# Super-PON Chromatic Dispersion and DCM for black link

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Google Fiber

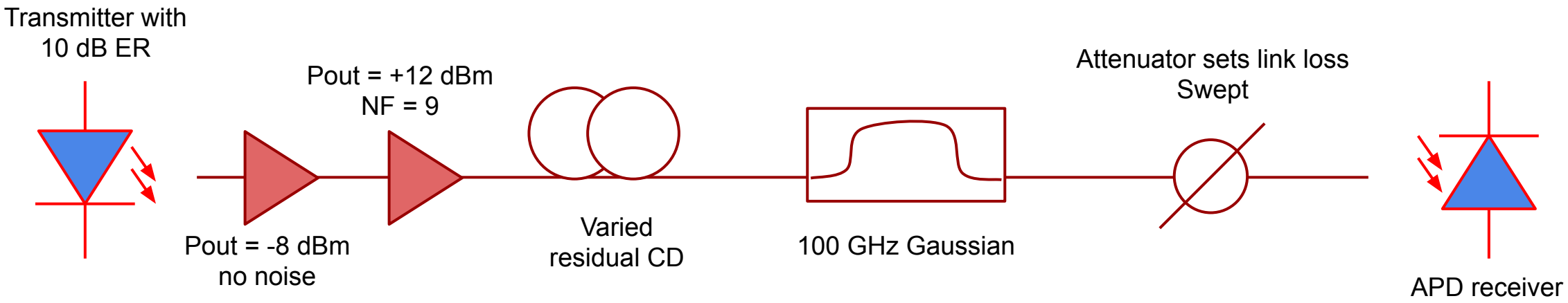
# Overview

- Recommendation for no DCM to be used for the DS direction
  - Ask for negatively chirped OLT transmitters
- Recommendation for 2 DCM values for the US
  - One for longer links: 25-50 km
  - One for shorter links: 0-30 km
  - This maximizes the ONU transmitter options, including DML and shallow biased EMLs
- Data based VPI simulations and experimental measurements were used

# Downstream OLT transmitter requirements

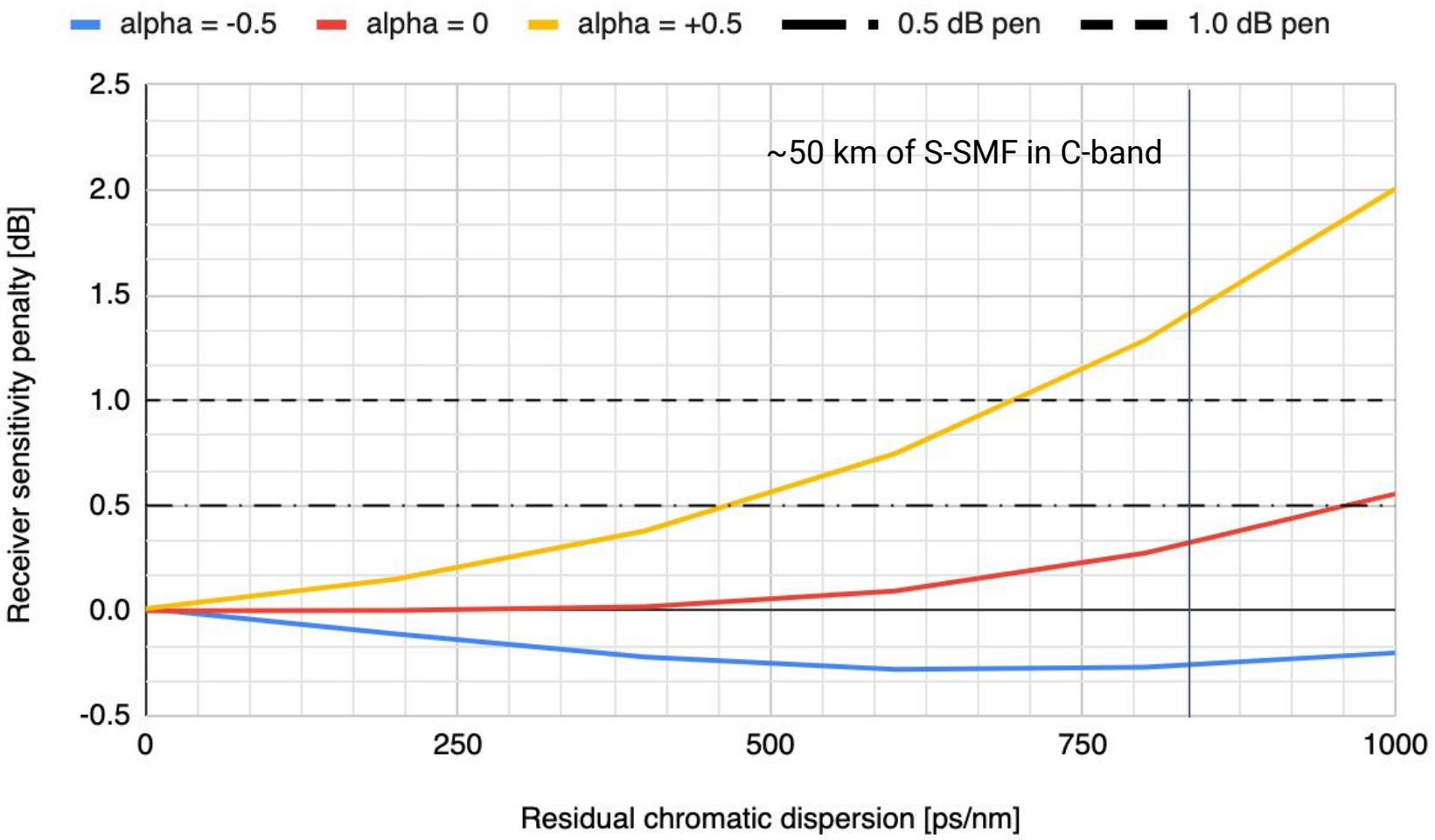
- A high extinction ratio: >8.2 dB
  - The signal power is boosted by a booster EDFA, which is likely power limited
  - ONU receiver will be an APD, which will have a shot noise component
- Low output power: -3 dBm to +2 dBm
  - Boosted by EDFA before the ODN
- For 10 Gb/s, external modulation will be needed to achieve the high extinction ratio
- Relatively lower required power allows for deep biasing on the electron absorption modulator or a Mach-Zehnder modulator
- Possible to achieve zero or negative chirp factors
  - Commonly done in 80 km or 120 km 10 Gb/s transceivers today

