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Proton LINAC for the Frankfurt Neutron Source FRANZ

- IAEA -

International Topical Meeting on Nuclear Research
Applications and Utilization of Accelerators

Oliver Meusel

4-8 May 2009

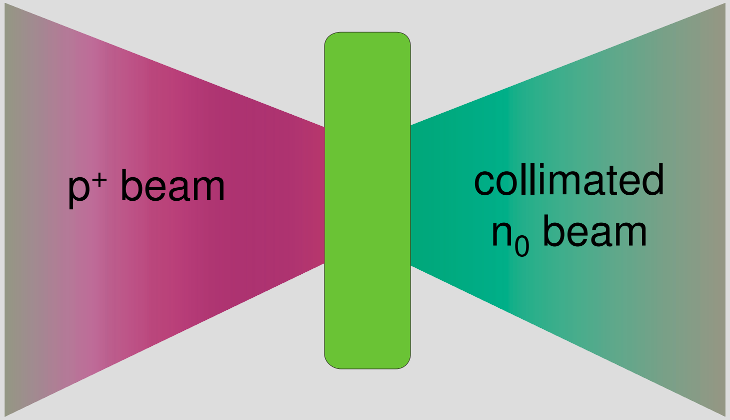
Vienna, Austria

Motivation

Frankfurt **N**eutron Source at the Stern - Gerlach- **Z**entrum

^{7}Li target

development of new accelerator concepts for intense proton and ion beams



nuclear astro physics, measurement of neutron capture cross sections

development of high power targets

Experimental Setup

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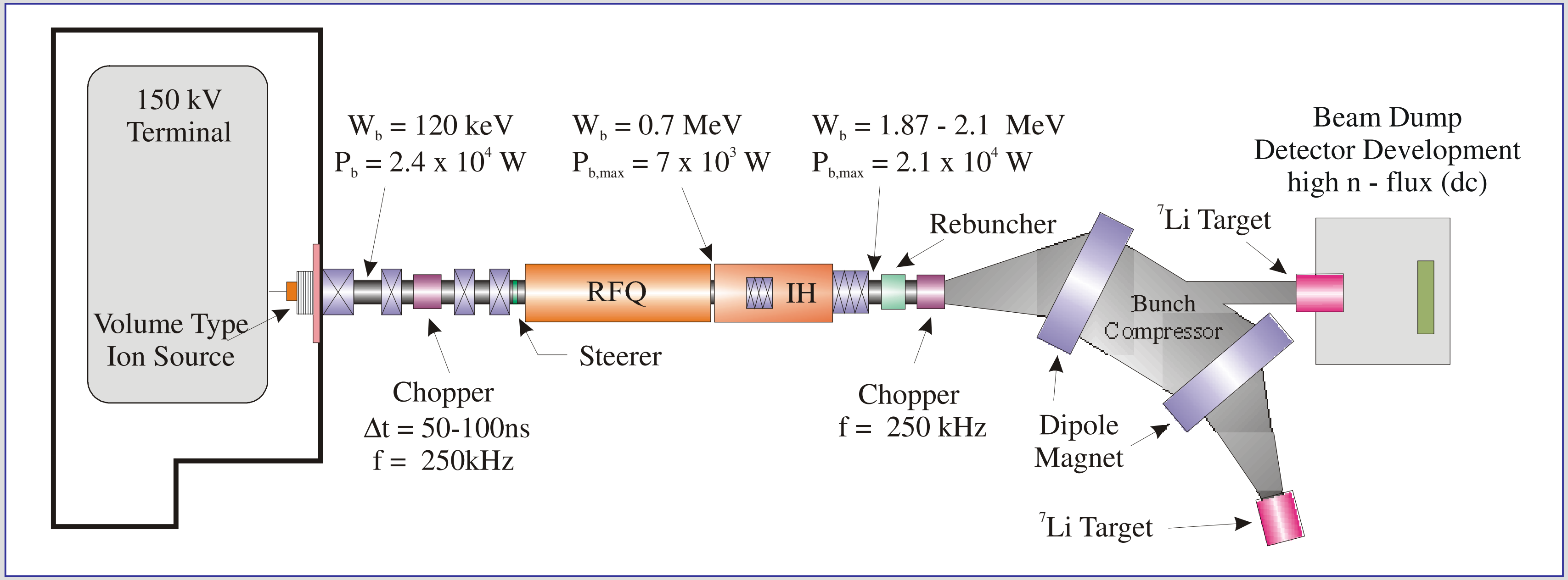
Scheme of the neutron source



dc extraction & transport

cw operation I_b ~ 30 mA

activation mode

pulsed operation, rep. rate 250 kHz, τ = 1ns
I_b ~ 2 mA

compressor mode

Compressor Mode

Primary beam properties and resuling neutron flux

low energy proton beam

Beam energy: 120 keV

Beam current: 200 mA

Pulse width: 50 - 150 ns

→

Proton beam at the target

Final energy (adjustable): 1.8 - 2.2 MeV

Repetition rate: 100 - 250 kHz

Pulse width : 1 ns

↓

Neutron production

$$^{7}Li(p,n)\rightarrow {}^{7}Be$$

target and detector – with kindly support by FZK and GSI.

