Hydraulic fracturing in reservoir rocks: Experiment & simulation

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SINTEF Petroleum Research
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- Objective: To improve our knowledge on hydraulic fracturing in porous media including fracture propagation & pattern.

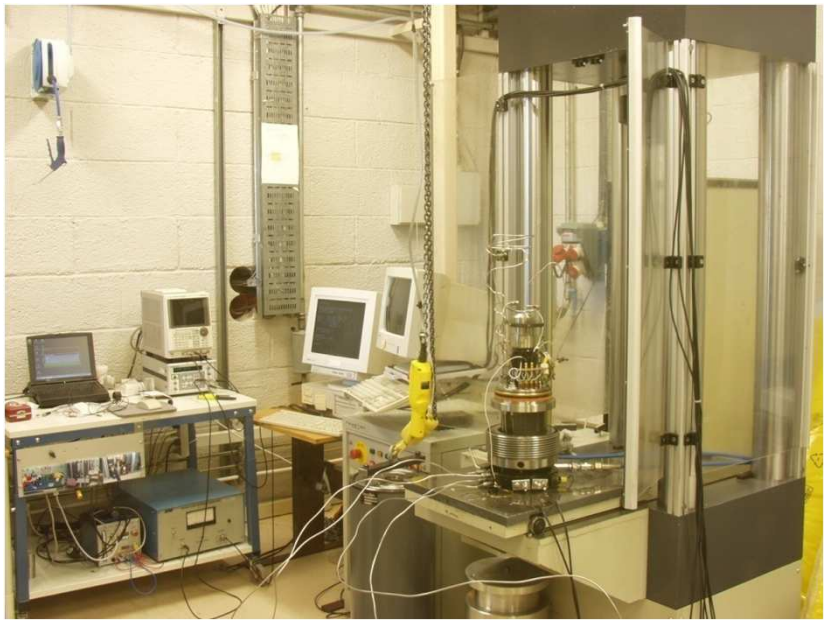
- Methods: We use different methods at different length scale
  1) Fracturing test on core sample
  2) PFC at pore scale
  3) Beam-lattice model at mesoscopic scale
  4) MDEM at macro scale (even resorvoir scale)

- Application:
  1) Planning safe & efficient drilling (geothermal, shale-gas)
  2) Reservoir characterisation (CO_2 storage)
  3) Prediction of well collapse & leakage
  4) Enhance production by increasing permeability.