# VPI simulation setup




- Sensitivity measured for BER = $1.0 \times 10^{-2}$

# Rx Power penalties

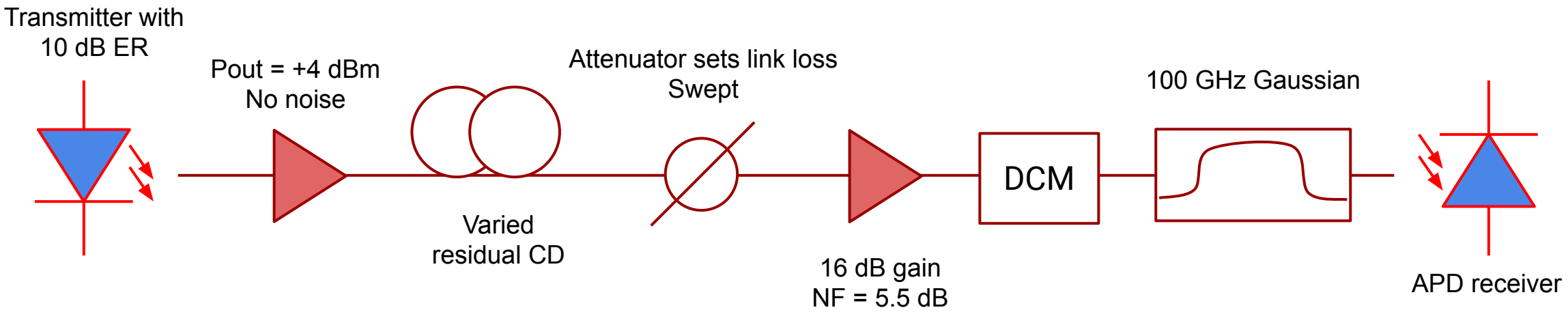



- Small positive chirp transmitter has >1.0 dB CD penalty after 50 km
- Zero chirp transmitter has a <0.5 dB penalty after 50 km
- Small negative chirp transmitter has a <0.0 dB penalty after 50 km
- **Conclusion: OLT transmitters need to have alpha ≤0**

