New Developments in Accelerators and Gantries for Particle Therapy

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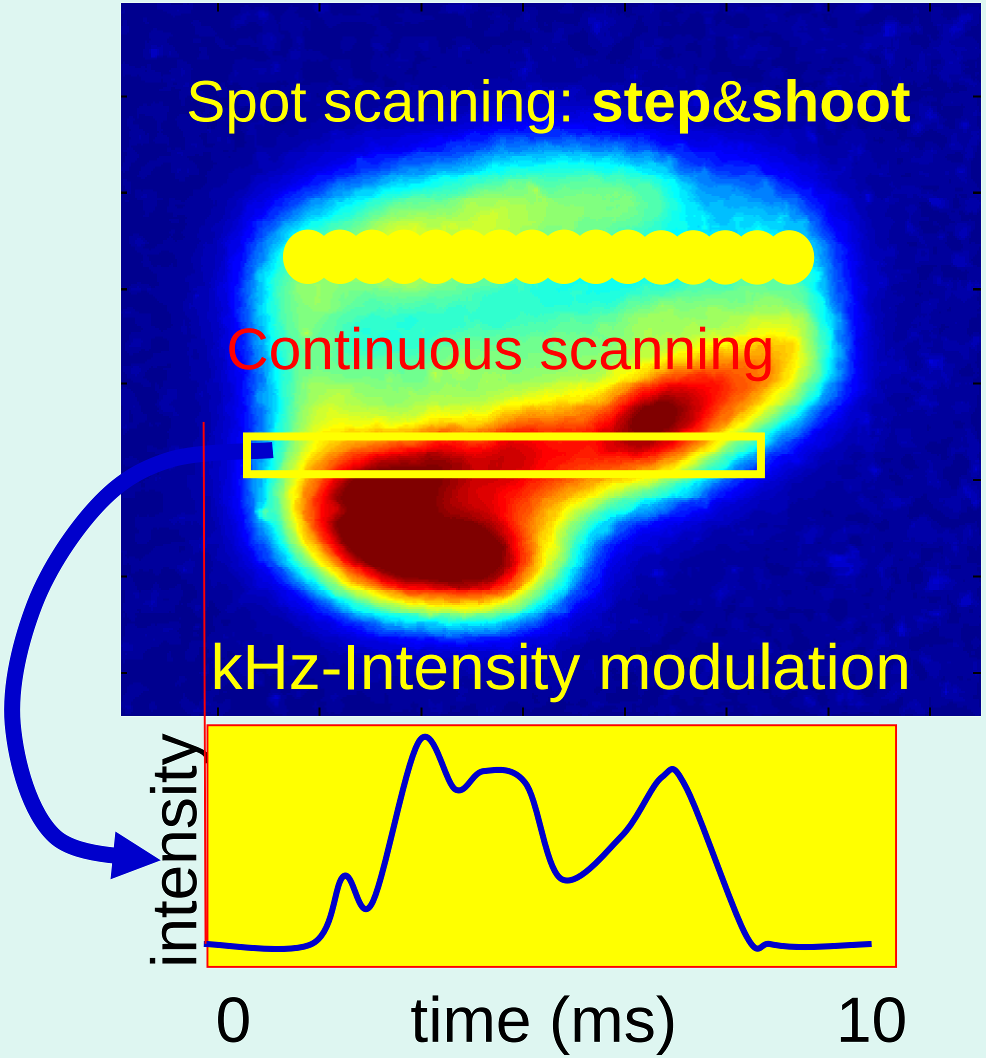


Continuous scanning:

Fast dose delivery

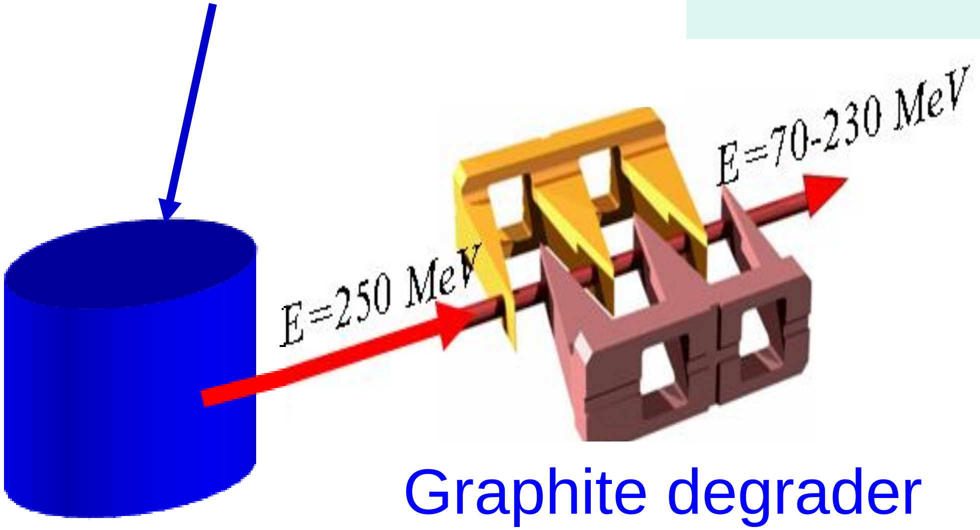
→ prevents motion effects

Dose delivery techniques: **Depth**

To vary energy at **Cyclotron:**

Decrease energy with degrader

230/250 MeV cyclotron



Graphite degrader

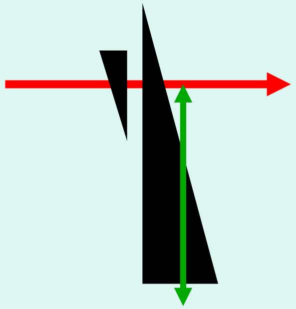
E-Steps →

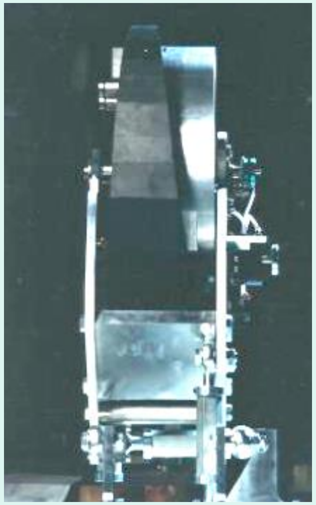
ΔR≈5 mm

+ all following magnets:

1% field change

50-80 ms (PSI)





Synchrotron

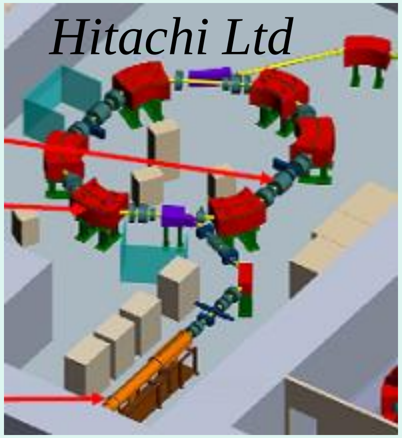
Protons only:

(∅ ~8 m)

synchrotron

Proton source

+ injector



Extracted

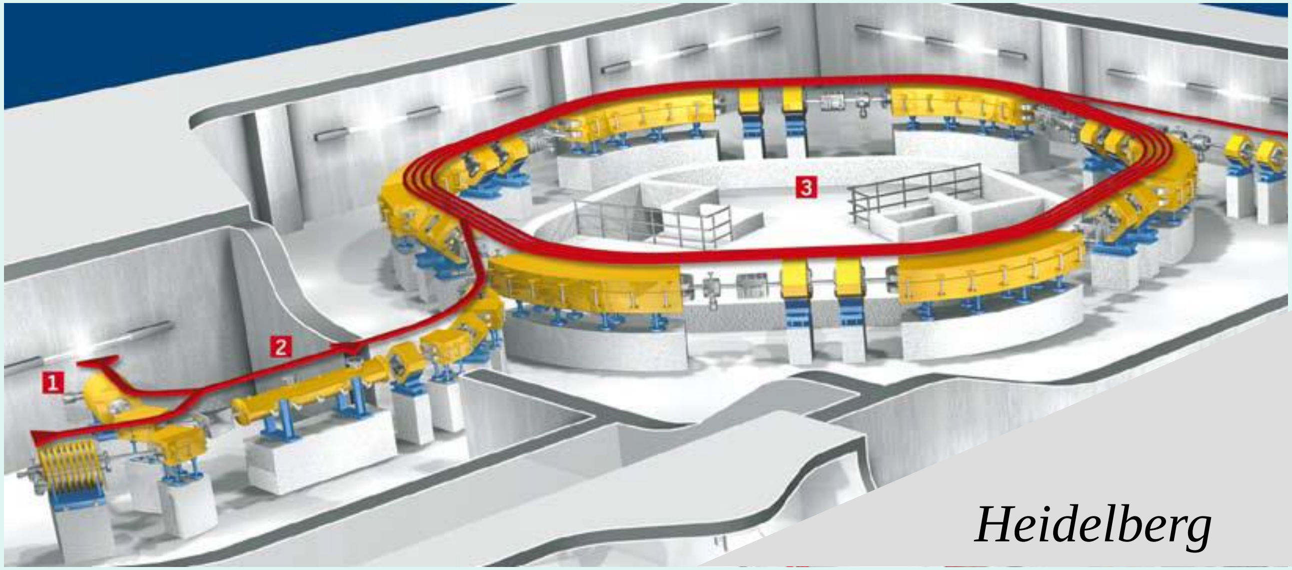
beam

Ions (p-C-…):

