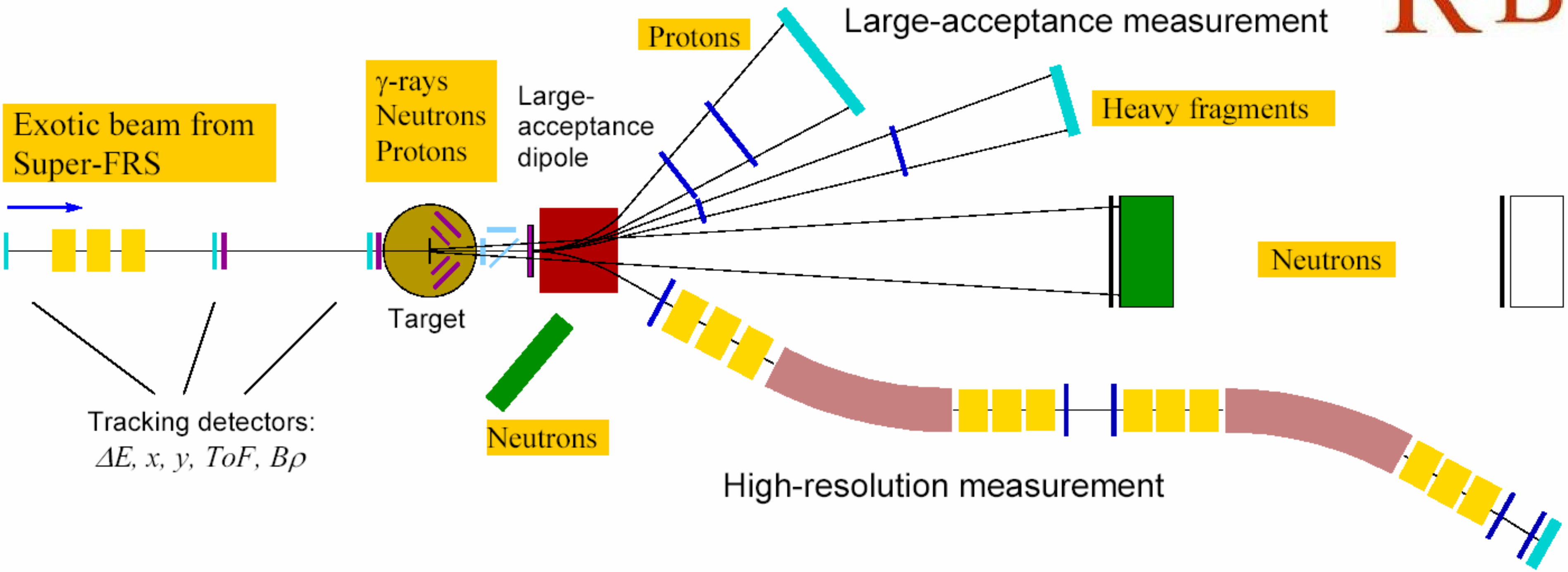
R^3B Detection systems

Reactions with Relativistic Radioactive Beams



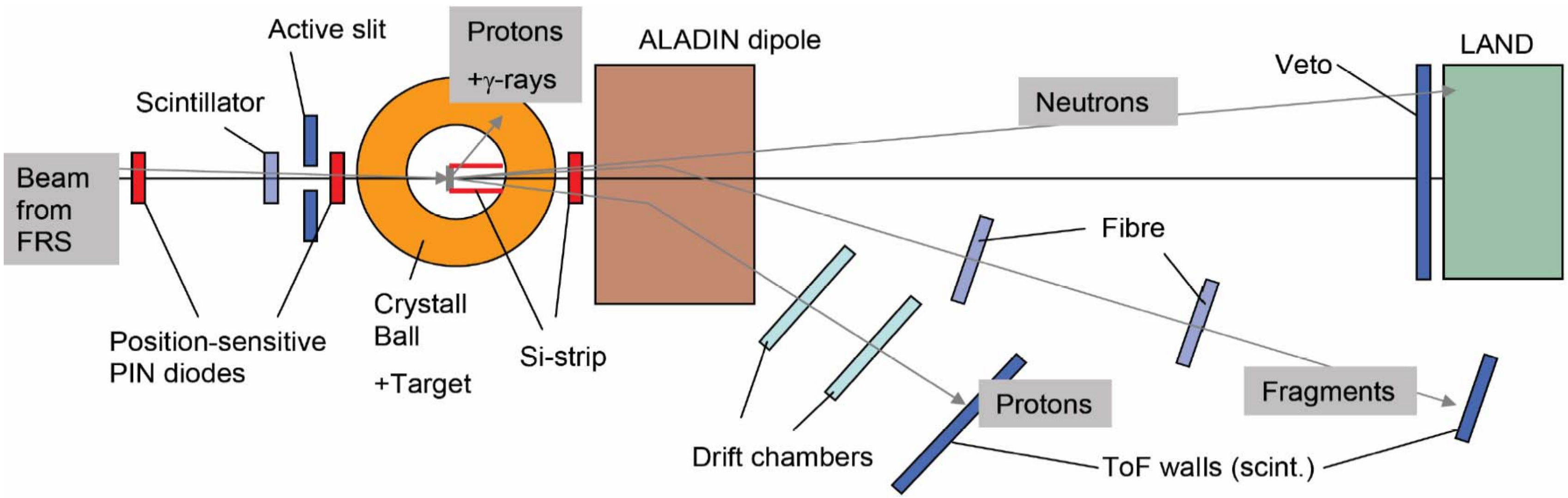
R³B experimental programme

Experiments	Physics goals
➢ elastic scattering	radii, matter distribution
➢ knockout and quasi-free scattering	single-particle occupancies, spectral functions, correlations, clusters, resonances beyond the drip lines
➢ electromagnetic excitation	single-particle occupancies, astrophysical reactions (S factor), soft coherent modes, giant resonance strength, B(E2)
➢ charge-exchange reactions	Gamov-Teller strength, spin-dipole resonance, neutron skins
➢ fission	shell structure, dynamical properties
