Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
Nationales Metrologieinstitut

research instruments

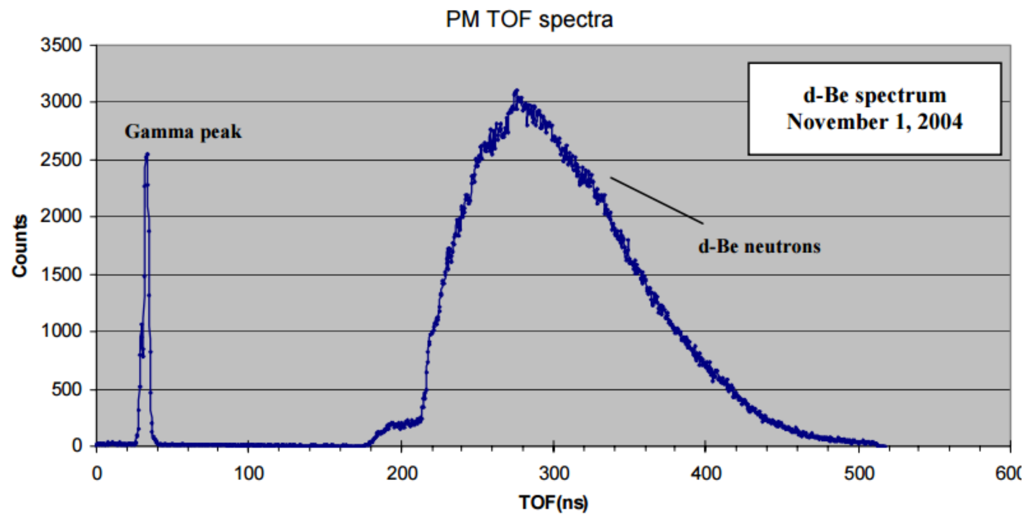
Development of a compact, intense and ns-pulsed neutron source for neutron radiography

UCANS V, May 12-15 2015

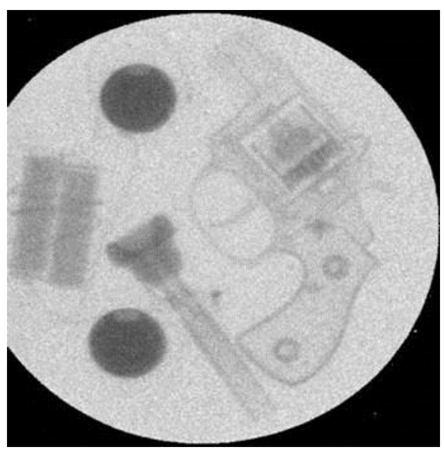
Benjamin Bromberger, Physikalisch- Technische Bundesanstalt (PTB)
and RI Research Instruments GmbH

Fast Neutron Radiography

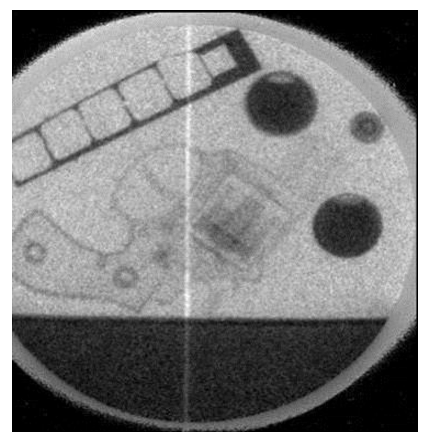
=>employing integrated total neutron flux

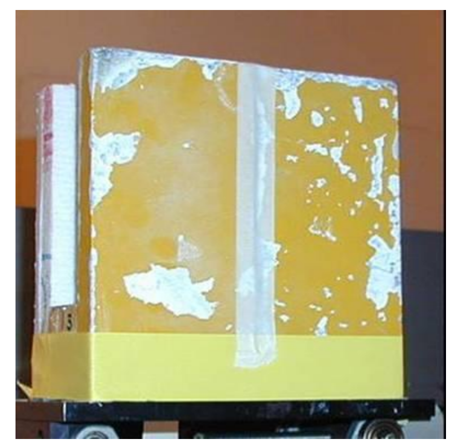


Phantom



Fast neutron image

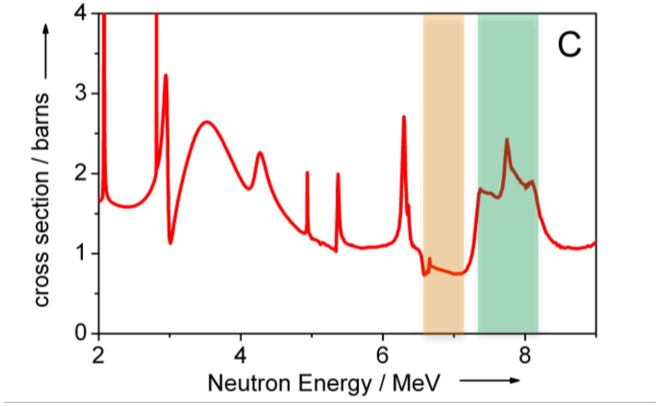


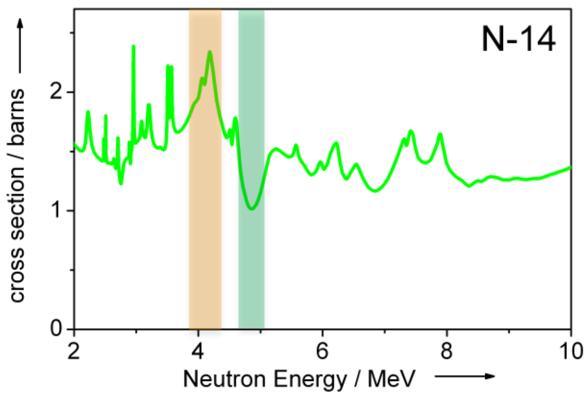


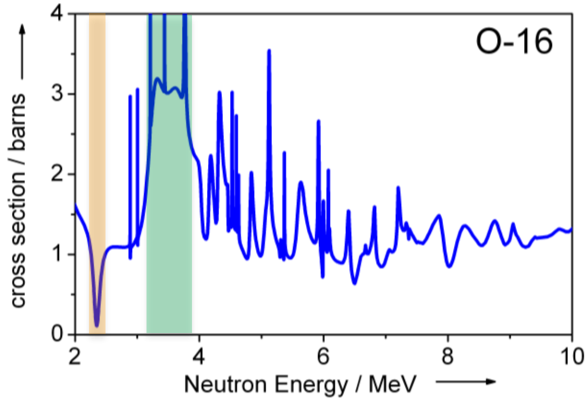
Different Phantom behind 1” thick lead bricks

