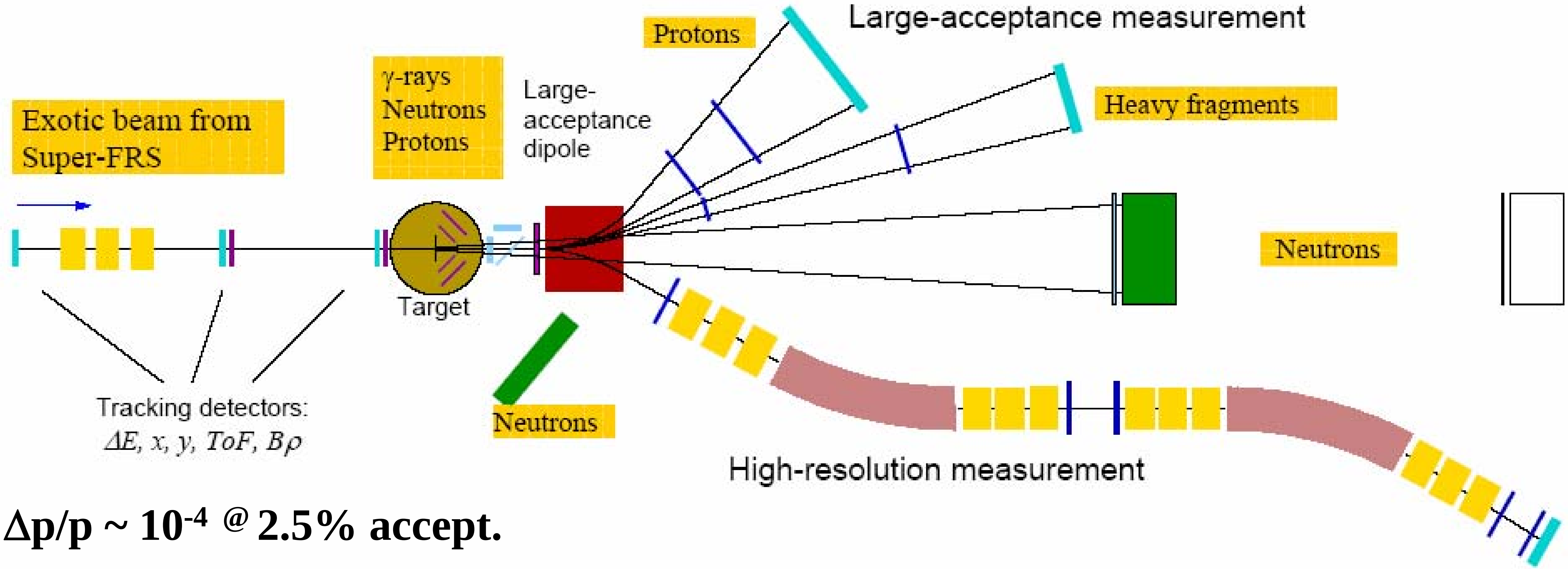
High Rate Diamond Detectors for Heavy Ion Tracking and TOF

Roman Gernhäuser, TU-München

- detector concept
- larger area prototypes
- electronics development
- test experiment

R^3B (Reactions with Relativistic Radioactive Beams) Setup



$\Delta p/p \sim 10^{-4}$ @ 2.5% accept.

Measurement of all kinematic variables in a HI reaction

Different tasks: Tracking in the Super-FRS, radiation hard 10^6 cm^{-1} s^{-1}

2 x TOF (SFRS – target) (reaction products)

low material budget and high resolution tracking @ R3B

Why PC-CVDD

TOF and position measurement with a single layer of 100 μm CVDD

material available in reasonable sizes (20 μm – 1 mm)

diameter up to 75mm

fast signal collection

radiation hardness and no doping

- C^{12} 1-2 AGeV 10^{12} cm $^{-2}$
- U^{238} 1 AGeV 10^{10} cm^{-2}

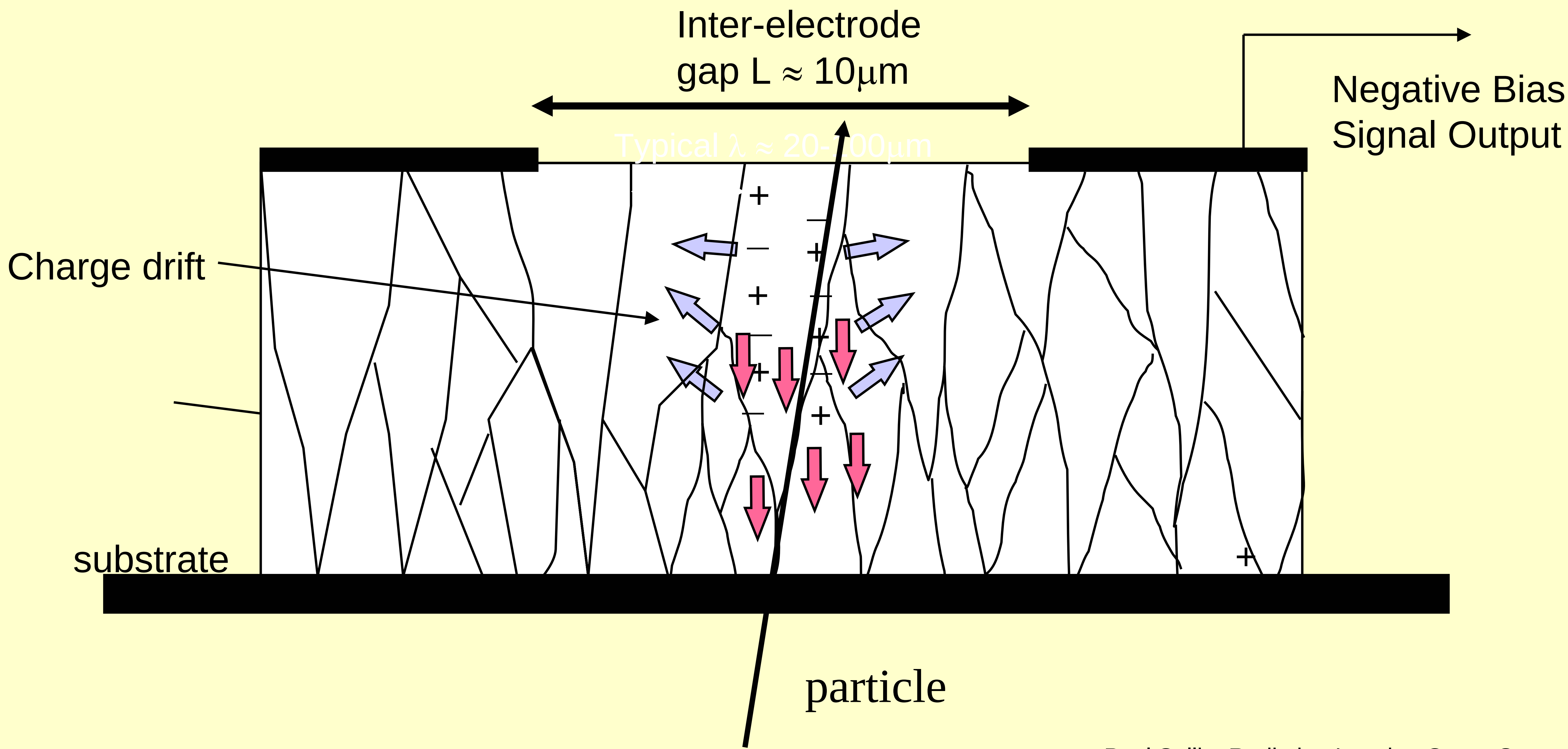
low noise (in principle)

- low dielectric constant – low cap.
- small leakage current – low noise

collection distance is less important in case of heavy ions

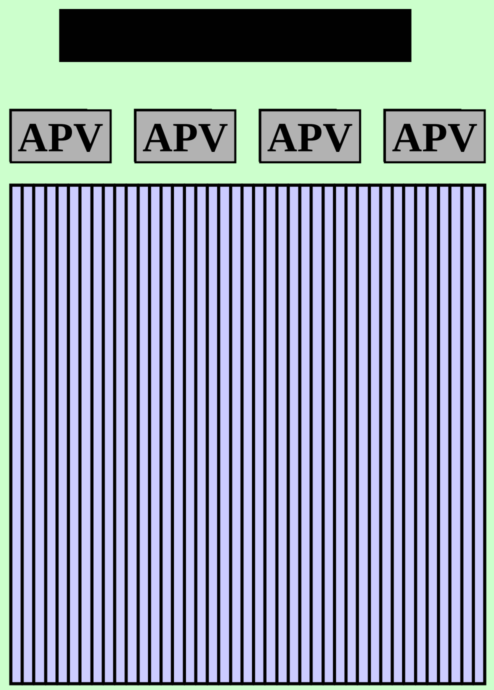
- > 99% of charge distribution above 10 keV, ΔE = 10MeV

Local CCE



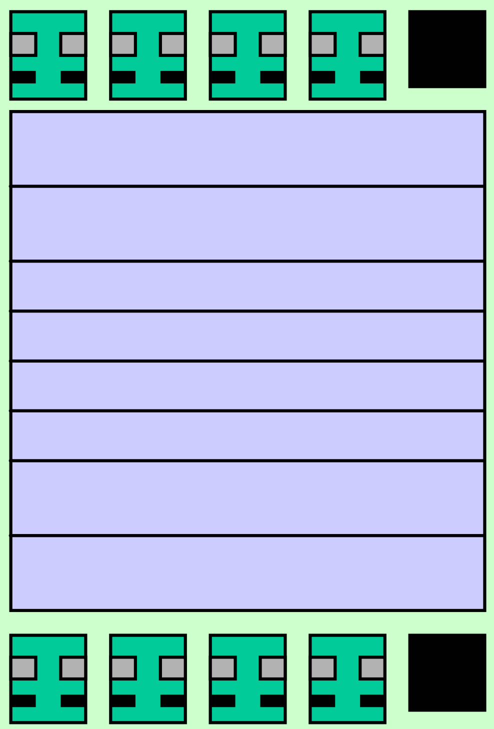
Paul Sellin, Radiation Imaging Group Surrey

R3B Detector Concept



tracking layer:

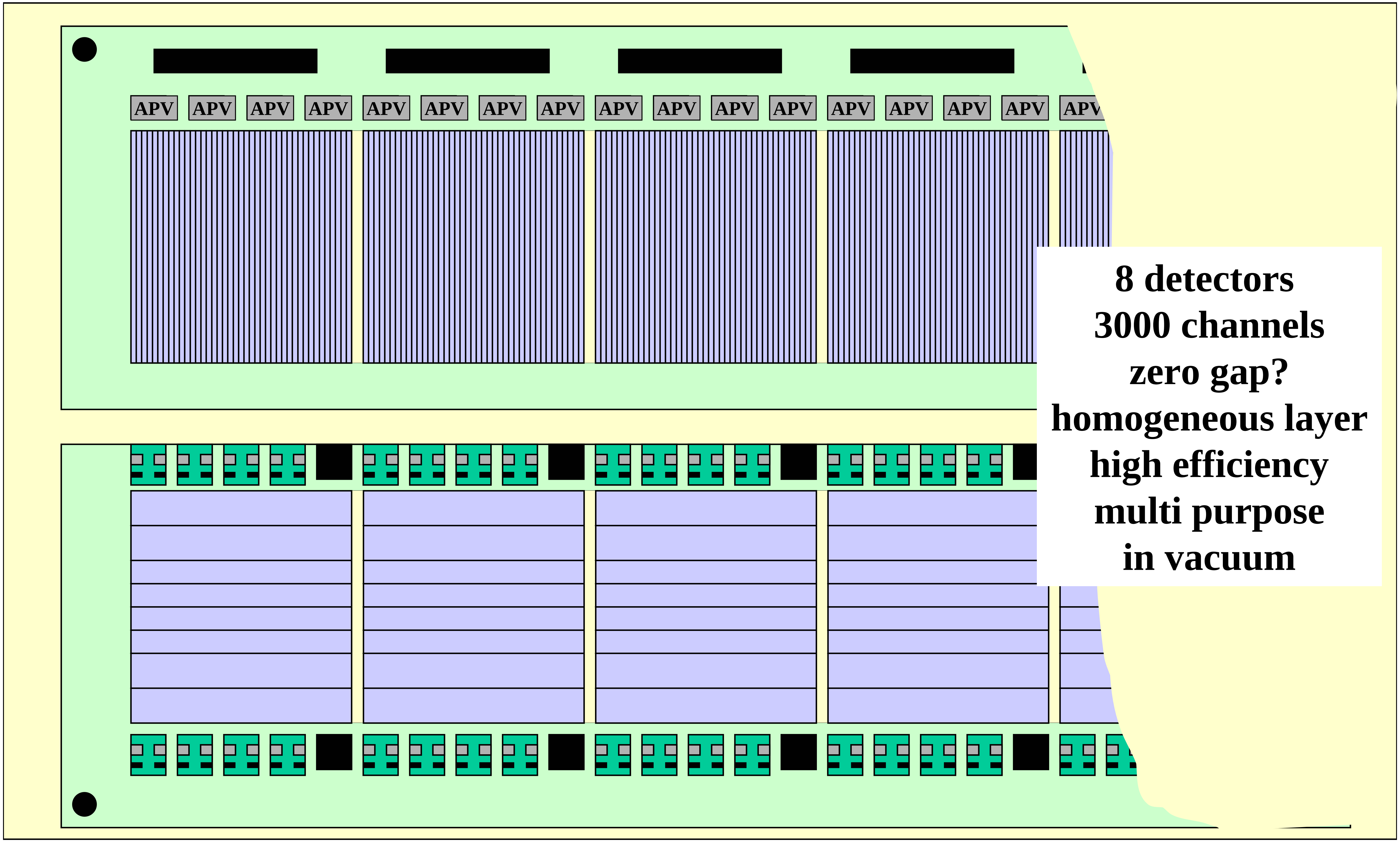
- 50 x 50 mm, d = 100 μm, PC-CVDD
- 200 μm pitch (170μm strips, 20 μm gap)
- only digital position information
- multiplexed readout in vacuum



timing layer:

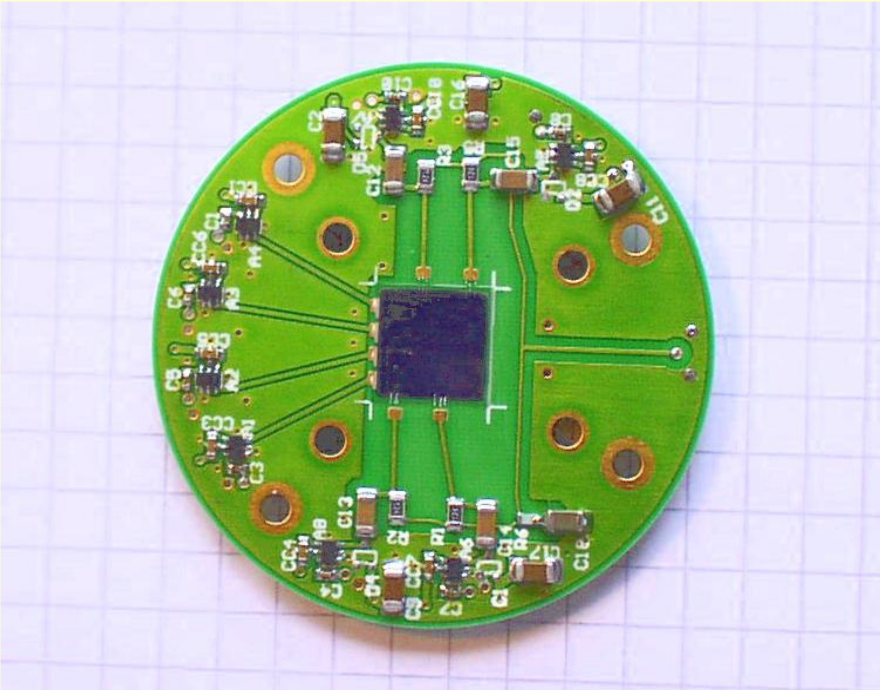
- 50 x 50 mm, d = 100 μm, PC-CVDD
- 16 rate matched strips, y information, trigger
- analog preamplification in vacuum
- discriminator @ 5 m distance

