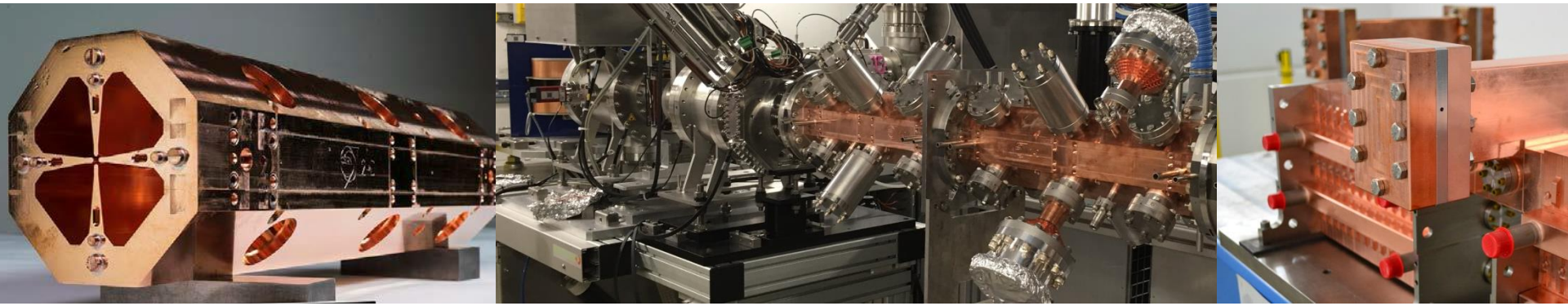
Alberto Degiovanni
06.06.2018

an ADVANCED ONCOTHERAPY company

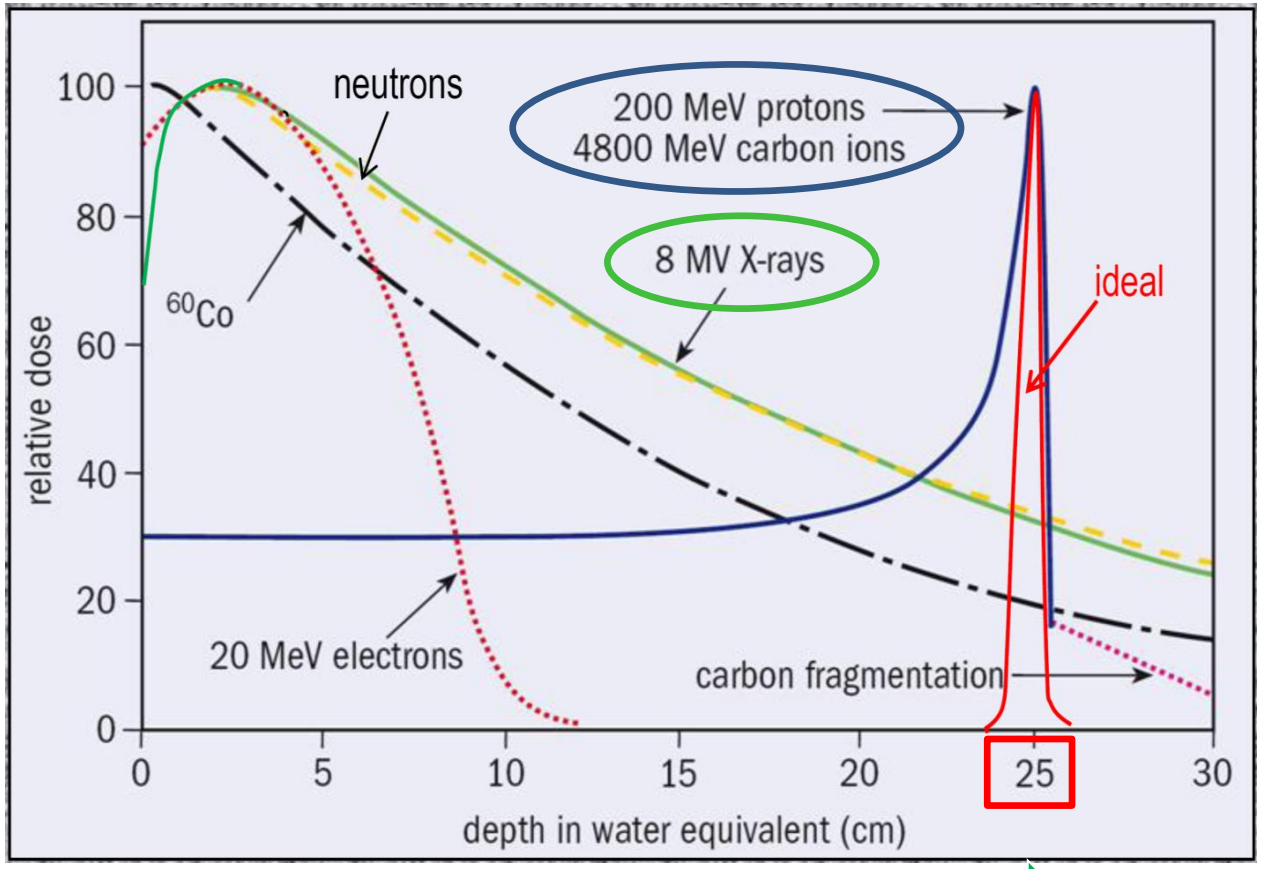
Update on the LIGHT prototype development



HG2018 Workshop - 04-08 June 2018 - Shanghai (China)

spin-off

Radiation therapy with charged hadrons

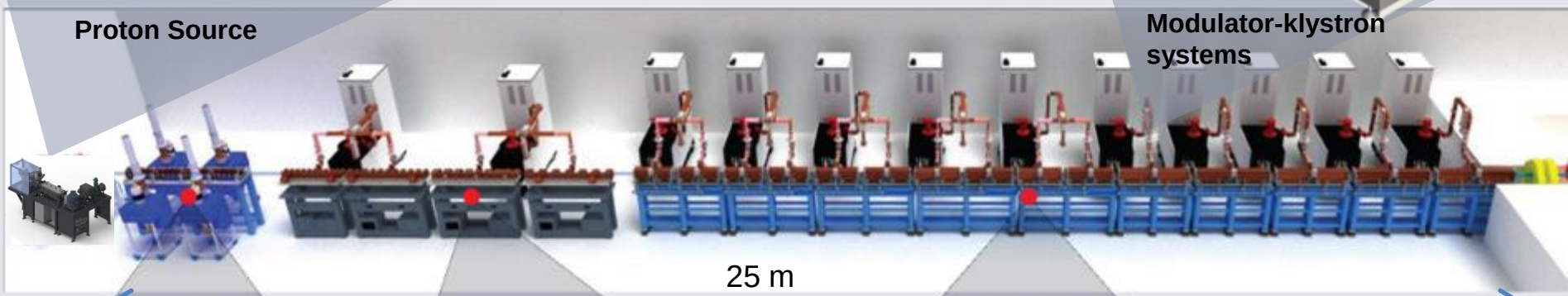


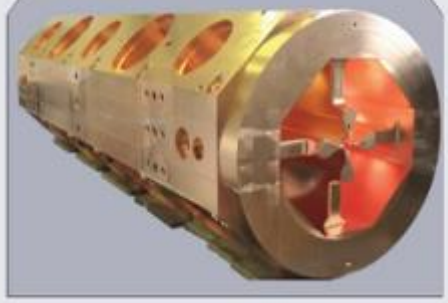
Radiation beam in matter

LIGHT = Linac for Image Guided Hadron Therapy

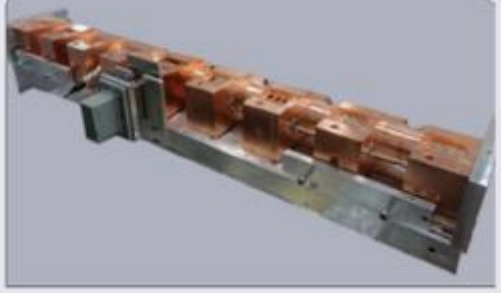
Proton Source

Modulator-klystron systems

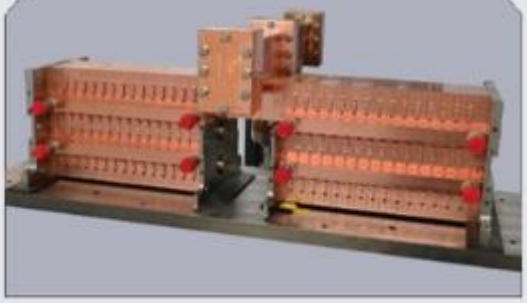




Radio Frequency Quadrupole (RFQ)



Side Coupled Drift Tube Linac (SCDTL)



Coupled Cavity Linac (CCL)

LIGHT = Linac for Image Guided Hadron Therapy

Features:

- **Active energy modulation.**

  → **No absorber and degrader.**

- **Pulsed beam at 200Hz.**

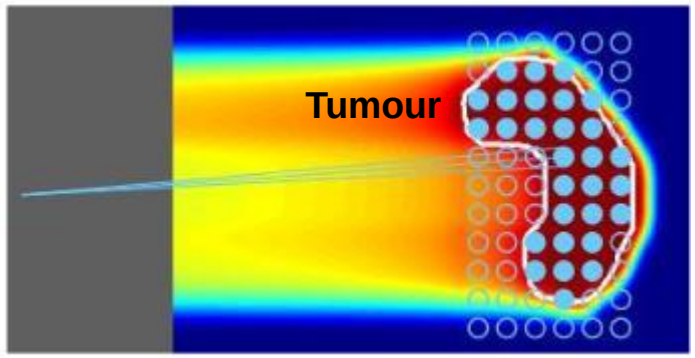
  → **Fast intensity and energy modulation.**

  → **Image guided hadron therapy.**

⇨ **Beam is suitable for 3D spot scanning.**

- **Pencil beam scanning or 'spot' scanning:**

Proton beam

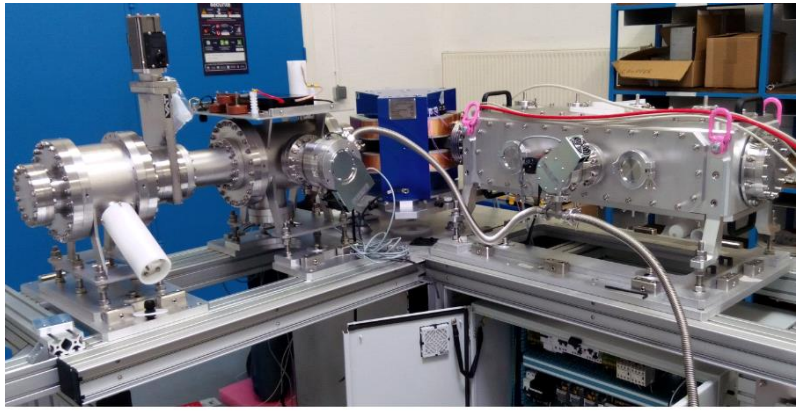


LIGHT DESIGN

LIGHT Main Parameters

Parameter	Value	Unit
Length	~25	m
Max. Energy	230	MeV
Output Peak Current (at the end)	0.3 - 90	μA
Pulse Length	5	μs
RF Frequency	2997.92	MHz
Max. Repetition Rate	200	Hz
Peak RF Power	~60	MW

Proton Source

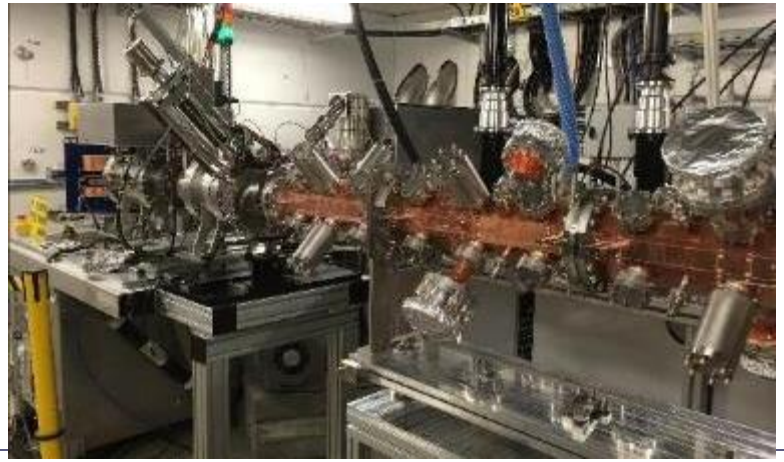


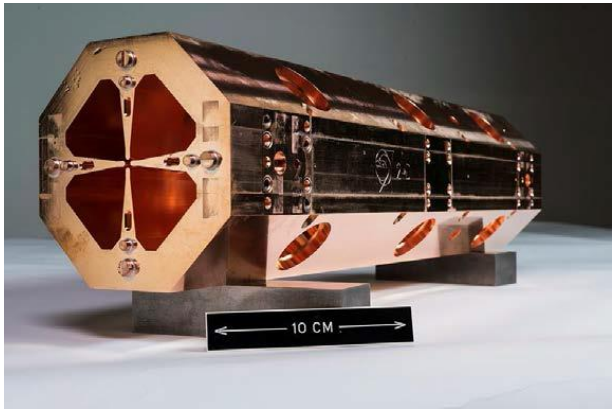
Quantity	Value	Unit
Output Energy	40 ± 0.4	keV
Output pulsed Current	Range: [1-300] ± 2%	µA
Current ripple during flattop	± 1	%
Pulse to pulse current reproducibility	± 2-3	%
Repetition rate	Range: [5-200]	Hz
Beam pulse width	Range: [0.5-5]	µs

The Radio Frequency Quadrupole (RFQ)

