New development of a profile grid electronic to measure the spatial and temporal resolution of an ion beam

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SEI-Meeting

GSI Darmstadt

21.-23.3.2011

Agenda

- Basic Principle of a SEM-Grid (**P**rofile **G**rid/Harps; **PG**)
- Currently Hardware Architecture
- Why new PG-Electronics ?
- QFW-ASIC by Dr. H. Flemming, EE
- Test boards with QFW-ASIC
- New prototype of PG-Electronics
- The new measurement system (prototype version)
- Experiments at profile grid UX2DGA at beam line X2
- Results of measurements
- Outlook – next steps
- Discussion

SEM-Grid (**S**econdary **E**lectron e**M**isson Grid)

QFW (**C**harge-**F**requency-**C**onverter)

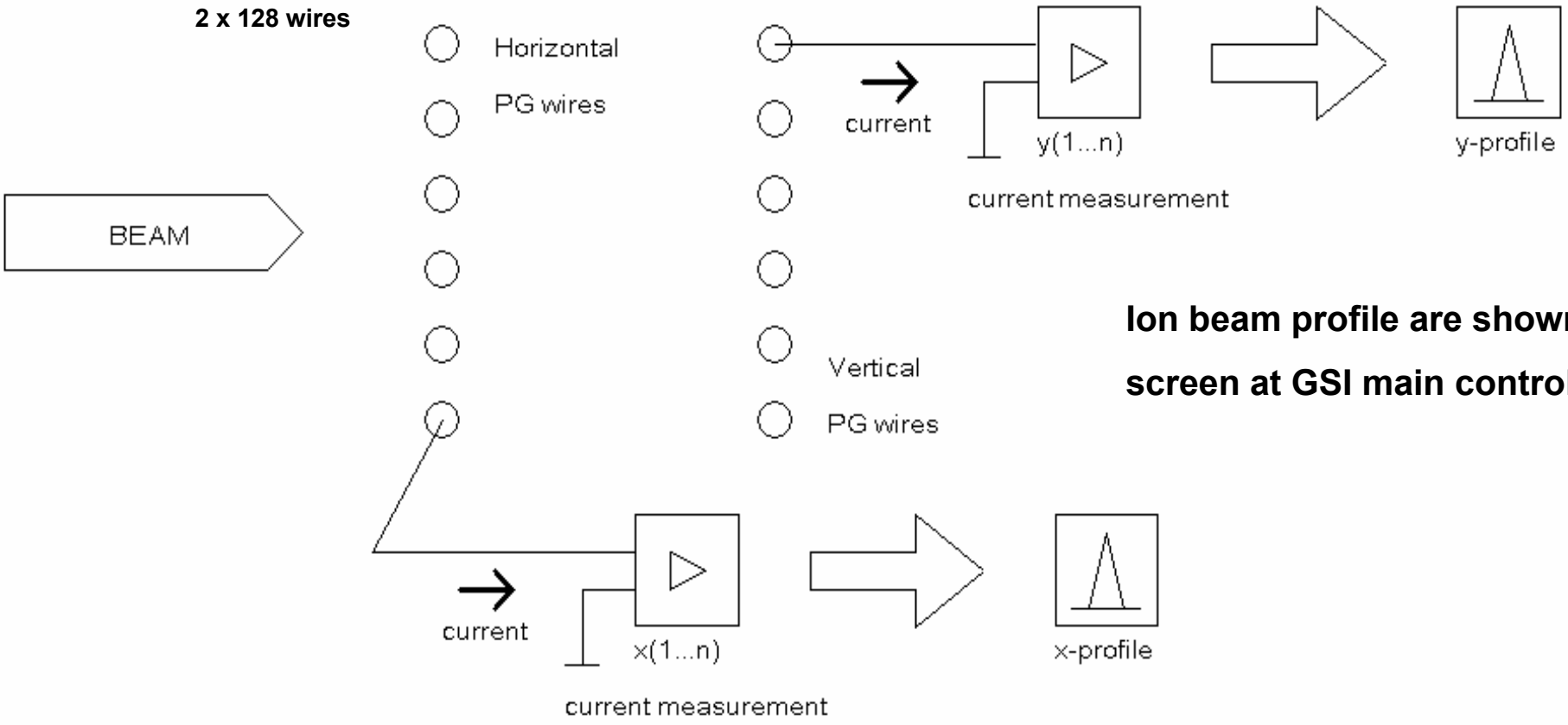
Basic Principle of a Profile Grid

SEM-Grid with 2 x 16 wires

2 x 32 wires

2 x 64 wires

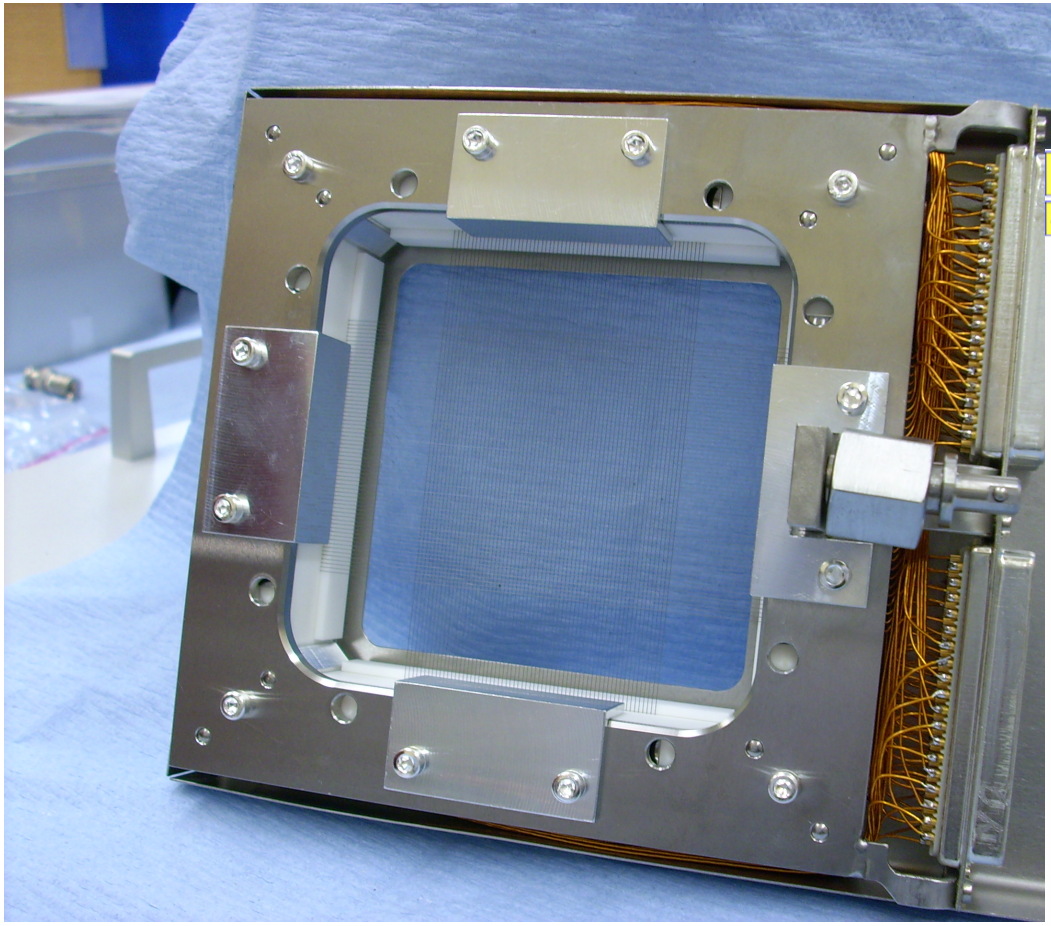
2 x 128 wires



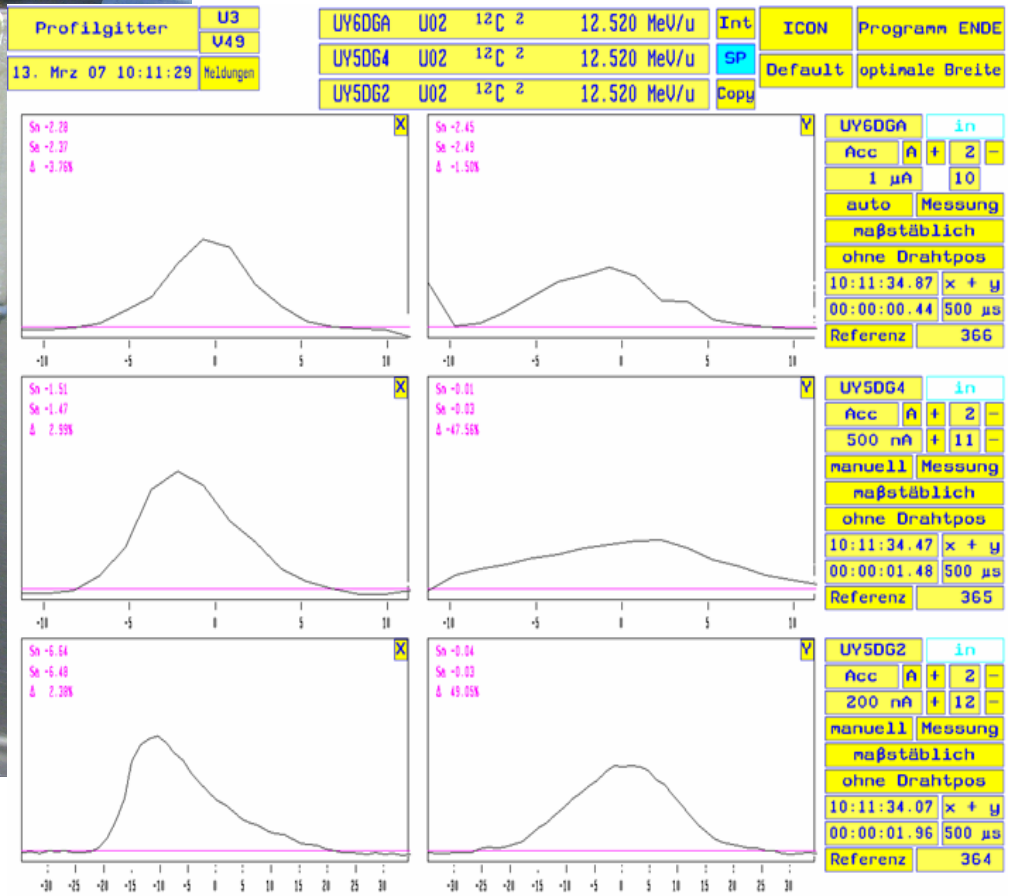
Ion beam profile are shown on PC screen at GSI main control room

Ion beam hit the wires and secondary electrons are produced.

Basic Principle of a Profile Grid

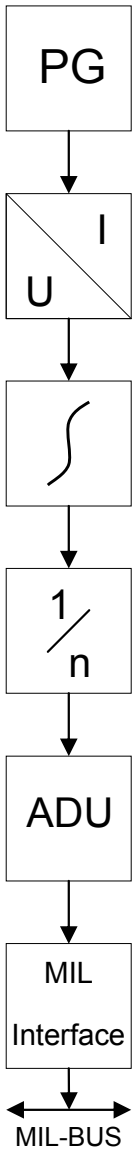


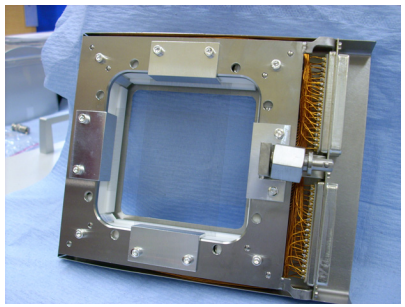
SEM-Grid with 2 x 64 wires



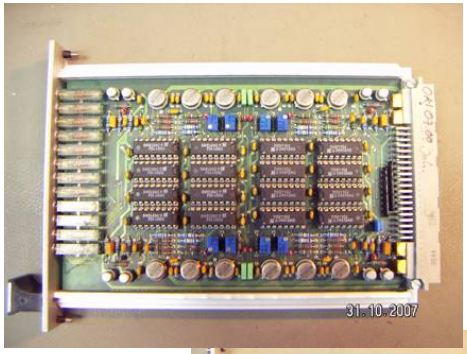
Ion beam profiles at main control room

