100GE PCS Modeling

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How Random is the PCS Data?

- The Proposed 100G PCS has the concept of virtual lanes
- A 100G stream is scrambled and then distributed and muxed to many lanes
- How does the distribution, muxing and skew affect the “randomness” of the streams?

  We rely on the scrambling to provide clock transitions for clock recovery, to control baseline wander etc…

- Can’t prove or disprove the randomness (at least easily?)

  So run some simulations

How Random is the PCS Data?

- Maximum run lengths

  Maximum burst of ones or zeros throughout the simulation.

- Running disparity

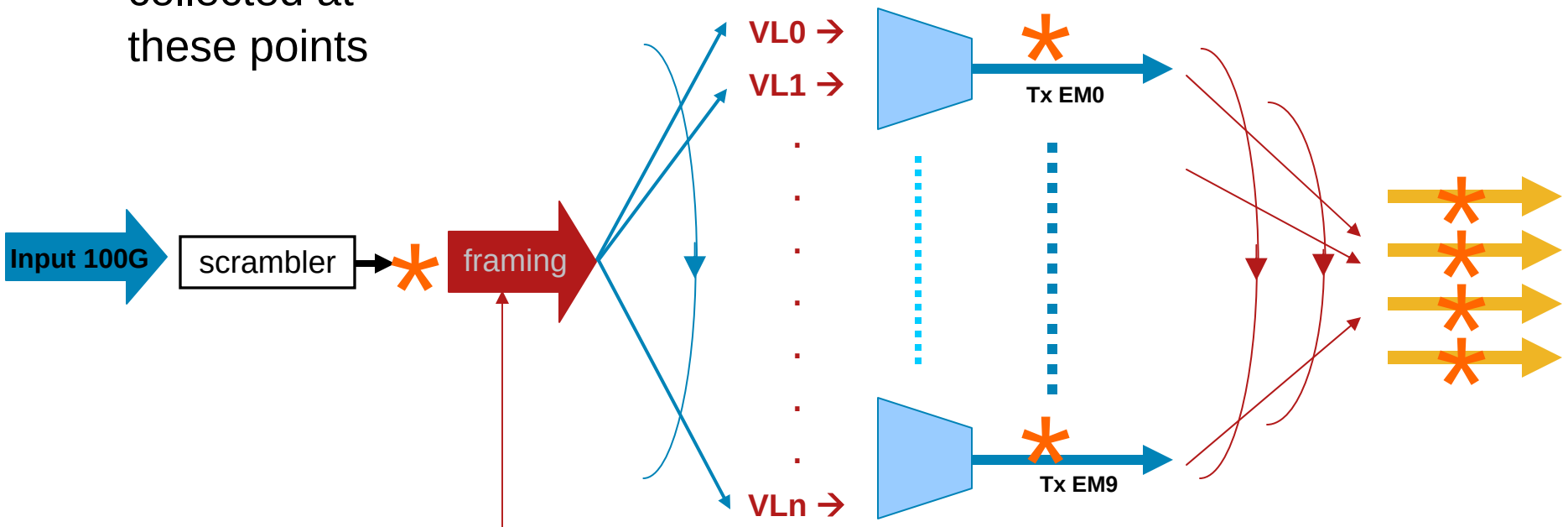
  (# of ones) – (# of zeros) in a 64,000bits sliding window.

- Number of transitions within a window

  No. of transitions in 128 bits sliding window

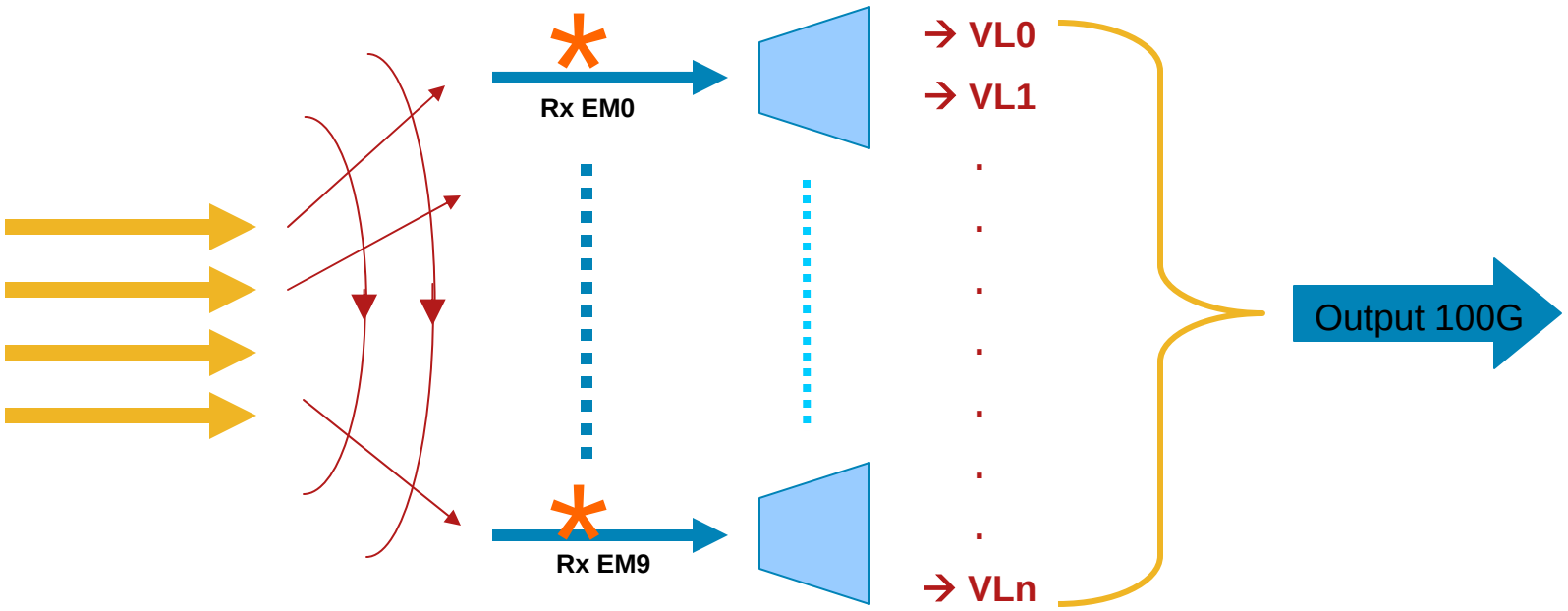
Model Block Diagram - Transmit

* - statistics are collected at these points



Scrambler	Framing	Round-Robin	Virtual lanes	Bit mux	Transmit Electrical media	Tx Gearbox	Optical lanes
Self synchronous with polynomial $X^{58}+X^{39}+1$ Random number is picked for seed	Adding sync bits and alignment words.	of 66b words between Virtual lanes	Config-urable no. of VLs		- configurable: - number - latency per SerDes	Round-Robin between electrical media and between optical lanes	configurable: - number - latency per lane

