Technische Universität Braunschweig

iBMB MPA TU BRAUNSCHWEIG

Risk assessment of cable fires under consideration of realistic ignition scenarios

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- Division of Fire Safety -

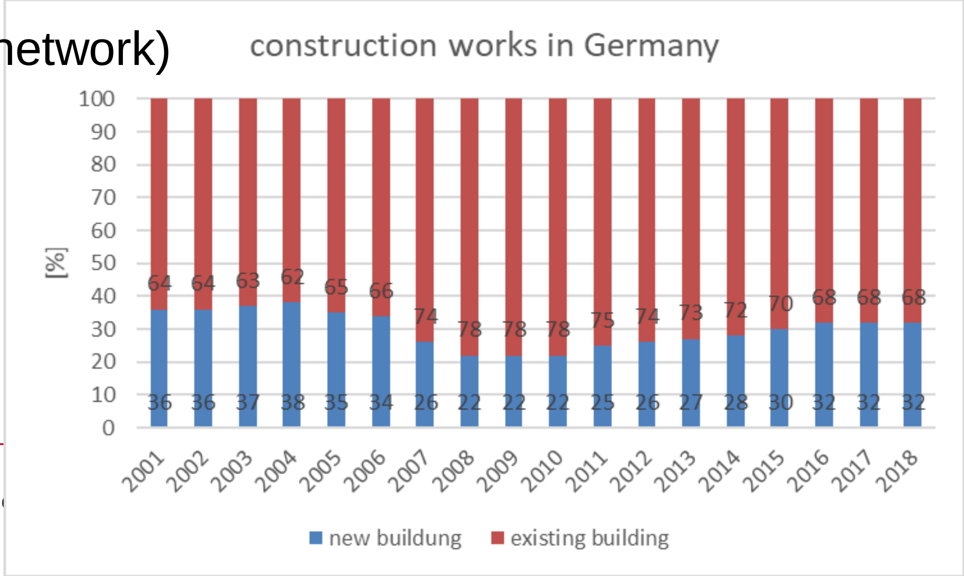
Content

- Motivation
- Assessment of current level of safety
- Possible ignition scenarios
- Burning behaviour of cables
- Burning behaviour of cable trays in false ceilings
- Investigations of cable tray fires for realistic ground plans

- Coming up in 2022: iBMB Advanced Fire Lab

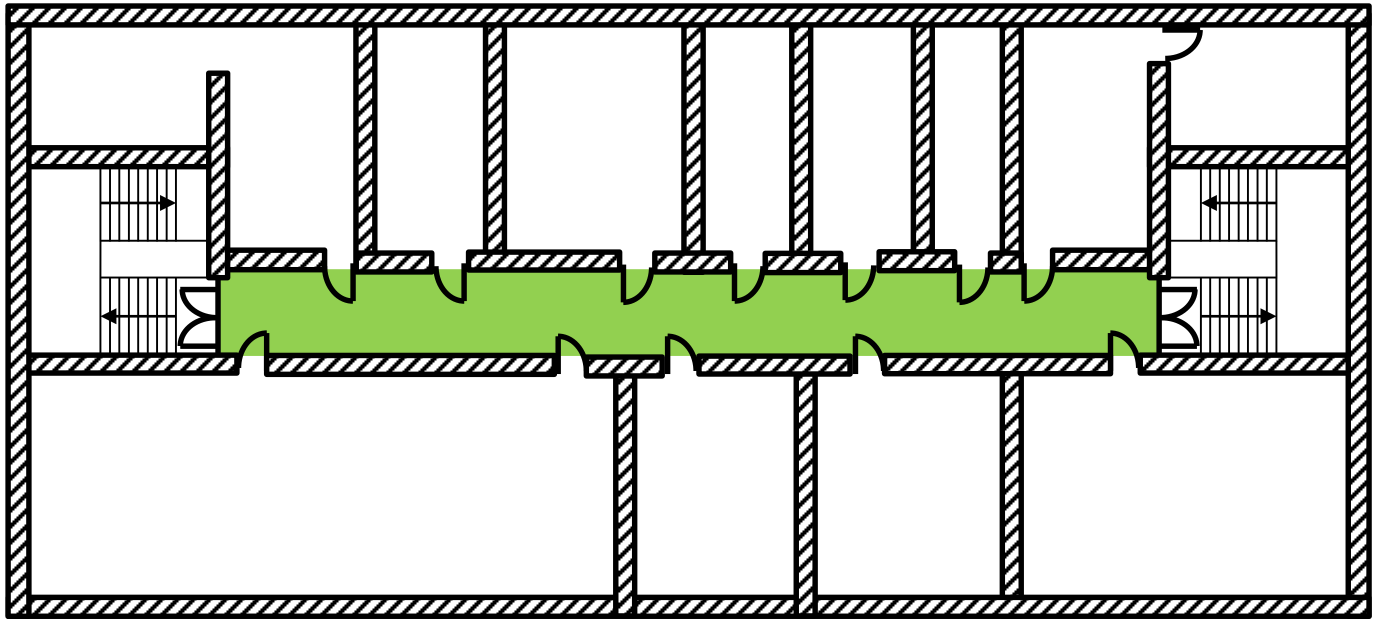
Motivation

- Fire protection requirements for electrical cable systems are strictly regulated
  - 16 building codes (one per federal state)
  - All fire protection requirements based on ISO 834 standard fire curve
  - No performance based approaches can be used
- Requirements lead to high costs for technical building equipment
  - Cable systems in escape routes
  - Expansion of cable systems in existing buildings
    - Cable systems are not static as e.g. columns
    - Many changes during lifetime of a building (e.g. local area network)



