Making DCI work in GÉANT

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GÉANT NETWORK ARCHITECT

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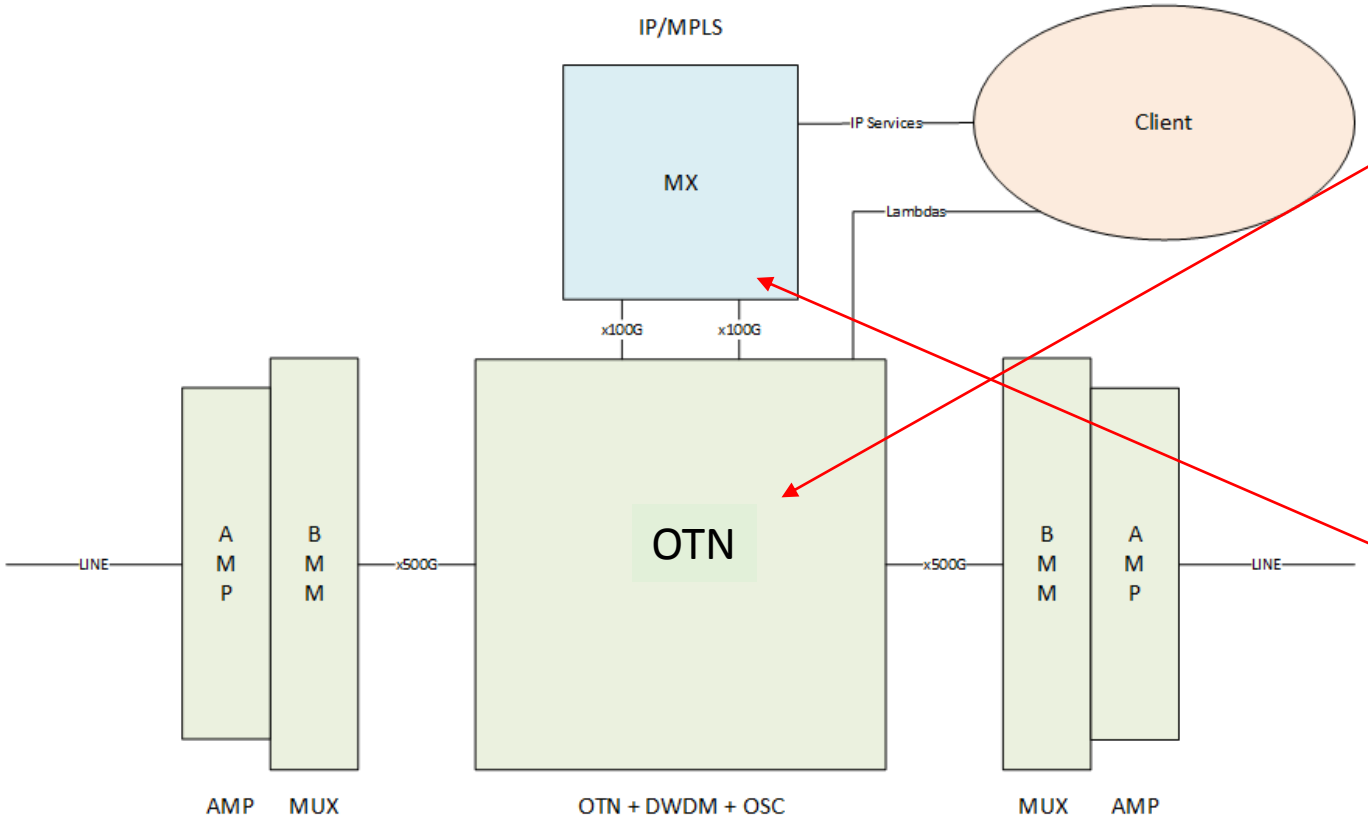
Current GÉANT pain points

Current architecture

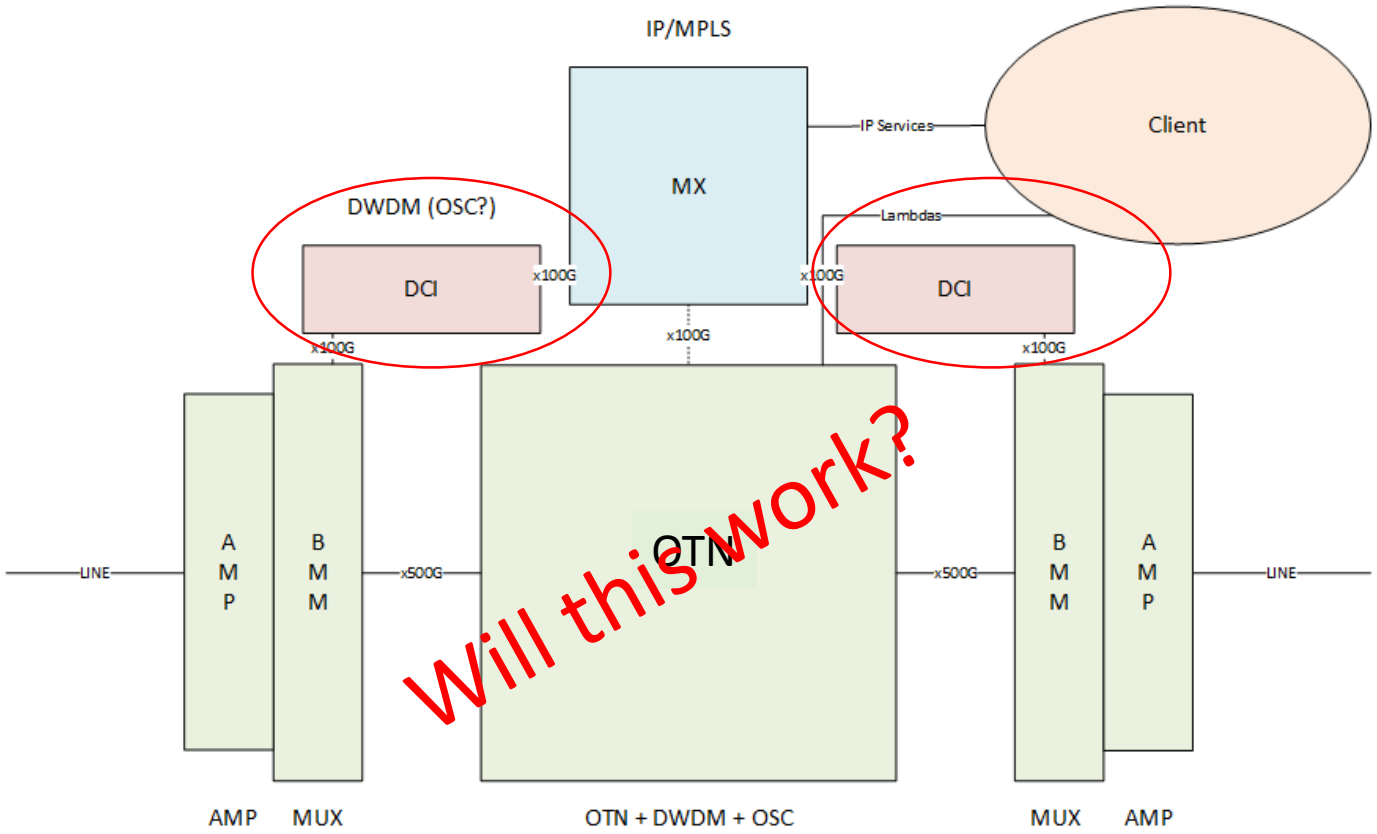


Problems with current architecture:

- OTN layer expensive
- OTN chassis **running out of slots** in central PoPs
- OTN useful for protection switching and multihop but traffic is **70% unprotected** and next hop
- OTN chassis are **DC powered** full rack cost is very high in some PoPs
- Proliferation of **IP/MPLS**