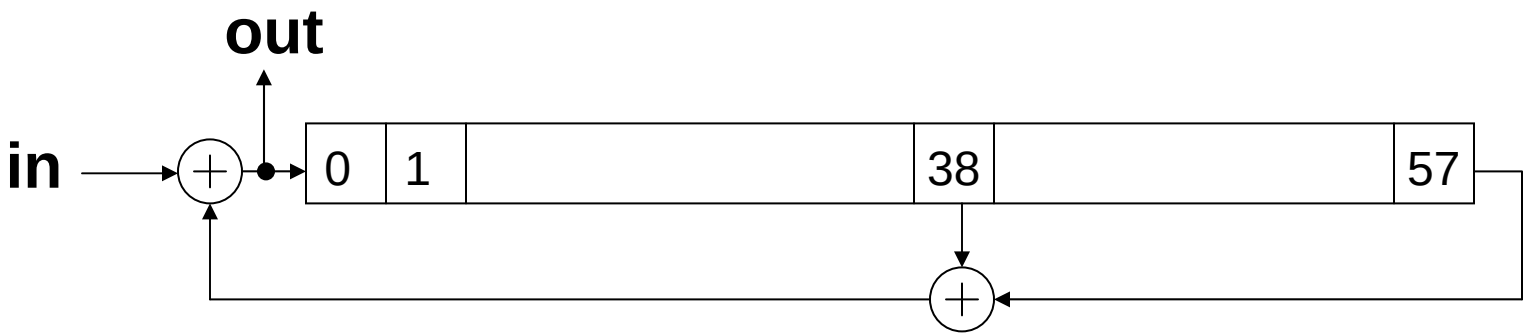
Model Block Diagram – Receive



Rx Gearbox	Receive electrical media	Bit demux	Virtual lanes		Verification
Round-Robin between optical lanes and between output electrical media	- configurable: - number - latency per SerDes		(same no. as input VLs)	-Word delimiter -Word alignment -Lane muxing	compare output with input

Scrambler Used

- Self synchronous
- Polynomial: $X^{58}+X^{39}+1$ (10GBASE-R)



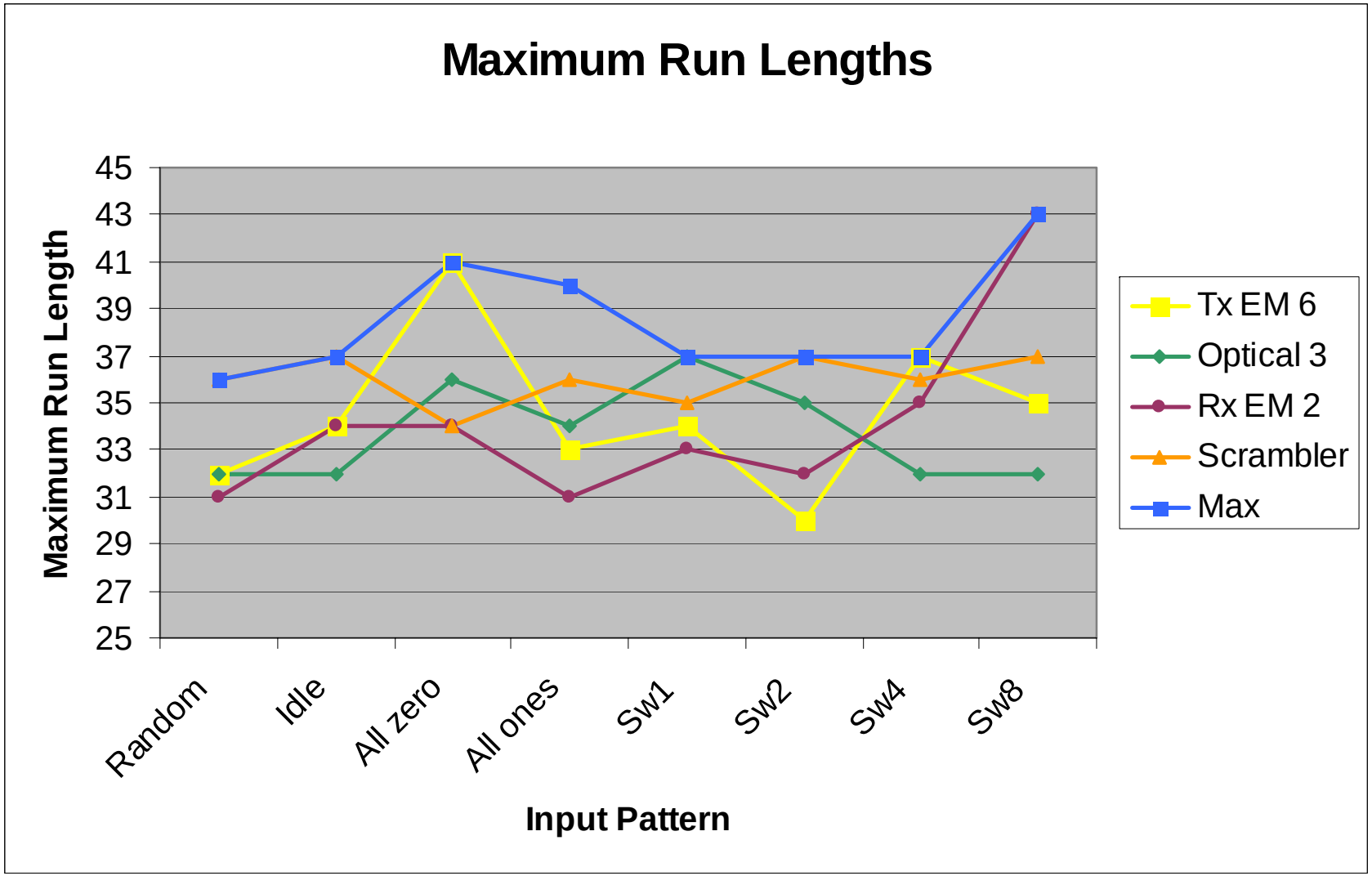
Various Input Patterns

- All simulation were run with 10 transmit and receive electrical media, 4 optical and 20 Virtual lanes, and with various inputs.
- Simulations length: $7.5x10^{10}$ bits (0.75 second at 100Gbps)
- Random input data
  - Random generated with “Mersenne Twister”.
- Idle data input
  - Repeating 0x1e00000000
- All zero input
- All ones input
- Square wave patterns
  - SW1: 0b010101010…
  - SW2: 0b00110011001100…
  - SW4: 0b0000111100001111…
  - SW8: 0xFF00FF00…

