# Vertex Detector Cable Considerations

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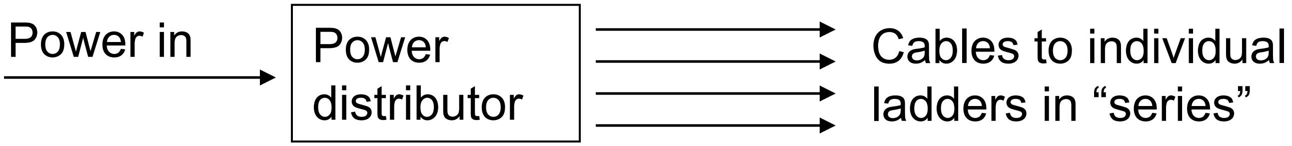
# Power Distribution

- This is a difficult problem with no ideal solution yet.
- One possibility is to provide power distributors a short distance from “ladders” so that ladders can be powered in series.
- That helps with cabling from the outside world to the distributors, but, by itself, doesn’t help with cabling from the distributors to ladder ends.
  - – The advantage is that serial connections between ladder locations are avoided.
  - – Some extent of serial powering within ladders would may still be needed to control the number of radiation lengths in cables.
    - For the moment, I’ve assumed a factor of two within each ladder half.
    - As you will see later, that was motivated by voltage drop in lines from the power distributor to sensors.



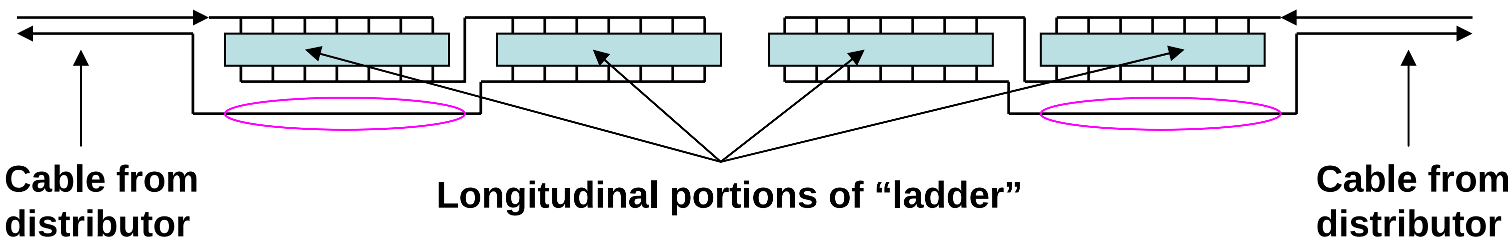
Power in

Power distributor

Cables to individual ladders in “series”

# Power Distribution

- One schematic representation of power distribution within a “ladder” (serialization components omitted)



