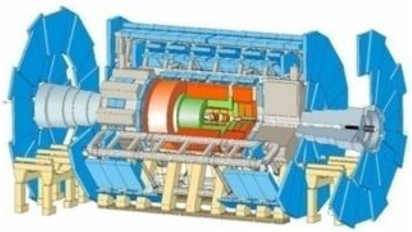
IHEP



ATLAS

Info. for IHEP Production Plan for 5k HGTD Modules

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IHEP HGTD one-day workshop

22/Aug./2019

Introduction

Basic content for HGTD module production plan:

1. Focus on the production process from bump bonding to module assembly
2. To collect (not develop) and well understand on each production step's technical details, know very clearly about qualification of quality and responsible manpower
3. Survey all necessary devices and workspace availability for the production
4. Based upon some real tests to correctly estimate production(test) time for each production step, so that can make a feasible plan for the whole HGTD module production scope, know well about difficulties and risks, and think related solutions.

Current Rough Layout (waiting to be in more details)

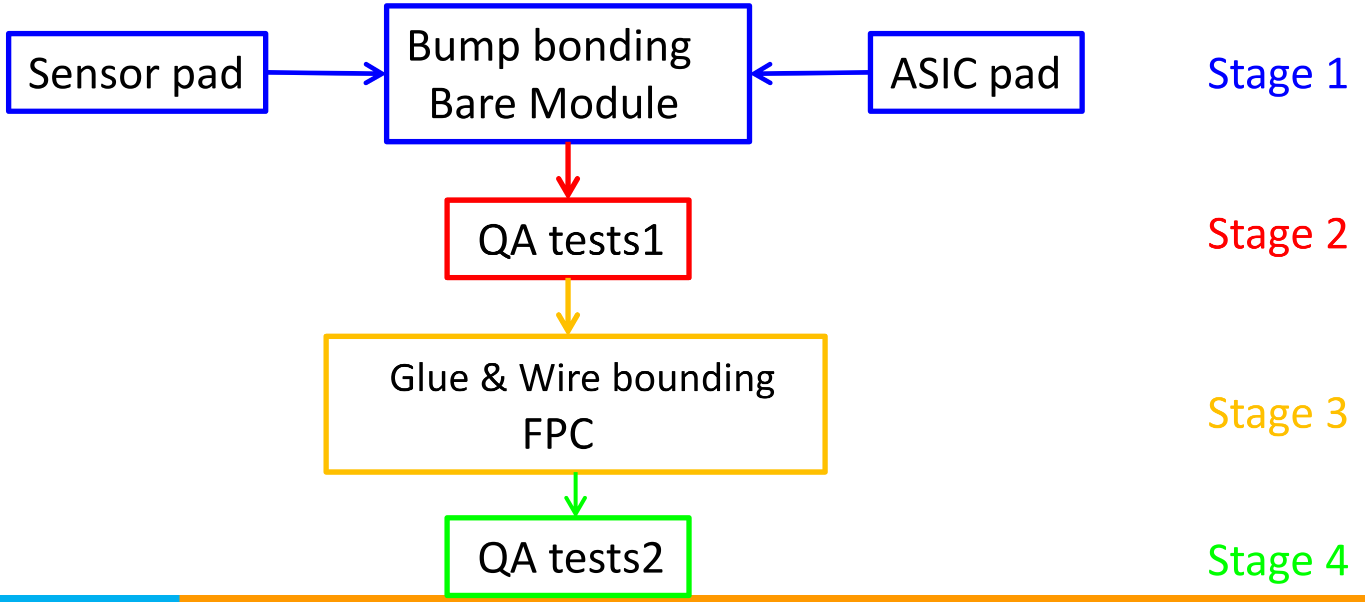
1. **A bare module assembly:** made by sensor, ASIC, and bump bonding foundry
   x-ray inspection also by the foundry or another company
   Zhijun. fabrication time **~1 month**

2. **Shear force** test locally (Dage-4000): **Zhijun**, test time ?

3. **Thermal cycling** test: **Feng LYU**, test time ?

4. **Electronical connection** test: **Shuo**, test time?

5. **FPC** design R & D: **Mingyi**, fabrication & test time ? …… …….



