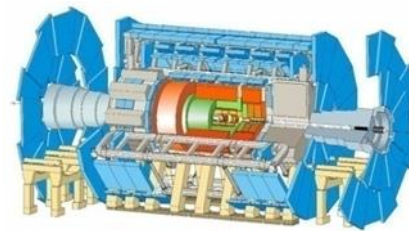




IHEP



ATLAS

Discussion for IHEP Production Plan of 5k HGTD Modules

Feng LYU

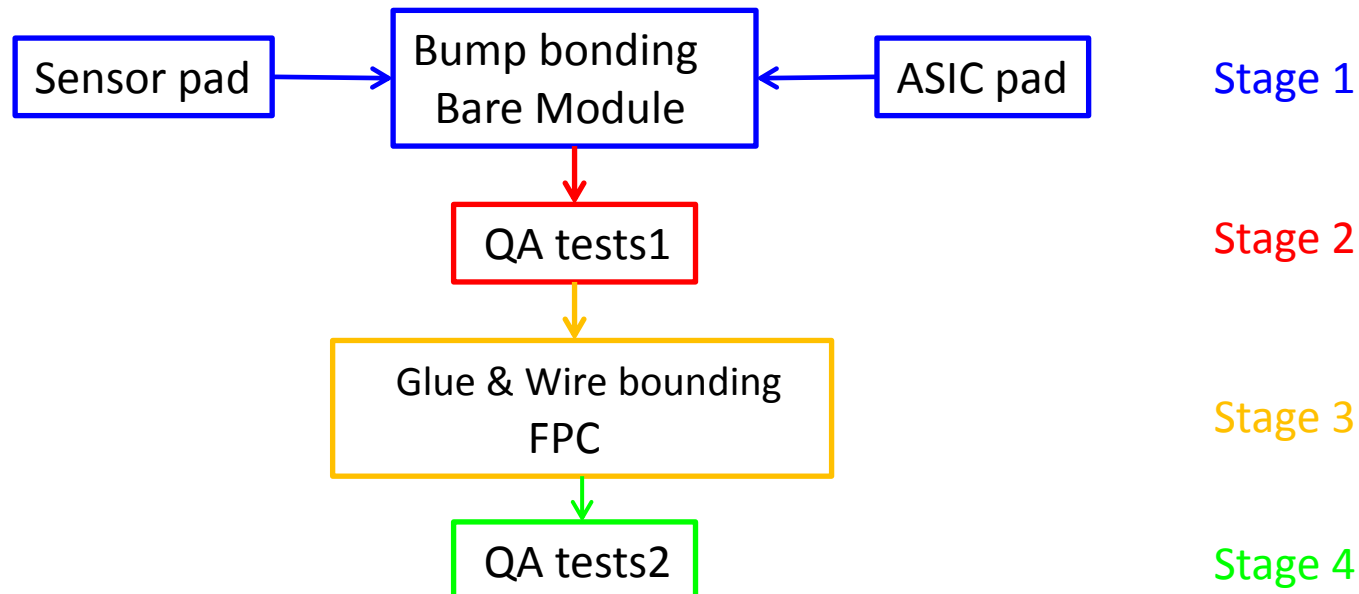
(luf@ihep.ac.cn)

IHEP HGTD one-day workshop

25/July/2019

Introduction

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



How many module will produced (assembly+QA) per day

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

There are $1.5 * (365 \text{ day} - 104 \text{ weekend} - 11 \text{ festival}) = 1.5 * 250 \text{ days} = 375 \text{ days}$

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:

$5000 / (375 * 0.8) = 5000 / 300 = 16.7 \text{ modules/day}$ or **17.9 modules/day** (**10711** modules)

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. Seřin

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	Module assembly total cost 1383 kCHF, ~9.5M yuan 1/7 relative to HGTD TOTAL
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				exchange rates to be used for HGTD TL 1 Euro=1.085 CHF 1 USD =0.986 Japanese Yen [100 JPY]=0.942 Chinese Yuan [CNY]=0.1461
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				

1CHF=6.845 Yuan
Now: 1CHF=7.0129 Yuan, -2.4%

HGTD Intro 08/04/19

HGTD TOTAL 66.51M 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

How much average time a bare module assembly will take ?

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

How much average time a bare module assembly will take ?

From **Zhijun** 20/06/19 talk, <https://indico.ihep.ac.cn/event/10262/>

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)

Implant gold ball in ASIC for this bare module bonding. Suggest to use copper pillar instead of SnAg solder bump for production, Bump bonding quality is good according to 3D X ray imaging. **Pull testing in next step to check bump quality.**

NCAP Quotation : In production phase, they offer 750k RMB(~108k USD) for producing 5000 bare modules. UBM for sensors not in quotation yet (estimated <100k RMB, to be confirmed)

Production hybridization strategy

Full size tests will be carried out as soon as the **final sized sensor and ASIC** become available. However, an effort is being made to advance this critical step in module assembly to **avoid** possible **bottlenecks** later in the overall activities.

