ATLAS sTGC前端读出电子学

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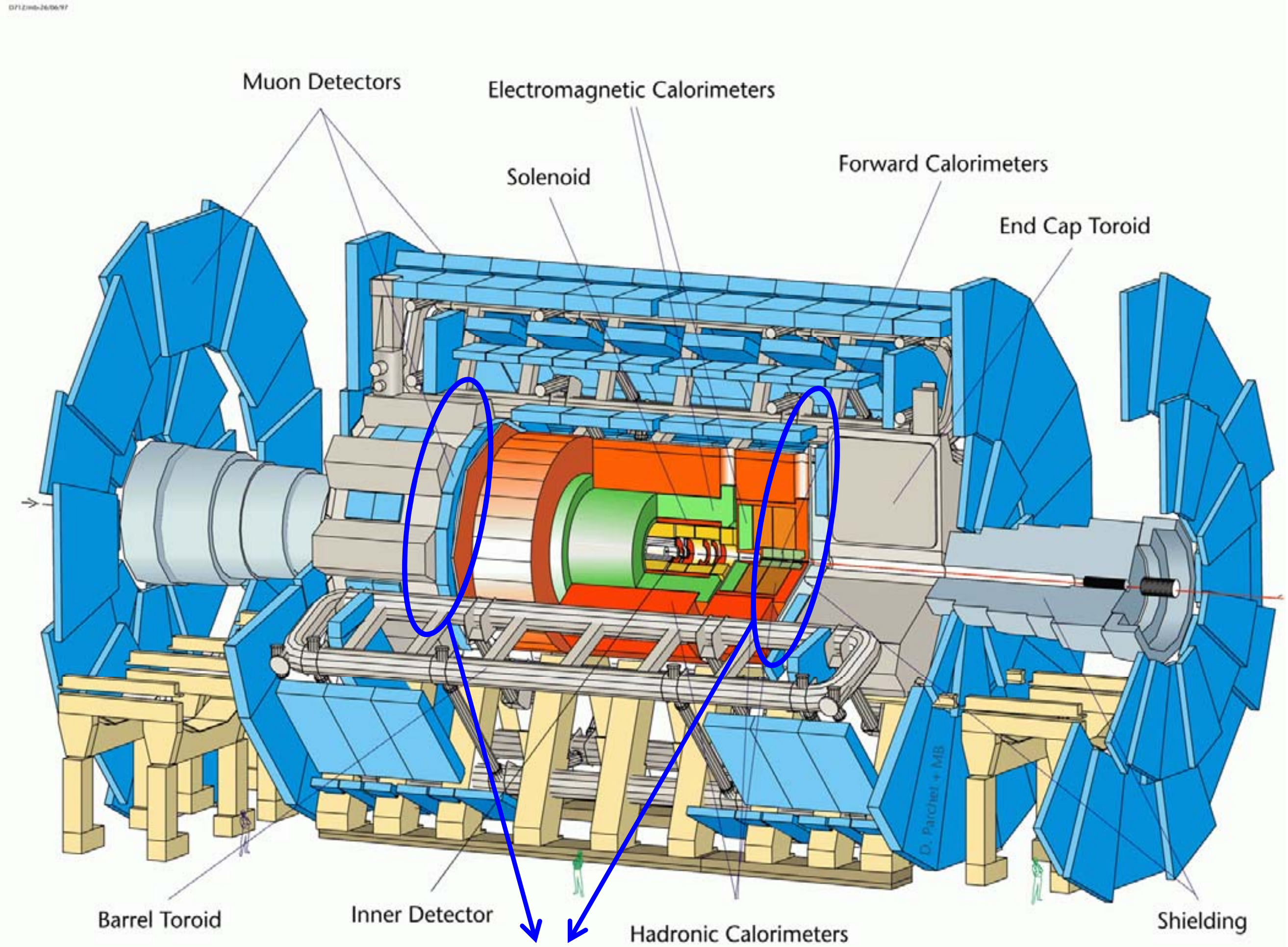
ATLAS Phase 1 Muon 探测器升级



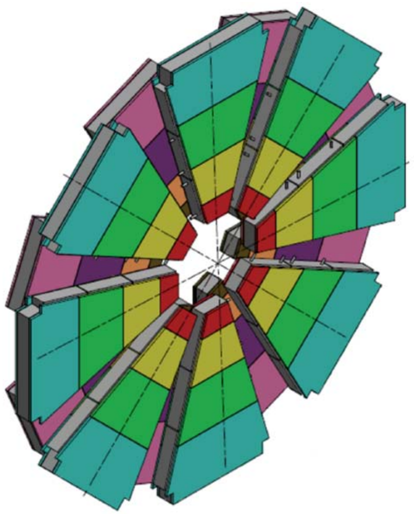
Muon谱仪端盖近端探测器

SW (Small Wheel)

- 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。



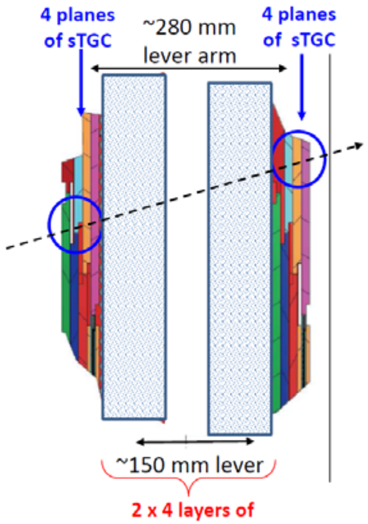
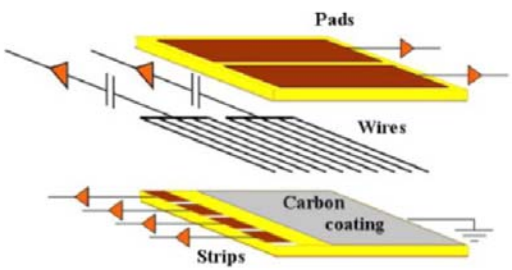
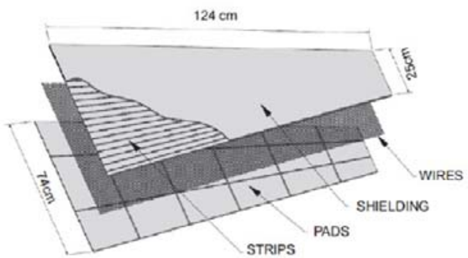


Table 12.1: Some sTGC and MM parameters

	sTGC	MM
strip width	3.2mm	0.5mm
strips/layer	~1050	8,192
strips/octant	17,260	131,072
triggering pads/octant at $\|\eta\| < 2.4$	2,362	–
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