FRS Detector Layout



8 detectors
3000 channels
zero gap?
homogeneous layer
high efficiency
multi purpose
in vacuum

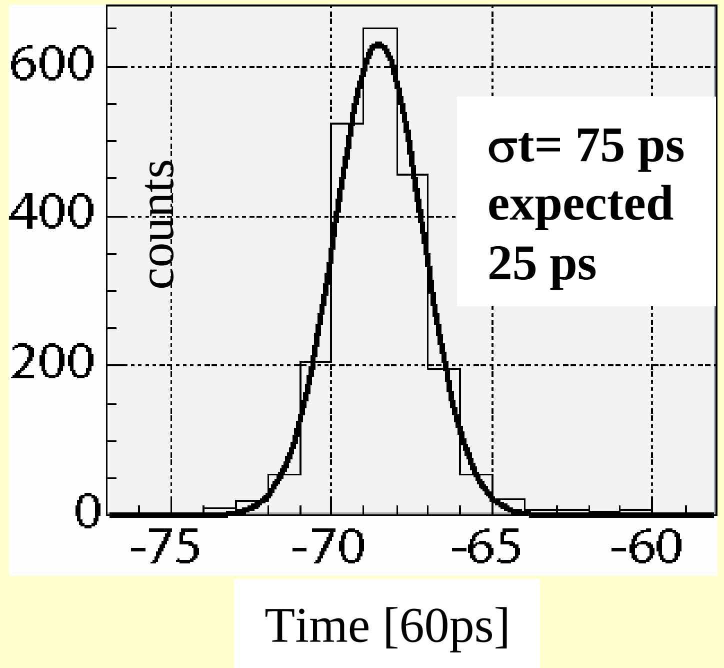
Status 2007

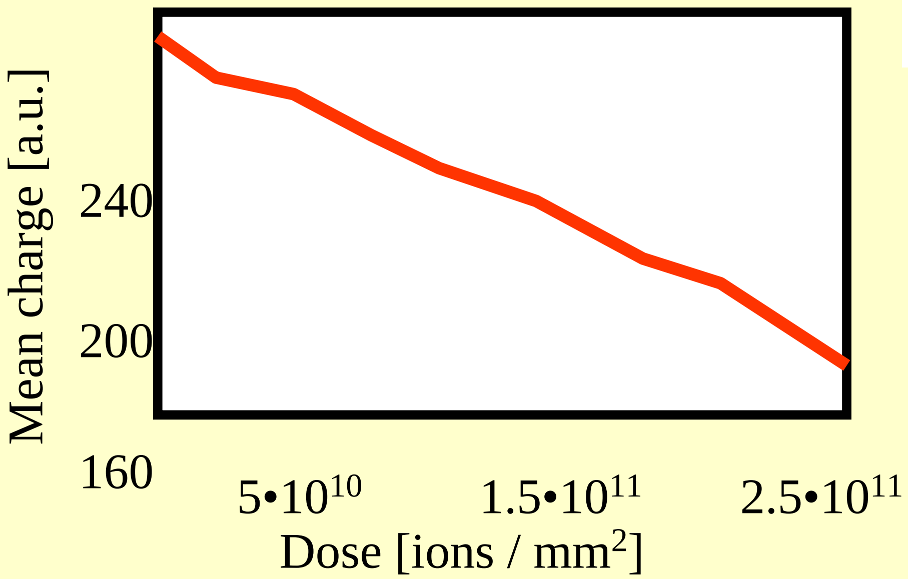


detailed investigations:

using ~ 100 x 1cm^2 sample detectors

- material properties checked
- radiation hardness proven
- segmentation scheme optimized
- lithography improved (15µm)
- efficiency > 98%
- fast preamps vacuum suited
- good TOF resolution
- 1st prototype of APV readout



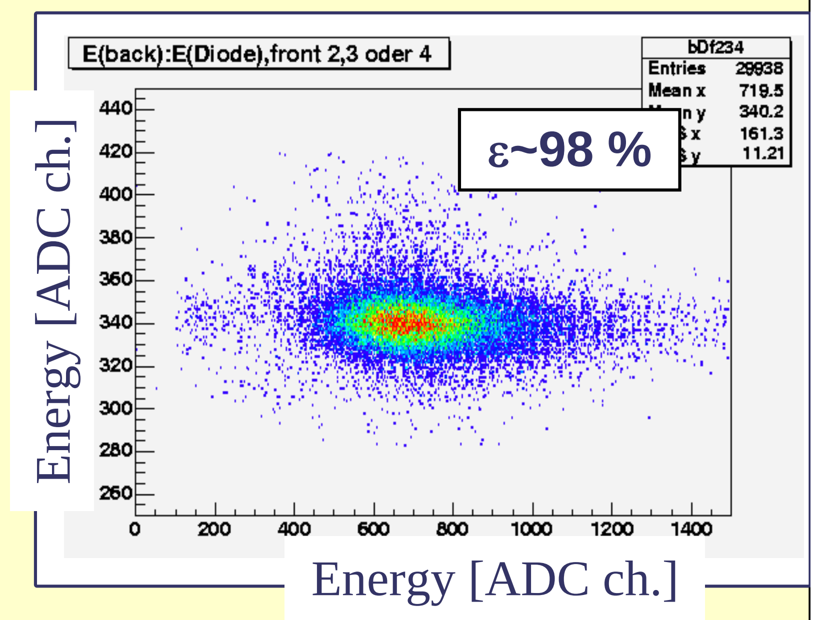


next steps:

intermediate size prototypes

separate detector – electronics

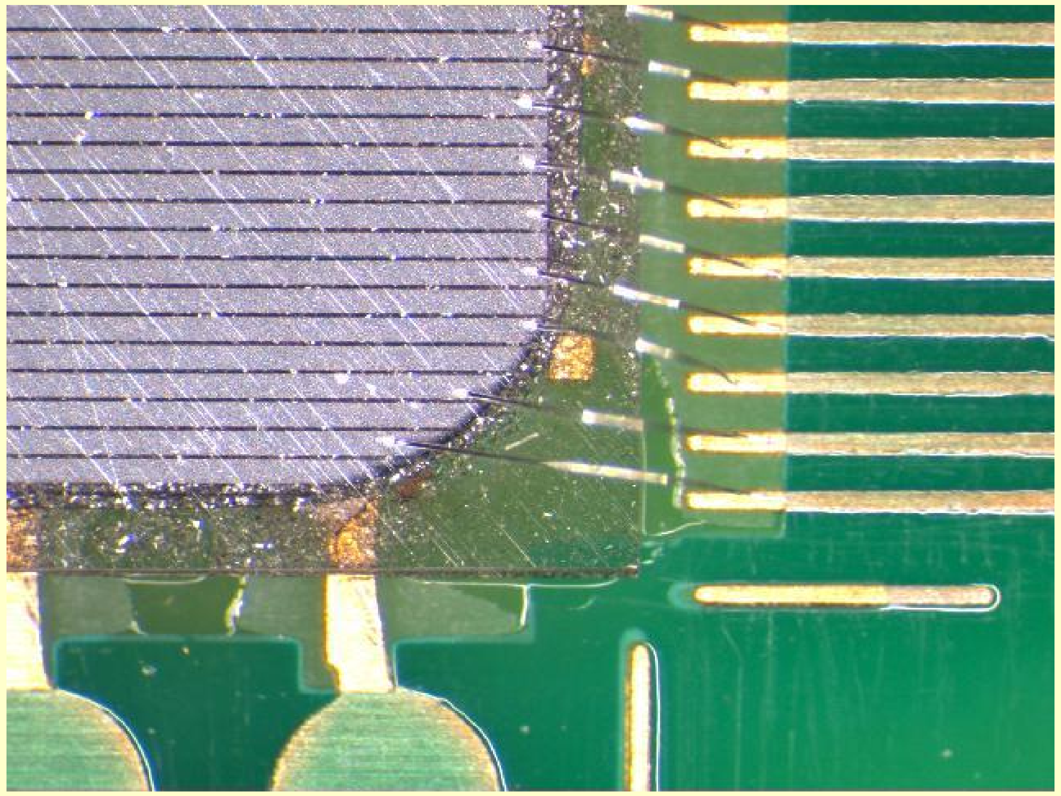
test of high resolution tracking

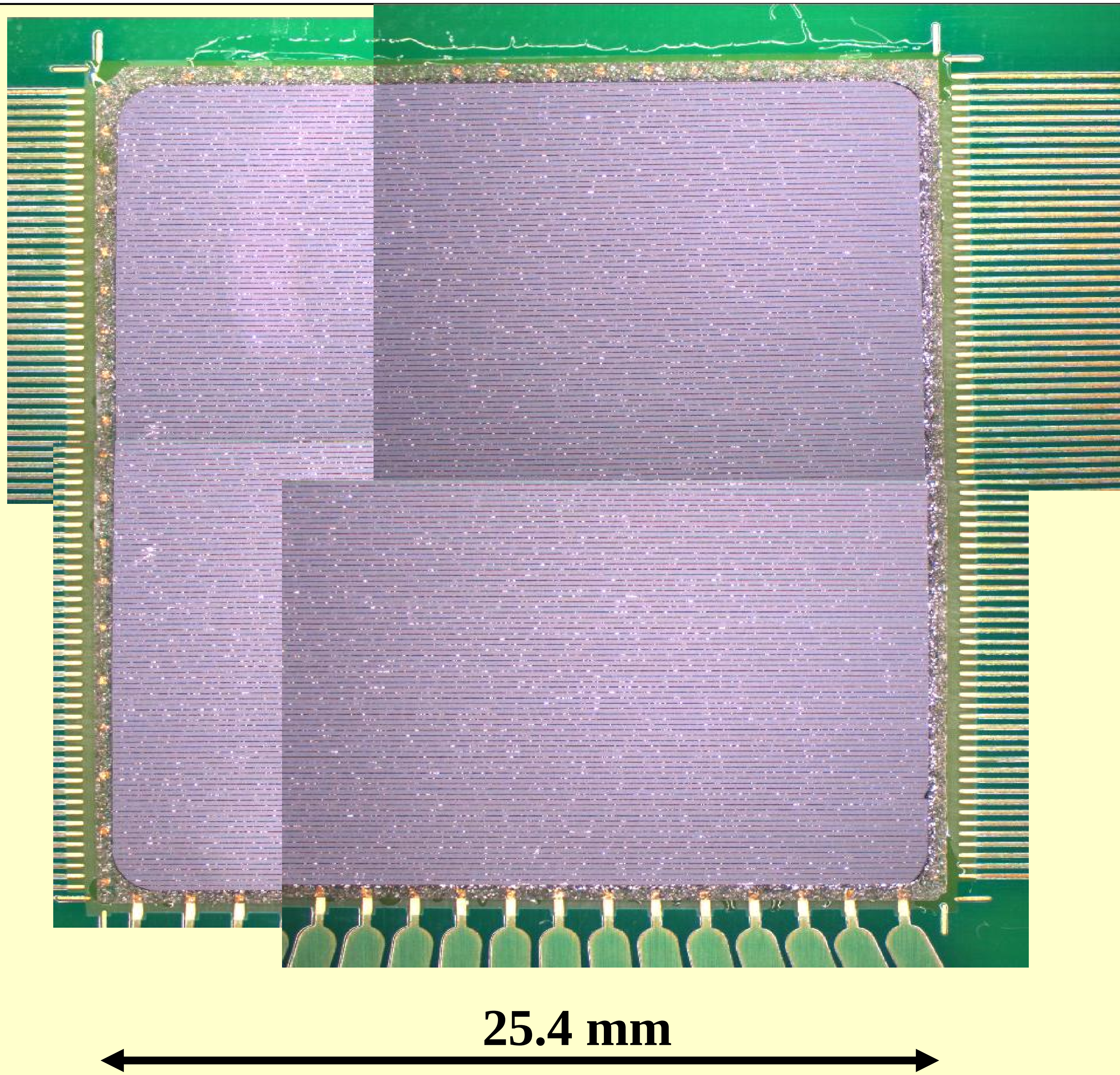


Larger Area Detector

4 prototypes produced
2 operational
lithography under control

Frontside:
128 strips
170 μm wide 20 μm gap
Backside:
16 strips

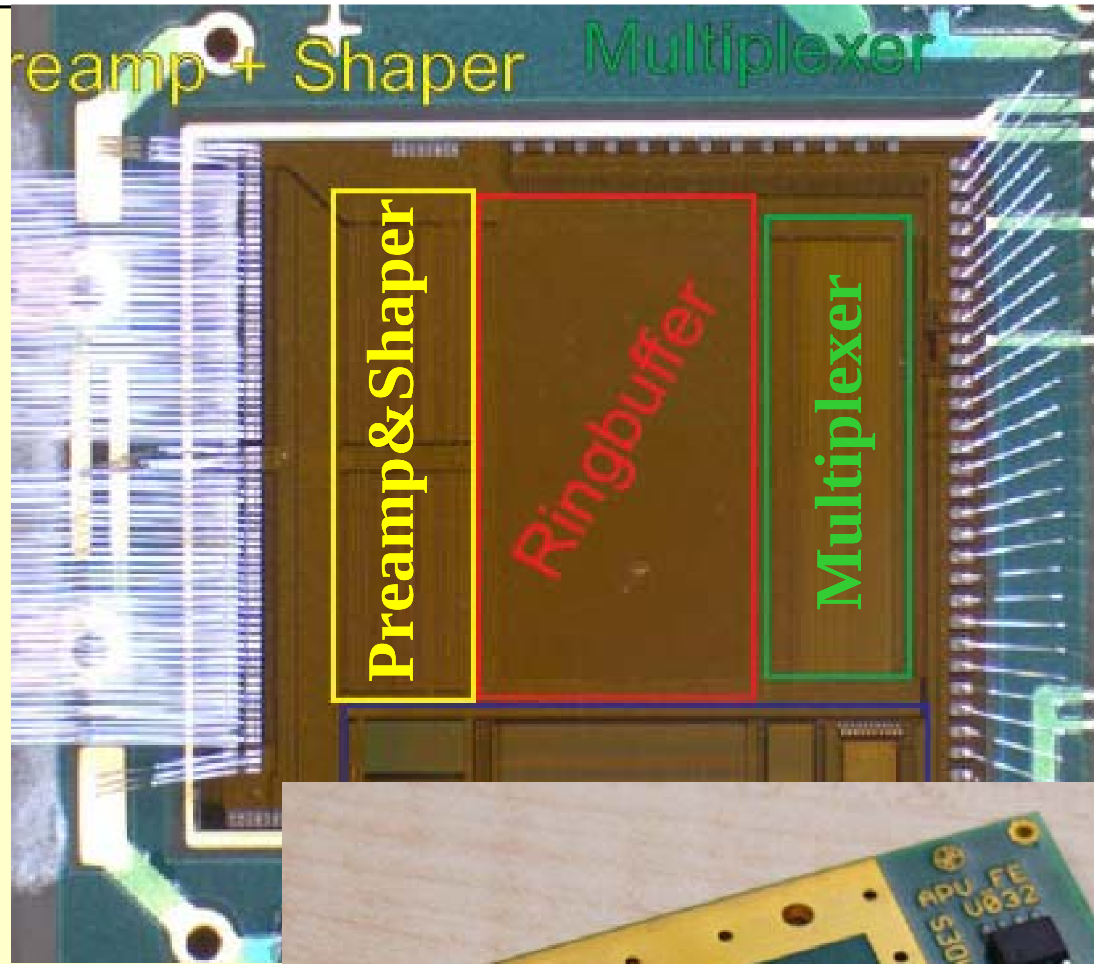


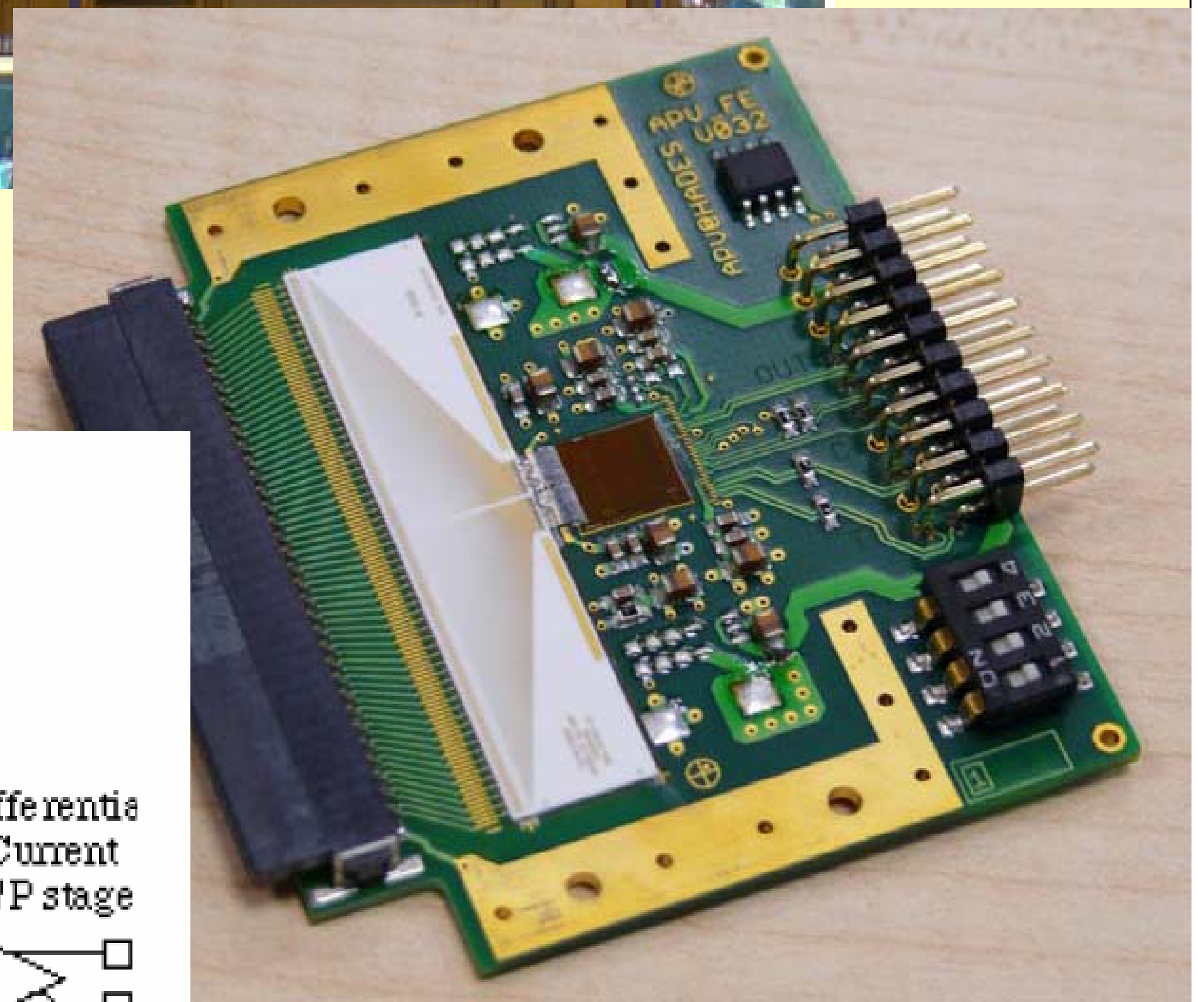


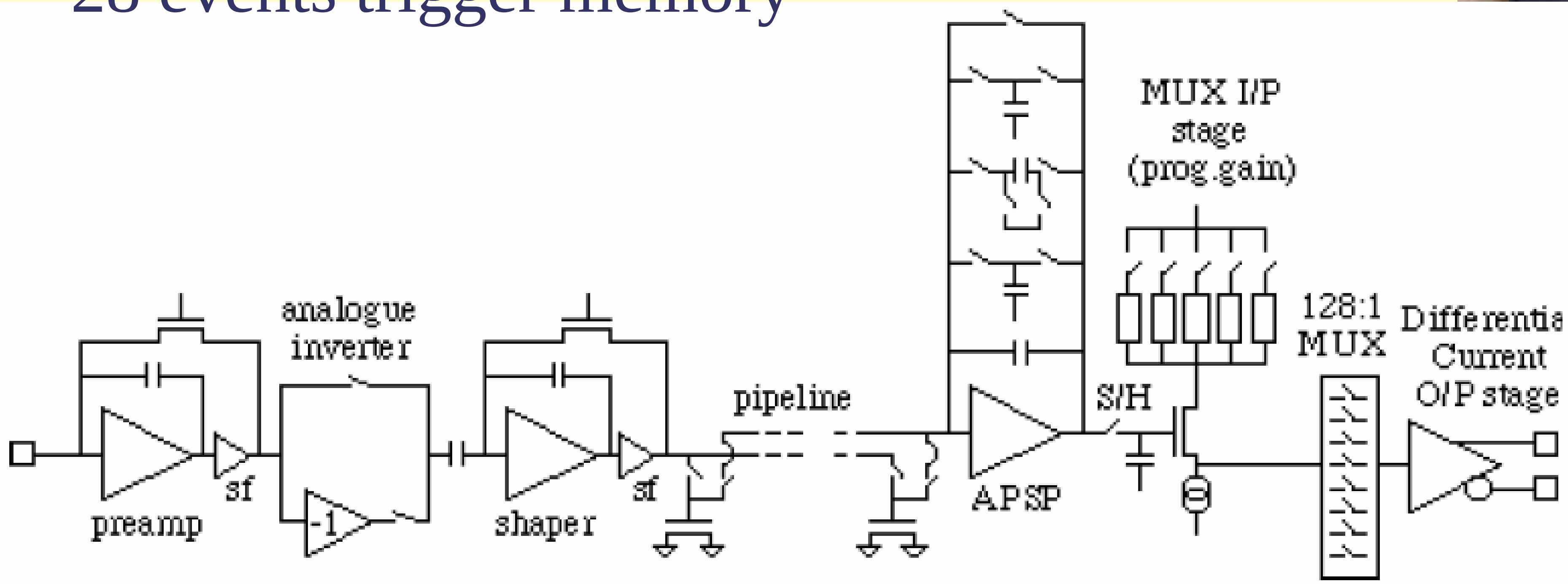
Micro Strip Readout

APV25S1 chip

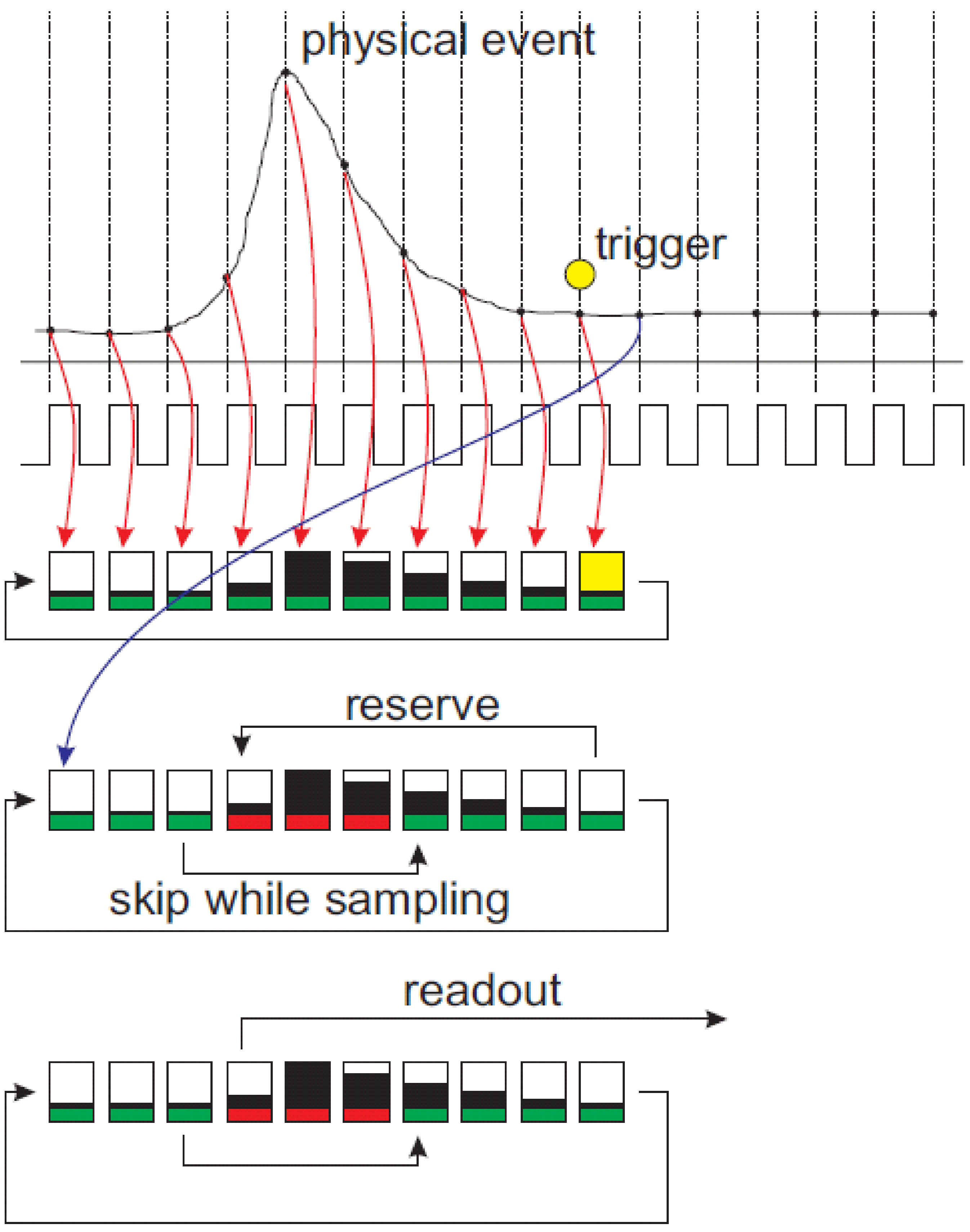
- 128 channels / chip (8.1 x 7.1 mm)
- 44 µm pitch
- preamplifier, shaper on chip
- peaking time 50-250 ns adjustable
- polarity select
- 8 MIPS dynamic range
- noise: $270e^{-} + 38e^{-}$ /pF
- vacuum suitable (2.4 mW/ch)
- differential output and control
- analog buffer (192 Samples = 4.8µs)
- 28 events trigger memory







Readout Scheme



permanent analog processing

analog ring buffer (25ns)

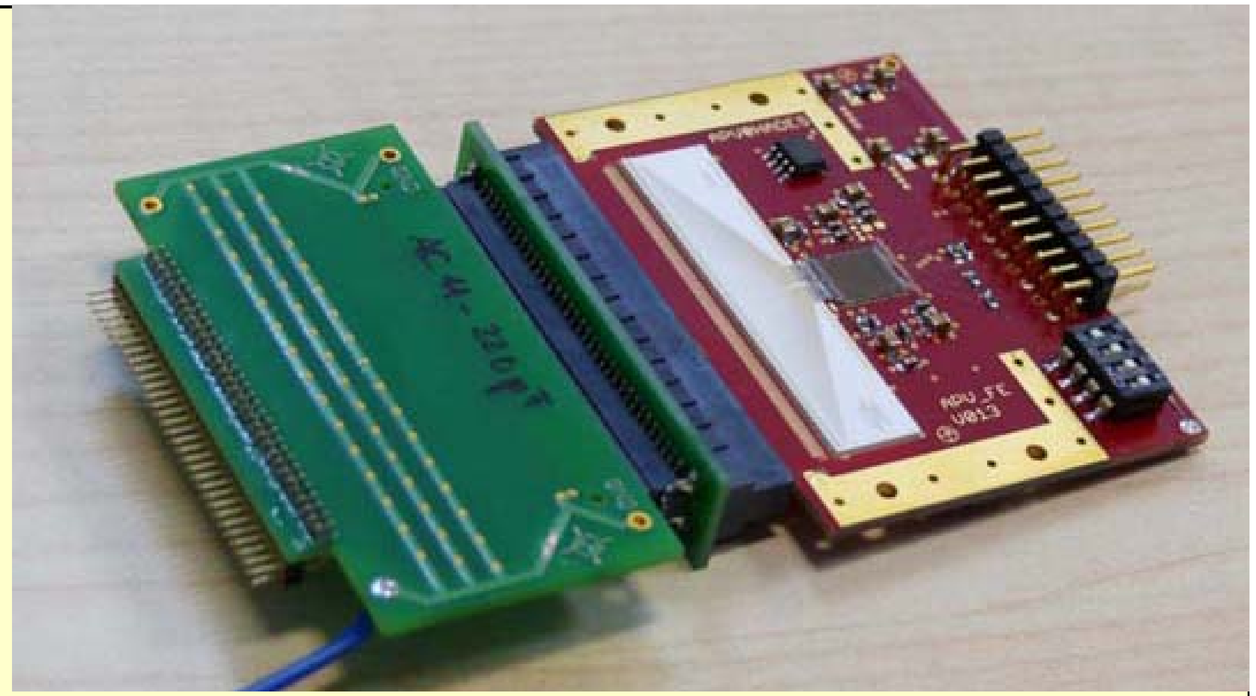
Trigger: one row in the
ring buffer is labeled
(length reduced)
up to 28 triggers are stored

