Detector Parallel Wafer Layout Introduction

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Brenna Flaugher, L2 Scientist (interim)
John Joseph CAM

CMB-S4

pBD has all Rhombus (except SAT HF), this is not well matched to Fab. site expertise

More hex layouts would improve flexibility to optimize based on cost, schedule, demonstrated yield and risk - This is really critical as the project moves forward

What are the impacts of shifting some of the wafer designs from Rhombus to Hex?

Toki will show Hex layouts for all wafers to see what actually fits

All: Discuss options based on these layouts and investigation into a switch to Hex

Need to resolve reasonably soon: implications for module design, optical design could be large

NOTE: Here "Horn diameter" means pixel pitch vs. the horn aperture size, which will include some sidewall thickness

Rhombus layout pixel count possibilities

Number of Rings	Pixels/wafer	Horn diameter (mm)	Horn diameter (mm)	Used in
Active wafer area diameter		130.00	134.00	
2	12	30.20	31.10	SAT 30/40GHz
3	27	20.70	21.10	LAT 20GHz
4	48	15.70	16.10	LAT 30/40GHz
5	75	12.70	13.0	
6	108	10.60	10.90	
7	147	9.10	9.40	SAT 85/145, 95/155
8	192	8.00	8.20	
9	243	7.10	7.30	
10	300	6.40	6.60	
11	363	5.80	6.0	
12	432	5.30	5.50	LAT 90/150, 220/280
13	507	4.95	5.10	
14	588	4.60	4.70	
15	675	4.30	4.40	
16	768	4.00	4.15	
17	867	3.80	3.90	
18	972	3.60	3.70	
19	1083	3.40	3.50	
20	1200	3.20	3.30	
21	1323	3.05	3.15	

HCP layout pixel count possibilities

Pixels on side of hex	Pixels across diameter	Pixels/wafer	Horn diameter (mm)	Horn diameter (mm)	Used in
			130.00	134.00	
1	1	1	130.00	134.00	
2	3	7	43.33	44.67	
3	5	19	26.00	26.80	
4	7	37	18.57	19.14	
5	9	61	14.44	14.89	
6	11	91	11.82	12.18	
7	13	127	10.00	10.31	
8	15	169	8.67	8.93	
9	17	217	7.65	7.88	
10	19	271	6.84	7.05	
11	21	331	6.19	6.38	
12	23	397	5.65	5.83	
13	25	469	5.20	5.36	SAT 220/280
14	27	547	4.81	4.96	
15	29	631	4.48	4.62	
16	31	721	4.19	4.32	
17	33	817	3.94	4.06	
18	35	919	3.71	3.83	
19	37	1027	3.51	3.62	
20	39	1141	3.33	3.44	

Extras

Path to potentially deployable wafers and pre-production

- We need to resolve a few issues before we can make production layouts (will be discussed in parallel sessions):
  - Number of darks (and what are they)
  - Hex vs rhombus
  - Internal pixel layouts (documentation)
  - Bondpad locations, materials and frequency mapping
  - RF coupling design and interfaces to detectors
  - Readout and module design and interfaces
  - Anything else?

Preproduction	FY22A	FY22B
Site 1 = ANL	LAT MF	LAT MF
Site 2 = JPL	SAT MF	SAT HF
Site 3 = SEEQC	SAT MF	SAT LF
Site 4 = NIST	LAT MF	LAT HF
Site 5 = SLAC		
Site 6 = Marvell	SAT LF	LAT LF

LATs and SATs both expressed preference for MF first, but if it is easier to settle all these issues for other types we should think about getting them started

Detector Fabrication Plan cont.

- Each detector type will be fabricated by at least 2 sites
- Build on existing experience (NIST - SO, LAT MF, JPL - SATs, LBL and UCB support each other, SLAC will start production in FY25, etc)
- Assignment of detector types to fab sites allows focused R&D

Pixels/ wafer		Number Wafers
12	SAT 30/40GHz	28
27	LAT 20GHz	4
48	LAT 30/40GHz	25
147	SAT 85/145, 95/155	168
432	LAT 90/150	162
432	LAT HF	64
469	SAT 220/280	52
		503

Site 1 = ANL	Site 2 = JPL	Site 3 = SEEQC	Site 4 = NIST	Site 5 = SLAC	Site 6 = Marvell
	6	10			12
					4
		8			17
	84	84			
66			64	32	
20			44		
	16			36	
86	**106**	**102**	**108**	**68**	**33**

