Simulation of beamstrahlung at LEP3

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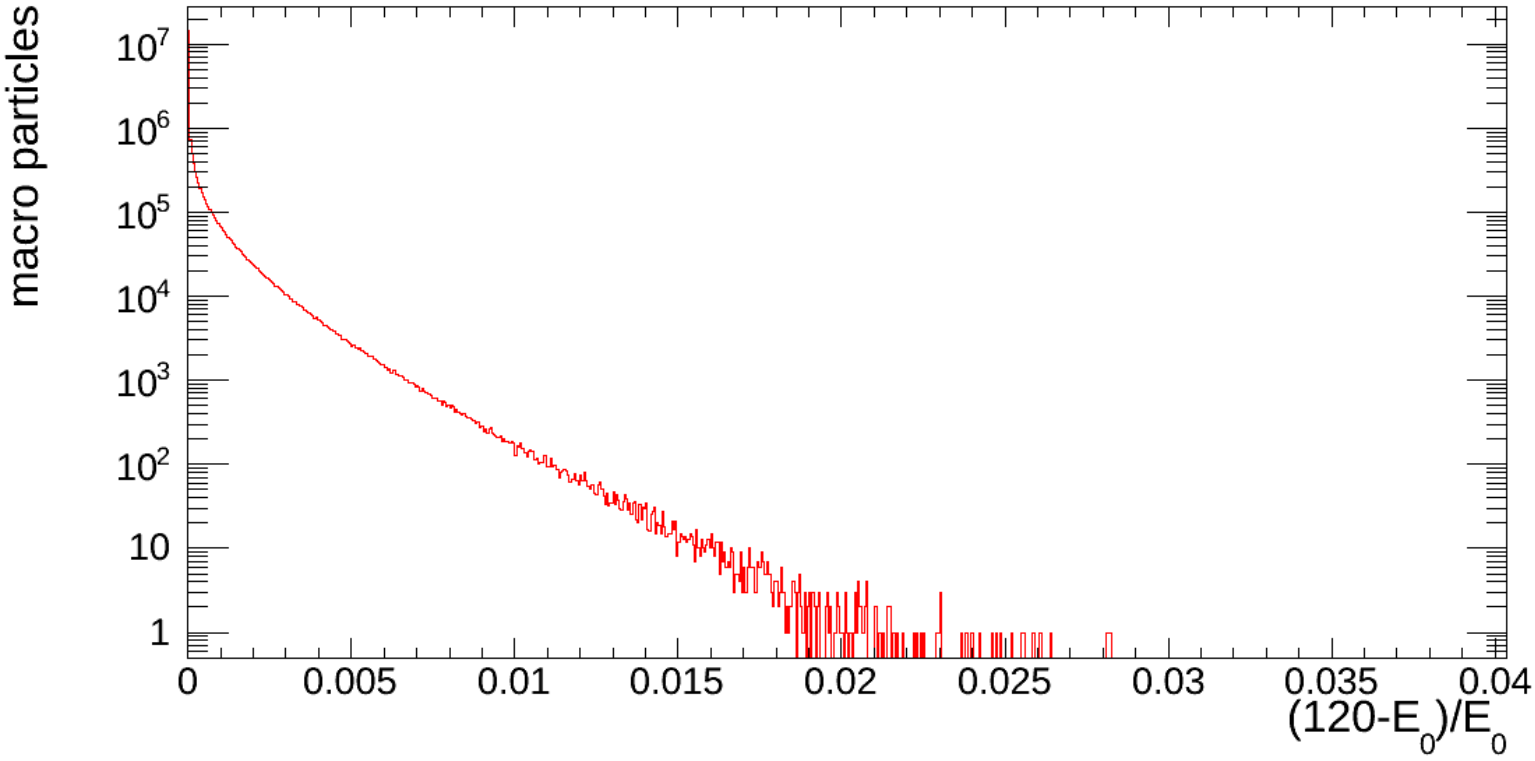
Introduction

- Firstly proposed beam parameters resulted to lead to unacceptable beamstrahlung effects
  - Lifetime of a few seconds
  - V. Telnov, http://arxiv.org/abs/1203.6563, based on analytic formulation of the problem
- We report on the studies done using a detailed simulation based on GuineaPig
- The goal was to find a working point such that:
  - The instantaneous luminosity results to be similar to the one originally proposed
  - The lifetime due to BS is ~30min

