TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät für Mathematik und Naturwissenschaften, Institut für Kern- und Teilchenphysik, Abteilung Kernphysik

A 2m x 0.5m prototype of a MRPC-based neutron detector with steel converter plates

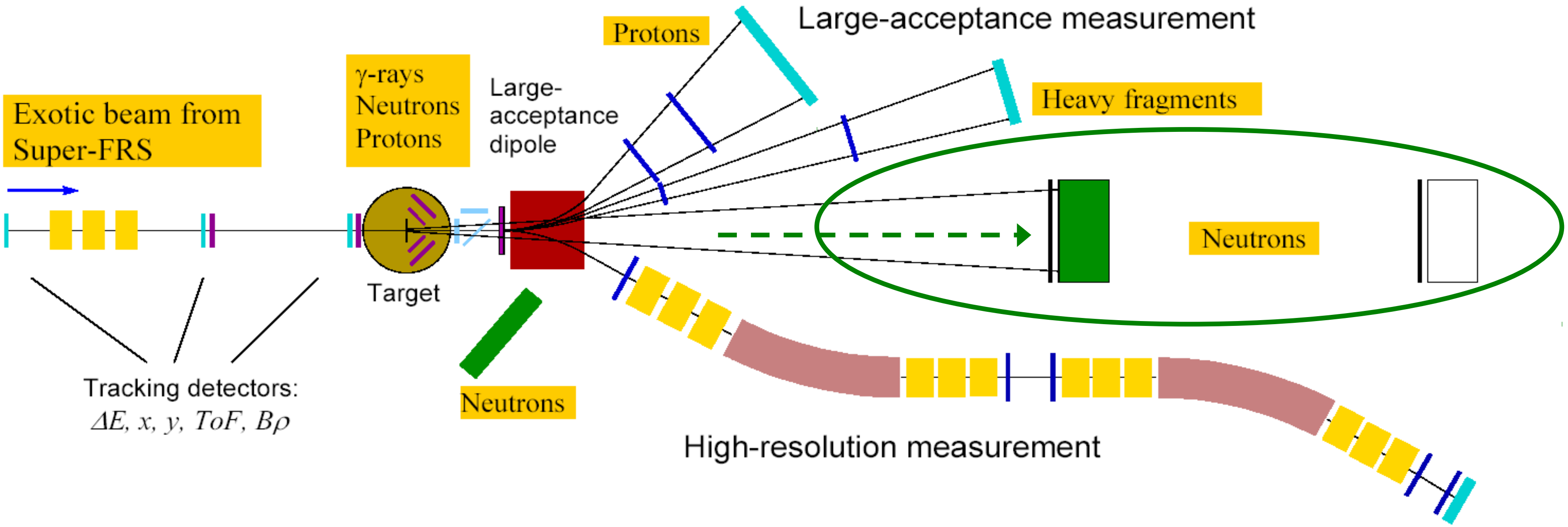
Marko Röder (TU Dresden, Helmholtz-Zentrum Dresden-Rossendorf)
for the R3B Collaboration

HZDR

HELMHOLTZ
ZENTRUM DRESDEN
ROSSENDORF

Frascati, 10th February 2012

R3B Experiment at FAIR



originally one option for the NeuLAND-Detector

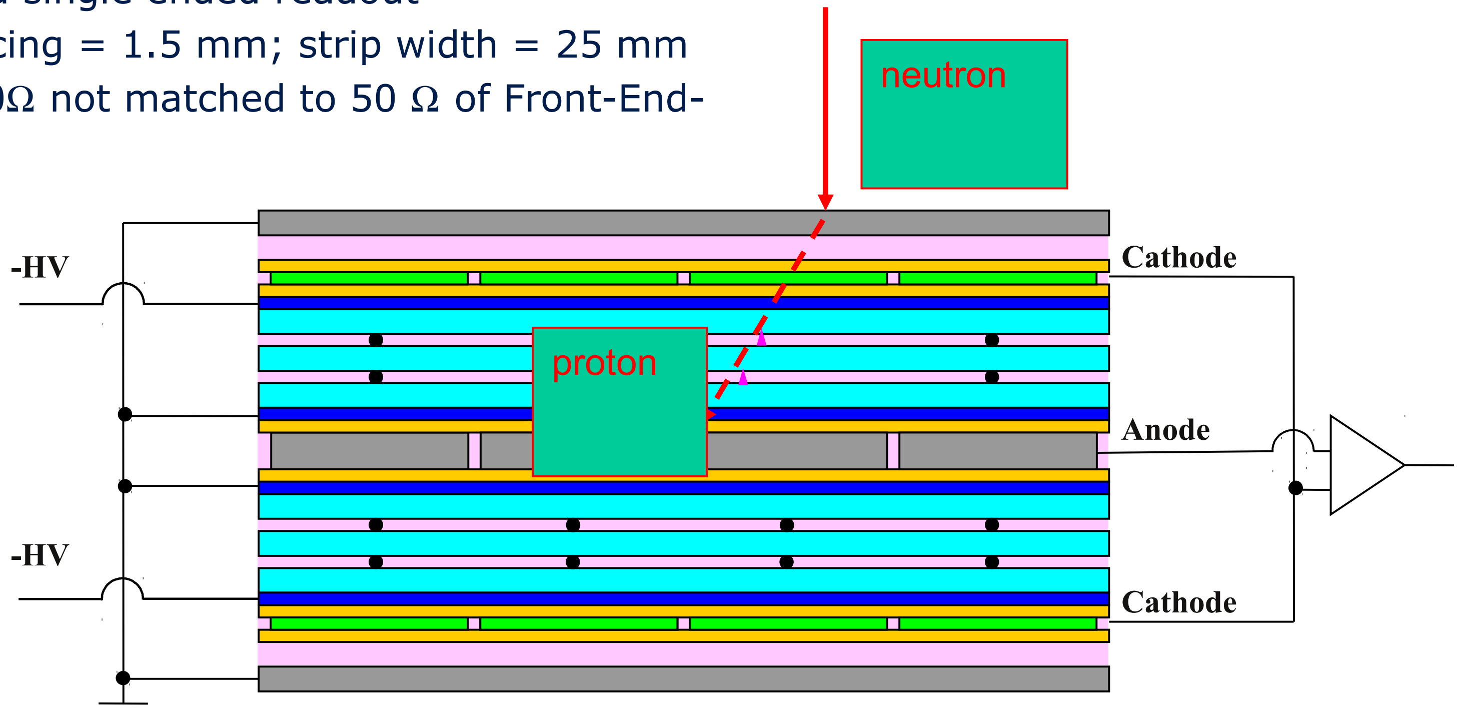
(New Large Area Neutron Detector) to detect high-energy neutrons at the new Facility for Antiproton and Ion Research (FAIR) at GSI, Darmstadt, Germany

design goals

- detect neutrons from 0.2 - 1 GeV
- efficiency for 400MeV neutrons: > 90%
- time resolution of σ < 100ps
- multi-neutron capability

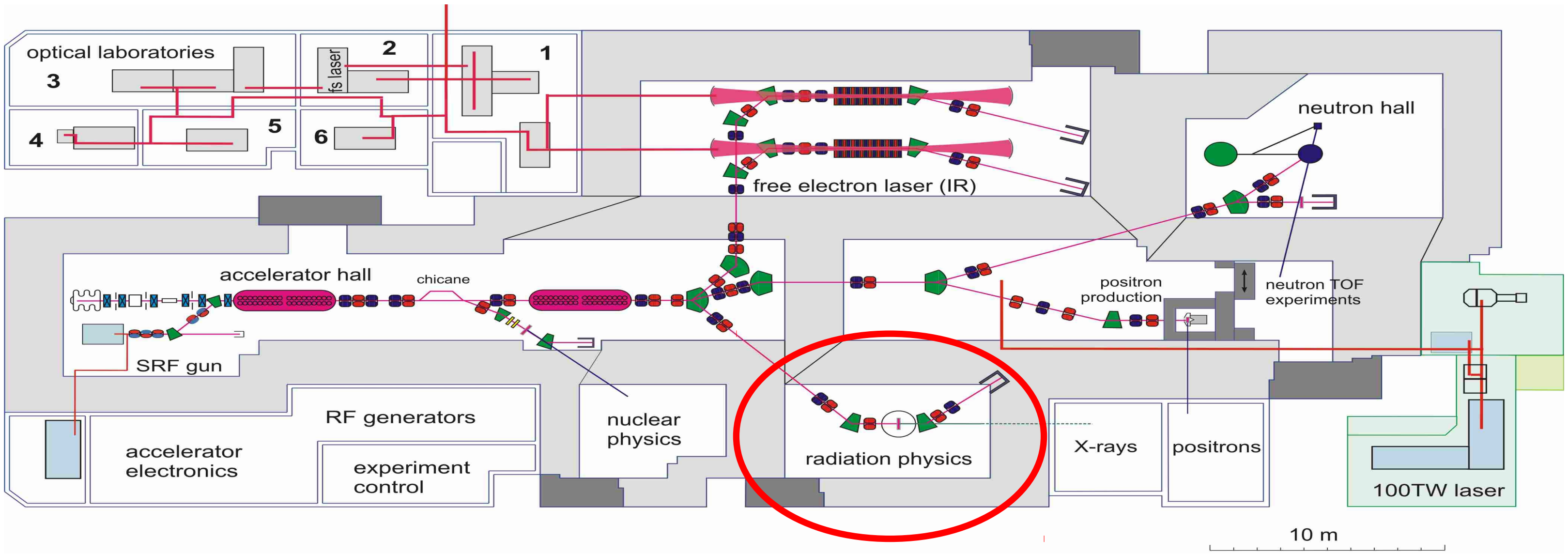
Adopted Design for the 2m x 0.5m prototype

- 2x2 gas gap structure is sufficient to reach the goals of $\eta>90\%$ and $\sigma<100ps$
- differential and single ended readout
- inter strip spacing = 1.5 mm; strip width = 25 mm
- with 12Ω to 20Ω not matched to 50 Ω of Front-End-preamplifiers



	Material	d [mm]
Resistive Plates	Float Glass	1.00
Dissipative Coating	Semiconductive Mylar	0.05
Electrodes	Copper	0.05
Insulator Layer	Mylar	0.1
Gas mixture	85 % Freon, 10 % SF_6, 5% i-Butane	0,3 (&~2.5)
Converter Plates	Stainless Steel	4 & 2
Spacer	Polyamid (Fishing lines)	0,3

