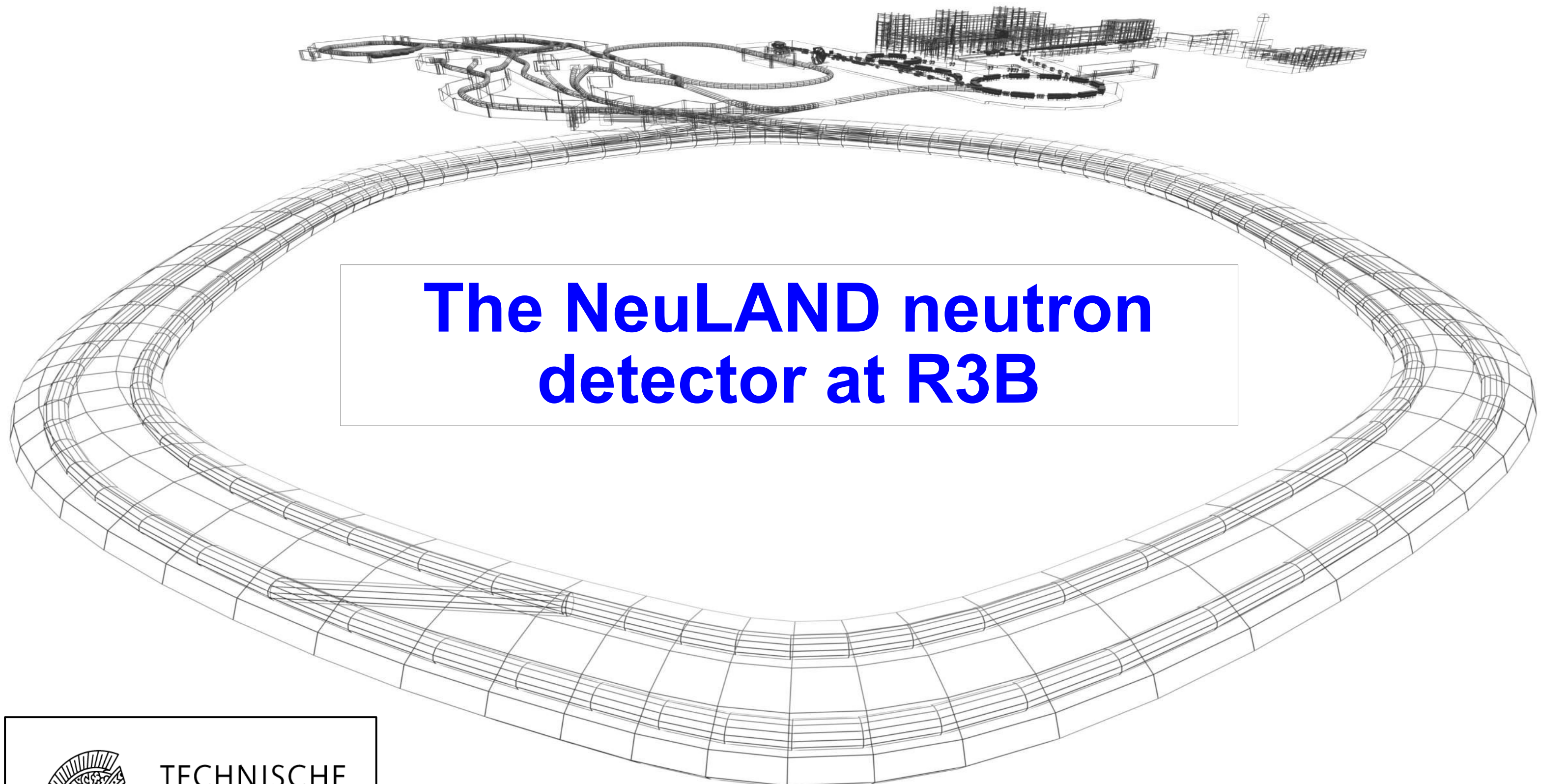
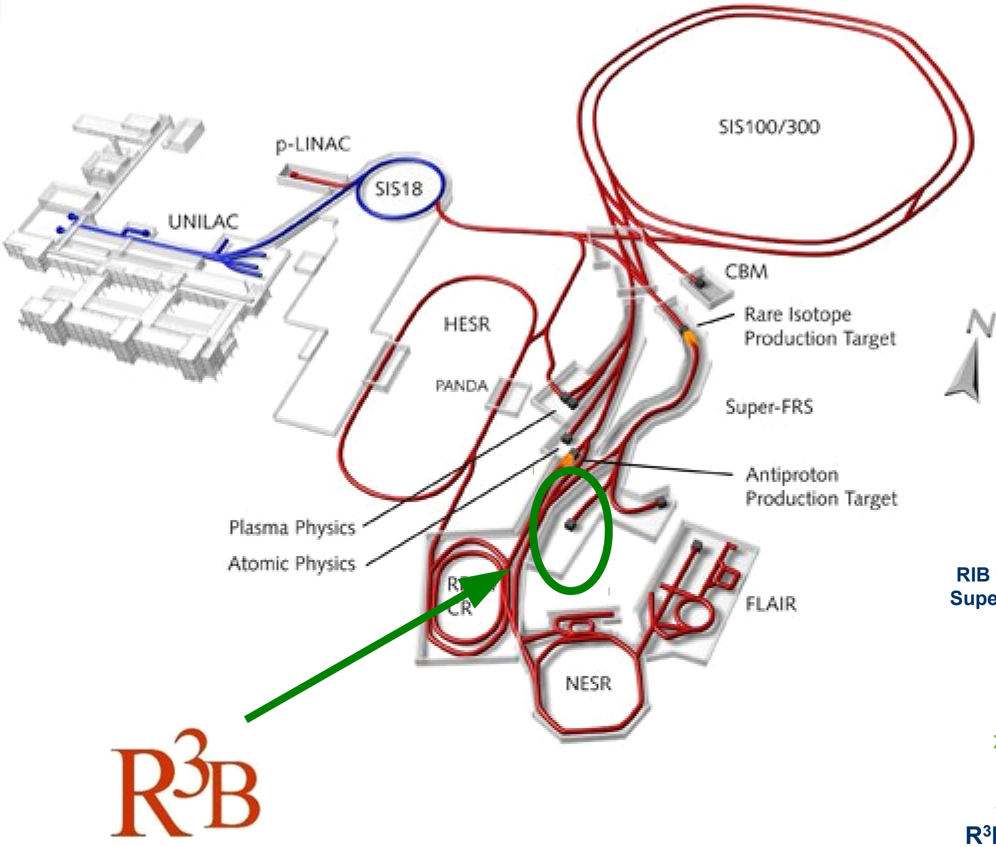


