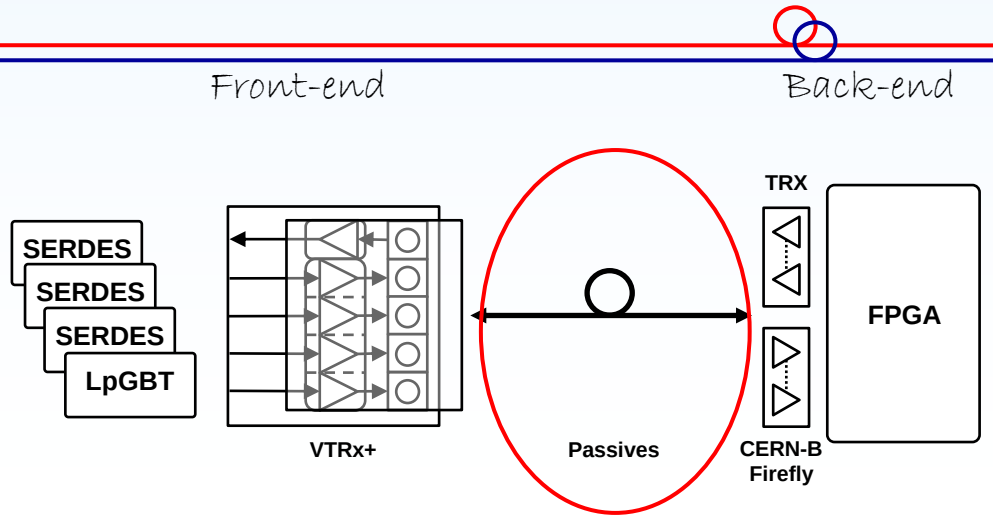
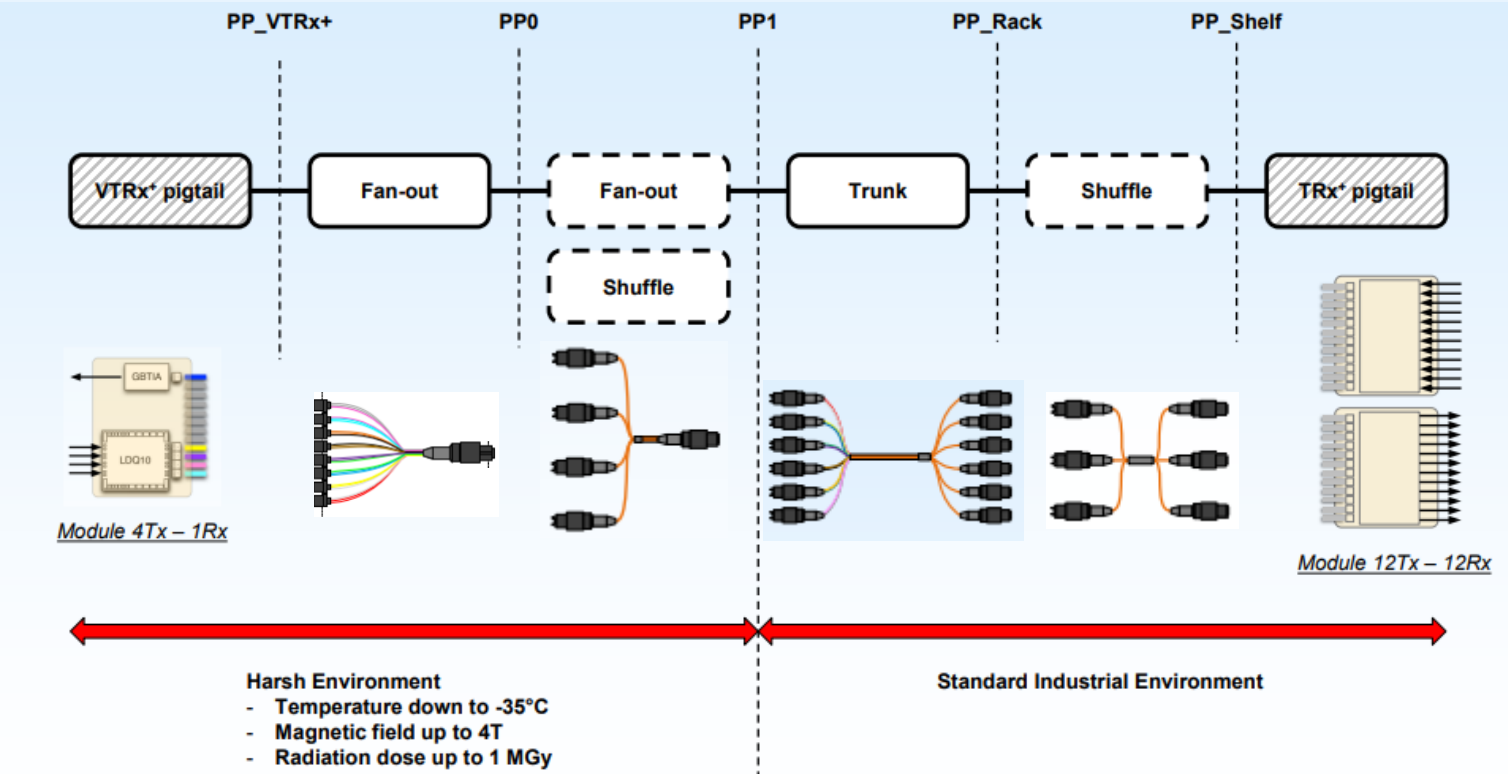
Versatile Link+
Cabling Plant Status and Plans

Francois Vasey, based on material by I. Toccafondo



Cabling plant

- VTRx+ interface (4Tx 1Rx) and Backend interface (12Tx 12Rx) are fixed by VL+ project
- Link length and number of breakpoints are specified by detector
  - Up to 150m, up to 5 breakpoints
  - The shorter the length and the fewer the breakpoints, the better the power margin
- Need aggregation (fan-out) and reshuffling functions in the cabling plant
  - Keep diversity low and manageable
  - Select from «catalogue»



