

Vertex Detector and Tracker Mechanics and Materials

Bill Cooper (Fermilab)

Outline of Vertex Detector Work for DBD

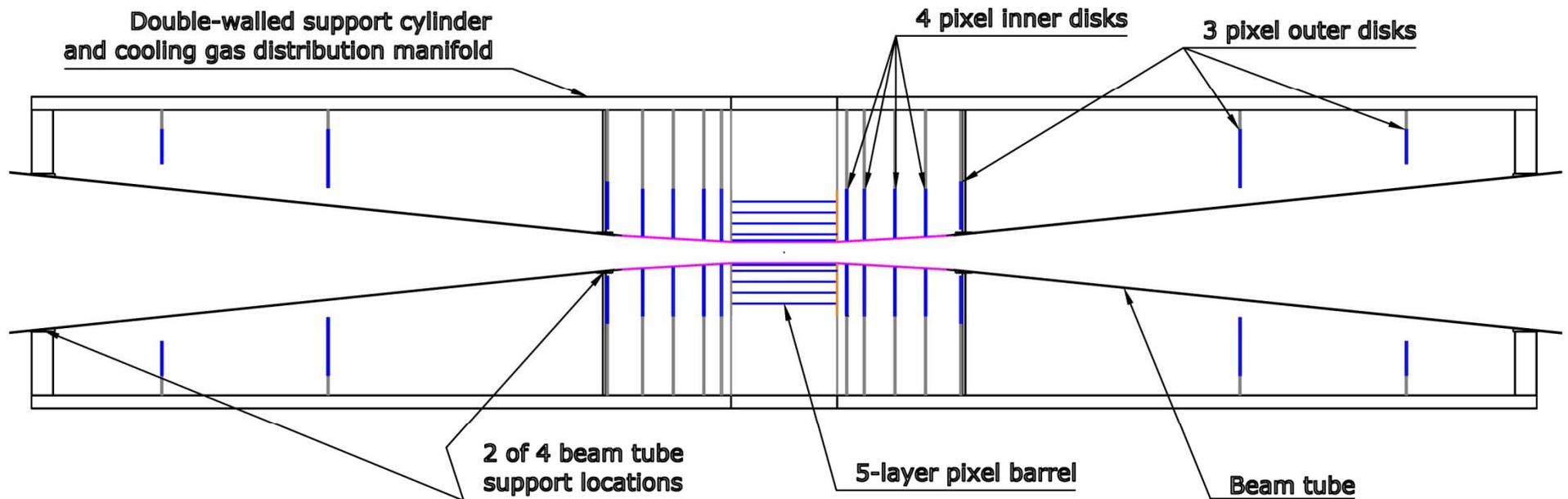
- Sensor R&D
- Power delivery and distribution R&D
 - Test LHC DC-DC converter: January 2010 – September 2010
 - Test serial power scheme: April 2010 – March 2011
 - Design pulsed power system: January 2011 – September 2011
 - Fabricate and test pulsed power system: June 2011 – September 2012
- Support R&D
 - Design, fabricate, and measure test support cylinder
 - October 2010 – March 2011
 - Design, fabricate, and measure module support test structures
 - June 2010 – December 2011
 - Thin ladder R&D
 - Fabricate and measure thin ladders
 - January 2010 – June 2012
 - Alignment monitoring system
 - Fabricate and test alignment monitoring system
 - March 2010 – September 2012

Outline of Tracker Mechanical Work for DBD

- Power delivery and distribution R&D
 - Design pulsed power system: January 2011 – August 2011
 - Determine locations of power conditioners: November 2010 – August 2011
 - Develop air flow paths for cooling the power conditioners: April 2011 – August 2011
 - Fabricate and test an R&D prototype with power sources and air flow: September 2011 – December 2011
- Mechanical Stability
 - Evaluate impact of power cycling: June 2010 – March 2011
 - Test vibrational stability of cylinders and test pulsed power system: April 2011 – August 2011
- Alignment with vertex detector
 - Continue development of FSI: January 2010 – December 2011

