SiD

http://silicondetector.org

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Thanks to: Marco Oriunno, Marcel Stanitzki, Harry Weerts

Outline

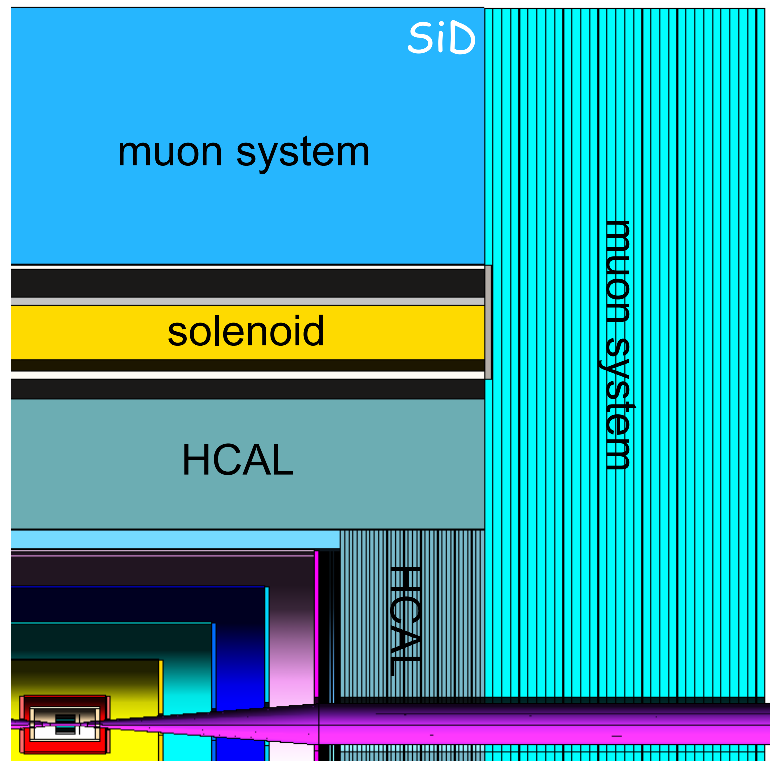
- **SiD overview**
- **Outline of SiD subsystems:**
  - **VXD + tracker**
  - **ECAL**
  - **HCAL**
  - **muon system**
  - **forward region**
  - **machine-detector interface issues**
- **Preparing for SiD LoI**

SiD session Wednesday 16.00

- Preparing for SiD LoI
- Vertex and tracking
- ECAL and KPIX
- HCAL
- PFA and bench-marking
- Discussion

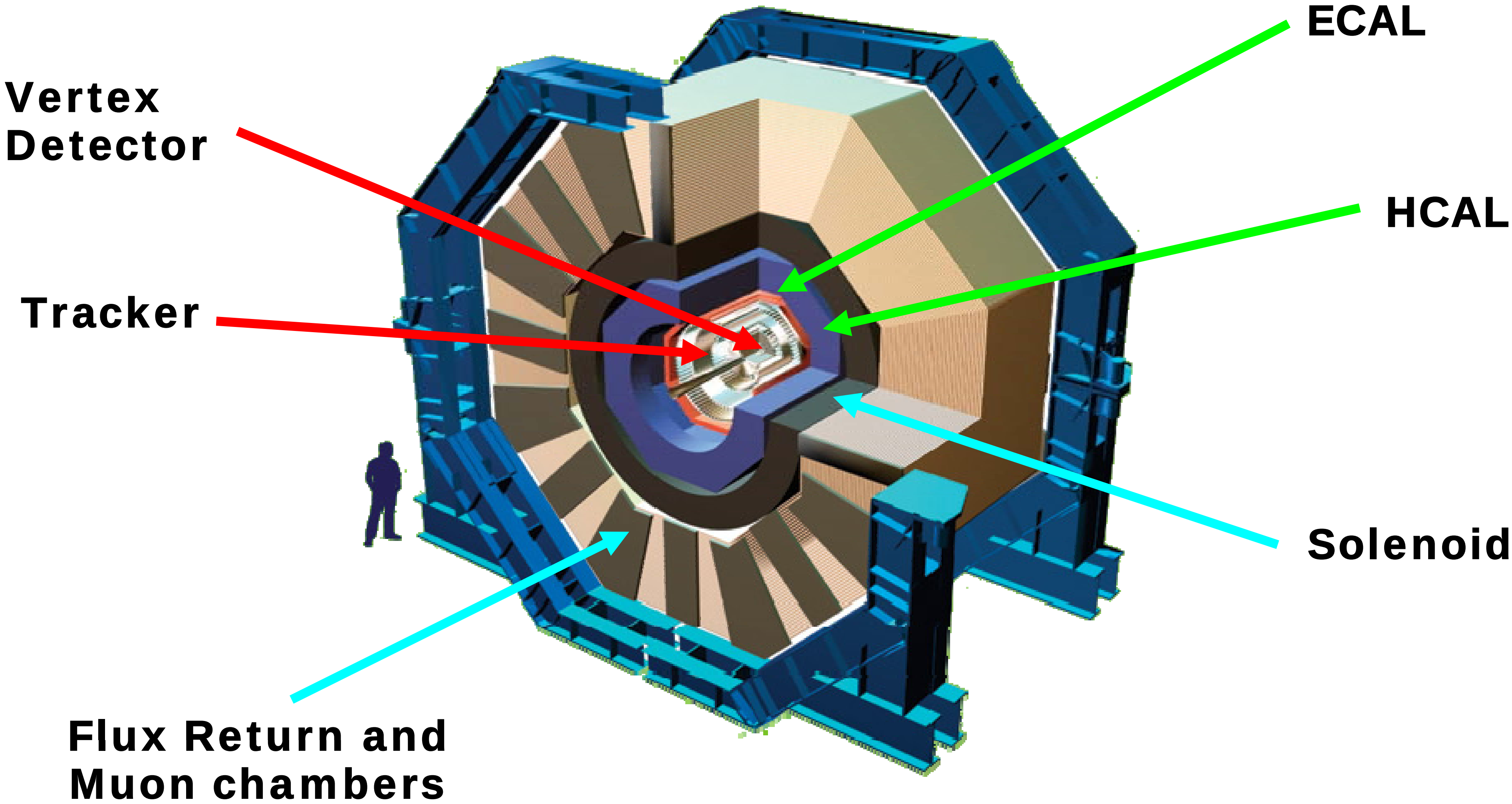
SiD Design Philosophy

- Particle flow calorimetry will deliver the best possible performance
- Si/W is the best approach for the ECAL and digital calorimetry for HCAL
- Limit calorimeter radius to constrain the costs
- Boost B-field to maintain BR^2
- Si tracking system for best momentum resolution and lowest mass
- Pixel vertex detector for best pattern recognition
- Keep close watch on costs



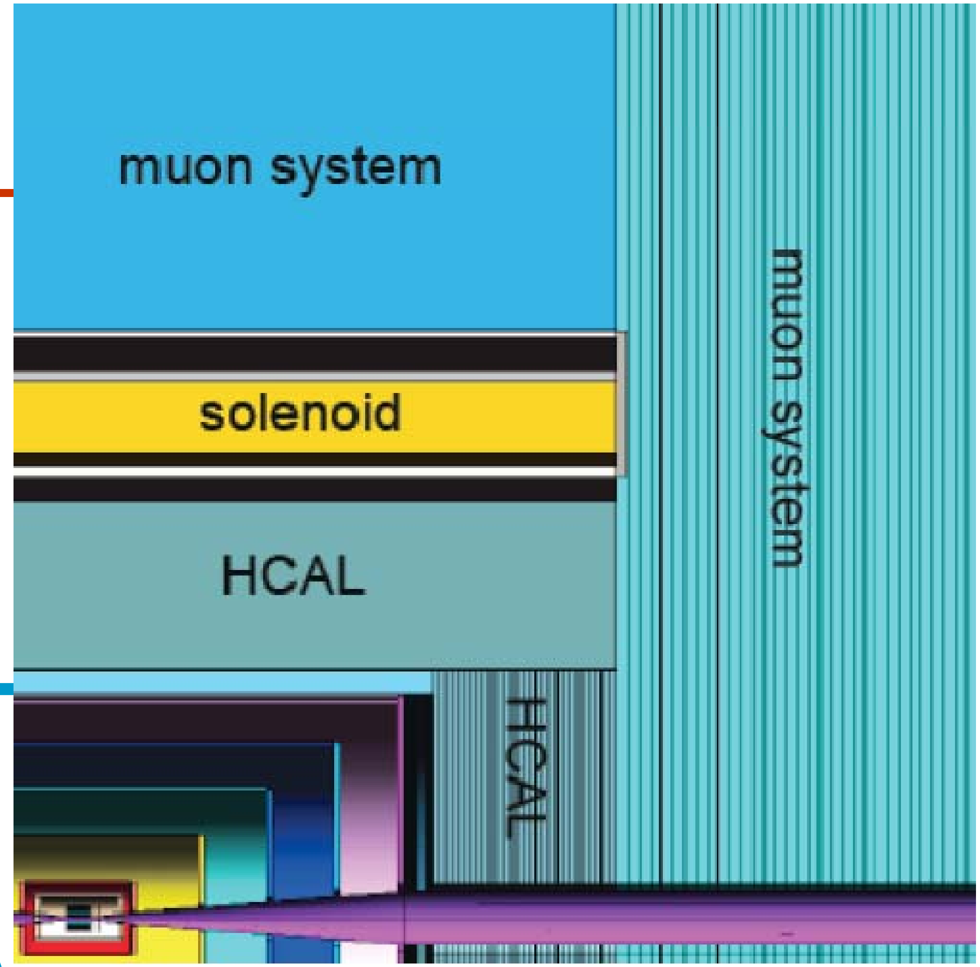
Detector is viewed as single fully integrated system, not just a collection of different subdetectors

The SiD Detector Concept



SiD Starting Point
Details & Dimensions

Flux return / muon
R_{in} = 333 cm
R_{out} = 645 cm



Solenoid: 5 T; R_{in} = 250 cm

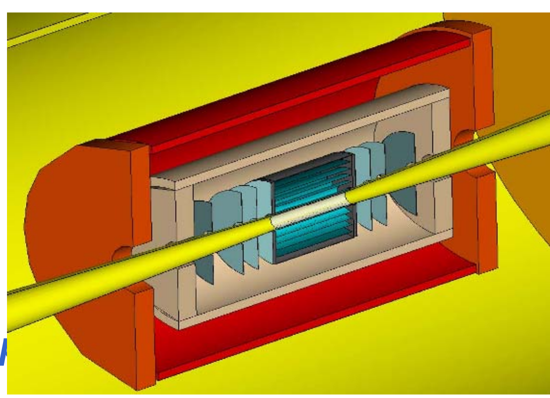
PFA

HCAL Fe: 38 layers; R_{in} = 138 cm

EMCAL Si / W: 30 layers R_{in} = 125 cm

Si

Si tracking: 5 layers; R_{in} = 18 cm

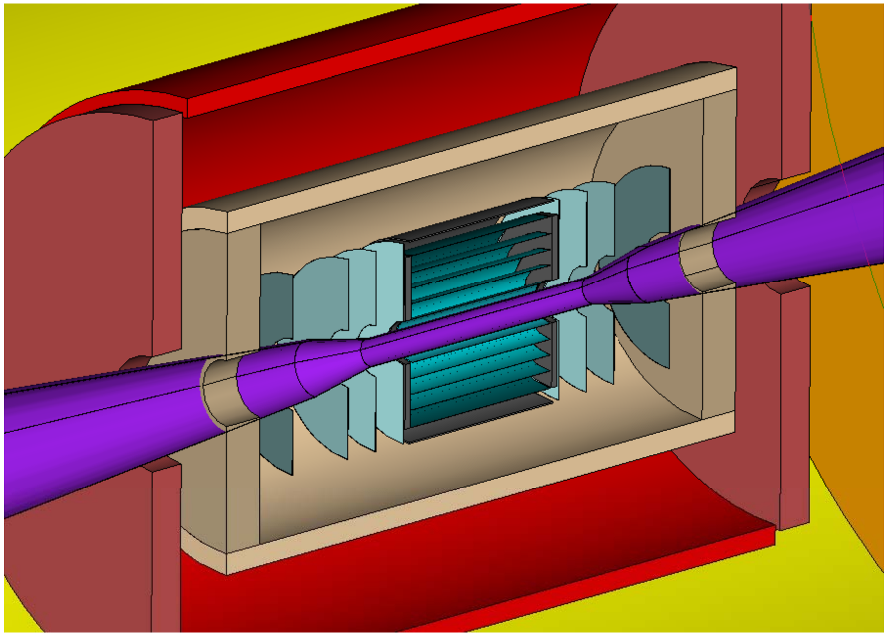


Vertex detector:
5 barrels, 4 disks; R_{in} = 1.4 cm

Vertexing and Tracking

Tracking system conceived as integrated optimized detector

- **Vertex detection**
  - **Inner central and forward pixel detector**
- **Momentum measurement**
  - **Outer central and forward tracking**
- **Integrated with calorimeter**
- **Integrated with forward systems**



Detector requirements (vertex)

- **Spacepoint resolution: < 4 μm**
- **Impact parameter resolution:**

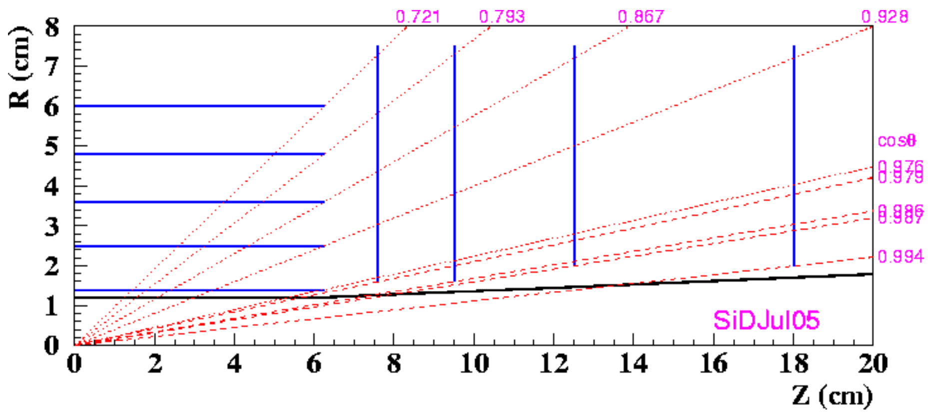
$\sigma_{r\phi} \approx \sigma_{rz} \approx 5 \oplus 10/(p\sin^{3/2}\vartheta)$

- **Smallest possible inner radius**
- **Momentum resolution 5 10^{-5} (GeV^{-1})**
- **Transparency: ~0.1% X_0 per layer**
- **Stand-alone tracking capability**

The Vertex Detector

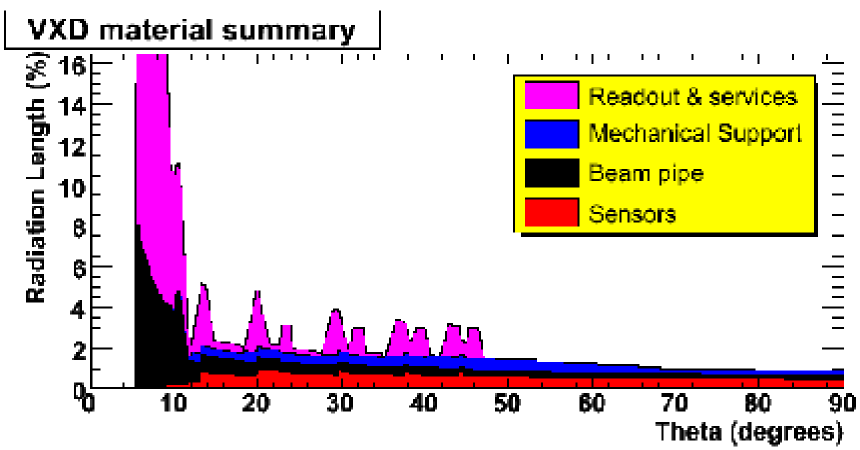
5 Barrels

- R_{in} = 14 mm to R_{out} = 60 mm
- 24-fold φ segmentation
- 12.5 cm each
- All barrel layers same length



2 x 4 Forward Disks

- radius increases with Z

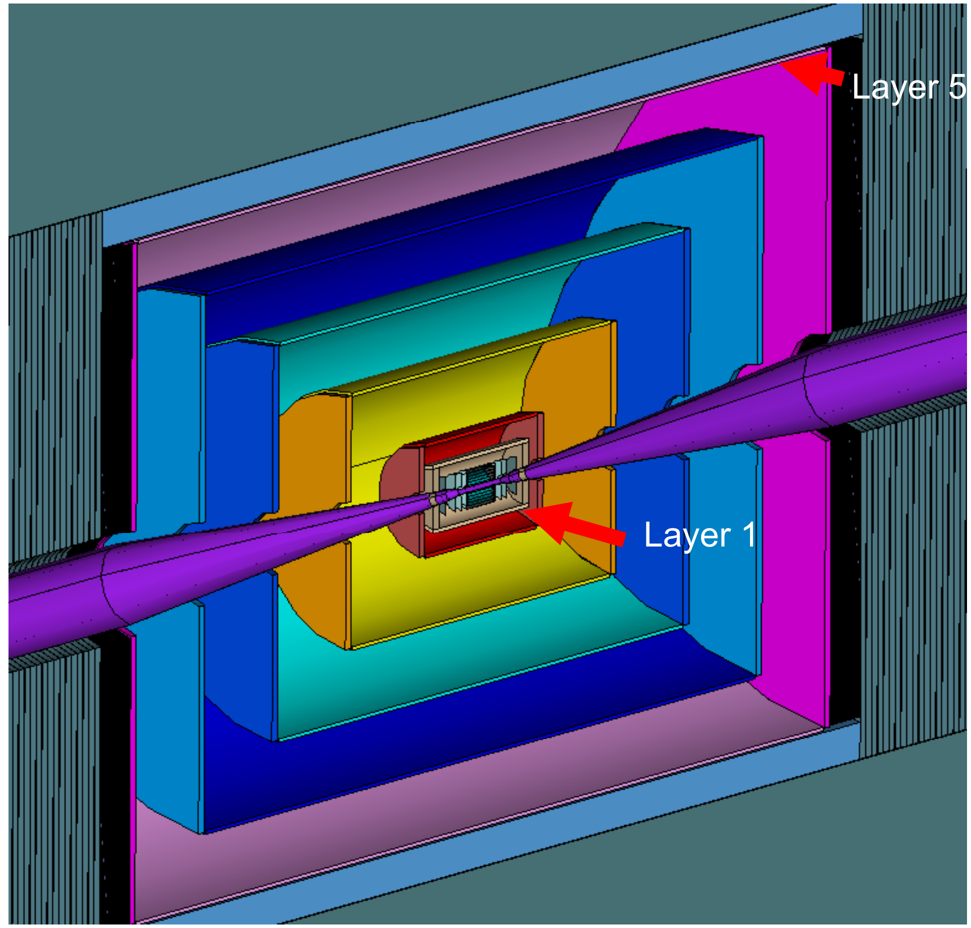


Low material, low power design

- 0.1 % X_0

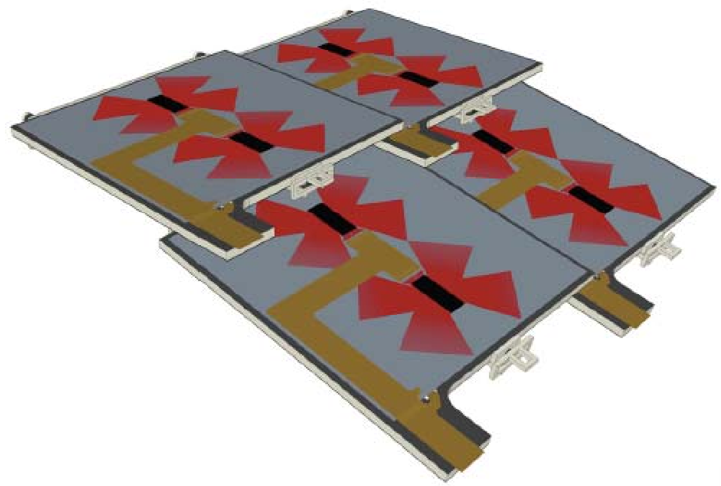
The Outer Tracker

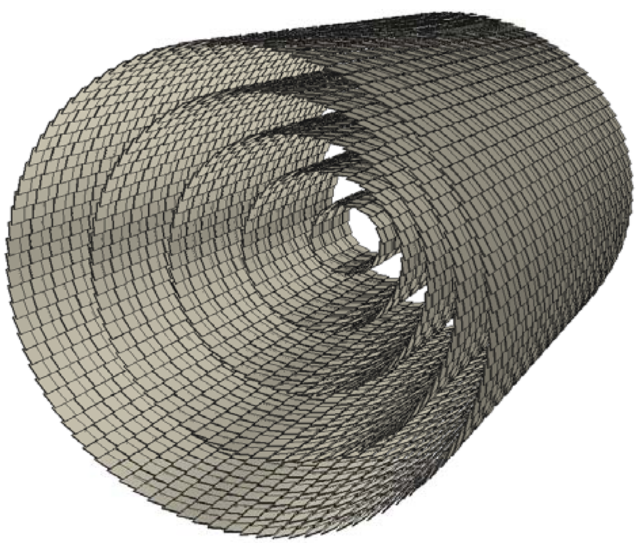
- **5 layer Si-Tracker**
- **5 barrel cylinders**
  - **φ readout only**
  - **10 cm z segmentation**
- **5 forward double disks**
  - **measure r and φ**
- **Material budget 0.8% X_0/layer**