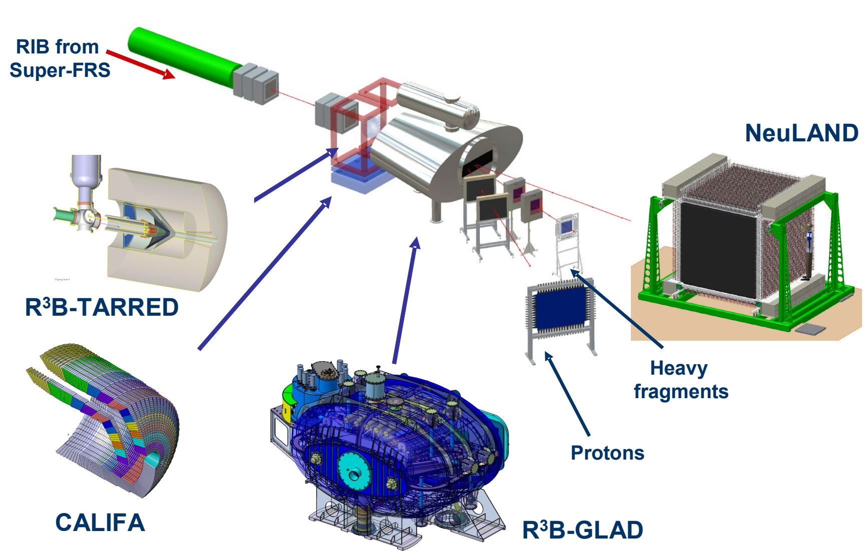
The NeuLAND neutron detector at R3B

TECHNISCHE UNIVERSITÄT DARMSTADT

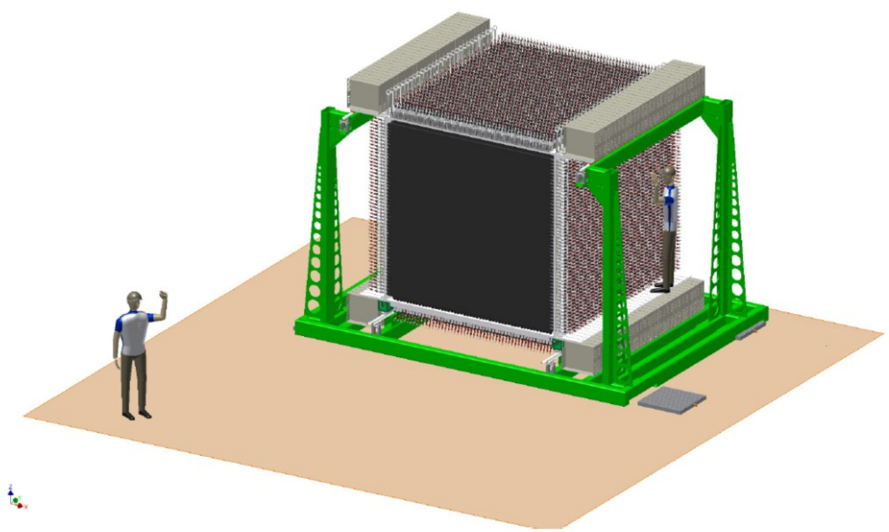
The R3B Collaboration

NeuLAND: The High Resolution Neutron Time-of-Flight Spectrometer for R³B





NeuLAND: The High Resolution Neutron Time-of-Flight Spectrometer for R³B



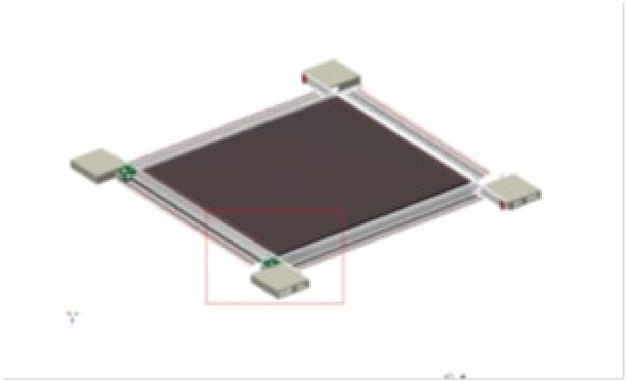
NeuLAND detector parameters:
- full active detector using RP/BC408
- face sice 250x250 cm2
- active depth 300 cm
- 32 tons

Constituents:
- 3000 scintillator bars
- 6000 PMTs / HV / readout channels
- 30 double-plane frames
- 3 detector frames

NeuLAND performance goals:
- >90% efficiency for 0.2-1.0 GeV neutrons
- Multi-hit capability for up to 5 neutrons
- invariant-mass resolution: NeuLAND-target distance 35 m

  ΔE < 20 keV at 100 keV above the neutron threshold
- "tetra-neutron" case: NeuLAND-target 35 m, 600 AMeV

  ΔE ≈ 40 keV at 100 keV for 4 n's at 60% tot. eff.!



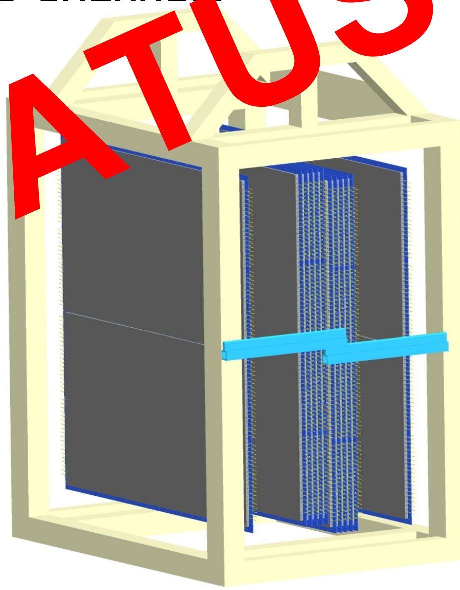
NeuLAND Technical Design Report has been approved on Jan. 18, 2013 by FAIR.

NeuLAND: Reminder from last years workshops

STATUS FEB. 2011

NeuLAND based on MRPC's:

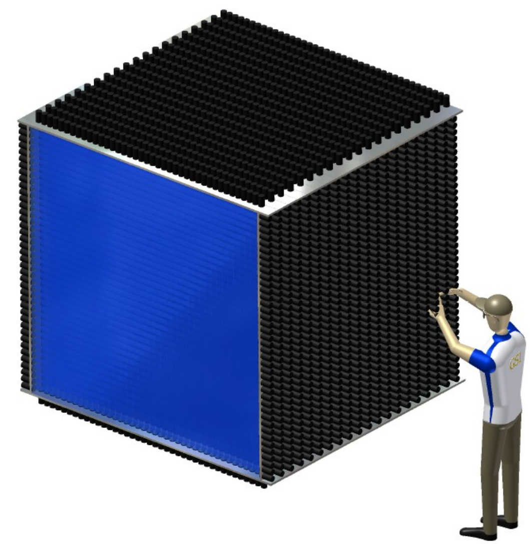
- Alternating layers of passive converter material and Resistive Plate Chambers (RPC) for the detection of secondary particles
- **Detector size 2*2*~1 m^3**
- ~7.000-8.000 channels
- Mass 4 tons



HZDR design

NeuLAND based on organic scintillator:

- Full active detector
- Bar structure read out from two sides by PMs/APDs
- **Detector size 2*2*~2-3 m^3**
- ~3.200-5.000 channels



GSI Design

high multi-neutron recognition demands calorimetry

→ full active detector required!

Perspectives for 2014 Beam Times at GSI

- demonstrator will be assembled (4 d.p.)
- HV distribution from PNPI not in time

  alternatives: 400 ch from LAND

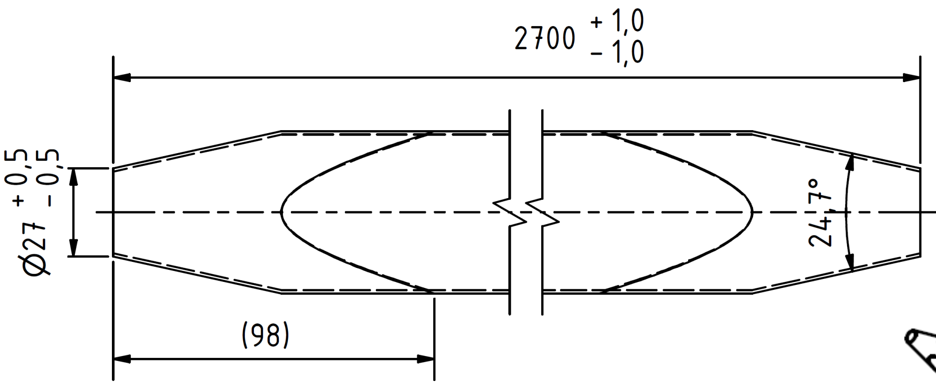
  > 300 ch borrowed for august (from HADES)
- electronics development at GSI (TAMEX) potentially delayed

  alternatives: TacQuila channels

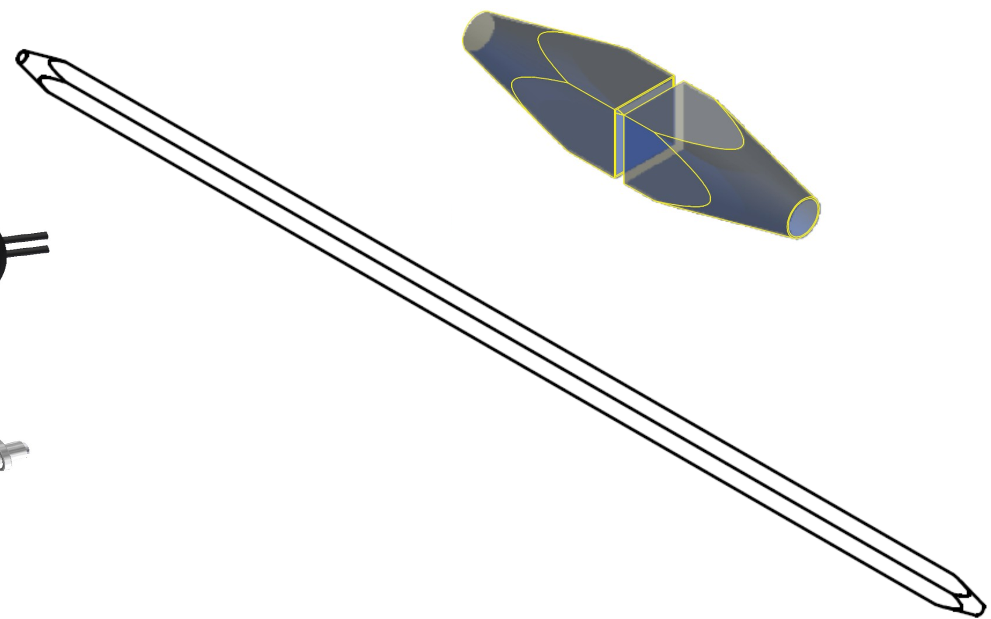
  400 ch. from LAND

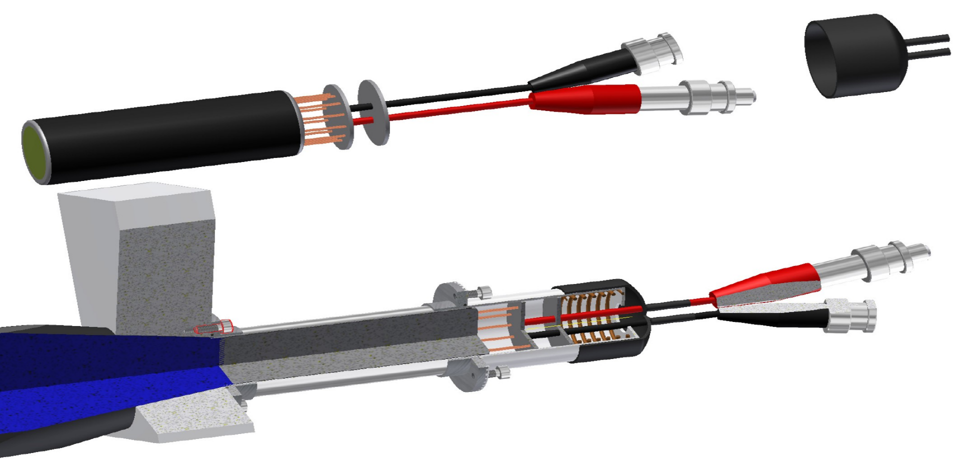
  400 ch. NeuLAND 2012
- exposure to fast neutrons requires magnetic field

