Building Hadron Therapy Center in the Republic of Moonland

By group of experts:

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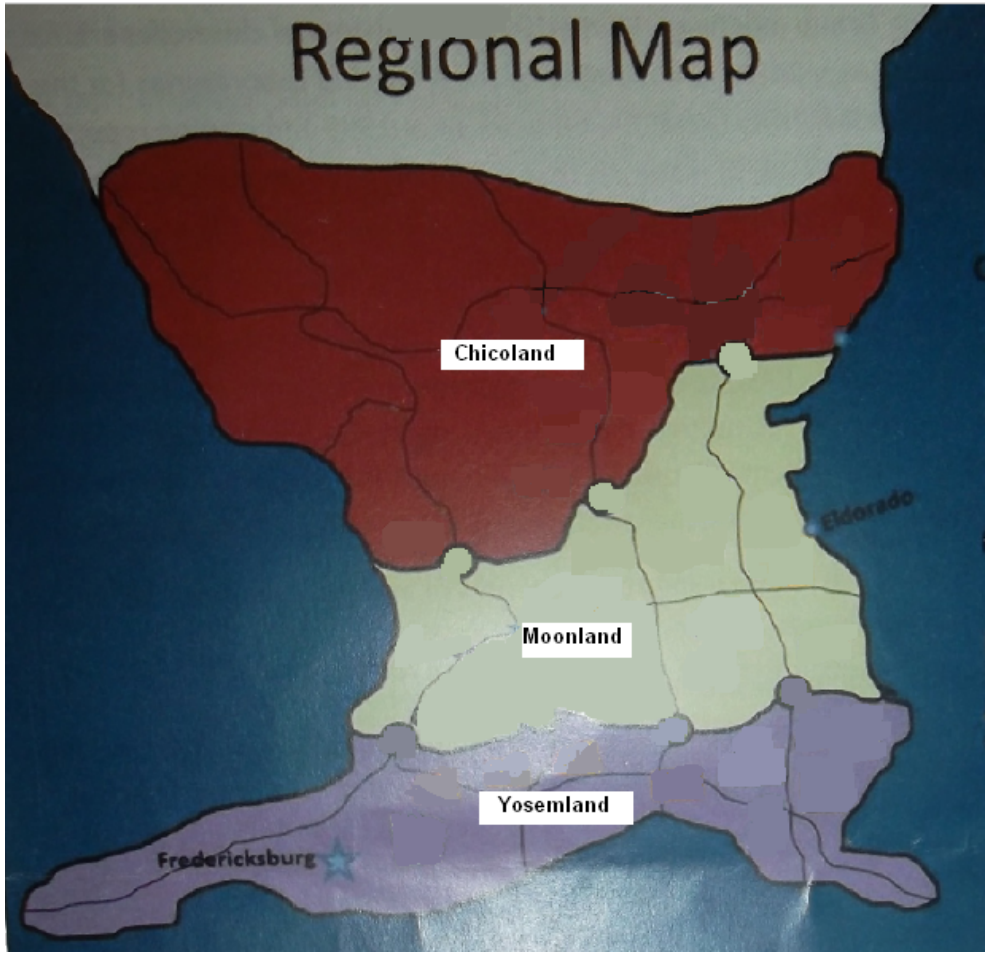
Concepción Oliver
Tobias Stadlbauer
Yuan Xu

The Republic of Moonland

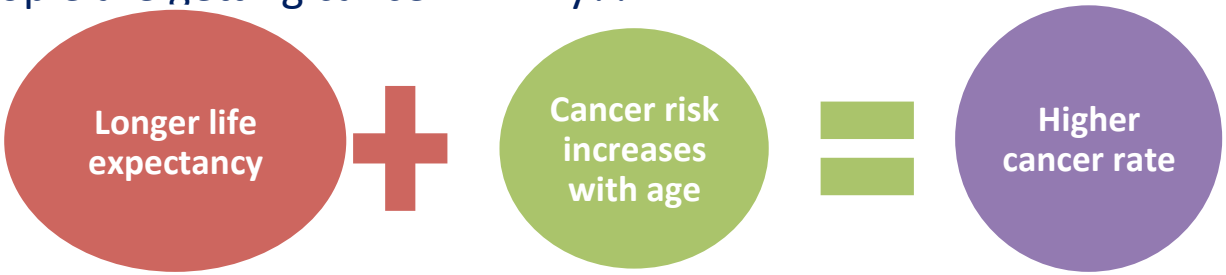


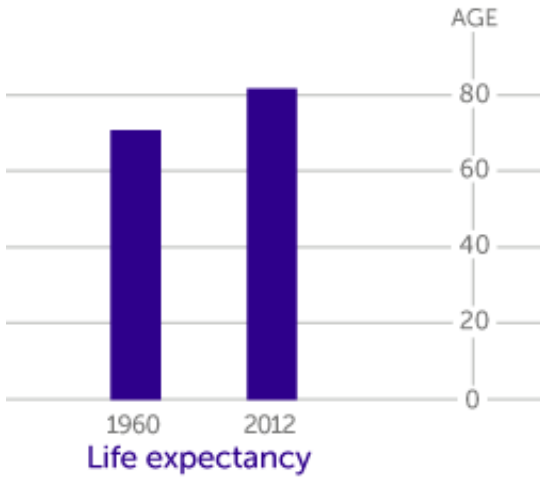
Government type: Social Democracy
Area: 367 332 sq. km
Population: 28 mln
GDP: 373,4 billion $
№ oncological patients a year: 9000-10000
Public health infrastructure: widely available private coverage and government subsidized care for low income residents
International Community: MoU with CERN, MedAustron
Academic Infrastructure: good educational tradition with low-cost post-secondary education, strong University system (with emphasis on natural Sciences). There is a significant governmental funding for research.
Political Climate: considered stable

Oncological treatment capabilities

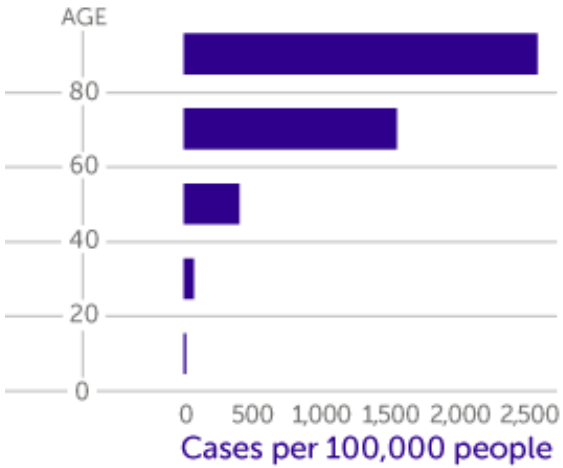
Oncology Center Moonland

- People are getting cancer … Why??





- Several regional and one national oncological centers (electron accelerators, gamma-knives, brachytherapy, powerful imaging systems)
- No facilities for radioisotope production
- Governmental subsidies for treatment in Rimerland's Proton Therapy Center (2500 km across the sea)
- **The Ministry of Health has approved building the next Moonland's Hardron Therapy Center**
- Government is interested in:
  - ✓ New facility for hadrontherapy
  - ✓ Medical research
  - ✓ Establishing an accelerator community
  - ✓ Some industrial development



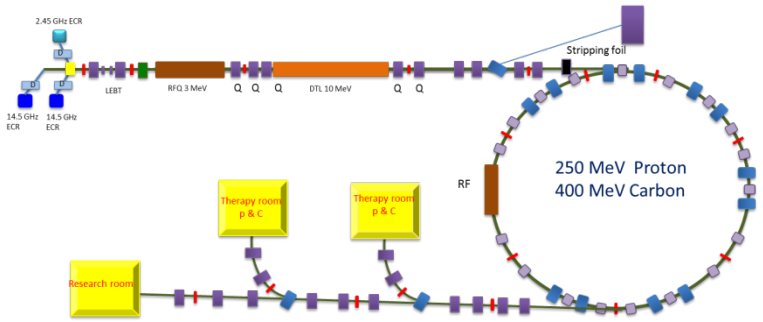
The Proposal

Oncology Center Moonland

Highly Modular Research + Treatment Center

Beam Parameters		
Proton Energy {Treatment}	[MeV]	1000 {250}
Carbon Ions	[MeV/u]	400
Future ions	He…O	