Fast Neutron Resonance Radiography

=>employing energy windows of total neutron cross-sections

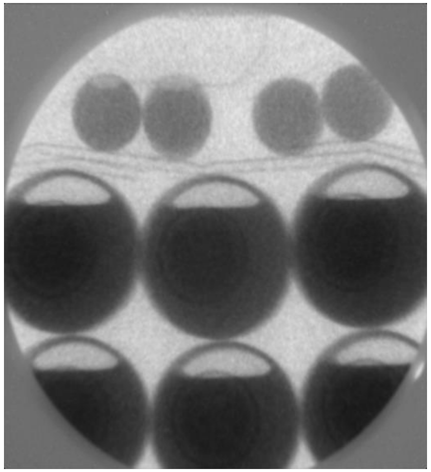




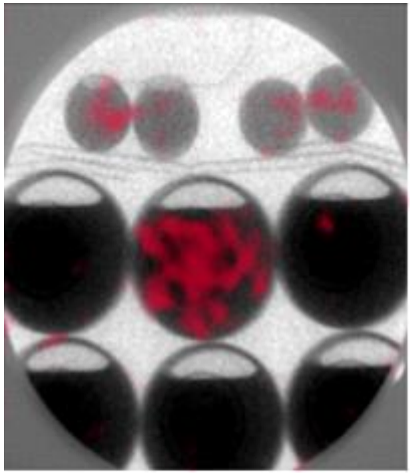


Propionic Acid (TATP simulant)

Picture of milk and TATP bottles



neutron radiograph



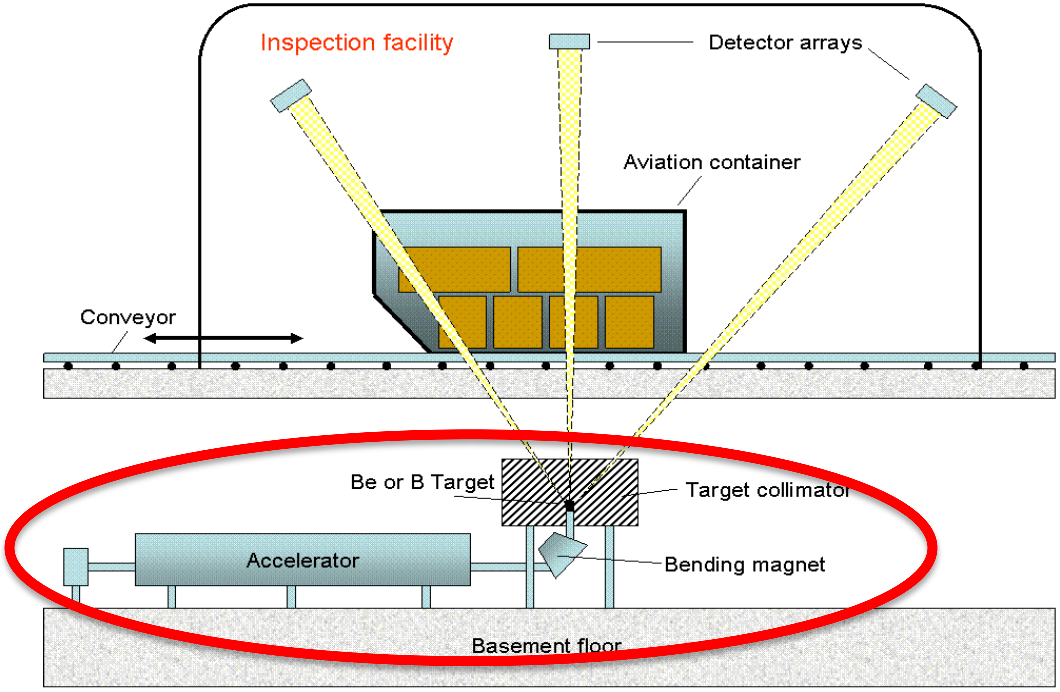
reconstructed FNRR image

Automated Cargo-Container Inspection System

$^{11}B(d,n+\gamma)^{12}C$ – Deuteron Energy 3-8 MeV

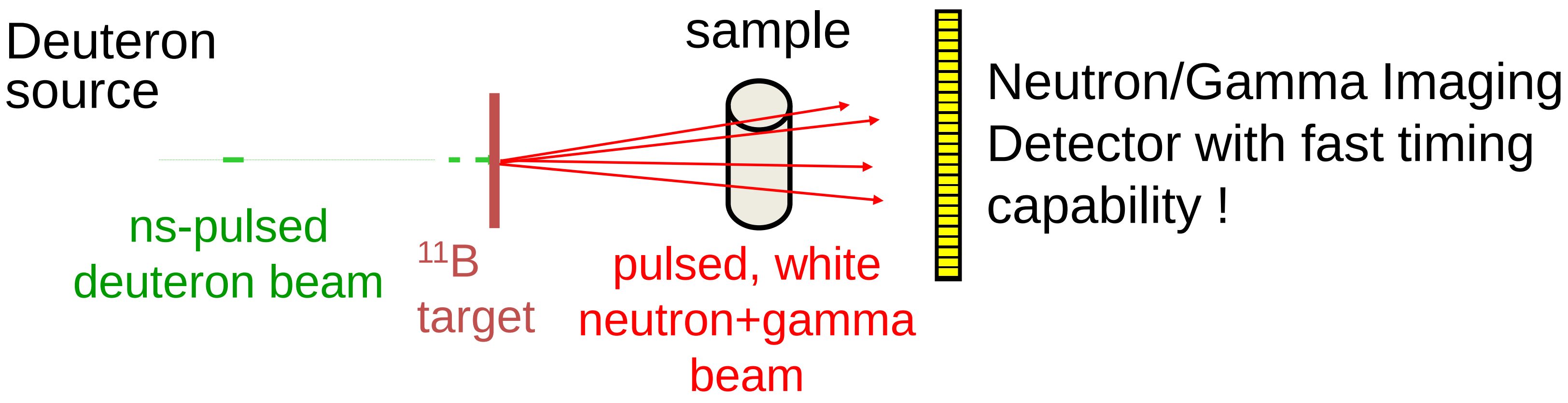
4.43, 15.1 MeV γ-rays
Dual **D**iscrete **E**nergy
Gamma **R**adiografie
=> SNM detection