Results: Max Run Length

	Random	Idle	All zero	All ones	Sw1	Sw2	Sw4	Sw8	max
Tx EM 0	33	34	33	31	34	31	31	34	**34**
Tx EM 1	**36**	33	33	**40**	33	35	31	31	**40**
Tx EM 2	31	32	33	31	31	33	33	31	**33**
Tx EM 3	32	32	35	32	31	32	32	30	**35**
Tx EM 4	33	32	34	30	32	32	33	38	**38**
Tx EM 5	33	33	33	32	30	35	31	32	**35**
Tx EM 6	32	34	**41**	33	34	30	**37**	35	**41**
Tx EM 7	33	33	32	32	31	31	35	30	**35**
Tx EM 8	31	34	34	31	33	32	35	**43**	**43**
Tx EM 9	32	34	32	33	31	33	33	31	**34**
Optical 0	35	32	33	33	33	34	32	39	**39**
Optical1	35	33	37	34	34	34	33	37	**37**
Optical 2	34	36	32	33	35	33	35	34	**36**
Optical 3	32	32	36	34	**37**	35	32	32	**37**
Rx EM 0	32	34	**41**	33	34	30	**37**	35	**41**
Rx EM 1	33	33	32	32	31	31	35	30	**35**
Rx EM 2	31	34	34	31	33	32	35	**43**	**43**
Rx EM 3	32	34	32	33	31	33	33	31	**34**
Rx EM 4	33	34	33	31	34	31	31	34	**34**
Rx EM 5	**36**	33	33	**40**	33	35	31	31	**40**
Rx EM 6	31	32	33	31	31	33	33	31	**33**
Rx EM 7	32	32	35	32	31	32	32	30	**35**
Rx EM 8	33	32	34	30	32	32	33	38	**38**
Rx EM 9	33	33	33	32	30	35	31	32	**35**
Scrambler	**36**	**37**	34	36	35	**37**	36	37	**37**
Maximum	**36**	**37**	**41**	**40**	**37**	**37**	**37**	**43**	**43**