- **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

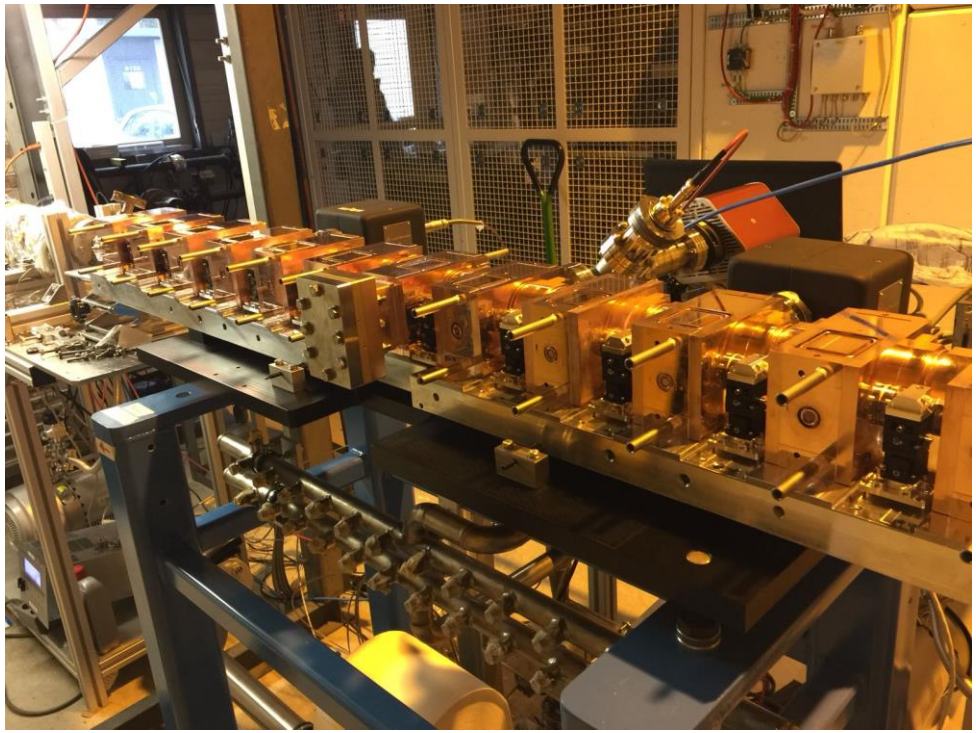




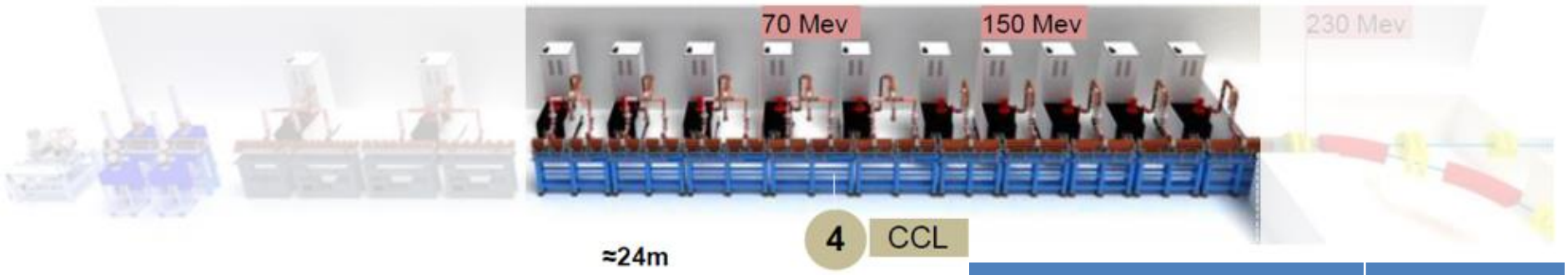
The Side Coupled Drift Tube Linac (SCDTL)

- **Designed in collaboration with ENEA (Frascati, I)**
- **Manufactured at TSC**

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



The Coupled Cavity Linac (CCL)

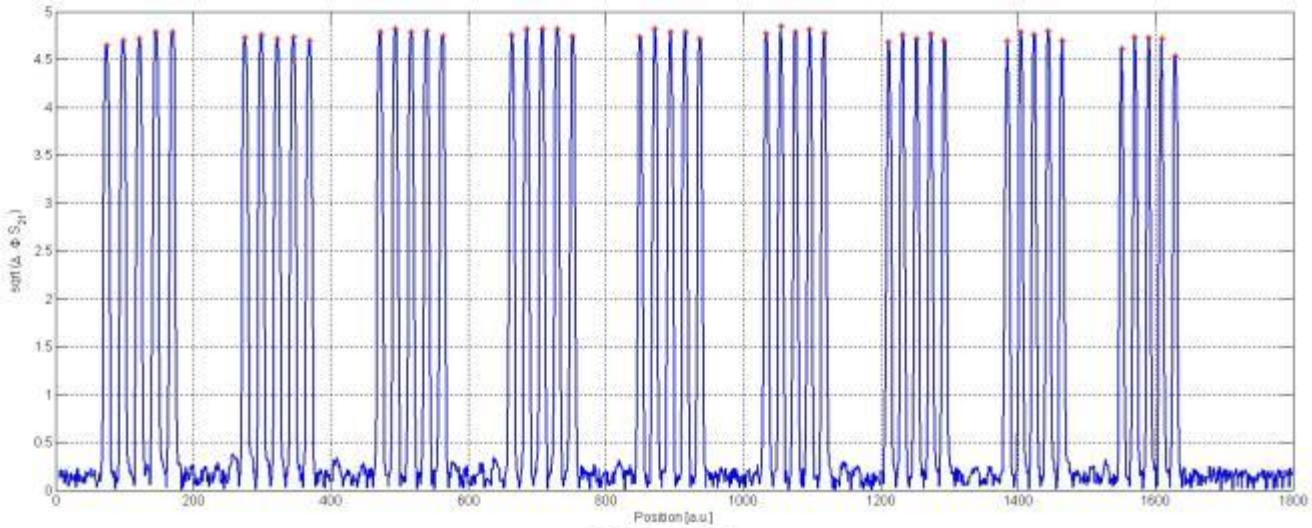


- **Designed by ADAM**
- **Manufactured by VDL**
- **4 modules already conditioned**

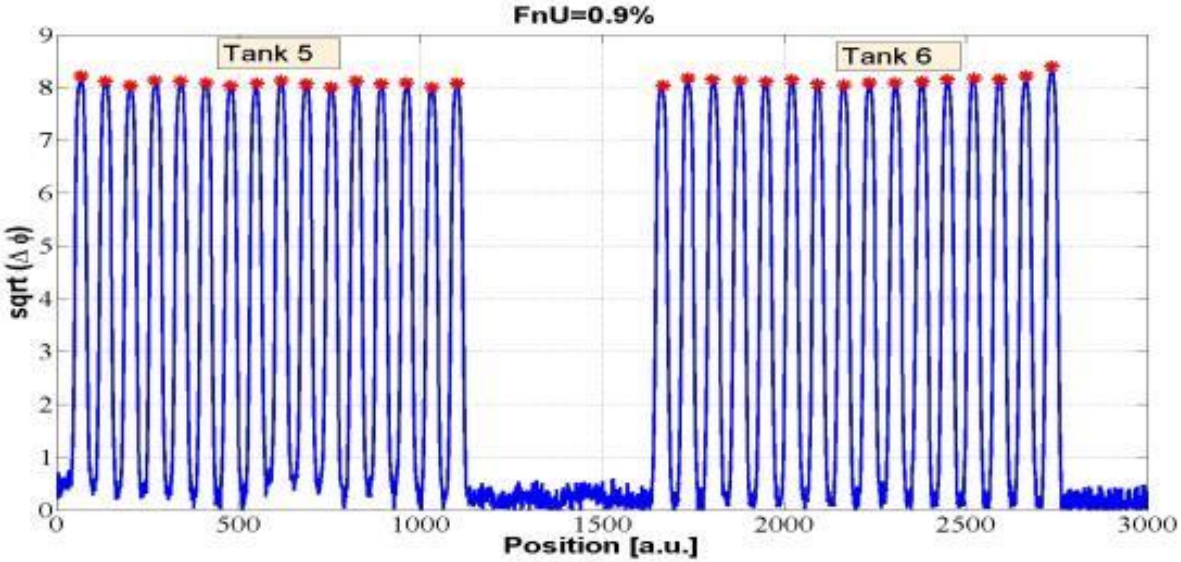
Section	CCL
RF frequency [GHz]	2.998
Energy [MeV]	37.5-230
Length [m]	15.5