Current Hardware Architecture





SEM-Grid: 16,32,...,96 wires



Analogue PCB

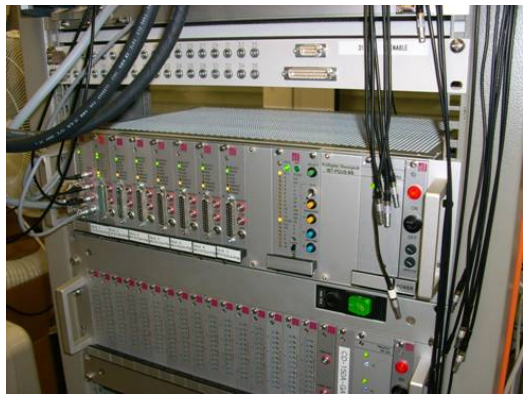
(Front-end amplifiers)

ADU-PCB with

Control & Info card

Data-Transfer- and

MIL-Interface card



Rack

Present Profile Grid Electronics

- **Assembled with outdated electronic components (> 20 years)**

- **High purchase costs**
  At present: ~30 k€ for one profile-grid analogue instrument with 64 wires/inputs

  ➔ ~500 € per analogue input channel

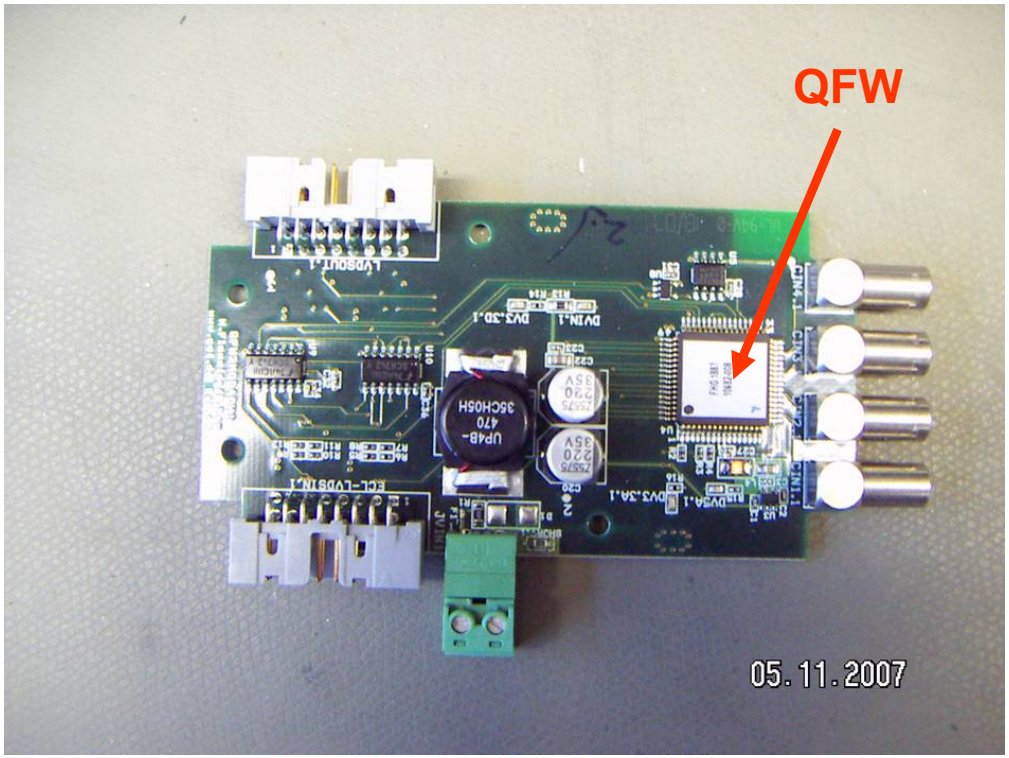
- **Extended delivery time of electronic components**

Additional objective with respect to the FAIR project:

Reduction of costs per unit ! **QFW from EE**

Proposal – Investigation of QFW

QFW module PCB with ASIC by Dr. H. Flemming/GSI-EE



- **ASIC provides 2 ranges (0.25 or 2.5 pC/pulse)**
- **Large dynamic range 300 fA …130 µA**
- **Power supply 5V and 3.3V (ASIC),**
  (module needs 5.2-7V)
- **4 analogue inputs/ASIC**
  (module has 4 LEMO coaxial inputs)
- **4 on-chip counters, 16bit**
- **Output frequency 40 MHz (10 or 100 µA)**
- **QFW has digital interface (serial or parallel)**
  (module only serial port in operation)
- **Module with additional drivers**
  (LVDS and ECL compatible)
- **Offset correction via parallel interface**
- **Price: <50 €/ASIC**

