SiD
Status & Plans

08/November/2013

Marcel Stanitzki

SiD Detector overview

- SID Rationale
  - *A compact, cost-constrained detector designed to make precision measurements and be sensitive to a wide range of new phenomena*
- Design choices
  - Compact design with 5 T field.
  - Robust silicon vertexing and tracking system with excellent momentum resolution
  - Time-stamping for single bunch crossings.
  - Highly granular Calorimetry optimized for Particle Flow
  - Iron flux return/muon identifier is part of the SiD self-shielding
  - Detector is designed for rapid push-pull operation

SiD – A short History

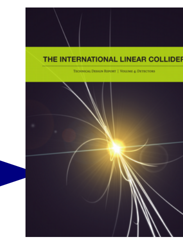
2003:SiD first appears at ALCPG.
SiD is aimed at the NLC

2006: Detector Outline Document

2008/9: CLIC_SiD Starts for Multi-TeV machines

2009: SiD Letter Of Intent

2009: SiD validated



2004 :WWS starts the detector concept studies at the Victoria meeting :SiD, GLD, LDC
Beginning of the Silicon Detector Concept Study

2007: Detector Concept Report
First SiD workshop

2011: CLIC Physics and Detectors Conceptual Design Report

Concept Phase

LoI Phase

DBD Phase

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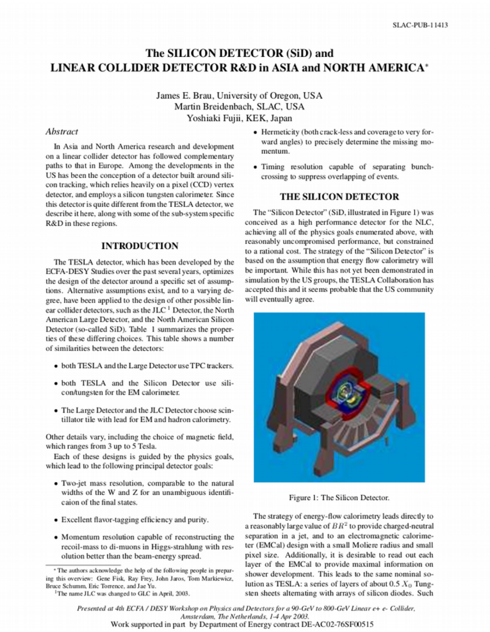
Many reports



SLAC-PUB-11413

The SILICON DETECTOR (SiD) and LINEAR COLLIDER DETECTOR R&D in ASIA and NORTH AMERICA*

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Martin Breidenbach, SLAC, USA
Yoshiaki Fujii, KEK, Japan

Abstract

In Asia and North America research and development on a linear collider detector has followed complementary paths to that in Europe. Among the developments in the US has been the conception of a detector built around silicon tracking, which relies heavily on a pixel (CCD) vertex detector, and employs a silicon tungsten calorimeter. Since this detector is quite different from the TESLA detector, we describe it here, along with some of the sub-system specific R&D in these regions.

INTRODUCTION

The TESLA detector, which has been developed by the ECFA-DESY Studies over the past several years, optimizes the design of the detector around a specific set of assumptions. Alternative assumptions exist, and to a varying degree, have been applied to the design of other possible linear collider detectors, such as the JLC [1] Detector, the North American Large Detector, and the North American Silicon Detector (so-called SiD). Table 1 summarizes the properties of these differing choices. This table shows a number of similarities between the detectors:

- both TESLA and the Large Detector use TPC trackers.
- both TESLA and the Silicon Detector use silicon/tungsten for the EM calorimeter.
- The Large Detector and the JLC Detector choose scintillator tile with lead for EM and hadron calorimetry.

Other details vary, including the choice of magnetic field, which ranges from 3 up to 5 Tesla.

Each of these designs is guided by the physics goals, which lead to the following principal detector goals:

- Two-jet mass resolution, comparable to the natural widths of the W and Z for an unambiguous identificaion of the final states.
- Excellent flavor-tagging efficiency and purity.
- Momentum resolution capable of reconstructing the recoil-mass to di-muons in Higgs-strahlung with resolution better than the beam-energy spread.
- Hermeticity (both crack-less and coverage to very forward angles) to precisely determine the missing momentum.
- Timing resolution capable of separating bunch-crossing to suppress overlapping of events.

THE SILICON DETECTOR

The "Silicon Detector" (SiD, illustrated in Figure 1) was conceived as a high performance detector for the NLC, achieving all of the physics goals enumerated above, with reasonably uncompromised performance, but constrained to a rational cost. The strategy of the "Silicon Detector" is based on the assumption that energy flow calorimetry will be important. While this has not yet been demonstrated in simulation by the US groups, the TESLA Collaboration has accepted this and it seems probable that the US community will eventually agree.

Figure 1: The Silicon Detector.

The strategy of energy-flow calorimetry leads directly to a reasonably large value of BR^2 to provide charged-neutral separation in a jet, and to an electromagnetic calorimeter (EMCal) design with a small Moliere radius and small pixel size. Additionally, it is desirable to read out each layer of the EMCal to provide maximal information on shower development. This leads to the same nominal solution as TESLA: a series of layers of about 0.5 X_0 Tungsten sheets alternating with arrays of silicon diodes. Such

* The authors acknowledge the help of the following people in preparing this overview: Gene Fisk, Ray Frey, John Jaros, Tom Markiewicz, Bruce Schumm, Eric Torrence, and Jae Yu.

[1] The name JLC was changed to GLC in April, 2003.

Presented at 4th ECFA / DESY Workshop on Physics and Detectors for a 90-GeV to 800-GeV Linear e+ e- Collider, Amsterdam, The Netherlands, 1-4 Apr 2003.

