SiD Beam Pipe Concepts

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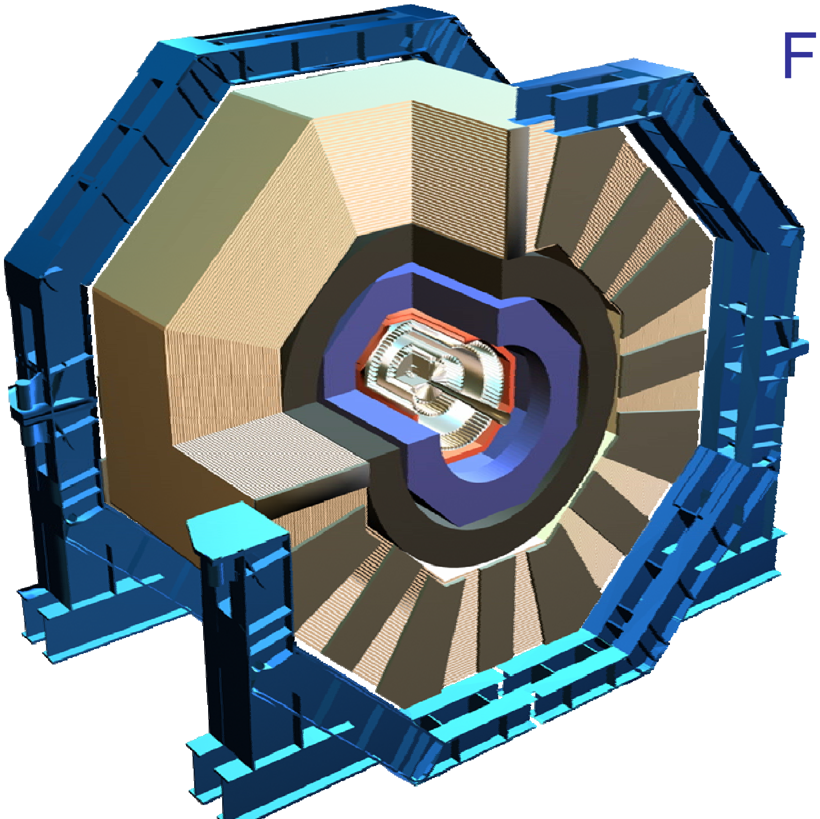
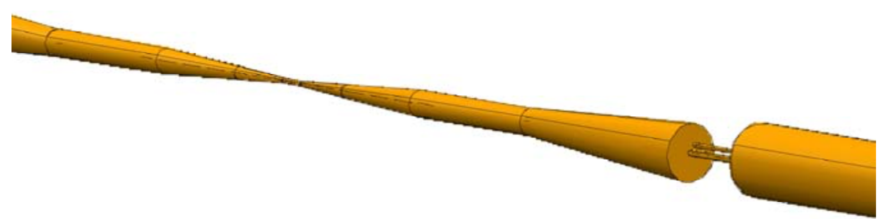


