# GLOBAL INDUSTRIAL DEVELOPMENT OF ACCELERATORS FOR CHARGED PARTICLE THERAPY

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# Hadron Therapy Accelerators
## Overview

1 | WHY HADRON THERAPY

2 | REQUIREMENTS & CONSTRAINS

3 | SOME EXAMPLES / ACCELERATORS IN USE

4 | OUTLOOK



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# WHY HADRON THERAPY

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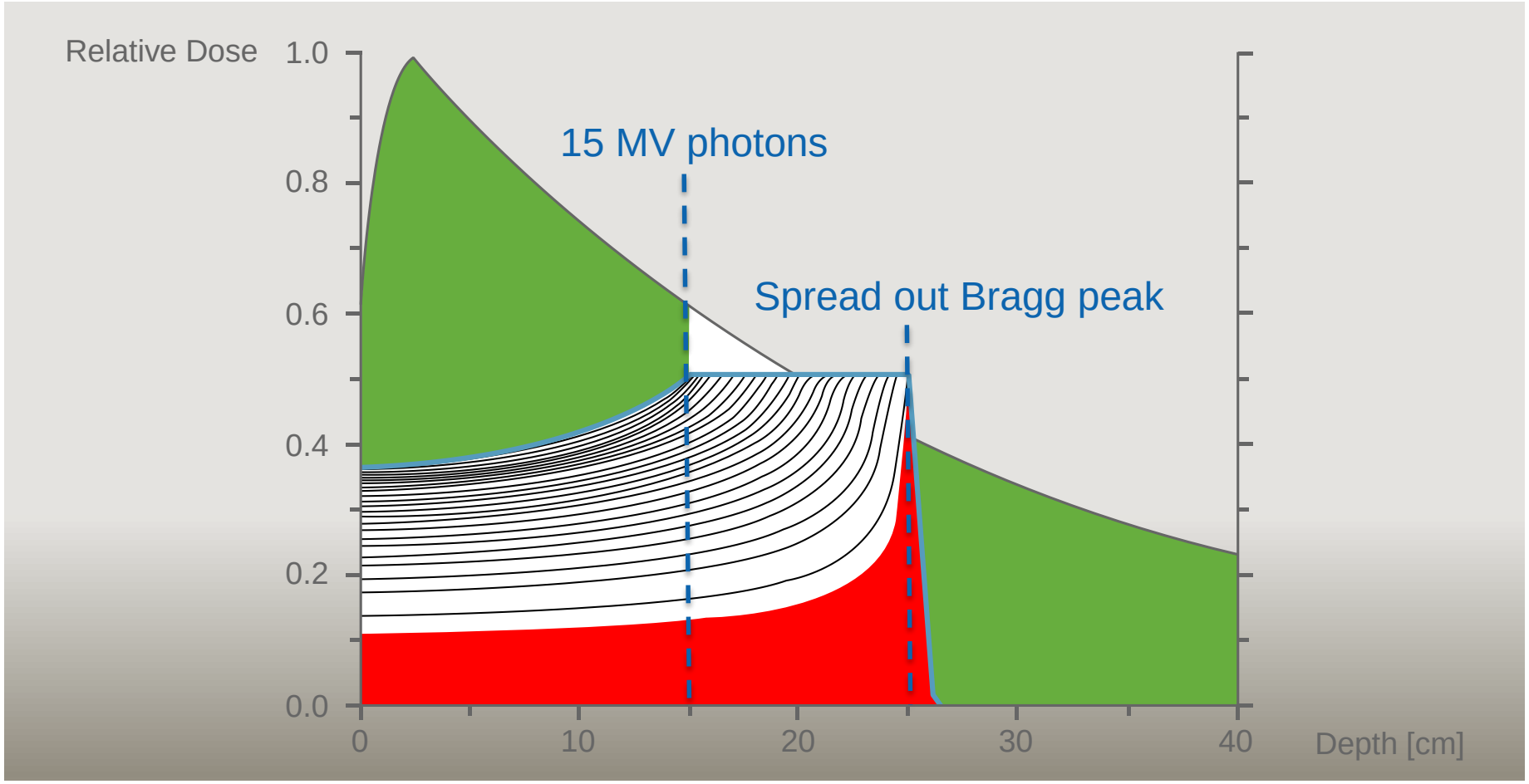
# Why Hadron Therapy?

