SiD

Philip Burrows

John Adams Institute

Oxford University

On behalf of the SiD Concept Team:

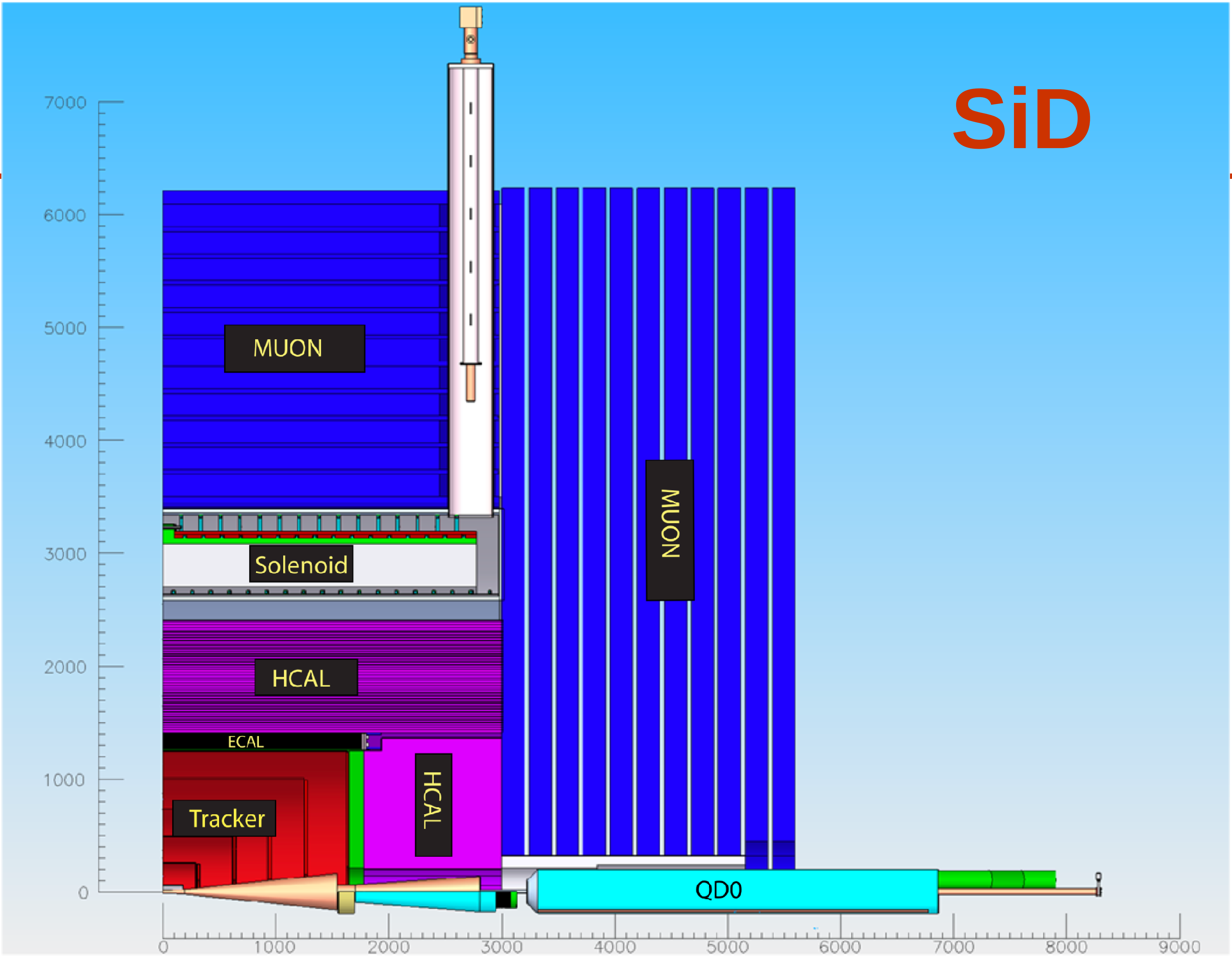
http://silicondetector.org

Thanks to: Andy White

Outline

- **SiD overview**
- **Preparations for 2012 Detector Baseline Document**
- **Outline of SiD subsystems + R&D status:**
  - **VXD + tracker**
  - **ECAL**
  - **HCAL**
  - **muon system**
- **Machine-detector interface issues**
- **Summary**

SiD



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

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**

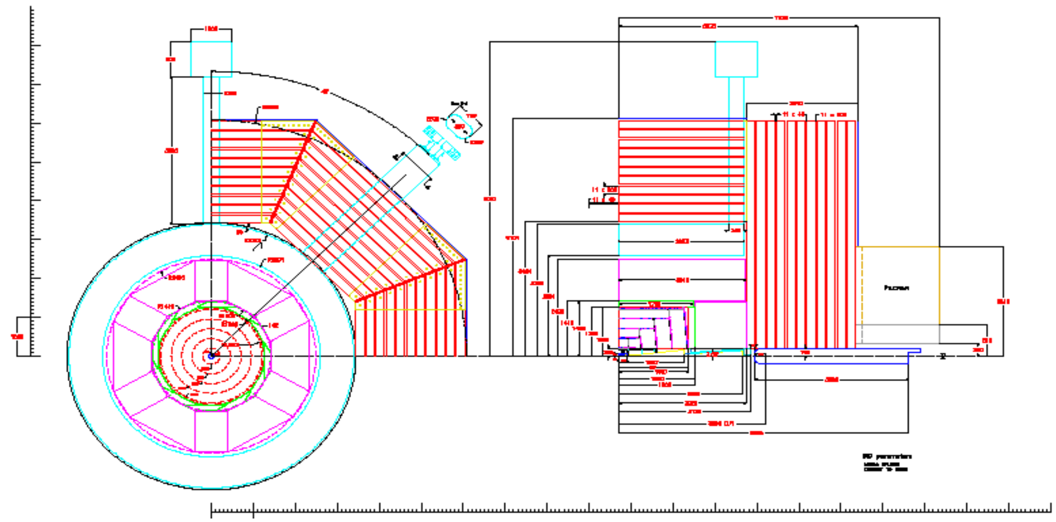
Calorimetry optimized for jet energy resolution

- **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 Global Parameters

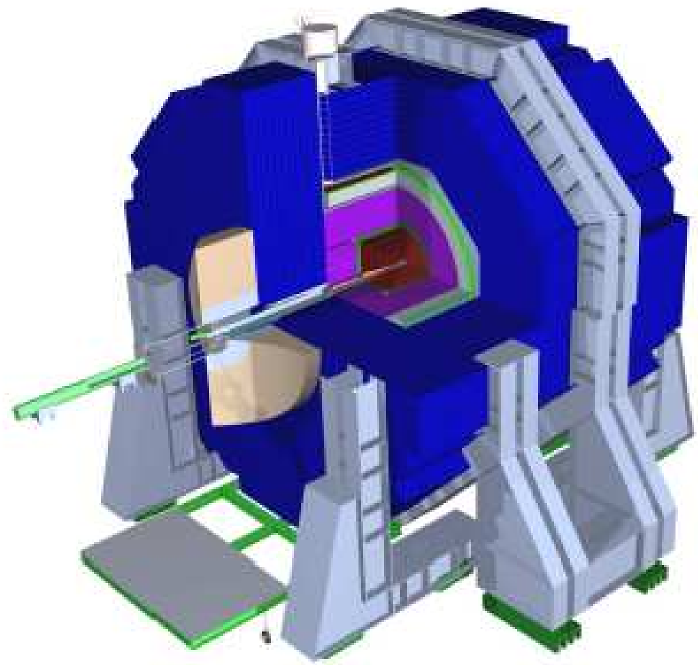


Detector	Technology	Radius (m)		Axial (z) (m)	
		Min	*Max*	*Min*	*Max*
Vertex Detector	Pixels	0.014	0.06		0.18
Central Tracking	Strips	0.206	1.25		1.607
Endcap Tracker	Strips	0.207	0.492	0.85	1.637
Barrel Ecal	Silicon-W	1.265	1.409		1.765
Endcap Ecal	Silicon-W	0.206	1.25	1.657	1.8
Barrel Hcal	RPCs	1.419	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

The SiD LoI (March 2009)

SiD Letter of Intent

31 March 2009



> 250 signatories

> 80 institutes

Validated by IDAG August 2009

Detailed Baseline Design

- **SiD accepts the need for detector concept reports to accompany the ILC TDP report in 2012**

- **Committed to deliver a Detailed Baseline Design (DBD) document**

- **October 2009: provided comprehensive work plan to Research Director**

SiD DBD scope

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

SiD Work Plan (October 2009)

- **Schedule**
- **Milestones**
- **List of resources**

October 23, 2009

The SiD Work Plan: 2010-2012

The SiD collaboration

I. Introduction

The SiD Work Plan has been designed to provide milestones, schedule, and a list of resources needed to develop a detailed baseline design of the SiD detector, suitable for producing a Detector Technical Report by the end of 2012 to accompany the GDE's Technical Report. With the GDE's Technical Report, it is to serve as a proposal to the world high energy physics community to engage in the construction of the ILC and its detectors. Like the GDE report, the Detector Technical Report is to make a compelling case that detectors capable of fully exploiting the physics potential of the ILC are feasible, cost effective, and based on demonstrated detector technologies. Specifically, the Detector Technical Report addresses the Work Plan proposed by the ILC Research Director, which calls out the following goals for the Technical Reports:

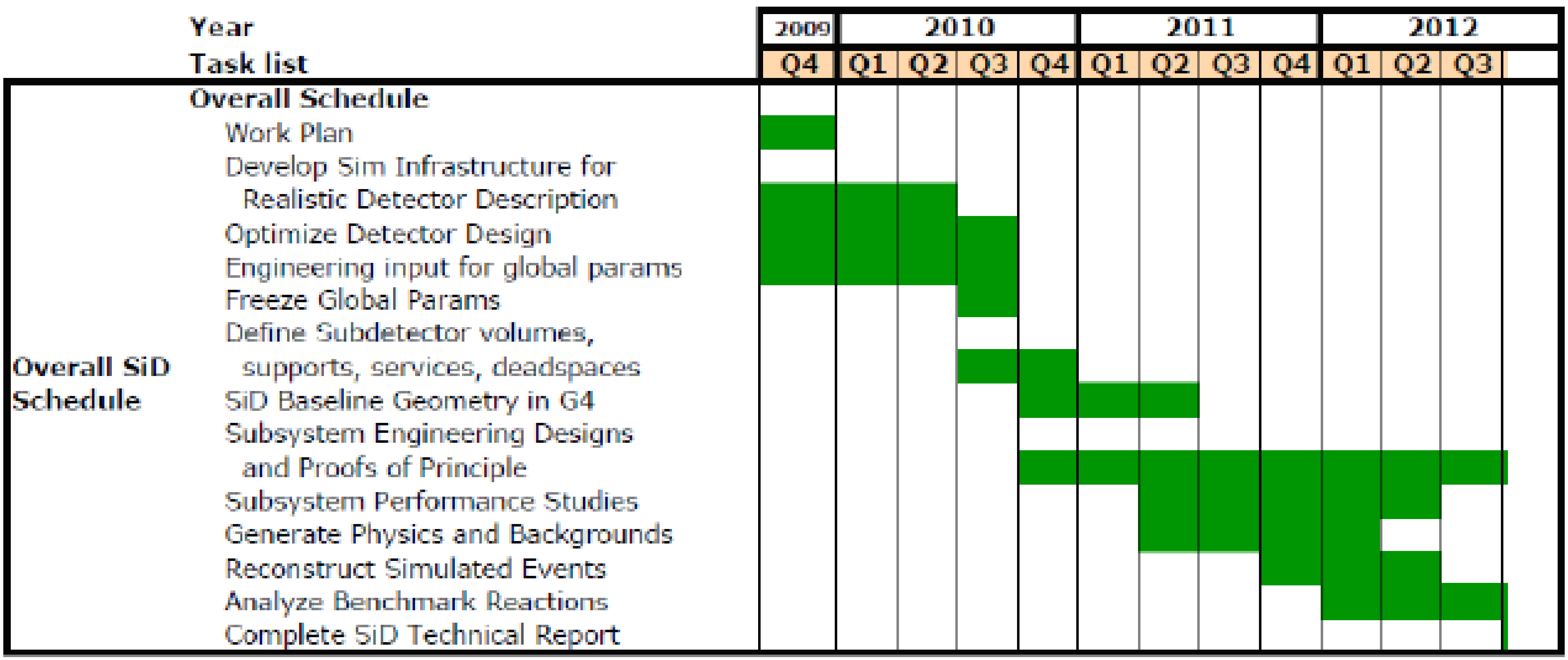
- Demonstrate proof of principle for critical components
- Define a feasible baseline design
- Develop a realistic integrated mechanical design for the detector
- Develop a correspondingly realistic simulation model of the detector
- Develop the push-pull mechanism and procedures needed to interchange ILC detectors
- Simulate and analyze updated benchmark reactions with a realistic detector model, including the effects of backgrounds
- Simulate and analyze new benchmark reactions at 1 TeV
- Develop an improved cost estimate

This document is the natural outgrowth of the SiD R&D plan which was included in the SiD Letter of Intent. It elaborates the plans put forward there.

This document also extends the SiD R&D plan in an essential way, by including estimates of the resources needed to fulfill the goals of the Research Director's Work Plan. As will become clear, the resources required to produce a believable Detector Technical Report have not yet been secured. Perhaps the most important use for the present document is to quantify the differences between resources in hand and those needed to produce a credible proposal, in the hopes of thereby facilitating securing additional support.

SiD has attempted to adopt a minimalist approach in estimating the resources needed for this next phase of detector development. Our conception of the Technical Report differs from the common notion of a "technical design report", in that it doesn't attempt to produce full engineering designs of all the detector components, nor does it include production and testing of full detector prototypes. These are not imaginable with the present level of support. Rather it attempts to establish technical feasibility for key detector systems, conceptually engineered designs of detector subsystems, and proofs of principle of key engineering assumptions, in addition to an accurate rendition of detector and physics performance with a level of simulation detail previously unmatched in high energy physics proposals.

SiD Work Plan: global schedule



Similar detailed schedules for all subsystems

SiD Work Plan: global resources

Appendix II: Resources required and available.

Version 0.6 10/23/09

		SiD all	2010		2011		2012	
			Need	Have	Need	Have	Need	Have
Summary	SiD all	Staff	18.7	11.7	19.0	11.1	18.5	10.3
		Postdoc	16.0	4.5	19.0	3.5	19.5	3.5
		Engineering	16.0	7.9	16.0	7.8	13.5	6.8
		Student	2.0	2.0	1.5	1.5	1.0	1.0
		M&S(k$)	1450.0	778.0	1270.0	453.0	1075.0	453.0

Discussed with Research Director + IDAG in Beijing (March)

- **Shortfall of resources in all categories**
- **Ongoing discussion of engineering resources**

SiD Work Plan: global resources

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Shortfall of resources in all categories

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SiD / ILD resources discussion

- **SiD and ILD each provided resources estimate**
- **Discussions with IDAG and RD (Beijing, March 2010)**
- **Since then, joint discussions:**

  Exploration of areas for joint approach

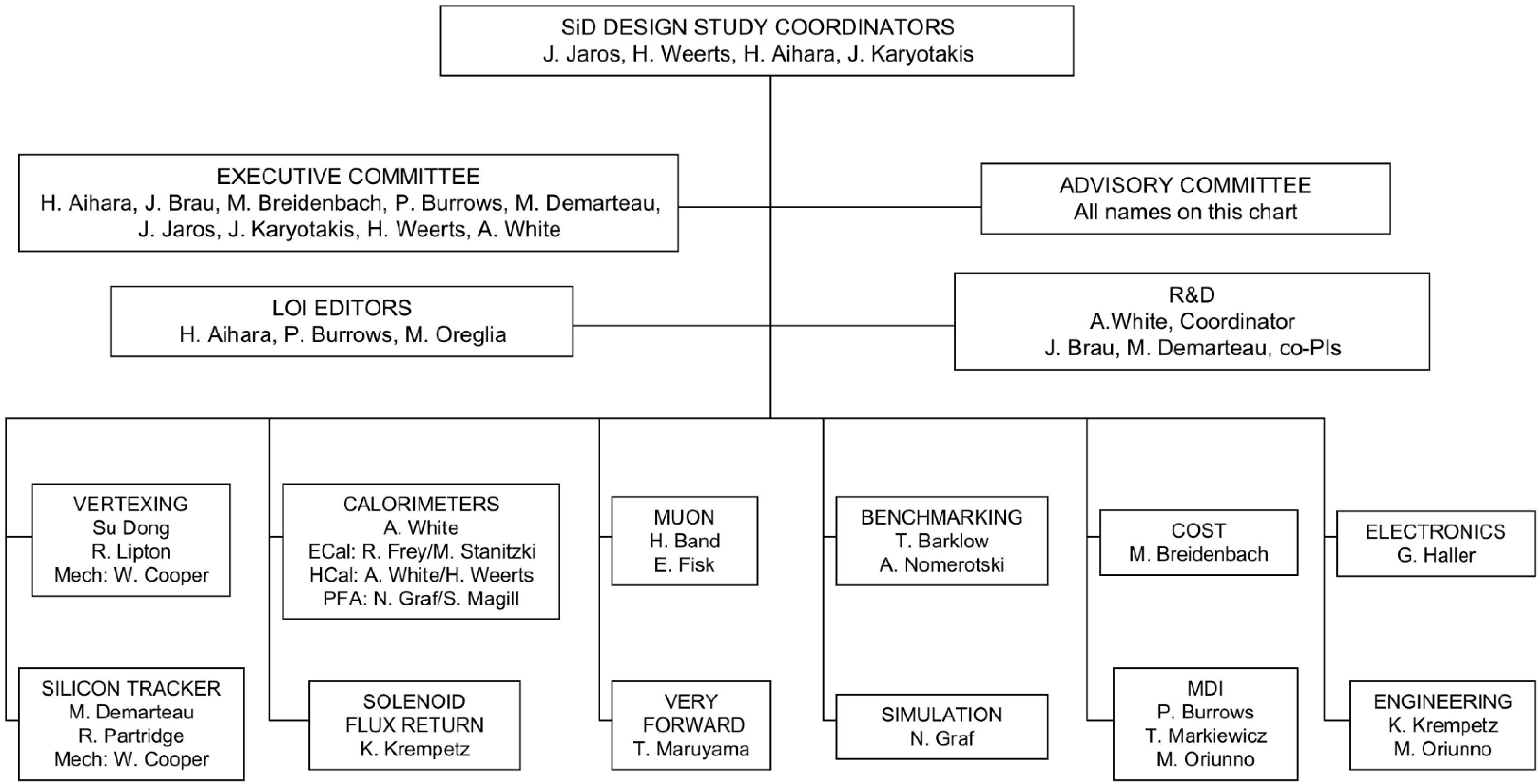
  costing, low-mass tracker mechanics, pulsed powering …

  Push - pull engineering resources (MDI-D Panel)

  Identification of areas for separate pursuit

→ Joint SiD / ILD document sent to RD this week!

SiD Organisation



SiD Meetings

- **Every 2 weeks:**

  SiD Executive Committee

  SiD Advisory Board

- **Twice / year: Global SiD meetings**

  Albuquerque (Oct 2009) and Beijing (2010)

Next SiD Workshop:

June 3-5, 2010 at Argonne National Laboratory

Argonne SiD Workshop

- **Review DBD 2012 goals:**

  Refine work plan + prioritise where appropriate

- **Discuss expanding engagement with CLIC:**

  Optimise scarce resources for R&D,

  including simulation software

  Definition of CLIC-compatible SiD

  Help with CLIC detector CDR

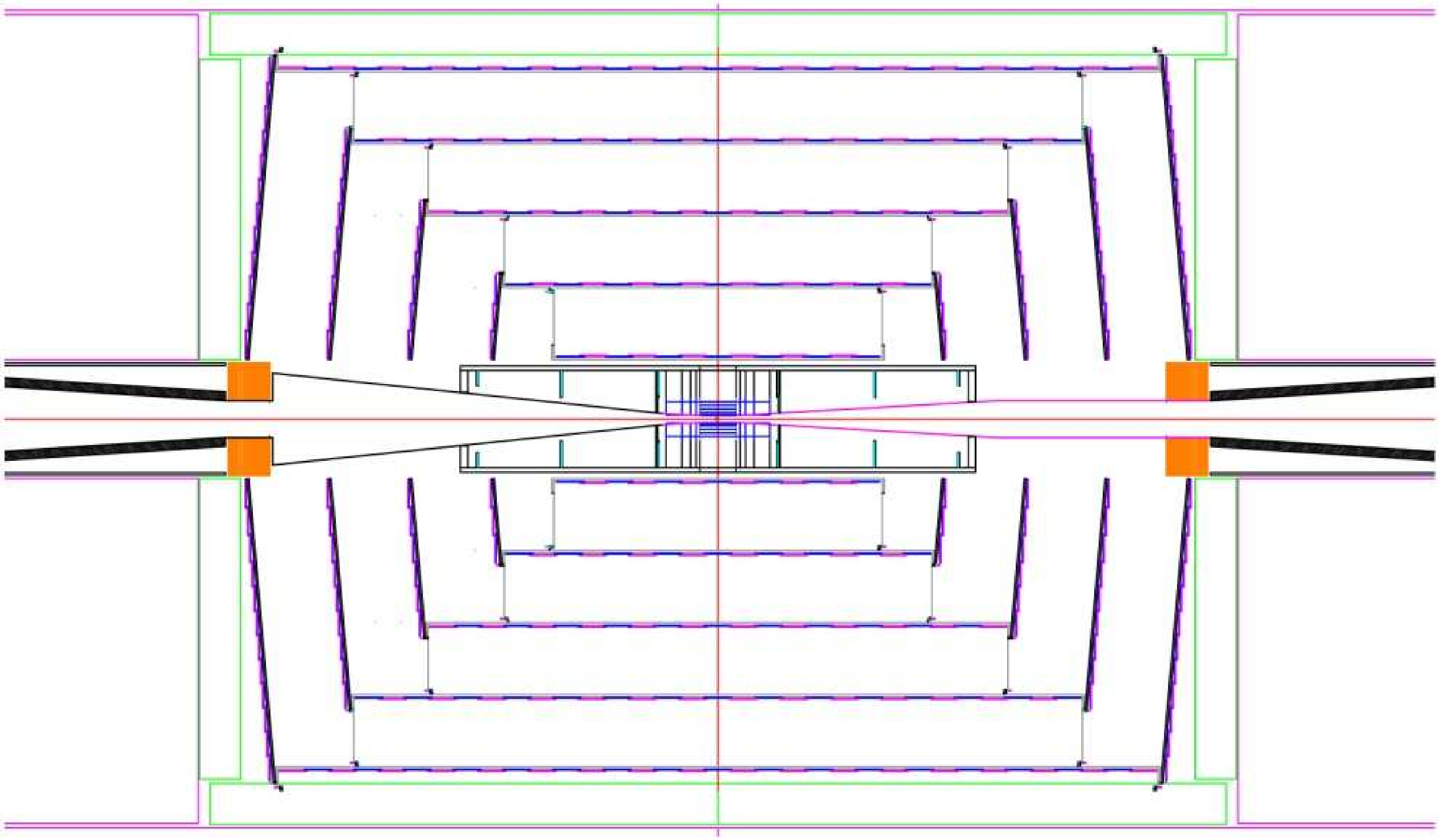
  Significant CLIC participation in workshop

ILC-CLIC Detector Working Group

- Felix Sefkow (CALICE/DESY)
- Francois Richard (WWS/Orsay)
- Lucie Linssen (CLIC/CERN)
- Marcel Demarteau (Detector R&D Panel/FNAL)
- Marcel Stanitzki (SiD/RAL)
- Mark Thomson (ILC/Cambridge)
- Sakue Yamada (RD/KEK)