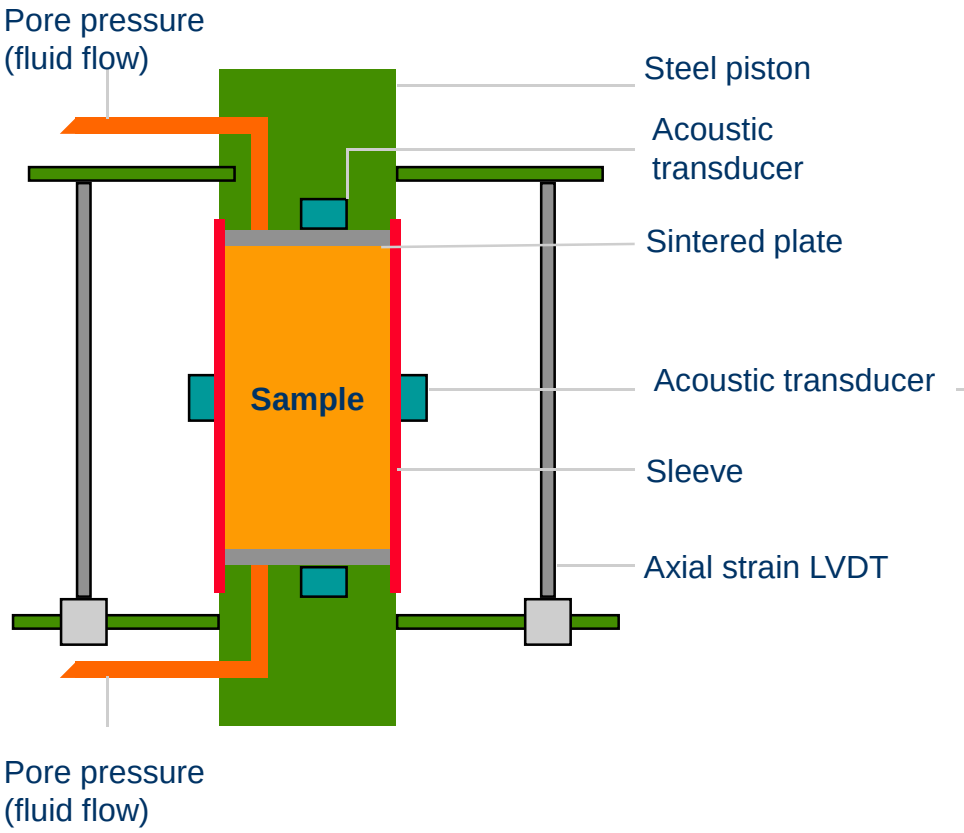
SINTEF Laboratory

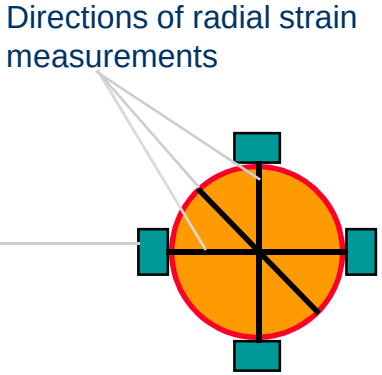
TerraTek system

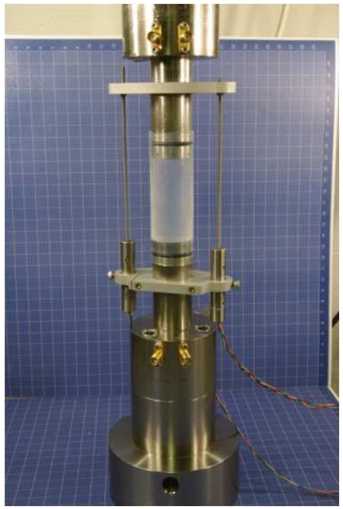
MessTek system

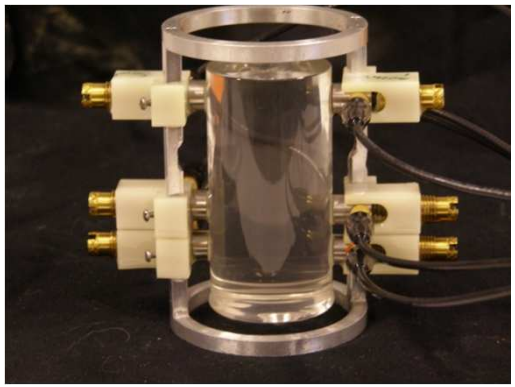


Triaxial cell instrumentation



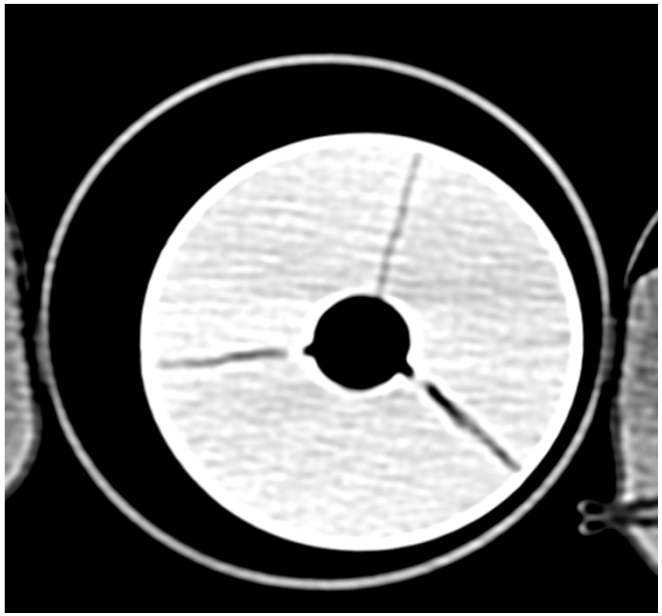




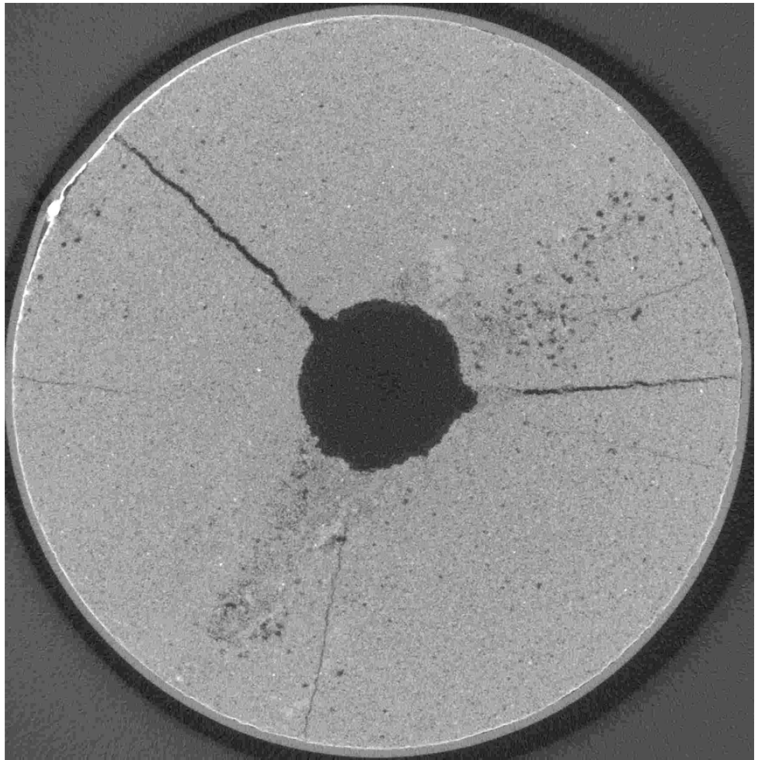


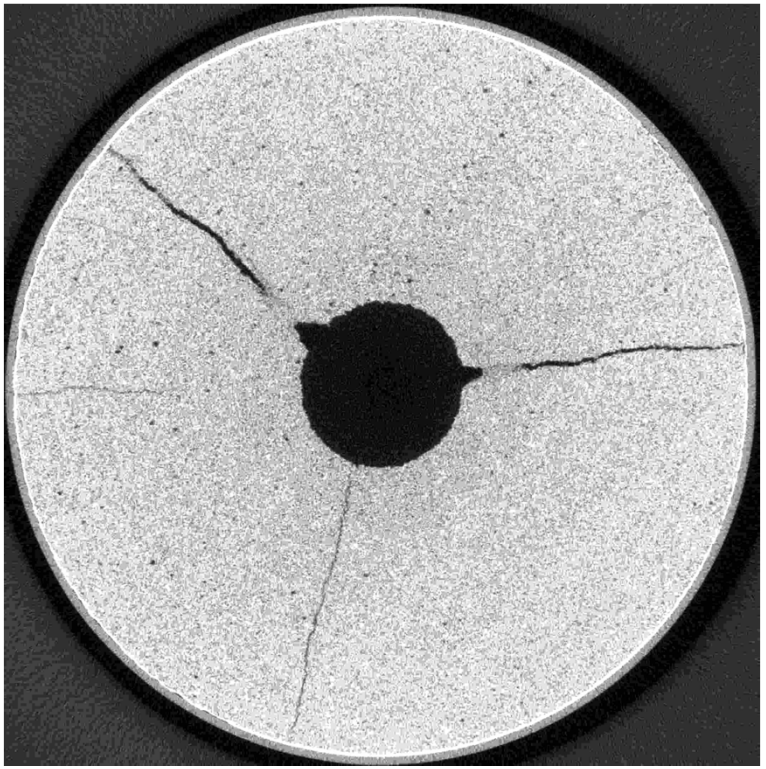
Test 1: Red sandston

Medical scan image

