DISCRETE LCLS FEL TAPERING

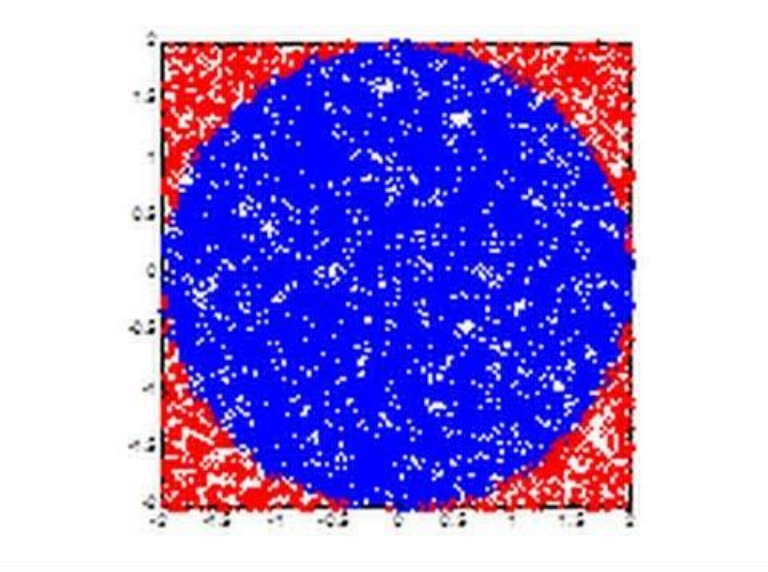
MARKOV CHAIN MONTE CARLO & SIMULATED ANNEALING

HAN SETIAWAN

SLAC, 10 AUGUST 2016

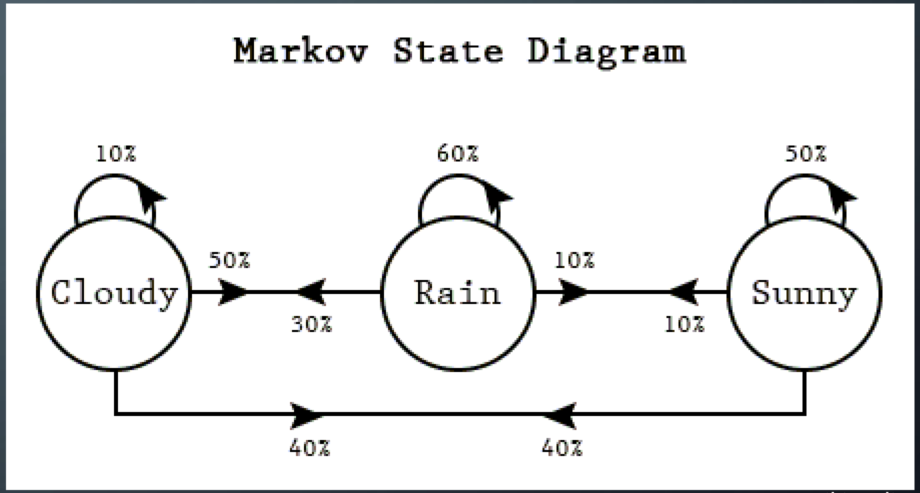
MONTE CARLO METHOD

- Random, probabilistic way to solve an optimization problem
  - For complicated problems
- No relationship between current and next step



MARKOV CHAIN MONTE CARLO OPTIMIZATION

- Improved!
- Find local/global maximum/minimum



wikipedia

ALGORITHM
EXAMPLE: FINDING LOCATION WITH HIGHER/EST TEMPERATURE

- **Start somewhere**
- Evaluate the local temperature
- Take the next step, based on a normal distribution
- Take temperature reading
- If the new T is greater, move there
- If not, find the ratio P=(T_new/T_old); generate random number from 0 to 1
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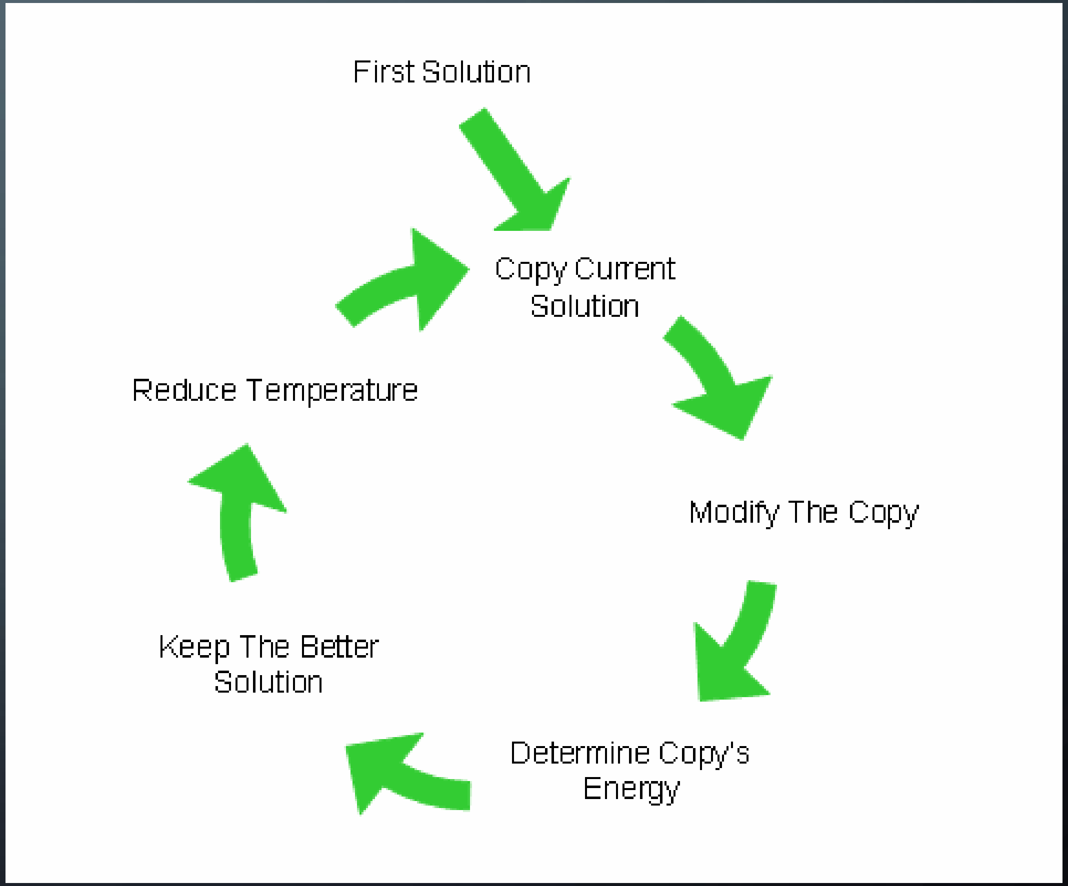
Repeat and Restart

