PERFORMANCE OF OPTIMIZATION ALGORITHMS

FOR DERIVING MATERIAL DATA FROM BENCH SCALE TESTS

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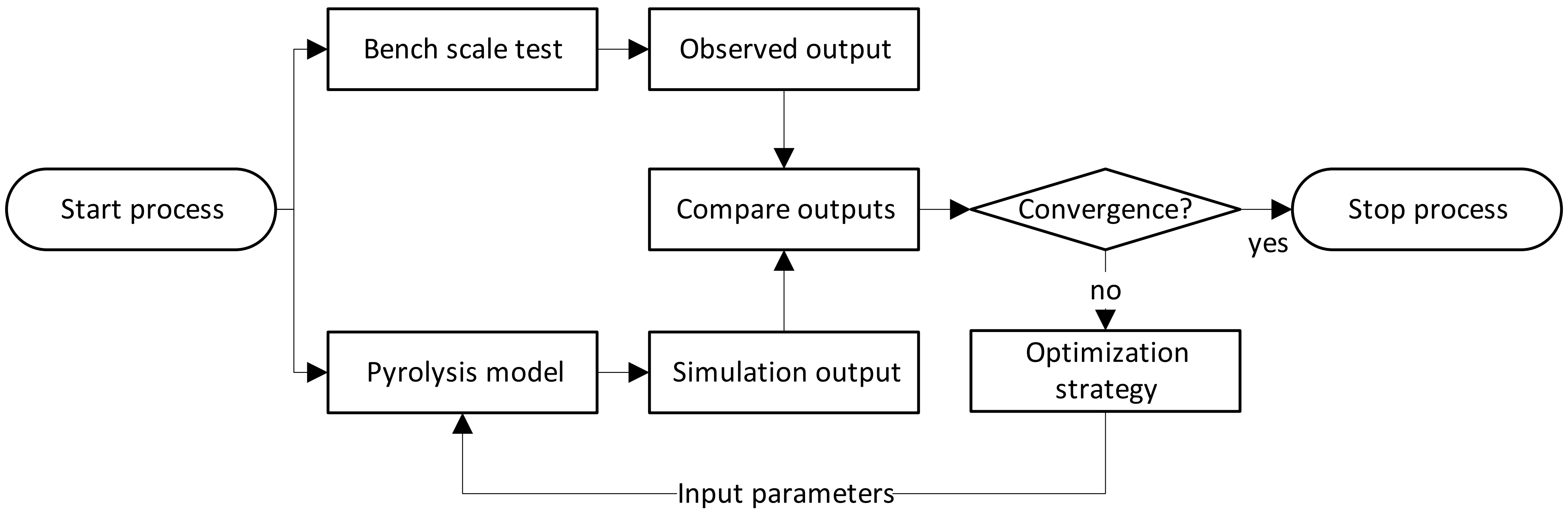
Content

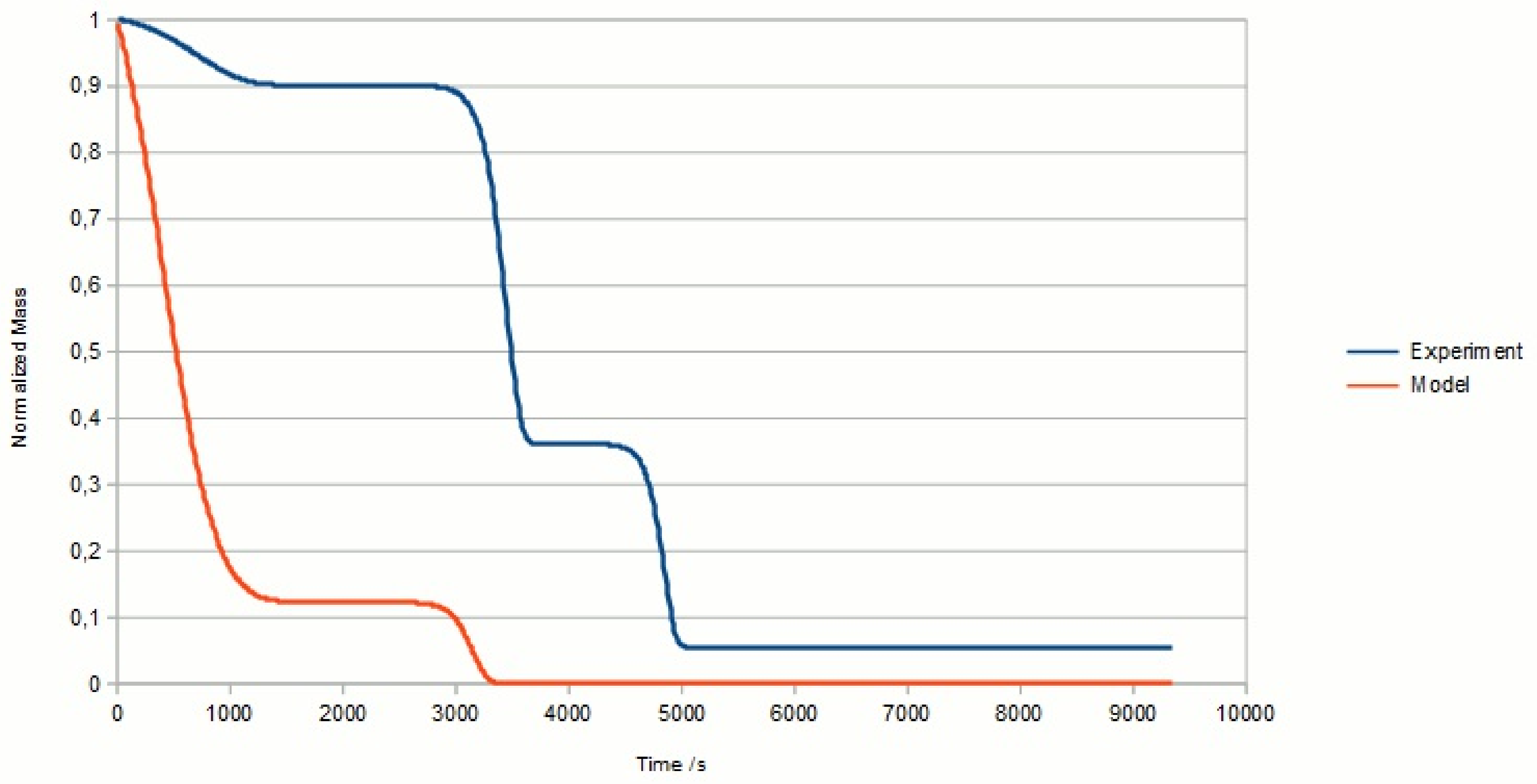
Introduction

- Aim: Find good performing optimization algorithm for material parameter estimation to simulate pyrolysis
- Way: Compare best known algorithm for material parameter estimation with two not yet evaluated algorithms utilizing synthetic data and bench scale tests

