Introduction

- New high power proton and heavy ion LINAC projects demand non-interfering beam diag-nostics due to the high inherent beam power

- The space for diagnostics insets shall be as small as possible to have nearly 100 % space for accelerating and focusing elements, necessary because of the high space charge forces

- The used methods shall have a large resistance against radiation defects due to beam losses and secondary processes

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Beam Diagnostics can profit from trends in industry

- Due to the high degree of automation in industry a huge market of remote controllable (sub-)devices has grown, which can be used as parts of diagnostic systems (nearly) without modifications

- Digital data treatment methods and devices like FPGAs and DSPs have become cheap and their capabilities are growing fast, as well as their integration is becoming easier

- A special industry segment, the vision systems, shows these trends exemplarily. Digital cameras with fast speeds or high resolution are capable to send their image data without any loss directly to the user

New Transformer Applications

- BNL Developments for SNS – M.Kesselman et al

- High current monitoring and transmission control at the GSI heavy ion LINAC (UNILAC) – H. Reeg et al

BNL Developments for SNS (M. Keselman et al)

Current transformers must have <1 ns rise time and droops of 0.1%/ms due to varying beam parameters along the accelerator facility → not achievable with a normal (active-)passive transformer (τ_r ◊ rLC, τ_d ◊ L/R)

Idea: Take commercially available transformer with necessary rise time and improve the droop by a factor of *1000* using a digital compensation technique, here an infinite impulse response (IIR) filter

BNL Developments for SNS

Digital Compensation Filter
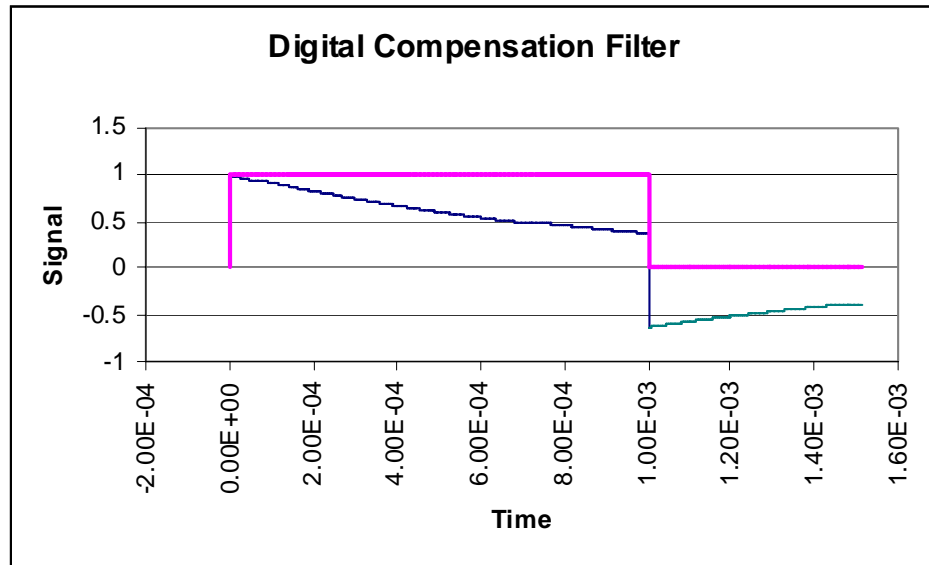
black: simulated transformer signal

violet: digitally compensated signal

$1/\tau_1$ is the transformer lower cut-off radian frequency (1 kHz),

$1/\tau_2$ is the desired new transformer lower cut-off radian frequency (1 Hz)

Infinite Impulse Response (IIR) filter:

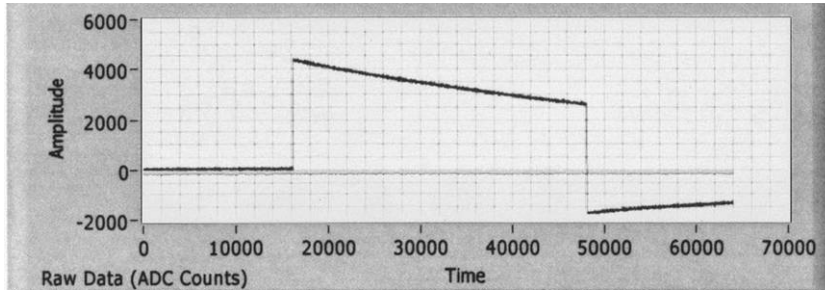$y(n)=\{1/(2/T+1/\tau_2)\}\{y(n-1)\ (2/T-1/\tau_2) + x(n)\ (2/T +1/\tau_1) + x(n-1)\ (-2/T +1/\tau_1)\}$
with:

$y(n) \rightarrow$ nth calculated output value, $x(n) \rightarrow$ the nth sampled input value
Coefficients are constants depending upon sampling period T