Motivation

- Fire protection requirements for cable systems in escape routes
  - Example



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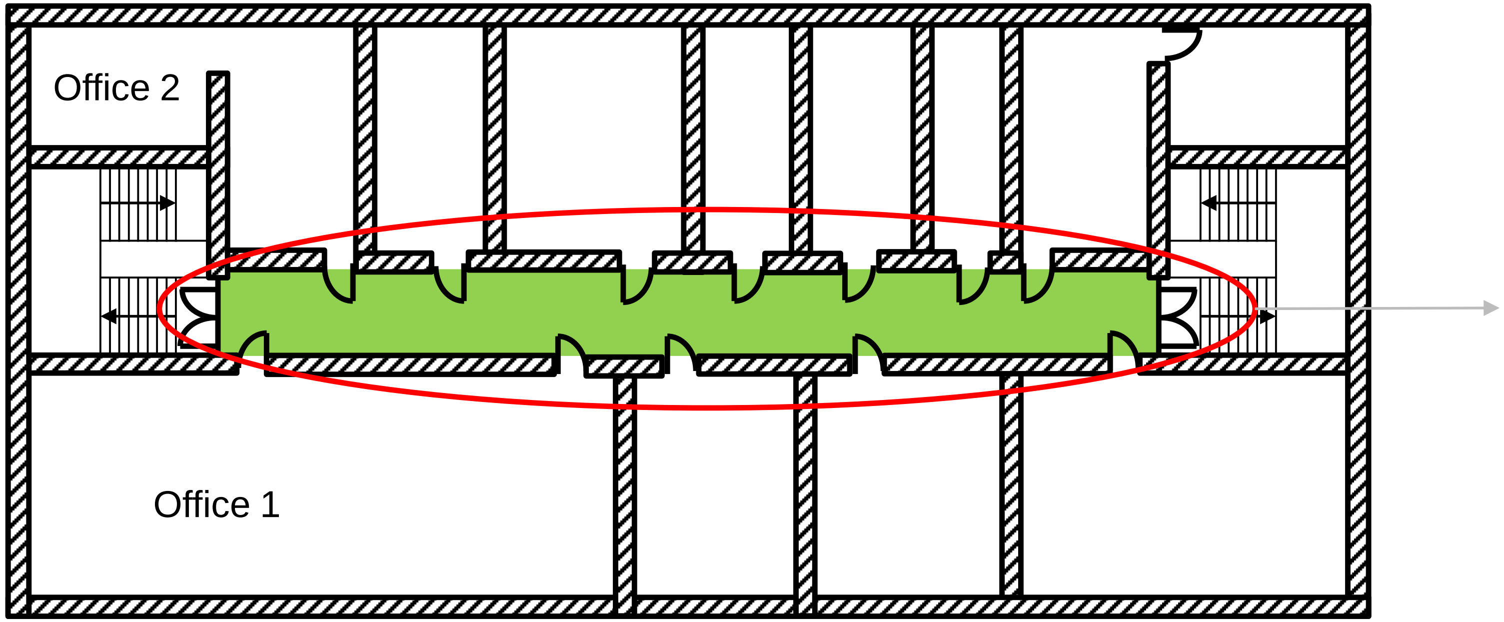
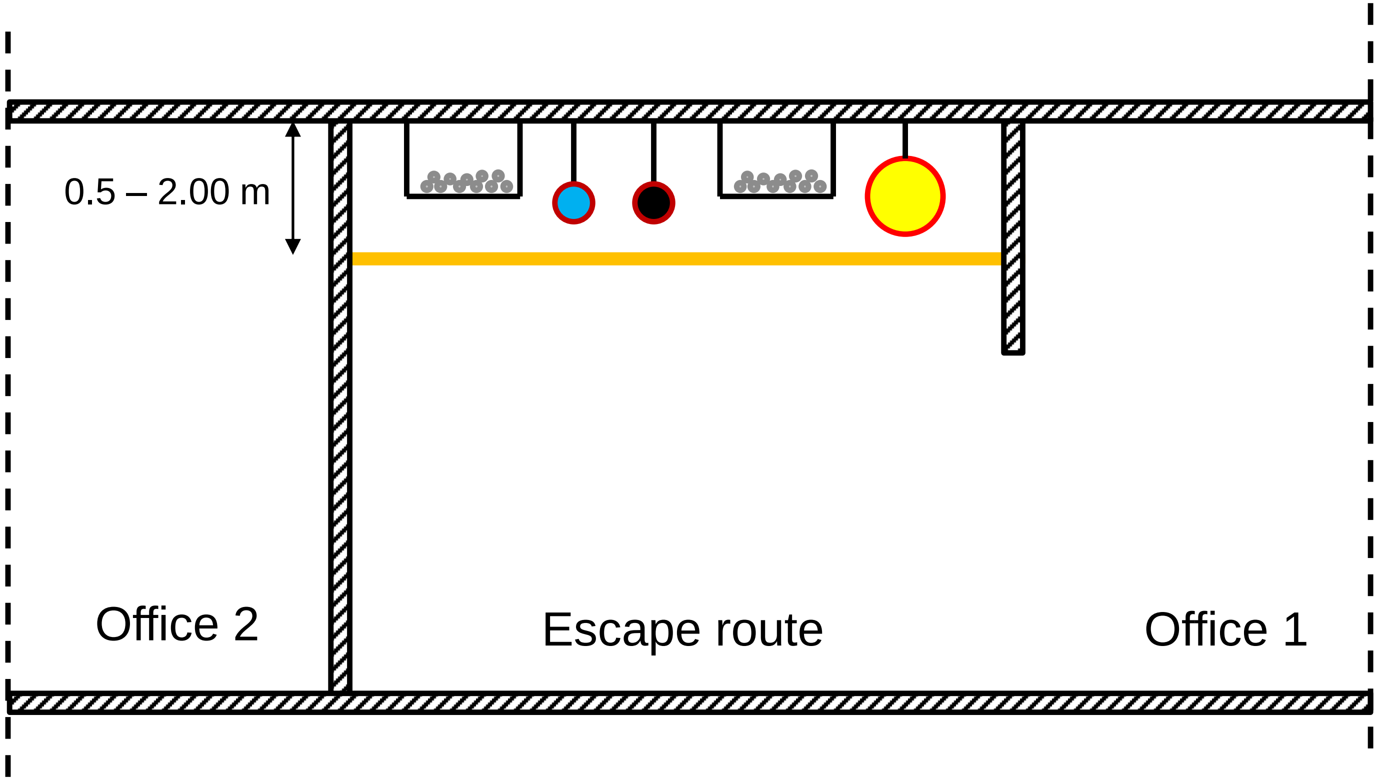


