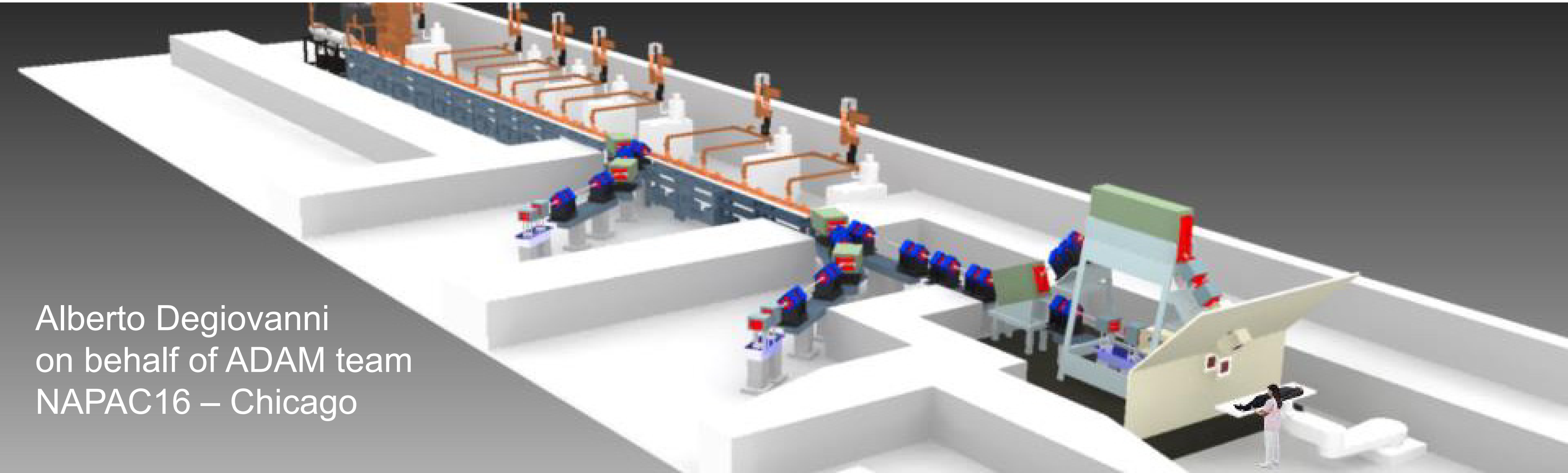
14th Oct 2016

ADVANCED ONCOTHERAPY

ADAM
Applications of Detectors and Accelerators to Medicine

CERN spin-off

LIGHT: a Linear Accelerator for Proton Therapy



Alberto Degiovanni
on behalf of ADAM team
NAPAC16 – Chicago

ADAM - Company's History

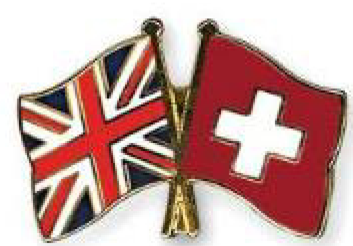
- **A.D.A.M.** SA (**A**pplication of **D**etectors and **A**ccelerators to **M**edicine) is a CERN spin-off, based inside CERN

- ADAM was founded in Dec 2007 by a private investor (A. Colussi) to develop, build and test accelerators for medical applications

Between 2008 and 2012 :

- two compact accelerators for conventional radiotherapy (X-eye and IORT)
- one dosimeter (based on CMS silicon detectors)
- one unit of a linear accelerator (called LIGHT) - for proton therapy

In 2013 the UK company AVO (listed on the market) bought ADAM, now involved in the construction of the full LIGHT accelerator



ADAM/AVO Today

In Geneva:
(Experimental Facility)

- Physics
- Mechanical Engineer
- RF
- Control System
- Regulatory
- Beam Diagnostic
- Health & Safety

In London:

- Finance
- Procurement
- Manufacturing
- Business development
- HR
- IP
- Regulatory

~65 employees

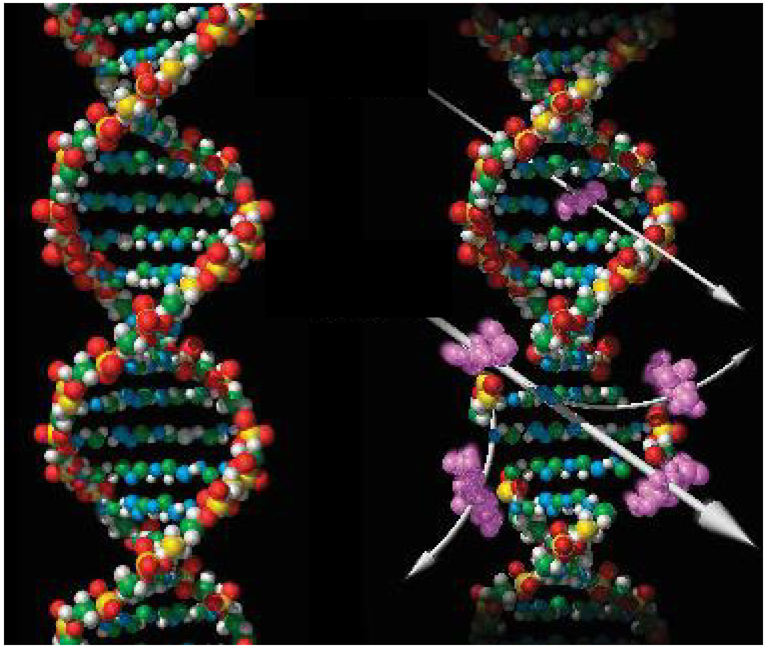
Outline of the talk

- Introduction
  - Proton therapy
  - Accelerators for proton therapy
- Overview of the LIGHT system
- "Technology transfer" into the LIGHT proton therapy system
- Integration and commissioning
- Conclusion

Radiation therapy

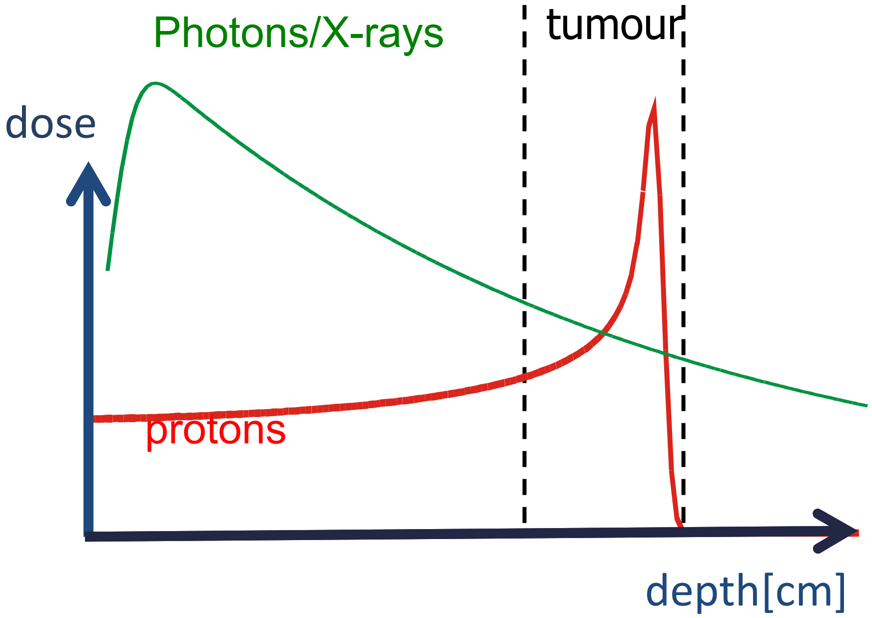
Radiotherapy methods

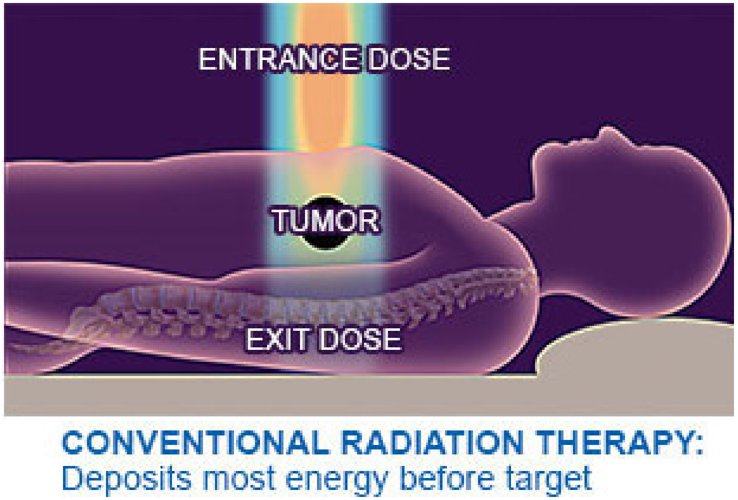
- X-rays/gamma rays/electron beams — Most current treatments
- Particle beams: E.g. protons — New treatments

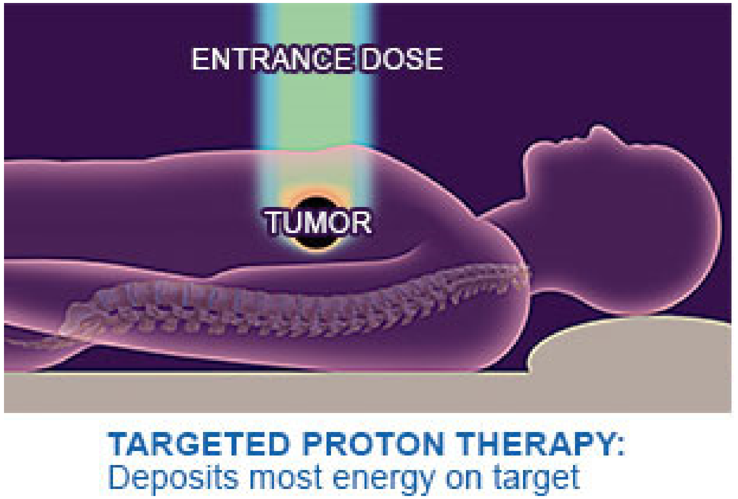


- Radiation can break the DNA of the cells they collide with
- Healthy cells get damaged too…
- **Advantage of protons (see next)**
  - Stop and loose dose in **well-localized** position
  - They are charged (can be steered with magnetic field)

Why use protons for radiotherapy?







