

ETL LV powering scheme

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Outline

Services scheme

- LV, BV, DSS, optical fibers

LV power calculations

- Voltage drop estimates
- Heat dissipation estimates

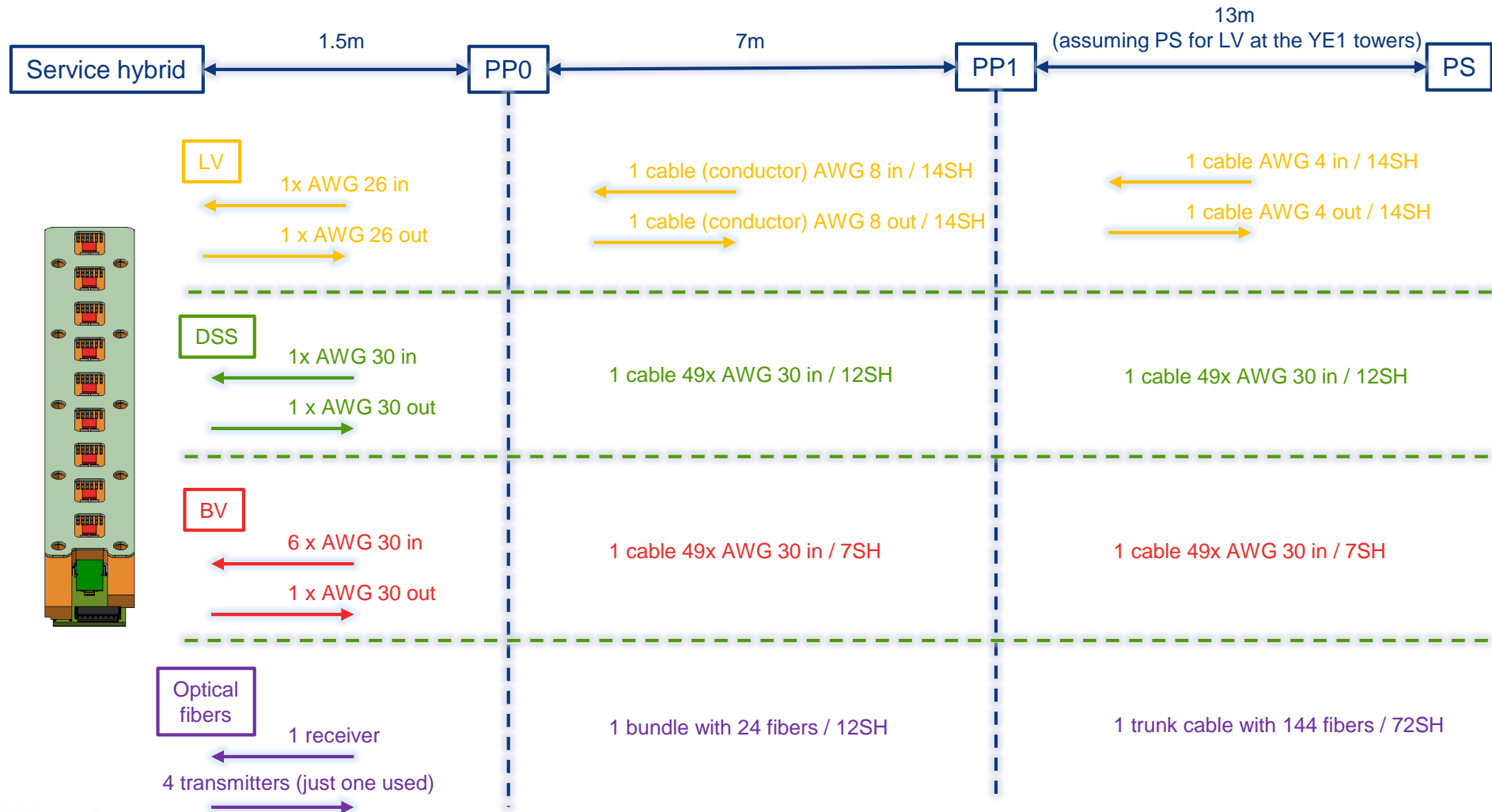
PP0 scheme

- PP0 v1 layout
- PP0 v2 layout

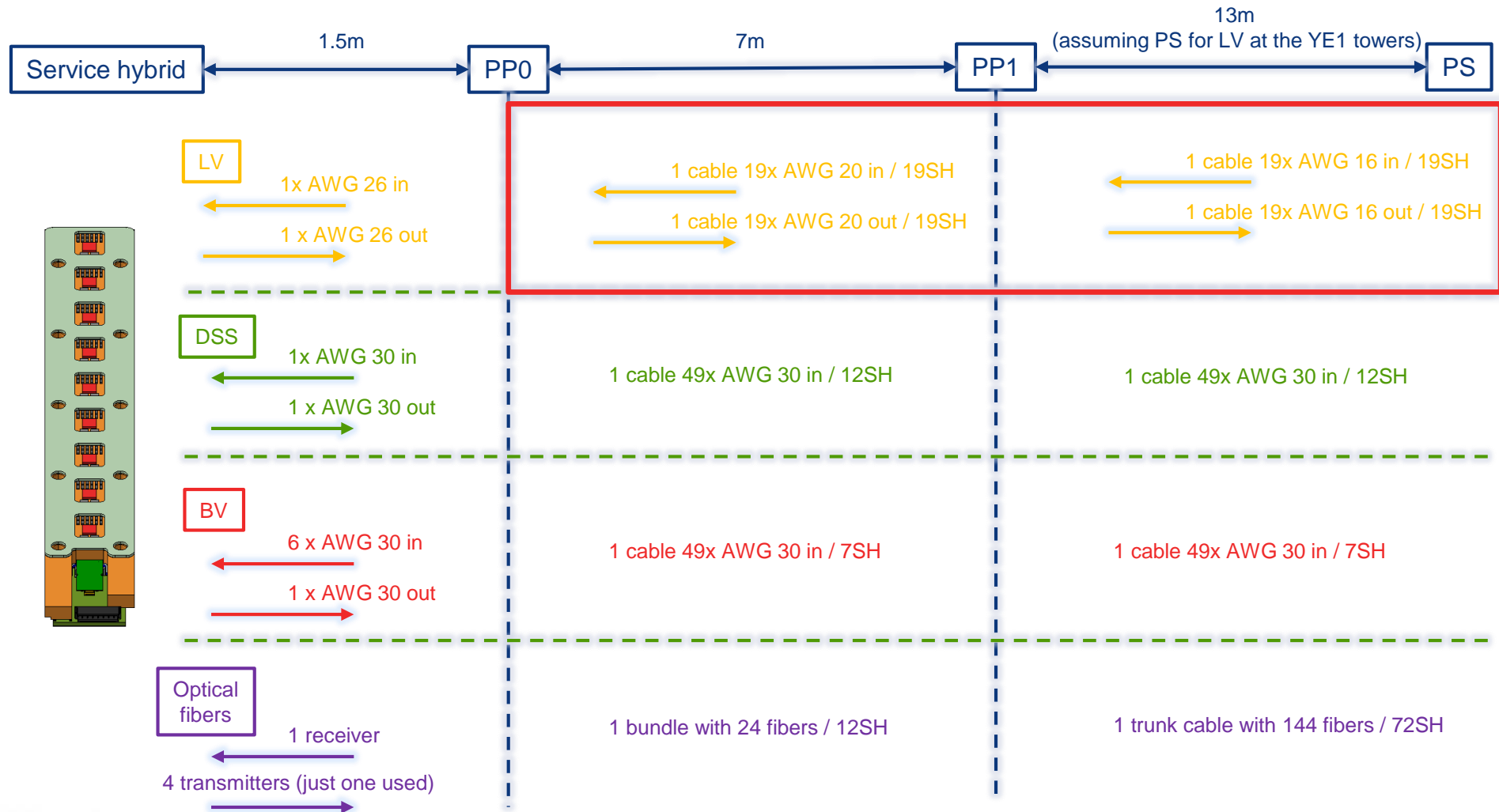
LV cable

- LV wire candidates
- LV cable candidates

Scheme of the services v1



Scheme of the services v2



LV power calculator v1

| ASIC | # | Vdd [V] | P [W] | I [A] | Cable run | Distance [m] | Wire for one supply/return [mm ²] (to have 1V drop) | Wire candidate | Cross section of the wire candidate [mm ²] | OD of the wire candidate [mm] - copper | OD of the wire candidate [mm] - with insulation | How many supply/returns? | How many SH? | Wire cross section [mm ²] per one supply/return from chosen wire candidate? |
|-------|----|---------|-------|-------|--------------------|--------------|---|----------------|--|--|---|--------------------------|--------------|---|
| VTRX | 1 | 2.5 | 0.28 | 0.11 | PS-PP1 | 13 | 1.21 | AWG 4 | 23.20 | 6.16 | 7.2 | 14 | 7 | 1.66 |
| LpGBT | 1 | 1.5 | 1 | 0.67 | PP1-PP0 | 7 | 0.32 | AWG 8 | 8.37 | 3.26 | 4.9 | 14 | 7 | 0.60 |
| SCA | 1 | 1.5 | 0.15 | 0.10 | PP0-Service Hybrid | 1.5 | 0.14 | AWG 26 | 0.154 | 0.504 | 0.8 | 1 | 0.5 | 0.15 |
| ETROC | 24 | 1.2 | 1 | 0.83 | | | | | | | | | | |