SCDTL and CCL E-field measurements

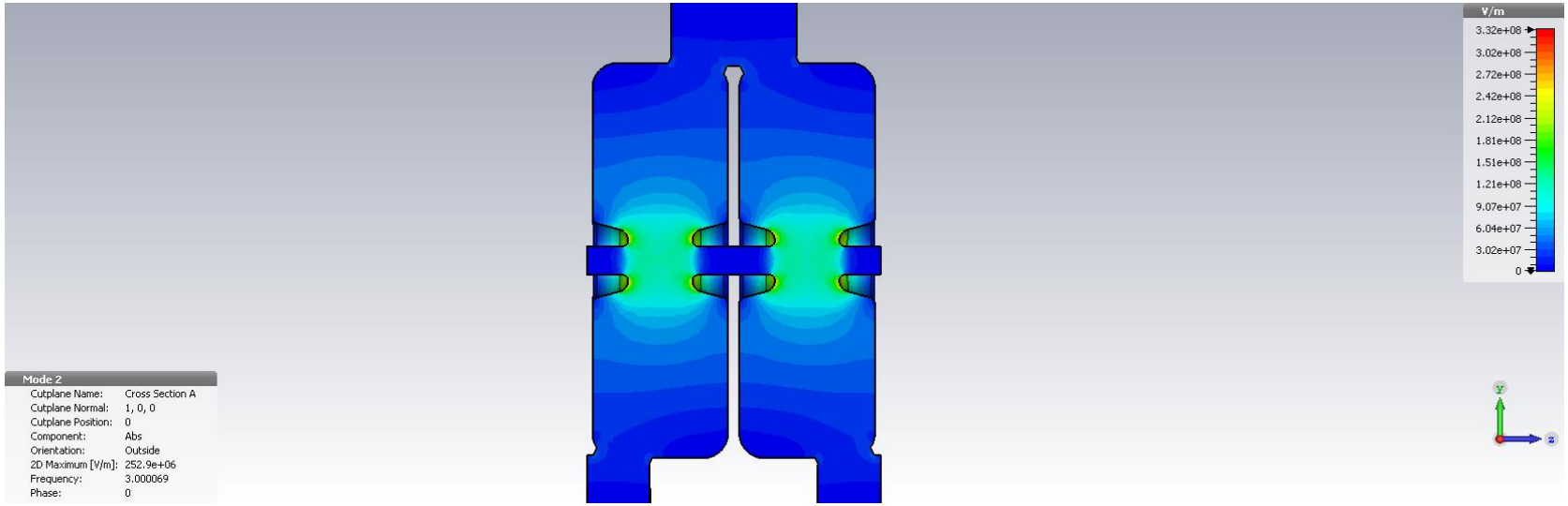
- **SCDTL**

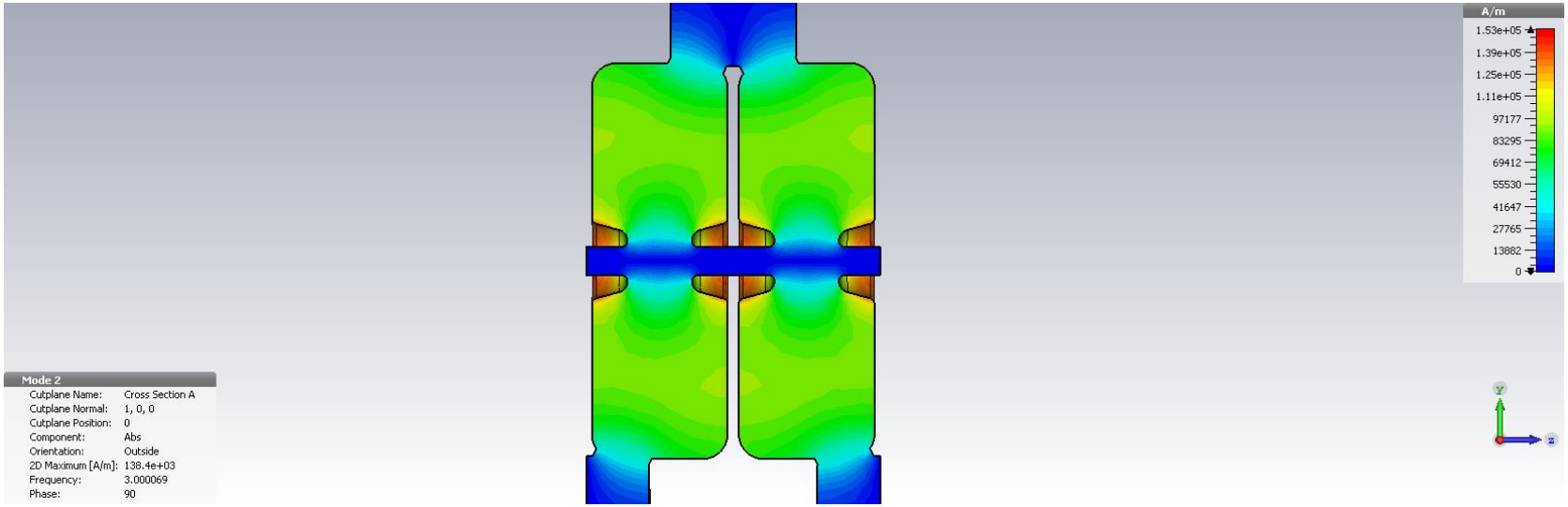


- **CCL**



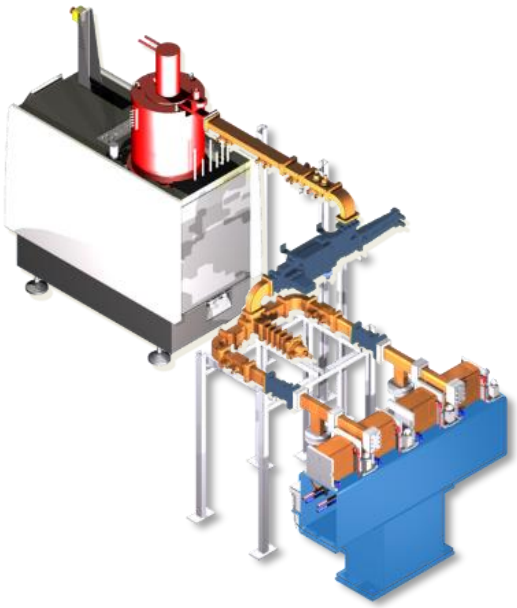
Fields in the CCL accelerating cells





Conservative/safety aspect in LIGHT 1

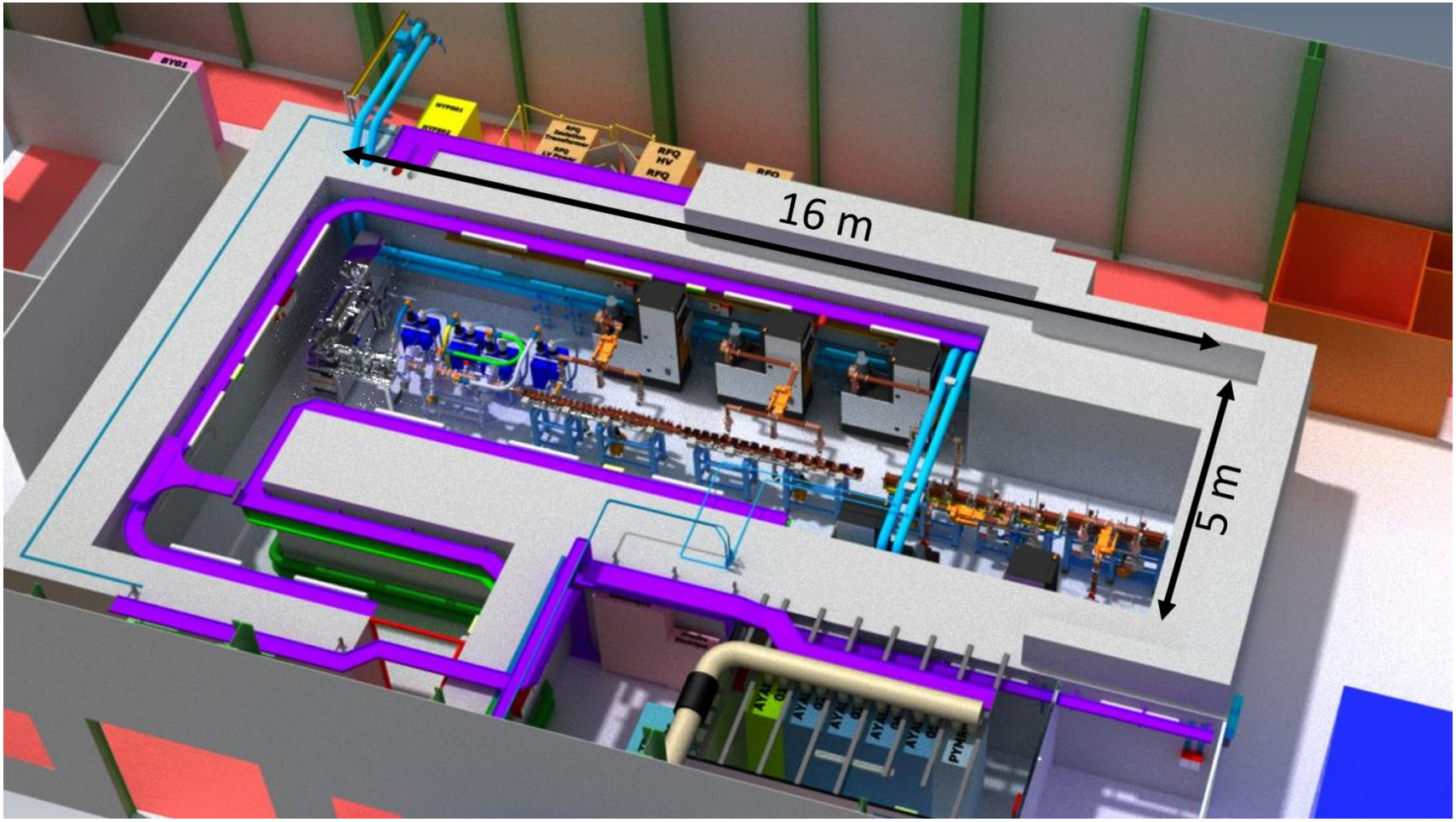
- **Power from klystron: 7.5 MW**
- **P_loss wg network: ~ 15%**
- **Power available per unit: ~ 6.4 MW**
- **Max power used: ~5 MW**
- **Power safety/operational margin: ~ 28%**
- **RF network includes Isolator for protection of the klystron from reflected power.**
- **Part of RF network under SF6 !**



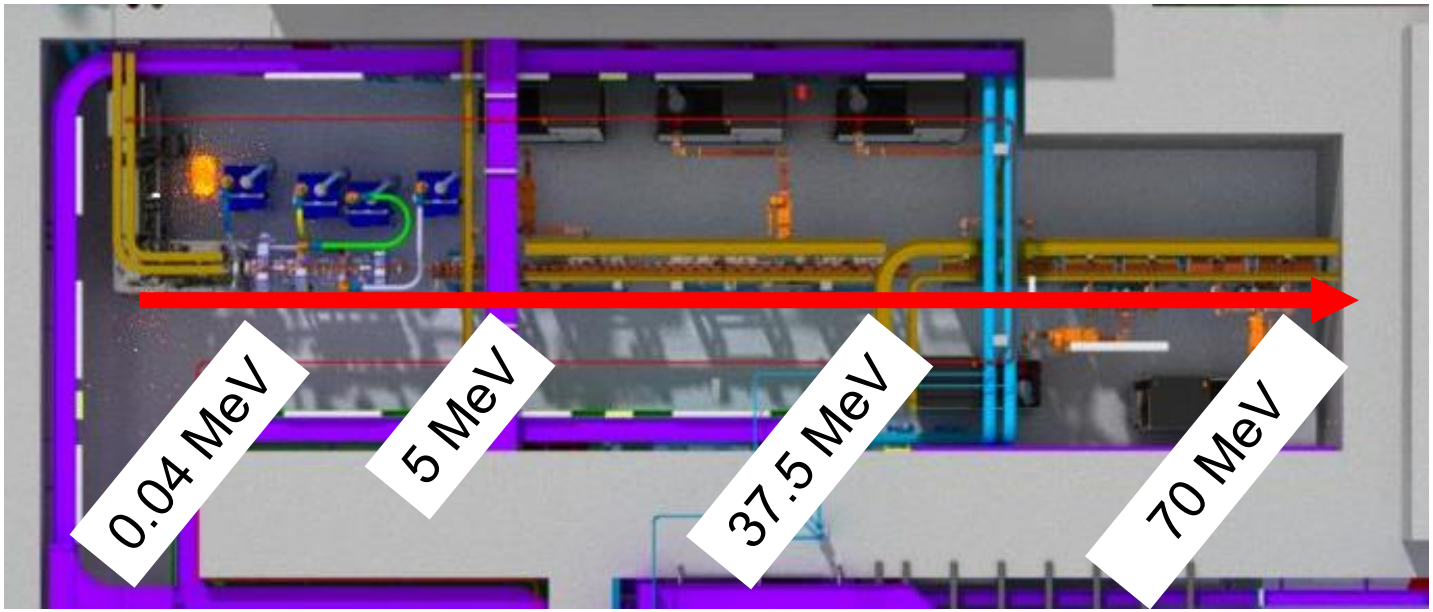
LIGHT: 70-230 MeV	
Peak power [Mw]	48
Total length [m]	12.3
Active length [m]	9.5
Fill factor	0.77
Number of kl.	8

LIGHT PROTOTYPE TEST RESULTS

LIGHT (Linac for Image Guided Hadron Therapy) @point 2



LIGHT (Linac for Image Guided Hadron Therapy) @point 2



SCDTL Module	Mod1	Mod2	Mod3	Mod4
Number of Tanks	11	13	9	7
Bore hole [mm]	4	4	4	5
Length [m]	1.12	1.70	1.52	1.60
Power [MW]	0.83	2.59	2.46	2.48
Energy [MeV]	7.5	16	26.5	37.5

CCL Module	Mod1	Mod2	Mod3	Mod4
Number of Tanks	2	2	2	2
Bore hole [mm]	5	5	5	5
Length [m]	0.80	0.83	0.76	0.81
Power [MW]	2.21	2.21	2.31	2.33
Energy [MeV]	44.9	52.9	61.3	70.2

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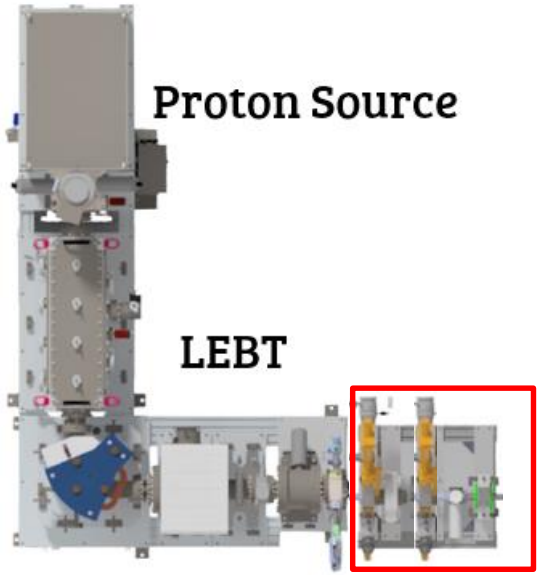
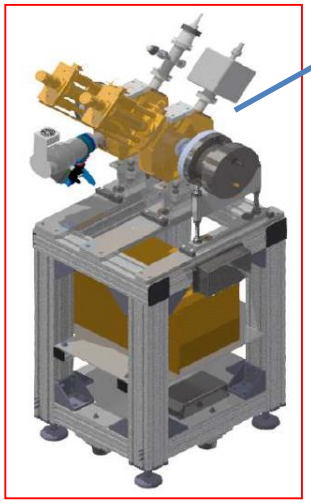
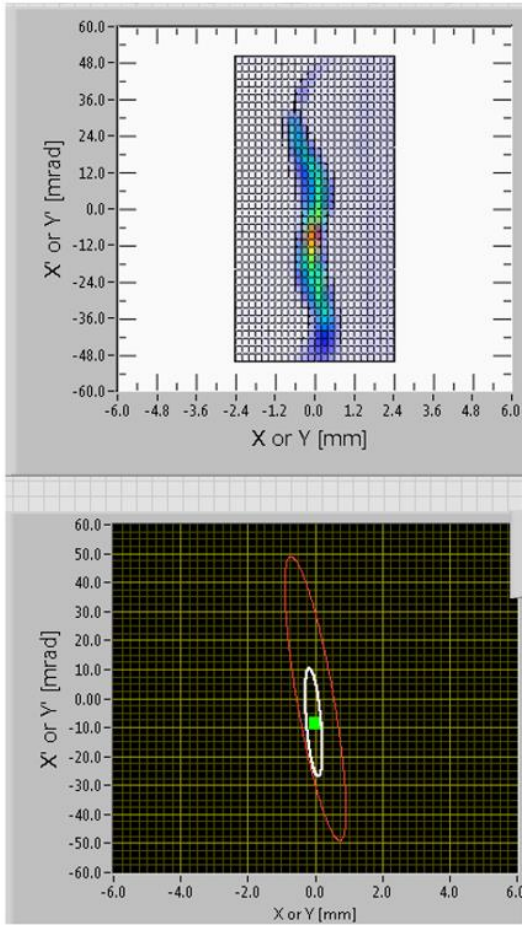
Proton source test results



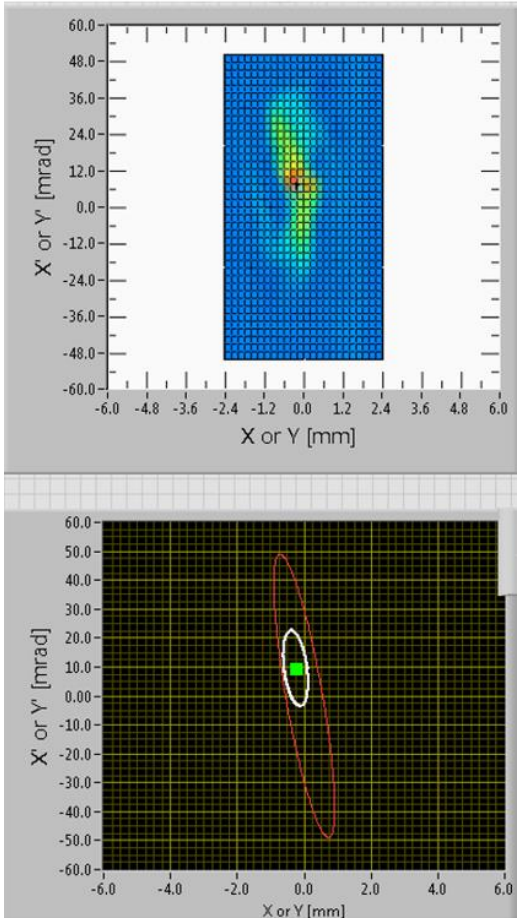


Emittance measurements and rms emittances (white) with the representation of the RFQ acceptance ellipse (red).