Draft Production Fabrication plan (v5)

- Rates and detector types discussed with each site and iterated.
- Production rates require minimum ramp-up in capabilities at all sites
- Additional capacity is possible at most sites, with appropriate warning
- Plan to reoptimize based on performance, cost and schedule at least annually

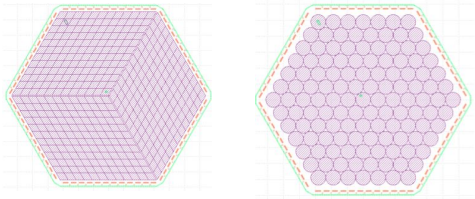
PRODUCTION		Split years into part A and B for transition to new detector type									
	FY23A	FY23B	FY24A	FY24B	FY25A	FY25B	FY26A	FY26B	FY27A	FY27B	Total
Site 1 = ANL	2	8	8	10	10	10	10	8	10	10	86
Site 2 = JPL	2	8	8	8	14	16	16	16	12	6	106
Site 3 = SEEQC	2	8	10	10	16	16	16	16	4	4	102
Site 4 = NIST	2	8	8	8	10	12	14	16	16	14	108
Site 5 = SLAC					8	12	16	11	11	10	68
Site 6 = Marvell	1	3	4	5	4	4	4	4	4		33
Total Science Grade	9	35	38	41	62	70	76	71	57	44	503
~ Number of wafer modules to test (inc. 12% overage and 67% yield)	15	59	64	69	104	117	127	119	95	74	841

Recent challenges: Matching wafer layouts to Fab. site expertise

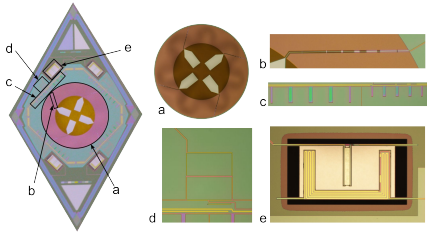
Fab sites have different equipment, experience and expertise

- Hex vs Rhombus layout
  - All sites could make Hex wafers (or square or rectangle)
  - Rhombus layout requires x3 more masks and lithography steps and stitching if sites do not have a stepper that can rotate
  - NIST, SLAC have equipment to do Rhombus, ANL is doing R&D for Rhombus layout with their existing equipment
  - LBL/Seeqc, Marvel and JPL prefer no crossovers and Hex layout
- Wiring Crossover/under and Mapping Freq. to bond pads:
  - Hex: bondpad pairs alternate frequencies, does not require crossovers: see Toki's talk (slide)
  - Rhombus: one freq per side, layout as implemented by NIST has lots of crossovers: see Shannon's talk (slides)
- RF structures internal to the pixel differ
  - Will need to document what was included in RF simulations (2D or 3D, coupling and horns) and what has been demonstrated for upcoming reviews
  - Size matters - some features may be too large for dense layouts
- Discussed with DSAC: supported allowing mix of approaches based on fab. site experience, but don't mix Hex and Rhombus in same wafer types. Different layouts for different bands seems fine.

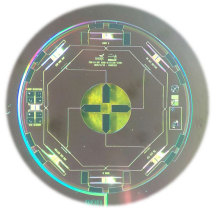
CDFG wafer layouts



NIST



LBL (Seeqc and UCB)



Detector Fabrication Plan Assumptions

- It is preferable to finish off detectors in integral units of cryostats (SAT and LAT)
  - integration and testing in the US
  - deployment after testing fully loaded cryostats
  - Preproduction modules could be used for some tests
- Plan (next page)
  - 1st SAT finished in FY24
  - SPLATR finished in first half of FY25
  - Assumes “sufficient” funding
- Many other distributions possible, this is just a start

Wafer type	Total Science Wafers	number per tube or cryostat
SAT 30/40GHz	28	14
SAT 85/145, 95/	168	28
SAT 220/280	52	13
SPLATR		
LAT 20GHz	4	4
LAT 30/40GHz	9	9
LAT 90/150	54	54
LAT HF	18	18
CHLATR		
LAT 30/40GHz	16	8
LAT 90/150	108	54
LAT HF	46	23