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2009/12/16

Proton Linac for the Frankfurt Neutron Source

Christoph Wiesner

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Frankfurt Neutron Source at Stern-Gerlach-Zentrum

FRANZ

Development of new accelerator concepts for intense proton and ion beams.

High intensity proton beam

^{7}Li target

Neutron beam

Measurement of neutron capture cross sections, nuclear astrophysics.

Development of high power targets.

Expertise of IAP in linac design

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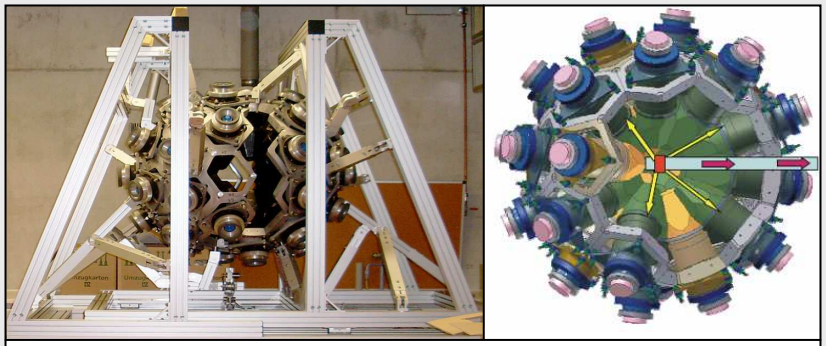
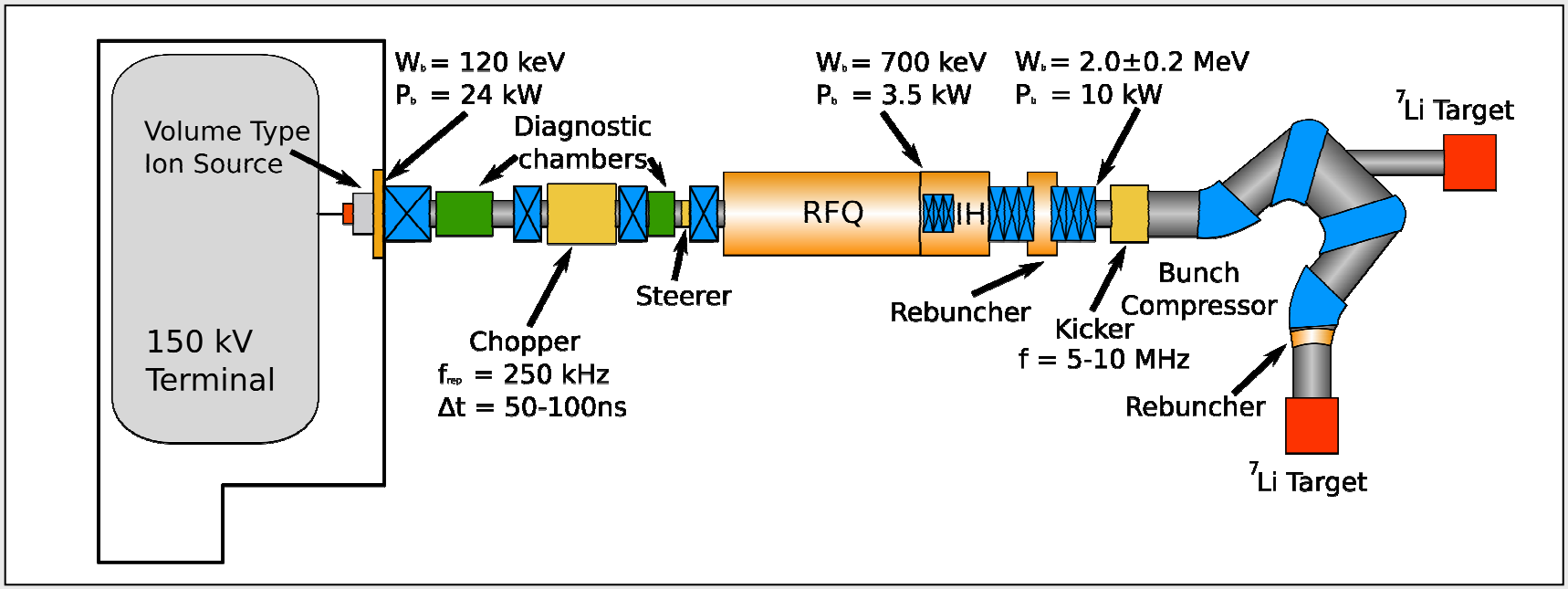
4-rod RFQ | IH-DTL

Technology and knowledge transfer from Karlsruhe.

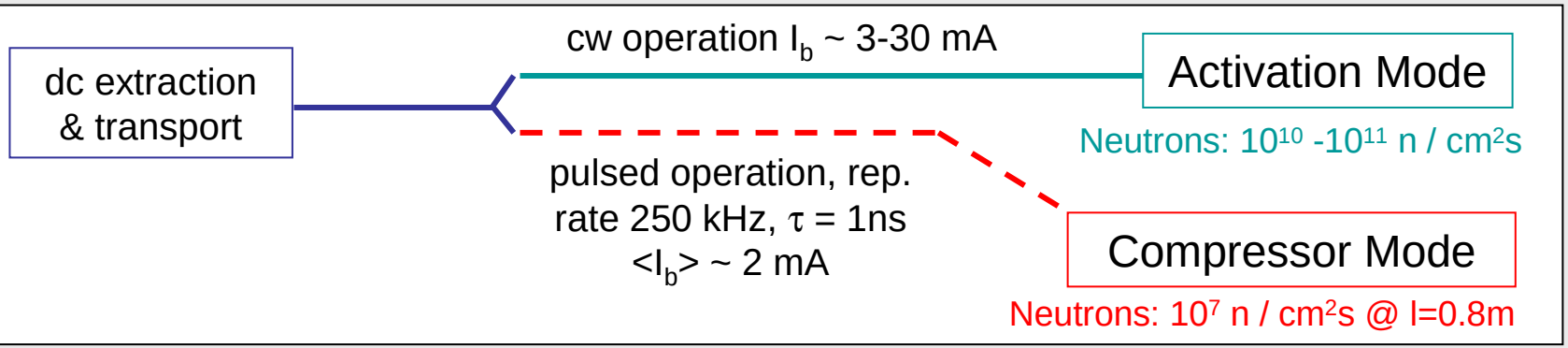


4π BaF_2 Detector

FRANZ Proton Linac

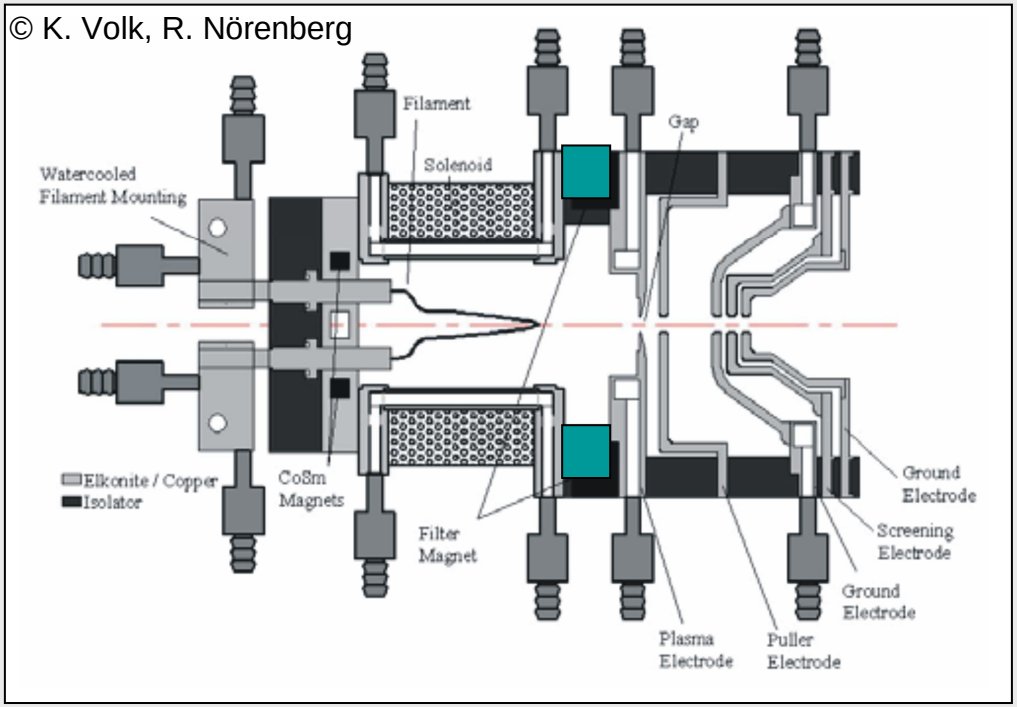


Scheme of the Frankfurt Neutron Source FRANZ.