MARKOV CHAIN MONTE CARLO
+ SIMULATED ANNEALING

- Mimics cooling down process of metal
- As T goes down =>

less likely to accept worse solution



ALGORITHM
EXAMPLE: FINDING LOCATION WITH HIGHER/EST ALTITUDE

- **Start somewhere; Set initial SA temperature**
- Find out current altitude
- Take the next step, based on a normal distribution
- Find out new altitude
- If the new altitude is greater, move there
- If not, find the ratio $P=\exp((A_{new}-A_{old})/A_{old}*1/T)$; generate random number from 0 to 1
- If P>random number, move there; reduce the SA temperature by a factor of alpha

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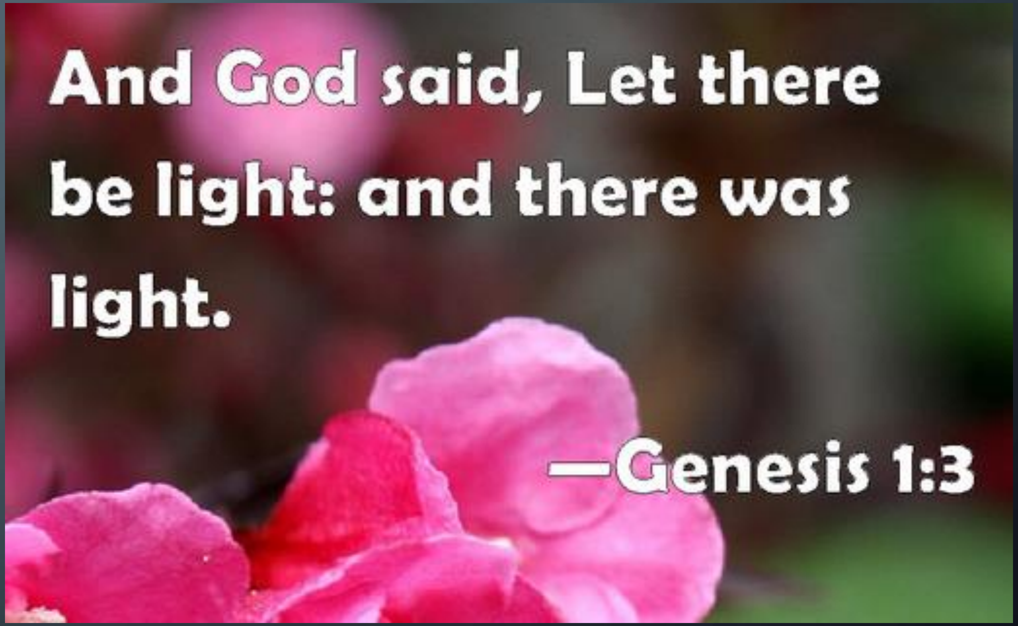
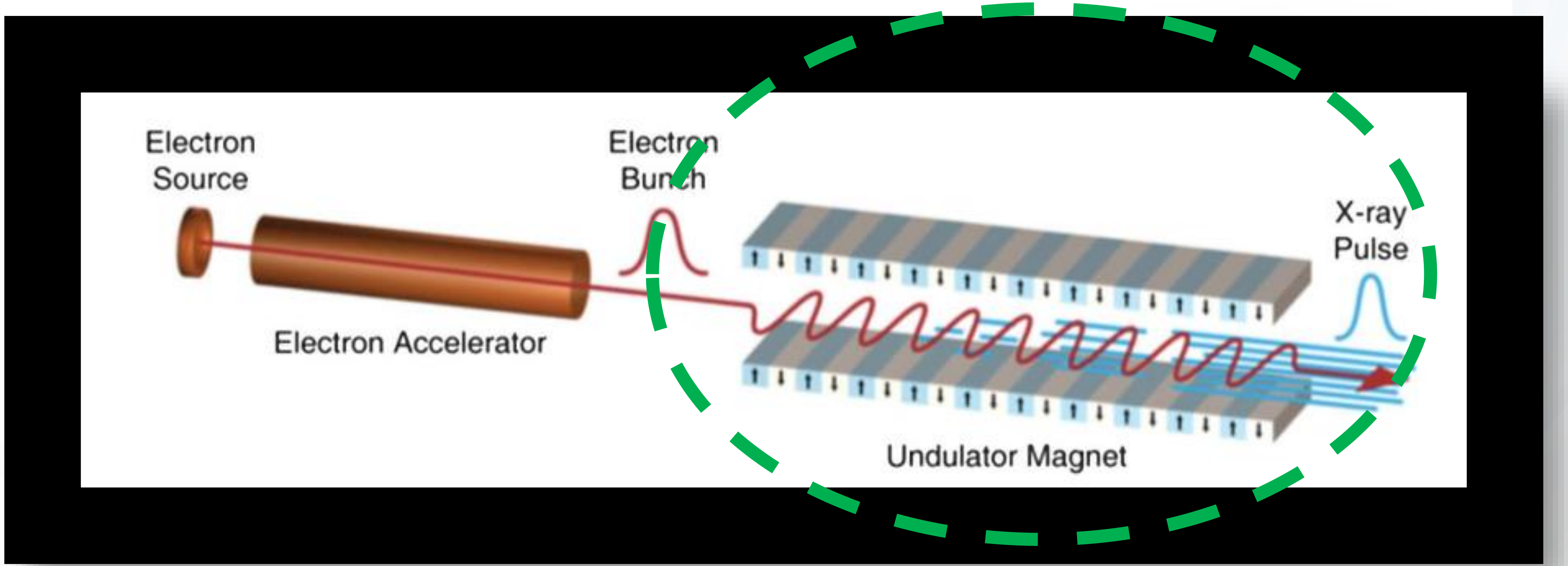
GENESIS 1.3 SIMULATION

