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Combined field grading and field shielding for double breaking vacuum chambers under lightning impulse stress

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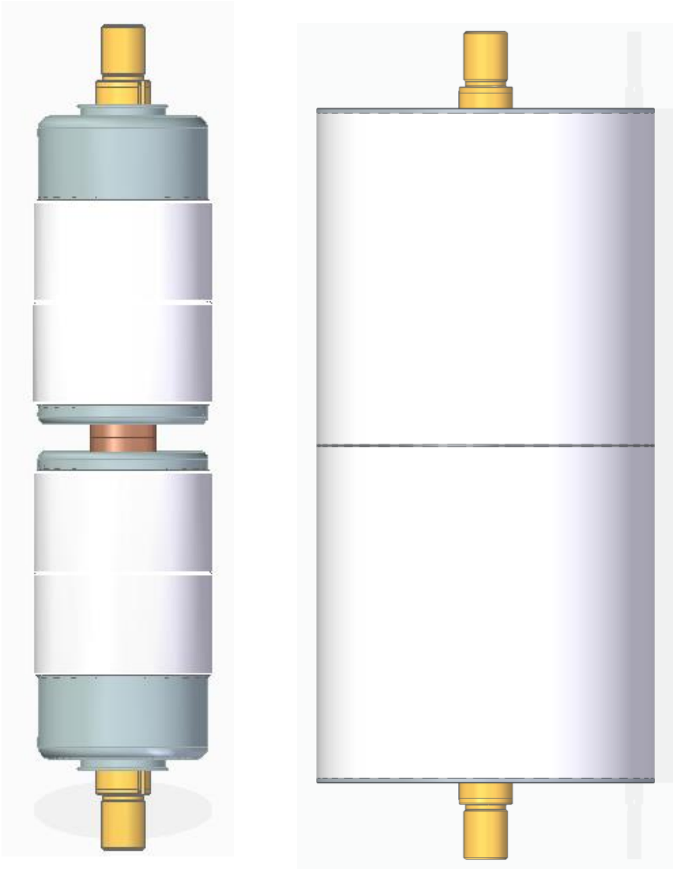
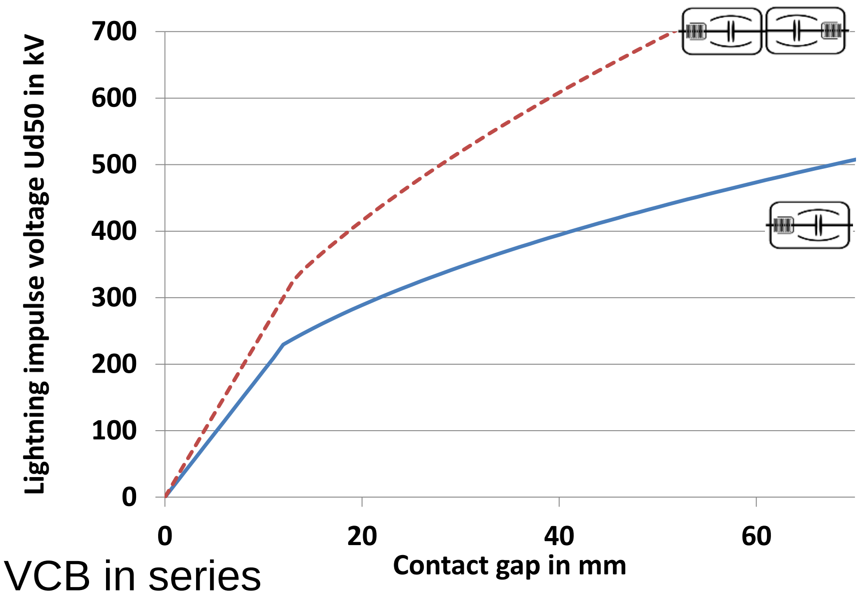
Agenda

- Motivation
- Simulations
- Challenge
- Results
- Summery and outlook



Motivation

- Qualification of VCB for high voltage operational level



- Two approaches possible
- Single break:
  - Solutions available up to 170 kV with enlarged contact gaps
  - Technical restricted, higher levels become difficult (maybe feasible up to 245 kV)
- Multi break:
  - Double or multiple break with common VCB in series
  - Feasible also in higher voltage levels

- In both cases dielectrically test in switched-off-position are a challenge → voltage distribution on floating parts in the chamber
  - Single break → potential of metal vapor shields
  - Multi break → potential of metal vapor shields and floating middle part

