STANDARDIZED METHODOLOGY

for the elaboration of ice throw risk assessments

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Empiric formula vs. risk assessments

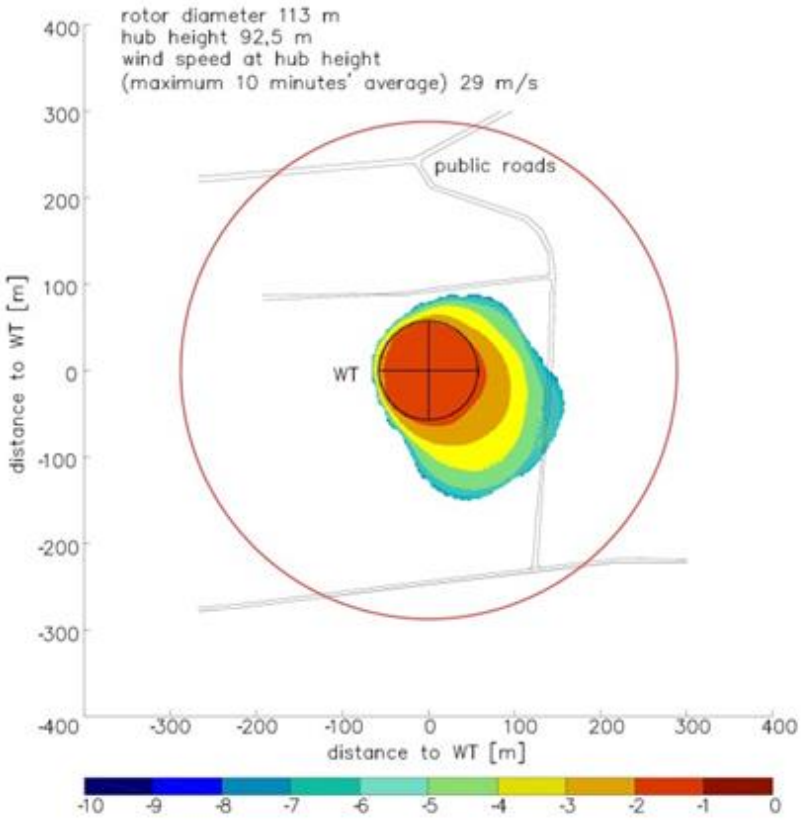
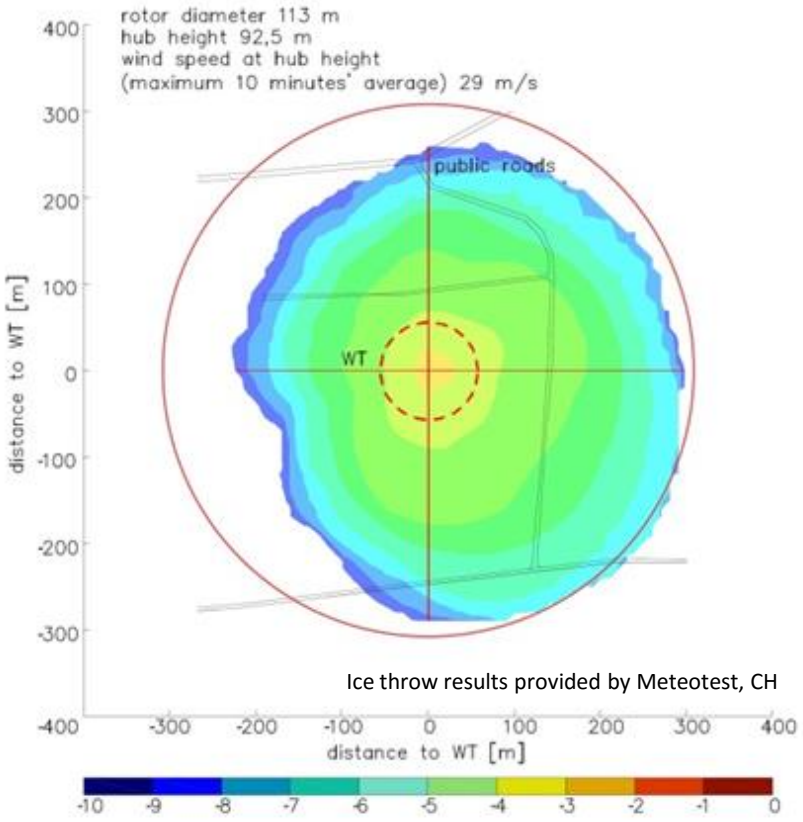