NeuLAND Submodule: Scintillator Bars



NeuLAND submodule
from BC408 equivalent,
250(270 incl. light guides)x5x5 cm³





light readout by one inch PM
Hamamatsu R8619

Scintillator Bars

- 200 bars existing from 2012 deliveries
- 2013: frame contract with REXON
  - first order in June 2013: 430 bars
  - 100 bars per month envisaged
  - First 100 have been delivered in August 2013
  - delay in delivery due to quality issues
- 2014: balance by now 232 bars
  - negotiations about rectification, quality checks etc.
  - completion of delivery by April 2014

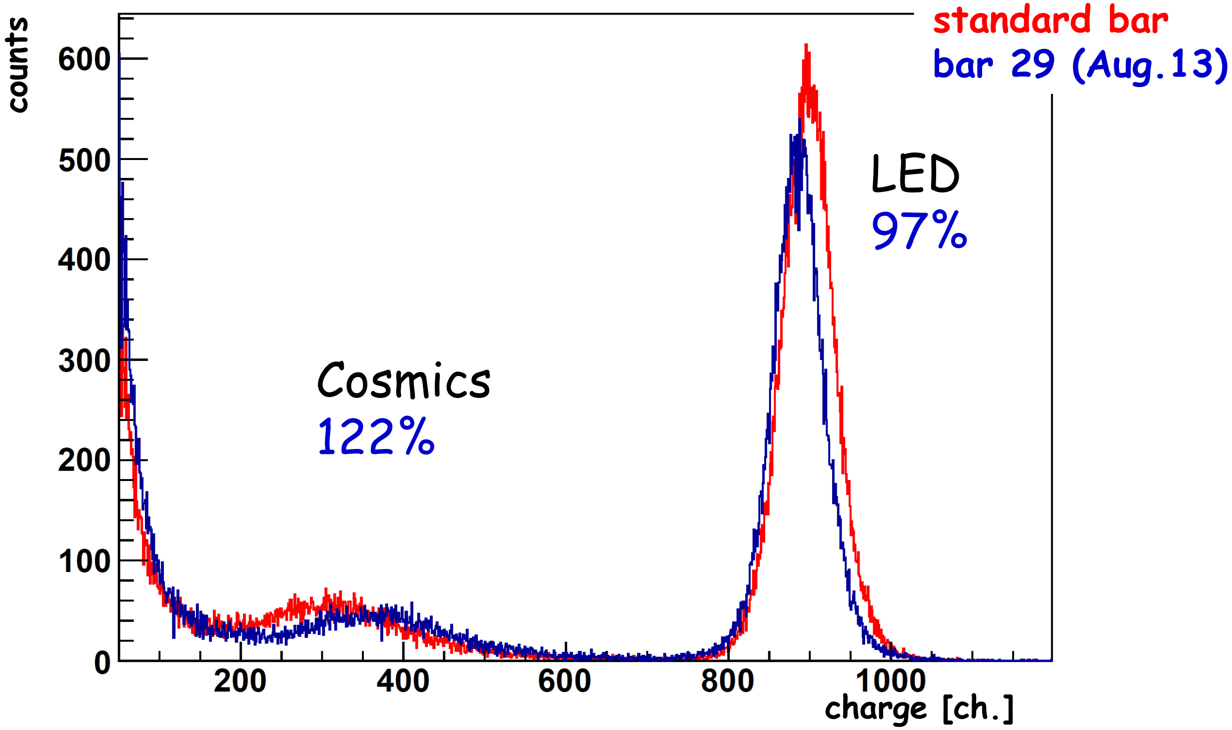
Scintillator Bars combined LED and Cosmic Test

Light-Production Measurement

- detect transversing cosmic rays
- read-out at one or two sides
- check on scintillation quality

Light-Output Measurement

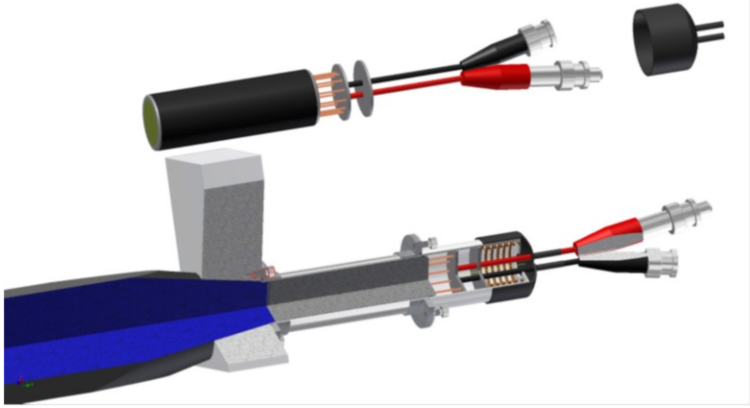
- LED light from one side of bar
- read-out at far side
- check surface quality



Photomultiplier

frame contract with Hamamatsu

- fixed price in Yen for four years
  (30.135 Yen / 223 Euro Nov. 2013)

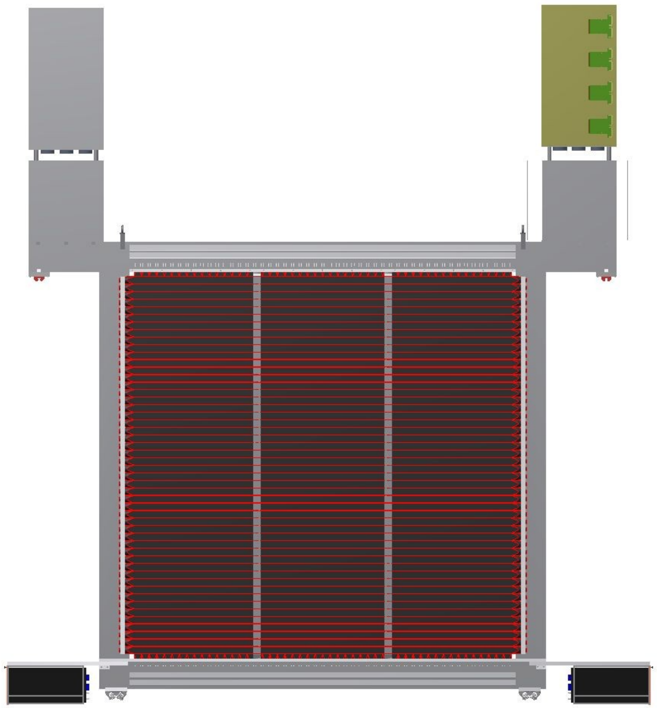


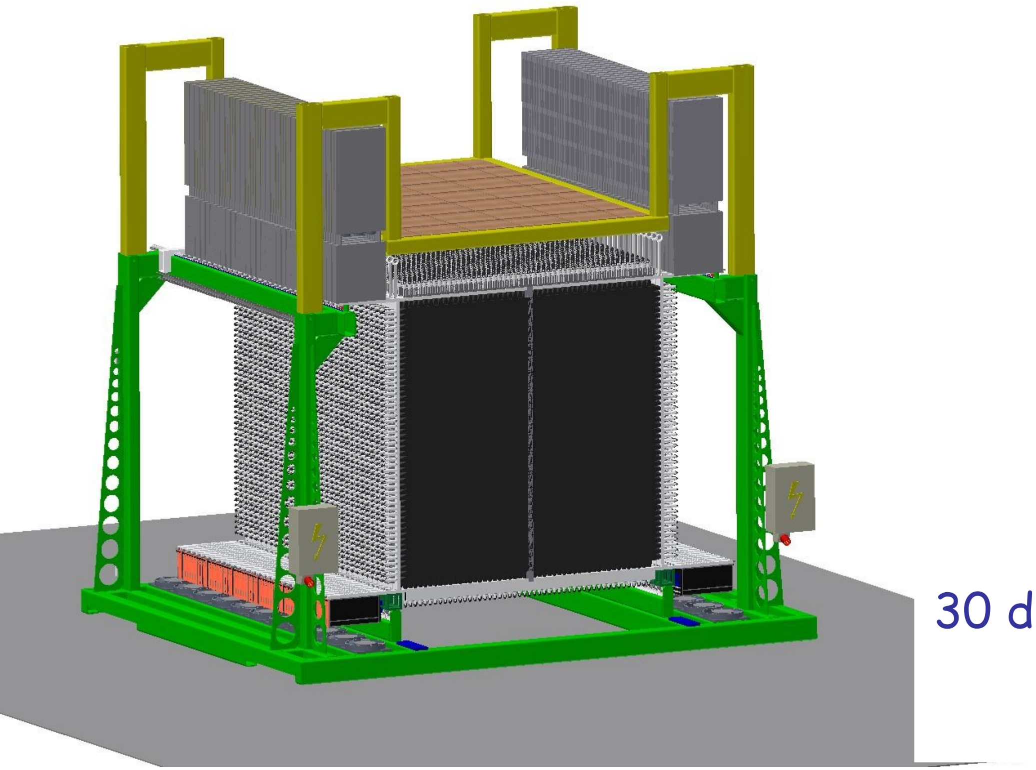
- low-cost version: no connectors
- H8619 with new active voltage divider
  (current down to 10 μA)

