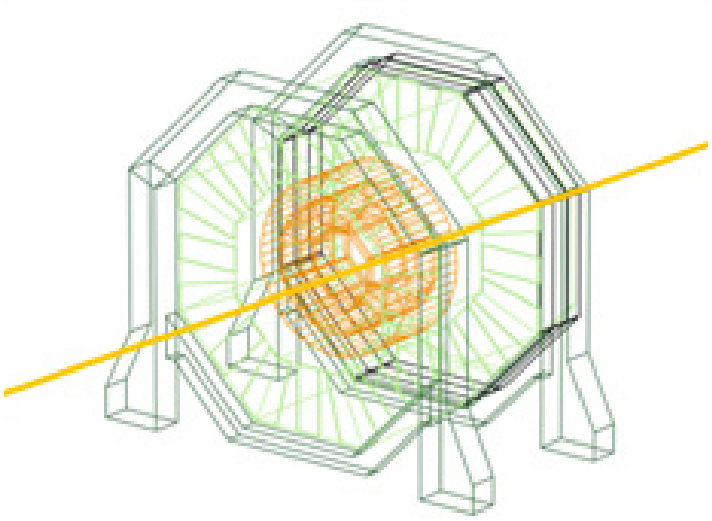
SiD Tracking and Vertexing

Towards the DBD



Marcel Demarteau

For the SiD Tracking and Vertexing Group

SiD Workshop
Eugene, Nov. 15-17, 2010

DBD Charge from RD

1. Demonstrate proof of principle on critical components
   - When there are options, demonstrate feasibility of at least one option
2. Define a feasible baseline design
   - Options may be considered.
3. Develop a realistic integrated mechanical design for the detector
   - Account for dead zones, support structures, cables, gaps, …
4. Develop a corresponding realistic simulation model of the baseline design, including the identified faults and limitations.
5. Develop a push-pull mechanism ✓ ANL workshop
6. Develop a realistic concept of integration with the accelerator including the IR design ✓ ANL workshop
7. Simulate and analyze updated benchmark reactions with the realistic detector model, including the effects of background
8. Simulate and study some reactions at 1 TeV
9. Develop an improved cost estimate

Resource Estimate at Argonne Workshop

- **Resource estimate that entered the overall SiD workplan**

		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

- **Top – Down approach. Didn't really work in my humble opinion**

- **Try Bottoms – Up approach**

Milestones and Timeline

- **This is the first time for the group to come together since the Argonne workshop. The group has had little interaction on the formation of a plan for the DBD (mea culpa).**

- **It does not seem correct to suggest timelines and milestones without a group discussion.**

- **Many open questions depend on the available resources and people's motivation and availability, which are characterized by large uncertainties.**

Resource Comparison

- **Rutherford workshop, March 2008**

J. Albert[3], F. Blanc[11], M. Breidenbach[9], W. Cooper[4], C. Damerell[8], C. Deaconu[9], M. Demarteau[4], J.F. Genat[6], N. Graf[9], J. Goldstein[8], S. Hillert[7], M. Hoeferkamp[12], J. Jaros[9], T. Johnson[9], R. Kutschke[4], K. Krempetz[4], R. Lipton[4], T. Markiewicz[9], T. Maruyama[9], J. McCormick[9], C. Meyer[10], C. Milstene[4], T. Nelson[9], A. Nomerotski[7], D. Onoprienko[5], R. Partridge[2], T. Rice[10], A. Savoy-Navarro[6], B. Schumm[10], S. Seidel[12], N. Sinev[13], K. Stefanov[8], D. Su[9], E. von Toerne[5], S. Wagner[11], H. Wenzel[4], S. Worm[8], H. Weerts[1]

- **Today**

M. Breidenbach[9], W. Cooper[4], C. Damerell[8], M. Demarteau[4], N. Graf[9], M. Hoeferkamp[12], J. Jaros[9], T. Johnson[9], K. Krempetz[4], R. Lipton[4], T. Markiewicz[9], T. Maruyama[9], J. McCormick[9], T. Nelson[9], R. Partridge[2], A. Savoy-Navarro[6], B. Schumm[10], S. Seidel[12], N. Sinev[13], D. Su[9], S. Wagner[11], H. Weerts[1]

