IBA Cyclone® 70P

Product Development and ongoing Projects Status

Benoit Nactergal on behalf of the team

R&D Manager

nactergal@iba-group.com

Cyclone 70P

First Cyclone® 70 P sold

IBA to Install the First Commercial 70 MeV Cyclotron Dedicated to the Production of Radiopharmaceuticals in the United States

IBA Announces Formal Contract Signature for Installation of its Cyclone® 70 System

Louvain-la-Neuve, Belgium, November 4th, 2013 - IBA (Ion Beam Applications S.A.), the world's leading provider of proton therapy and radiopharmacy solutions, today announces it has signed a formal contract with Zevacor Molecular for the installation of its Cyclone® 70 in the United States. This will be the first commercial 70 MeV Cyclotron dedicated to radiopharmaceuticals production in the country. The installation of the system is worth between $16 and 20 million to IBA. The project financing is fully secured. The Cyclone® 70 Cyclotron is expected to be operational in the second half of 2016.

zevacor MOLECULAR

04/11/2013

United States – Nobblesville (Indiana)

Cyclone 70 + 6 beam lines + 2 solid targets

Second Cyclone® 70 P sold

Press release |
Regulated information

IBA Signs Contract to Install a 70 MeV Cyclotron Dedicated to the Production of Radiopharmaceuticals in Russia

Louvain-la-Neuve, Belgium, July 2nd, 2014 - IBA (Ion Beam Applications S.A.), the world's leading provider of proton therapy and radiopharmacy solutions, today announces it has signed a contract with a significant upfront payment with the Centre for Development of Nuclear Medicine in Moscow, Russia, for the installation of its Cyclone®70. The installation of the system is worth between

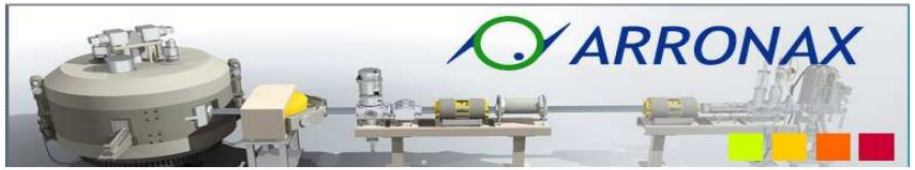
02/07/2014 Center for Development of Nuclear Medicine

Russia– Moscow

Cyclone 70 + 6 beam lines + 2 solid targets

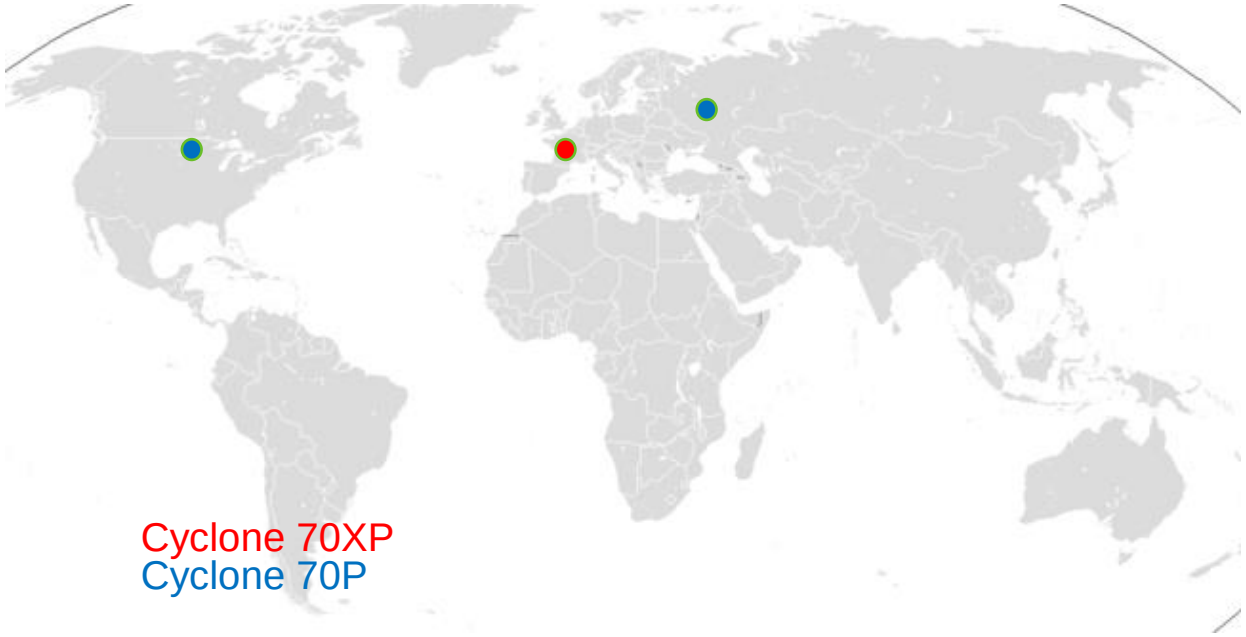
Protect, Enhance and Save Lives

Goal : From Cyclone® 70XP (multi-particles) to proton only optimized solution



Accelerated Beam	Extracted Beam	Extracted Energy (MeV)	Beam Intensity (eμA)	Exit Ports
H^-	H^+	30 - 70	750	dual
D^-	D^+	15 - 35	50	dual
$^4He^{2+}$	$^4He^{2+}$	70	70	single
HH^+	HH^+	35	50	single

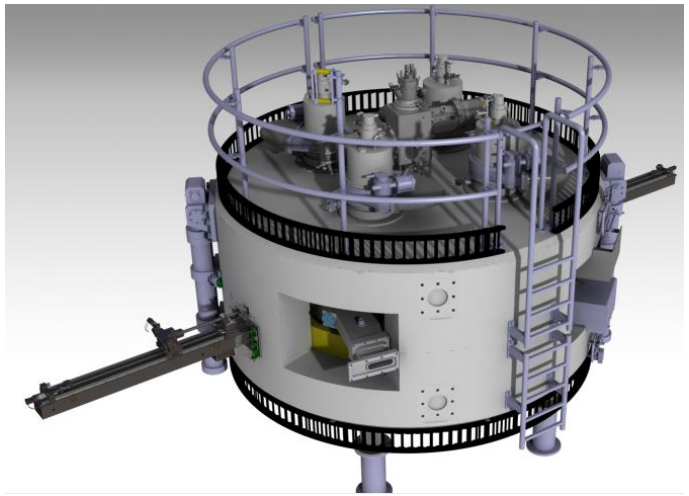
- **Optimization for industrial applications**
  - ✓ High reliability system
  - ✓ Easy to use solution
- **Activation reduction**
  - ✓ RF, magnet and vacuum optimization for efficiency
  - ✓ Use of local shield
  - ✓ High tech material use