General production(including tests) speed estimation

Assuming to finish 5k (1/2 of 10k total) modules in 1.5 years:

There are 1.5* (365 day – 104 weekend -11 festival) =1.5*250days= **375 days**

Considering 80% time for production and test scheduled time, leave **20%** time to compensate any accident and delay. (extreme case we also can use weekends~**40%**)

So module number averagely finished(including assembly and tests) per day:
5000/(375*0.8) = 5000/300 = **16.7 modules/day** or **17.9 modules/day** (**10711** modules)

~17 models/day, very ambitious/tough goal !

New (reduced) baseline is 10.7MCHF (including 1 MCHF for TDAQ). It assumes:
- 5% pre-production for most components (all good to be used in the detector)
- 2 modules per HV line (instead of 1)
- A production model for modules production ,sensors, asics leading to a produced amount of modules = 10711 (instead of 12000 assumed in the TDR draft 1)
- If 12000 modules were considered and 1HV channel/module HGTD Core would increase by 1MCHF. From 08/April/2019 3-Day HGTD Meeting Introduction A. Henriques, L. Serin

From 3-Day HGTD Meeting Introduction A. Henriques, L. Serin 08/April

New Core costs table baseline for TDR

PBS/WBS	HGTD Deliverable	TDR Cost (KCHF)	TP cost	(TDR-TP) KCHF	Cost TDR/TP	Nominal Quantity (NQ)	Purchased Q (NP)	NQ/NP	prod model
8.1	**Sensors**	**2275**	**1700**	**575**	1,3	7 984	10790	**1,35**	**7984/.74+0% pre-prod**
8.2	**Electronics**	**3199**	**2744**	**455**	1,2				
8.2.1	ASIC	833	730	**103**	1,1	15 968	26950	**1,69**	**2x10790/.80 +0% pre-p**
8.2.2	Peripheral Electronics cards	767	717	**50**	1,1	160	180	**1,13**	
8.2.3	High Voltage power supplies ; crates	532	897	**-365**	0,6	84 ;	88;	**1,05**	
8.2.4	LV in US15 ; DCDC(300->10V) ;crates	299	400	**-101**	0,7	14; 28 ; 4	16;32 ; 4	**1,14 ; 1,14**	
8.3	**Luminosity/TDAQ**	**395**	**280**	**115**	1,4				
8.3.1	Luminosity boards	315	200	**115**	1,6	20	21	**1,05**	
8.3.2	DCS and Interlocks	80	80	**0**	1,0				
8.4	**Module assembly and staves Loading**	**1483**	**1500**	**-17**	1,0				
8.4.1	Bump-bonding ASIC/Sensor	450	900	**-450**	0,5	7984	10790	**1,35**	
8.4.2	Flex cables	547	400	**147**	1,4	7984	10790	**1,35**	
8.4.3	Modules assembly	386	100	**286**	3,9	7984	10790	**1,35**	
8.4.4	Modules loading on staves/plates	100	100	**0**	1,0				
8.5	**Mechanics, Services and Infrastructure**	**2264**	**1305**	**959**	1,7				
8.5.1	HGTD hermetic vessel	160	150	**10**	1,1	1	1	**1,00**	
8.5.2	Moderator	0	0	**0**		4	4	**1,00**	
8.5.3	On detector cooling/support plate	180	155	**25**	1,2	8	8	**1,00**	
8.5.4	CO2 +water Cooling + Nitrogen systems	1237	450	**787**	2,7				
8.5.5	Tools for assembly and installation	100	100	**0**	1,0				
8.5.6	Services (cables,fibers,connectors,..)	526	450	**76**	1,2				
8.5.7	Patch panel boxes	61	50	**11**	1,2				
8.6	**Detector Assembly and QA on surface**	**100**	**0**	**100**					
8.6.1	Test bench for detector certification	100							
HGTD TOTAL		**9716**	**7529**	2187	1,3				
(*) TDAQ total		**995**	970	25	1,0				
HGTD+TDAQ		**10711**	8499	2212	1,3				

Module assembly total cost 1383 kCHF, ~9.5M yuan 1/7 relative to HGTD TOTAL

exchange rates to be used for HGTD TD
1 Euro=1.085 CHF
1 USD =0.986
Japanese Yen [100 JPY]=0.942
Chinese Yuan [CNY]=0.1461

1CHF=6.845 Yuan

Now: 1CHF=7.1813 Yuan, -4.9%

HGTD TOTAL 66.51M Yuan

HGTD Intro 08/04/19 7

1/2Module production cost ~5M yuan

Content of HGTD Module production

Distilled by Kevin on 08/April/2019:

Need to develop a much more detailed production plan for the ~10K modules needed - bottom-up time to assemble and test modules => number of assembly and testing sites => how much time and manpower is required to build and test ~10K modules ? Historically, the testing development is complex and requires significant specialized hardware, and the time required in production for testing is significantly underestimated.

