WBS 6.2.4
Strips Modules

G. Sciolla
Level-3 Manager & CAM
Brandeis University

U.S. ATLAS HL-LHC Upgrade Project Scrubbing Meeting
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Upton, NY
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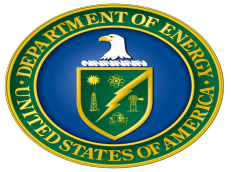
Outline

- Technical Details
  - Deliverable Overview, institutional responsibilities
  - Technical Progress since FY19
  - Pending Issues
  - Plans for pre-production
  - Plans for production
- Schedule and Cost
  - How has the schedule changed since CD-3a?
  - How as cost changed since CD-3a
- Risk and Uncertainty
- Closing Remarks



Technical Details

WBS Dictionary Description

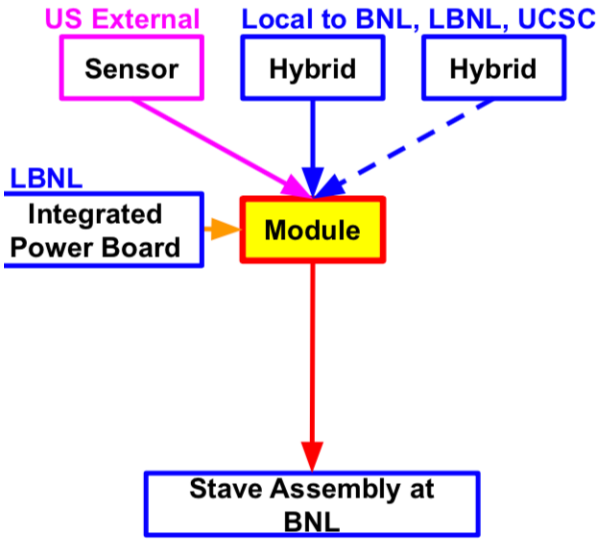
WBS Dictionary Definition:

This WBS refers to the **fabrication of hybrids and modules for the barrel** part of the ITk silicon strip tracker. A **hybrid is a flex circuit with passive components, carrying** a controller chip, the **HCCstar** (6.2.2.3.2, 6.2.2.4.2) and **10** front end readout chips, the **ABCstar** (6.2.2.3.1, 6.2.2.4.1).
Hybrids are mounted on **modules**, which is **the basic unit of the strip detector**. The module contains a **sensor** which is divided into either **four (short strip or SS) and two (long strip or LS) longitudinal segments** and has **1280 readout strips/segment** with a **75 um pitch**. Each module is approximately **100 mm x 100 mm.** The strip sensors are read out with electronics mounted on the hybrids. There is(are) **one (two) hybrid(s) on the long(short) strip version of the module**. A third(second) circuit board, the **PowerBoard** (6.2.2.X), is affixed to the sensor to **provide regulated power and services to the readout hybrids**. The modules are mounted on to stave cores (6.2.1). Each loaded stave (6.2.5) consisting of 14 modules on each side. The ITk barrel detector has 392 staves configured in 4 readout layers, requiring 10,976 modules and 14,784 hybrids. **The US will deliver 196 staves, which require 5,488 modules and 7,392 hybrids.**

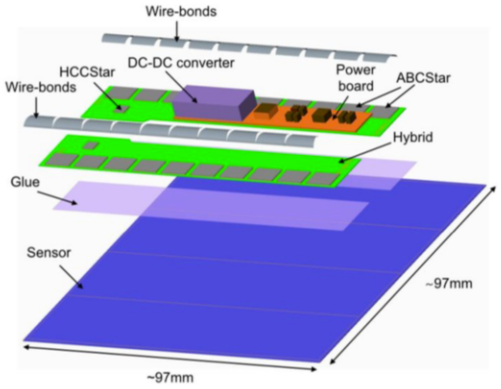
There will be **three module/hybrid production sites in the U.S.**, each doing an equal share of the production. The sites will be **BNL, LBNL and UCSC**. At each site, **hybrids and modules will be assembled following an identical process of parts loading and wire bonding.** Each module will then be **electrically tested**. The module **passing QA/QC criteria will be shipped to BNL** where they will be mounted on stave cores.

Hybrids started	Hybrids finished and working	Modules started	Modules finished and working	Staves to assemble at BNL	US staves completed
9119	8499	6310	5762	206	196
	Hybrid inverse yield		Module inverse yield		Stave inverse yield
	1.073		1.095		1.051

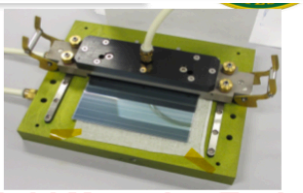
ITk Strips Module Comonents



- 2560 or 5120 active element silicon strip Sensor
  - external deliverable
- 1 or 2 Hybrids glued to the surface of Sensor
  - same Hybrid assembly site as Module
  - 2560 or 5120 wire bonds needed to Sensor
- 1 Integrated Power Board glued to the surface of Sensor
  - IPB assembled at LBNL
  - Minor amount of wire bonds to Hybrid(s)
- All Modules delivered to Stave Assembly at BNL