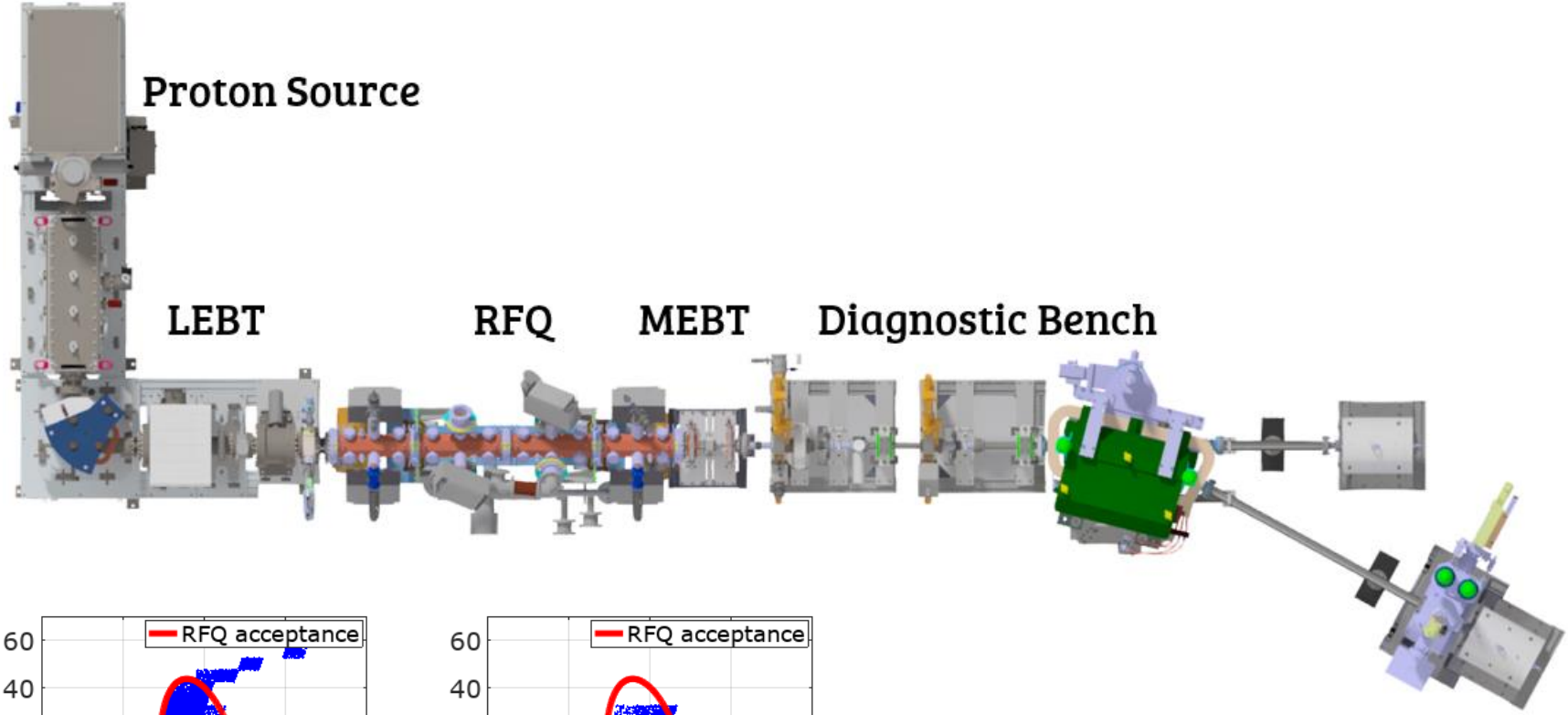
a) horizontal

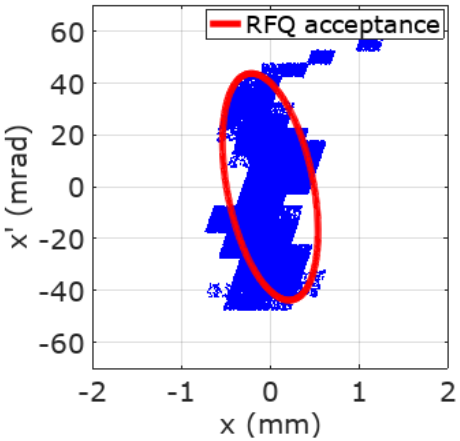


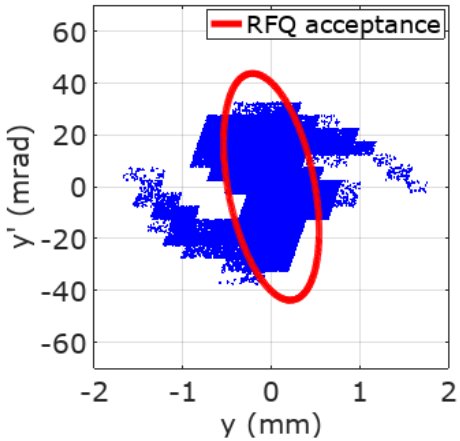
b) vertical



Results from RFQ commissioning







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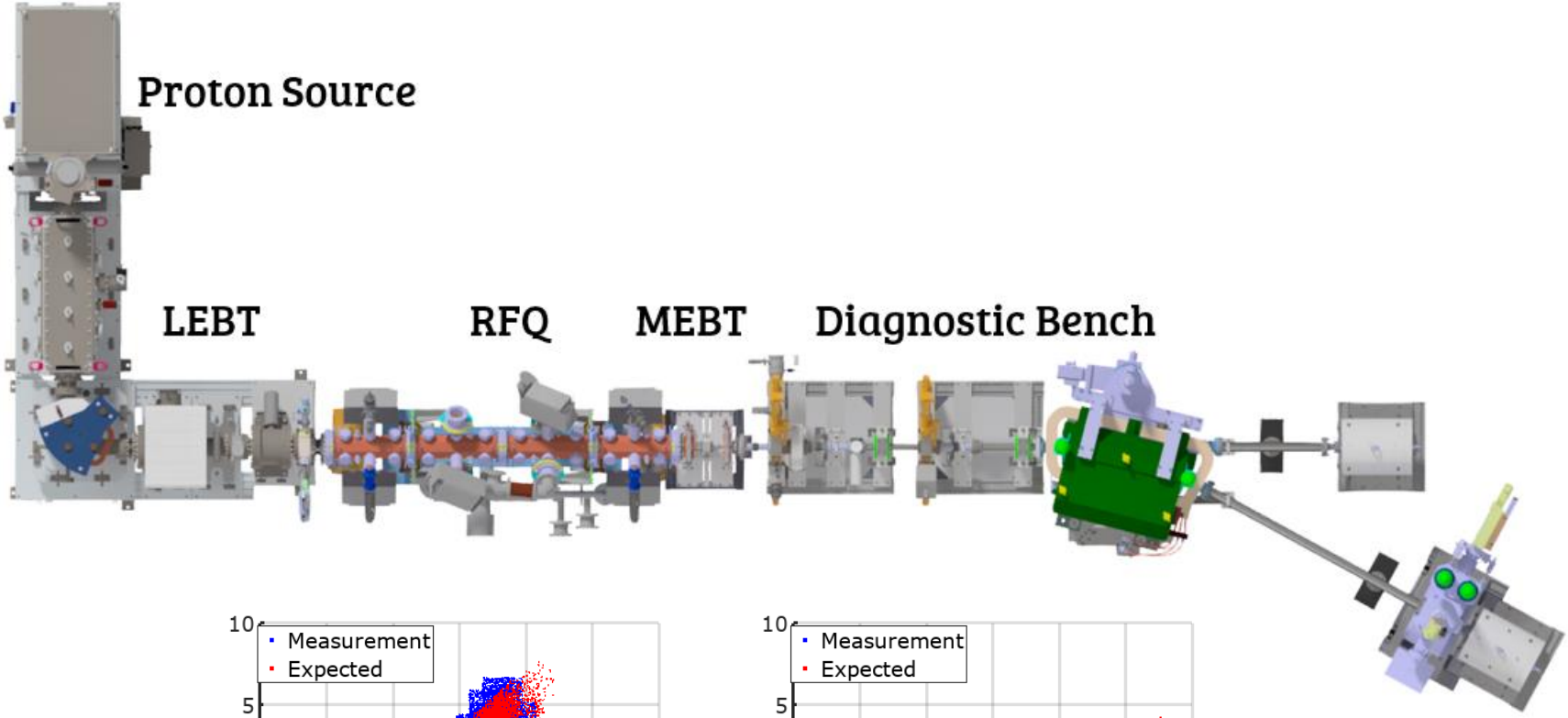
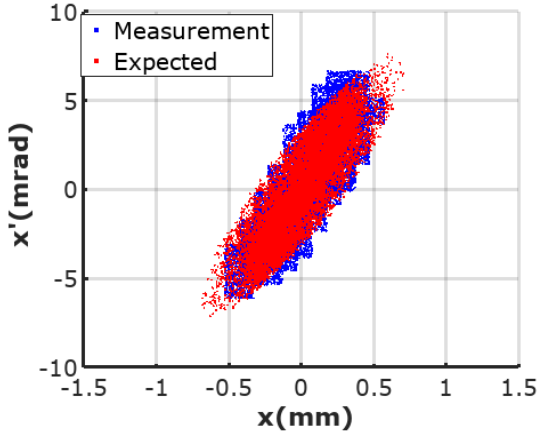
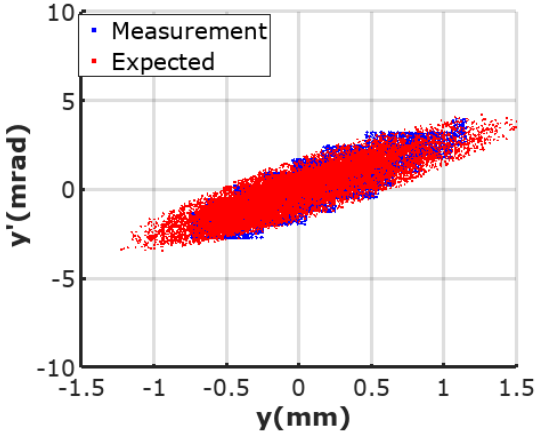
Results from RFQ commissioning







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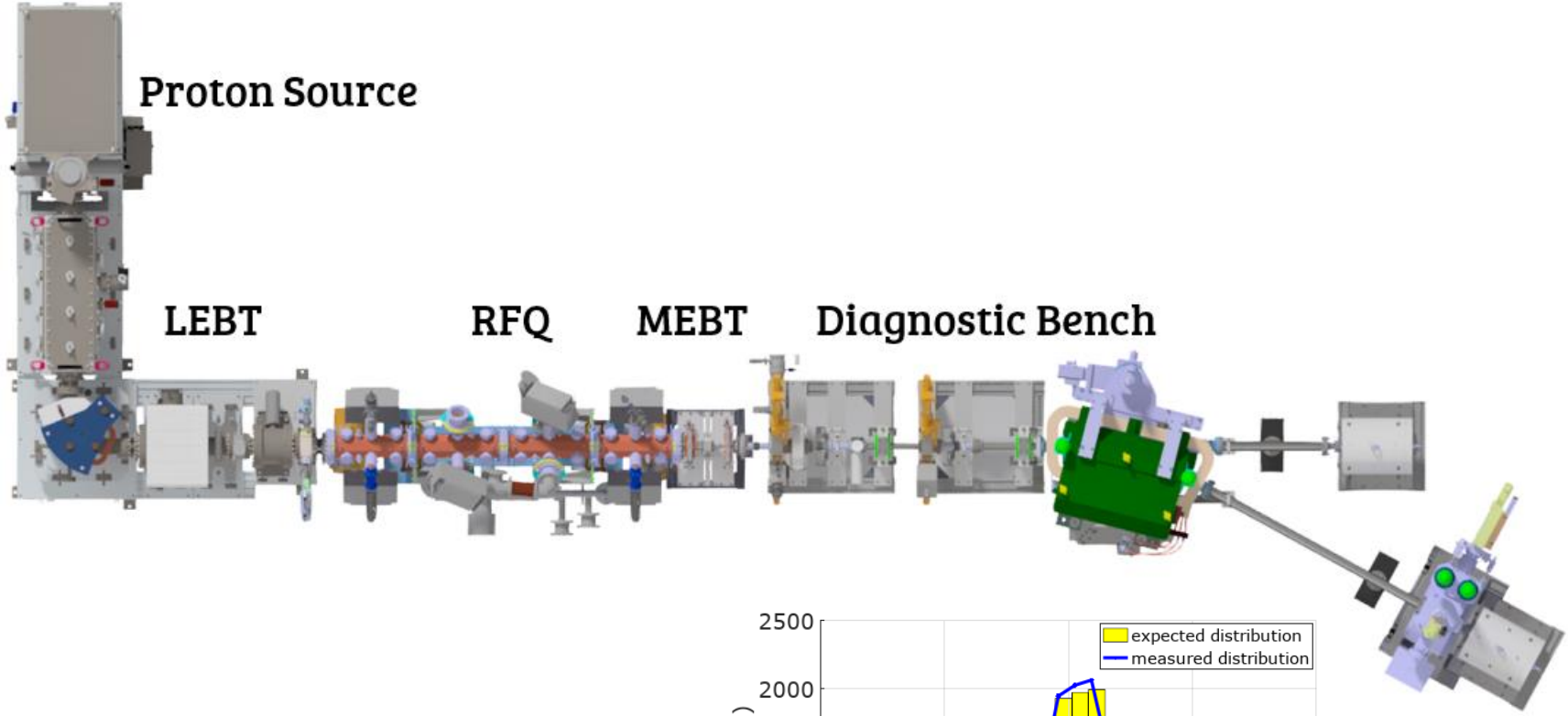
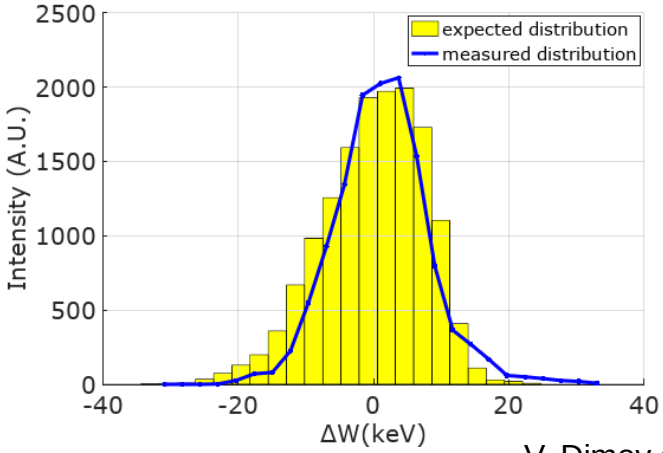
Results from RFQ commissioning