➢ spallation	reaction mechanism, applications (waste transmutation, ...)
➢ fragmentation	γ-ray spectroscopy, isospin-dependence in multifragmentation

Experimental Technique:

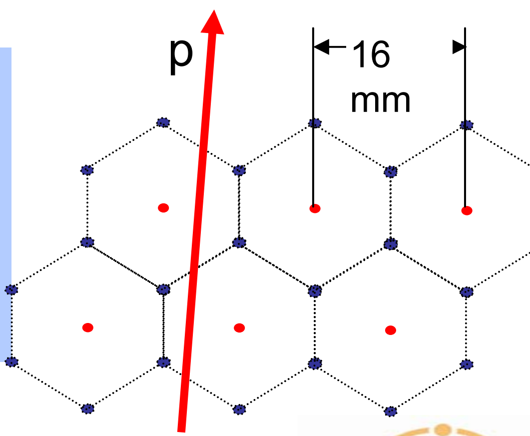
- identification and beam "cooling" (tracking and momentum measurement, $\Delta p/p \sim 10^{-4}$)
- exclusive measurement of the final state:
  - identification and momentum analysis of fragments
    (large acceptance mode: $\Delta p/p \sim 10^{-3}$, high-resolution mode: $\Delta p/p \sim 10^{-4}$)
  - coincident measurement of neutrons, protons, gamma-rays, light recoil particles
- applicable to a wide class of reactions

