

# Virtual visit to CNAO Accelerator system

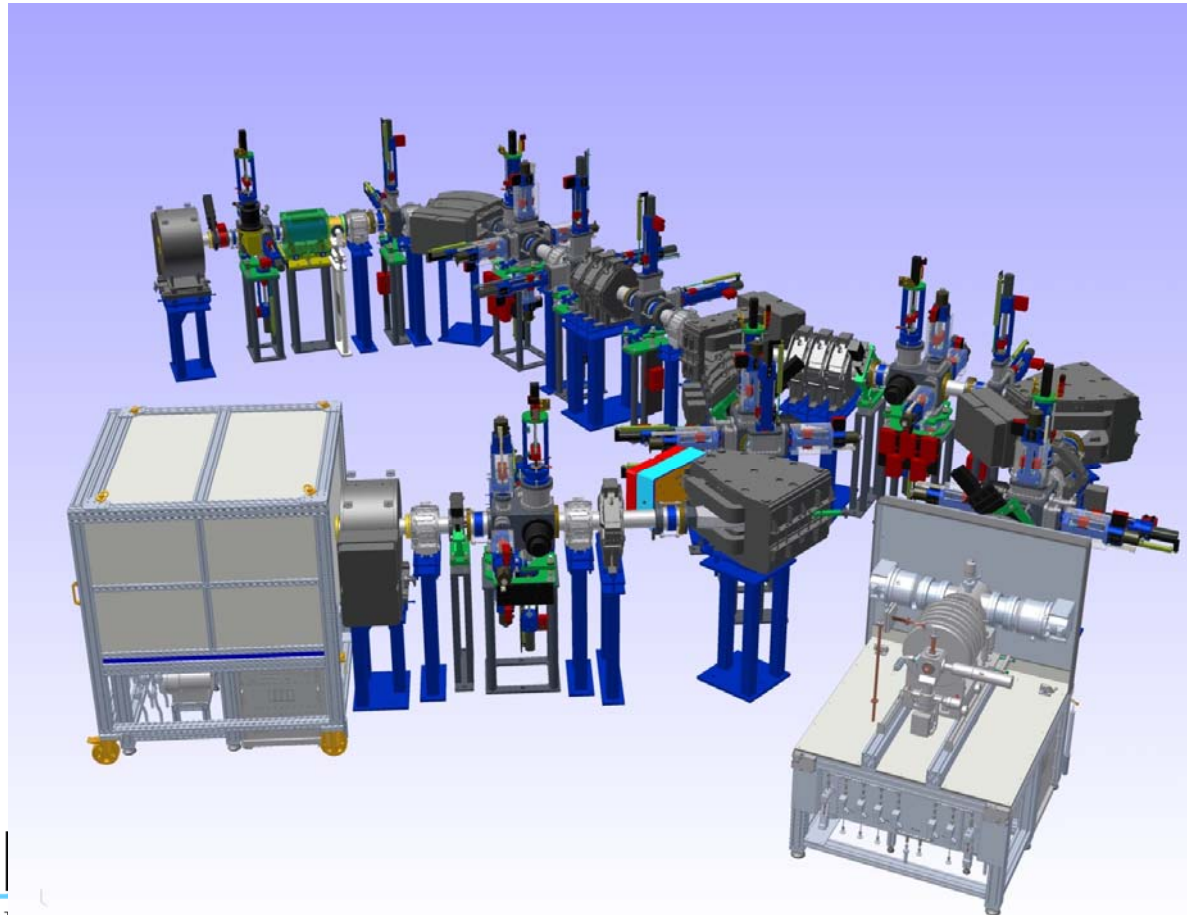
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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101008548

# Sources and LEBT



0.008 MeV/u  $\text{H}_3^+$   
0.008 MeV/u  $\text{C}^{4+}$

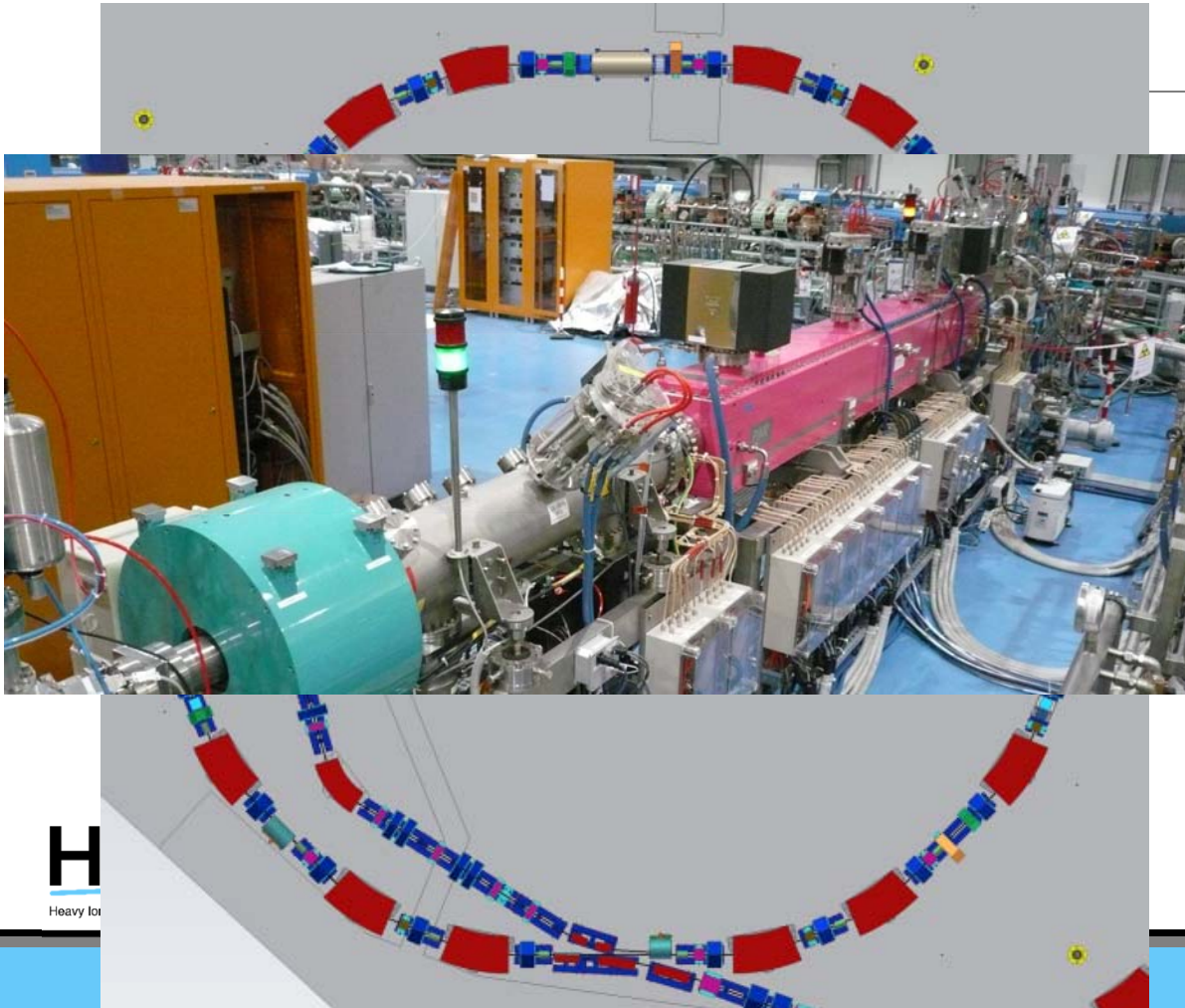
$I \sim 0.5 \text{ mA}$  ( $\text{H}_3^+$ )  
 $I \sim 0.2 \text{ mA}$  ( $\text{C}^{4+}$ )

