Detectors, DAQ and slow control issues at the SuperFRS (an overview)

H.Simon, C. Nociforo, J. Winfield,
➔ J. Gerl, S. Pietri, H. Schaffner, N. Kurz, ...

AIMS: detector system used for

1. initial beam steering ➔ ACS/FESA
   → simple, reliable, slow control interface

2. machine safety ➔ ACS/FESA
   → slow control interface, interlocks

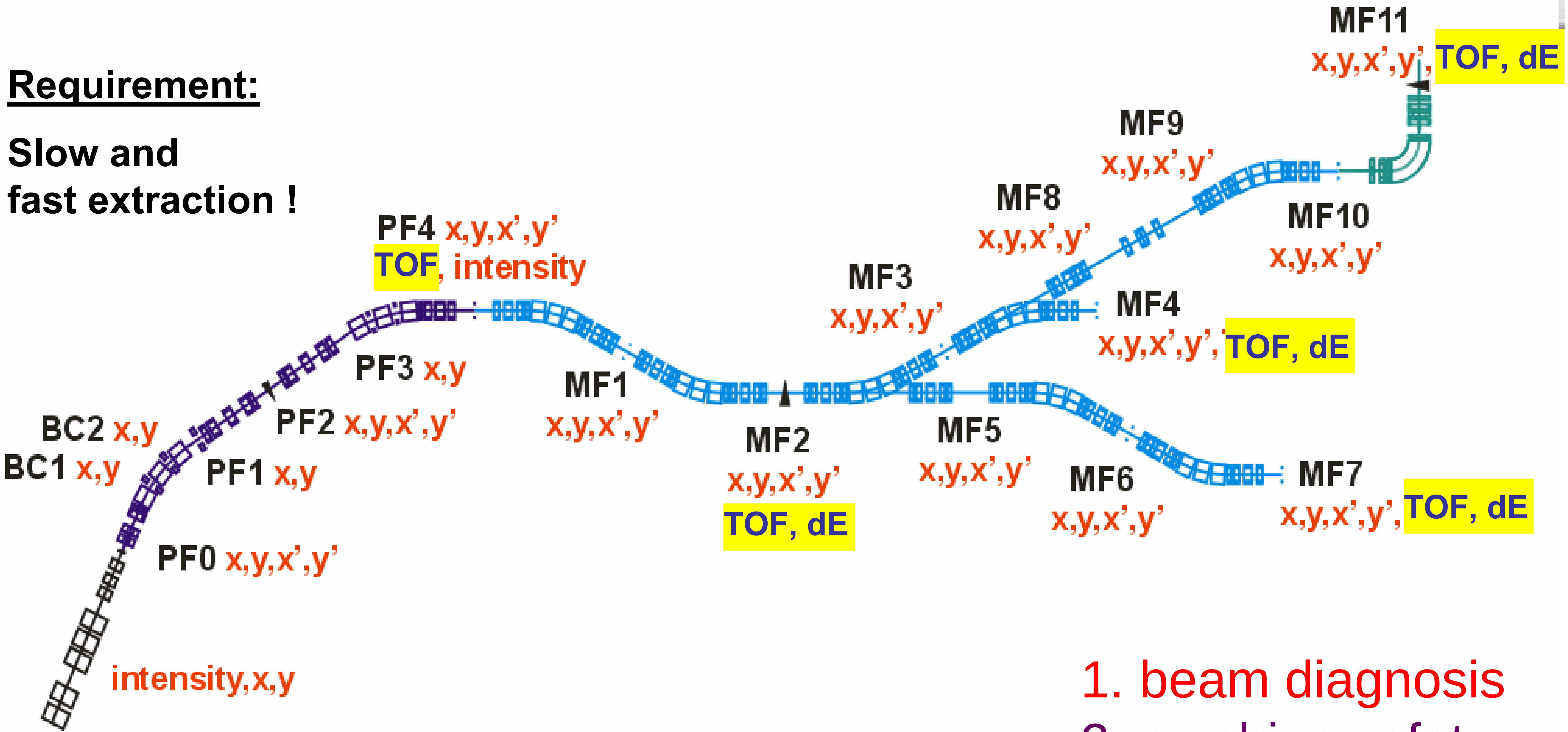
3. part of the experiments ➔ MBS/DABC/EPICS
   → interface to DAQ system

GSI FAIR

Detector Instrumentation of the SuperFRS

Requirement:

Slow and fast extraction !



1. beam diagnosis
2. machine safety
3. experiments

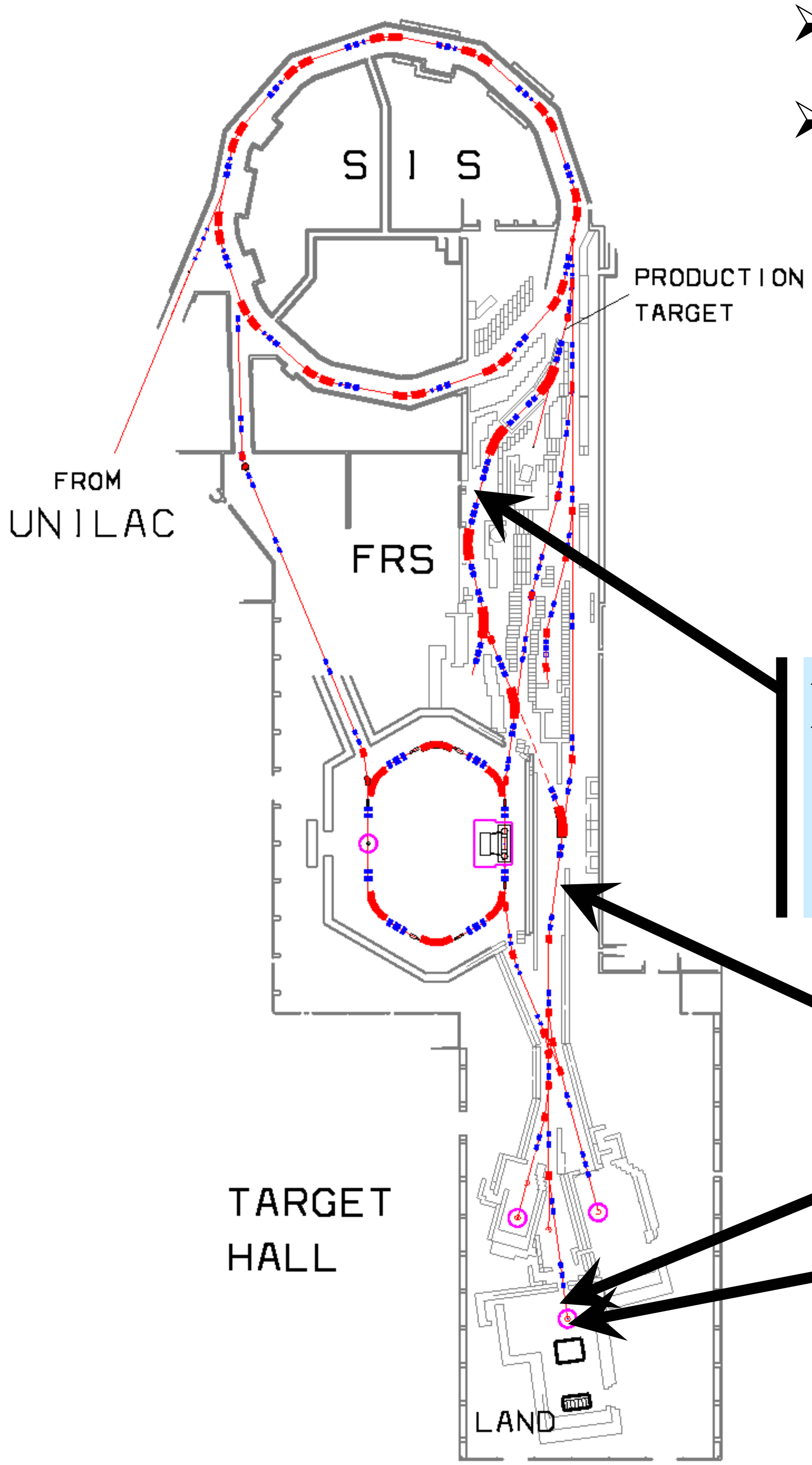
10^{12} /s	$<10^{10}$ /s	$<10^{9}$ /s	$<10^{7}$ /s	$<10^{5}$ /s

FAIR

Continous beam ID is integral part of experiments

Example: ^{132}Sn PDR studies

- Primary: $3 \cdot 10^8$ ^{238}U/spill @550Mev/u
- Secondary (mixed): 50 ions ^{132}Sn/spill

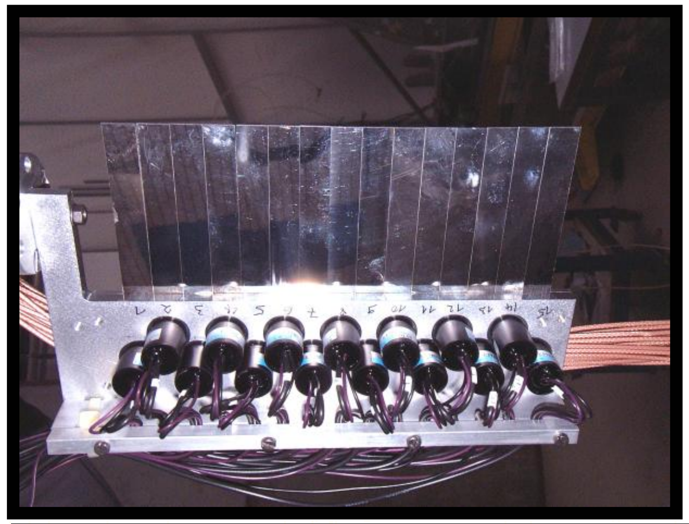


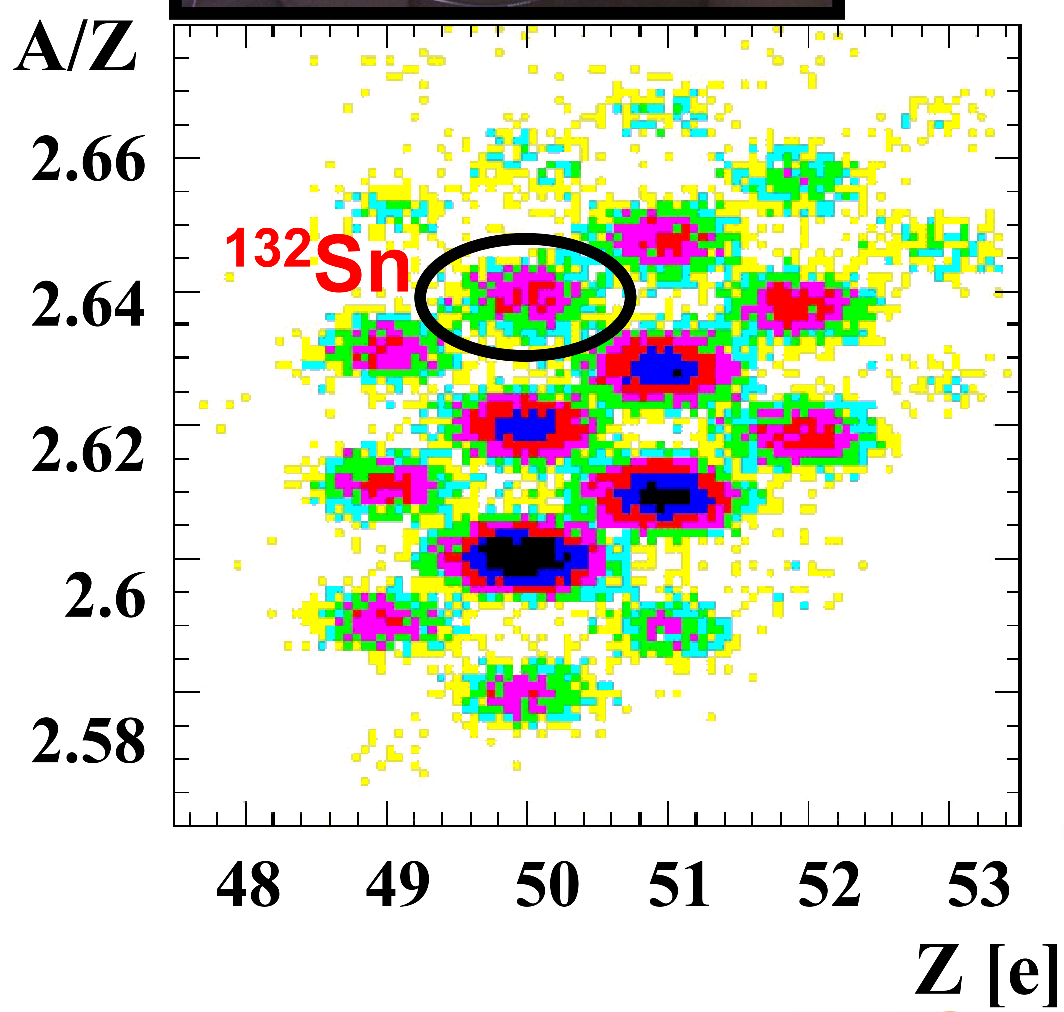
$$\frac{A}{Z} = \frac{m_u c}{e} \frac{B\rho}{\beta\gamma}$$

Bρ – from position at middle focal plane of the FRS

β – from TOF

Z – from ΔE





NO CHARGE STATES !

$B\rho$-ΔE-TOF method: Requirements

$B\rho = A/Z \cdot \beta \cdot \gamma$ ⇒ A/Z, P

$TOF = L/\beta$

$\Delta E \sim Z^2/\beta^2$ ⇒ Z

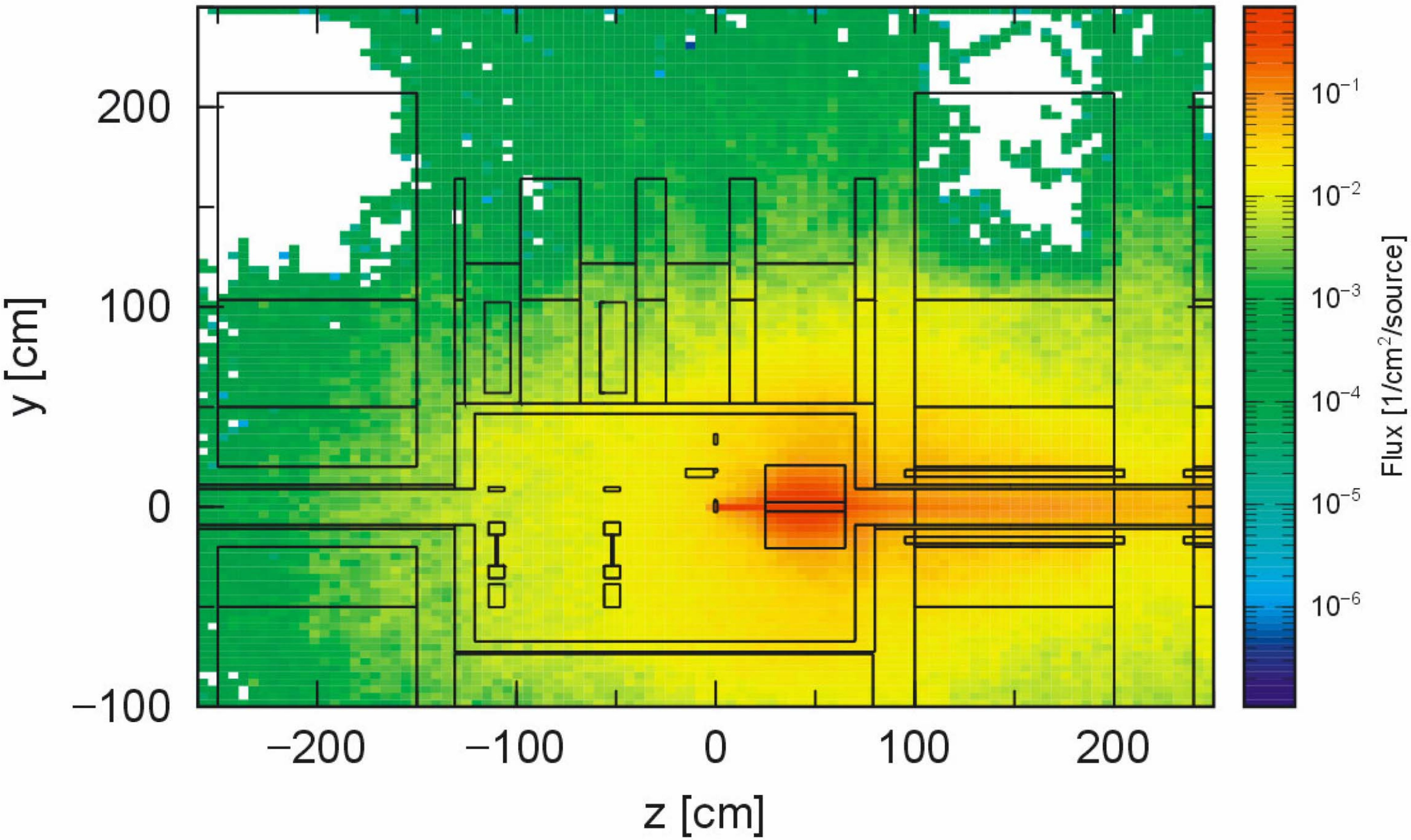
Pos res.	$\sigma \leq 1$ mm
Timing res.	σ: 50 ps
ΔE resolution	σ: 1-2 %