Prologue: Extended experimental Setup at Cave C

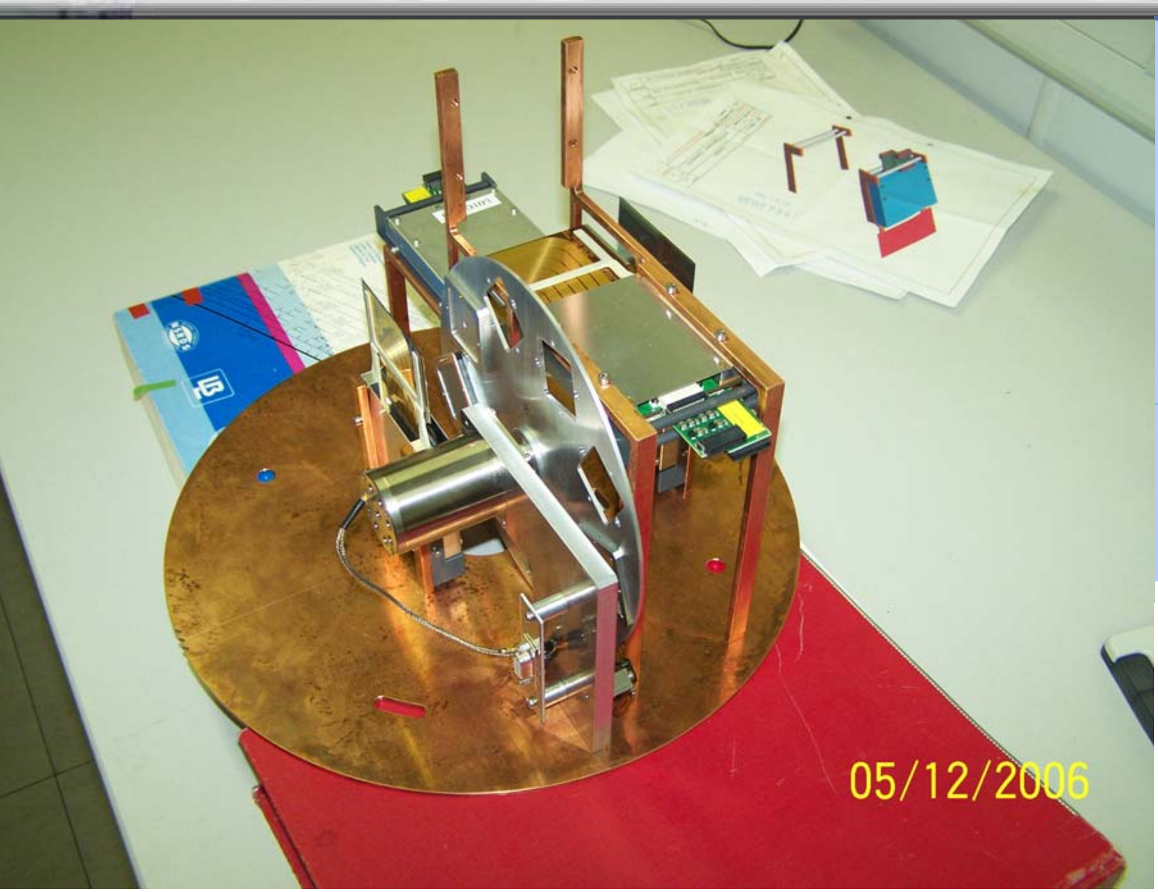


For 2007:
proton tracking around the target with Si-strip detectors

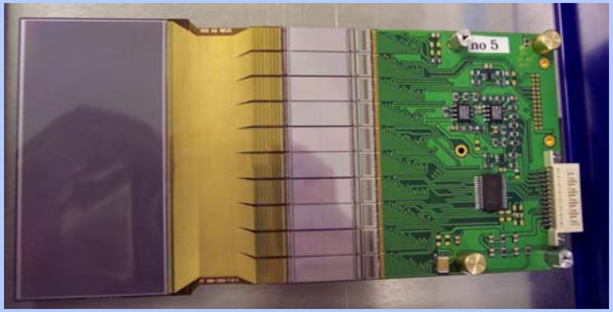
For 2007:
proton tracking behind magnet with drift chambers (100×80 cm^2)
resolution ~200 μm



Proton recoil/Ion detection in vacuum



Front of the SSD (thickness 300µm)

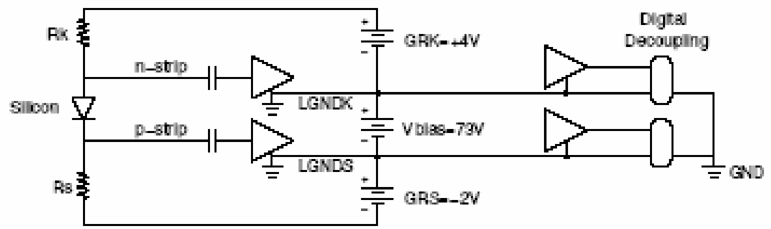


41 × 72 mm^2 , strip pitch 100µm
Dynamic range – 100 keV - 14 MeV
Resolution 50keV for 5.5MeV alphas

FEE
AMS(-02) readout:
e.g. NIM A 439 (2000) 53

6+10 read out 2*5(320) + 6(384)
VA_hdr.AMS64 resp. 9a chips
IDEAS/Norway →FEE: < 3W / detector

→SIDEREM (GSI/EE)
→NO self trigger/ calib. pulser !



