Revisit MPI Penalties for 400GBASE-FR8/LR8 Links

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Goals

- **Based on worst statistical MPI measurement and simulation results, provide inputs to the following "TBD" parameters for 400GbE-FR8 and –LR8 links in IEEE802.3bs/D1.1:**
  - Table 123-7: Transmitter reflectance (max) in dB
  - Table 123-8: Receiver reflectance (max) in dB
  - Table 123-9: Maximum discrete reflectance in dB

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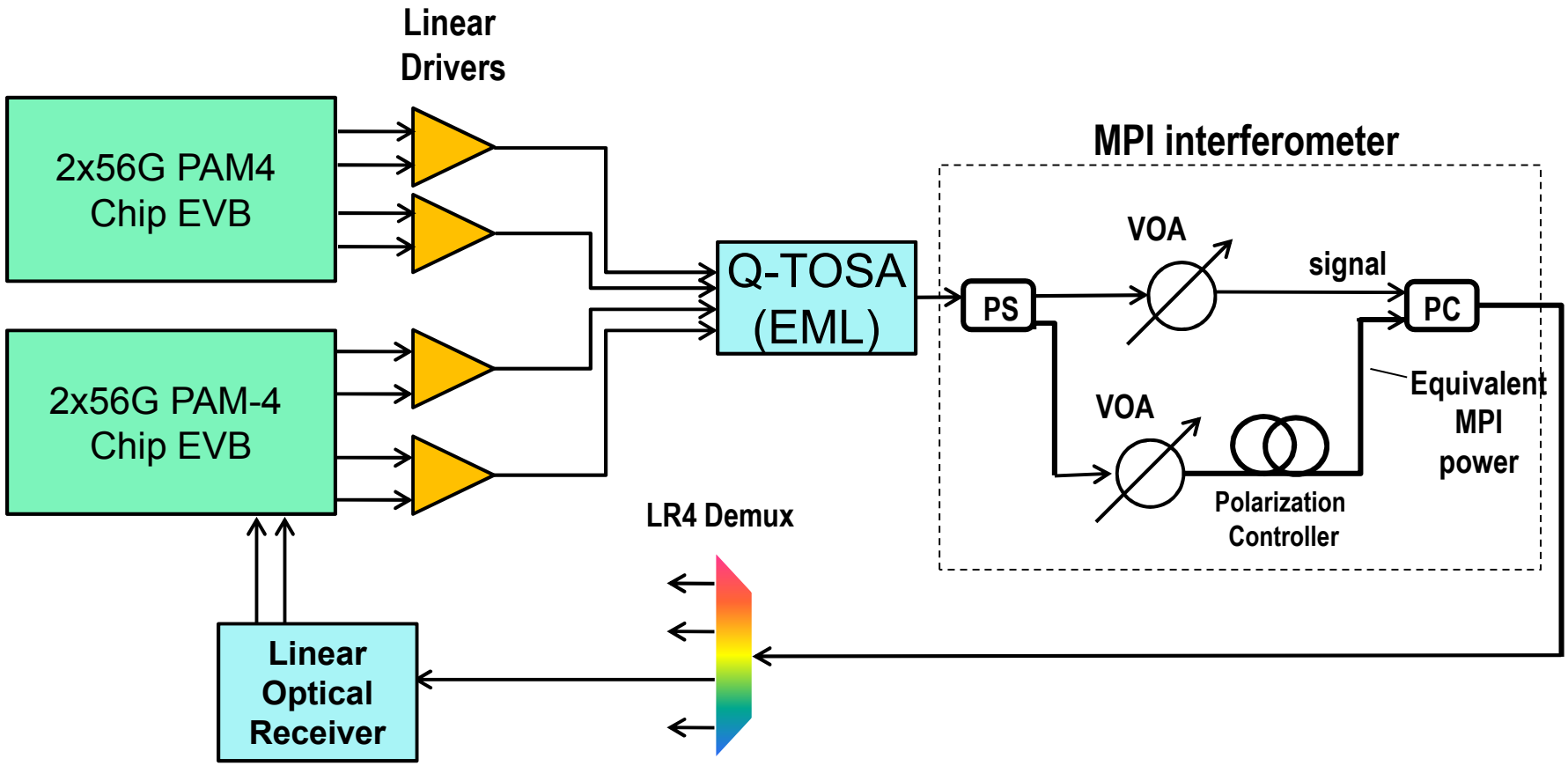
Worst case MPI setup for 28Gbaud PAM4