| Overall load voltages | I [A] |
|-----------------------|-------|
| 2.5 V | 0.88 |
| 1.2 V | 20.00 |

| bPOL12 input voltage [V] | # |
|-------------------------------|--------|
| 8 | 8 |
| bPOL12 Max output current [A] | 3 |
| bPOL12 Efficiency | 60.00% |
| # of Converters for ETROCs | 6 |
| # of ETROCs per Converter | 4 |

| 8V input current [A] | 8V power consumption | SH heat dissipation |
|-------------------------------|----------------------|---------------------|
| 5.46 | 43.66 | 17.46 |
| 6 modules heat dissipation | 26.20 | 2.91 |
| 1/6 SH power dissipation | 2.18 | 2.18 |
| Half module power dissipation | | |

| Total current flow supply/return [kA] | Total current flow to calculate heat dissipation [kA] |
|---------------------------------------|---|
| 2.18 | 4.37 |

| Cable copper cross section | Distance [m] | Heat dissipated in the service channel [kW] |
|---|--------------|---|
| Voltage drop PS-PP1 [V] | 1 | 400.00 |
| Voltage drop PP1-PP0 [V] | 2 | 57 |
| Voltage drop PP0-Service hybrid [V] | 1 | 57 |
| # of Service Hybrids per SIDE of one END | 400.00 | |
| # of LV wires per service channel PS-PP1 | 57 | |
| # of LV wires per service channel PP1-PP0 | 57 | |
| Heat dissipated in the service channel [kW] | 13.10 | |

Comment: Based on the given voltage drop (1.5V) along one wire and calculated input current

| Recalculated values with chosen wire candidates | 0.04kW/m for tracker |
|--|----------------------|
| Voltage drop PS-PP1 [V] | 0.73 |
| Voltage drop PP1-PP0 [V] | 1.09 |
| Voltage drop PP0-SH [V] | 0.90 |
| Heat dissipated PS-PP1 per SIDE of one END [kW] | 3.17 |
| Heat dissipated PP1-PP0 per SIDE of one END [kW] | 4.73 |
| Heating power per unit length PS-PP1 [kW/m] | 0.24 |
| Heating power per unit length PP1-PP0 [kW/m] | 0.68 |
| Total voltage drop PS-detector-PS [V] | 5.44 |