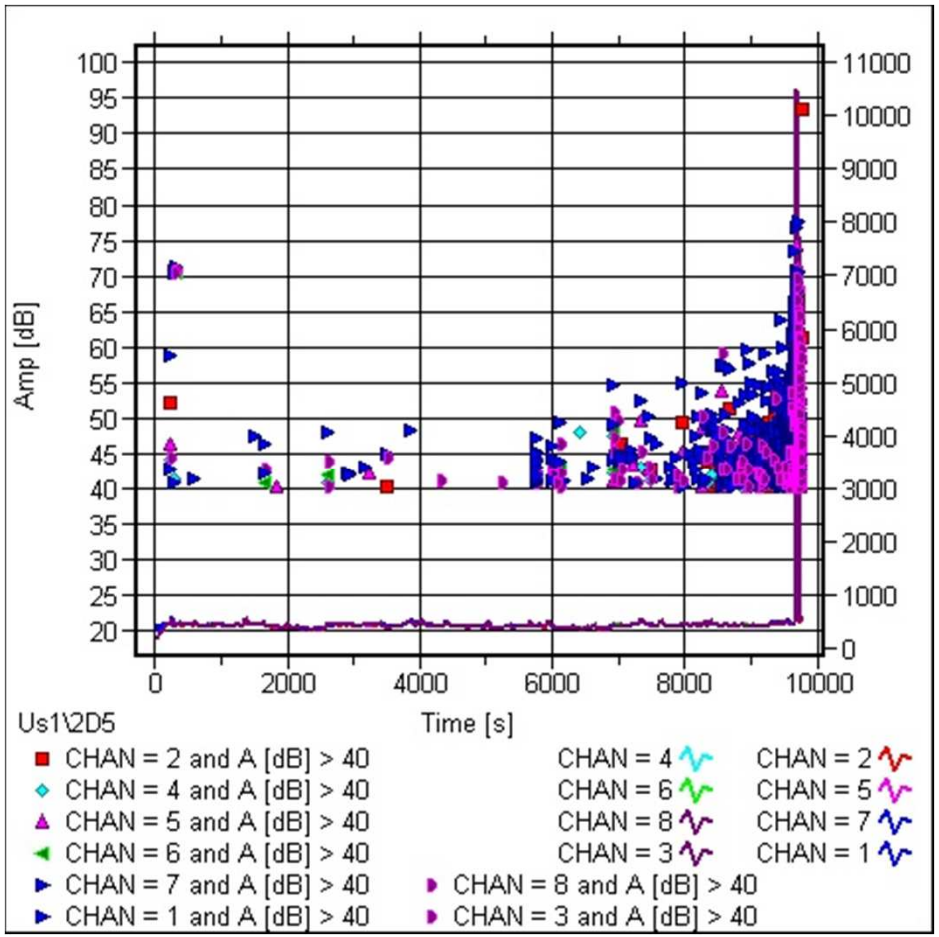


CT Scan Image





Amp. Vs. time


Amp [dB]
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2000
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Time [s]
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CHAN = 2 and A [dB] > 40
CHAN = 4 and A [dB] > 40
CHAN = 5 and A [dB] > 40
CHAN = 6 and A [dB] > 40
CHAN = 7 and A [dB] > 40
CHAN = 1 and A [dB] > 40
