SiD

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On behalf of the SiD Concept Team:

http://silicondetector.org

Thanks to: Andy White, Norm Graf

Outline

- SiD overview
- Preparations for 2012 Detector Baseline Document
- Outline of SiD subsystems + R&D status:
  - VXD + tracker
  - ECAL
  - HCAL
  - muon system
  - forward systems

- Simulations, reconstruction and benchmarking

- Summary

SiD Design Philosophy

Compact, cost-contained detector designed for precision measurements:

5T solenoidal B field.

Robust silicon vertexing and tracking system

- **excellent momentum resolution**
- **live for individual bunch crossings**

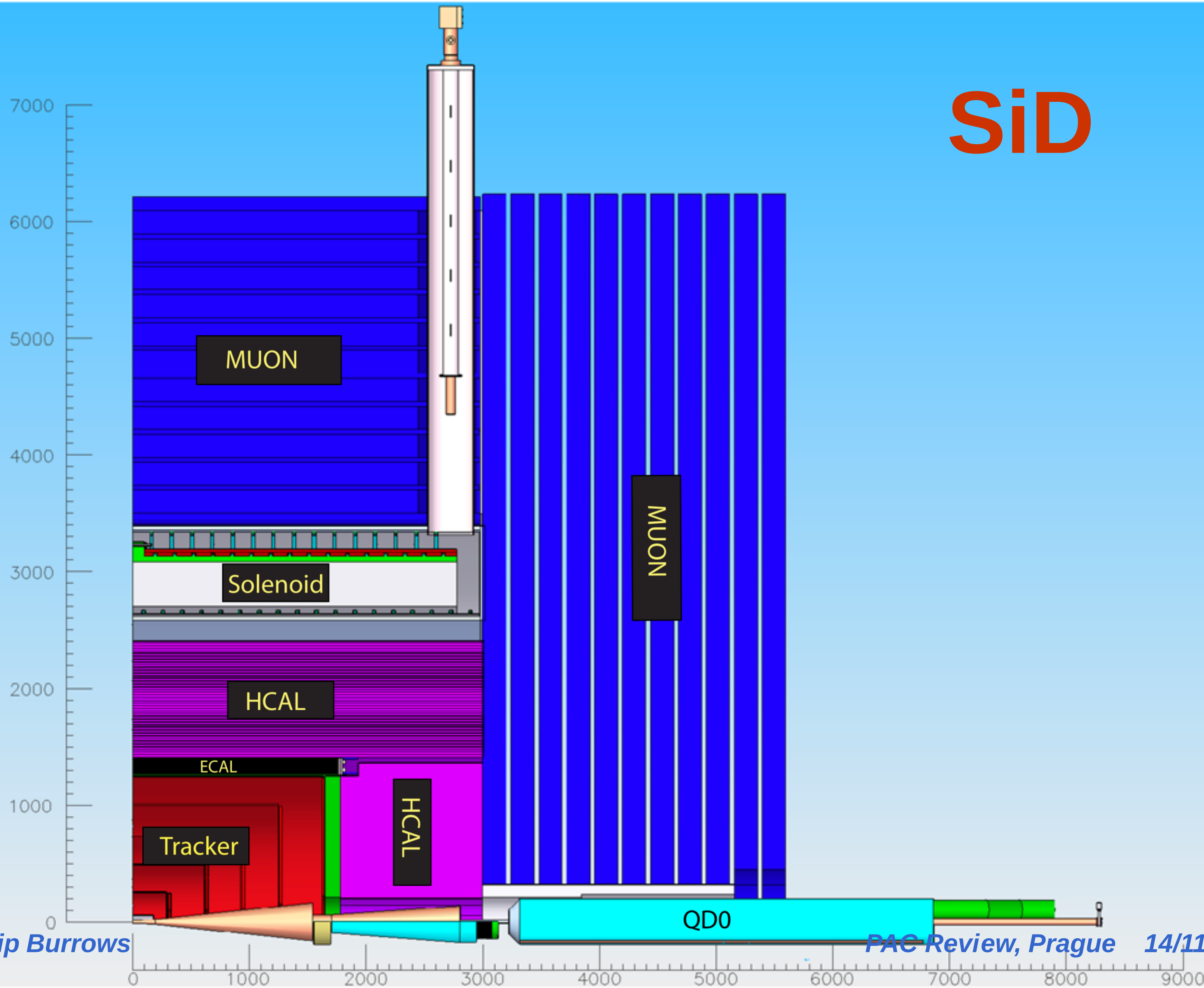
Calorimetry optimized for jet energy resolution

- **based on a Particle Flow approach, "tracking calorimeters"**
- **highly segmented (longitudinally and transversely) ECal and HCal**

Iron flux return/muon identifier – provides self-shielding

Detector designed for rapid push-pull operations

SiD


MUON
MUON
Solenoid
HCAL
ECAL
HCAL
Tracker
QD0
7000
6000
5000
4000
3000
2000
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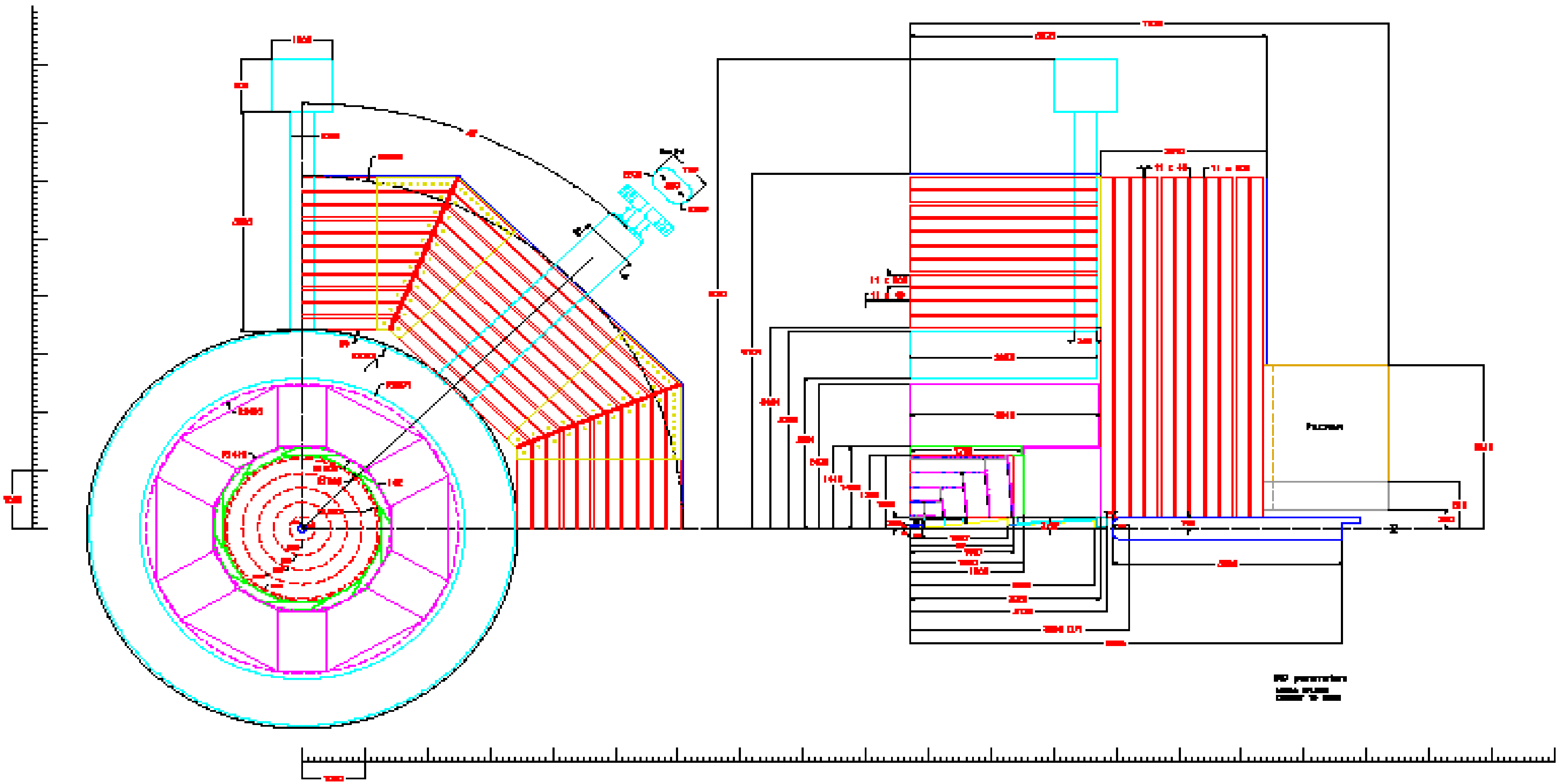
0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000