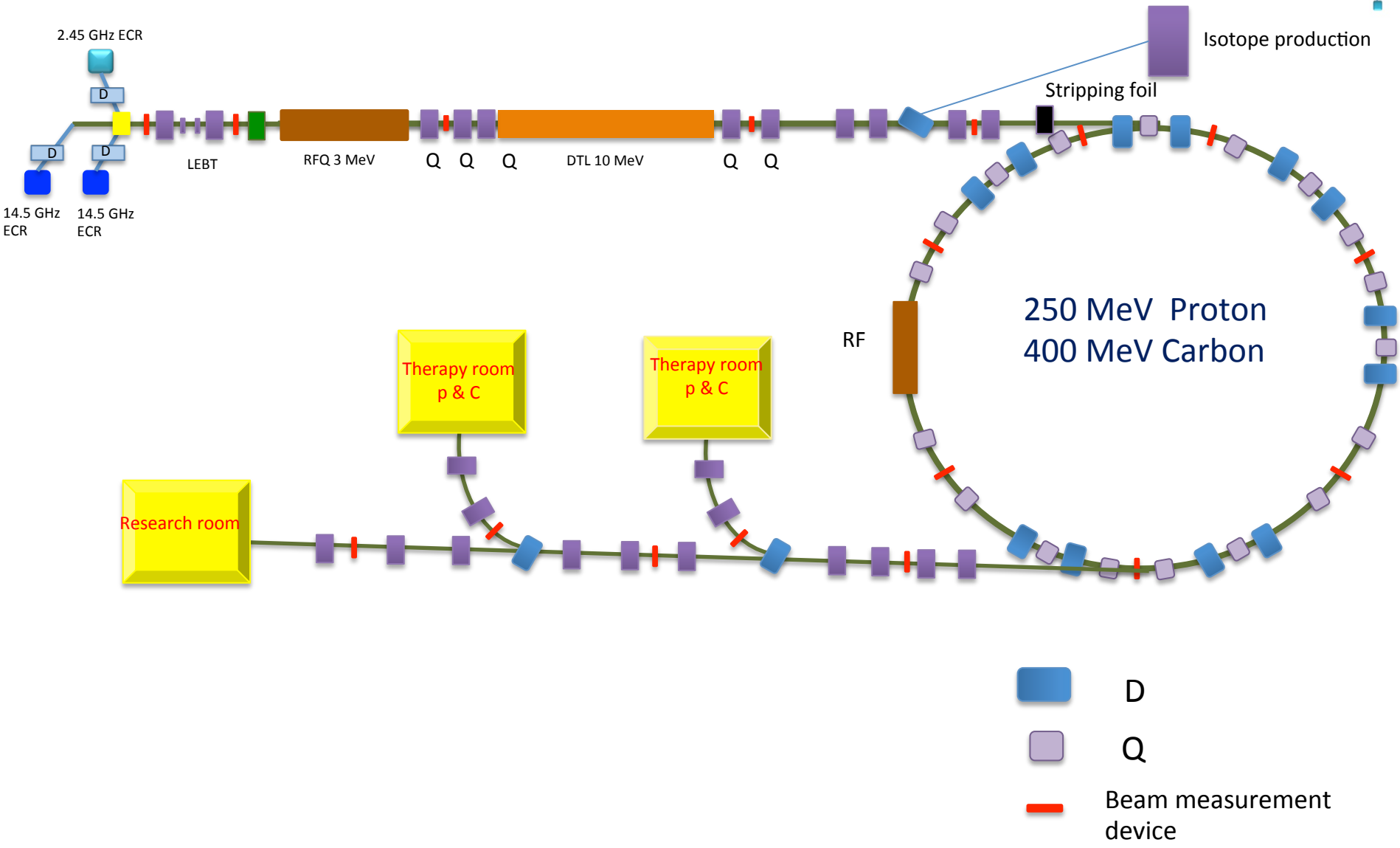
Treatment Specifications		
Fraction time	[mins]	20
Avg fractions x treatment	[-]	8
Max Dose	[Gy/ fraction]	8



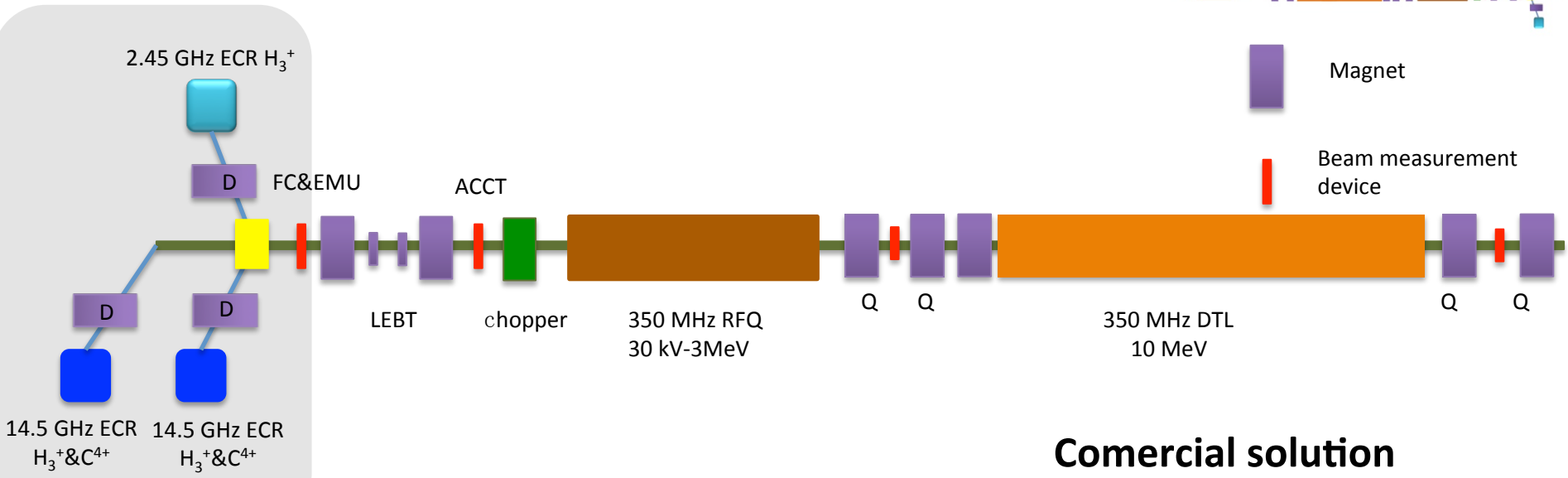
Expected Number of Patients : 1350

Cost x Treatment: 16k$

Overview of hadron therapy facility



Injector



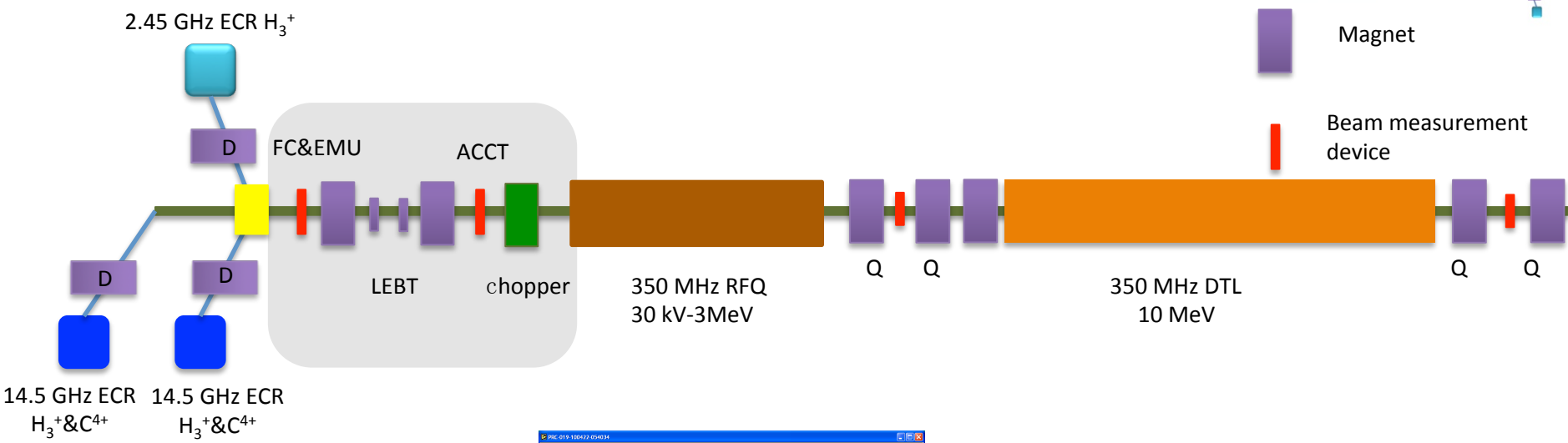
Ion sources

Parameters	H_3^+	C^{4+}
Ion source type	2.45&14.5 GHz ECR	14.5 GHz ECR
Current (uA)	500	200
Voltage (kV)	30	
Frequency (Hz)	0.5	
Pulsed duration (s)	1	
Possible ions	H, He……O	