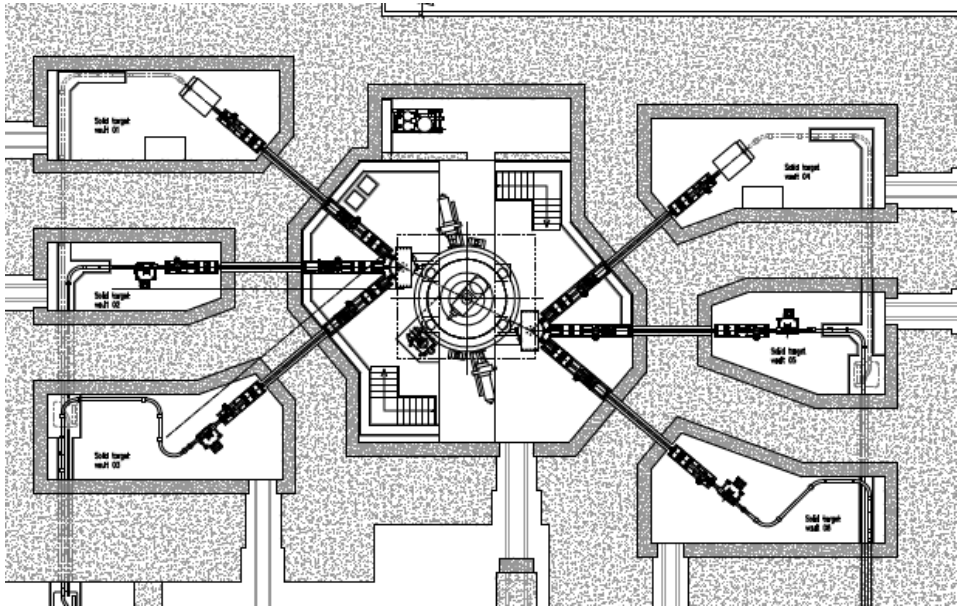


Cyclone 70P Main characteristics

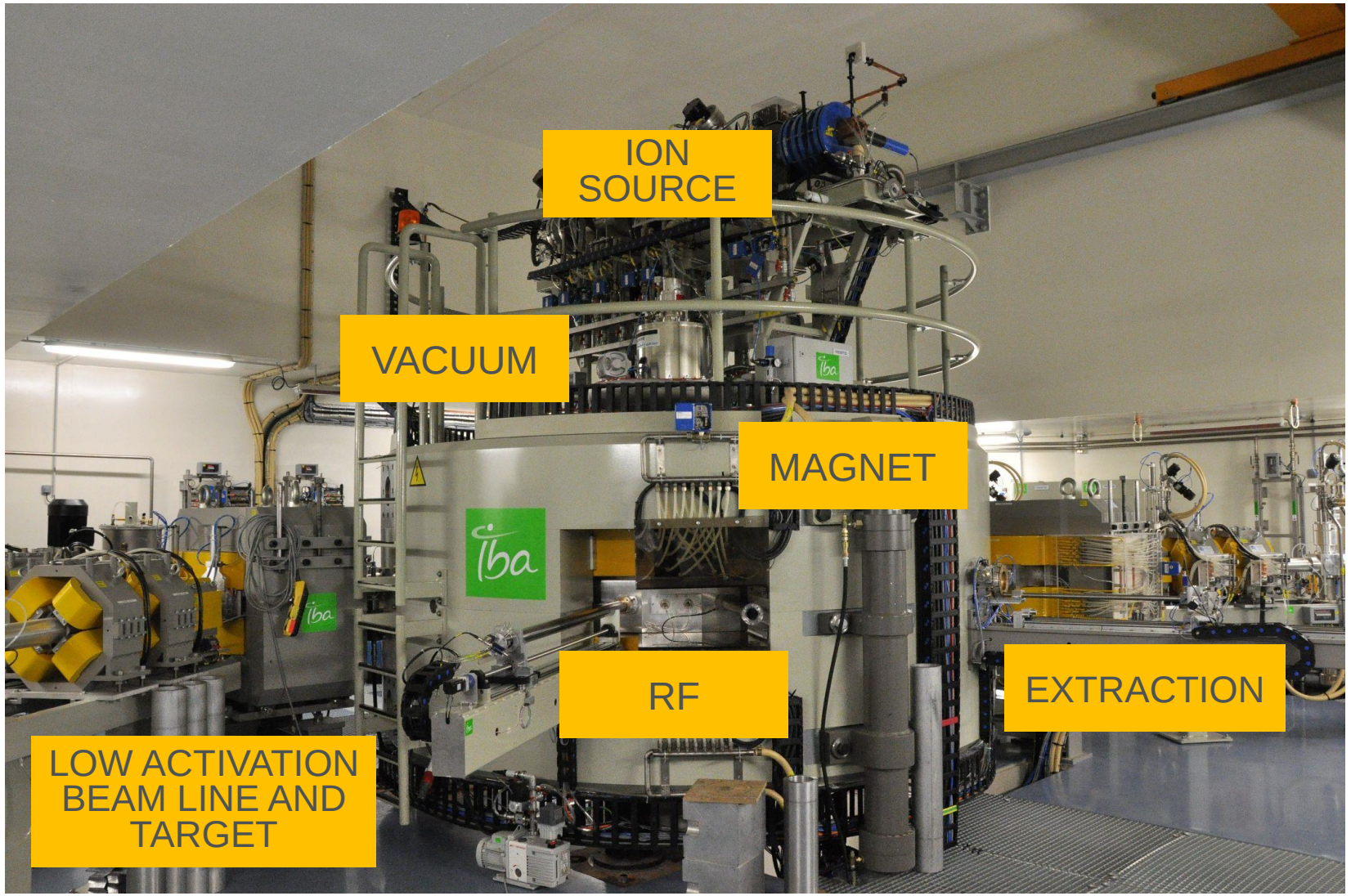
Proton Energy	30 -70 MeV	Continuously range
Beam current	**750 µA**	Dual beam
Beam exit	2 exits	2 x 3 ports
Cyclotron weight	145 Tons	On 4 pillars
Ion source	External	Multicusp H- source
Vacuum system	Cryo pumps	Clean vacuum cyclotron
	Turbo pumps	Clean vacuum ion source
Electrical load	60 kW	Stand-by
	< 250 kW	Full beam /2 Beam lines (%)
(two beam lines)	~25 kW	Load included in (%)
Cooling load	< 200 kW	Full beam, water chiller

Frequency	58 MHz
Dee's voltage	Mean 65 kV
Power - cavity	22 kW (2 cavities)
Power – full beam	56 kW (beam load)



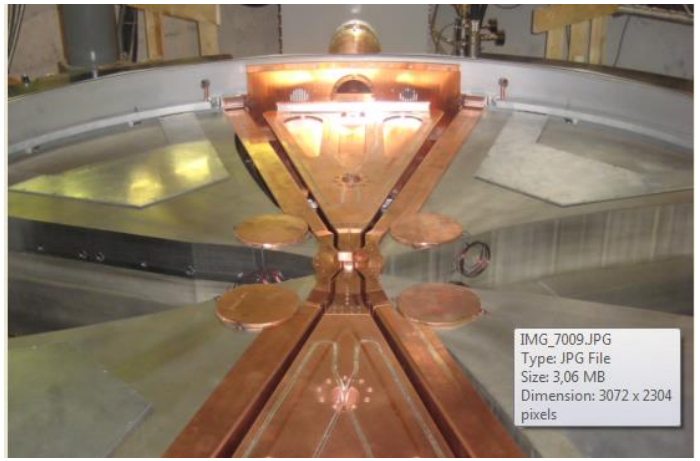


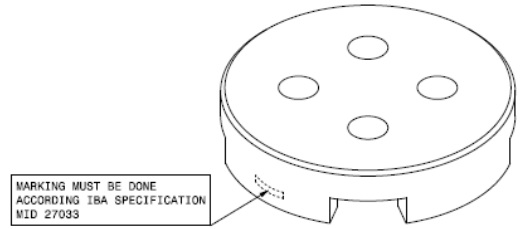
Overview of sub systems optimized

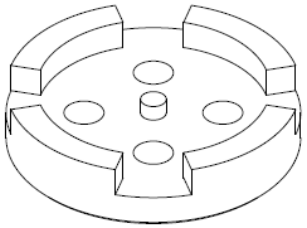


Magnet optimization

- Main goal:
  - Single particle optimization
  - Robust, easy to use and easy to produce solution
  - Capitalized on Cyclone 230 improvement (25+ machines)