The specifications have already been provided to **two companies** (one in **Germany** and one in China) and discussions of a possible early qualification of the bump bonding process with the currently available devices (**ALTIROC1**) is being discussed.

The possibility of using **dummy ASICs and sensors for the vendor qualification** will also be investigated.

The target is to eventually carry out **the final hybridization qualification** on two to four companies, though the impact on cost and schedule will have to be evaluated.

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

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

- ✓ **Bump shear force:** typical **60 gr/bump**
- ✓ **thermal cycling tests:**
 1. IFAE format : 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**;

Shear test for bond quality FOR NCAP (provided by Zhijun)

■ Proper tools needed

- DIE SHEAR
- FLIP CHIP PULL

■ Operator

Dage 4000 | Standards

The Dage 4000 conforms to and in some cases exceeds the following industry standards:

CBP/HBP	JEITA EIAJ ET-7407
BGA BUMP SHEAR	JEDEC JESD22-B117
AU BALL SHEAR	JEDEC JESD22-B116
BALL BOND SHEAR	ASTM F1269
WIRE PULL DT/NDT	MIL STD 883
DIE SHEAR	MIL STD 883
STUD PULL	MIL STD 883
FLIP CHIP PULL	JEDEC JESD22-B109

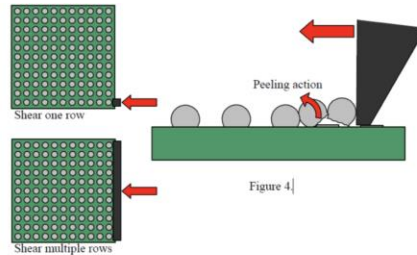
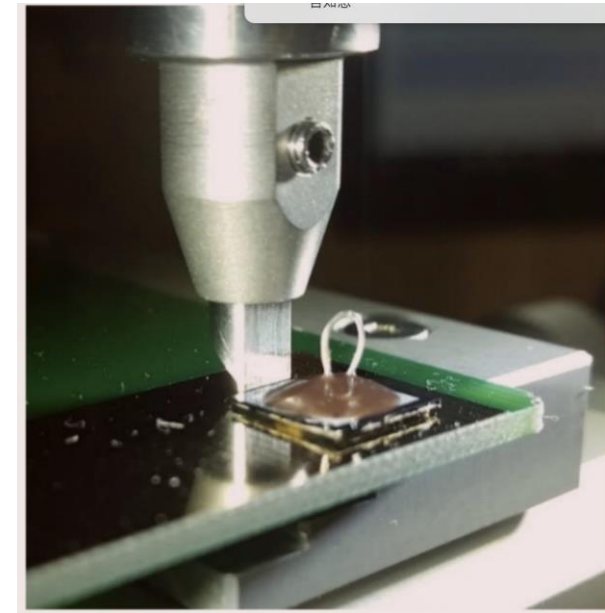
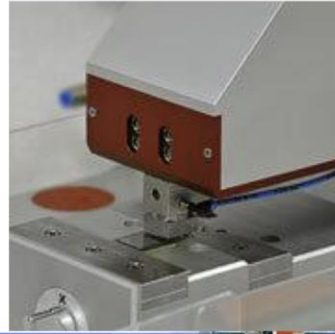
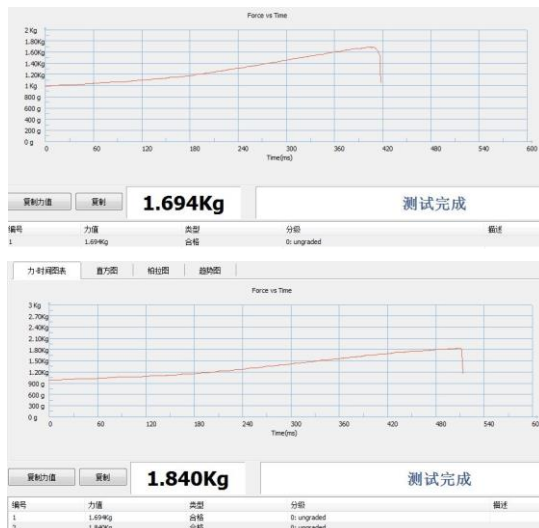


Figure 4



- Shear test result for NCAP 2 bump bonding
 - 1.694Kg
 - 1.840Kg
 - Both >1Kg



thermal cycling tests

thermally cycled between **-40 C and 130 C**, 高低温一体机, **High-low temperature integrator**



LNEYA(无锡冠亚恒温制冷技术有限公司高低温一体机)

<https://www.cnzlj.com/xinpian/tes-85.html>

东莞爱佩实验设备有限公司

<http://www.apkjgroup.com/Products/gaodiwenjiaobianshiy.html>

上海廷翌仪器设备厂

<http://www.ty-xw.com/product/gaodiwen/gaodiwenjiaobianshireshiyanxiang/2016/0101/99.html>