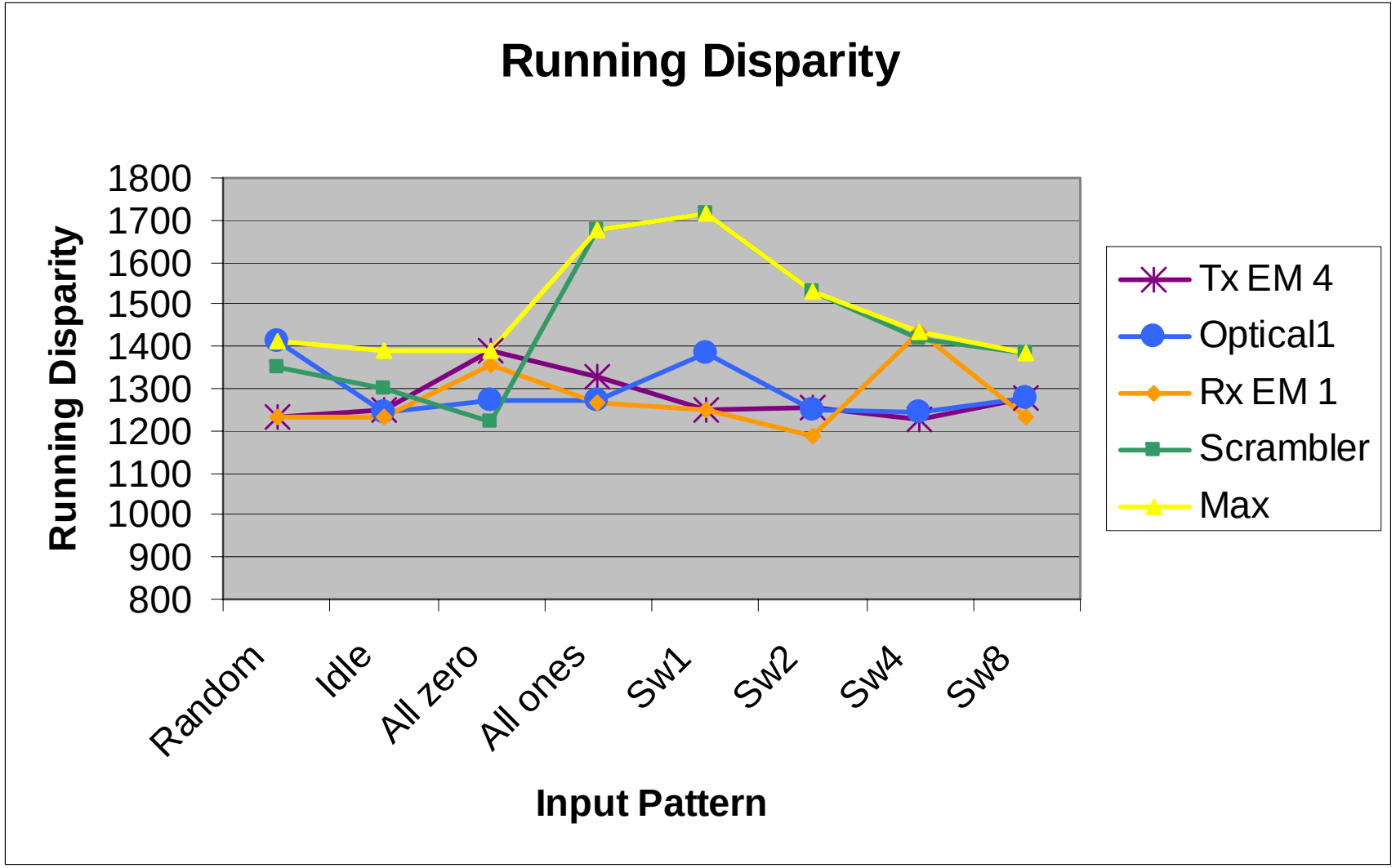
Results: Max Run Length



Results: Max Running Disparity

	Random	Idle	All zero	All ones	Sw1	Sw2	Sw4	Sw8	max
Tx EM 0	1330	1228	1296	1350	1260	1208	1184	1256	**1350**
Tx EM 1	1328	1358	1184	1532	1128	1336	1196	1158	**1532**
Tx EM 2	1318	1232	1230	1214	1236	1326	1290	1274	**1326**
Tx EM 3	1238	1194	1268	1250	1222	1356	1324	1176	**1356**
Tx EM 4	1232	1250	**1392**	1326	1250	1254	1226	1278	**1392**
Tx EM 5	1190	1210	1192	1196	1244	1320	1296	1264	**1320**
Tx EM 6	1208	**1388**	1244	1426	1260	1176	1246	1218	**1426**
Tx EM 7	1230	1230	1358	1268	1250	1188	**1436**	1234	**1436**
Tx EM 8	1252	1226	1172	1350	1264	1502	1356	1152	**1502**
Tx EM 9	1206	1172	1332	1260	1248	1236	1252	1172	**1332**
Optical 0	1260	1282	1310	1220	1360	1462	1330	1346	**1462**
Optical1	**1412**	1242	1272	1274	1386	1252	1246	1276	**1412**
Optical 2	1250	1272	1216	1260	1300	1306	1354	1352	**1354**
Optical 3	1386	1256	1296	1300	1264	1360	1222	1226	**1386**
Rx EM 0	1208	**1388**	1244	1426	1260	1176	1246	1218	**1426**
Rx EM 1	1230	1230	1358	1268	1250	1188	**1436**	1234	**1436**
Rx EM 2	1252	1226	1172	1350	1264	1502	1356	1152	**1502**
Rx EM 3	1206	1172	1332	1260	1248	1236	1252	1172	**1332**
Rx EM 4	1330	1228	1296	1350	1260	1208	1184	1256	**1350**
Rx EM 5	1328	1358	1184	1532	1128	1336	1196	1158	**1532**
Rx EM 6	1318	1232	1230	1214	1236	1326	1290	1274	**1326**
Rx EM 7	1238	1194	1268	1250	1222	1356	1324	1176	**1356**
Rx EM 8	1232	1250	**1392**	1326	1250	1254	1226	1278	**1392**
Rx EM 9	1190	1210	1192	1196	1244	1320	1296	1264	**1320**
Scrambler	1352	1302	1220	**1678**	**1714**	**1530**	1418	**1386**	**1714**
Max	**1412**	**1388**	**1392**	**1678**	**1714**	**1530**	**1436**	**1386**	**1714**