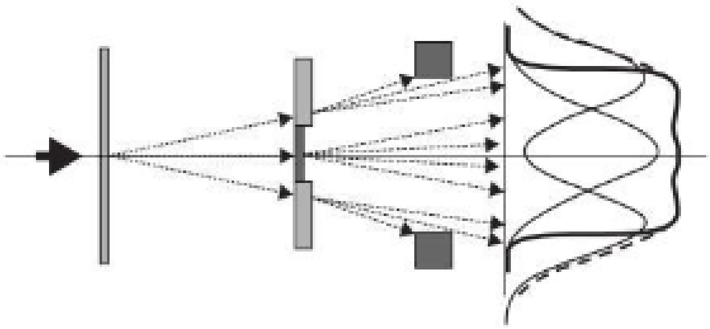
- Dose to close-by organs-at-risk is much lower with protons than with photons!

→ Better quality of life after treatment (less side-effects), and less chance for developing secondary cancer

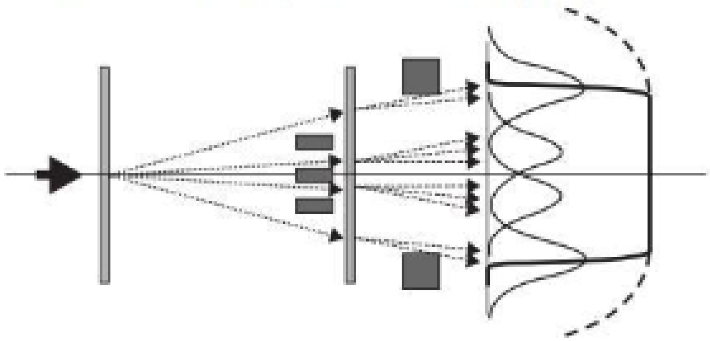
Dose delivery techniques

- Passive beam spreading or scattering technique

Double Scattering with dual ring



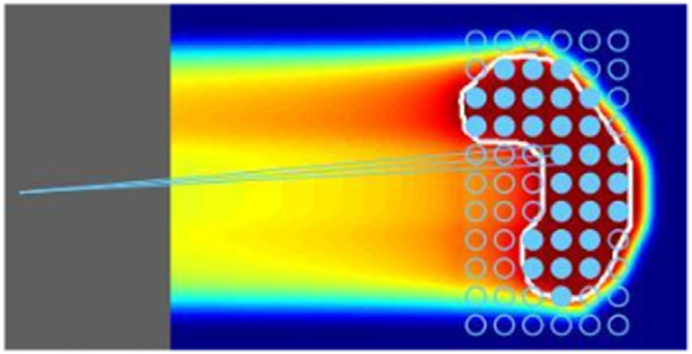
Double Scattering with occluding ring



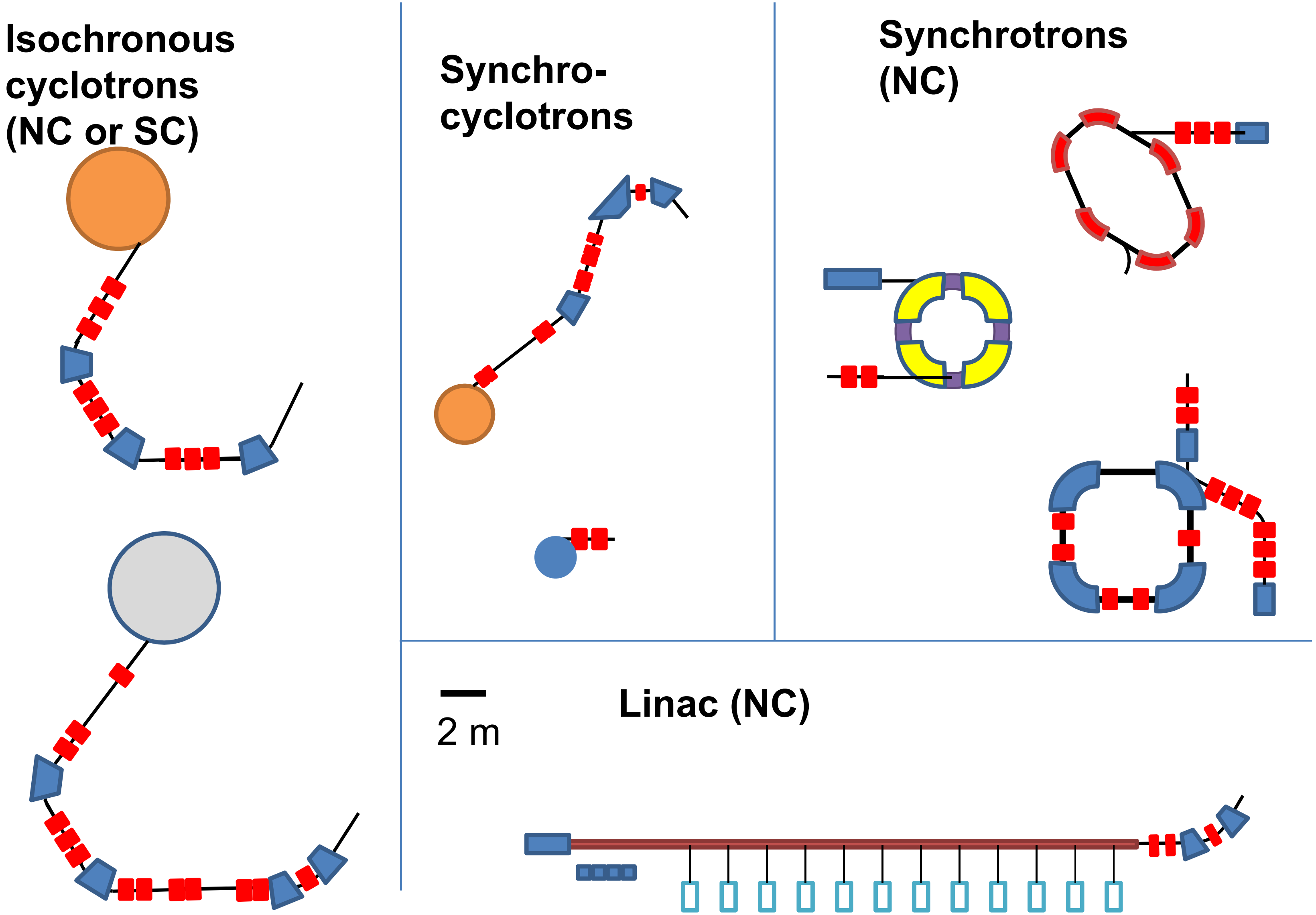
- Pencil beam scanning or 'spot' scanning

70-230 MeV

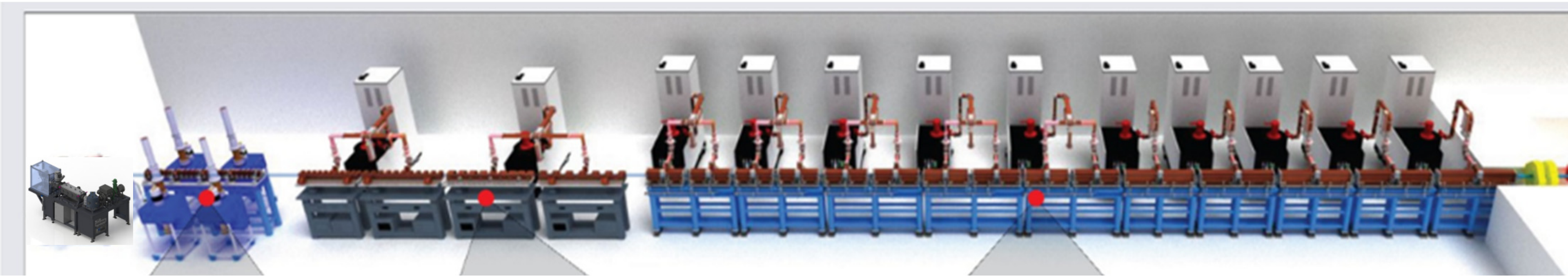
~1 nA



Accelerators for Proton Therapy



A linac for protontherapy



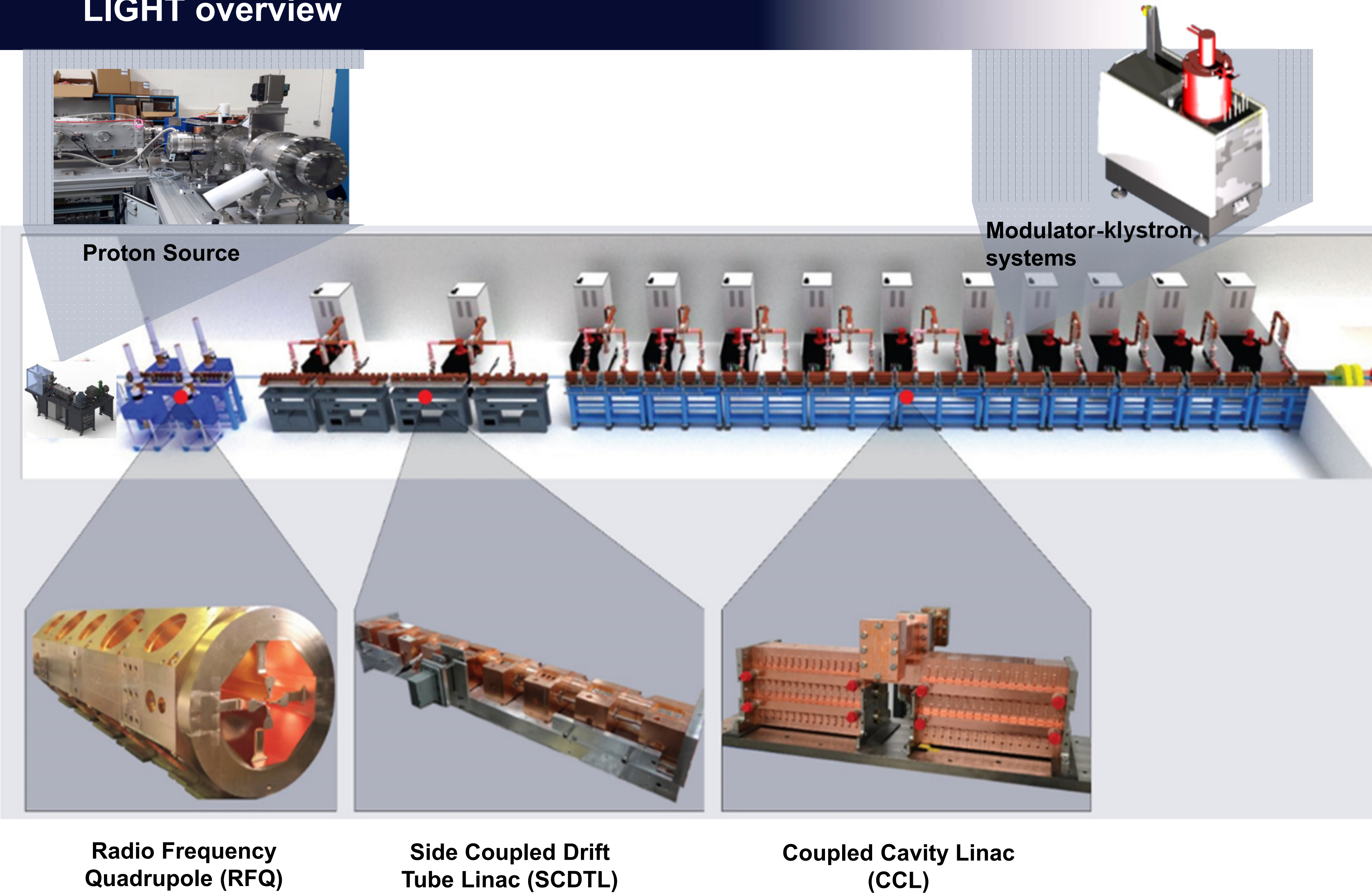
LIGHT =
Linac for Image Guided Hadron Therapy