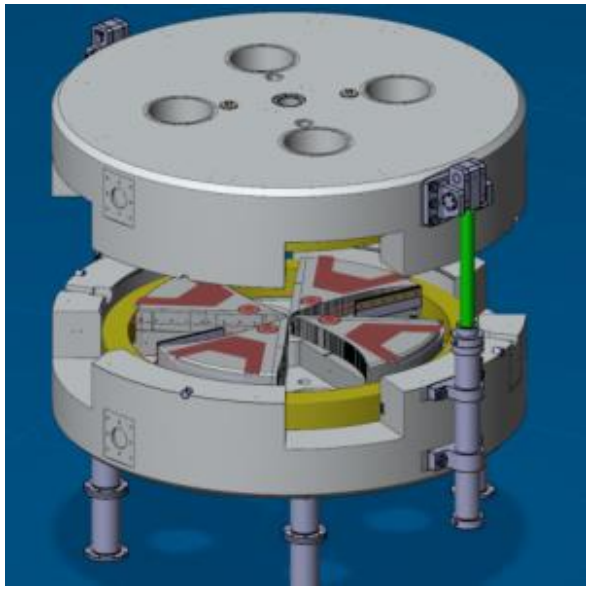


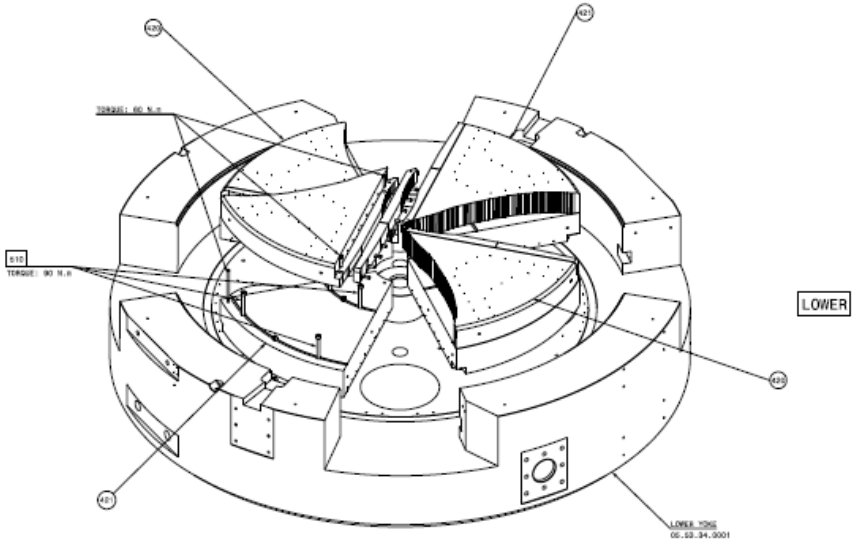


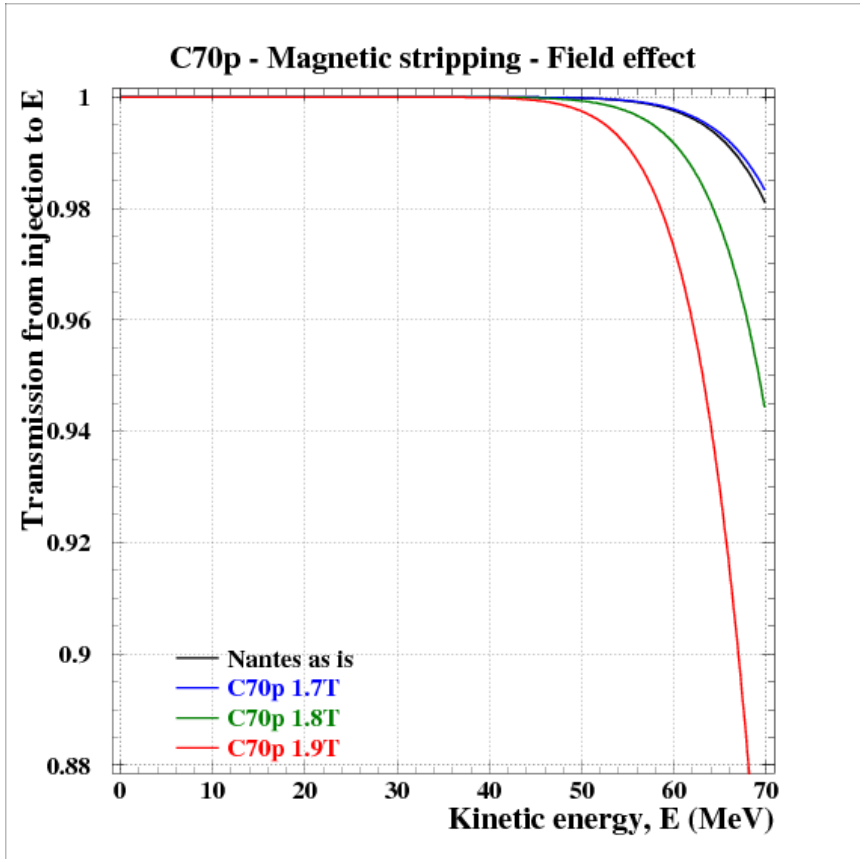
- Yokes/flux returns single casted
- No more compensation coil or pole extension (He++ focalisation)

Magnet optimization

- Pole/sector shape design optimized
- Optimized power consumption
- Pole edges to speed up mapping phase
- Magnet optimized to reduce magnetic stripping losses (~1.7 T).
- Spiralization : no compromize optic and tune
- Nickel plating and gap increased (30mm ->40mm) to optimize vacuum pumping and reduce vacuum stripping losses.





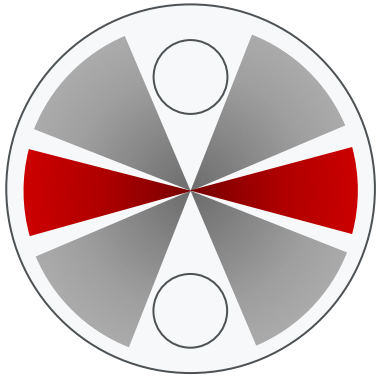


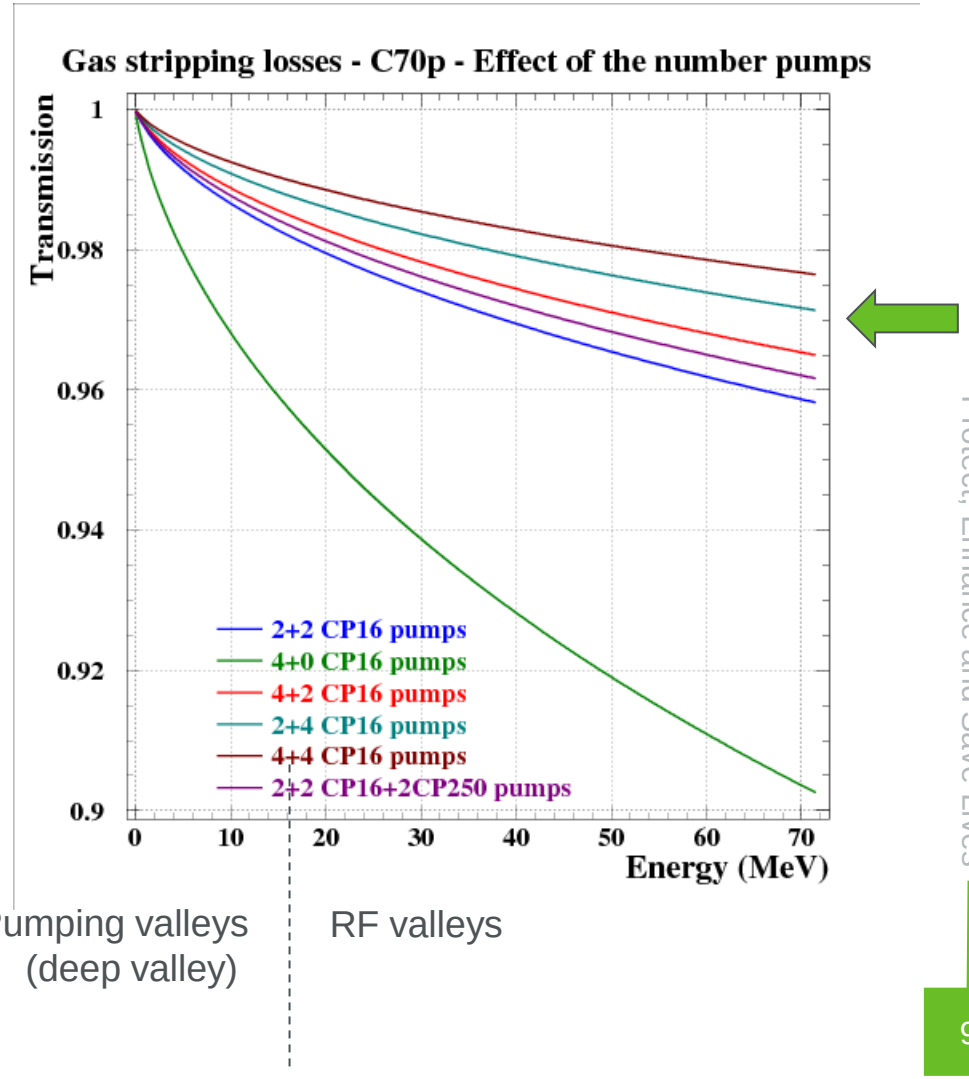
See dedicated poster

Vacuum system : pumping improvement

- GOAL : >97% transmission yield at 750µA / 70MeV

- Mild steel slightly rusty
- *See: Nickel plating (next)*
- Results with 6 pumps
  - **2 + 4** CP16 pumps is the best compromise (cyan line)