- first order in July 13 : 950 PMTs (250 PMTs/month)
- All PMTs have been delivered

From Submodules to Full Detector

100 submodules
build one double-plane with
alternating horizontal and
vertical orientation

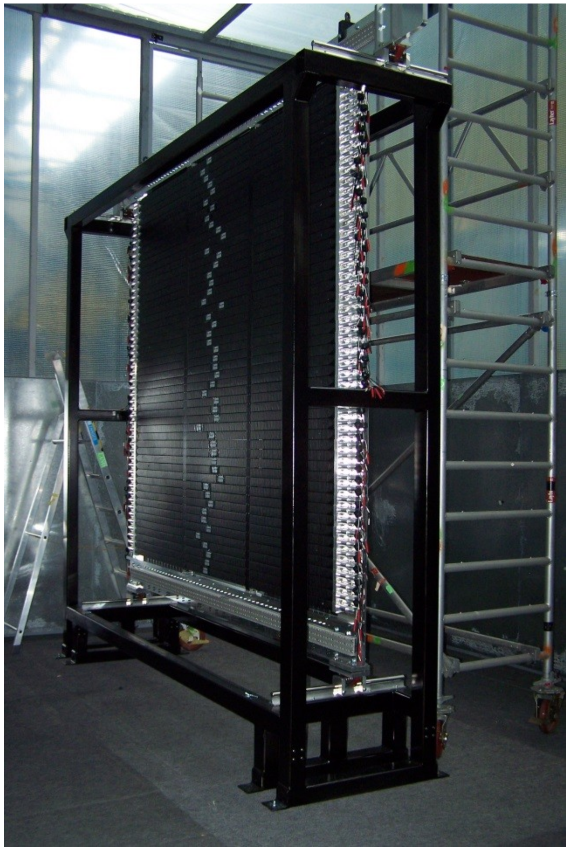


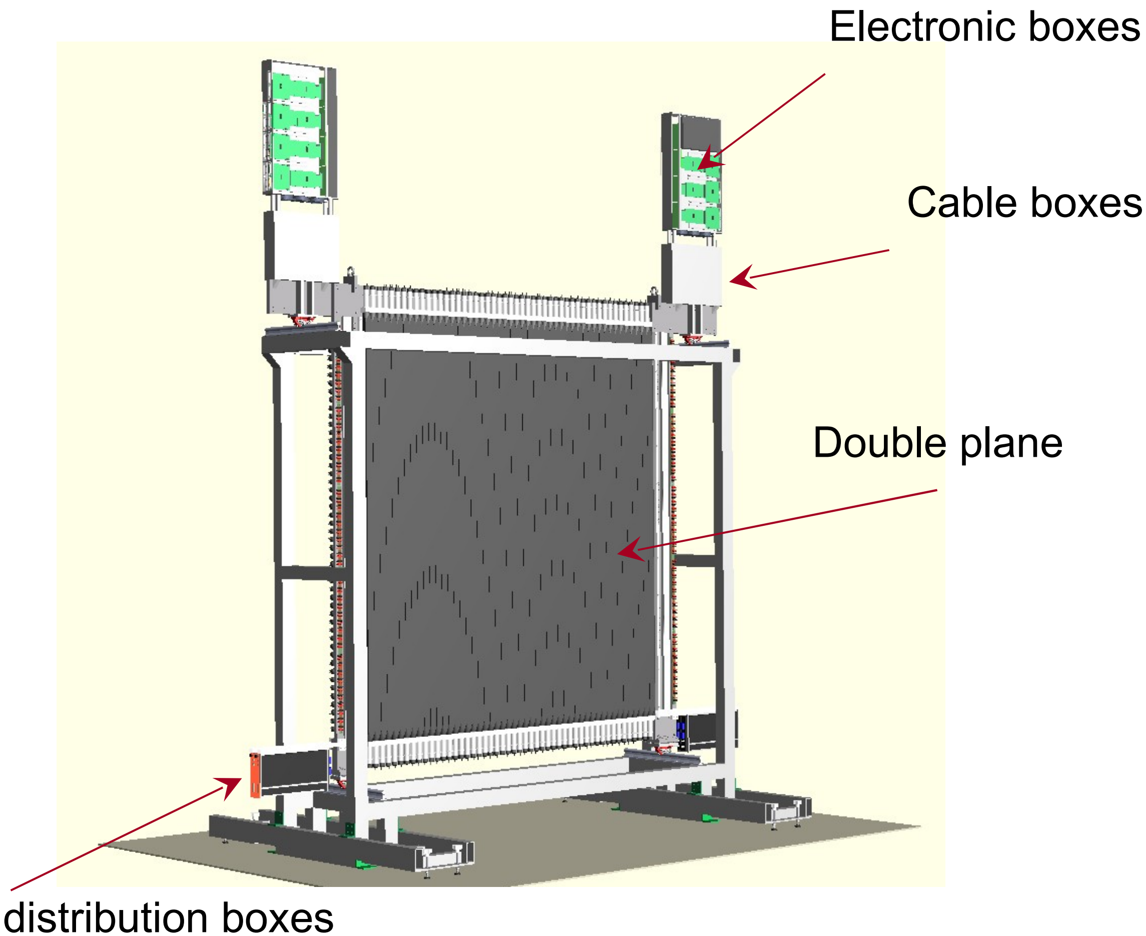


30 double-planes build up NeuLAND
face sice 250x250 cm²
active depth 300 cm

From Submodules to Full Detector

- Mounting rack to be used for the assembly of double planes has been built. It can also serve as a mid-term frame for the 20% NeuLAND demonstrator.



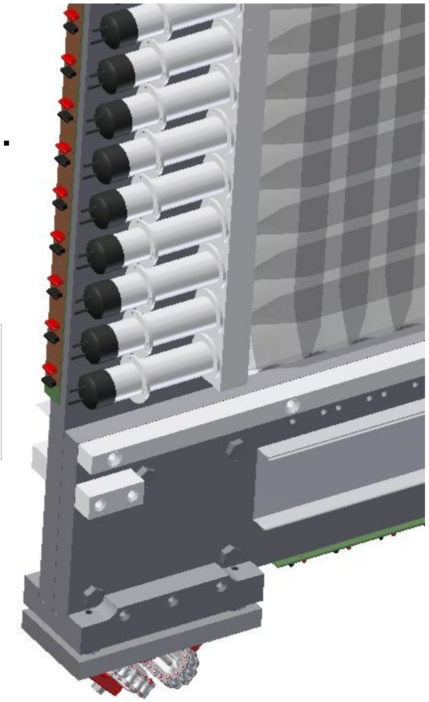


Assembly of Double-Plane 3

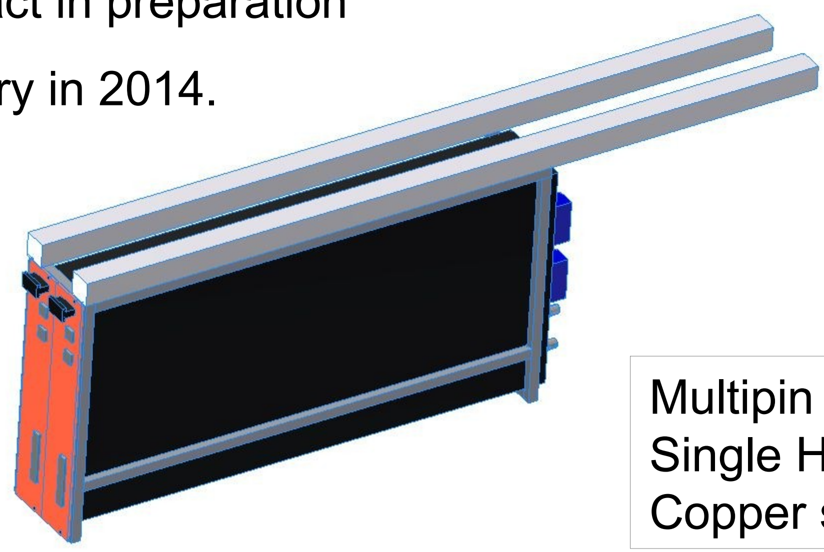
personnel for assembly is coming from the funding institutes (Univ. DA, FFM, Cologne, FAIR@GSI)

NeuLAND HV system – Started production

- For the full size detector 6000 HV channels are needed.
  HV system is based on 2kV main supply with controllable dividers.
- Solution proposed by PNPI (Russia) was accepted by the FAIR council as in-kind contribution.
- Technical Specifications ready
- Collaboration Contract in preparation
- Demonstrator delivery in 2014.