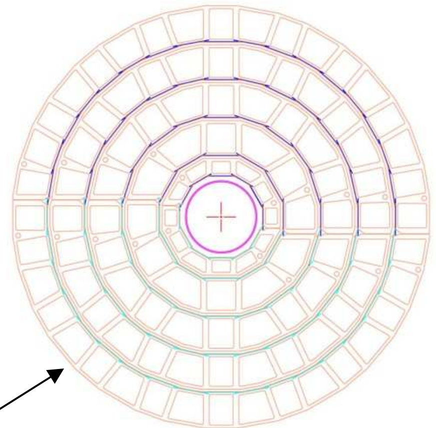
SiD subsystem status / R&D

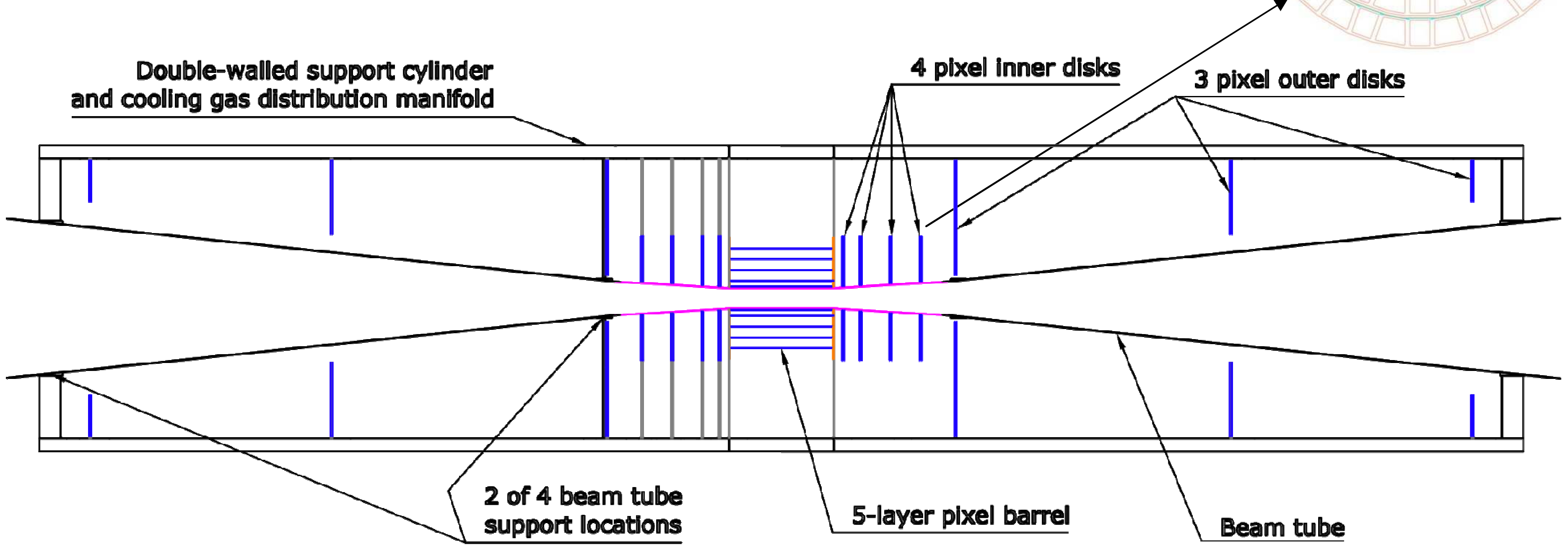
SiD Tracking System



Vertex Detector

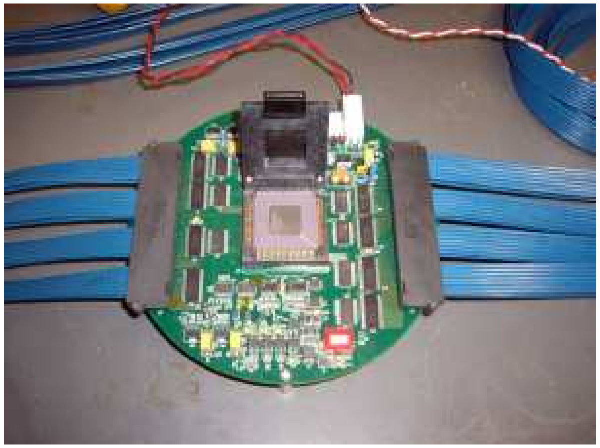
- Sensors glued on edges to form cylinders
- Gas cooled, power pulsed, low mass
- Sensor technology to be decided:
  Chronopix, 3D, DEPFET

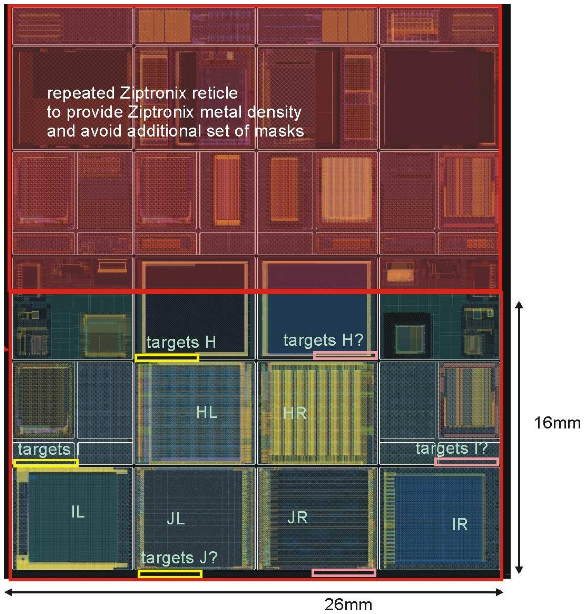


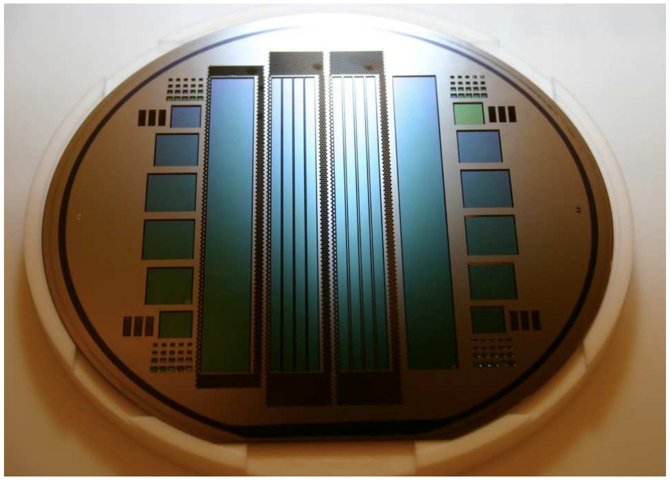


Vertex Detector Programme

- Demonstrate working sensor by 2012/3
- Mechanical design of sensor support structure
- Integration of cooling, powering, data transmission

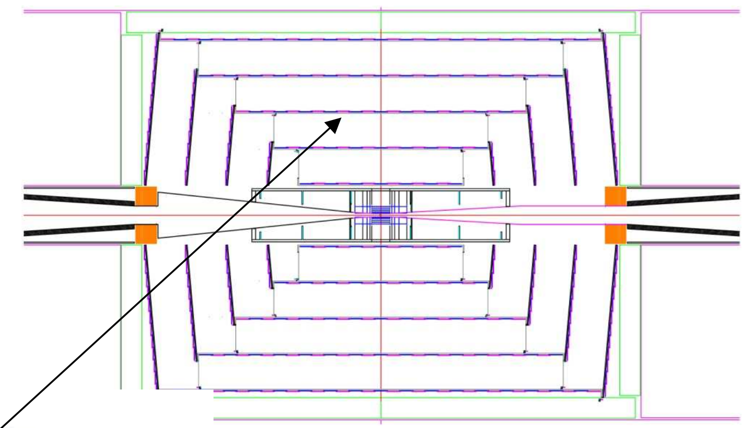


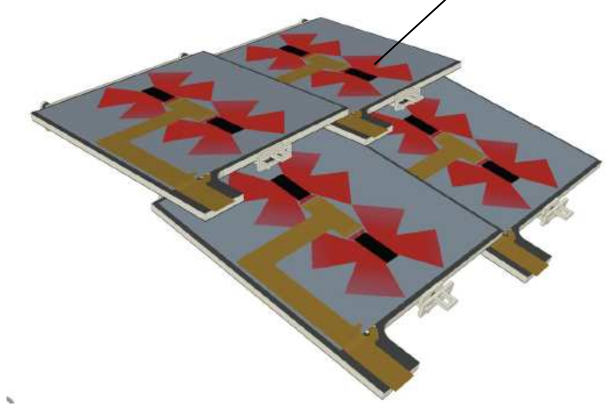




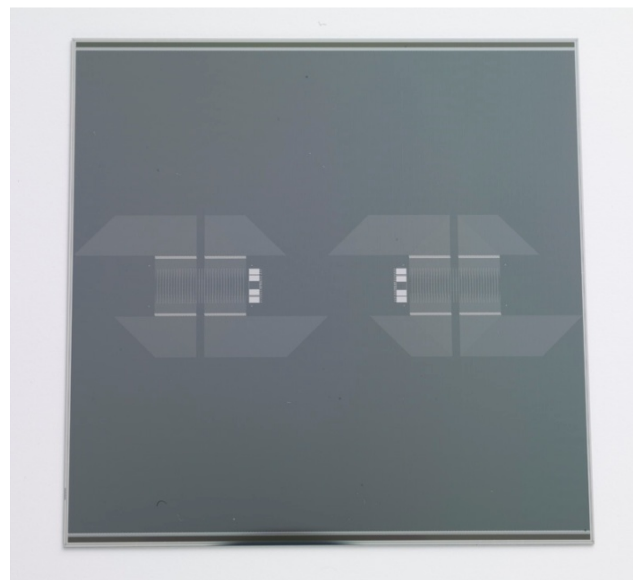
SiD Outer Tracker – Silicon strips

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



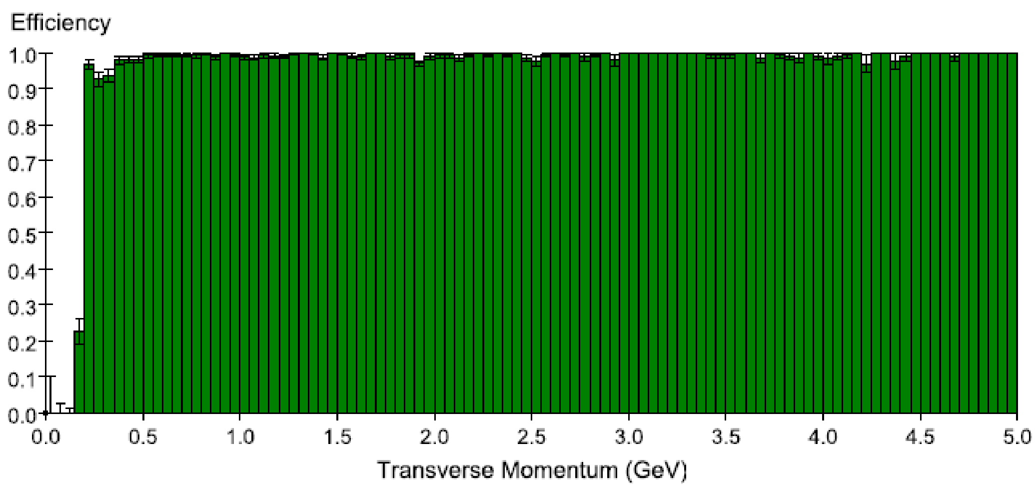


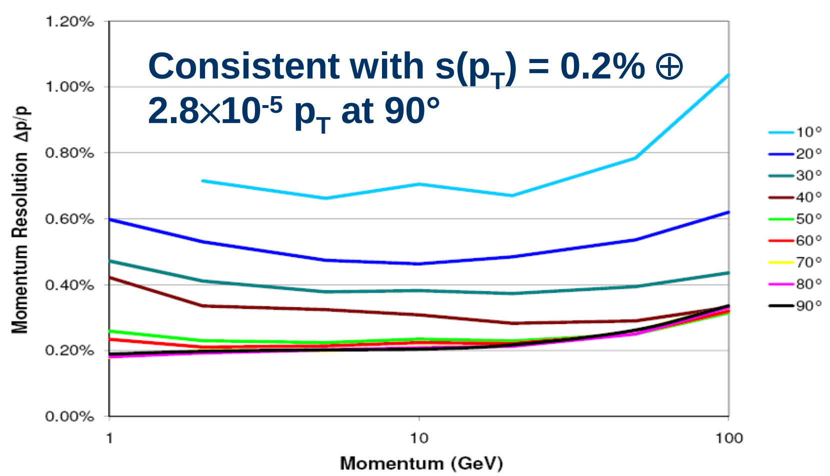
Tiling of tracking layer with Si sensors and on-board KPiX chips



Tracker Programme

- Design optimisation + performance studies
- Sensor tests (in 5T field), including with KPix r/o chip
- Power pulsing
- Mechanical stability of C fibre support cylinders
- FSI alignment system feasibility

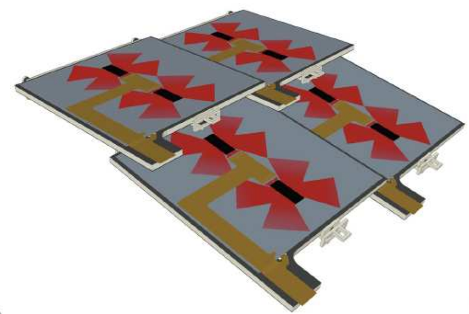




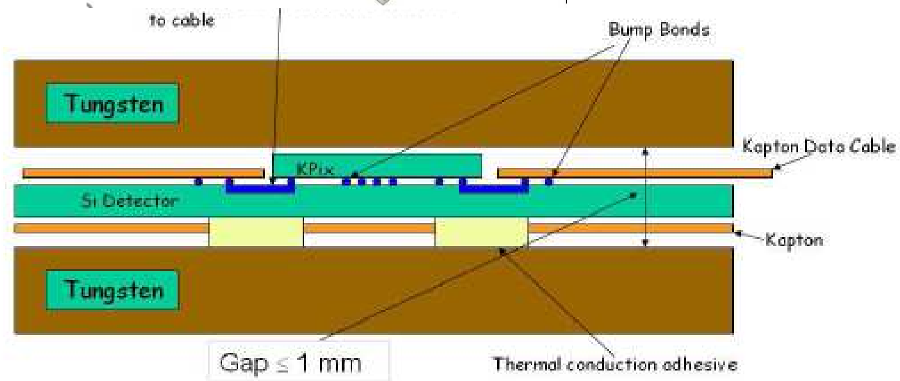
SiD Electronics

KPiX readout for all SiD subsystems except VTX and FCal

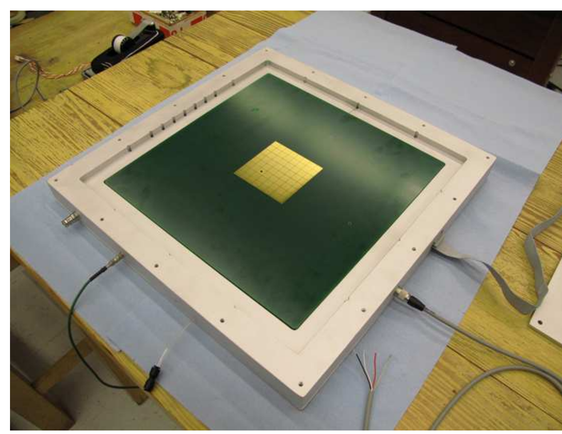
Tracker



ECal



HCal (GEM version)

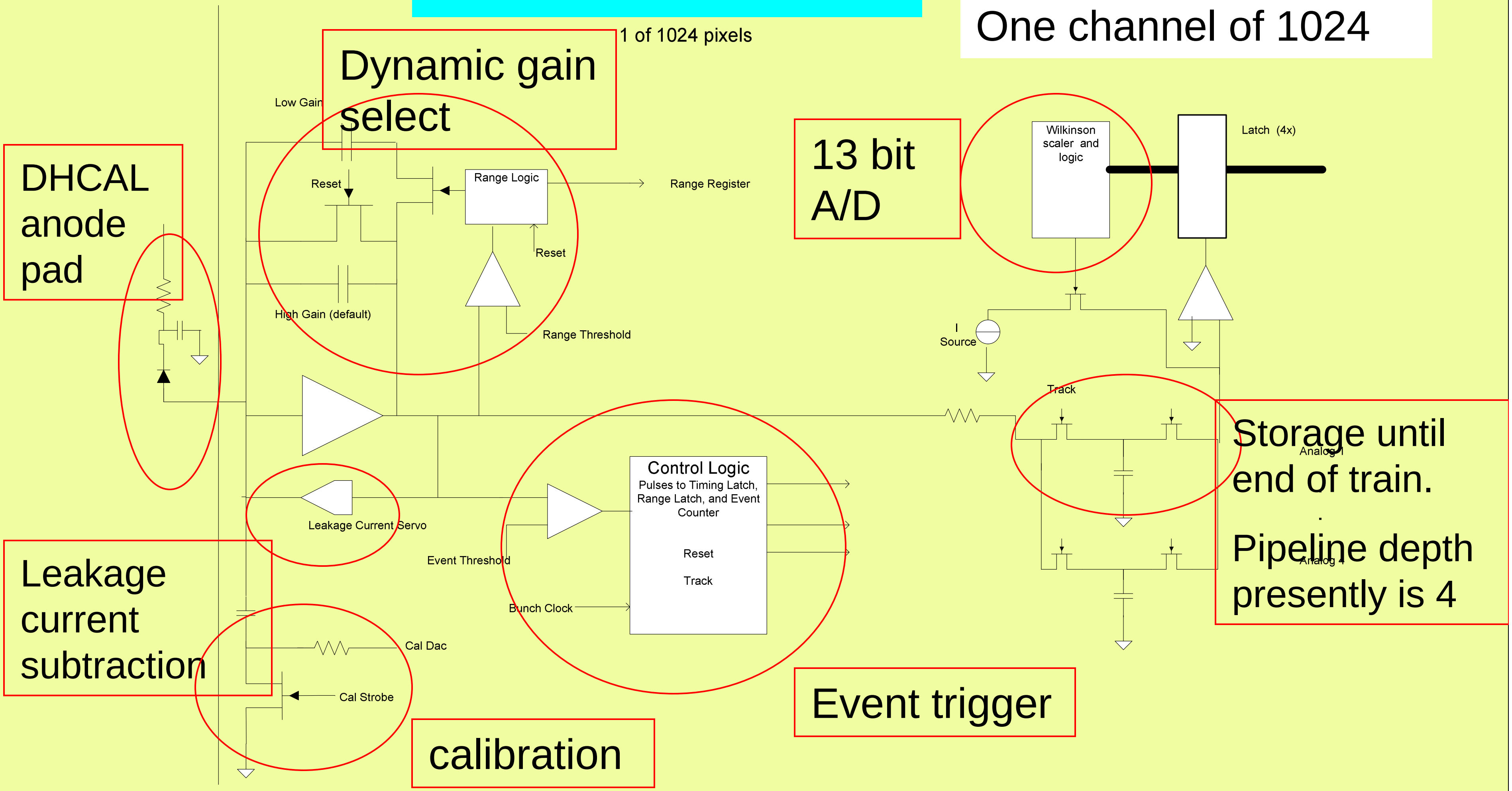


…and Muon!

KPiX/GEM/DHCAL

KPiX chip

One channel of 1024



Simplified Timing:

There are ~ 3000 bunches separated by ~300 ns in a train, and trains are separated by ~200 ms.

Say a signal above event threshold happens at bunch n and time T0.
The Event discriminator triggers in ~100 ns and removes resets and strobes the Timing Latch (12 bit), range latch (1 bit) and Event Counter (5 bits).
The Range discriminator triggers in ~100 ns if the signal exceeds the Range Threshold.
When the glitch from the Range switch has had time to settle, Track connects the sample capacitor to the amplifier output. (~150 ns)
The Track signal opens the switch isolating the sample capacitor at T0 + 1 micro s. At this time, the amplitude of the signal at T0 is held on the Sample Capacitor .
Reset is asserted (synched to the bunch clock) . Note that the second capacitor is reset at startup and following an event, while the high gain (small) capacitor is reset each bunch crossing (except while processing an event)
The system is ready for another signal in ~1.2 microsec.
After the bunch train, the capacitor charge is measured by a Wilkinson converter.

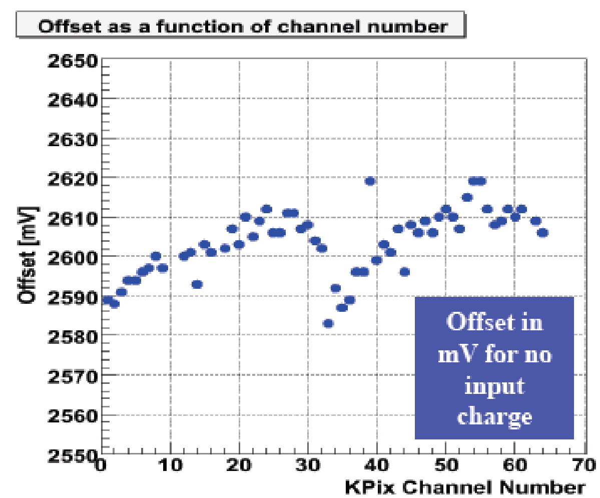
Electronics Programme

Demonstrate operation of 1024 channel version of KPiX chip

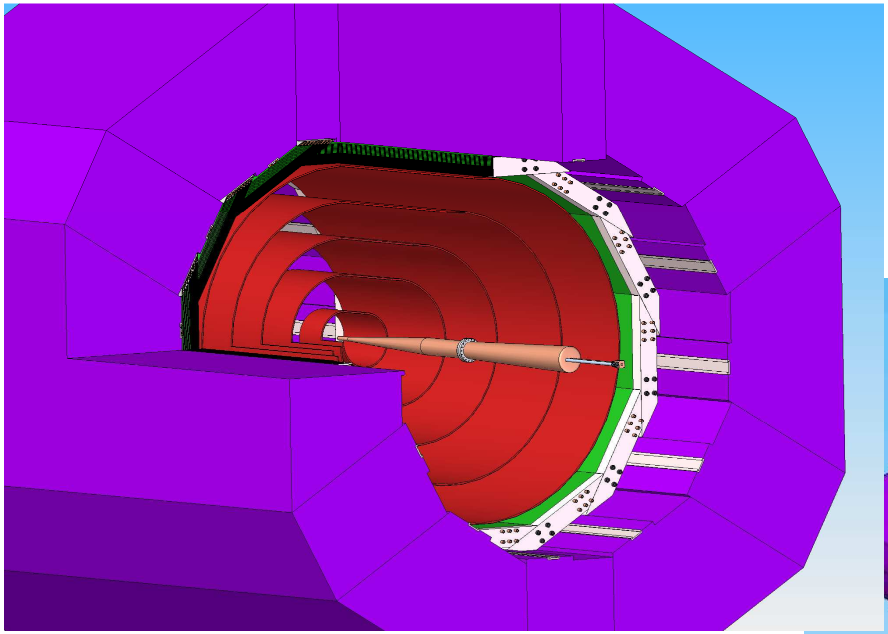
Develop + test control, readout, timing boards

Adapt and test KPiX readout to the tracker, calorimeters, and muon systems

Develop power distribution schemes for the vertex detector and tracker

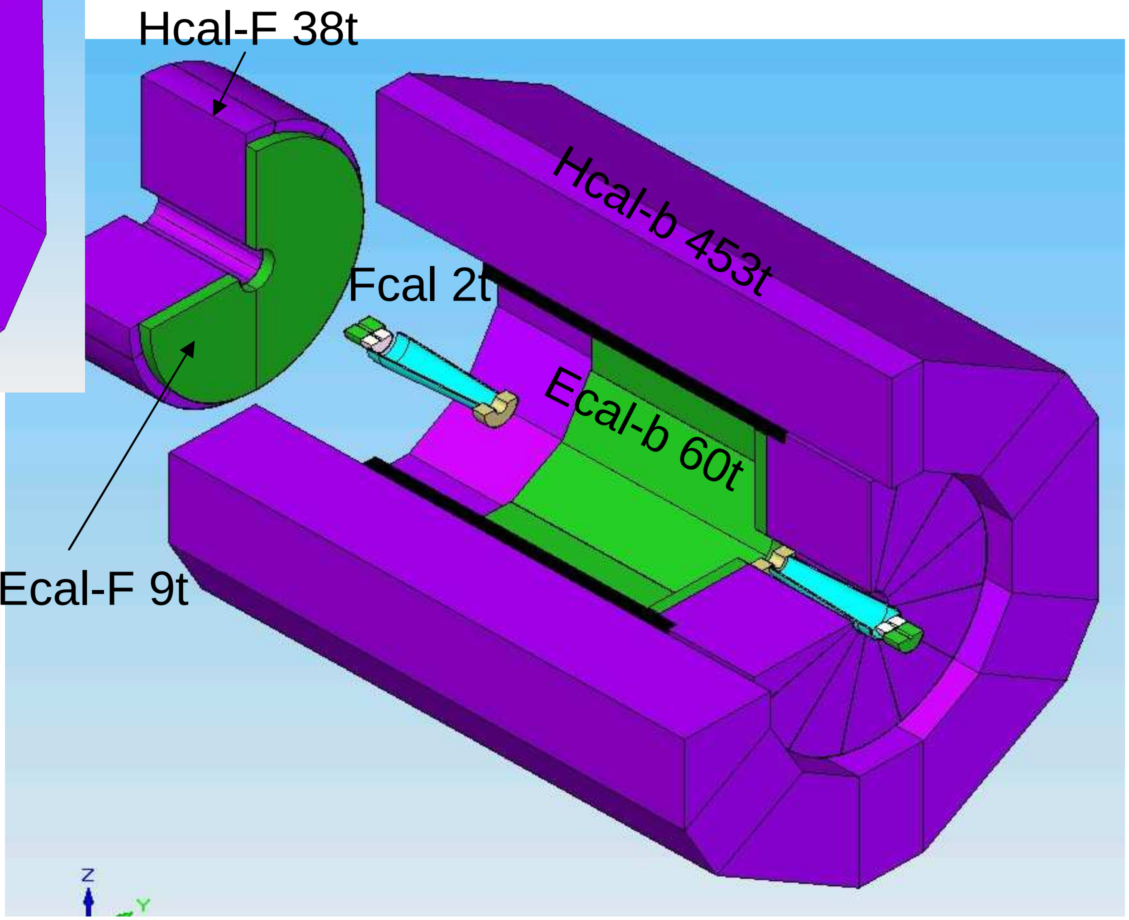


SiD Calorimeter System



ECAL: 26 X0 W

HCAL: 4.5 lambda Fe



PFA → jet E ~ 4%

EM Calorimeter (ECAL)

