ePIC SVT configuration for eRD104/111/113 work

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EIC SC general meeting – 7 November 2022

EIC SC work for FY23

- The work of the EIC SC for the development of the EPIC silicon vertex and tracking (SVT) detector proceeds within the eRD104, eRD111, eRD113 projects.

- The combined aim of eRD104/111/113 for FY23 is to

  Be ready to design the LAS sensor in FY24.

  Reach a mature conceptual design of all items of the EPIC SVT (supported by prototyping/testing of components).

  Full details in the proposals at https://wiki.bnl.gov/conferences/index.php/ProjectRandDFY23

- Work needs to start work towards these goals. Clearly, there still many open points and unknowns, but we need to start working on technical details and engineering aspects that will feed back important information to evolve the design.

- Let's discuss a starting point today → ePIC SVT configuration v0.0

Current status: ePIC SVT layout

- EPIC SVT layout developed for the first simulation campaign

    5 barrel layers, 5 disks per side

    See Ernst's talk at https://indico.bnl.gov/event/17418/

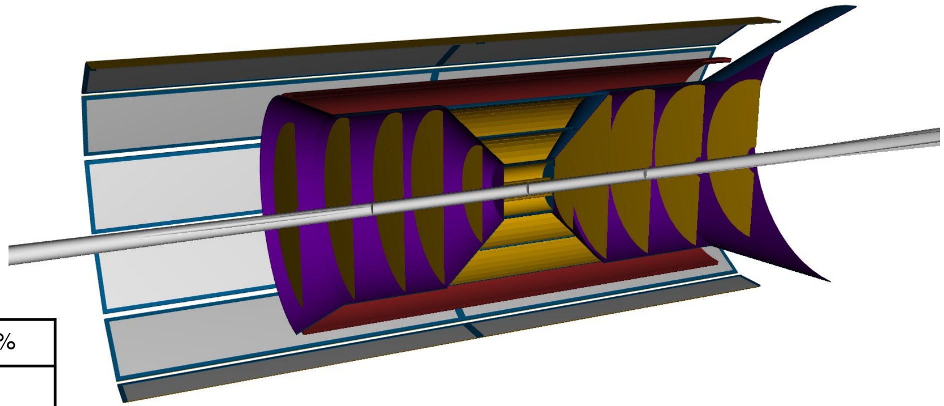
    Current implementation in DD4Hep in Shujie's talk at https://indico.bnl.gov/event/17394/

    This design includes only Si active area and simplified description of support structures and services → Engineering details need to be worked out and added, see Nikki's talk next.

    Also, we are still using truth seeding and have no background embedded in simulations, so this layout might still change.

BARREL	r [mm]	l [mm]	X/X0 %
Layer 0	36	270	0.05
Layer 1	48	270	0.05
Layer 2	120	270	0.05
Layer 3	270	540	0.25
Layer 4	420	840	0.55

DISKS	+z [mm]	-z [mm]	X/X0 %
Disk 1	250	-250	0.24
Disk 2	450	-450	0.24
Disk 3	700	-650	0.24
Disk 4	1000	-900	0.24
Disk 5	1350	-1150	0.24



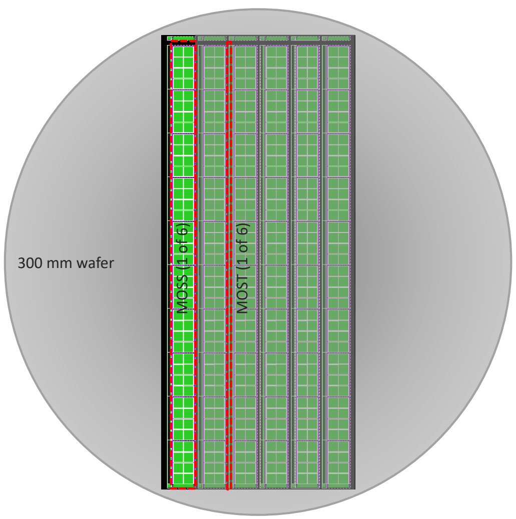
Current status: Sensor technology

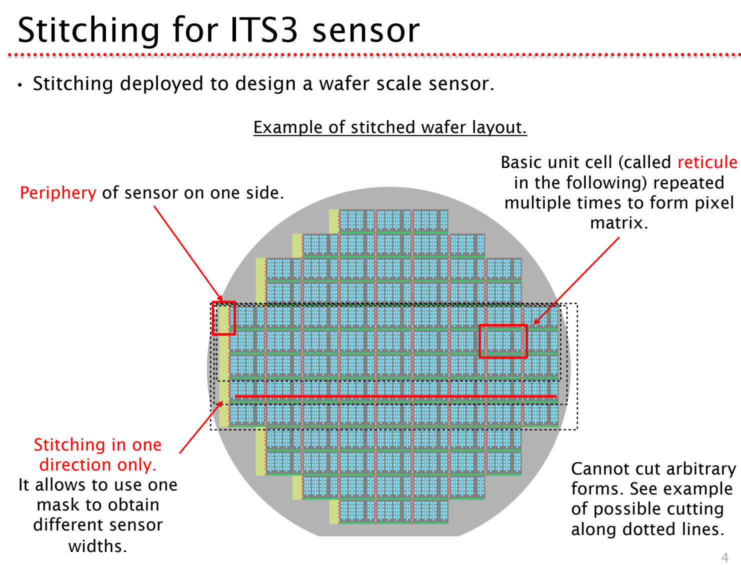
- 65 m technology validation almost completed with testing of MLR1 structures → no show stopper.
- ER1 submission of first, wafer-scale sensor by end of the year. Scope: learning about stitching and yield of large area sensor.

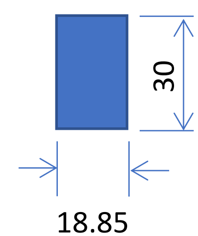
  Expect to know yield in about 9 months to one year from now.

- Reticule size not yet fixed, current assumption to progress our work on LAS and conceptual designs 18.85 mm x 30 mm.

  Expect to know final reticule size at ITS3 ER2, currently scheduled for Q1 24.







Layout Studies

- EIC Vertex Layers

  Use ITS3 curved wafer-scale stitched sensors

  Three layers (L0, L1, L2); Radii = 36 mm, 48 mm and 120 mm (see note below)

- EIC Sagitta Layers

  Baseline is smaller format stitched sensors (EIC LAS) on staves

  Two layers (L3, L4); Radii = 270 mm and 420 mm

- EIC Disks

  Several sensor variants (different sizes) needed for improved yield and tiling flexibility

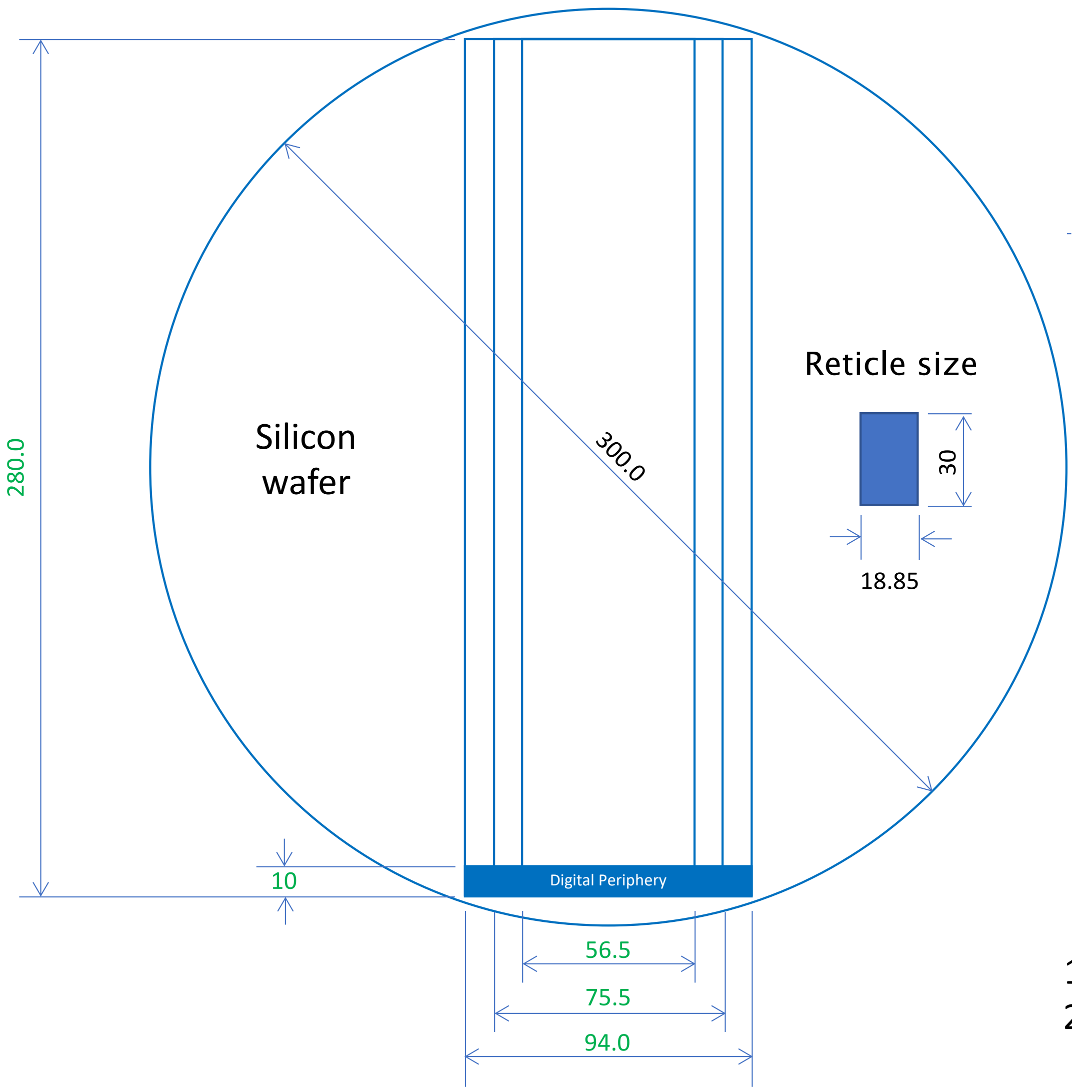
  Requires changes to stitching plan & periphery