HV connected
via pcb+ connectors

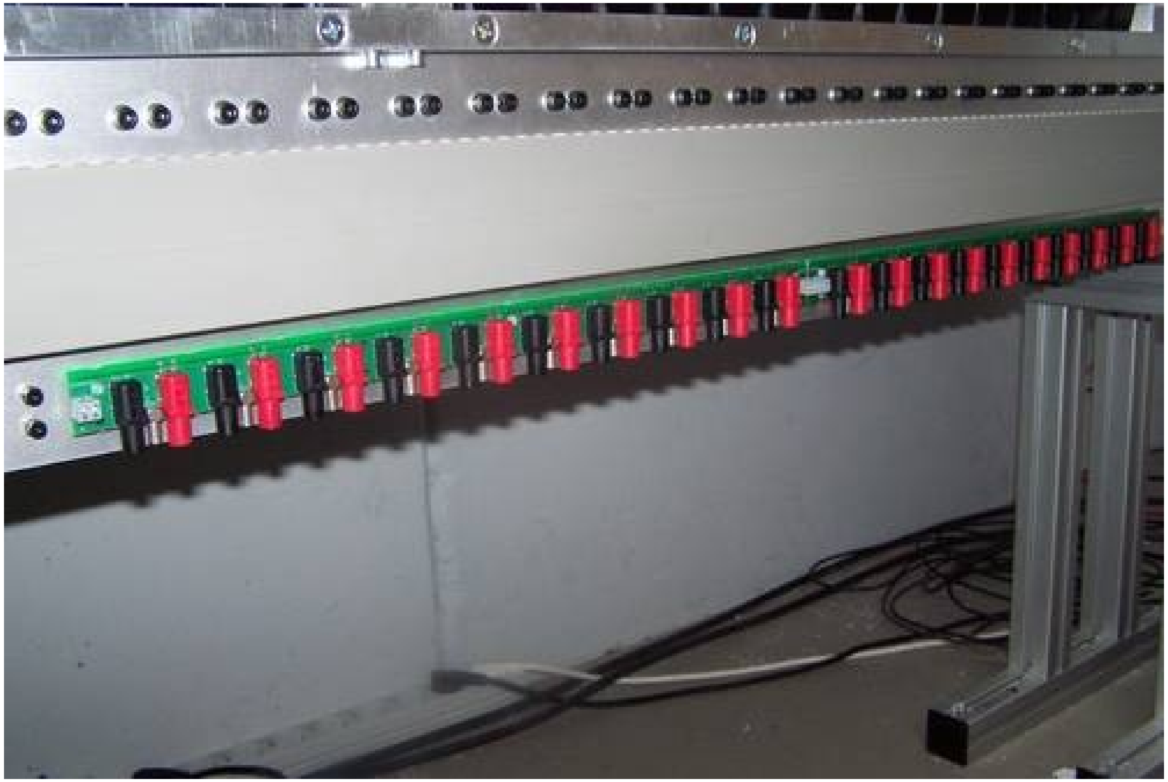


Multipin connector:
Single HV wires
Copper screen on detector

Two boards each 100 ch.

NeuLAND HV system – Completed production

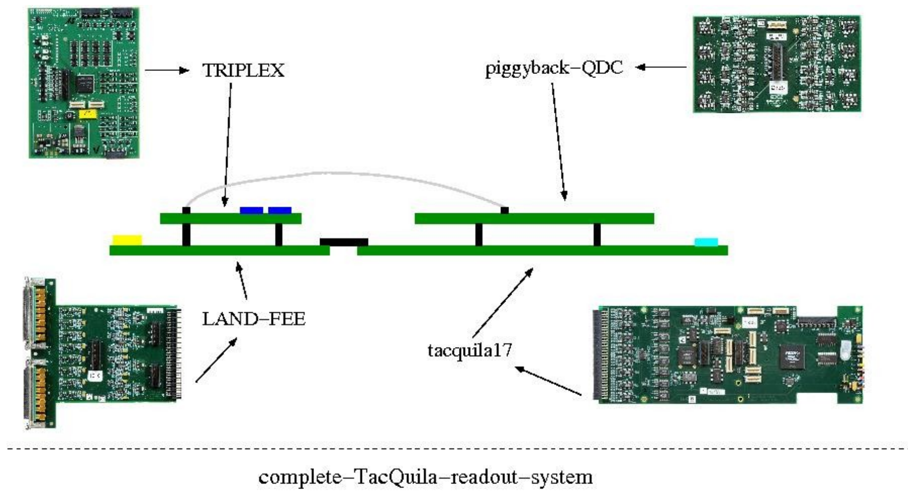
- The high voltage distribution boards have arrived at GSI in Oct 2013. The boards will allow to distribute the HV to each PM and collect the signal cables at the same time. The connectors will allow an easy substitute of photomultipliers.



- boards have been installed and are fully functional since this week.

NeuLAND electronics – Started production

- In-house solution from the GSI CSEE group. Based on the Tacquila system which has been tested during S406 experiment in Oct 2012:



Fully Integrated System: Precision timing, energy, trigger, monitor.

- Ongoing improvements: a new multichannel front-end electronic card TAMEX for high-resolution time and charge measurements has been designed by the GSI CSEE group and ordered. The card is a combination of the existing LAND TACQUILA FEE and a FPGA TDC from the VFTX module. .

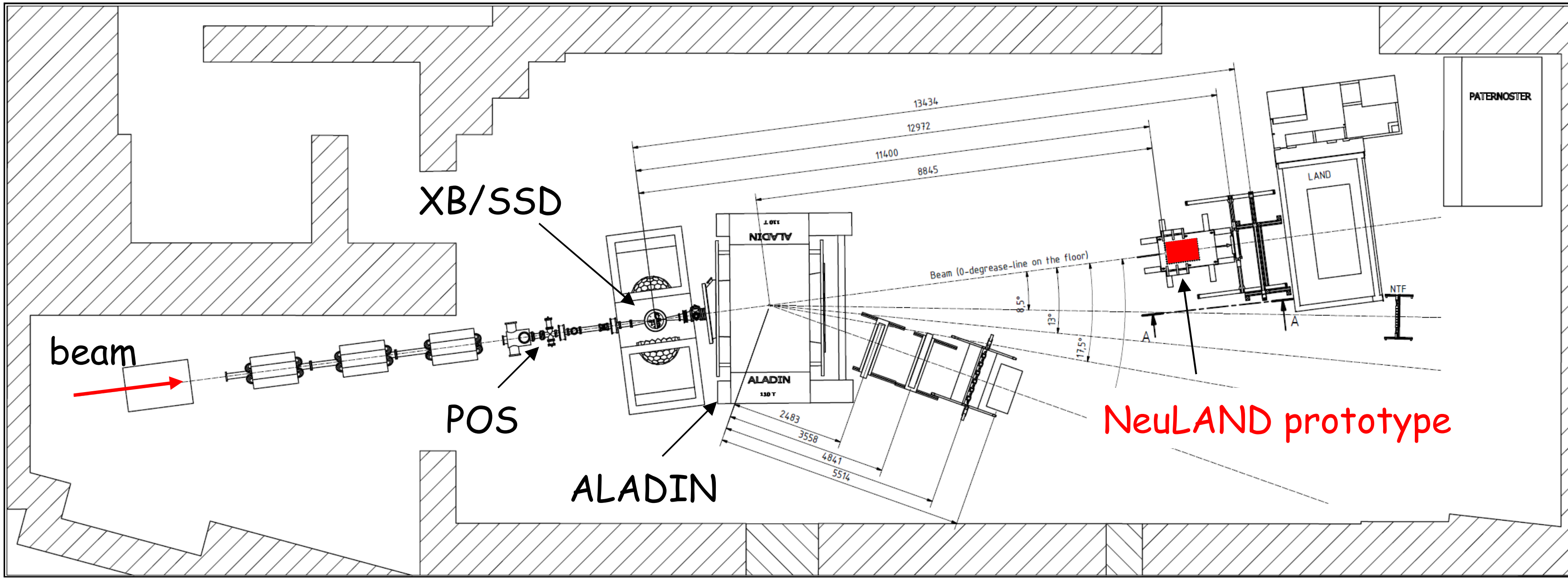
Pictures of the NeuLAND test setup designed of exp. S406 (Nov. 2012)