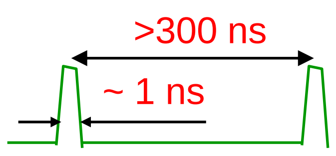
0-17 MeV neutron spectrum
Fast **N**eutron
Resonance **R**adiografie
=> Explosives detection

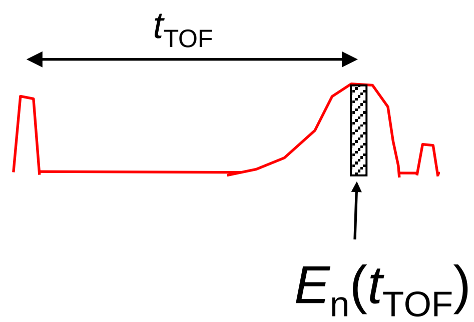


- (Semi-) Automatic Inspection
- Isotope specific Detection
- Combined Explosives & SNM Detection

Essential: TOF Measurements







$$E_N = \frac{m_N d^2}{2 \cdot t_{TOF}^2}$$

<u>Deuteron pulse:</u>

1 ns Pulse length

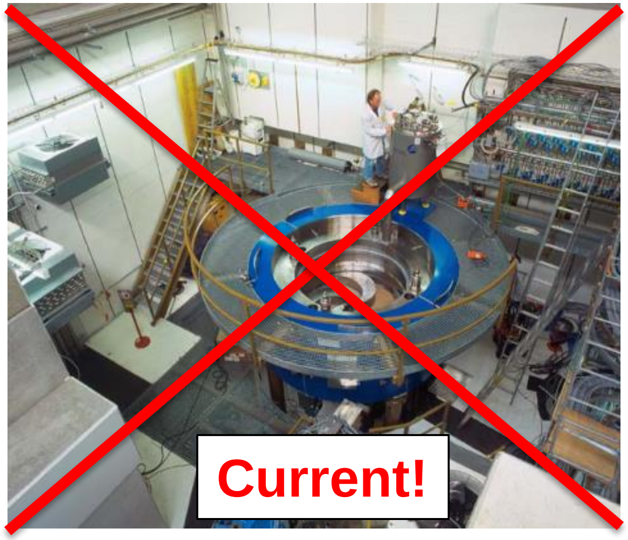
>300 ns Pulse distance

→ Time-of-Flight determines neutron energy and discriminates n/γ

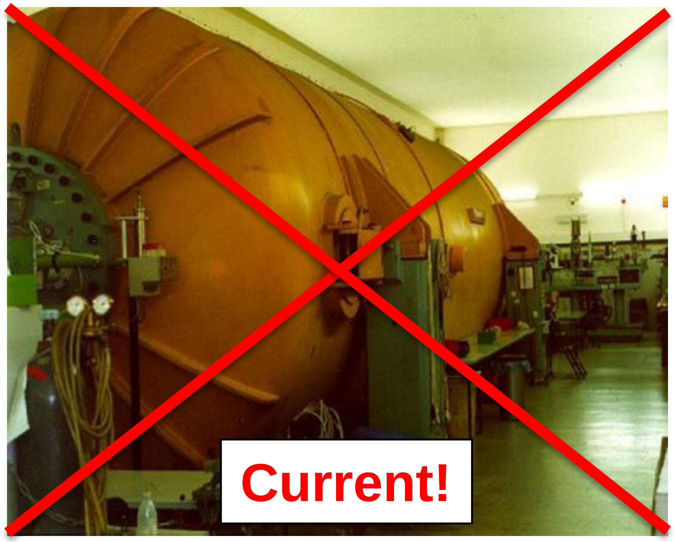
Accelerator System Parameters

- Required deuteron energy **5-7 MeV**
- Focal spot < **5 mm** (to detect thin-sheet explosives)
- Timing structure (**1-2 ns** pulse width, < **3 MHz** rep. rate)
- Required deuteron current **~ 600 µA** (time average) or **~200 pC** (per bunch)
- possibly **compact and light weight** (**mobile** or **relocatable**)