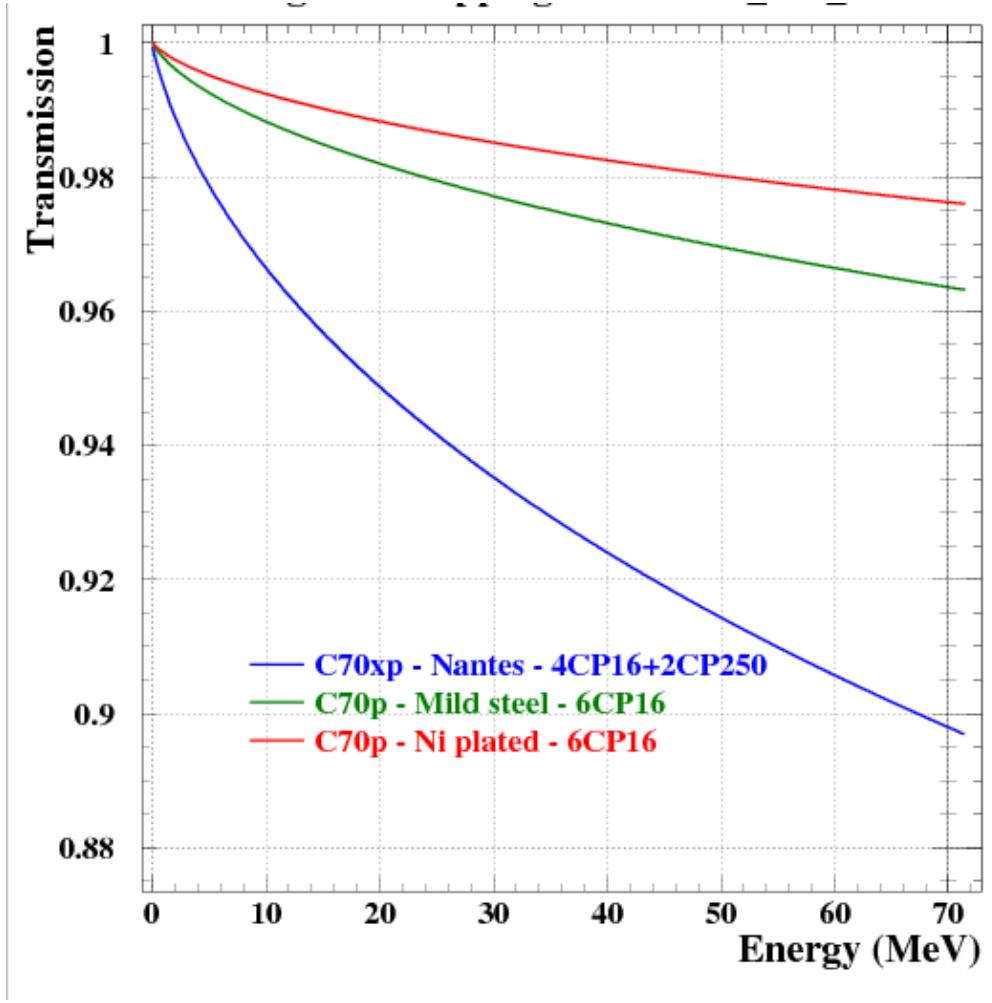




Effect of Ni plating

Computation of the Ni plating gain
Overall gain ~1.5 % transmission (1MeV to 70 MeV)

First machine in Nantes was not Ni plated.

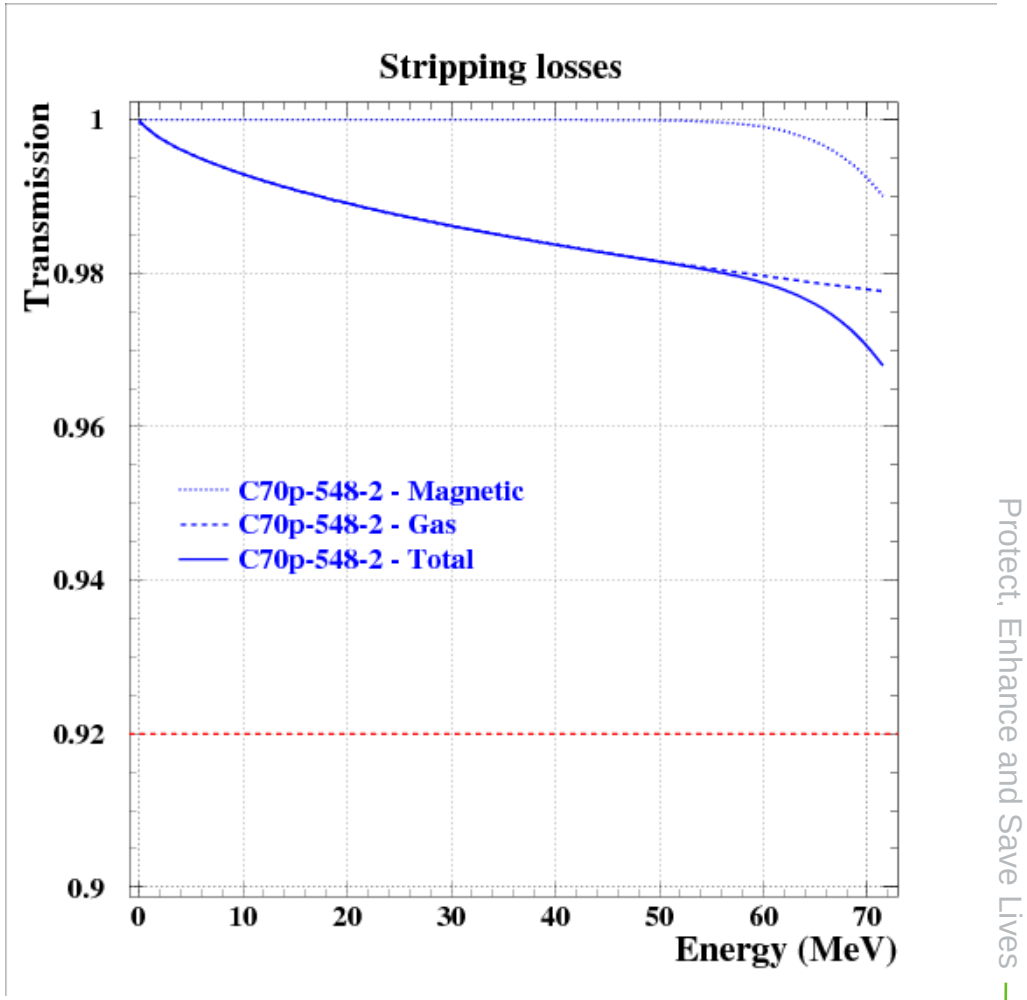


Vacuum system conclusions

- Cyclone®70P configuration:
  - 2 + 4 CP16 cryopumps
  - **Ni-plated** system
  - RF harmonic 4

- Main expected result : Total loss ~ 3%

(Nantes was computed at 10-12 % and is running at 8 %)

