BAM
Bundesanstalt für Materialforschung und -prüfung

Sicherheit in Technik und Chemie

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# HICON EXPERIMENTAL CAMPAIGN 3: IGNITION OF HYDROGEN DUE TO SINGLE IMPACT

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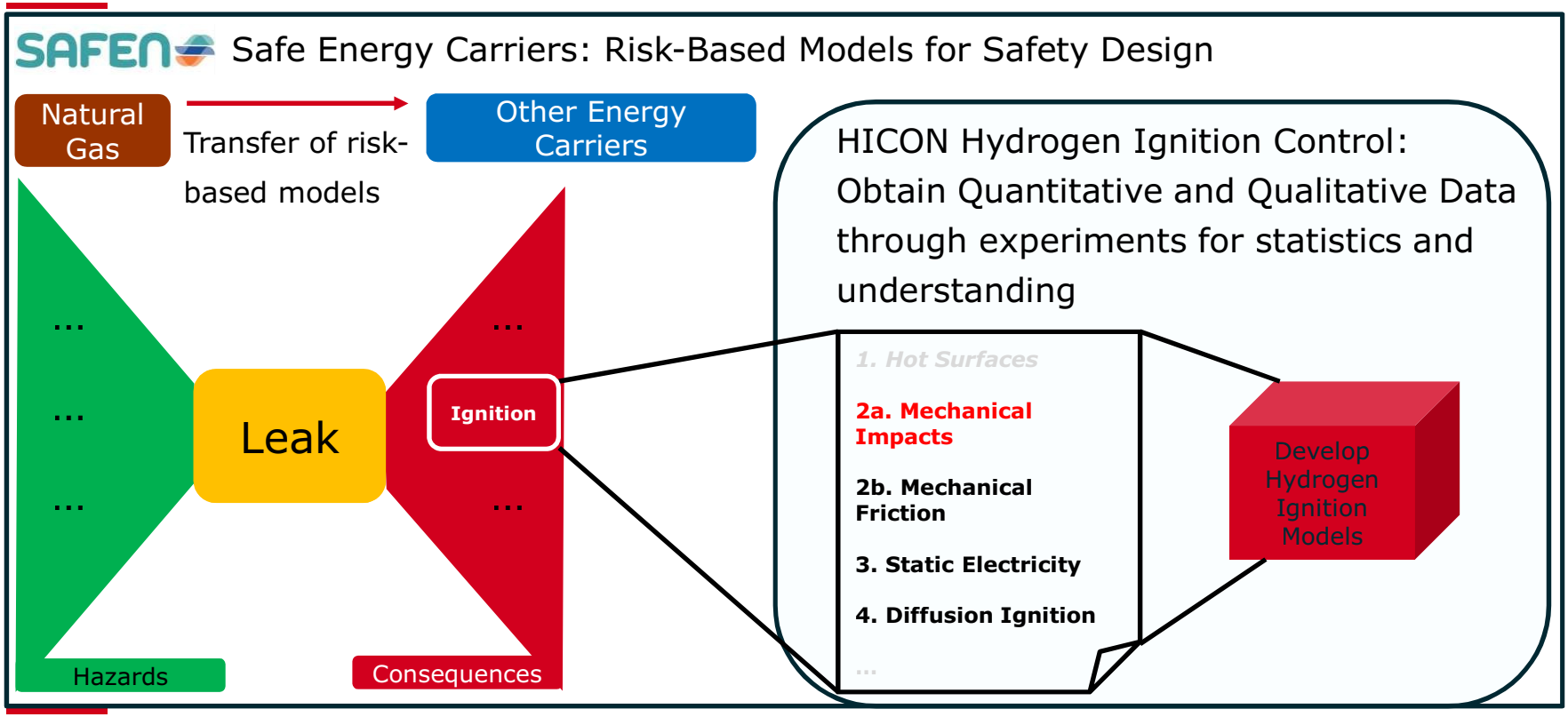
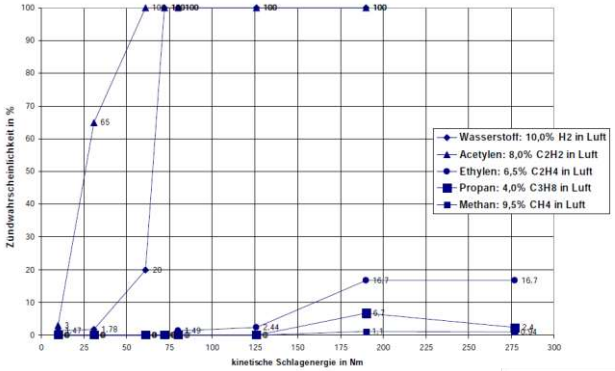
See https://fabig.com/publications-and-videos/technical-presentations-videos/technical-meeting-111/ for all presentations and presentation recordings.