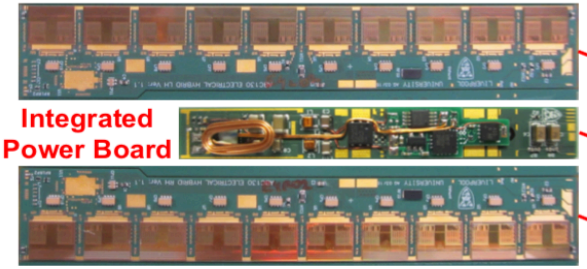


ITk Module



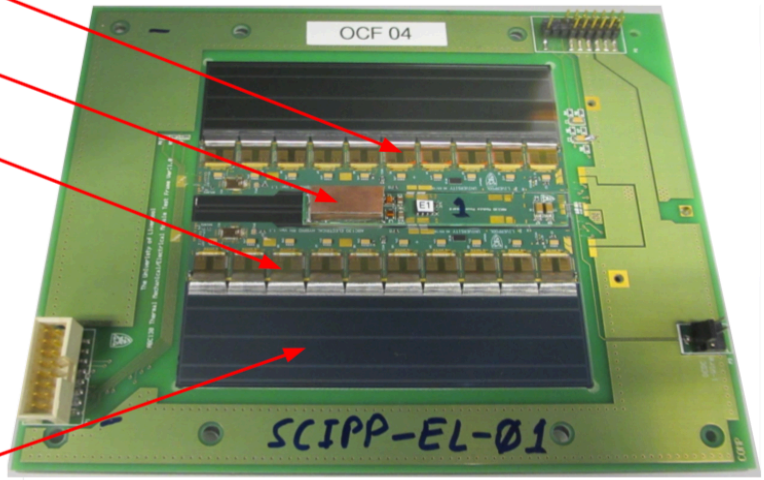
Hybrid Mounting Tool

Left Handed Hybrid

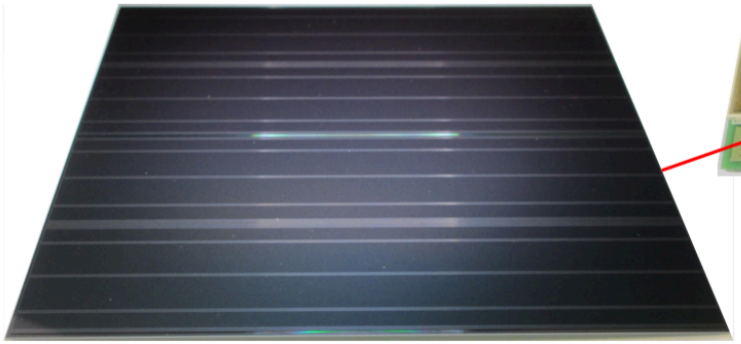


Integrated Power Board

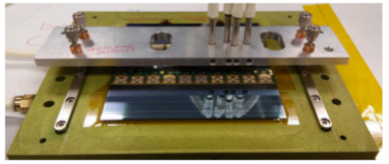
Right Handed Hybrid



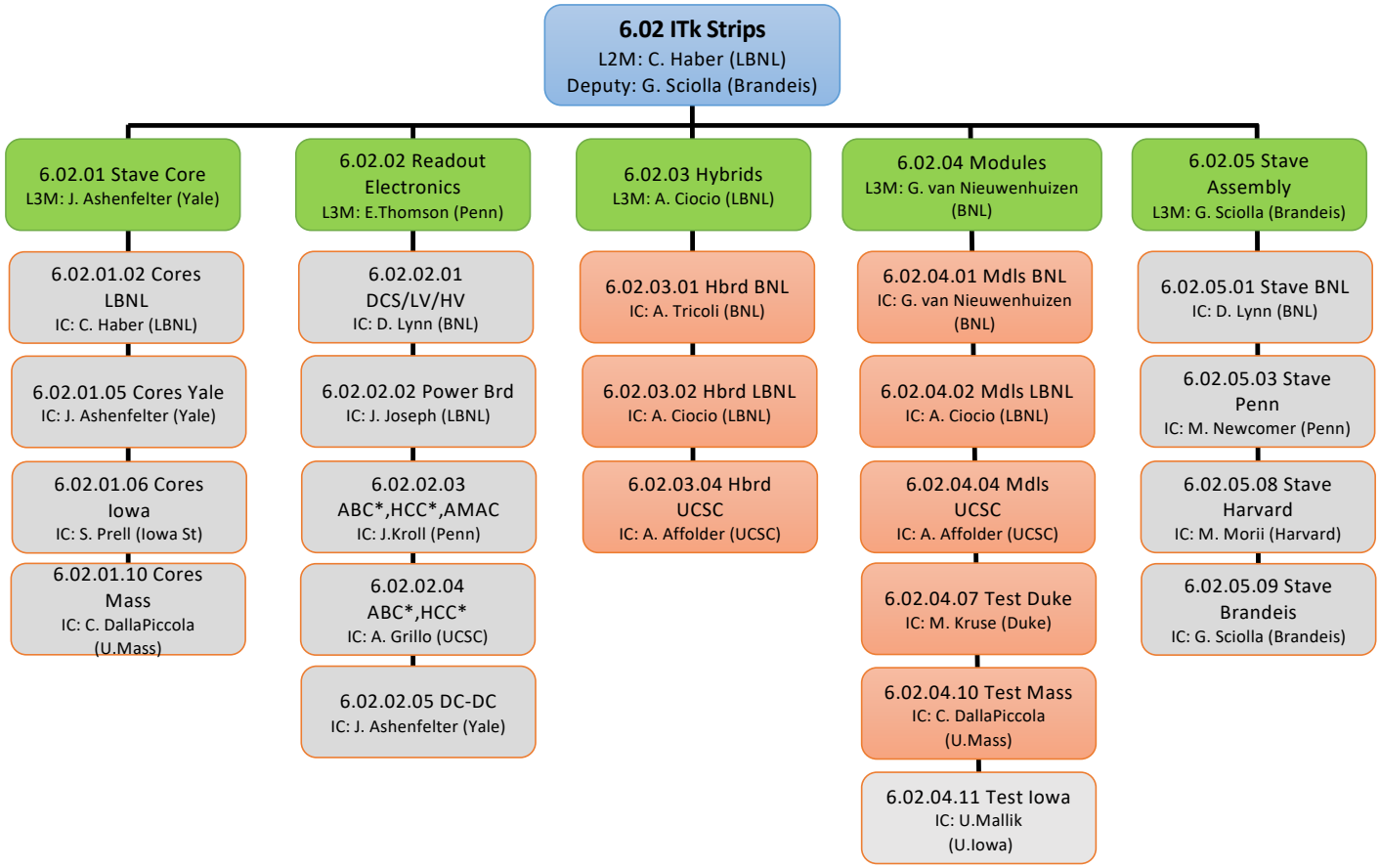
Assembled Module in Test Frame



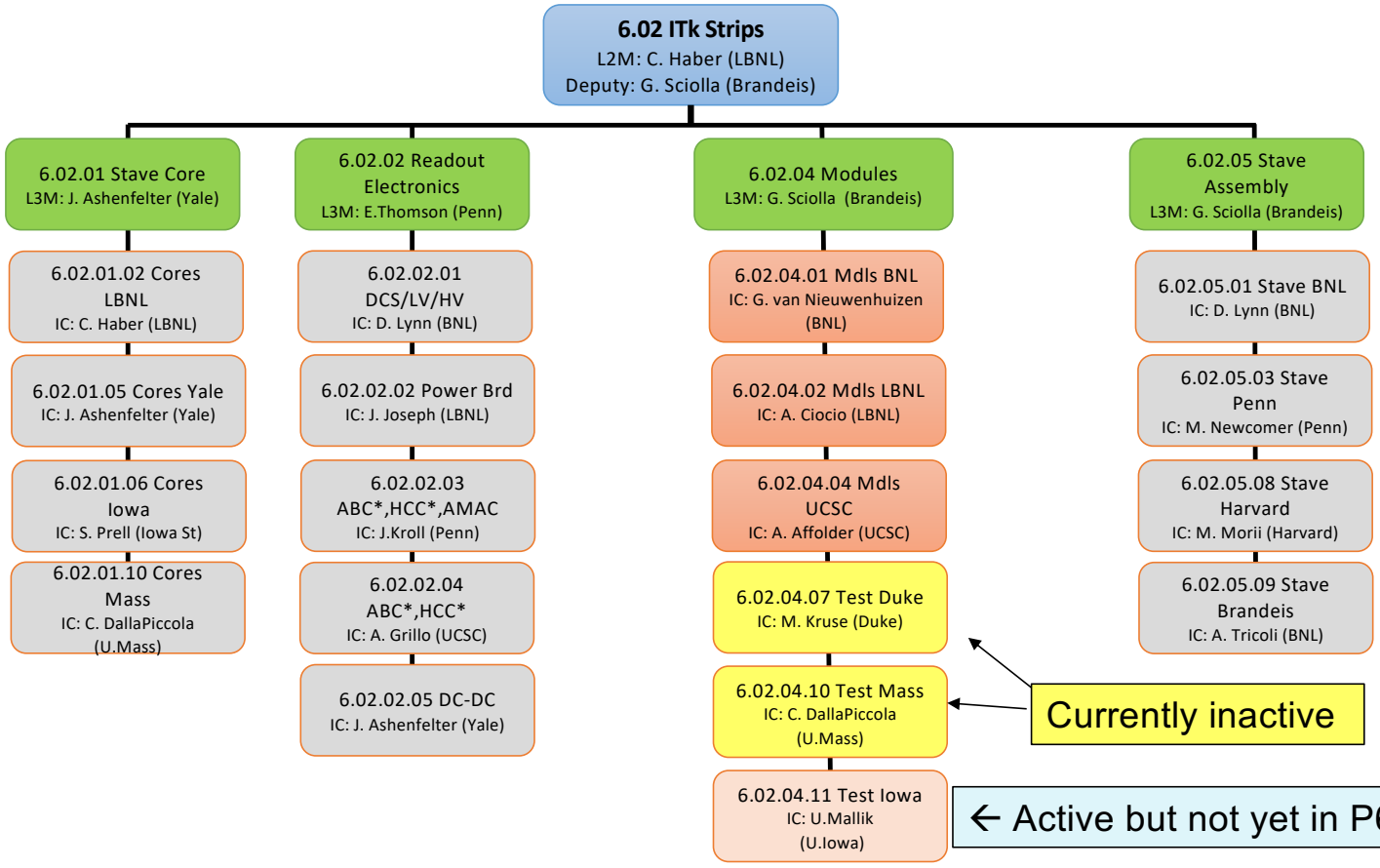
Silicon Strip Sensor



US Organization at L4 @ CD3A



US Organization at L4 Now



Technical Progress & Plans

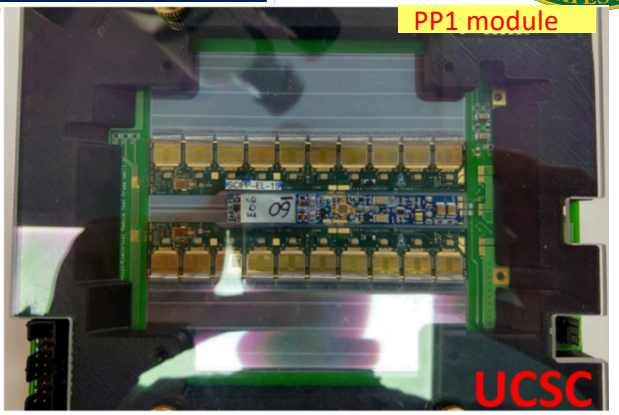
Modules: Recent History

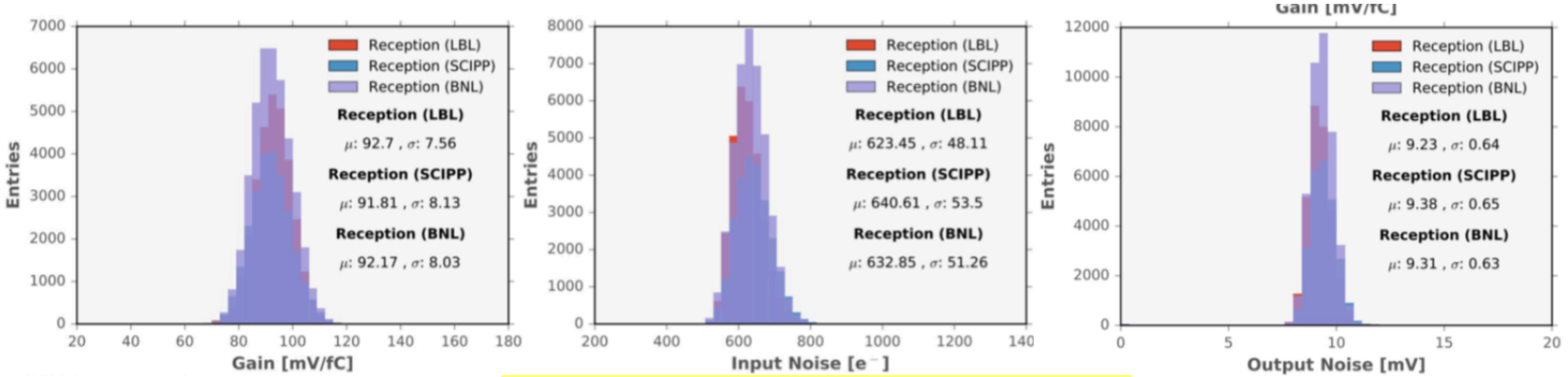
- ✓ FY17-2018: TM prototype: 1 stave with 26 SS modules
  - Assembled 60 Thermo-Mechanical Hybrids → 30 Thermo-Mechanical Modules, 10/site
- ✓ FY18: Electrical prototype: 1 stave with 3 SS electrical modules
  - Assembled 6 Thermo-Mechanical Hybrids → 3 Thermo-Mechanical Modules (1/site)
  - New: first electrical modules built in the US
- ✓ FY18-19: Preproduction 1: 2 one-sided electrical staves, 13 SS modules each
  - ABC130 chipset, 13-module bus tape design
  - About 20 hybrids/site and 10 modules/site
- FY19-20: Preproduction 2: 2 double-sided staves, 28 LS modules each
  - New: First use of Star chipset and first LS modules built in the US
  - ✓ Stave 1: completed and used for the Module Mounting FDR -- very successful for US group!
  - Stave 2: in progress