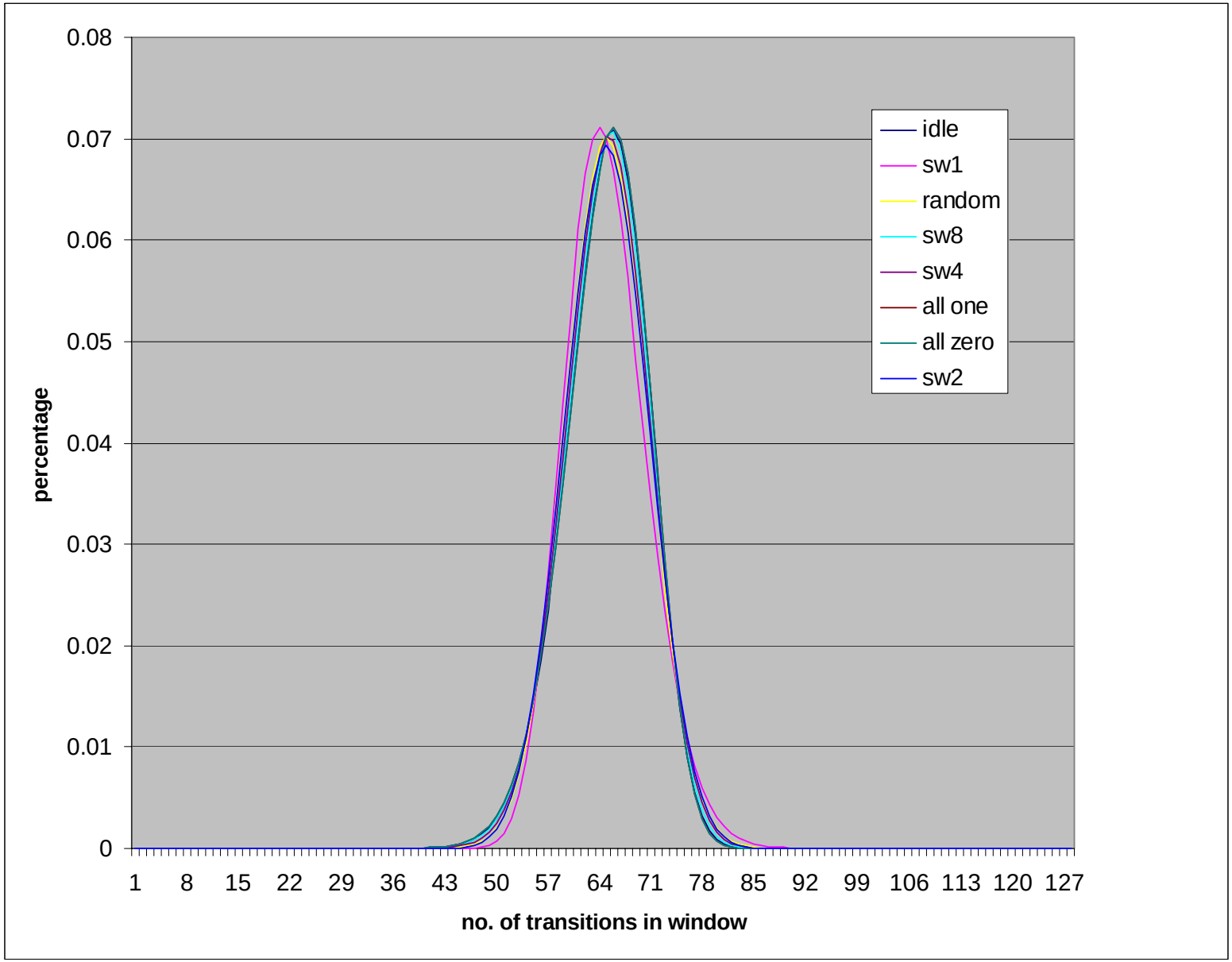
Results: Max Running Disparity



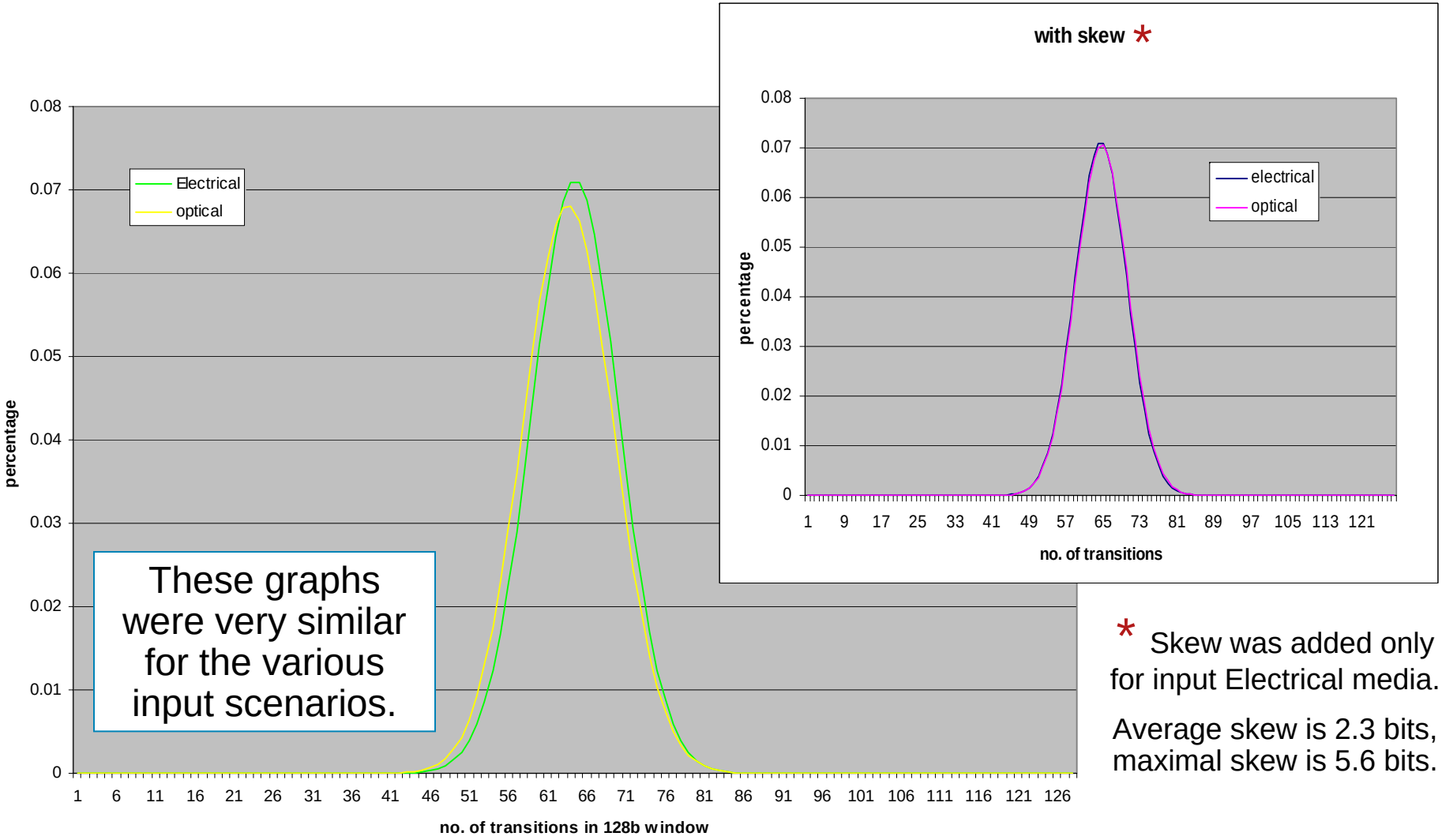
Results: Min Running Disparity

	Random	Idle	All zero	All ones	Sw1	Sw2	Sw4	Sw8	min
Tx EM 0	-1294	-1264	-1278	-1198	-1230	-1256	-1324	-1228	**-1324**
Tx EM 1	-1252	-1260	-1356	-1216	-1322	-1226	-1210	-1196	**-1356**
Tx EM 2	-1220	-1270	-1366	-1220	-1268	-1216	-1532	-1232	**-1532**
Tx EM 3	-1318	-1292	-1368	-1274	-1178	-1214	-1324	-1258	**-1368**
Tx EM 4	-1272	-1204	-1230	-1278	-1244	-1316	-1218	-1226	**-1316**
Tx EM 5	-1244	-1390	-1242	-1254	-1284	-1352	-1292	-1244	**-1390**
Tx EM 6	-1238	-1316	-1250	-1360	-1168	-1372	-1346	-1280	**-1372**
Tx EM 7	-1268	-1324	-1282	-1262	-1202	-1250	-1268	-1226	**-1324**
Tx EM 8	-1224	-1248	-1234	-1262	-1426	-1164	-1172	-1230	**-1426**
Tx EM 9	-1250	-1280	-1386	-1280	-1186	-1270	-1290	-1164	**-1386**
Optical 0	-1314	**-1512**	-1336	-1266	-1232	-1394	-1262	-1262	**-1512**
Optical1	-1288	-1262	-1280	-1234	-1272	-1310	-1322	-1252	**-1322**
Optical 2	-1310	-1264	-1262	-1284	-1286	-1274	-1316	**-1470**	**-1470**
Optical 3	-1278	-1268	-1304	-1274	-1316	-1242	-1438	-1228	**-1438**
Rx EM 0	-1238	-1316	-1250	**-1360**	-1168	-1372	-1346	-1280	**-1372**
Rx EM 1	-1268	-1324	-1282	-1262	-1202	-1250	-1268	-1226	**-1324**
Rx EM 2	-1224	-1248	-1234	-1262	-1426	-1164	-1172	-1230	**-1426**
Rx EM 3	-1250	-1280	-1386	-1280	-1186	-1270	-1290	-1164	**-1386**
Rx EM 4	-1294	-1264	-1278	-1198	-1230	-1256	-1324	-1228	**-1324**
Rx EM 5	-1252	-1260	-1356	-1216	-1322	-1226	-1210	-1196	**-1356**
Rx EM 6	-1220	-1270	-1366	-1220	-1268	-1216	-1532	-1232	**-1532**
Rx EM 7	-1318	-1292	-1368	-1274	-1178	-1214	-1324	-1258	**-1368**
Rx EM 8	-1272	-1204	-1230	-1278	-1244	-1316	-1218	-1226	**-1316**
Rx EM 9	-1244	-1390	-1242	-1254	-1284	-1352	-1292	-1244	**-1390**
Scrambler	**-1400**	-1478	**-1674**	-1234	**-1492**	**-1410**	**-1616**	-1430	**-1674**
Min	**-1400**	**-1512**	**-1674**	**-1360**	**-1492**	**-1410**	**-1616**	**-1470**	**-1674**

Transitions in 128 bits Window – Scrambler Output



Transitions in 128 bits Window
optical and electrical media



* Skew was added only for input Electrical media.