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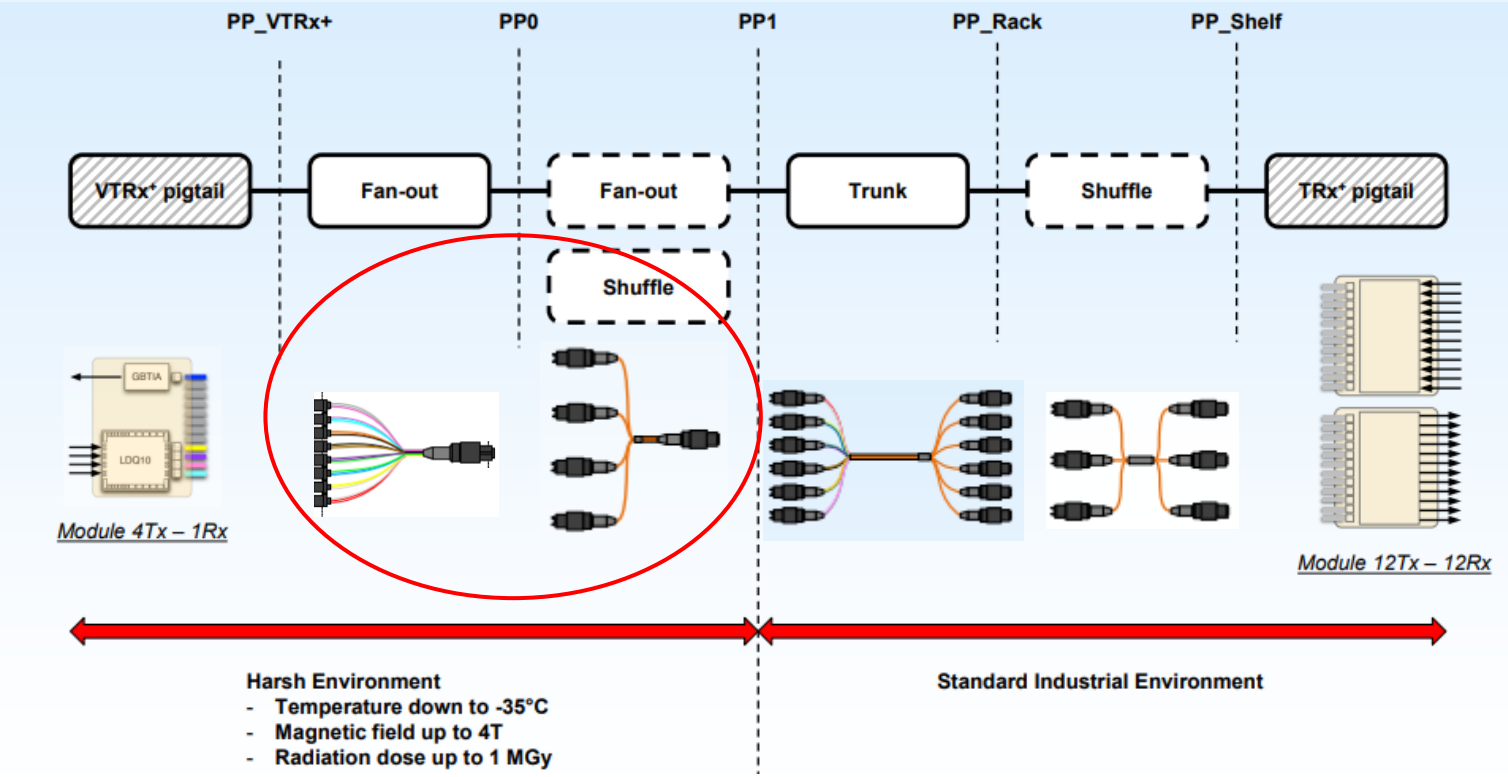
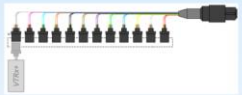


Designing and Prototyping the front-end plant

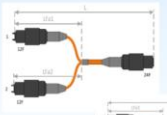
- Objective:
  - define a cabling plant optimized to meet the specific requirements of each detector (high radiation resistance, cold environment, high channel density, high data rate...)
  - Limit the diversity and decrease the overall cost
- Market survey sent out to firms in August 2019
  - 39 firms contacted, replies from 16 different countries worldwide
  - 8 firms qualified in 2020
  - 4 firms added at request of procurement in 2021
  - Currently still in prototyping/evaluation phase
- Questionnaires sent to detectors in Oct 2019
  - Evaluation of designs and specifications, discussion with detectors during 2020
  - First wave of prototypes
  - Feed back from detectors and Quality evaluation
- Iteration with detectors in 2021
  - Confirmation of requirements
  - Second wave of prototypes based on feedback from first wave
  - Finalization of cable plant details

Ordered quantities

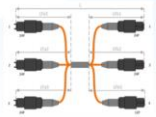
- 15 different naked fan-out types



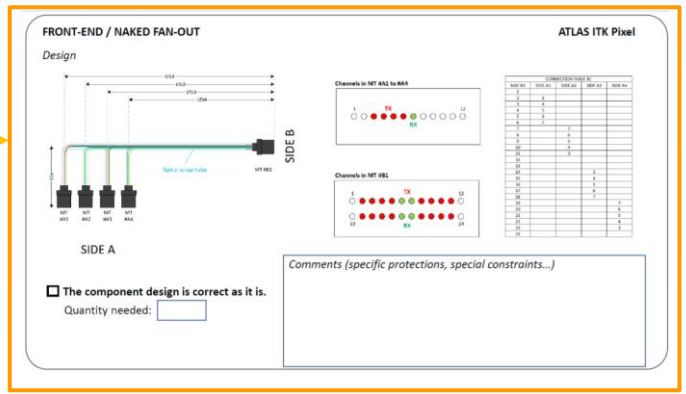
- 3 different fan-out patch cords



- 4 different shuffle patch cords



Each component has been ordered at least from two different companies.