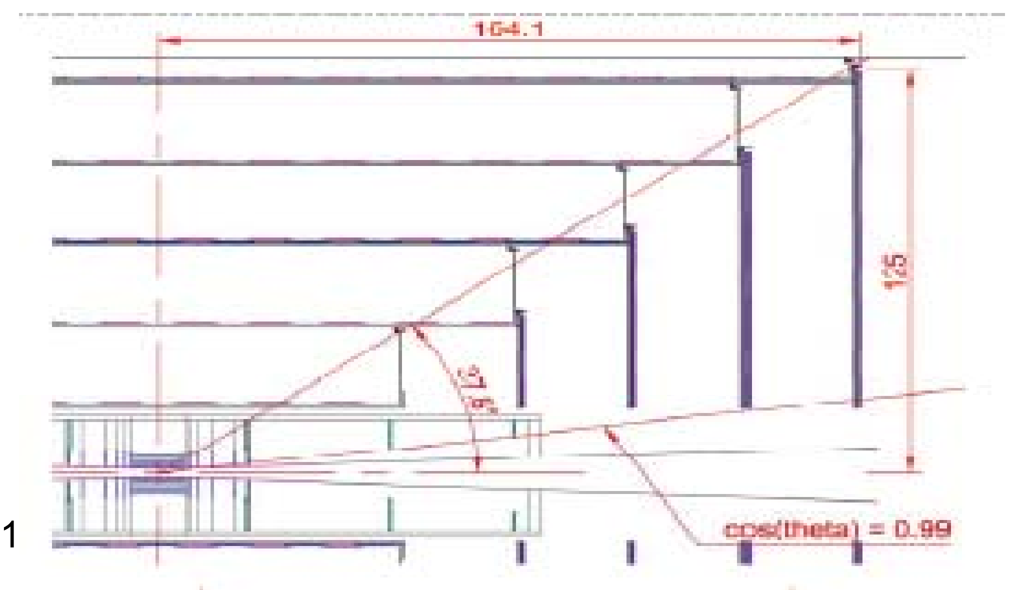


Tracker Mechanics

- Sensor Tiles for barrel
- Kapton cables for signal routing
- Lightweight space frame







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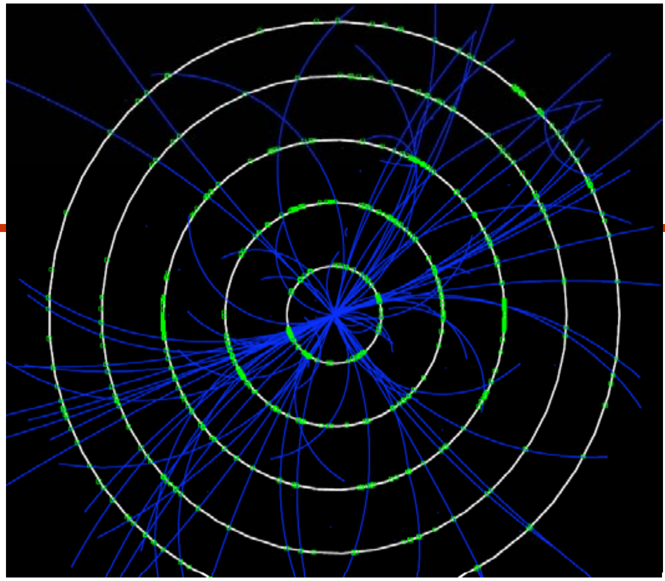
Tracking Performance

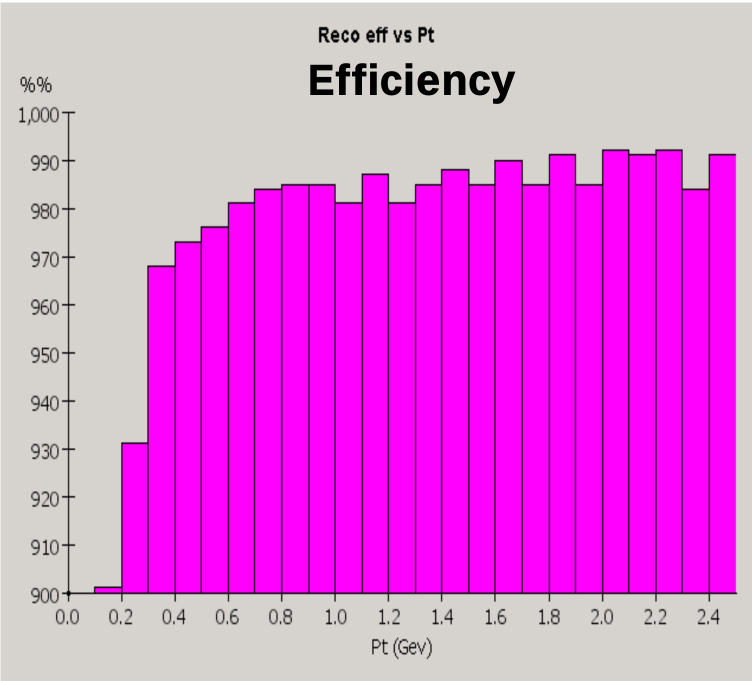


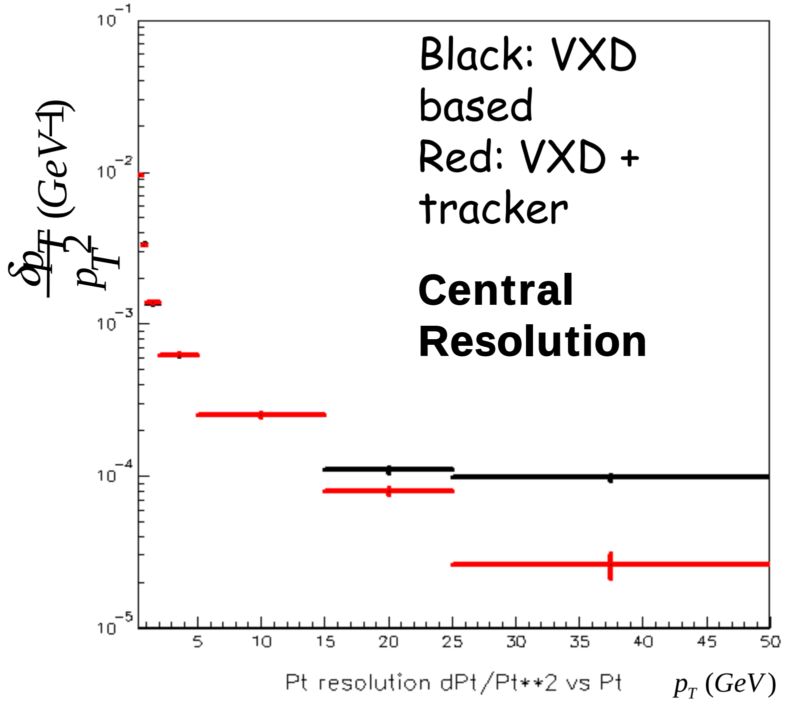
Full simulation

Vertex detector seeded pattern recognition (3 hit combinations)

Event Sample

- **ttbar-events, √s = 500 GeV**
- **background included**





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

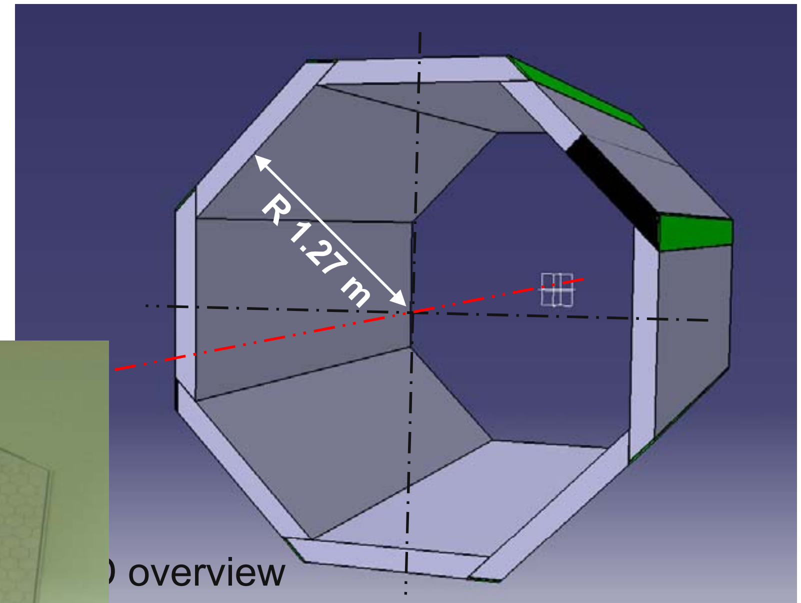
- **Maintain Molière radius by minimizing the gap between W plates**
  ~ 1mm Si detector gaps → Preserve $R_M(W)_{eff}$= 12 mm
- **Requires aggressive integration of electronics with mechanical**
- **Pixel size ~ 4 x 4 mm^2**
- **Energy resolution ~ 15%/√E + 1%**

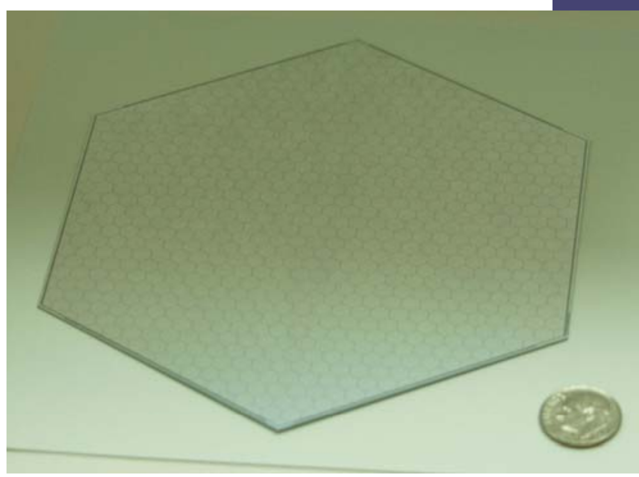
The Si-W ECAL

30 layer Si-W
- **20/10 configuration**
- **2.5 / 5 mm W**

16 mm^2 hexagonal Si-Pads

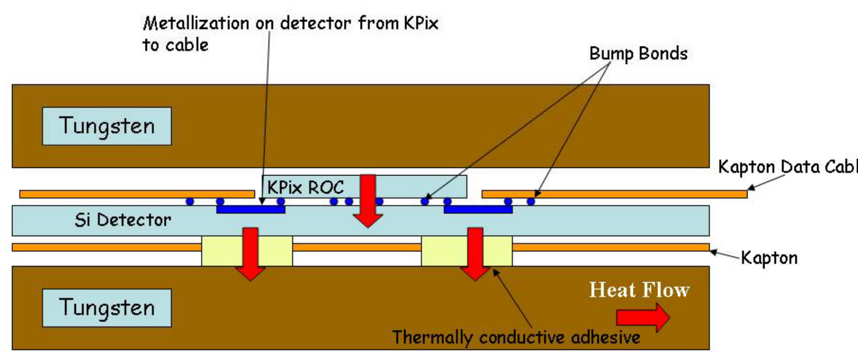
1300 m^2 Si area (CMS 205 m^2)





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

(MAPS advanced Tpixel alternative)



The hadron calorimeter (HCAL)

Role of hadron calorimeter in context of PFA is to measure neutrals and allow "tracking" i.e. matching of clusters to charged particles.

Number of technology choices:

Absorber

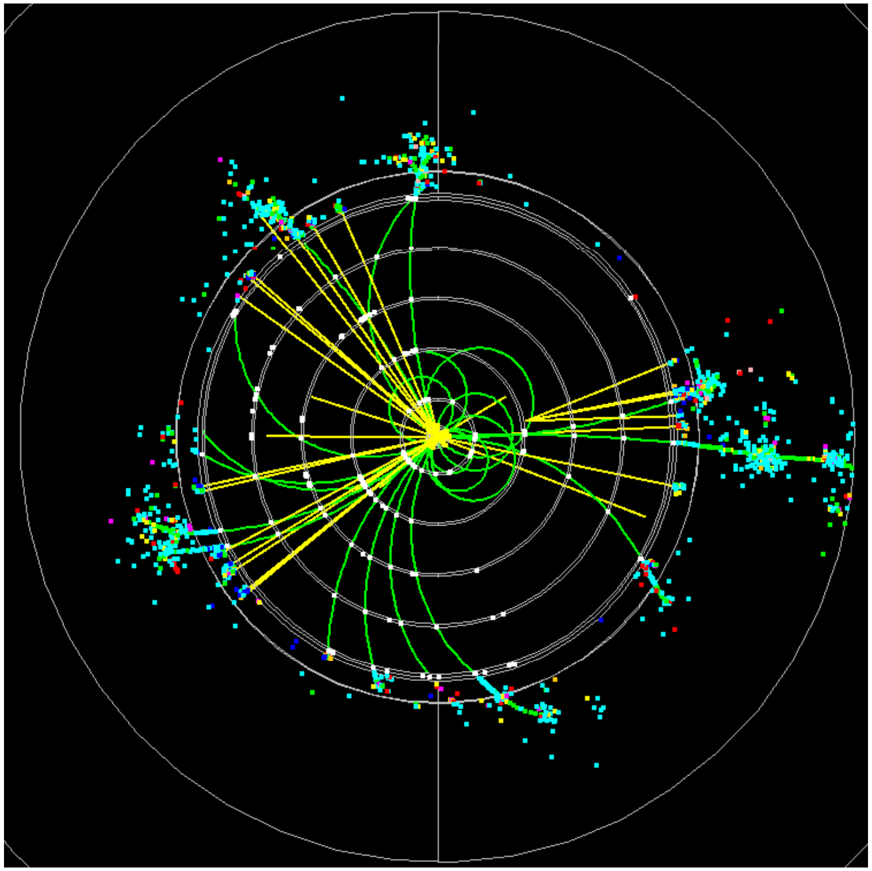
- **Tungsten/Steel/Copper**

Readout

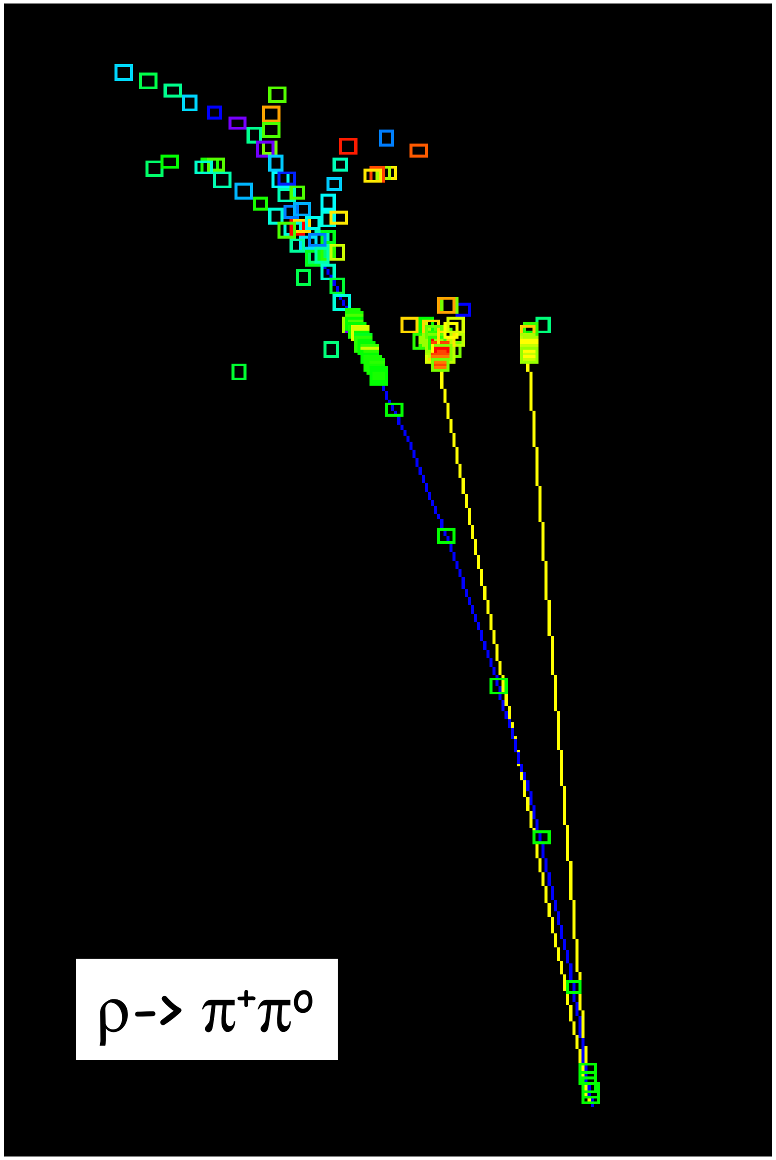
- **Digital (RPC/GEM/micromegas)**
- **Analog (Scintillator SiPM)**