Slide by Sebastiano Buscaglione

Current GÉANT pain points



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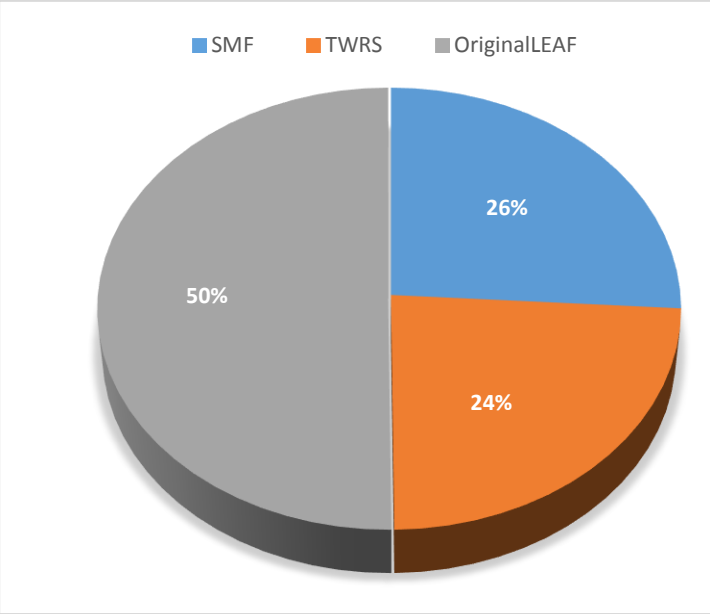
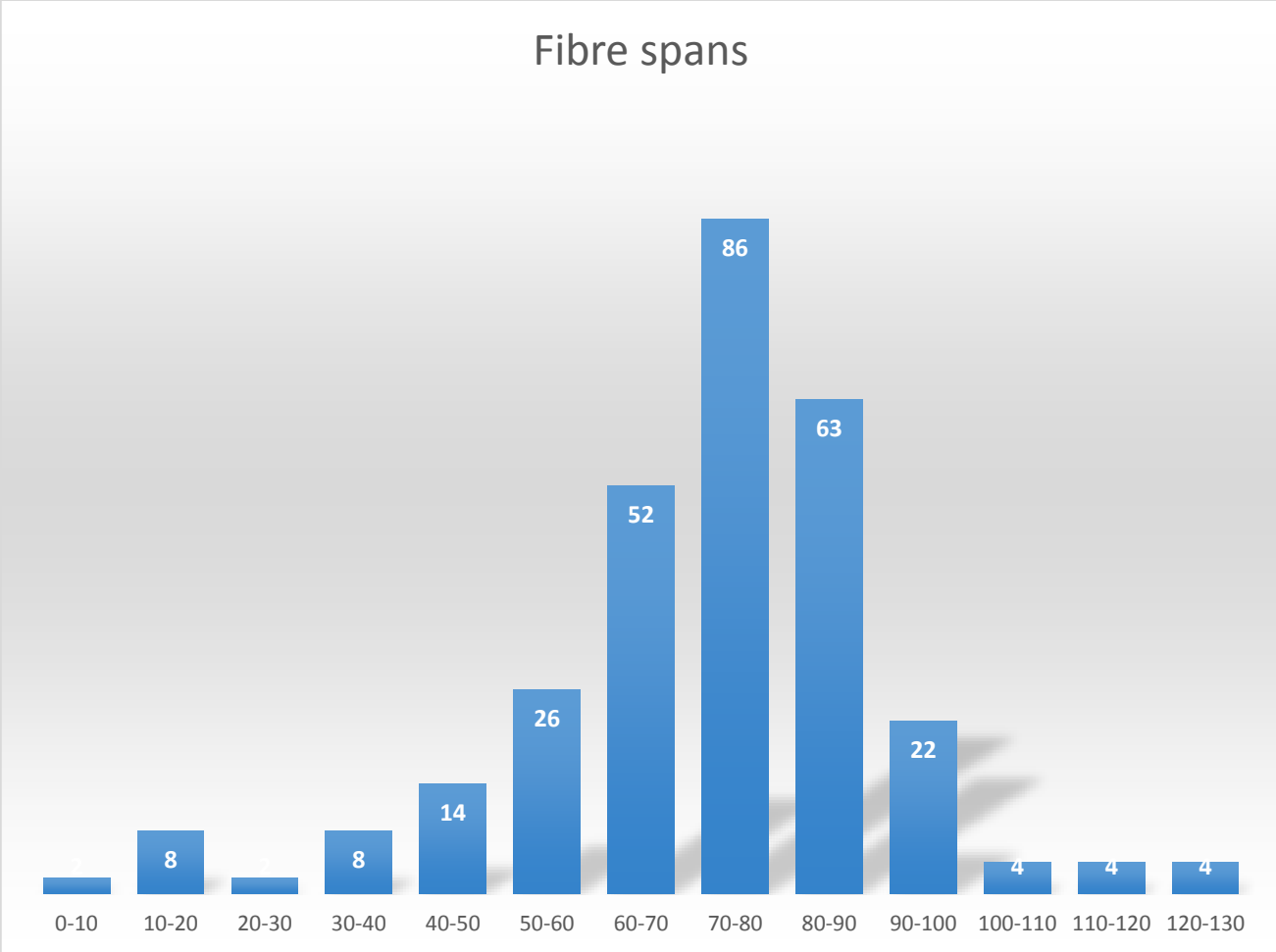
Part 1: GÉANT fibre and ONSR characteristics

GÉANT fibre infrastructure

Fibre types

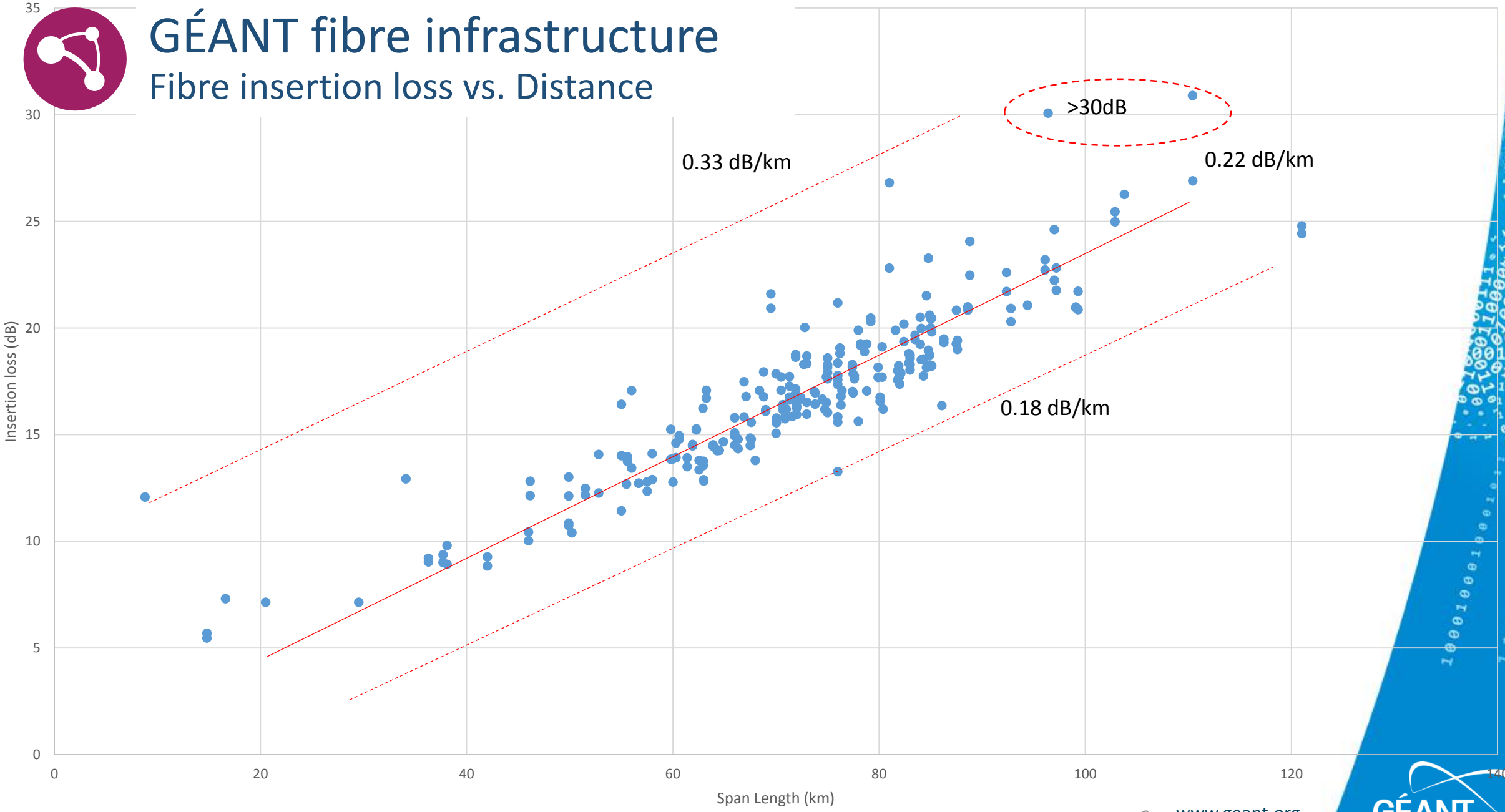




- Typical span is 65-85km
- 74% of fibre is Original LEAF or TWRS
- 95% of links <100km
- 99% of links <120 km