(∅ ~25 m)

Several

Ion sources



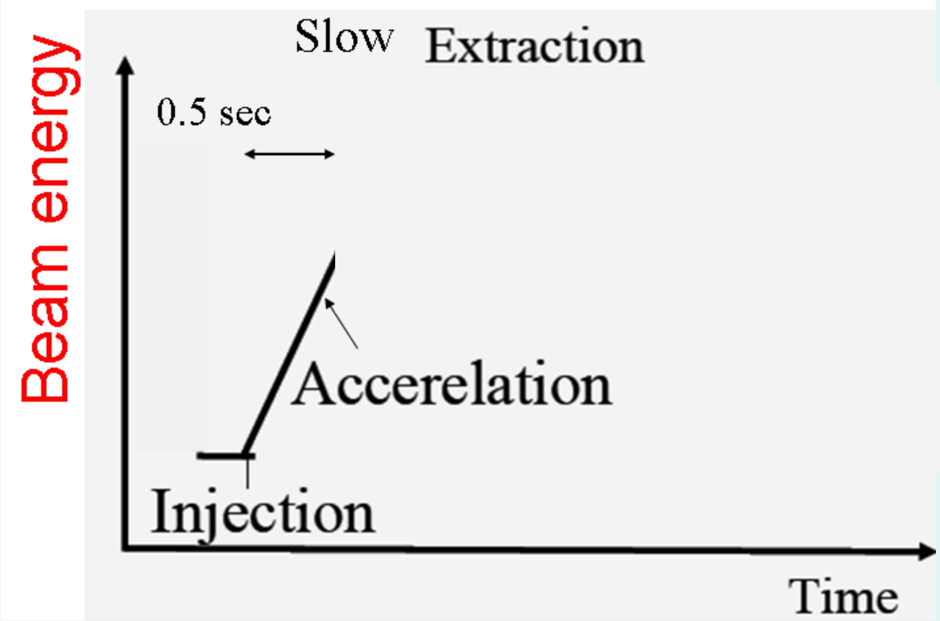
Set beam energy

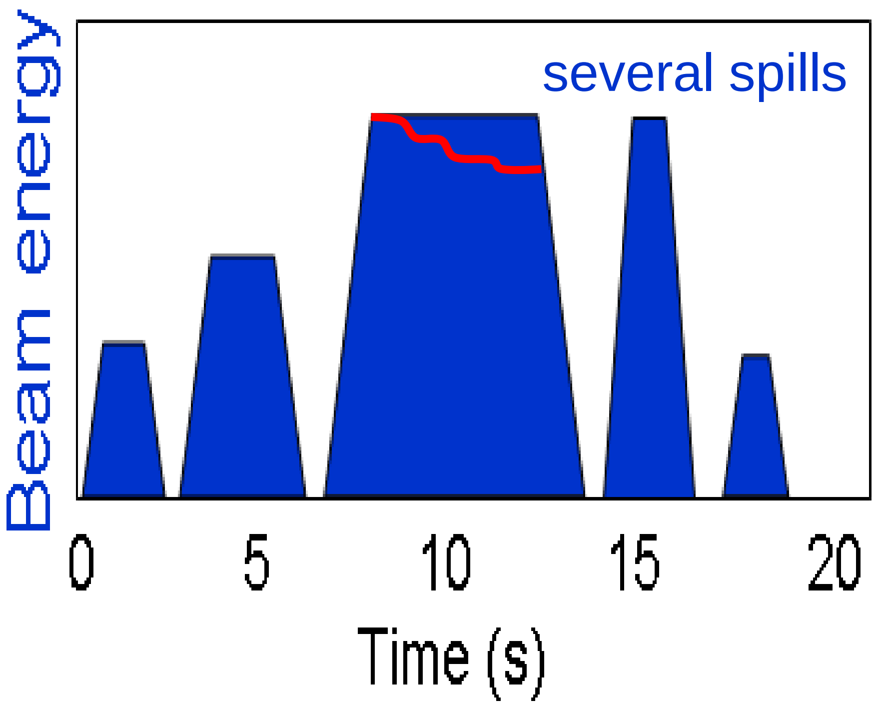
Energy adjustable per spill

recent development:

Energy adjustable **during** spill: Multi E

1 spill



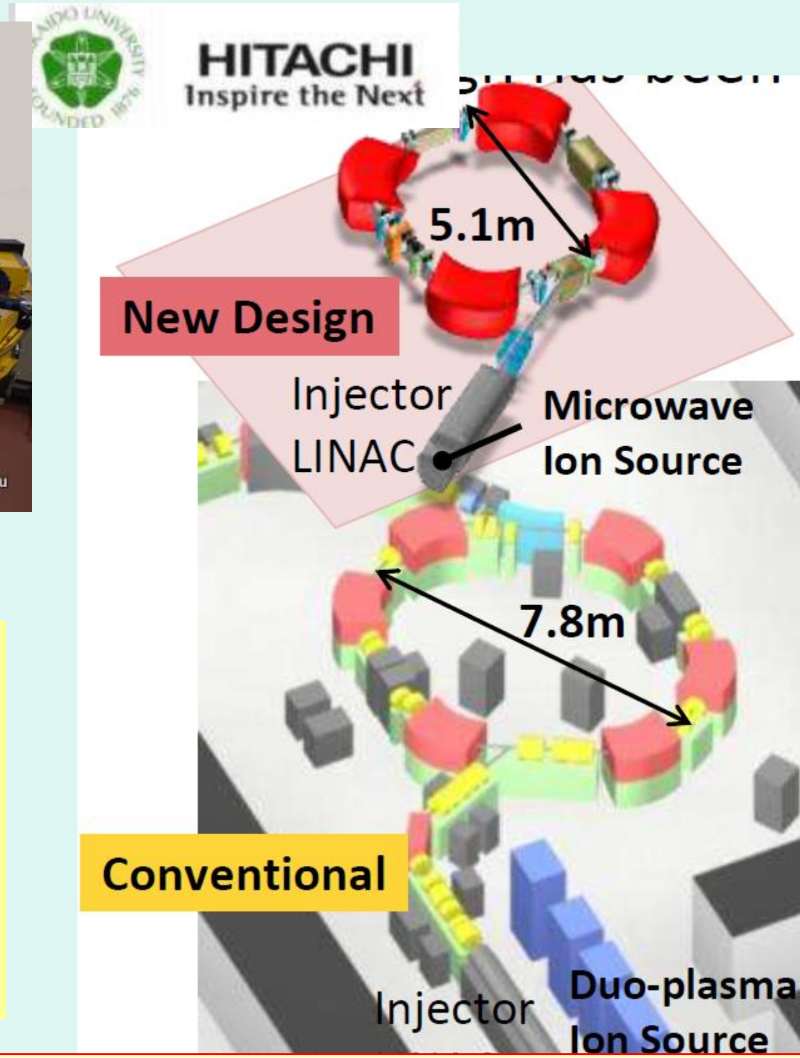


NIRS: Y. Iwata et al., MOPEA008, Proc. IPAC'10

Compact synchrotron

ProTom 330 MeV

Installed at:
2013 McLaren, Flint (Mi)
2019 MGH Boston (Ma)



