# A novel $LN_2$ fill level meter

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# Motivation



AGATA detectors are operated at $90\,\mathrm{K}$ and $p \approx 10^{-7}\,\mathrm{mbar}$

- When detector gets warm: getter starts gasing out and HV-sparks may damage electronics in the cold part $\rightarrow$ long downtimes
- Temperature-monitoring via PT100-sensor: detector system reacts slow on changes of temperature in cold part
- Leakage current-monitoring: Detector is not operational anymore
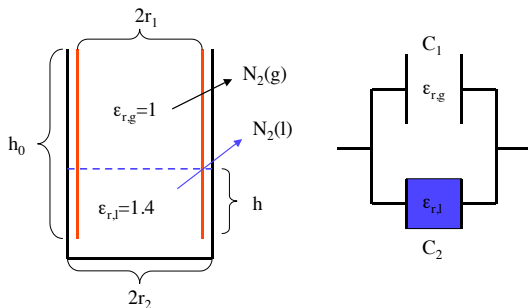- Direct monitoring of the $\mathrm{LN_2}$-level

# The capacitive LN$_2$-level-monitor

- Each AGATA-dewar is equipped with a further (inner) cylinder in the interior $\rightarrow$ cylindrical capacitor
- Capacity is measured as function of the LN$_2$-filling-level
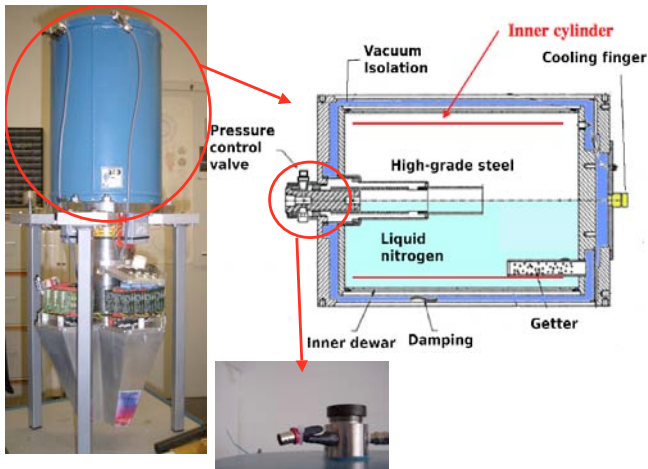
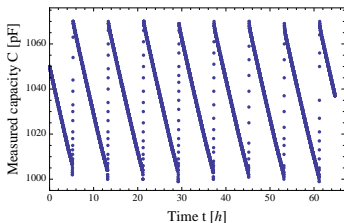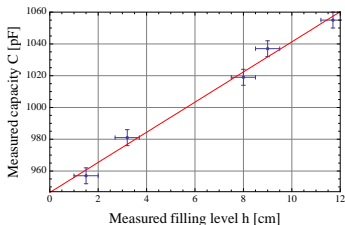# The capacitive $LN_2$-level-monitor



$C_1 \sim \epsilon_0 A(h_0 - h)$

$C_2 \sim \epsilon_0 \epsilon_{r,l} A(h)$

The capacity $C$ as function of the $LN_2$-filling-level $h$ of a cylindrical capacitor with radius $r_1$ and $r_2$:

$$C(h) = C_1 + C_2 = 2\pi\epsilon_0 \cdot \ln\left(\frac{r_2}{r_1}\right)^{-1} \cdot \left(h_0 + 0.4h\right)$$
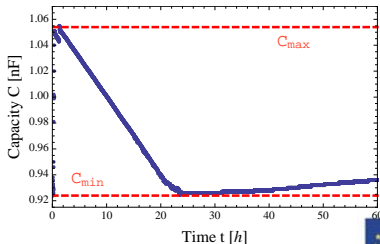
# The capacitive $LN_2$-level-monitor