Module Recent History: results

TM modules used to validate thermo-mechanical model of the ITk staves

PP1 module



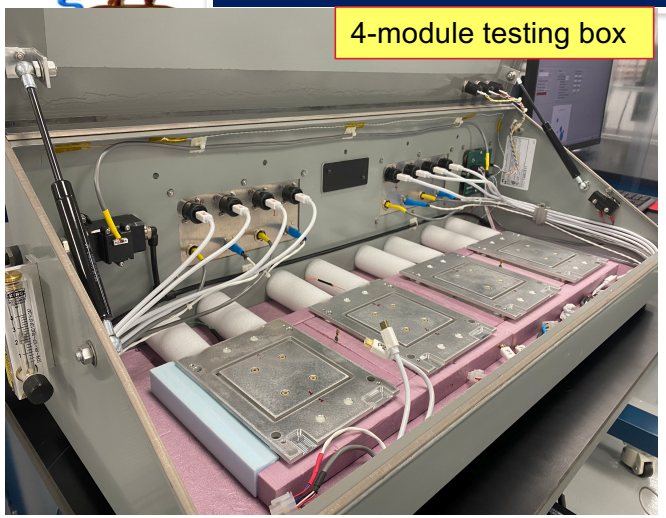


Results of PP1 module standard testing within specs and consistent between the 3 sites