Trigger latency < 4.8 ms

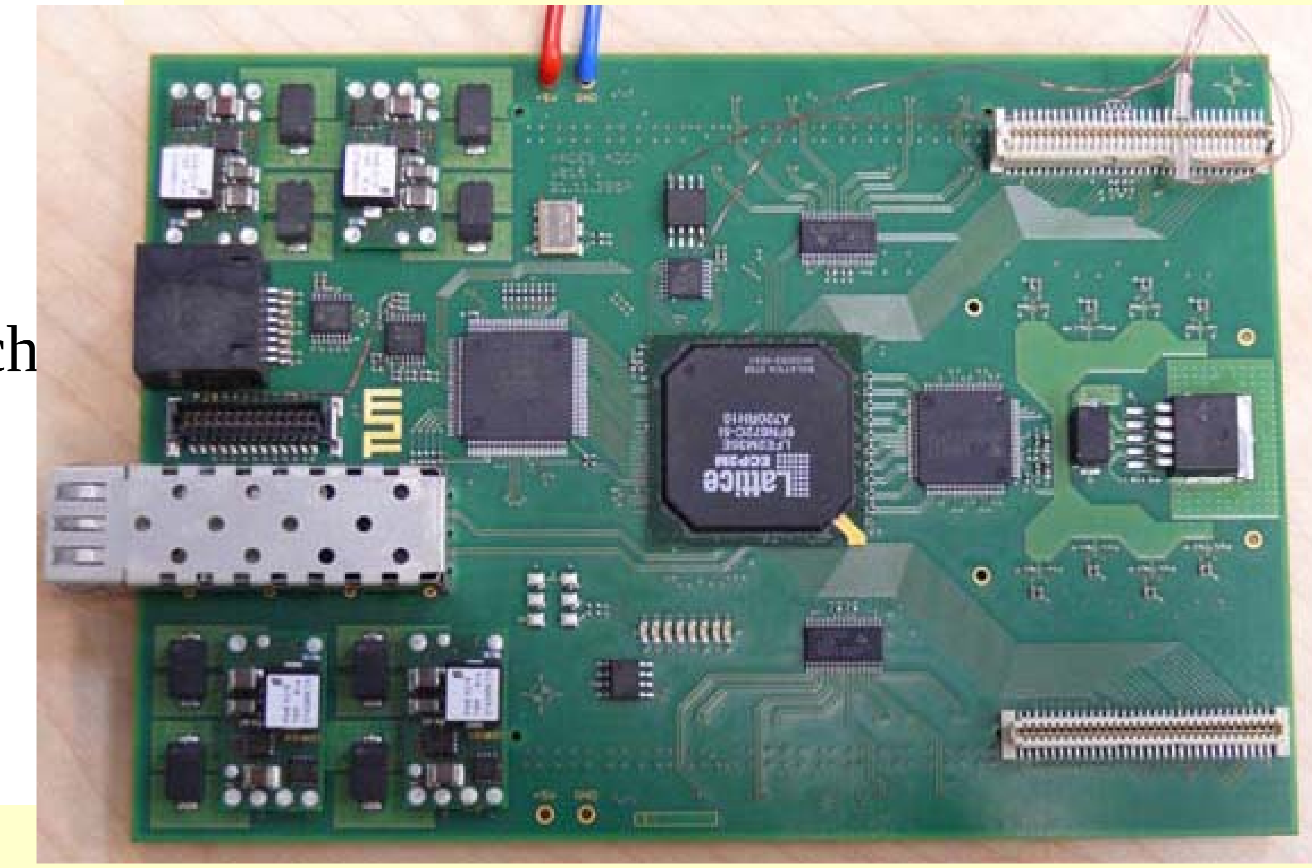
Trigger asynchronous readout

dead time free readout

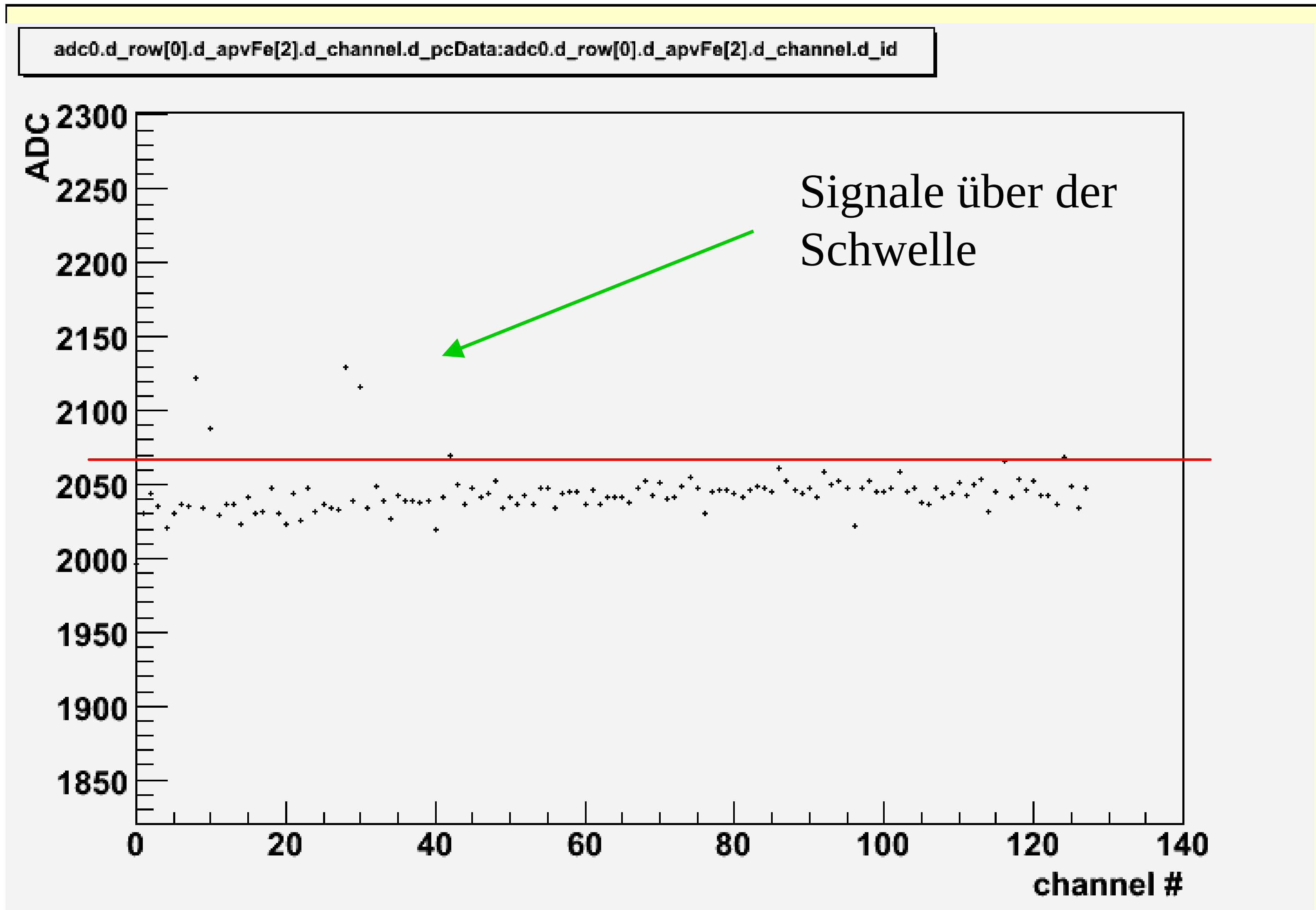
Board Development

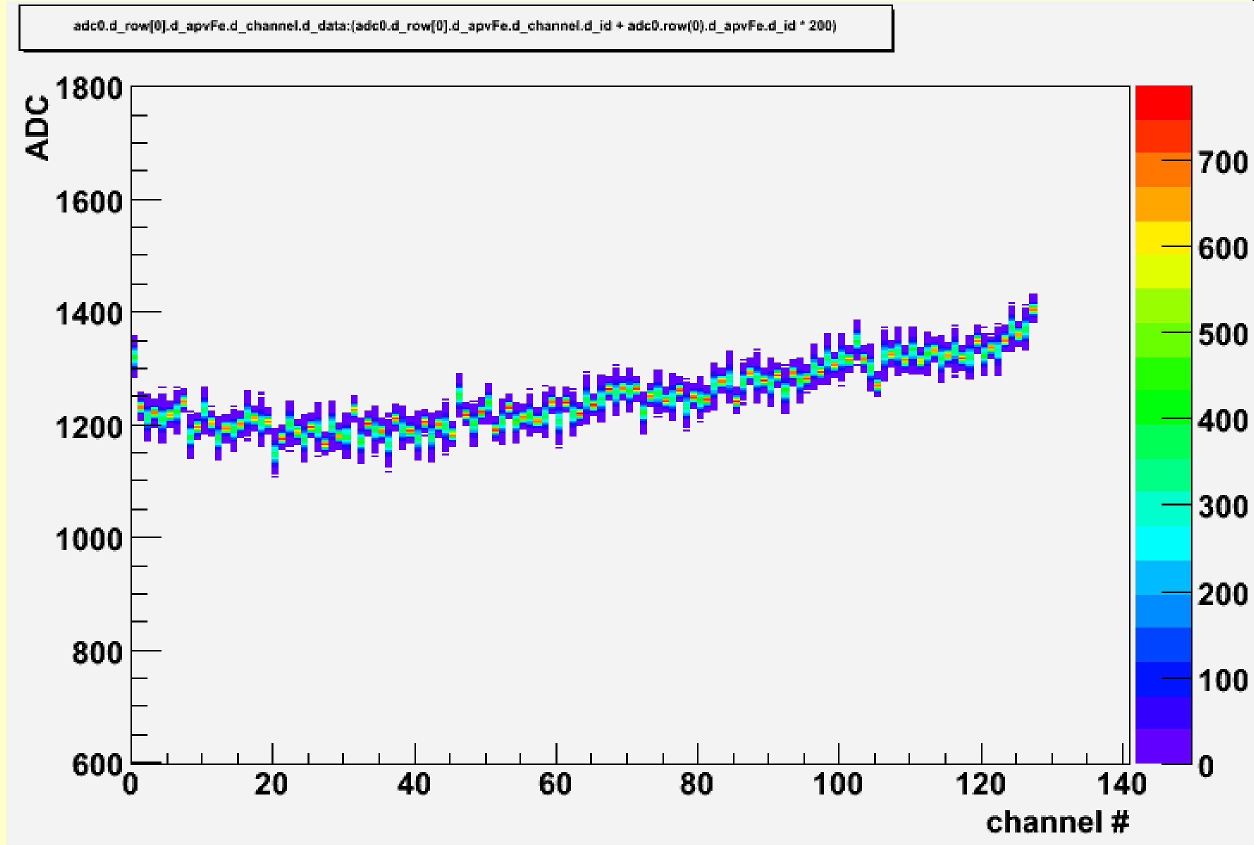


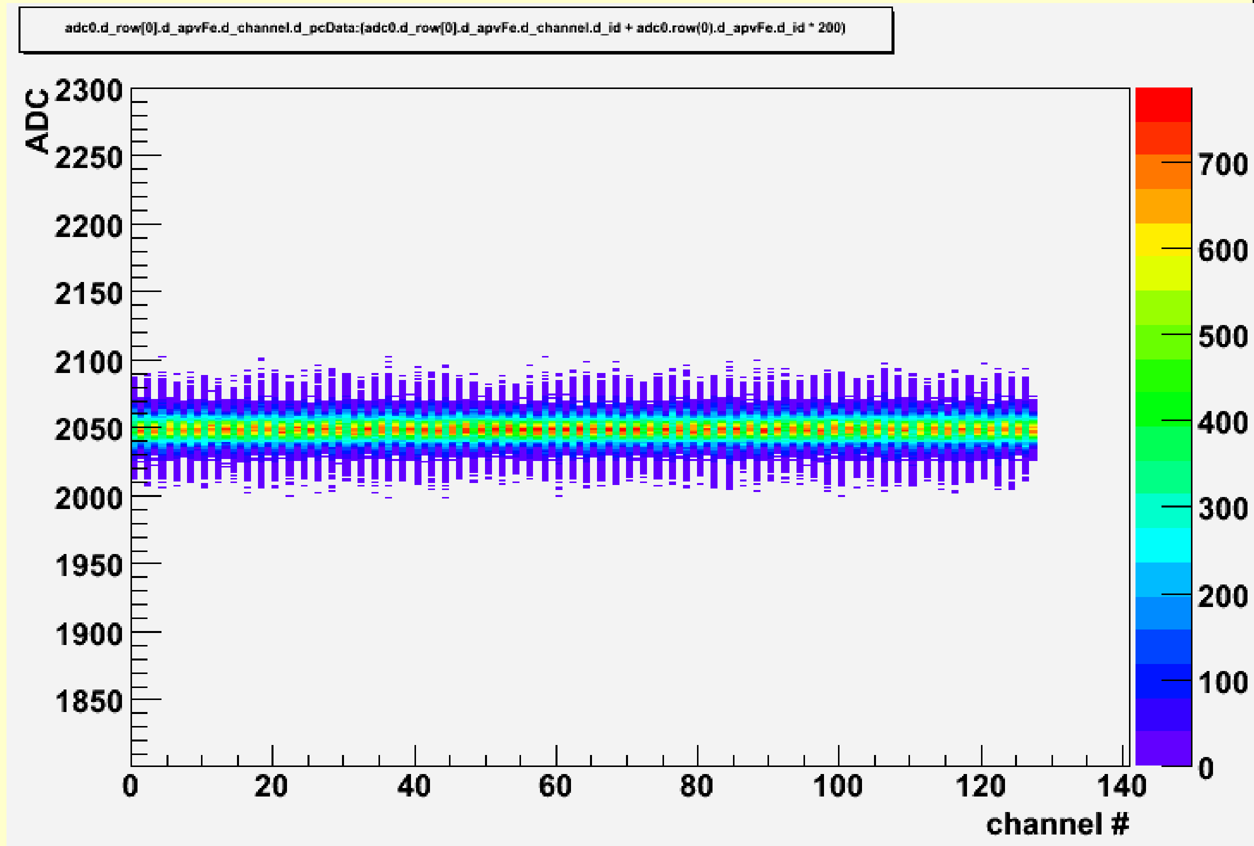
- 3rd revision of APV board with pitch adapter
- Attenuator and protection board
- 8 ADC board (1024 ch
- Large FPGA
- GTB and TRB interface



