

Thoughts on VXD Sensor Configuration

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Sensor Requirements

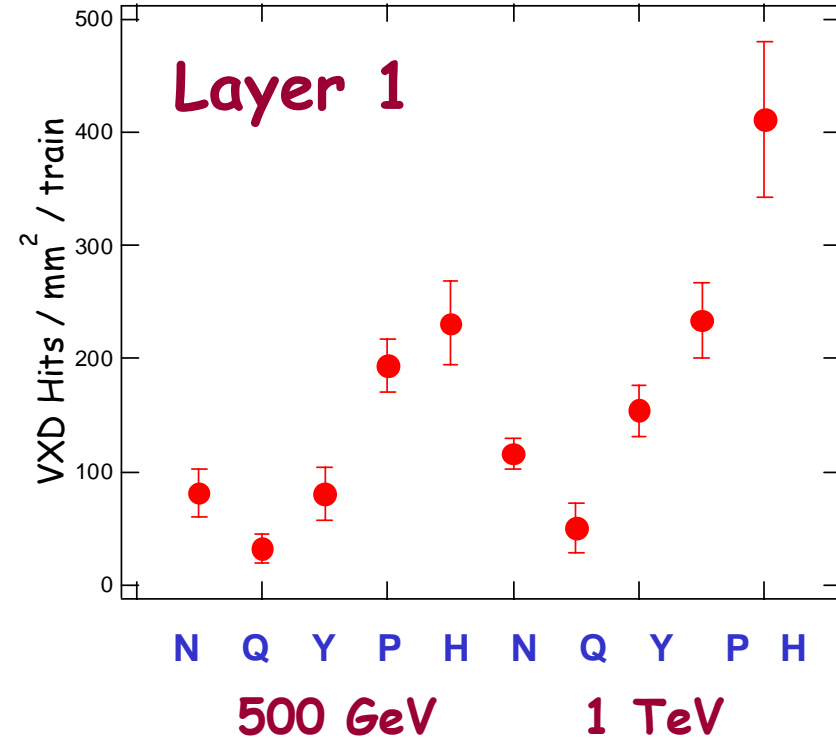
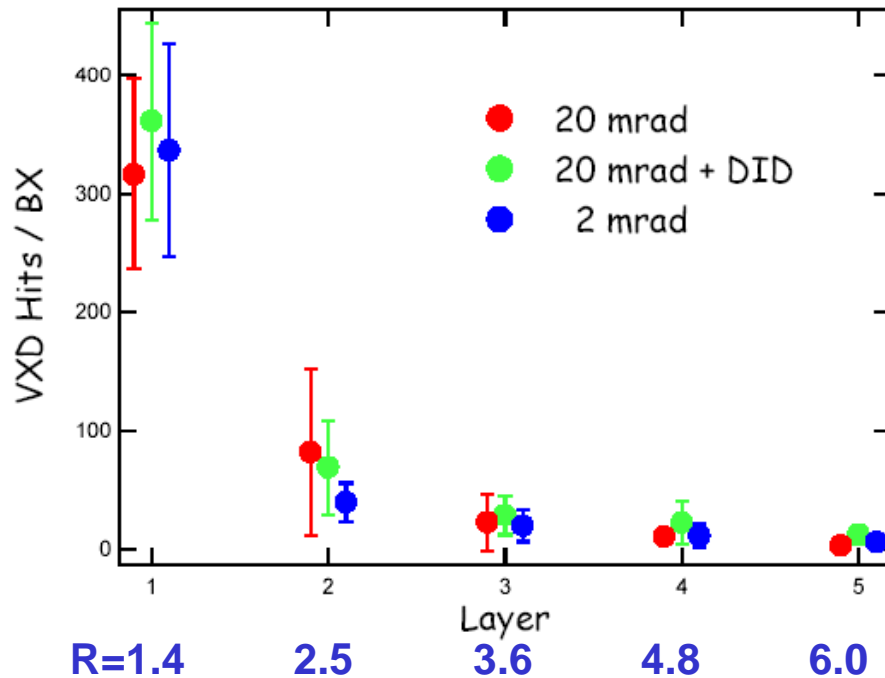
As of the DOD writeup, we have defined the following requirements:

- 1) Spatial resolution $< 5\mu\text{m}$ in all dimension for track entrance angles 15° - 90° .
- 2) Two track resolution $< 40\mu\text{m}$.
- 3) $< \sim 0.1\%$ XO material per layer.
- 4) $\sim 30\text{W} + 30\text{W}$ total power in barrel+endcap. Gas cooled.
- 5) Operable at 5T with little resolution loss.
- 6) $< 5 \text{ hits}/\text{mm}^2$ at Layer 1; $< 1 \text{ hit}/\text{mm}^2$ in outer layers.
- 7) Low noise to allow threshold for $> 99\%$ hit efficiency and readout noise $< 30\%$ of all hit data.
- 8) EMI immunity.
- 9) Can withstand: $> 20\text{Krad}/\text{year}$; $> 10^9/\text{cm}^2/\text{yr}$ 1 MeV Neutrons.

Comments on Sensor Requirements

- The 5 μ m resolution is very generous and one ought to be able to do better. One should still give extra credit for significantly better resolution (which may need the combination of thin EPI, low noise and perhaps not fully depleted).
- The power requirement is not only bound by the need for gas cooling. The necessary copper to deliver the instantaneous current is also an important factor.
- The hit density requirement has some uncertainties. We have not fully explored the tracking robustness at these limiting densities. Given the pivoting role of VXD in SiD tracking, capability for lower density could be important insurance to leave necessary margin to accommodate significant machine background variations.

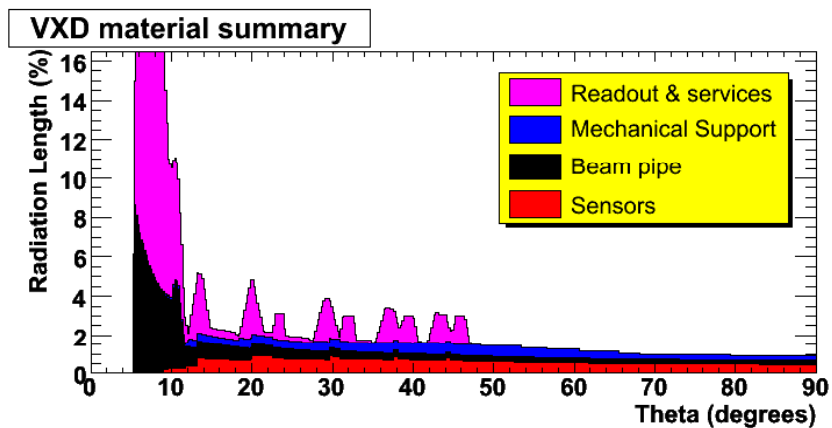
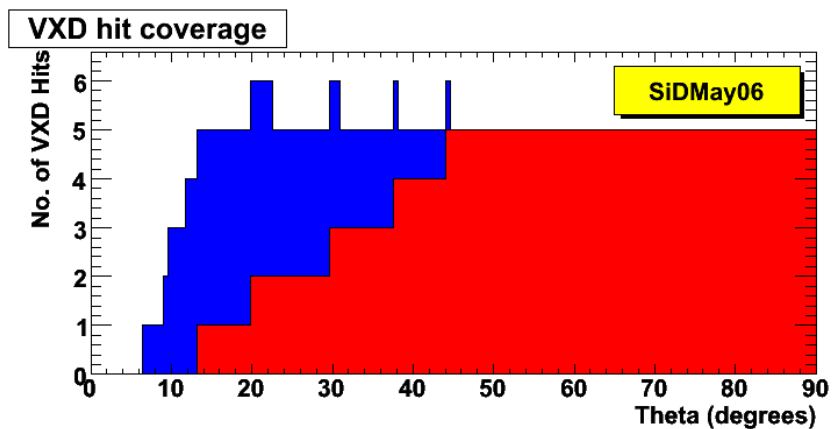
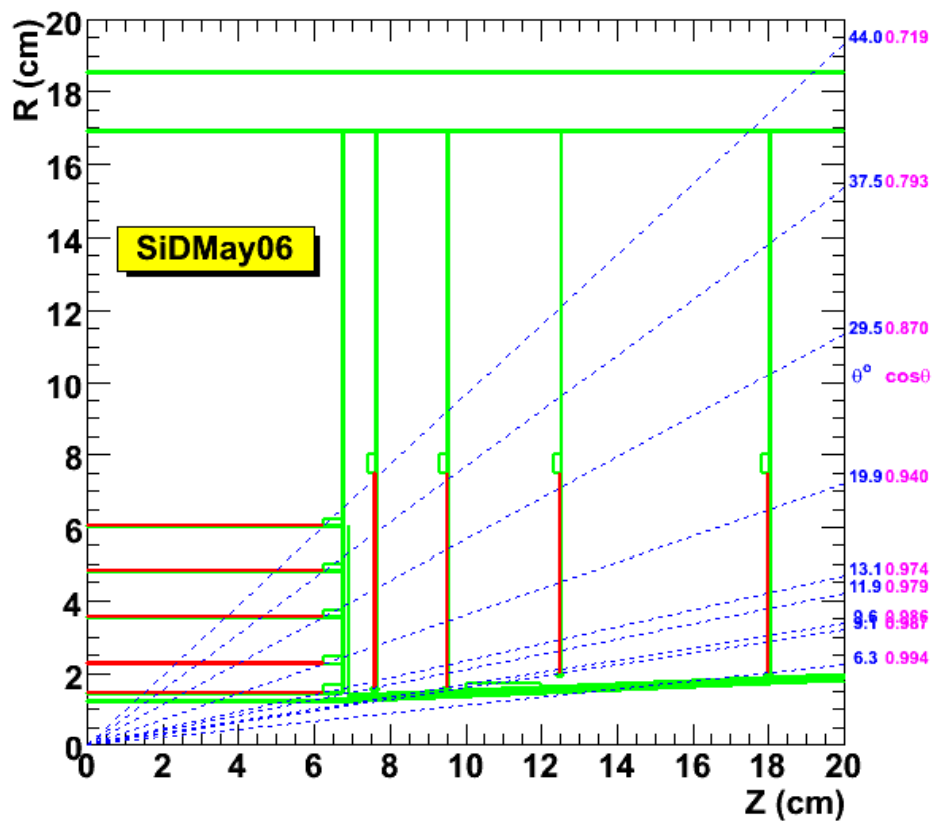
VXD Background Rate Variations