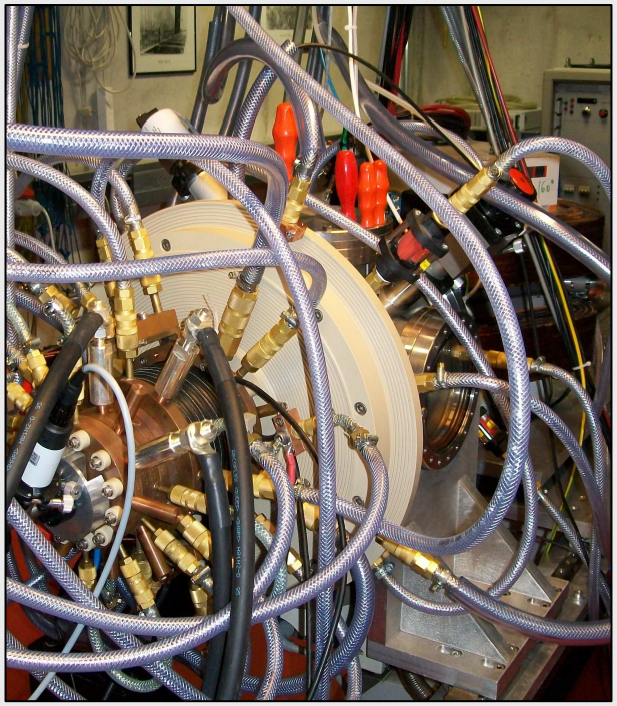


Operation Modes of the Frankfurt Neutron Source FRANZ.

Volume type ion source



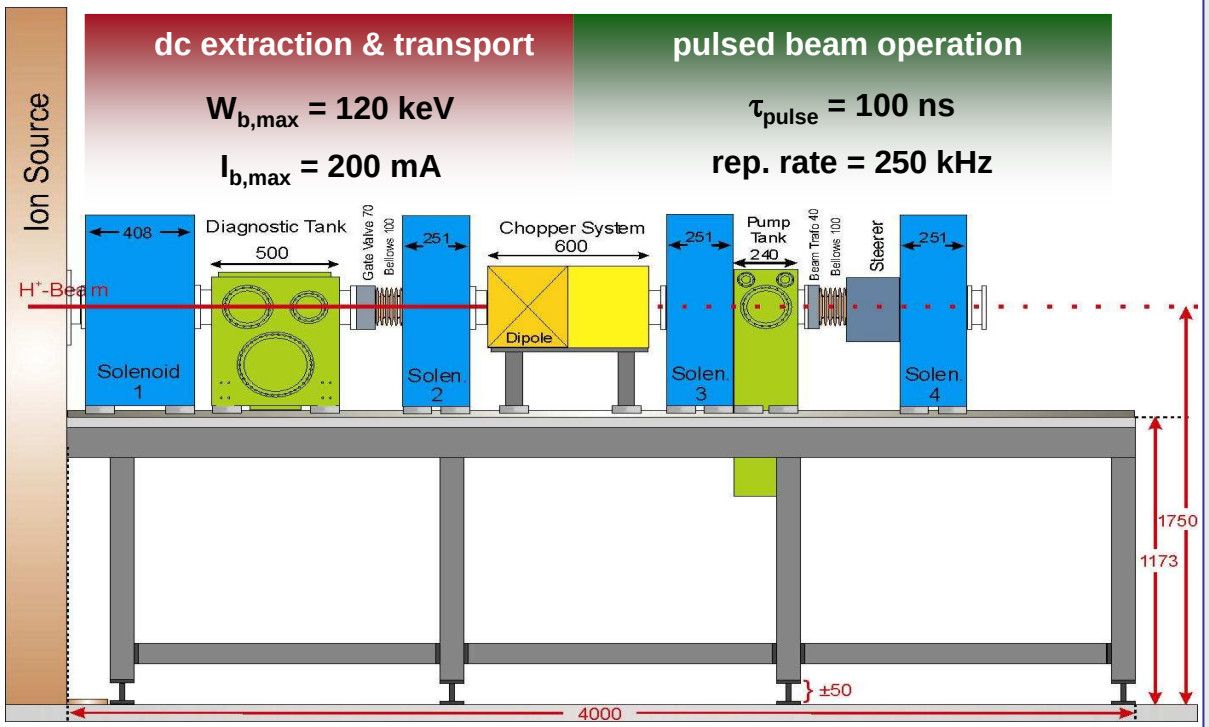
Cross-sectional view of the ion source.

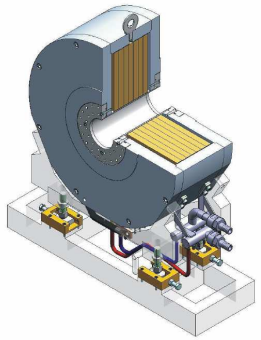


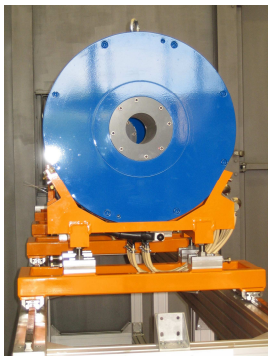
Ion Source during Test Operation.

Operation Mode	dc	Extraction Voltage	62 kV
Ion Species / Fraction	Protons / 90 %	Beam Output Energy	120 keV
Extraction Current	200 mA	Emittance (rms norm.)	0.07 π mm mrad

Low Energy Beam Transport (LEBT) Section







- High voltage terminal operational.
- Water and electricity supplies installed.
- Solenoids and diagnostics chambers are being tested.

Solenoid Lenses:
Aperture 100 mm, B_z = 0.78 T,
length 251 mm

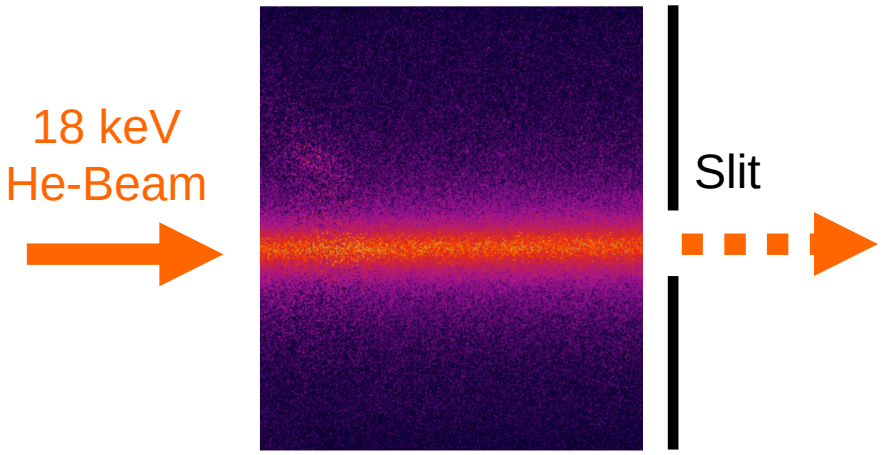
ExB Chopper System

Chopping of High Intensity Beams:

- *Avoiding long drifts* due to high space charge.
- *Minimizing duty factor for electrostatic beam deflection* in order to reduce risk of voltage breakdowns.
- *Beam dumping outside transport line* preferable in order to avoid high power deposition and uncontrolled production of secondary particles.

