

# iRPC 后端触发电子学进展



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2020年8月11日

2020年LHC 探测器升级研讨会

# 报告内容

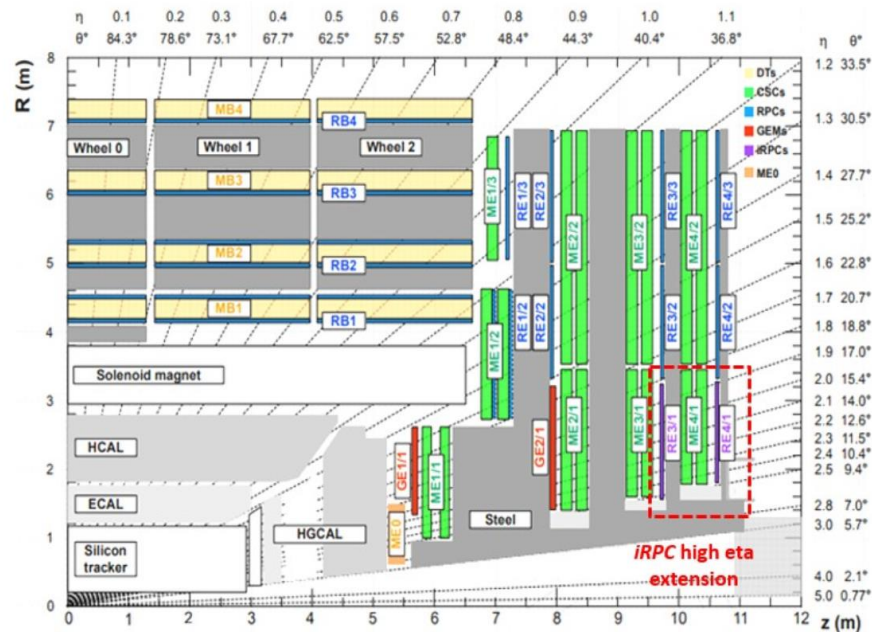


- 课题任务
- 现状与进展
  - 后端读出电子学设计及批量生产进展
  - 在CERN 904楼2D 读出RPC联调取得巨大进展
  - iRPC后端固件开发
  - 文章合作组审核通过
- 小结及后续计划

# 课题任务



- 任务书验收名称及指标：
  - 一级径迹触发模式识别和海量数据触发高速传输板
  - $\geq 32\text{K}/\text{单板}$
  - 单路速率 $\geq 10\text{Gbps}$
  - 单板速率 $\geq 400\text{Gbps}$
- 触发电子学二期升级任务
  - 缪子端盖触发预处理的设计建造
  - iRPC后端电子学的设计与建造



# iRPC后端系统与前端系统的基本框图

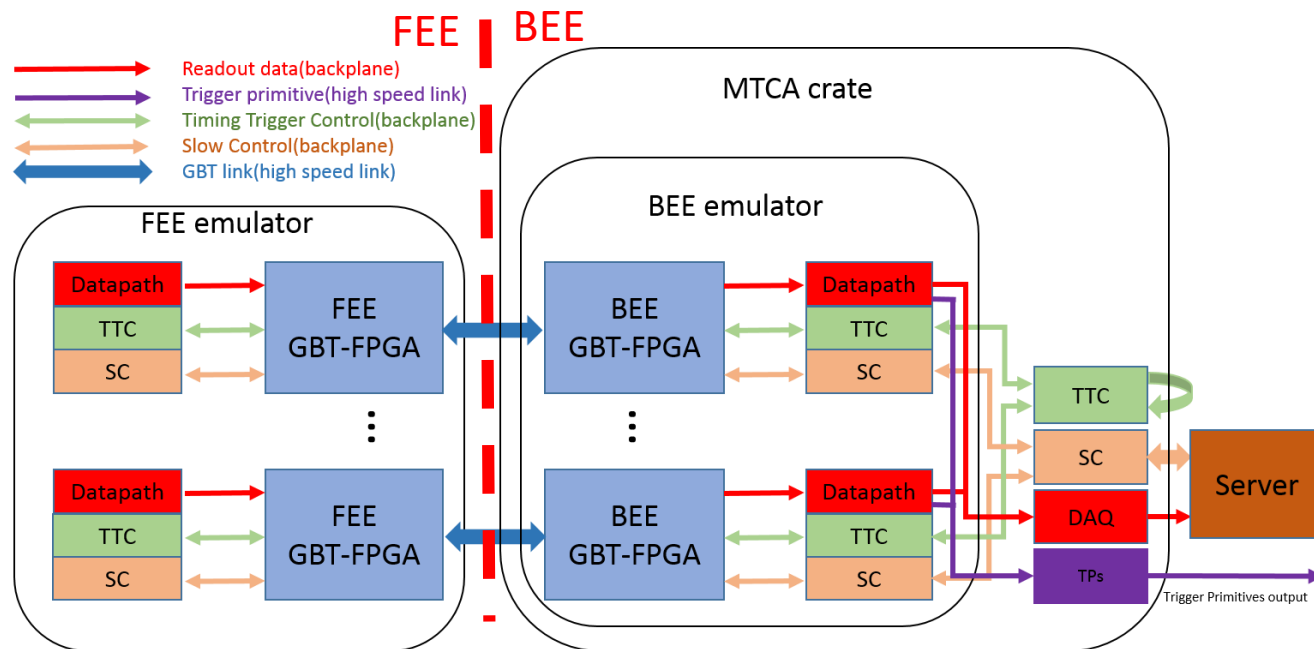


- 重要接口

- 到FEE高速链路
- 到控制PC的接口(SC, RunControl,...)
- 时钟分配(GBT-FPGA)