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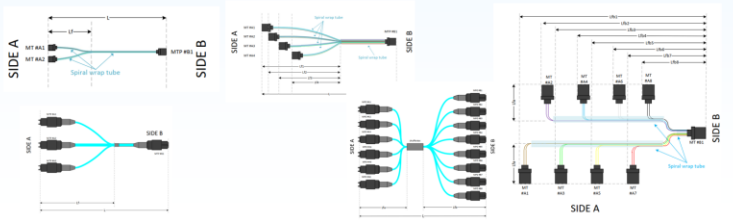
Prototyping, 2nd wave

(Sub)-detector	Naked Fan-out	Fan-out	Shuffle	Total (sub)-detector
ATLAS ITk Pixel	2 + 42	0	1	45
ATLAS ITk Strip (Barrel)		2		
ATLAS ITk Strip (EndCap)	3	0	0	3
ATLAS LAr	12	4	0	16
CMS BTL	4			
CMS ETL	2	0	0	2
CMS ECAL			12	
CMS ITk Pixel	5	0	0	5
CMS OT Strip (Barrel)	16	0	0	16
CMS OT Strip (TEDD)	2	1	0	2
TOTAL component	**84** +4	**5** +2	**1** +12	**90** +18

Distribution and Evaluation in Q4-2021

- Over 20 different flavours of naked fan-outs, 4 flavours of fan-out patch cords and 7 flavors of shuffle.



Future Procurement

Overview of components' families

Component

Family

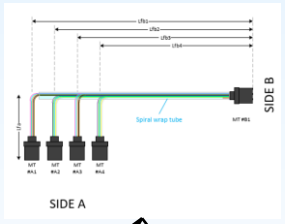
Connector type (MT12/24 or MTP12/24) and number of connectors on both sides fixed

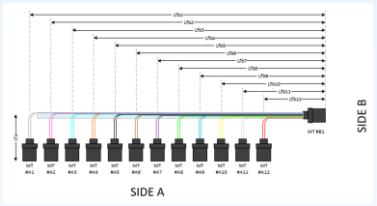
Type

+ length for each component type, protection details may vary

Naked fan-out

NK 1 NK 2 NK 3 … NK 10 NK 11



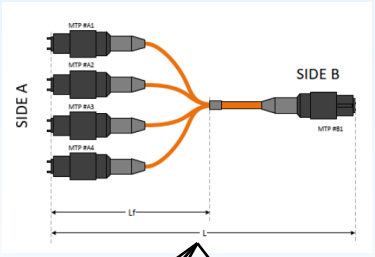


n_1 fibres in each connector … n_q fibres in each connector

L_1 L_2 L_n L_1 L_2 L_n

Fan-out patch cord

FN 1 FN 2 FN 3 FN 4

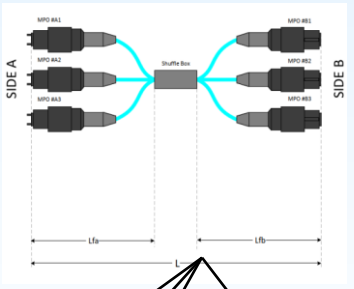


n_1 fibres in each connector … n_q fibres in each connector

L_1 L_2 L_n L_1 L_2 L_n

Shuffle patch cord

SH 1 SH 2 SH 3 SH 4 SH 5 SH 6



n_1 fibres in each connector … n_q fibres in each connector

L_1 L_2 L_n L_1 L_2 L_n

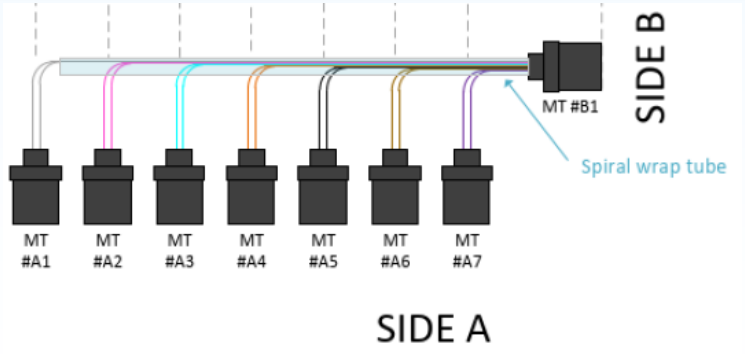
Naked fan-out

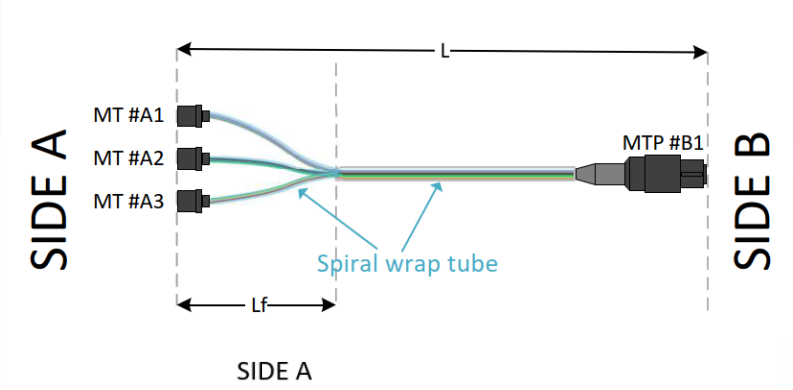
Design

- Bundle of fibres with one multi-fibre connector (either MT or MTP) on one side and multiple (N) multi-fibre connectors on the other side.
- The connectors may contain either 12 or 24 fibres.
- Characterized by a total length L and individual branch/cord lengths L_1,...,L_N

Protection

- The component can be left naked, without any protection
- The trunk part of the naked fan-out can be protected by a spiral wrap tube.
- In some specific cases, 3 spiral wrap tube can be used.