Two ECR sources

Continuous beam

LEBT Chopper

# LINAC system



217 MHz

RFQ

0.008-0.4 MeV/u  $\text{H}_3^+$

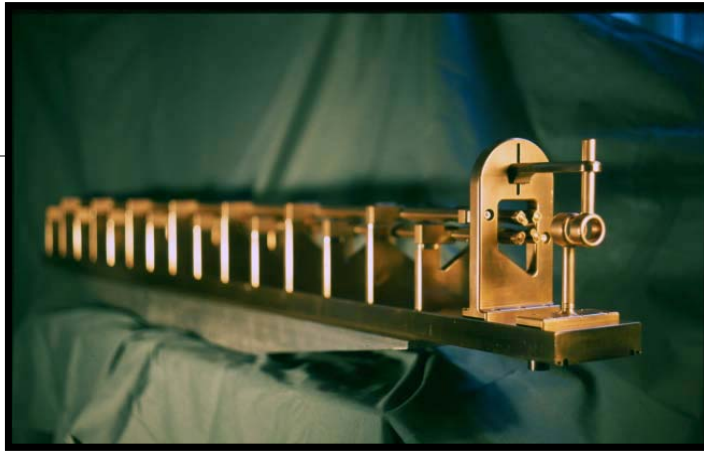
0.008-0.4 MeV/u  $\text{C}^{4+}$

IH

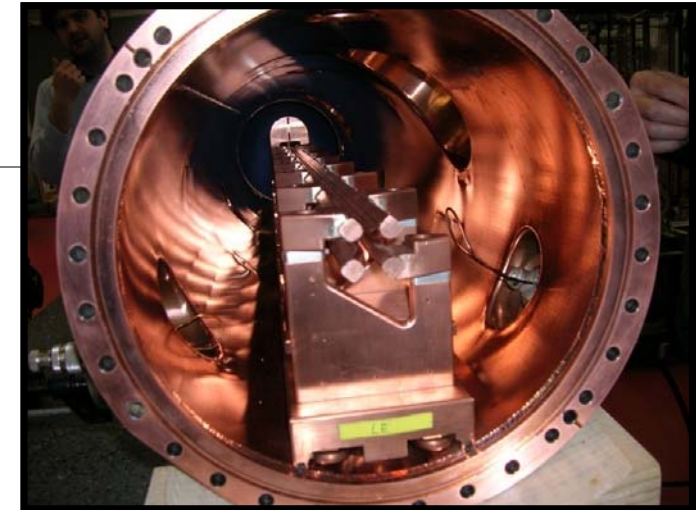
0.4-7 MeV/u  $\text{H}_3^+$

0.4-7 MeV/u  $\text{C}^{4+}$

# RFQ



Internal structure



Ion entrance

217 MHz

Four-rod like type

Energy range = 8 – 400 keV/u

Electrode length = 1.35 m,

Electrode voltage = 70 kV

RF power loss (pulse): about 100 kW

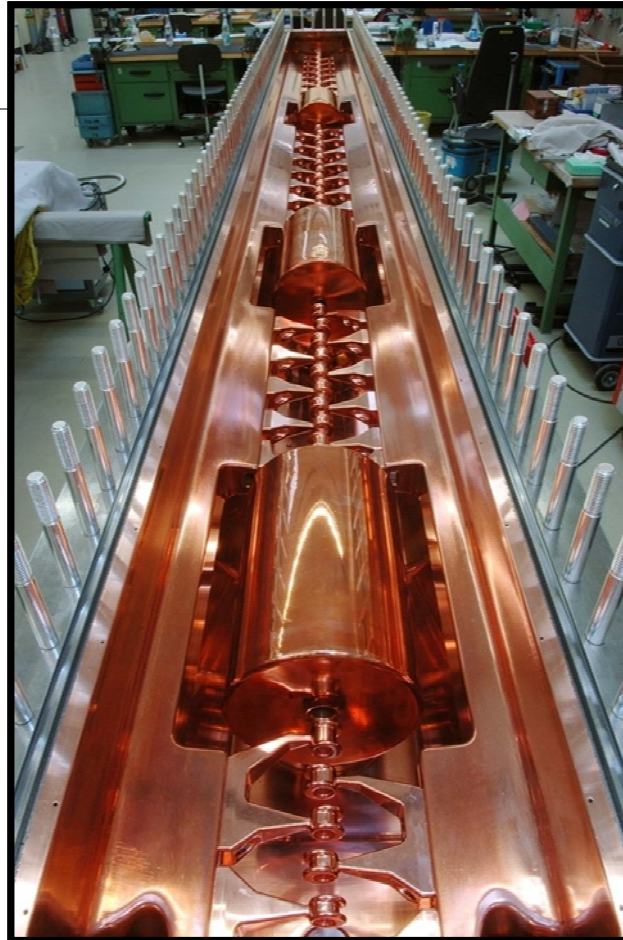
Low duty cycle: around 0.1%



Ion exit



# LINAC



## 3 Integrated magnetic triplet lenses

## 56 Accelerating gaps

|                           |               |
|---------------------------|---------------|
| Energy range              | 0.4 – 7 MeV/u |
| Tank length               | 3.77 m        |
| Inner tank height         | 0.34 m        |
| Inner tank width          | 0.26 m        |
| Drift tube aperture diam. | 12 – 16 mm    |
| RF power loss (pulse)     | ≈ 1 MW        |
| Averaged eff. volt. gain  | 5.3 MV/m      |

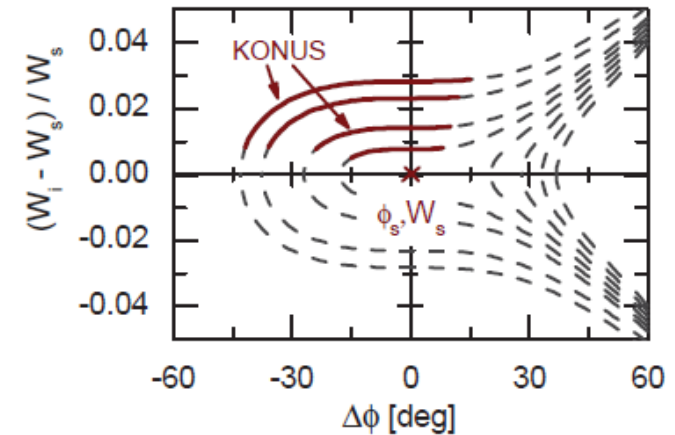
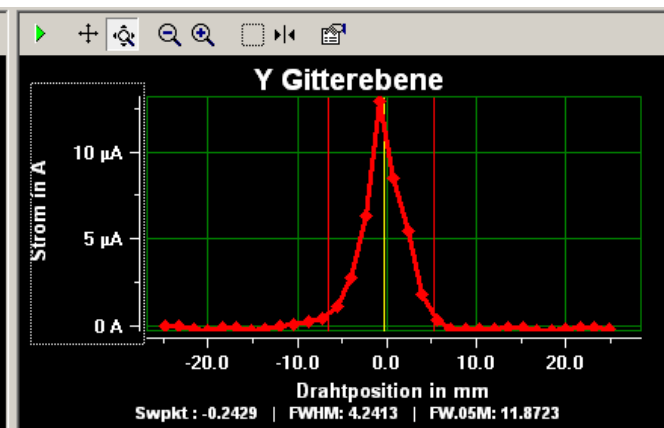
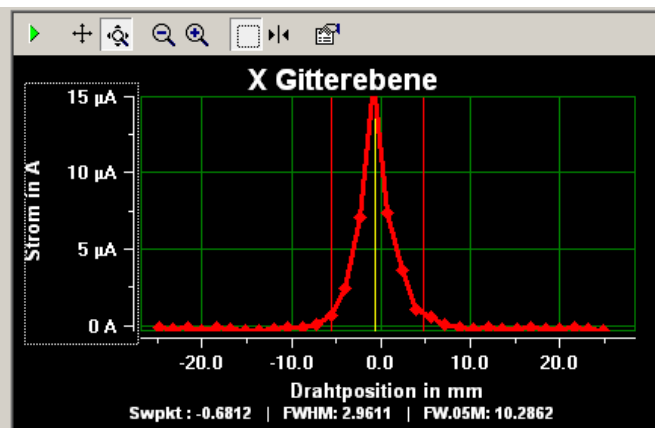
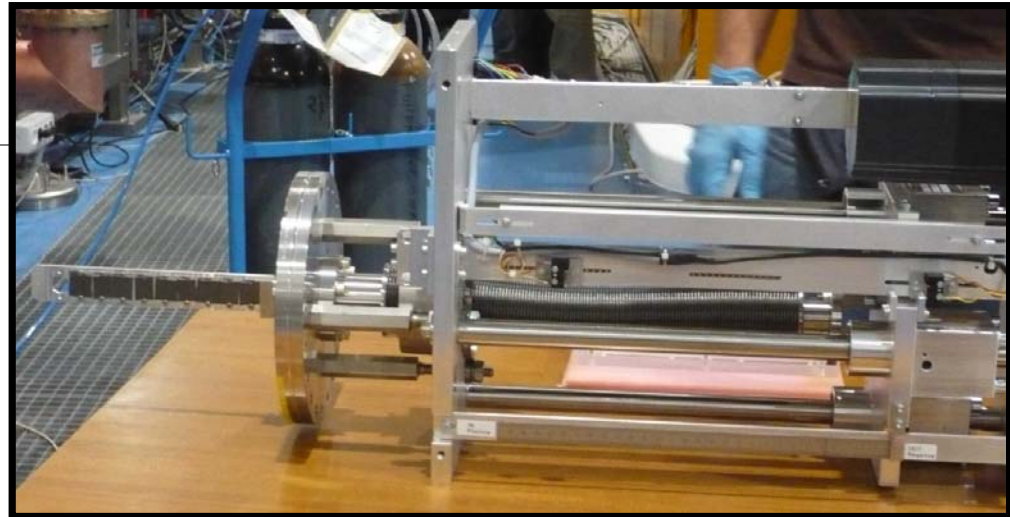