Method (Flow Chart)



Method

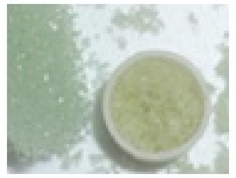


1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
Normalized Mass
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Time /s
Experiment
Model

Bench Scale Tests

- Thermogravimetric Analysis (TGA)
- Mass Loss Cone Calorimeter (MLC)

TGA

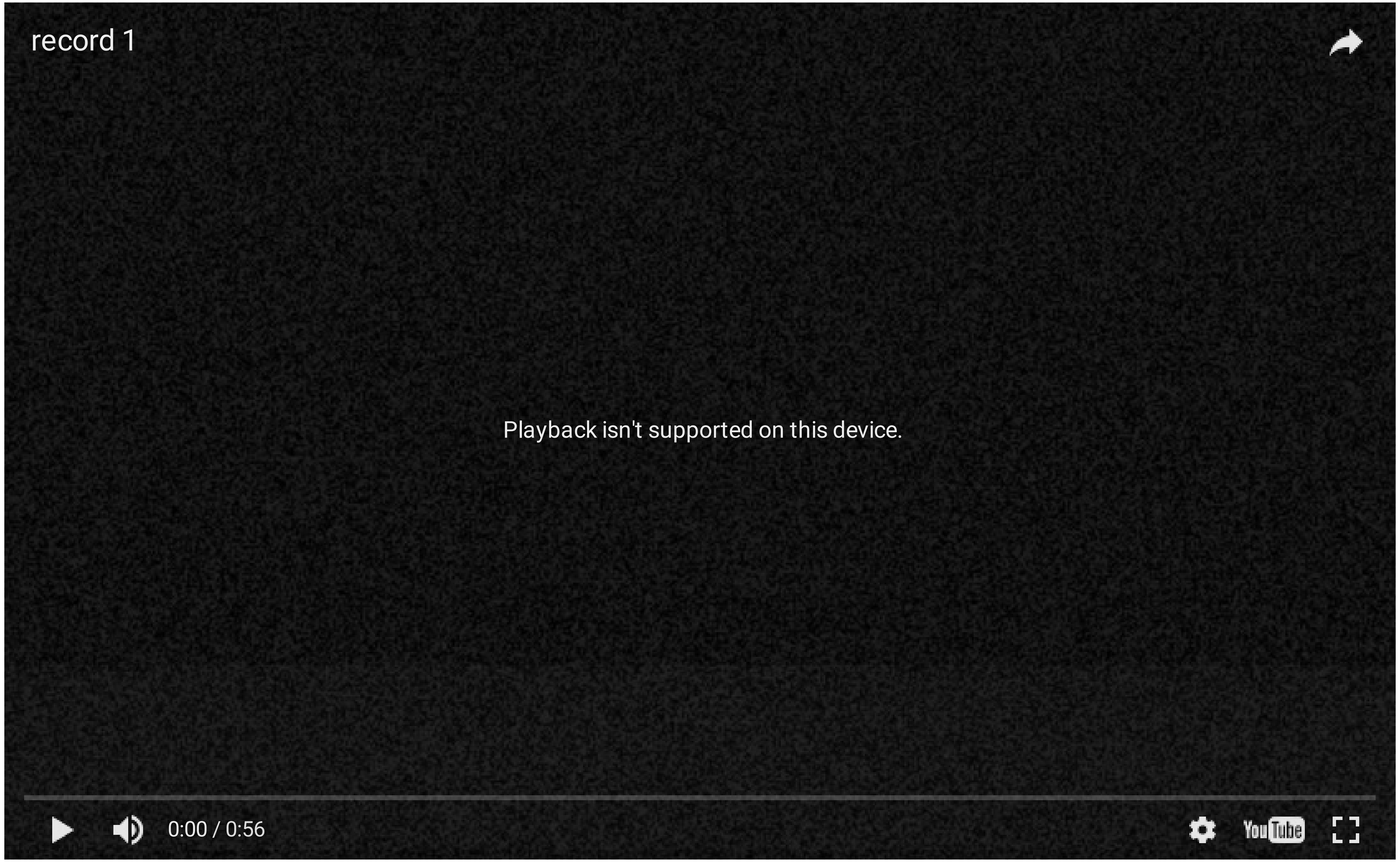


- Sample size: few mg
- Defined heating rate
- Defined atmosphere
- Capturing mass loss and mass loss rate