Fan-out patch cord

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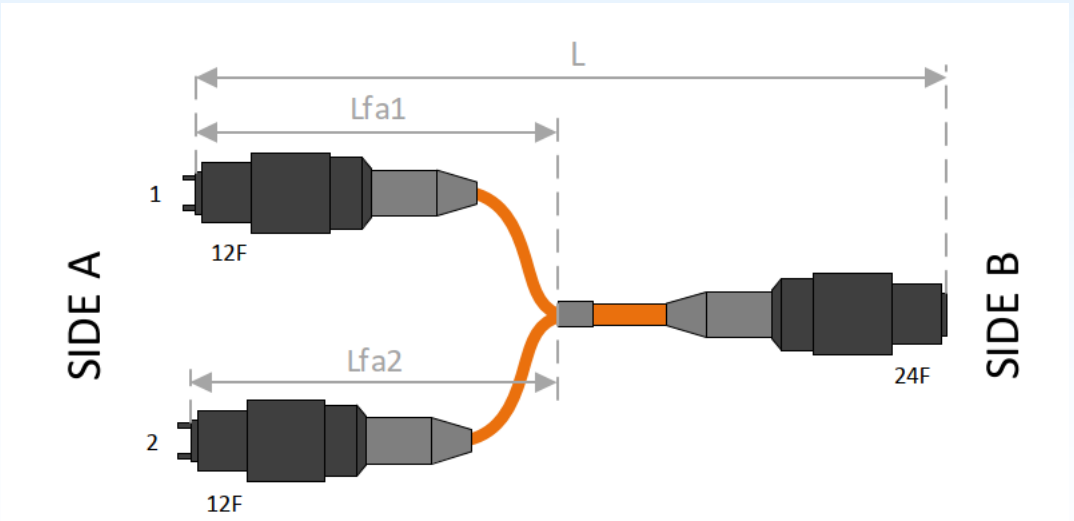
- The connectors may contain either 12 or 24 fibres.
- Characterized by a total length L and individual branch/cord lengths L_1,...,L_N

Protection

- The component is rugged.

Fan-out box

- Cylindrical: Ø < 5mm



Fan-out patch cord

Design

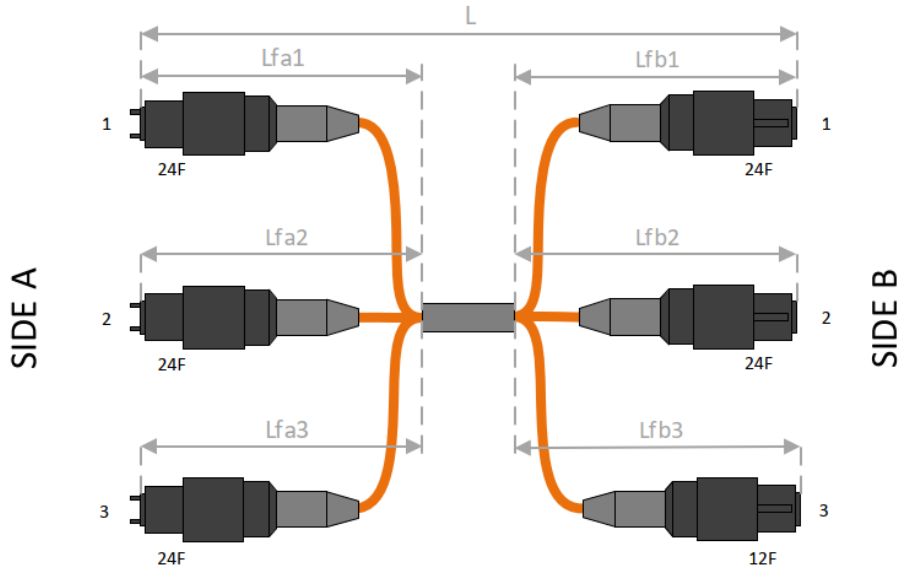
- Shuffle patch cords shall consist of multiple multi-fibre cords with multi-fibre connectors at one end, and a shuffle box and multiple multi-fibre cords with multi-fibre connectors at the other end.
- The connectors may contain either 12 or 24 fibres.
- Characterized by the number of individual cords, a total length L and individual branch/cord lengths L_1,...,L_N

Protection

- The component is rugged.

