# Study on $Loss_Q$ for 800G-ER1

Qirui Fan[(1)], Chendi Jiang[(2)], Xiang Liu[(1)], Chris Cole[(3)], Rang-Chen (Ryan) Yu[(4)], Nobuhiko Kikuchi[(5)], Frank Chang[(6)], Maxim Kuschnerov[(7)], and Frank Effenberger[(8)]

[(1)]Huawei Hong Kong Research Center, China; [(2)]Huawei Technologies, Wuhan, China; [(3)]Coherent, USA; [(4)]InnoLight; [(5)]Hitachi, Japan; [(6)]Source Photonics; [(7)]Huawei European Research Institute, Germany; [(8)]Futurewei, USA.

# Supporters

- Roberto Rodes (Coherent)
- Vincent Ferretti (Corning)

# Introduction

- In the November 2023 IEEE 802 plenary meeting, the baseline proposal for 800GBASE-LR4 (rodes_3dj_01a_2311) was approved, with the chromatic dispersion (CD) values to be specified by using a statistical methodology similar to $PMD_Q$.
- The same statistical methodology has also been used for fiber loss to specify the link design attenuation (LDA) (20190717-Link_Loss and 20191112-Ferretti_3cs_01), which has been adopted in IEEE 802.3cs (SuperPON) (20200617-Du_3cs_01a).
- In this contribution, we extend the statistical methodology to fiber loss and evaluate the $Loss_Q$ values for G.652 fibers in the O-band.
- The use of the $Loss_Q$ methodology may make it feasible for 800G-ER1 and 800G-LR1 to operate in the O-band with the same FEC, and provide more link margin for IMDD-based solutions.

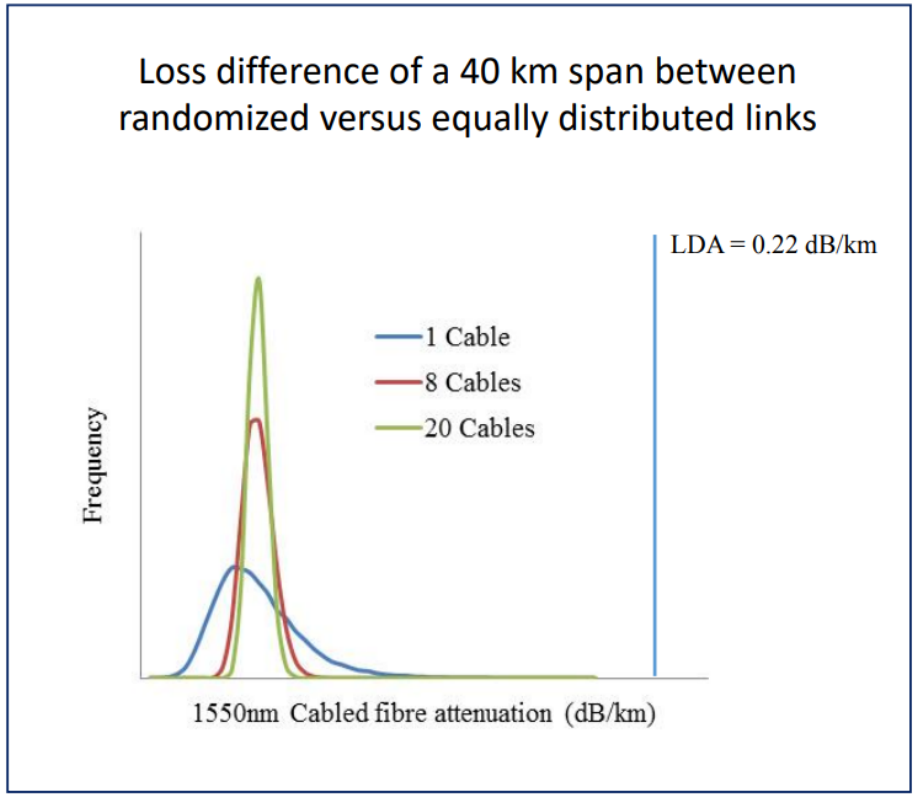
# Background on LDA

- According to 20190717-Link_Loss and 20191112-Ferretti_3cs_01, when optical links have multiple (>8) concatenated links, statistical modeling can be used to determine more realistic and economical design models

- IEEE 802.3cs (SuperPON) has adopted the LDA model that reduces the G.652 fiber loss spec from 0.3dB/km to 0.22dB/km in the C-band by assuming M=8 and Q=1E-3, as shown on the right hand side.

