A compact decay spectroscopy set-up for SHN research
Si Detectors for SHE Research

- decay spectroscopy for SHN

- nuclear structure features of superheavy nuclei
  (decay spectroscopy after separation)
  - quasi-particle excitations → deformation/K-isomers
  - single particle levels - trends towards the next closed p- and n-shell
  - X-ray Z-identification

- reaction studies
  - isospin dependent investigations towards n-rich SHN
  - investigating feature of the interaction barrier via reaction dynamics

- detection
  - DSSD/SSSD array
  - combined with large volume Ge's
  - APFEL ASIC & FEBEX digital ADC's
  - mobile set-up

[Diagram showing superheavy nuclei with spherical and deformed shell-stabilised structures]
Nuclear Structure of SHE
- Decay Spectroscopy at SHIP/TASCA

- Isomer surviving separation
- $\gamma$ emission after $\alpha$ decay
- CE for highly converted transitions + X-ray emission
Particle Identification and Discrimination

- Spectroscopy of SHE at SHIP/TASCA

Target (rot. wheel) → Separator (e.g. SHIP, TASCA...) → Focal Plane Detectors

- Beam
- 48Ca
- 40Ar
- 50Ti
- 54Cr
- 206Pb
- 207Pb
- 208Pb
- 209Bi

- ER
- TOF (anti-coincidence)
- 'STOP'
- 'Backward'
- γ - ray (segmented)

High eff. ε ≈ 15%
Particle Identification and Discrimination
- Spectroscopy of SHE at SHIP/TASCA

Target (rot. wheel)  Separator (e.g. SHIP, TASCA)

Focal Plane

high eff. $\varepsilon \approx 15\%$

- inclusive measurement
- ER, $\alpha$'s, $\gamma$'s and e-
- clean
- particle discrimination
- ER-\$\alpha$-\$\gamma$ correlations
- highly efficient
- close geometry
- stopped source

**Mobile Decay Spectroscopy Set-up - MoDSS**

- Si stop+box (DSSD+SSSD) combined with large volume Ge-detectors

**Configuration**

- **Stop detector:** 1 × DSSD (60×60 strips)
- **Box detectors:** 4 × SSSD (32 strips, TASiSpec)
- Overall efficiency similar to TASiSpec (40%)

**Chamber**

- Compact (overall length 35 cm)
- Al-cap with thin γ window (1,5 mm)
- Compatible due to 150 mm standard flange
- Electronics partly integrated (vacuum)

**DSSD**

- Integrated cooling (Cu-frame) and connection (flex-PCB)
- 60×60 strips/mm (pitch 1 mm)
- 300 µm
Electronics and read out
- 2 integrated options

2 read out options:

1. ASIC APFEL (fast shaping and amplification)
   - integrated in PCB vacuum feed through
   - cooled (separate detector and ASIC cooling)
   - 64 input channels (8 piggybacks)
   - 2 amplification factors
     - 1
     - 16/32 switchable
   - differential output

2. classic PA
   - PCB vacuum feed through
   - 2×32 channels
   - differential output

In total max. 256 channels
Electronics and DAQ
- compact front end and MBS/NUSTAR DAQ

MBS architecture

- local server + mass storage (standalone)
- 2 MBS branches

1. RIO power PC/VME
   - analog shaping and amplification (Mesytech STM16+)
   - 32-fold 12bit ADCS (Mesytec MADC, CAEN V785)

2. FEBEX + MBS-Linux PC
   - 1 FEBEX frame – 198 channels
   - event builder
   - 3 operation modes
     1. classic PA + RIO power PC/VME
     2. classic PA + FEBEX
     3. ASIC APFEL + FEBEX
Digital electronics
- **FEBEX: the GSI approach**

pipeline ADC Front End Board with optical link Extension actual version: FEBEX 3a
- 16 channels
- 50 Ms/s (optional/future 100+ Ms/s)
- 14 bit flash ADC

**J. Hofmann GSI/EE**

FEBEX + conventional PA
- fast timing
- deadtime free
- pulse shape analysis options