GuineaPig Simulation

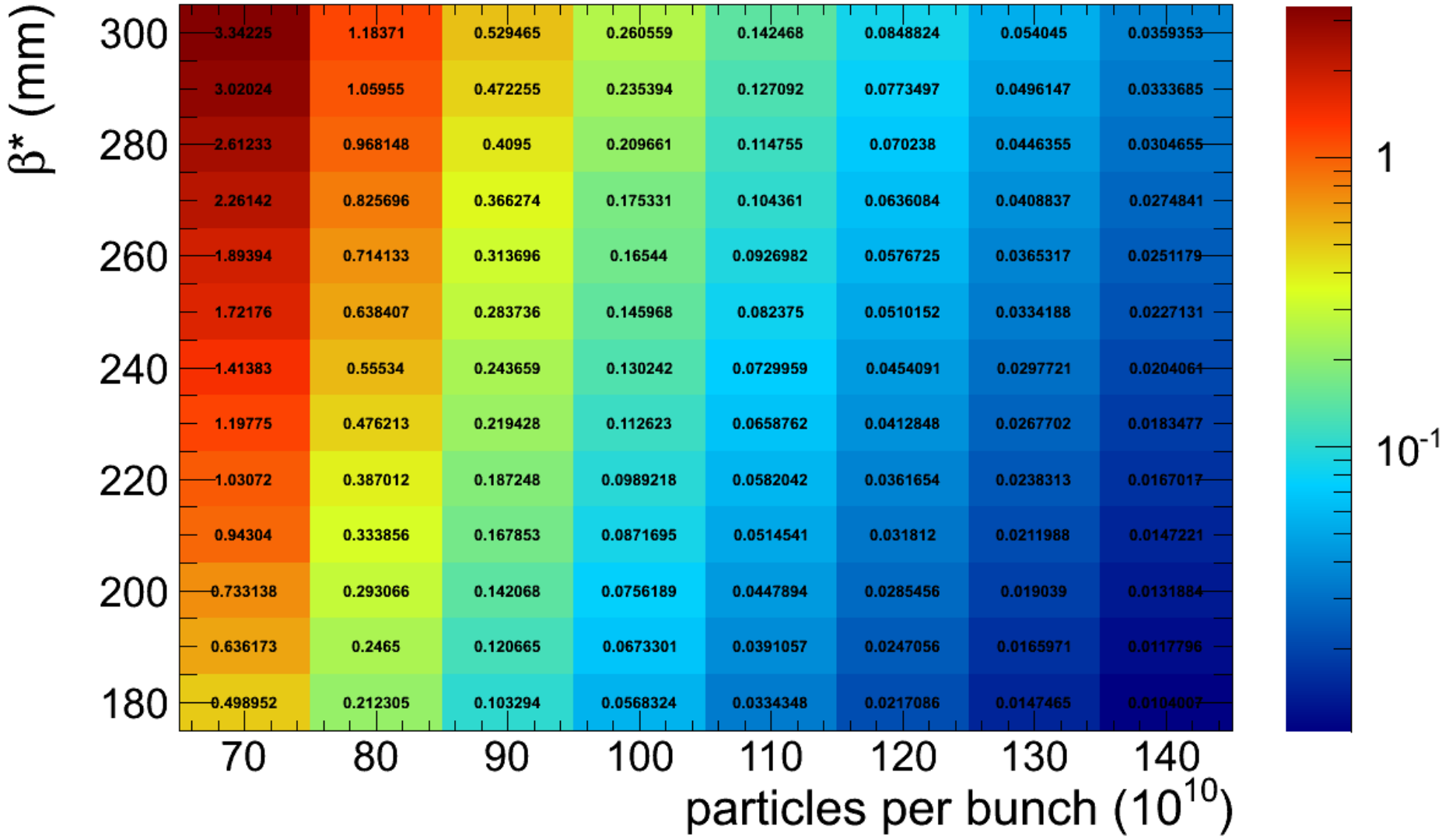
- Use template datacard with default parameters reflecting LEP3 ones
  - http://mzanetti.web.cern.ch/mzanetti/accTemplate.dat
- Scan number of particles per bunch and β^* and keep the other parameters constant
  - Number of charges and horizontal beam size affect BS the most
  - Enable "energy spread" an "energy loss", switch off the rest
- Compute lifetime from the fraction r of particles beyond max allowed energy spread, $E<E_0(1-\eta)$
  - Lifetime = $1/r\nu$
- Use enough macroparticle (20M) to allow estimating lifetime of the order of ~30 min
- Example of output:
  - http://mzanetti.web.cern.ch/mzanetti/gp_workingpoint.out

