CAS15 - Case Study Work

Group 12 – ACCORDION Collaboration

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Jerome: "As our brain was already irradiated by accordion music, I propose
ACCORDION
as the acronym, which obviously means ACCeleratOR for Delivering IONs"

Context & Business Case

We choose a country ... … of **considerable size**
(e.g. Spain ca. 50 million inhabitants)

currently **2%** inhabitants treated with X-rays
12% of those *would be better* treated with protons
3% of those *would be better* with Carbon-ions

→ 50000000 x 0.02 x 0.15 = **15000 potential HT patients**

capacity/treatment room: **345** patients/y with protons,
690 patients/y with Carbon-ions

→ more than enough patients for whom HT is the better option!

If proton therapy would cost the same as X-ray therapy, 90% of patients would be treated with protons.

Amaldi et al, NIM in Physics Research A 620 (2010) 563-577

Context & Business Case

We choose a country …

- … part of the **industrialised** countries:

→ Money, even for a big facility, is ***in principle available***.

Context & Business Case

In these circumstances, we want to be ambitious!

→ Go for a combined "heavy" ion facility …

- … which delivers both **p and C^{6+}** beams
  This brings the to-date cutting edge technique to our country.

- … has got multiple irradiation rooms
  optimise efficiency of operation, more treatments per year

Context & Business Case

Clinical goal is most important → use established technologies

Several C/p facilities in operation (HIMAC, HIT, CNAO, Shanghai, ...) or in commissioning (MedAustron, MIT)

HIT, www.klinikum.uni-heidelberg.de

Context & Business Case

Cost estimate

→ 1 patient treated with HT costs ~ 20-25 k€ (~**40 M€** for 1810 patient/y*)

→ 1 patient treated with X-rays costs ~ 15 k€ : short-term & very long-term side effects (2ndary cancers, irreversible organ failure)

→ facility of 200 M€ investment & yearly operation cost of ~35M€ (2M€ power, 20M€ salaries, maintenance cost 10M€, misc 10%)

Be ready to finance the construction and operation of the facility from **public funds**.

Time estimate

→ 5 years from approval until first clinical operations

→ operation for at least 20 years

*Capability based on *Amaldi et al, (2010), assuming 1 p patient every 3 C-ion patients*

Context & Business Case

Additional benefits

- As our country does not have (any) hadrontherapy centre yet, a hadrontherapy facility is an opportunity for capacity building for future high-tech industry.
- **There are also no other p or ion accelerators** (reaching hundreds of MeV/u) dedicated to other fields of research.
- Co-operation with **other academic fields** outside of medicine creates synergy effects, and comes "almost for free" for a high rigidity accelerator complex.
  University research opportunities in Biology, Physics, Dosimetry
  Training of accelerator physicists and engineers ...

Technical Description

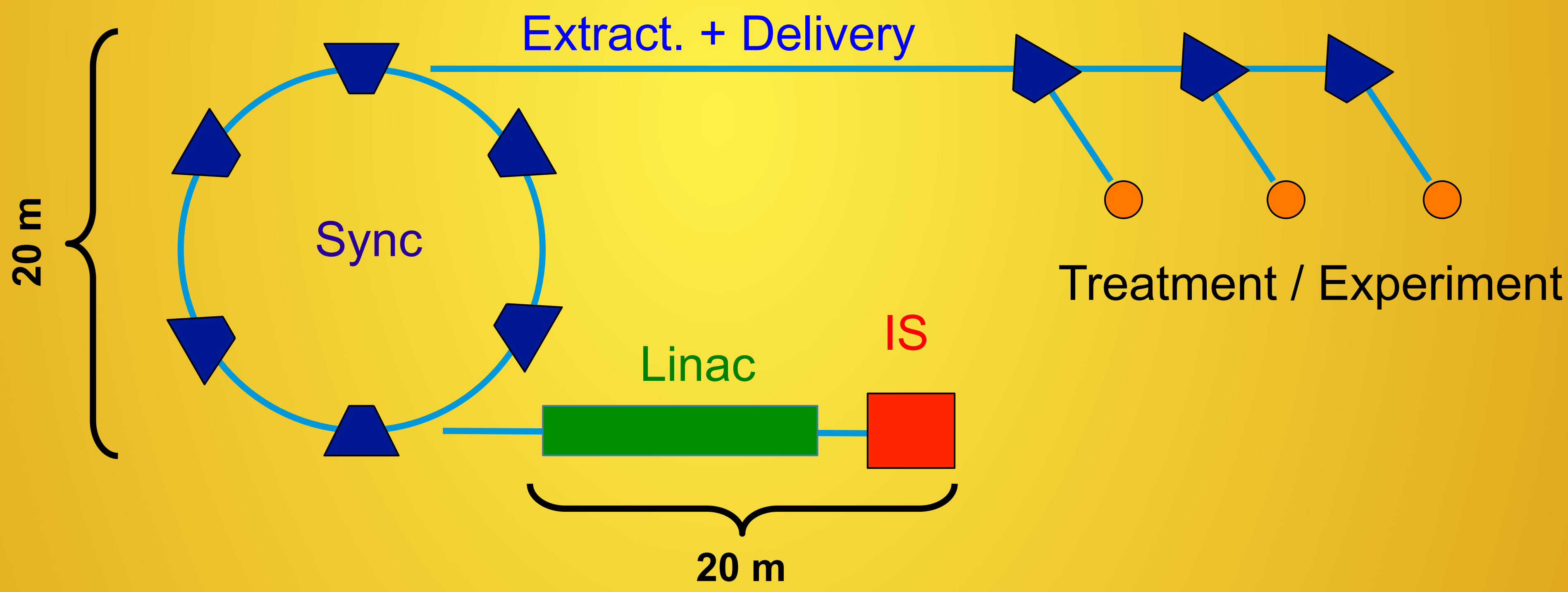
clinical requirements:

- 250 MeV/u p (Bρ = 2.4 Tm) **10^{10} / s**
- 400 MeV/u C^{6+} (Bρ = 6.4 Tm) **10^{8}-10^{9} / s**

possibly even higher energy for research purposes?
→ Even stronger magnets and/or larger facility

Higher energetic protons come „for free“ ...

Technical Description



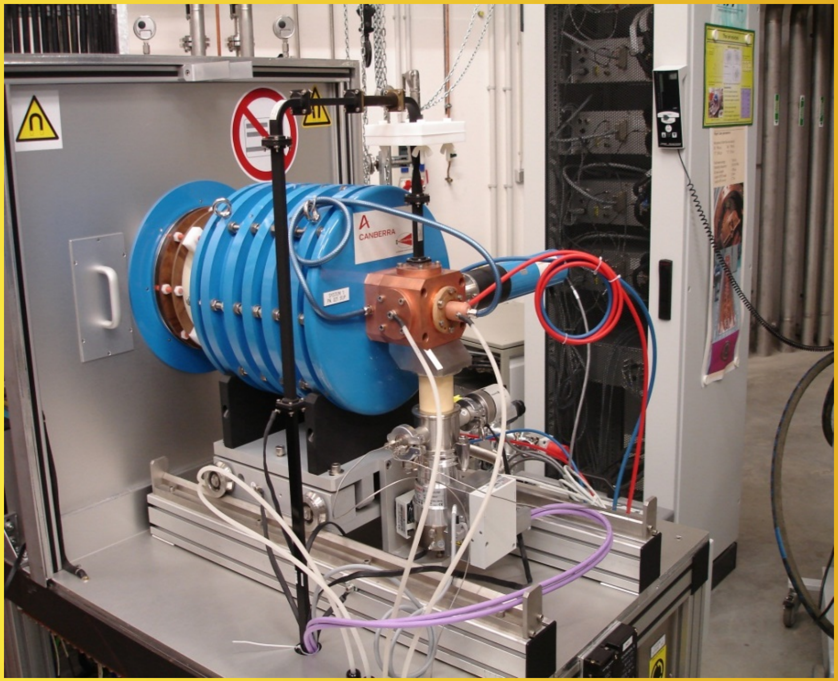
Ion Source: Supernanogan

Choice for established source:

Electron Cyclotron Resonance (ECR) Ion Source

Has been proven in a number of installations:

- MedAustron (H_3^{1+}, C^{4+})
- HIMAC
- CNAO
- HIT

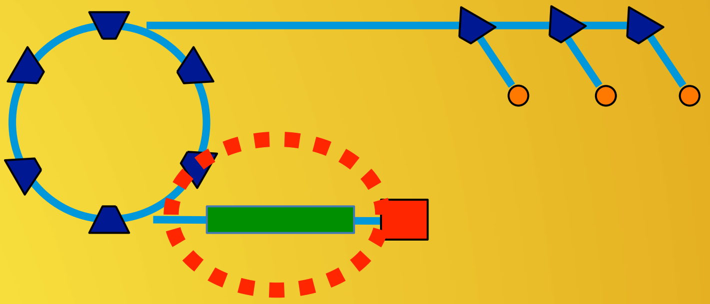


Beam intensity (within emittance): C^{4+} H_3^{1+}	200 μA 500 μA
Emittance (95%)	180 π mm mrad
IS-HT, energy spread	30 kV, < 1%
24h Beam Stability (peak to peak) : Intensity and Emittance	< 4%
Reproducibility of all beam parameters after restart before tuning	5%
Maintenance interval Duration (1 ion source)	> 12 month < 2 weeks
Synchrotron injection	< 100 μs

- permanent magnet
- Frequency 14.25-14.75 GHz
- Operation mode: continuous wave
- Extraction voltage: 24 kV@C^{4+}

[Source: Ion Sources for MedAustron, CERN-BE-Note-2010-001]