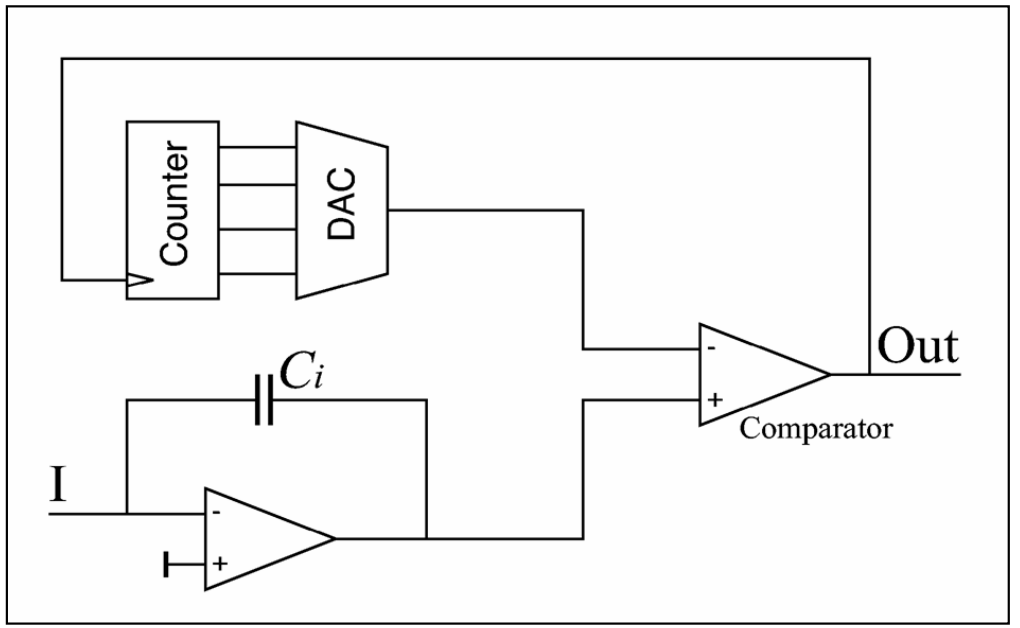
QFW-ASIC - Working Principle

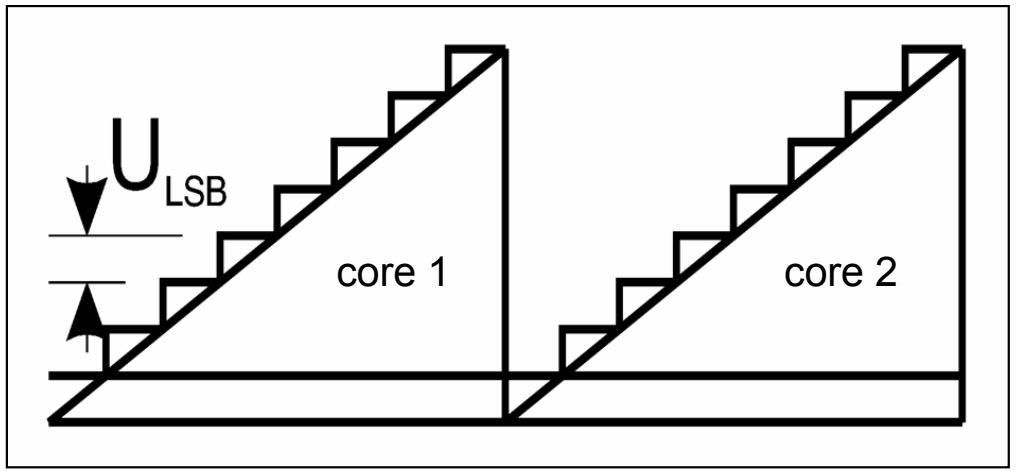
Block diagram of QF converter core

(with 4-bit DAC)

- 2 QF cores per channel
- Input current is integrated in active core #1
- Comparator incriminates integrator voltage and DAC reference
- If comparator trips the counter advances one step (or LSB value)
- On overflow the integrator of core #1 is reset while core #2 gets activated
- The measured charge per step is defined by $dQ = U_{LSB} * C_i$
- The output frequency is linearly dependent of the input current:

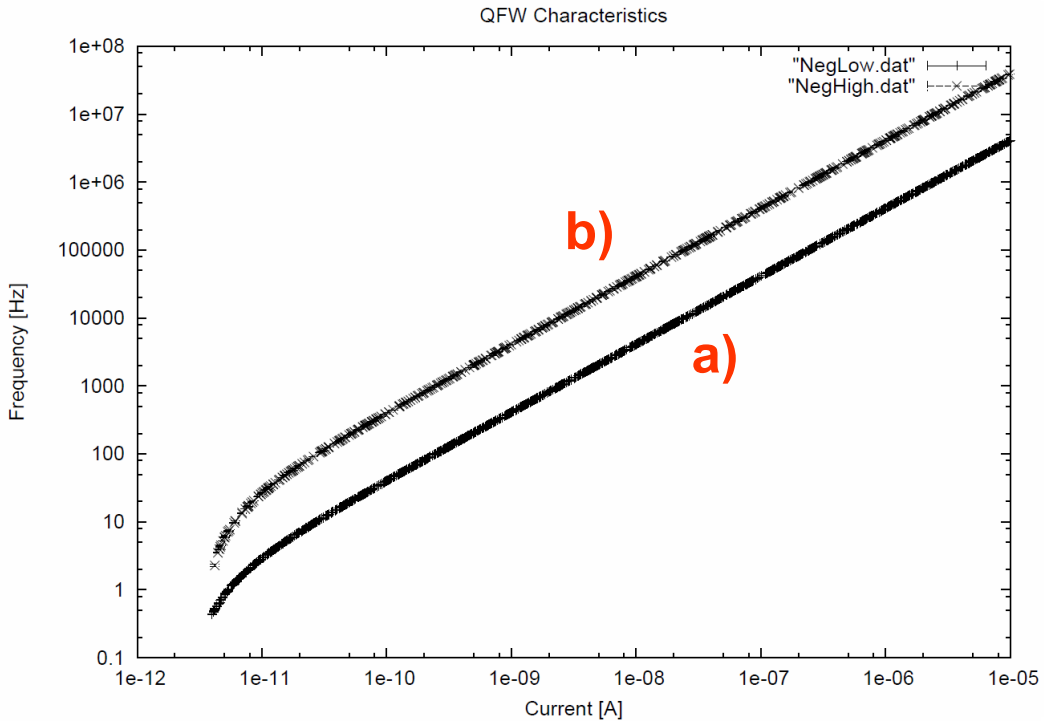
  $f = I / dQ$



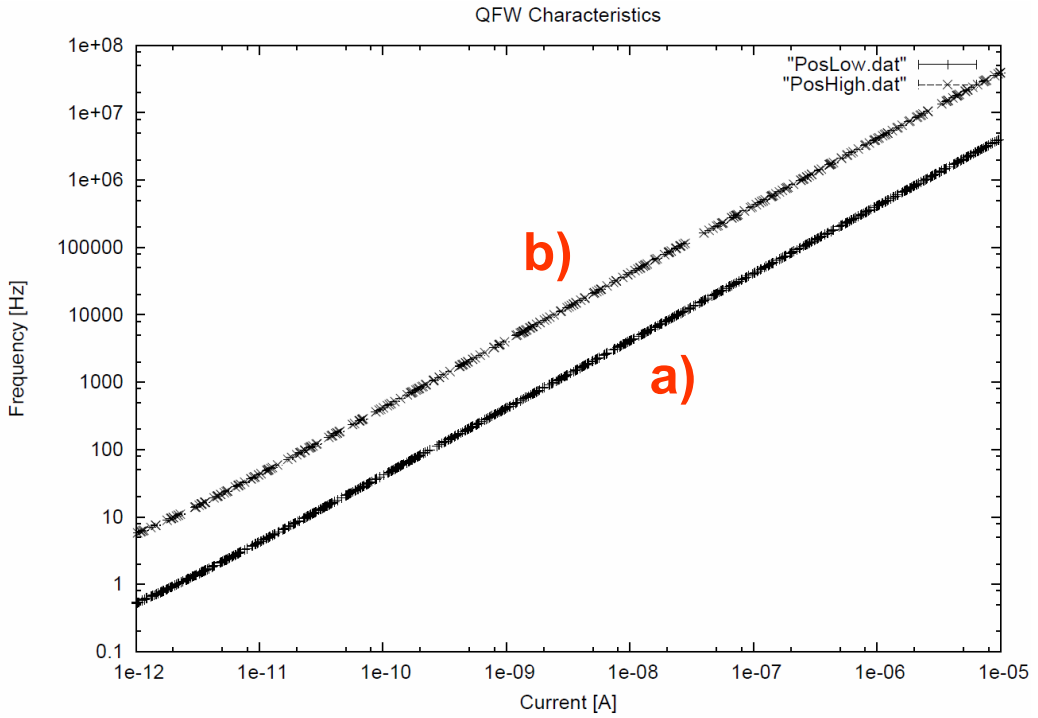


QFW output characteristics

QFW converter output characteristics for negative and positive currents over seven orders of magnitude in current.