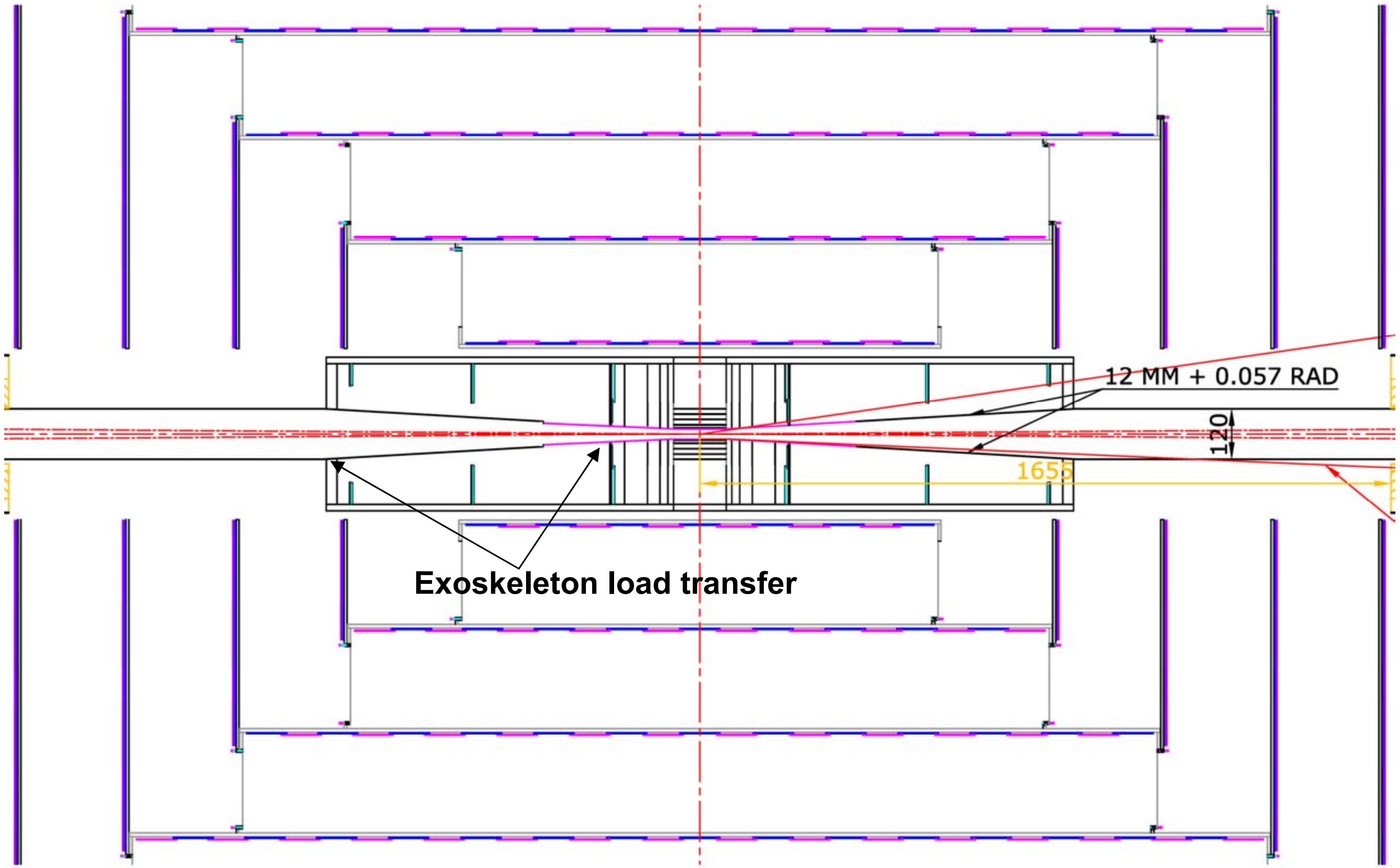


Geometry of Beam Pipe Region

- Beam pipe geometry for SiD is driven by vertex detector, outer tracker, forward calorimeter, and servicing considerations.
  - The vertex detector is assumed to be supported from the beam pipe.
    - To allow a beam pipe inner radius of 12 mm in the central region, bending of the beam pipe is controlled via an exoskeleton.
    - The exoskeleton, based upon carbon fiber laminate, also supports and positions vertex detector sub-assemblies.
  - The boundary between the outer tracker and vertex detector (R ≈ 200 mm) allows the outer tracker to be moved longitudinally for vertex detector removal or servicing.
  - In the forward direction, the shape of the beam pipe must accommodate forward calorimetry requirements.

Vertex Detector Geometry

- Vertex detector geometry is shown below.



Vertex Detector Design

- The baseline design assumes that the vertex detector and associated support structures are split at their equator and clamshell around the beam pipe.
  - That allows them to be installed or removed without disconnecting the beam pipe.
- An alternative would be to assemble the vertex detector around the beam pipe in a clean room, then install the completed (and tested) vertex detector / beam pipe assembly.
  - Work on a spare assembly could begin immediately after completion of the first.
  - A spare beam pipe is implied, but having one on hand may be wise in any case.
  - Flanges outboard of the vertex detector support structure and inboard of Lumi-CAL appear to be necessary in this option.
- Given push-pull detectors in which beam pipes are regularly disconnected, both options are under consideration.

Tentative Beam Pipe Materials

Z (mm)	Material	IR (mm)	Wall (mm)
<62.5	Be	12	0.4
62.5 to 379	Be	12+0.0571*(Z-62.5)	0.7
379 to 904	SS	12+0.0571*(Z-62.5)	1.07
904 to 1688	SS	60	1.07
1688 to 2833	SS	60.04+0.0614*(Z-1688), centered on outgoing beam	2.23 (to be confirmed)

- Support connections to exoskeleton at Z = ± 214, ± 882 mm
- A titanium liner of thickness ≈ 0.025 mm is assumed in the central region. Extent in Z remains to be determined.