Energy spectrum

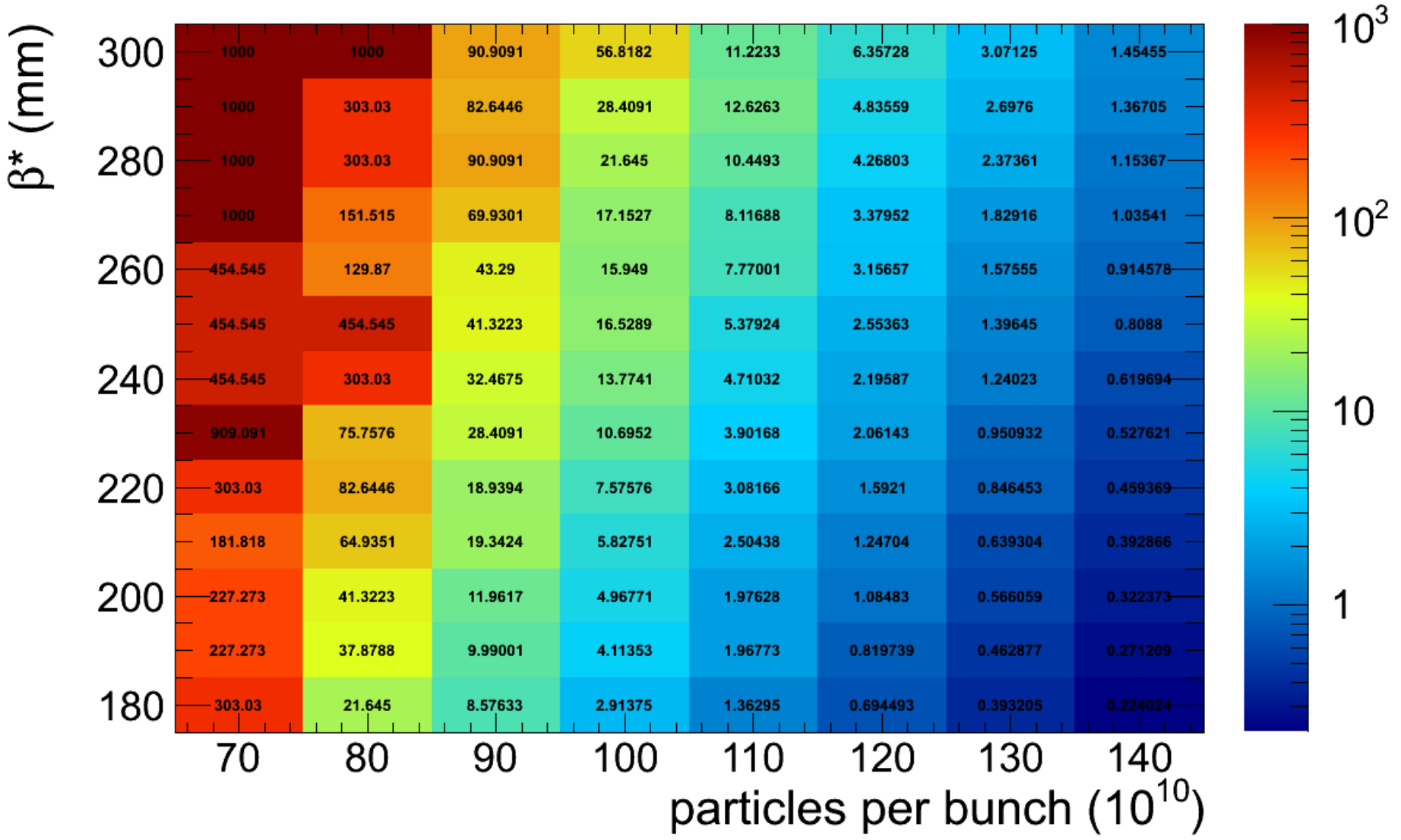


- Lifetime has an exponential dependency on energy acceptance

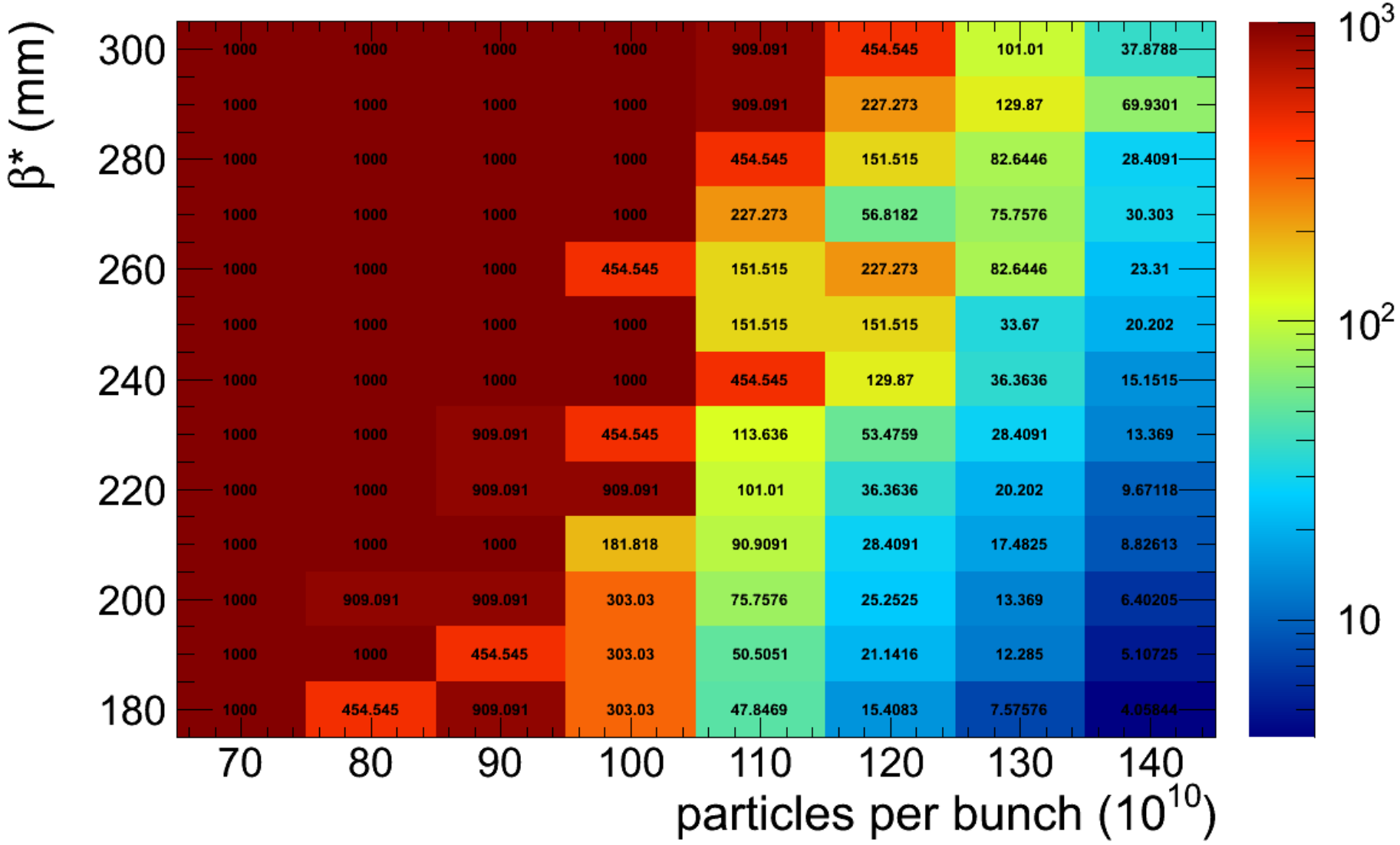
Results η=1


β* (mm)
300
280
260
240
220
200
180
3.34225 1.18371 0.529465 0.260559 0.142468 0.0848824 0.054045 0.0359353
3.02024 1.05955 0.472255 0.235394 0.127092 0.0773497 0.0496147 0.0333685
2.61233 0.968148 0.4095 0.209661 0.114755 0.070238 0.0446355 0.0304655
2.26142 0.825696 0.366274 0.175331 0.104361 0.0636084 0.0408837 0.0274841
1.89394 0.714133 0.313696 0.16544 0.0926982 0.0576725 0.0365317 0.0251179
1.72176 0.638407 0.283736 0.145968 0.082375 0.0510152 0.0334188 0.0227131
1.41383 0.55534 0.243659 0.130242 0.0729959 0.0454091 0.0297721 0.0204061
1.19775 0.476213 0.219428 0.112623 0.0658762 0.0412848 0.0267702 0.0183477
1.03072 0.387012 0.187248 0.0989218 0.0582042 0.0361654 0.0238313 0.0167017
0.94304 0.333856 0.167853 0.0871695 0.0514541 0.031812 0.0211988 0.0147221
0.733138 0.293066 0.142068 0.0756189 0.0447894 0.0285456 0.019039 0.0131884
0.636173 0.2465 0.120665 0.0673301 0.0391057 0.0247056 0.0165971 0.0117796
0.498952 0.212305 0.103294 0.0568324 0.0334348 0.0217086 0.0147465 0.0104007
70 80 90 100 110 120 130 140
particles per bunch (10^{10})
1
10^{-1}