High power scenario

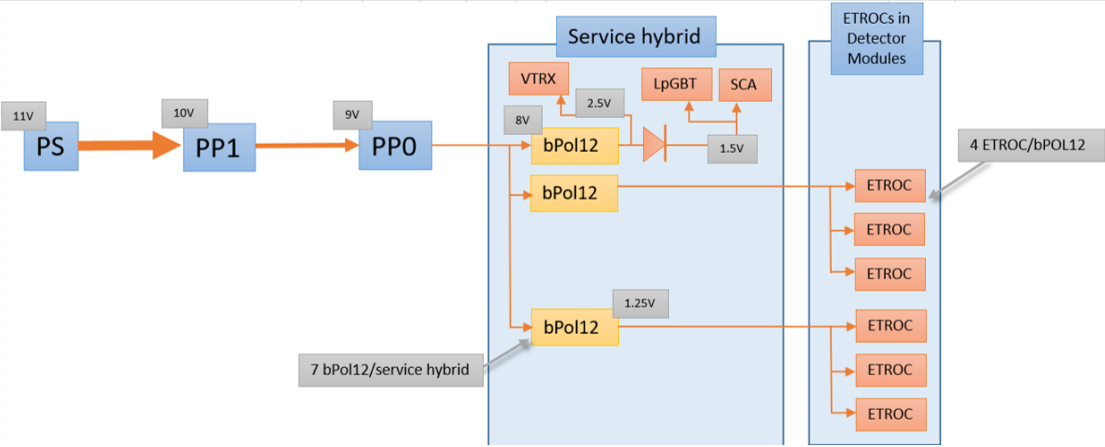
Lower than recently measured

Assumption → PS for LV at the YE1 towers

LV cable OD

Voltage drop at each section, total 2.72V < 3V

Heat dissipation at each section



LV power calculator v2

| ASIC | | | | | Cable copper cross section | | | | | | | | | | |
|---|--------|---------|-------|-------|--|--------------|---|----------------|---|--|---|--------------------------|--------------|--|--|
| ASIC | # | Vdd [V] | P [W] | I [A] | Cable run | Distance [m] | Wire for one supply/return [mm2] (to have 1V drop) | Wire candidate | Cross section of the wire candidate [mm2] | OD of the wire candidate [mm] - copper | OD of the wire candidate [mm] - with insulation | How many supply/returns? | How many SH? | Wire cross section [mm2] per one supply/return from chosen wire candidate? | |
| VTRX | 1 | 2.5 | 0.28 | 0.11 | PS-PP1 | 13 | 1.21 | AWG 16 | 1.34 | 1.5 | 1.73 | 1 | 0.5 | 1.34 | |
| LpGBT | 1 | 1.5 | 1 | 0.67 | PP1-PP0 | 7 | 0.65 | AWG 20 | 0.62 | 1.009 | 1.24 | 1 | 0.5 | 0.62 | |
| SCA | 1 | 1.5 | 0.15 | 0.10 | PP0-Service Hybrid | 1.5 | 0.14 | AWG 26 | 0.16 | 0.504 | 0.74 | 1 | 0.5 | 0.16 | |
| ETROC | 24 | 1.2 | 1 | 0.83 | | | | | | | | | | | |
| Overall load voltages | | | | I [A] | | | | | | | | | | | |
| | | | | 2.5 V | 0.88 | | | | | | | | | | |
| | | | | 1.2 V | 20.00 | | | | | | | | | | |
| bPOL12 input voltage [V] | 8 | | | | | | | | | | | | | | |
| bPOL12 Max output current [A] | 3 | | | | | | | | | | | | | | |
| bPOL12 Efficiency | 60.00% | | | | | | | | | | | | | | |
| # of Converters for ETROCs | 6 | | | | | | | | | | | | | | |
| # of ETROCs per Converter | 4 | | | | | | | | | | | | | | |
| 8V input current [A] | 5.46 | | | | | | | | | | | | | | |
| 8V power consumption | 43.66 | | | | | | | | | | | | | | |
| SH heat dissipation | 17.46 | | | | | | | | | | | | | | |
| 6 modules heat dissipation | 26.20 | | | | | | | | | | | | | | |
| 1/6 SH power dissipation | 2.91 | | | | | | | | | | | | | | |
| Half module power dissipation | 2.18 | | | | | | | | | | | | | | |
| Total current flow supply/return [kA] | 2.18 | | | | | | | | | | | | | | |
| Total current flow to calculate heat dissipation [kA] | 4.37 | | | | | | | | | | | | | | |
| | | | | | Voltage drop PS-PP1 [V] | 1 | | | | | | | | | |
| | | | | | Voltage drop PP1-PP0 [V] | 1 | | | | | | | | | |
| | | | | | Voltage drop PP0-Service hybrid [V] | 1 | | | | | | | | | |
| | | | | | # of Service Hybrids per SIDE of one END | 400.00 | | | | | | | | | |
| | | | | | # of LV wires per service channel PS-PP1 | 800 | | | | | | | | | |
| | | | | | # of LV wires per service channel PP1-PP0 | 800 | | | | | | | | | |
| | | | | | Heat dissipated in the service channel [kW] | 8.73 | Comment: Based on the given voltage drop (1.5V) along one wire and calculated input current | | | | | | | | |
| | | | | | Recalculated values with chosen wire candidates | | | | | | | | | | |
| | | | | | Voltage drop PS-PP1 [V] | 0.90 | | | | | | | | | |
| | | | | | Voltage drop PP1-PP0 [V] | 1.05 | | | | | | | | | |
| | | | | | Voltage drop PP0-SH [V] | 0.82 | | | | | | | | | |
| | | | | | Heat dissipated PS-PP1 per SIDE of one END [kW] | 3.93 | | | | | | | | | |
| | | | | | Heat dissipated PP1-PP0 per SIDE of one END [kW] | 4.60 | | | | | | | | | |
| | | | | | Heat dissipated PP0-SH per SIDE of one END [kW] | 3.80 | | | | | | | | | |
| | | | | | Heating power per unit length PS-PP1 [kW/m] | 0.30 | 0.03 kW/m for tracker | | | | | | | | |
| | | | | | Heating power per unit length PP1-PP0 [kW/m] | 0.66 | | | | | | | | | |
| | | | | | Total voltage drop PS-detector-PS [V] | 5.65 | | | | | | | | | |