CHAN = 8 and A [dB] > 40
CHAN = 3 and A [dB] > 40
CHAN = 4
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CHAN = 8
CHAN = 3
CHAN = 2
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CHAN = 7
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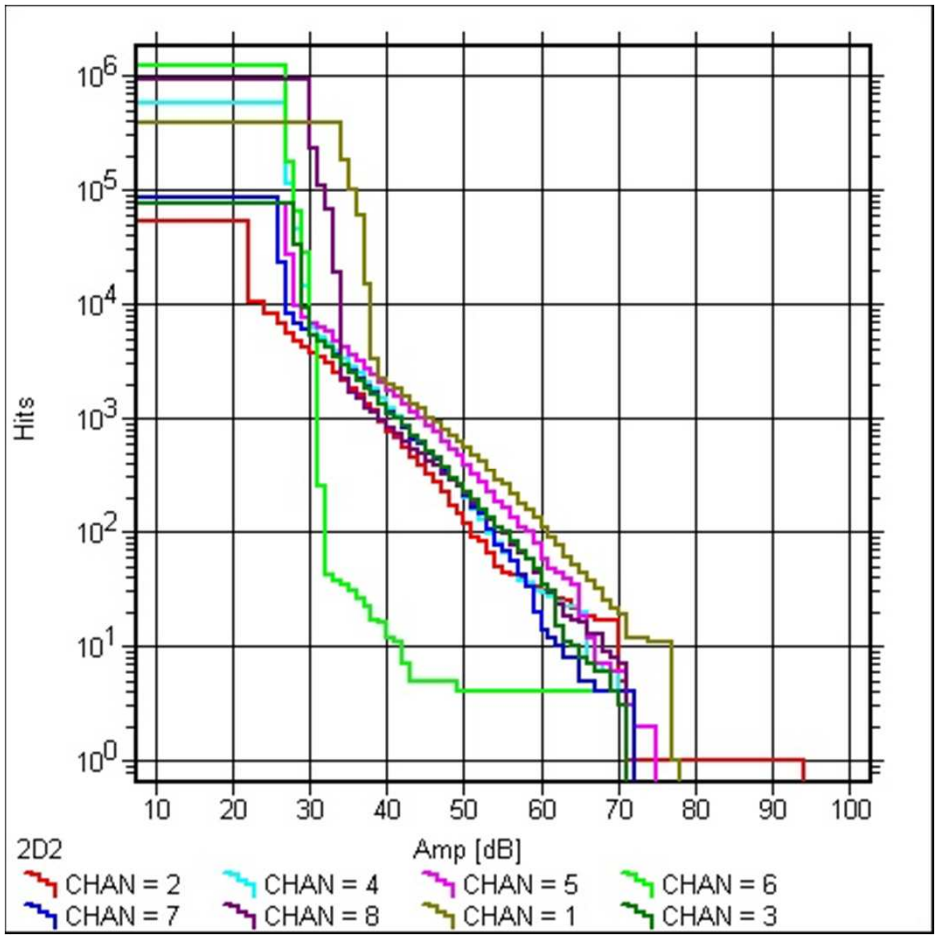
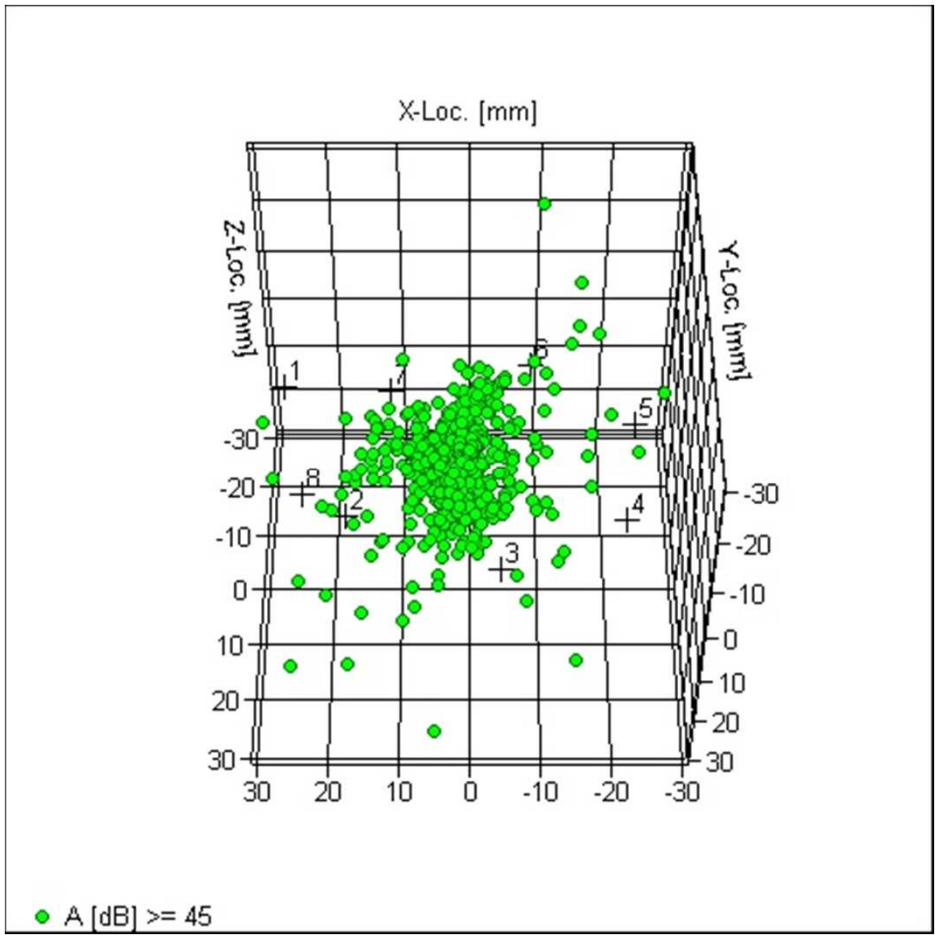
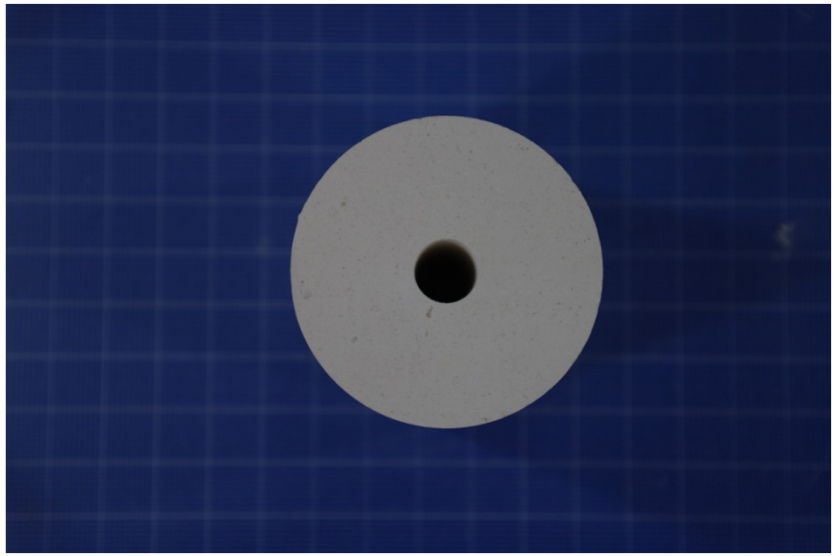
AE data: Amplitude distribution