# Upstream ONU transmitter requirements

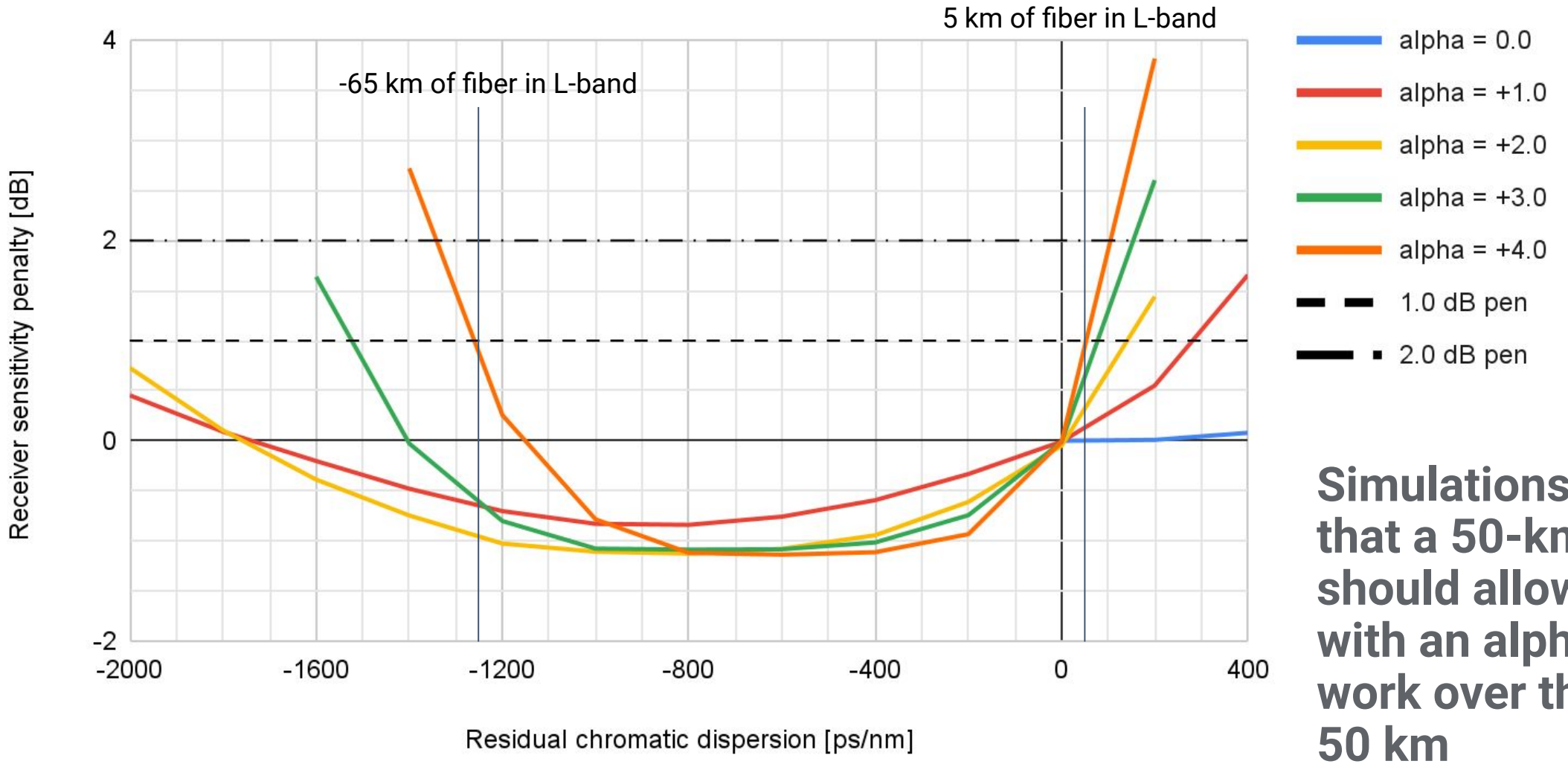
- Lower extinction ratio: >6.0 dB
  - Even lower is possible but must be traded for a higher Tx power
- Higher output power: +4 dBm to +9 dBm
  - No optical amplification until right before the OLT Rx
- Need to be low cost
- DML solution:
  - Likely to have a high positive chirp
  - Lowest potential cost so want to enable this solution
- EML solution
  - Higher output power will mean there will be some positive chirp

# VPI simulation setup



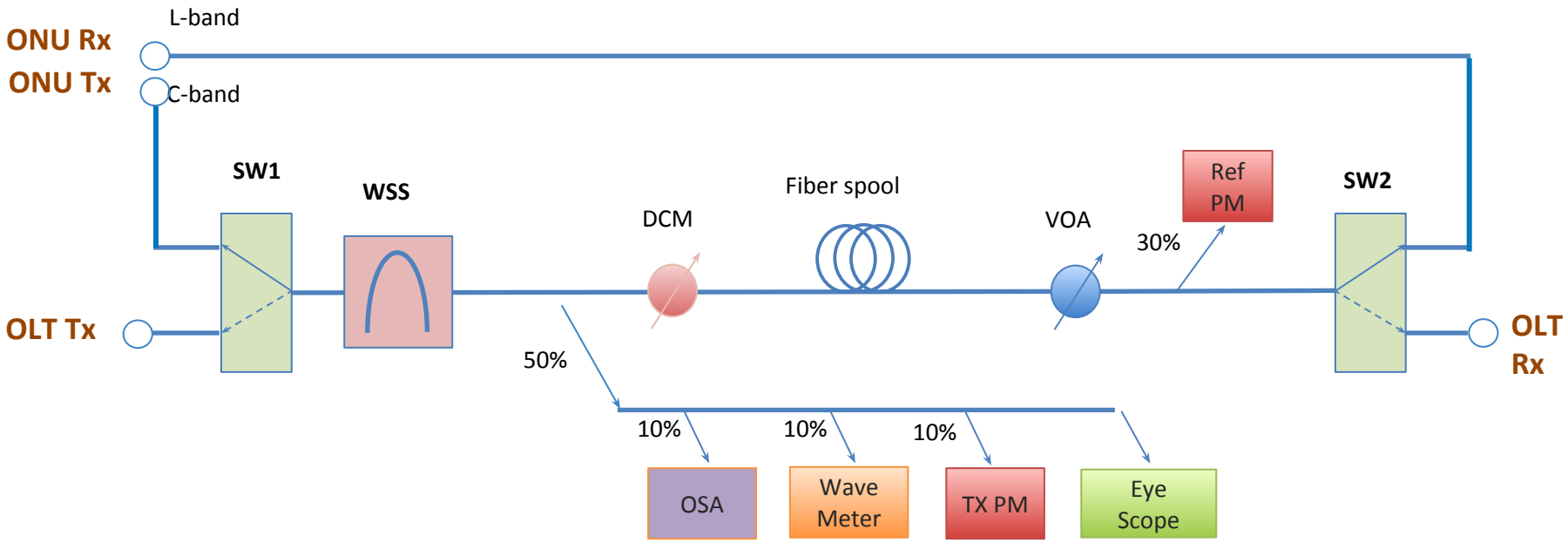

- Sensitivity measured for BER = $1.0x10^{-2}$
- ER in simulations were a bit high

