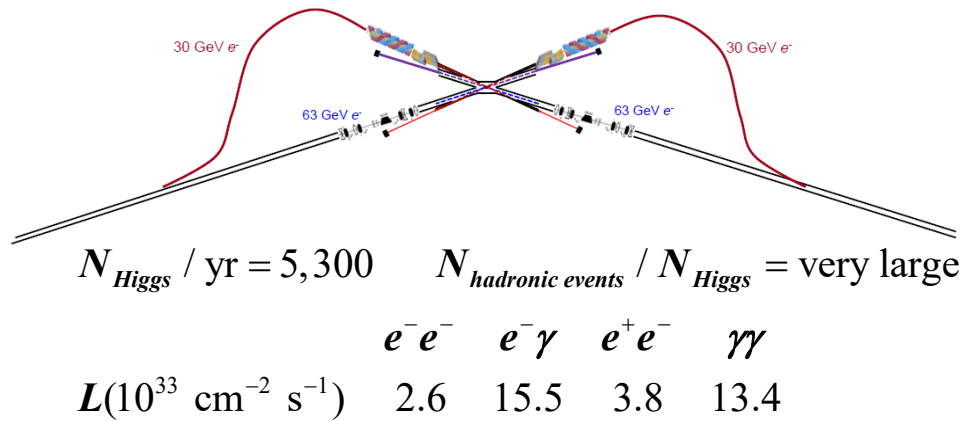


# XCC as a Single C3 Accelerator + SLC Arcs + CEH

Tim Barklow  
XCC Meeting  
May 19, 2021

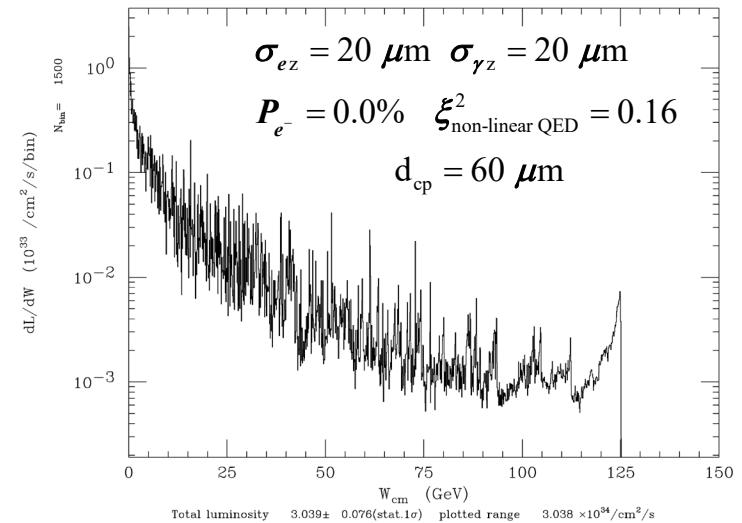
# Config with $\sigma_z=20\text{ }\mu\text{m}$ $d_{cp}=60\text{ }\mu\text{m}$



XCC  $\gamma\text{-}\gamma$  Higgs Factory v01914

Luminosity Spectrum ( $\gamma,\gamma$ )

20210507(193513) CAIN



| ILC                                                        |                        |                        |  |
|------------------------------------------------------------|------------------------|------------------------|--|
| Polarization                                               | $-80\% e^- + 30\% e^+$ | $+80\% e^- - 30\% e^+$ |  |
| $N_{Higgs} / \text{yr} *$                                  | 19,000                 | 13,000                 |  |
| $N_{hadronic\ events} / N_{Higgs}$                         | 228.5                  | 54.7                   |  |
| * assumes 45% of year spent at each of these polarizations |                        |                        |  |

Currently writing interface between CAIN and the particle physics Monte Carlo Generator WHIZARD so that I can calculate  $N_{hadronic\ events} / N_{Higgs}$  for this config.