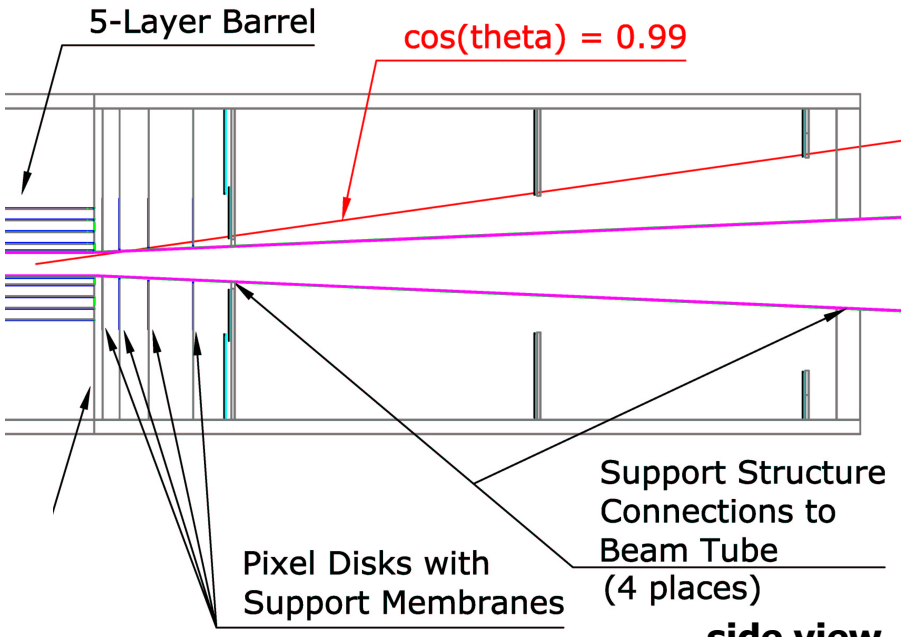
Plus CLIC efforts on simulation

Milestones and Timeline

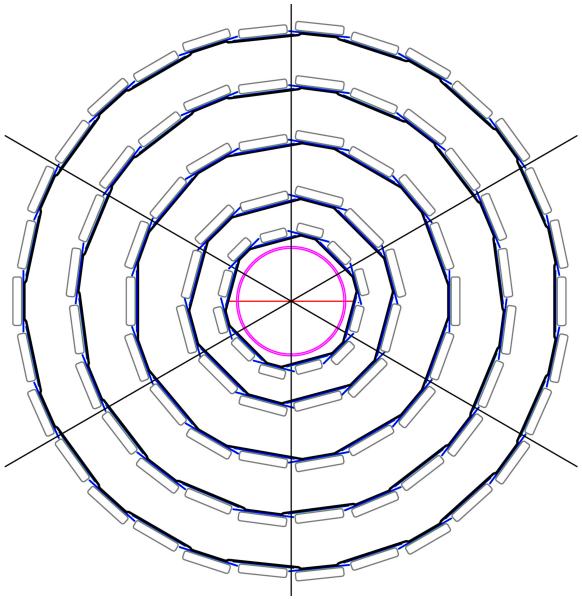
- **This is the first time for the group to come together since the Argonne workshop. The group has had little interaction on the formation of a plan for the DBD (mea culpa).**
- **It does not seem correct to suggest timelines and milestones without a group discussion.**
- **Many open questions depend on the available resources and people's motivation and availability, which are characterized by large uncertainties.**
- **The collaboration as a whole needs to be involved to identify priorities; not everything can be accomplished for the DBD**
- **Based on the discussions at this workshop – now – we will develop a timeline with milestones and submit those in the next month.**

Pixel Detector Mechanical Design

- **Baseline vertex detector assumes a central, 5-layer barrel, two 4-plane end disk assemblies and three additional disks per end for extended coverage**
- **All elements are supported indirectly from the beam tube via double-walled, carbon fiber laminate half-cylinder**
- **Barrel Region**
  - **Five layers**
  - **Longitidunal coverage: ± 62.5 mm**
  - **Radial coverage: 14 < R < 61 mm**
- **Forward regions**
  - **Four disks**
  - **z = ± 72, ± 92, ± 123, ± 172 mm**
  - **Radial coverage: R < 71 mm**