- Measurements show linear dependency between capacity and $LN_2$-filling-level
- Filling-capacity is also a linear function of time
- Difference $\Delta C$ between empty and full dewar:
  $\Delta C = C_{max} - C_{min} =$
  $1054\,\mathrm{pF} - 924\,\mathrm{pF} \approx 12\,\%$
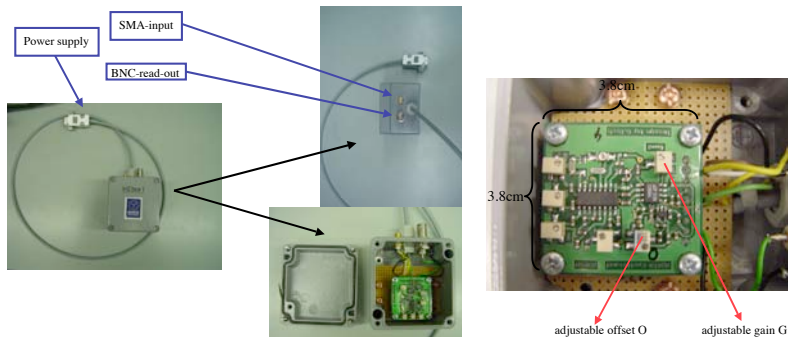
# $LN_2$-consumption-Measurements

- Another advantage of capacitive $LN_2$-read-out: information about $LN_2$-consumption
- Consumption influenced by configuration of the cold part (e.g. cabling, electronics, applied low voltage)
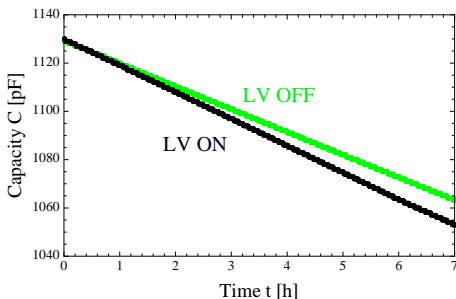


| LV || $\nu\left[\frac{\mathrm{ml}}{\mathrm{h}}\right]$ | $\tau[\mathrm{h}]$ |
|-----|-----------------|-------------|
| ON  | $419 \pm 19$    | $11 \pm 0.5$ |
| OFF | $378 \pm 23$    | $12 \pm 0.7$ |

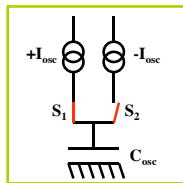# The C/V-transducer



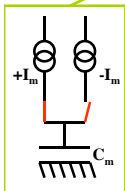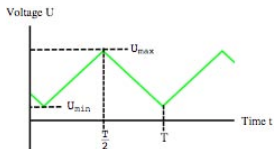adjustable offset O         adjustable gain G

- C/V-transducer: does not measure whole range of $1000\,\mathrm{pF}$, but difference $C_m - C_r \rightarrow$ sensitive to $\Delta C \sim 12\,\%$
- The filling capacity $C_m$ is translated into a DC-voltage signal $V(G, O, C_m) = m(G) \cdot C_m + V_0(G, O)$ with adjustable gain G and offset O
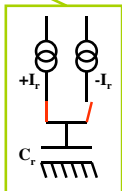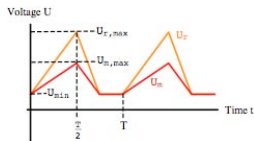
# The C/V-transducer
## Principle



- Capacitor is charged / discharged by constant current $\rightarrow$ triangular wave signal
- Reference oscillator drives phase-locked and clock-synchronized two identical integrators with capacities $C_r$ and $C_m$
- Difference signal $C_m - C_r$ is filtered and amplified $\rightarrow$ DC-voltage

# The C/V-transducer
Adjusting and calibrating

- Last AGATA-week: prototype of $LN_2$-read-out was successfully tested at ATC(4)
- 4 further devices @ Cologne and tested at ATC(4) ($C_{min} = 924\,\mathrm{pF}$, $C_{max} = 1054\,\mathrm{pF}$, $\Delta C = 130\,\mathrm{pF}$)
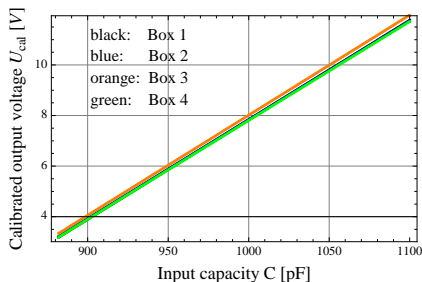