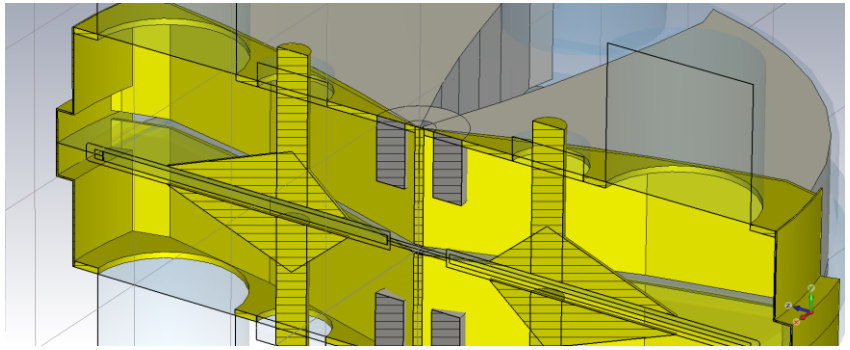


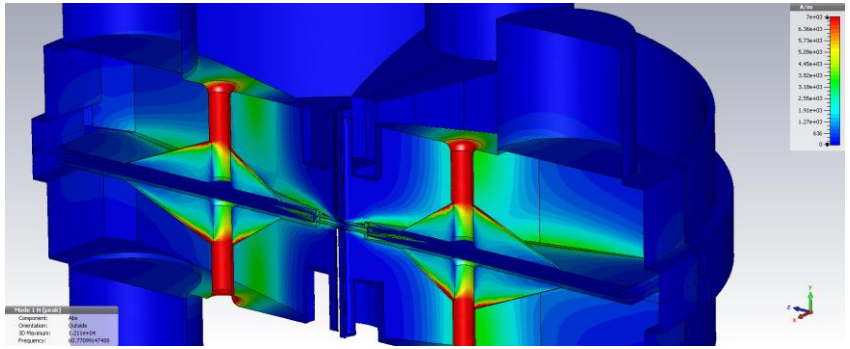
RF optimization

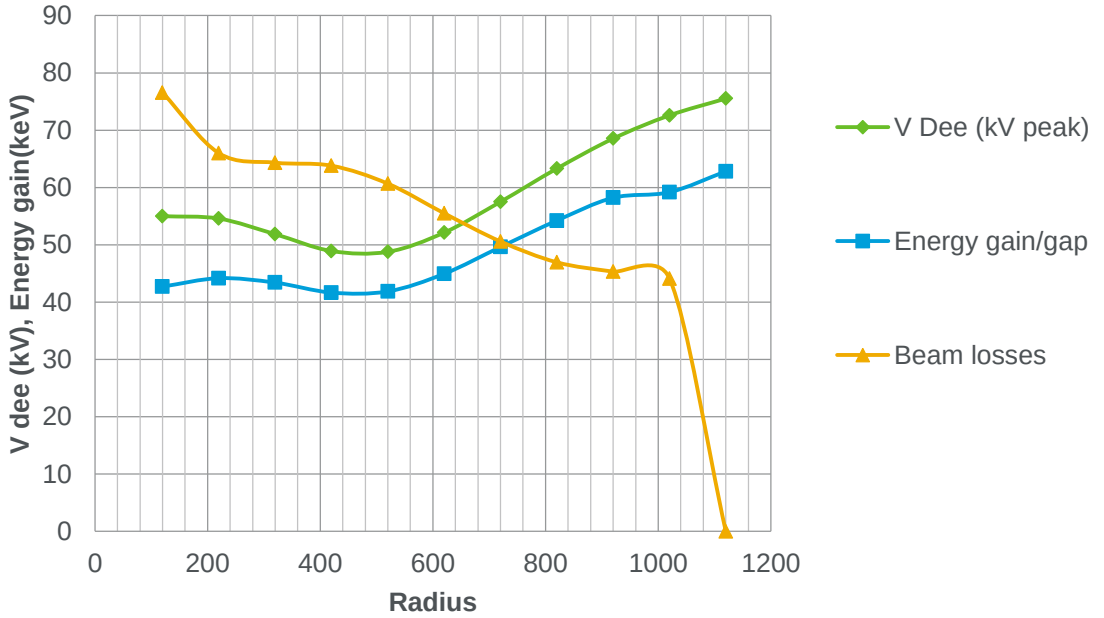
Goal : From Harmonic 2 in multi particles to Harmonic 4 in proton

Switch from H2 accelerating mode to H4

- Better energy gain per turn
- Reduce turn number (less losses then less activation)
- Reduce the Dee voltage (less RF sparks)



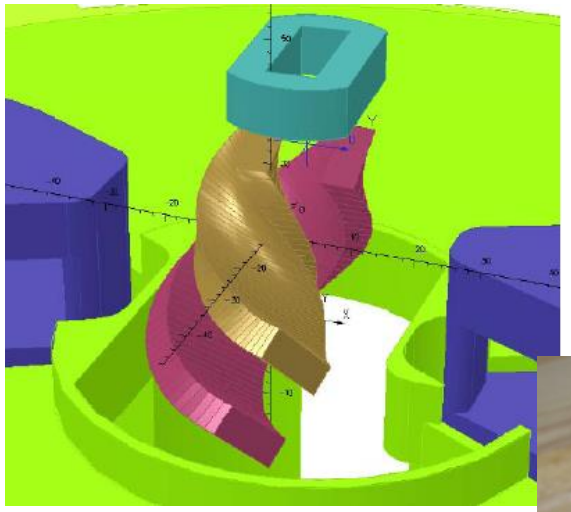


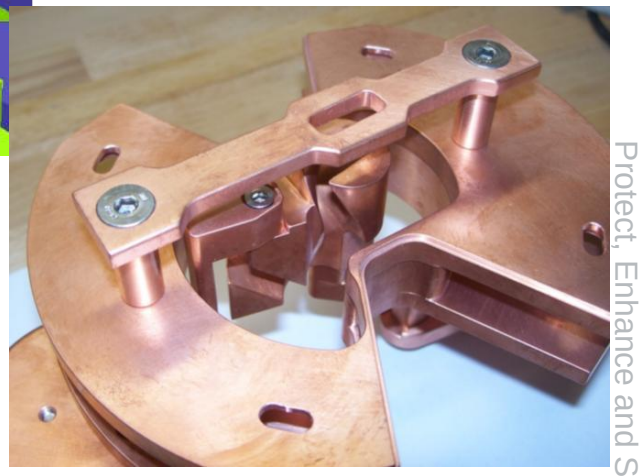


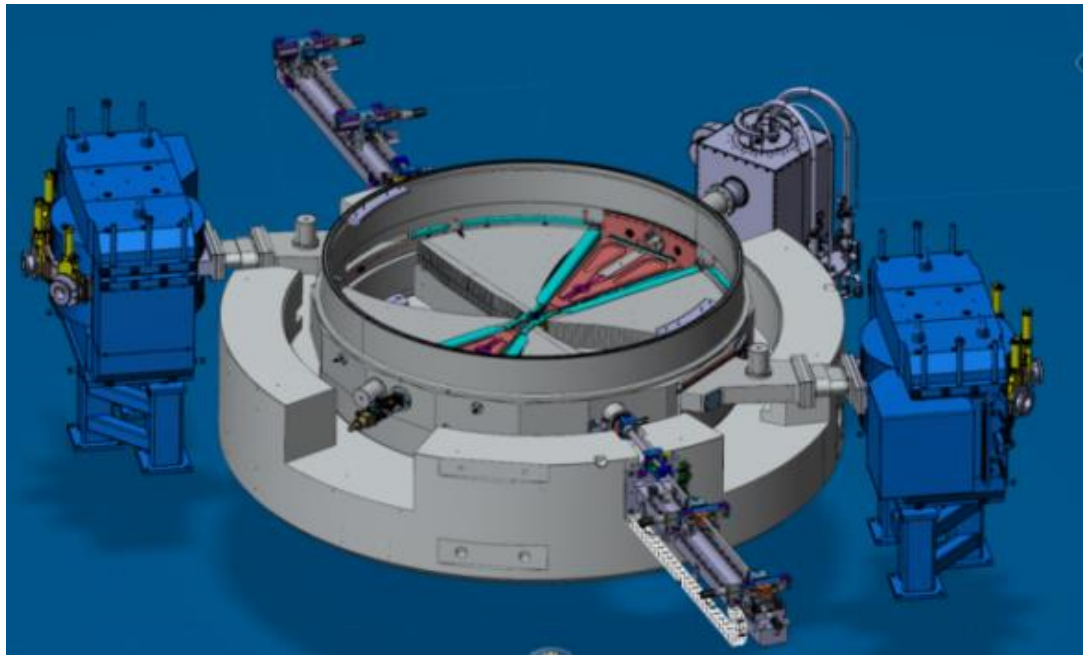
V centre: 50kV
Power dissipated: 32.7kW
N°of turns: 321

Other RF improvements

- **Central region** optimized for proton only
- Capacitor coupling in median plane
- **100kW amplifier** output power :
  -> margin for current increase
- Industrialization : less parts/easy to manufacture