High power scenario

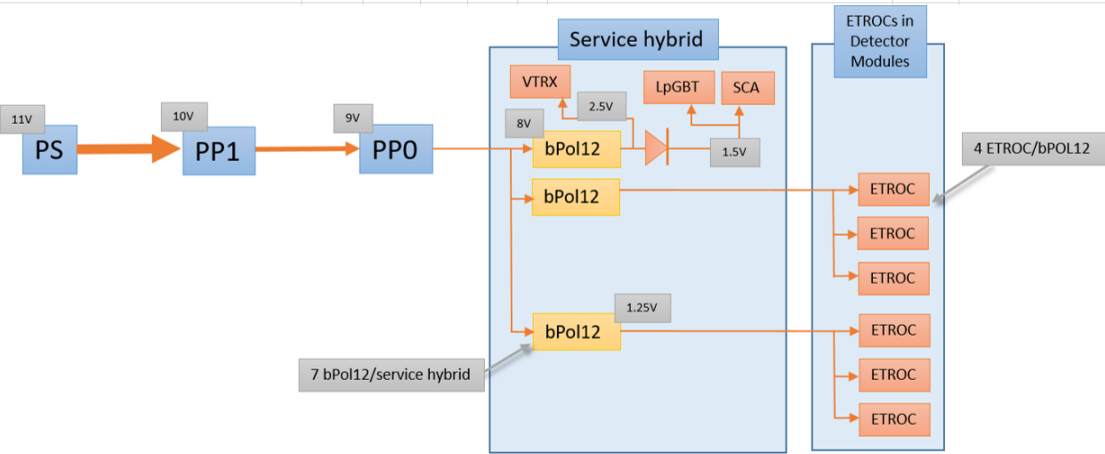
Lower than recently measured

OD of LV single conductor
OD of the cable ~8.6mm

2.82V < 3V

calculated for a single wire that could be supply or return

3.8kW heat dissipated per SIDE, 7.6kW in total per END (2.7kW assumed in the TDR)



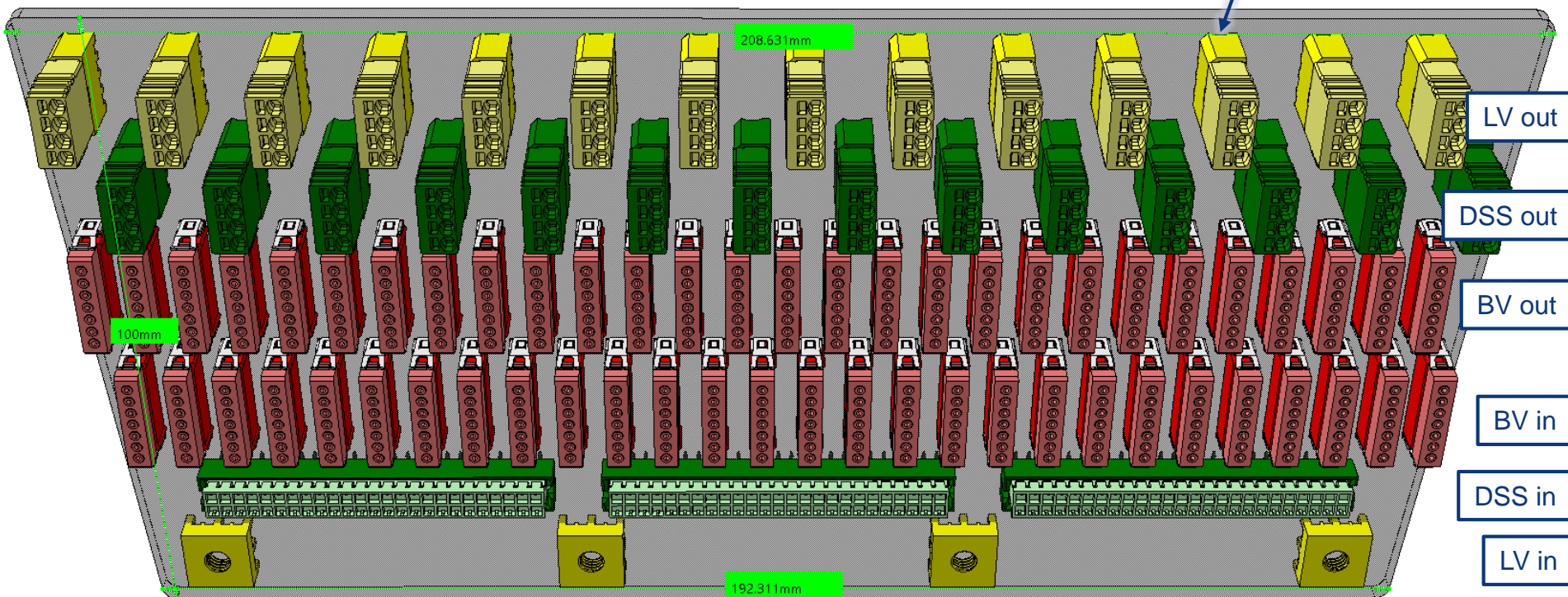
PP0 v1

28 service hybrids/PP0 → 14 PP0s per SIDE (10deg segments)

- 14 LV out and 14 DSS out → 2 SH/connector
- 28 BV out and 28 BV in → 1 SH/connector
- 2 LV in and 2LV out → 14 SH/connector
- Fuses still to be implemented
- Preliminary layout presented by S. Los → https://indico.cern.ch/event/820512/contributions/3429658/attachments/1842929/3023621/ETL-Cabling-S_Los-May13-2019.pdf

<https://www.phoenixcontact.com/online/portal/us?uri=pxc-oc-itemdetail:pid=1815280&library=usen&tab=1>