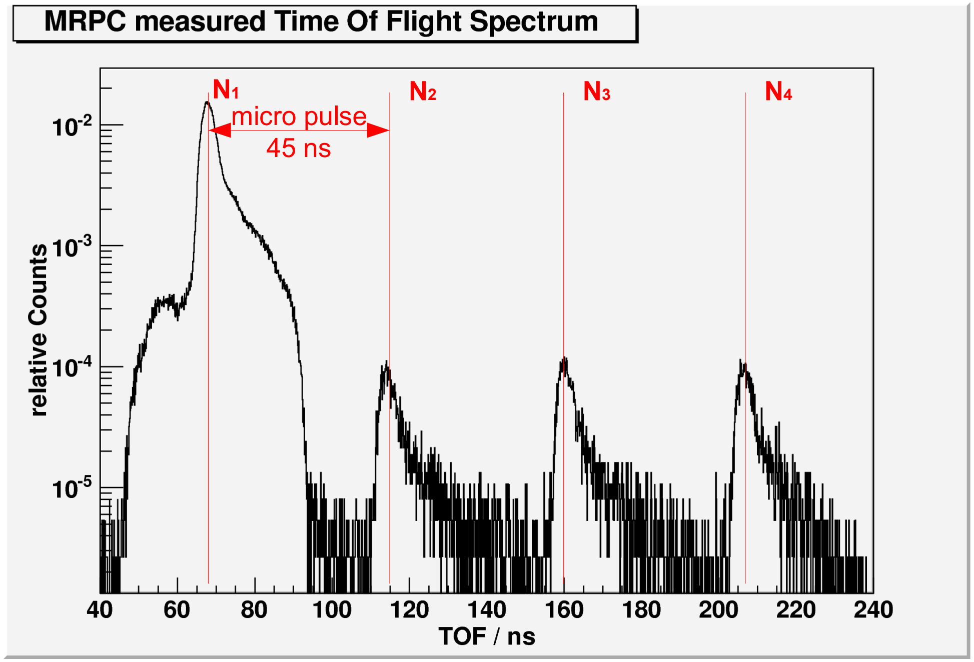
Detector tests at ELBE

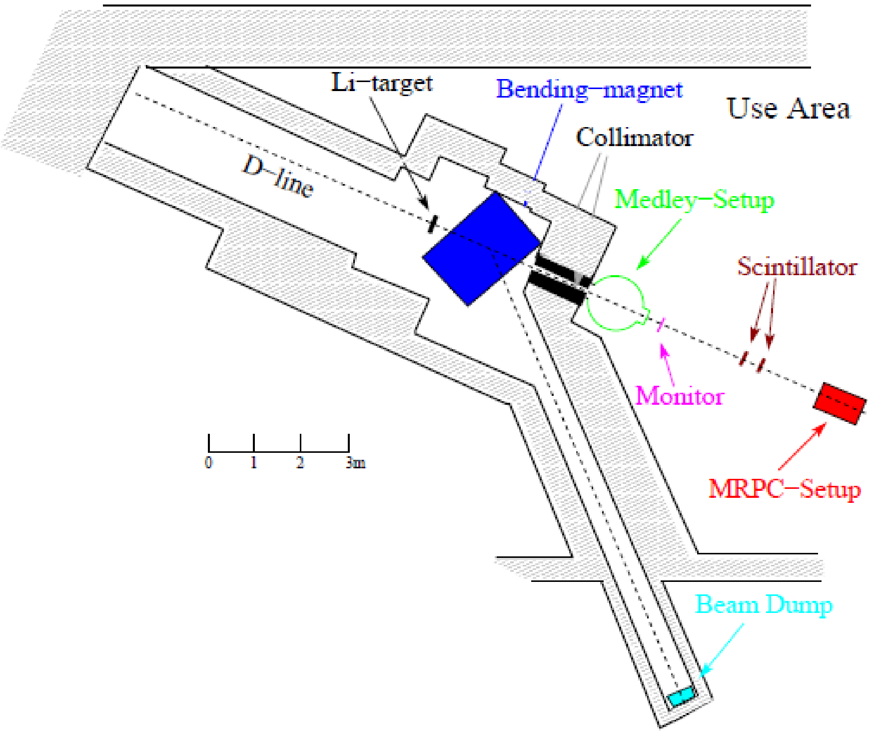


ELBE (Electron Linac with high Brilliance and low Emittance) at Helmholtz-Zentrum Dresden-Rossendorf

- E_e = 30 MeV
- using accelerator RF as time reference providing a σ_t=35 ps
- single electron bunches (L. Naumann et al., 2011, NIM A 635, p. 113-116)
- first performed with small size prototypes to find out best design parameters; details: **D. Yakorev et al., 2011, NIM A 654, p. 79-87**
- also used for a completely different detector (talk by A. Laso Garcia, Thursday)

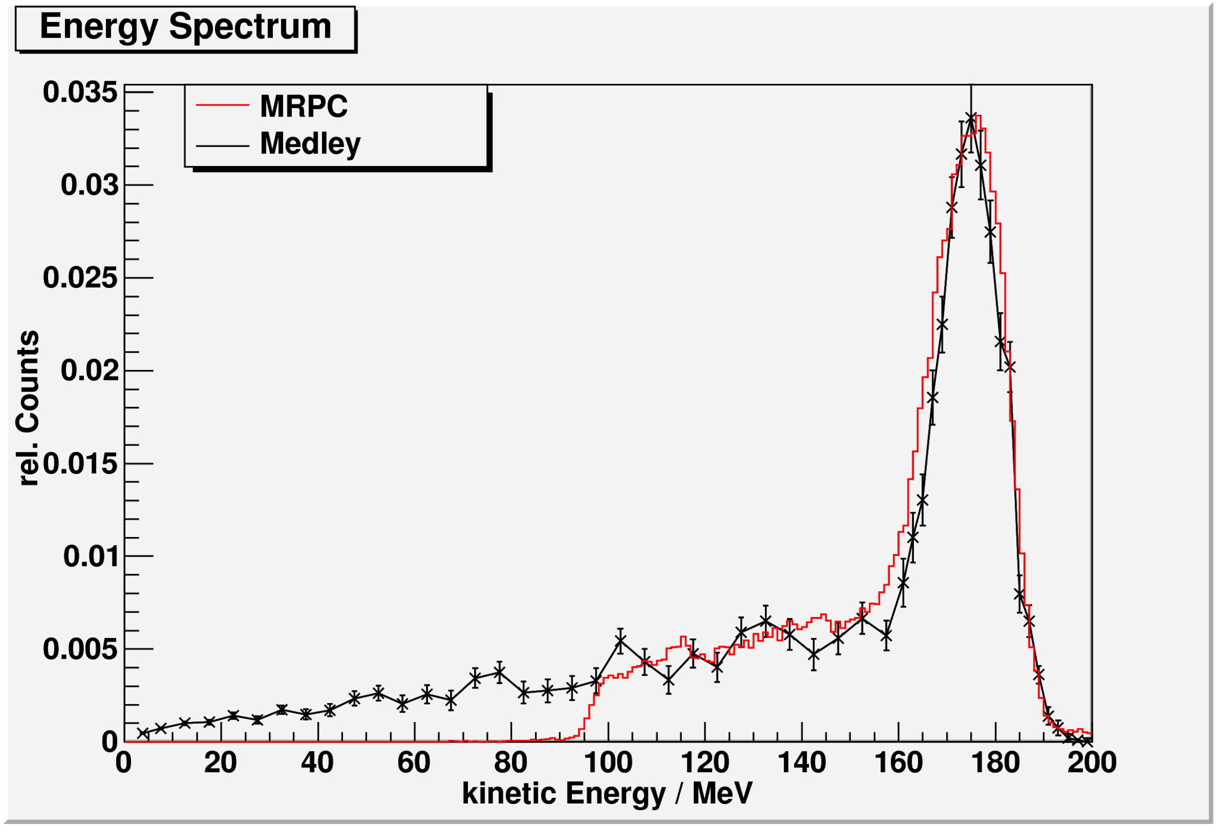
Detector tests of small prototypes with 175 MeV neutrons at TSL in Uppsala (1)





- TSL Cyclotron accelerates protons to 179,3 (+/- 0,8) MeV
- these interact with a 7-Li target producing quasi-monochromatic neutrons of ~ 175 (+/- 2,5) MeV
- n moving onto the MRPC-Detector-Setup

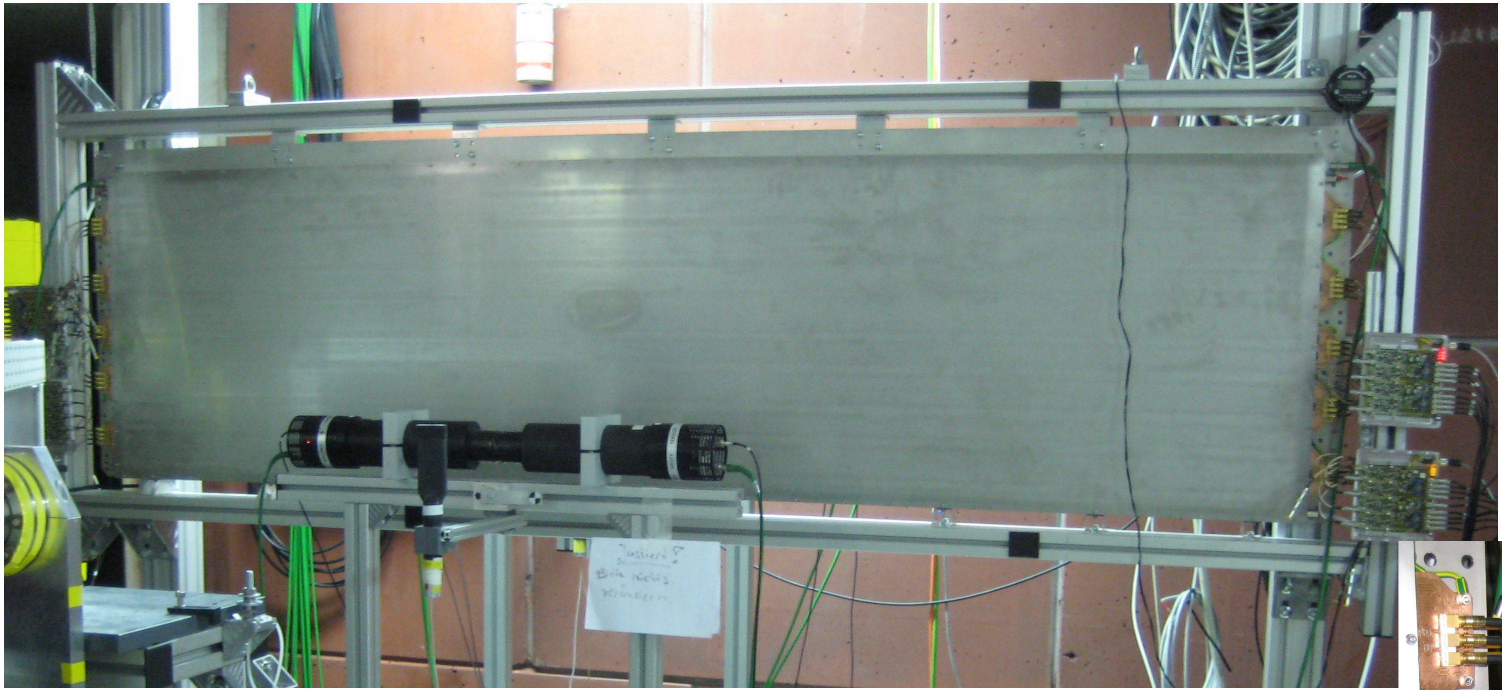
Detector tests of small prototypes with 175 MeV neutrons at TSL in Uppsala (2)