LIGHT features for proton therapy

- Active energy modulation → no absorber and degrader
- Pulsed beam at 200 Hz → intensity and energy modulation in 5 ms
- Small beam emittance → small magnets aperture
- Almost no losses! → reduced shielding

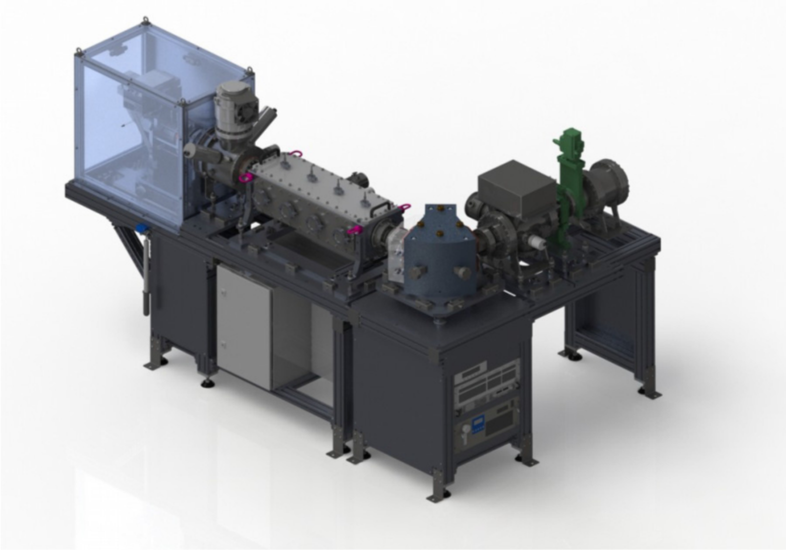
→ beam suited for 3D spot scanning

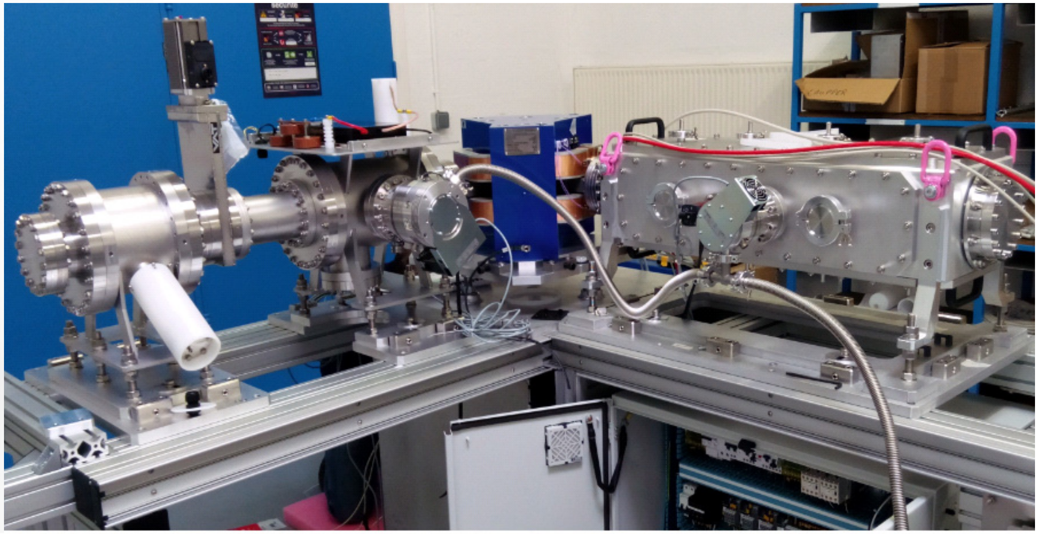
LIGHT overview



The proton source

- Proton source:
  - MONO 1000 ECRIS (Pantechnik)
  - RF frequency 2.45 GHz
  - chopped at 200 Hz
  - 300 -1 uA

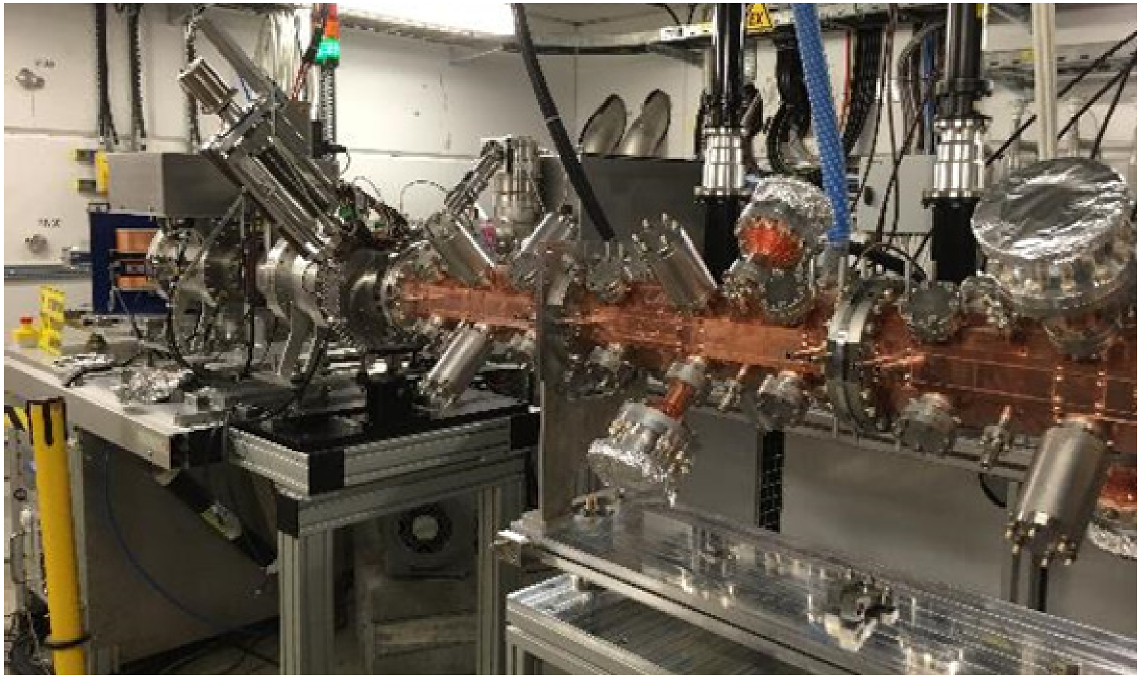


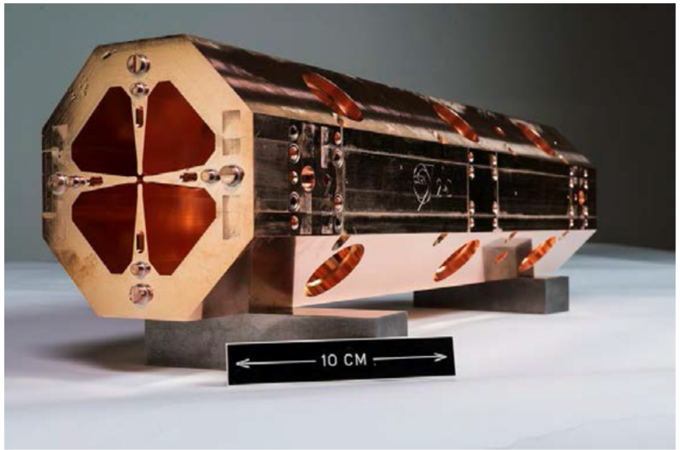


The Radio Frequency Quadrupole

- High frequency RFQ designed by CERN
  - 4 vanes type
  - 750 MHz
  - 4 modules - 2 m
  - 5 MeV energy gain