# Rx Pow pen. before EDFA -> OSNR penalty



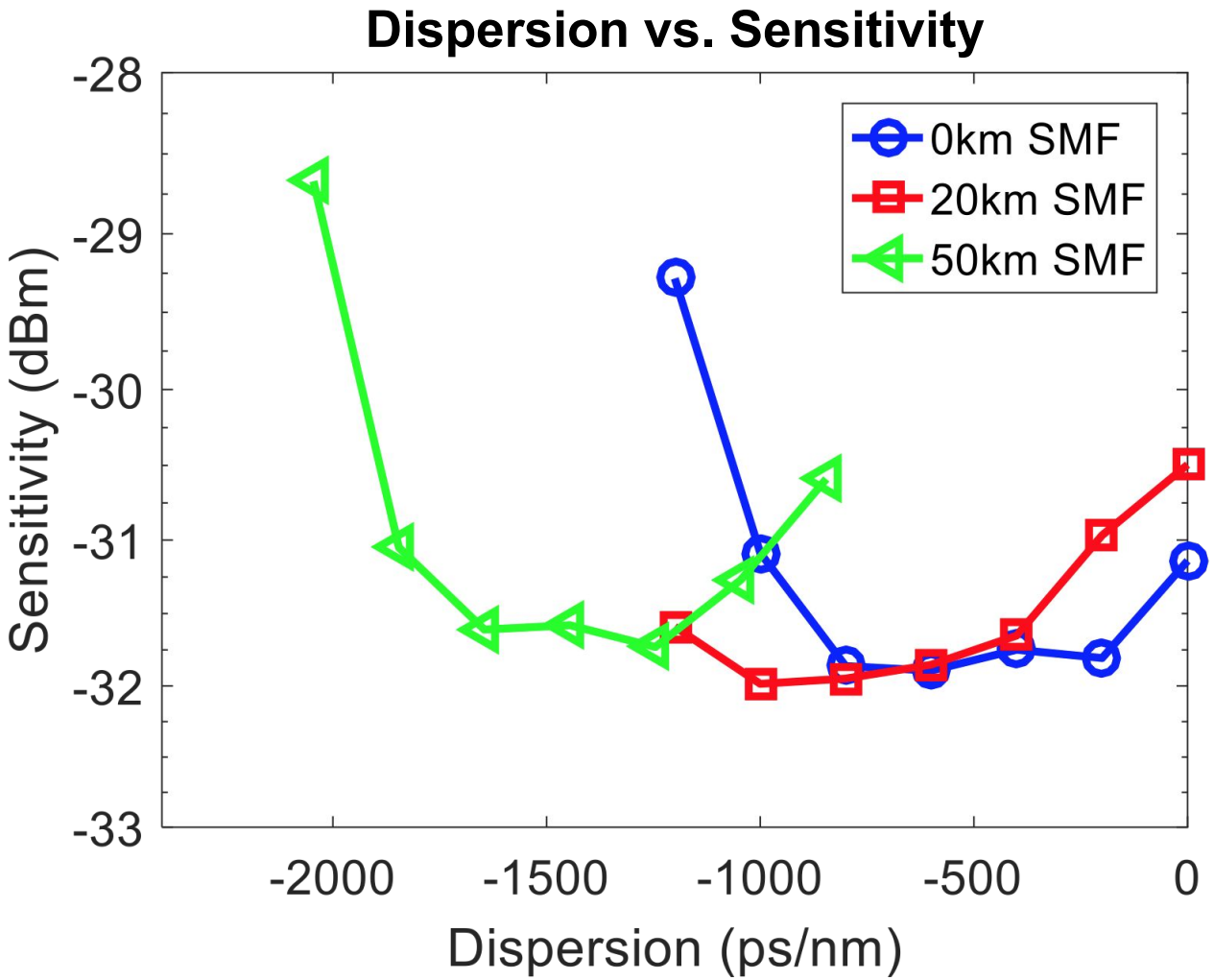

**Simulations suggest that a 50-km DCM should allow ONU Tx with an alpha<4.0 to work over the whole 50 km**

# Experimental measurements: EML and DML examples



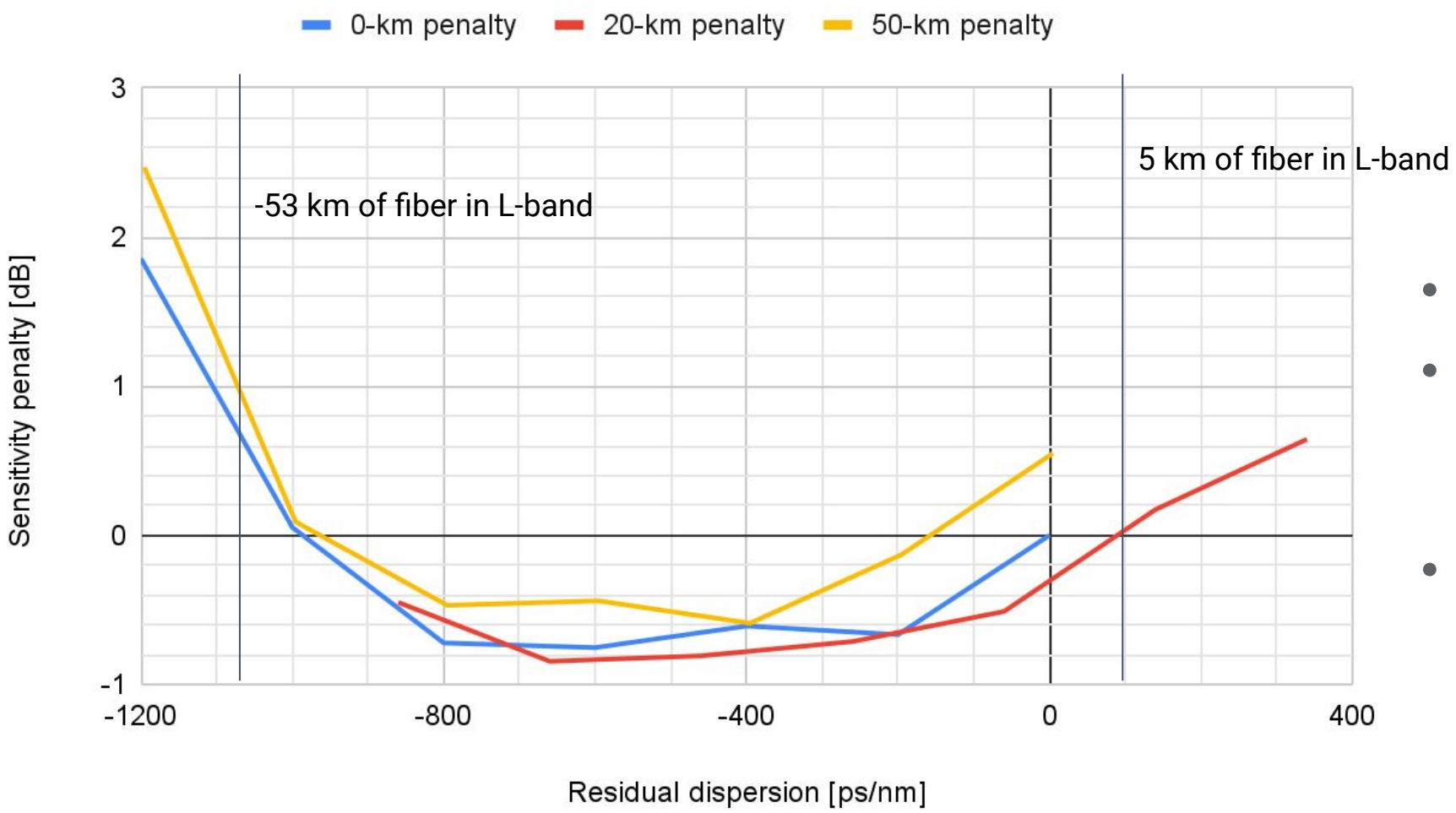

- Previous measurements