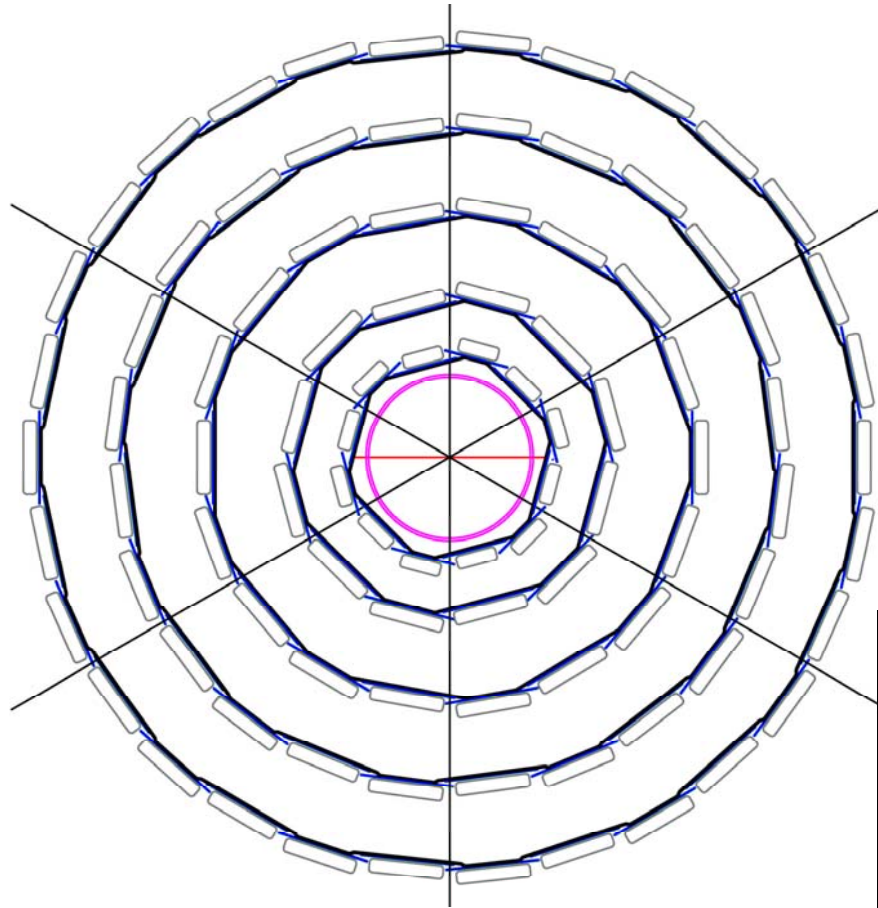
Layer 1's problem is in its own league (current Layer 2 is at slightly lower R of 2.2cm).