MLC

- Sample size: g…kg
- Defined heat flux
- Capturing mass loss and mass loss rate

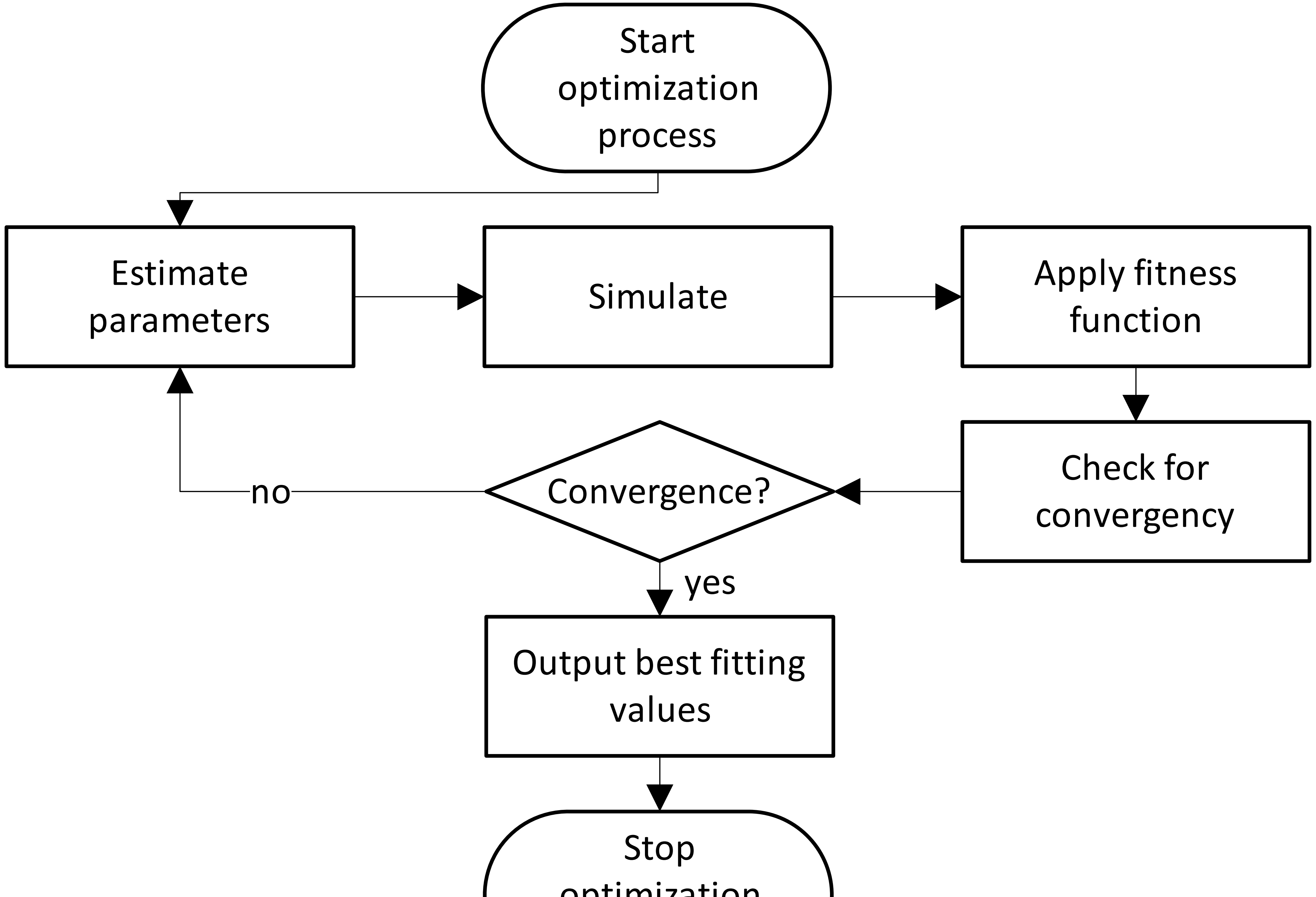
MLC Video



Setups

- TGA model
  - Synthetic data
  - TGA experiment with PU
- MLC model
  - Material: PMMA
  - Isolating and conducting background layer
  - Two experiments:
    - Single heat flux (50 kW/m^2)
    - Five heat fluxes parallel (20…75 kW/m^2)

Optimization Process



Algorithms

- Shuffled Complex Evolution (SCE)
- Artificial Bee Colony (ABC)
- Fitness Scaled Artificial Bee Colony (FSCABC)

SCE

- Introduced for hydrologic model calibration
- Evolutionary algorithm
- State of the technology for material parameter estimation
- Divides a population into complexes
- Two phases after initialization:

1. Local search per complex
2. Global evolution between complexes

ABC I

- Swarm intelligence optimization algorithm
- Mimics foraging behavior of a honey bee swarm
- Combines local, global and random search
- Outperformes standard benchmark tests for optimization algorithms

- Quite simple
- Three phases after initialization:
  - Employed bee phase
  - Onlooker bee phase
  - Scout bee phase

ABC II

- Initialization
  - Find random food source for half oft the bees
- Employed bees
  - Find food source in neighborhood of each bees known food source

ABC III

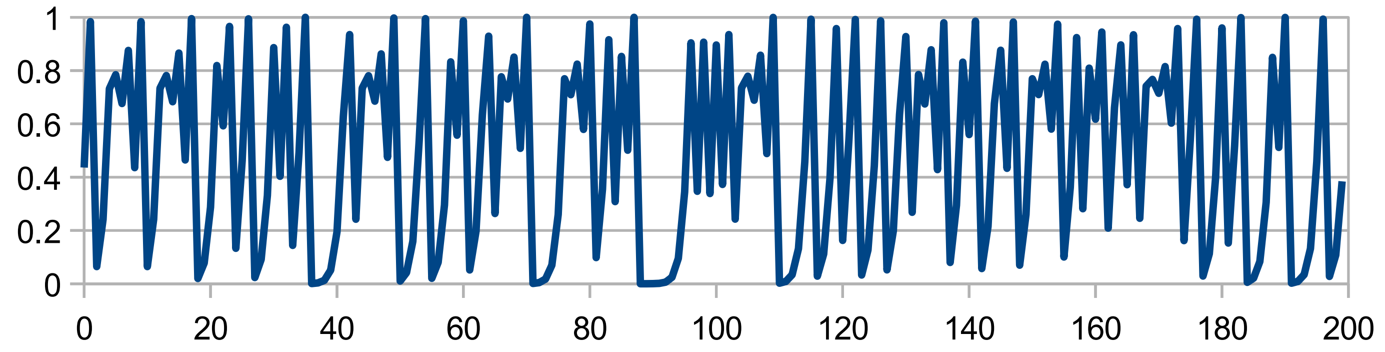
- Onlooker bee phase
  - Find food source based on food sources of all employed bees.
  - Assignment probability is based on quality of employed bees food source
- Scout bee phase
  - New random food source if no improvement