## Proton Bragg Peak allows highest dose conformity to tumor and lowest dose to healthy tissue



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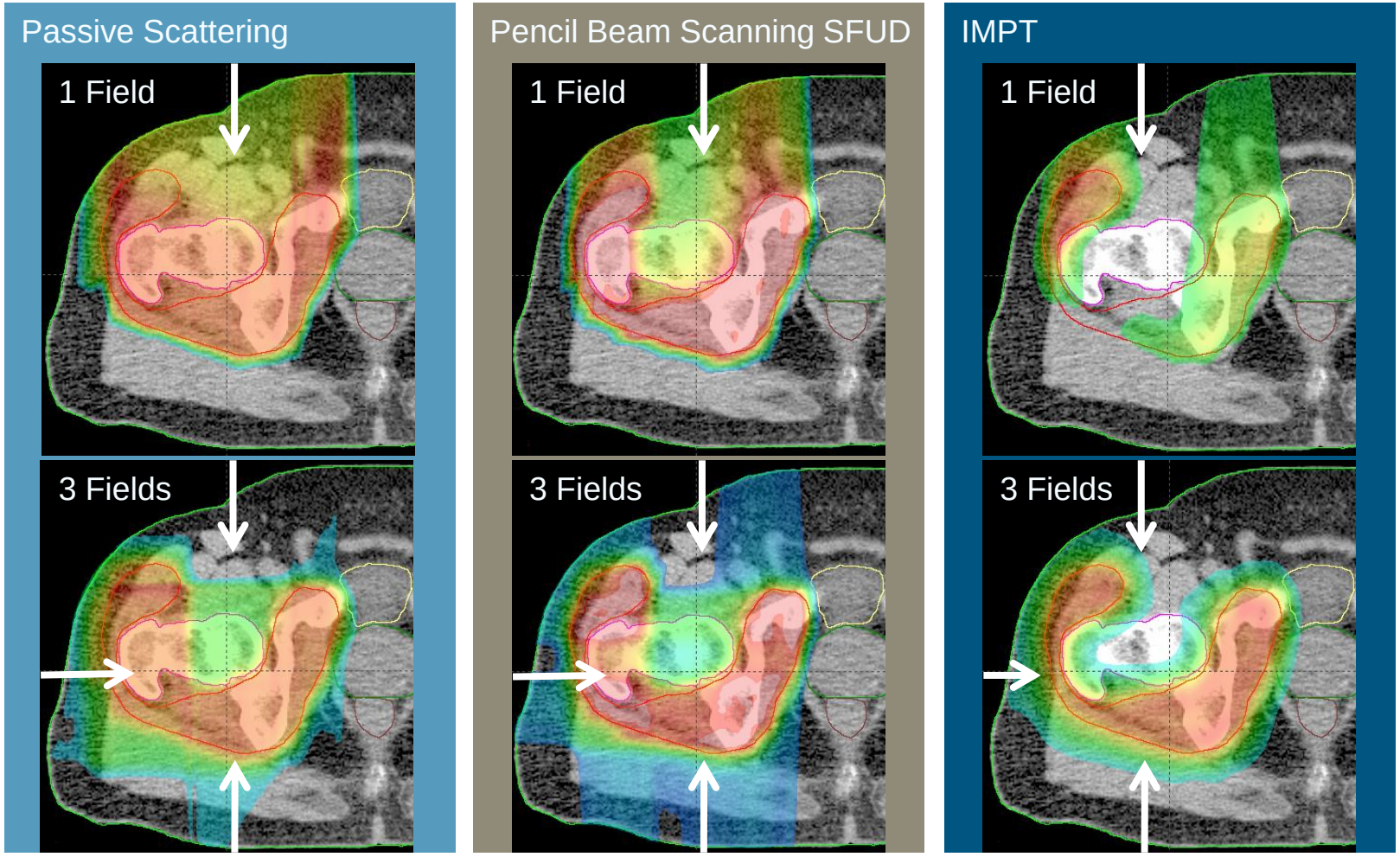
# Beam Delivery – Proton Planning Comparison

## IMPT delivers best conformity




Tony Lomax, PSI



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Proton therapy is used for a variety of cancer cases including head & neck, lung and pediatric.
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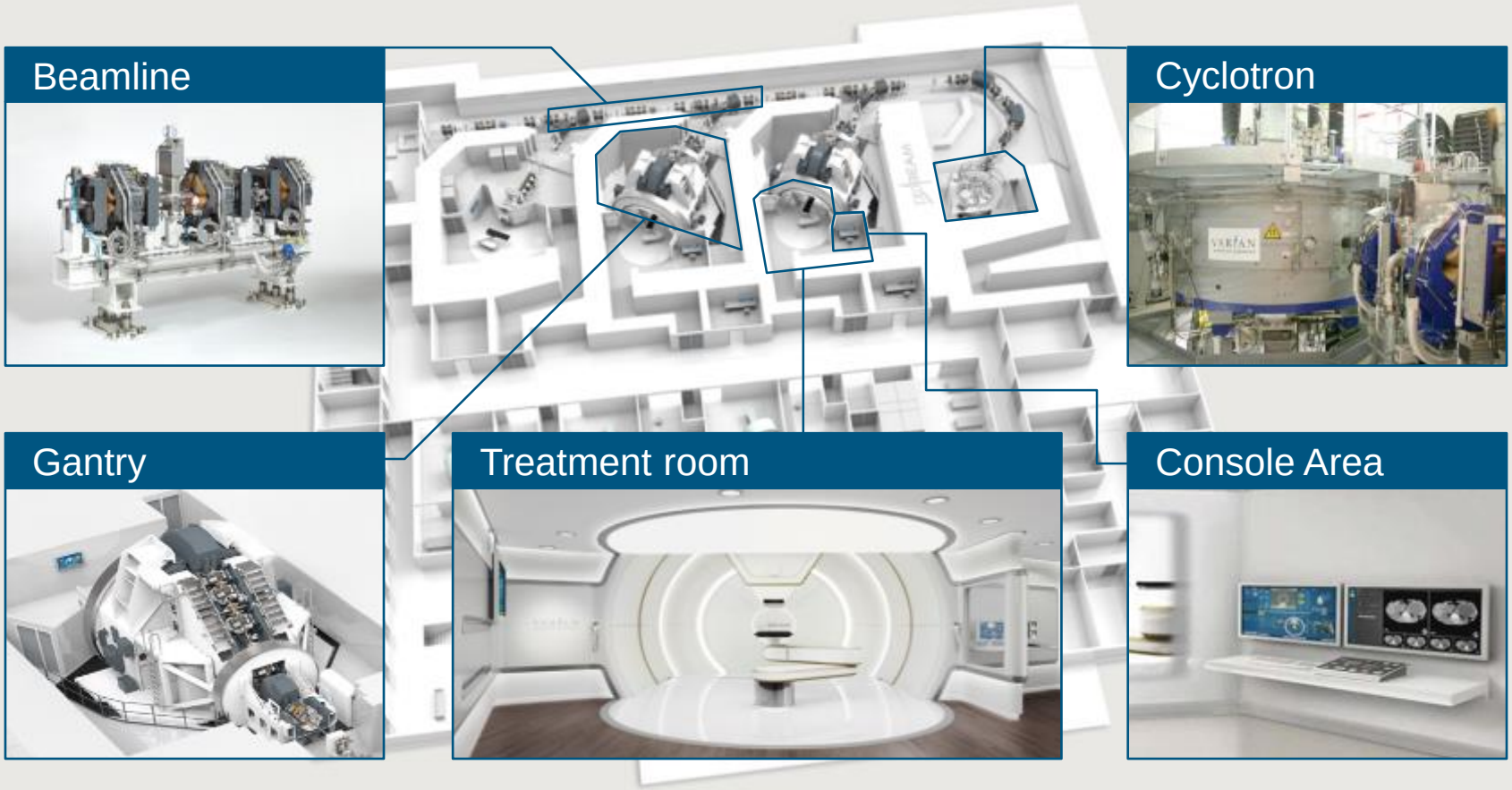
# Hadron Therapy Facility