- Simulates perfect phase and polarization match among multiple MPI



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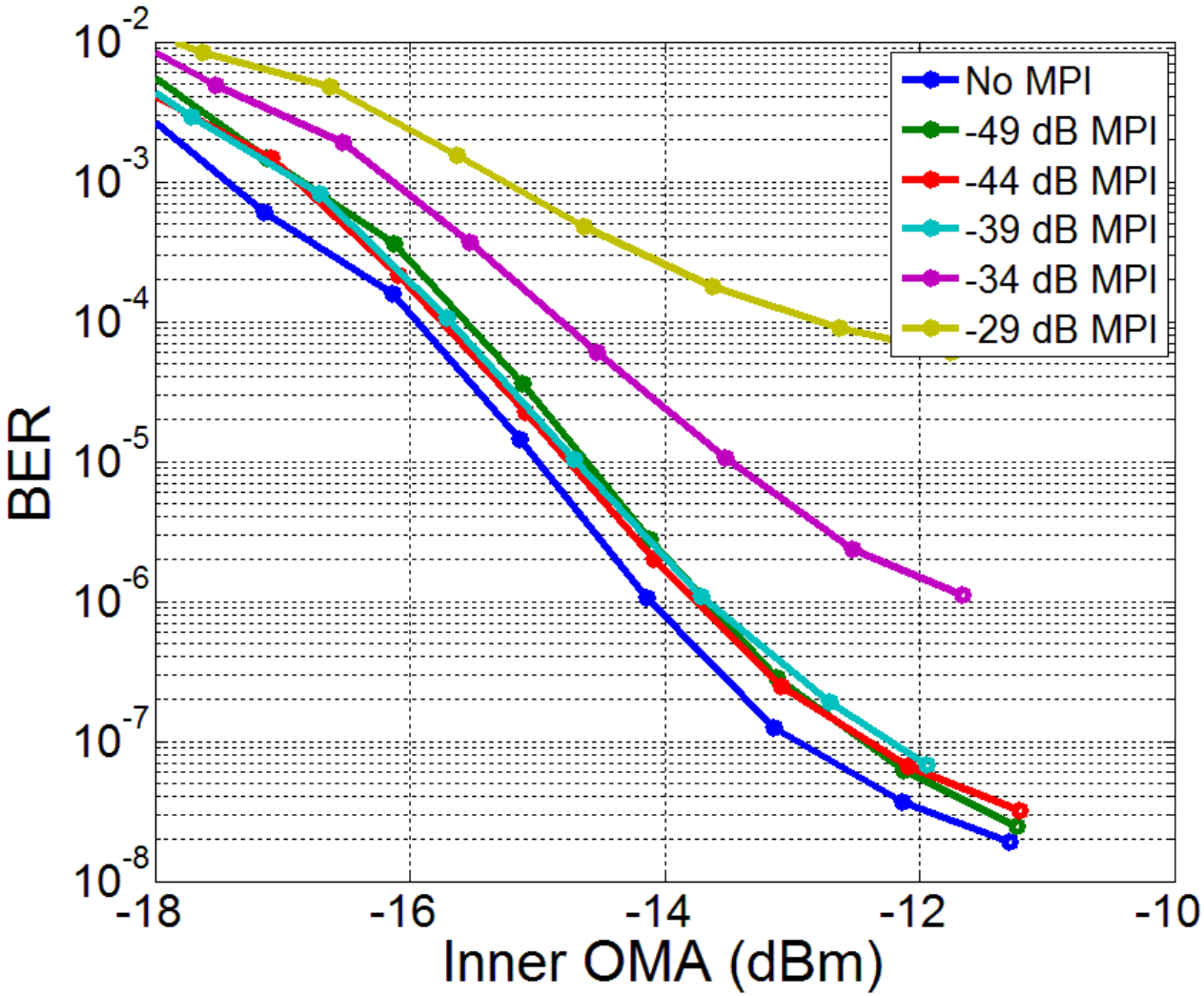
BER vs. OMA curve for MPI Measurement