- Position: Wirechambers (single event readout)/Diamond
- ΔE: MUSIC/TEGIC
- TOF: Plastic/Diamond

Standard detectors at the FRS

- Beam diagnostics : Current Grid (CG)
- Intensity : Secondary Electron Emission Transmission Monitor (SEETRAM)
- x,y : Multi Wire Proportional Chamber (MWPC)
  ΔE : Multi Sampling Ionization Chamber (MUSIC)
  Tof : Scintillators

Radiation environment target area



Detector Scheme for Super-FRS target area

available/possible systems

Fast extraction		Slow extraction
	Intensity	
Resonance Transformer		Cryogenic Current Comparator (SQUID)
Diamond (single crystal, current readout)		SEETRAM
		Diamond (poly crystal & particle)
	Position	
Pickups		
	Profile	
Beam induced fluorescence(BIF)		BIF
Rest Gas Monitor (RGM)		RGM
Current Grids		Current Grids/Wire chambers
	Monitoring	
Camera on target (IR)		Camera on target (IR)

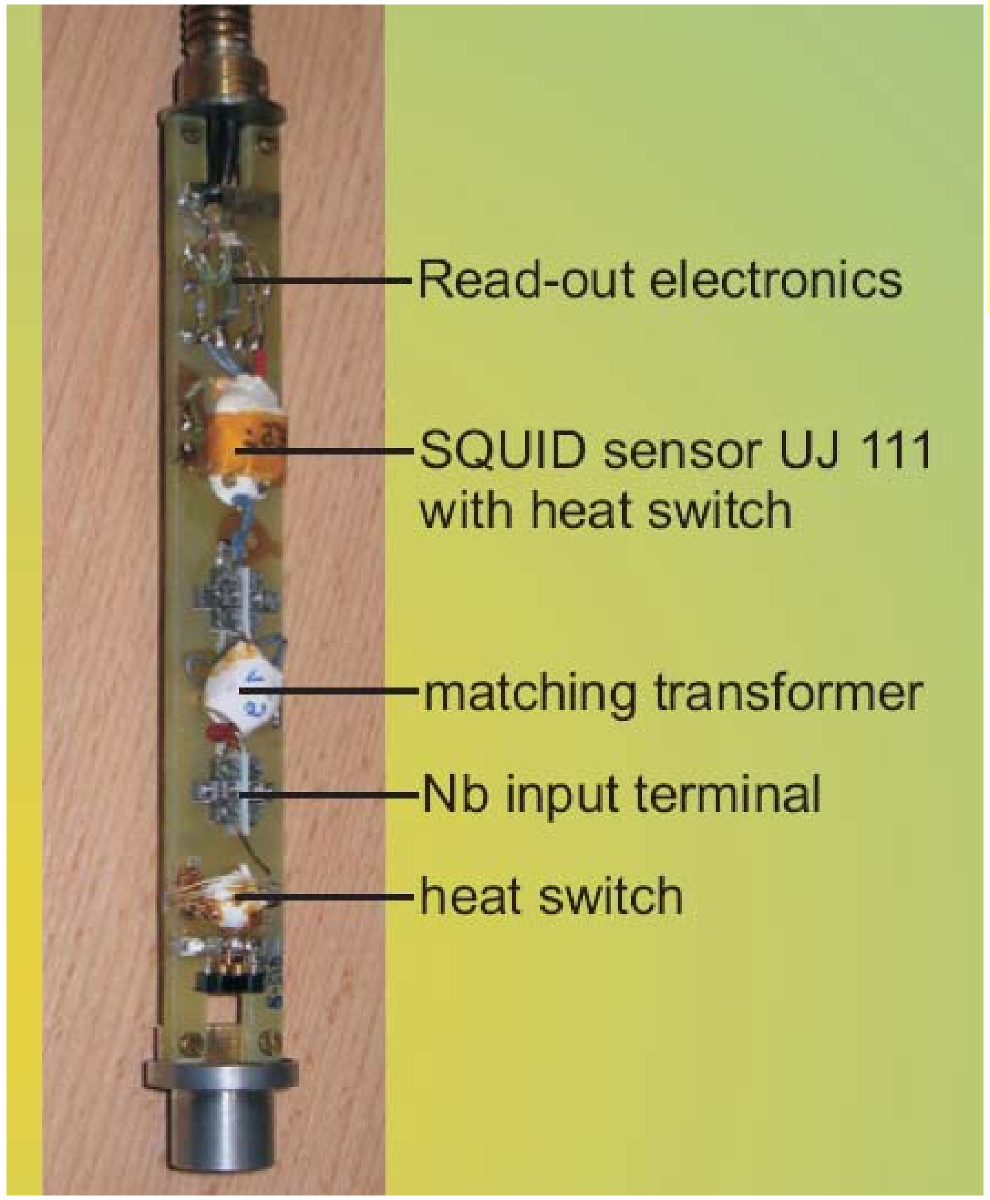
full intensity | *reduced intensity (< about 1 nA)*

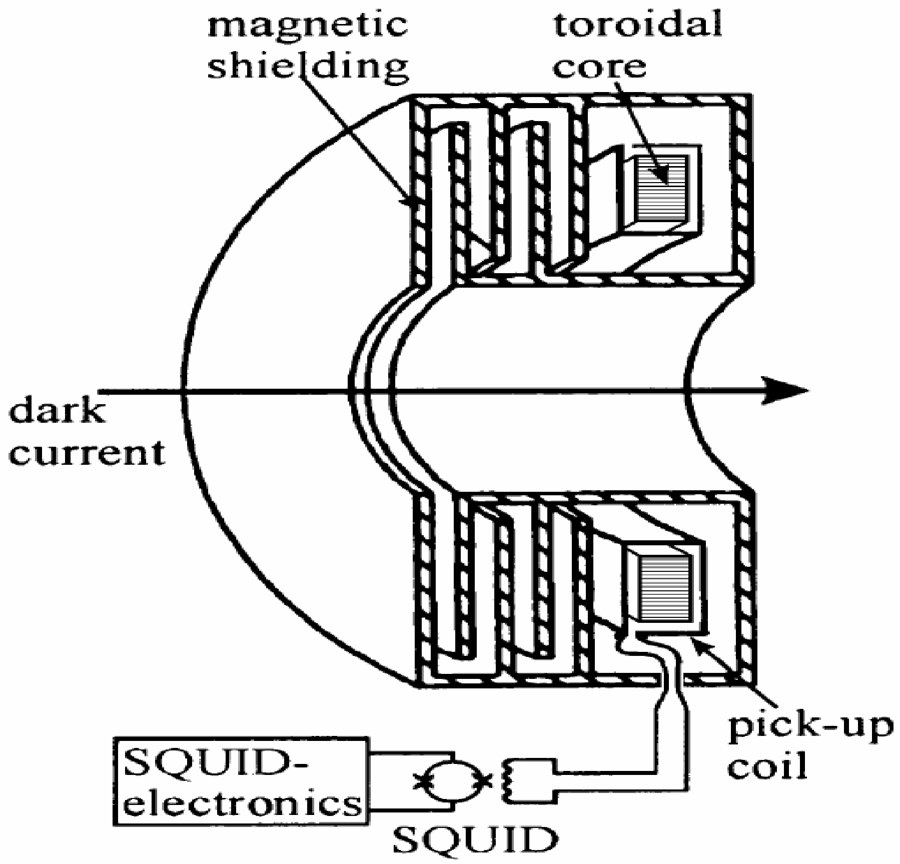
Cryogenic Current Comparator

W. Vodel , R. Neubert , S. Nietzsche , R. Nawrodt , K. Knaack , K. Wittenburg
A. Peters

- About 100 k€ / system
- > 1nA, pulse to DC

The design of the CCC is realized as co-operation of
DESY Hamburg, Jena University and
GSI Darmstadt.



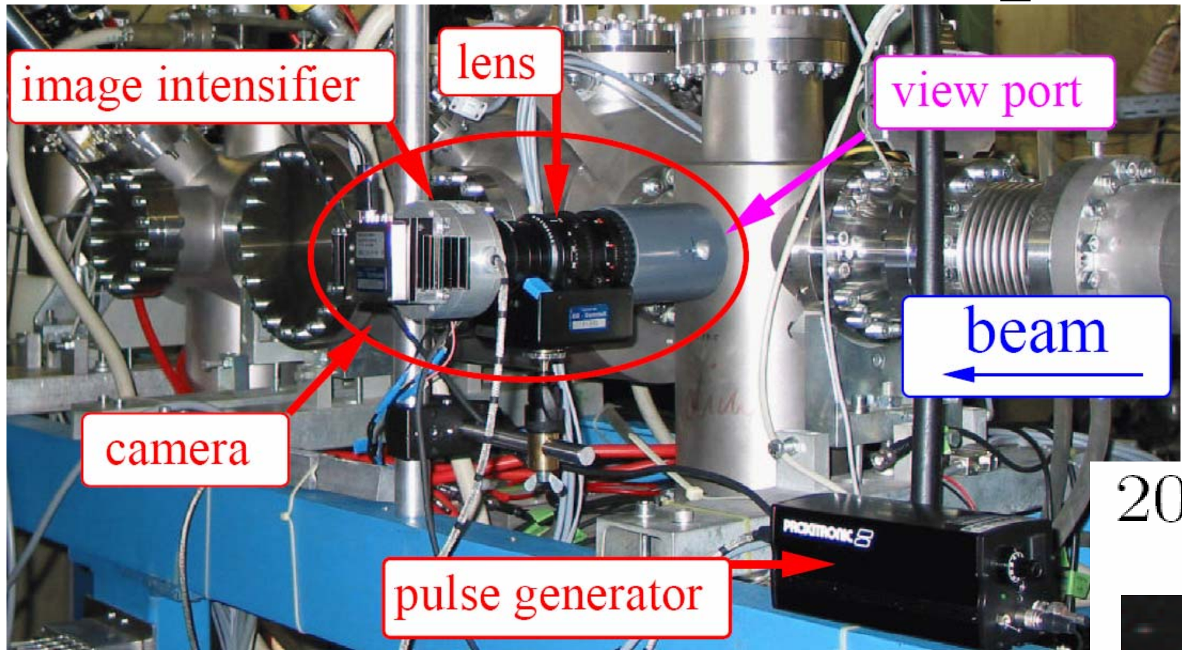


- R&D: Radiation Hardness/Shielding of SQUID

Beam Induced Fluorescence

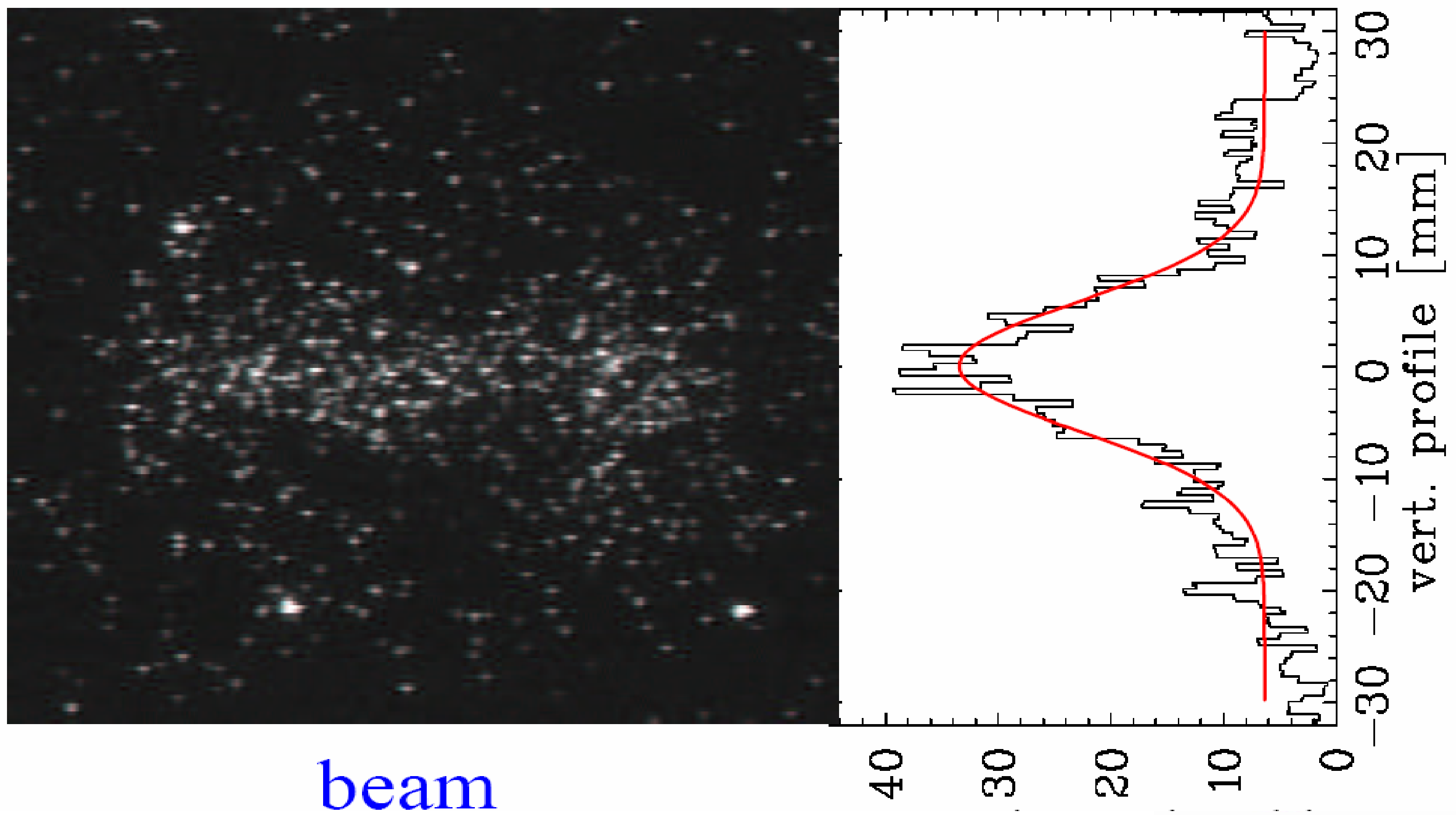
P. Forck / GSI

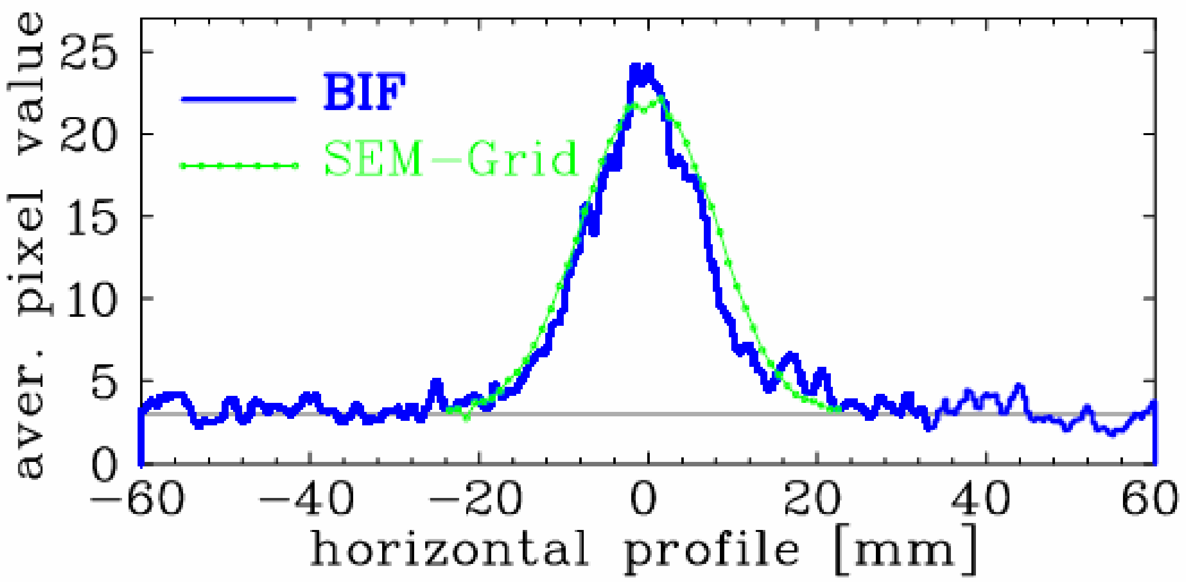
- about 100 k€ / system
- Optical imaging of a N_2-filled test volume (MCP + camera)



