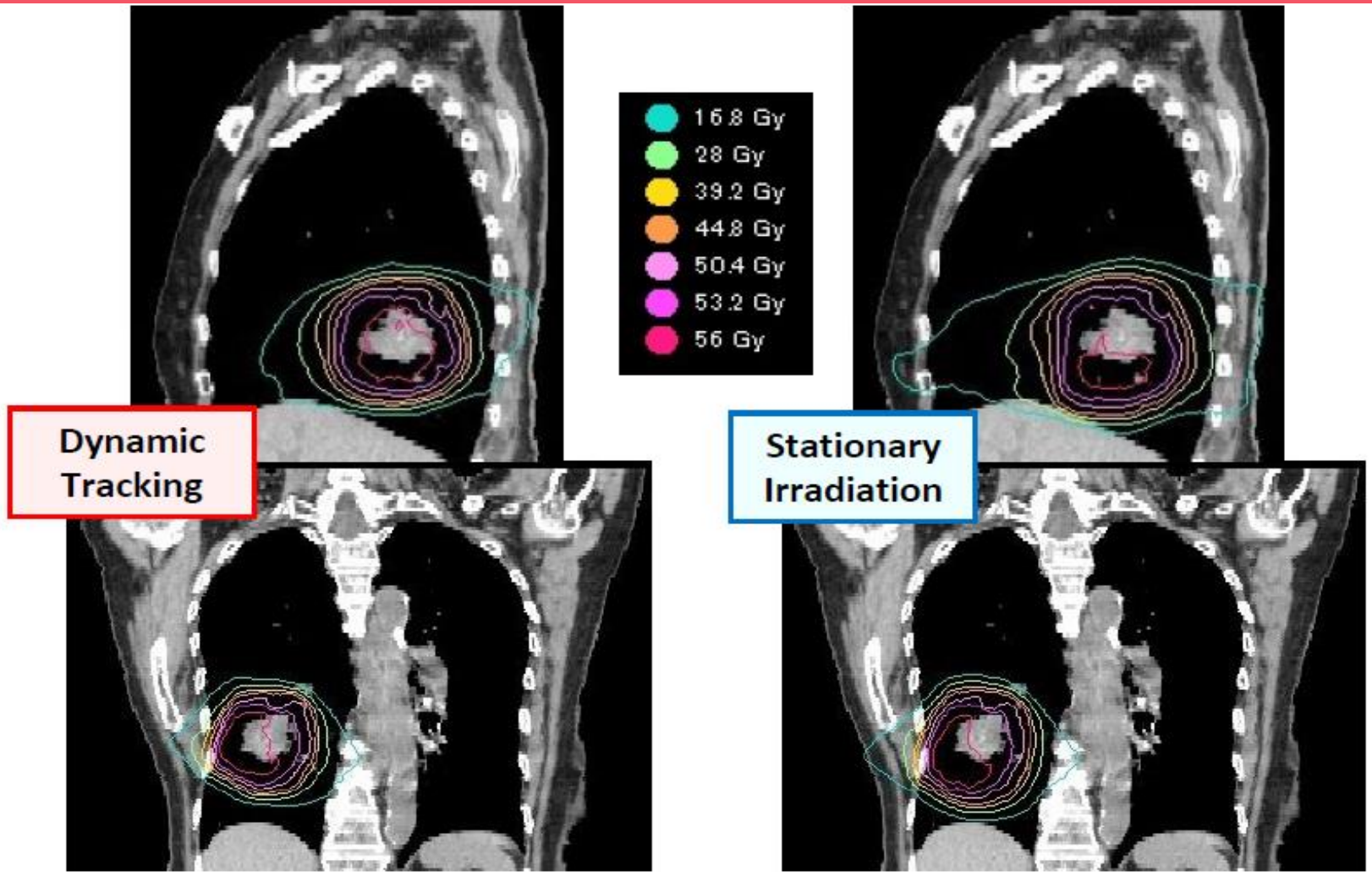
8. Innovation cascade triggered

All technologies are integrated and make the difference.