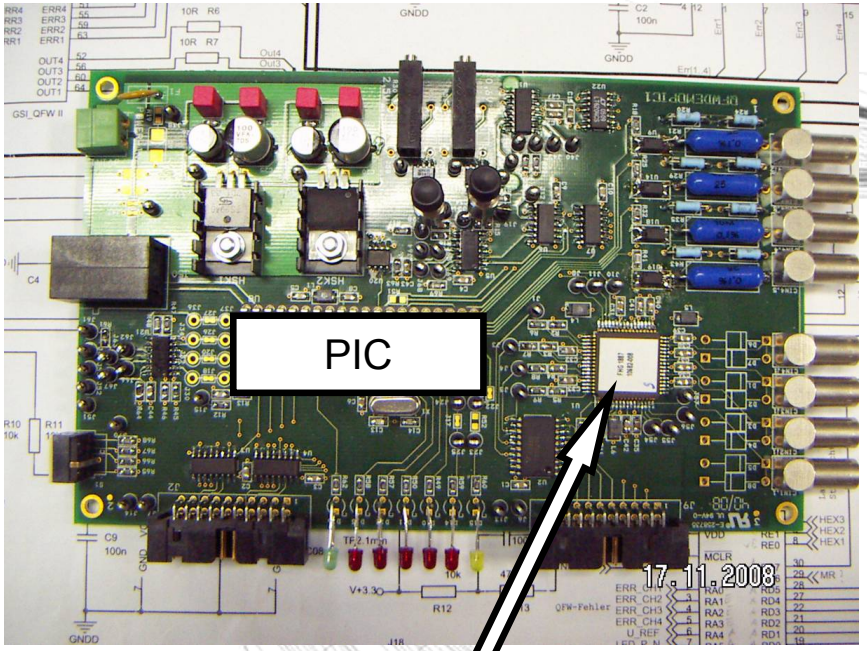


Converter characteristics for **negative** currents
a) low current range (up to 10 µA)
b) high current range (up to 100 µA)



Converter characteristics for **positive** currents
a) low current range (up to 10 µA)
b) high current range (up to 100 µA)

Further Development



Previous Investigations

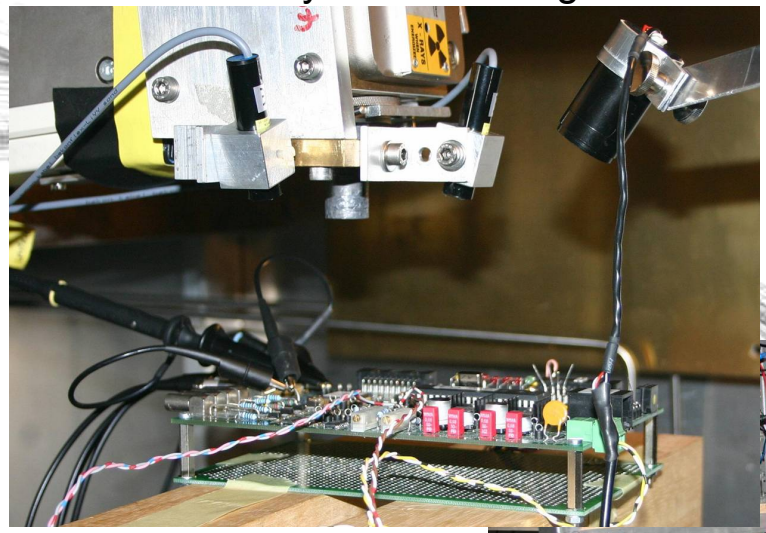
- Linearity in different ranges
- Range extension (current divider)
- Range of errors (variance)
- Gain synchronicity between channels
- Channel crosstalk
- Radiation hardness (TID with X-ray)
- Temperature drifts
- Offset stability