  Studying optimum tiling geometry

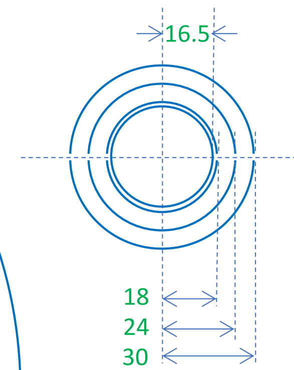
- What follows is based on studies done by Peter Jones

Note: beryllium beampipe outer radius = 31.75 mm
Require spacing of 5 mm to first vertex layer for beam pipe bakeout

ALICE ITS3 Sensor Layout



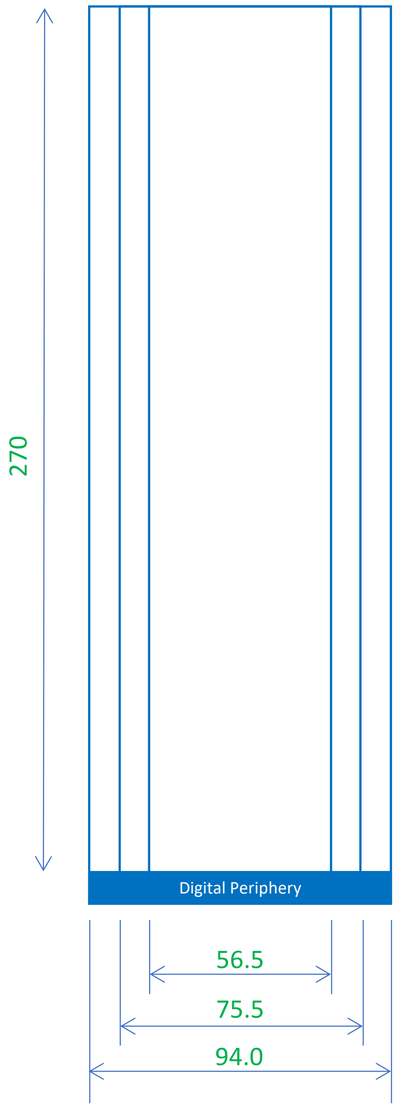
ALICE – ITS3



Units = mm

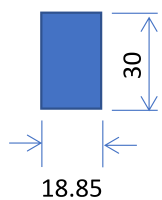
ITS3
3 sensor formats:
L0 = 3 x 9 reticles
L1 = 4 x 9 reticles
L2 = 5 x 9 reticles
1 sensor per wafer
2 sensors per layer

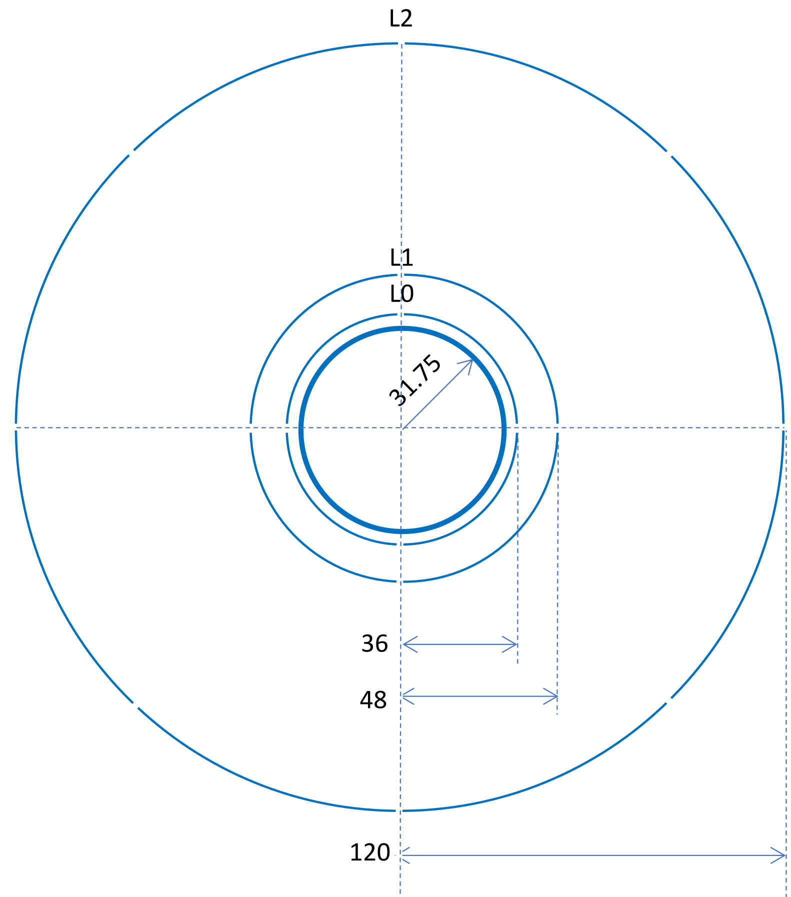
EPIC Vertex Layers



L0 = 4 x 56.5; R = 36
L1 = 4 x 75.5; R = 48
L2 = 8 X 94.0; R = 120

ePIC - SVT
Same 3 sensor formats:
L0 = 3 x 9 reticles
L1 = 4 x 9 reticles
L2 = 5 x 9 reticles
1 sensor per wafer
4 or 8 sensors per layer