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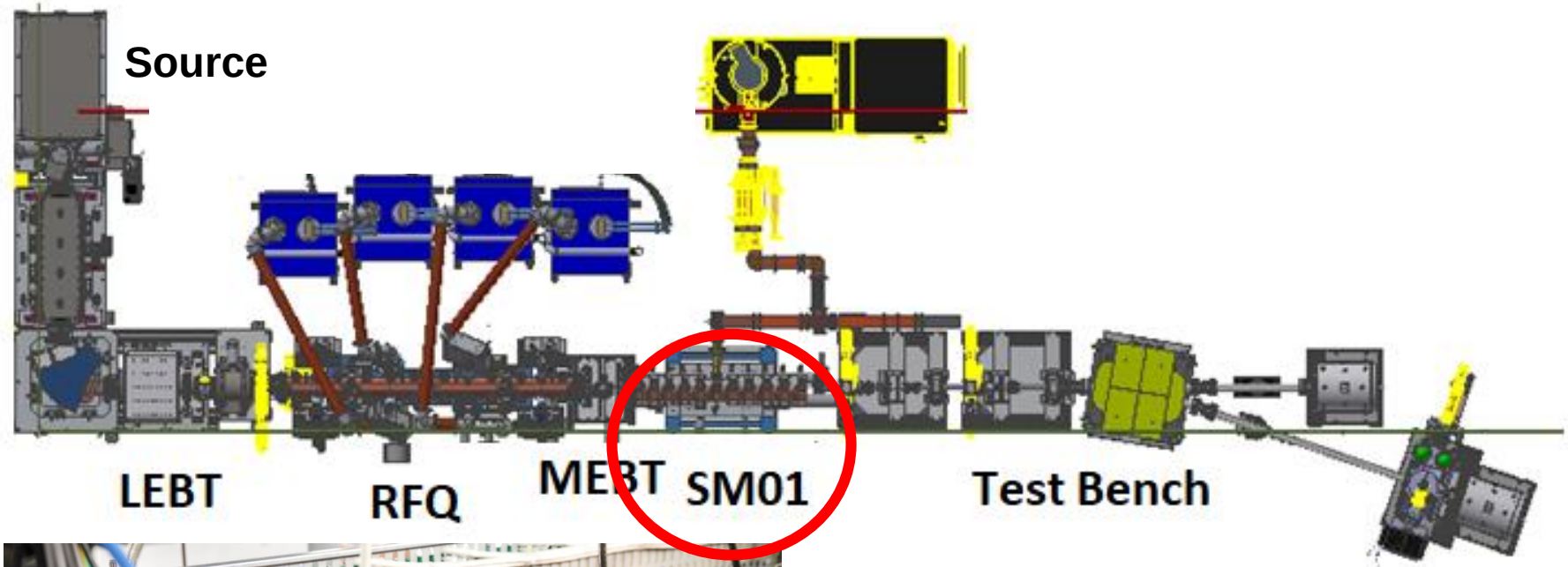
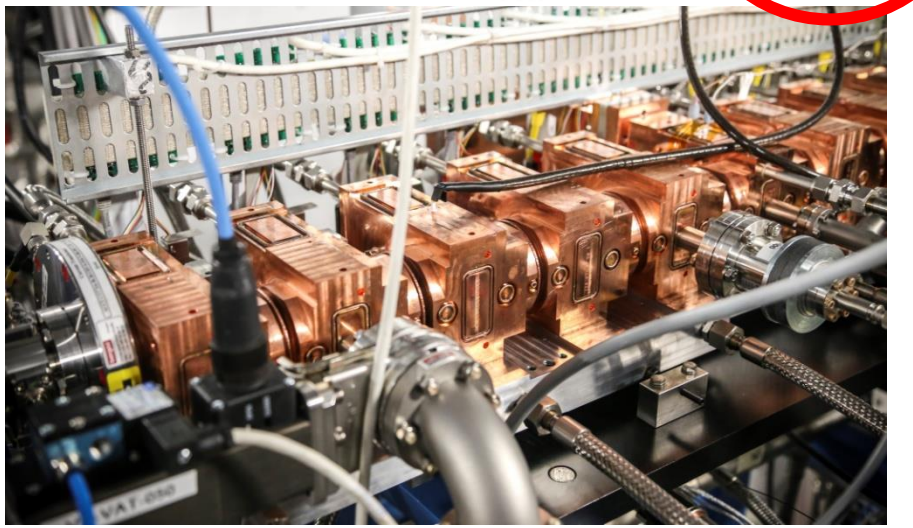
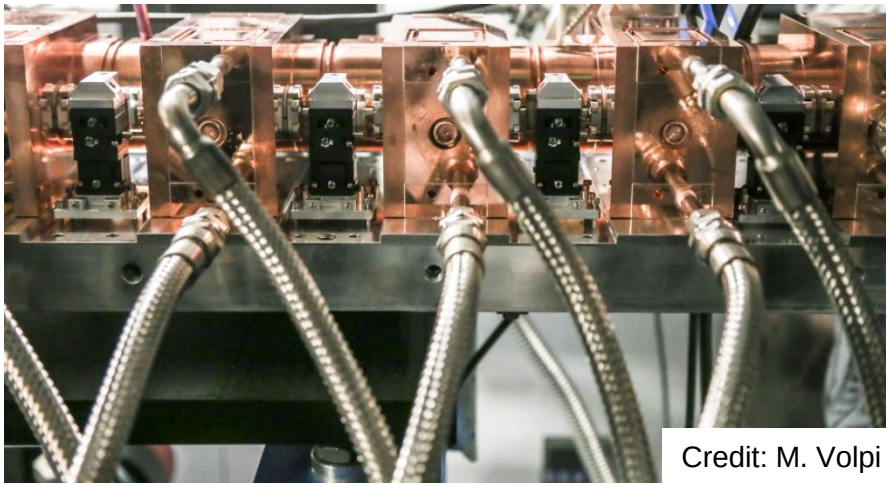
Commissioning: Jan-Apr 2018

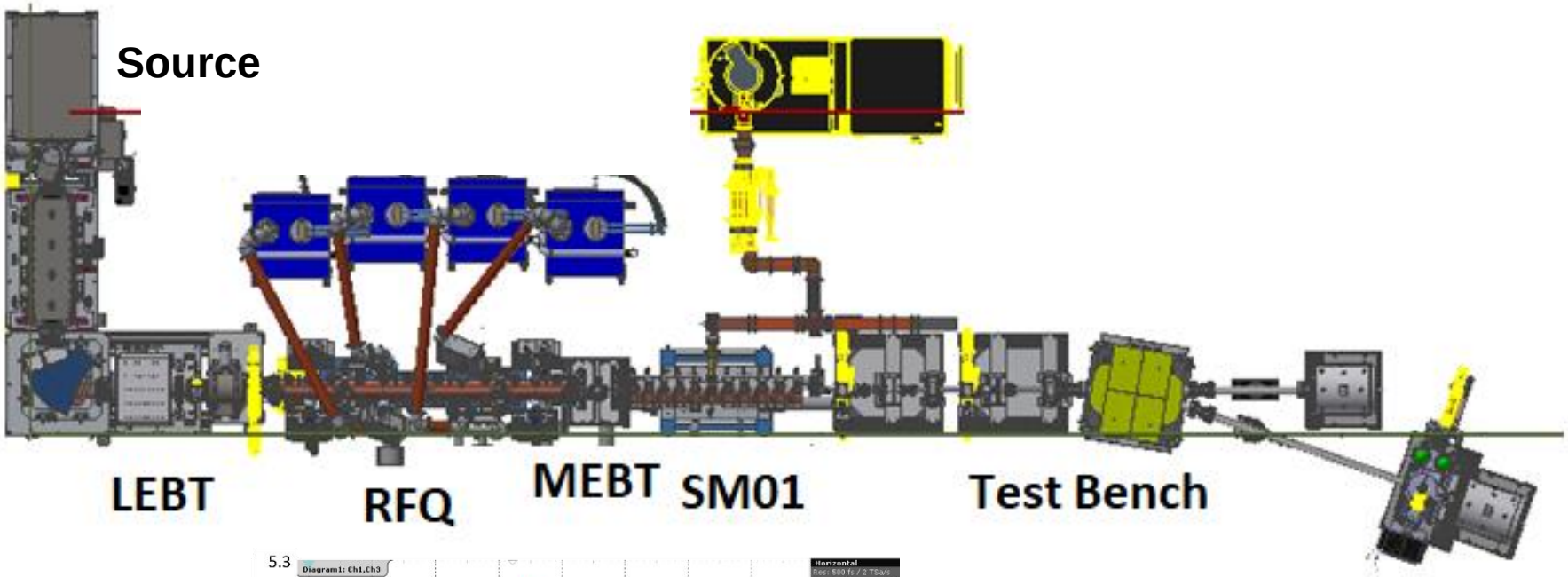


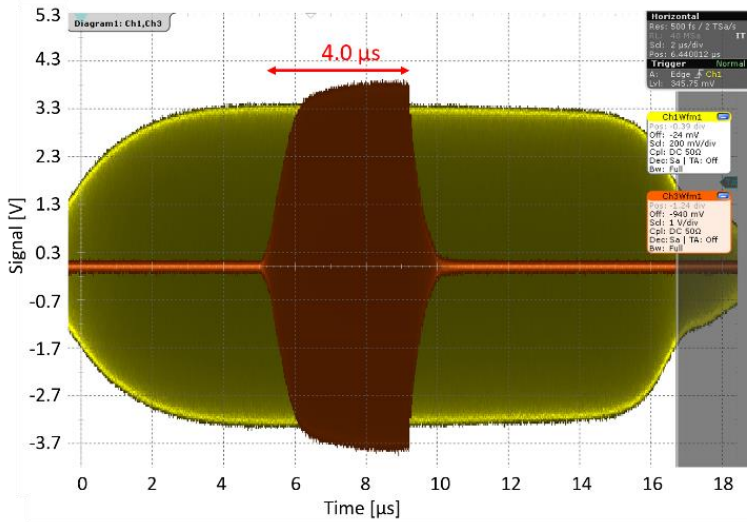




Credit: M. Volpi

Commissioning: Jan-Apr 2018





Example of RF pulse envelopes measured from RF pickups installed on RFQ (yellow) and SCDTL (red).

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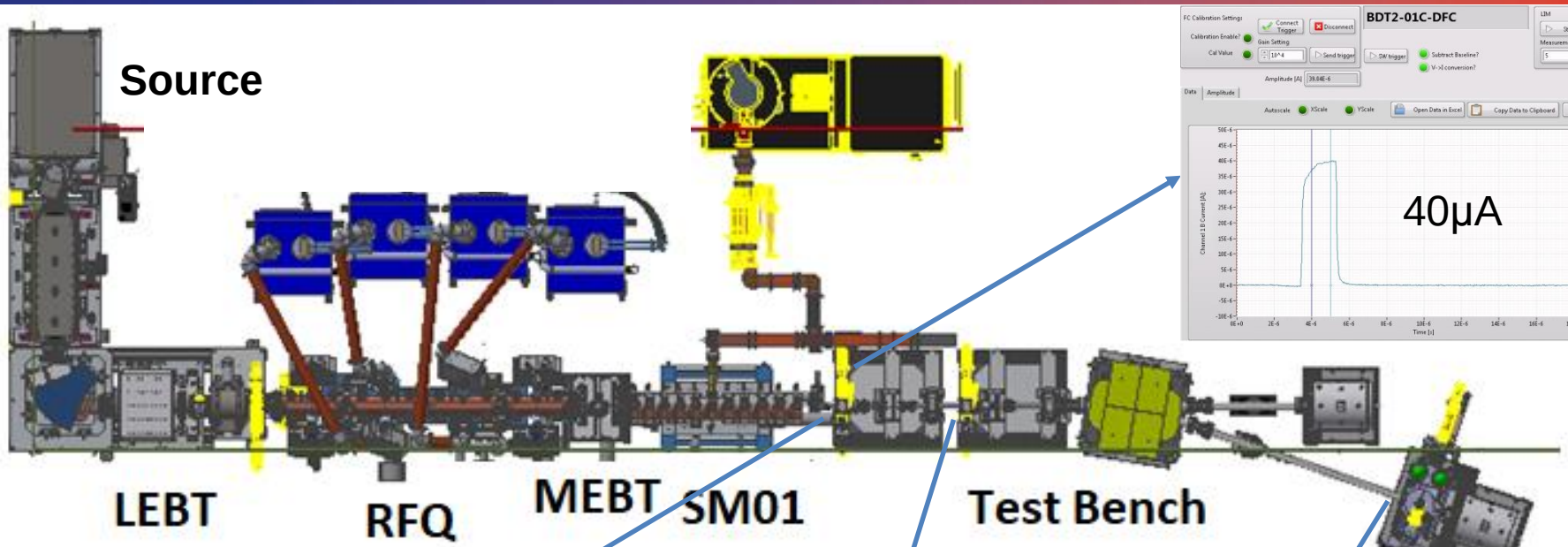