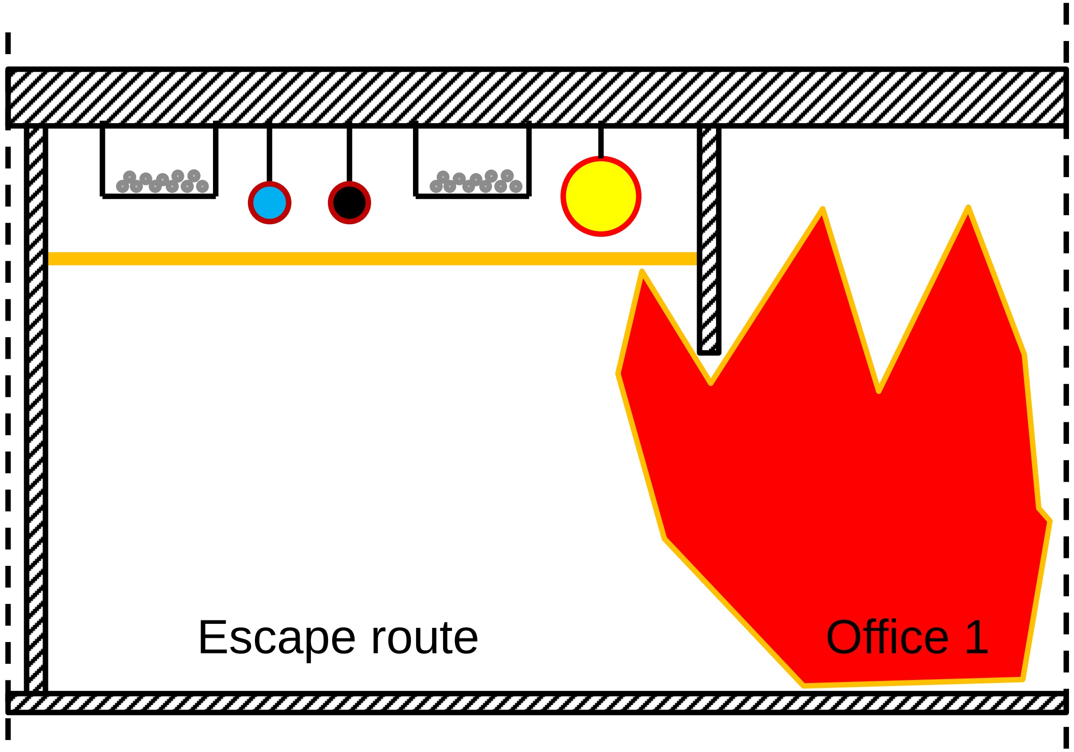
Corridor = horizontal escape route

Motivation

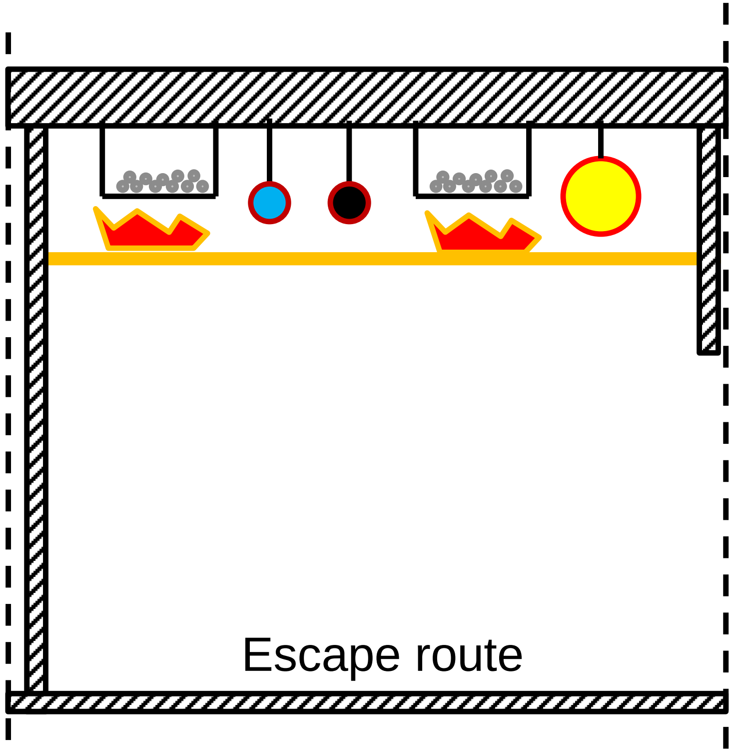
- Fire protection requirements for cable systems in escape routes



- Fire protection requirements for cable systems in escape routes
  - Two different scenarios