FEBEX + ASICS “APFEL”
- fast shaping (<250 ns)
- 2 amplification ranges (1x and 16x/32x)
- PANDA development – P. Wieczorek

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48\text{Ca} + 176\text{Yb} \quad \alpha_1 \quad \alpha_2 \quad t_{1_2}: 7.7 \mu s \quad t_{2_3}: 308 \text{ ns}

J. Khuyagbaatar
R. Mändl

R. Mändl
bachelor thesis
Test and first application
- spectroscopy at the LISE velocity filter @ GANIL

Tests with sources summer 2014

- all solutions have been tested singly with $\alpha$-source

- resolution for classic PA + analog ADC
  \[ \Delta E(6\text{MeV}) < 30 \text{ keV} \]

- APFEL/classic PA + FEBEX needs some more effort
  \[ \Delta E(6\text{MeV}) > 50 \text{ keV} \]

First in beam test november 2014

- $^{40}\text{Ar} + ^{174}\text{Yb} \rightarrow ^{214}\text{Ra}^*$

- test of all options (analogue and digital)

- integration in the LISE focal plane set-up

- $\alpha$ and $\alpha$-\gamma correlations

First experiment spring/summer 2015$^*$

- $^{50}\text{Ti} + ^{209}\text{Bi} \rightarrow ^{257}\text{Db} + 2\text{n}$

- $\alpha$ and $\alpha$-\gamma spectroscopy for $^{257}\text{Db}$, $^{253}\text{Lr}$ and $^{249}\text{Md}$

*) not scheduled yet
Test and first application
- spectroscopy at the LISE velocity filter @ GANIL

Tests with sources summer 2014
- all solutions have been tested singly with α-source
- resolution for classic PA + analog ADC
  - ∆E(6MeV) < 30 keV
- A PFEL/classic PA + FEBEX needs some more effort
  - ∆E(6MeV) > 50 keV

First in beam test November 2014
- 40Ar + 174Yb → 214Ra*
- test of all options (analogue and digital)
- integration in the LISE focal plane set-up
- α and γ correlations

First experiment spring/summer 2015*
- 50Ti + 209Bi → 257Db + 2n
- α and γ spectroscopy for 257Db, 253Lr and 249Md

*) not scheduled yet
Test and first application
- spectroscopy at the LISE velocity filter @ GANIL

Tests with sources
- summer 2014
  - all solutions have been tested singly with α-source
  - resolution for classic PA + analog ADC
    - $\Delta E(6\text{MeV}) < 30\text{ keV}$
  - A PFEL/classic PA + FEBEX needs some more effort
    - $\Delta E(6\text{MeV}) > 50\text{ keV}$

First in beam test
- November 2014
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*) not scheduled yet

DSSD camber connected to LISE back end
Acknowledgement

- set-up working group and experiment collaboration

Preparation of the set-up

**GSI:**

J. Hoffmann (electronics design)
N. Kurz (MBS)
J. Maurer (chamber design)
S. Voltz (PCB lay-out)
P. Wieczorek (APFEL ASIC)
D. A.

**GANIL:**

M. Vostinar
J. Piot

PROPOSAL FOR AN EXPERIMENT

Title: Decay spectroscopy of $^{157}$Db

**Collaboration:** Participant names, institutions, and indicate students (S), and post-doctoral fellows (PD): M. Vostinar,1 H. Savajols,1 E. Clément,1 C. Stodel,1 B. Gall,2 D. Ackermann,2 S. Antalic,3 B. Bastin,1 L. Caceres,1 F. Dechery (PD),2 O. Dorvaux,2 A. Drouart,6 H. Faure (S),2 J. Gibelion,7 K. Hauschild,8 G. Henning (PD),8 R.-D. Herzberg,9 F.P. Heßberger,4 J. Konki,3 W. Korten,6 J. Ljungvall,8 A. Lopez-Martens,8 T. Roger,1 M. Sandzelius,3 J. Sorri,3 B. Sulignano,6 C. Theisen,6 and J.C. Thomas,1 J. Uusitalo3

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