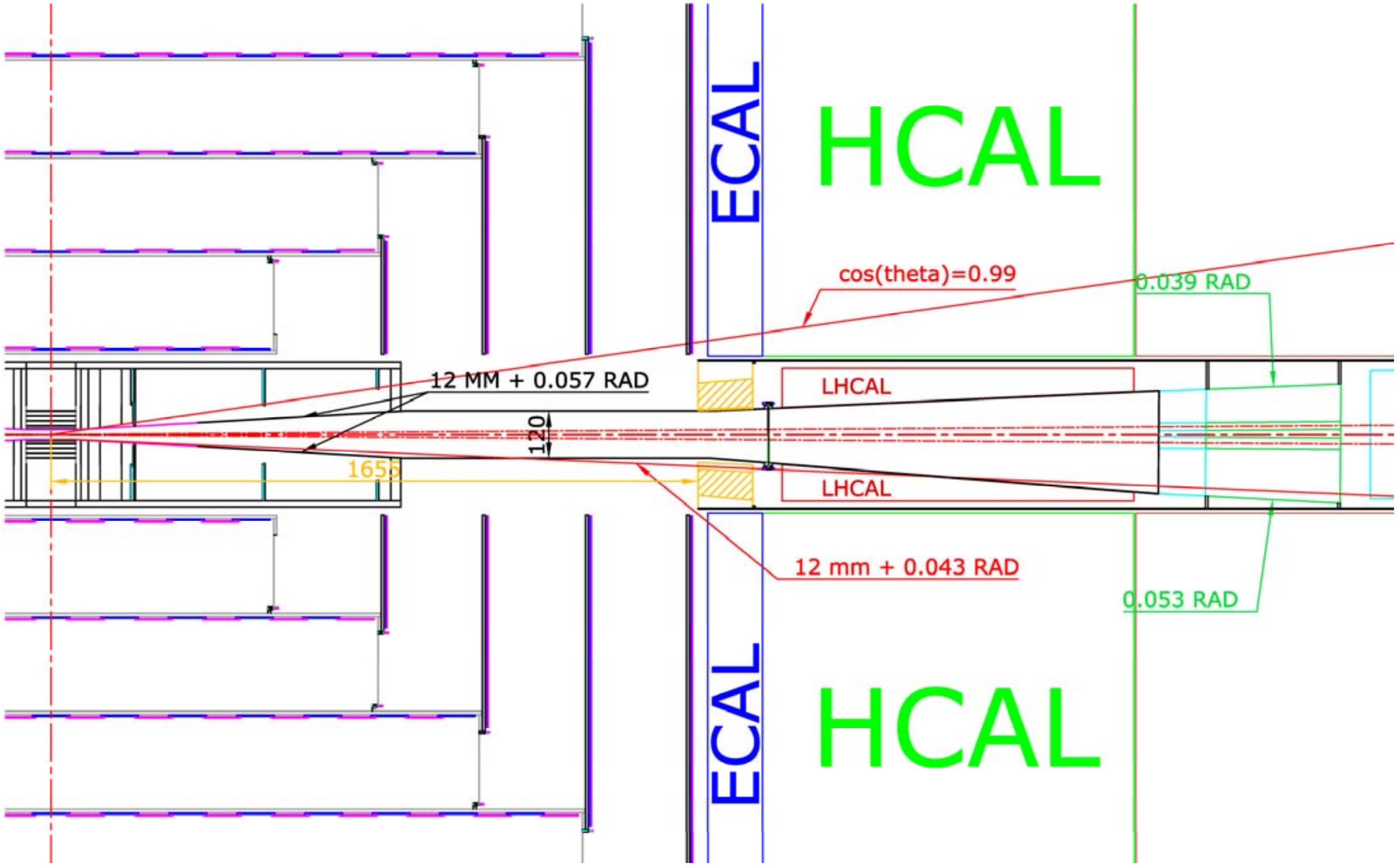
Forward Region

- The general layout of forward calorimetry follows parameters provided by Bill Morse and concepts suggested by Tom Markiewicz.

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....

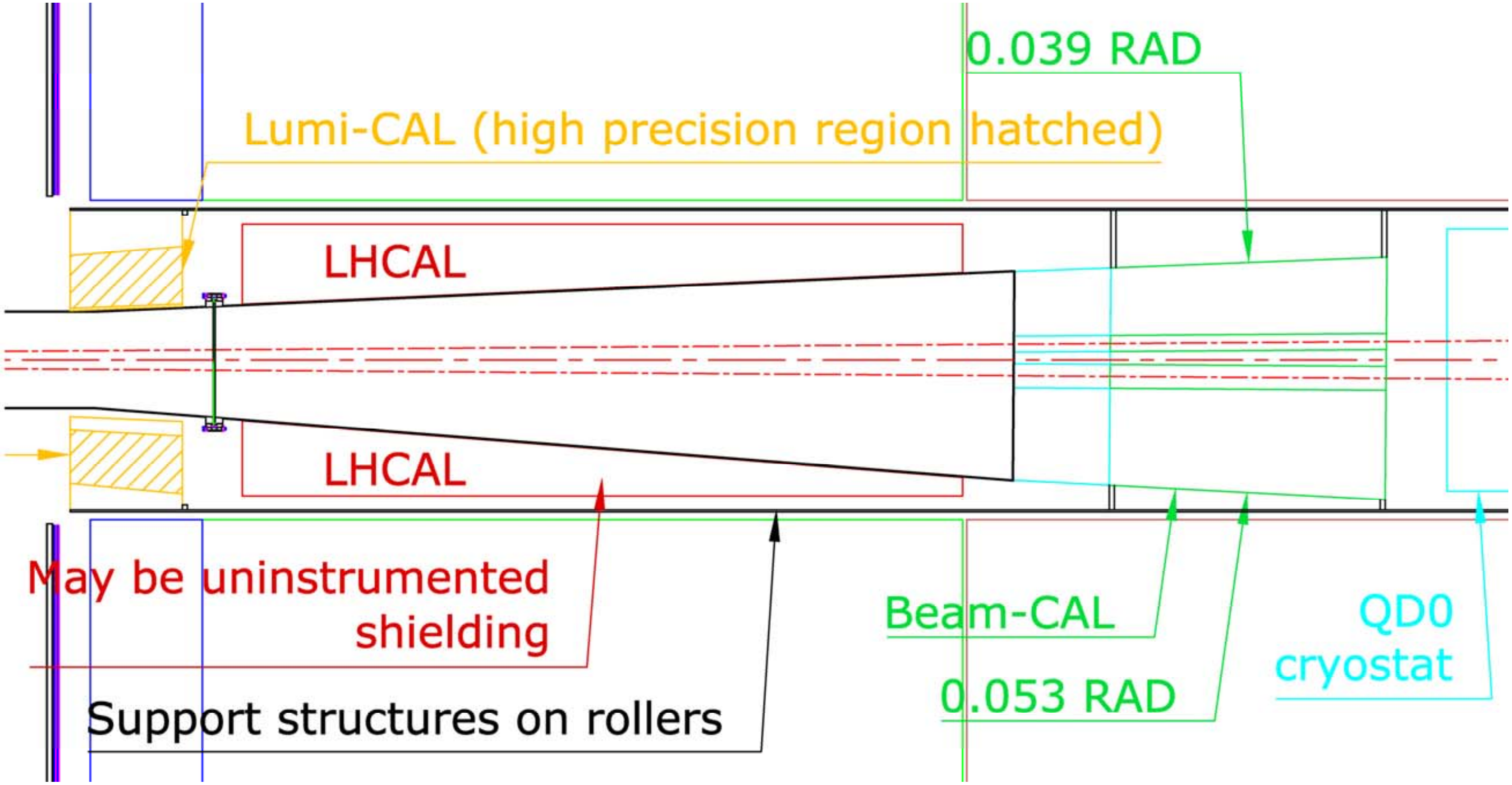
Beam Pipe

- The beam pipe shape in the forward region is shown below.