Work supported in part by Department of Energy contract DE-AC02-76SF00515

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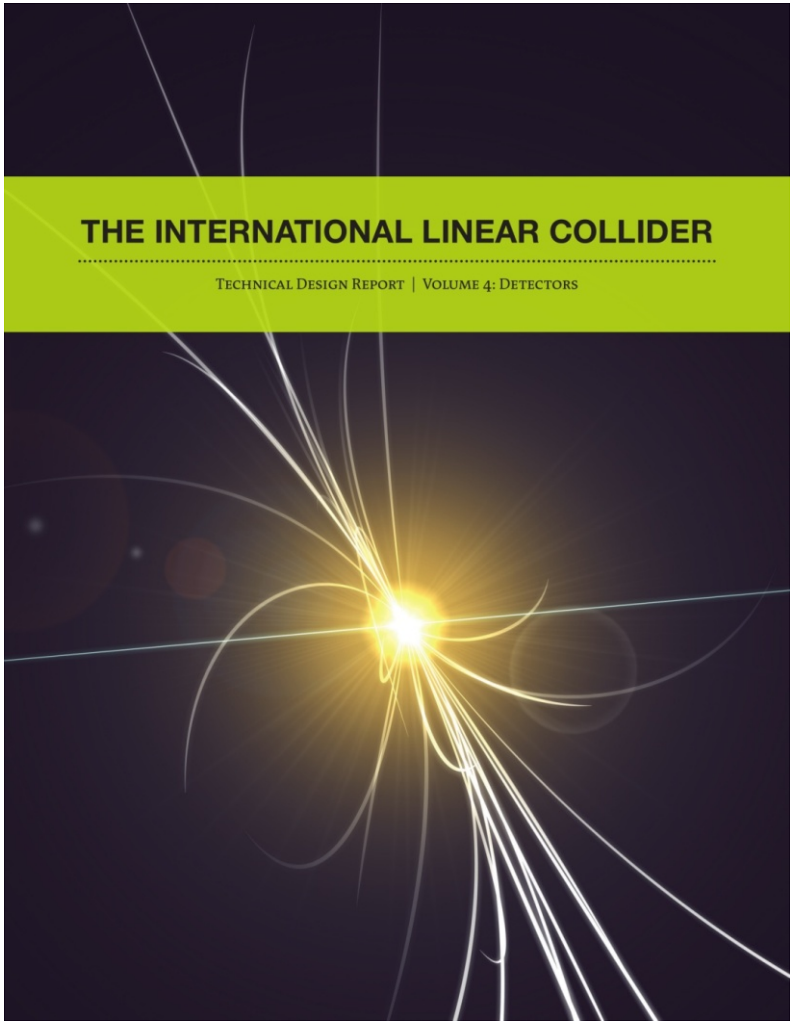
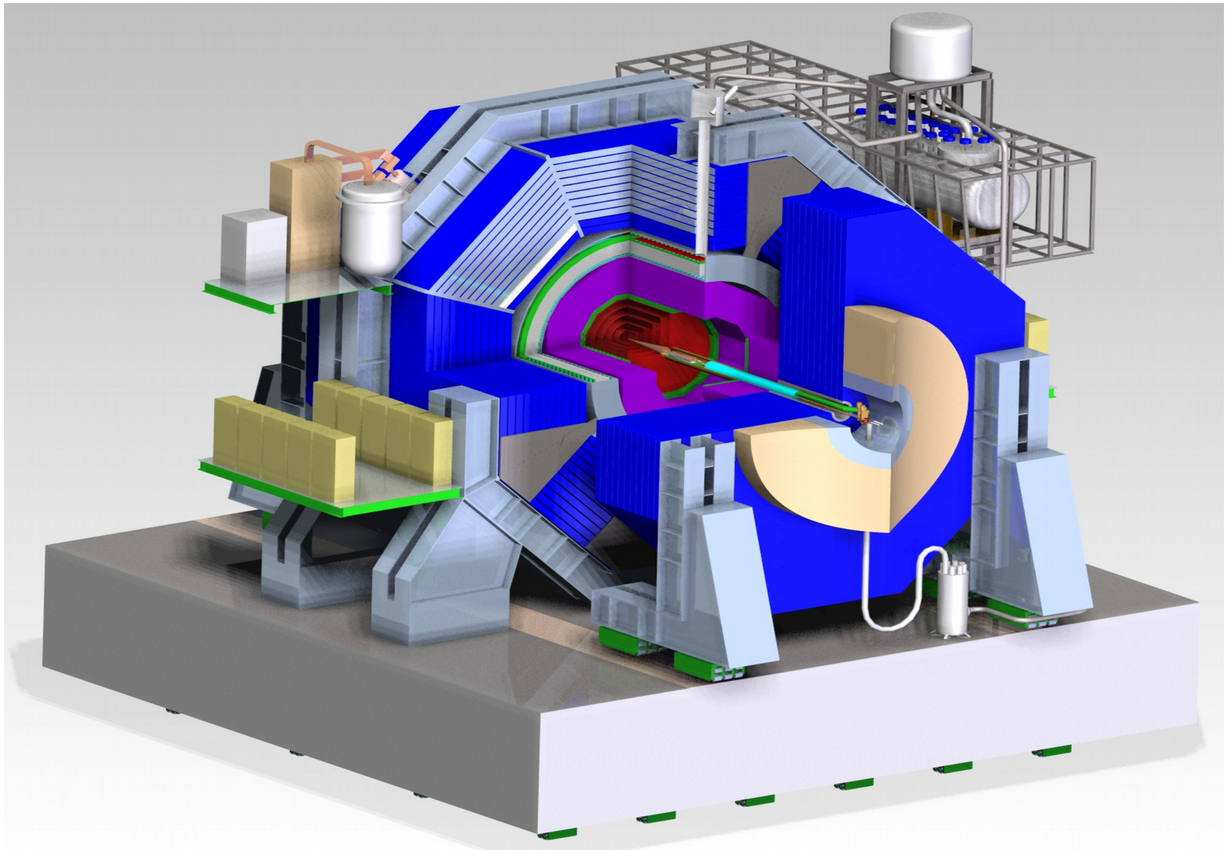
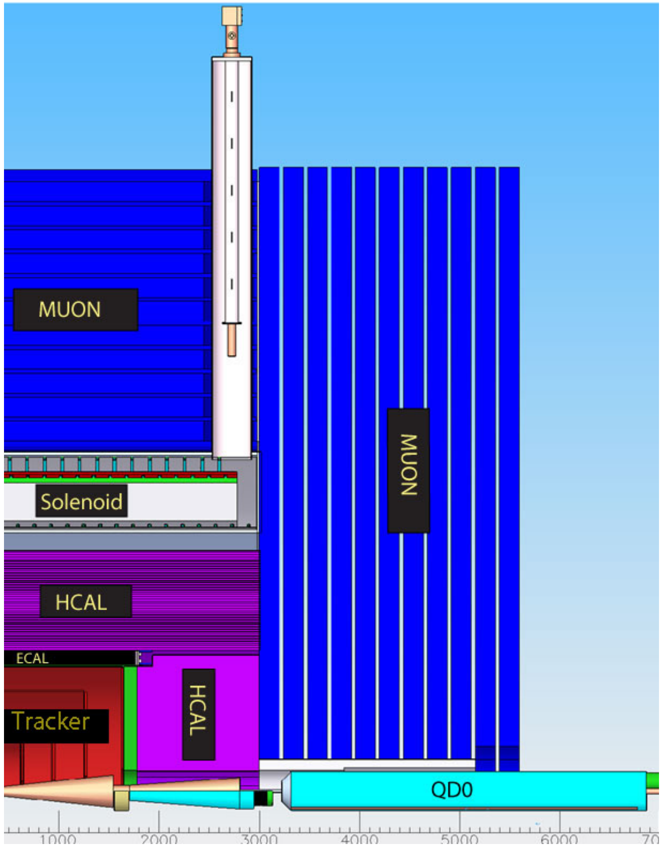
The DBD is done



The ILC Accelerator/Detectors TDR/DBD set the “gold standard” for documentation on future projects at Snowmass 2013

The DBD detector





- SiD is fully designed for push-pull (using a platform)
- Particle flow paradigm has driven design choices

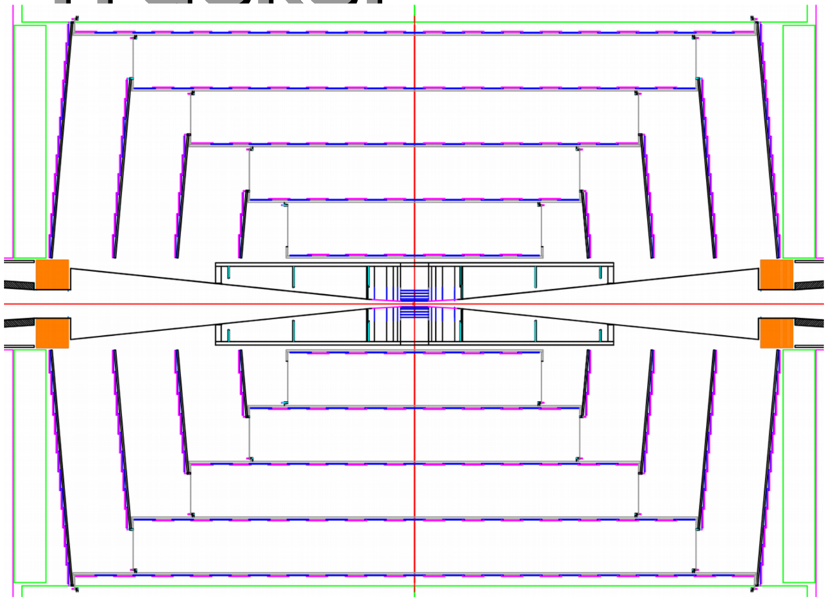
DBD baseline parameters

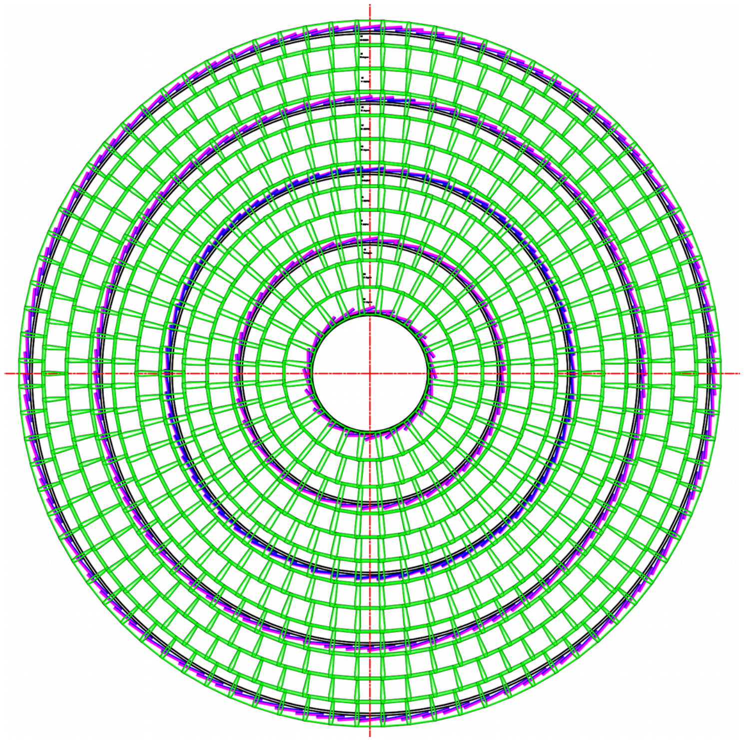
SiD BARREL	Technology	Inner radius	Outer radius	z max
Vertex detector	Silicon pixels	1.4	6.0	± 6.25
Tracker	Silicon strips	21.7	122.1	± 152.2
ECAL	Silicon pixels-W	126.5	140.9	± 176.5
HCAL	RPC-steel	141.7	249.3	± 301.8
Solenoid	5 Tesla	259.1	339.2	± 298.3
Flux return	Scintillator/steel	340.2	604.2	± 303.3

SiD ENDCAP	Technology	Inner z	Outer z	Outer radius
Vertex detector	Silicon pixels	7.3	83.4	16.6
Tracker	Silicon strips	77.0	164.3	125.5
ECAL	Silicon pixel-W	165.7	180.0	125.0
HCAL	RPC-steel	180.5	302.8	140.2
Flux return	Scintillator/steel	303.3	567.3	604.2
LumiCal	Silicon-W	155.7	170.0	20.0
BeamCal	Semiconductor-W	277.5	300.7	13.5

Silicon Strip Tracker

- All silicon tracker
  - Using silicon micro-strips
  - Double metal layers
- 5 barrel layers and 4 disks
- Cooling
  - Gas-cooled
- Material budget
  - less than 20 % X_0 in the active area
- Readout using KPiX ASIC
  - Bump-bonded directly to the modules