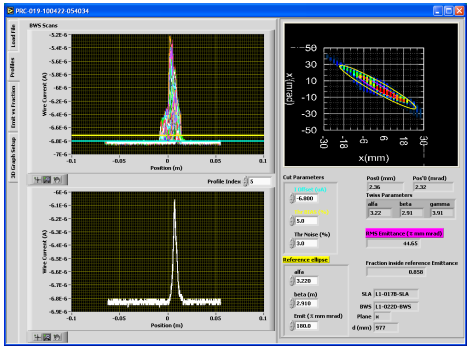
Comercial solution

PANTECHNIK

Injector

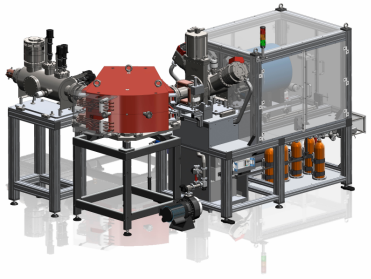


LEBT



-Extraction system
- Diagnostic:
  - slits
  - wirescanners
  - faraday cups
  - alisson scanner for emittance measurements
- Solenoid
- Steerers

PANTECHNIK



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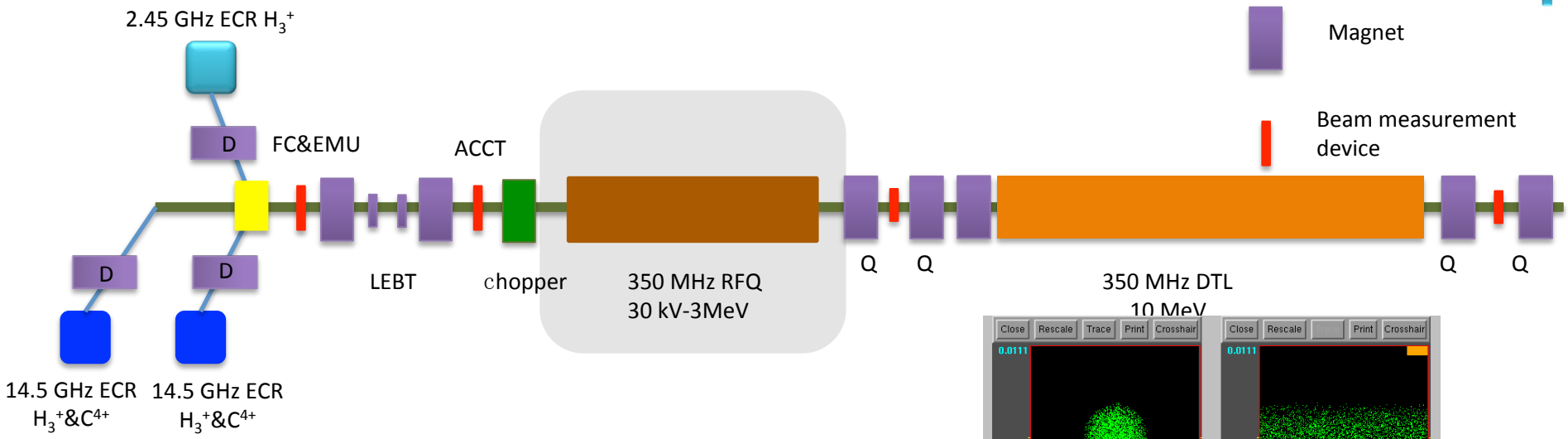
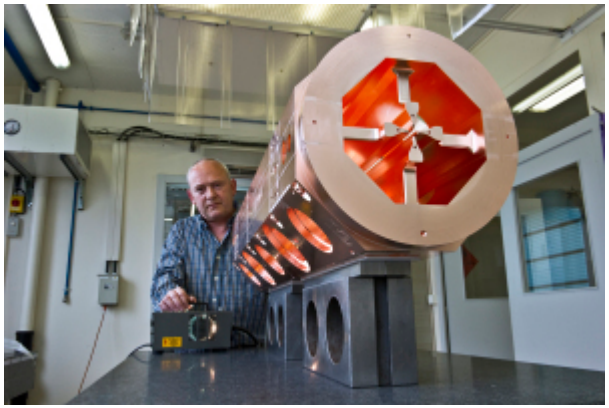


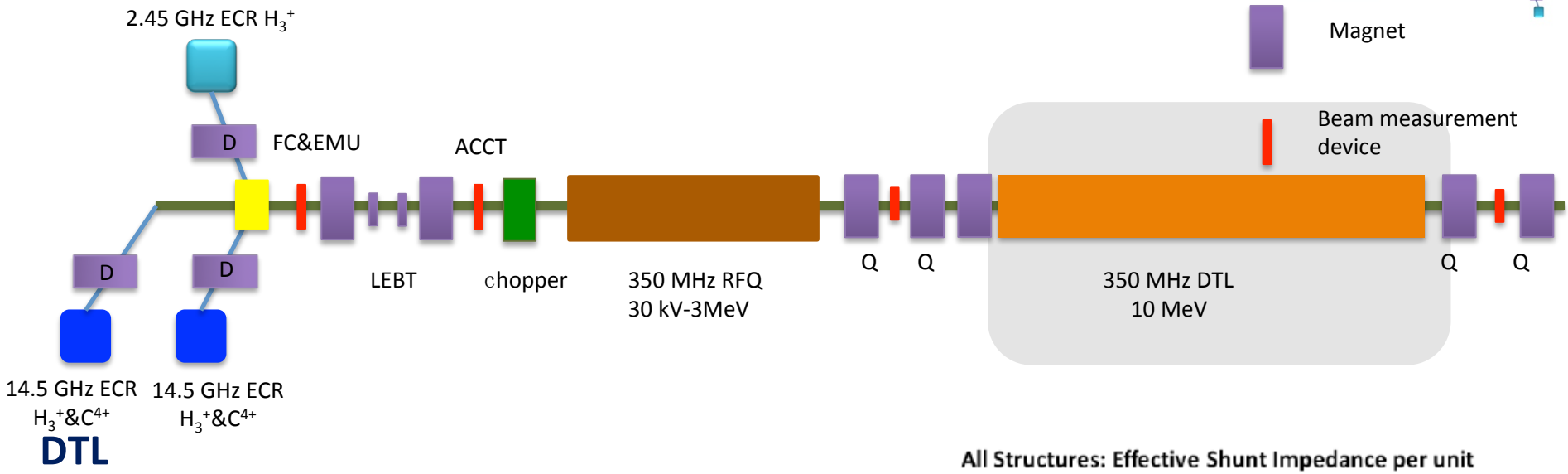
RFQ

- ❑ Acceleration up to 3 MeV/u
- ❑ 350 MHz
- ❑ 4 vane RFQ solution for such RF frequencies
- ❑ Peak surface voltage → 1.8 kilpatrick limit (good vacuum)
- ❑ Contacts with companies (Bevatech) for RFQ design and fabrication