## Much more than only the Accelerator



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# REQUIREMENTS & CONSTRAINS

Photons / Hadrons

Scattering / Scanning

Requirements

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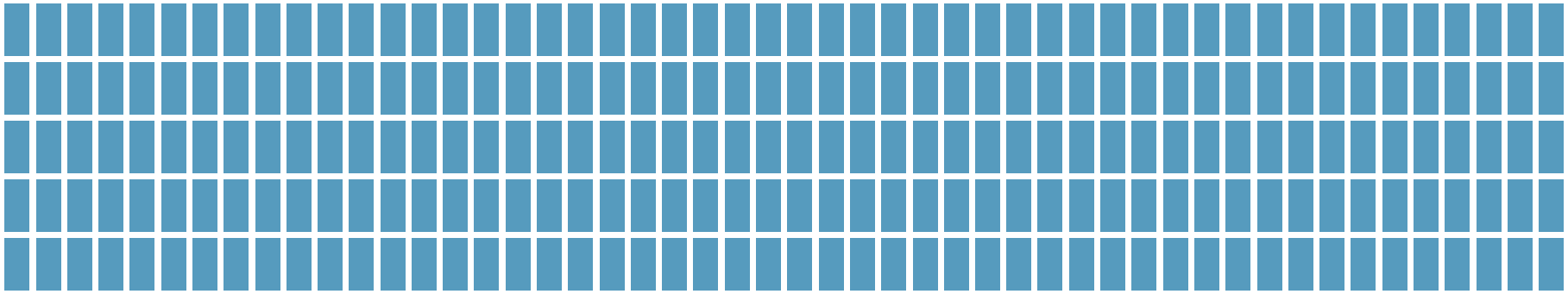
# Hadron Market

## Patients Treated Worldwide



50,000,000 patients treated with photons

. 100,000 patients treated with hadrons



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# Proton Therapy
## Current State of Affairs

| | PHOTONS | PROTON |
|---|---|---|
| PRICE | 2 – 3.5 MUSD | 20 – 35 MUSD |
| FOOTPRINT | 100 $m^2$ | 200 – 400 $m^2$ |
| COST PER TREATMENT* | 400 Euro | 1000 Euro |
| PATIENTS PER YEAR | 2,500,000 | 12,000 |

* M. Goitein, M. Jermann, Clinical Oncology (2003) **15**: S37-S50


Company confidential

# Proton Therapy Business Model
## Financing

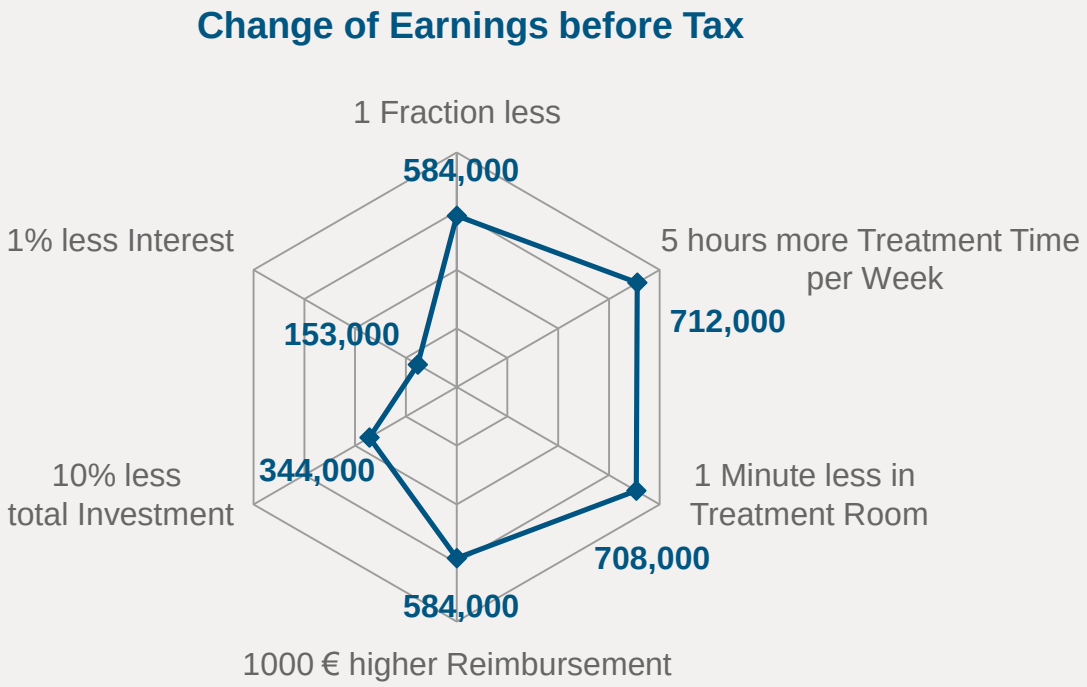
Different Financing for Public and Private Sector

Financeability for Private Project depends on:

- Profitability shown by robust business model
- Low Risks

Simple Business Model:

- 3 year from start to first patient
- Single room
- 500 Patients per year





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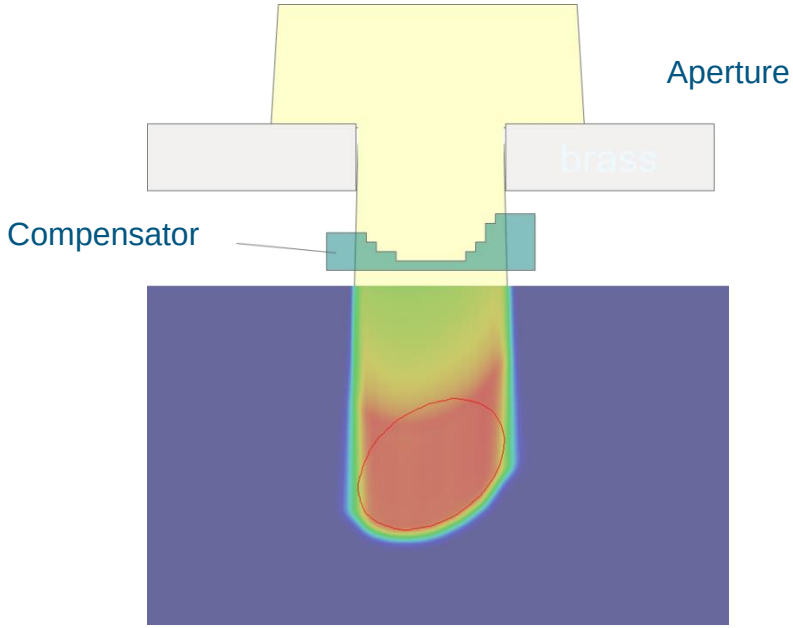
# Beam Delivery – Scattering

## The Price – Patient specific hardware ....

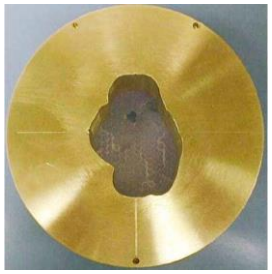
### Transversally spread beam is created by scattering




A compensator is used to shape the proton beam to the distal edge of the target

For each field:

- Machining of patient specific aperture and range compensator
- Manual exchange of patient specific HW before irradaition





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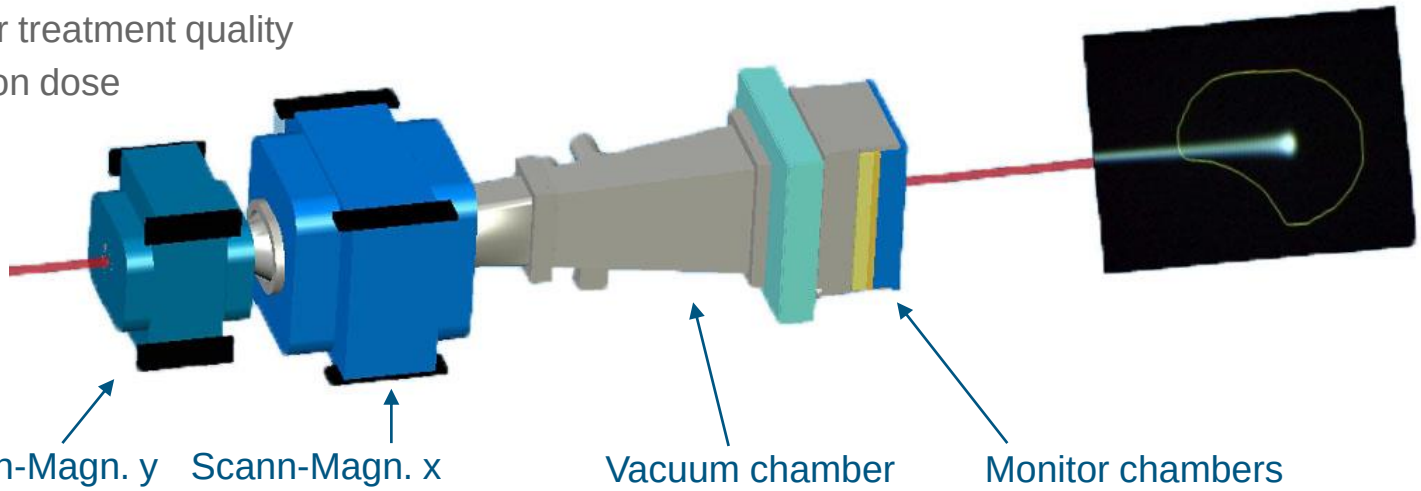
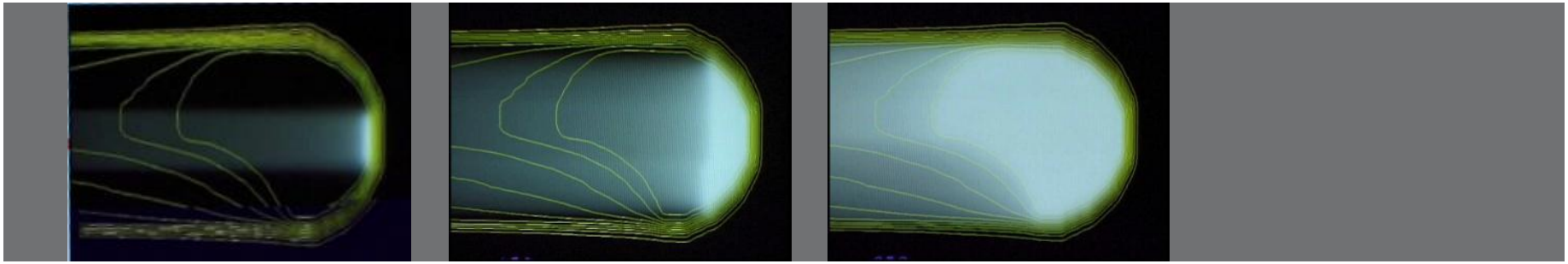
# Beam Delivery – Scanning

## Higher patient throughput and higher treatment quality

### Benefits

- Higher patient throughput – No HW changes for fields
- IMPT – higher treatment quality
- Lowest neutron dose





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# Varian ProBeam Scanning Nozzle - 2nd Generation IMPT

## ProBeam® Scanning System

- 2nd Generation IMPT
- High Precision
- Optimized Dose Rate
- Eclipse Robustness Program
- >40,000 fractions delivered
- IMPT program 4 years clinical
- Focus on dedicated scanning nozzles




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# Proton Therapy
## High level Requirements