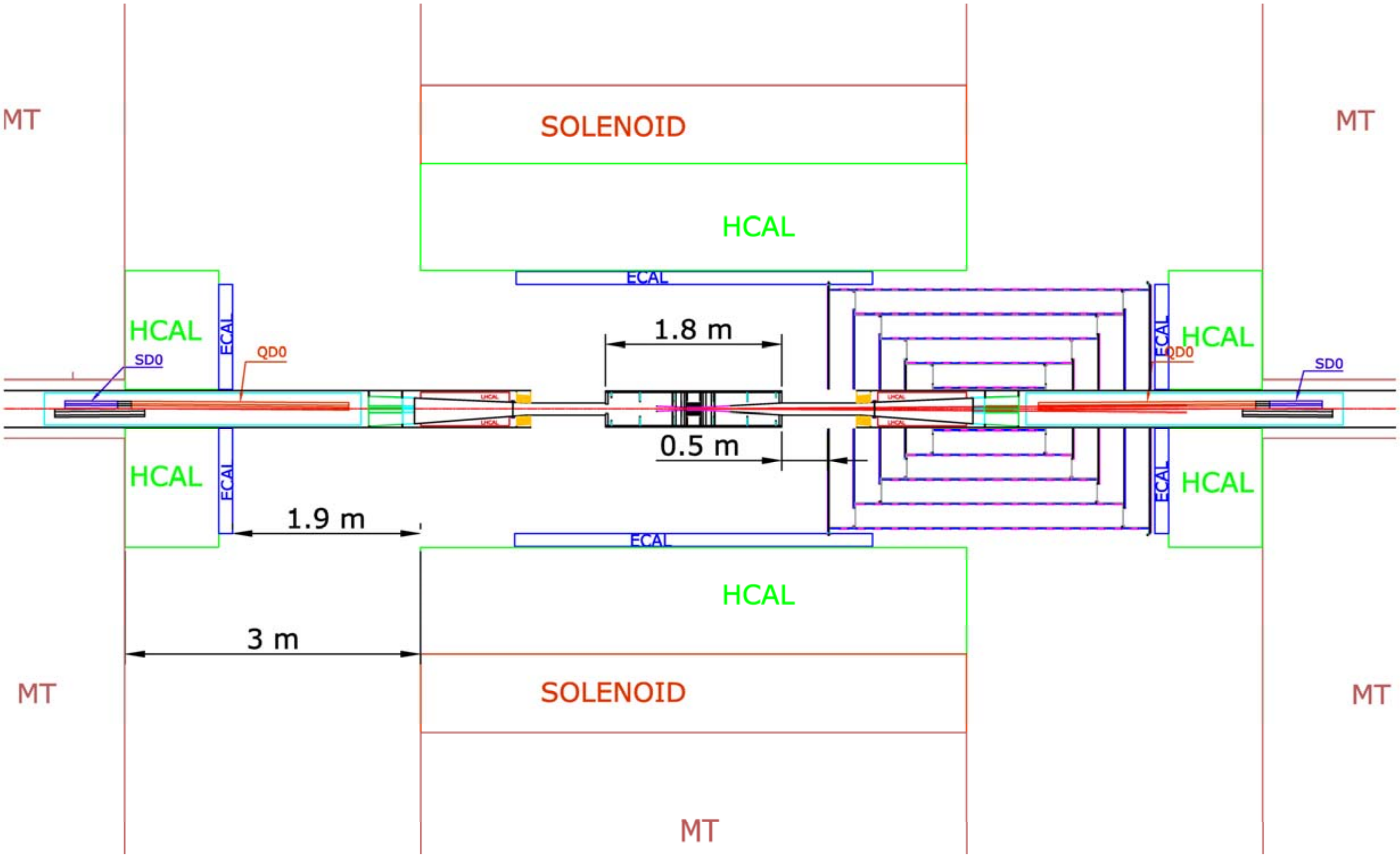
Support of Forward Calorimeters

- Deflection calculations have been made for two types of support:
  - Bars at 3, 6, 9, and 12 o'clock
  - Cylinders of stepped wall thickness