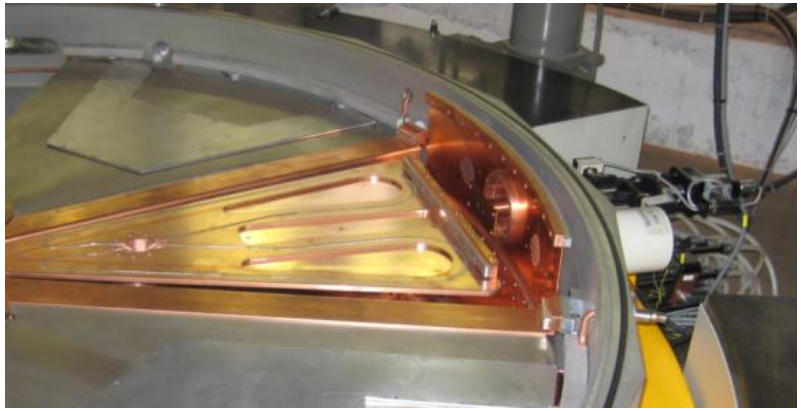


Protect, Enhance and Save Lives

See dedicated poster

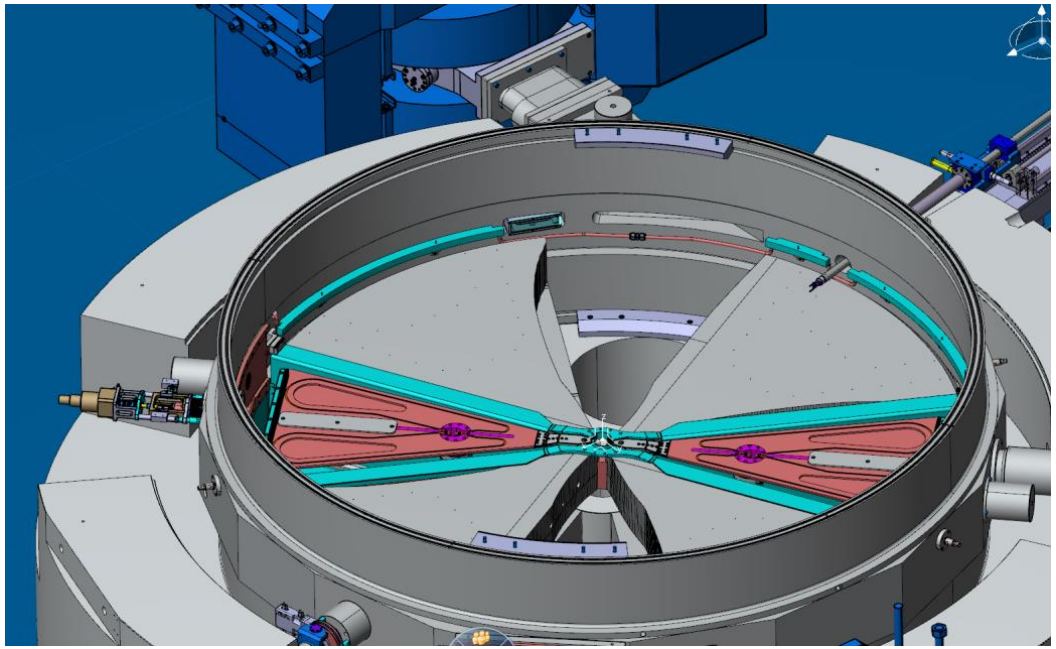
RF amplifier

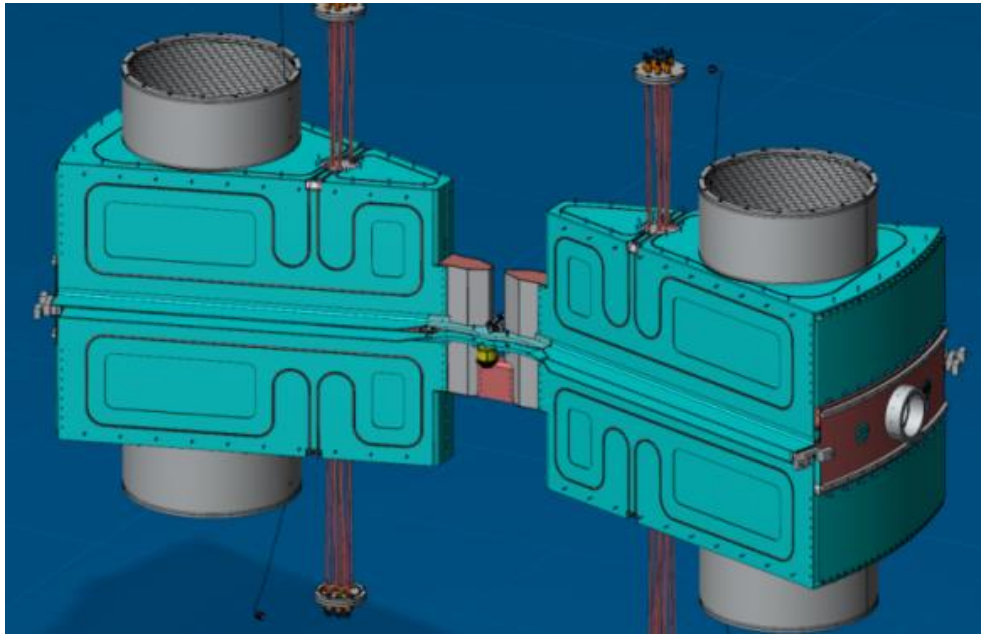
- Cyclone 30 high current amplifier
- Resonant coupling in median plane
  - No asymmetry between cavities
  - No beam loading
  - Low amplifier and coupler dissipation at 80kW total RF
- Only one cavity tuning at the opposite side of the coupler.



RF cavities

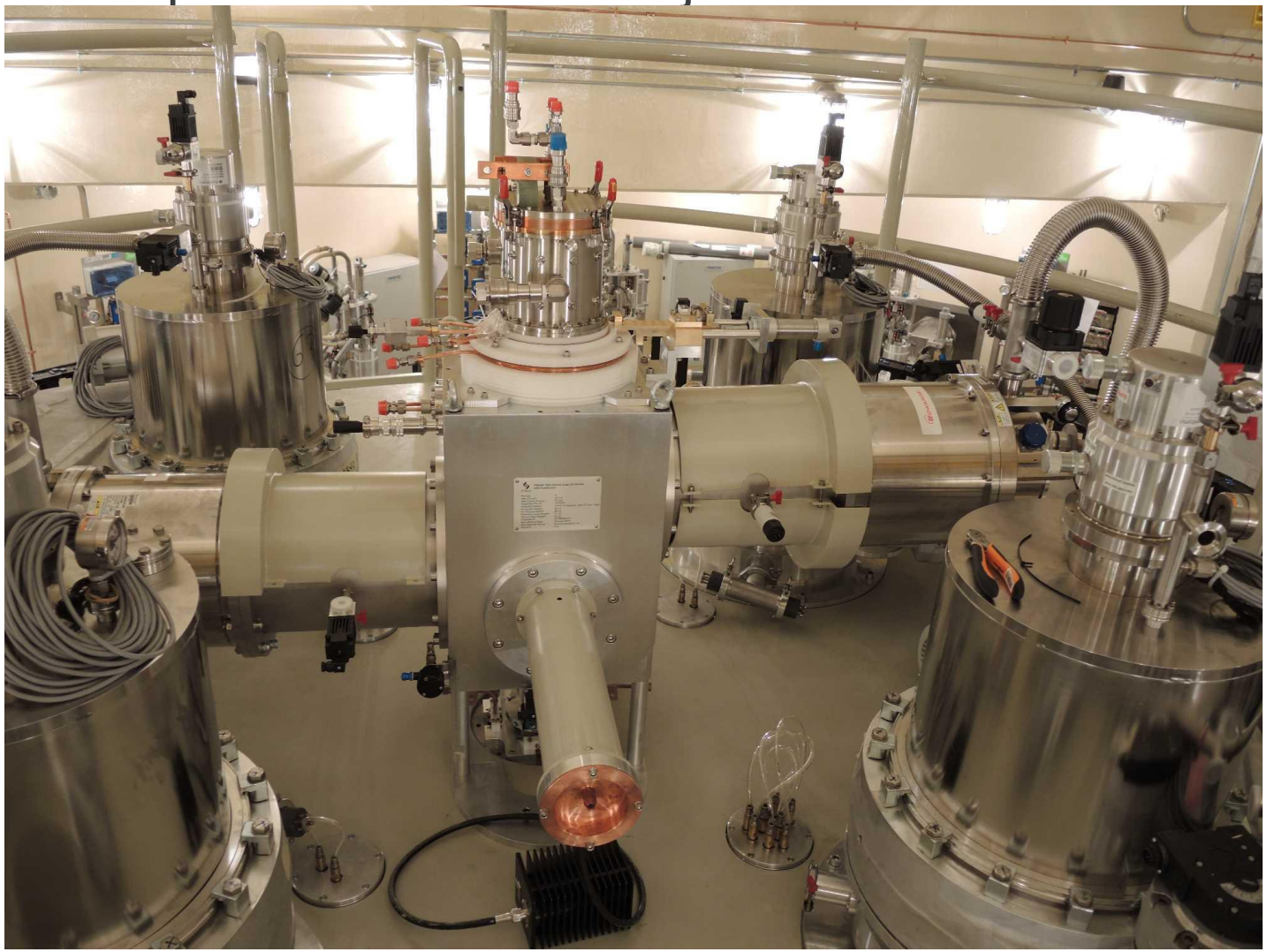
- H4 new cavities / Dees / stems
- Central region RF bridge + Dee coupling
- Central region optimized for H-
- Large pumping holes in valley to cavities