FSCABC I

- Modified version of ABC
- Introduced for path planning of unmanned combat air vehicles
- Outperformed ABC in this application
- Changes two parts:
  - Fitness function for assigning in onlooker bee phase
  - Random number generator in scout bee phase

FSCABC II

- Fitness function is replaced by a fitness power scaling function
  - Sorted ascending by rank
  - Best solution is weighted to the power of k
- RNG replaced with a chaotic random number generator
  - Pseudorandom
  - Travels ergodically over [0,1]



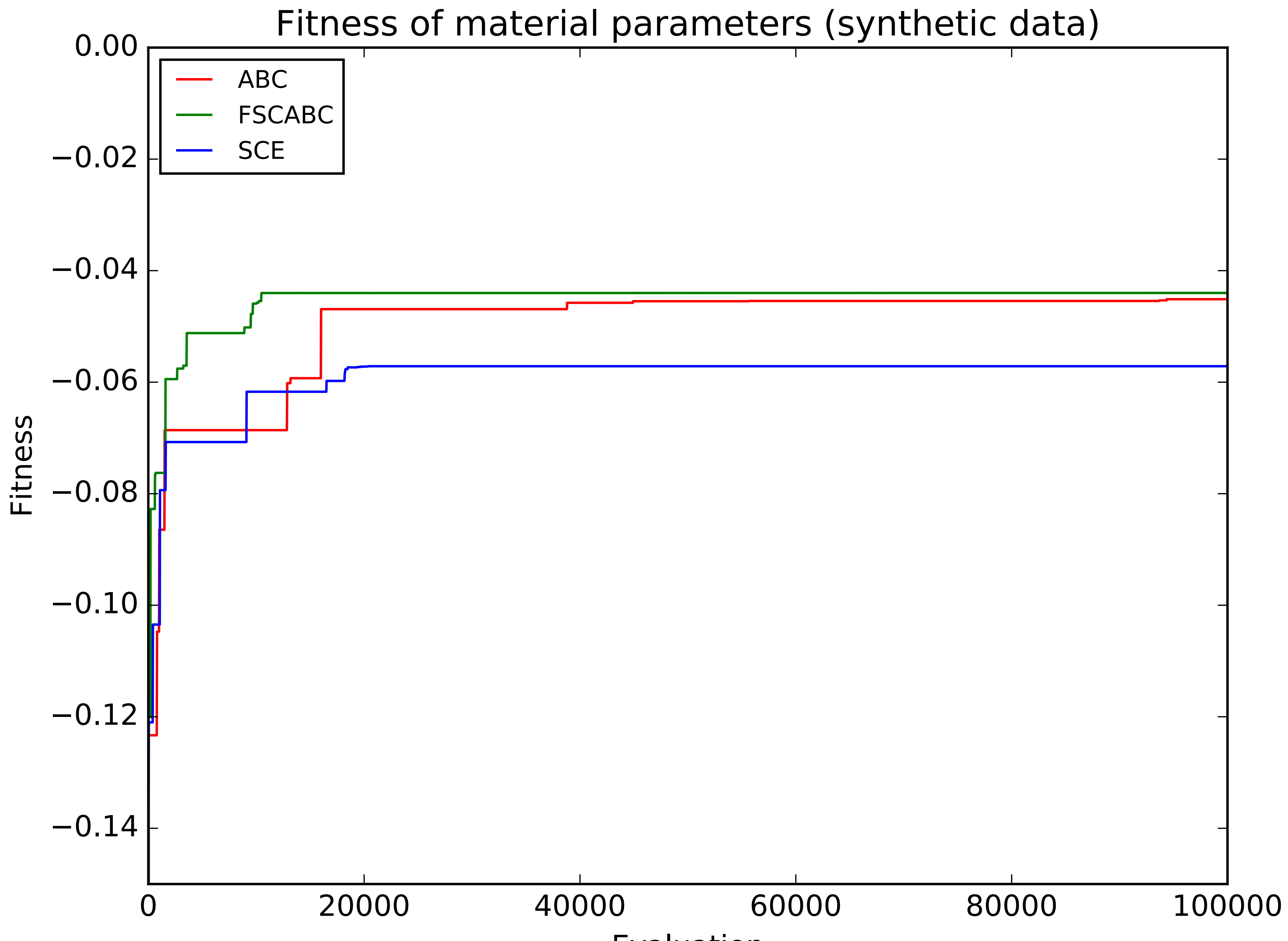
Results

- Synthetic data
- TGA
- MLC_{50}
- MLC_{all}

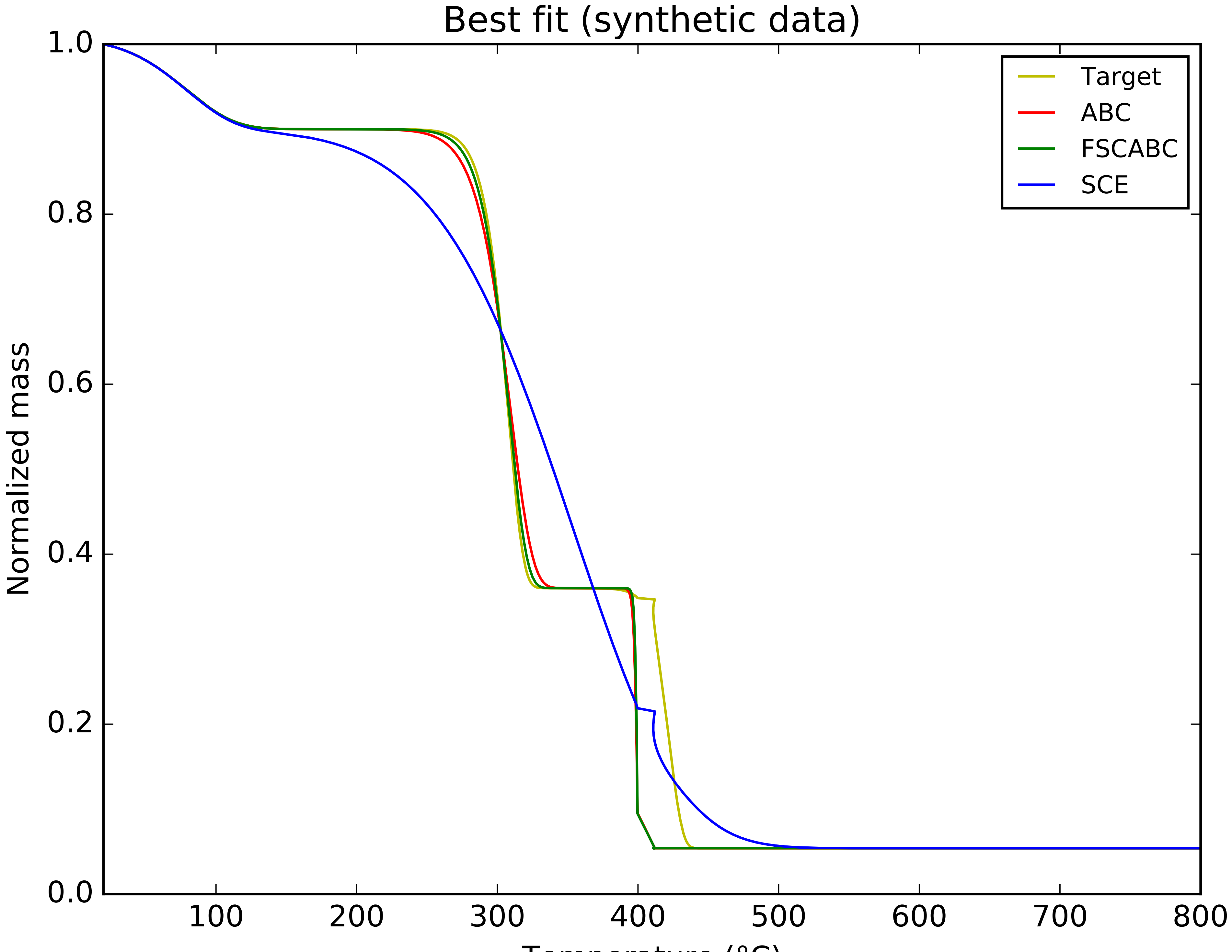
Synthetic Data I

- TGA setup
- Two reactions
- Input parameters
  - Density
  - Conductivity
  - Specific Heat
  - Reference Temperature
  - Reference Rate
- Target: normalized mass loss