@UNILAC

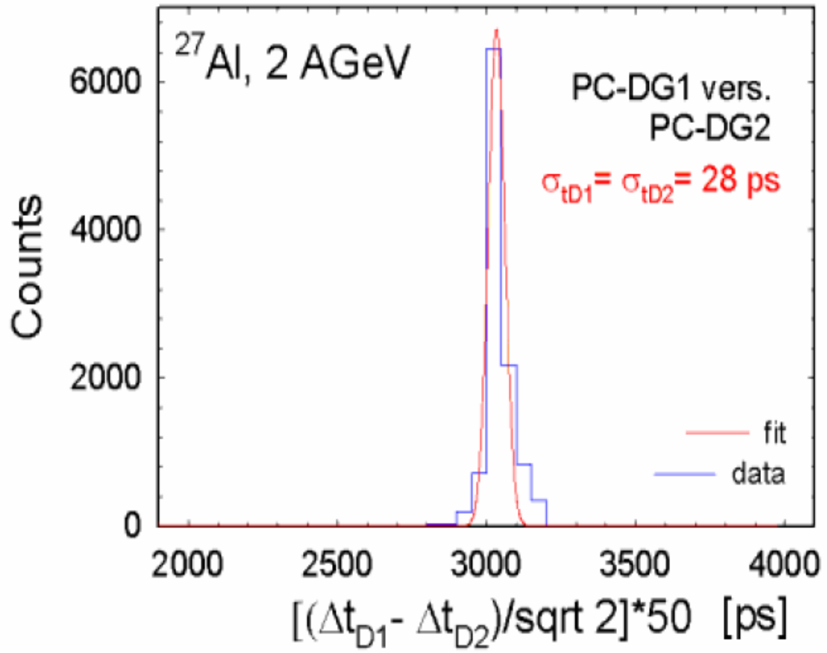
200 μs Ar^{11+} beam of $I = 700\ \mu$A with 6 MeV/u

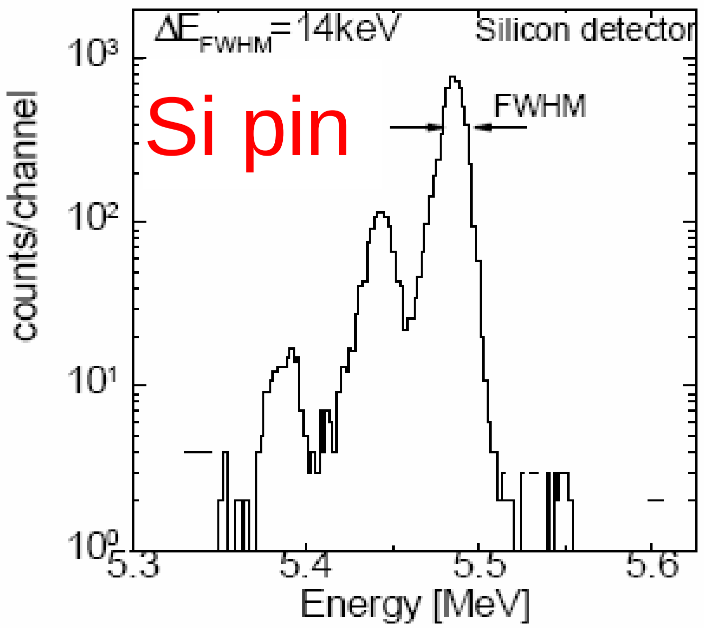


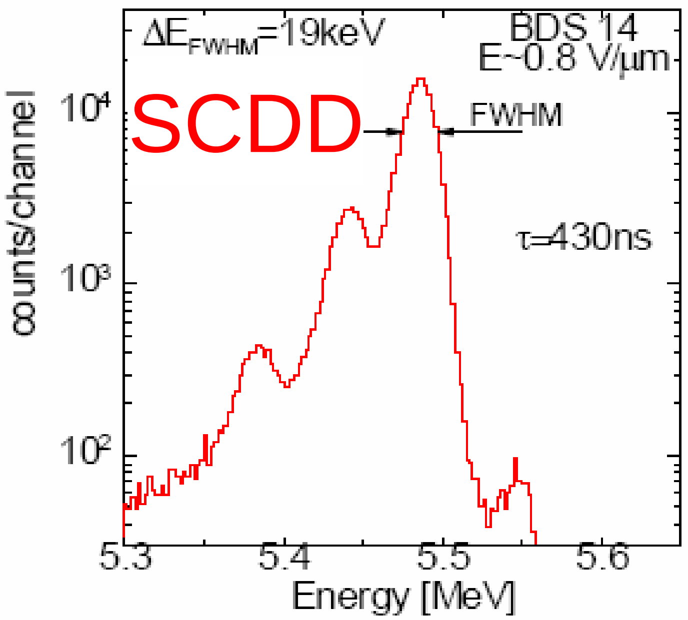


Throughout the separator:
Diamond Detectors

- current readout for single crystal (a few mm²)
- cheaper polycrystaline diamonds (a few cm²)
- very good homogenity and radiation hardness
- price from a few 100 €/cm² to 1000 €/cm²
- expertise inhouse



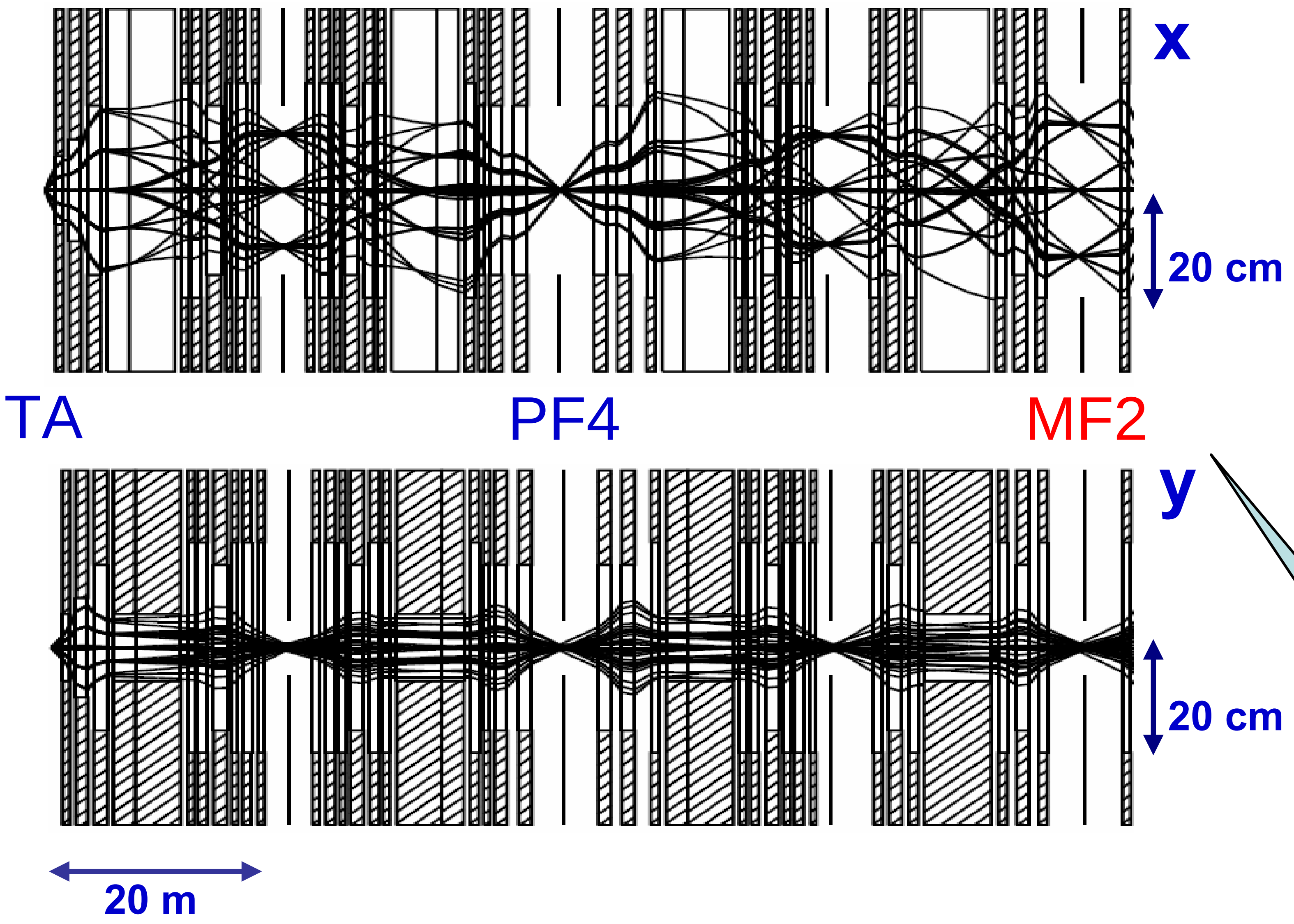




M. Pomorski,
E. Berdermann
et al. Nordhia, RD42

Detector sizes: Super-FRS

→ dipole gaps 140mm



TA — (6x12)mm² slow extr.; (12x72)mm² fast extr.

PF4 — (30x30)mm² slow extr.; (60x60)mm² fast extr.

MF2 — Dispersive/full appert. (380x140)mm² slow/fast extr.

MF4 — (90x30)mm² slow extr.

MF7 — (120x30)mm² fast extr.

MF9 — (90x30)mm² slow extr.

Bookkeeping (i)

2.4. 6 Diagnostics

Fluorescent Screen		
Number of elements		1
Overall length	mm	50
Horizontal aperture	mm	100
Vertical aperture	mm	100

CVD-DD (diamond detectors, calibration)		
Number of elements		1
Overall length	mm	100
Horizontal aperture	mm	100
Vertical aperture	mm	100
Rate	Hz	$1 - 500\cdot10^{6}$

Luminosity Monitor (SEETRAM)		
Number of elements		2
Overall length	mm	200
Horizontal aperture	mm	100
Vertical aperture	mm	100
Intensity range	particles/spill	$<10^{11}$

Bookkeeping (ii)

Position Monitor (CG)		
Number of elements		32
Overall length	mm	300
Horizontal aperture	mm	400
Vertical aperture	mm	250
Intensity range (energy deposition)	mW/mm	<100

Tracking Detector (MW)		
Number of elements		32
Overall length	mm	300
Horizontal aperture	mm	400
Vertical aperture	mm	250
Rate	kHz	<100

Capacitive Pick-up		
Number of elements		2
Overall length	mm	300
Horizontal aperture	mm	150
Vertical aperture	mm	150
Intensity range	particles/spill	$<10^9$

MUSIC Detectors		
Number of elements		4
Overall length	mm	500
Horizontal aperture	mm	400
Vertical aperture	mm	80
Rate	kHz	200 … 1000

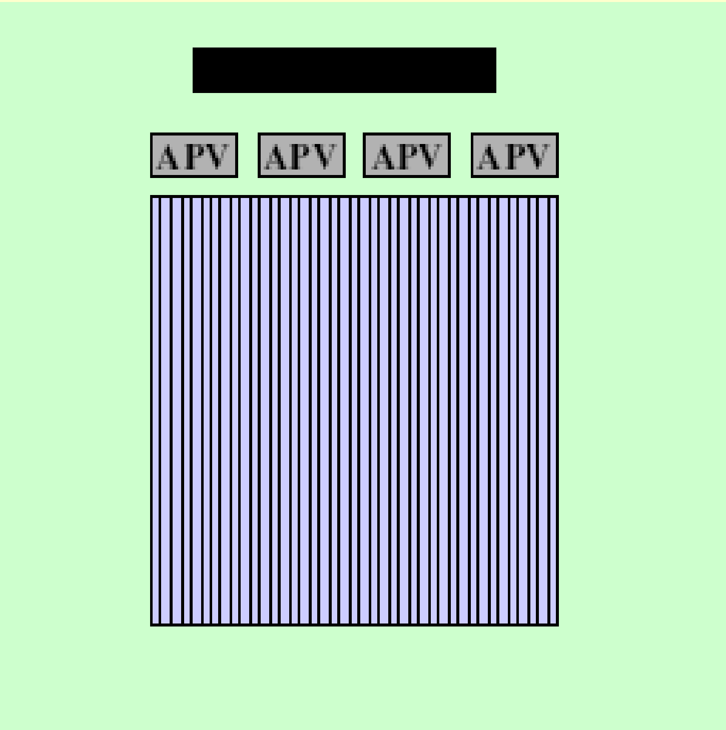
ToF (diamond detectors, PC-CVD-DD)		
Number of elements		4
Overall length	mm	200
Horizontal aperture	mm	400
Vertical aperture	mm	50
Pitch	mm	1
Time resolution	ps	<50

R³B diamond detector layout:

→ MF2 SuperFRS: × 8(h)

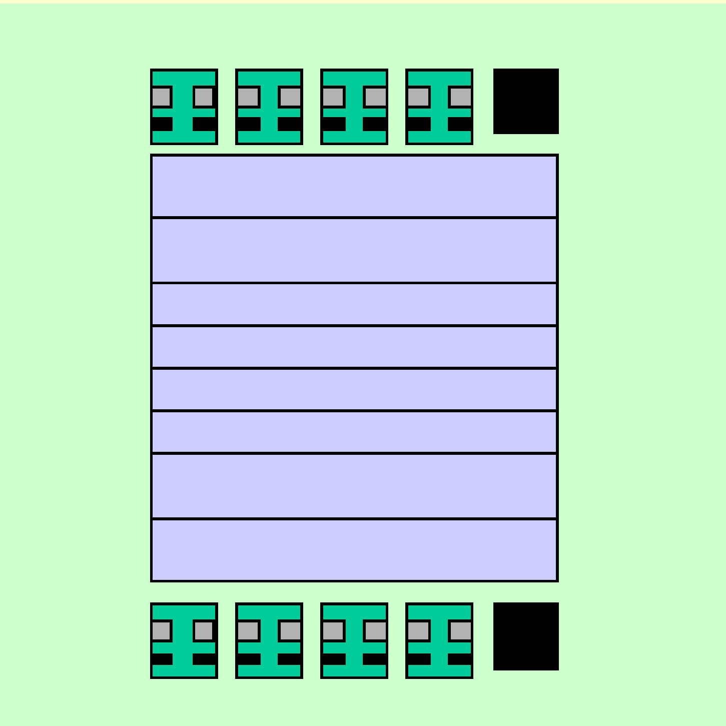
Test exp. 04/08

R. Gernhäuser (TU-München)



tracking layer:

- 50 x 50 mm, d = 100 µm, PC-CVDD
- 140 µm pitch (125µm strips, 15 µm gap)
- only digital position information
- multiplexed readout in vacuum



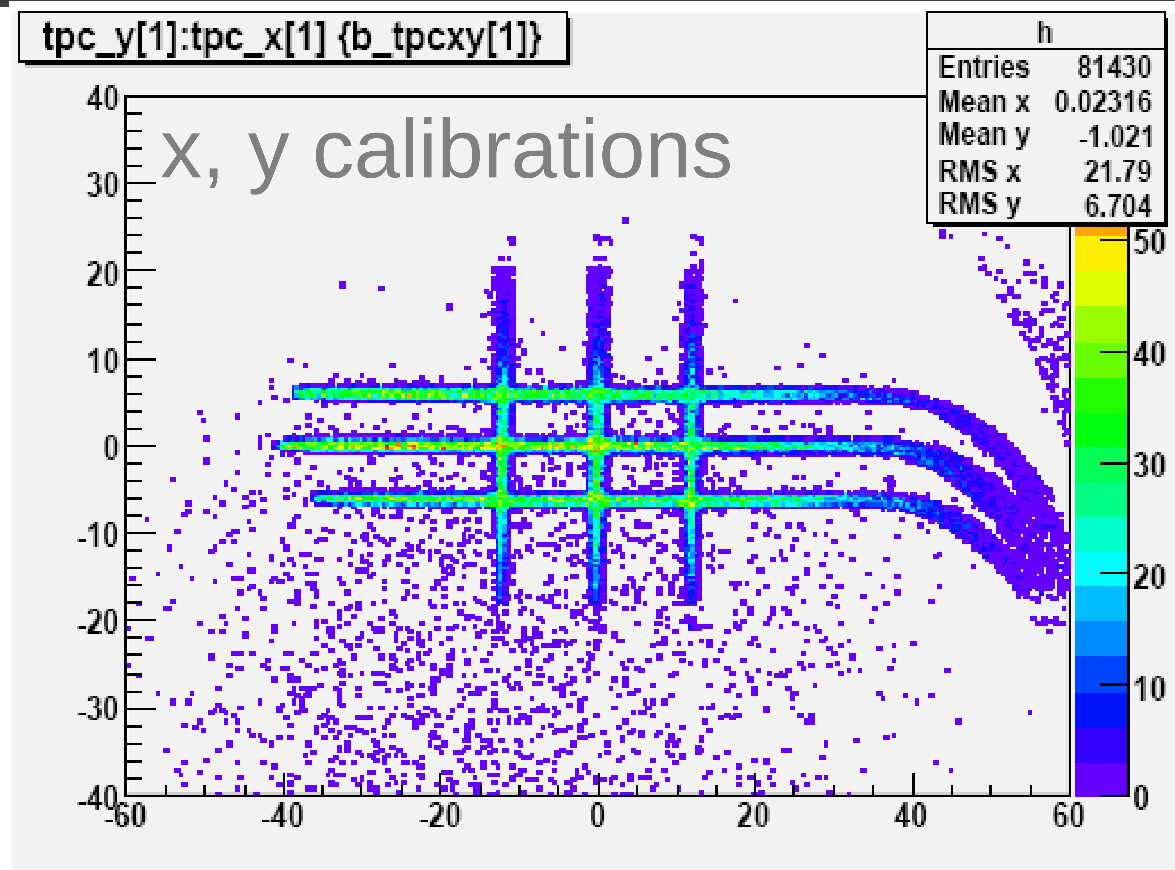
timing layer:

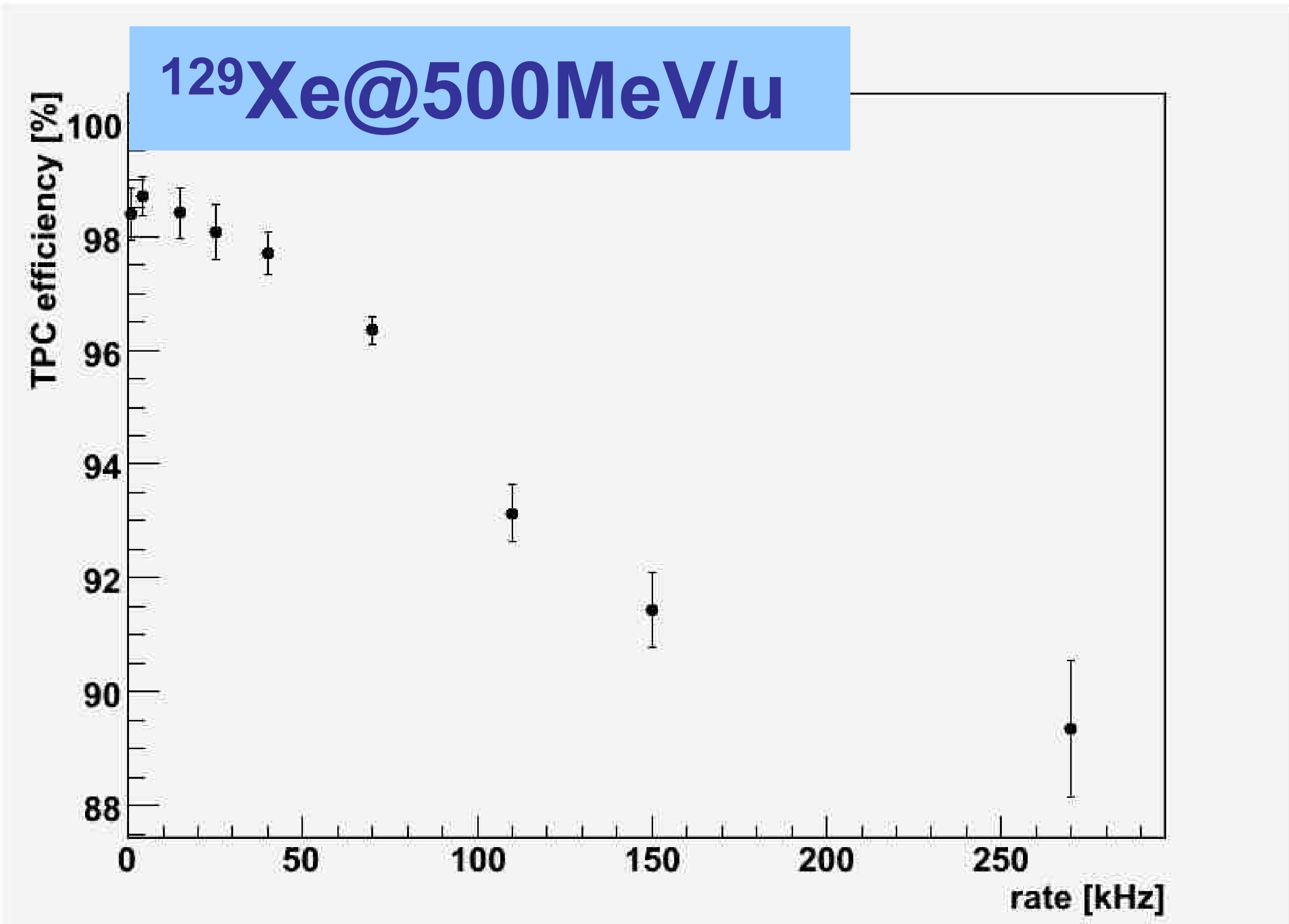
- 50 x 50 mm, d = 100 µm, PC-CVDD
- 8 rate matched strips, y information, trigger
- analog preamplification in vacuum
- discriminator @ 5 m distance

Time Projection Chamber

- CUB Bratislava

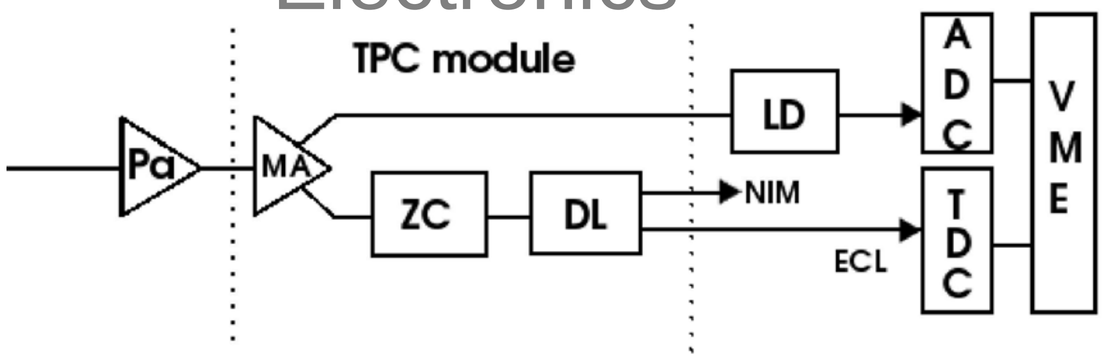
- (240x100) mm^2 active area
- Gas P10 at 1 atm
- Integrated delay lines (2x-pos, 4y-pos)
- $\sigma_x \sim 0.1$ mm, $\sigma_y \sim 0.05$ mm





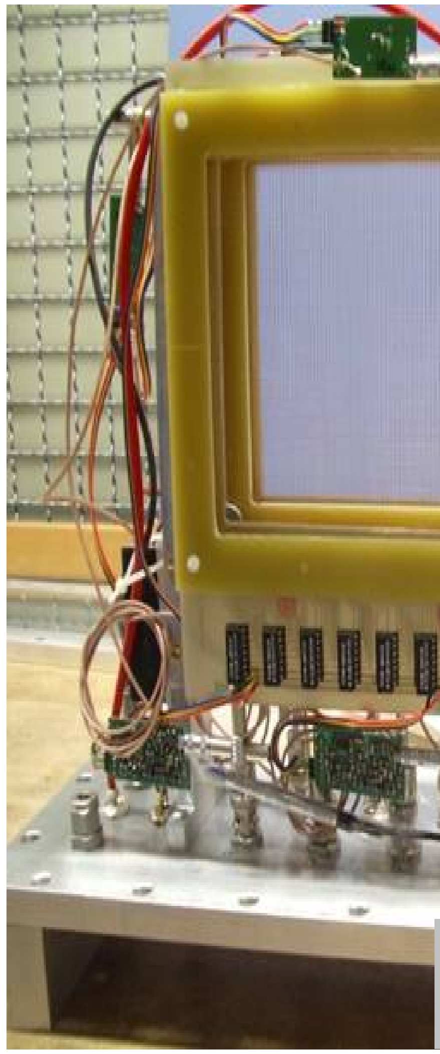
- VME standard electronics
- 90% efficency at ~100kHz

Electronics



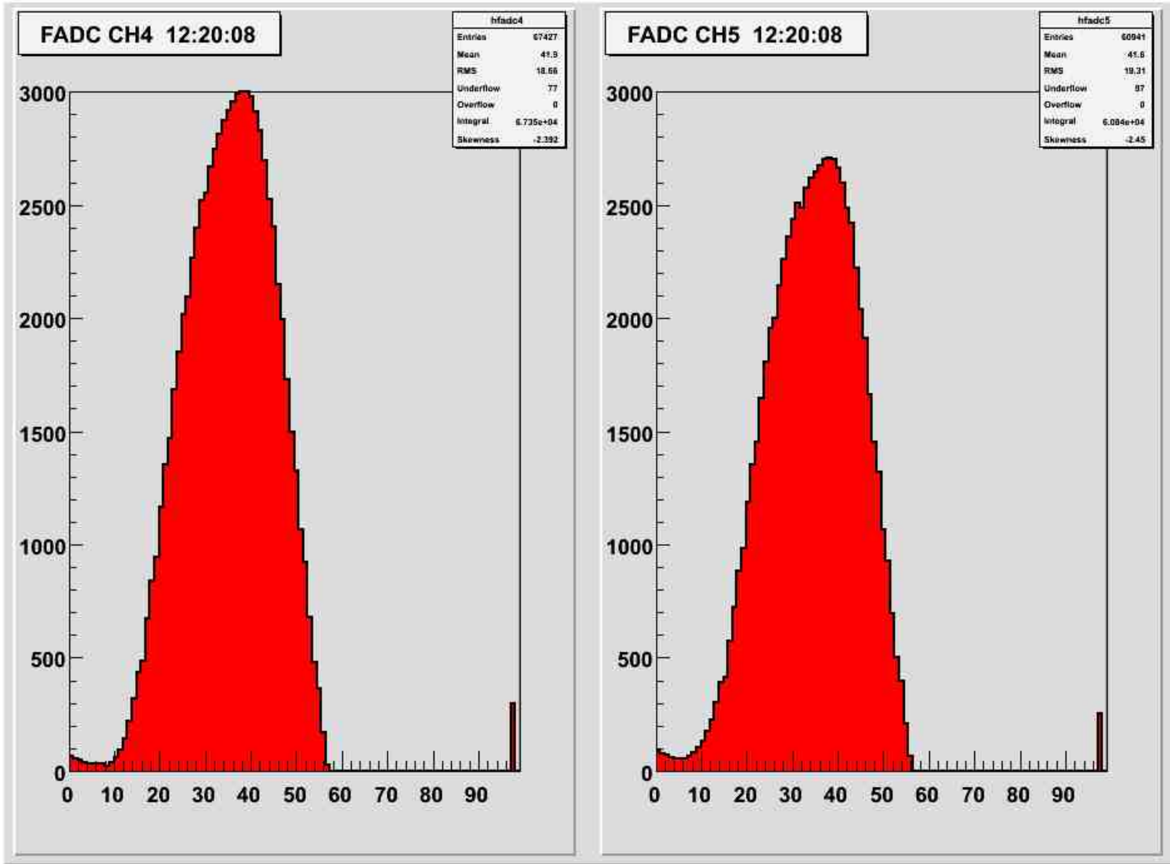
Beam Profile Detector - CUB Bratislava
for intense fast extracted and slow extracted beams

- Basic module (120x120) mm^2
- 5mbar < gas Ar+(10%)CO_2 < 1bar
- Wires 2mm pitch directly connected to delay lines



(240x120) mm^2

Beam profile



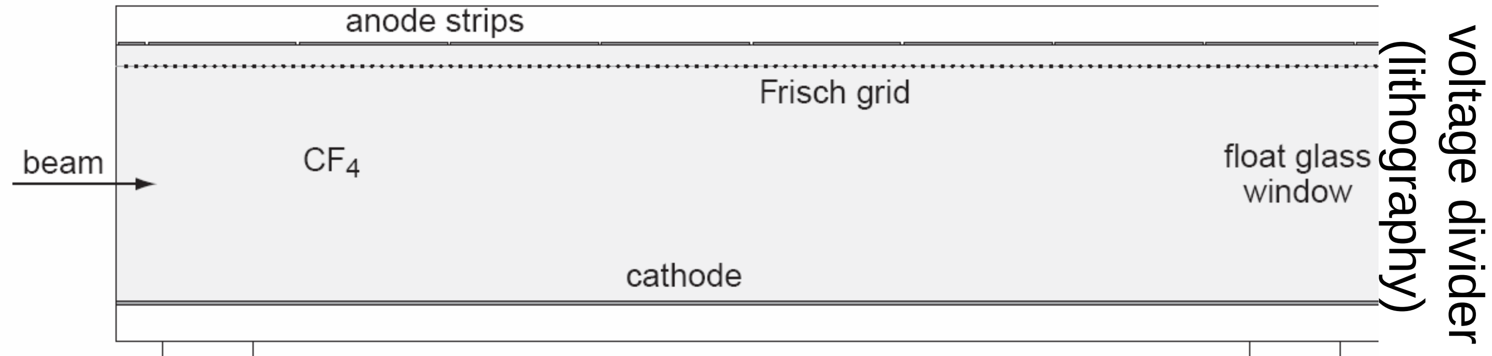
^{12}C@200-400 MeV/u
10^4- $1.6\cdot10^9$ ions/spill
Spill length: 300 ns
FADC SIS3301(100MHz)

A. Procházka, C. Nociforo et al.

Missing items:

FRS MUSIC

- Fast ΔE counter
  100 kHz – 1MHz, res. 1-2%,
  large dynamic range
  (no MIPS Z → ~100)
  - TEGIC (RIKEN, ca 1MHz)
  - Silicon stacks ?
  - sc-CVDD ?
- Fast Tracking detectors
  large dynamic range
  - PC-CVDD with continous readout
  - ?
- Fast TOF (currently SCI, ca. 10MHz)
  large dynamic range
  - PC CVDD
  - ?



Geometry

active area:	200 mm × 80 mm
active length:	400 mm
anode:	8 anode strips with 50 mm active length each
total gas length:	420 mm
entrance windows:	float glass D263 (DESAG), thickness 210 μm
distance anode – grid:	7 mm
grid wire diameter:	100 μm
grid wire spacing:	1 mm

Gas supply

counting gas:	CF_4 (tetrafluoromethane)
counting gas pressure:	atmospheric pressure (≈1 bar)
maximum differential pressure:	± 5 mbar to atmospheric pressure
total gas volume:	8.6 l
recommended gas flow:	4 – 6 l/h
typical drift velocity:	10–12 cm/μs @ 1kV/cm for electrons
gas supply connectors:	Swagelok tube fittings, 8 mm

High voltage supply

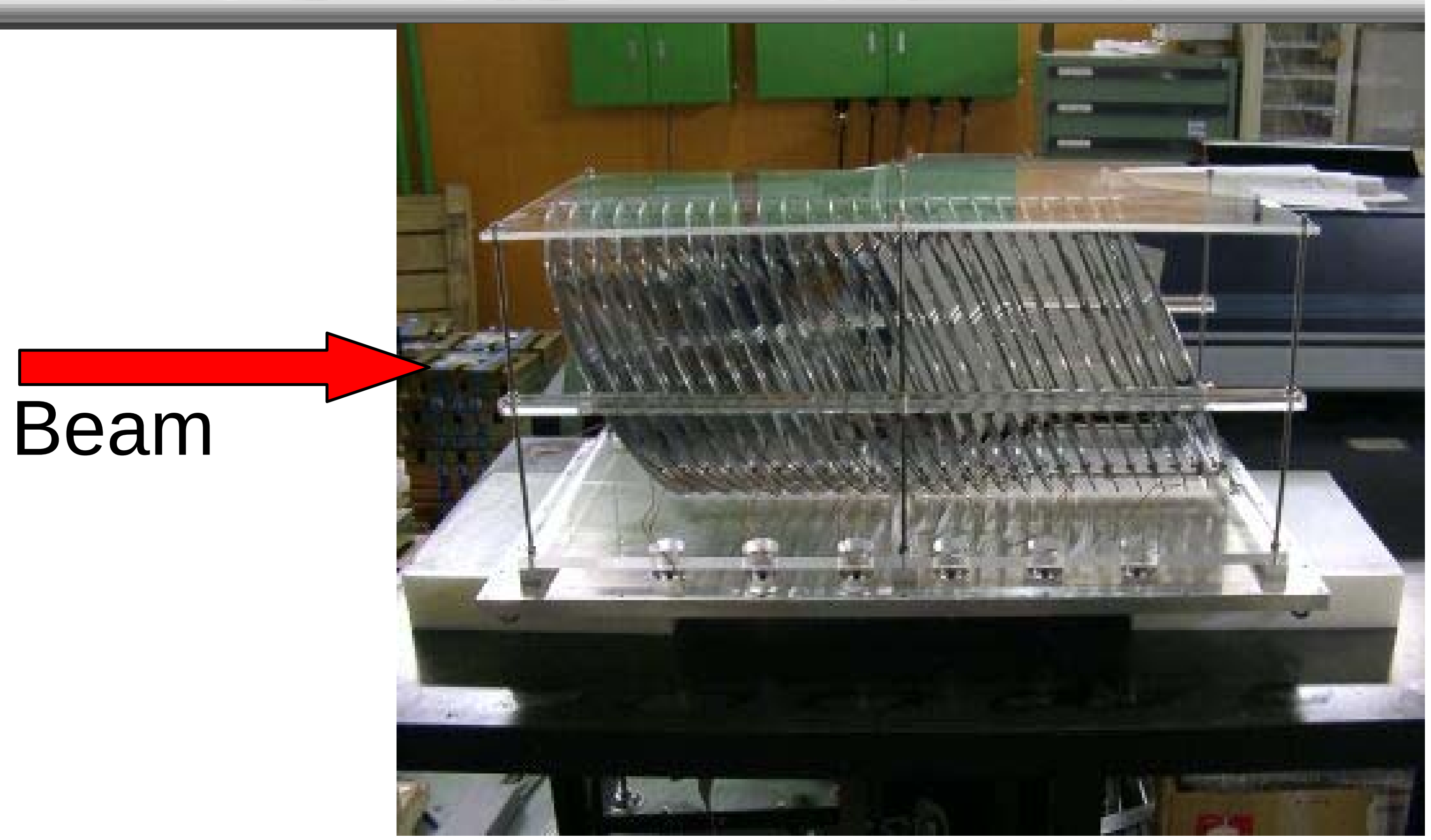
maximum input voltage:	-10 kV
operating input voltage:	-8 kV – -10 kV
field homogenization current:	32 μA @ 10 kV
high voltage connector:	SHV connector

~200 kHZ

Missing items:

TEGIC

- Fast ΔE counter
  100 kHz – 1MHz, res. 1-2%,
  large dynamic range
  (no MIPS Z → ~100)
  - TEGIC (RIKEN, ca 1MHz)
  - Silicon stacks ?
  - sc-CVDD ?
- Fast Tracking detectors
  large dynamic range
  - PC-CVDD with continous readout
  - ?
- Fast TOF (currently SCI, ca. 10MHz)
  large dynamic range
  - PC CVDD
  - ?