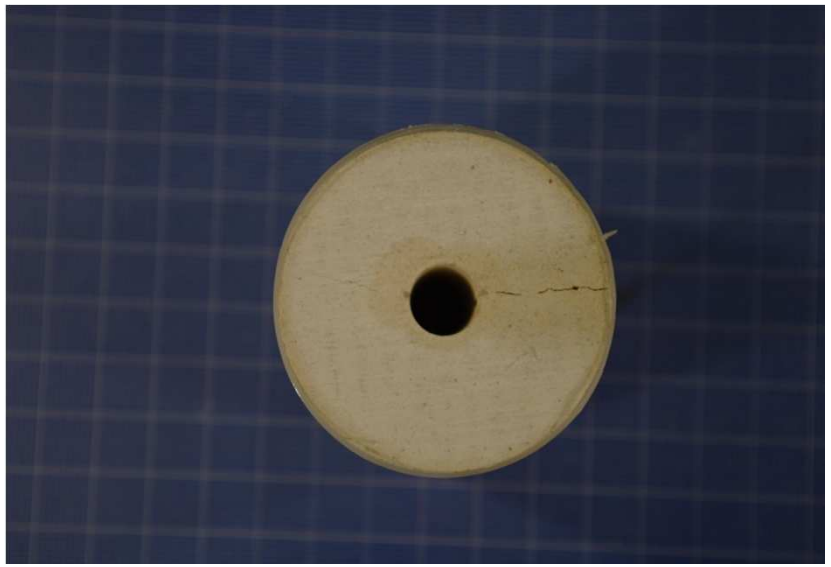


AE data: Location

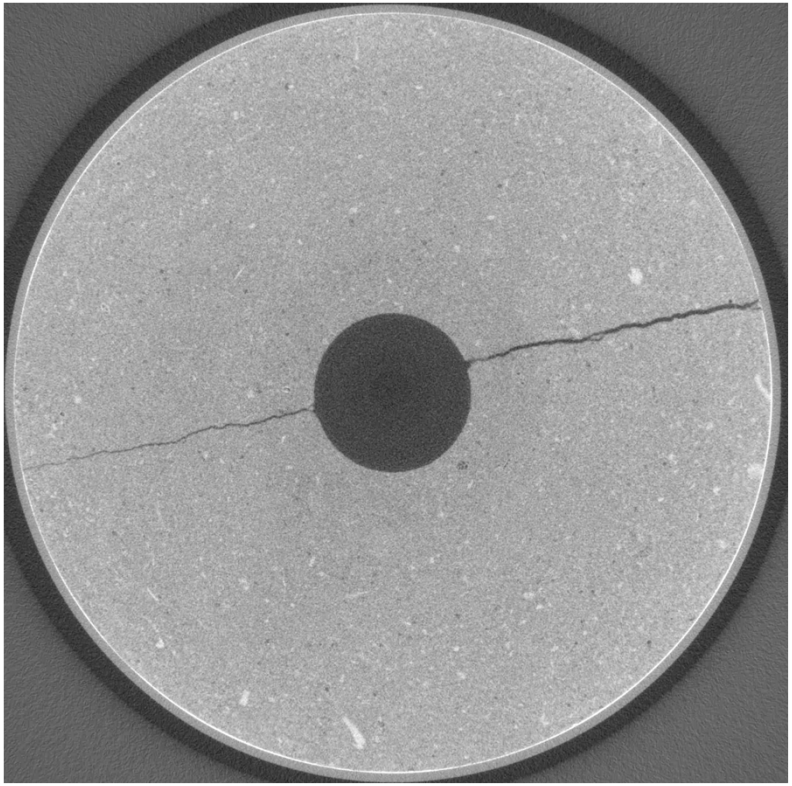


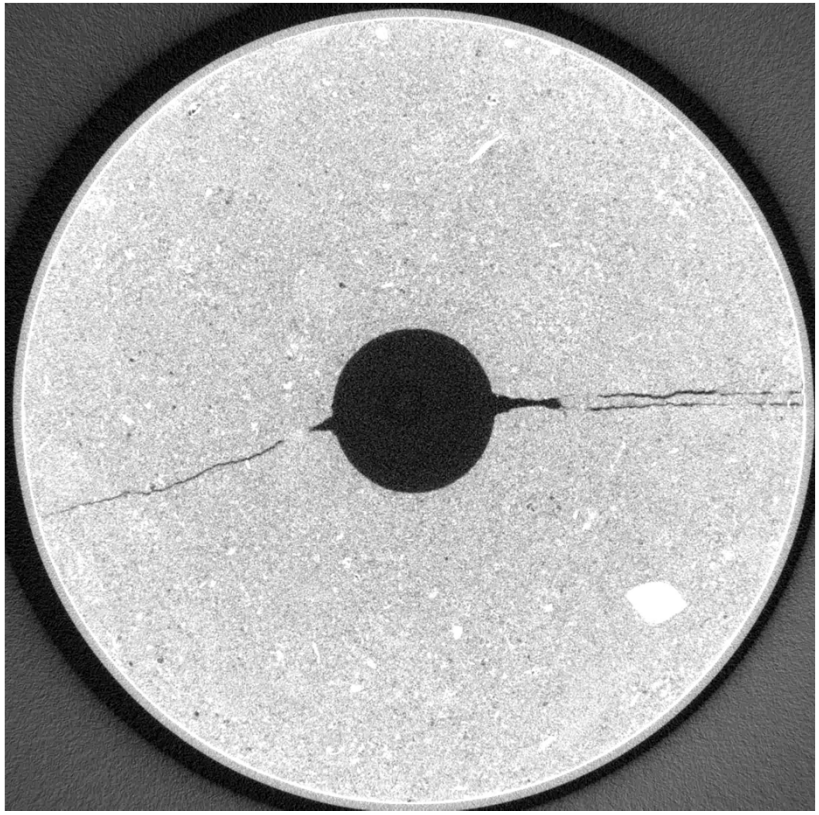
Test 2: Limestone



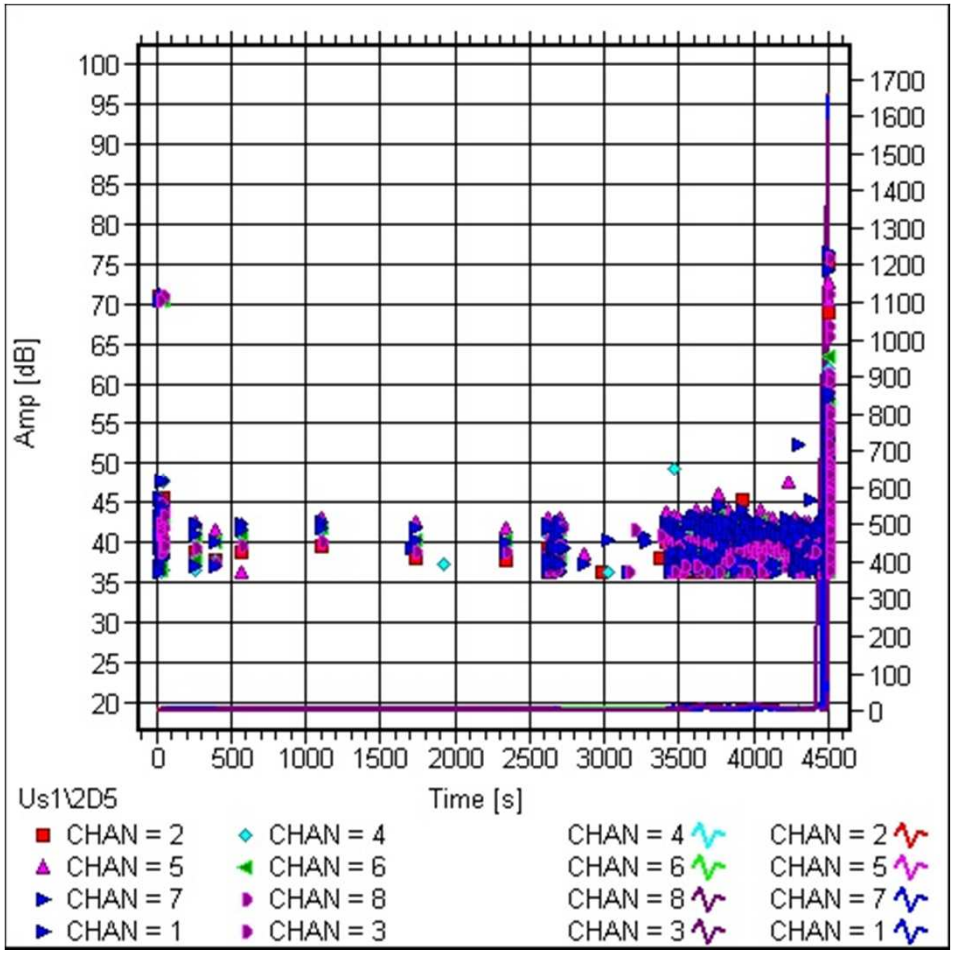


CT scan image





Amp vs. Time


Amp [dB]