PFA requires high transverse and longitudinal segmentation and dense medium

Absorber	X_0 [mm]	R_M [mm]
Iron	17.6	18.4
Copper	14.4	16.5
Tungsten	3.5	9.5
Lead	5.8	16.5

Choice: Si-W <u>can</u> provide very small transverse segmentation and minimal effective Molière radius

- **Maintain Molière radius by minimizing the gap between W plates**
  1.25mm Si detector gaps → Preserve $R_M(W)_{eff}$= 13.5 mm
- **Requires aggressive integration of electronics with mechanical**
- **Pixel size ~ few mm^2**
- **Energy resolution ~ 15%/√E + 1%**

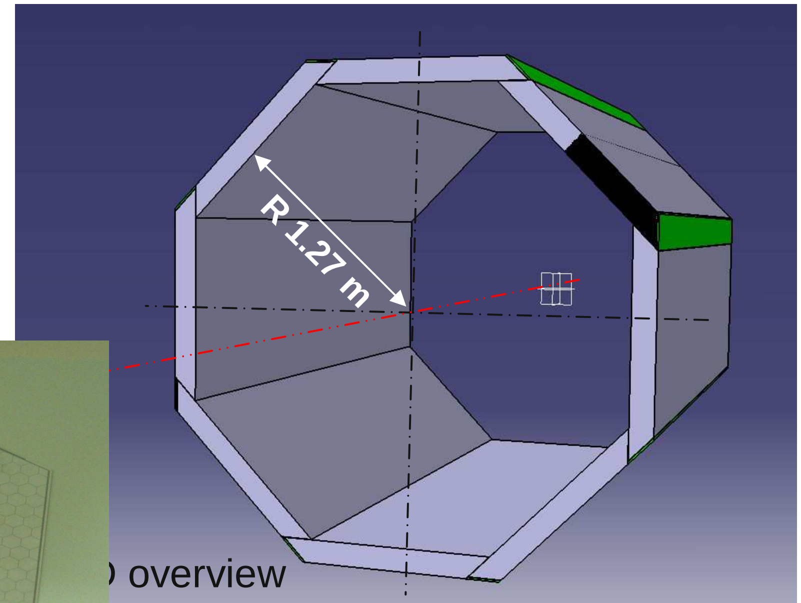
The Si-W ECAL

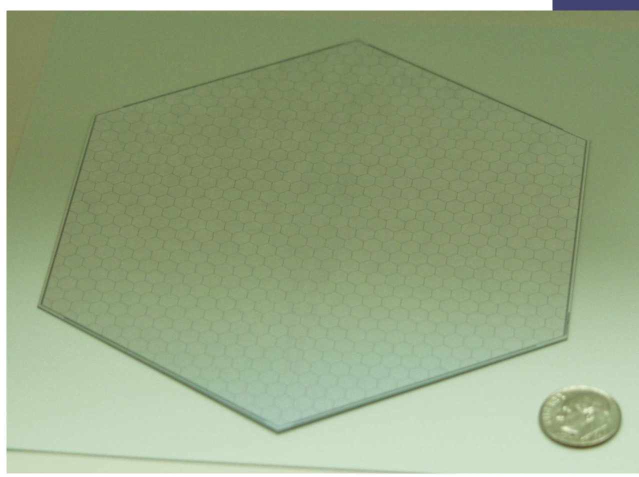
30 layer Si-W

- 20/10 configuration
- 2.5 / 5 mm W

16 mm² hexagonal Si-Pads

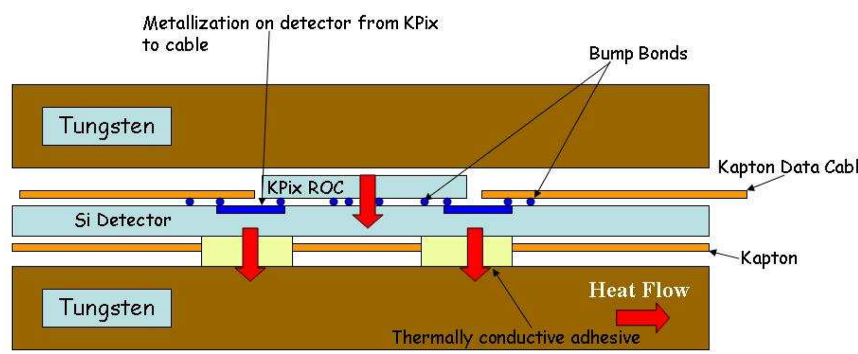
1300 m² Si area **(CMS 205 m²)**





KPIX Chip for readout

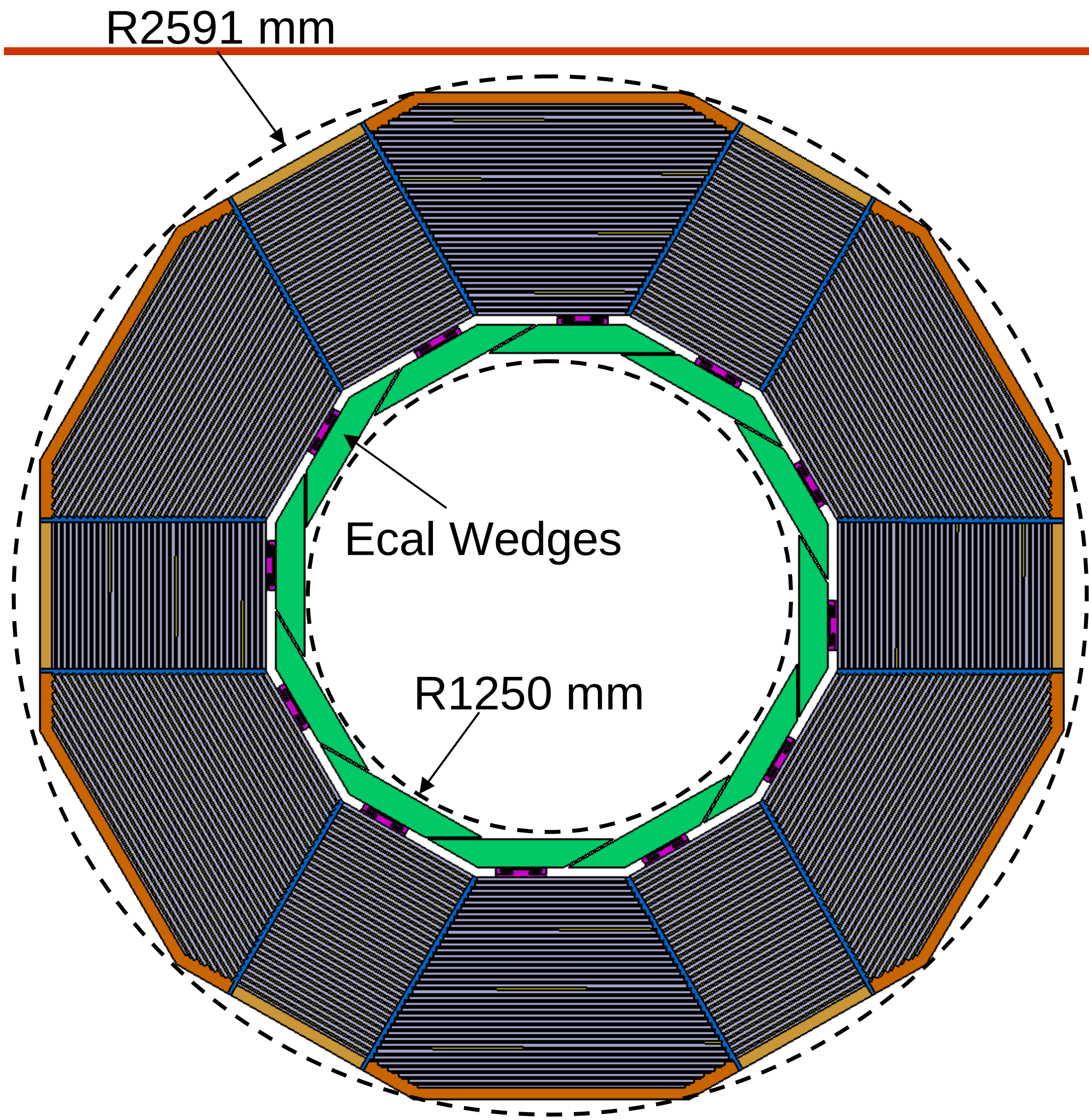
- bump-bondable
- 1024 channels
- time stamping of bunch Xing
- 4 buffers per pad
- < 40 mW/wafer (pulsing)

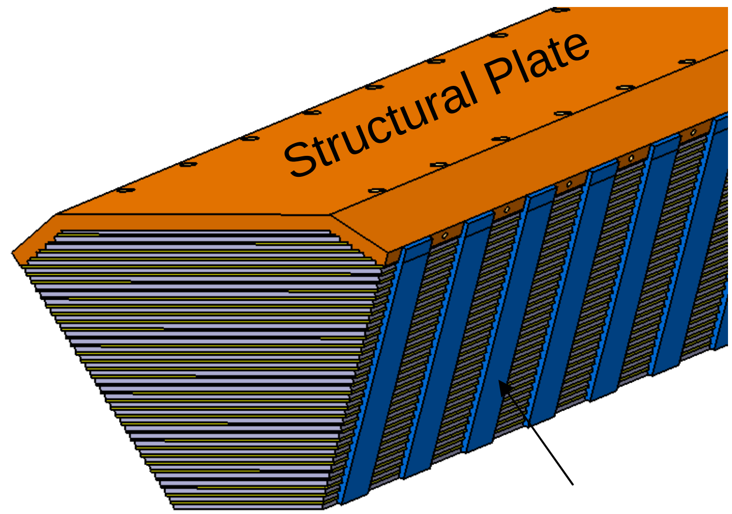


ECAL Programme

- **Design optimisation + performance studies**
- **Sensor R&D: bump bonding, cable design, KPix integration**
- **Mechanical feasibility + prototype**
- **Single tower prototype (2011) for beam testing**
- **Pursue alternative sensor (MAPS) for 'digital' calorimeter approach**

SiD HCal – example design





Nicolas Geoffroy - LAPP

Resistive Plate Chamber (Baseline)

Construction of $1m^3$ prototype RPC stack:

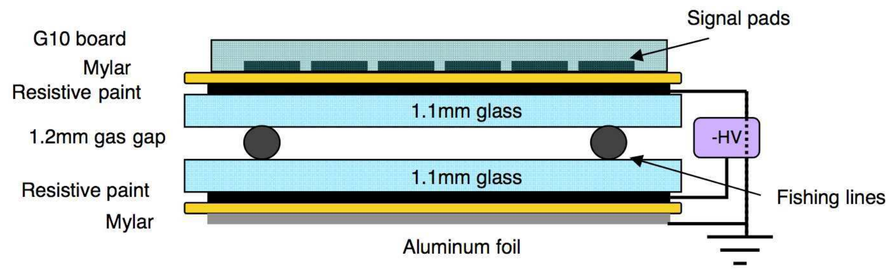
- 114 chambers + spares

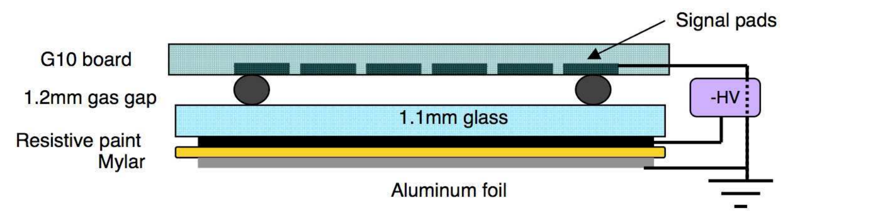
- Essentially all materials in hand

- 2 man-days/chamber

- 3 assembly lines

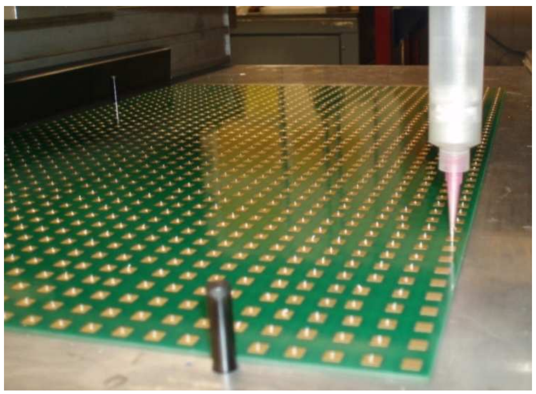
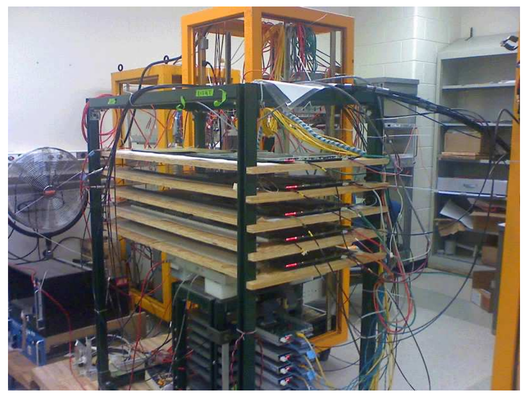
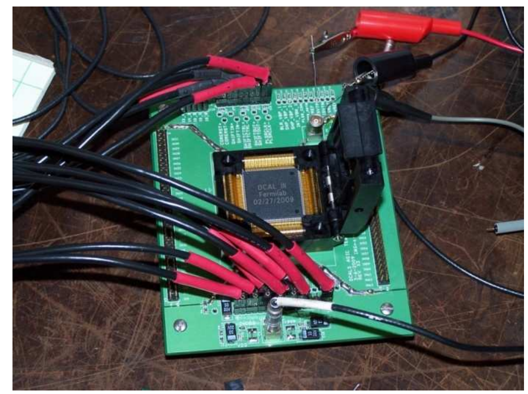
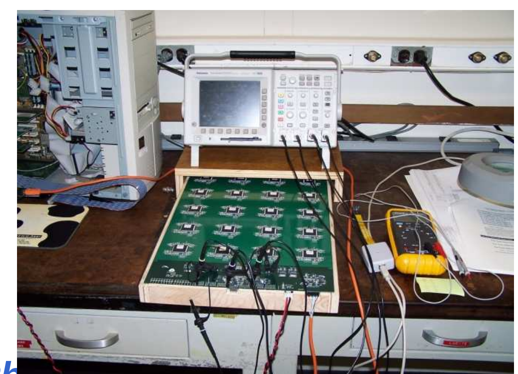
- Start tests at Fermilab in September (after shutdown)





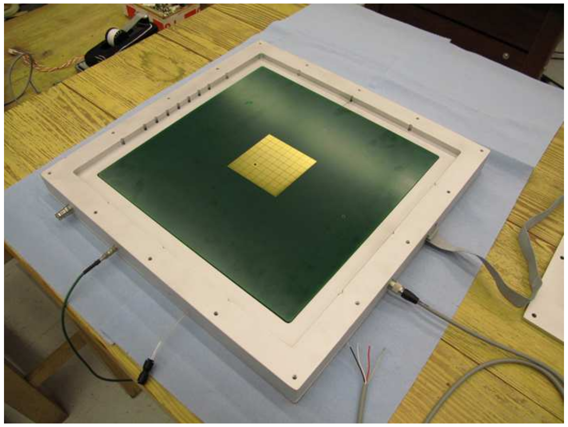
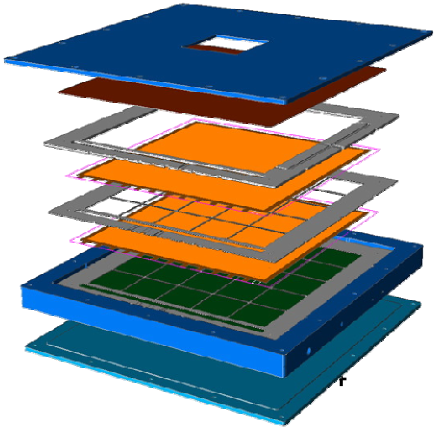
RPC chamber construction/services for 1m^3 stack



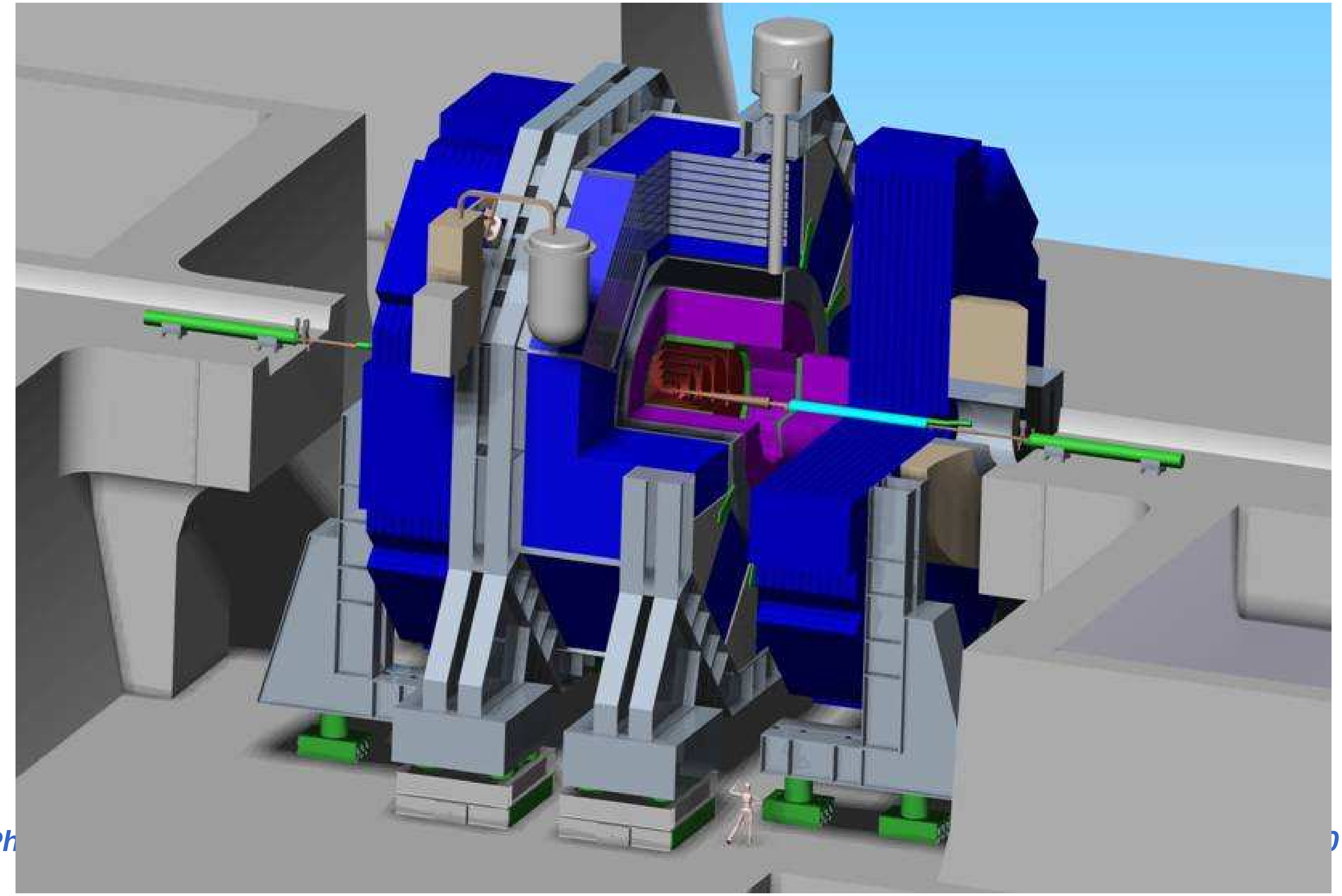






HCAL Programme

- Beam tests of cubic-meter prototype (CALICE)
- Technical prototype: gap thickness, gas + HV distribution …
- Alternatives: GEMs, Micromegas, scint. tiles …
- (Scintillator alternative pursued by CALICE)
- Crystal/PM calorimeter alternative


Muon System

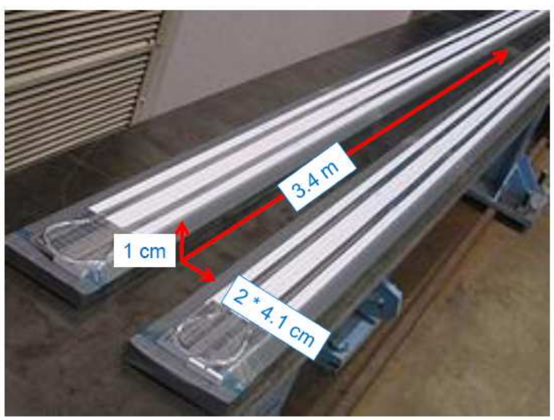


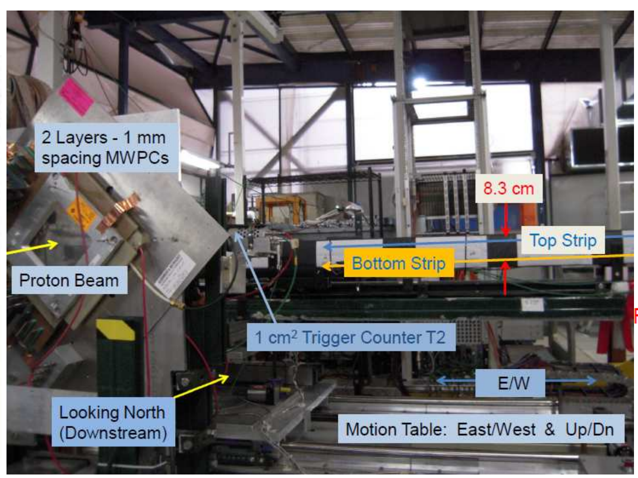
Muon System Programme

- **Two candidate readout technologies:**

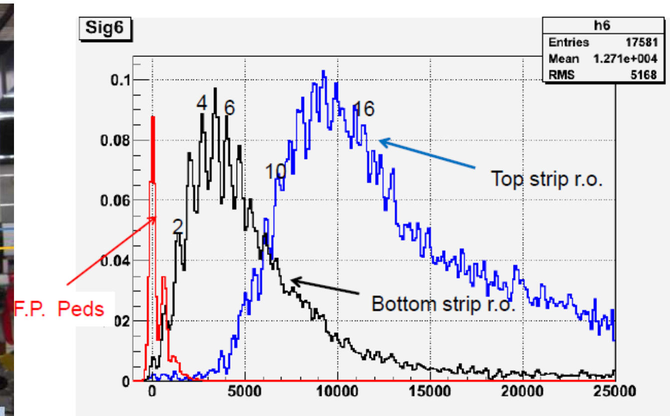
  RPCs, scintillator strips
- **Prototype chambers + r/o being developed**
- **Baseline selection mid 2011**
- **Iron will accommodate either choice**

T-995 Beam Tests at Fermilab MTBF





Beam in the top strip 10 cm from readout end.

