# IEEE P802.3dj 200G per Lane PAM4 Optical PMD’s

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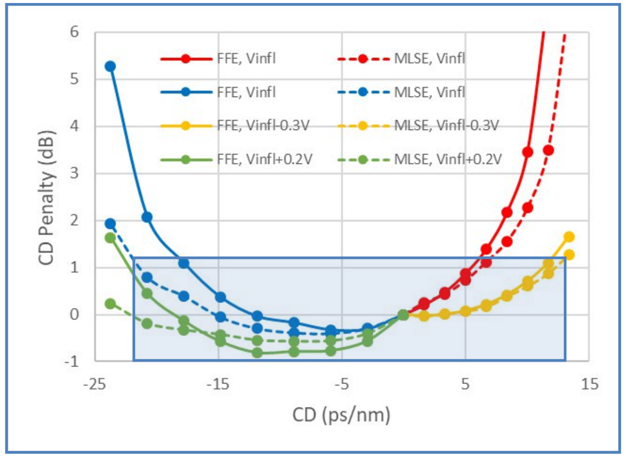
# 200G per Lane PAM4 challenges

- The doubling of bit rate from 100G to 200G has created new challenges
- Increased bandwidth drives more challenging link power budgets
  - Increased noise bandwidth, reduced RX sensitivity
  - Increased TX OMA to close the link
- Increased optical chromatic dispersion (CD) penalty has more severe impacts
  - CWDM for 2km links becomes challenging for the first time
  - 10km links require a LAN-WDM grid close to zero dispersion wavelength (ZDW)
  - Four-wave mixing (FWM) must be addressed for LAN-WDM operation in the ZDW range
- The need for low latency for AI/ML applications complicates FEC adoption
  - Stronger FEC is not a viable solution for all intra-datacenter links

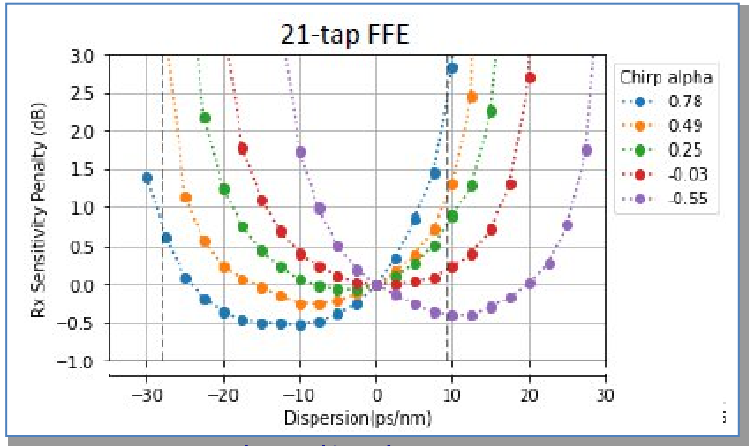
# Mitigation approaches adopted in IEEE P802.3dj

- Statistical models for chromatic dispersion
  - Avoid excess margin by using a channel model representing actual CD distributions
  - IEEE P802.3dj is engaged with SG15/Q5 on the G.652 revision, but also doing our own statistical modeling
  - For single cable segment links (< 2km):
    - Define CD limits at multiple confidence levels based on manufacturers' distributions
  - For multiple cable segment links (2-10km):
    - Fiber cable segments are typically limited by the spool size and installation methods to ~2.5km
    - Use the statistically defined single cable segment limits defined above
    - Use Monte Carlo analysis to average CD over uncorrelated fiber cable segments at specified confidence levels.
- Inner FEC for mitigation of 2km and 10km CD penalties
  - Hamming(128,120) SD FEC encode/decode with convolutional interleaver in the module
  - SD FEC complicates BER allocation between AUI and PMD and TX/RX testing
  - New 800GBASE-FR4-500 PMD without inner FEC to address low latency duplex fiber applications
- Optical link training (OLT)
  - Control of bypassing the precoder for improved interoperability
  - Ready-to-send (RTS) token passing for deterministic end-to-end link start up
  - Future capability: In-service adjustment of transmitter for BER optimization