Motivation

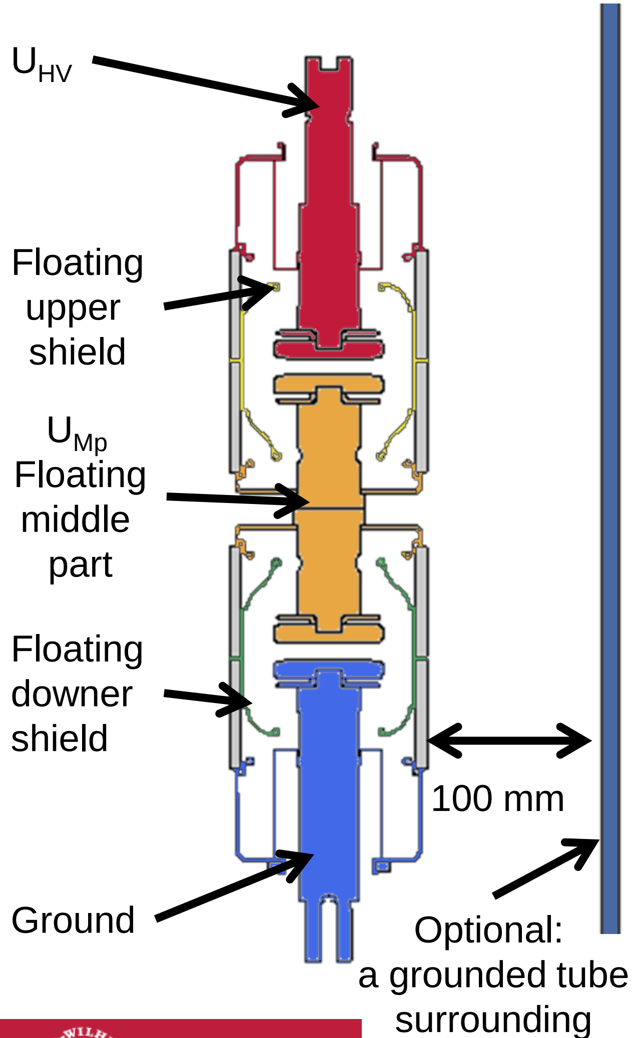
Chosen approach in this work: double break with 2 commercial available VCBs as one solution for a great range of high voltage levels

- In case of double break, grading capacitors are a common solution
- Common grading capacitors are in the range between 100 of pF up to nF → additional coasts, additional failure factors, influence the switching performance

Main question:

→ How can we stabilize the floating potentials in VCB and is there a practicable approach for a great range in high voltage levels due to upscaling?

Simulation model



- Two common 36 kV interrupters in a series arrangement → 72.5 kV rated voltage (325 kV lightning impulse voltage LIV)
- Simulations with Comsol Multiphysics
  - 2 D rotational symmetric
  - Electrostatic (es) and electrical current (ec) physics
  - Transient and DC simulations
- Evaluation of voltage distribution and electrical field distribution
- Electrical potential of the floating middle part with or without disturbances (U_{Mp}/U_{HV})