HGTD TDR(ATL-COM-UPGRADE-2019-003): Sec.7 Module Assembly and Loading:

A HGTD **module assembly**, consists of **a sensor bump-bonded** to **two readout chips** which are in turn connected to a **flexible printed circuit** (**FPC, flex cable**) for communication, power distribution and data output. The flex cable also provides high voltage for the silicon sensor. Modules quality assurance (**QA**) by various control tests are necessary.

Module Production == module assembly + module QA
Module assembly == Bare module assembly (1 15x30 sensor + 2 15x15 ASIC **bump-bonding/** hybridization process + chip QA) and to **be connected** on **FPC**
Module QA == various **tests and inspections** at each quality control step/stage

So far, not considering to include stave loading in the module production

Bare module assembly TIME TAKING (short)

A bare module assembly: made by sensor, ASIC, and bump bonding foundry, how long a bare module assembly finish averagely? **~1 month**, **Zhijun**

- **A LGAD sensor** has a total size of 20.0mm x 39.5mm, with an array matrix of 15 x 30 1.3mm x 1.3mm pads,produced in 150mm wafers, current baseline: active and total thickness is 50 μm and 300 μm. After under-bump metalization (**UBM**) the wafers will be diced and the selected sensors will be destined for hybridization.
- **An ALTIROC ASIC** has a total size of 21.7mm x 19.9mm and a matrix of 15x15 channels, produced in 200mm wafers with current baseline thickness is 300 μm. The chips will be probed to identify the good dies. This will be followed by **UBM** and **solder bump deposition**
- **A bump-bonding (hybridization process):** an LGAD sensor interconnected through solder bumps to two ALTIROC front-end chips. The **flip-chip process** is the final step in the hybridization procedure.
- The baseline bump-bonding technology for HGTD relies on **solder bumps**.. Inspection of the bare assemblies with a high resolution (sub-micron) **x-ray machine** to discard devices with disconnected pad bumps

More specification pls see HGTD TDR (ATL-COM-UPGRADE-2019-003)

Bare module assembly related info.

From **Zhijun**

Two company identified for **bump bonding**（both are top 10 packaging company)

1. Tianshui Huatian Technology Co., LTD (天水华天科技， TSHT, China，甘肃天水市)
   http://en.tshtkj.com/index.html, 半导体集成电路封装测试业务，销售电话：0938-8299022
2. The National Center for Advanced Packaging (华进，NCAP China，江苏无锡)
   http://www.ncap-cn.com/en/index.aspx，华进半导体封装先导技术研发中心有限公司电话：0510-66679336

NCAP： Two ASIC（ALTIRCO1，without UBM） and two HPK 5x5 sensors (with UBM)
Bump bonding quality is good according to 3D X ray imaging. Shear testing is fine

NCAP Quotation : NCAP offers 3345k RMB(~475k CHF, Higher 5.6% related to page-5) for producing 10k bare modules included UBM for sensors.

1/2bare module cost ~1.7M yuan, 1.056*1.049-1~11% higher to budget

How much average time all QA tests/inspections will take ?

Mechanical testing: (equipment, environment, manpower, technical operation ?)

- ✓ **Bump shear force**: typical **60 gr/bump,** we already have Dage-4000
- ✓ **Thermal cycling tests**:
  1. IFAE fromat : about **1 week** of: **4 hour** cycles between **-30C and +120C**, **1000gr shear test before and after cycling.**
  2. TDR-HGTD format: **2 weeks** the modules will be thermally cycled between **–40 C and 130 C**. The solder connections will be then verified with **x-ray imaging** and **shear tests** were carried out on the modules. The devices should be able to sustain the maximum applied **shear force of 1000 gf**. And should sustain a **perpendicular (with respect to the plane of the sensor) pull test of 100 gf before and after the two week thermal cycling**.
- ✓ **Wire bond tests** (for later): typical **8 gr/wire**; Dage-4000

More QA inspection

1. Bare modules will be **optically inspected and weighted**.

2. The **distance** between the substrates (**dump height**) will also be **measured**.

3. Inspection with x rays for disconnected channels before module assembly (dressing with the flex hybrid) will follow. If the yield of the bump-bonding process is found to be high after the initial production and the modules are found to be highly uniform, these time consuming steps (X-ray inspection and substrate separation) can be performed only on a small fraction of devices.