- Sensitivity gathered for BER = $10^{-3}$

# Experimental results: EML example



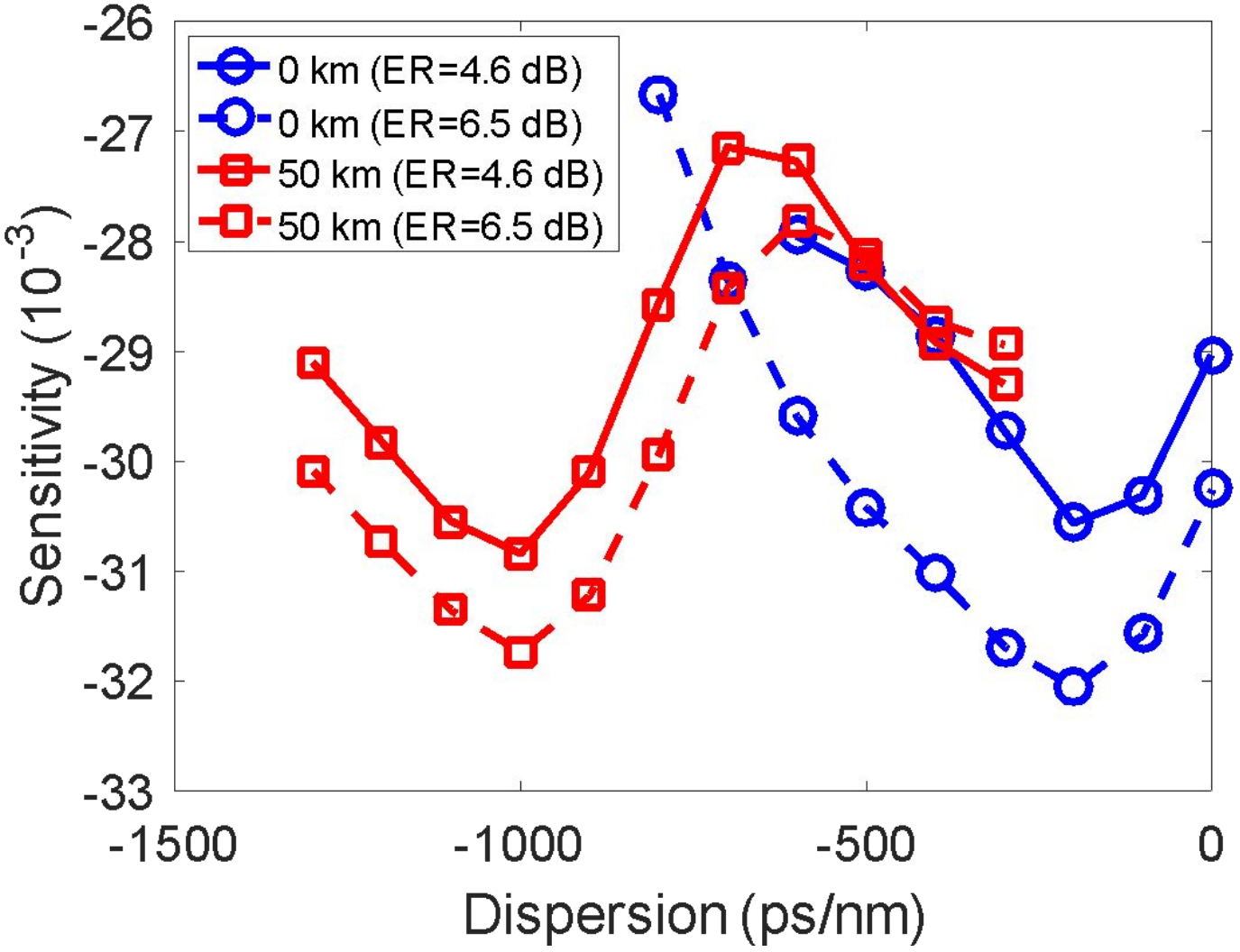

- Experimental test results using a commercially available C-band EML
- Tunable DCM used to measured sensitivities with varying residual CD at 3 fiber lengths
- Graph shows the DCM dispersion value