Accelerator



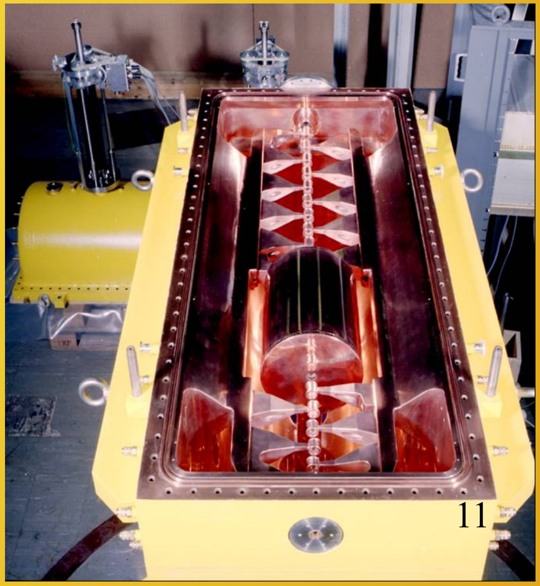
Linear accelerator

(8 keV/u → 7 MeV/u)

RFQ (8 keV/u → 0.4 MeV/u)

takes cw-beam from source

bunches and accelerates simultaneously



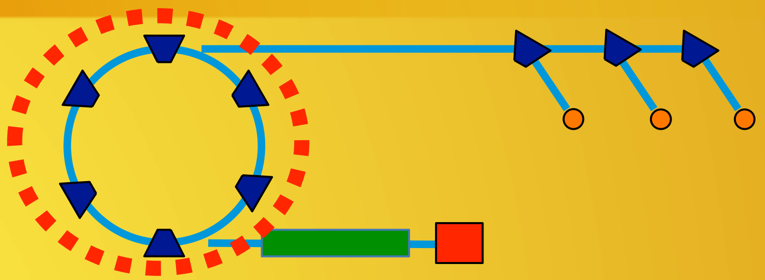
IH Structure (0.4 MeV/u → 7 MeV/u)

Needs pre-bunched beam

Accelerating field between drift tubes

Accelerator

Synchrotron



Rigidity $B\rho = p/q$

min: 0.38 Tm (p at injection)

max: 6.4 Tm (for C at 400 MeV/u)

Normal conducting magnets: $B \sim 1 - 1.5$ T

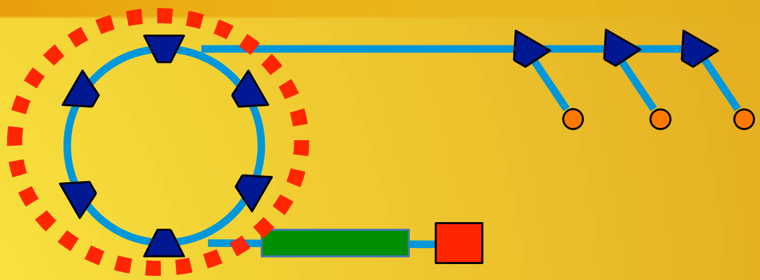
→ $\rho > 6$ m

+ space for quads, rf, injection, extraction ...