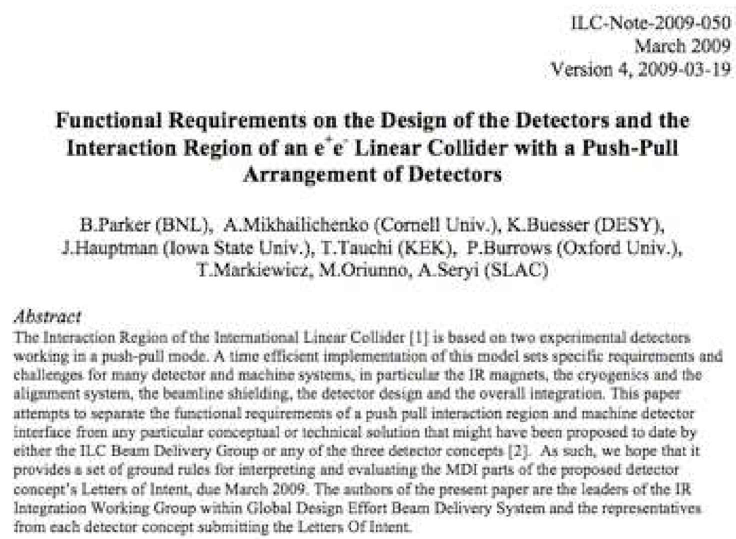


Runs 5045 and 5046 2/20/2010

Machine-Detector Interface

MDI functional requirements

- **SiD complies with MDI functional requirements document:**
- **Participate in MDI Common Task Group (Oriunno, Burrows)**
- **Working closely with ILD colleagues on relevant push-pull detector interface issues**



ILC-Note-2009-050
March 2009
Version 4, 2009-03-19

Functional Requirements on the Design of the Detectors and the Interaction Region of an e^+e^- Linear Collider with a Push-Pull Arrangement of Detectors

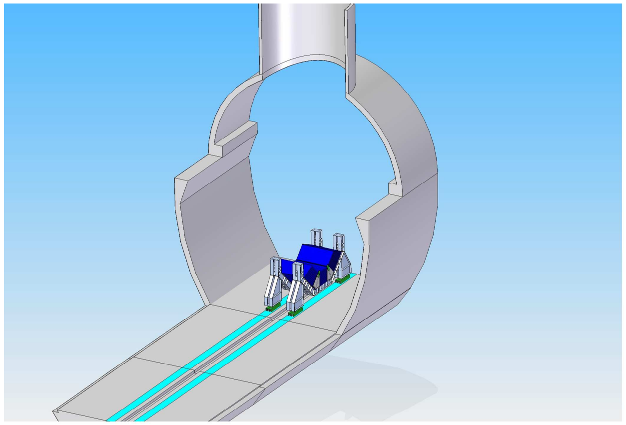
B.Parker (BNL), A.Mikhailichenko (Cornell Univ.), K.Buesser (DESY), J.Hauptman (Iowa State Univ.), T.Tauchi (KEK), P.Burrows (Oxford Univ.), T.Markiewicz, M.Oriunno, A.Seryi (SLAC)

Abstract
The Interaction Region of the International Linear Collider [1] is based on two experimental detectors working in a push-pull mode. A time efficient implementation of this model sets specific requirements and challenges for many detector and machine systems, in particular the IR magnets, the cryogenics and the alignment system, the beamline shielding, the detector design and the overall integration. This paper attempts to separate the functional requirements of a push pull interaction region and machine detector interface from any particular conceptual or technical solution that might have been proposed to date by either the ILC Beam Delivery Group or any of the three detector concepts [2]. As such, we hope that it provides a set of ground rules for interpreting and evaluating the MDI parts of the proposed detector concept's Letters of Intent, due March 2009. The authors of the present paper are the leaders of the IR Integration Working Group within Global Design Effort Beam Delivery System and the representatives from each detector concept submitting the Letters Of Intent.

Detector assembly considerations

- **Iron built in sub modules with a mass suitable for transportation, and bolted together at the ILC**
- **Solenoid fabricated by industry**
- **VXD, ECAL, and HCAL modules built outside and transported to ILC site**
- **Detailed assembly strategy depends on site:**

  ‘shallow’ vs. ‘deep’
- **Shape of an underground hall and the capacity for underground bridge cranes may depend on the site geology**
- **Optimal strategy will depend on ILC construction schedule**



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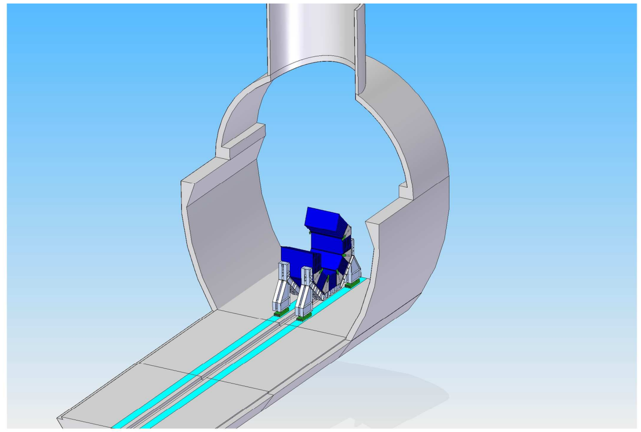

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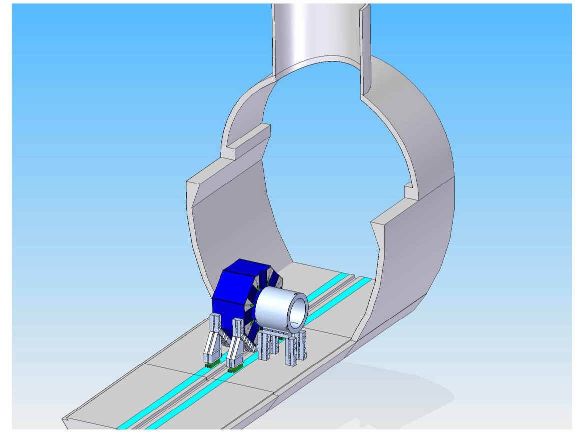

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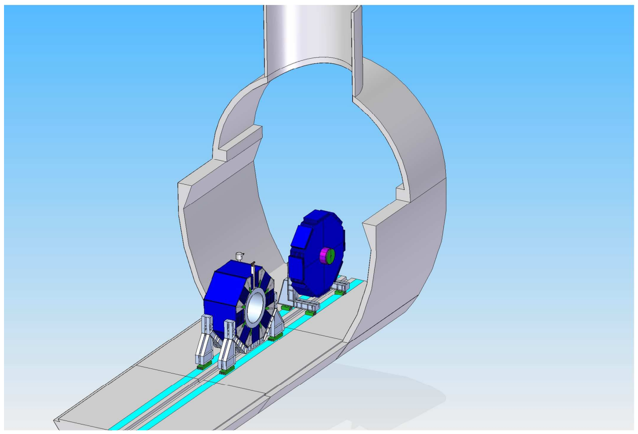

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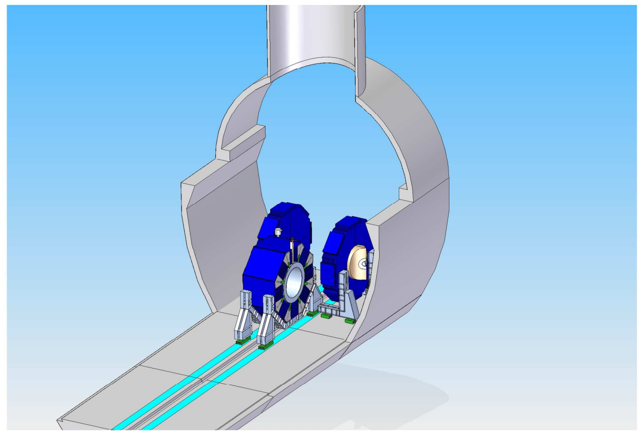

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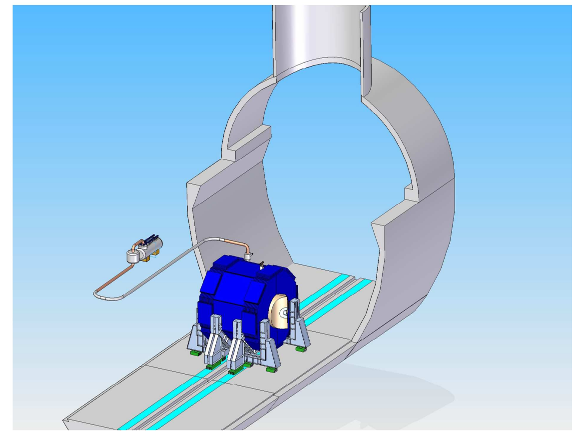

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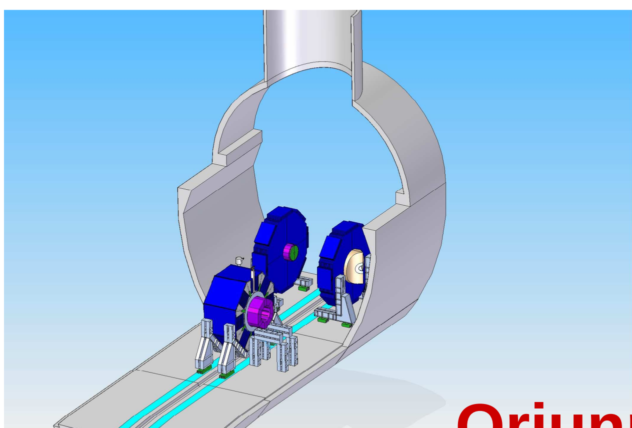

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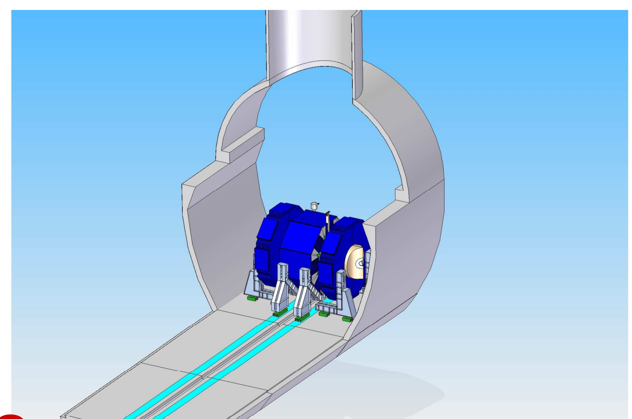
Oriunno



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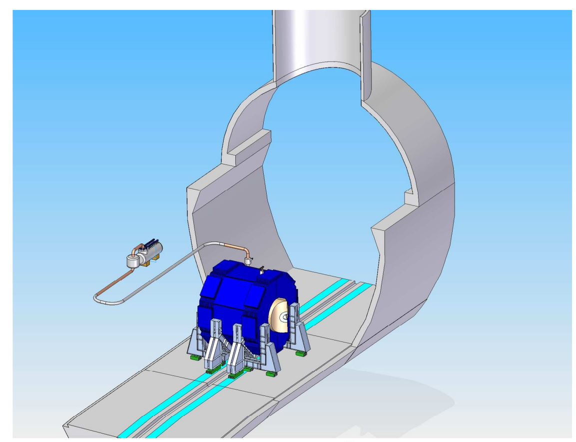


9

Possible detector assembly (1)
(underground site)

1. Underground assembly of iron flux return barrel
2. Barrel Octants lowered in pre-assembled pieces of 400t max.
3. Solenoid lowered and inserted in the flux return barrel.
4. Doors preassembled on surface and lowered in one piece of 2400t max.
5. Doors closed around flux return barrel
6. Complete iron+solenoid moved to garage position, hooked up to cryogenics and commissioned
7. Doors move leaving access to the barrel for insertion of HCAL (380t), ECAL (60t) and tracker (2t)
8. Doors close around fully assembled barrel
9. SiD moved into garage position, hooked up to cryogenics

Detector positioning

Accurate positioning critical for push-pull model

General concept:

SiD moves into beam position as a single large unit, carrying end doors with the barrel

Detector moves on multi-roller supports, each with an integrated drive: steel structure minimally stressed

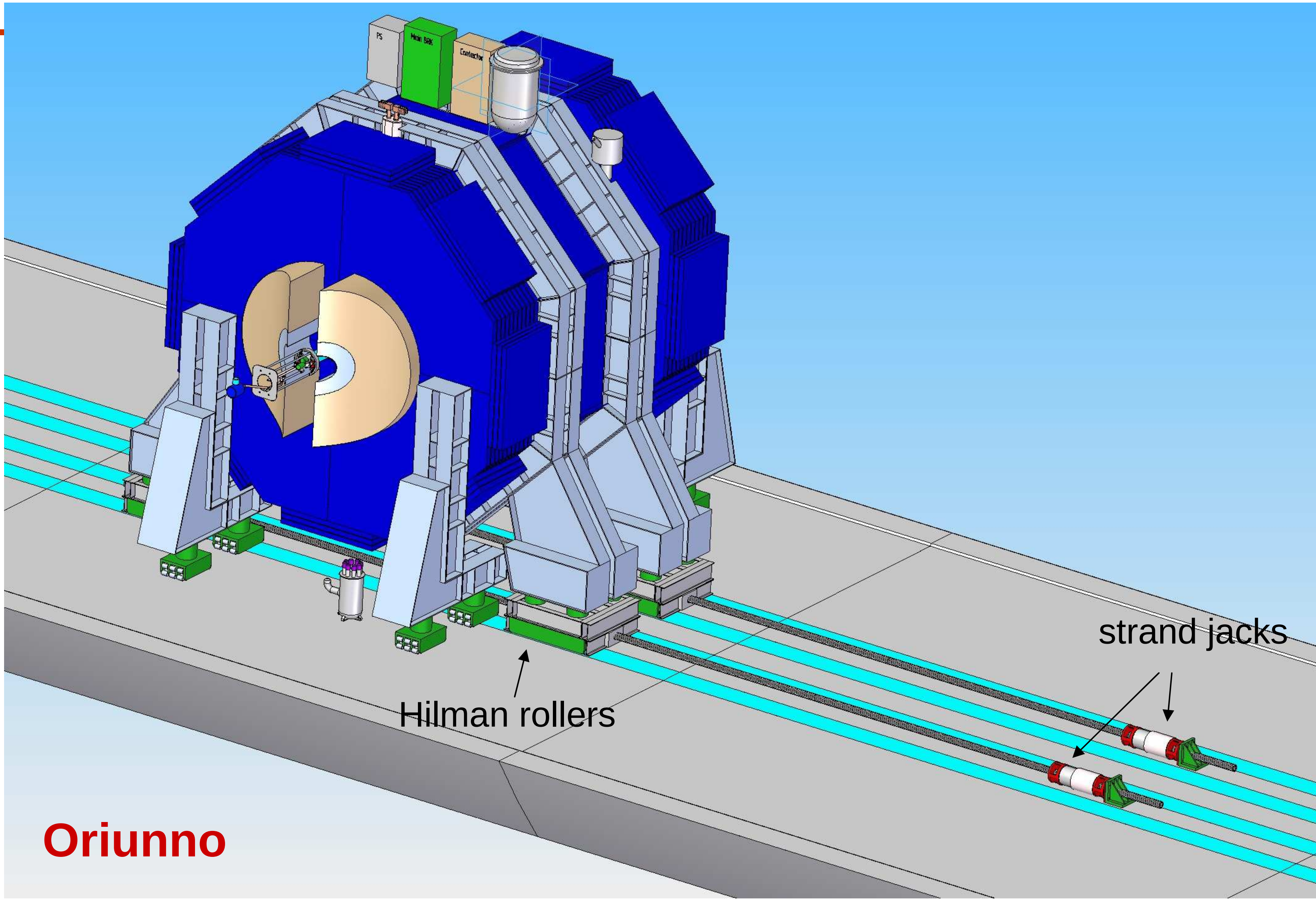
Smooth acceleration + deceleration: max. speed 1 - 5 mm/sec

Permanent mechanical stops

→ Position accuracy +- 1 mm

Acceptable for positioning of iron structure, muon system, solenoid, calorimetry and outer tracker

Detector motion: concept

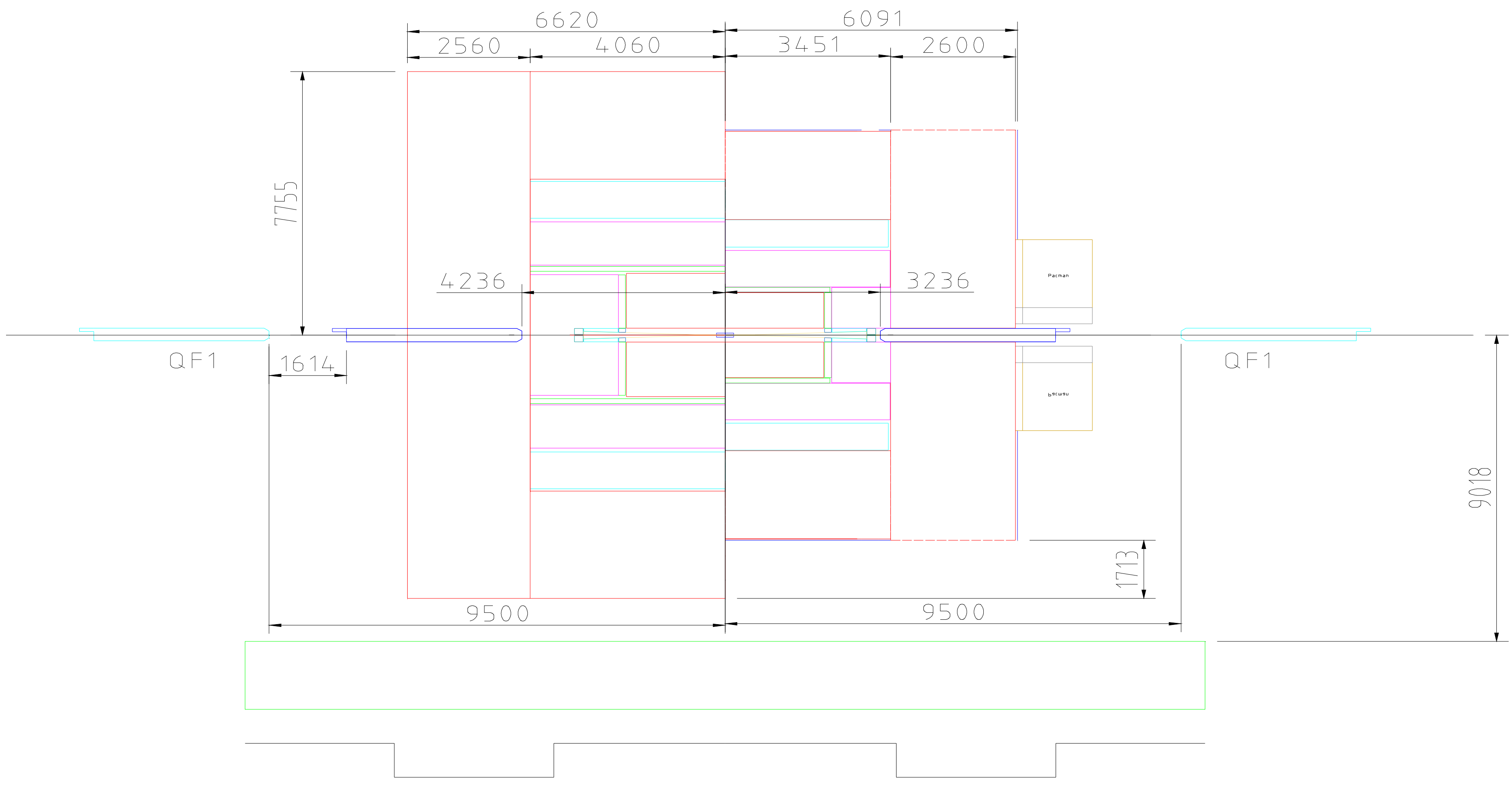


Push-pull compatibility with ILD

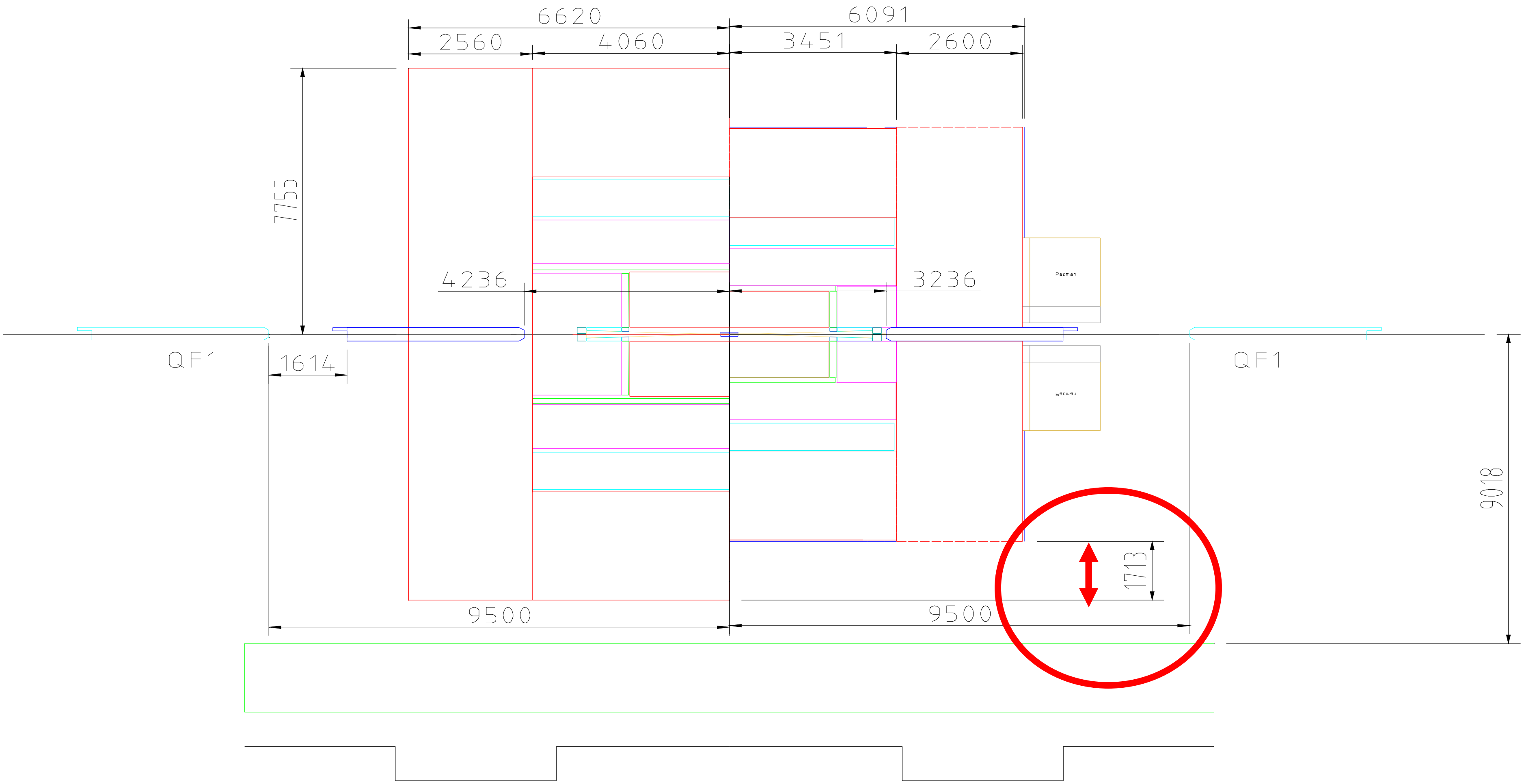
Main issues:

- **Height difference**
- **Preferred detector support mechanism**
- **Preferred detector motion mechanism**
- **Interface to machine tunnel**
- **…**