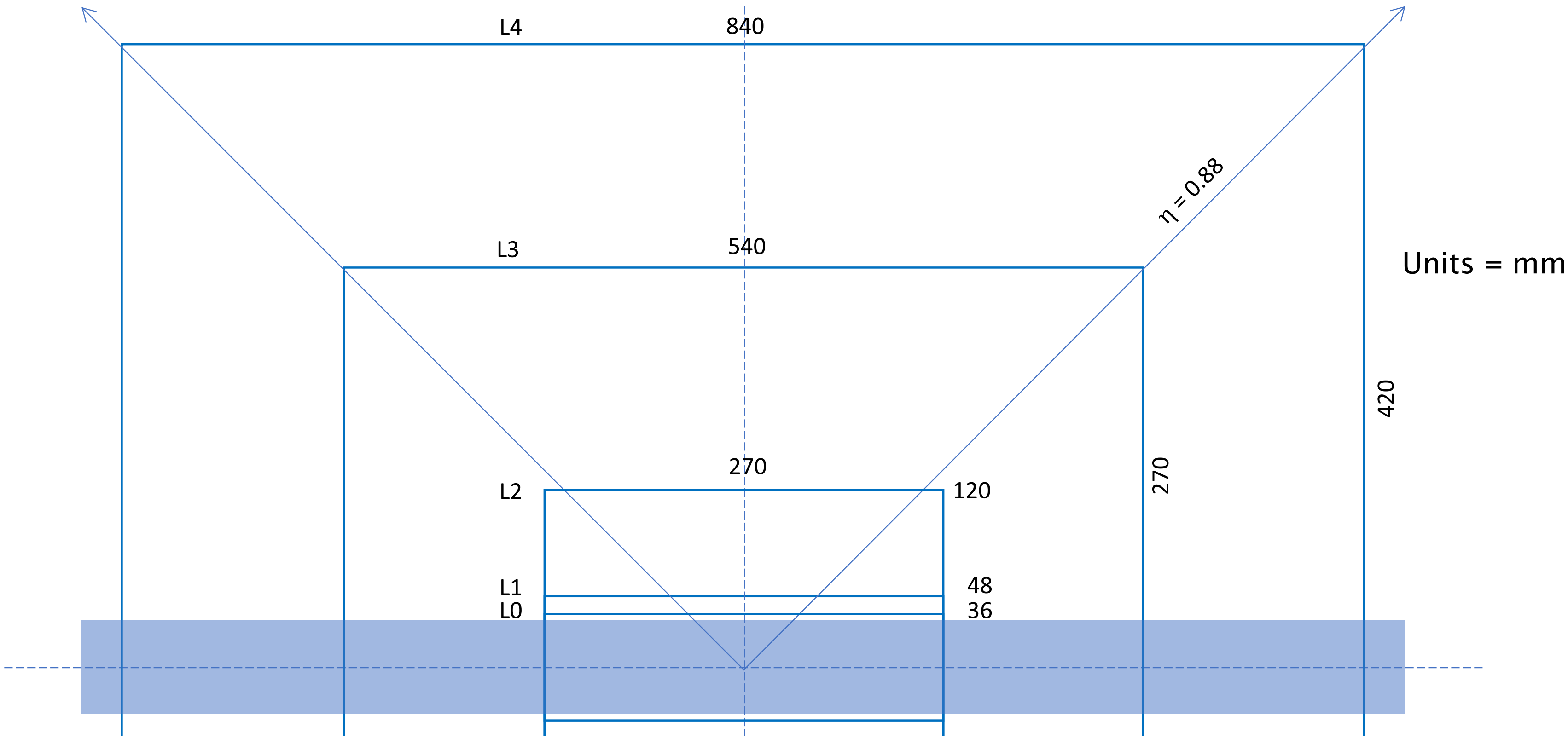




Units = mm

EPIC Vertex and Sagitta Layers

Note: these are active lengths; they do not include the periphery

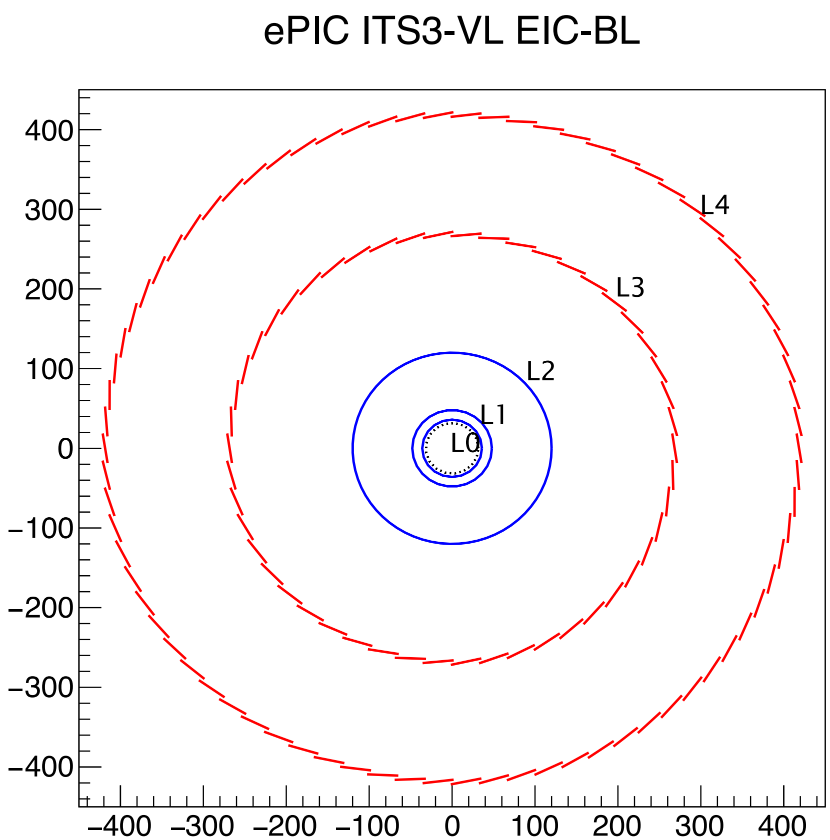


L0, L1 and L2 lengths are single sensors that are 270 mm long (9 reticles)

L3 length can be achieved using two sensors 270 mm long (9 reticles), or three sensors 180 mm long (6 reticles)
Choice of two or three sensors may be decided by sensor yield

L4 length can be achieved using four sensors 210 mm long (7 reticles)

EPIC Sagitta Layers



- Sagitta Layers

  Default design consists of ITS2-like staves

- L3

  50 staves, 2 x 18.85 = 37.7 mm wide

  Mean radius = 268.4 mm

  Rϕ overlap = 3.5 mm ~ 10%

  2 x 2 = 4 or 2 x 3 = 6 sensors per stave

  Require 200 1x9 sensors or 300 1x6 sensors

- L4

  78 staves, 2 x 18.85 = 37.7 mm wide

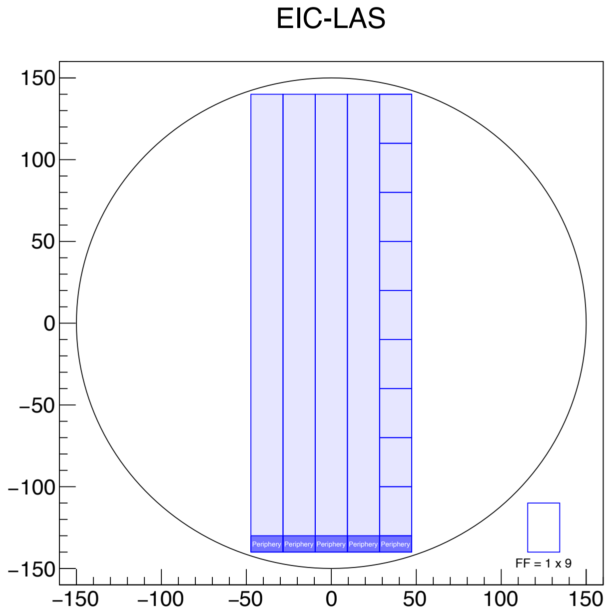
  Mean radius = 418.5 mm

  Rϕ overlap = 3.5 mm ~ 10%

  2 x 4 = 8 sensors per stave

  Require 624 1x7 sensors

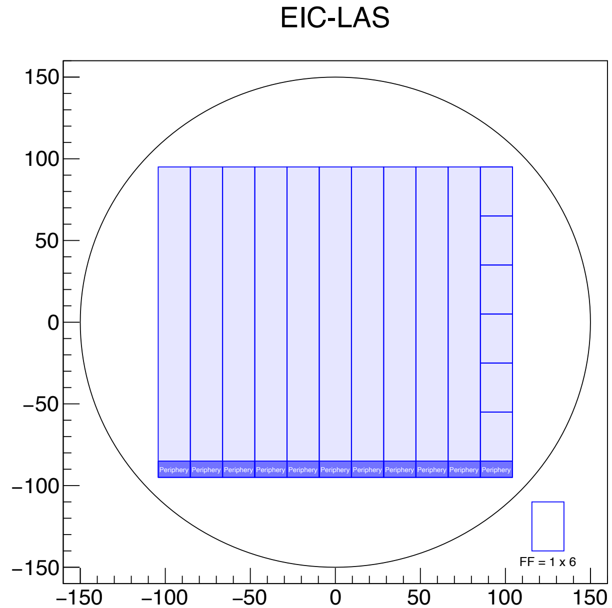
Wafer Usage – Sagitta Layers



L3 Option 1
1 x 9 sensors
5 sensors per wafer
45 reticles per wafer
200 sensors (40 wafers)

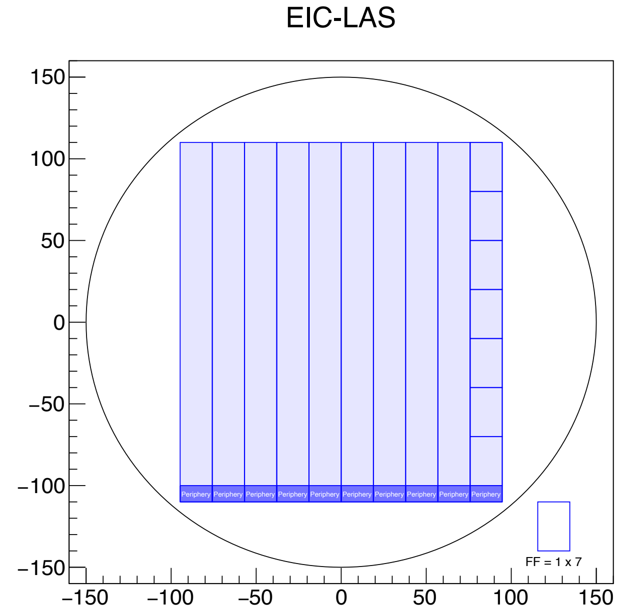
Higher cost, lower material

Use as default.



L3 Option 2
1 x 6 sensors
11 sensors per wafer
66 reticles per wafer
300 sensors (28 wafers)

Lower cost
Higher material



L4 Option 1
1 x 7 sensors
10 sensors per wafer
70 reticles per wafer
624 sensors (63 wafers)

Note #1: 100 micron dicing lanes between each sensor assumed
Note #2: if using 2 x 9 or 2 x 6 sensors, both L3 options will require more wafers;
module concept needed (one module made of two 1x9/1x7 sensors for L3/L4)