- Simulates LCLS
- Why not use LCLS directly?



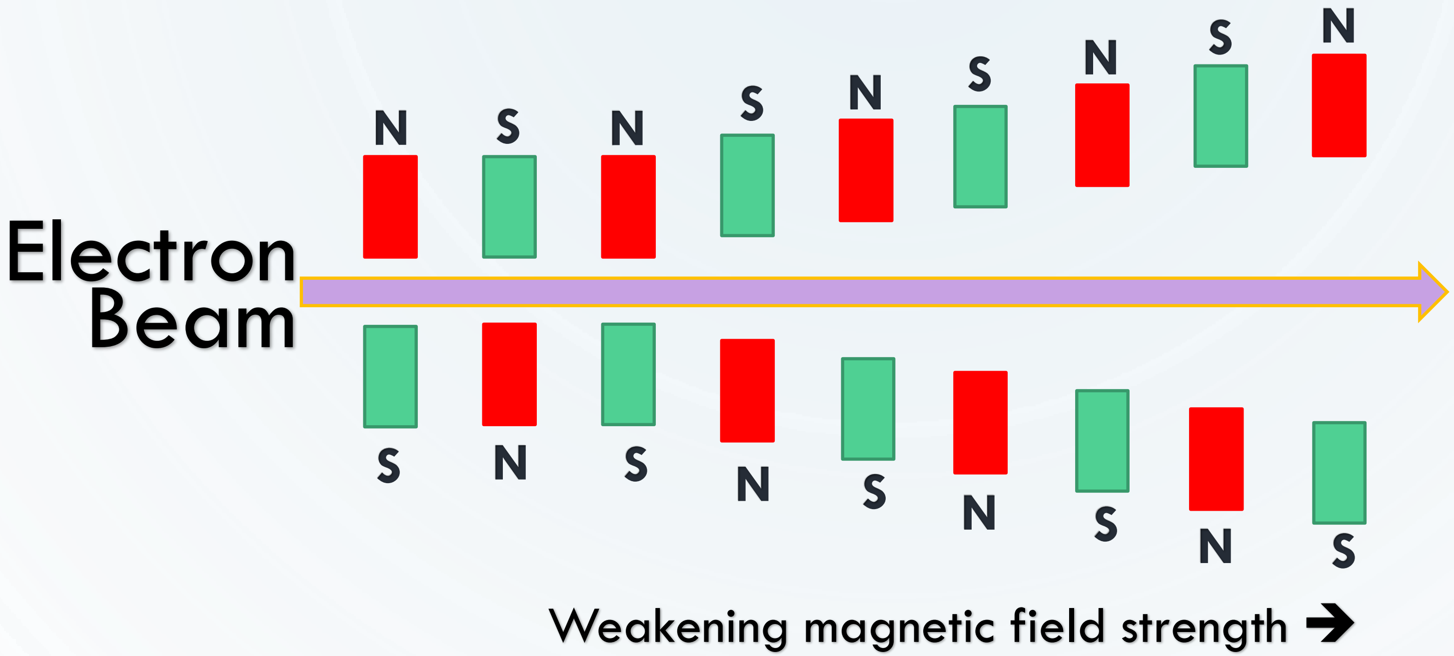

YC15 OJN

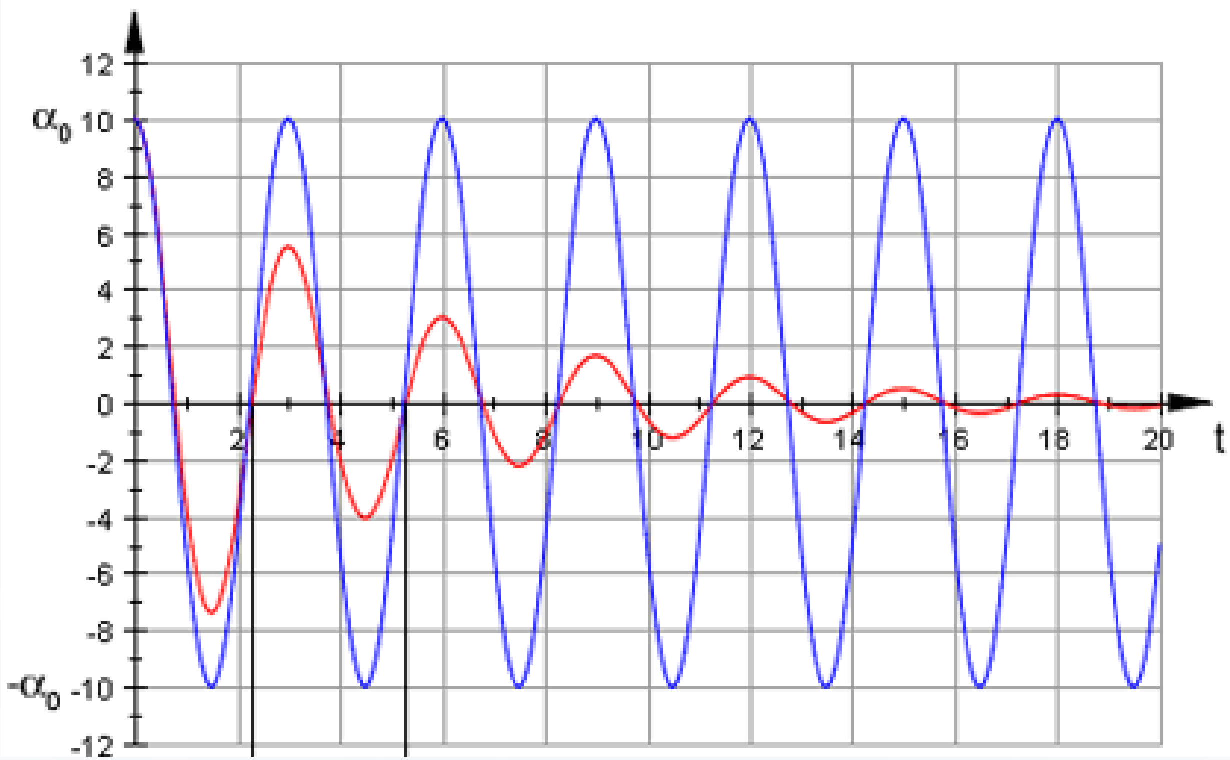
LCLS (LINAC COHERENT LIGHT SOURCE)



PROBLEM