Signals





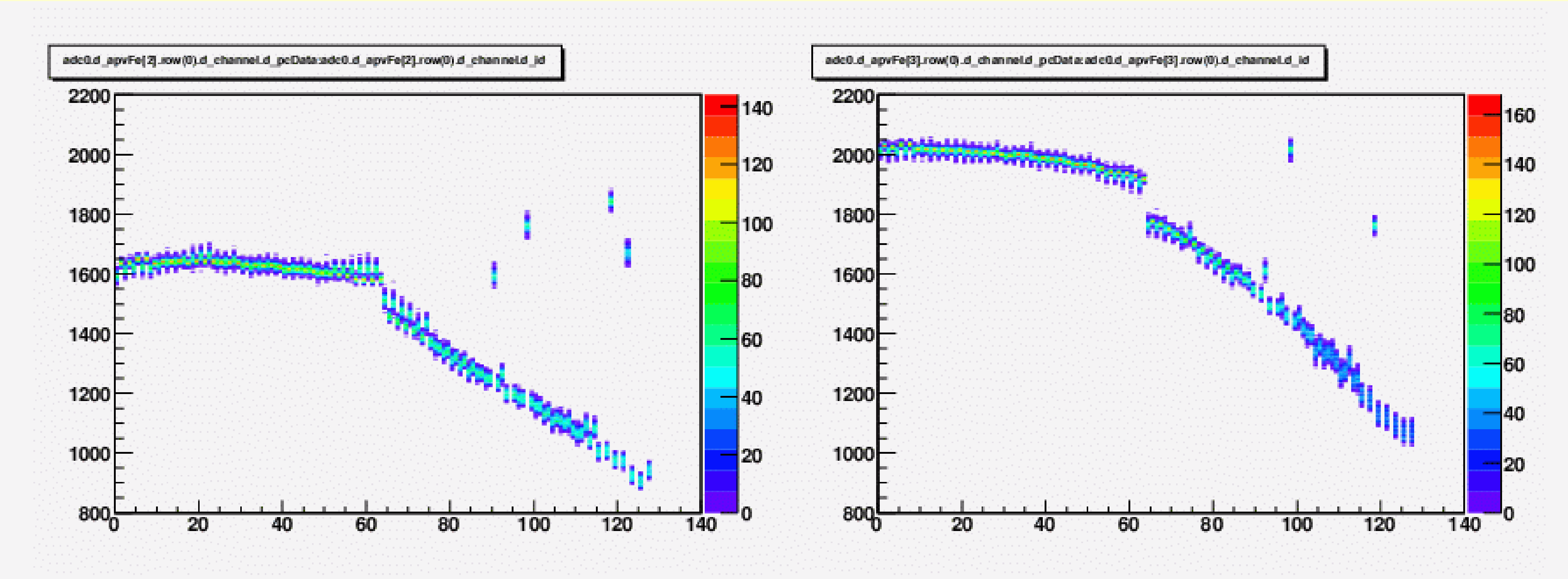


- electronics noise chip only:

  σ ~6 [ch.] (300e$^-$)
- electronics noise with detector:

  σ ~12 [ch.] (600e$^-$)
- Base line correction needed

Large Signals2



- Baseline drop partially compensated by :
  - capacitors
  - diodes in supply chain

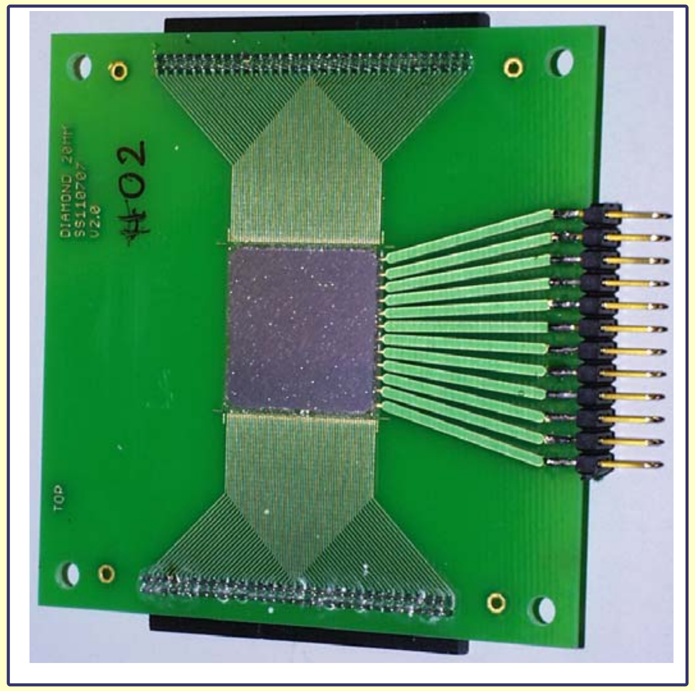
→ effect reduced by 80%

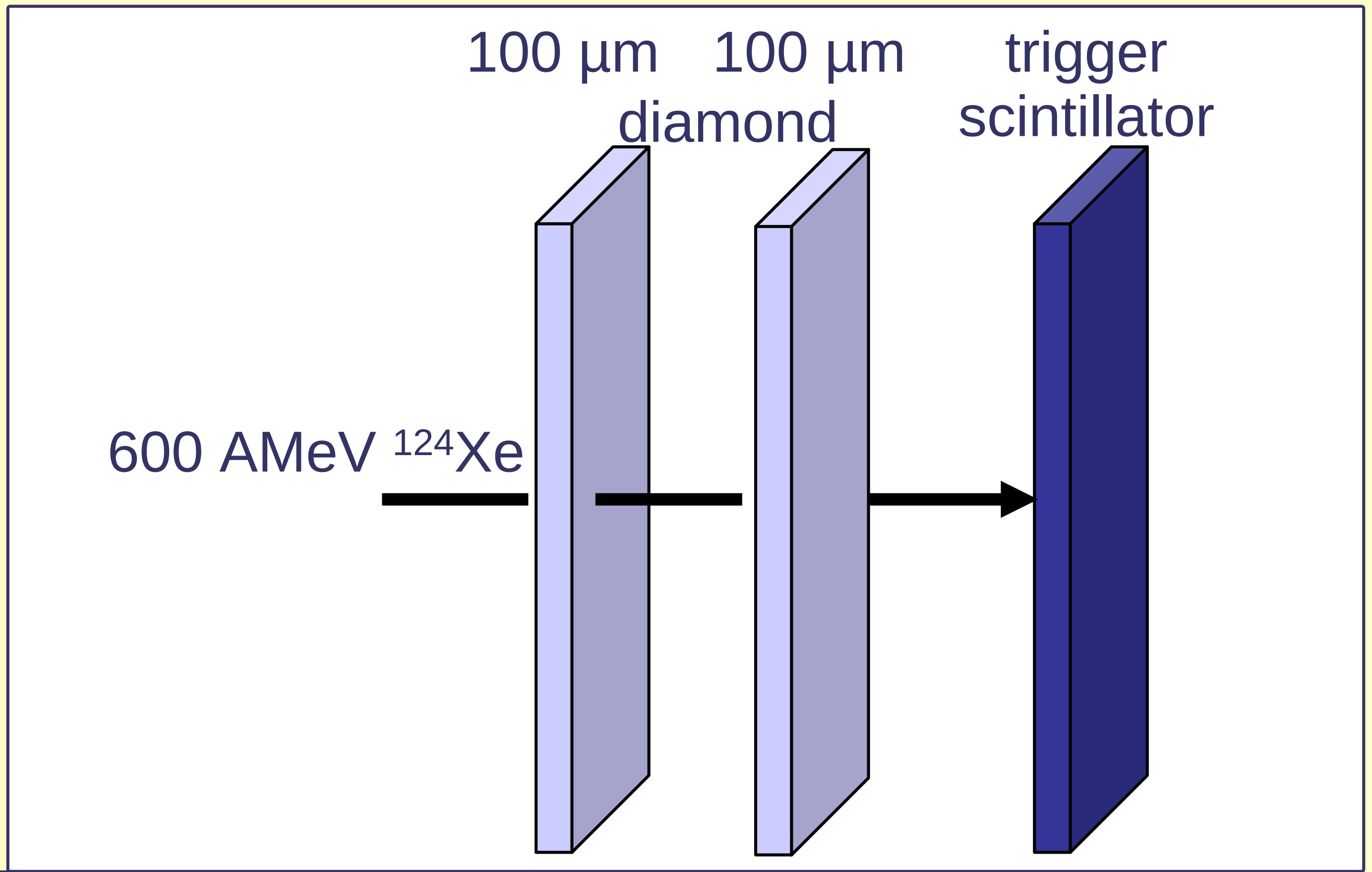
→ linearity of amplifier conserved up to 6MeV

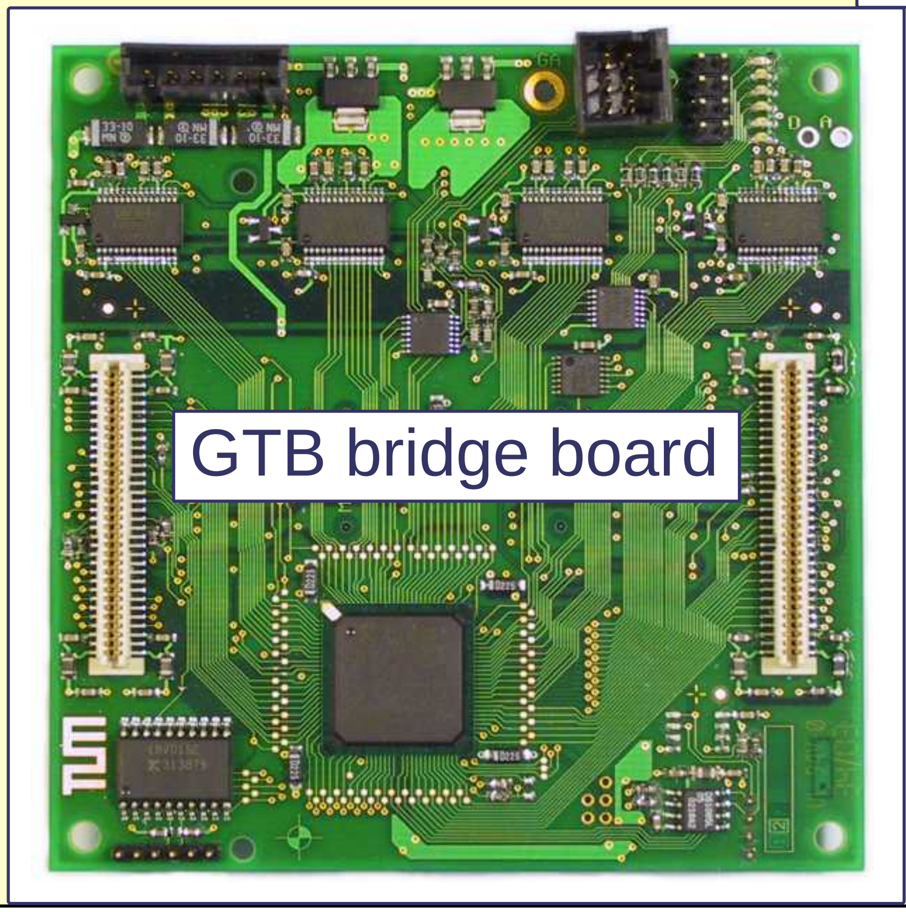
→ complex pattern of signal coupling inside the chip