<u>BNL Developments for SNS</u>
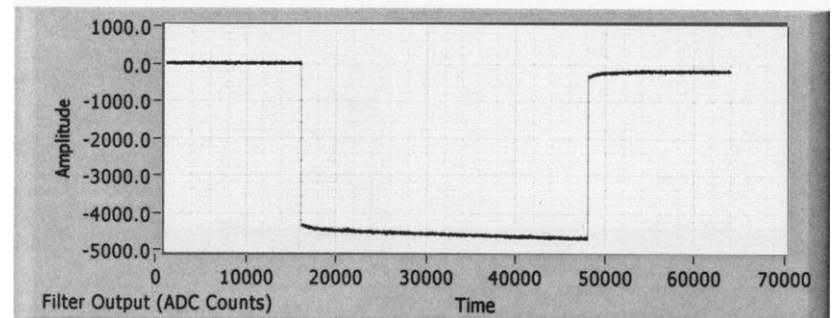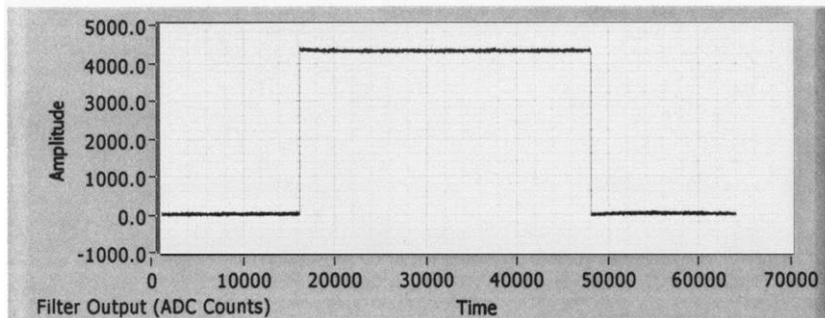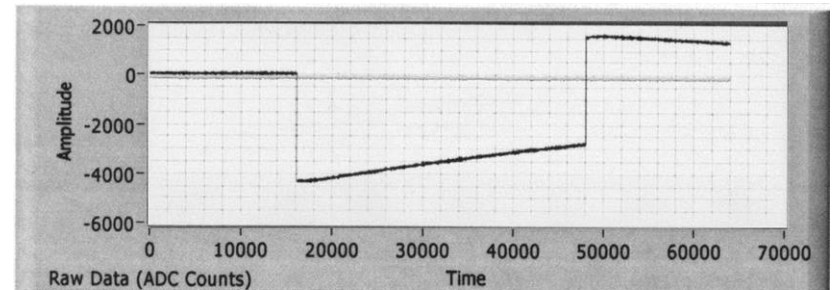
Measurements verify the function of the filter (left pictures) but pulses in the opposite direction (right pictures) indicate a slight variation of the transformer´s inductance due to hysteresis effects ➔ ***Solution:*** online calibration using a test pulse in the gap between two beam pulses, implementation of evaluation and correction in a FPGA/DSP
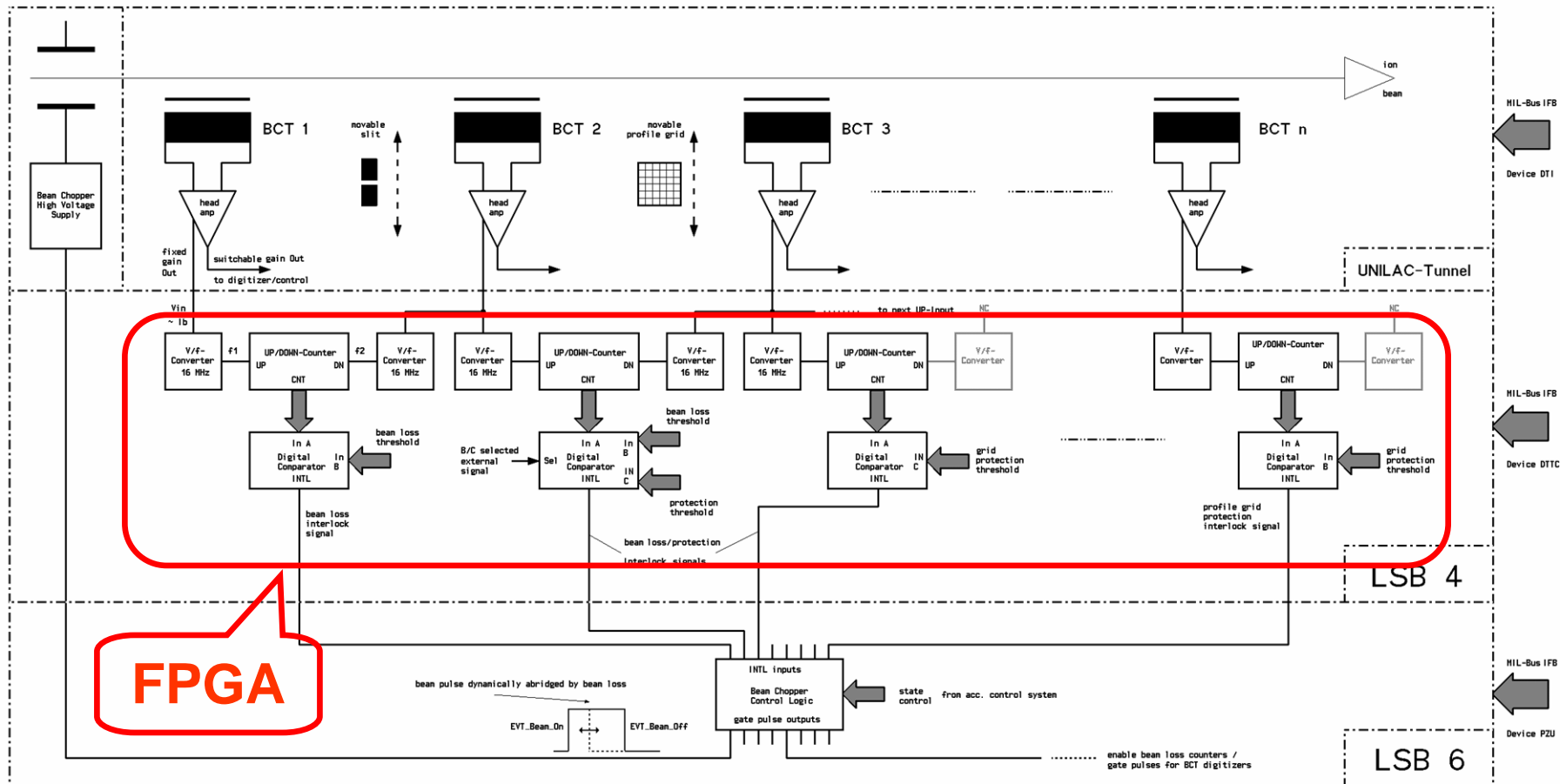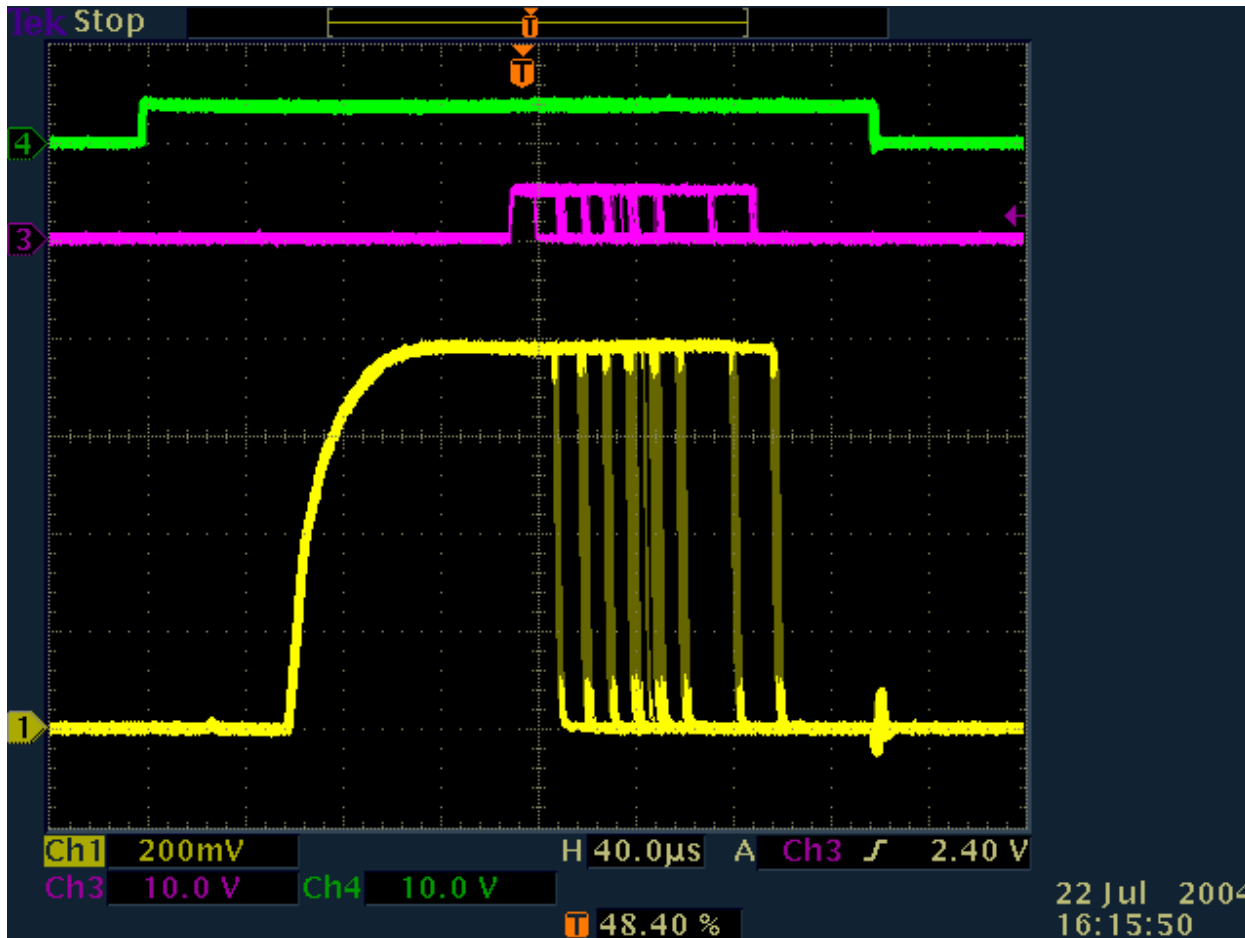
High current transmission control at GSI´s UNILAC
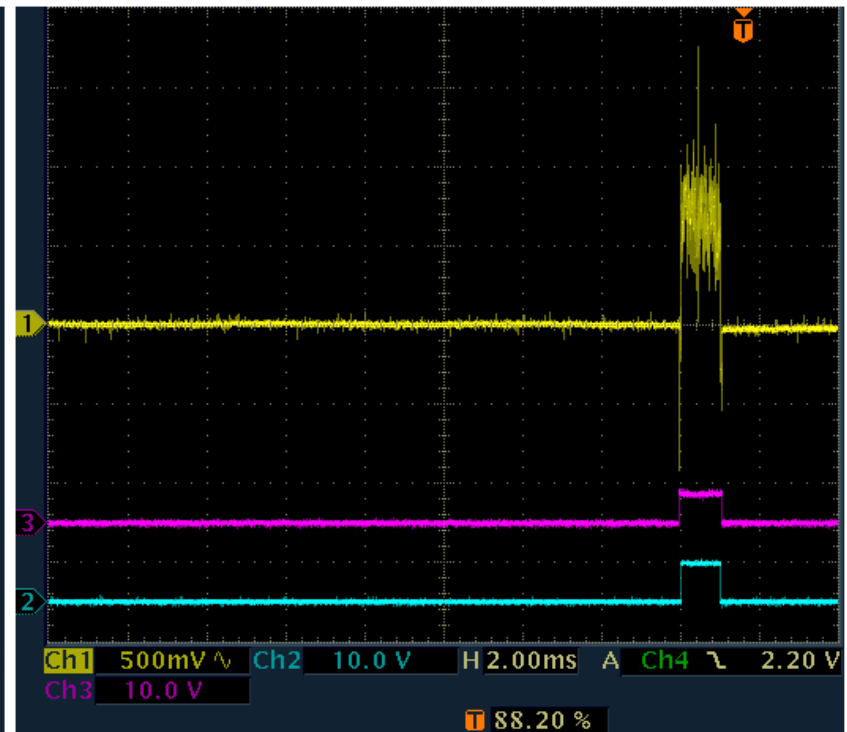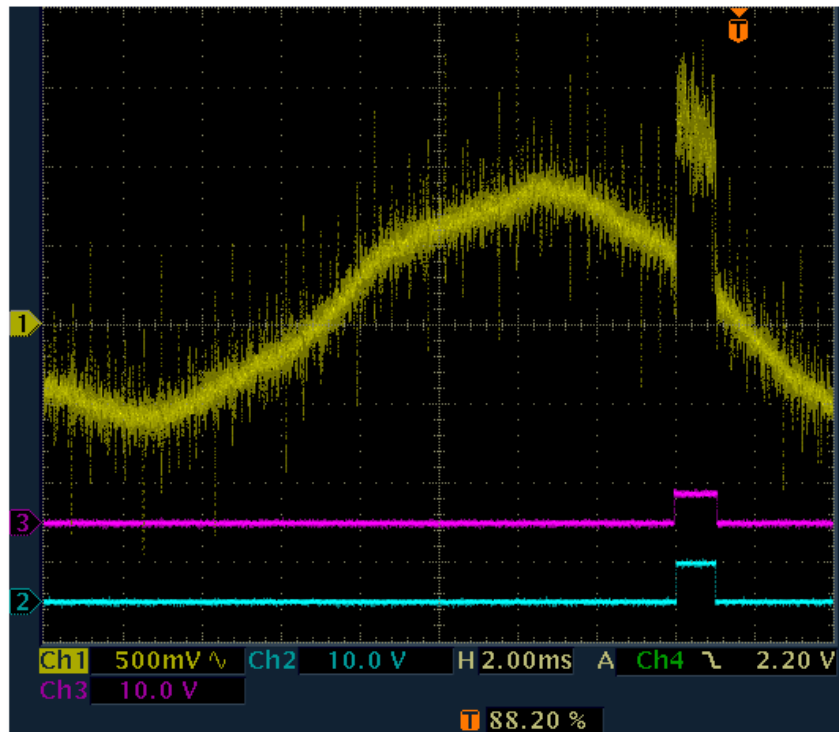
Analog signal processing is the first step to get rid of
EM interferences, here: clamping technique