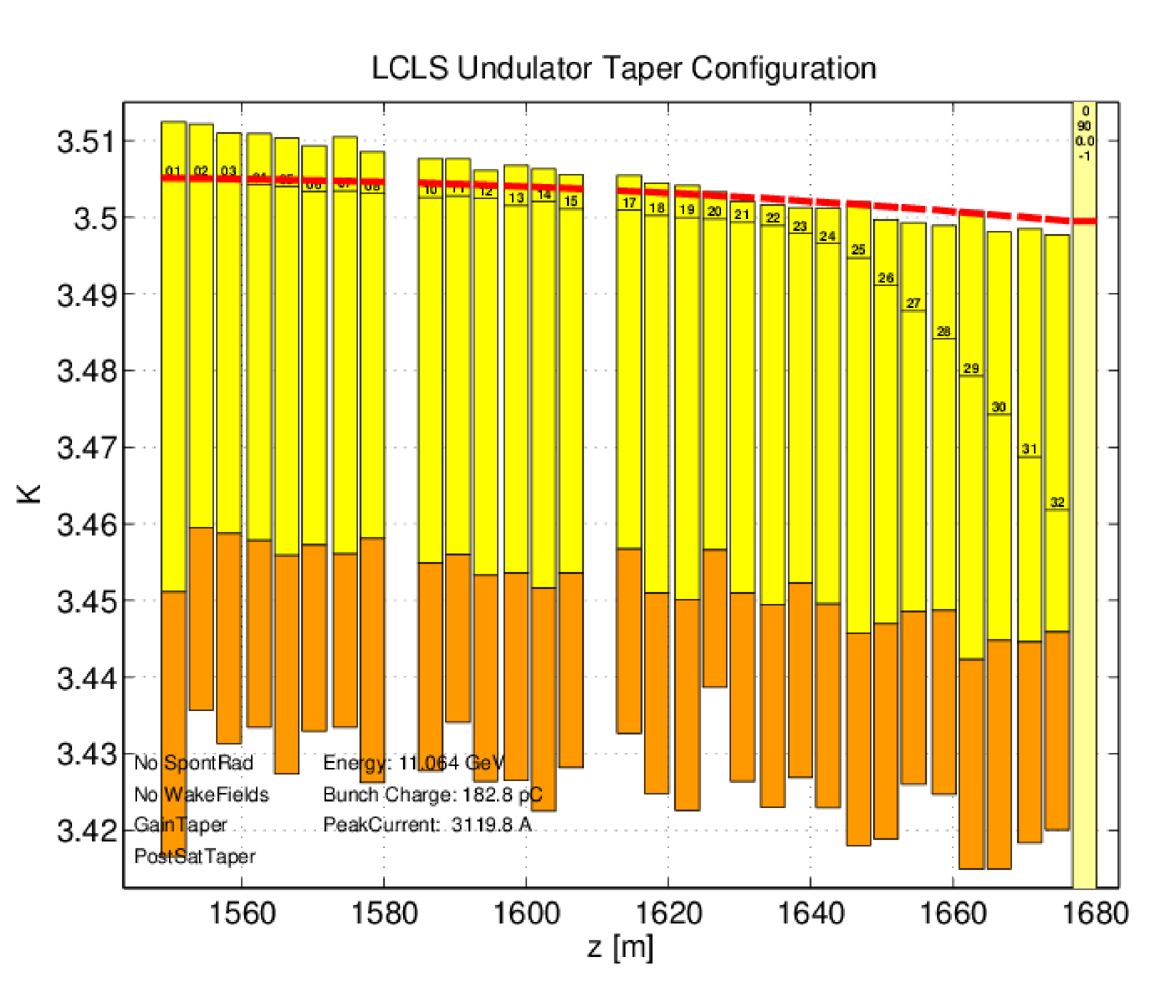
- As electron emits photons, it loses energy
- Slightly gets out of phase; not good
  - Destructive interference
- Solution? Taper the Undulator magnetic field