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Time [s]
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CHAN = 6
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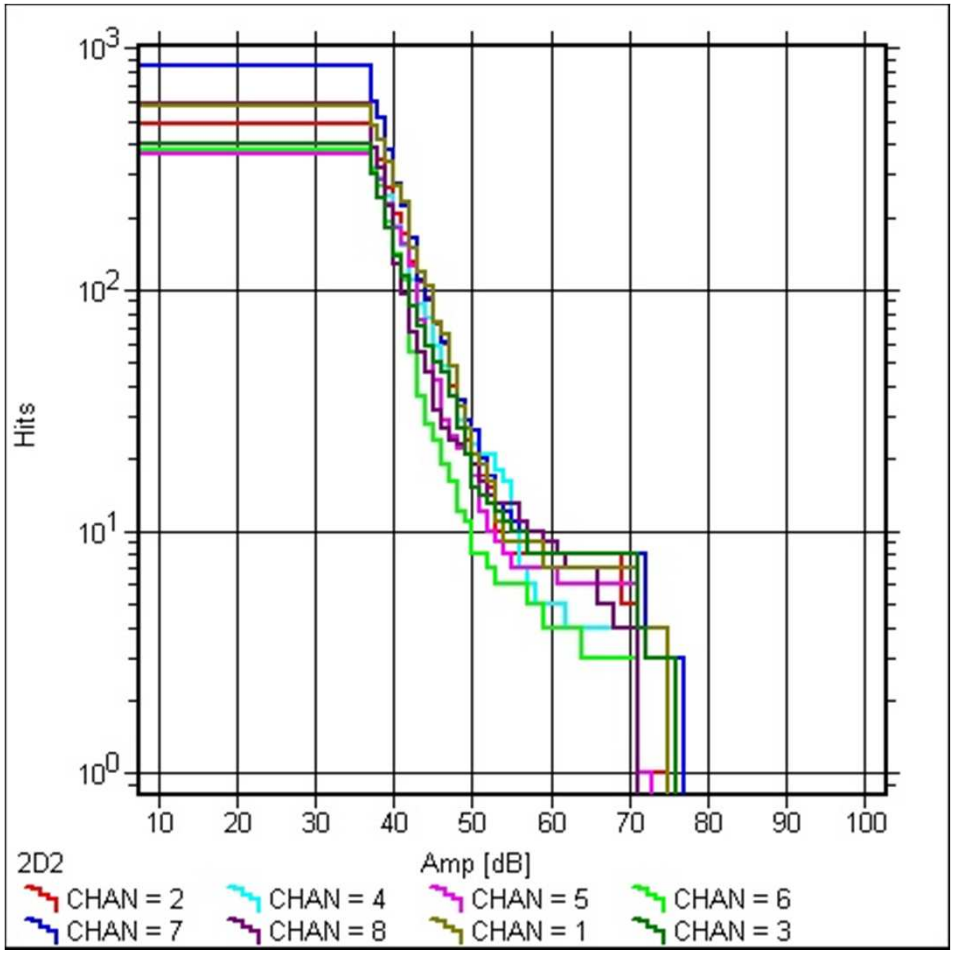
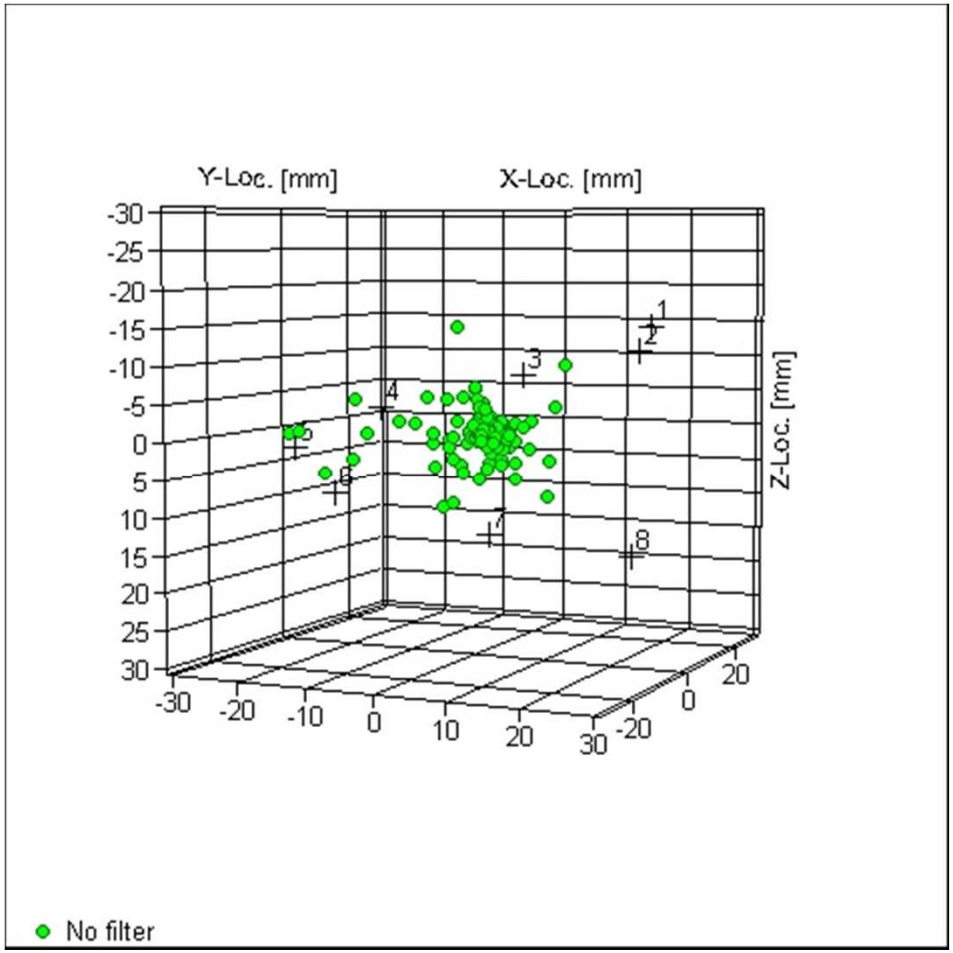
CHAN = 3
CHAN = 2
CHAN = 5
CHAN = 7
CHAN = 1