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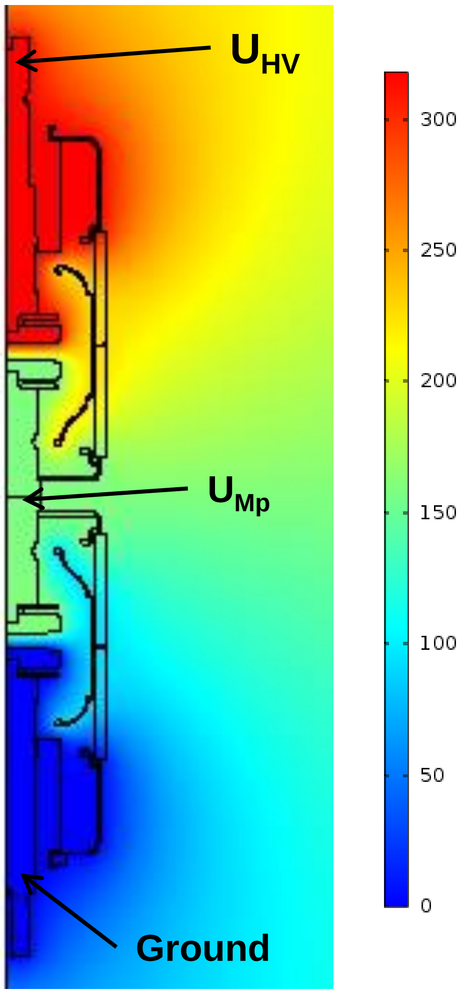
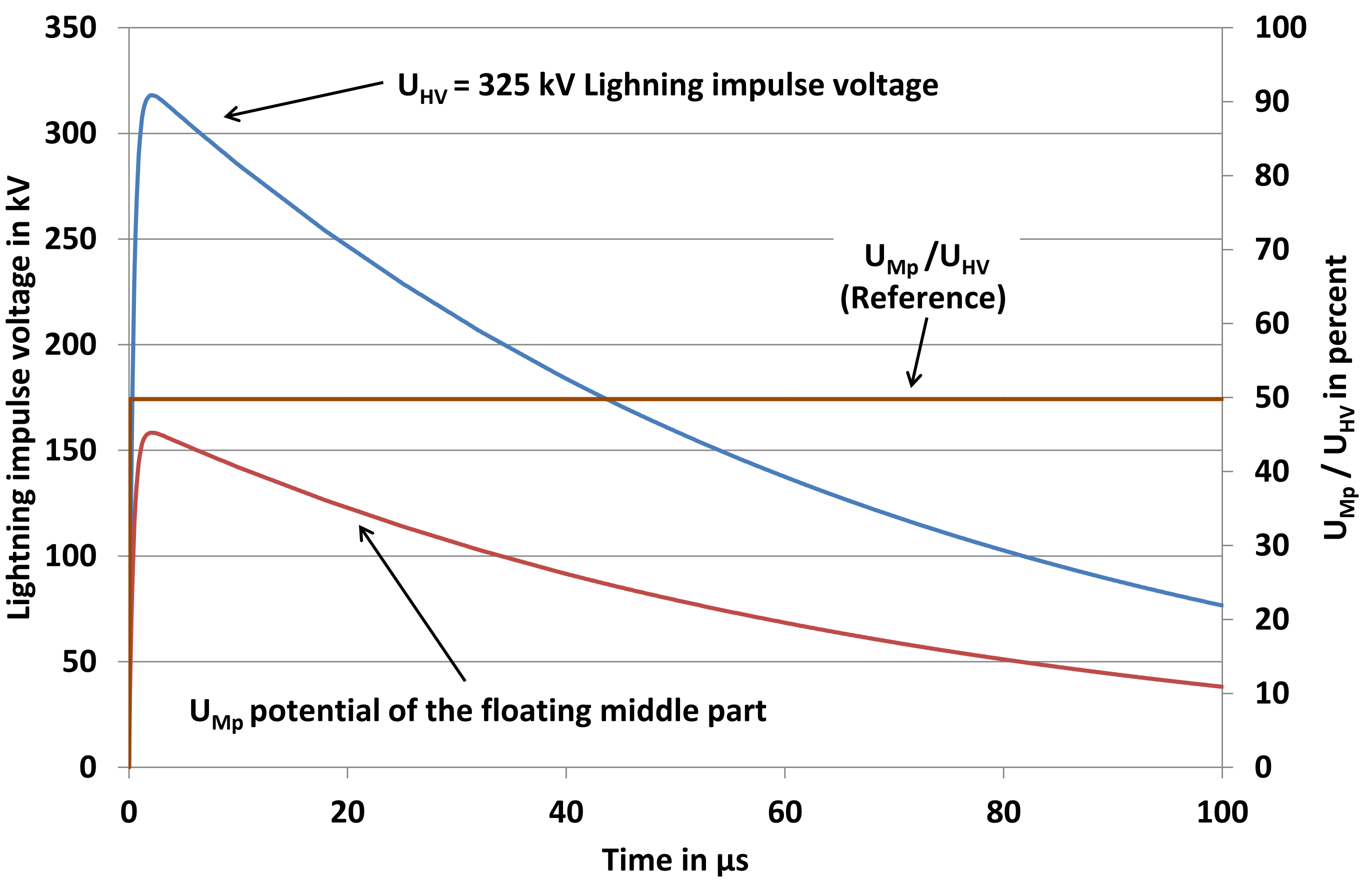
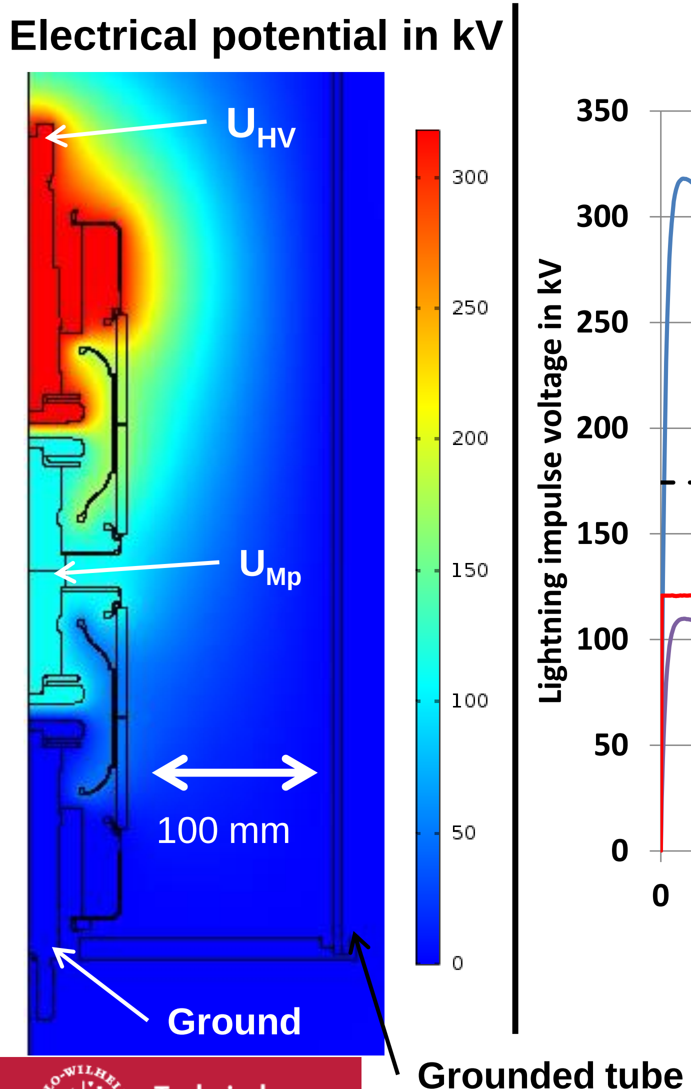
Electrical potential simulations without external disturbances (Reference)