Fan-out box

- Cylindrical: Ø < 25 mm



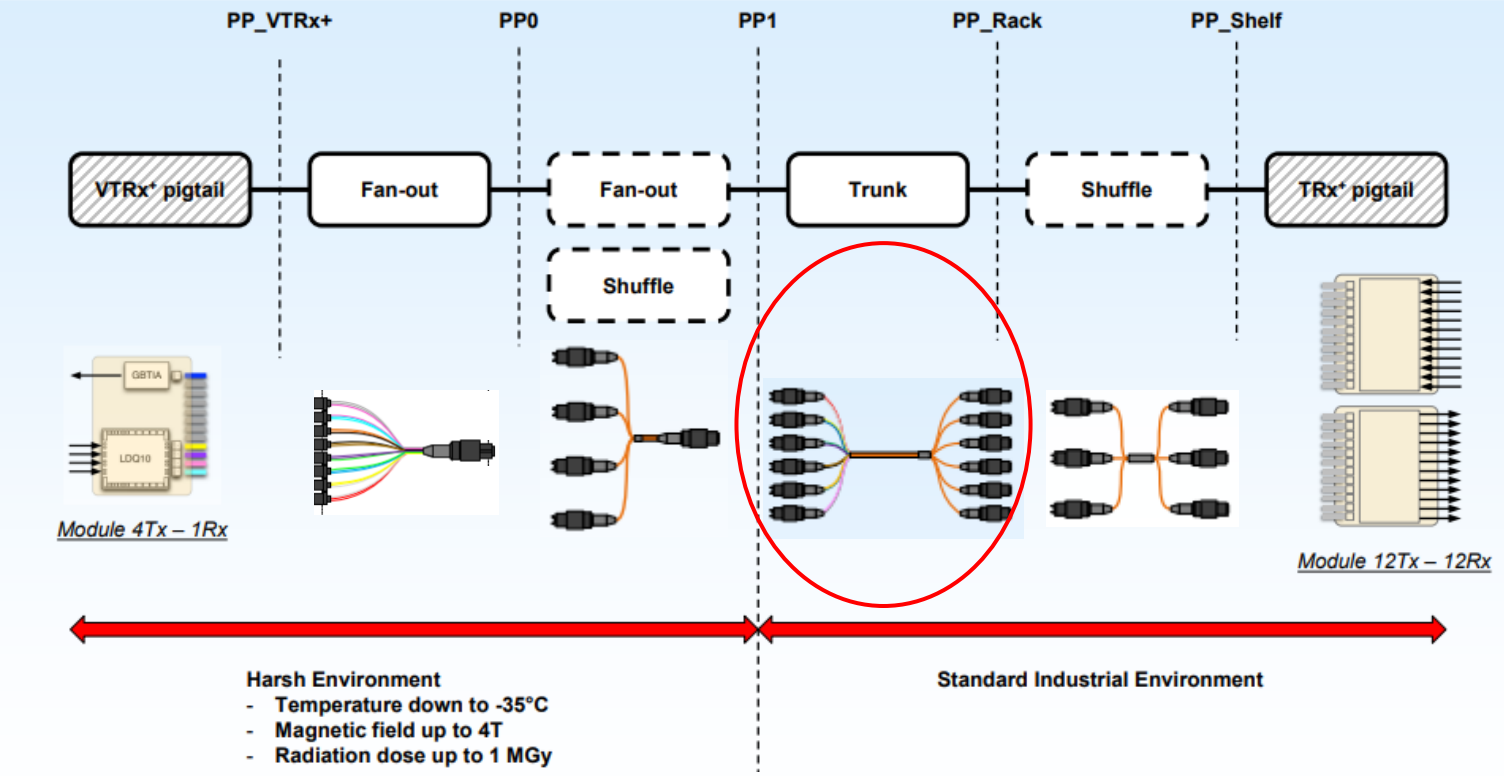
Future Procurement

Timeline

- **Q4 2021**:
  - Delivery and evaluation of prototypes (2nd wave)
  - Best possible estimation of production quantities
  - Freeze of components Families and Types
  - Freeze of qualified companies
- **Q4 2021**: IT dispatch to Qualified Firms.
- **Q1-2 2022**: contract award.
- **Q2-3 2022**: the contract can be used.
  - It will be possible to order components and customizing lengths, number and type of connectors.

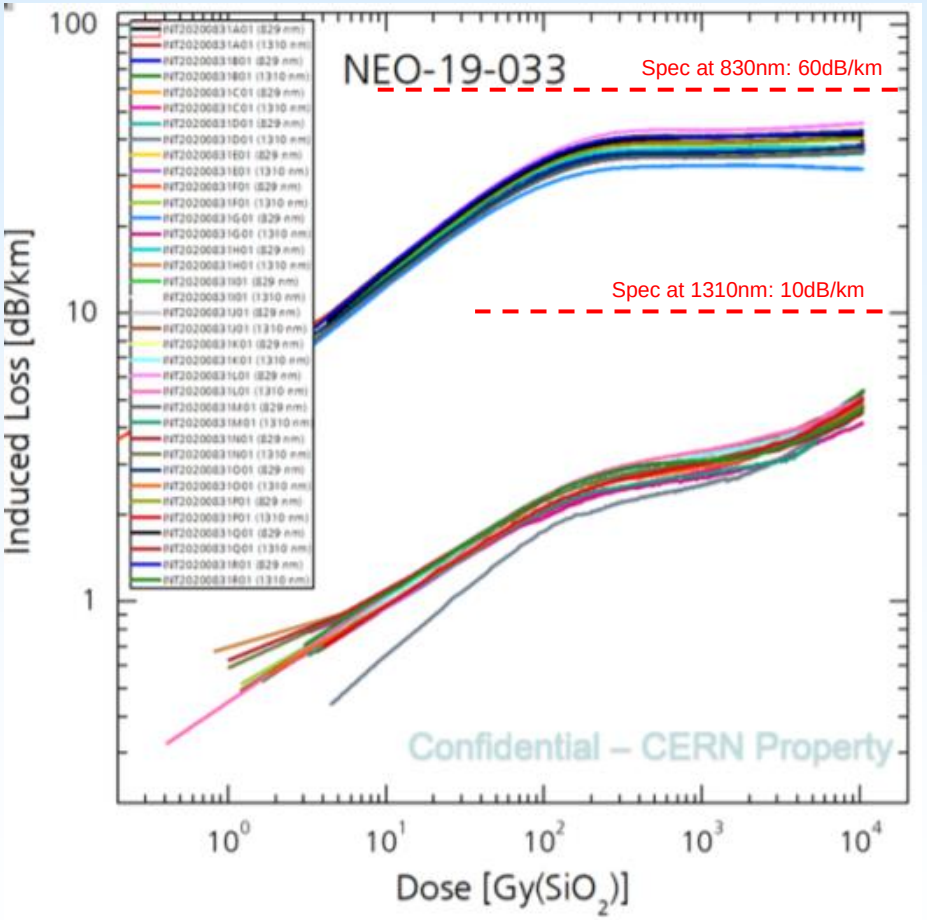
Trunk Cable

- Will be part of CERN EN-EL standard frame contract
- Prototype evaluations for VL+ project foreseen Q1-2022