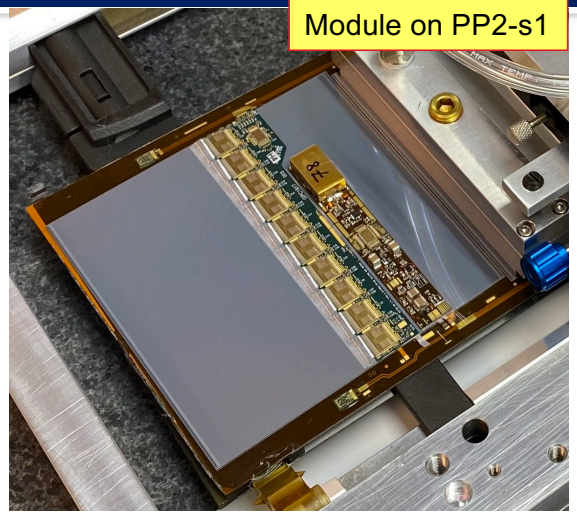
Most recent results: PP2 stave 1

FY19

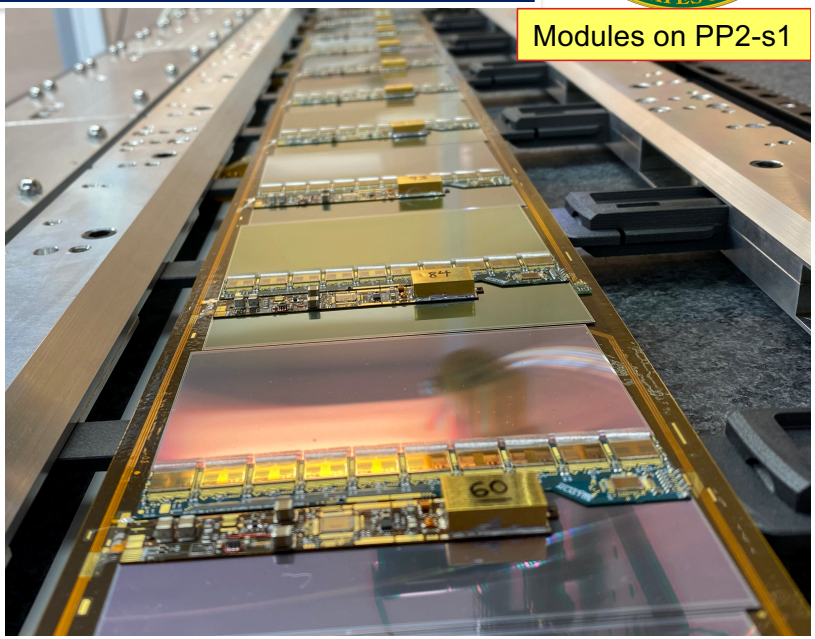
4-module testing box

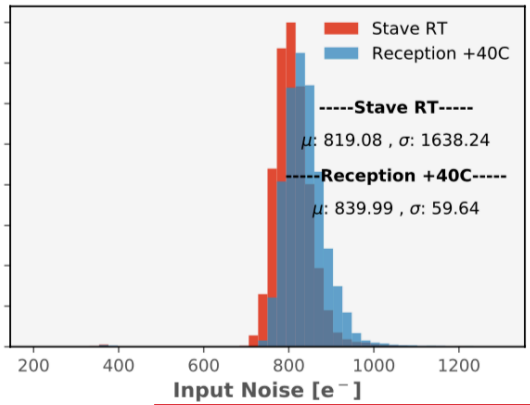


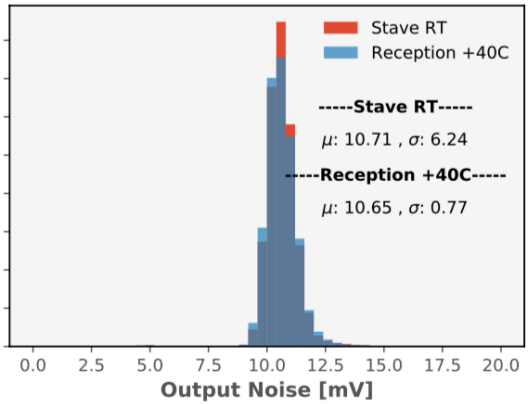
Module on PP2-s1



Modules on PP2-s1







Comparison of noise measured on modules off/on staves

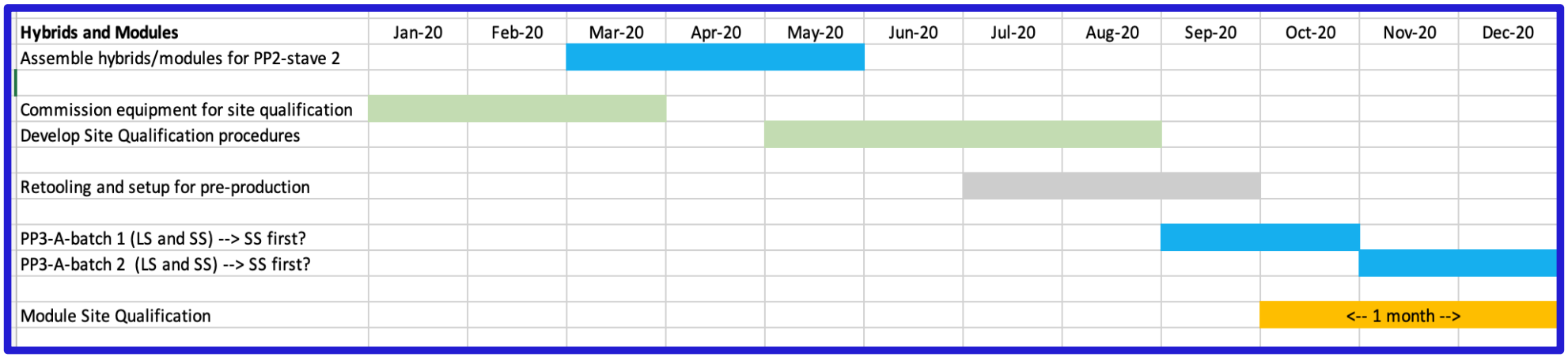
Modules: Present and Near Future

FY19

- FY19-20: Preproduction 2: 2 full 28-module LS staves
  - ✓ Stave 1: completed
  - ✓ Stave 2: in progress (FY20 Q2-3)
    - Build 10 hybrids and modules/site
    - Parts are scarce: use them to prep for Site Qualification
- FY20-21: Preproduction 3: 9 full 28-module LS/SS staves
  - PP3-A – 2 LS staves – Fall 2020
    - ~20 Hybrids + Modules /site
    - Use Preproduction ABCstar and Prototype HCC/AMAC chips
    - Used for Hybrids/Module and SA Site Qualification
  - PP3-B – 3 SS staves + 4 LS staves – FY21 Q2-4
    - SS: 60 Hybrids/site → 30 SS Modules /site
    - LS: 77 Hybrids/site → 71 LS Modules /site
    - Use Preproduction ABCstar, HCC, AMAC chips
    - These modules will be used for PRR, CERN System Test and Production Ramp-up
- Production: Jul 2021 – Dec 2024 consistent with international ATLAS schedule

Hybrids and Modules Site Qualification Schedule

- 3 sites, each building equal amounts of hybrids and modules
- Assuming Site Qualification needs an in-person visit, we planned for each site to pass Site Qualification for hybrids and modules at once
- We expect all 3 sites to be ready ~ same time and to qualify on Preproduction-A hybrids/modules



NB: all sites will build both SS and LS modules during site qualification

Schedule and Cost

Schedule Evolution since CD3A

- Successfully completed PP1 achieving planned goals
  - Two half staves of which one is being used in RAL system test
- PP2 stave 1 (including modules and hybrids) was a success!
  - Allowed us to develop near-final tooling for hybrid/module assembly
  - Refined assembly procedures
  - Refined testing procedures
  - Tested star chips both in modules AND STAVE!
- Substantial change in schedule in FY20-21 due to ASICs delay
  - Original schedule:
    - PP2 end in Spring 2020; PP3 2020-3/2021; Production: Mar 2021-Jul 2024
  - Current schedule:
    - Use PP2 stave 2 to develop Site Qualification procedure in Spring/Summer 2020
    - Use PP3A to exercise Site Qualification procedures and pass it in Fall 2020
    - PP3B: Jan-Sep 2021
    - Production in Oct 2021 – Dec 2024

Overall, 5 mo delay…

Simplified Schedule – Modules

Schedule at CD3A

WBS	Deliverable Task	FY 17				FY 18				FY 19				FY 20				FY 21				FY 22				FY 23				FY 24				FY 25		
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
	RED=Critical Path																																			
6.2.4	**Modules**																																			
	prototypes																																			
	PP1																																			
	PP2																																			
	PP3																																			
	Production																																			
	Need at CERN																												X							