- 主要功能:

- 数据处理,
- 快 / 慢控制处理,
- 时钟处理

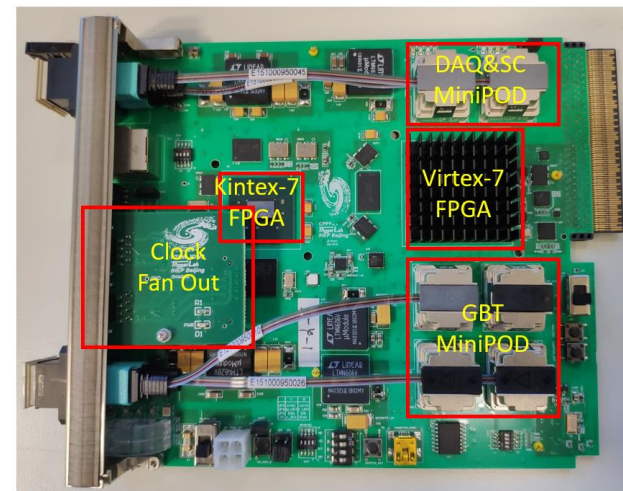
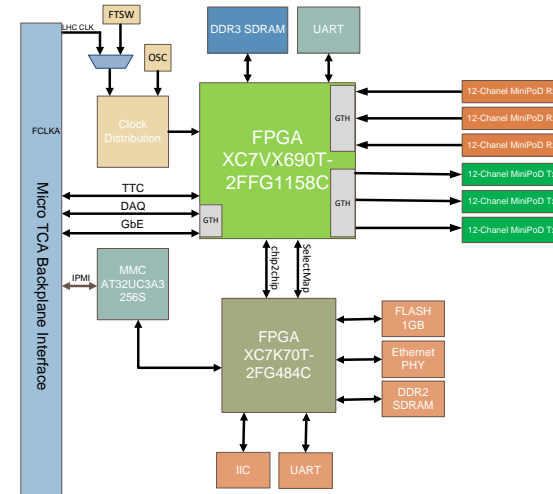


# iRPC后端触发电子学设计



## 后端触发电子学板功能模块:

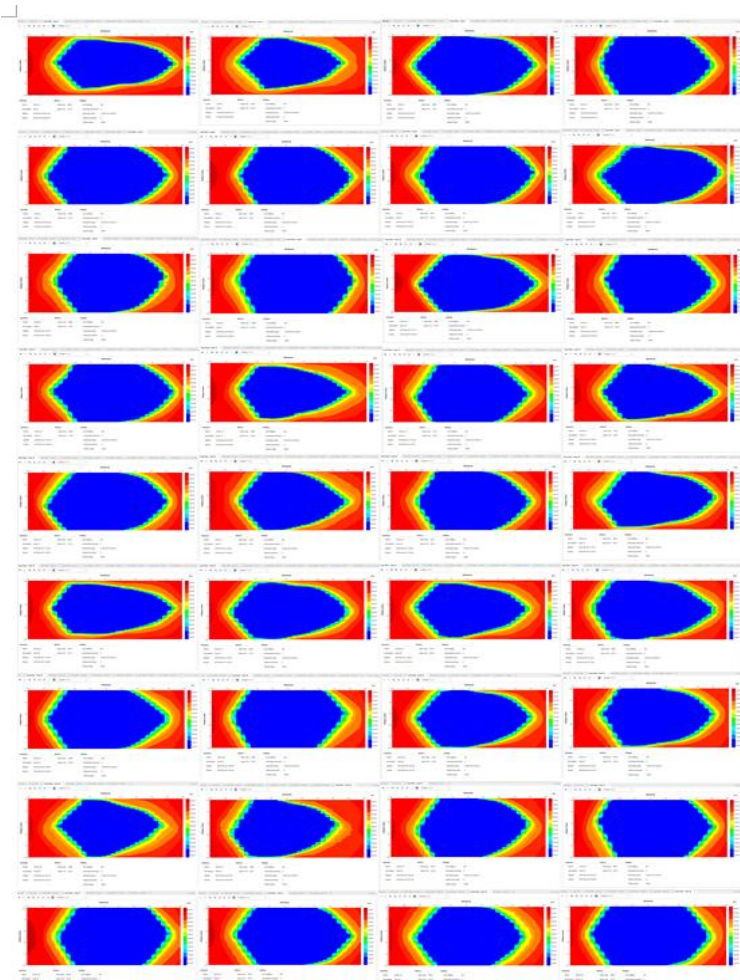
- Clock module
  - Fan out to FEE for temporary test
- Virtex-7 FPGA
  - GBT-FPGA
  - Process
- Kintex-7 FPGA
  - Clock manager for BEE
- MiniPODs
  - DAQ
  - SC
  - GBT links
  - 36 GTH, 11.3Gbps/ch



