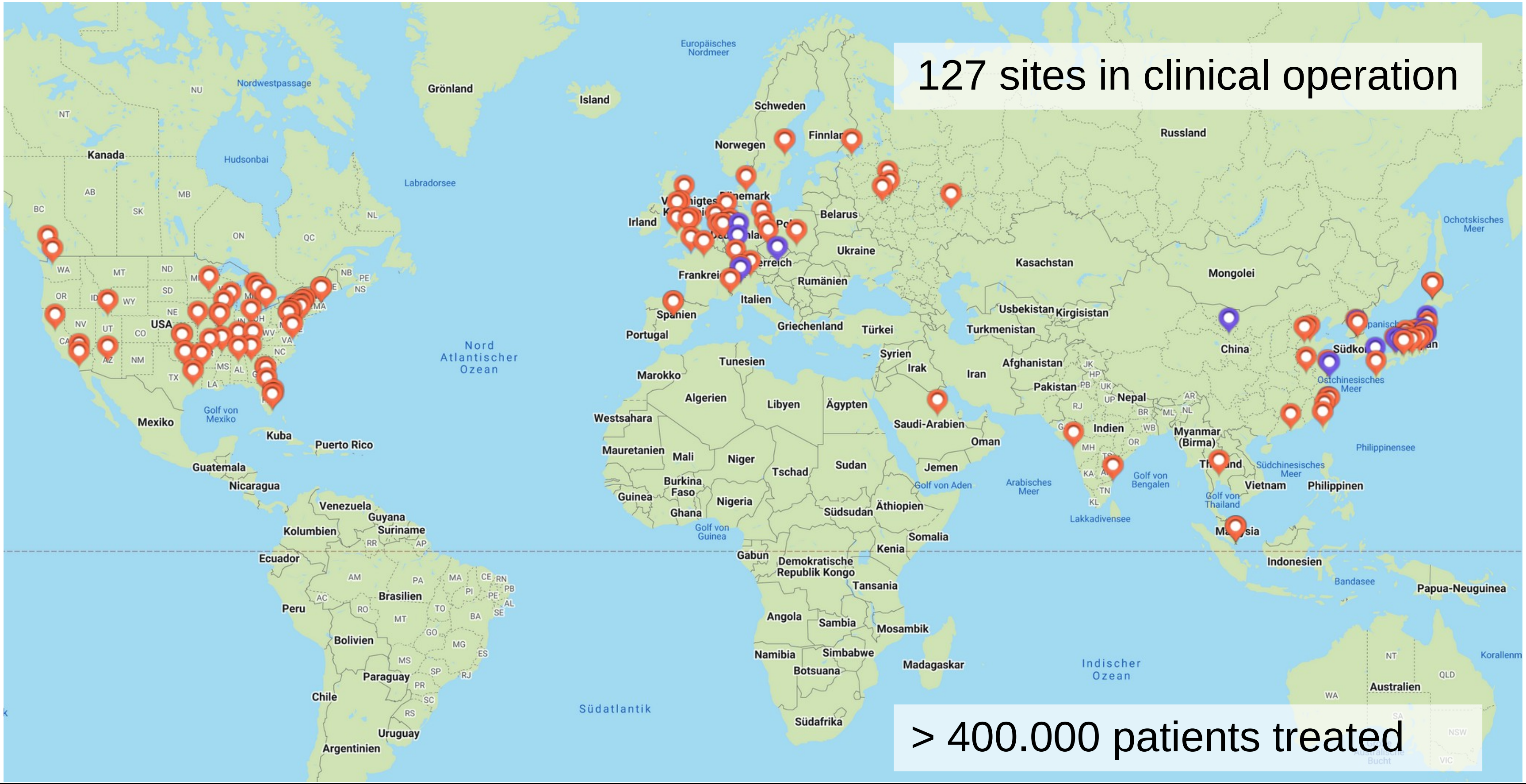
A New System Concept to Democratize Proton Therapy

Overview June 2024

Particle Therapy Sites Today (May 2024)



Why not more?