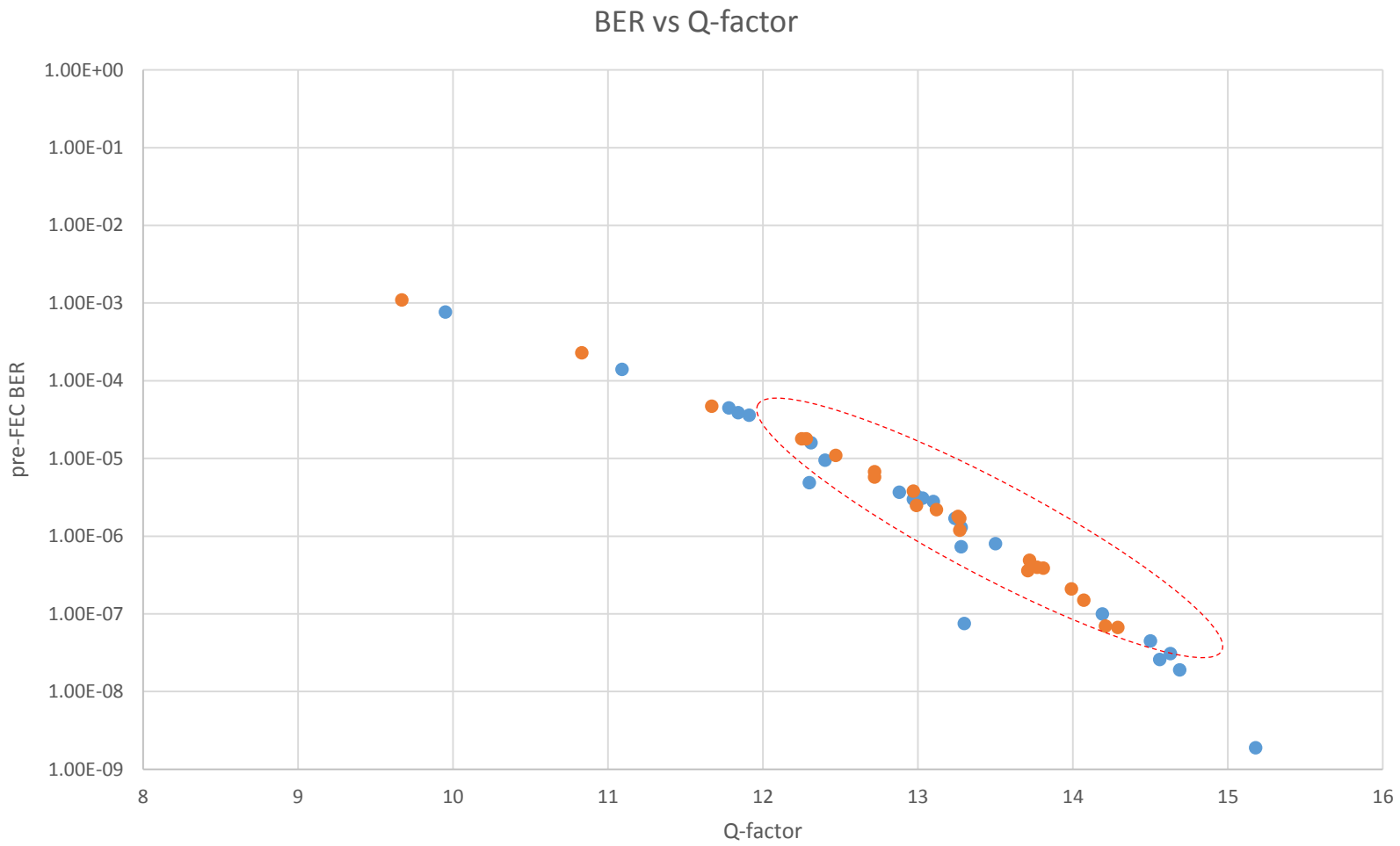
GÉANT fibre infrastructure

Fibre insertion loss vs. Distance



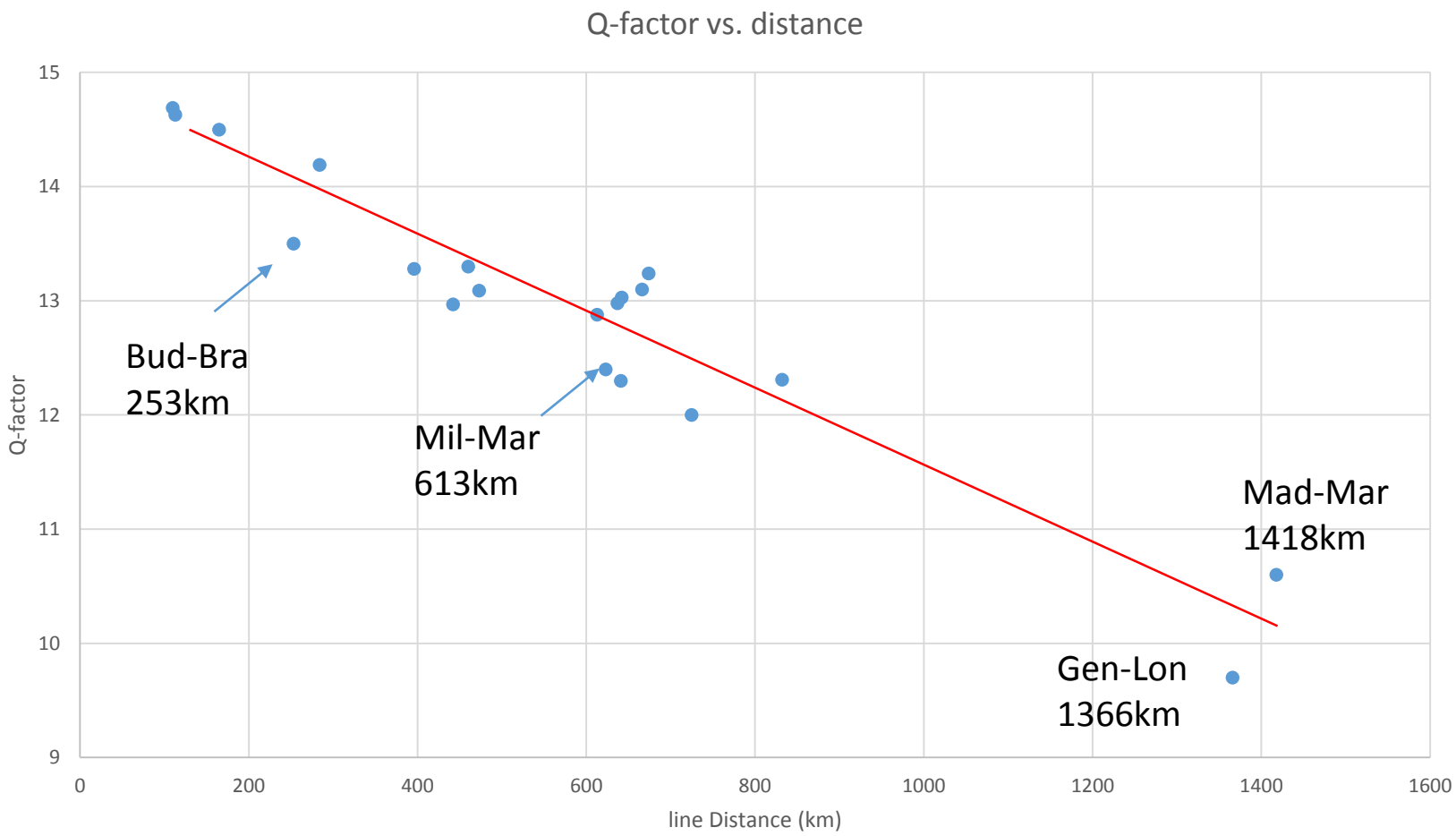
GÉANT fibre infrastructure

Q-factor and preFEC BER



- Forward (•) and reverse (•) Q-factors on 20 routes
- All modulation is currently DP-QPSK
- Link pre-FEC BER clustered between: 1e-4 →1e-8
- Operational margin determined by the grade of FEC deployed on the link
- SD FEC deployed on newer/longer links

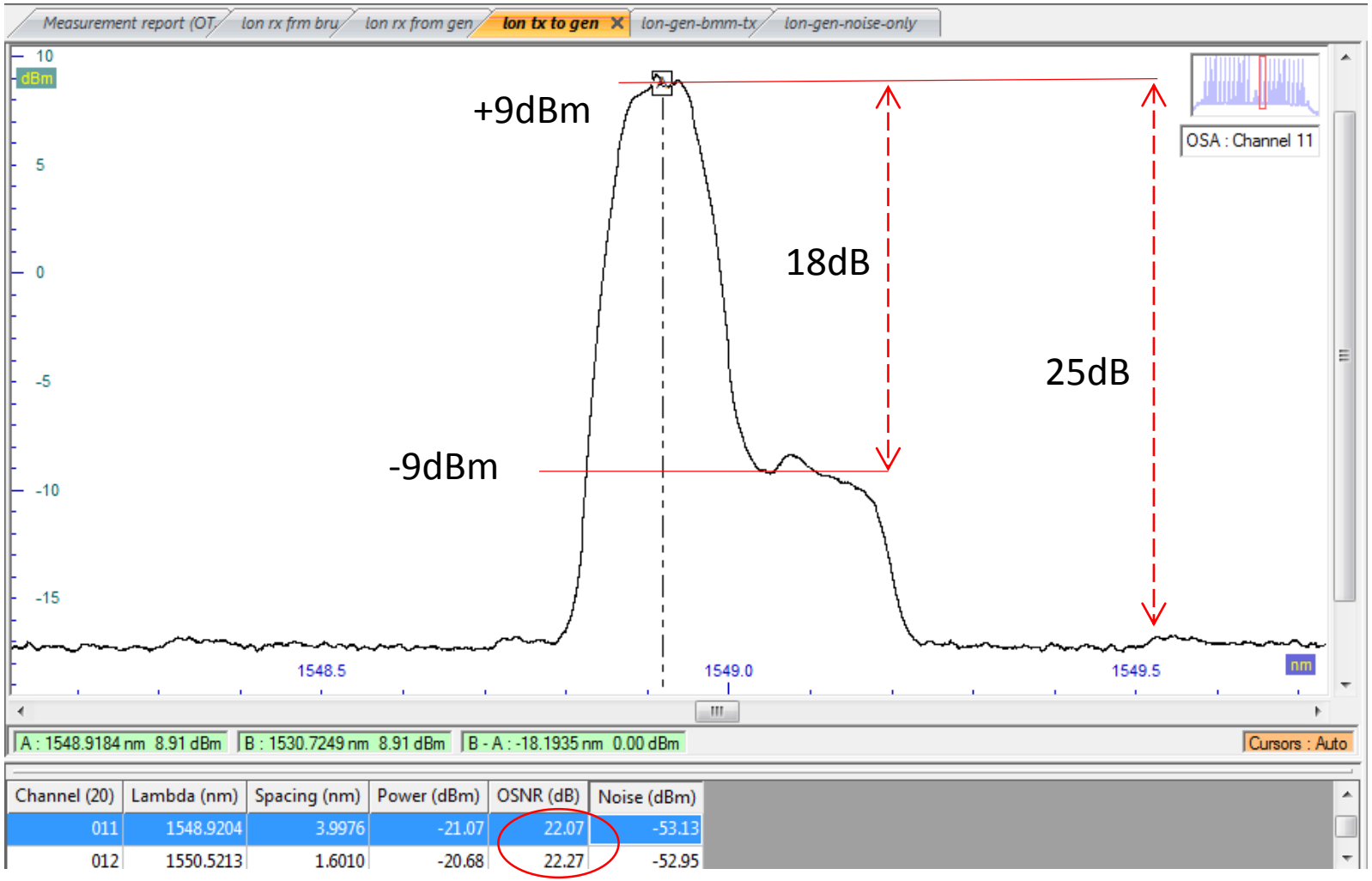
GÉANT fibre infrastructure
Q-factor vs. distance



- 20 routes shown
- No ROADMs, just 4 physical by-passes
- Bulk of routes are 400-800km
- Worst Q is 9.75
- Best Q is 14.7

GÉANT fibre infrastructure

OSNR measurement problem in coherent system



Channel (20)	Lambda (nm)	Spacing (nm)	Power (dBm)	OSNR (dB)	Noise (dBm)
011	1548.9204	3.9976	-21.07	22.07	-53.13
012	1550.5213	1.6010	-20.68	22.27	-52.95

- OCG1 from Geneva (1548.915nm), measured after receiver amp
- +9dBm/-9dBm
- OSNR = 18dB
- OSA measures 22.3dB
- OSA measurement of OSNR is not reliable

GÉANT fibre infrastructure
Measured DWDM ONSR

- OSNR measurements from OSA compared to modelling
- There seems to be a reasonable match to the ‘total (required) OSNR’ from the modelling
- Coriant G30 gives an OSNR measurement… this is probably the most reliable.