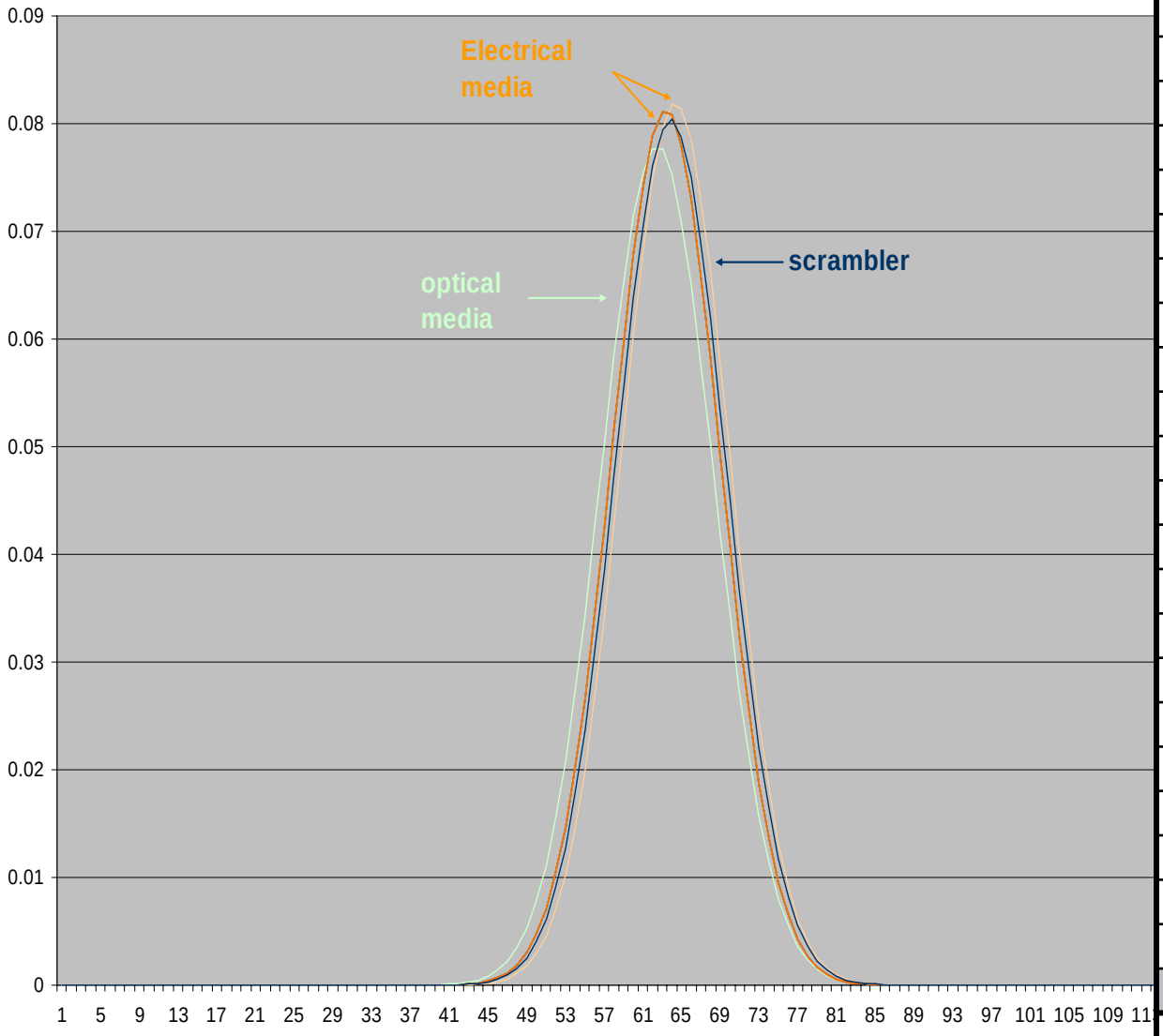
Average skew is 2.3 bits, maximal skew is 5.6 bits.

Stage 2 - Long Simulation, Setup A

Simulations length: 10^{12} bits, 10 seconds

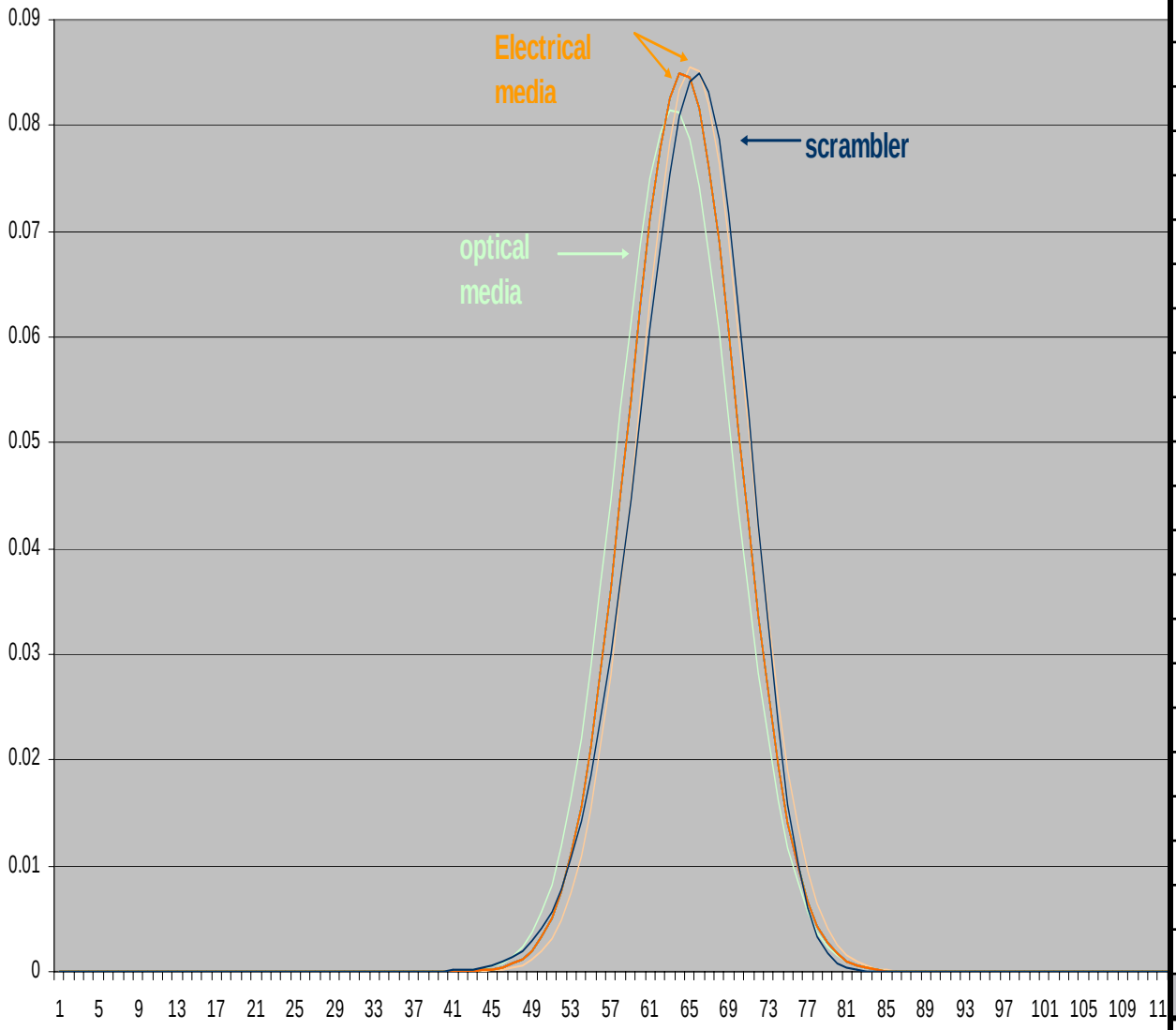
- 10 input and output Electrical media, 4 optical
- Skew:
  - None in electrical media
  - Max skew in optical: 5 bits (latencies in bit-time: 1, 2, 4, 6)
- Input scenarios:
  - Random input
  - All ones input
  - All ones input, scrambler seed randomized every $6x10^6$ bits (every 60µs, total 185649 times)