Figure 2: Single particle orbits in  $\Delta W/W_s - \Delta\phi$  phase space at  $\phi_s = 0^\circ$  with color marking of the area used by KONUS.

# Stripping foils

|                    |                                   |
|--------------------|-----------------------------------|
| Positions:         | 10                                |
| Foil material:     | Carbon                            |
| Foil thickness:    | 100-200 $\mu\text{g}/\text{cm}^2$ |
| Foil diameter:     | 15 mm                             |
| Beam diameter:     | 5 mm                              |
| Position accuracy: | $\pm 0,5$ mm                      |



# MEBT



7 MeV p  
7 MeV/u C<sup>6+</sup>

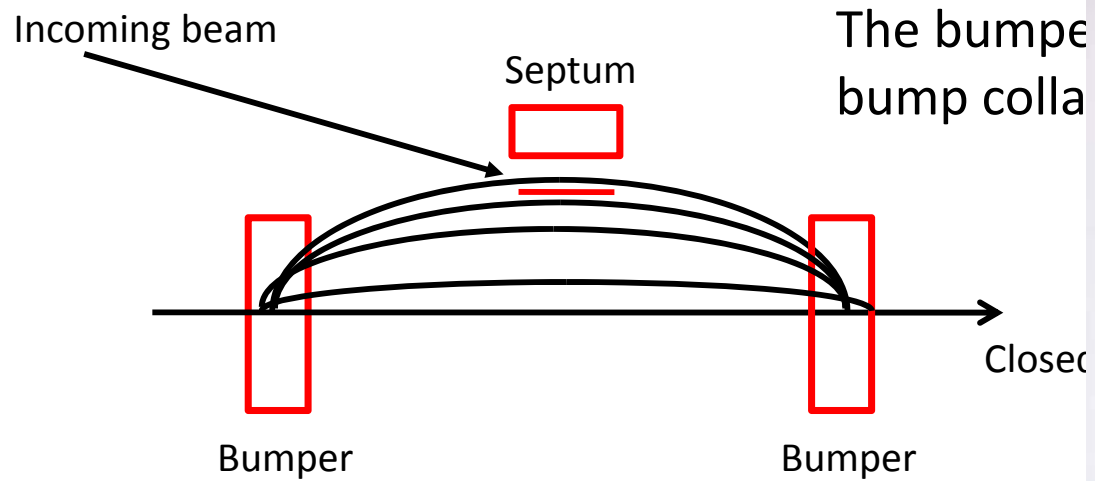
$I \sim 0.75$  mA (p)  
 $I \sim 0.12$  mA (C<sup>6+</sup>)