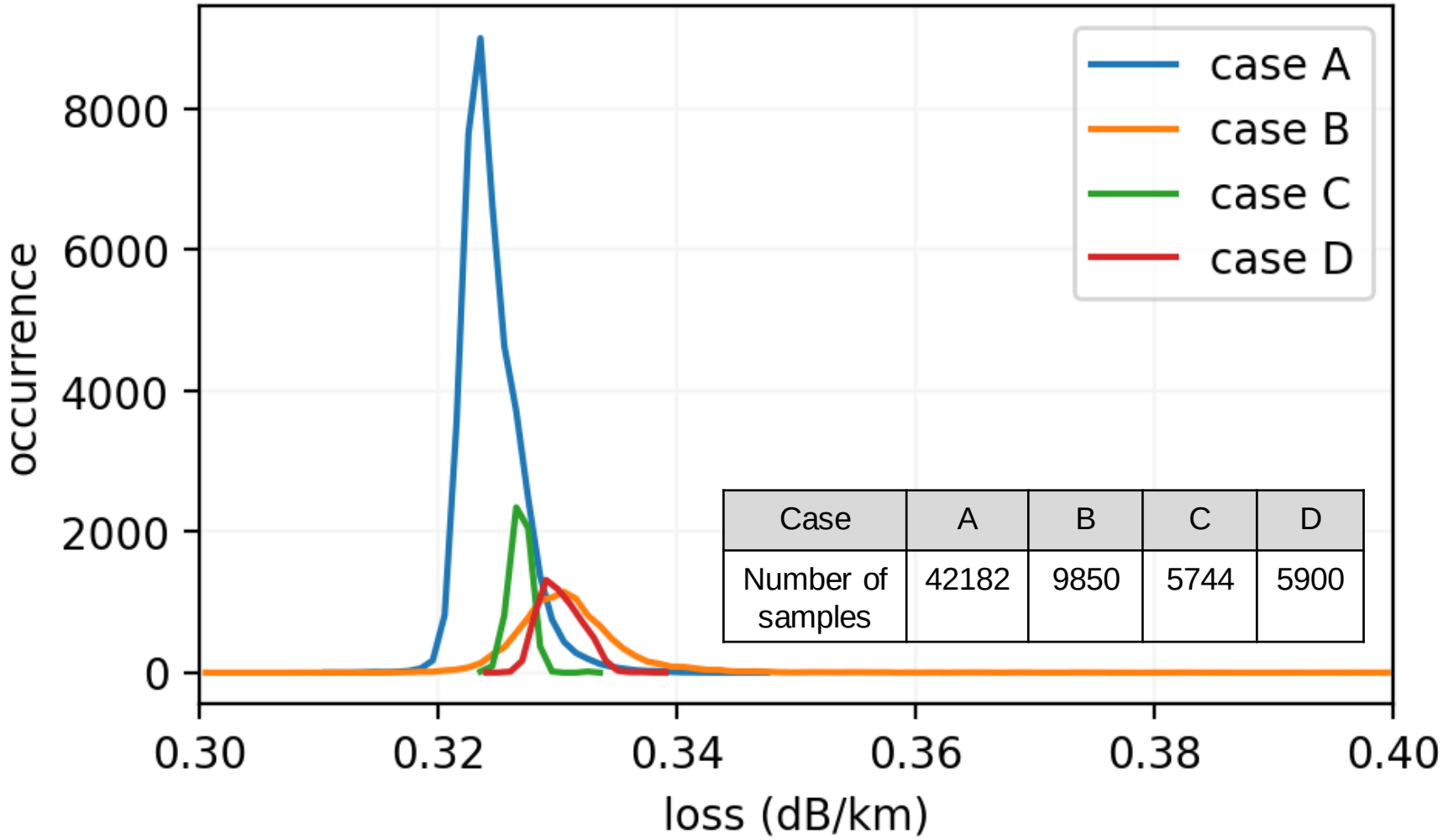
- The LDA model adopted in IEEE 802.3cs also reduces the L-band loss spec from 0.35dB/km to 0.24dB/km (20200617-Du_3cs_01a).

- We can apply the LDA model to O-band fiber loss spec for IEEE 802.3dj.




After 20190717-Link_Loss slide 8.