Fig.: Case example – ice fall



Ice throw results provided by Meteotest, CH

Fig.: Case example – ice throw

Assumptions and uncertainties

- **Ballistic model**
  - Aerodynamic parameters (rotation, drag & lift, flight trajectories…)
  - Consideration of different ice fragments
- **Data basis for the specific location**
  - Icing intensity (number of icing events, amount of relevant ice fragments, weight distribution…)
  - Wind speed and wind direction distribution
- **Risk Assessment**
  - Probability of persons in the danger zone
  - What is the acceptable risk level for persons, for cars …
  - Assessment of mitigation measures

Sensitivity Analysis

Case Example – Ice Fall

- Average Location in Lower Austria
- Blade tip height of WT: 200 m
- Wind data based on neighbouring wind met mast (50m, 1 year)
- Icing intensity:
  - 5 icing events/year (evaluation of wind measurement data)
  - Intensity estimated by experience: Light/moderate icing

  → 500 fragments / year (conservative)
- Superposition of 4 different fragments

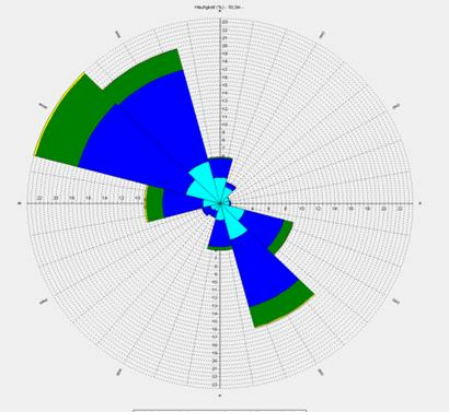


Fig.: Wind direction

	Dimensions	Mass	Numbers
50 %	3x4x8cm	86g	250
35 %	5x8x10cm	240g	175
10 %	5x10x50cm	1,5kg	50
5 %	3x20x100cm	5,4kg	25

Fig.: Weight distribution

Different weight distributions

	Dimensions	Mass	Numbers
50 %	3x4x8cm	86g	250
35 %	5x8x10cm	240g	175
10 %	5x10x50cm	1,5kg	50
5 %	3x20x100cm	5,4kg	25

	Dimensions	Mass	Numbers
77 %	3x5x10cm	90g	385
14 %	3x9x10cm	243g	69
9 %	10x13x20cm	1,6kg	44
0,4 %	16x19x20cm	5,5kg	2