→

Neutron beam

Energy: 10 - 200 keV

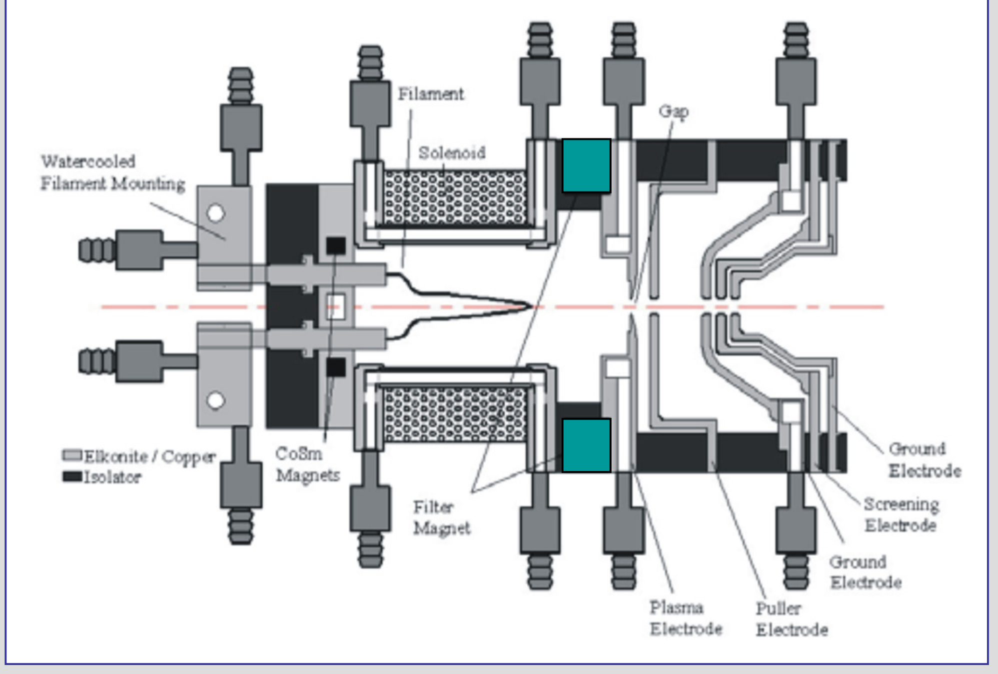
Production rate:

$$\leq 2\cdot 10^{5}\,\mathrm{n/pulse} \rightarrow \leq 5\cdot 10^{10}\,\mathrm{n/s}$$

Neutron flux at the target:

$$\leq 120\,\mathrm{n/pulse} \rightarrow \leq 3\cdot 10^{7}\,\mathrm{n/s} \rightarrow \leq 1\cdot 10^{7}\,\mathrm{n/cm^2 s}$$

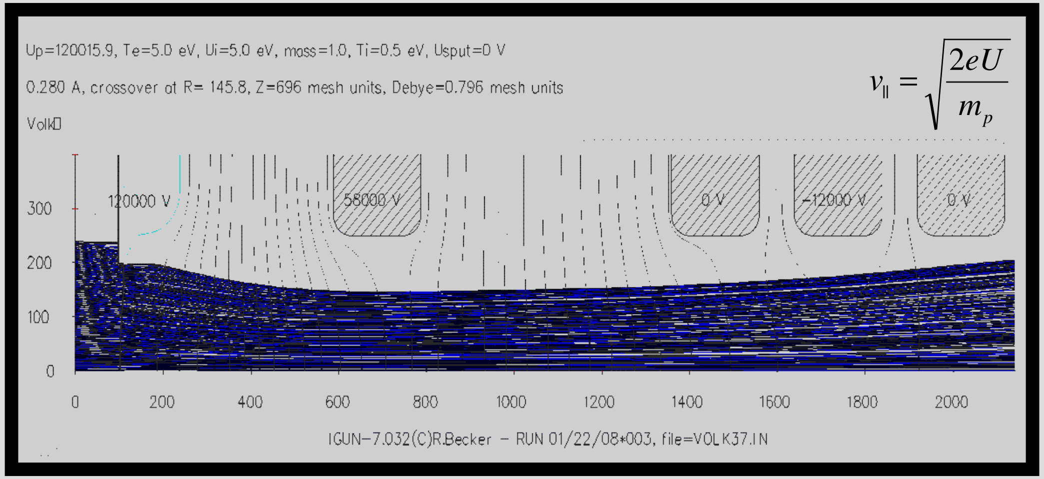
Volume type ion source with hot filament driven gas discharge



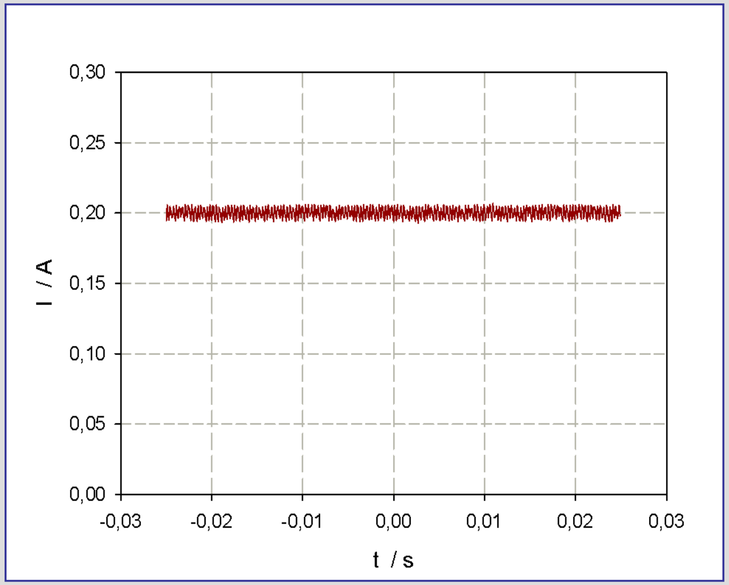
Cross-sectional view of the ion source

Operation mode	dc
Ion species / fraction	Protons / 90 %
Discharge power	10 – 12 kW
Extraction current	200 mA
Extraction voltage	62 kV
Extraction field strength	5 kV/mm
Beam energy	120 keV
Input emittance (norm. rms)	0.07 π mm mrad
Aspect ratio	0.2