High granularity reqd. for PFA;

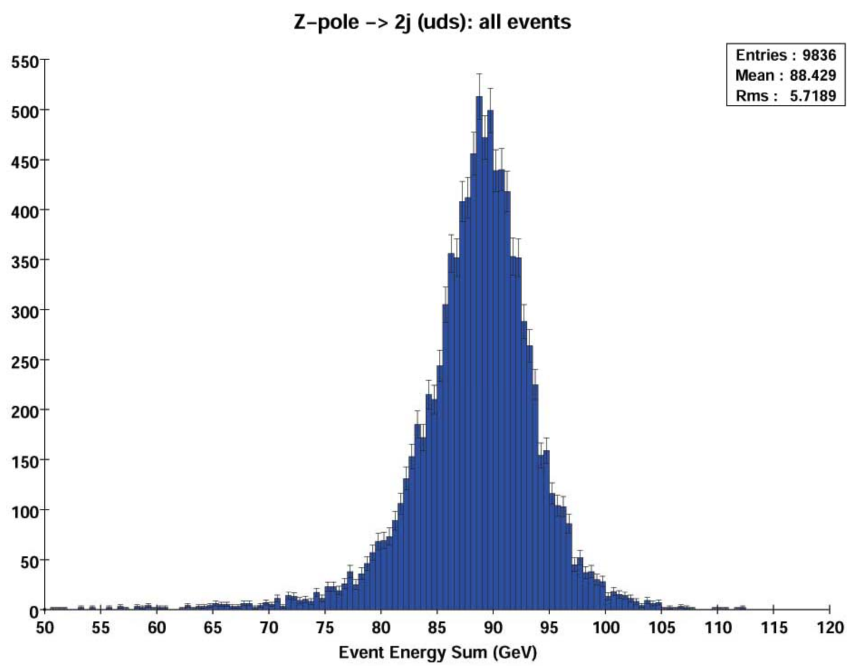
ECAL/HCAL integrated unit

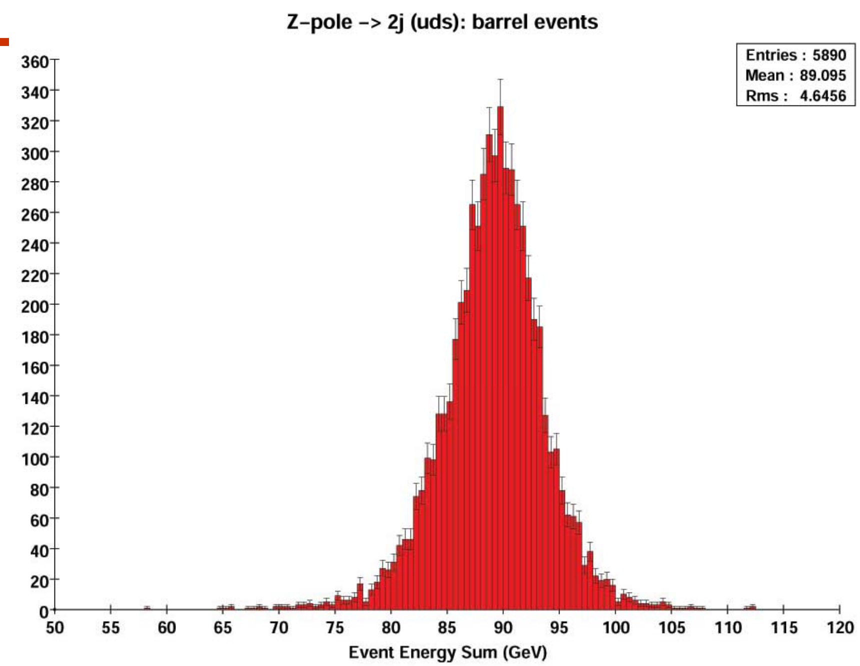


Example of response



SiD PFA performance: $e^+e^- \rightarrow$ qqbar(uds) @ 91GeV





All events, no cut

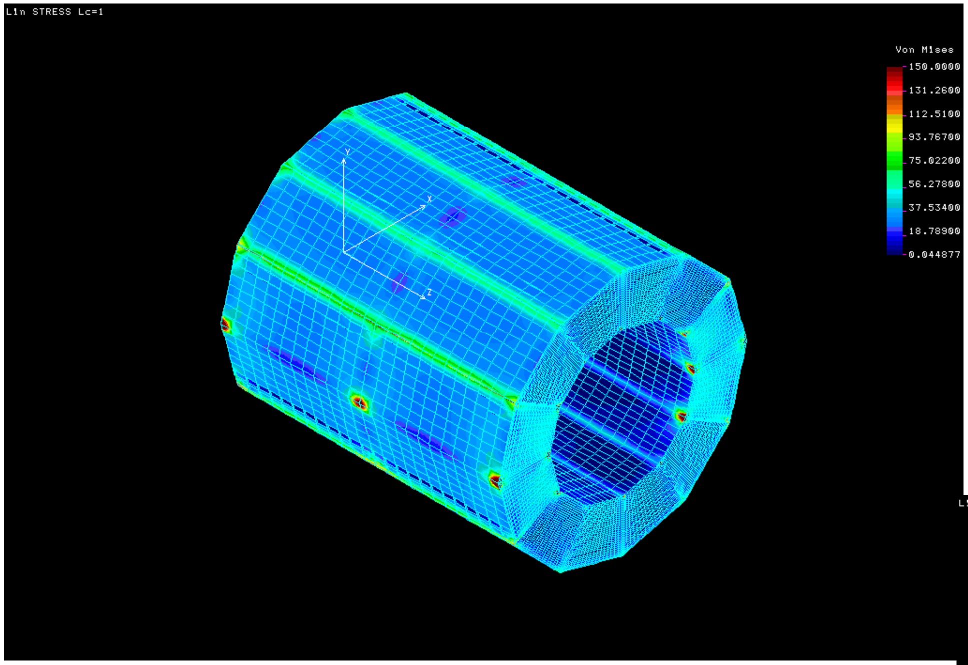
Mean 88.43 GeV
RMS 5.718 GeV
RMS90 3.600 GeV
[42.6 %/sqrt(E) or σ_{Ejet} /Ejet=6.4 %]

Barrel events (cos(theta[Q]) < 1/sqrt(2))

Mean 89.10 GeV
RMS 4.646 GeV
RMS90 3.283 GeV
[**34.7 % / sqrt(E)** or σ_{Ejet} /E_{jet}=5.2 %]

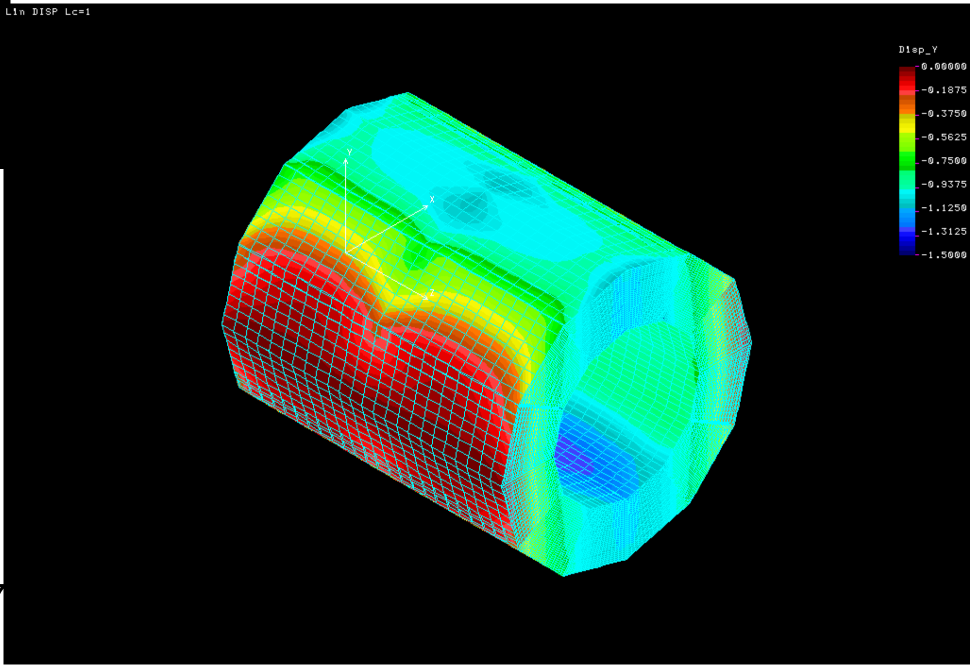
Still not quite 30%/sqrt(E) or 3-4% yet, but close now

SiD HCal Engineering Design



Guarino (ANL)

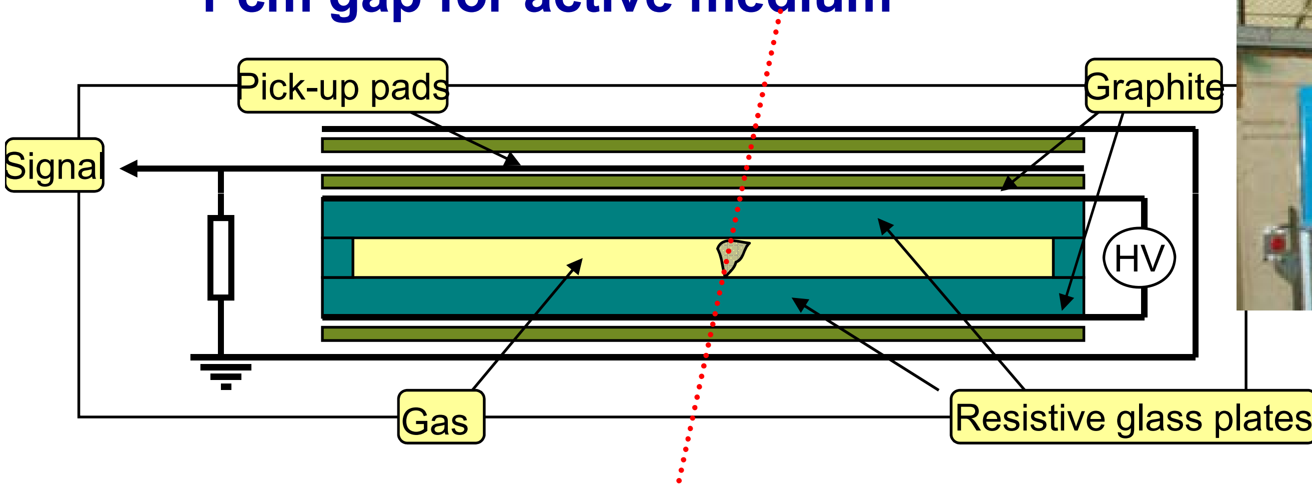
Geffroy (LAPP)



Current Baseline HCAL

– Digital calorimeter, inside the coil
  - R_i = 139 cm, R_o =237 cm
– Thickness of 4λ (thin)
  - 38 layers of 2.0cm steel
  - 1 cm gap for active medium

– Readout (one of choices)
  - RPC's as active medium (ANL)
  - 1 x 1 cm**2 pads



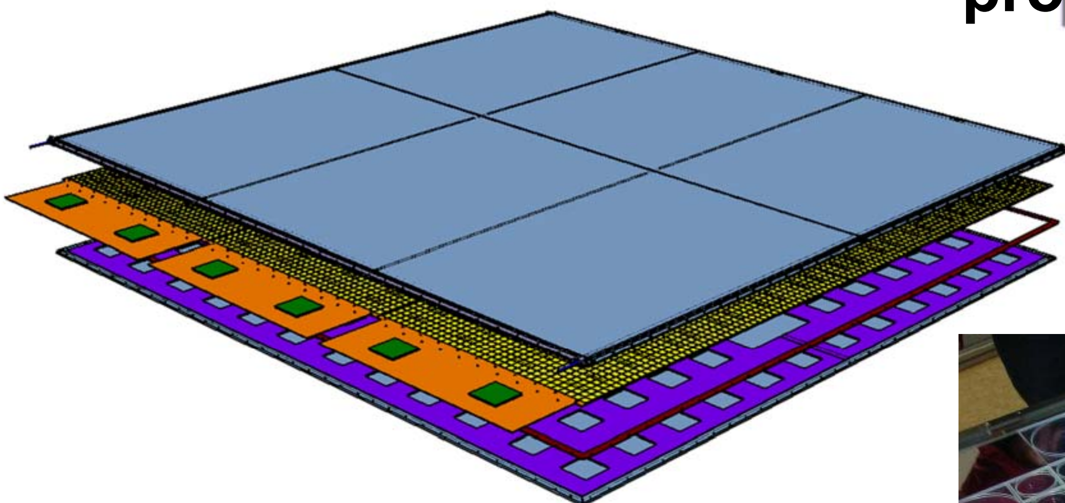
Vertical Slice beam test (FNAL)

All other options being explored and pursued (eg. R&D in CALICE):
- Gas based: RPC, GEM and micromegas (single bit /multibit)
- Scintillator based

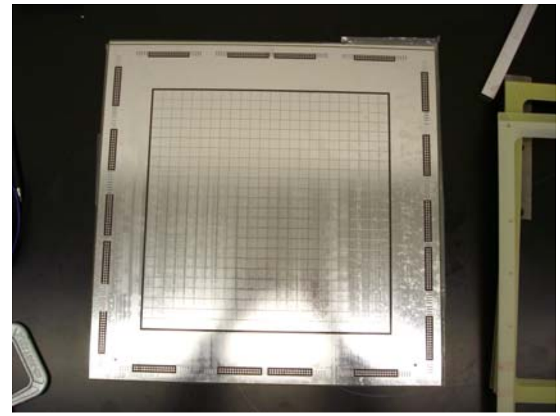
protoypes, cosmic + beam test results …

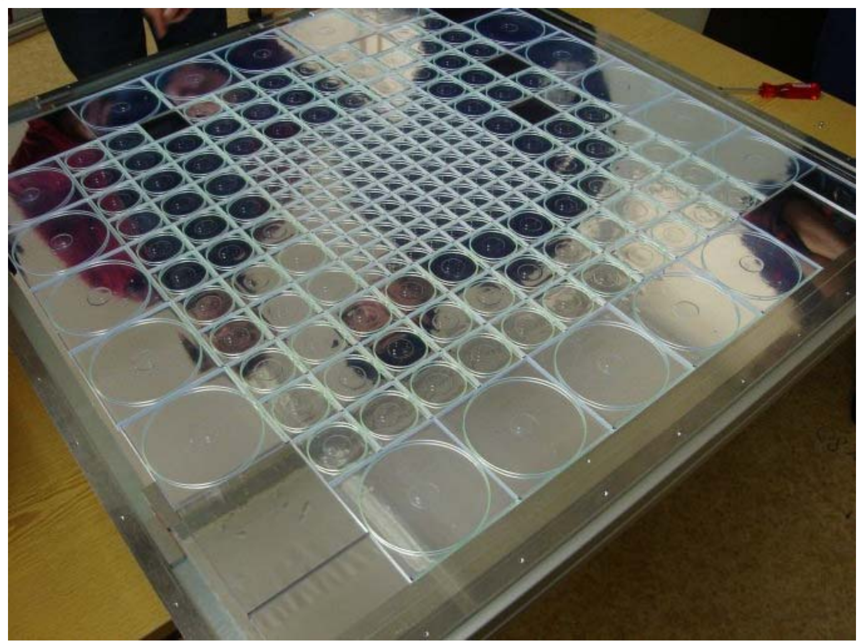
HCAL prototype R&D

Design for 1m**2
micromegas prototype



GEM-based
prototype





Analogue readout:
- Scintillator tiles
- 3 x 3 cm
- Si-PM as readout
- Test beam – CALICE

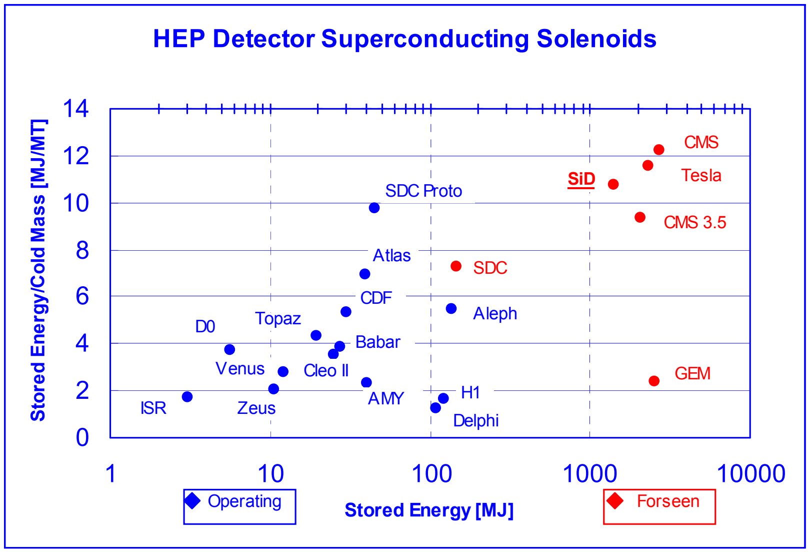
Dual Readout?