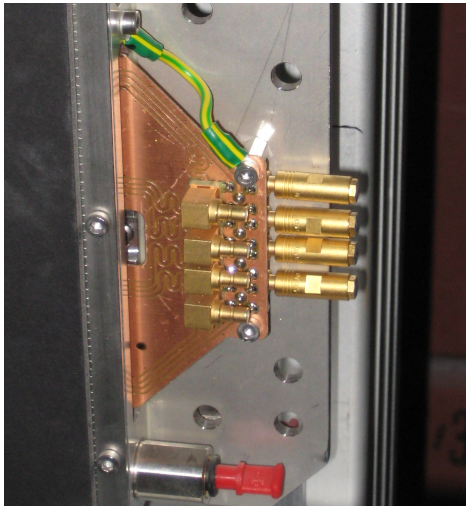


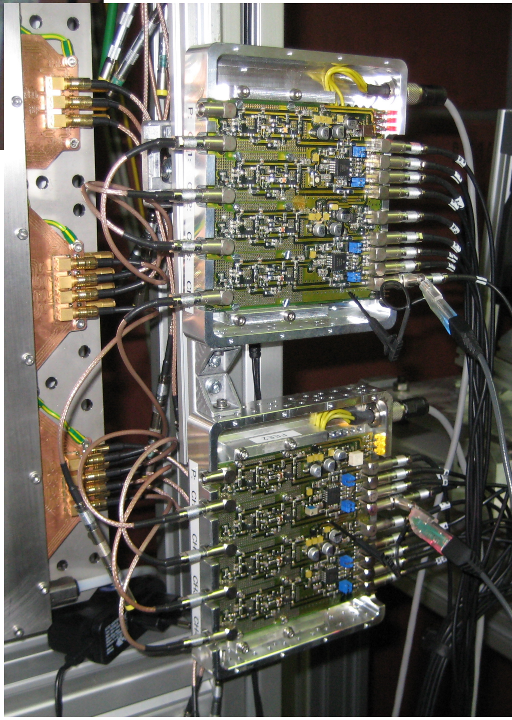
- preliminary neutron efficiency ~(0.77±0.33) %

