



# ATLAS/TGC前端读出电子学

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## ATLAS Phase 1 Muon 探测器升级 \_\_\_\_





- Phase 1升级任务之一 是新建一个Small Wheel(SW)用于L1触发 和测量Muon轨迹
- 由Micromegas和sTGC 二个探测器组成
- 中国组(中国科学技 术大学和山东大学) 参加sTGC的建设
- 山东大学负责1/6的 sTGC探测器(144个) 的建造
- 中国科学技术大学负责全部前端电子学读出板(pFEB&sFEB,33万通道)的研制和生产



### **NSW Detector**



- NSW由由2个4层sTGC和2个MicroMegas探测器组成。
- NSW由16个扇面组成,前后各8个,每个扇面3个sTGC探测器模块。
- 每个sTGC模块需要一个sFEB板读出512通道Strip信号和1个pFEB板读出192通道的 pad和wire信号。
- sFEB共计768块, pFEB共计768块, 共计1536块FEB, 约33万通道。



Table 12.1: Some sTGC and MM parameters								
	sTGC	MM						
strip width	$3.2 \mathrm{mm}$	$0.5 \mathrm{mm}$						
strips/layer	$\sim \! 1050$	8,192						
strips/octant	17,260	131,072						
triggering pads/octant	2,362	_						
at $ \eta  < 2.4$								
All pads/octant	2,738	_						
wires/octant	736	_						
channels/octant	20,734	131,072						
$channels/two \ end-caps$	331,744	2,097,152						
VMM chips/octant	382	2,048						
MM trigger elements	_	32,768						

Strips

coating

STRIPS

SHIELDING

PADS



#### NSW Trigger Electronics









- (1)通道密度:由于sTGC空间限制,每个FEB的尺寸不能超过 27cm×6cm(sFEB,512通道)和16cm×6cm(pFEB,192通道)。在如此有限的空间里,集成模拟处理、数字化、触发、高速通信全部功能在一个前端板上,在国内外还是第一次;
- (2) 数据通信技术: 在FEB 与level-1 触发系统之间有两类数据需要高速 传输,一类是原始数据,另一类是触发数据。数据率为4.8Gb/s,如 何进行高速高保真的数据传输是FEB 设计中需要解决的难题;
- (3) 抗辐照需求:由于FEB安装在sTGC探测器上,暴露在强辐射场中, 板级抗辐照要求是一个不可回避的难题。
- (4)所有器件均为定制品:没有经过完整检测、存在意想不到问题、资料不全。
- (5) 时间紧: 工程进度与器件开发存在严重冲突。











- 2015年5月,完成基于VMM2的pFEB1.0的设计,并在Michigan大学与 Mini-sTGC进行了联合调试;
- 2016年4月,完成基于VMM2的pFEB1.2和sFEB1.1原型版,并在2016年6 月通过了在USTC的现场验收;
- 2017年4月,完成了基于VMM3的pFEB2.0原型板;
- 2017年6月,完成了基于VMM3的pFEB2.1和sFEB2.1的工程版,并在7月的CERN VS实验中进行了集成实验,实现了通过FELIX进行配置,4.8Gbps数据上下行传送;
- 2017年8月,在以色列的Weizmann Institute、加拿大的McGill大学和山东 大学同时在sTGC探测器上进行了测试,结果显示,所有性能指标都达到 设计要求;
- 2017年10月,在CERN进行了束流测试,结果表明达到了预期目标。
- 2017年10月,进行最终版设计(ROC版),已基本完成,等待ROC器件;
- 2018年4月起,将根据ASIC供应情况,开始按计划批量生产。



### pFEB v2.1





PCB size: 16×6cm, 12 layers, 192 Channel;

Produced 42+20 boards;

Soldered 25 board ;

NSW upgrade committee ordered 38 boards for chamber site Test.





Current sFEB v2.1









• Noise of pad signal on pFEB:

			IGNIM		114440
Gain (mV/fC)	RMS (mV)	Amplitude (mV)			
0.5	0.41	2.5			
1	0.50	3.0			
3	0.44	4.9	2 2 200mV	800ns 1.256S/s <b>1</b> →▼313.6000ns 10k points	2 ∕ 636mV
4.5	0.50	5.3	ValueMean2RMS568mV2Mean568mV2Amplitude32.0mV32.8m	Min Max 568m 571m 568m 571m 32.0m 40.0m	Std Dev :

41-21-21-21

#### The typical intrinsic noise of pFEB is < 0.5mV for all gains





• Noise of strip signal on sFEB:

Gain (mV/fC)	RMS (mV)	Amplitude (mV)	$\mathbf{PT}=50\mathrm{ns}, \mathrm{Gain}=1\mathrm{mV/fC}$
0.5	0.42	3.2	1
1	0.50	3.8	
3	0.52	4.0	800ns 1.256S/s 1 ∕ 1 20.0mV ∿ ¶1 50.90 % 10k points 97.6mV
4.5	0.54	4.2	Value Mean Min Max Std Dev   1 RMS 500μV 500μ 500μ 0.00   1 Peak-Peak 3.80mV 3.80m 3.80m 0.00 26 Sep 2017   1 Mean 30.0μV 30.0μ 30.0μ 0.00 10:58:18

The typical intrinsic noise of sFEB is  $\sim 0.5 \text{mV}$  for all gains



## FEB v2.1 sTGC test @ SDU & WZ <u>NEK</u>



- ► Full size QS2 with soldered adapter board and sFEB/pFEB
- > External trigger by scintillator cosmic coincidence
- Configure and readout via a simple DAQ board
- ➢ Good detector grounding and efficient chip cooling are vital



• pFEB noise on sTGC @ WZ: Yield QS2, pad # 13, C = 2 nF Intrinsic noise of pFEB w/o sTGC Noise level, pFEB # 6 300 G = 3 mV/fC, PT = 50 nsis reported as 700-800e of ENC <A> = 186.6 +/- 0.1 200  $\sigma = 2.5 + - 0.1$  $\succ$  When connected to a particular ENC = 5200 esTGC pad of  $\sim 2nF$  and powered 100 up to 3.2kV, the level of noise is  $\sim$ 5200e ENC 180 120 140 160 200 220 Amplitude (mV)



## FEB v2.1 sTGC test @ SDU & WZ <u>NEK</u>

#### • Cosmic signals:



- Clean and good analog signals of both sFEB and pFEB can be observed.
- ▶ No pFEB signal if gains of < 3mV/fC used, due to π-network attenuation
- > No sFEB signal if gains of  $\geq 3mV/fC$  used, due to pull-up resistor



#### • Analog/digital response via VMM3 on pFEB@WZ QS2:



Both VMM3 analog and ADC work properly.



Summary of FEB v2.1



- All ASICs on FEB can be configured by the full chain from OPCUA client, to DCS to FELIX to L1DDC, and finally to pFEB/sFEB.
- The pFEB/sFEB noise level has been measured w/o and w/ full size sTGC detector. The intrinsic electronic noise RMS is ~ 0.5mV, and is less than 2.5mV when connected with powered sTGC.
- Clean analog signals of cosmic have been seen, and digital readout of VMM3 have been tested at chamber sites
- No dead channel observed at chamber sites
- > It's demonstrated that proper grounding is required for sTGC detector.
- ➢ Good cooling is mandatory for FEBs.



### Beam Test at CERN, October 5,2017 \_\_\_\_\_

Full setup with pFEB and sFEB installed

(reduced TTC, L1DATA to 80 Mbps; changed the firmware to support VMM daisy chain cfg.)





#### 5<sup>th</sup> Oct.: Full setup (view from top)





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### Signals and Noise from FEB



#### One Cosmic ray event





## Signals and Noise from FEB



#### One high energy muon signal from the beam





## Signals and Noise from FEB



-ile I	Edit	Vertical	Horiz/Acq	Trig Display	Cursors	Measure	Mask Math	MyScope	Analyze	Utilities Help		DP05104B	Tek	<b>_</b>
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Pads: VMM gain = 3mV/fC, PT=50 ns Strips: VMM gain = 1mV/fC, PT=50 ns



sTGC Pad效率测试





- 只测了三层sTGC Pad的效率
- 在3000V左右探测效率接近100%



## pFEB v2.2 Layout



#### • Layout completed.







#### • Ready for production.





## FEB test board







结束语



- pFEB2.1和FEB2.1版已经在3个不同的实验室进行了与sTGC的联合测试,同时完成了束流测试。测试结果显示,可以满足PHASE I升级要求和用于sTGC批量生产的测试;
- 将为6个sTGC生产单位生产38套pFEB2.1和sFEB2.1;
- pFEB和sFEB2.2版(准最终版)的设计已经完成,等待ROC芯片;
- pFEB和sFEB批量生产的准备工作正进行中,在等待VMM3a和ROC流 片、封装完成(预计明年4月份);
- 2017年9月份专程去BNL和Michigan大学拜访VMM、TDS和ROC芯片的设计者和测试者,了解专用定制器件VMM、TDS、ROC的细节。
- 完成了用于批量生产的自动测试系统
- 按照目前进展,USTC按计划完成任务没有问题。
- 希望能与国内同行在气体探测器数据读出方面开展更深入的合作。





## **THANKS**!