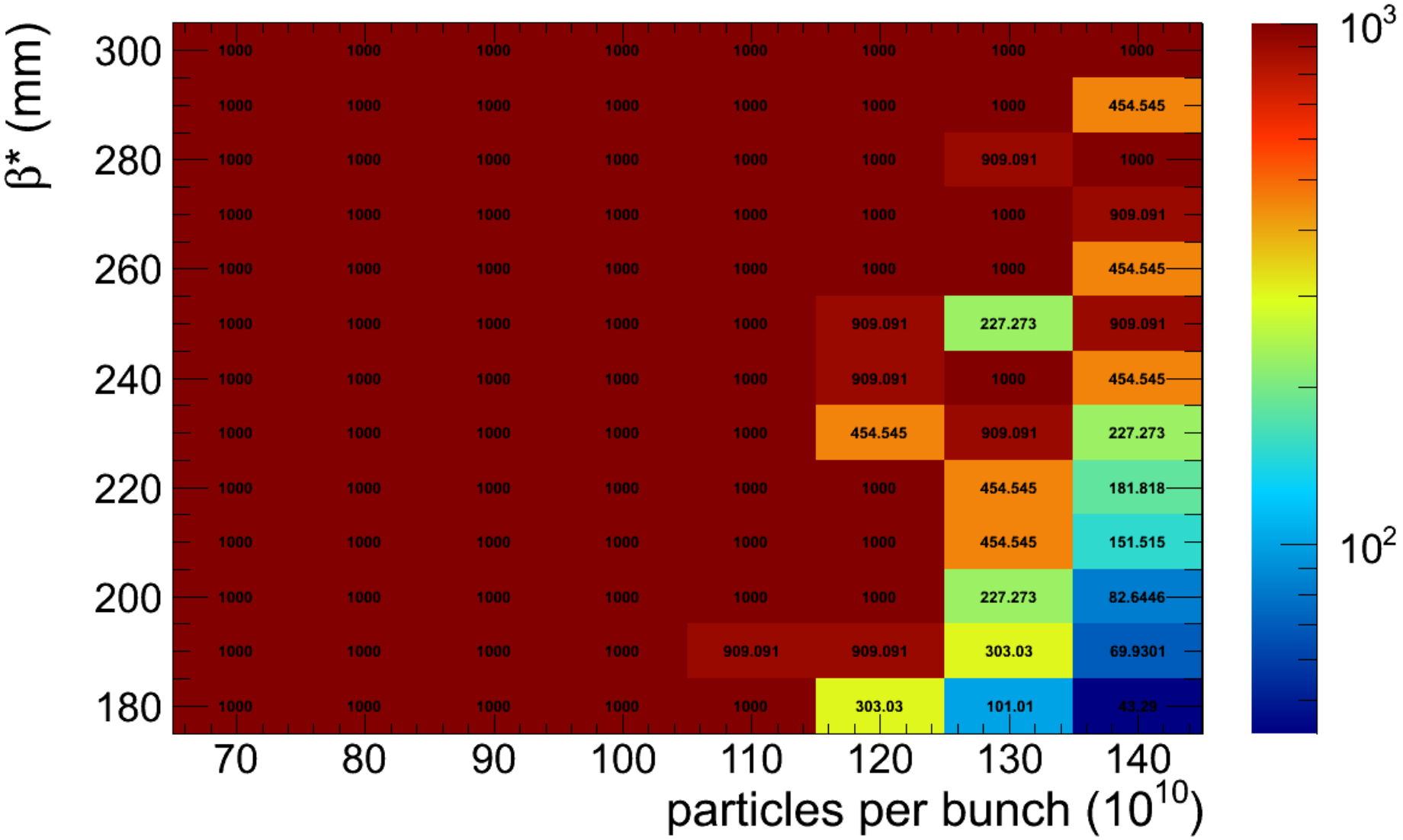
Results η=2


β* (mm)
300
280
260
240
220
200
180
1000 1000 90.9091 56.8182 11.2233 6.35728 3.07125 1.45455
1000 303.03 82.6446 28.4091 12.6263 4.83559 2.6976 1.36705
1000 303.03 90.9091 21.645 10.4493 4.26803 2.37361 1.15367
1000 151.515 69.9301 17.1527 8.11688 3.37952 1.82916 1.03541
454.545 129.87 43.29 15.949 7.77001 3.15657 1.57555 0.914578
454.545 454.545 41.3223 16.5289 5.37924 2.55363 1.39645 0.8088
454.545 303.03 32.4675 13.7741 4.71032 2.19587 1.24023 0.619694
909.091 75.7576 28.4091 10.6952 3.90168 2.06143 0.950932 0.527621
303.03 82.6446 18.9394 7.57576 3.08166 1.5921 0.846453 0.459369
181.818 64.9351 19.3424 5.82751 2.50438 1.24704 0.639304 0.392866
227.273 41.3223 11.9617 4.96771 1.97628 1.08483 0.566059 0.322373
227.273 37.8788 9.99001 4.11353 1.96773 0.819739 0.462877 0.271209
303.03 21.645 8.57633 2.91375 1.36295 0.694493 0.393205 0.224024
70 80 90 100 110 120 130 140
particles per bunch (10^{10})
10^3
10^2
10
1

Results η=3


β* (mm)
300
280
260
240
220
200
180
70
80
90
100
110
120
130
140
particles per bunch (10^{10})
1000 1000 1000 1000 909.091 454.545 101.01 37.8788
1000 1000 1000 1000 909.091 227.273 129.87 69.9301
1000 1000 1000 1000 454.545 151.515 82.6446 28.4091
1000 1000 1000 1000 227.273 56.8182 75.7576 30.303
1000 1000 1000 454.545 151.515 227.273 82.6446 23.31
1000 1000 1000 1000 151.515 151.515 33.67 20.202
1000 1000 1000 1000 454.545 129.87 36.3636 15.1515
1000 1000 909.091 454.545 113.636 53.4759 28.4091 13.369
1000 1000 909.091 909.091 101.01 36.3636 20.202 9.67118
1000 1000 1000 181.818 90.9091 28.4091 17.4825 8.82613