Detector heights

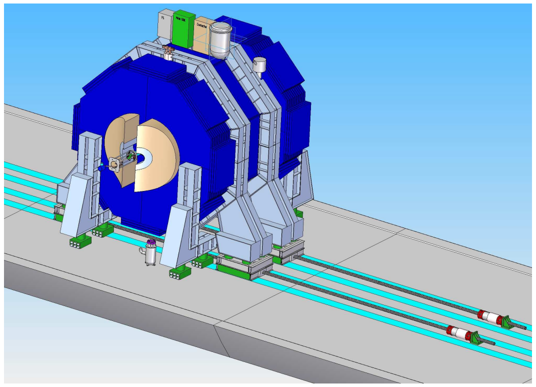


Detector heights

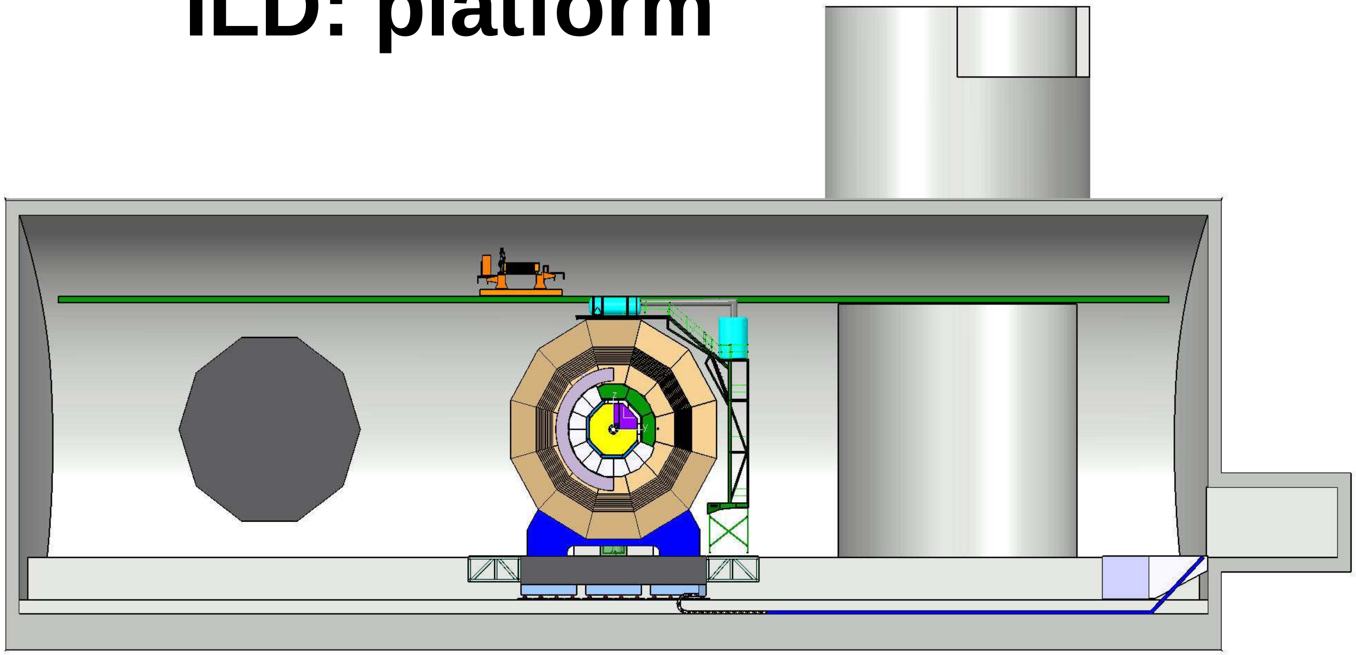


Detector support mechanism

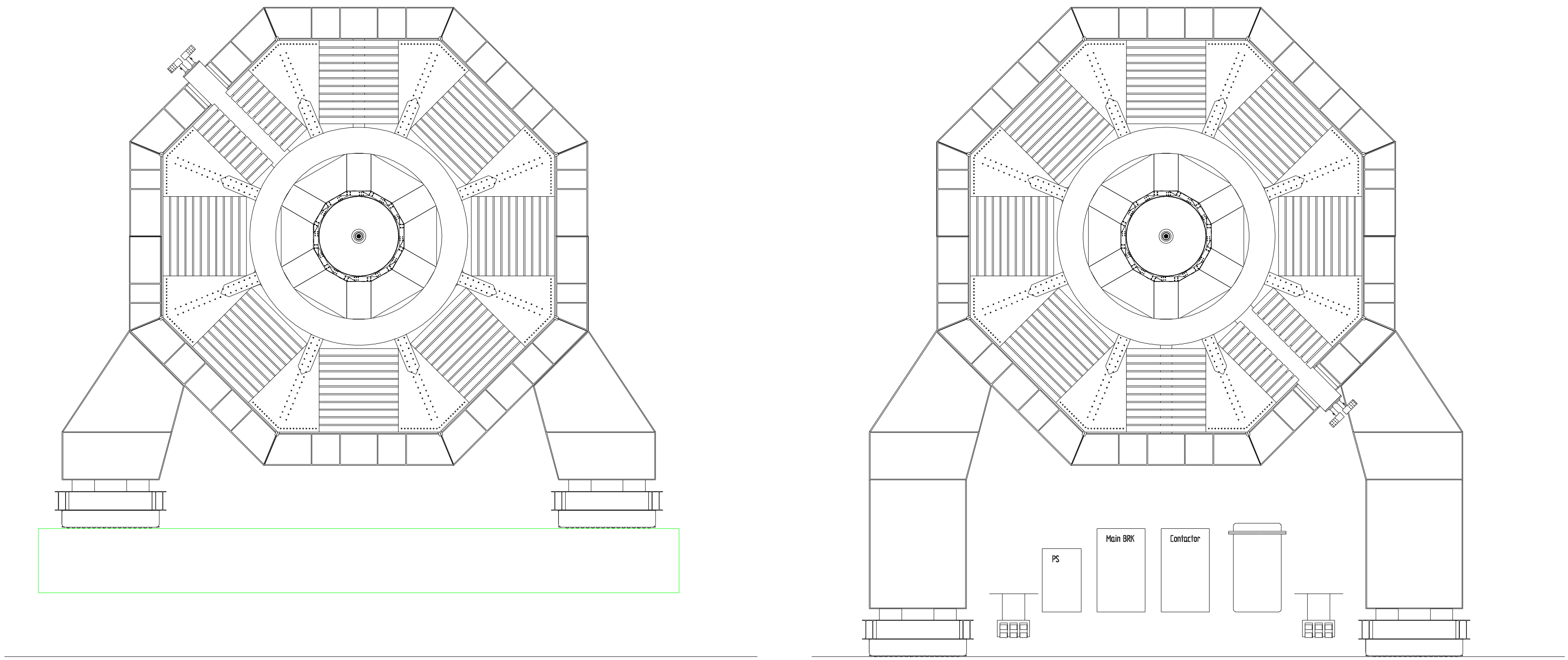
SiD: legs



ILD: platform

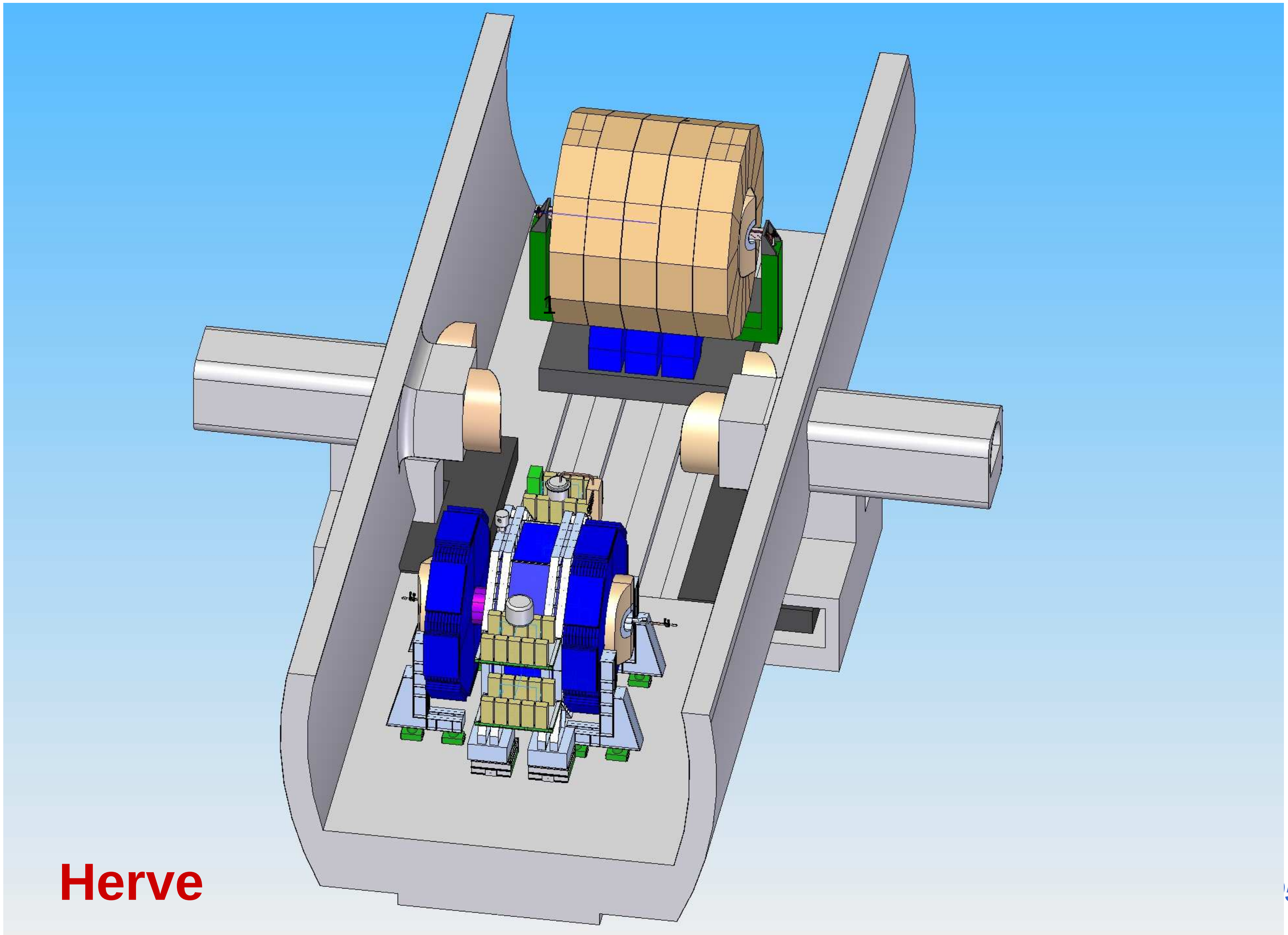


1) Lengthen SiD's legs?

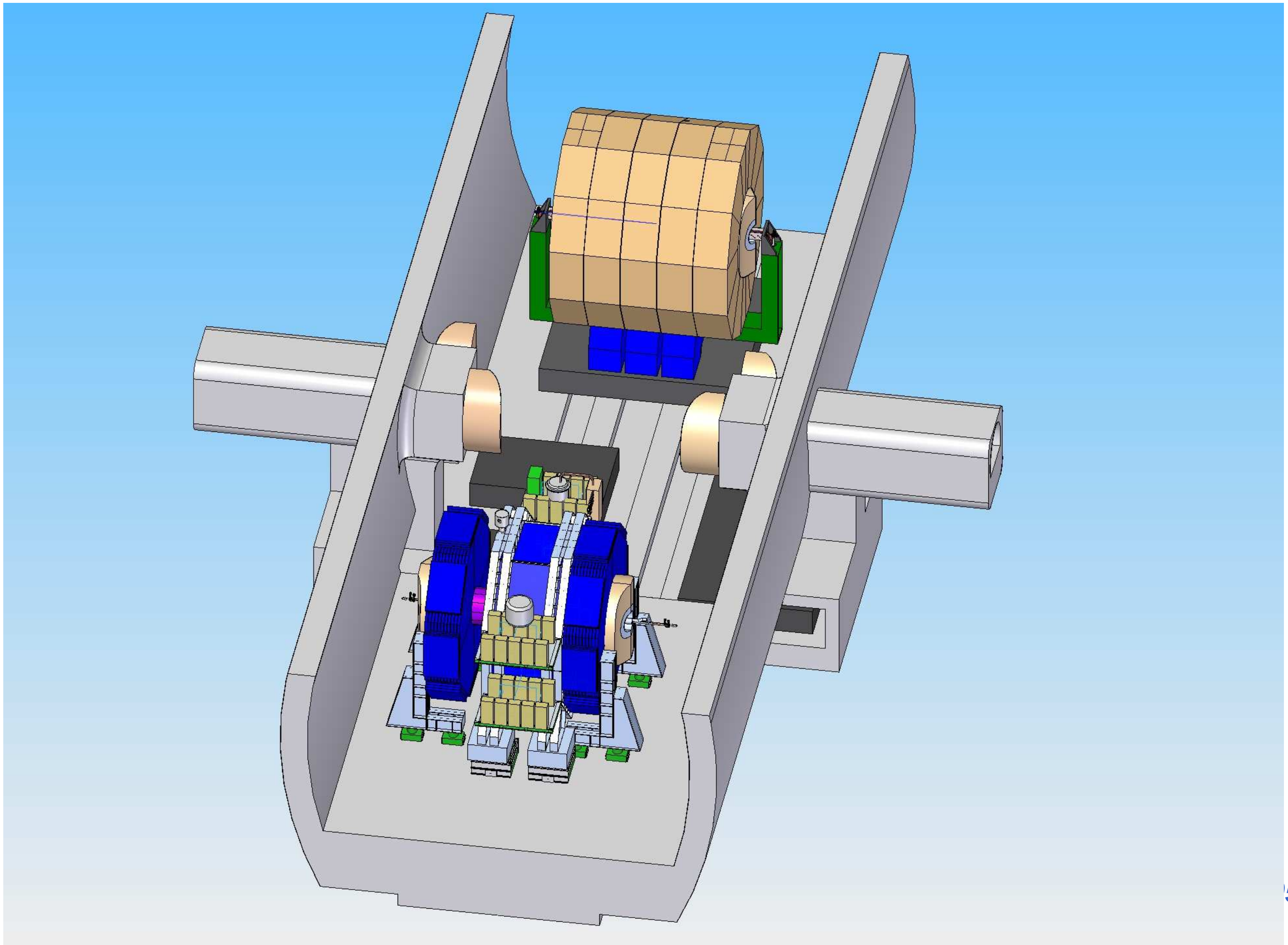


→ increased exposure to vibrations?