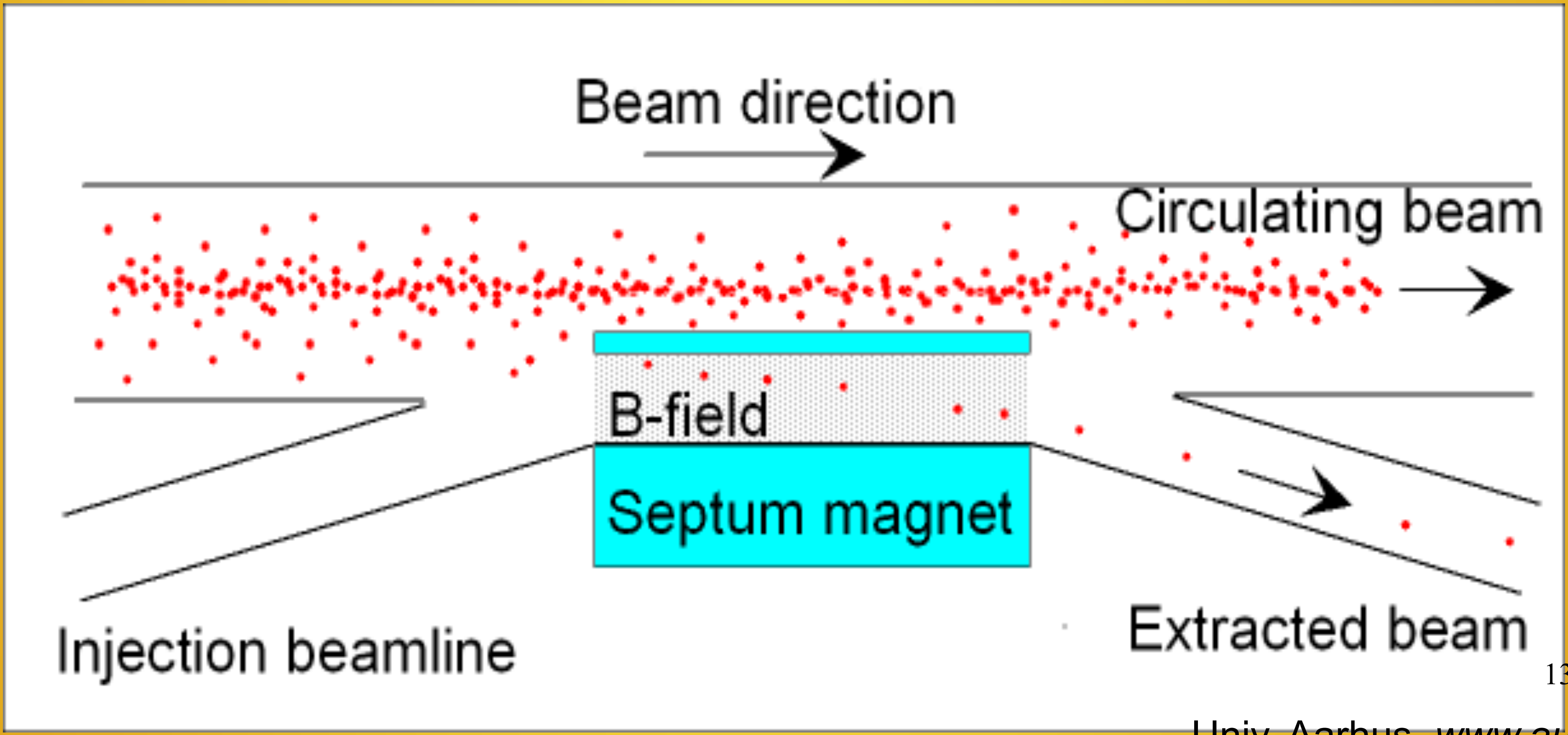
→ diameter of ring ~ 20 m

Accelerator

Synchrotron cycle



- Inject every **few seconds**



Univ. Aarhus, *www.au.dk*

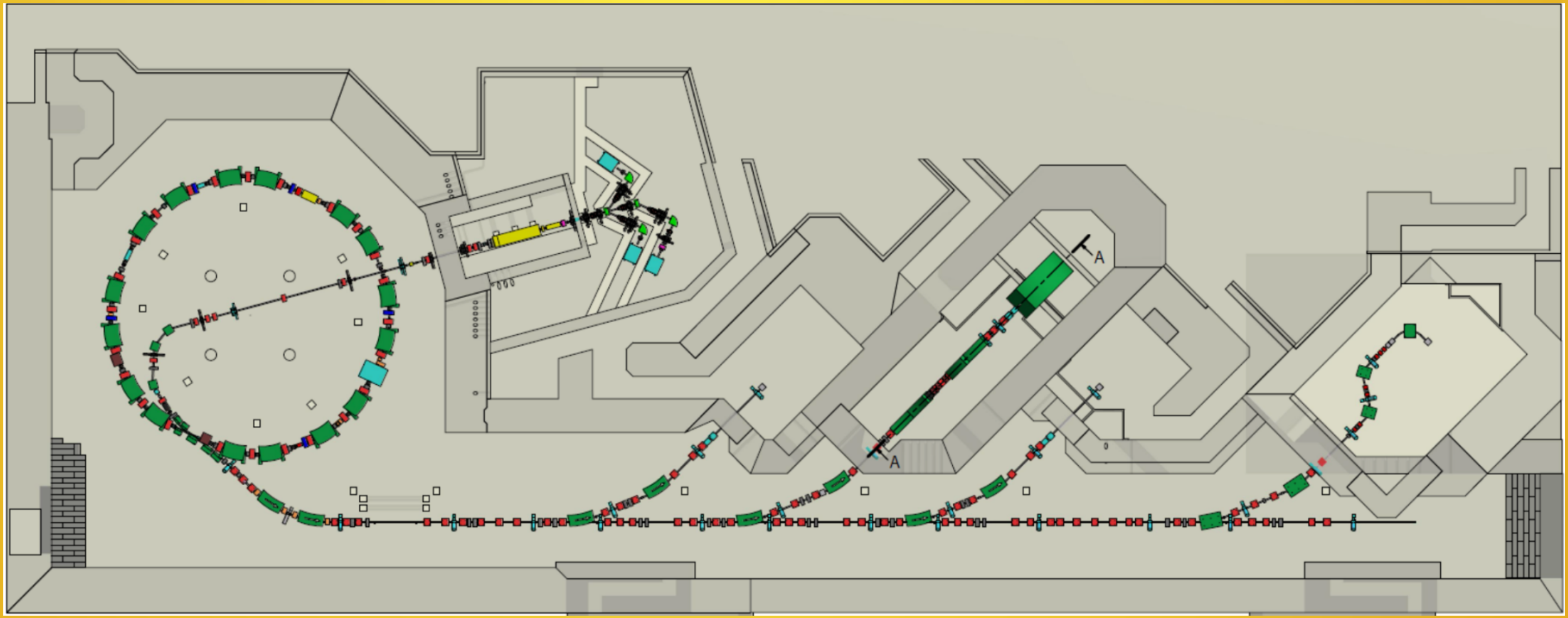
Treatment Rooms

3 treatment rooms

- horizontal + vertical beamline, horizontal beamline, 1 proton gantry (established technology)
- optimize patient workflow: 3 set-up rooms

1 NCR general purpose room w/ v+h beamline (60MeVfrom below)

- Radiobiology, dosimetry R&D, radiation hardness studies, nuclear research
- other ions be provided with ion source upgrade (e.g. Li)