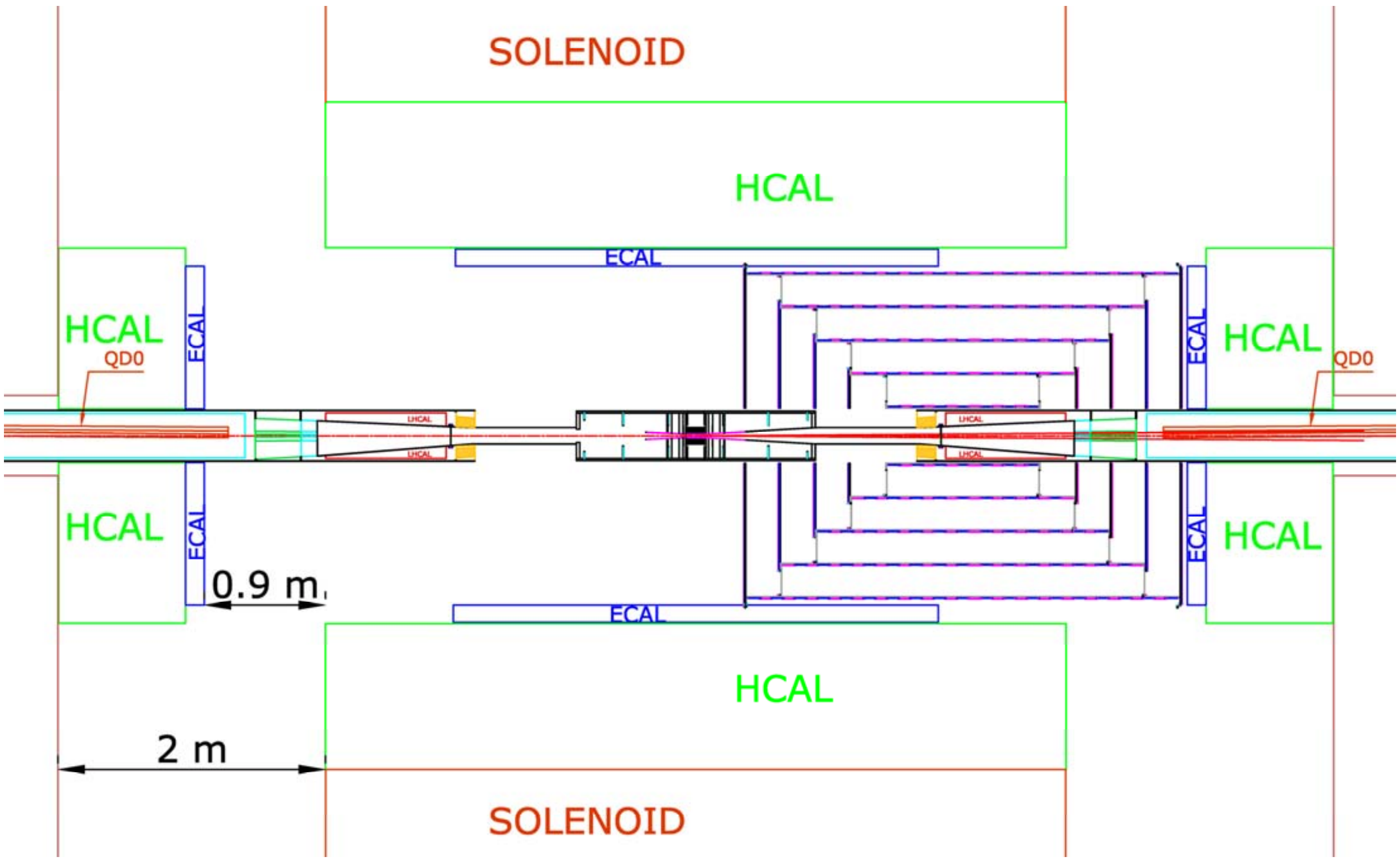
Servicing Vertex Detector & Tracker

- Detector open 3 m for off-beamline servicing
- Vertex detector can be removed / replaced.



Servicing Vertex Detector & Tracker

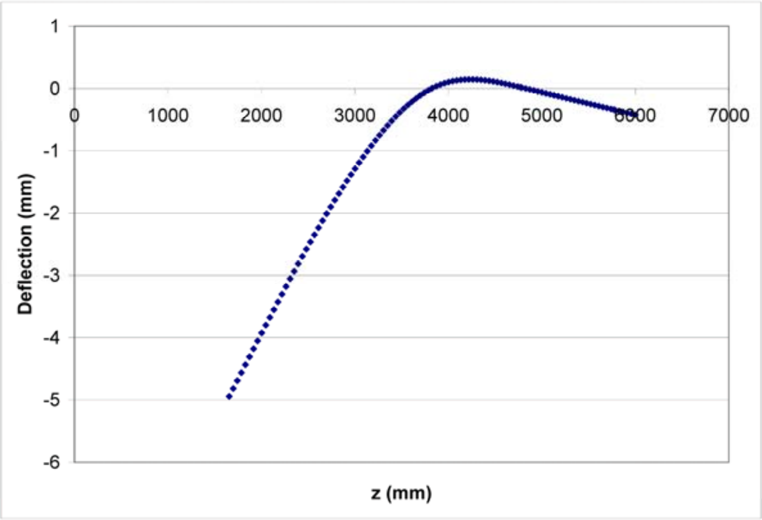
- Detector open 2 m for on-beamline servicing
- Ends of tracker and outer surfaces of vertex detector are accessible.

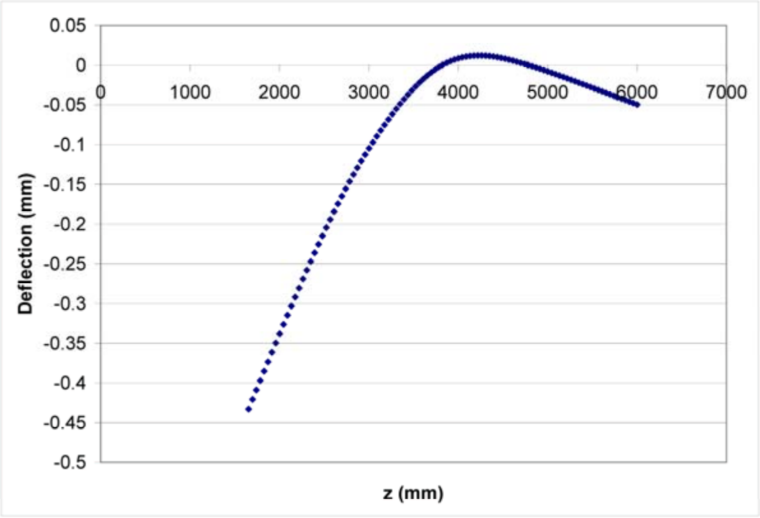


Deflections when Open 2m

- Support points with rollers were assumed at front and rear of HCAL (Z = 3820, 4770 mm).
- Forward calorimeters supported at their ends as dead weights
- QD0 weight ignored