# Motivation



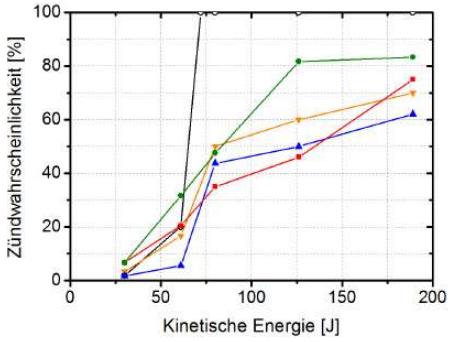
# Literature Review on Ignition by Single Impacts in Context of Explosion Protection

## Variation of Fuel Gas



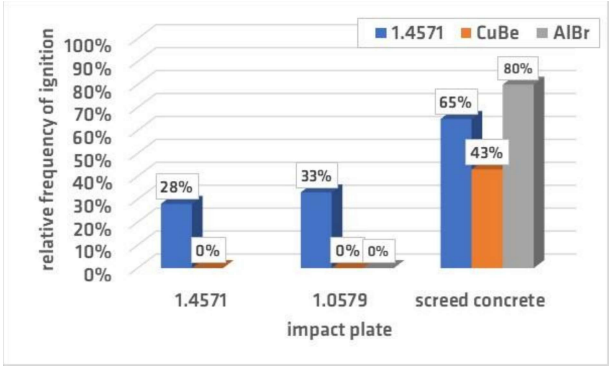

Source: BAM Research Report 292, 2010

## Variation of Homogeneous Material Pairing




Source: Research Report NAMES, 2015

## Inhomogeneous Material Pairings & Non-Metallic Materials




Source: Research Report HySpark, 2023

# Project „HICON“ – Subproject EC3 „Mechanical Impacts“ - Goals

**Project Owner & Contractual Partner:**

**HICON Experimental Campaigns (EC):**

**Main Goal:**

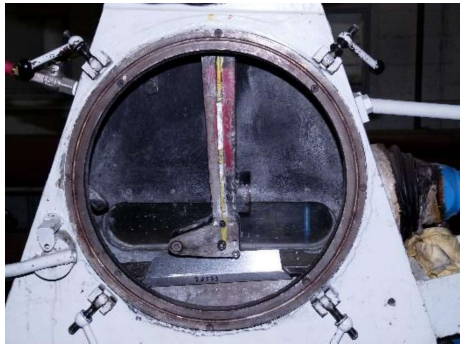
Obtain experimental data to assess the ignition probability in hydrogen atmospheres comparatively in case of

1. stirred-up gravel

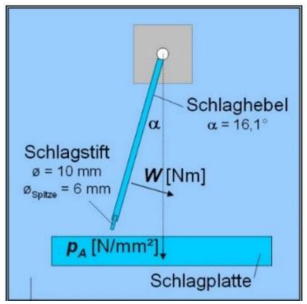
2. contaminated surfaces (oil & sand)