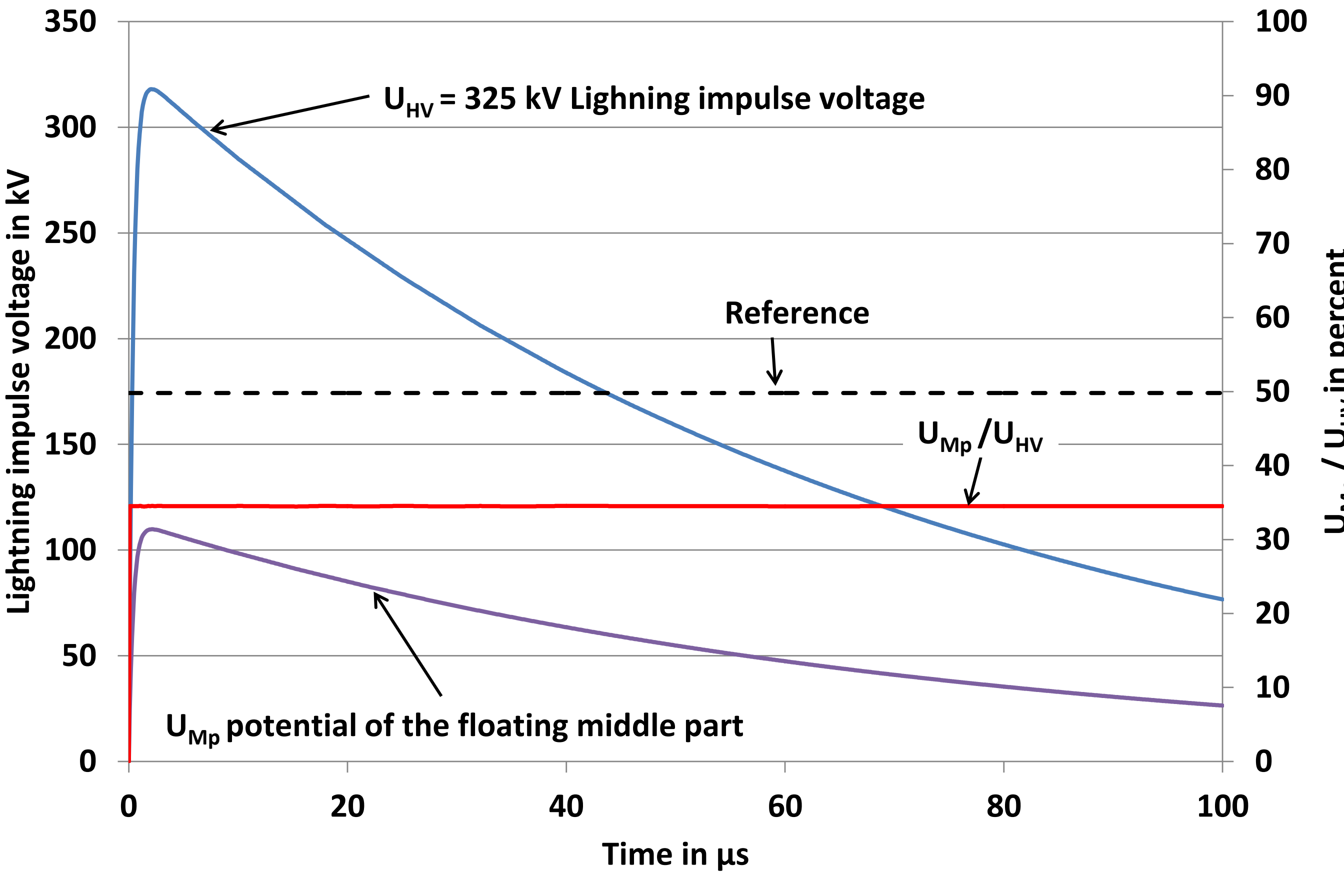
Electrical potential in kV



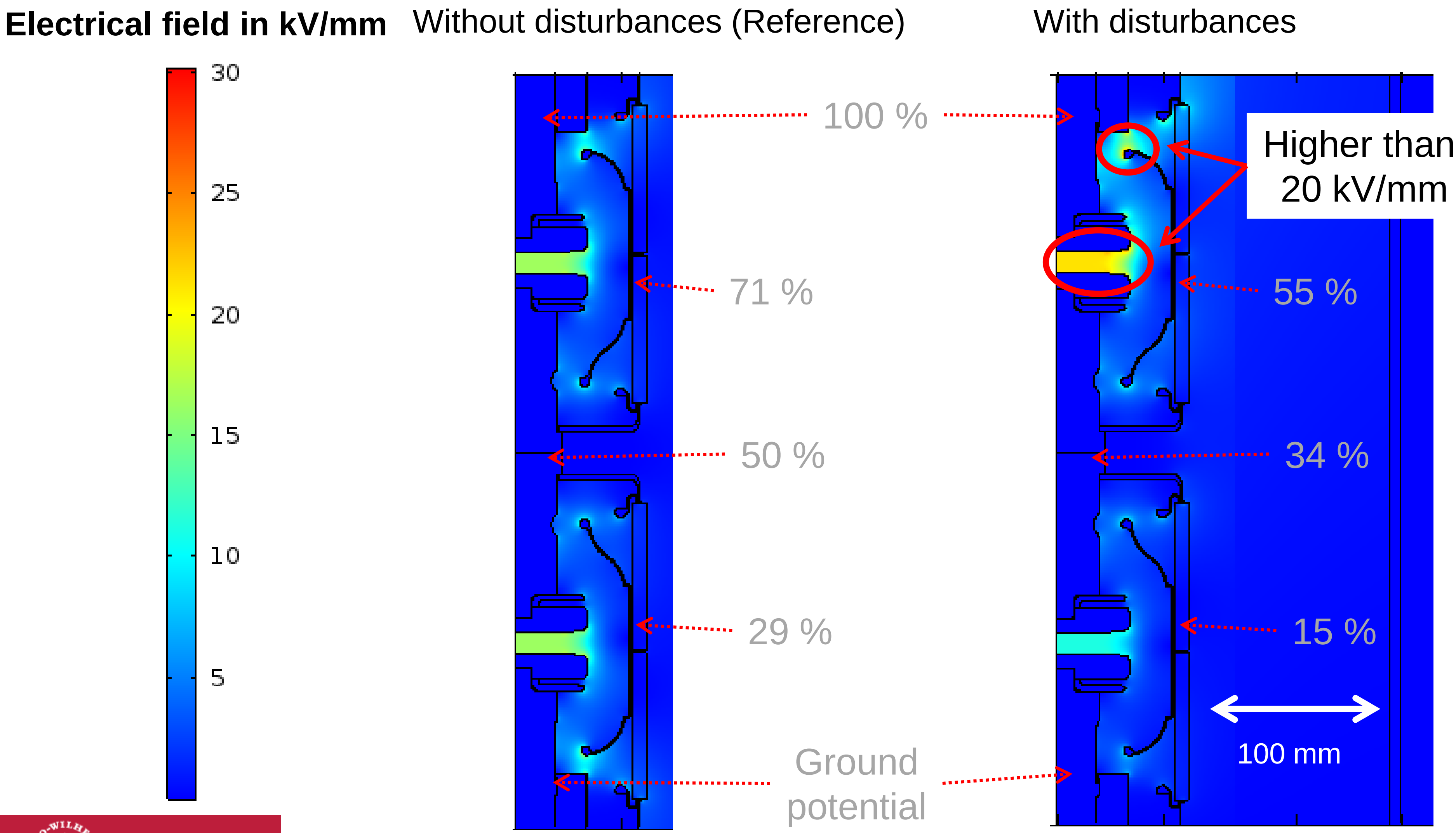


Electrical potential simulations with external disturbances

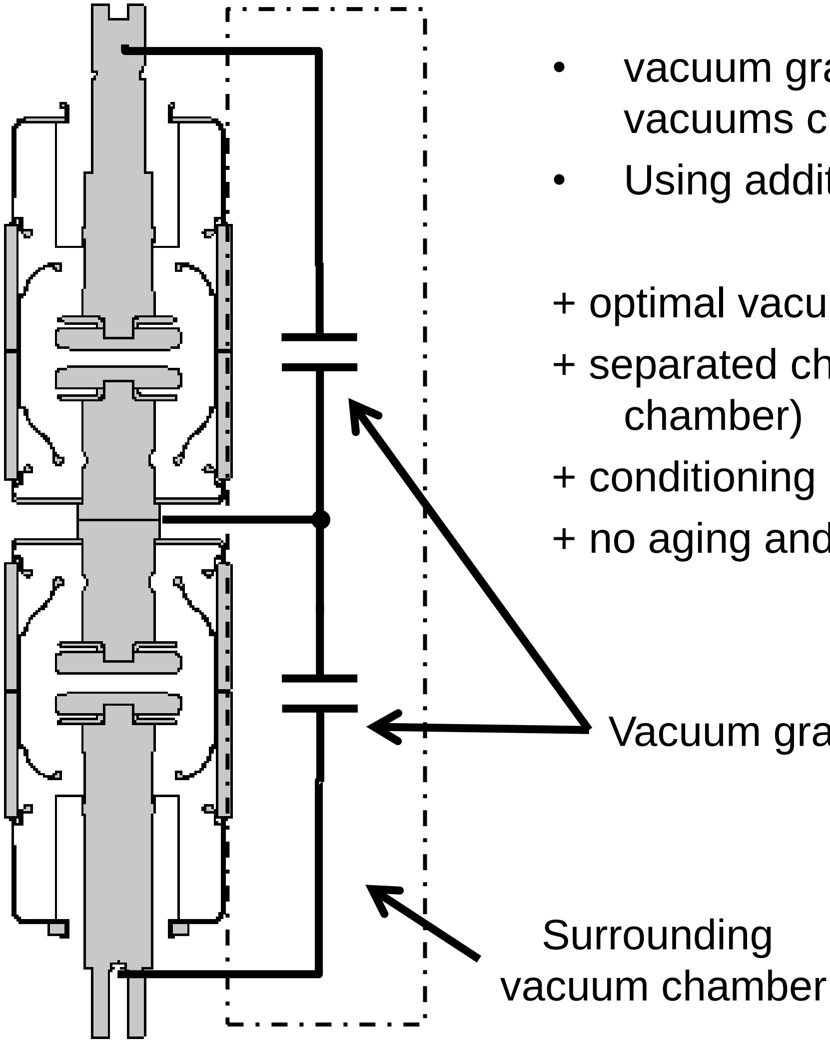




Electrical field distribution with and without external disturbances