Ion beam extraction



simulated beam extraction using a pentode system



extracted beam current with 3% noice (simulated)

$$n_p = \frac{I}{2\pi e \cdot v_{\parallel} \cdot r_b}$$

$$K = \frac{1}{4\pi\varepsilon_0}\sqrt{\frac{A}{2q}} \cdot \frac{I}{U^{3/2}}$$

$$\eta = \frac{I_{peak}}{I_0}$$

proton density $n_p = 8.2 \cdot 10^{14}\ m^{-3}$

gen. Perveance $K = 3.1 \cdot 10^{-3}$

compression ratio $\eta = 1$,

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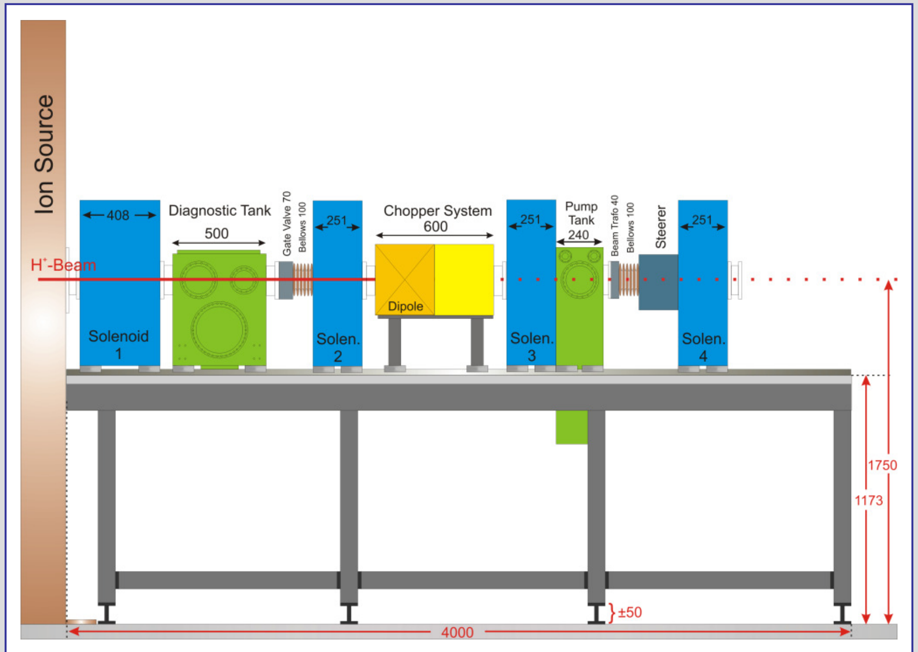
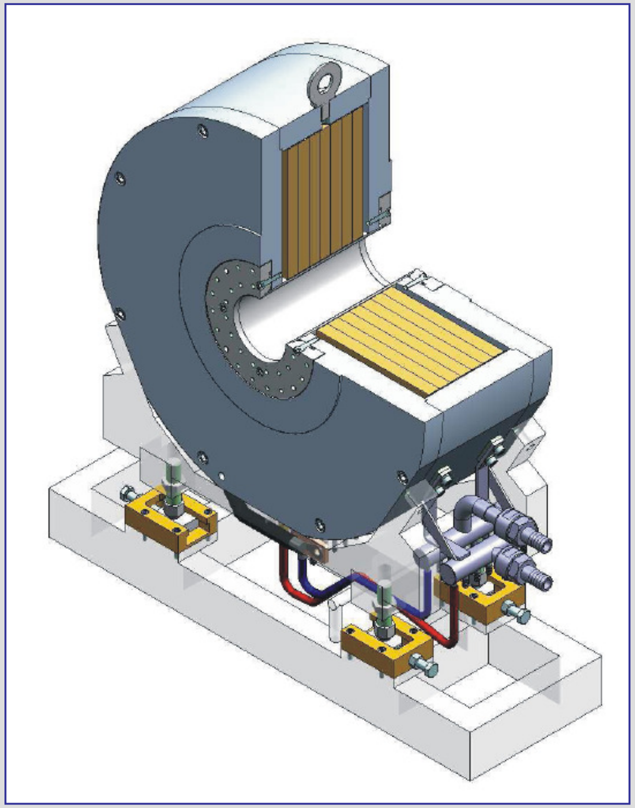
Solenoidal transport section to provide space charge compensation

$$\frac{d^2}{dz^2} r_S = \frac{\varepsilon^2}{r_S^3} + \frac{K}{r_S} - \kappa(z) r_S$$