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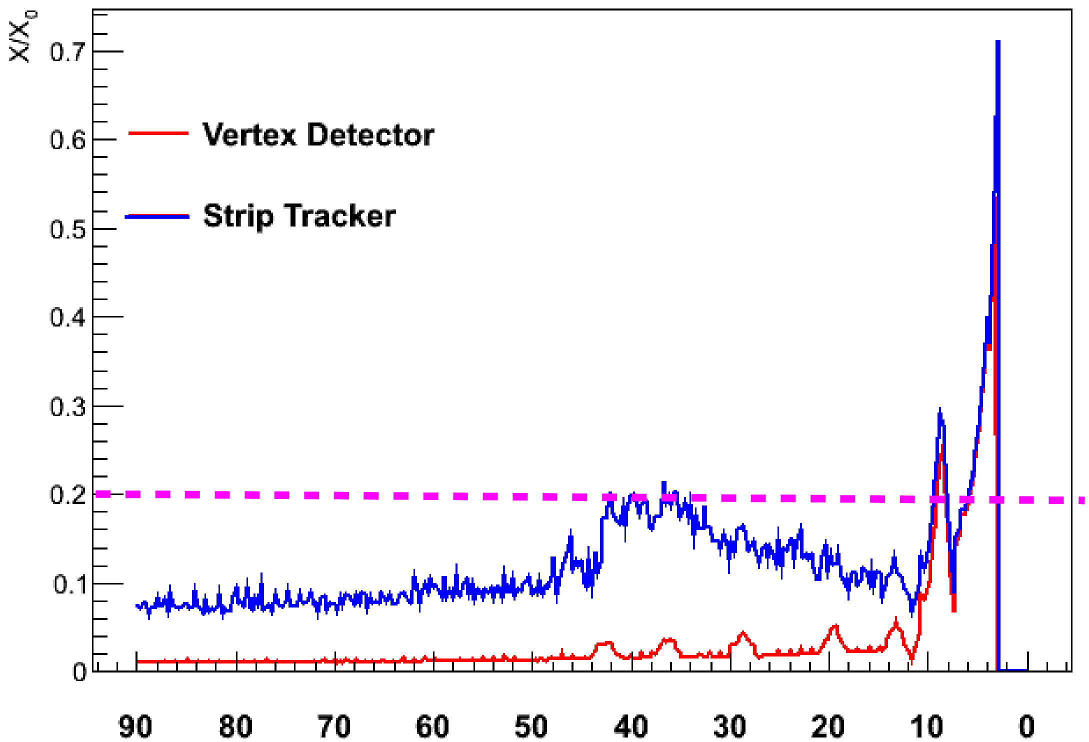
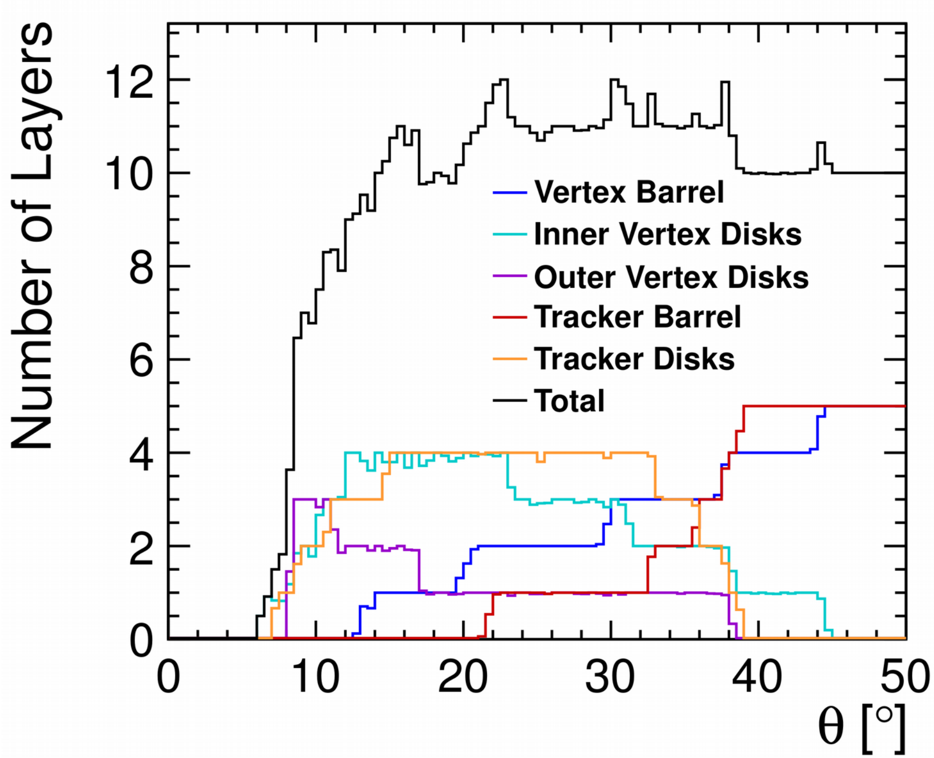
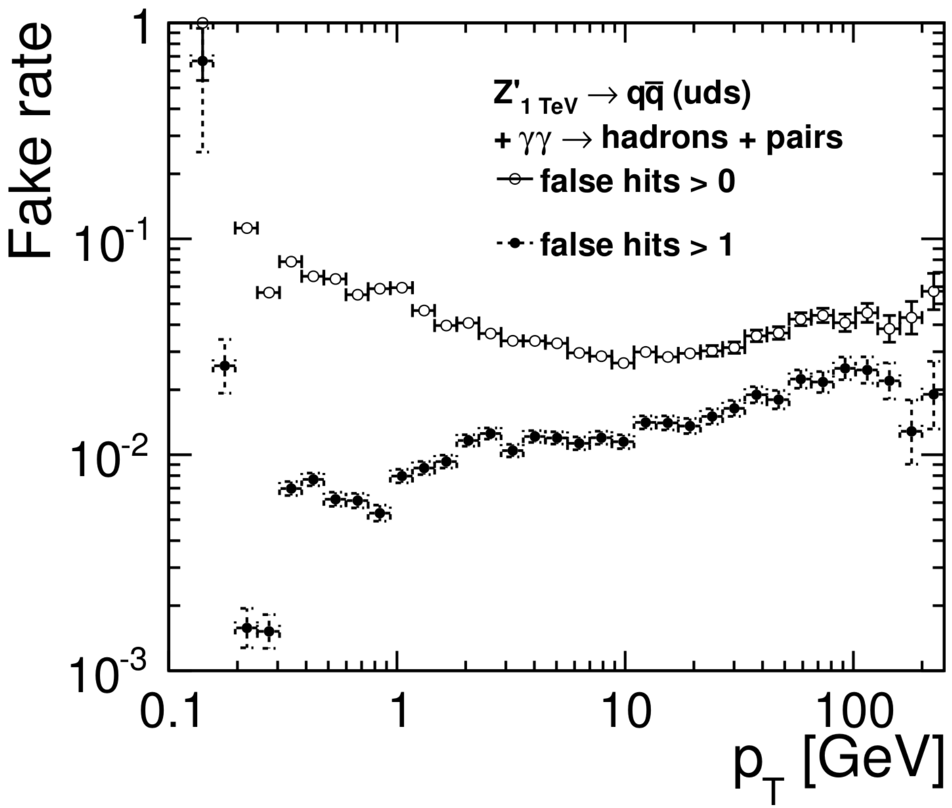
SiD Tracking System

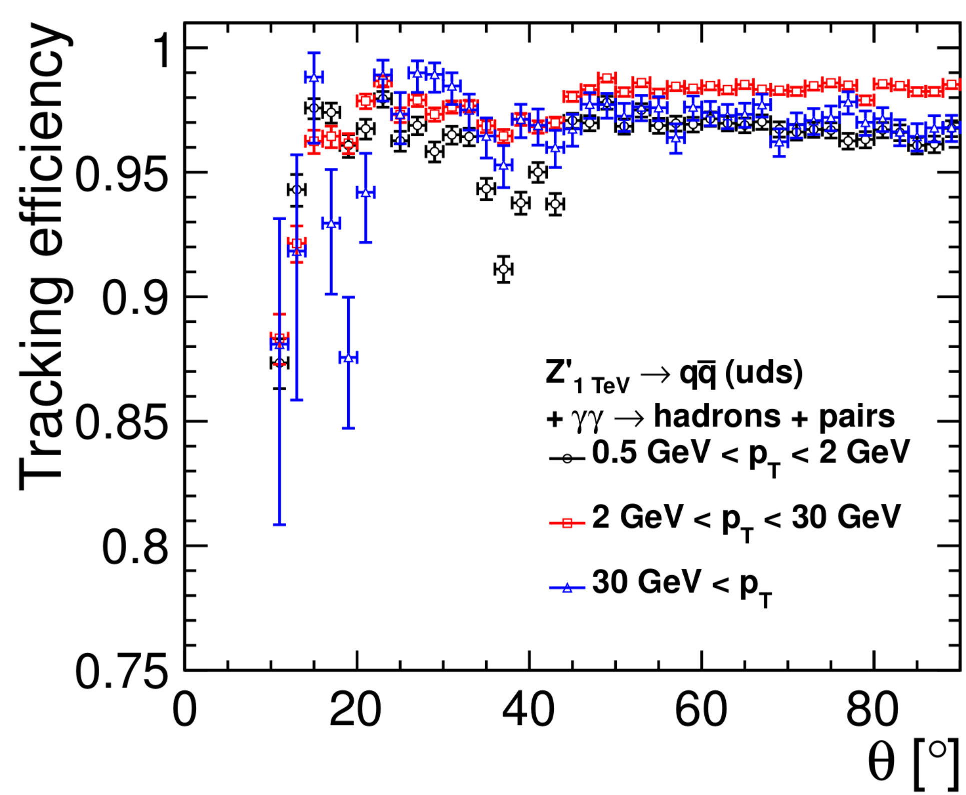




- Track seeding and fitting uses entire tracking system
  - 7 hits required (6 in second pass)
  - Calorimeter seeding (V_0 finder)