# Test Apparatus for „HICON EC3“

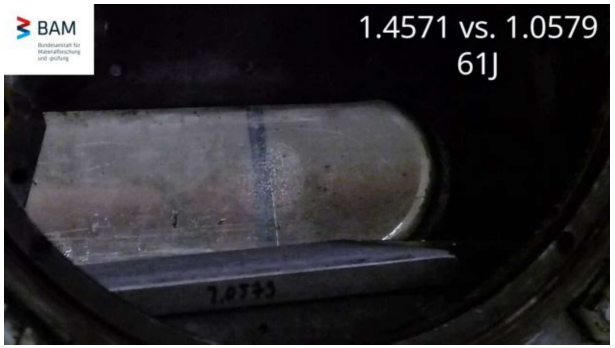
## Picture of Impact Spark Apparatus



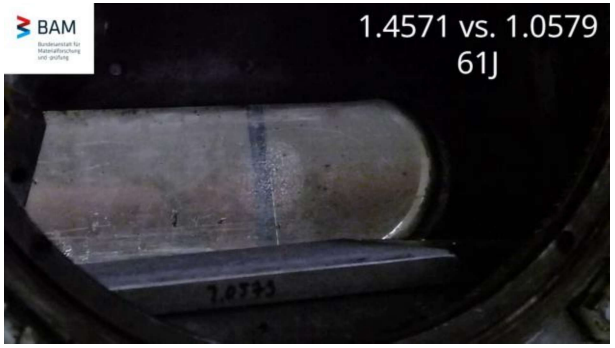
## Schematic Image




## Video Recording of Impact




Normal velocity

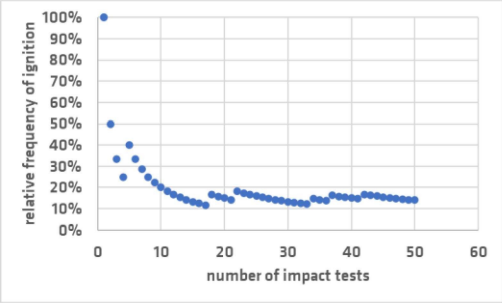



1/4 velocity

# Reproducibility of Test Results

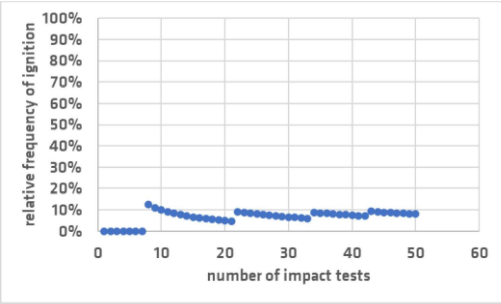
Influence of number of impacts on relative frequency of ignition (10% $H_2$ in air, 31 J)

**HICON_PRE3: 1.4571 vs. concrete**



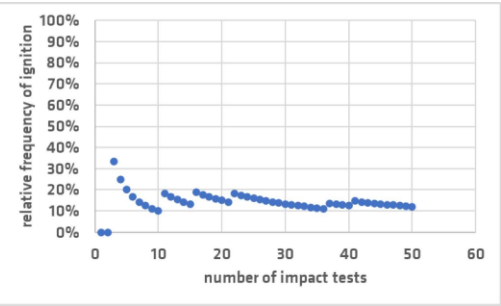

Ignition Freq. (after no. 50): 14.0%
Max. (after no. 10): 20.0%
Min. (after no. 10): 11.8%
HySpark (100 impacts): 10%

**HICON_PRE5: 1.4541 vs. 1.4541**




Ignition Freq. (after no. 50): 8.0%
Max. (after no. 10): 9.3%
Min. (after no. 10): 4.8%
NAMES (60 impacts): 6.7%

**HICON_PRE4: 1.4541 vs. 1.4541**




Ignition Freq. (after no. 50): 12.0%
Max. (after no. 10): 18.8%
Min. (after no. 10): 10.0%
NAMES (60 impacts): 6.7%

- Reproducibility of tests within range of few per cent proven
- At least 10 tests per series needed to draw meaningful conclusions