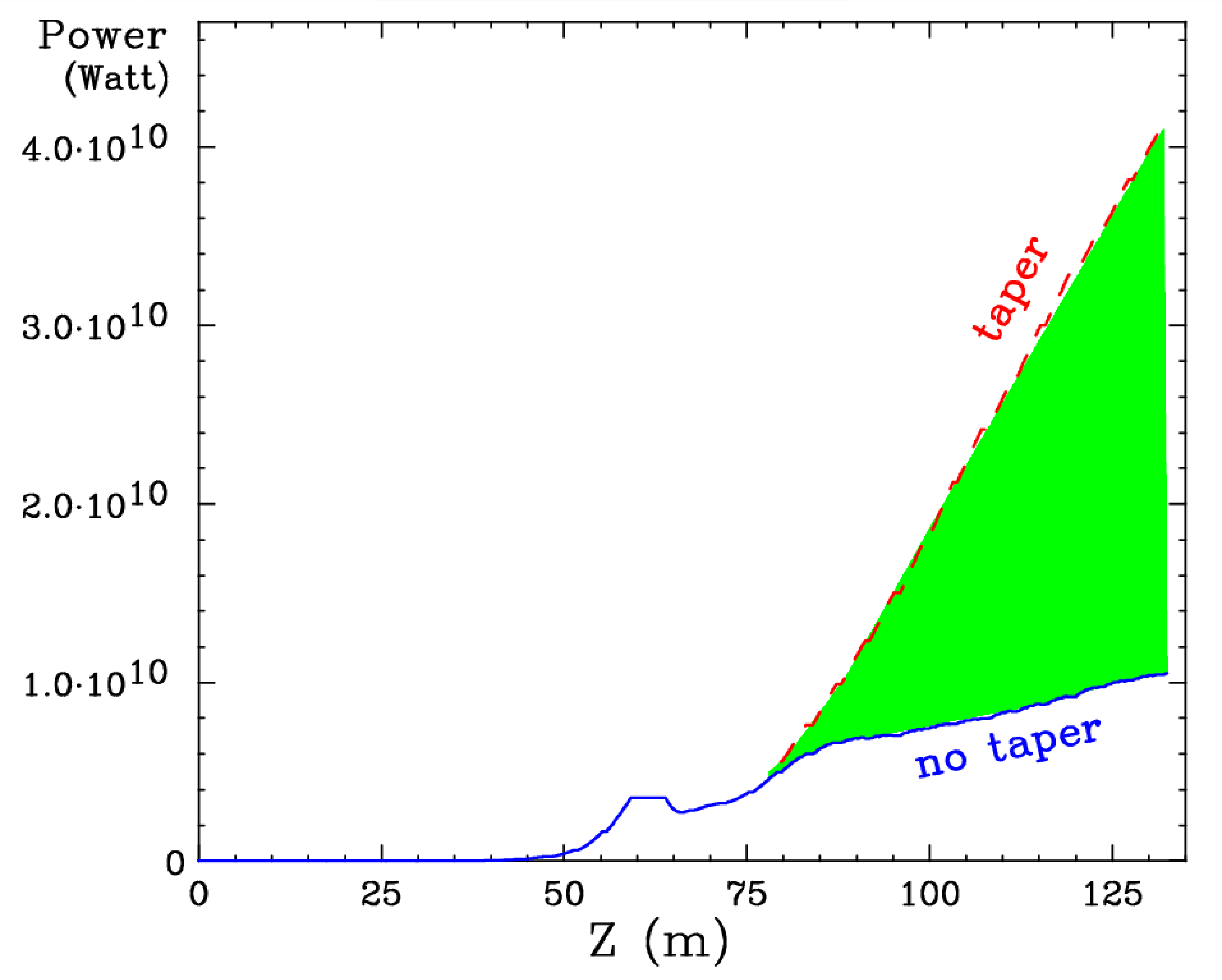

Electron Beam
N
S
N
S
N
S
N
S
N
S
N
S
N
S
N
S
N
S
Weakening magnetic field strength ➔