# Normalizing for residual dispersion



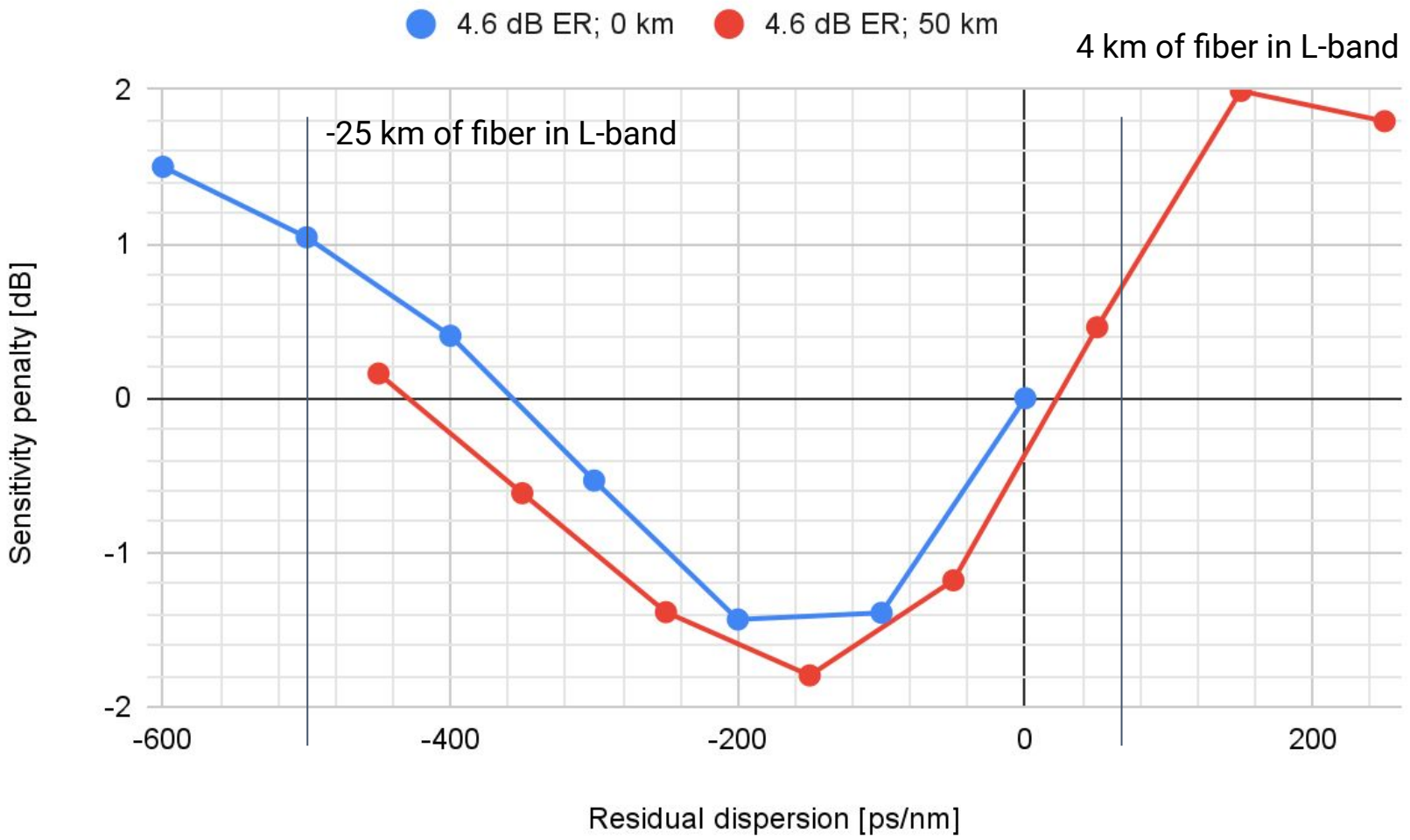

- Graphs align well
- Low Tx power means there is no fiber nonlinearity penalty
- This EML can cover a 0 to 50 km link if a -50 km DCM is used

# Experimental results: DML example




- Experimental test results using a commercially available C-band DML
- Tunable DCM used to measured sensitivities with varying residual CD at 2 fiber lengths
- Laser bias adjusted to generate two different ERs
- Laser has high adiabatic chirp
  - See slide 14 of [3av_0701_schrans_1.pdf]