# iRPC后端触发电子学板测试



Name	Tx	Rx	Status	Bits	Errors	BER	BERT/Reset	Tx Pattern	Rx Pattern	DFE Enabled	Injrd Emr	Tx Reset	Rx Reset	Rx PLL Sta	Tx PLL St	Loopback Mode	Tx Point
Link 0	MGT_X028TX	MGT_X028RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 1	MGT_X029TX	MGT_X029RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 2	MGT_X030TX	MGT_X030RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 3	MGT_X031TX	MGT_X031RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 4	MGT_X032TX	MGT_X032RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 5	MGT_X033TX	MGT_X033RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 6	MGT_X034TX	MGT_X034RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 7	MGT_X035TX	MGT_X035RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 8	MGT_X036TX	MGT_X036RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 9	MGT_X037TX	MGT_X037RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 10	MGT_X038TX	MGT_X038RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 11	MGT_X039TX	MGT_X039RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 12	MGT_X116TX	MGT_X116RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 13	MGT_X117TX	MGT_X117RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 14	MGT_X118TX	MGT_X118RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 15	MGT_X119TX	MGT_X119RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 16	MGT_X120TX	MGT_X120RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 17	MGT_X121TX	MGT_X121RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 18	MGT_X122TX	MGT_X122RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 19	MGT_X123TX	MGT_X123RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 20	MGT_X124TX	MGT_X124RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 21	MGT_X125TX	MGT_X125RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 22	MGT_X126TX	MGT_X126RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 23	MGT_X127TX	MGT_X127RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 24	MGT_X128TX	MGT_X128RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 25	MGT_X129TX	MGT_X129RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 26	MGT_X130TX	MGT_X130RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 27	MGT_X131TX	MGT_X131RX	11.300 Gbps	4.043E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 28	MGT_X132TX	MGT_X132RX	11.300 Gbps	4.044E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 29	MGT_X133TX	MGT_X133RX	11.300 Gbps	4.044E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 30	MGT_X134TX	MGT_X134RX	11.300 Gbps	4.044E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 31	MGT_X135TX	MGT_X135RX	11.300 Gbps	4.044E14	0E0	2.154E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 32	MGT_X136TX	MGT_X136RX	11.300 Gbps	4.038E14	0E0	2.156E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 33	MGT_X137TX	MGT_X137RX	11.300 Gbps	4.038E14	0E0	2.156E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 34	MGT_X138TX	MGT_X138RX	11.300 Gbps	4.038E14	0E0	2.156E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗
Link 35	MGT_X139TX	MGT_X139RX	11.300 Gbps	4.038E14	0E0	2.156E-15	Reset	PRBS 7.0d	PRBS 7.0d	✓	Injrd	Reset	Reset	Locked	Locked	None	✗



后端触发电子学板测试结果:

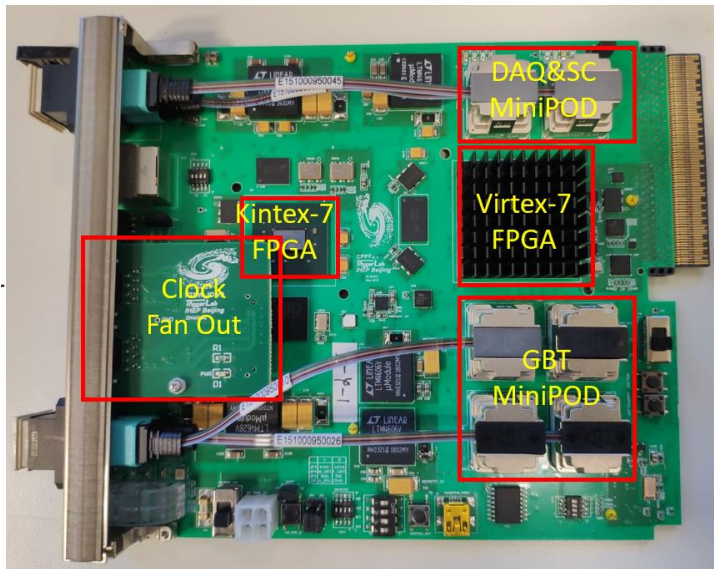
- 单通道达到 11.3Gbps 满足验收指标  $\geq 10\text{Gbps}$
- 单板: 406.8Gbps (36ch\*11.3Gbps/ch) 满足验收指标单板  $\geq 400\text{Gbps}$

# iRPC后端触发电子学板小批量生产进展



iRPC后端触发电子学板生产情况:

- PCB板已经完成;
- 主要芯片FPGA已经到国内;
- 其余芯片已经全部下单,并部分到货。



# 二维读出探测器的联调

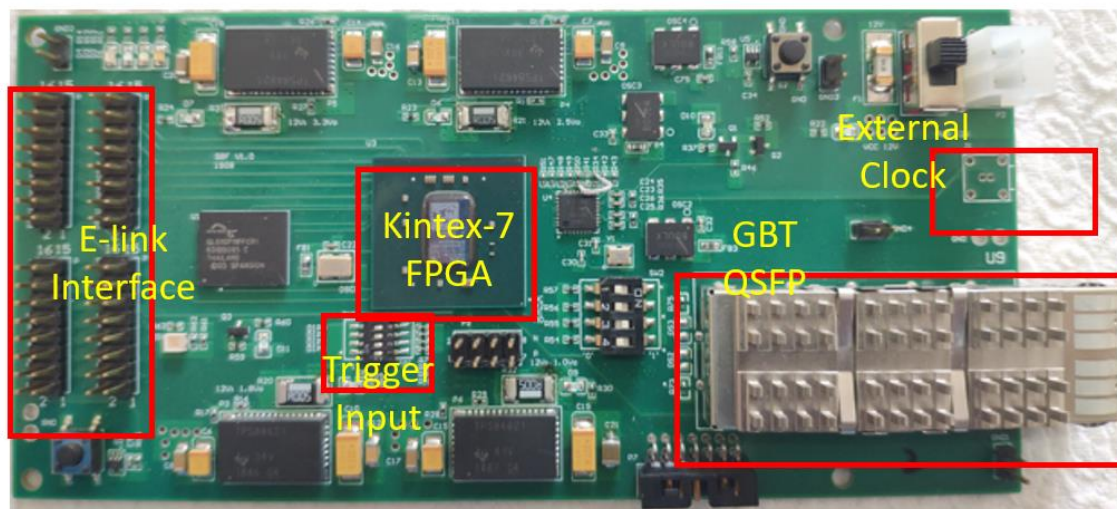
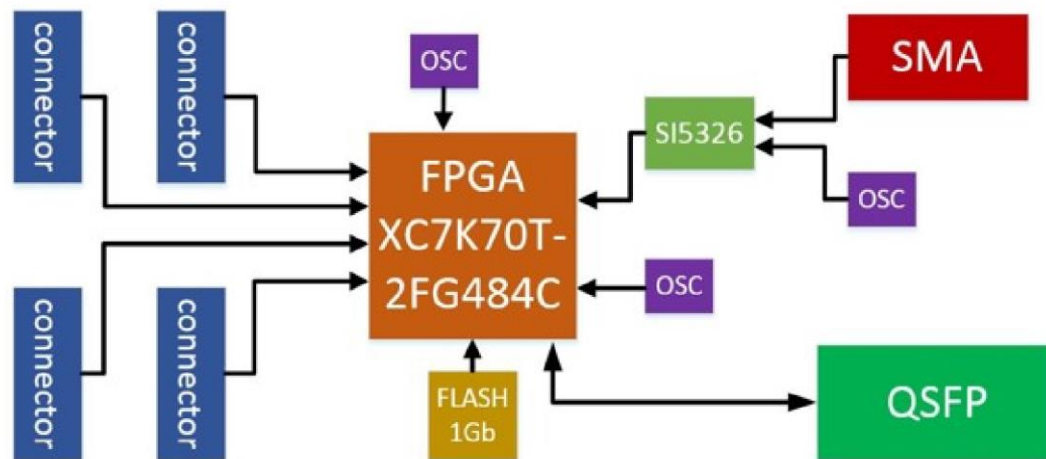
- 为什么二维读出？
  - CMS二期升级将采用双端读出的前端电子学（A方案）
  - 但法国合作者的进度一再拖延
  - 故跟RPC合作组讨论决定联调采用B方案，即二维读出的电子学
- 困难
  - 二维读出的电子学有经过甄别器输出到TDC输入
  - 我们必须基于甄别器输出，设计FEE前端读出电路（数据汇总板GBF。见下页）