# Manufacture of Test Specimens

**Gravel**

1. Basalt 2. Granite 3. Quartz

**Impact Bolts**


**Impact Plates**

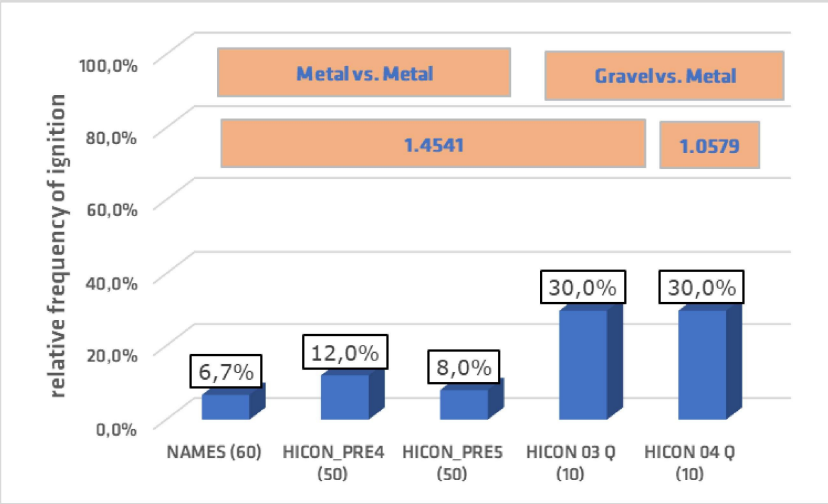
**Oil Contaminated Impact Plate**

**Sand Blasted Impact Plate**

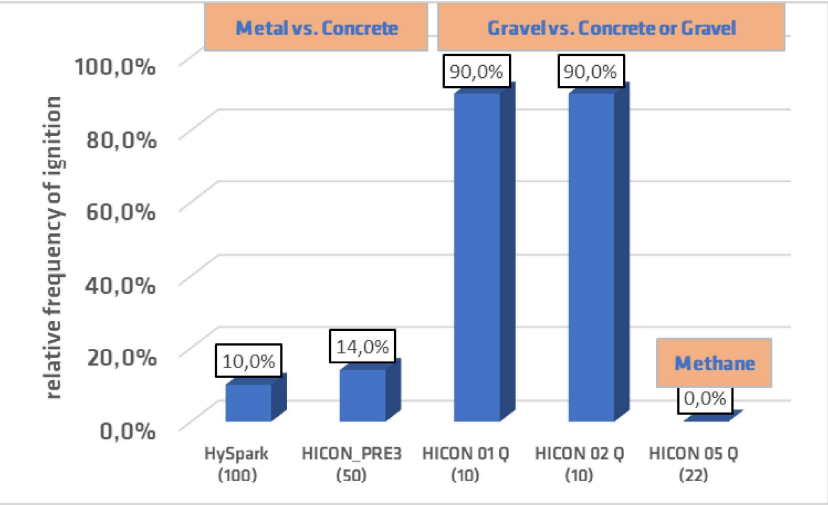
**Sand Coated Impact Plate**

# Ignition Probabilities (31 J) – Metal Pins Compared to Gravel Pins (Quartz)

**on Metallic Plates**

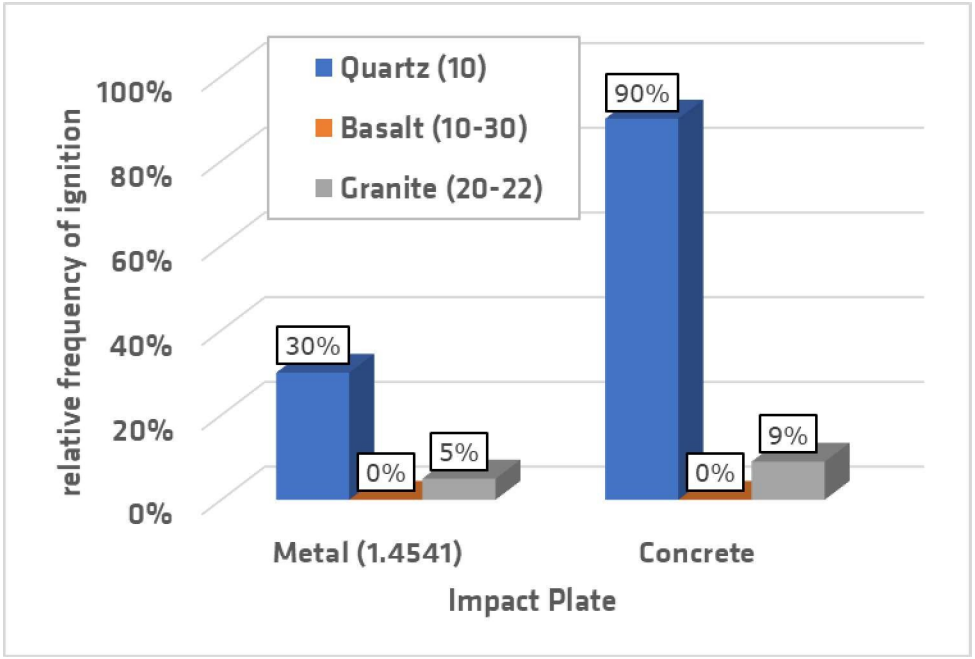



**on Non-Metallic Plates**




- If gravel is involved the relative frequency of ignition is significantly increased, particlualry in case of (gravel) vs (concrete or gravel)
- No effective ignition in case of methane