Section	RFQ
RF frequency [GHz]	0.749
Energy [MeV]	0.04-5
Length [m]	2





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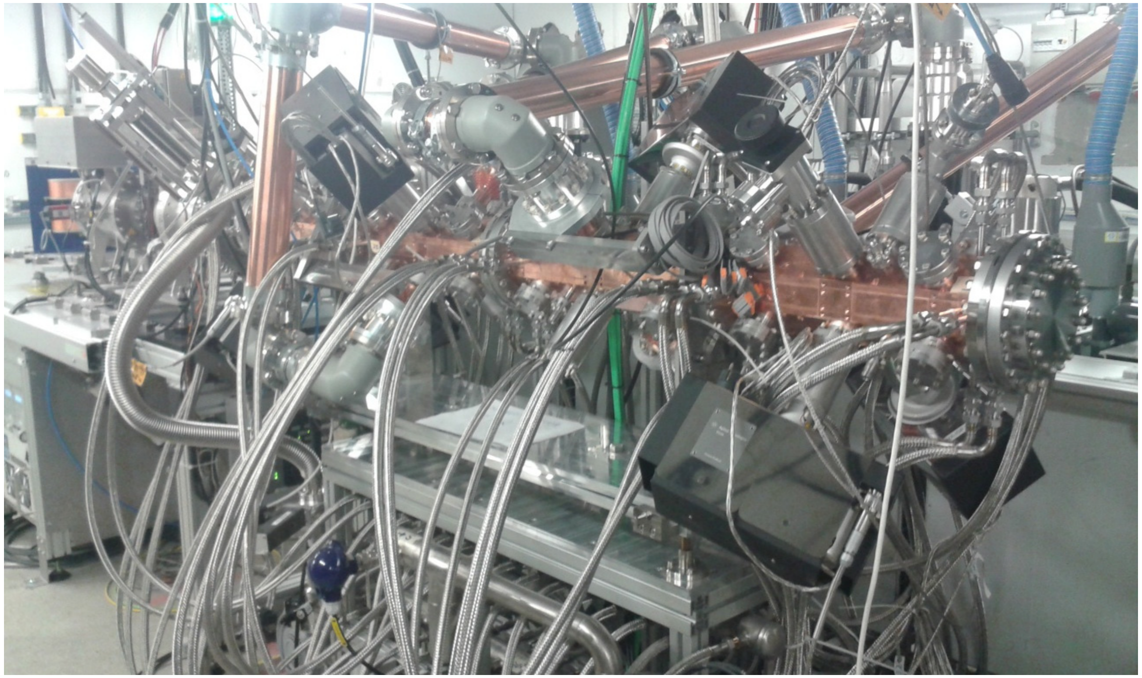
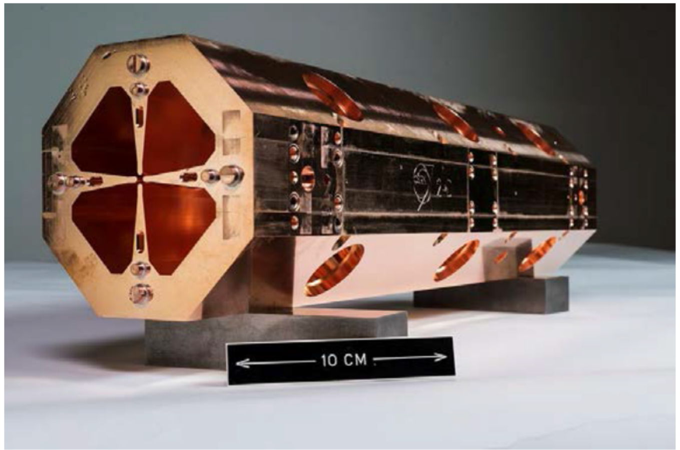
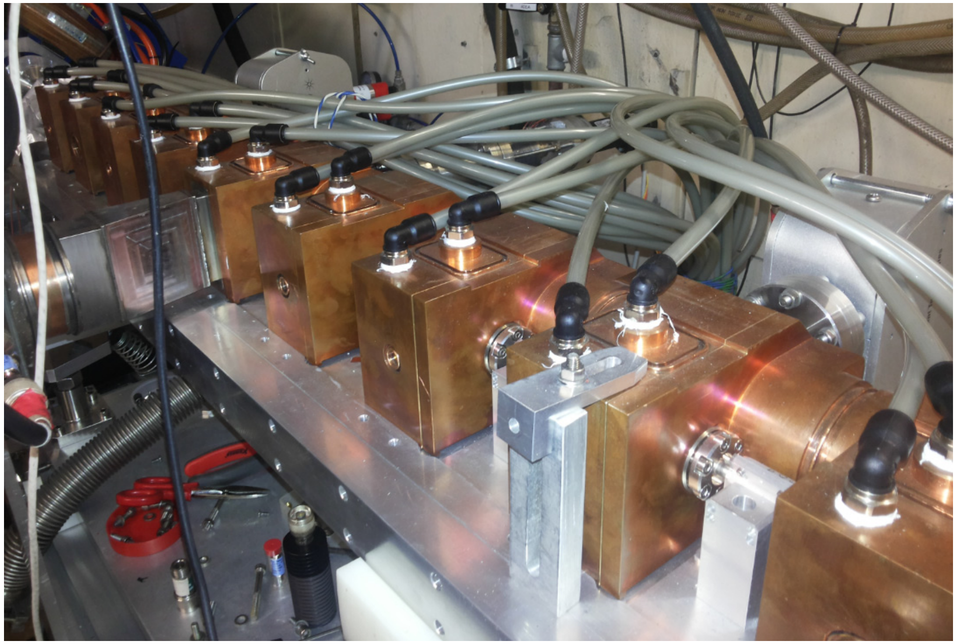




The Side Coupled Drift Tube Linac

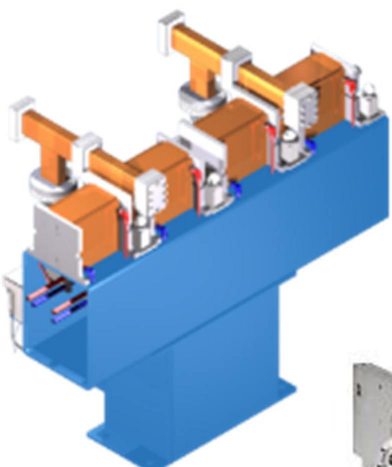
- Designed by ENEA (Frascati, I)
- Manufactured at TSC/VDL
  - SCDTL3 (TSC)
  - SCDTL1, SCDTL2, SCDTL4 (VDL)

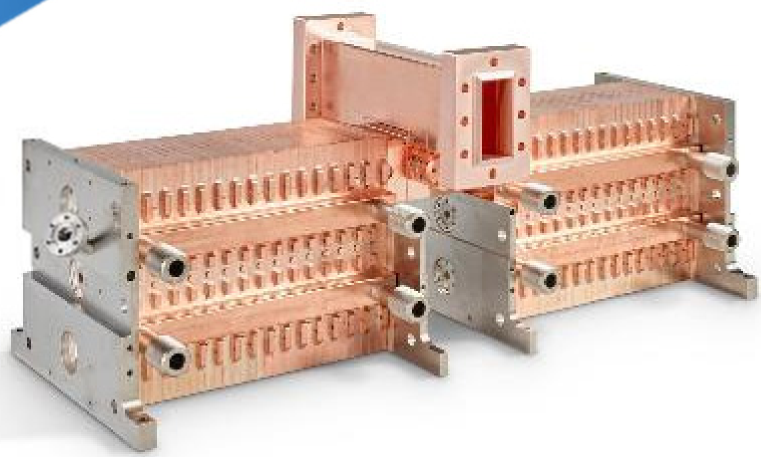
Section	SCDTL
RF frequency [GHz]	2.998
Energy [MeV]	5-37.5
Length [m]	6.2

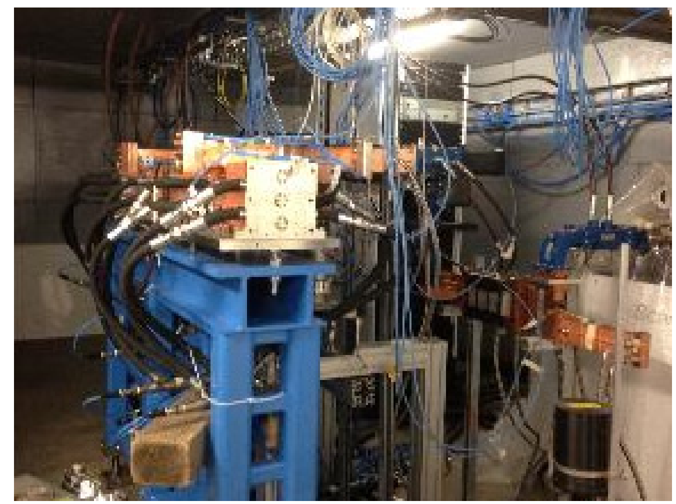


- Designed by ADAM
- Manufactured by VDL
- 4 modules already in the bunker (conditioned)
- All remaining modules in production

Section	CCL
RF frequency [GHz]	2.998
Energy [MeV]	37.5-230
Length [m]	15.5







The RF Power System

- Commercial modulator and klystron systems

SCANDINOVA Modulator

Parameter	Value
Pulse Voltage	155 KV
Pulse Current	110 A
Pulse Rep. Rate	5 to 200 Hz
Pulse Length (top)	0.5 to 5 μsec
Pulse Flatness (top)	<1%

Toshiba Klystron

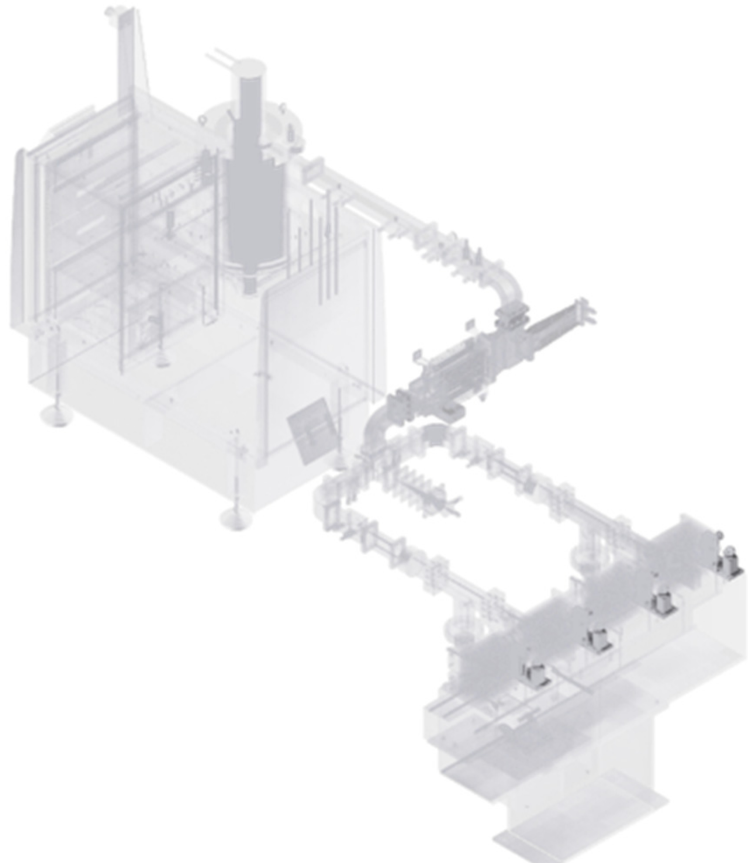
Parameter	Value
Frequency	2998.5 MHz
Peak RF Drive Power	120 W
Peak RF Output Power	7.5 MW
Gain	48 dB
Pulse Width (RF Out P.)	5 μsec