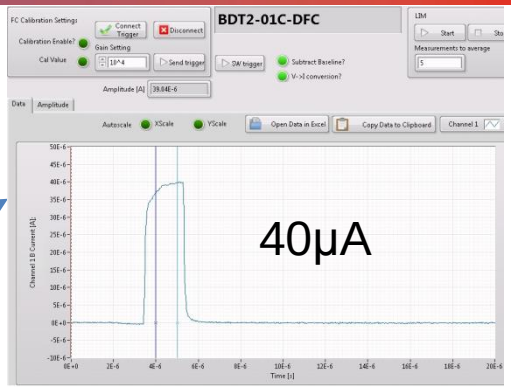

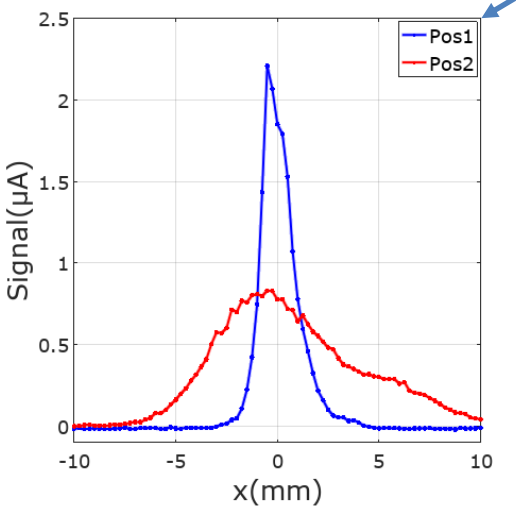

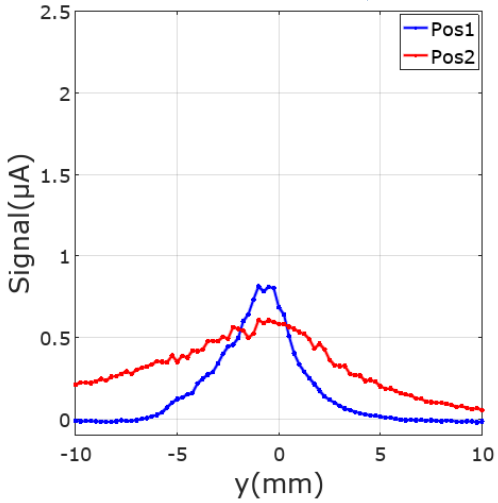

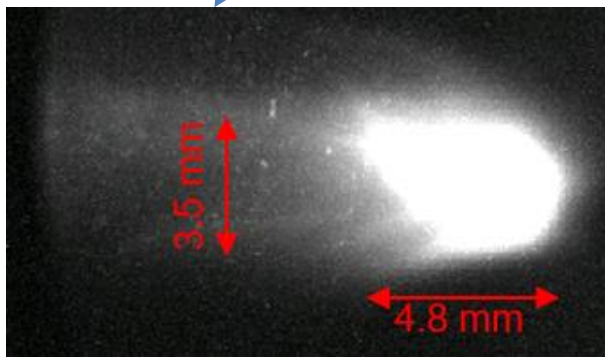

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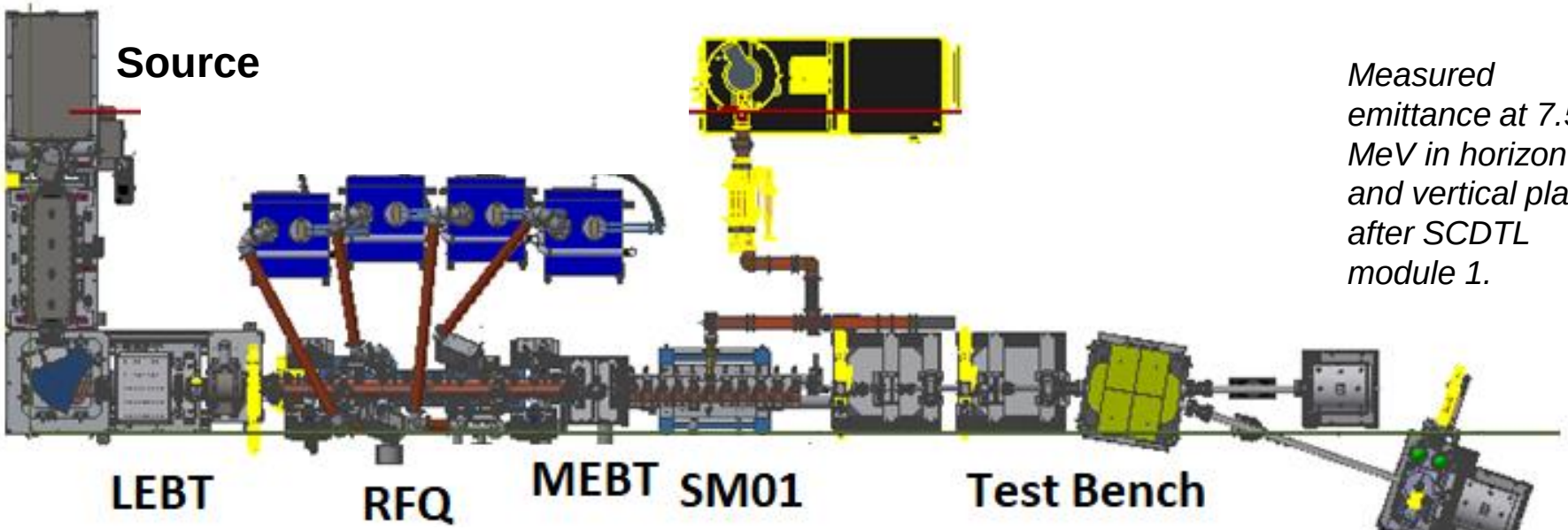
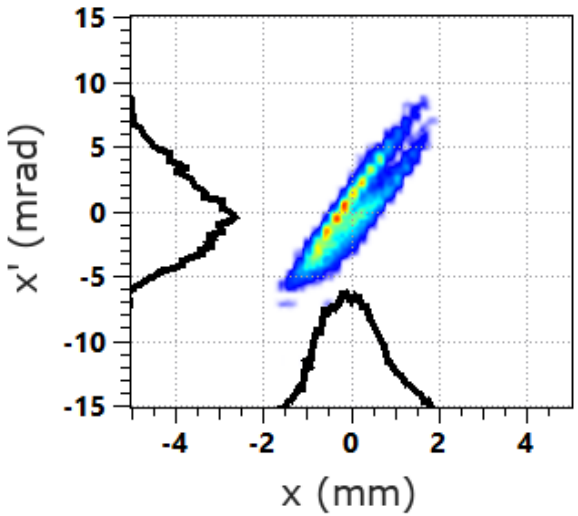
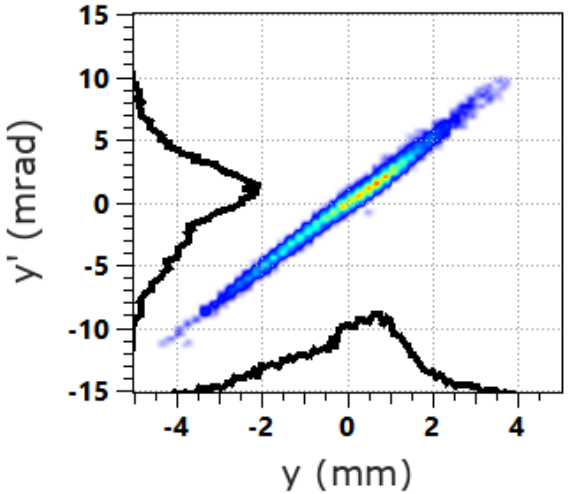


Measured emittance at 7.5 MeV in horizontal and vertical plane after SCDTL module 1.





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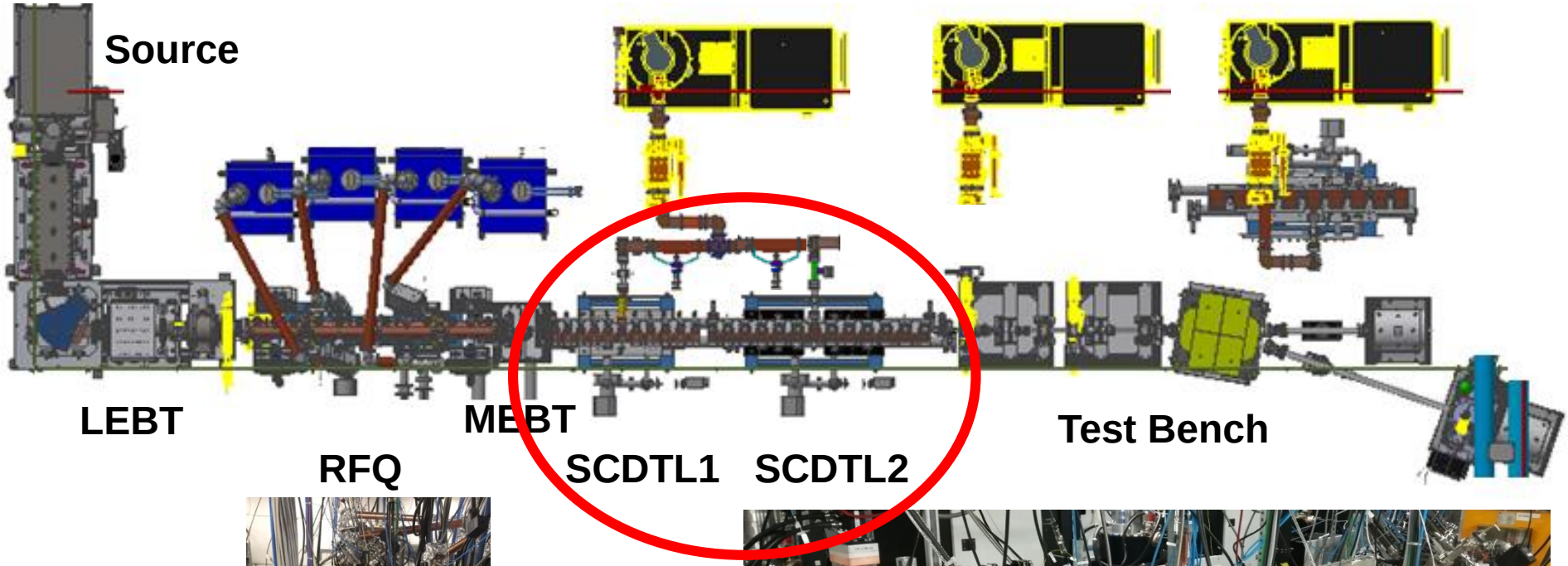
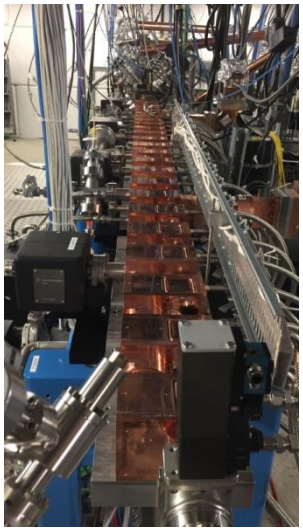
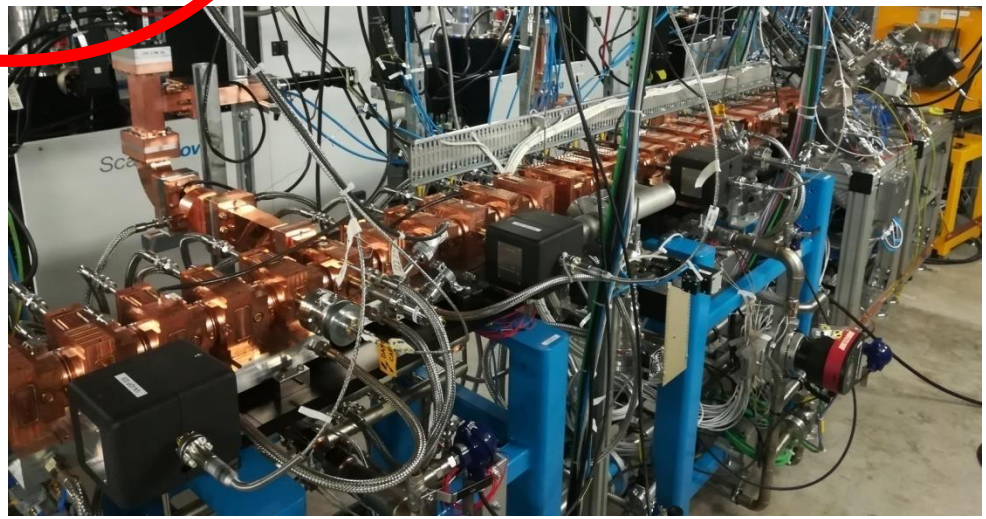
Commissioning: May-June 2018