Digital position information still available for single hits

Full system test @ FRS



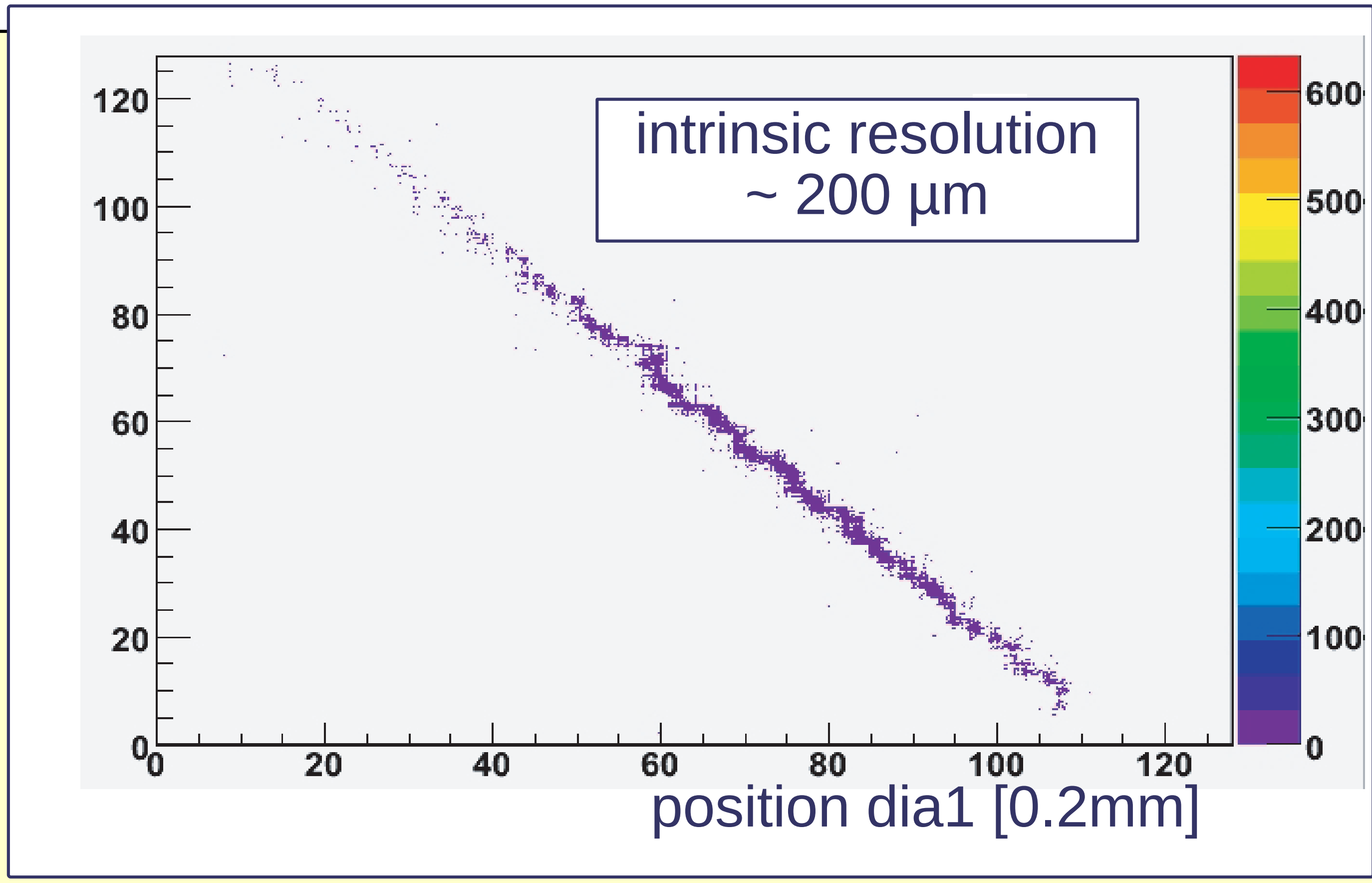


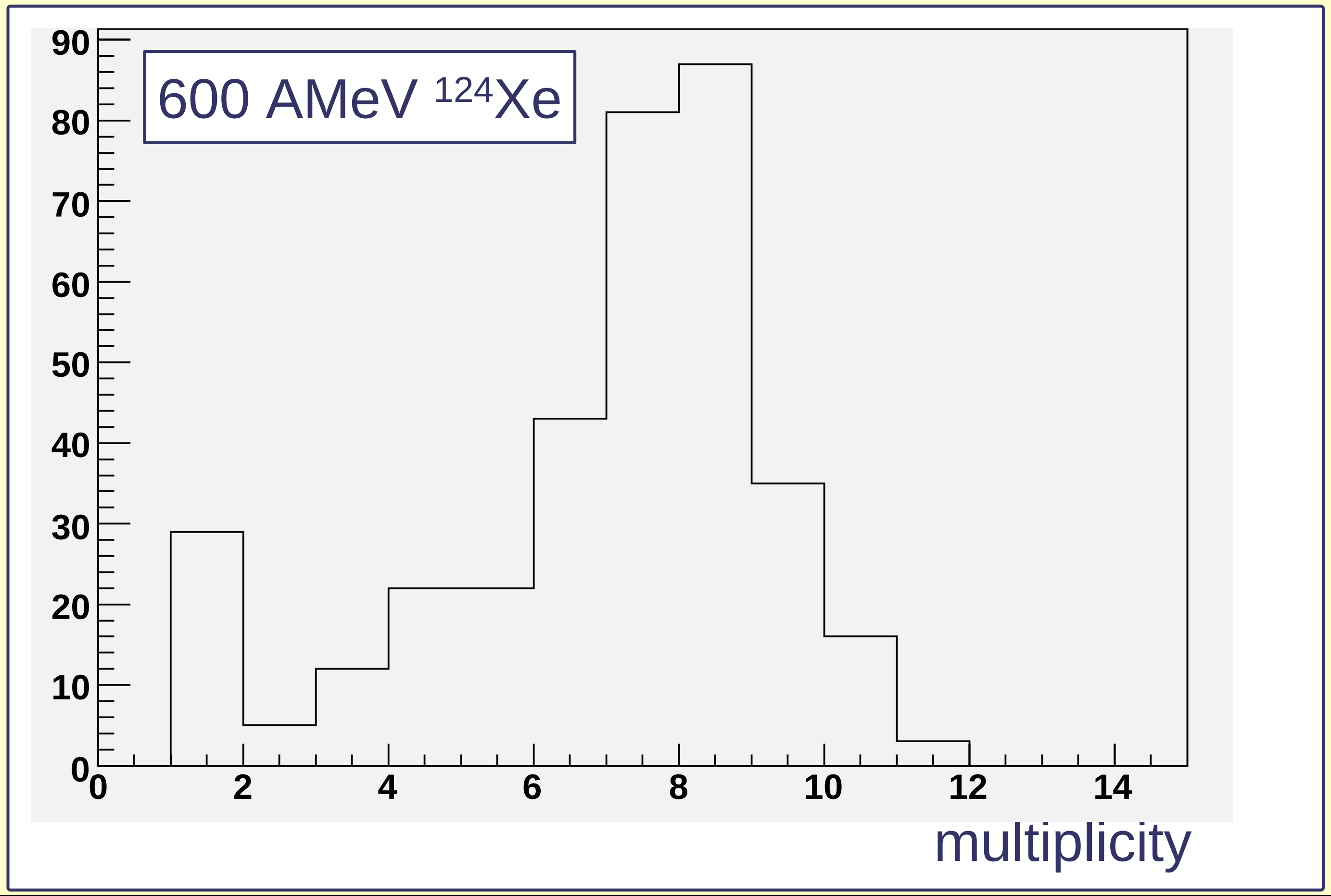


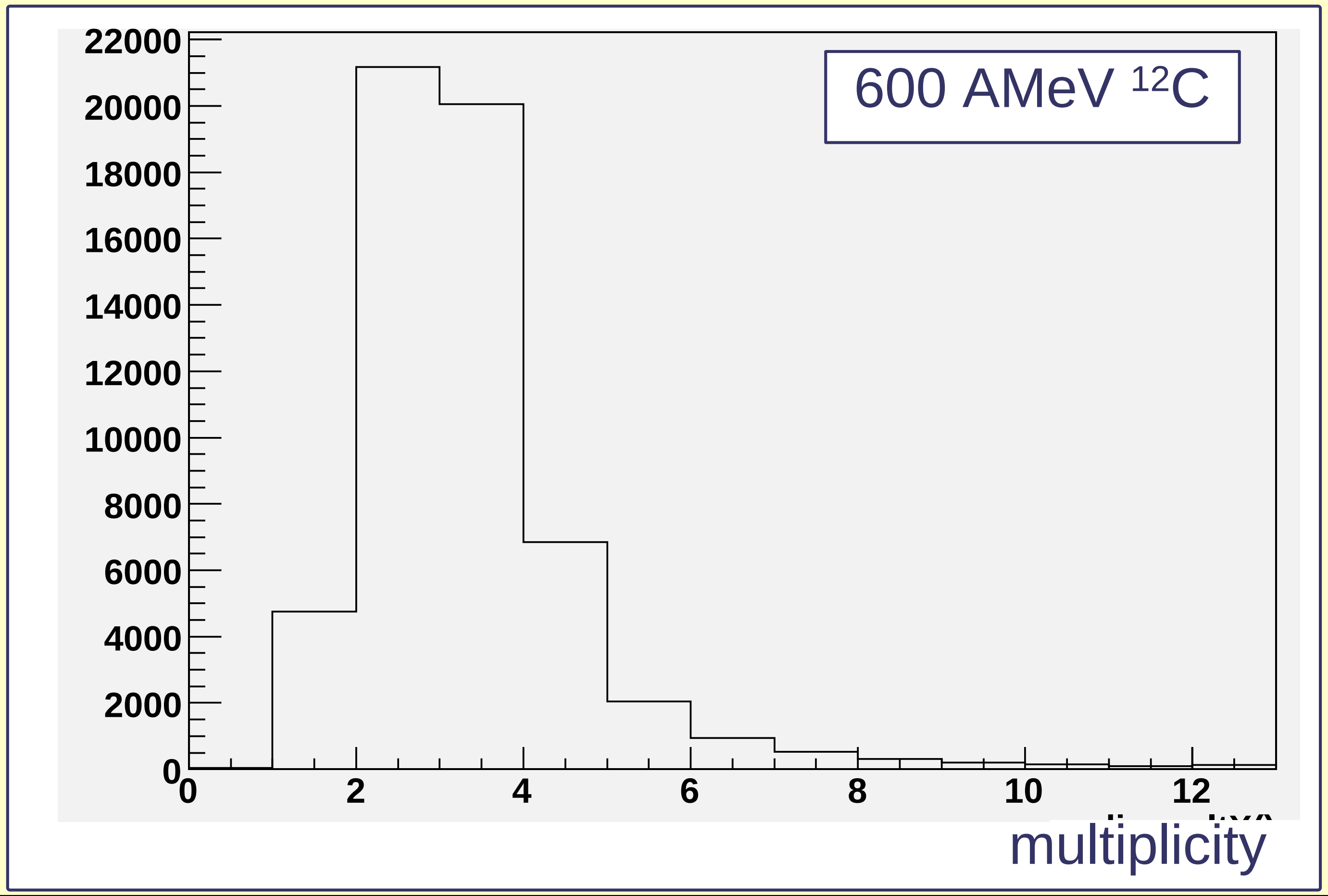
- 25.4 x 25.4 mm^2
- 128 micro strips (200 µm)
- external trigger
- large focus

Position Resolution

maximum signal off range
attenuators needed







S. Schwertel et al., GSI Scientific Report 2007 (GSI Report 2008-1) 216

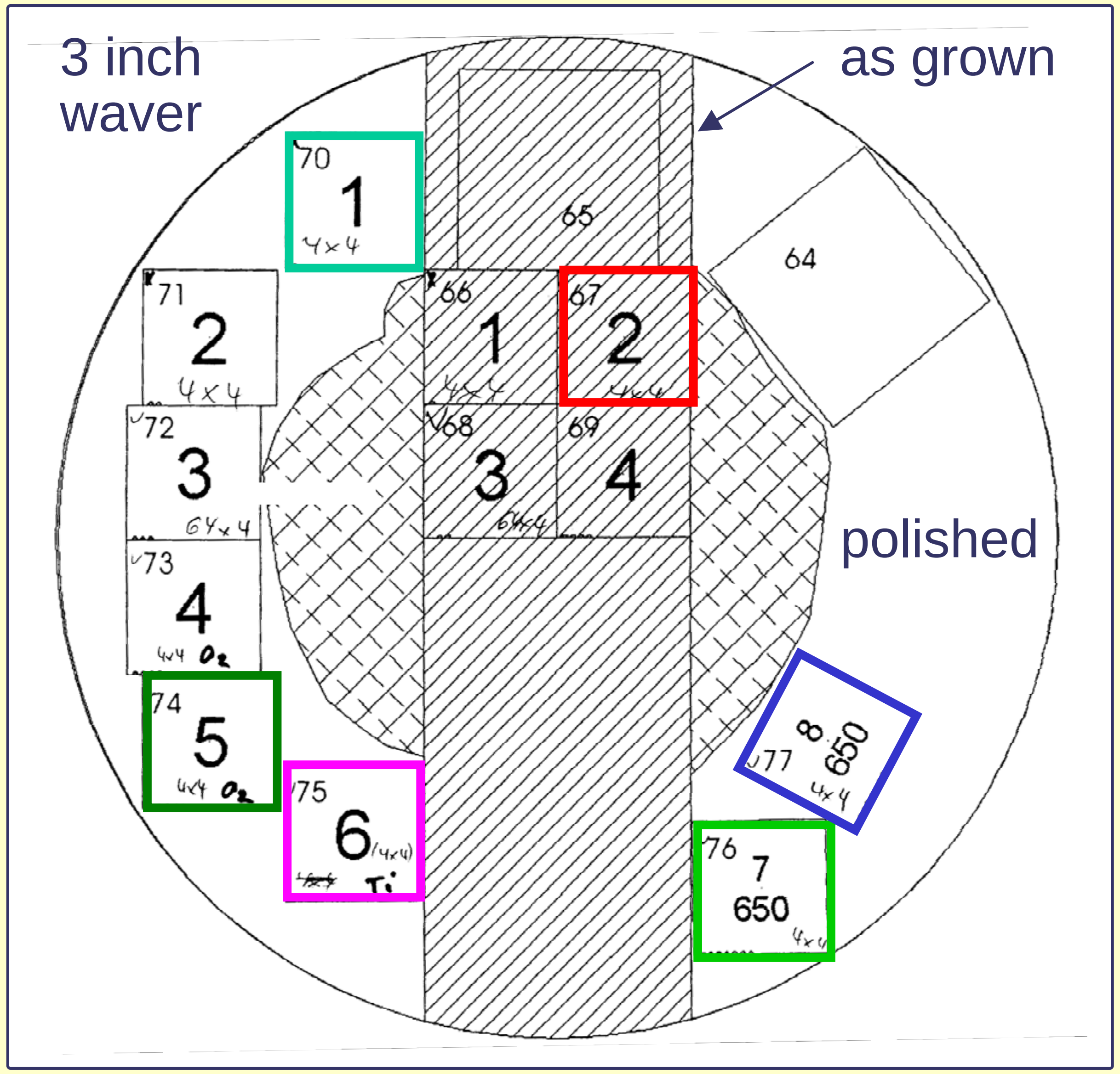
Persistent Particle Induced Currents

many samples were investigated

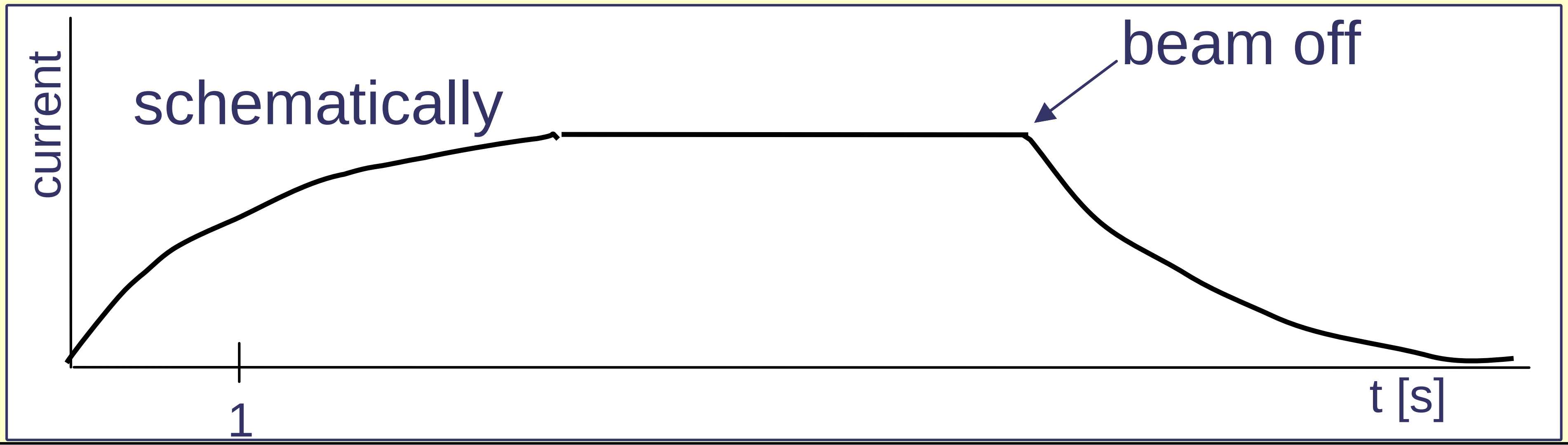
- 70 % show particle induced current
- variation with time and producer
- same production parameters