		Min OSNR (dB)		Total (Required) OSNR		measured OSNR at input to OAM		
Node A	Node Z	A->Z Min-OSNR	A<-Z Min-OSNR	penalty (A<-Z)	Penalty (A->Z)	A->Z OSNR	A<-Z OSNR	Difference total/measured
Lon	Ams	19.41	19.16	16.61	16.9		17.4	0.5
Lon	Bru	20.72	21.38	19.13	18.46		17.95	-0.51
Gen	Lon	16.48	17.87	15.2	12.69	14.95		-0.25

Part 2: DCI evaluation and procurement

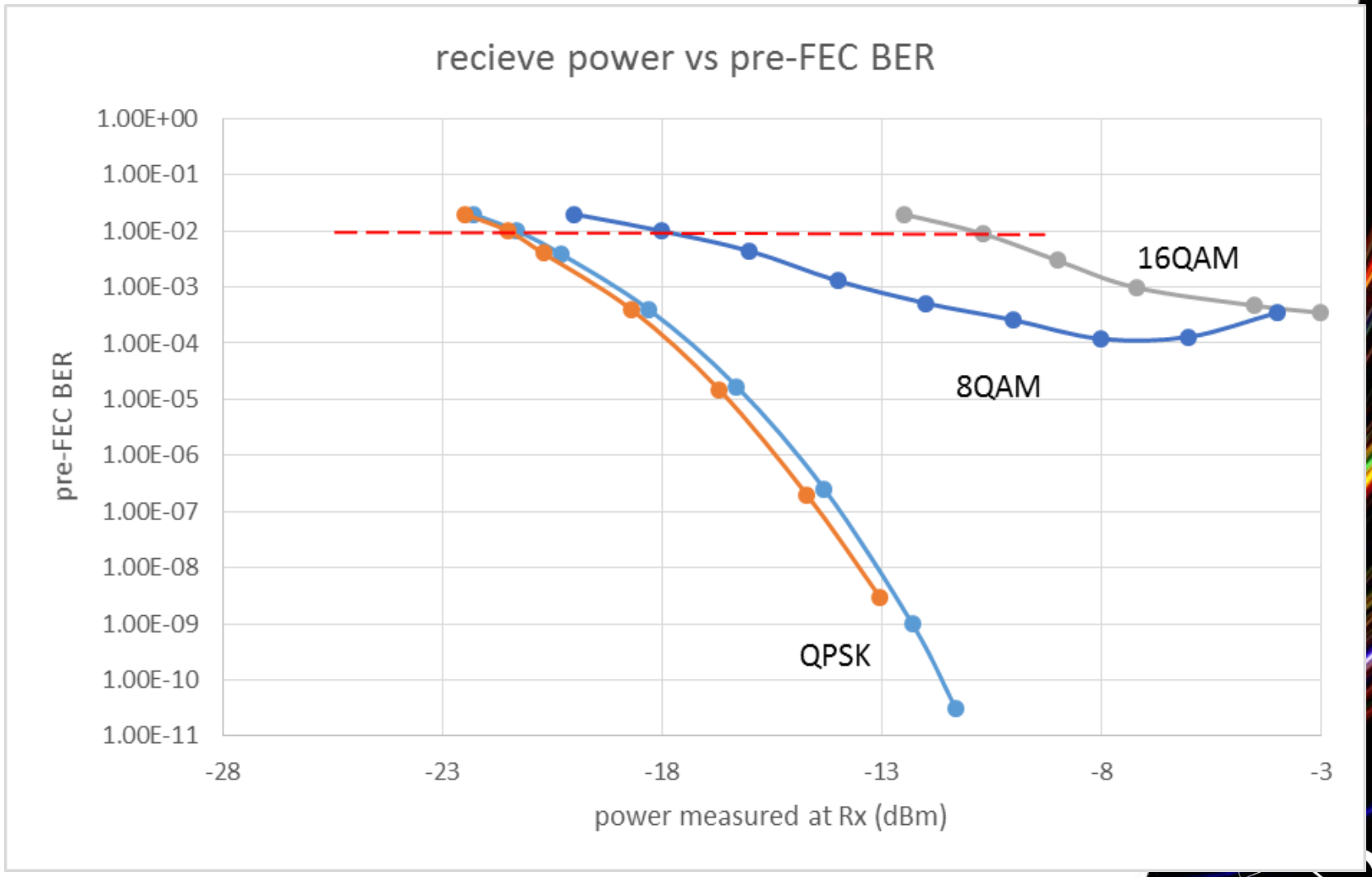
DCI pre-procurement evaluation

Optics	First Vendor	Second Vendor
Acacia AC400	Equipment: Facebook Voyager Status: Cambridge lab testing ✓ GÉANT field trial Lon-Bru ✓ NREN evaluation by PSNC and UNINETT ✓	Equipment: ADVA FSP3000 Status: Testing under consideration.
Acacia CFP2 ACO	Equipment: Juniper DWDM CFP2 100G ACO Status: Cambridge lab testing ✓ GÉANT field trial Mil-Mar ✓	Equipment: Coriant Groove G30 Status: Lab testing in Cambridge ✓
Acacia CFP2 DCO	Equipment: Vendor in DWDM stealth mode Status: GÉANT field trial on Mil-Mar ✓	Equipment: Juniper DWDM CFP2 100G DCO Status: Testing expected mid 2018
Ciena WaveServer	Equipment: WaveServer AI ✓ Status: Cambridge lab testing ✓ Field trial on CESNET fibre Prague to Vienna	NA
Infinera	Equipment: XT3300/3600 ✓ Status: Compatible with GÉANT DWDM system	NA

Voyager Tx power vs pre-FEC BER (Lab test)

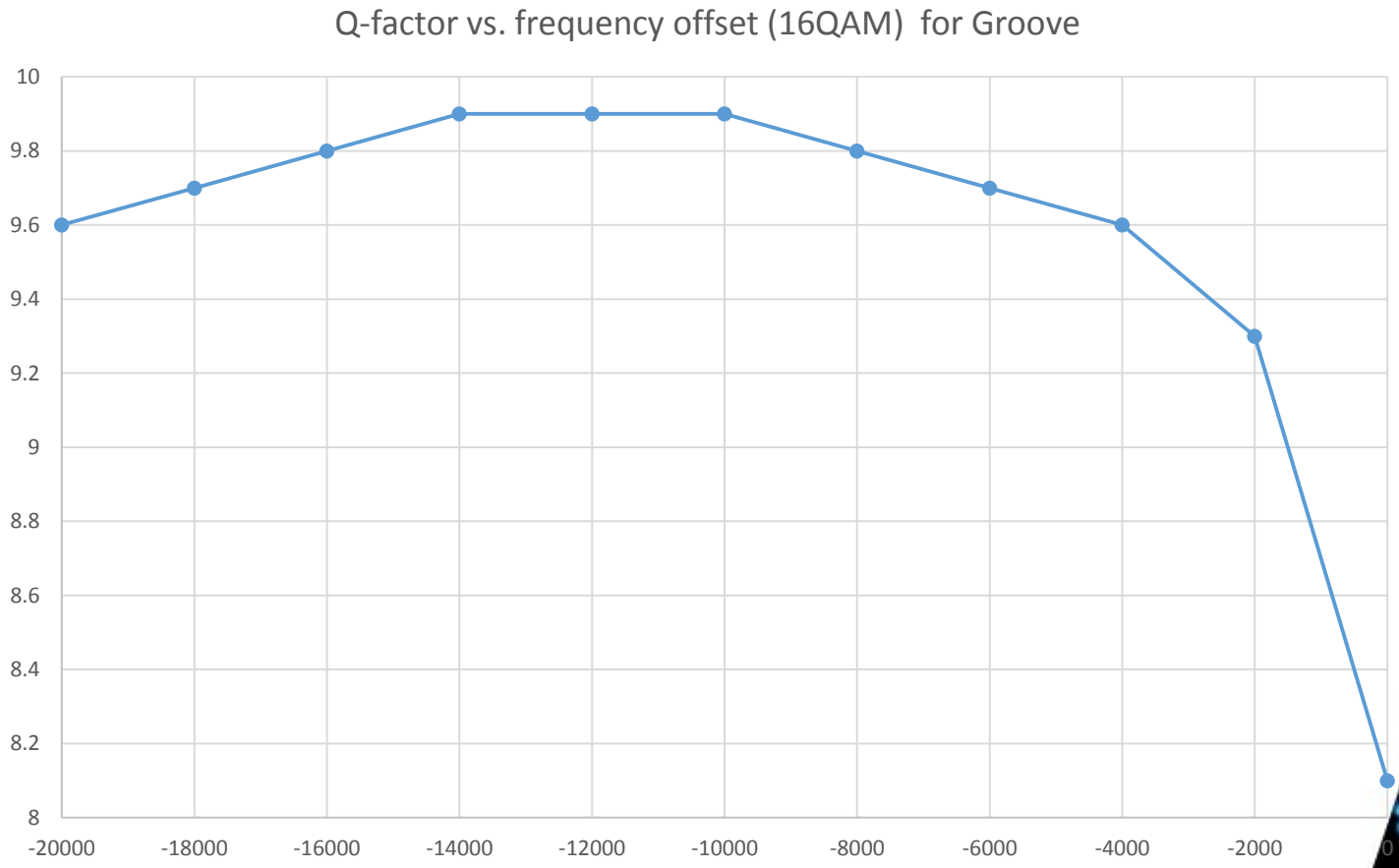
Lab test results

- Tested over 100km of fibre lit with Infinera DTN-X
- To get optimal performance wavelength needs to be de-tuned
- For QP-DPSK the system can work without de-tuning, but several dB of performance penalty.
- Measurements made before understanding Infinera 12.5GHz offset – see next slide