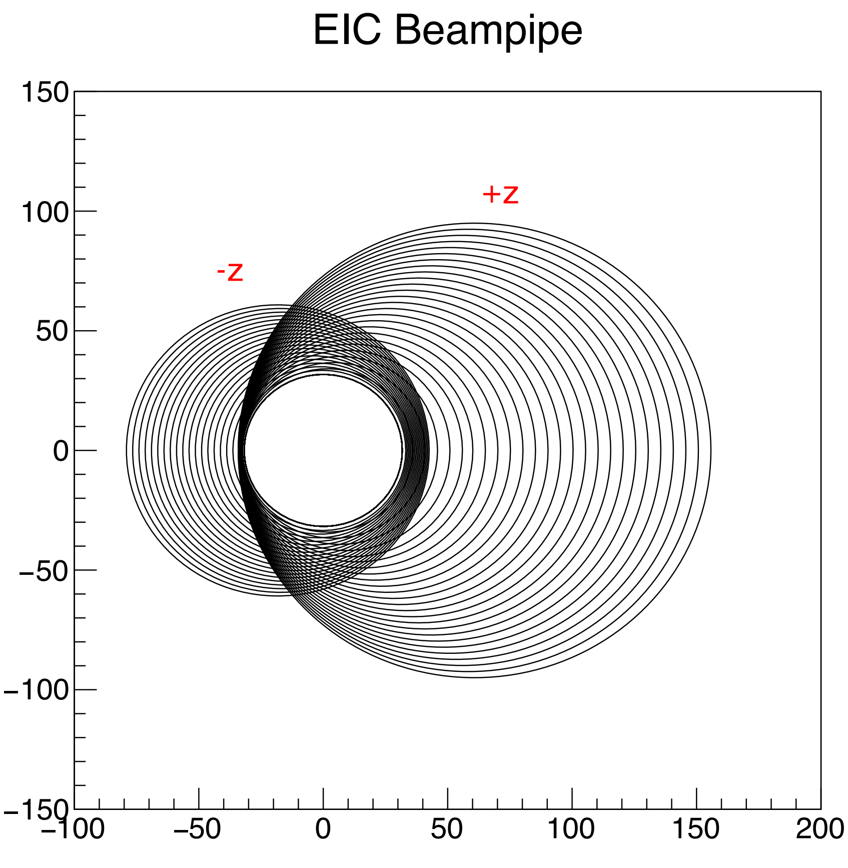
Summary – Barrel v0.0

Note: these are active lengths; they do not include the periphery

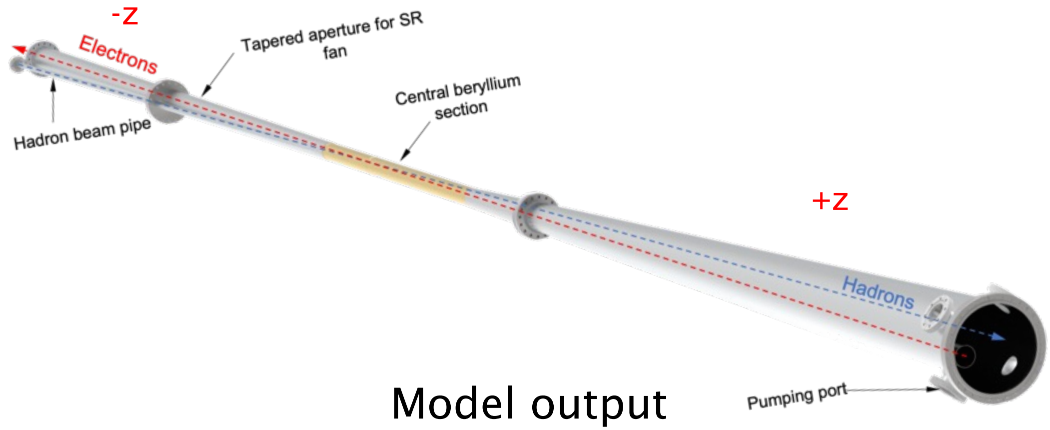
Layers	Reticules	Sensor width x length [mm^2]	Layer length [mm]	Layer radius [mm]	Number of sensors per layer	Number of staves
L0	3 x 9	56.55 x 270	270	36	4	NA
L1	4 x 9	75.4 x 270	270	48	4	NA
L2	5 x 9	94.25 x 270	270	120	8	NA
L3	1 x 9	18.85 x 270	540	268.4	200	50
L4	1 x 7	37.7 x 210	840	418.5	624	78

Forward and Backward Disks

- Beam pipe model



Beampipe profile; 100 mm steps



Model output

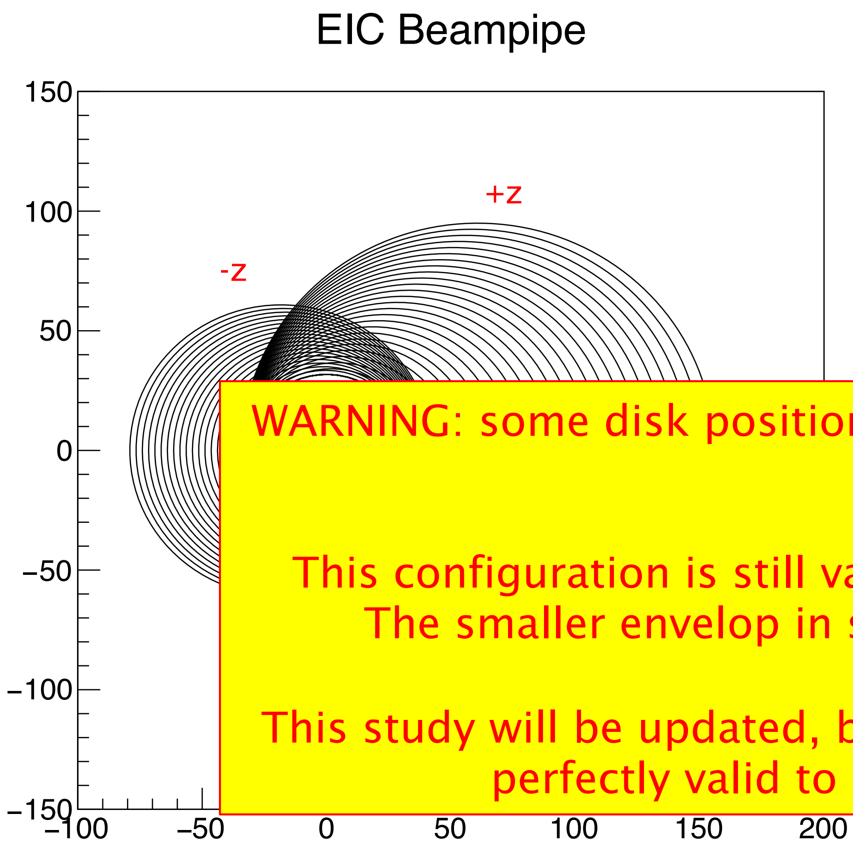
The beam pipe radius has been modelled as a function of z from the original CAD drawings

	Z - ePIC	R_bpipe	x_offset	R_inner	R_outer
5n	-1350	41.08	-5.30	46.1	430
4n	-1000	35.76	-1.81	40.8	430
3n	-700	31.76	0.00	36.8	430
2n	-450	31.76	0.00	36.8	430
1n	-250	31.76	0.00	36.8	230
1p	250	31.76	0.00	36.8	230
2p	450	31.76	0.00	36.8	430
3p	700	32.86	0.56	37.9	430
4p	1000	40.58	7.85	45.6	430
5p	1350	49.12	16.02	54.2	430

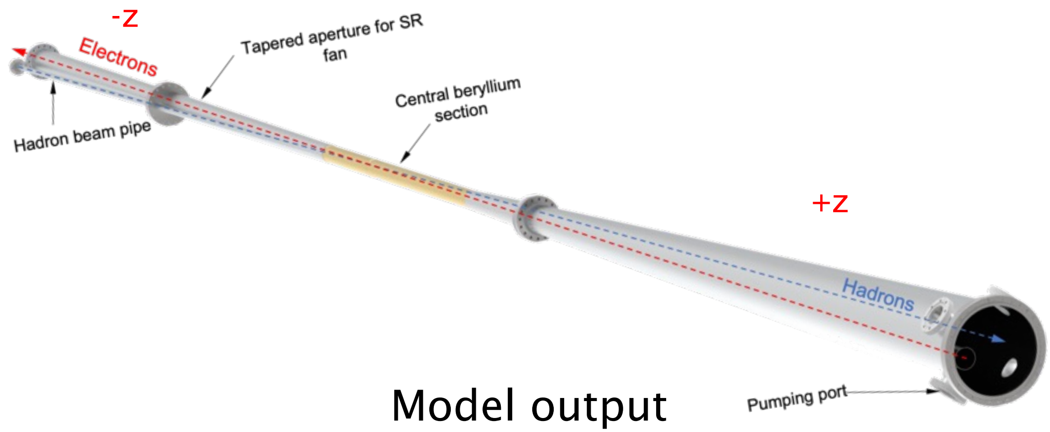
Dimensions are mm

Forward and Backward Disks

- Beam pipe model



Beampipe profile; 100 mm steps



Model output

The beam pipe radius has been modelled as a

WARNING: some disk positions (3n/4n/5n) have changed since this work was done.

This configuration is still valid if the mRICH is used in the BW region.
The smaller envelop in slide 3 is needed if the pfRICH is used.

This study will be updated, but in the meantime these positions are still perfectly valid to kick-off the engineering studies.

					R_outer
					430
					430
					430
					430
					230
					230
					430
3p	700	32.86	0.56	37.9	430
4p	1000	40.58	7.85	45.6	430
5p	1350	49.12	16.02	54.2	430

Dimensions are mm

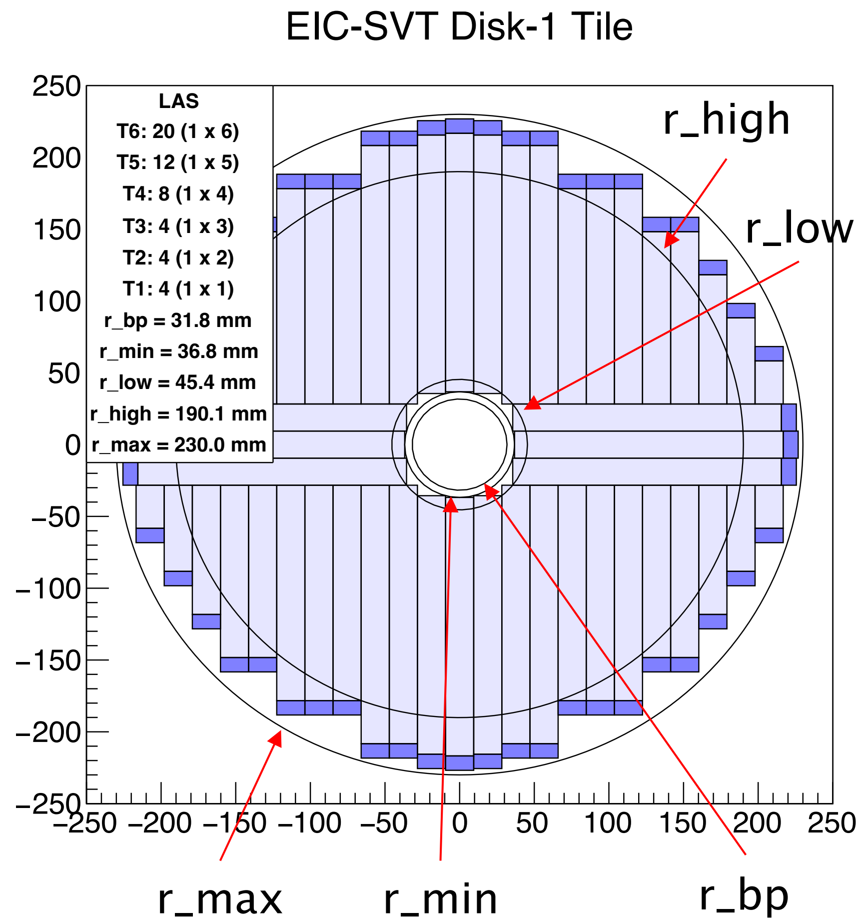
Disk Tiling

- More details on the disks tiling study and methods in the backup and here https://indico.bnl.gov/event/17073/