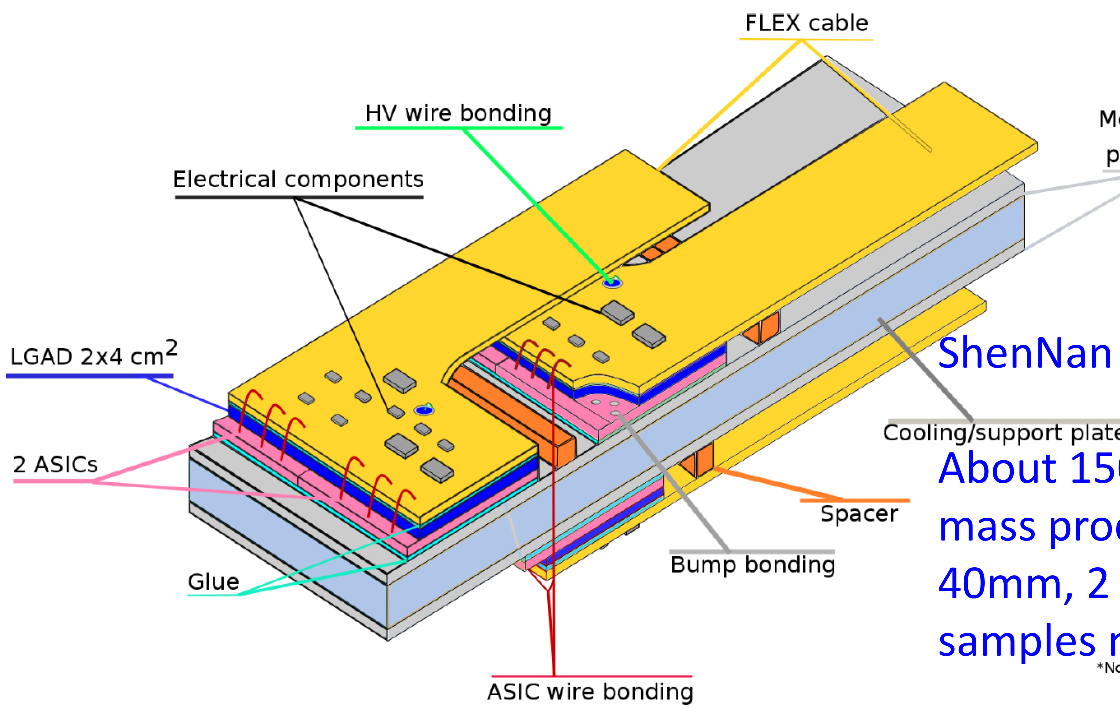
4. Note that the **channel connectivity** will be anyhow tested during the **module electrical tests**.

5. A small number of ASICs will be sacrificed to test the bump quality with **shear tests** before flip-chipping.

6. a small number of devices will be **tested destructively** to verify the robustness of the hybridization process. **Burn-in tests** will be carried out on some devices to test specifically for the degradation of the bump-bonding. How many percent of module for destructively tests?

Module design and assembly

The bare module described above is glued with accurate positioning to the flex cable. ASIC signals and low voltage, as well as bias voltage for the sensor (HV) will be connected by wire bonding. Fig. 7.4 shows three modules with the different components stacked in the z direction of the HGTD. The total thickness of a module is about 1 mm with the sensor, the ASIC and the flex cable contributing about 300 µm each.



FPC Design ?
Position glue ?
Wire bonding ?

ShenNan company (from Mingyi)

About 150RMB/piece for 10000 pieces mass production (dimension: 750mm* 40mm, 2 layers cable), including 2~3 samples making. 5000FPC ~0.75M yuan?

Figure 7.4: Schematic drawing of two adjacent modules on the top side and one on the bottom side of the cooling plate; the modules are mounted on thin support plates.