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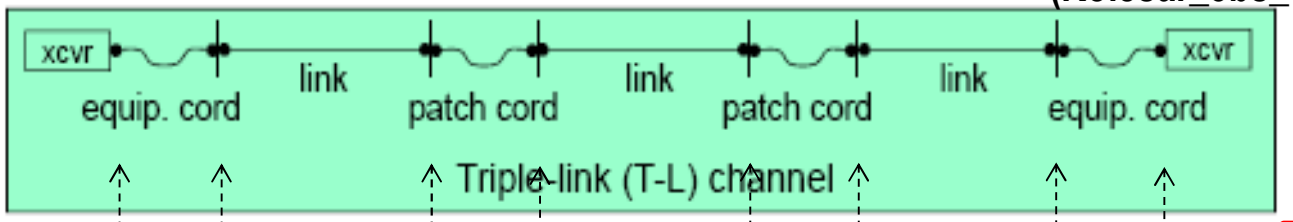
Equivalent MPI Power when Using Power or Field Addition

(Kolesar_3bs_01_0514)



Return loss assumption

Case 1:	-26dB	-35dB		-35dB	-35dB		-35dB	-35dB	-35dB	-26dB
Case 2:	-12dB	-35dB		-35dB	-35dB		-35dB	-35dB	-35dB	-26dB
Case 3:	-26dB	-26dB		-26dB	-26dB		-26dB	-26dB	-26dB	-26dB
Case 4:	-12dB	-26dB		-26dB	-26dB		-26dB	-26dB	-26dB	-26dB

	Power addition	Field addition
	Equivalent MPI Power	Equivalent MPI Power
Case 1:	-48 dB	-35 dB
Case 2:	-35 dB	-26 dB
Case 3:	-38 dB	-23 dB
Case 4:	-29 dB	-17 dB

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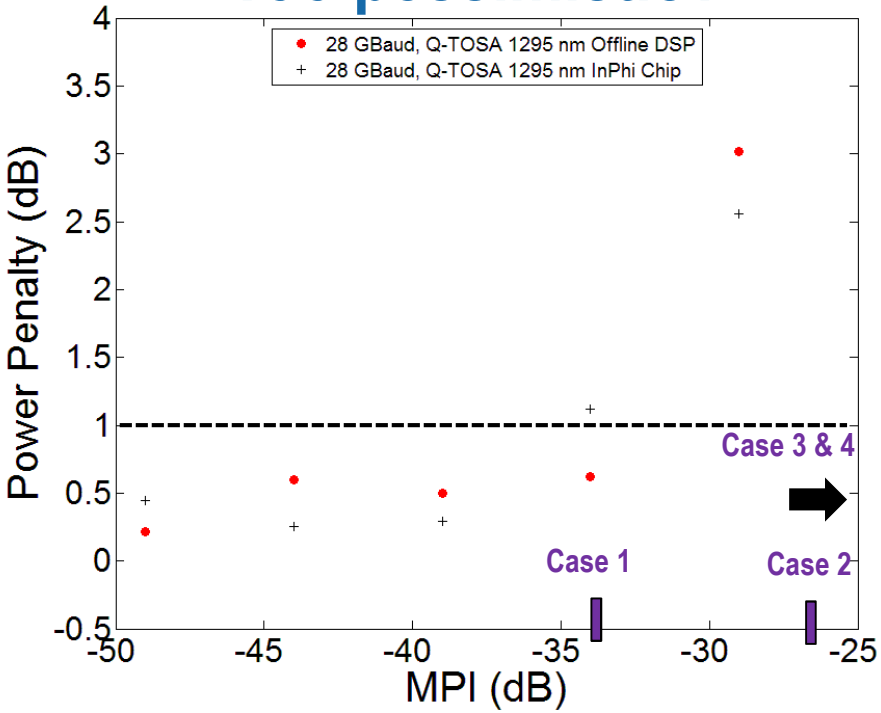
Very Different Connector RL Requirements for Field or Power Addition Assumptions

For power penalty < 1 dB,
Can barely use connectors with RL=-35dB
(TX & RX RL= -26dB)

