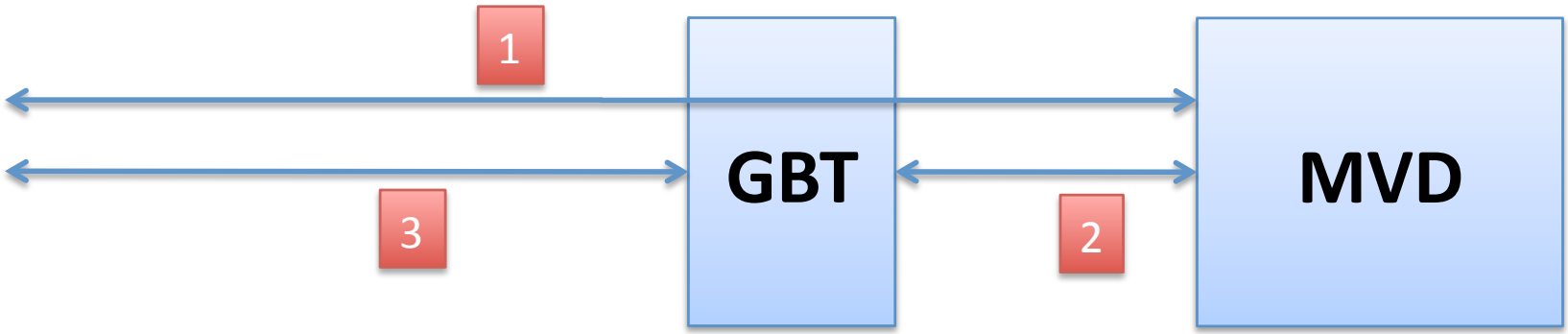
Routing Calculations – Required Cables

- From the outside to the MVD (through GBT area):
  - powering of the chips (analog and digital) for strips (FE) and pixels (ToPiX)
  - powering of the MDCs (strip part only)
  - powering of the sensors (HV) for strips and pixels
- From the GBT boards to the MVD:
  - flat data cables
- From the outside to the GBT boards:
  - powering of the GBT boards
  - optical fibers



1. Supply Cables

Routing Calculations – Supply cables

Input parameters for supply cables:

- cable length: 4m
- material:
  - inside MVD area: Al/Cu ($\rho=2.65\cdot10^{-8}$ Ω·m)
  - outside MVD area: Cu ($\rho=1.68\cdot10^{-8}$ Ω·m)
  - plastic cladding: 1 mm in diameter
- allowed voltage drop: 100 mV

Formula for diameter:

$$d[mm] = 2\cdot\sqrt{\frac{L\cdot\rho\cdot I}{\pi\cdot V_{drop}}}\cdot 1000$$

Power consumption:

- MDC: 0.25 A @ 2.5 V = 625 mW
- FE analog: 0.55 A @ 1.2 V = 660 mW
- FE digital: 0.3 A @ 1.2 V = 360 mW
- ToPiX analog: 0.2 A @ 1.2 V = 240 mW
- ToPiX digital: 1.2 A @ 1.2 V = 1440 mW

Routing Calculations – Pixels Disks

Occupancy is calculated considering each cable as a square with the side equal to the diameter of the cable (core + cladding) – the safety factor w.r.t. the round section is ~27%.

1. Pixel part:
   - Disks (Al/Cu):
     - ToPiX supply, 2 chips:
       - analog: 0.4 A → diam. 0.75 mm (1.75 with cladding)
         232 cables → 710.5 mm^2
       - digital: 2.4 A → diam. 1.8 mm (2.8 with cladding)
         232 cables → 1818.88 mm^2
     - ToPiX supply, 3 chips:
       - analog: 0.6 A → diam. 0.9 mm (1.9 with cladding)
         160 cables → 577.6 mm^2
       - digital: 3.6 A → diam. 2.2 mm (3.2 with cladding)
         160 cables → 1638.4 mm^2
     - HV:
       - 1 mm total diameter with cladding
         224 cables → 224 mm^2

Routing Calculations – Pixel Barrels

- Barrels (Cu):
  - ToPiX supply, 2 chips:
    - analog: 0.4 A → diam. 0.58 mm (1.58 with cladding)
      56 cables → 139.8 mm^2
    - digital: 2.4 A → diam. 1.43 mm (2.43 with cladding)
      56 cables → 330.67 mm^2
  - ToPiX supply, 3 chips:
    - analog: 0.6 A → diam. 0.72 mm (1.72 with cladding)
      188 cables → 556.18 mm^2
    - digital: 3.6 A → diam. 1.76 mm (2.76 with cladding)
      188 cables → 1432.11 mm^2
  - HV:
    - 1 mm total diameter with cladding
      128 cables → 128 mm^2