- 220 MeV
- First facility in Hokkaido started 2013

Characteristics of Synchrotron

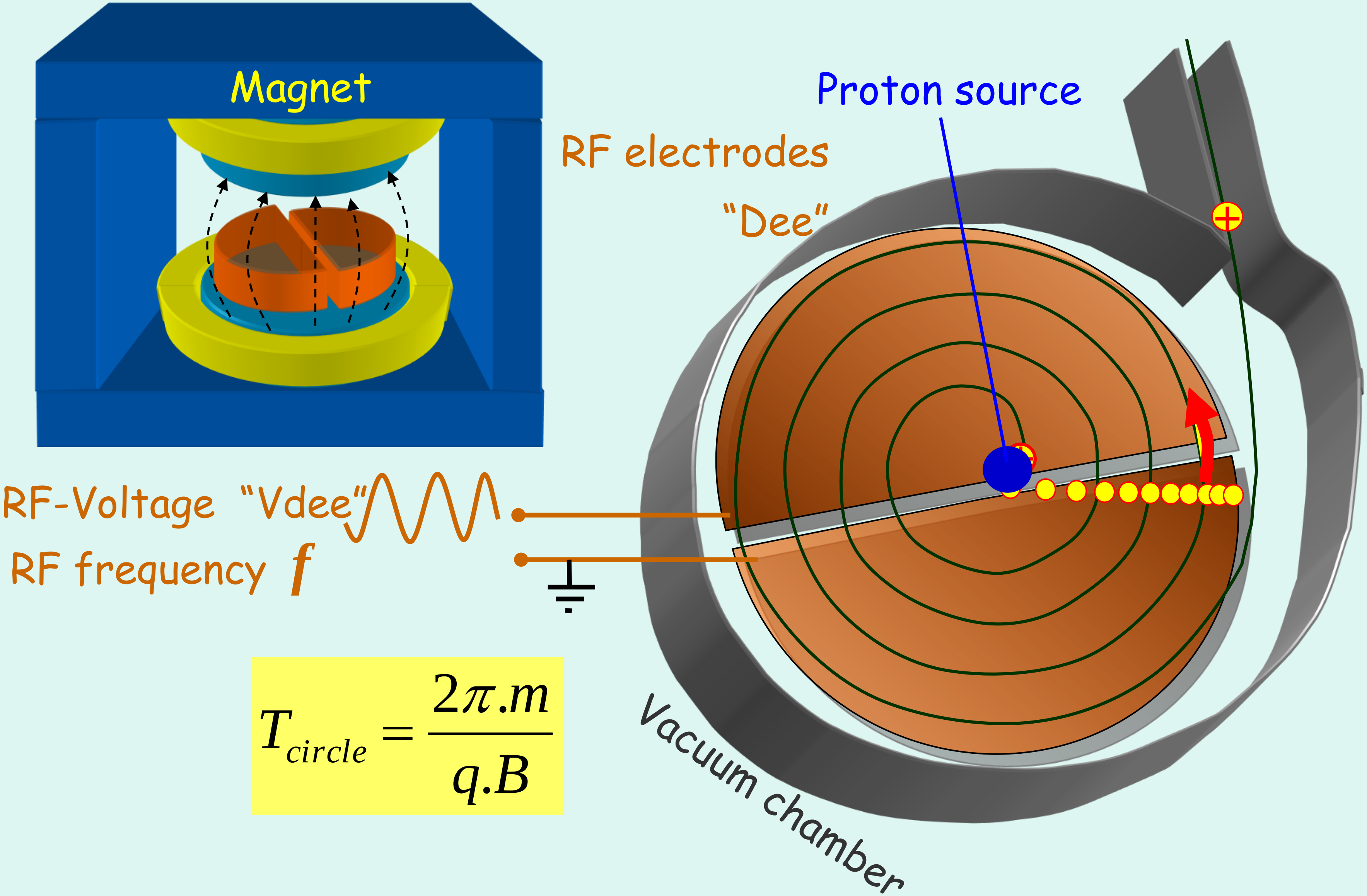
=> a synchrotron provides:

- ions (if designed for)
- adjustable energy per spill (recently: during spill)

Working on:

- increase average intensity (→ increase ring filling)
- reduce intensity noise (→ feed back to RF-knock Out)
- decrease footprint (→ layout + SC magnets)

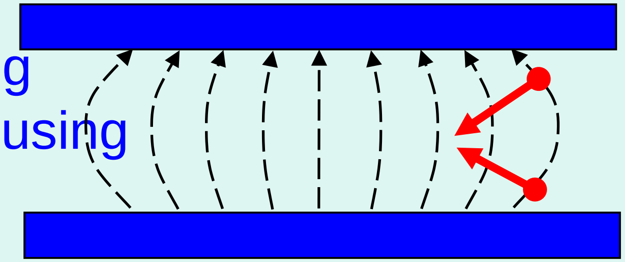
Cyclotron



$$T_{circle} = \frac{2\pi .m}{q.B}$$

Small cyclotron: strong Magn.-field

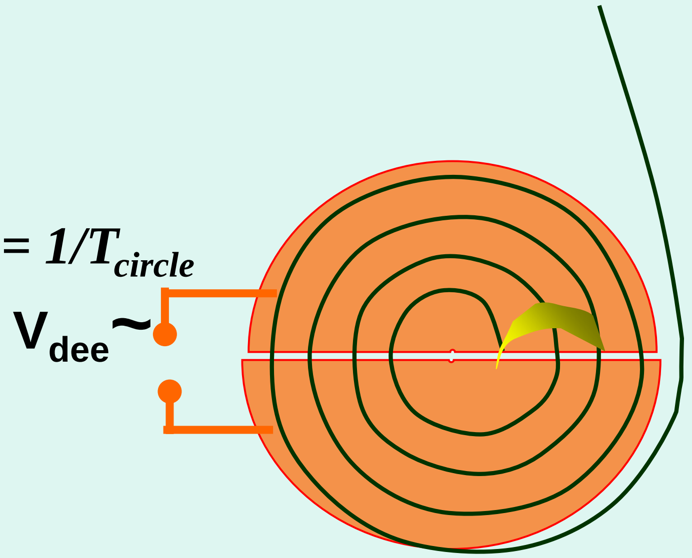
<u>However:</u> at very strong magnetic fields:
Iron is saturated
→ no iron hills/valleys for vertical focusing
→ Use natural field shape for vertical focusing



⇒ **BUT then…**
Magnetic field decreases with radius

⇒ $T_{circle} \uparrow$

$Freq = 1/T_{circle}$



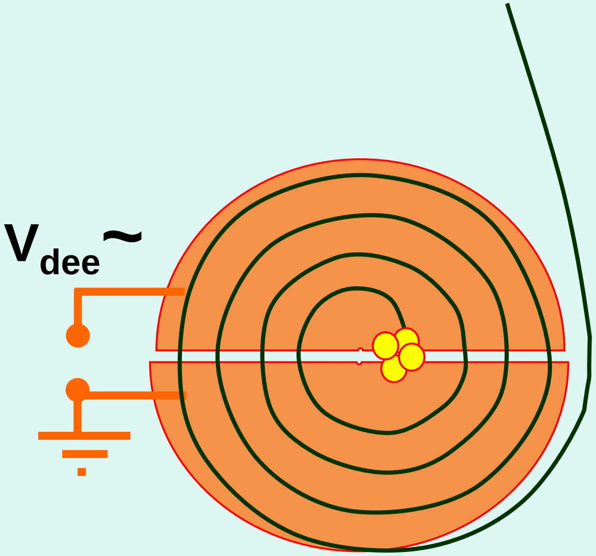
Synchro-Cyclotron

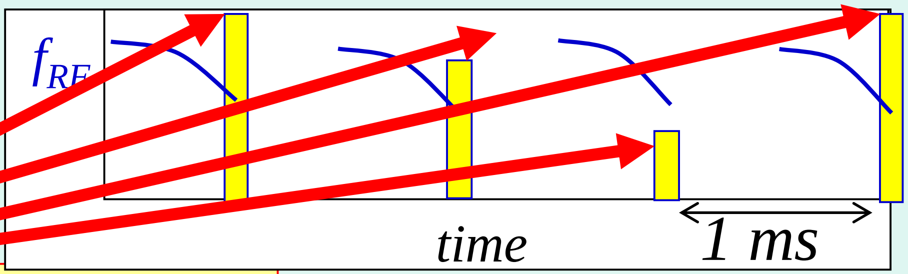
T_{circle} increases with radius.