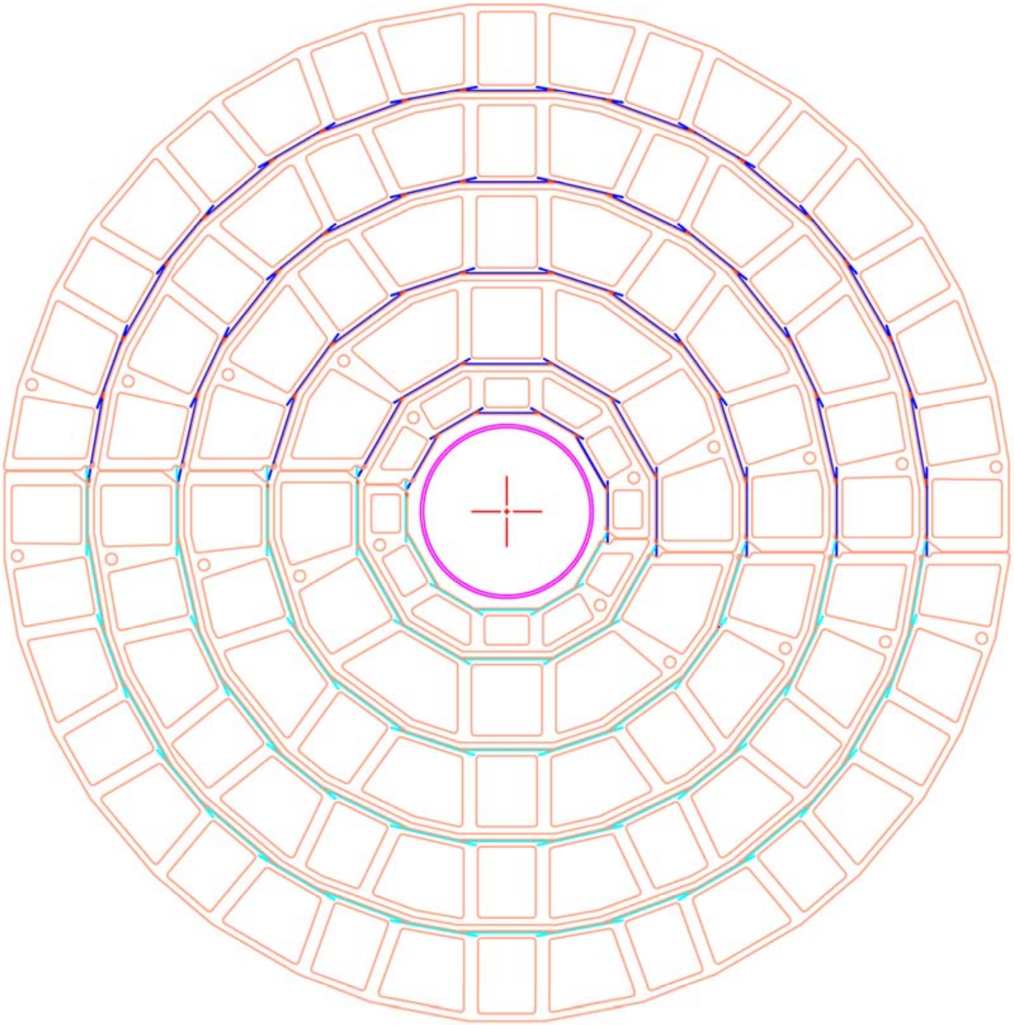
- Note that material within magenta ovals is, in a sense, “extra” metallization that should have an appropriate current carrying capability.
  - With this scheme, it adds to ladder material, as do serialization components.
  - Of course, there are other possibilities, but details matter.

# Power with ILC Beam Structure

- Vertex detector
  - Barrel assumptions
    - **20 watts average power dissipated at the barrel and a power cycling factor of 80 (1600 watts dissipated at the barrel when ramped up)**
    - **Power distributors located 0.3 m from sensors.**
      - **Serial powering of ladders occurs at the distributors.**
      - **Serial powering within ladders as well.**
    - **0.4 volt drop in cables to ladders and back**
    - **2.9 volts at distributors (2.5 volts at ladders)**
    - **Ladder arrangement as on the following slide (108 r-phi locations)**
    - **Two cables for power per R-Phi location**
      - **One cable per end**
    - **Ladder length = 125 mm.**
    - **Current per ladder is proportional to the ladder width (8.6 mm for layer 1, 12.5 mm for layers 2-5).**
  - Then when powered “up”
    - **256 watts dissipated in cables (16% of barrel power)**
    - **Current per end when up = 2.11 amp for layer 1 and 3.07 amp for layers 2-5.**
  - **Average power density at sensor over a cycle = 142 μW/mm$^2$ (not too different from what was assumed a few years ago).**