SiD Global Parameters



SiD Global Parameters

Detector	Technology	Radius (m)		Axial (z) (m)	
		Min	*Max*	*Min*	*Max*
Vertex Detector	Pixels	0.014	0.06		0.18
Central Tracking	Strips	0.206	1.25		1.607
Endcap Tracker	Strips	0.207	0.492	0.85	1.637
Barrel Ecal	Silicon-W	1.265	1.409		1.765
Endcap Ecal	Silicon-W	0.206	1.25	1.657	1.8
Barrel Hcal	RPCs	1.419	2.493		3.018
Endcap Hcal	RPCs	0.206	1.404	1.806	3.028
Coil	5 tesla	2.591	3.392		3.028
Barrel Iron	RPCs	3.442	6.082		3.033
Endcap Iron	RPCs	0.206	6.082	3.033	5.673

SiD Organisation

SiD DESIGN STUDY COORDINATORS
J. Jaros, H. Weerts, A. White

EXECUTIVE COMMITTEE
H. Aihara, J. Brau, M. Breidenbach, P. Burrows, M. Demarteau,
J. Jaros, J. Karyotakis, H. Weerts, A. White

ADVISORY COMMITTEE
All names on this chart

DBD EDITORS
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J. Brau, M. Demarteau, co-PIs

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Su Dong
R. Lipton
Mech: W. Cooper

SILICON TRACKER
M. Demarteau
R. Partridge
Mech: W. Cooper

CALORIMETERS
A. White
ECal: R. Frey/M. Stanitzki
HCal: A. White/H. Weerts
PFA: N. Graf/S. Magill

SOLENOID FLUX RETURN
K. Krempetz
W. Craddock

MUON
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E. Fisk

VERY FORWARD
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BENCHMARKING
T. Barklow
A. Nomerotski

SIMULATION
N. Graf

COST
M. Breidenbach

MDI
P. Burrows
T. Markiewicz
M. Oriunno

ELECTRONICS
G. Haller

ENGINEERING
K. Krempetz
M. Oriunno

Plans 2011/12

- **Focussed on Detailed Baseline Design (DBD)**
- **Continuing detector sub-systems R&D**

  specific to SiD

  in partnership with pan-detector groups
- **Collaborating with CLIC physics and detector groups, including MDI group**

SiD DBD scope

- **Proof of principle for critical components**
- **Feasible baseline design**
- **Integrated mechanical design**
- **Push-pull mechanism and MDI integration**
- **Realistic simulation model of detector**
- **Updated study of benchmark reactions (w. bkgds)**
- **Study of agreed benchmark reactions for 1 TeV**
- **Improved cost estimate**

DBD scope

Resources do not allow:

- **full engineering designs of all detector sub-systems**
- **production and testing of full detector prototypes**

But certainly we can:

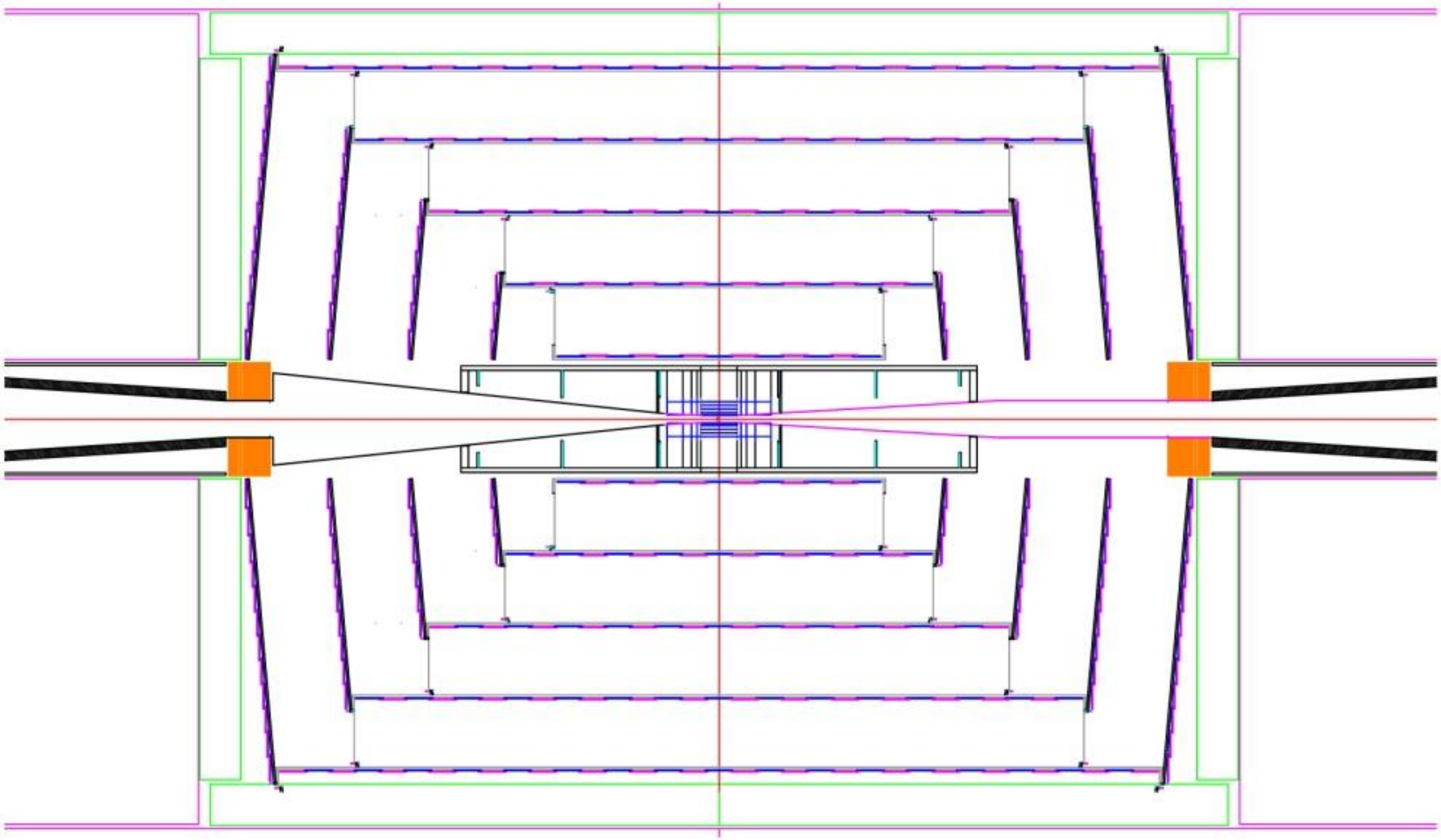
- **produce a conceptually engineered design for whole detector and its key sub-systems**
- **establish technical feasibility for key detector sub-systems**

DBD structure

1. SiD concept overview
2. Vertex detector (Cooper, Lipton)
3. Tracker (Cooper, Demarteau, Nelson)
4. Calorimetry (Frey, Stanitzki, White, Xia)
5. Muon system (Fisk, Band)
6. Forward systems (Maruyama, Schumm)
7. Magnet (Craddock, Oriunno)
8. MDI systems (Burrows, Markiewicz)
9. Simulations/reconstruction (Graf, Strube)
10. Benchmarking (Barklow, Roloff)
11. Costs (Breidenbach, Krempetz)