# Typical G.652 fiber loss distributions in the O-band ( ~1310nm)

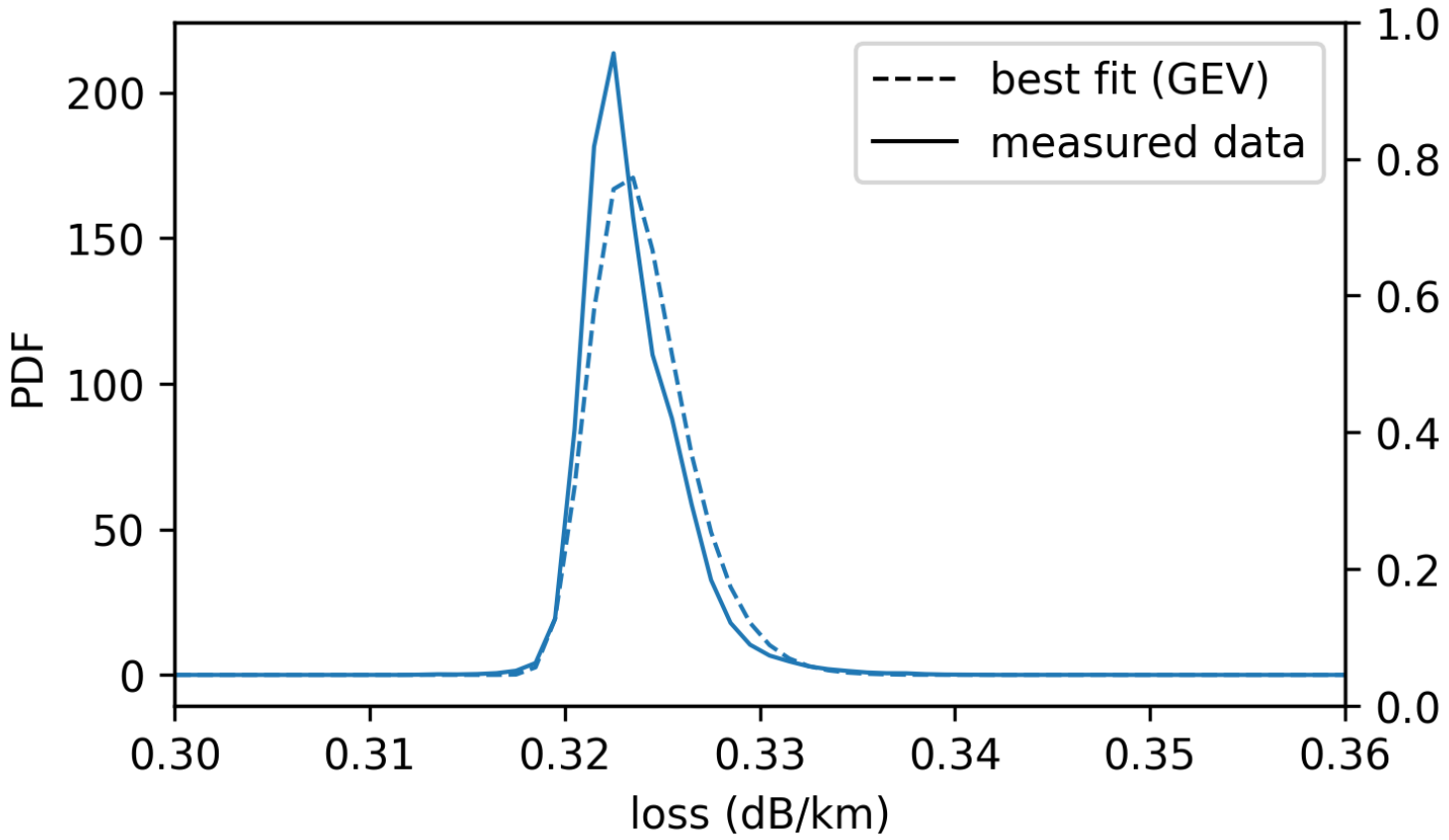



| Case | A | B | C | D |
|---|---|---|---|---|
| Number of samples | 42182 | 9850 | 5744 | 5900 |

Here, Case A is the best case, while Case B is the worst case.

# Analytical modeling of the fiber Loss distribution

GEV( Generalized extreme value) distribution achieves the best likelihood among several statistical models




Insights: fiber loss has minima by nature, and GEV can both describe data maxima/minima and the distribution.