KV - envelope equation



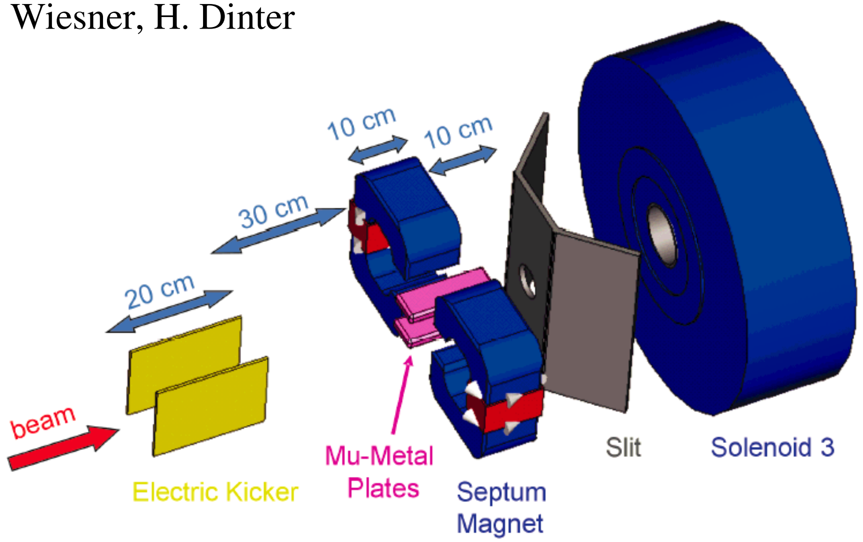
scheme of LEBT section



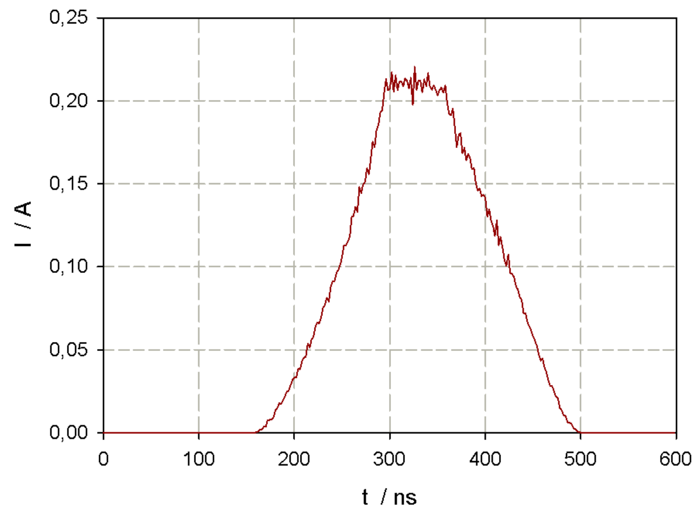
aperture 100 mm, $B_z = 0{,}6$ T

Chopper for macro pulse generation

© C. Wiesner, H. Dinter



scheme of the chopper system



macro pulse current distribution (simulated)

compression ratio η = 1

gen. Perveance $K = 3.1 \cdot 10^{-3}$

$n_p = 8.2 \cdot 10^{14}\ m^{-3}$

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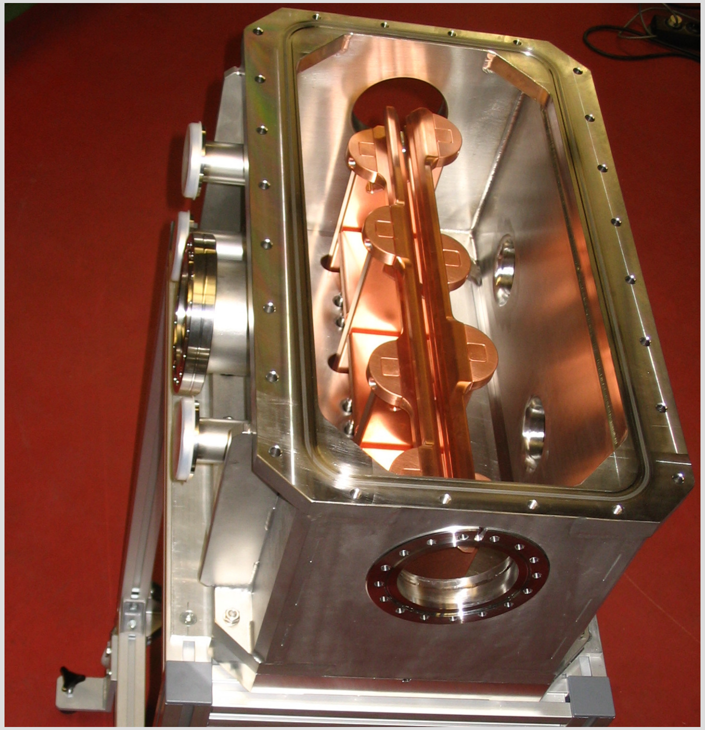
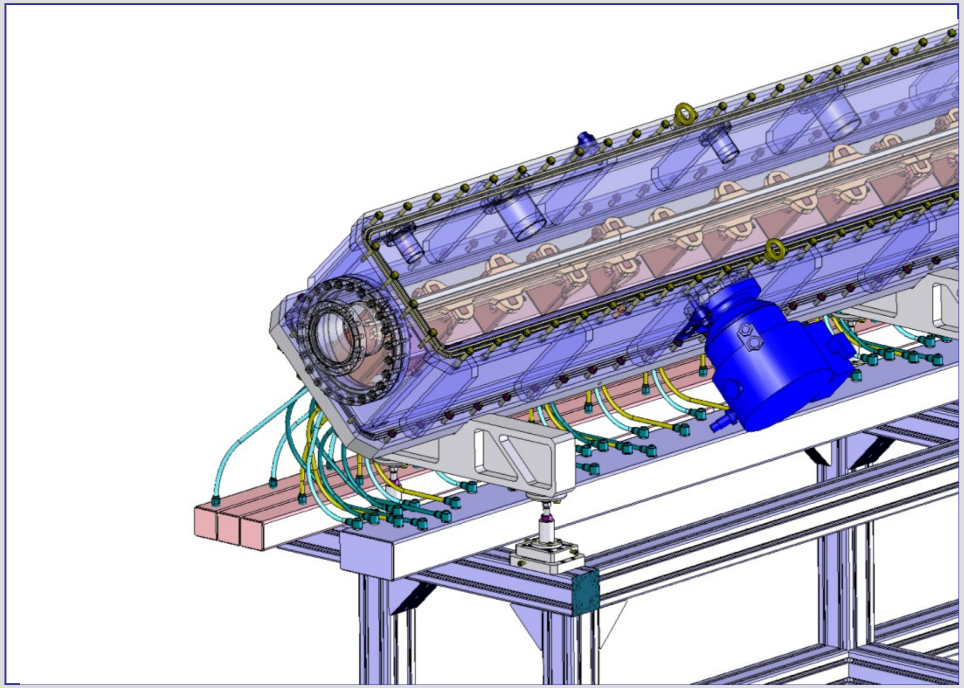
Radio Frequency Quadrupol - RFQ