SiD subsystem R&D / status

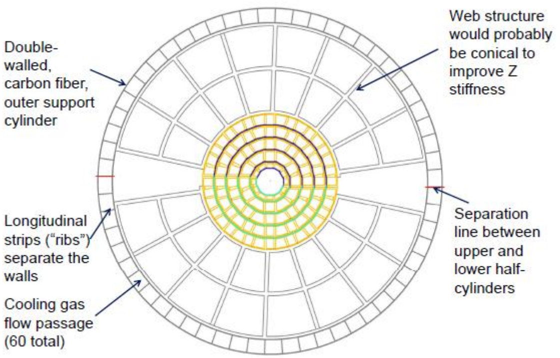
SiD Tracking System

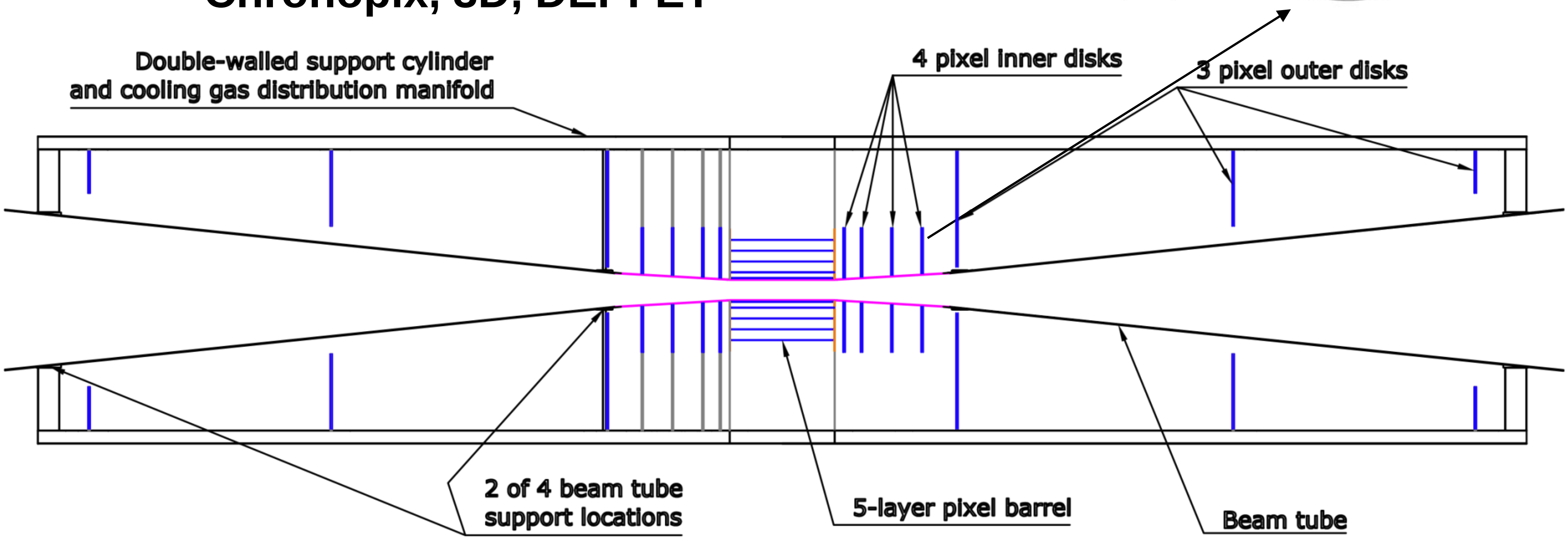


Vertex Detector

- Sensors arranged to form barrel cylinders
- Gas cooled, power pulsed, low mass
- Sensor technologies:

  Chronopix, 3D, DEPFET





Rin=14mm
Rout=60mm

VXD options

Baseline: **Silicon pixels, all-silicon barrel, carbon fiber end rings & support cylinder**

Option 1: **Silicon on foam sensor supports**

Option 2: **Silicon on carbon fiber sensor supports**

Option 3: **Silicon micro-strip outer disks (vs. pixels)**

Critical R&D topics + goals

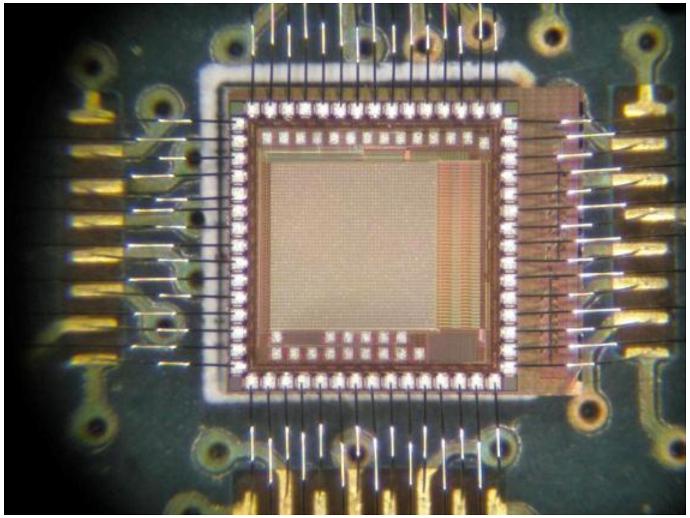
Sensor technology R&D: Incorporate latest developments

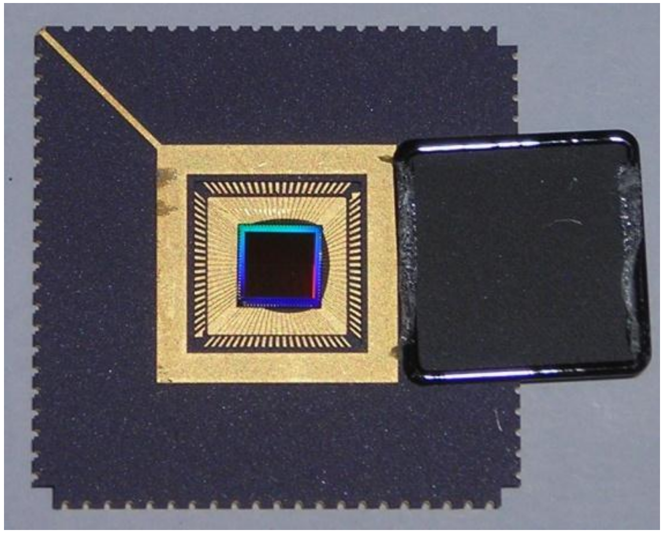
Low-mass structures: Demonstrate all-silicon, silicon on carbon fiber, & silicon on foam structures

Power delivery: Develop DC-DC conversion & serial power

Cooling/cabling/vibrations: Fabricate & test R&D structures for vibrations due to air cooling & pulsed power

Sensor R&D results





VIP 2a – 3 tier MIT-LL

Analog and digital sections work well:

8e + 0.5 e/ fF.

VIP2b (2-Tier Tezzaron/Global foundries) is in process.
Sensors for 3D integration of VIP2b produced and tested.

Chronopixel
Measured noise 24e, spec. 25e
Sensitivity 35.7μV/e, exceeding design spec of 10μV/e.
Comparator accuracy 3 times worse then spec, need to improve this in prototype 2.
Readout time satisfactory
Prototype 2 late 2011, 65nm TSMC

Critical R&D topics status

Sensor technology R&D:

On-going Chronopixel, 3D prototypes produced

Low-mass structures:

Silicon structures of each type have been made; R&D is paused on all structures except silicon on foam, which is progressing well

Power delivery:

R&D is expected to resume at the start of FY2012

Cooling/cabling/vibrations:

R&D awaits power delivery results

Expect to include in DBD

Conceptual VXD + beam pipe design

- **PLUME low mass ladder results**
- **3D sensor integration with readout (VIP2b chip), Chronopixel tests v2.**
- **CMOS MAPS + DepFET experience in STAR, BELLE**
- **Benefit from other work: e.g. CMS Track Trigger Upgrade**

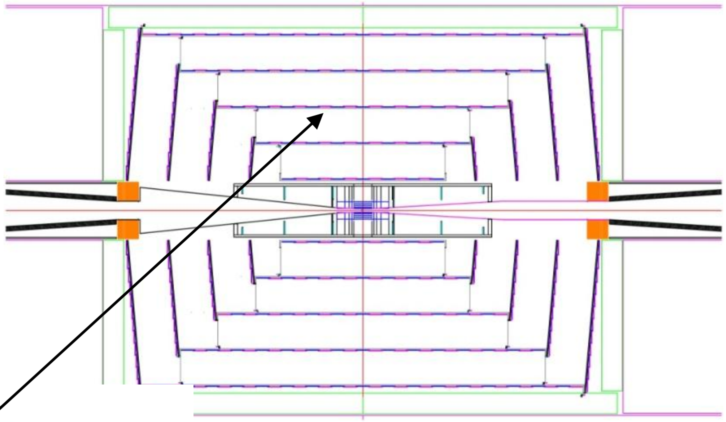
Issues for DBD + beyond

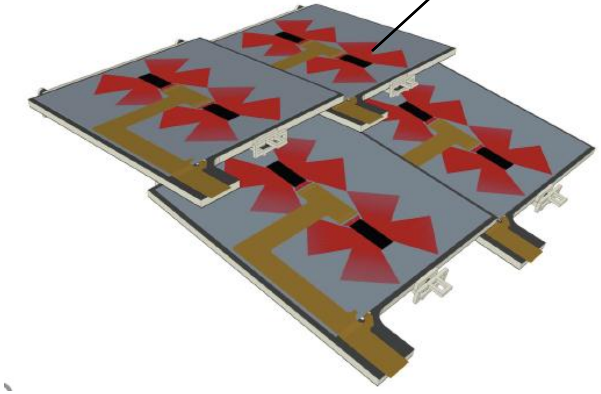
No funding to proceed on support structure R&D: expertise, mandrels, … available

- **Limited ability to consider system aspects of designs**
- **No ability to demonstrate low mass ladder/sensor concepts beyond PLUME work**

SiD Outer Tracker – Silicon strips

5 barrel (axial strip) + 4 disk (stereo strip)
→ 10 precision hits per track (incl. VXD)