LIGHT: RF Power System installation

A modular approach towards industrialization

Unit Systems

1) Accelerating System
2) Control System
3) Cooling System
4) Focusing System
5) RF Network System
6) RF Power System
7) Support System
8) Vacuum System



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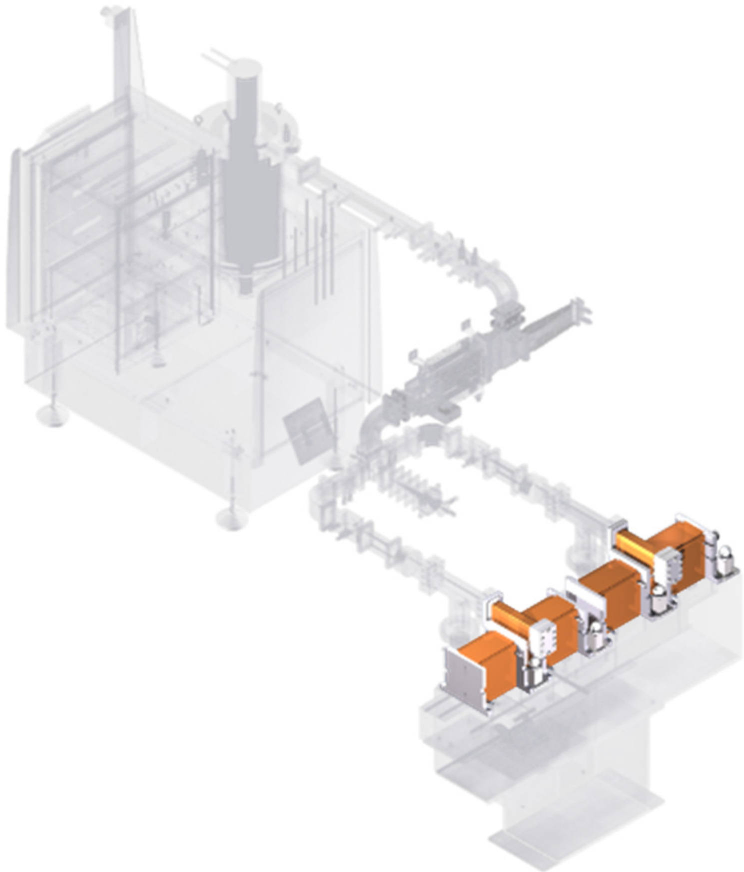

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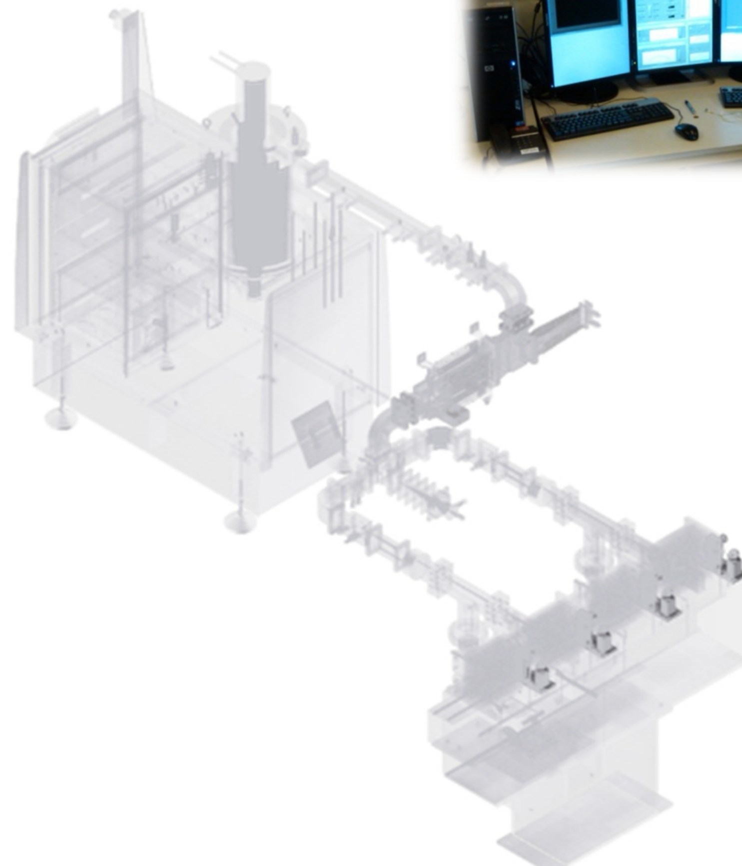

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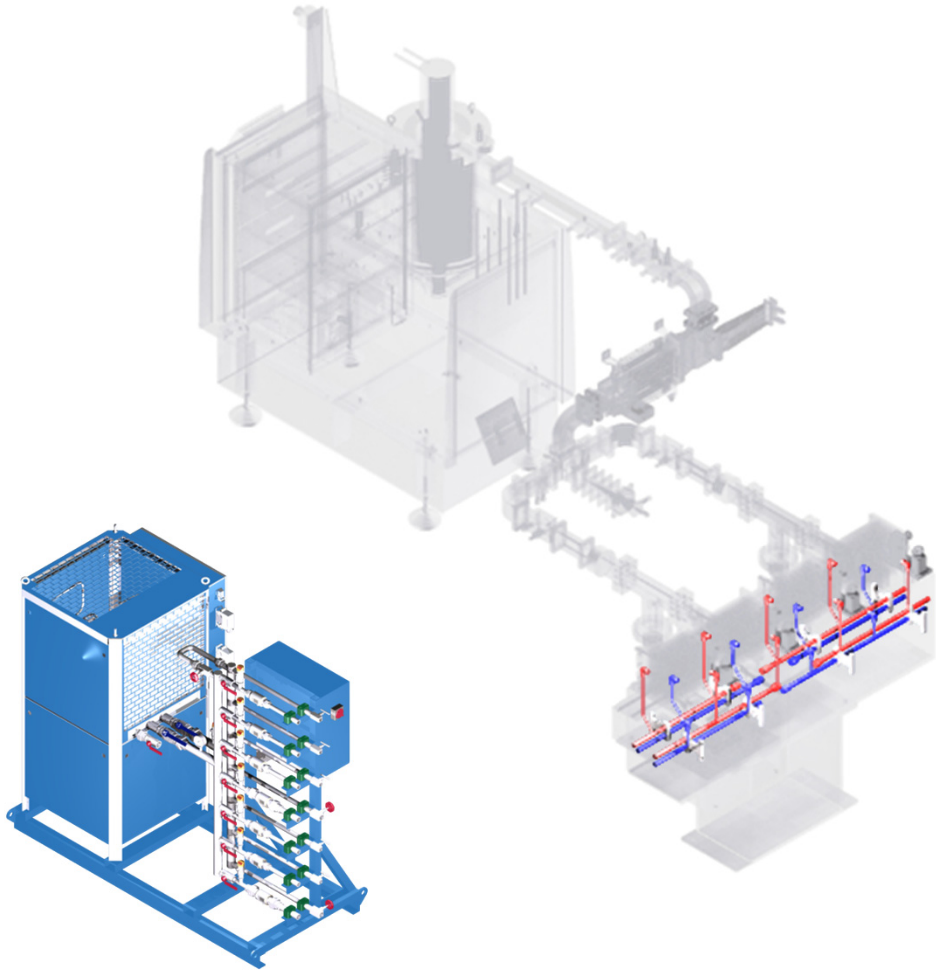

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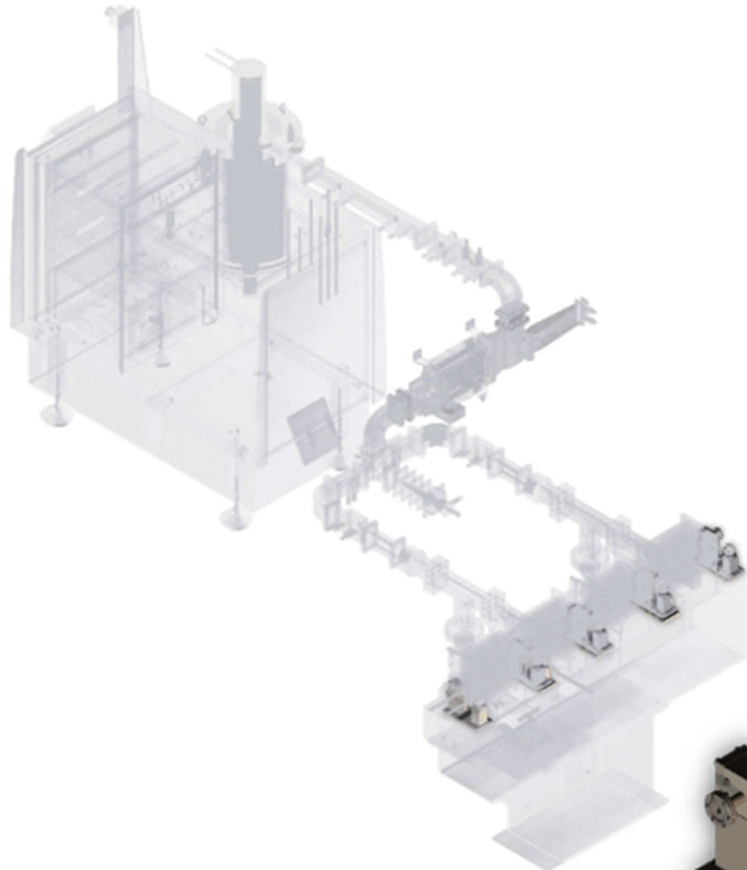