Medley: Bevilacqua R. et al., 2011, NIM A 646, p. 100–107

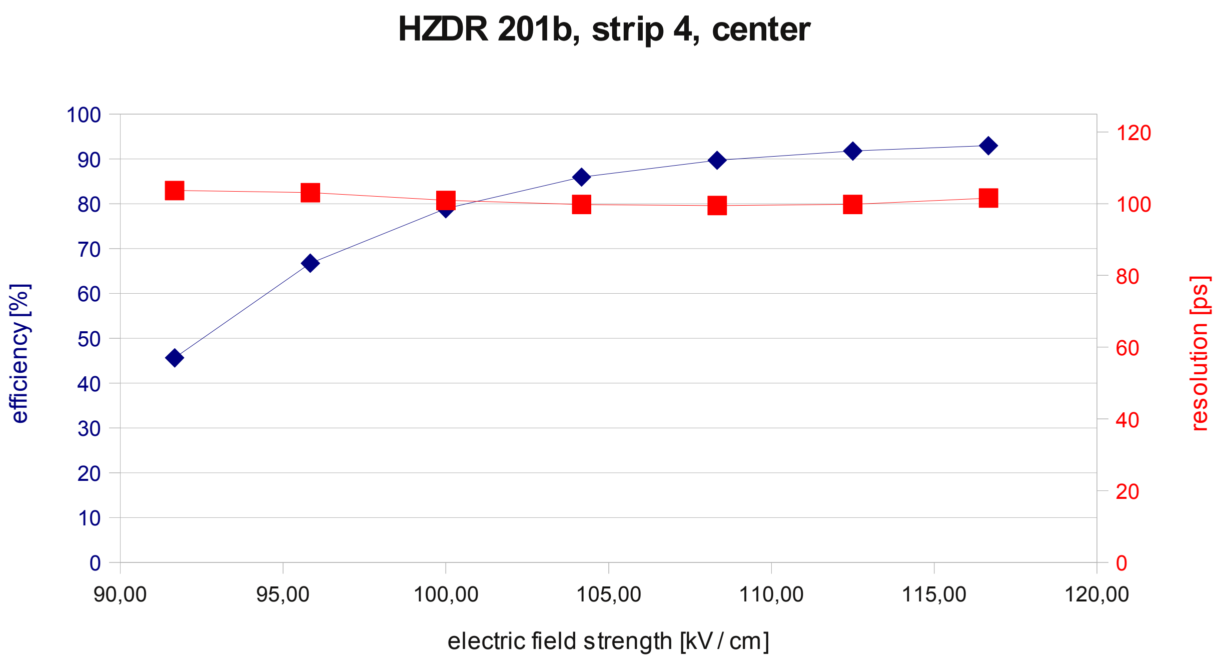
2m x 0.5m large prototype HZDR 201b



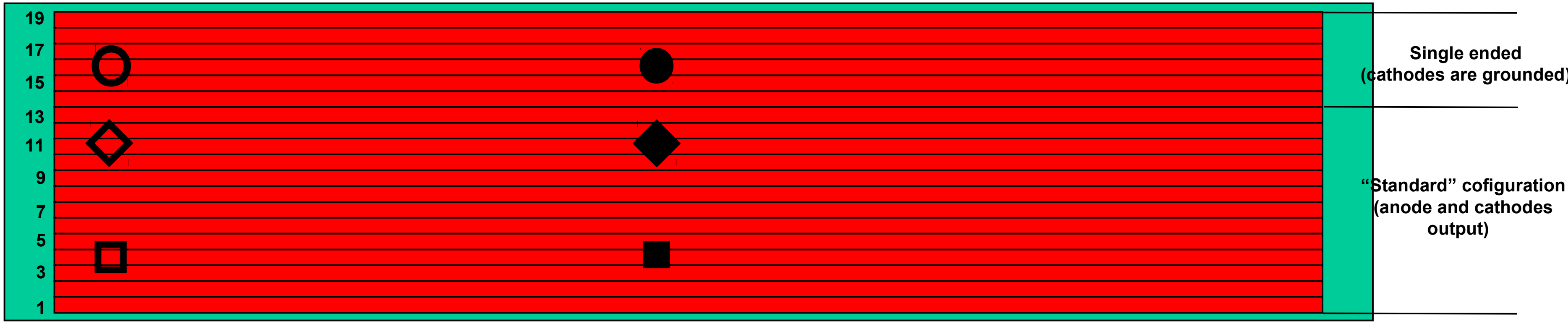


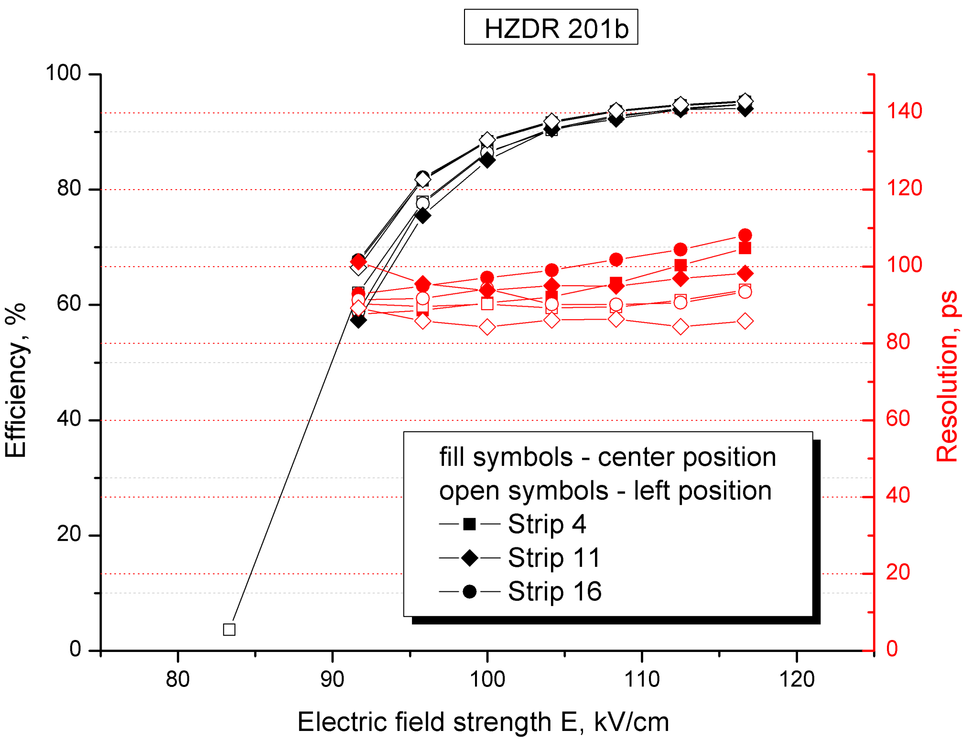


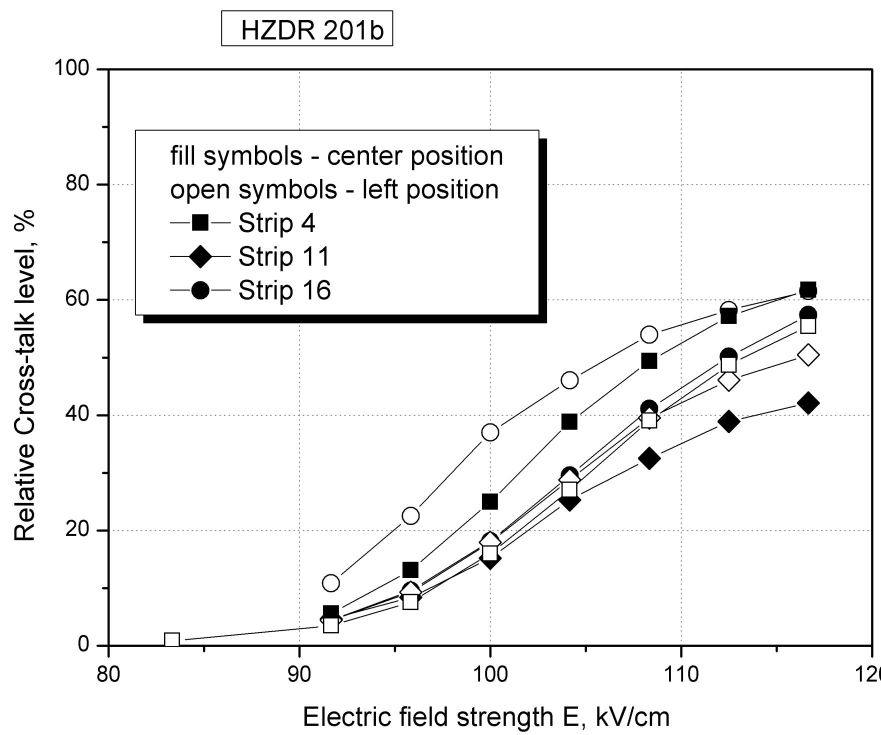
Results of Tests of HZDR 201b with TacQuila



Results of HZDR 201b as function of position







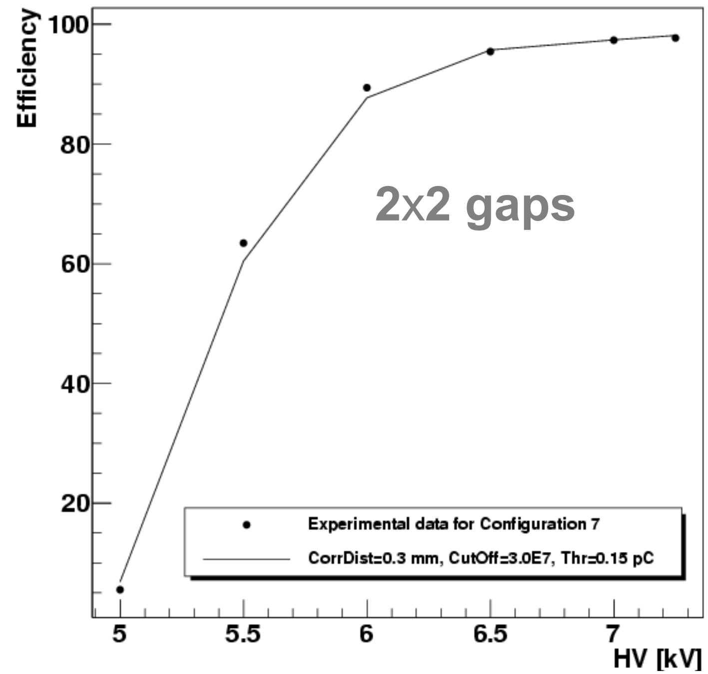
Monte Carlo Simulations

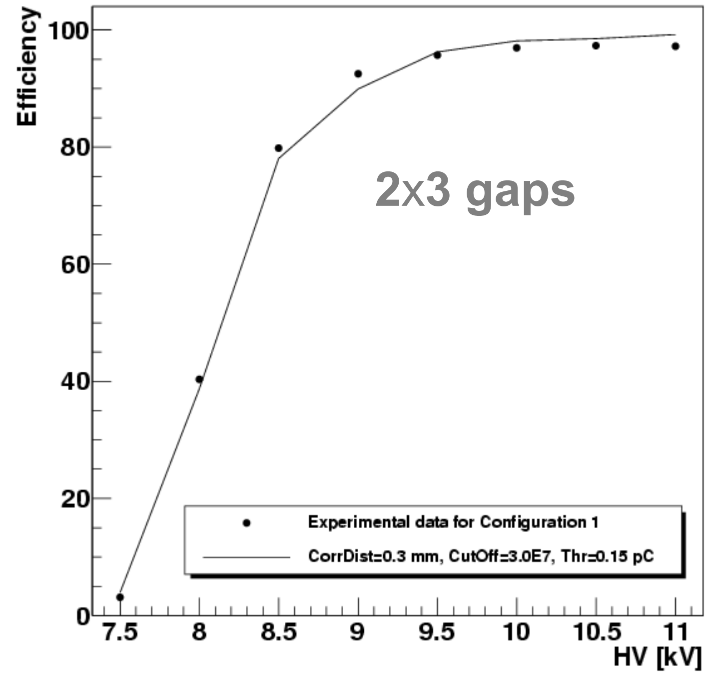
All simulations done in 2 steps:

- Geant4 for tracking particles in the detectors
- generate electron avalanches and signals

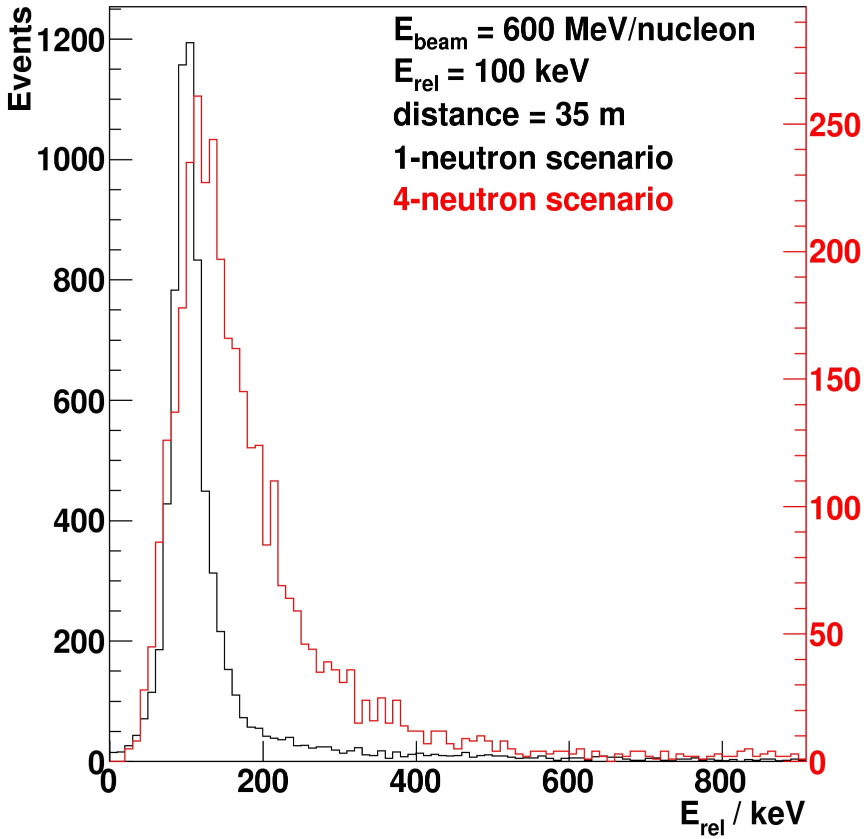
2 consecutive simulations with Geant4

1. small prototypes coded to extract calibration parameters for Geant4 by comparison with experimental data
   - **space charge effect**; **interplay** between close avalanches (merging); **threshold** for final read-out-signal
2. response of full setup to neutrons
   - using hypothetic eventfiles with up to 4 neutron emission at 200, 600, 1000 MeV/nucleon asuming different relative energies between fragments
   - reconstruct relative energy spectrum using a reconstruction algorithm





Results for the full setup



- resolution σ = 17 keV (1-neutron)
- resolution σ = 42 keV (4-neutron)
- design goal of η = 90% for 400 MeV neutrons can be reached with 50 layers leading to total depth of 1.2m

using hypothetic eventfiles $^{132}Sn \rightarrow (132-x)Sn + xn$ (x=1,2,3,4)

Summary and Outlook

Summary:

- **detection of 1GeV neutrons with MRPCs is possible**
- efficiency and time resolution tests performed using minimum ionising electrons
  - $\sigma_t < 100$ ps with $\eta > 90\%$ reached for 2m long counter
- simulations showed high detection efficiency of the full setup for primary neutrons and limited but good multi-neutron detection capability

Outlook:

1. an alternative for neutron detection with MRPCs is with glass converter plates (see talk by Jorge Machado on Wednesday)
2. further analysis of data with 175 MeV neutrons with small prototypes is ongoing
3. test of large prototype with fast neutrons at GSI in summer 2012
4. open for collaboration

Thank You for your attention

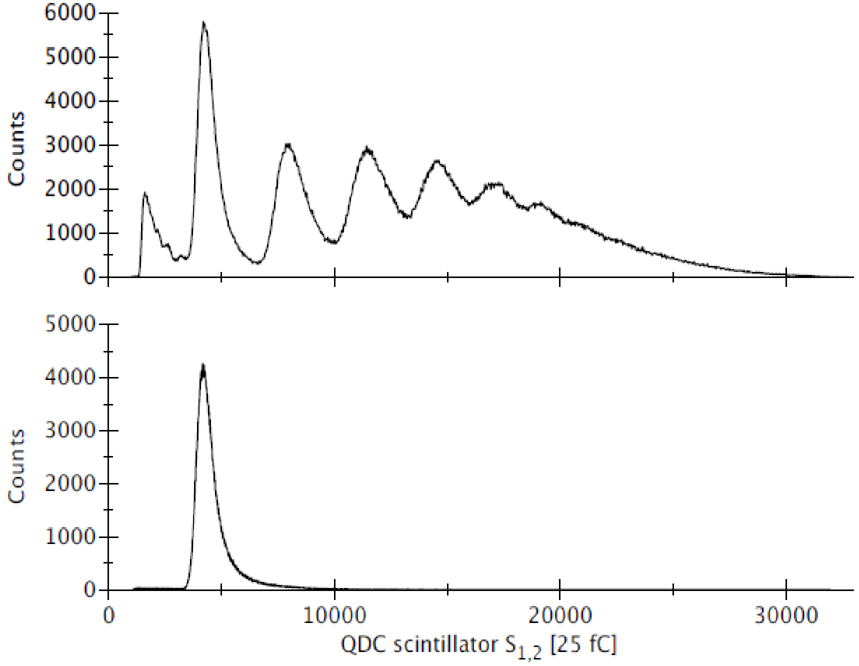
- supported by BMBF (06DR9058I) and
  GSI F&E (DR-ZUBE)