Tiling of tracking layer with Si sensors and on-board KPiX chips

Tracker R&D programme (1)

First priority R&D:

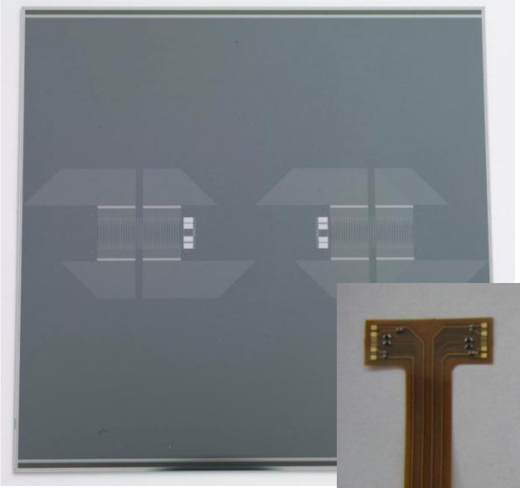
- **Development of KPIX chips + associated sensors**
- **Studies of signal to noise and crosstalk**
- **Development of sensors, modules and overall support structures for the barrels and disks**
- **Studies of pulsed power, power delivery, and associated vibrations**
- **Studies of heat removal, esp. from the disks**
- **Studies of alignment precision and monitoring**

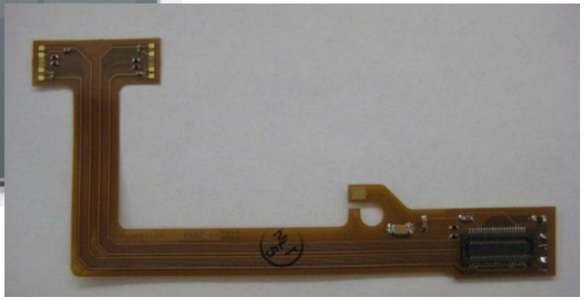
Tracker R&D programme (2)

Second priority R&D:

- **Studies of alternative sensors and readout to provide z information**
- **Development of cabling**
- **Development of module fabrication techniques**

Tracker status





Module

- **All components in hand**
  - **1024 channel KPiX chip**
  - **Sensor**
  - **Cable**
- **Difficulties bump bonding of KPiX to sensors; contacted IZM to address issues**

Software

- **Optimized tracking algorithms for CLIC_SiD studies at 3TeV**
  - **Silicon tracking performs very well under severe conditions: Z' → qqbar @ 3 TeV**

Tracker timeline

Modules:

- **Complete full Si module: bonding KPiX, cable and readout**
- **Bench test (noise, crosstalk, …) and, if time permits, beam tests at SLAC (available March 1, 2012)**

Alignment:

- **Resume FSI (U. Michigan/K. Riles) 2012**

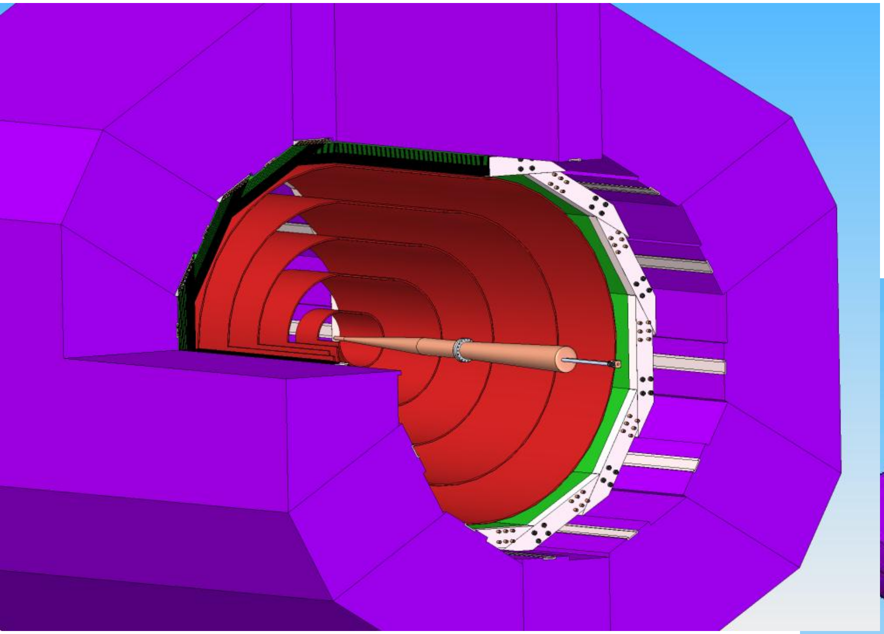
Reconstruction:

- **Study tracking algorithms and optimize the layout and segmentation if effort available**

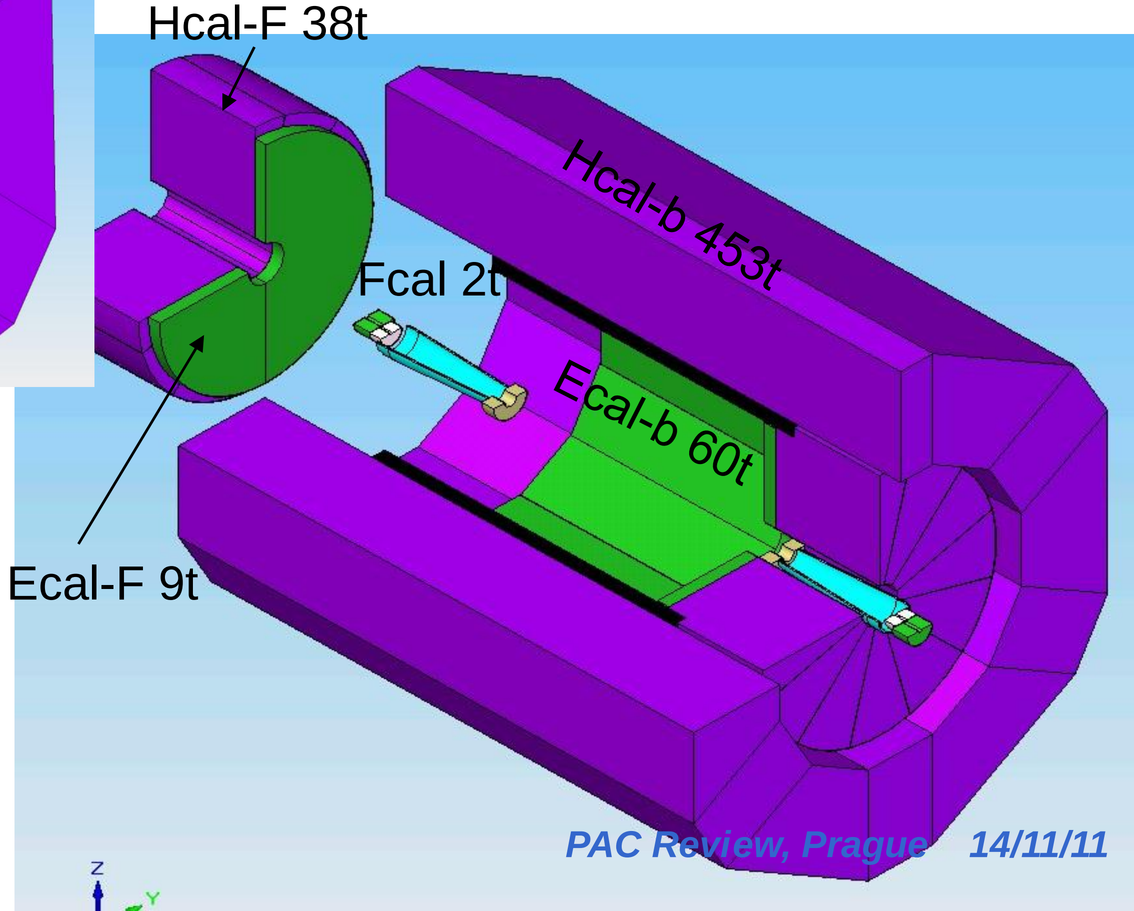
Concerns:

- **Personnel to construct/test Si module, pulse powering and associated vibration tests**