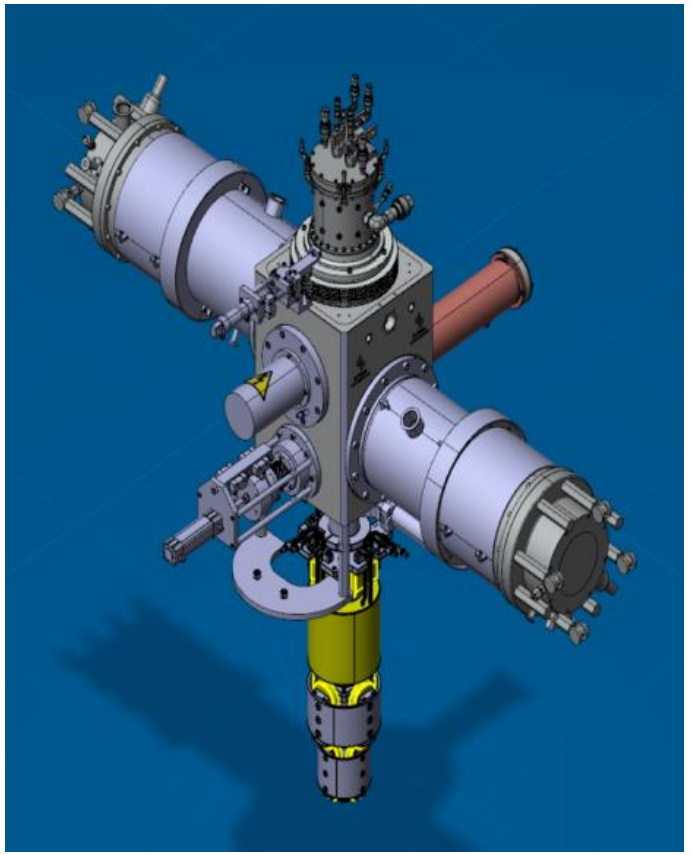




Injection : for proton only

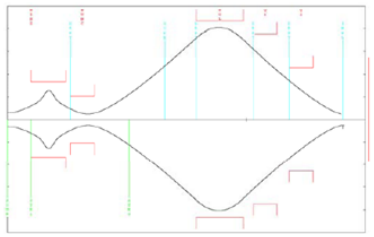
H- proton source and injection

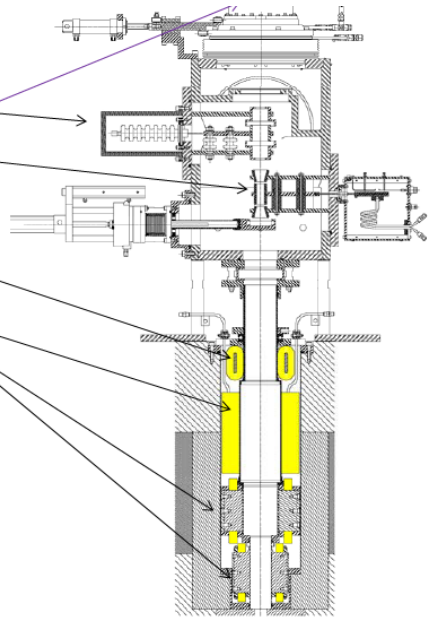




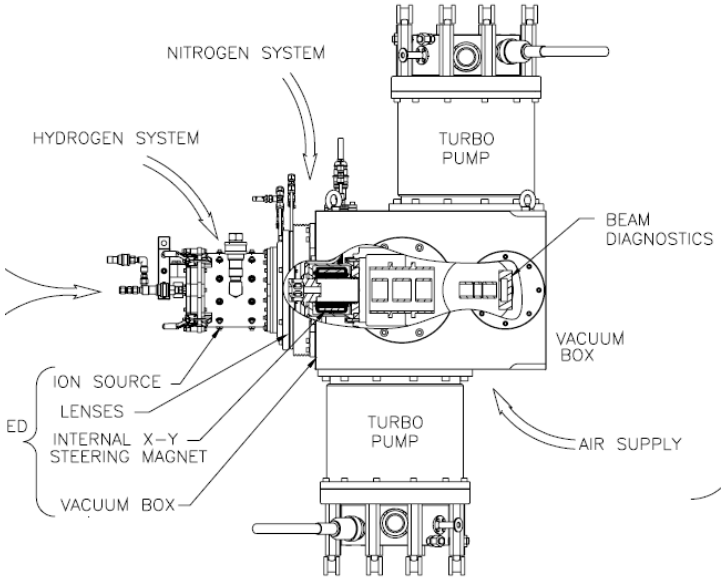
Injection overview

- Turbo pump injax
- New Einzell lens
- No wire RF buncher
- XY steering (2)
- Glaser lens
- Set of quadrupoles (squew)
  - Match cyclo acceptance



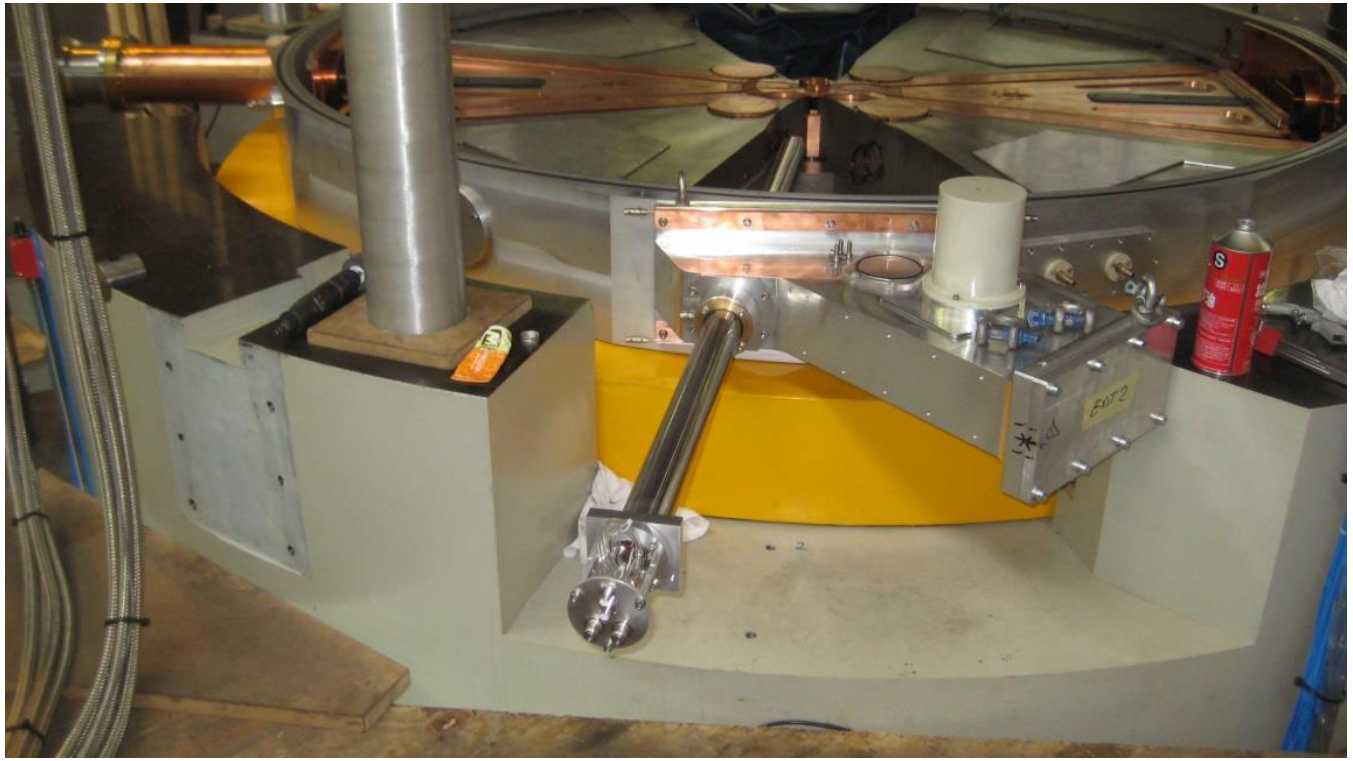


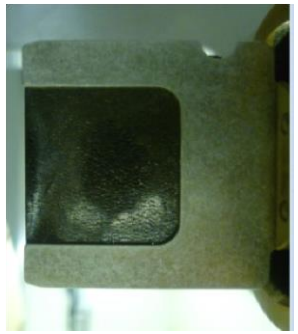
- Capacity 10mA H-, superbright emittance
- 30 kV platform
- Easy maintenance (one back plate with 4 filaments)
- Differential pumping system for high vaccum level