Robustness vs. backgrounds



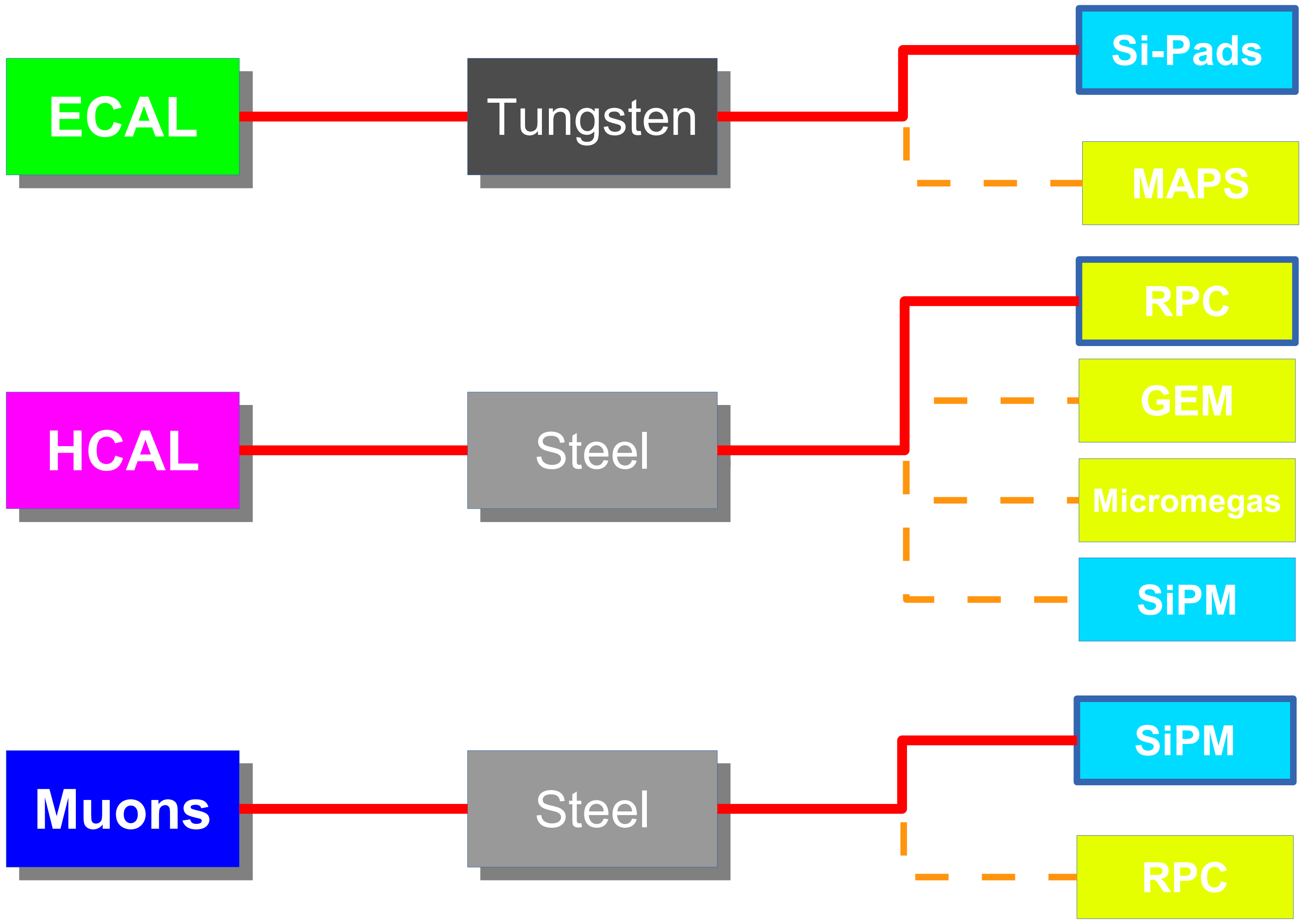


- Z' → uds at 1 TeV with one bunch crossing of background overlaid
- Demonstrates robustness of SiD Tracking

Calorimetry

- SiD ECAL
  - Tungsten absorber
  - 20+10 layers
  - 20 x 0.64 + 10 x 1.30 X_0
- Baseline Readout using
  - 5x5 mm^2 silicon pads
- SiD HCAL
  - Steel Absorber
  - 40 layers
  - 4.5 Λ_i
- Baseline readout
  - 1x1 cm^2 RPCs
- SiD has selected baseline choices for its Calorimeter
  - Options are being considered

Calorimetry Tree



Analog Readout
Digital Readout
Baseline
Option

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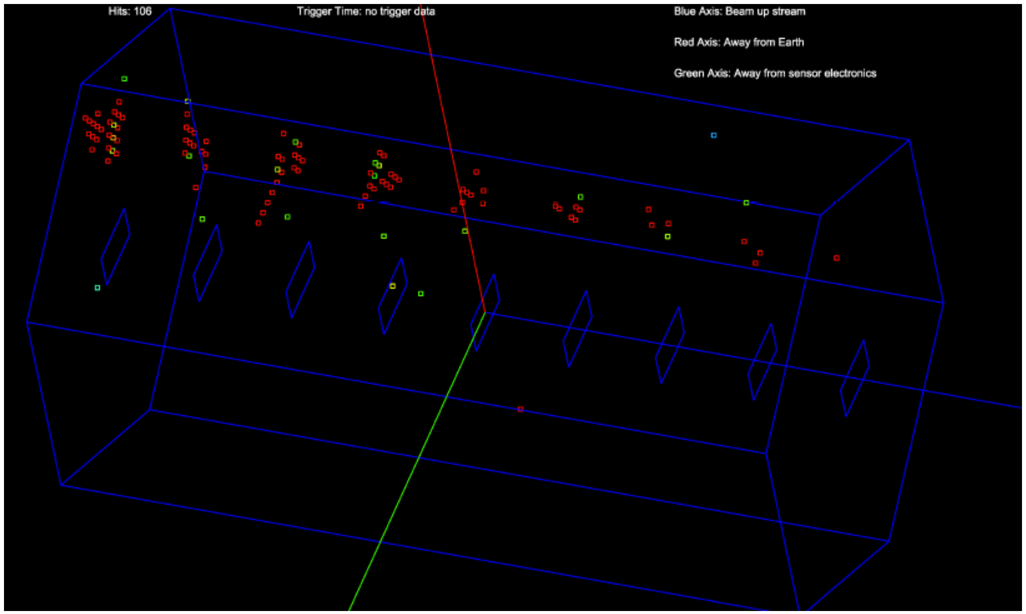
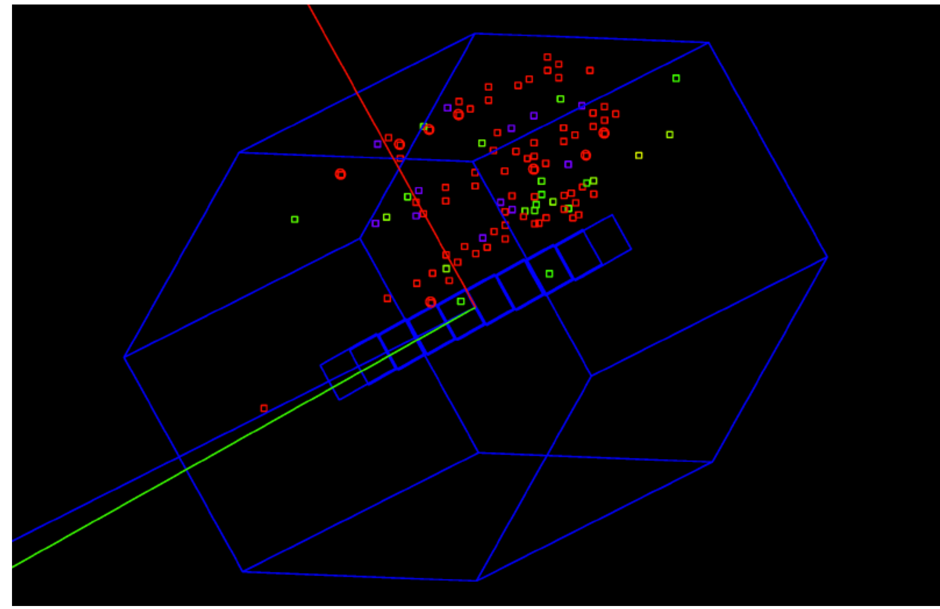
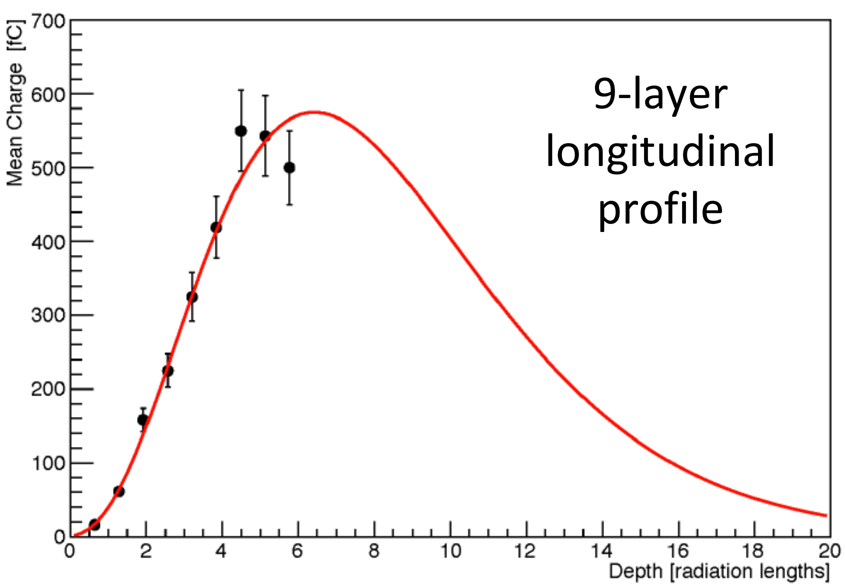
SiD Detector – Ecal – Test beam