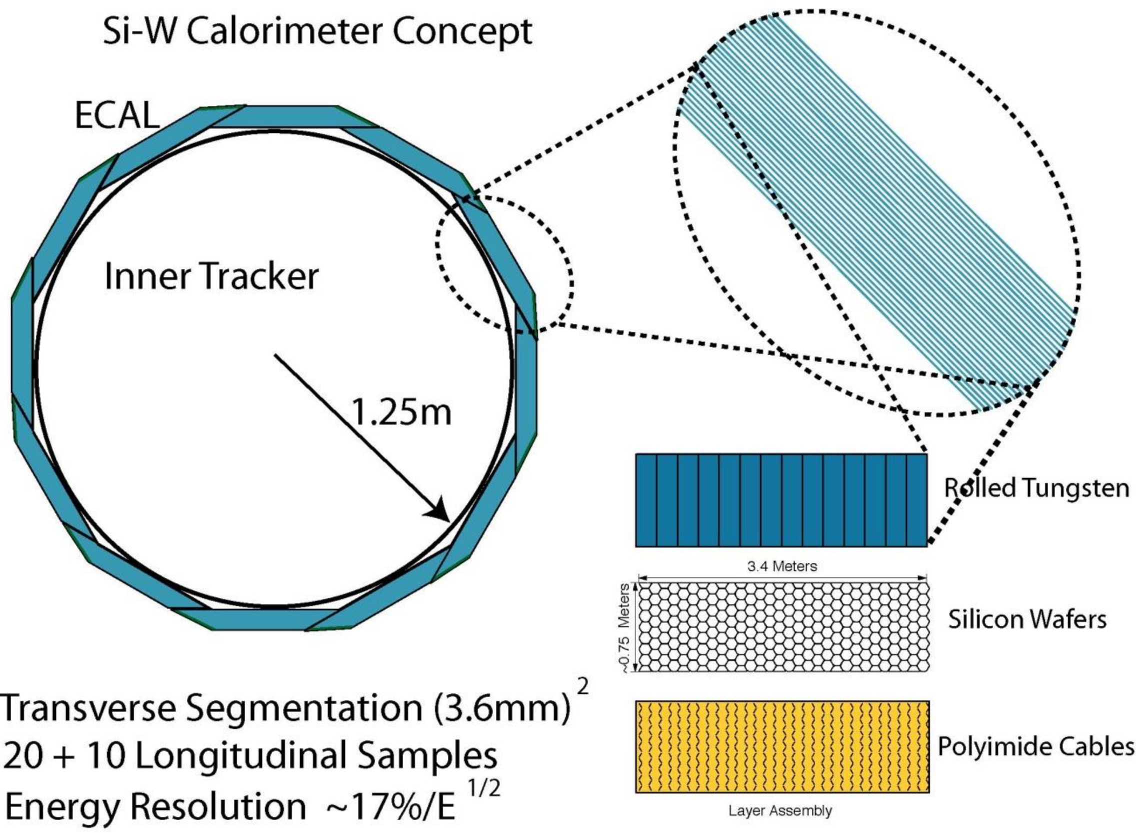
SiD Calorimeter System



ECAL: 26 X0 W
HCAL: 4.5 lambda Fe

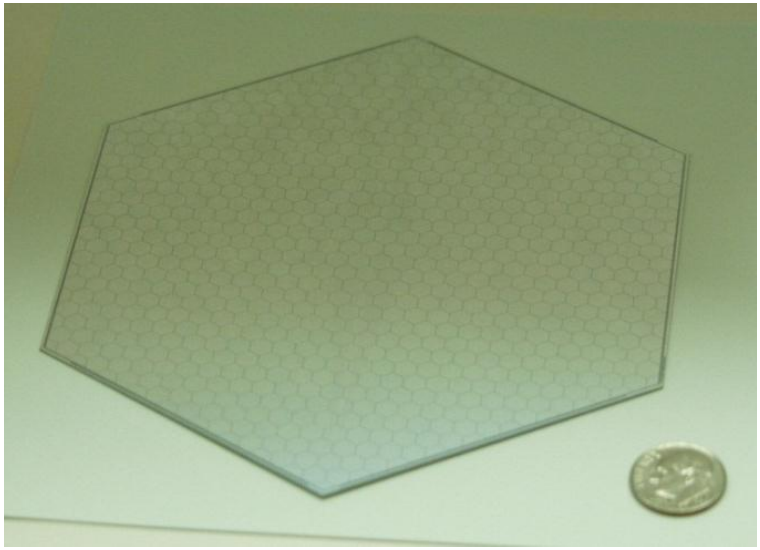


Si-W ECAL



Baseline: Silicon-tungsten (13 mm^2 pixels) with highly integrated readout (KPiX chip)

Option: MAPS – uses same tungsten and mechanical structure



ECAL R&D programme

Critical R&D:

Build test beam prototype module using components of final SiD ECal:

- **1024-channel integrated readout chip (KPiX)**
- **1024-pixel silicon sensors**
- **interconnects**

ECAL status

<u>**Silicon sensors**</u>**: Meet specs. for SiD ECal**

- **Hamamatsu**
- **low leakage current; DC coupled**
- **sufficient number for prototype (30 layers)**

<u>**Integrated readout chip (KPiX)**</u>**: prototypes meet SiD specs.:**

- **low noise (10% of MIP)**
- **large dynamic range: ~10^4**
- **full digitization and muliplexed output**
- **passive cooling (power pulsing)**

<u>**Interconnects**</u>**:**

- **Flex cables – successful attachment to dummy sensors**
- **Main focus of recent R&D is KPIX – sensor interconnects**

Timeline

Timeline for R&D

- Need to converge on reliable KPiX-sensor interconnects
- Then can proceed to assemble test module
- Target is revived End Station test beam at SLAC, which is scheduled to be ready for use in Spring 2012

Expect to include in DBD

Results expected for inclusion in DBD

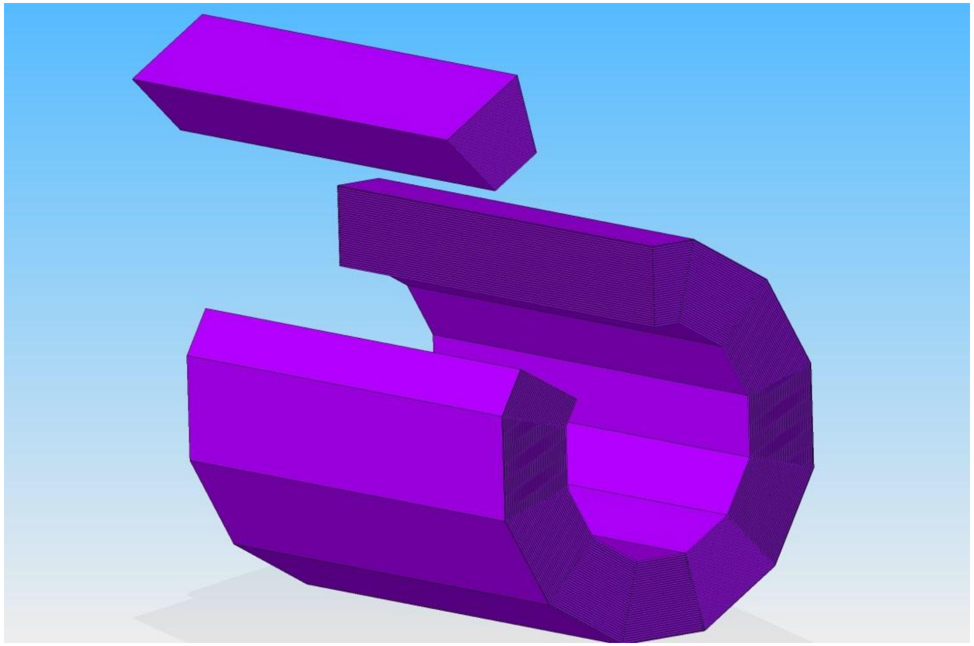
- **Technical results on components – updates to LOI**
- **Successful assembly of fully functional prototype will demonstrate feasibility of the design**
- **First test beam results, if available in time**

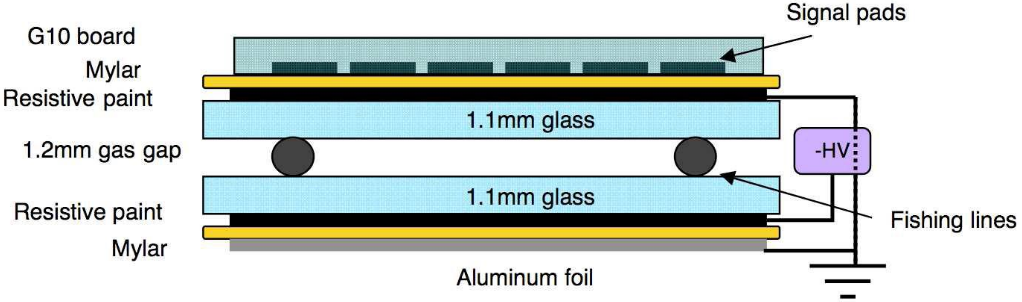
Issues for DBD + beyond

Issues/concerns for DBD and beyond

- **Personnel also engaged in other experiments**
- **The MAPS option (UK based) needs resources to continue**

