Solving 3D frictional contact problems: Formulations and comparisons of numerical methods.

RESEARCH

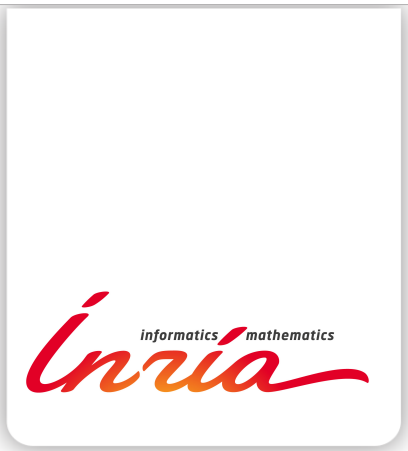
REPORT

N° 123456789

September 18, 2017

Project-Team Bipop

ISSN 0249-6399 ISRN INRIA/RR--123456789--FR+ENG



Solving 3D frictional contact problems: Formulations and comparisons of numerical methods.

Project-Team Bipop

Research Report n° 123456789 — September 18, 2017 — 148 pages

Abstract: TBW

Key-words: Multibody systems, nonsmooth Mechanics, unilateral constraints, Coulomb friction, impact, numerical methods

RESEARCH CENTRE
GRENOBLE – RHÔNE-ALPES

Inovallée

655 avenue de l'Europe Montbonnot

38334 Saint Ismier Cedex

Sur la résolution du problème de frottement tridimensionnel. Formulations and comparaisons des méthodes numériques.

Résumé : TBW

Mots-clés : Systèmes multi–corps, Mécanique non régulière, contraintes unilatérales, frottement de Coulomb, impact, Schémas numériques de résolution

Contents

1 LMGC_100_PR_PerioBox

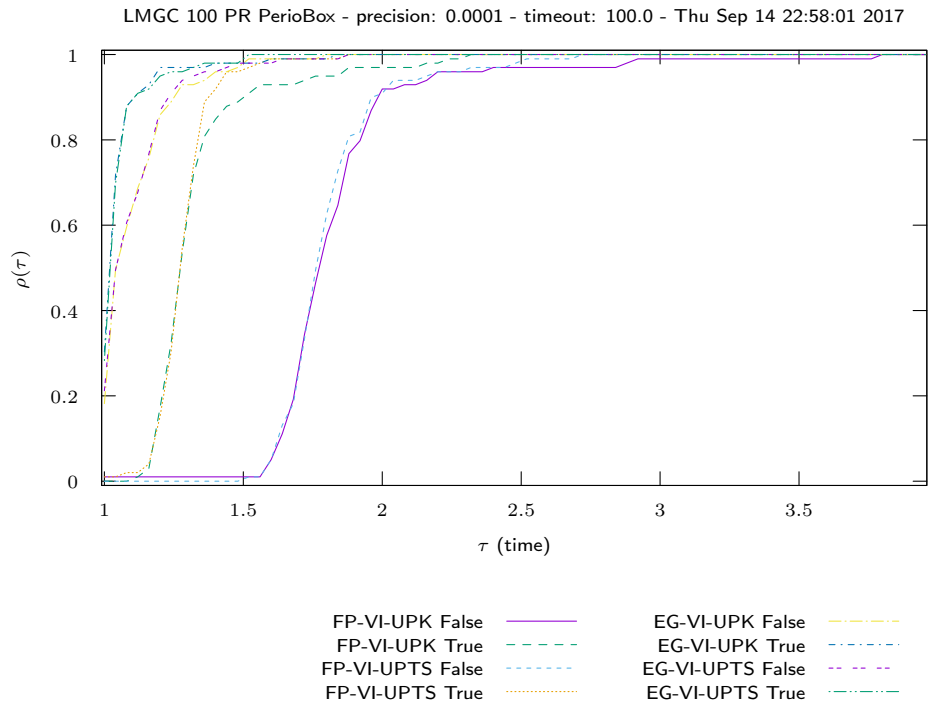


Figure 1: LMGC_100_PR_PerioBox time VI/UpdateRule

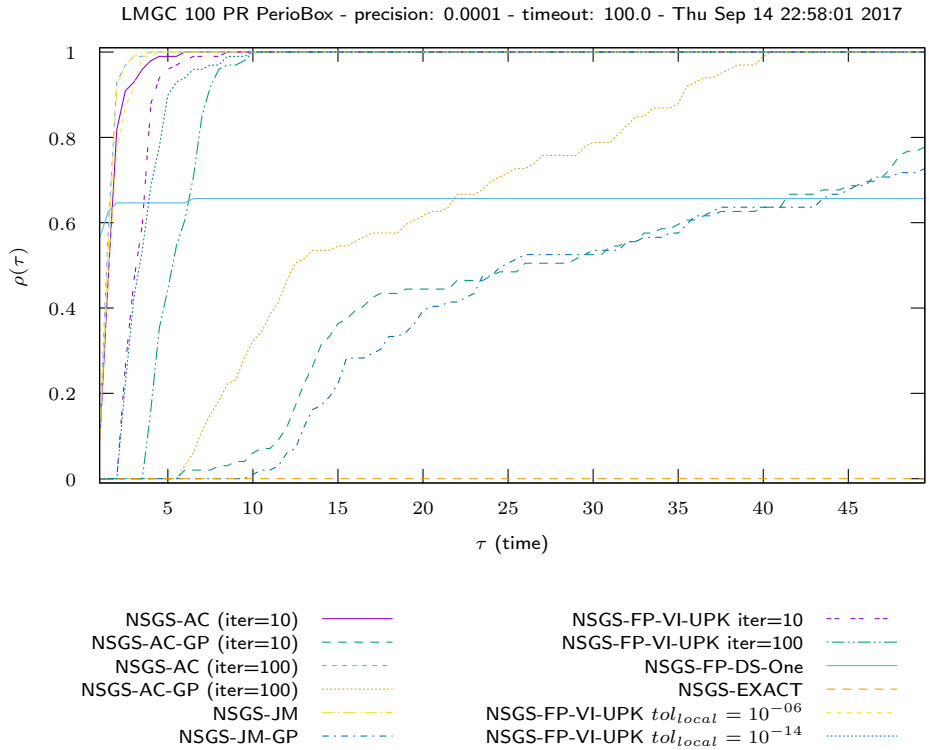


Figure 2: LMGC_100_PR_PerioBox time NSGS/LocalSolver

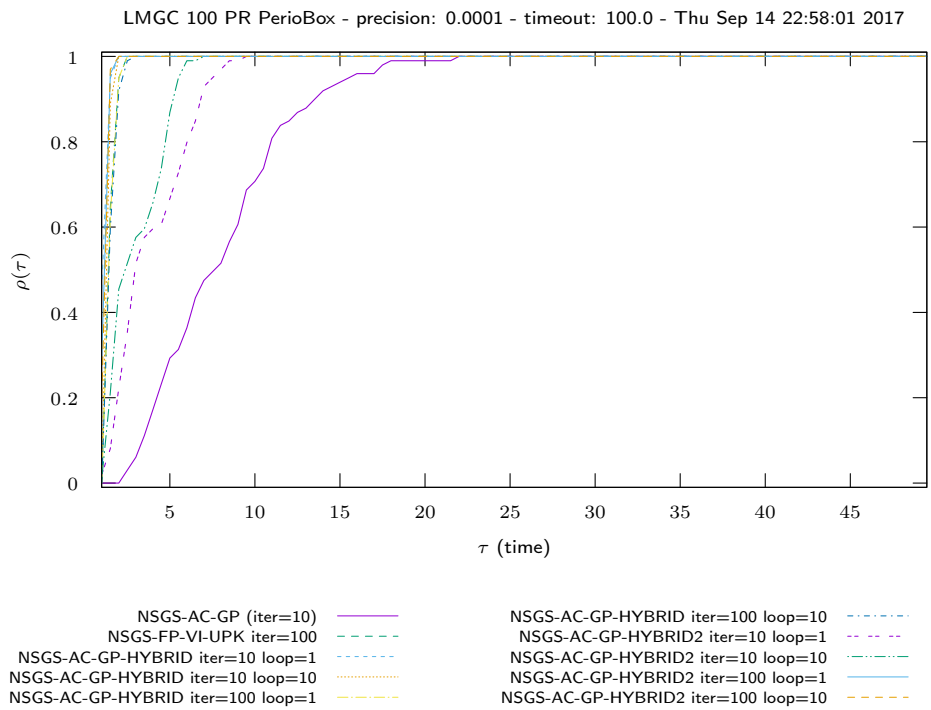


Figure 3: LMGC_100_PR_PerioBox time NSGS/LocalSolverHybrid

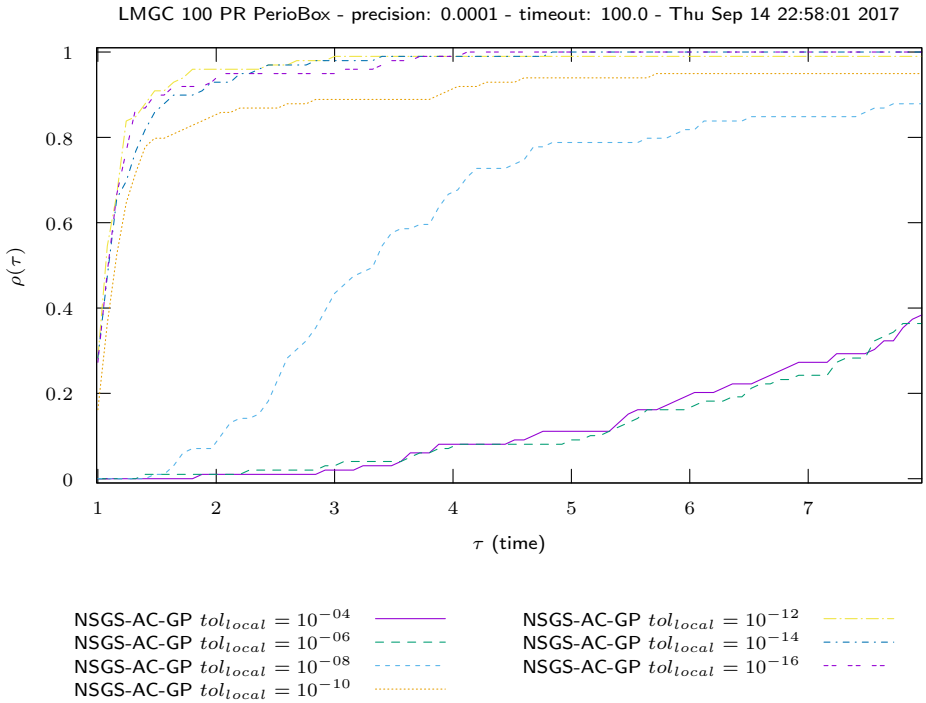


Figure 4: LMGC_100_PR_PerioBox time NSGS/LocalTol

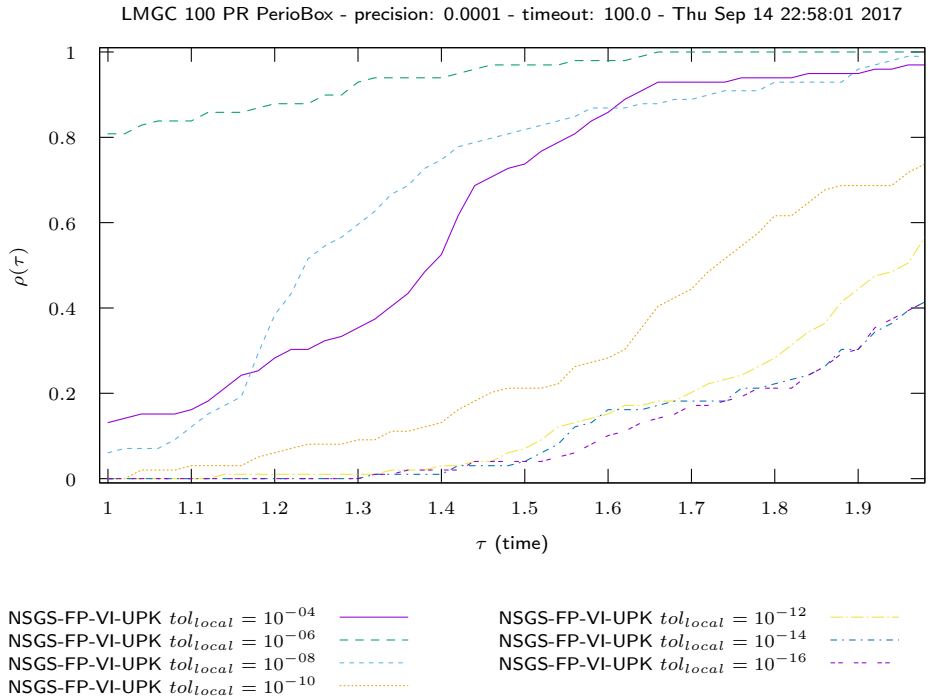


Figure 5: LMGC_100_PR_PerioBox time NSGS/LocalTol-VI

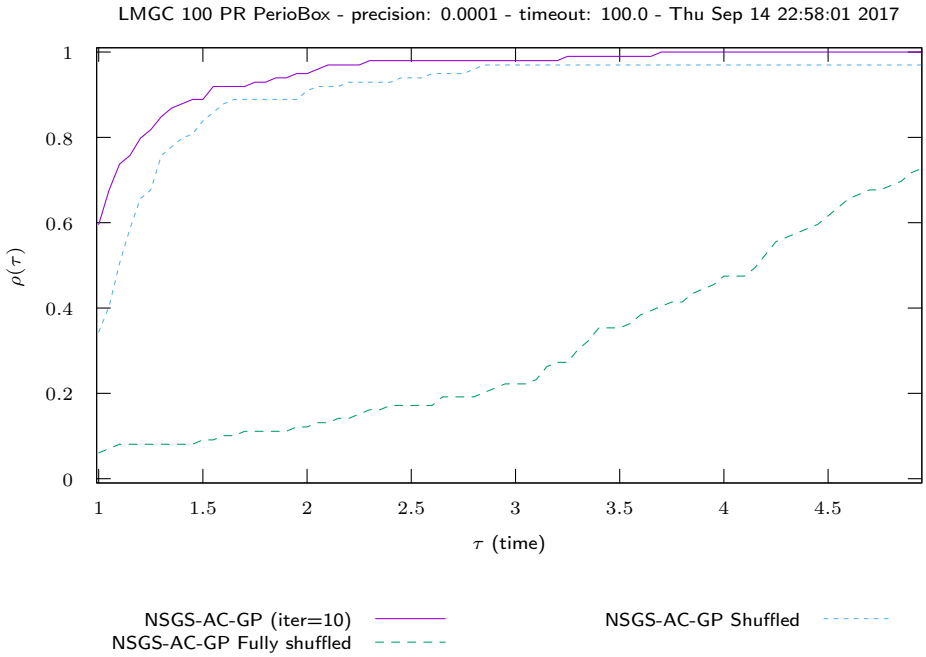


Figure 6: LMGC_100_PR_PerioBox time NSGS/Shuffled

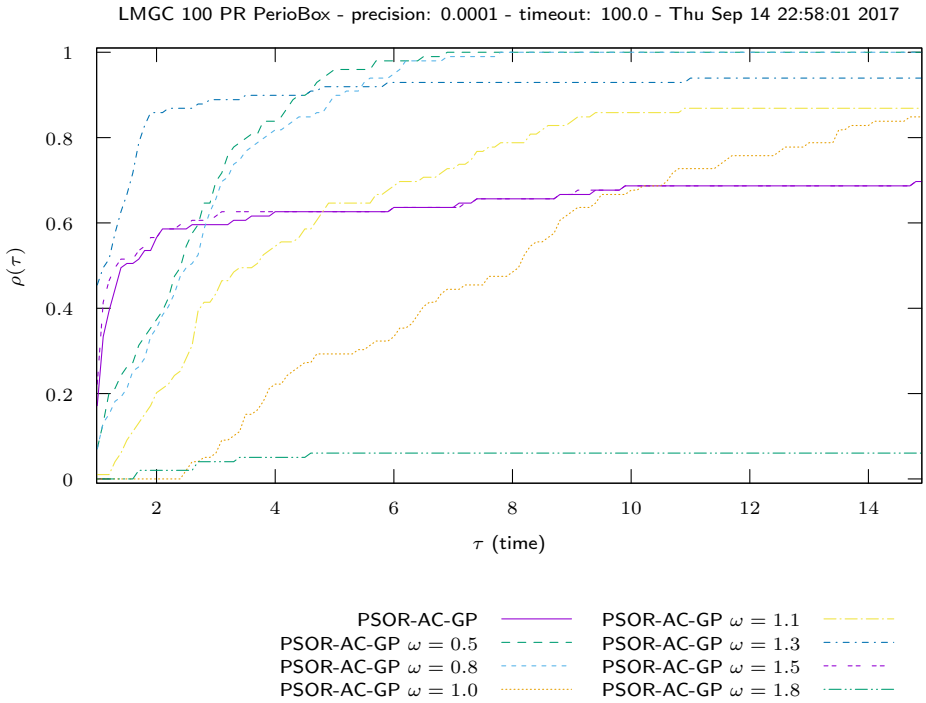


Figure 7: LMGC_100_PR_PerioBox time PSOR

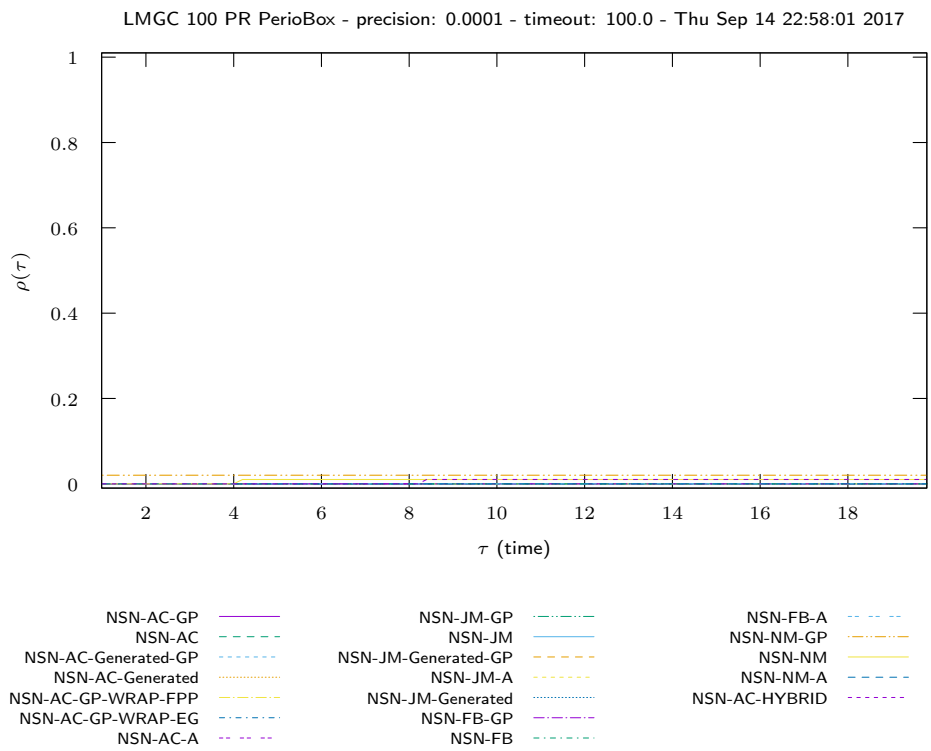


Figure 8: LMGC_100_PR_PerioBox time NSN

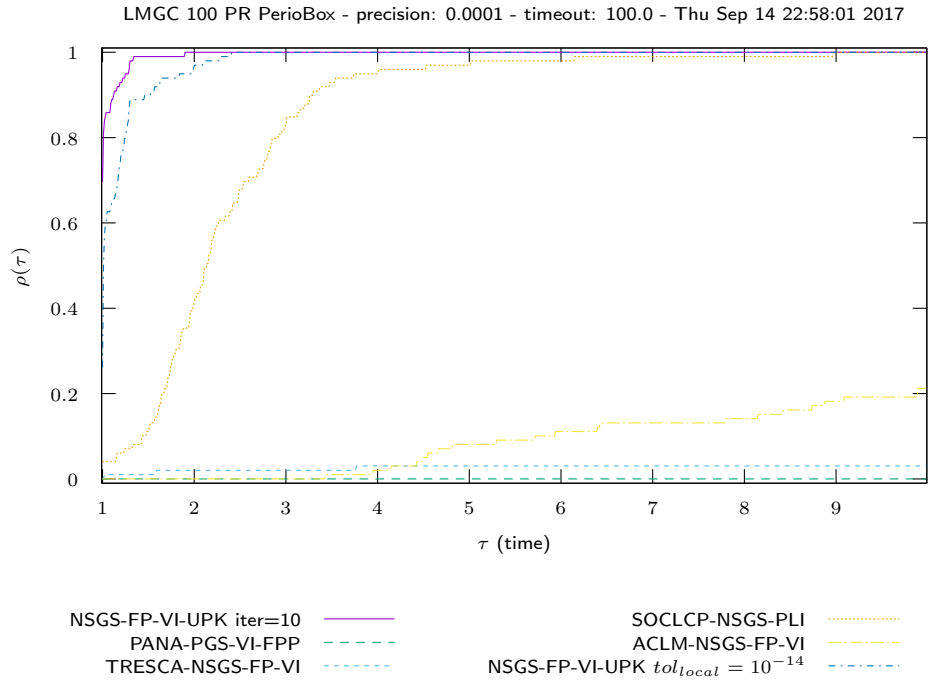


Figure 9: LMGC_100_PR_PerioBox time OPTI

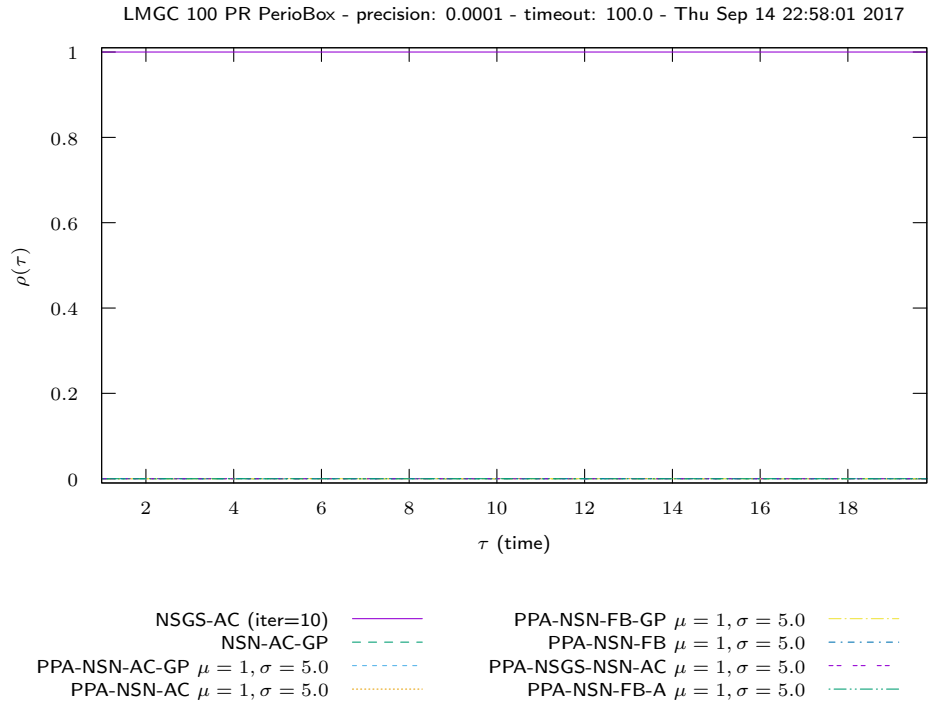


Figure 10: LMGC_100_PR_PerioBox time PROX/InternalSolvers

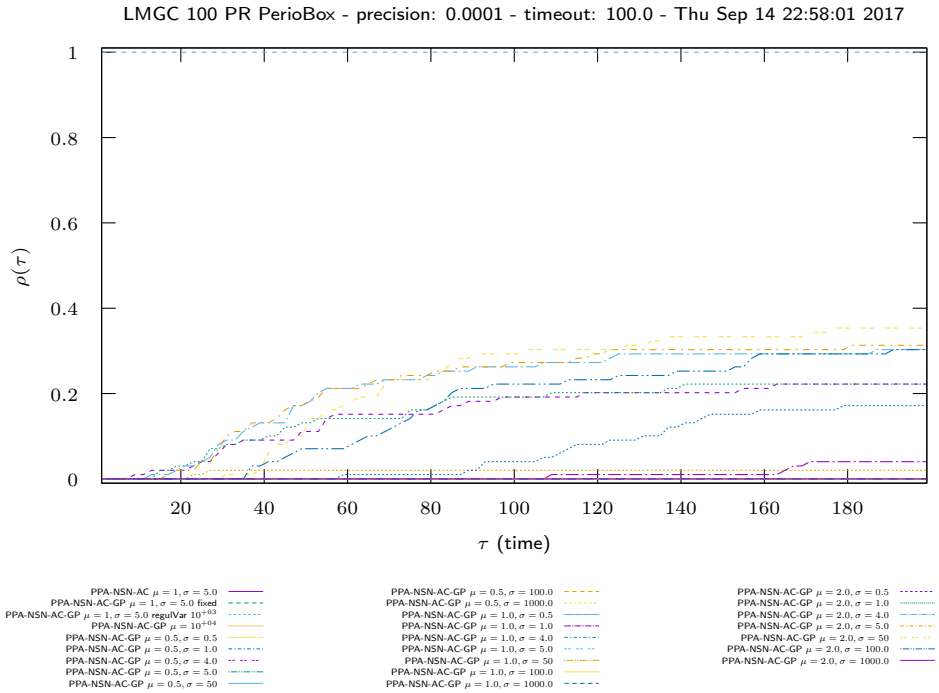


Figure 11: LMGC_100_PR_PerioBox time PROX/Parameters

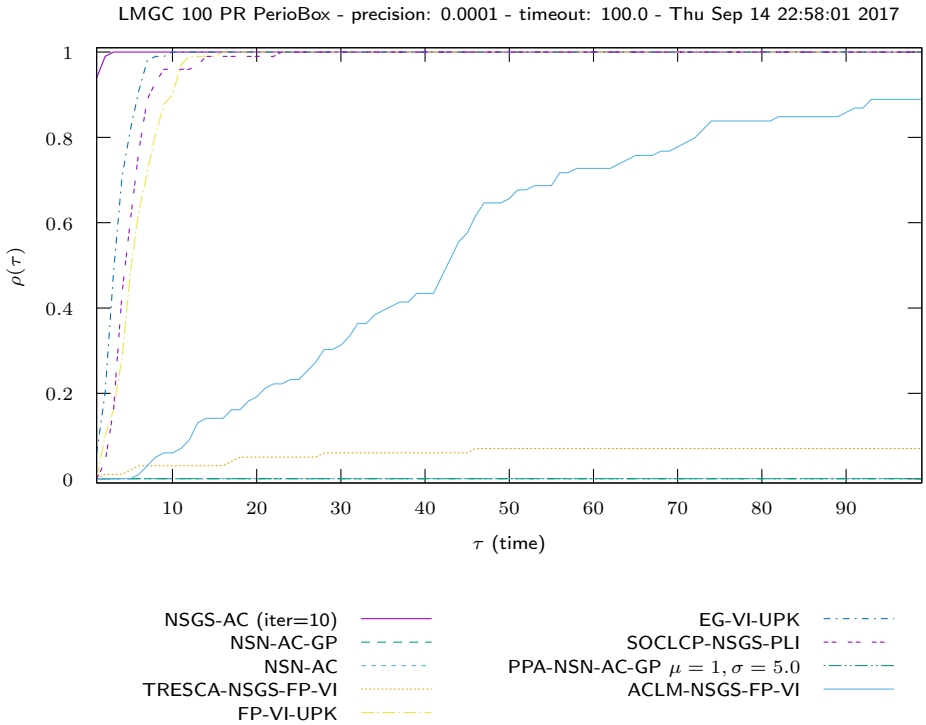


Figure 12: LMGC_100_PR_PerioBox time COMP/large

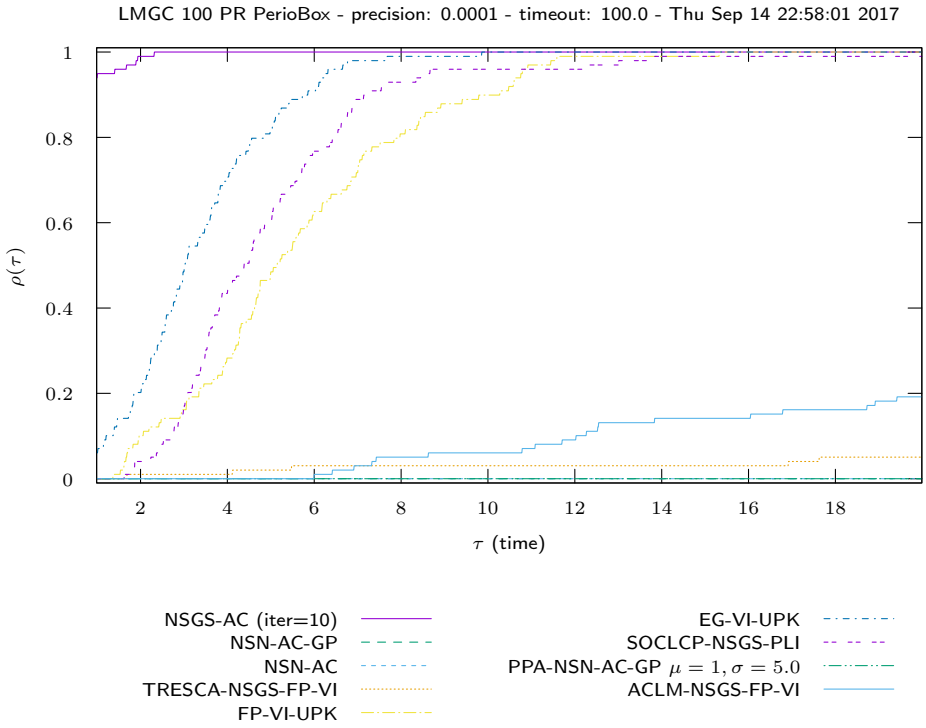


Figure 13: LMGC_100_PR_PerioBox time COMP/large

1.1 Comments

1. VI solvers:
   (a) The EG-VI solvers are better than FP-VI solvers.
   (b) The local update rule UPK vs. UPTS is not important
   (c) The update in the loop improves greatly the convergence rate.
2. NSGS Solvers:
   (a) Local solvers
      i. NSN local solvers without line-search are the best solvers.
      ii. GP line-search method is slowing a lot the efficiency of the solver. Since we do need to improve to robustness of the solver, there is no interest in this set to use a line-search
      iii. Quite surprisingly, the local solvers based on FP-VI-UPK are also efficient, especially when we limit the number of iteration or the local tolerance of the local algorithm.
   (b) Local Tolerances: The study of the local tolerances of the local solvers shows that the local tolerance has to be lower than 1e-10 to get robustness and a good convergence rate of the NSGS-AC-GP solver. For the NSGS-FP-VI-UPK, a limited tolerance improves the efficiency without reducing the robustness
   (c) Shuffling techniques: The shuffling of contact does not improve the convergence.

PSOR Solvers.

1. For the values of the relaxation parameters ω in $[1.3, 1.5]$, the relaxation increases the efficiency of the solver but decreases the robustness
2. For low values of the relaxation parameters ω in $[0.5, 0.8]$, the relaxation increases the the robustness but decreases the efficiency

NSN and PROX solvers. The direct Newton techniques on such rigid-body test set are inefficient. (link to the distribution of ranks of the matrices)

OPTI solvers. On this problem, the ACLM and TRESCA approaches do not improve the efficiency. The problems are also better solved by the SOCLCP technique. Convexification is working well.

2 LMGC_945_SP_Box_PL

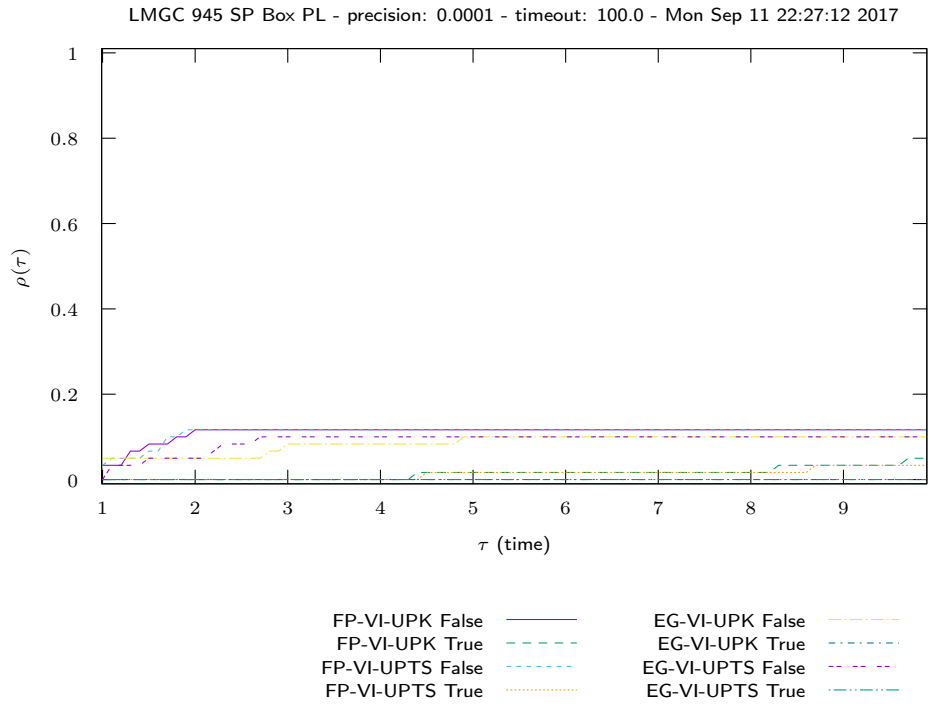


Figure 14: LMGC_945_SP_Box_PL time VI/UpdateRule

1. VI solvers: difficult to draw conclusions since a lot of solvers are not able to converge within timeout
2. NSGS Solvers:
   (a) Local solvers
      i. NSGS-FP-VI-UPK are the best solvers.
      ii. NSGS-NSN suffers from huge robustness problem.
      iii. GP line-search method improves a bit the efficiency of the solver
      iv. Hybrid solvers seems to succeed but it is difficult to say if the Newton method helps to improve results
   (b) Local Tolerances: For the NSGS-FP-VI-UPK, a limited tolerance improves the efficiency without reducing the robustness
   (c) Shuffling techniques: The shuffling of contact does not improve the convergence.