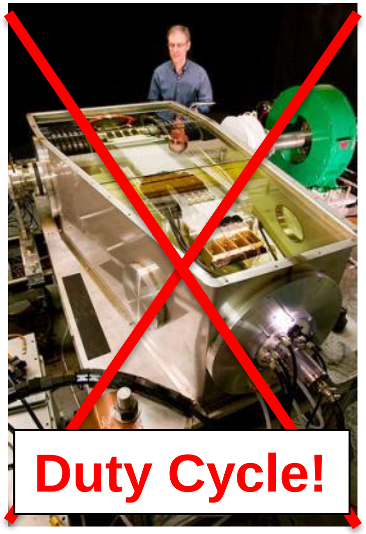
Possible Accelerator Systems



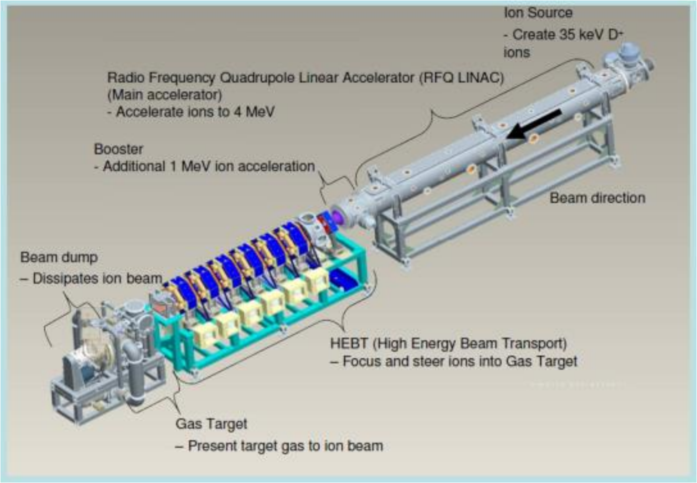
VARIAN **Cyclotron** 250MeV @ PSI



10 MV **Tandem** @ University of Cologne



100 MeV **DWA** @ LLNL

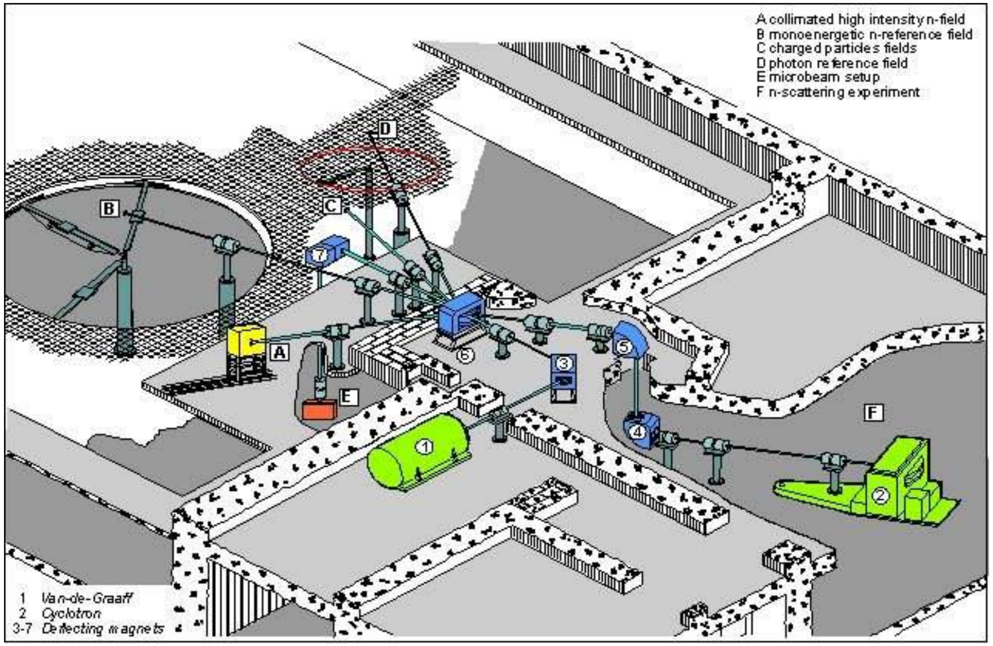


5 MeV, 50 mA, 200 MHz **RFQ** @ NECSA

Single Pulse Injection!

Existing Expl. Detection Systems

Present Workbench:



PTB:

- Cyclotron
- Be(d,n) / $^{11}B(d,n+\gamma)$
- E_d = 12 MeV
- I_d ca 2 uA
- 1.7 ns pulse width, 2 MHz rep rate

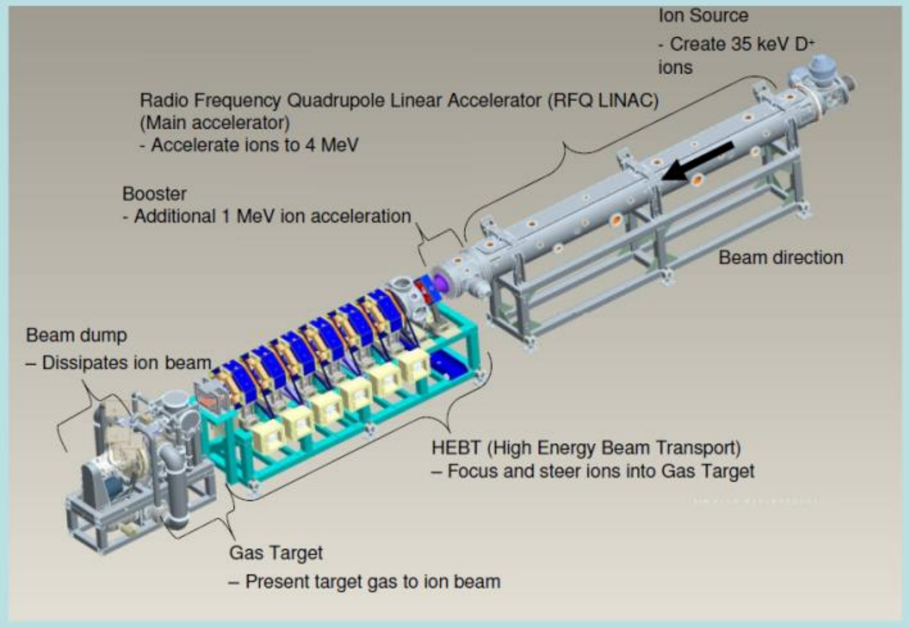
n-Flux: ~ 2* 10^4 s^{-1} cm^{-2} (Be)

Future Workbench:

DWIK @ NECSA, South Africa:

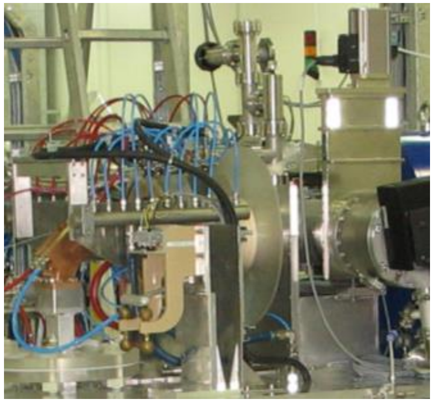
- RFQ
- $^{11}B(d,n+\gamma)$
- E_d = 5.0 MeV
- I_d up to 450 uA (average)
- But: Pulsing system has to be designed
- <2 ns pulse width, 3 MHz rep rate

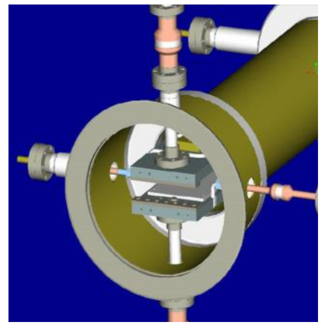
expected n-Flux: **~ 10^5 s^{-1} cm^{-2} (B^{11})**