High current transmission control at GSI´s UNILAC

High current transmission control at GSI´s UNILAC

Example of threshold variation (8 different values):

Green: Clamping pulse

Violet: Integration window

Yellow: Analog signal

Transverse Profile Measurements using Beam Induced Fluorescence (BIF)

• Developments done by LANL, D. P. Sandoval, J.D. Gilpatrick et al in the 90ies up for c.w. and pulsed proton beams

• Measurements of P.Ausset et al at Orsay with low energy dc or pulsed ion beams from an ECR source

• Latest developments at GSI for short pulsed ion beams with energies in the MeV region
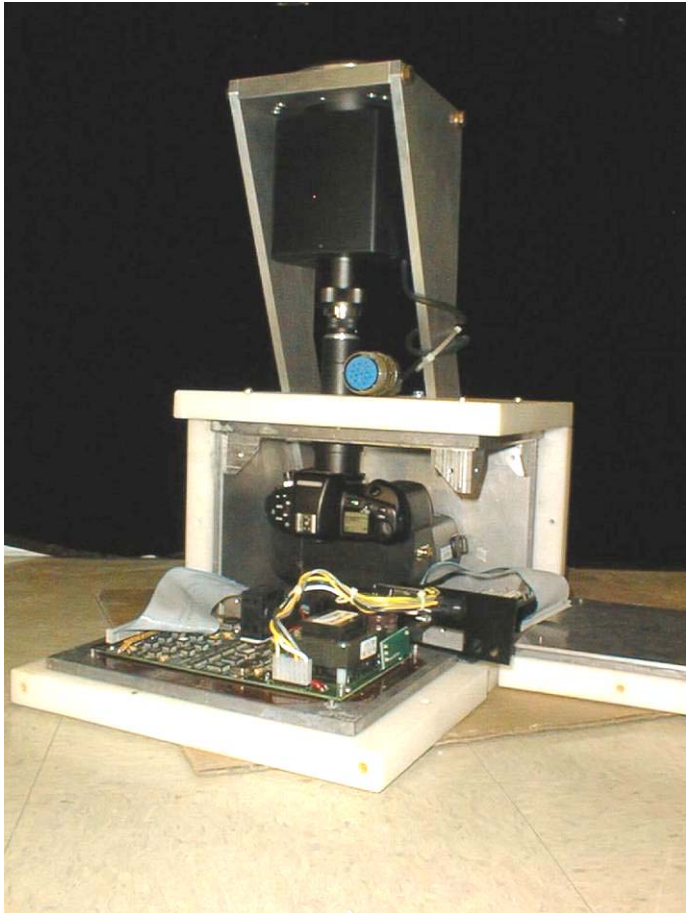
Transversal Profile Measurements using BIF

