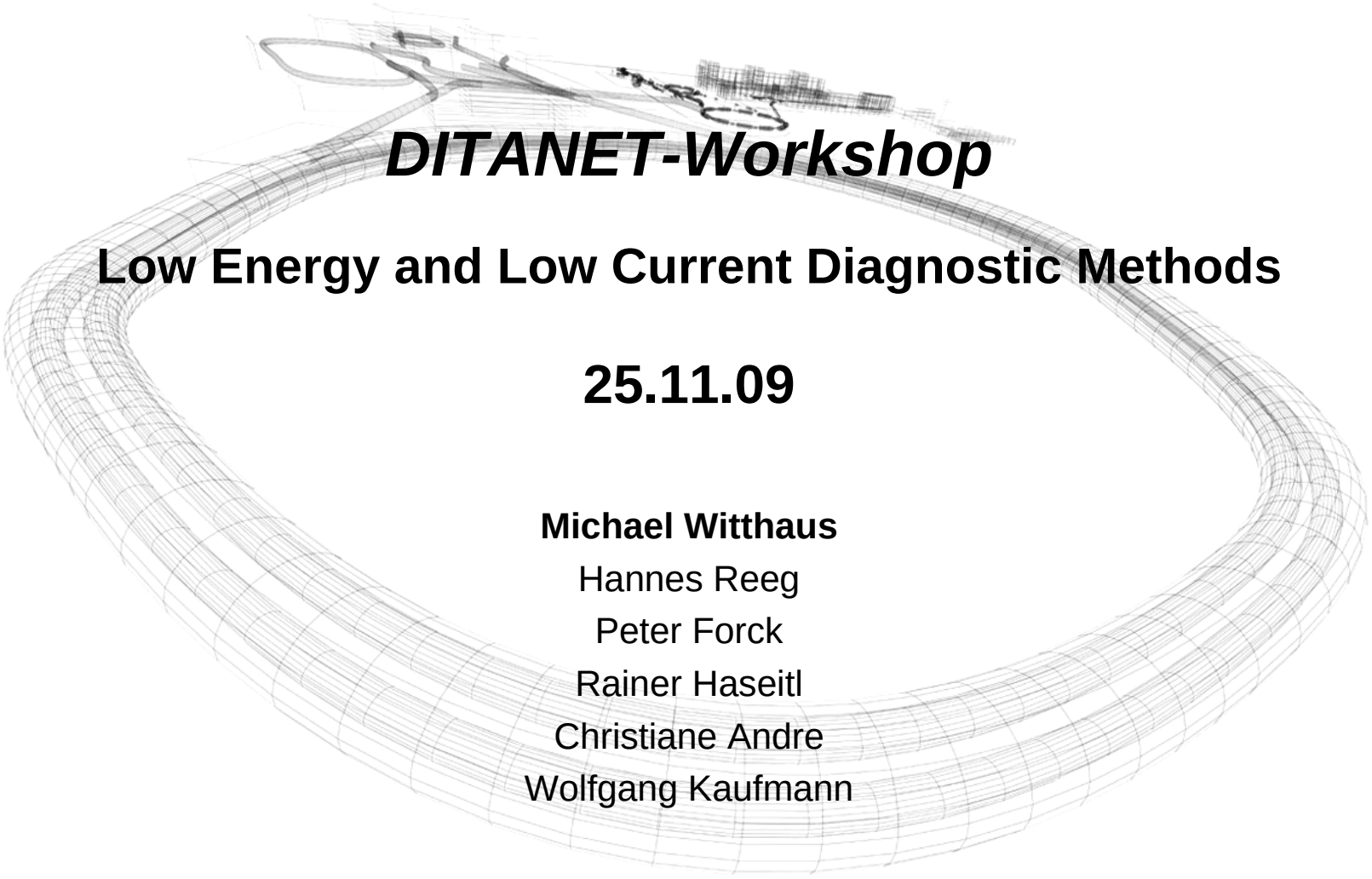
Beam Diagnostics for Decelerator HITRAP



DITANET-Workshop

Low Energy and Low Current Diagnostic Methods

25.11.09

Michael Witthaus

Hannes Reeg

Peter Forck

Rainer Haseitl

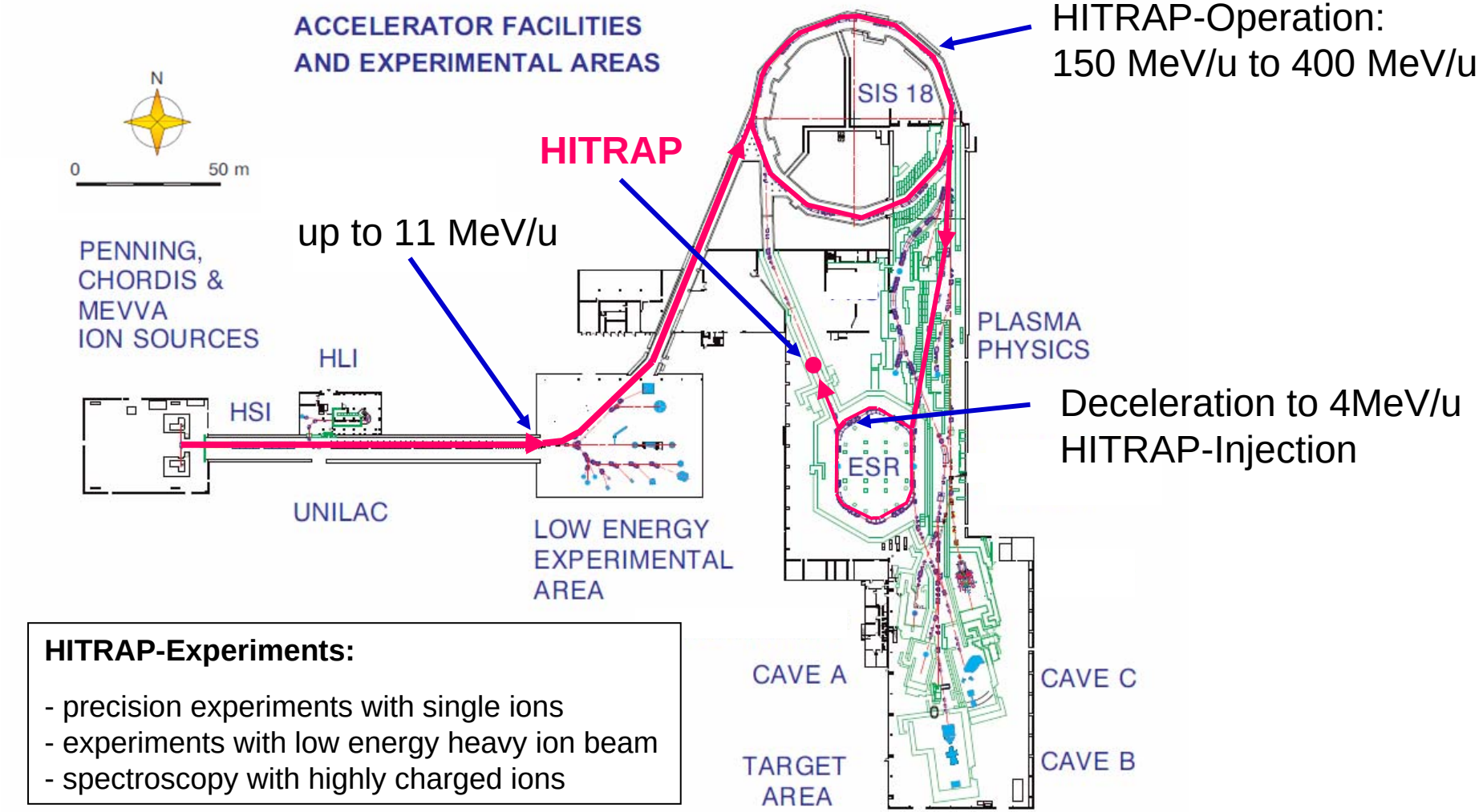
Christiane Andre

Wolfgang Kaufmann

Overview

- HITRAP-facility
- Beam Diagnostic Devices
- Measurement-Results
- Summary and Outlook

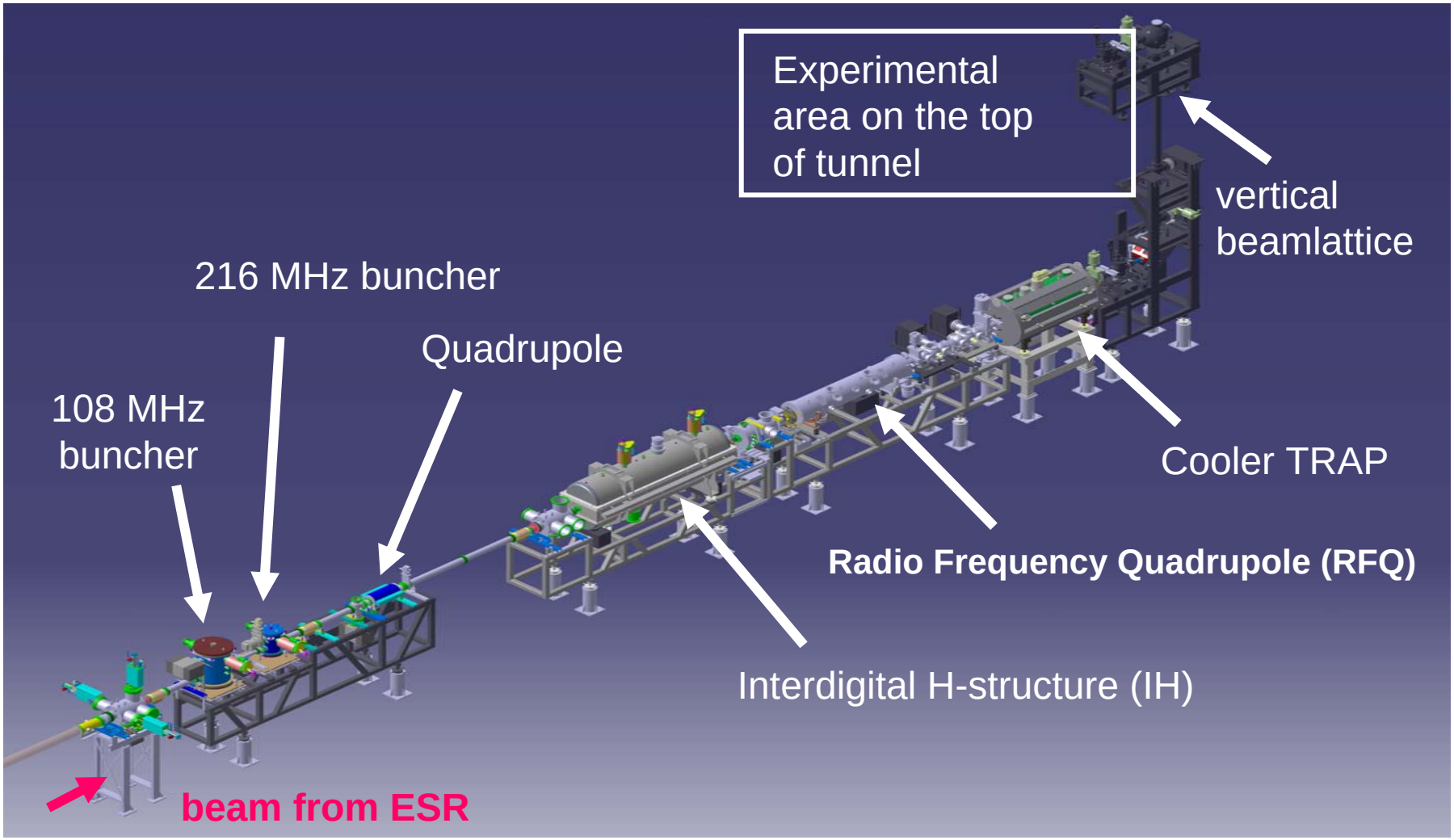
HITRAP



HITRAP-Experiments:

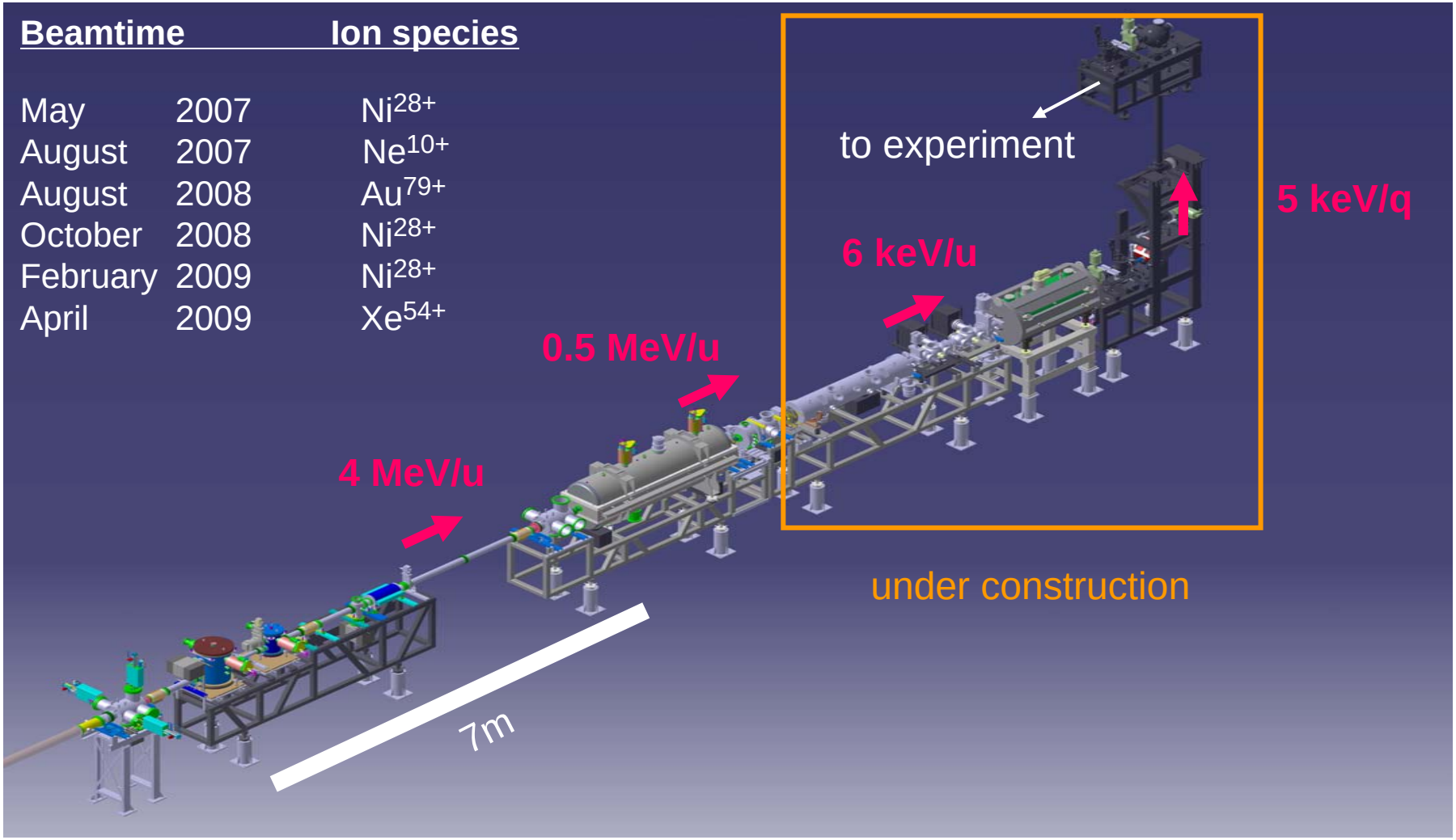
- precision experiments with single ions
- experiments with low energy heavy ion beam
- spectroscopy with highly charged ions

HITRAP - Beamline



HITRAP - Beamline

Beamtime		Ion species
May	2007	Ni^{28+}
August	2007	Ne^{10+}
August	2008	Au^{79+}
October	2008	Ni^{28+}
February	2009	Ni^{28+}
April	2009	Xe^{54+}



Beam Diagnostics of HITRAP

Objectives of Beam Diagnostics (BD) for HITRAP:

- beam intensity (transmission through beamline)
  - ▶ Faraday cups
- beam position and profile
  - ▶ scintillation sreens, harp systems
- detection of particles and energy
  - ▶ Faraday cups, capacitive pick ups

⇨ Different beam diagnostic devices are necessary

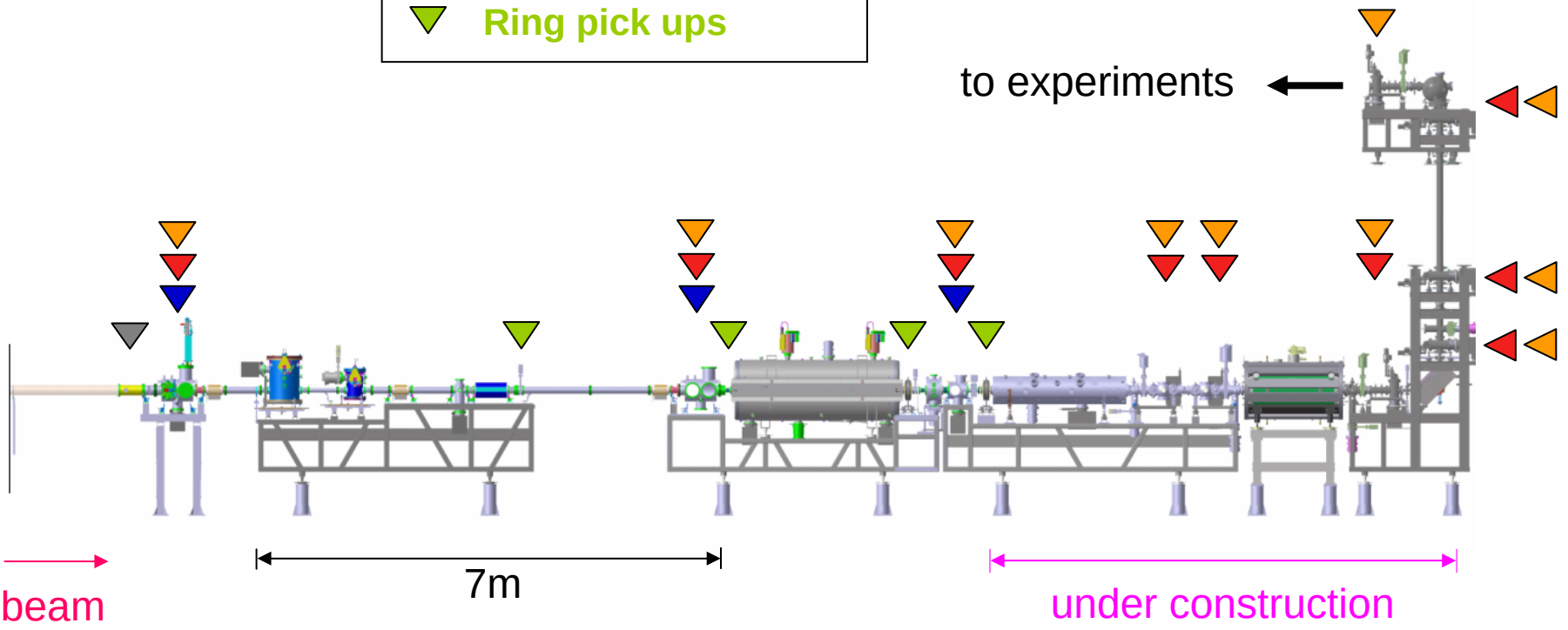
Challenges:

- low beam intensity (~1E6 ions / pulse; µA -range)
- low repetition rate (1 pulse in ~ 70 sec., via ESR)
- single beam pulse with length of 3 µs

Locations of HITRAP Beam Diagnostic

Overview:

- Faraday cups
- Scintillation screens
- Harps
- „Tubular" pick ups
- Ring pick ups

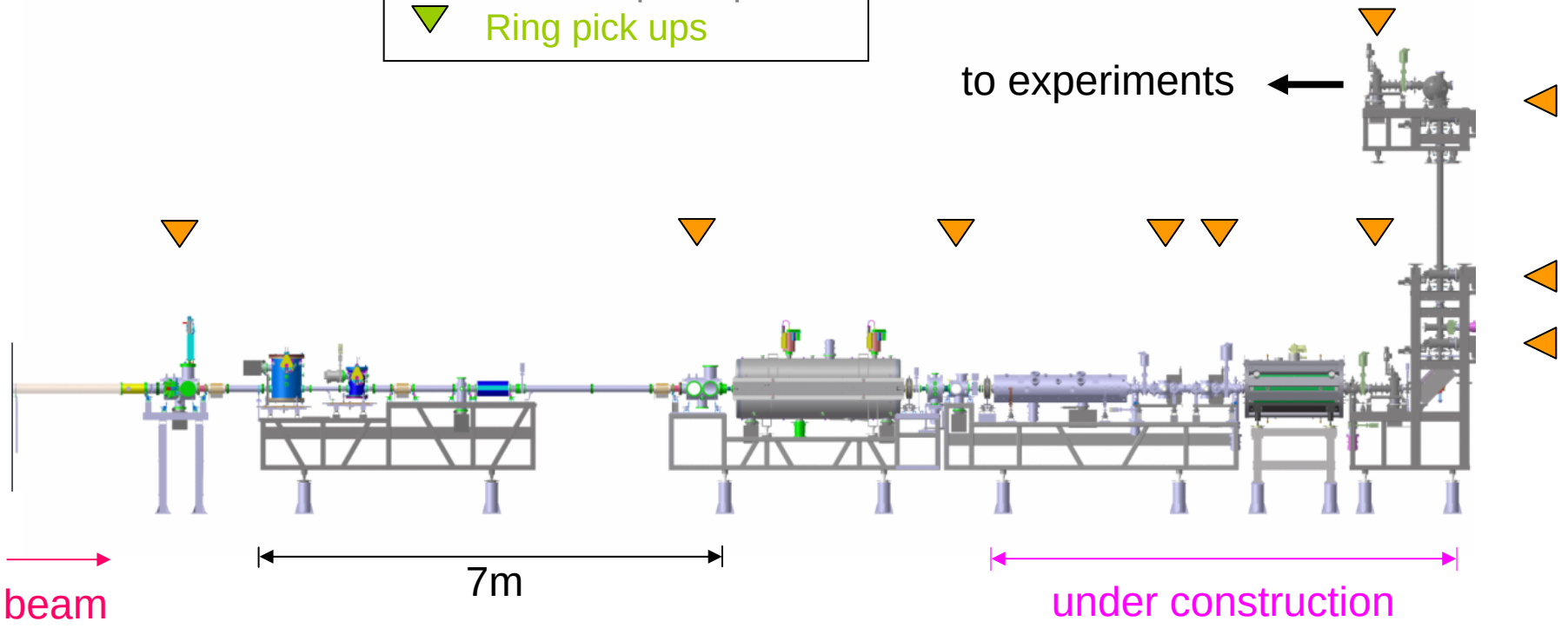


two bunchers IH-structure RFQ TRAP

Locations of Faraday Cups over HITRAP Lattice

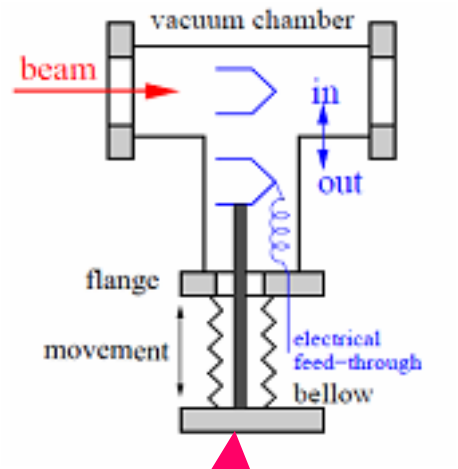
Overview:

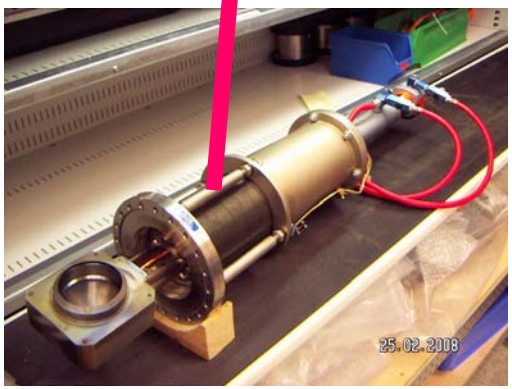
- Faraday cups
- Scintillation screens
- Harps
- „Tubular" pick ups
- Ring pick ups



Faraday Cup

Mechanics

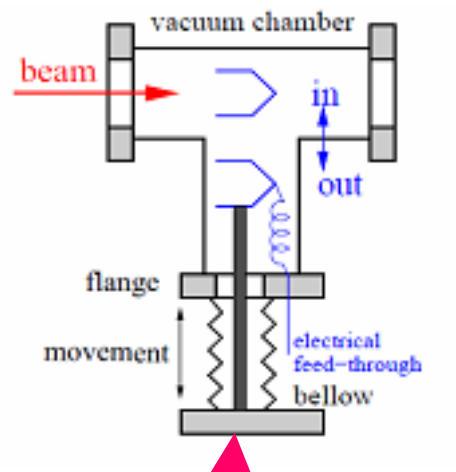


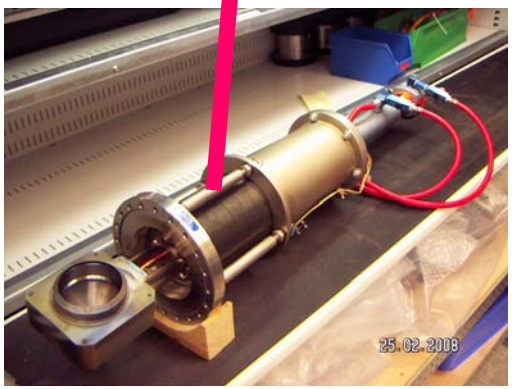


pneumatic drive

Faraday Cup

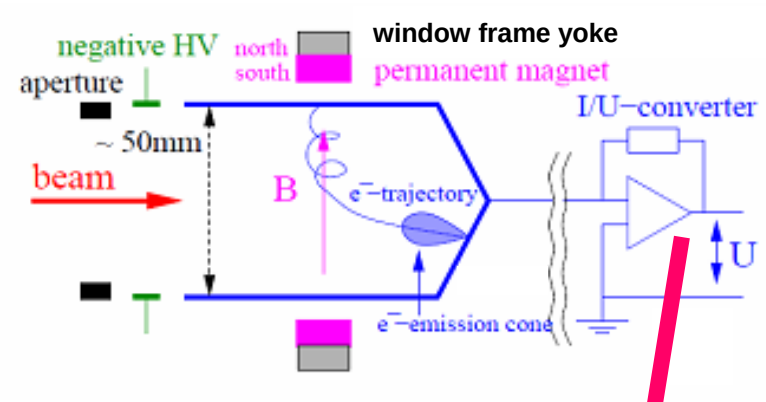
Mechanics



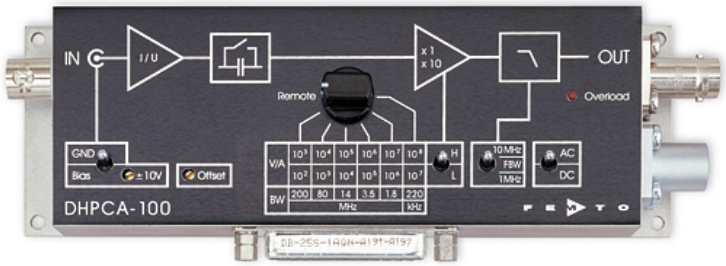


pneumatic drive

Electronics



Scheme of Faraday cup



transimpedance amplifier from FEMTO (Berlin)