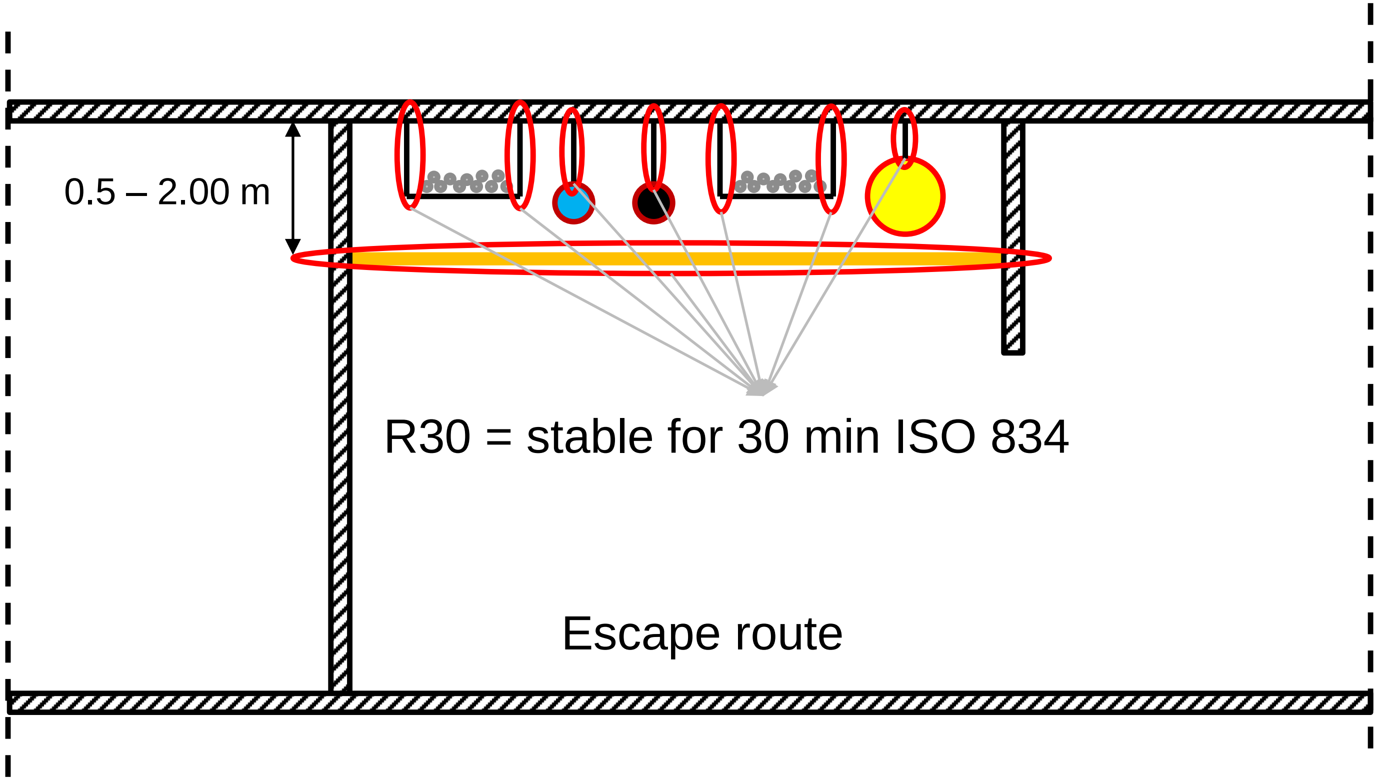
Scenario 1: Compartment Fire → protect fire load against ignition



Scenario 2: Fire within the false ceiling → protect the escape route

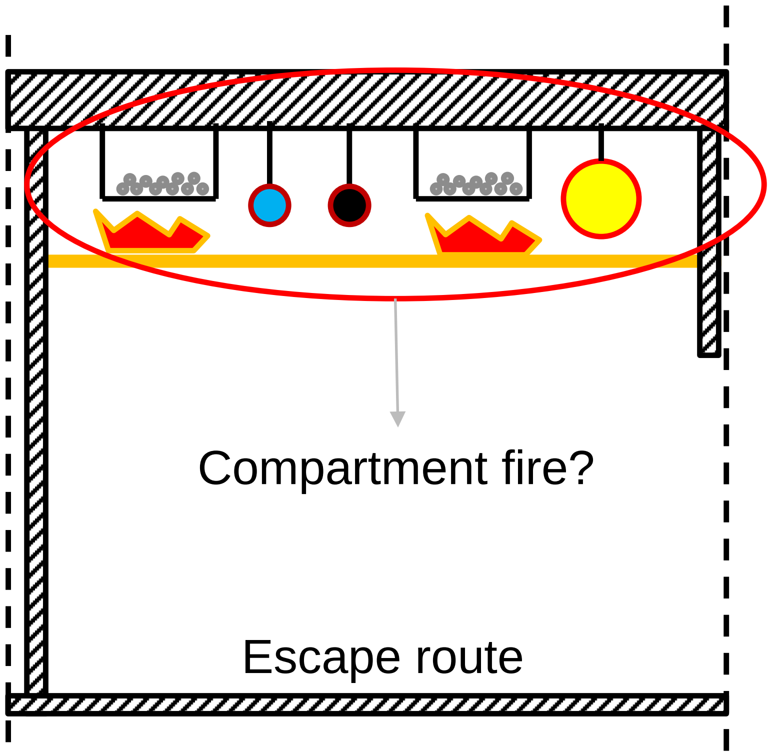
Motivation

- Fire protection requirements for cable systems in escape routes
  - Each component between ceiling and false ceiling has to be fire resistant for 30 minutes of ISO 834 standard fire curve



Motivation

- ISO 834 standard fire curve is based on findings from compartment fires
- Fire development between false ceiling and ceiling different to a compartment fire
  - Low ventilation (leakage between false ceiling and surrounding area ≈ cm²)
  - Small height to width x depth ratio
  - Strong ceiling jet in corridor direction