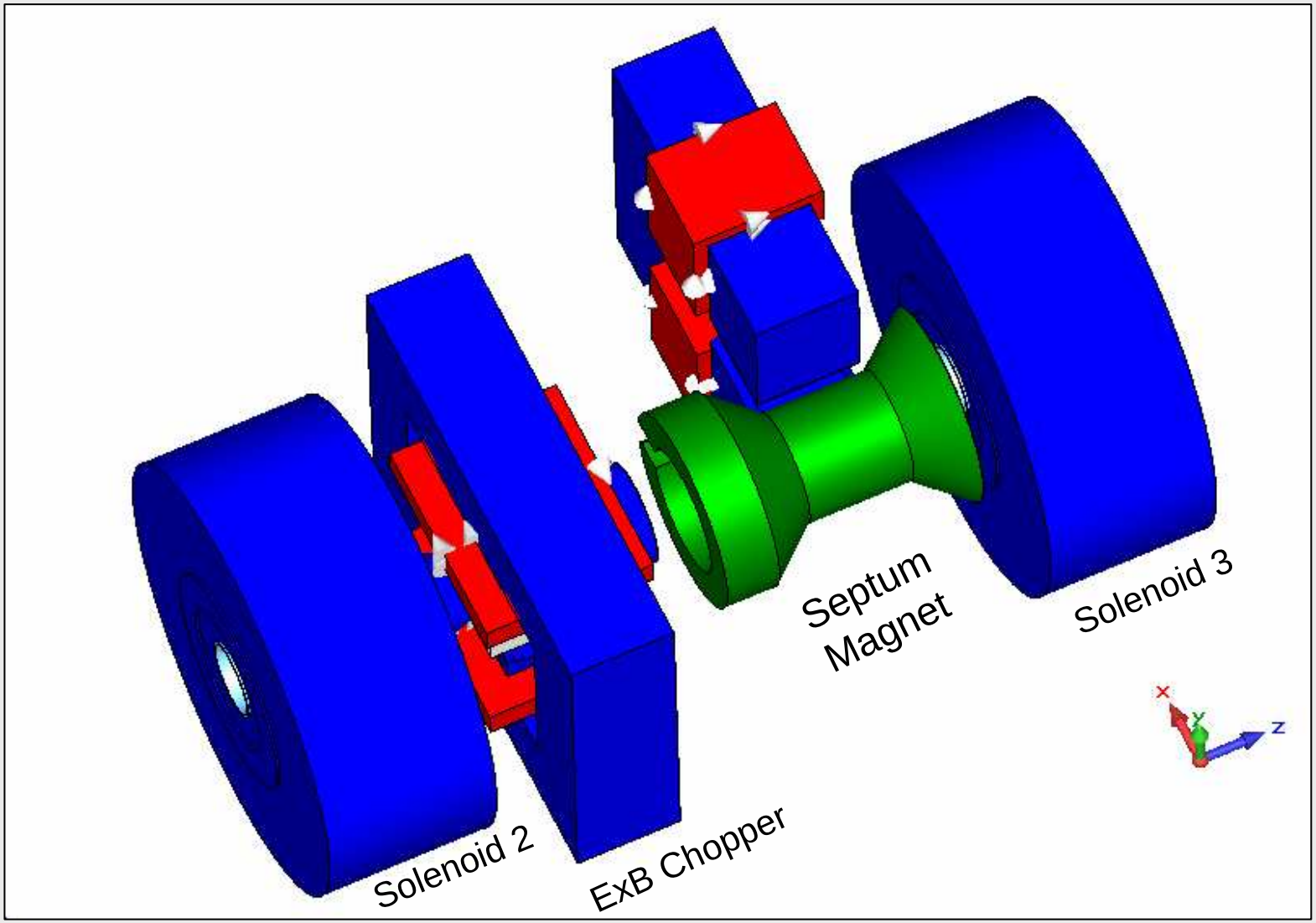
Chopping Parameters

- Beam Current: 200 mA
- Beam Energy: 120 keV
- Beam Power: 24 kW
- Input: DC Beam
- Output: Pulsed Beam
- Pulse Time: 100 ns
- Rep. Time: 4 µs