- goals
  - test NeuLAND prototype
  - time resolution, efficiency, data pattern
  - (determination of present LAND properties)
- d beam at different energies on CH_2 target

  (C target for background)
- neutrons from quasifree scattering (p,2p) reaction

  with defined energy and angle

Experimental Setup

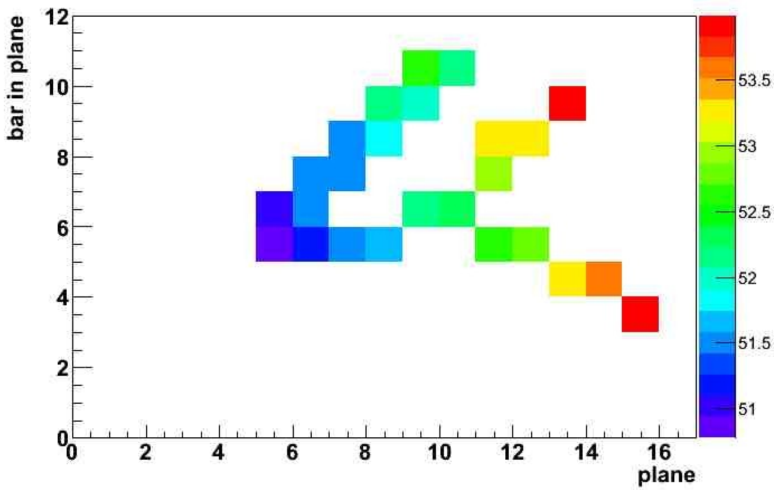


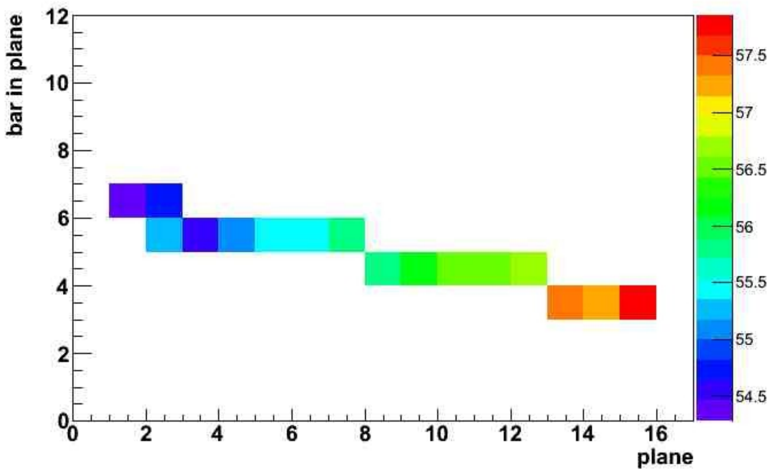
- detectors
  - NeuLAND prototype
  - POS - start detector
  - XB/SSD – Crystal Ball and Silicon Strip Detector
  - ALADIN magnet

- NeuLAND at 5 m
  - 200, 300, 500, 800, 1500 AMeV
- NeuLAND at 10 m
  - 1000, 1500 AMeV

Neutron tracks in NeuLAND test array

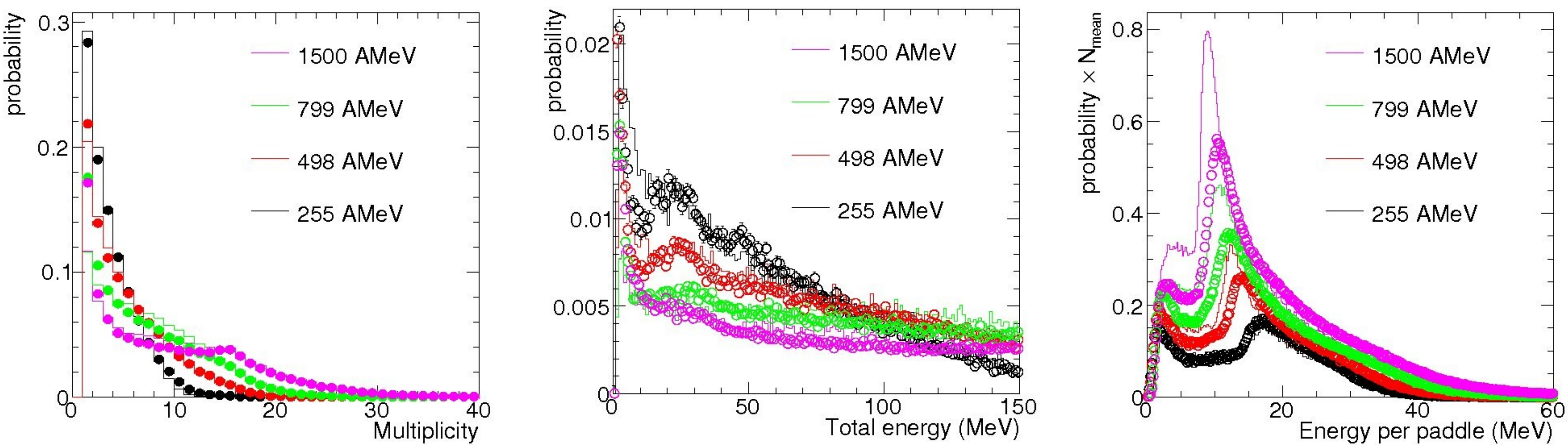
- neutrons knock out charged particles
- propagation in time
- clustering algorithm will be applied (already in simulations)





NeuLAND simulations

- Simulations have been performed using FairRoot simulation package.
- Excellent agreement between simulation and experimental data measured during the S406 experiment has been obtained.

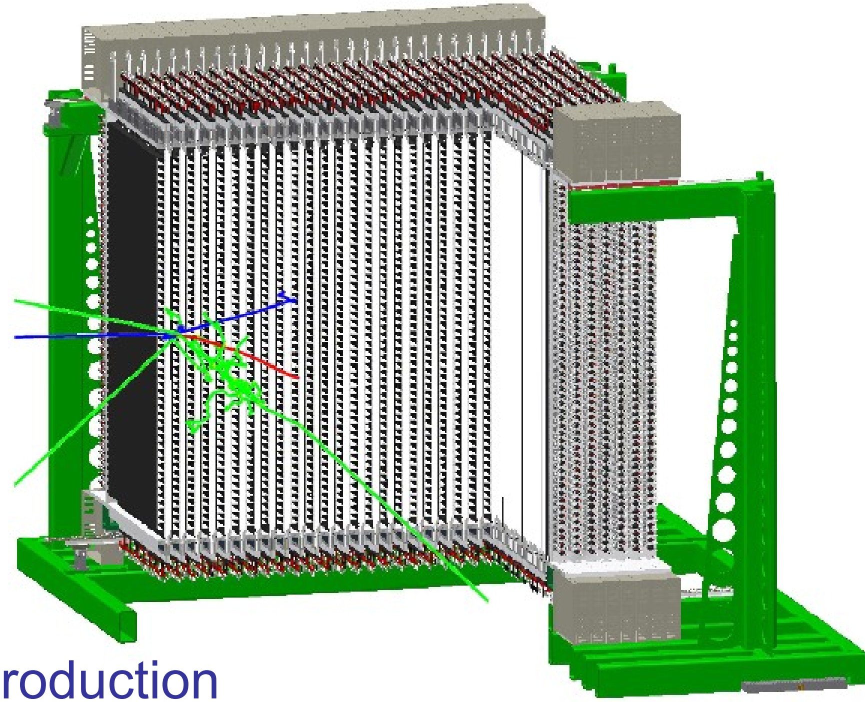


Perspectives for 2015 /2016

- No GSI beam times
- up to four d.pl. are foreseen to be brought to RIKEN for further „in-beam tests."

  (in conjunction with NEBULA @ SAMURAI)
- Production of further planes will continue at GSI

Summary



NeuLAND
a versatile instrument
to detect
multiple high energy neutrons
with high resolution

- transition from exploratory phase to production
- 20% detector envisaged for Q2/2014
- NeuLAND production "independent" of FAIR timelines
- relevance of beam times for detector development!
- exploratory experiments foreseen at Cave C:
  - neutron calibration with NeuLAND double-planes
  - (physics experiments including fast neutrons)