side view



end view

Mechanical Layout

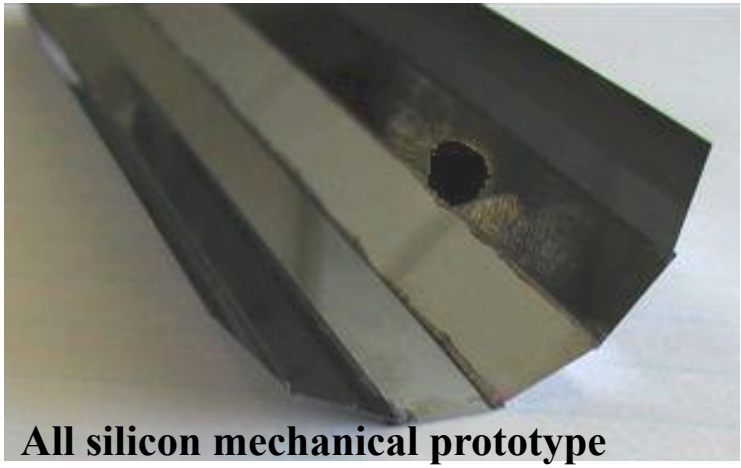
- All Silicon layout is the baseline choice: proposed to mitigate CTE issues
  - Uses only the silicon sensors in "cylindrical" portions of the structure
- Sensors glued to one another along edges by thin beads of epoxy and supported by thin, flat carbon fiber/epoxy end membranes

- 75 μm silicon thickness assumed
  - Could be modified for thicker or thinner sensors

- Parametric FEA model for all 5 layers of this detector (UW)

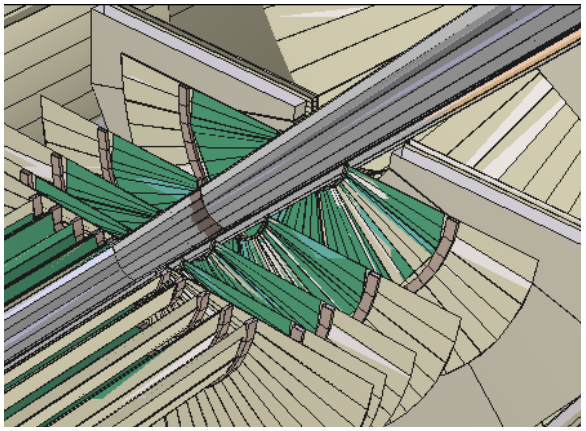
- *Monte Carlo assumes regular support structure*

- *Demonstrate mechanical robustness of an all-silicon vertex detector without intrinsic support?*

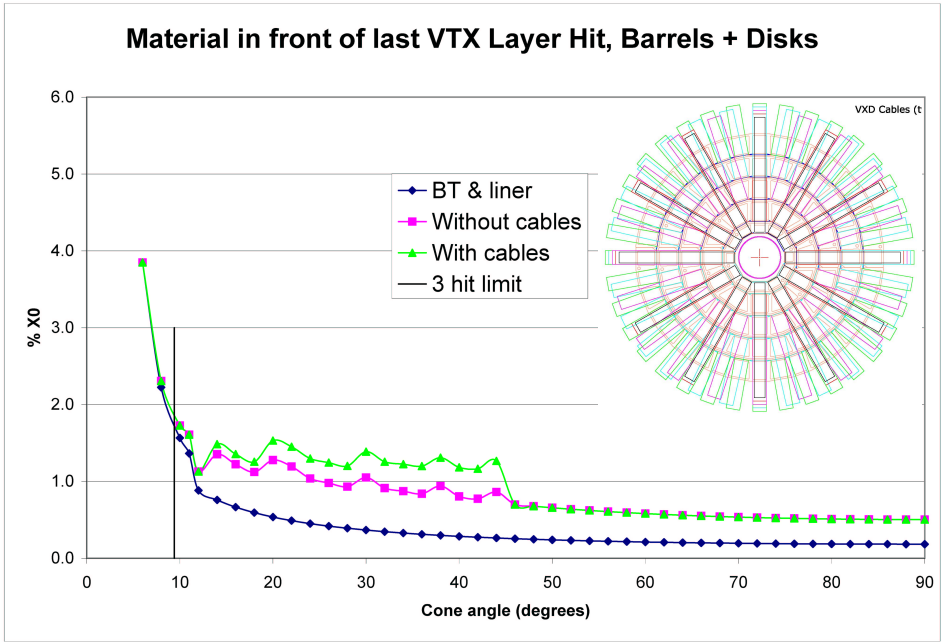

All silicon mechanical prototype

Mechanical Layout: Forward Region

- **Forward pixel detectors are notoriously difficult to build in low mass, low power configuration with very little additional mass due to cables**
- **Silicon disks with support and readout at the periphery is in the LOI**
  - **Silicon pixel disks have never been built to date as far as I know**