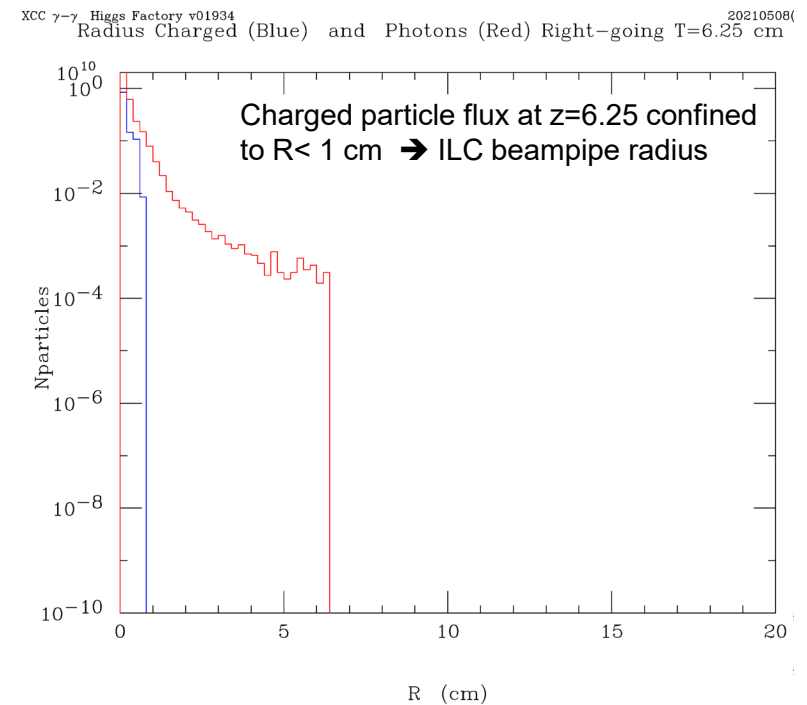
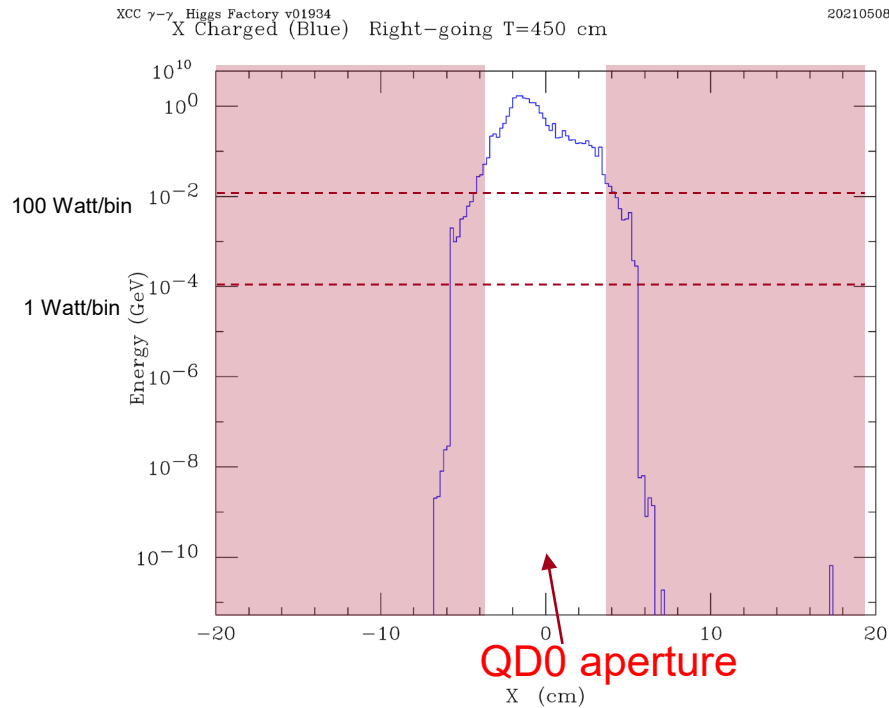
$B_{\text{solenoid}} = 10\text{ Tesla}$

$$\sigma_{ez} = 20\text{ }\mu\text{m} \quad \sigma_{\gamma z} = 20\text{ }\mu\text{m}$$

$$P_{e^-} = 0.0\% \quad \xi_{\text{non-linear QED}}^2 = 0.16$$

$$d_{cp} = 60\text{ }\mu\text{m}$$

2 mrad crossing angle    e- Energy vs X at QD0 faces (450 cm from IP)



QD0 = final quad for 62.6 GeV beam assuming same aperture as ILC 2mrad design

# XCC as single C<sup>3</sup> accelerator + SLC Arcs + CEH (Bldg 750)

From M. Kagan, C. Vernieri talk at e+e- Retreat Prep Meeting May 7, 2020:

## Priorities towards the next P5 decision



- Try to enlarge efforts into R&D → target EoI
  - Only have small funding, and small amounts of people's time
  - Key avenues: Tracker(& Vertex), and Silicon Calorimeter
  - Simulation studies of detector performance to evaluate design choices.
- Keep on eye on the physics case for the Higgs factory
  - Important to actively engage with the discussions broadly within Snowmass
  - The broader community is polarizing towards a discovery lepton machine
  - The Higgs-factory-only physics case is losing traction / interest
  - Need to understand what energy is important to target
- C3
  - Want to build a 2 raft prototype with Program Development support, followed by a 4-6 Cryomodule string test. Hope to be there for Snowmass.