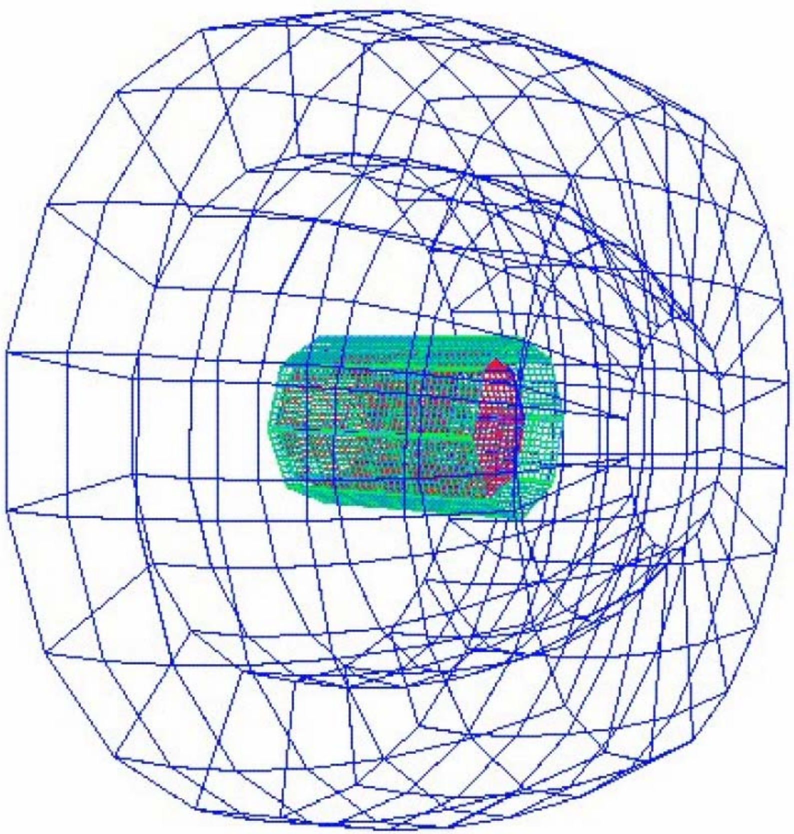
System Design Study:

- Very compact design, barrel-like,
  first layer of DSSDs
  with radius of 2.5 cm,
  thickness 100 µm, pitch 100 µm,
  energy resolution 50 keV(FWHM);

- second layer –radius 5 cm,
  thickness 300 µm, pitch size 100 µm,
  energy resolution 50 keV(FWHM)