### MEDICAL DEVICE INTERNATIONAL REGULATIONS AND STANDARDS

### INVESTMENT:

- Low Cost of Equipment ⇔ **Accelerator Cost**
- Low Cost of Transport ⇔ **Size and Weight**
- Low Cost of Installation and Commissioning ⇔ **Automation**
- Low Building cost / Shielding / Footprint ⇔ **Energy-variation and Size**

### RETURN OF INVEST:

- High Patient throughput ⇔ **Scanning and Dose rate**
- Operation 16h per day/ 6d per Week ⇔ **Automation, Robustness**
- Low Cost of Personnel ⇔ **Automation**
- Low Cost of Service ⇔ **Automation, Robustness**
- Low Cost of Power ⇔ **Superconductivity**
- Fast ramp up ⇔ **Robustness**
- High Number of Patient Referrals ⇔ **Quality of Treatment**



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# SOME EXAMPLES / ACCELERATORS IN USE

Accelerator Requirements

ProBeam superconducting Cyclotron

Other Accelerators in Use

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# Hadron Accelerator

## „Ideal“ Requirements for Proton Accelerator

| REQUIREMENTS | |
|---|---|
| Low Cost | |
| Small Footprint | |
| Automated Operation | 16h/6d |
| Particle Range in Water | 41 – 33 cm |
| Energy at Isocenter | 70 – 230 MeV |
| Typical Current at Isocenter | ~ 2nA or<br>~3.2x$10^{10}$ protons per second |
| Current timestructure | cw |
| Duty Factor | near to 1 |
| Low Service Effort | no long downtime |
| Production Capacity and Documentation | |



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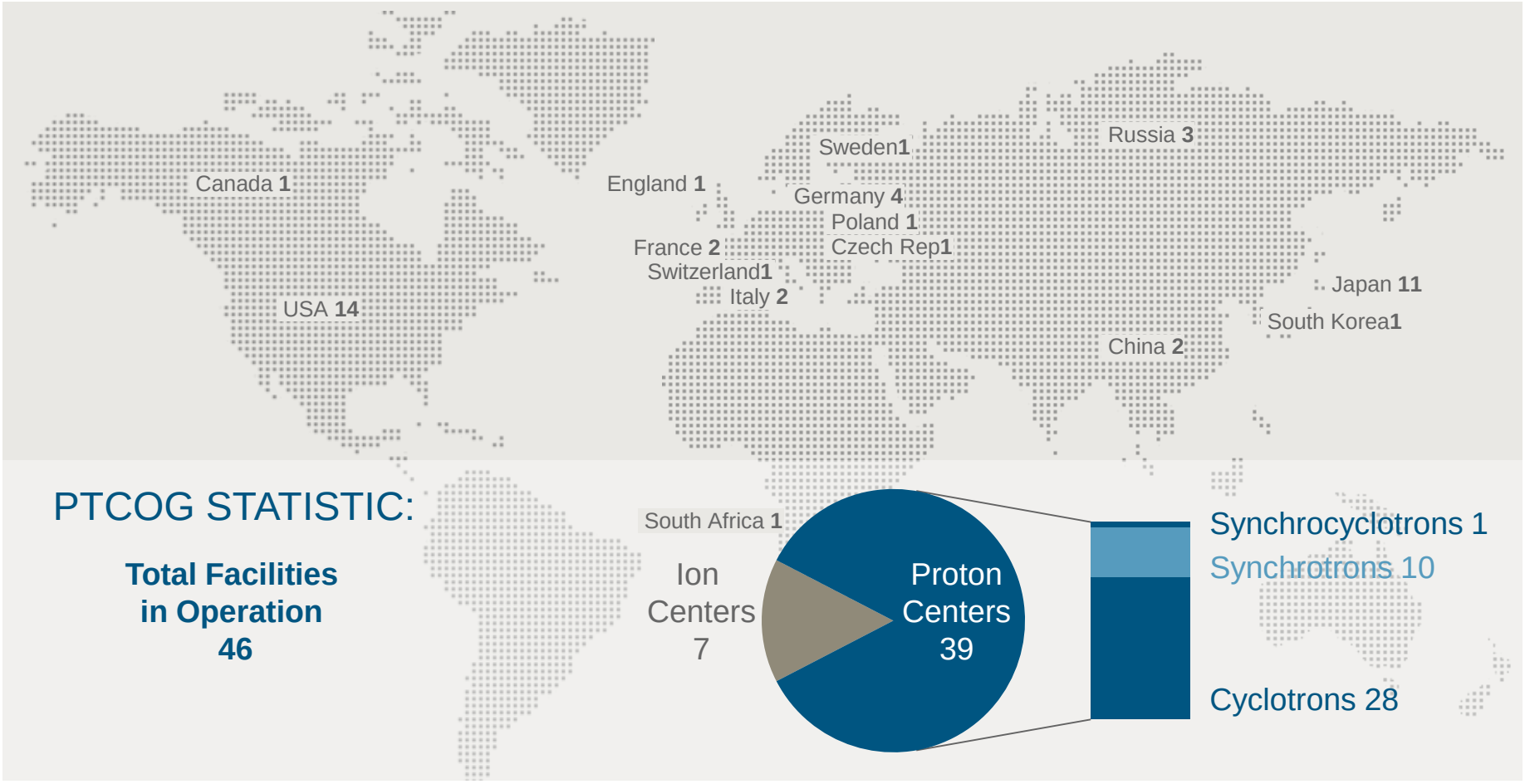
# Hadron Centers Worldwide

## Statistic of Accelerators in Use




PTCOG STATISTIC:

**Total Facilities in Operation 46**



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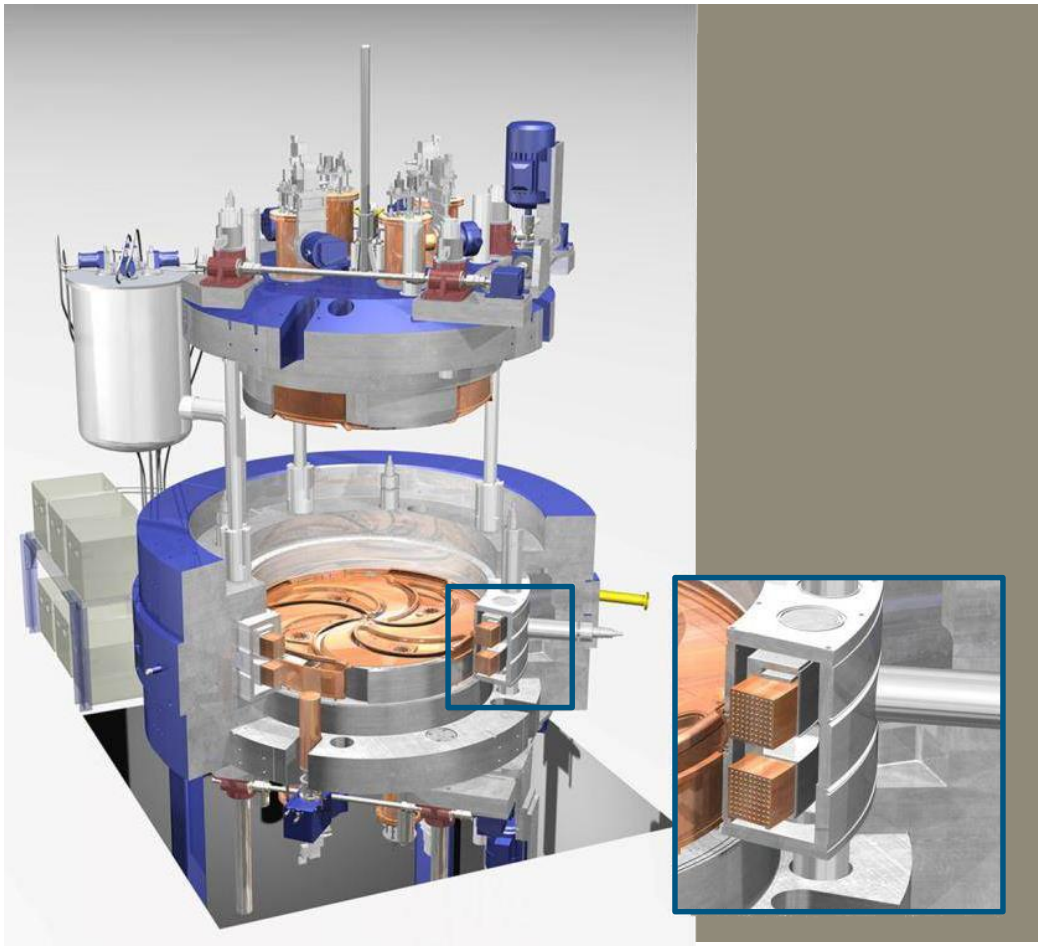
# Why a Cyclotron?

- Low Cost
- Compact due to  Superconductivity
- Continuous, high intensity beam (IMPT)
- Low activation (Service)
- Reproducible behavior (Operations)

# ProBeam 250 Mev Isochronous Cyclotron

## Superconducting Isochronous Cyclotron

| | |
|---|---|
| Diameter | 3 m |
| Weight | < 90t |
| Automated Op. | 16 h / 6 d |
| Energy | 70 - 250 MeV |
| Max Current | 800 nA |
| Current timestr. | cw |
| Duty Factor | 1 |
| Service Effort | Low |





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# Varian Project Update
## Overview

### SCRIPPS PT CENTER
- Equipment order finalized Q4 FY11
- 3 Rotational and 2 Fixed Beam Rooms

### RINECKER PROTON THERAPY CENTER
- Equipment order finalized Q1 FY02
- 4 Rotational Gantries and 1 Fixed Beam Rooms

### KFMC-KING FAHD MEDICAL CITY
- Equipment Order finalized Q2 FY12
- 3 Rotational and 1Eye Tx

### UNIVERSITY OF MARYLAND
- Ground breaking occurred April 2012
- 4 Rotational and 1 Fixed Beam Rooms

### PTC ST PETERSBURG, RUSSIA
- Equipment Order finalized/booked Q2 FY12
- 2 Rotational Gantries

### GEORGIA PT CENTER (EMORY)
- Purchase agreement finalized Q1 FY13
- 4 Rotational and 1 Fixed Beam Room

### UT SOUTHWESTERN MEDICAL CENTER
- Purchase agreement finalized Q1 FY14
- 4 Rotational and 1 Fixed Beam Room

### CINCINNATI CHILDREN'S HOSPITAL MEDICAL CENTER
- Purchase agreement finalized Q1 FY14
- 3 Rotational Rooms

# ProBeam SC Cyclotron

## Series Production – Capacity 3 Cycls per year / ramping up to 6 per year



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# ProBeam Cyclotron

## Transport and Installation – Disassembly and packaging





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# ProBeam Cyclotron

## Transport and Installation – Installation into building





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# Hadron Accelerator
## IBA Proteus 235 / S2C2

| | |
|---|---|
| Diameter | 4,3 m |
| Weight | 220 t |
| Max Energy | 230 MeV |
| Max Current | 300 nA |
| Time structure | cw |