Synthetic Data II



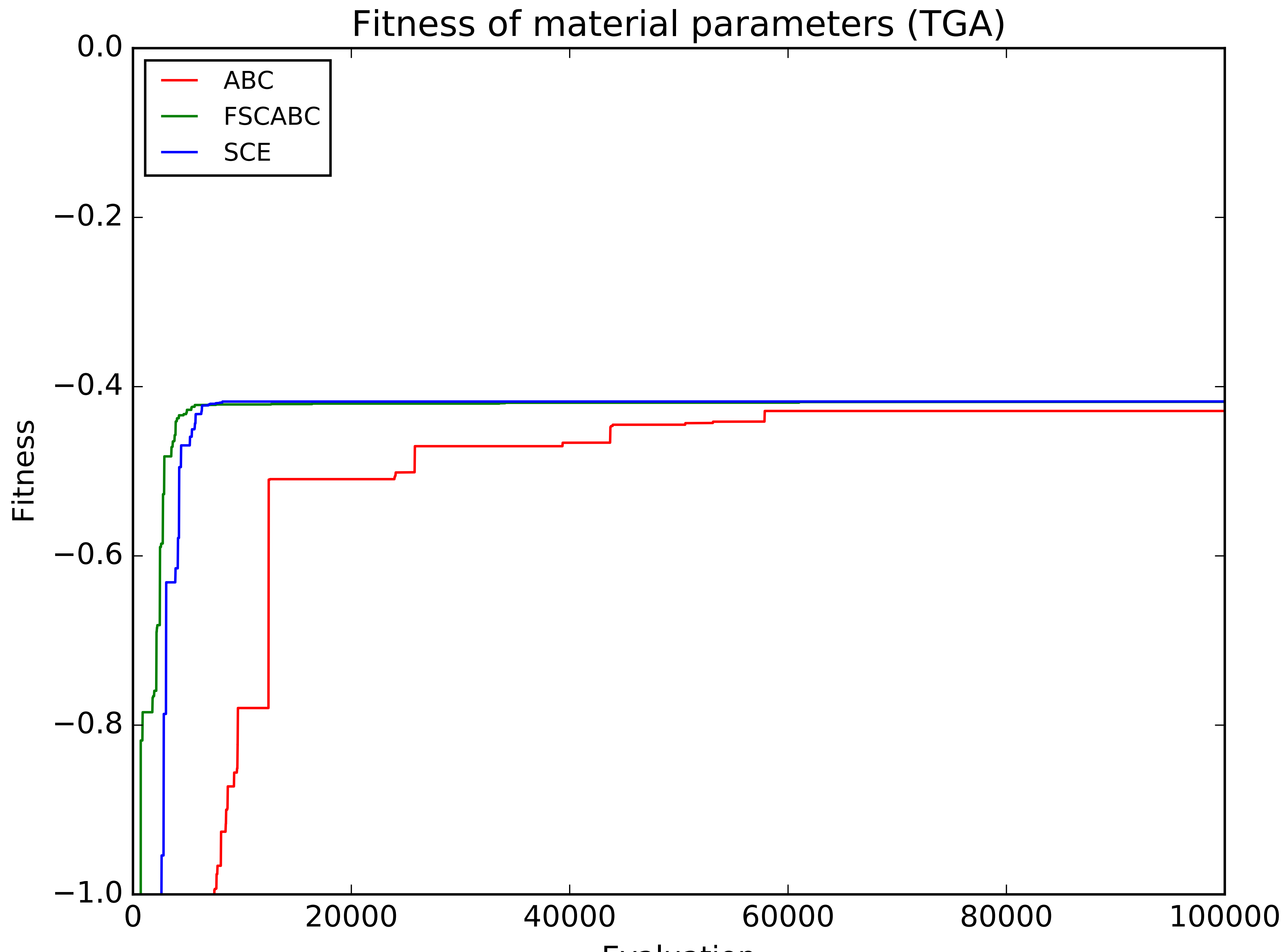
Synthetic Data III



TGA I

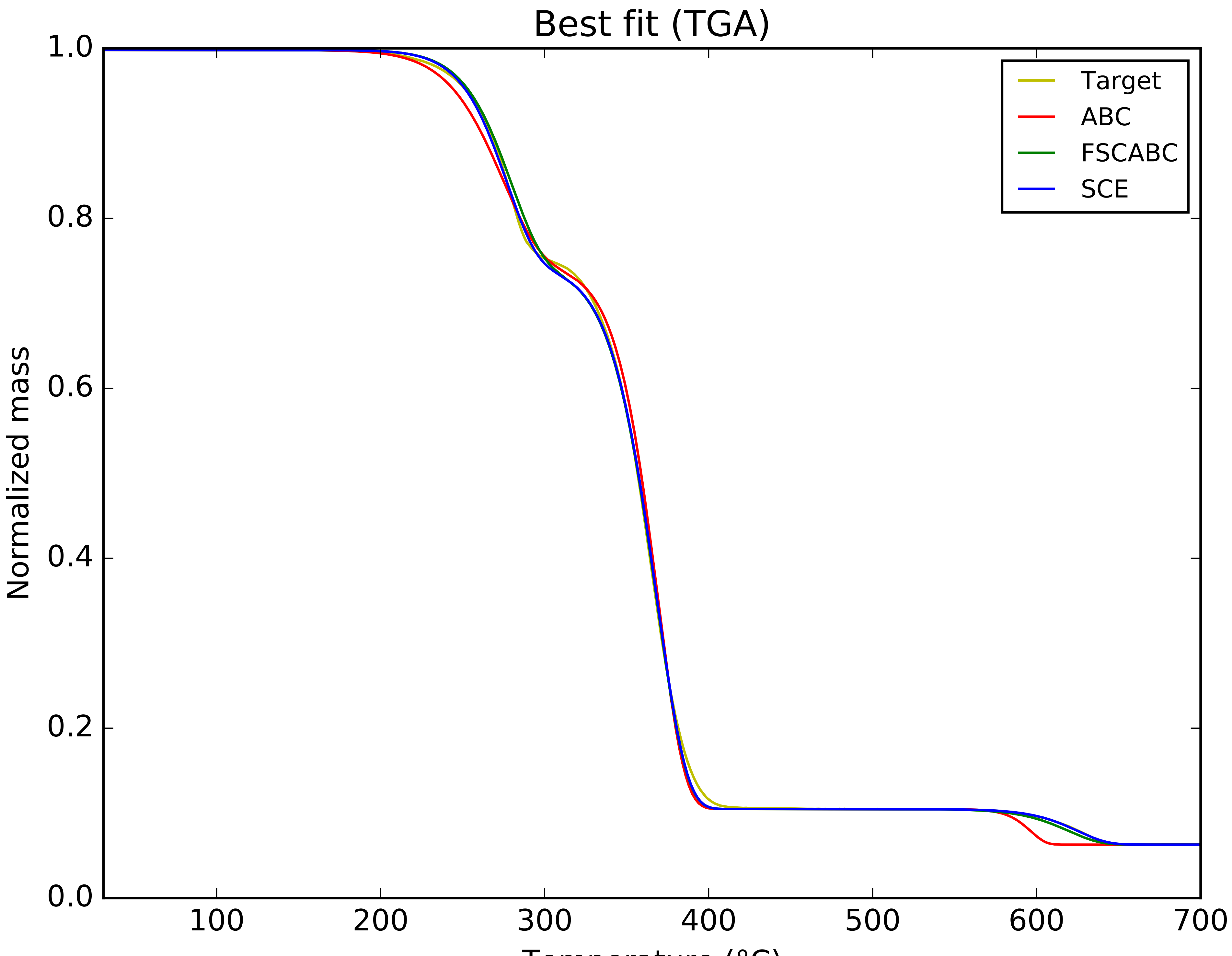
- TGA setup
- Material: PU
- Three reactions
- Input parameters
  - Reference temperature
  - Pyrolysis range
- Target: normalized mass loss

TGA II



Fitness of material parameters (TGA)
ABC
FSCABC
SCE
Fitness
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
0
20000
40000
60000
80000
100000