$$N_2^+ \quad B^2\Sigma_u^+ \rightarrow X^2\Sigma_g^+$$

$$N_2 \quad C^3\Pi_u \rightarrow B^3\Pi_g$$
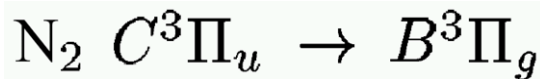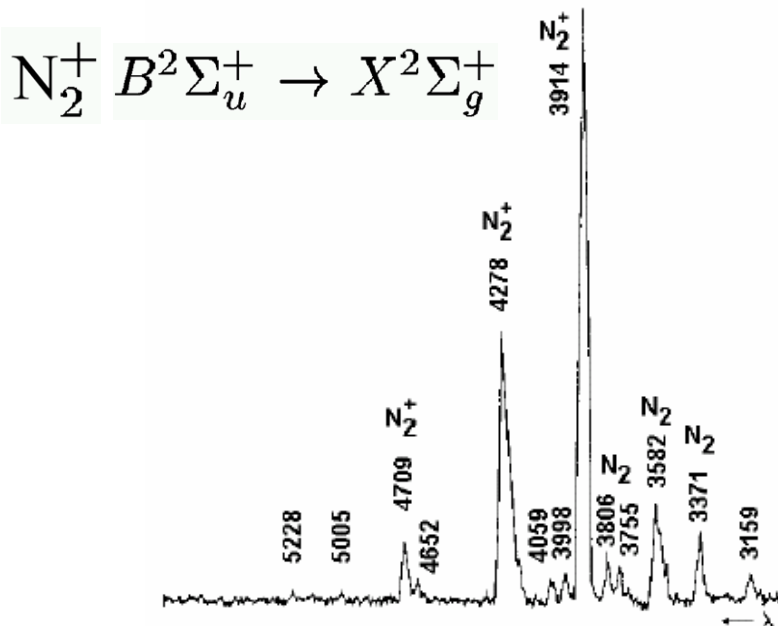
Spectrum measured by R.H.Hughes, 1961, using 200 keV protons
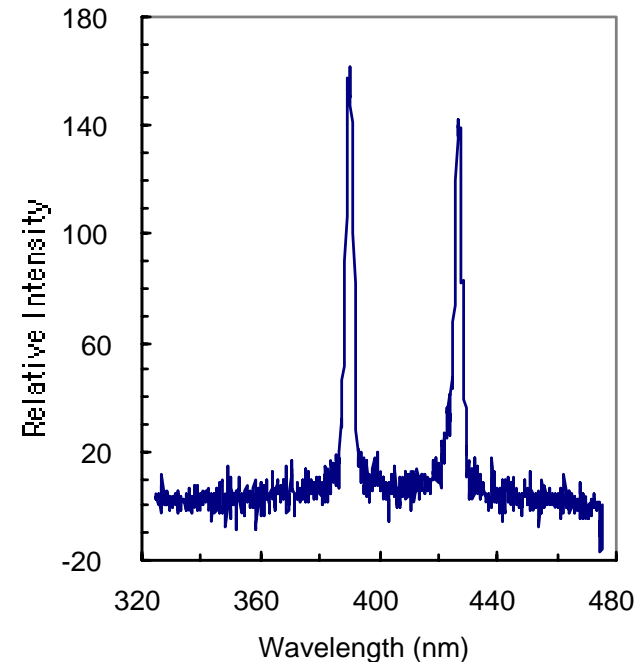
Spectrum measured by D. Gilpatrick (LANL), N_2 partial pressure: 5 x10^{-6} Torr, excited by a MeV proton beam

Transversal Profile Measurements using BIF


Setup for LANL measurements:

- Camera: Kodak DCS 420m w/ DEP image intensifier, variable gain from 1 to 4000

- Lens system: Computar f/1.8, remote controlled

- N_2 gas injection system:

  - Maxtek piezoelectric valve, through-put range: 0-6 torr-liters per sec

  - Backpressure control system, maintains auxiliary N_2 gas supply pressure for piezoelectric valve delivered by Balzers

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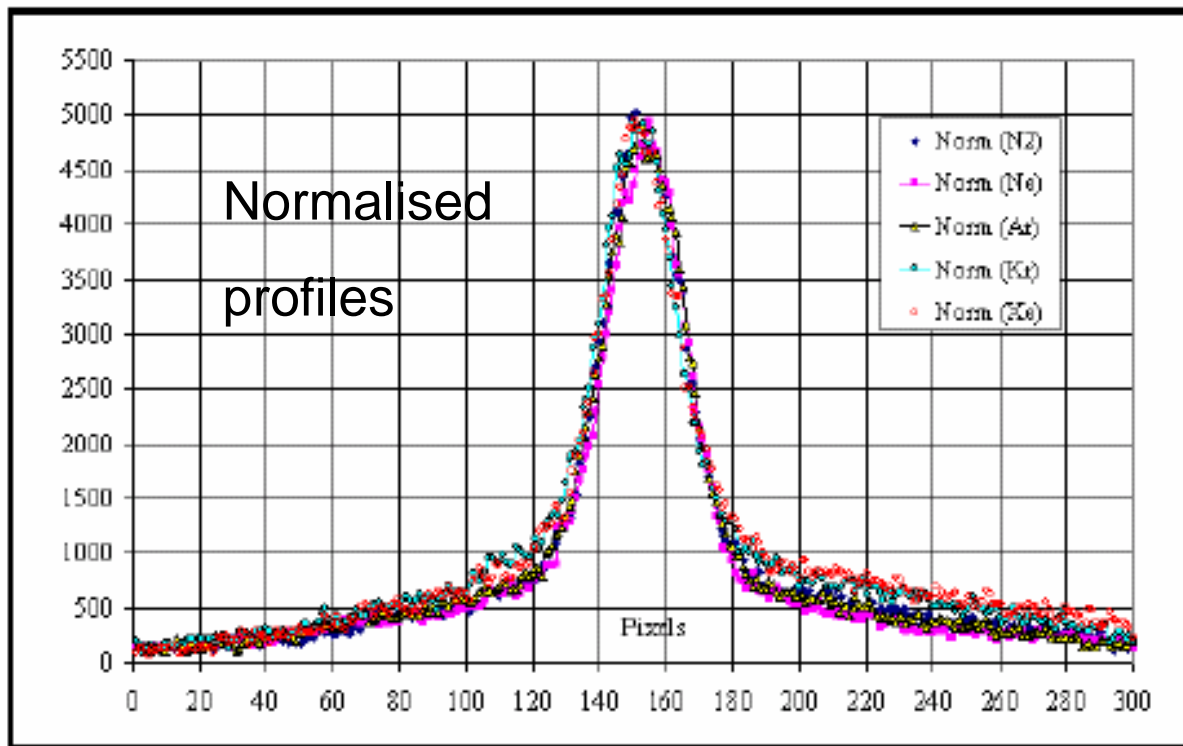# Transversal Profile Measurements using BIF

Series of comparative measurements with a wire scanner (LANL);