K. Kimura et al., Nucl. Instr. and Meth. A538(2005)608

P10 425mm normal pressure
Electrodes(anode/cathode) 4μm×25 Mylar
14 mg/cm²
Distance(anode-cathode) 2cm
Detector Window 150μm Kapton

~1 MHZ

Readout using MBS

- Basic system (http://daq.gsi.de)
  - Trigger module + VME processor
    Modules (CAMAC, VME)
- Integrates foreign DAQ Systems
  (via Time Stamps)
- various FEE integrated

  via GTB/SAM (Bus / DSP&FPGA VME board)

lightweight, scalable, N x M, full VME speed
allows for staged transition !!!
SuperFRS, R^3B, PRESPEC(High/Despec)

APV Frontend (triggered) - M. Böhmer, TUM

- APV25-S1 RAL
  → CMS (Si, …)

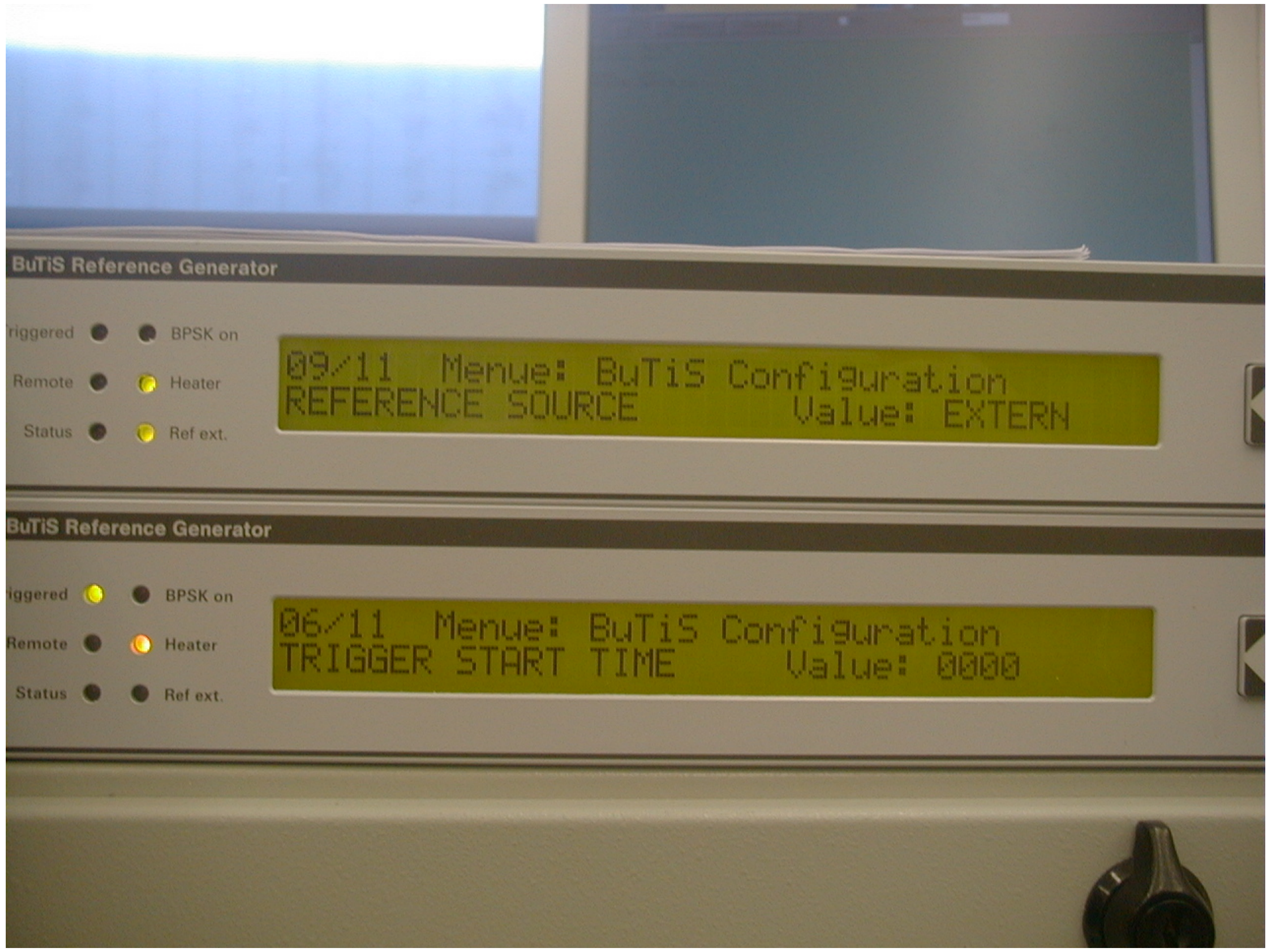
(128 channel analogue pipeline
192 columns analogue storage.
50 ns shaped pulses
100mV / 25,000 electrons
40MHz sample
Useful data marked
test pulser, pos/neg, …)

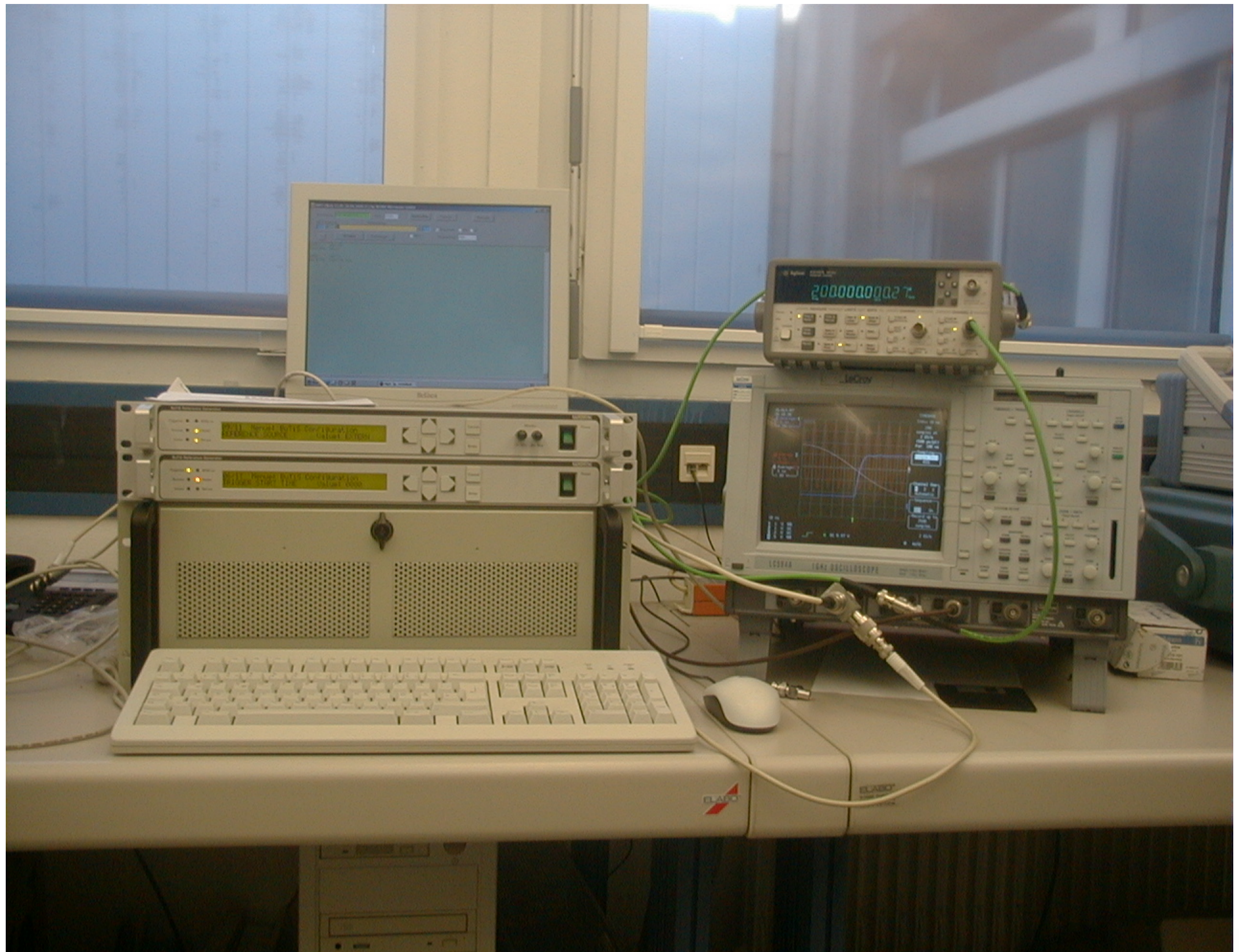
- I^{2}C control
- Clck, Trg
- Low power consumption
- Readout to MBS (ADC/FPGA/DSP)

Extended Time distribution (BuTiS)

P.Moritz/GSI

- Campus wide time distribution via fibre optics
- Synchronized local oscillators (100kHz, 10Mhz, and e.g. 200, 155 or 76 Mhz) with +/-100ps/km absolute uncertainty and << 10ps oscillator jitter
- Master Clock for Accelerator Events → 01/09: ~1ns TS via Mezzanine (CERN/GSI)

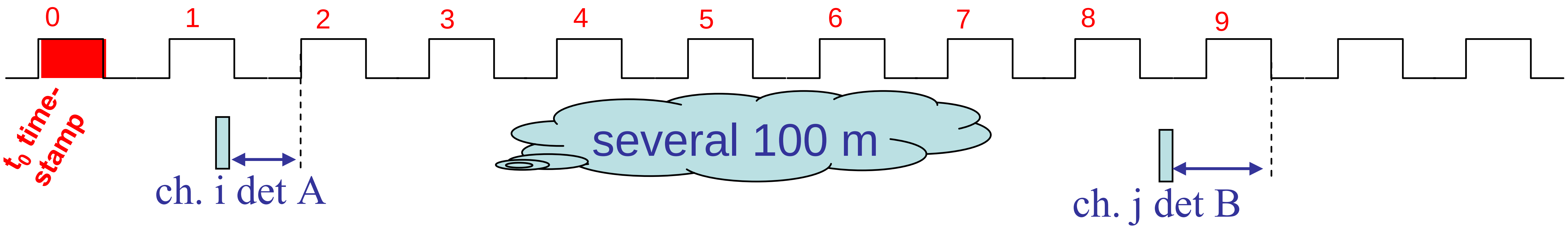


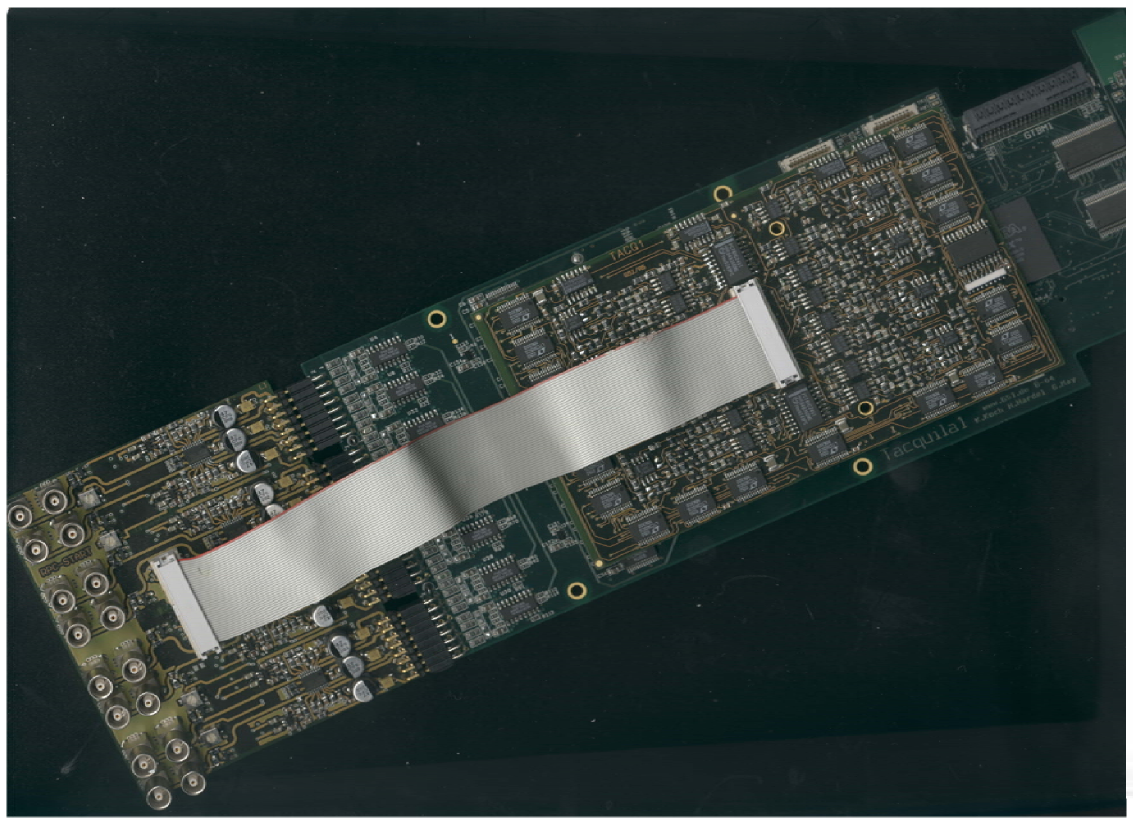


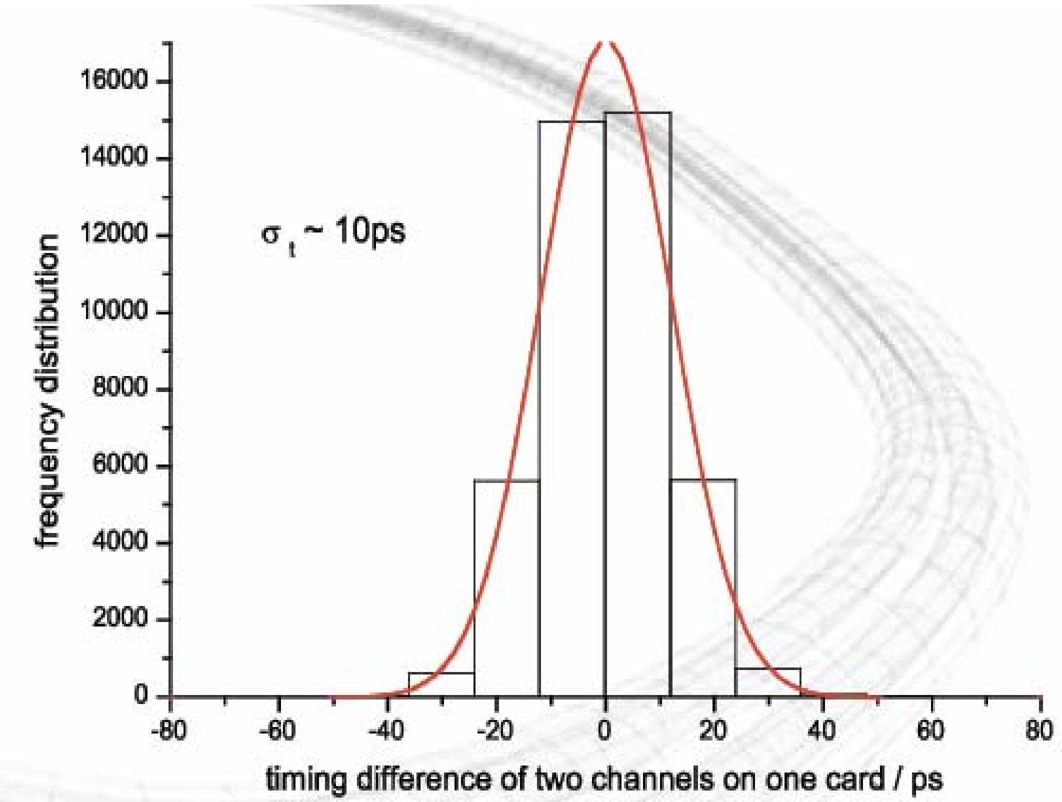
Precision timing (<50ps) vs. Campus Clock