Treatment Rooms

Robotic positioning coach

7 DoF (incl pitch & roll & longitudinal)

Interlock system (dose control, beam off)

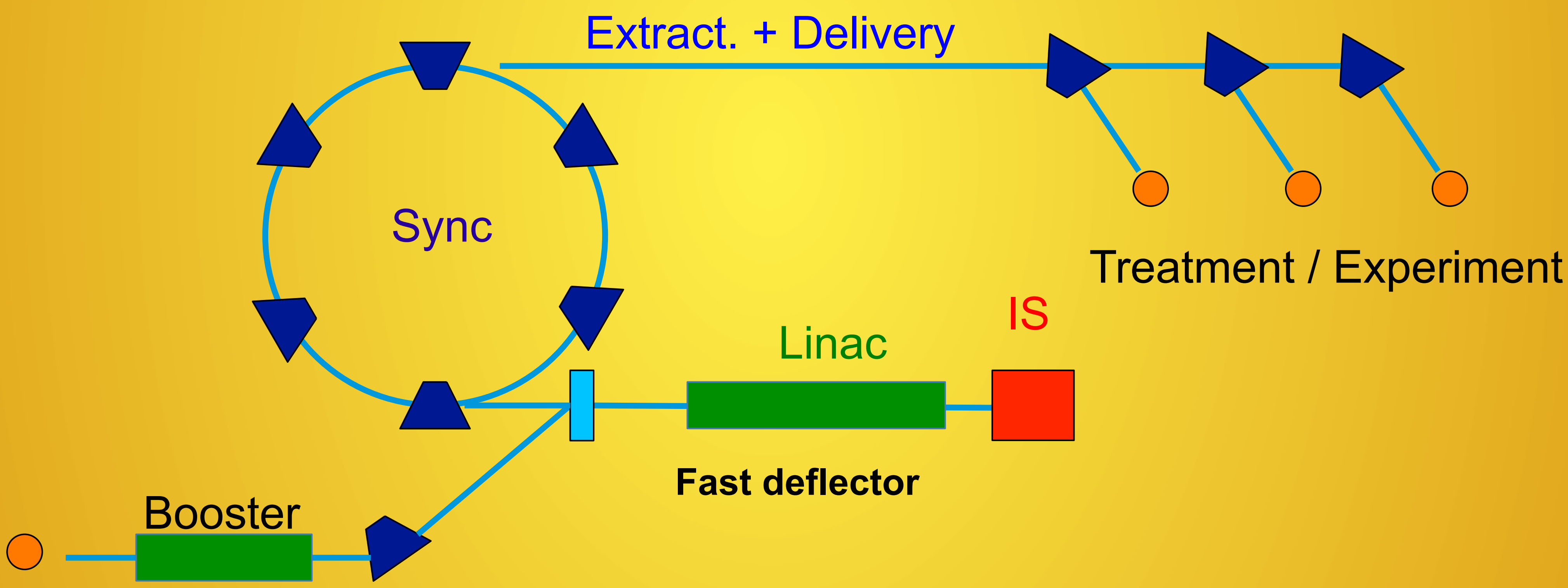
Quality Assurance water phantom

Imaging/Control in same room

CT scanner around couch (alignment!)

... The cherry on the cake

Use the in-between-injection time for isotope production or other NCR activities?



Investing in this p/C facility will bring our Country to the forefront of contemporary HealthCare

And build the capacity for further high-tech in Spain!

Thank you!

Possible Upgrade: Helium gantry

<u>Just some estimations:</u>

-At fixed energy per nucleon, alpha particles and protons have the same range

-At a given energy per nucleon, Brho(He)~2Brho(p)

-The max Brho of a gantry for protons is ~ 2.5Tm.
Assuming a conventional 90° magnet with Bmax=1.5 T will have a length ~ 2.81 m