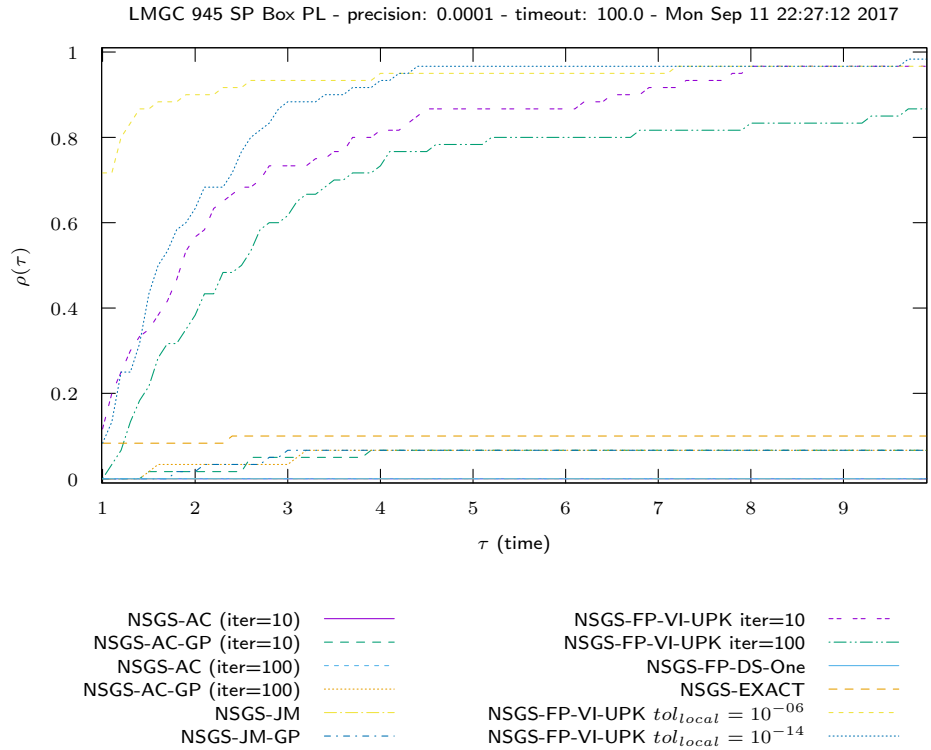


Figure 15: LMGC_945_SP_Box_PL time NSGS/LocalSolver

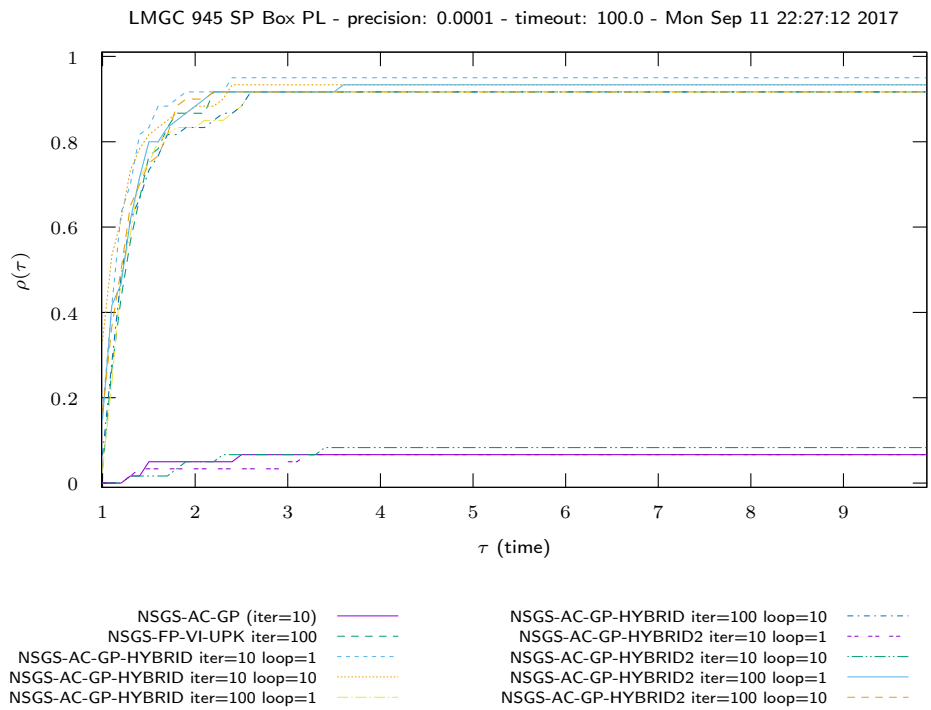


Figure 16: LMGC_945_SP_Box_PL time NSGS/LocalSolverHybrid

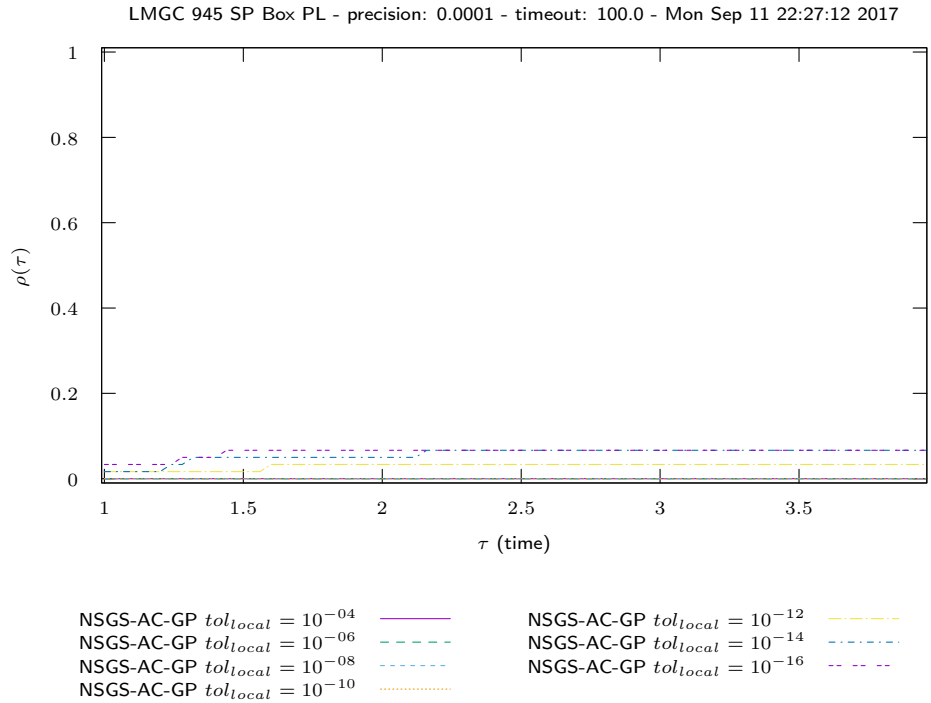


Figure 17: LMGC_945_SP_Box_PL time NSGS/LocalTol

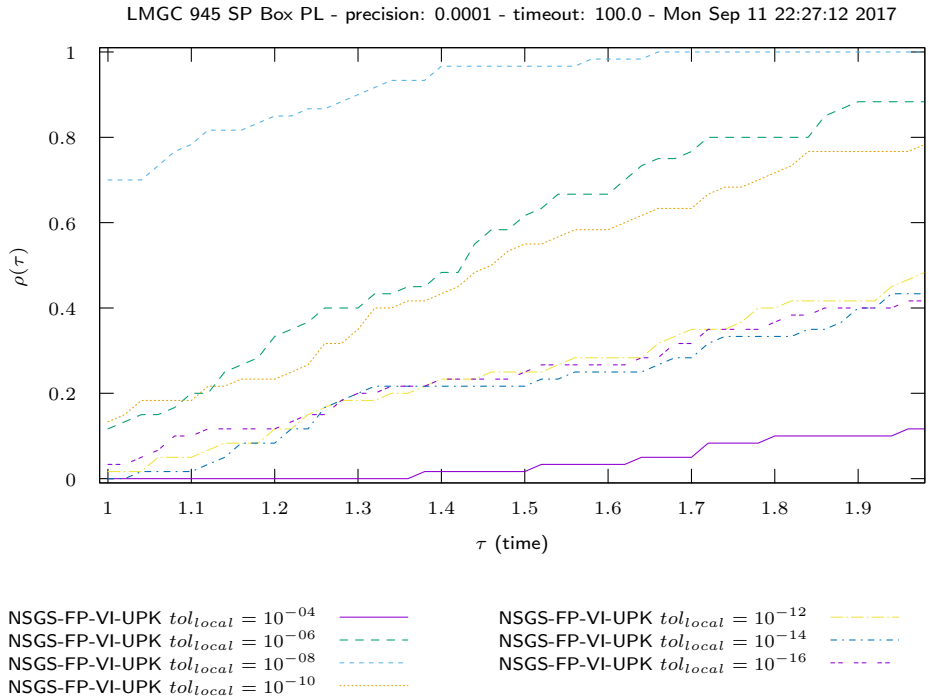


Figure 18: LMGC_945_SP_Box_PL time NSGS/LocalTol-VI

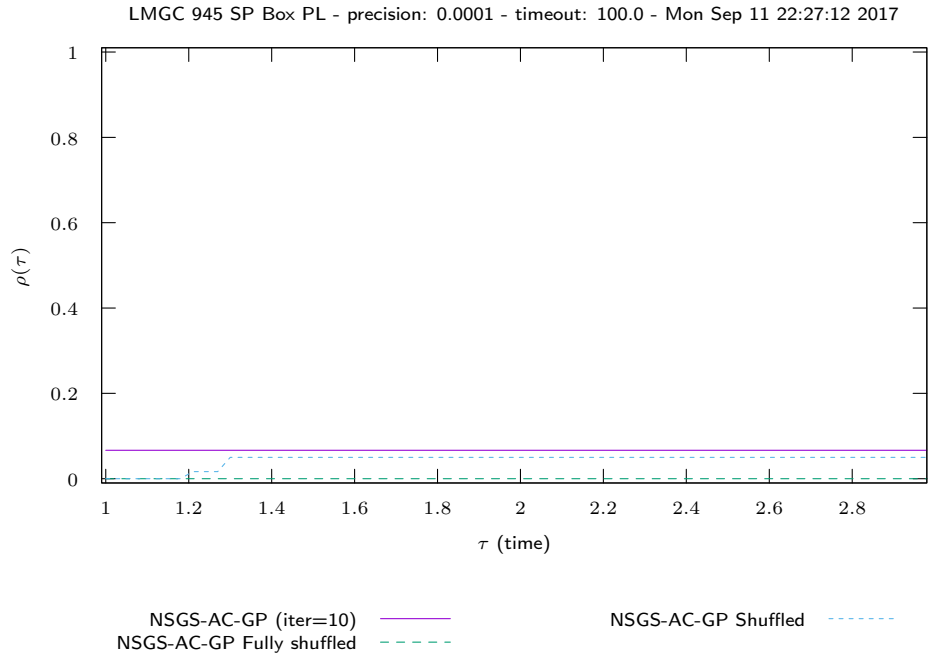


Figure 19: LMGC_945_SP_Box_PL time NSGS/Shuffled

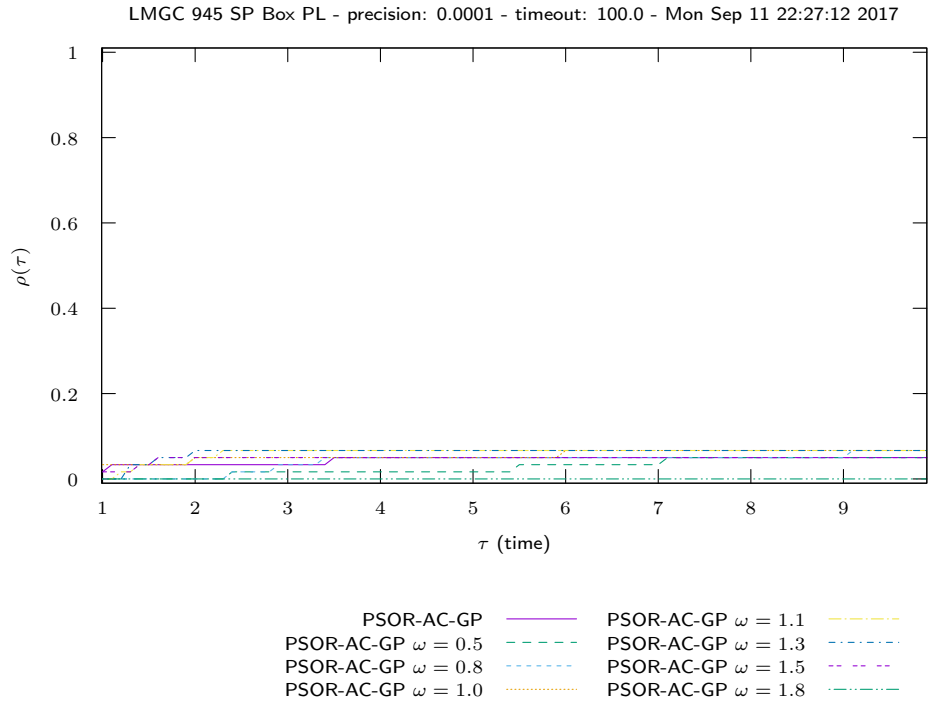


Figure 20: LMGC_945_SP_Box_PL time PSOR

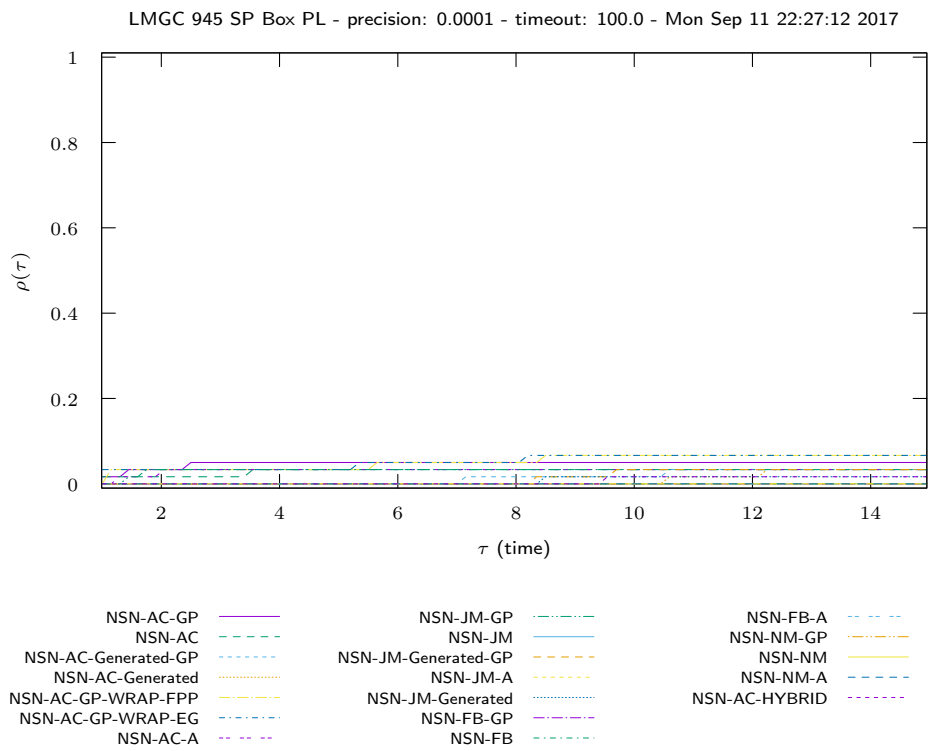


Figure 21: LMGC_945_SP_Box_PL time NSN

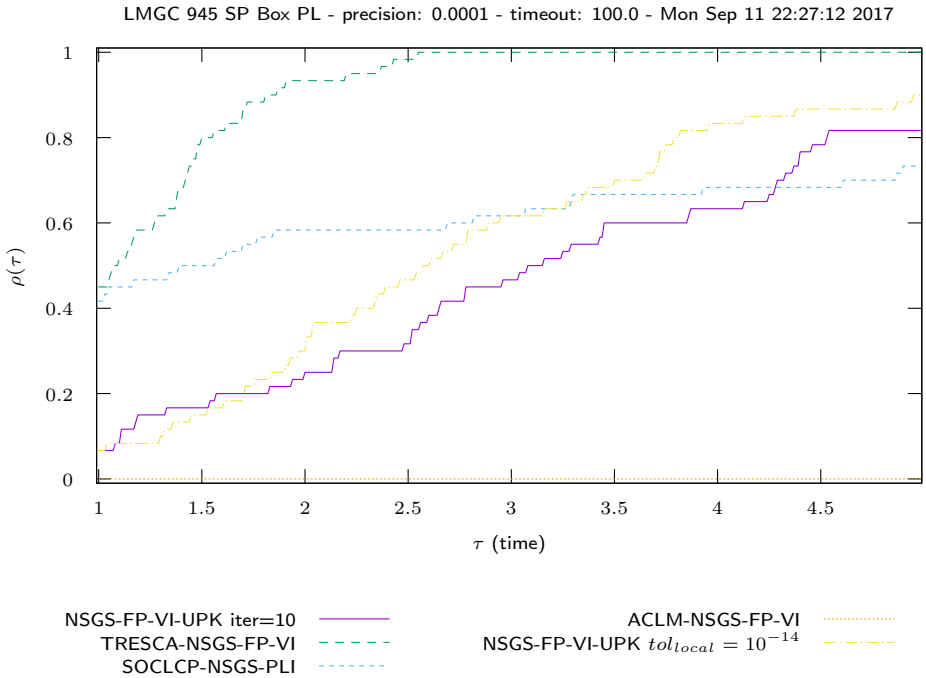


Figure 22: LMGC_945_SP_Box_PL time OPTI

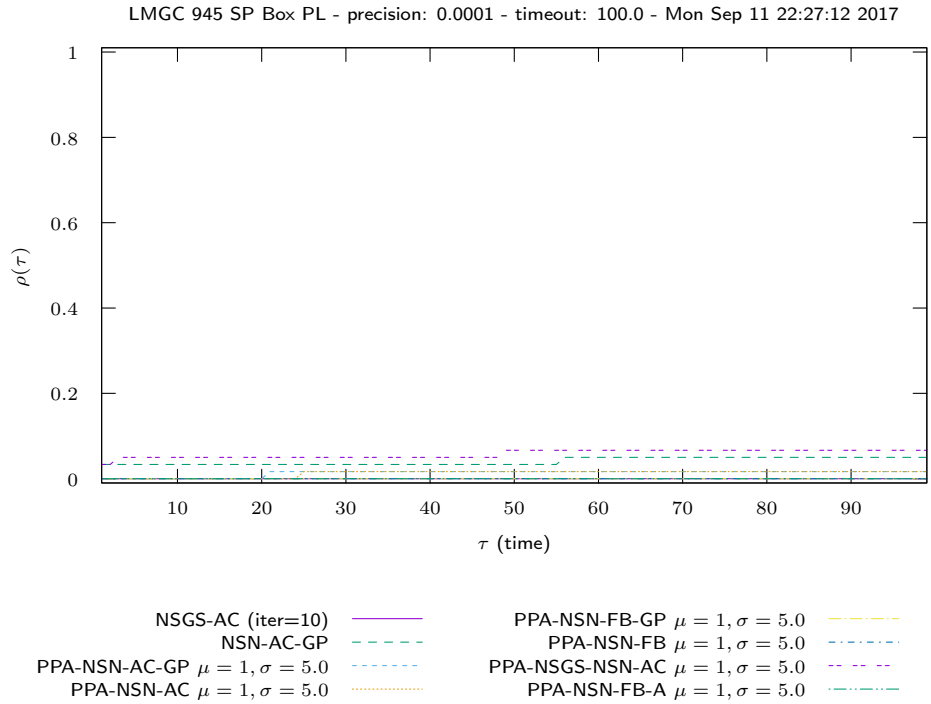


Figure 23: LMGC_945_SP_Box_PL time PROX/InternalSolvers

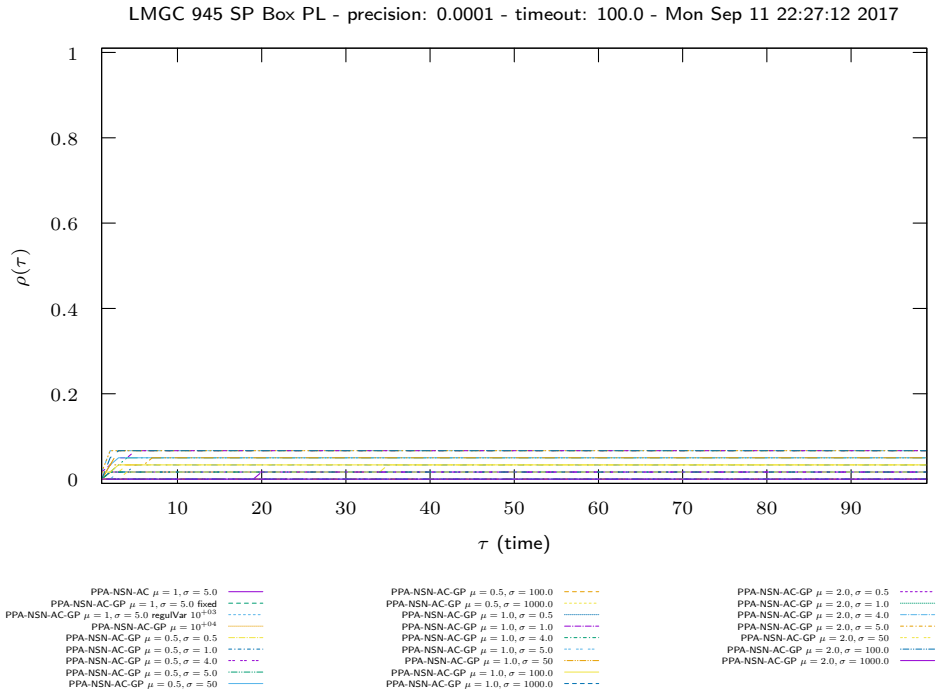


Figure 24: LMGC_945_SP_Box_PL time PROX/Parameters

PSOR Solvers. No conclusion due to robustness problems

NSN and PROX solvers. The direct Newton techniques on such rigid-body test set are inefficient. (link to the distribution of ranks of the matrices)

OPTI solvers. On this problem, the TRESCA approach improves a lot the efficiency. The problems are also better solved by the SOCLCP technique/ Convexification is working well.

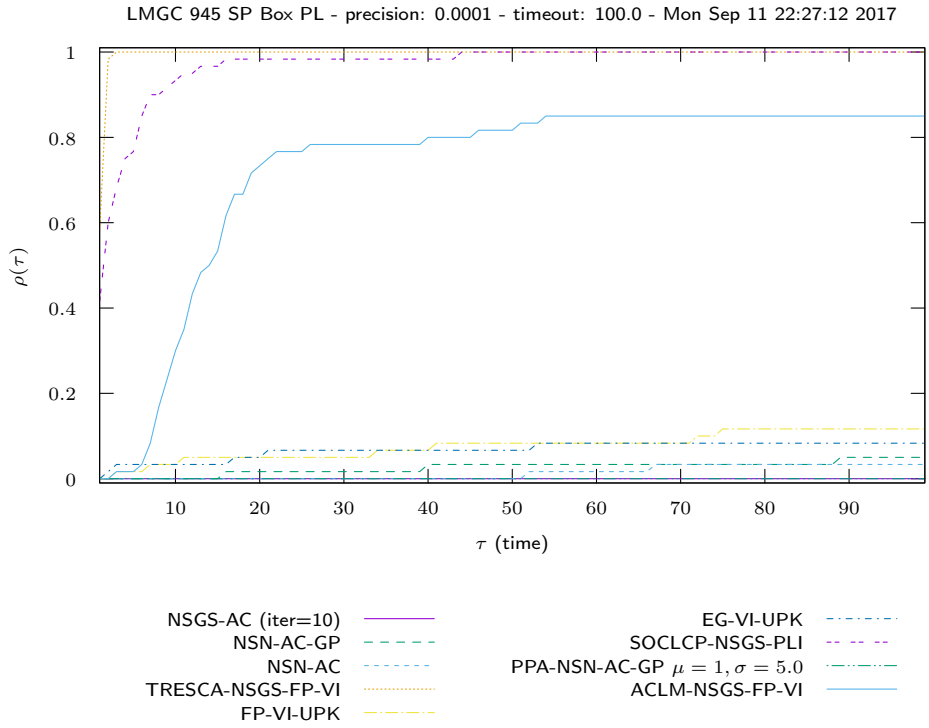


Figure 25: LMGC_945_SP_Box_PL time COMP/large

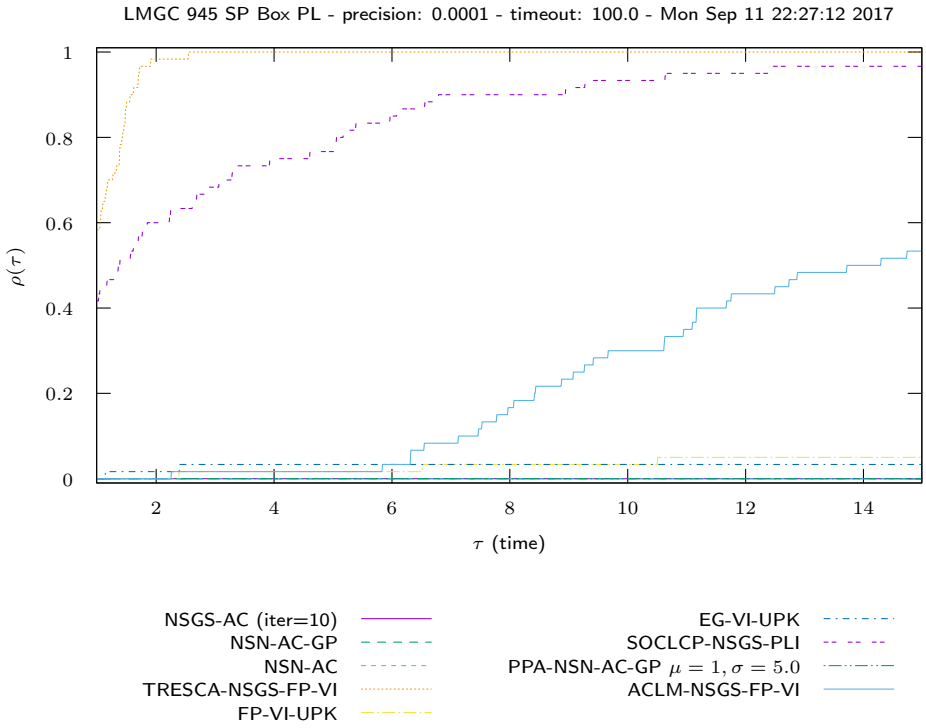


Figure 26: LMGC_945_SP_Box_PL time COMP/large

3 LMGC Aqueduc PR

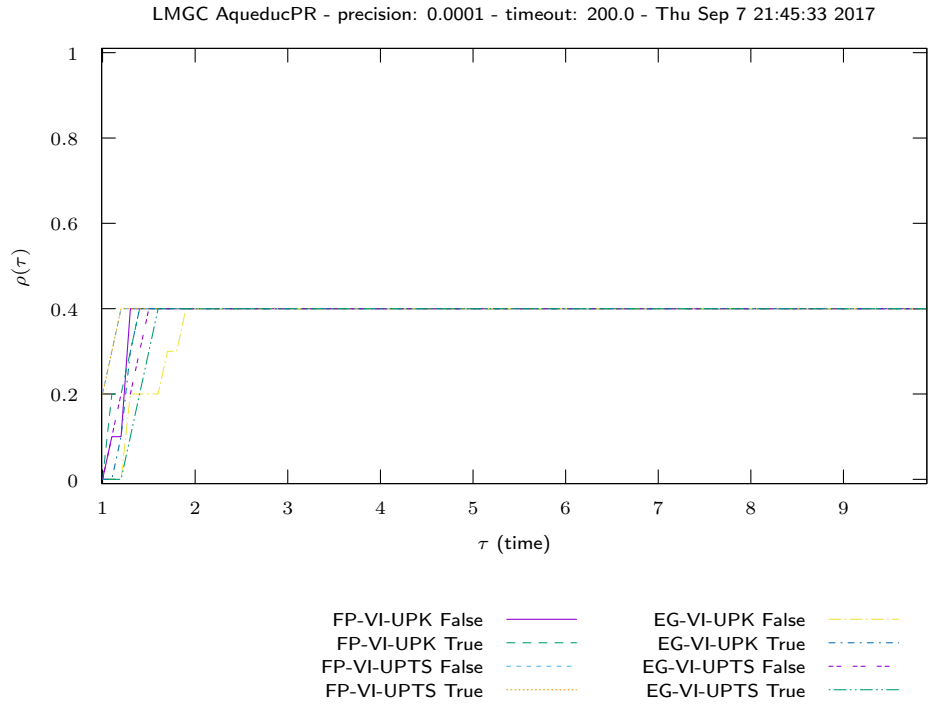


Figure 27: LMGC Aqueduc PR time VI/UpdateRule

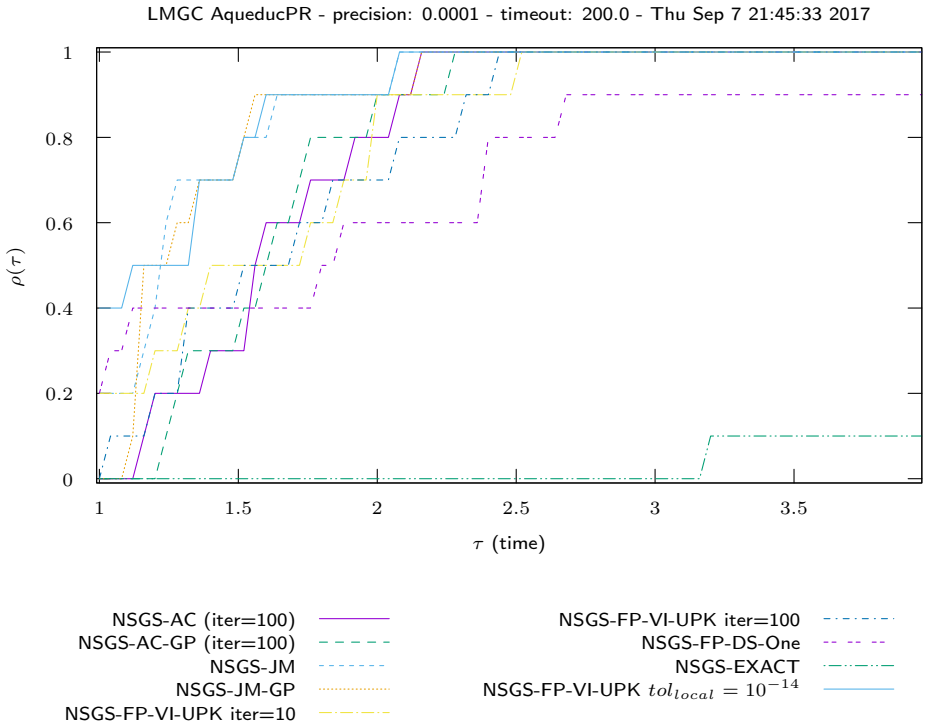


Figure 28: LMGC Aqueduc PR time NSGS/LocalSolver

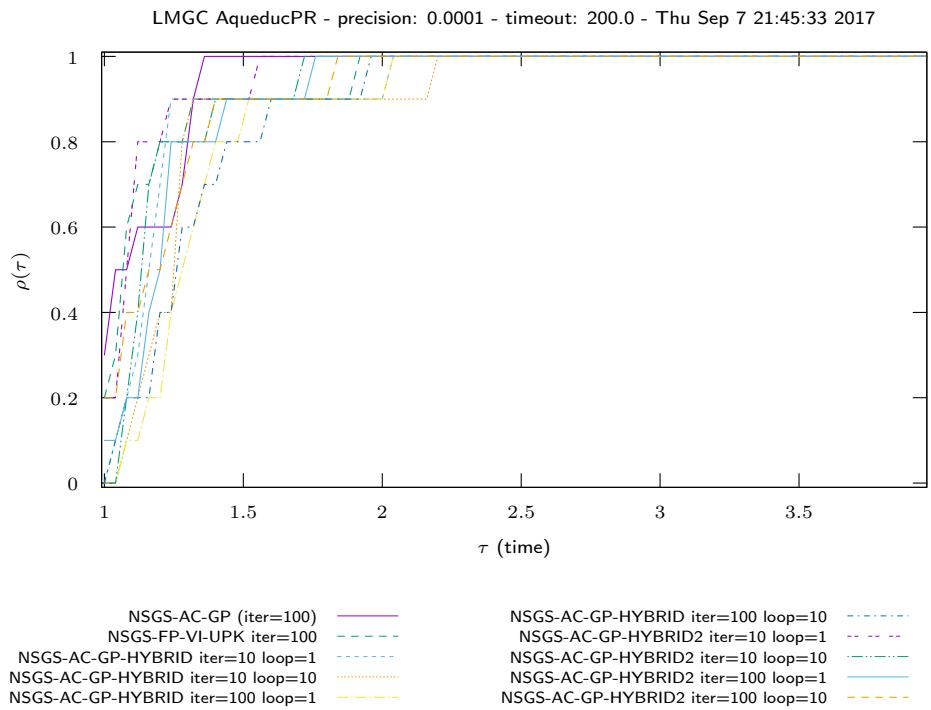


Figure 29: LMGC Aqueduc PR time NSGS/LocalSolverHybrid

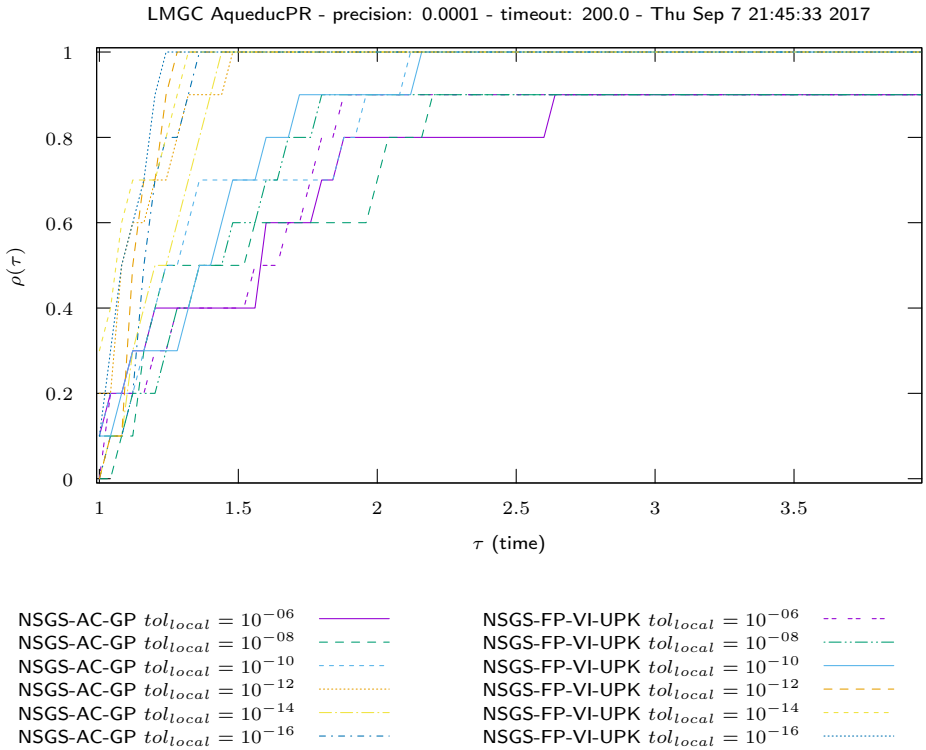
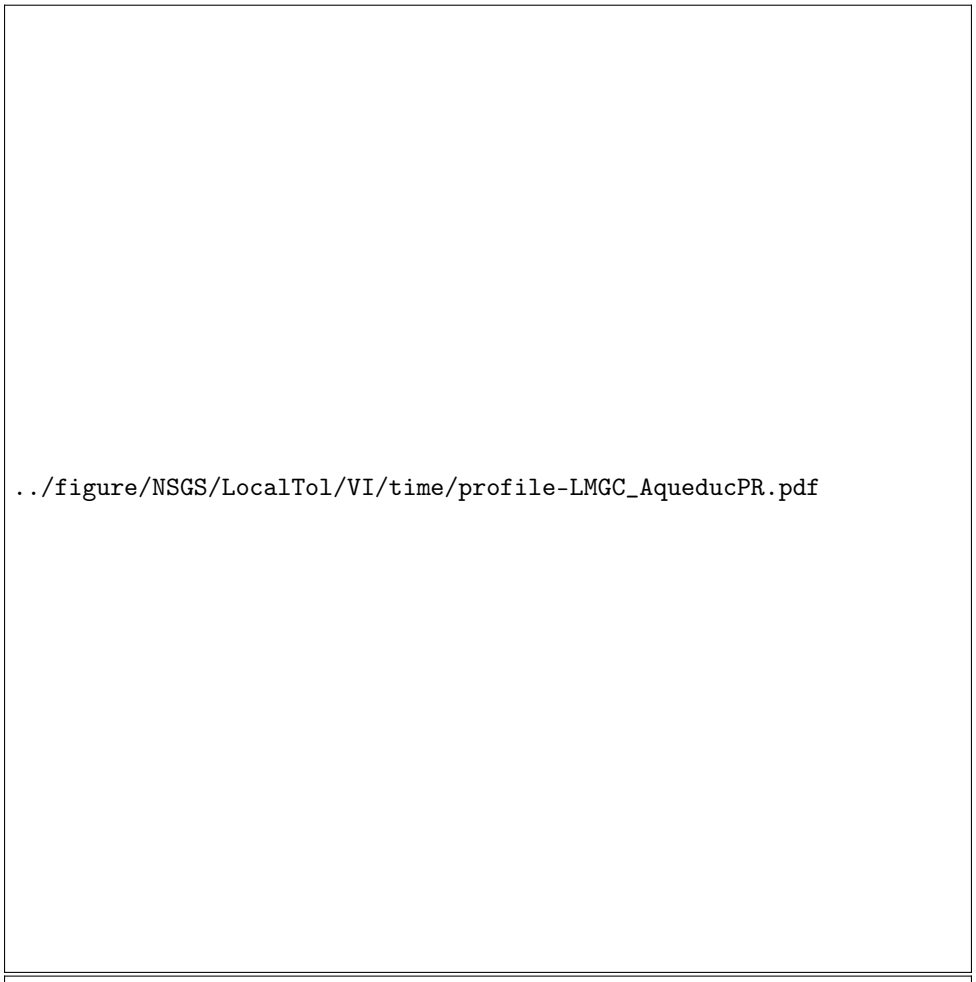
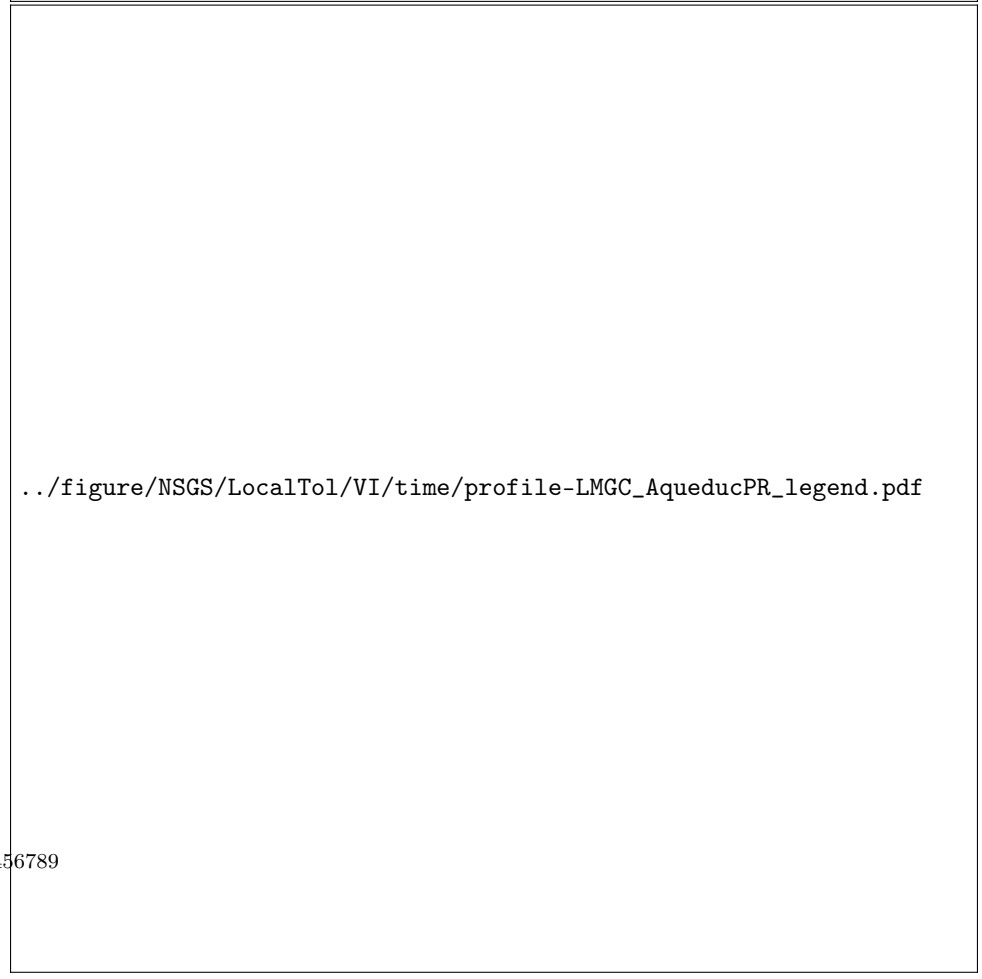


Figure 30: LMGC Aqueduc PR time NSGS/LocalTol


../figure/NSGS/LocalTol/VI/time/profile-LMGC_AqueducPR.pdf


../figure/NSGS/LocalTol/VI/time/profile-LMGC_AqueducPR_legend.pdf

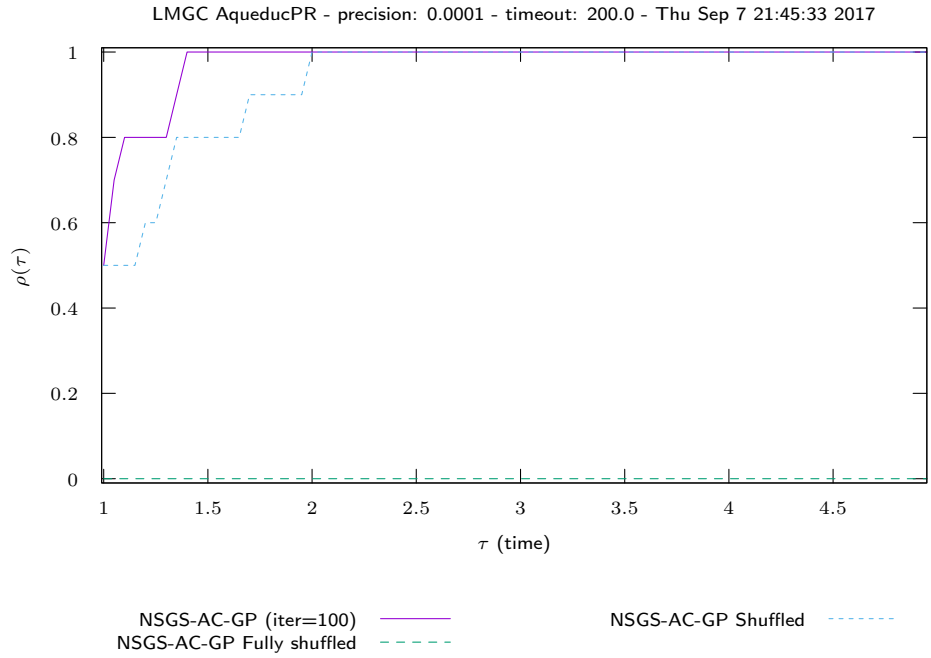


Figure 32: LMGC Aqueduc PR time NSGS/Shuffled

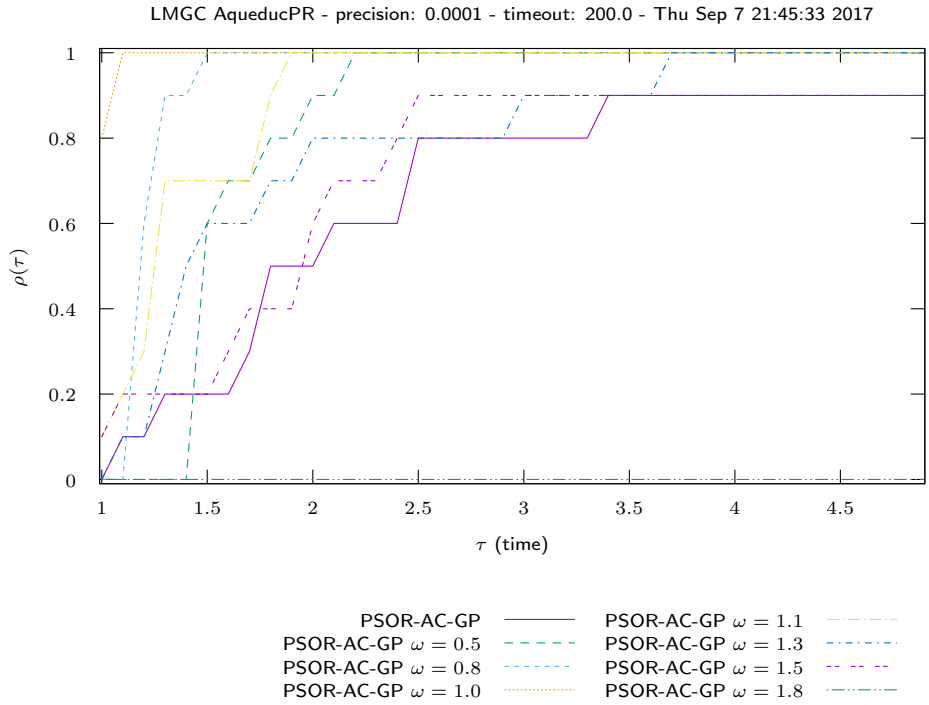


Figure 33: LMGC Aqueduc PR time PSOR

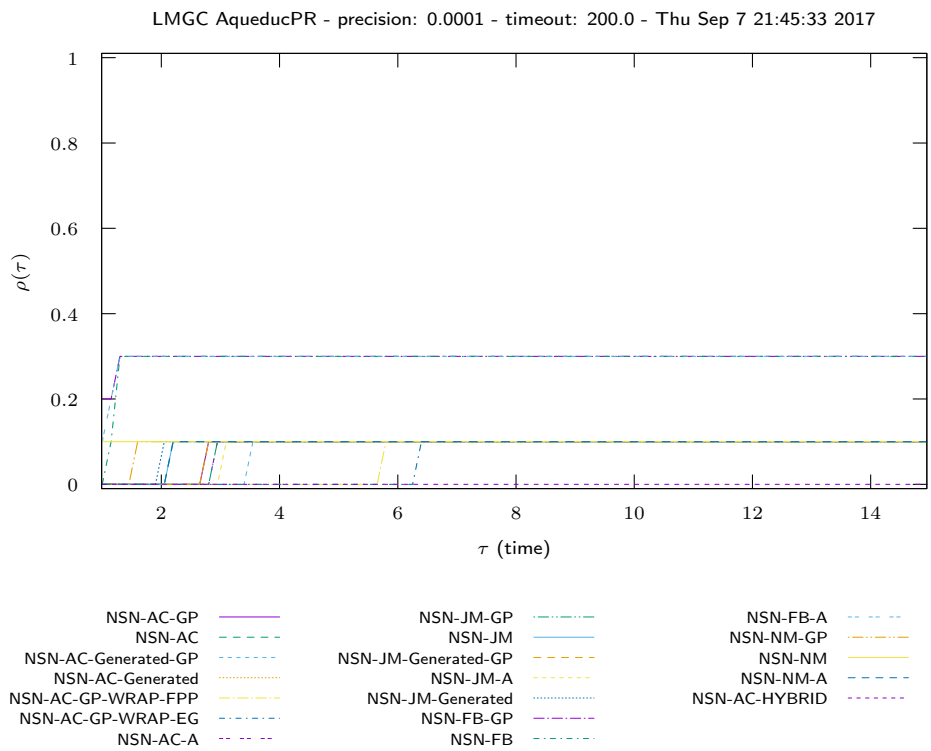


Figure 34: LMGC Aqueduc PR time NSN

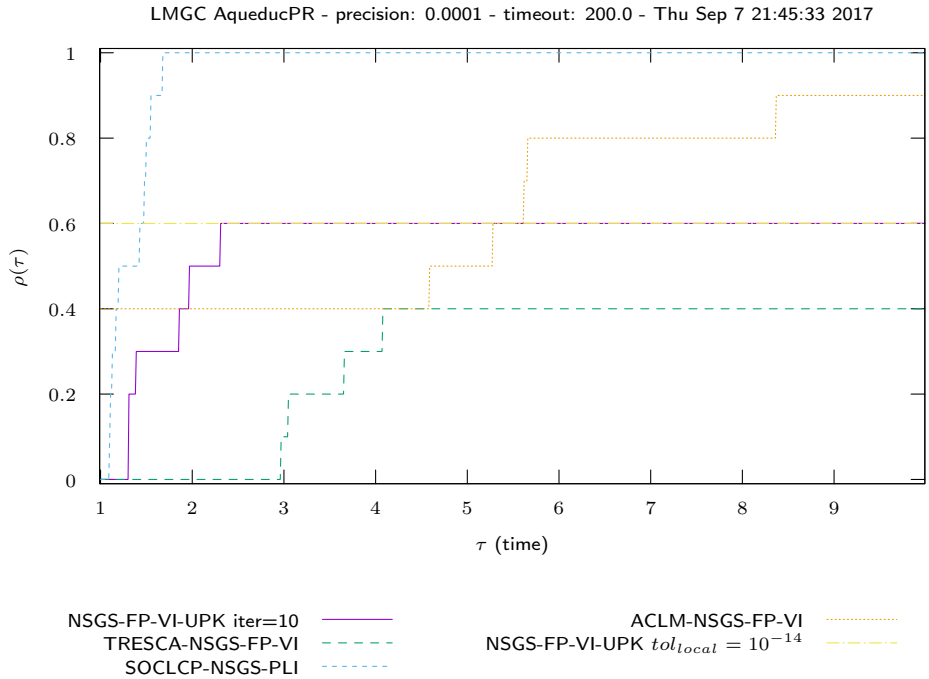


Figure 35: LMGC Aqueduc PR time OPTI

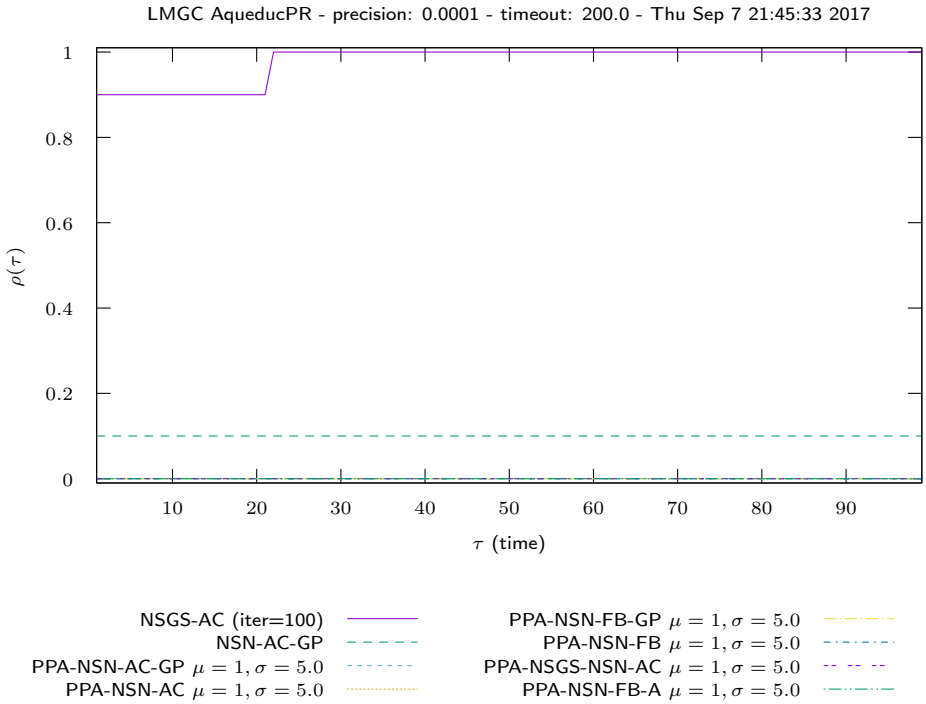


Figure 36: LMGC Aqueduc PR time PROX/InternalSolvers

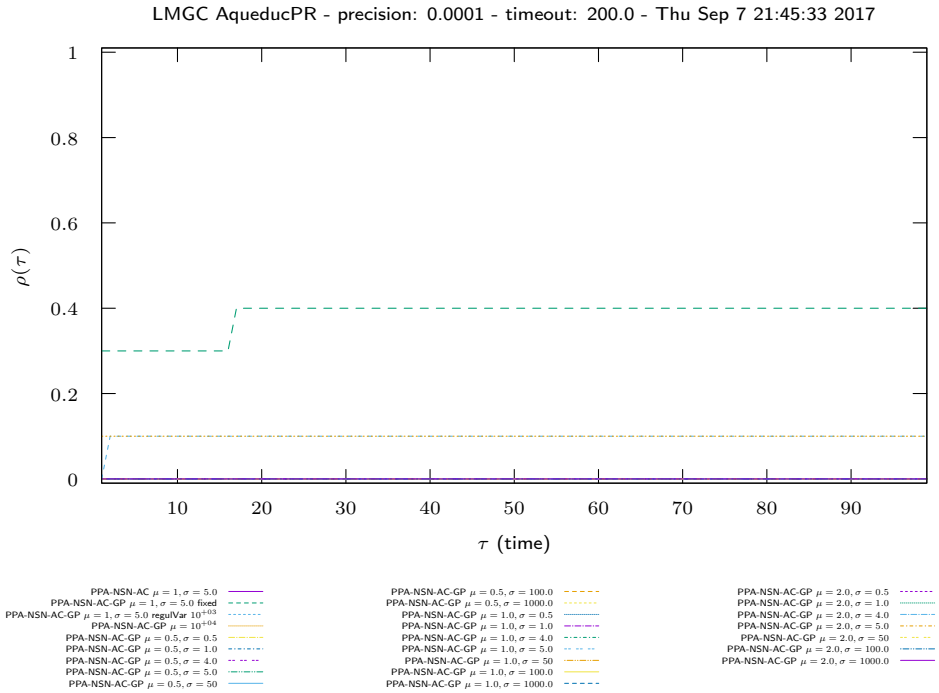


Figure 37: LMGC Aqueduc PR time PROX/Parameters

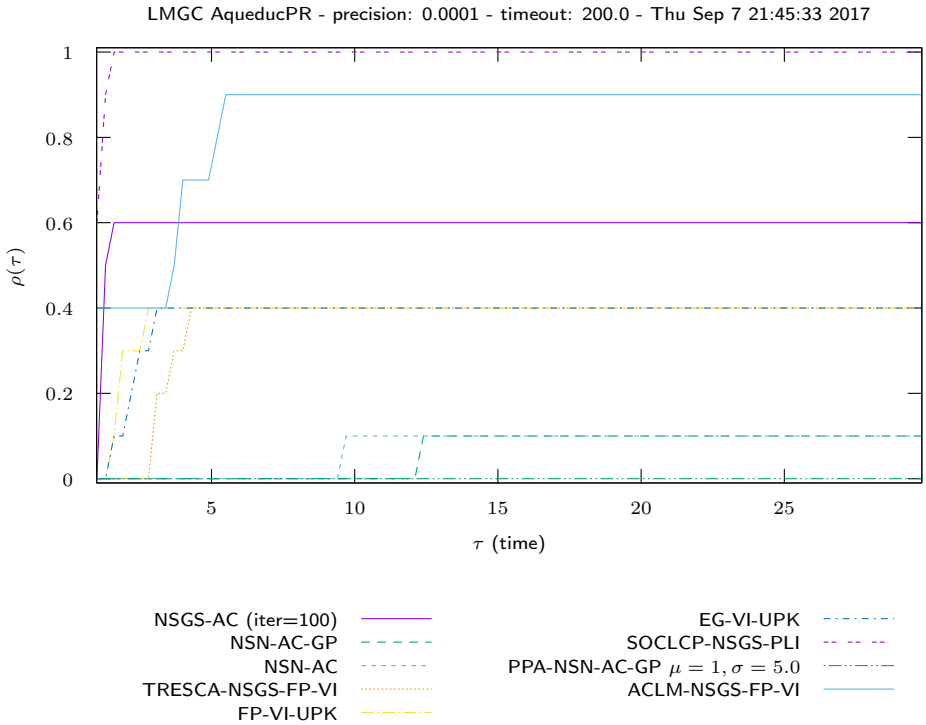


Figure 38: LMGC Aqueduc PR time COMP/large

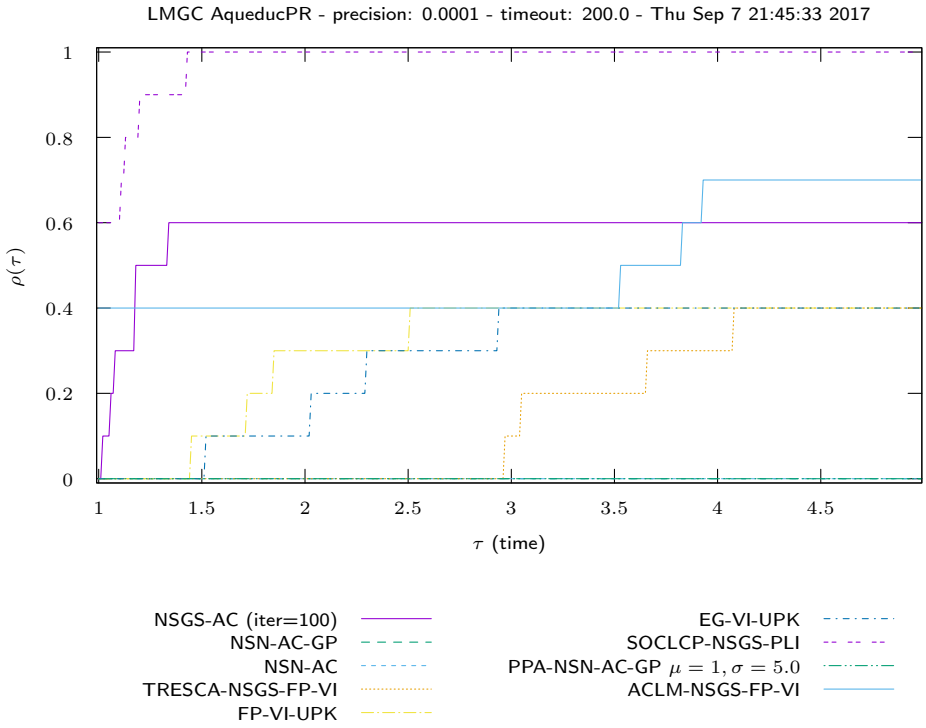


Figure 39: LMGC Aqueduc PR time COMP/large

3.1 Comments

1. VI solvers: difficult to draw conclusions since a lot of solvers are not able to converge within timeout
2. NSGS Solvers:
   (a) Local solvers
      i. NSGS-NSN-*-GP are the best solvers. Line search improves efficiency of the solvers.
      ii. Hybrid solvers do not bring new advantages which is not surprising since NSGS-NSN solvers are the best
   (b) Local Tolerances:
   (c) Shuffling techniques: The shuffling of contact does not improve the convergence.

PSOR Solvers. The relaxation is not interesting in this example

NSN and PROX solvers. The direct Newton techniques on such rigid-body test set are inefficient. (link to the distribution of ranks of the matrices)

OPTI solvers. On this problem, the ACLM approach improves a lot the efficiency and the robustness. The problems are also better solved by the SOCLCP technique. Convexification is working well.