4 - 20 mm x 20 mm bars	Stepped cylinders (3, 10, 20 mm walls)
Deflection at front of Lumi-CAL = 4.9 mm	Deflection at front of Lumi-CAL = 0.43 mm
Stress in bars = 12.7 ksi	Stress in cylinders = 1.0 ksi

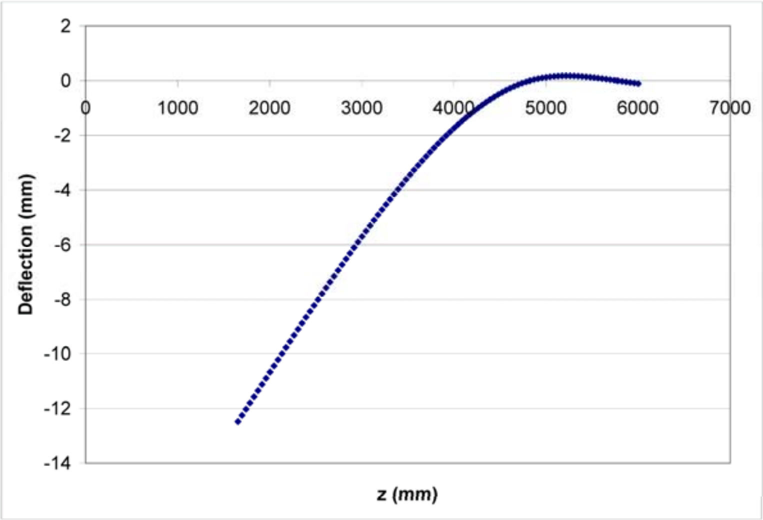


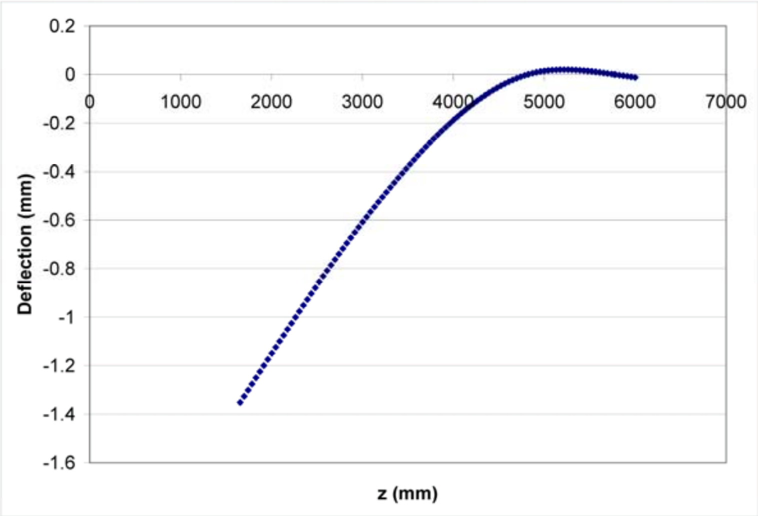


Deflections when Open 3m

- Support points with rollers were assumed at front and rear of HCAL (Z = 4820, 5770 mm).
- Forward calorimeters supported at their ends as dead weights
- QD0 weight ignored

4 - 20 mm x 20 mm bars	Stepped cylinders (3, 10, 20 mm walls)
Deflection at front of Lumi-CAL = 12.5 mm	Deflection at front of Lumi-CAL = 1.4 mm
Stress in bars = 16.6 ksi	Stress in cylinders = 1.8 ksi





Comments on Supports

- Multiple beam pipe bellows may be necessary with support via bars.
- Running tie rods from the front of Lumi-CAL to the central HCAL would help.
- It isn’t clear whether tie rods or bellows to address this particular issue would be needed with support via cylinders.
- Bellows to address alignment and thermal contractions of the beam pipe are likely to be needed in any case.
- Laser interferometry between the central ECAL and the beam pipe is expected to be used to monitor alignment in the closed position and as the detector is opened.