FPC design

Signal name	Signal type	No. of wires	Comments
HV	1 kV max.	1	Clearance
POWER	$1 \times$ Vdda, $1 \times$ Vddd, 1.2 V	2	2 planes, $R < 2.7\,\mathrm{m}\Omega\,\mathrm{cm}^{-1}$
GROUND	Analog, Digital	1(2) plane(s)	Dedicated layer $R < 0.7\,\mathrm{m}\Omega\,\mathrm{cm}^{-1}$
Slow control	Data, Ck (opt. + rst, error)	2 to 4	I^2C link
Input clocks	320 MHz, Fast command e-link (opt. 40 MHz (L1))	4 or 8	CLPS
Data out lines	Readout data (TOT, TOA, Lumi)	4 pairs	4 e-links differential CLPS
ASIC reset	ASIC_rst	1	Digital
Monitoring	Temperature, Vdda, Vddd	6	DC voltage
Debugging	ASIC_debug	2	Analog

Table 7.4: Type and number of signal lines for two ASICs included in the flex cable design

Finally, the same radiation tolerance is required as for sensors and ASICs, i.e. up to at least 4.7 MGy, as well as operation at a temperature of about –30 °C (see Fig. 7.15).

More specification pls see HGTD TDR (ATL-COM-UPGRADE-2019-003)

FPC QA

FLEX QA proposal (to be discussed), from Lucia Masetti’s talk 18/July

- Optical inspection, size measurements and weighing
- Minimal set of electrical tests not requiring modifications (like loopback wire bonding or additional components) on all flexes to avoid wasting hybrids due to non-working flexes if electrical tests are performed only after module assembly
- Special tests requiring modifications and potentially destructive mechanical tests only on a small subset of flexes
- Note: once the flex is split into two (or more) pieces, it might be easier to create test boards to be connected to each piece without having to modify the flexes themselves

Need to discuss with Mingyi to know how to do them practically ?

Equipment list (from Zhijun)

Unit: 10k RMB Yuan, Sum: 153.2

	exist	buy	Unit price	Total price
Sever	0	5	3.00	15.00
Keithley 2410 (with high voltage source)	0	3	9.5	28.5
Laser	0	1	9.5	9.5
Low voltage	0	8	0.9	7.2
High bandwith scope (fast timing)	0	1	20	20
thermal cycling chamber	0	1	65	65
chiller	0	2	4	4
Dage 4000	1	0	/	/
More ??				

Any things missing ?

Module assembly schedule: from HGTD-TDR_ATL-COM-UPGRADE-2019-003

		Start time	End time	Working days	
8.4-Module assembly and loading in staves					
8.4.1- Bump-bonding	PDR	Jan 2020			
	FDR	Jan 2021			No 20% dicount
	Pre-production	01/12/21	28/2/22	64	
	PRR	April 2022			
	Production	01/06/22	30/10/23	369	13.6/day
8.4.2-Flex cables	PDR	Jan. 2020			
	FDR	Jan. 2021			
	Pre-production	01/03/21	28/02/22	261	
	PRR	April 2022			
	Production	01/06/22	30/10/23	369	13.6/day
8.4.3-Modules assembly	PDR	April 2020			
	FDR	March 2021			
	Pre-production	01/06/21	30/07/22	305	
	PRR	Sept 2022			
	Production	01/11/22	30/08/24	479	10.5/day
8.4.4-Modules loading on staves	PDR	May 2020			
	FDR	April 2021			
	Pre-production	01/08/21	30/9/22	306	
	PRR	Oct 2022			
	Production	01/01/23	30/12/24	522	9.6/day

mon to all the the ATLAS Phase-II upgrade projects: the Specifications Review (SPR), Preliminary Design Review (PDR), Final Design Review (FDR) and Production Readiness Review (PRR). These reviews are run by a review team external to HGTD and appointed by

WorkSpace

Know from Xin that there is no seriously conflict with ITK project for HGTD to use ITK production workspace, the two projects can well share workspace.
Need to make detail workspace usage plan?

NEXT TO DO:

Will know much more concrete details of the module production to make sure we can produce them and time control:

What to do?

How to do?

What are equipment , environment and manpower ?

What is skill and QA in production?

How much time for each step?

Hope to get first version of the HGTD module production feasible plan before the end of August. If realistic?