The R3B Collaboration

A next generation experimental setup for studies of

Reactions with **R**elativistic **R**adioactive **B**eams

spokesperson: Tom Aumann

>50 institutes

20 countries

>220 participants

embedded in NUSTAR


THE END

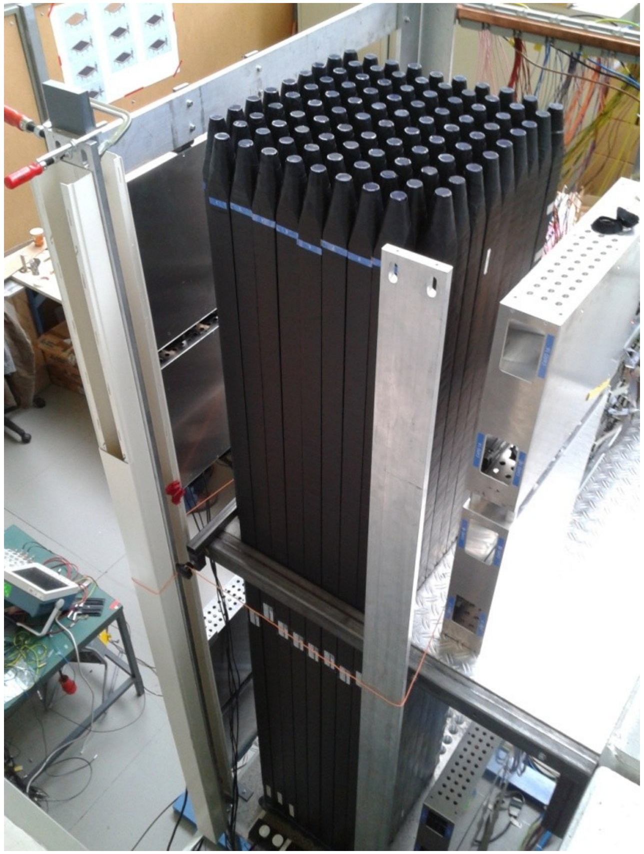
The R3B Collaboration

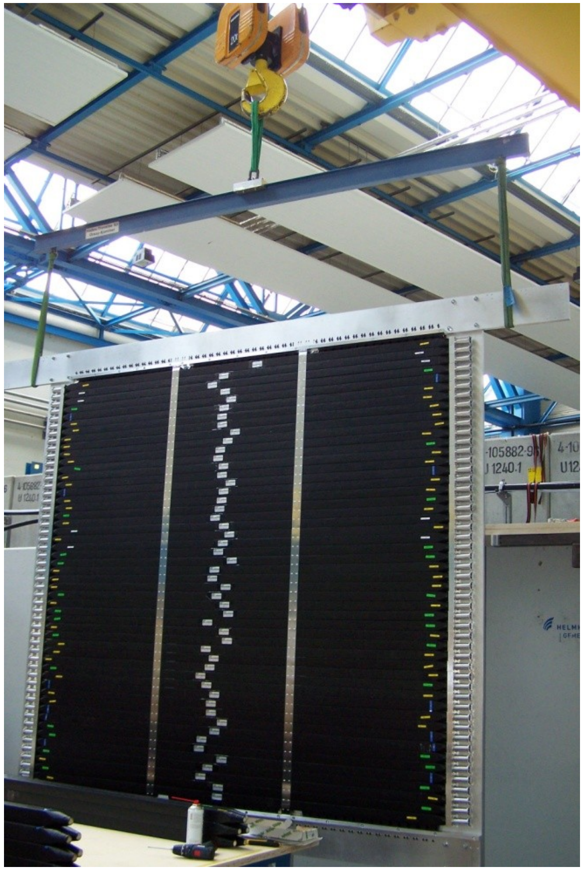
T. Adachi[1], Y. Aksyutina[2,15], J. Alcantara[3], S. Altstadt[4], H. Alvarez-Pol[3], N. Ashwood[5], T. Aumann[6,2], M. Barr[5], S. Beceiro[3], D. Bemmerer[7], J. Benlliure[3], K. Boretzky[2], G. Burgunder[8], M. Caamano[3], C. Caesar[6], E. Casarejos[3], W. Catford[9], S. Chakraborty[10], M. Chartier[11], D. Cortina-Gil[3], U. Datta Pramanik[10], P. Diaz[3], I. Dillmann[2], J. Enders[6], O. Ershova[4], A. Estrade[2], F. Farinon[2], L.M. Fraile[12], M. Freer[5], M. Freudenberger[6], D. Galaviz Redondo[13], D. Gonzalez Diaz[6], J. Hagdahl[8], T. Heftrich[4], M. Heil[2], M. Heine[6], A. Henriques[13], M. Holl[6], A. Ignatov[6], H. Johansson[8], B. Jonson[8], N. Kalantar[1], R. Knöbel[2], T. Kroell[6], R. Krücken[14], J. Kurcewicz[2], M. Labiche[7], C. Langer[4], T. LeBleis[14], R. Lemmon[7], J. Machado[13], J. Marganiec[15], A. Movsesyan[6], A. Najafi[1], T. Nilsson[8], C. Nociforo[2], V. Panin[6], S. Pietri[2], R. Plag[4], A. Prochazka[2], A. Rahaman[10], G. Rastrepina[2], R. Reifarth[4], G. Ribeiro[9], M.V. Ricciardi[2], C. Rigollet[1], K. Riisager[1], M. Röder[16], D. Rossi[2], J. Sanchez del Rio[12], D. Savran[15,17], H. Scheit[18], H. Simon[2], O. Sorlin[8], B. Streicher[1], J. Taylor[11], O. Tengblad[12], S. Terashima[2], R. Thies[8], T. Yasuhiro[18], E. Uberseder[19], J. Van de Walle[1], P. Velho[13], V. Volkov[6], A. Wagner[7], F. Wamers[6], H. Weick[2], M. Weigand[4], C. Wheldon[5], G. Wilson[9], C. Wimmer[4], J. Winfield[2], P. Woods[20], D. Yakorev[7], M. Zoric[2], and K. Zuber[16]

[1]KVI Groningen, Netherlands; [2]GSI Darmstadt, Germany; [3]University of Santiago de Compostela, Spain; [4] University of Frankfurt, Germany; [5]Birmingham University, United Kingdom; [6] TU Darmstadt, Germany; [7] HZDR Dresden-Rossendorf, Germany; [8]GANIL, Caen, France; [9] University of Surrey, United Kingdom; [10] SINP Kolkata, India; [11] University of Liverpool, United Kingdom; [12] Universidad Complutense of Madrid, Spain; [13]University of Lisbon, Portugal; [14] TU Munich, Germany; [15]ExtreMe Matter Institute EMMI and Research Division, GSI Darmstadt, Germany; [16]TU Dresden, Germany; [17]Frankfurt Institut for Advanced Studies FIAS, Frankfurt, Germany; [18] RIKEN, Japan; [19]University of Notre Dame, United States; [20]University of Edinburgh, United Kingdom

NeuLAND scintillator bars – Completed production

- Full detector contains 3000 scintillator bars arranged in 30 double planes.
- 150 bars tested with fast neutrons in Nov. 2012 during S406 experiment at GSI.
- In July 2013 the first double-plane has been built. In Nov 2013 2nd and 3rd double planes have also been built. Buildup of the 4th plane started (Dec 2013).

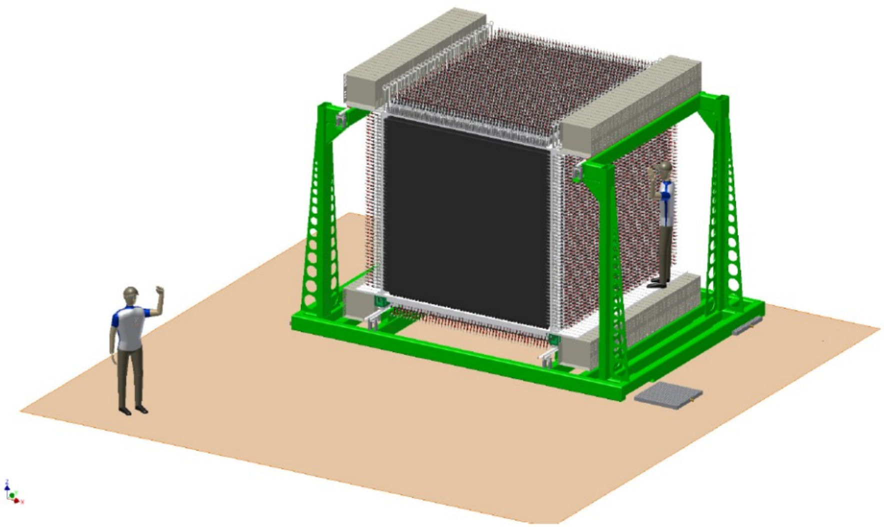




Test setup used during S406 experiment.

First NeuLAND double plane built at GSI.

Constituents of NeuLAND



NeuLAND detector parameters:

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- face sice 250x250 cm2
- active depth 300 cm
- 32 tons

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- 6000 PMTs / HV / readout channels
- 30 double-plane frames
- 3 detector frames

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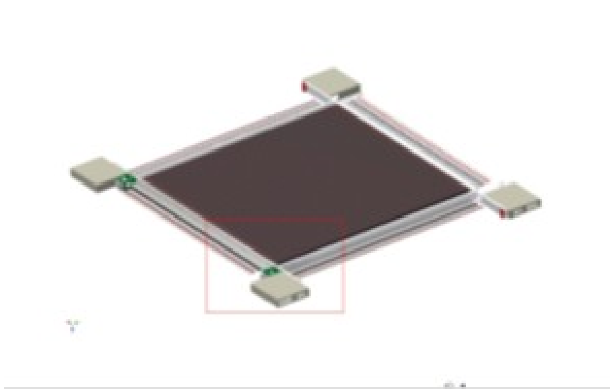
- >90% efficiency for 0.2-1.0 GeV neutrons
- Multi-hit capability for up to 5 neutrons
- invariant-mass resolution: NeuLAND-target distance 35 m
  ΔE < 20 keV at 100 keV above the neutron threshold
- "tetra-neutron" case: NeuLAND-target 35 m, 600 AMeV
  ΔE ≈ 40 keV at 100 keV for 4 n's at 60% tot. eff.!