- avoid extended cabling and dead time domains

➔ free running time stamped systems SuperFRS -- Caves







Timing FEEs:

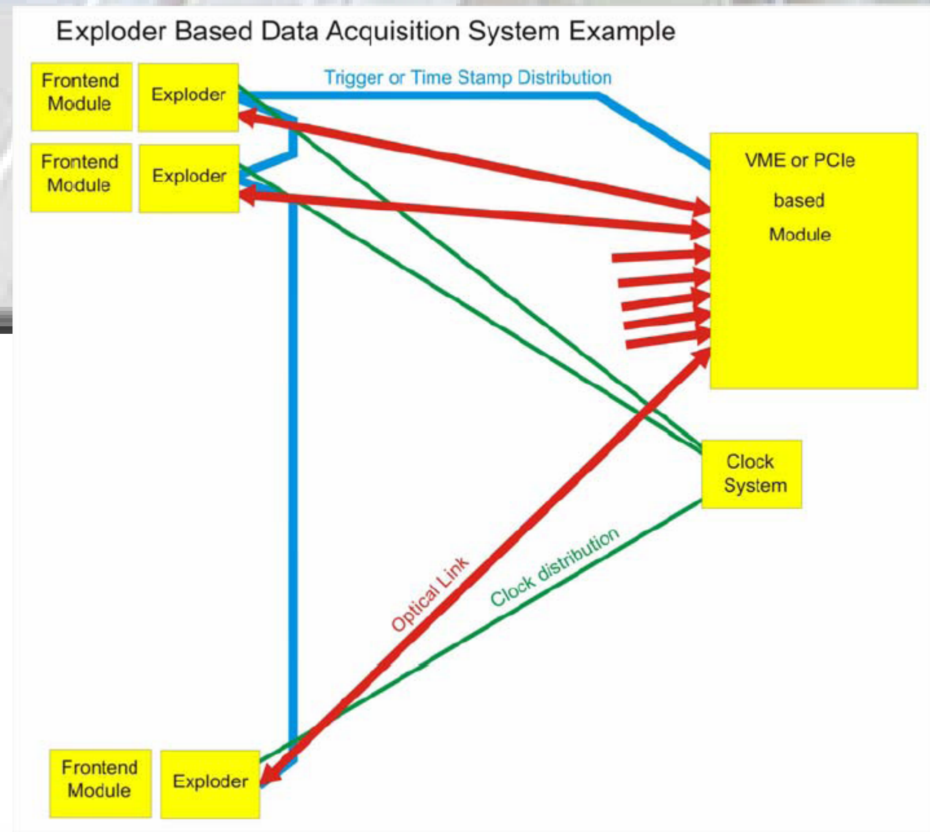
Tacquila system
(ASIC FhG/GSI)

New systems
(ASIC dev. GSI)

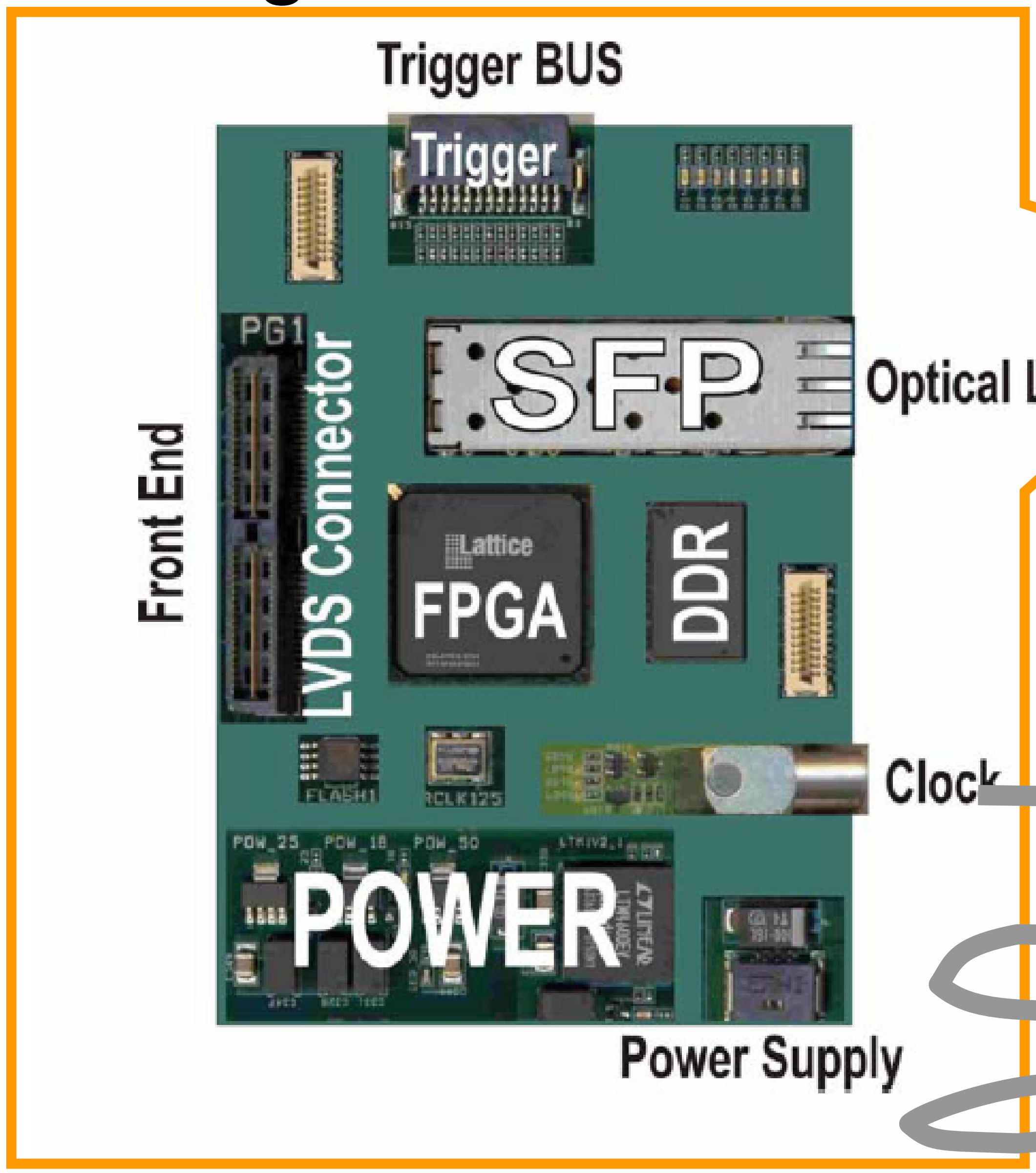
Readout Chain revisited …

- NUSTAR uses MBS, a (in principle) triggered DAQ system …

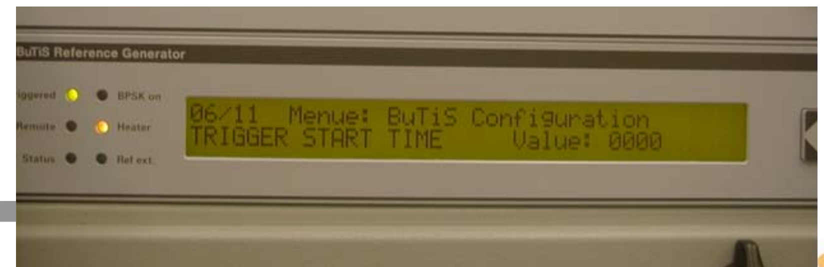
➔ preprocessing



any LVDS input



VME Readout or PCIe



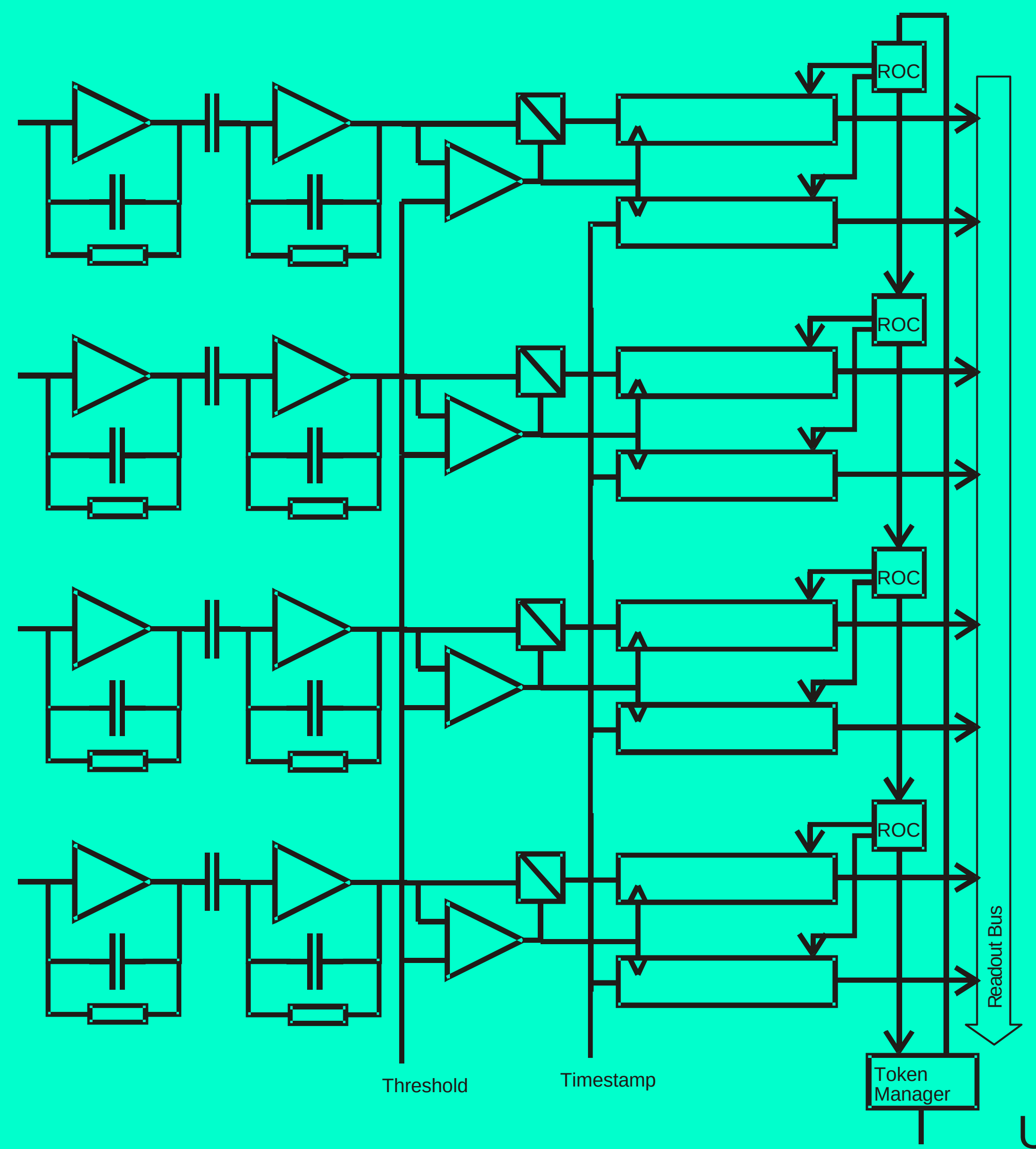
Token Ring Scheme (NXYTER)

→ "deadtime free"

Ch. Schmidt (GSI)

ASIC Labor Heidelberg

Sparse & derandomized readout



- Periodic readout at 20MHz
- Token asynchronously passes from channel to channel in search of data
- Within one readout cycle token could pass through all channels
- If token encounters occupied channels, data readout is initiated.
- After readout the token passes to the next channel.

→**20 MHz/128 Ch ≈ 160 kHz**

ENOB 10.4

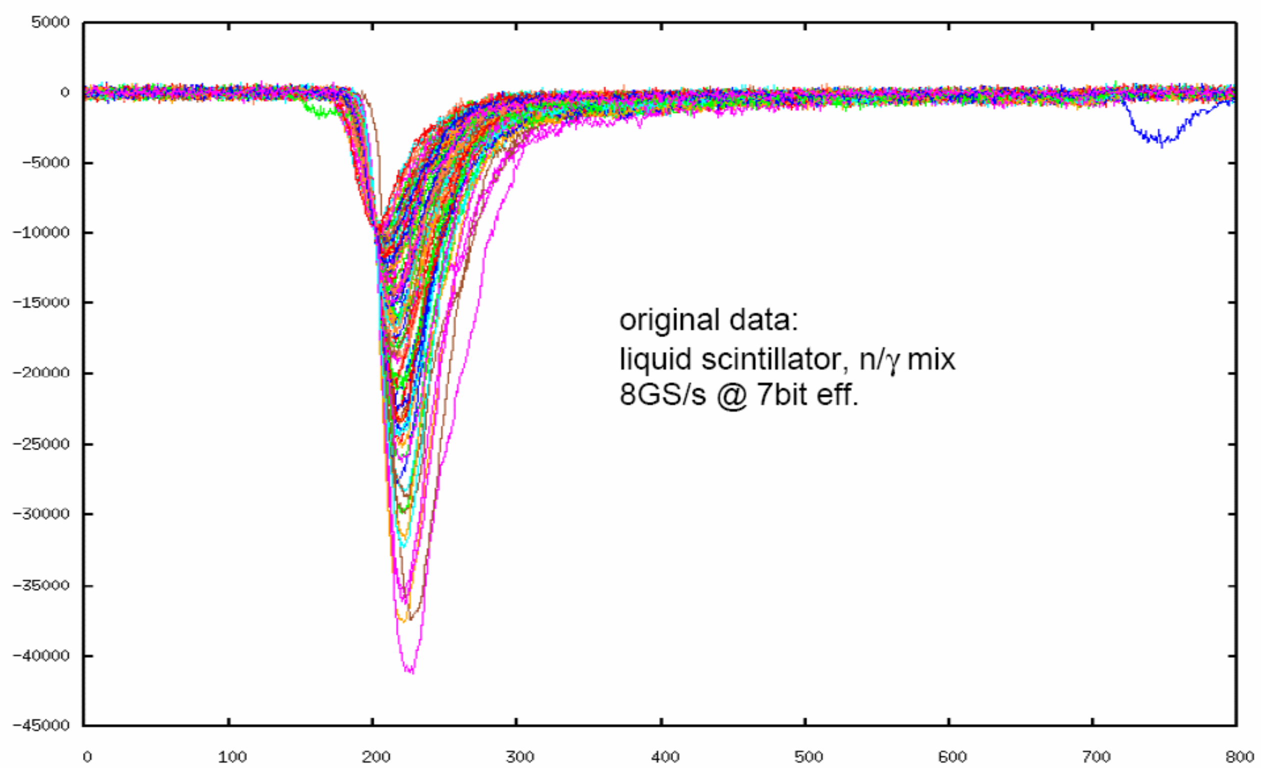
Ulrich Trunk
Physikalisches Institut der Universität Heidelberg

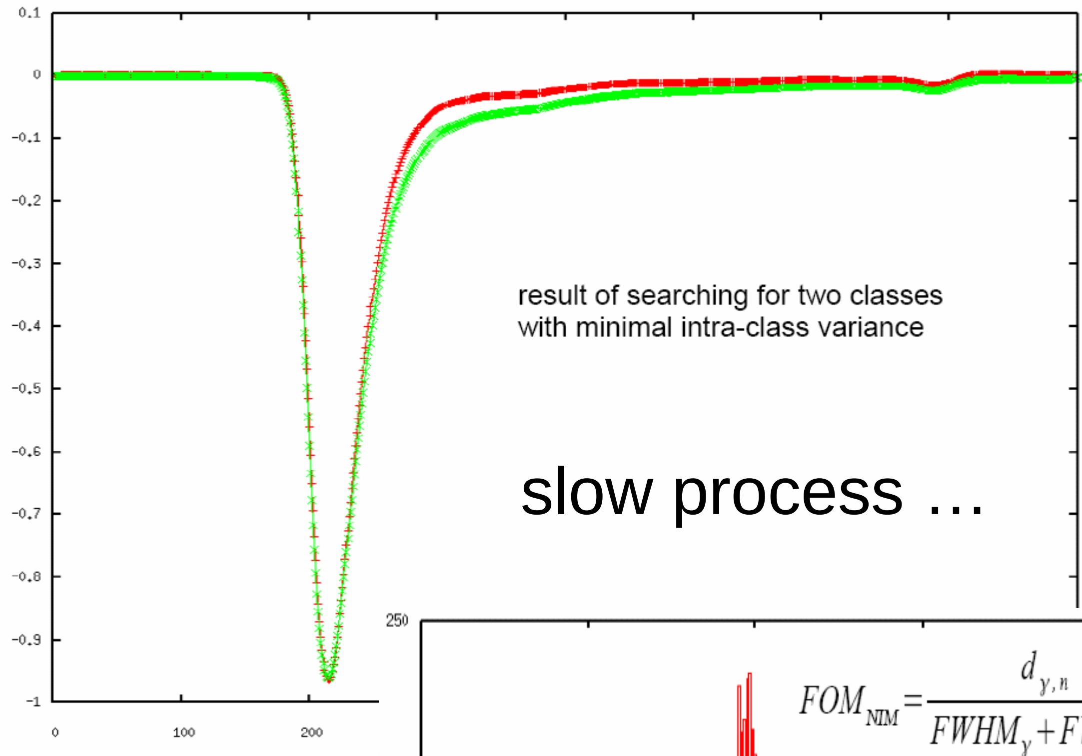
Variety of applications: Test with single wire readout foreseen !