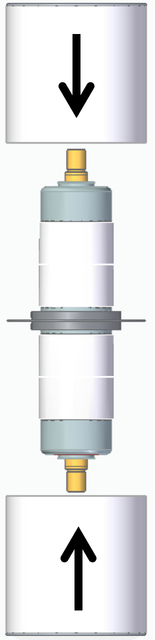


1st approach: vacuum grading capacitors in an additional vacuum grading chamber



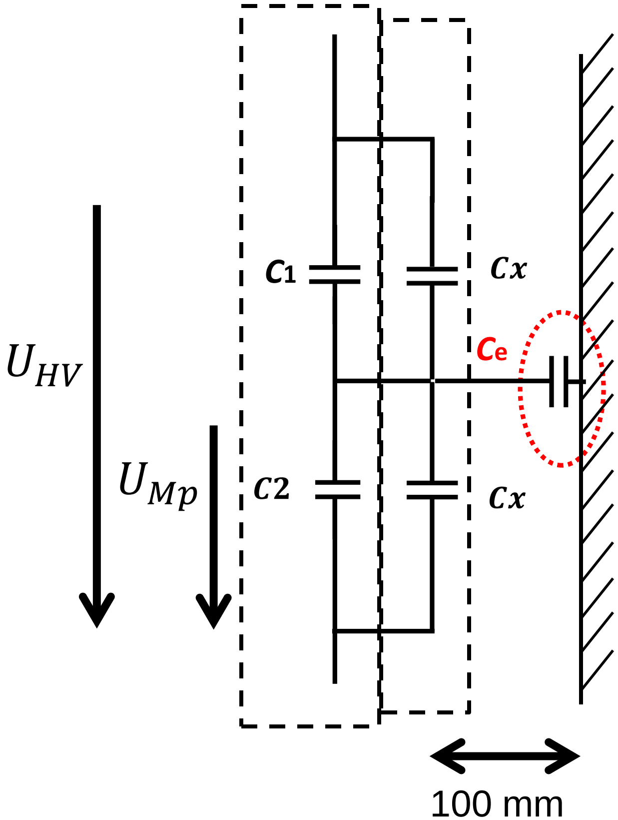
- vacuum grading capacitors in a separate surrounding vacuums chamber
- Using additional shields

+ optimal vacuum conditions
+ separated chamber → no metal vapor (in grading chamber)
+ conditioning possible
+ no aging and self healing insulation medium



Necessary capacitances
Analytical calculation of grading capacitance

Assumptions → The grading capacitances should prevent a voltage drift over 5 % from the reference (U_{Mp}/U_{HV})