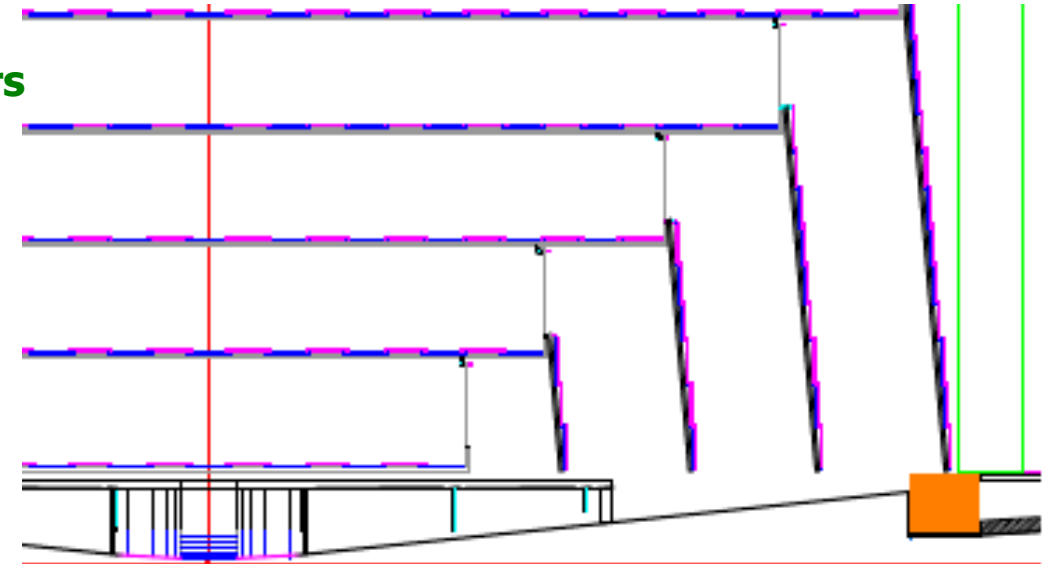


- ***Frankly, this area is not well studied.***
- ***There are many open issues***
  - ***Mass budget***
  - ***Sensor layout***
  - ***Power delivery, pulsing and Lorentz forces***



Tracker Design

- **Support**
  - Double-walled CF cylinders
  - Allows full azimuthal and longitudinal coverage
- **Barrels**
  - Five barrels, measure Phi only
  - 10 cm z segmentation
  - Barrel lengths increase with radius



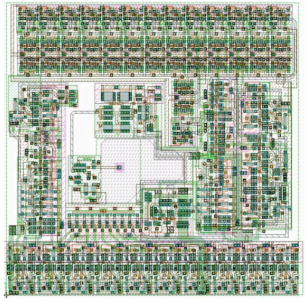
- **Disks**
  - Four double-disks per end, lampshade geometry
  - Measure R and Phi
  - Varying R segmentation
  - Disk radii increase with Z

- ***Tracker Design seems quite adequate***
- ***Demonstrate the mechanical stability of the lightweight carbon fiber support structures, especially under power pulsing (Lorentz forces) power pulsing to be addressed***

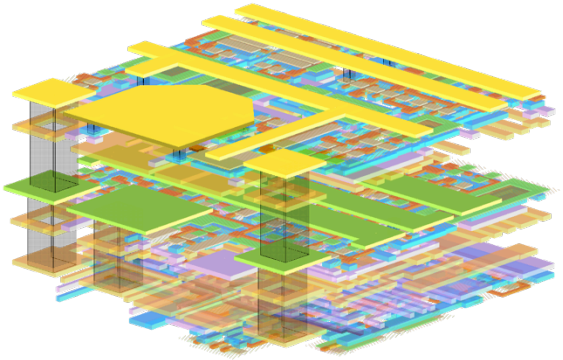
Vertex Sensor Technology

- **Given the scale of the vertex detector, it has been our position that we don't need to have a baseline design for the sensors at the time of the DBD.**