Perhaps instead of selling XCC as a big-machine alternative to the ILC, we present it as a C<sup>3</sup> technology prototype collider with modest physics goals (5000 Higgs/year with no electron polarization and  $ILC_{background} < XCC_{background} << LHC_{background}$ ). The XCC would provide model independent measurements of the Higgs couplings from the outset, and this would be unique with respect to the LHC. Granted, the results would be statistically limited compared to ILC. However, we know through our studies over the past few months that there is an upgrade path to ILC-like Higgs precision using a polarized gun and/or deflector beams. We could further strengthen the case for this machine by arguing that the collider would serve as a prototype for a multi-TeV  $\gamma\gamma$  Collider.

To keep costs to a minimum and/or to minimize the amount of greenfield site construction (the latter might be more important for project approval) we build just one 63 GeV accelerator and utilize the SLC Arc tunnels and Collider Hall.

# Layout of XCC as single $C^3$ accelerator + SLC Arcs + CEH (Bldg 750)



# Layout of XCC as single $C^3$ accelerator + SLC Arcs + CEH (Bldg 750)



SLC FF straight sections are each about 100 m long. Is this sufficient for XCC FF and XFEL lines?

# Emittance growth in SLC Arcs

SLAC - PUB - 4013  
June 1986  
(A)

## Beam Optical Design and Studies of the SLC Arcs\*

S. KHEIFETS, T. FIEGUTH, K. L. BROWN, A. CHAO,<sup>(a)</sup>  
J. J. MURRAY, R. V. SERVANCKX,<sup>(b)</sup> AND H. WIEDEMANN<sup>(c)</sup>

Stanford Linear Accelerator Center  
Stanford University, Stanford, California, 94305