4 LMGC Bridge PR

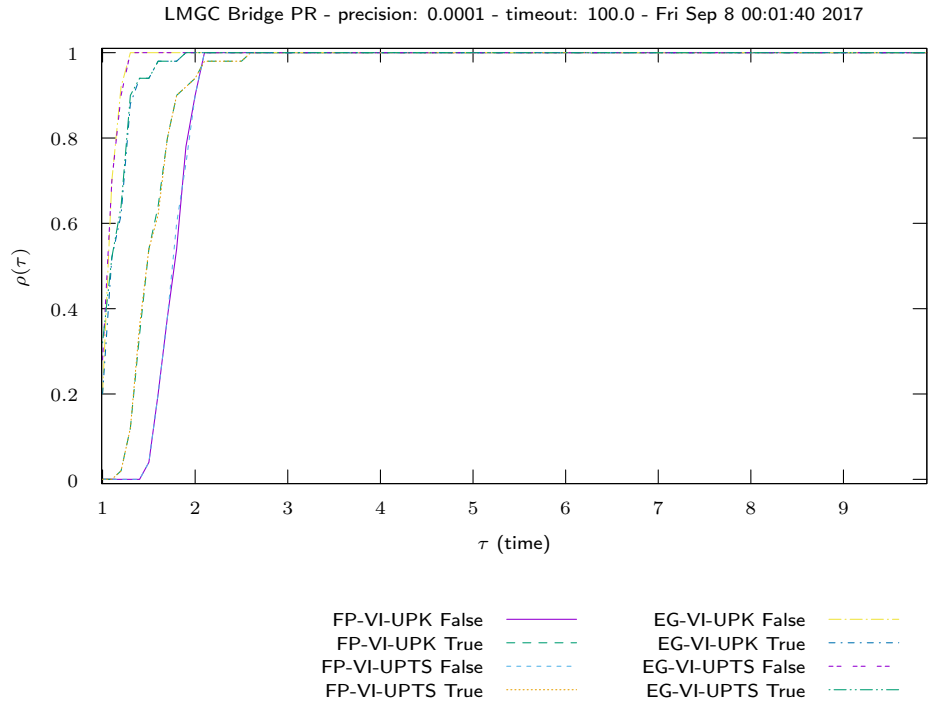


Figure 40: LMGC Bridge PR time VI/UpdateRule

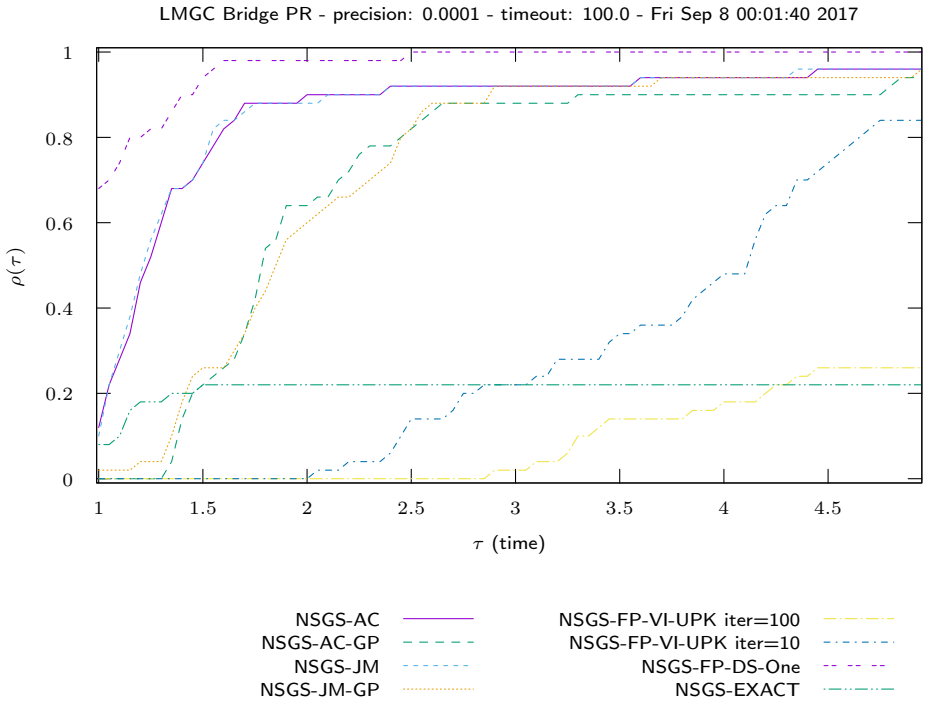


Figure 41: LMGC Bridge PR time NSGS/LocalSolver

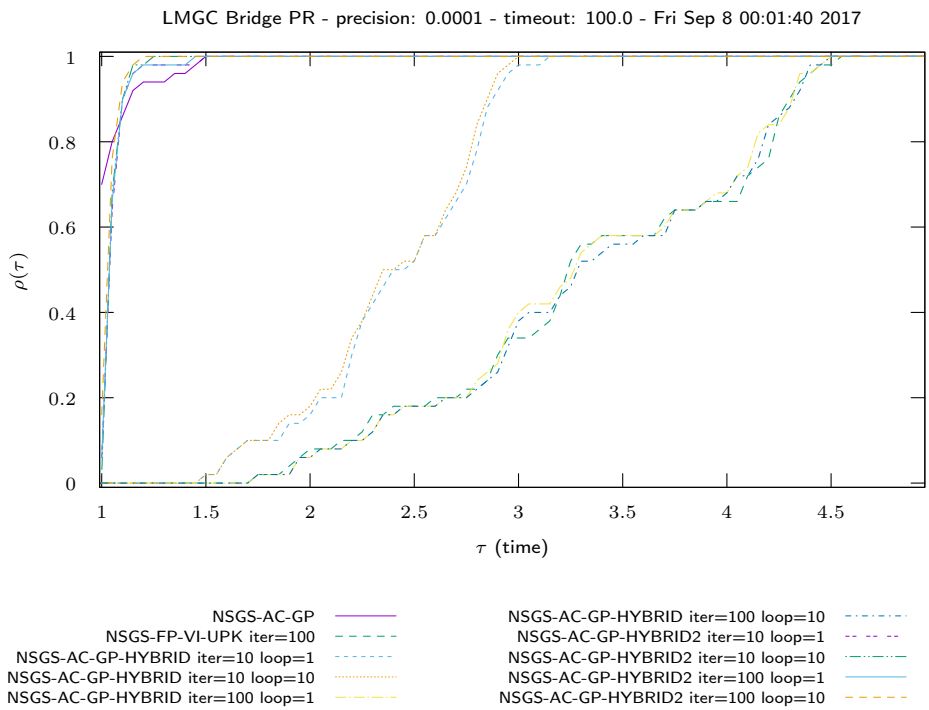


Figure 42: LMGC Bridge PR time NSGS/LocalSolverHybrid

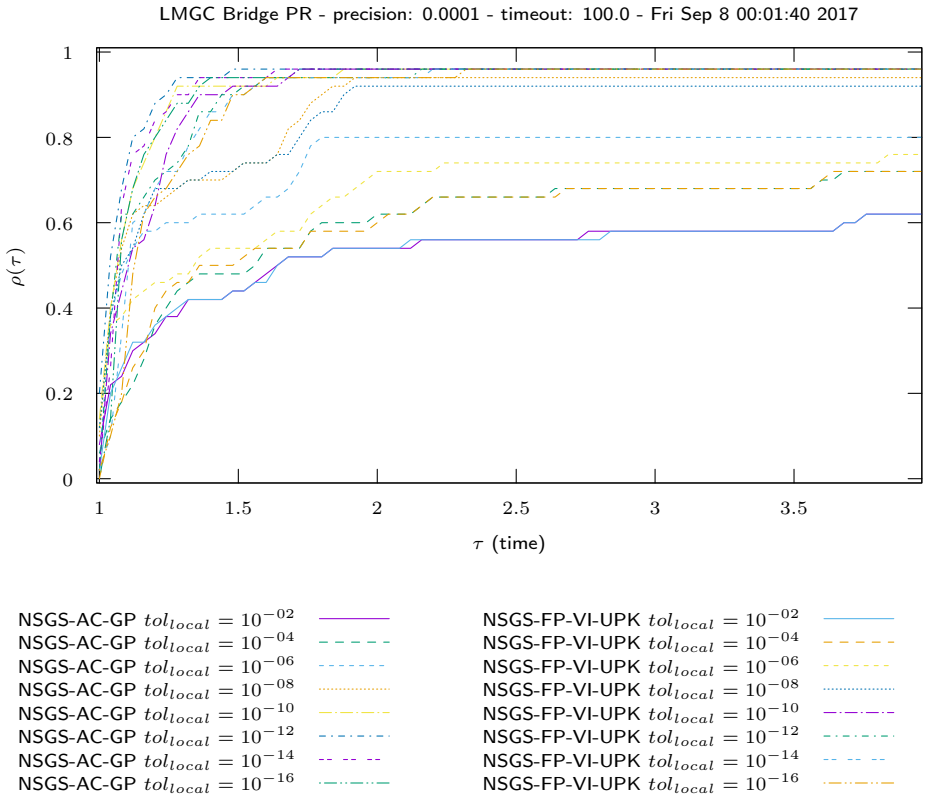
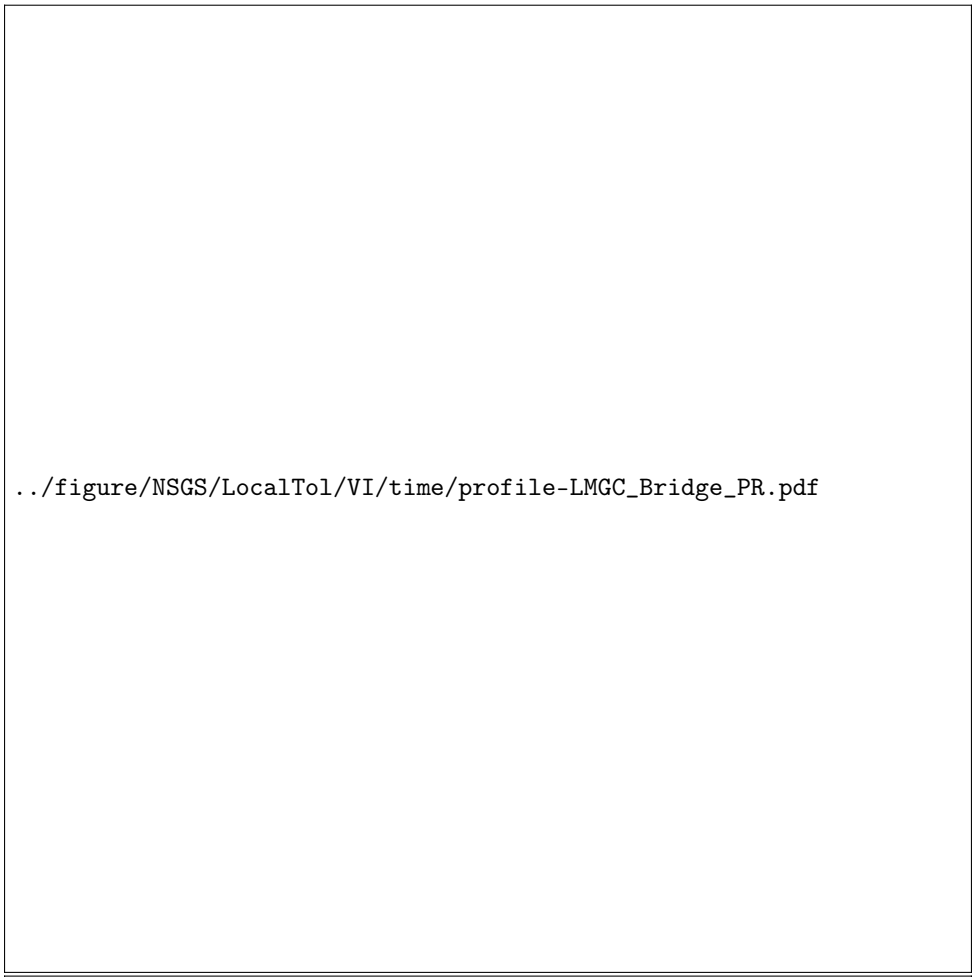
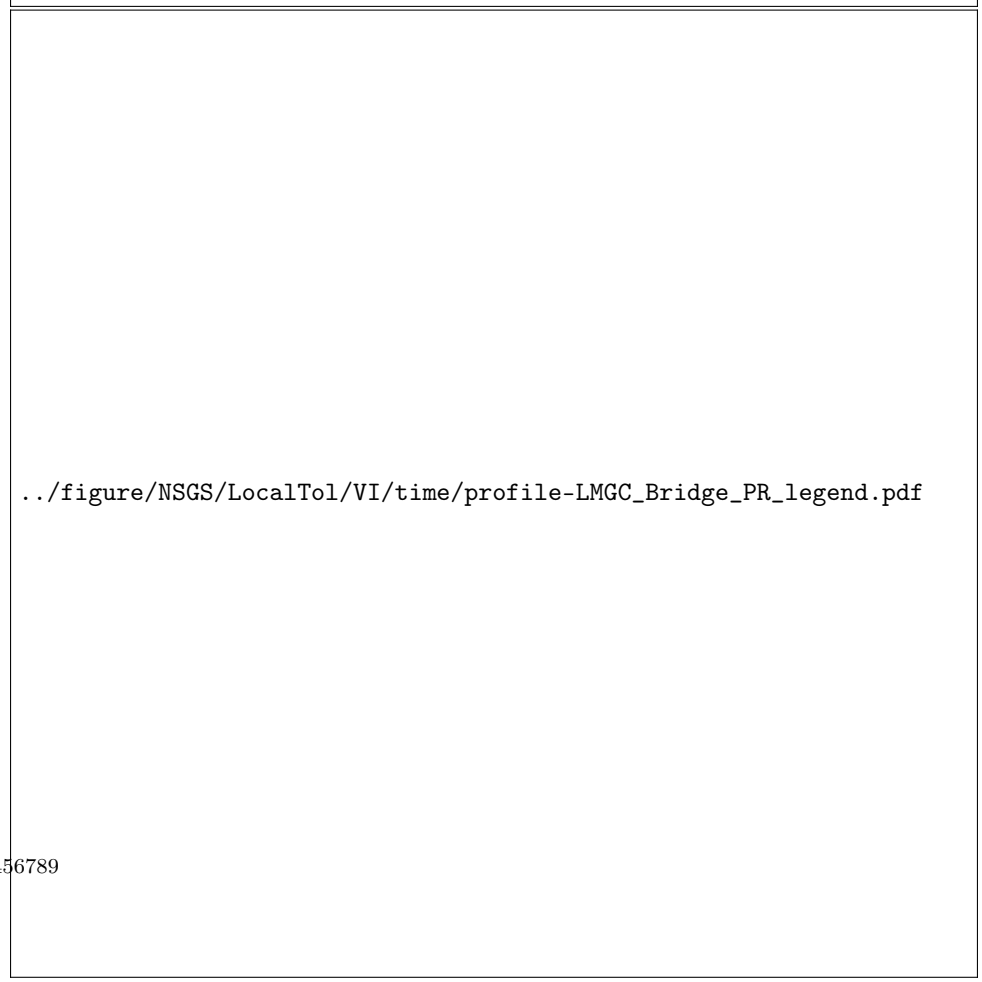


Figure 43: LMGC Bridge PR time NSGS/LocalTol


../figure/NSGS/LocalTol/VI/time/profile-LMGC_Bridge_PR.pdf


../figure/NSGS/LocalTol/VI/time/profile-LMGC_Bridge_PR_legend.pdf

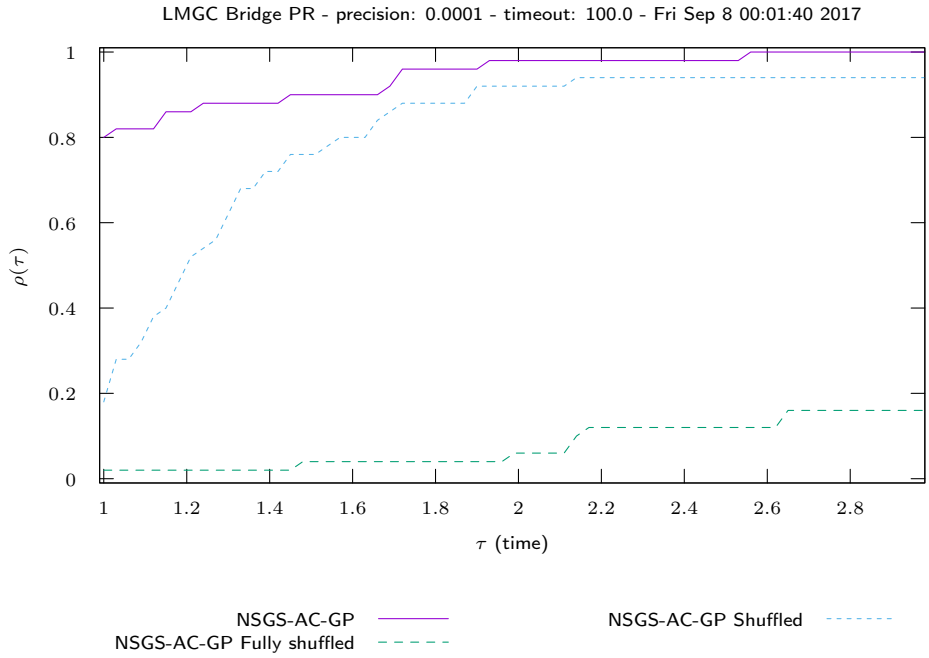


Figure 45: LMGC Bridge PR time NSGS/Shuffled

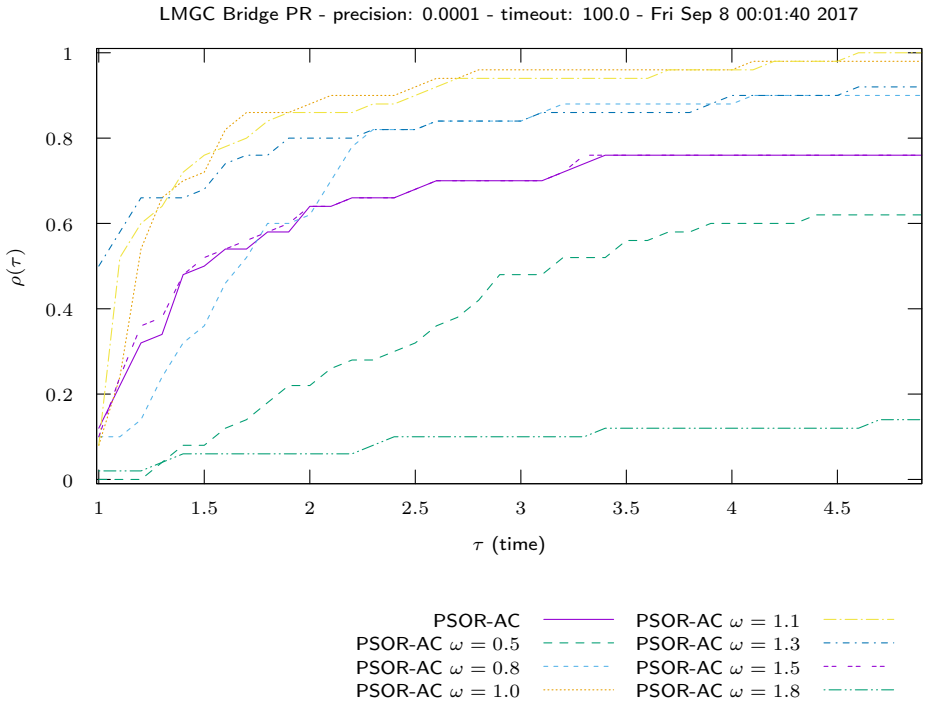


Figure 46: LMGC Bridge PR time PSOR

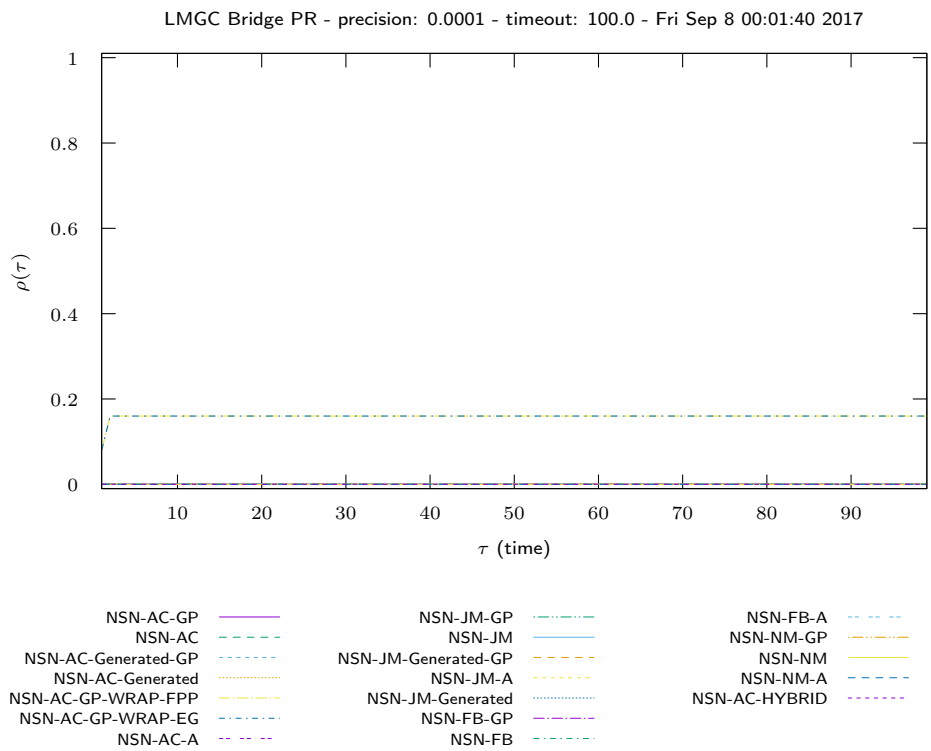


Figure 47: LMGC Bridge PR time NSN

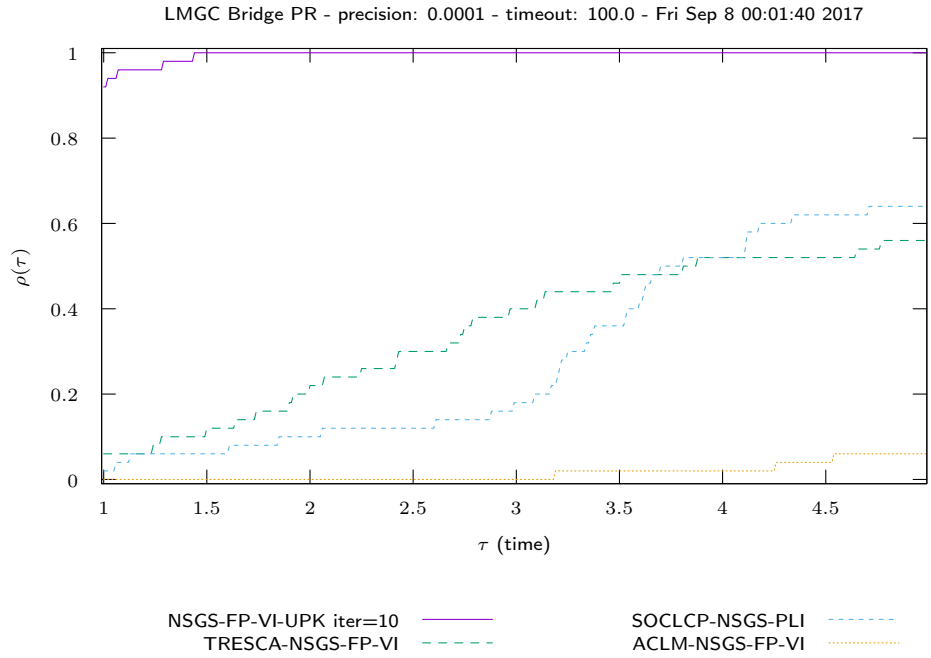


Figure 48: LMGC Bridge PR time OPTI

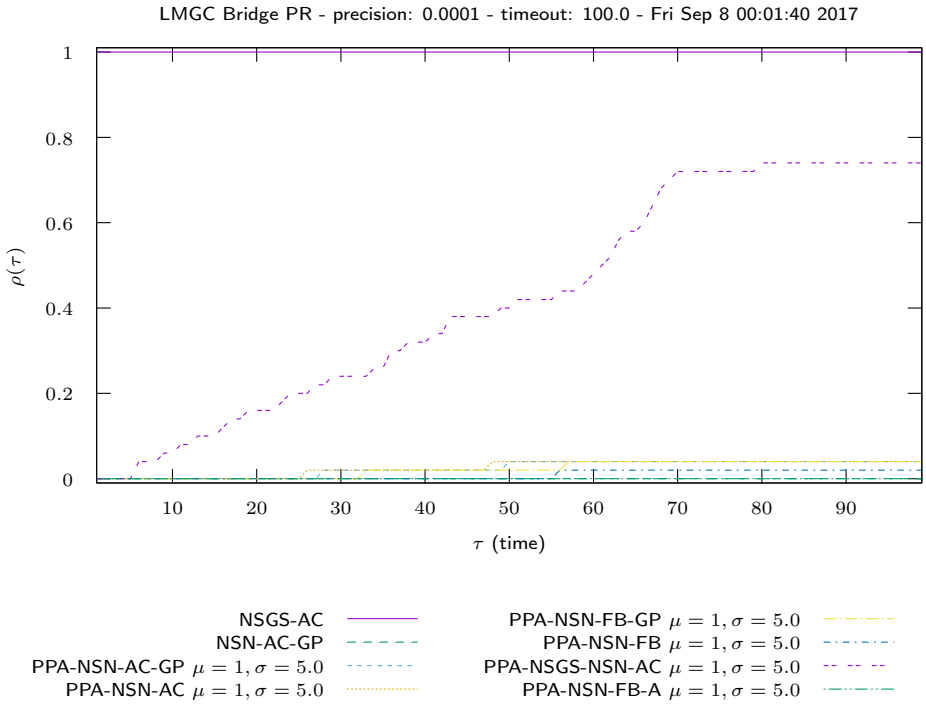
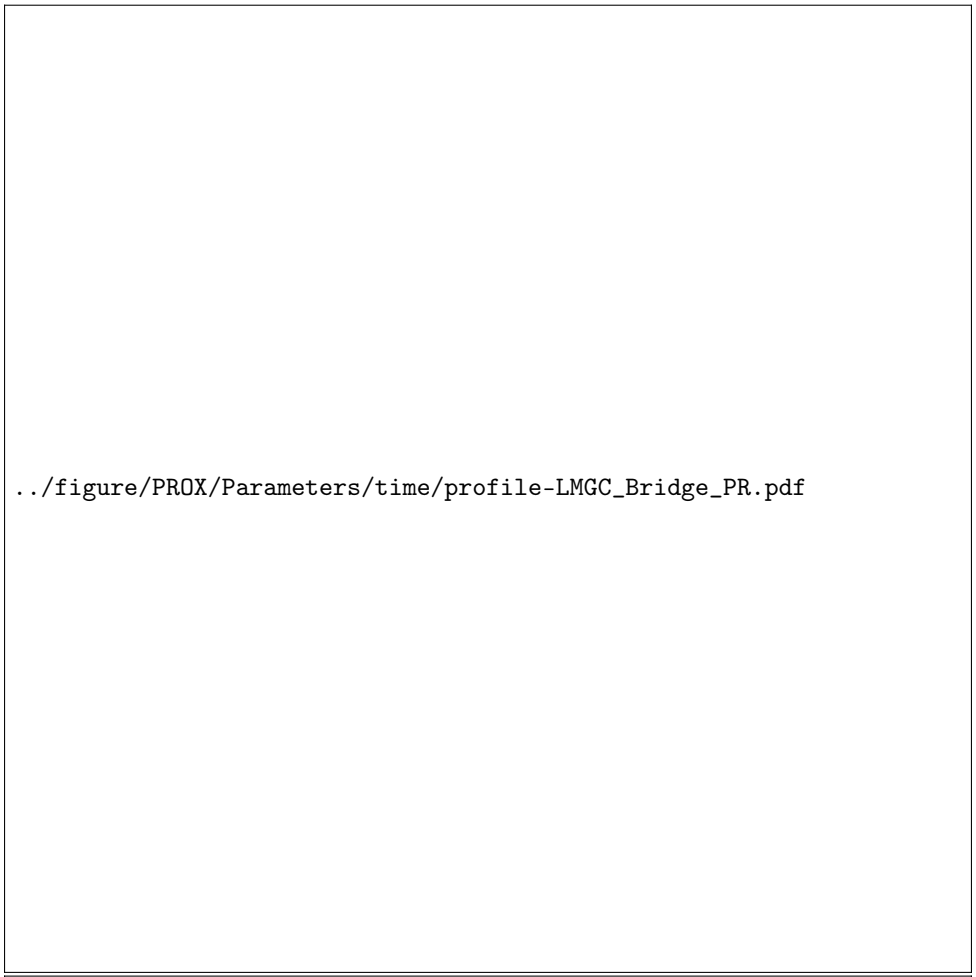
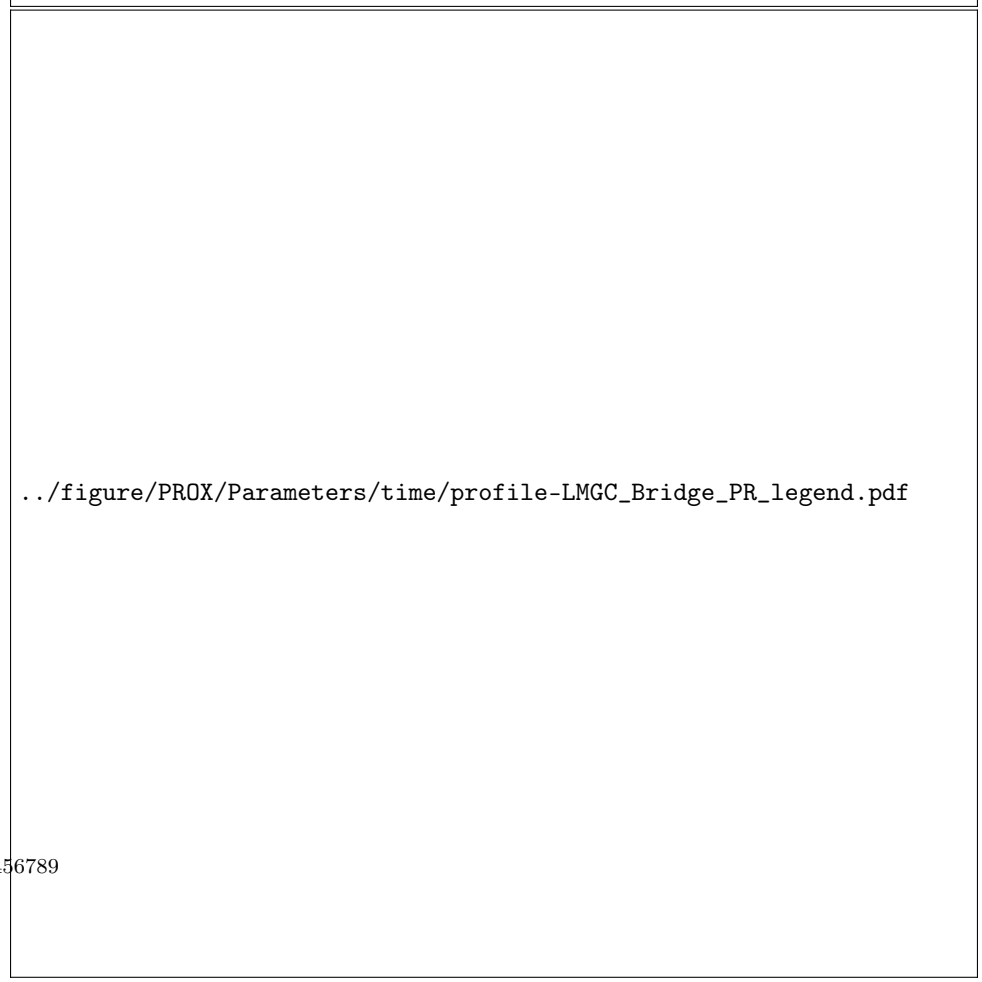


Figure 49: LMGC Bridge PR time PROX/InternalSolvers


../figure/PROX/Parameters/time/profile-LMGC_Bridge_PR.pdf


../figure/PROX/Parameters/time/profile-LMGC_Bridge_PR_legend.pdf

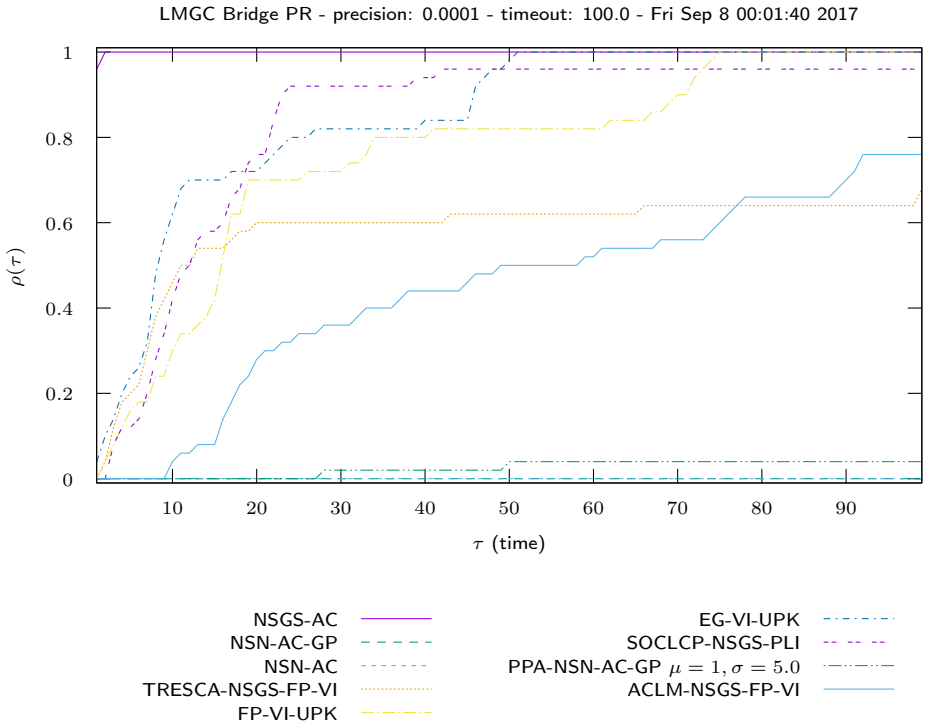


Figure 51: LMGC Bridge PR time COMP/large

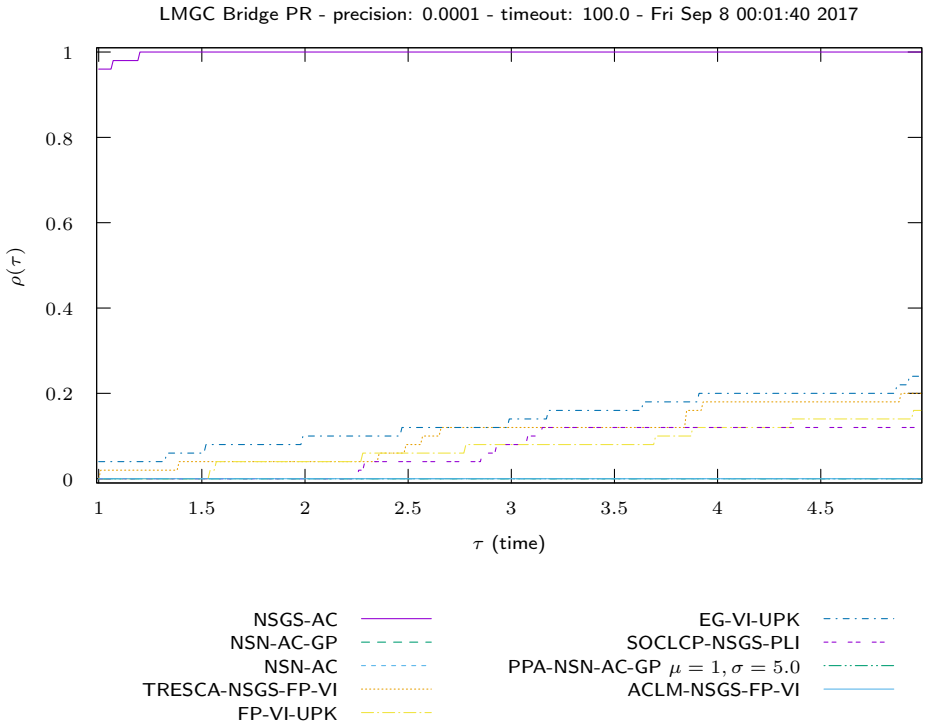


Figure 52: LMGC Bridge PR time COMP/large

5 LMGC LowWall FEM

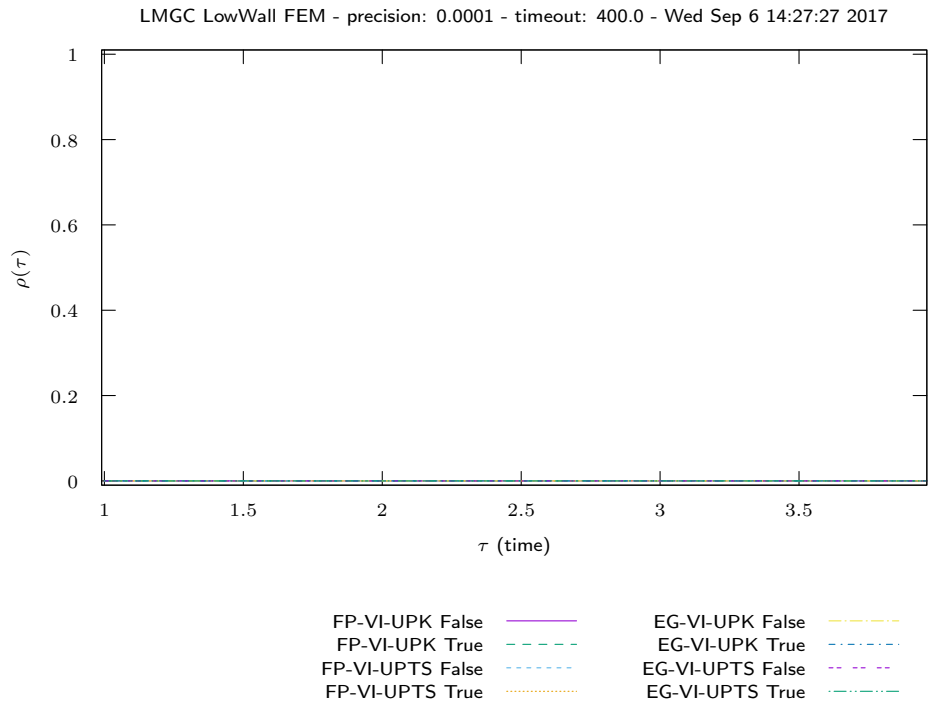


Figure 53: LMGC LowWall FEM time VI/UpdateRule

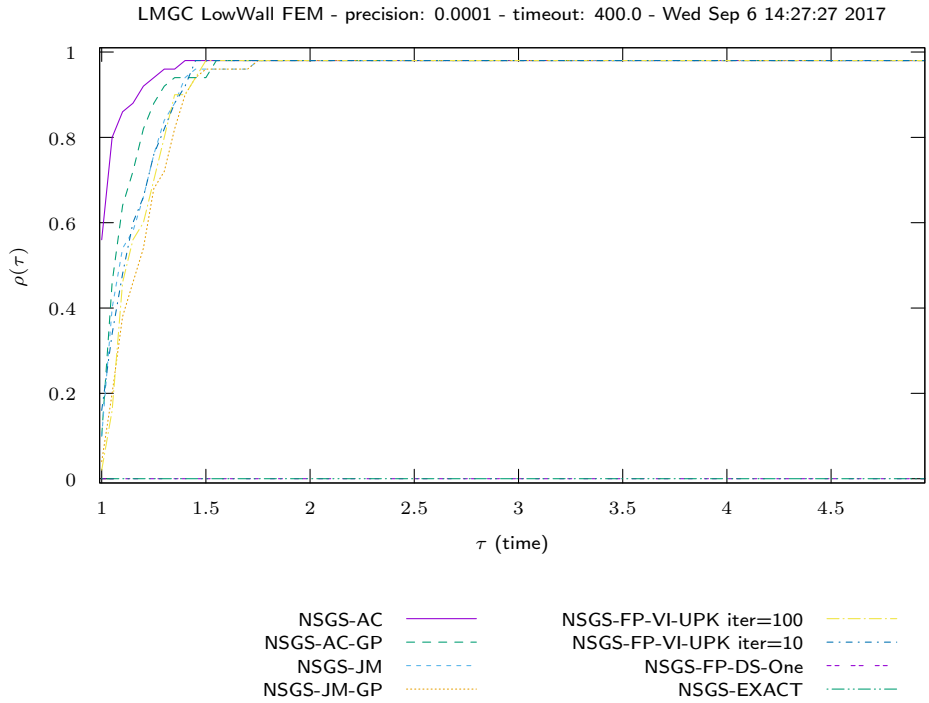


Figure 54: LMGC LowWall FEM time NSGS/LocalSolver

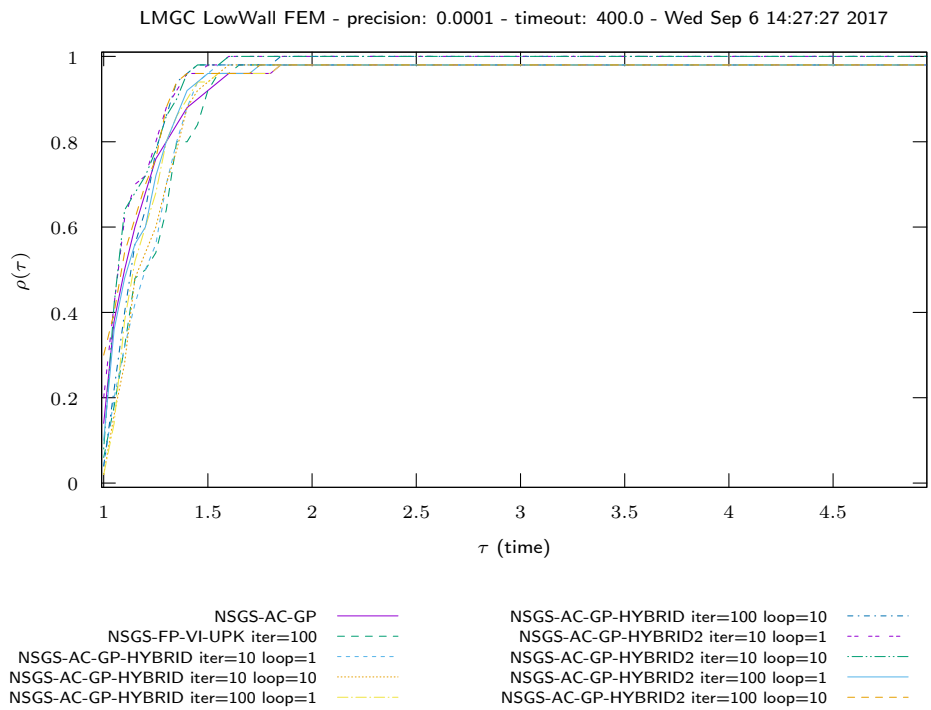


Figure 55: LMGC LowWall FEM time NSGS/LocalSolverHybrid

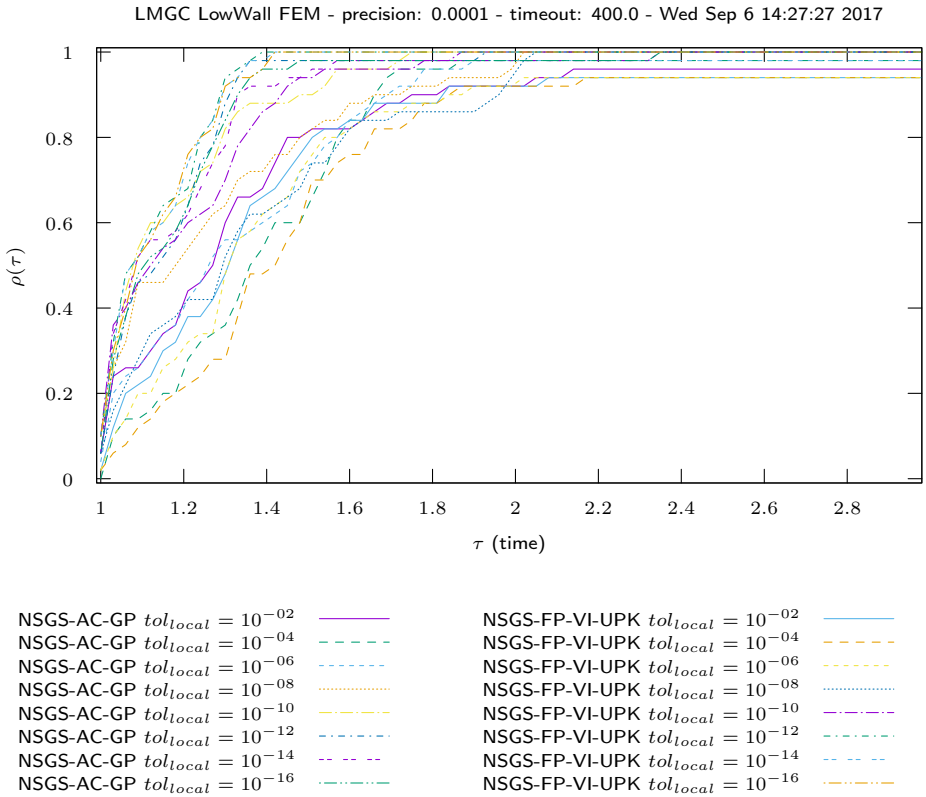
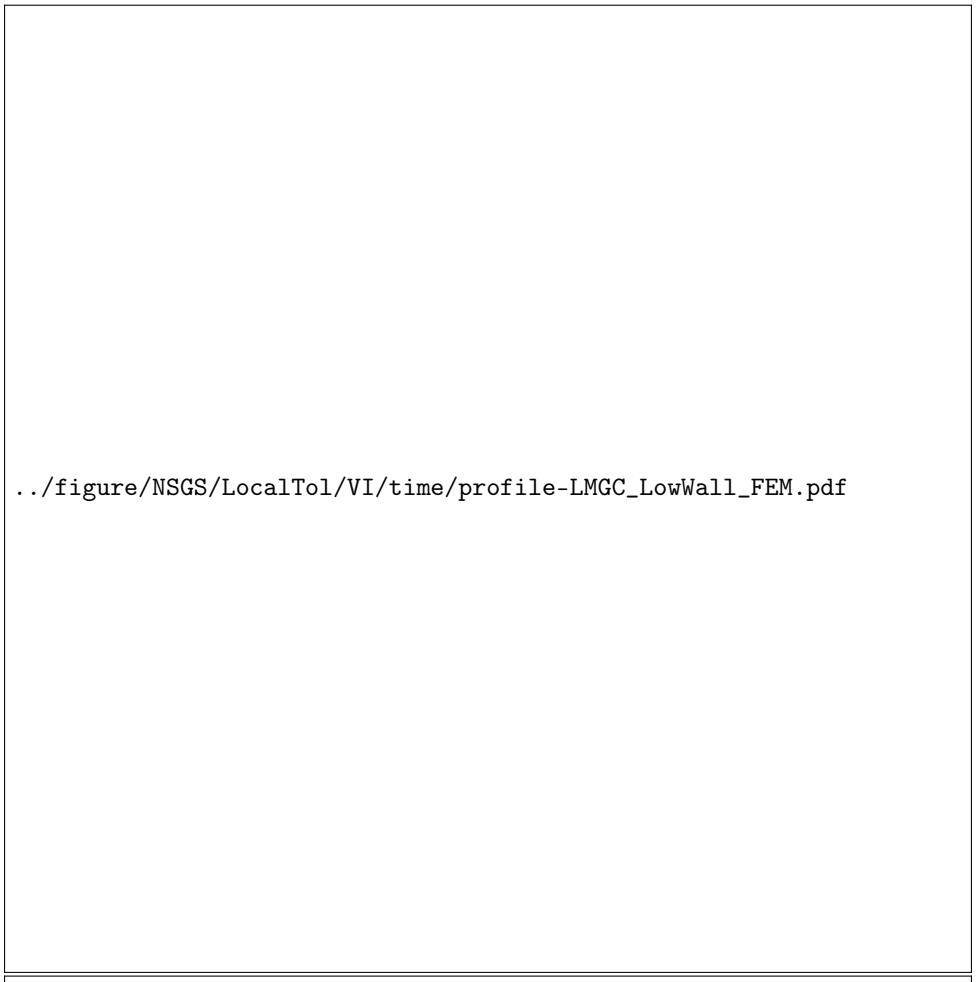
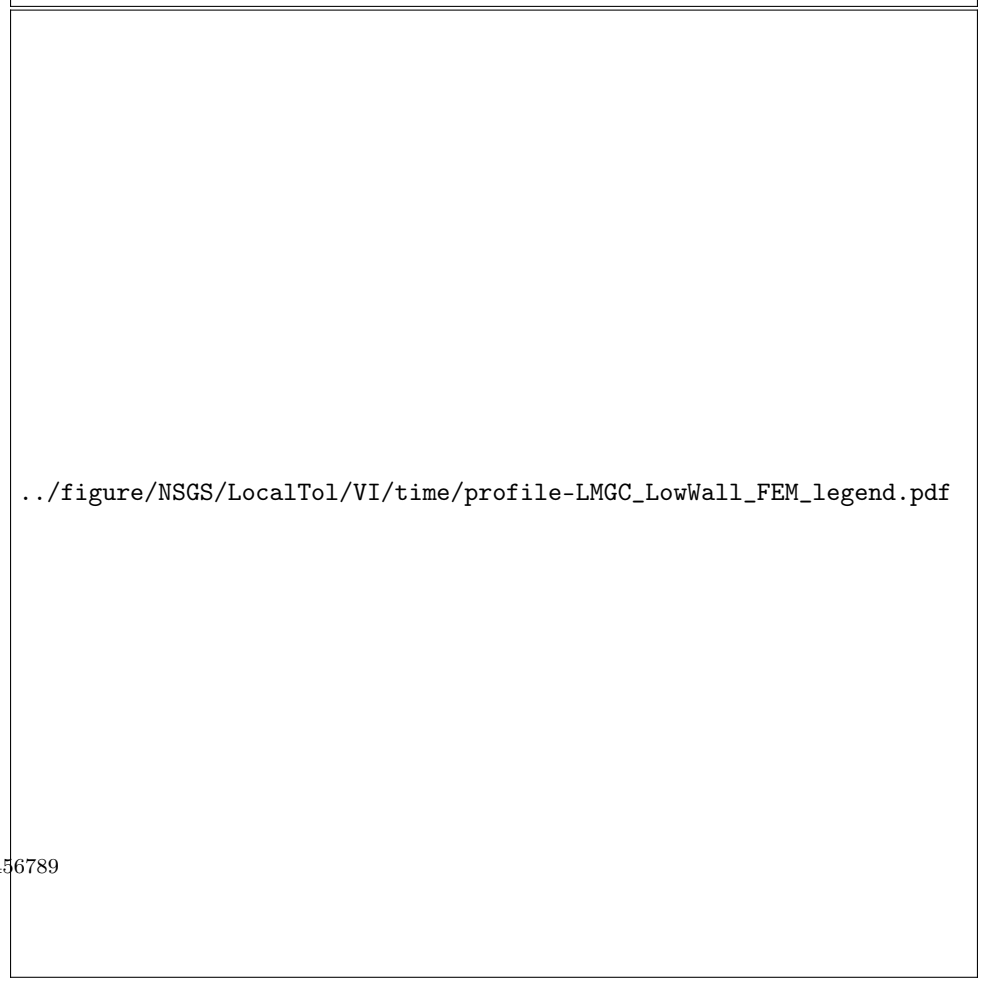