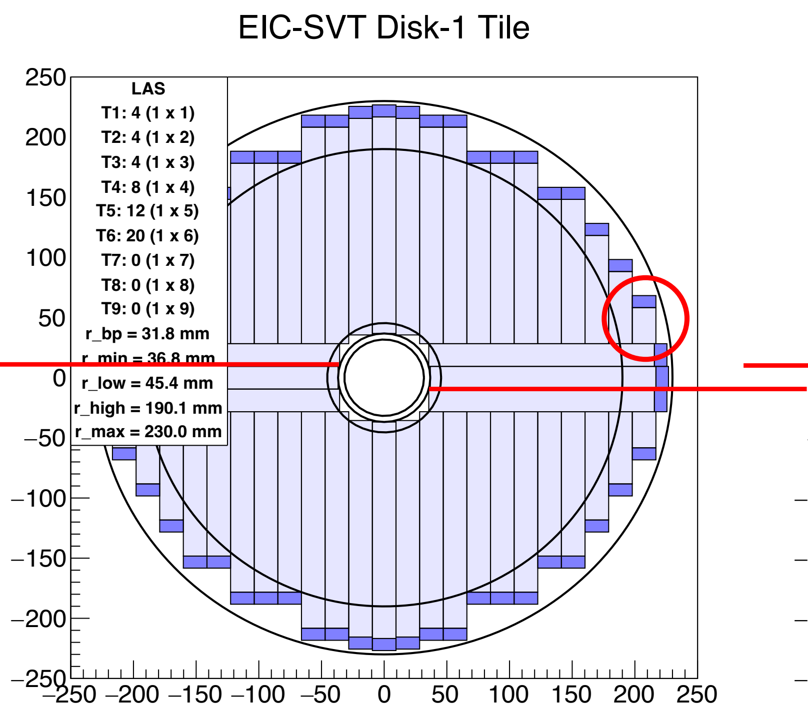
r_bp = beam pipe radius
r_min = r_bp + 5 mm
r_max = outer disk radius
r_low = smallest radius with full acceptance
r_high = largest radius with full acceptance

TX: YY (1x X) → on the disk there are YY Tiles made of one stitched row of X reticules.

Example: T5: 12 (1x5) → on the disk there are 12 tiles made of one stitched row of 5 reticules (i.e. 18.85 mm x 150 mm).

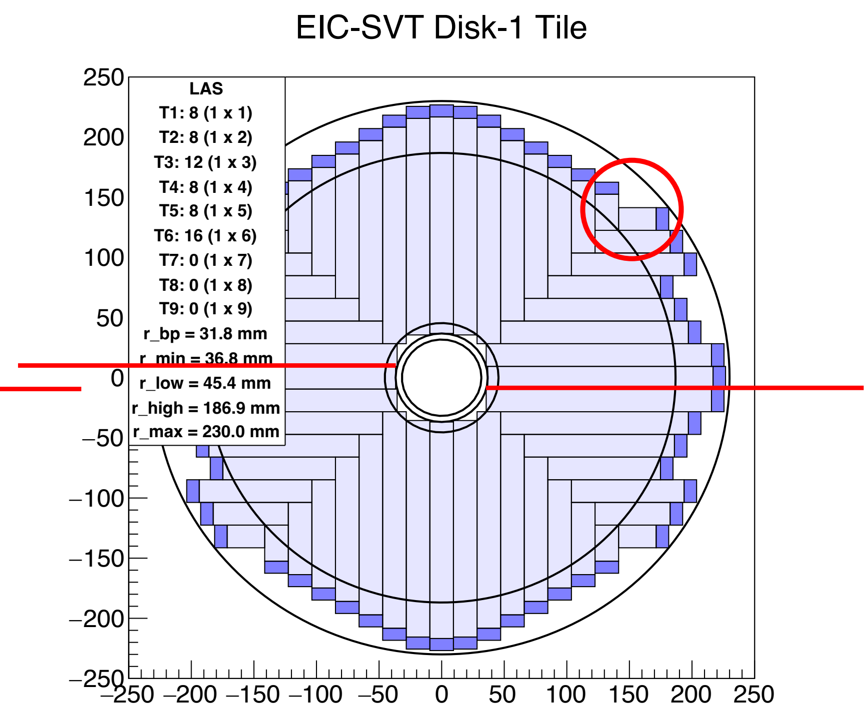


Disk 1 – Tiling Options



52 sensors
236 reticles

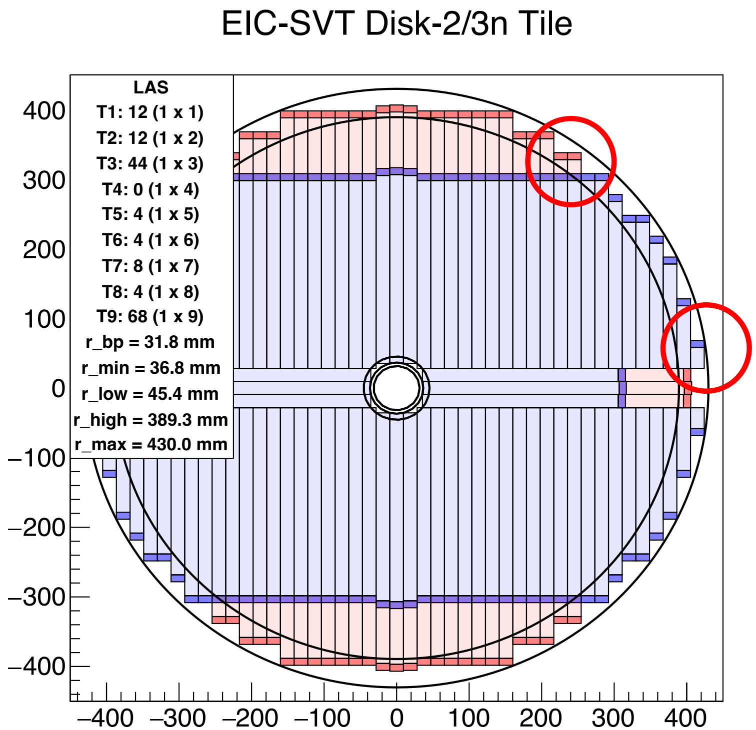
Fewer connections
More coverage

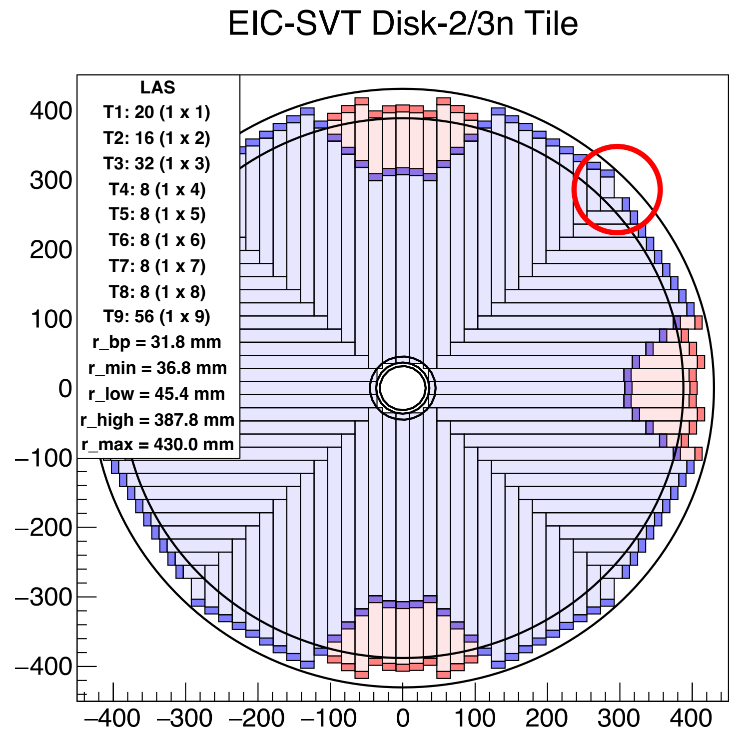


60 sensors
228 reticles

Note #1: no restriction on sensor variants but disk size imposes its own constraint
Note #2: lines indicate possible division of disk into two halves for assembly around the beam pipe