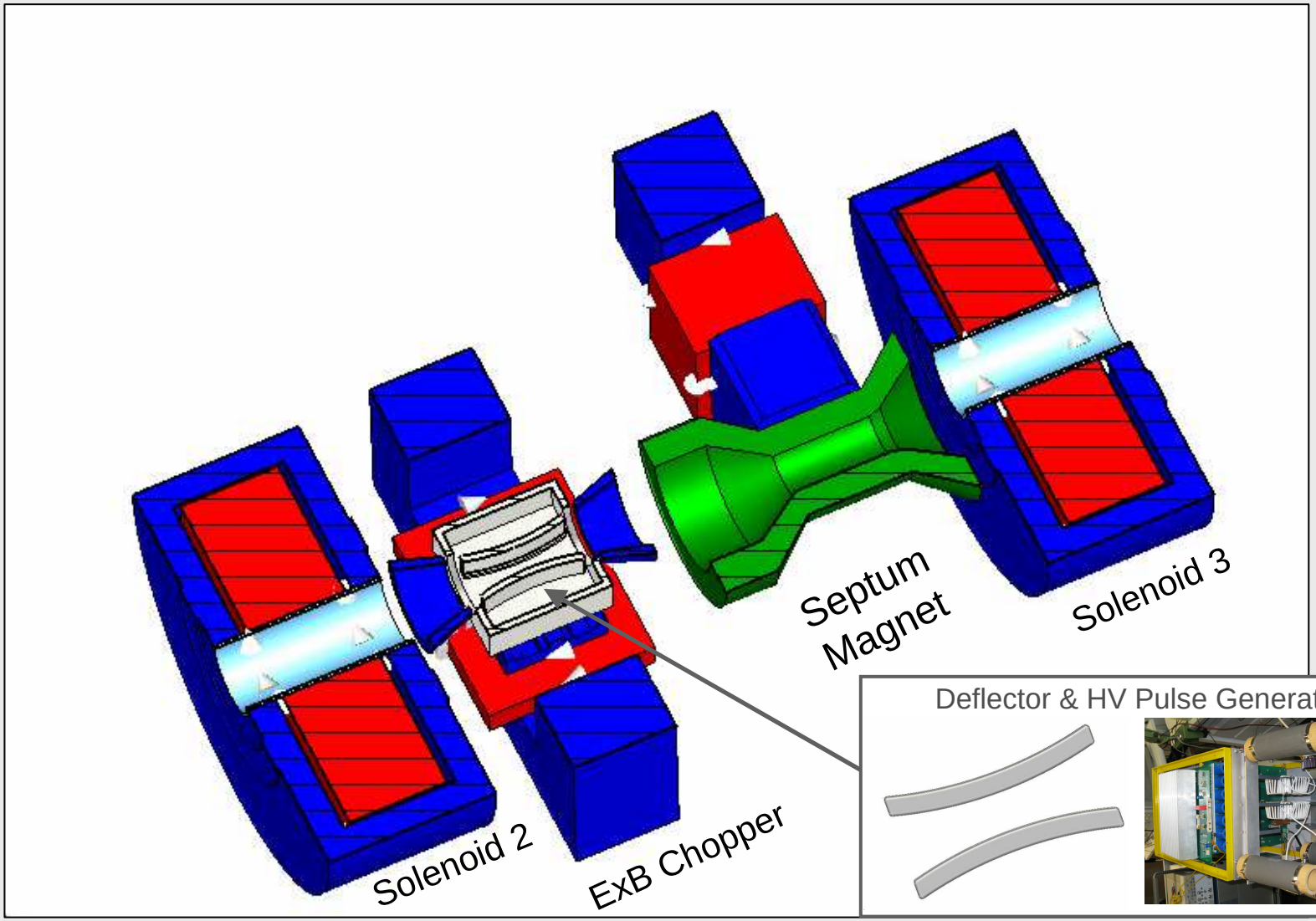


Optical Diagnostics of
Beam Deflection Measurements

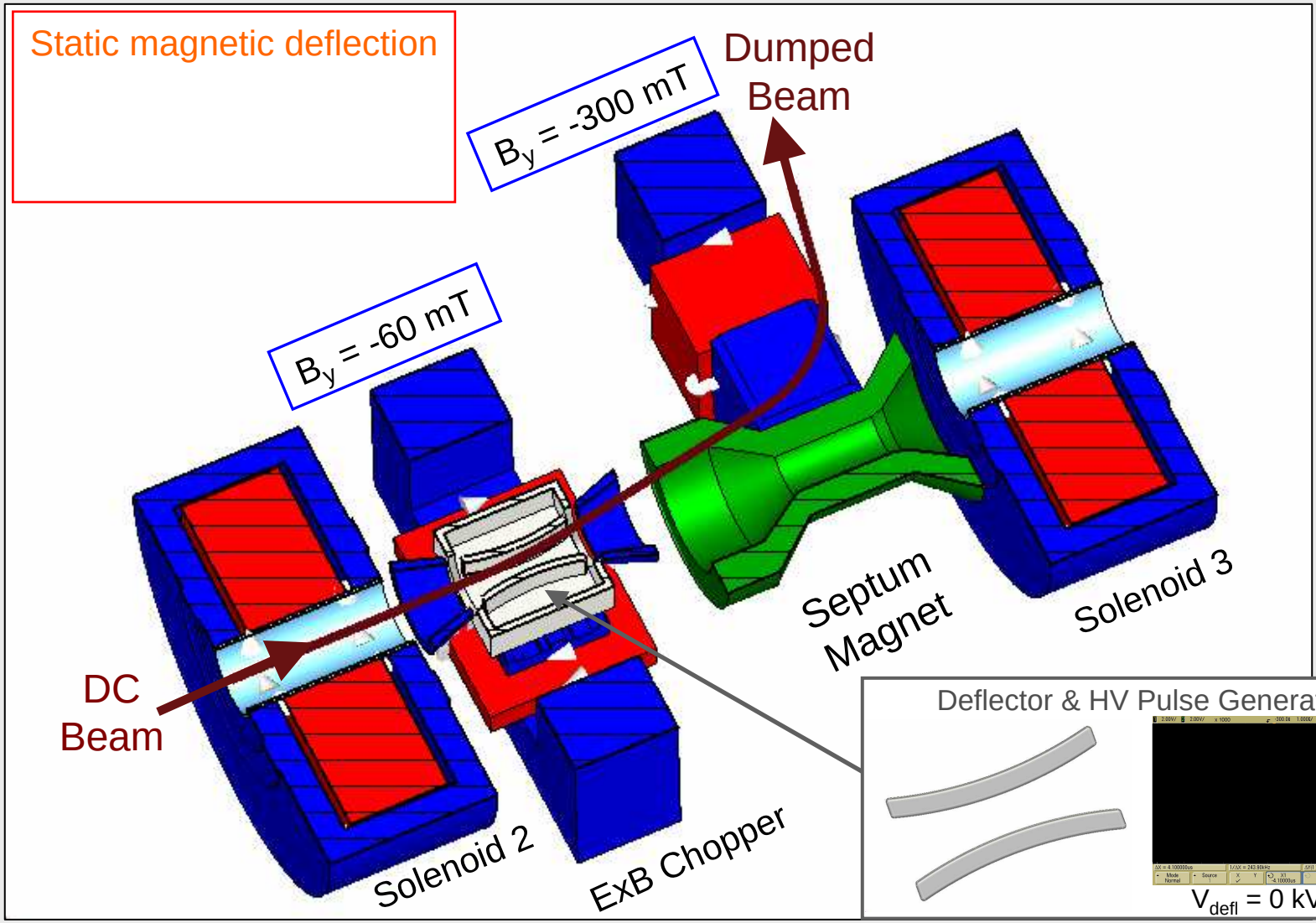
ExB Chopper System



ExB Chopper System

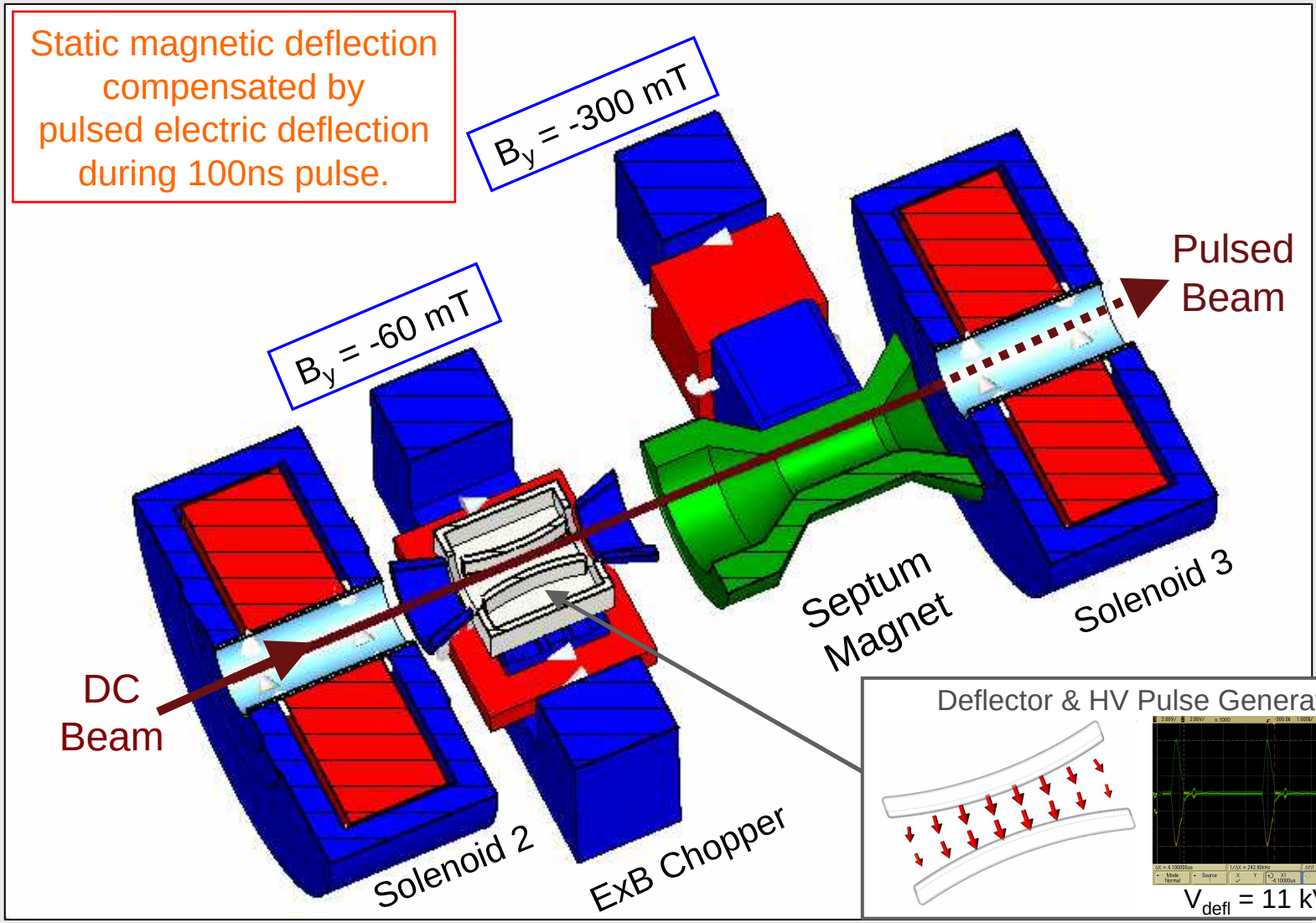