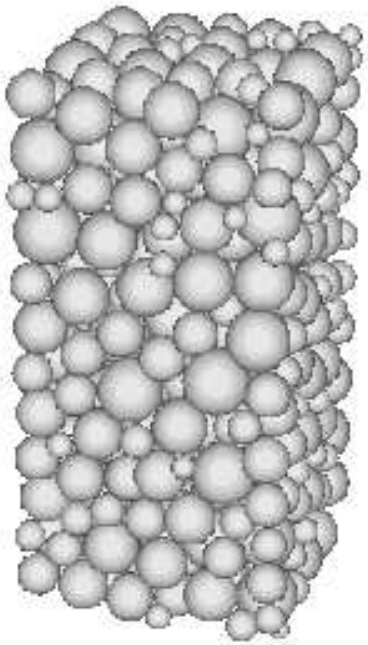
AE data: Amplitude distribution



Event location



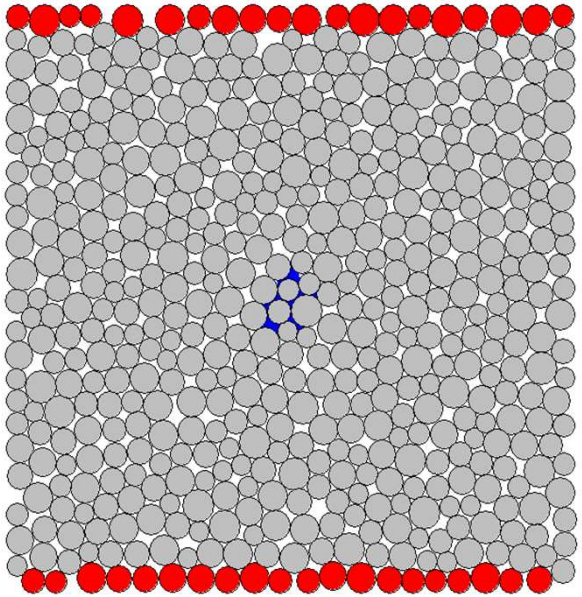
Pore scale modeling: using PFC

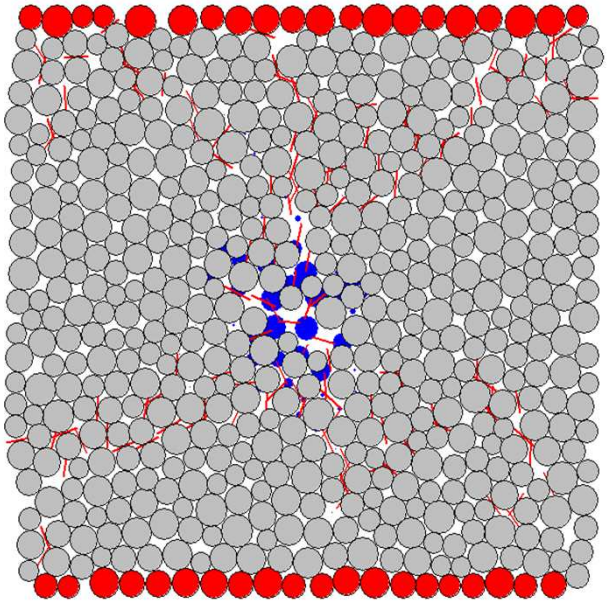


- PFC (Particle Flow Code) is a code based on the Discrete Element Method (DEM).
- PFC solves the equations of motion directly.
- In each time step, the movements of all the particles are calculated according to the motion law, and the forces at all the contacts are calculated according to a contact law.