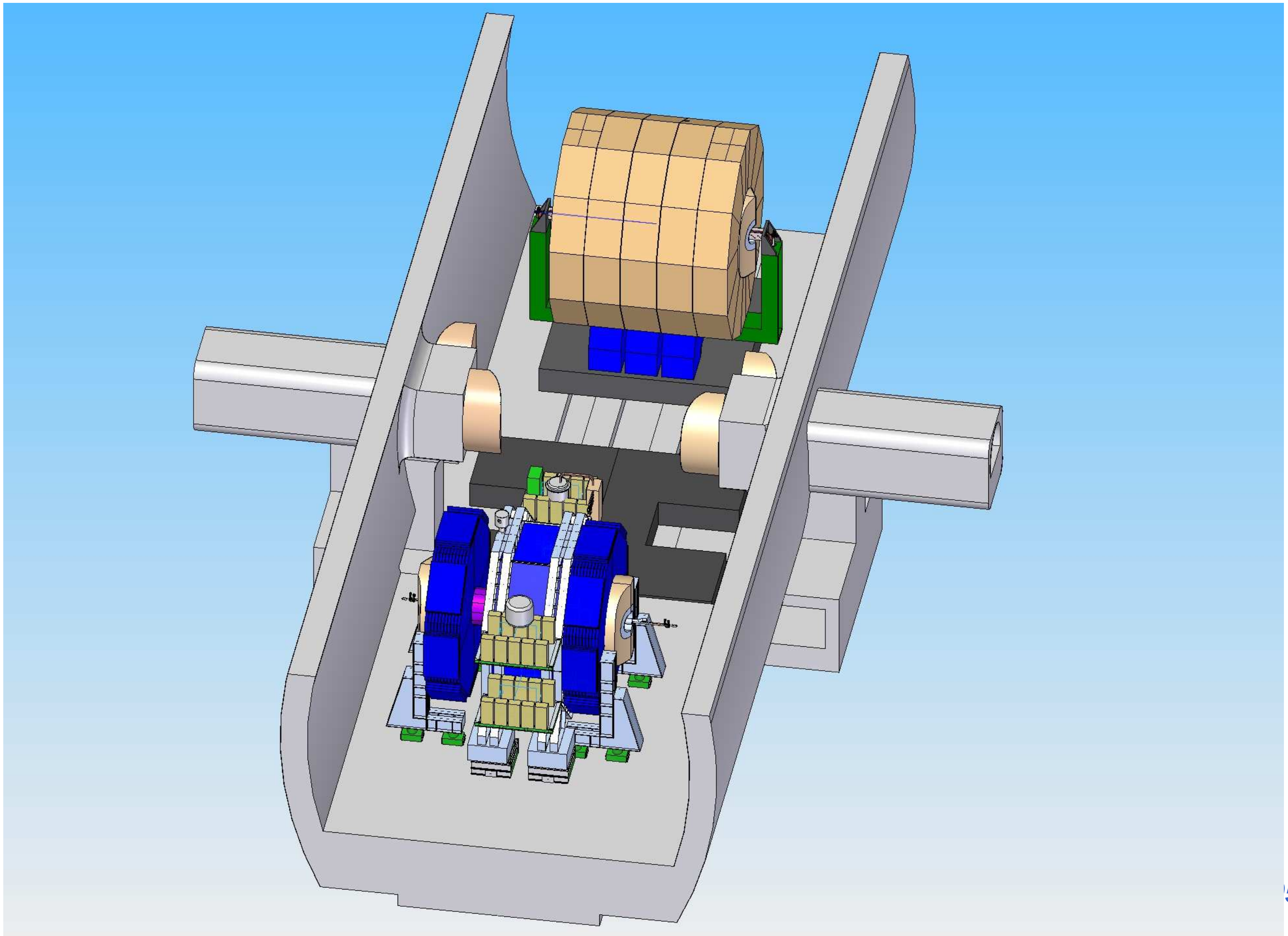
2) Half platforms in lateral alcoves



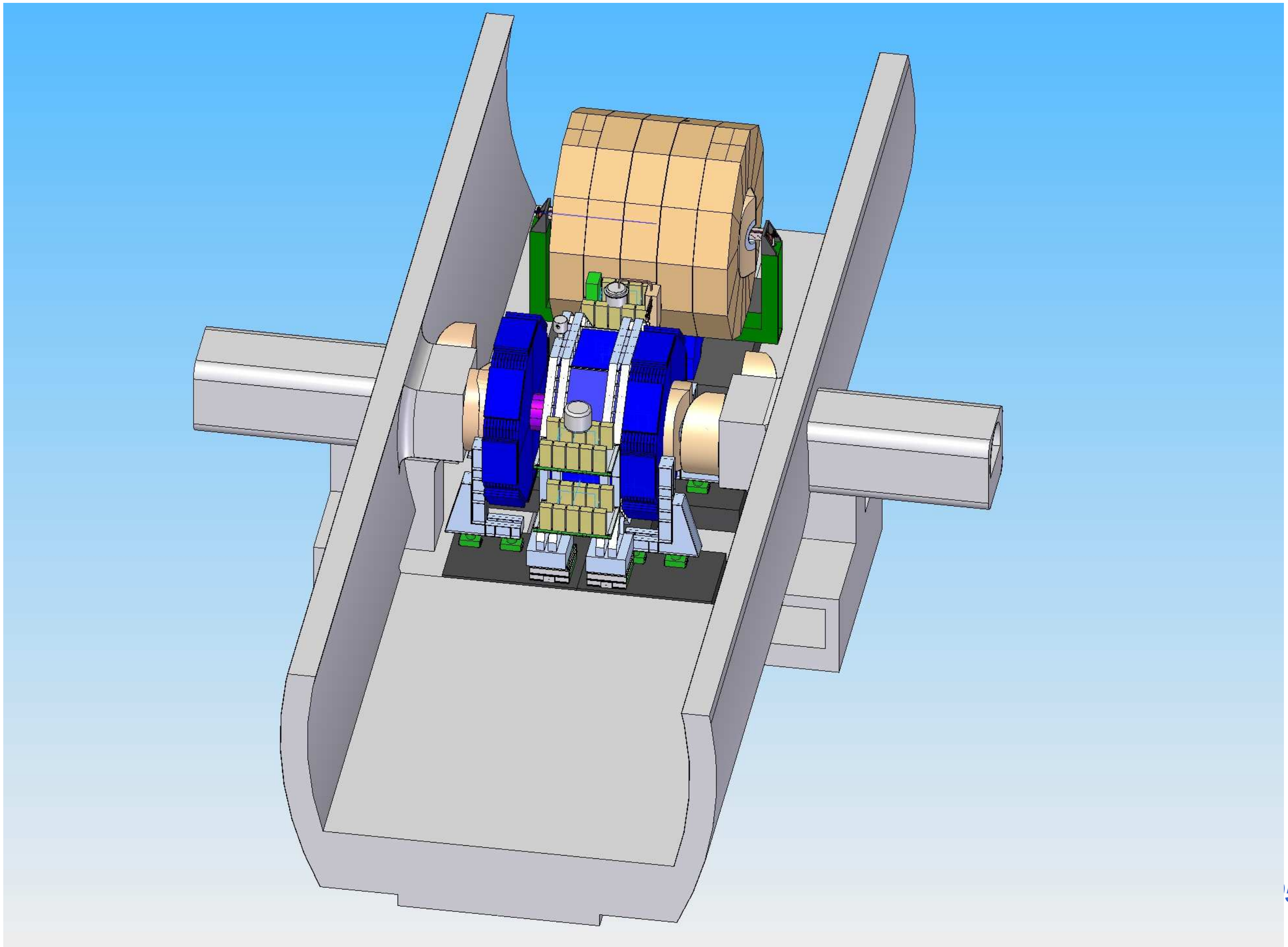
2) Half platforms in lateral alcoves



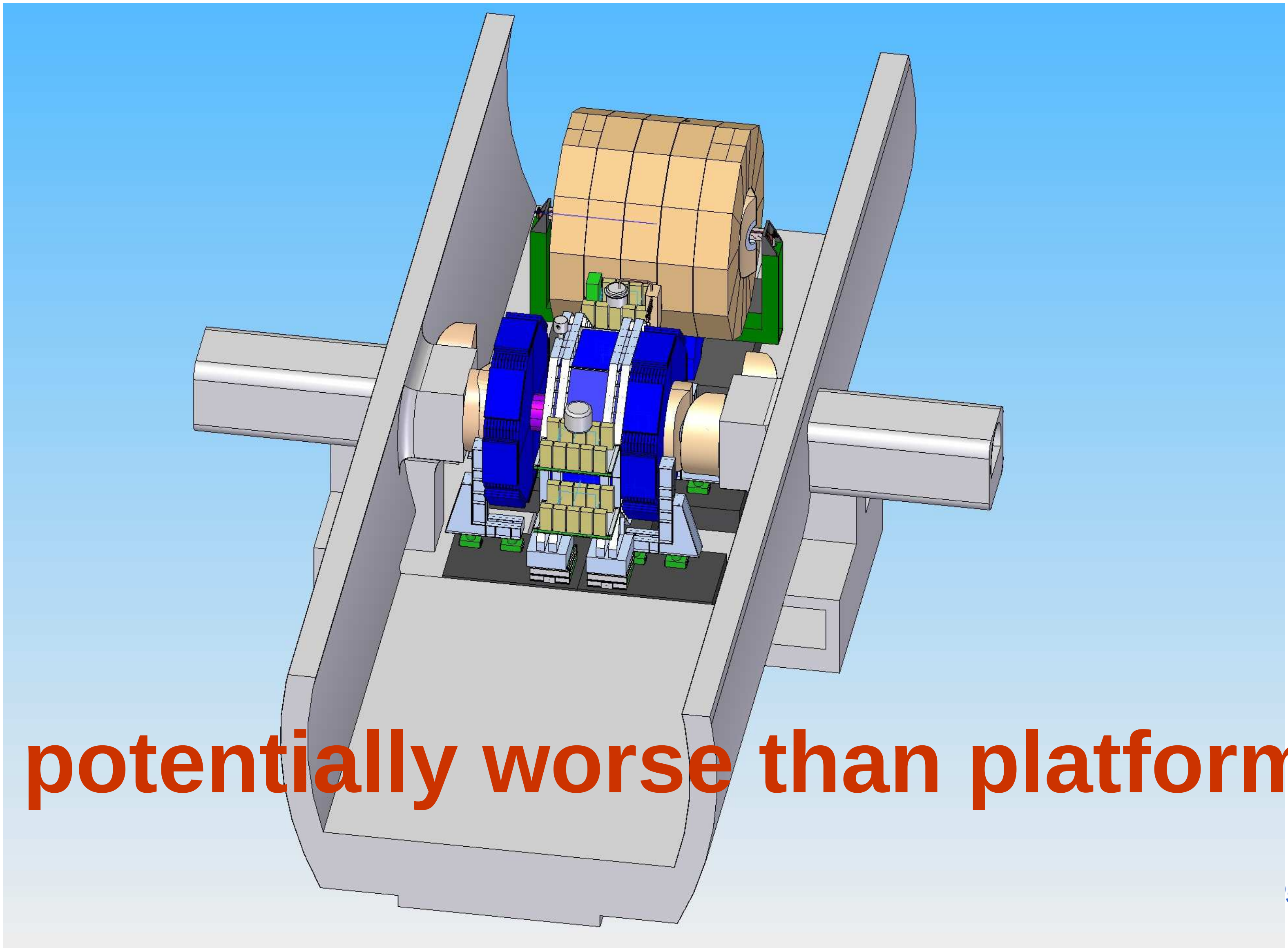
2) Half platforms in lateral alcoves



2) Half platforms in lateral alcoves

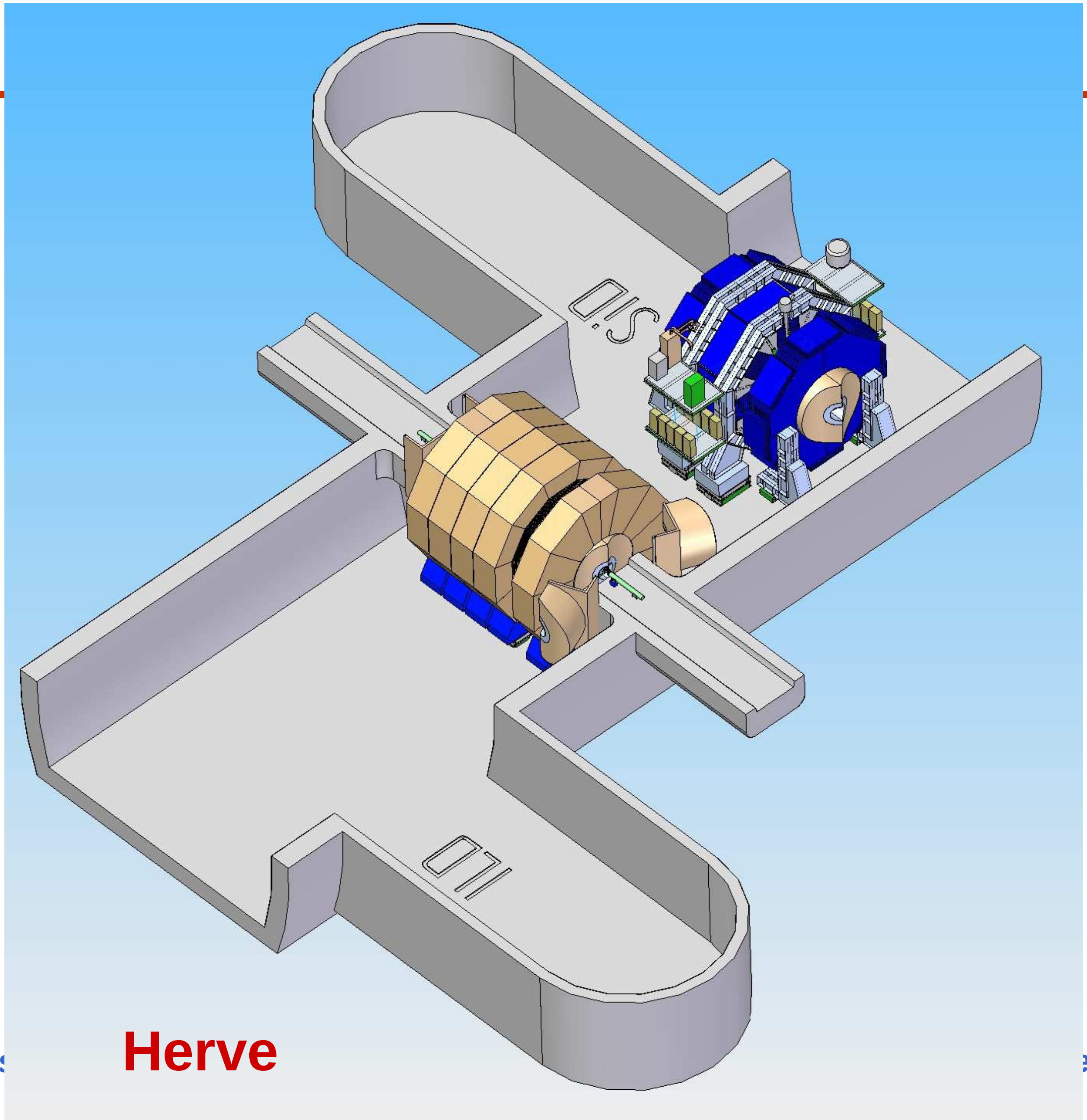


2) Half platforms in lateral alcoves



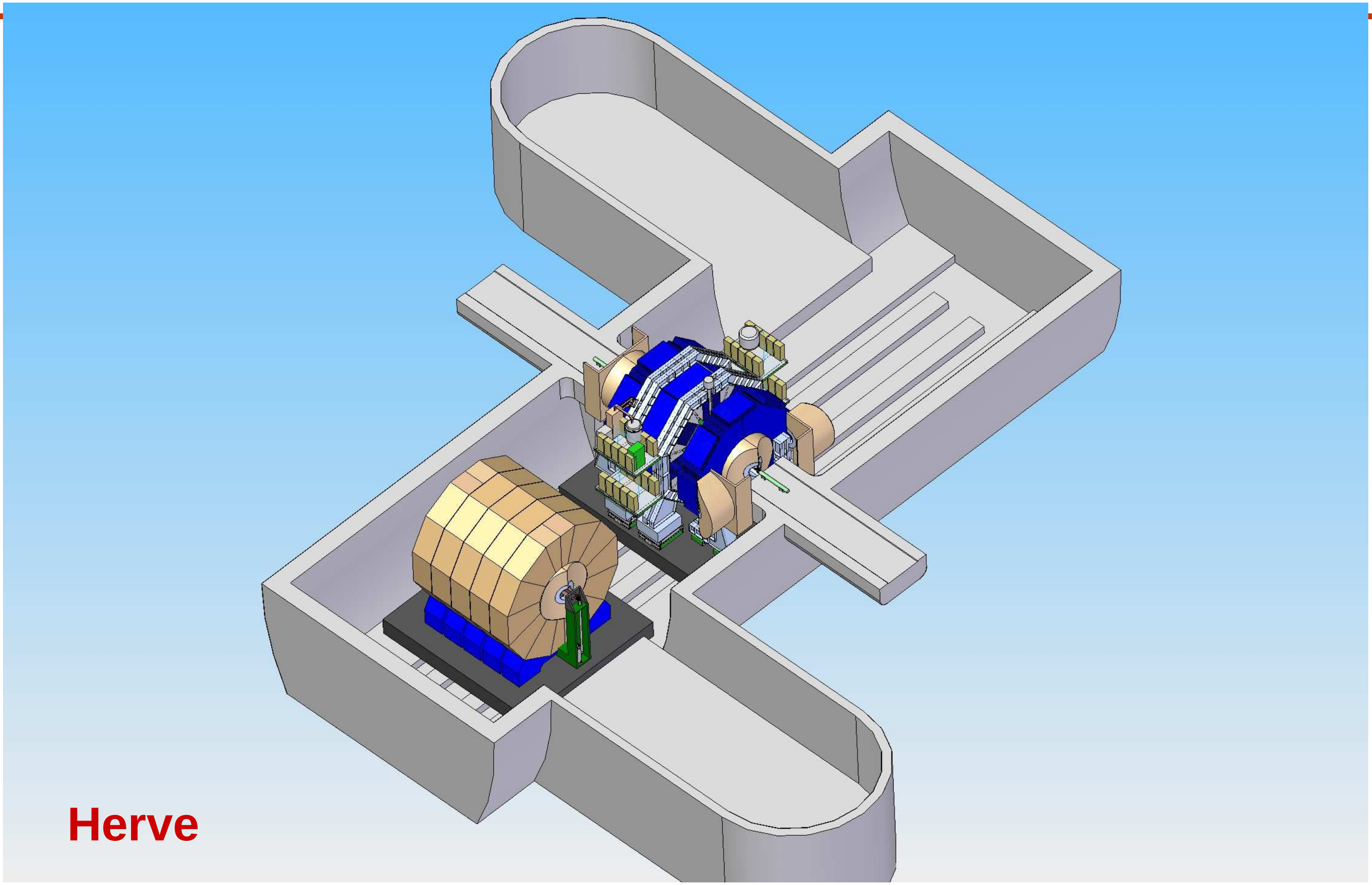
→ potentially worse than platform?

3) Both detectors on legs?



Herve

4) Both detectors on platform?



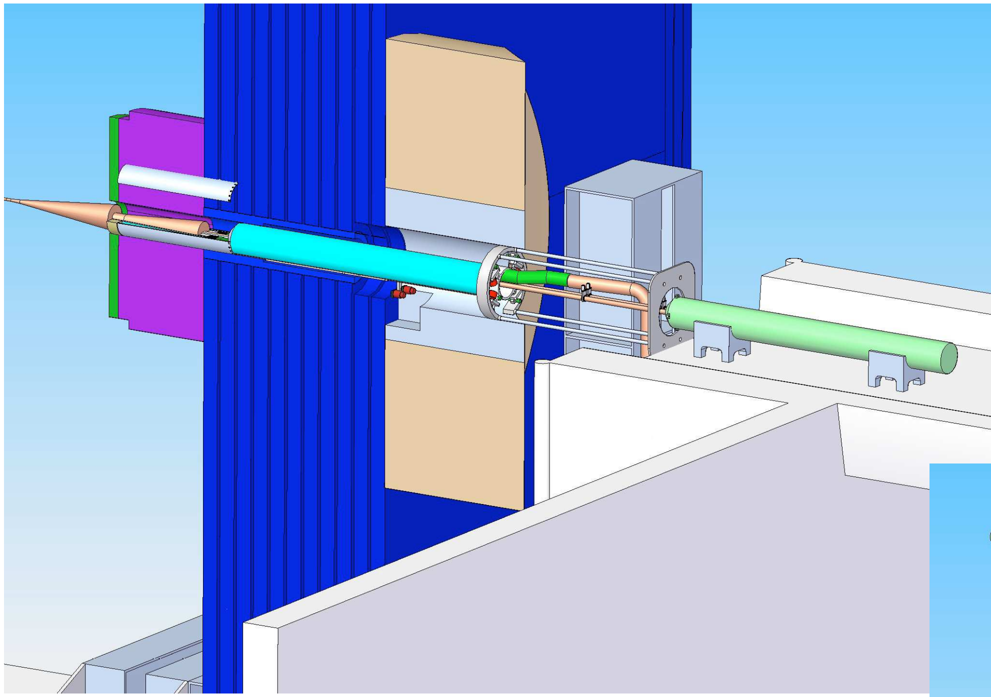
Issue for quantitative study

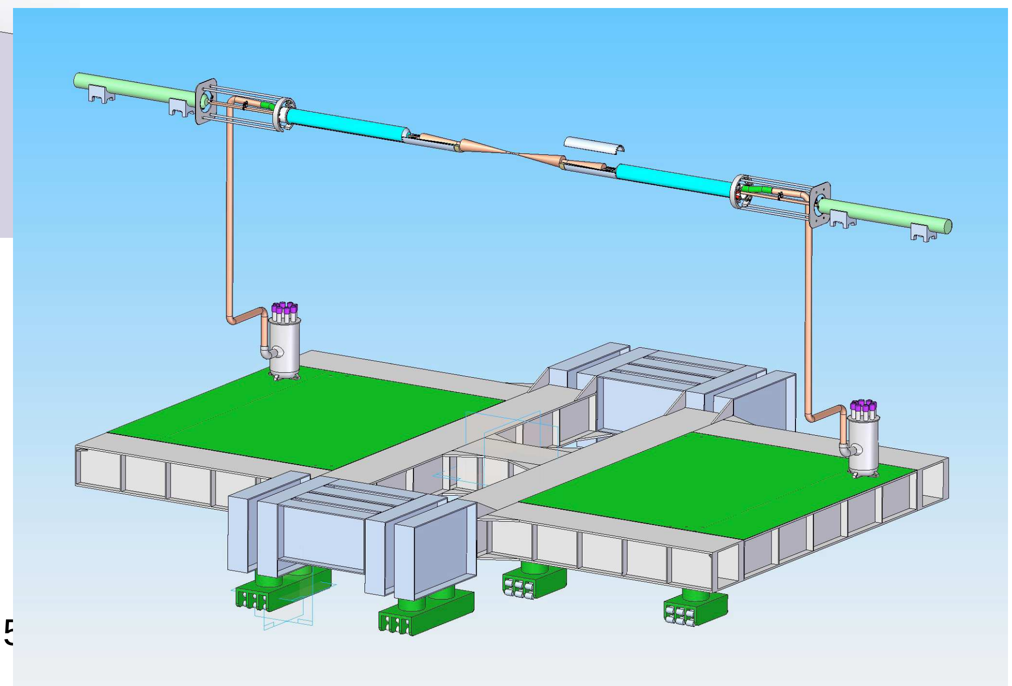
What are merits of platform vs. no platform in terms of minimising the detector and QD0 susceptibility to ground vibrations?