Disk 2/3n – Tiling Options





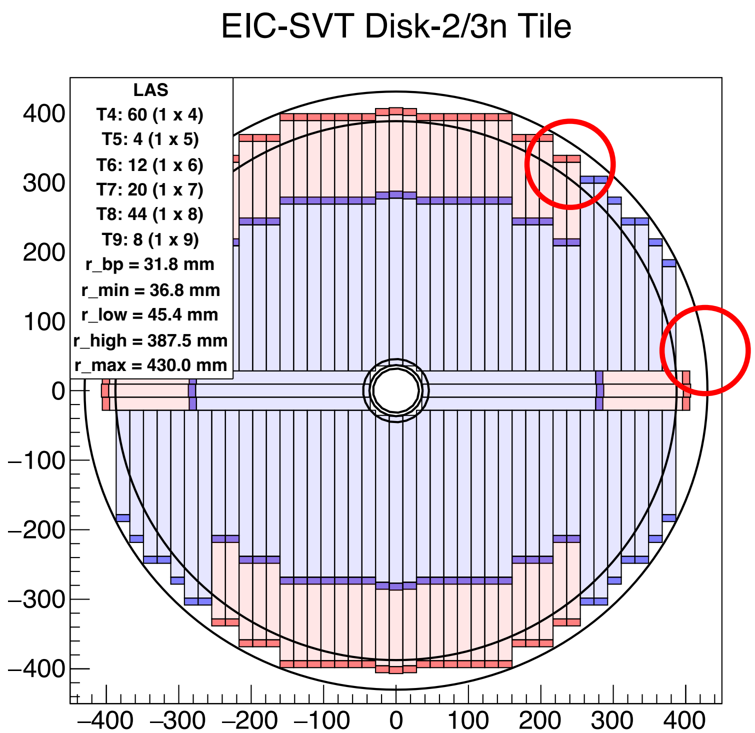
156 sensors
912 reticles

Fewer connections
More coverage

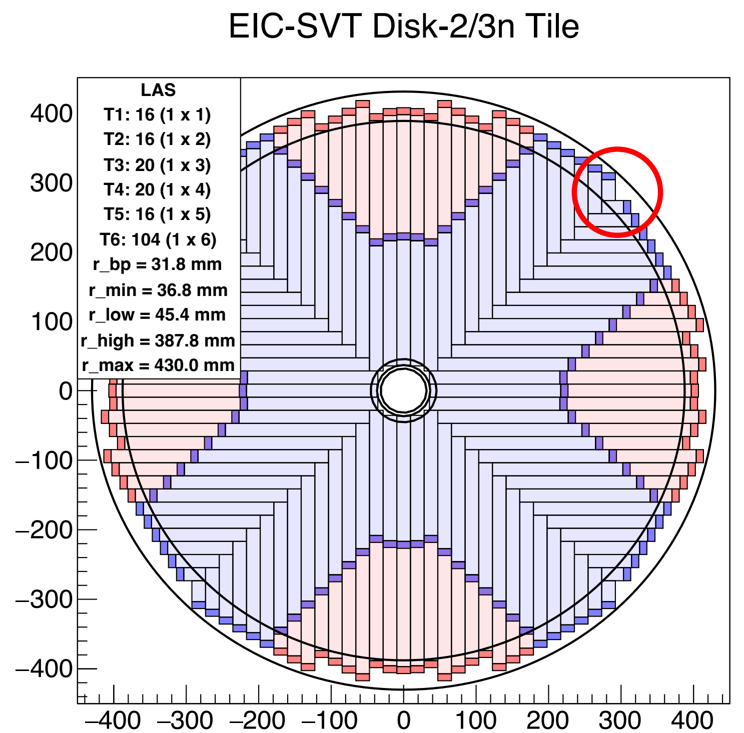
164 sensors
892 reticles

Note #1: no restriction on sensor variants
Note #2: Sensors in red on reverse side of disk overlap digital periphery of inner sensors in blue

Disk 2/3n – Restricting Sensor Size



148 sensors
896 reticles
Fewer, longer sensors T4 – T9

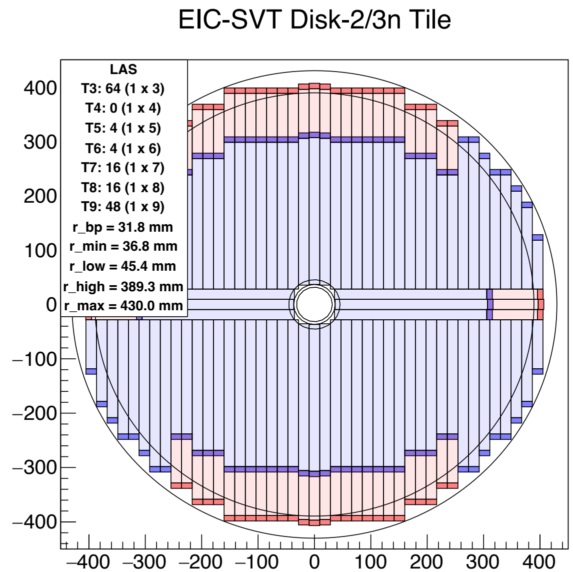


192 sensors
892 reticles
More, shorter sensors T1 – T6

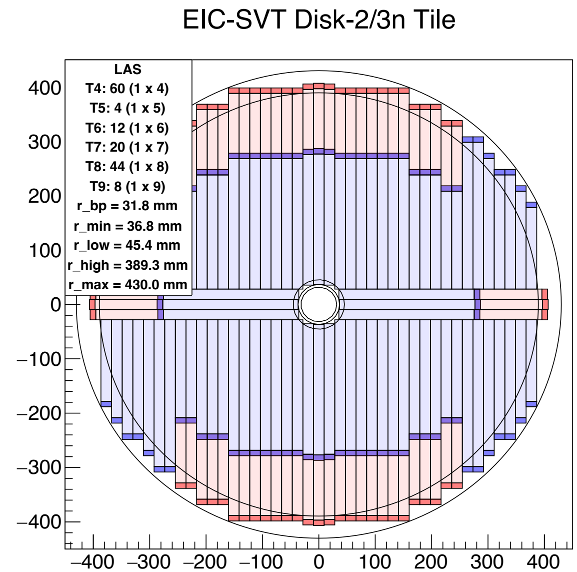
Use picket fence design as default for all disks.

Disk2/3n – Varying Restriction on Sensor Size

T3 – T9

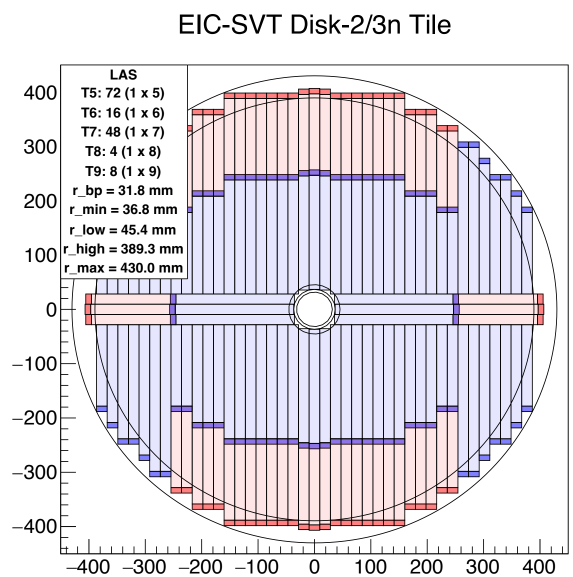


T4 – T9



Use T4 – T9 as default for disks 2 to 5.

T5 – T9



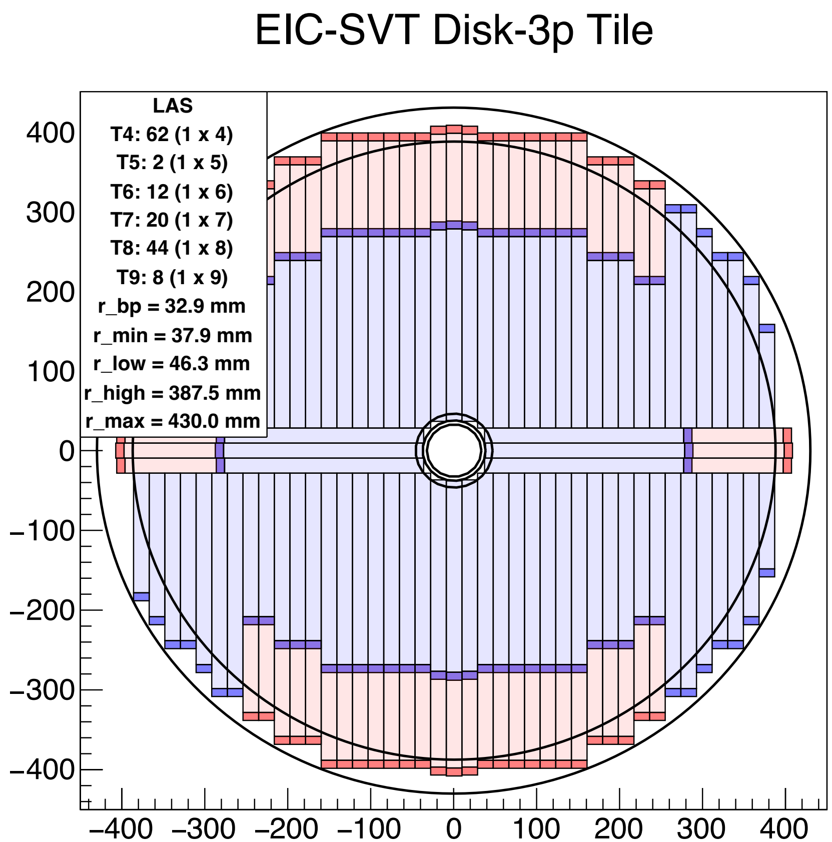
Greater prospect of reducing number of sensor types with the simple tiling design

However, the reduction in sensor types pushes periphery inwards, adding material due to flex cables running over the outer sensors at larger radii