Vertex Detector

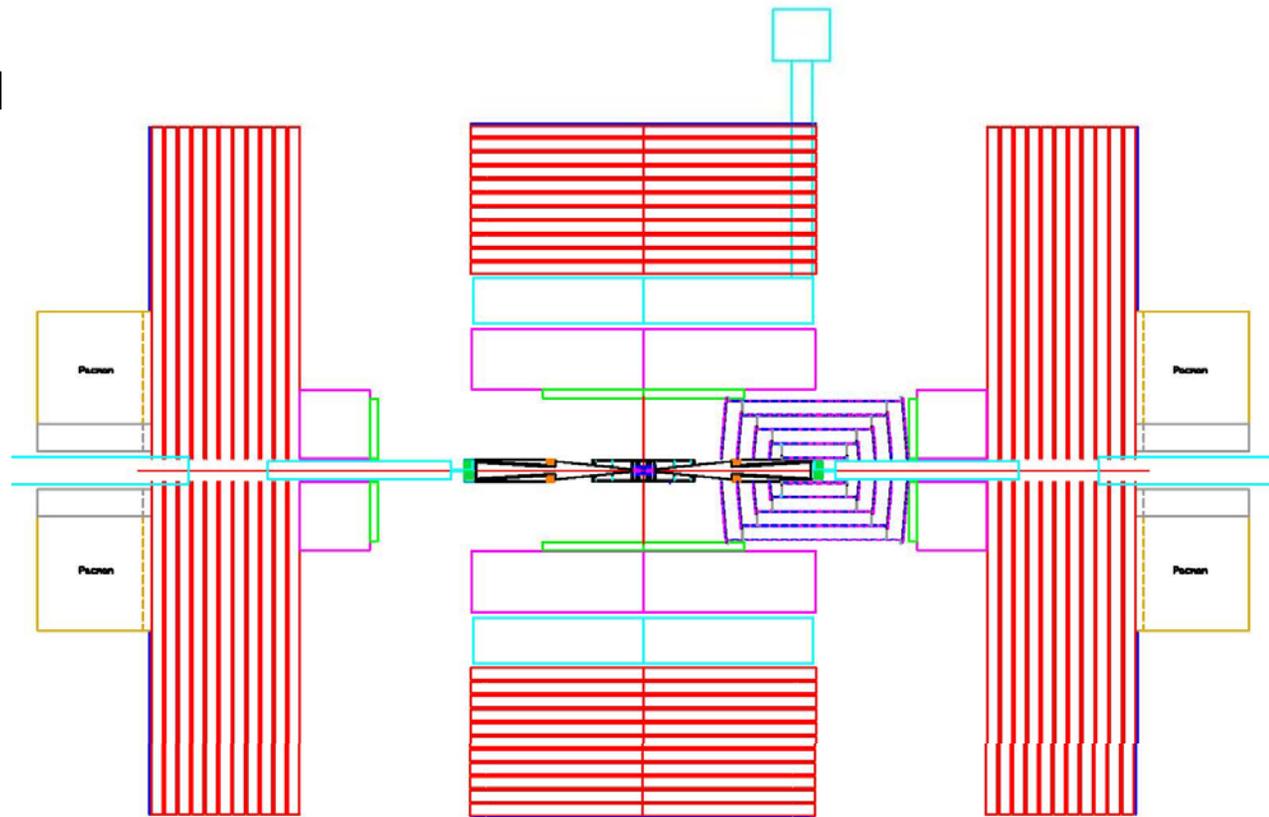
- The present arrangement of the vertex detector is shown below.



- The vertex detector is assumed to be made in top and bottom halves, which are clamped around the beam pipe.
- The vertex detector outer support cylinder maintains beam straightness of the beryllium portion of the beam pipe.