Random Input (128b window)



	Max run length	Min running disparity	Max running disparity
Tx EM 0	35	-1440	1424
Tx EM 1	38	-1296	1418
Tx EM 2	35	-1394	1444
Tx EM 3	35	-1382	1374
Tx EM 4	35	-1372	1348
Tx EM 5	37	-1344	1476
Tx EM 6	33	-1418	1366
Tx EM 7	35	-1308	1312
Tx EM 8	35	-1364	1332
Tx EM 9	36	-1350	1396
Optical 0	37	-1444	1454
Optical1	37	-1444	1410
Optical 2	36	-1466	**1548**
Optical 3	**41**	-1418	1402
Rx EM 0	37	-1398	1374
Rx EM 1	36	-1384	1374
Rx EM 2	35	-1372	1412
Rx EM 3	37	-1344	1476
Rx EM 4	36	-1326	1434
Rx EM 5	35	-1308	1314
Rx EM 6	39	**-1534**	1354
Rx EM 7	38	-1350	1396
Rx EM 8	36	-1316	1466
Rx EM 9	37	-1296	1418
Scrambler	39	-1510	1514
Max (min)	**41**	**(-1534)**	**1548**

All Ones Input (128b window)



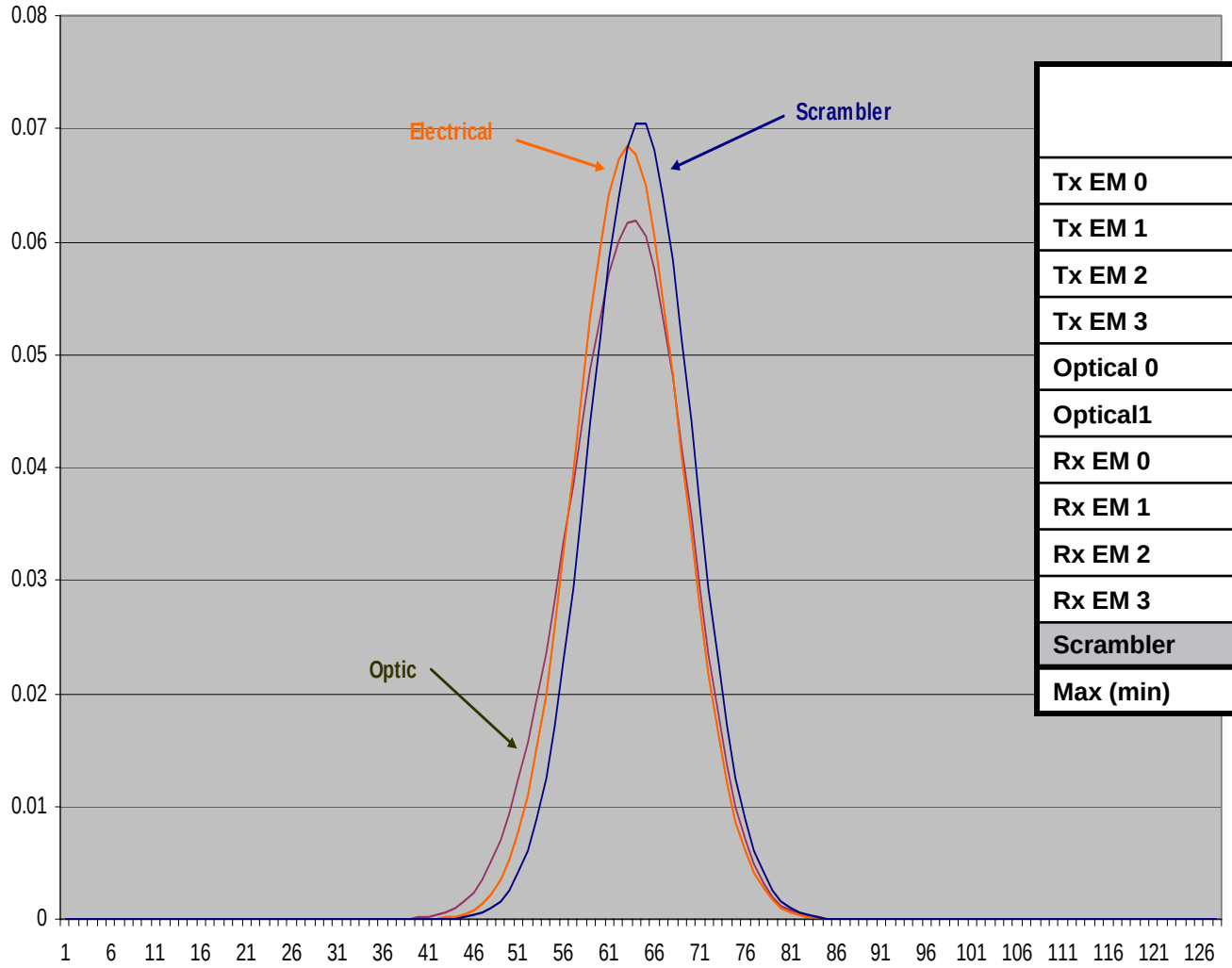
	Max run length	Min running disparity	Max running disparity
Tx EM 0	36	-1374	1358
Tx EM 1	39	-1334	1400
Tx EM 2	35	-1334	1428
Tx EM 3	36	-1404	1368
Tx EM 4	36	-1328	1394
Tx EM 5	37	-1394	1494
Tx EM 6	34	-1320	1410
Tx EM 7	37	-1298	1390
Tx EM 8	37	-1422	1336
Tx EM 9	42	-1408	1390
Optical 0	40	**-1460**	1502
Optical1	37	-1408	1466
Optical 2	40	-1384	1482
Optical 3	36	-1362	1468
Rx EM 0	39	-1350	1398
Rx EM 1	35	-1404	1370
Rx EM 2	37	-1344	1438
Rx EM 3	38	-1394	1494
Rx EM 4	37	-1438	1398
Rx EM 5	37	-1302	1390
Rx EM 6	37	-1428	1318
Rx EM 7	40	-1408	1390
Rx EM 8	40	-1378	1368
Rx EM 9	39	-1334	1400
Scrambler	**43**	-1284	**1934**
Max (min)	**43**	**(-1460)**	**1934**