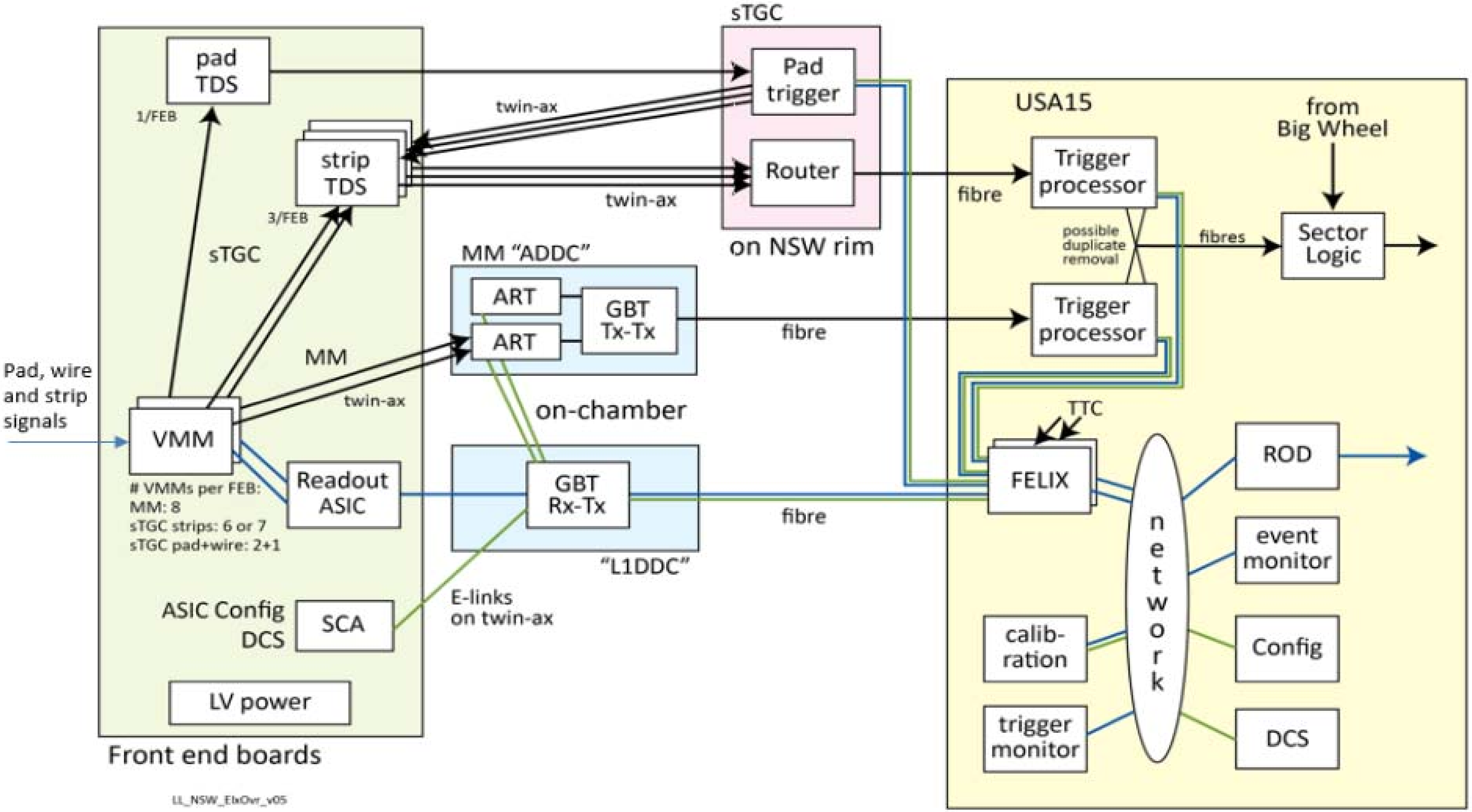


(a) a



(b) b

NSW Trigger Electronics



FEB设计面临的挑战

(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；

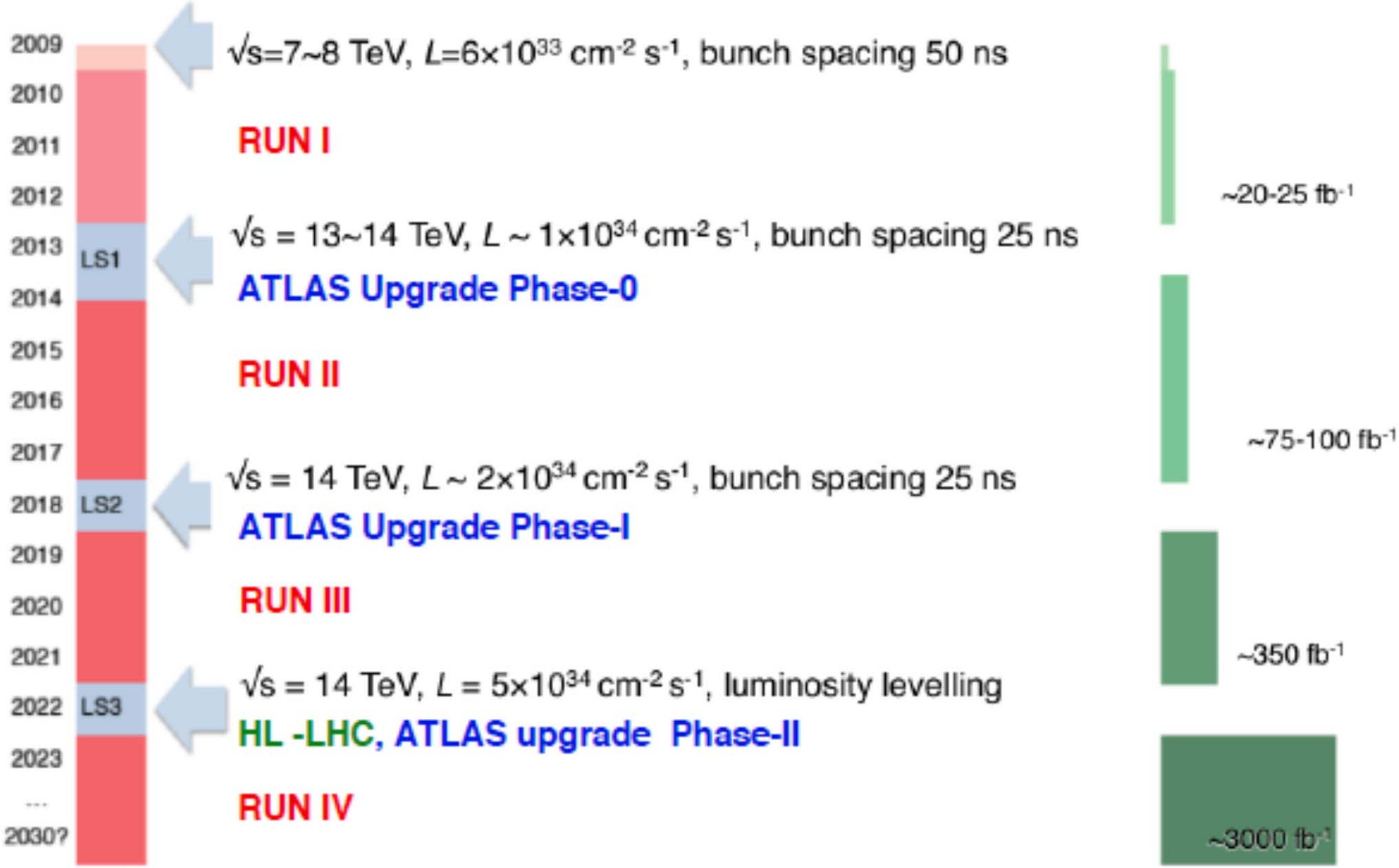
(2) 数据通信技术：在FEB 与level-1 触发系统之间有两类数据需要高速传输，一类是原始数据，另一类是触发数据。数据率为4.8Gb/s，如何进行高速高保真的数据传输是FEB 设计中需要解决的难题；