# Chromatic dispersion penalty at 200G per lane




johnson_3df_01a_221011

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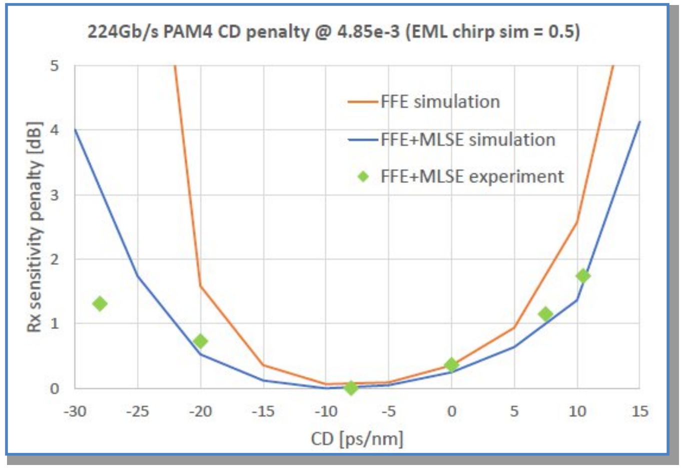
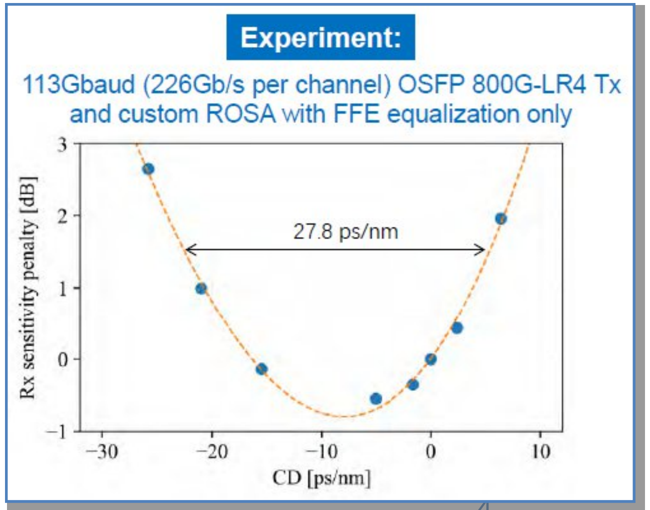



kuschnerov_3df_02a_221012



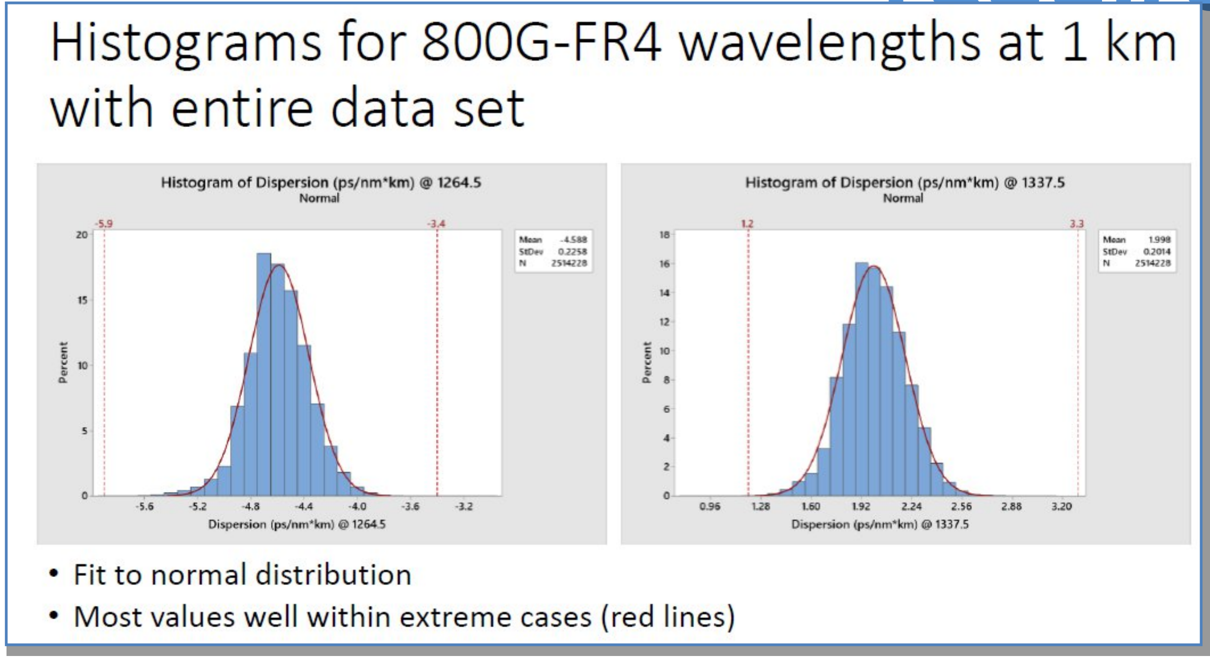

fan_3dj_01a_2405

| Worst case CD limits | Min | Max |
|---|---|---|
| 800G-FR4: CWDM 1264.5-1337.5nm | -11.9 | 6.7 |
| 800G-LR4: LAN-WDM 1294.5-1310.2nm | -28.3 | 9.4 |