1000 909.091 909.091 303.03 75.7576 25.2525 13.369 6.40205
1000 1000 454.545 303.03 50.5051 21.1416 12.285 5.10725
1000 454.545 909.091 303.03 47.8469 15.4083 7.57576 4.05844
10^3
10^2
10

Results η=4


β* (mm)
300
280
260
240
220
200
180
70
80
90
100
110
120
130
140
particles per bunch (10^{10})
1000 1000 1000 1000 1000 1000 1000 1000
1000 1000 1000 1000 1000 1000 1000 454.545
1000 1000 1000 1000 1000 1000 909.091 1000
1000 1000 1000 1000 1000 1000 1000 909.091
1000 1000 1000 1000 1000 1000 1000 454.545
1000 1000 1000 1000 1000 909.091 227.273 909.091
1000 1000 1000 1000 1000 909.091 1000 454.545
1000 1000 1000 1000 1000 454.545 909.091 227.273
1000 1000 1000 1000 1000 1000 454.545 181.818
1000 1000 1000 1000 1000 1000 454.545 151.515
1000 1000 1000 1000 1000 1000 227.273 82.6446
1000 1000 1000 1000 909.091 909.091 303.03 69.9301
1000 1000 1000 1000 1000 303.03 101.01 43.29
10^3
10^2

LEP3 parameters

	LEP3.1	LEP3.2
β_x^* (m)	0.15	0.2
ε_x^* (nm)	20	25
β_y^* (mm)	1.2	1
ε_y^* (nm)	0.15	0.1
charges/bunch	4e12/3	4e12/4
h	2%	4%
L/IP ($10^{32c}cm^{-2}Hz$)	1.3	1.1

- Try to recover in vertical what lost in horizontal
- 4 instead of 3 bunches
- Much more relaxed conditions in case energy acceptance is larger
- Possible to recover the initially proposed instantaneous luminosity

Summary

- Analytic computation verified by simulation
  - Very short lifetime for original beam parameters
  - Negligible effect on energy spread
  - Number of gammas <1 (0.6)
- 10^{34} $cm^{-2}Hz$ can still be reached with a BS lifetime of 30 min if:
  - energy acceptance is increased to 3-4%
  - Horizontal beam size is enlarged, partially recover from diminishing vertical one