NeuLAND from Feb. 2011 to now

- May 2011: decision on final design
  fully active scintillator concept
- Nov. 2011: submission of Technical Design Report (TDR)
- 2012:
  - purchase of 150 submodules
  - development of quality control
  - assembly of NeuLAND test array
  - exposure to fast neutrons in GSI exp. S406
- Jan. 2013: approval of NeuLAND TDR by FAIR
- ongoing:
  - purchase of about 20% of NeuLAND modules
  - finalization of mounting structures
  - selection of HV distribution system

NeuLAND: The High Resolution Neutron Time-of-Flight Spectrometer for R³B

Performance goals:

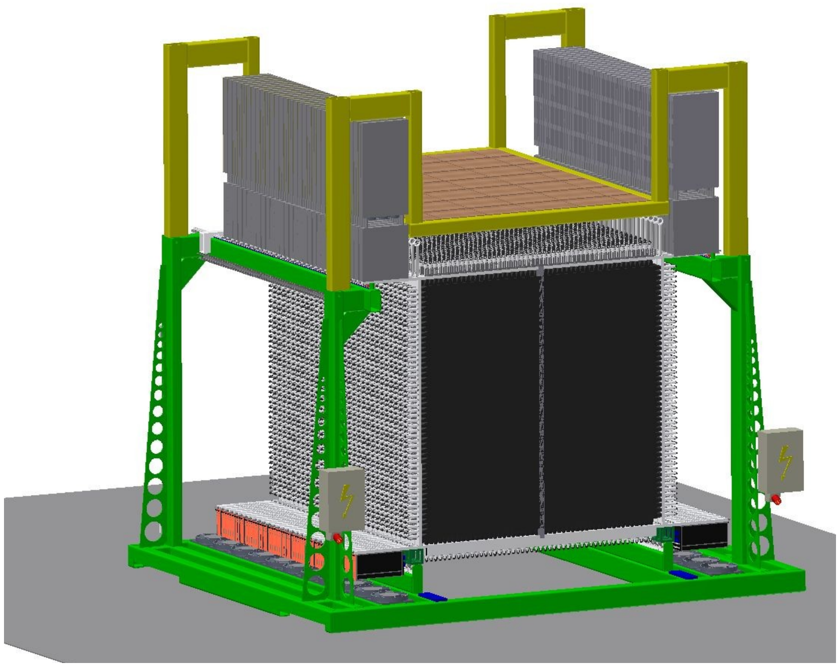
- >90% efficiency for 0.2-1 GeV neutrons
- Multi-hit capability for up to 5 neutrons
- <150 ps time resolution
- 20 keV excitation-energy resolution at 100 keV above neutron threshold.

Detector parameters:

- Full active detector using organic scintillator
- Face size 250x250 cm^2, active depth 300 cm
- 3000 scintillator bars
- 6000 photomultiplier and readout channels
- Modular design.

Detector financing:

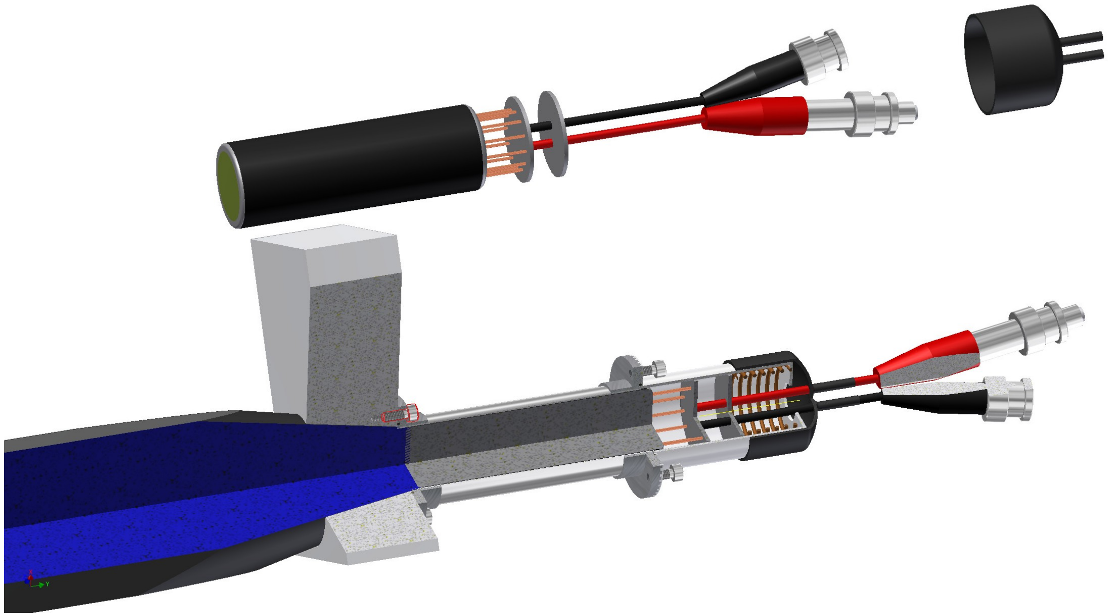
- 20% demonstrator (1020 k€) already financed by BMBF and PMA; demonstrator ready by Q1/2014
- Upgrade to 45% detector (1180 k€) will be financed by secured funds of BMBF and PMA plus proposed in-kind contribution by PNPI, Russia (3.6.2013); 45 % detector ready by Q4/2015
- High Voltage system (527k Euro) proposed as in-kind contribution by PNPI, Russia (3.6.2013)
- NeuLAND mechanics and infrastructure (248k Euro) financed through PMA.



NeuLAND Technical Design Report has been approved on Jan. 18, 2013 by FAIR.

NeuLAND planes – Completed and started procurement

- **Scintillator bars**: Call for tender for the remaining scintillator bars closed, frame contract signed with REXON. First charge has been delivered in Aug 2013, 2nd charge in Nov 2013.
- **Photomultipliers**: For the full-size detector 6000 PMs are needed. Frame contract signed with HAMAMTSU. First charge of PMs has been delivered to GSI in Sept 2013. Second charge arrived in Dec 2013.



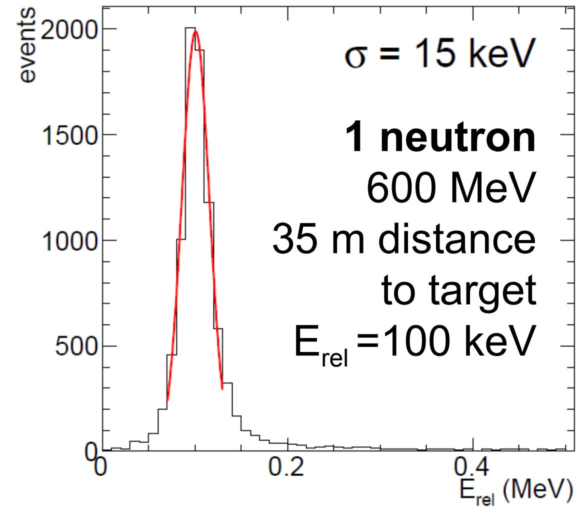
- Goal for 2014 – to purchase and assemble in total 6 double planes.

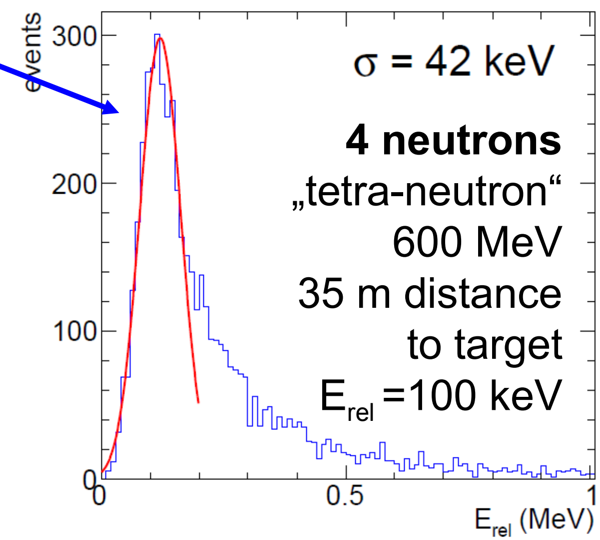
Performance Examples

high multi-neutron recognition:

	%	600 MeV generated 1n	2n	3n	4n	5n
detected	1n	**93**	21	2	0	0
	2n	3	**72**	31	5	1
	3n	0	6	**55**	32	8
	4n	0	0	10	**60**	51
	5n	0	1	1	3	**35**
	6n	0	0	0	0	5

high resolution at the particle threshold:





high efficiency for low neutron energies:

E_n [MeV]	Eff. [%]
50	79
100	94
150	95
200	91