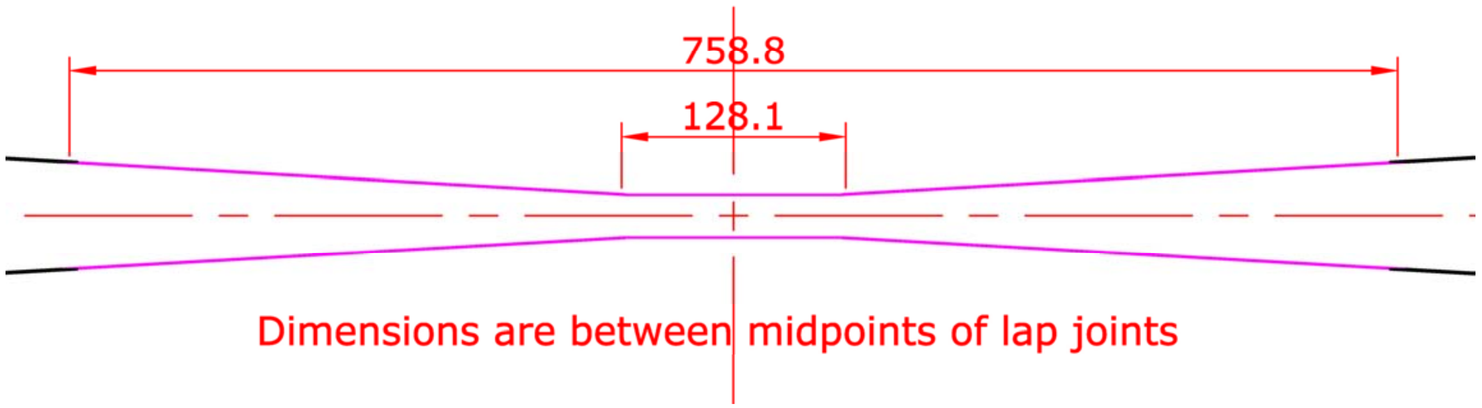
Beam Pipe Fabrication

- The main US fabricator of beryllium beam pipes is Brush-Wellman Electrofusion.
- Historically, their beam pipes have been made of rolled material with a brazed longitudinal joint the full length of the pipe (splitter joint with aluminum braze and an additional beryllium strip).
- Recent beam pipes have been made from billet and have no longitudinal joint.
  - Length of a segment of beam pipe has generally been limited to 0.75 m.
  - Segments of a longer pipe are connected via circumferential electron-beam-brazed half-lap joints.
  - Requirements for the SiD central straight pipe are comparable to those for the existing D0 straight pipe (CDF pipe is similar, but longer).
- Z-extent, fabrication, and addition of the titanium liner need to be understood.

	IR (mm)	Wall (mm)	Beryllium length (mm)
D0 (3 segments)	14.22	0.51	1750 = 750 + 500 + 500
SiD central	12.00	0.40	128

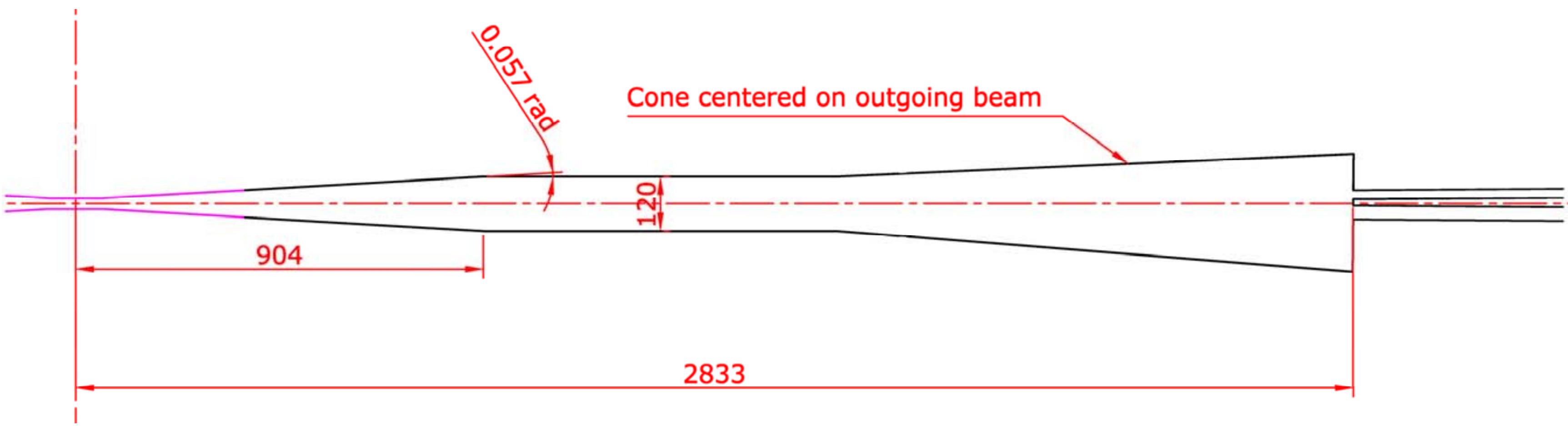
Beam Pipe Fabrication

- We think that SiD conical beryllium portions could also be made from billet, but that machining the cones and developing fixturing to align and connect them to the central straight portion will require R&D.
  - Present length of each of two conical portions = 315 mm
  - Estimated wall thickness = 0.7 mm
  - Overall beryllium length = 759 mm
  - Maximum cone radius = 30.5 mm
  - Note that the area of a cylindrical billet is a factor of ~ 4.5 larger than for D0 ➔ higher cost per unit length.
- Fabricating the entire beryllium portion from a single billet may also be possible, but would be more of a challenge and require a greater R&D effort.



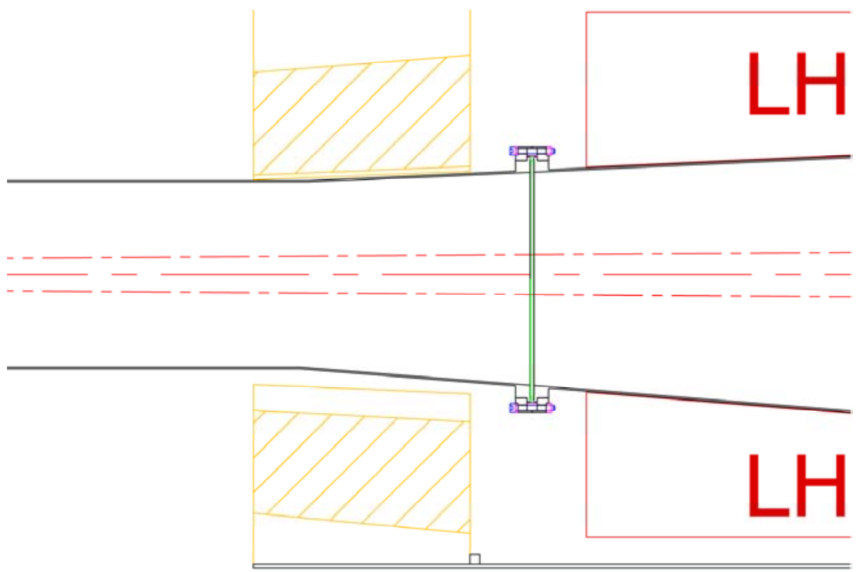
Beam Pipe Fabrication

- The present SiD design assumes stainless steel beyond Z = 759 mm.
  - That allows more standard welding and fabrication techniques.
  - Beryllium to stainless transitions should be done by the fabricator of beryllium portions, but the stainless steel portions could be made by a different vendor.
  - Uriel Nauenberg has asked about the feasibility of using other materials (beryllium, aluminum) in the BeamCAL region; materials for that region are under discussion.