One electron



Three electrons





Uncovered some unexpected behavior

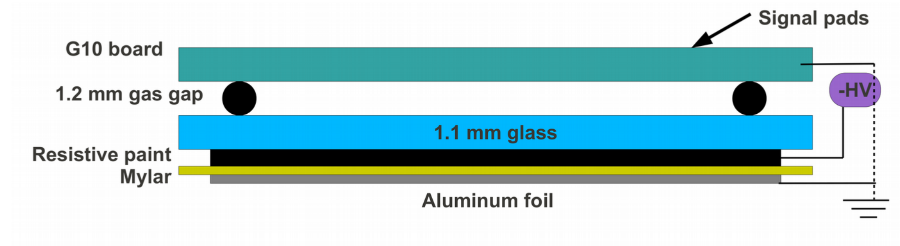
Unphysical negative-amplitude hits – current hypotheses:

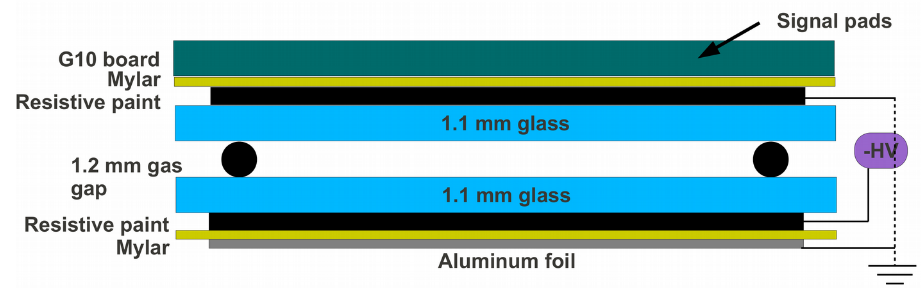
- Small number of in-time hits: cross-talk in sensor and baseline shift of KPiX virtual ground
- Many out of time hits for some layers when many hit pixels: associated with KPiX resets? cascading?

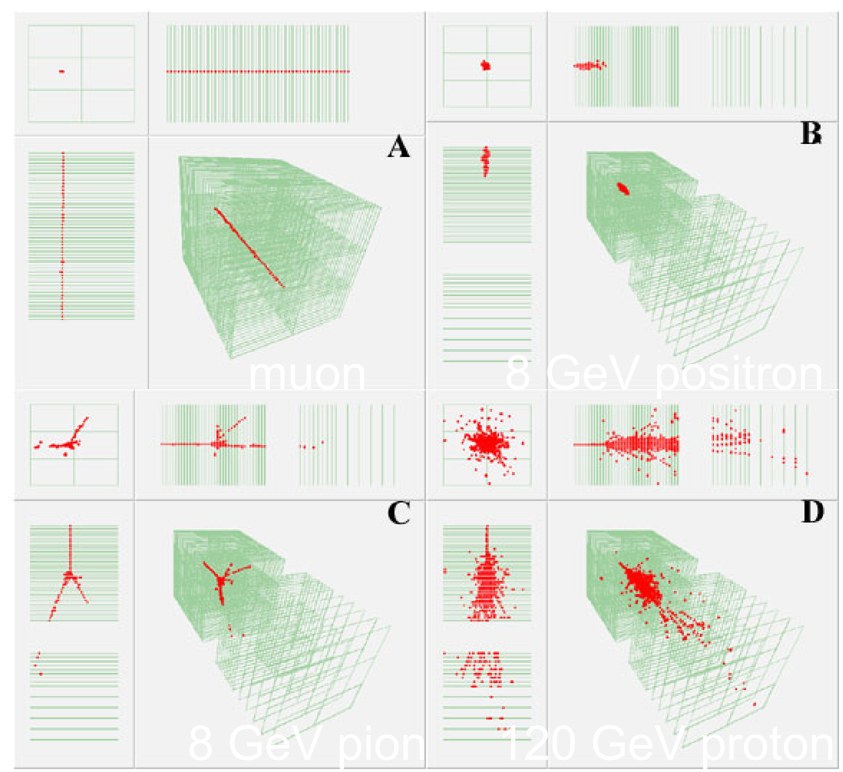
Second generation sensor – potentially with shielding between traces and pixels

HCAL Baseline

- Digital HCAL
  - Counting shower particles
  - $N_{particles}$ ~ Energy
- Using Glass RPCs
  - 1 x 1 cm^2
- 1 m^3 prototype built
  - 500.000 channels
  - Largest Calorimeter by channel so far







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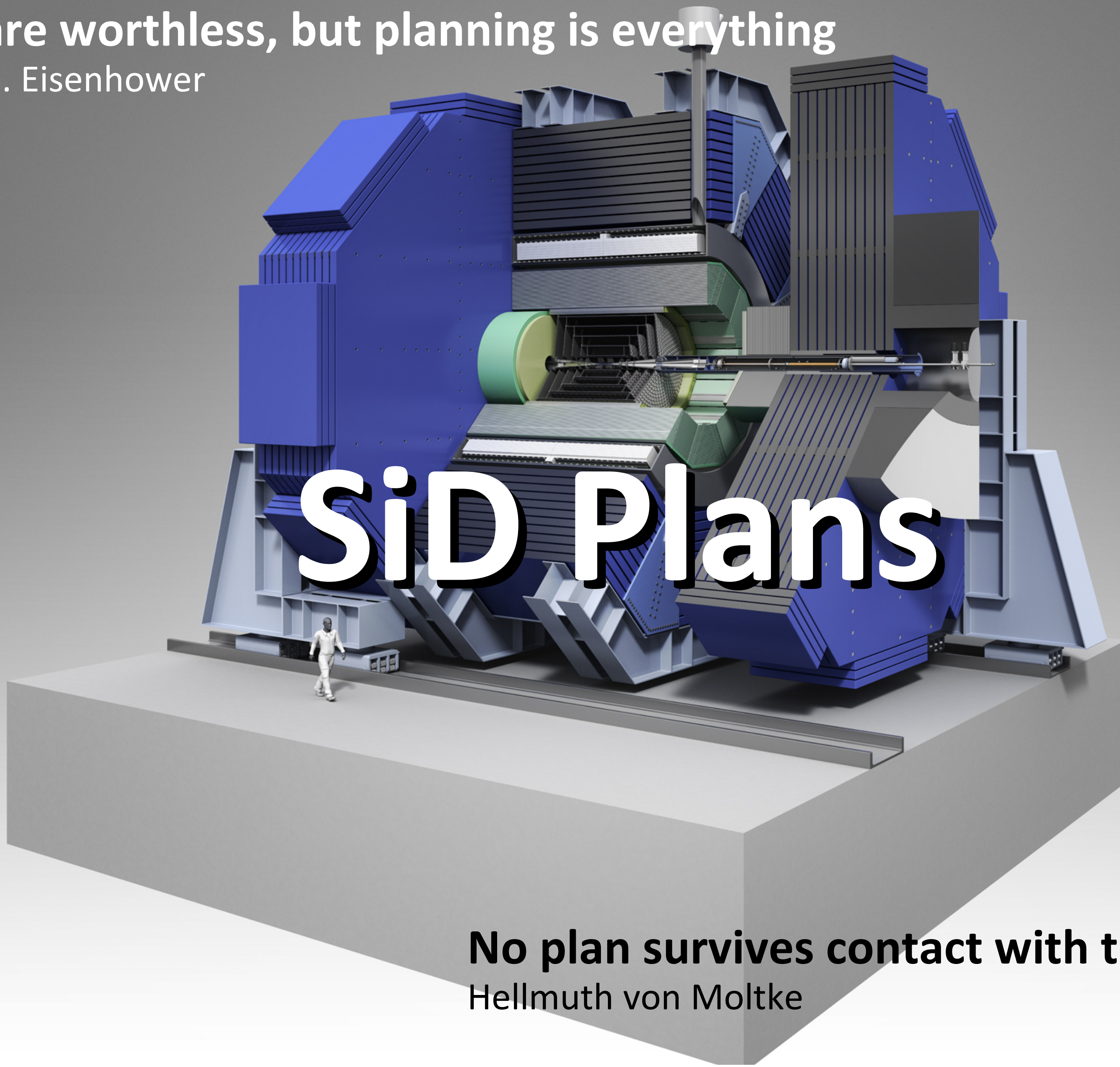
Plans are worthless, but planning is everything
Dwight D. Eisenhower