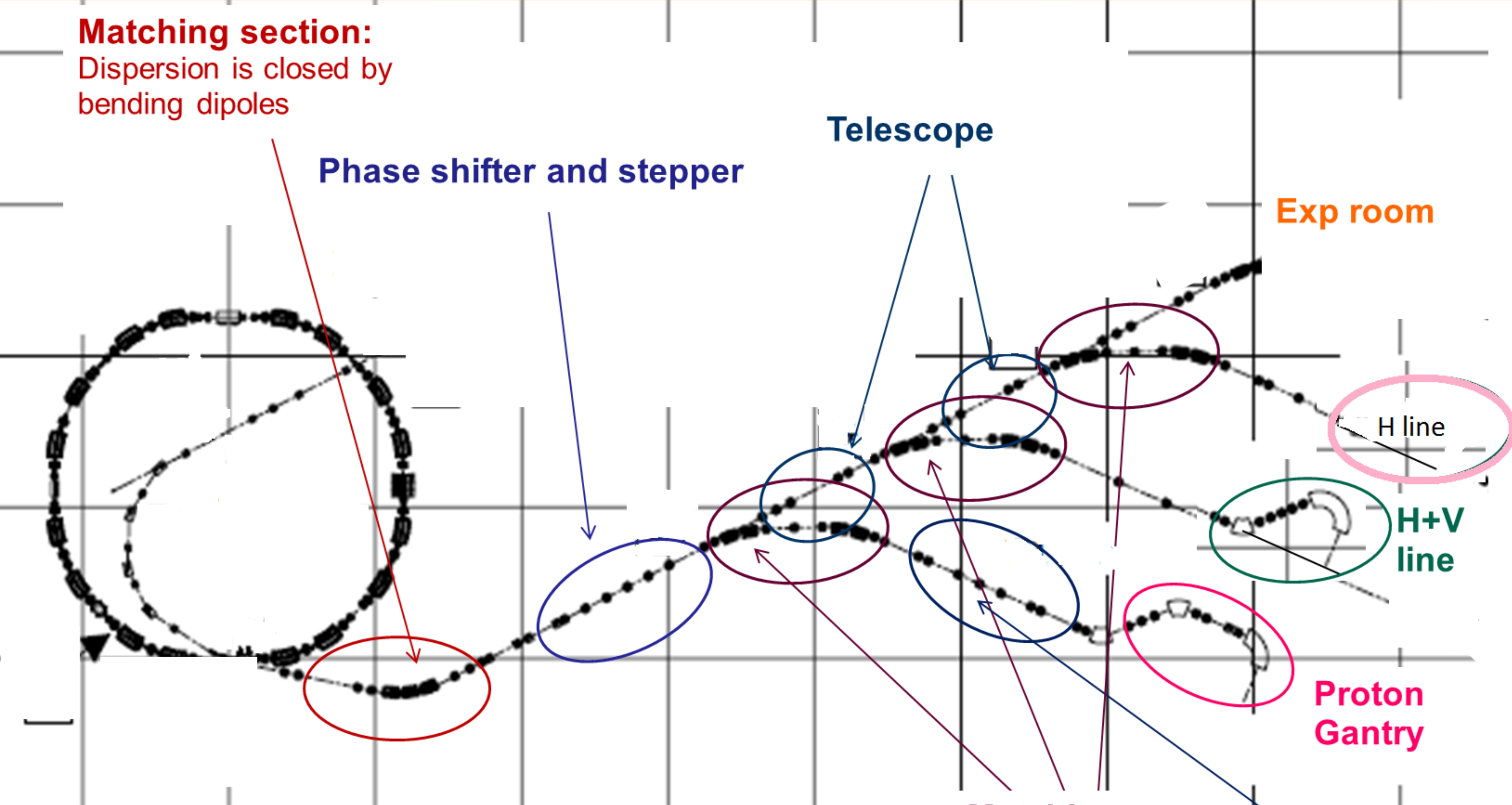
-He4 with a Brho of 2.5Tm will stop, approx., after 4 cm in water (unuseful)

-He4 with a range of ~10(*8*) cm in water has a Brho of ~3.25(*3.02*) Tm. PEADIATRIC APPLICATIONS?
This would imply that a conventional 90° magnet with Bmax=1.5 T will have a length = 3.66(*3.0*) m, i.e. 30(*20*)% longer than 2.81 for 250 MeV protons

-Increasing the magnetic field a little bit* (superferric magnet?) or considering a bit longer-larger-heavier magnets, we could treat pediatric tumours with a helium gantry. Could it be an idea?