RFQ test module

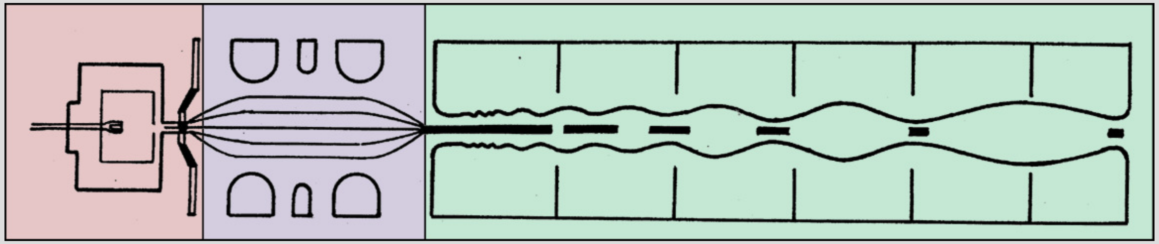


RFQ technical design

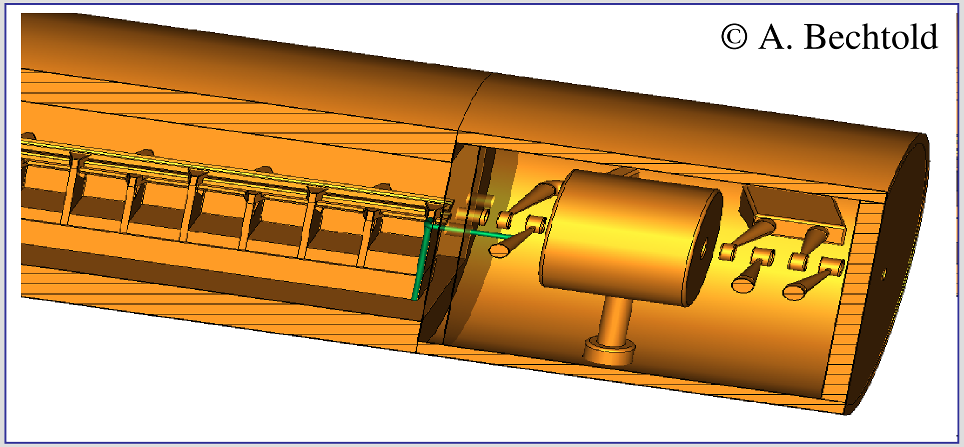
Focussing, Compression and Acceleration

Operating frequency	175 MHz
Ion species	Protons
Length of RFQ	1.7 m
Length of IH-DTL	0.6 m
Tank diameter IH	510 mm
# of RFQ cells	97
# of IH gaps	8
Input energy	120 keV
Input emittance (norm. rms)	0.56 π mm mrad
Electrode voltage (RFQ)	75 kV
Max. gap Voltage IH-DTL	300 kV
Exp. Power consumption RFQ	150 kW ←
Exp. Power consumption IH	45 kW ←
Current	max. 200 mA
Output eenergy RFQ	700 keV
Output ebergy IH	2 MeV
Coupling factor	0.03