»Wissen schafft Brücken.«

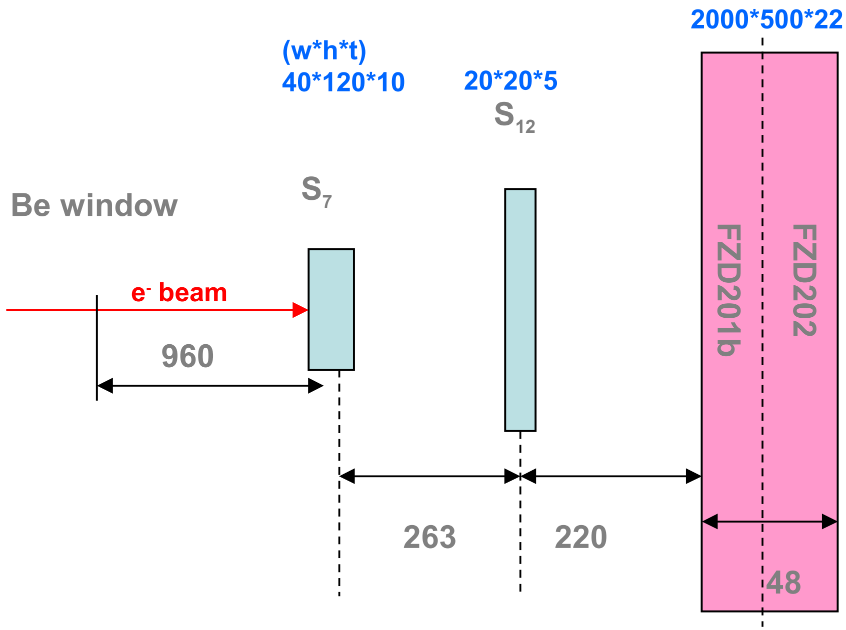
HZDR

TECHNISCHE UNIVERSITÄT DRESDEN

HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

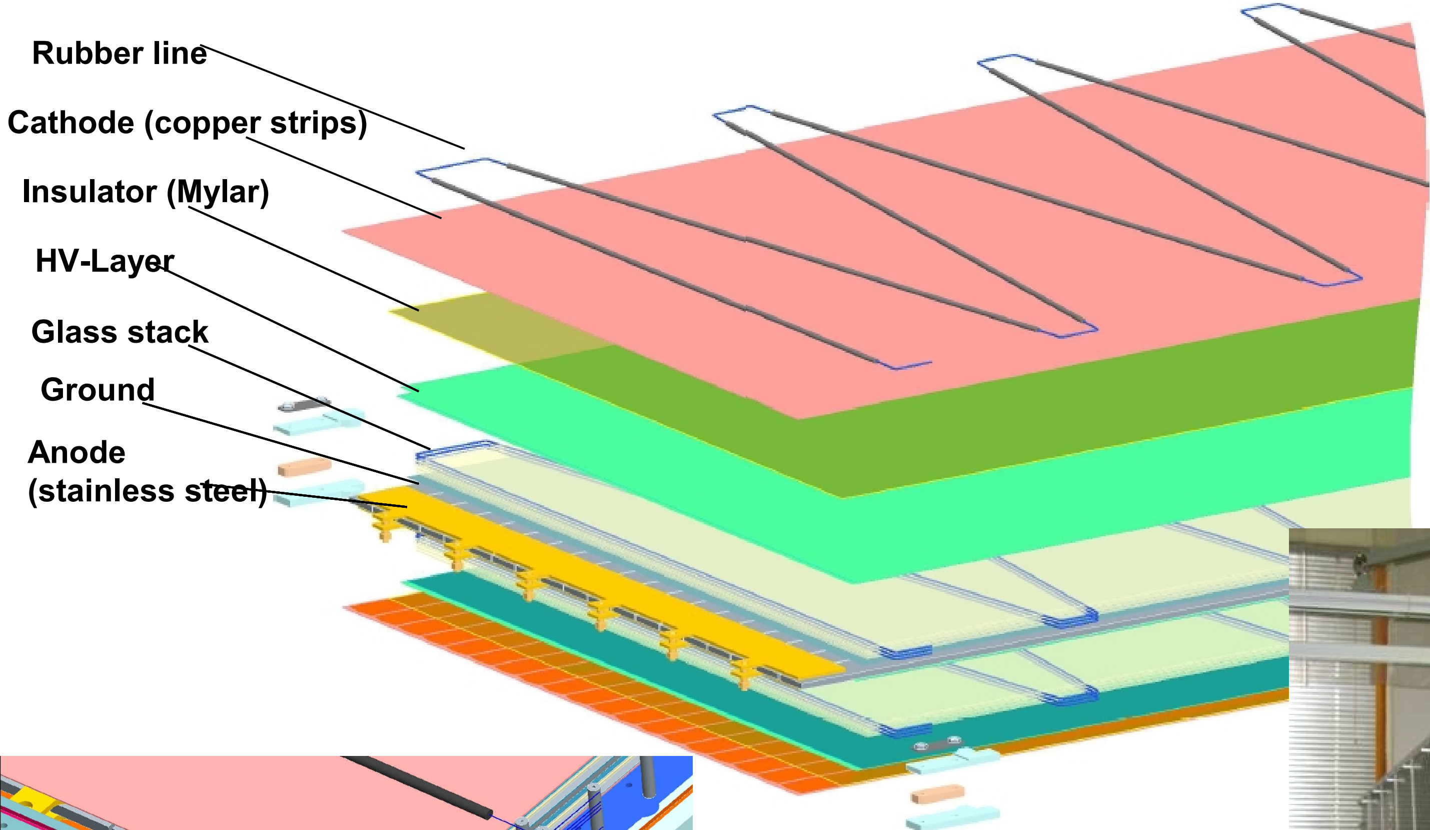


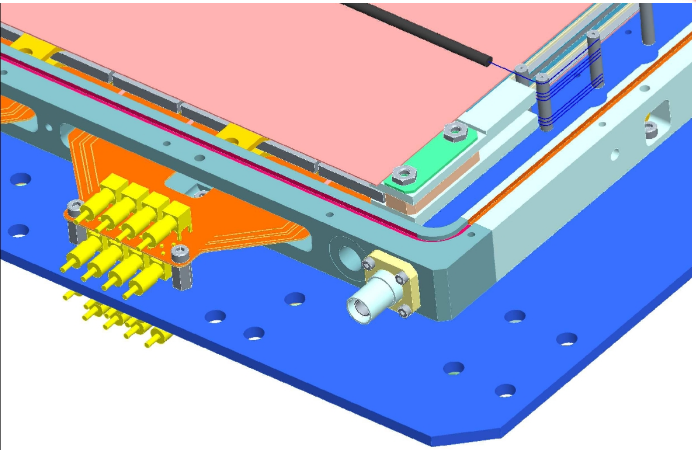
Counts
QDC scintillator $S_{1,2}$ [25 fC]



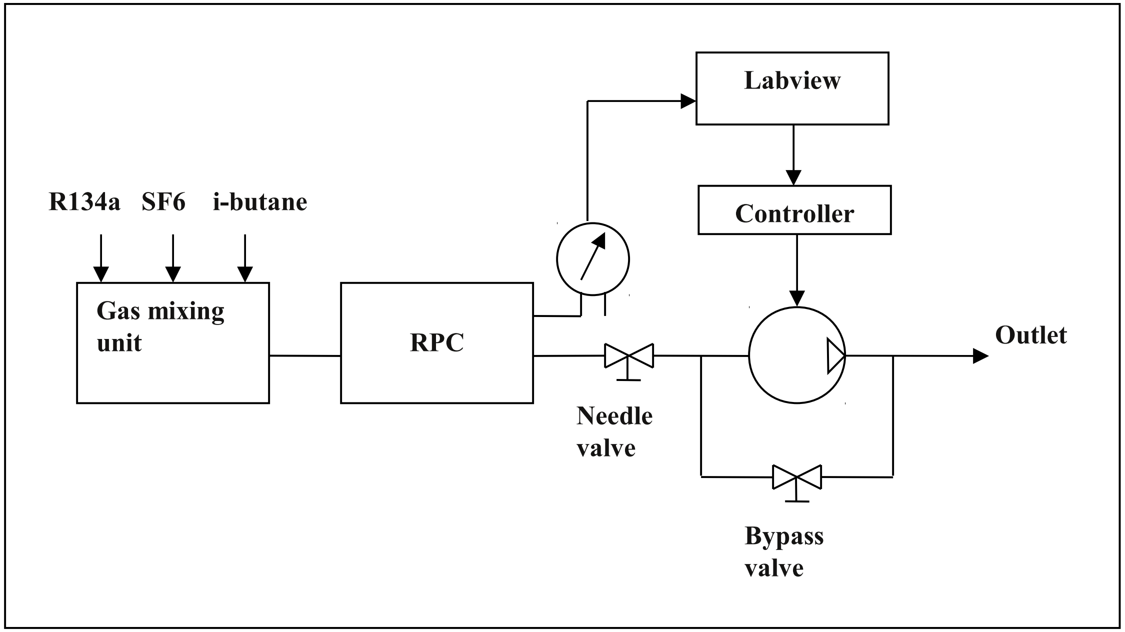
2000*500*22
(w*h*t)
40*120*10
20*20*5
S_{12}
S_7
Be window
e^- beam
960
263
220
48
FZD201b
FZD202