- Adjustment of output-voltage with gain- and offset-potentiometer
- Output-voltage of each device defined: $V_{min}(C_{min}) = 5\,\mathrm{V}$, $V_{max}(C_{max}) = 10\,\mathrm{V}$
- $\Delta C = 130\,\mathrm{pF} \rightarrow \Delta U = 5\,\mathrm{V}$
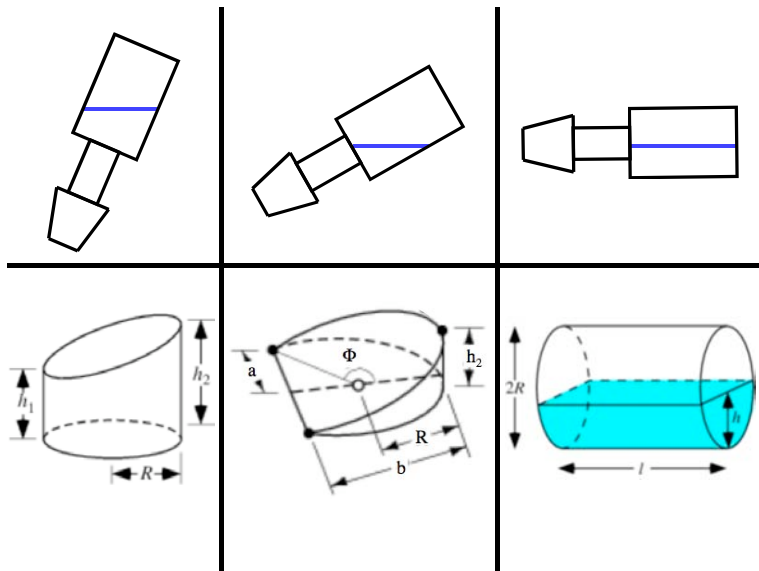
# Position-dependent measurements
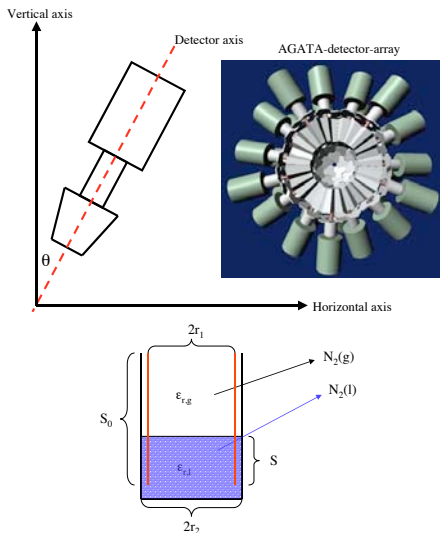


- Different detector positions in array
- Influence of inclination $\theta$ on $LN_2$-read-out
- Geometrical shape of liquid nitrogen inside dewar
- Parameterisation: Surface $S(\theta)$ covered with liquid nitrogen is proportional to filling-capacity $C$: $S(\theta) \propto C$
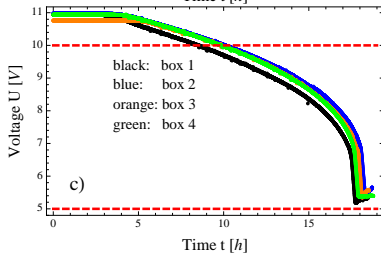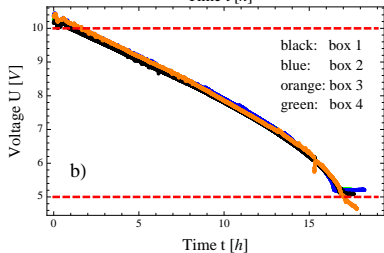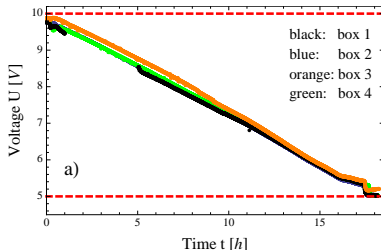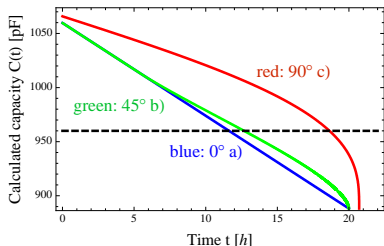
# Geometrical shapes of $LN_2$ inside the dewar

# Position dependent measurements

Calculations and results

# Summary and outlook

- The capacitive $LN_2$-read-out is working
  - $C$ is a function of filling height $h$
  - Difference between full and empty dewar: $\Delta C \sim 12\,\%$
- Implementation of the C/V-transcenducer
- Position dependent measurements of the filling capacity
  - Inclination have an influence on the filling capacity
  - Common operation time
  - Define common treshold
- Integration of C/V-transducer in AGATA-patchpanel and the cryogenic filling system