Stripping foil

Debuncher

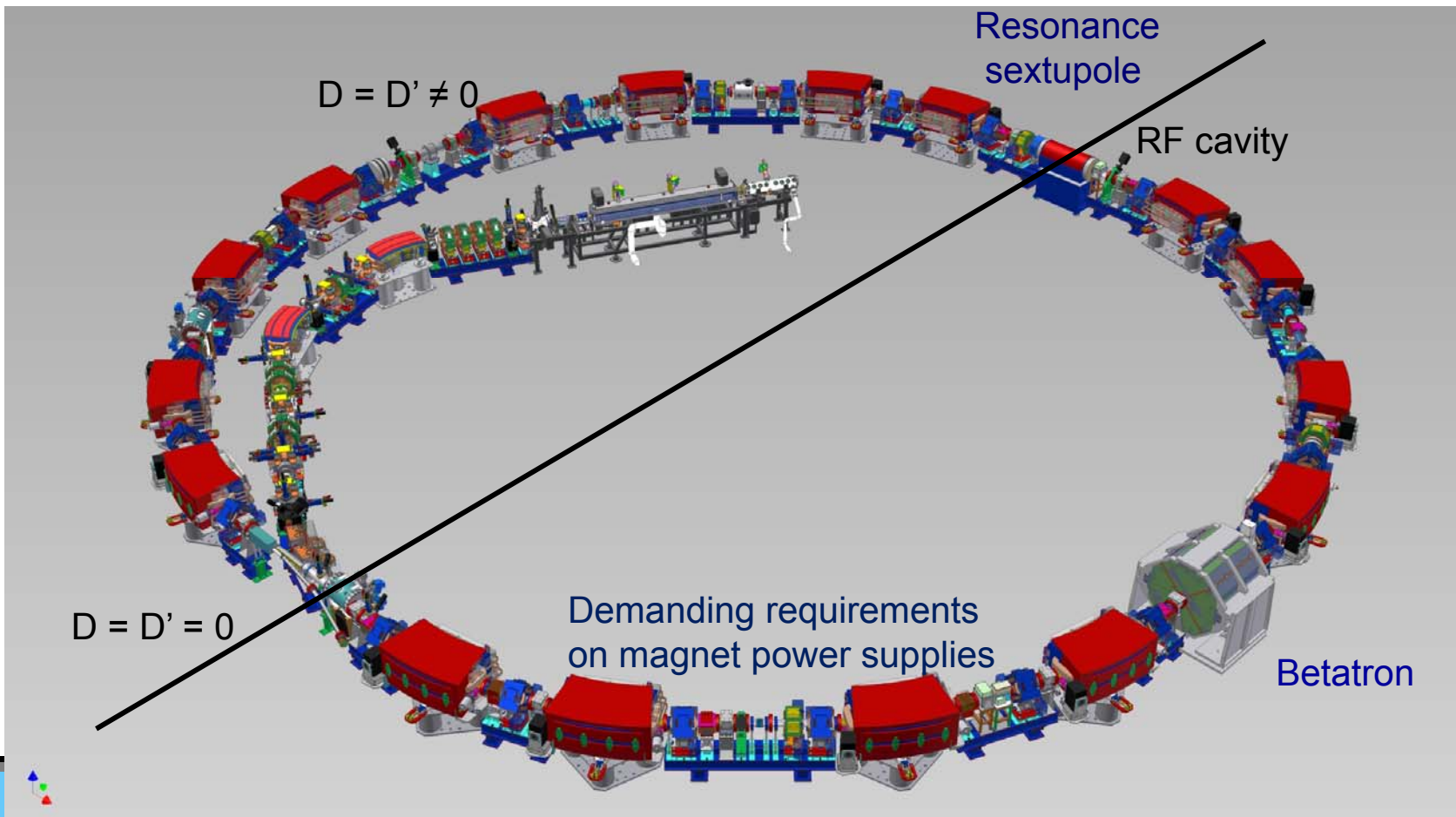
Match betas

# Multi turn injection





# Synchrotron



7-250 MeV p  
7-400 MeV/u C

$I \sim 0.1\text{-}5\text{ mA (p)}$   
 $I \sim 0.03\text{-}1.5\text{ mA (C)}$

Multi turn injection

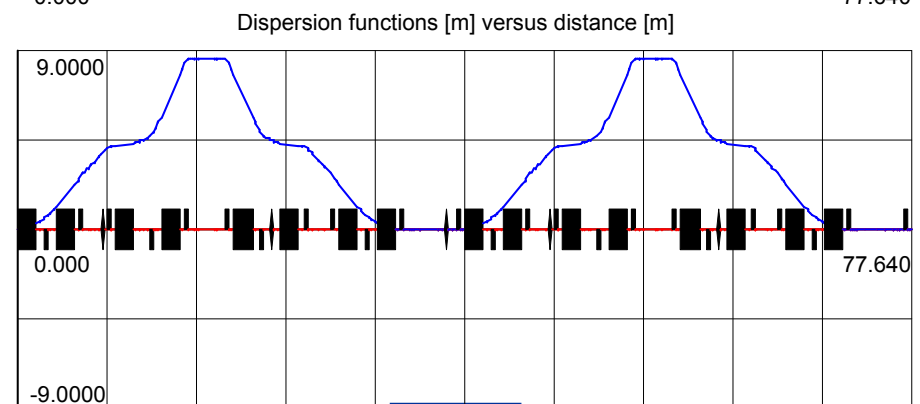
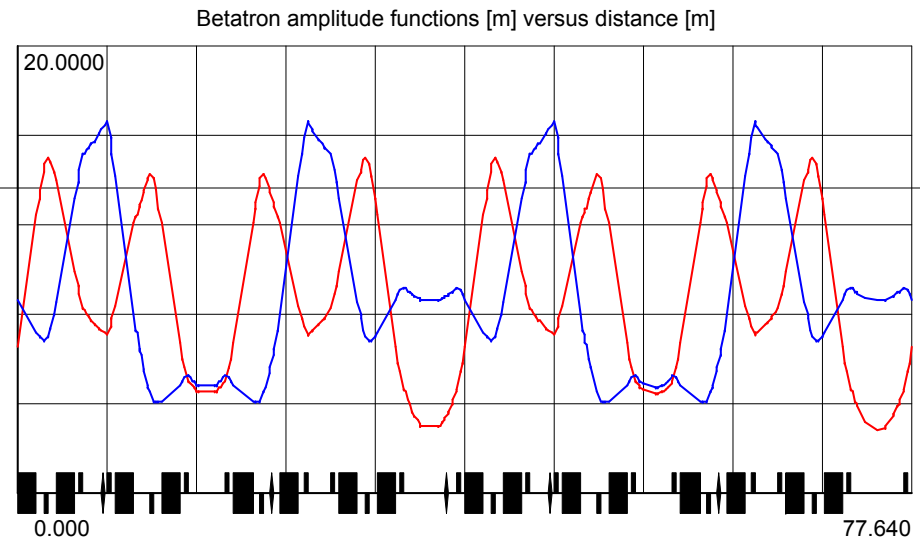
Slow extraction

Betatron core

received funding from the European Union's Horizon 2020  
innovation programme under grant agreement No 101008548

# Optics

- 2 Superperiods**
- 2 Closed dispersion bumps**
- 1 Dipole Family**
- 3 Quadrupole Families**
- 3 Sextupole Families**