Note: shorter variants produce more sensors per wafer

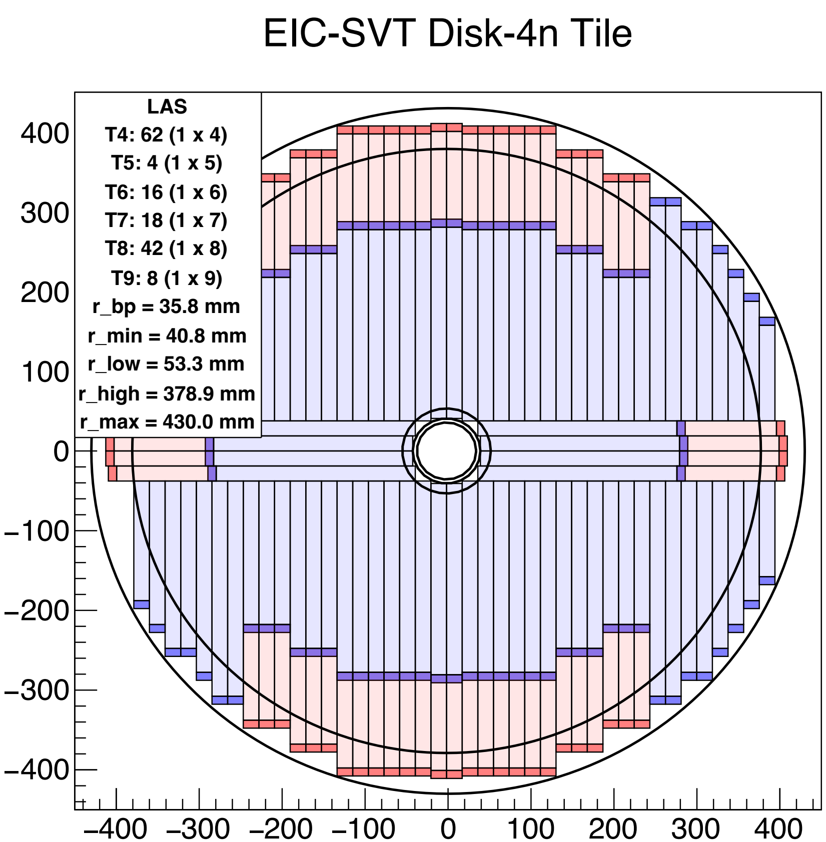
Disk 3p

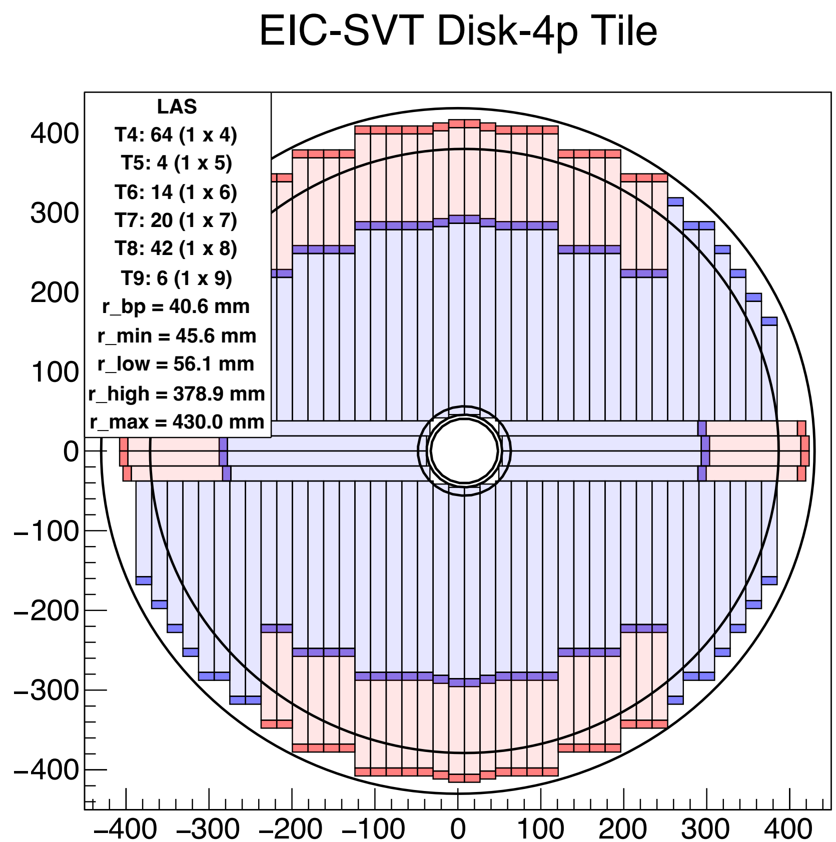
Note: disk center offset from x = 0 to accommodate beam pipe fan out



Disk 4n/p

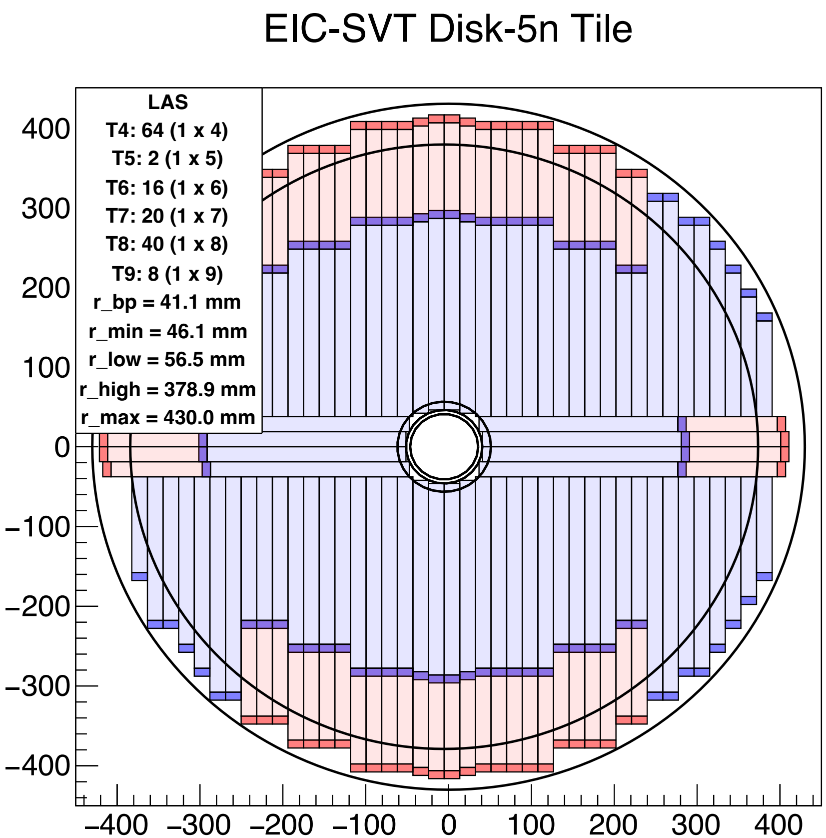
Note: disk center offset from x = 0 to accommodate beam pipe fan out

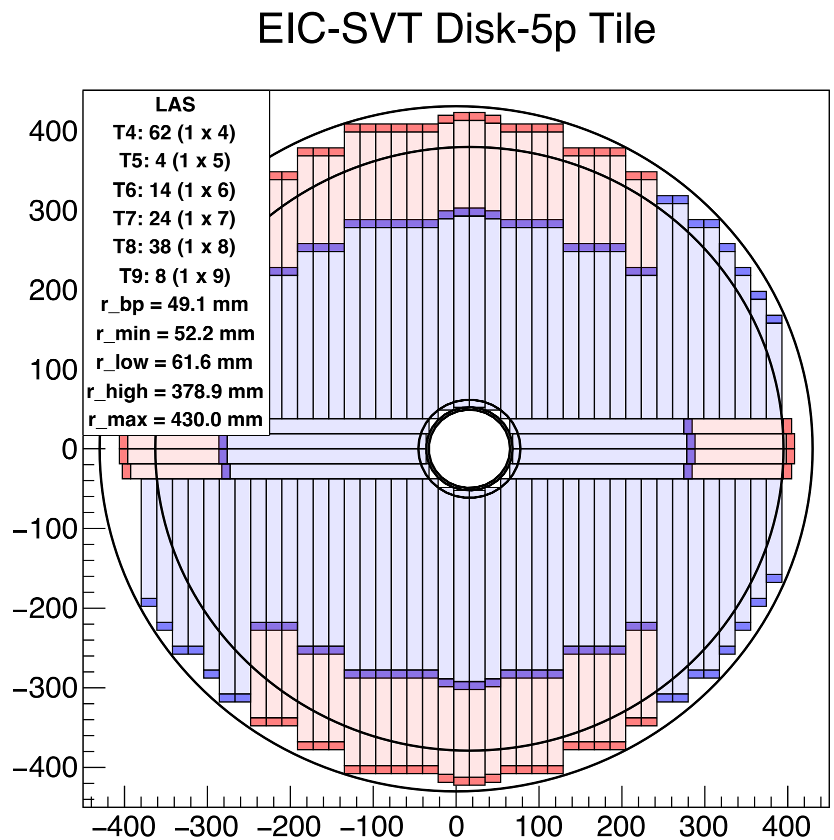




Disk 5n/p

Note: disk center offset from x = 0 to accommodate beam pipe fan out





Summary – Disks v0.0

BACKWARD									
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**
Disk 1	4	4	4	8	12	20	0	0	0
Disk 2	0	0	0	60	4	12	20	44	8
Disk 3	0	0	0	60	4	12	20	44	8
Disk 4	0	0	0	62	4	16	18	42	8
Disk 5	0	0	0	64	2	16	20	40	8
FORWARD									
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**
Disk 1	4	4	4	8	12	20	0	0	0
Disk 2	0	0	0	60	4	12	20	44	8
Disk 3	0	0	0	62	2	12	20	44	8
Disk 4	0	0	0	64	4	14	20	42	6
Disk 5	0	0	0	62	4	14	24	38	8

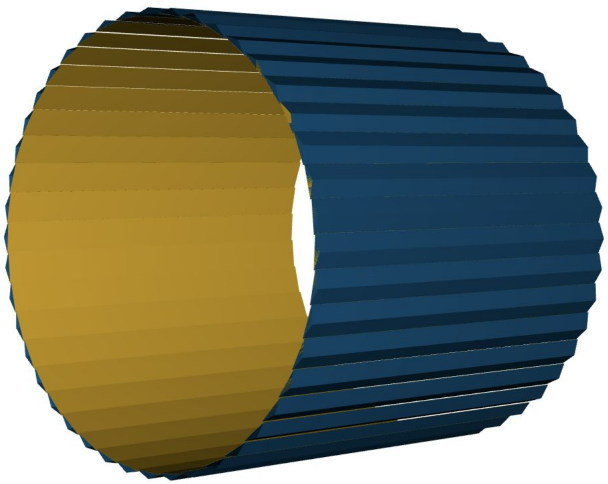
Mechanical Design as Implemented in DD4HEP

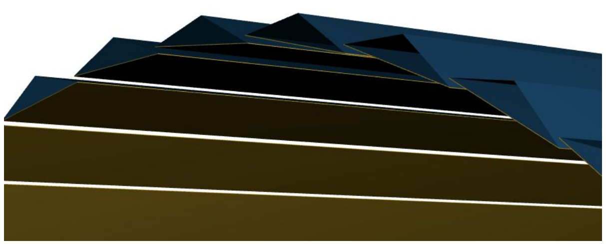
- Basic model for sagitta layers

  44 tilted triangular staves (not 50 or 78)

  Silicon + Al + carbon fiber plates

  No truss structure; cooling pipes, etc.