230 MeV , 2.4m Dia., 45t, Superconducting Synchrocyclotron under development



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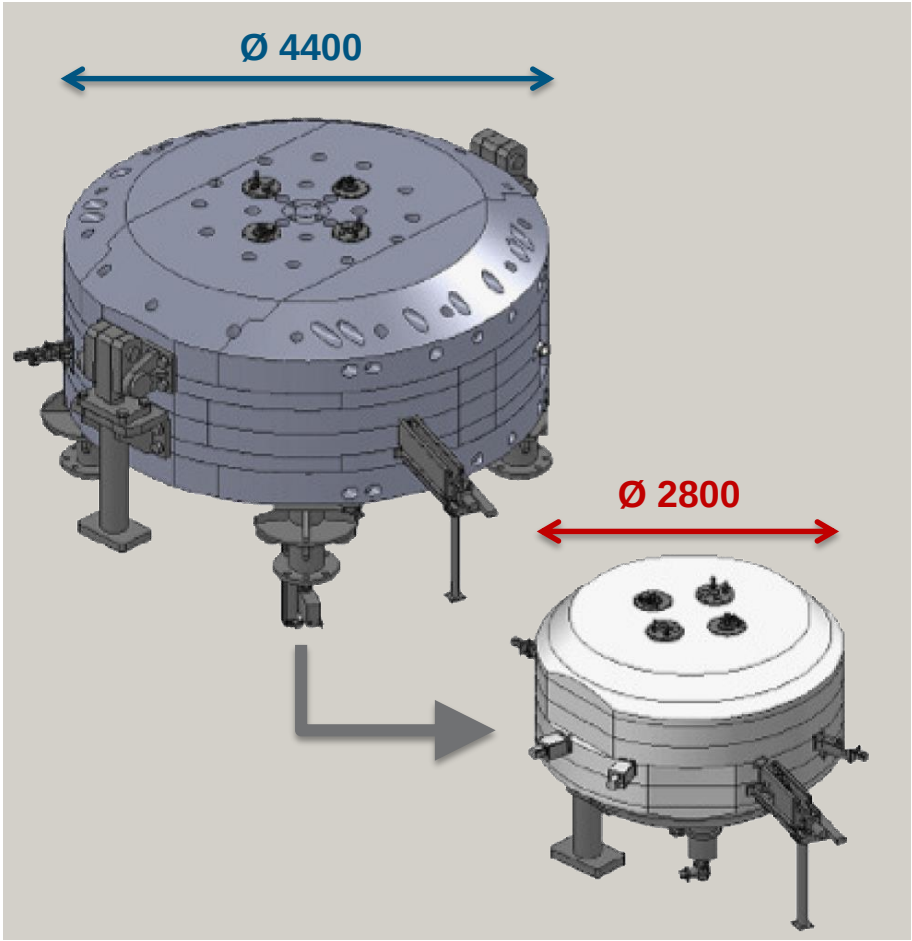
# Proton Accelerator

## Sumitomo P235 Isochronous Cyclotron

| | |
|---|---|
| Diameter | 4,4 m |
| Weight | 220 t |
| Max Energy | 230 MeV |
| Max Current | 600 nA |
| Time structure | cw |

New Development planned 230 MeV , 2.8 m Dia., 55t, Superconducting Isochronous Cyclotron



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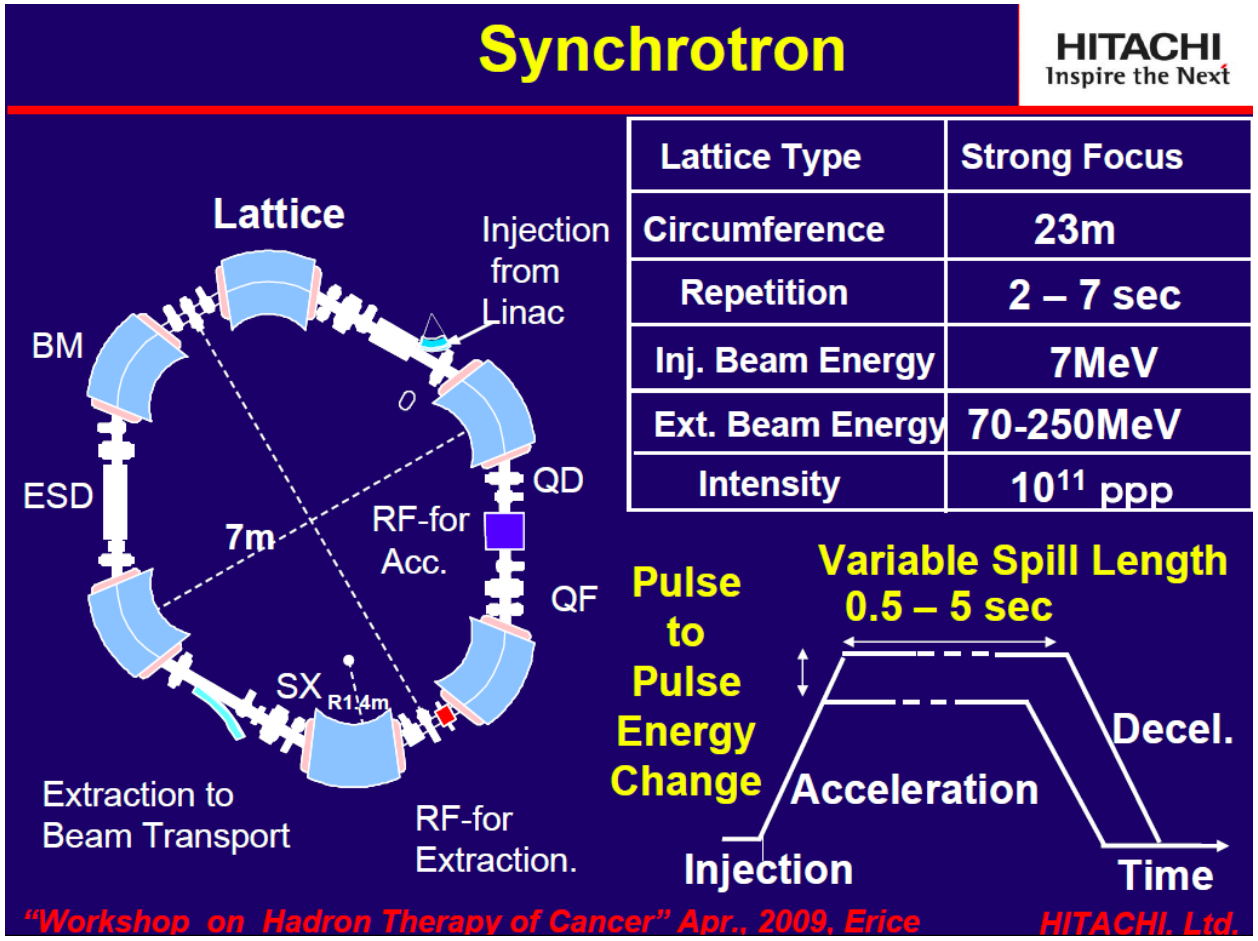
# Hadron Accelerator
## Hitachi ProBEAT