Range: 10nA to 10mA Output: 1V f.s. (50 Ω load)

Farady Cup – Data Acquisition

4 FCs are installed

USB-Digital I/O-Box

PC with LabVIEW at HITRAP container

FC 1

FEMTO 1

USB-DIO96H (NI)

FC 1+n

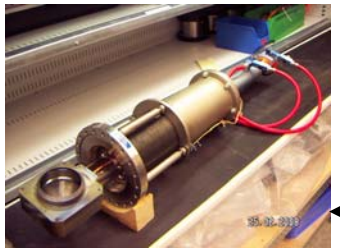
FEMTO 1+n

Relay Multiplexer

FEMTO-Amplifier

LeCroy 6100A Oscilloscope

Remote-Desktop-PC at CR

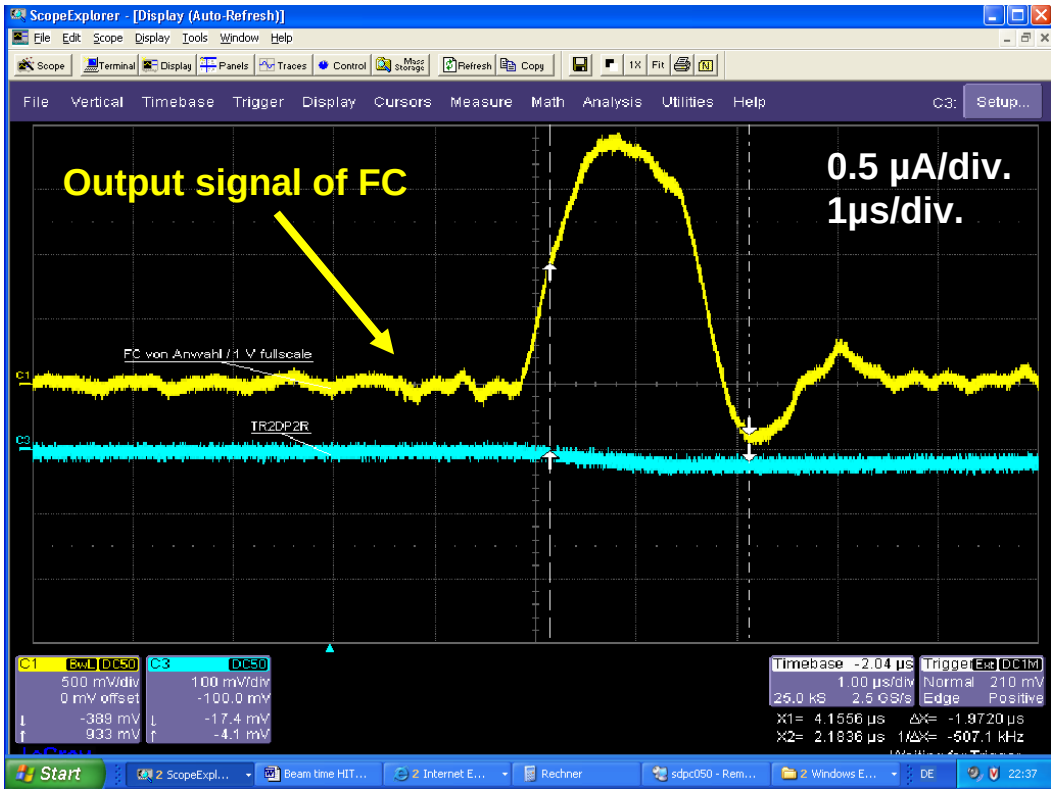


Pneumatic drives are controled by operator at control room (CR).

FC-Measurement-Results

- Hardware was reliably operating
- Time-resolved measurements of low currents
- Transmissions can be calculated

Ne^{10+}, ~1.8E6 particles, 1.5µA

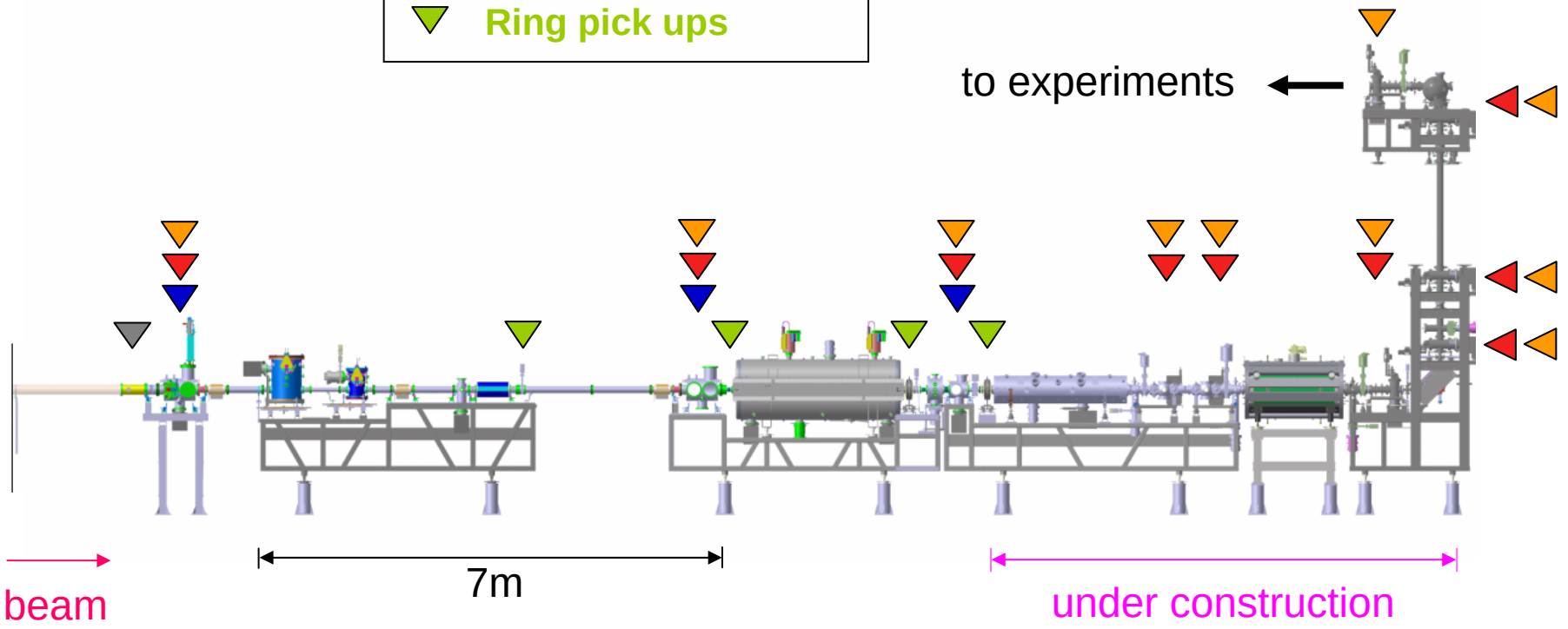


Faraday cups are very helpful for beamline setups

Locations of HITRAP Beam Diagnostic

Overview:

- Faaraday cups
- Scintillation screens
- Harps
- „Tubular" pick ups
- Ring pick ups

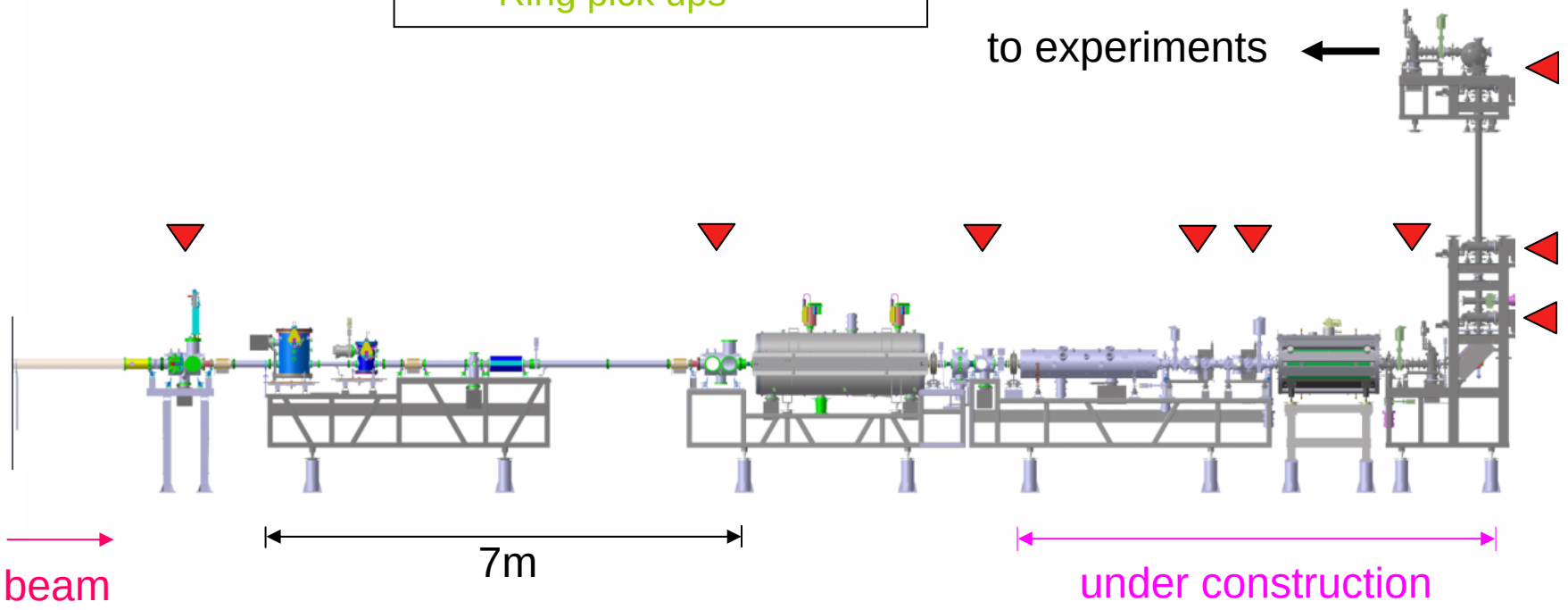


two bunchers IH-structure RFQ TRAP

Locations of Scintillation Screens over HITRAP Lattice

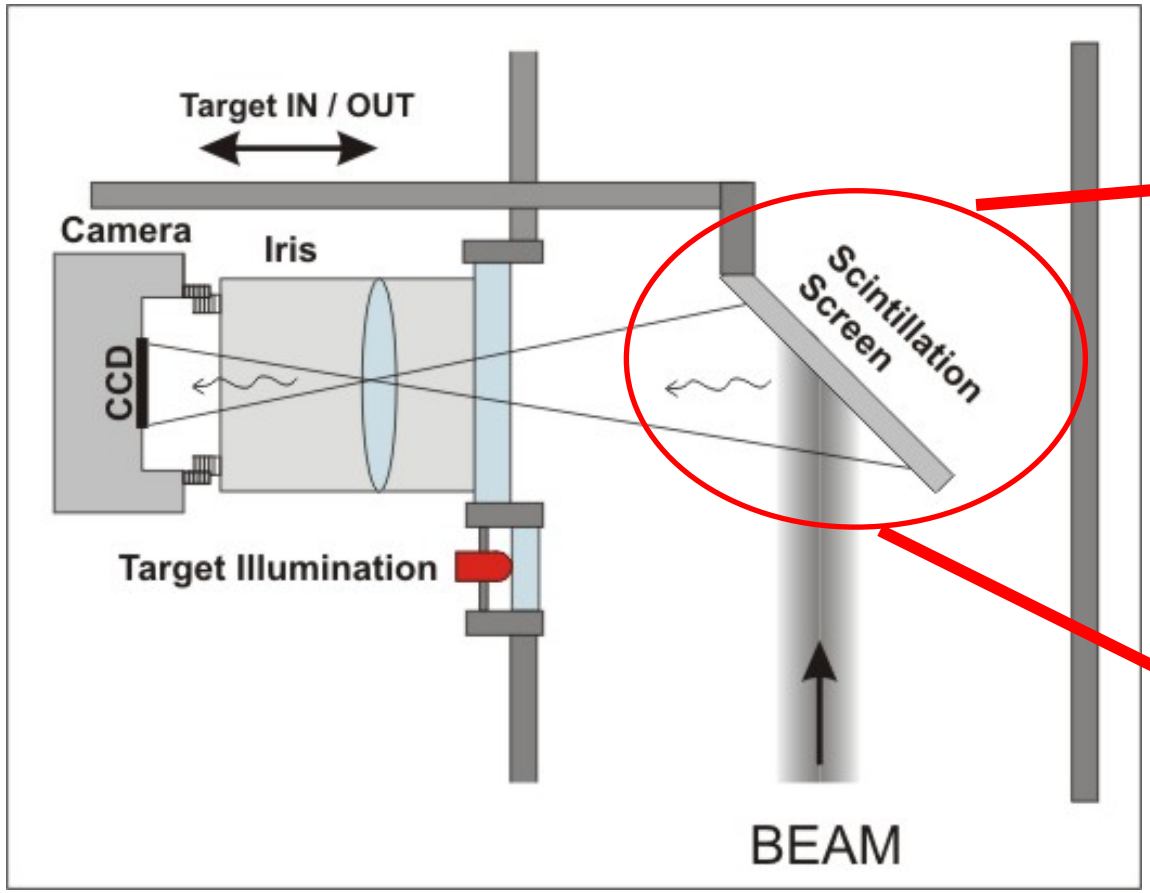
Overview:

- Faraday cups
- **Scintillation screens**
- Harps
- „Tubular" pick ups
- Ring pick ups

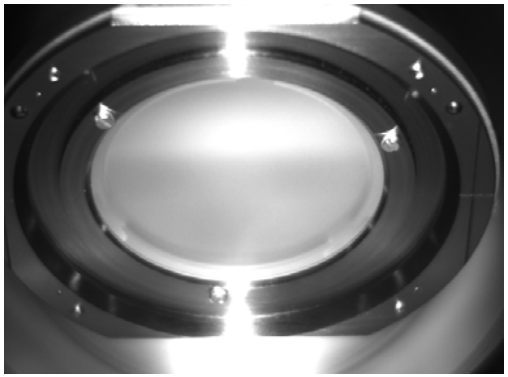


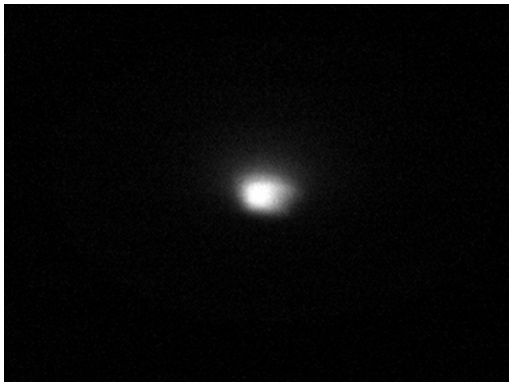
two bunchers IH-structure RFQ TRAP

Scintillation Screen - Setup



Screen illuminated:



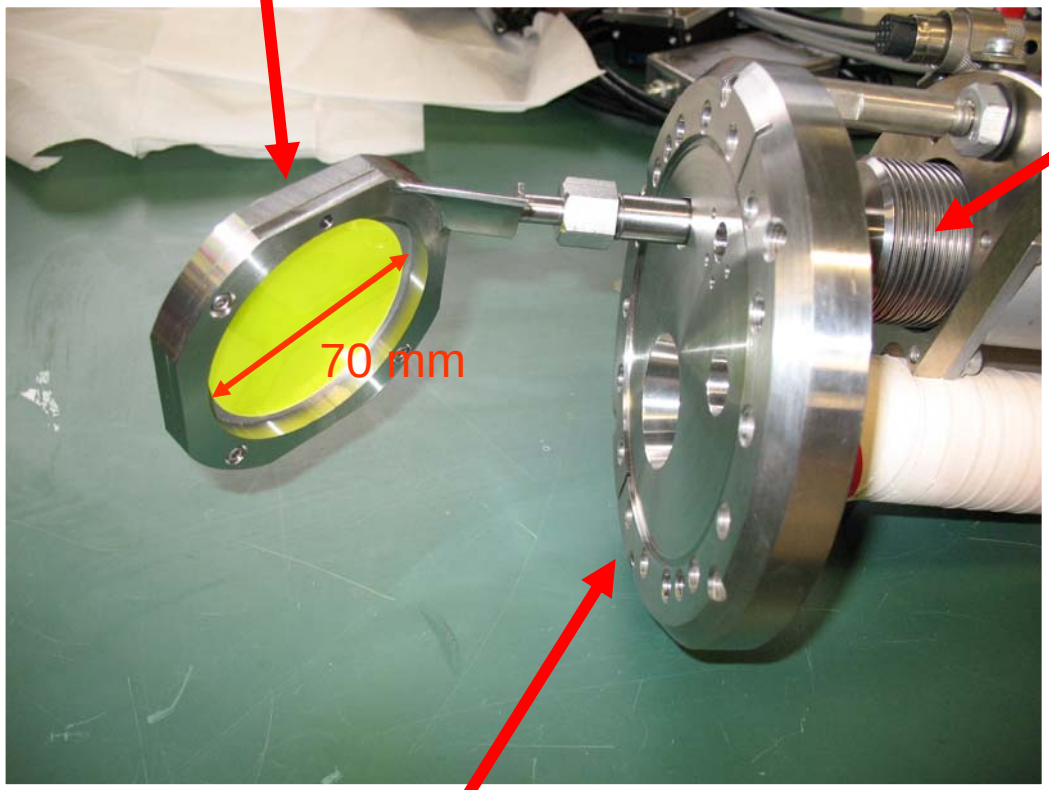


Beam spot on screen

For beam profile measurements

Scintillation Screen - Mechanic

Scintillation screen



Part of the pneumatic drive

Scintillation screen:

- YAG ($Y_3Al_5O_{12}$)

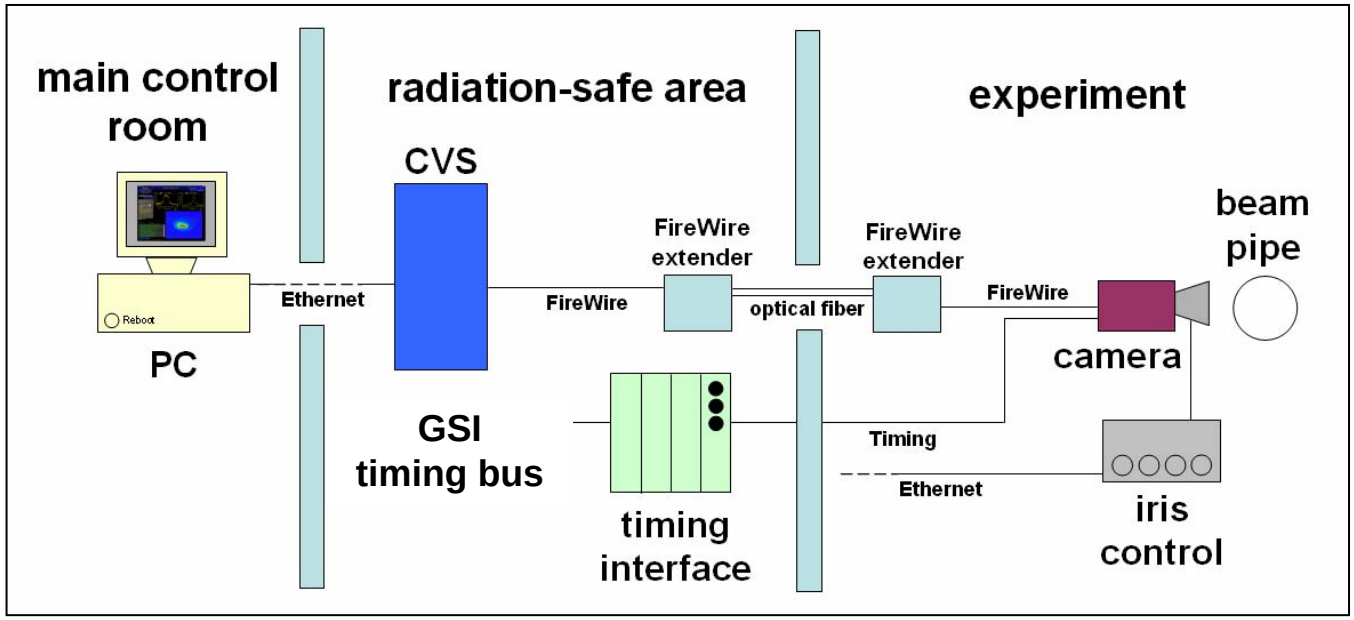
  Yttrium-**A**luminium-**G**arnet

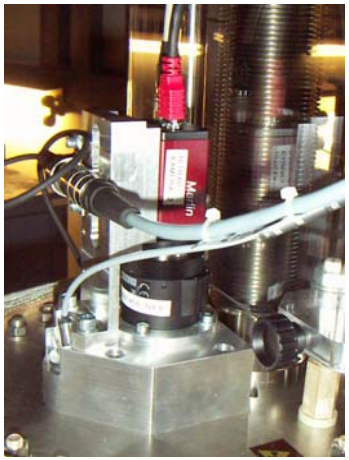
- mono crystalline

Good light yield at low energy

Flange diameter 100 mm, CF 100

Data Acquisition for Scintillation Screens





Digital-Camera on diagnostic chamber

CCD Digital Camera for precise triggering:

- fast scintillation material can be used
- short pulses can be detected

Digital-Camera with CVS

optical fiber for long-distance (> 1km)

FireWire (IEEE1394): up to 5 meters

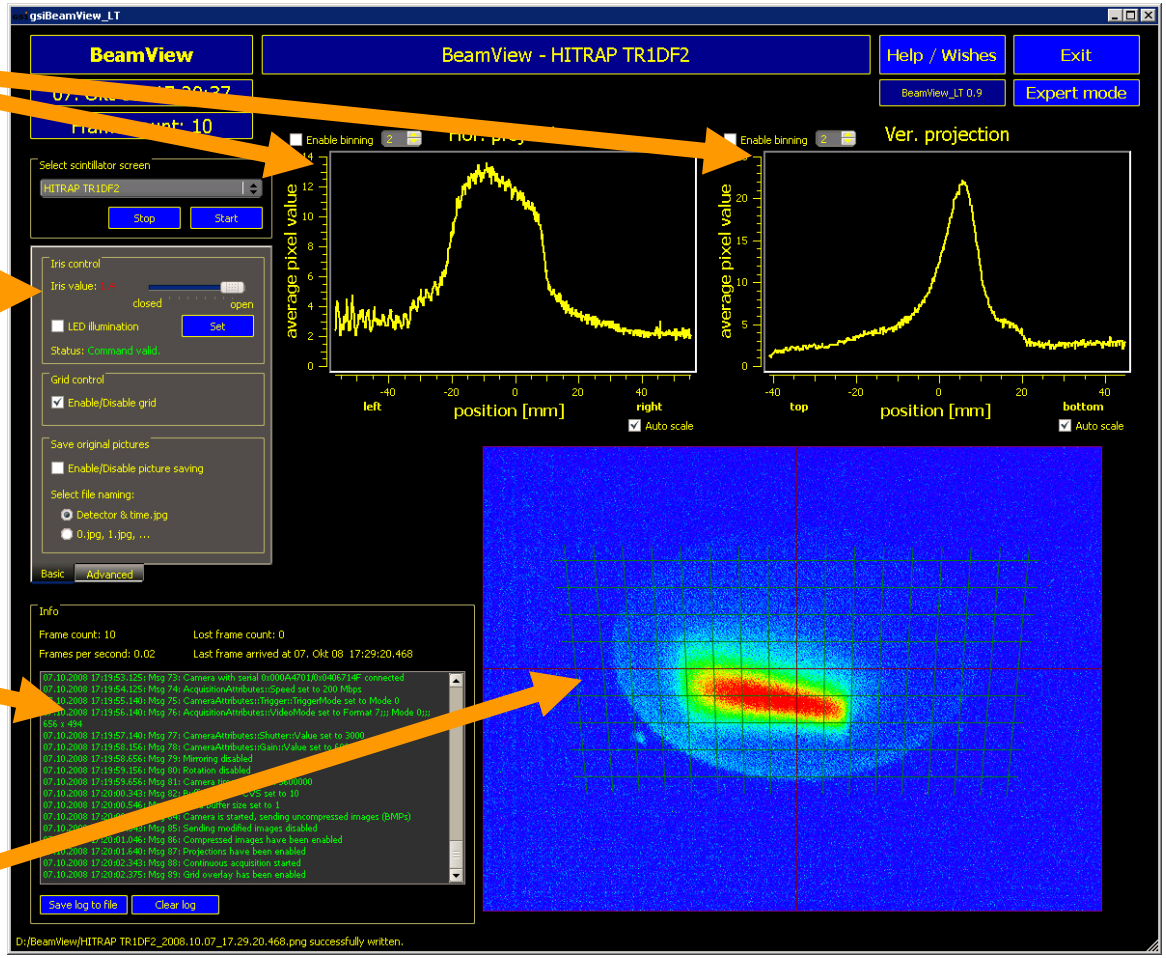
Scintillation Screens Software - "BeamView"