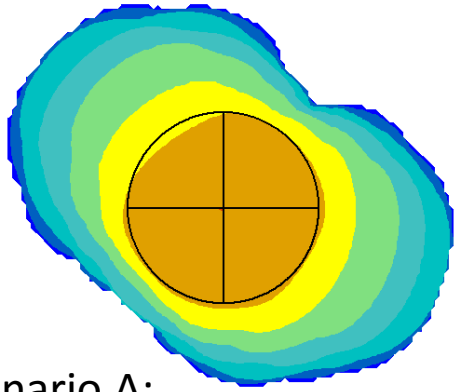


Fig.: Scenario A;
Dmax = 154m

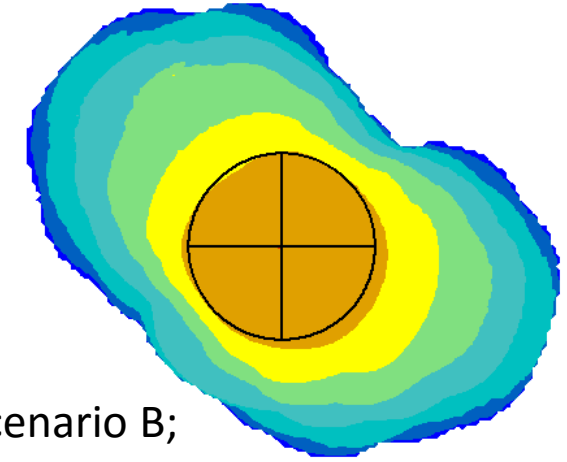


Fig.: Scenario B;
Dmax = 190m

Distribution of ice accretion on the blade