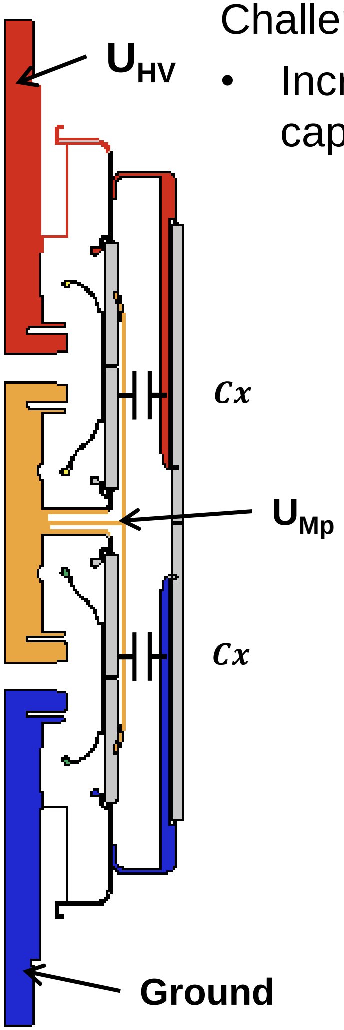
Assumed general values for 36 kV VCB and for parasitic capacitances of $C_e = 20\,pF$ (from literature, simplification):

→ $\boldsymbol{Cx = 400\,pF}$ necessary capacitance (in accordance with the literature)

Simple calculations show → Max, Cx’ of 86 pF is possible

⇨ Reducing the parasitic capacitances C_e while maximizing C_x

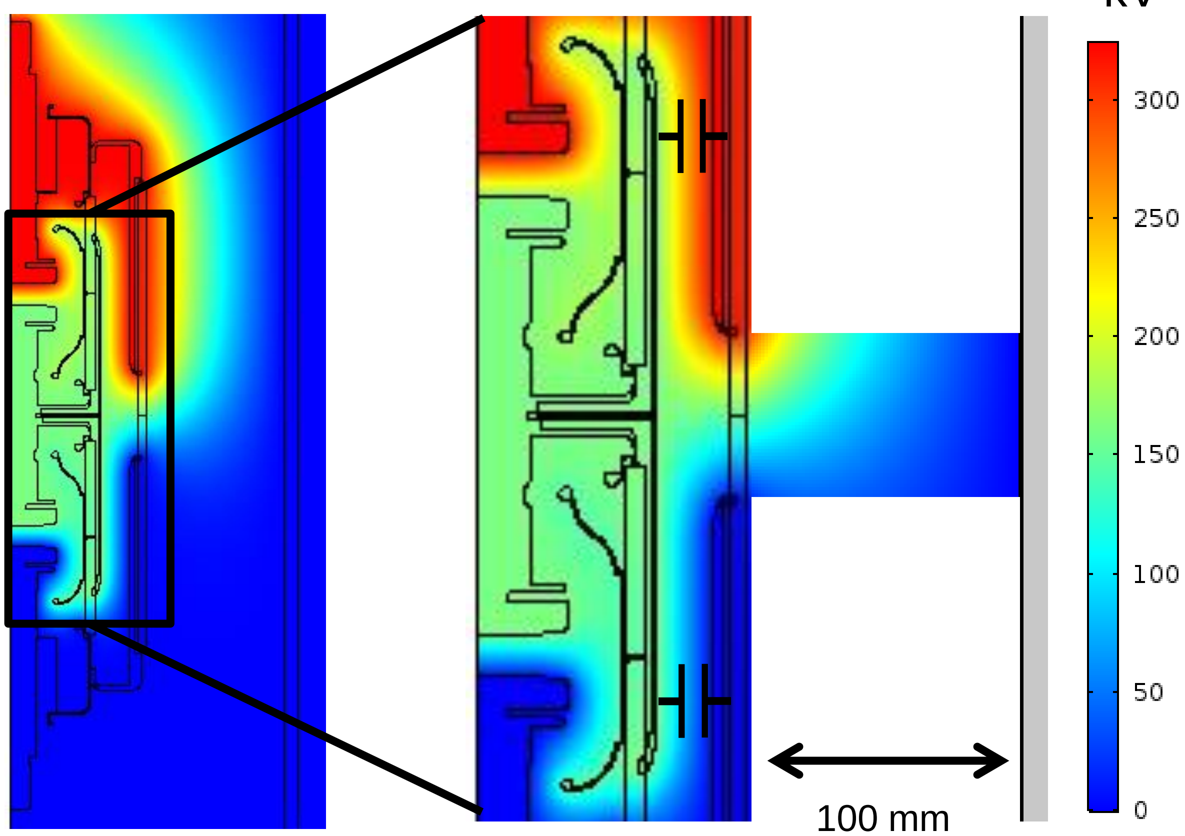
2nd approach: combined field shielding and grading



Challenge:

- Increasing the grading capacitances while decreasing the influence of parasitic capacitances