Figure 56: LMGC LowWall FEM time NSGS/LocalTol


../figure/NSGS/LocalTol/VI/time/profile-LMGC_LowWall_FEM.pdf


../figure/NSGS/LocalTol/VI/time/profile-LMGC_LowWall_FEM_legend.pdf

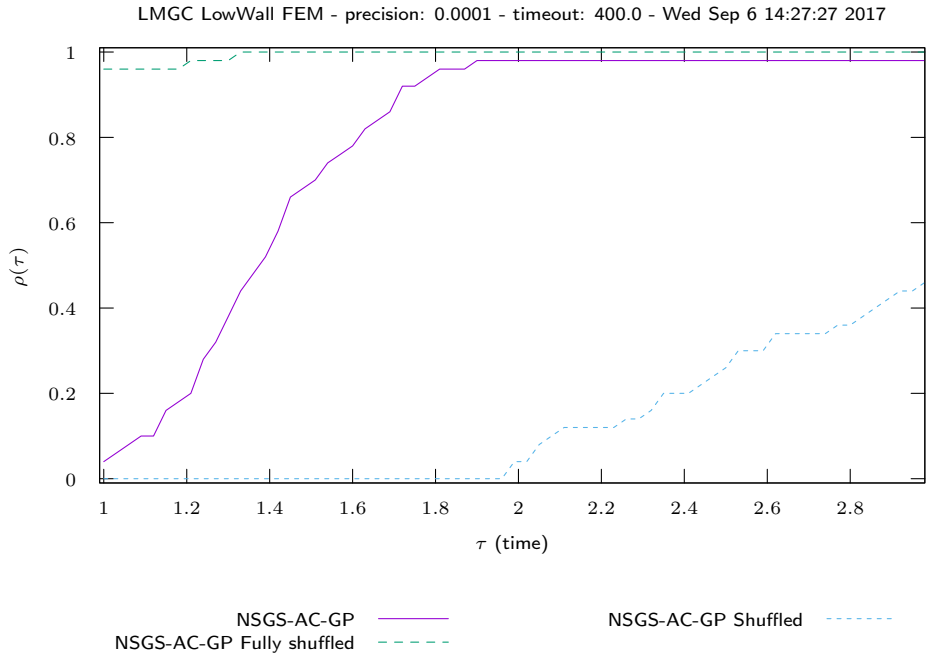


Figure 58: LMGC LowWall FEM time NSGS/Shuffled

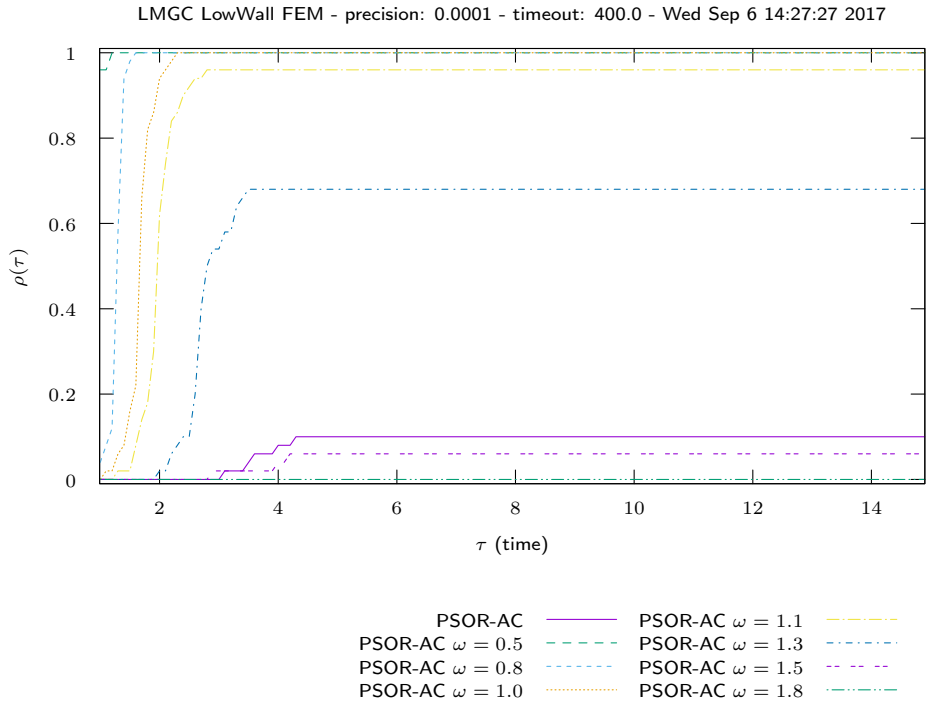


Figure 59: LMGC LowWall FEM time PSOR

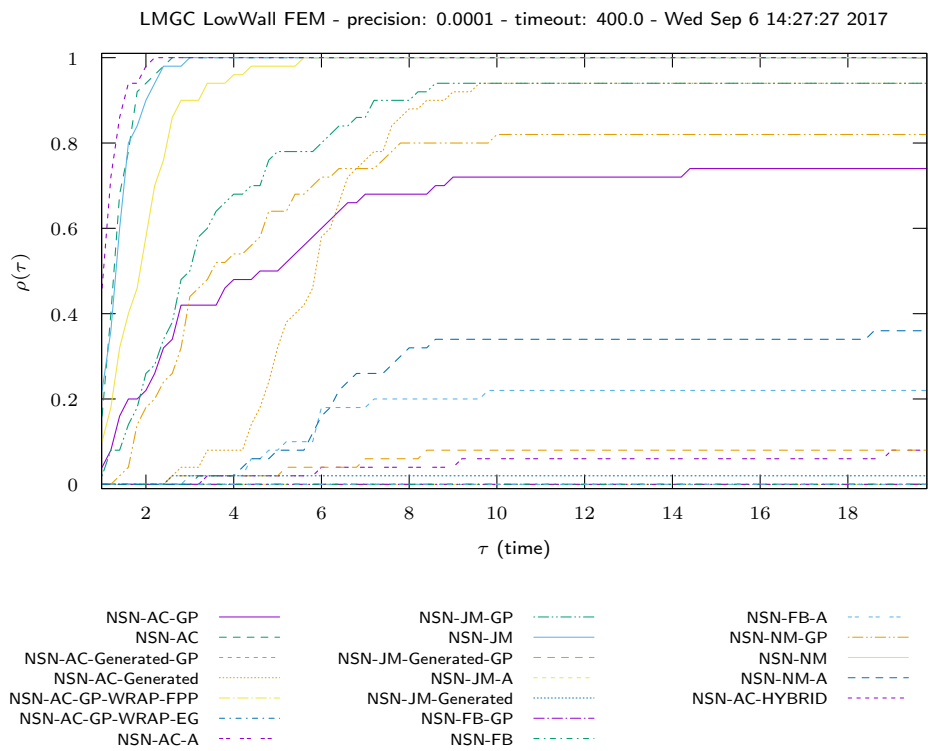


Figure 60: LMGC LowWall FEM time NSN

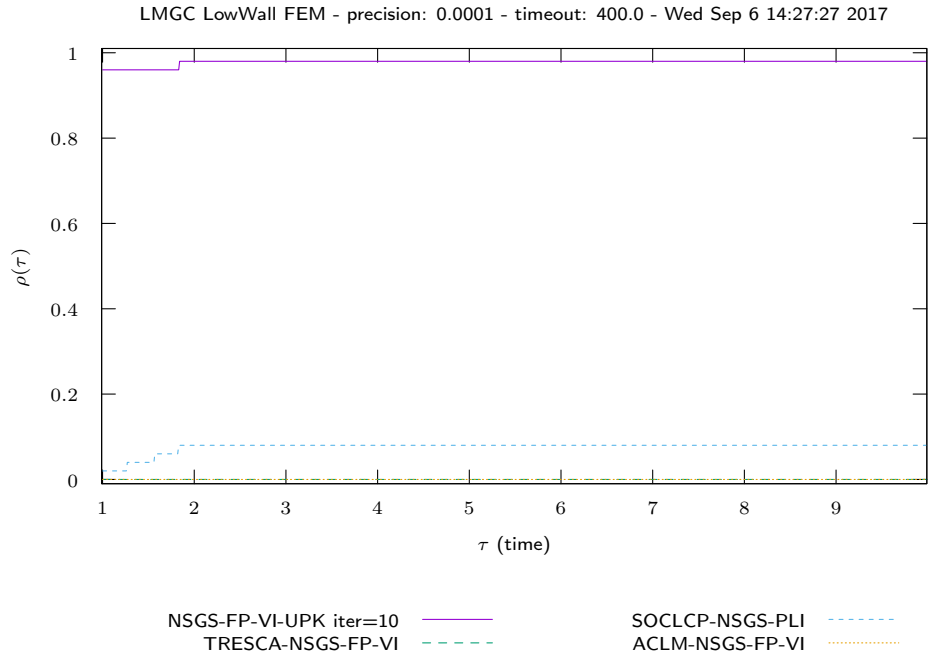


Figure 61: LMGC LowWall FEM time OPTI

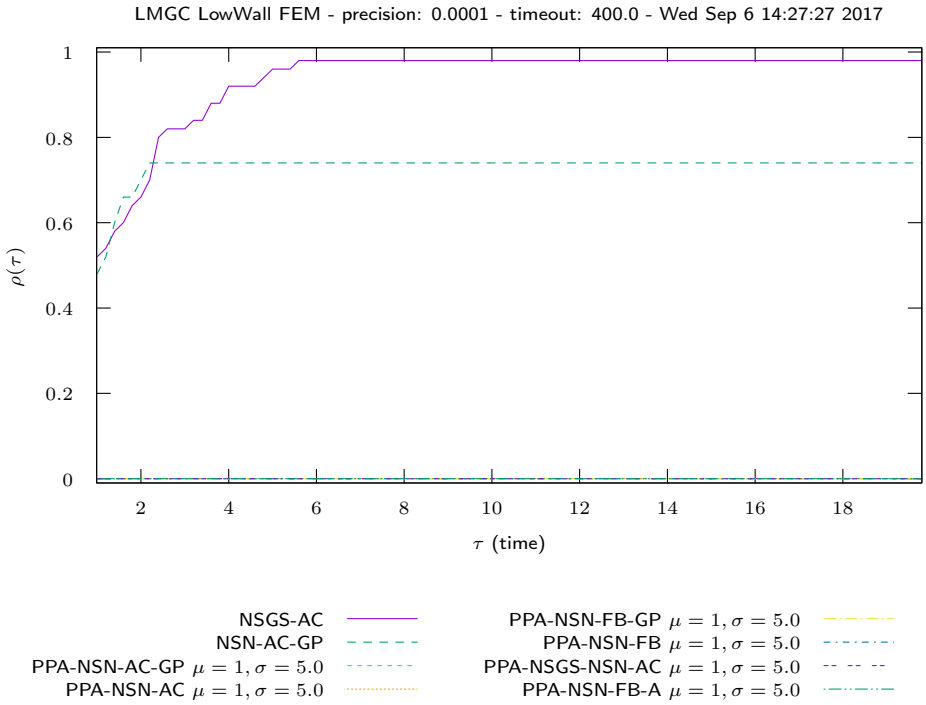
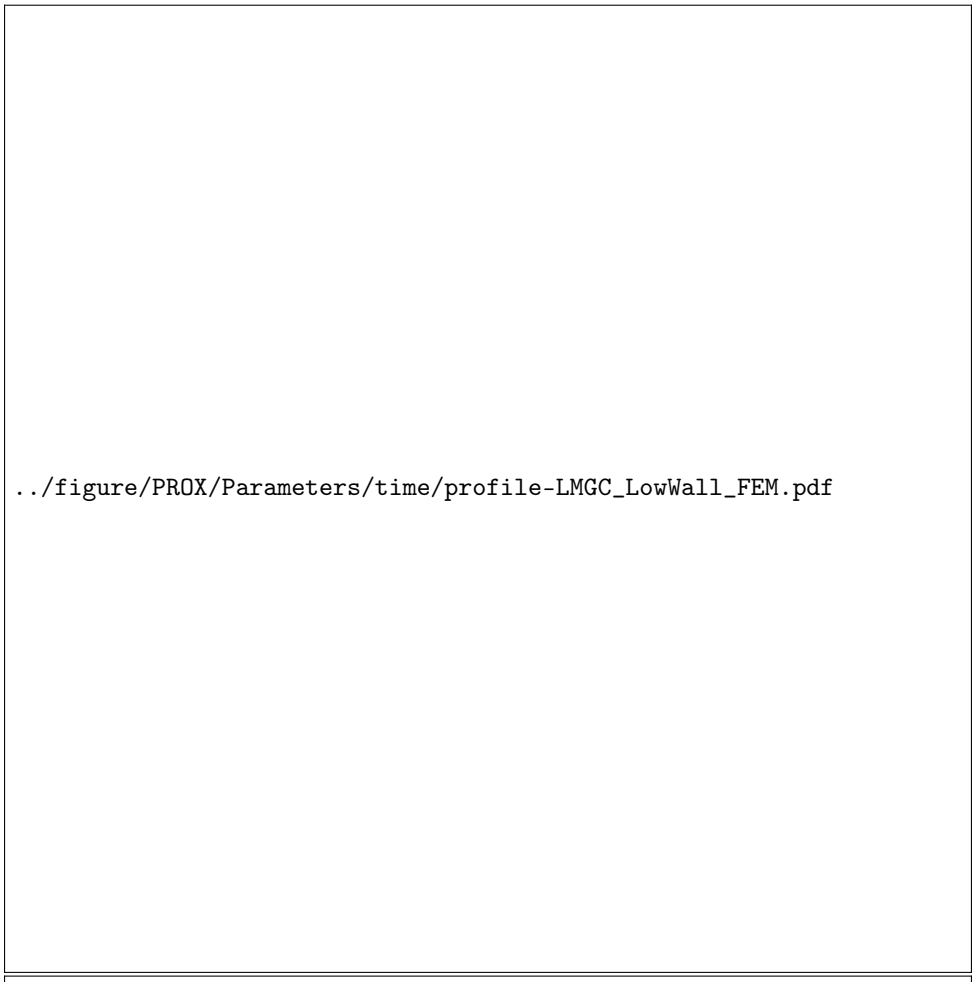
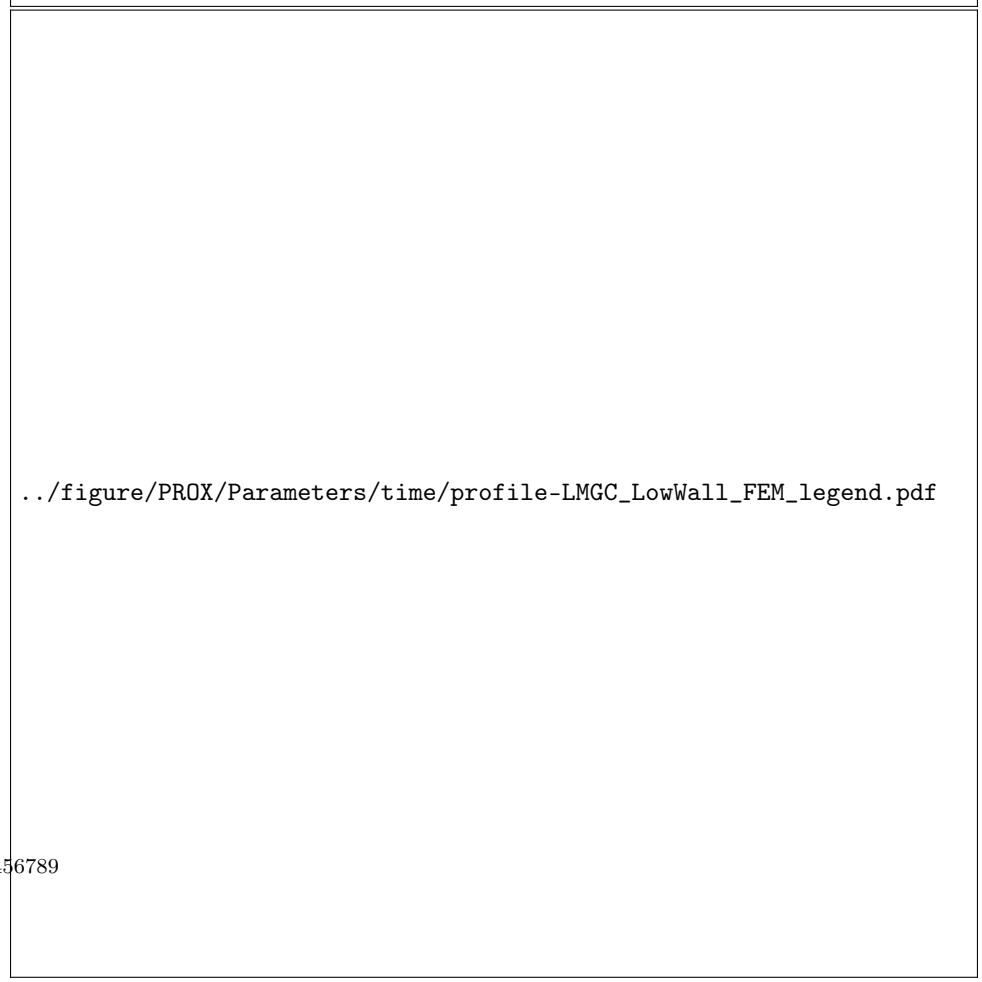


Figure 62: LMGC LowWall FEM time PROX/InternalSolvers


../figure/PROX/Parameters/time/profile-LMGC_LowWall_FEM.pdf


../figure/PROX/Parameters/time/profile-LMGC_LowWall_FEM_legend.pdf

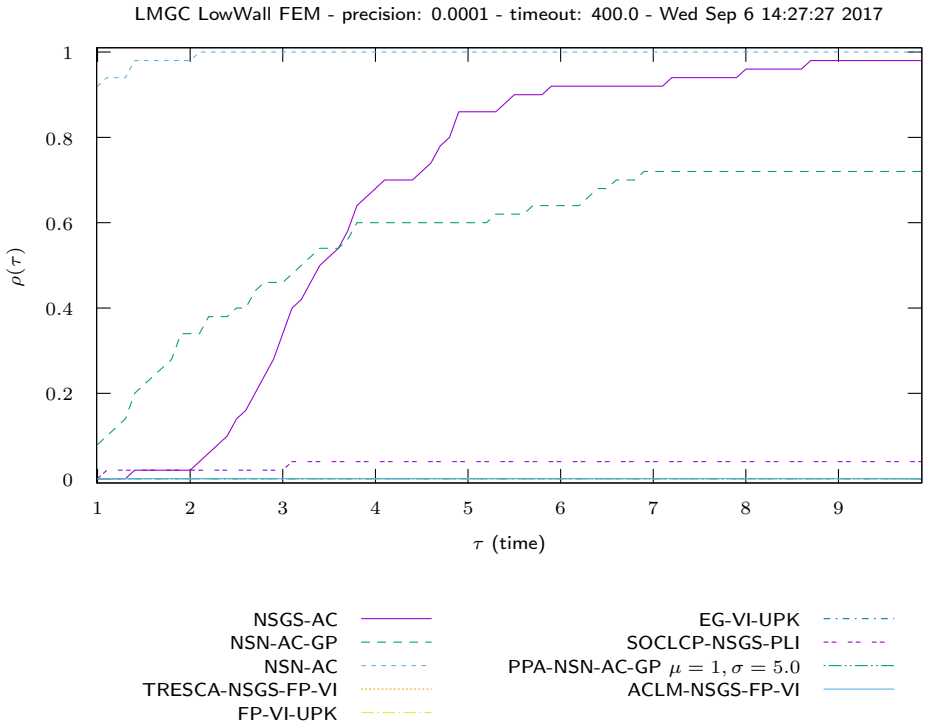


Figure 64: LMGC LowWall FEM time COMP/large

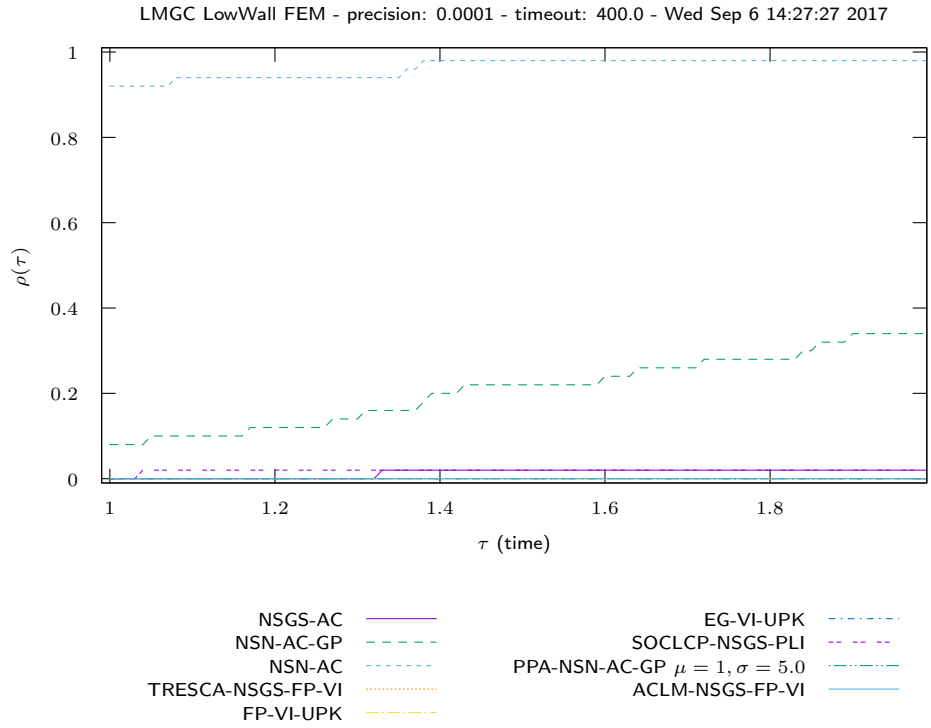


Figure 65: LMGC LowWall FEM time COMP/large

6 LMGC Cubes H8

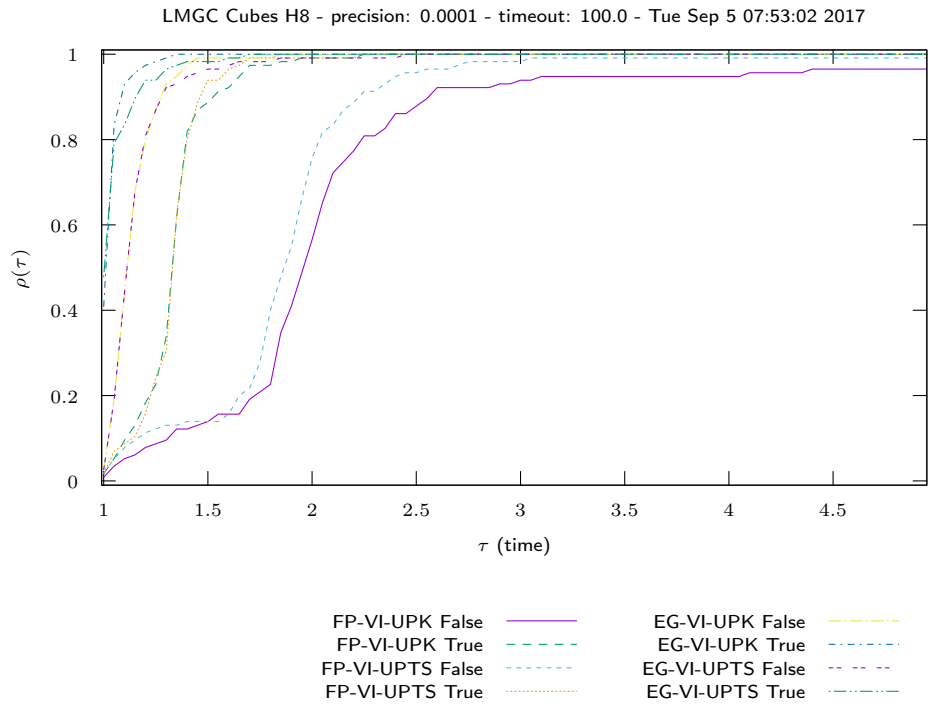


Figure 66: LMGC Cubes H8 time VI/UpdateRule

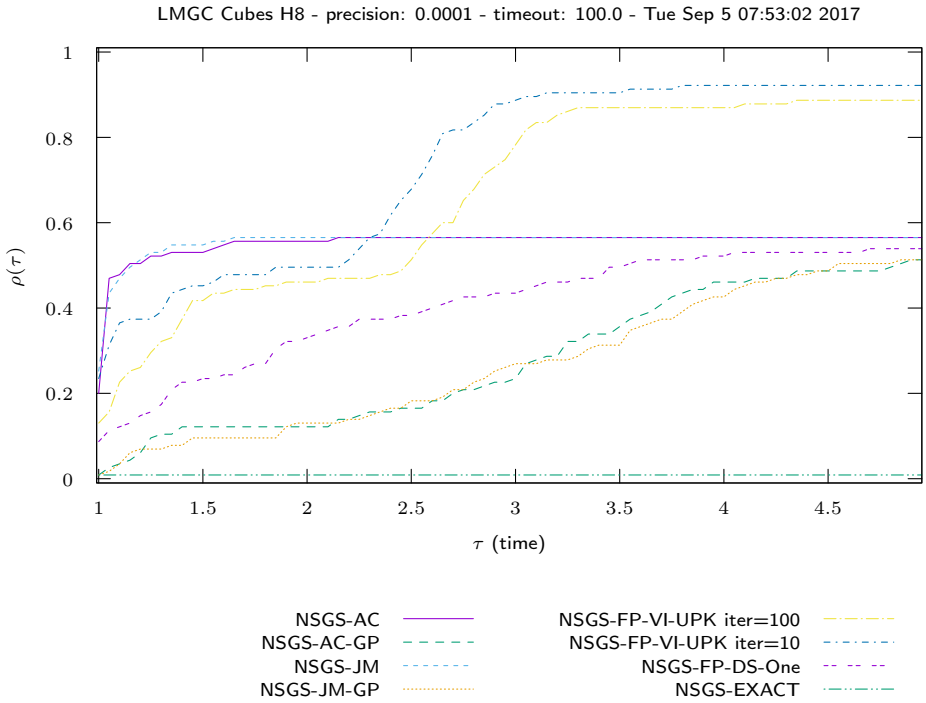


Figure 67: LMGC Cubes H8 time NSGS/LocalSolver

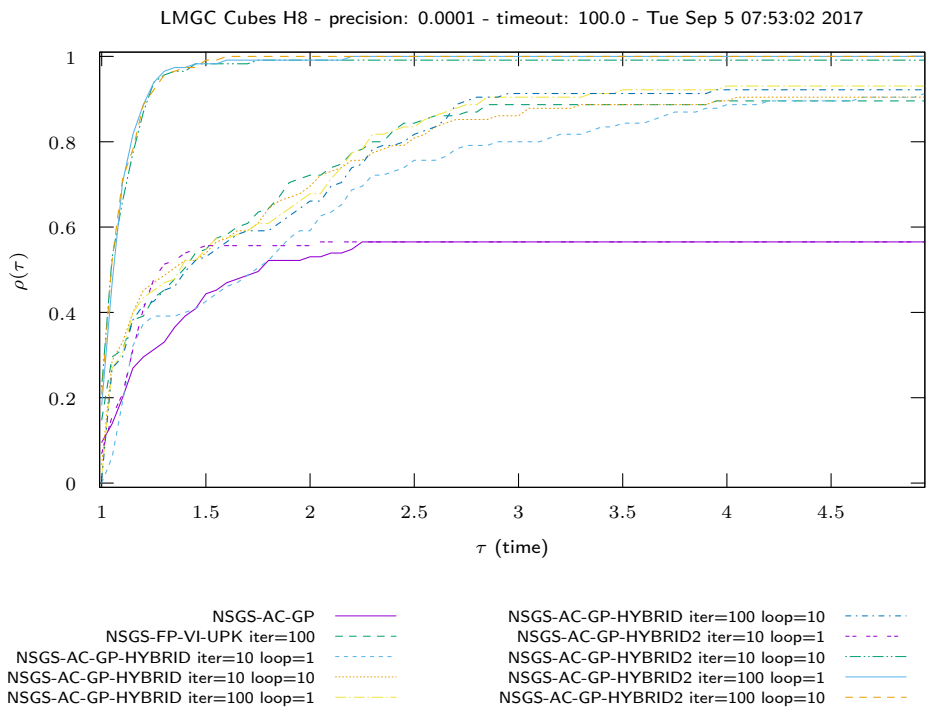


Figure 68: LMGC Cubes H8 time NSGS/LocalSolverHybrid

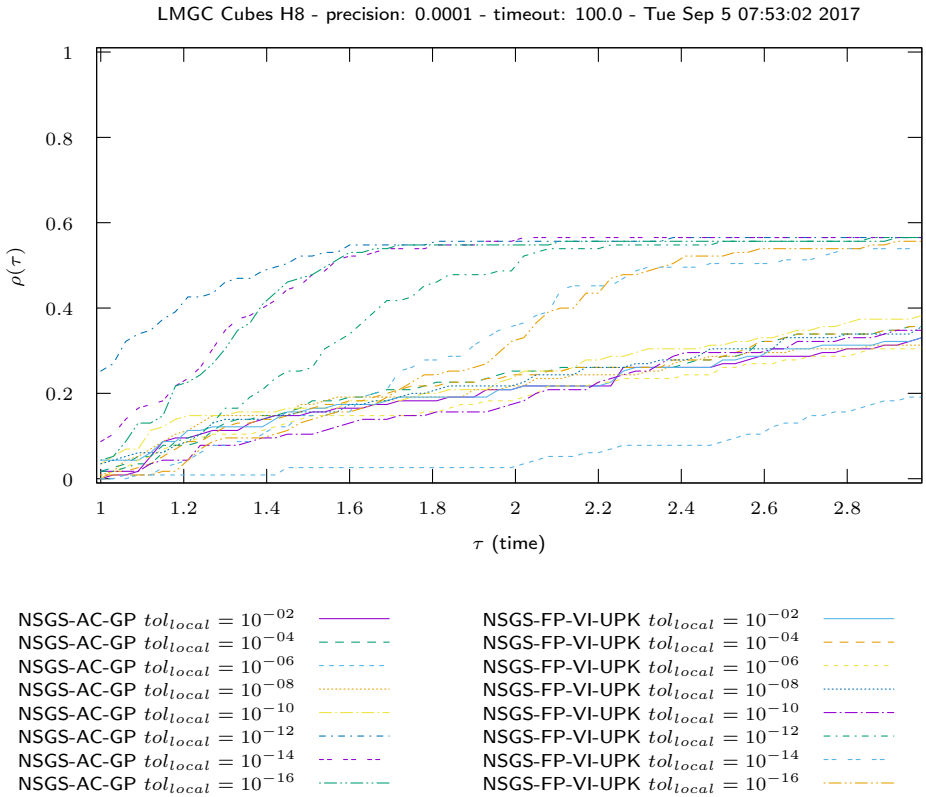
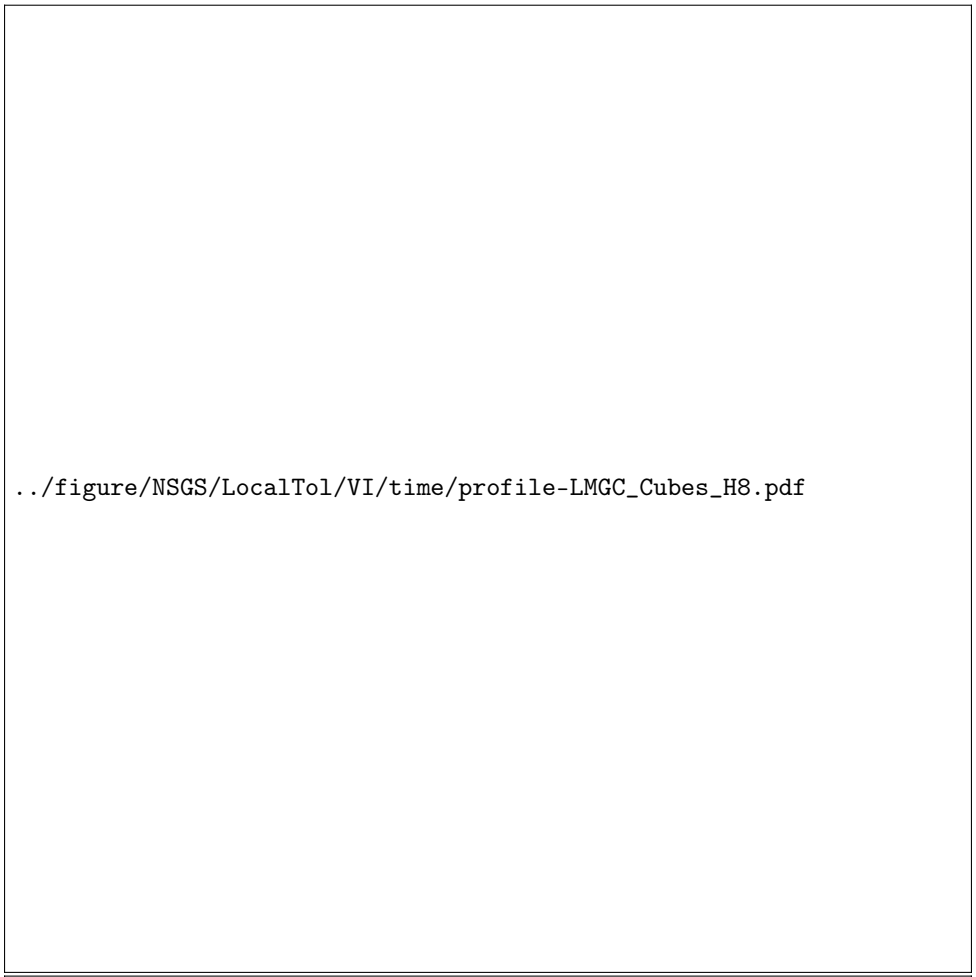
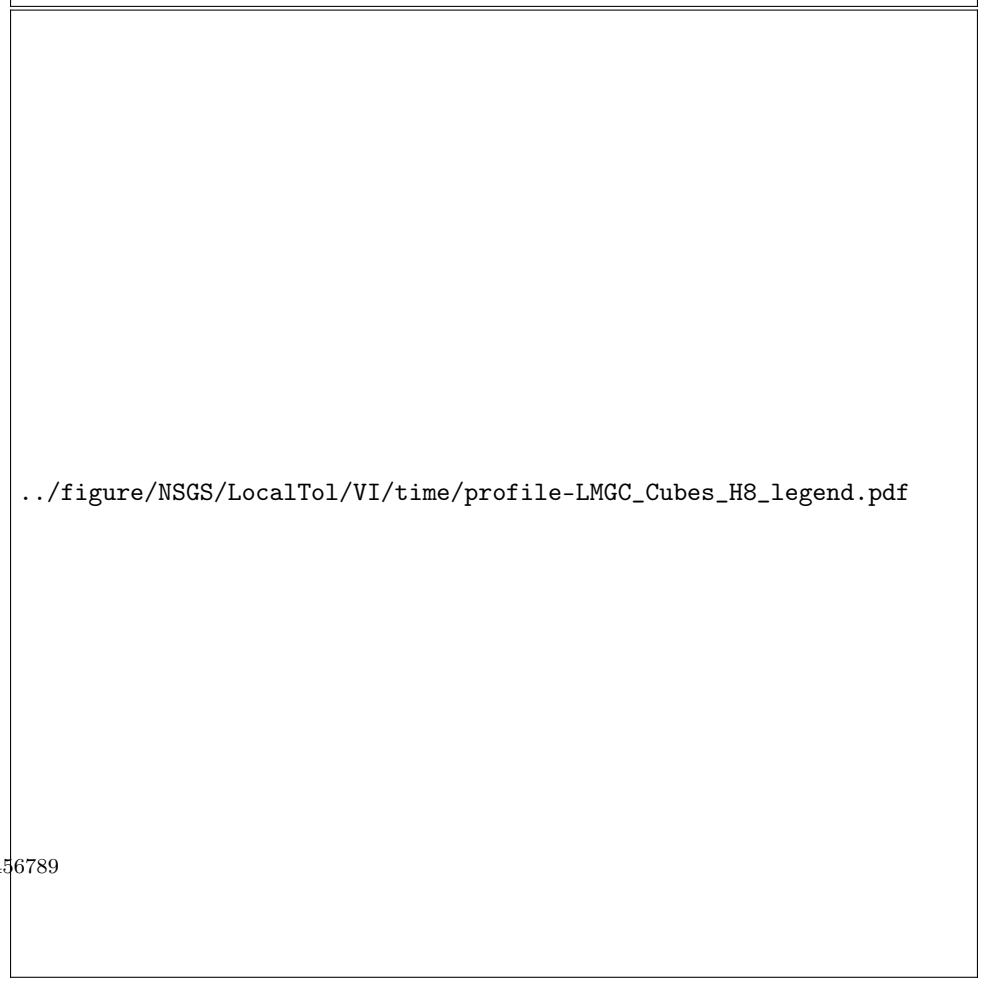