Remedy: decrease f_{RF} **as** f_{RF} **= 1/T_{circle}**

= synchronous with radius
and extract

Repeat 100-1000/sec → PULSED beam





Each pulse: set intensity at source **within ms**

(=> typ 10-30% accuracy)

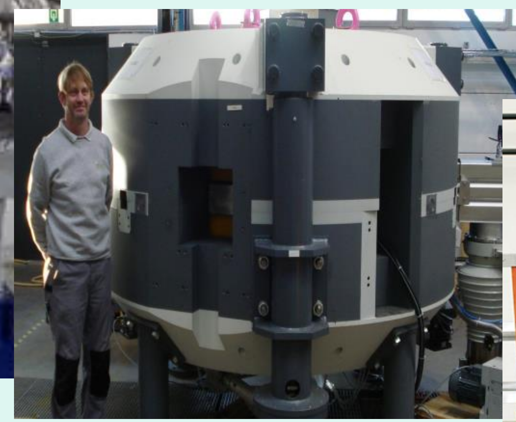
=> Spot scanning requires >2 pulses per spot.

Cyclotrons for proton therapy

Superconducting Coils

IBA (1996) , SHI
250 Tons
Isochronous
Cyclotron

Varian (2005)
90 Tons
Isochronous
Cyclotron

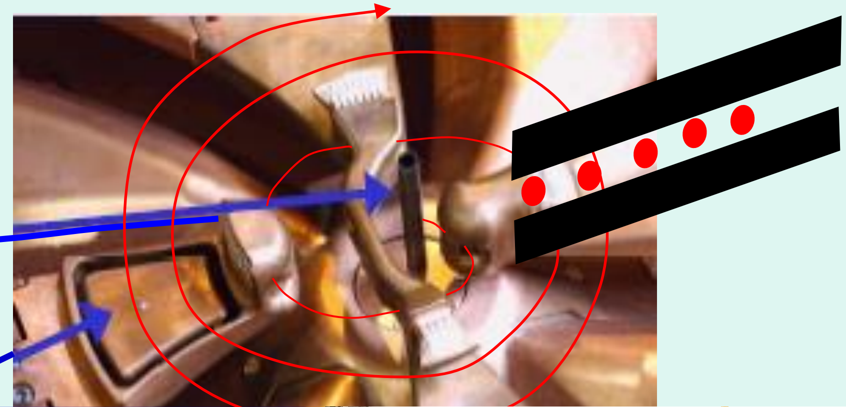


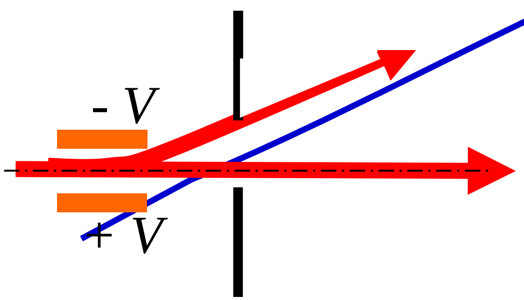
IBA (2018)
60 Tons
Synchrocyclotron

MEVION (2013)
15 Tons
Synchrocyclotron

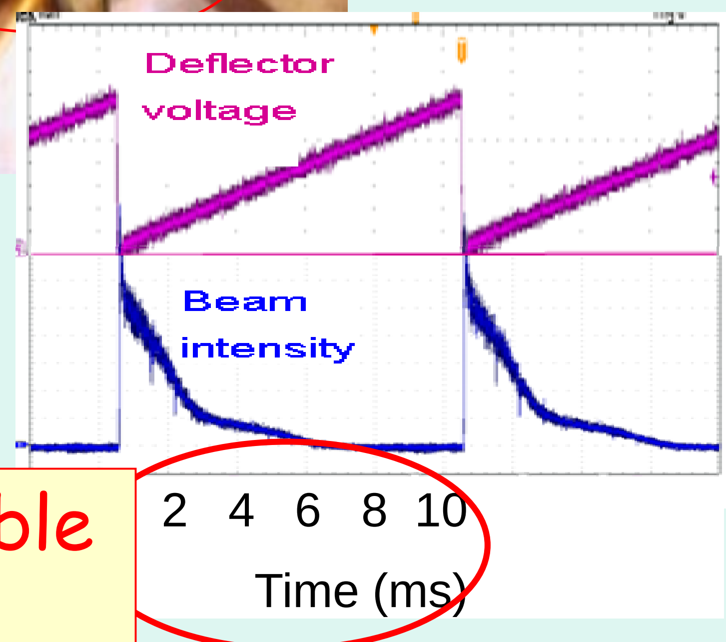
fast intensity control

Max. intensity set by:
proton source





Deflector plate:
sets intensity
- within 50 μs
- 3% accuracy



currently only possible with a **cyclotron**

Characteristics of a cyclotron

=> a cyclotron provides:

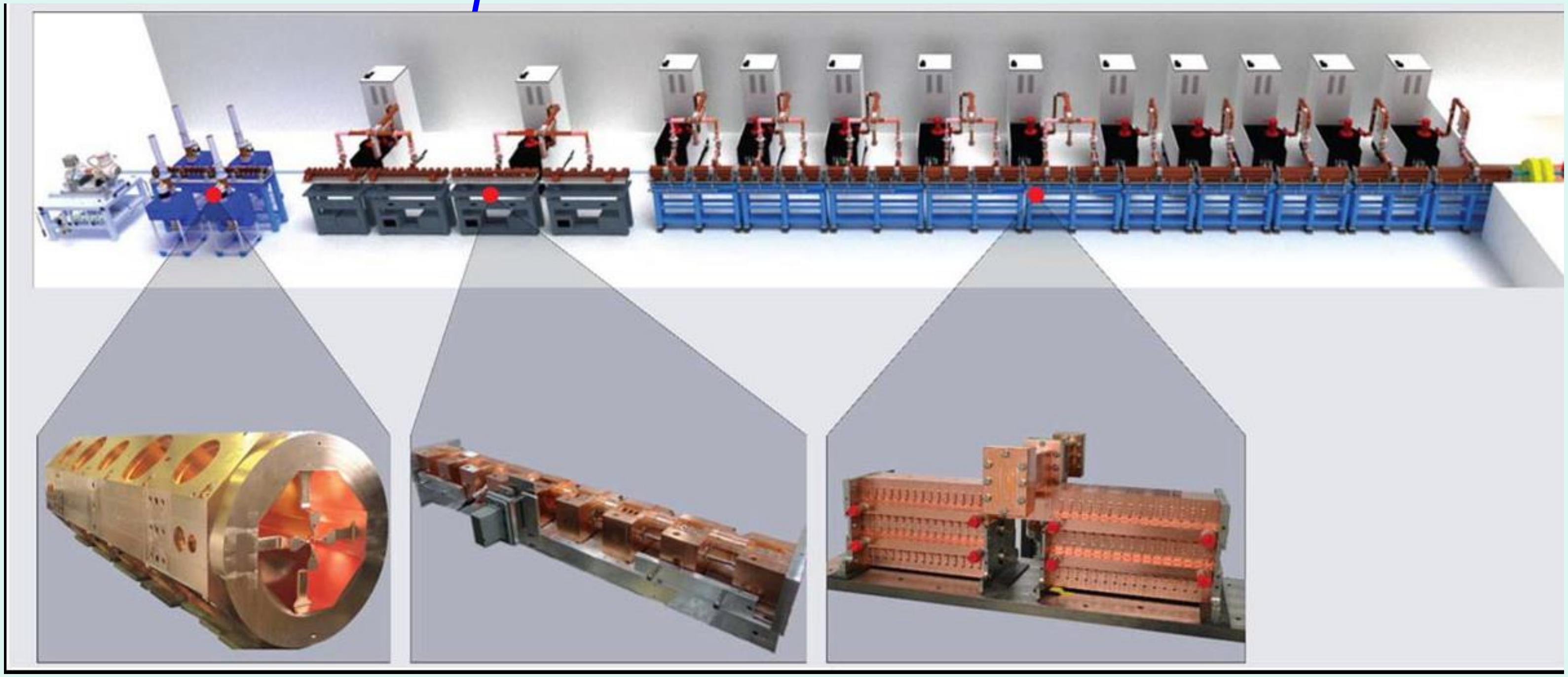
- continuous beam (but **synchro**cycl: **pulsed**)
- very fast and accurate intensity control
- fast E change with degrader and fast magnets
- small footprint

In development:

- higher dose rate
- smaller/ lighter /cheaper
- carbon ions

Linac 230 MeV

Spin-off from TERA and CERN:



RFQ
→5 MeV

Side Coupled
DTL →37 MeV

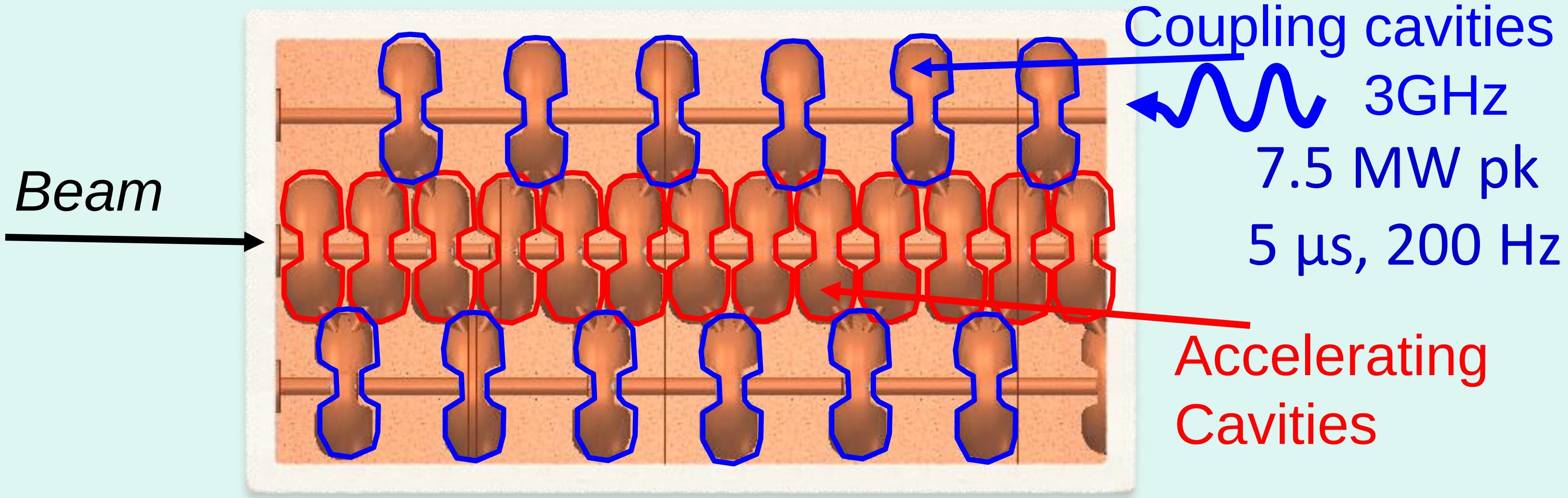
Coupled Cavity Linac
20 MeV/m →230 MeV

AVO, ADAM: A. Degiovanni et al. 2016

Coupled Cavity Linac

Standing wave

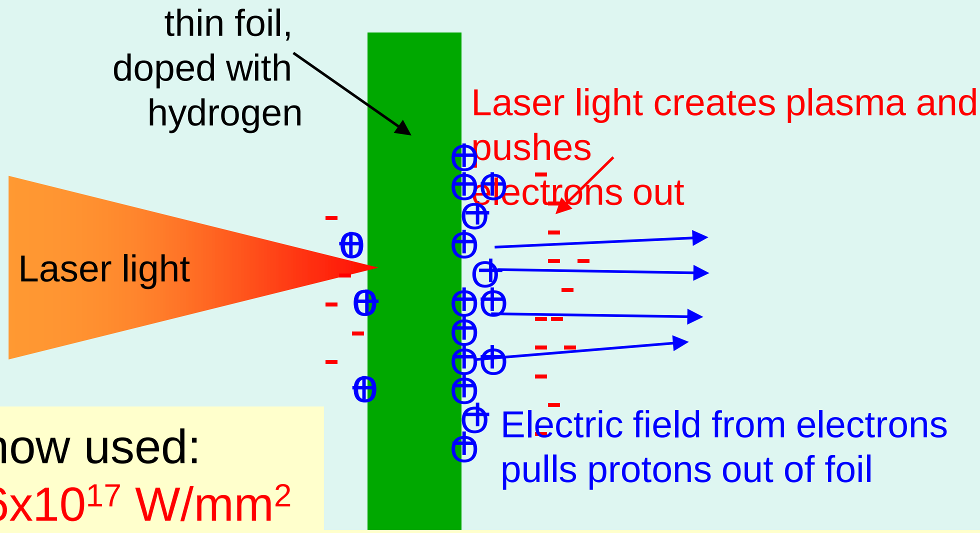
3 GHz: **strong E field** possible: 20 MeV/m



Linac advantage: Fast Energy change by switching cavity power

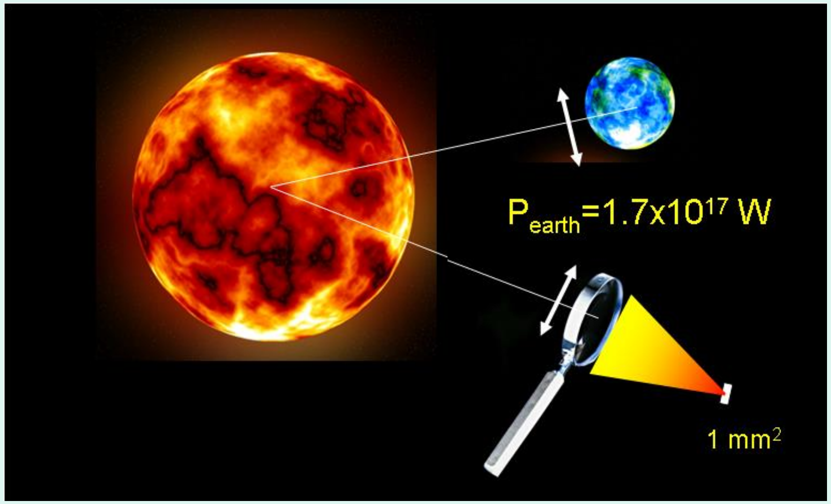
Other Developments
in
Accelerators and Gantries

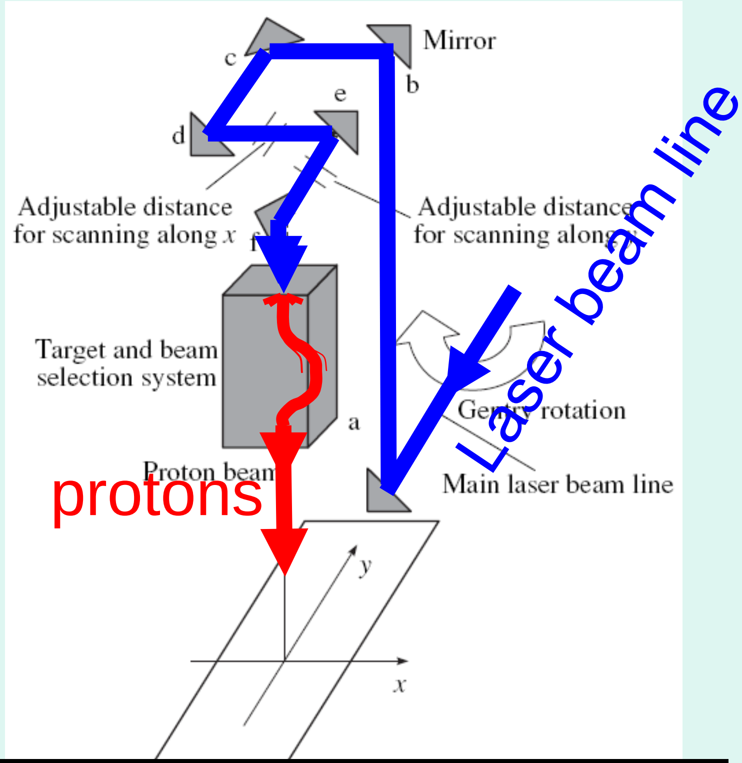
Laser driven proton accelerator



now used:
6×10^{17} W/mm^2

≈ total solar power on earth, focused at 1 mm^2

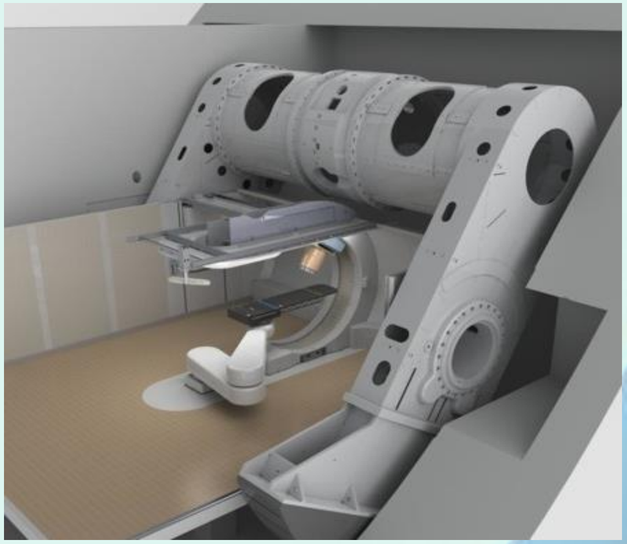




But:
- 100x more power is needed
- Energy spectrum: not homog.