Scenario 2: Fire within the false ceiling
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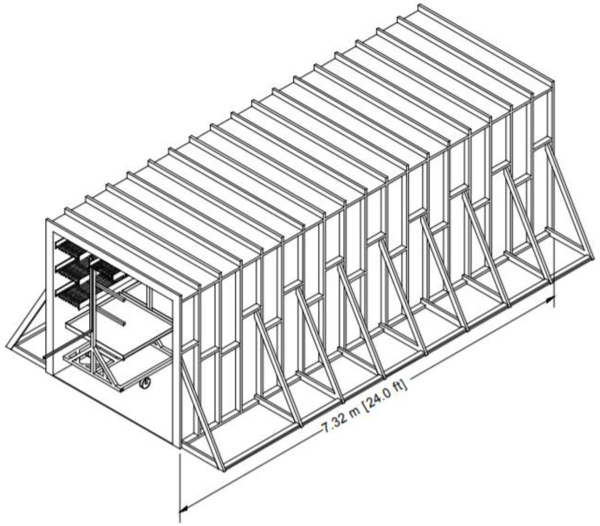
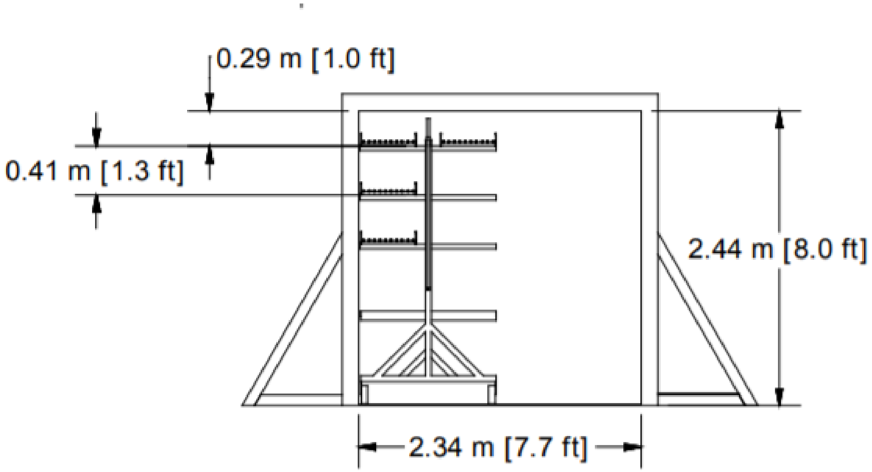
Motivation

- Many cable tray fire experiments in context of safety in nuclear power plants (CHRISTIFIRE/PRISME)
  - CHRISTIFIRE Corridor experiments





NUREG/CR-7010, Vol. 2: Cable Heat Release, Ignition, and Spread in Tray Installations During Fire (CHRISTIFIRE) Phase 2: Vertical Shafts and Corridors

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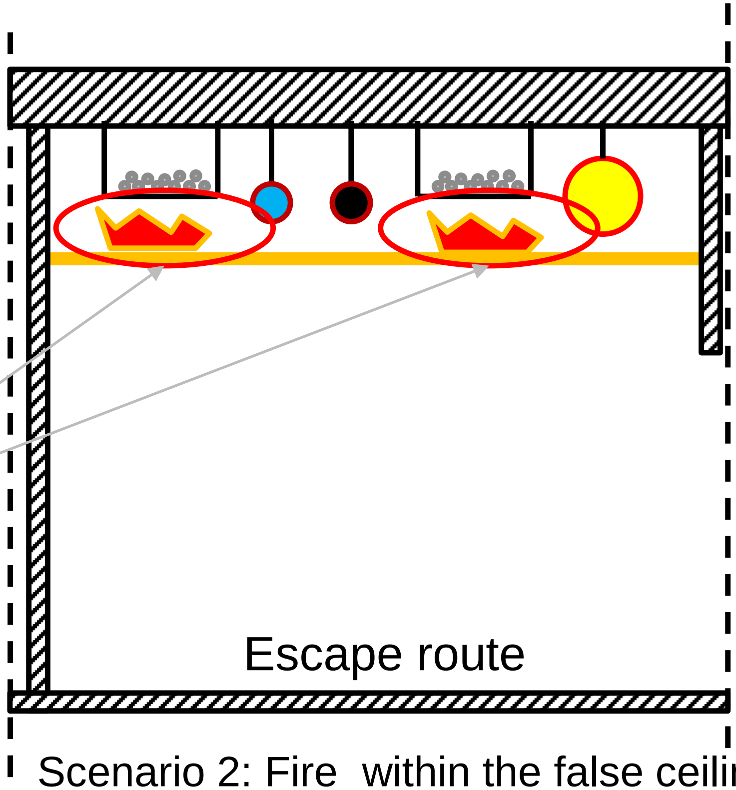
Where is the gas burner?



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NUREG/CR-7010, Vol. 2: Cable Heat Release, Ignition, and Spread in Tray Installations During Fire (CHRISTIFIRE) Phase 2: Vertical Shafts and Corridors

Motivation

- Risk assessment of cable fires with more realistic ignition scenario
  1. Assessment of the current level of safety
  2. Assessment of possible ignition scenarios
  3. Assessment of burning behaviour of cables (cone calorimetry)
  4. Assessment of burning behaviour of cable trays in false ceiling (mid-scale experiments)
  5. Investigations of cable tray fires for realistic ground plans

(Items 2–4: experimental; item 5: numerical)

Assessment of current level of safety

- Using ISO 834 standard fire curve as benchmark for securing escape routes
- Limitations of ISO 834 regarding safety of people:
  - No information on chemical composition of smoke (important e.g. for FED)
  - No overpressure taken into account (important for mass transport through leakages)
- ISO 834 standard fire curve alone does not reflect reality
  - False ceiling often monitored by smoke detectors
    - Early fire detection → no threat for escape routes
  - Performance of fire brigades
    - **“fires in false ceiling can’t be extinguished by fire brigades”**
    - Controllability of fire by fire brigades depends on
      - Arrival at the scene (fire development),
      - Man power,
      - Availability of water,
      - Time to equip personal protective equipment and to start first attack

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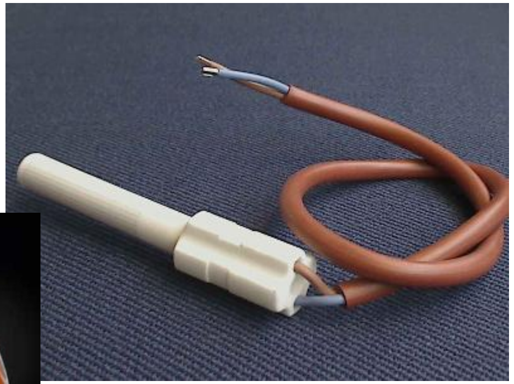
Can this statement be confirmed?