# 前端数据汇总板设计

根据需要临时开发的  
汇总板

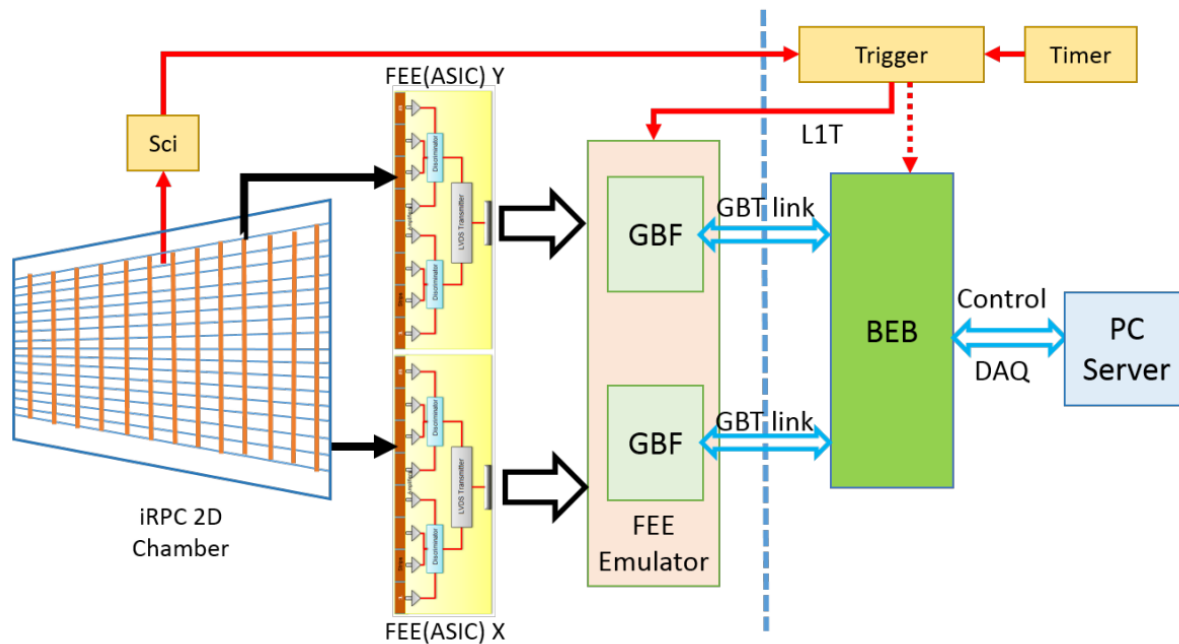
- Kintex-7 FPGA:
  - GBT-FPGA,
  - TDC-FPGA,
  - Rising&Falling Edge, 2.5ns
- E-link Interface:
  - 32 pairs of LVDS input
- SMA Interface:
  - External clock input from BEE
- Trigger Interface:
  - Pulse Generator or Scintillator
- QSFP:
  - 4-channel optical module, GBT link



# 904楼探测器联调测试



- FEE(ASIC)-X
- FEE(ASIC)-Y
- 触发
  - Scintillator
  - Timer
- GBF前端板
  - Data-Collector
- BEE 后端板
- 控制 PC

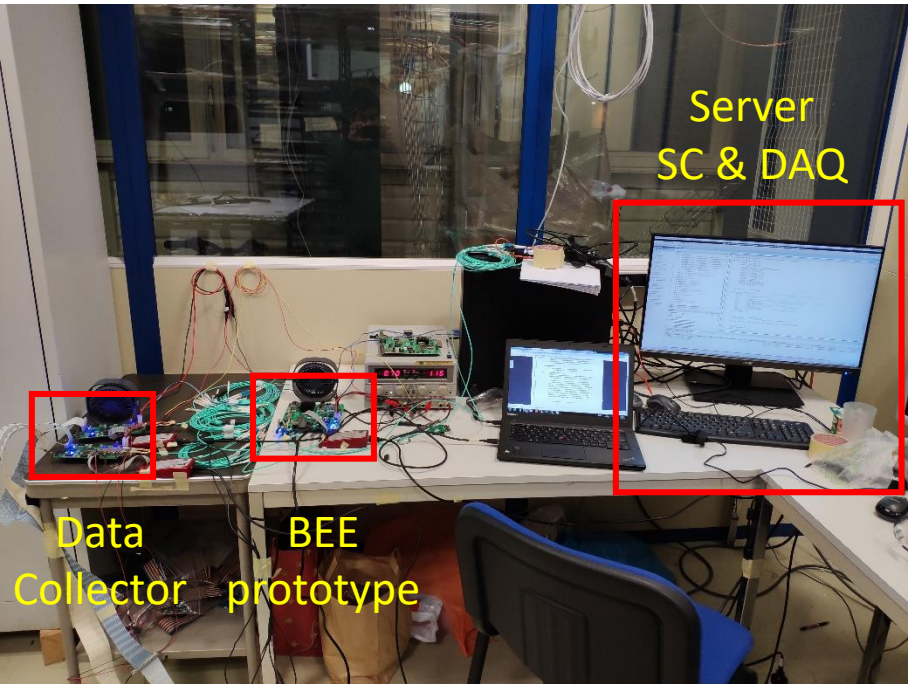
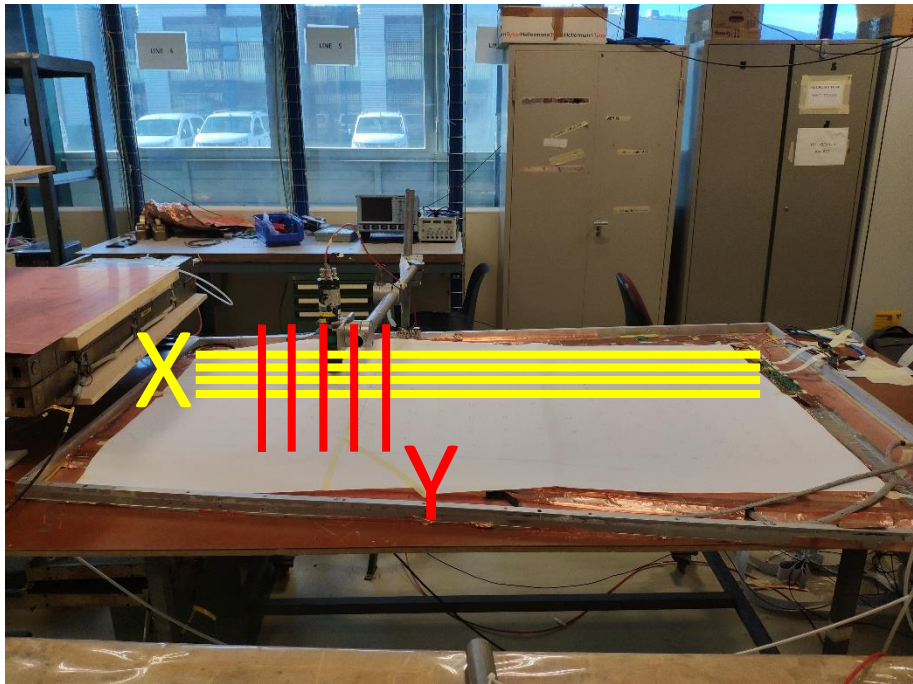