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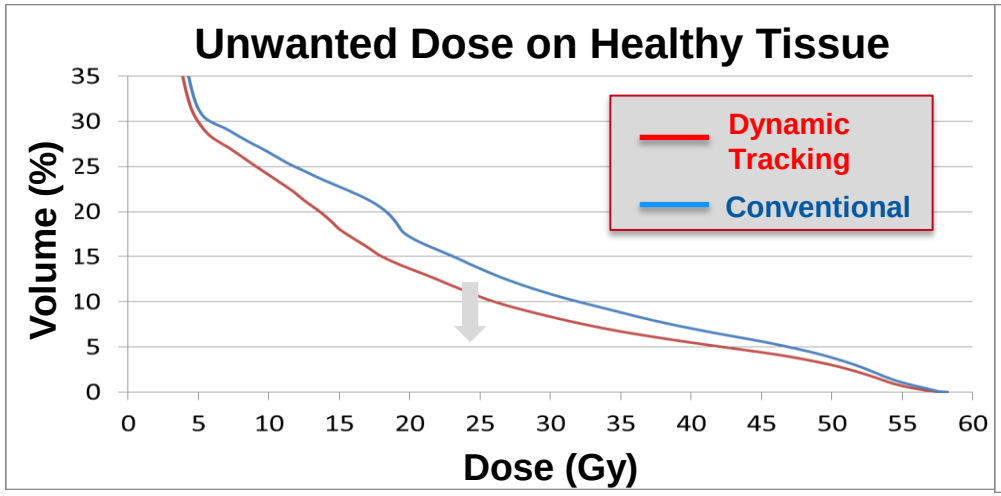
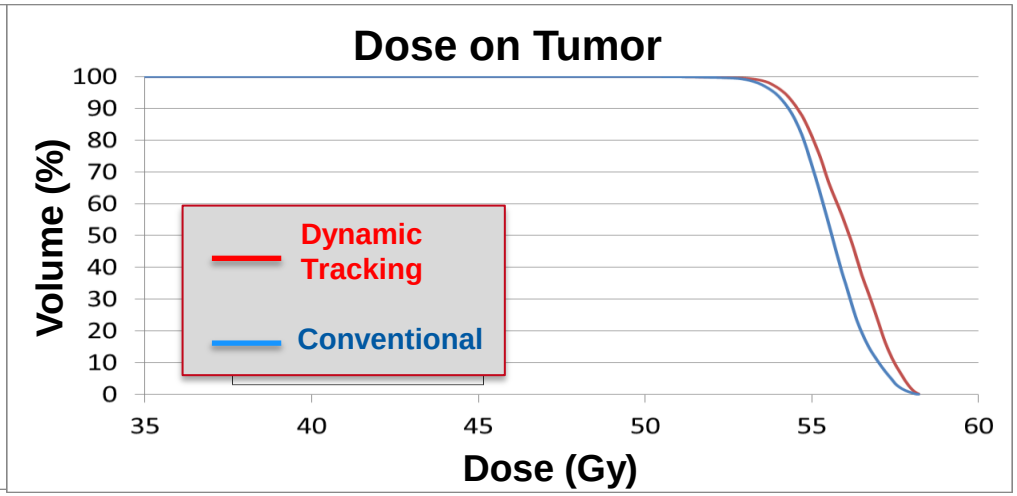
8. Innovation cascade triggered

Clinical gain has been established and many lives are being saved.





Case	Unwanted Dose	Conventional	Dynamic Tracking	Reduction
1	Mean (Gy)	9.3	8.0	-14.0%
	V20 (%)	17.2	13.7	-20.3%
2	Mean (Gy)	2.7	2.5	-8.5%
	V20 (%)	4.1	3.5	-13.2%
3	Mean (Gy)	4.3	3.1	-27.2%
	V20 (%)	6.2	4.2	-32.4%
4	Mean (Gy)	5.1	4.3	-17.0%
	V20 (%)	7.0	5.5	-22.0%