Infinera BMM2C are tuned off by 12.5GHz

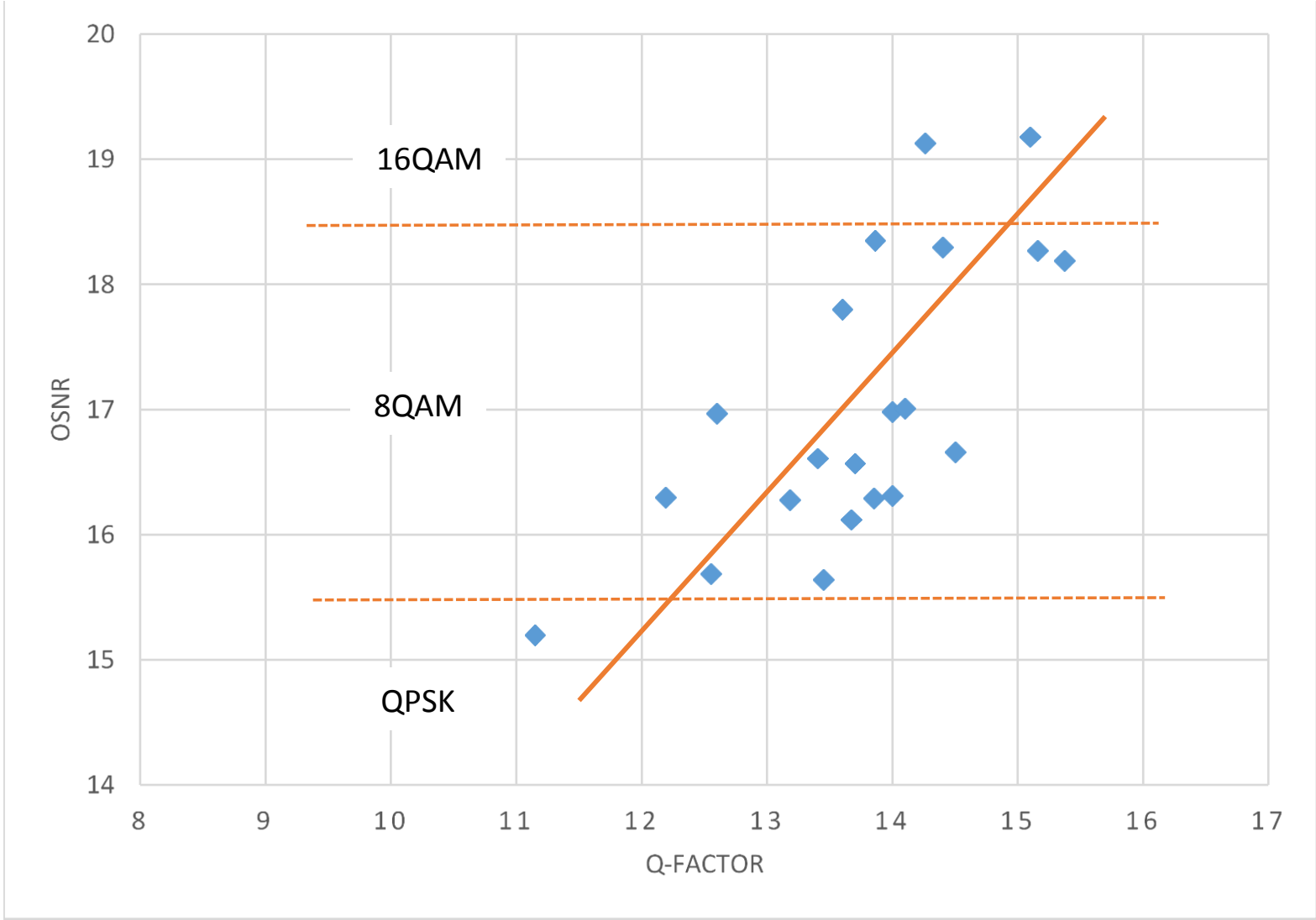
- The centre frequency of the Infinera band muxes are tuned off the ITU-T grid by 12.5 GHz
- In this test the best Q-factor is achieved at -12,000 MHz
- 1.7dB Q-factor penalty for not offsetting
- In the field wider baudrate FEC mode fails



*Tests by Karim Boudjemaa

All GÉANT fibre routes – modulation scheme available

- Of the 21 fibre routes in GÉANT, we can expect that most will work with 8QAM modulation.
- Only 1 route will require DP-QPSK
- At least 2 routes will work with 16QAM modulation



AW Field Trials/ Lab conclusions

What did we learn from the evaluation?

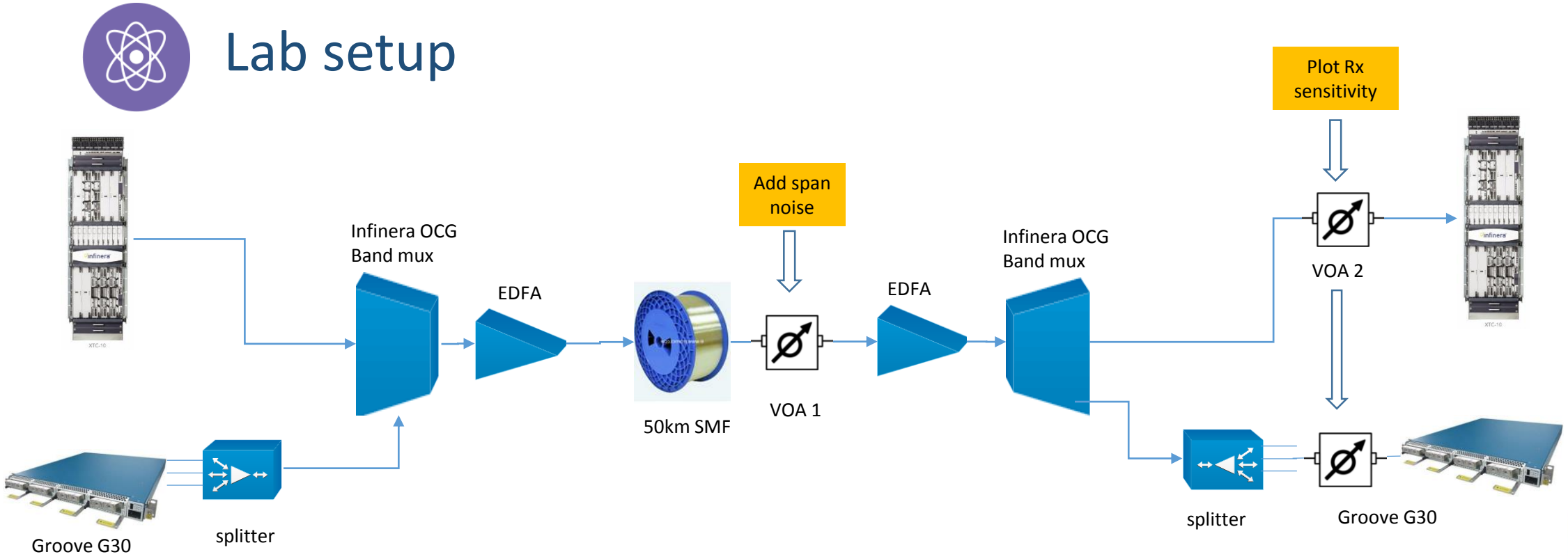
- We like the products that we tested, in particular the optical performance is very good.
- Performance of latest generation of DWDM pluggables is very good –8QAM will work on most (all?) links in GÉANT network and 16QAM on many.
- Very large cost savings in the network.
- Optical power management is critical in an alien wave environment.
- Software selectable modulation makes planning much easier.
- An optical modelling tool will help scale up number of AWs.
- Turning up AWs is best done in small slow steps

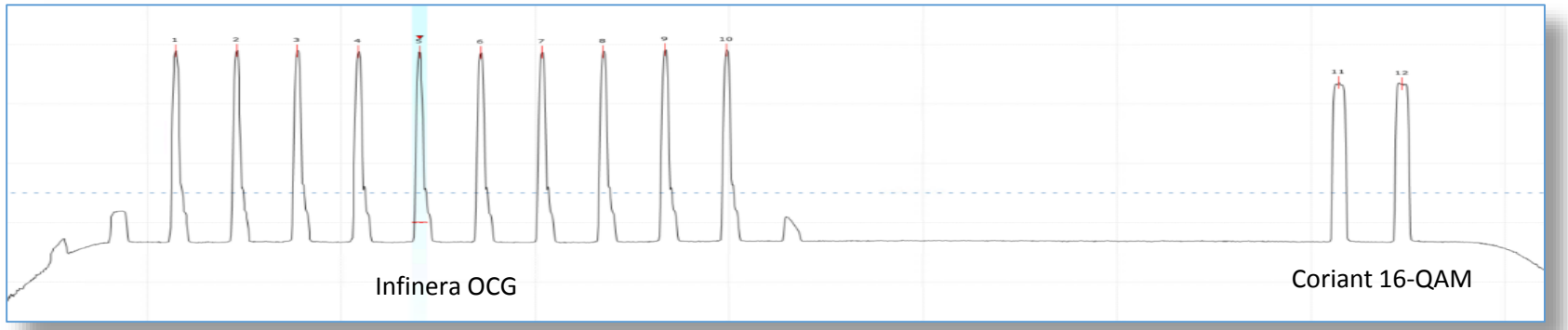
DCI Choice – Coriant Groove G30

- I RU stackable
- 4 sleds, each up to 4 x 100G
- Optics are based on Acacia CFP2 ACO
  - 200G up to 1000km with 16 QAM modulation
  - 150G up to 2000km with 8 QAM modulation
  - 100G up to 5000km with DP-QPSK
- Client side is QSFP28
- *Next generation to support up to 600Gbps using 64QAM*