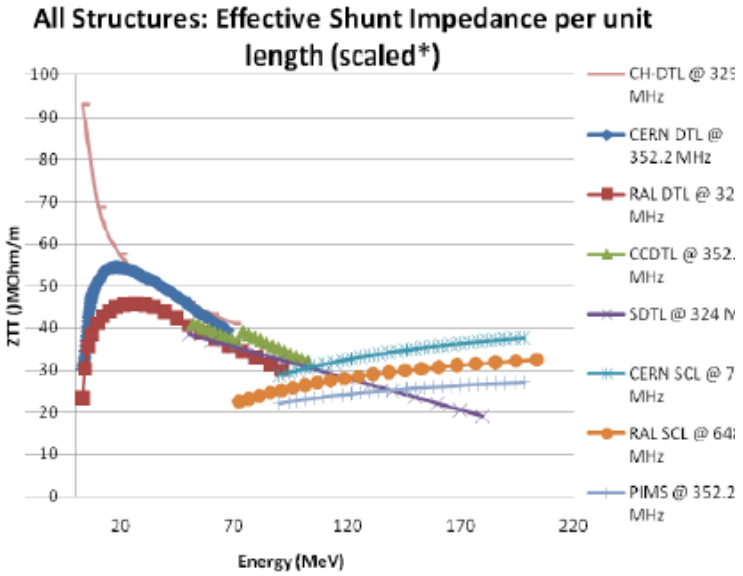


BEVATECH

Injector

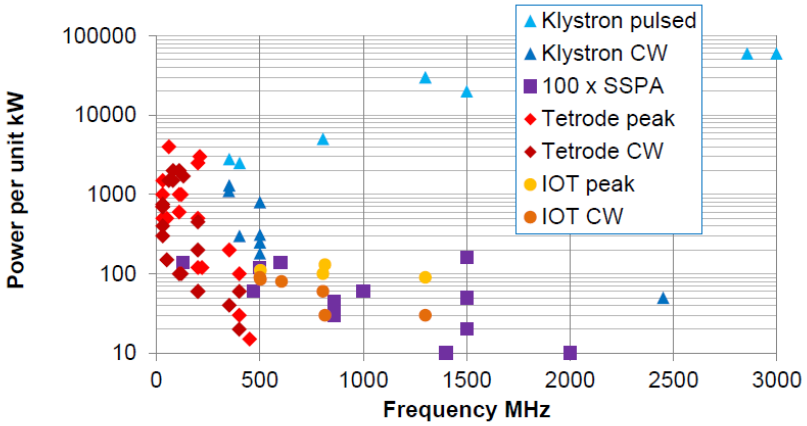


- ✓ Higher effective impedance at low energies
- ✓ Focusing quads inside tubes
- ✓ Effective gradient 3.5 MV/m at 350 MHZ
- ✓ 2 m long
- ✓ Peak surface field up to 2*Kilpatrick field



RF system

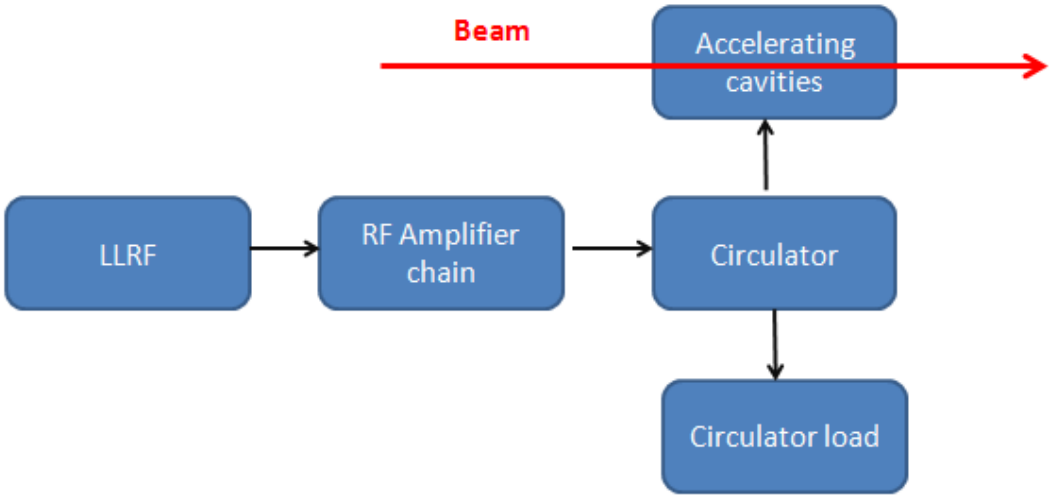
Frequency



Acquisition & operation costs

Technology * Including SSPA driver	Very rough estimates for a 100 kW CW 352 MHz RF system including RF power + Power Supplies + circulators + cooling + controls (lines not included)	Lifetime ** x 1000 hours	20 years Maintenance Tubes, HVPS, workshop	20 years Electrical bill 3000 hours / year 10 hours/day 6/7 days 50 weeks/year 0.15 € / kWh η = 45 %	Total 20 years
Tetrode	500 k€	20	350 k€	200 k€	1050 k€
IOT	600 k€	50	200 k€	200 k€	1000 k€
Klystron	750 k€	100	100 k€	200 k€	1050 k€
SSPA	850 k€	200	50 k€	200 k€	1100 k€
Circulator	75 k€	-	-		75 k€
Lines	1 k€/m	-	-		1 k€/m

Tetrode → optimum solution for 350 MHz

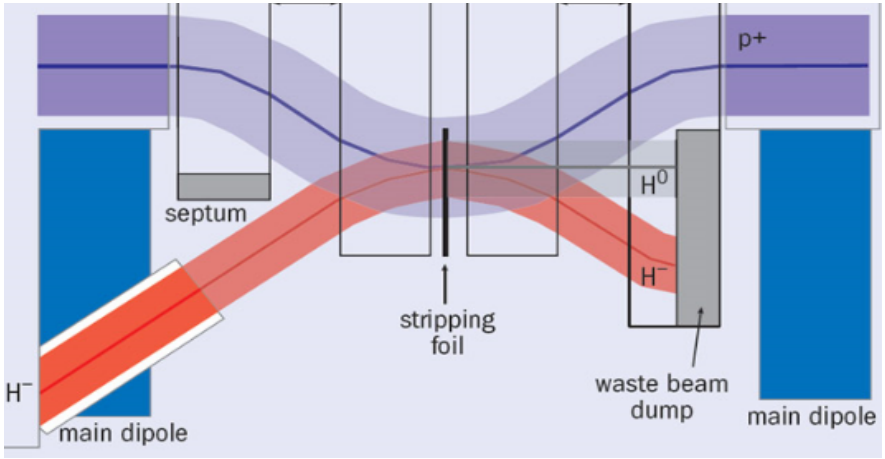


Linac 2 Synchr. Injection

Studies ongoing:

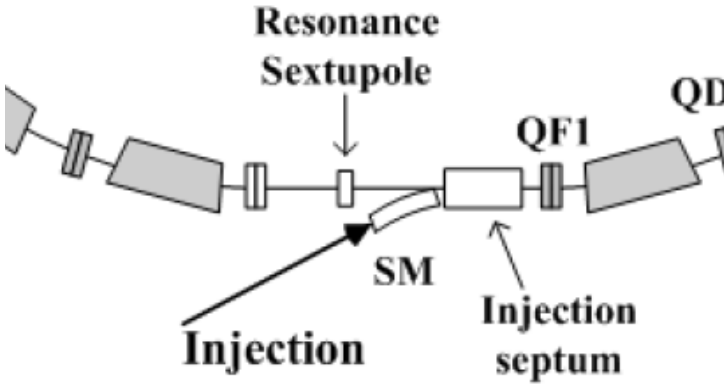
Injection Chicane

Beam Intensity Optimization (no intensity limits due machine aperture and septum geometry, as in phase space painting)