SiD HCal





Baseline – RPC/Steel

Option 1 – GEM/μmegas/Steel

Option 2 – Scint/Steel

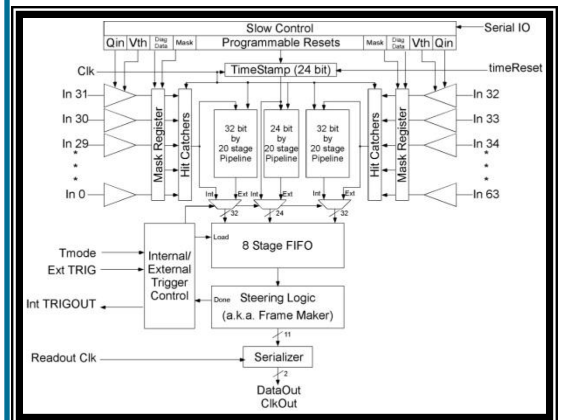
HCAL R&D programme

Critical R&D:

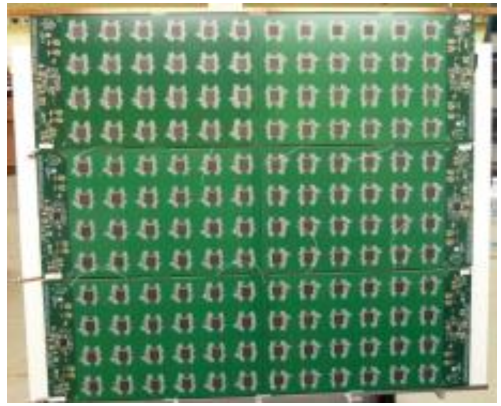
- **Large area glass chambers**
- **Module design (projective/non-projective)**
- **Gas (re-)circulation/routing**
- **Improved readout boards**
- **HV/LV distribution**
- **Data transmission**

R&D results to date

Readout – DCAL chip



Front-end board

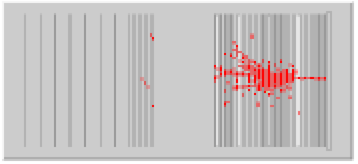


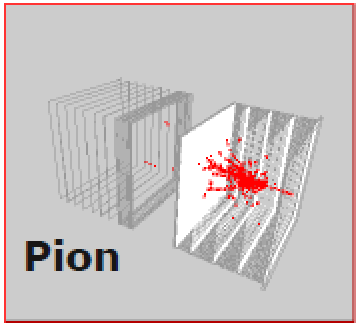
DHCAL:

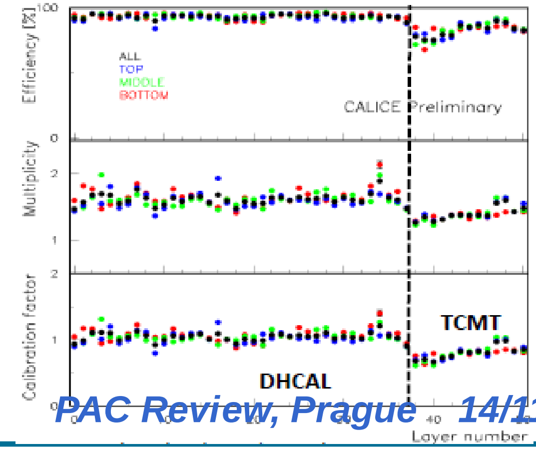
480,000 readout channels

Had 4 test beam runs so far

- 10/2010: 38 layers
- 2/2011: completed 38 + 14 during run
- 4/2011: SiW ECAL + RPC DHCAL
- 6/2011: RPC DHCAL alone
- More test beam in 2011 - 2013







Timeline

Timeline for R&D

- **Completed prototype construction by Dec 2010**
- **Beam test at FNAL in November 2011 (Tertiary beamline, DHCAL without absorber)**
- **Beam test at CERN in Summer/Fall 2011 (DHCAL with Tungsten absorber)**
- **R&D on HV distribution system, high-rate RPCs, 1-glass RPCs, gas recirculation… ongoing**

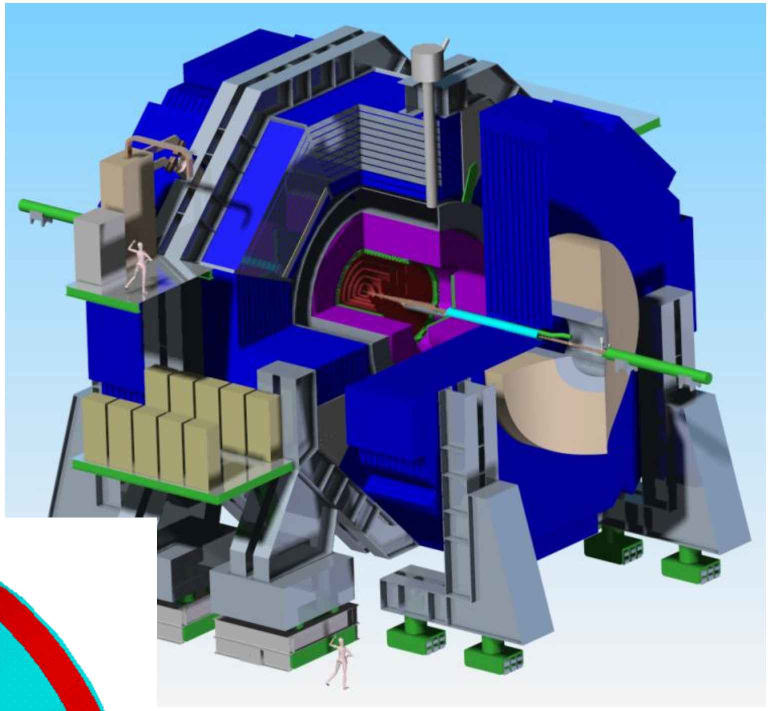
Expect to include in DBD

- Description of DHCAL/RPCs/Readout system (instrumentation paper)
- Detailed measurement of noise in the DHCAL (noise paper)
- Calibration of the DHCAL with Muons
- DHCAL response to positrons and pions
- Measurements with large 1-glass RPCs (viability of design)
- **Conceptual engineering design (if resources permit)**

Issues for DBD + beyond

- Conceptual engineered design
- Detailed RPC pulse simulation
- Analysis of DHCAL data incomplete
- Viability of gas recirculation still unproven

Magnet System

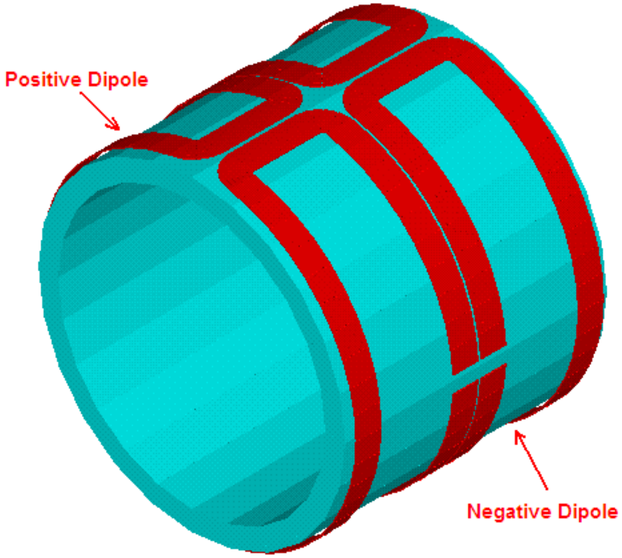


Baseline
Modified CMS Conductor

Option 1
Al-0.1% Ni (ATLAS)
Stabilizer

Option 2
Advanced Next Generation
Stabilizer

Note: The only significant option choices based on technological advancements are with the conductor.