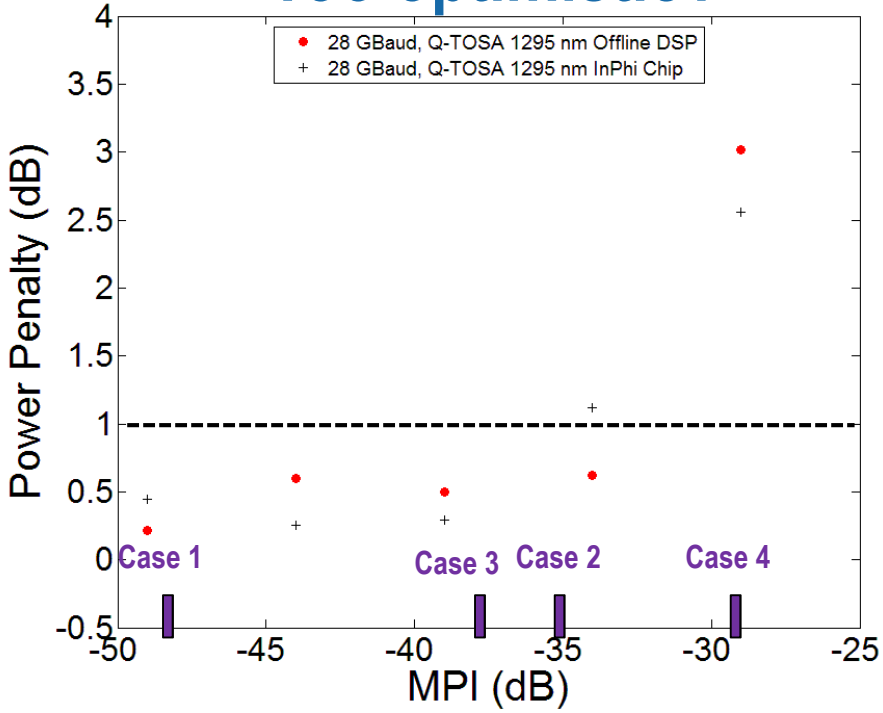
Too pessimistic?



(Field addition)

For power penalty < 1 dB,
can use connectors with RL=-26dB
(TX & RX RL = -26dB)

Too optimistic?



(Power addition)

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Monte Carlo Simulation

- Assuming random phase, amplitude, and polarization

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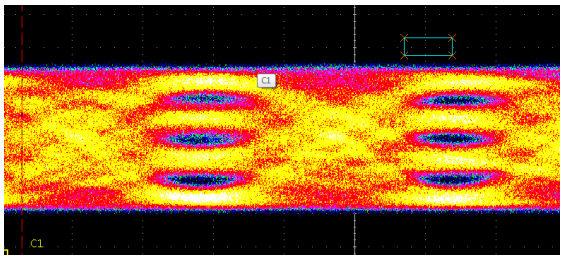
MPI using a Monte Carlo Simulation

Signal: $Ae^{-i\phi}\hat{u}$

Multipath Interference: $r_m r_n A_{mn} e^{-i\phi_{mn}} \hat{u}_{mn}$

Connector return loss

[0, 2π]



Possibilities for A_{mn}

Monte Carlo Random Variables

$$\vec{E} = Ae^{-i\phi}\hat{u} + \sum_m \sum_n r_m r_n A_{mn} e^{-i\phi_{mn}} \hat{u}_{mn}$$

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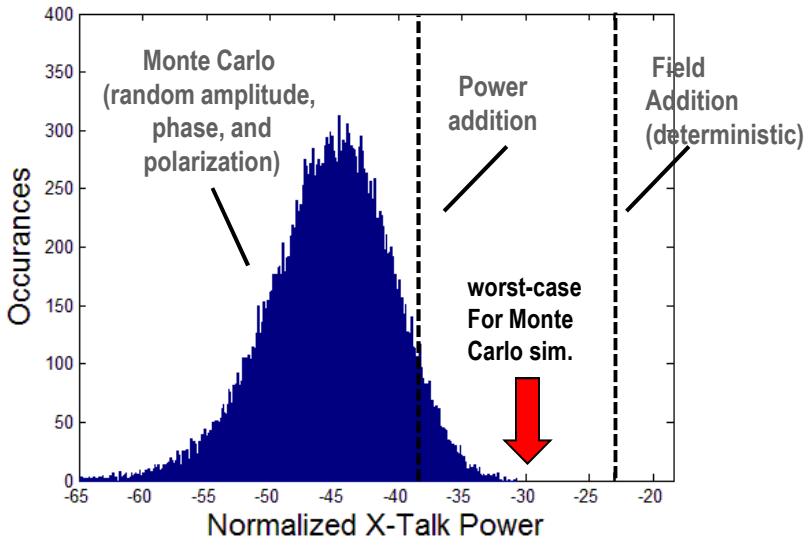
Monte Carlo simulation of MPI – Case 3 Example