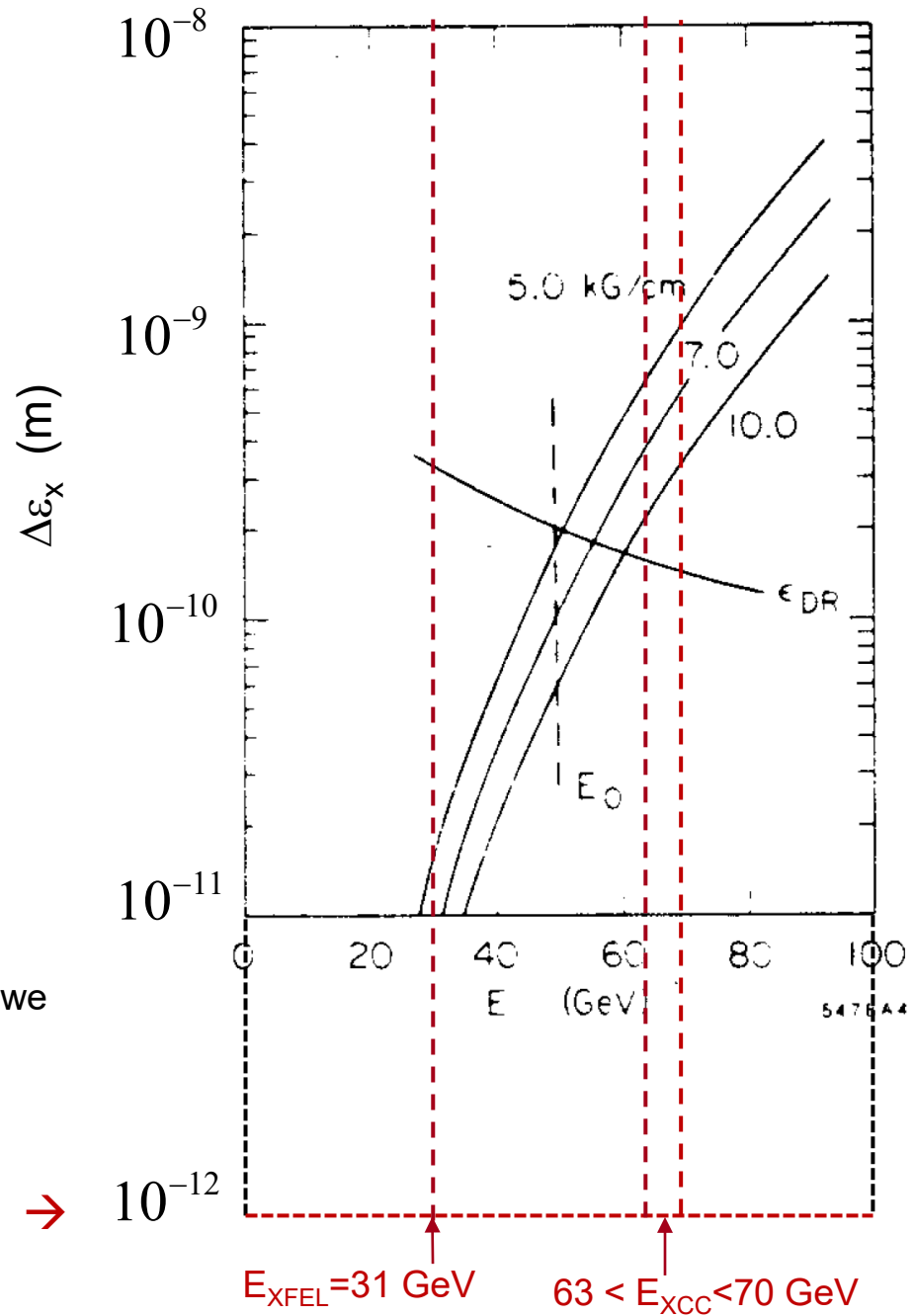
$$\Delta\epsilon(\text{rad-m}) = 2.1 \times 10^{-11} \phi E_0^5 \frac{1}{\rho} \langle \chi/\rho \rangle \frac{l_c}{2l_b}$$

$$\langle \chi/\rho \rangle = \langle (\gamma\eta^2 + 2\alpha\eta\eta' + \beta\eta'^2)/\rho \rangle$$

For XCC we need at least a two orders of magnitude improvement in  $\Delta\epsilon_x$

SLC arcs designed for  $\delta E/E=0.5\%$  while for XCC we have  $\delta E/E=0.05\%$ . Perhaps this could help us produce a design with  $\Delta\epsilon_x=10^{-12}$  m at  $E=70$  GeV?

XCC emittance →



# 62.5 GeV XFEL

Separate arc transport lines would be needed for the 31 GeV and 62.5 GeV electron beams if we kept the 31 GeV XFEL electron energy. To keep initial costs to a minimum it might be advantageous to switch to a 62.5 GeV electron beam for the XFEL so that only one transport line is required per Arc. Or would this complicate the XFEL design to the point that building two transport lines per Arc would be easier?

Calculations below assumed 200 fs bunch duration. We are now assuming 133 fs bunch duration. How does that alter the XFEL calculations?

XFEL for g-g collider Higgs factory: initial crude calculations – by Adham Naji and Zhirong Huang (Stanford/SLAC, 2020)