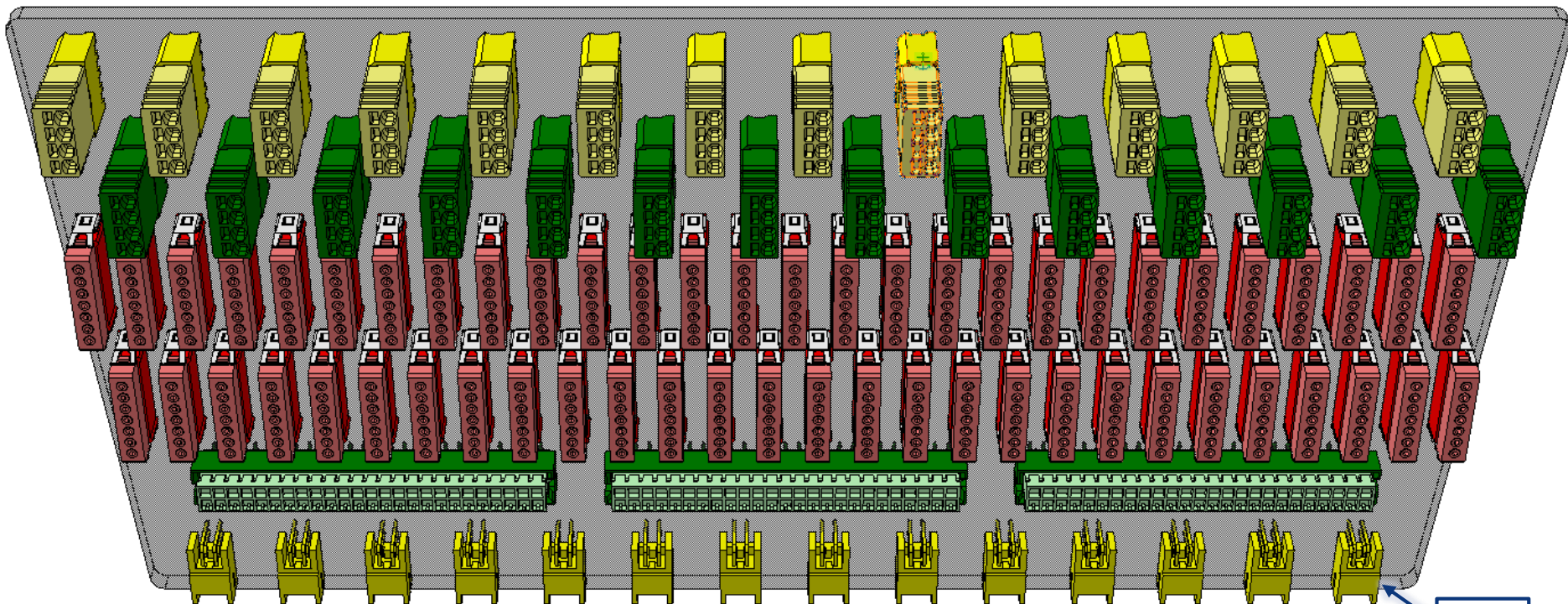
https://indico.cern.ch/event/820512/contributions/3429658/attachments/1842929/3023621/ETL-Cabling-S_Los-May13-2019.pdf



PP0 v2

28 service hybrids/PP0 → 14 PP0s per SIDE (10deg segments)

- LV in screw connectors replaced with 4-pin connectors
- No need of having fuses
- LV in connectors still have to be selected



LV in

LV cable selection for v1

PP0-PP1

- Single conductor **AWG 8 for 14 SH**
 - **OD 5mm** (assuming 0.9mm of insulation)
 - Bending radius **~50mm**
 - **55** cables per SIDE
- ↓
- LV cross section – **27.5cm²** (assuming filling factor 50%)

PP1-PS

- Single conductor **AWG 4 for 14 SH**
 - **OD 8mm** (assuming 0.9mm of insulation)
 - Bending radius **~80mm**
 - **55** cables per SIDE
- ↓
- LV cross section – **70.4cm²** (assuming filling factor 50%)

LV wire selection for v2

Single wires

TYPE FHT xxxx SPC or SCA

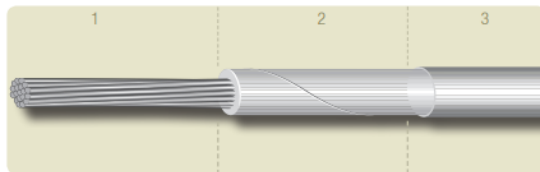
Insulation : POLYIMIDE tape halogen free / LSZH

Operating temperature : -100°C up to +200°C

Voltage rating : 250 VAC

Radiation resistance : 10 MGy (1000 Mrad) in standard atmosphere,
50 MGy (5000 Mrad) in inert atmosphere