- 参加人员
  - CERN: 曹鹏程, 寇含君, 刘振安
  - 北京: 赵京周, 宋嘉宁, 陶嘉, 龚文煊

# 904楼探测器联调测试



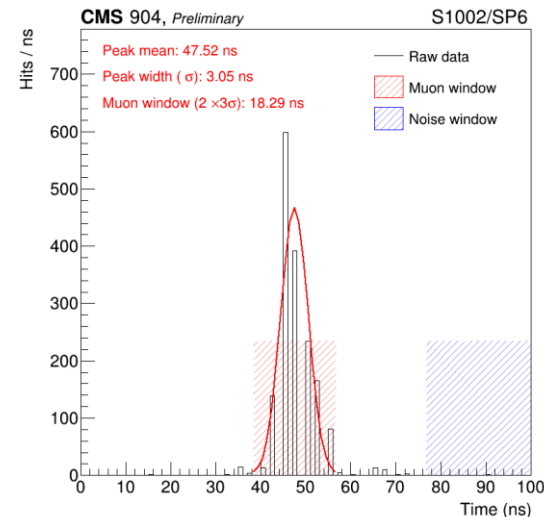
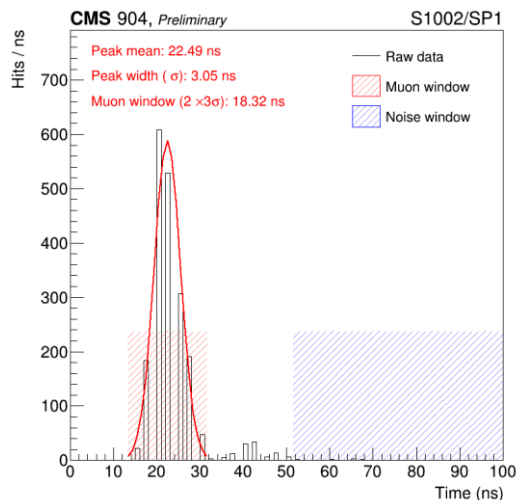
- iRPC 2D chamber
  - X 16 strips, 3 dead
  - Y 10 strips, 1 dead
- Trigger: Timer/Scintillator
- one BEE board
- two Data Collector boards
  - 16 inputs each
- One server for SC and DAQ



# 904楼探测器联调测试结果

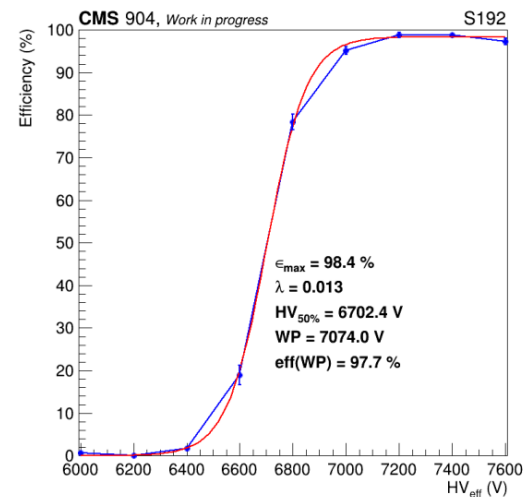
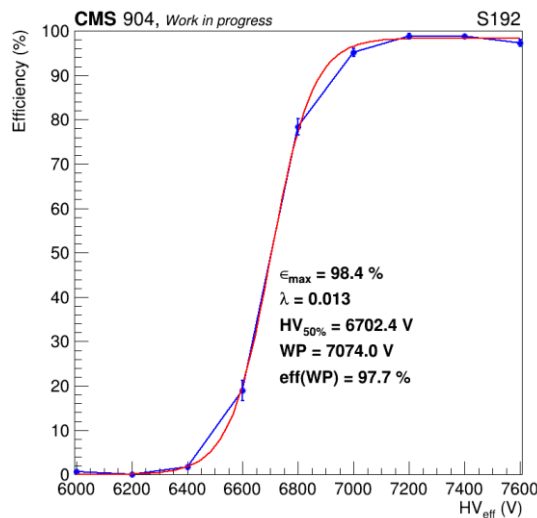