Magnet R&D programme

Areas of Critical R&D / Goals

1. 3-D Magnet Field FEM Analysis
2. Integration of DID Coil into Cryostat
3. Assembly and Installation Procedures
4. Structural and Thermal Design
5. Cryogenic Systems Integration with QD0

Expect to include in DBD

3-D Magnetic Field, Force & Stress including DID Coil and Vacuum Shell

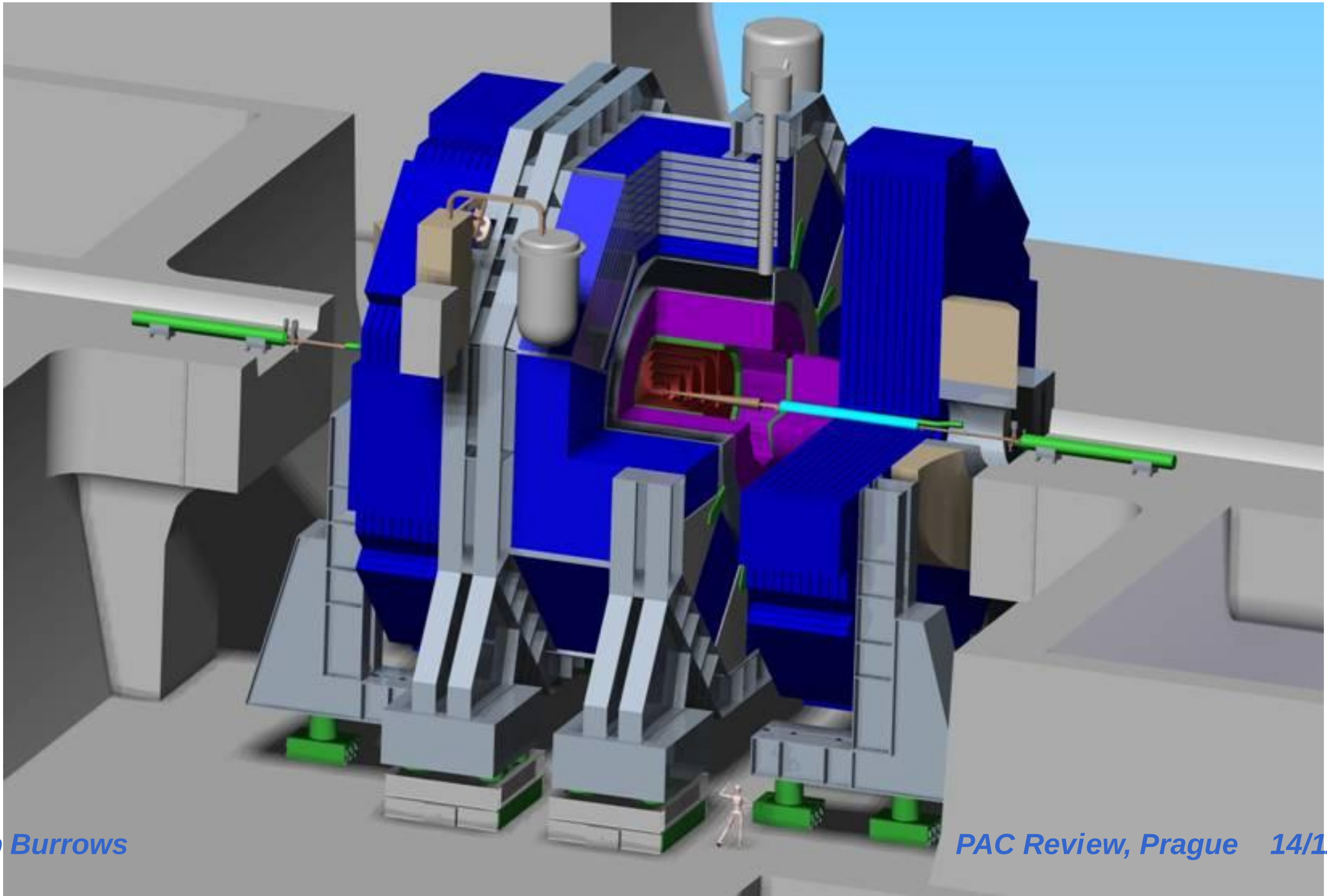
- **Structural and Thermal Design including Integration with Iron and Detector**
- **Assembly and Construction Procedure**
- **Size and Tolerances for Major Components**
- **Cryogenic Scheme integrated with QD0**
- **Power Supply, Dump Circuit, Grounding, Instrumentation**

Issues for DBD + beyond

The main concern is SLAC manpower committed to other projects

- **Potential cost savings exist using advanced high purity Al stabilizers and conductor fabrication techniques. There will be negligible time to pursue this before the DBD**

Muon System



Muon System R&D

Two candidate readout technologies:

- **Baseline: Resistive Plate Chambers (double layers)**
- **Option: Strip-scintillator/WLS fiber & Avalanche Photo-Diodes**

Iron will accommodate either choice

Areas of critical R&D/goals:

RPC – need to complete aging studies

- test new HF resistant RPC's

- develop large area chamber design

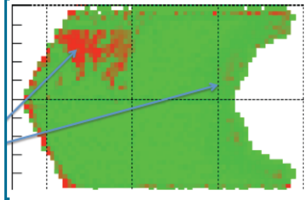
Scintillator - Need to build and test strips with robust techniques.

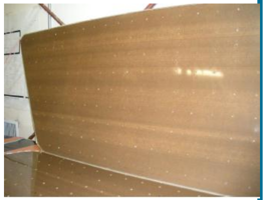
R&D and results to date

RPC

Aging studies with BaBar RPC muon chambers:

-Good efficiency, but clear signs of aging

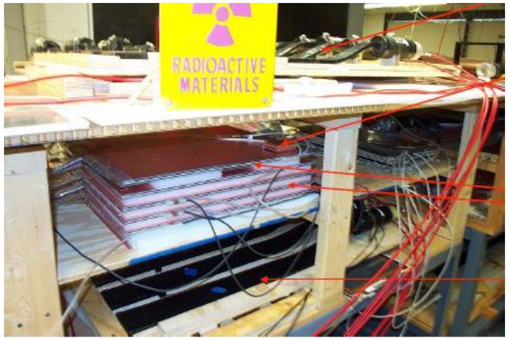




- No evidence of graphite problems
- linseed oil dry/smooth
- inefficiency could be due to high rate?
  - RPC r/o w Kpix

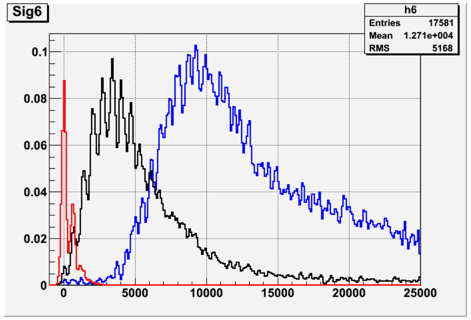
RPC

Aging studies with BES-III RPC's:



-w/o oil coating RPC vulnerable to HF attack
- surface morphology studied
- new variant Bakelite electrode developed
  - search for other gases

Scint/WLS Option: FTBF results



Timeline for R&D

RPC:

- Ongoing aging tests of new HF resistant Bakelite RPCs

- **Search for alternative non-fluorine gases/or develop recirculation system**
- **Explore production of new resin-based RPC with Chinese company**

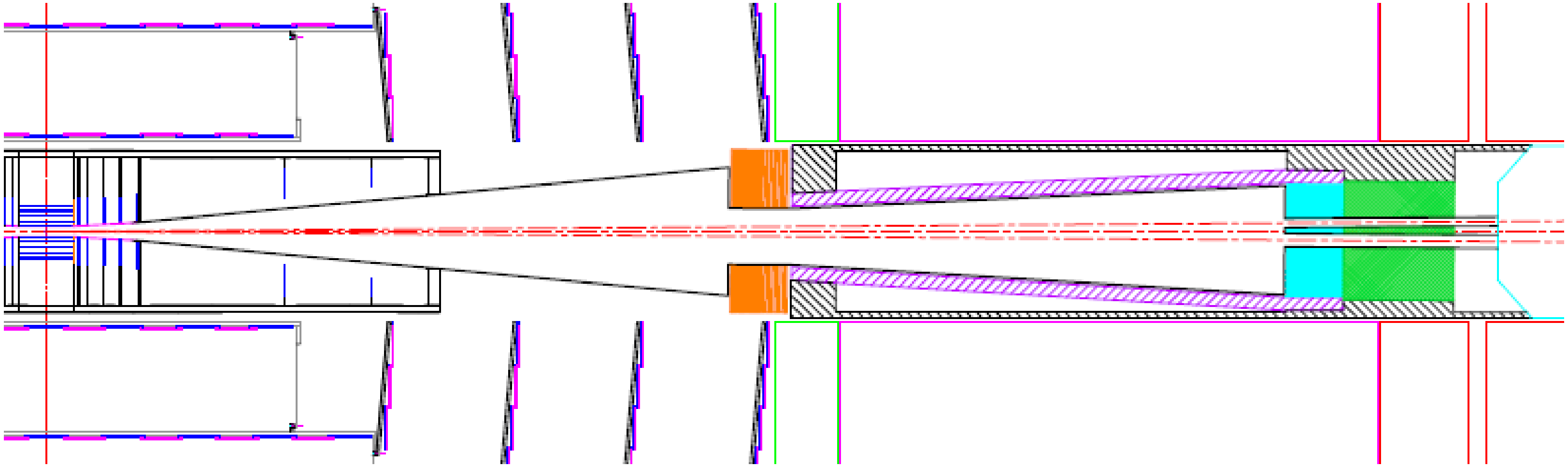
Scintillator: New design of mechanical /optical coupling scheme using tooling: Jan 31, 2012. Try with short strips Feb. 2012

- **Set-up tests with 4 strips and new optical/mechanical coupling. June 2012**

Expect to include in DBD

- RPC: Results/conclusions from BaBar/BES-III/new RPCs
- Scintillator: First results from cosmic ray tests of new coupling scheme.
- General: Conceptual design of barrel and endcaps
- (limited resources in US)

Forward Systems



Baseline: Si / W sampling calorimeter

Areas of critical R&D:

- **Radiation hard Silicon sensors**
- **FCAL chip development**
- **Simulation study of BeamCal tagging**

FCAL R&D

Radiation hard sensor R&D (SCIPP/SLAC)

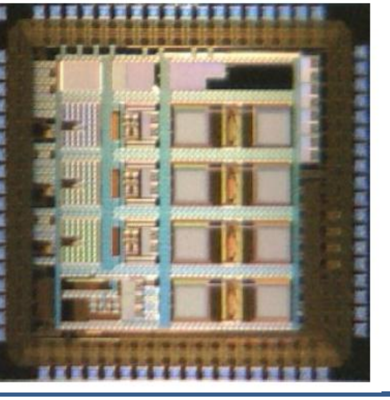
- Micron sensors from ATLAS R&D
- Runs of up to 100 Mrad (Spring 2012)
- Will assess the bulk damage effects and charge collection efficiency degradation.
- Charge collection apparatus being upgraded at SCIPP to process many samples quickly.