(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。

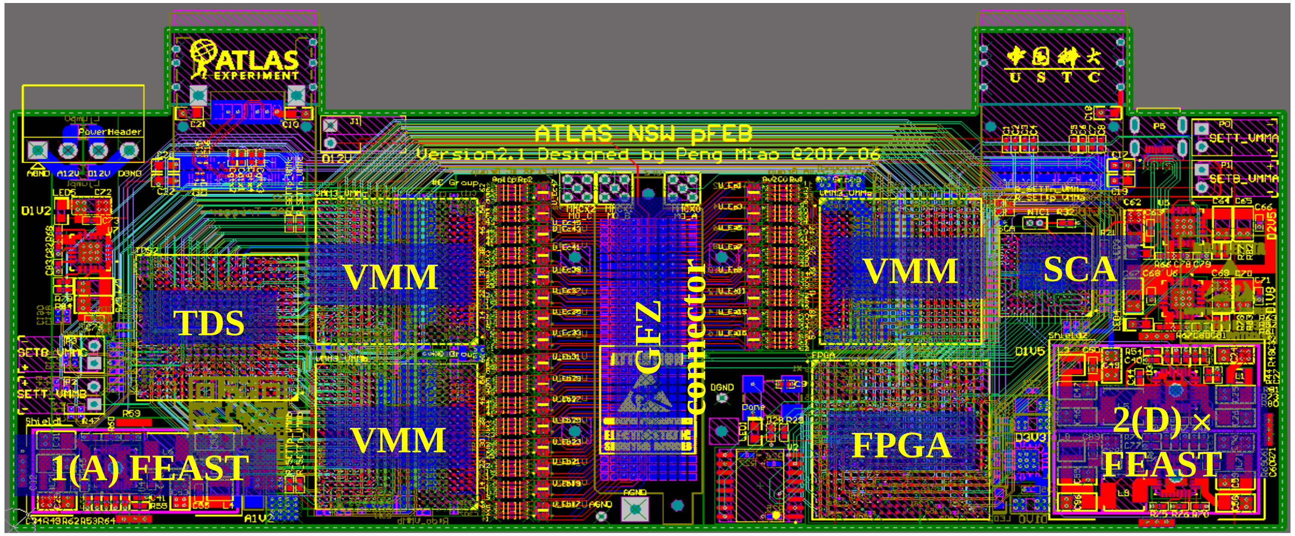
An Approximate Timeline

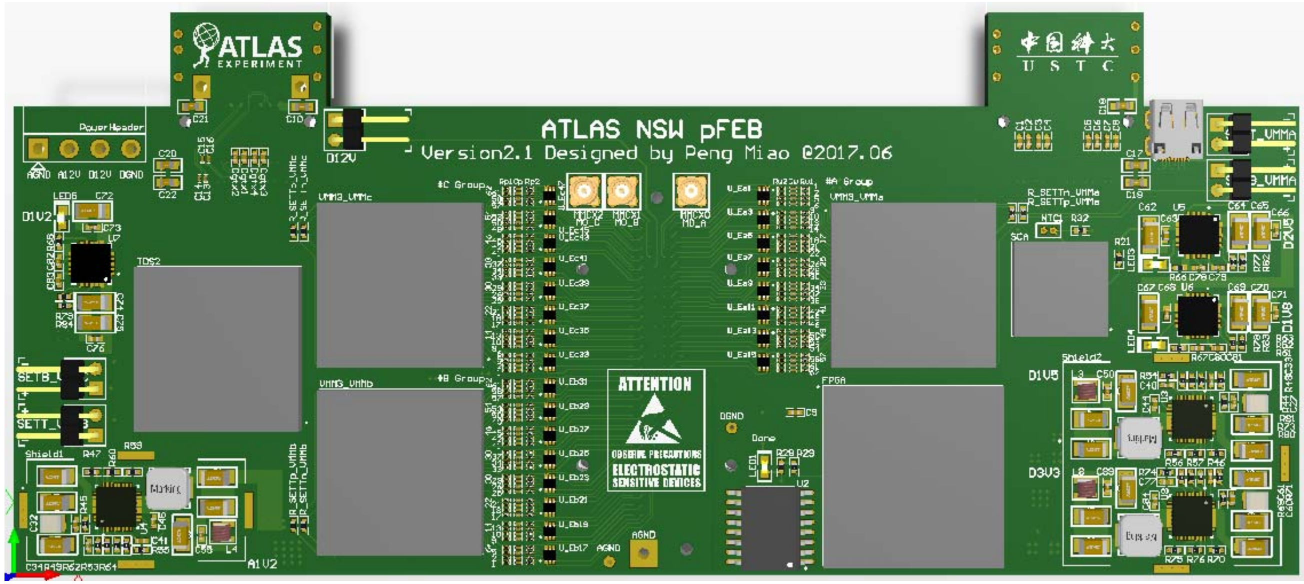


前端电子学板FEB实际进展

- 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





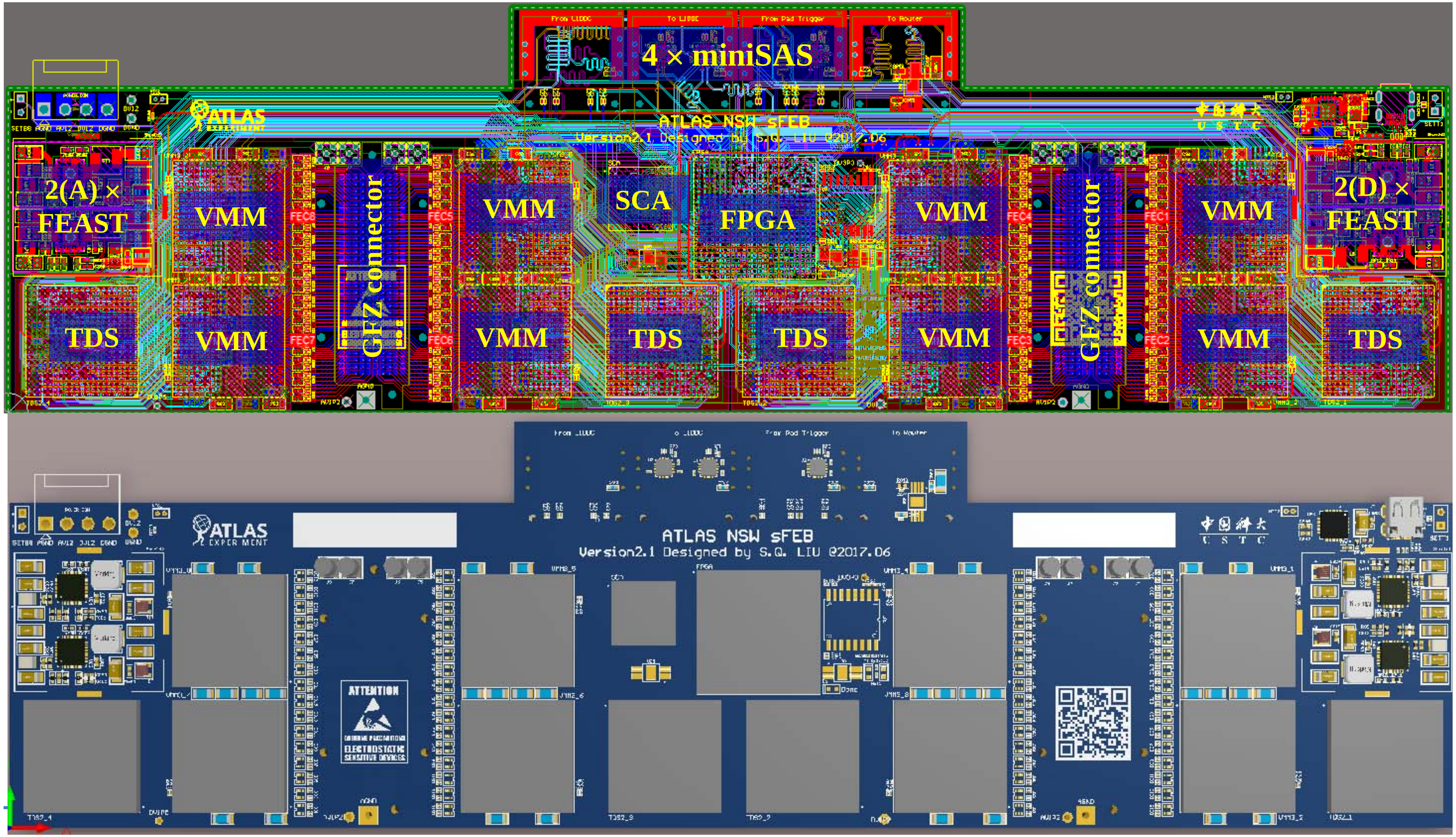
PCB size: 16×6cm, 12 layers, 192 Channel;

Produced 42+20 boards;

Soldered 25 board ;

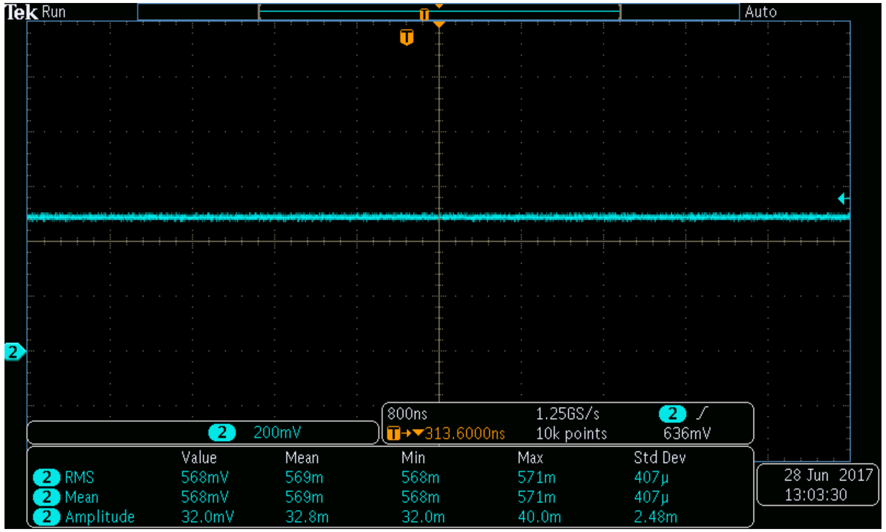
NSW upgrade committee ordered 38 boards for chamber site Test.

Current sFEB v2.1



- Noise of pad signal on pFEB:

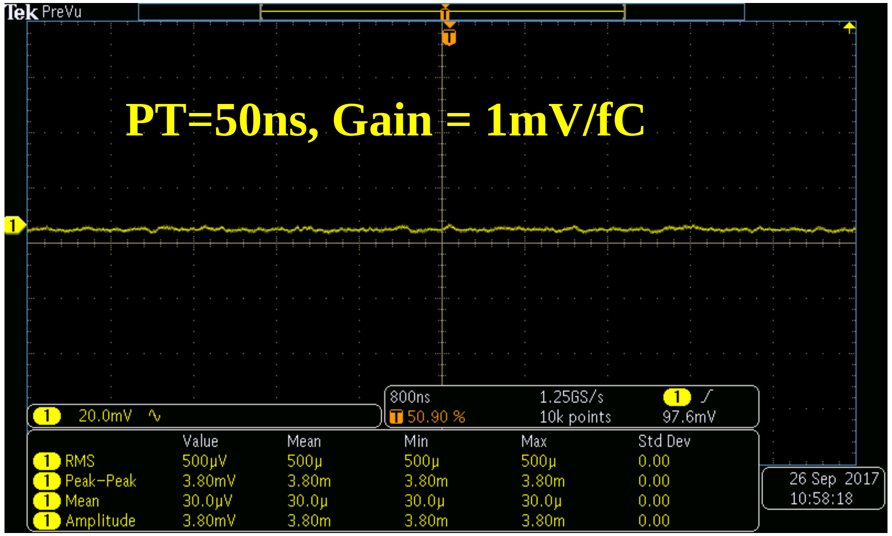
Gain (mV/fC)	RMS (mV)	Amplitude (mV)
0.5	0.41	2.5
1	0.50	3.0
3	0.44	4.9
4.5	0.50	5.3