Figure 69: LMGC Cubes H8 time NSGS/LocalTol


../figure/NSGS/LocalTol/VI/time/profile-LMGC_Cubes_H8.pdf


../figure/NSGS/LocalTol/VI/time/profile-LMGC_Cubes_H8_legend.pdf

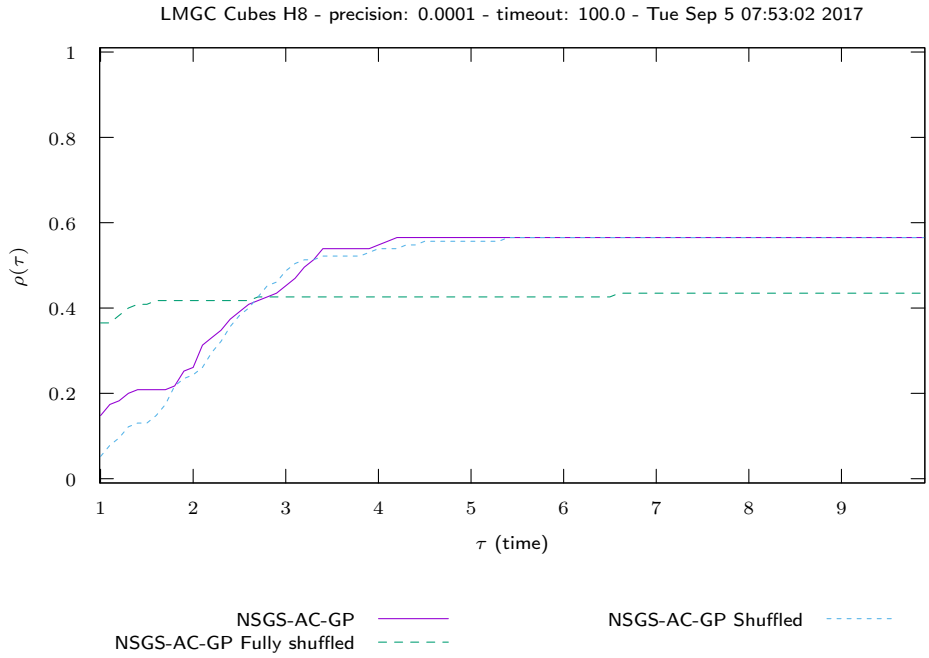


Figure 71: LMGC Cubes H8 time NSGS/Shuffled

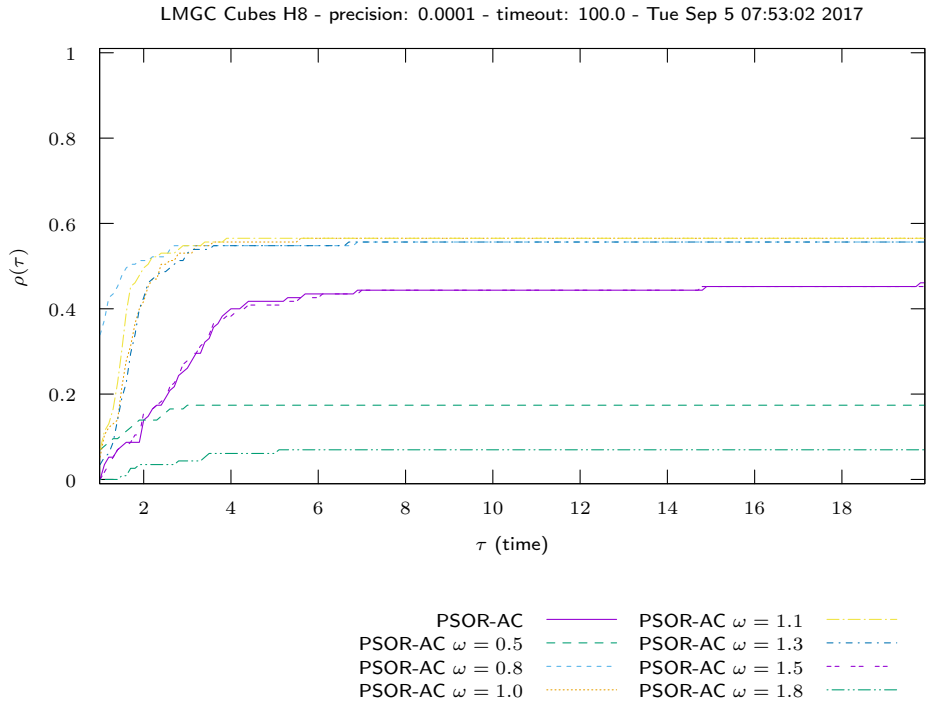


Figure 72: LMGC Cubes H8 time PSOR

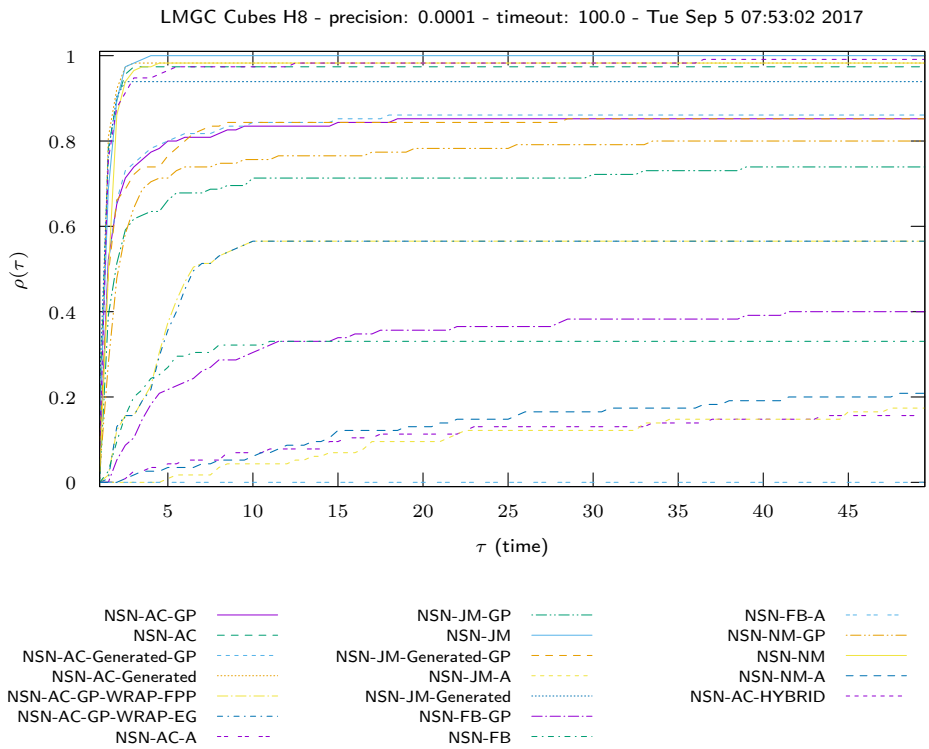


Figure 73: LMGC Cubes H8 time NSN

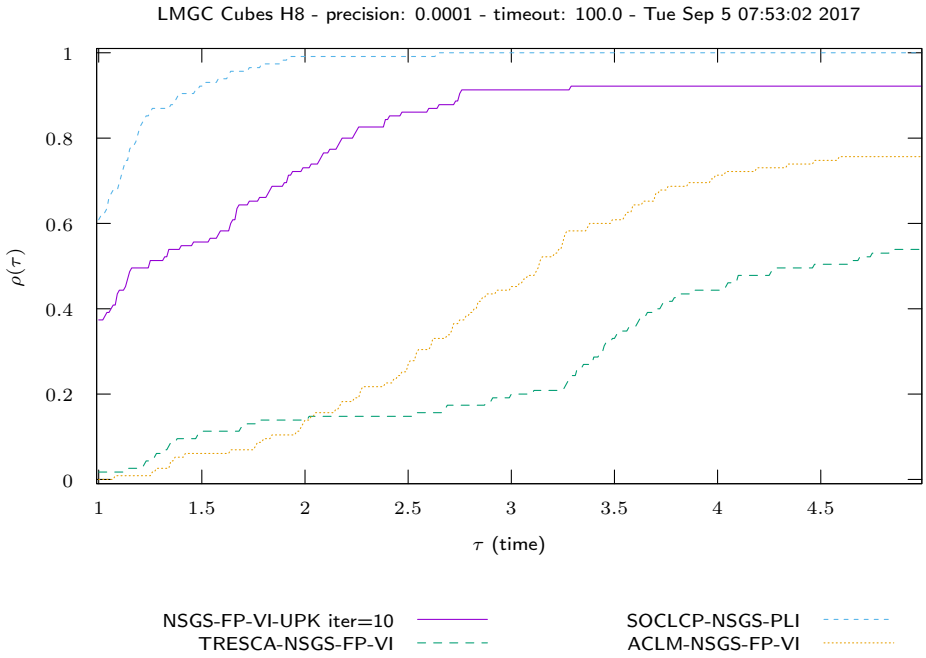


Figure 74: LMGC Cubes H8 time OPTI

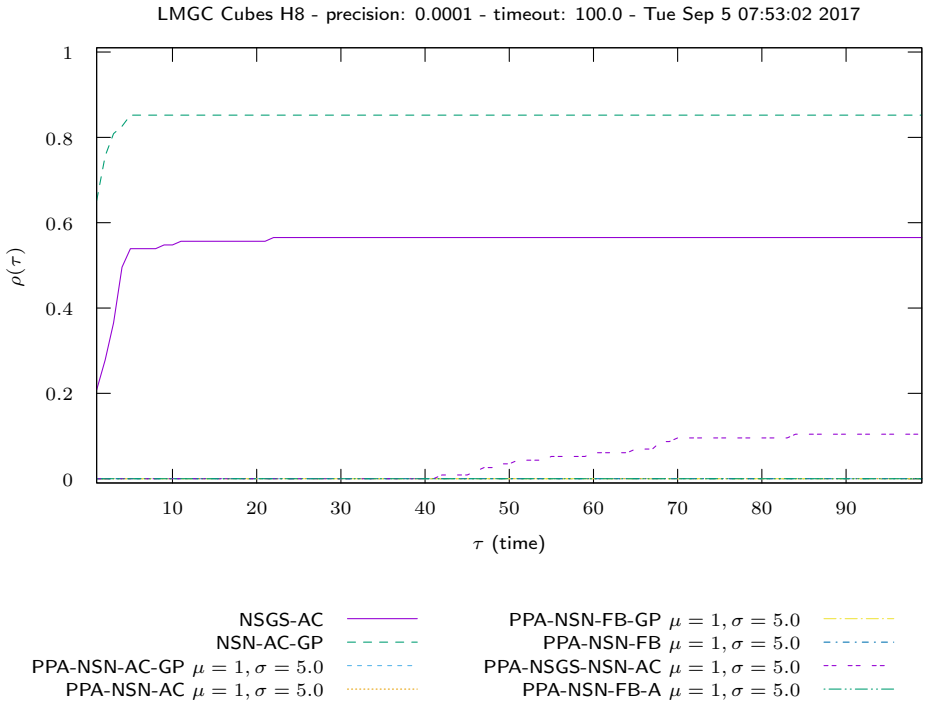
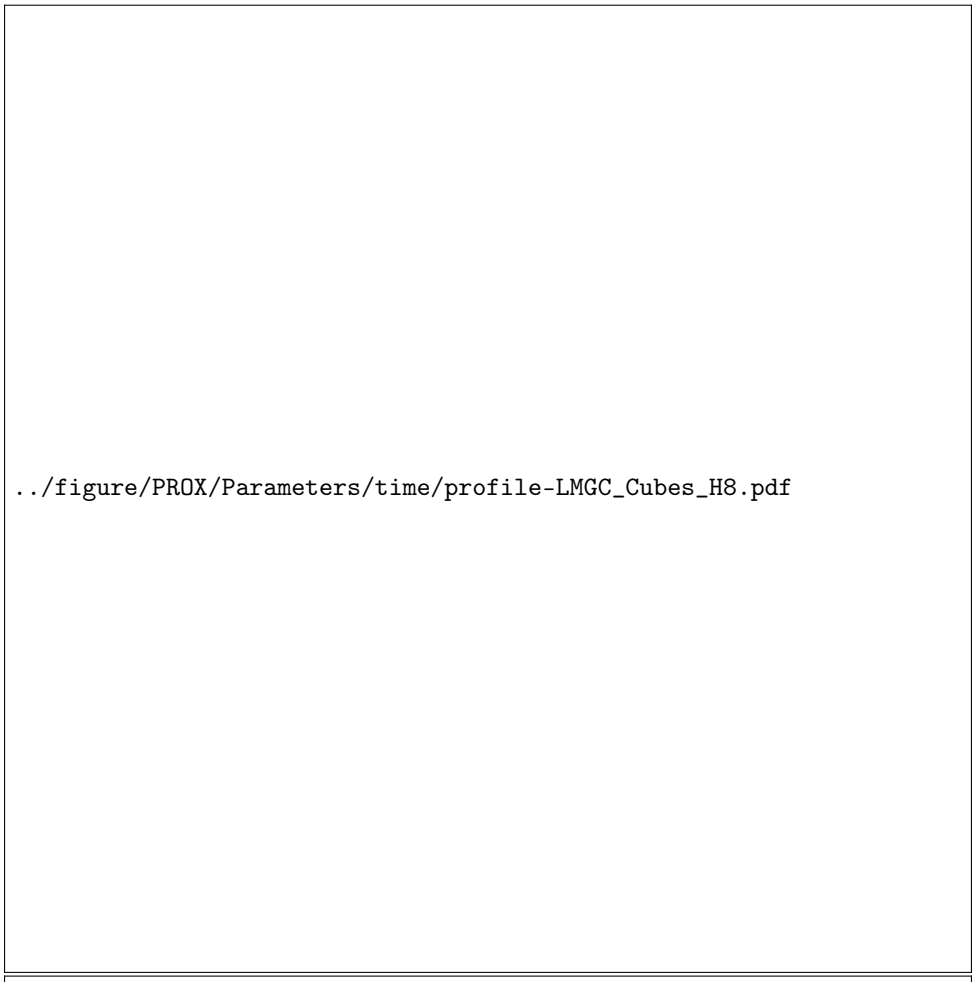
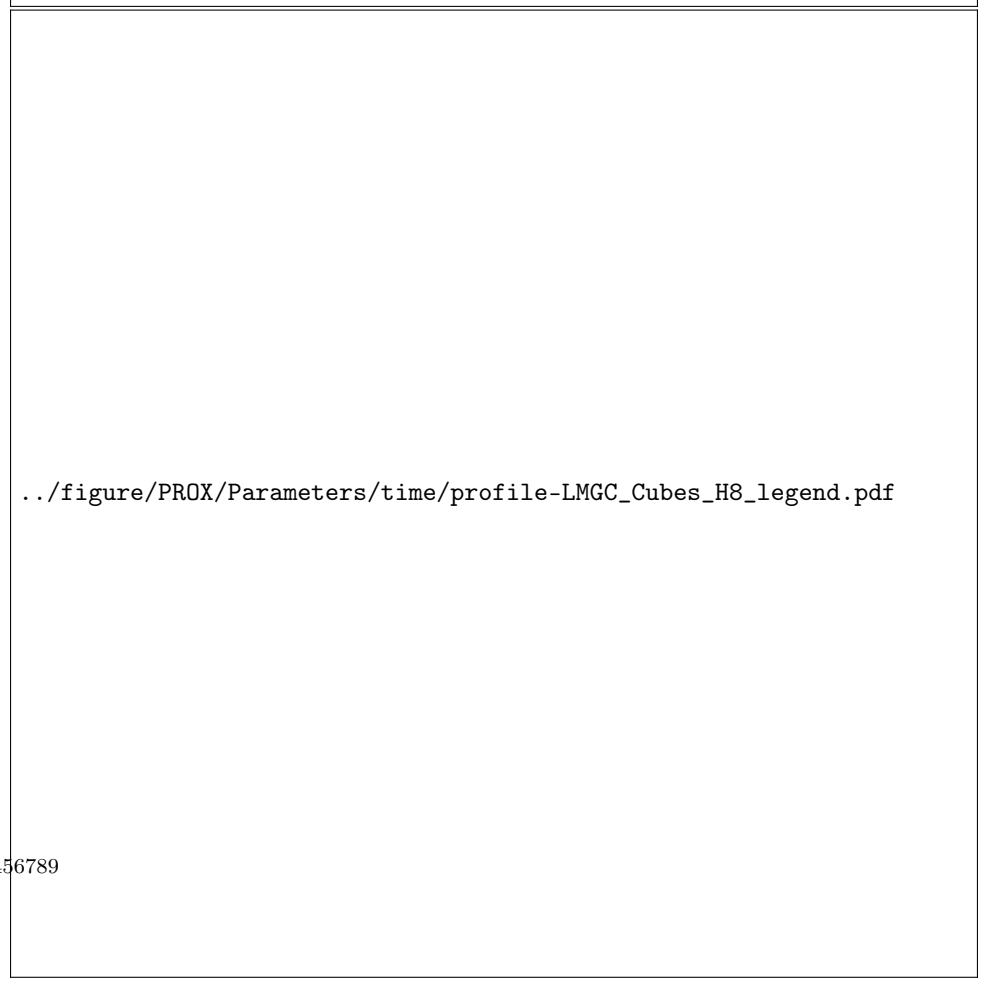


Figure 75: LMGC Cubes H8 time PROX/InternalSolvers


../figure/PROX/Parameters/time/profile-LMGC_Cubes_H8.pdf


../figure/PROX/Parameters/time/profile-LMGC_Cubes_H8_legend.pdf

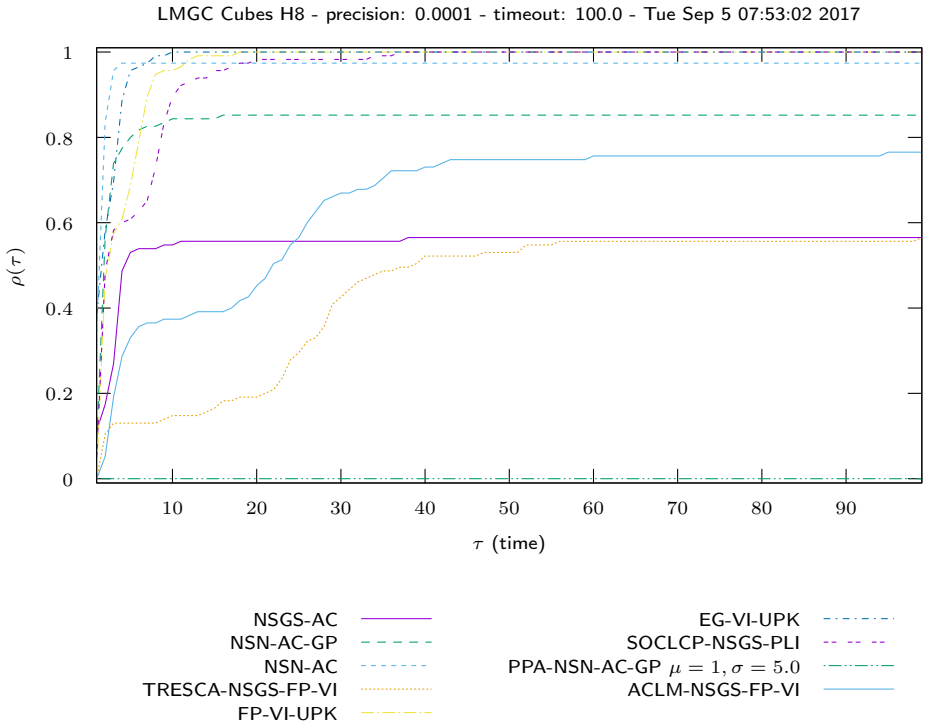


Figure 77: LMGC Cubes H8 time COMP/large

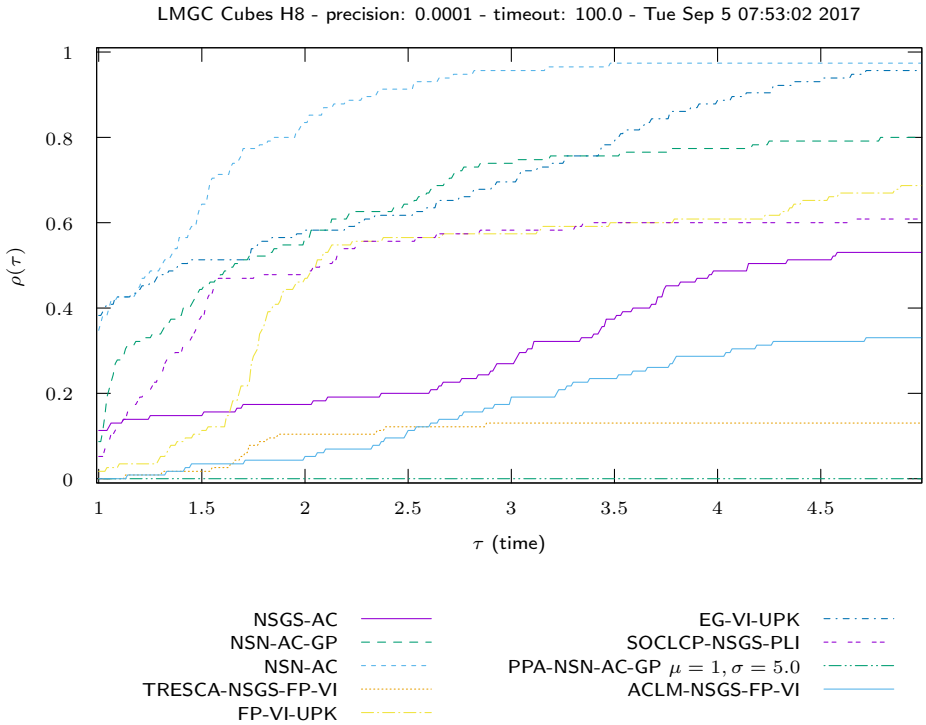


Figure 78: LMGC Cubes H8 time COMP/large

7 Capsules

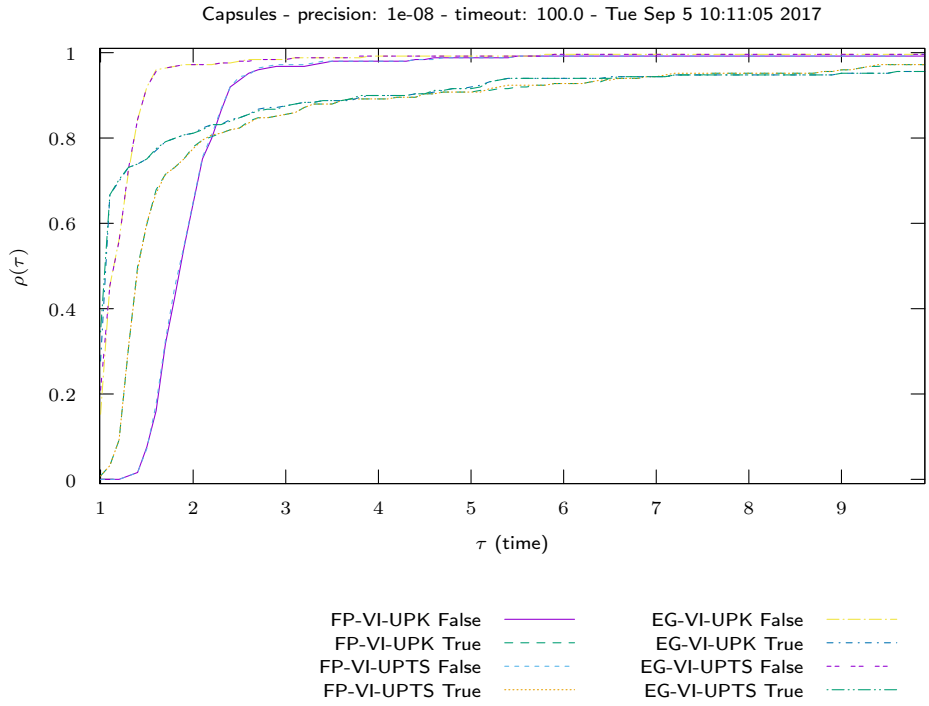


Figure 79: Capsules time VI/UpdateRule

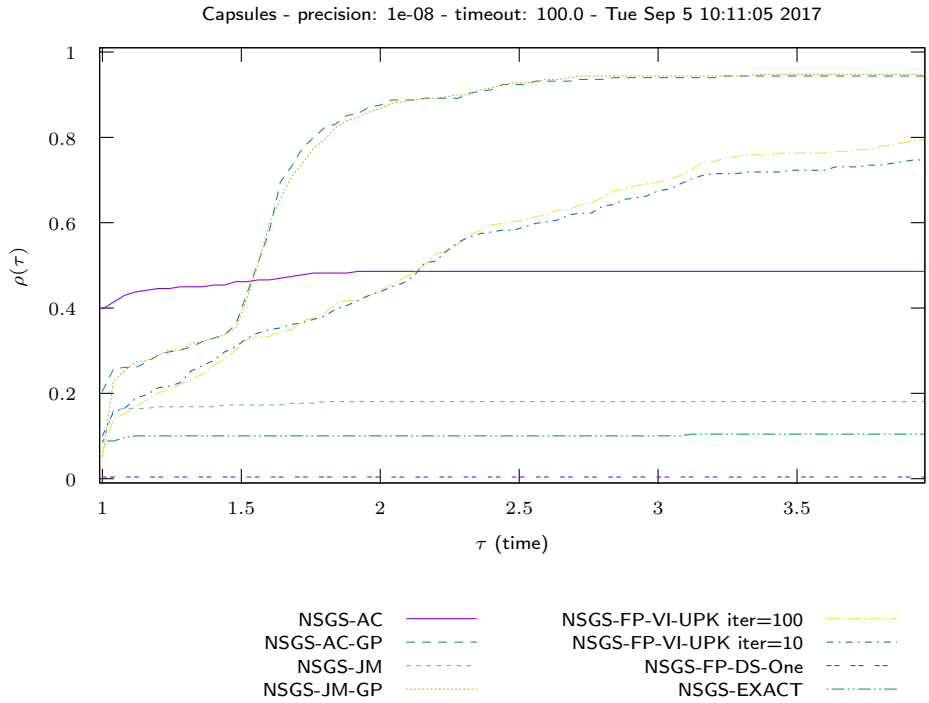


Figure 80: Capsules time NSGS/LocalSolver

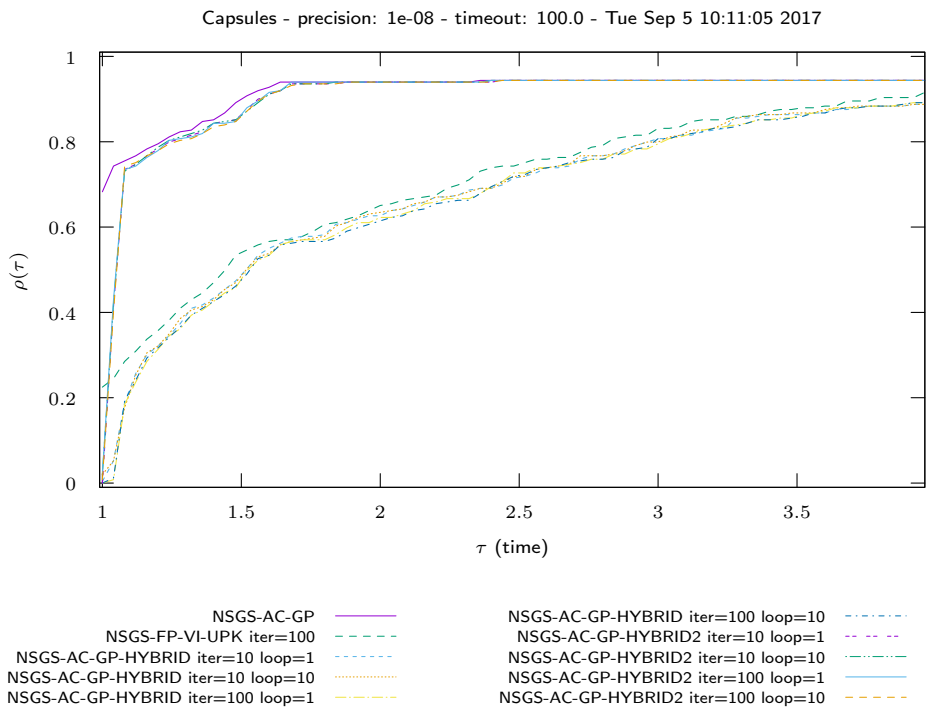


Figure 81: Capsules time NSGS/LocalSolverHybrid

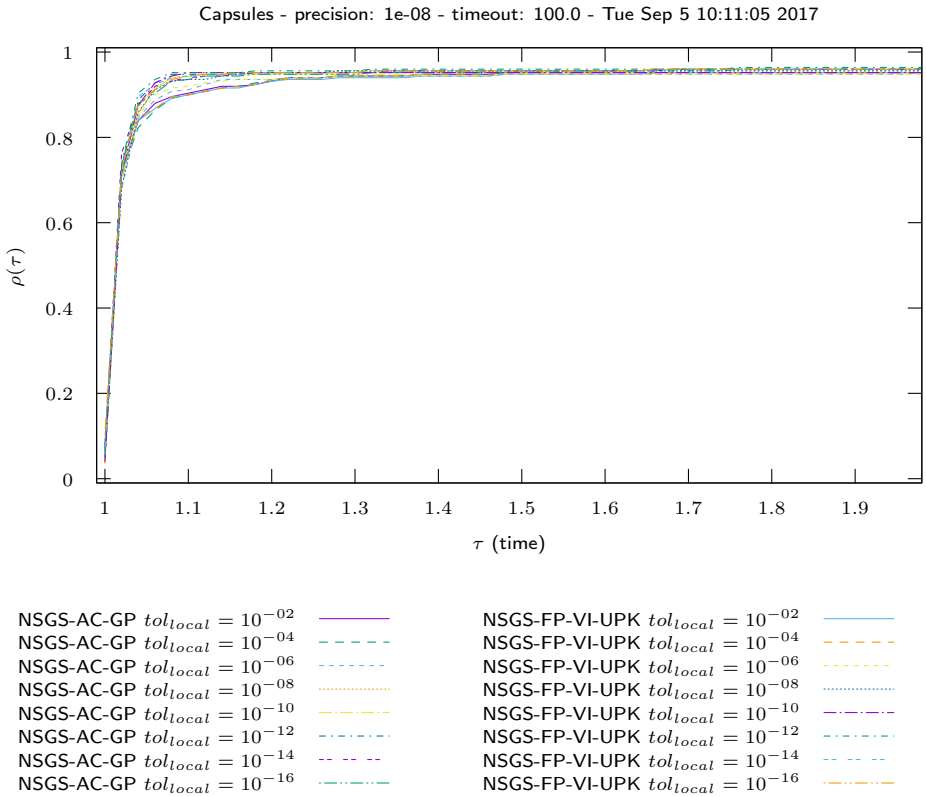
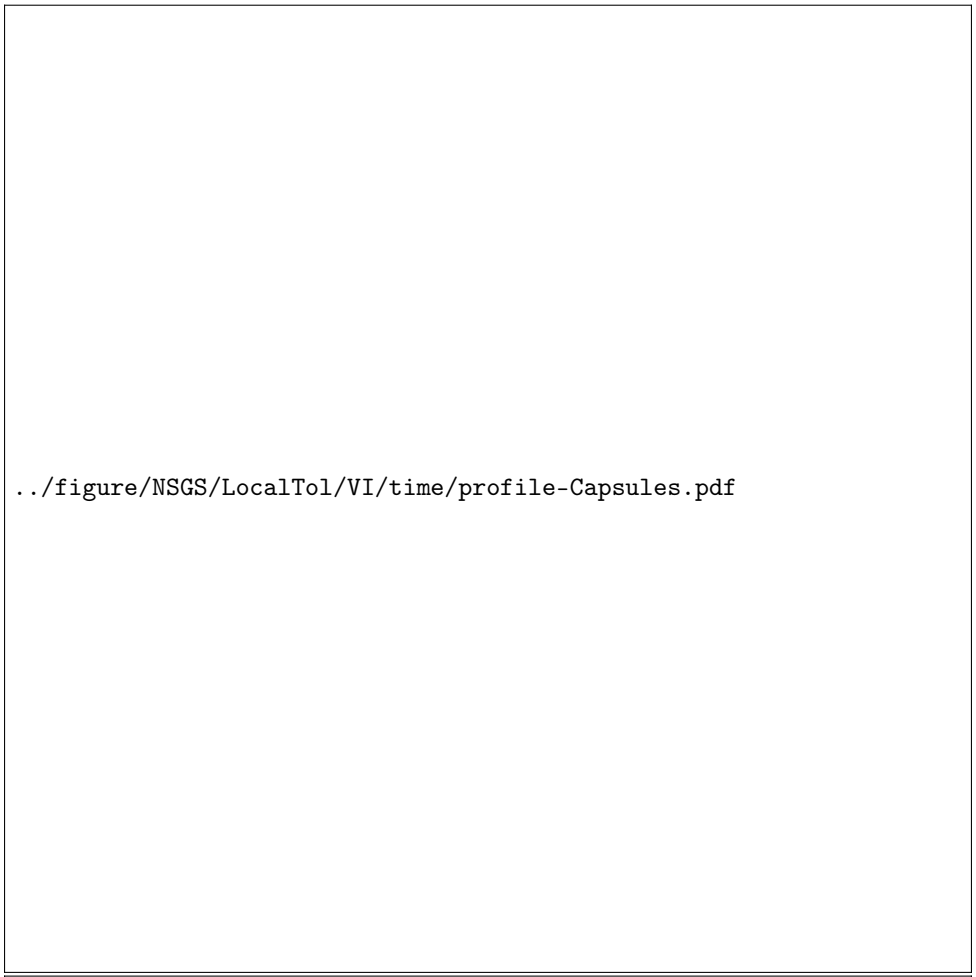
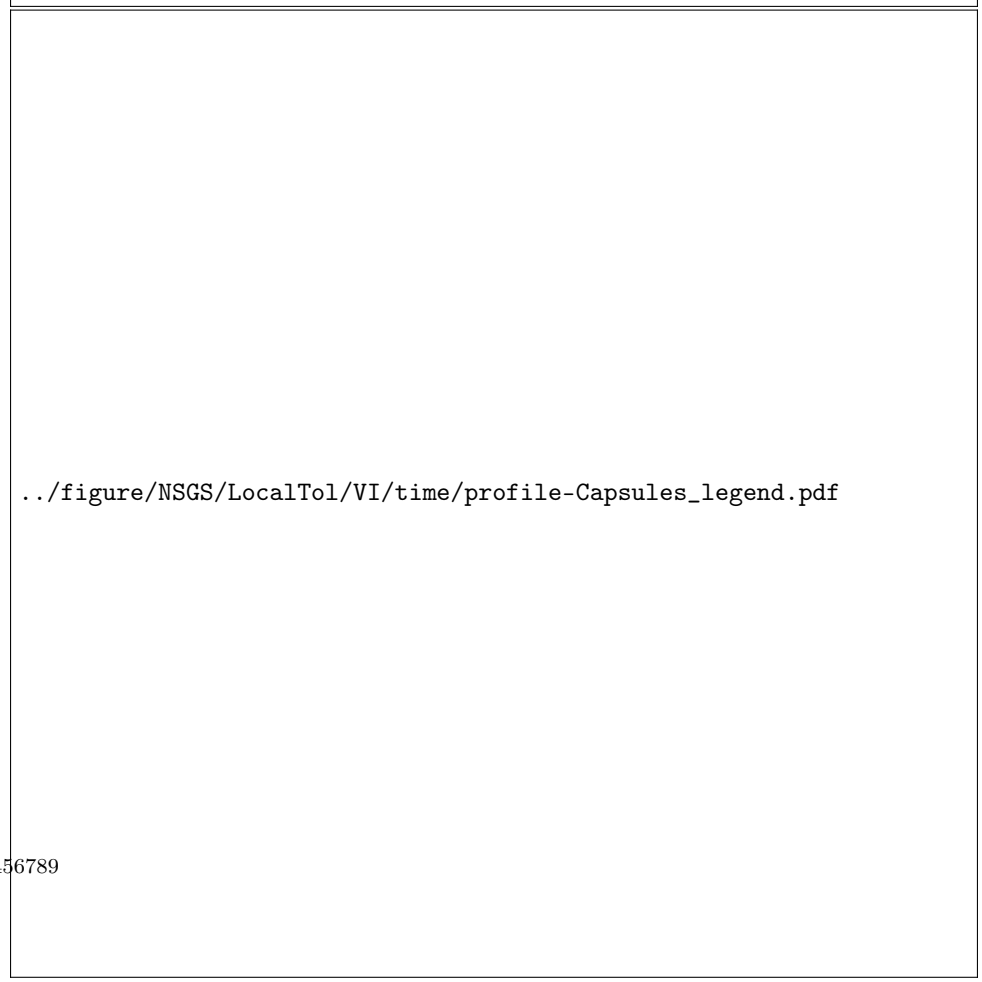


Figure 82: Capsules time NSGS/LocalTol


../figure/NSGS/LocalTol/VI/time/profile-Capsules.pdf


../figure/NSGS/LocalTol/VI/time/profile-Capsules_legend.pdf

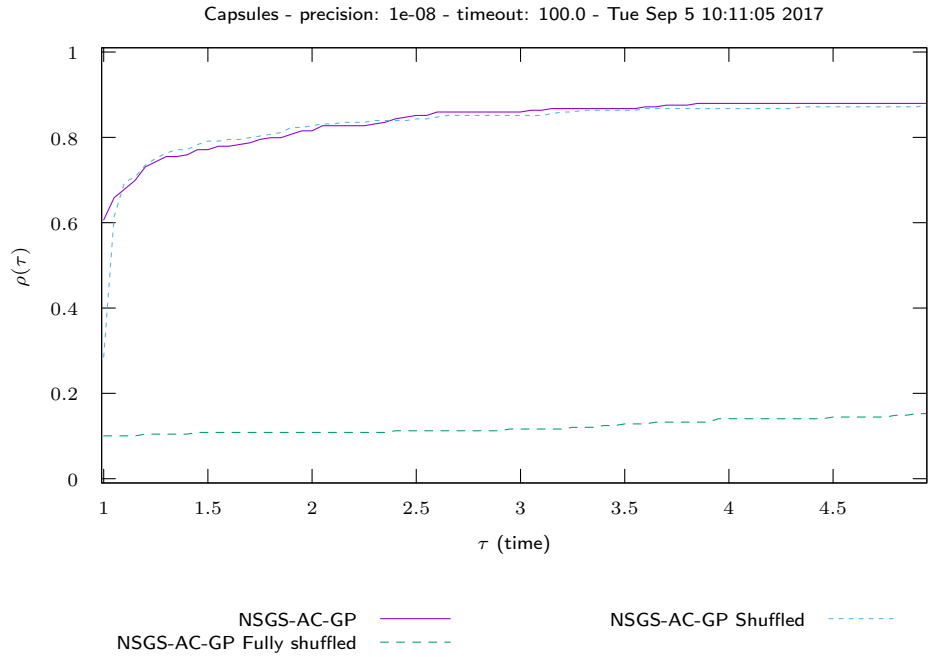


Figure 84: Capsules time NSGS/Shuffled

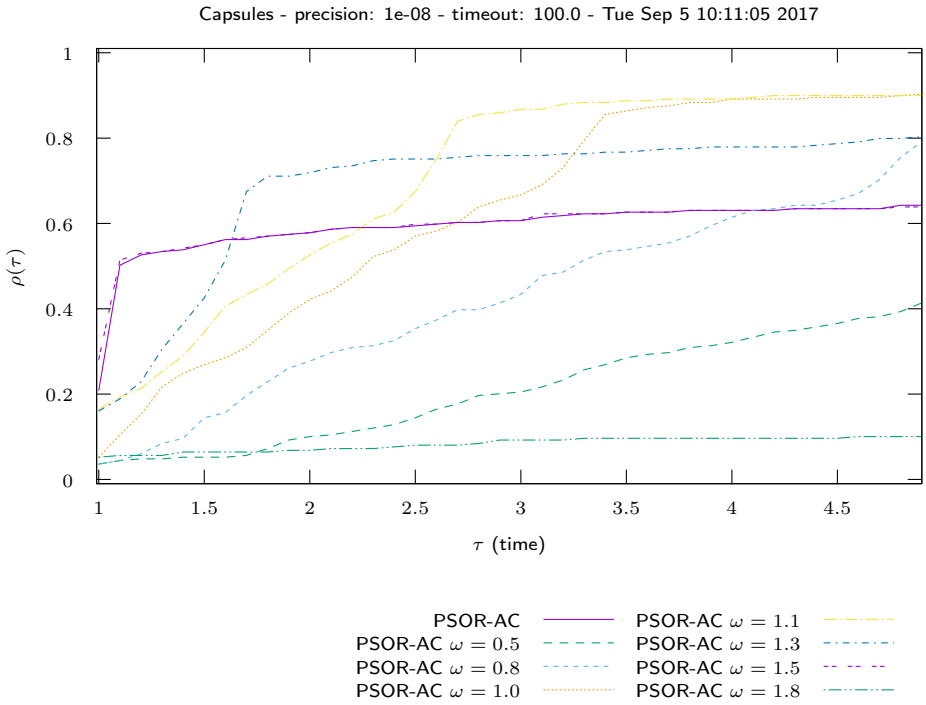


Figure 85: Capsules time PSOR

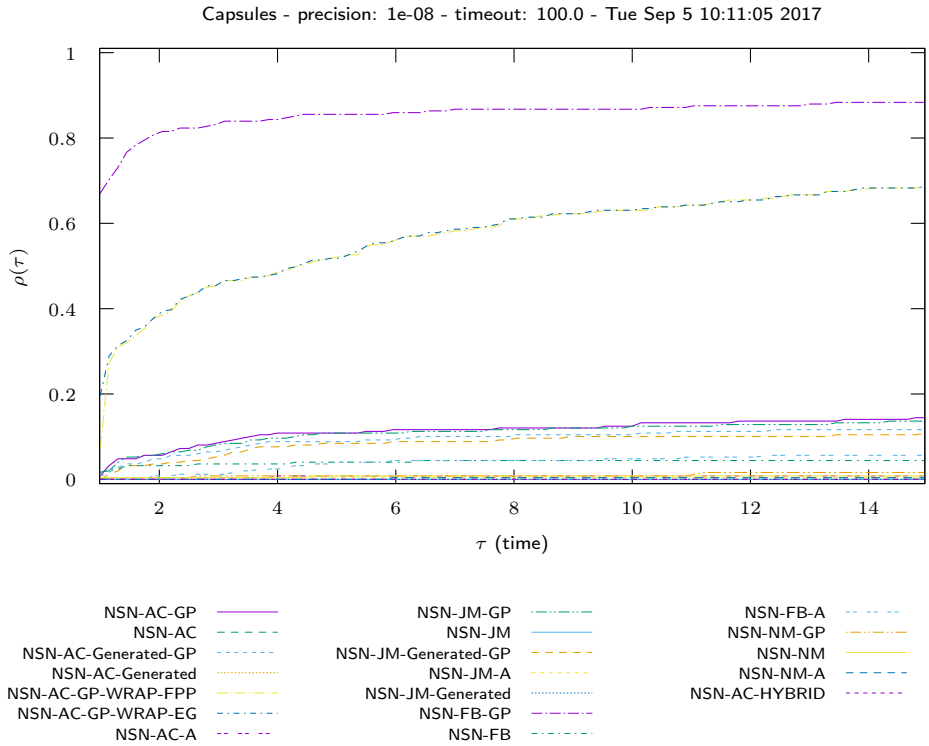


Figure 86: Capsules time NSN

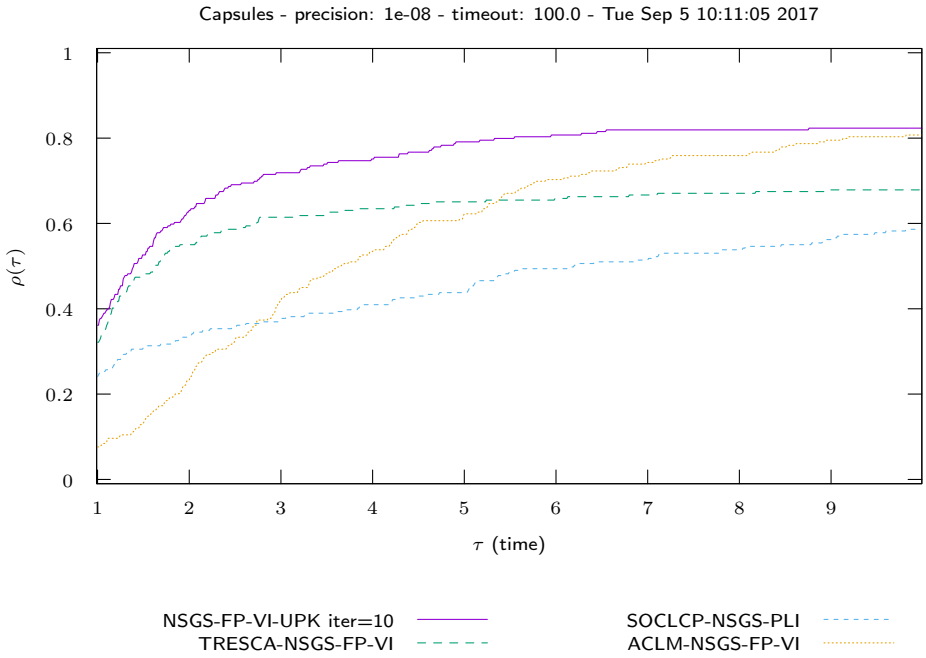


Figure 87: Capsules time OPTI

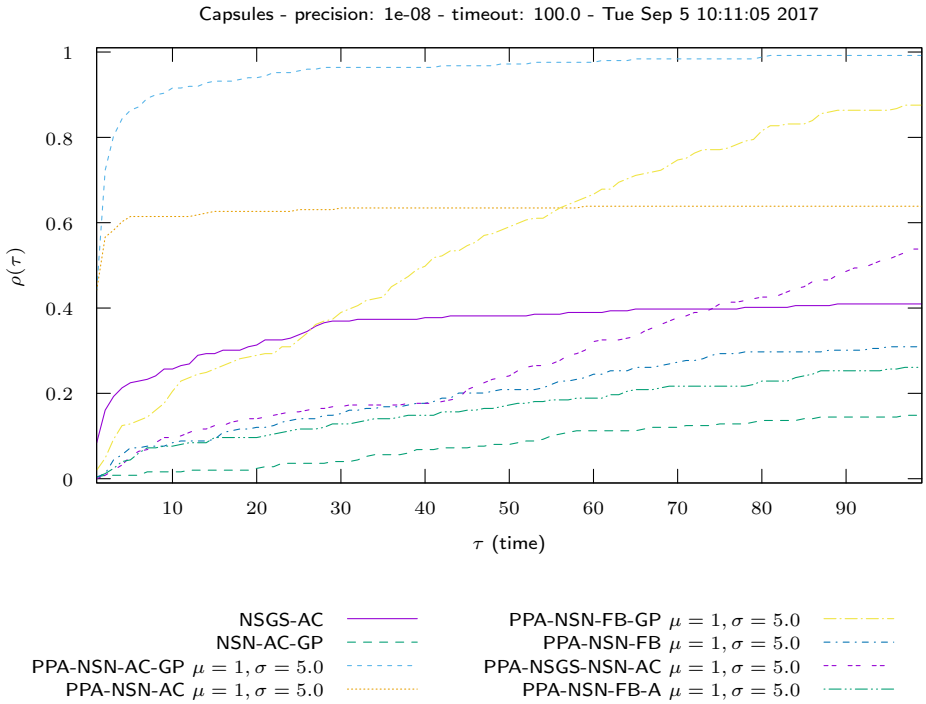
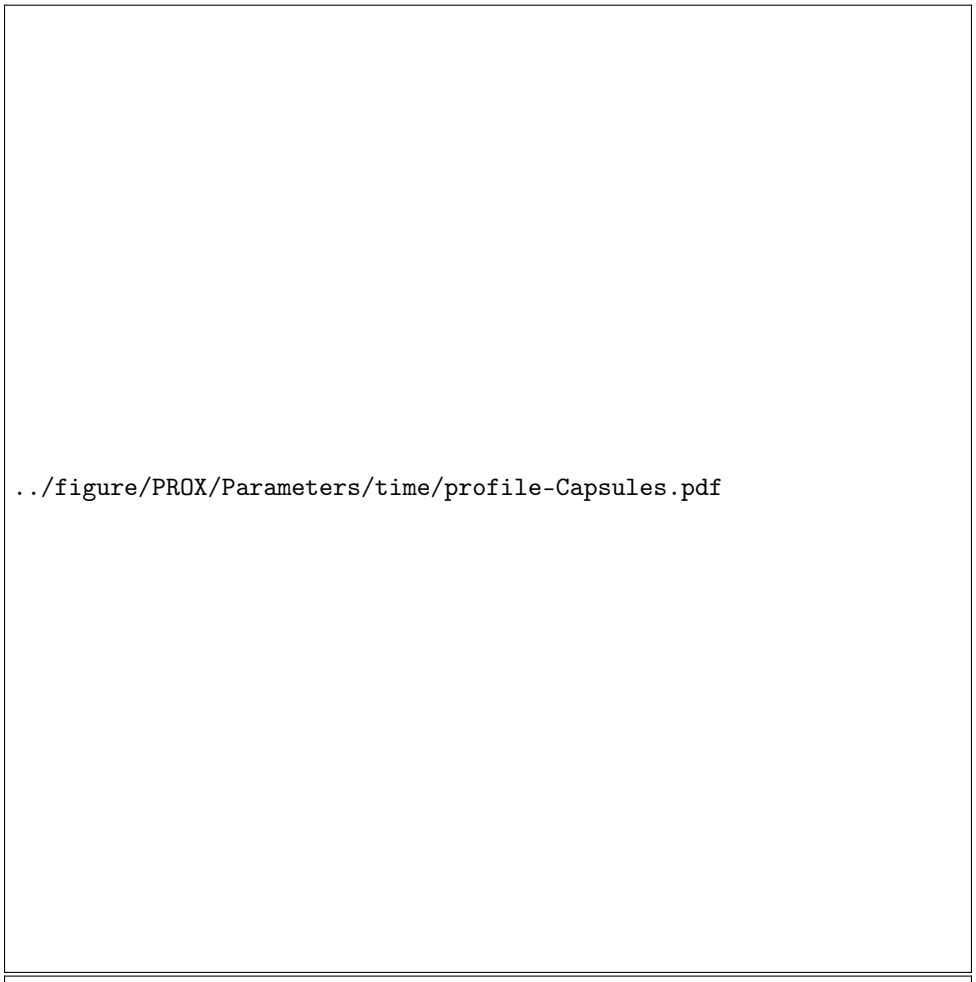
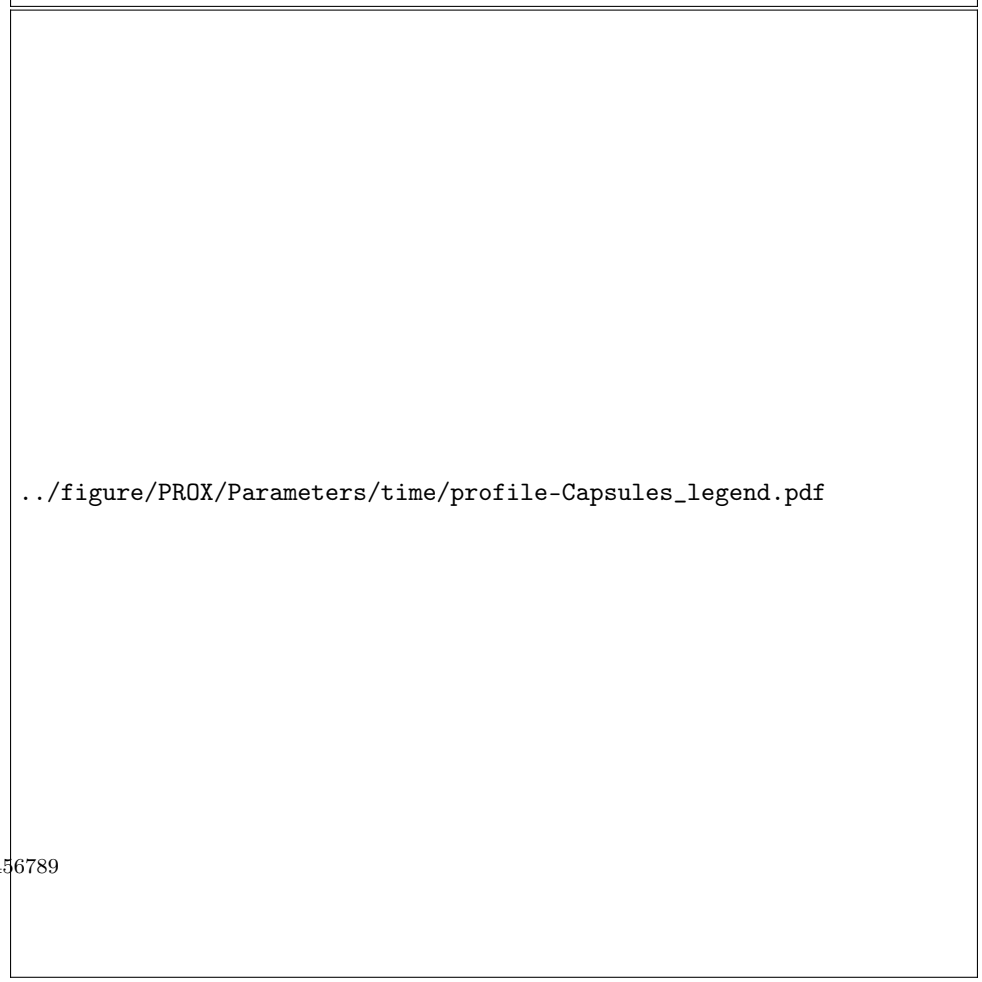