|                   |                                                                                                                                  | Option 1                      |        |      | Option 2      |        |     | Option 3 |       |     | Option 4 |        |     | Option 5 |       |     | Option 6 |       |     |          |        |       |           |        |       |           |        |       |         |        |       |           |        |       |           |       |       |       |
|-------------------|----------------------------------------------------------------------------------------------------------------------------------|-------------------------------|--------|------|---------------|--------|-----|----------|-------|-----|----------|--------|-----|----------|-------|-----|----------|-------|-----|----------|--------|-------|-----------|--------|-------|-----------|--------|-------|---------|--------|-------|-----------|--------|-------|-----------|-------|-------|-------|
| Given data        | Beam electron energy (GeV)                                                                                                       | 62.5                          |        |      | 50            |        |     | 40       |       |     | 31       |        |     | 20       |       |     | 10       |       |     |          |        |       |           |        |       |           |        |       |         |        |       |           |        |       |           |       |       |       |
|                   | RMS energy spread (slice), $\sigma_{\eta} = \langle \frac{\Delta\gamma}{\gamma} \rangle$ (%)                                     | 0.05                          |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          |        |       |           |        |       |           |        |       |         |        |       |           |        |       |           |       |       |       |
|                   | Normalized emittance (um) $\epsilon_{x,n}$                                                                                       | 0.12                          |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          |        |       |           |        |       |           |        |       |         |        |       |           |        |       |           |       |       |       |
|                   | Bunch charge $Q$ (nC)                                                                                                            | 1                             |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          |        |       |           |        |       |           |        |       |         |        |       |           |        |       |           |       |       |       |
|                   | Bunch duration $T$ (fs)                                                                                                          | 200                           |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          |        |       |           |        |       |           |        |       |         |        |       |           |        |       |           |       |       |       |
|                   | x-ray wavelength $\lambda_x$ (nm)                                                                                                | 1.19                          |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          |        |       |           |        |       |           |        |       |         |        |       |           |        |       |           |       |       |       |
|                   | x-ray pulse energy (J)                                                                                                           | 0.72                          |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          |        |       |           |        |       |           |        |       |         |        |       |           |        |       |           |       |       |       |
| Calculated data   | Lorentz factor $\gamma$                                                                                                          | 122309                        |        |      | 97847         |        |     | 78278    |       |     | 60665    |        |     | 39140    |       |     | 19569    |       |     |          |        |       |           |        |       |           |        |       |         |        |       |           |        |       |           |       |       |       |
|                   | Beam peak current (A)                                                                                                            | 5000                          |        |      | 5000          |        |     | 5000     |       |     | 5000     |        |     | 5000     |       |     | 5000     |       |     |          |        |       |           |        |       |           |        |       |         |        |       |           |        |       |           |       |       |       |
|                   | Beam energy (J)                                                                                                                  | 62.5                          |        |      | 50            |        |     | 40       |       |     | 31       |        |     | 20       |       |     | 10       |       |     |          |        |       |           |        |       |           |        |       |         |        |       |           |        |       |           |       |       |       |
|                   | Beam power (TW)                                                                                                                  | 312.5                         |        |      | 250           |        |     | 200      |       |     | 155      |        |     | 100      |       |     | 50       |       |     |          |        |       |           |        |       |           |        |       |         |        |       |           |        |       |           |       |       |       |