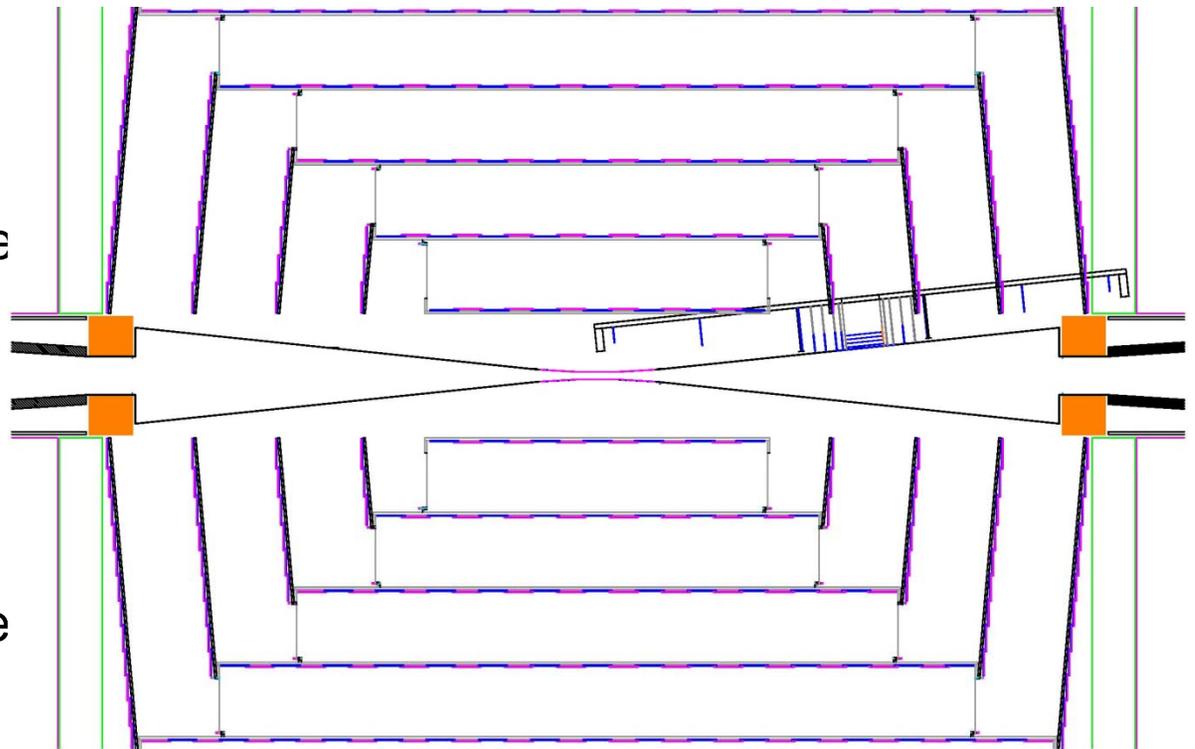
A reminder

- The figure from the LOI associated with vertex detector servicing is shown below.
- The detector would be opened, tracker cables would be removed from one end, and vertex detector cables from one or both ends.
- The vertex detector would then be fully accessible.