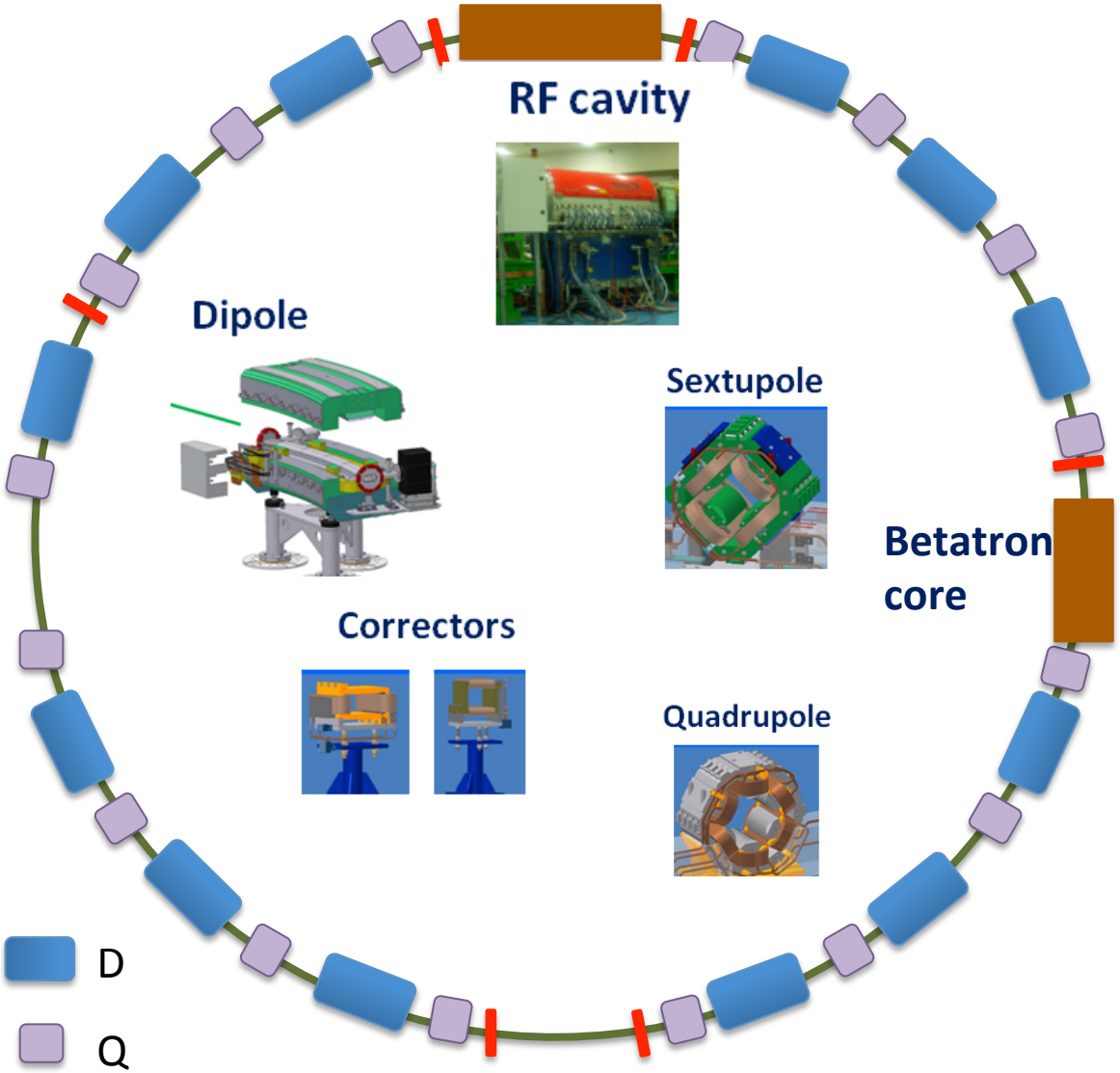
4m injection region, keeping 1T magnet limit

Injection via Septum



<4m injection region, ca 0.5T

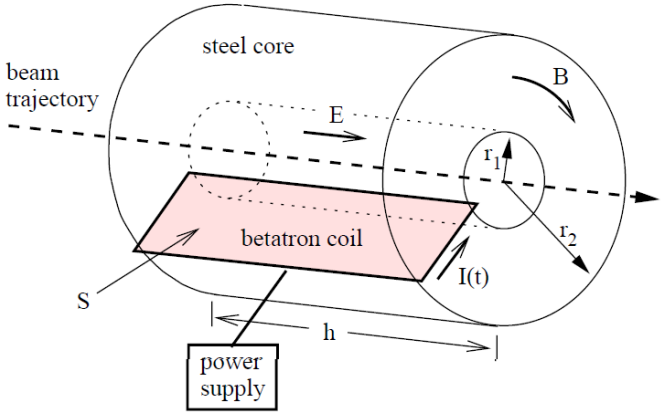
Synchrotron



Parameters	Value
Circumference	80 m
Number of dipole	12
Magnet rigidity	6.8 T m
B	1.5 T
Effective length	2.1 m

- Quadrupoles
- Sextupoles
- H/V correctors
- Vacuum pumps
- Beam diagnostics

Betatron core driven slow extraction



	PIMMS
Length h [m]	1.5
Internal radius r_1 [m]	0.08
External radius r_2 [m]	0.75
Lamination thickness x [mm]	0.5
Number of coil turns	10
Max. flux variation $\Delta\phi$ [Wb]	2.38
Max. inductance L [H]	0.43
Total coil resistance R_{tot} [Ω]	0.11

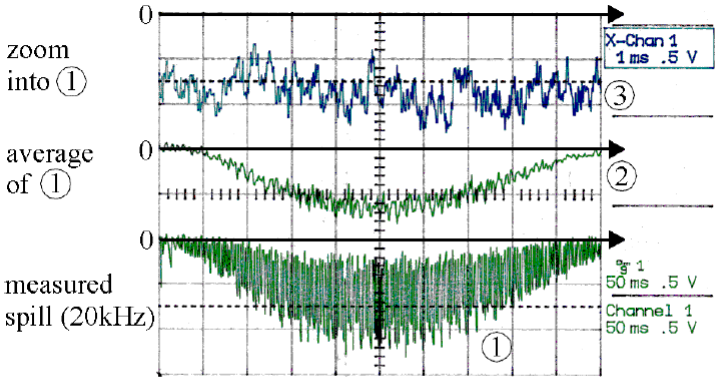
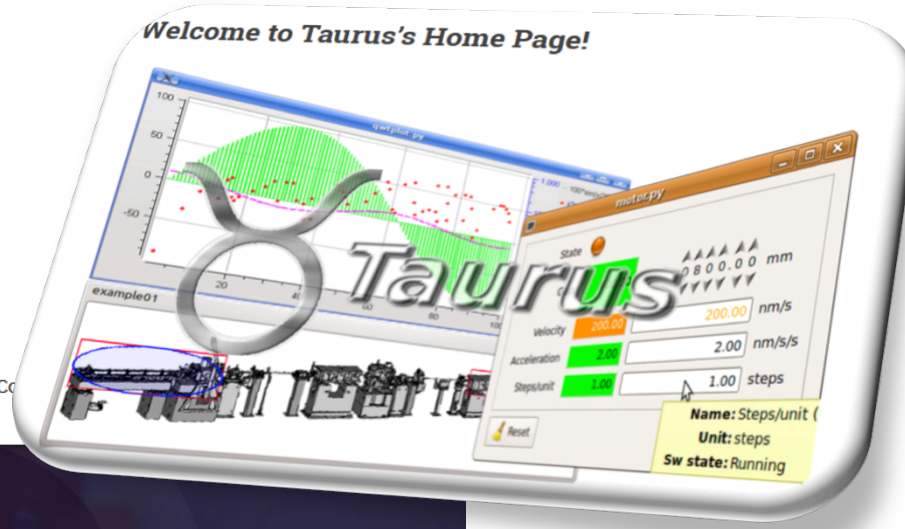


Figure 2: Spill measurement. The time scale for curve one and two is 50 ms/division, for curve three 1 ms/division.

- Spill measurement
- Slow extraction allows precise control of the applied dose

Open Source Control System



TANGO

About us Downloads Resources Community Partners Co

Connecting things **together**

What is **TANGO Controls ?**

A free open source device-oriented controls toolkit for controlling any kind of hardware or software and building **SCADA** systems...