- 6 connectors: -26 dB RL
- TOSA/ROSA: -26 dB RL
- More than 2 reflections are considered negligible
- Random phase and polarization from each double reflection
- MPI generates random interfering amplitudes for amplitude levels 2, 3 and 4



Analytical

-Field addition = -23.1 dB (worst case)

-Power addition = -37.5 dB

Monte Carlo (40000 samples considered)

-Interference with highest PAM4 amplitude

- Maximum x-talk power = -26.5 dB
- Average x-talk power = -38.0 dB

-Random Amplitude

- Maximum x-talk power = -30.7 dB
- Average x-talk power = -43.0 dB

Worst-case Monte Carlo simulation result is a more realistic condition

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Measurement of Statistical, Accelerated MPI

- *Phase randomness*
- *Amplitude randomness*
- *Accelerated polarization randomness*

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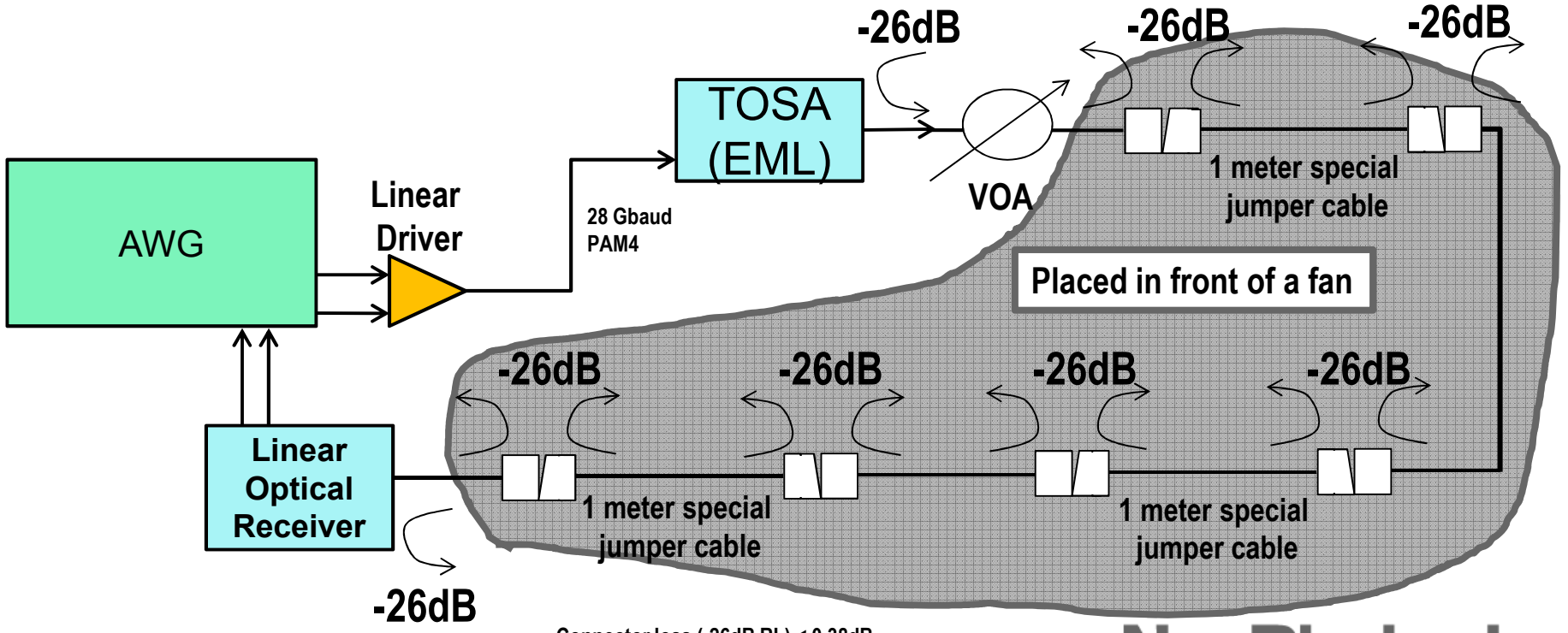
Measurement System