Beam Pipe Flanges

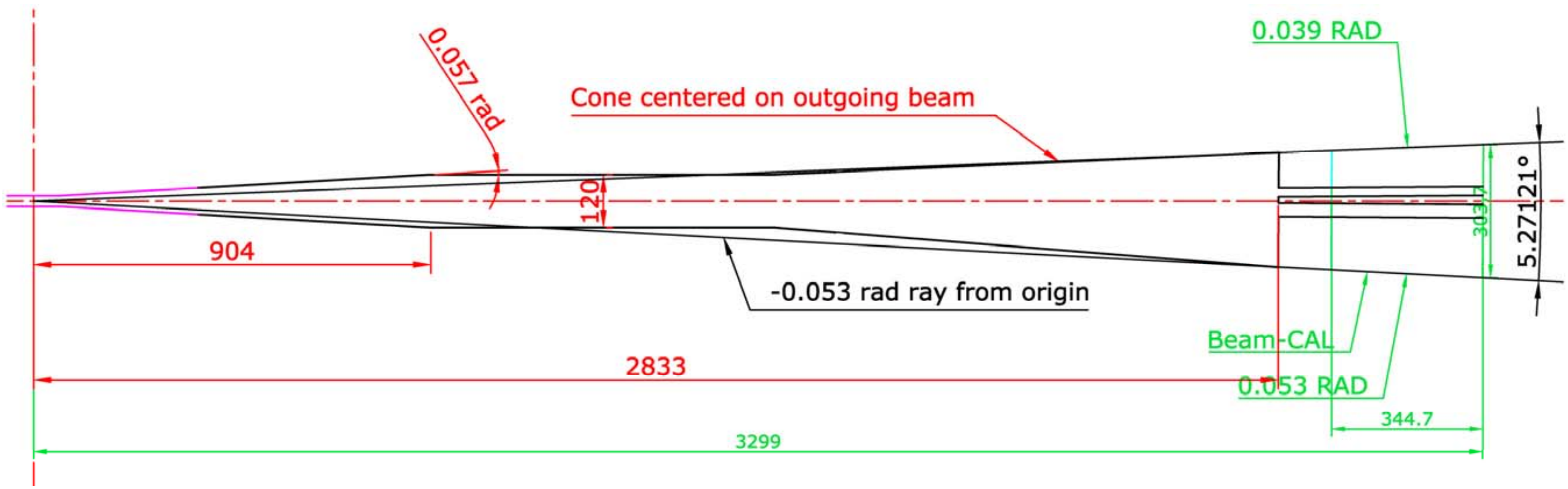
- Flanges and bellows assemblies will be needed.
- A low profile split flange is shown after Lumi-CAL.
- The flange design was scaled from one in use at DZero.
- The flange material is in the Lumi-CAL shadow, but that location presents other issues.
  - Disconnecting the flange would require Lumi-CAL removal.
  - Lumi-CAL support bars or cylinders probably need to end at the back face of Lumi-CAL to allow the beam pipe to be removed.



Questions to Be Investigated

- Are there special beam-related requirements for bellows assemblies?
- What are cable paths for the vertex detector and forward calorimetry?
- Where should bellows and flanges be located?
- What are the advantages and disadvantages of the straight sections of beam pipe upstream of Lumi-CAL?

- Back-up slides follow


0.057 rad
Cone centered on outgoing beam
0.039 RAD
120
5.27121°
303.7
904
-0.053 rad ray from origin
Beam-CAL
2833
0.053 RAD
344.7
3299

SiD Masses

Cal	Mass
LumiCal	≈325 kg
LHCal	≈270 kg
BeamCal	≈130 kg

From Bill Morse’s talk

Pair Radius in cm at Z=168 cm

	4 Tesla			5 Tesla		
	ANTI-DID	NO DID	DID	ANTI-DID	NO DID	DID
Nominal	5.2 / 4.7	5.1 / 5.5	5.8 / 6.5	4.7 / 4.1	4.4 / 5.1	5.3 / 6.1
Low Q	4.7 / 4.2	4.4 / 5.1	5.3 / 6.0	4.2 / 3.8	3.8 / 4.6	4.8 / 5.6
High Y	4.6 / 4.2	4.6 / 5.1	5.5 / 6.0	4.3 / 3.9	4.1 / 4.6	4.9 / 5.7
Low P	6.3 / 6.0	6.2 / 6.8	6.8 / 7.6	5.7 / 5.3	5.5 / 6.1	6.4 / 7.0
High Lumi	7.0 / 6.6	6.8 / 7.3	7.4 / 8.2	6.2 / 5.9	6.1 / 6.7	6.7 / 7.5

Radius in black is measured from solenoid axis (x,y) = (0., 0.).
Radius in red is measured from extraction line (x,y) = (-1.176 cm, 0.)

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