SiD Plans

No plan survives contact with the enemy
Hellmuth von Moltke

Current Plans

- Optimizing the DBD detector (performance, cost)
- Continuing Detector R&D
- Engineering studies
- Establishing SiD Consortium
- Waiting for news from Japan ;-)

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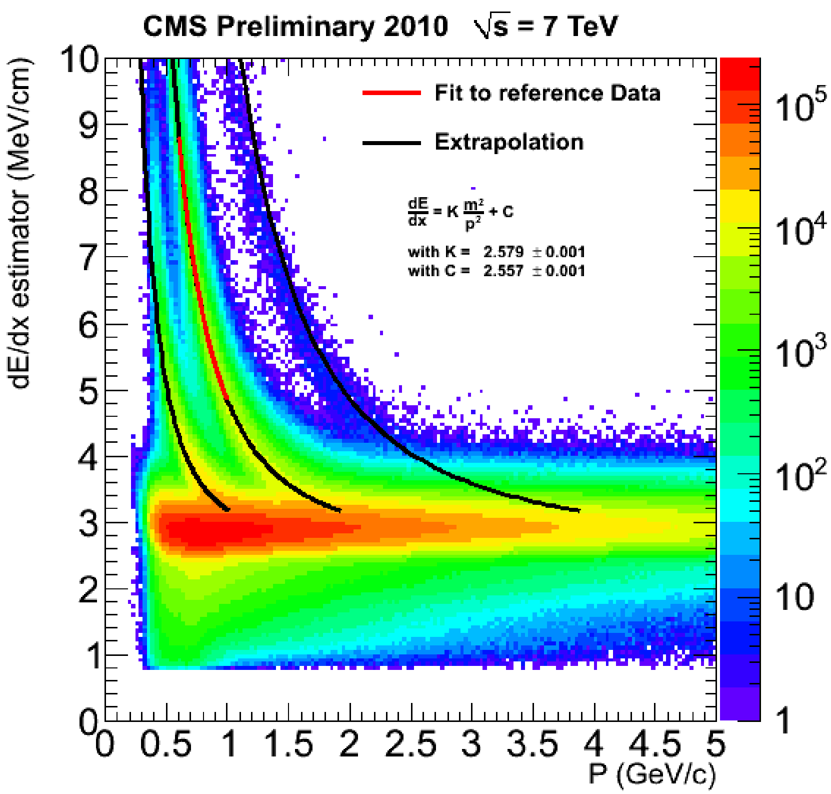
The DBD detector

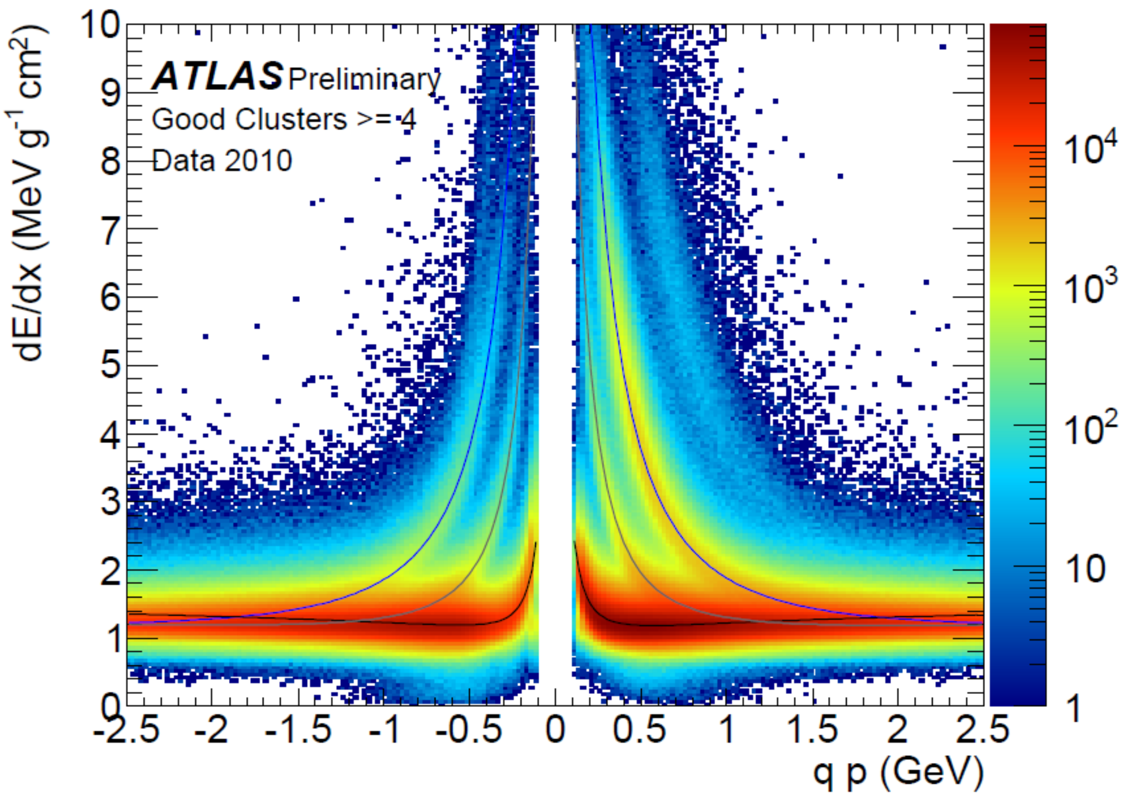
- The current SiD has been optimized with a cost-constraint in mind
- Detector has performed very well in all benchmarks
  - That doesn't mean we can lean back ...
- Now's a window of opportunity to revisit a few choices
- Will focus on
  - Tracker design
  - ECAL depth
  - HCAL technology and depth

The Tracker

- CMS has answered the question
  - Is silicon stand-alone feasible
  - In an harsh environment
- The basics mechanical structures have been demonstrated
  - ATLAS and D0 used carbon fiber super-structures
- SiD Tracker performs well
  - Meets performance goal
- Can we do better ?
  - Make barrel a bit longer
  - Remove more material from the endcaps
  - Increase granularity in the forward region
- Revisit tracking at the same time

dE/dx





- The folklore
  - Can't do dE/dx with silicon tracker
  - ATLAS and CMS shown otherwise (with low resolution front-ends)

ECAL depth

- SiD's ECAL is the most expensive component
  - Obvious question: do you really need 30 layers
- First studies indicating
  - Maybe not ..
- Need to study this with SiD
- No intention to move away from SiW
  - Need compact ECAL to fit inside the coil