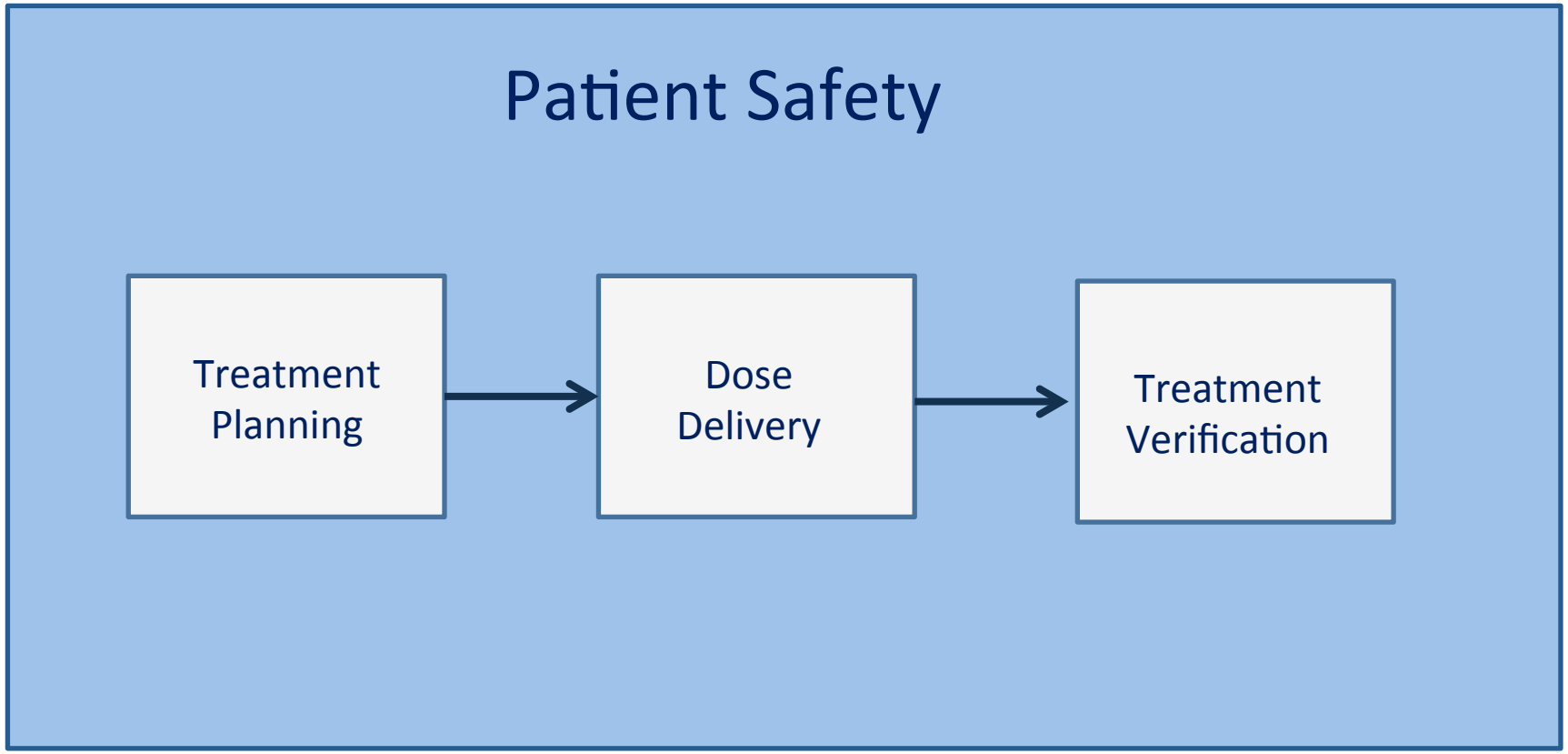
Why choose **TANGO Controls ?**

Because it is easy to use, flexible, and highly scalable. It provides a complete set of features for controlling equipment and lot of services for managing systems.

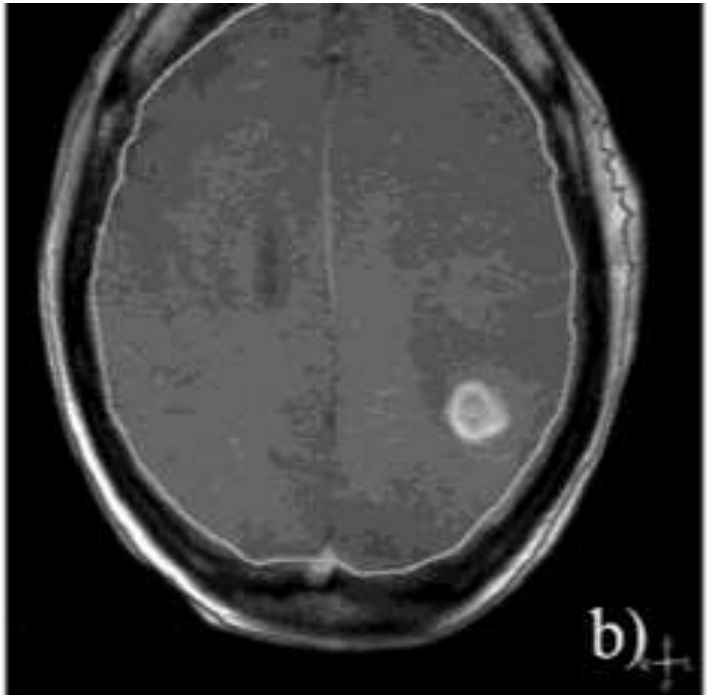
How to use **TANGO Controls ?**

Just download it and install it. Then reuse or write a device server, deploy and marvel at how it works!