ExB Chopper System



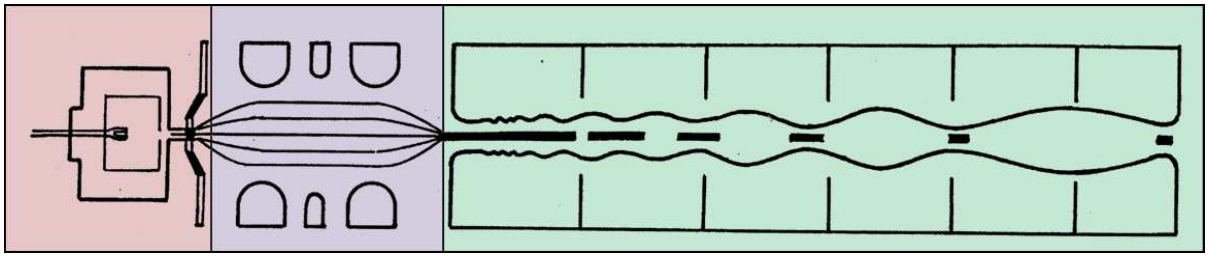
ExB Chopper System

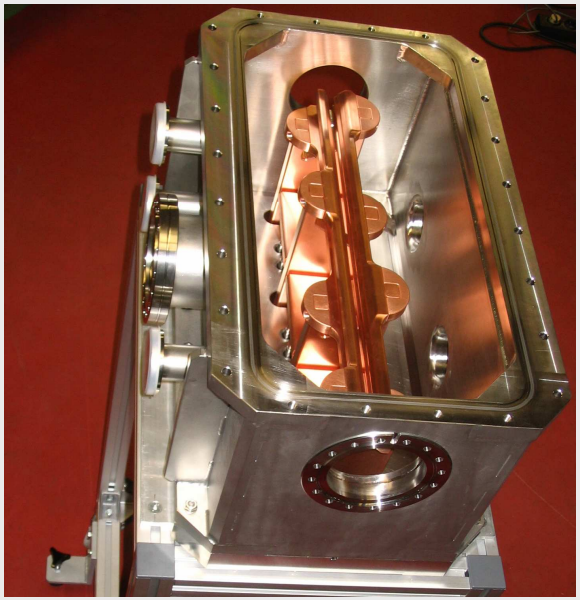
Static magnetic deflection compensated by pulsed electric deflection during 100ns pulse.