proton source



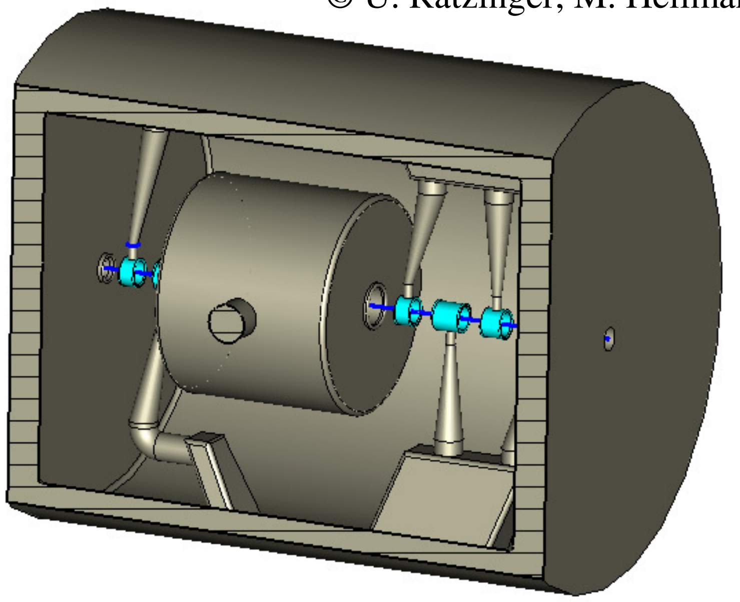
LEBT RFQ



IH-DTL and CH-Rebuncher

final energy 2 MeV

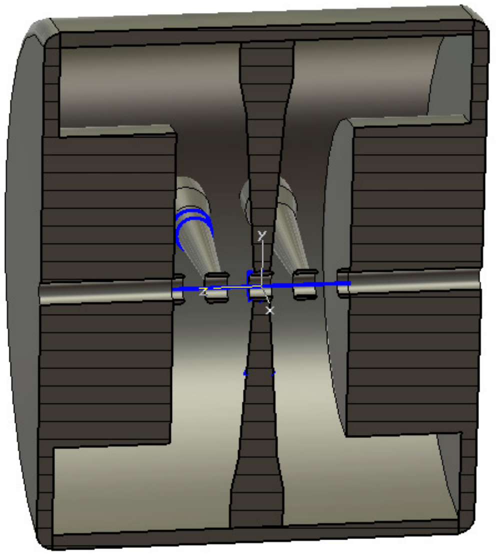
© U. Ratzinger, M. Heilmann



8 gap and internal msq triplet
output beam enrgy 2MeV

energy variation ± 0.2 MeV

© H. Podlech, A. Metz

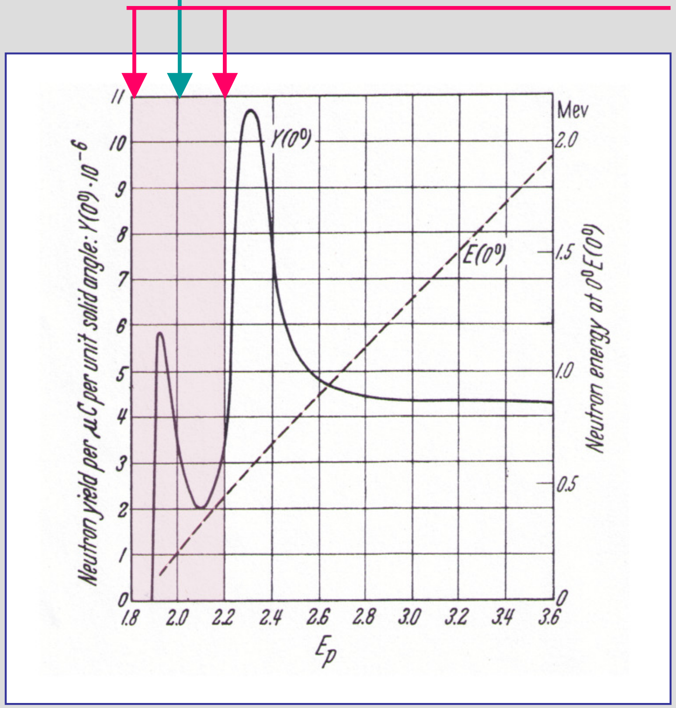


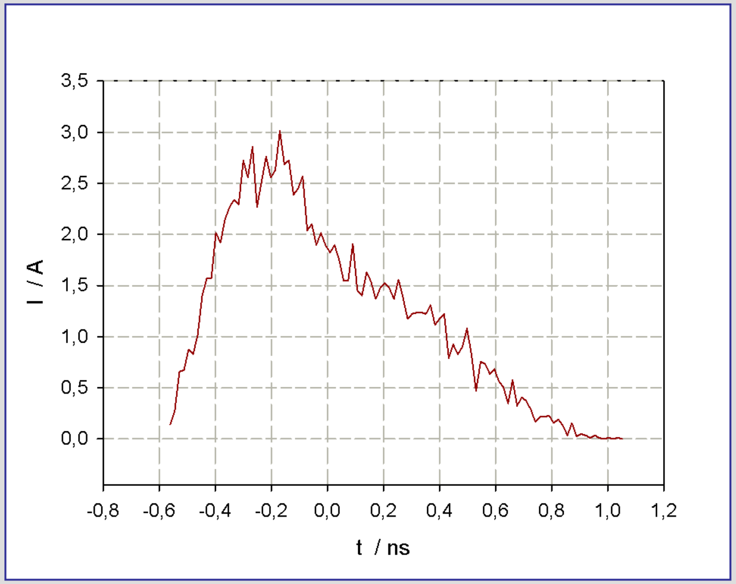
CH type cavity 4gap

Properties of a single micro bunch downstream of the accelerator

RFQ-IH E_p = 2 MeV

CH $\Delta E_p = \pm$ 0.2 MeV





microbunch current distribution (simulated)