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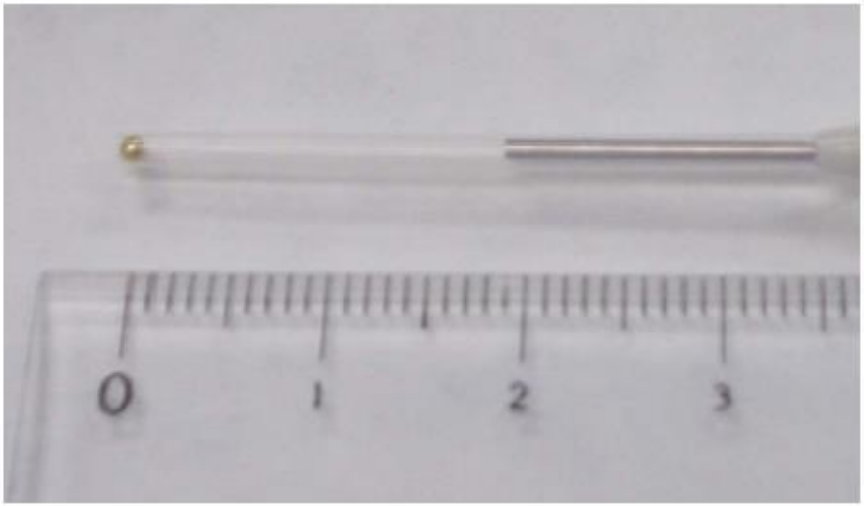
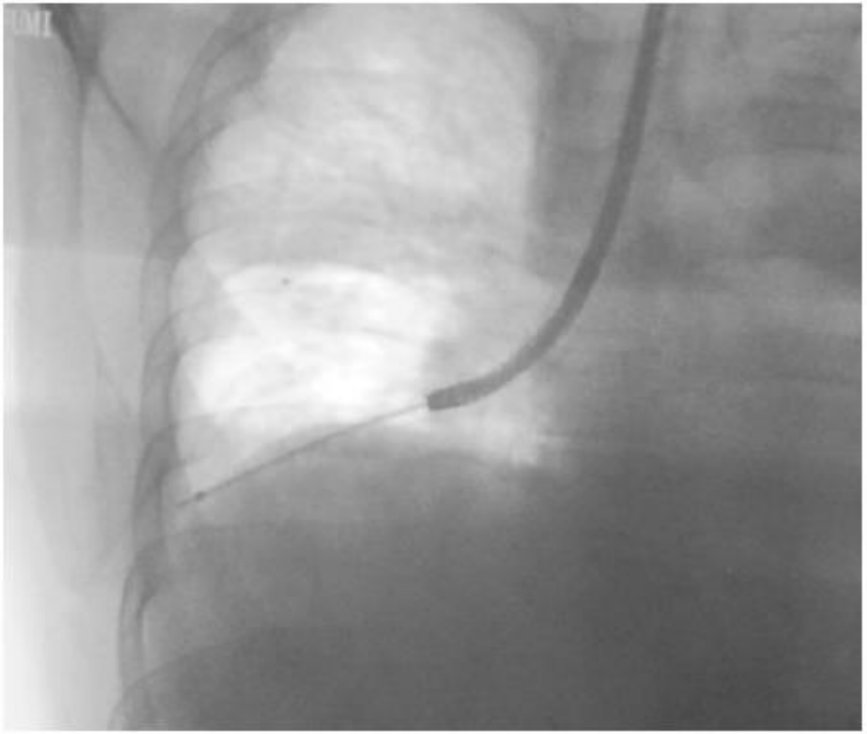
8. Innovation cascade triggered

Many peripheral technologies are being developed.





- Disposable Gold Marker
  (FMR-201CR, Olympus, Tokyo, Japan)
- Marker diameter: 1.5 mm