New Synchotron with 5.1m Diameter under development



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# Proton Accelerator

## Mitsubishi 250 MeV Synchrotron



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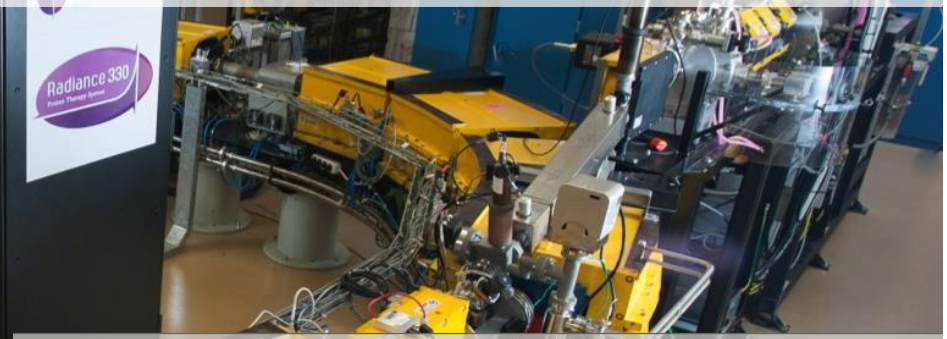
# Linear Accelerator and Compact Snychroton

## Radiance 330 Proton Therapy System – ProTom International

Linear Accelerator RFQ Injector: Energy ~1.6 MeV. Compact Synchrotron: Low-cost, novel high-energy synchrotron. Energies from <70 MeV to 250 MeV for therapy applications, and up to 330 MeV for proton imaging techniques. Proton Beam Intensity: 2 Gy/liter/minute dose rate. ~ 1 E(10) protons/cycle. Extracted beam emittance between 1.0 $x10^{-6}$ and 2.5 $x10^{-6}$ m-rad. Energy and Momentum Spread: $\Delta E/E \leq 0.2\%$; $\Delta p/p \sim 0.0012$ (rms). Diameter = 16 ft.




| | |
|---|---|
| Diameter | 4,8 m |
| Energies for therapy | 70 - 250 MeV |
| … for proton imaging | up to 330 MeV |
| Dose rate | 2 Gy/liter/minute |
| Protons per pulse | ~ $1x10^{10}$ |
| Extracted beam emittance | 1.0 $x10^{-6}$ to 2.5 $x10^{-6}$ m-rad |



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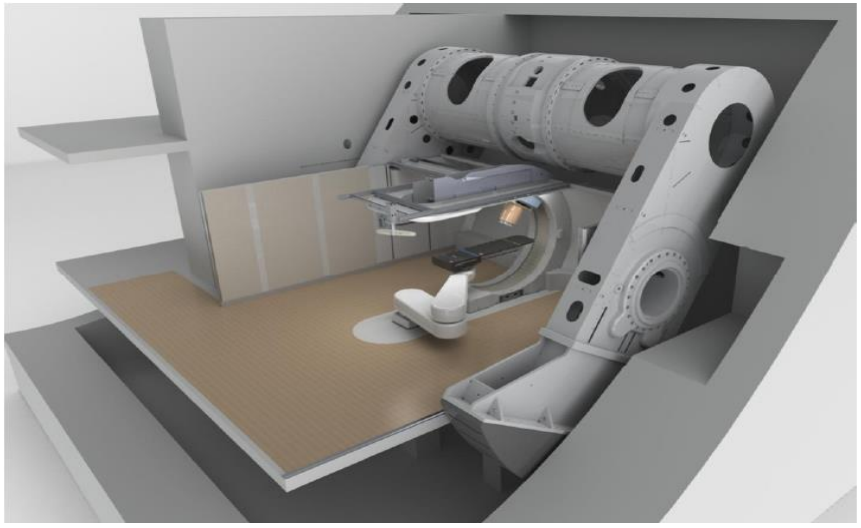
# Hadron Accelerator
## Mevion 9T Synchrocyclotron

| | |
|---|---|
| Diameter | ~2 m |
| Weight | ~20 t |
| Max Energy | 250 MeV |
| Max Current | ? |
| Current. | ? |
| Duty factor | low |





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# OUTLOOK

Cyclotrons

Synchrotrons

Other

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# Outlook
## Cyclotron / Synchrotron Improvements

### CYCLOTRONS

**Trend goes to superconducting cyclotrons**

- Mevion, 9T lightweight synchrocyclotron mounted on gantry
- Sumitomo, 3T isochronous cyclotron
- IBA S2C2 6T synchrocyclotron
- Higher fields for isochronous cyclotron limited due to flutter
  **What can be done to reduce cost further?**
- Synchrocyclotrons with high fields are very compact
  **What can be done to improve duty factor?**

### SYNCHROTRON

**Synchrotron:**

- Protom and Hitachi show more compact and simple synchrotron design

**Can cost be reduces to compete with superconducting cyclotron?**

**Can footprint be reduced to compete with superconducting cyclotron?**

**What can be done to improve average current and duty factor?**



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# Outlook
## Other Accelerator Concepts

### LINEAR ACCELERATORS

**Dielectric Wall Accelerator - still ongoing? Chances?**

**Other?:**

**How can cost be reduced ?**

**Can length be reduced ?**

**Improved acceleration gradient ?**

**How can puls rate be increased ?**

### LASER ACCELERATION

**Big Interest and Potential – Development ongoing at many sites:**

**What is total cost ?**

**Achievable Puls Rate ?**

**Robust 16h/6d Operation?**



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To make the benefits of Hadrontherapy available to more people:
Reduce cost of systems
Reduce footprint
Simplify systems
Simplify operation
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# THANK YOU

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