but different behaviour about 50 % yield

investigation of properties not yet finished

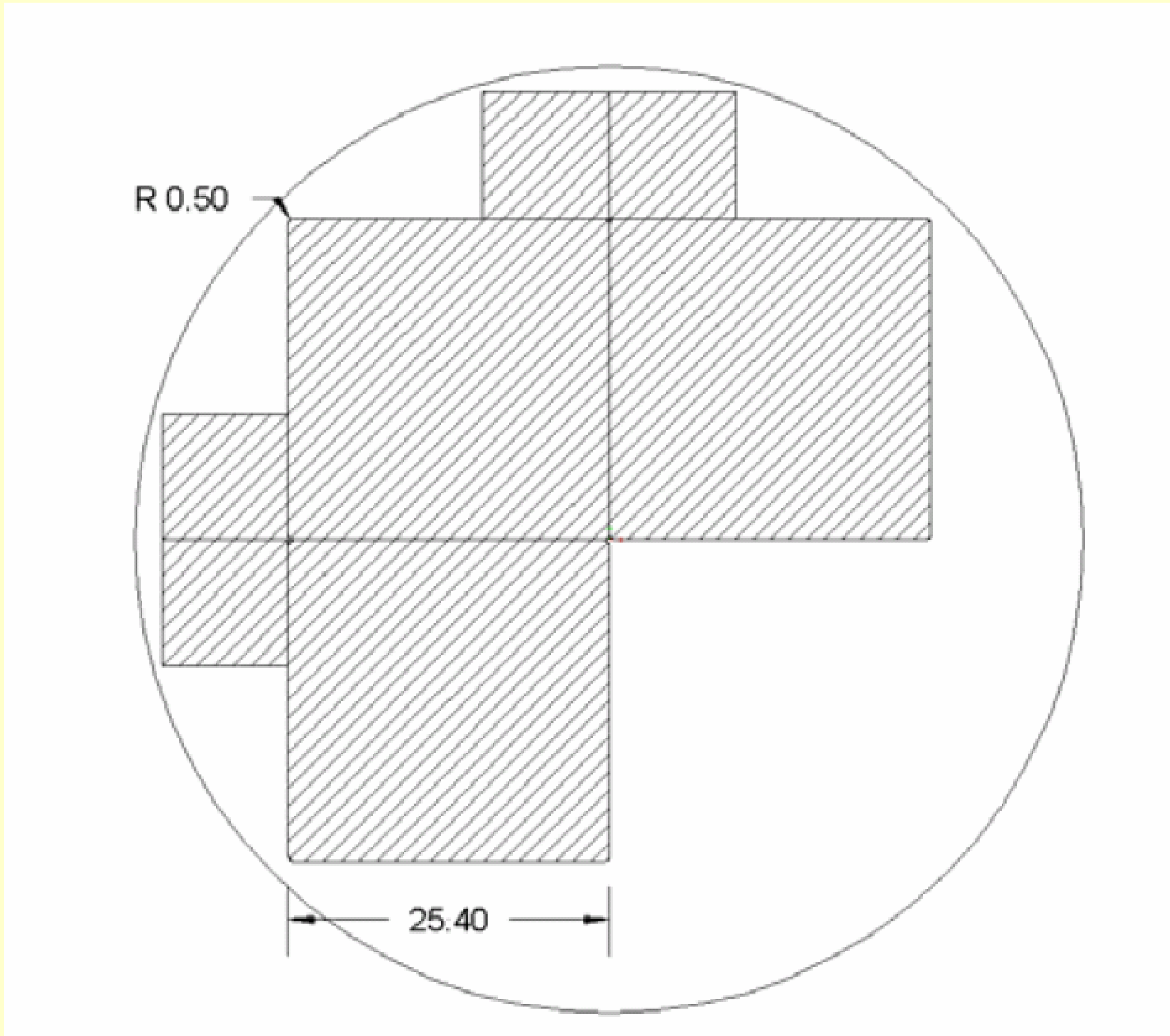


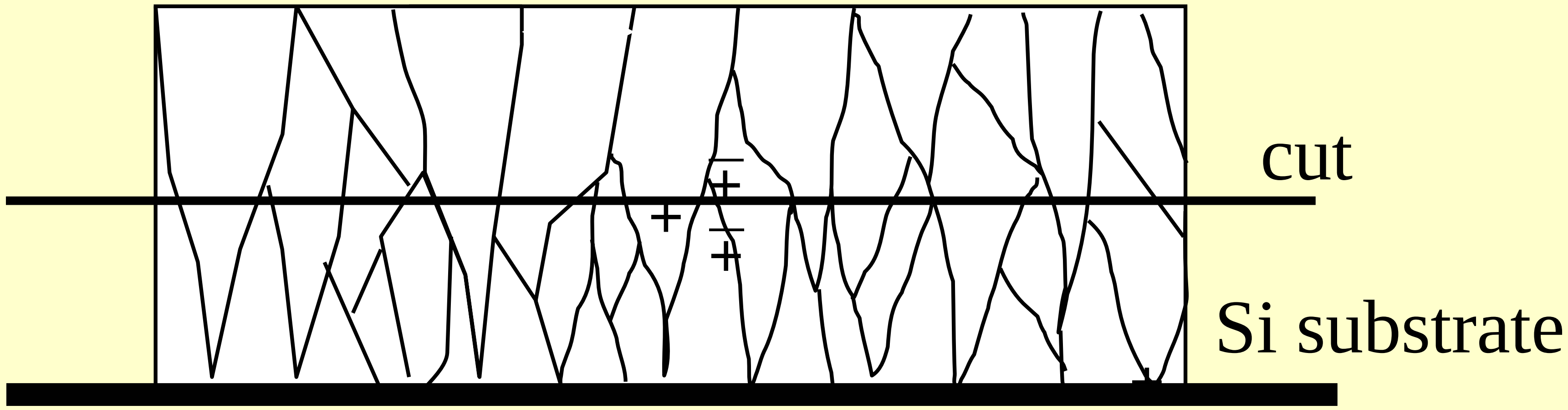
	current [nA]	
Nr.	@ 15 kHz	@ 200 kHz
67	10	420
70	80	1800
74	290	1200
75	5	230
76	35	650
77	30	400



Improved Samples

1. Diamond Detector material
2. polishing process to reduce stress
3. round shaped corners
4. metallization by sputtering (secret)
5. Additional heat treatment
(We saw much better performance
on single crystal material)

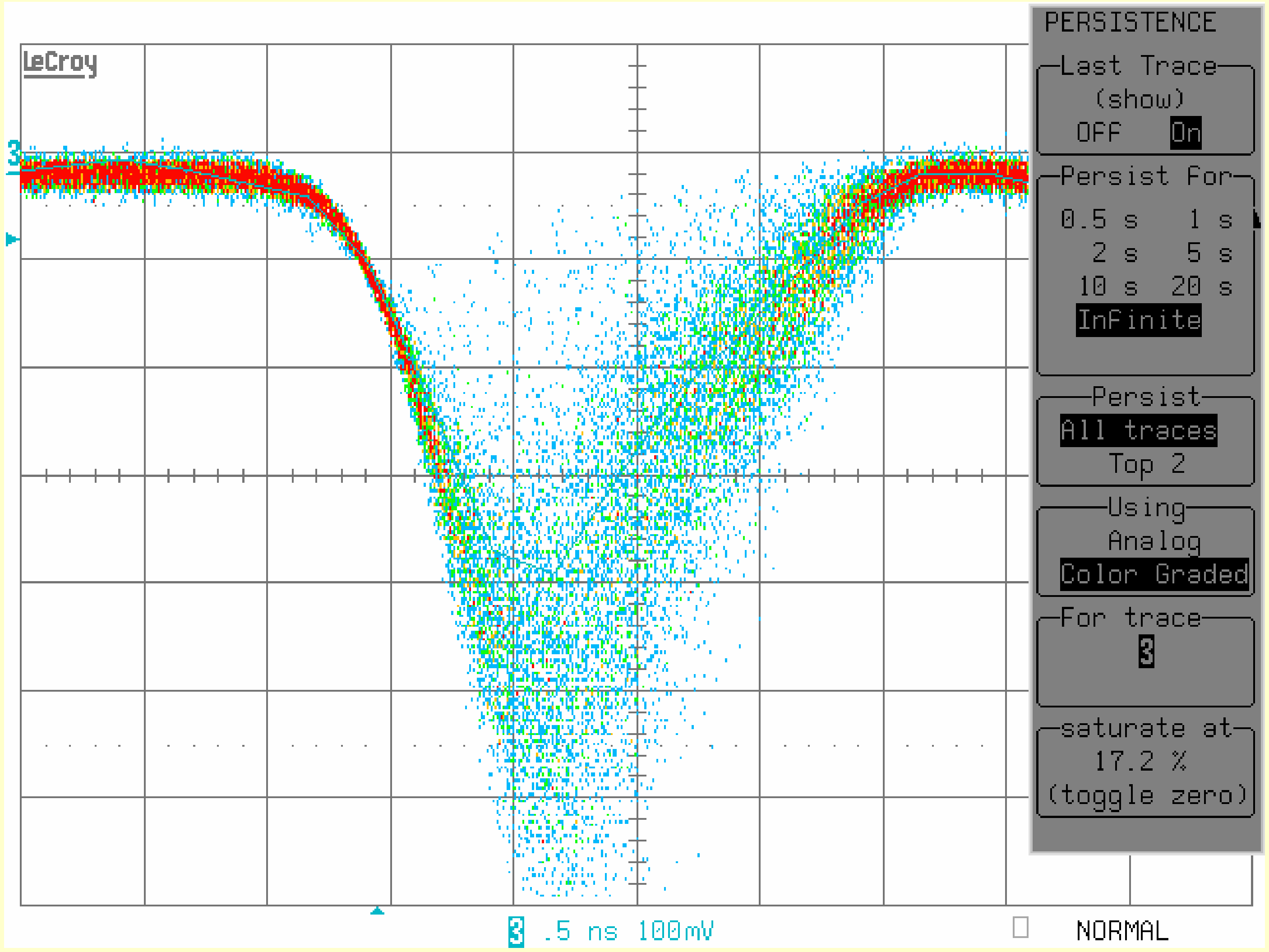




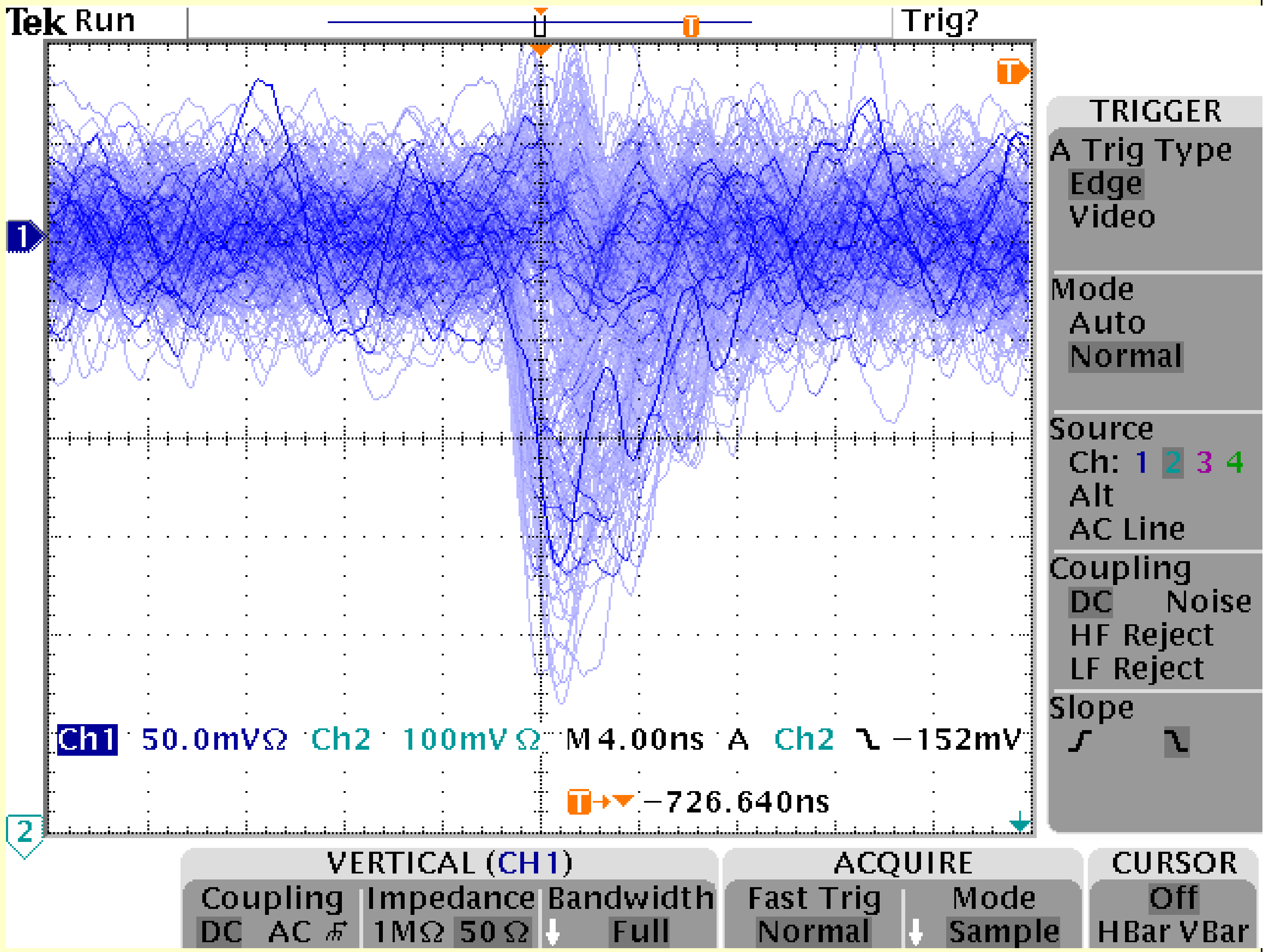
Less stress
larger grains

TOF measurement

small detector



large detector



C = 5pF
50Ω impedance on both sides

C = 50pF
APV impedance matching?

1ns Shaping

New shaping amplifier

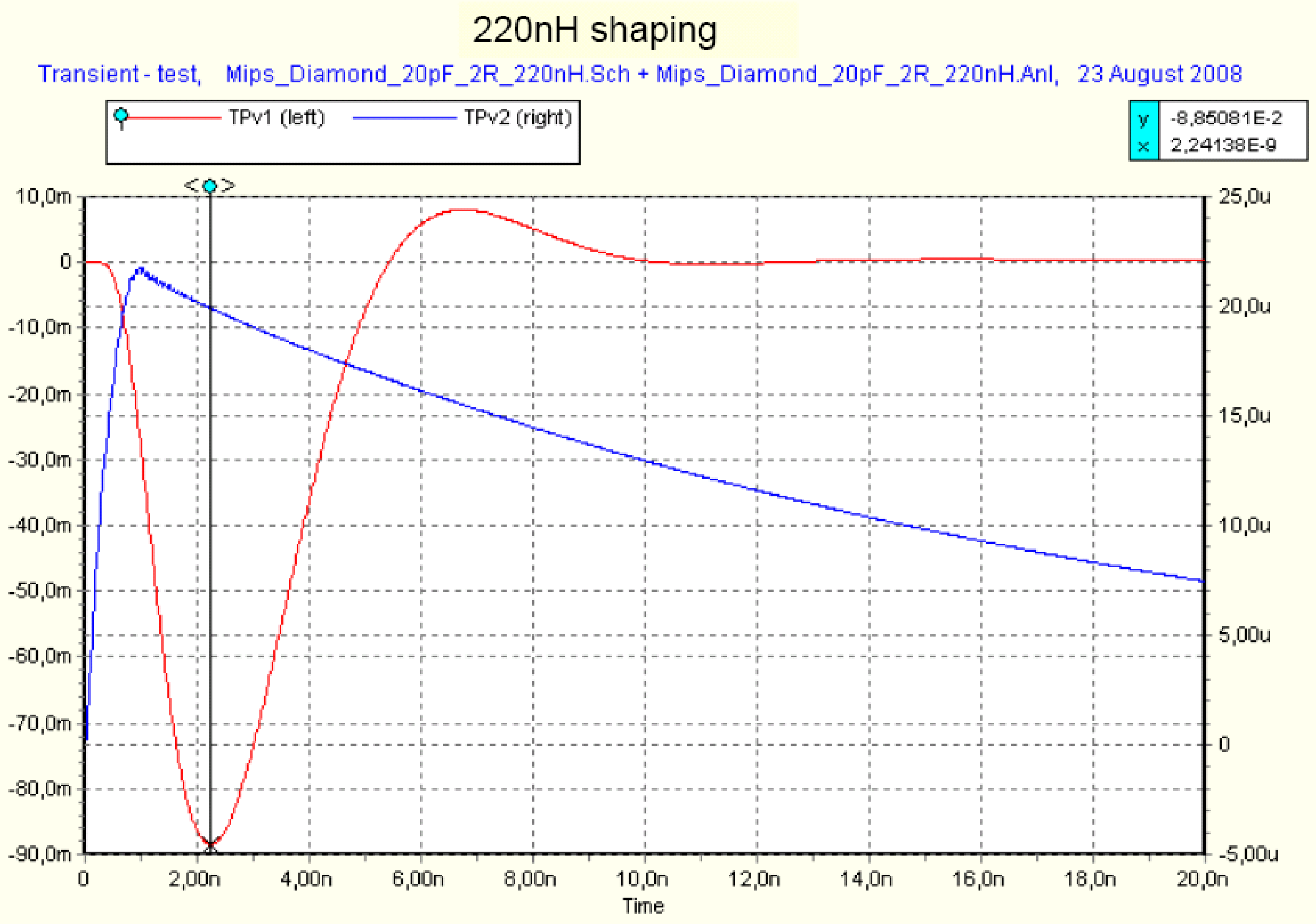
larger impedance
less noise sensitive
better adopted to APV

simple signal transport

use of standard
discriminators

GSI (W.Koenig)

Input signal (**blue**, right scale) and output signal (**red**, left scale):



Amp Type	Shaping	T_r [ns]	S / N	T_{res} [ps]	Det. Thickness
Op-Amp	22 kOhm	4.9	9.4	521,5	100u
Transistor	220 nH	1.1	41.6	26,7	100u
Transistor	120 nH	0.9	38.5	23,9	100u
Transistor	220 nH	1.0	21.4	46,7	50u