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

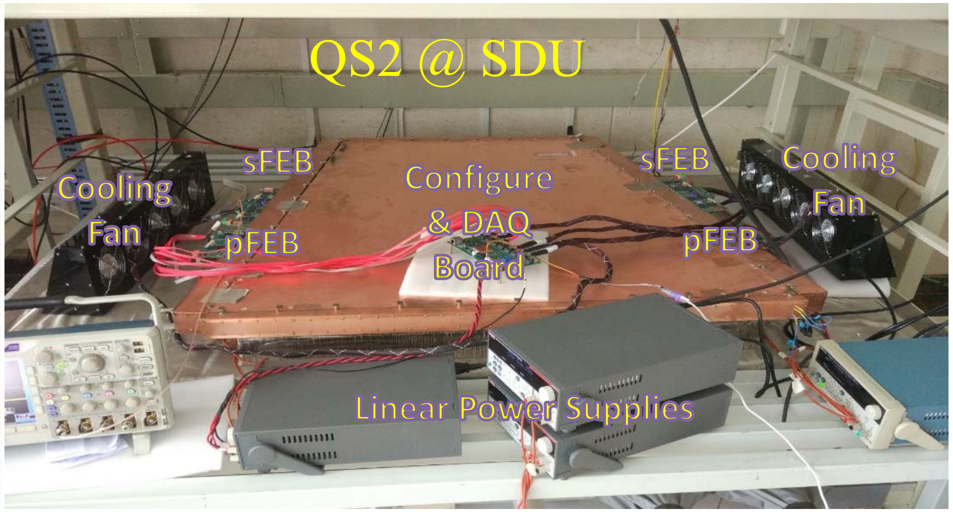
- Noise of strip signal on sFEB:

Gain (mV/fC)	RMS (mV)	Amplitude (mV)
0.5	0.42	3.2
1	0.50	3.8
3	0.52	4.0
4.5	0.54	4.2



The typical intrinsic noise of sFEB is ~ 0.5mV for all gains

FEB v2.1 sTGC test @ SDU & WZ

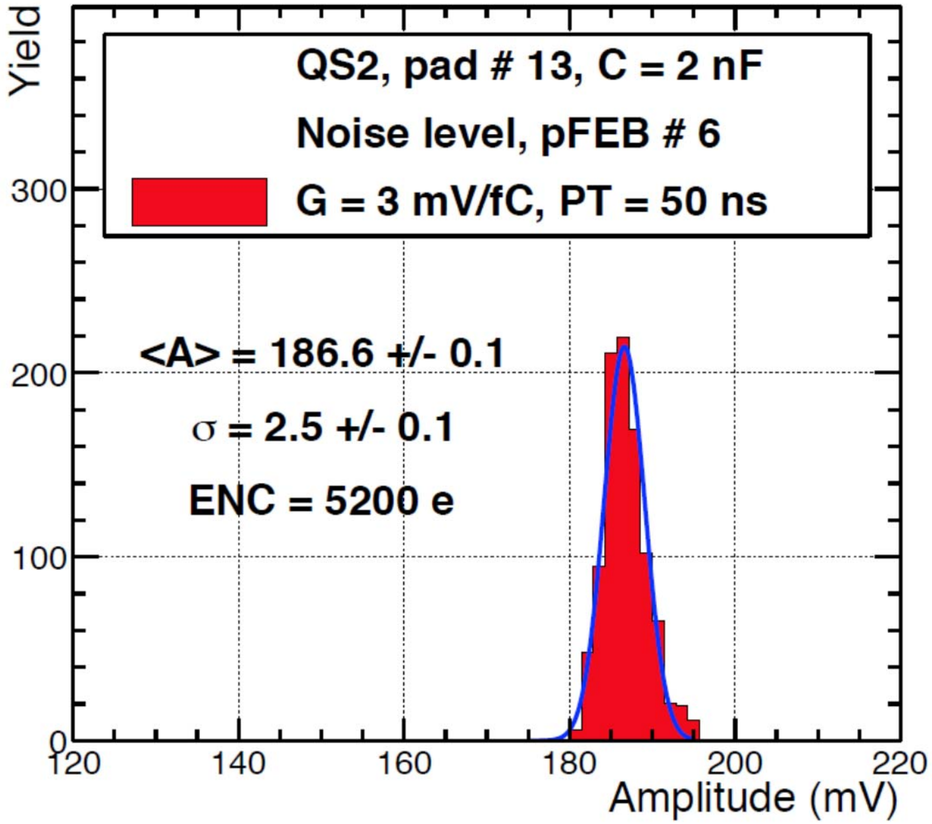


- Full size QS2 with soldered adapter board and sFEB/pFEB
- External trigger by scintillator cosmic coincidence
- Configure and readout via a simple DAQ board
- Good detector grounding and efficient chip cooling are vital

FEB v2.1 sTGC test @ SDU & WZ

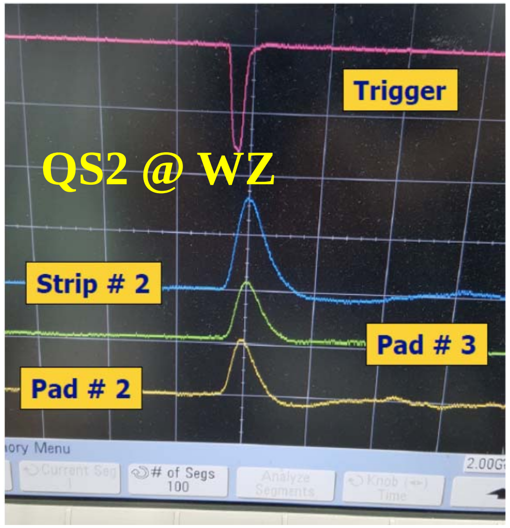
- pFEB noise on sTGC @ WZ:

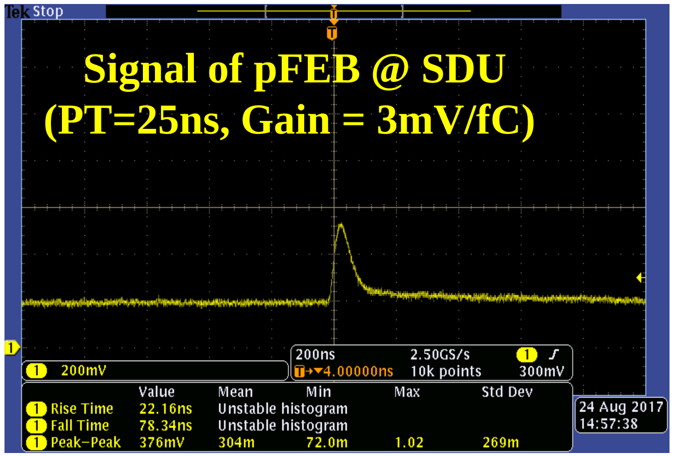
  - Intrinsic noise of pFEB w/o sTGC is reported as 700-800e of ENC
  - When connected to a particular sTGC pad of ~ 2nF and powered up to 3.2kV, the level of noise is ~ 5200e ENC

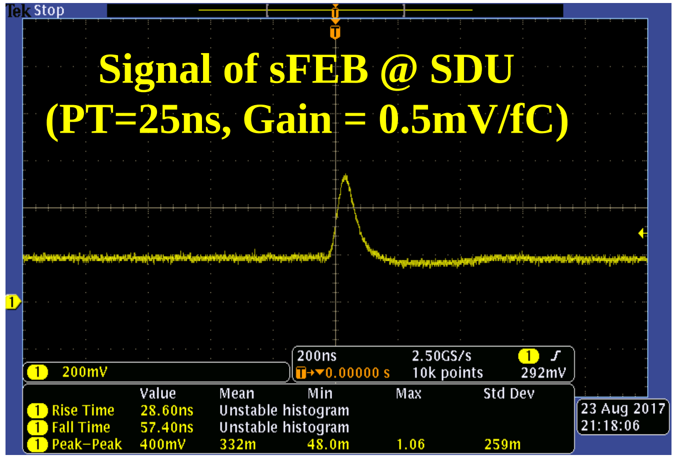


FEB v2.1 sTGC test @ SDU & WZ

- Cosmic signals:



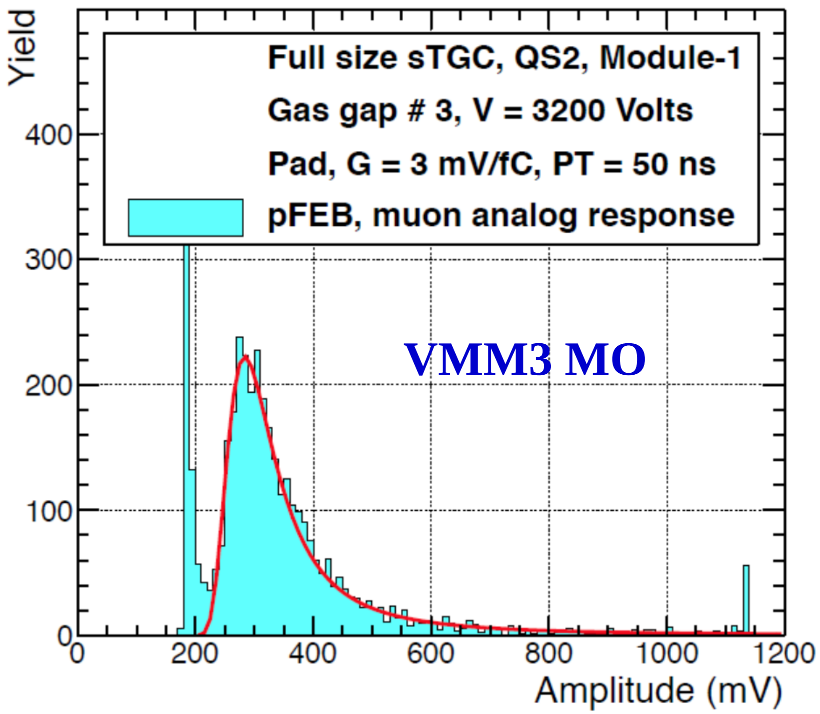


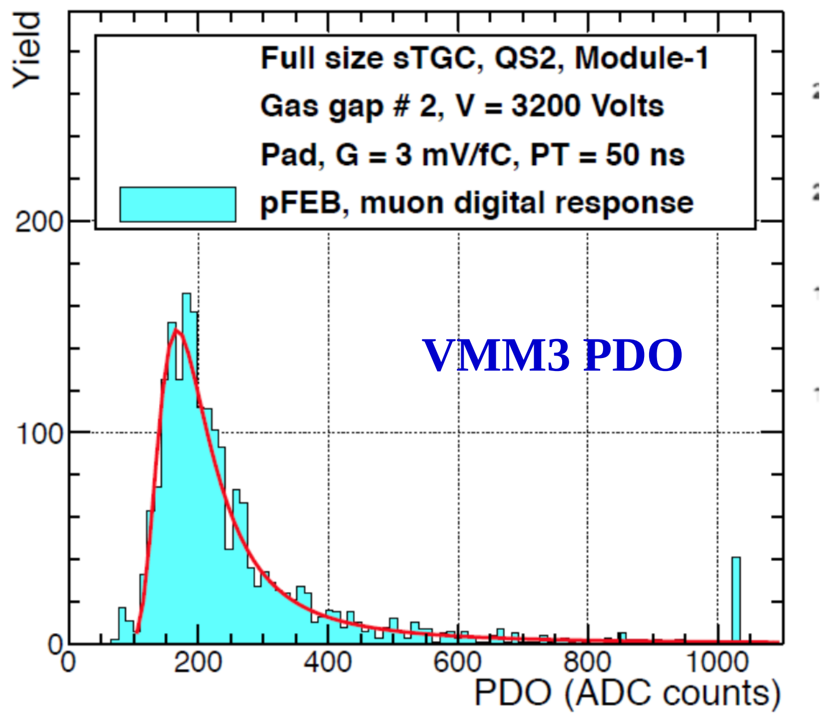


- Clean and good analog signals of both sFEB and pFEB can be observed.
- No pFEB signal if gains of < 3mV/fC used, due to π-network attenuation
- No sFEB signal if gains of ≥ 3mV/fC used, due to pull-up resistor

FEB v2.1 sTGC test @ SDU & WZ

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





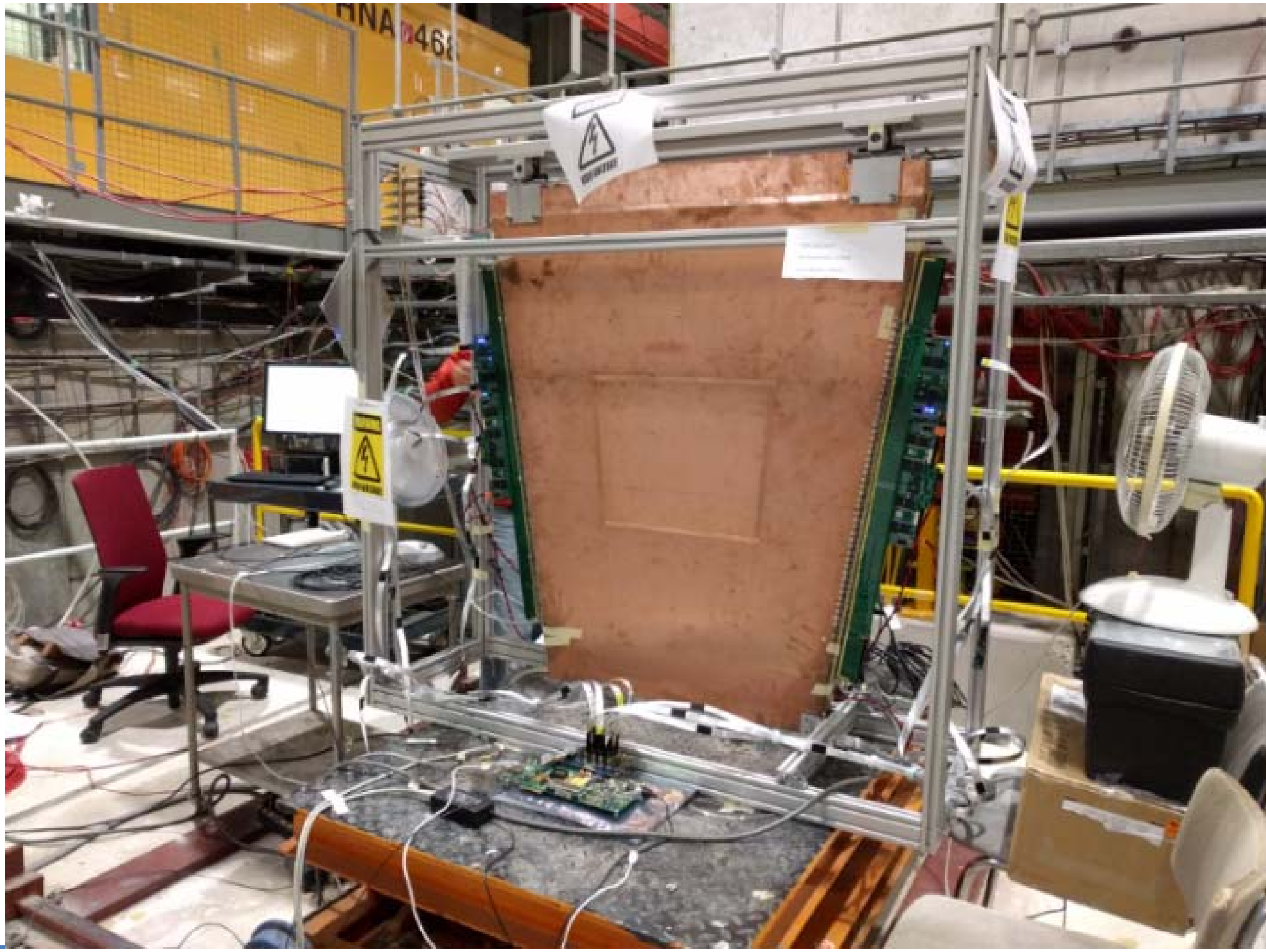
Both VMM3 analog and ADC work properly.

Summary of FEB v2.1

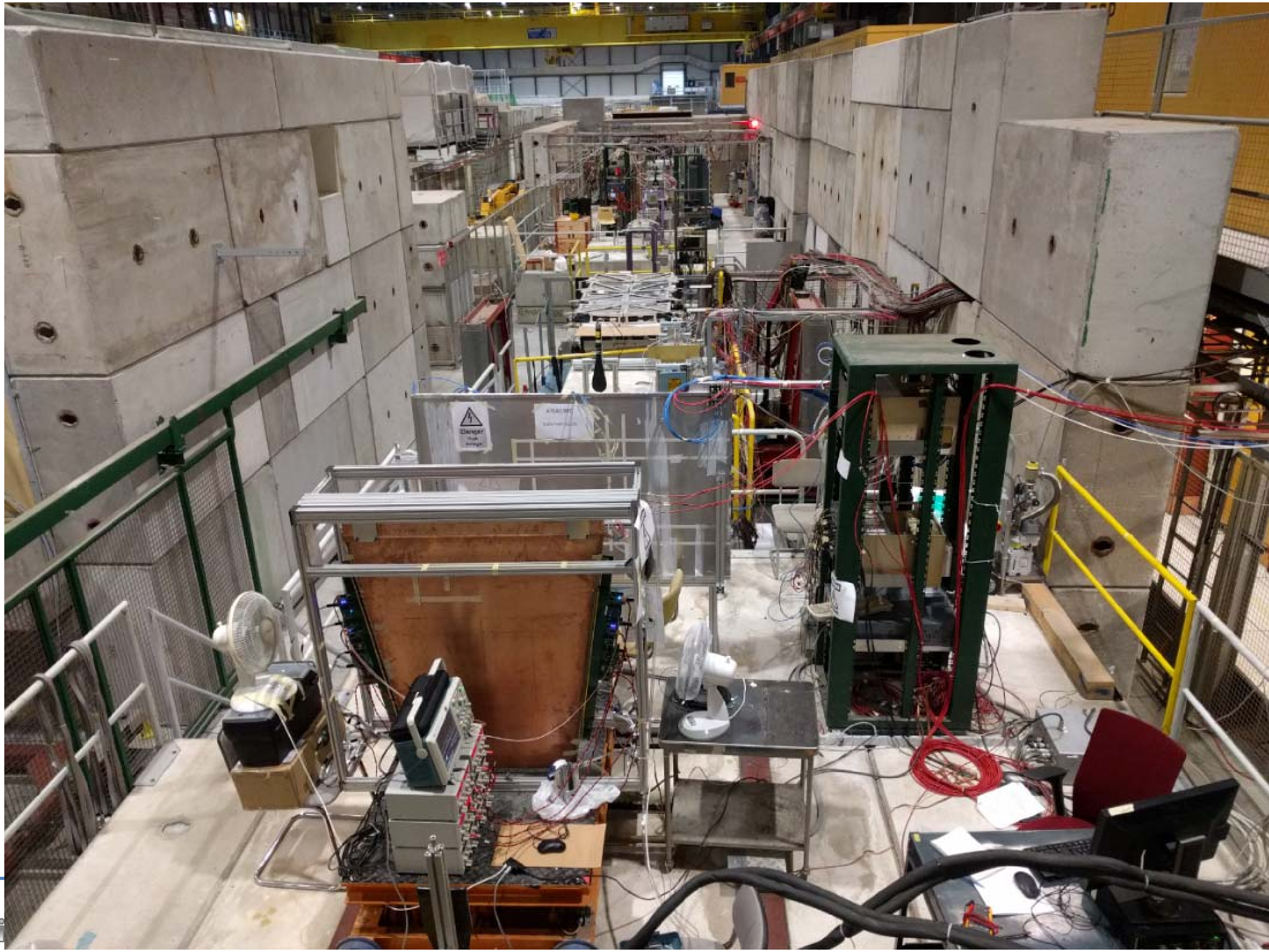
- All ASICs on FEB can be configured by the full chain from OPCUA client, to DCS to FELIX to L1DDC, and finally to pFEB/sFEB.
- The pFEB/sFEB noise level has been measured w/o and w/ full size sTGC detector. The intrinsic electronic noise RMS is ~ 0.5mV, and is less than 2.5mV when connected with powered 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.)