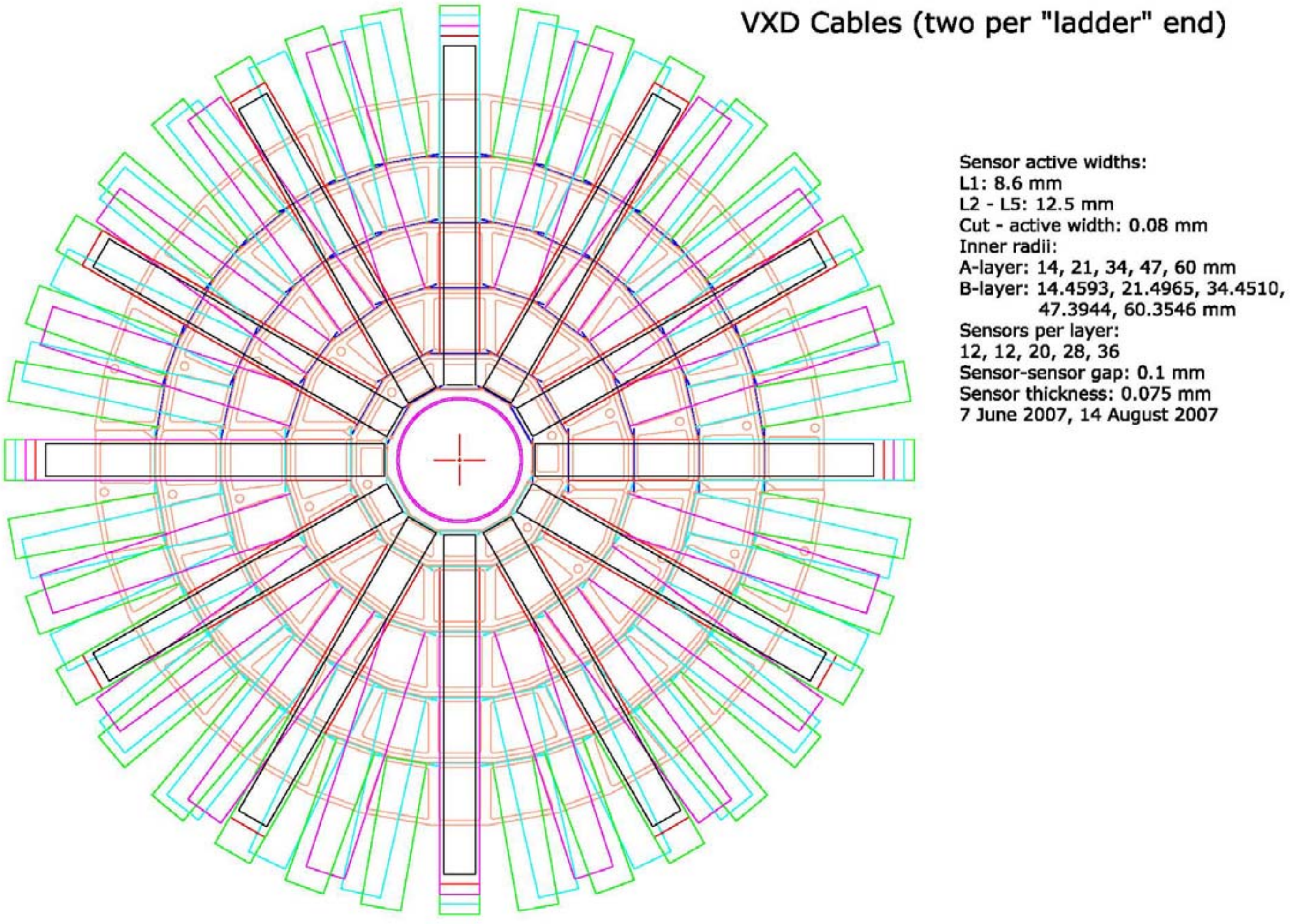
# Barrel End View

- 108 ladders locations



Sensor active widths:
L1: 8.6 mm
L2 - L5: 12.5 mm
Cut - active width: 0.08 mm
Inner radii:
A-layer: 14, 21, 34, 47, 60 mm
B-layer: 14.4593, 21.4965, 34.4510,
47.3944, 60.3546 mm
Sensors per layer:
12, 12, 20, 28, 36
Sensor-sensor gap: 0.1 mm
Sensor thickness: 0.075 mm
7 June 2007, 14 August 2007

# Barrel End View with Cables



VXD Cables (two per "ladder" end)