Assessment of possible ignition scenarios

- In contrast to compartment fires there are no user related ignition scenarios
  - „Forgotten“ cigarette,
  - Arson
- Cable systems can self-ignite due to electrical failure and overheating of cables
- Different safety system within cable system
  - Circuit breaker (over current protection [OCP]) shuts down when electric current is to high
  - Residual-current device (RCD) shuts down when electric current is not balanced
  - Arc-fault detection device (AFDD) shuts down when an electric arc occurs
- Safety system shut down the electrical system within 1 – 5 ms [1/1000 s]
- High amount of heat released by electrical failure
  - Temperature of electrical arc 5.000 – 15.000 °C

Burning behaviour of cables

- How to investigate the ignition due to electrical failure?
  - Short time period (challenging for measurement technologies)
  - Possible deadly threat
    - 230 – 400 V
    - > 16 A
- Solution approach
  - Electrical failure represented by an electrical igniter
  - Electrical igniter:
    - Used in pellet stove
    - Ceramic head
    - Heating power: 165 W
    - Surface temperature up to 1.000 °C



Burning behaviour of cables

- Electrical igniter within PVC-Cable
  - Surface temperature 1.000 °C over 10 minutes
- Results
  - Thermal degradation of PVC
  - Formation of char layer
  - High mass loss and visible smoke production
  - **No combustion occurred**
- Possible reason
  - Char insulates igniter from fuel-oxygen mixture
  - Temperature in gas phase to low to ignite mixture

Burning behaviour of cables

- Further ongoing experiments
  - Open cross section of cable
  - Longer duration for electrical igniter
  - Two cable layer
  - Preheating
  - Different heat powers (35 – 165 W)
- First results
  - Ignition and fire development are highly influenced by
    - Heating power and duration of igniter
    - Heat loss to surrounding gas phase
    - Cable arrangement
    - preheating
  - Self-sustaining combustion needs preheating

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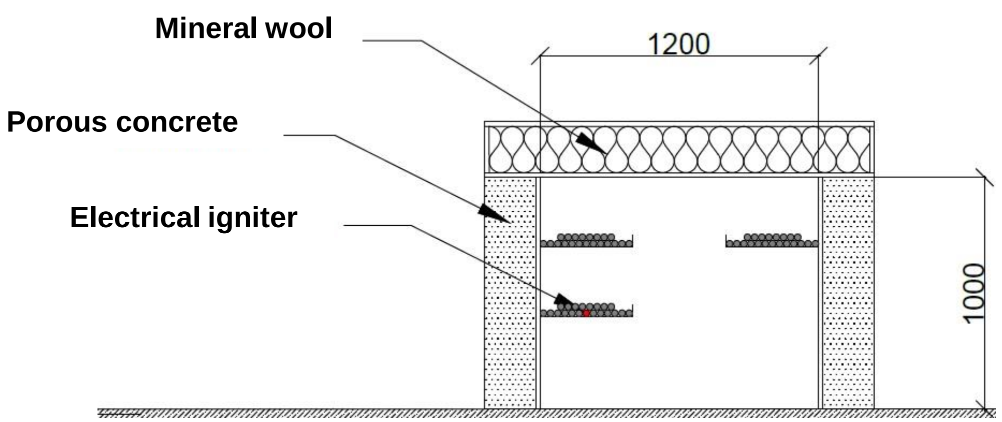
It is more difficult than expected to ignite PVC-Cable!

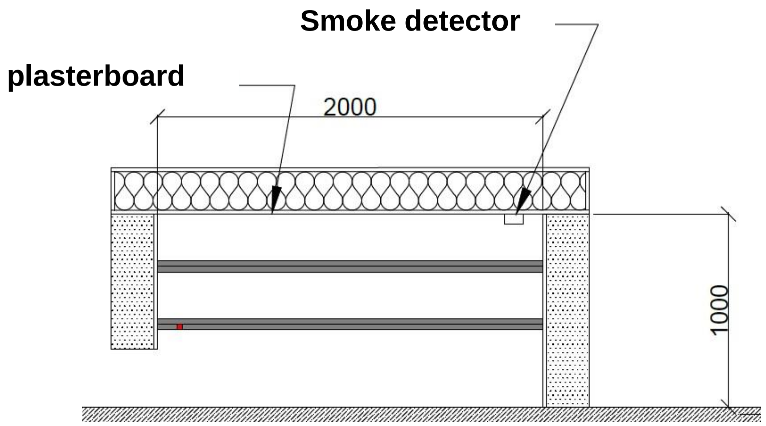
Assessment of burning behaviour of cable trays in false ceiling

- Mid-scale experiments to assess fire development of cable trays in false ceilings
- Goals
  - Verification of the transferability of the findings from cone tests to cable trays
  - Integration of safety-related infrastructure (smoke detectors) in the test set-up and
  - Create a database for calibration and validation of fire simulation codes in dimension between small-scale and compartment fire
- Solution approach
  - Own test chamber with reproducible boundary conditions

Assessment of burning behaviour of cable trays in false ceiling

- Solution approach:
  - Own test chamber with reproducible boundary conditions





  - 1.2 x 2.0 x 1.0 = 2.4 m³
  - New plasterboards for every experiment to ensure constant emissivity of surrounding walls and ceiling in each experiment

Assessment of burning behaviour of cable trays in false ceiling

- Test parameter
  - Cable arrangement — tight vs. loose
  - Ignition — Electrical igniter vs. gas burner
  - Origin of ignition — Upper tray vs. lower tray
  - Combustion regime — well-ventilated* vs. under-ventilated
  - Start temperature — 20 °C / 70 °C / 90 °C