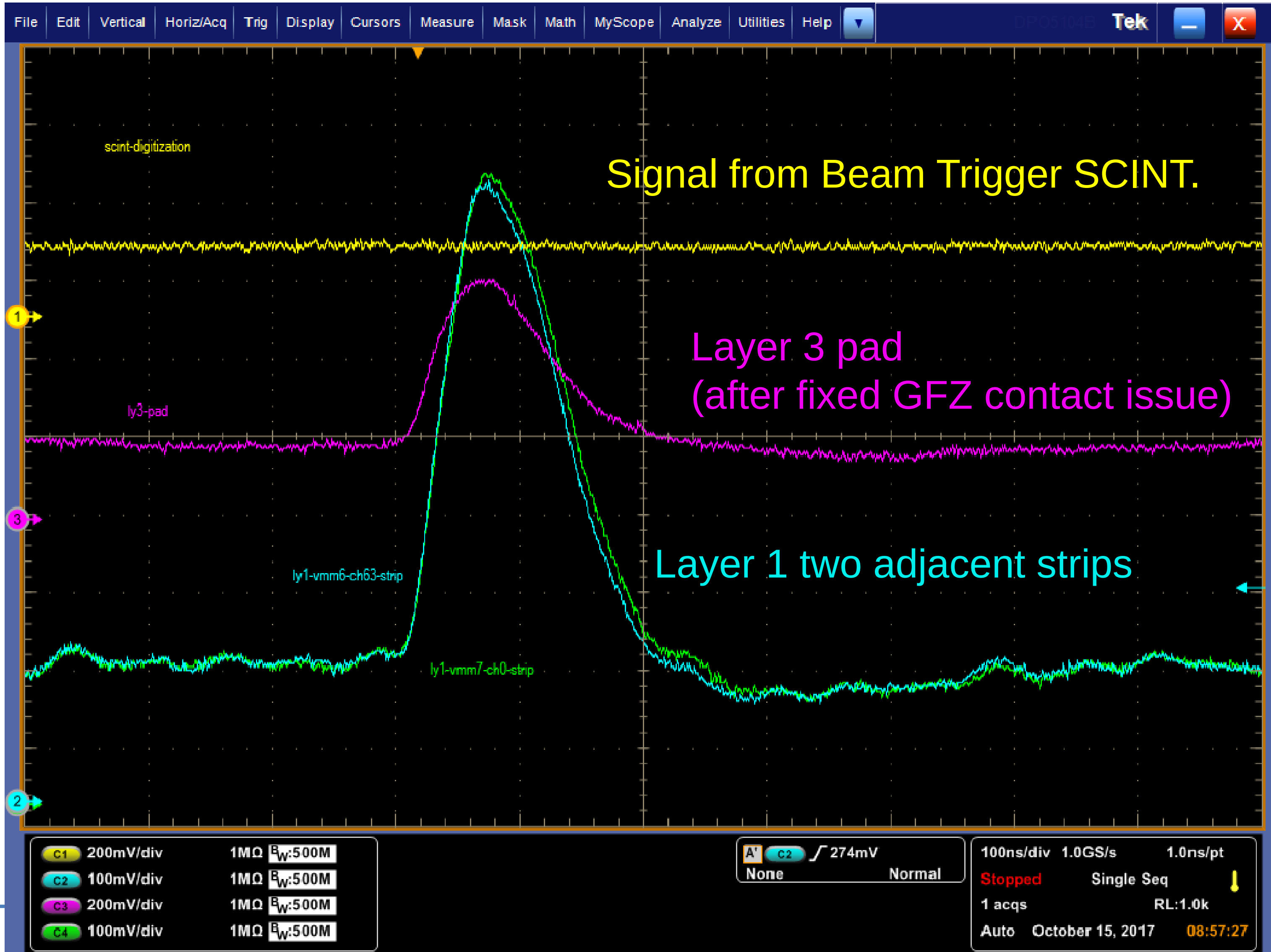


5^{th} Oct.: Full setup (view from top)