With a field of 1.8 T, the same dipole would be 3.05(*2.54*) m

Modular Extraction Lines - PIMMS

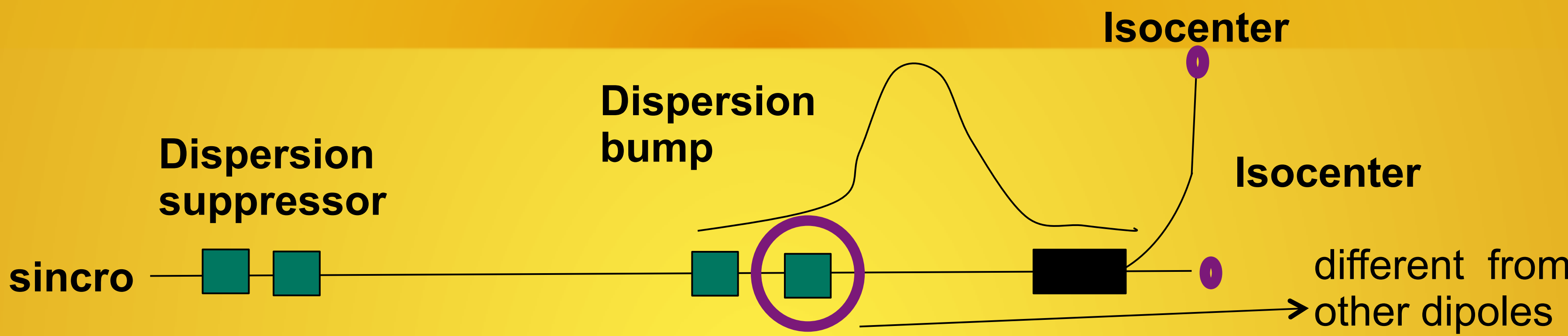


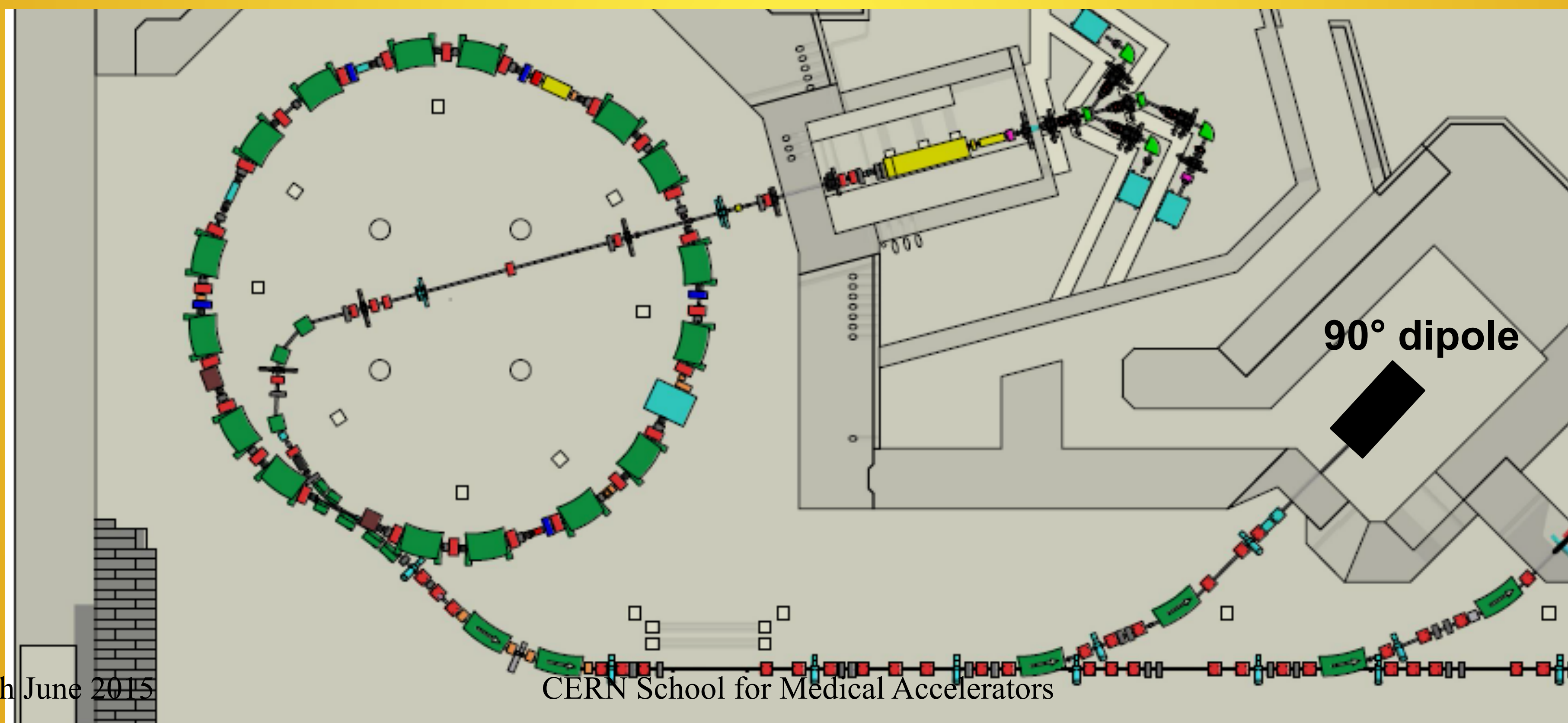
Phase shifter and stepper is a set of quads. Playing with k's it adjusts vertical beta function and orizontal phase advance (orientation of the bar of charge) to have the desired FWHM

Matching section:
Colsed dispersion bump

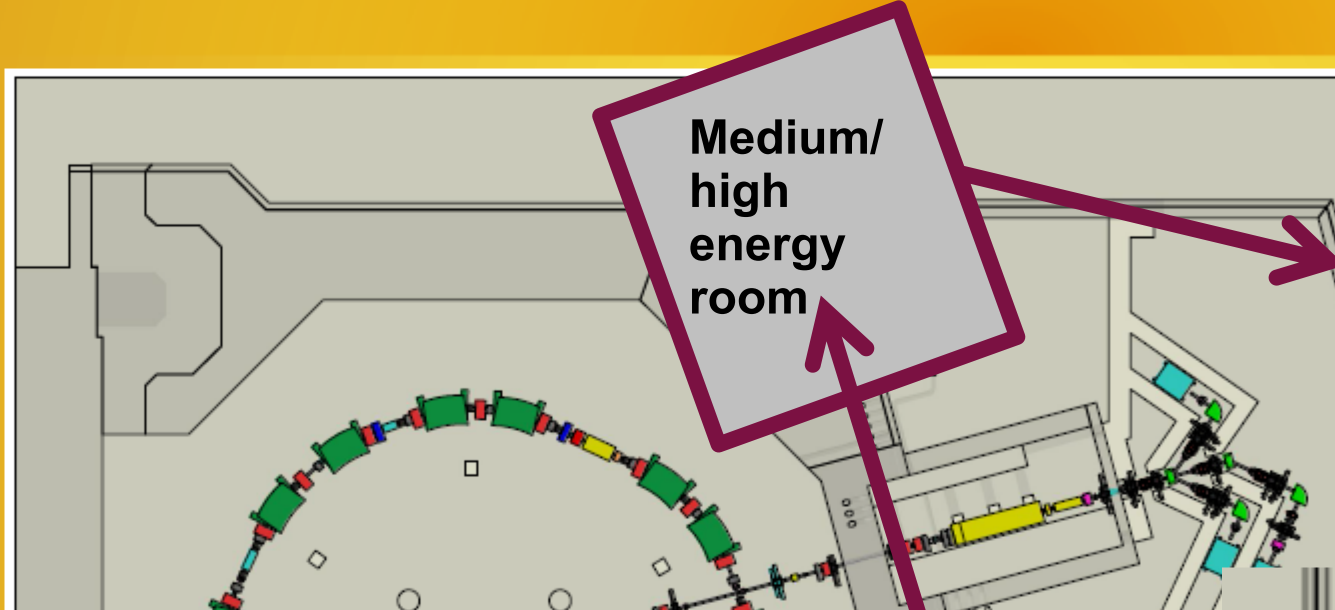
Rotator:
Match fixed and rotating part.