Sensor active widths:
L1: 8.6 mm
L2 - L5: 12.5 mm
Cut - active width: 0.08 mm
Inner radii:
A-layer: 14, 21, 34, 47, 60 mm
B-layer: 14.4593, 21.4965, 34.4510,
47.3944, 60.3546 mm
Sensors per layer:
12, 12, 20, 28, 36
Sensor-sensor gap: 0.1 mm
Sensor thickness: 0.075 mm
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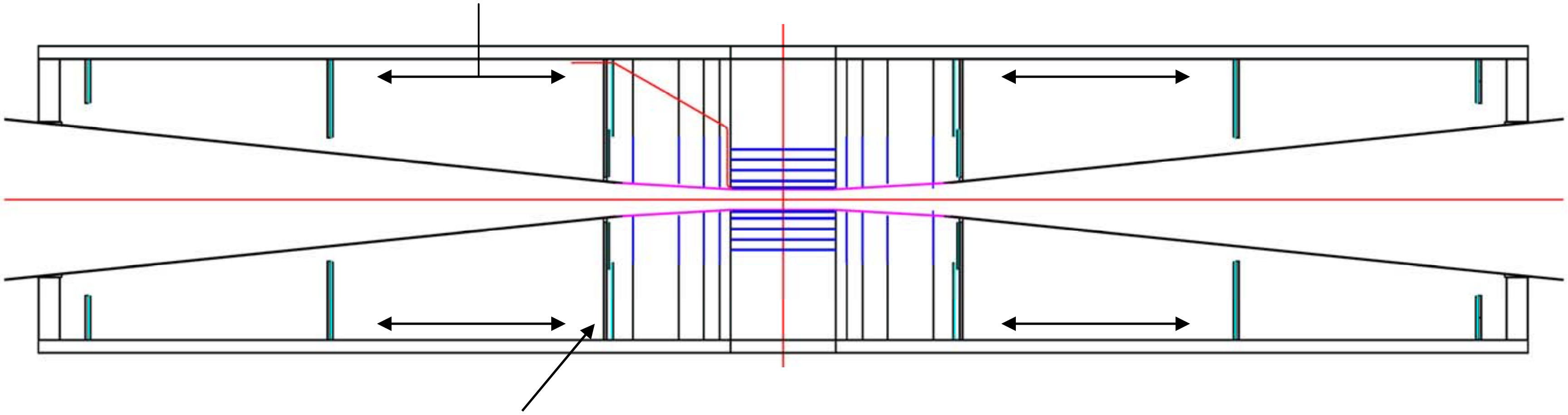
# Vertex Detector Elevation

- Length of red curve = 282 mm.



Power distributors here

Radial coverage of this
disk can be decreased to
allow cables to pass

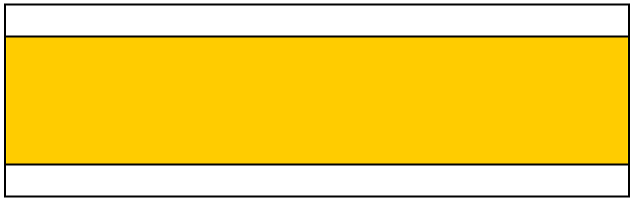
# Power Cable Conductor (Ramped Up)

- Assume aluminum conductor with ρ = 2.8 x $10^{-6}$ ohm-cm.
- Assume a conductor length of 60 cm and that 16% of sensor power is dissipated over the 30 cm cable length.
- Width available = 6.4 mm (Layer 1), 8 mm (Layers 2-5)
- Assume width used = 4 mm (Layer 1), 5.6 mm (Layers 2-5).
- Then conductor thickness = ~ 23 μm (22.2 μm for Layer 1).
- Checks assuming thickness = 23 μm
  - Layer 1
    - Cable resistance = 600/0.023/4*2.8e-5 = 0.183 ohm
    - Power dissipated in cable = 0.183*2.11^2 = 0.813 watt
    - Power dissipated in ladder = 0.813/.16 = 5.08 watt
    - 2.11 amp * 2.5 volts = 5.28 watt ✓
  - Layers 2-5
    - Cable resistance = 600/.023/5.6*2.8e-5 = 0.130 ohm
    - Power dissipated in cable = 0.130*3.07^2 = 1.229 watt
    - Power dissipated in ladder = 1.229/.16 = 7.68 watt
    - 3.07 amp * 2.5 volts = 7.68 watt ✓

Total for 1 end =
12*5,28 + 96*7.68
= 800.6 watt ✓

# Cable Layers

- **Assume two conductor layers with 0.075 mm kapton insulation between them.**
  - **In addition, thin passivation layers on the outer surfaces would probably be needed.**