Treatment delivery

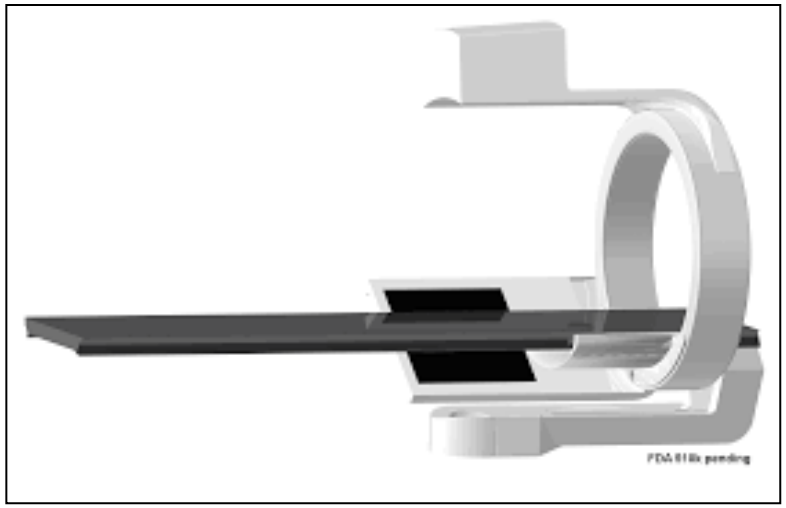


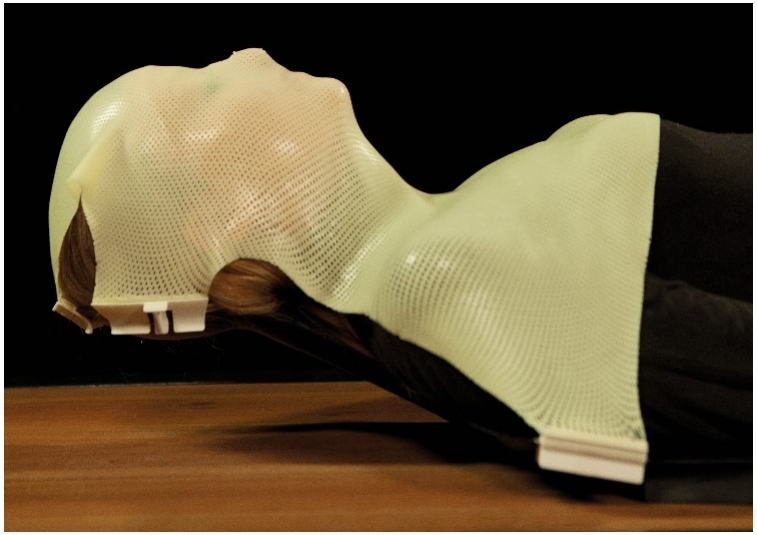
Treatment planning



Tumour localization and Treatment planning at site

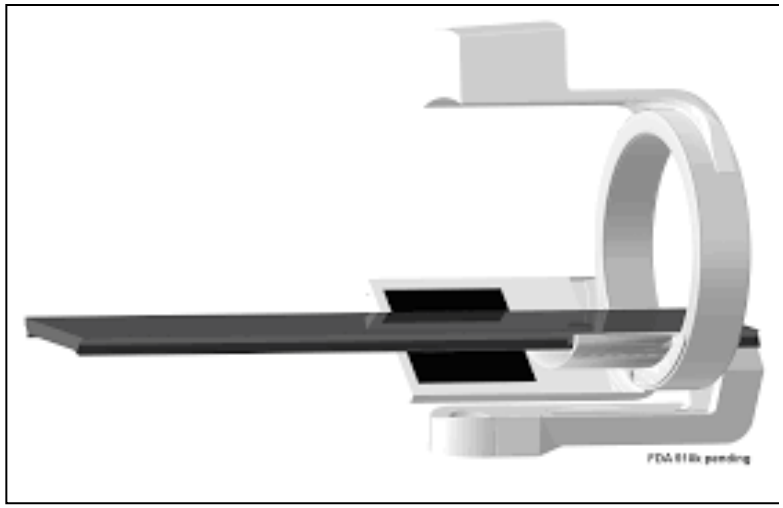
Patient positioning

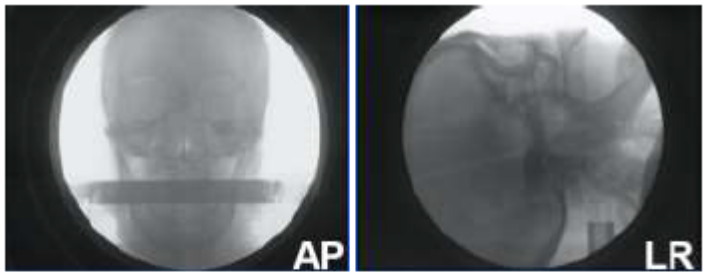


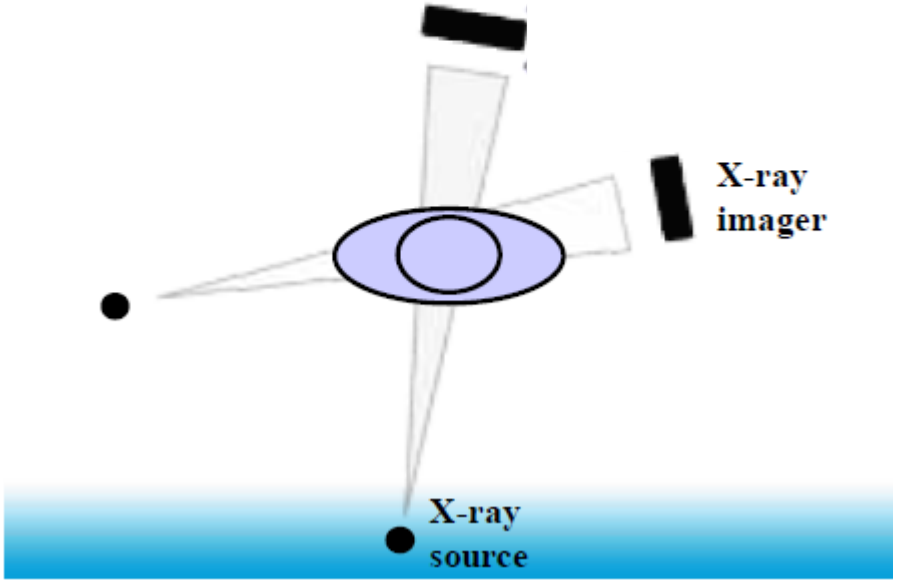


- CBTC for in room patient positioning
- Patient fixation in house

Patient positioning

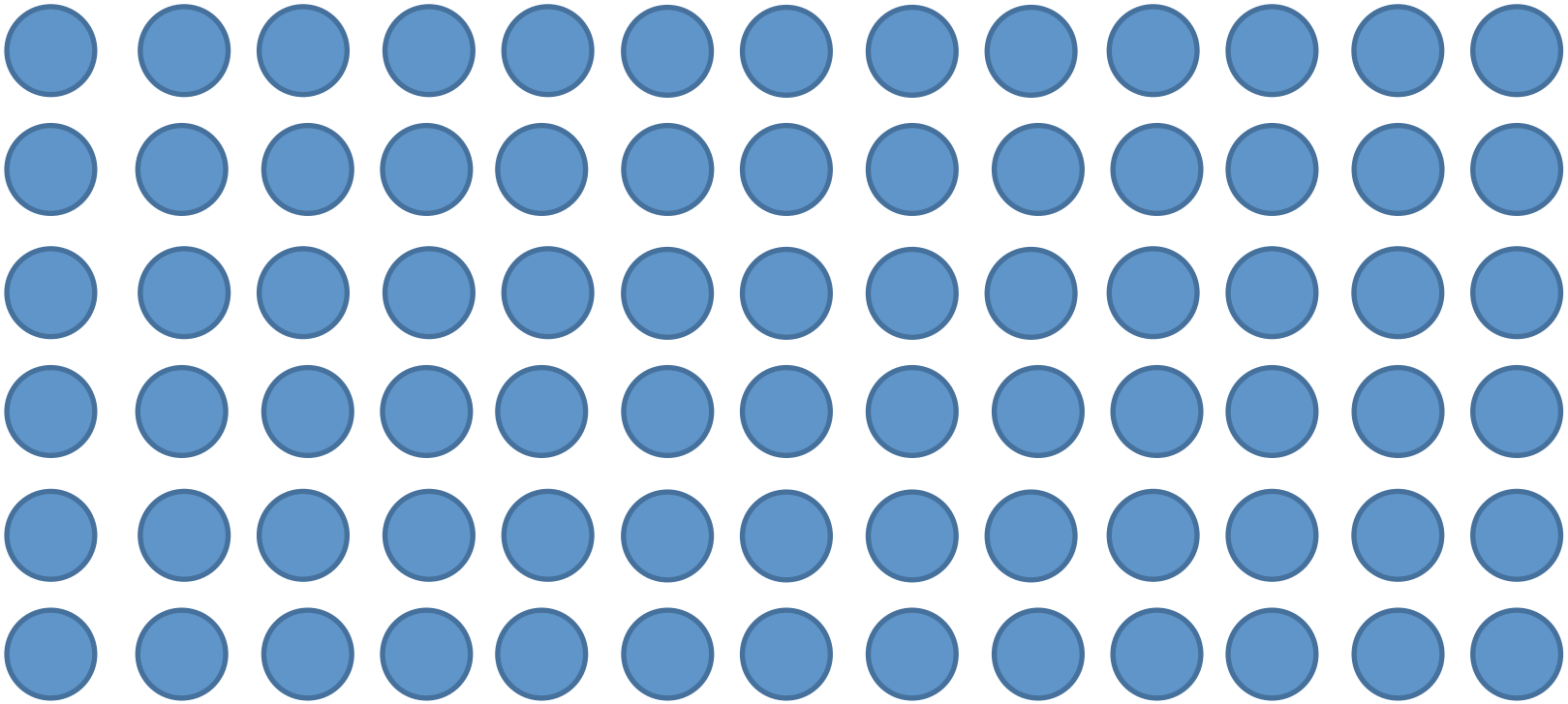






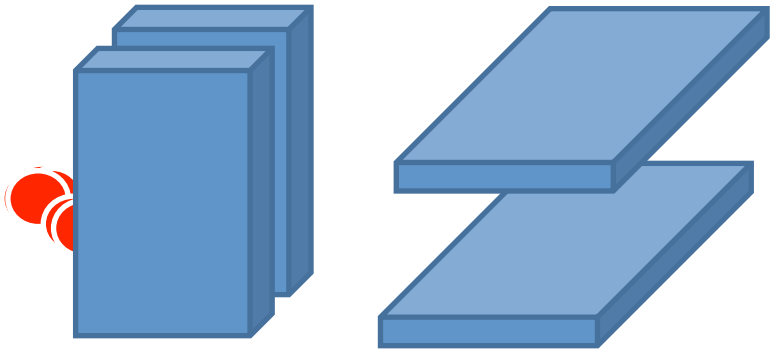
- Position verification before each fraction

Beam Delivery
Quasi-Discrete Scanning

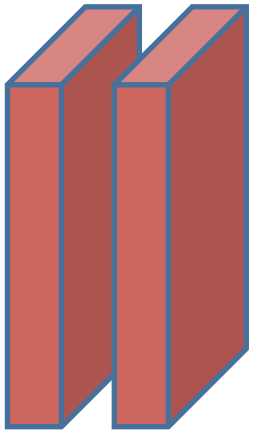


Beam velocity: 20 m/s
Typical Step : 1 mm
Spot size: 4 – 10 mm

Beam Delivery System



Scanning Magnets with
B = 0.4 T
Field ramp 62 T/s



20x20x cm^2 IC strip chambers
128 channel

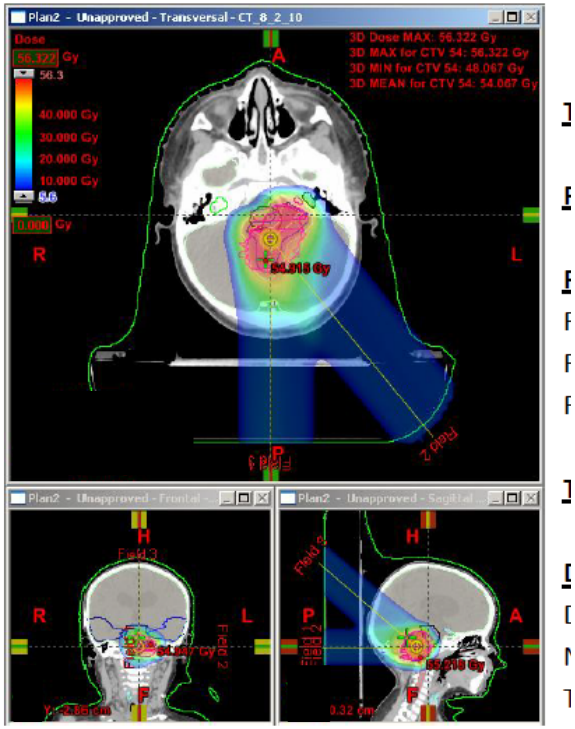
X

But wait, no Gantry?