Routing Calculations – Strip Disks

2. Strip part
   - Disks (Al/Cu):
     - FE supply, 4 chips:
       - analog: 2.2 A → diam. 1.72 mm (2.72 with cladding);
         192 cables → 1420.5 mm^2
       - digital: 1.2 A → diam. 1.27 mm (2.27 with cladding);
         192 cables → 989.36 mm^2
     - MDC:
       - 0.25 A → diam. 0.58 mm (1.58 with cladding);
         96 cables → 239.65 mm^2
     - HV:
       - < 0.5 A → 1 mm total diameter with cladding;
         96 cables → 96 mm^2

Routing Calculations – Strip Barrels

- Barrels (Cu):
  - FE supply, 2 chips:
    - analog: 1.1 A → diam. 0.97 mm (1.97 with cladding);
      624 cables → 2421.68 mm²
    - digital: 0.6 A → diam. 0.72 mm (1.72 with cladding);
      624 cables → 1846.04 mm²
  - FE supply, 4 chips:
    - analog: 2.2 A → diam. 1.37 mm (2.37 with cladding);
      368 cables → 2067.02 mm²
    - digital: 1.2 A → diam. 1 mm (2 with cladding);
      368 cables → 1472 mm²
  - MDC:
    - 0.25 A → diam. 0.47 mm (1.47 with cladding);
      496 cables → 1071.81 mm²
  - HV:
    - < 0.5 A → 1 mm total diameter with cladding;
      496 cables → 496 mm²

Routing Calculations – Power Supply

Totals:

- Disks (Al/Cu):
  - Pixels: **1008 cables → 4970 mm²**
  - Strips: **576 cables → 2752 mm²**
- Barrels (Cu):
  - Pixels: **616 cables → 2589 mm²**
  - Strips: **2976 cables → 9375 mm²**

Includes power supply of the front-ends, of the MDCs and the HV of the sensors.

2. Flat data cables

Routing Calculations – Flat Data Cables

Parameters of a cable:

- 18 differential pairs
- cross section: 210µm · 14mm
- large safety factor included

Number of cables:

- Pixels:
  - Barrels: **122 cables → 427 mm²**
  - Disks: **196 cables → 686 mm²**
- Strips:
  - Barrels: **48 cables → 168 mm²**
  - Disks: **248 cables → 868 mm²**

Total: **614 cables, 2149 mm²**

3. Cables from GBT boards

Routing Calculations – GBT cables

Input parameters for supply cables:

- cable length: 3m
- material: Cu ($\rho = 1.68 \cdot 10^{-8}\ \Omega \cdot m$)
    - plastic cladding: 1 mm in diameter
- allowed voltage drop: 100 mV

Formula for diameter:

$$d[mm] = 2 \cdot \sqrt{\frac{L \cdot \rho \cdot I}{\pi \cdot V_{drop}}} \cdot 1000$$

Power consumption:

- GBT 2.5: 0.943 A @ 2.5 V = 2358 mW
- GBT 1.5: 0.425 A @ 1.5 V = 638 mW

Number of GBT boards:

- Pixel barrels: 34
- Pixel disks: 88
- Strip barrels: 37
- Strip disks: 12

Routing Calculations – GBT cables

Powering of one GBT board:

- 2.5 V supply: ~1 A → diam. 0.8 mm (1.8 with cladding);
  - Pixel barrels: **68 cables → 220.32 mm^2**
  - Pixel disks: **176 cables → 570.24 mm^2**
  - Strip barrels: **74 cables → 239.76 mm^2**
  - Strip disks: **24 cables → 77.76 mm^2**
- 1.5 V supply: ~0.5 A → diam. 0.57 mm (1.57 with cladding);
  - Pixel barrels: **68 cables → 167.61 mm^2**
  - Pixel disks: **176 cables → 433.82 mm^2**
  - Strip barrels: **74 cables → 182.40 mm^2**
  - Strip disks: **24 cables → 59.16 mm^2**

Total GBT cables:

- Pixels: **488 cables, 1392 mm^2**
- Strips: **196 cables, 560 mm^2**

Routing Calculations – Optical fibers

Input parameters for supply cables:

- 2 optical fibers per GBT board
- cross section 1 mm^2

Number of GBT boards:

- Pixel barrels: 34 → 68 fibers, 68 mm^2
- Pixel disks: 88 → 176 fibers, 176 mm^2
- Strip barrels: 37 → 74 fibers, 74 mm^2
- Strip disks: 12 → 24 fibers, 24 mm^2

Total fibers: **342 fibers, 342 mm^2**

Routing Calculations – Total occupancy

1. From the outside to the MVD (through GBT area):
   - from disks: **1584 cables, 7722 mm^2**
   - from barrels: **3592 cables, 11964 mm^2**
     - TOTAL: **5176 cables, 19686 mm^2**

2. From the GBT boards to the MVD:
   - **614 cables, 2149 mm^2**

3. From the outside to the GBT boards:
   - **1026 cables, 2294 mm^2**