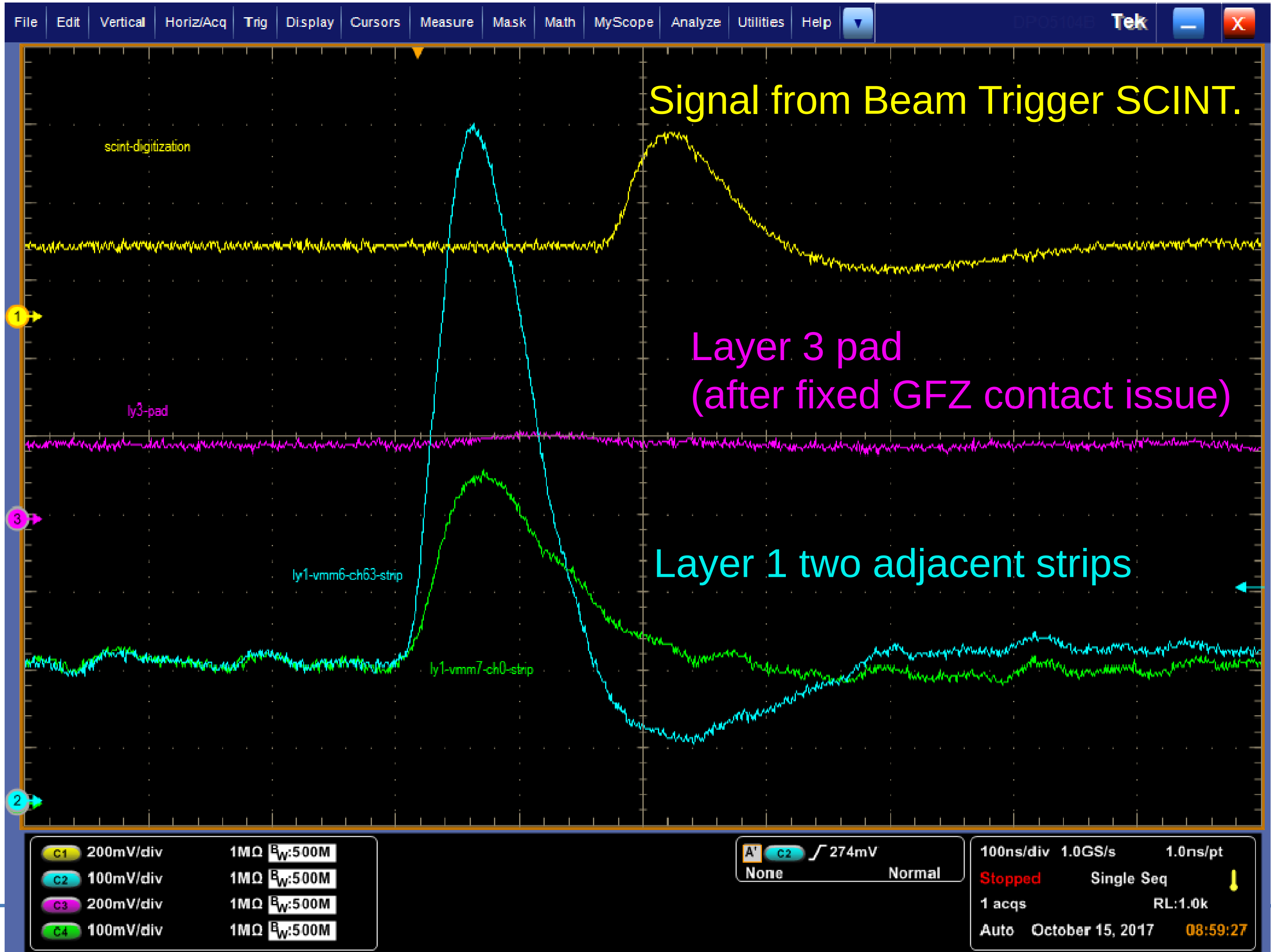
Signals and Noise from FEB

One Cosmic ray event

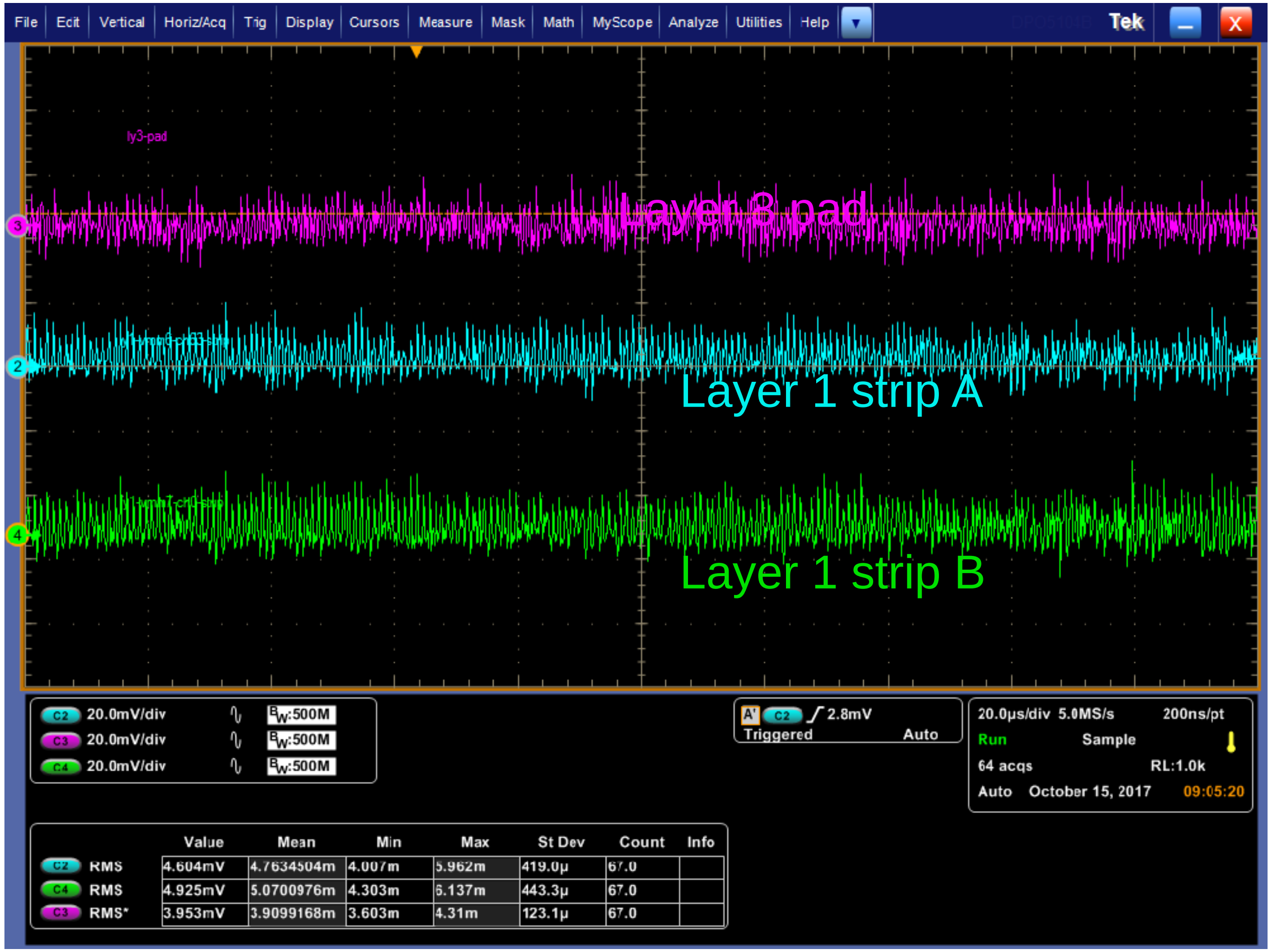


Signals and Noise from FEB

One high energy muon signal from the beam

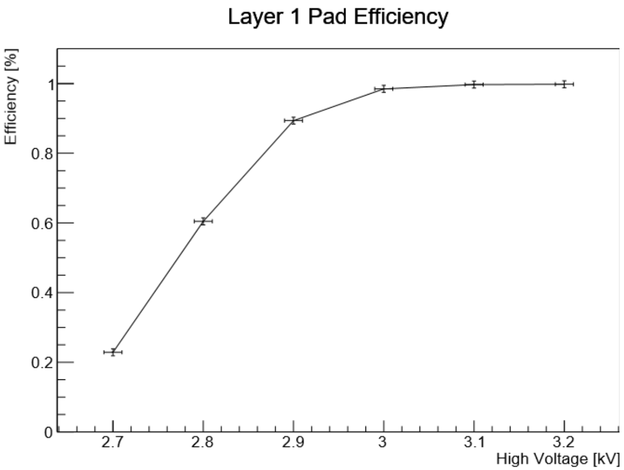


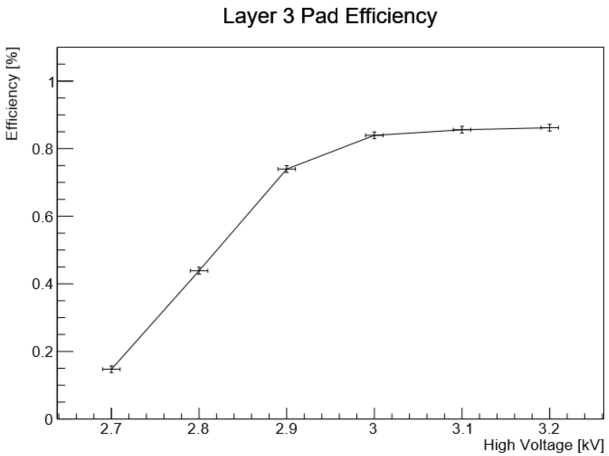
Signals and Noise from FEB

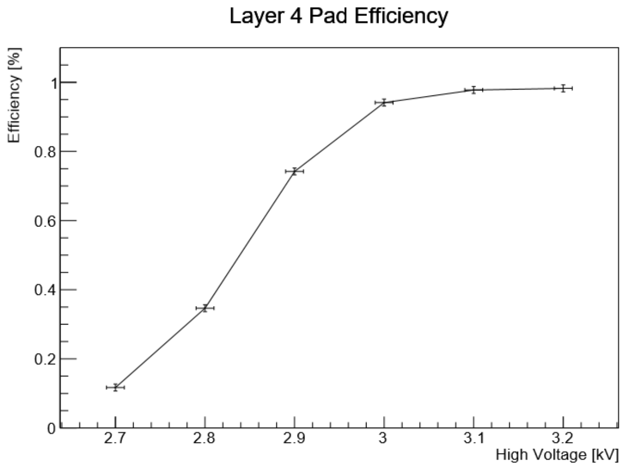


Pads: VMM gain = 3mV/fC, PT=50 ns
Strips: VMM gain = 1mV/fC, PT=50 ns