Schedule now in P6

WBS	Deliverable Task	FY 17				FY 18				FY 19				FY 20				FY 21				FY 22				FY 23				FY 24				FY 25		
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
	RED=Critical Path																																			
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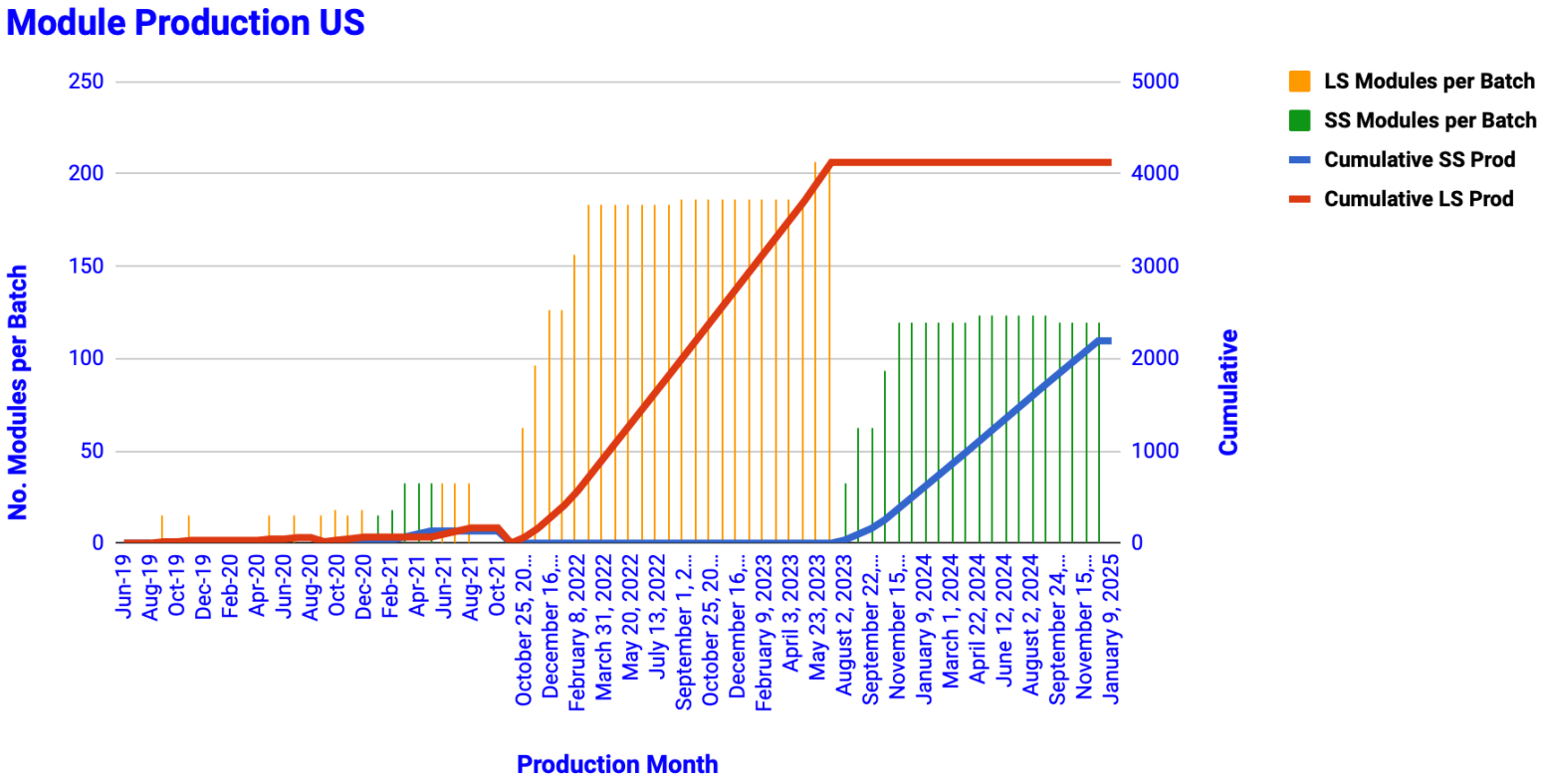
	prototypes																																			
	PP1																																			
	PP2																																			
	PP3																																			
	Production																																			
	Need at CERN																																		?	

We are here

Module Production Schedule



Dependencies

- Internal Dependencies for Hybrids/Modules
  - HCC star from Penn (+4-7m)
  - Powerboards from LBNL (+4-7m due to AMAC delay)

- External dependencies for Hybrids/Modules
  - ABC star from the UK (+2-3m)
  - Sensors from HPK (via UCSC)
  - Hybrids (including passive components) from the UK (via LBNL)

- Important:
  - Module availability is driving the overall Strips schedule in the 3 years of production
  - Any further delay in HCC/AMAC will translate in a delay in the completion of this project

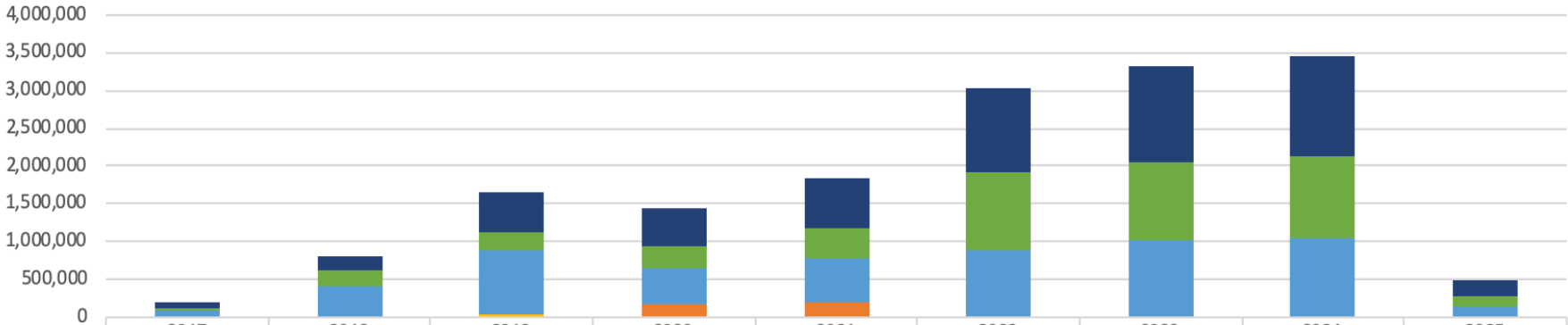
Milestones for Modules

- List of Milestones for this L3

Milestone	Date after BCP31	Date at CD3A	Comments
FDR	**Sep 2019 (passed)**		
End of PP2	Summer 2020	FY20-Q1	Extended to prepare for Site Qualification
End of PP3A	Dec 2020	NA	PP3 was supposed to be all PP3B
Site Qualification	Fall 2020	NA	Not considered as a milestone at CD3A
End of PP3B	Aug 2021	FY21-Q2	
PRR	Sep 2021 ?		Need to wait for feedback from CERN system test
Start of Production	**Oct 2021**	**FY21-Q3**	**Late start waiting for AMAC/HCCstar**
End of Production	**Dec 2024**	**Jul FY24**	**+5 m**