# Analytical evaluation of link $\text{Loss}_Q$ distribution

We can derive the GEV distribution of the fiber loss from the measured data

$$\text{Loss}(\lambda) = GEV(\mu, \sigma, \xi),$$

where $\mu$ is the location parameter, $\sigma$ is the scale parameter, and $\xi$ is the shape parameter [1],

which are determined through maximal likelihood estimation (MLE).

In the case of cable segmentations,

$$Loss_M(\lambda) = \sum_{i=1}^{M} L_{Cab} Loss_i(\lambda)/M$$

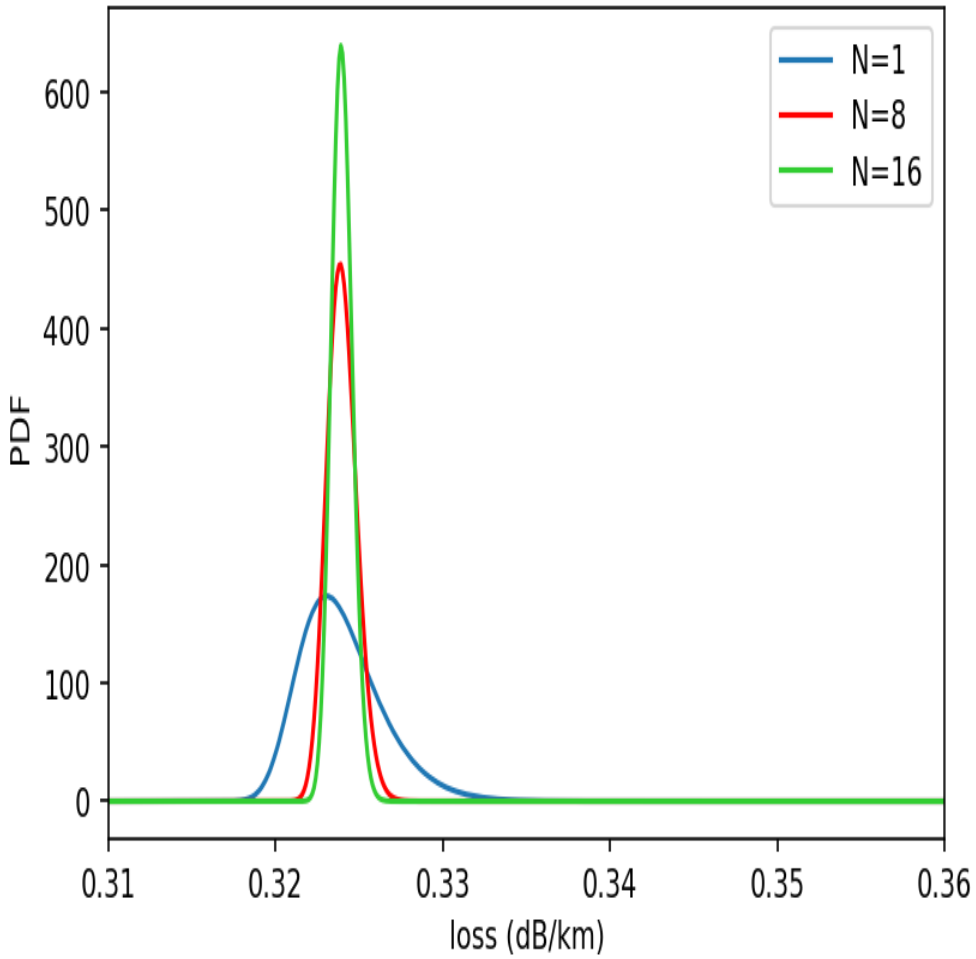
$$where\ L_{Cab} = 40\ \text{km for ER}$$