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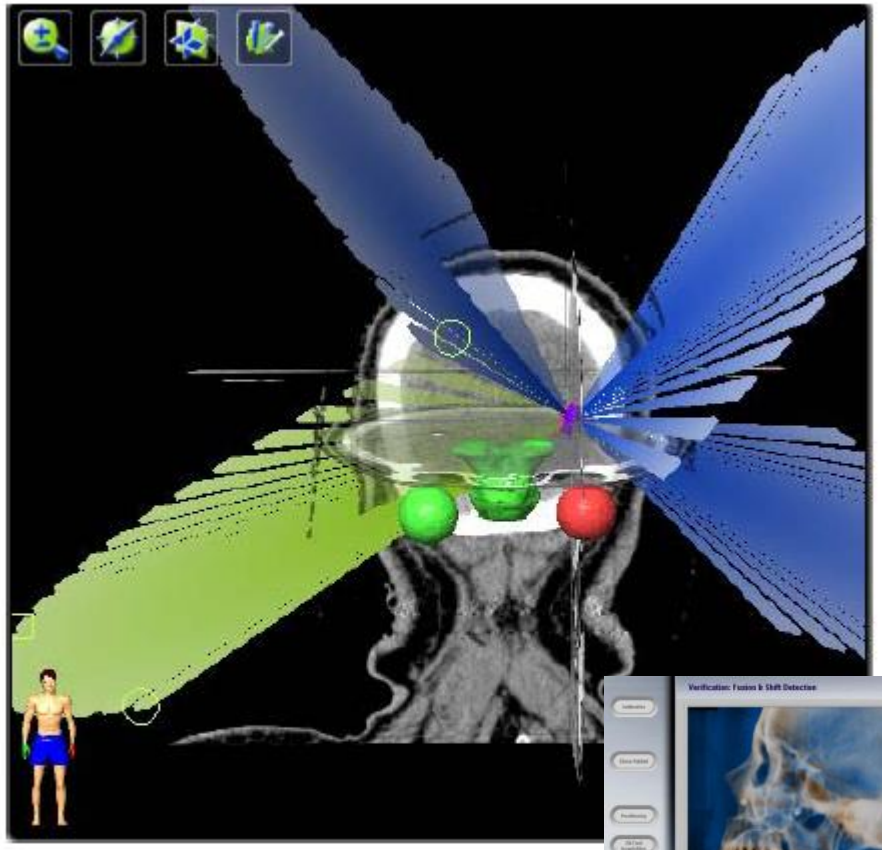
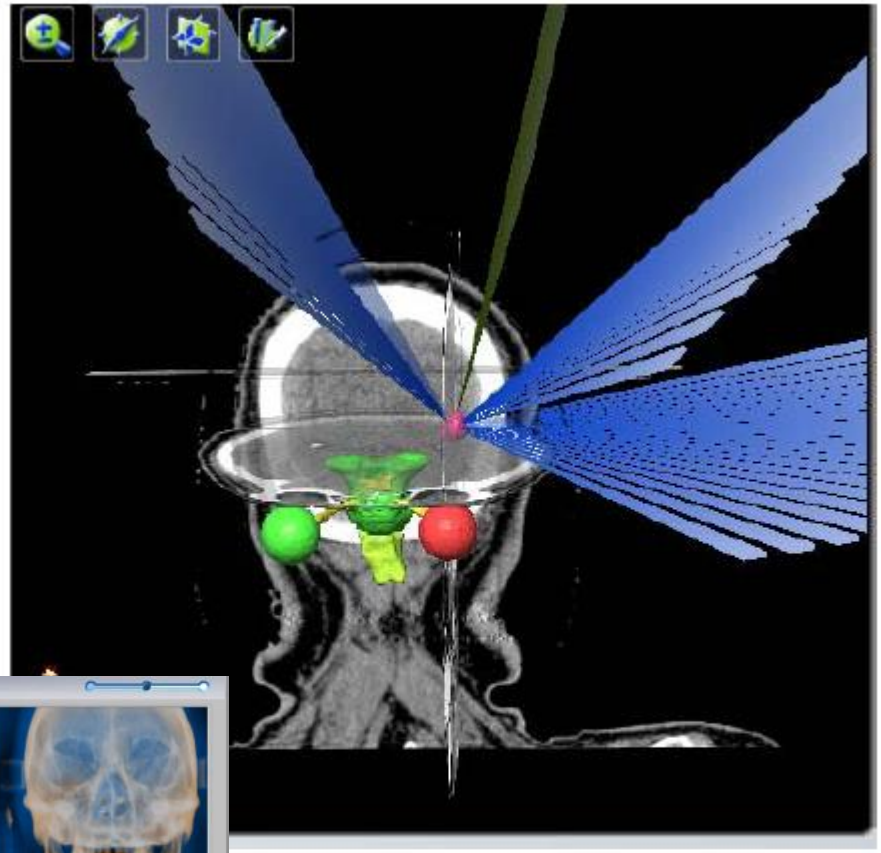
9. Spin-off Medical Technologies

MD's are developing many other clinical technologies.