|                   | Required Efficiency (target):                                                                                                    | Total required (%)            | 1.15 % |      |               | 1.44 % |     |          | 1.8 % |     |          | 2.32 % |     |          | 3.6 % |     |          | 7.2 % |     |          |        |       |           |        |       |           |        |       |         |        |       |           |        |       |           |       |       |       |
|                   |                                                                                                                                  | Pre-taper (draft value) (%)   |        |      | ~ 0.1 – 0.4 % |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          |        |       |           |        |       |           |        |       |         |        |       |           |        |       |           |       |       |       |
|                   |                                                                                                                                  | Taper gain range (typical)    |        |      | ~ 10 – 50     |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          |        |       |           |        |       |           |        |       |         |        |       |           |        |       |           |       |       |       |
| Design parameters | undulator type →                                                                                                                 |                               |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     | plan.    | helic. | H+SC. | plan.     | helic. | H+SC. | plan.     | helic. | H+SC. | plan.   | helic. | H+SC. | plan.     | helic. | H+SC. |           |       |       |       |
|                   | B0 (Tesla)                                                                                                                       |                               |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     | 2.15     | 1.2    | 5     | 2.1       | 1.2    | 5     | 1.98      | 1.1    | 4.9   | 1.95    | 1.1    | 4.9   | 1.95      | 1.0    | 4.7   | 1.95      | 1.0   | 4.7   |       |
|                   | Wiggler/undulator period $\lambda_u$ (cm)                                                                                        |                               |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     | 12.07    | 14.13  | 5.46  | 10.56     | 12.17  | 4.71  | 9.46      | 11.11  | 4.11  | 8.05    | 9.36   | 3.47  | 6.00      | 7.43   | 2.66  | 3.74      | 4.63  | 1.67  |       |
|                   | Wiggler/undulator gap (mm), for planar undulator (NdFe/SmCo alloys) or Helical-superconducting (Nb3Sn)                           |                               |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     | 11.5/9.9 | -      | 16.7  | 10.6/9.17 | -      | 14.0  | 10.6/9.29 | -      | 12.0  | 9.8/8.6 | -      | 9.4   | 6.95/6.07 | -      | 6.6   | 4.34/3.79 | -     | 2.90  |       |
|                   | Wiggler/undulator deflection parameter $K$                                                                                       |                               |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     | 24.24    | 15.84  | 25.51 | 20.72     | 13.64  | 21.98 | 17.50     | 11.41  | 18.81 | 14.68   | 9.62   | 15.86 | 10.93     | 6.94   | 11.67 | 6.83      | 4.32  | 7.32  |       |
|                   | Average beta function $\beta$ (m)                                                                                                |                               |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     | 25.0     | 37.1   | 14.3  | 19.5      | 26.1   | 10.1  | 15.0      | 19.0   | 7.03  | 10.5    | 12.11  | 4.48  | 5.2       | 5.7    | 2.03  | 1.5       | 1.5   | 0.53  |       |
|                   | Wiggler/Undulator scaling (Pierce) parameter $\rho$ :                                                                            |                               |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     | 0.004    | 0.004  | 0.004 | 0.004     | 0.004  | 0.004 | 0.004     | 0.005  | 0.005 | 0.004   | 0.005  | 0.005 | 0.005     | 0.005  | 0.006 | 0.006     | 0.008 | 0.008 |       |
|                   | Total* RMS energy spread                                                                                                         | Without quantum diffusion     |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          | 0.050  | 0.050 | 0.050     | 0.050  | 0.050 | 0.050     | 0.050  | 0.050 | 0.050   | 0.050  | 0.050 | 0.050     | 0.050  | 0.050 | 0.050     | 0.050 | 0.050 |       |
|                   |                                                                                                                                  | Initial quantum diffusion (†) |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          | 0.098  | 0.071 | 0.268     | 0.076  | 0.061 | 0.192     | 0.063  | 0.055 | 0.137   | 0.056  | 0.052 | 0.099     | 0.052  | 0.050 | 0.065     | 0.050 | 0.050 | 0.052 |
|                   | $\sigma_{\eta} = \langle \frac{\Delta\gamma}{\gamma} \rangle$ (%)                                                                | Final quantum diffusion (‡)   |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          | 0.137  | 0.072 | 225       | 0.080  | 0.061 | 66        | 0.063  | 0.055 | 0.196   | 0.056  | 0.052 | 0.103     | 0.052  | 0.050 | 0.065     | 0.050 | 0.050 | 0.052 |
|                   |                                                                                                                                  |                               |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          |        |       |           |        |       |           |        |       |         |        |       |           |        |       |           |       |       |       |
|                   | Ming Xi's scalar $\Delta$ :                                                                                                      | Without quantum diffusion     |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          | 1.44   | 1.09  | 1.09      | 1.30   | 1.02  | 1.02      | 1.19   | 0.97  | 0.97    | 1.09   | 0.92  | 0.92      | 0.97   | 0.86  | 0.86      | 0.85  | 0.80  | 0.80  |