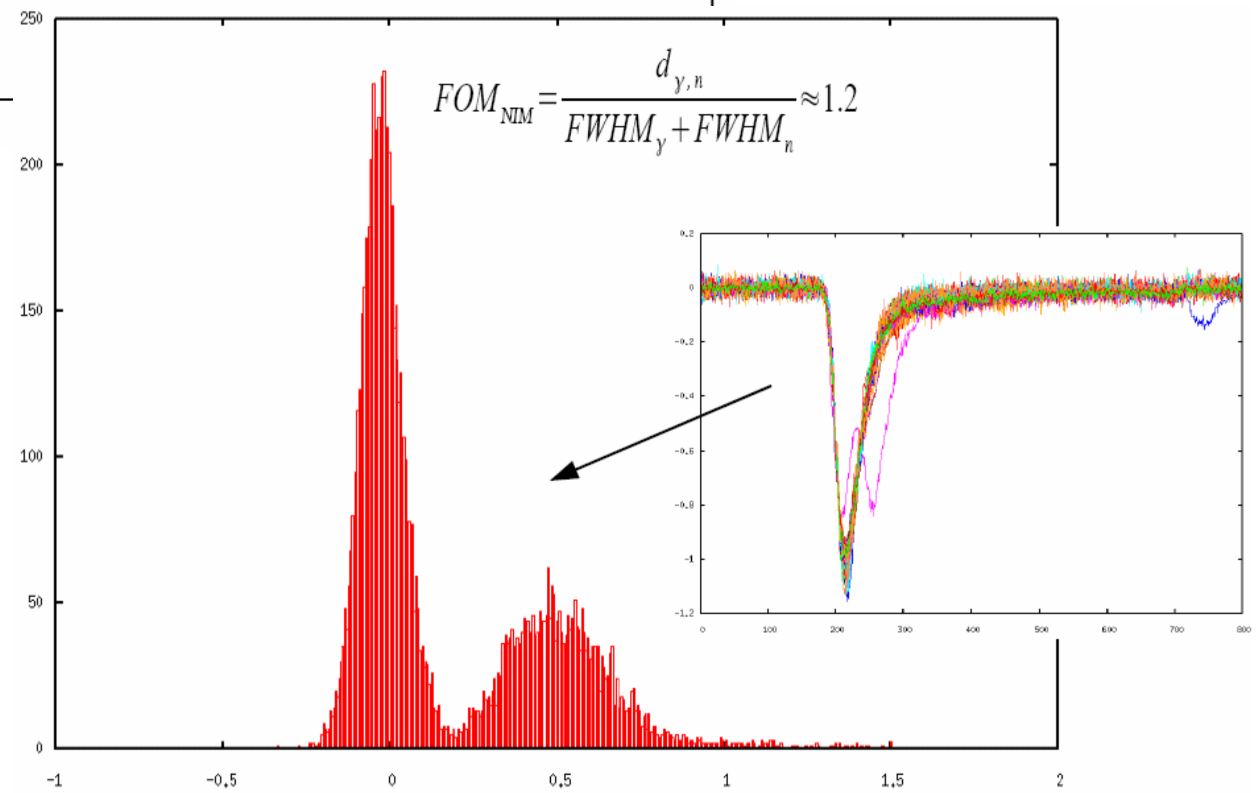
FAIR

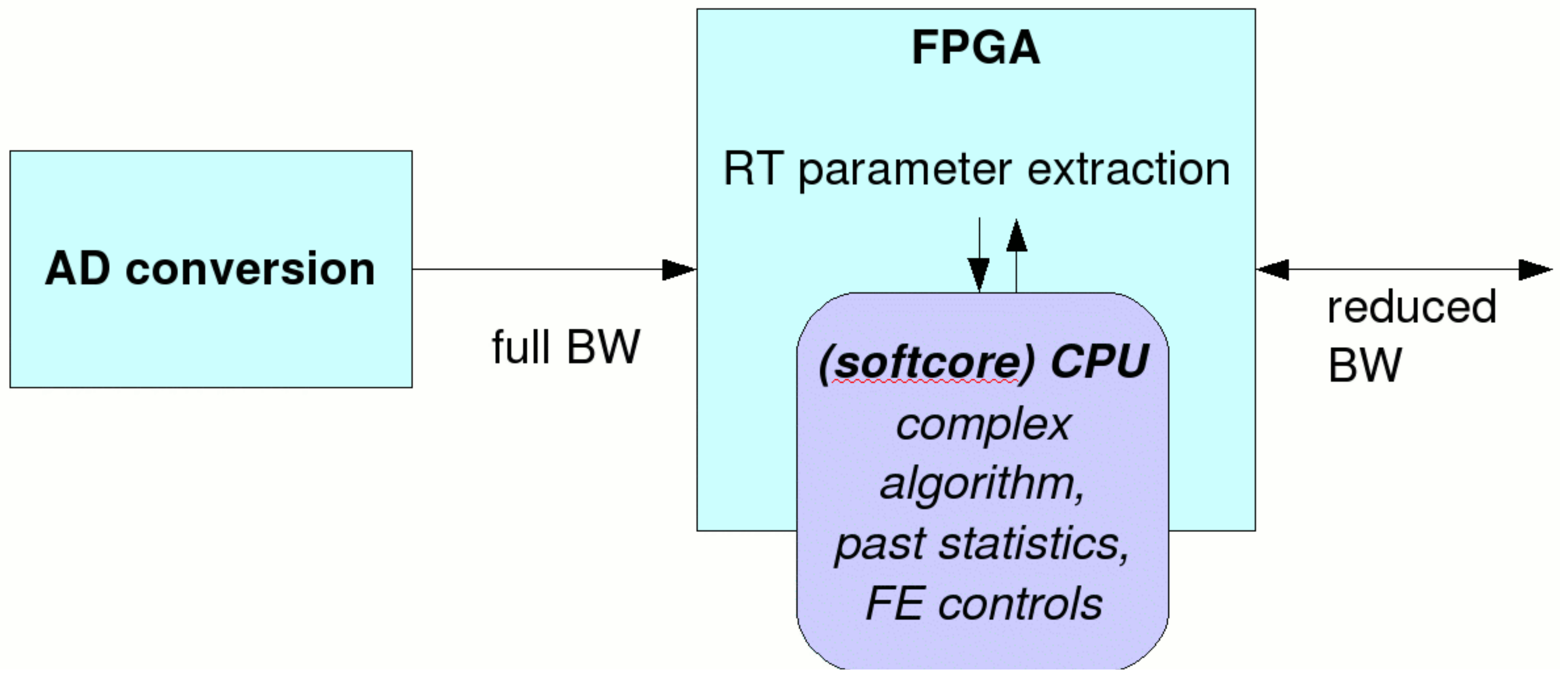
Digital Signal Processing (PULSE SHAPE)

M. Vencelj et al. (JSI)





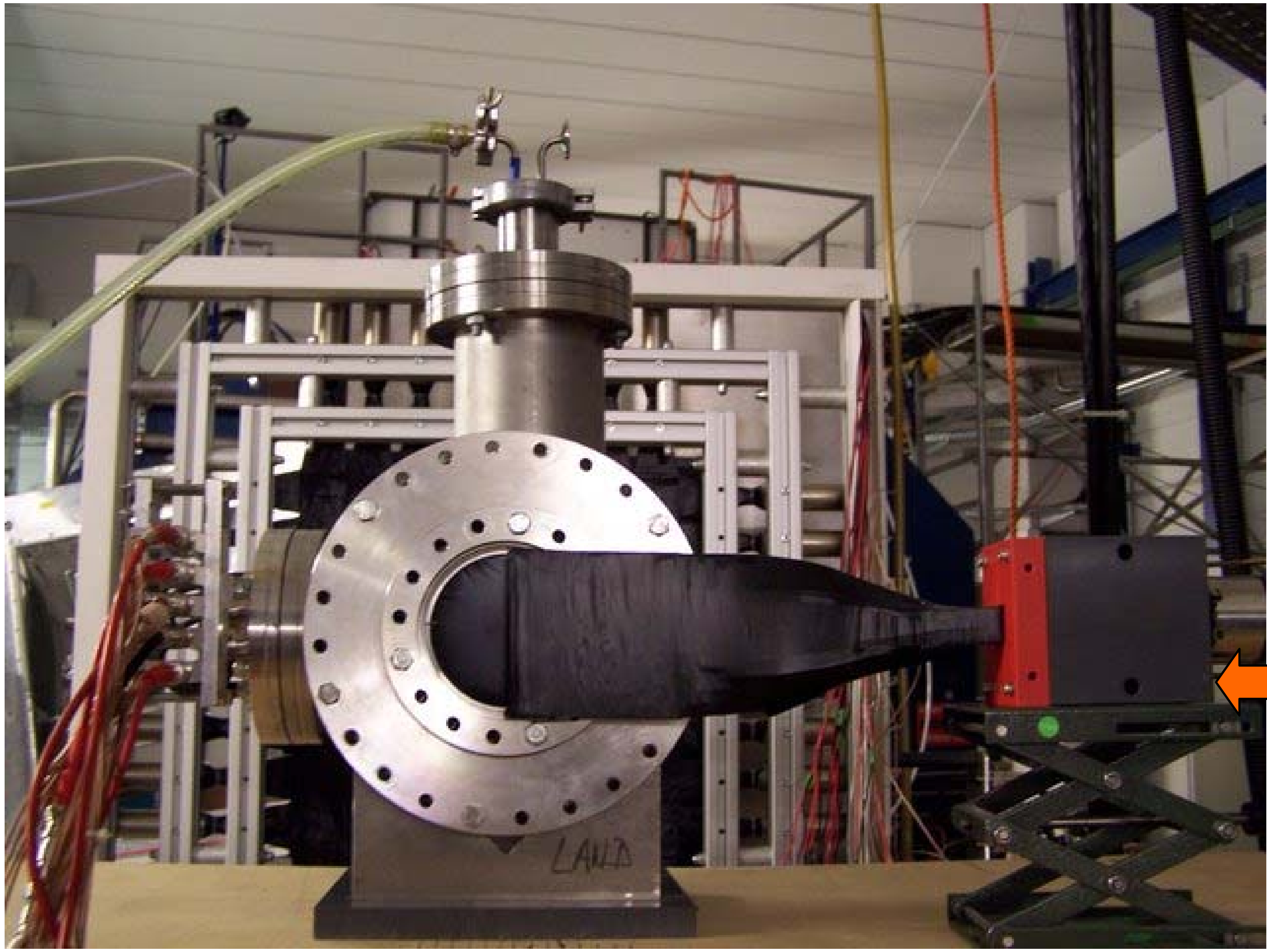


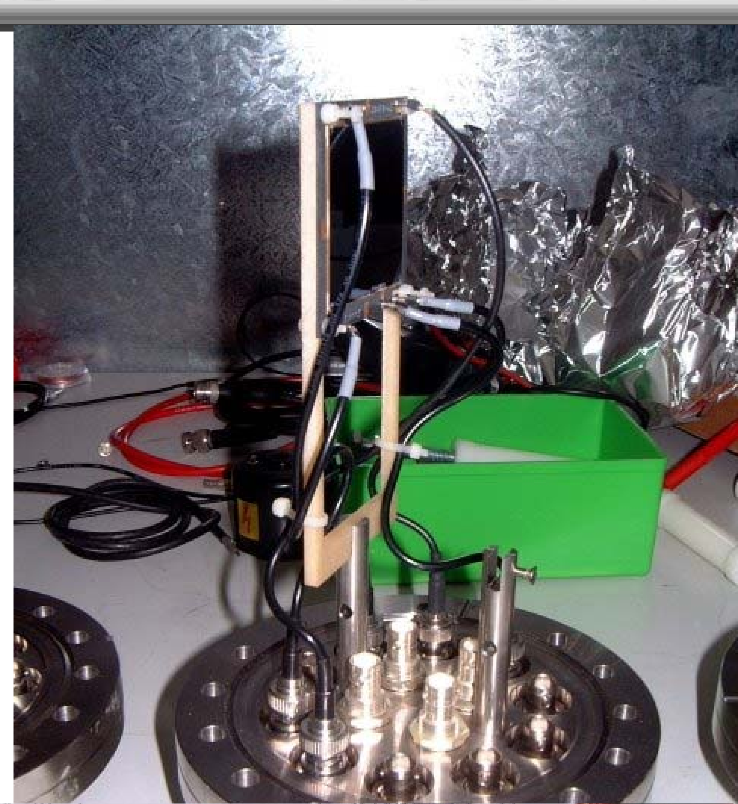


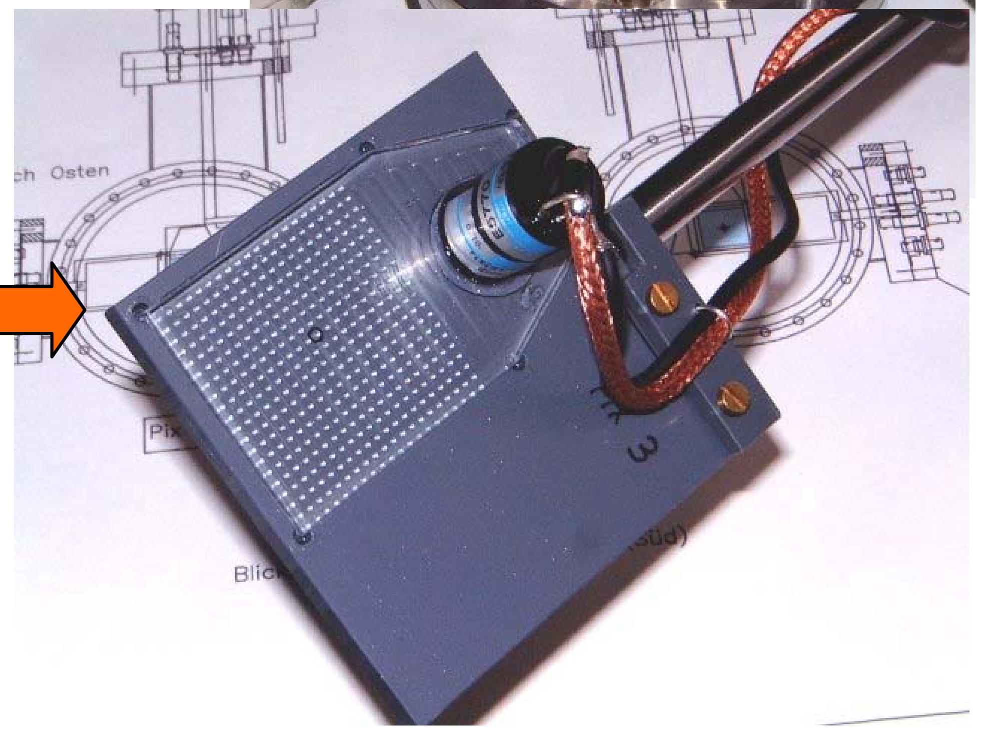
similar: energy loss/position

→ fast pos. sens. PIN tracker project (P. Lubberdink, H. Wörtche, H. Simon)