# Ignition Probabilities (31 J) – Different Gravel Pins (Quartz, Basalt, Granite)




- With different types of gravel different relative frequencies of igniton observed
- Probably due to mechanical/physical properties, e.g. hardness and brittleness, allowing to produce sparks easily
- Basalt fractures differently and just brakes without sparks
- Thermal conductivity of quartz is low

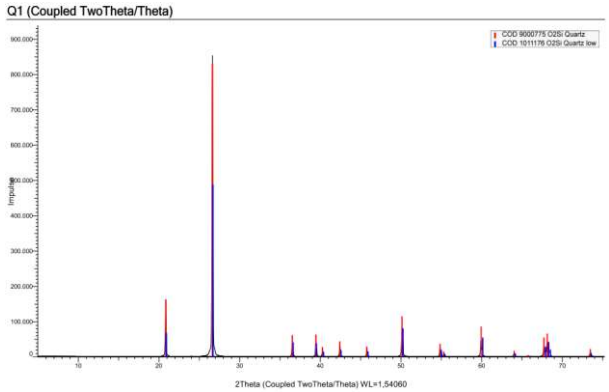
# Comparison of Sparking (Quartz vs Basalt)


Impact of basalt pin against concrete
(HICON02-20-B)

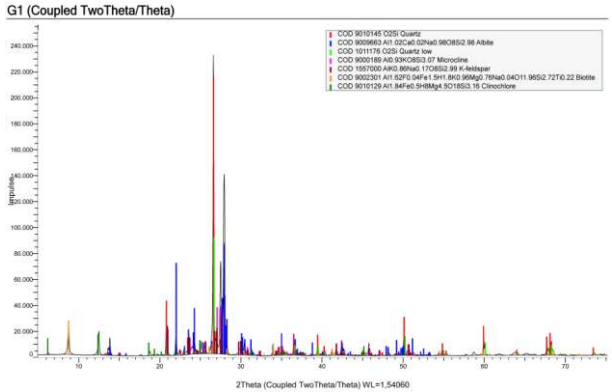
Impact of quartz pin against metal
(HICON04-09-02-Q)

- The spark pattern in impacts with quartz is much more pronounced compared to basalt

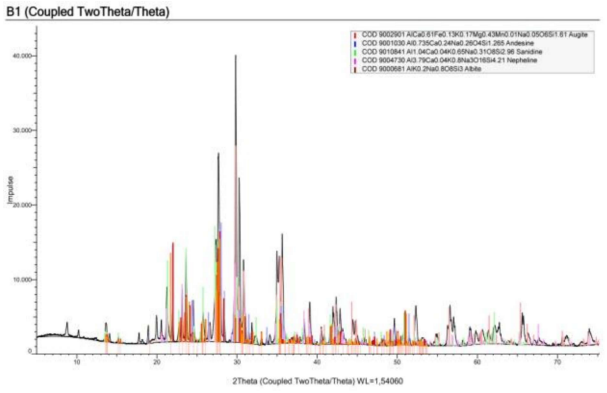
# Chemical Analysis of Gravel Specimen (xRD-Diagrams)