horizontal and
vertical projection

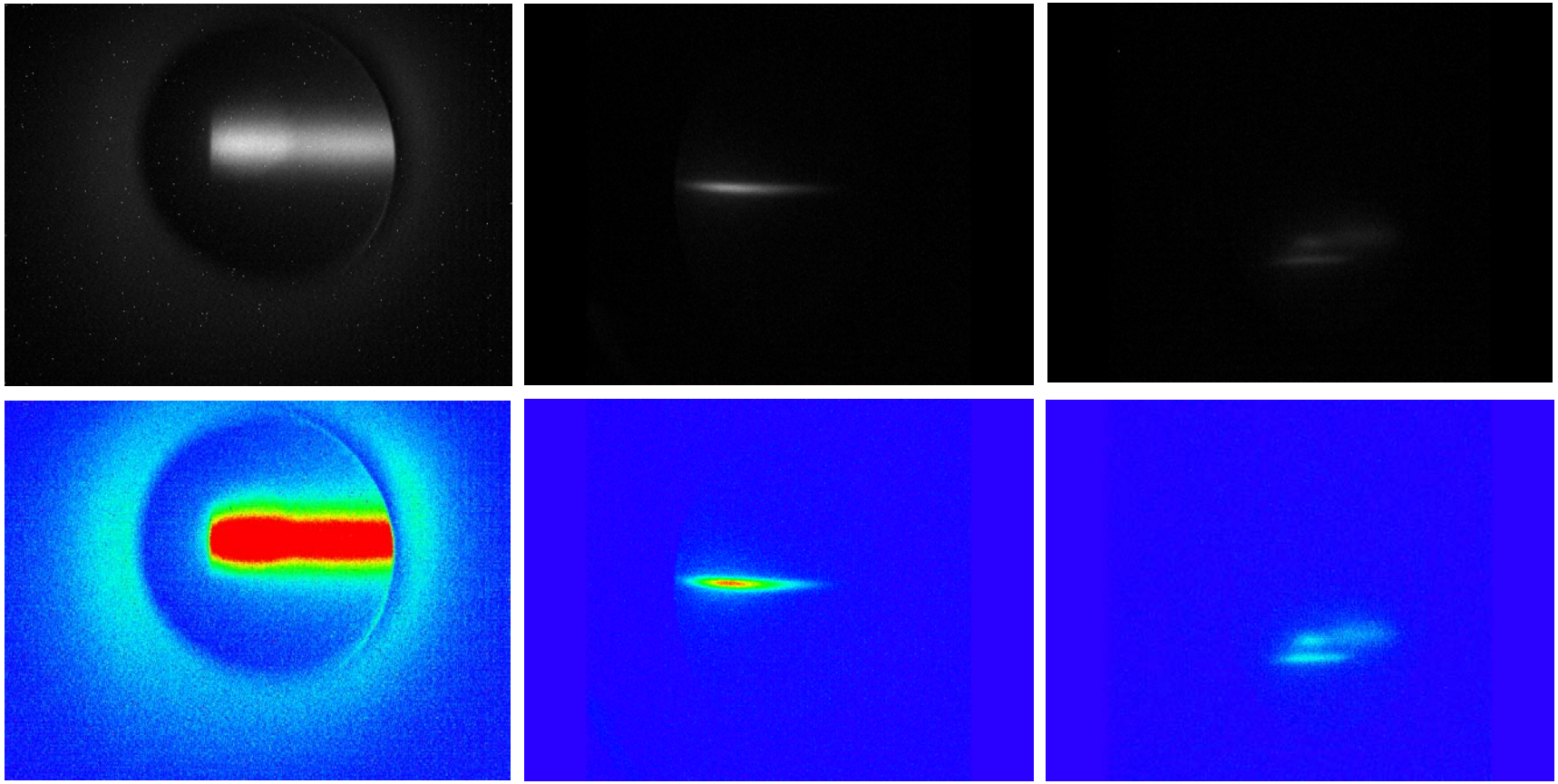
camera controls

log window and
image information

live image with
up to 35 frames/s

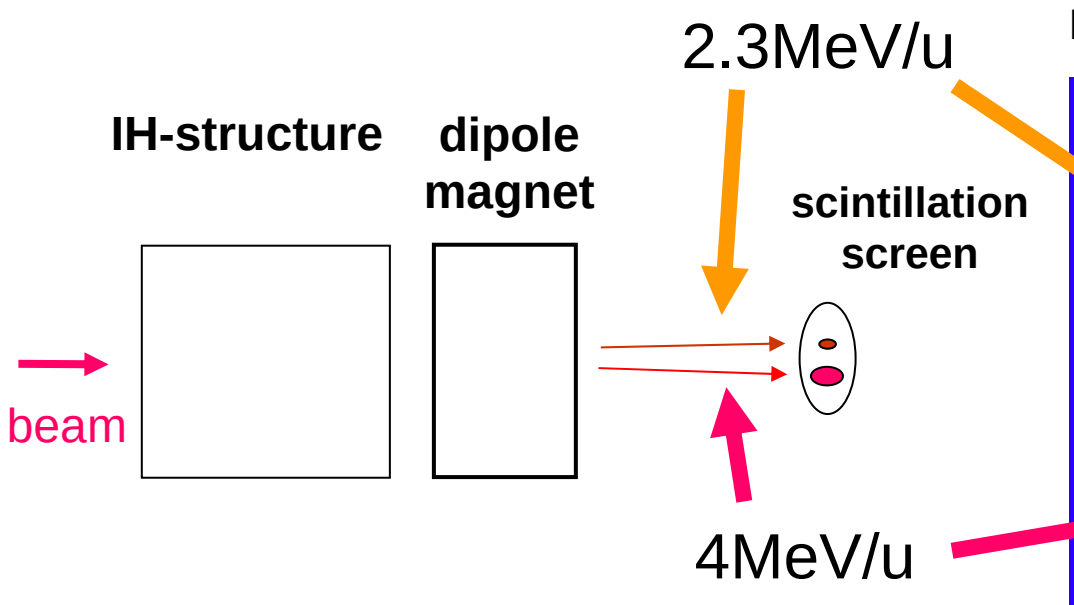


Scintillation Screens
Examples of measurements



False colour pictures show more details

Scintillation Screens Measurements-Results



Beamtime October 2008, Ni^{28+}

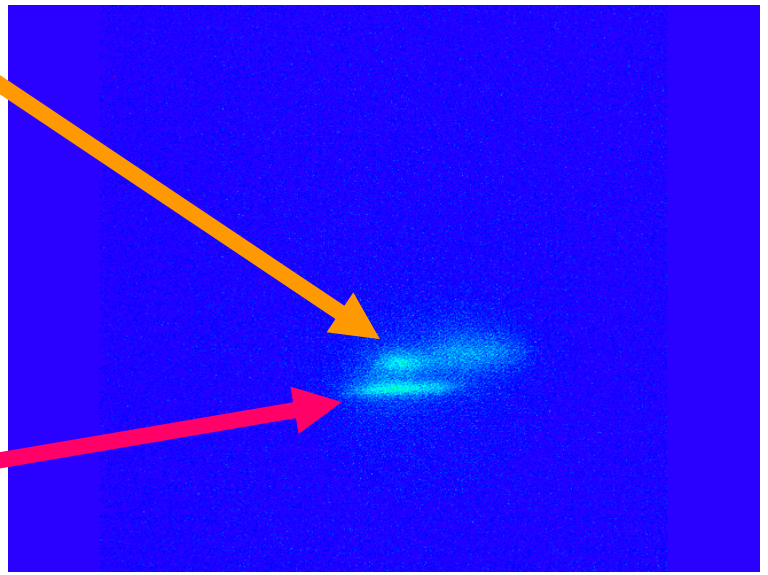


Image from scintillation screen behind the IH-structure and dipole magnet

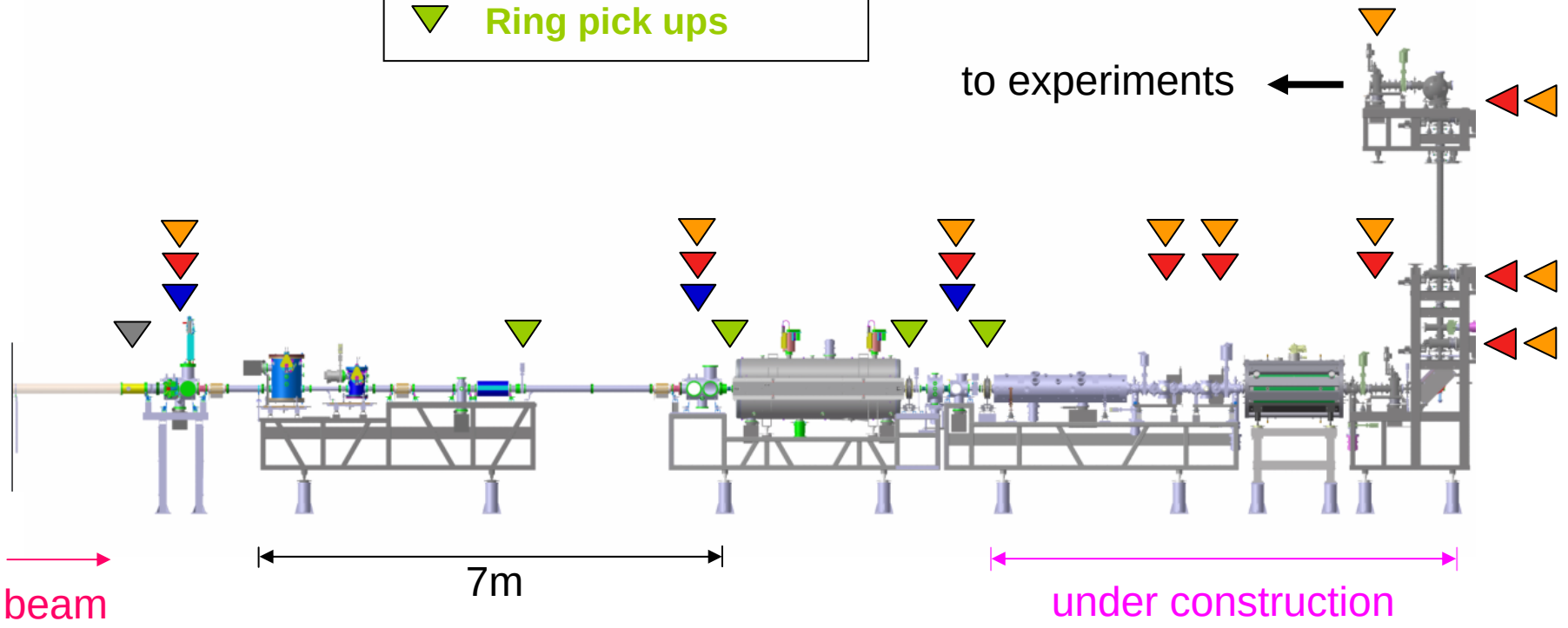
Separated spots represent different energies → Not detectable with harp systems and ring pick ups

→ **The scintillator screens are very helpful for operating !**

Locations of HITRAP Beam Diagnostic

Overview:

- Faaraday cups
- Scintillation screens
- Harps
- „Tubular" pick ups
- Ring pick ups

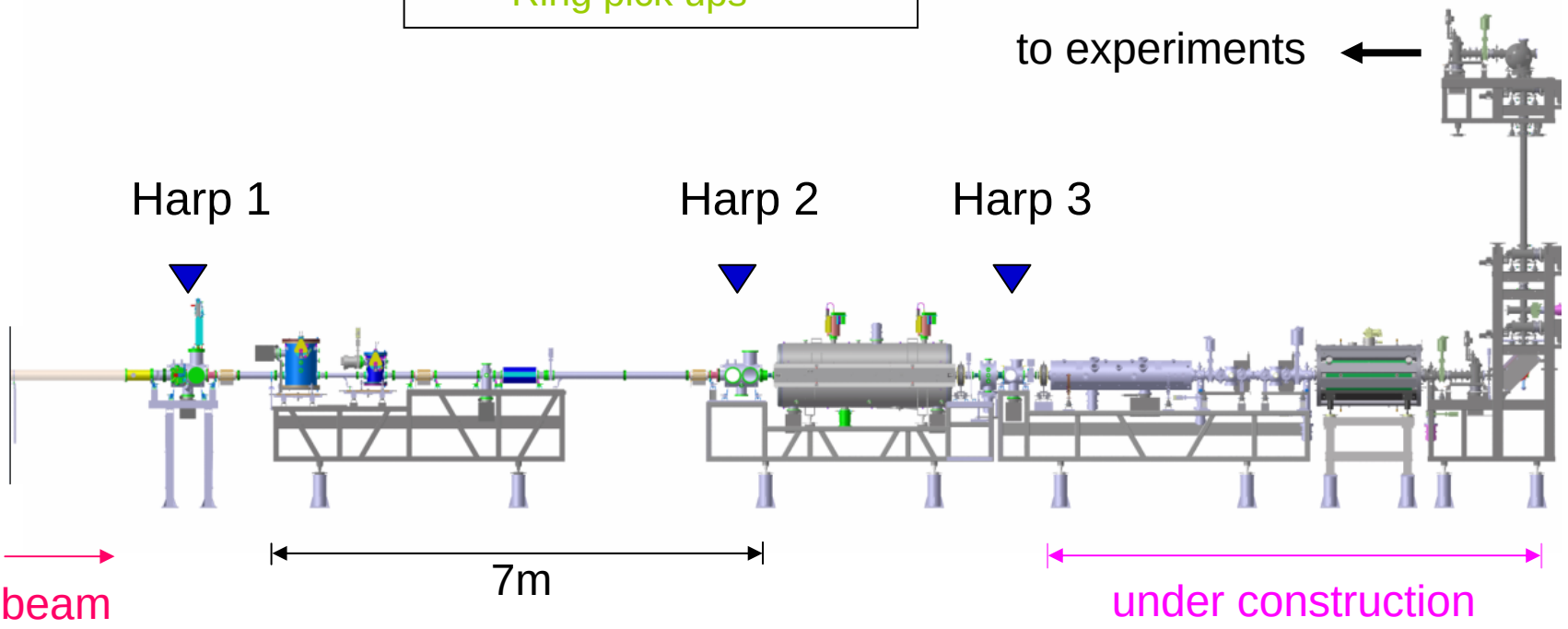


two bunchers IH-structure RFQ TRAP

Locations of Harps over HITRAP Lattice

Overview:

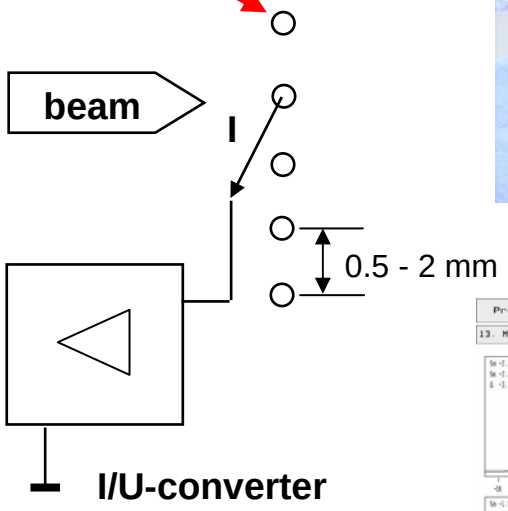
- Faraday cups
- Scintillation screens
- **Harps**
- „Tubular" pick ups
- Ring pick ups

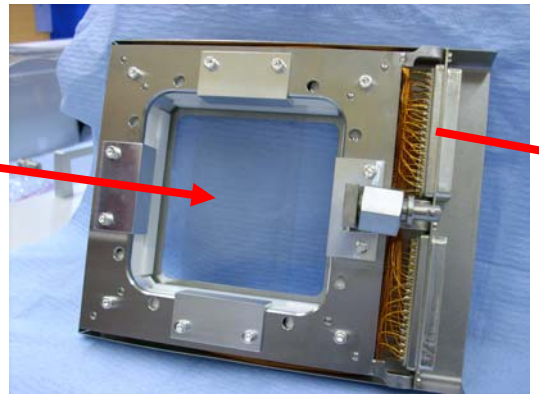


two bunchers IH-structure RFQ TRAP

Harp Systems - Layout

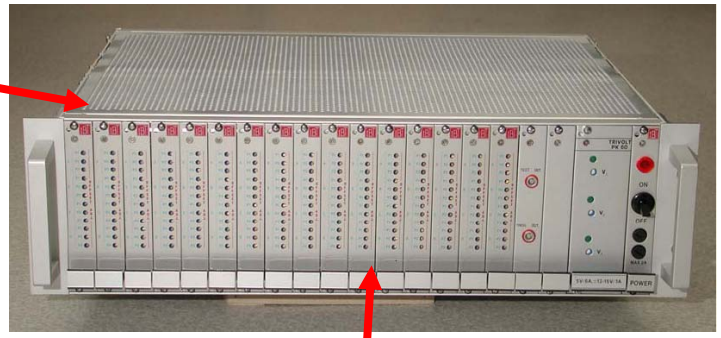
function diagram

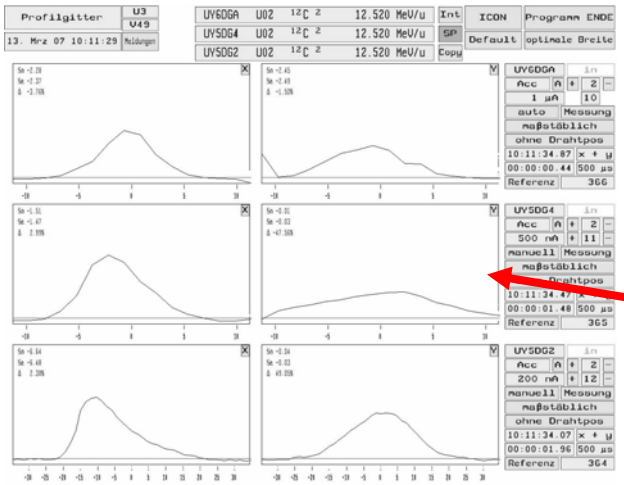




harp assembly

analog and control devices

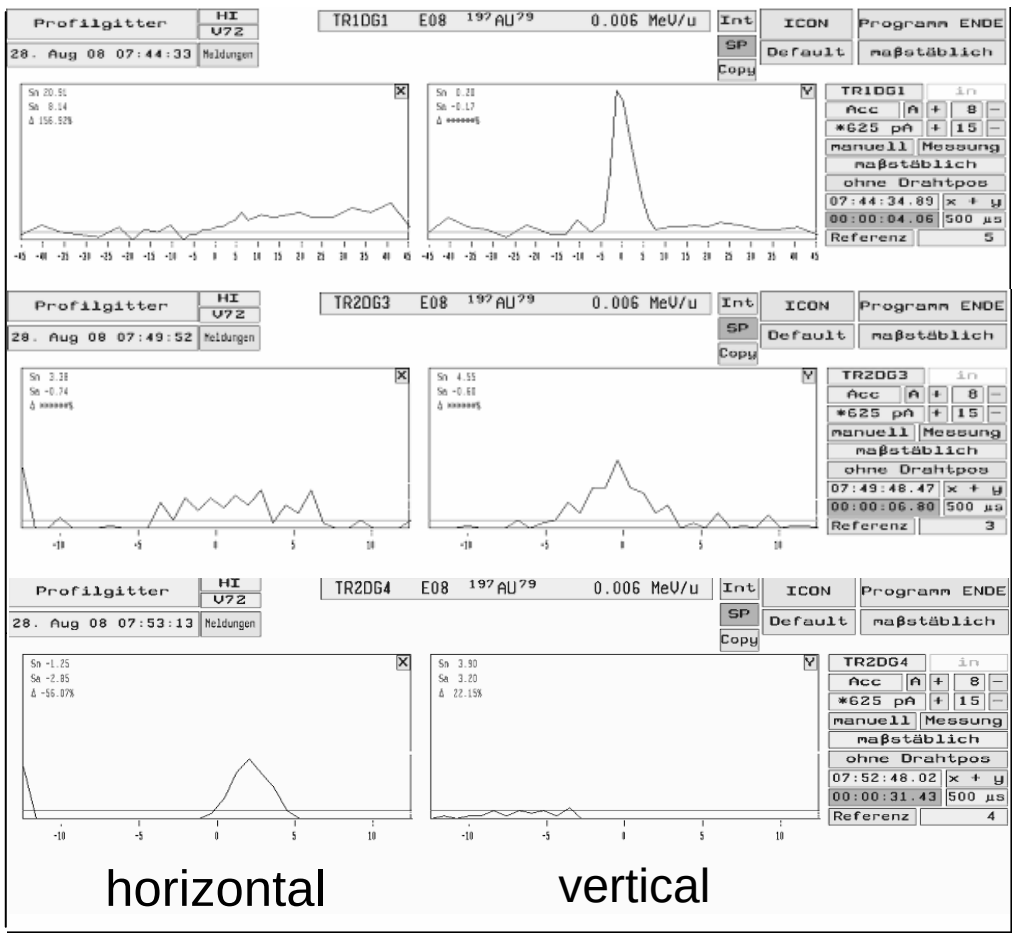




Harp systems are not destructive !

control program on screen at CR

Harps Results – Measured Profiles



HARP 1

beam

HARP 2

HARP 3

Range: 2nA/V 20nA f.s.

Results:

- **intensities were too low**
- **Measurements useful only in lowest range (625 pA „Soft“-zoom necessary)**

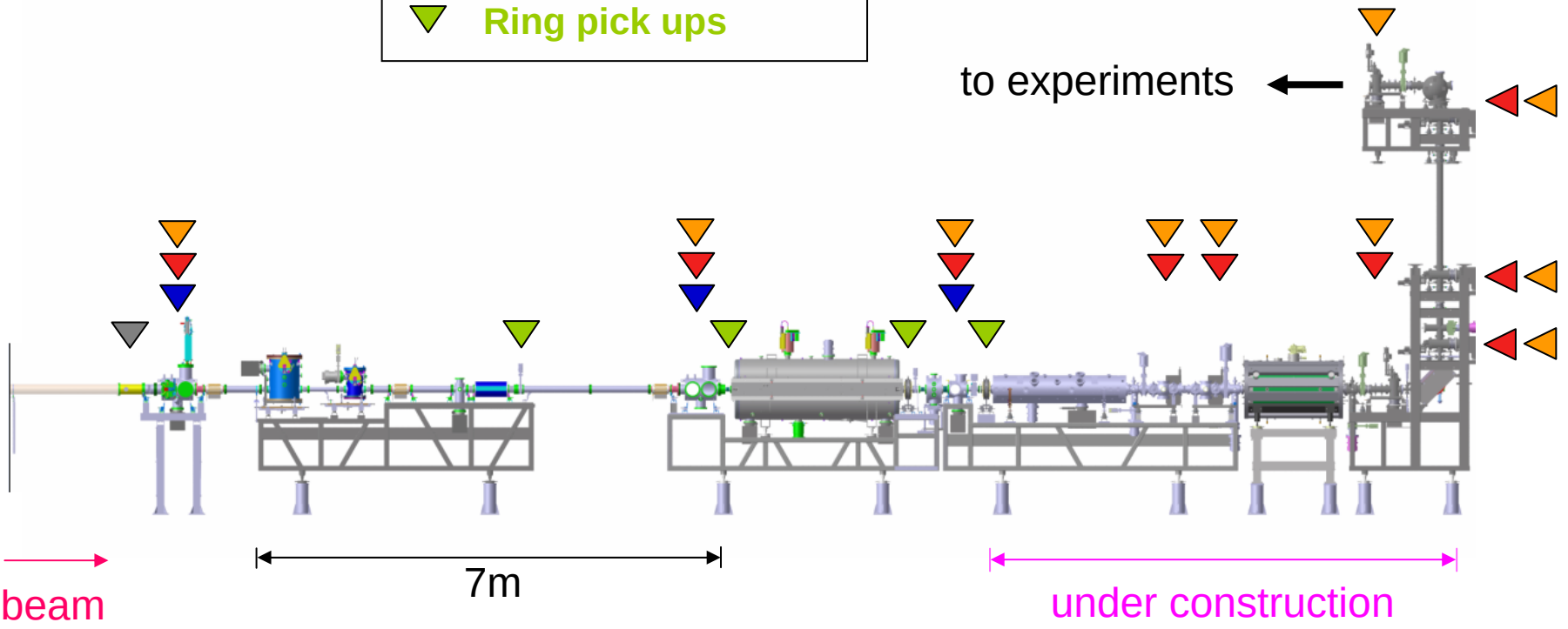
Operating was heavily affected

Profiles were measured in August 2008 (Au^{79+})

Locations of HITRAP Beam Diagnostic

Overview:

- Faaraday cups
- Scintillation screens
- Harps
- „Tubular" pick ups
- Ring pick ups