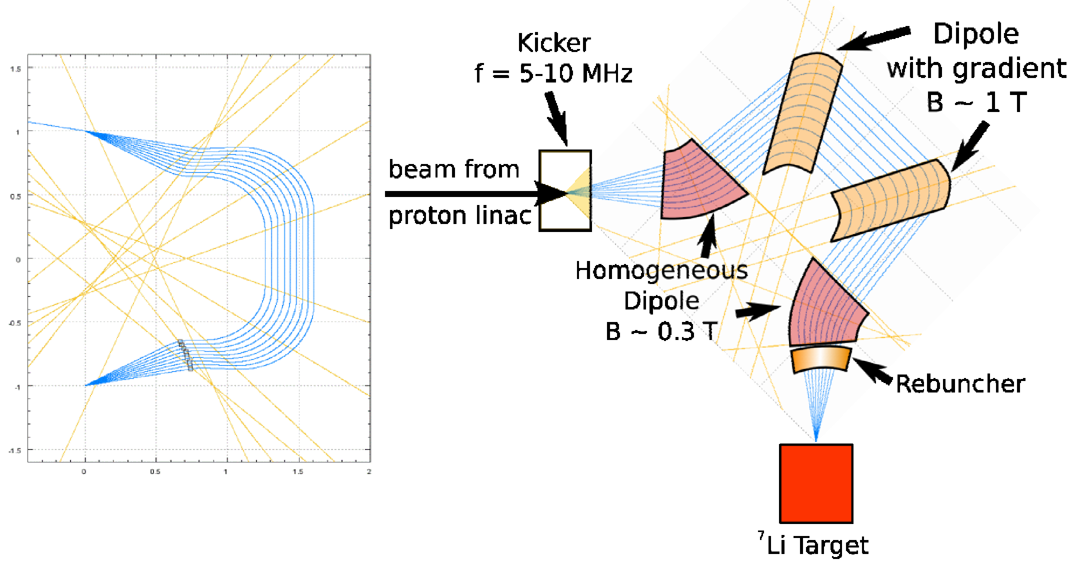
compression ratio $\eta = 6$

gen. Perveance $K = 2.7 \cdot 10^{-4}$

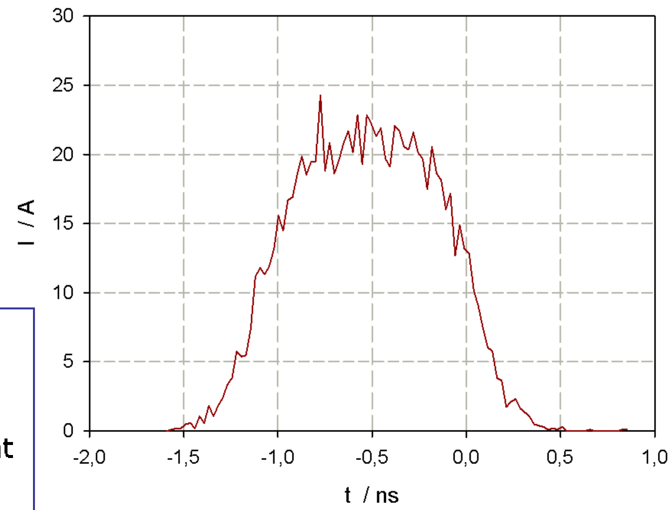
$n_p = 1.2 \cdot 10^{15}$ m^{-3}

Bunch Compressor

Layout based on Mobley - typ bunch compressor



scheme of the bunch compressor



compressed micro bunch current distribution (simulated)

compression ratio $\eta = 48$

gen. Perveance $K = 2.2 \cdot 10^{-3}$

$n_p = 9.75 \cdot 10^{15}\ m^{-3}$

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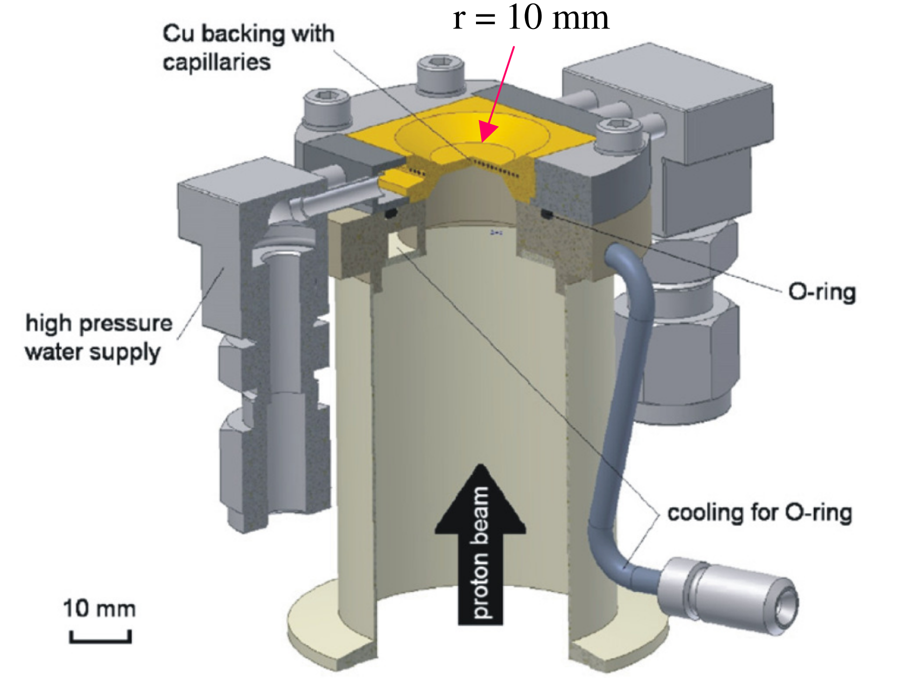
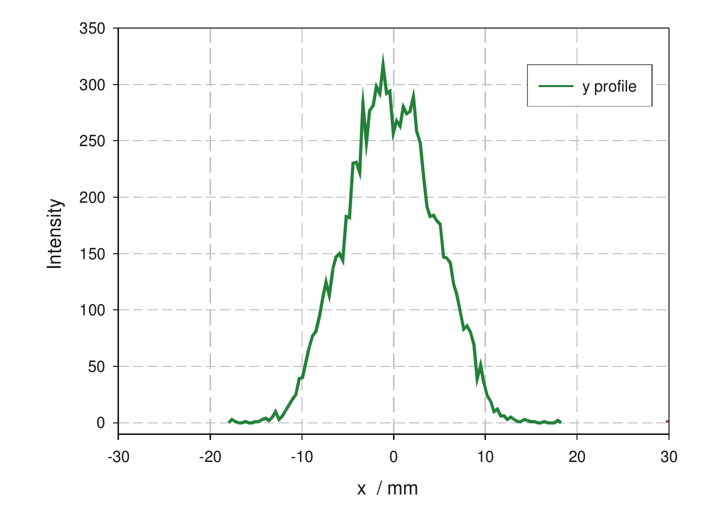
Development of high power target at FZ Karlsruhe and KALLAS - Laboratory

© D. Petrich, F. Käppeler



target prototype for beam power up to 6 kW



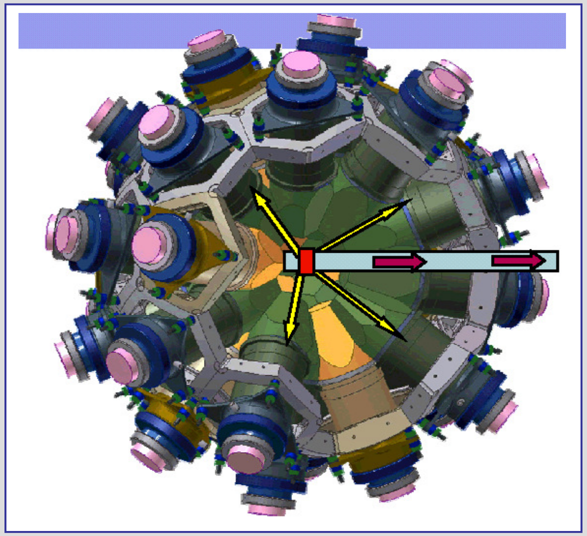
transverse beam profile (simulated)