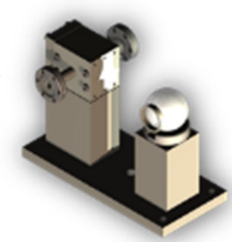

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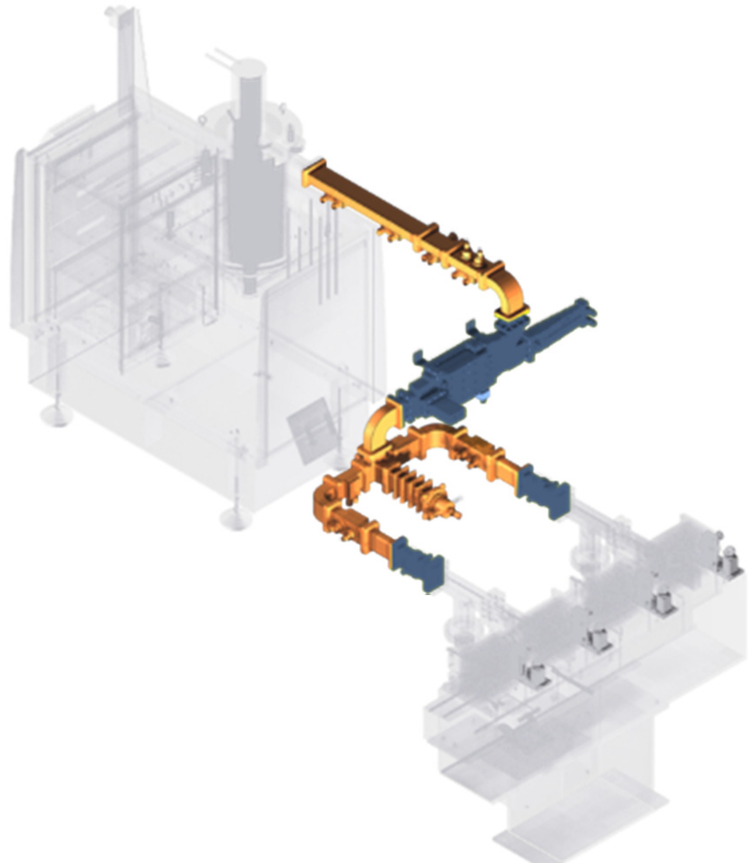

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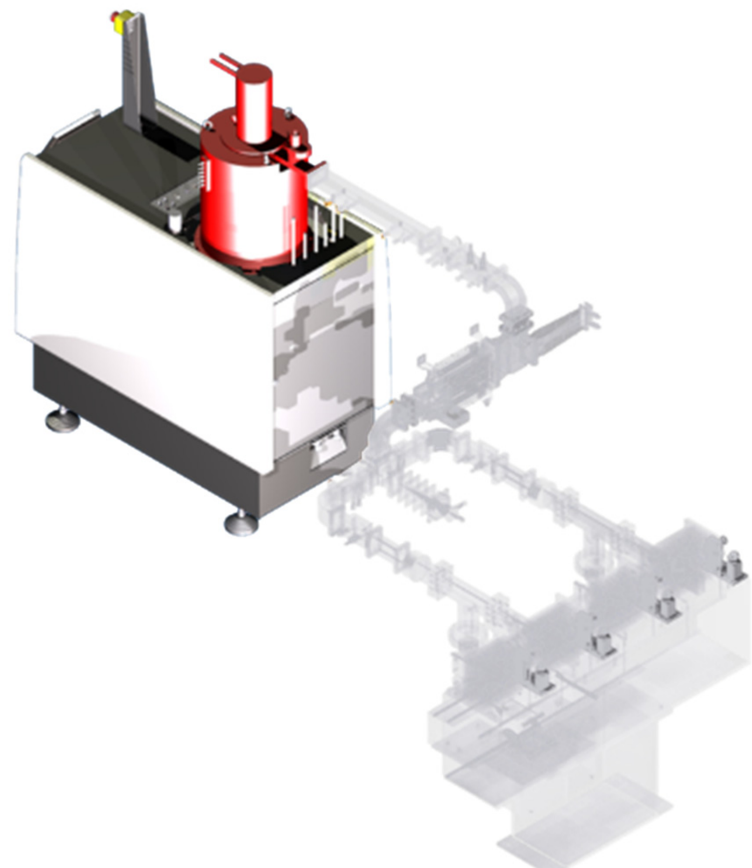

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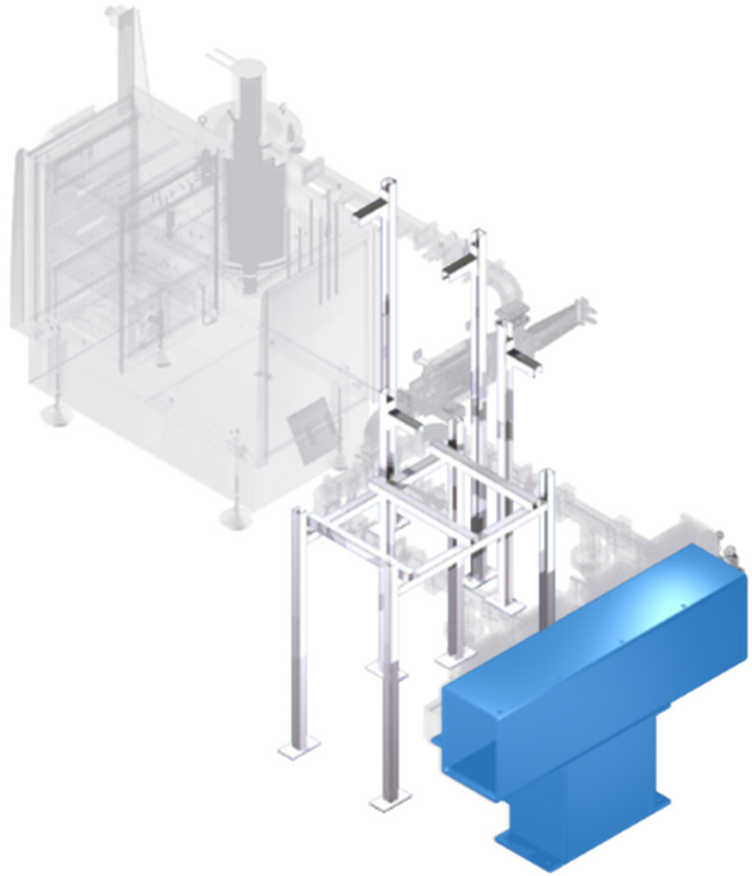

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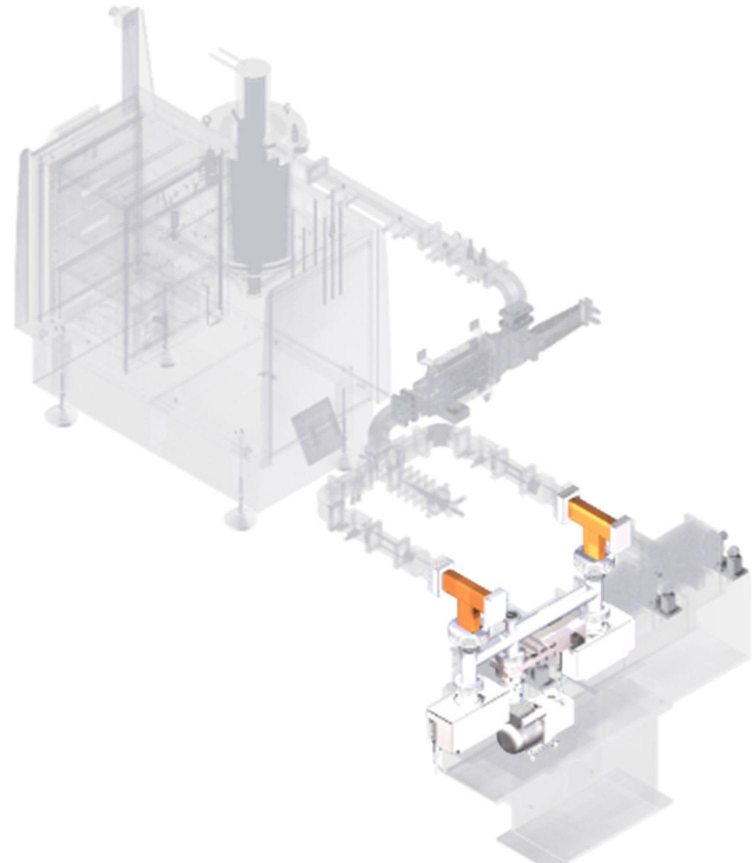

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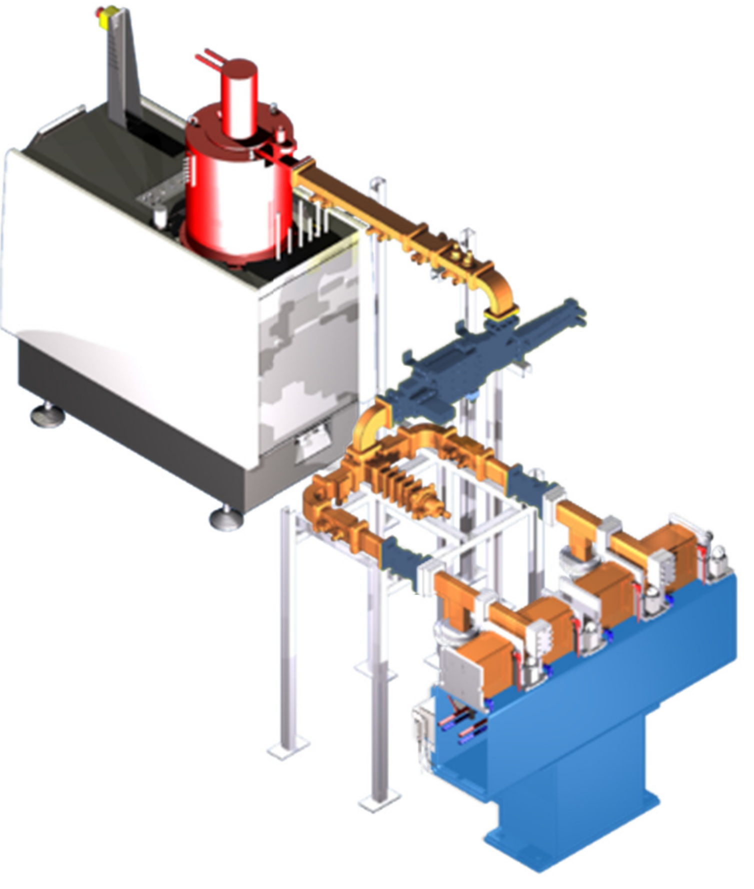
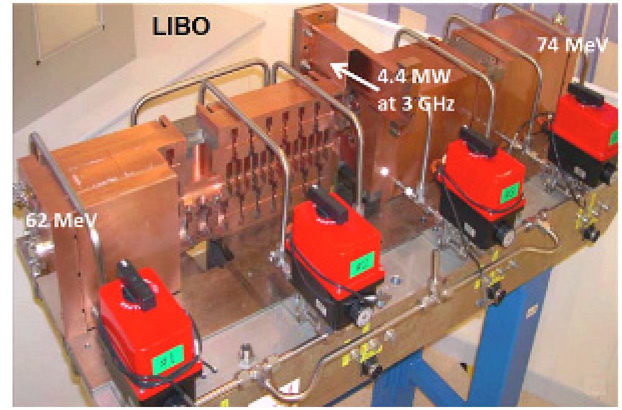