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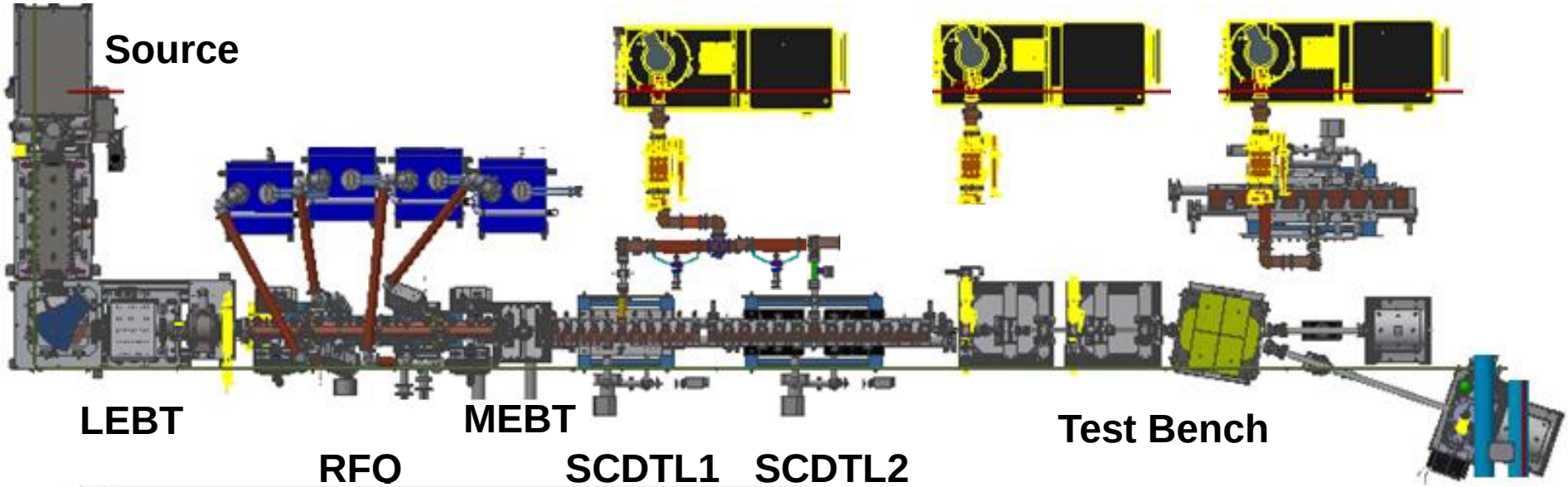
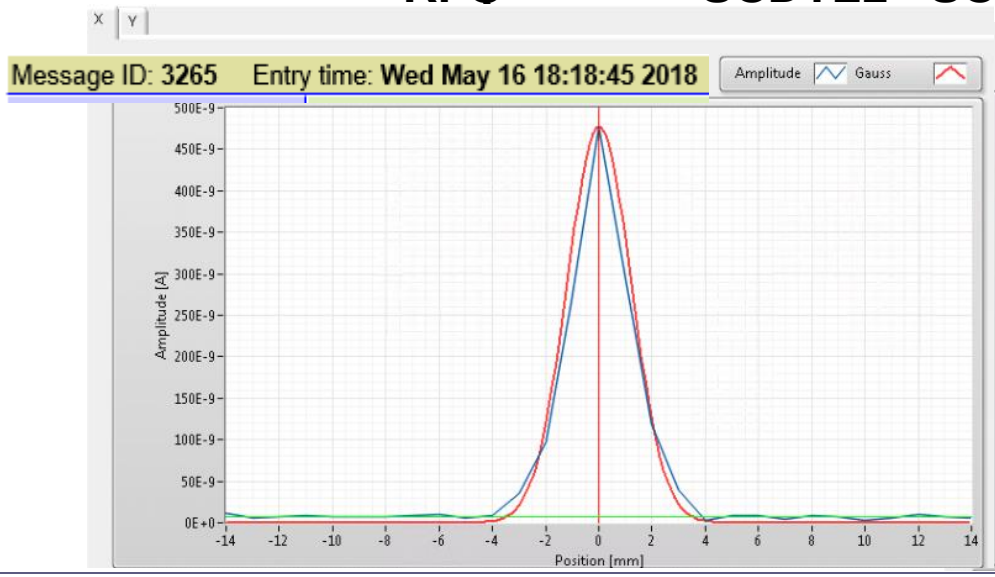
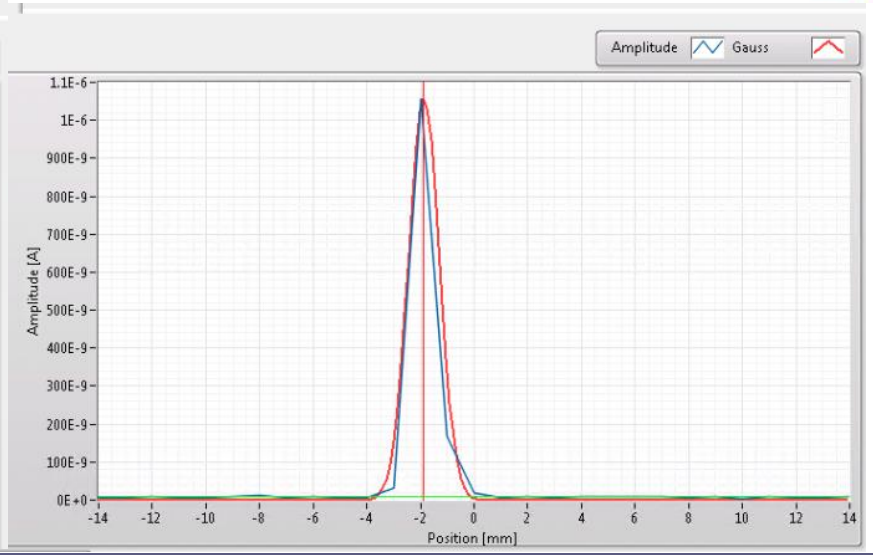
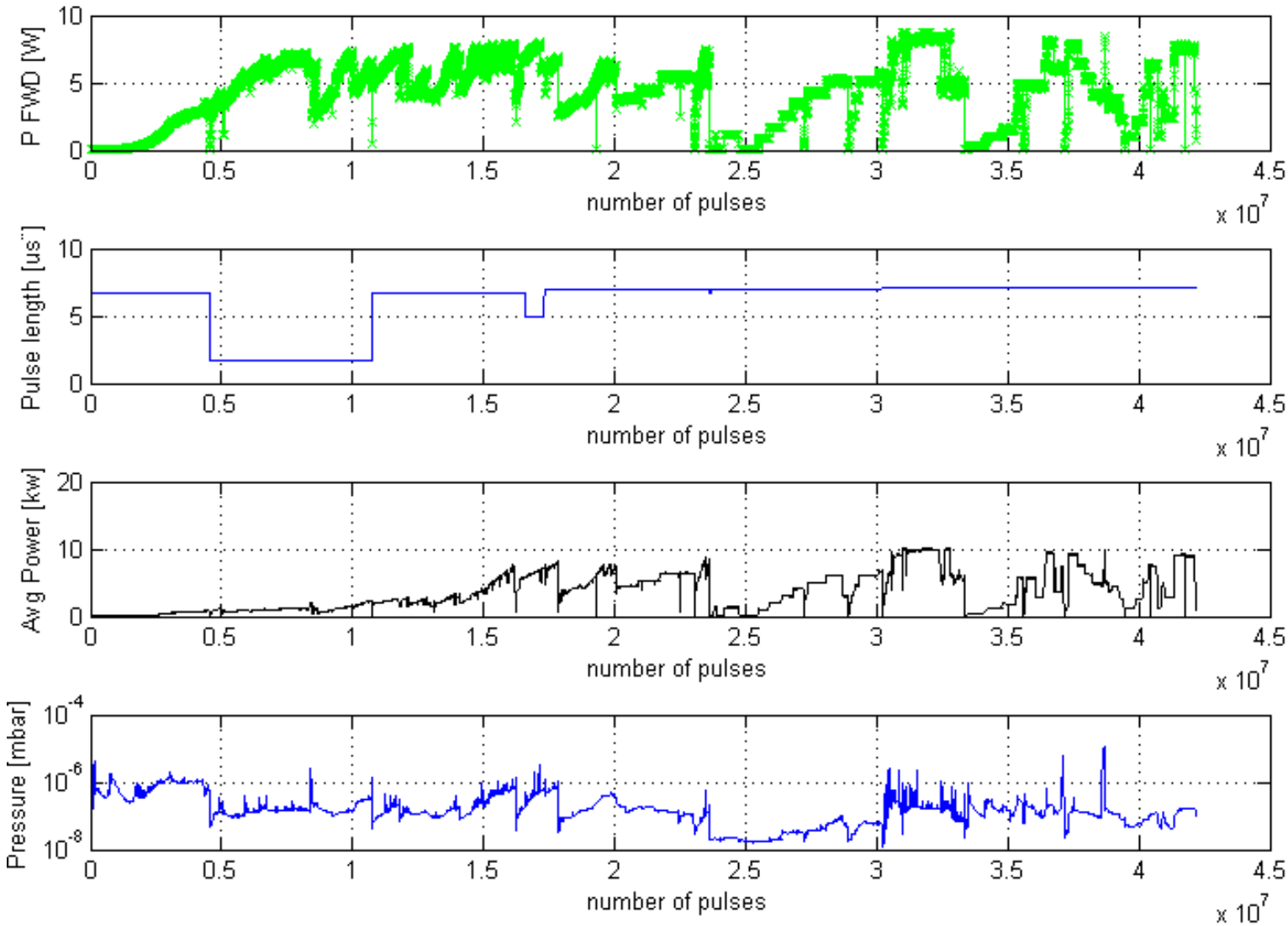


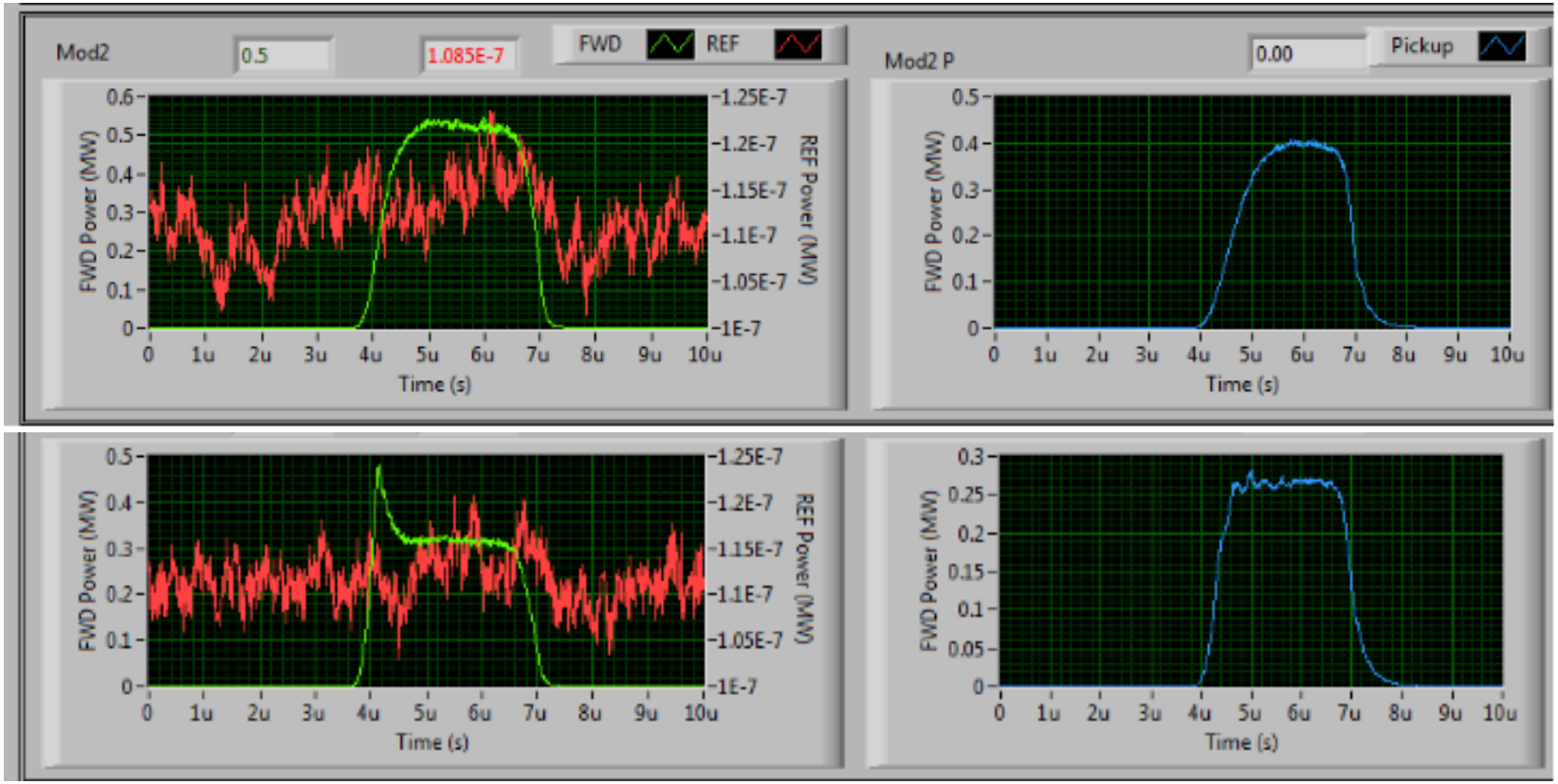




Experience with conditioning and operation



Some RF gymnastics – reducing the filling time



CONCLUSION

Conclusion

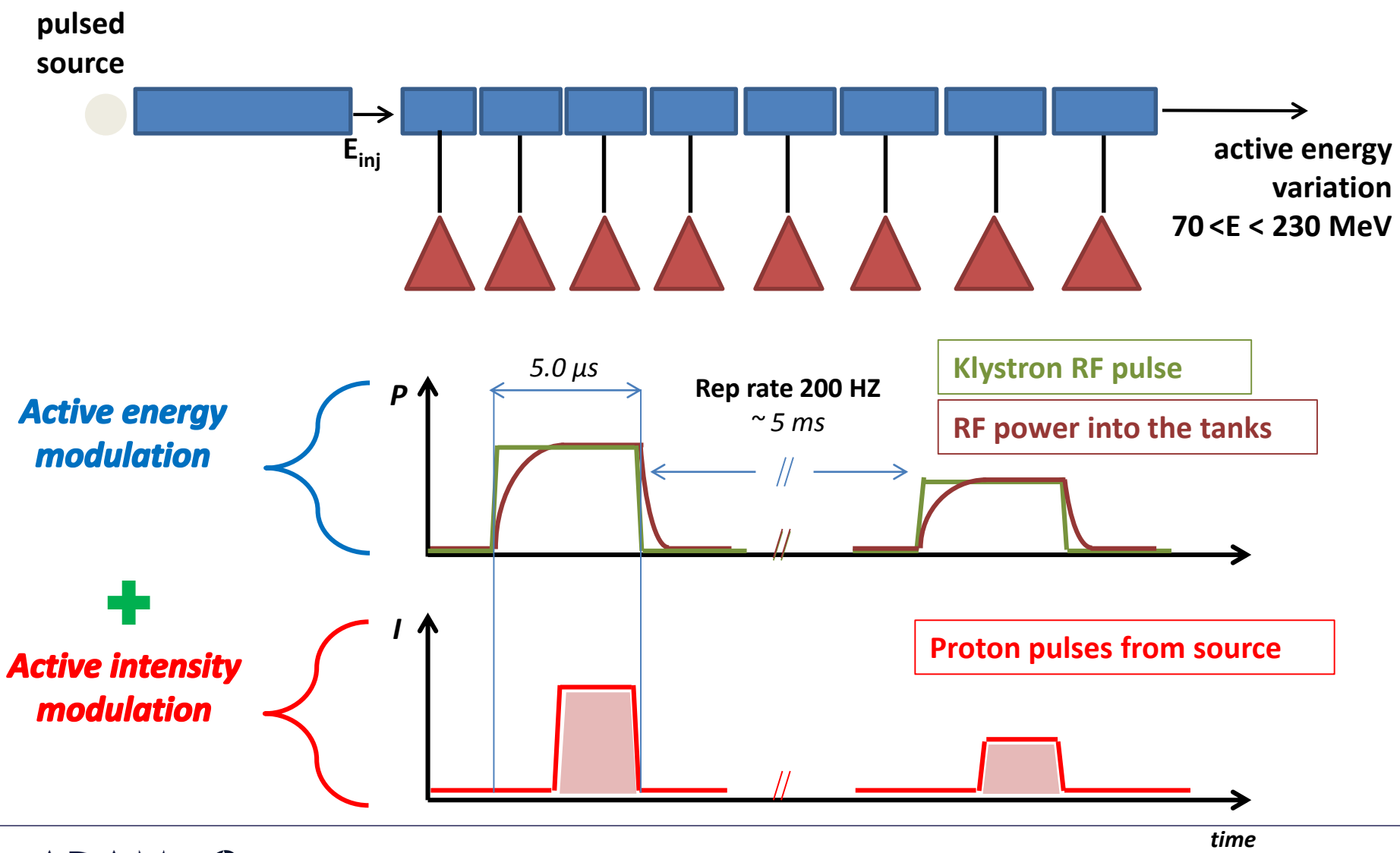
- **First prototype of LIGHT is under construction and test with beam at CERN P2.**
- **Beam commissioning has advanced during this year, with energies now up to 16 MeV.**
- **Beam characterization is perfomed in stages, with measurements of beam current, beam profiles, energy, energy spread and transverse emittance.**
- **The ongoing activity is crucial for gaining experience in machine operation and beam tuning.**