Beam conditions: 100 mA, 1 to 10 ms, 6 Hz, 6-7 averages per picture
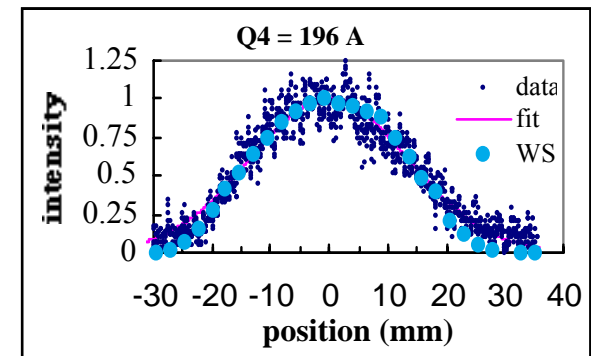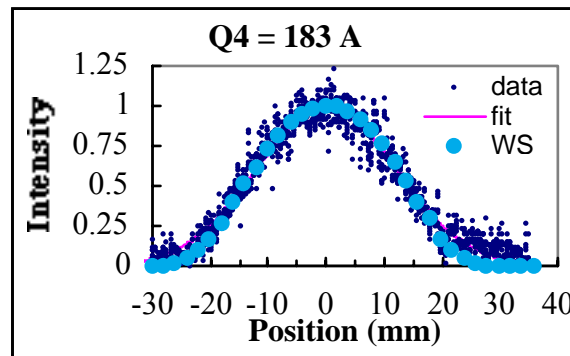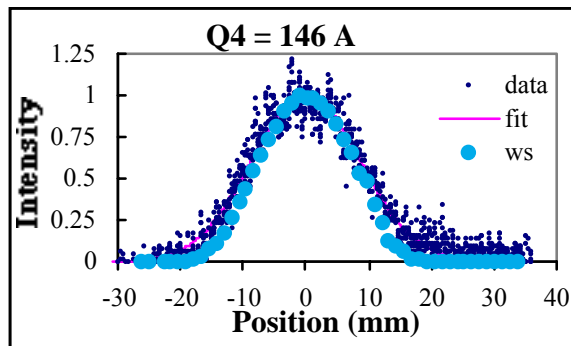
The profile measurement data agree within < 10%, while the BIF profiles show always a slight broadening, maybe caused by a space charge effect
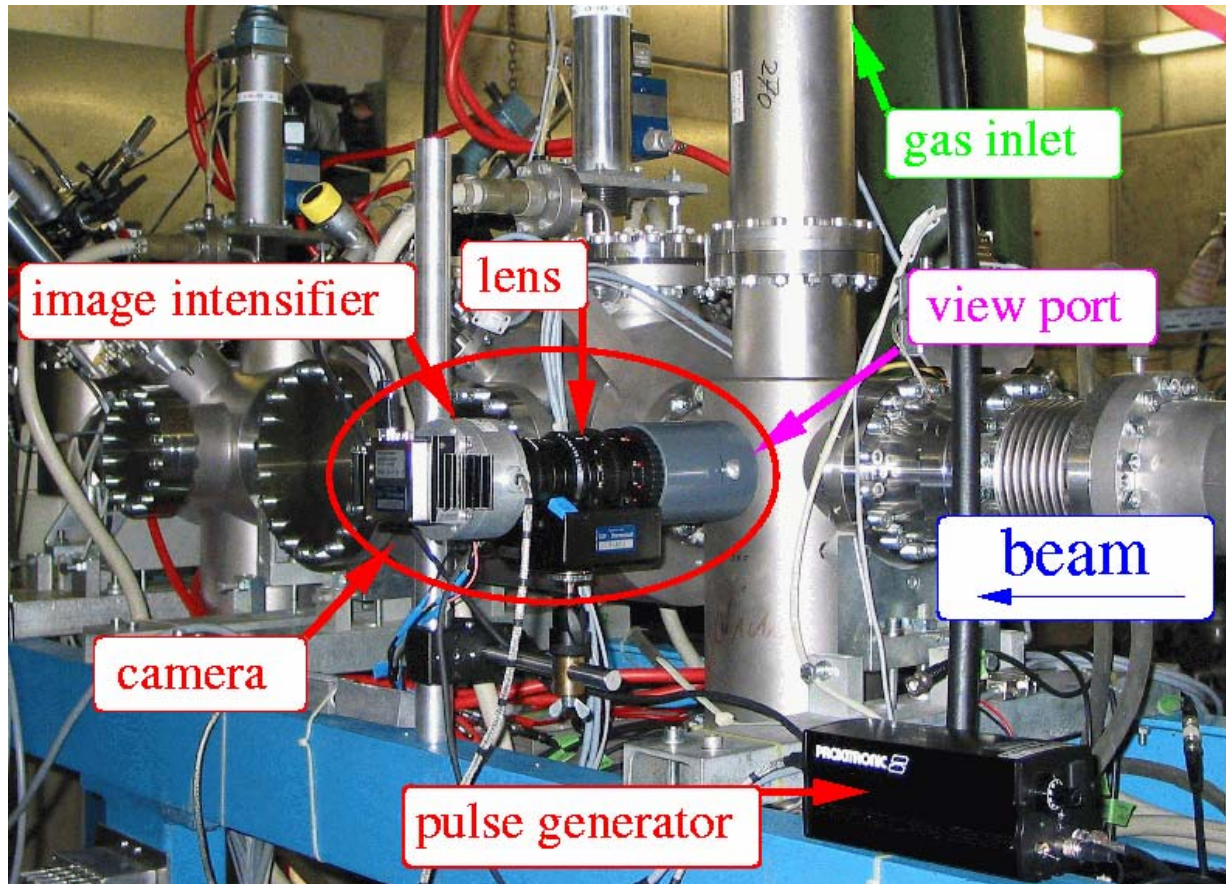
Transversal Profile Measurements using BIF

Measured profiles have the same geometrical shape for all gases at the same pressure,

N_2 shows the largest cross section for the excitation → no special gas like Krypton necessary

P. Ausset et al, using 95 keV, 100 mA proton beam

Transversal Profile Measurements using BIF

First set-up at GSI:

Motorized lens

Double MCP intensifier with a gain of up to 10^6

CCD camera with Firewire/IEEE1394 interface

Optical link to PC

Gas inlet system

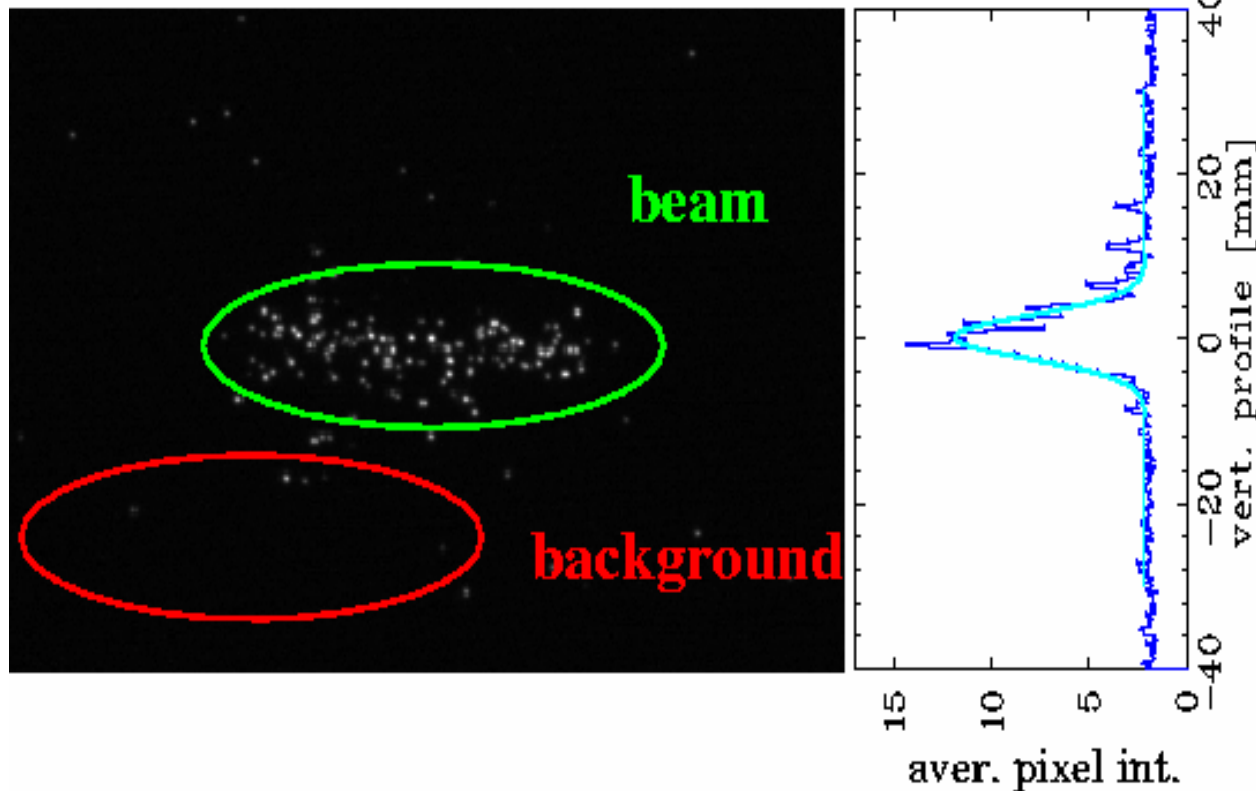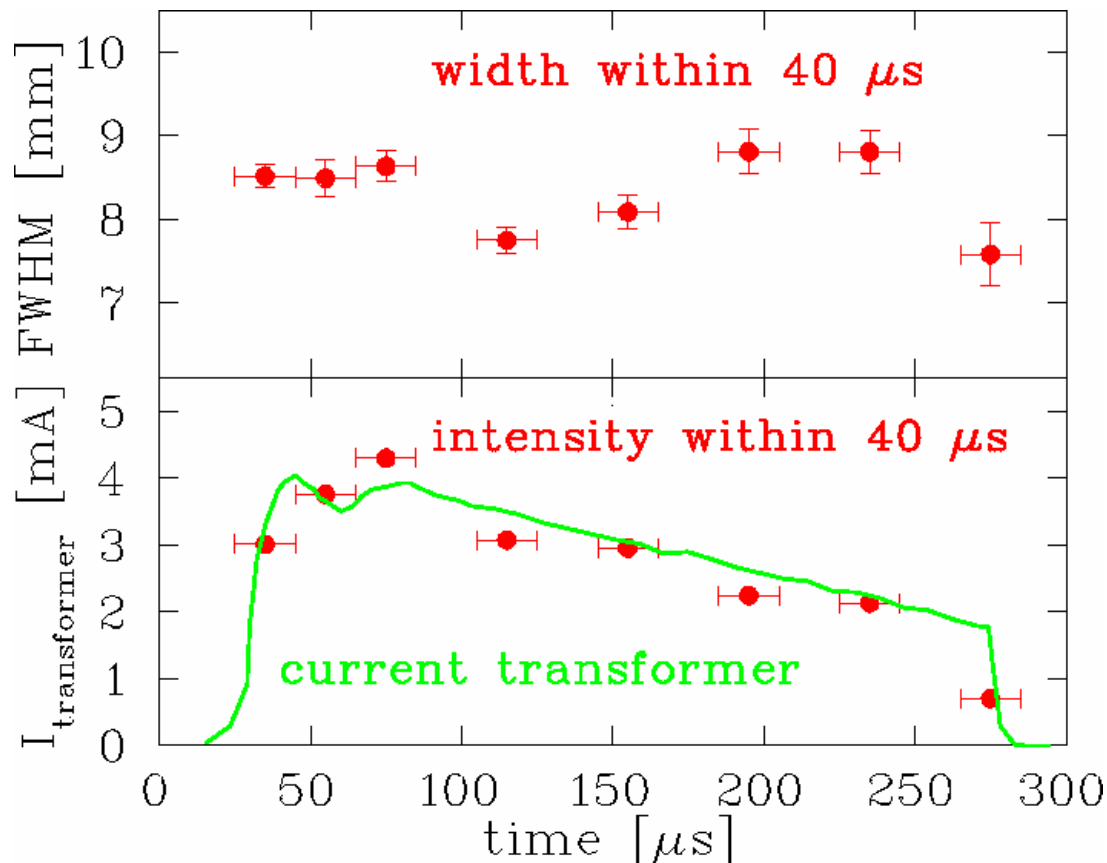# Transversal Profile Measurements using BIF

Image of a 200 μs U^{28+} beam with I=700 μA recorded during **one** UNILAC macro-pulse with a vacuum pressure of about 10^{-5} mbar. The two dimensional image from the intensifier (left) and the projection for the vertical beam profile (right) is shown
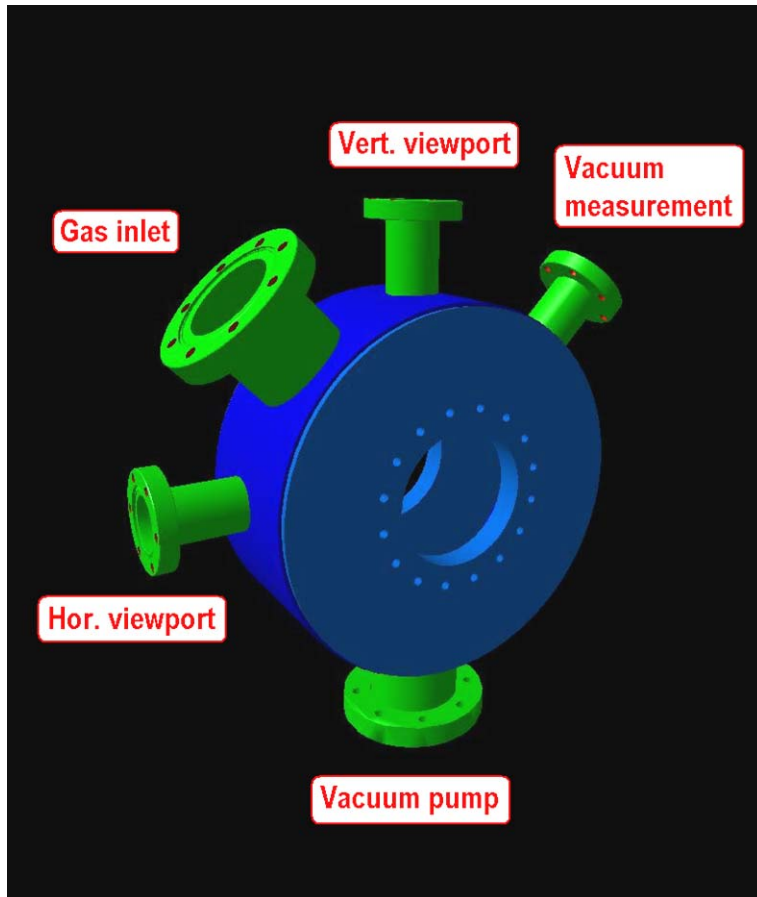
Transversal Profile Measurements using BIF

A measurement of the width variation during macro pulse (each data point taken in *one* pulse) is shown.

The lower graph shows the normalized image intensity together with the measured beam current.

<u>Transversal Profile Measurements using BIF</u>

**<u>Top:</u>** Digital measurement system (without subsystems)

<u>Left:</u> Prototype design of a BIF measure-ment vac. chamber → length only 120 mm!