- 84K consecutive symbols @ 28 GBaud measured for each acquisition period of 3μs (~30 100GBase-KP4 FEC frames)
- Unlike PAM4 IC chip which reports BER average over a period of about 1sec, here every the BER average period is shortened to 3μs
- The worst 3μs-period BER in an 8-hour period is reported



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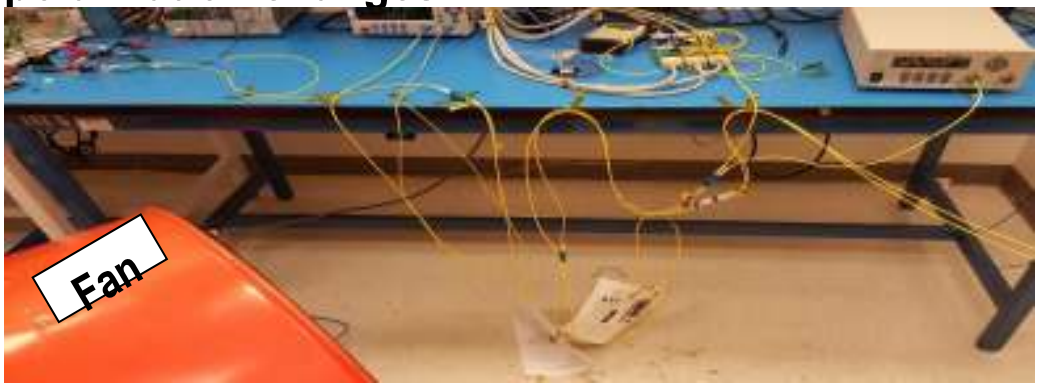
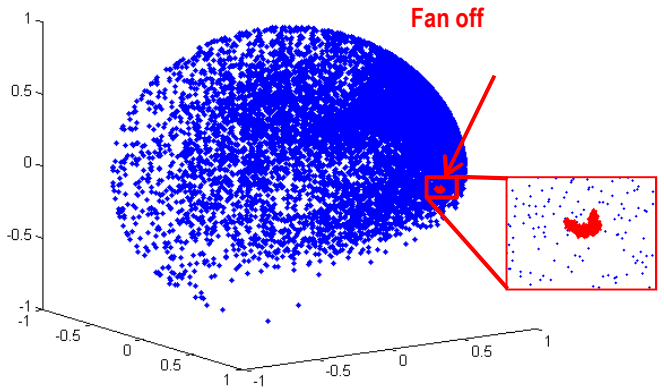
Experimental setup

- **Fibers are suspended and a big fan was turned on to accelerate the state of polarization changes**

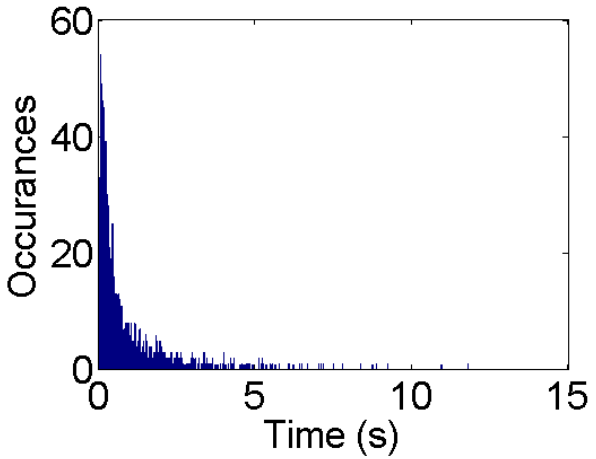


8 hour SOP measurement



- **50% SOP decorrelation time used to quantize fiber sway** *(OFC 2001 ThA3)*
  - Accelerated case: 0.8s average (probability distribution shown on the right)
  - Static case: >> 8 hours
  - **Acceleration factor >> 36000x**