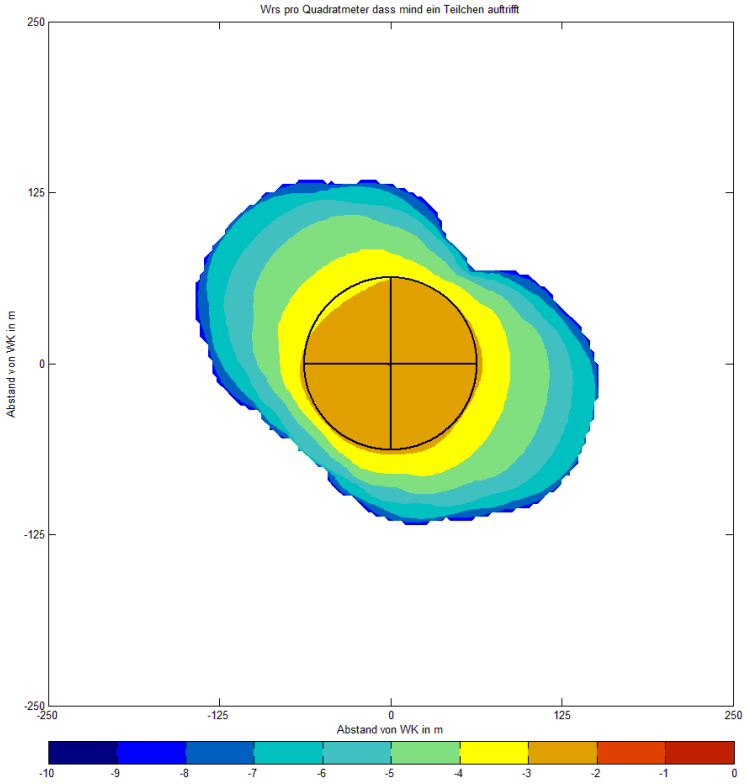


Fig.: Break-off of ice-fragments from the entire rotor radius

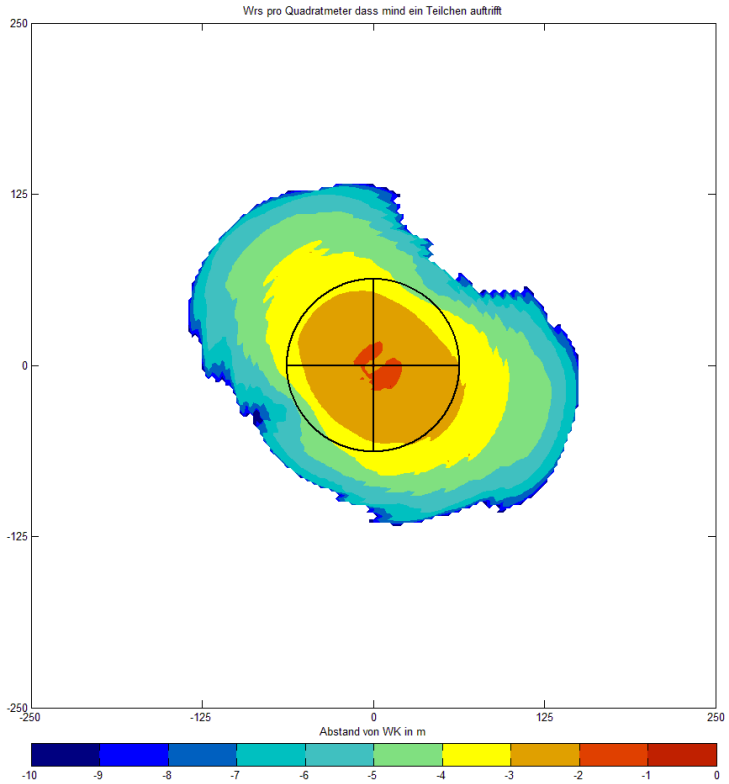
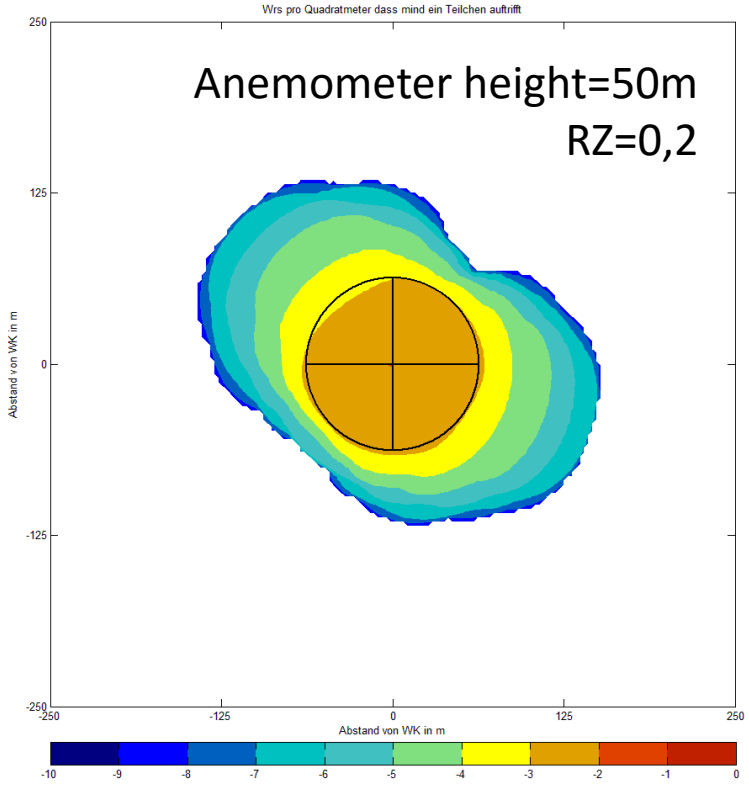
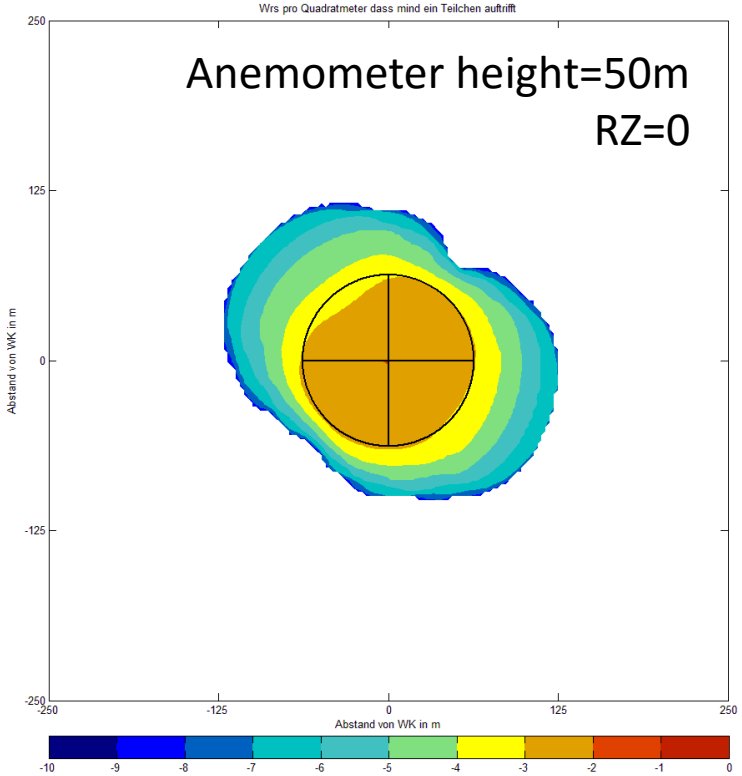