感谢您的关注！

THANK YOU FOR YOUR ATTENTION

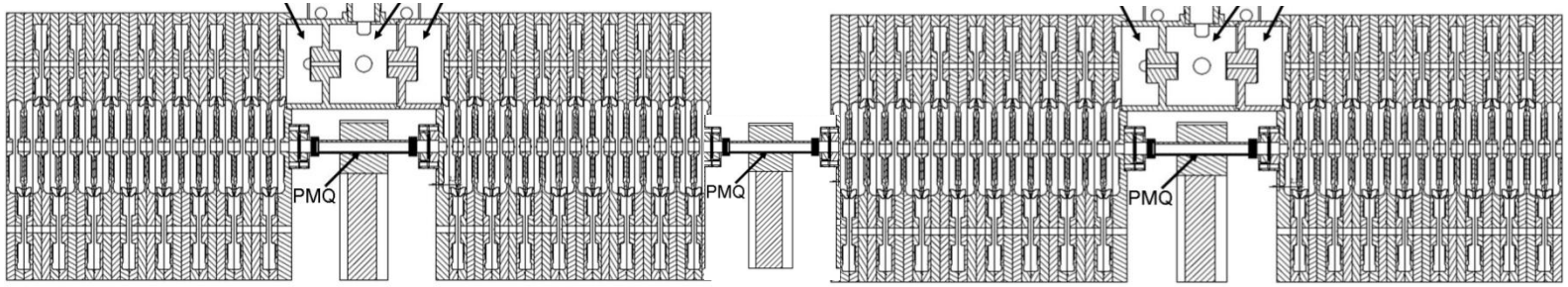
EXTRA

Energy and Intensity modulations



Accelerating gradient and real estate gradient

- **Presence of electric field free spaces (for PMQ and flanges!) reduces real estate gradient!**



- **Typical filling factor is ~ 70-75%**

Gradient vs Power

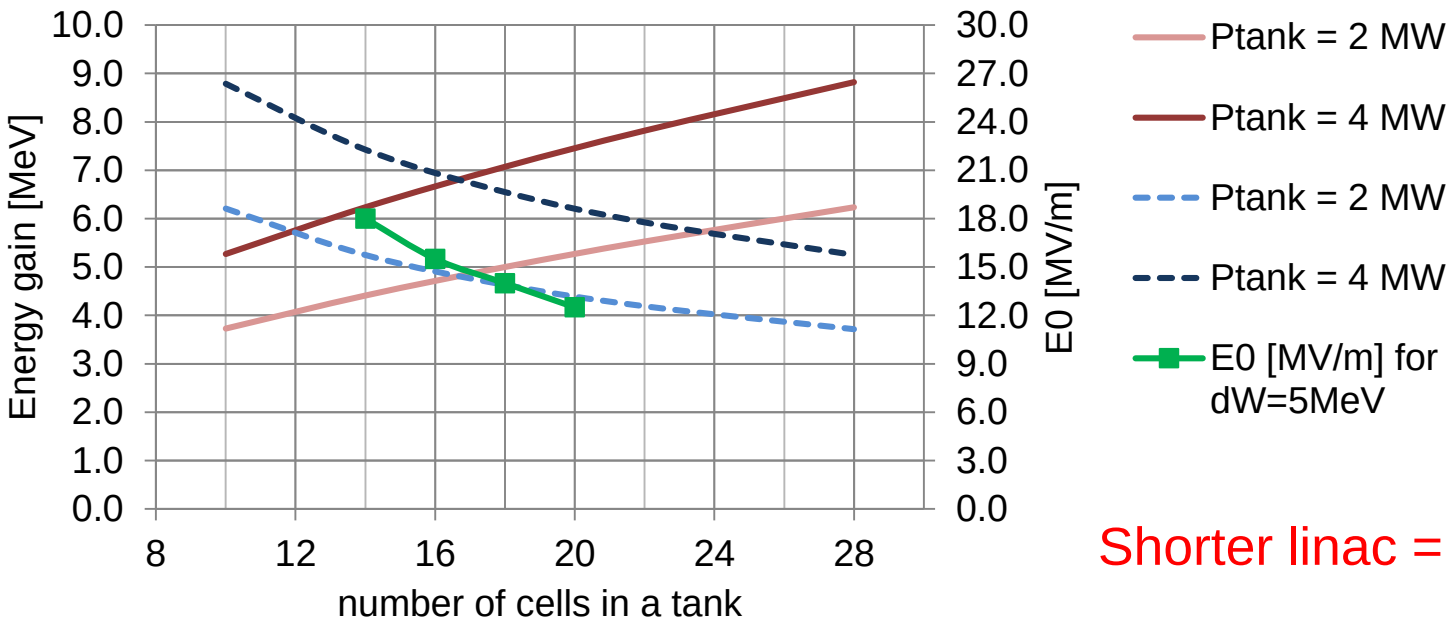
$$ZT^2 = \frac{(E_0T)^2}{\frac{P}{L}}$$

$$W = q(E_0T)L\cos(\bar{\varphi} + \varphi_s)$$

$$W = q\sqrt{E_0T \cdot P \cdot L}\cos(\bar{\varphi} + \varphi_s)$$

L = n*lc

$$W \sim \sqrt{(ZT^2) \cdot P \cdot nl_c}$$

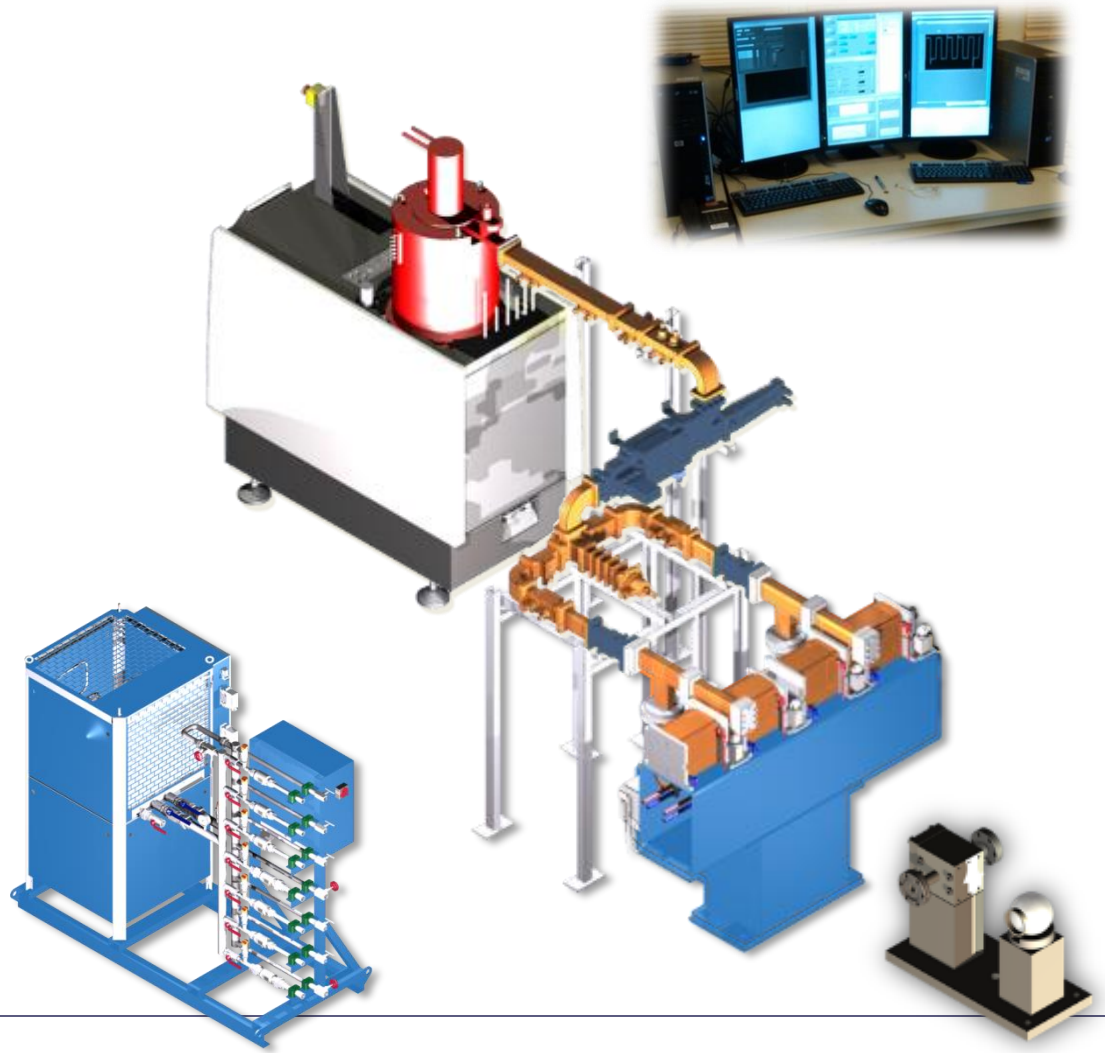


Shorter linac = higher power !

A modular approach towards industrialization

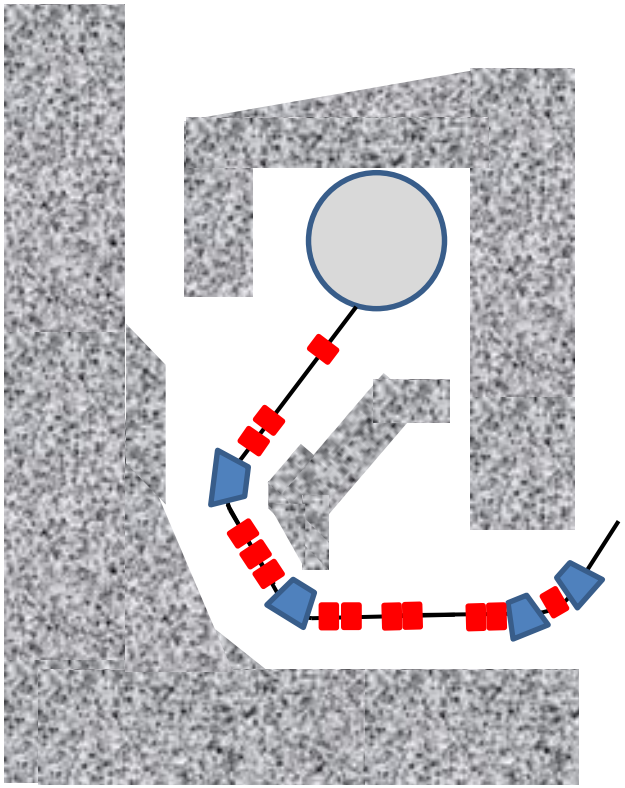
Unit Systems

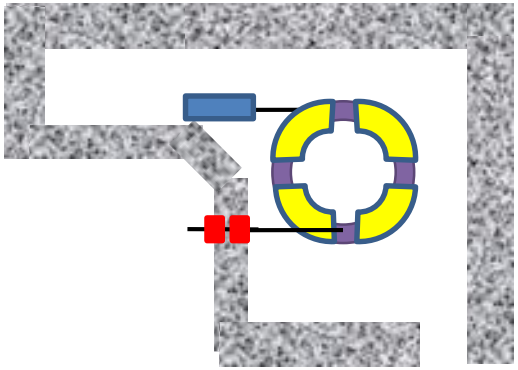
1) Accelerating System
2) Control System
3) Cooling System
4) Focusing System
5) RF Network System
6) RF Power System
7) Support System
8) Vacuum System

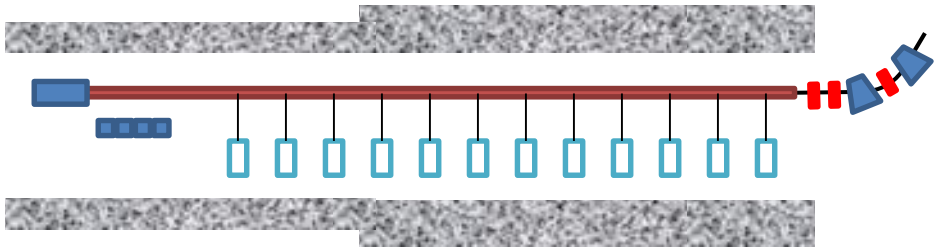


Accelerator shielding

Example of shielding impact on the foot-print (only accelerator is considered, since treatment room will be all the same independent of accelerator)







Typical beam spot at the output of the linac