FCAL chip development (Santiago/SCIPP)

- 180 nm TSMC process
- 72 pads, 2.4 mm × 2.4 mm
- 7306 nodes, 35789 circuit elements
- 3 channels
- No digital memory

Second prototype starts towards the end of 2011.

Bean v1.0 prototype

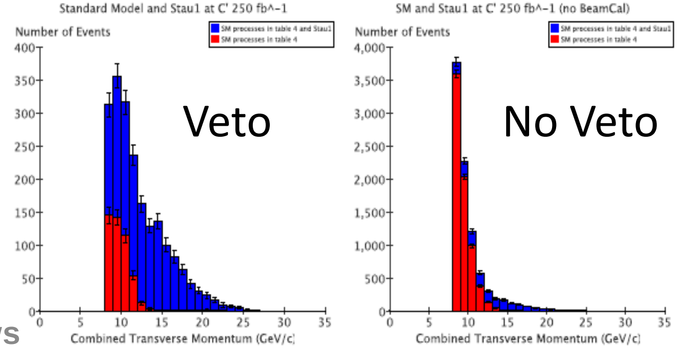


Study of stau production (Colorado)

- Stau production in co-annihilation points: M. Battaglia et al hep-ph/0306219 $\sigma \sim 10$ fb
- Background

$\gamma\gamma \rightarrow \tau\tau$, $\sigma \sim 10^6$ fb

BeamCal veto is essential.



Timeline for R&D

- Summer 2012: Initial (100 MRad) study completed
- Summer 2012: Submission of second BEAN prototype
- BeamCal simulation study has been completed

Results to be included in DBD

Issues for DBD and beyond

- **Availability of SLAC 13.6 GeV test beam**
- **Chilean support for BEAN chip development (and continue US support for digital components)**

Machine-Detector Interface

See next talk by Karsten!

Simulation and reconstruction

Results expected for inclusion in DBD:

- **Full simulation of realistic detector design including support structures**
- **Full tracker hit digitization and ab initio track finding and fitting**
- **Digital RPC signal simulation, including cross-talk, noise & inefficiencies**
- **Full reconstruction using slicPandora & LCFIVertex (LCFIPlus if available)**

Benchmarking

Simulation of SiD

- Event generation

- Full detector simulation

- Detector variants

- Analysis tools

Benchmark reactions …

Benchmark reactions (1)

- **e+e- → nu nu H, H→ mu mu / bb / cc / gg / WW***
  baseline detector, 1 TeV
  also H → gg, WW* w. detector variants

- **e+e- → W+W-   1 TeV**
  Four jet topology
  Two jets + leptons topology
  Beam polarization measurement
  Triple gauge couplings

Benchmark reactions (2)

- **e+e- → t t H 1 TeV**

  Eight jet topology

  Four jets + leptons topology

  Top Yukawa coupling measurement

- **e+e- → tau tau   500 GeV**

  Cross section and *A_FB* precision

  Tau decay mode efficiencies and purities

  Tau polarization

Costs in DBD

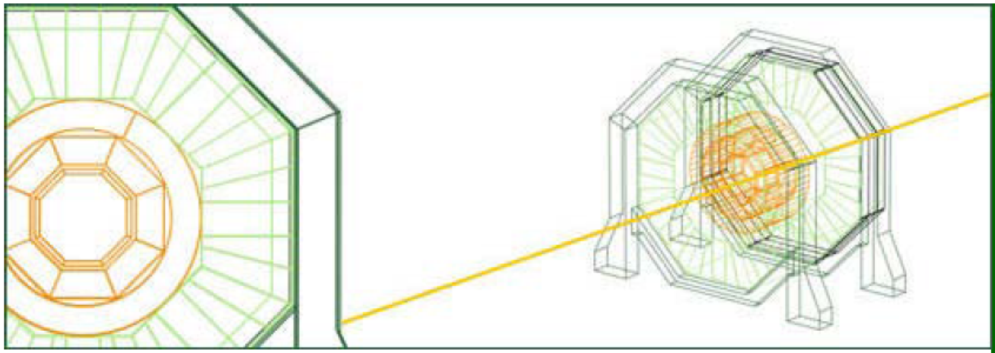
- **Cost estimates by subsystem**
  - **Tables**
  - **M&S graph**
  - **Labor graph**
- **Parametric Results**
  - **Cost vs tracker radius**
  - **Cost vs HCal thickness**
  - **Cost vs B**
  - **Cost vs aspect ratio**
- **Cost – physics sensitivity analysis**

Summary

- **The SiD Concept remains a key element of future ILC/CLIC plans**
- **R&D progress being made as resources allow**
- **Simulation/reconstruction well tested/robust for CDR – soon to be applied to DBD**
- **Benchmarking will start soon**
- **Cooperation with CLIC colleagues worked well for CDR – will now work together on DBD**
- **DBD editors in place, plans developing towards SiD Workshop at SLAC, December 14-16, 2011**

SiD and the CLIC CDR

Chapter 1: Introduction	*Main editors* Akiya Miyamoto, Marcel Stanitzki, Harry Weerts, Lucie Linssen
Chapter 2: CLIC physics potential	Gian Giudice, James Wells
Chapter 3: CLIC experimental conditions and detector performance requirements	Mark Thomson
Chapter 4: Physics requirements	*Main editors*
Chapter 5: CLIC detector concepts	Jim Brau, Dieter Schlatter, Frank Simon, Graham Wilson
Chapter 6: CLIC vertex detectors	Bill Cooper, Dominik Dannheim, Steve Worm
Chapter 7: Tracking systems	Marcel Demarteau, Carlos Lacasta, Takeshi Matsuda, Tim Nelson, Jan Timmermans
Chapter 8: Calorimetry	Felix Sefkow, Tohru Takeshita, Andy White
Chapter 9: Solenoids and magnet systems	Andrea Gaddi, Yasuhiro Makida
Chapter 10: Muon systems at CLIC	Burkhard Schmidt
Chapter 11: Very forward calorimeters	Halina Abramowicz, Wolfgang Lohmann
Chapter 12: Readout electronics and data acquisition	Alex Kluge
Chapter 13: Detector integration	Hubert Gerwig, Marco Oriunno
Chapter 14: Physics performance	Jean-Jacques Blaising, Jan Strube, Frederic Teubert
Chapter 15: Future plans and R&D proposals	*Main editors*
Chapter 16: Detector costs	Marty Breidenbach, Catherine Clerc, Markus Nordberg
Chapter 17: Conclusion	*Main editors*



SiD Workshop

December 14-16, 2011

SLAC National Accelerator Laboratory

- Agenda
- Participants
- Registration
- Location
- Directions
- SiD Web page

The Silicon Detector (SiD) Design Study will hold its next workshop at the SLAC National Accelerator Laboratory on Wednesday-Friday, December 14-16, 2011.

The workshop will focus on planning and preparations for the SiD Detailed Baseline Design (DBD), which is due to be completed at the end of 2012. It will include reviews of the current status of SiD detector R&D, and the overall SiD design. In addition, we'll discuss the CLIC Conceptual Design Report (CDR) and future cooperation between SiD and the CLIC detector team, review ongoing efforts to provide support for future lepton collider detector studies in the US, and discuss SiD's future beyond the DBD.

The meeting will be held in SLAC's Research Office Building (ROB), in the Redwood Rooms.

Registration will be open starting about September 15. A $15 registration fee will be required of all participants to cover coffee and refreshments over the course of the meeting. An additional fee will be collected at the meeting from those wishing to attend the SiD Collaboration Dinner on Thursday evening.