- Support cone design issues

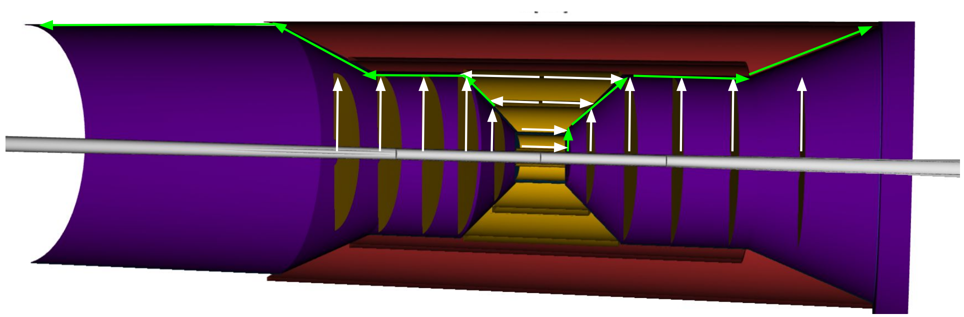
  Routing of cables to/from first two vertex layers is assumed to be radially outwards

  Implies a 90-degree bend in the FPC

  No location identified for the patch panel needed to connect FPC to external cables

  Length of vertex and sagitta layers does not include periphery or FPC

  Radius of last disk is smaller than the radius of the support cone



Figures from Shujie Li (LBNL)

More engineering challenges discussed in Nikki's talk.

Summary

- Vertex Layers (L0, L1, L2)
  - Will use ITS3 wafer-scale sensors
  - L2 now at R = 120 mm
  - R1 – R0 = 12 mm
  - R2 – R1 = 72 mm
  - For ITS3 the layer spacing is 6 mm
  - Requires new mechanical design
- Sagitta Layers (L3, L4)
  - L3 length (540 mm) can be made with 2 sensors of length 270 mm (9 reticles)
  - L3 could also made with 3 sensors of length 180 mm (6 reticles) to improve wafer usage
  - Second option requires services running over the stave; also cooling for the periphery → First option as default for now
  - L4 length (840 mm) can be made with 4 sensors of length 210 mm (7 reticles)
  - Same comment about services and cooling
  - Module concepts needed for L3 and L4
- Tiling of disks
  - Method to tile the disks developed
  - Vertical tiles (design #1) are preferred
  - Fewer sensors providing greater coverage
  - Studies of restricted sensor sizes on-going
  - Need to convert this into estimate for the number of wafers needed (with inputs from designers)
- Mechanical Design
  - Need to investigate an ITS2-like stave option for the sagitta layers
  - Need to address cable routing, cooling and compatibility with EPIC support cone
  - No conceptual design the disks; not clear that air cooling will work here

Conclusion

- The proposed configuration is based on
  1. The ePIC SVT configuration for the first simulation campaign (Oct/Nov 2022).
  2. A reticule size of 18.85 mm x 30 mm.
  3. An exercise of how to best tile staves and disks using 1. and 2.

- This starting point is not yet informed by
  - Sensor yield (i.e. stitched rows of 9 reticules might not be possible) → biggest unknown!
  - Engineering aspects of staves/disks, mechanics, cooling, integration, etc.
  - Designers input on LAS.
  - …

Let's use this configuration as starting point to work on some of these missing inputs and iterate on the SVT design with more information.

Backup

Disk Tiling Study

- Aim of the study

  Investigate sensor (LAS) formats needed

  Try to restrict the number of variants

  Try to keep periphery to outer radius of disk

- Tiling strategy

  Two designs starting with a central cross

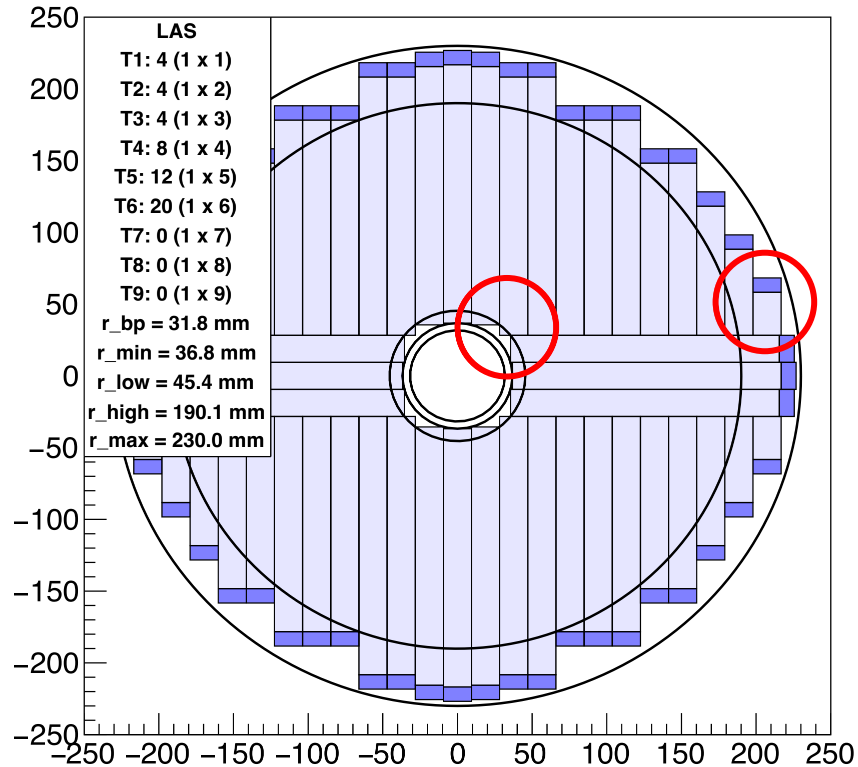
  Design #1 = vertical tiles/sensors (shown)

  Design #2 = herringbone pattern (alternating vertical and horizontal tiles)

  No sensor overlap on same side of disk

  Sensor variants are assumed to be 1 reticle width by up to 9 reticle lengths

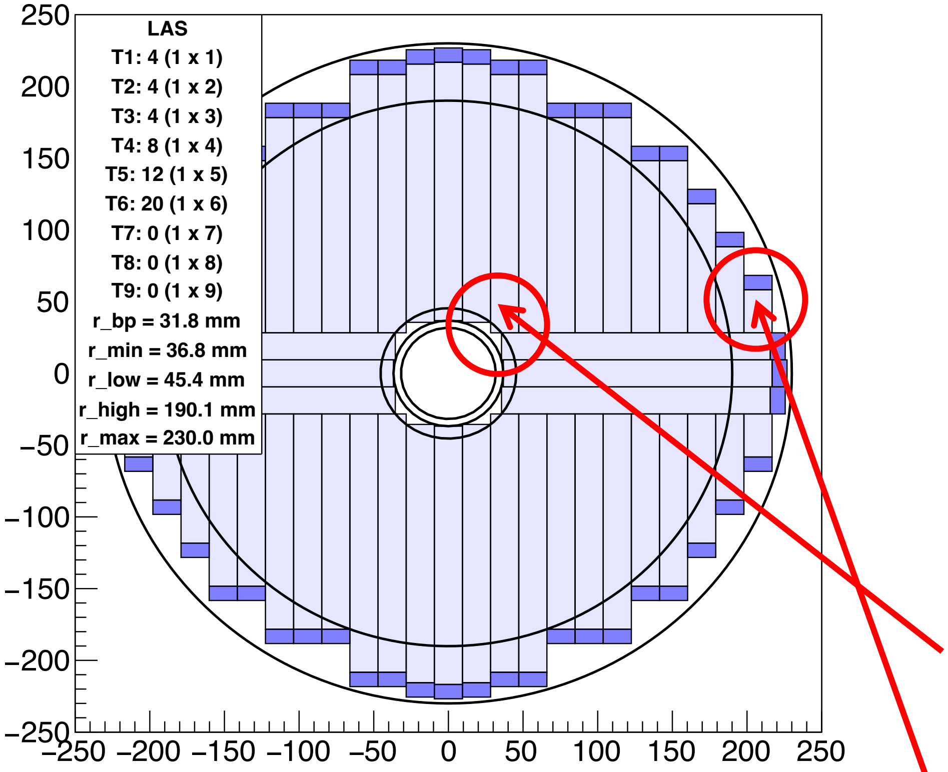
EIC-SVT Disk-1 Tile



Example: Disk 1
z = +/- 250 mm

Disk Tiling Algorithm

EIC-SVT Disk-1 Tile



z = +/- 250 mm

Central cross = 3 sensors

The algorithm

- Try to keep periphery to larger radii
- Two designs, each based on a central cross pattern smaller than the inner diameter of the disk
- Design #1 = vertical tiles (shown)
- Design #2 = herringbone pattern (alternating vertical and horizontal tiles)
- The minimum disk radius (r_min) is 5 mm larger than the beam pipe radius (r_bp) for bake out
- Sensor and periphery must be contained within the min and max radii of the disk (r_min and r_max).
- For each disk, the algorithm calculates the smallest and largest radii with full acceptance (r_low and r_high)
- The algorithm does not permit any sensor overlap
- Acceptance at small radii could be improved by allowing some sensor overlap; placing overlapping sensors on the reverse side of the disk (in progress)
- Limits on the max and min sensor length can be applied
- Study the number of sensor variants that are needed

Disk Tiling Method