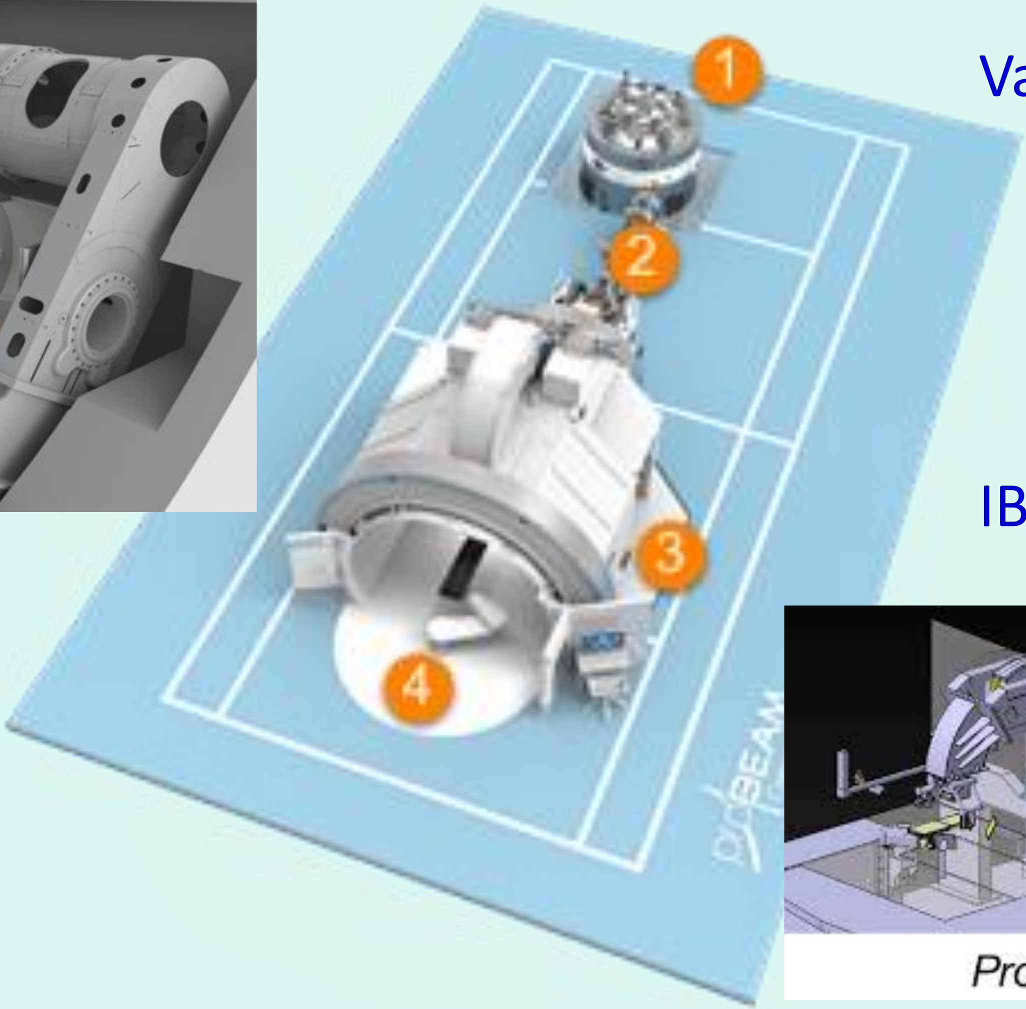
→ takes time!!