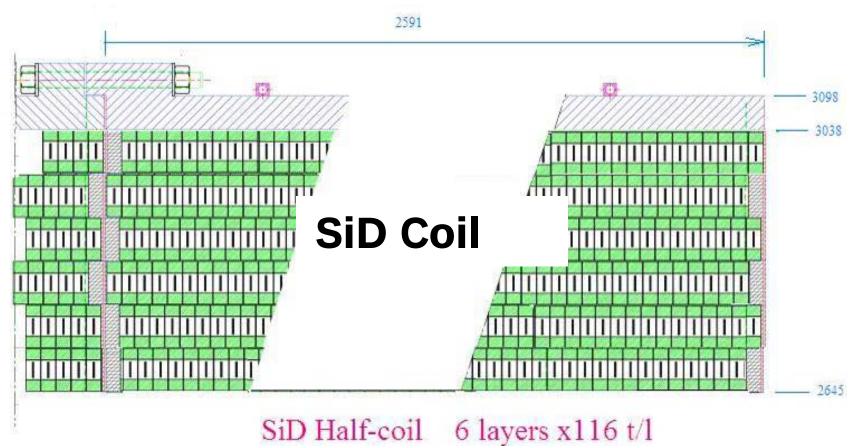
Solenoid

Design is solenoid with B(0,0) = 5T (not done previously)

– **Clear Bore Ø ~ 5 m; L = 5.4 m: Stored Energy ~ 1.2 GJ**

- **For comparison, CMS: 4 T, Ø = 6m, L = 13m: 2.7 GJ**





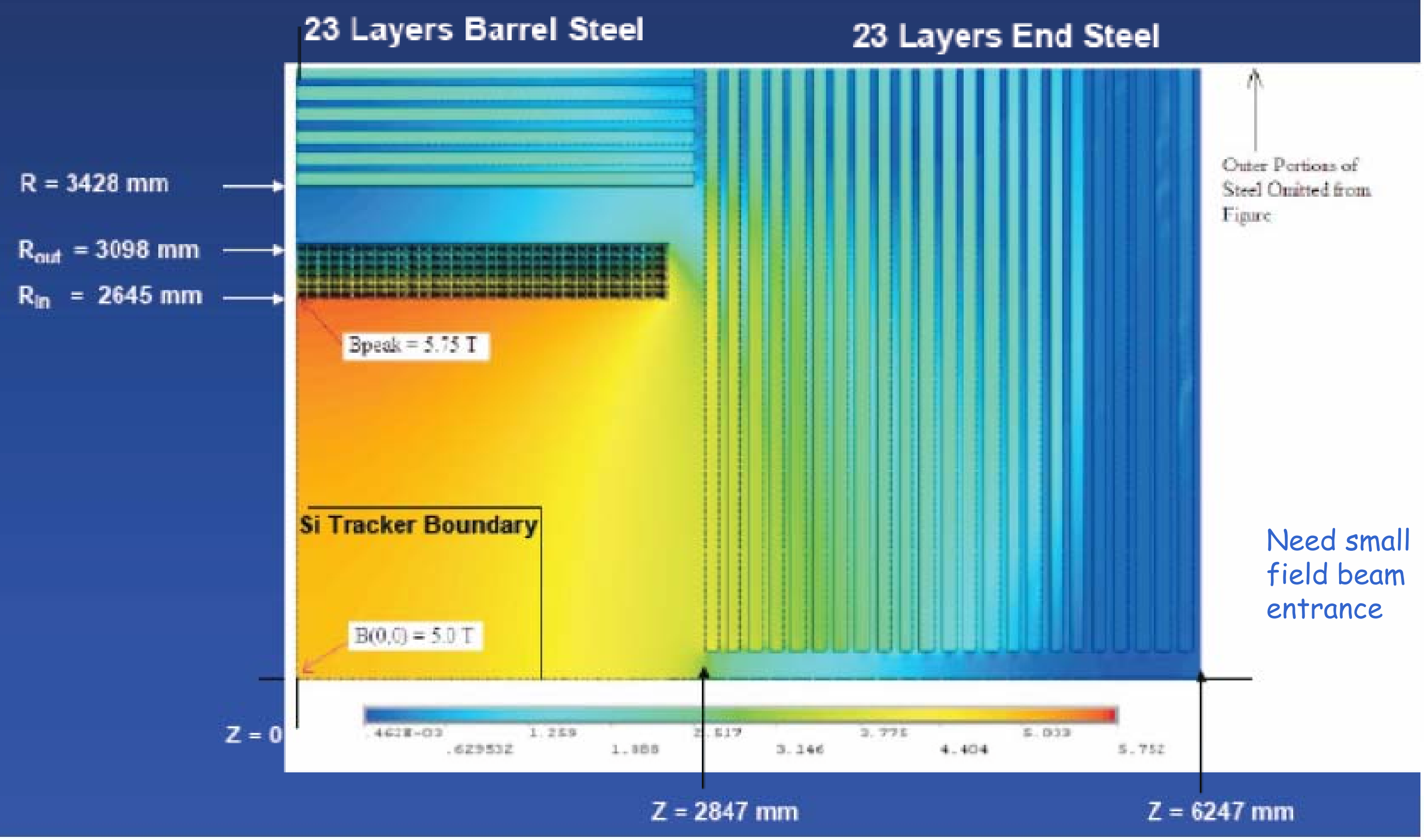
Full feasibility study of design based on CMS conductor:

Start with CMS conductor design, but increase winding layers from 4 to 6

- **I(CMS)= 19500 A, I(SiD) = 18000 A; Peak Field (CMS) 4.6 T, (SiD) 5.8 T**
- **Net performance increase needed from conductor is modest**

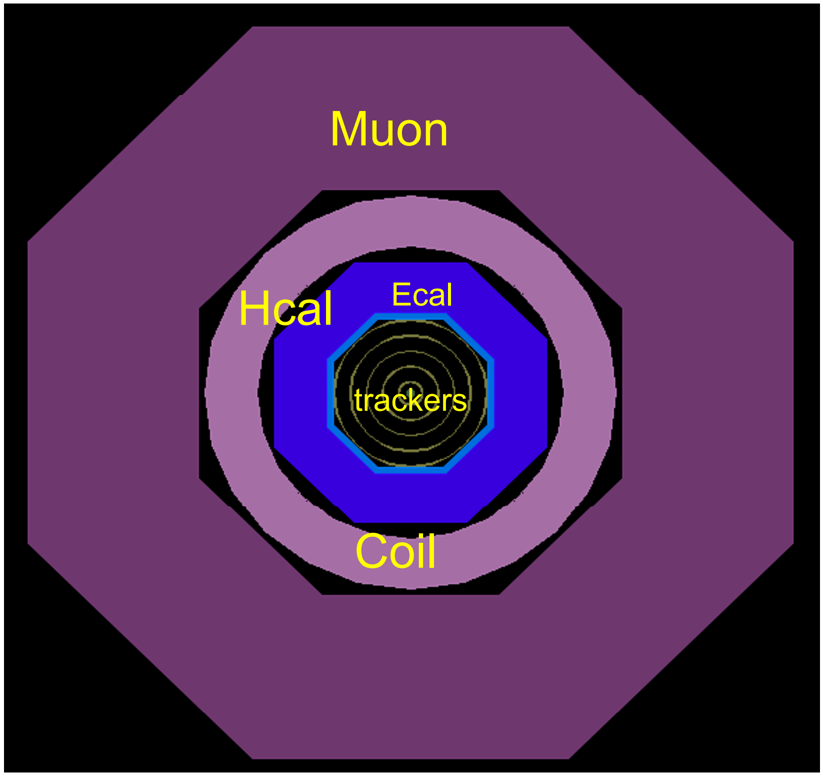
Field simulation

- ANSYS modeling of solenoid (2d, 3d)



Need small field beam entrance

Muon System



Muon System Baseline Configuration

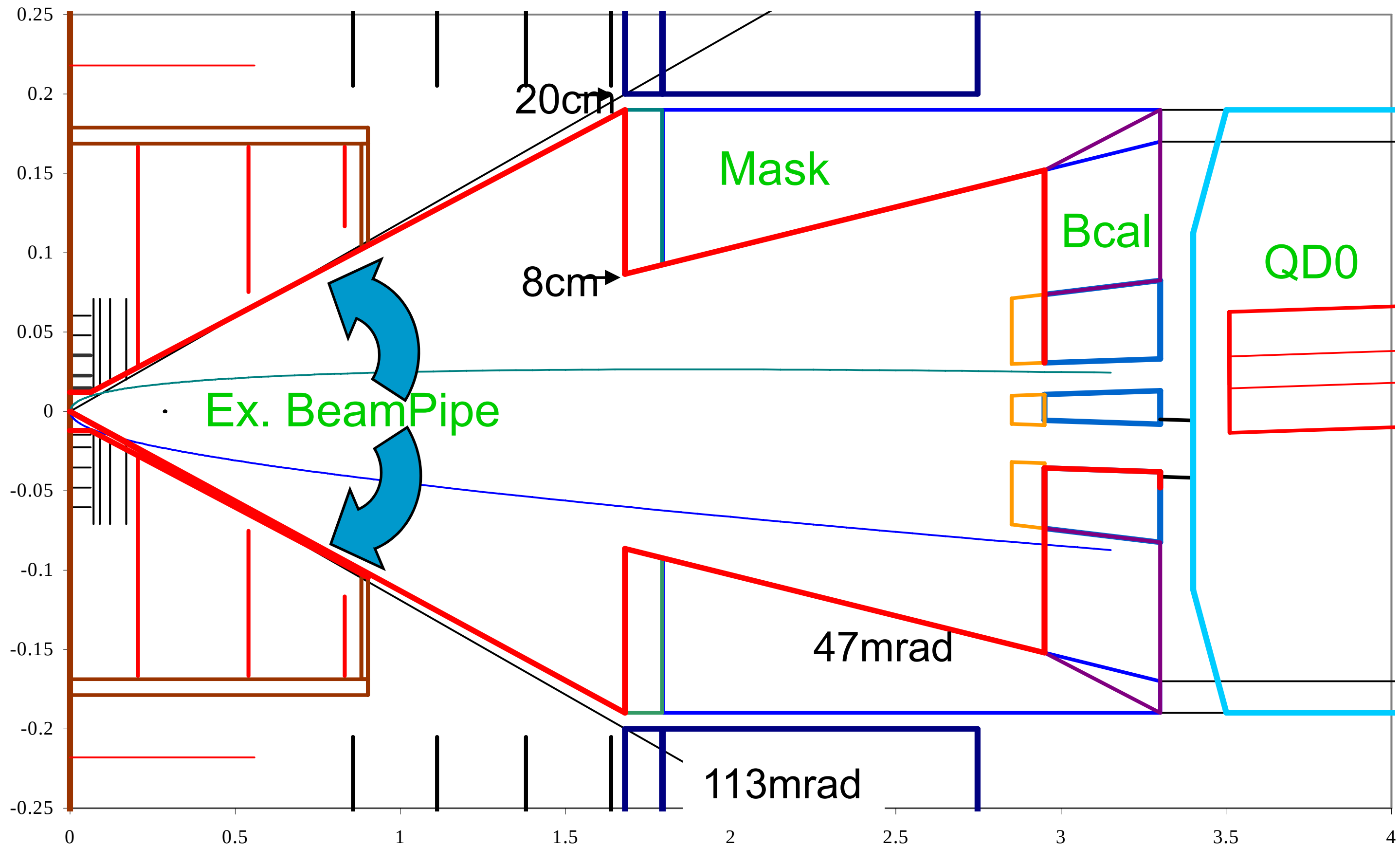
- Octagon: 48 layers, 5 cm thick steel absorber plates
- Six planes of x, y or u, v upstream of Fe flux return for xyz and direction of charged particles that enter muon system.
- instrumented gaps
- ~1 cm spatial resolution

Issues

- Technology: RPC, Scin/SiPMs, GEMS, Wire chambers
- HCAL punch-through: is the muon system needed as a tail catcher?
- How many layers are needed (0-23)? use HCAL ?
- Position resolution needed?

Machine-Detector Interface

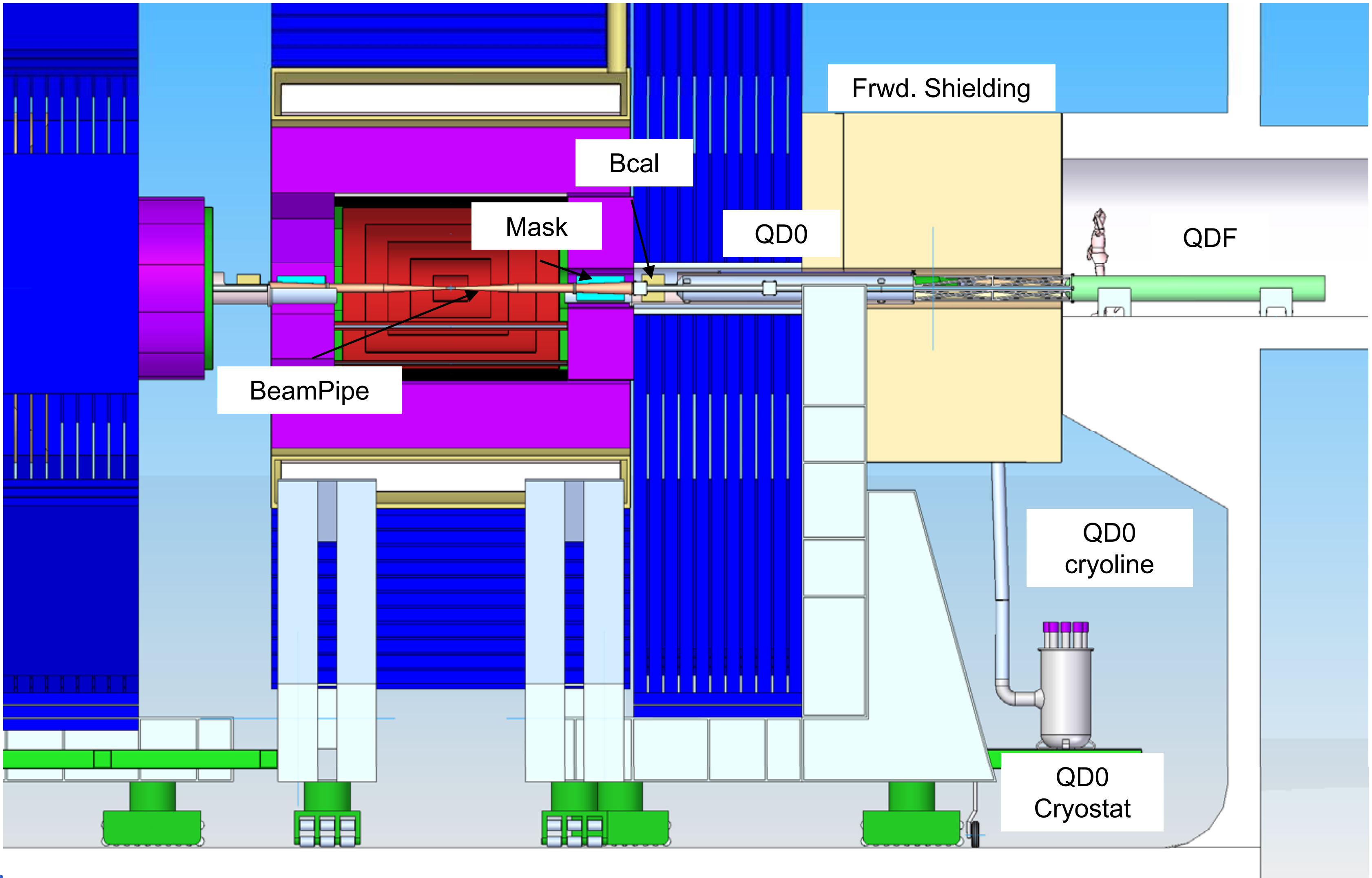
A layout of the SiD Forward Region is currently under discussion



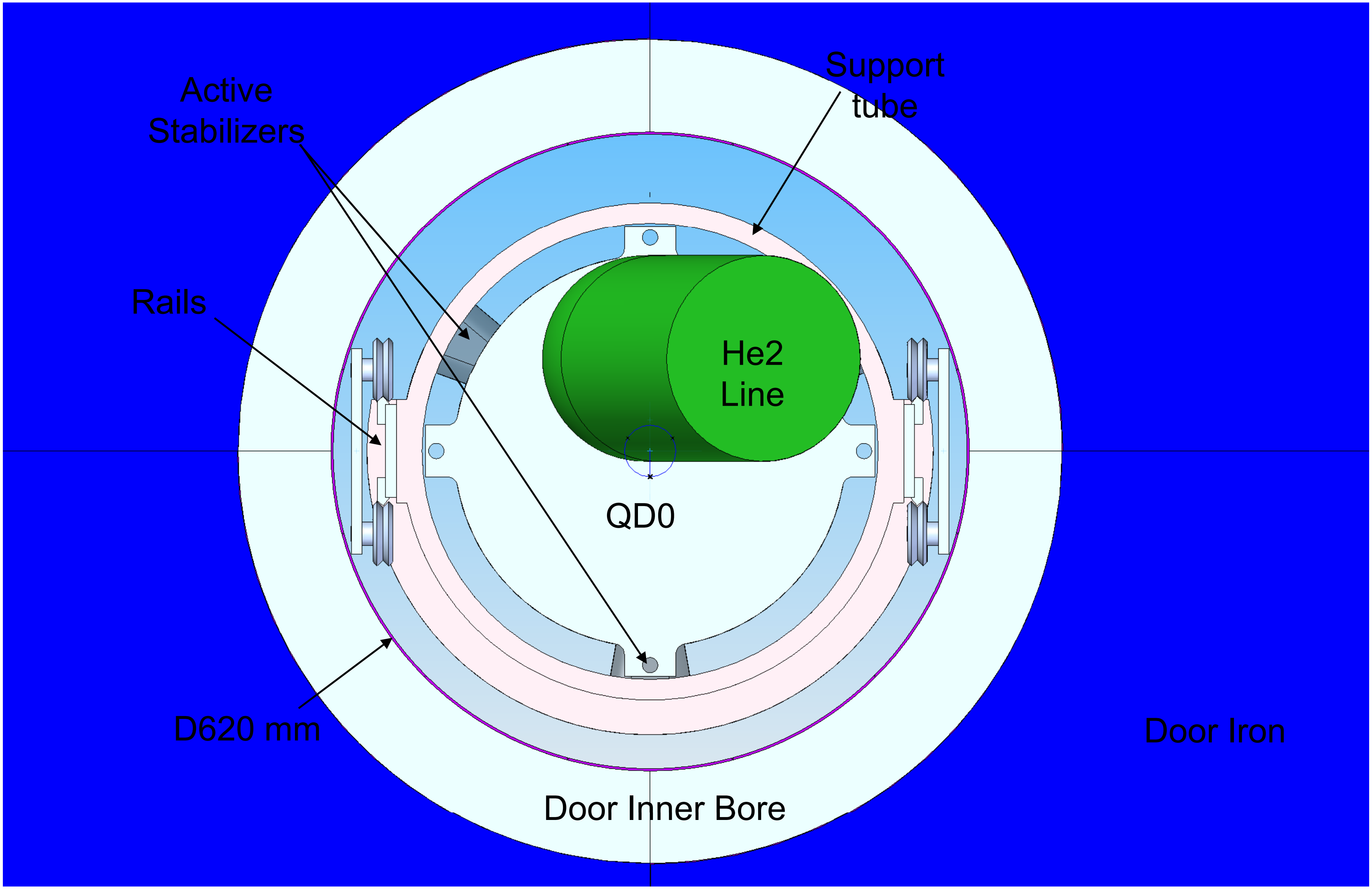
SiD LumiCal and BeamCal

LumiCal inner edge	≈36mrad about outgoing
LumiCal outer edge	≈113mrad about 0mrad
LumiCal fiducial	≈46-86mrad about outgoing
BeamCal outer edge	≈46mrad about outgoing
LumiCal	$30X_0$ Si-W
BeamCal	$30X_0$ rad-hard Si,diamond....