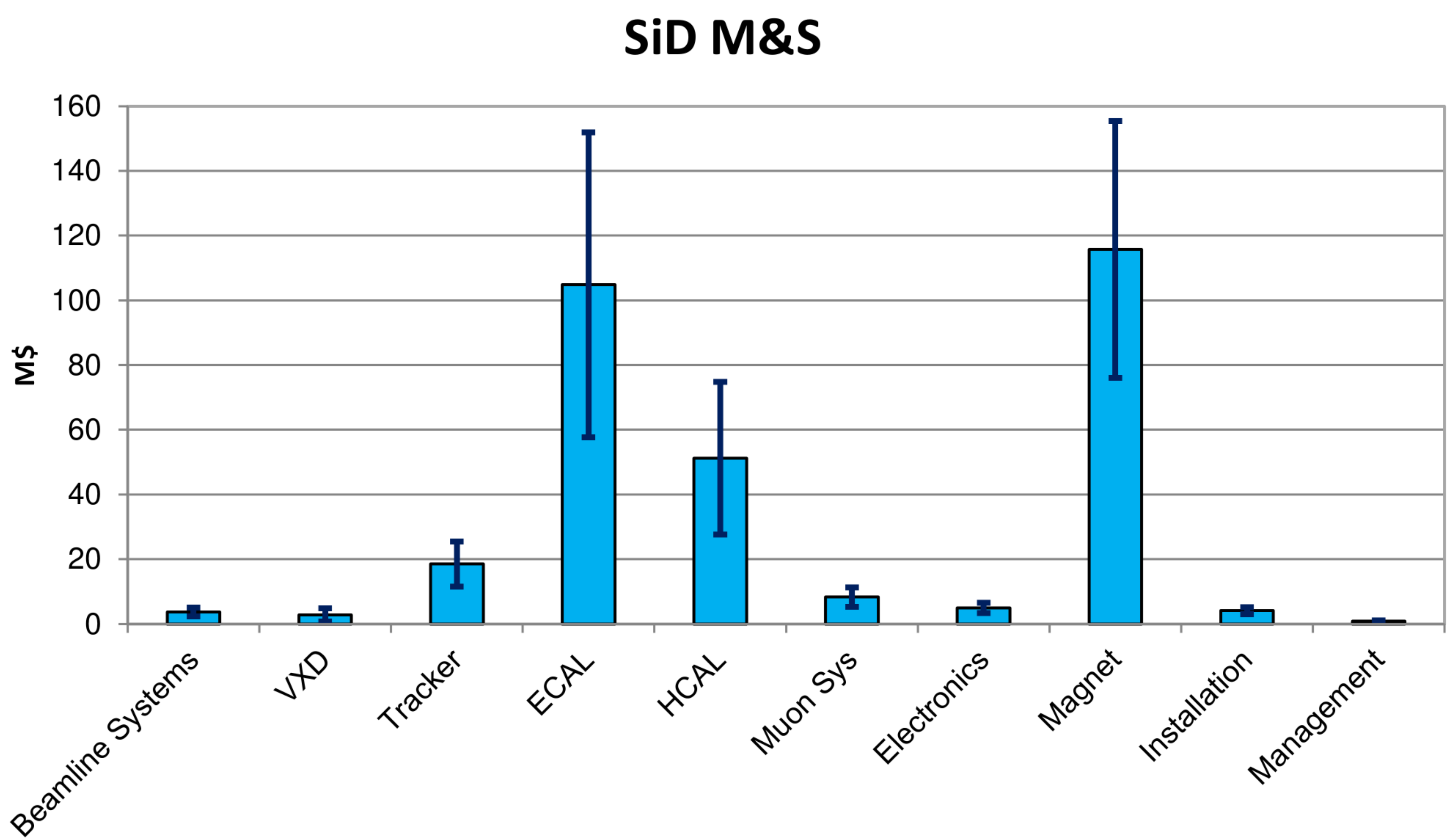
HCAL technology

- DBD baseline was
  - Digital HCAL using RPC's
  - Worked well for the simulations
- Three options
  - Scintillator AHCAL
  - DHCAL with GEMS/Micromegas
- Revisit this
  - Do we see performance differences
  - Engineering implications
  - Cost

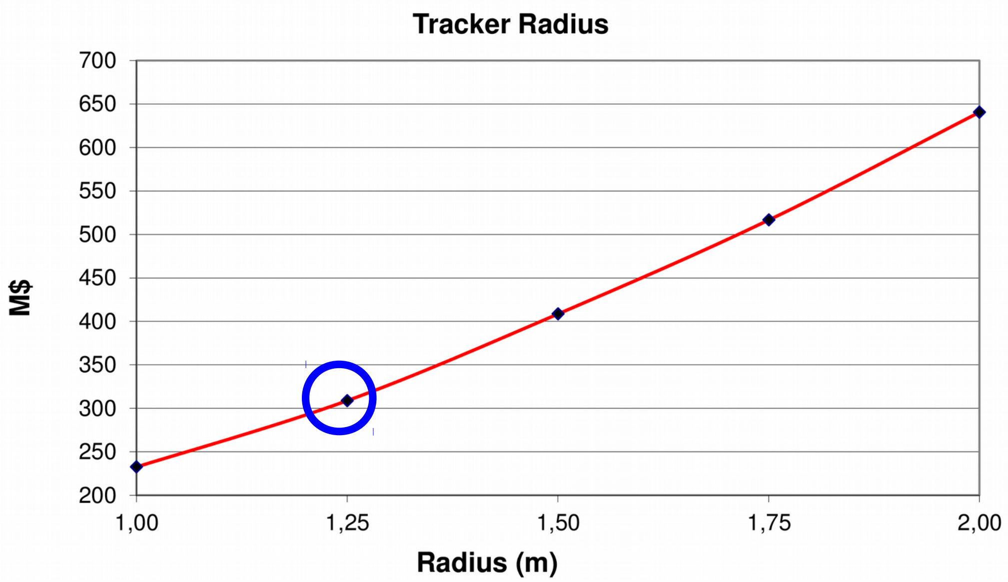
Unnderstanding Cost

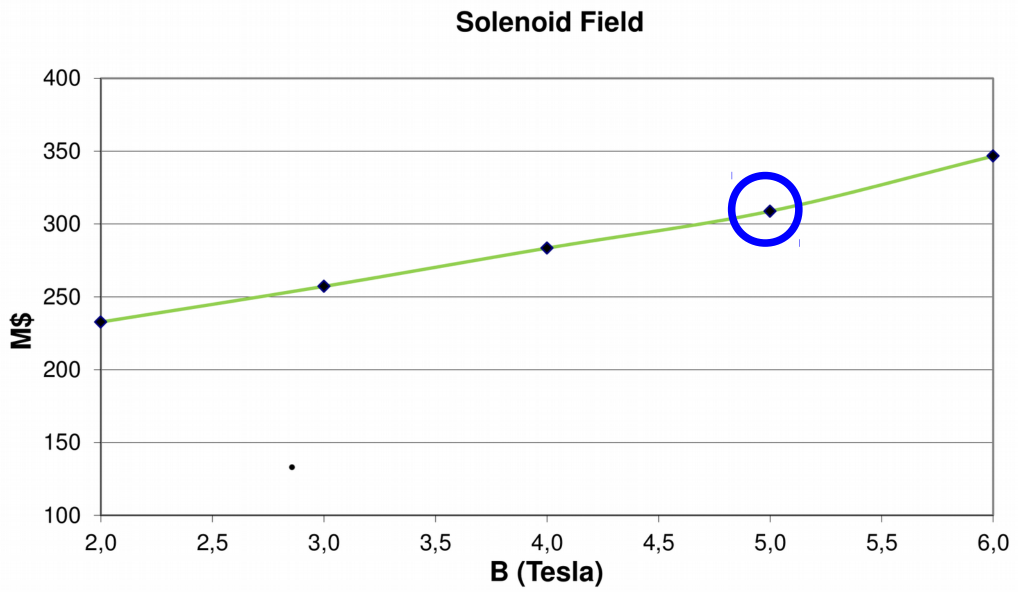
- SiD assumes common unit costs
  - As agreed by all groups
- Assuming "almost everything beyond the platform" is machine cost
- Follows machine costing model
- Costs in 2008 US-S
  - M&S : 315 M$
  - Contingency: 127 M$
  - Effort: 748 MY

Costing M&S


SiD M&S
M$
160
140
120
100
80
60
40
20
0
Beamline Systems
VXD
Tracker
ECAL
HCAL
Muon Sys
Electronics
Magnet
Installation
Management

Cost Dependence



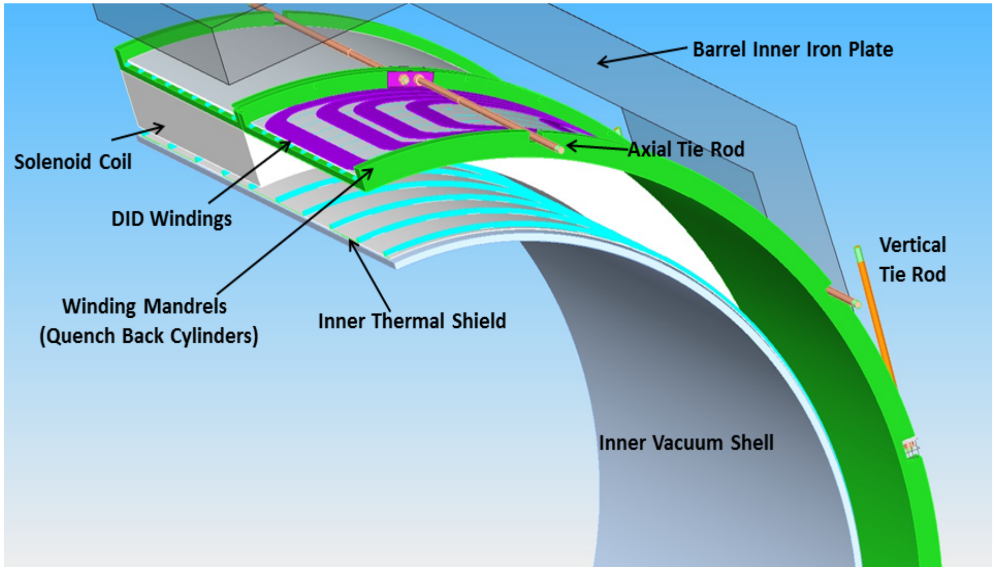


- Parametric Detector costing model allows study of main parameter dependencies
- Shown is Base M&S cost
  - Labor and Contingency excluded