Exploded schematic view





Underpressure Pump to reduce the bulging of the front housing plates

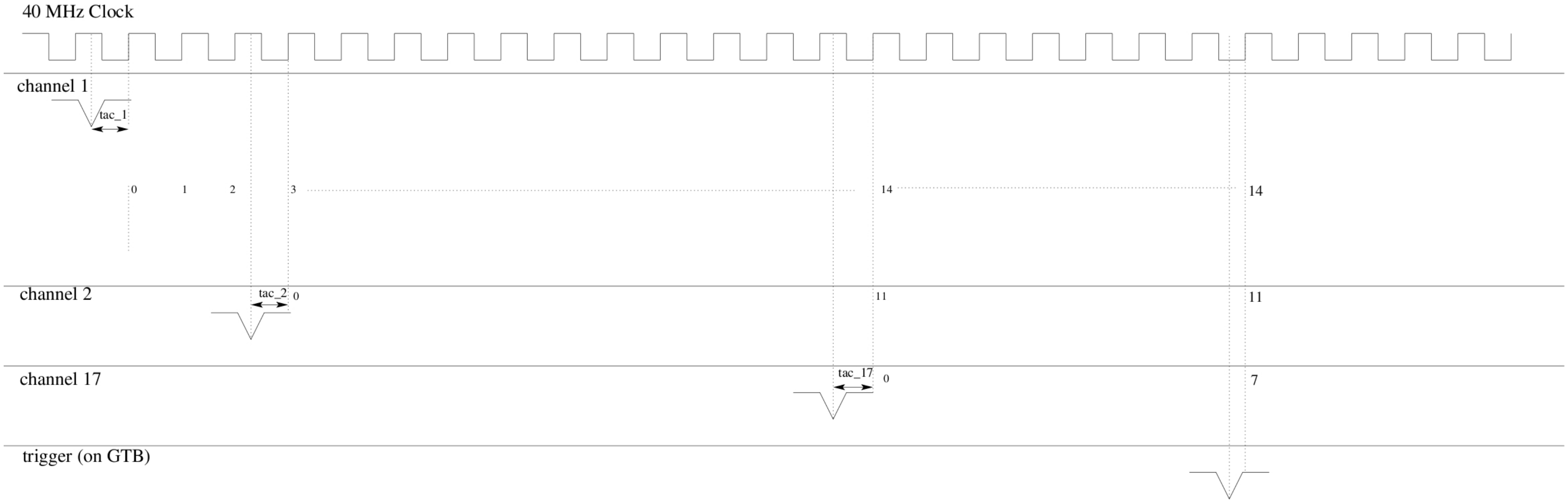


usually underpressure of 40 Pa is applied (1 m² surface → 40 N)

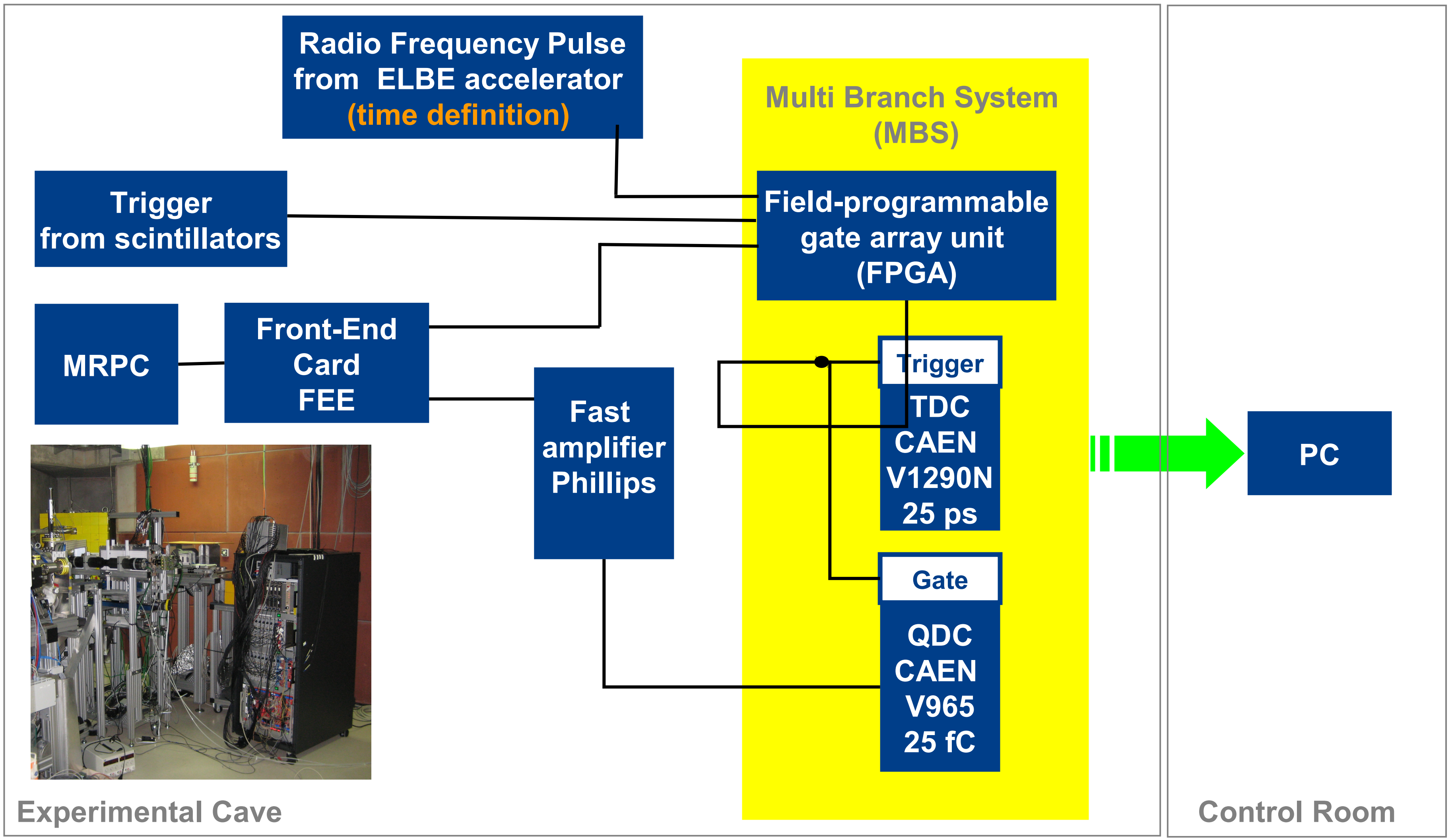
Electronics used during detector tests

TacQuila[17] Electronics

- time resolution of 10ps sigma possible (usually 12ps to 13ps reached)
- 16 signal channels, 17th channel used as common stop signal
- includes: preamplifier, splitter, multiplexer, sum-units, TDC and QDC
- 40 MHz clock; fine measurement (within 25 ns gate relative to next clock cycle); coarse measurement counts nbr. of clock-cycles
- not multi-hit-system; event recognised by TacQuila, signals is kept until either the common stop (delayed trigger) is recognized or the reset-time has expired
- reset-time: 75 ns to 6375 ns; in 100 ns



Usual Data Acquisition System



MRPC prototypes with area of 40cm x 20cm

- first approach to build 2m x 0.5m large prototype
- built several small prototypes with variation of design parameters:
  - number of gas gaps (2x2, 2x3, 2x4)
  - glass thicknes (0.58mm, 1mm)
  - strip width (12mm, 25mm)
  - inter strip spacing (0.3mm, 0.6mm, 1mm, 1.6mm, 3mm)
  - several different Front-End-Electronics (FOPI, ALICE, PADI)
  - several different read-out schemes (signal cathodes terminated or grounded, differential readout)

for further details see: D. Yakorev et al., NIM A 654 (2011), p79-87

MRPC prototypes with area of 40cm x 20cm

Prototype	Gas gaps	Glass thickness	Strip width	Interstrip spacing	Readout
HZDR-1a	2×2	0.58 mm	25 mm	3.0 mm	FOPI (signal cathodes terminated) or PADI-1/PADI-3
HZDR-1b	2×3	1.0 mm	25 mm	3.0 mm	
HZDR-2a	2×2	0.58 mm	12 mm	3.0 mm	ALICE
HZDR-2b	2×3	0.58 mm	12 mm	3.0 mm	
HZDR-3a	2×2	0.58 mm	25 mm	3.0 mm	FOPI, with various impedance transformers (fig. 9) [1]
HZDR-3b	2×3	0.58 mm	25 mm	3.0 mm	and signal cathodes grounded
HZDR-3c	2×3	1.0 mm	25 mm	3.0 mm	
HZDR-4	2×3	1.0 mm	25 mm	1.6 mm	FOPI (signal cathodes grounded) HV electrode from acrylic paint
GSI-1a	2×4	0.58 mm	25 mm	0.3 mm	FOPI
GSI-1b	2×4	1.0 mm	25 mm	1.0 mm	FOPI
GSI-2	2×4	1.0 mm	25 mm	0.6 mm	FOPI and transformers

D. Yakorev et al., NIM A 654 (2012), p79-87

Summary of the test of small prototypes at the ELBE facility - design parameters

Table 2
Summary of the experimental results. In the first column, the design parameter(s) addressed are recalled giving their code as listed in Section 5.3. For each experiment, the efficiency η (uncertainty 1%) and the time resolution σ_t (uncertainty 7 ps) are given.

Parameter	**Prototype**	**Front-end**	**Remark**	η (%)	σ_t (ps)
a,d	HZDR-1b	FOPI	2 × 3 gaps; glass thickness 1.0 mm	97	99
a,g	HZDR-1a	FOPI	2 × 2 gaps	98	96
c,e	HZDR-4	FOPI	2 × 3 gaps; interstrip spacing 1.6 mm; HV electrode from acrylic paint	95	106
a,c	GSI-1a	FOPI	2 × 4 gaps; interstrip spacing 0.3 mm	98	95
c	GSI-2	FOPI	2 × 4 gaps; interstrip spacing 0.6 mm	97	115
c	GSI-1b	FOPI	2 × 4 gaps; interstrip spacing 1.0 mm	97	127
f	HZDR-3a	FOPI	2 × 2 gaps; no impedance transformer	97	80
f	HZDR-3a	FOPI	2 × 2 gaps; imped.transf with C_x = 4.7 pF; glass thickness 0.58 mm	98	94
f	HZDR-3a	FOPI	2 × 2 gaps; imped.transf with C_x = 2.7 pF; glass thickness 0.58 mm	98	89
f	HZDR-3b	FOPI	2 × 3 gaps; imped.transf with C_x = 4.7 pF; glass thickness 0.58 mm	98	84
f	HZDR-3b	FOPI	2 × 3 gaps; imped.transf with C_x = 2.7 pF; glass thickness 0.58 mm	99	82
f	HZDR-3b	FOPI	2 × 3 gaps; imped.transf with C_x = 2.2 pF; glass thickness 0.58 mm	99	75
d,f	HZDR-3b	FOPI	2 × 3 gaps; imped.transf with C_x = 0 pF; glass thickness 0.58 mm	99	88
f	HZDR-3c	FOPI	2 × 3 gaps; imped.transf. with C_x = 3.3 pF; glass thickness 1.0 mm	97	114
g	HZDR-1a	FOPI	Positive HV, only Cathode 1 connected	66	88
g	HZDR-1a	FOPI	Positive HV, only Cathode 2 connected	69	91
g	HZDR-1a	PADI-1	Only anode connected	90	80
g	HZDR-1a	PADI-1	Anode and both cathodes connected	97	111
g	HZDR-1a	PADI-1	Only one of two cathodes connected	54	113
g	HZDR-1b	PADI-3	Low threshold	98	83
g	HZDR-1b	PADI-3	High threshold	91	87
b,g	HZDR-2a	ALICE	2 × 2 gaps; strip width 12 mm	89	113
b,g	HZDR-2b	ALICE	2 × 3 gaps; strip width 12 mm	96	