Standard colour : natural (amber). Other colours upon request



Construction

PRIMARY WIRE

1 - Conductor : electrolytic silver plated annealed copper (SPC) or silver plated copper alloy (SCA)

2 - Insulation : wrapped Polyimide tape

3 - Insulation : Polyimide coating

Other constructions on request

LV wire selection

1. SH-PP0
2. PP0-PP1
3. PP1-PS

| AXON REFERENCE | AWG | CONDUCTOR | | | | INSULATED WIRE | |
|----------------|-----|--------------------------|--------|-------------------------|-----------------------------|----------------|--------------|
| | | CONSTRUCTION (Nb x Ø mm) | Ø (mm) | AREA (mm ²) | NOMINAL RESISTANCE (Ω/100m) | NOMINAL Ø (mm) | WEIGHT (g/m) |
| FHT 3007 SCA | 30 | 7 x 0.102 | 0.304 | 0.057 | 37 | 0.53 | 0.76 |
| FHT 3001 SCA | 30 | 1 x 0.254 | 0.254 | 0.051 | 39 | 0.48 | 0.69 |
| FHT 2807 SCA | 28 | 7 x 0.127 | 0.381 | 0.089 | 23 | 0.61 | 1.11 |
| FHT 2801 SCA | 28 | 1 x 0.320 | 0.320 | 0.080 | 26 | 0.55 | 1.00 |
| FHT 2619 | 26 | 19 x 0.102 | 0.504 | 0.16 | 12 | 0.74 | 1.79 |
| FHT 2601 | 26 | 1 x 0.404 | 0.404 | 0.13 | 13 | 0.63 | 1.48 |
| FHT 2419 | 24 | 19 x 0.127 | 0.634 | 0.24 | 7.6 | 0.86 | 2.65 |
| FHT 2401 | 24 | 1 x 0.511 | 0.511 | 0.20 | 8.4 | 0.74 | 2.26 |
| FHT 2219 | 22 | 19 x 0.160 | 0.800 | 0.38 | 4.7 | 1.03 | 4.73 |
| FHT 2201 | 22 | 1 x 0.643 | 0.643 | 0.32 | 5.3 | 0.87 | 3.41 |
| FHT 2019 | 20 | 19 x 0.203 | 1.009 | 0.616 | 3.2 | 1.24 | 6.26 |
| FHT 2001 | 20 | 1 x 0.812 | 0.812 | 0.52 | 3.3 | 1.04 | 5.30 |
| FHT 1819 | 18 | 19 x 0.254 | 1.269 | 0.96 | 2.1 | 1.50 | 9.63 |
| FHT 1619 | 16 | 19 x 0.300 | 1.500 | 1.34 | 1.4 | 1.73 | 12.30 |

1.

2.

3.

AXON catalogue:

<http://www.axon-cable.com/publications/Halogen-free-cables.pdf>

LV cable selection for v2

Example of the composite cable given by AXON:

Composite cable

TYPE XZT 19x0.59 / AWG 20 LSZH

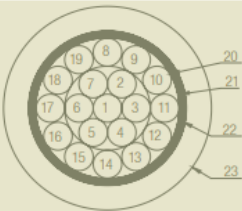
Z_T OPTIMIZED

Insulation : ASC3 - 55J

Operating temperature : -40°C up to +70°C

Voltage rating : 600 VAC

Standard colour : black.



Single wires are replaced with the candidates from the previous slide

Example of construction

1 TO 19 - SINGLE WIRES

AWG 20 / X 2037 TPC

Conductor : tin plated copper.
Construction : 37 x 0.142 mm.
Diameter : 0.97 mm.
Area : 0.59 mm².
Resistance : 3.5 Ω/ 100 m.
Insulation : POLIAX.
Diameter : 1.50 mm.

20 - POLYESTER SEPARATING TAPE

21 & 22 - SHIELDING

tin plated copper double braid,
Z_T optimized. (see table below).

23 - BLACK ASC3-55J JACKET

LSZH thermoplastic elastomer.

Main characteristics

DIMENSIONS AND WEIGHT

- Diameter on assembled wires : 7.50 mm.
- Diameter on shielding : 9.00 mm.
- Diameter on outer jacket : 10.70 ± 0.50 mm.

- Nominal cable weight : 275 g/m.

MECHANICAL CHARACTERISTICS

- Allowable traction : 80 daN.
- Minimum bend radius : 110 mm.

BEHAVIOUR TO FIRE

- a- Reaction to fire : category A according to IEC 60332-3.
- b- Opacity of fumes : test passed according to IEC 61034-2.
- c- Toxicity of gas emitted during the combustion process : conventional index of the toxicity < 10.
- d- Corrosivity of fumes : test according to IEC 60754-2 passed.