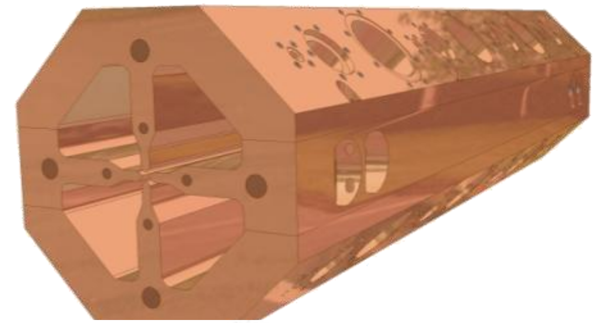


Pulsing: First Approach

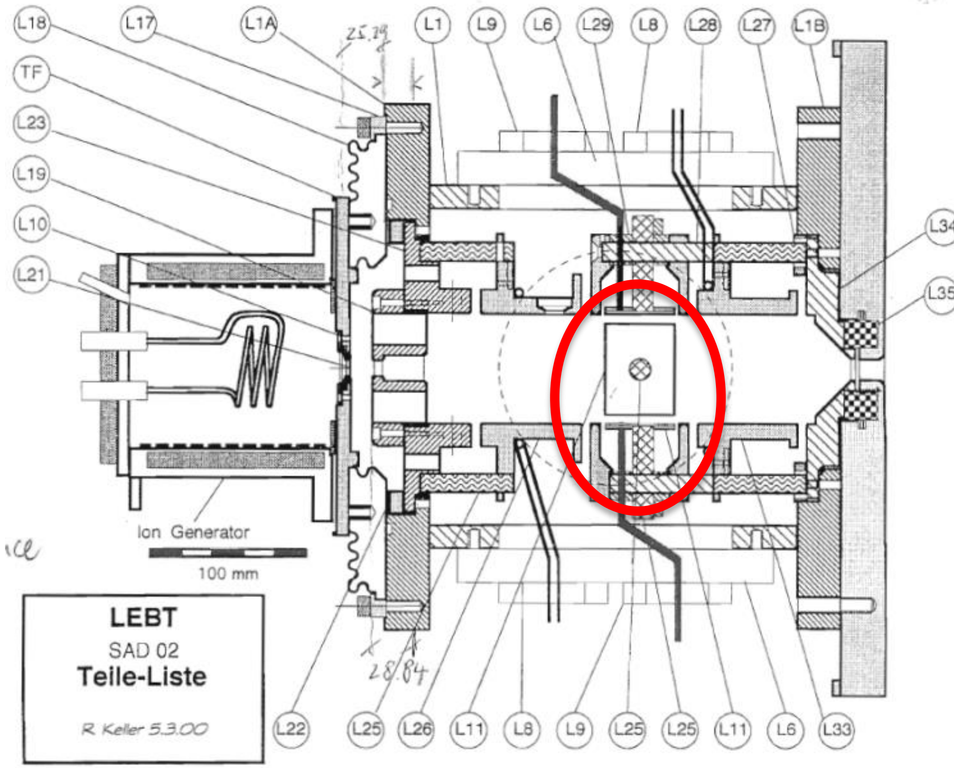
Pulse selector RFQ Target





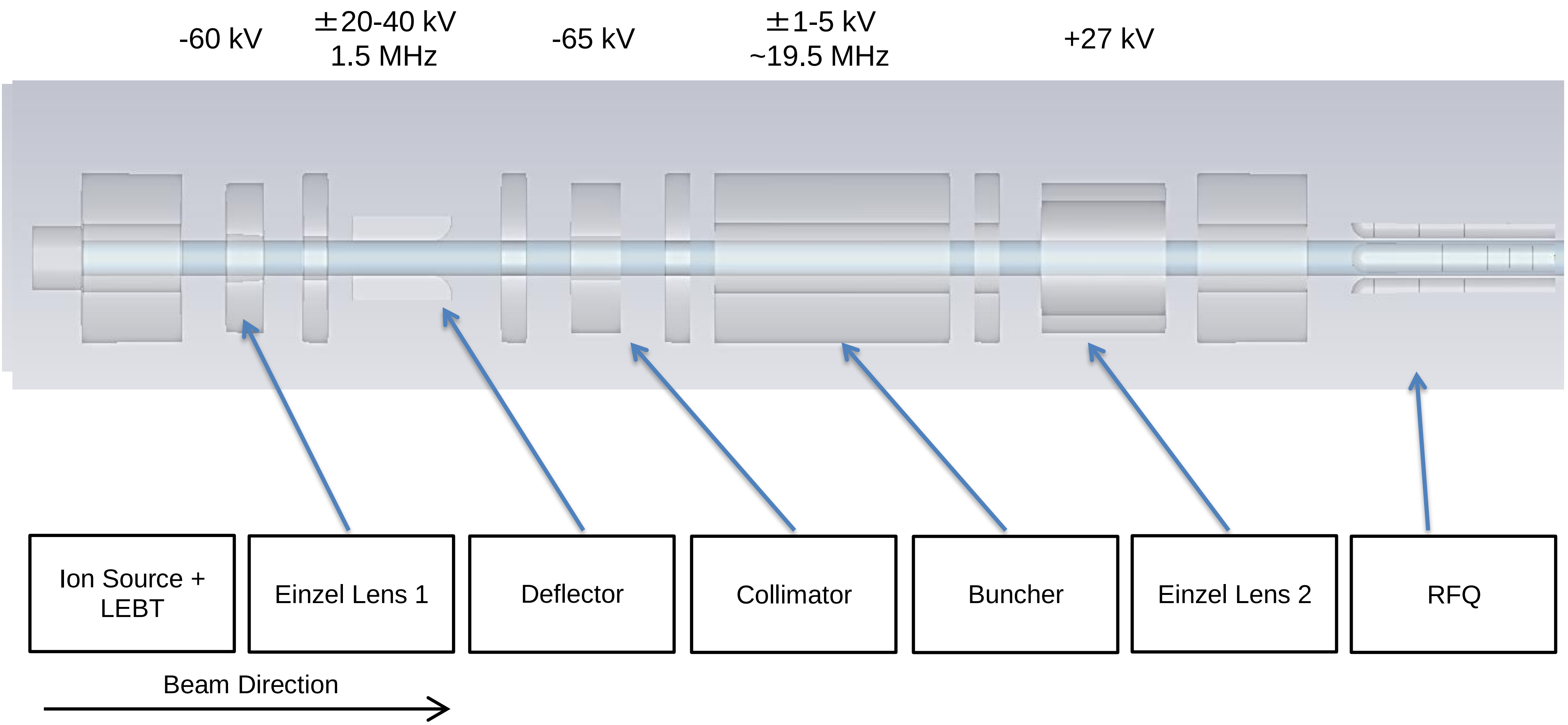


250ns

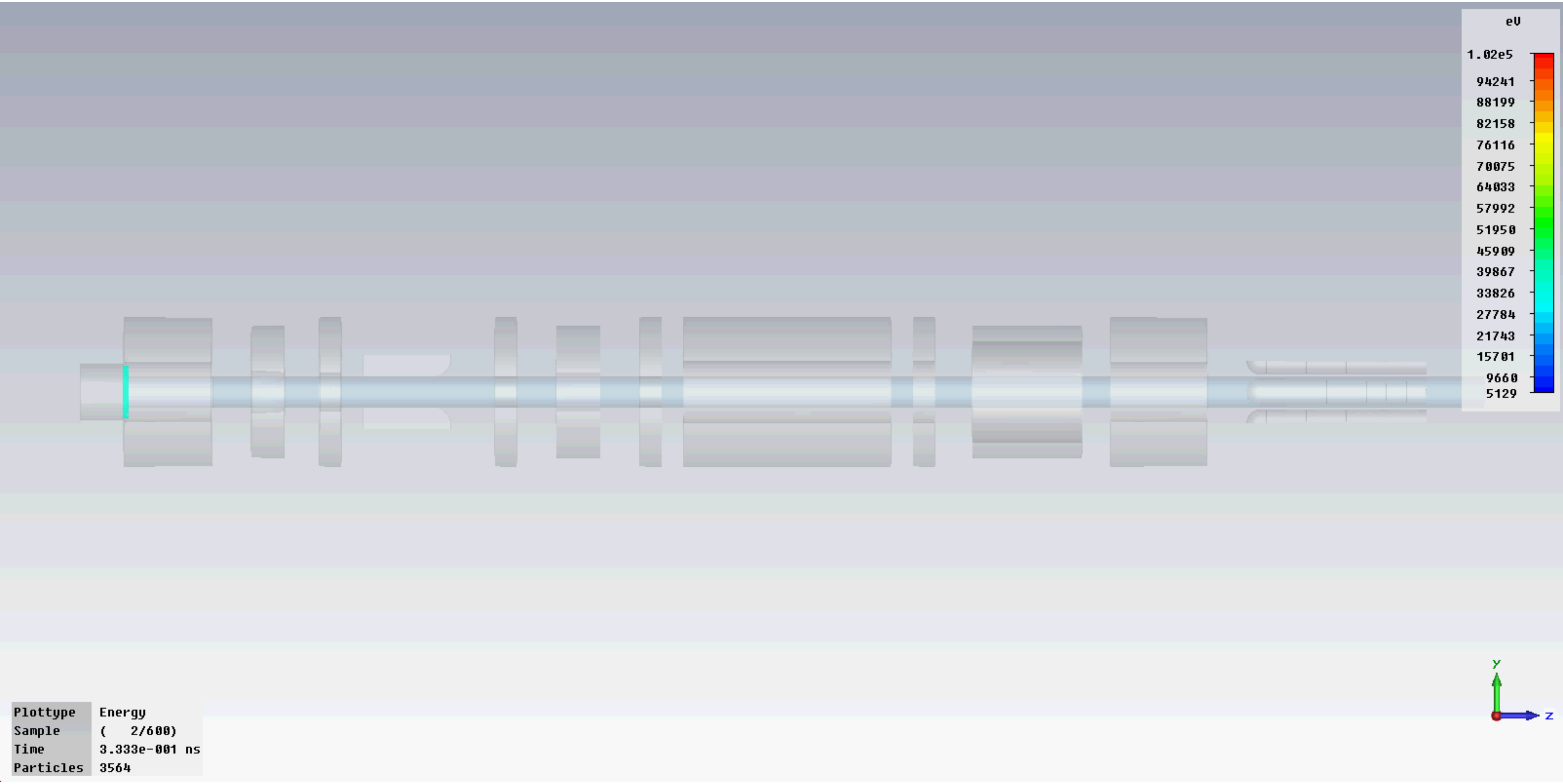