- Large **investment** > 20 Mio. EUR for the machine, only
- Huge space demand: **Building cost**

- **Decoupled** from conventional radiation therapy facilities
  ⇒ No patient referral
  ⇒ No amortization

What has to change?

- Reduce investment cost: **< 10 Mio. EUR**
- Much **more compact** devices
- **Integration** with conventional radiation therapy facilities

How?

- Adjust technical requirements **to what is really needed.**
  - ⇒ Smaller and cheaper devices

- Implement PT device as **complementary** device for conventional systems.
  - ⇒ No competition
  - ⇒ Greatly improved patient referral

- **No quality restrictions!**

Beam Energy Requirements – the Roots

2.1.1. Energy Range: 70-250 MeV protons at the gantry exit measured with the beam monitors used during patient treatments, but before the vacuum exit window.[6]

Based on the range in the patient and the total amount of absorbing materials in the beam line such as monitors and windows, the energy of extracted protons will be continually variable over the limits of 70 to 250 MeV at the exit of the gantry.

The actual stopping range in the patient will depend on the nature of the beam spreading process, scanning vs. scattering, and how much material such as scatterers and monitors downstream of the gantry exit are present in the beam. The upper energy corresponds to a proton range of 38 cm in water, and may be reduced by minimizing the material in the beam line as long as the range of the 32-cm beam in patient [C-1] is satisfied.

Bill Chu et al. 1993, LBL-33749

$32\ g/cm^2 \triangleq 226.3$ MeV

Clinical Specifications

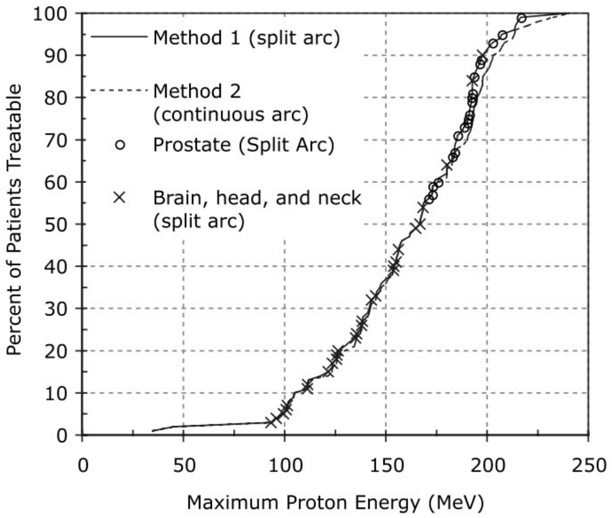
Parameter	Specification
Range in Patient	$32\ g/cm^2$ Max $3.5\ g/cm^2$ Min
Range Modulation	Steps of $< 0.5 g/cm^2$
Range Adjustment	Steps of $<0.1 g/cm^2$
Avg. Dose Rate	25cmx25cm modulated to $32 g/cm^2$: 2Gy in < 1min
Spill Structure	Scanning Ready
Field Size	Fixed >40cmx40cm Gantry >40cmx30cm
Dose Uniformity	2.5%
Effective SAD	~2.5m
Distal Dose Fall-off	$<0.1 g/cm^2$
Lateral Penumbra	<2mm

J. Flanz et al., CYC 1995

Beam Energy Requirements – Newer Investigations

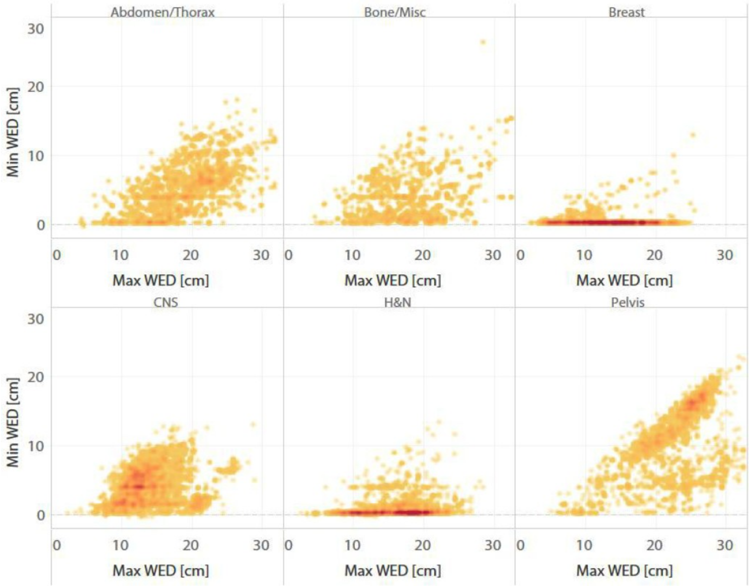
- E. Sengbusch et al. (Med. Phys. 36 (2) Feb. 2009) based on 100 IMRT plans:

  ***90%–95%** of patients can be treated by a proton therapy system that provides a clinically useful beam with a maximum kinetic energy of about **200 MeV**.*



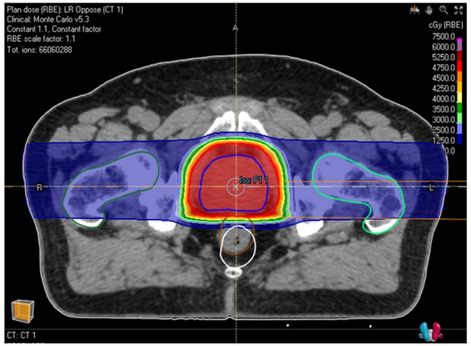
- A. J. Deischer et al. (poster PTCOG 58, 2019) based on 2963 proton plans:

  ***95%** of the fields reached a maximum WED of no more than **26.4 cm**.* (202 MeV)



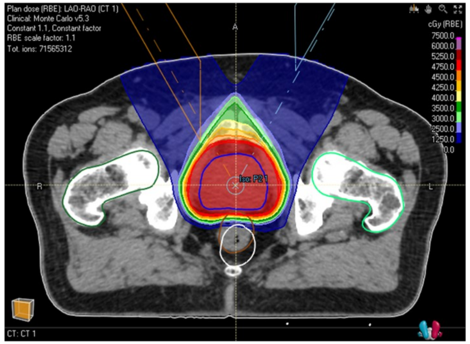
New Planning Approaches – Prostate

Standard parallel-opposed Lats

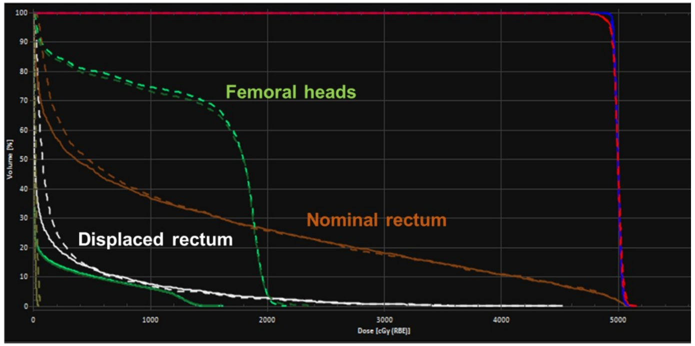


Highest beam energy = **205 MeV**

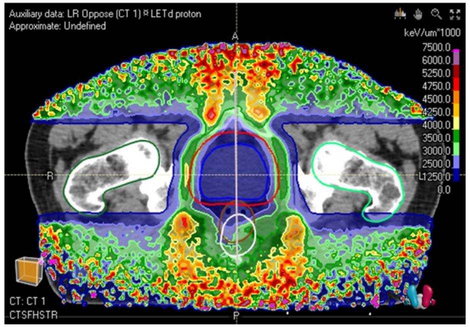
Lt and Rt Anterior Obliques



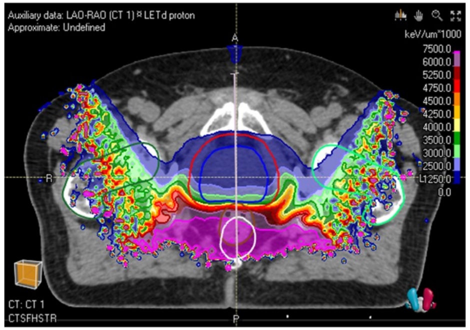