Detector: with / without platform

QD0 support: from pillar, from detector door …

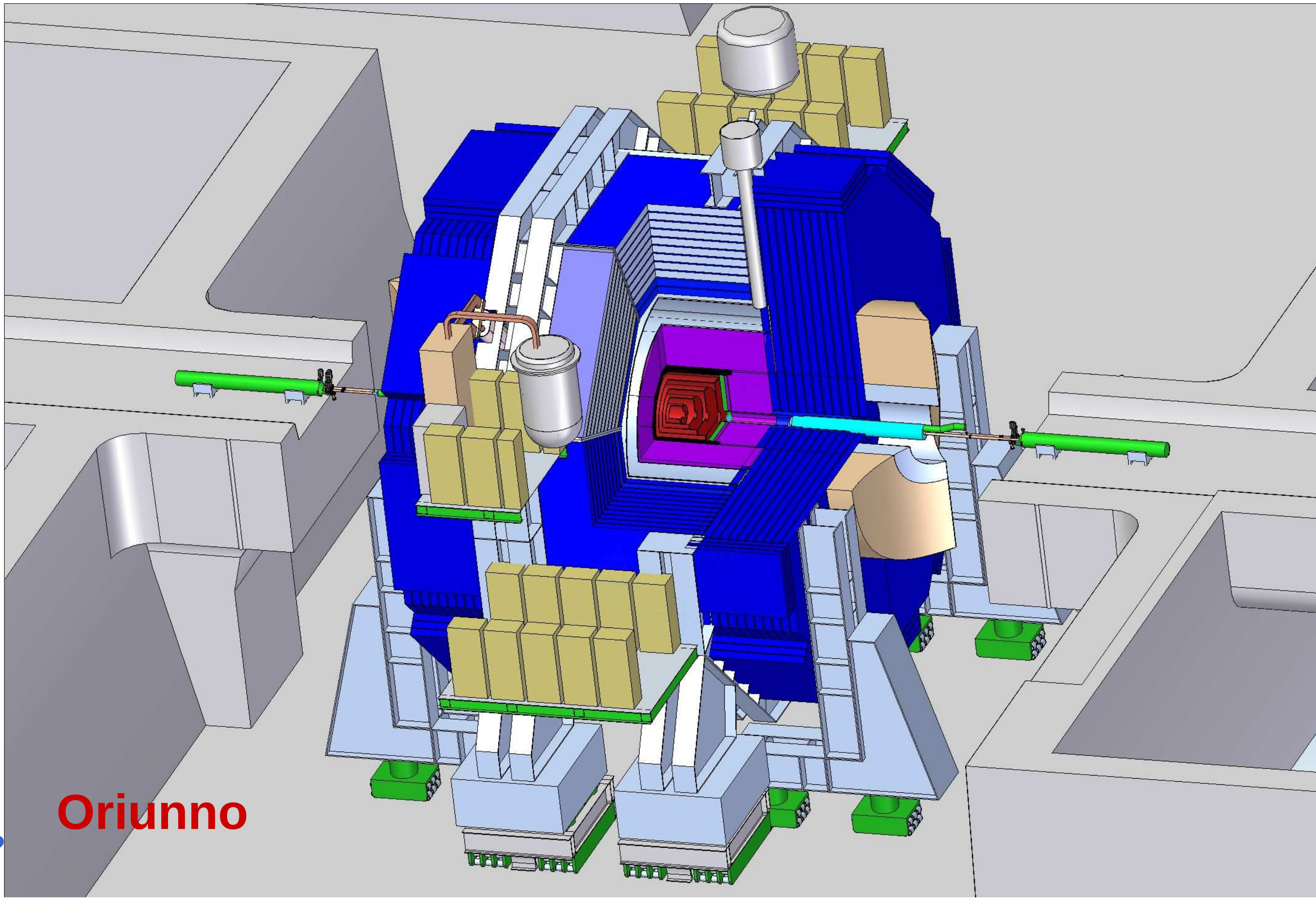
QD0 support

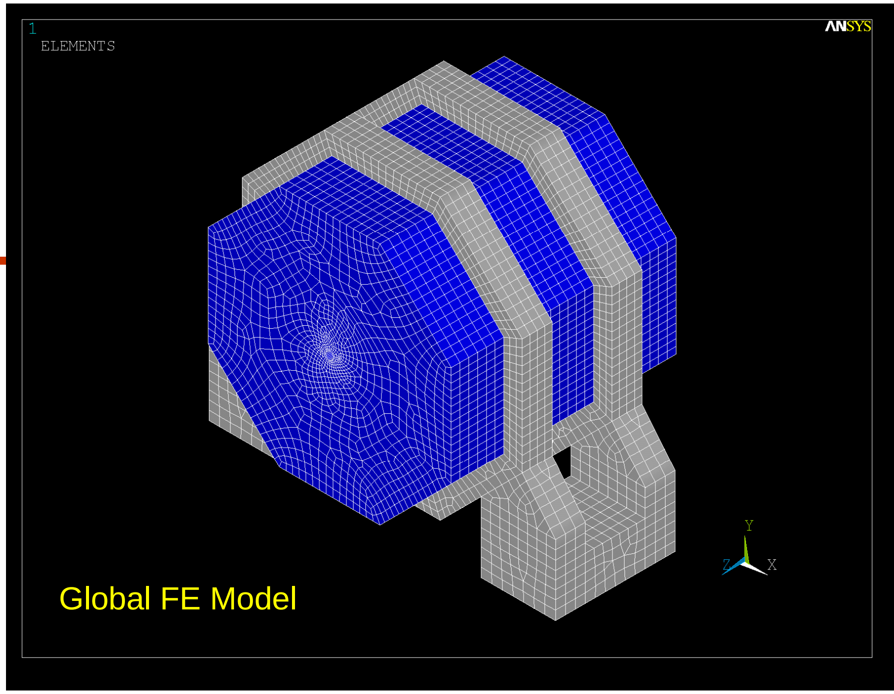


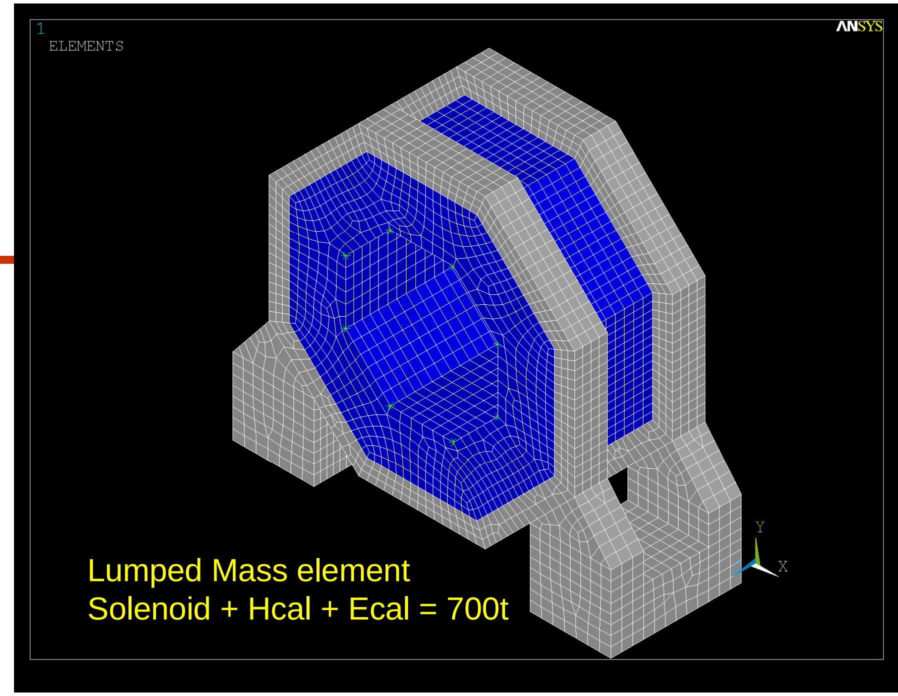


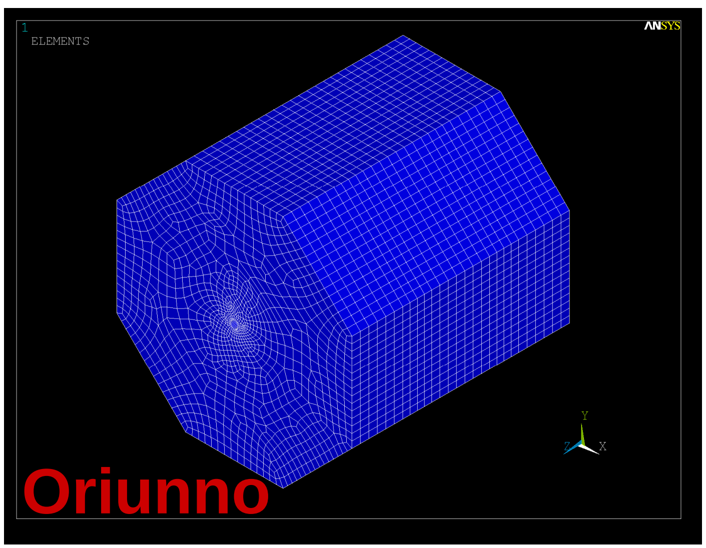
Oriunno

SiD on legs

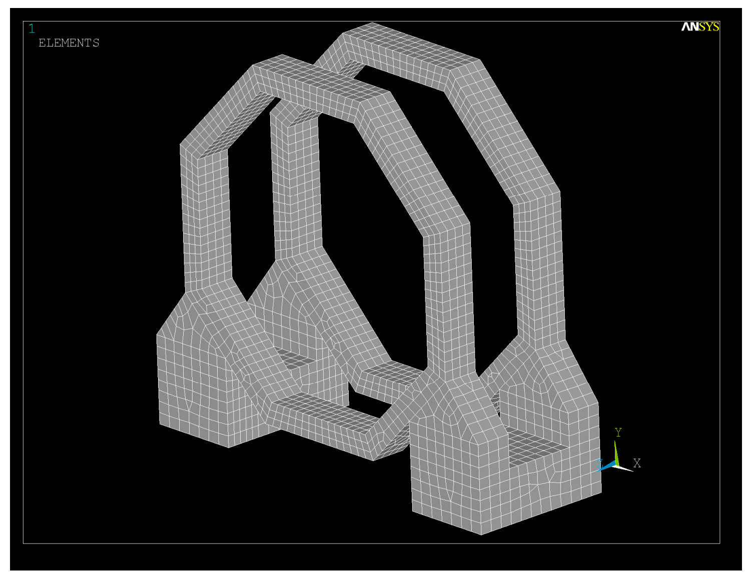






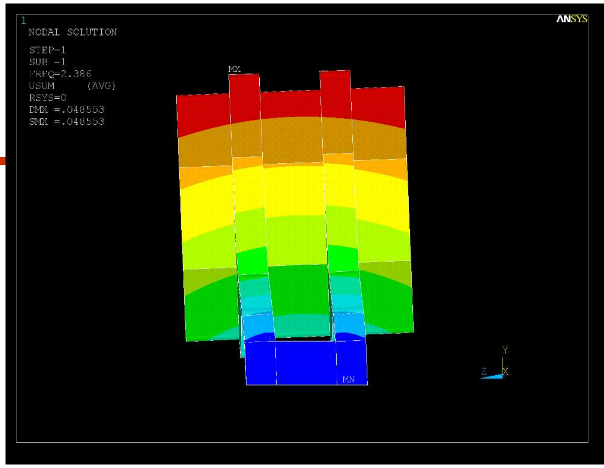


3D Solid Elements for the Iron Yoke, 9000 t

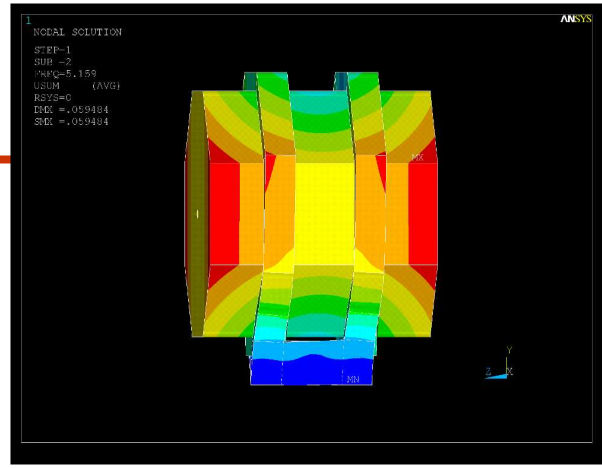


3D Shell Elements for the Arch, thickness 50mm

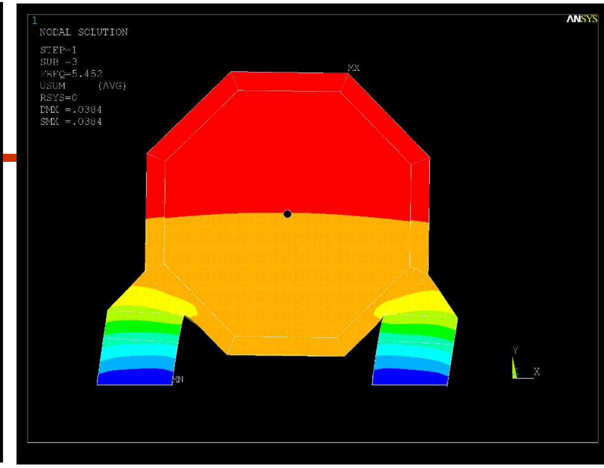
Free Vibration Modes



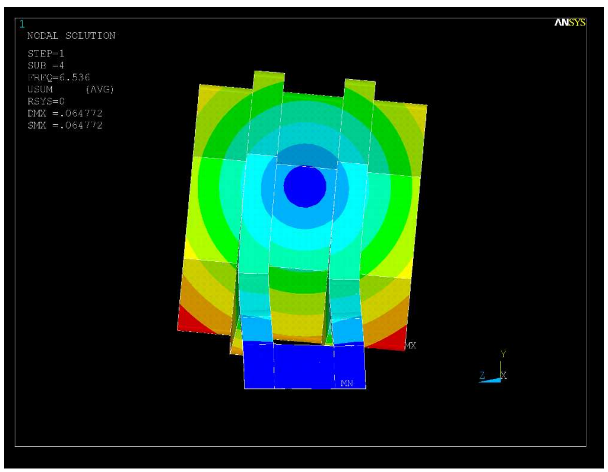
1st Mode, 2.38 Hz



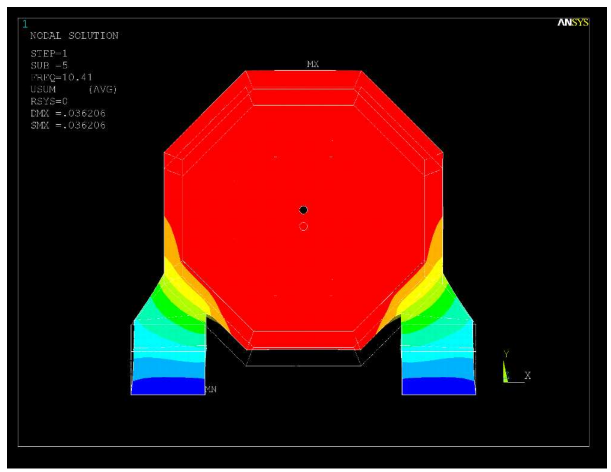
2nd Mode, 5.15 Hz



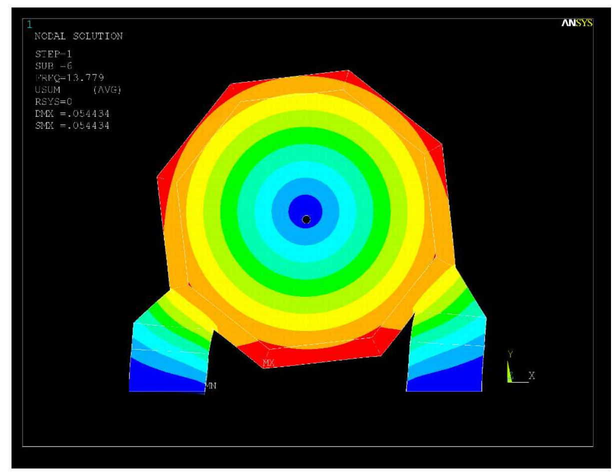
3rd Mode, 5.45 Hz



4th Mode, 6.53 Hz



5th Mode, 10.42 Hz

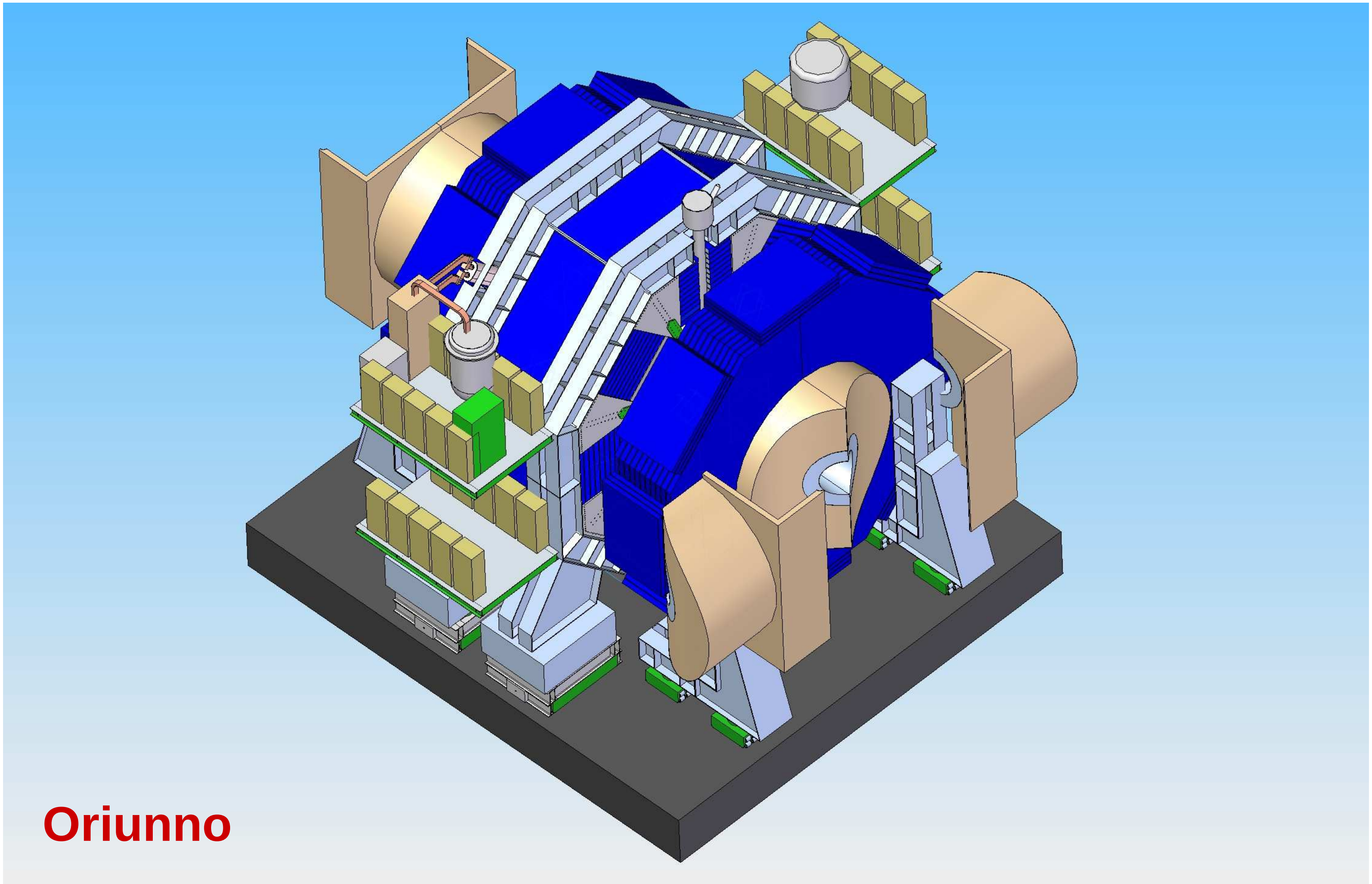


6th Mode, 13.7 Hz

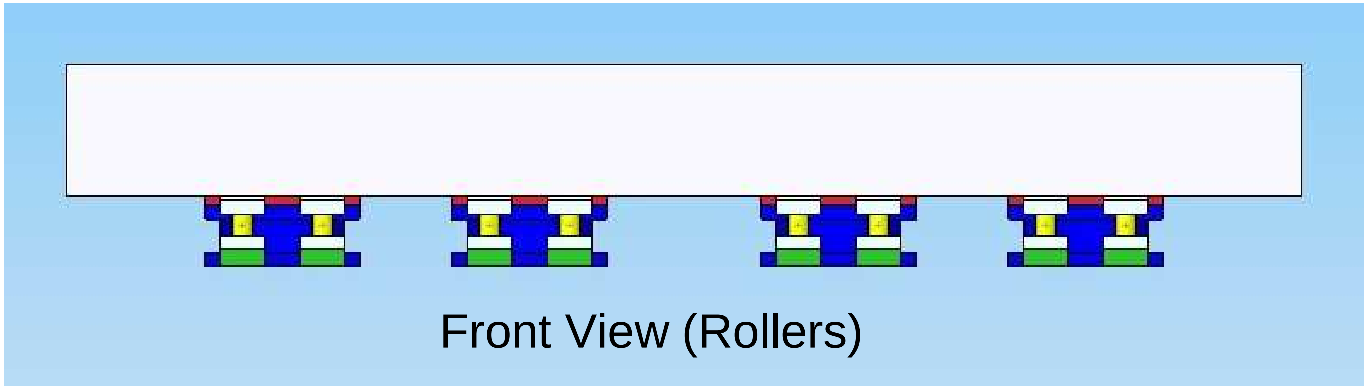
Oriunno

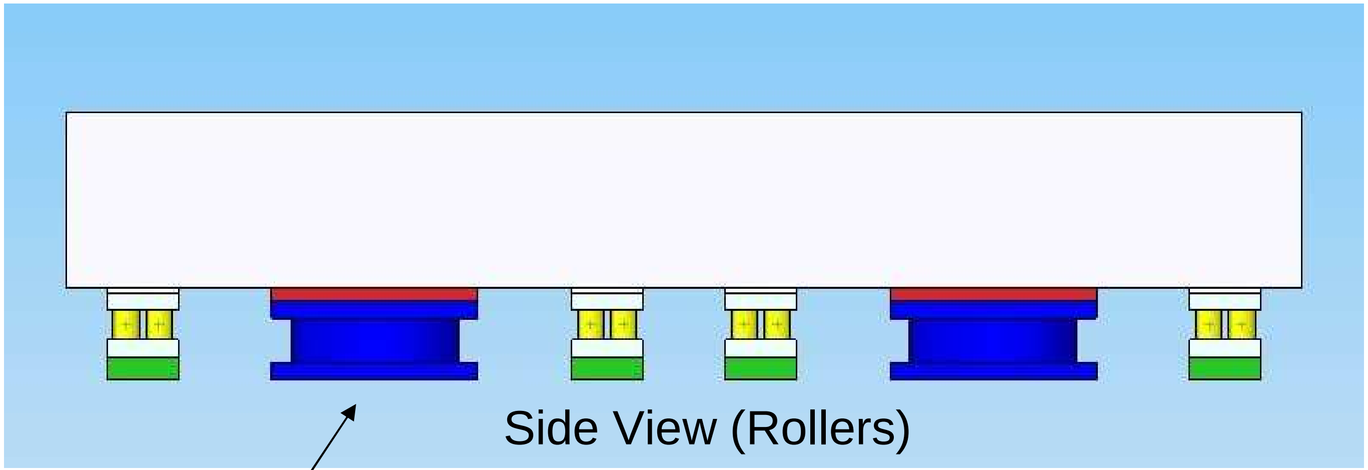
Vertical motion

SiD on platform



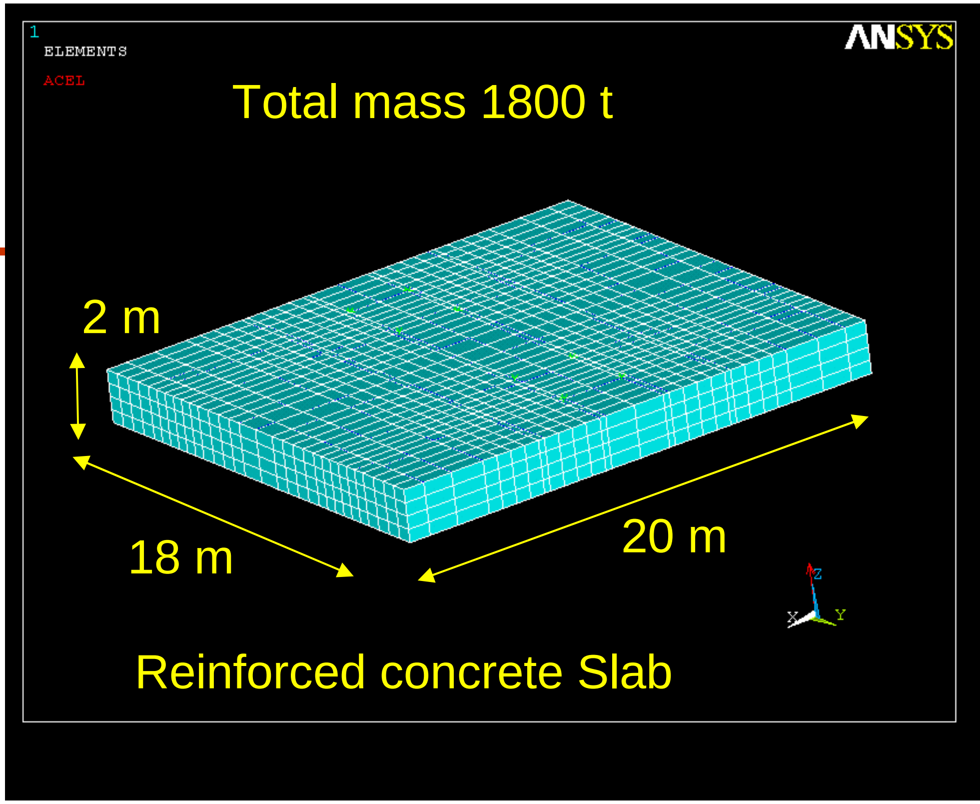
Platform concept

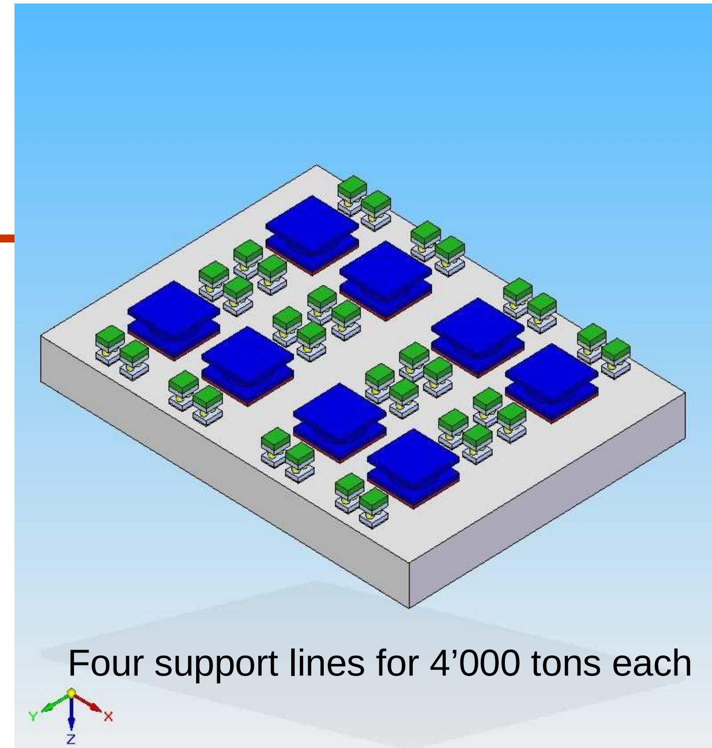


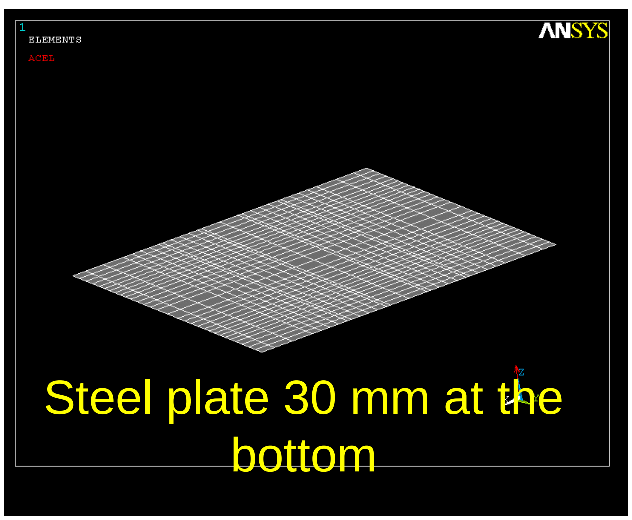


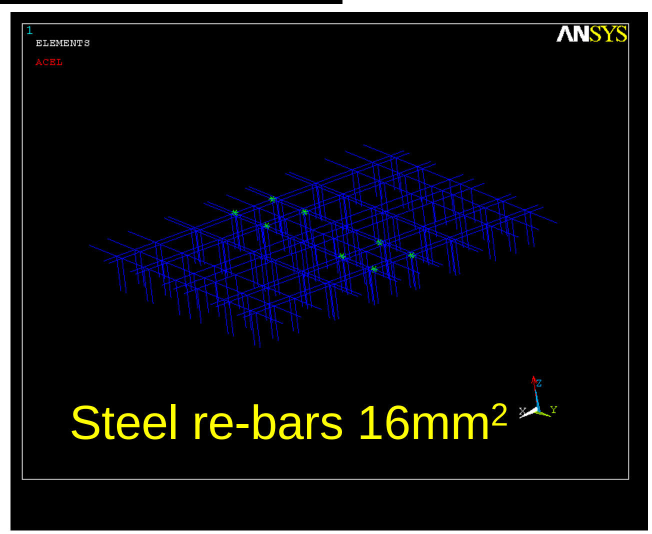
Oriunno

Anti-seismic Supports





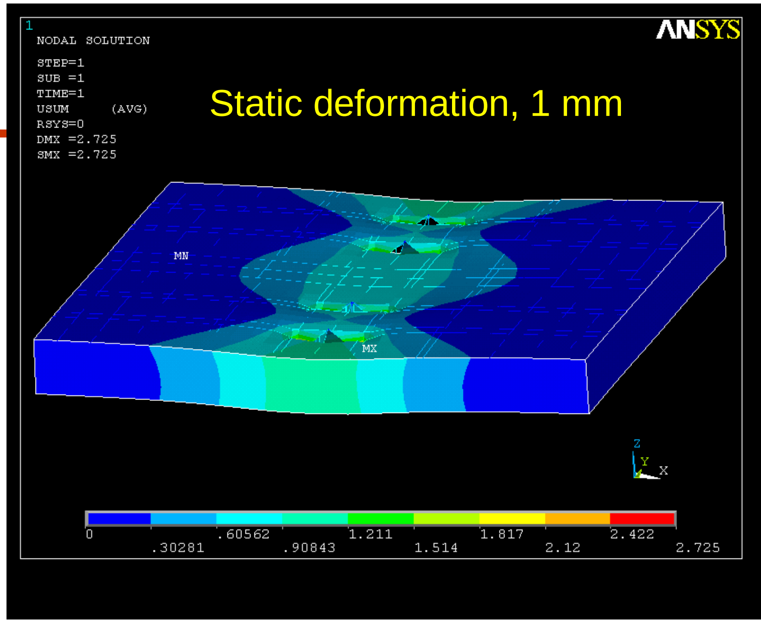


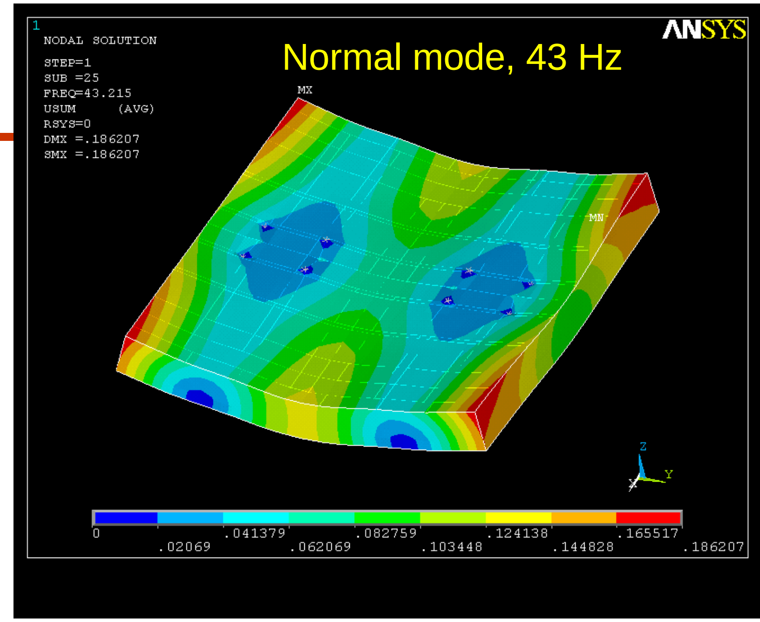


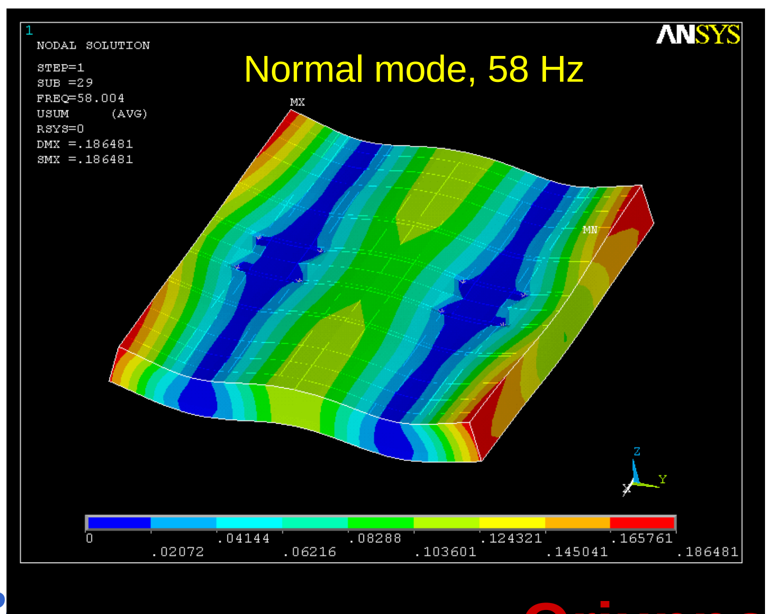
10kt Anti-seismic supports

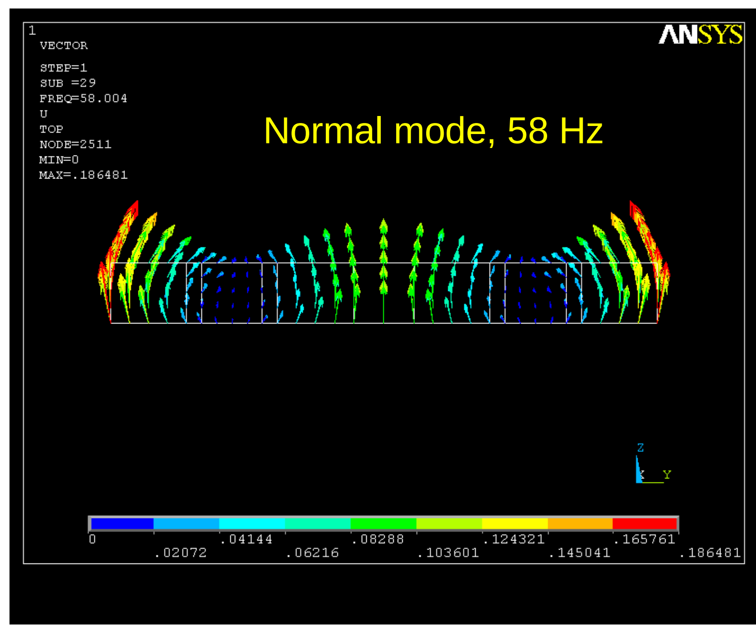
Oriunno

Vibration Modes









Summary

- Significant progress since SiD LoI
- Next goal is DBD in 2012
- Comprehensive Work Plan defined

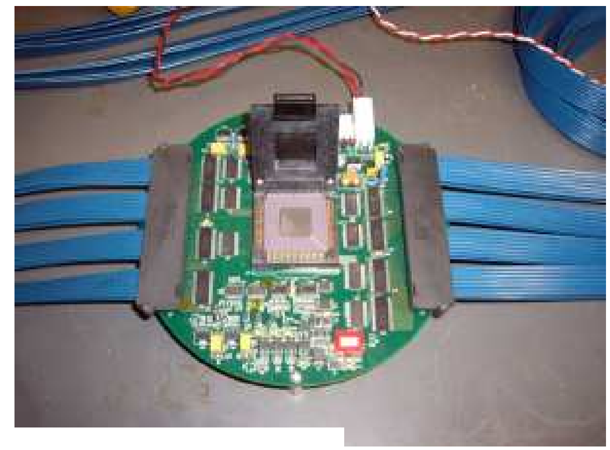
    completion depends on human and financial resources
- Ongoing R&D in all subsystems
- Review of R&D at SiD Workshop: June 3-5 at ANL
- Excellent cooperation with ILD on MDI issues
- Evolving collaboration with CLIC detector study team

Extra material

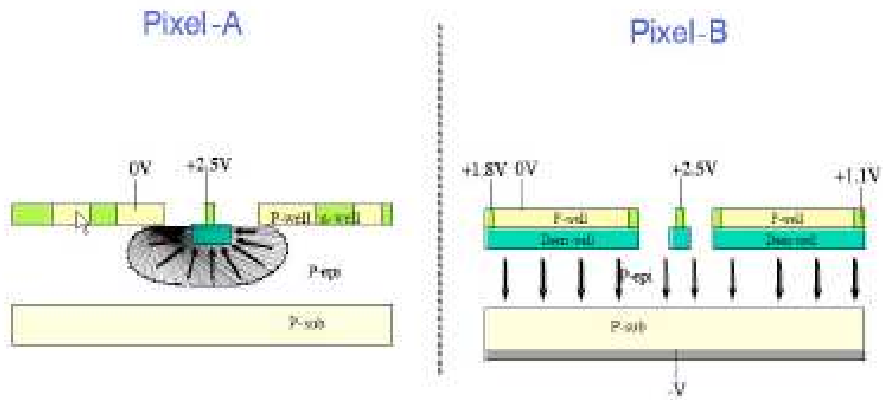
VXD sensor: Chronopix

Specifications:

Detector sensitivity
10 μV/e (eq. to 16 fF)
Detector noise
25 electrons
Comparator accuracy
0.2 mV rms (cal in each pixel)
Memory/pixel
2 x 14 (will be 4 x 14)
Designed for scalability
eg. No caps in signal paths
Provisionally use limited pixel active area
use pı



Two sensor options used for first prototype



Status: First prototype (SARNOFF) tested, validates general concept

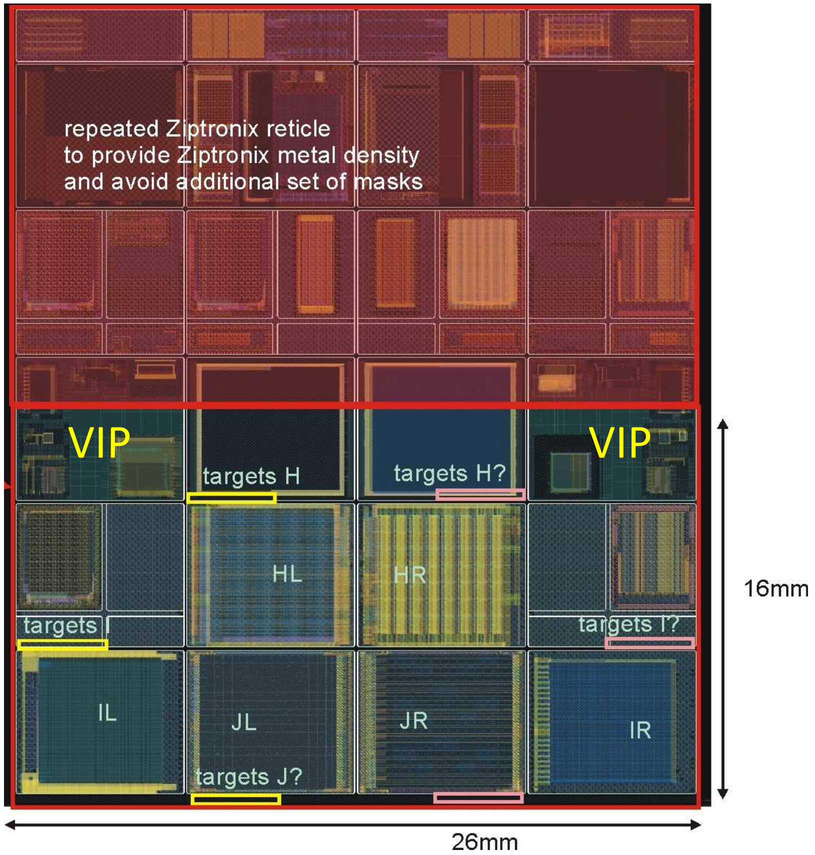
Second prototype: Fall 2010 after more design evolution and simulation.