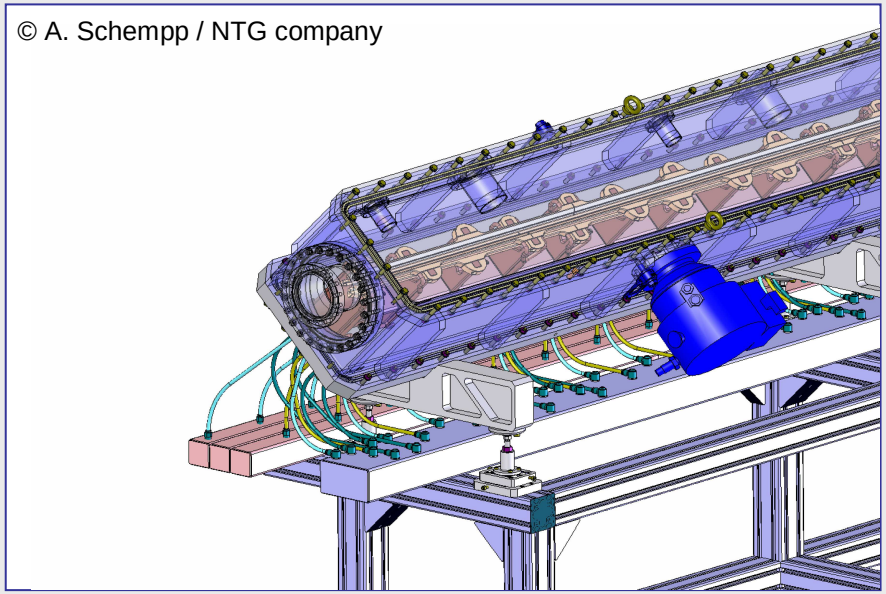
Radio Frequency Quadrupol - RFQ

Focusing, Bunching and Acceleration



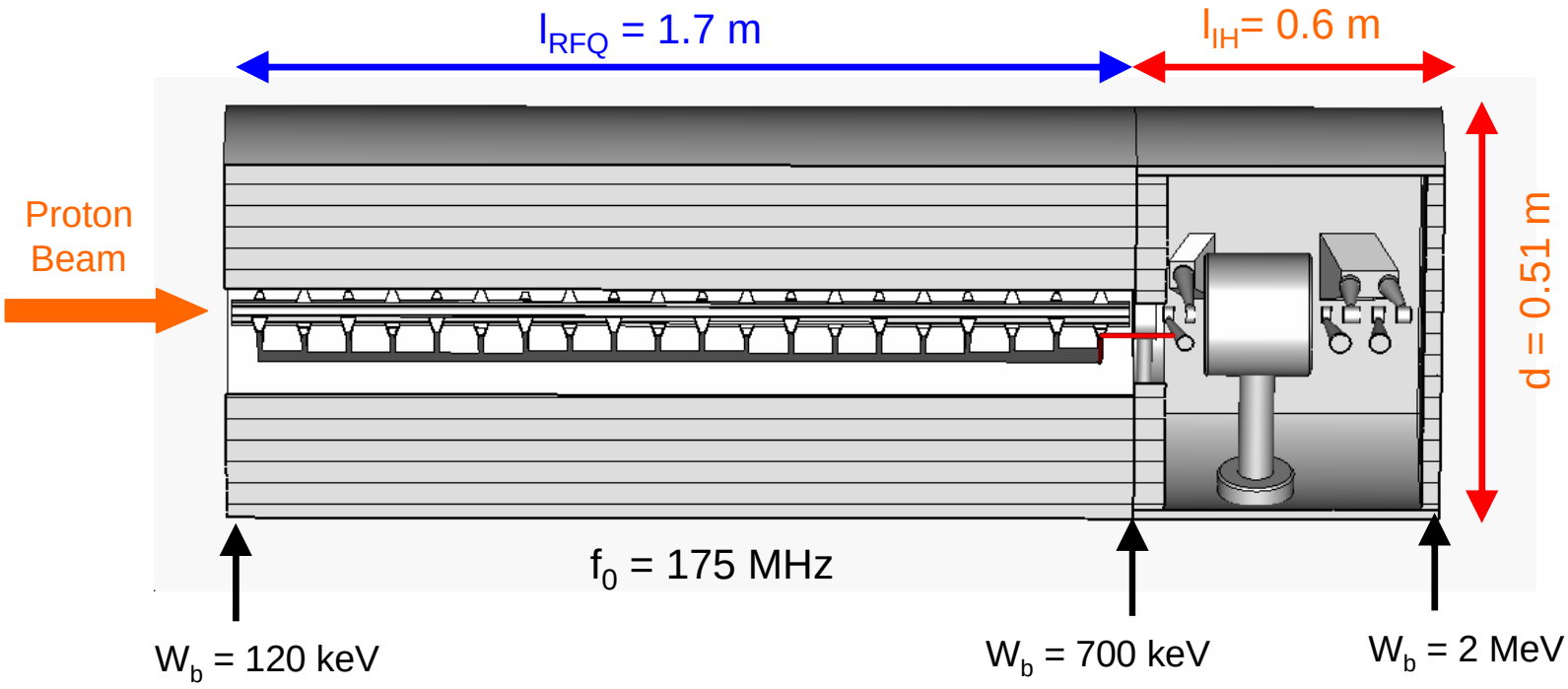


RFQ test module



RFQ technical design

Coupled RFQ-IH-Structures

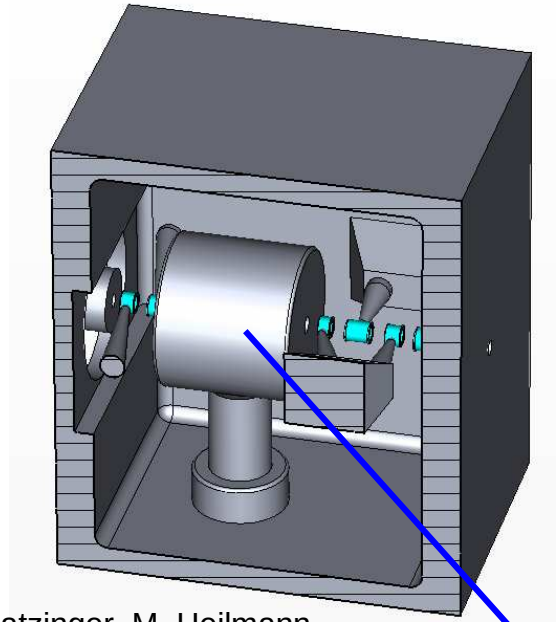


Max. Proton Current	200 mA
Exp. Power Consumption RFQ	150 kW
Exp. Power Consumption IH	45 kW
RFQ Acceptance (norm. rms)	0.56 π mm mrad

Coupling of RFQ and IH-DTL: Only one power amplifier → lower investment costs.
RFQ: Bunching and first acceleration stage.
IH-DTL: Main acceleration stage.

IH-DTL and CH-Rebuncher

IH-Drift Tube Linac: Acceleration from 0.7 MeV to final energy of 2 MeV.



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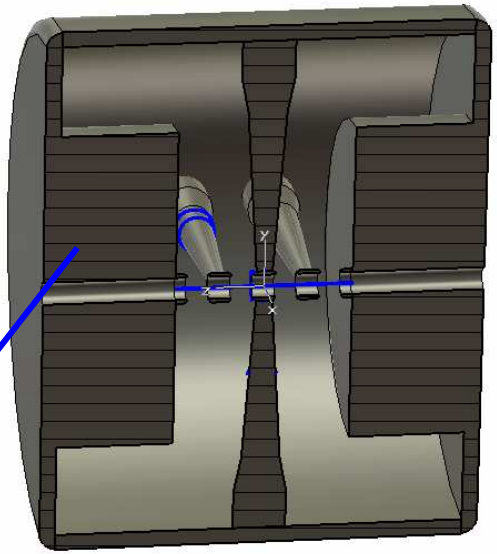
CH-Rebuncher:
Energy variation ± 0.2 MeV.



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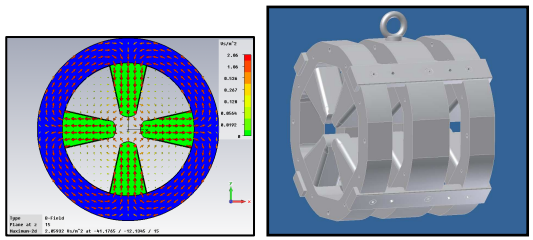
- 8 accelerating gaps

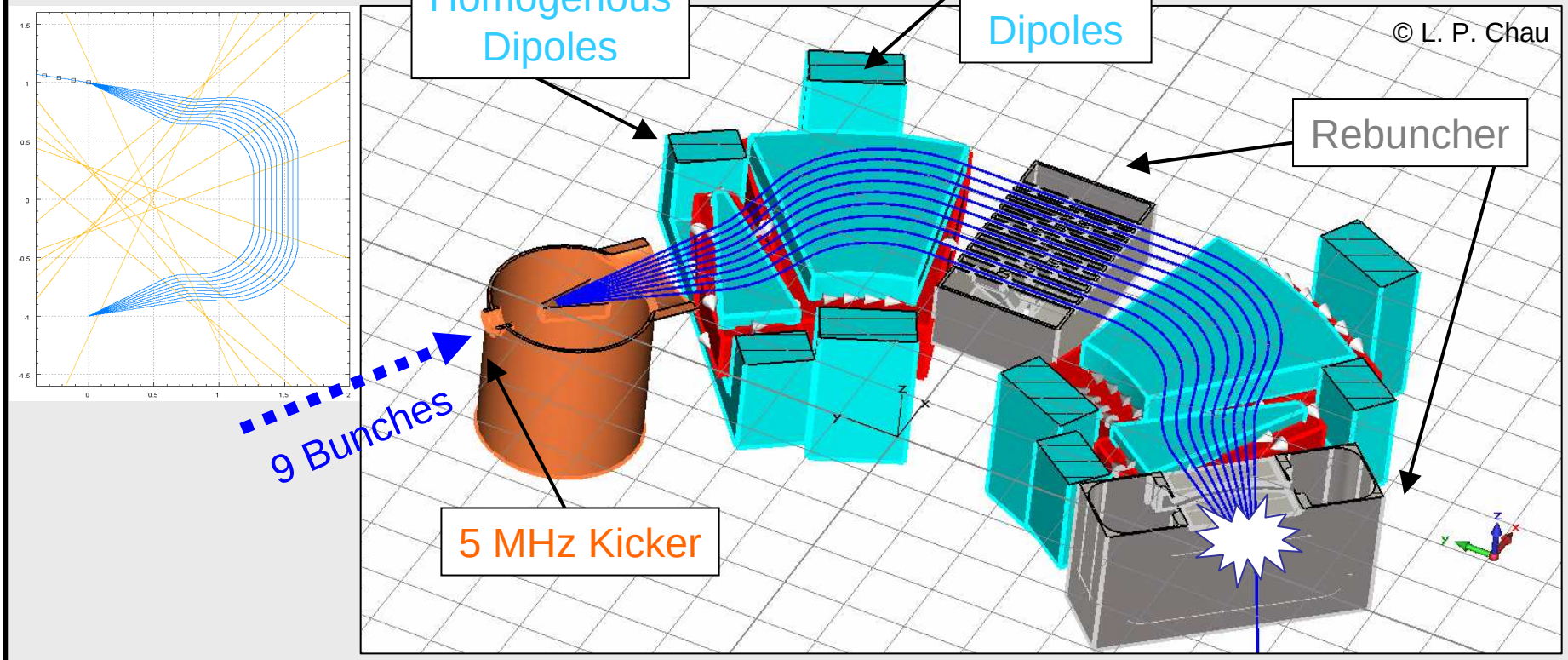
Magnetic quadrupole triplets



- 4 gaps for accelerating/ decelerating

Bunch Compressor

Design was based on Mobley-type bunch compressor and extended for high intensity beams.