- **That said, sensor R&D on Chronopixel and 3D technology actively pursued within SiD**
  - **Chronopixel:**
    - Two more rounds of fabrication with deep p-well and high resistivity epi layer
    - Will be demonstrator and not achieve pixel size needed given the feature size available in process



  - **3D:**
    - First devices are imminent (end of the month)
    - If successful, demonstrator devices at the end of the year
    - In future years start building real prototype devices and test in beam tests



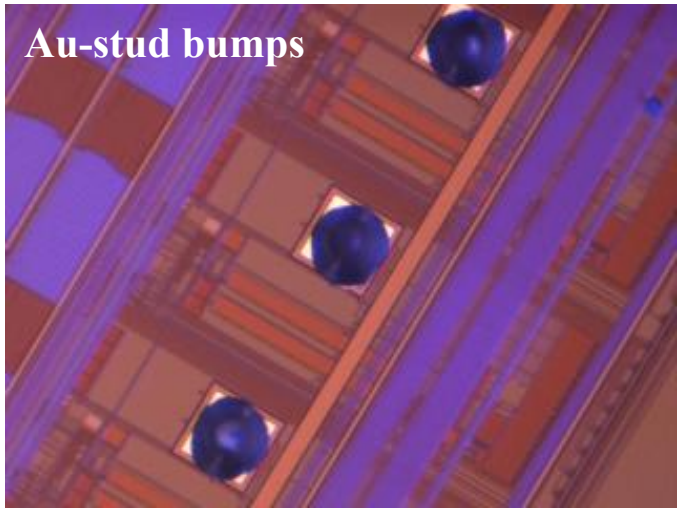
- **Many other technologies being pursued by other groups**

- **Self-sufficient efforts**

Tracking Sensor Technology

- Module is hybrid-less design with 3 components:
  - Silicon Sensor
  - kPix readout ASIC
  - Flexible readout cable
- All components in hand

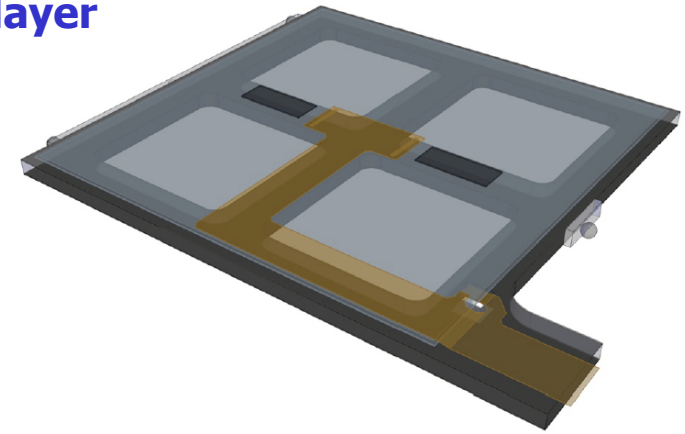
- Thought to be relative straightforward extension of existing technology
- However, wirebonding of the HPK single-sided Si strip detectors causes shorts to the double-metal layer
  - Bump bonding seems to be okay



- *Need to build a full readout chain and test it, preferentially in beam*
  - *Sensor*
  - *1024-channel kpix*
  - *Readout cable*
- *In high B-field?*

Tracking Module

- **Material budget goal for tracker is 0.8% X_0 per layer**
- **Module Frame**
  - **Minimal frame to hold silicon flat and provide precision mounts**
    - CF-Rohacell-Torlon frame w/ ceramic mounts
    - CF-Torlon clips glue to large-scale supports
  - **Ease of large scale production, assembly and installation/replacement**