12
α0 10
8
6
4
2
0
-2
-4
-6
-8
-α0 -10
-12
2
4
6
8
10
12
14
16
18
20
t

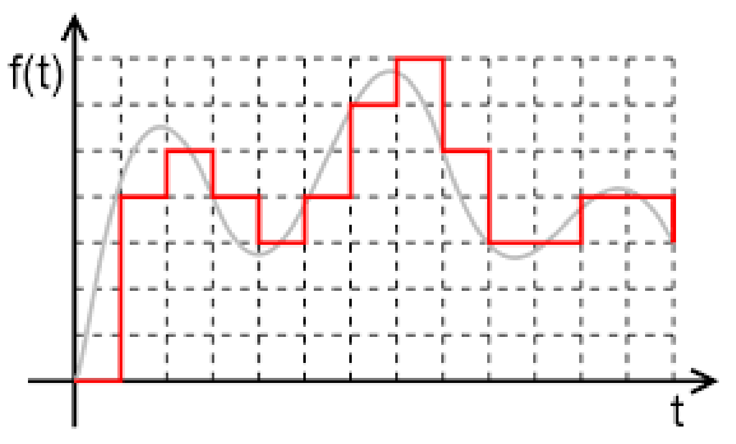
LCLS NOW: CONTINUOUS TAPERING




Power (Watt)
4.0·10^10
3.0·10^10
2.0·10^10
1.0·10^10
0
0
25
50
75
100
125
Z (m)
taper
no taper

LCLS NOW: CONTINUOUS TAPERING

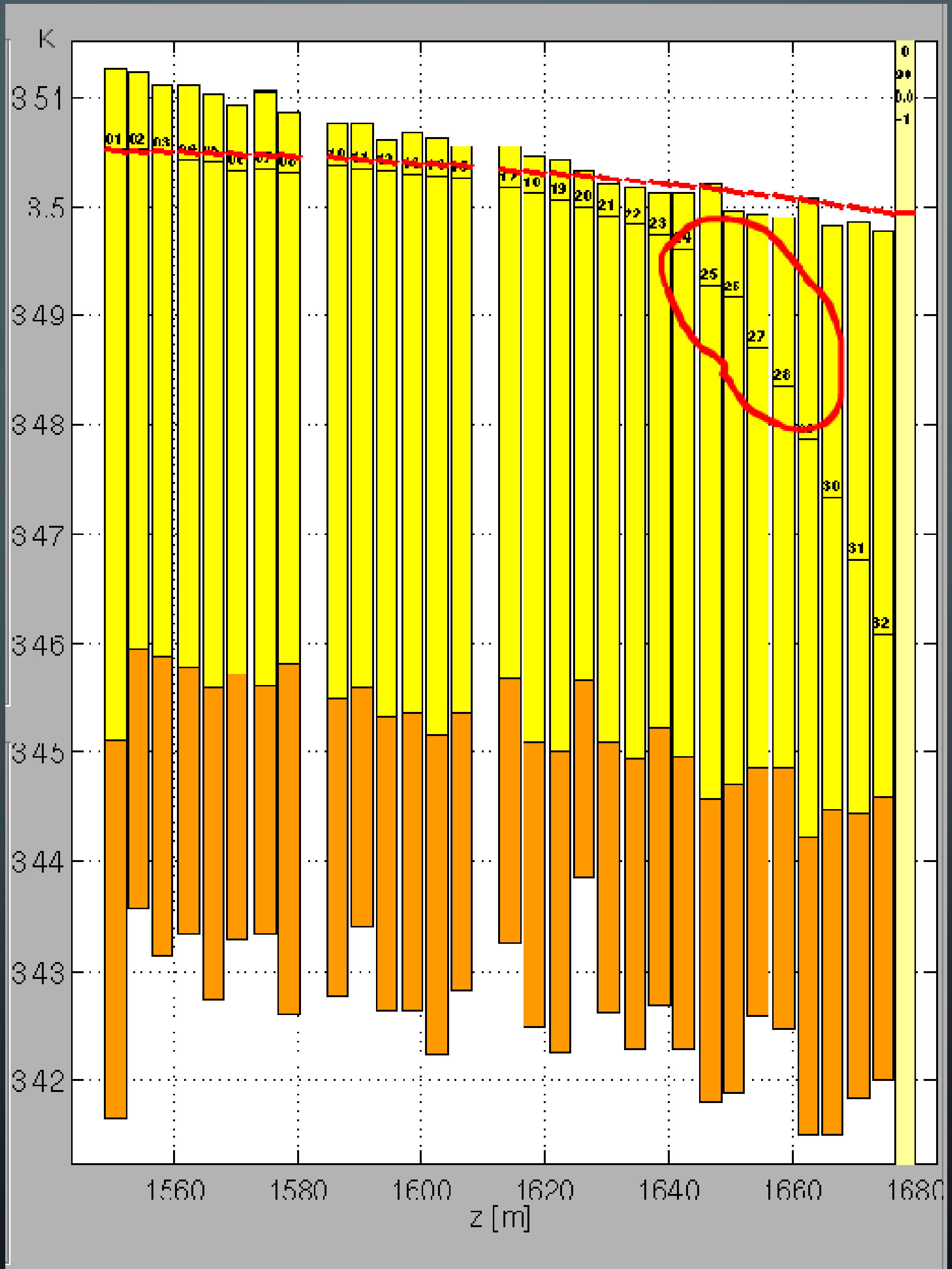
- Can we increase power of x-ray?
- Instead of continuous, maybe discrete?
    - Allows flexibility