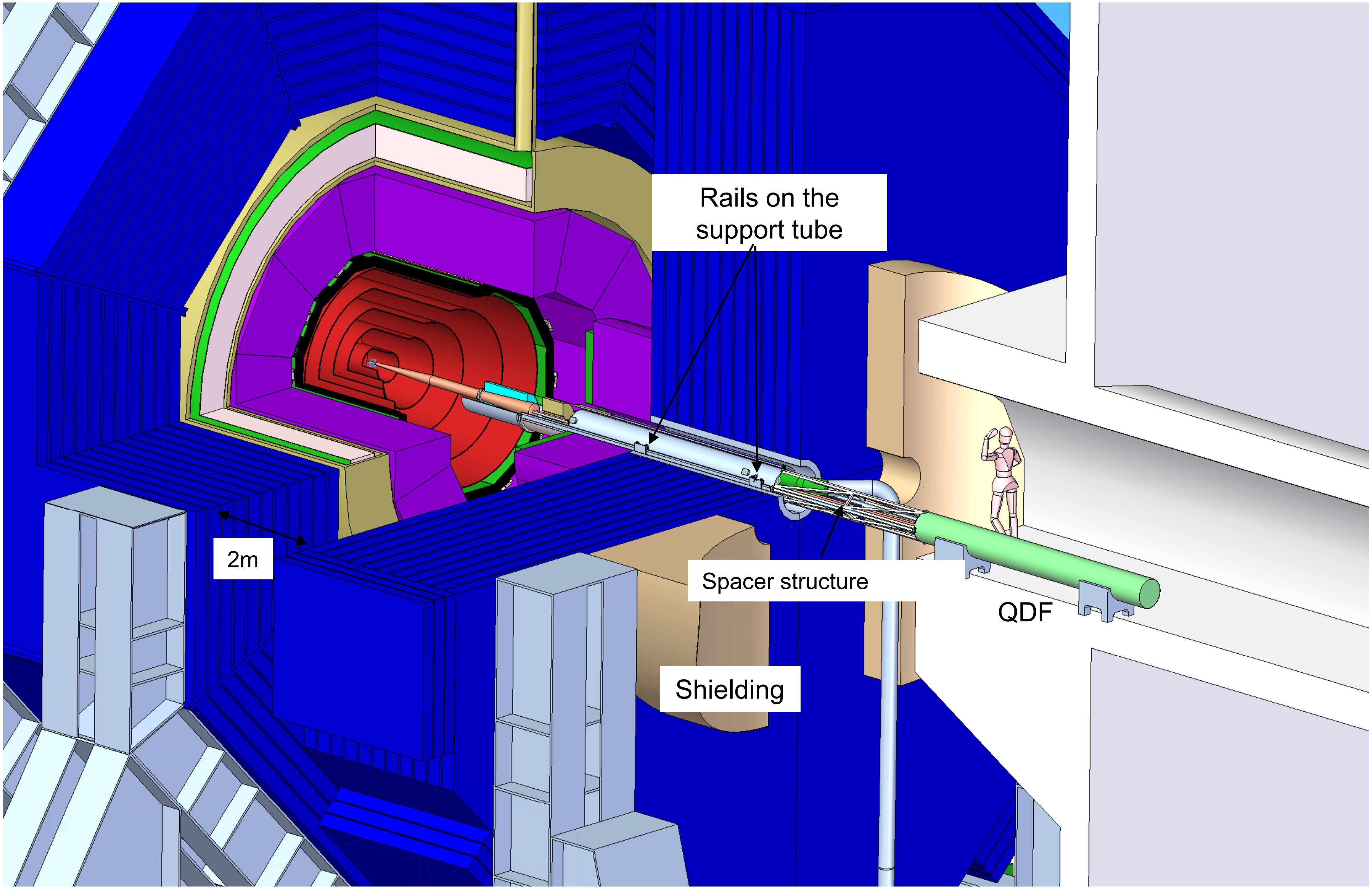
Developing engineered solutions



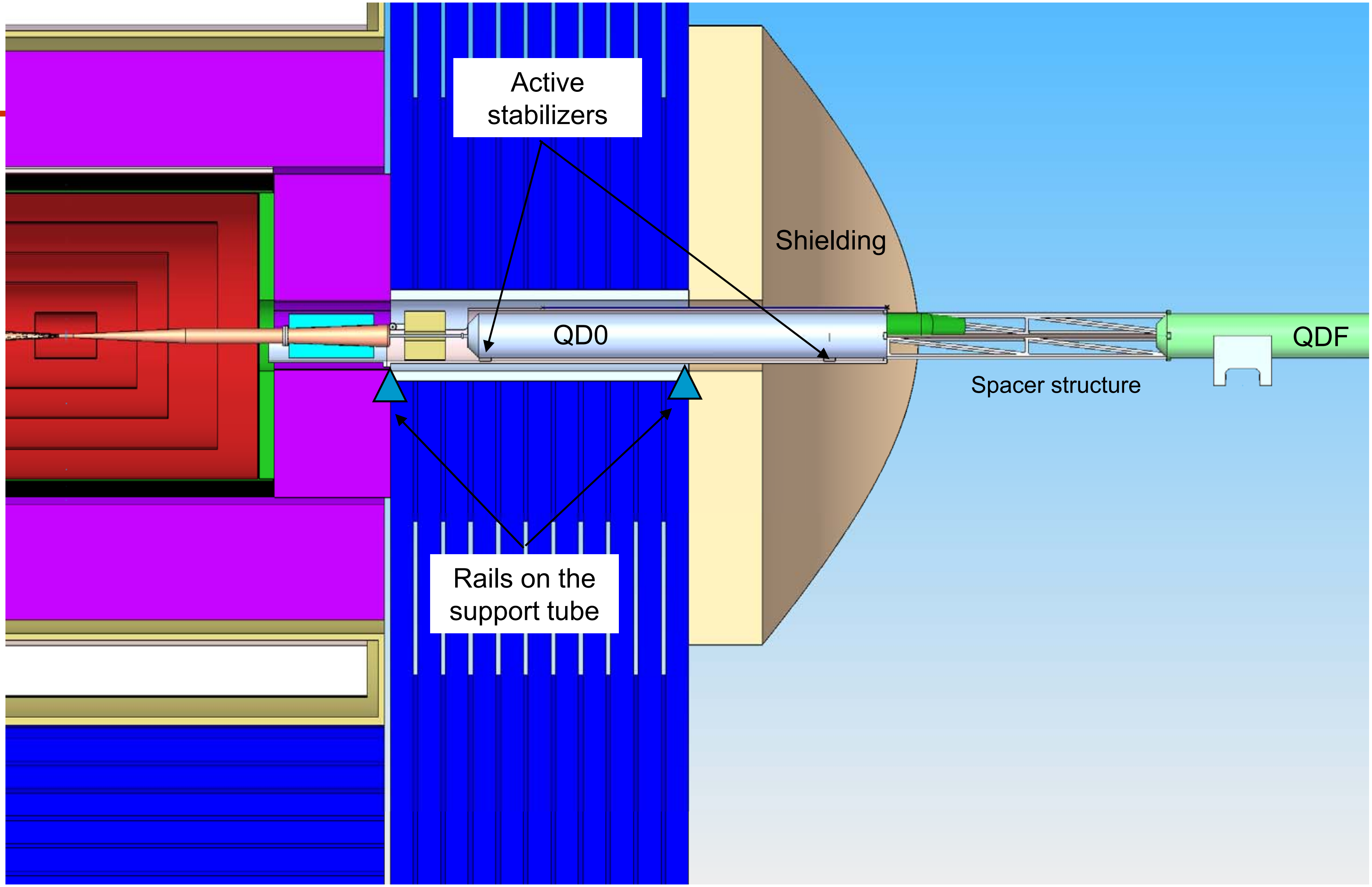
QD0 support in the door



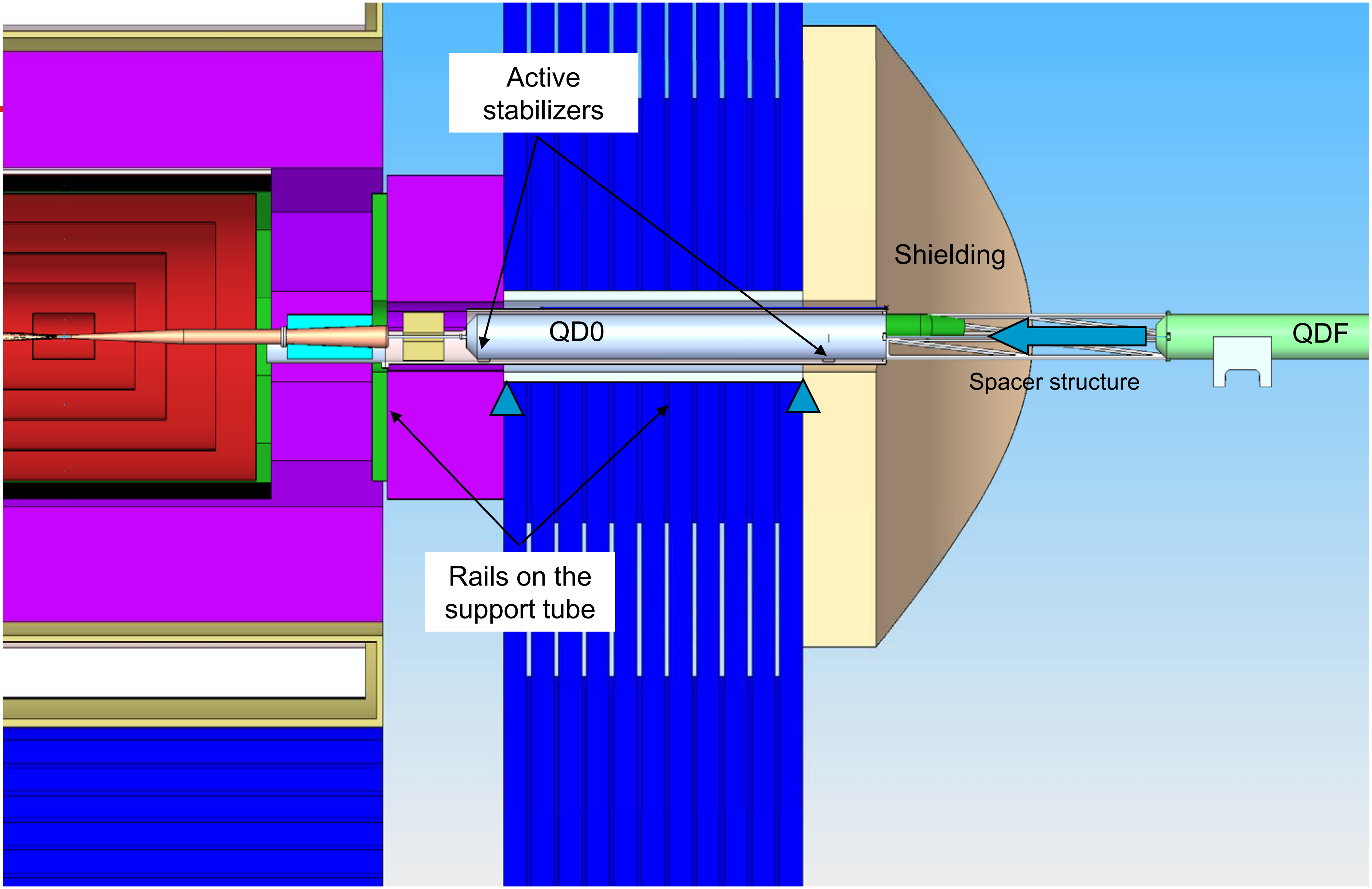
2m Door opening Procedure, on the beam



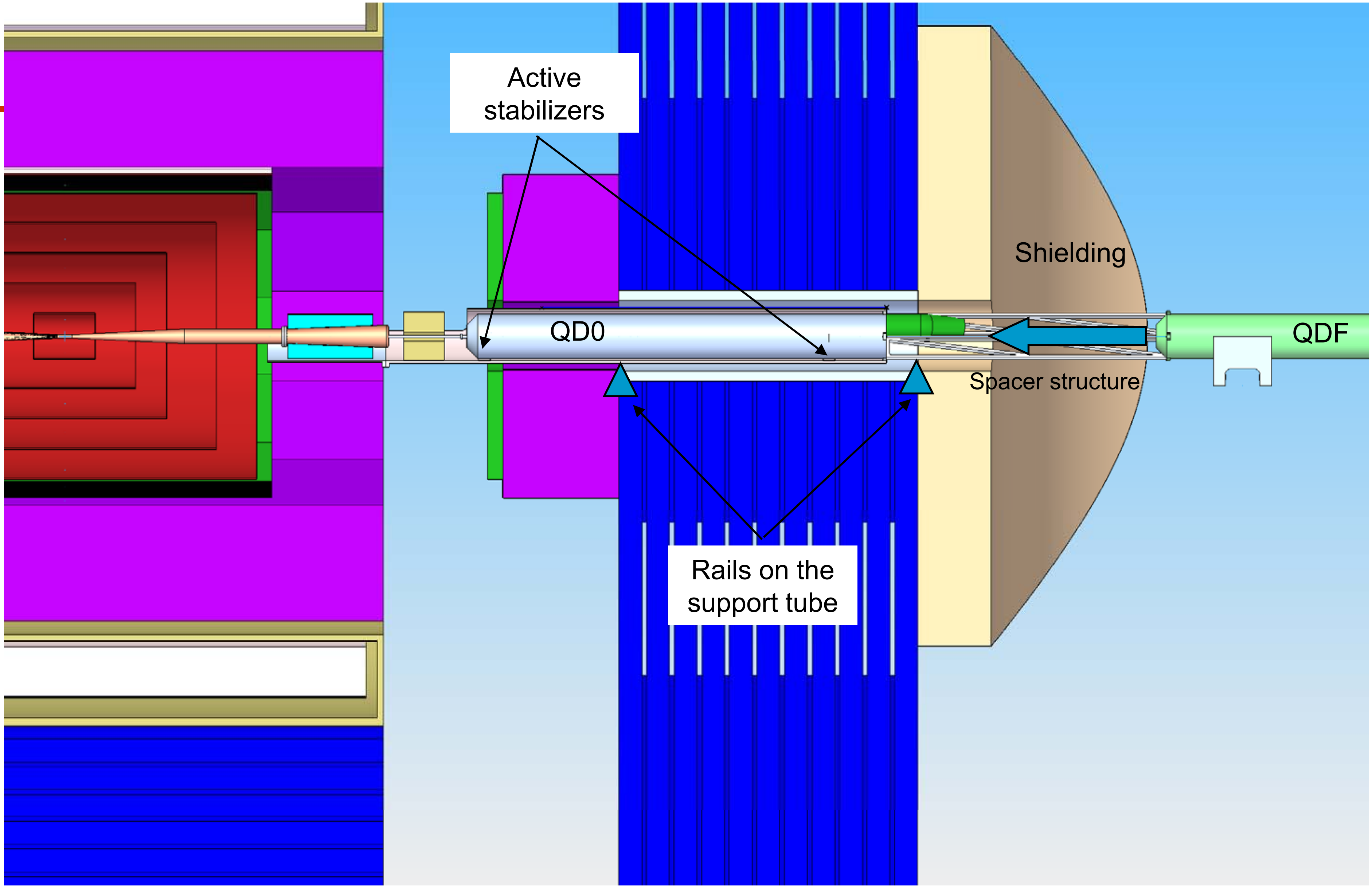
2m Door opening Procedure, on the beam I



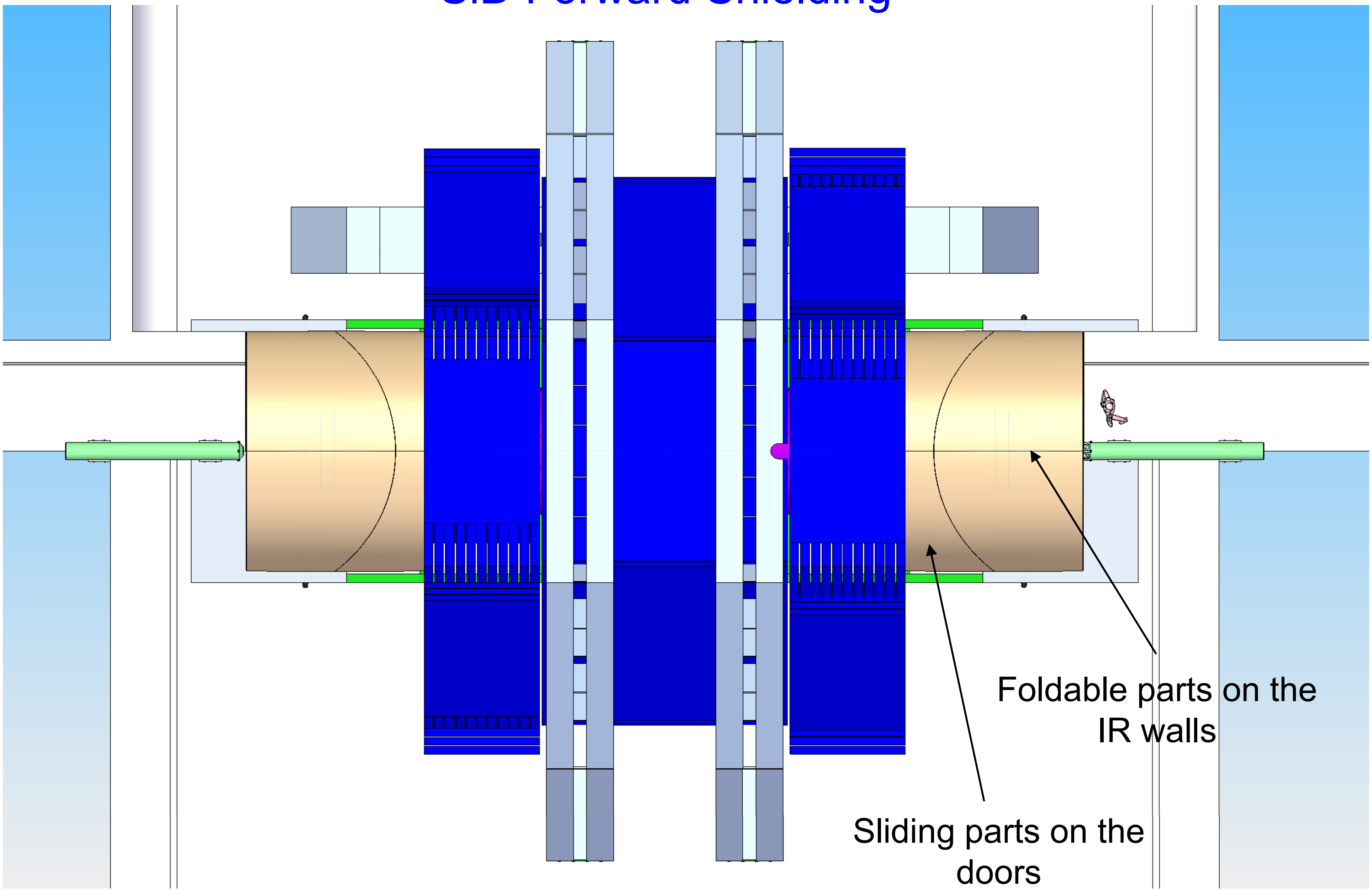
2m Door opening Procedure, on the beam II