PP0-PP1

- Multicore cable serving 19SH
- **OD 8mm** (assuming 0.9mm of insulation)
- Bending radius **~80mm**
- **42** cables per SIDE

PP1-PS

- Multicore cable serving 19SH
- **OD 11mm** (assuming 0.9mm of insulation)
- Bending radius **~110mm**
- **42** cables per SIDE

- LV cross section – **53.76cm²** (assuming filling factor 50%)

- LV cross section – **101.64cm²** (assuming filling factor 50%)

Almost factor of two larger cross section than in v1.
These cables **WON'T FIT** in the feedthrough and in the service channel

Conclusions

- v1 assumes power grouping of 14 service hybrids
 - Worse power granularity (comparing to the TDR)
 - Cables
 - More compact cables, easier to bend and fit (5mmOD)
 - Less space needed for the LV cables (in the feedthrough, service channel and behind the detector)
 - In order to validate the layout, we should ask suppliers for the drawings and samples
 - Preliminary PP0 layout is ready
 - Fuses need to be implemented
 - Connectors for LV and DSS out have to be reselected
- v2 assumes one channel per one service hybrid
 - Power granularity as in the TDR
 - Cables
 - Composite cables → **DON'T FIT IN THE FEEDTHROUGH AND IN THE SERVICE CHANNEL**
 - More space needed for the LV cables (in the feedthrough, service channel and behind the detector)
 - Preliminary PP0 layout is being prepared
 - No need of fuses
 - Connectors for LV in have to be selected

Backup



BV cable candidates

| REV | MODIFICATIONS | DRAWN | CHECKED | DATE |
|-----|------------------|-------|---------|-----------|
| A | CREATION | JCD | DAM | 29APR2019 |
| B | JACKET THICKNESS | JCD | DAM | 30APR2019 |

CABLE COMPOSITION

- 7x Wires FH3007SCA
Conductor
Material: Silver Plated Copper alloy
Construction: AWG30 or 7 x 0.102 mm nom.
Diameter: 0.303 mm nom.
Area: 0.057 mm² nom.
Resistance: 37 Ohms/100m nom.
Insulation
Material: Wrapped and sealed Polyimide tape
Diameter: 0.60 mm nom.
Color: TBD
- Polyimide tape
- Jacket
Material: Poliax™
Color: Red

GENERAL CHARACTERISTICS

Overall diameter: 2.33 mm nom.
Voltage rating: 600 V AC
Temperature rating: -40°C / +130°C
Approximate weight: 8.5 g/m

| Control Range | Material |
|--|---|
| Interpret per ASME Y14.5M-1994 Unless otherwise specified dimensions are in millimeters (inches) XX ± 0.13 (0.005) X ± 0.25 (0.01) Angles ± 1° | This document is the property of AXON CABLE INC and can be neither reproduced nor communicated with third parties without written authorization of a person appointed specially for that purpose by the aforementioned company. |

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| | | | |
|-------------------------|-----------|-----------|----|
| Plan No.: A24826B01 DWG | Format A4 | CAGE Code | RE |
| THIRD ANGLE PROJECTION | N/A | 0K0J2 | A |

The same cable could be used for DSS.

| REV | MODIFICATIONS | DRAWN | CHECKED | DATE |
|-----|------------------|-------|---------|-----------|
| A | CREATION | JCD | DAM | 29APR2019 |
| B | JACKET THICKNESS | JCD | DAM | 30APR2019 |

CABLE COMPOSITION

- 7 bundles of 7 Wires FH3007SCA
Conductor
Material: Silver Plated Copper alloy
Construction: AWG30 or 7 x 0.102 mm nom.
Diameter: 0.303 mm nom.
Area: 0.057 mm² nom.
Resistance: 37 Ohms/100m nom.
Insulation
Material: Wrapped and sealed Polyimide tape
Diameter: 0.60 mm nom.
Color: 1 color per bundle, TBD
- Drain wire
Material: Silver Plated Copper
Construction: AWG24 or 7 x 0.203 mm nom.
Diameter: 0.609 mm nom.
Area: 0.228 mm² nom.
Resistance: 7.9 Ohms/100m nom.
- Helical shielding
129 strands Ø0.127 mm
- Jacket
Material: Poliax™
Color: Red

GENERAL CHARACTERISTICS

Overall diameter: 6.66 mm nom.
Voltage rating: 600 V AC
Temperature rating: -40°C / +130°C
Approximate weight: 77 g/m

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| THIRD ANGLE PROJECTION | N/A | 0K0J2 | A24826B02 |

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TEMPORARY DESIGN NUMBER WILL BE REPLACED WITH PRODUCTION NUMBER UPON ORDER. VERIFIED AT ORDER CONFIRMATION.

Drawings provided by S. Los



Scheme for the optical fibers