|                   |                                                                                                                                  | Initial quantum diffusion (†) |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          | 2.53   | 1.22  | 11.70     | 1.65   | 1.07  | 4.01      | 1.30   | 0.97  | 1.78    | 1.13   | 0.92  | 1.13      | 0.98   | 0.86  | 0.88      | 0.85  | 0.80  | 0.80  |
|                   |                                                                                                                                  | Final quantum diffusion (‡)   |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          | 4.69   | 1.23  | 10^9      | 1.71   | 1.07  | 10^8      | 1.30   | 0.98  | 3.34    | 1.13   | 0.92  | 1.16      | 0.98   | 0.86  | 0.88      | 0.85  | 0.80  | 0.80  |
|                   | 3D Efficiency 1.6 $\rho/(1 + \Delta)^2$ (%)                                                                                      | Without quantum diffusion     |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          | 0.094  | 0.151 | 0.151     | 0.110  | 0.173 | 0.173     | 0.127  | 0.196 | 0.197   | 0.149  | 0.226 | 0.227     | 0.19   | 0.285 | 0.287     | 0.28  | 0.401 | 0.408 |
|                   |                                                                                                                                  | Initial quantum diffusion (†) |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          | 0.045  | 0.133 | 0.004     | 0.083  | 0.165 | 0.028     | 0.116  | 0.196 | 0.098   | 0.145  | 0.225 | 0.184     | 0.19   | 0.285 | 0.280     | 0.28  | 0.401 | 0.407 |
|                   |                                                                                                                                  | Final quantum diffusion (‡)   |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          | 0.017  | 0.132 | 0         | 0.080  | 0.165 | 0         | 0.116  | 0.193 | 0.040   | 0.145  | 0.225 | 0.179     | 0.19   | 0.284 | 0.280     | 0.28  | 0.401 | 0.407 |
|                   | Saturated power $P_{sat}$ (TW):                                                                                                  | Without quantum diffusion     |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          | 0.29   | 0.47  | 0.47      | 0.27   | 0.43  | 0.43      | 0.25   | 0.39  | 0.39    | 0.23   | 0.35  | 0.35      | 0.19   | 0.285 | 0.29      | 0.14  | 0.20  | 0.20  |
|                   |                                                                                                                                  | Initial quantum diffusion (†) |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          | 0.14   | 0.42  | 0.01      | 0.21   | 0.41  | 0.07      | 0.23   | 0.39  | 0.20    | 0.22   | 0.35  | 0.29      | 0.19   | 0.284 | 0.28      | 0.14  | 0.20  | 0.20  |
|                   |                                                                                                                                  | Final quantum diffusion (‡)   |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          | 0.05   | 0.41  | 0         | 0.20   | 0.41  | 0         | 0.23   | 0.39  | 0.08    | 0.22   | 0.35  | 0.28      | 0.19   | 0.284 | 0.28      | 0.14  | 0.20  | 0.20  |
|                   | 3D gain length $L_G$ (m):                                                                                                        | Without quantum diffusion     |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          | 3.87   | 3.29  | 1.27      | 3.07   | 2.56  | 0.99      | 2.49   | 2.12  | 0.78    | 1.89   | 1.59  | 0.59      | 1.16   | 1.03  | 0.37      | 0.53  | 0.47  | 0.17  |
|                   |                                                                                                                                  | Initial quantum diffusion (†) |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          | 5.60   | 3.50  | 7.73      | 3.52   | 2.63  | 2.45      | 2.61   | 2.12  | 1.10    | 1.92   | 1.59  | 0.65      | 1.16   | 1.03  | 0.37      | 0.53  | 0.47  | 0.17  |
|                   |                                                                                                                                  | Final quantum diffusion (‡)   |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          | 9.02   | 3.52  | 10^9      | 3.60   | 2.63  | 10^8      | 2.61   | 2.13  | 1.72    | 1.92   | 1.59  | 0.66      | 1.16   | 1.03  | 0.37      | 0.53  | 0.47  | 0.17  |
|                   | Approximated** $L_{sat}$ (m):                                                                                                    | Without quantum diffusion     |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          | ~ 153  | ~ 126 | ~ 48      | ~ 119  | ~ 97  | ~ 38      | ~ 96   | ~ 80  | ~ 29    | ~ 72   | ~ 60  | ~ 22      | ~ 44   | ~ 38  | ~ 14      | ~ 20  | ~ 17  | ~ 6   |
|                   |                                                                                                                                  | Initial quantum diffusion (†) |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          | ~ 243  | ~ 134 | ~ 671     | ~ 141  | ~ 100 | ~ 122     | ~ 101  | ~ 80  | ~ 44    | ~ 73   | ~ 60  | ~ 24      | ~ 44   | ~ 38  | ~ 14      | ~ 20  | ~ 17  | ~ 6   |
|                   |                                                                                                                                  | Final quantum diffusion (‡)   |        |      |               |        |     |          |       |     |          |        |     |          |       |     |          |       |     |          | ~ 481  | ~ 135 | 10^19     | ~ 145  | ~ 100 | 10^16     | ~ 101  | ~ 80  | ~ 80    | ~ 73   | ~ 60  | ~ 25      | ~ 44   | ~ 38  | ~ 17      | ~ 20  | ~ 17  | ~ 6   |
|                   | Deterioration in Efficiency (%) due to quantum diffusion energy spread (including iterative adjustment (evolving) of $L_{sat}$ ) |                               | 82 %   | 13 % | 100 %         | 28 %   | 5 % | 100 %    | 9 %   | 1 % | 79 %     | 3 %    | 0 % | 21 %     | 0 %   | 0 % | 2 %      | 0 %   | 0 % | 0 %      |        |       |           |        |       |           |        |       |         |        |       |           |        |       |           |       |       |       |