TGA III

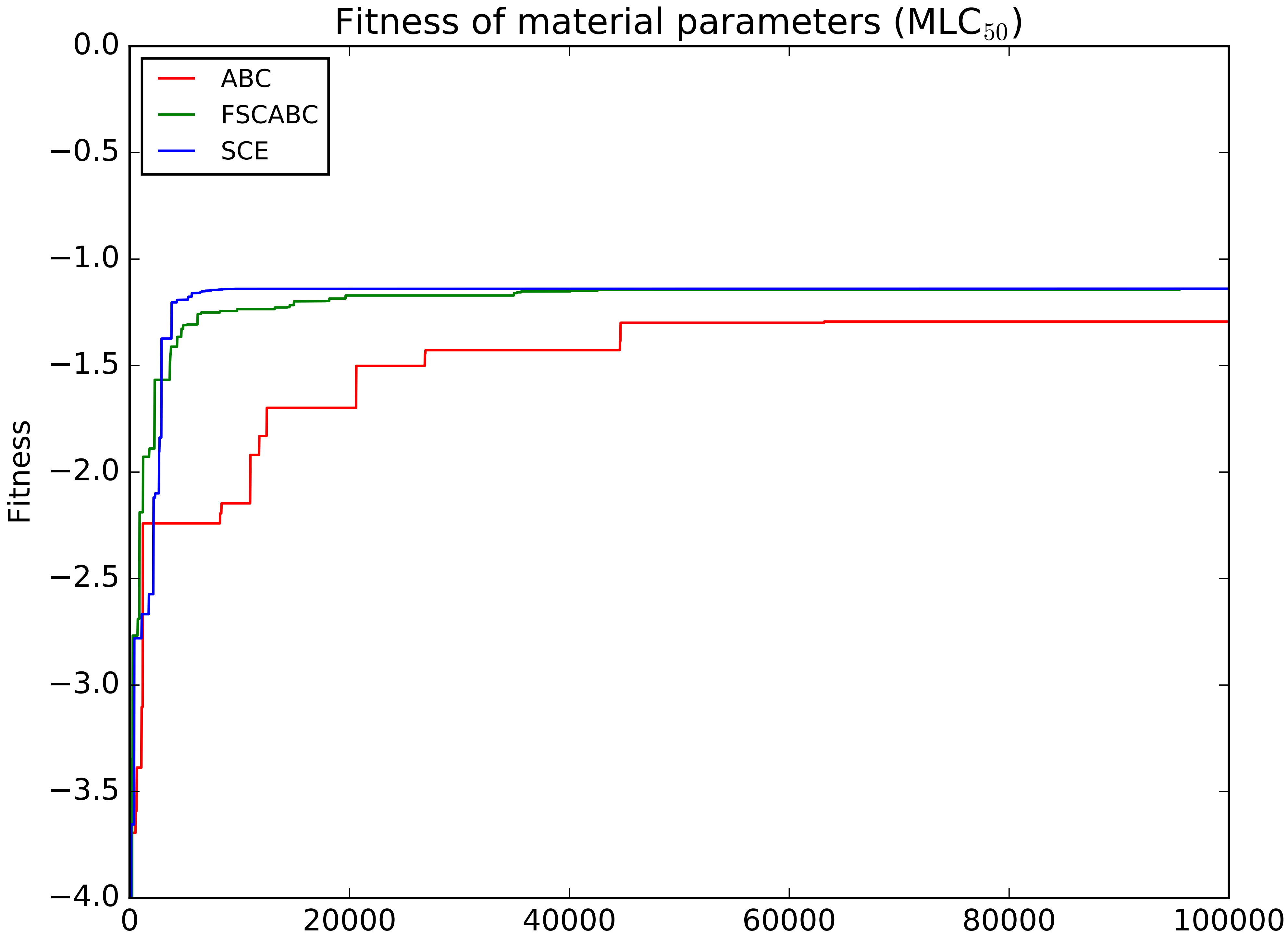


Best fit (TGA)
1.0
0.8
0.6
0.4
0.2
0.0
Normalized mass
100
200
300
400
500
600
700
Target
ABC
FSCABC
SCE

MLC_{50} I

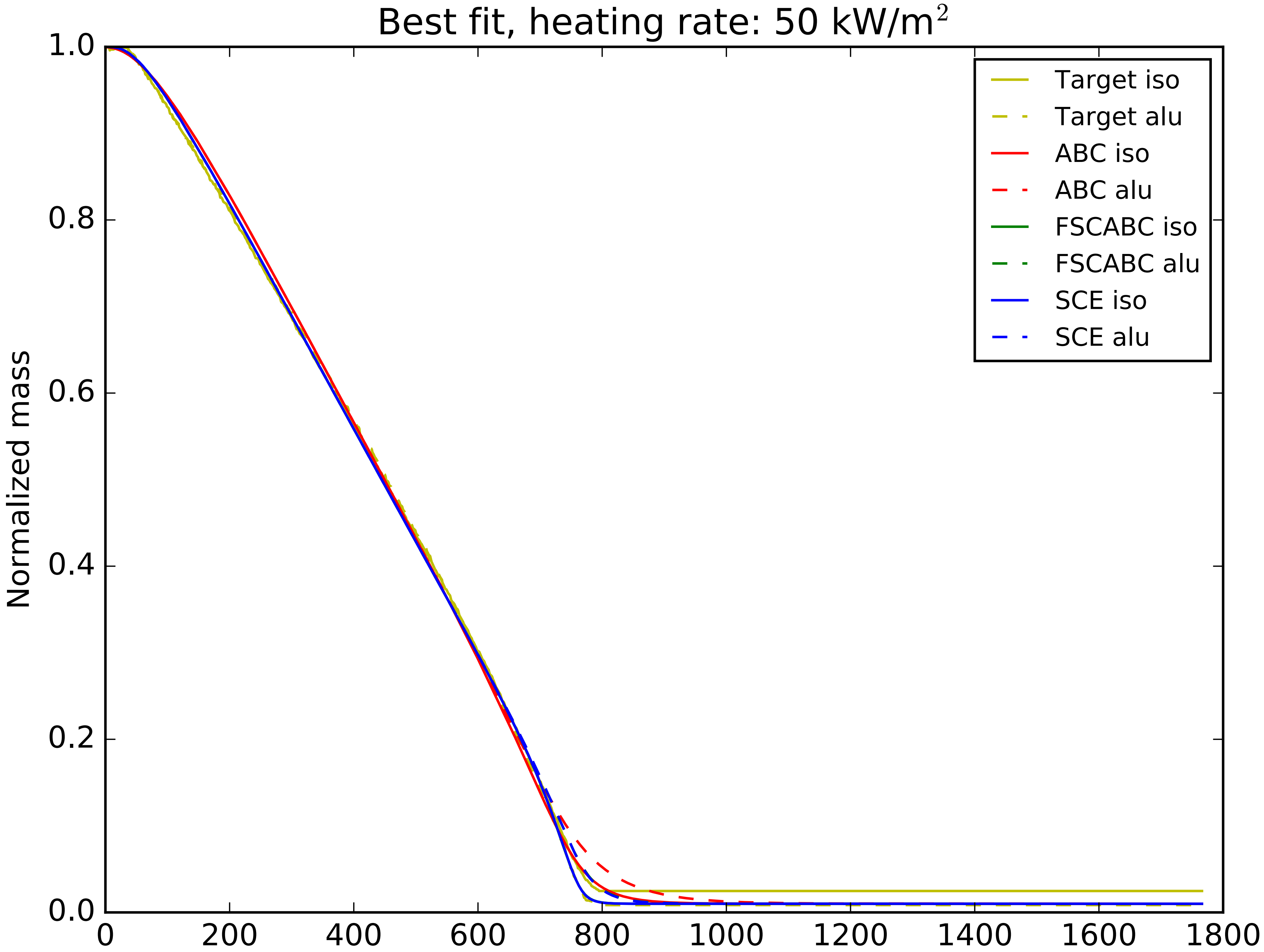
- MLC setup
  - Heat flux: 50 kW/m^2
- Material: PMMA
- Input parameters
  - Density
  - Conductivity
  - Specific Heat
  - Reference Temperature
  - Pyrolysis range
- Target: normalized mass loss