Electrical potential in kV



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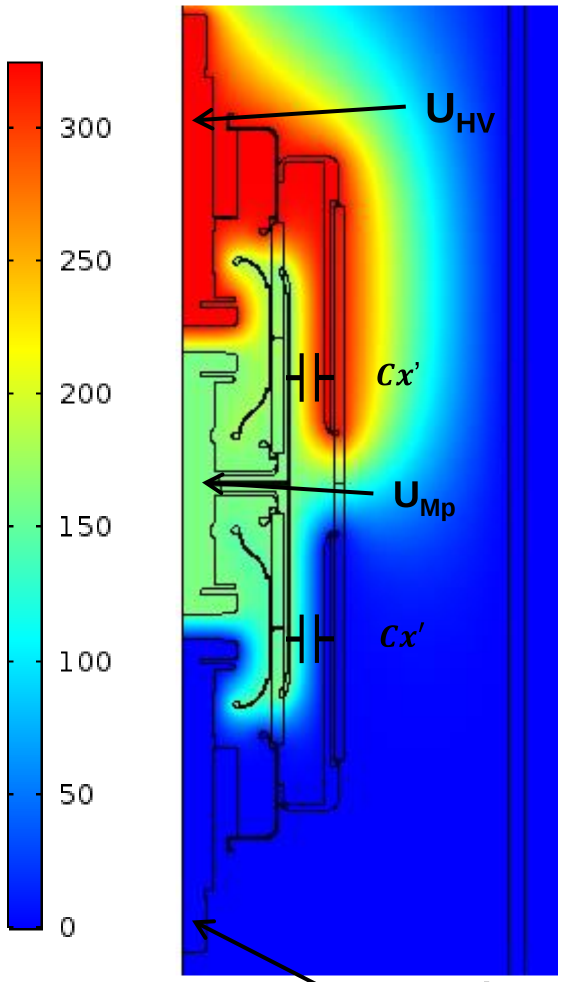
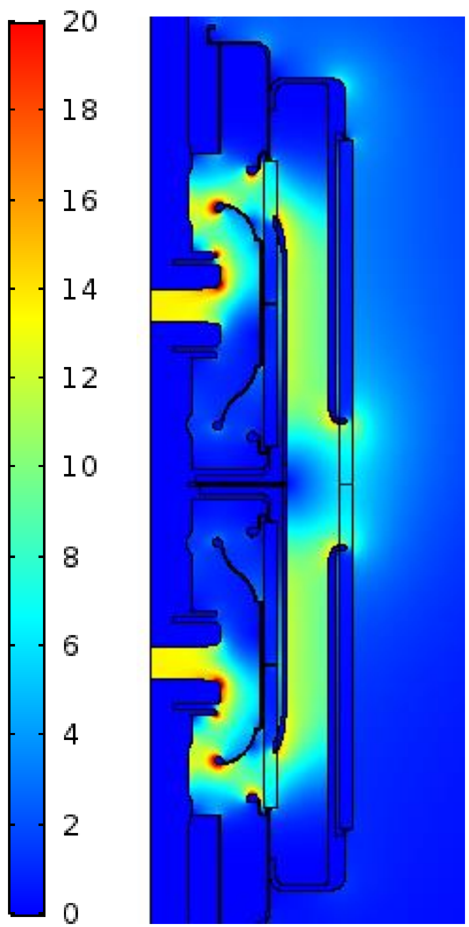
Electrical field distribution and voltage drift

Electrical potential in kV



Electrical field in kV/mm



< 20 kV/mm

Shielding reduces the influence of parasitic capacitances to $C_e' \approx 3\,pF$

Reached capacitance $C_x{}' \approx 60\,pF$

$$\Rightarrow \frac{U_{Mp}{}'}{U_{HV}} \approx 50\%$$

Interaction with floating metal vapor shields
→ Changed potential distribution in the chamber
→ Changed electrical field distribution

Simulation results

	Without any shielding		Combined shielding and grading	
Mode	Without dist. (Reference)	With dist.	Without dist.	With dist.
U_{Mp}	163 kV	112 kV	163 kV	162 kV
$\frac{U_{Mp}}{U_{HV}}$	50 %	34 %	50 %	50 %

- Simulated drift with shielding is not detectable
- Design depended interaction with other parts on floating potentials like metal vapor shields

- Stabilizing the potential of the floating middle part of double break arrangements and the potential of floating shields on single – and double break cases

Summary and conclusion

- A combined shielding and grading for vacuum interrupters
- Shield arrangement in an additional outer vacuum chamber surrounding the main chambers → good implementation in the production process and optimal vacuum conditions with a high reliability based on well known technology
- Developed design based on lightning impulse voltage (LIV)
- Next step

Paper:
Novel field grading shield design for double breaking vacuum chambers under lightning impulse stress
on ISDEIV

Finish – Thank you for your attention

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