- System in vacuum
- 90k readout channels

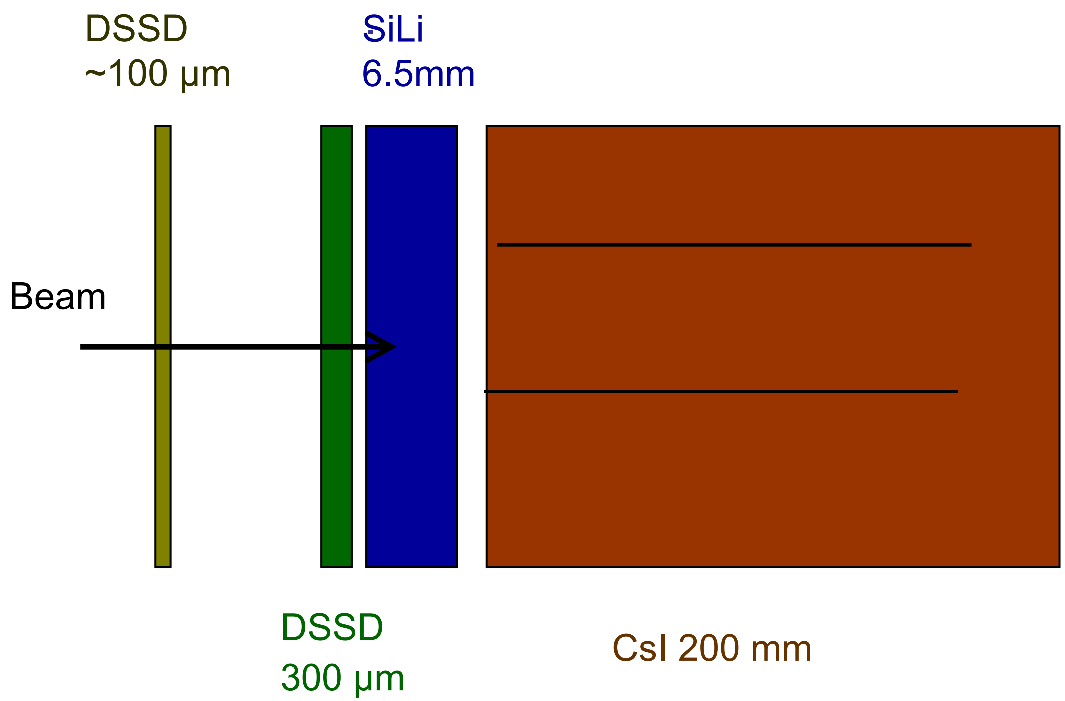
- surrounding e.g. liq. H_2 target



- Foreseen problems: alignment, calibration, monitoring

Common Demonstrator Layout

R^{3}B, EXL, others (?)



- modular
- vacuum compatible
- readout ?

(self triggerable,
test/calib. facilities,
high dyn. range,
time stamps …)

First DSSD – e.g. 2.1 x 2.1 cm^2, 0.3/1.25 mm pitch (PTI, EXL) or 0.1/0.1 mm pitch R^{3}B
Second DSSD – e.g 5.2 x 6.7 cm^2, 0.1/0.2 mm pitch (Micron, EXL) or 0.1/0.1 mm pitch R^{3}B
Si(Li) or Si – e.g. 9 x 5 cm^2, 4 x 2 pads ---- EXL
CsI – e.g. volume 3 x 3 cm^2 x 20 cm

Purpose of the R³B/EXL Demonstrators – Topics to be Investigated and Questions to be Solved

- Detection of MIP`s with thin DSSD`s
- Tracking with high resolution
- Performance of CsI in combination with Si detectors
- Energy and position resolution for protons, alphas for various energies
- Performance of DSSD`s with larger pitch size (from 0.3-1.5 mm)
- Very low threshold detection
- PSA
- Combination of DSSD`s with Si(Li)`s
- Vacuum compatibility
- Heat production
- Feedthroughs
- Noise Analysis
- Evaluation of realistic background conditions
- Definition of demands for the final ASIC design

Possible Design of the Demonstrators

- frames and readout boards:

  should be common for EXL- and R³B demonstrators

  should be made from ceramics

  potential producers are PTI, Mesytech, Uppsala, India

  the design of MUST could be a basis

  responsible for design and construction: O. Kiselev, H. Simon

- readout:

  number of readout channels: around 1000, frontend in (high) vacuum

  (for EXL: bakeable to at least 150 ºC see CHICSI setup)

  trigger: external trigger → self triggerable

  dynamic range: 150 keV – 5 MeV (in Si(Li) up to 100 MeV)

  data rate: 1-10 kHz

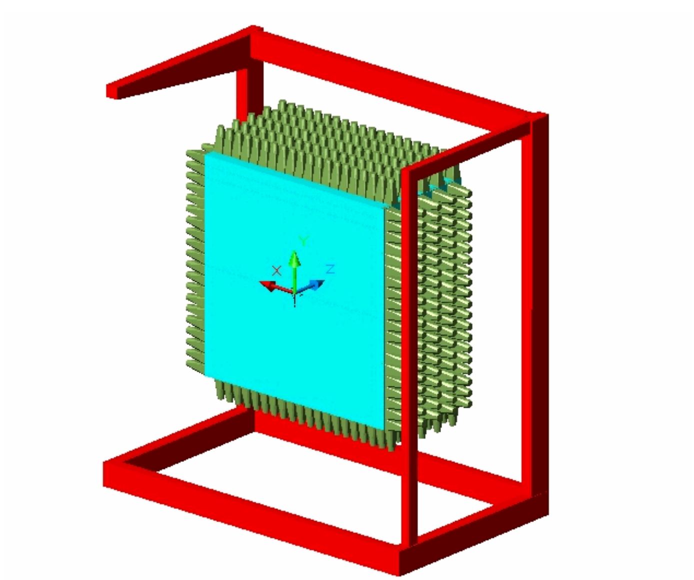
  options: Jülich, Daresbury, AMS, GSI nXYTER