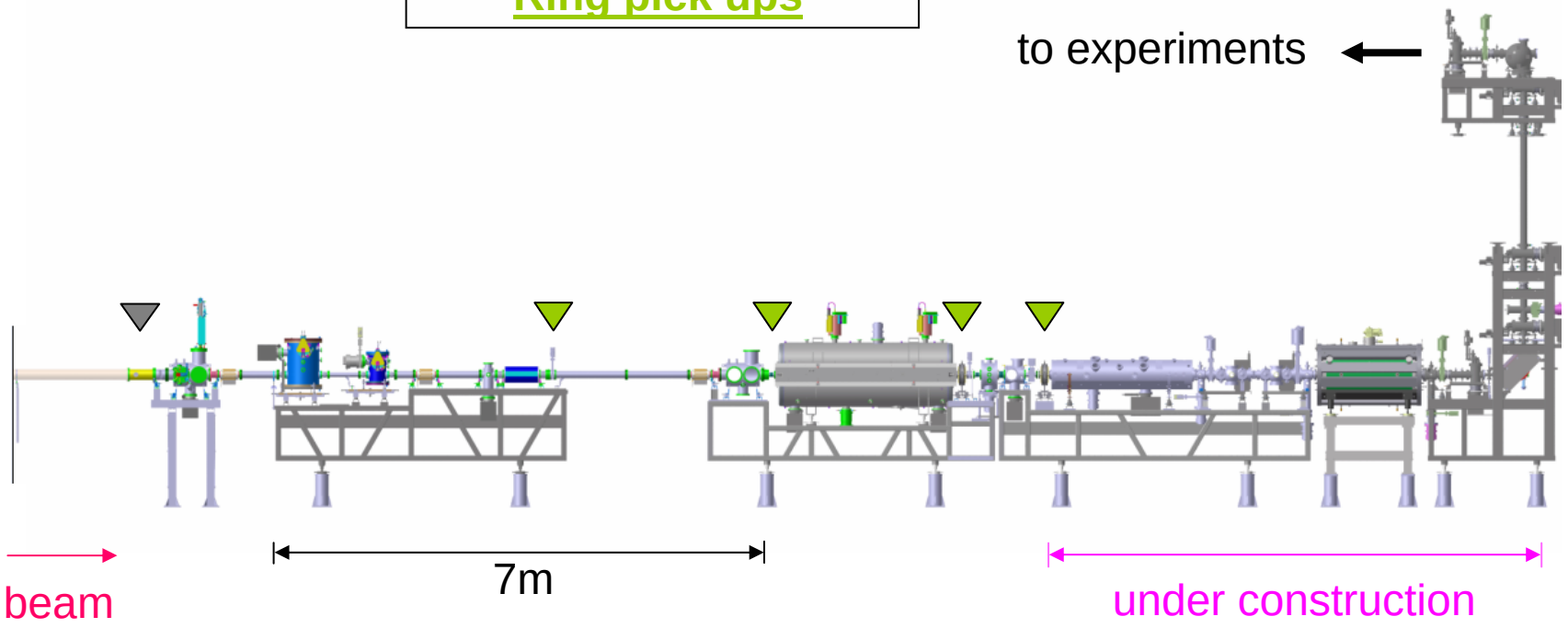


two bunchers IH-structure RFQ TRAP

Locations of Pick Ups over HITRAP Lattice

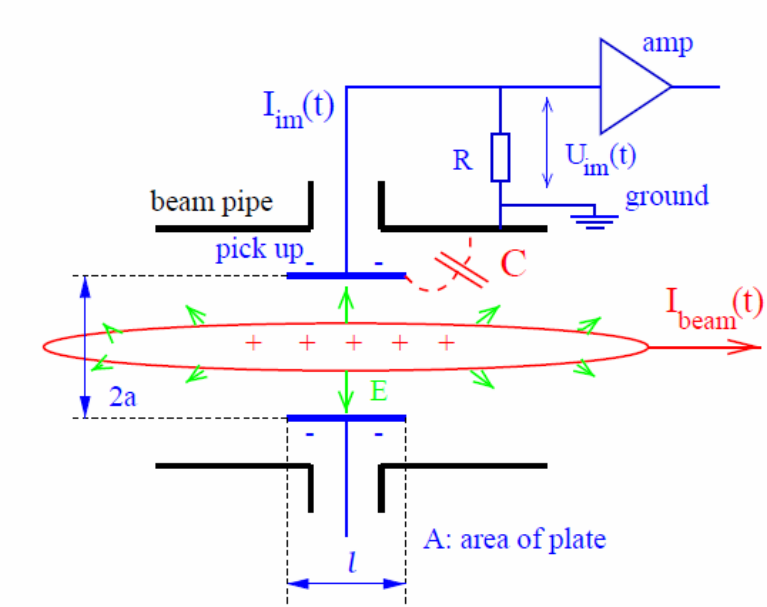
Overview:

- Faraday cups
- Scintillation screens
- Harps
- „Tubular" pick ups
- Ring pick ups



two bunchers IH-structure RFQ TRAP

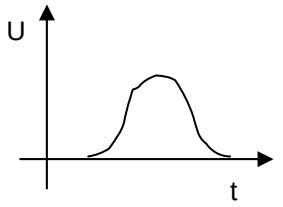
Capacitive Pick Up – Function Diagram



- **Beam (ion bunch) influences charge on the pick up plates**
- **Charge (current) flows over the pick up plates through R into ground**

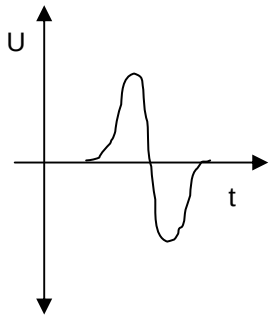
High impedance **High frequency range $\omega >> \omega_{cut}$:**

$$U_{im}(t) = \frac{1}{\beta c C} \cdot \frac{A}{2\pi a} \cdot I_{beam}(t)$$



Low impedance **Low frequency range $\omega << \omega_{cut}$:**

$$U_{im}(t) = \frac{R}{\beta c} \cdot \frac{A}{2\pi a} \cdot \frac{dI_{beam}}{dt}$$



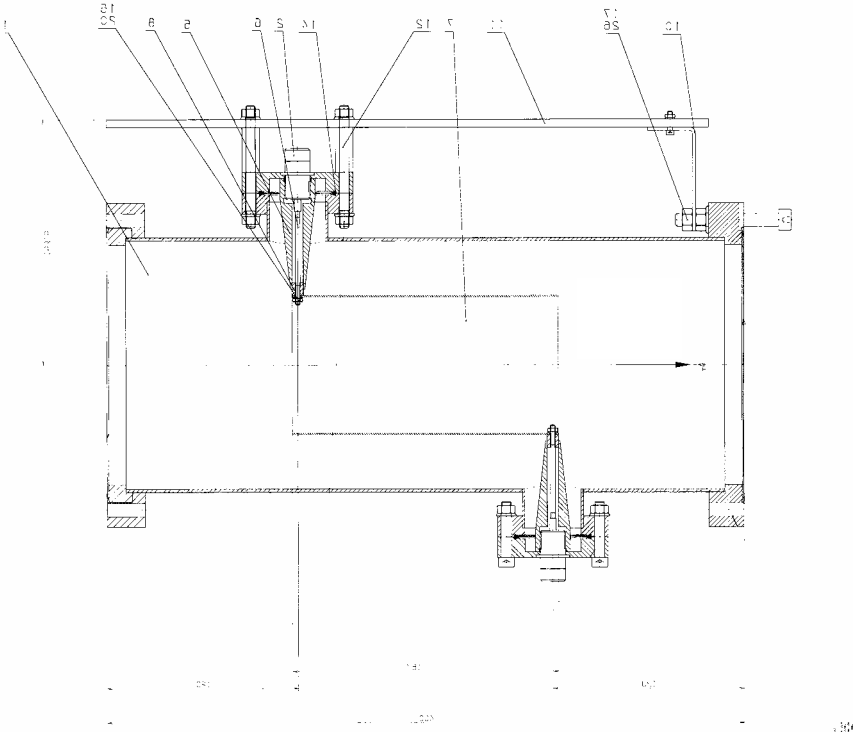
Time-of-Flight (TOF) measurement is possible with two pick ups

⇨ determination of beam energy

$u_{noise,RMS} = \sqrt{4kTBR}$ B = bandwidth $\omega_{Cut} = \frac{1}{RC}$

High Impedance „Tubular" Pick Up

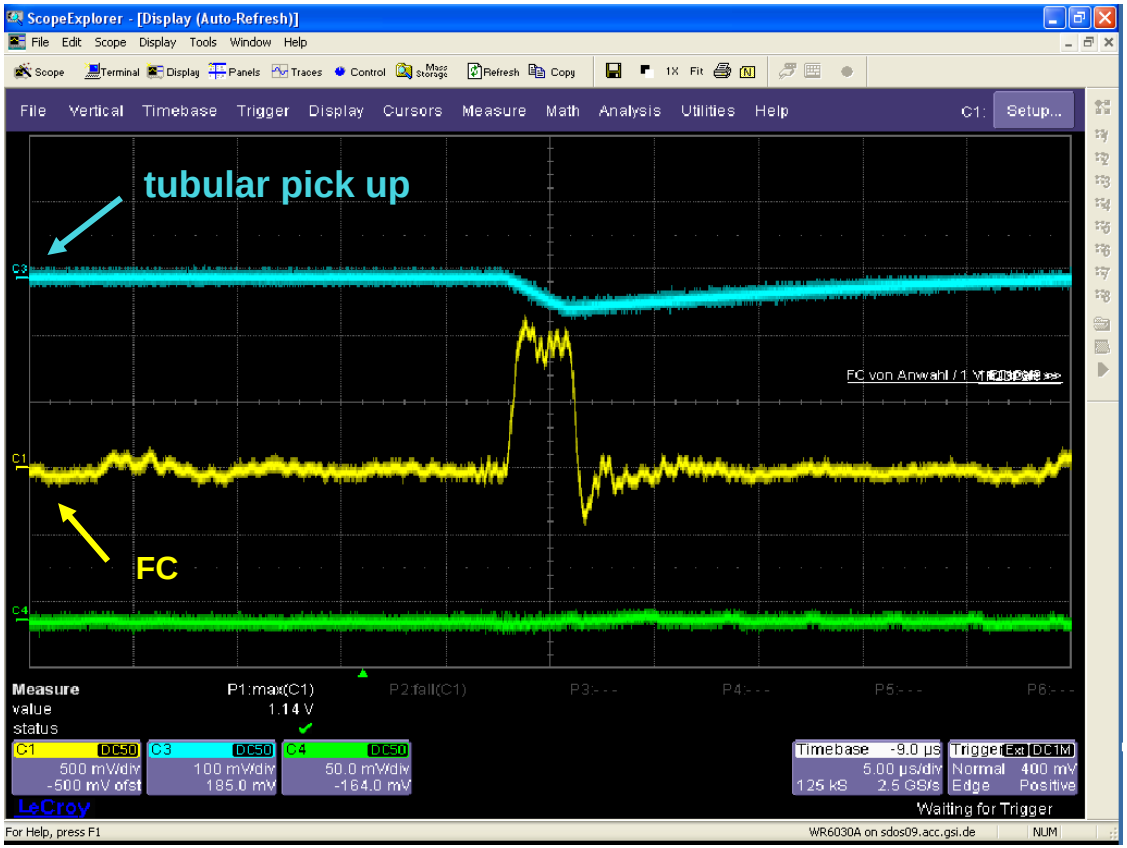
high-impedance amplifier (1MOhm, 10 MHz Bandwidth)



„Tubular“ pick up in the HITRAP beamline

Tubular Pick Up - Measurement-Results

Beamtime February 2009 (Ni^{28+})



Yellow trace: 500mV/div.; 5 µs/div.

Blue trace: 100mV/div.; 5 µs/div.

- Output signal of the tubular pick up should look simular to a FC-signal.
- The tubular pick up did not show signal induced by the extracted ESR-beam.