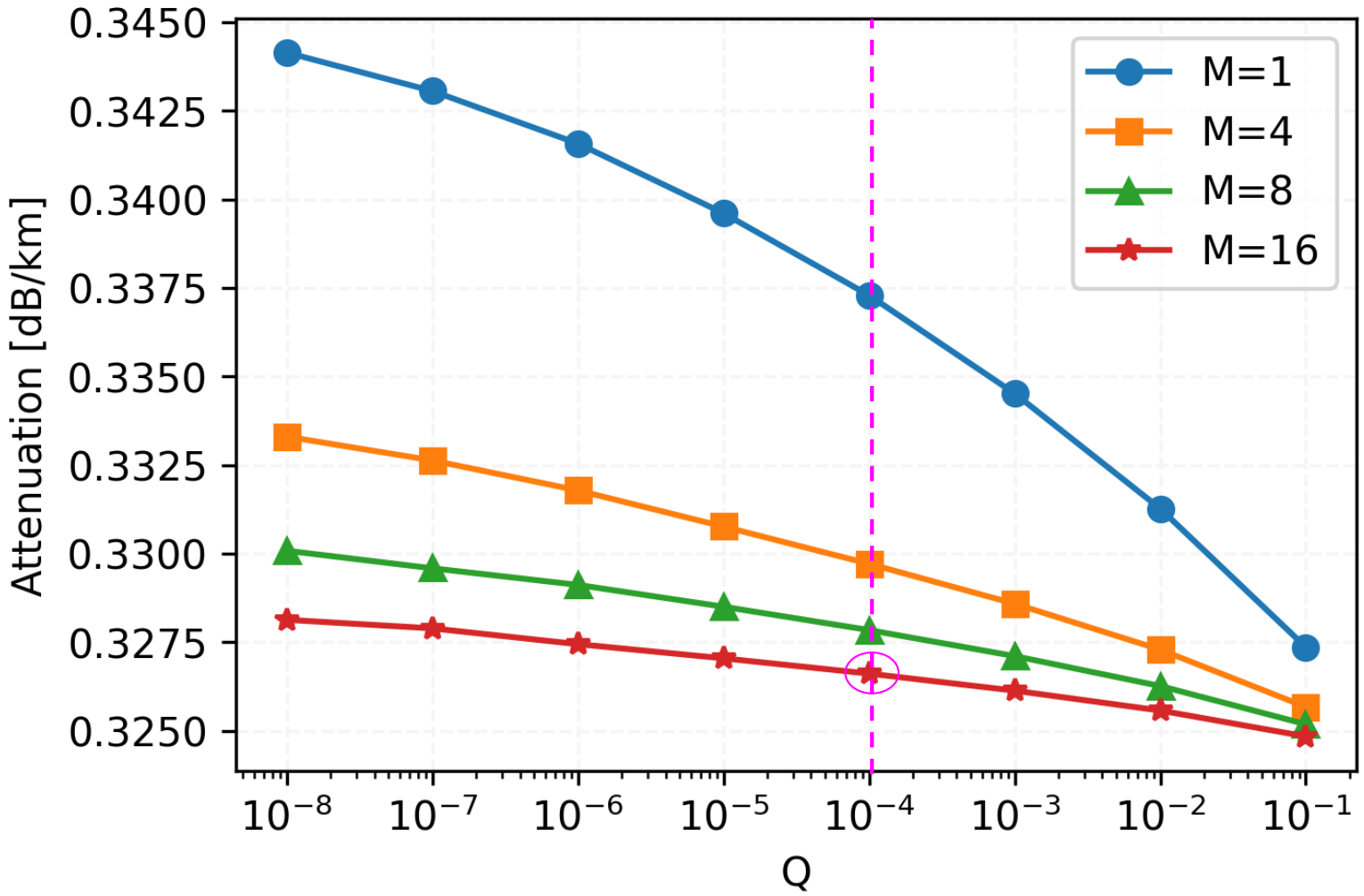
Numerically, $\text{Loss}(\lambda)$ and $Loss_M(\lambda)$ are evaluated via Monte Carlo Analysis.

[1] See, for example, https://en.wikipedia.org/wiki/Generalized_extreme_value_distribution