One example from LNEYA : SUNDI-9A25W

<https://detail.1688.com/offer/38675089501.html?spm=a2615.7691456.autotrace-offerGeneral.1.1b4924e4HP2tKv>

Price: 552k yuan

Specifications: internal size 1500*1250*2050 (mm)

temperature range: -90℃ ~ 250℃ (℃)

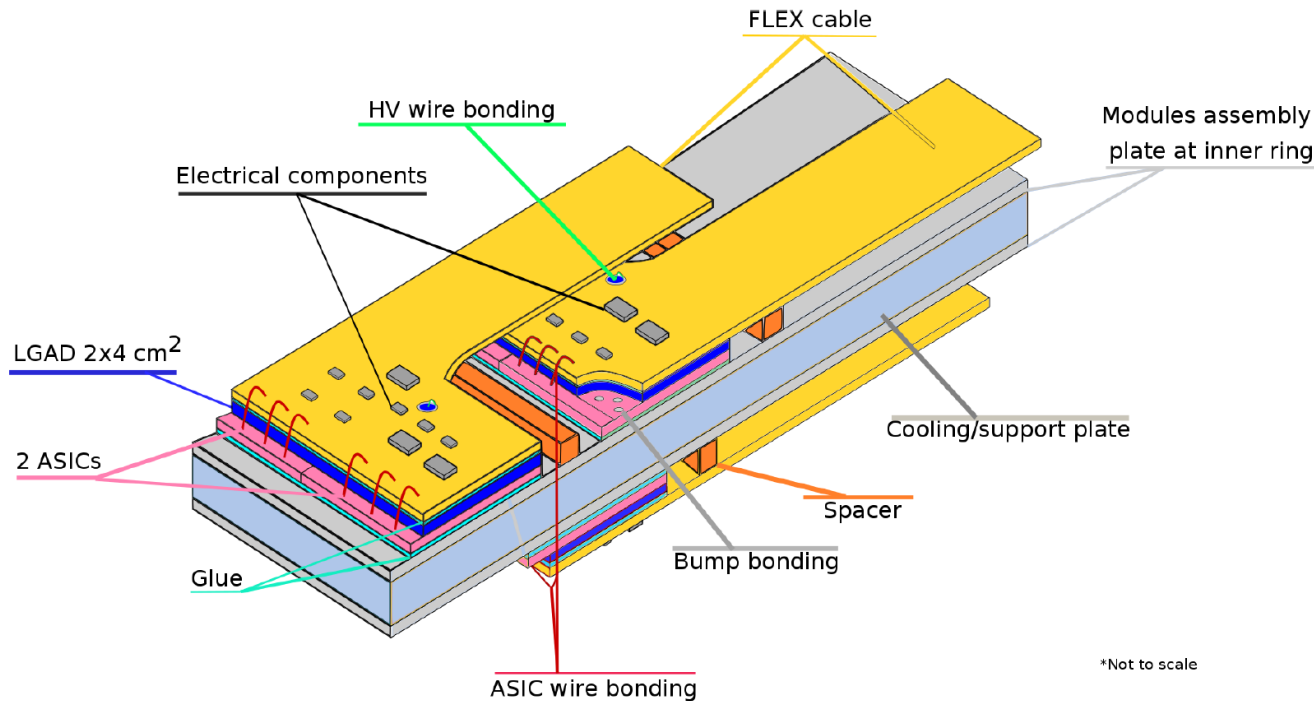
power: 50kw

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.

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.



FCP Design ?

Position glue ?

Wire bonding ?

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	$1 \times V_{dda}$, $1 \times V_{ddd}$, 1.2 V	2	2 planes, $R < 2.7 \text{ m}\Omega \text{ cm}^{-1}$
GROUND	Analog, Digital	1(2) plane(s)	Dedicated layer $R < 0.7 \text{ m}\Omega \text{ cm}^{-1}$
Slow control	Data, Ck (opt. + rst, error)	2 to 4	I ² C 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)

Equipments 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 bandwidth scope (fast timing)	0	1	20	20
thermal cycling chamber	0	1	65	65
chiller	0	2	4	4
Dage 400	1	0	/	/
More ??				

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 FDR Pre-production PRR Production	Jan 2020 Jan 2021 01/12/21 April 2022 01/06/22	28/2/22 30/10/23	64 369
					No 20% discount
					13.6/day
	8.4.2-Flex cables	PDR FDR Pre-production PRR Production	Jan. 2020 Jan. 2021 01/03/21 April 2022 01/06/22	28/02/22 30/10/23	261 369
					13.6/day
8.4.3-Modules assembly		PDR FDR Pre-production PRR Production	April 2020 March 2021 01/06/21 Sept 2022 01/11/22	30/07/22 30/08/24	305 479
					10.5/day
	8.4.4-Modules loading on staves	PDR FDR Pre-production PRR Production	May 2020 April 2021 01/08/21 Oct 2022 01/01/23	30/9/22 30/12/24	306 522
					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

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.

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.