2m Door opening Procedure, on the beam III



SiD Forward Shielding



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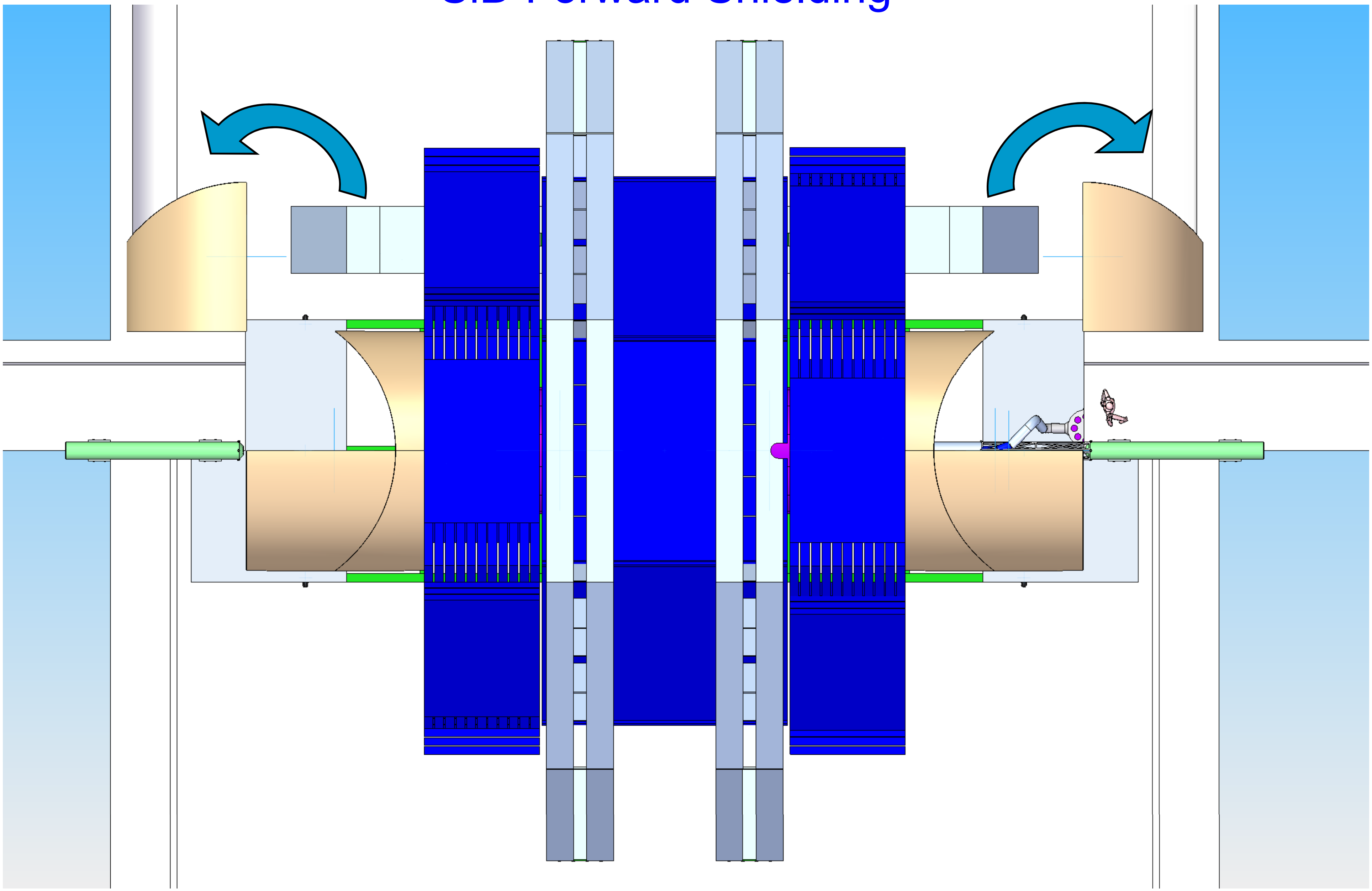

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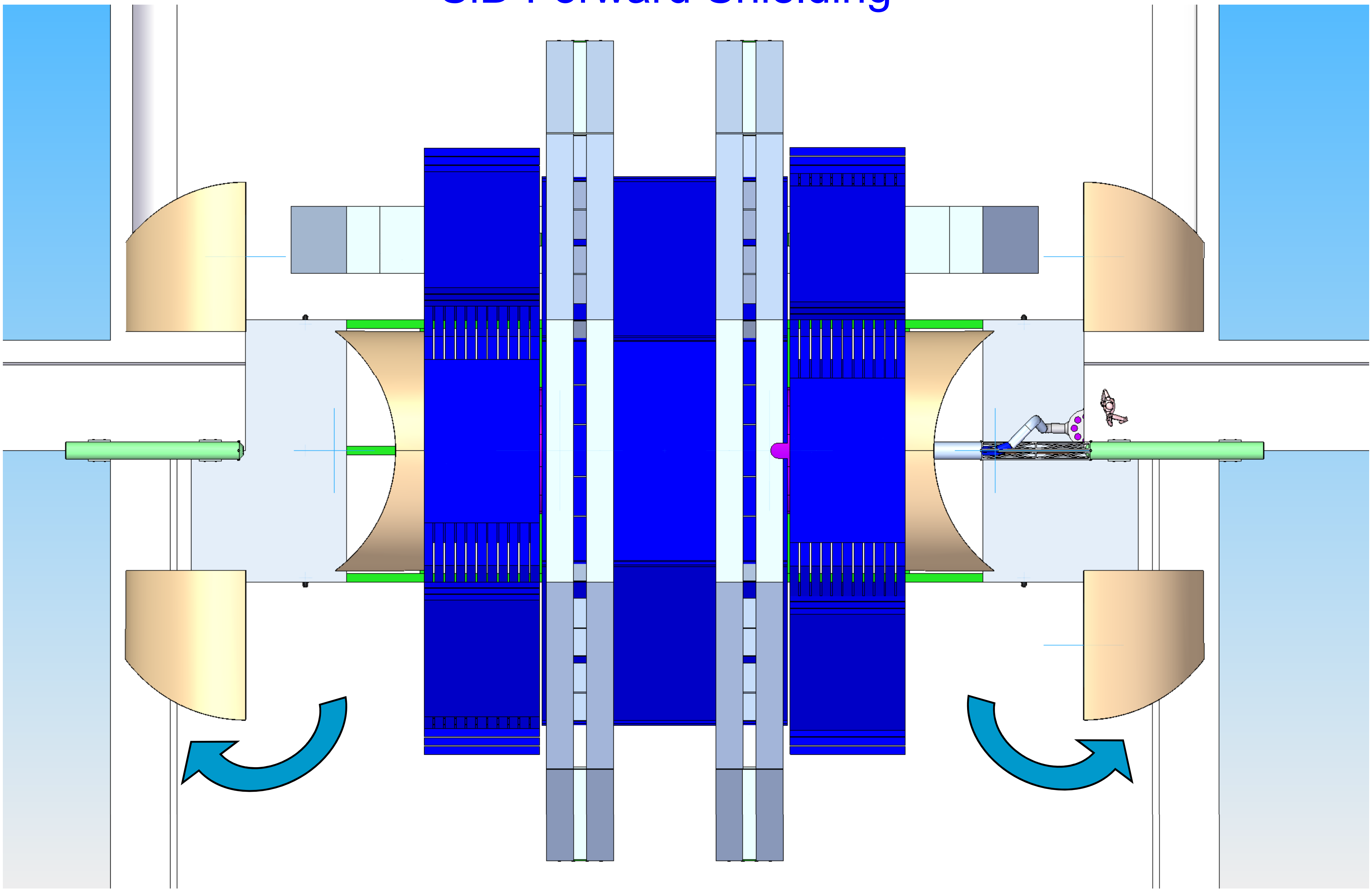

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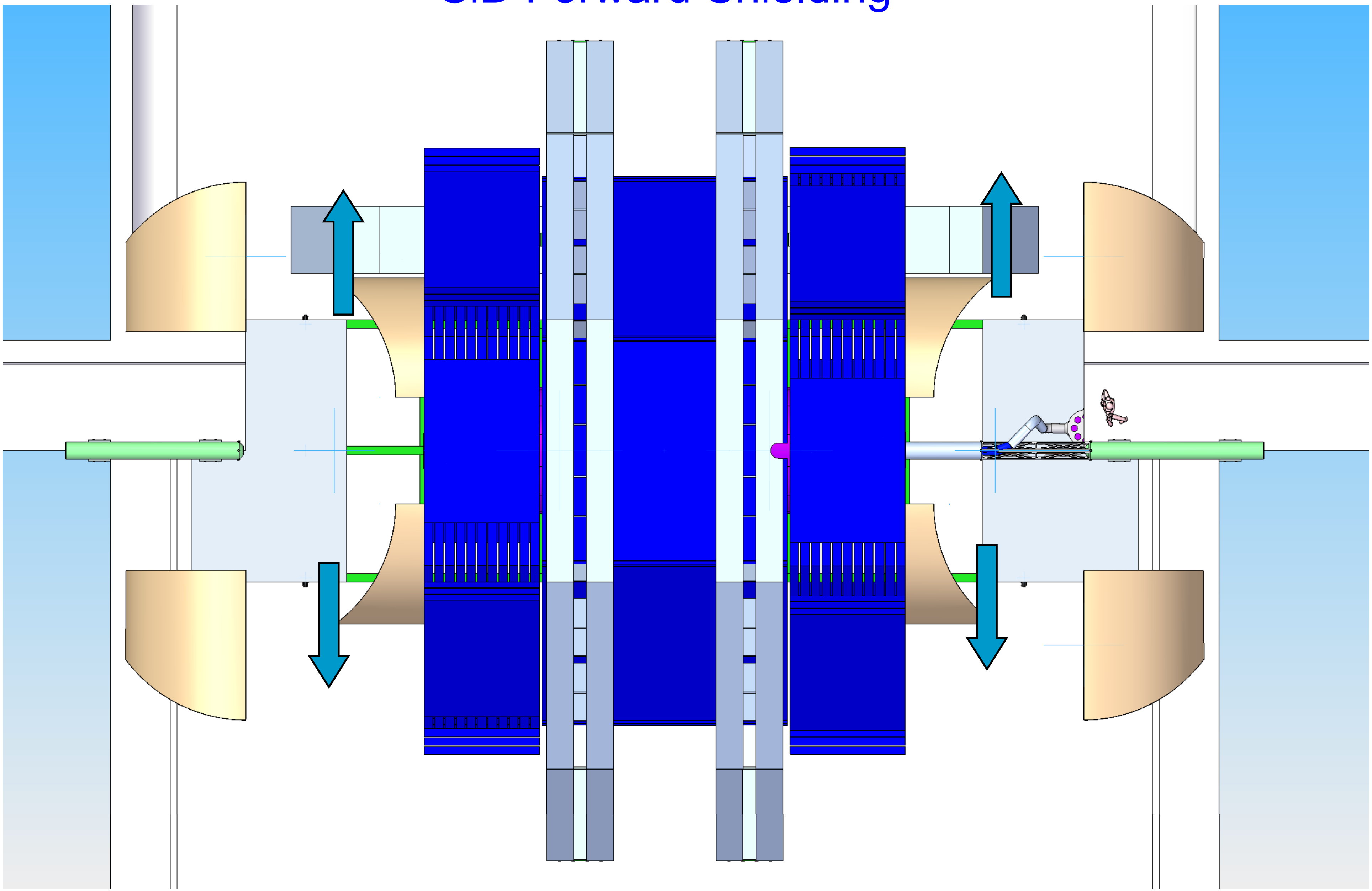

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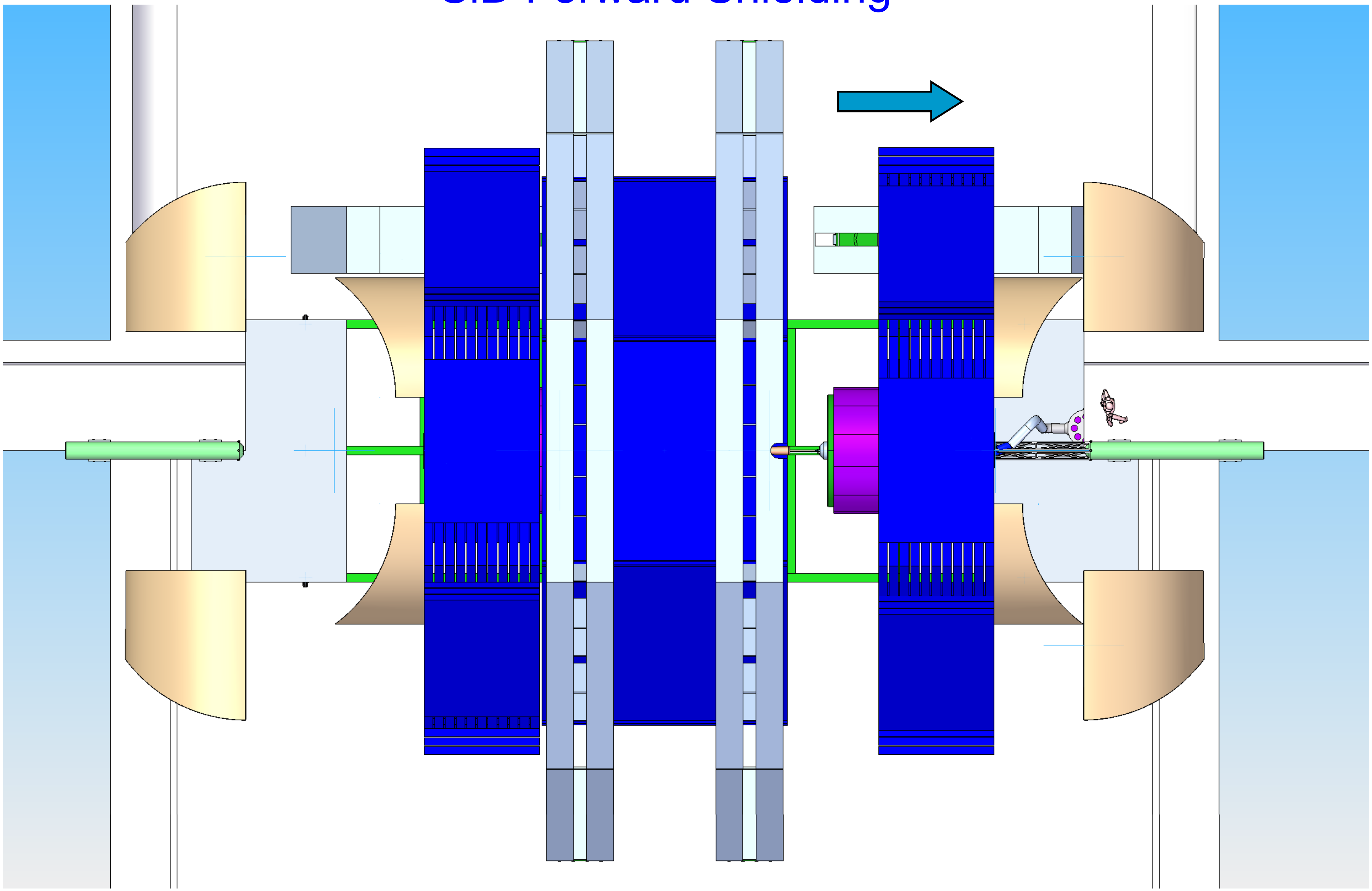

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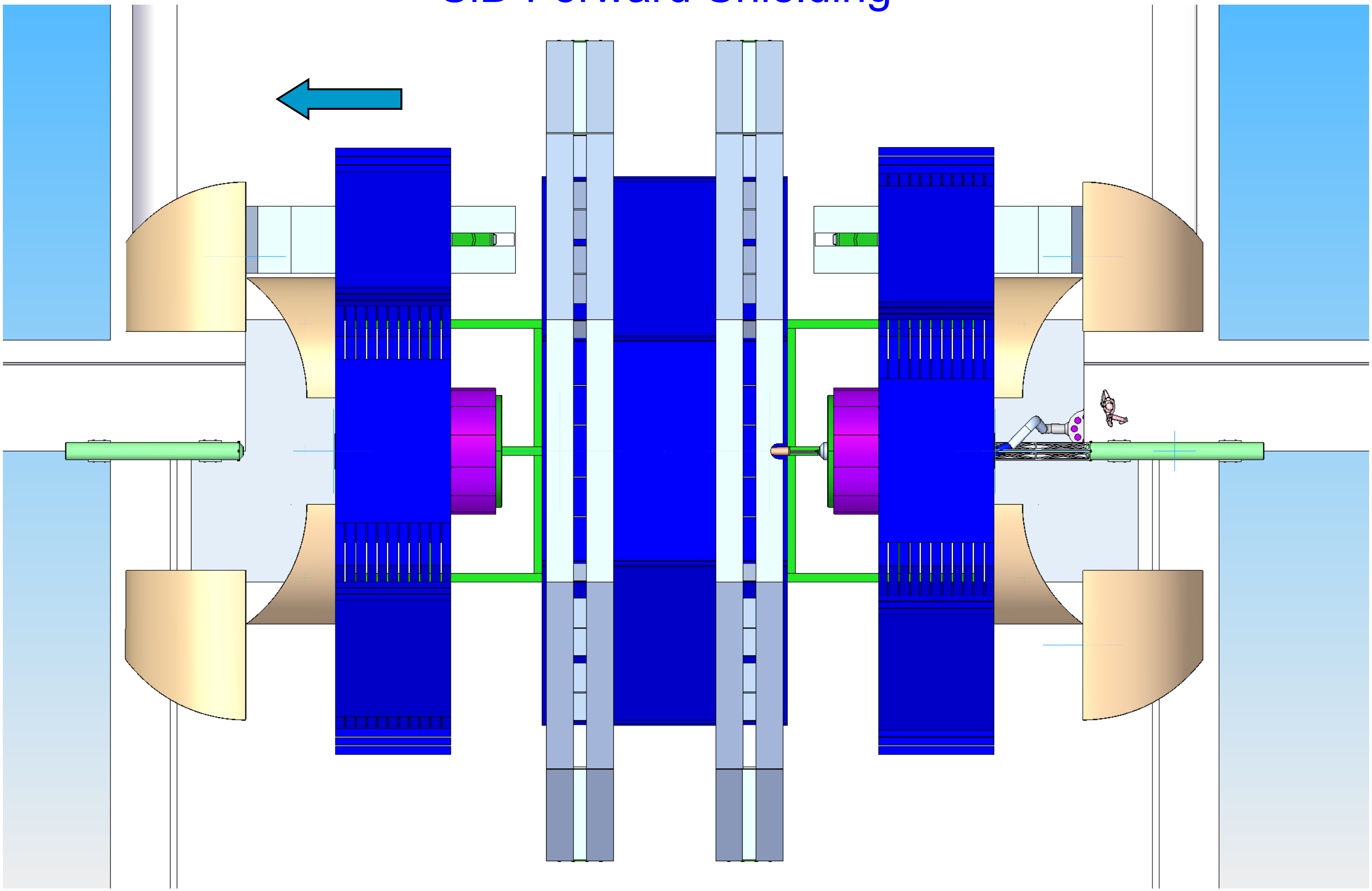
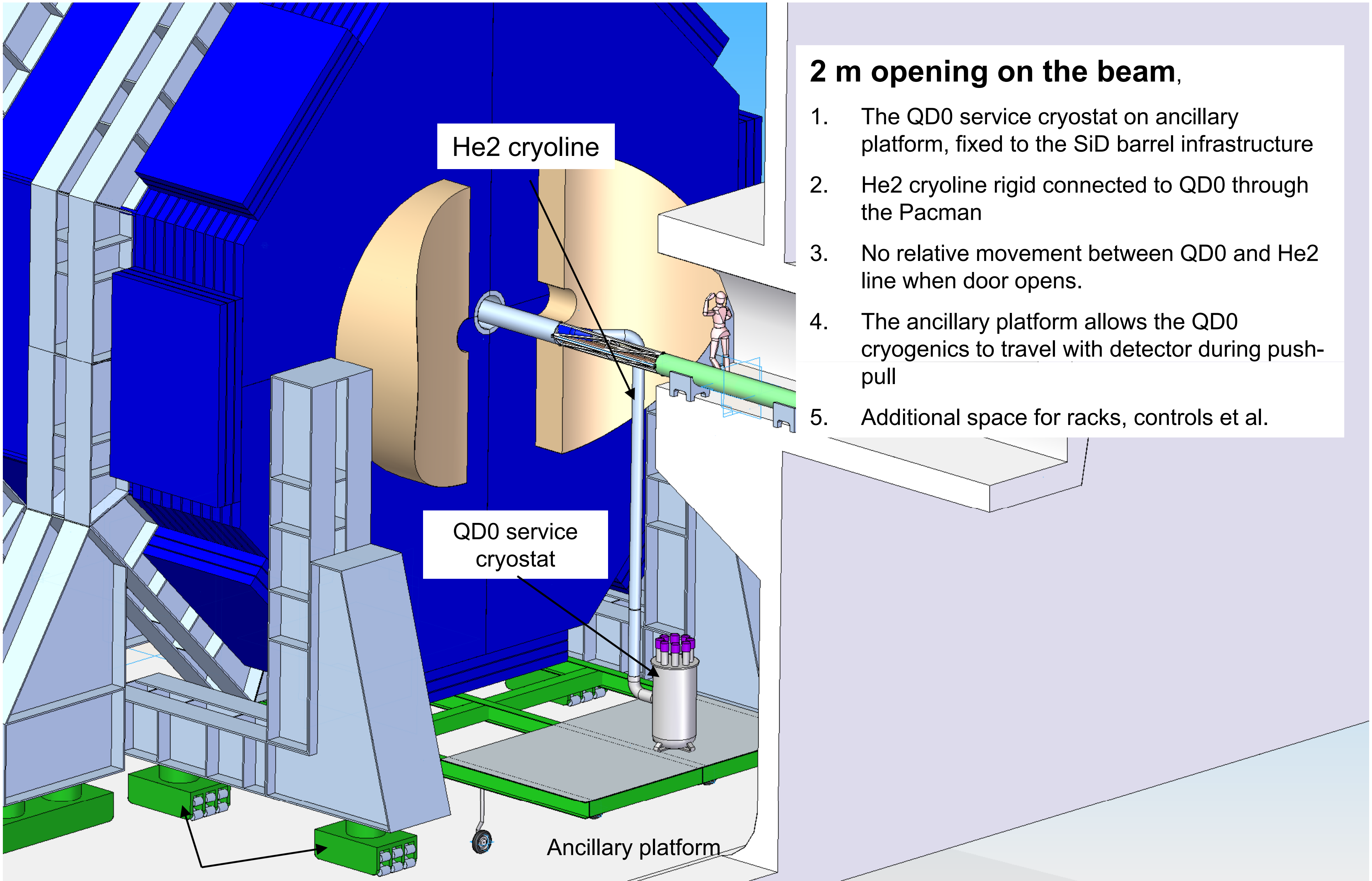