# Normalizing for residual dispersion: 4.6 dB ER

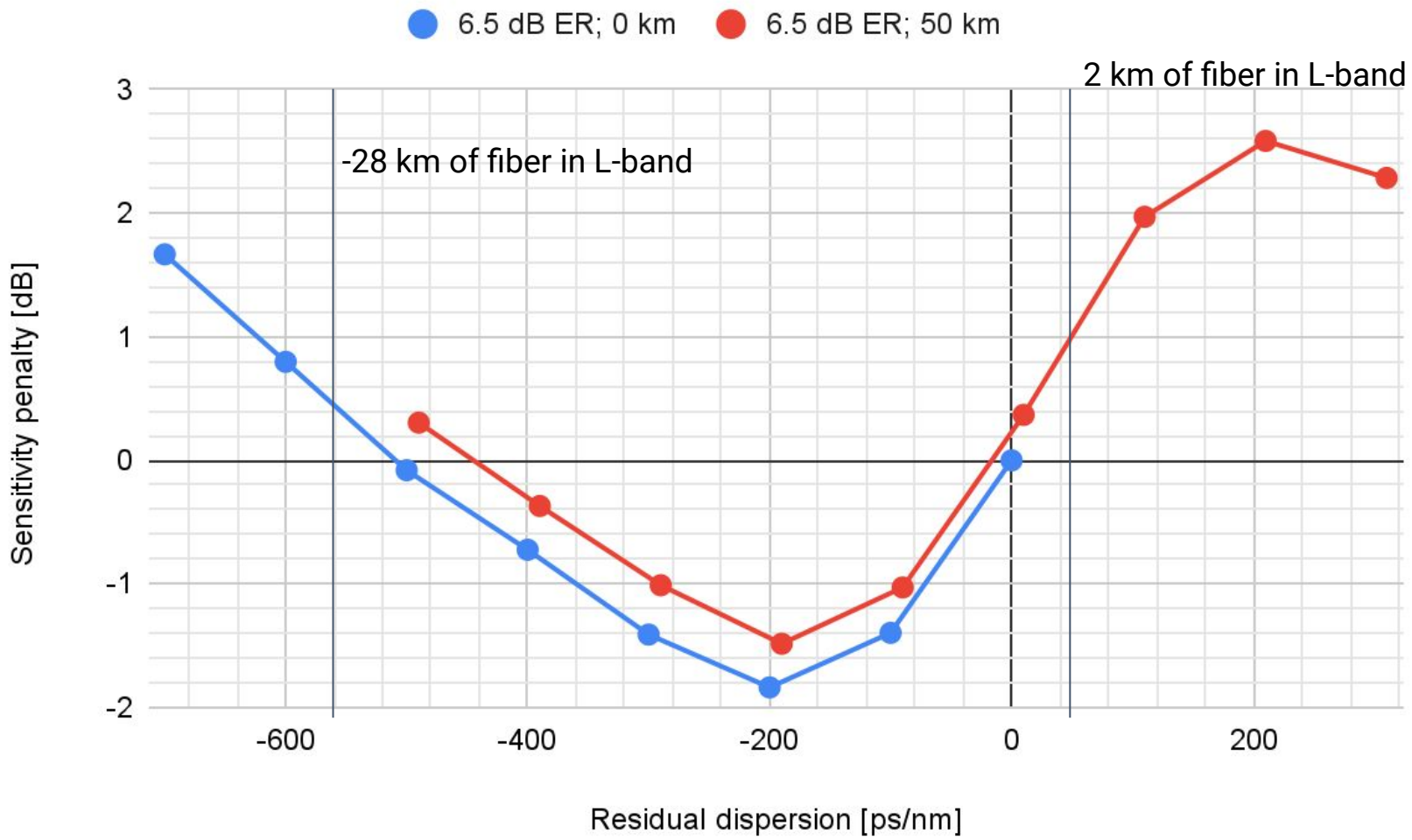



This DML cannot cover 50-km of differential with any DCM value

Two different DCMs are needed for different distances

Optimizing for this DML would allow 29 km of operational range

# Normalizing for residual dispersion: 6.5 dB ER



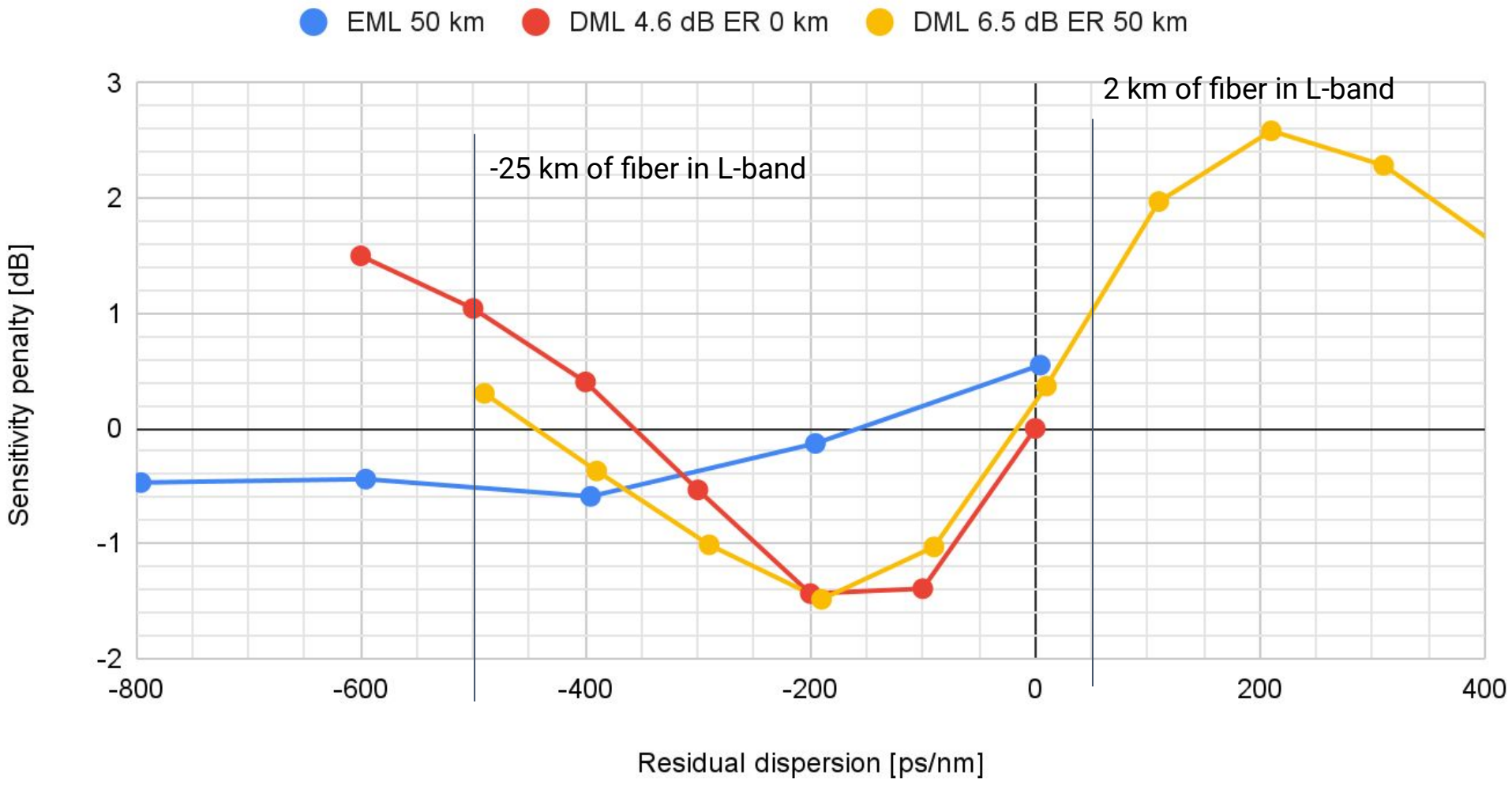

This DML cannot cover 50-km of differential with any DCM value.

Two different DCMs are needed, for different distances

Optimizing for this DML would allow 30 km of operational range

Range is offset from 4.6 dB ER bias by 3 km

# Combining the worst of the 3 lasers




Worst case of all 3 lasers has a range of 25 km where they can all operate over

# Summary

- Assume 20 ps/nm/km in the L-band
- 25-50 km link
  - Use a 50-km DCM (-1000 ps/nm)
  - Total residual dispersion in the link will be -500 ps/nm for 25 km and 0 ps/nm for 50 km
- 0-30 km link
  - Use a 30-km DCM (-600 ps/nm)
  - Total residual dispersion in the link will be -500 ps/nm for 5 km and 0 ps/nm for 30 km
  - Specify a 3-dB CD penalty for -600 ps/nm to -500 ps/nm for 0-5 km links

# Next steps

- Gather data on the distribution of CD over the L-band for fiber types commonly used in access applications
- Based on likely dispersion ranges, update draft with residual CD ranges and acceptable TDP penalties
- Update the required OSNR for the higher penalty region of residual CD

# Thank you