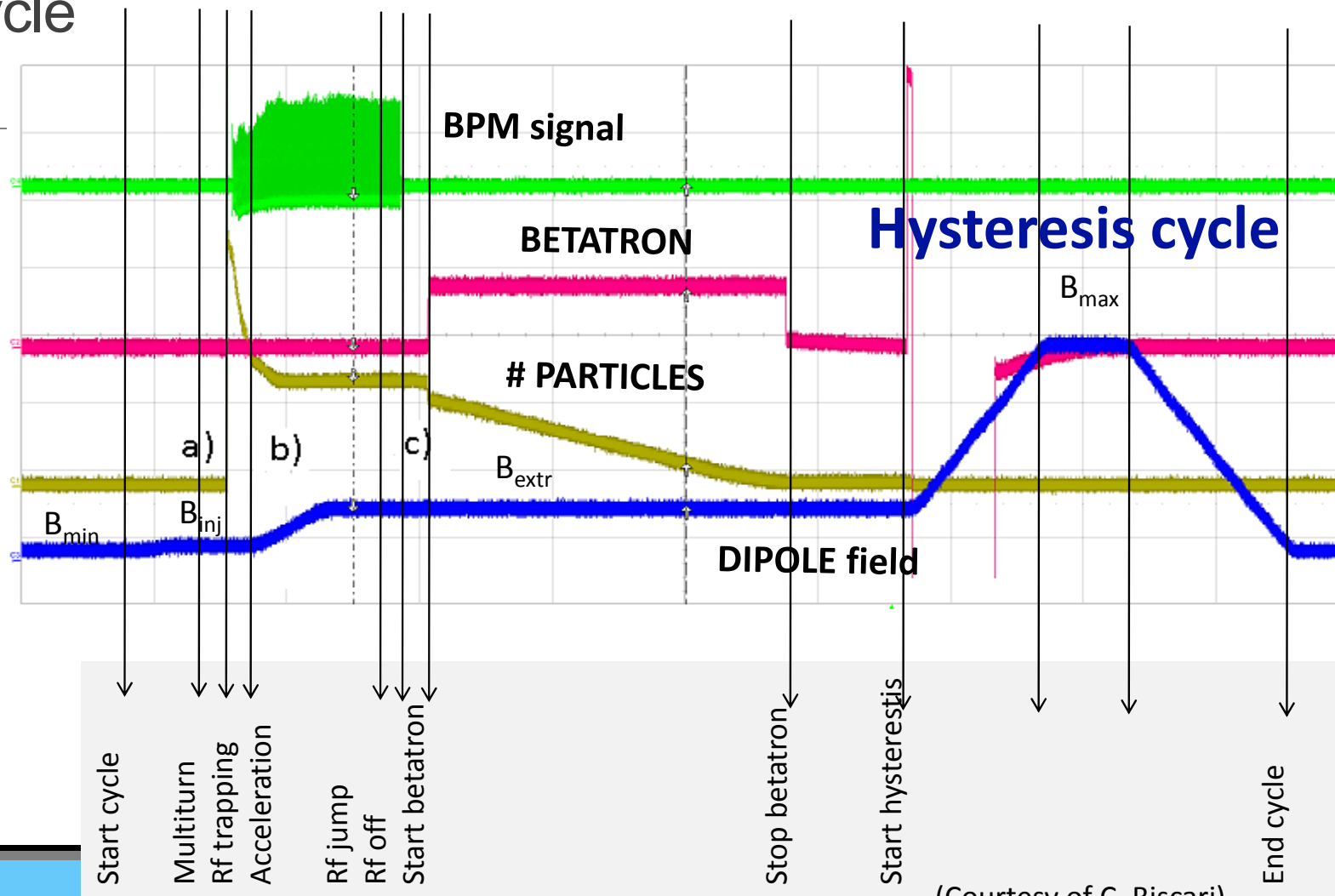


Horizontal

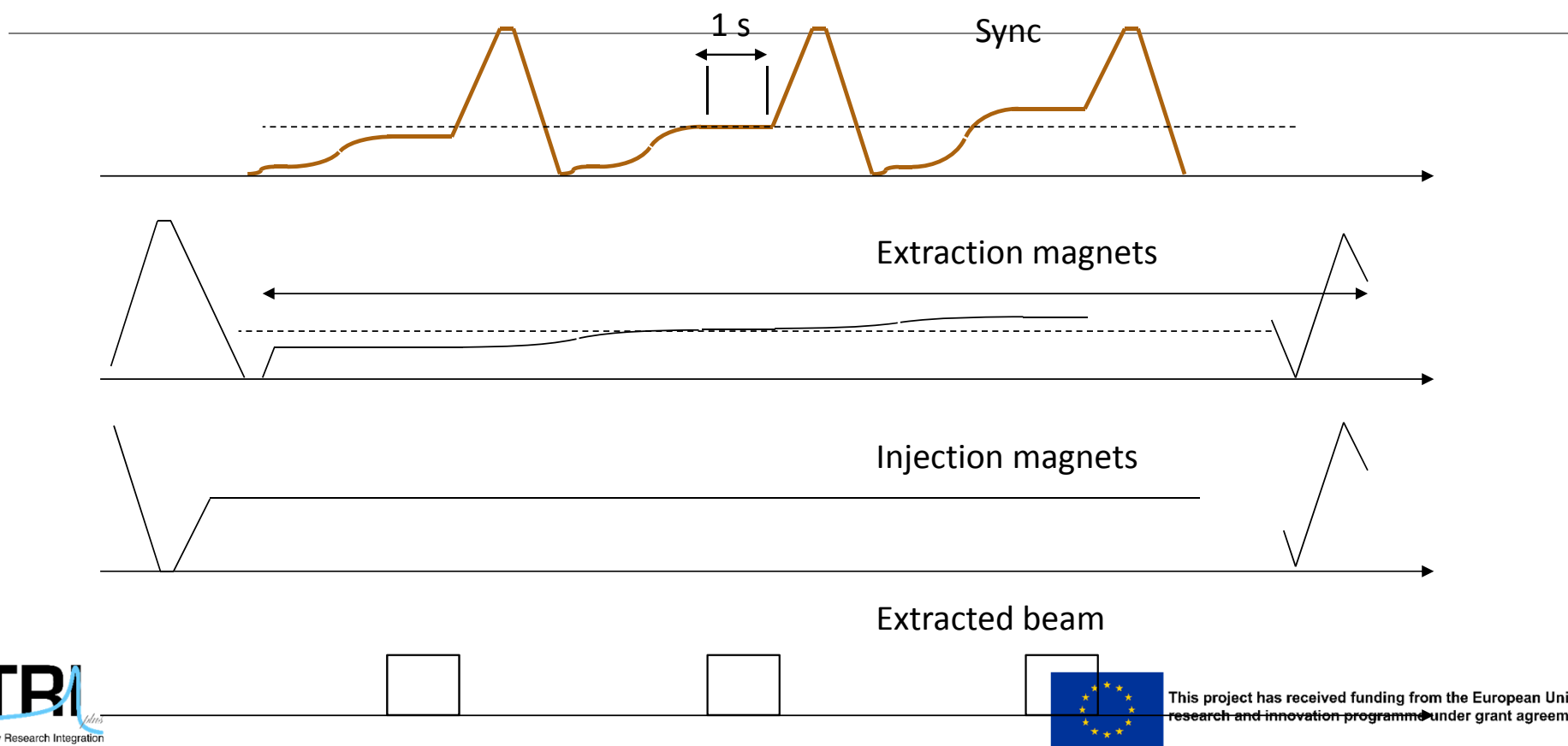


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# Machine cycle



# Treatment execution



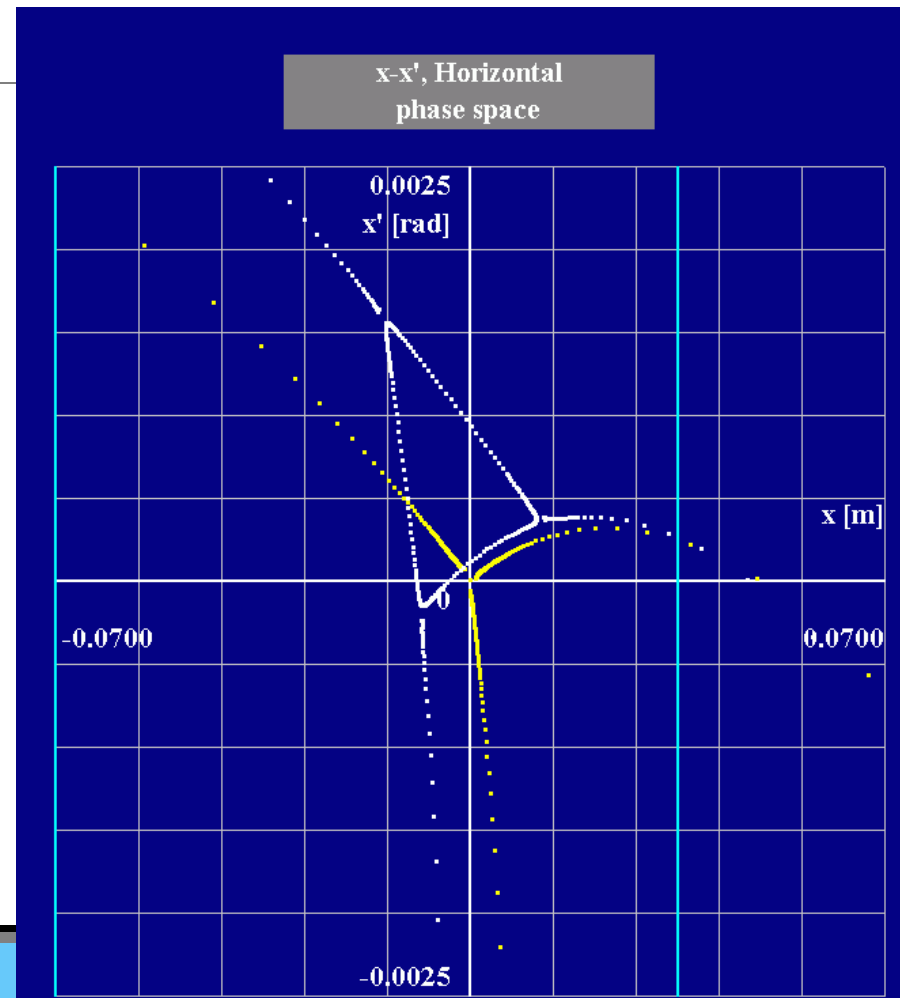
# Slow Extraction

Betatron core

Empty bucket channelling

Air core quadrupole

RF-KO