ITASCA, USA

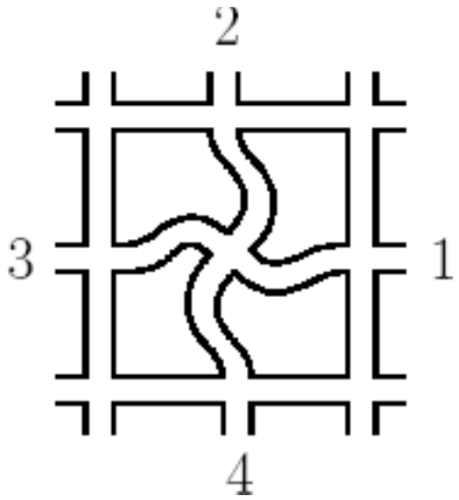
Hydraulic fracture: PFC 2D



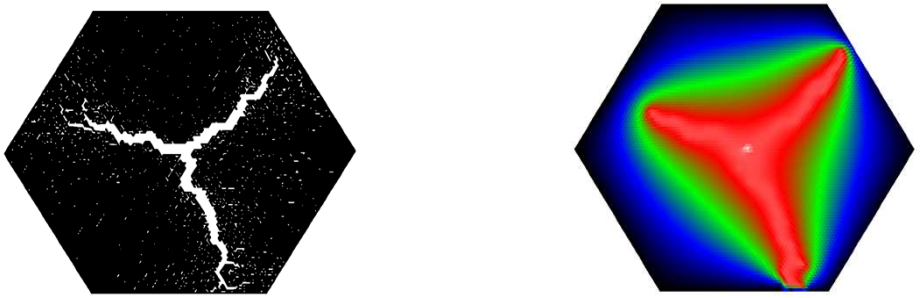


Fracture modeling at mesoscopic scale

Bjørn, NTNU



Elastic beam lattice model

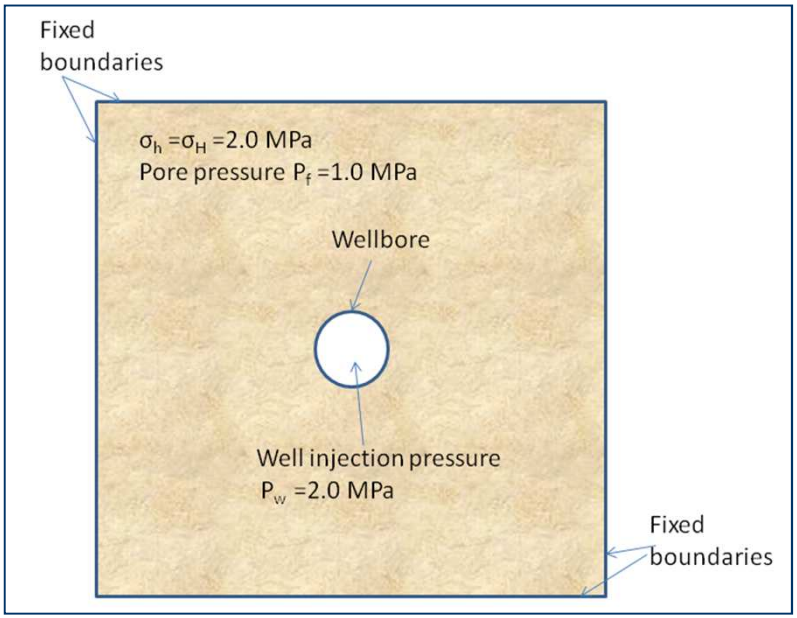


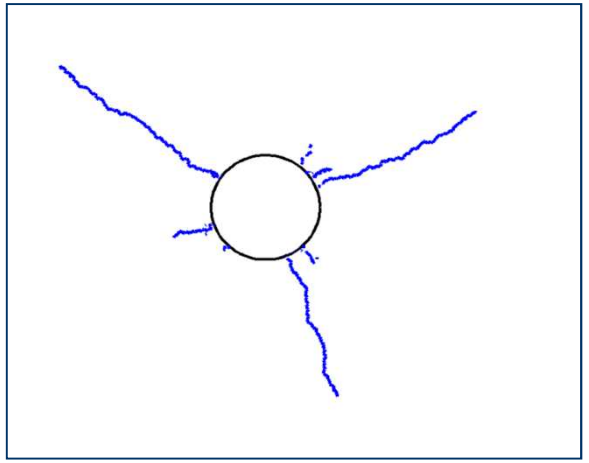
Fracture pattern and pressure distribution

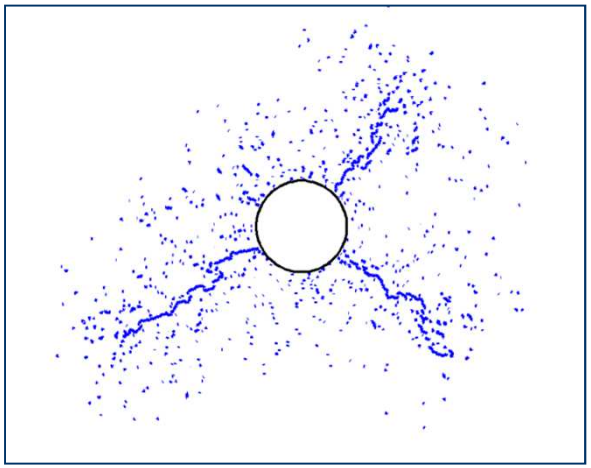
s0039.avi

Macro-scale modeling: MDEM

Haitham, SINTEF

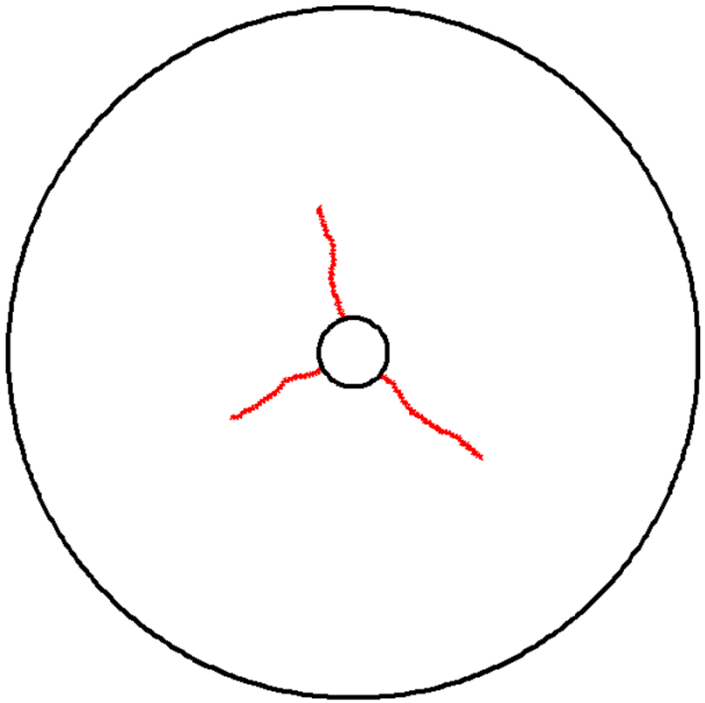




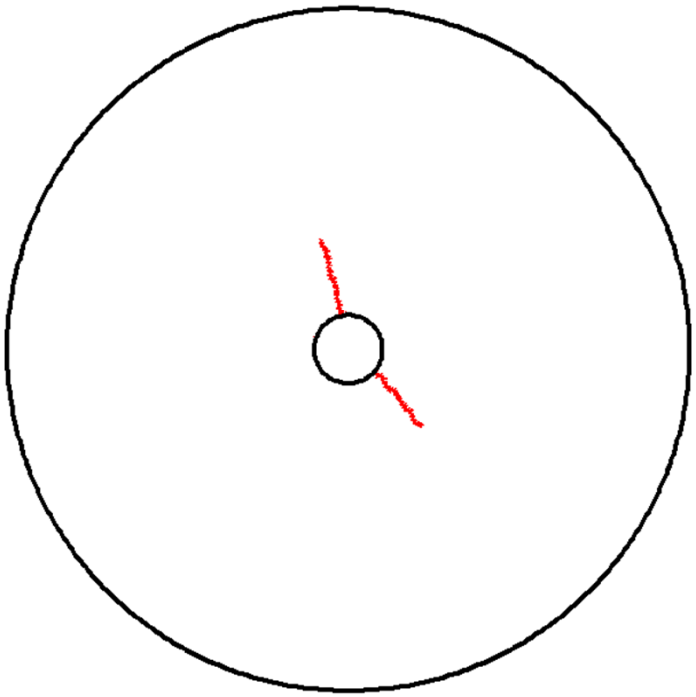


Effect of Poisson's ratio

Poisson's ratio =0.25



Poisson's ratio=0.4



Conclusions

- Lab test on core sample: Fracture pattern depends on strength & brittleness of the cores.
- PFC: Ratio between tensile & shear strength influnces fracture pattern & numbers.
- Beam-lattice: Disorder in strength and pressure distribution are responsible for different fracture pattern.
- MDEM: Number of fracture branches depends on Poisson ratio.
- Effect of pre-existing ferctures ??