MLC_{50} II



Fitness of material parameters (MLC_{50})
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
−3.5
−4.0
Fitness
0
20000
40000
60000
80000
100000
ABC
FSCABC
SCE

MLC_{50} III

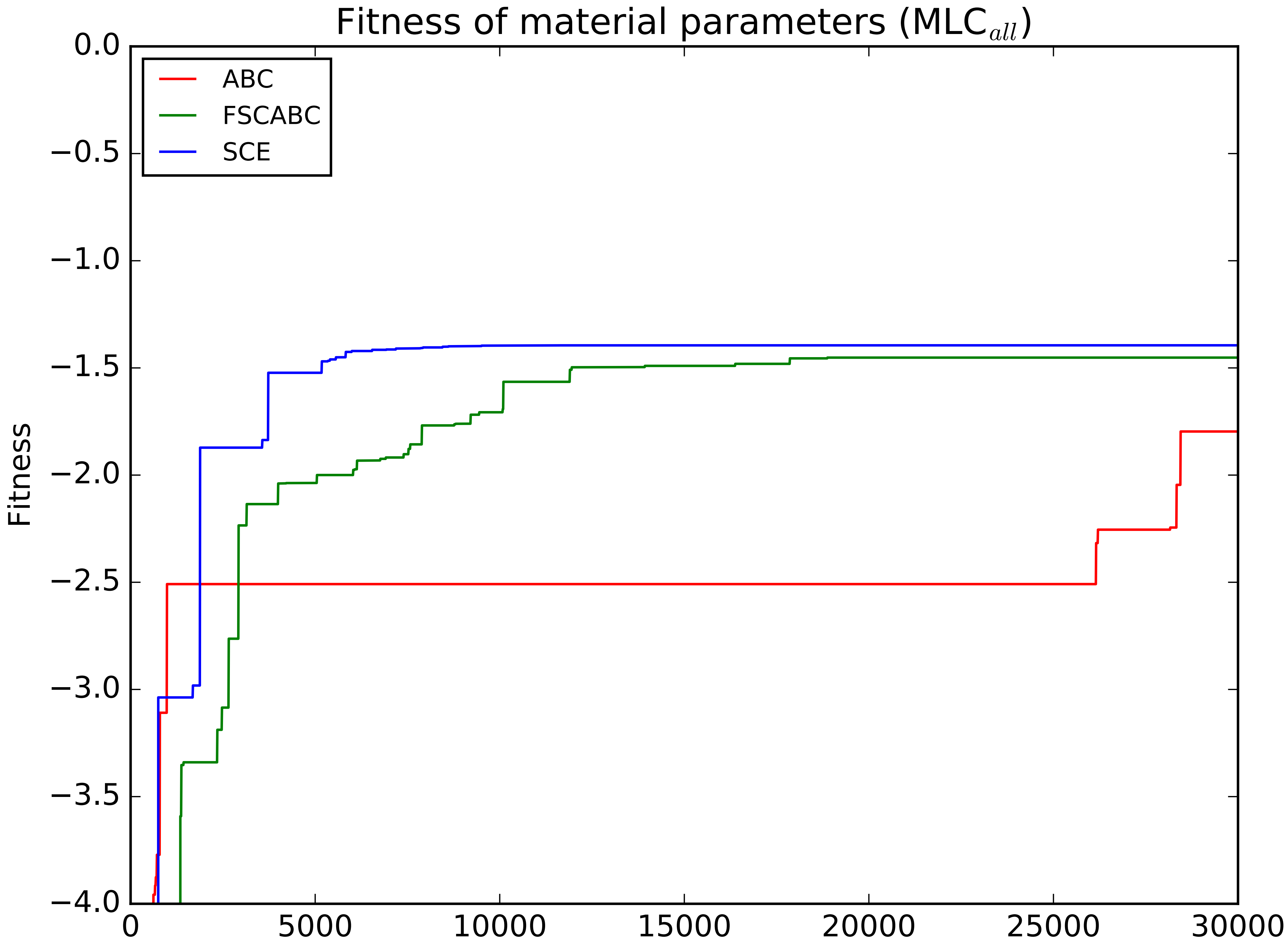


Best fit, heating rate: 50 kW/m²
Normalized mass
1.0
0.8
0.6
0.4
0.2
0.0
0
200
400
600
800
1000
1200
1400
1600
1800
Target iso
Target alu
ABC iso
ABC alu
FSCABC iso
FSCABC alu
SCE iso
SCE alu

MLC_{all} I

- MLC setup
  - Heat flux: 20, 30, 40, 50, 75 kW/m^2
- Material: PMMA
- Input parameters
  - Density
  - Conductivity
  - Specific Heat
  - Reference Temperature
  - Pyrolysis range
- Target: normalized mass loss

MLC_{all} II



Fitness of material parameters (MLC_{all})
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
−3.5
−4.0
Fitness
0
5000
10000
15000
20000
25000
30000
ABC
FSCABC
SCE

Conclusion

- Comparsion of three algorithms with synthetic and bench scale data
- All three generate similar accurate solutions
- SCE most efficient, but FSCABC often not significant inferior
- Future tasks:
  - Tune FSCABC parameters
  - Apply on other models