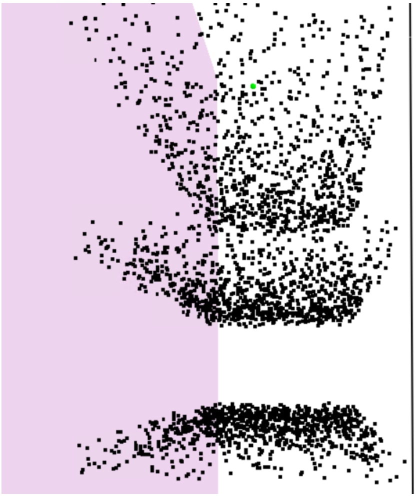
* Change in combustion regime during test is expected for full cable tray burning

Investigations of cable tray fires for realistic ground plans

- Cone and mid-scale experiments are used for numerical investigations using FDS (calibration and validation)
  - Pyrolysis parameter (E, A, R),
  - Ignition temperature […]
- Last step: extrapolation to realistic ground plans
  - Visibility
  - Chemical composition of smoke
  - Temperatures
  - […]
- Is it possible to reduce the fire protection requirements in false ceiling?

Open question

- Loose cable arrangement is modelled in FDS using particles



- Drag force of particle highly influences the flow field → ignition of particles → overall mass loss rate → heat release rate

$$F_D = \frac{1}{2} \rho v^2 C_D A$$

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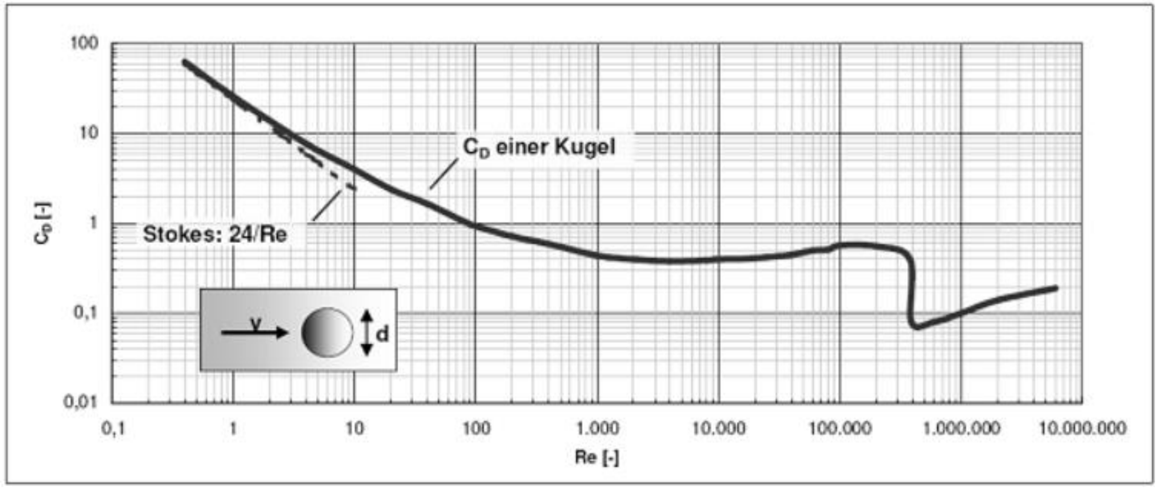
$$F_D = \tfrac{1}{2}\rho v^2 C_D A$$

- For low mach number assumption drag coefficient for a single particle is a function of Reynolds number RE_D:

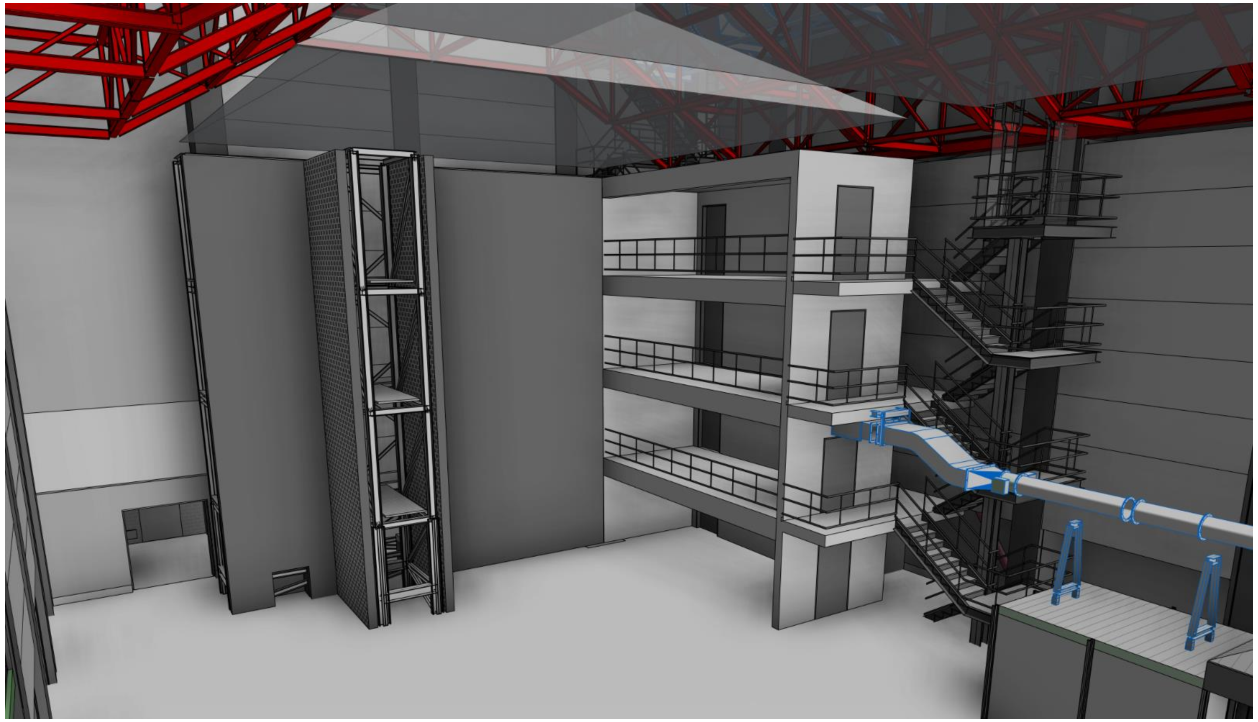
$$RE_D = \frac{\rho |u_p - u| 2r_p}{\mu(T)}$$