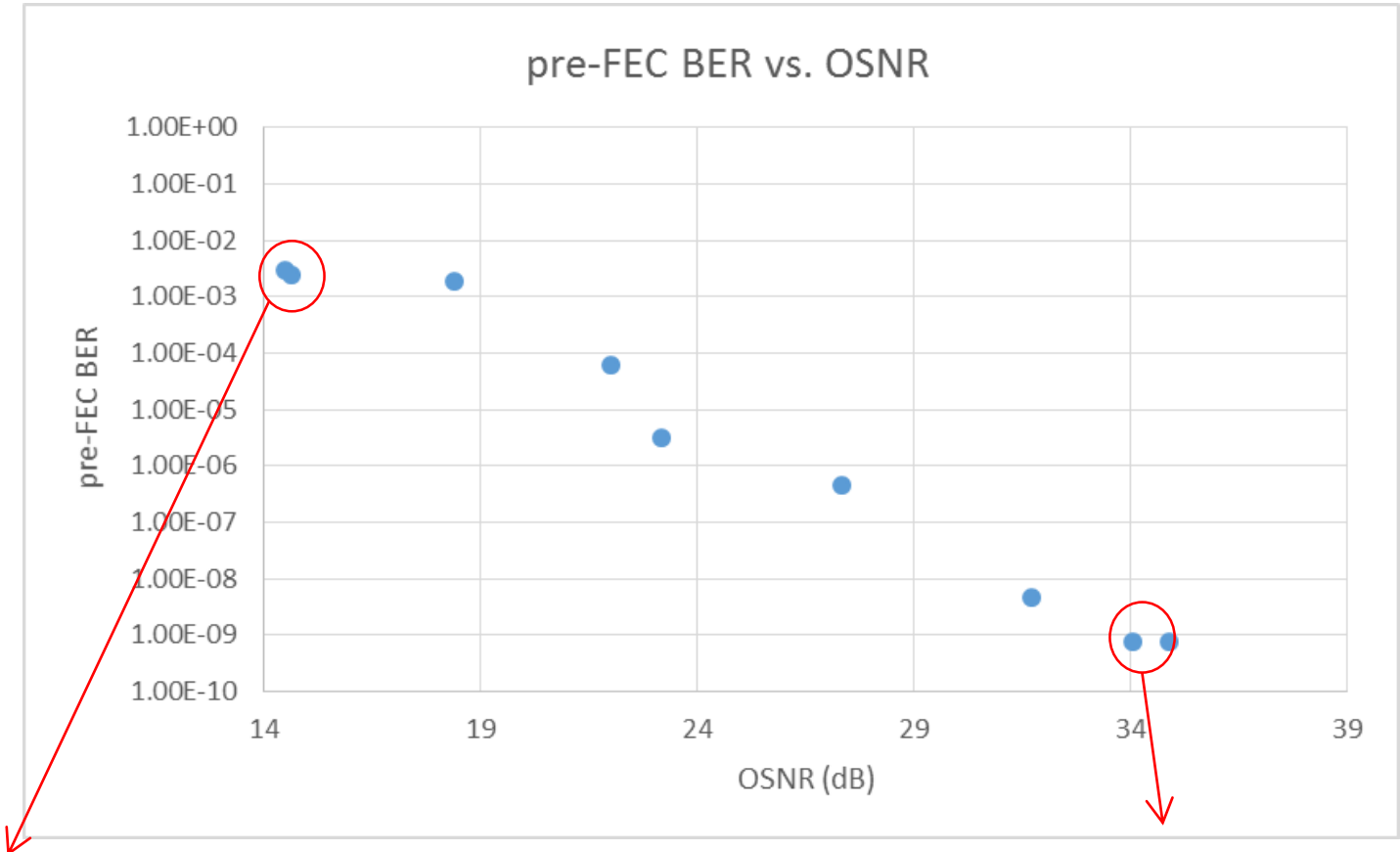
Part 3: Lab testing the Coriant G30

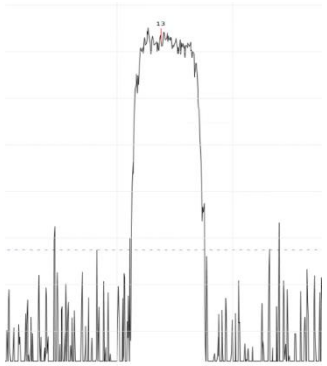
Lab setup

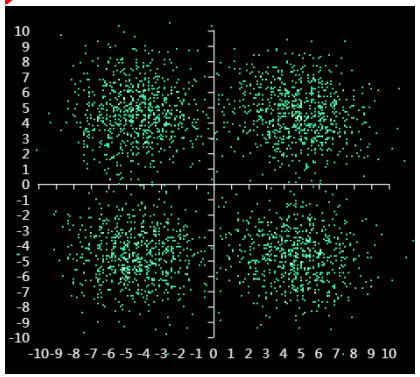

Plot Rx sensitivity
Add span noise
Infinera OCG Band mux
EDFA
50km SMF
VOA 1
EDFA
Infinera OCG Band mux
VOA 2
Groove G30
splitter
splitter
Groove G30