  responsible for readout: R. Lemmon, O. Tengblad, P. Golubev

Specialized Frontends:
(i) RPCs → Tacquila, Hades, CBM, … for MIPs

Existing LAND detector:
- σ_t < 250 ps
- $\sigma_{x,y,z} \approx$ 3 cm
- Size: 2 x 2 x 1 m^3
- Plastic scintillator / Fe converter sandwich structure

Th. Blaich *et al*., NIM A **314** (1992), 136



NeuLAND design goals:
- σ_t < 100 ps
- $\sigma_{x,y,z} \approx$ 1 cm
- Size : approx. 2 x 2 x 0.8 m^3
- Efficiency > 90% for 1-n hits
- Improvement of multi-n recognition

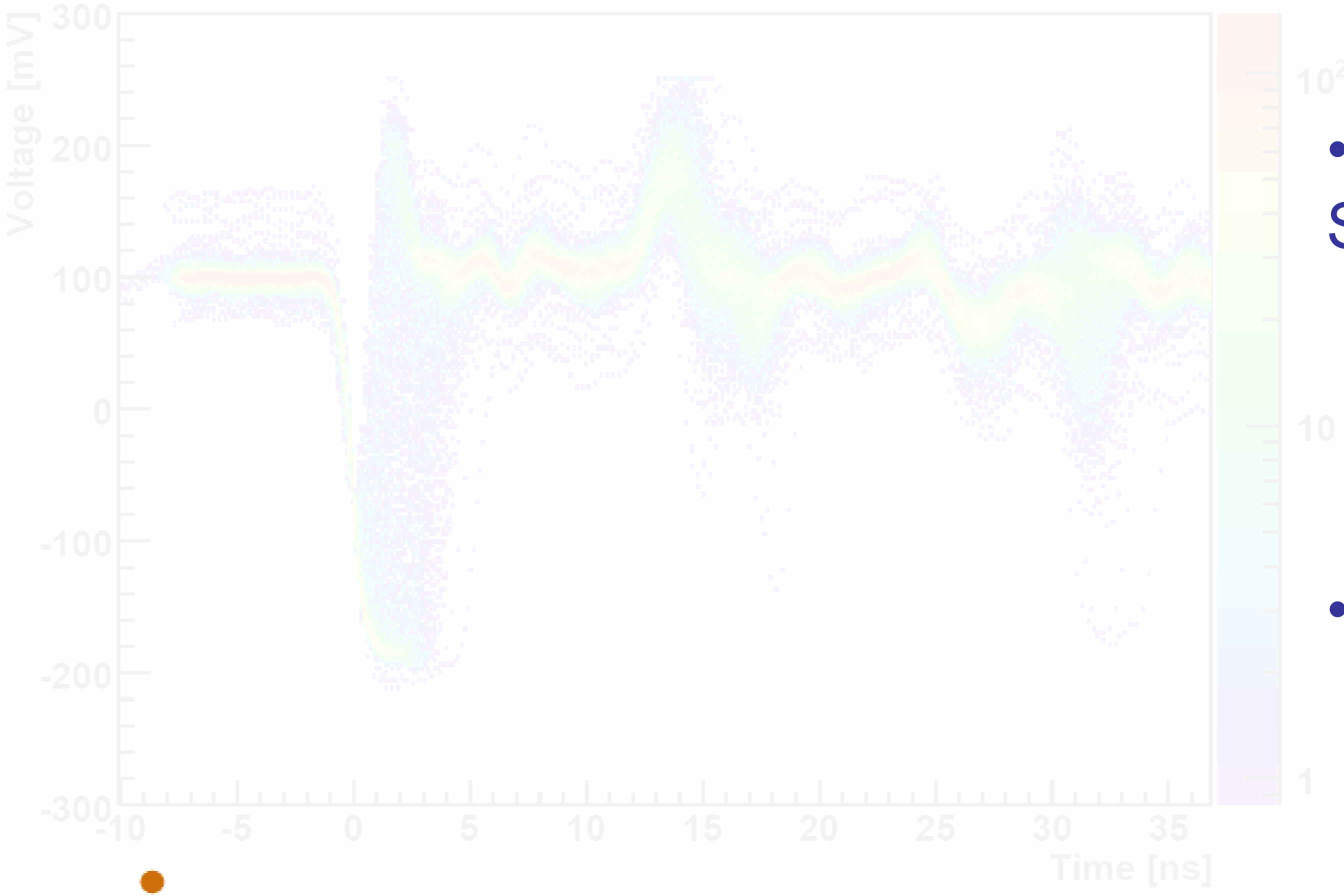
Timing RPC concept:
- Total of 140 m^2 RPC
- Approx. 10'000 channels
- Converter material: integrated in RPC structure