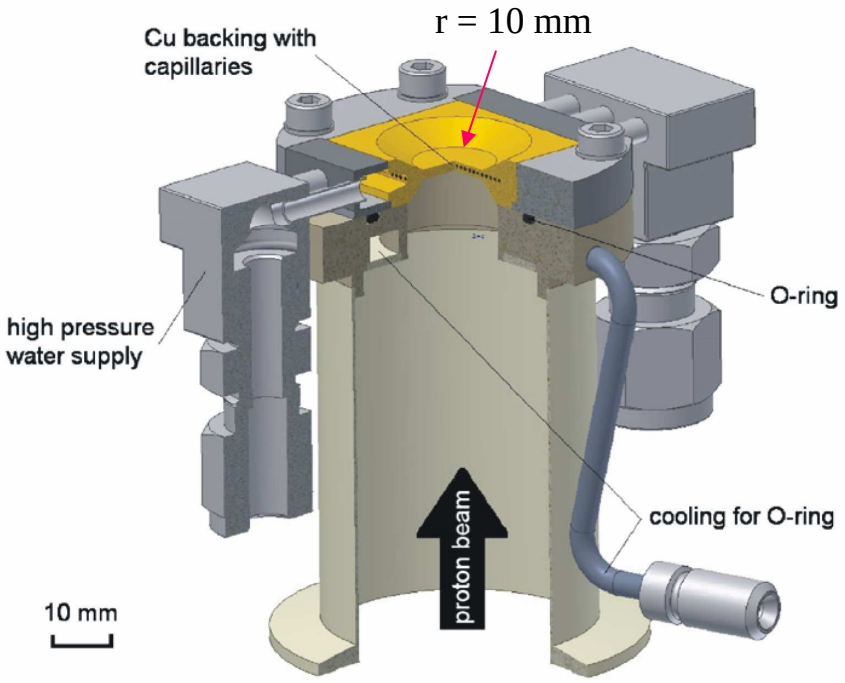


High Power Target

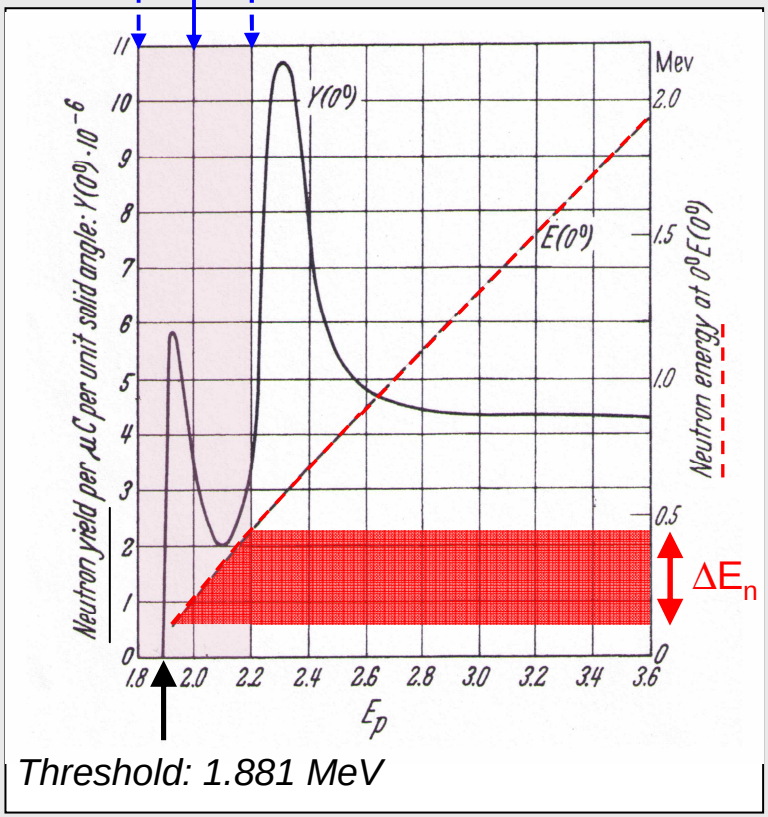
Compressor Mode:
Average power ~ 4 kW

$$_1H^1 + {}_3Li^7 \rightarrow {}_4Be^7 + {}_0n^1 - 1{,}646\ \text{MeV}$$

$E_p = 2 \pm 0.2$ MeV



Target prototype development at Karlsruhe for beam power up to 6 kW.



Neutron yield and maximum neutron energy in forward direction (0°).

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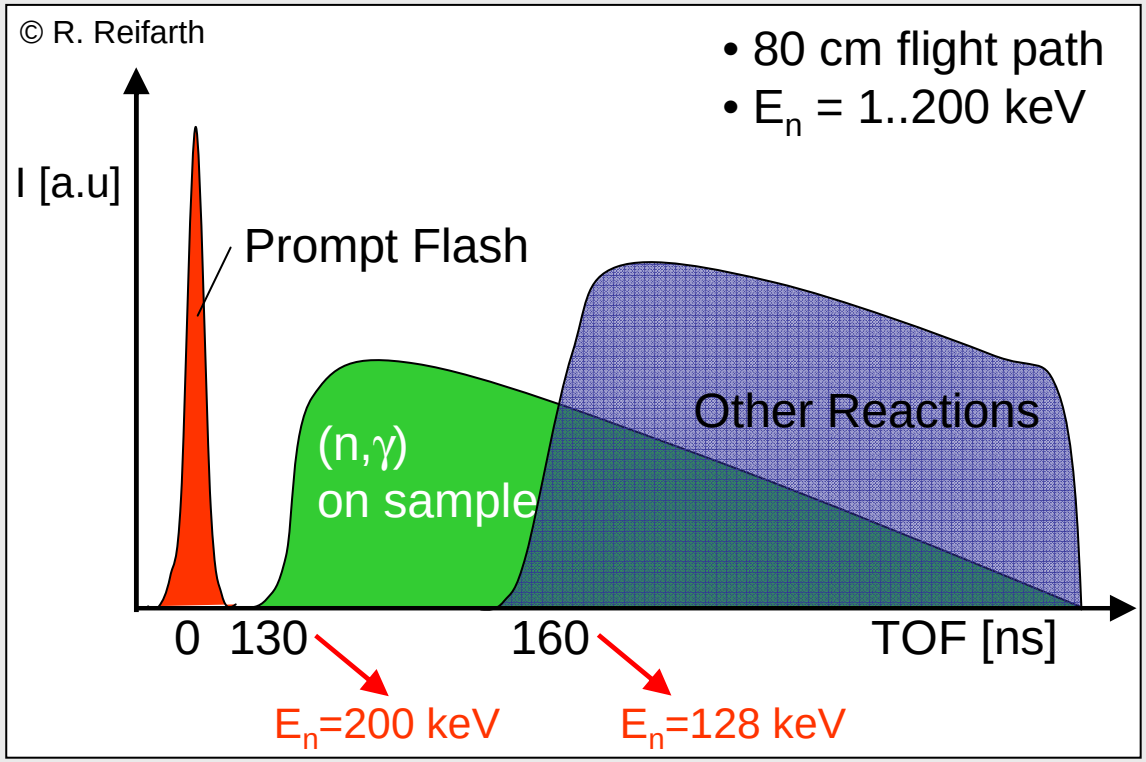
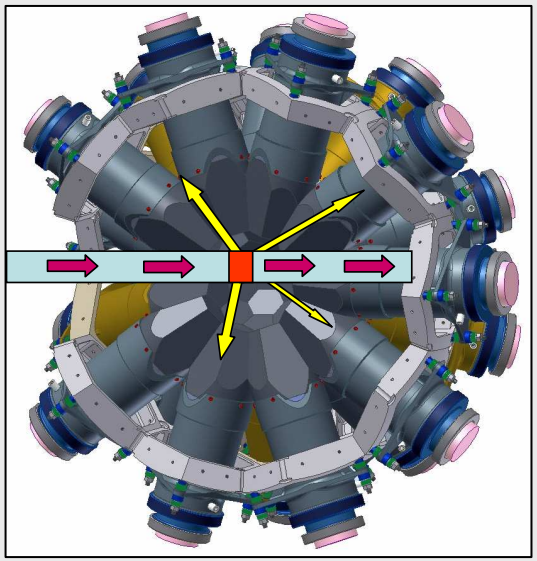
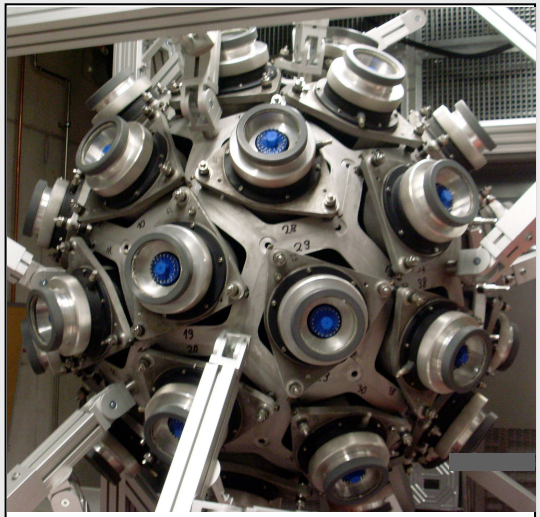
4π BaF_2 Detector Array

- Gamma calorimeter
- Fast timing (<1 ns) for acceptable TOF resolution
- Low neutron sensitivity



Time of Flight Method





4π BaF_2- detector after transfer from Karlsruhe to Frankfurt.