Highest beam energy = **171 MeV**



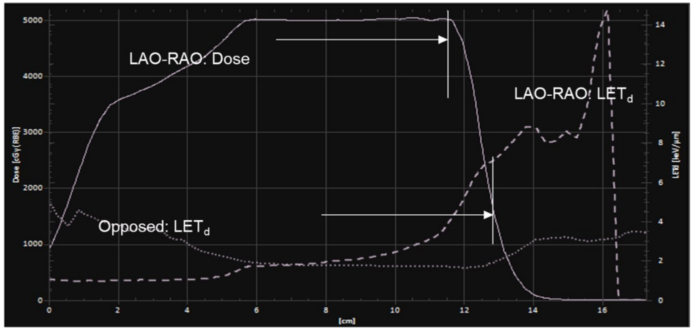
LAO-RAO - - - - - Opposed Lats



LET_d distribution



LET_d distribution

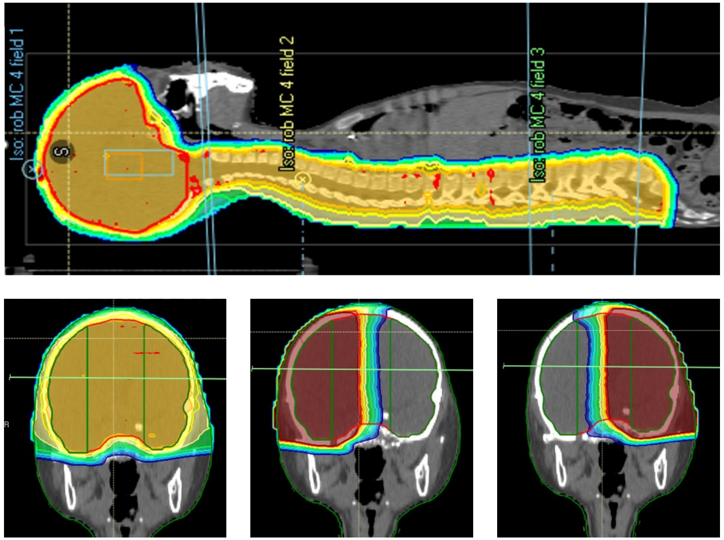


Dose and LET_d data along central AP axis:

- Higher LET_d in rectum for LAO-RAO plan, but at onset of dose fall-off (25% of Rx).

R. Amos, E. Traneus, S. Schmidt 2022

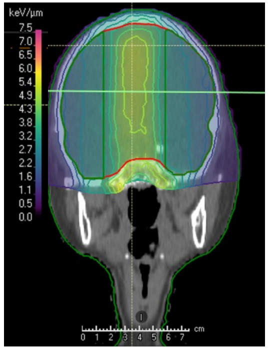
New Planning Approaches – Cranio-Spinal / Brain



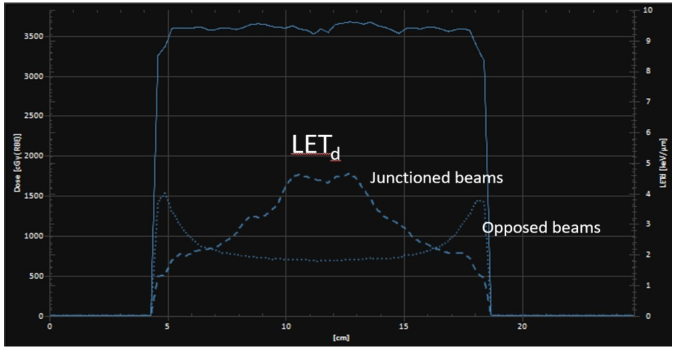
CSI with standard matched PA fields for the spine, and Rt and Lt lateral “junctioned” fields for whole brain by use of LETd penalty functions. The junctioned fields match distally at mid-plane.