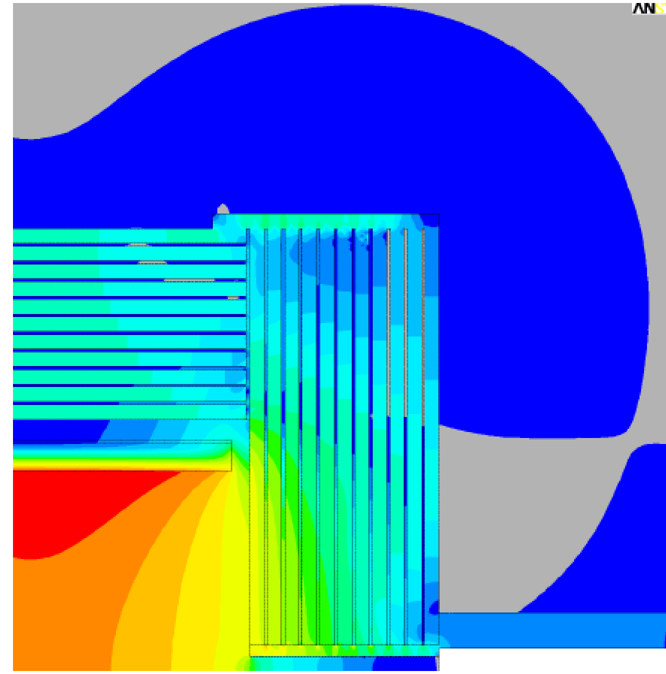
Cost Sensitivity

- How the magnet is costed
  - SiD assumes magnet made by industry (risk is with vendor)
  - Change to CMS-style model (Collaboration takes risk)
- Cost Sensitivity analysis (double unit costs)
  - Silicon sensors and magnet have largest impact
  - 26 and 14 % cost increase respectively
- "Optimizing costs"
  - Half the price of silicon, CMS-style magnet pricing, reducing RPC costs
  - Total SiD cost changes from 315 to 222 M$

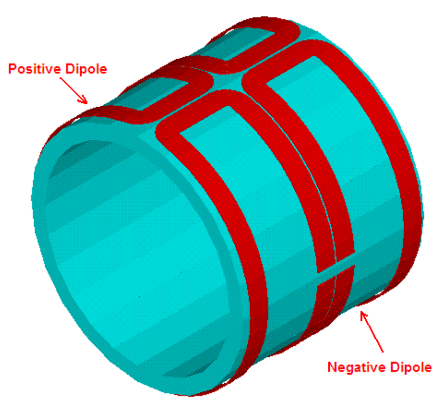
SiD Solenoid

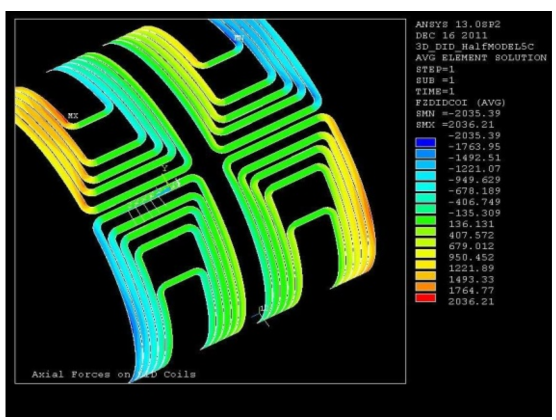


CMS style conductor – others/variation may be developed.

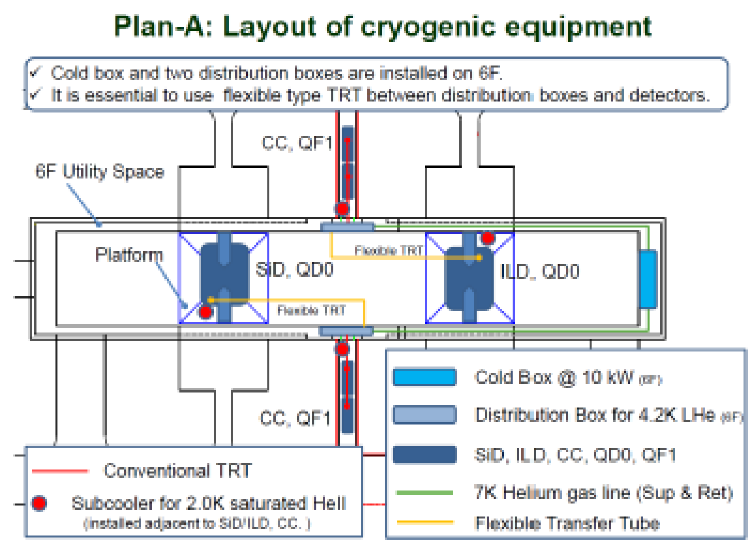


Field map – external (blue) 200 G





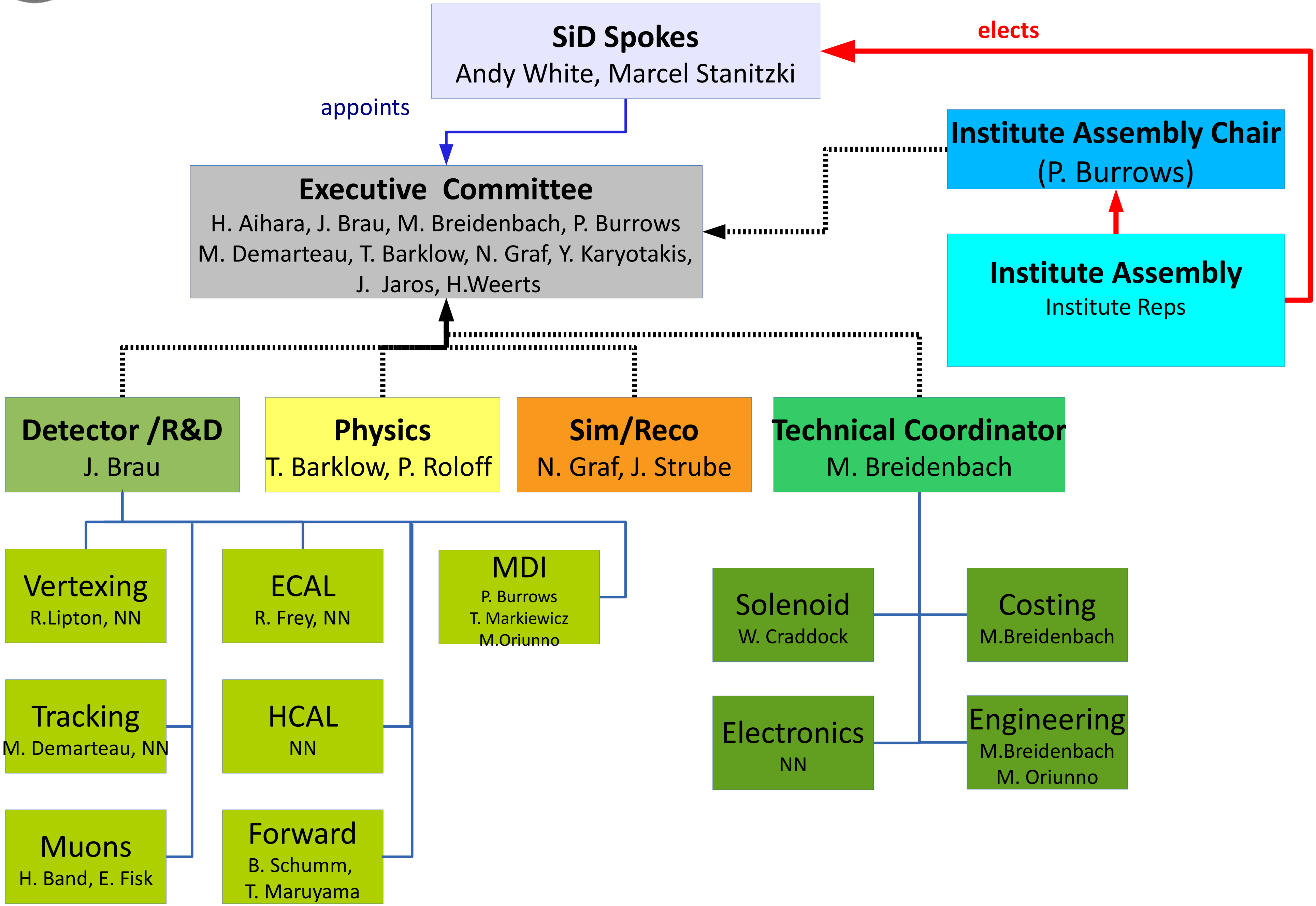
Detector Integrated Dipole



SiD Consortium

- As a next step towards project realization, we are going ahead with establishing the “SiD Consortium” as a precursor to a full collaboration.
- SiD will remain open to all interested people and groups
  - SiD is neither a closed nor exclusive club
- Membership in SiD
  - Representation in the Institute Board (IB)
  - Actively take part in decisions
  - Become an Author (once we start having SiD publications)
- Both individuals and institutes can be members
- How to become a member
  - A letter to the Institute Board Chair
  - Vote on membership by the IB

Draft Organigram



New faces

IB char
Philip Burrows
Oxford

RD Coordinator
Jim Brau
U Oregon

Technical Coordinator
Marty Breidenbach
SLAC

Keeping updated

- We have a new *sid-general* mailing list
- Easy to subscribe to
  - Send a mail with `subscribe sid-all John Doe` in the body to `listserv@slac.stanford.edu`
- List will be used for
  - Meeting and Workshop announcements
  - General SiD news

Summary

- The DBD is done !
- DBD detector has clearly demonstrated its potential
- Window of opportunity to study design choices
  - SiD has started looking at some of its DBD choices
  - This will continue for the coming years
  - Continue shaping SiD
- Waiting for news from Japan
  - Community needs a "plan" for this interim period