Need to be able to deal with 200 hits/mm²/train - reading 40 times/train to reduce down to 5 hits/mm²

SiD Geometry and Material



Barrel Geometry



Sensors:

IR_A = 14, 22, 35, 47.6, 60 mm

IR_B = 15.15, 23.13, 35.89, 48.41, 60.77 mm

Active widths: 9.1, 13.3 mm

Cut widths: 9.6, 13.8 mm

Beam pipe IR: 12 mm

Beam pipe OR: 12.4 mm

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Oblong boxes are openings in end rings and end membranes for cables, optical fibers, and air flow.

Layer 1 sensor has a narrower width

Layer 1 area is 9% of barrel total

Layer	Ladder	Area (cm ²)
1	12	144
2	12	207
3	18	311
4	24	414
5	30	518

SiD Geometry Implications

- No track at very shallow entrance angle. Full coverage of 5 VXD hits up to $|\cos\theta|\sim 0.98$.
 - Sensors has slightly thicker active region would not cause too much resolution degradation.
 - Less fear in barrel wafer shape issues when pushing for thin ladders with a shorter barrel.
 - Endcap sensors don't care much about Lorentz effect.
- Need to work harder on the barrel endplate service material.
 - *The R&D to achieve lightweight power delivery and signal communications are as important as the sensor technology and mechanical design !*

Service Material Model

Due to the lack of a real design, this is unfortunately a very crude toy model in GEANT:

- 1) Readout/service connection at each barrel layer end is represented by a solid ring of G10 5mm wide in Z and 3mm high in radius.
- 2) The power and signal cables are represented by a 300 μ m diameter copper wire and 250 μ m diameter fiber at each end of a ladder. The cables all focus down to the beampipe to exit from there to be out of fiducial volume, but this causes a significant clumping of material at lower radius which may not work mechanically.

The R&D which can lead to a real design that is not far off from the total material of this model will be a crucial step to validate the layout concept.

A Different View at the Sensor Requirements

So far no `ideal' technology performs best in all categories. In particular, attempts to reduce hit density via faster readout or time stamping seemed to be invariably associated with more power.

Have we dug a hole for ourselves by having the one size shoe fit all requirements ?

We have seen that the problems at inner and outer barrels and the endcap are different in some important aspects.

If we can tolerate the loss of elegance, is it so bad to consider the option of a mixed sensor technology ? Life may get significantly easier if the sensor only need to meet the requirement for a specific region of the detector.

Innermost Barrel

The first layer carries a huge weight in determining the ultimate impact parameter resolution and is in the most hostile environment of highest hit density. So one might desire:

- Small, thin pixels with low noise to gain the ultimate spatial resolution of $<3\mu\text{m}$ (or even 2?)
- Time stamping or other means of tagging bunch crossings to bring the effective hit density down to $\ll 5$ hits/ mm^2 .
- Yes it needs more power but we may afford that:
 - The end service section is falling out of fiducial so that a bit more service material may be OK.
 - Power lines still axial along beamline - no Lorentz force.
 - Layer 1 is only 9% of the total barrel area.
 - There is also a possibility of some liquid cooling around the beampipe region out of the fiducial.

Outer Barrels

- Many more sensors and services will suffer Lorentz force and in fiducial region. It is therefore highly preferable to be a low power technology.
- In exchange, do not have to work as hard for the readout hit density.
- With Layer 1 at very fine resolution, we need to revisit the spatial resolution requirement for outer layers. Larger pixels may not be OK ?
- Still cares about Lorentz angle.
- If service light enough, routing them radially outwards outside the endcap may not be paying too much penalty on material ? This will reduce clutter around beampipe and reduce multiple scattering problem at low angles.

Endcap

- The access to power is in less critical fiducial regions so that there are more sensor options to choose from.
- Tracks are more perpendicular so that thicker sensors may be OK.
- Don't care about Lorentz angle.
- Cooling delivery is also somewhat easier.

Summary

Once lowered the elegance requirement on a single technology, one suddenly has some interesting freedom to consider more options to better optimize for the different regions.

Question:

- Asynchronized readout of mixed technology may interfere ?
- Separate spatial resolution requirements for outer barrel ?
- ...

Hopefully a useful starting point for discussions.