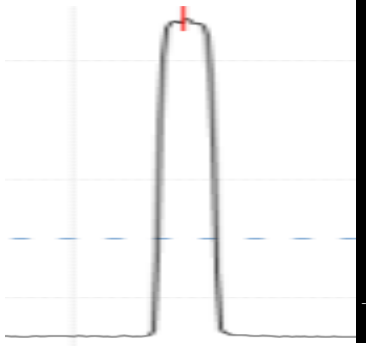

Infinera OCG
Coriant 16-QAM

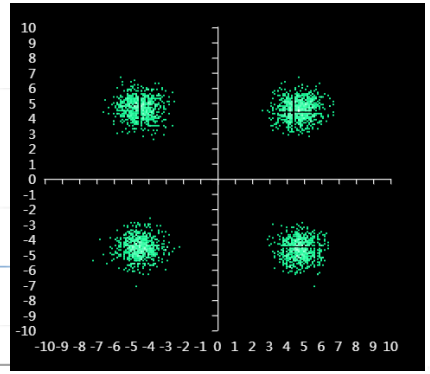
DP-QPSK





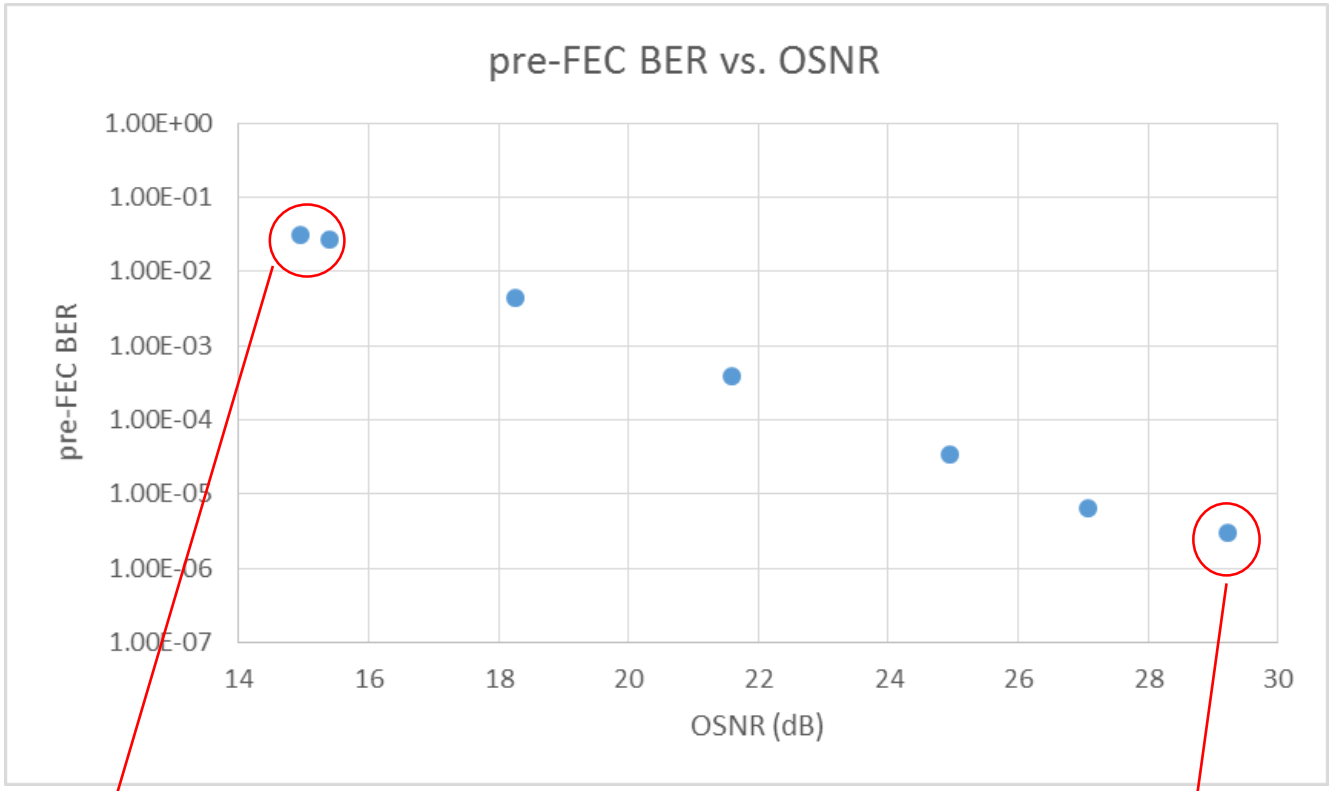


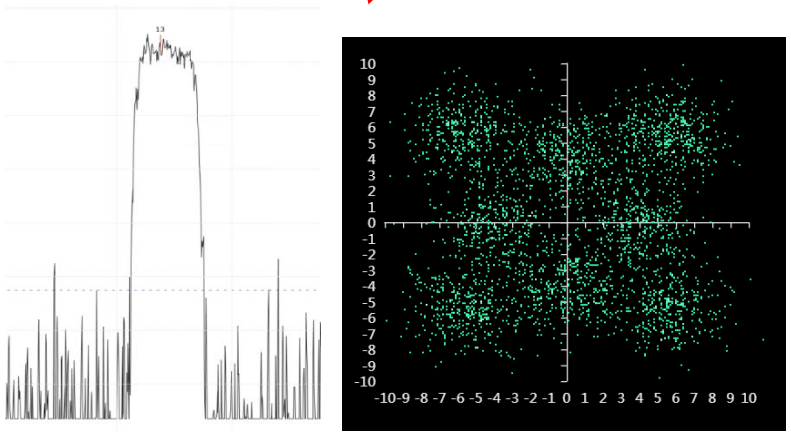


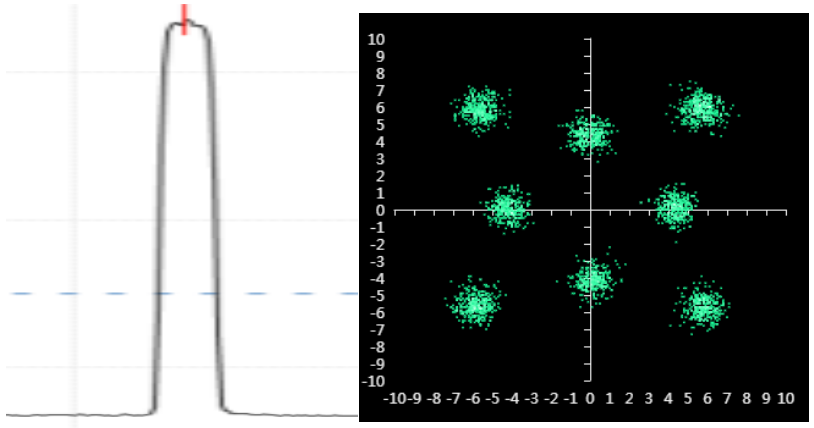


*Tests by Michal Altmann

8-QAM







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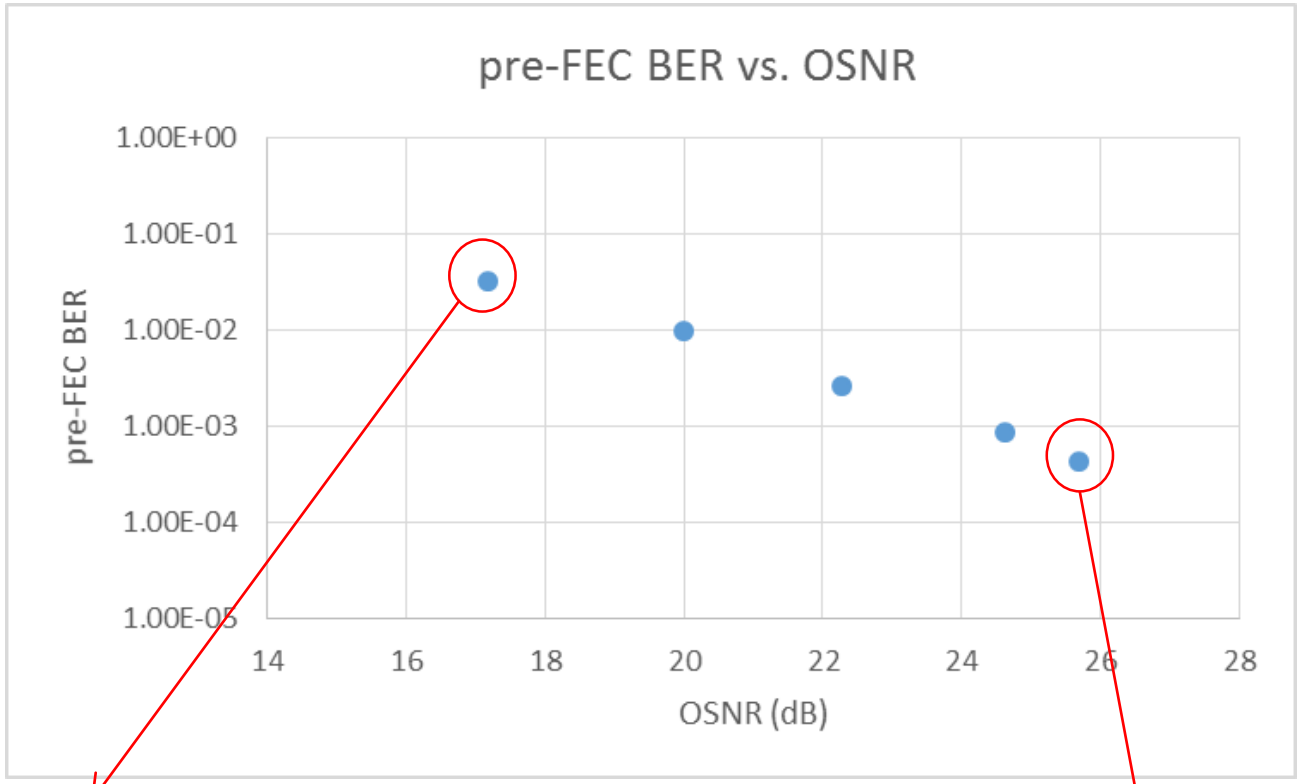
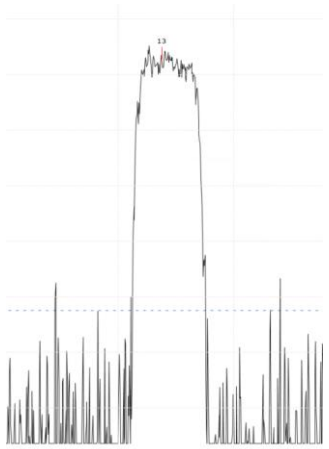
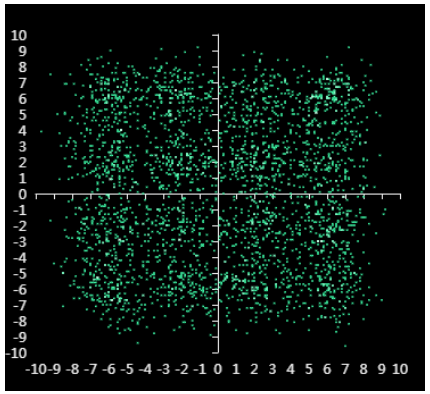
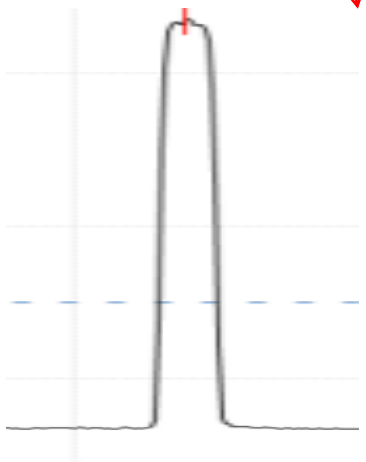
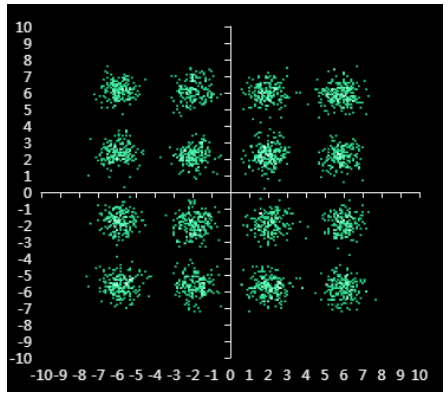
16-QAM











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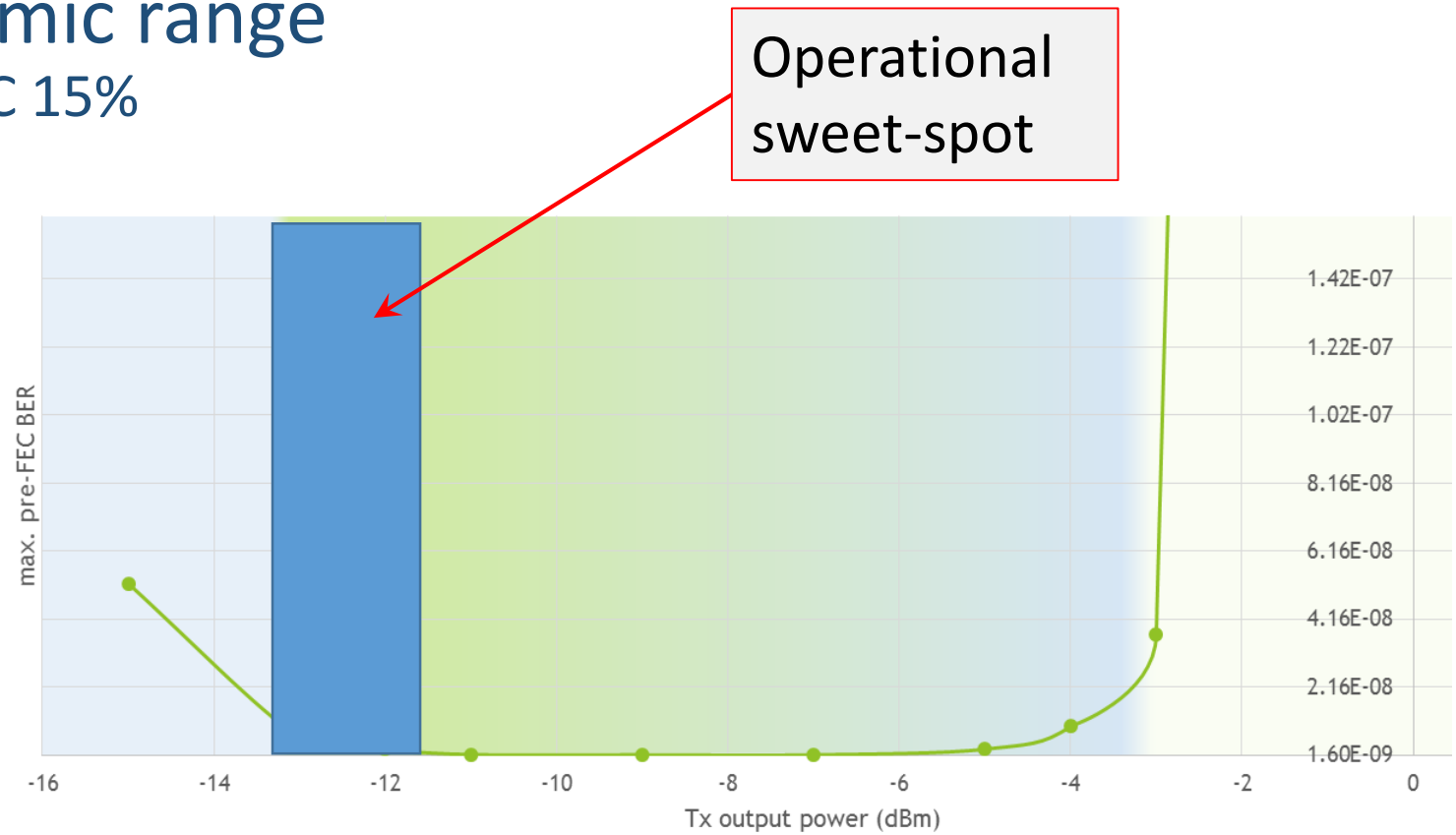
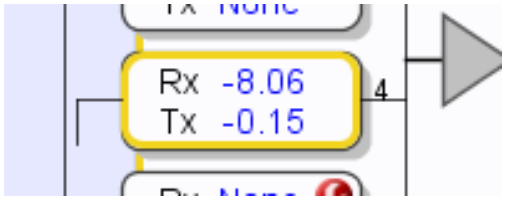
G30 Input dynamic range
DP-QPSK with SD-FEC 15%

- Good dynamic range in DPQPSK mode with 100km of fibre and 15% SD-FEC
- Infinera over power warning at -11dBm