Cost profile

New



	2017	2018	2019	2020	2021	2022	2023	2024	2025
6.02.04.01 Modules-BNL	65,981	177,133	522,125	513,576	644,715	1,124,304	1,272,353	1,338,905	212,181
6.02.04.02 Modules-LBNL	29,998	212,357	242,174	300,064	405,147	1,018,219	1,022,896	1,063,474	131,464
6.02.04.04 Modules-UCSC	97,624	414,116	836,288	466,304	576,253	895,917	1,018,594	1,057,209	142,335
6.02.04.07 Modules-Duke			49,820						
6.02.04.31 Modules-BNL - CD-3a					16,741				
6.02.04.32 Modules-LBNL - CD-3a				171,510	162,793				
6.02.04.34 Modules-UCSC - CD-3a					23,110				

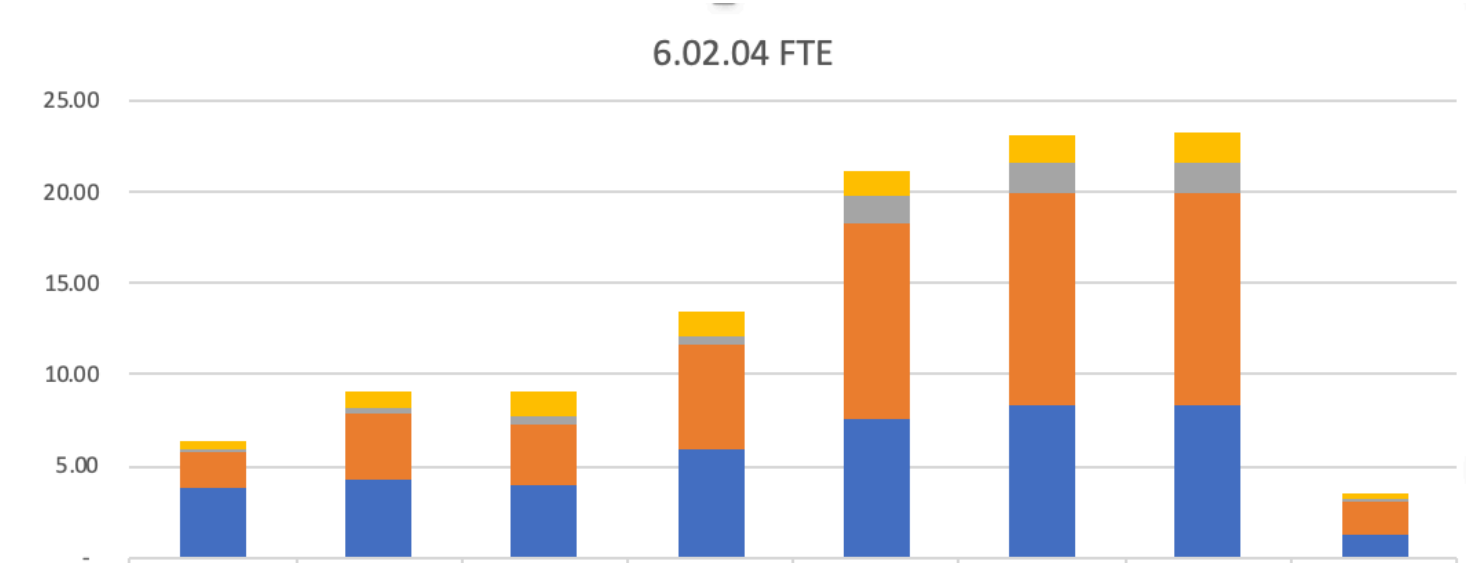
Cost Profile (2)

New

Sum of Value	Column La							
Row Labels	6.02.04.34 Modules- UCSC - CD-3a	6.02.04.32 Modules- LBNL - CD-3a	6.02.04.31 Modules- BNL - CD-3a	6.02.04.07 Modules- Duke	6.02.04.04 Modules- UCSC	6.02.04.02 Modules- LBNL	6.02.04.01 Modules- BNL	Grand Total
2017					97,624	29,998	65,981	193,603
2018					414,116	212,357	177,133	803,606
2019				49,820	836,288	242,174	522,125	1,650,407
2020		171,510			466,304	300,064	513,576	1,451,453
2021	23,110	162,793	16,741		576,253	405,147	644,715	1,828,759
2022					895,917	1,018,219	1,124,304	3,038,439
2023					1,018,594	1,022,896	1,272,353	3,313,843
2024					1,057,209	1,063,474	1,338,905	3,459,588
2025					142,335	131,464	212,181	485,979
Grand Total	23,110	334,302	16,741	49,820	5,504,640	4,425,793	5,871,272	16,225,678

FTE vs Time

New



	2018	2019	2020	2021	2022	2023	2024	2025
ENG	0.46	0.92	1.22	1.42	1.43	1.56	1.57	0.24
STU	0.22	0.32	0.48	0.38	1.51	1.61	1.66	0.25
TECH	1.85	3.57	3.43	5.86	10.62	11.57	11.62	1.75
UNCOST	3.87	4.30	3.88	5.84	7.60	8.39	8.38	1.27

FTE vs Time

New

Sum of Value	Column La				
Row Labels	UNCOST	TECH	STU	ENG	Grand Total
2018	3.87	1.85	0.22	0.46	6.40
2019	4.30	3.57	0.32	0.92	9.11
2020	3.88	3.43	0.48	1.22	9.02
2021	5.84	5.86	0.38	1.42	13.51
2022	7.60	10.62	1.51	1.43	21.15
2023	8.39	11.57	1.61	1.56	23.13
2024	8.38	11.62	1.66	1.57	23.23
2025	1.27	1.75	0.25	0.24	3.51
Grand Total	43.54	50.26	6.43	8.80	109.04

RLS changes and BCP description

BCP19 – Merge Hybrids and Modules in PP3 and Production

- Merge Hybrids and Modules WBSs for PP3 3 and Production
- Move first two payments to the UK for hybrid panels closer to start of production
- Replace some technical manpower at LBNL with a post-bac in PP3 and Production

BCP22 – Introduced 2m delay due to ASICS + Merge Hybrids and Modules in PP2

- Hybrids → Modules -428k$ -- tasks for FY20
- Escalation due to ASICs delay (2mo): +70k$

BCP24 - Essential equipment at BNL and UCSC

- Pull Tester (49k$) + Smart Scope (86k$) @ BNL for site qualification
- Added equipment ($20k) and manpower ($12k) to UCSC to test sensors