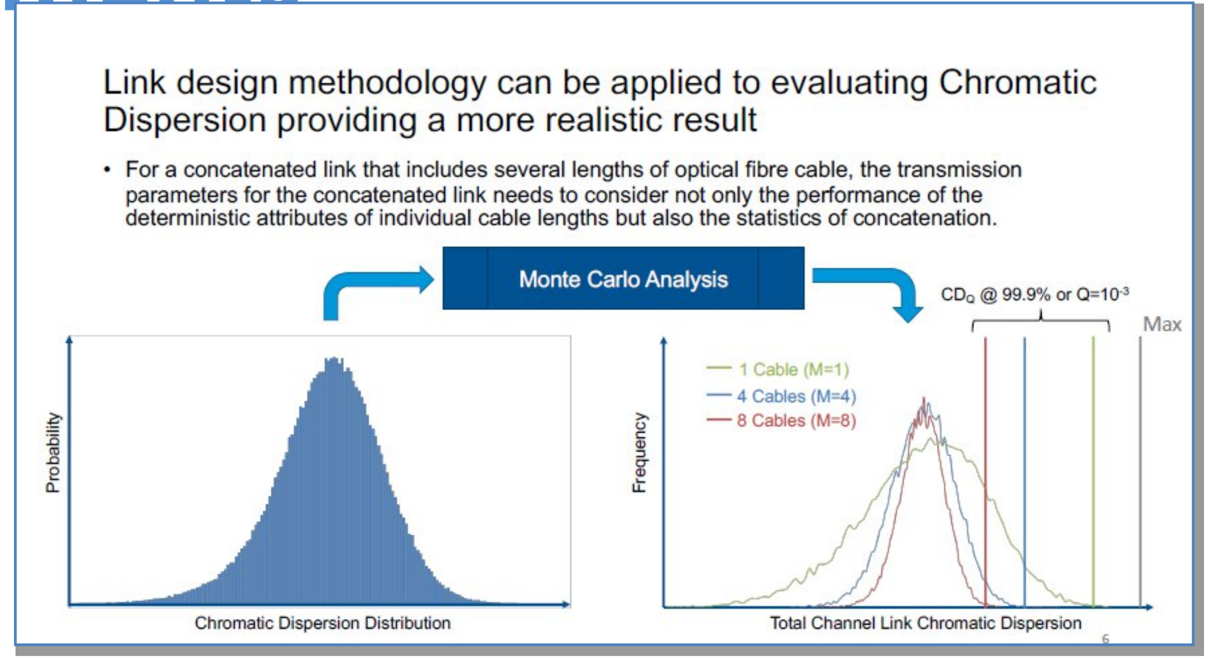
| CD at 1dB penalty | Min | Max |
|---|---|---|
| Johnson, α = 0.6 (sim) | -17.4 | 5.4 |
| Kuschnerov, α = 0.5 (sim) | -18 | 5 |
| Rodes, α = 0.49 (sim) | -25 | 9 |
| Fan (experiment) | -21 | 4 |

Relaxation of G.652 worst case CD limits is necessary to provide margin on both FR4 and LR4 PMDs.

# Statistical methods to reduce CD requirements




parsons_3dj_01a_2405




ferretti_3dj_optx_01b_230615

G.652 worst case CD limits are much wider than actual distributions of fiber cable being shipped. Relaxation of single cable segment channel CD limits is possible by choosing reasonable confidence limits (Q).

Additional CD limit relaxation is possible for links > 2km by averaging the CD over multiple uncorrelated fiber cable segments (M).