Fig.: Break-off of ice-fragments from the outer third of the rotor

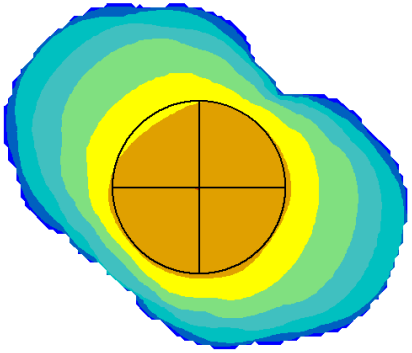
Influence of roughness length



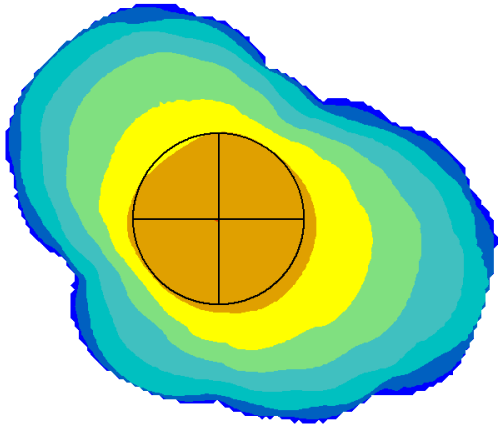


- Maximum distance: 154m vs. 126m
- Average hits/sqm: $9{,}7 * 10^{-3}$ vs. $1{,}3 * 10^{-2}$