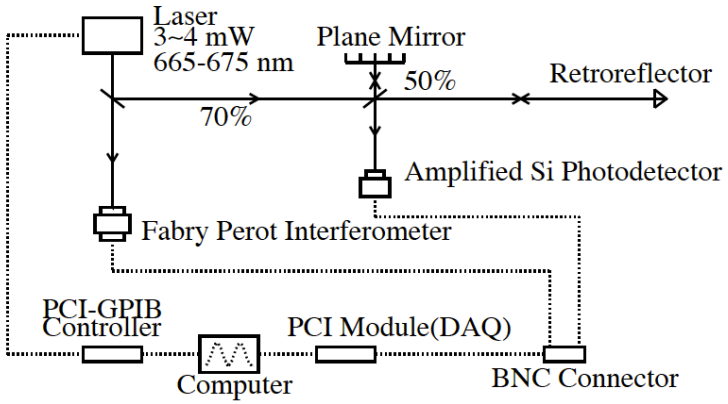


- **Module Chain**
  - **Connect N modules through common cable to optical drivers at the end of tracking volume**
- **Mechanical support structure**
  - **Have all issues related to gas cooling been laid to rest?**

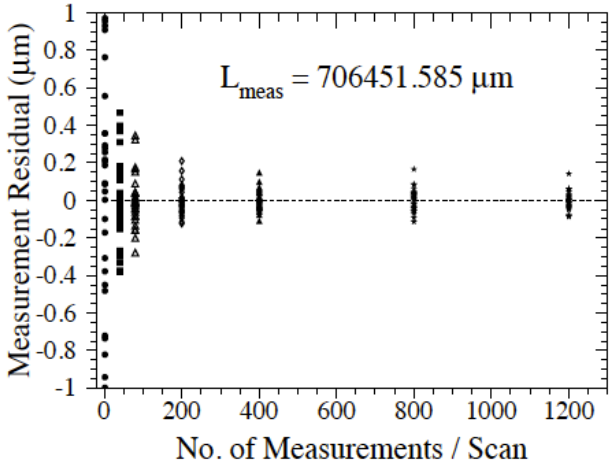
- ***Build a module and larger scale structure to show that material and power budget can be met for the tracker ?***

Push-Pull

- **Given the push-pull configuration of the detectors, establishing an alignment procedure and establishing the technology is important**
- **Baseline for SiD is the Frequency Scanned Interferometry (FSI)**
- **Project currently funded at 50% level of request for this fiscal year**

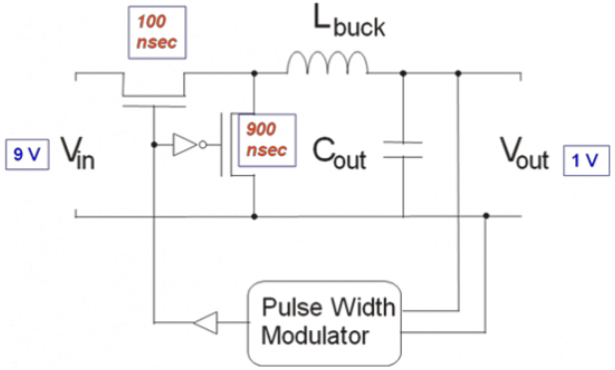


- ***Develop the alignment procedure and establish the technology***
  - ***Implement multiple channels/dual laser***
  - ***Demonstrate 3-dimensional reco of reference point***
  - ***Produce conceptual design***