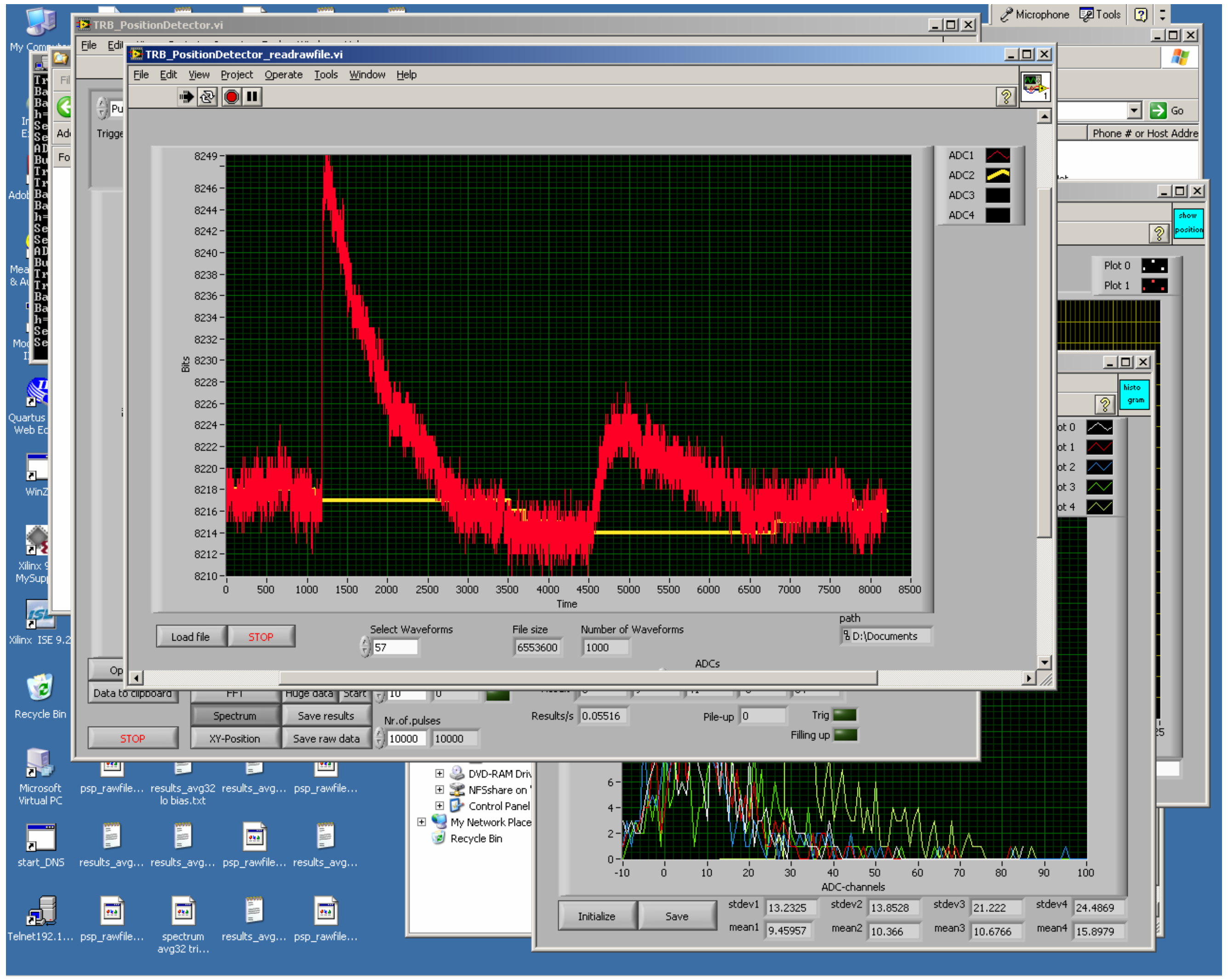
Test experiment S327 (16.-18.4.2008)
^{12}C: 550-700 MeV/u ; 2-50 kEv/s

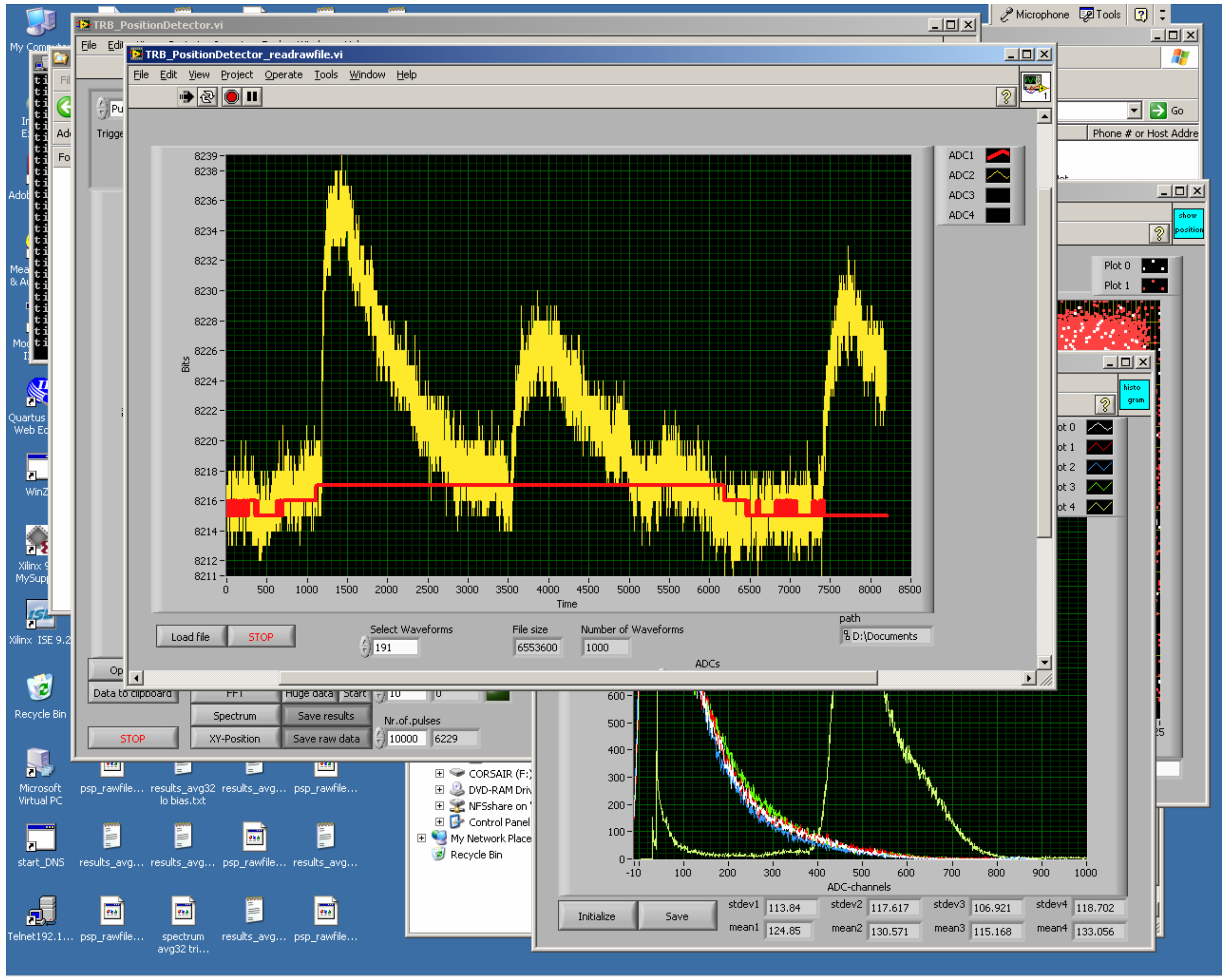






First Results: Baseline

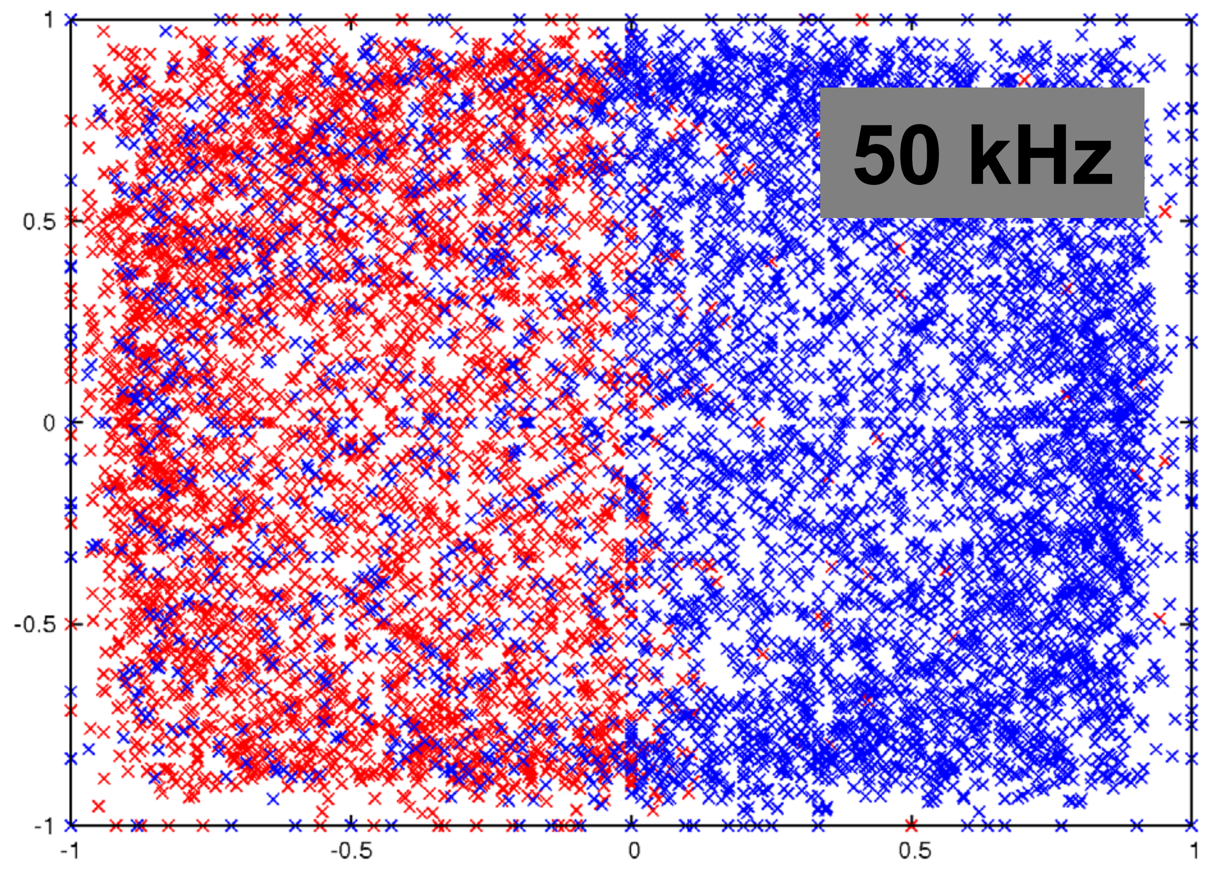


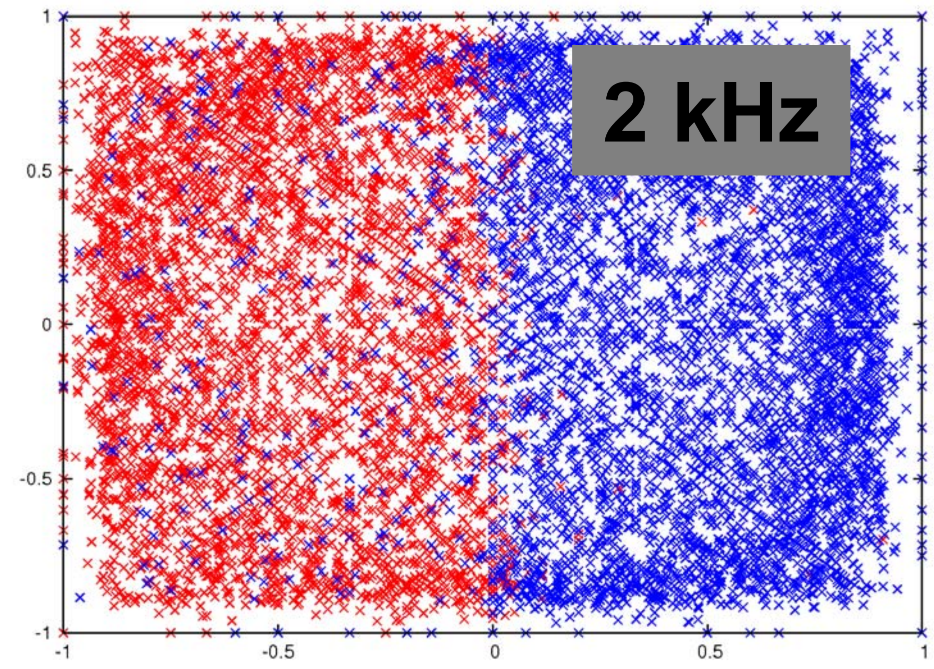


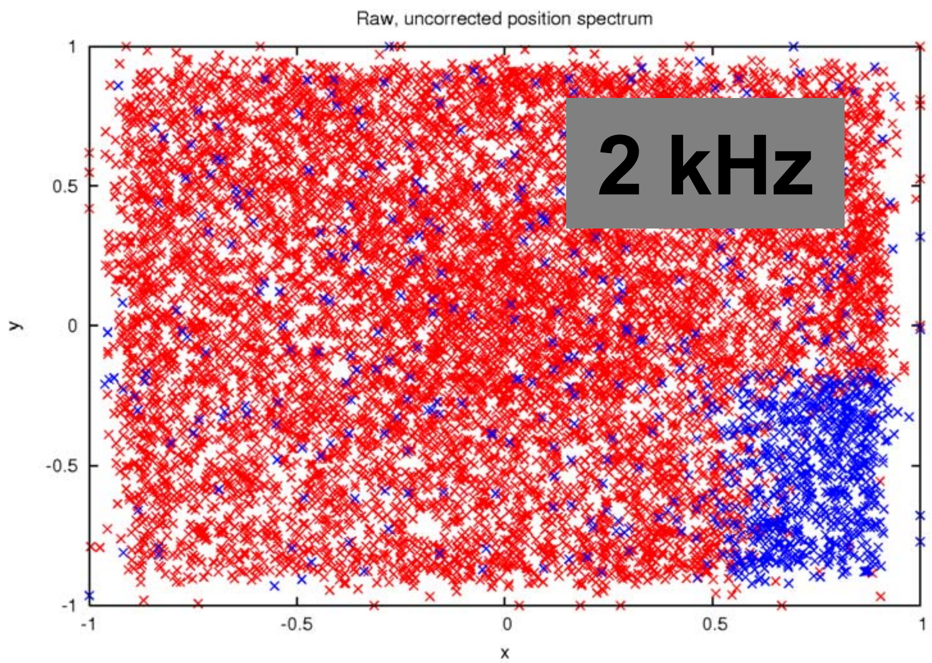
Baseline follower works !
(Bimodal Kalman Filter)

Treatment of double hits !

Results: Position







minimal distortions

Online reconstruction of positions:

i. @ full rate (i.e. 50+ kHz, theoretical limit: ADC speed !)
ii. no correction yet

→ development of a “slow process”

DAQ Concept for Beam Diagnostics @ FAIR

courtesy
M. Schwickert

FAIR – Accelerator Control System

Responsibility
of Controls

CORBA-based Middleware, e.g. CMW

Responsibility
of Beam
Diagnostics

FESA on
embedded
controller

FESA on
data concentrator (PC)

DAQ module

DAQ module

single board
PC, DSP,
FPGA...

single board
PC, DSP,
FPGA...

Analog signal

Analog signal

Analog signal

Analog signal

Summary

- fast tracking & ID for experiments
  - clean beams required
- most detector systems available (in principle)
  → but better performance would be welcome !
- adaption to Super-FRS needs
- staged implementation
- readout concept → share between
  ACC readout FESA/ACS &
  EXP readout MBS/EPICS controls
- interfaces/Procedures for machine safety develop
- fast sampling and PSA (pile up treatment)

Collaborators

- CU Bratislava - B. Sitar et al. (MWs)
- TU Munich - R. Gernhäuser et al. (Diamond)
- JSI Ljubljana - M. Vencelj et al. (PSA)
- KVI Groningen - H. Wörtche et al. (FE-Controls)
- HIP Helsinki - E. Tuominen, F. Garcia (GTPC/Si)

Additional @ GSI

- Detector Laboratory - Ch. Schmidt et al.
- Experimental Electronics - E. Badura et al.
- Accelerator Group - R. Bär, P. Forck, et al.