Figure 88: Capsules time PROX/InternalSolvers


../figure/PROX/Parameters/time/profile-Capsules.pdf


../figure/PROX/Parameters/time/profile-Capsules_legend.pdf

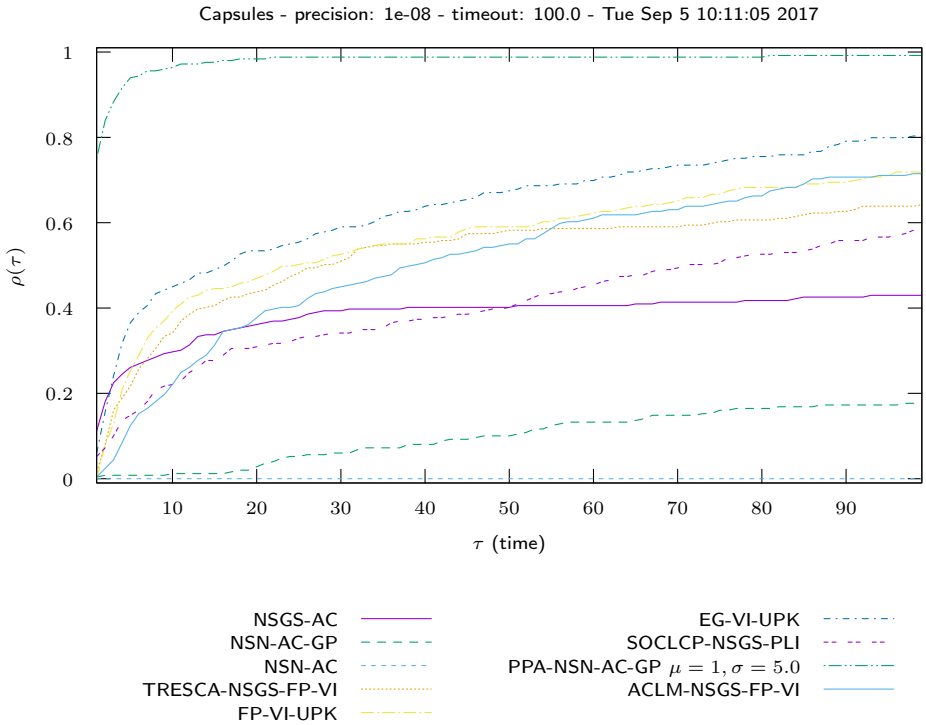


Figure 90: Capsules time COMP/large

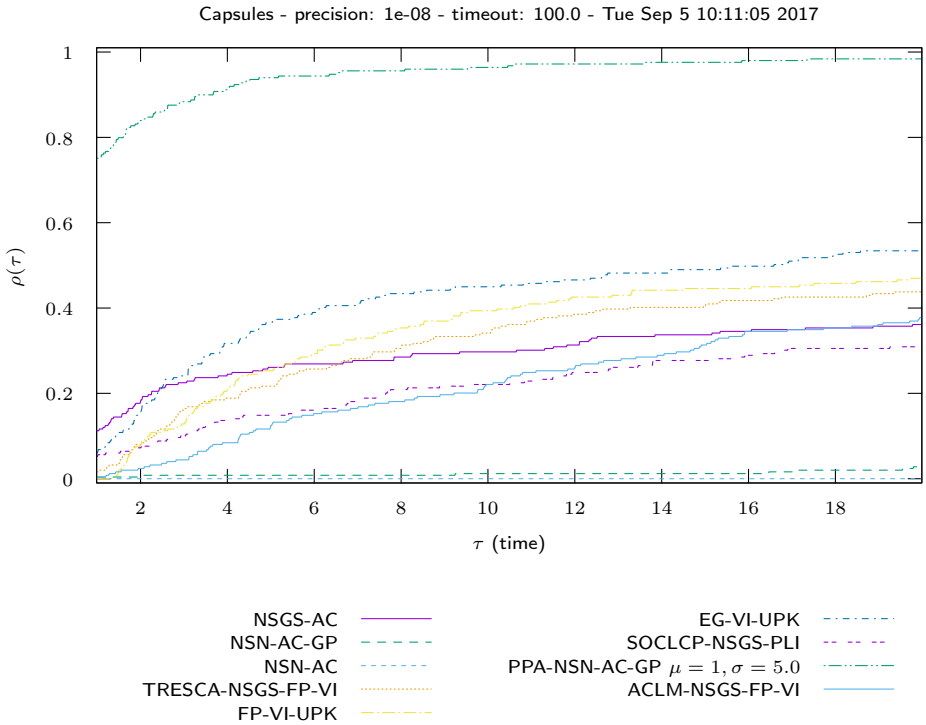


Figure 91: Capsules time COMP/large

8 Chain

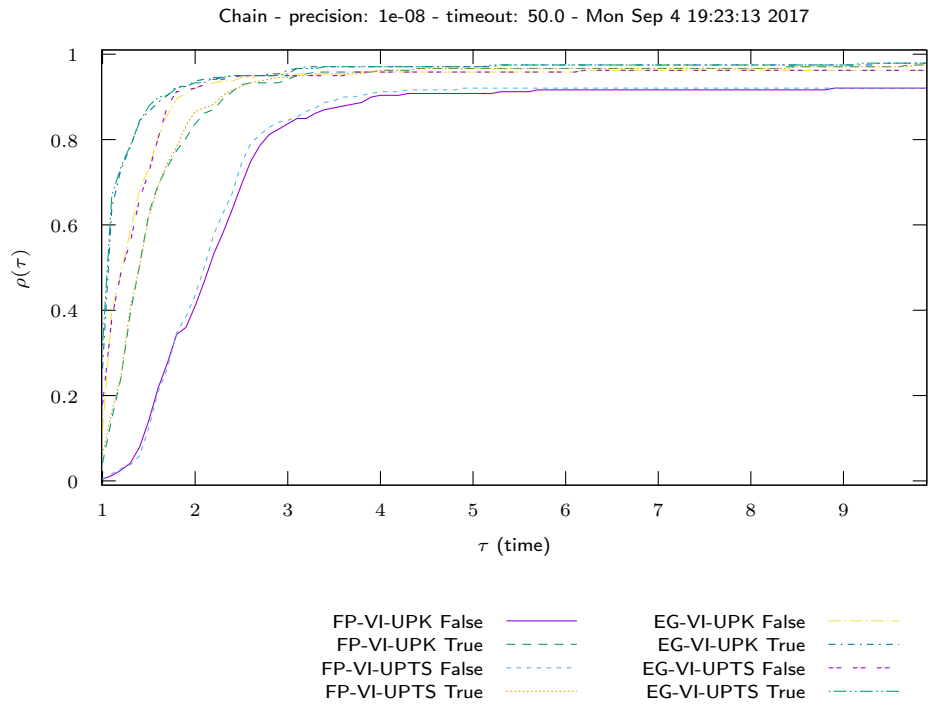


Figure 92: Chain time VI/UpdateRule

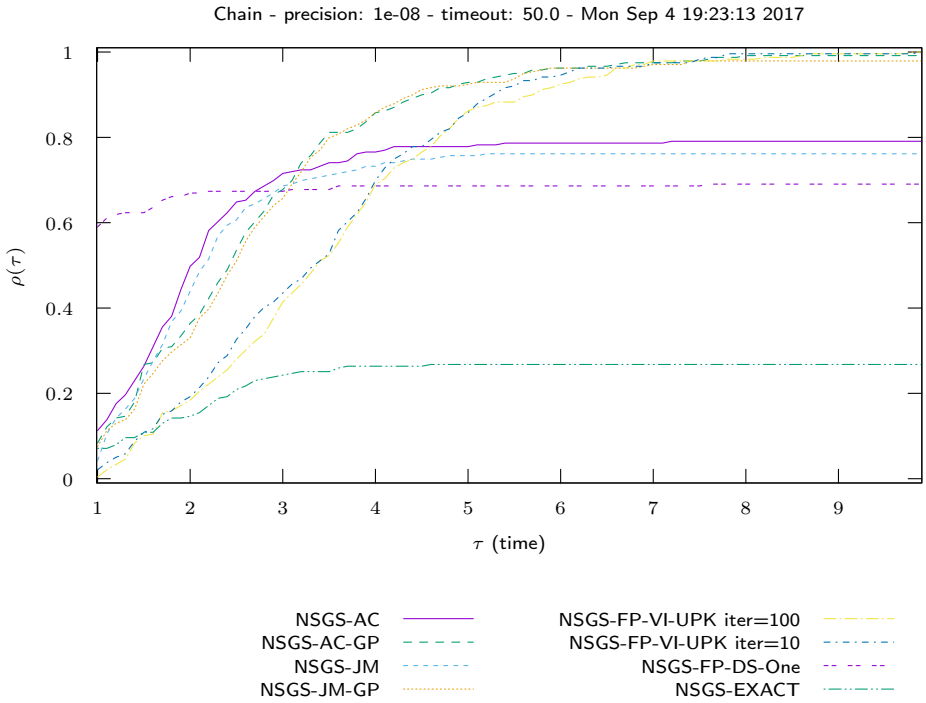


Figure 93: Chain time NSGS/LocalSolver

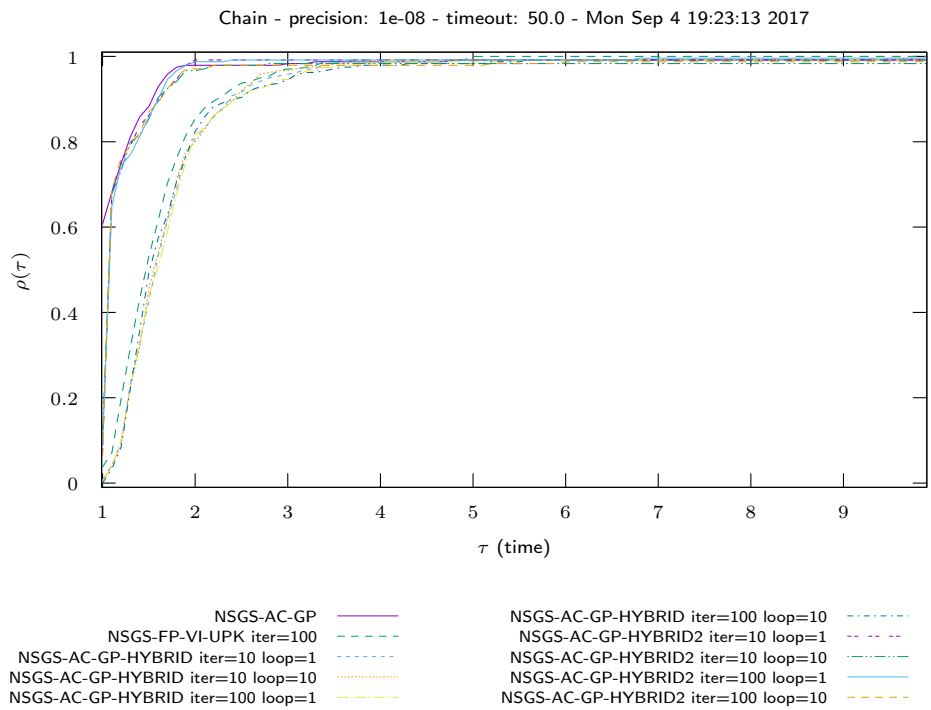


Figure 94: Chain time NSGS/LocalSolverHybrid

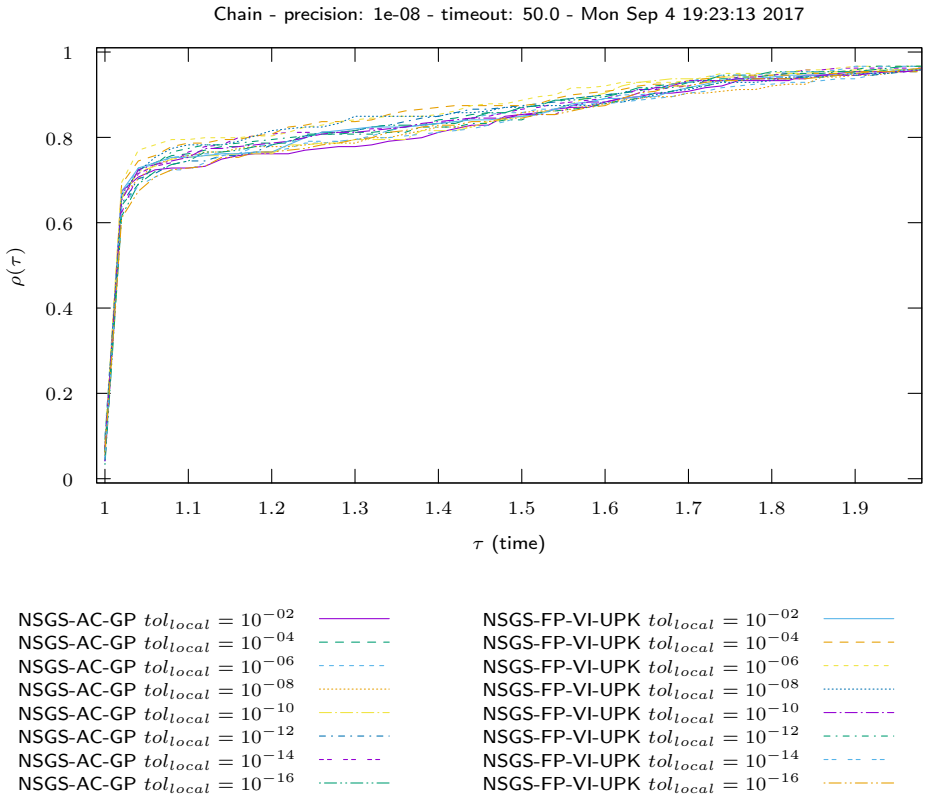
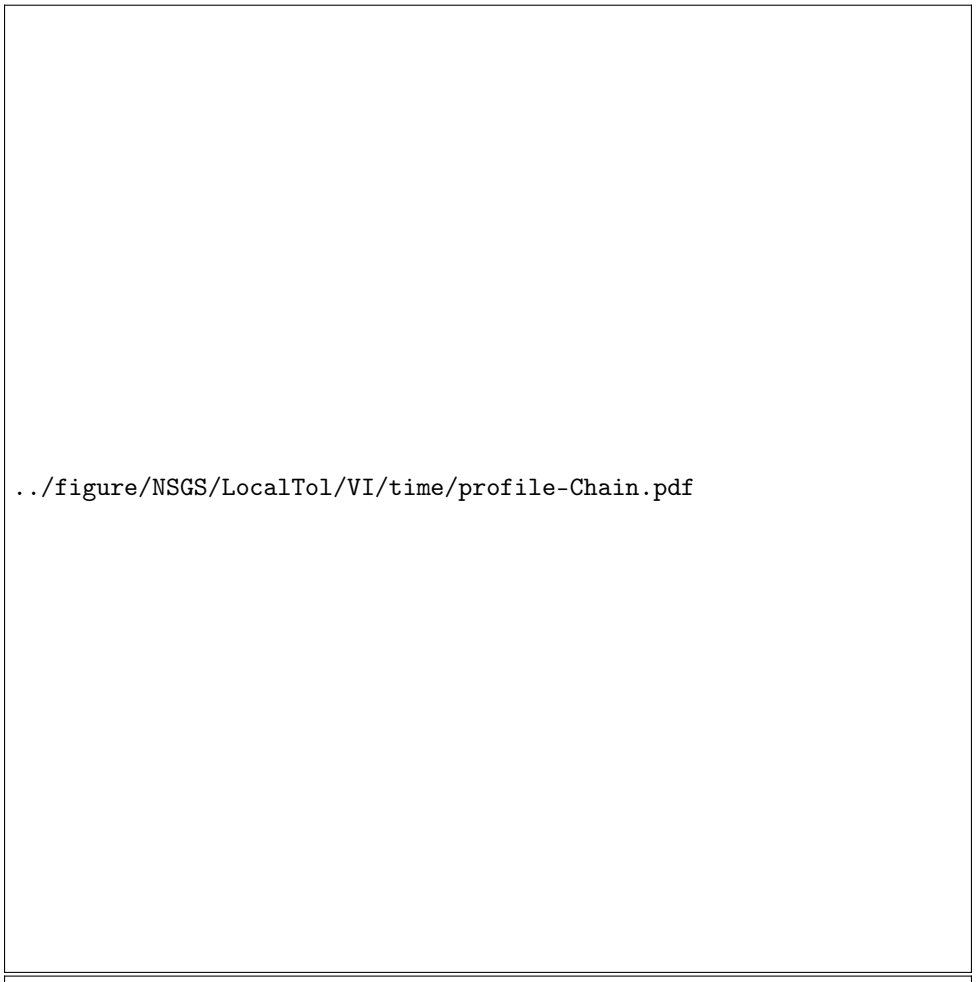
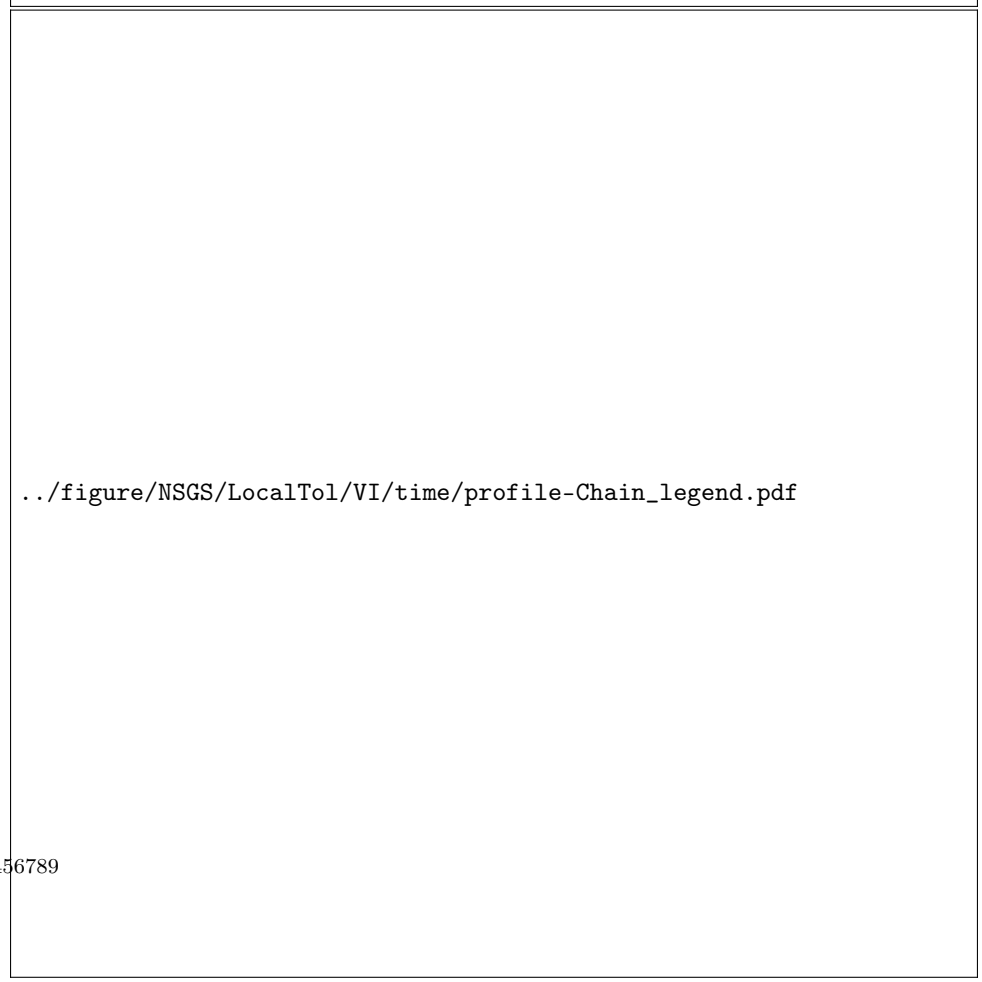


Figure 95: Chain time NSGS/LocalTol


../figure/NSGS/LocalTol/VI/time/profile-Chain.pdf


../figure/NSGS/LocalTol/VI/time/profile-Chain_legend.pdf

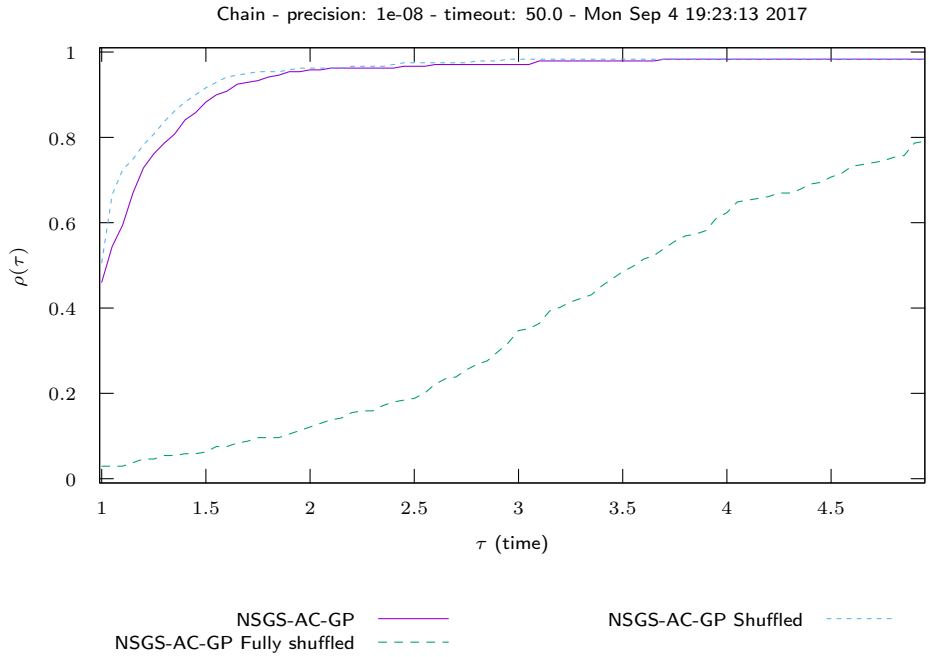


Figure 97: Chain time NSGS/Shuffled

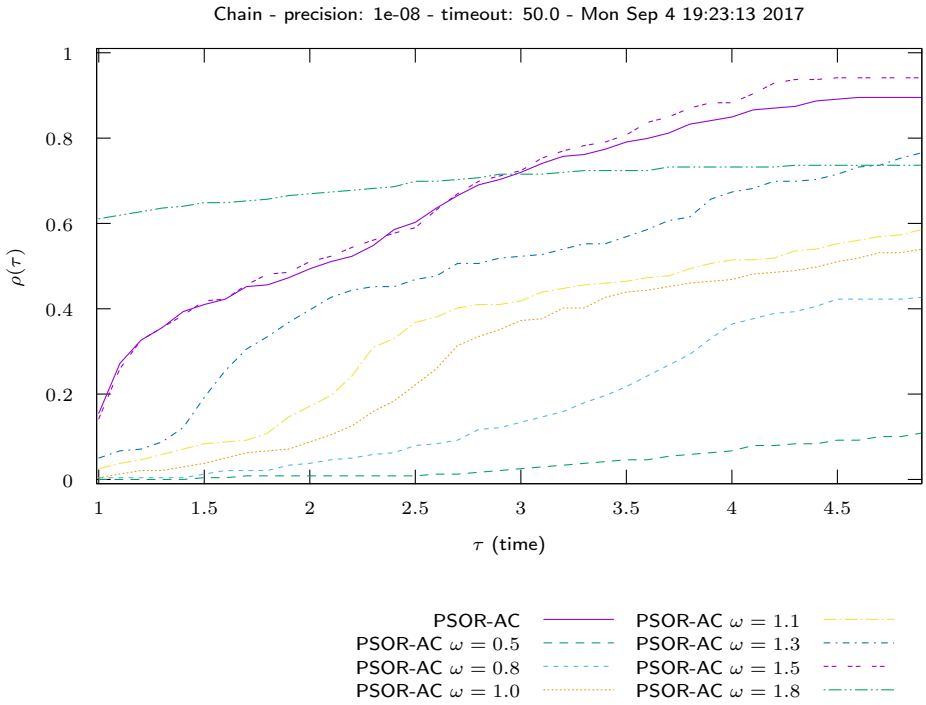


Figure 98: Chain time PSOR

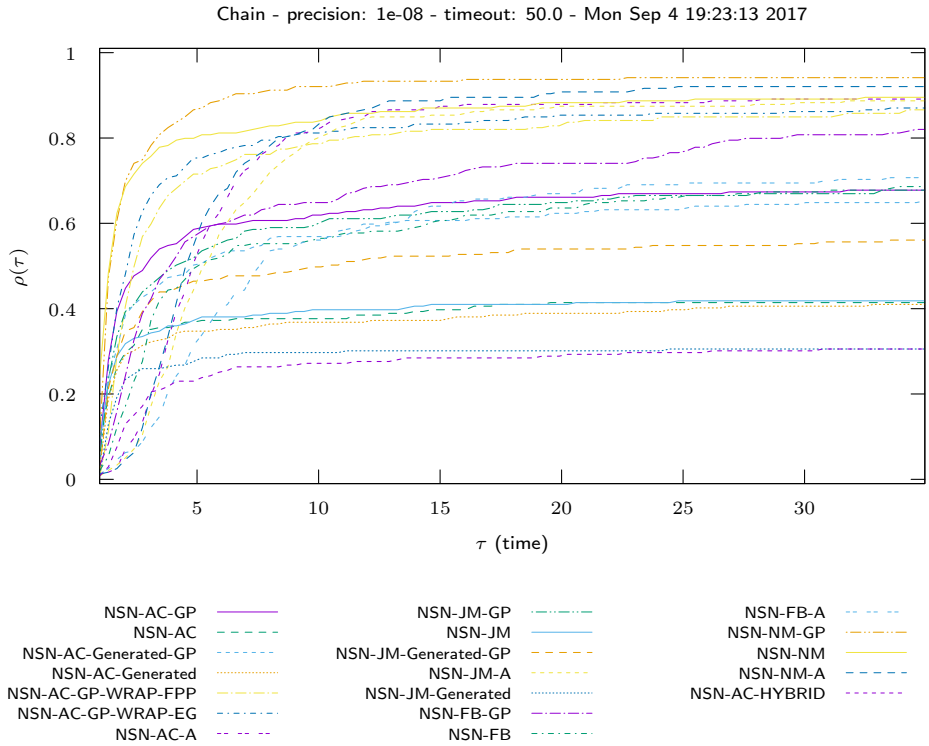


Figure 99: Chain time NSN

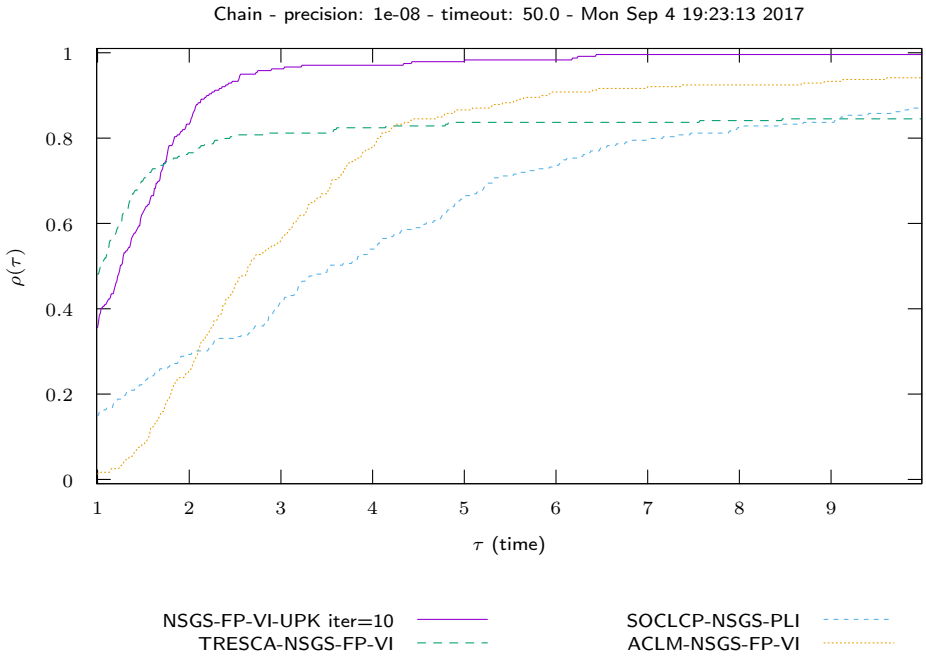


Figure 100: Chain time OPTI

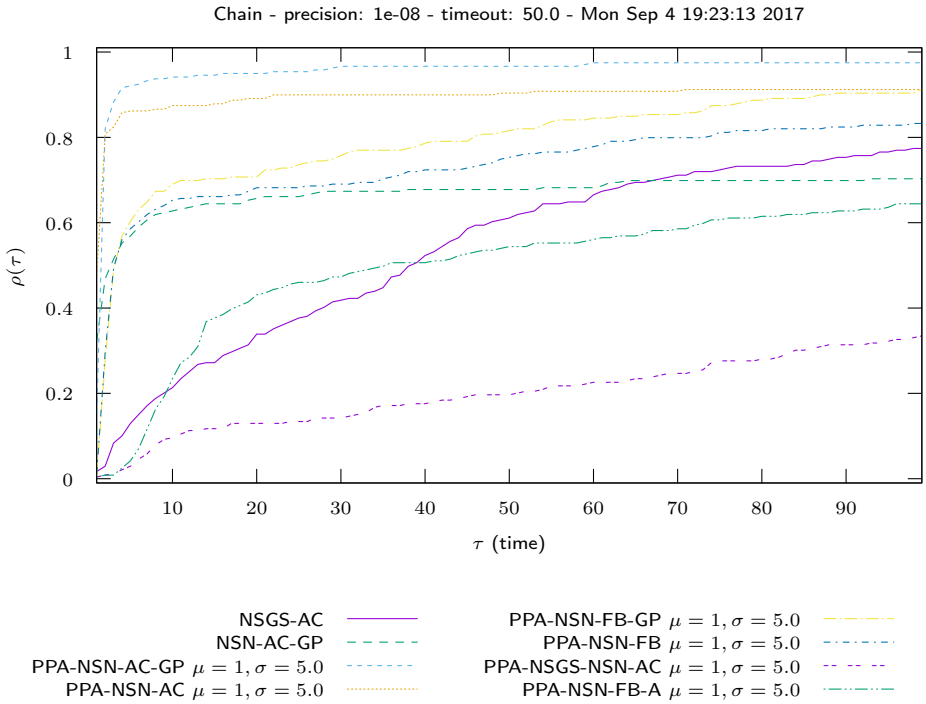
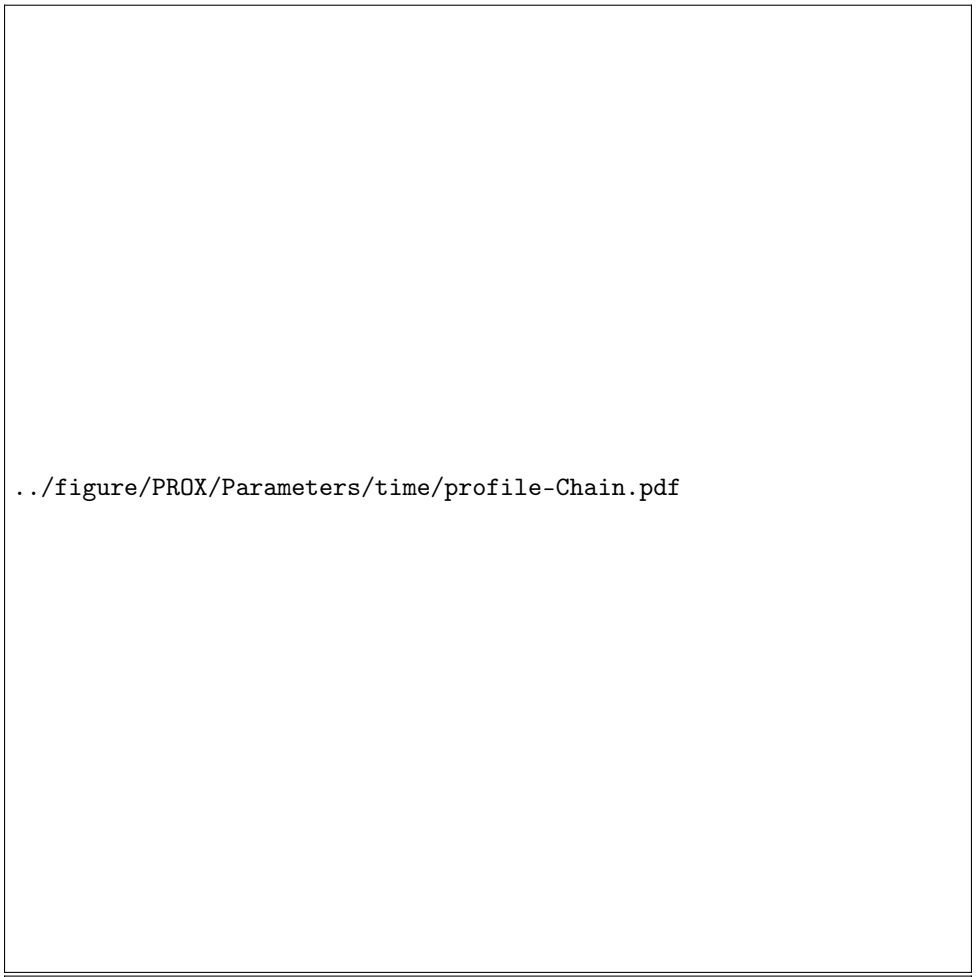
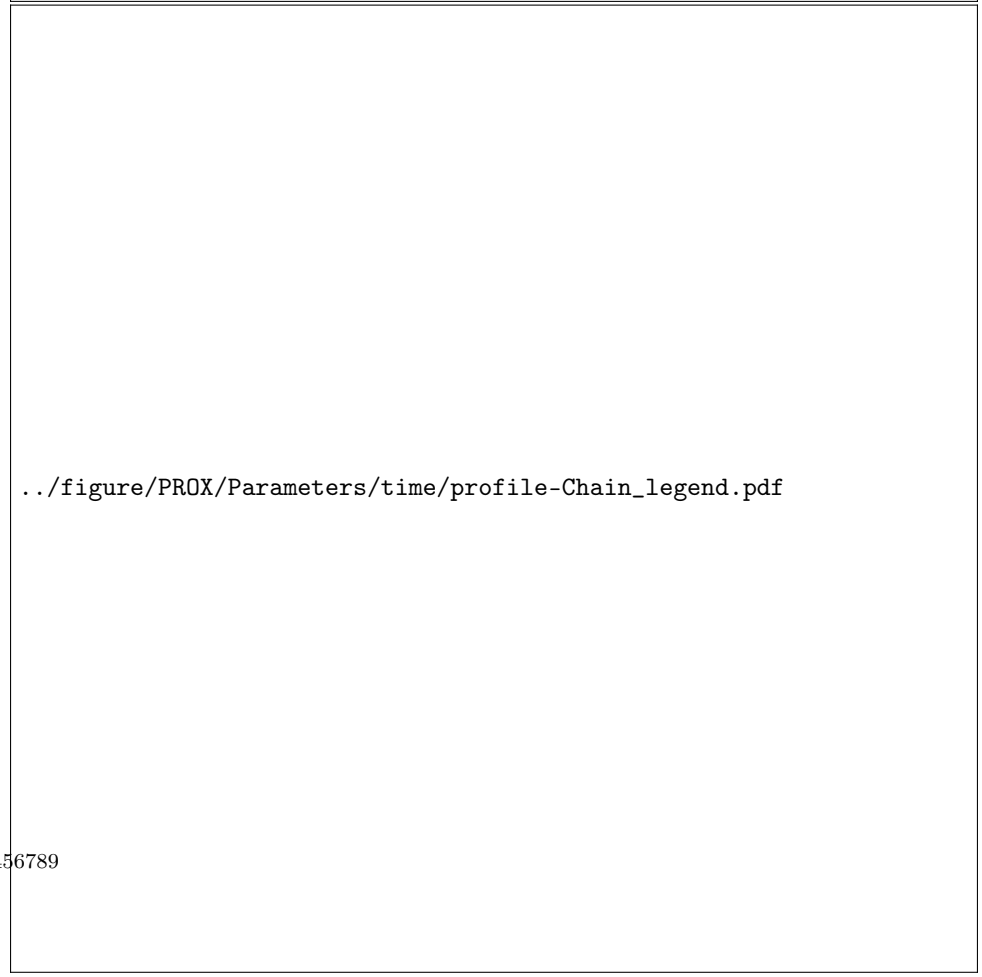


Figure 101: Chain time PROX/InternalSolvers


../figure/PROX/Parameters/time/profile-Chain.pdf


../figure/PROX/Parameters/time/profile-Chain_legend.pdf

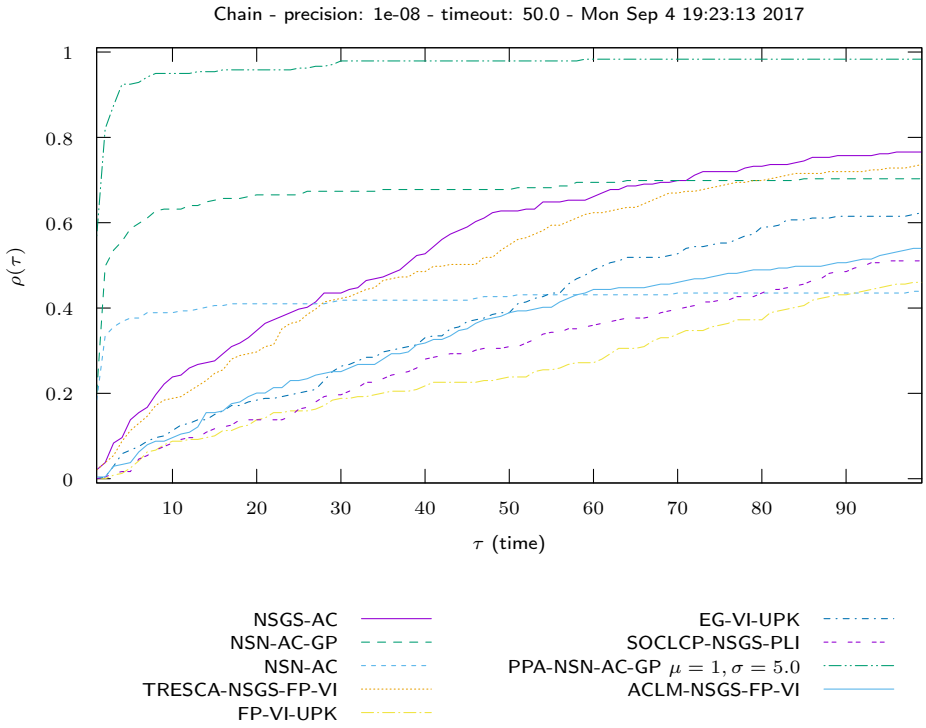


Figure 103: Chain time COMP/large

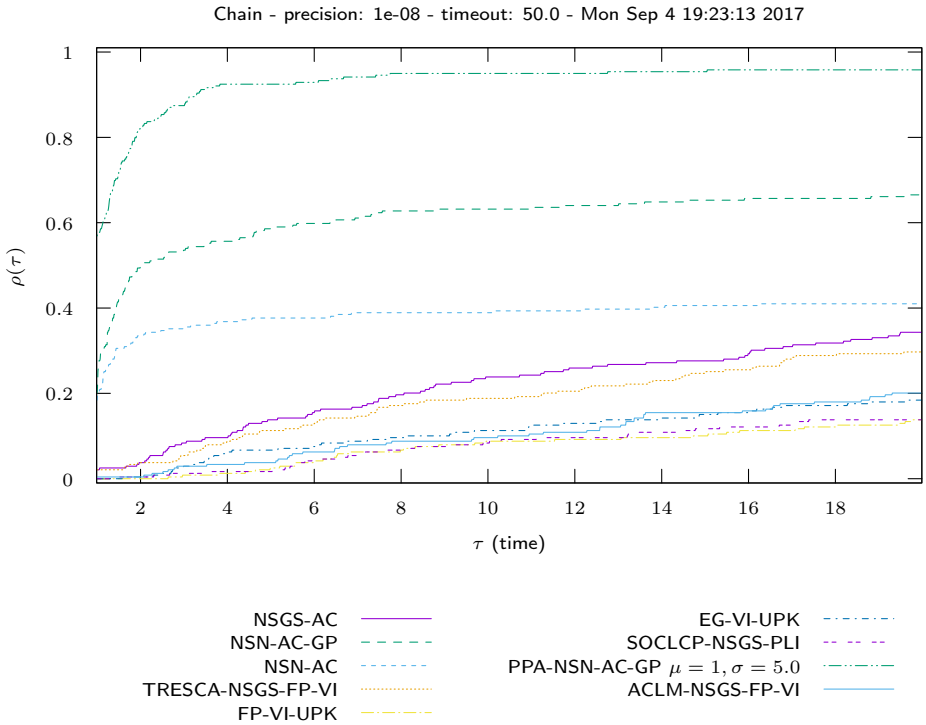


Figure 104: Chain time COMP/large

9 BoxesStack1

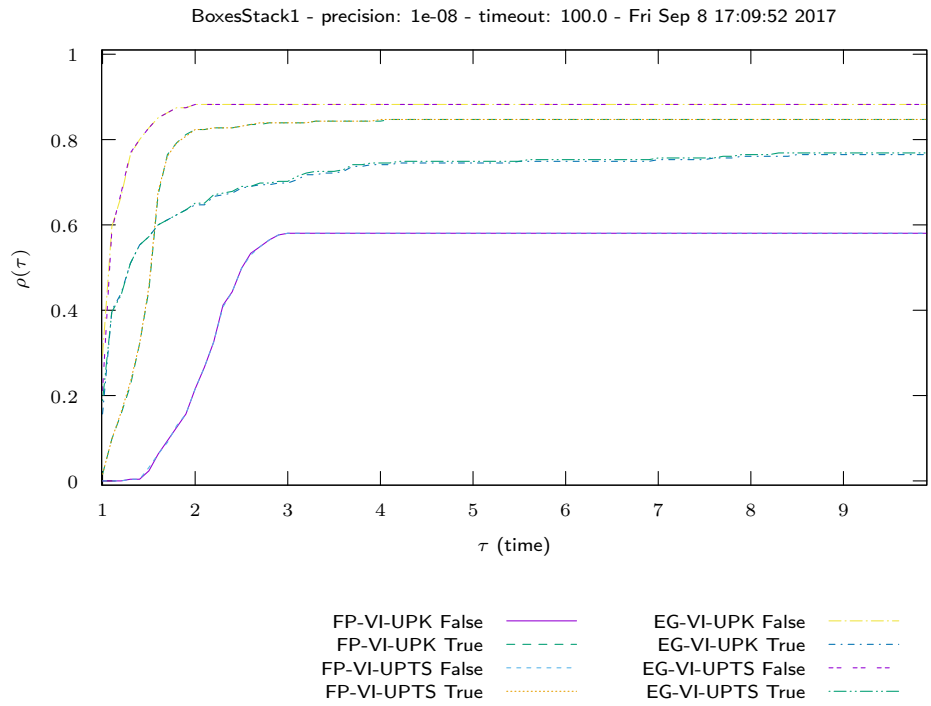


Figure 105: BoxesStack1 time VI/UpdateRule

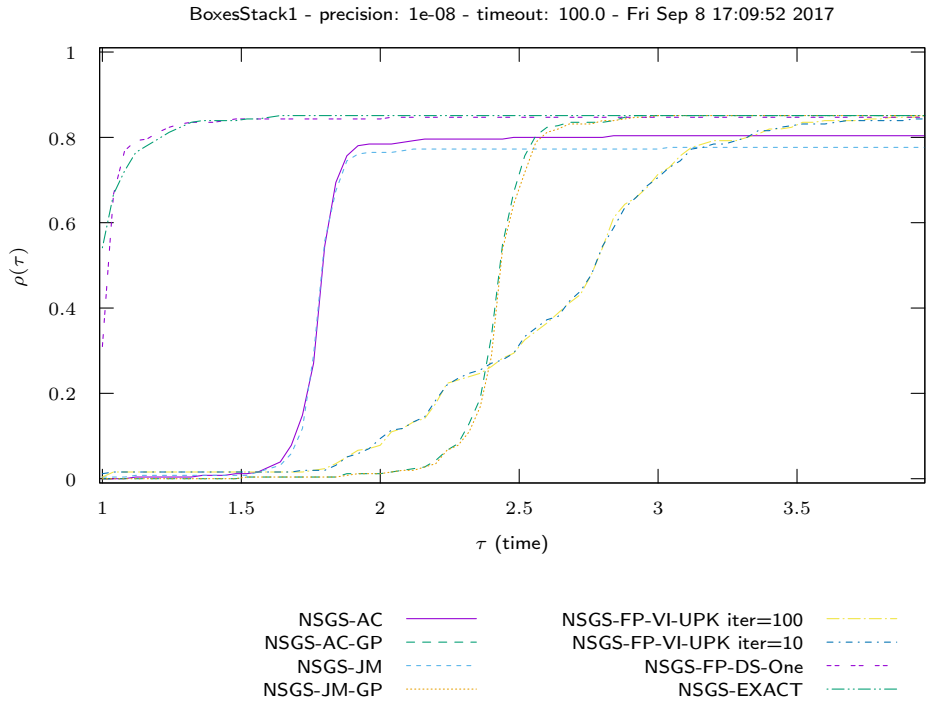


Figure 106: BoxesStack1 time NSGS/LocalSolver

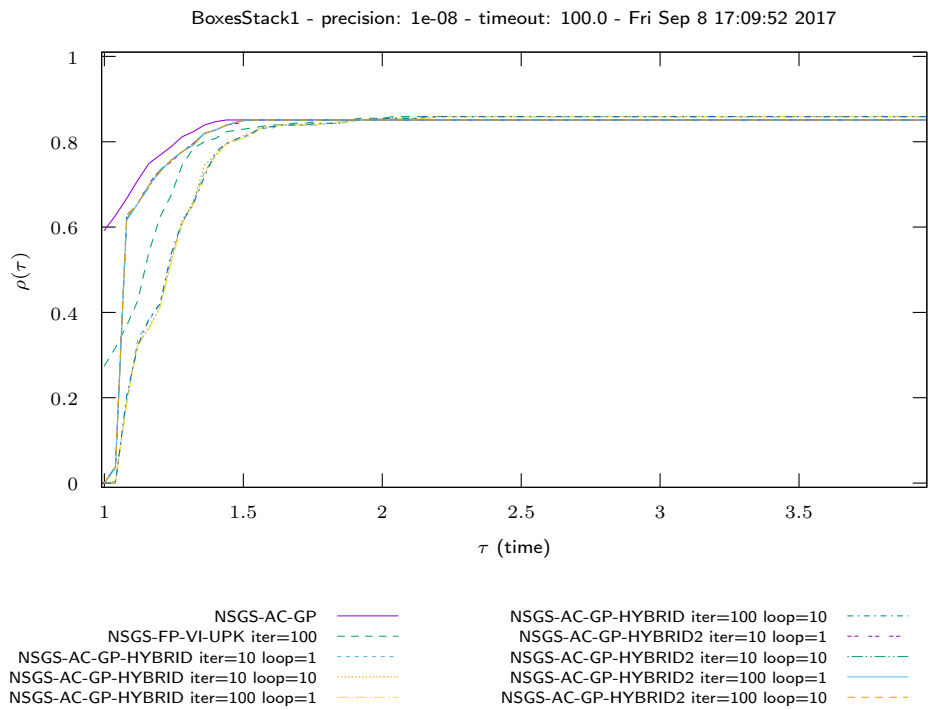


Figure 107: BoxesStack1 time NSGS/LocalSolverHybrid

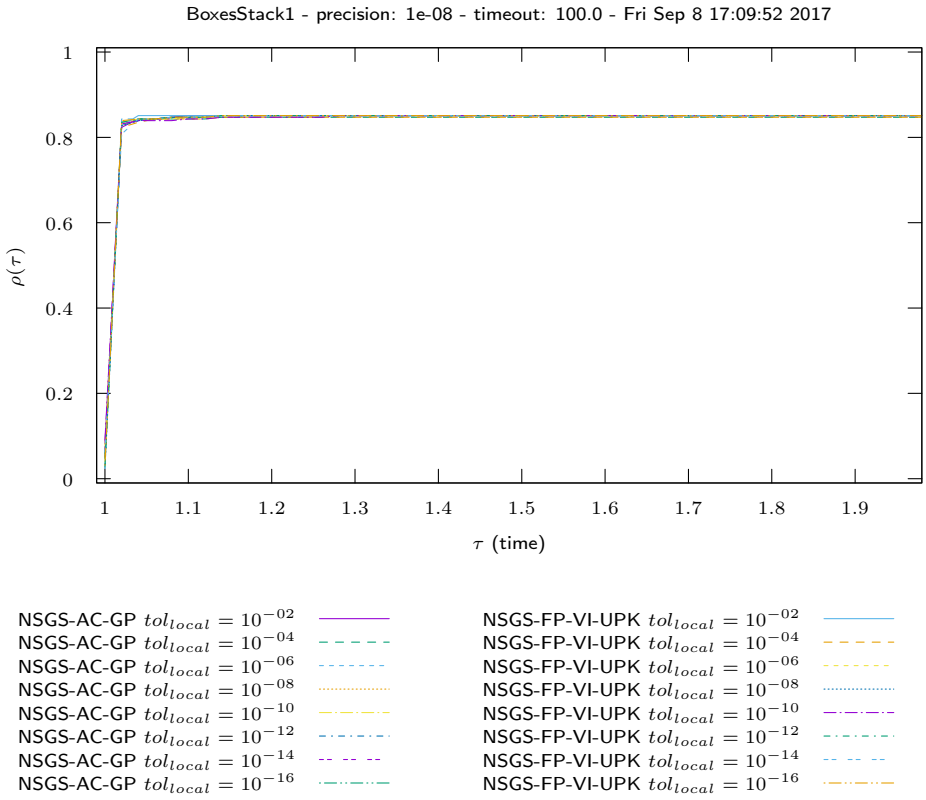
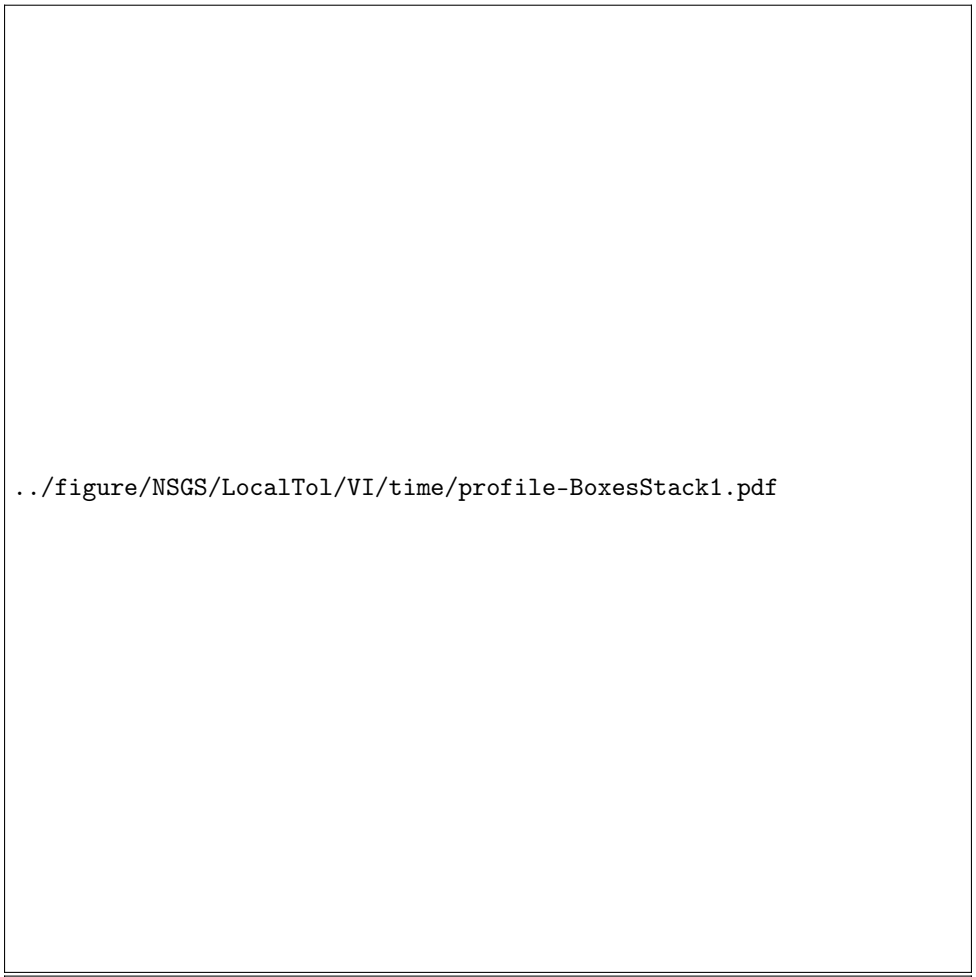
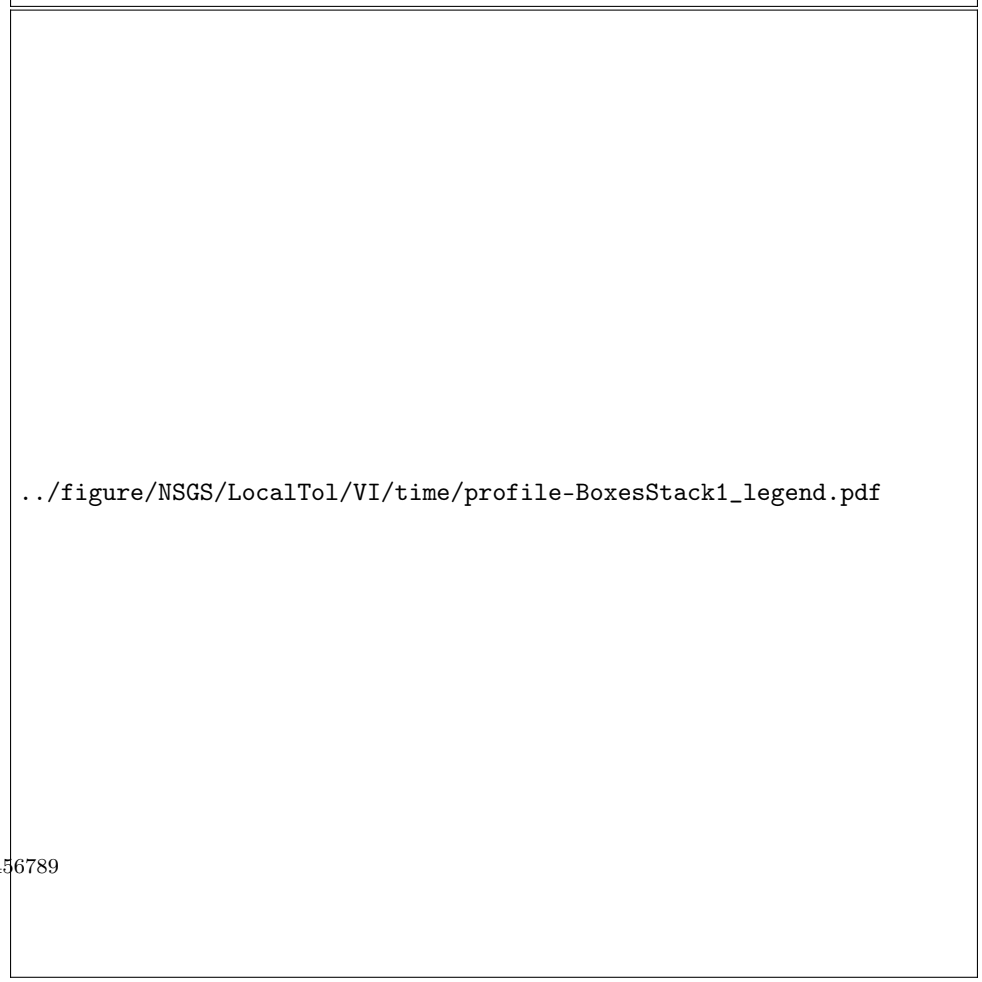