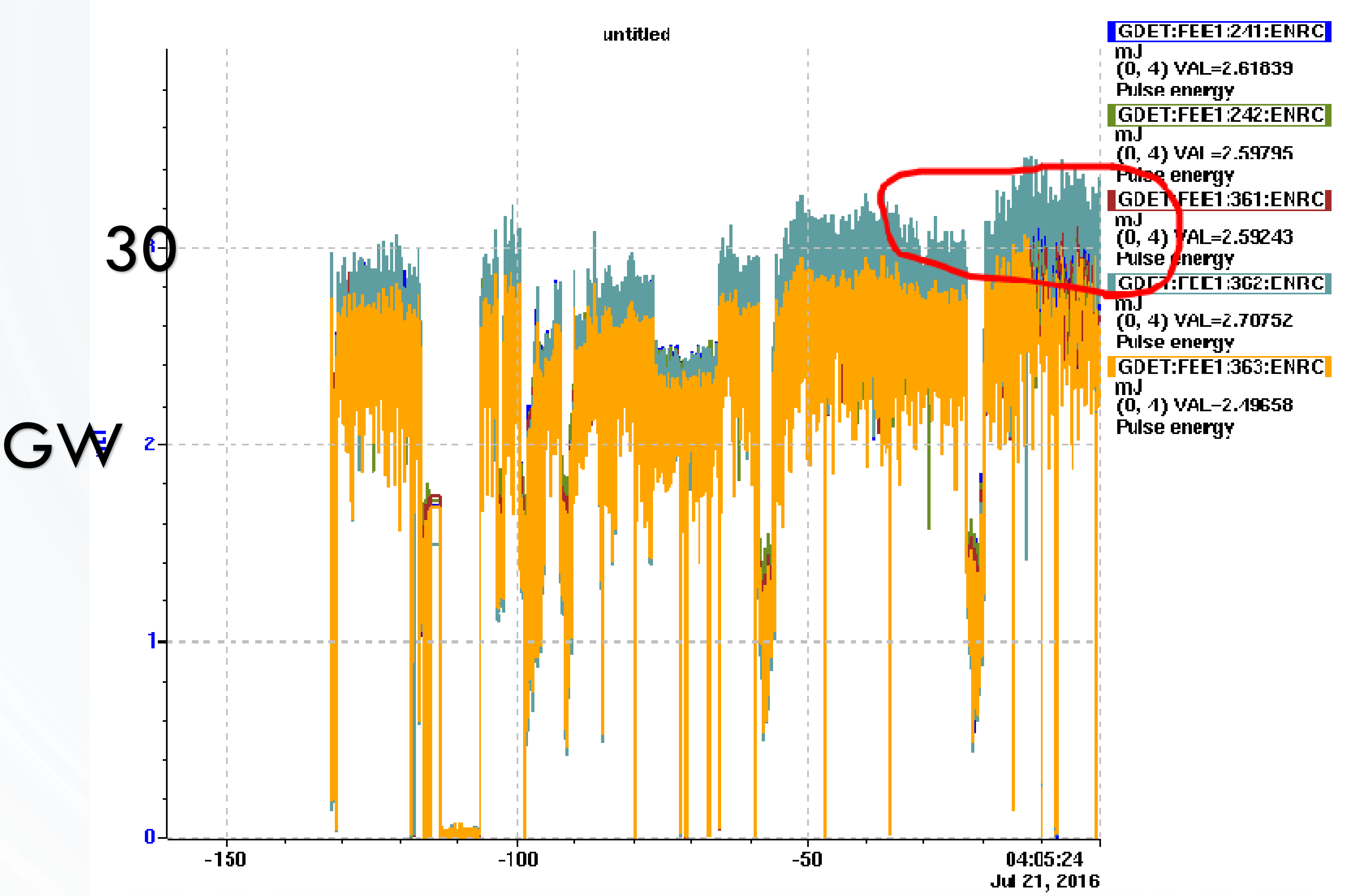


IMPORTANCE OF BRACKET IN DISCRETIZATION

- Define scan range at every undulator
- To ensure that K-values are inside the allowed (practical) range

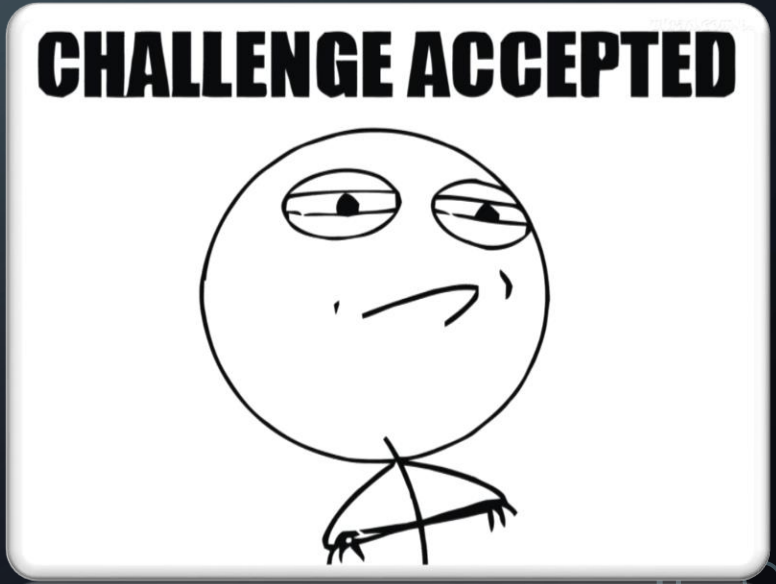
DISCRETE


K
3.51
3.5
3.49
3.48
3.47
3.46
3.45
3.44
3.43
3.42
1560
1580
1600
1620
1640
1660
1680
z [m]