- Max. beam energy: spine fields = **150 MeV**
- Max. beam energy: brain fields = **165 MeV**

Standard opposed brain fields were 187 MeV

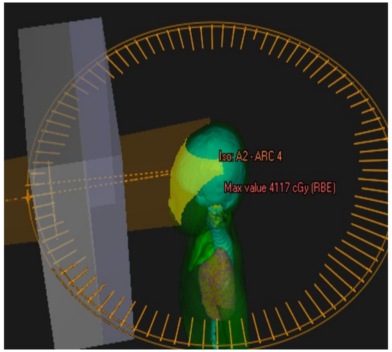


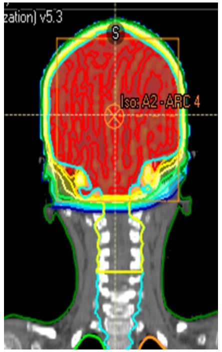
LET_d for junctioned fields



Comparison of LET_d across whole brain for standard parallel opposed fields and lateral junctioned fields.

- Single 360° arc
- Max. energy = **159 MeV**
- Homogeneous LET_d





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Beam Energy – Interim Conclusion

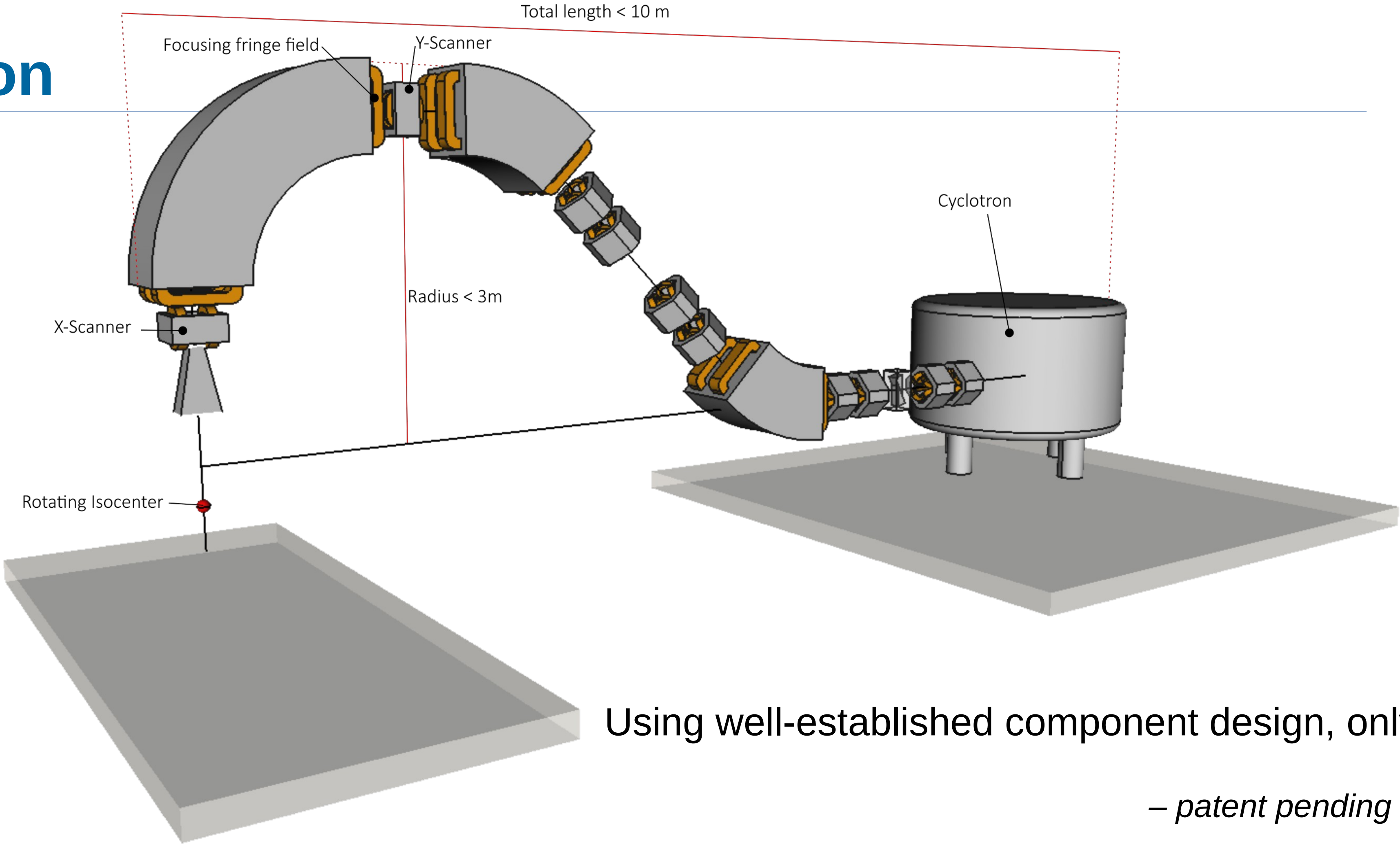
- Treatment plans can be optimized to reduce the maximum required beam energy.
- A maximum beam energy of **170 MeV** (range in water: 19.6 cm) seems sufficient to treat most patients eligible to PT.