2 NCR: 1 H + 1 V (for radiobiology)

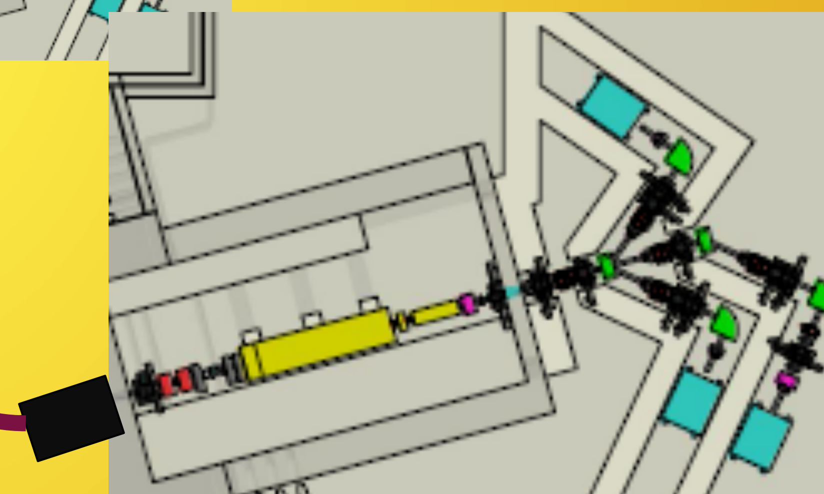


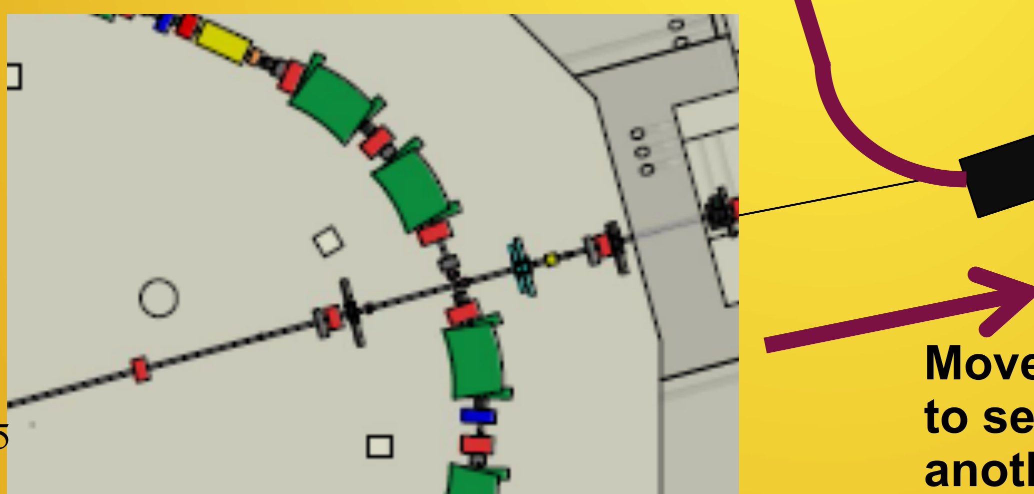


Add a medium energy room



1) Is a 15 MeV/u linac possible as injector? Would this energy enough for a radiopharmacy? *we should have made some calculus...*
2) Use conventional 7 Mev/u linac as injector in another linac for radiopharmacy in the range of few tens of MeV
3) Other?





Move a bit back to include a deflector to send the medium energy beam into another room

Possible Daily Schedule

	QA	clinical	TP measur.	maintena nce	R&D
Mon	3	12	3	3	3
Tue	3	12	3	3	3
Wen	3	12	3	3	3
Thu	3	12	3	3	3
Fri	3	12	3	3	3
Sat	NA	5	5	3	11
Sun	NA	NA	5	3	16

Approx. 2000 hours/y dedicated to R&D