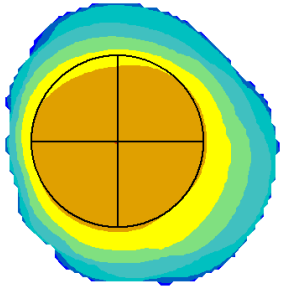
Wind speed data



10 Minutes averages,
Measuring height = 50m



3 sec. Maximum readings
Measuring height = 50m



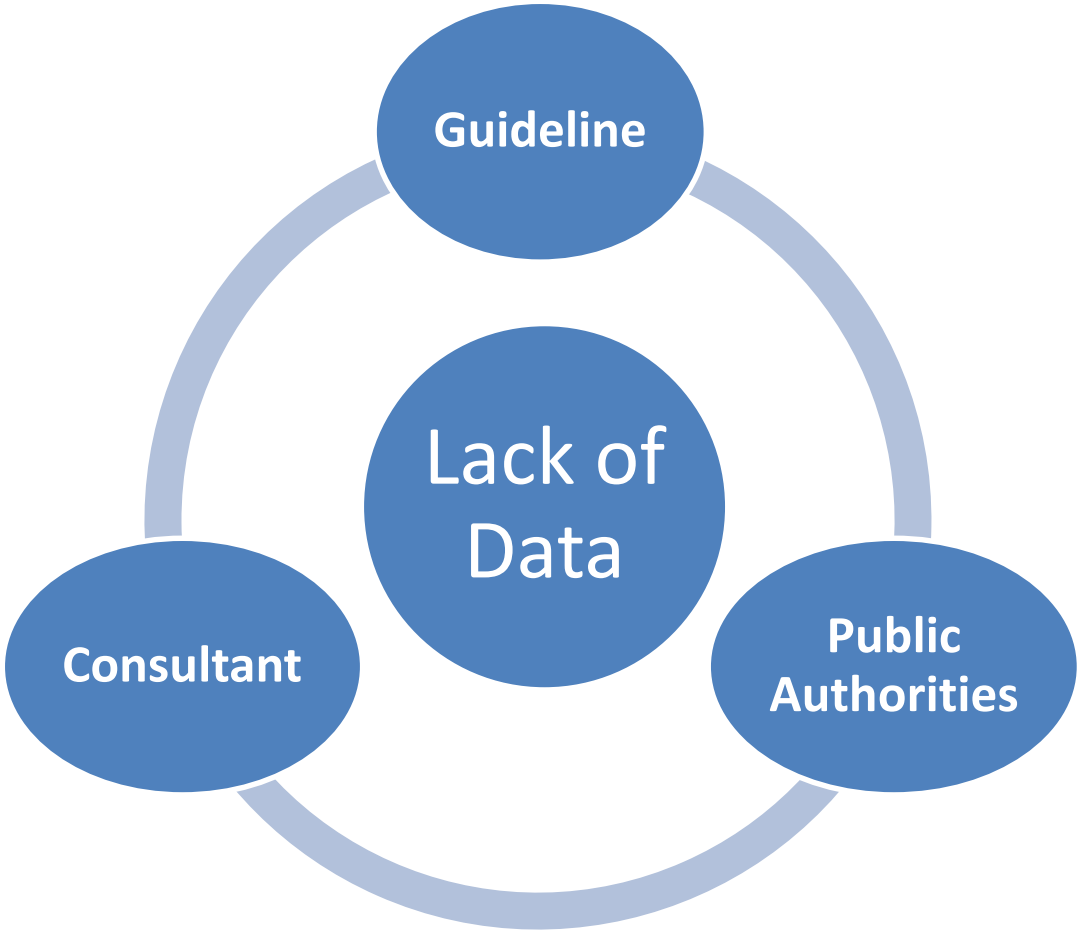
1-h Reanalysis Data
Measuring height = 50m

Wind Data	Max. Wind speed [m]	Max Range [m]	Average hits per sqm
10 Minutes averages	21	154	$9{,}7 * 10^{-3}$
3 Seconds maximum readings	27	180	$8{,}4 * 10^{-3}$
1 Hour reanalysis Dara	17	118	$1{,}6 * 10^{-2}$

Assumptions for risk assessment

- **Commonly accepted risk level**
  - Individual risk vs. collective risk
  - ALARP vs. MEM (levels range from 10^{-5} to 10^{-7})
- **Thresholds for lethal injuries**
  - Kinetic energy vs. weight
  - Hits per m^2 vs. hits per size of head
- **Mitigation measures (warning signs, flashing lights…)**
  - Efficiency / effectiveness of the individual measures
  - Reduction ration: One order of magnitude?

Where do we stand?



Project objectives

- **Main Targets**
  - International guidelines/recommendations for the elaboration of ice-throw / ice-fall risk assessments
    - Paving the way to more transparency
    - Awareness of consultants and authorities about crucial parameters
- **Working procedure**
  - Cooperation within Task 19 plus interested external experts
  - Comparing different approaches and results
  - Detailed setup (meetings, case examples…) dependent on number and origin of partner companies
- **Positive side effect for participants**
  - Learning effect and further improvement of their models

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for the elaboration of ice throw risk assessments

Photo: The Alps
Source: Energiewerkstatt

Thanks for your Attention.