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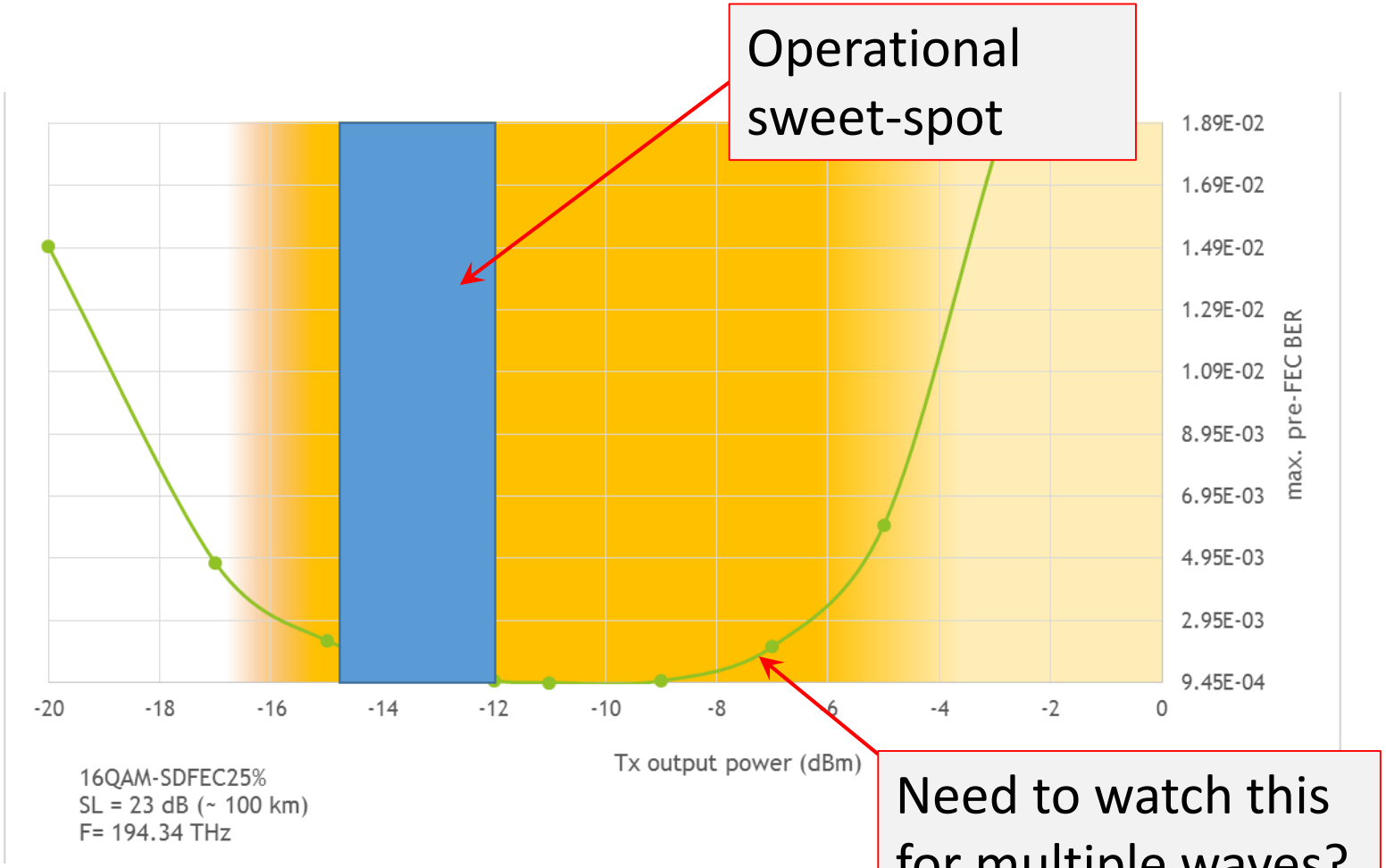
G30 Input dynamic range
16-QAM with SD-FEC 25%



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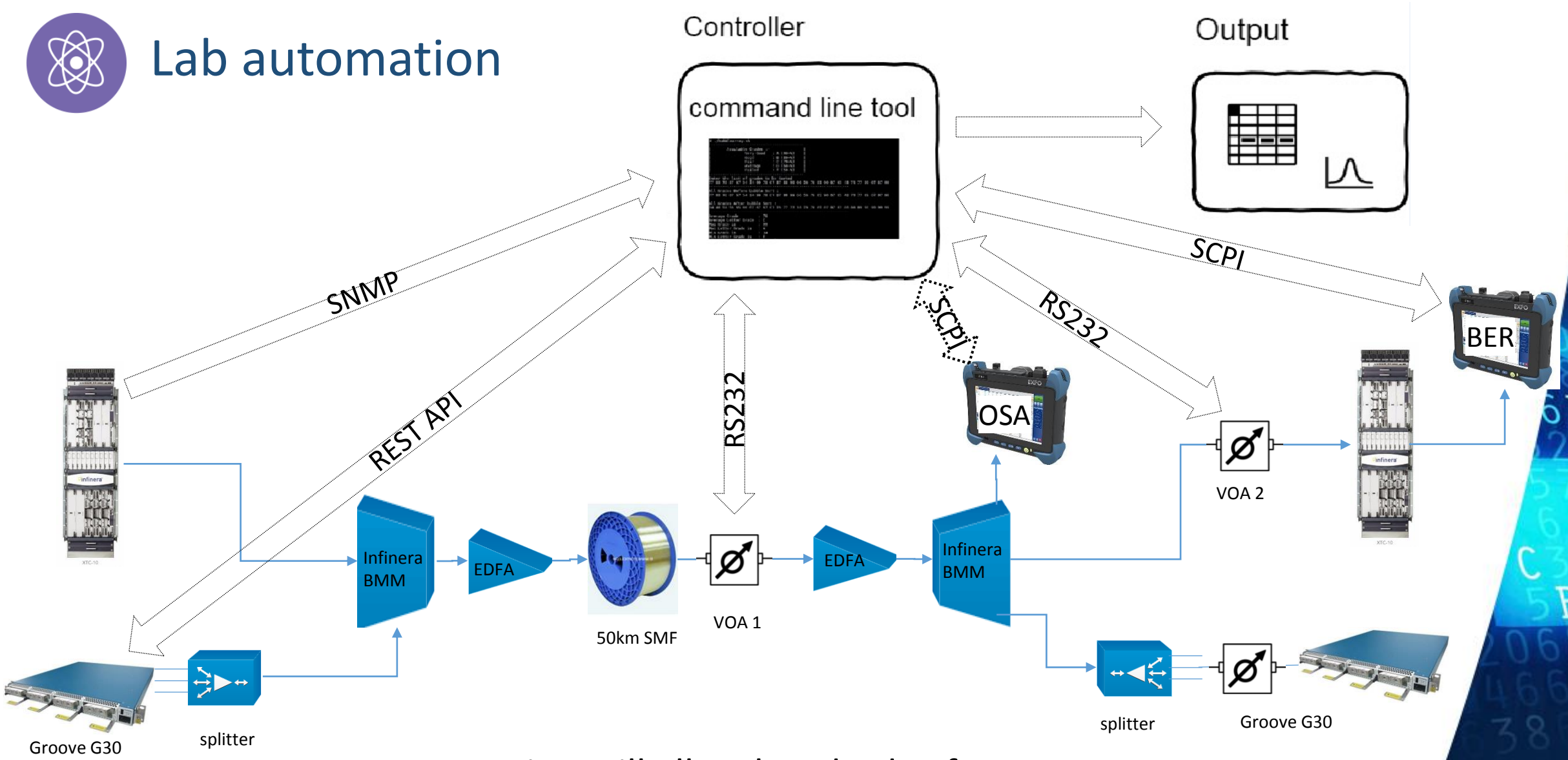
Lab automation

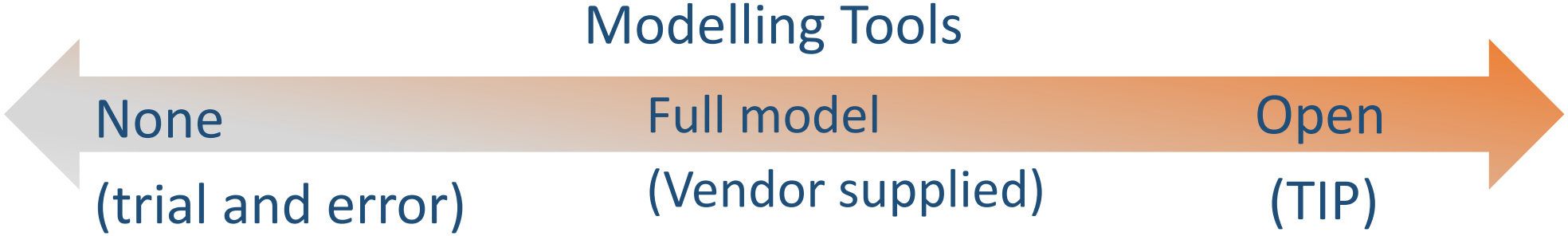


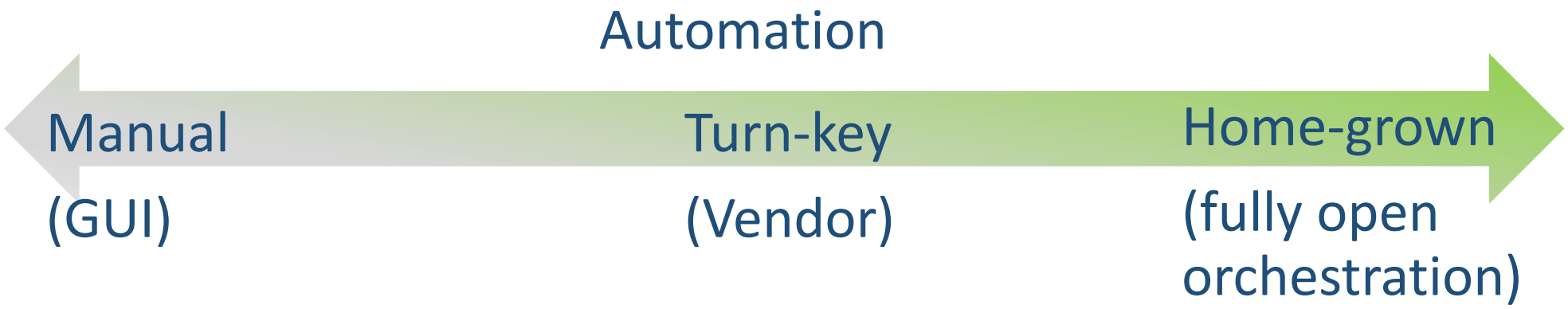
- Automation will allow hundreds of tests to be carried out in a repeatable way

Turn-up procedure

- We need to develop an AW commissioning process.
- Use a modelling tool (TIP?) to predict the expected performance.
- Model will be used to select a modulation type.
- What margin should we allow for ageing?
- During service commissioning the pre-FEC BER should agree with the modelling prediction.
- What performance tolerance should we allow?

Optical software – how much is enough?





Summary

- GÉANT fibre and the current OSNR have been analysed
- The results are compared to the lab test results of the Coriant G30 equipment
- We need to tune the wavelengths off by half of a 25Ghz spacing
- The Optimal launch power is around -11dBm to -12dBm. The system margin is good at this launch power
- We will automate our lab bench to achieve fine-grained data set
- The out put of these will be used to validate the TIP modelling tool and define the Coriant A/W turn up procedure.

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Thank you

Any questions?

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