Procurement of radiation resistant fibre

- Ordered 800 km of radiation resistant multimode fibres.
- Full quantity received and qualified
- Need to re-assess total fibre need by end-2021 to make sure we have enough

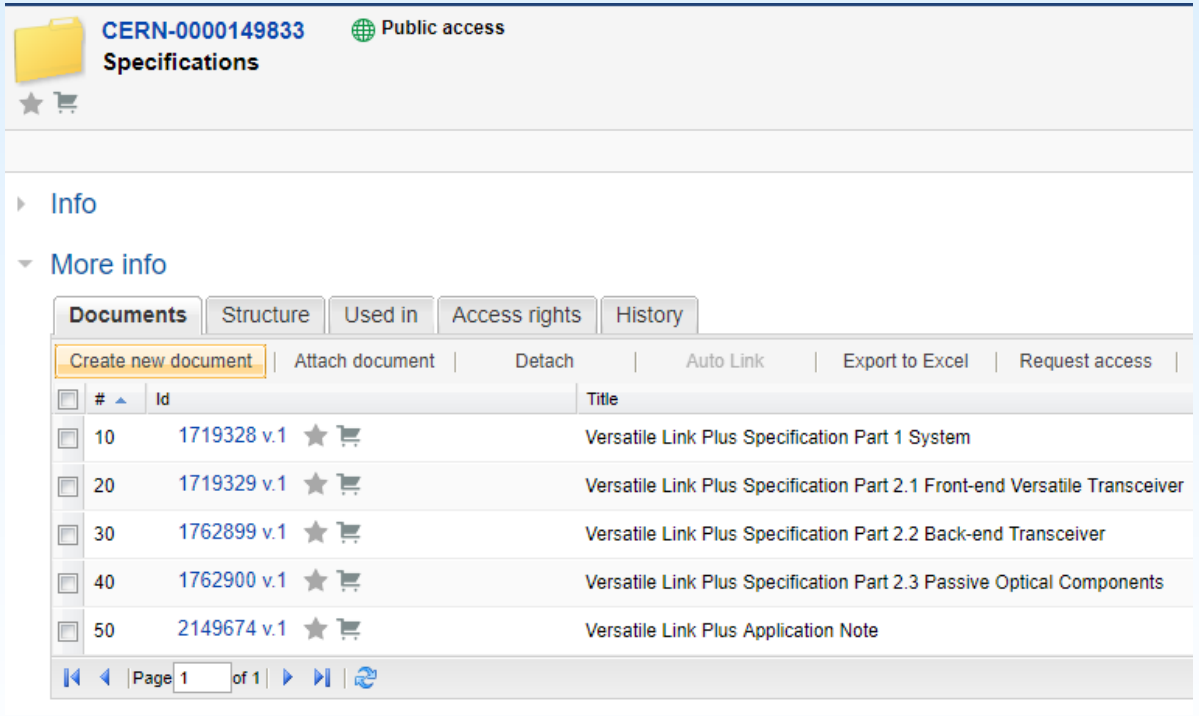


References

- VL+ specifications in EDMS

  https://edms.cern.ch/ui/#!master/navigator/project?P:1930058715:1767090345:subDocs

  Including Samtec product brief and VL+ application note draft



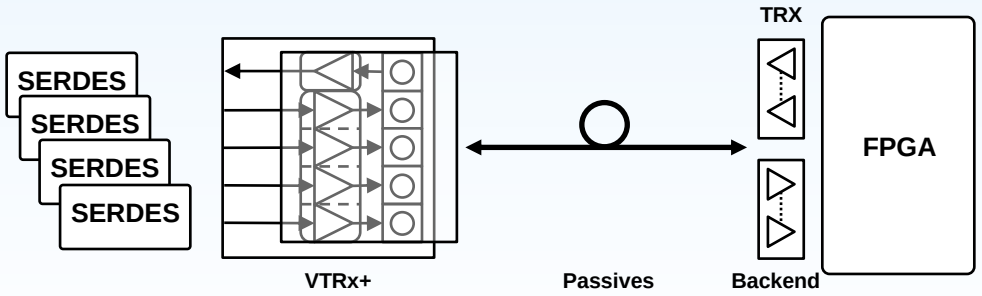
- VL+ Sharepoint site

  https://espace.cern.ch/project-Versatile-Link-Plus/SitePages/Home.aspx

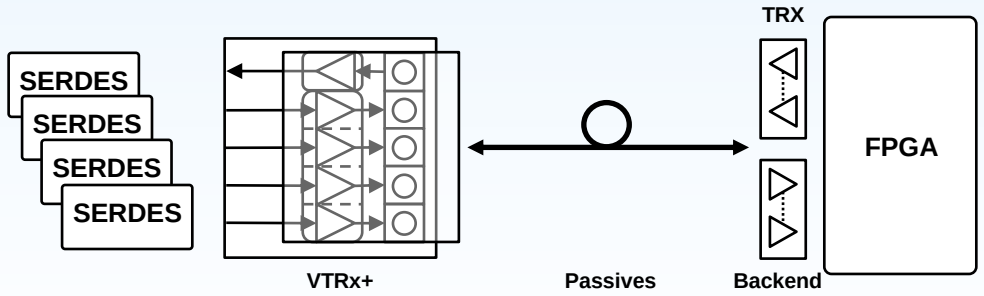
Thank you

https://espace.cern.ch/project-Versatile-Link-Plus

EDMS: CERN-0000149833



Backups


SERDES
SERDES
SERDES
SERDES
TRX
FPGA
VTRx+
Passives
Backend

5.1 Power Budget

- Upstream Power Budget is tight. Depending on link length and radiation environment, extended grade components must be used.
- Best margin achieved for short links with few breakpoints