- Combined proton/X-ray plans would treat **100%** of the patients

Other Specifications Supporting Democratization

Feature	Technical Impact	Clinical Impact
Reduced Energy of **170 MeV or smaller**	☺ Simpler accelerator, ☺ smaller magnets → ☺ reduced cost and size But also: ☺ Higher transmission, ☺ reduced neutron flux → ☺ less shielding	☹ Max. range of 19.6 cm, ☹ treats >90% of all PT cases (estimation, further studies planned) ! 100% treatable with proton/X-ray combination
No energy filter / ESS	☺ Reduced cost	☹ Slightly increased distal fall-off
Reduced field size of 10 × 10 cm^2	☺ Smaller scanning magnets, ☺ simpler scanning power supplies, ☺ smaller and simpler Nozzle components → ☺ reduced cost and size	! Larger field sizes available by field patching
Scanning through last bending magnet (one direction, only)	☺ Reduced gantry diameter → ☺ reduced cost	None (only feasible with reduced field size)
Reduced SAD ~1.40/2.50 m	☺ Reduced gantry diameter → ☺ reduced cost	☹ Somewhat increased surface dose
Non-isocentric gantry/table geometry	☺ Reduced gantry diameter → ☺ reduced cost	None
"Flexible Gantry" (reduced rigidity, high reproducibility)	☺ Less steel → ☺ reduced cost	☹ Compensation by table motion / automated beam tuning correction required

Solution



Using well-established component design, only

– patent pending –

Other Features

- Integrable **standard imaging solutions**
  - Dual X-rays
  - CBCT

- **Proton-Arc** compatible

- **FLASH** compatible (design supporting large dose rates)