**23 µm aluminum**

**75 µm kapton**

**23 µm aluminum**

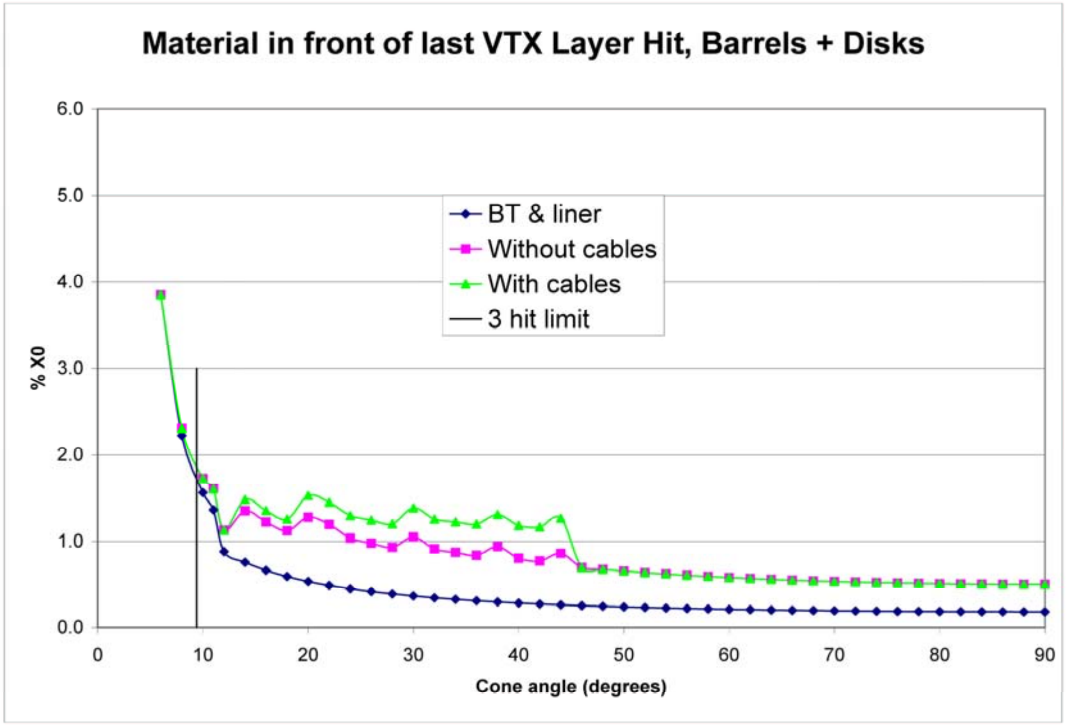
  - **Radiation lengths at normal incidence = 0.026% + 0.026% + 0.026% = 0.078% X0**
  - **Note that kapton contribution is significant, so an effort should be made to make cables with thinner kapton.**

**Plot assumes:**

**These cables (0.078% X0)**

**"All-silicon" SiD barrel**

**Sensor thickness = 0.08% X0**



**Material in front of last VTX Layer Hit, Barrels + Disks**

# Magnetic Field Effects (1)

- Assume 5 T field and a radial cable run of length 5 cm.
- Assume a common ground for all “ladders” at the barrel.
- Assume supply power is removed from one ladder and all other ladders are powered.
  - Then return current of each cable from that ladder is an appropriate fraction of the total return current: ~ 640 amp / 2 * 107/108^2 = 2.9 amp.
  - Since supply and return currents do not balance in that cable, a lateral force is exerted on the cable.
  - F = 2.9 amp * 0.05 m * 5 T = 0.72 N (equivalent to 72 grams)
  - Half that is too much force to apply to a ladder end.
  - Depending on the way in which distributors work, this effect might be reduced by a factor of n if n ladders were in series.
- Solution:
  - Provide power isolation at supplies.
  - Please note that end-to-end power isolation would probably be needed in any case to avoid a significant ground loop.

# Magnetic Field Effects (2)

- Consider a standard flex-cable with two conductor layers.
  - Assume 0.075 mm kapton between layers.
  - Torque on the radial run (layers 2-5) = 3.07 amp * 5 T * 75 e-6 m * 0.05 m = 5.8 e-5 N-m = 0.058 N-mm (equivalent to 5.8 gram-mm).
  - For a cable width of 8 mm, that might be acceptable if power were steady-state.
  - With power cycling, I think vibration would be a real issue.
- Solution:
  - Provide three conductor layers in the cable, for example, return – supply – return.
    - **Then torques cancel.**
    - **In principle, the total amount of conductor can remain the same.**
    - **Due to the added kapton layer, the number of radiation lengths at normal incidence represented by a cable increases from 0.078% to 0.104%.**
      - **Perhaps the kapton could be thinner.**
    - **Cable bending stiffness increases by a factor ~ 1.9.**

# Conclusions

- There has been some progress.
- Considerable development and prototyping remain.
- There is ample room for new and better ideas.