Improved Electronics

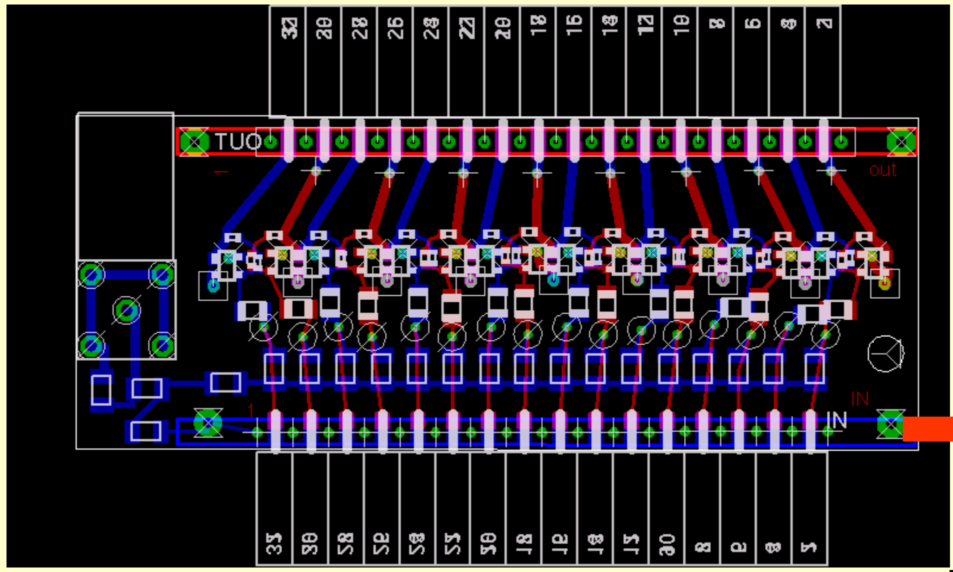
Impedance matching and Shaping

very sensitive cabeling

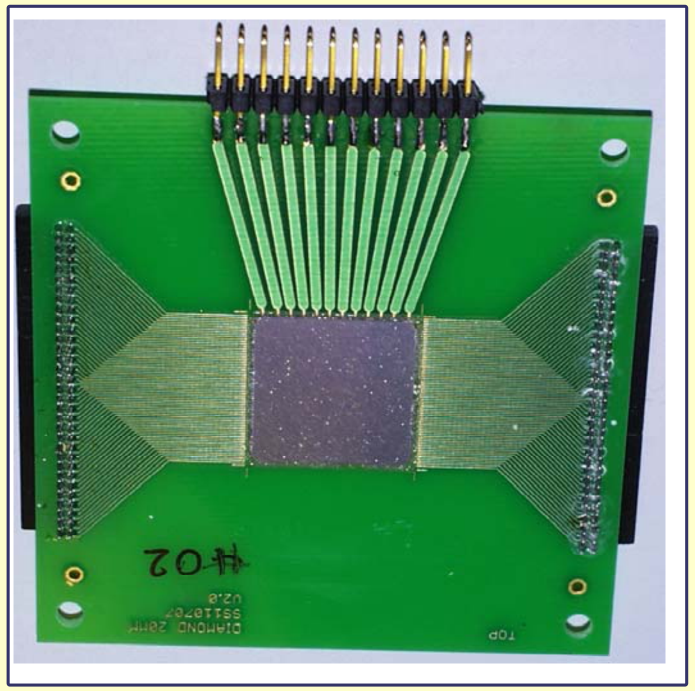
Amplifier

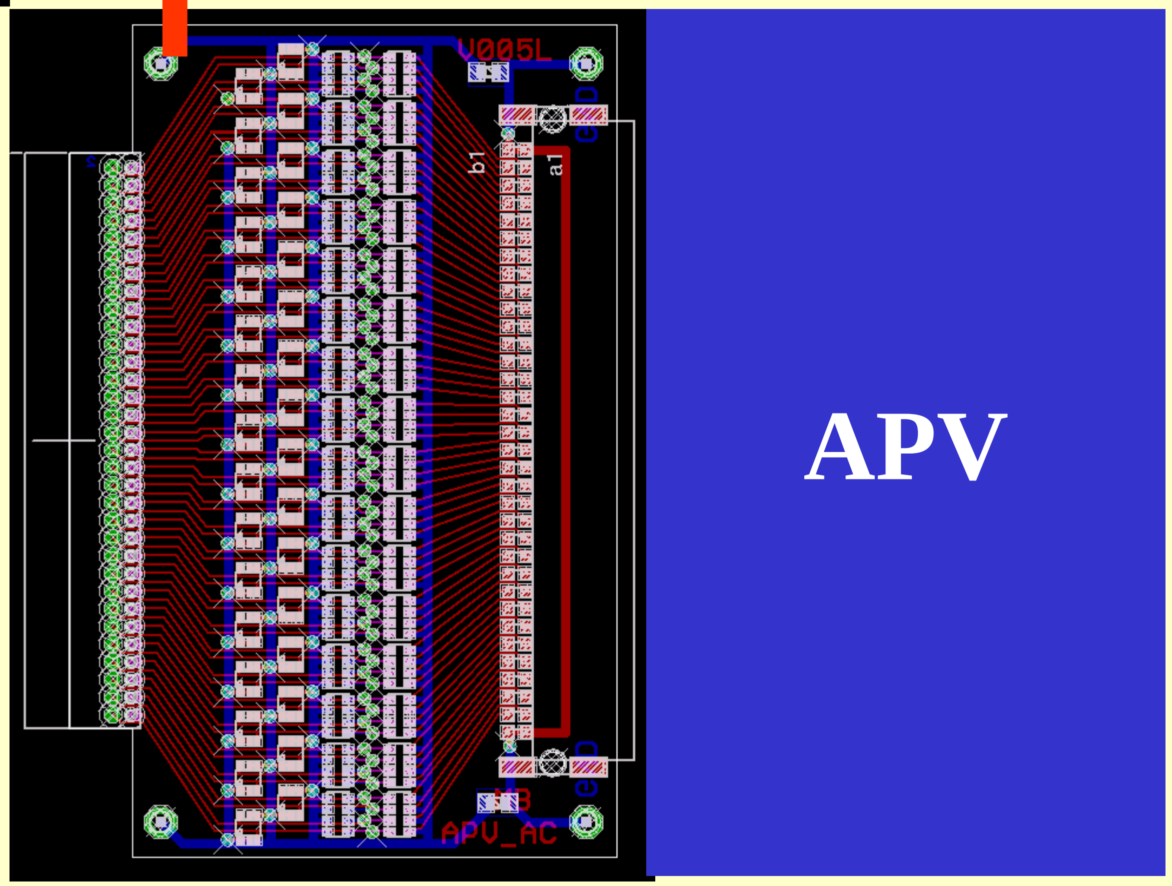
Discriminator

TOT measurement



Capacitive charge splitter





VME

TRB

Task List

Detector Production

- New material with less persistent photo current (PPC) during irradiation
- Full size detectors (just ordered)
- Application for FRS Detector (20 cm x 5 cm) (handed in)

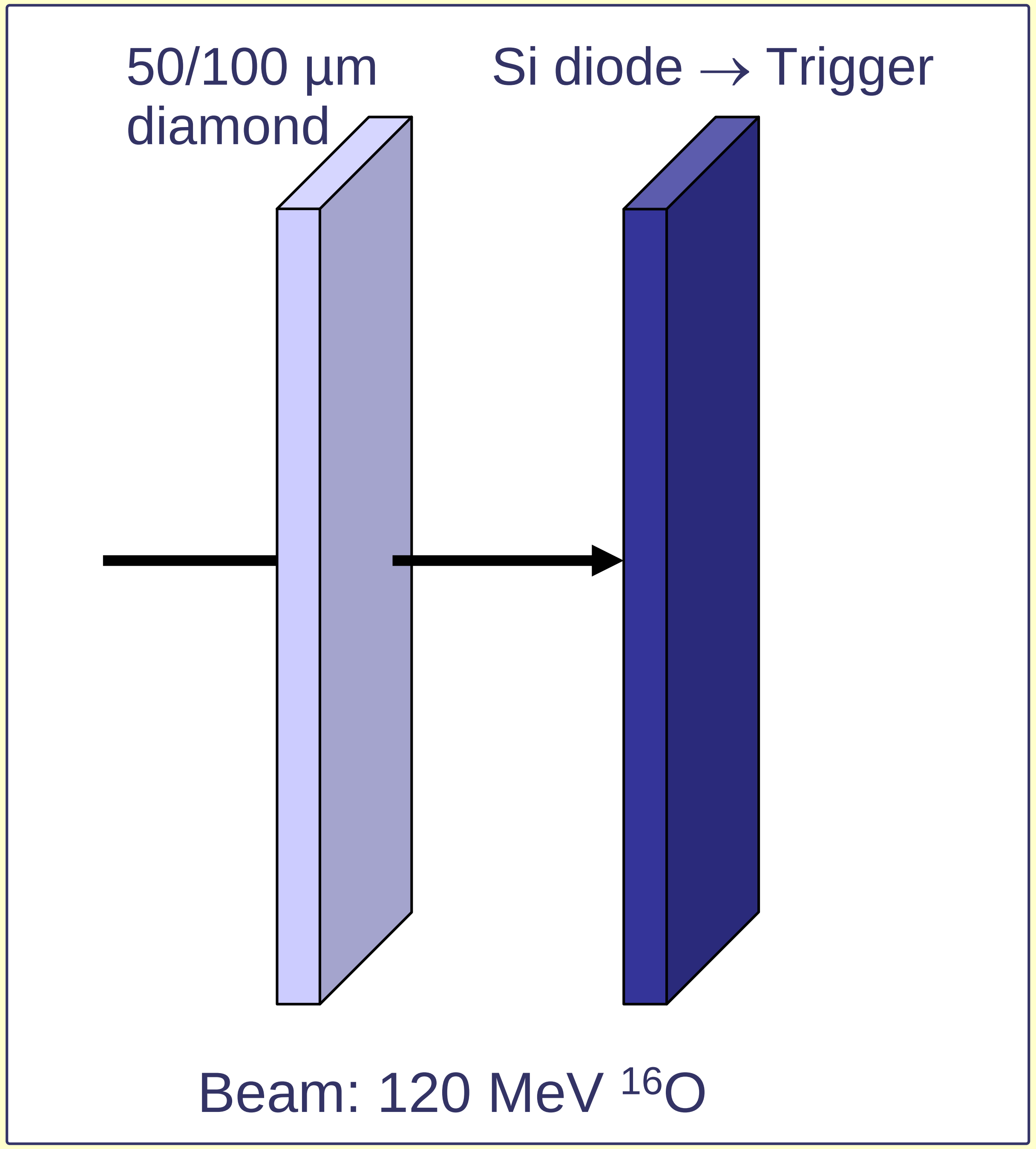
Signal Properties

- New shaping preamplifiers
- Signal splitting to fit APV range
- New discriminators

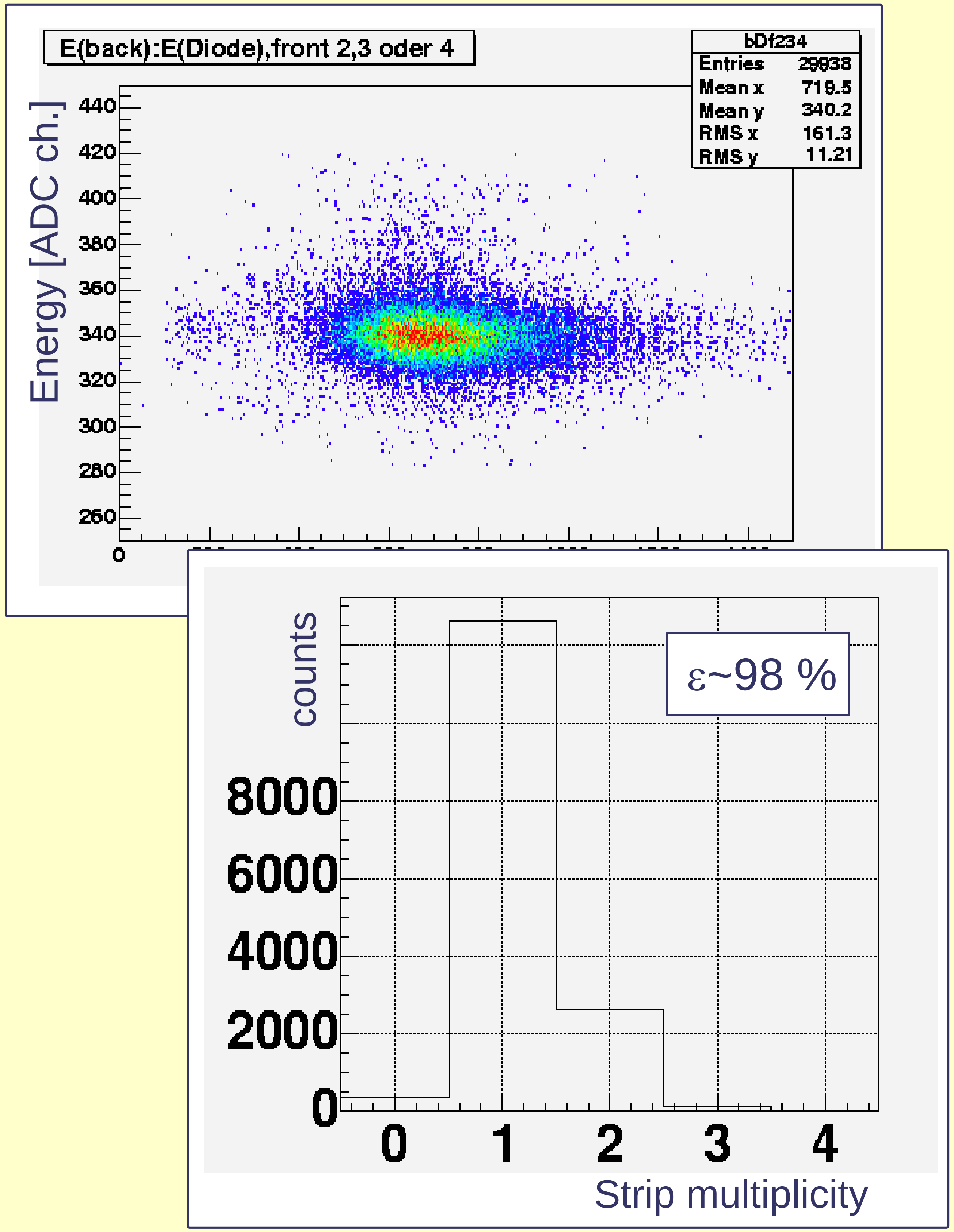
Test experiments

- 48MeV Li beam in Munich (two detectors) (June 2009)
- 1GeV beam GSI (four detectors in a row) (2009?)

Efficiency



50/100 µm diamond
Si diode → Trigger
Beam: 120 MeV ^{16}O



E(back):E(Diode),front 2,3 oder 4
bDf234
Entries 29938
Mean x 719.5
Mean y 340.2
RMS x 161.3
RMS y 11.21
Energy [ADC ch.]
440
420
400
380
360
340
320
300
280
260
0
counts
ε~98 %
8000
6000
4000
2000
0
0 1 2 3 4
Strip multiplicity