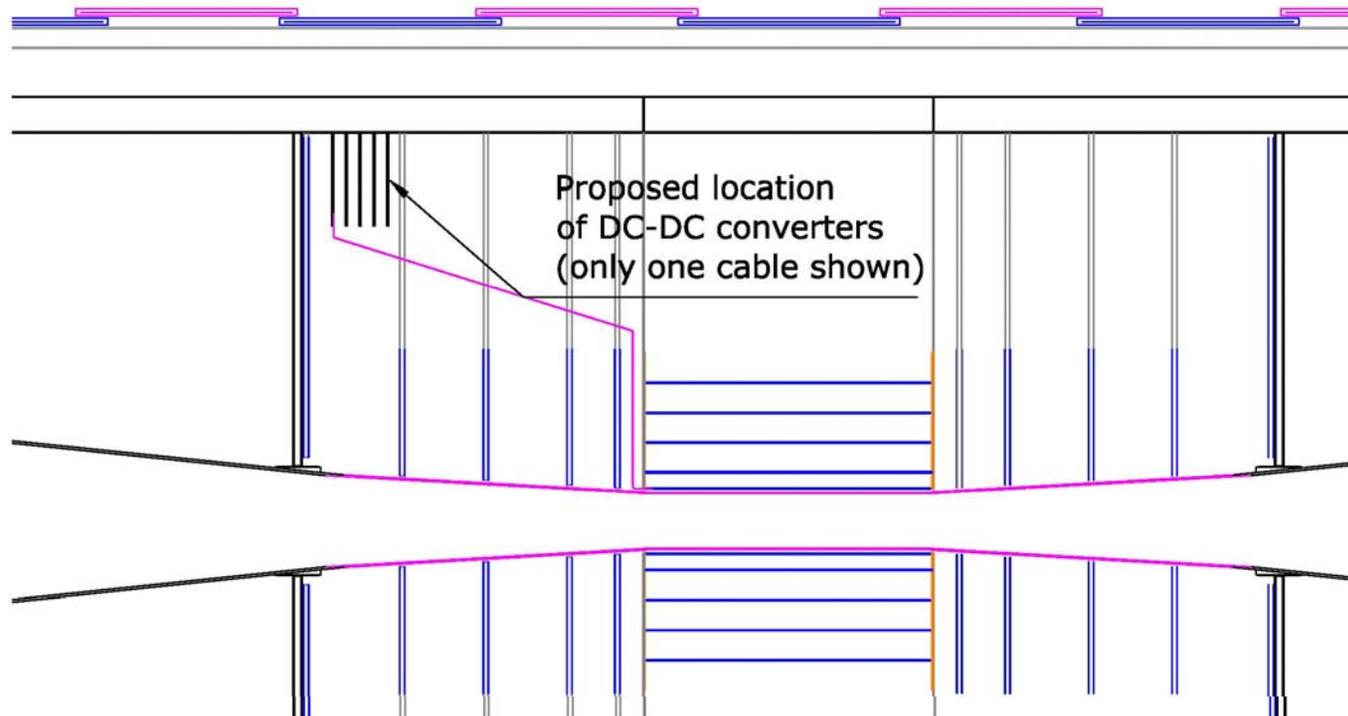
Vertex Detector

- Some time ago, I was asked if installation of the vertex detector could follow the method used by CMS rather than withdrawing the tracker to expose the vertex detector region.
- That doesn't work for SiD.
- It might be possible for CLIC, provided constraints on tracker and vertex detector geometry are taken into account.
- Risks are likely to be greater due to limitations in ability to observe and control the vertex detector / beam pipe interface.



Vertex Detector

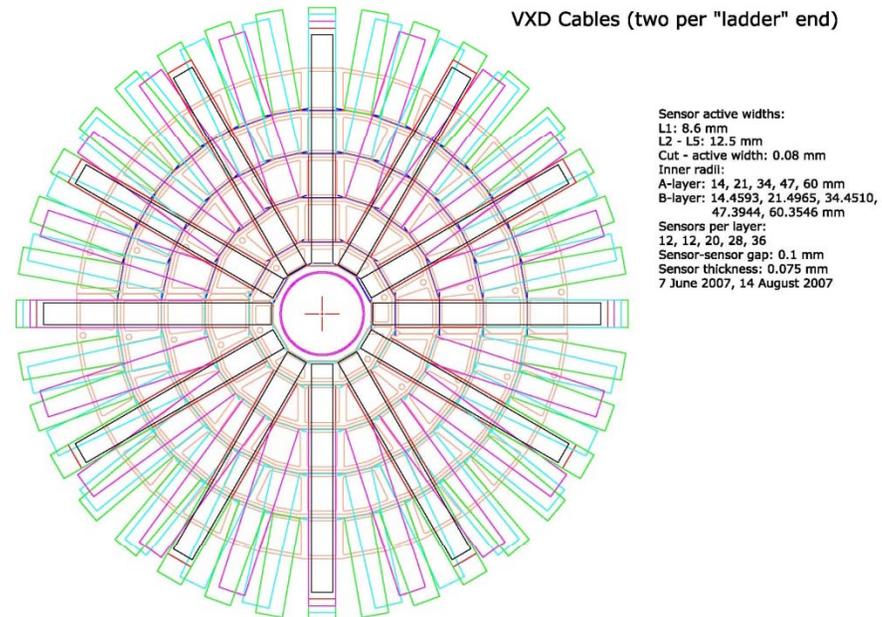
- Cables and power delivery will take substantial effort and testing.



- In the US, Satish Dhawan has made substantial progress on DC-DC conversion (~80% efficiency with commercial parts).
- Some degree of serial powering may also be necessary.

Vertex Detector

- Though cable layouts have been proposed, the cable requirements depend on the sensors.



- Once those requirements are known better, cables can be made and tried.
- Fiber optics are a clear alternative for signals, but cables appear to be necessary for power delivery.
- In principle, cable motion from pulsed power is calculable, but the predictions should be checked.

Vertex Detector “Ladders” and Support

- The development of low-mass structures has been stimulated by the development of specific sensor designs.
- That development will likely continue independent of the ILC and CLIC, but SiD and CLIC should remain sources of motivation.

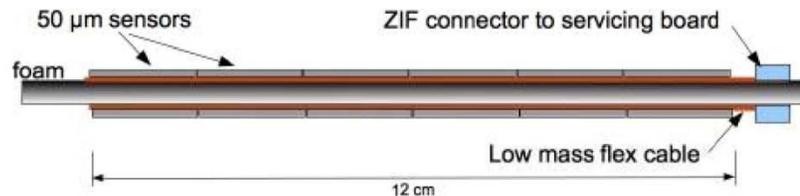
LCWA 2009,
Rita De Masi

Only a few examples are shown to suggest areas of effort.

My apologies for not including a wider variety of possible examples.