Technology Transfer highlights

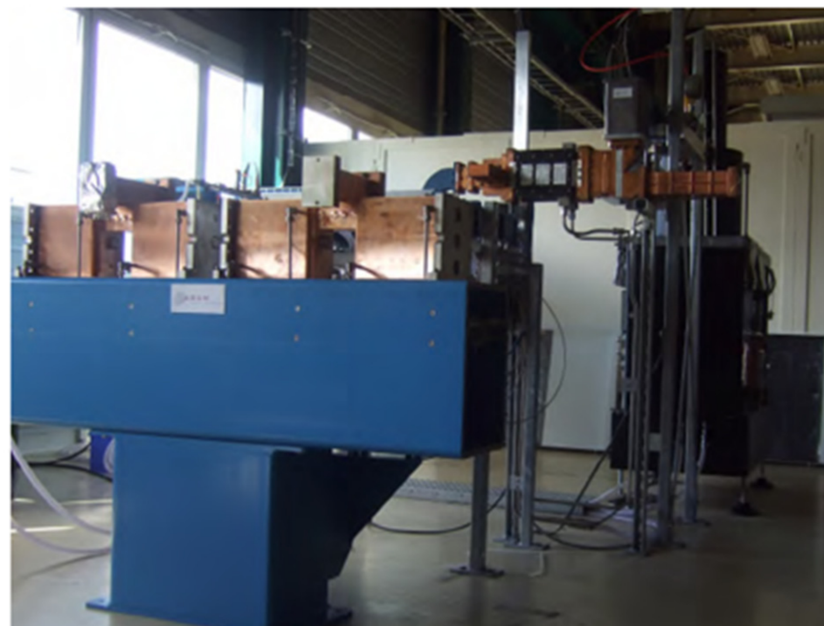
Technology transfer I: the LIBO and the first unit

- LIBO (Linac Booster) prototype by TERA-CERN-INFN
  - Built in 1999-2000
  - First proof of principle



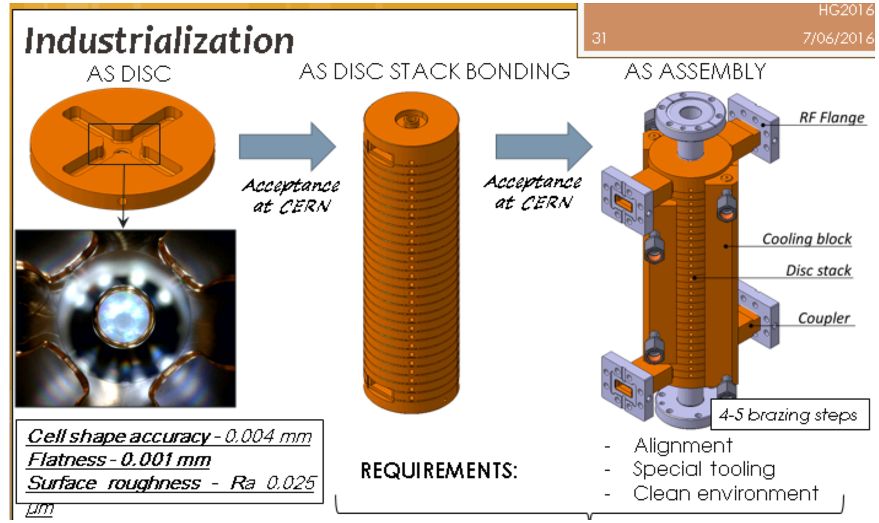
Amaldi et al., NIM A(521), 512-529, 2004

- First Unit of ADAM
  - first industrial 3 GHz linac unit for PT
  - Optimized for industrial production

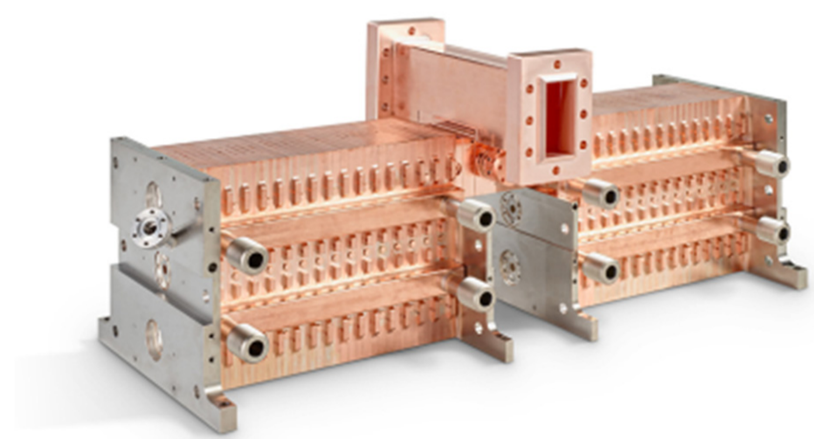


Technology transfer II: high-precision machining

- Experience developed by CLIC group at CERN in design and production of copper structures with µm precision machining



- ADAM - VDL for production of accelerating structures



Technology transfer III : the RF power source

- At CERN: ‘Xboxes’ X-band test stand at 12 GHz with:
  - Scandinova K1mod
  - Toshiba E37113

- ADAM → similar approach with
  - SCANDINOVA K1
  - Toshiba E3779,A

Commissioning ongoing (LINAC4 experience)

- Not only ‘technology’ transfer, but also **KNOWLEDGE transfer**

Proceedings of HB2016, Malmö, Sweden Pre-Release Snapshot 8-July-2016 11:30 UTC MOAM2P20