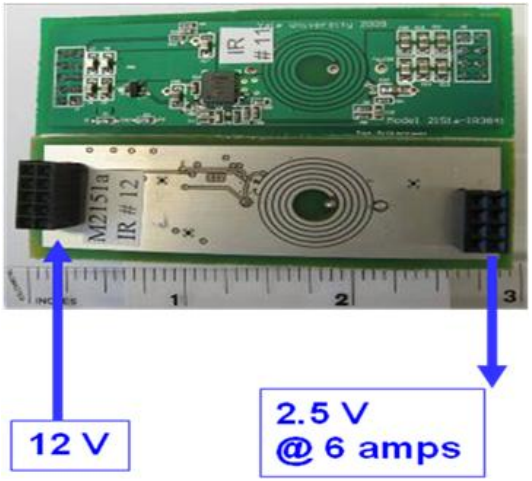


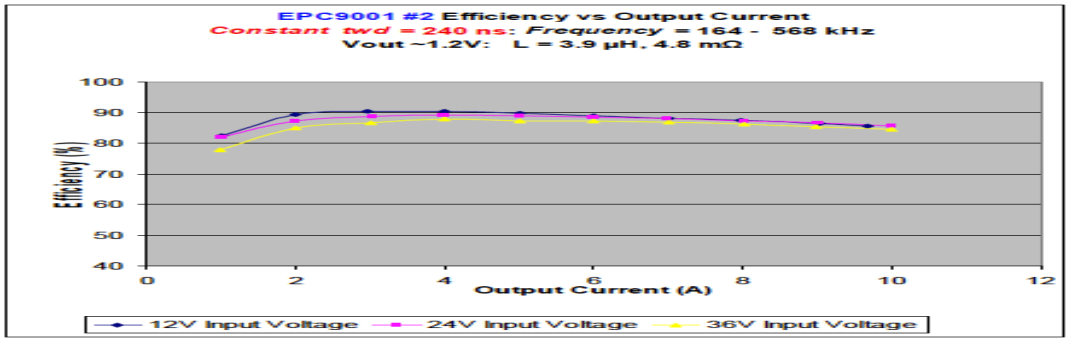
Power Delivery

- **Power delivery and consumption is an integral part of the inner detector system**
- **R&D on power, both power provision and power pulsing is rather limited, given it's importance**
- **Studies on commercial Si and GaN devices are promising for LHC and ILC**



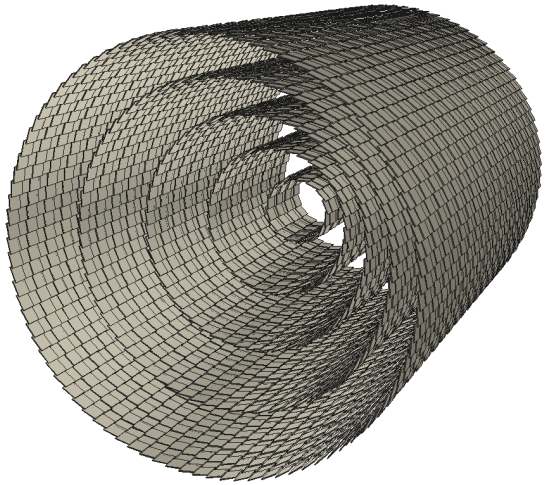
- ***Demonstrate the power pulsing for the vertex and tracking system with kPIX for the DBD, and obtain significant reduction in power consumption***
- ***Synergies with LHC is substantial***





Simulation

- Simulation studies for LOI were carried out with virtual segmentation
  - Barrel sensors have been approximated by thin cylinders, while the disk sensors have been approximated by planar disks perpendicular to bea
- Poly-hydra geometry definition now exists
  - Fully segmented detector with individual sensors, overlap and dead material



- *Need to implement in the simulations and analysis:*
  - *Improved modeling of tracker elements*
  - *More realistic hit digitization and clustering*
  - *Implementation of a Kalman filter track fitting algorithm*
  - *Further optimization of the detector layout*
  - *Additional studies of calorimeter assisted tracking*
  - *Studying impact of hit inefficiencies / dead channels, non-uniform magnetic field, beam backgrounds, etc.*

Tracking: Future Work

- Further optimization of the detector layout
  - Number and position of layers
  - Strip and pixel size and layout
  - All pixel tracker option
- Additional studies of calorimeter assisted tracking
  - Assist in kink finding and identification
  - Identification of long-lived resonance decays & γ conversions
- Systematic studies of the impact of:
  - hit inefficiencies / dead channels,
  - non-uniform magnetic field,
  - beam backgrounds,
  - …

Norman Graf's Talk Yesterday

DBD Charge

- **What really "critical" subsystem R&D should be demonstrated for the DBD?**

  Critical = of the utmost importance, cannot do without, indispensable

1. ***Demonstrate mechanical robustness of an all-silicon vertex detector without intrinsic support?***
2. ***Demonstrate the mechanical and electrical feasibility of forward pixel disks: mass budget, withstand Lorentz forces, sensor layout***
3. ***Demonstrate the mechanical stability of the lightweight carbon fiber support structures, especially under power pulsing (Lorentz forces) power pulsing to be addressed***
4. ***Demonstrate full readout chain of HPK double-metal sensor with kPIX and readout cable. In testbeam? In high B-field?***
5. ***Build a module and larger scale structure to show that material and power budget can be met for the tracker ?***
6. ***Develop the alignment conceptual design and establish the technology***
7. ***Demonstrate the power pulsing for the vertex and tracking system with kPIX for the DBD, and obtain significant reduction in power consumption***
8. ***Optimize the tracking software in the simulation and analysis:***