The PLUME project

- Pixel Ladder with Ultra-low Material Embedding.
- Double sided ladder equipped with 2x6 M26 (TDR 2012).
- 0.2-0.3 % X_0 .
- Explore feasibility, performances and added value of double-sided ladders.
- Allows for improved time resolution (outer layer with larger and fewer pixels).
- First prototype (reduced scale) to be tested in SPS beam next November.
- Full scale prototype expected in 2010.



LCWA 2009

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Vertex Detector “Ladders” and Support

- LCWA2009, Ryan Page



Low-Mass Vertex Detector Structures Using Silicon Carbide Foam

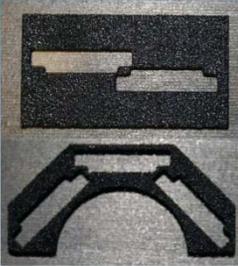
Ryan Page





Machining SiC foam

- Methods of machining analysed so far include: milling, laser cutting, dicing
- To look at the cut precision the measurement of waviness (wc) from a surface trace can be used
- The benefit being that there is a cutoff for high frequencies that allows the effects of the pores to be filtered out leaving only the effect on the SiC caused by the machining



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Building and Measuring Si-SiC Ladders

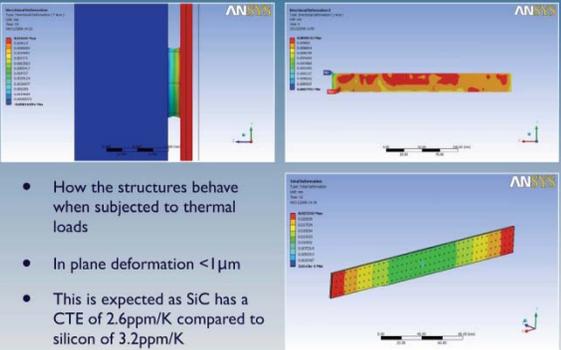


- High precision vacuum jigs hold Si Nusil is applied using a pre-programmed glue pattern then brought together using linear stage
- Survey Si surface with a laser micrometer flatness over whole modules of 100-200µm
- Flatness and straightness measured to within $\pm 5\mu\text{m}$
- The material budget for a single ladder of relative density of 6% at 1.2mm thick is $0.11\%X_0$ for a ladder of 3.2% and 1.3mm thick and using the same glue quantity and silicon is $0.079\%X_0$

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Thermal Stress Analysis



- How the structures behave when subjected to thermal loads
- In plane deformation $< 1\mu\text{m}$
- This is expected as SiC has a CTE of 2.6ppm/K compared to silicon of 3.2ppm/K

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Vertex Detector “Ladders” and Support

- Beijing2010, Nathalie Chon-Sen

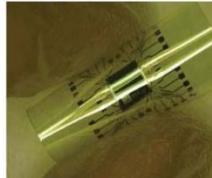
SERWIETE *SE*nsor *R*aw *W*rapped *I*n an *E*xtra-*T*hin *E*nvelope (HP2, EU-FP7)

Goals :

- to achieve a sensor assembly mounted on flex and wrapped in polymerised film with **<0.15 % X₀** for 1 **unsupported layer** (sensors – flex cable – film)
- to evaluate the possibility of mounting supportless ladder on cylindrical surface like beam pipe (used as mechanical support). Proof of principle expected in 2012

Working program :

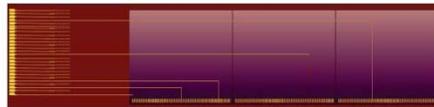
- prototype Nr. 1 (2010) made of 1 **analog** sensor : **MIMOSA-18** (analog output, ~4 ms @16MHz)
- prototype Nr. 2 (2011) made of 3 **digital** sensors : **MIMOSA-26** (binary output, ~100 μs @80MHz)



Fully functional microprocessor chip in flexible plastic envelope. Courtesy of Piet De Moor, IMEC company, Belgium



prototype Nr. 1 : April 2010



prototype Nr. 2 : summer 2011

Context of development :

- Collaboration with IK-Frankfurt and GSI/Darmstadt (CBM coll.) within **HP2 project** (WP26)
- Synergy with Vertex Detector R&D for CBM, ALICE (?) etc.