Longitudinal Profile Measurements

• Intersecting method, developed by A.V.Feschenko, P.N. Ostroumov et al, INR, Moscow

• A new adoption of this method but with a non-intersecting approach is under development at GSI, P. Forck et al
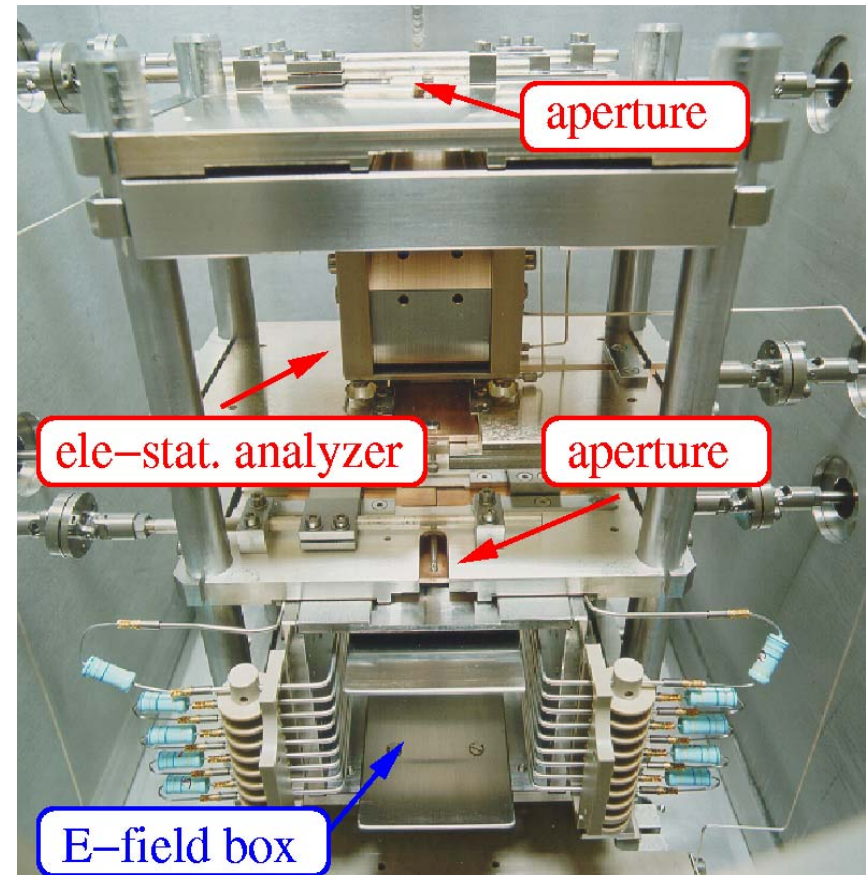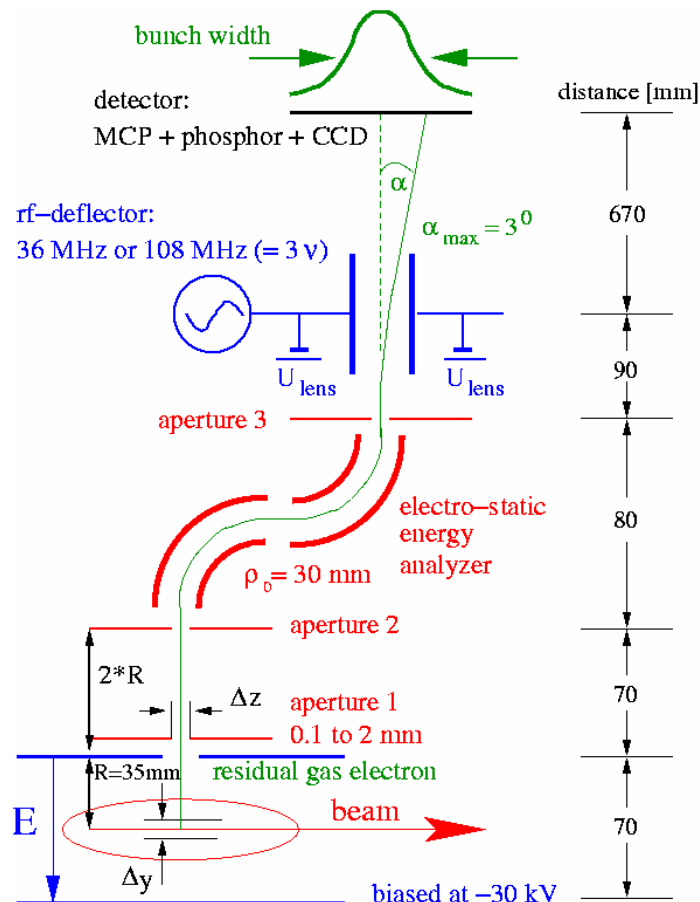
Longitudinal Profile Measurements

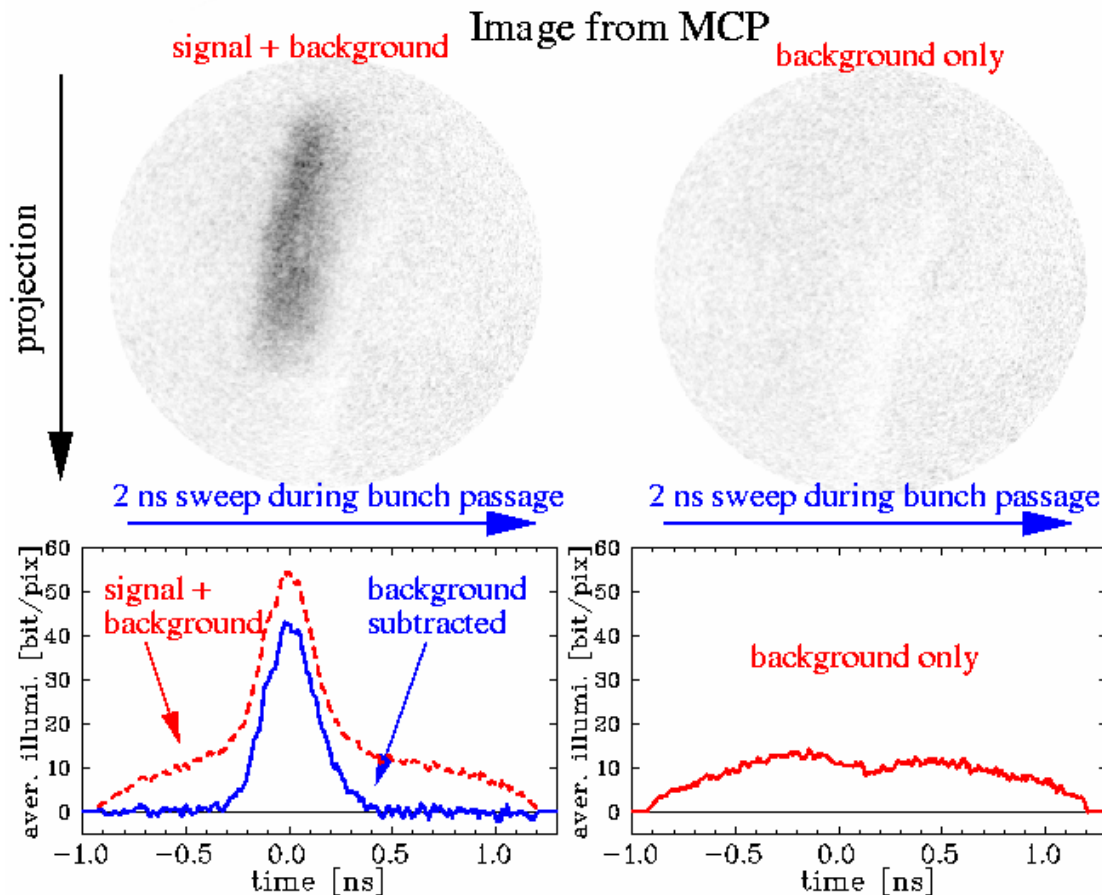Mechanical set-up of intersecting 3D-BSM for CERN Linac-2
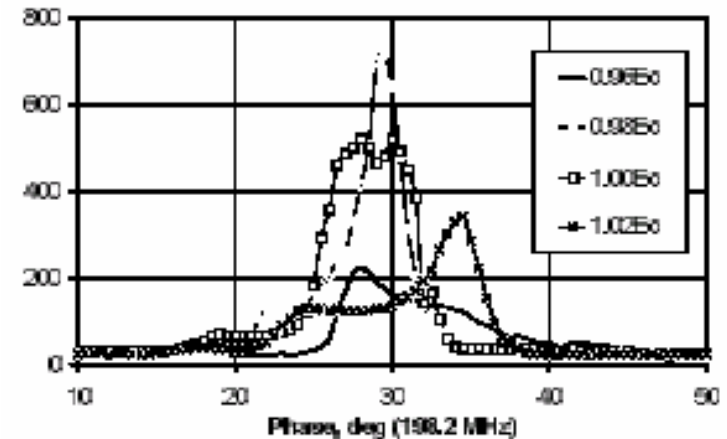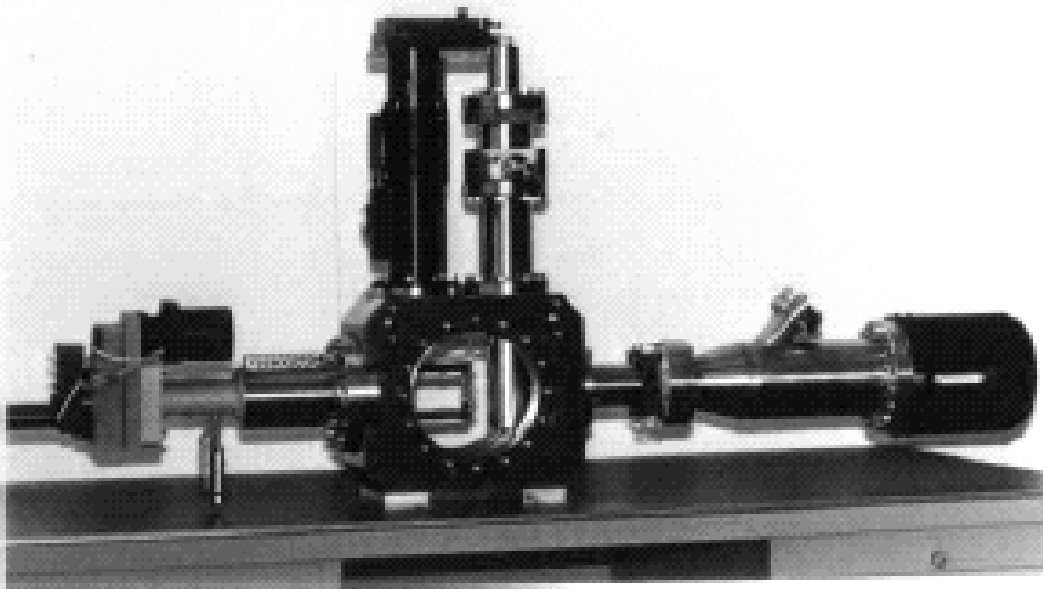
Bunch shapes at the exit of the first tank of INR linac for different accelerating fields