Table 5.1 Versatile Link Plus Power Budget

	Upstream VTx+_Rx (10Gbps)		Downstream Tx_VRx+ (2.5Gbps)	
	Standard Grade	**Extended Grade**	**Standard Grade**	**Extended Grade**
Tx OMA	> -5.2 dBm	> -5.2 dBm [3]	> -5.6 dBm	>-1.6 dBm
Rx sensitivity	< -11.5 dBm	< -12.5 dBm	< -13.1 dBm	< -13.1 dBm [3]
Power budget	**> 6.3 dB**	**> 7.3 dB**	**> 7.5 dB**	**> 11.5 dB**
Fiber attenuation (50m/100m/150m)	<0.125 dB / 0.25 dB / 0.375 dB		< 0.375 dB	
Insertion loss	< 1.75 dB		< 1.75 dB	
Link penalties[1] (50m/100m/150m)	1.7 dB / 1.9 dB / 2.3 dB		< 0.5 dB	
Tx radiation penalty	1.0 dB		NA	
Rx radiation penalty	NA		< 1.4 dB	<5.4 dB
Fiber radiation penalty	< 0.5 dB	<1.5 dB	< 0.5 dB	<1.5 dB
Margin (50m/100m/150m)	**1.225/0.9/0.375 dB**	**1.225/0.9/0.375 dB**	**> 2.975 dB**	**> 1.975 dB**
Coding Gain[2]	**1dB**		**1 dB**	

Note 1: The link lengths documented here represent the actual link length where the first 7 meters consists of radiation hard OM2 fiber. For example, the length of 100 m is an overall link length of 100, which includes 7 m of OM2 fiber followed by 100 – 7 = 93 m of OM3 fiber.

Note 2: Error coding scheme, for example, the lpGBT FEC coding will result in an additional gain in margin.

Note 3: VTRx+ devices targeting extended grade should be selected to have high coupling efficiency and low VCSEL forward voltage to ensure robust operation to extreme fluence levels.

4.2 Standard or Extended Grade ?

1. Consider VTRx+ environment

Tolerance level	Dose and fluence (1Mev neutron equivalent)
Standard Grade	1 MGy 1.7×10^{14} neutrons/cm^2 1×10^{14} hadrons/cm^2
Extended Grade	1 MGy 1×10^{15} neutrons/cm^2 1×10^{15} hadrons/cm^2

If fluences at VTRx+ position are:

a. above standard grade levels > select Extended Grade
b. at/ or below standard grade levels: move to step 2

2. Consider Fibre environment

calculate Radiation Induced Attenuation (RIA) in fibre (choice of standard and rad hard fibre types)

a. If RIA is below 0.5dB > select Standard Grade
b. If RIA is above 0.5dB > select Extended Grade

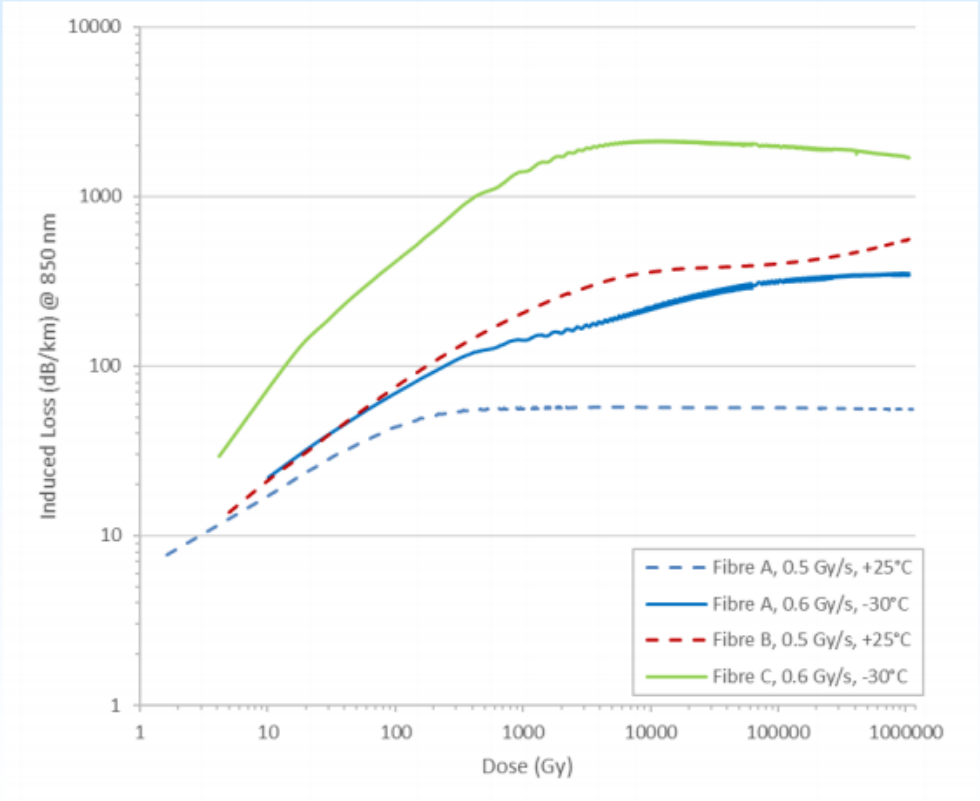
3. If unsure, contact VL+ team with:

- detector ionising radiation map
- fibre route and patch panel locations
- Position of Cold / Warm transition (if applicable)

To determine fibre type(s), calculate total RIA, and select VL+ grade

4.3 Fibre radiation resistance

- Radiation Induced Attenuation is rate and temperature dependent
  - Must be prudent with choice of fiber
  - Qualification tests must be performed in all conditions
- Commercial Rad-Hard fibre (fibre A) is not OM3
  - Can only be used for short lengths