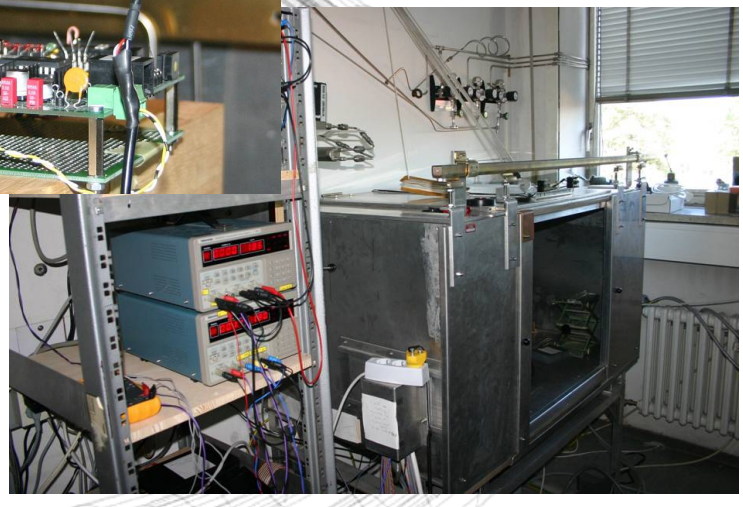
Investigation with X-ray

TID investigation

at research centre Karlsruhe

Shielded X-ray tube with target board

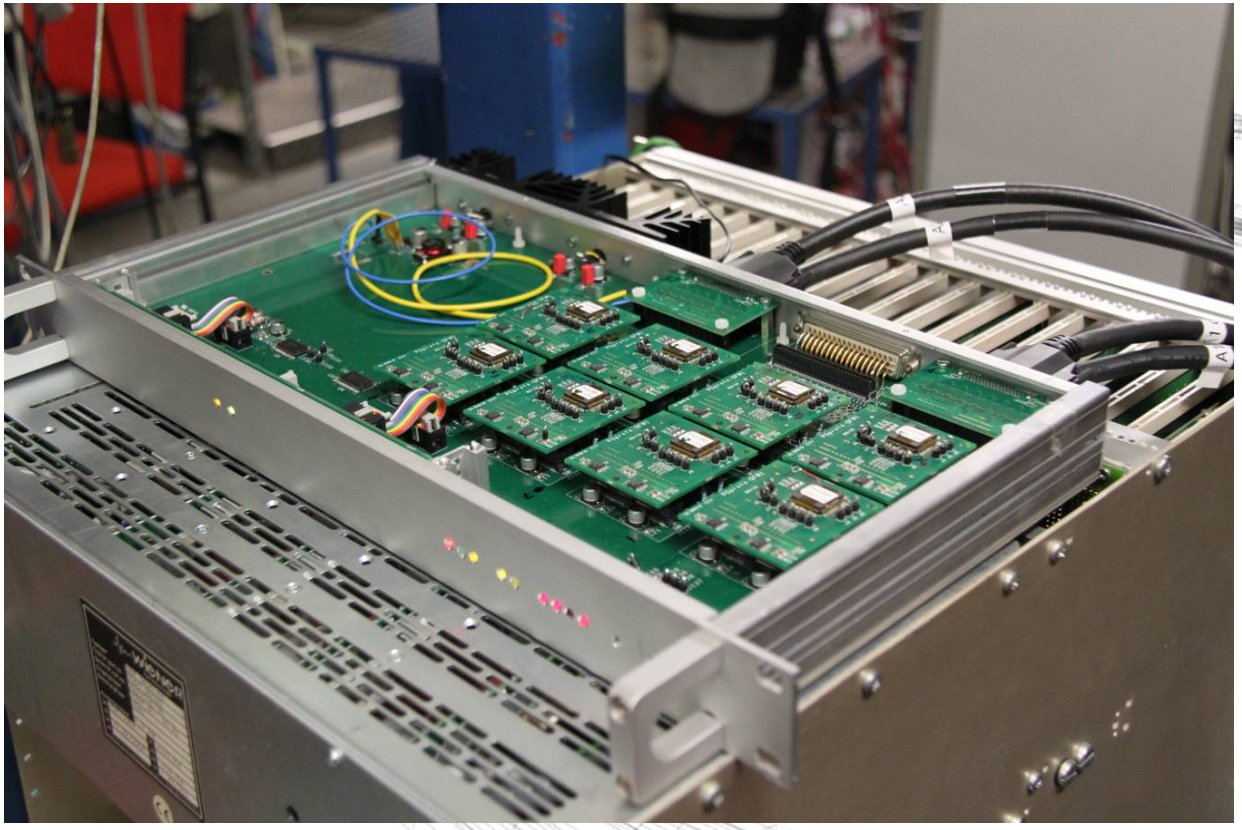




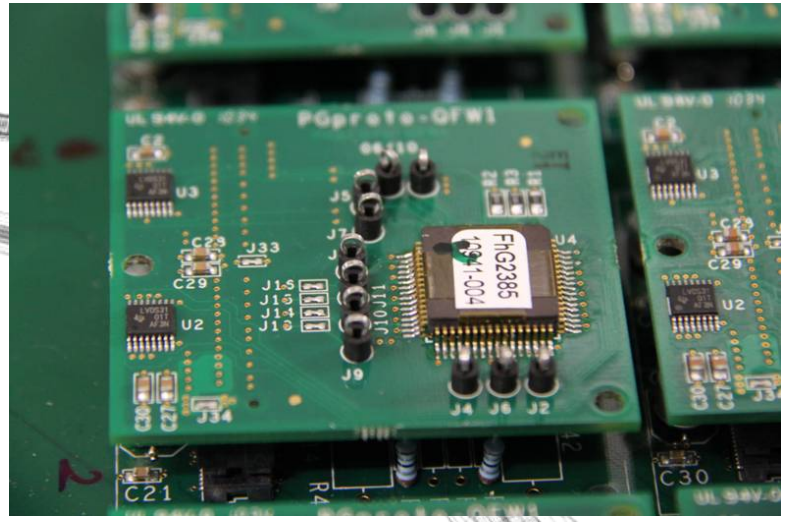
"X-ray cupboard" at lab

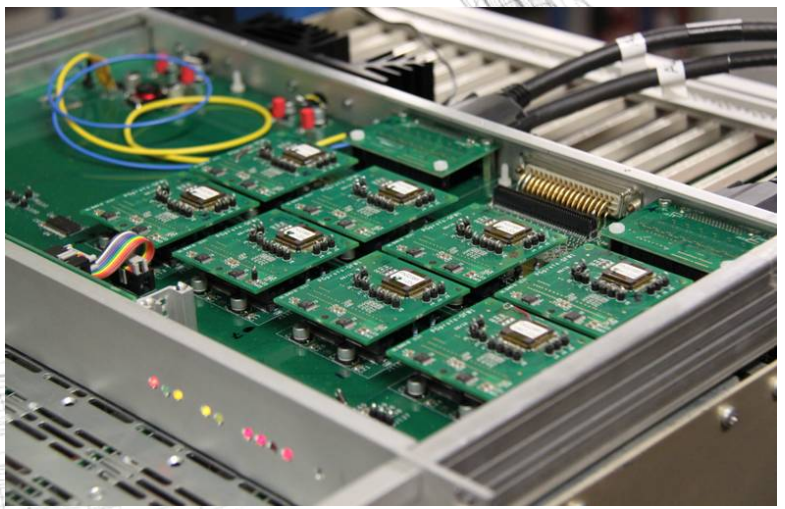
- X-ray tube @ 60kV
- Tests until **11 kGy** (SiO_2)
- **all ASICs functional**
  after radiation
- **increasing** of offset-current (<10nA)
- **immediate** of self-annealing
  after radiation switch-off
  (after several weeks the QFW has the same parameters like before radiation)
- *Compare: PIC didn´t work after radiation of under 0.6 kGy*

Prototype Development



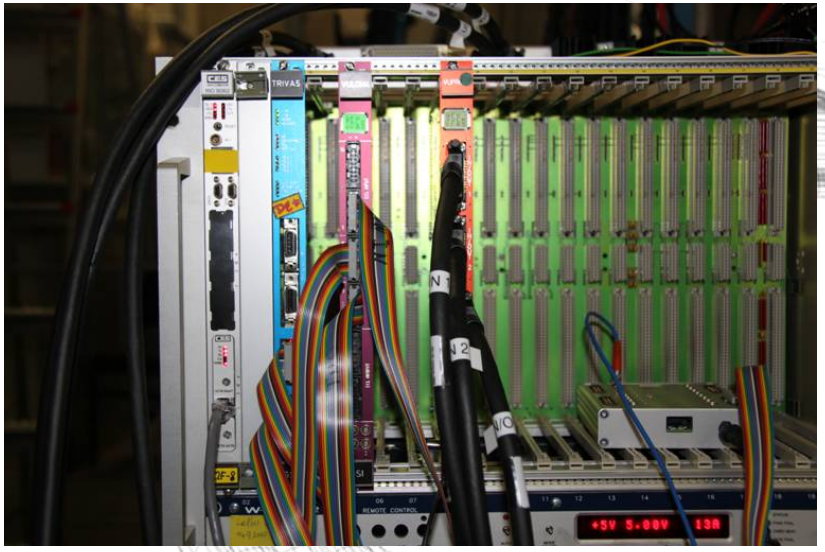
New QFW-Board

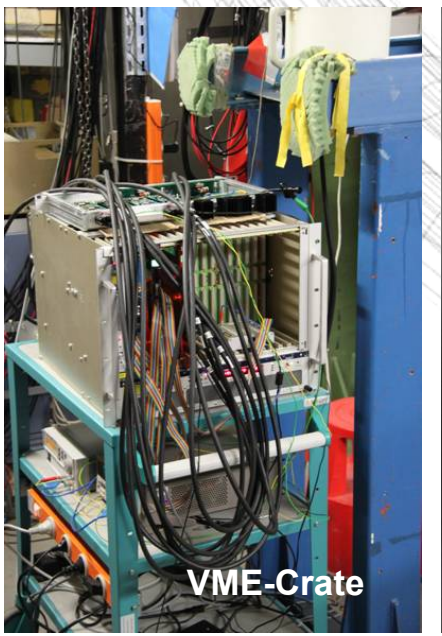


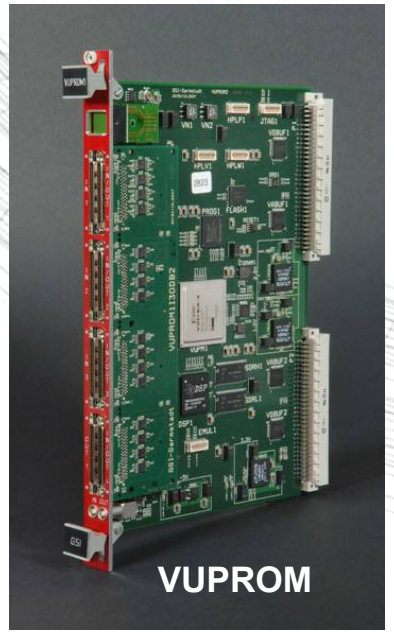


Setup with 8 QFW-ASICs / 32 input channels !

Measurement Equipment







Hardware:

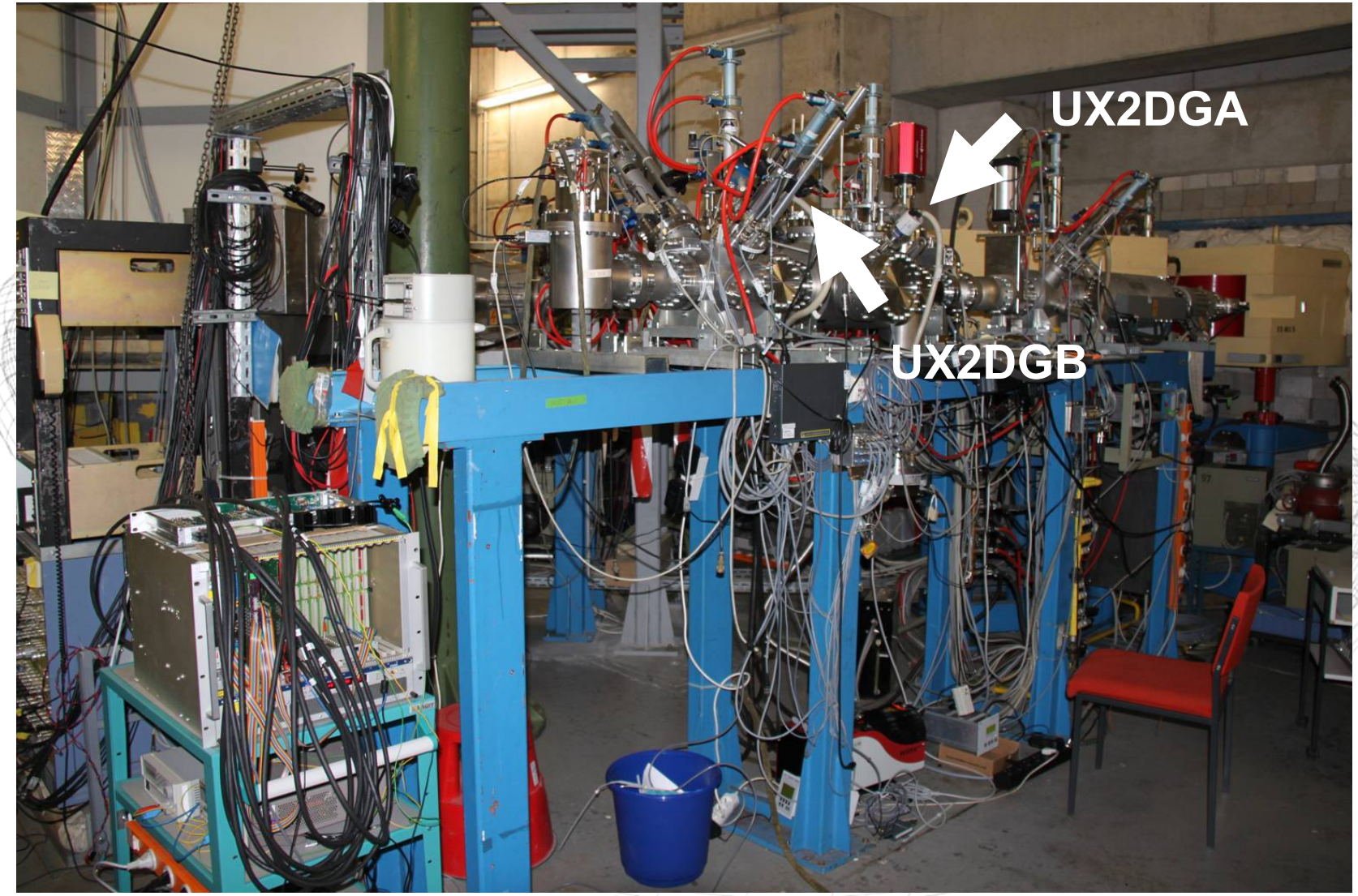
- **RIO 2** (CPU and network connection)
- **VULOM** (for MBS system, trigger dead time operation)
- **VUPROM** (FPGA, QFW-control unit)
- **TRIVA** (Trigger module for MBS)
- **LEVCON** (Level converter box)
- **VME-Crate**
- **QFW-motherboard with external power supply**

Software:

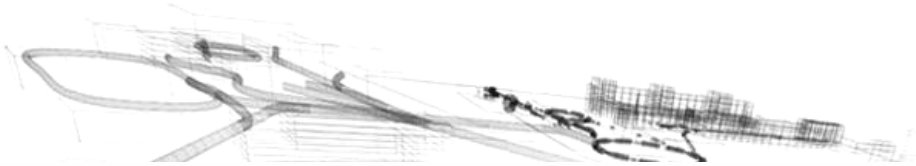
- **Go4*** (program for analysis)
- **C program** (setting QFW registers)
- **MBS** (DAQ - Multi Branch System)

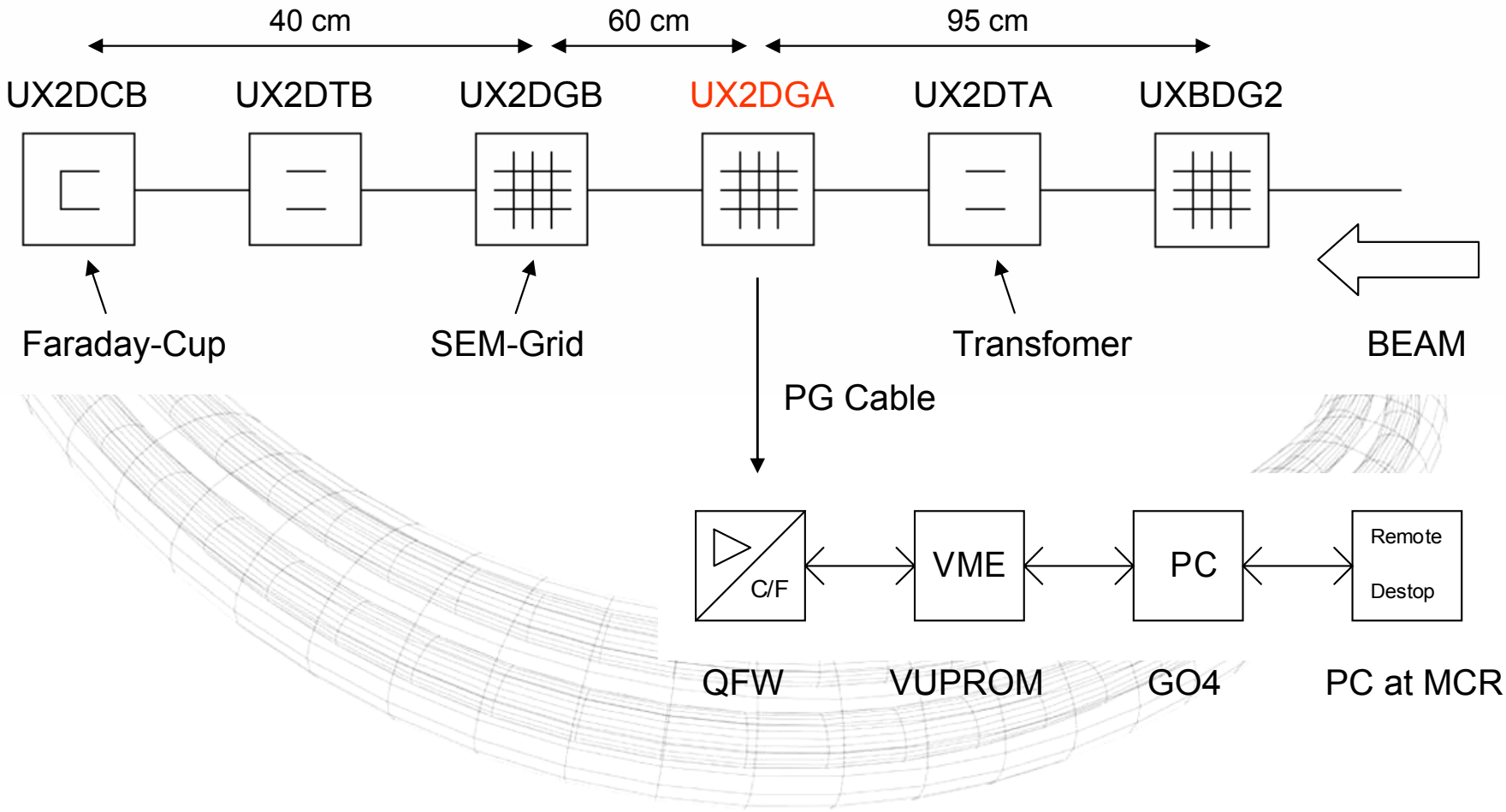
*Go4 (GSI Objected Oriented On-line Off-line system)