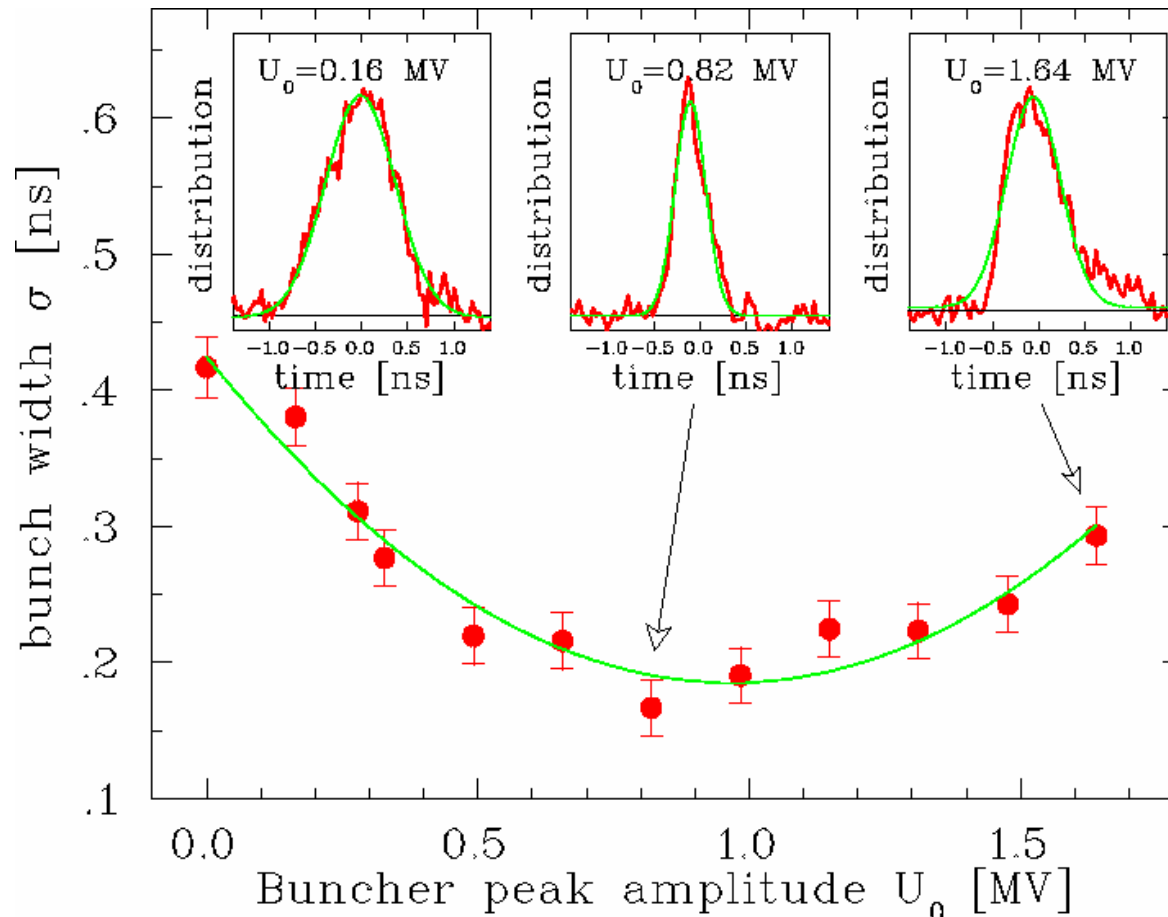# Longitudinal Profile Measurements

<u>Longitudinal Profile Measurements</u>

Typical image (inverted colour) from the MCP for a 60 μA Au^{25+} beam averaged over 16 macro-pulses with 1 ms length. The background only is displayed on the right side.

Longitudinal Profile Measurements

Longitudinal emittance estimation:

Measurement of the bunch width (one standard deviation) as a function of the buncher voltage, buncher around 30 m upstream to the detector, performed with a 2 mA Ni^{14+} beam using only 4 averages per data point

<u>Summary</u>

- Some remarkably new or enhanced diagnostic systems are under development using non-interfering methods

- Digital techniques from customisable FPGAs up to high speed digital cameras support these development trends, especially with a large variety of commercially available systems

- Only a few developments could be shown, there are a lot of others, e.g. the SNS Laser Profile Monitor for H^- beams, which had been worth mentioning

- Thanks to all colleagues contributing to this talk with their papers, measurement results and pictures!!!