Beam Delivery System

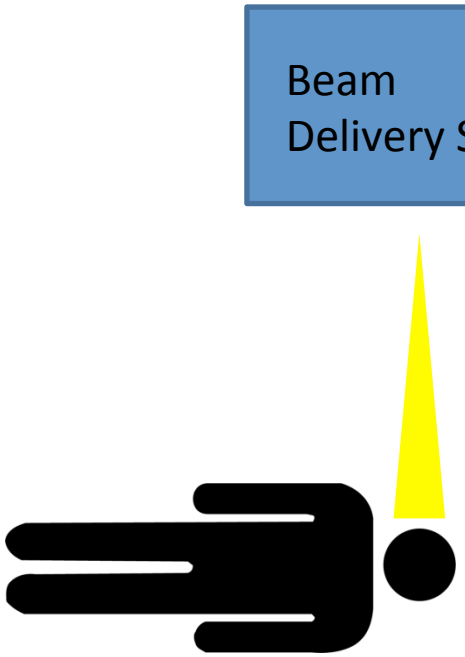
Oncology Center Moonland

- ✓ Extensive analysis campaign on different tumours (pediatric, head & neck..):
- ✓ 80% treatable with (3+1)x directions (0 & 180, 90, 135) and couch movement



V. Rizzeria, S. Bakegey, "Treatment Planning Efficiency for MoonLand Hadrontherapy Center: a comparison between multiple and four-fixed beam angles"

Treatment Verification

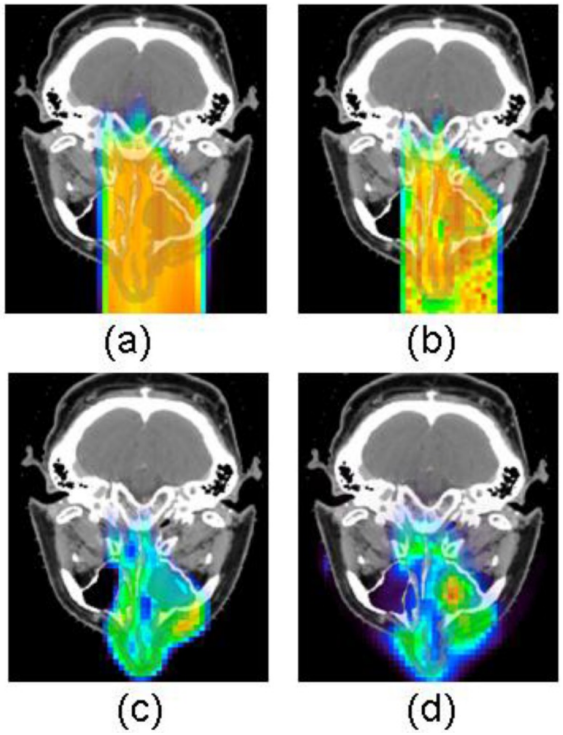


Treatment Verification

Oncology Center Moonland

Beam
Delivery System

PET



Patient safety

- On line super vision of Beam Spot size and Position
- On line super vision of Patient patient
- Interlock system to prevent patient harm

Day & Yearly Schedule

Running 24:7

20 Days: Integrated Shutdown

(Expected Uptime Efficiency = 90%)

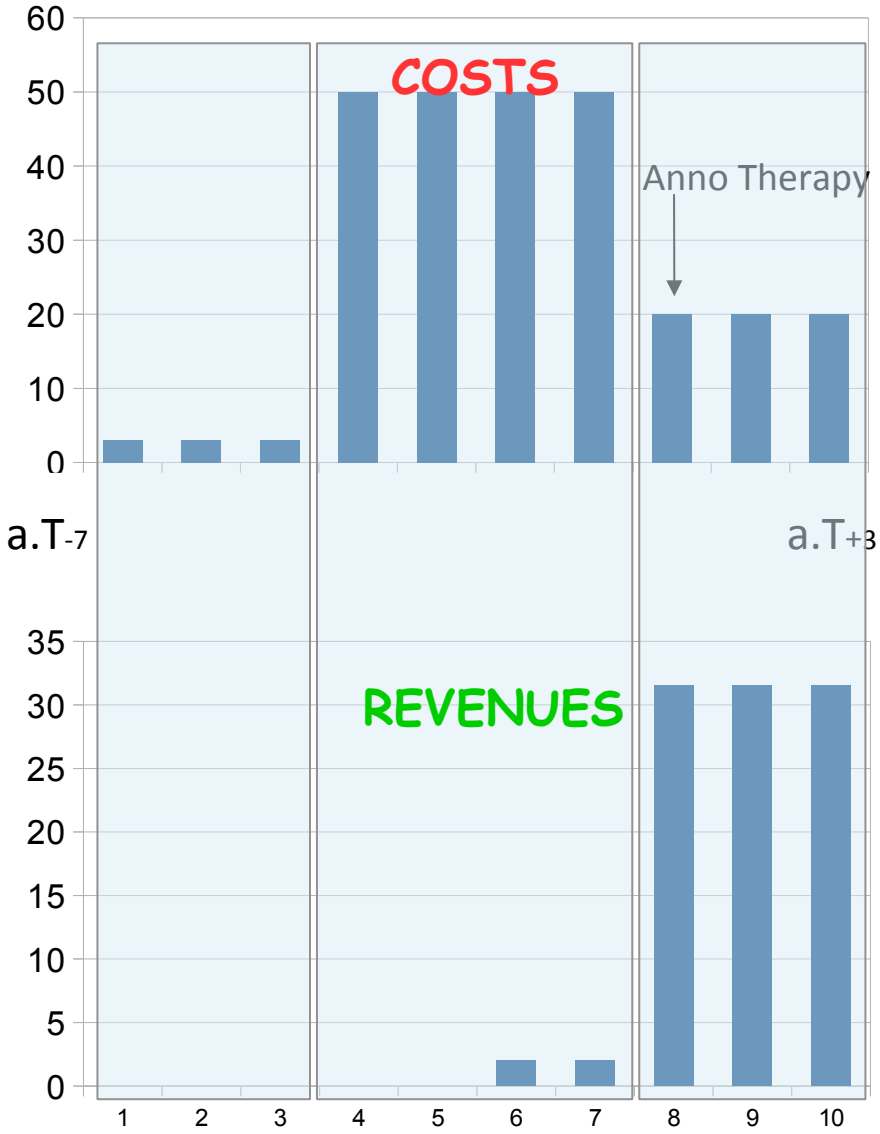
5.00 → 8.00 : Q.A.

8.00 → 20.00 : Treatment

20.00 → 22.00 : Machine Dvlp & Maintenance

22.00 → 5.00 : Research & RI production

Time & Cost Estimation



3 years for design (3.2M$/year):
Collaborations ongoing with other centers
15x Fully paid Scholarships
25x Staff
- 2x Doctors
- 20x Technical (Beam & RF, Magnets, Control...)
- 2x Admin

4 years for construction/qualification & commissioning :) (180M$ TOTAL):
80x Staff
- decreasing Design Engineering Staff,
- Increasing:
  Management, Admin
  Technicians & commissioning staff
  → Medical staff

From 3rd year, **Isotope production (2M$)**

Running Full Throttle:
29M$ Revenue (7% Isotopes, 13% Research, 80% Treatment)
19M$ Running Costs
Break even after **27** years

Thank you!