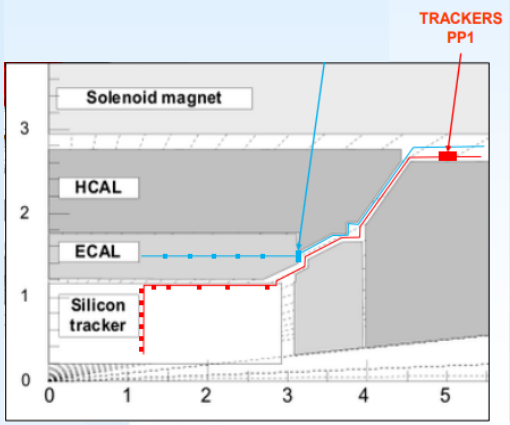
Optical fibre specification:

		Fibre A	Fibre B	Fibre C
Bandwidth		OM2	OM3	OM3
Attenuation (w/o radiation)	850 nm 1300 nm	≤ 2.5 dB/km ≤ 0.5 dB/km	≤ 2.4 dB/km ≤ 0.6 dB/km	≤ 2.3 dB/km ≤ 0.6 dB/km
Fibre profile		Graded Index	Graded Index	Graded Index
Core dopant		Fluorine	Germanium	Germanium
Cladding dopant		Fluorine	Fluorine	Fluorine

Radiation Induced Attenuation (dB/km):

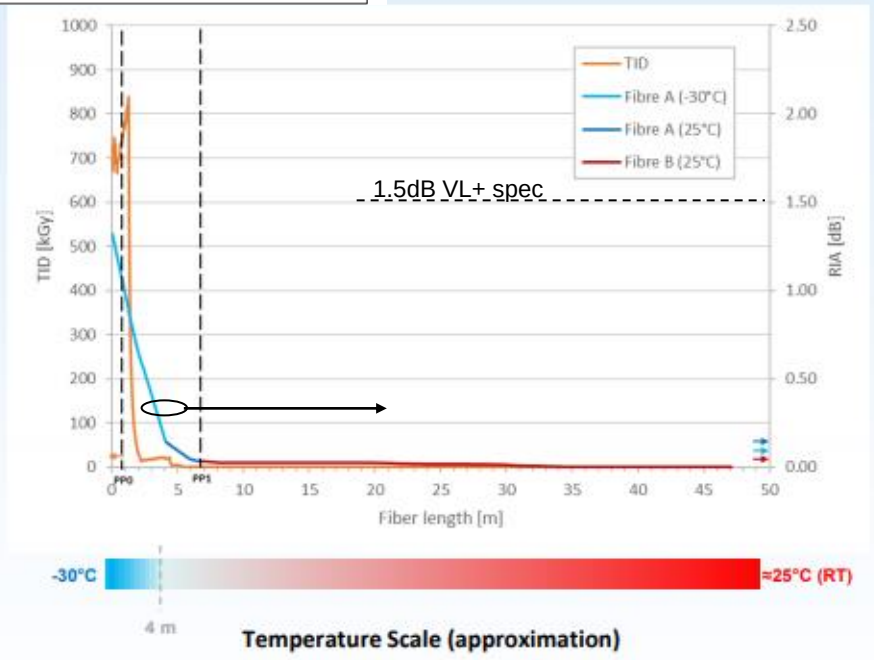
Dose	Fibre A (+25°C)	Fibre A (-30°C)	Fibre B (+25°C)	Fibre C (-30°C)
1 kGy	56	142	205	1250
10 kGy	57	220	360	2050
100 kGy	57	310	405	2000
1 Mgy	56	350	555	1500

4.4 Cumulative Radiation Induced Attenuation



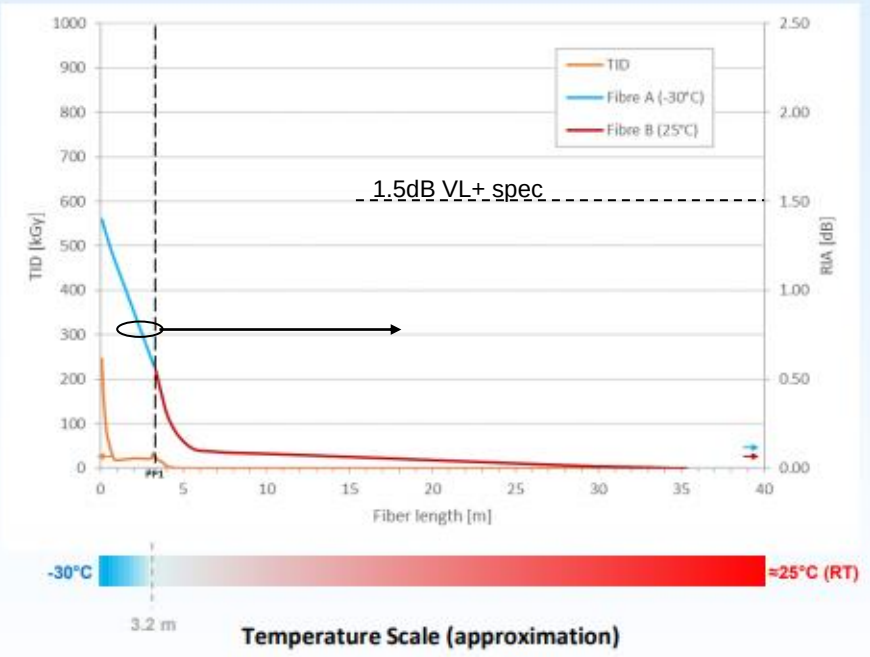
- All fibres subject to significant doses to be qualified for radiation hardness
- Trunk cable to be built with standard OM3 fibre
- 1.5dB RIA in power budget
- Best to leave fibre and cable selection/procurement to VL+ team

CMS



→ **Total RIA ≈ 1.32 dB**

ATLAS



→ **Total RIA ≈ 1.40 dB**

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