sTGC Pad效率测试



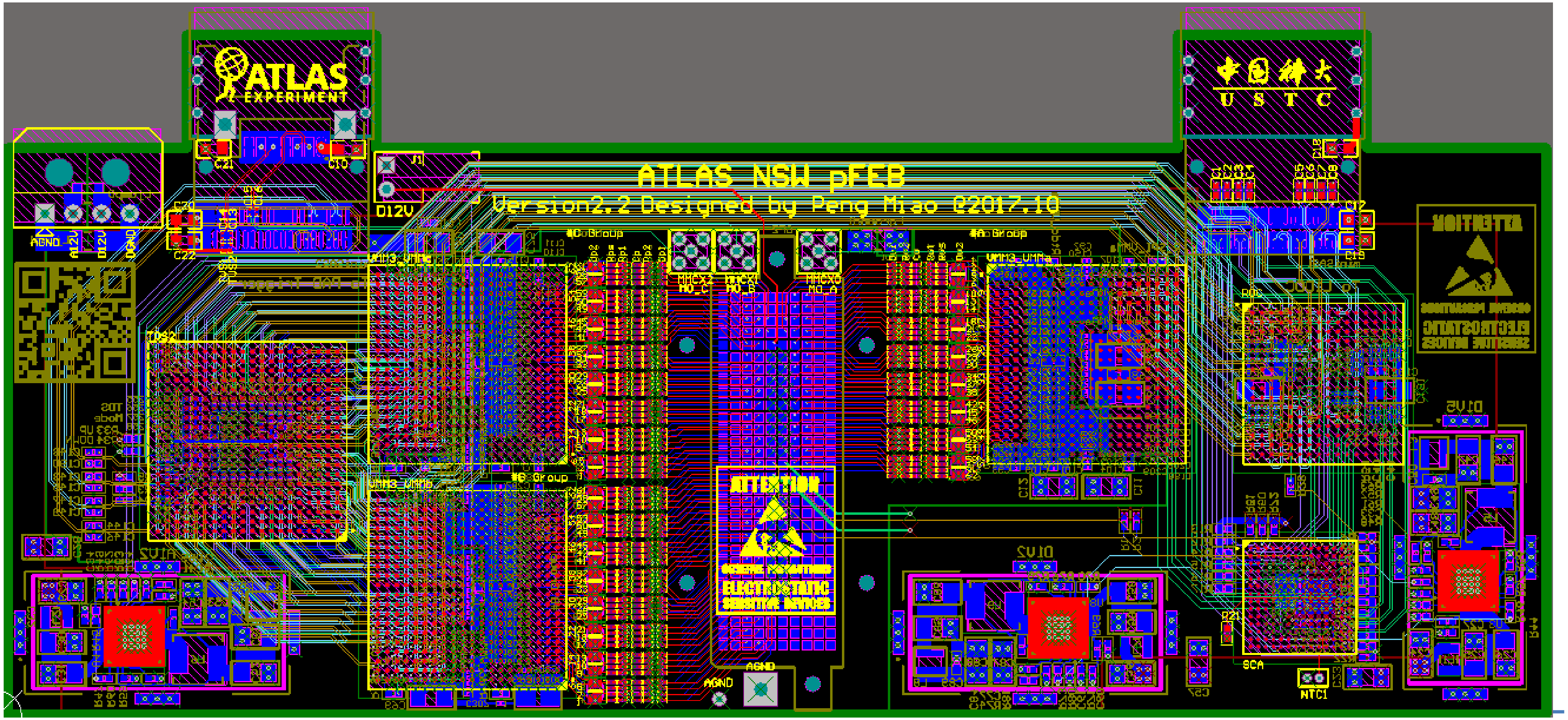




- 只测了三层sTGC Pad的效率
- 在3000V左右探测效率接近100%

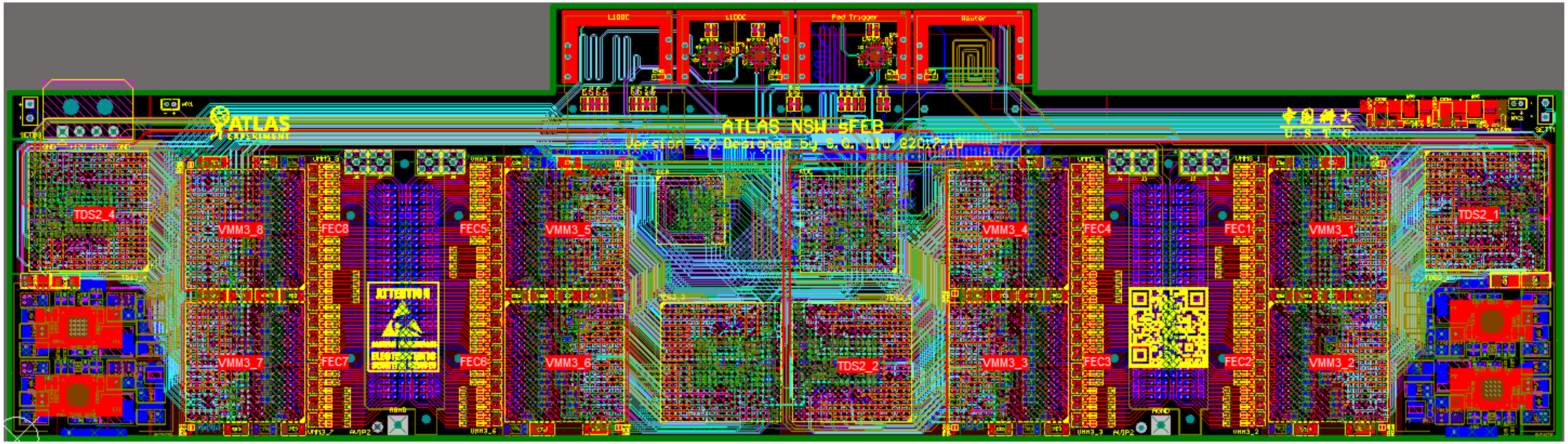
pFEB v2.2 Layout

- Layout completed.

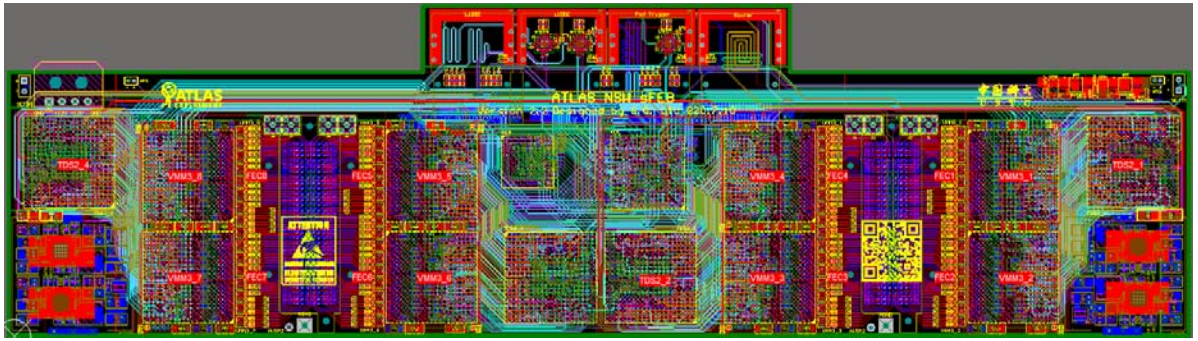


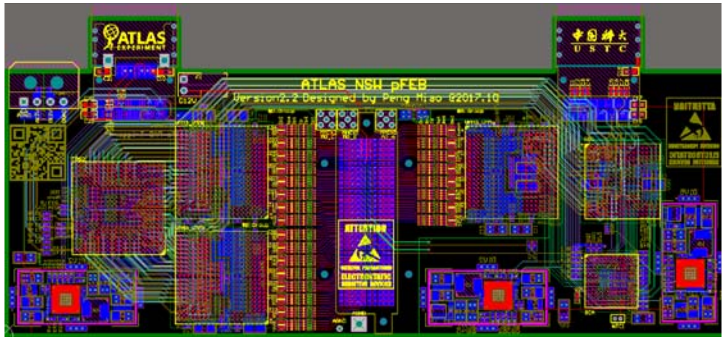
sFEB v2.2 Layout

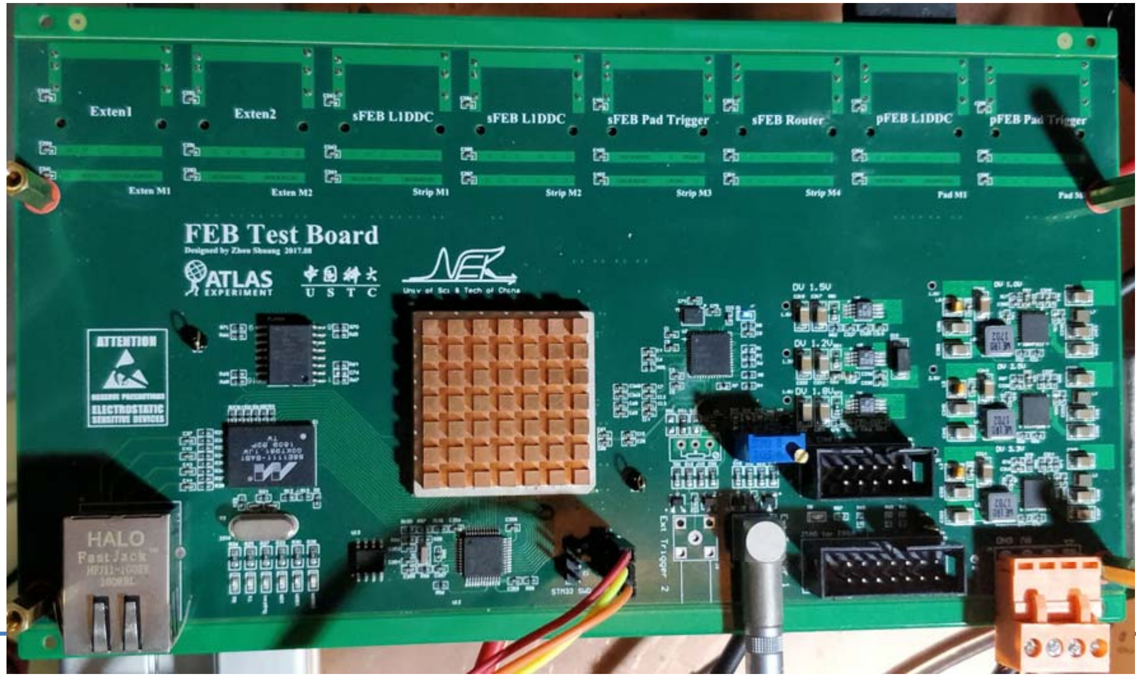
- Ready for production.



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！