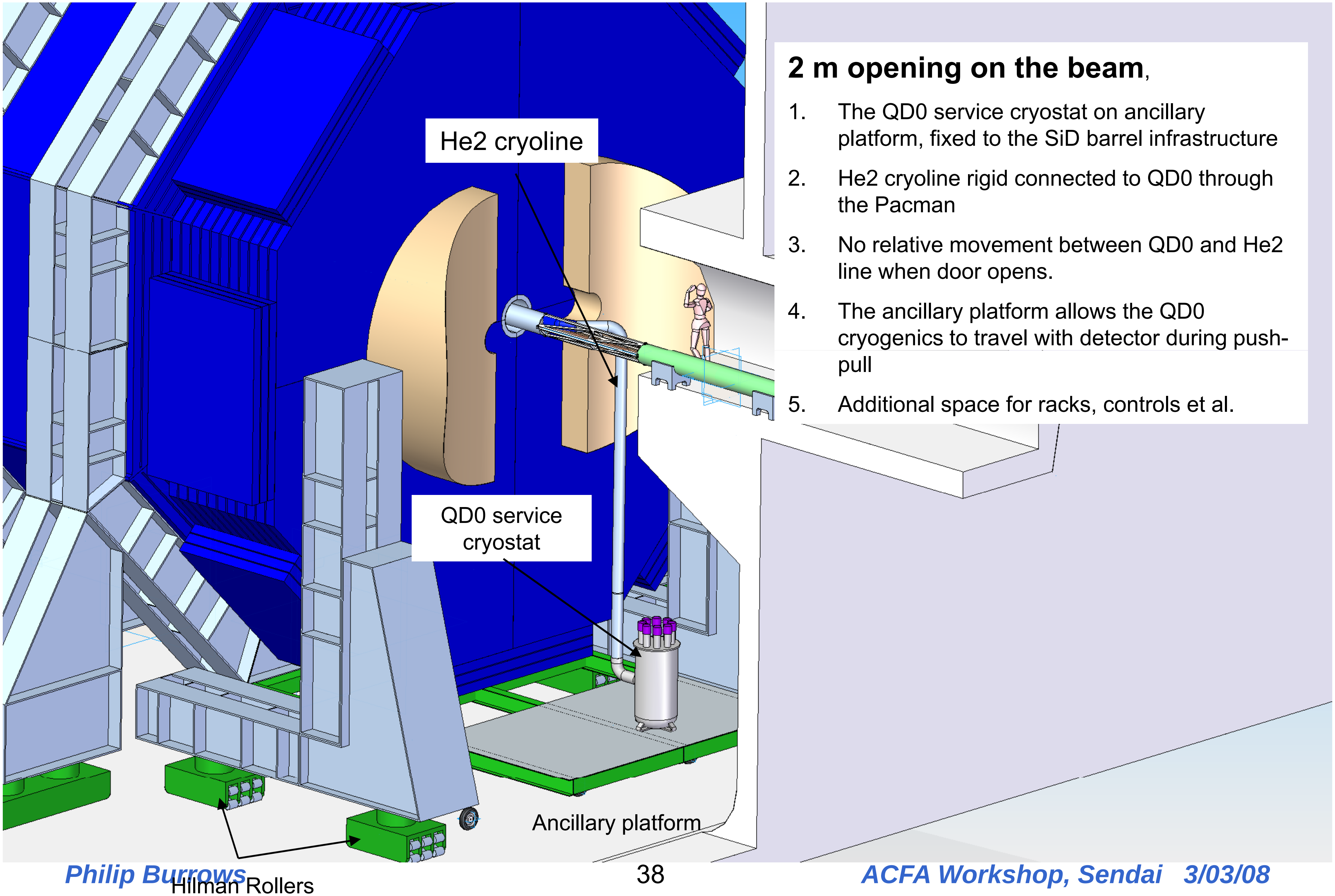
Integration of the QD0 cryoline



2 m opening on the beam,

1. The QD0 service cryostat on ancillary platform, fixed to the SiD barrel infrastructure
2. He2 cryoline rigid connected to QD0 through the Pacman
3. No relative movement between QD0 and He2 line when door opens.
4. The ancillary platform allows the QD0 cryogenics to travel with detector during push-pull
5. Additional space for racks, controls et al.

Integration of the QD0 cryoline



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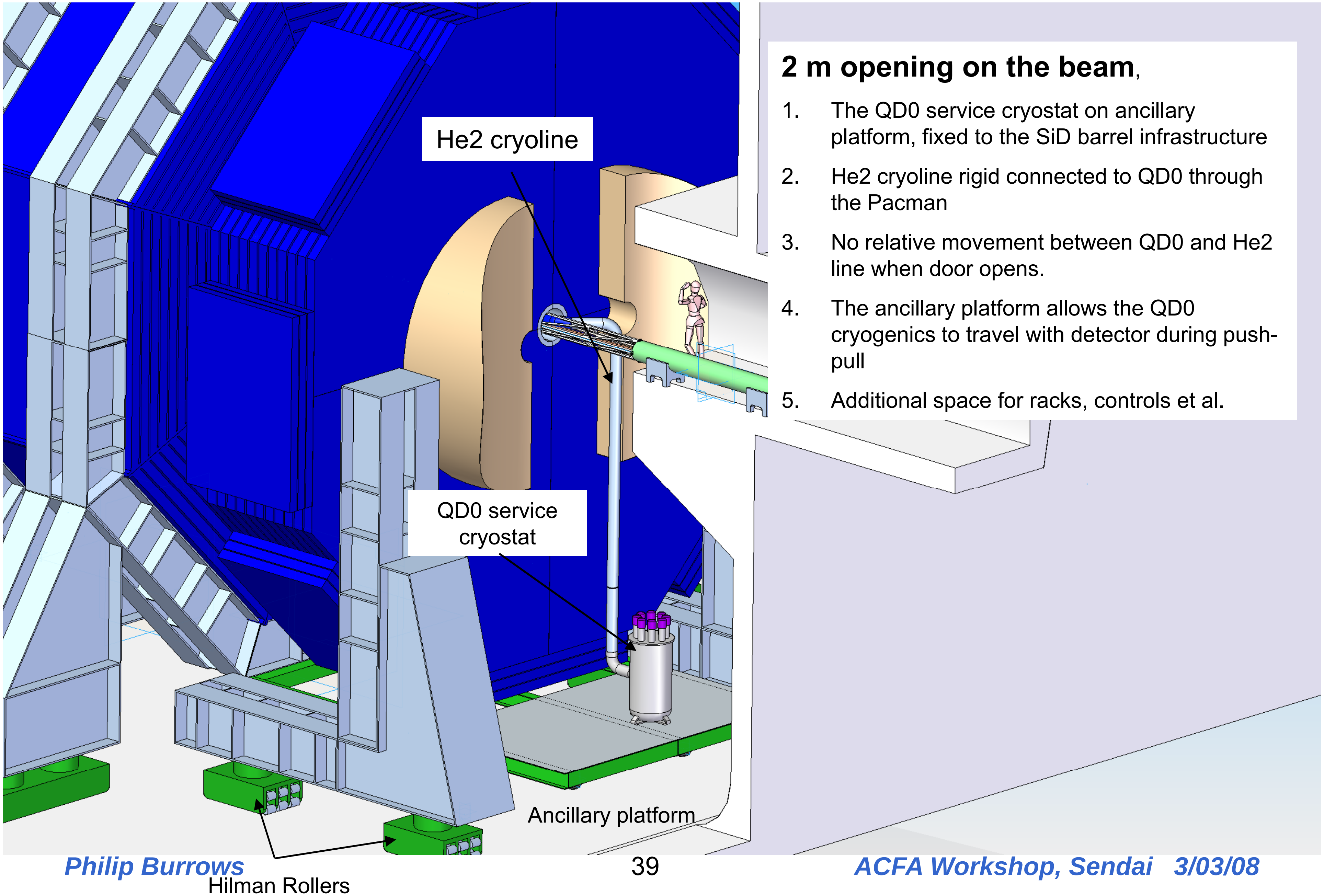

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Push-pull: SiD assumptions

- **Having two detectors on beamline 'permanently', and sharing the luminosity, i.e. two IPs, is clearly the ideal solution for physics**
- **Luminosity delivery to two IPs, with fast switchover between IPs, is not possible**
- **Two detectors in push-pull mode will:**

  - save cost of one BDS

  - increase likelihood of two detectors from start

  - provide equal access to luminosity for both detectors

SiD statement on technical Issues

- Push-pull can probably be engineered to work

  - many technical issues will need to be solved
- Full access to offline detector is mandatory
- Best accomplished with self-shielding detectors

  - self shielding is technically feasible
- Mechanisms for moving detector should not reduce acceptance
- Need to align ‘captured’ beamline components independent of overall detector position

SiD: technical questions

- **Can detector be engineered so magnetic field map remains invariant under detector in/out?**
- **Can tracking chamber alignment be restored without calibration runs (eg. with internal alignment system)?**
- **Can detector remain fully operable in ‘out’ position?**

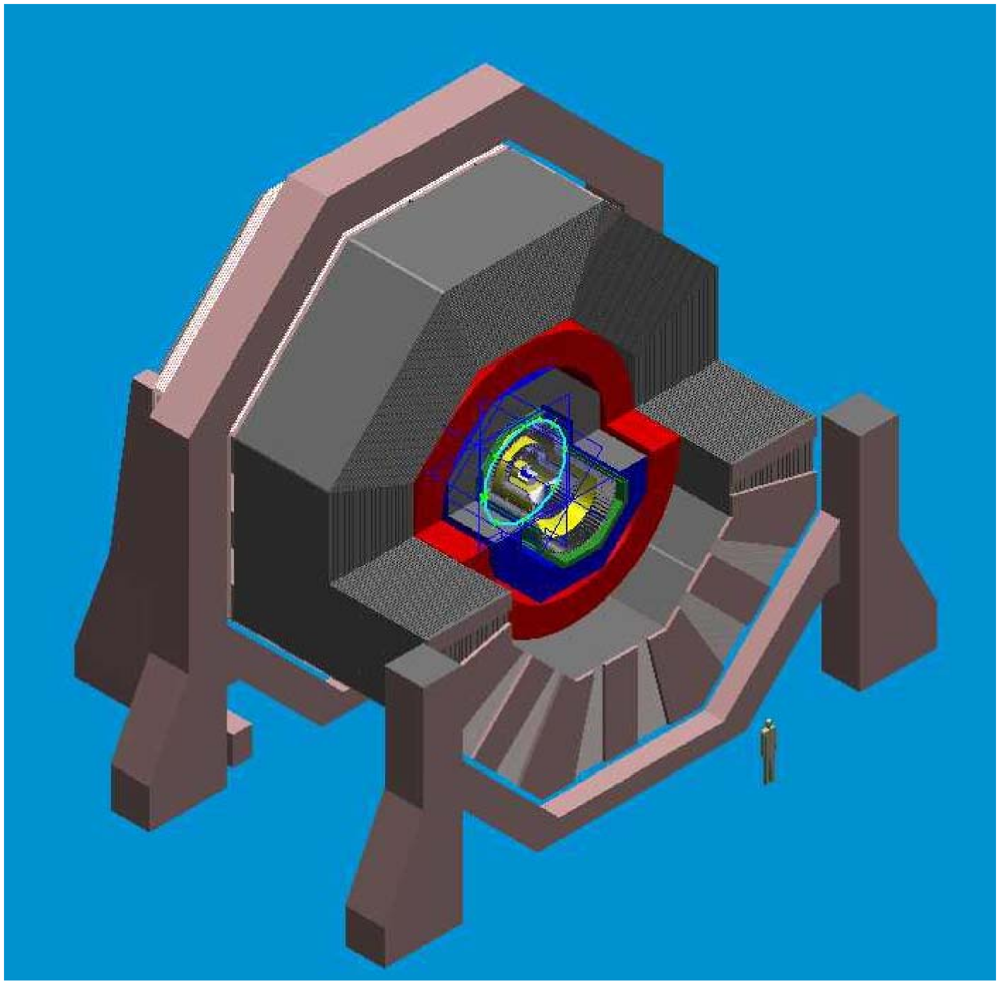
  - cosmic ray data-taking to maintain operability
- **Can switchover time be made short enough?**

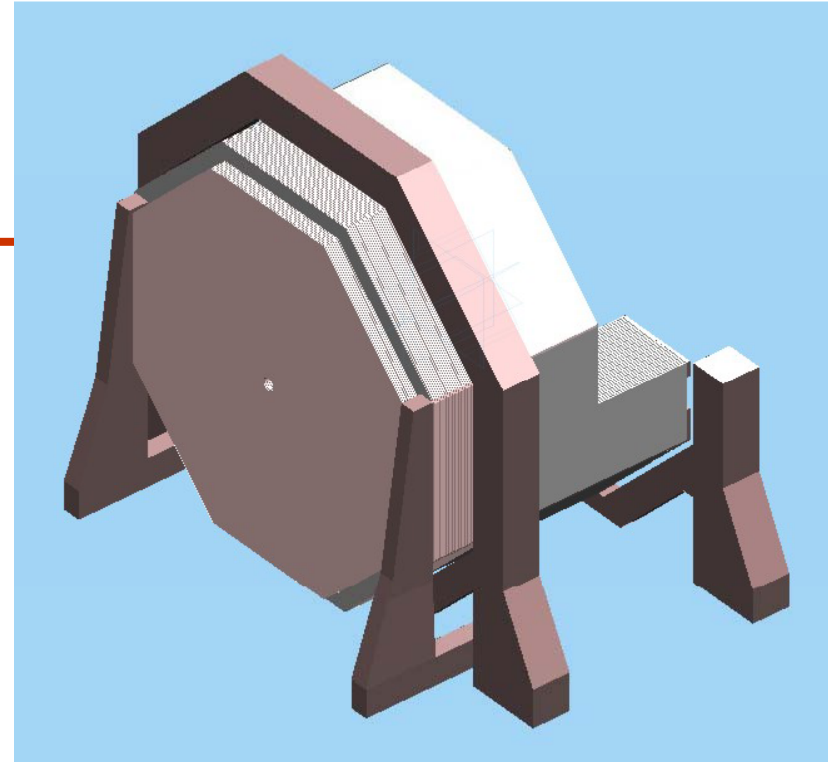
SiD: sociological issues

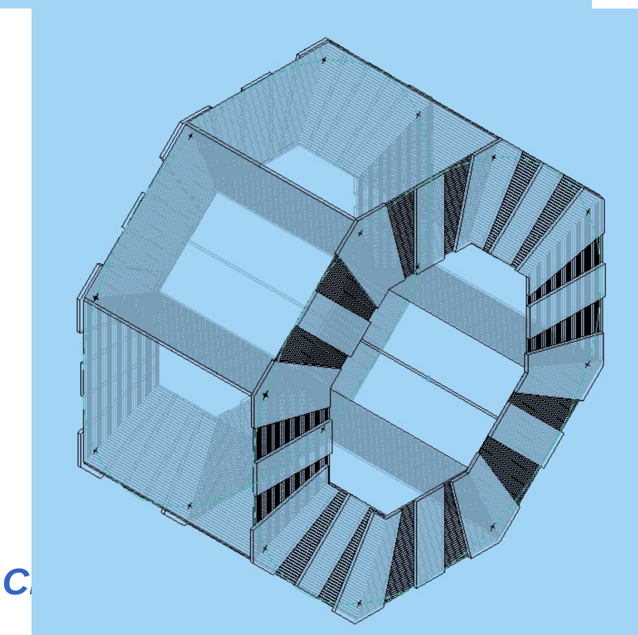
- **Need well defined procedure for scheduling swaps**
- **Machine luminosity must be shared equitably**
- **Period between swaps should be of order 1 month:**
  - **neither detector can gain significant lumi advantage in 1 period**
- **Switch-over time << running period**

SiD surface assembly considerations (Breidenbach)

Solid Edge Model







Sequence of Operations

Detector subassembly construction & surface tests

- Octants of muon chamber instrumented barrel yoke, barrel Hcal, barrel Ecal
- Four sub-modules of EC return flux instrumented with muon chambers, donut Hcal, Ecal
- Tracker, vertex and FCAL packages

Surface Magnet test

- Assemble barrel support and the bottom 5/8 flux return octants
- Drop in coil & cover with remaining 3/8 octants
- Assemble two door legs and 4 360° (180 °?) plates of flux return
- Test magnet and disassemble

Lower detector chunks

- Reassemble lower barrel iron with supports below ground
- Load barrel HCAL and ECAL modules into coil cryostat via threaded beam
- Lower loaded coil package and capture with upper barrel yoke segments
- Depending on crane capacity
  - Lower fully assembled door
  - Lower door pieces, the last plate with the Endcap Ecal & Hcal, and reassemble

Tracker, VXD and FCAL installed below ground at end

'Surface assembly seems ok, but will require careful planning'

Summary

SiD is a silicon-centric design offering

- excellent vertexing and tracking precision
- new potential in calorimetry
- excellent muon identification

Complementary to other concepts

Many opportunities for new effort and expertise.