Compared to existing RPC types:
- Low count rates (< 1 Hz/cm^2)
- Massive detector for higher efficiency
- Particles at various energies (non-MIPs)

Signal Processing !

- RPC impedance matching, protons at various energies

- Messy signal structure Dedicated analog FEE



- Digization & Signal Processing on-line

vs.

- Offline/Near line energy -- time correlations

Beam Tracking:
Diamond Detectors

- current readout for single crystal (a few mm^2)
- cheaper polycrystaline diamonds (a few cm^2)
- very good homogenity and radiation hardness
- price from a few 100 €/cm^2 to 1000 €/cm^2

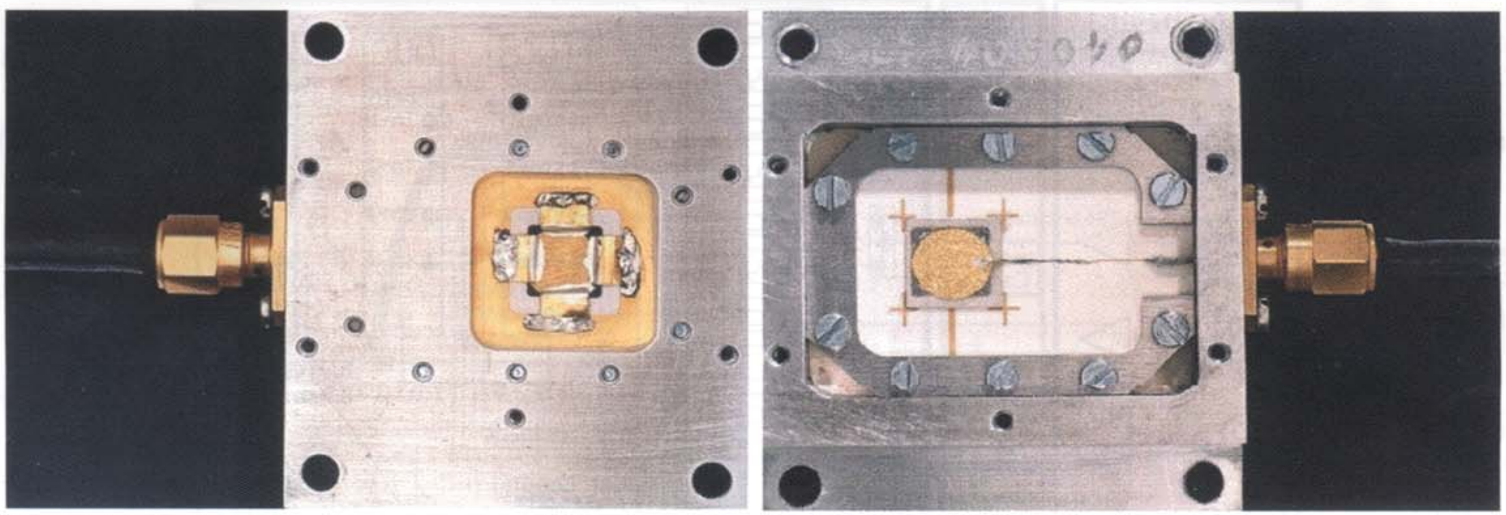
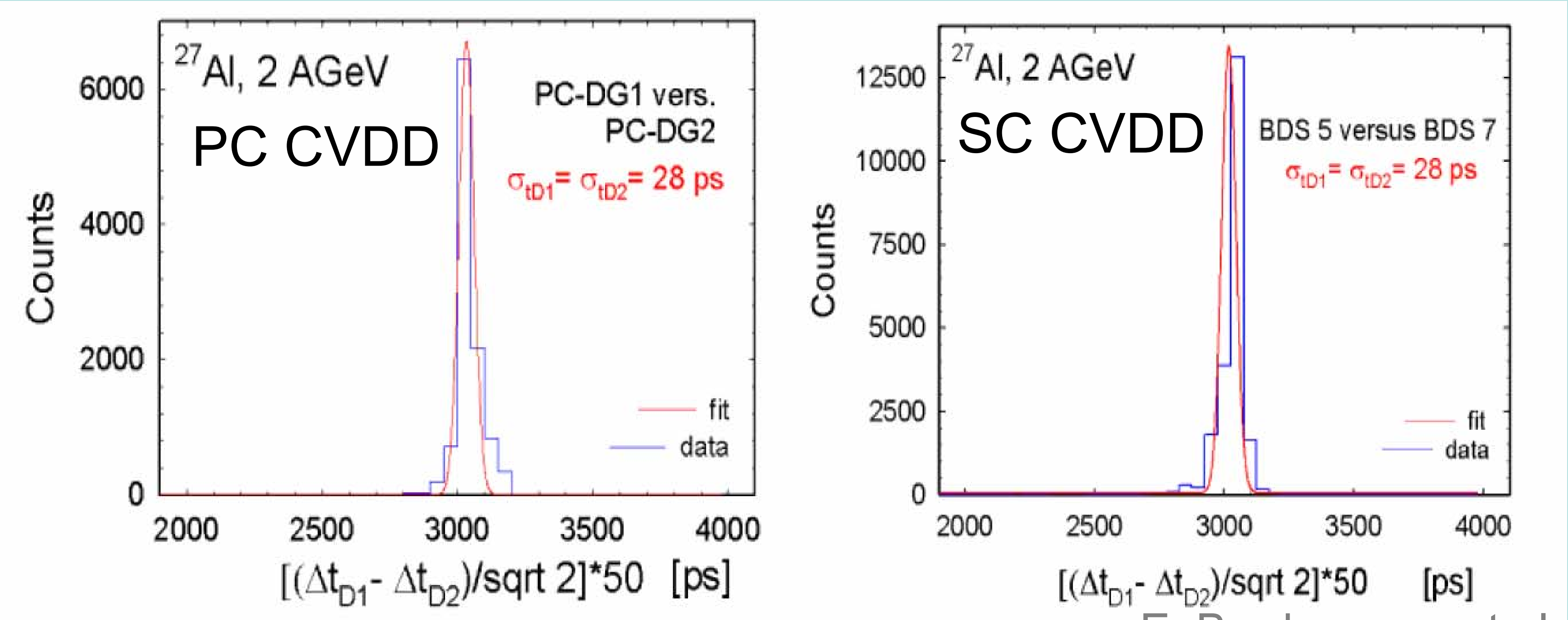


Fig. 1. Each single-channel of a CVD-diamond HI detector is connected via a 50-Ω microstrip line to the amplifier. The fully metallized backside of the ceramic pcb at ground potential is connected to the nucleation side (left) and the growth side (right) to an r.f. suitable coaxial connector (SMA).

Diamond Detectors (Strip detectors)

TOF, position



E. Berdermann et al.

- good timing (eg. R^3B req. σ_t~50ps)
- Further studies with slow(er) heavy ions
- R&D: detector geometry strips or pxl / readout electronics

Specialized Frontends
(ii) APV Frontend -- 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, …)

- I²C control
- Clck, Trg
- Low power consumption
- Readout board (ADC + control) under devel.

Summary

- Demonstrators for DSSD, Si(Li), CsI systems seem to be common for many experiments → SGFD
- Specialized Frontends exist partially but full system design is overdue
- Digital signal processing
- Diamond detector (tracking and TOF) solutions become available
  - via external sources → applicability for Nucl. Struct. ?