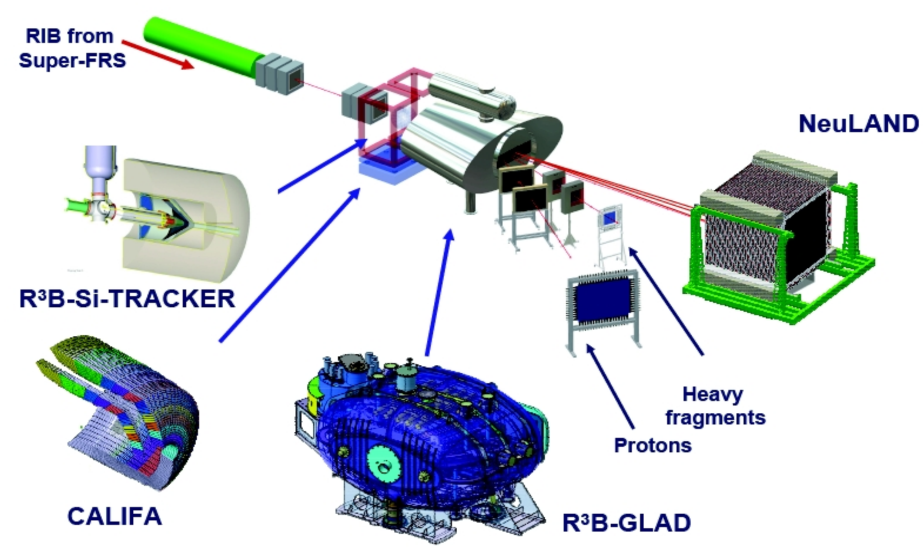
D. Yakorev et al., NIM A 654 (2012), p79-87

R3B @ FAIR

- all elements, H to U
- intensity >1012 ions/s
- high energy, 1.5 GeV/u
- pulsed and CW beams

Kinematically complete measurements of Reactions with Relativistic Radioactive beams

- Knockout reactions
- Electromagnetic excitation
- Charge-exchange reactions



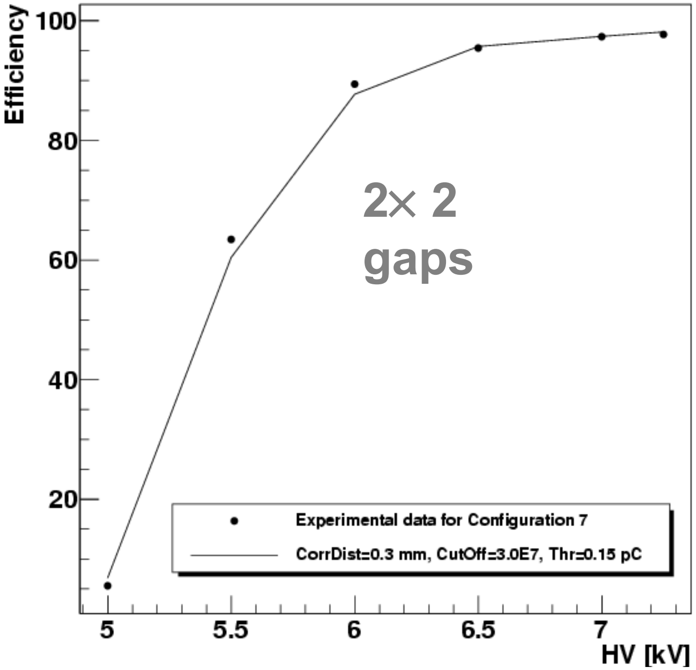
Simulations

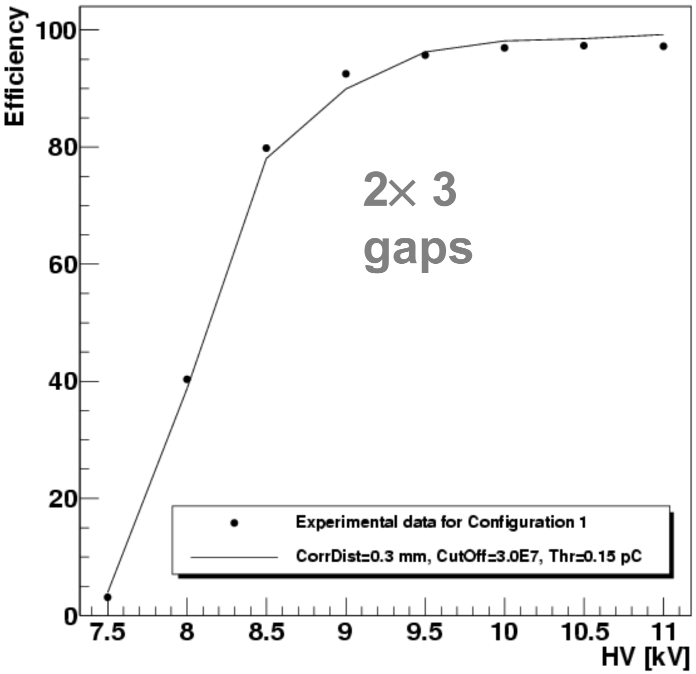
2 consecutive simulations with Geant4

1. small prototypes coded to extract calibration parameters for Geant4 by comparison with experimental data
    - **space charge effect**; **interplay** between close avalanches (merging); **thresold** for final read-out-signal
2. big prototype coded with data from calibration simulations
    - random/white noise included
    - using σ_t = 150 ps (worst case scenario)
    - using hypothetic eventfiles
        - ^{132}Sn → (132-x)Sn + xn (x=1,2,3,4) at 200, 600, 1000 MeV/nucleon
    - distance to target: 12.5 m
    - efficiency of 90% for 400 MeV neutrons leading to 50 layers with a total depth of 1.2 m

All simulations done in 2 steps:

- Monte Carlo engine providing primary particles and their properties
- electrons grow to electron avalanche governed by Townsend and attachment coefficients (resp. for multiplication and recombinatin effects)

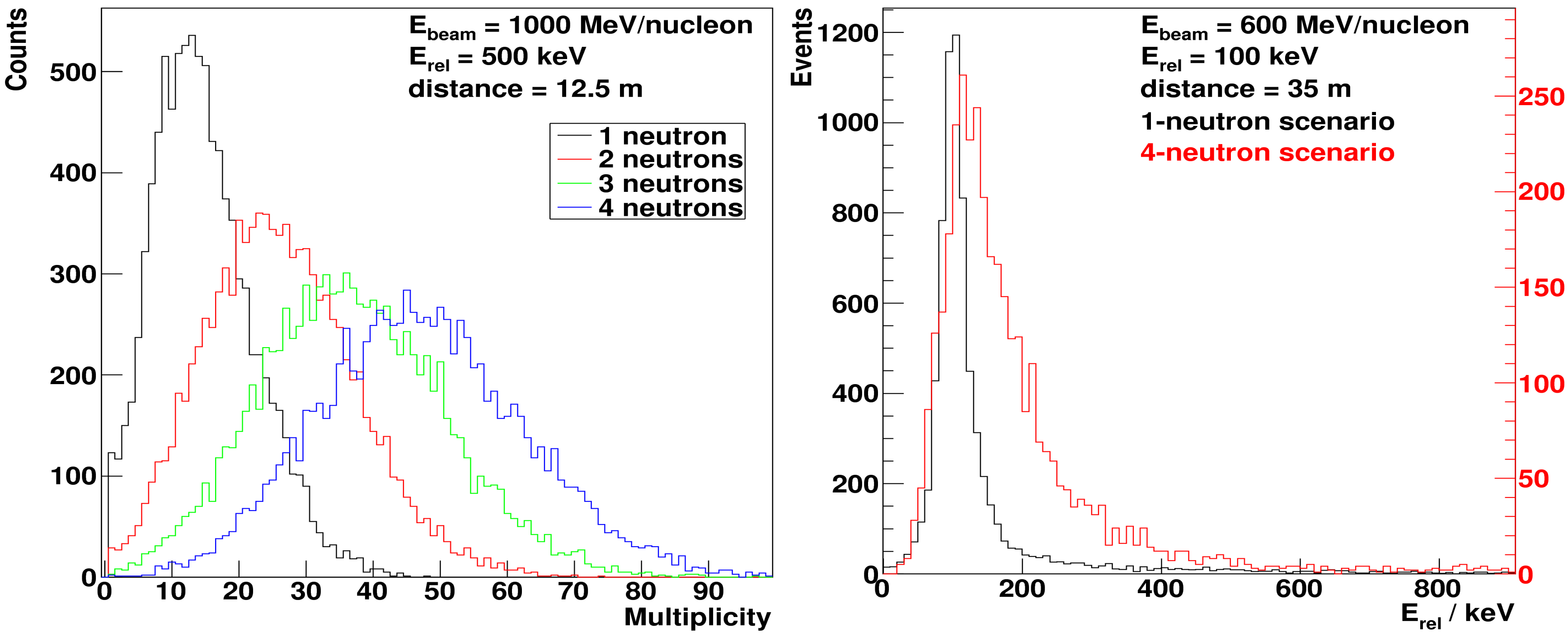




Multi-neutron Reconstruction Algorithm

Multi neutron reconstruction algorithm

- clusterization (hits within a certain distance are grouped together)
- if speed between two clusters in one event is smaller than the beam velocity it is excluded
- number of surviving hits gives number of incoming neutrons