BCP 25 – Introduced 5 mo delay in ASICS

- Escalation due to 5m delay in ASICs

BCP 28 – Mitigate 5m delay from BCP 25, add site qualification tasks, implement PP3A/B

- +170k$ due to additional work related to site qualification
- -18k$ moved to CERN Payments

BCP31 – Mainly changes in cores

- LBNL: conversion of manpower between two categories and more uniform distribution of manpower over FY20 (~cost neutral)

Hybrids/Modules Cost Evolution

WBS	CD3A	BCP-19	BCP-22	BCP-24	BCP-25	BCP-27	BCP-28	BCP-31	Cost Now	Delta wrt CD3A	% change
6.2.3 Hybrids	$ 6,626,336	$ (4,883,140)	(427,825)	-	-	$ -	$ 0	$ 0	$ 1,315,371	$ (5,310,965)	-80.1
6.2.4 Modules	$ 10,402,351	$ 4,867,430	495,331	167,894	136,039	$ -	$ 152,860	$ 3,811	$ 16,225,716	$ 5,823,365	56.0
Hybrids+Module	$ 17,028,687	$ (15,710)	$ 67,506	$ 167,894	$ 136,039	$ -	$ 152,860	$ 3,811	$ 17,541,087	$ 512,400	3.0

Comments

- Lots of changes to reduce management effort of Hybrids/Modules
- Some increase in actual costs but "only" 3% of entire WBS
  - Considering schedule delay introduced by ASICS, almost consistent with escalation

Risk and Uncertainty

Risk Overview

- Risks in current registry in Black, Changes/New Risks in Red

Risk ID	Title	Risk Rank	Phase	In RR?
RD-06-02-04-001	Lower than expected throughput in module wirebonding	70	Production	Yes
RD-06-02-04-002	Electrical performance of modules	140	Production	Yes
RD-06-02-04-003	Modules are damaged during shipping	140	Pre-Prod. III to Prod.	Yes
RD-06-02-04-004	Delay in sensor shipments	140	Production	Yes
RD-06-02-05-005	Loss of key personnel	60	Now to Prod.	Yes
RD-06-02-04-006	Delay in site qualification		Prod.	No
RD-06-02-04-007	Hybrids are delayed from non-US vendor	140	Now to Production	Yes
RD-06-02-04-008	Problems in wirebonding of hybrids	140	Now to Prod.	yes
RD-06-02-04-009	Problem with UV cure adhesives used in hybrid assembly when applied as a high throughput process	60	Production	Yes

- Not implemented in Risk Register yet, but changes are minor. Will send an email to George.
- The only new risk (Delay in Site Qualification) is getting better; no change for the rest
- One risk may be missing: delays from ABCstar but it may be in RE – check with Evelyn

G. Sciolla

Closing Remarks

- Technical progress is on track
  - No major surprises, everything is progressing as expected
  - Next major challenge: Site Qualification
- Major gain in restructuring Hybrids/Modules WBS
  - Less administrative burden allows to free up critical manpower and speed up progress in the lab
- Tried to contain effects of ASICs delays (+ ~7 months since CD3a)
  - Cost increase has been contained: +3%
  - Schedule:
    - Schedule slipped by 5 months
      - End of production: July 2024 → Dec 2024
    - There is little we can do – we already maximized our production yields
      - Optimized PP3 (PP3-A/B) to move forward with site qualification even if preprod HCC/AMACs are late
      - Ramped up production in PP3 as much as reasonably possible

BACKUP

Be sure to include, at least, the following

Bio Sketch of L3 Manager

Gabriella Sciolla, Professor of Physics, Brandeis University

- Member of ATLAS since 2011
- ITK responsibilities
  - US ATLAS L2 Strips Deputy
  - L3 Manager for Strips Modules (5.2.4), 2019-present
  - L3 Manager for Strips stave assembly (5.2.5), 2017-2019
  - Group heavily involved on stave assembly and module testing at BNL
- Other ATLAS roles
  - Muon Combined Performance Convener (2014-2016)
  - US Physics Advisor (2013-present)
- Selected committee activity:
  - HEPAP, Fermilab PAC, SNOLab Board of Directors, SNOLab Science and Technical Review Committee, R&D BNR, CPAD
- Previous experiments: DELPHI, BaBar, DMTPC

Institute Capabilities

Institute	Senior Members	Past Experience Relevant to this Deliverable
BNL	D. Lynn	STAR Silicon Drift Detector, Former ITk local support activity coordinator, ITk HVMux leader, Strips R&D, ATLAS ITk since 2008
	G. van Nieuwenhuizen	WA98 Silicon Drift Detectors, PHOBOS Silicon Detectors, STAR Intermediate Silicon Tracker, ATLAS ITk since 2015
	A. Tricoli	ATLAS SCT assembly and testing, ATLAS ITk since 2015
LBNL	A. Ciocio	ATLAS Silicon Detectors, SCT production QC, Commissioning, Ops, in ITk since 2015
UCSC	A. Affolder	CMS and LHCb Silicon detectors, ATLAS ITk Strip Project Leader since 2017, ATLAS ITk since 2007
	V. Fadeyev	ATLAS SCT construction, ATLAS Strip sensors activity coordinator, ATLAS ITk since 2012
Duke	M. Kruse	ATLAS SCT and ITk DAQ systems, ATLAS ITk since 2011
U.Mass	C. Dallapiccola	Silicon testing systems, ATLAS ITk since 2017
U. Iowa	U. Mallik	ATLAS Silicon Pixel detector, ATLAS ITk since 2019

GS Backup

Hybrids

- The hybrid is a flex multilayer circuit of polyimide dielectrics with multiple copper layers of thickness of 18 µm, plated up to 36 µm
- Dimensions: 97.5mm (l) 15.5mm (w) 300 µm(thick)
- Populated with passive components and ASICs
- Interfaces to a sensor and to the bus tapes
- All barrel hybrids are electrically equal and carry:
  - 1 HCCstar (controller) chip and 10 ABCstar (FE) chips (WBS 6.2.2)
- ABCstar ASICs (external) and HCCstar ASICs (internal US) are glued on the PCB using UV cured glue, wire-bonded to test before using the hybrid on a module
- Hybrids which are found electrically and mechanically within specs are "delivered" to the same institute that assembles them to be mounted on the sensor to make a module (WBS 6.2.4)