Stage 3 - Long Simulation, Setup B

Simulations length: 10^{12} bits, 10 seconds

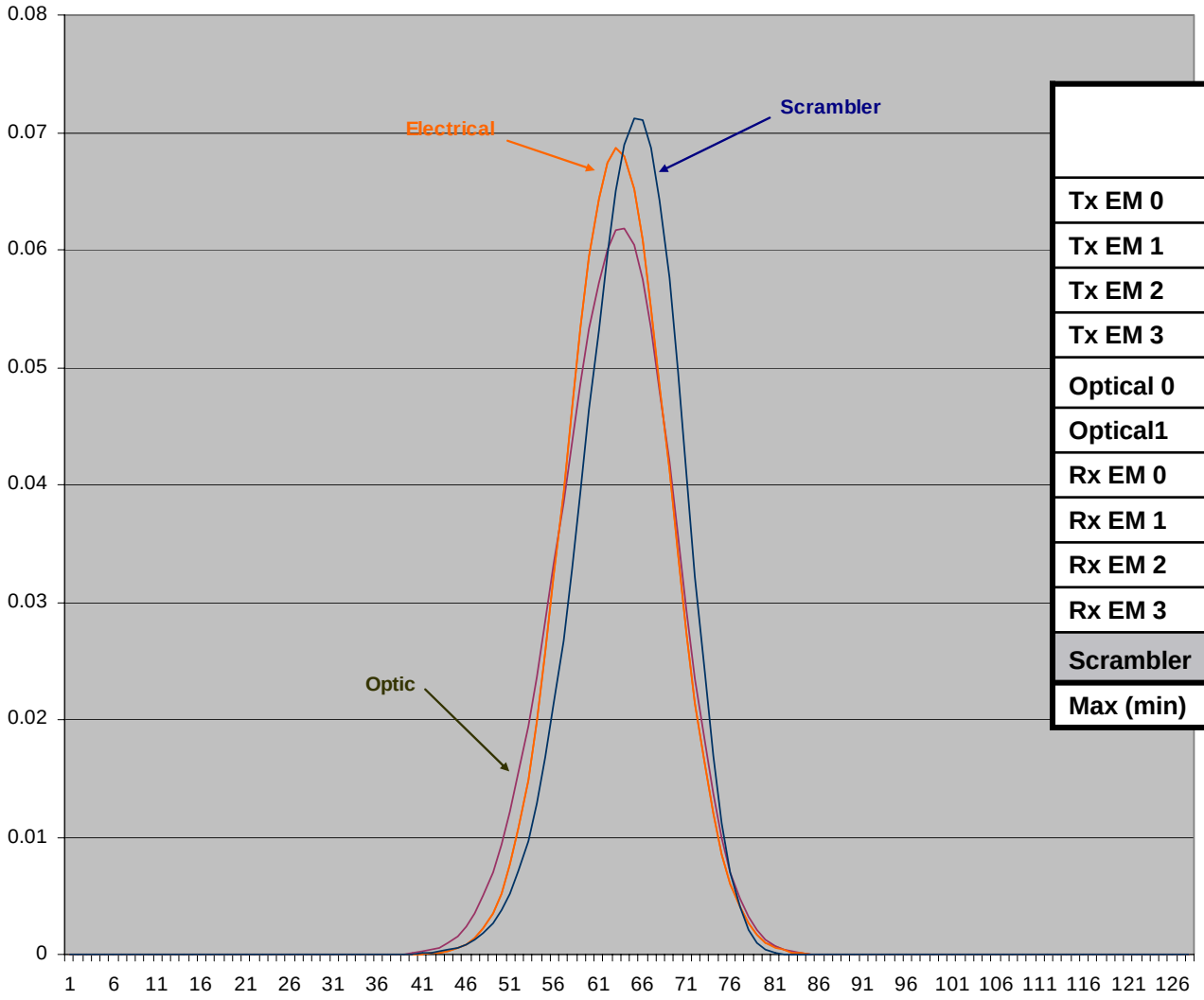
- 4 transmit and receive electrical media, 2 optical
  - Possible future evolution
- Skew:
  - None in electrical media
  - Skew in optical: 7 bits (latencies in bit-time: 1, 8)
- Input scenarios:
  - Random input
  - All ones input

Random Input



	Max run length	Min running disparity	Max running disparity
Tx EM 0	38	-1422	1468
Tx EM 1	38	-1404	1424
Tx EM 2	36	-1368	1400
Tx EM 3	42	-1372	1414
Optical 0	**51**	-1428	**1438**
Optical1	43	**-1420**	1412
Rx EM 0	36	-1368	1400
Rx EM 1	38	-1404	1424
Rx EM 2	38	-1422	1468
Rx EM 3	42	-1372	1414
Scrambler	40	-1602	1446
Max (min)	**51**	**(-1602)**	**1468**

All Ones Input



	Max run length	Min running disparity	Max running disparity
Tx EM 0	39	-1328	1522
Tx EM 1	37	-1386	1499
Tx EM 2	38	-1404	1538
Tx EM 3	36	-1446	1496
Optical 0	**51**	-1328	1624
Optical1	43	-1380	1508
Rx EM 0	38	-1404	1538
Rx EM 1	37	-1386	1494
Rx EM 2	39	-1328	1522
Rx EM 3	36	-1446	1496
Scrambler	44	-1384	**2008**
Max (min)	**51**	**(-1446)**	**2008**

Conclusion

The multiplexing of the Universal PCS has a negligible effect on the scrambler properties for the various data paths