Setup at Beam Line X2



Beam Diagnostic Devices at X2





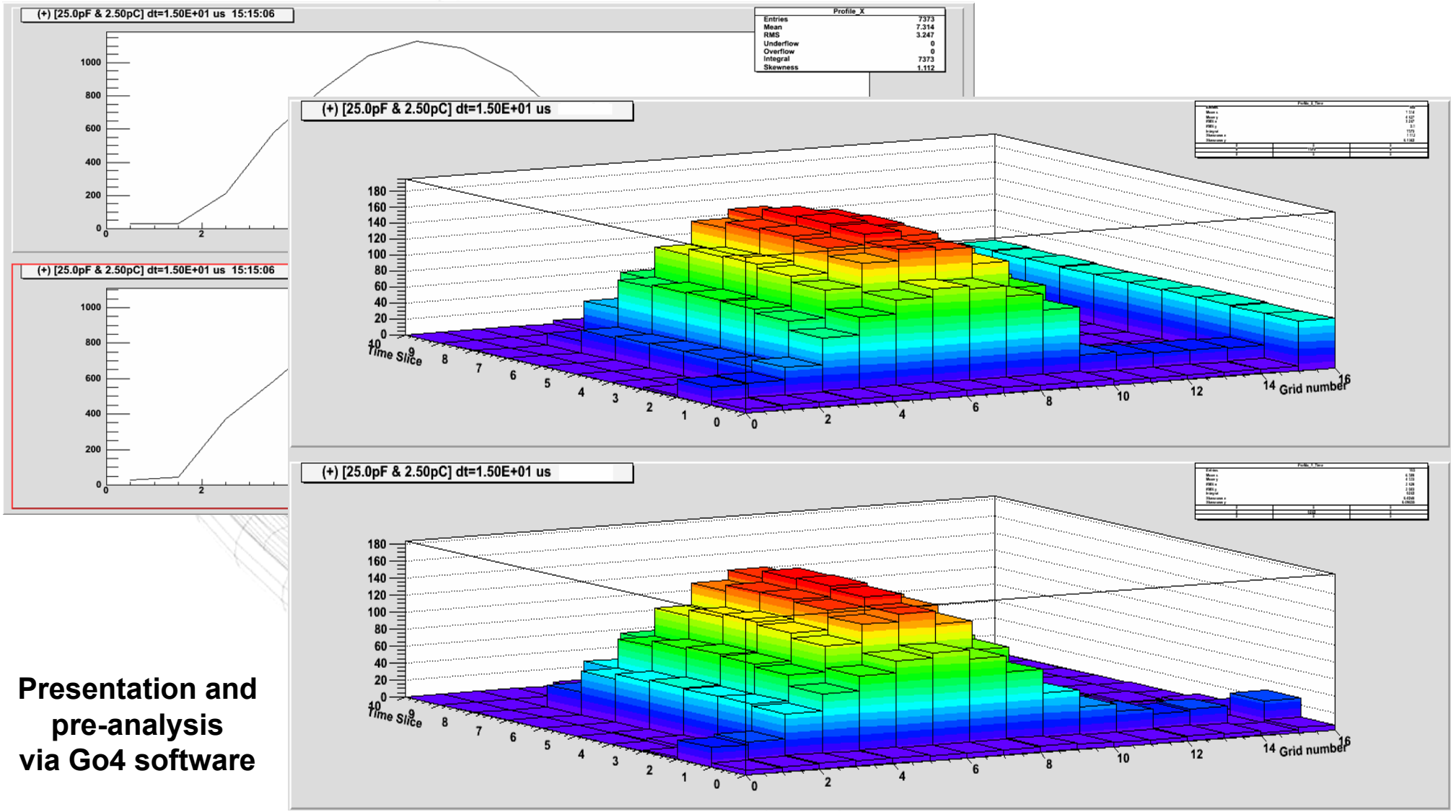
Beam Tests - November 2010

1. Beam Test Block (5.-7.11.2010)
   - Xe-124, 4.8 MeV/u, max. 1mA pulse peak, 1 Hz
   - **Functional test** of new readout electronics (with 21m cable)

2. Beam Time Block (9.-10.11.2010)
   - Xe-124, 4.8 MeV/u, max. 1mA pulse peak, 1 Hz
   - **New software** „3D“ record of beam profile (XY and Time)

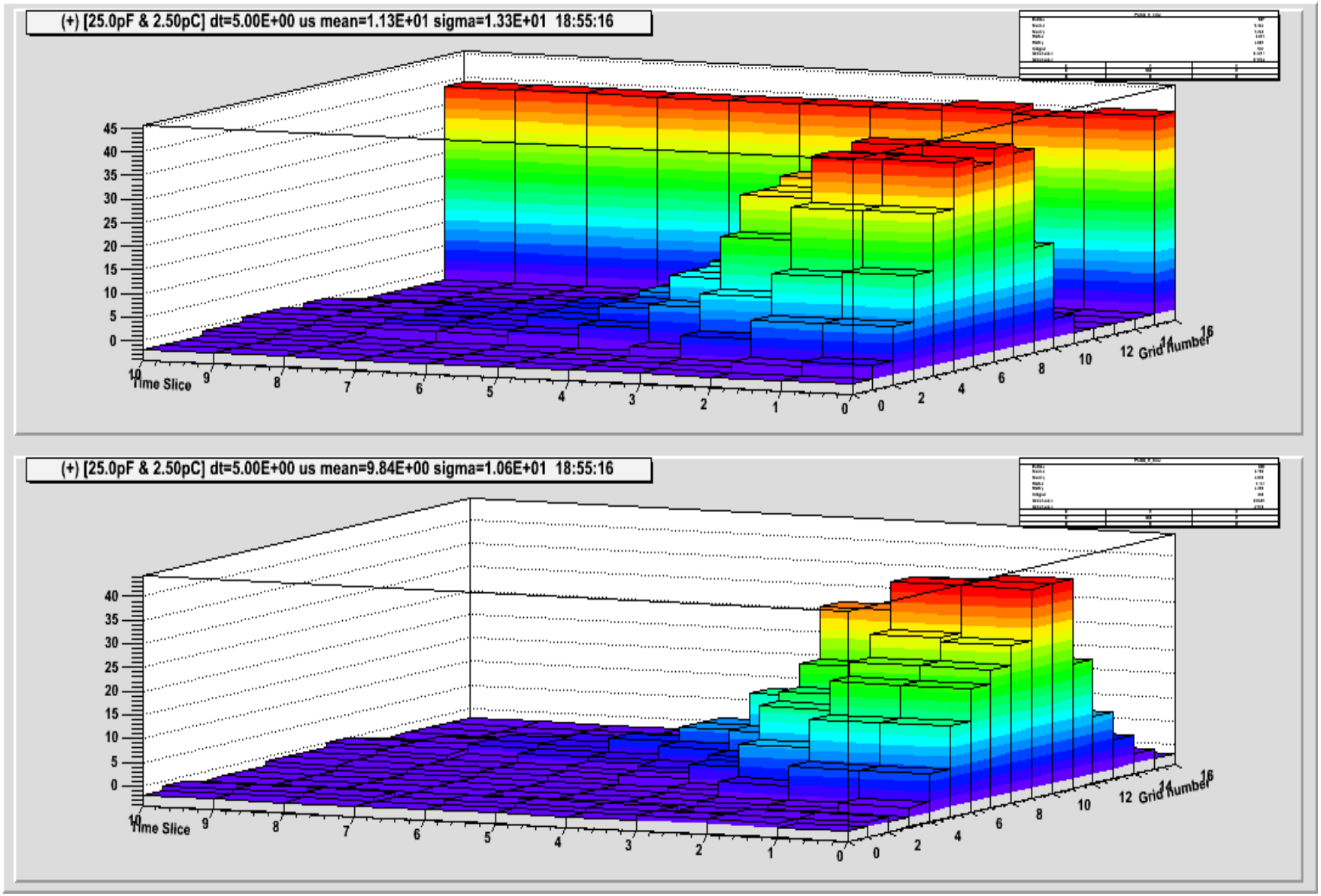
3. Beam Time Block (22.-24.11.2010)
   - U-238, 8.6 MeV/u, max. 2mA pulse peak, 1 Hz
   - **Extended current range.** Measurements up to 10 mA now possible

Measurement Results



Presentation and pre-analysis via Go4 software

“End of Beam”



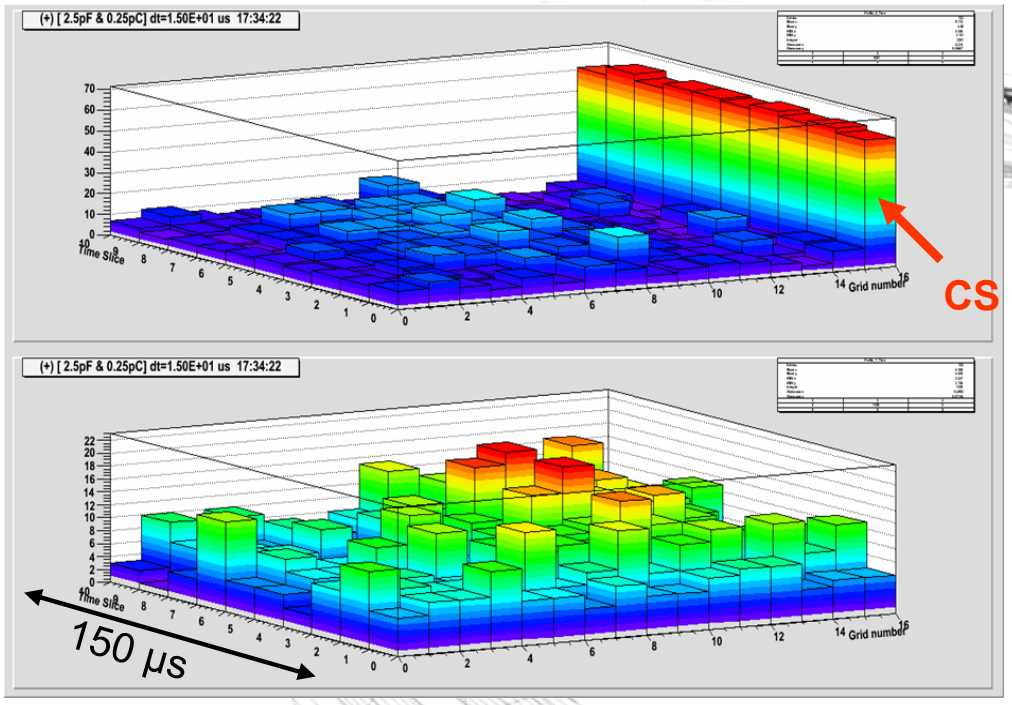
X-Profile

“falling edge”