50% SOP Decorrelation Times



8 hours under the fan represents >> 26 years of static operation

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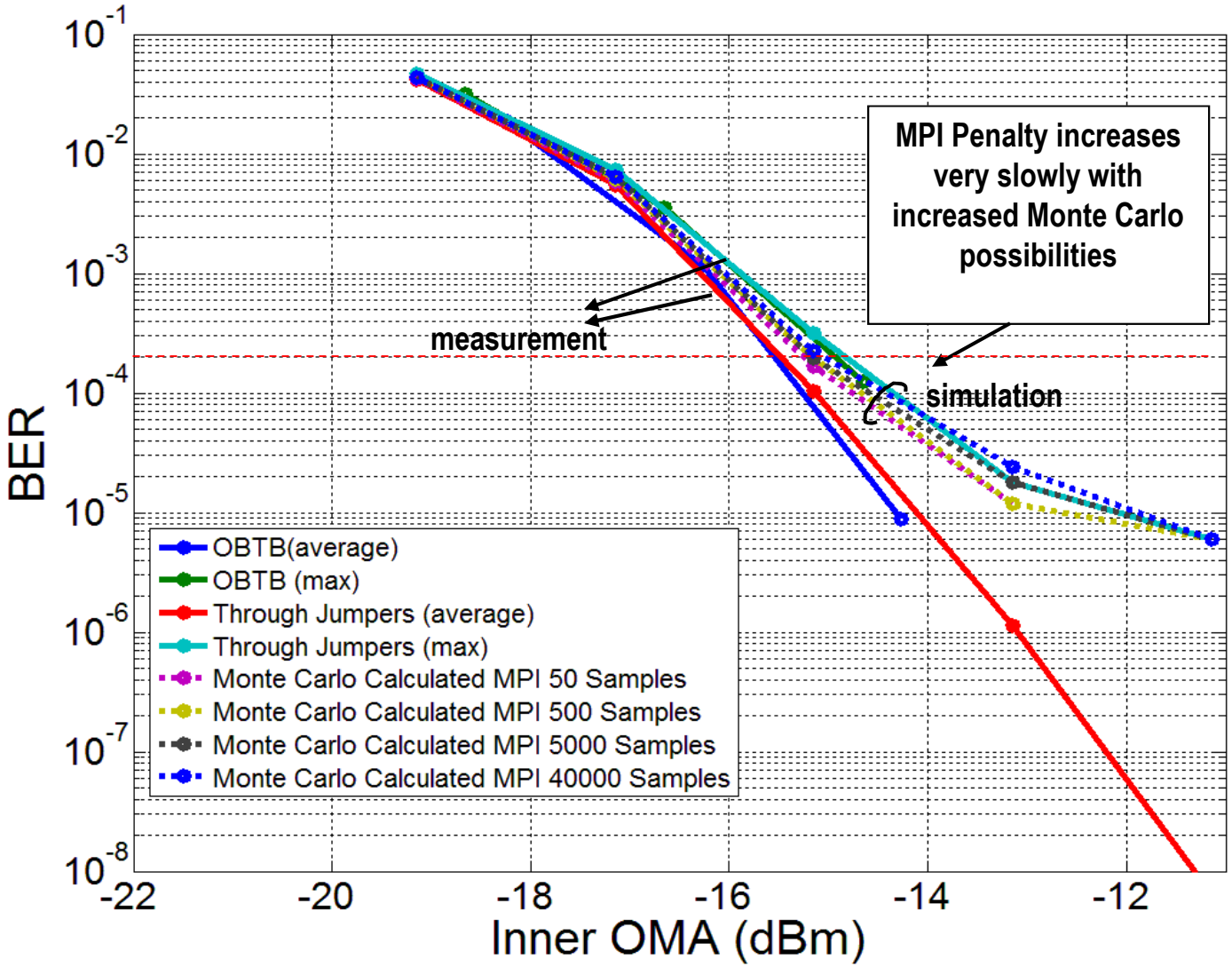
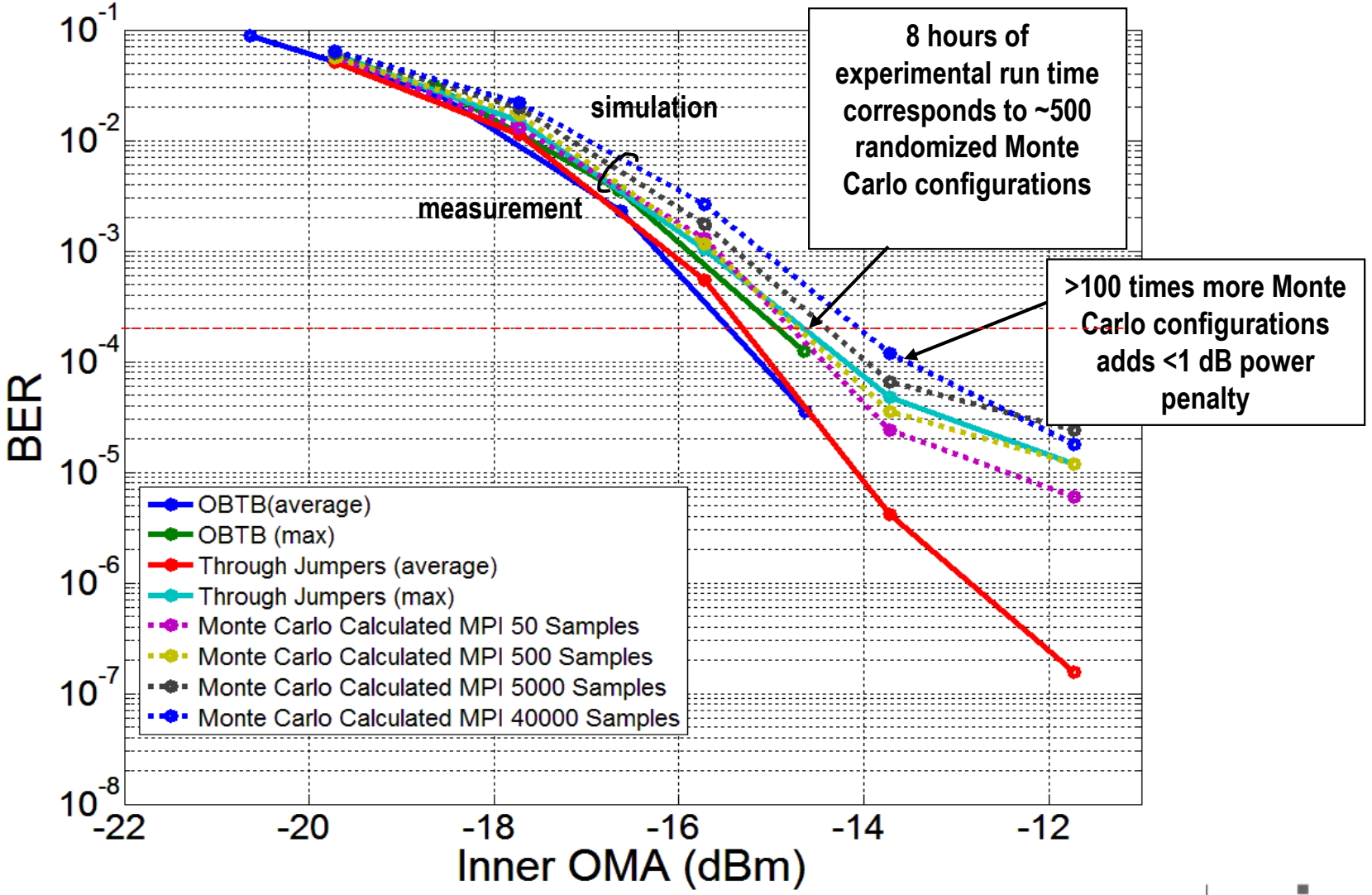
Case 1: -26 dB ROSA & TOSA, -35 dB Jumpers



Case 3: -26 dB ROSA & TOSA, -26 dB Jumpers



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Summary

- **Measurement sampling taken for consecutive 84000 symbols, no missing burst event**
- **Average of 8 hours (under strong vibration on jumper cables) per measured data point**
  - Each data point represents >> 25 years of normal operation
- **Observations**
  - **Case 1** (connector RL=-35dB, TX/RX RL=-26dB) with negligible power penalty is a very safe conclusion - with 6 LC connectors (if MPO connectors with -55dB RL are added, the effect should be small)
  - **Case 3** (connector RL=-26dB, TX/RX RL=-26dB) with <1dB power penalty @ BER=2e-4 is also a very safe conclusion - with 6 LC connectors (if MPO connectors with -55dB RL are added, the effect should be small)
    * <0.3dB penalty (@ BER=2e-4) from MPI under 8-hour accelerated polarization randomness
    * Extrapolation from simulations shows under -14dBm receiver sensitivity, with 100x longer time than our >>25 year representative experiment

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Thank You!

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