Tools and organization in place to support efficient development and to get started.

Great opportunity to explore ILC detector/physics.

Open to new ideas, collaborators, increased internationalization

http://silicondetector.org

Draft time line for the SiD LoI

3/08 **First Pass Global Parameters**

4/08 **Freeze Global Parameters:** First Pass Detector Design

6/08 **Freeze Detector Design**
- SubSystems Fully Specified
- Subsystem Technologies/Alternates Selected
- Conceptual Designs Ready

9/08 **GEANT4 Description Ready**
- Performance Studies Ready
- Benchmarking Studies Ready

2/09 **Complete LOI Draft**: Collaboration Review and Comment

3/09 **Final Edit of LOI**

4/09 **Submit LOI**

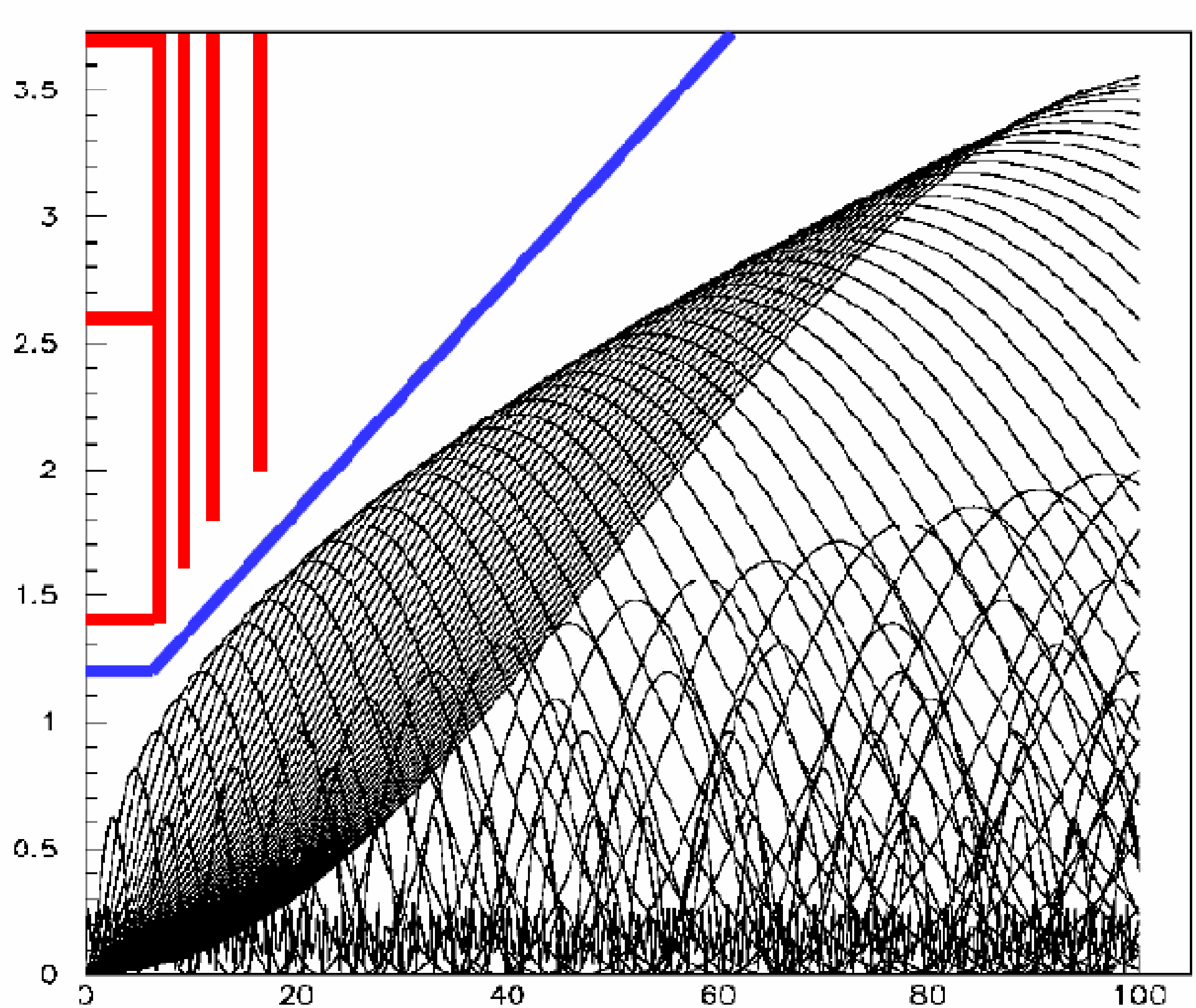
Next SiD Workshop

Cosener's House, Abingdon, UK April 14-16 2008

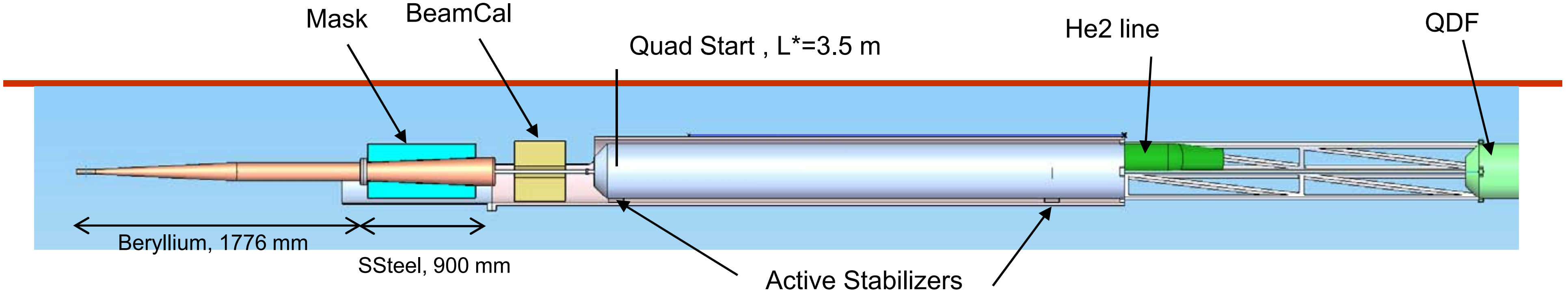
http://hepwww.rl.ac.uk/sidmeetinguk/

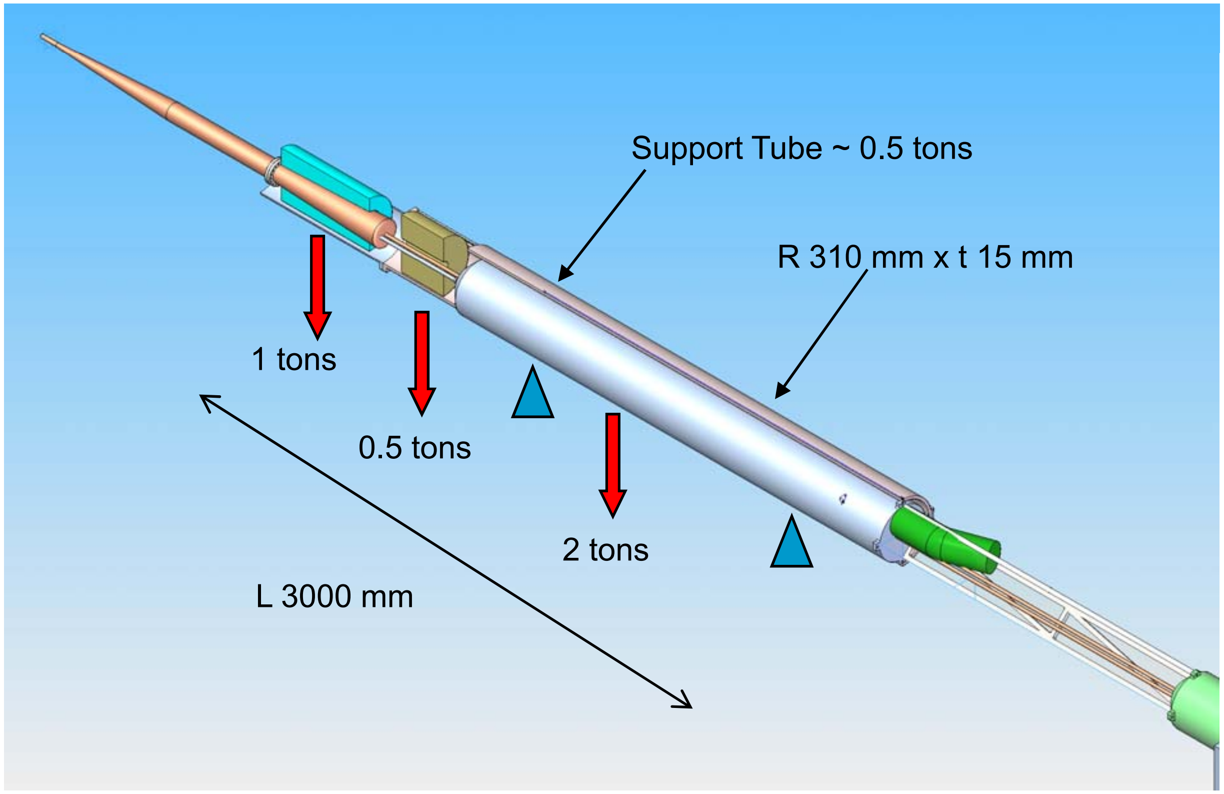
Extra material follows

12mm Beam Pipe and VXD Detail



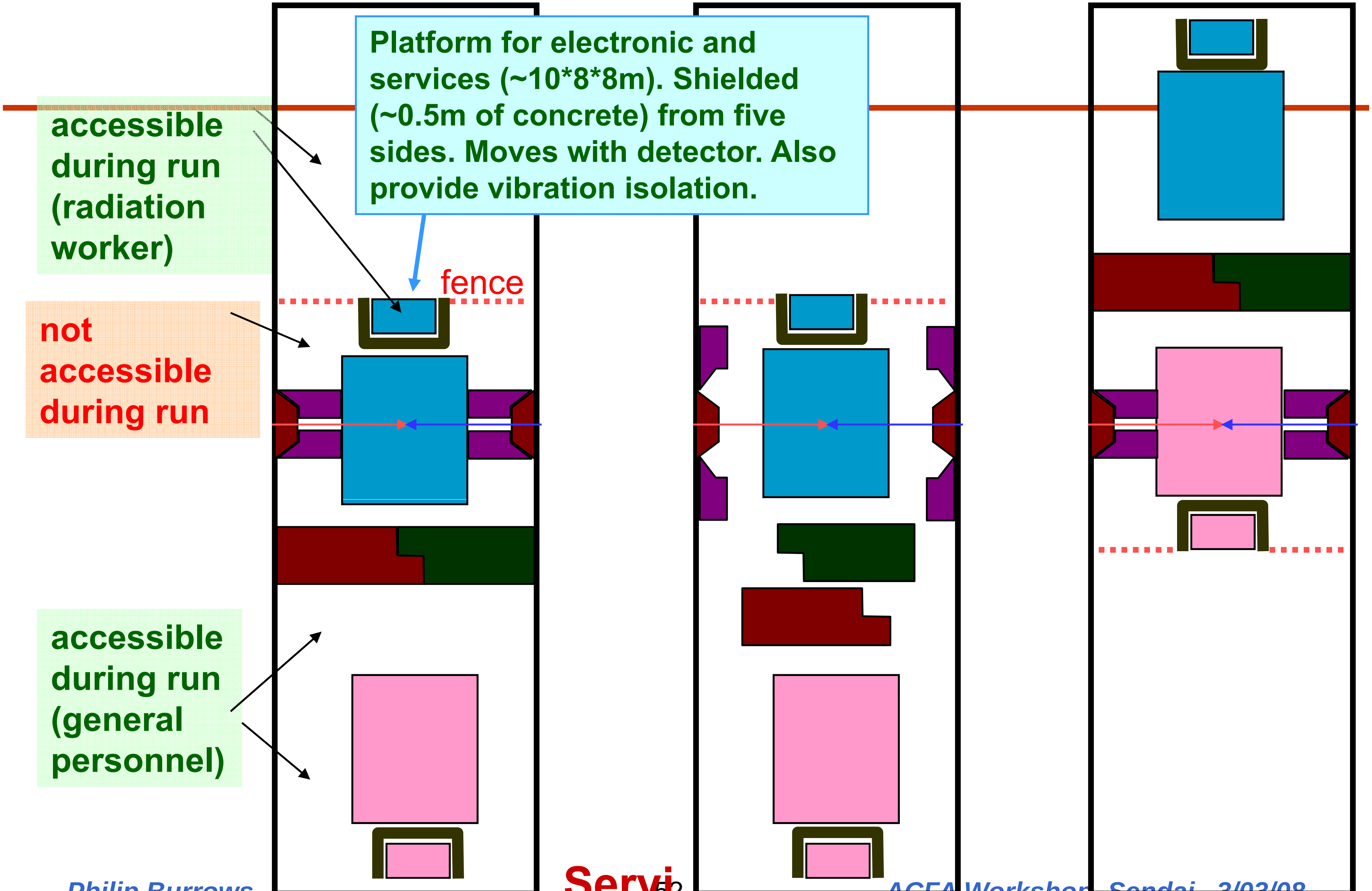
Support Tube for QDO and Frwd instrumentations





- The support tube provide an interface to the door to support for QD0,
- In addition provide the supports for the vacuum chamber, the beam instrumentation and the forward detectors
- Alternative option having sliding rail directly on the QD0 cryostat and cantilever from the Qd0 front the vacuum and detector instrumentations. Actuators directly on the door.

Concept which does not rely on self-shielding detector



Surface assembly parameters (Marty)

M-Tons	Stainless HCAL Radiator		Tungsten HCAL Radiator	
	Barrel	Endcap x2	Barrel	Endcap x2
EM Cal	59	19	59	19
HCAL	354	33	367	46
Coil	160		116	
Iron	2966/8= 374.5	2130/4= 532.5	1785/8= 223.125	1284
Support x 2 (each ~5%Fe)	150	110	90	65
Total to Lower	Loaded Coil=573	Assembled Door=2402	Loaded Coil=542	Assembled Door=1479
Shaft Diameter(m)	8.3m	10.4+2.0m		

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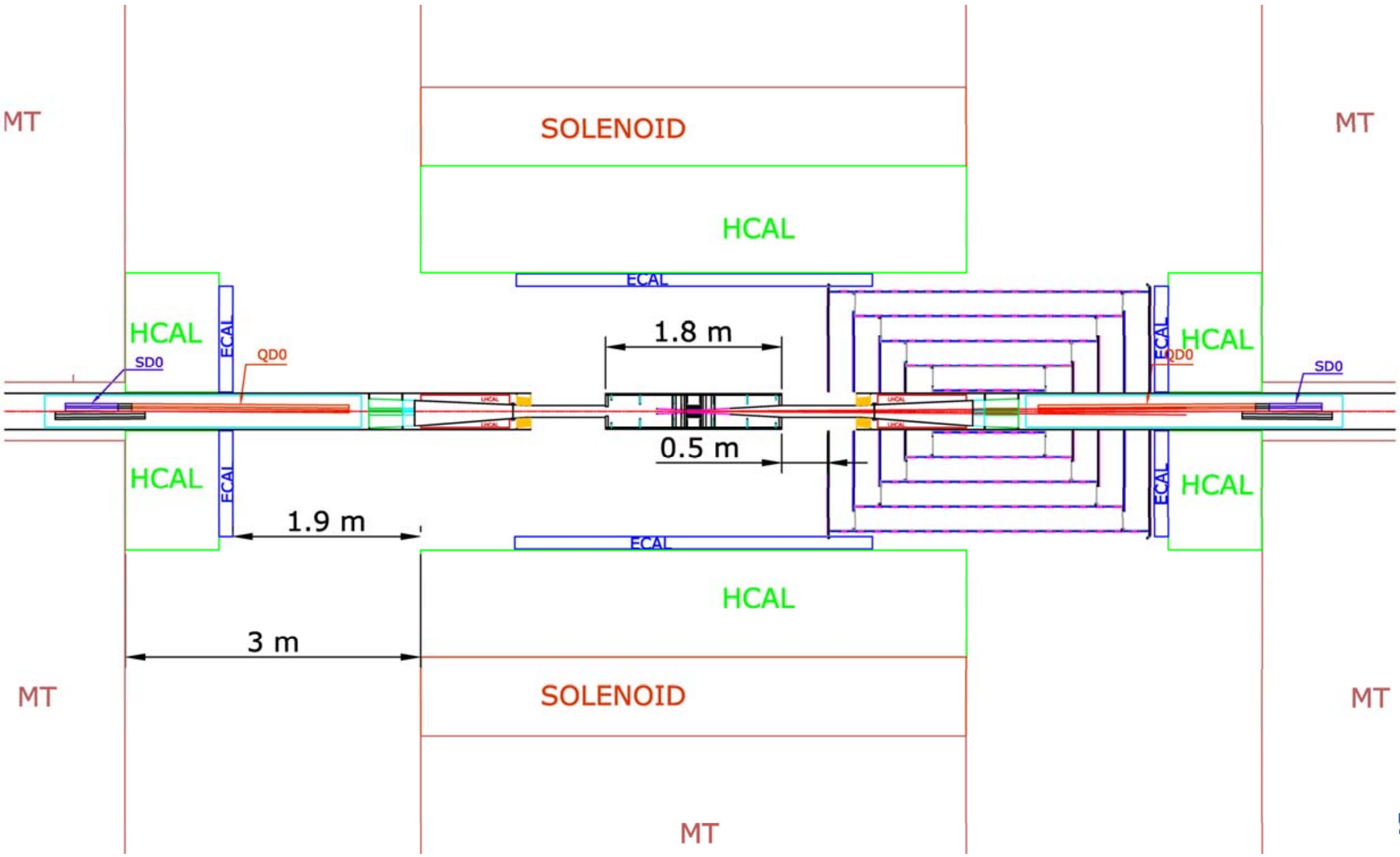
Servicing Vertex Detector & Tracker

Detector open 3 m for off-beamline servicing

Vertex detector can be removed / replaced.



Servicing Vertex Detector & Tracker

Detector open 2 m for on-beamline servicing

Ends of tracker and outer surfaces of vertex detector are accessible.