30
GW
untitled
GDET:FEE1:241:ENRC
mJ
(0, 4) VAL=2.61839
Pulse energy
GDET:FEE1:242:ENRC
mJ
(0, 4) VAL=2.59795
Pulse energy
GDET:FEE1:361:ENRC
mJ
(0, 4) VAL=2.59243
Pulse energy
GDET:FEE1:362:ENRC
mJ
(0, 4) VAL=2.70752
Pulse energy
GDET:FEE1:363:ENRC
mJ
(0, 4) VAL=2.49658
Pulse energy
0
1
2
-150
-100
-50
04:05:24
Jul 21, 2016

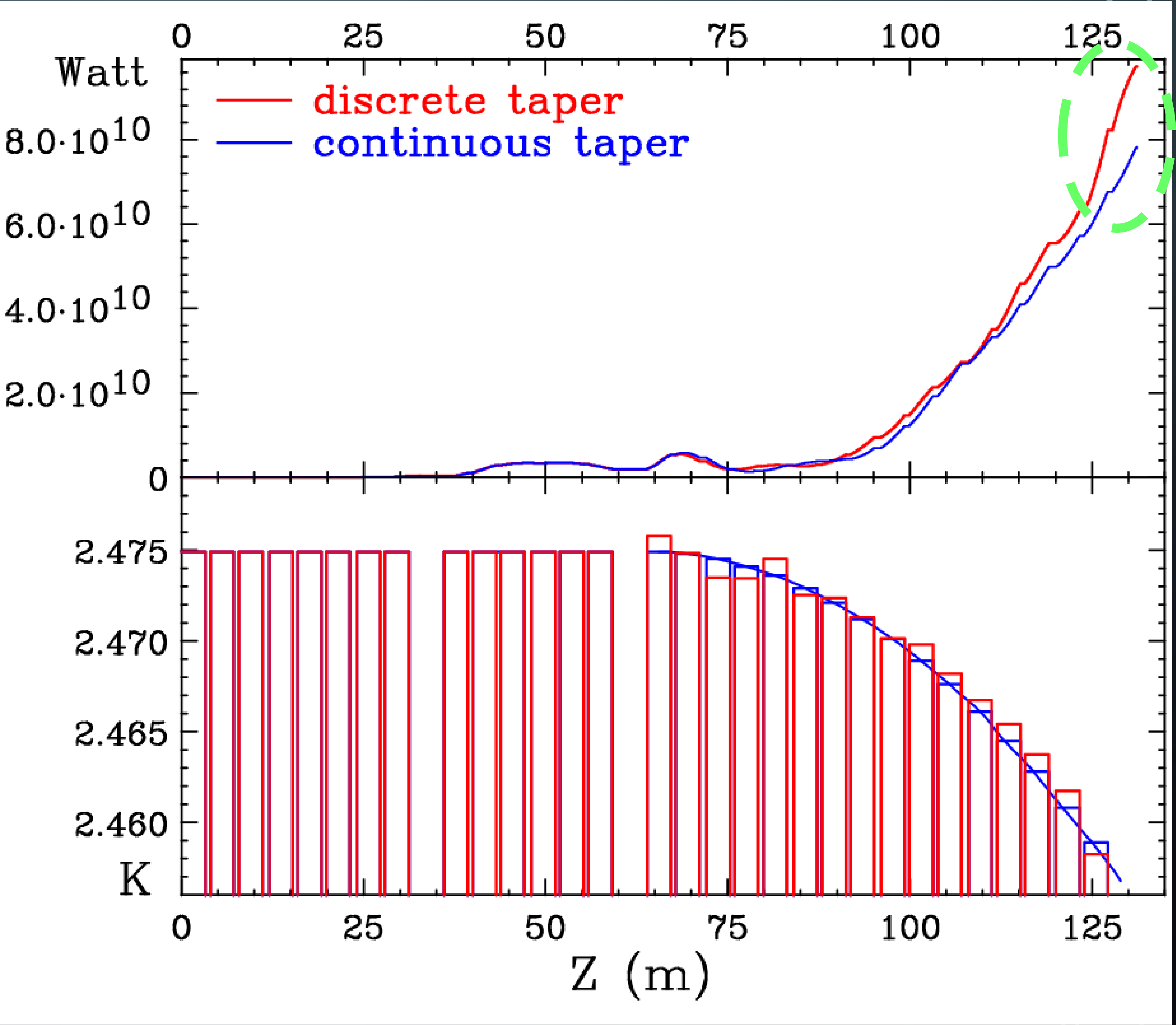
CHALLENGES

- 16 Undulators => 16 dimensional problem, some maybe coupled
- Runtime of Genesis (~65 seconds)
- Enough iterations needed. But how to define enough?



PRELIMINARY RESULT

- Highest power, first try (~ 1 hour run): starting from continuous taper profile
- 97 GW Peak Power
  - Improved from 78 GW; 20% increase
- 19 and 20, 22 and 23, 25 and 26 look somewhat related together



Confirms previous experimental attempt:

Discretizing the taper profile increases the x-ray power by 20%

FUTURE WORK

- Run more
- Produce set of data for Anna's Neural Network
- Possible implementation

FIN.

- Email: setiawan@nscl.msu.edu
- Advisor: Dr. Juhao Wu
- J-Crew/LCLS Style Group:
  - Tanner Worden and Anna Leskova
- Dr. Enrique Cuellar and Ms. Nancy Qatsha

- Thank you for paying taxes!

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