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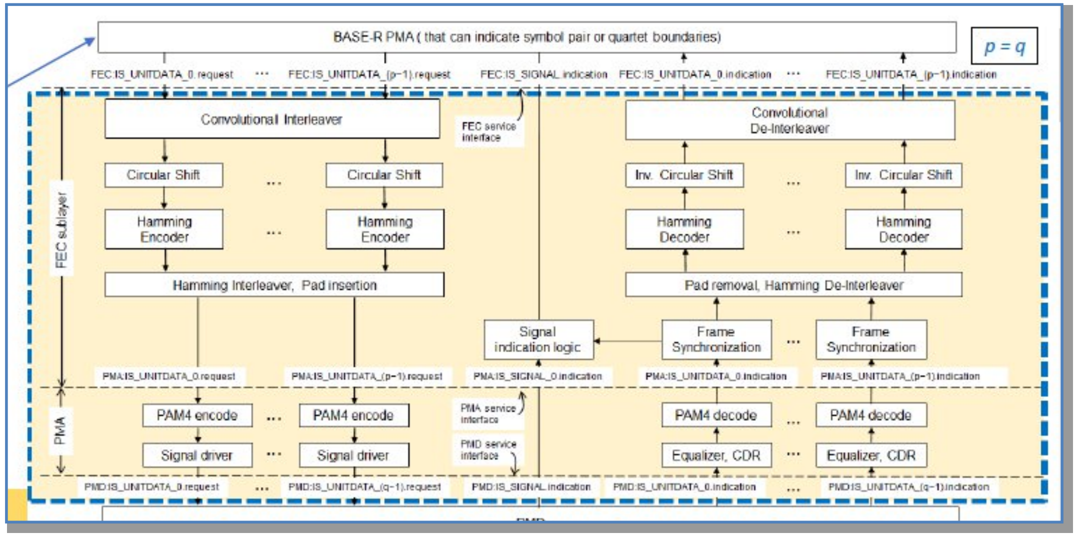
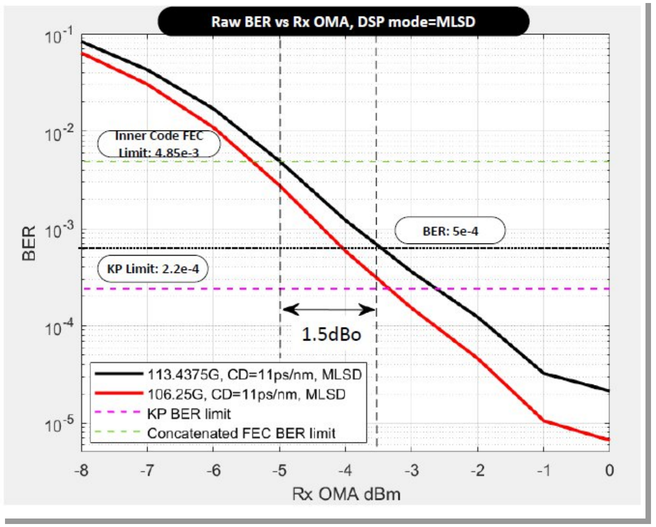
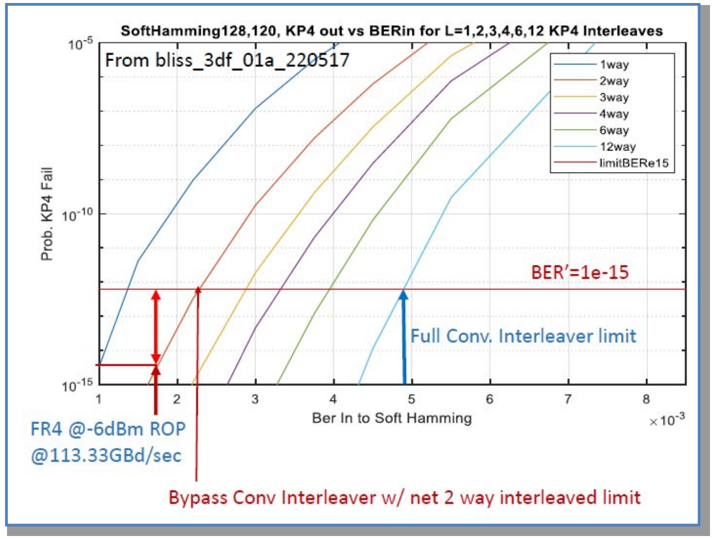
# Inner FEC for 2-10km optical links




he_3dj_01_2307




parthasarathy_3dj_01_2303

- Hamming(128,120) SD Inner FEC provides up to 1.5 dBo gain, enabling improved module power and BER margin in the face of challenging dispersion penalty
- Optional bypass of the convolutional interleaver allows end users to fine tune latency and BER performance to the application

# Summary

- The challenges caused by 200G PAM4 optical transmission have necessitated the development of new Ethernet PHY features
  - Statistical based CD specification in optical channel specs
    - CD limits based on fiber manufacturers' actual distributions
    - Averaging CD over uncorrelated fiber cable segments
  - Inner FEC adds additional CD tolerance over 2km and 10km
  - OLT for pre-coder control and deterministic link start up
- These issues will become even more challenging as the data rate increases. IEEE P802.3dj penalty mitigation methodology paves the way for future 400G per lane IMDD PHYs

# Contributors

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