- 通过慢控调整触发窗口结果



- 缪子探测器在不同高压下的效率扫描。

详见曹鹏程报告:  
*iRPC*后端触发电子  
学与2D探测器联调  
测试



# iRPC探测器FEE数据模拟



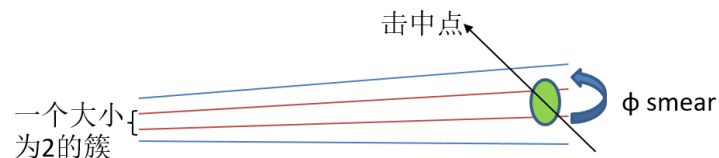
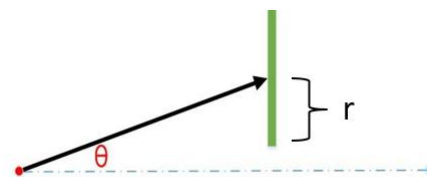
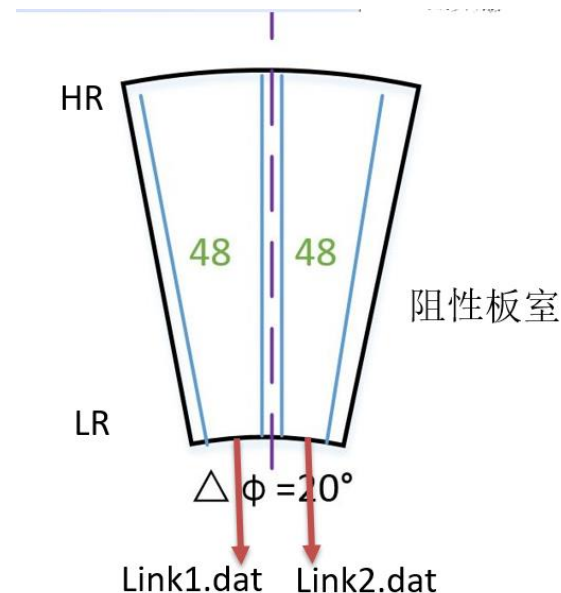
## • 前端电子学模拟

### • 出发点

- iRPC双端读出前端电子学板目前无法联调
- 实验室缺乏实际的前端板和探测器来验证后端电子学系统可行性

### • 解决方案

- 模拟iRPC探测器击中情况产生一个数据源: 根据TDR提供的iRPC参数模拟产生数据文件
- FEE emulator: 模拟前端电子学功能, 与后端进行交互



# iRPC前后端固件开发



## • 前端电子学打包、发送

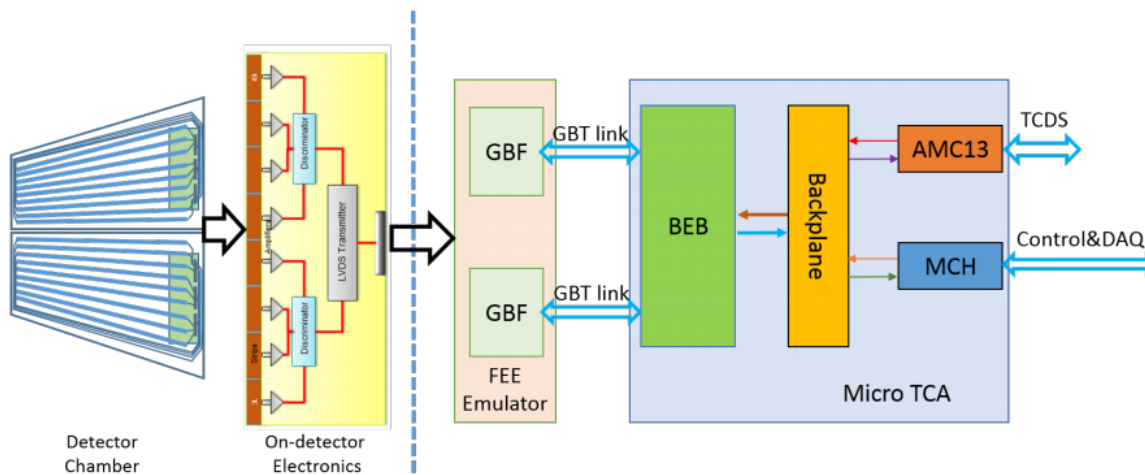
- FEE根据event rate读取模拟数据并加入bcn信息， bcn间隔与event rate相关；
- 数据依次进入mux FIFO、transmission FIFO，通过GBT链路发送给BEE；

## • 后端电子学接收解码、簇查找

- 数据接收后放入demux FIFO；
- 解码后的数据按簇查找算法进行簇查找，给出中心条号，使用查找表给出击中角度 $\phi$ 和半径 $r$ ；

详见寇含君报告：  
*iRPC*触发电子学功能仿真及实现

该部分内容作为  
我们的提议将提交  
合作组，争取被  
采纳



iRPC读出电子学原型系统架构设计示意图

# RPC合作组对工作的认可



- PRC合作组负责人Gabriella对触发组的工作认可：



Università degli Studi di Bari  
Politecnico di Bari

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Dipartimento Interateneo di Fisica  
Via Amendola 174, Bari Italy  
Tel. +390805442346  
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- 1. RPC后端电子学系统做的ATCA的原型设计
- 2. iRPC后端电子学板的设计和原型系统的搭建
- 3. 在CERN 904 原型系统的搭建及与探测器的联调测试