NECSA Ion Source
+ LEBT

Design of Pulsing System

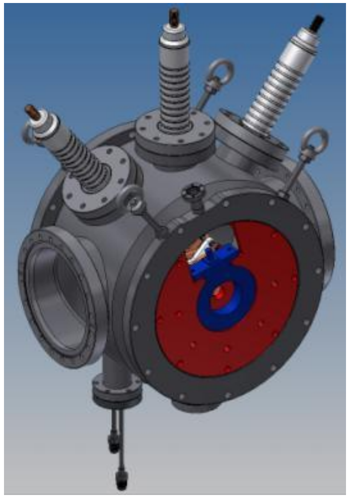


Deflector Simulation

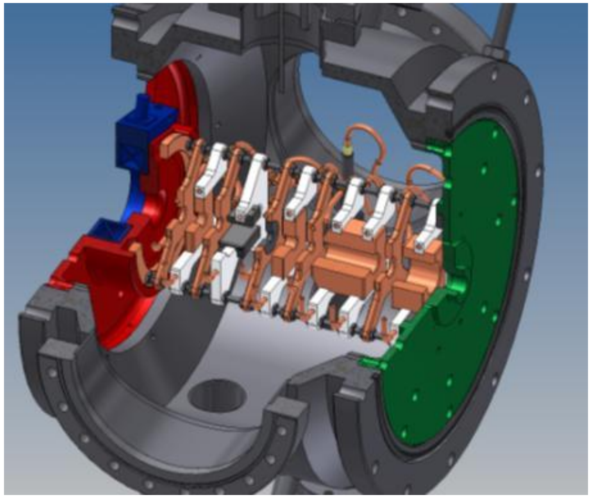


- Buncher focus not optimized!
- RFQ Disabled
- ~350 pC in bunch!