Figure 108: BoxesStack1 time NSGS/LocalTol


../figure/NSGS/LocalTol/VI/time/profile-BoxesStack1.pdf


../figure/NSGS/LocalTol/VI/time/profile-BoxesStack1_legend.pdf

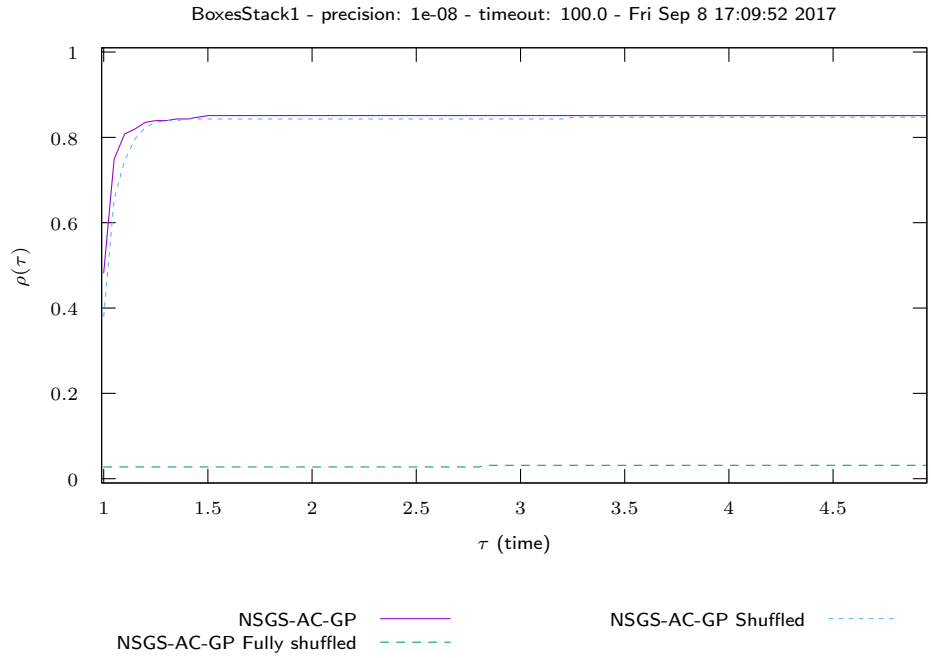


Figure 110: BoxesStack1 time NSGS/Shuffled

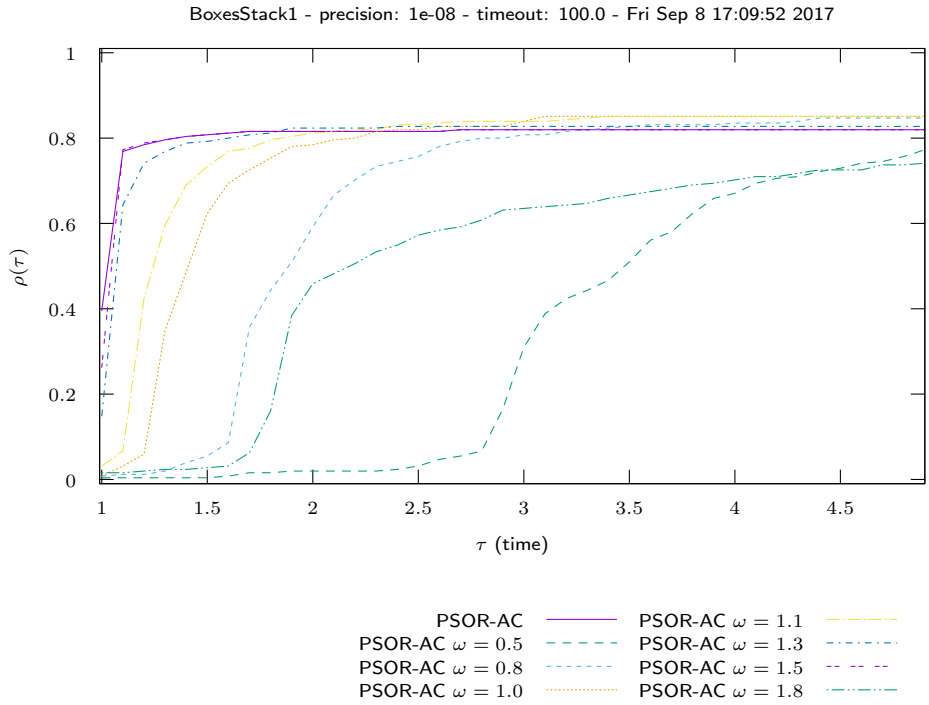


Figure 111: BoxesStack1 time PSOR

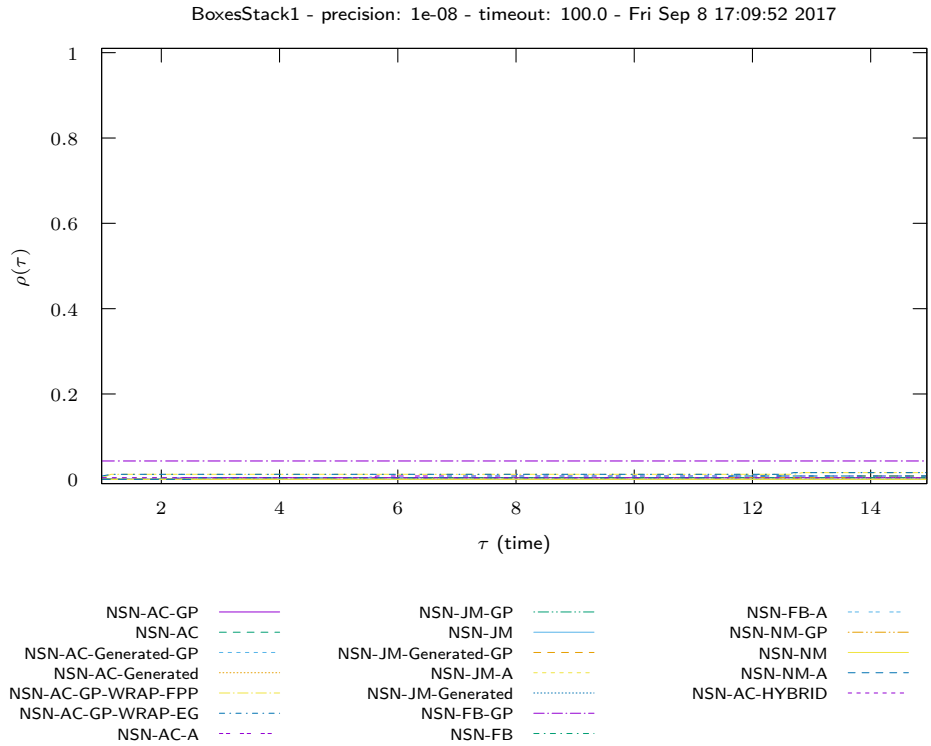


Figure 112: BoxesStack1 time NSN

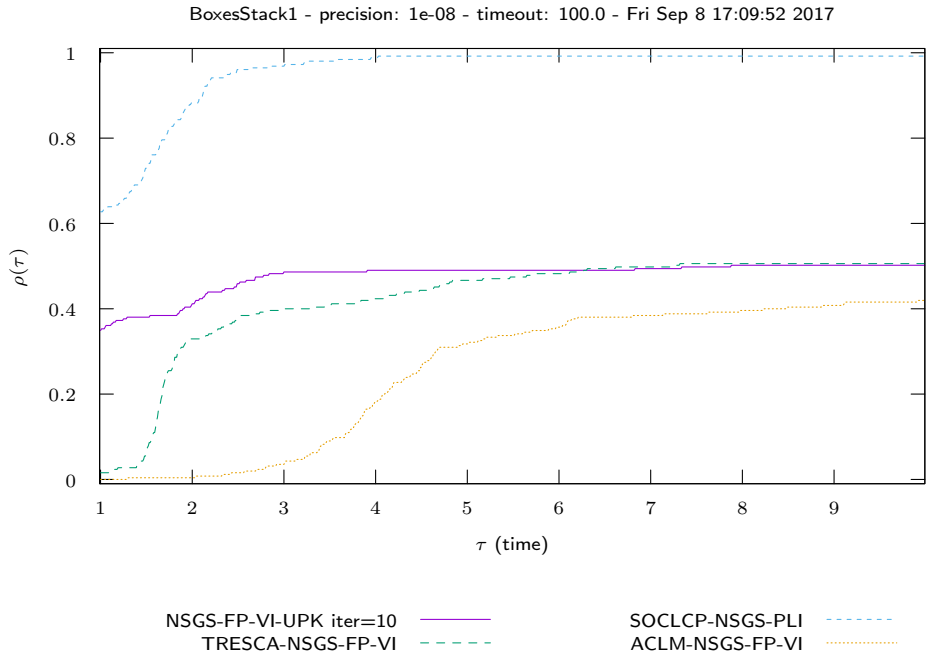


Figure 113: BoxesStack1 time OPTI

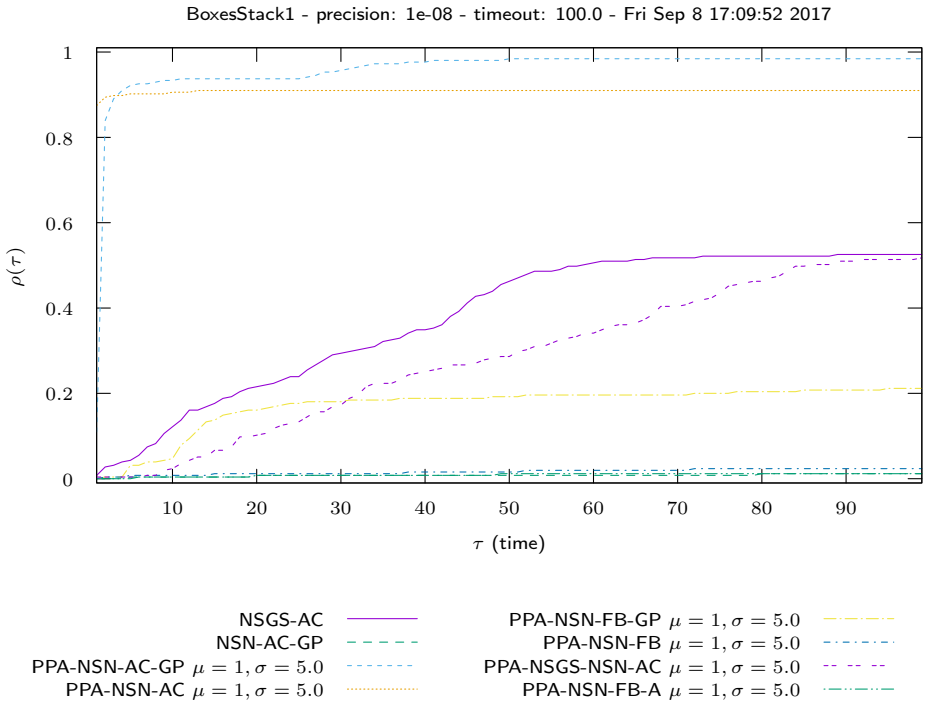
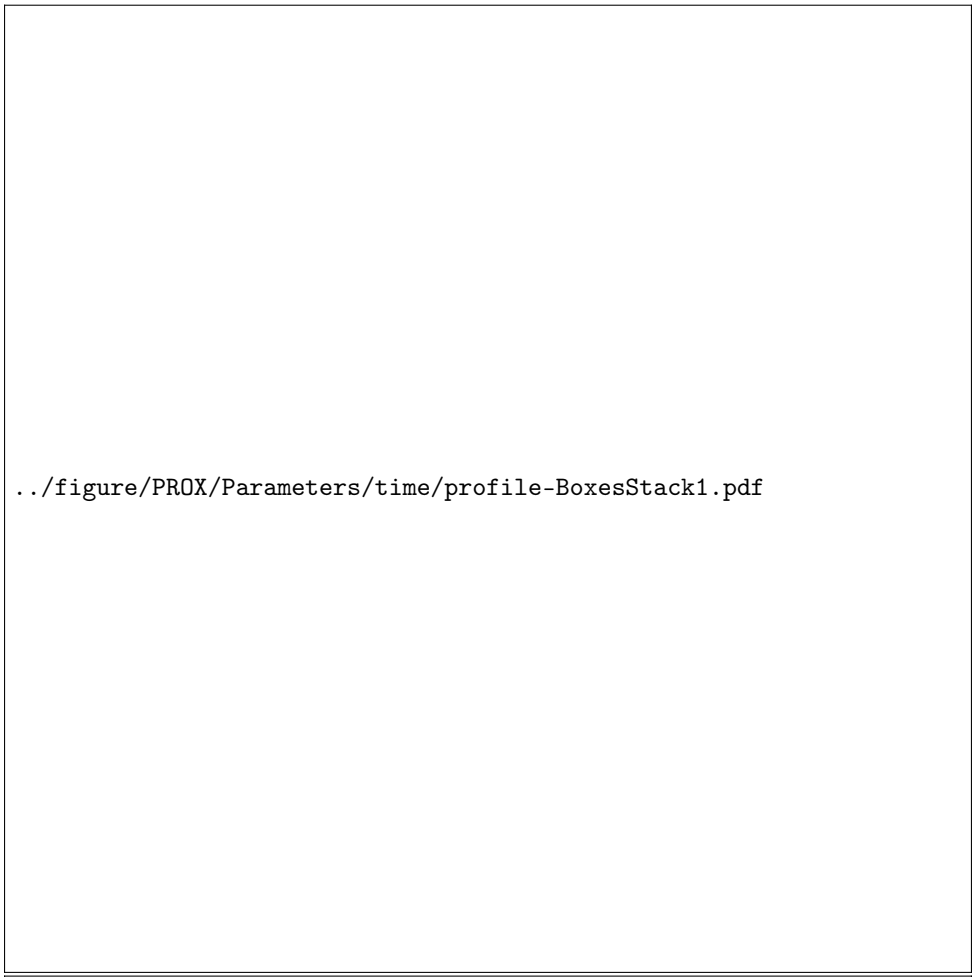
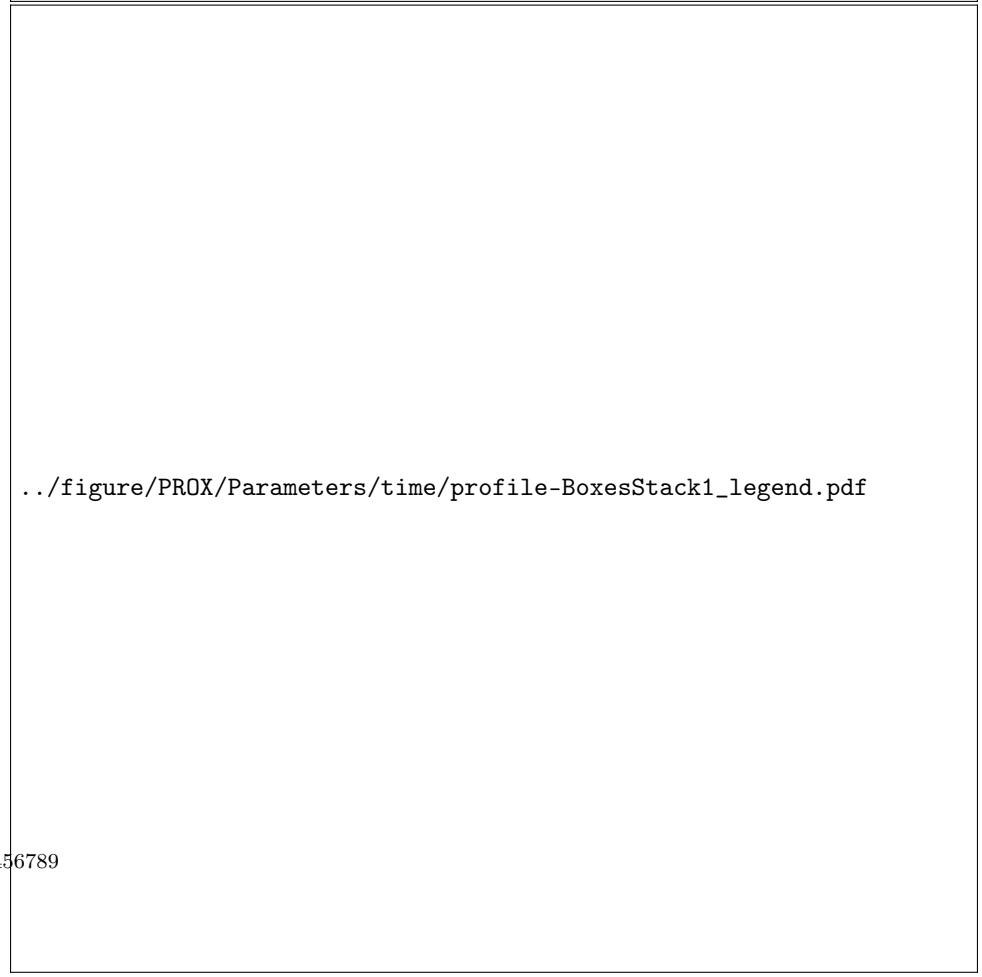


Figure 114: BoxesStack1 time PROX/InternalSolvers


../figure/PROX/Parameters/time/profile-BoxesStack1.pdf


../figure/PROX/Parameters/time/profile-BoxesStack1_legend.pdf

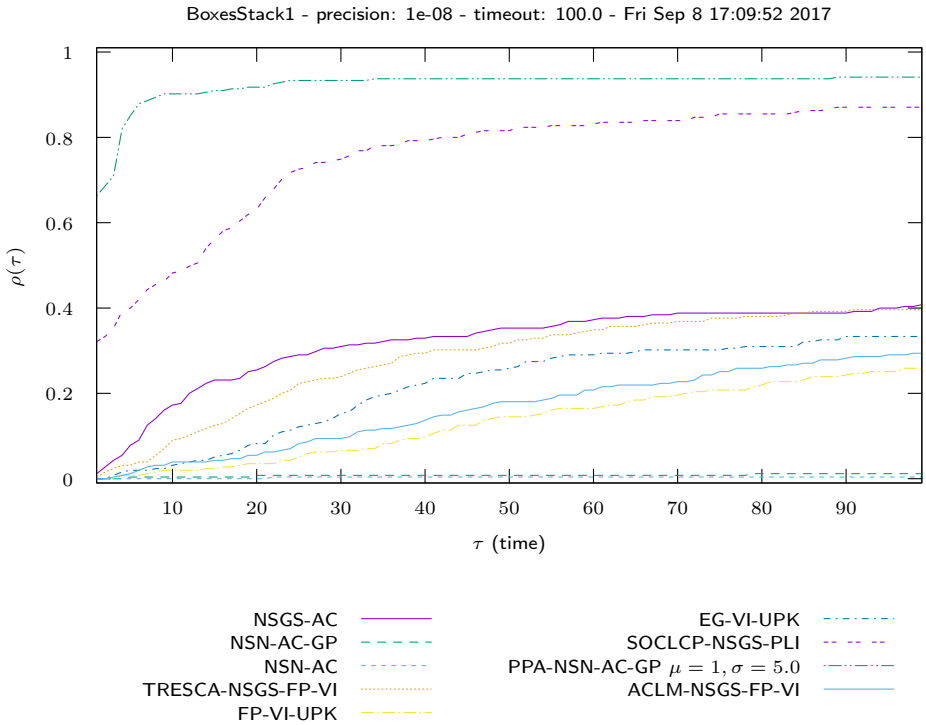


Figure 116: BoxesStack1 time COMP/large

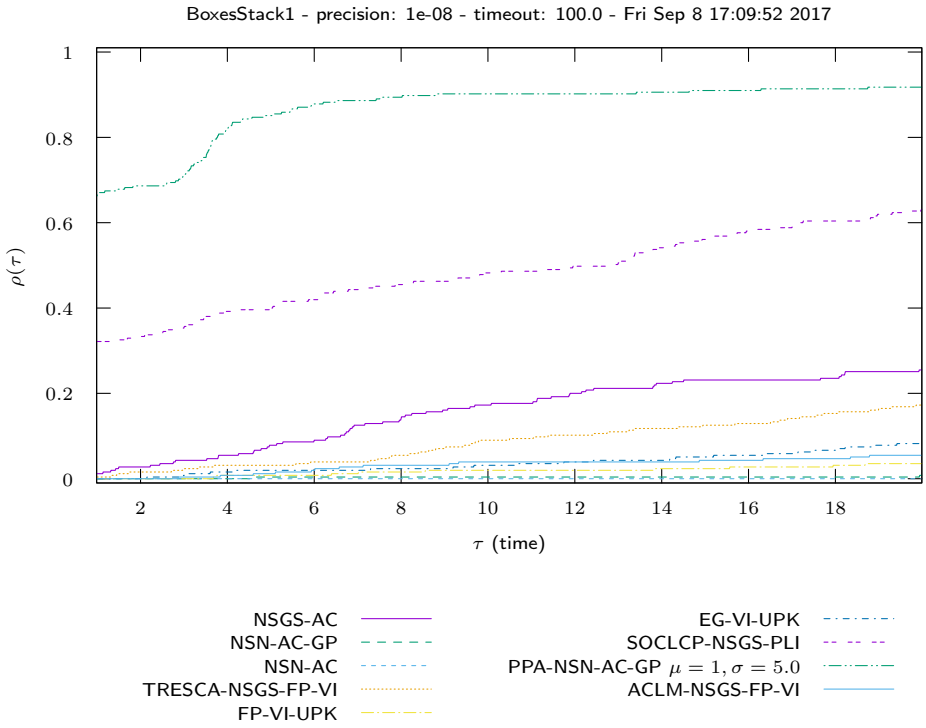


Figure 117: BoxesStack1 time COMP/large

10 KaplasTower

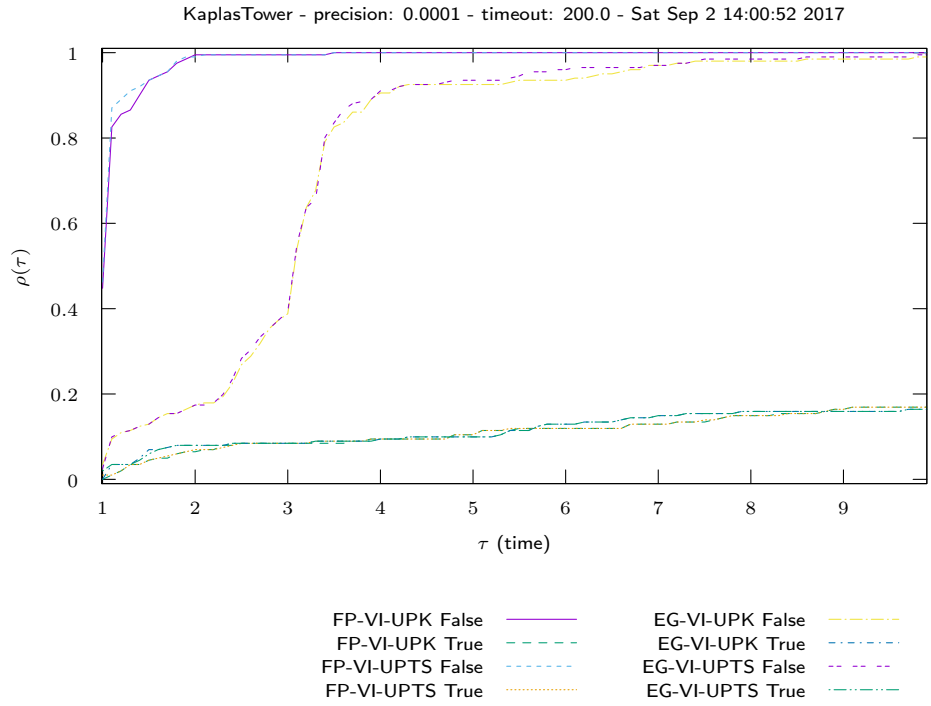


Figure 118: KaplasTower time VI/UpdateRule

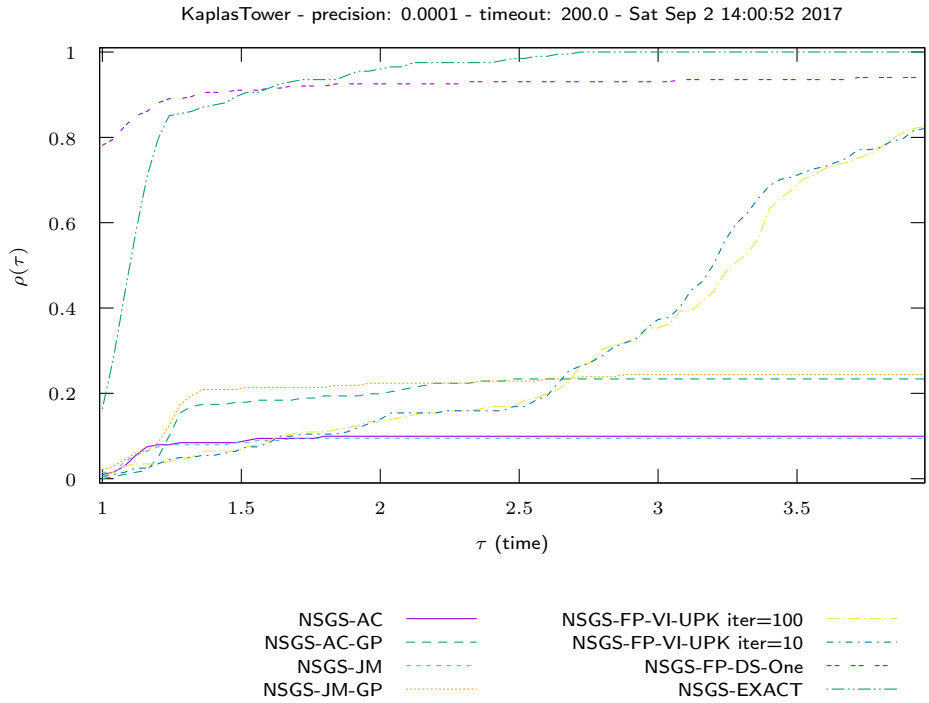


Figure 119: KaplasTower time NSGS/LocalSolver

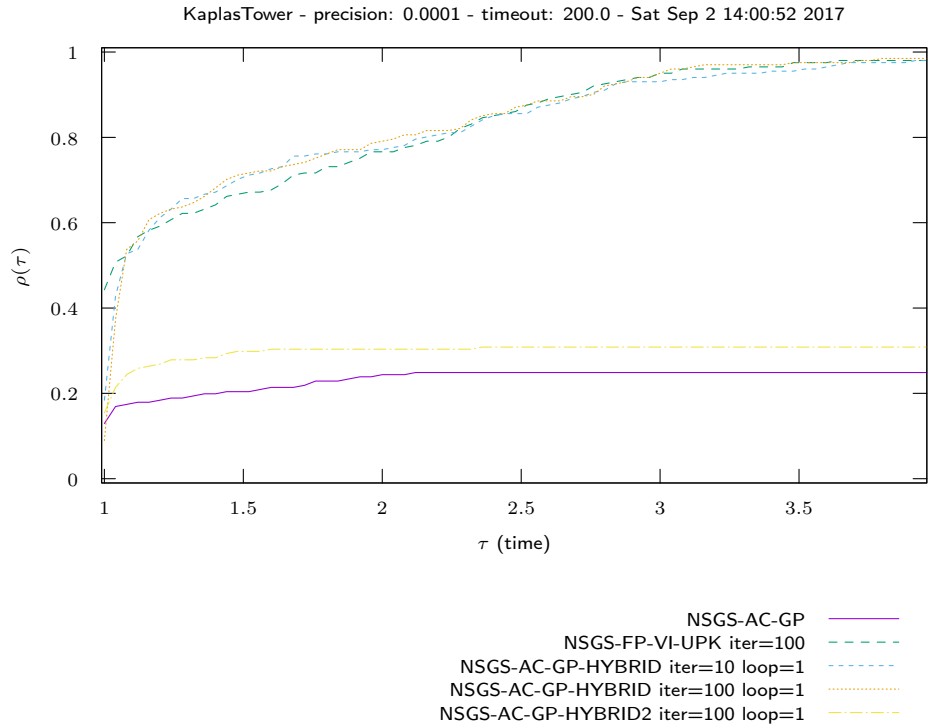


Figure 120: KaplasTower time NSGS/LocalSolverHybrid

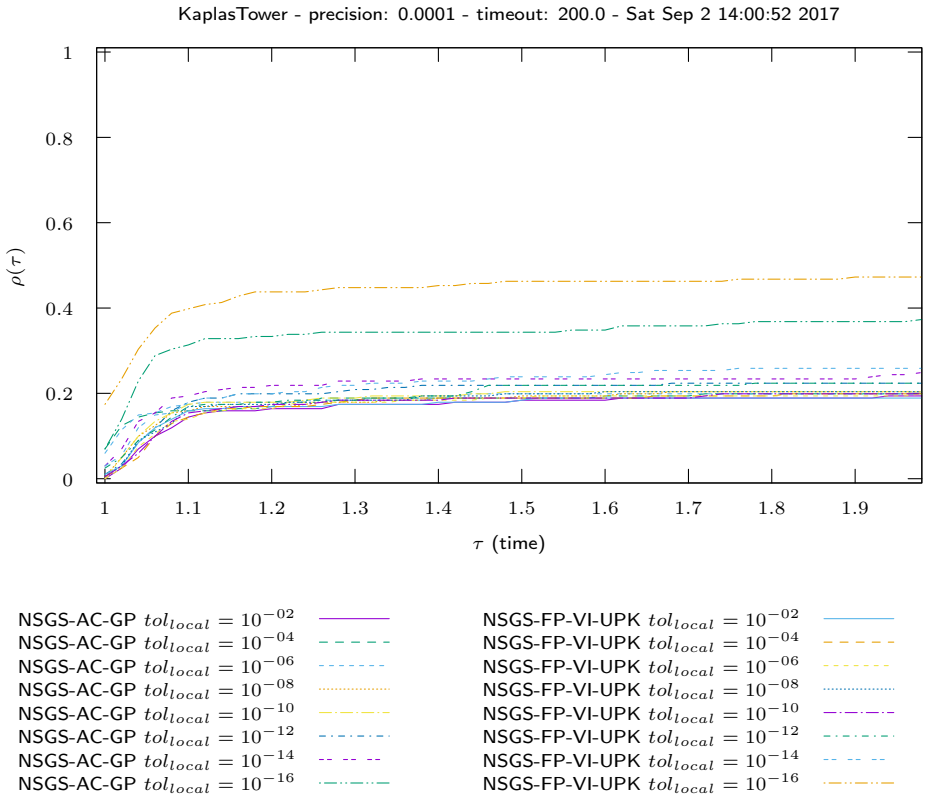
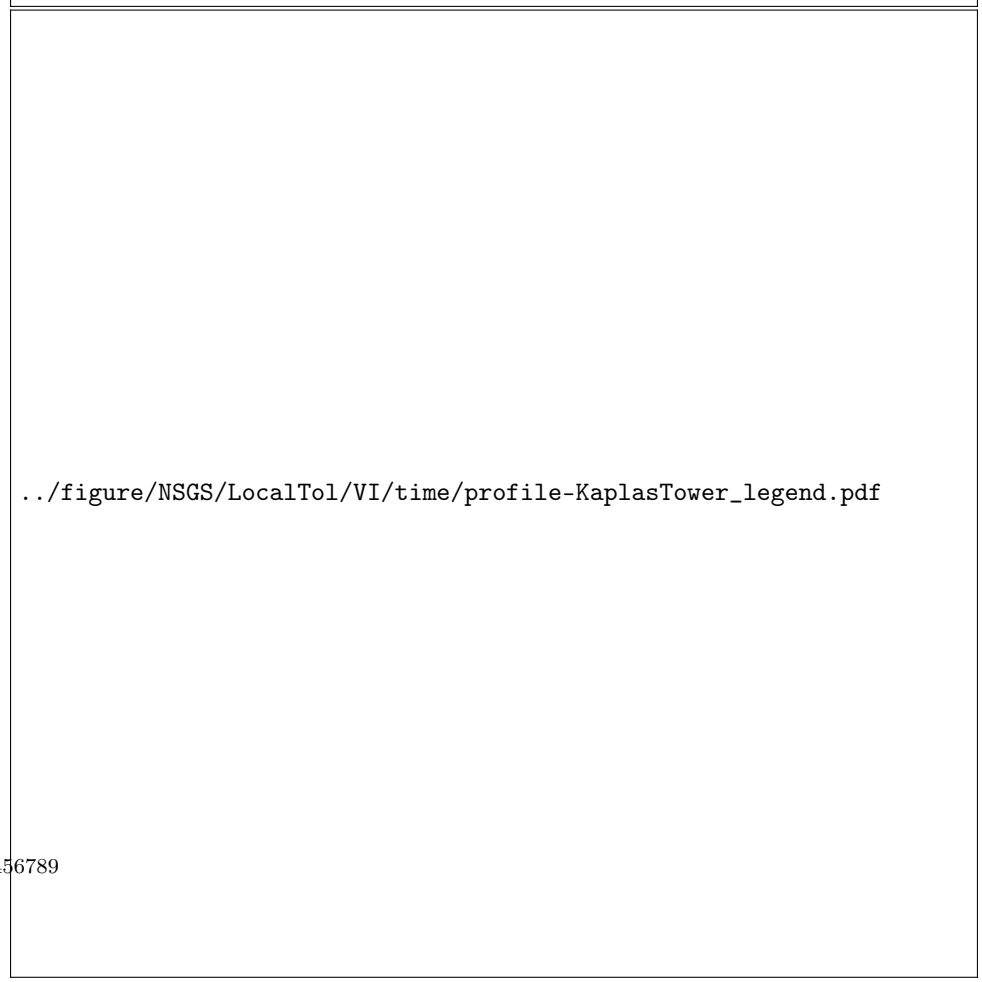


Figure 121: KaplasTower time NSGS/LocalTol


../figure/NSGS/LocalTol/VI/time/profile-KaplasTower.pdf


../figure/NSGS/LocalTol/VI/time/profile-KaplasTower_legend.pdf

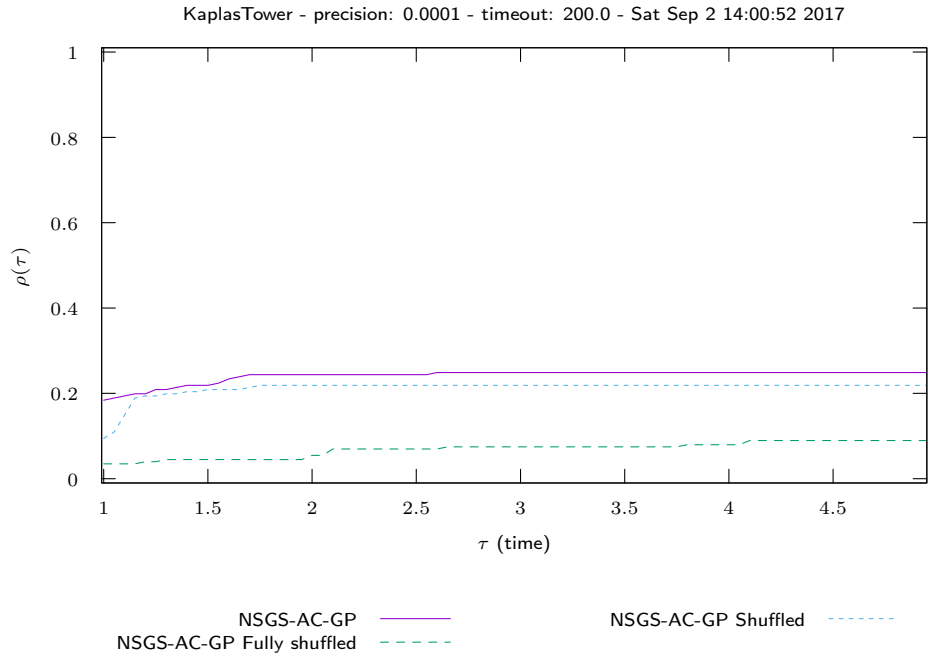


Figure 123: KaplasTower time NSGS/Shuffled

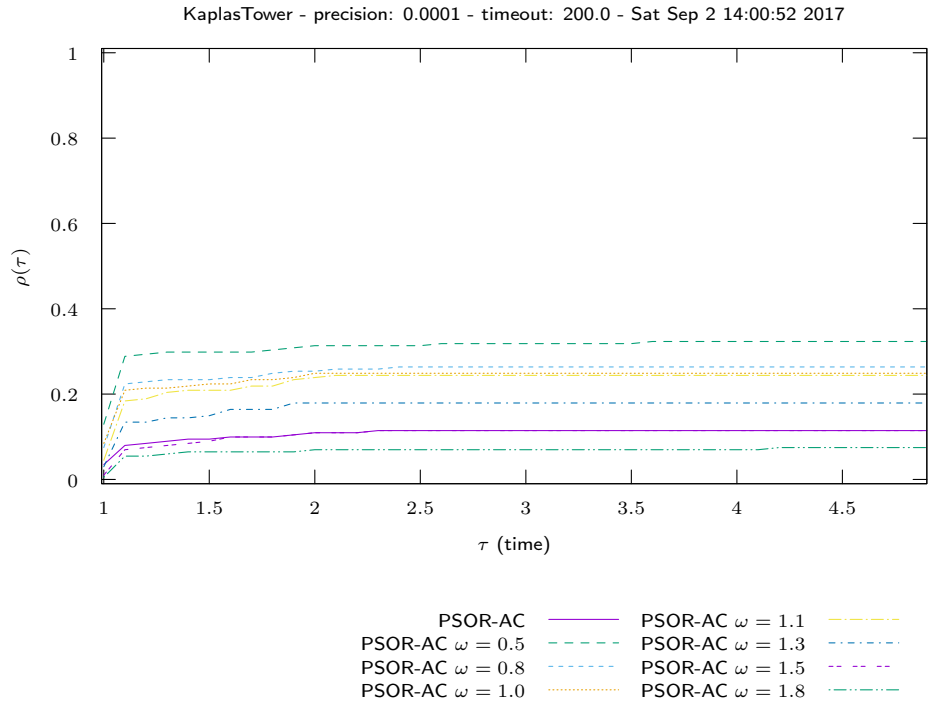


Figure 124: KaplasTower time PSOR

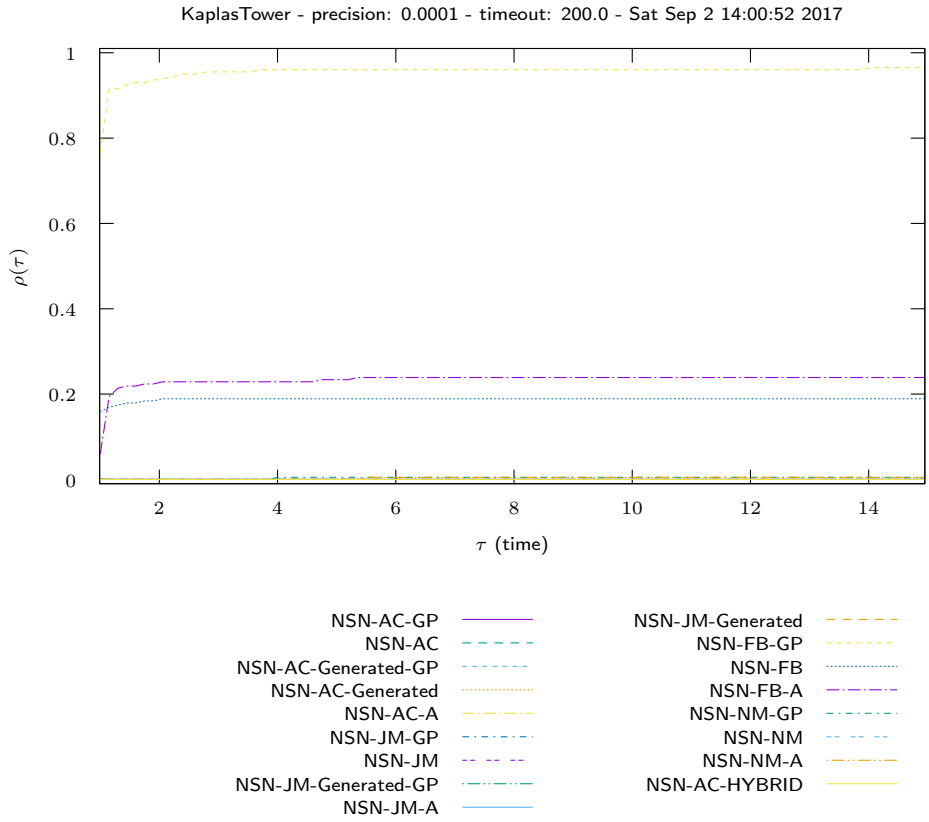


Figure 125: KaplasTower time NSN

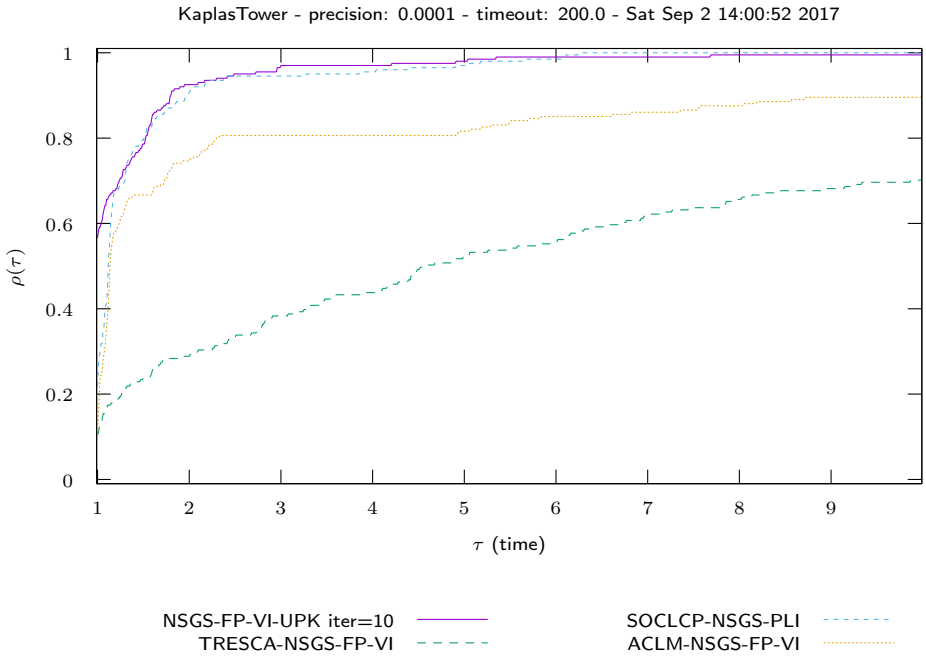


Figure 126: KaplasTower time OPTI

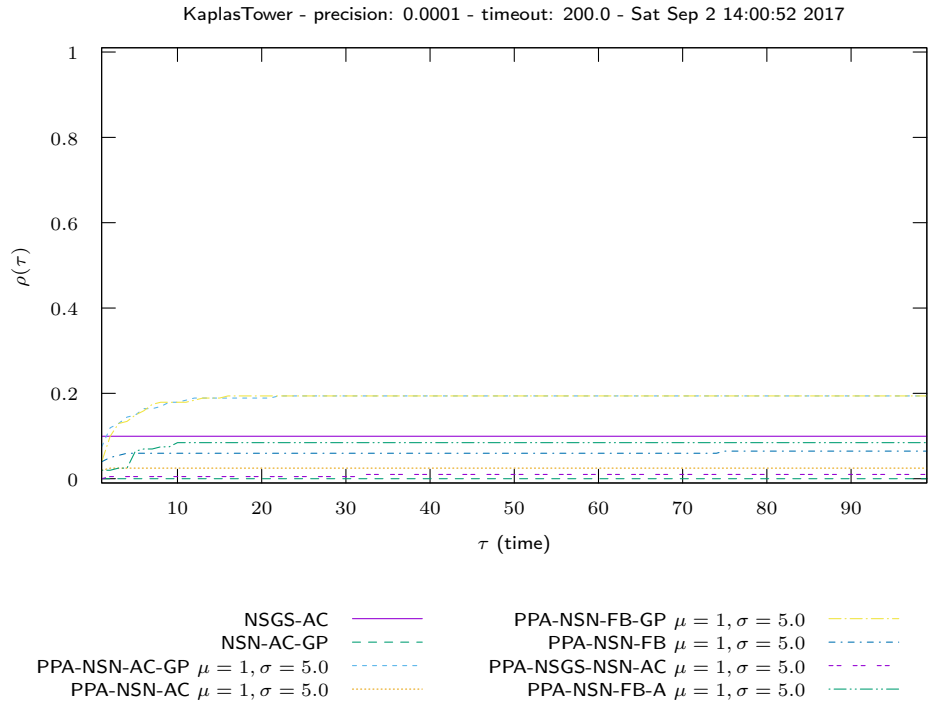
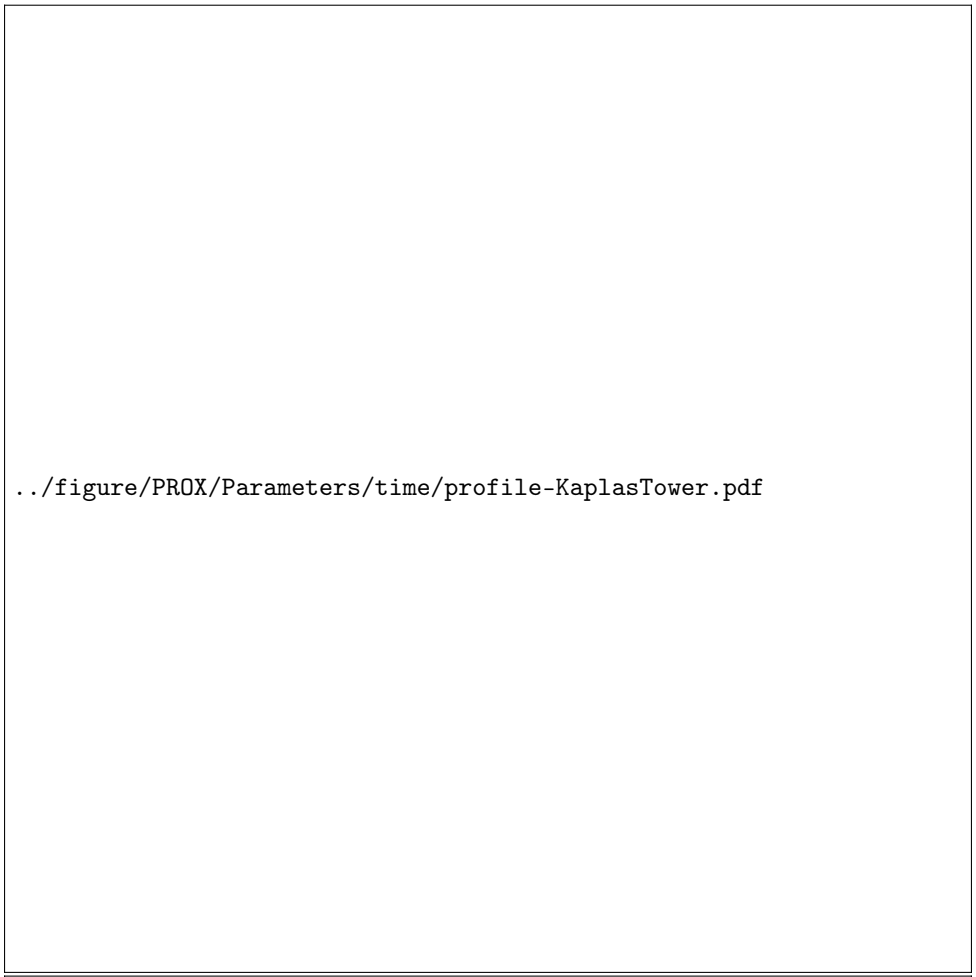
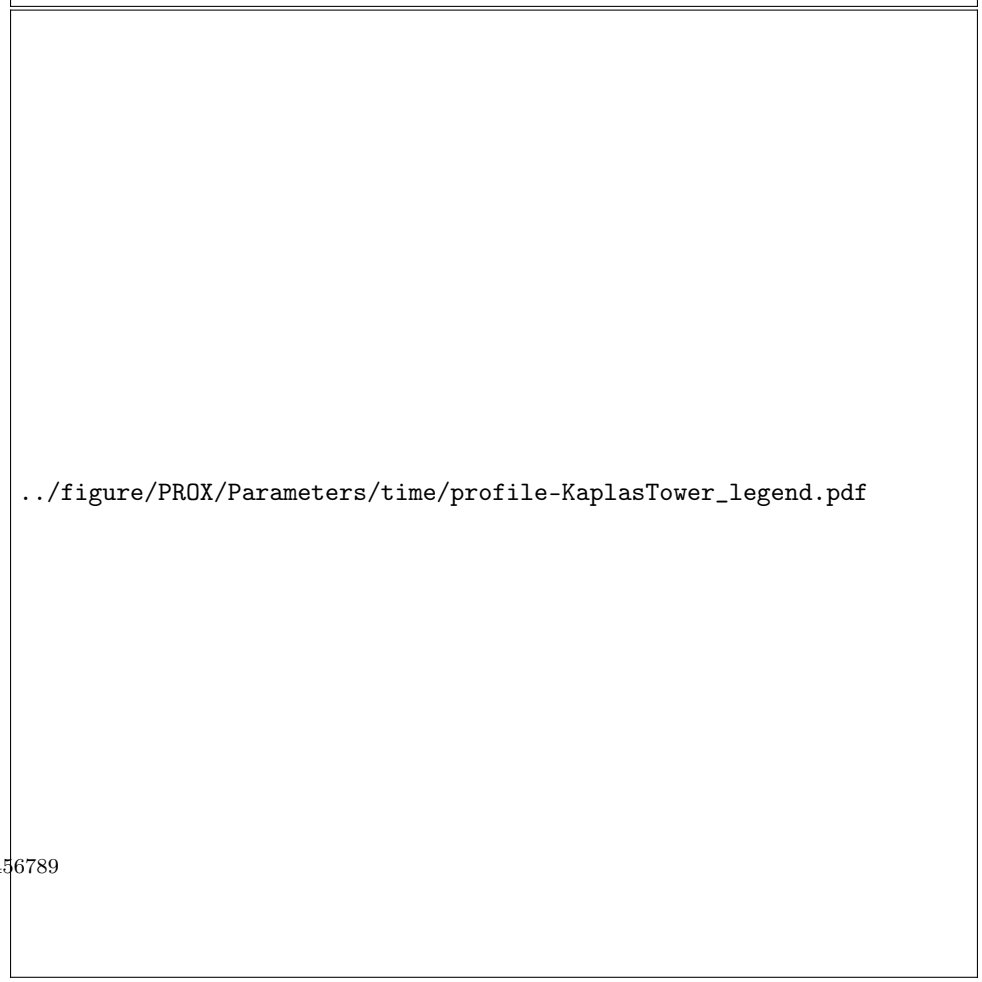