Vero4DRT

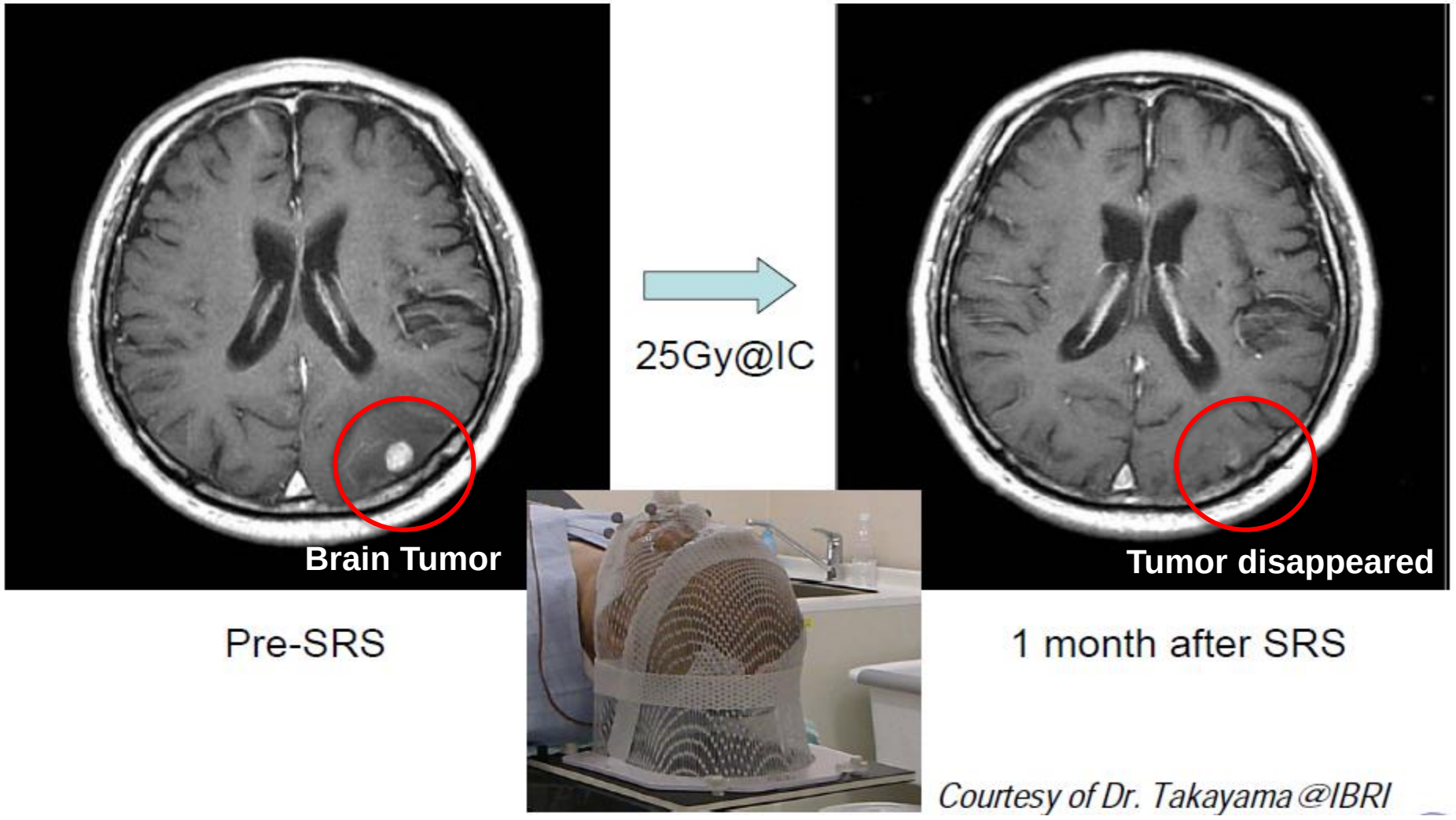


NOVALIS

Courtesy of Dr. Takayama @IBRI

9. Spin-off Medical Technologies

Many people are saved and have a better QOL.



10. Conclusion

>KEK's C-band LINAC technology has enabled the development of the dynamic tracking radiation therapy system.

>The system development has triggered technology innovation cascade in the imaging and computational medicine field.

>Many clinical Know-Hows have been accumulated clinically.

>The total technology cluster is saving many lives daily.

>Technologies developed in the ILC project will trigger much higher and deeper technology cascade in much wider area,

>The ILC project and superconducting accelerator technology will open the door to the future in an unimaginable scale.

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