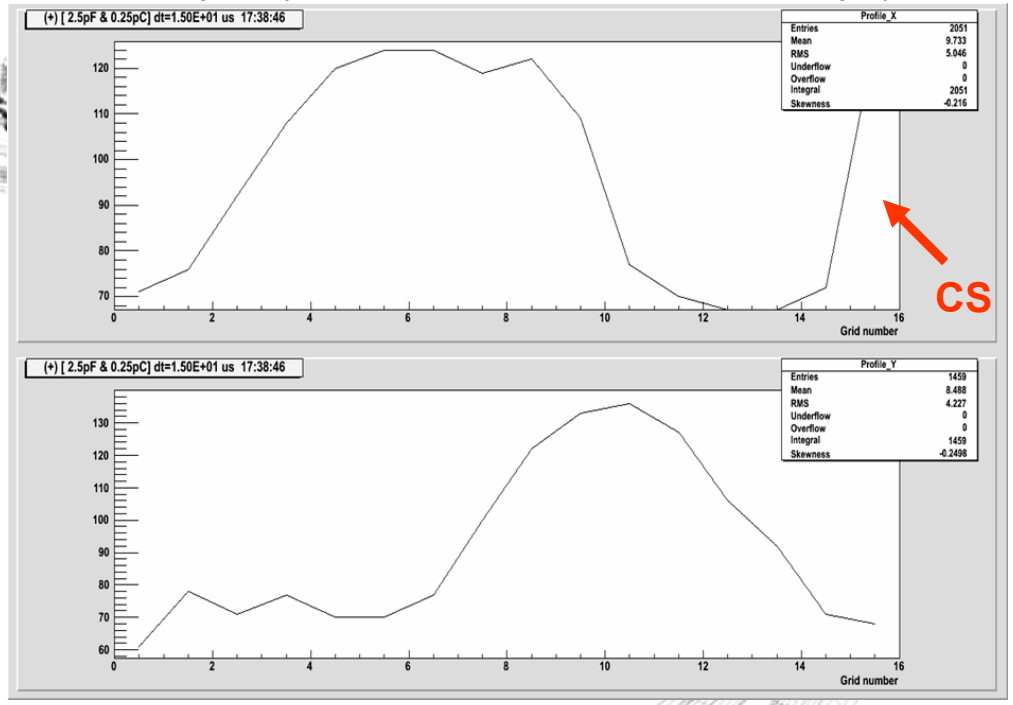
Y-Profile

Detection Limit

3D plot (15 µs per time slice)

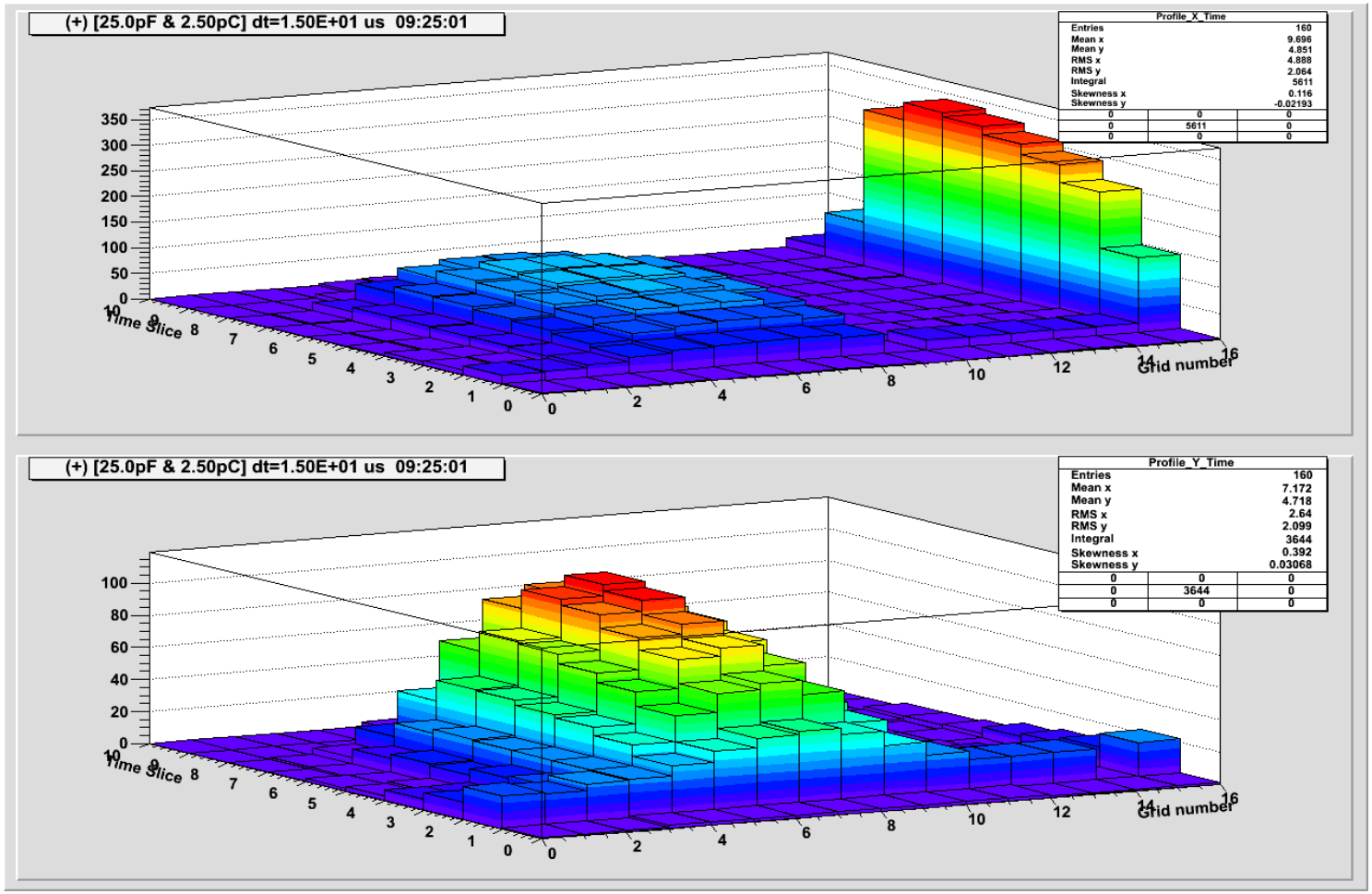


2D plot (accumulated counts over 150 µs)



- QFW is a **Charge** Frequency Converter.
- In the sensitive range charges are measured with **0.25 pC/pulse**.
- The smallest possible current to be measured depends strongly on the time for the measurement. **I = Q/t**
- E.g.: $I_{min,15\mu s}$ = 0.25pC/15µs = 16nA
  $I_{min,150\mu s}$ = 0.25pC/150µs = 1.6nA
  $I_{min,500\mu s}$ = 0.25pC/500µs = 500pA

Profile Grid and Faraday-Cup Measurement



Faraday-Cup connected to X-profile channel 16

Preliminary Results of Measurements

- Readout electronic with QFW ASICs were successfully tested
  - All objectives were successfully achieved during beam times
  - Temporal resolution of ion beam possible (order of few µs)
- Good agreement between new and old readout system in determining the beam position.
- Beam profile identification was still possible at a beam current of approx. 30-50 nA @ 100 µs integration time
  ➔ could be improved by increasing the measurement time

Outlook

- Further analysis of beam time data
- Upgrading of the FPGA readout software
  - Data talking not limited to 10 time slices (maybe several 100 ???)
  - New features (e.g. automatic offset calibration via FPGA)
- Measurement with MWPC
- Beam measurements with higher beam energies (for FAIR)
- Measurement of longer beam pulses
- Test further applications
  - "multiple" Faraday-Cups (Uni Kiel, IEAP)
  - Source beam measurements (Quellenstand)
  - Online monitoring for Biophysics group at X6 (before/after radiation)

Many Thanks...

to

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