Figure 127: KaplasTower time PROX/InternalSolvers


../figure/PROX/Parameters/time/profile-KaplasTower.pdf


../figure/PROX/Parameters/time/profile-KaplasTower_legend.pdf

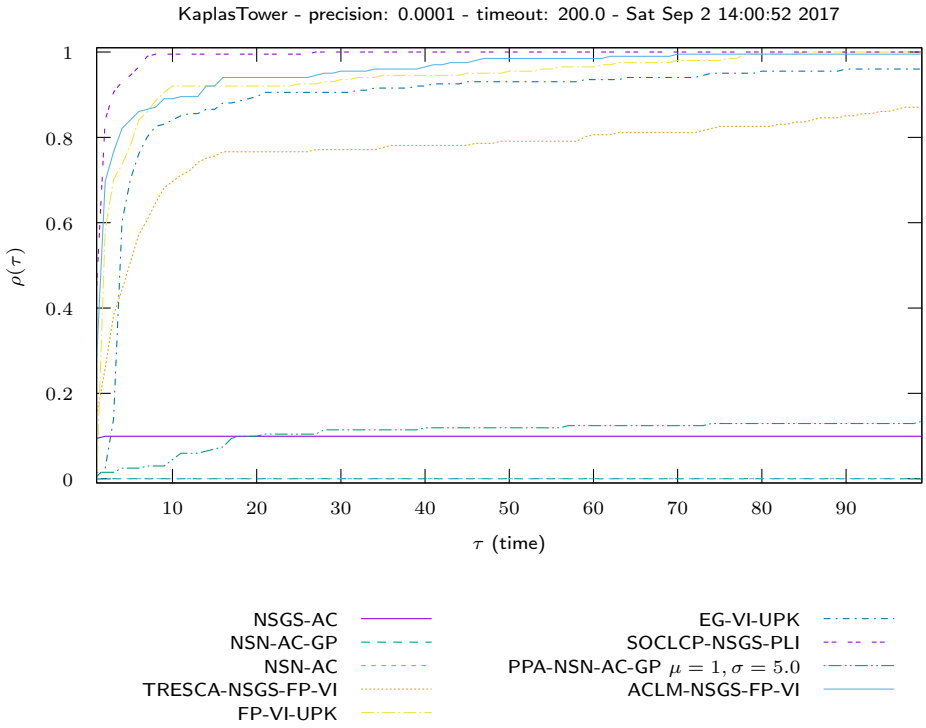


Figure 129: KaplasTower time COMP/large

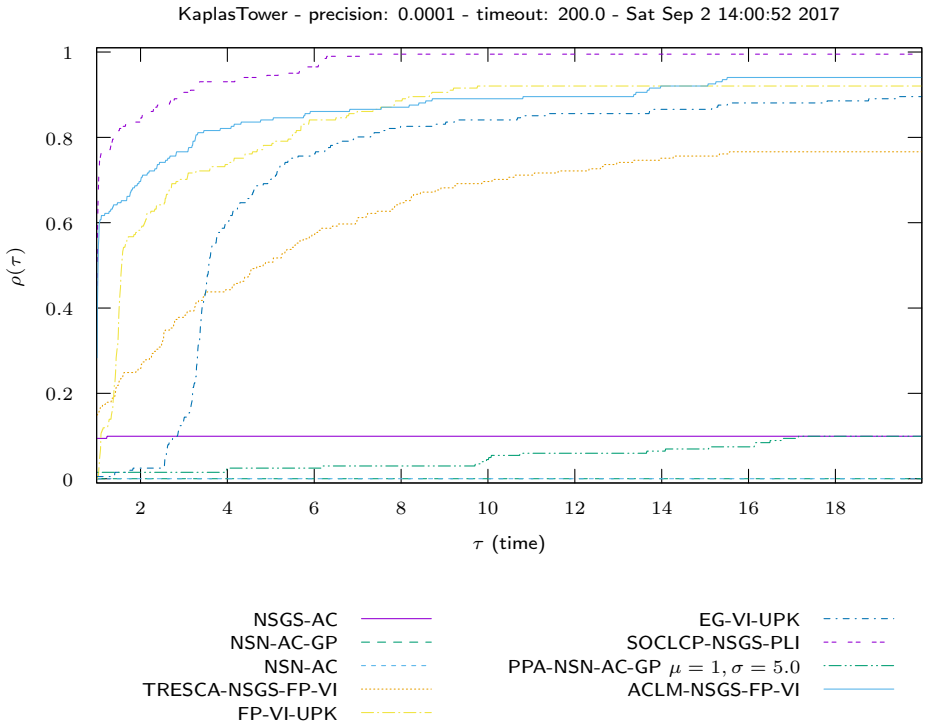


Figure 130: KaplasTower time COMP/large

11 Chute_1000

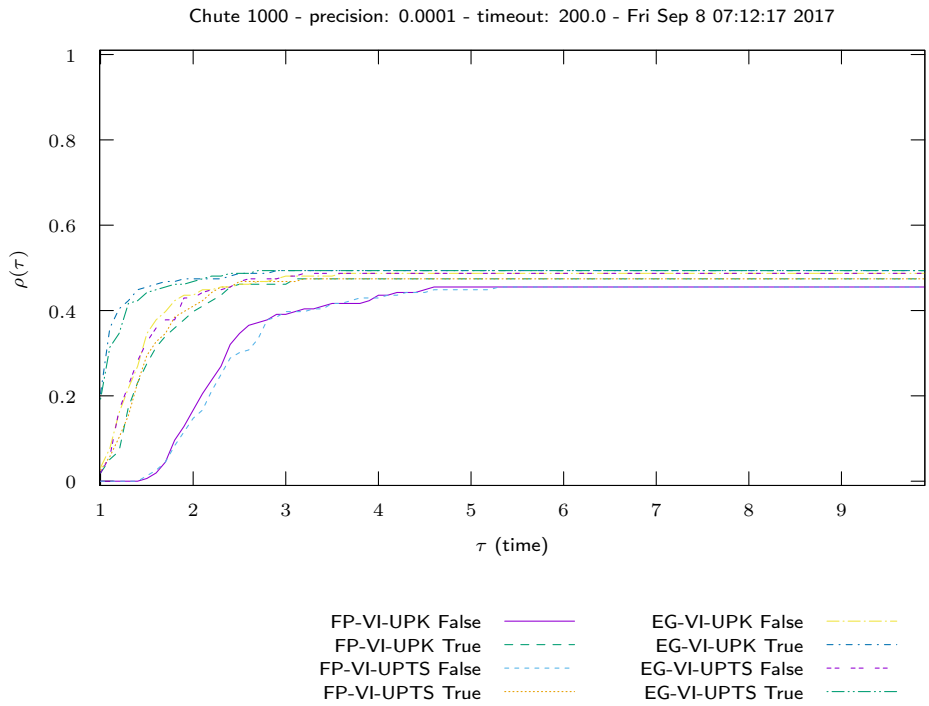


Figure 131: Chute_1000 time VI/UpdateRule

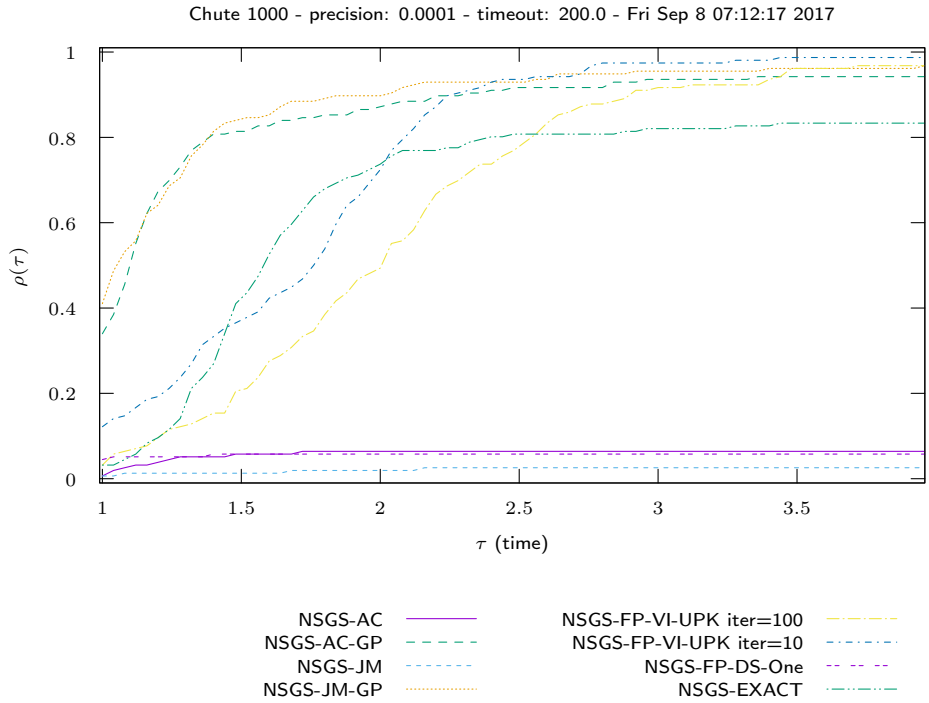


Figure 132: Chute_1000 time NSGS/LocalSolver

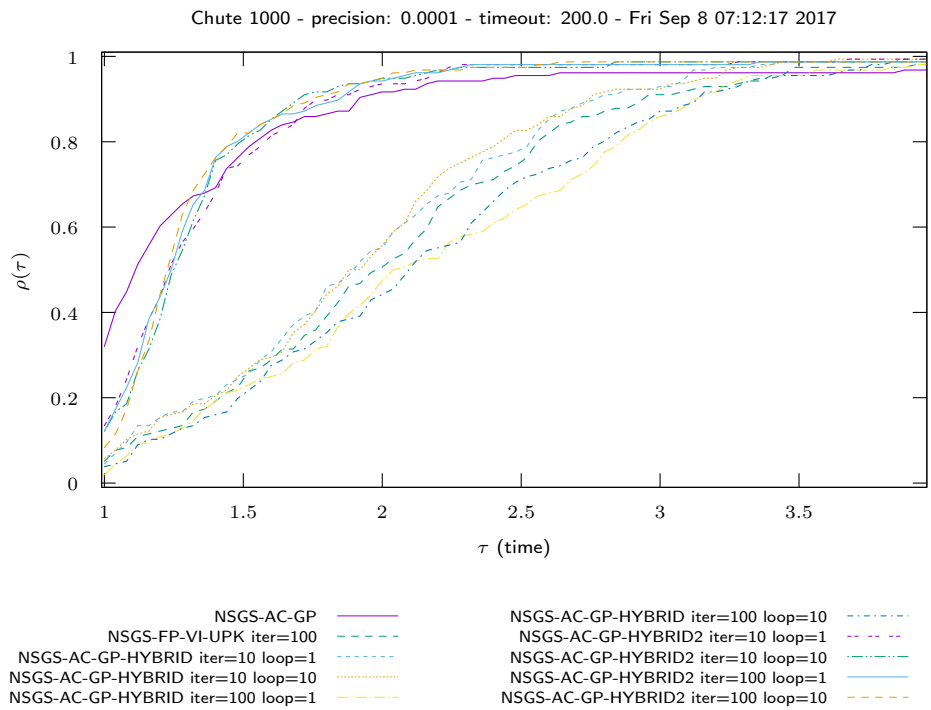


Figure 133: Chute_1000 time NSGS/LocalSolverHybrid

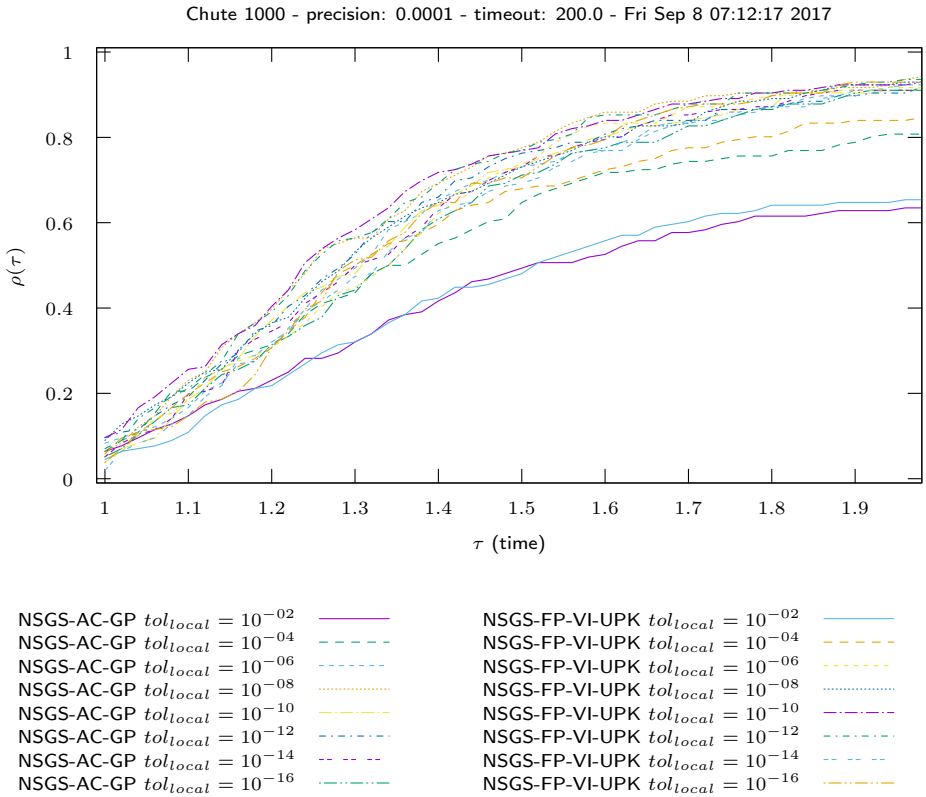
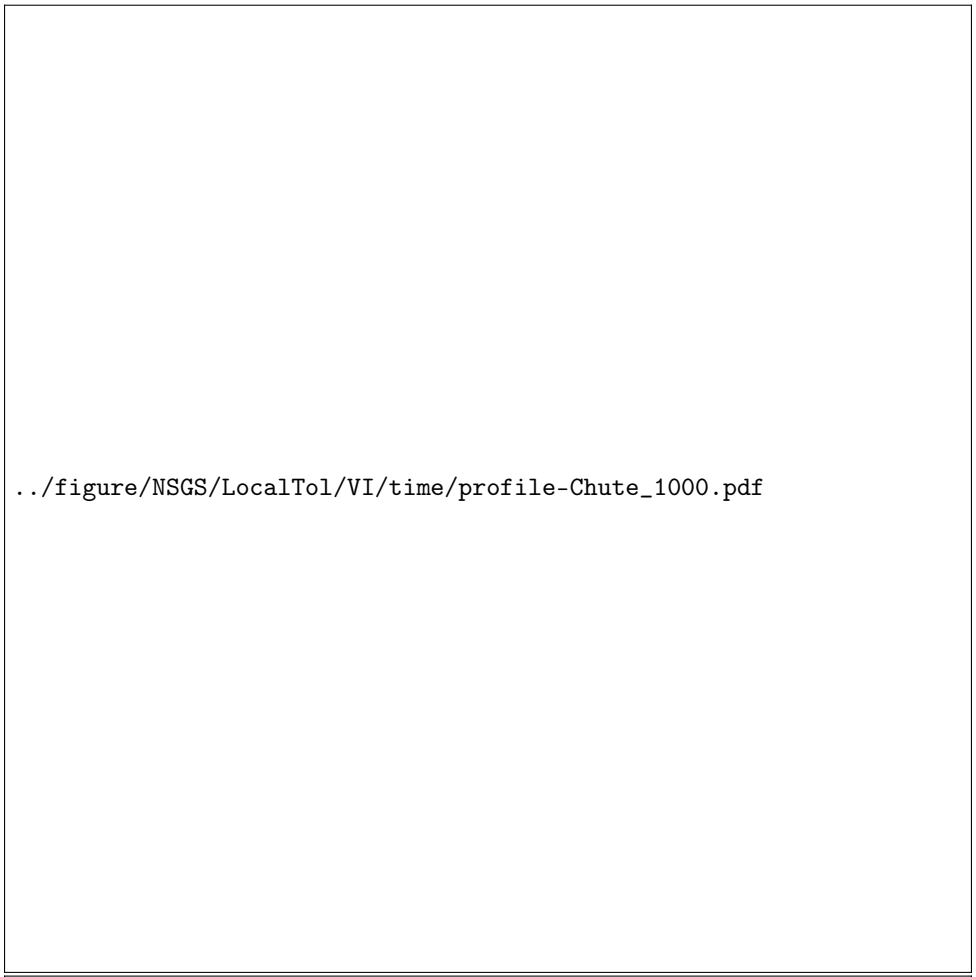
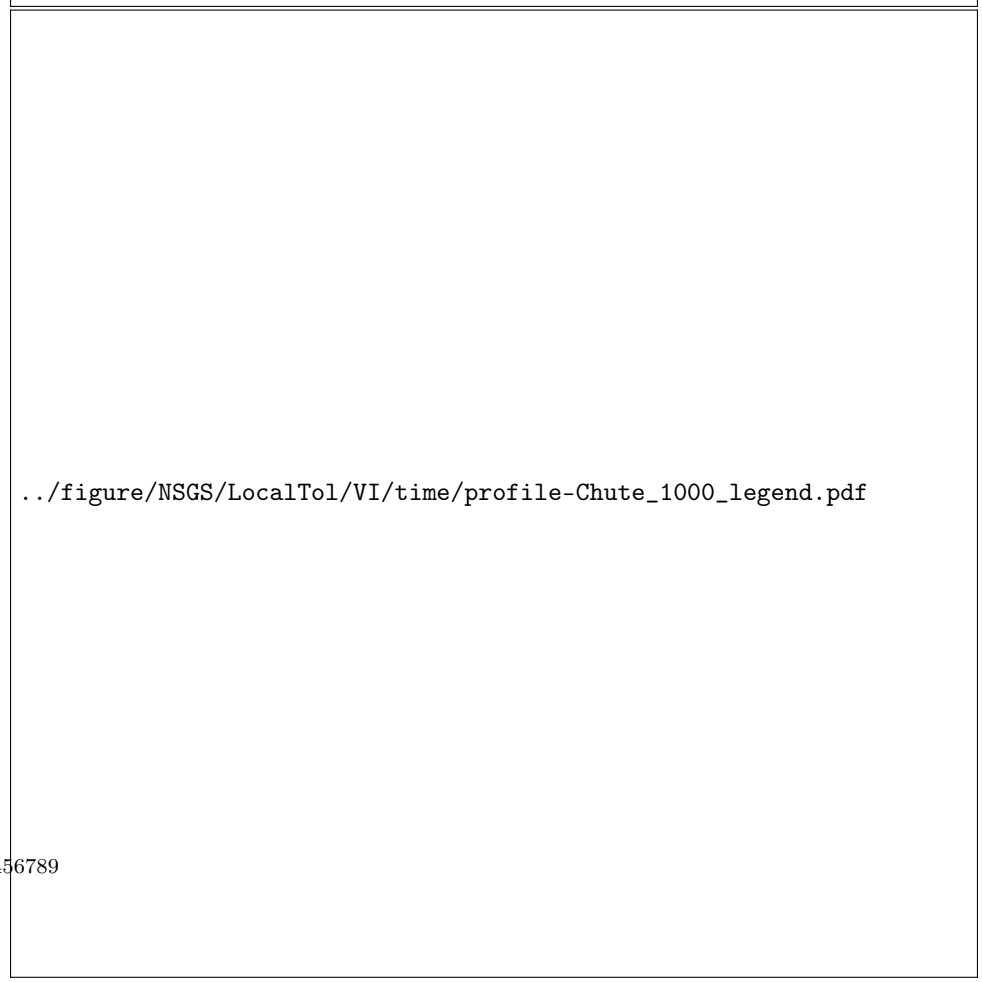


Figure 134: Chute_1000 time NSGS/LocalTol


../figure/NSGS/LocalTol/VI/time/profile-Chute_1000.pdf


../figure/NSGS/LocalTol/VI/time/profile-Chute_1000_legend.pdf

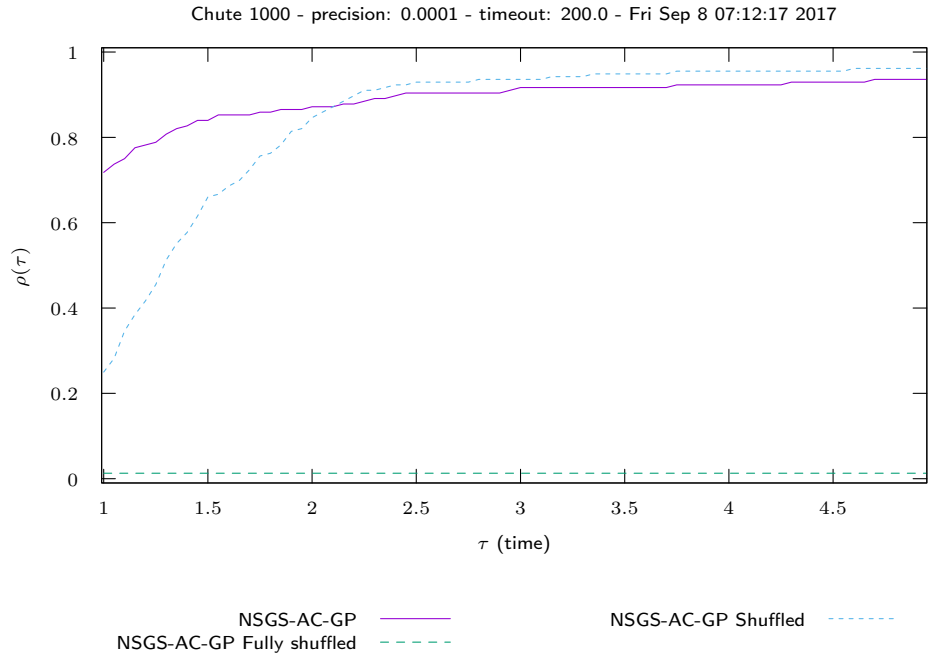


Figure 136: Chute_1000 time NSGS/Shuffled

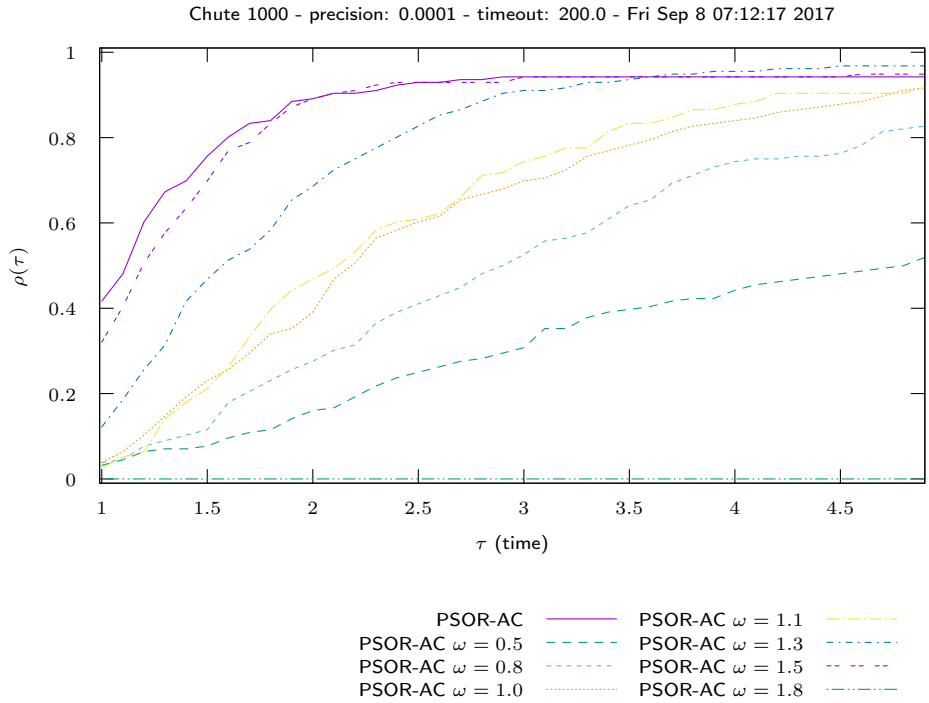


Figure 137: Chute_1000 time PSOR

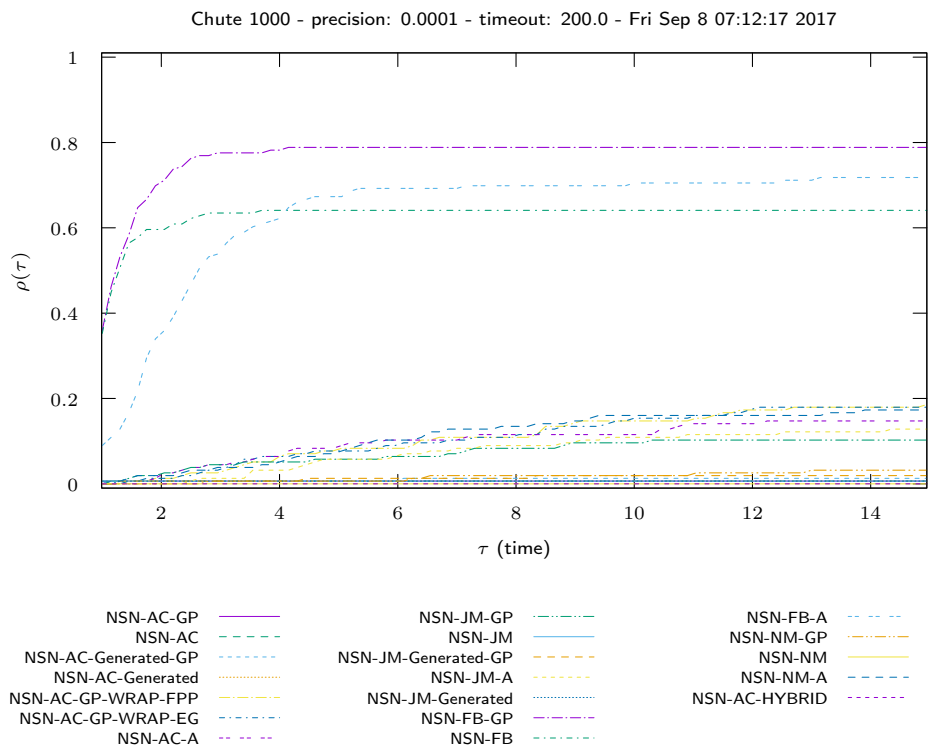


Figure 138: Chute_1000 time NSN

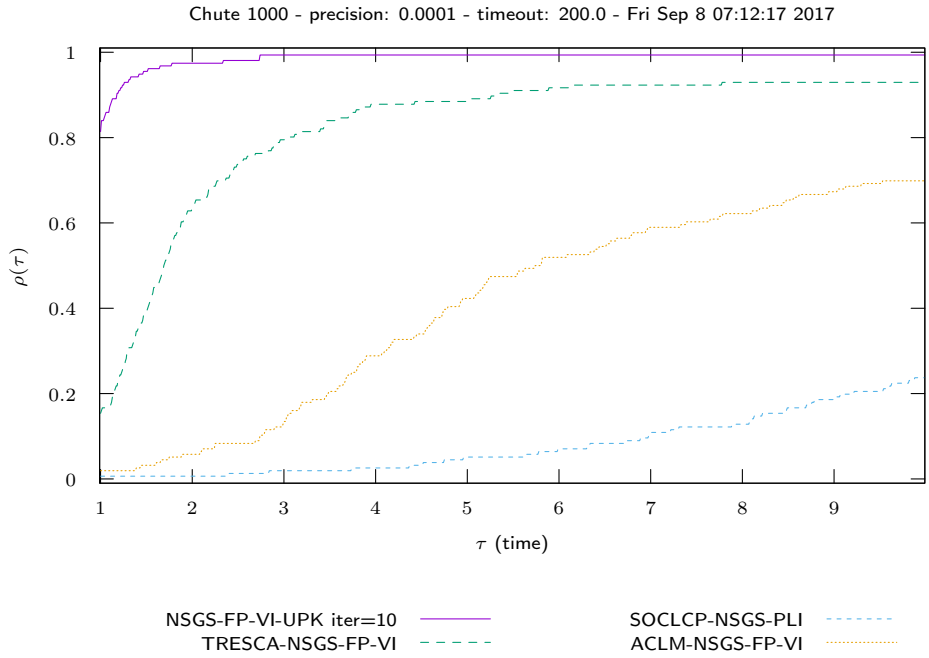


Figure 139: Chute_1000 time OPTI

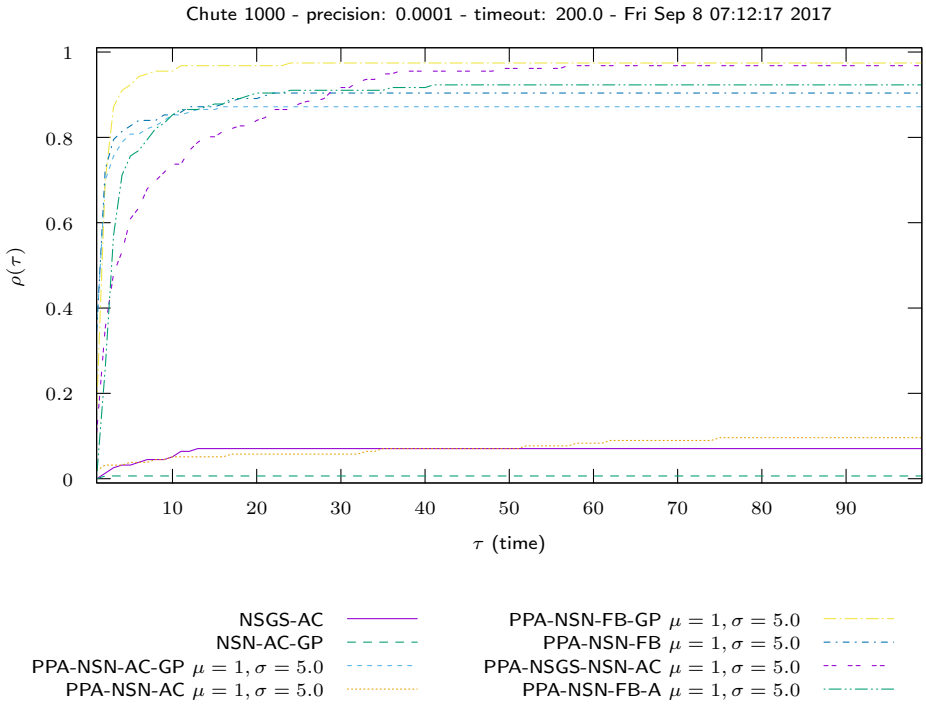
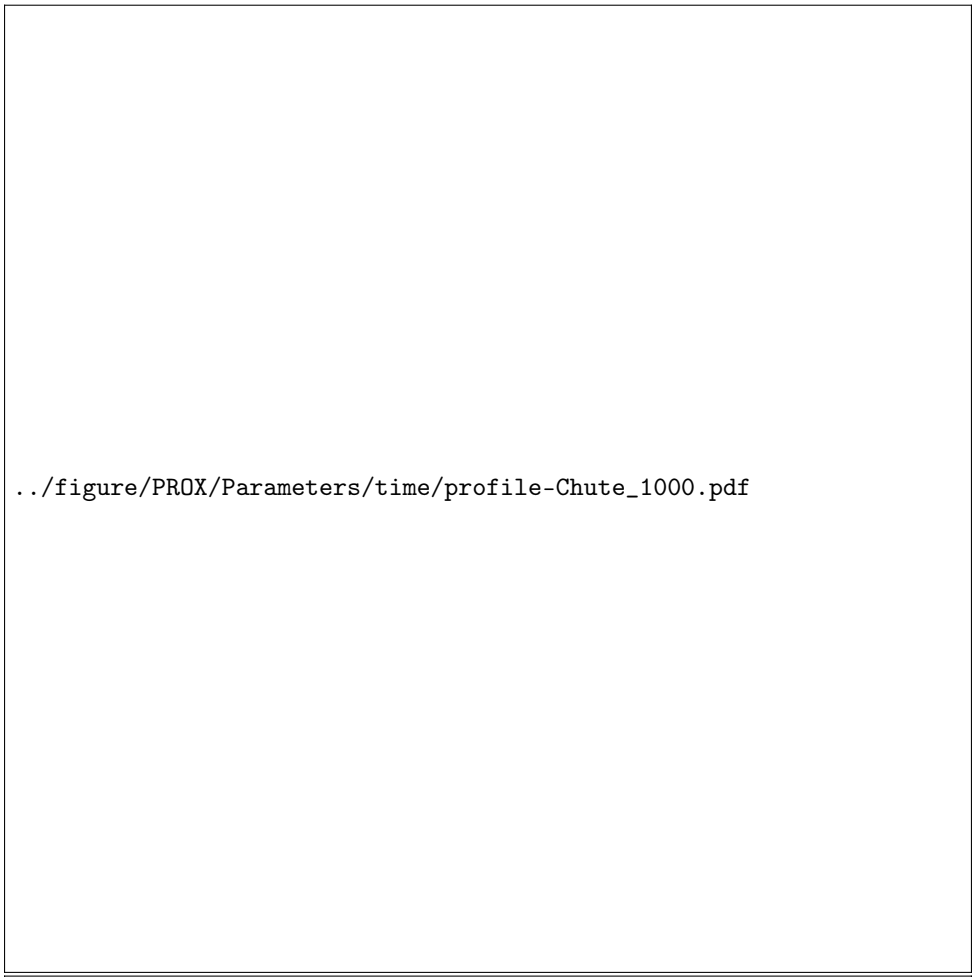
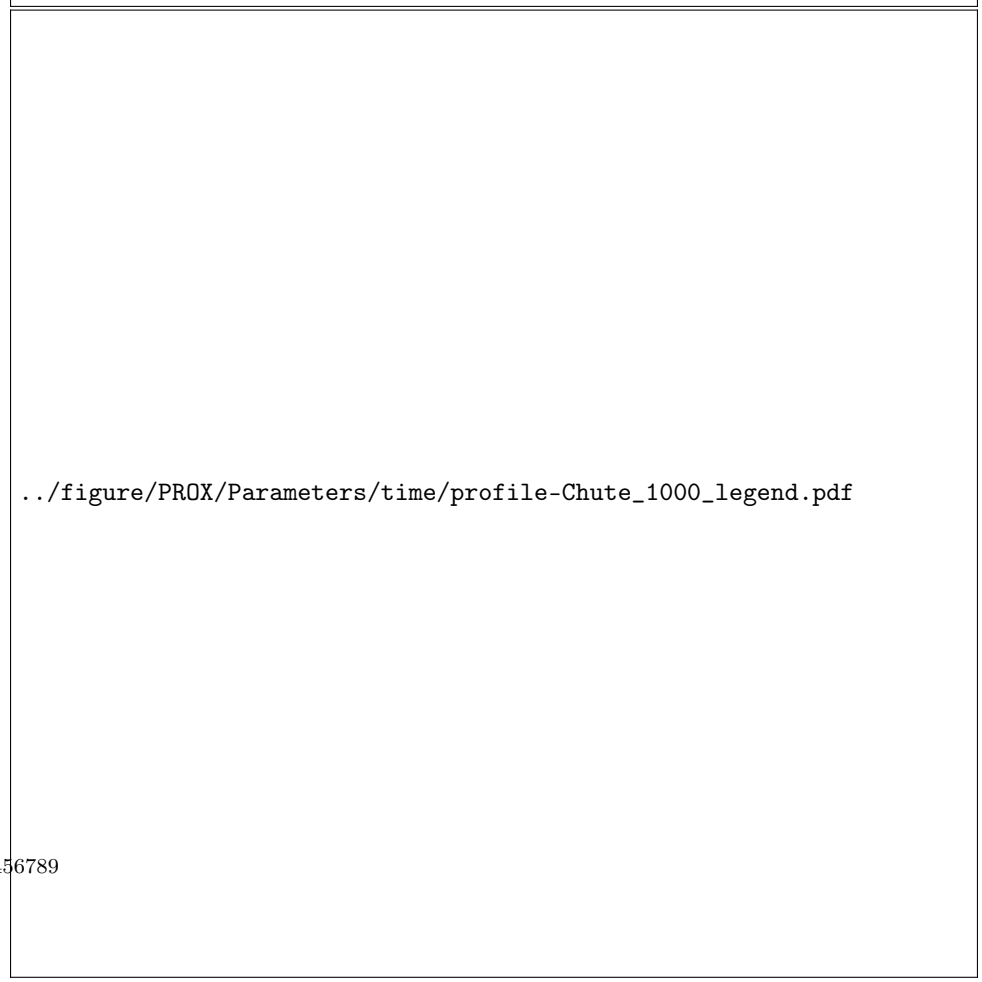


Figure 140: Chute_1000 time PROX/InternalSolvers


../figure/PROX/Parameters/time/profile-Chute_1000.pdf


../figure/PROX/Parameters/time/profile-Chute_1000_legend.pdf

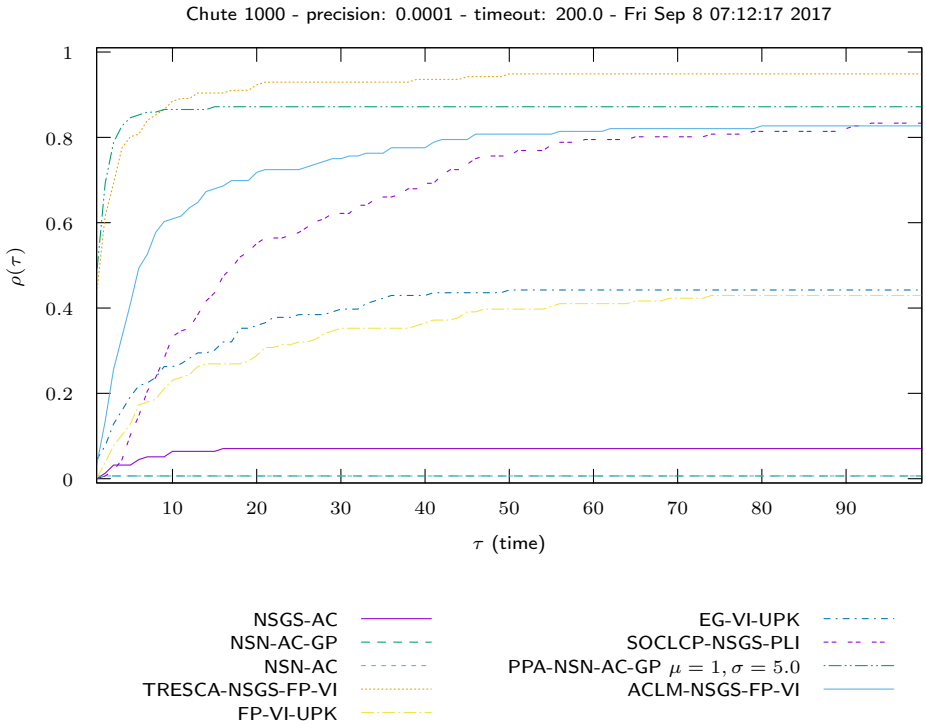


Figure 142: Chute_1000 time COMP/large

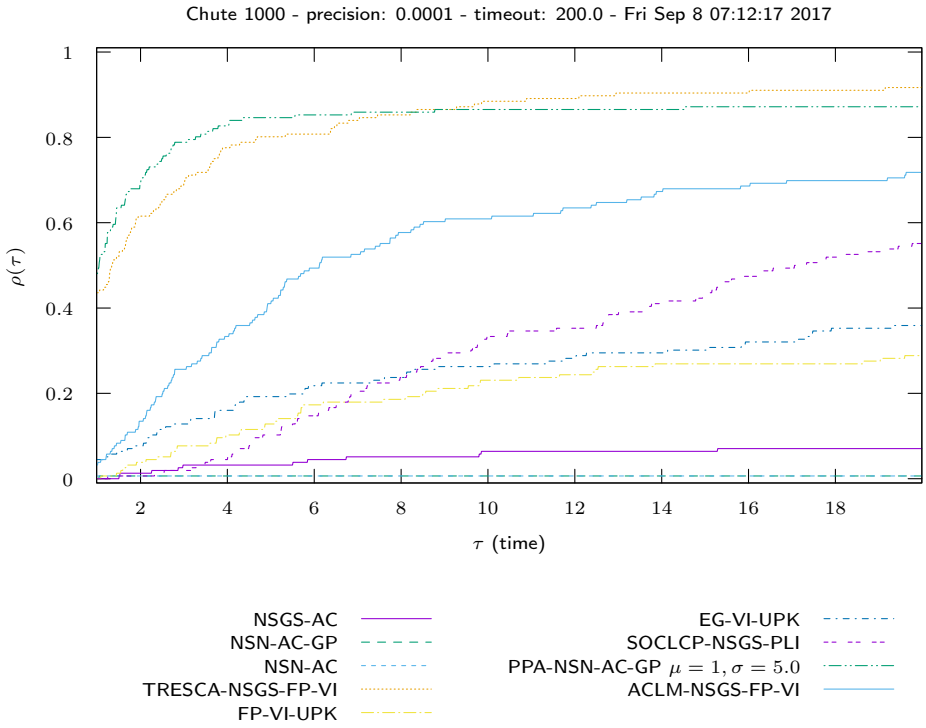
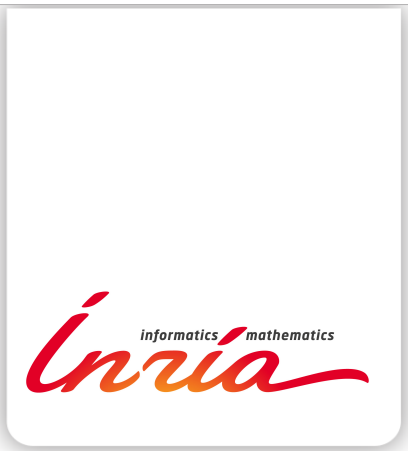


Figure 143: Chute_1000 time COMP/large



RESEARCH CENTRE
GRENOBLE – RHÔNE-ALPES

Inovallée

655 avenue de l'Europe Montbonnot

38334 Saint Ismier Cedex

Publisher

Inria

Domaine de Voluceau - Rocquencourt

BP 105 - 78153 Le Chesnay Cedex

inria.fr

ISSN 0249-6399