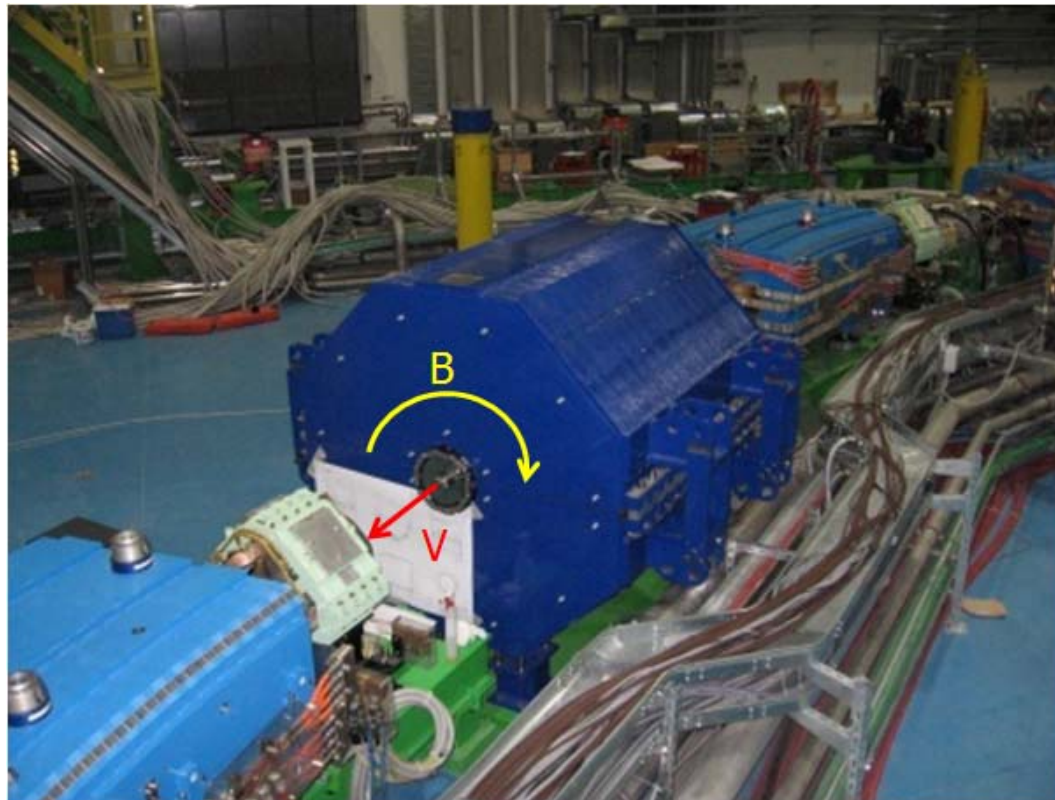




Pushes the beam  
against the  
resonance

$$\Delta\Phi = 2.46 \text{ Wb}$$

Magnetic screen  
needed

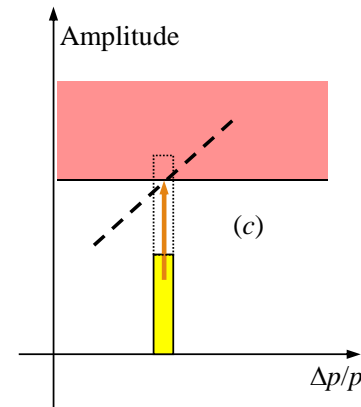
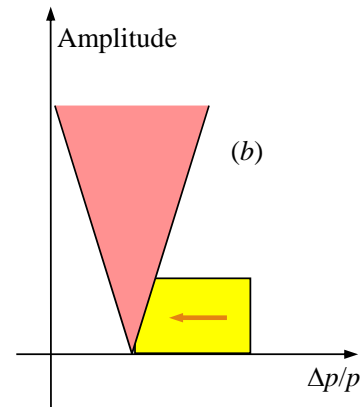


# RFKO

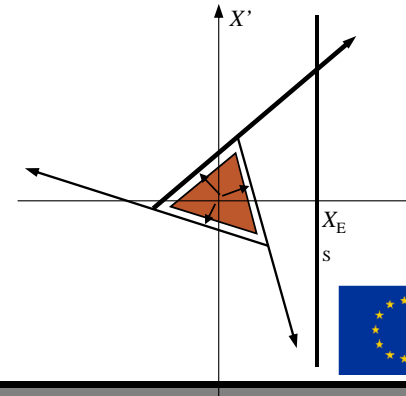
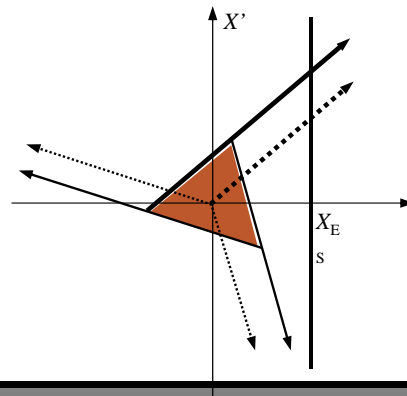
Amplitude-momentum  
selection