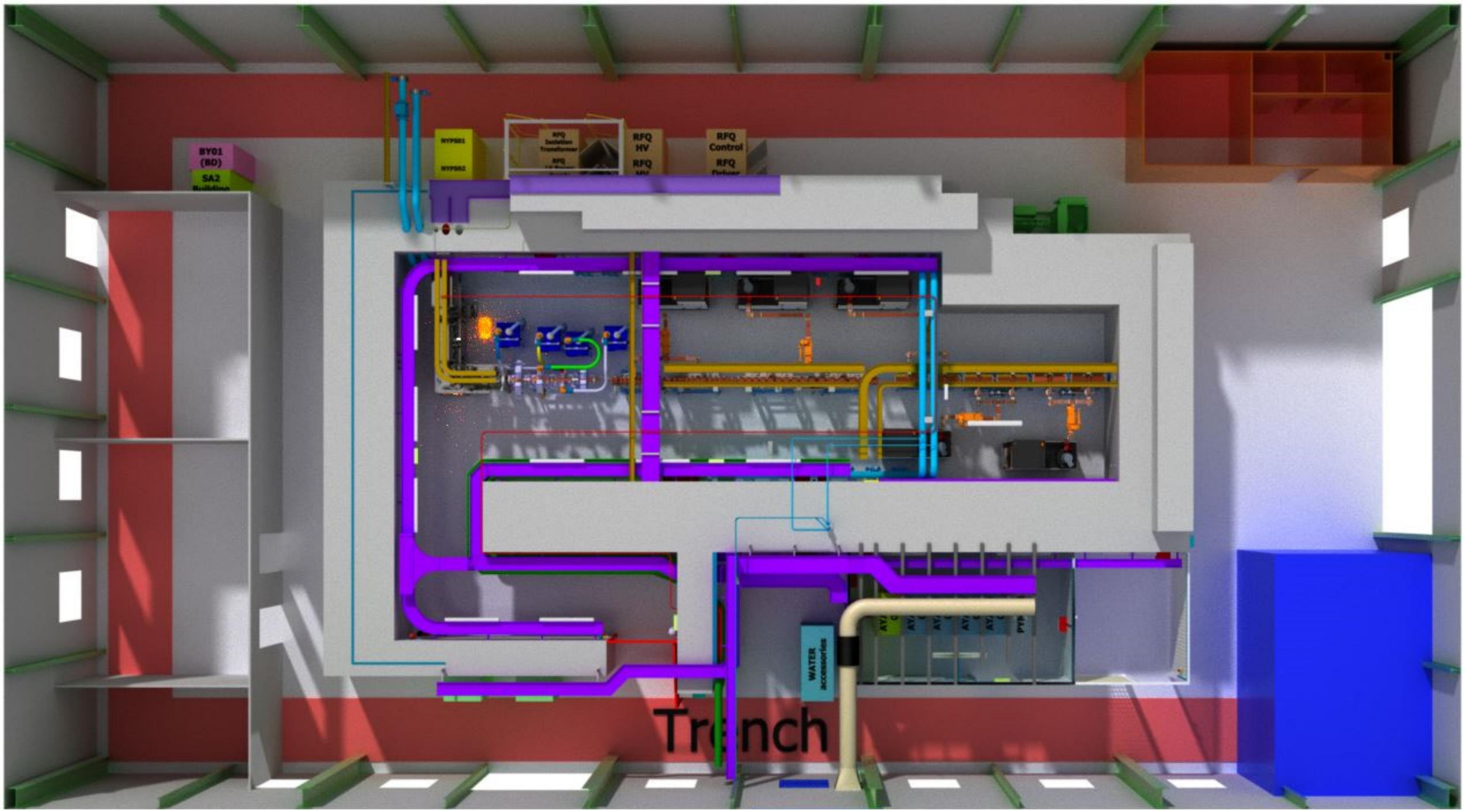
THE LINAC4 PROJECT

A. M. Lombardi for the LINAC4 team , CERN, Geneva, Switzerland

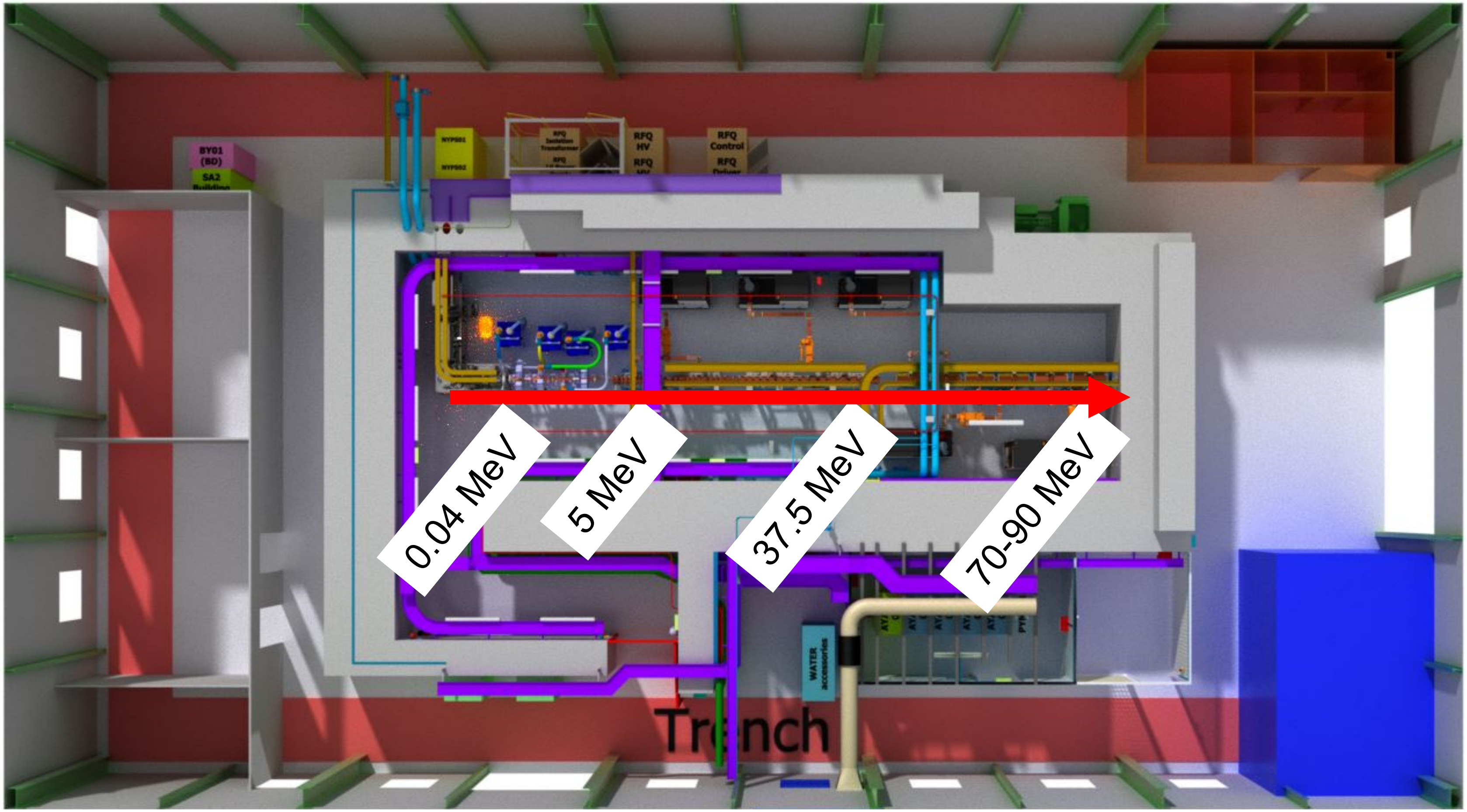
Beam Commissioning stages					
45 keV	3 MeV	12 MeV	50 MeV	105 MeV	160 MeV
Not yet the final source	Octobre2013	August 2014	November 2015	June 2016	Octobre 2016 (foreseen)

3.3 Commissioning Breakdown (Step-by-step)

source	RFQ	SCDTL1	SCDTL 2-3		SCDTL4	CCL1-2	CCL3-6
40 keV	5 MeV	7.5 MeV	16 MeV	26.5 MeV	37.5 MeV	52 MeV	70-90 MeV


BY01
(BD)
SA2
RFQ
Isolation
Transformer
RFQ
HV
RFQ
Control
RFQ
WATER
accessories
Trench

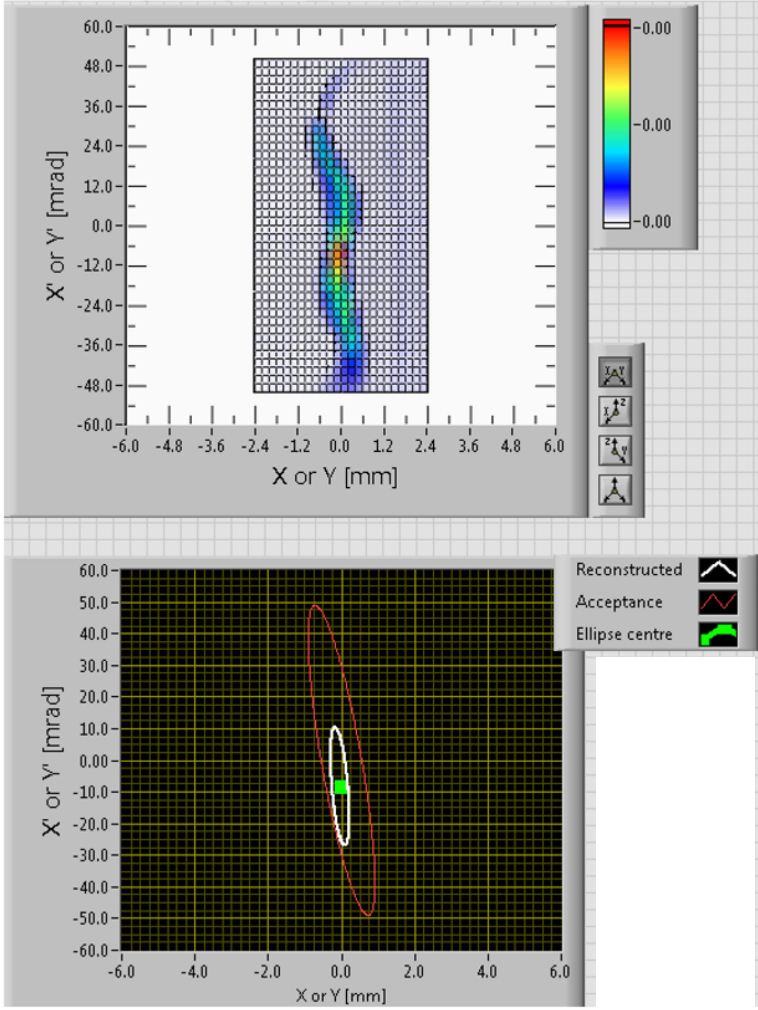
Commissioning of LIGHT @ CERN

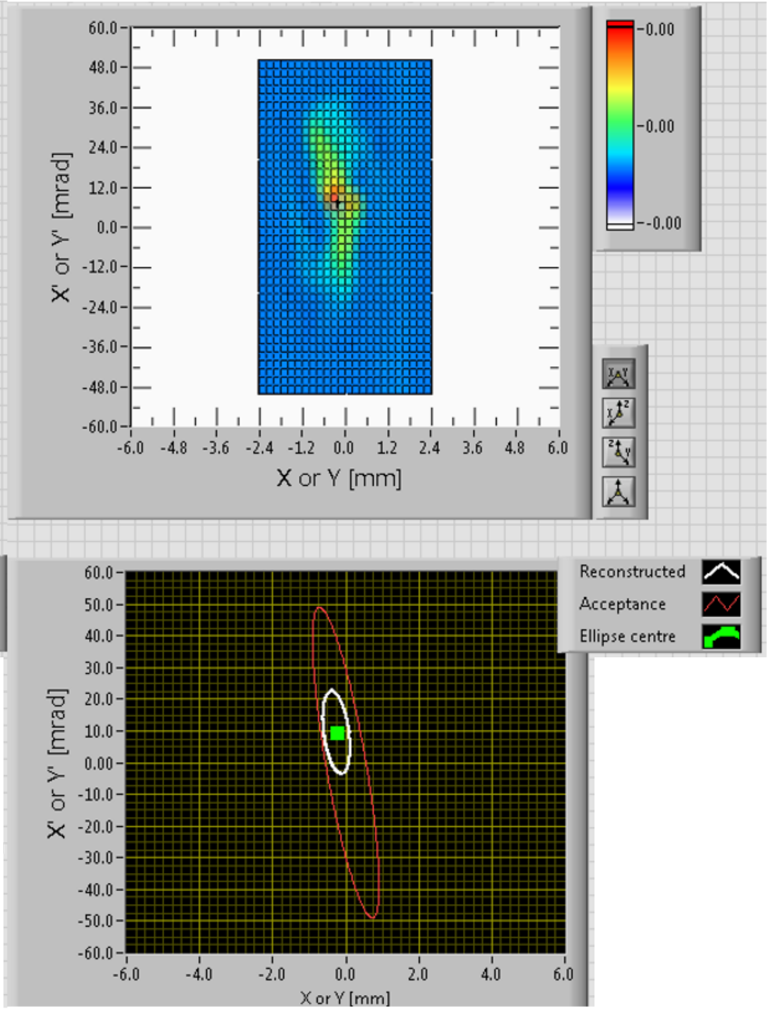


Commissioning of LIGHT @ CERN

a) horizontal

b) vertical





Conclusions

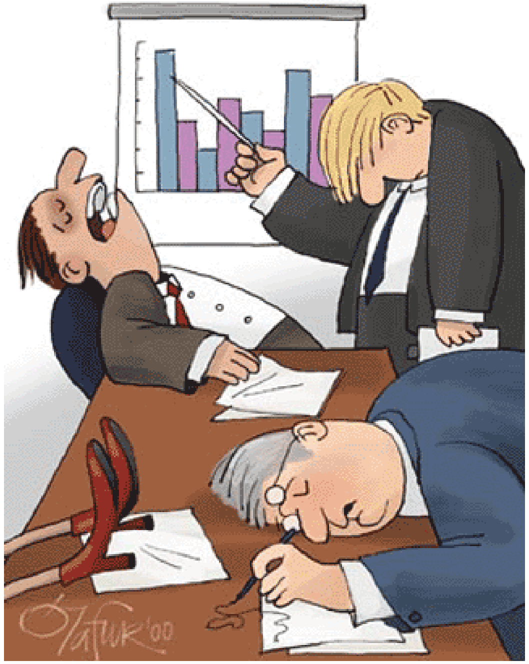
- **LIGHT** is the first commercial 3 GHz linac for proton-therapy
- The beam properties are well suited for **active spot scanning technique**
- **Technologies** developed and in use at CERN have inspired the present design
- **The highest frequency RFQ** in the world is used as injector – allowing for extremely small emittance
- LIGHT represents a good example of **technology and knowledge transfer** to industry and medical applications!

Acknowledgement

- We would like to acknowledge all CERN colleagues for their continuous and crucial support with this work.

  A special thanks go to CERN BE and KT divisions.

Acknowledgement



Acknowledgement

THANK YOU FOR YOUR ATTENTION !