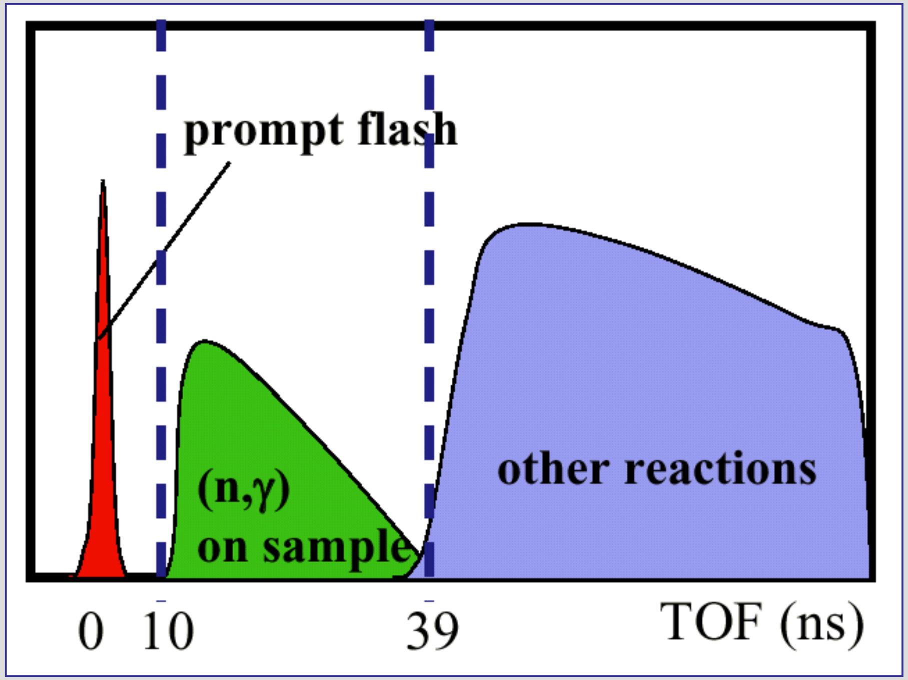
avg. power ~ 4 kW

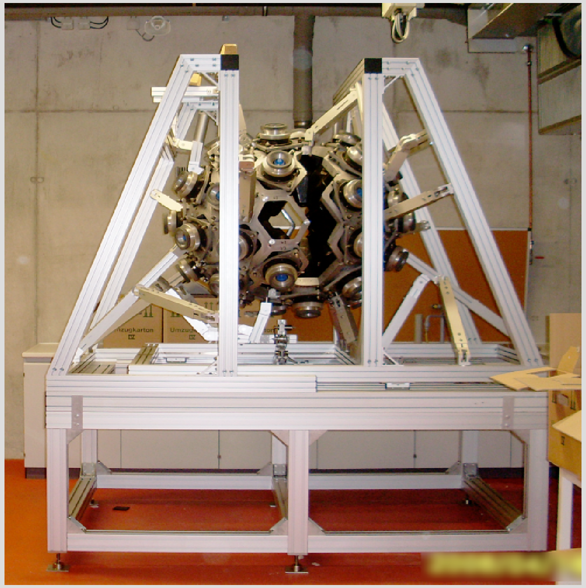
peak power ~ 20 MW

$4\pi BaF_2$ Detector Array

- high granularity (#43) to reduce count rate per module
- fast timing (600 ps) to achieve acceptable TOF resolution
- good energy resolution
- low neutron sensitivity







Systems Perspective

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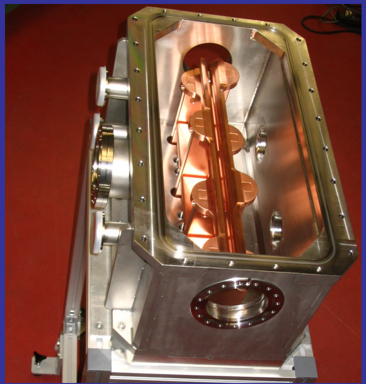
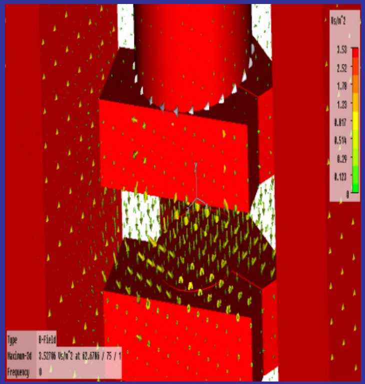
source is constructed

LEBT vacuum tests

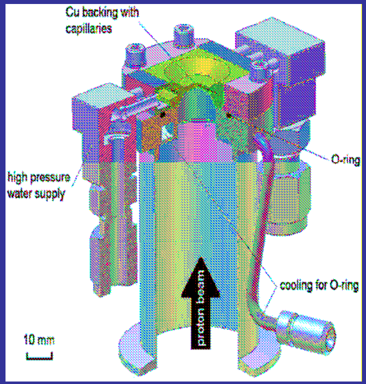
RFQ test module



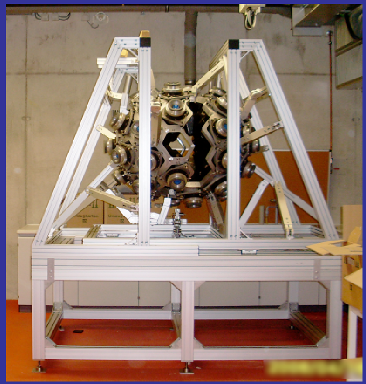
First Beam 2010



compressor design



high power target test



detector reassembled

Thank you for your attention.

on behalf of:

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acknowledgment:

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NNP-AG http://nnp.physik.uni-frankfurt.de

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