- **Integrated** solution using **combined proton/X-ray plans**

One Word about Seated Treatment

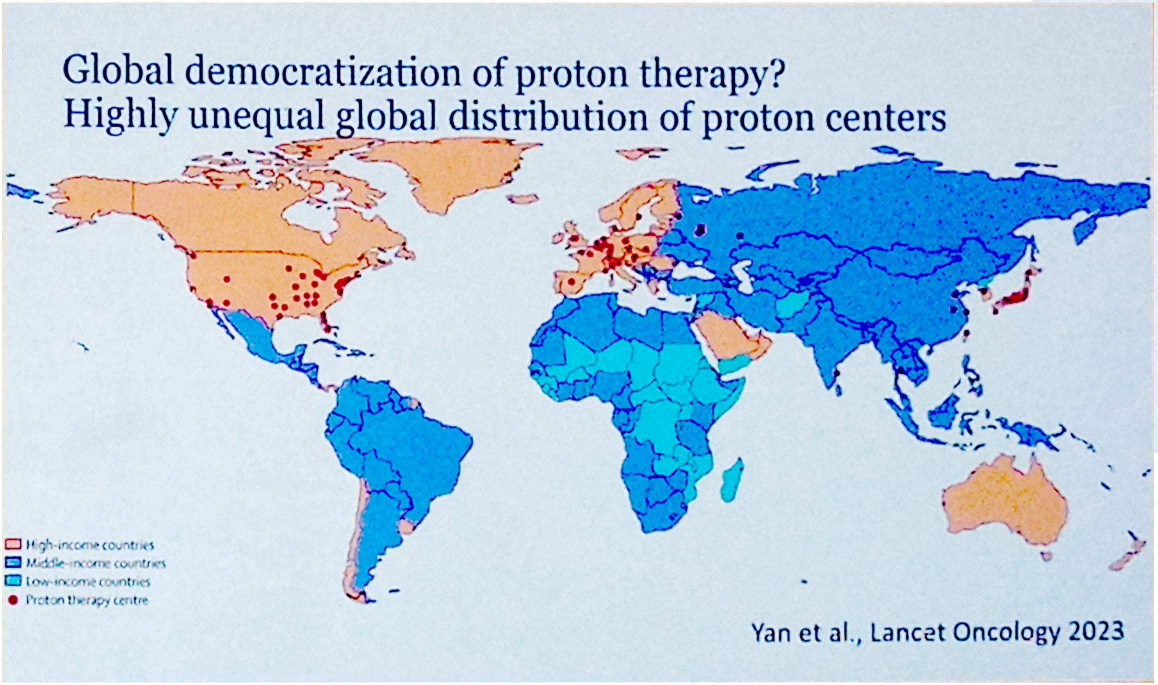
Yes, but …

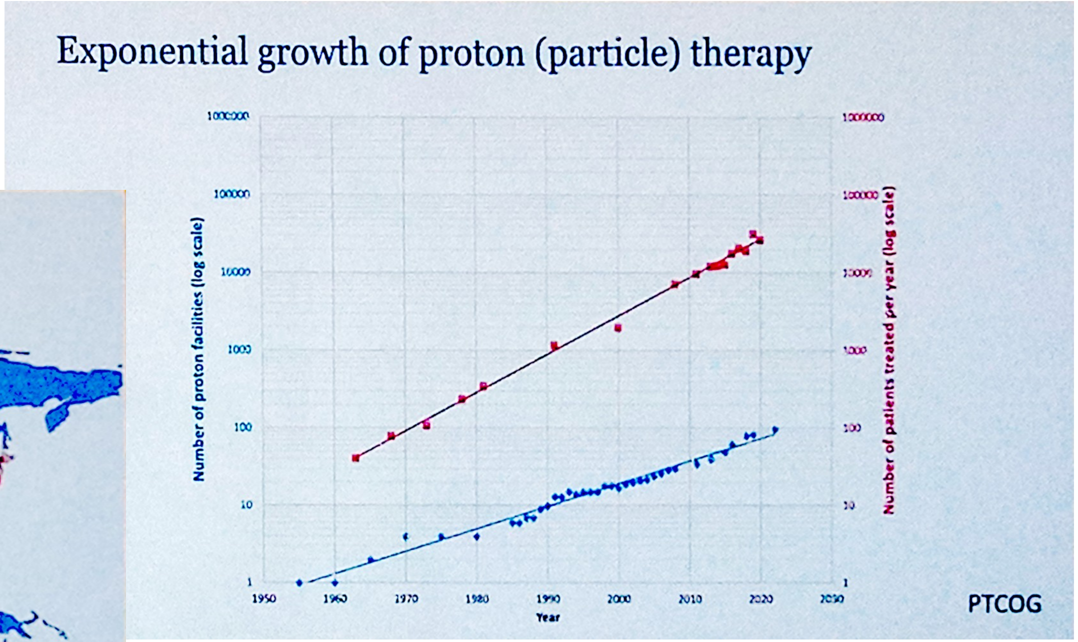
- Cost of vertical CT > 1 M€
- Cost of small gantry < 1 M€

Buzz Words

- Low cost
- Small size
- Integration: Complement to conventional RT
- No development risk

Impressions from PTCOG 61





More Information

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