Superposition of results for ice fragments

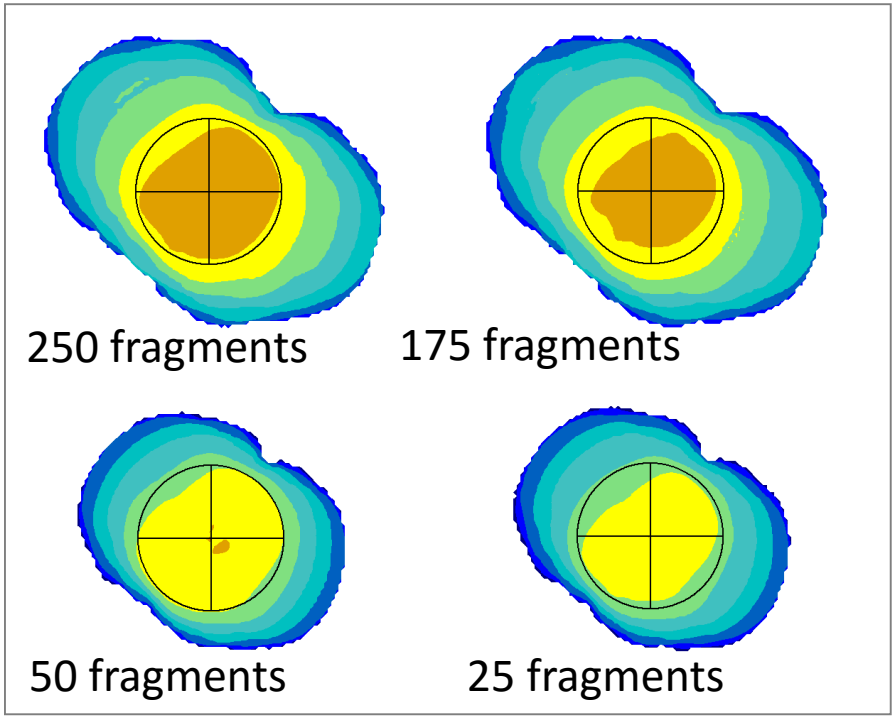

Fig.: Results for 4 different fragments

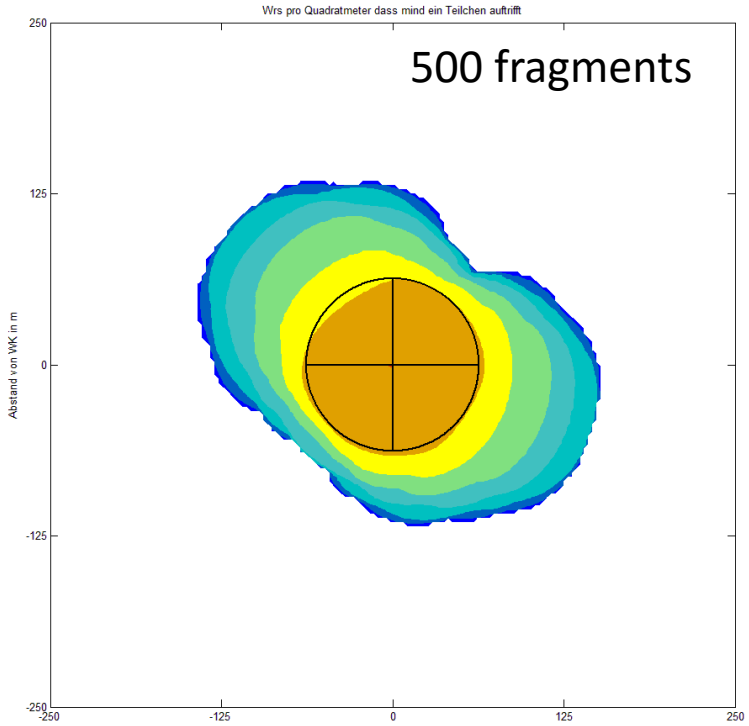

Fig.: Overall result

Overall result significantly dependent on scenario for smallest fragments!