Open question

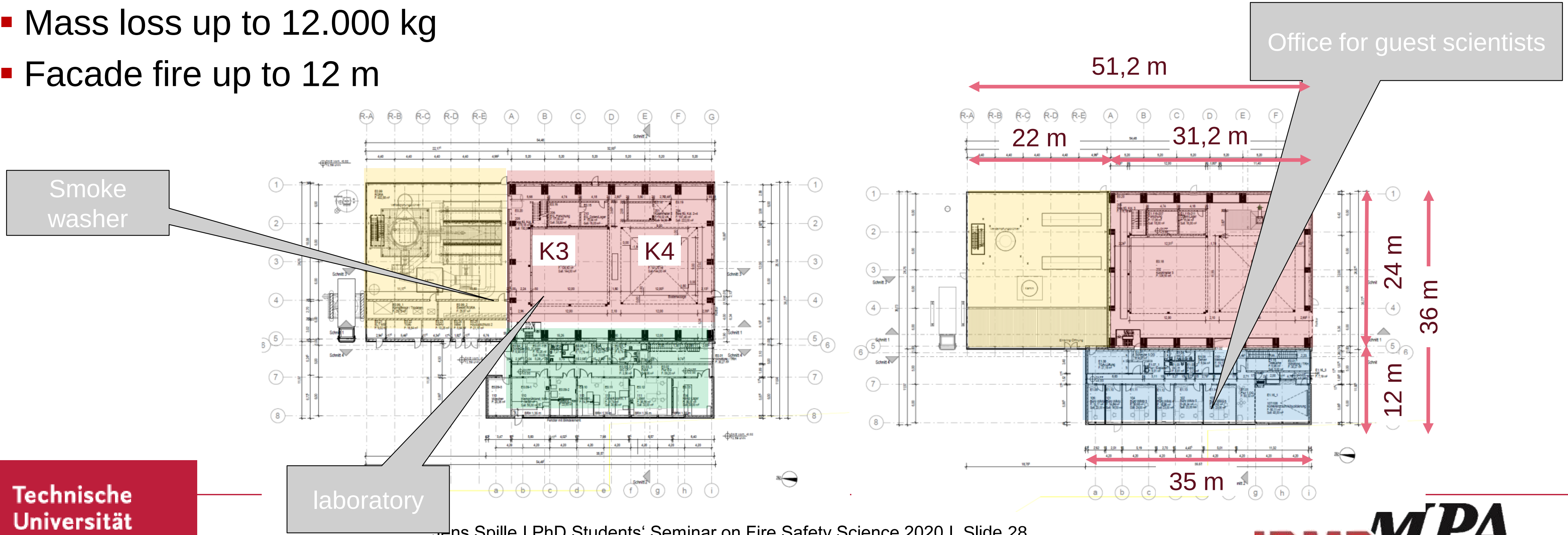
- For particles representing cables drag of single particles interact
- Drag coefficient depends on:
  - Mesh size
  - Porosity (particle cross section area to mesh area ratio)
  - […]
- By trial and error: drag coefficient between 16 and 26 leads to good agreement between experimental and numerical data (16 – 60 times higher than for a single particle)
- **Does anyone have experience using particles in FDS?**
- **Do you know literature or calculation methods to determine drag coefficient for accumulation of particle?**

iBMB Advanced Fire Lab
(ZeBra: Zentrum für Brandforschung Braunschweig)



Coming up in 2022: iBMB Advanced Fire Lab

- Research possibilities from small to big scale:
  - Cone calorimeter, FTIR, TGA, Pyrolysis–gas chromatography–mass spectrometry
  - Room corner
  - Oxygen consumption calorimetry up to 20 MW [biggest calorimeter in Europe]
  - Mass loss up to 12.000 kg
  - Facade fire up to 12 m



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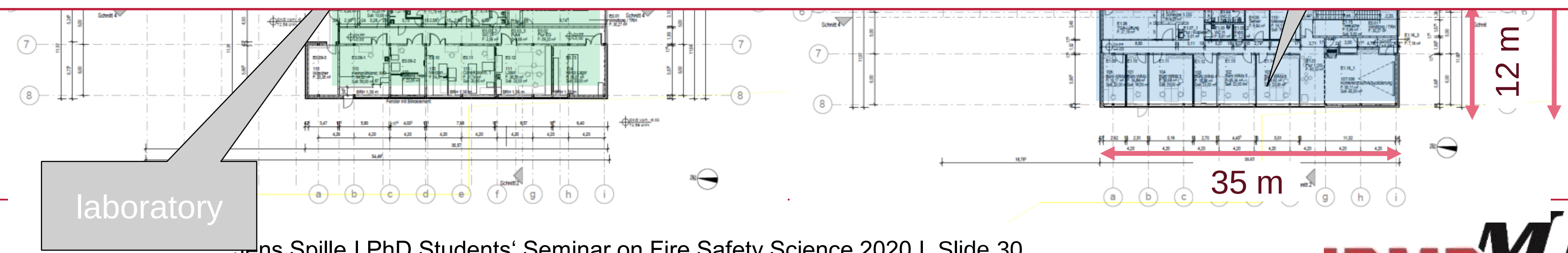
Do you want to set compartments, cars, busses, trams on fire for science?
Are you looking for research collaborations in fire safety science?
Do you have experimental and or numerical research ideas regarding fire safety science looking for validation experiments?
Are you looking for a research stay at the heart chamber of German fire safety science?

Just feel free to contact iBMB – Division of Fire Safety!



Thank you for your attention!