CHON-SEN Nathalie, 26th-31st March 2010

LCWS 2010 - Beijing

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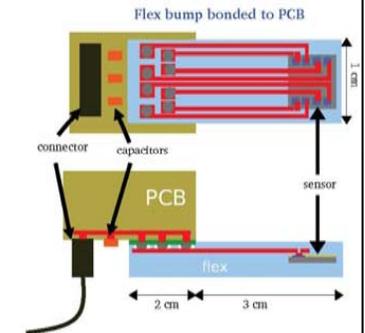
(current) IMEC technology for SERWIETE

Thickness budget :

- 6.5 μm backend (metal and oxide on chip) = **6.5 μm Si equivalent**
- 20-25 μm Si (14 μm epitaxial layer) = **20-25 μm Si equivalent**
- 2x 20 μm polyimide + Solder mask (25 μm) = **22 μm Si equivalent**

Sensor thinned down to 30 μm

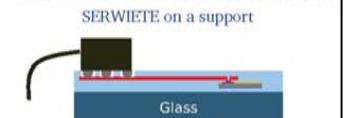
Total = 48.5 – 53.5 μm Si equivalent



Schedule :

January-February :
Tests on line width and spacing
Fabrication of the PCB acquisition board

April : First prototype of the device equipped with one MIMOSA-18 CMOS sensor



glass carrier (CBM, feasibility study) as a mechanical support and thermal conductor (vacuum operation)

CHON-SEN Nathalie, 26th-31st March 2010

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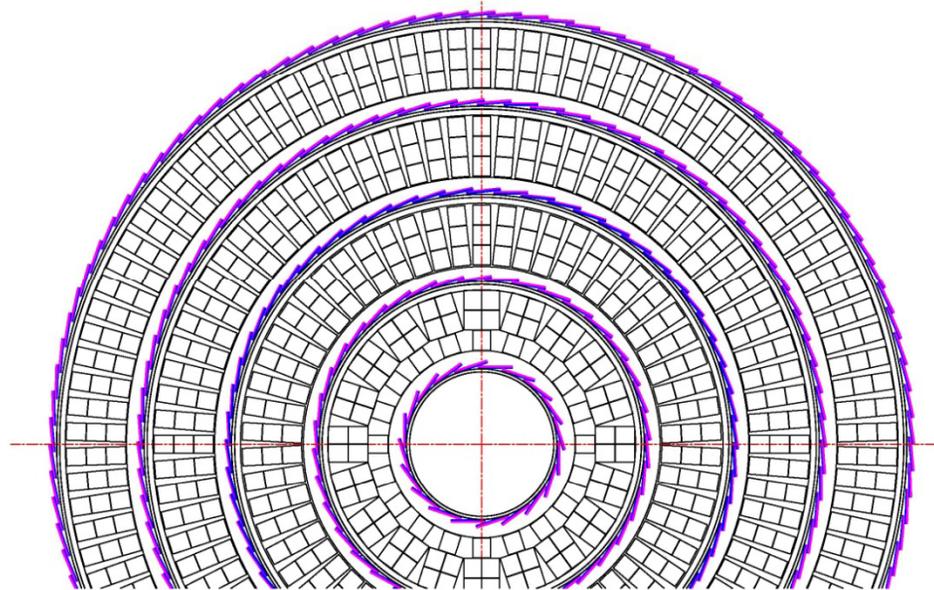
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Cooling

- Though not on the list of work proposed for the DBD, both the vertex detector and the outer tracker would benefit from studies to understand cooling gas delivery paths.
- For the vertex detector, some effort should go towards understanding how the gas is delivered at an appropriate, low temperature.
 - That could involve heat exchangers from “liquid” to gas near the ends of the silicon region or within the vertex detector support cylinder.
 - Augmented local cooling may allow a wider range of sensor varieties to be considered.
 - Evaporative CO₂ cooling may be appropriate to limit material.
 - That ties to R&D in progress for LHC upgrades and other experiments.

Tracker

- As in the vertex detector, power distribution will need attention.
- The present assumptions are that power conditioning boards would be on the rings which connect barrels to one another and cables would bring power to individual sensor modules.
- The layout below isn't optimized but gives an idea of the space available with 50 wide x 56 mm tall power conditioning cards.
- It assumes that conditioners for a barrels 2-5 are inboard of their respective barrels and conditioners for barrel 1 are outboard of barrel 1.
- Power conditioning for disks will also be needed.
- We should include an update on tracker modules and their mounting.