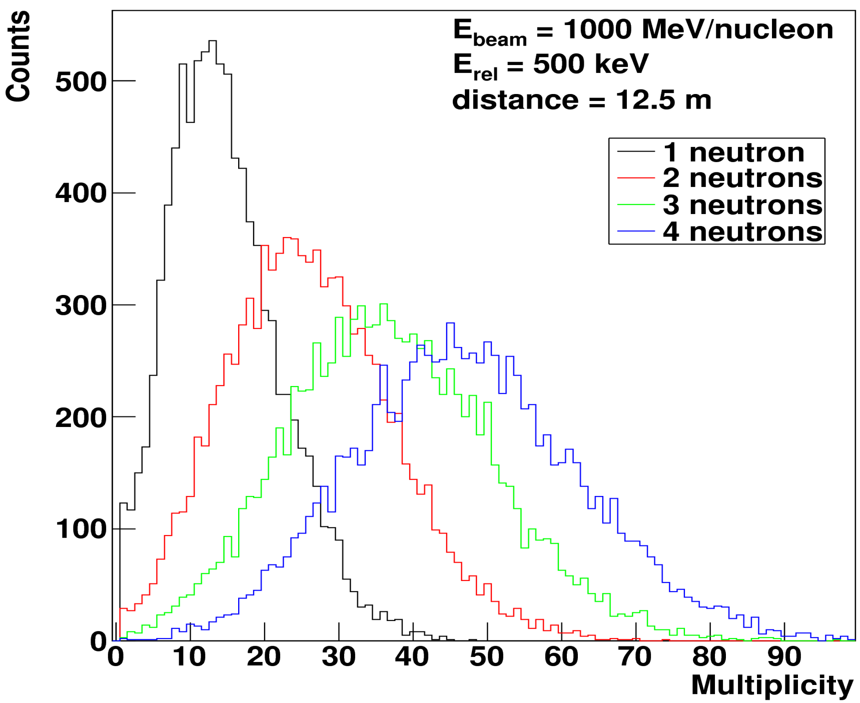


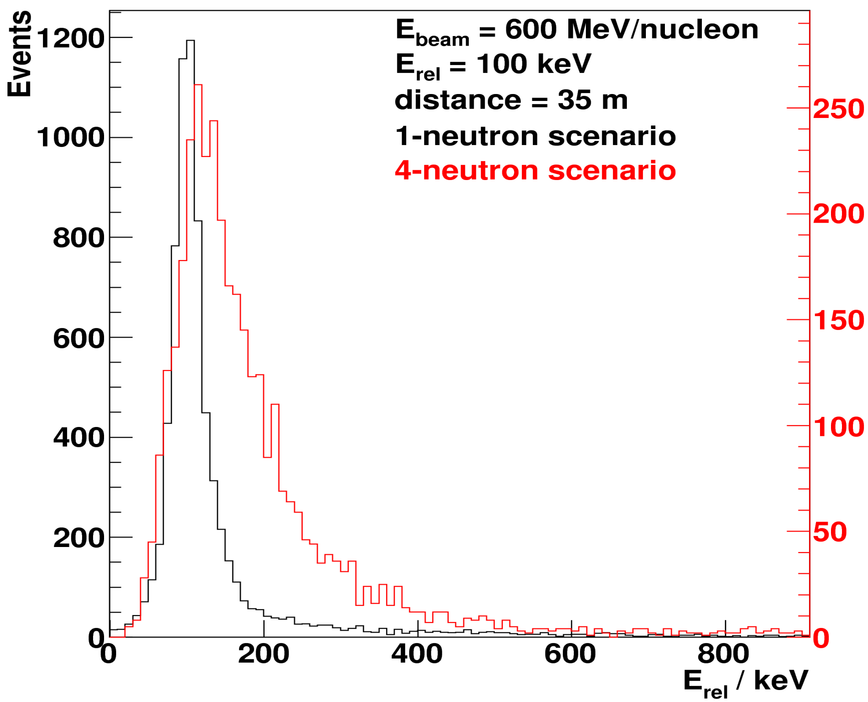
using hypothetic eventfiles $^{132}Sn \rightarrow (132-x)Sn + xn$ (x=1,2,3,4)

Multi-neutron Reconstruction Algorithm

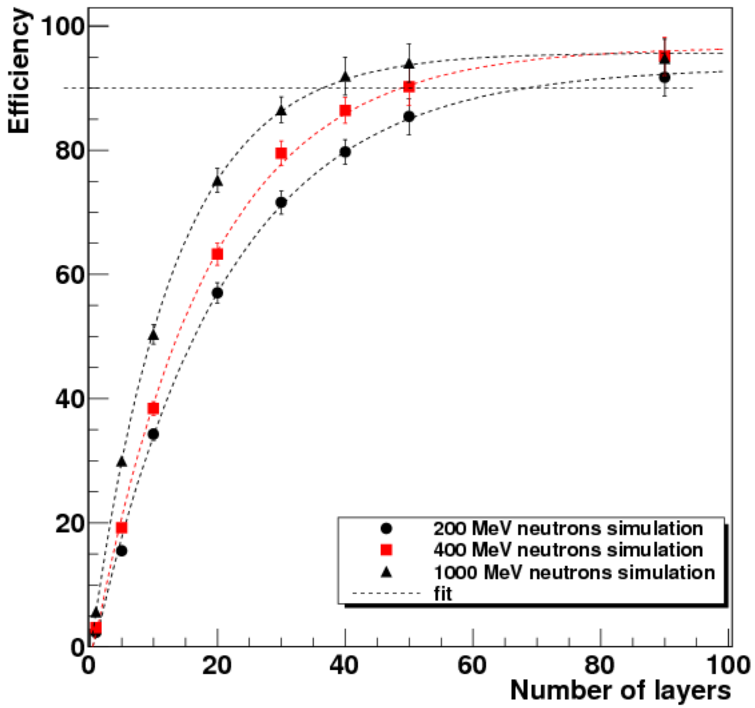
Multi neutron reconstruction algorithm

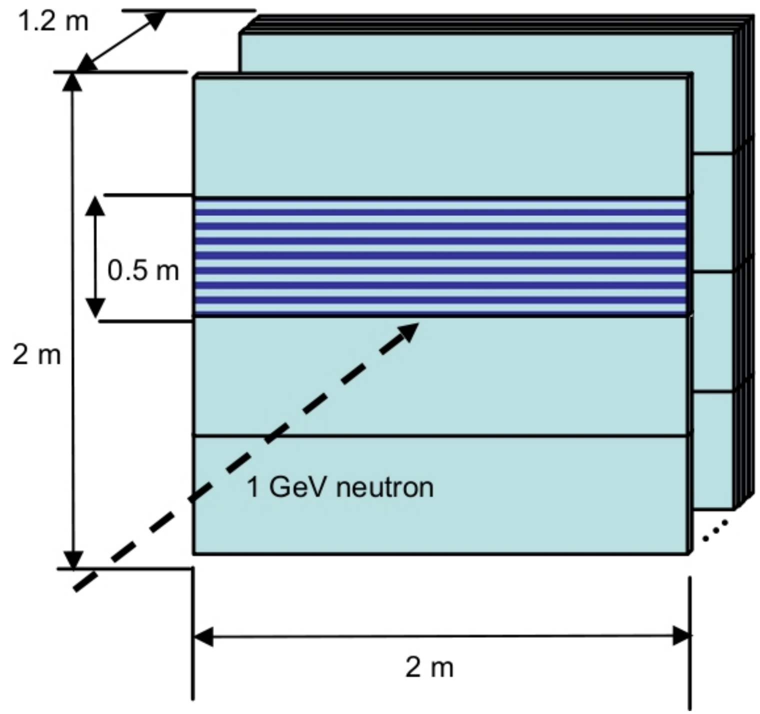
- sort hits according to latend velocity (travel time from source to hit position)
- **clusterization** (hits within a certain distance are grouped together; this certain distance was optimized for each beam energy and source-to-target-distance)
- each group characterized by its fastest member
- single-member clusters are allowed
- after that, speed between remaining hits were calculated
- if speed between two hits in one event is smaller than the beam velocity it is **excluded**
- number of surviving hits gives number of incoming neutrons





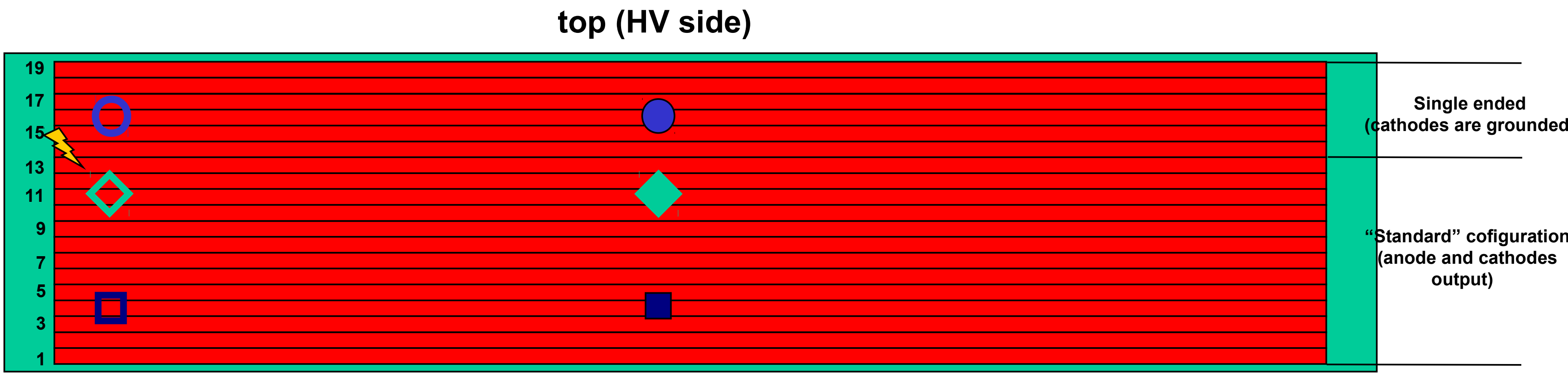
Simulations and Full Size Detector





1. efficiency curve well understood by Geant4 simulations including avalanche formation
2. these serve as basis for a neutron efficiency of ~2% for each layer
3. 50 layers (~1.2m thickness, 4t mass, 8 k output channels) are needed for a total neutron efficiency of >90% (for 400 MeV neutrons)

HZDR 201b



- taken from:
- /net/files/share/fwk/fwkk/NeuLAND/data/Exp_100711/Beam_100711.ppt

- Nomenklatur: [Detektor_Streifen_Elektrode(A=Anode, C=Kathode)], Konfiguration, Impedanz
-
- HZDR201b_S10_A, diff, 16,5 Ohm
- HZDR201b_S10_K, diff, 9,8 Ohm
-
- HZDR201b_S15_A, SE, 11,4 Ohm
-
- HZDR201b_S18_A, SE, 12,4 Ohm
-
- HZDR202_S05_A, SE, 13,6 Ohm
-
- HZDR202_S10_A, diff, 18,1 Ohm
- HZDR202_S10_K, diff, 9,7 Ohm
-
- HZDR202_S15_A, SE Trafo 0pF, 63,8 Ohm
-
- HZDR202_S18_A, SE Trafo 1pF, 64,8 Ohm
-
- Den Fehler der Messung müsste man mal nachrechnen, ca. 3-5%