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Neutron Characteristics

- **Short 1ns Pulse** (Compr. Mode).

→ Time-of-Flight-Method: Energy-dependent measurement of neutron capture cross sections.

- **Intensities** of up to 10^7 n/cm^{2}s (Compr. Mode) resp. 10^{10} n/cm^{2}s (Activat. Mode).

→ Increase of up to a factor of 1000 compared to previous setup at FZK. Allows measurement of small samples.

- **Neutron Energy**: E_{min} = 1 keV; E_{max} = 400 keV; Neutron spectrum of Red Giant stars is reproduced in the laboratory (Activat. Mode).

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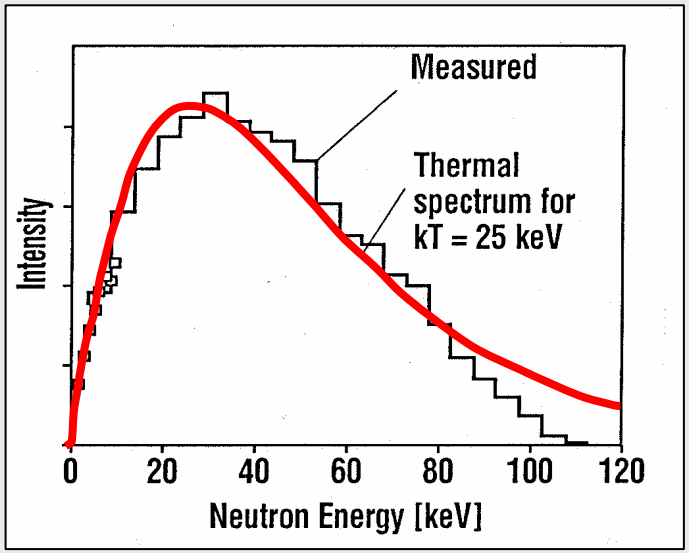

Summary

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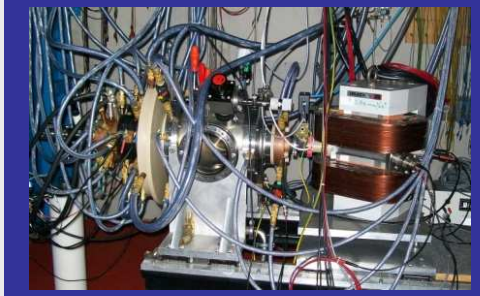
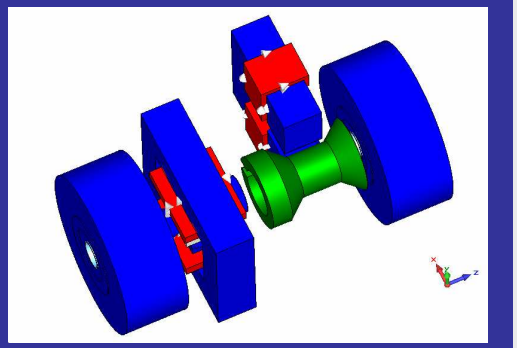
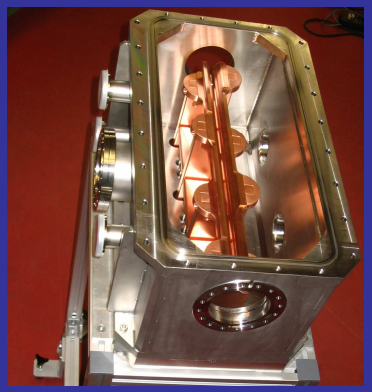
Source constructed



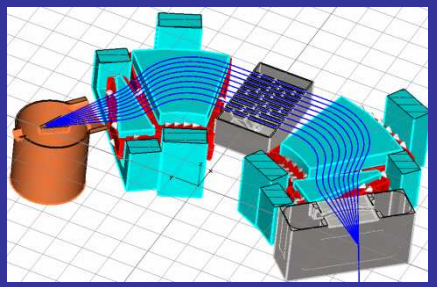
LEBT vacuum tests

Chopper design





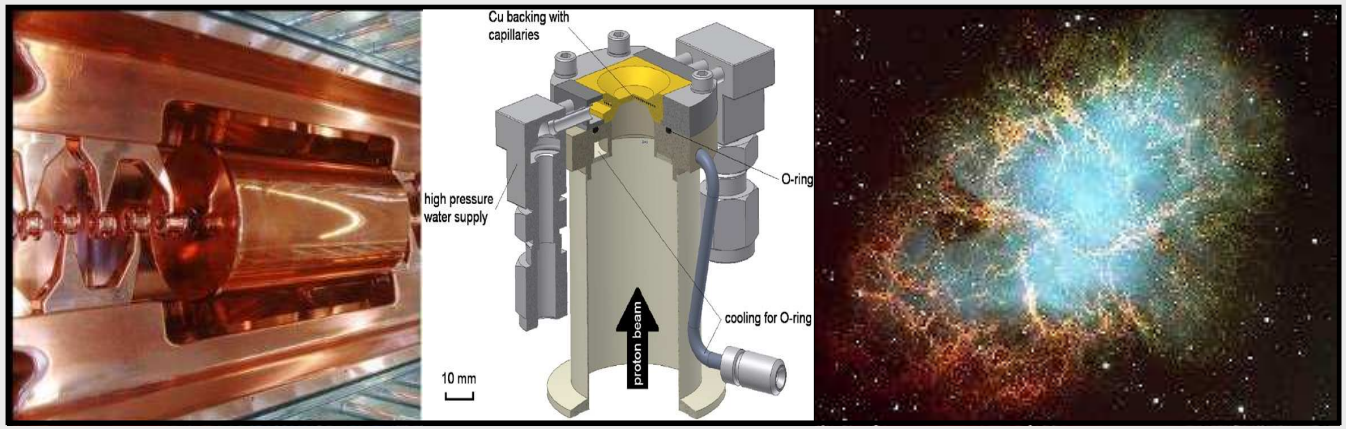
RFQ test module



Compressor design

Detector reassembled

Summary



FRANZ will provide a rich experimental program:

- Accelerator physics (high intensity beam transport, shaping, acceleration).
- High power target development.
- Detector development.
- Measurement of neutron capture cross sections.
- Nuclear astrophysics.

FRANZ is a university project:

- Education of students in the fields of nuclear and accelerator physics.

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Thanks to

A. Bechtold, L.P. Chau, H. Dinter, M. Droba, M. Heilmann, N. Joshi, O. Meusel, I. Müller, D. Noll, H. Podlech, U. Ratzinger, A. Schempp, S. Schmidt, K. Volk, C. Wagner / *IAP, Goethe University Frankfurt*

M. Heil, R. Plag, R. Reifarth / *GSI, Darmstadt*

K. Stiebing, J. Stroth / *IKF, Goethe University Frankfurt*

F. Käppeler, D. Petrich / *IKF, FZ Karlsruhe*

Acknowledgment:

LINAC Group	http://linac.physik.uni-frankfurt.de/
Group Schempp	http://iaprfq.physik.uni-frankfurt.de/
NNP Group	http://nnp.physik.uni-frankfurt.de

FZK / **GSI** / **IAEA**

Thank you for your attention