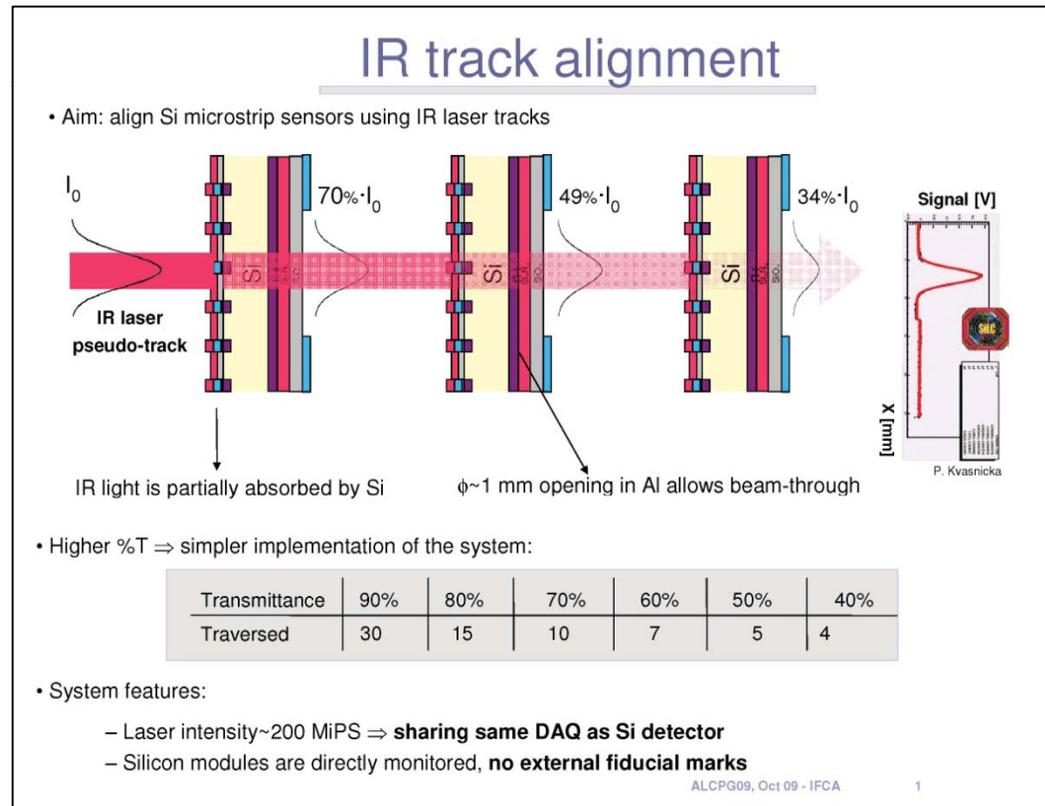


Vibration

- It is better to measure vibrations of cables and support structures due to power pulsing and other mechanisms rather than try to calculate them.
- A suitable magnet and support structures are needed.
- We had hoped to fabricate a vertex detector outer support cylinder and at least one tracker barrel support cylinder.
- Fabricating a vertex detector support cylinder seems realistic in the not too distant future.
 - Cylinder dimensions wouldn't be exactly those assumed in the design, but would approximate them well enough for stiffness and vibration studies.
 - Gas flow and distribution via the support cylinder could also be checked.
 - The vertex detector support cylinder would serve as a test of the support cylinders for the outer tracker barrels.