**Quartz**

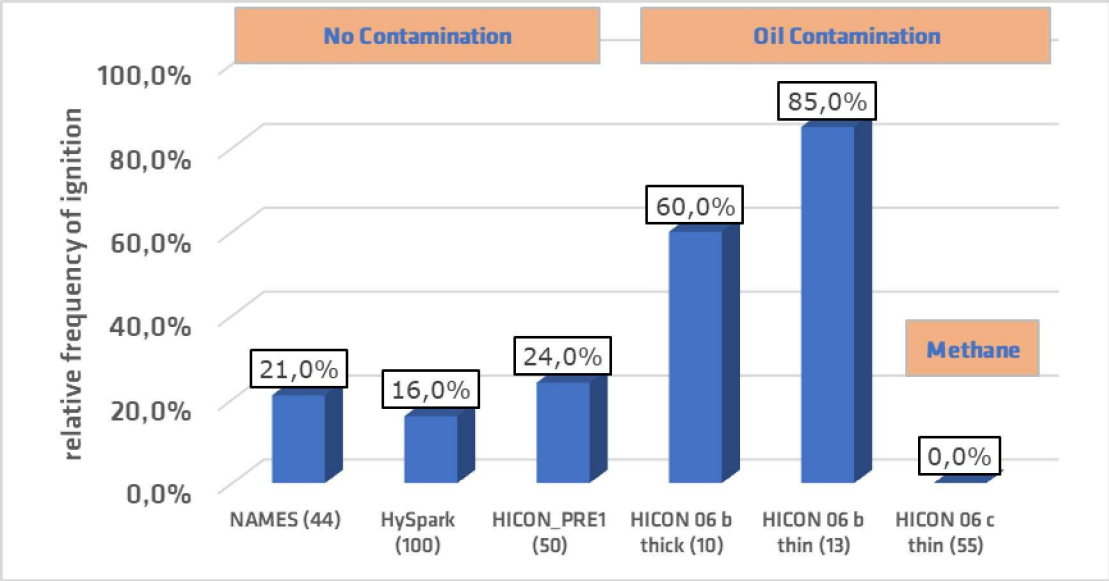



**Granite**



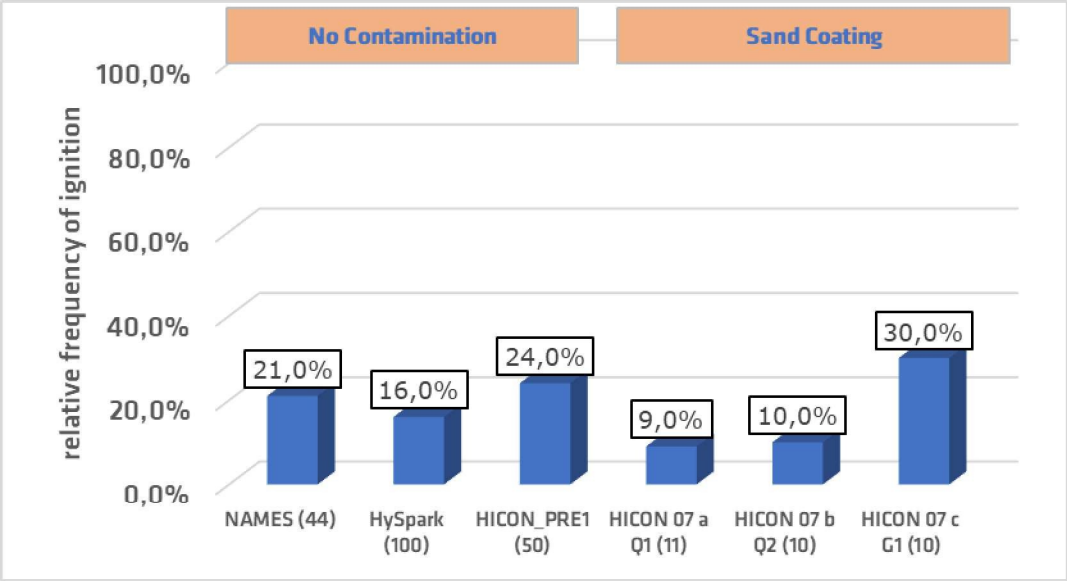

**Basalt**

# Ignition Probabilities (61 J) – Oil Contamination (1.4541 vs. 1.4541)



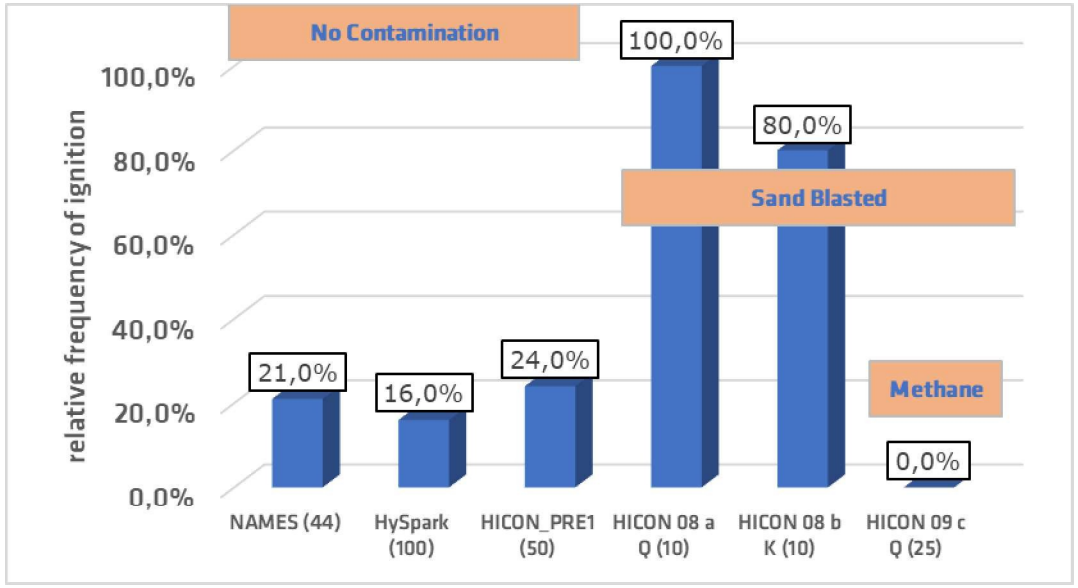

- Oil contamination can increase frequence of ignition under otherwise similar conditions
- Oil distribution can play a role
- No effective ignition in case of methane

# Ignition Probabilities (61 J) – Sand Coating (1.4541 vs. 1.4541)




- No significant influence of sand coatings observed
- Different types of sand considered (Ø 0.125 mm – 2,0 mm, quartz, grenade)

# Ignition Probabilities (61 J) – Sand Blasted Surface (1.4541 vs 1.4541)




- For sand blasted surfaces particularly high frequencies of ignition were observed
- Type of sand can play a role (Ø 0.5 mm – 1,0 mm quartz & Ø 0.6 mm – 0,85 mm corundum) used
- No effective ignition in case of methane

# Conclusions

- Ignition probabilty of hydrogen atmospheres by mechanical impacts can be highly increased when
  - gravel is involved, especially in case of the combination gravel vs. gravel or concrete.
  - surfaces are contaminated with oil or with fine sand (sandblasted surfaces)

- The type of gravel plays an important role. Probably, physical properties like hardness and brittleness allowing to produce sparks easily are crucial.

- Natural gas atmospheres cannot be ignited under similar conditions even with the most critical material pairing (quartz vs. concrete) or with oil or sandblasted surfaces.

- If possible avoid gravel and contaminations, where hydrogen release is possible.

# Open Issues & Challenges

**Open Issues:**

- What is the exact ignition location? → **General understanding** of the ignition process could help to estimate ignition probabilities without experiments?

- What are the **limiting parameters** (e.g. impact energy, material properties) to allow effective ignition of hydrogen for critical material pairings?

**Challenges:**

- How to transfer the ignition probabilities determined under lab-conditions (reproducible grazing impact as worst case) to the **various impact scenarios possible in reality** (e.g. impacting rocks).

- How to consider the **probability of impact events** for integration into risk models when models are transfered from natural gas to hydrogen.

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# Thanks! Any Questions?

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