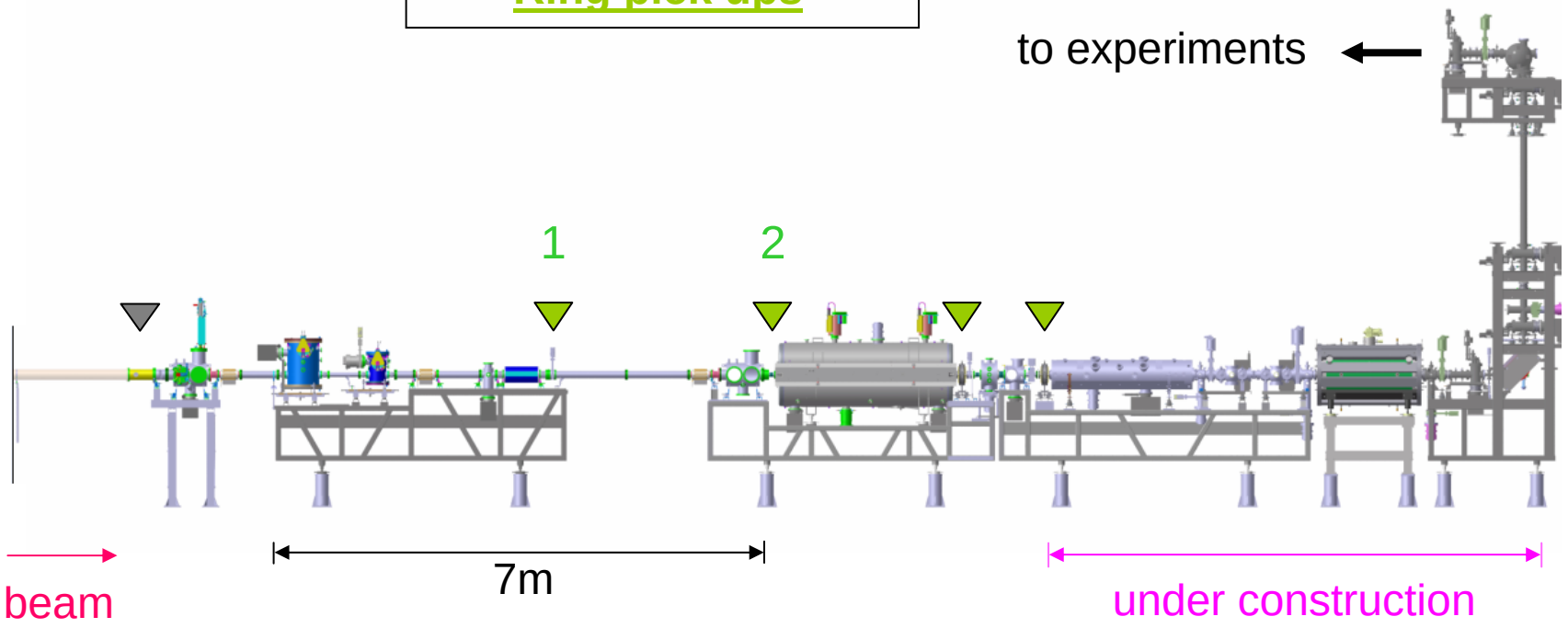
➡ direct irradiation of pick up plate

- **Suggestion: reduced-length tubular pick up should help**

Locations of Pick Ups over HITRAP Lattice

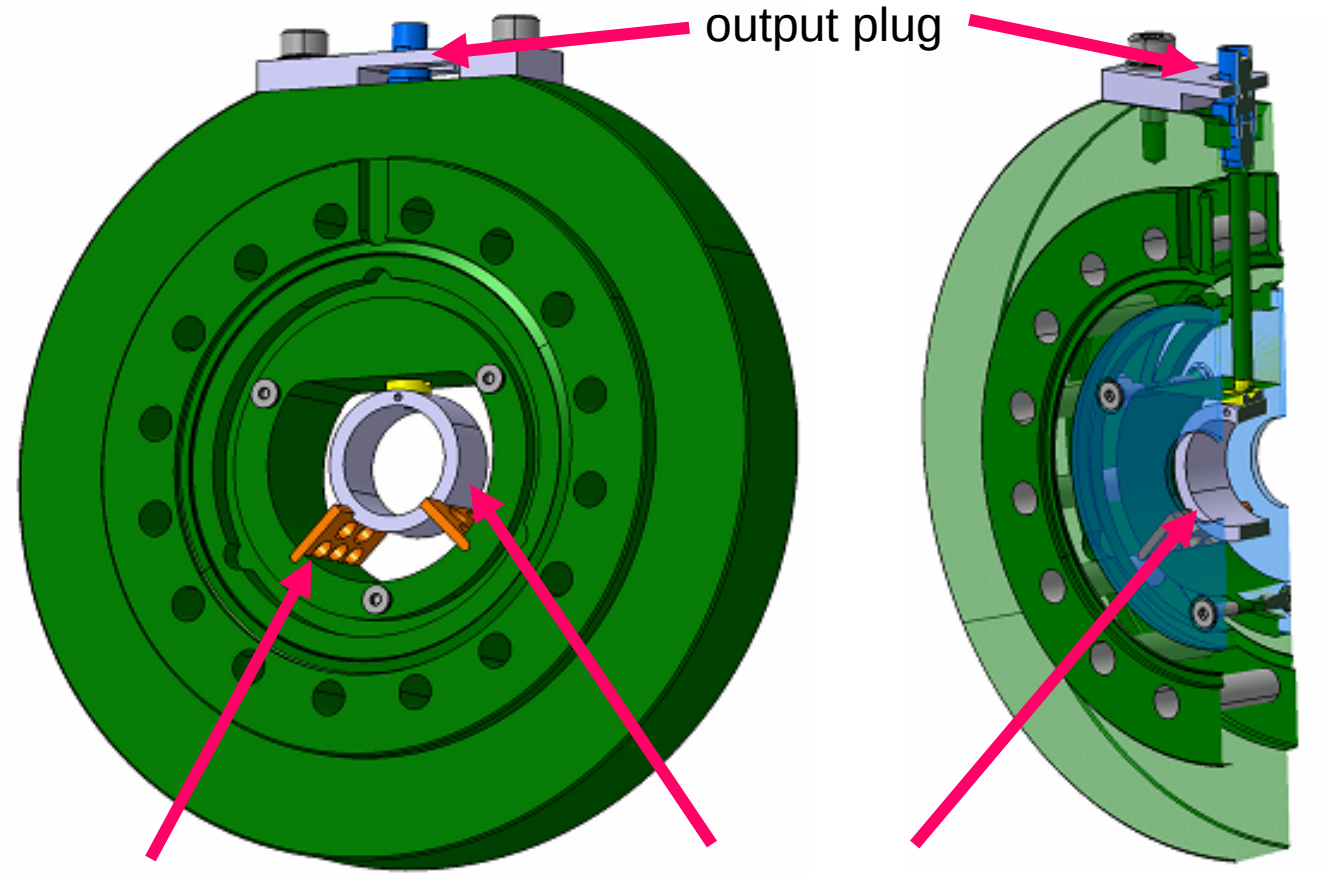
Overview:

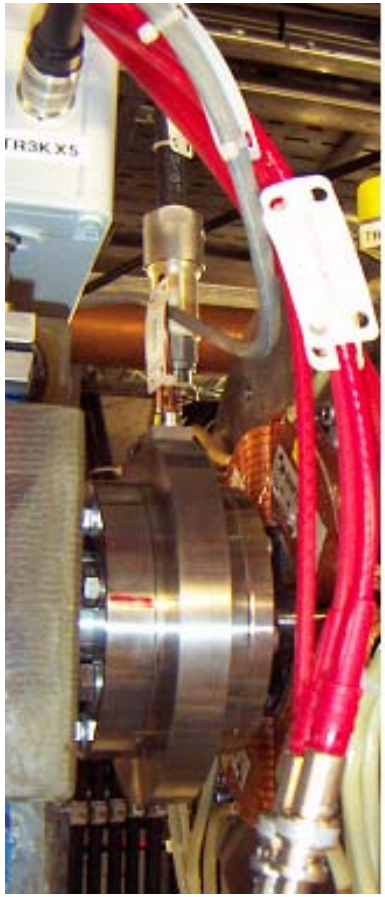
- Faraday cups
- Scintillation screens
- Harps
- „Tubular" pick ups
- **Ring pick ups**



two bunchers IH-structure RFQ TRAP

Ring Pick Up – Design Mechanic





pick up at HITRAP

Ring pick up: design optimized for 50 Ohm impedance

Capacitive Ring Pick Ups - Results

Beamtime October 2008 (Ni^{28+})

- Image shows typical signals of beam bunches

→ TOF-calculations possible

but

- The pick up signals could only be detected with averaging of 6 measurements

→ Long waiting period (here 7 minutes)

Note: 20mV/Div. and 5ns/Div.; beam current was > 1,5 µA

Capacitive Ring Pick Ups - Results

Beamtime October 2008 (Ni^{28+})

- Unfortunately in most of the cases measurements are not possible
- Sensitivity of the system is not high enough (signal/noise ratio to low)

Pick up 1 after quadrupole

RF-reference

Pick up 2 in front of IH

Note: red trace: 50mV/div.; 10 ns/div.; blue and green traces: 20mV/div.; 10 ns/div.

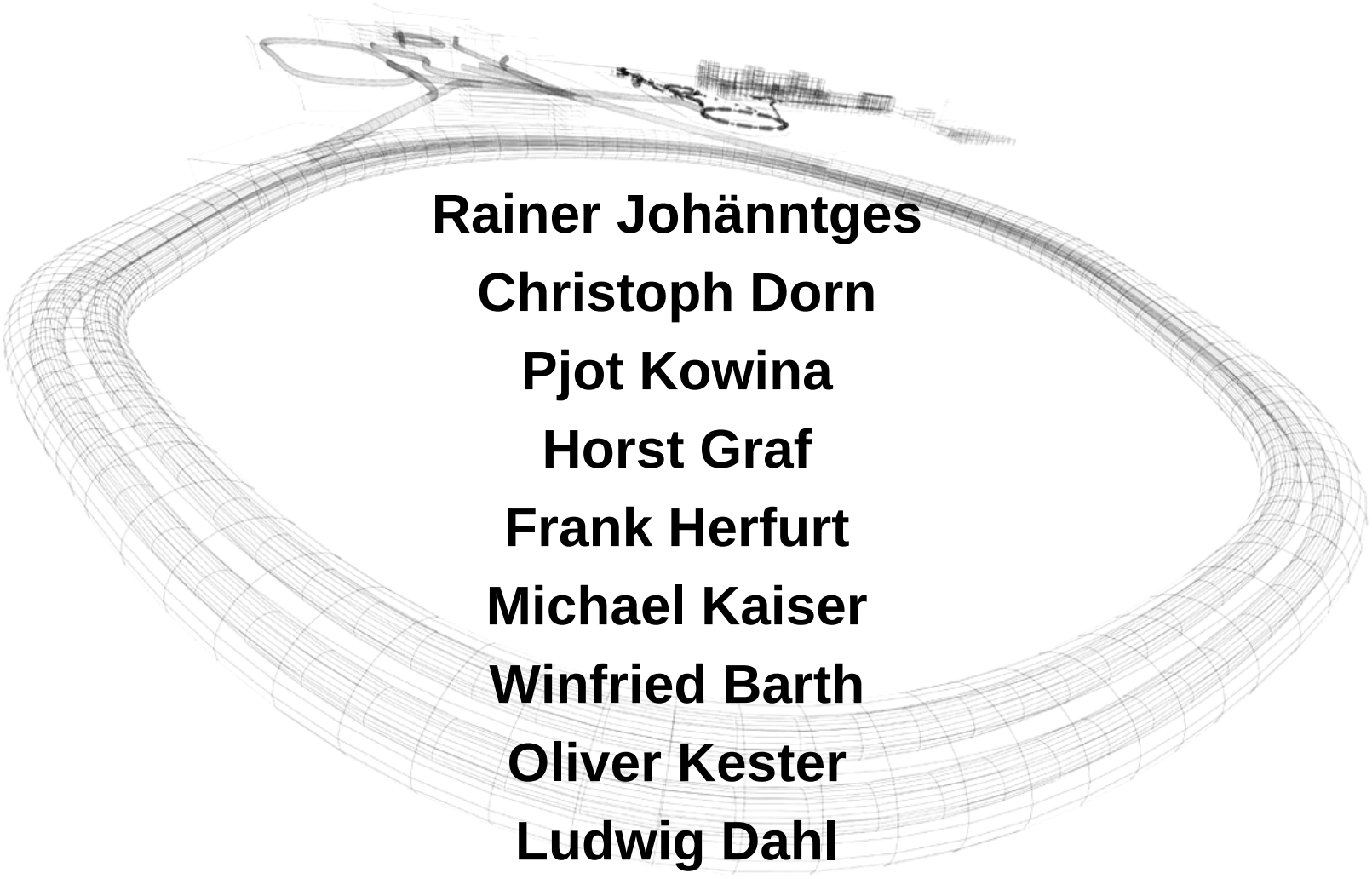
Summary and Outlook

- With Faraday-cups we can detect the low energy / intensity beams !
  (Calculation of transmissions, time-resolved measurement)
- The scintillator screens are essential for operating !
  (detection of position up to 300 nA and < 2 µs beam pulse)
- Pick ups are important for operating, but the sensitivity presently is not high enough (signal/noise ratio to low)

March 2010

- Next beamtime
- Modify tubular pick up ?
- Suggestion for ring pick ups:
  low-noise head amplifiers between pick ups and transmission lines to improve S/N ratio
  (not yet decided)

Thanks to



Rainer Johänntges

Christoph Dorn

Pjot Kowina

Horst Graf

Frank Herfurt

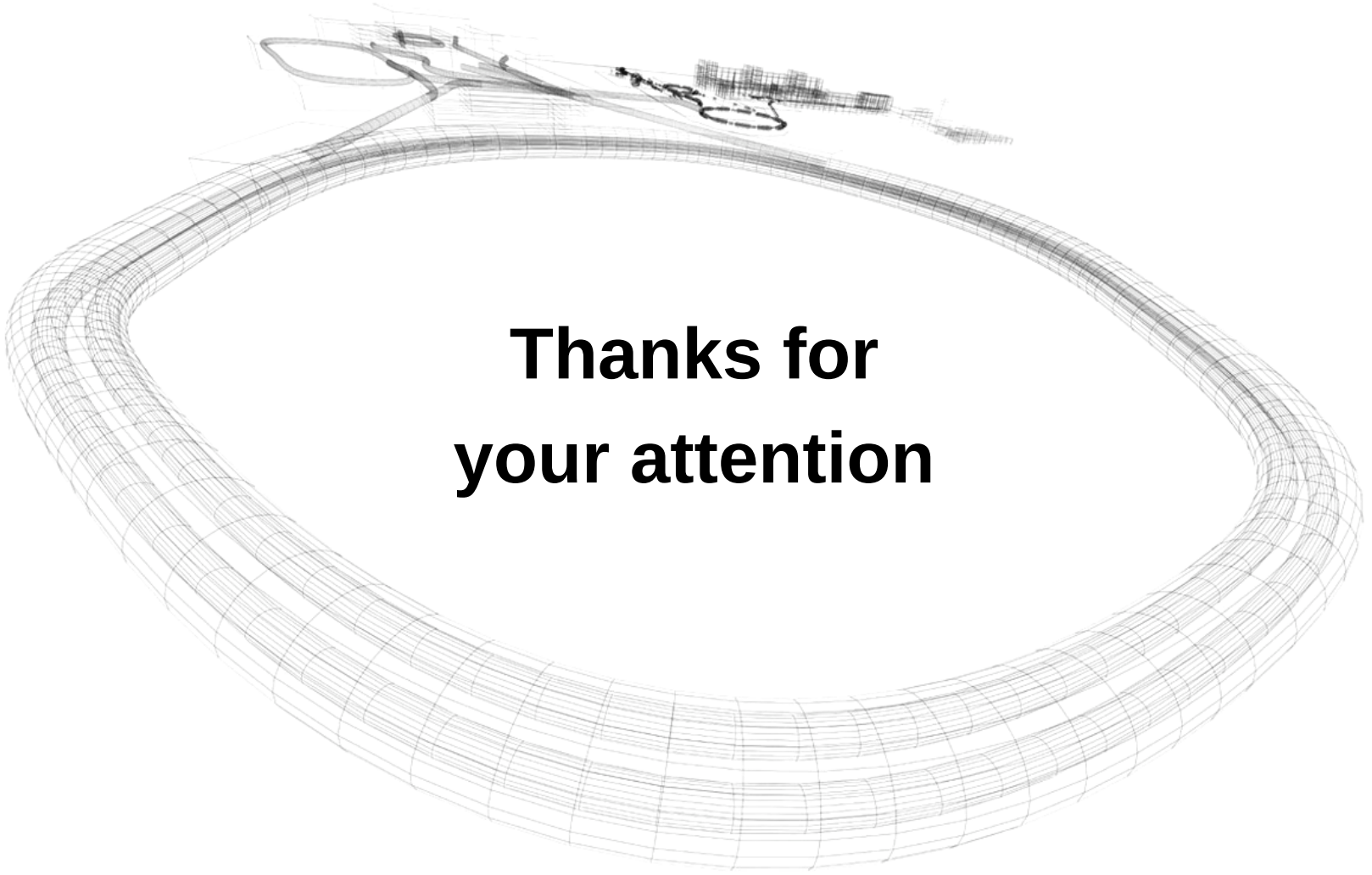
Michael Kaiser

Winfried Barth

Oliver Kester

Ludwig Dahl

END



Thanks for
your attention