RF-KO

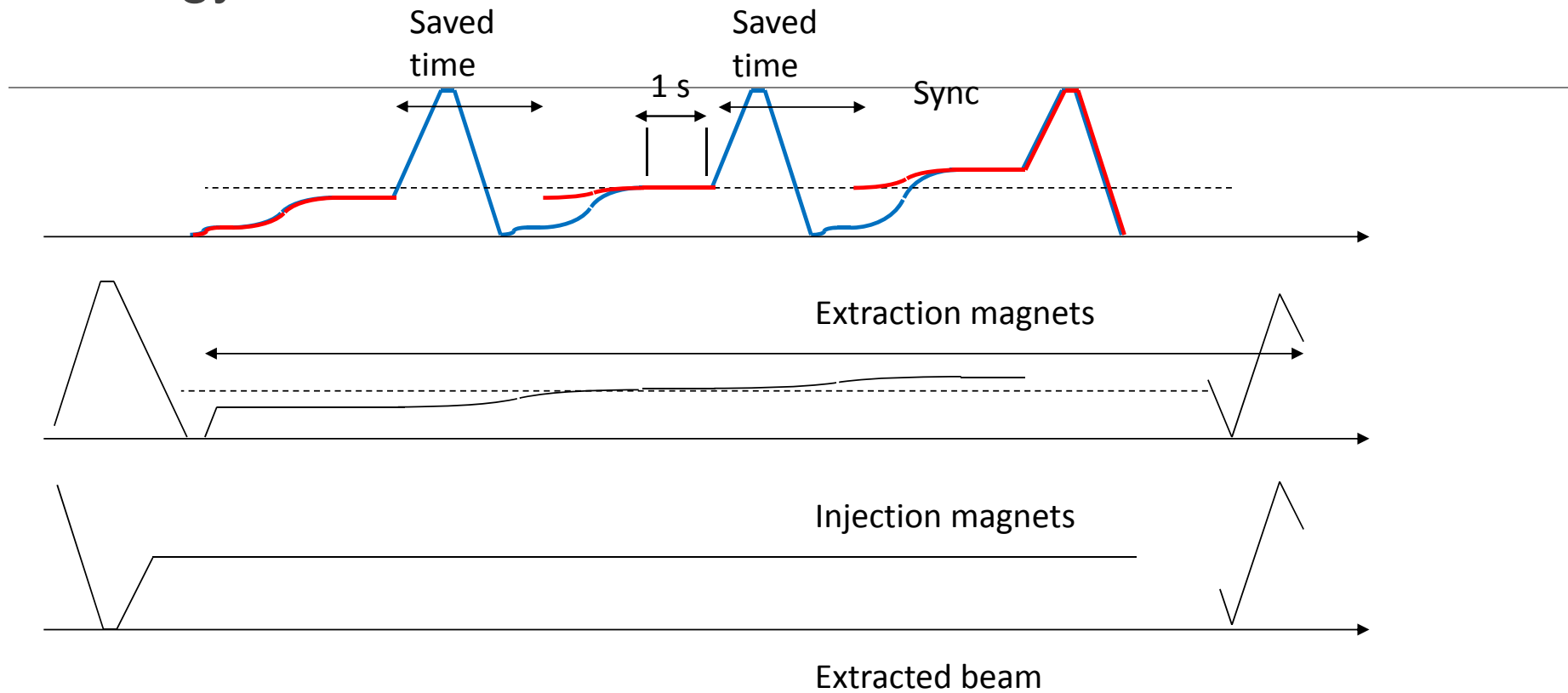
Standard method  
at CNAO



Being implemented  
for multi energy  
extraction

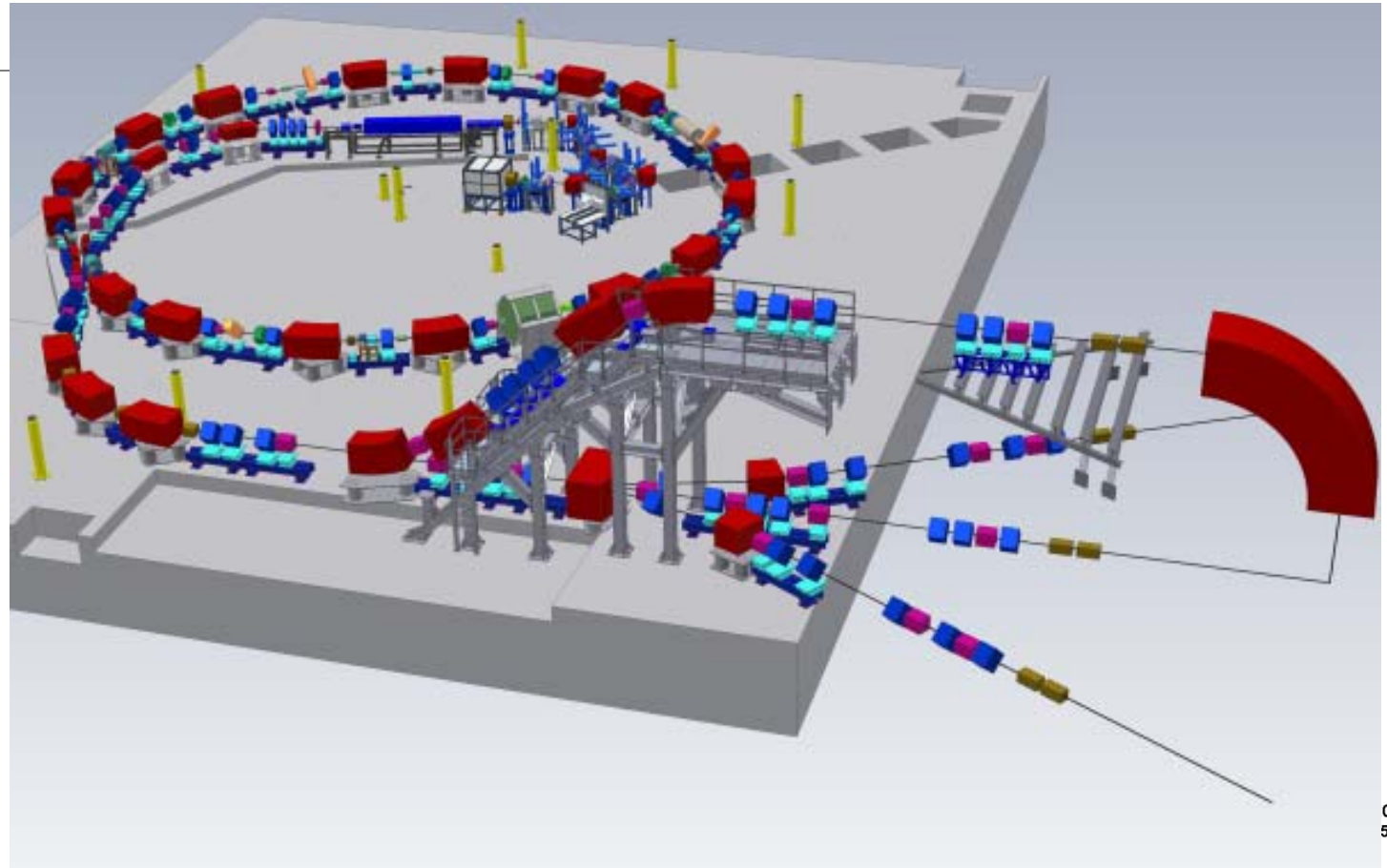


# Multi Energy Extraction

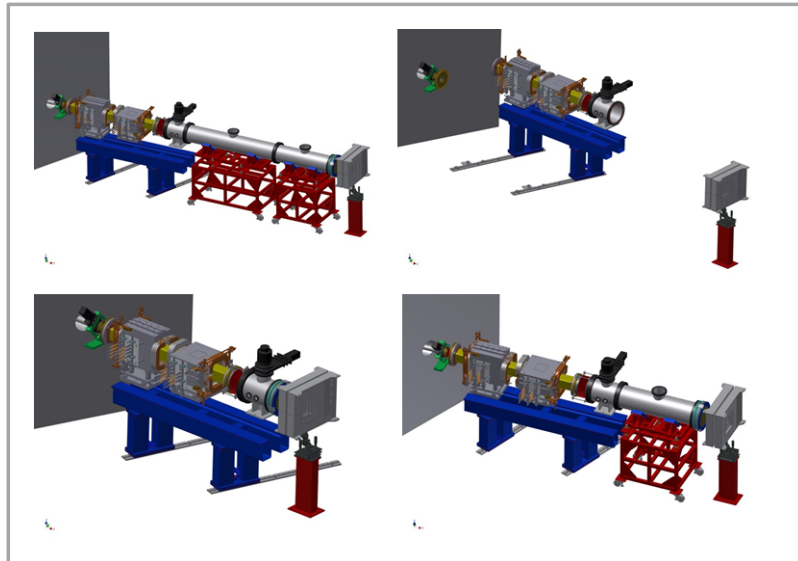


# HEBT – Treatment rooms

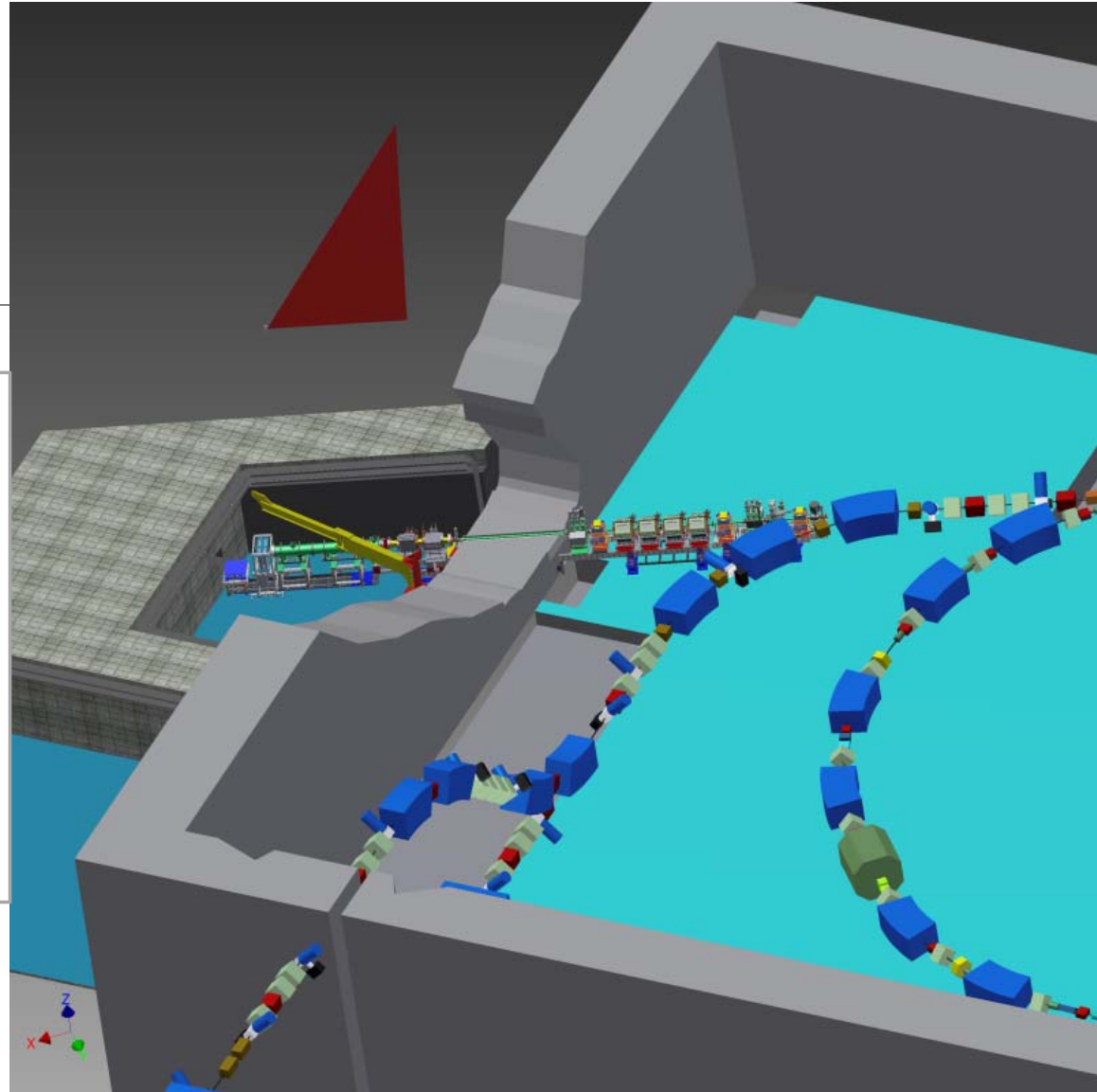
3 treatment rooms  
4 beamlines  
for treatment