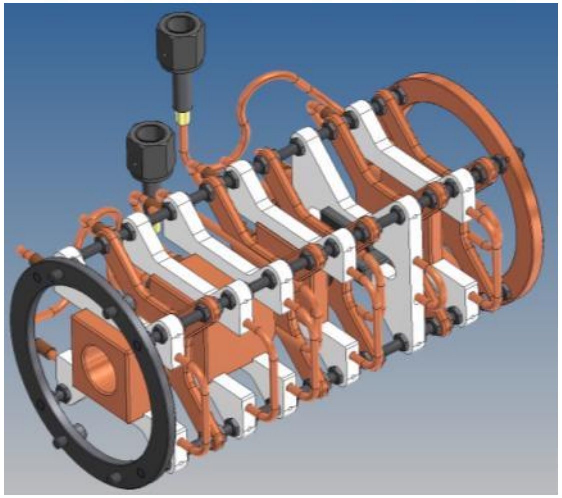
Design/Manufactoring of Chopper



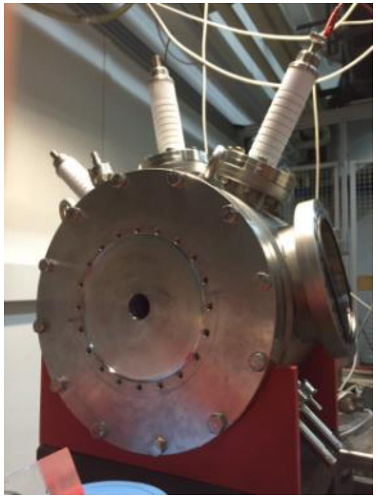
Exterior view

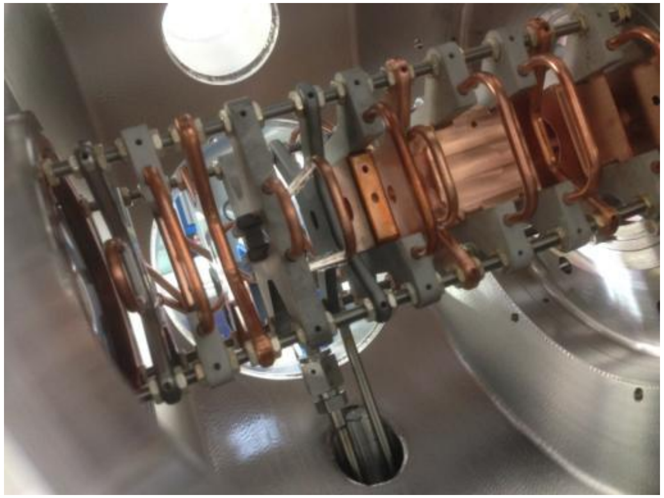


Interior view

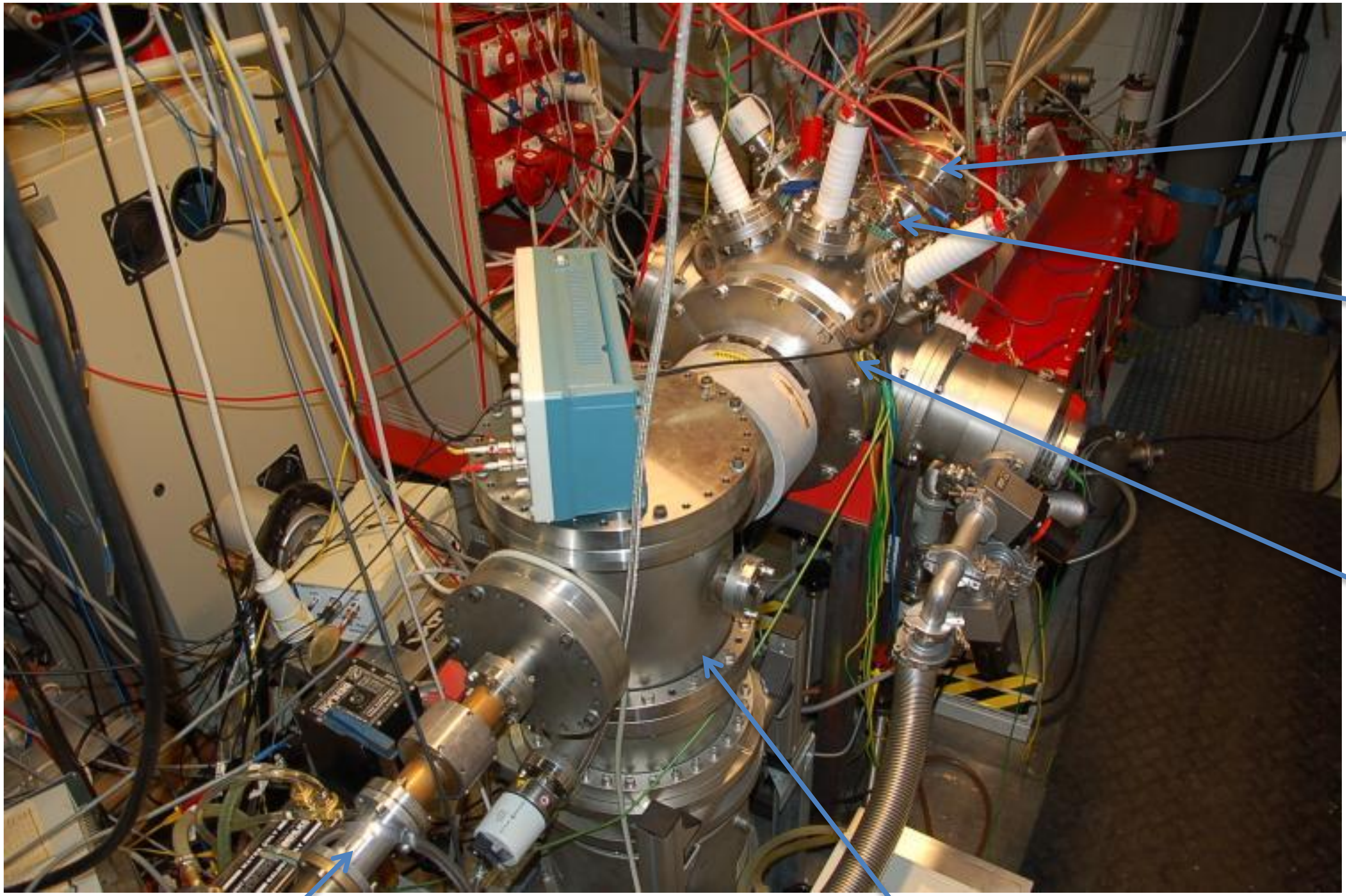


Inlay

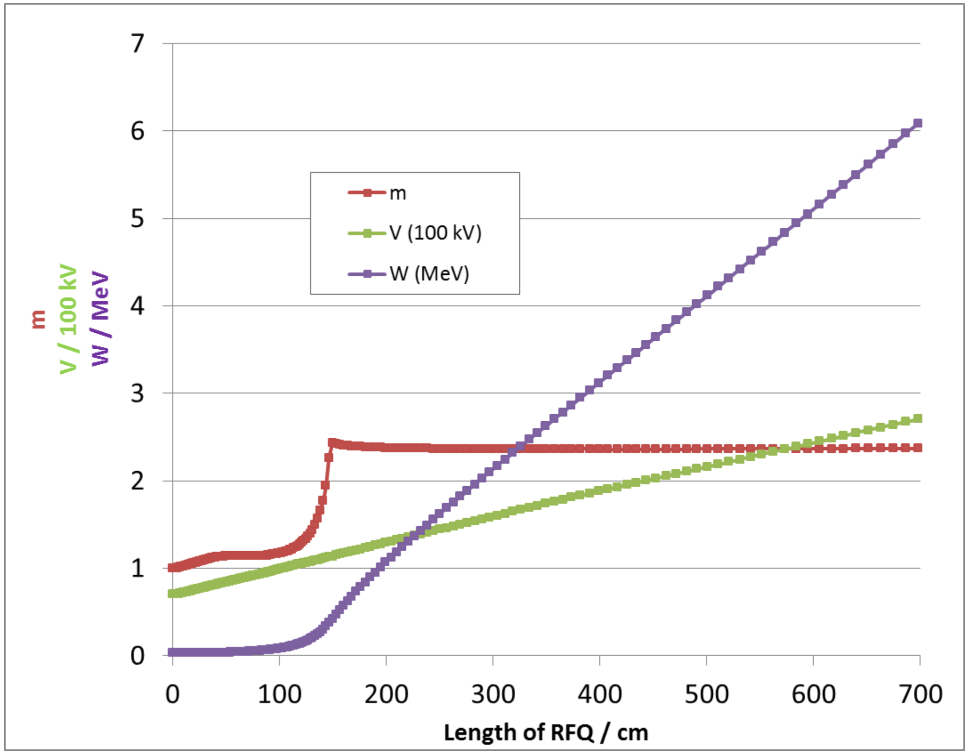


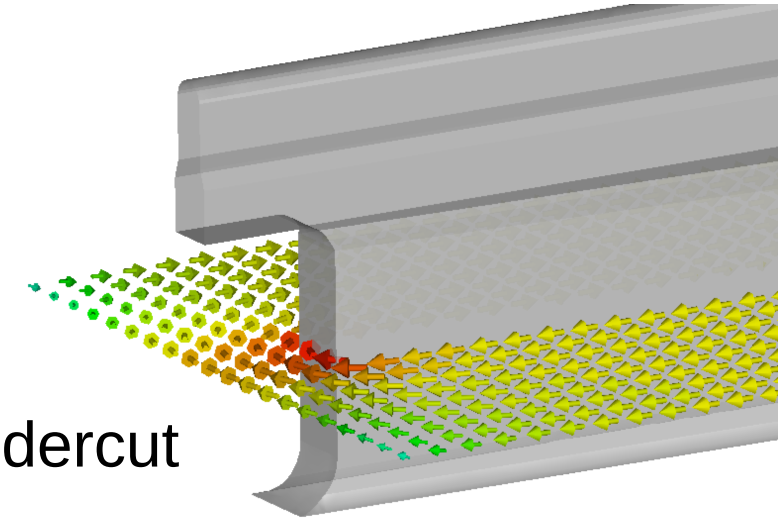


Recent Setup @ PTB Test Bench

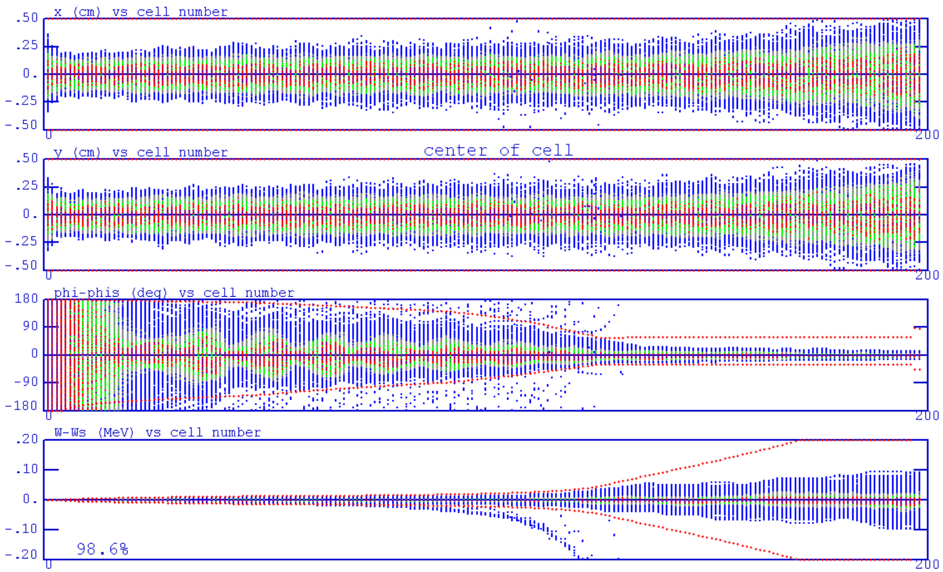


ACCIS-RFQ Design Study





Undercut



Simulation

- 100 MHz, 6 MeV, 20 mA, D^+
- Vane Type
- Octagonal Shaped
- Voltage Ramp -> 7m length
- 420 kW Dissipated Power

Summary

- RFQ is accelerator of choice for fast neutron radiography/tomography
- Essential for FNRR: Single Pulse Injection
- Pulsing System combining chopping and bunching designed
- Pulsing System just in Conditioning/Testing Phase
- Future: Implementation and final test at Necsa RFQ
- ACCIS RFQ Design as a distinct Neutron Radiography Accelerator

Thank you for your attention!