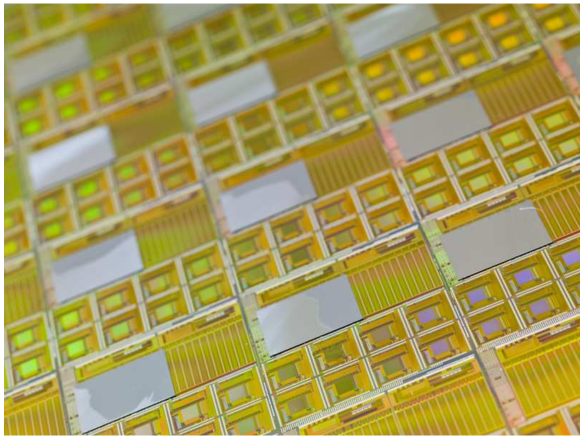
VXD sensor: 3D

3D Sensors and electronics
- VIP1 three tier chip from MIT-LL received and tested last year
- VIP2 - improved reliability due soon.
- Two-tier version of VIP(2b) in Tezzaron/Chartered 3D process in fabrication
- Sensors being produced at BNL

Direct Oxide bonding
- Demonstrated with FPIX chips
- Will be used for VIP2b sensor

Thinning and laser anneal



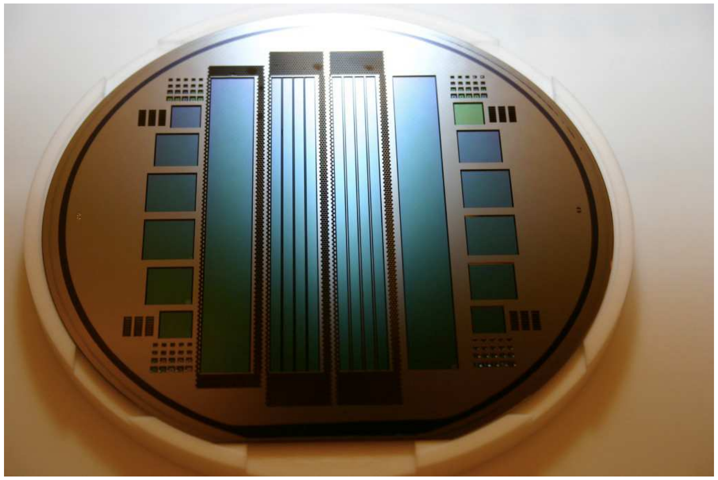


VXD sensor: DEPFET

Demonstrated SOI-based wafer thinning

Building DEPFET-based Belle vertex detector

– many similarities to ILC design



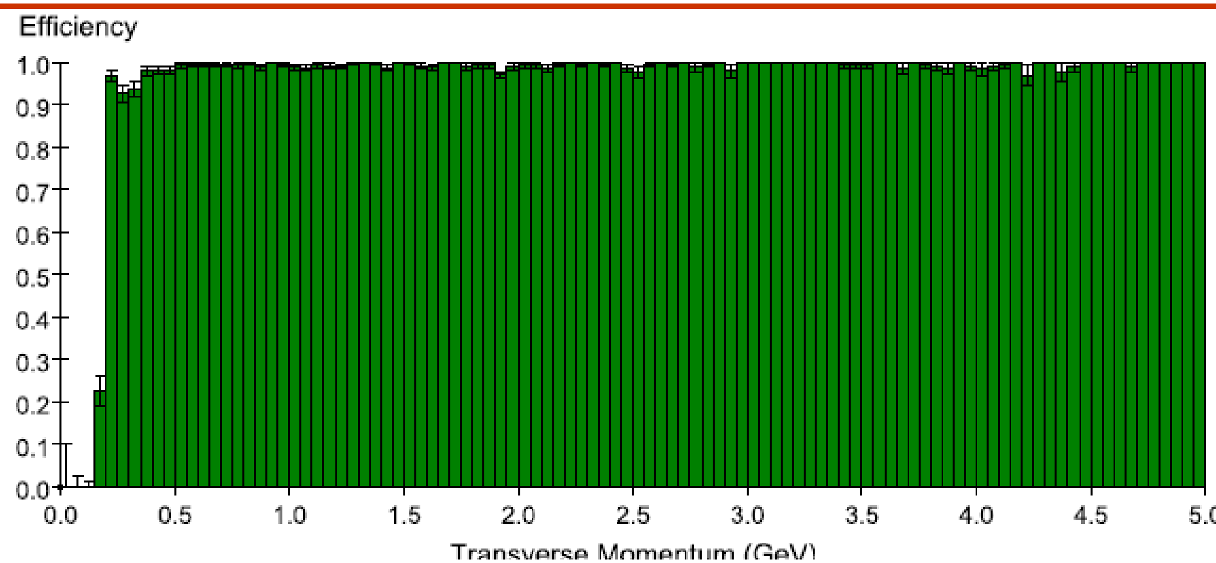
	ILC	*Belle 2*
occupancy	0.13 hits/μm²/s	0.4 hits/μm²/s
Frame time	25-100 μs	10 μs
Duty cycle	1/200	1
	Excellent spatial resolution (3- 5 μm) AND material budget (0.12 % X_0/layer)	Lowest possible material budget (0.15 % X_0/layer) Moderate pixel size (50 x 75 μm²)

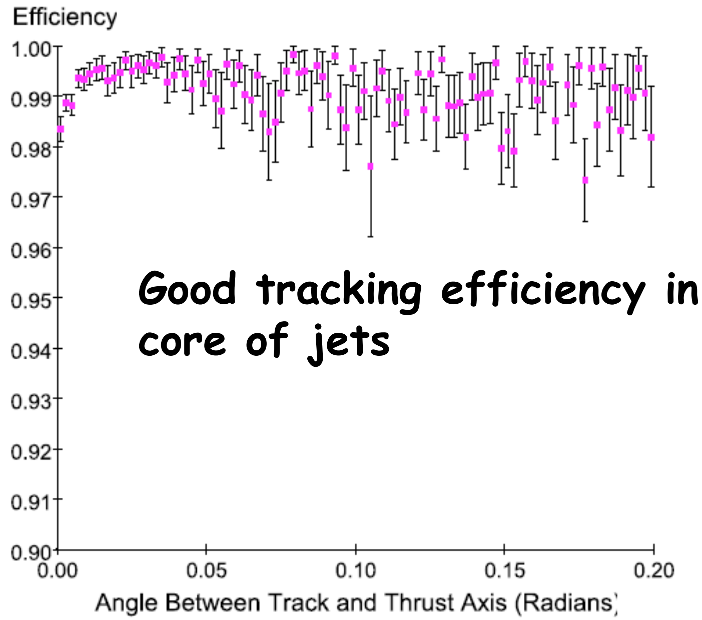
Belle-II presents a more severe challenge than the ILC in several aspects (Vos)

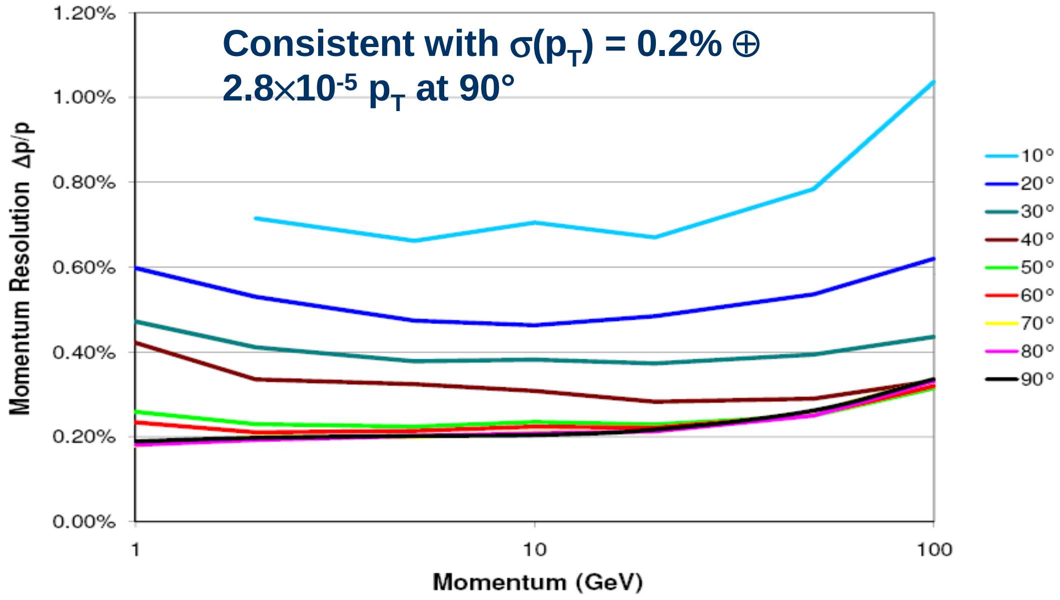
Tracking system performance

Generally find high tracking efficiency for tracks with:

- pT > 0.2 GeV
- $|\cos(\theta)| < 0.99$



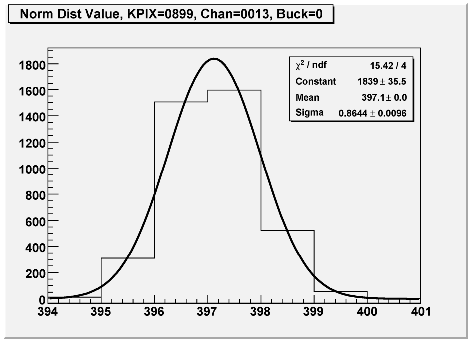




SiD Electronics - KPiX

- Some problems (lock-up) with KPiX 7 (64-channel), and KPiX 8 (256-channel).

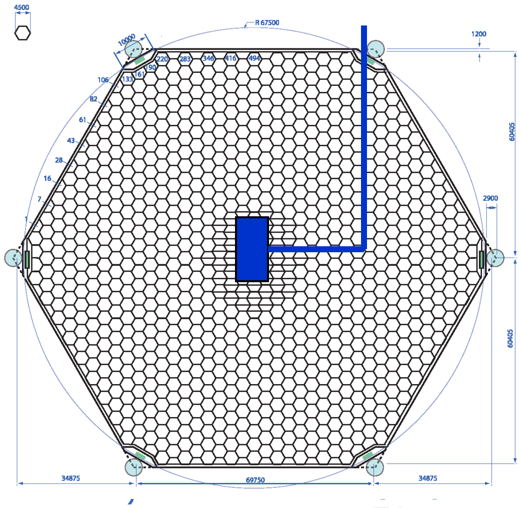
-> Noise measurement



1300 e rms

- Version 9 submitted: 512 channels – back in few weeks.

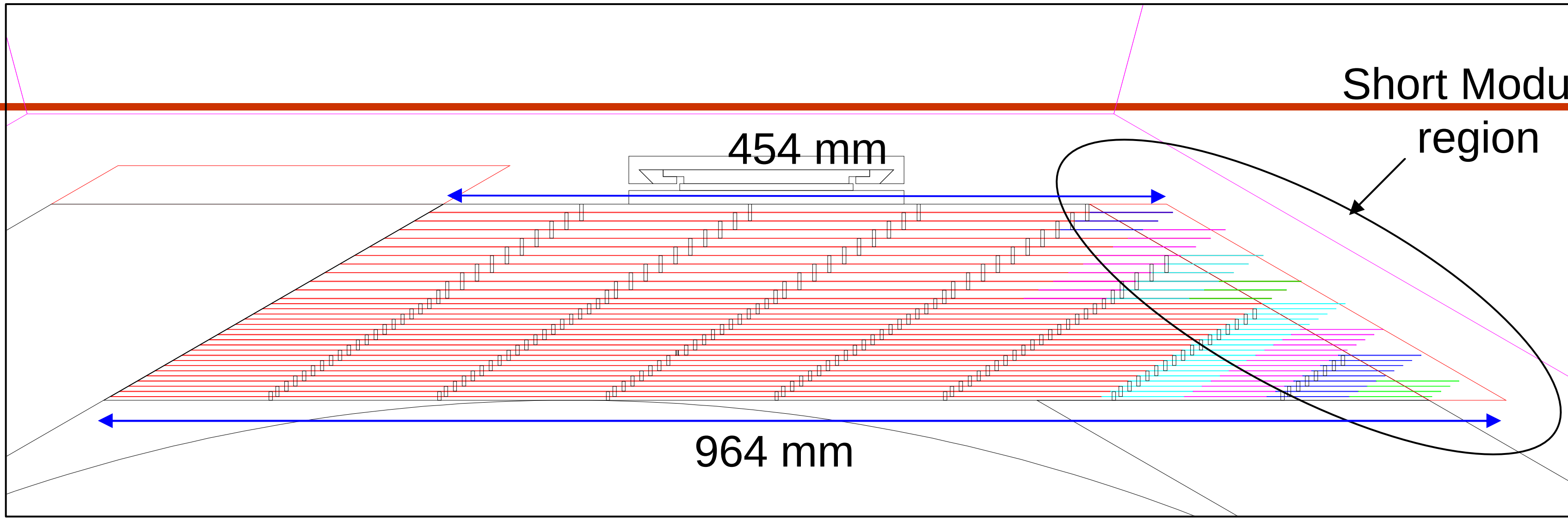
SiD ECal

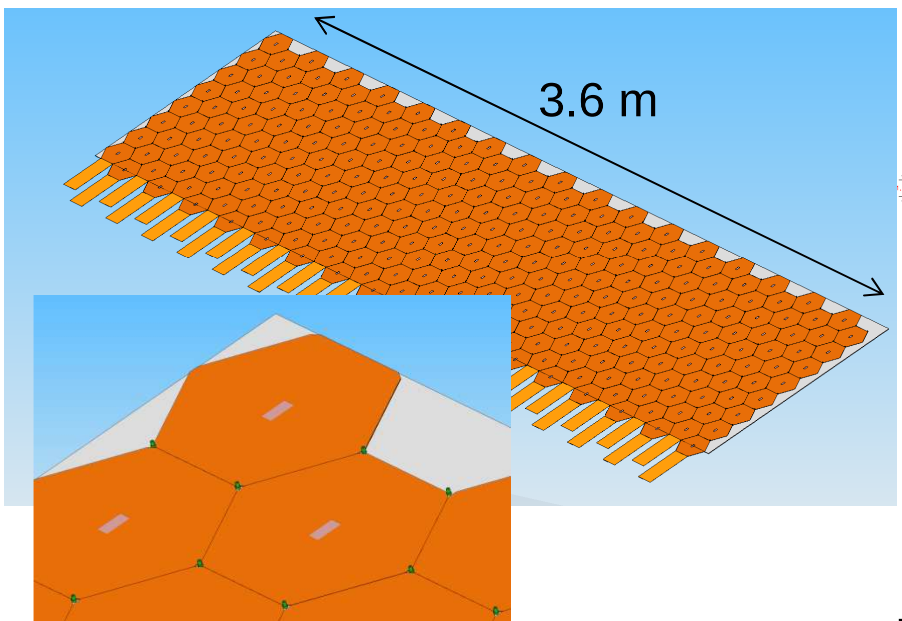


With a 512-channel KPiX-9 bump-bonded to a sensor, can get noise measurements for the full range of input capacitances and resistances. Goal for ~ Spring.

1024-channel KPiX by Summer

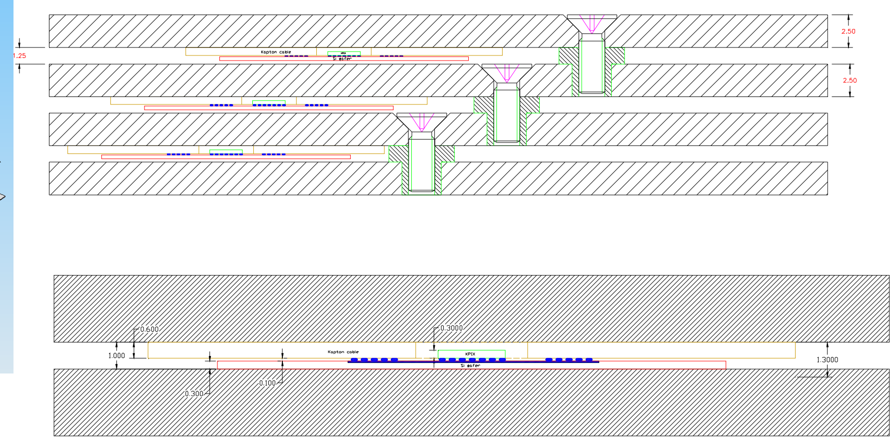
SiD Electromagnetic Calorimeter



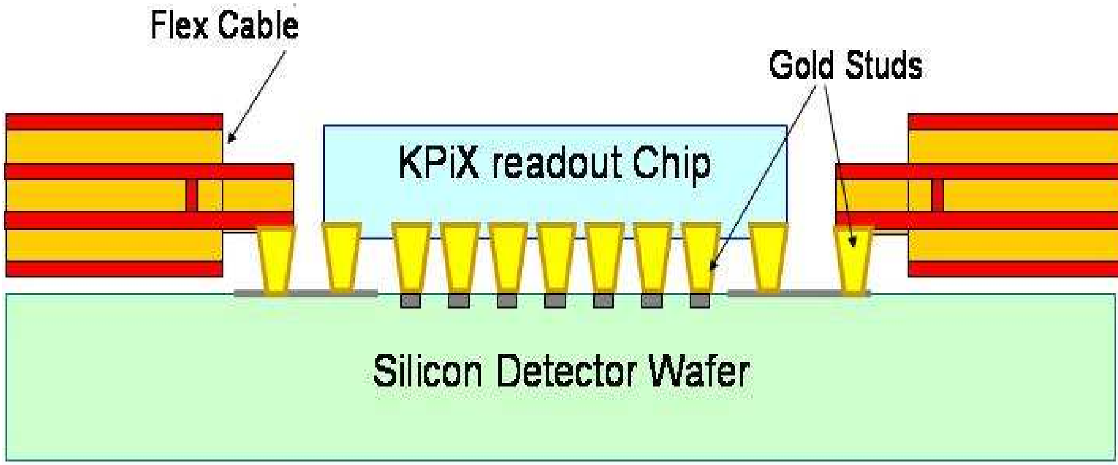


Staggered layout

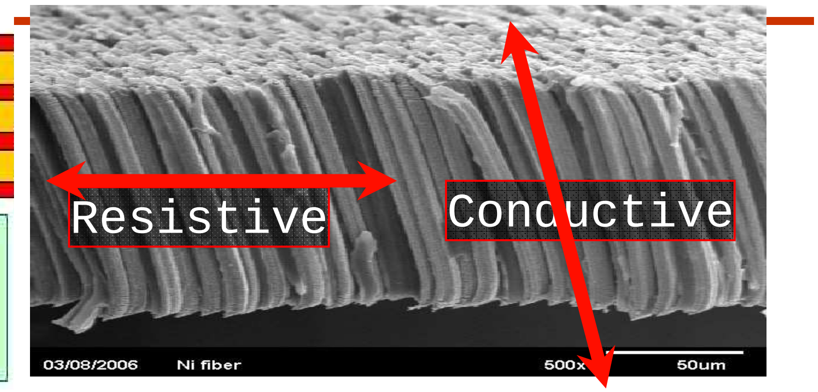
Only 2 masks for the wafer and 8 for the kapton

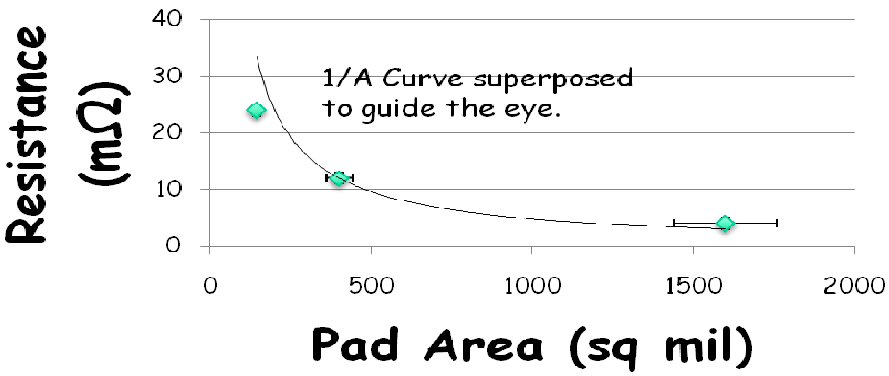


SiD Electromagnetic Calorimeter

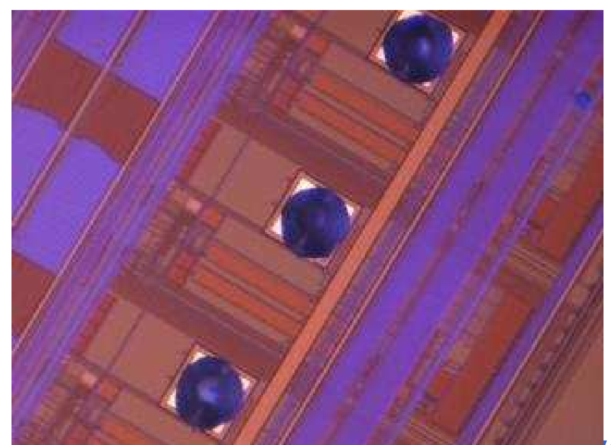


Anisotropic Conducting Film





Gold-stud bonding for prototypes



Initial results are promising. Goal for Flex Cable pads (100 sq mil) is ~100 mΩ, which is achievable.