# HEBT - XPR

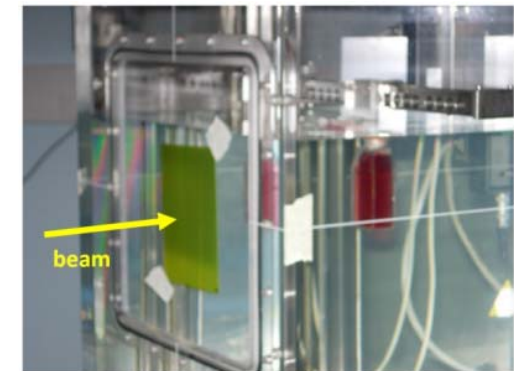
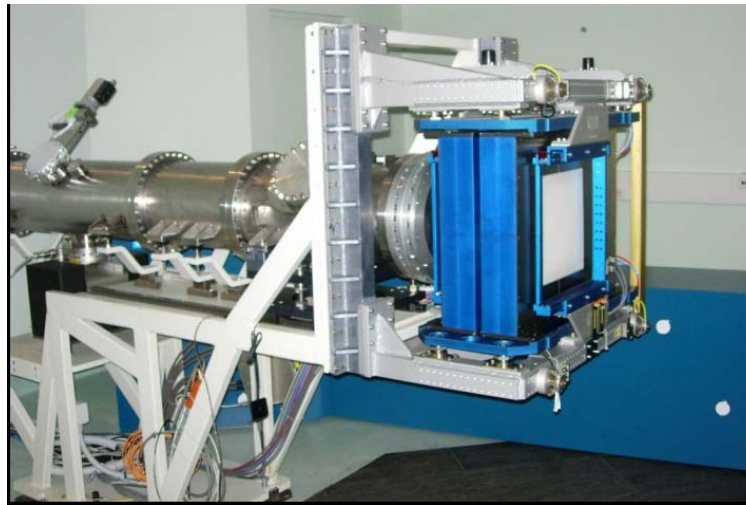
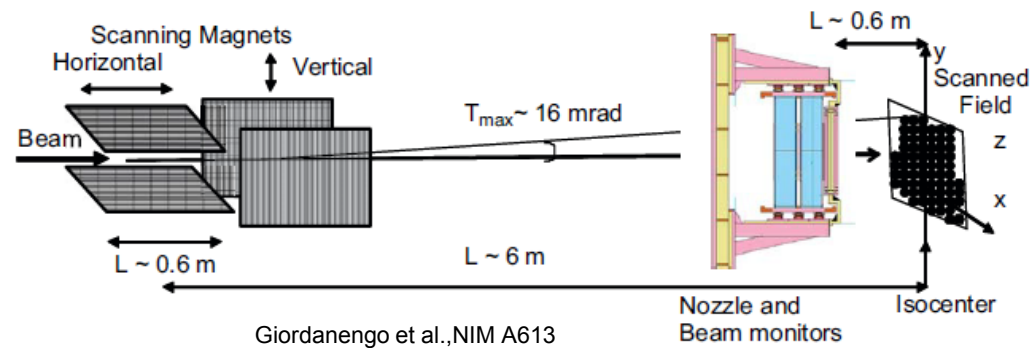


4 configs





# Dose delivery



# Treatment room

## 3D Real-time IR Optical Tracking (OTS)

- Real time reconstruction of spherical markers
- Sub-millimeter accuracy : peak 3D errors <0.5 mm
- 3D data flow @70 Hz

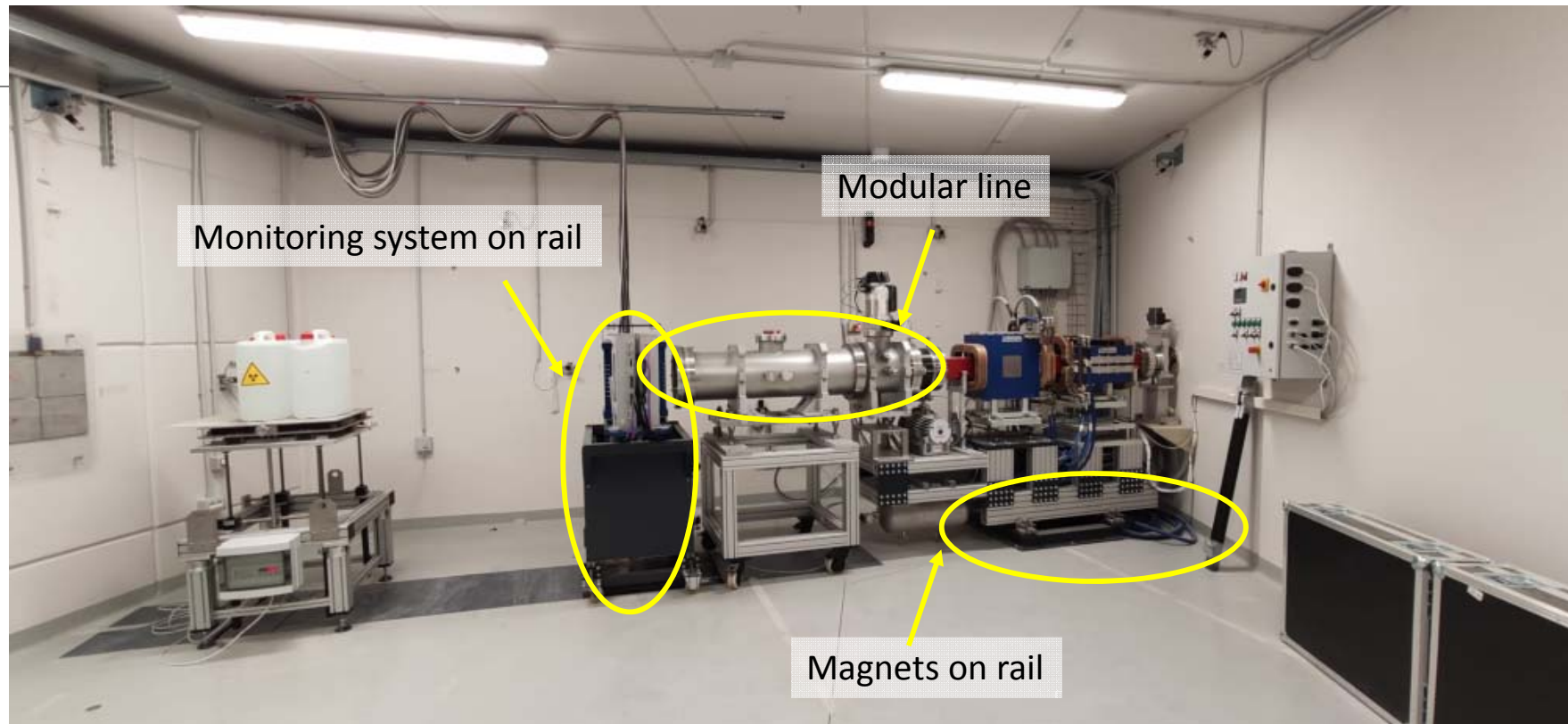
## X-ray Patient Verification System (PVS)

- 2 X-ray tubes (deployable),
- 2 flat panels (deployable)
- Supporting structure rotation:  $\pm 180^\circ$
- Rotation and deployment accuracy:  $\pm 0.15\text{mm}$ ,  $\pm 0.1^\circ$

## Patient Positioning System (PPS)

- Automatic couch or chair docking
- Absolute accuracy:  $\approx 0.3\text{ mm}$

# XPR



# Thank you for your attention

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“Physics is like sex: sure, it may give some practical results, but that's not why we do it. ”

R. Feynmann