Extraction

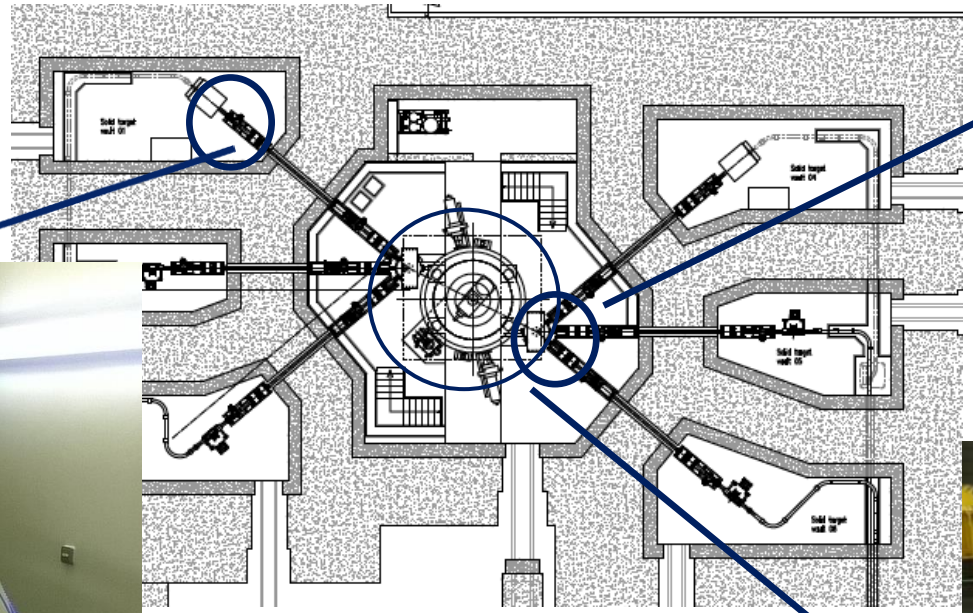
- 2 extraction shaft
- Permanent radial probe
- Stripper charger
- Low activation materials





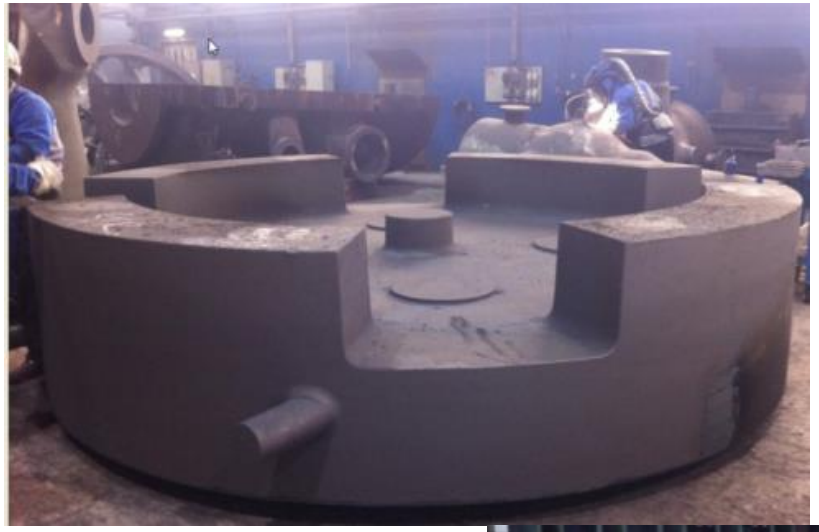
Project : General Overview

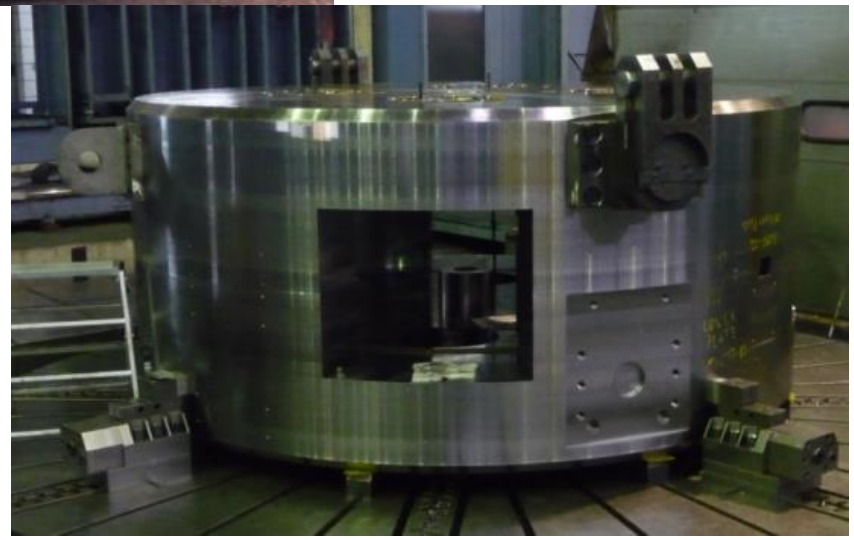
- Cyclone 70P – 6 beam Lines configuration and 2 solid targets

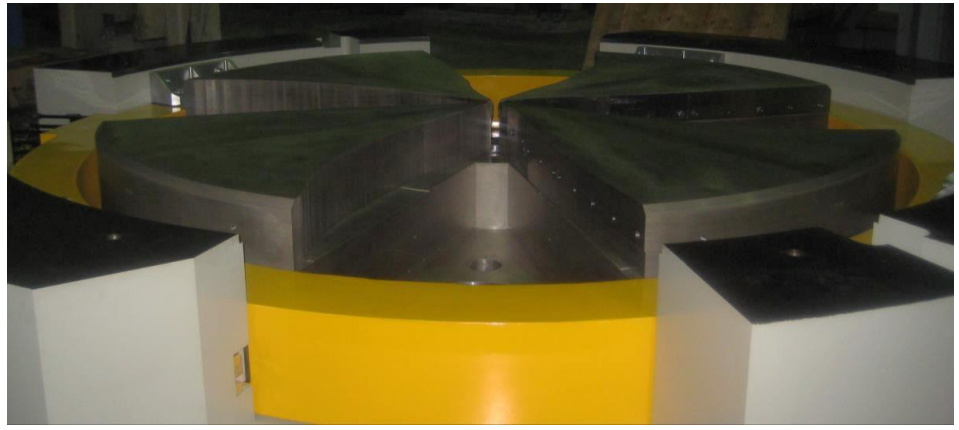


1st Unit - Zevacor : Project Key Milestones

- Mapping phase started 12 months after contract signature







FAT : June 2015

- Acceptance tests performed in factory 19 months after contract signature

Ex work Milestone

July 2015 : 2 Cyclone® 70 in our factory

September 8th : Rigging Phase in US

Status on 15/09 : machine re assembled in customer vault

Next milestones

- Zevacor : contract signature : 4th November 2013
  - Complete installation, commissioning and acceptance by Q2 2016

- CDNM
  - Mapping phase ended by Q4 2015
  - Installation, commissioning and acceptance tests in 2017

RadioPharma Solution Team : stronger together !

Questions? Comment? Thank you

Benoit Nactergal

R&D Manager

nactergal@iba-group.com

/company/iba

/ibaworldwide

/ibagroup

/iba