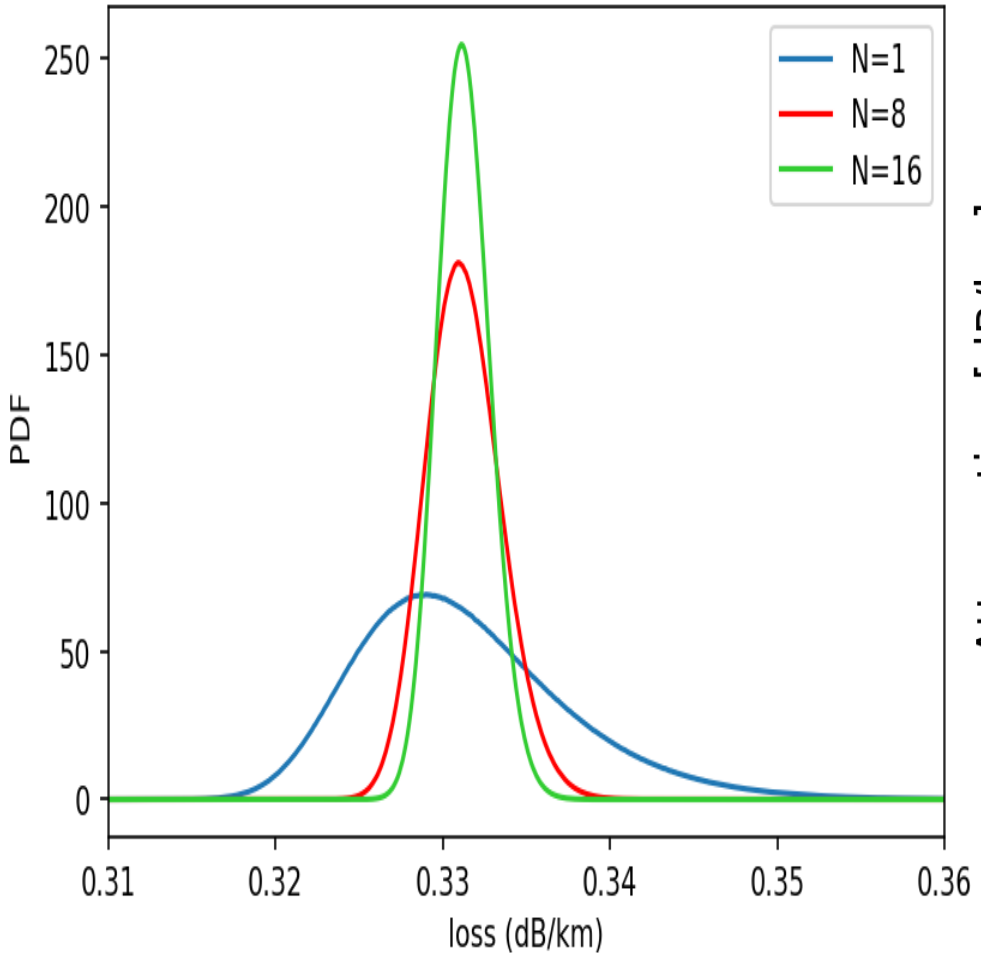
# $Loss_Q$ for Case A (the best case)