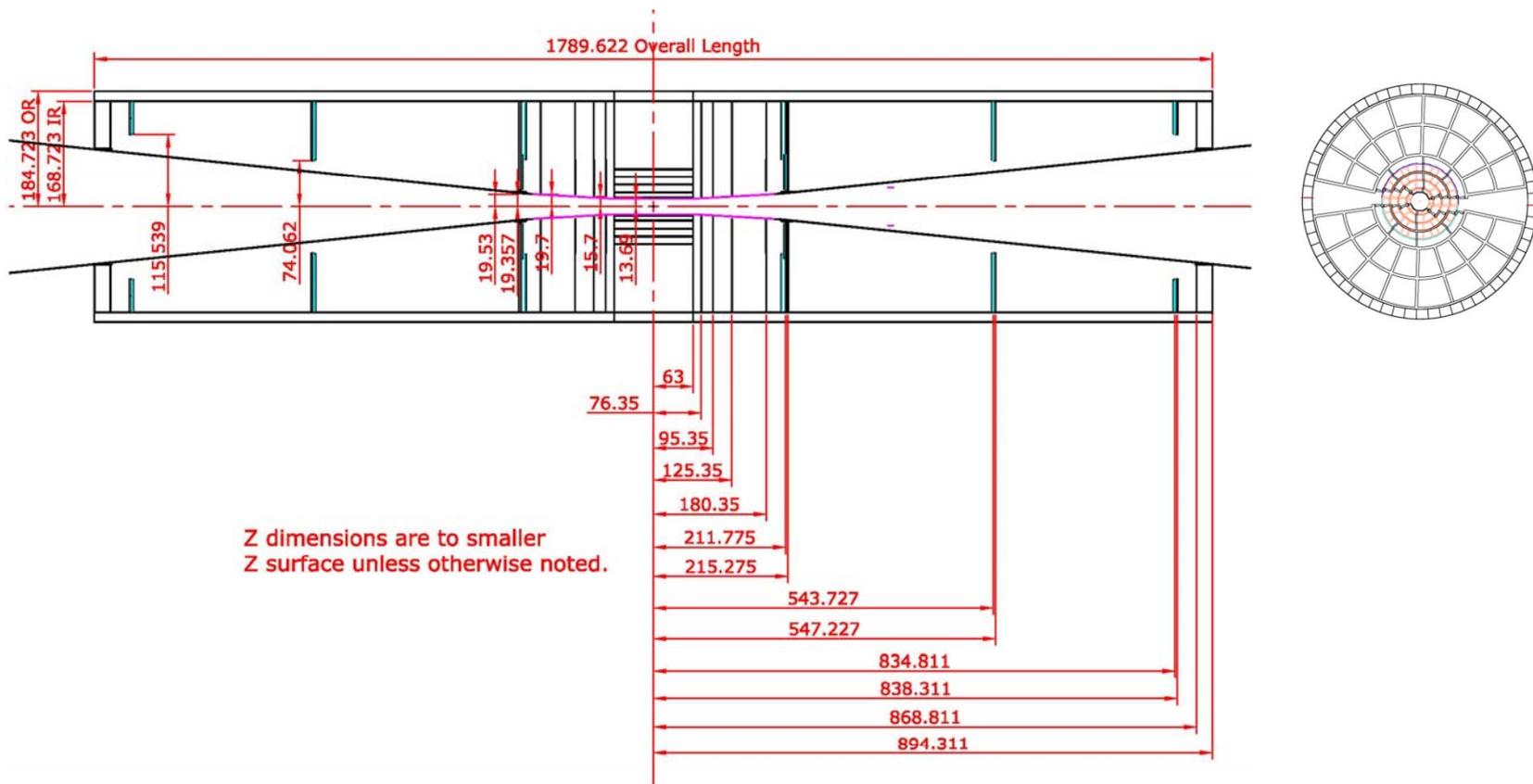
Measurement Methods

- We've been counting on FSI (as developed by Keith Riles, U. of Michigan) as a tool to measure vibrations and monitor alignment.
 - Renewed support for Keith's work would be important.
- Another approach to alignment monitoring has been under development by Alberto Ruiz Jimano and colleagues.
- It depends on shining a laser through overlapping sensor regions which are free of metallization.



Vertex Detector Support Cylinder

- Drawings have been ready since spring 2008.
 - Recently updated for current beam pipe geometry



Material Properties

- Measurements of carbon fiber electrical conductivity were begun early this year in conjunction with CMS tracker upgrade needs.
- Similarly, measurements of carbon fiber thermal conductivity are beginning.
- Both sets of properties are affected by the carbon fiber ply lay-up.
- In principle, measurements are available with a quasi-isotropic lay-up, though agreement of published results is not very good.
- We need results for high-modulus fiber (not so well studied by others) and for specific ply lay-ups which optimize the use of material.
- We should be careful about ground paths which extend from one detector end to the other.
- Such paths, plus a magnetic field, could lead to requirements regarding ground isolation of pulsed power sources at the two detector ends.
- Will an electrical break be needed at $Z=0$?

Resources

- Tight, at best

		2010		2011		2012	
		Need	Have	Need	Have	Need	Have
VTX	Staff	3	1.8	3	1.8	3	1.8
	Postdoc	2	0	2	0	2	0
	Engineering	0	0	0	0	0	0
	Student	0	0	0	0	0	0
	M&S (K\$)	410	225	380	200	330	200
Tracker	Staff	1.25	0.5	1.25	0.5	1.25	0.5
	Postdoc	0.5	0	0.5	0	0.5	0
	Engineering	0	0	0	0	0	0
	Student	0	0	0	0	0	0
	M&S (K\$)	50	0	50	0	50	0

- R&D on mechanics is sufficiently generic that resources may come from related efforts with common goals, for example, resources for measurements of material properties, cooling performance, alignment, and vibrations.