Proton therapy: **single-room** facility

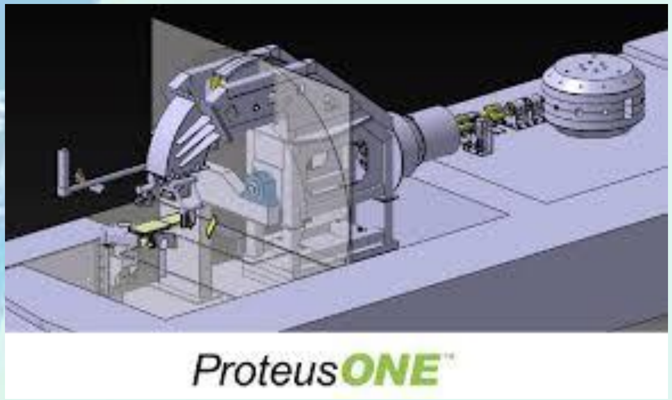


Mevion

Varian Probeam

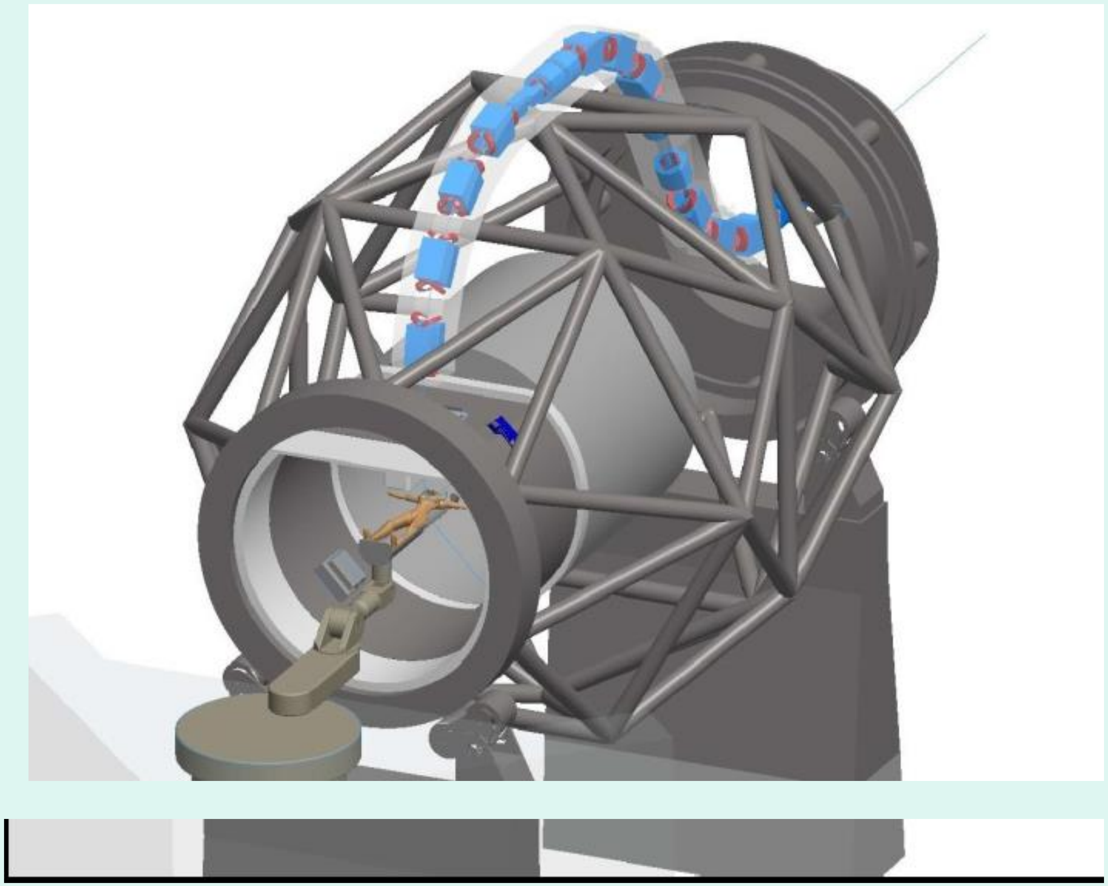


IBA Proteus one

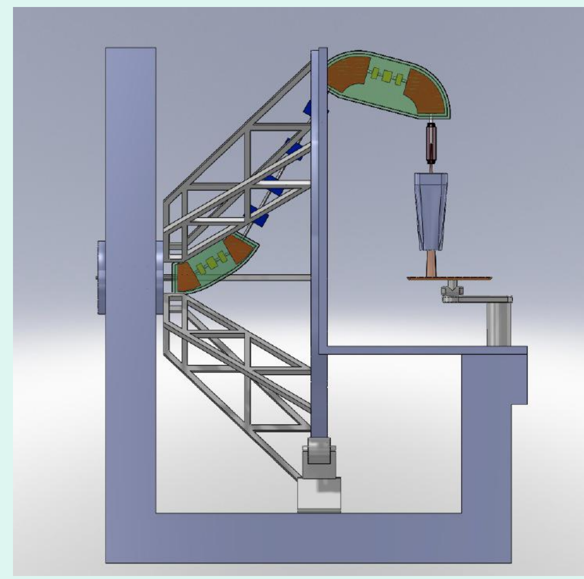


NEW: SC gantries

NIRS, Japan, since 2017: C-ions

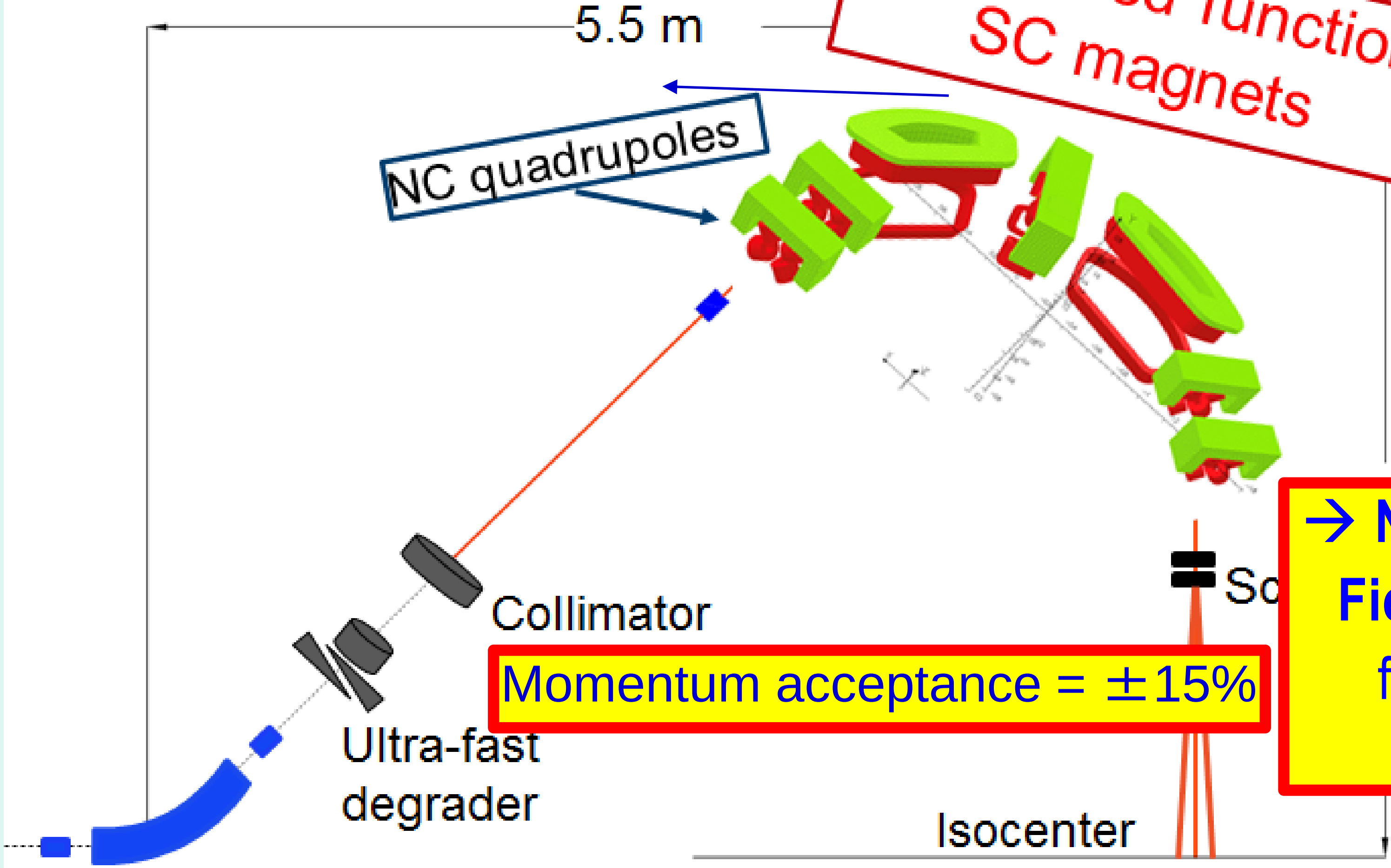


SC360 of ProNova: protons



NEW optics in SC gantry design

Proton SC Gantry (PSI)



Momentum acceptance = ±15%

→ **NO Magnetic Field change**
for tumors
15-30 cm

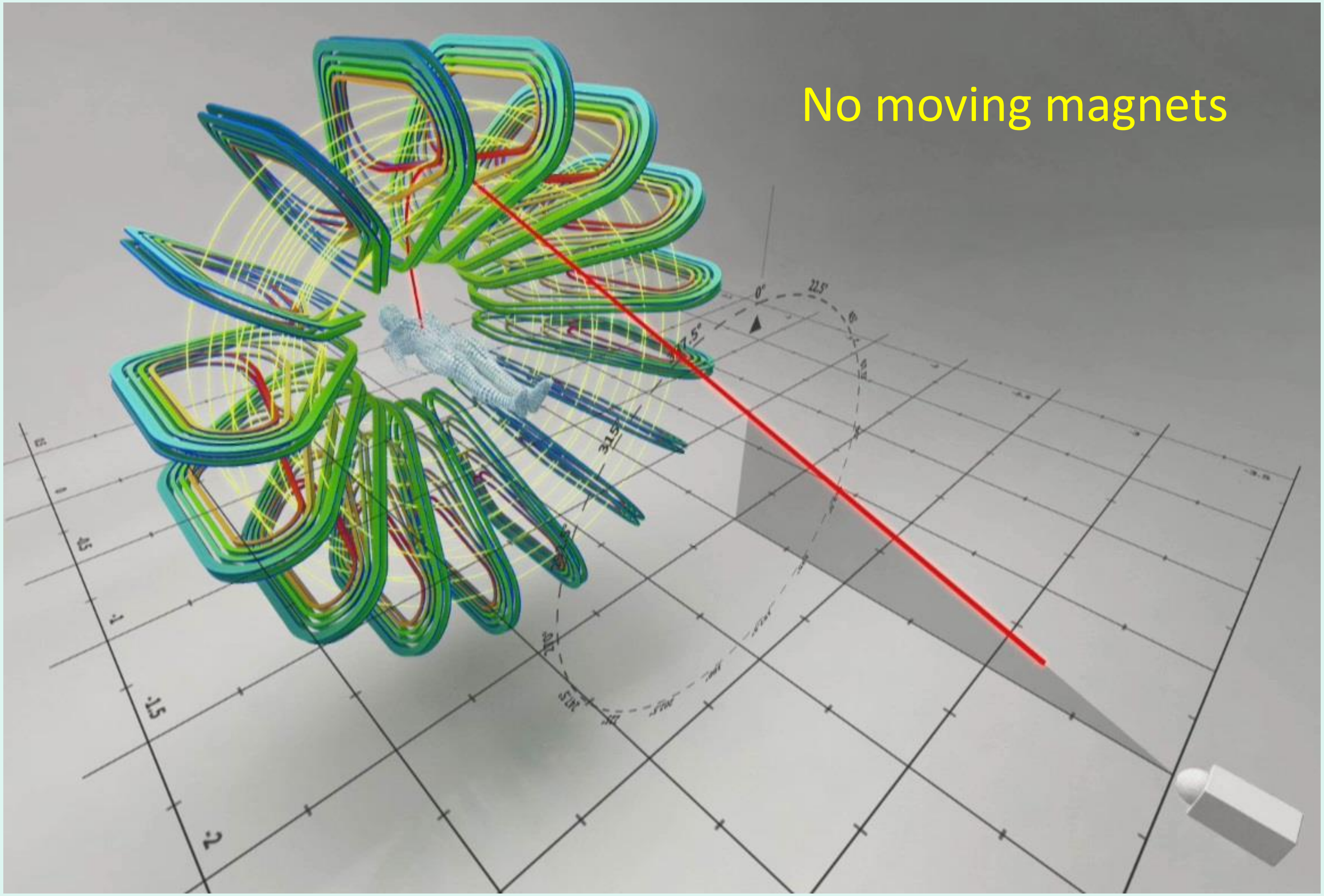
SC magnets in GANTRY:

Proton gantries **Not** much smaller diameter

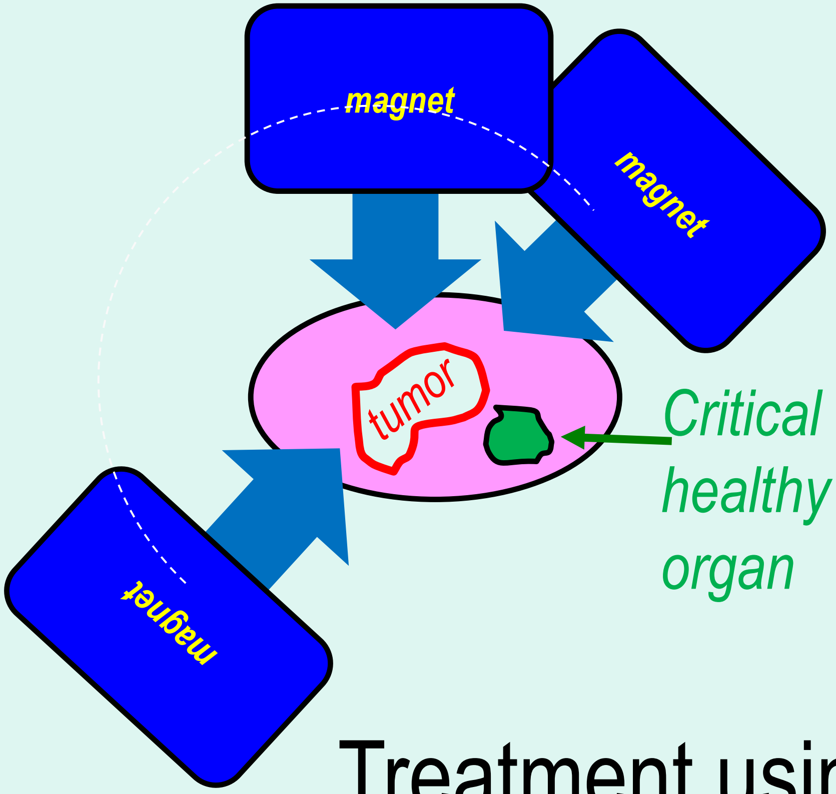
Much **less weight**

New beam **optics** (→ treatments) possible

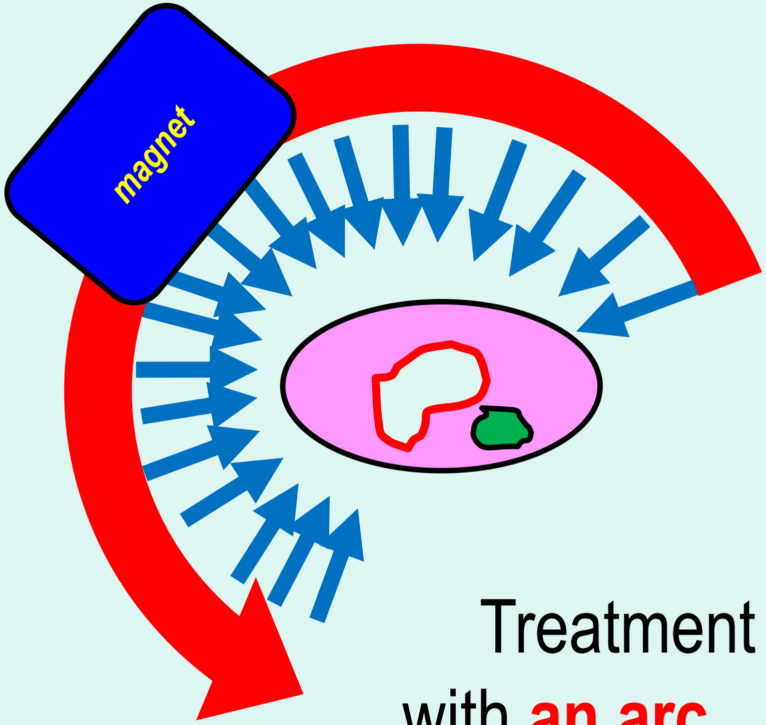
GaToroid (CERN)



Arc Scanning

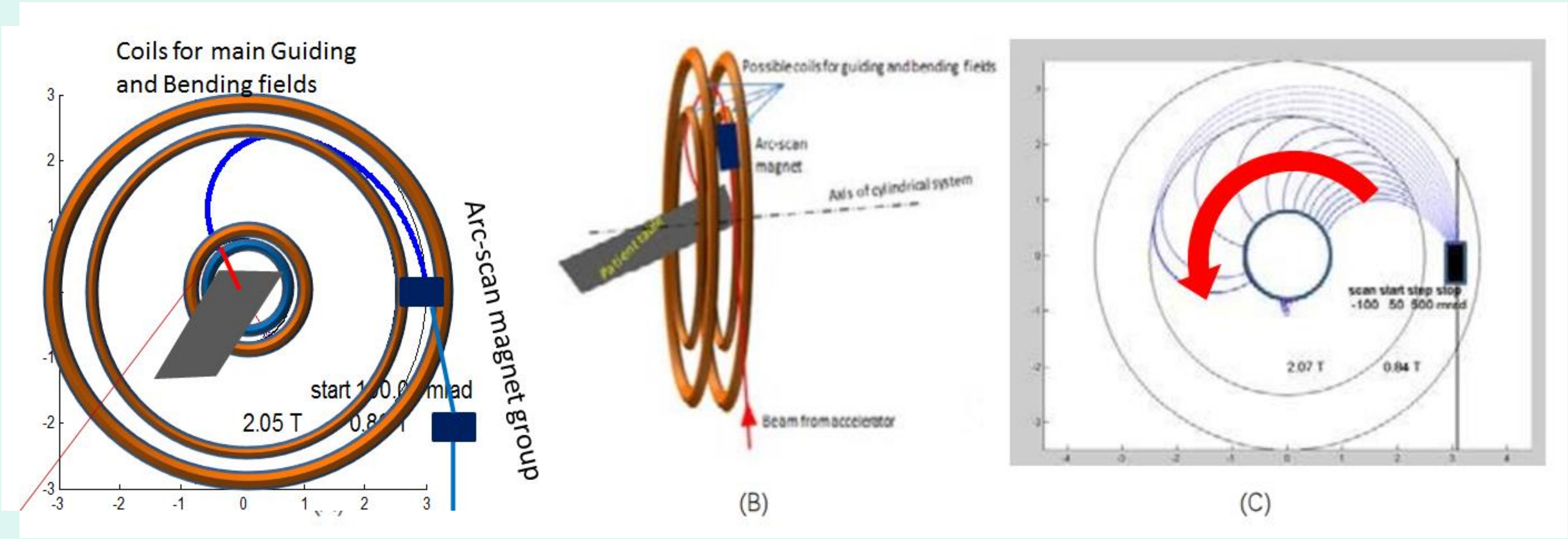


Treatment using
3 beam directions



Treatment with **an arc,** (= **continuous angular range**)

Fast Proton-**Arc** Scanning (PSI)



- No moving magnets
- Extremely fast **continuous arc** irradiation

Patent pending (applied for)

New Developments

New accelerator types:

Nice ideas and great developments!

But do not only check price:

- What is the **advantage**?
- **When** available?
- Is **treatment quality ≥** now ?
- How is **organisation of supplier**:
  Certification (FDA CE…), service, upgrades?

THE ONLY MOTIVATION for Particle Therapy !!

first scanning gantry : PSI, 1996

Thank you !!

Gantry: Eros Pedroni

Tumours in kids: Beate Timmermann, Gudrun Goitein