For ER (40km), $Loss_Q$ (M=16, Q=1E-4)~0.327dB/km

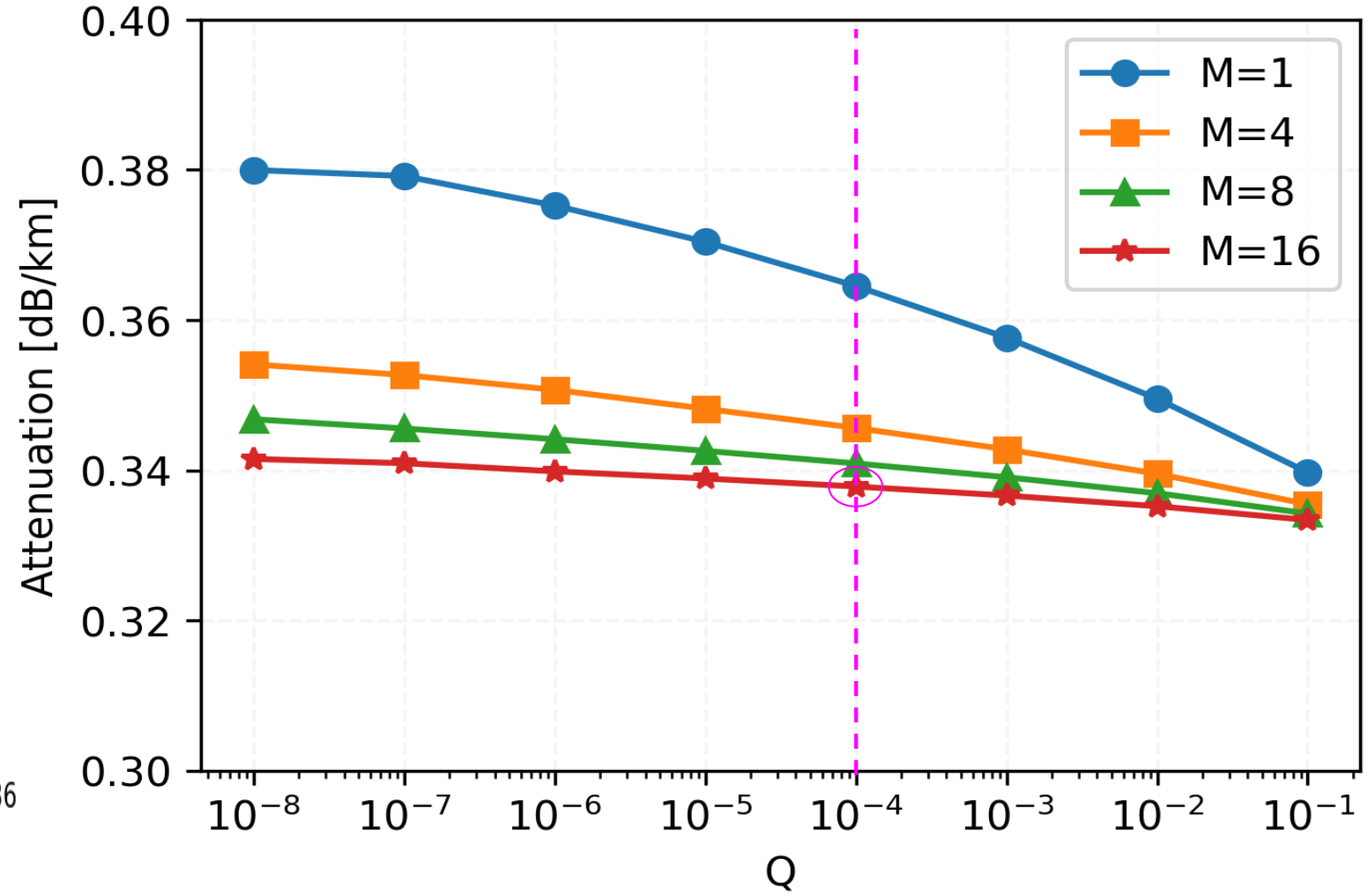


# $Loss_Q$ for Case B (the worst case)




For ER (40km), $Loss_Q$ (M=16, Q=1E-4)~0.34dB/km



# 800G-ER1 link budget analysis

1) The minimum transmitter power can be increased to 0 dBm (e.g., via SOA or BDFA [1])

2) The receiver sensitivity can be set conservatively as -17 dBm [2]

| ROP (dBm) | OB2B | LR | | ER | | |
|---|---|---|---|---|---|---|
| | | typical+300kHz | Worst+2MHz | typical+300kHz | worst+2MHz | worst+2MHz+OA |
| OFEC@BER=2E-2 | -20.98 | -20.92 | -20.48 | -20.46 | -19.72 | -19.56 |
| KP4 + BCH @BER=1.1E-2 | -19.8 | -19.75 | -19.24 | -19.25 | -18.41 | -18.21 |
| Difference in ROP (dB) | 1.18 | 1.17 | 1.24 | 1.21 | 1.31 | 1.35 |

3) Allocating 1 dB for transmission penalty [2], the loss budget becomes 16 dB.

4) Assuming $Loss_Q$=0.34dB/km for ER (M=16, Q=1E-4), we have 2.4dB (=16dB-0.34dB/km*40km) extra margin, which can be used for accommodating connector losses, bending losses, and splice losses (e.g., 16*0.015dB/splice=0.24dB [3]).


[1] D. Elson et al., “9.6-THz Single Fibre Amplifier O-band Coherent DWDM Transmission”, Post-deadline paper Th4B.4, OFC 2023.
[2] stassar_3dj_01a_2307.
[3] C. Zhang et al., "Optical Layer Impairments and Their Mitigation in C+L+S+E+O Multi-Band Optical Networks With G.652 and Loss-Minimized G.654 Fibers," in Journal of Lightwave Technology, vol. 40, no. 11, pp. 3415-3424, 1 June, 2022.

# Conclusion

- The statistical methodology used for $PMD_Q$ and $CD_Q$ has been applied to fiber loss by defining LDA in the C-band and the L-band.
- Based on some measured G.652 fiber loss data, we have evaluated *preliminary* $Loss_Q$ values in the O-band.
- The use of the $Loss_Q$ methodology may make it feasible for 800G-ER1 and 800G-LR1 to operate in the O-band with the same FEC (KP4+BCH), as well as more link margin for IMDD-based solutions.

***Thank you!***