To whom it may concern

As project manager of the RPC subsystem of the CMS experiments at CERN, I certify the progress made by the group of the Institute of High Energy Physics, Chinese Academy of Sciences (IHEP), under the supervision of Prof. Zhen-An Liu. Within the RPC upgrade program for HL-LHC phase, the IHEP group is responsible of developing the new Backend for the present RPC system and for the new RPC stations to be installed at high eta region of CMS. These stations, RPC 3/1 and 4/1, will be equipped with a new generation Resistive Plate Chambers (RPC) detectors (iRPC). In detail, the following milestones have been fulfilled:

➤ **Early 2019:**

- IHEP proposal for a new RPC backend system
- HEP modular ATCA prototype development for the proposal
- Serenity joint work recommendation

➤ **Middle 2019:**

- Development of uTCA board for iRPC backend/off-detector electronics
- Development of iRPC backend demonstration setup

➤ **Early 2020:**

- Development and validation of a backend system at CERN in 904 Laboratory
- Joint test between Backend and an iRPC detector prototype equipped with a new FEB electronics.
- Chamber test with cosmic muons and validation of the Backend system.

I would like to express my congratulation with the great progress done and successfully results obtained.

In case you need more information feel free to contact me.

Yours sincerely,

# 发表文章1篇



- 关于iRPC电子学读出文章1篇，CMS合作组审核通过。
- RDTM已接收。

## 文章在RPC合作组内审核通过（邮件）

Hi Pengcheng,

Yes, from the RPC side the approval is over.  
Thank you for your accurate work.  
Now we are waiting for a Muon decision.  
I think a Muon group reviewer should be already assigned.  
Best!  
Roumyana

• **Roumyana Mileva Hadjiiska**

To: Pengcheng Cao; Sijin Qian  
Cc: Borislav Pavlov

• You forwarded this message on 16/07/2020 11:16.

Hi Pengcheng,

Yes, from the RPC side the approval is over.  
Thank you for your accurate work.  
Now we are waiting for a Muon decision.  
I think a Muon group reviewer should be already assigned.  
Best!  
Roumyana

Noname manuscript No.  
(will be inserted by the editor)

## 1 Research and Development of the Readout 2 Electronics System for the Improved Resistive Plate 3 Chambers in CMS

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18 C. Combaret<sup>i</sup>, M. Gouzevitch<sup>i</sup>,  
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20 H. Mathez<sup>1</sup>, L. Mirabito<sup>1</sup>, K. Shchablo<sup>1</sup>,  
21 I. Bagaturia<sup>1</sup>, D. Lomidze<sup>1</sup>, I. Lomidze<sup>1</sup>,  
22 L.M. Pant<sup>k</sup>, V. Bhatnagar<sup>1</sup>, R. Gupta<sup>1</sup>,  
23 R. Kumar<sup>1</sup>, M. Lohan<sup>1</sup>, J.B. Singh<sup>1</sup>,  
24 V. Amoozegar<sup>m</sup>, B. Boghrati<sup>m,n</sup>,  
25 H. Ghasemy<sup>m</sup>, S. Malmir<sup>m</sup>,  
26 M. Mohammadi Najafabadi<sup>m</sup>,  
27 M. Abbrescia<sup>o</sup>, A. Gelmi<sup>o</sup>, G. Iaselli<sup>o</sup>,  
28 S. Lezki<sup>o</sup>, G. Pugliese<sup>o</sup>, L. Benussi<sup>o</sup>,  
29 S. Bianco<sup>o</sup>, D. Piccolo<sup>o</sup>, F. Primavera<sup>o</sup>,  
30 S. Buontempo<sup>o</sup>, A. Crescenzo<sup>o</sup>,  
31 G. Galati<sup>o</sup>, F. Fienga<sup>o</sup>, I. Orso<sup>o</sup>, L. Lista<sup>o</sup>,  
32 S. Meola<sup>o</sup>, P. Paolucci<sup>o</sup>, E. Voevodina<sup>o</sup>,  
33 A. Braghieri<sup>o</sup>, P. Montagna<sup>o</sup>,  
34 M. Ressegotti<sup>o</sup>, C. Riccardi<sup>o</sup>,  
35 P. Salvini<sup>o</sup>, P. Vitulo<sup>o</sup>, S.W. Cho<sup>o</sup>,  
36 S.Y. Choi<sup>o</sup>, B. Hong<sup>o</sup>, K.S. Lee<sup>o</sup>,  
37 J.H. Lim<sup>o</sup>, S.K. Park<sup>o</sup>, J. Goh<sup>o,t,t</sup>,  
38 T.J. Kim<sup>o</sup>, S. Carrillo Moreno<sup>u</sup>,  
39 O. Miguel Colin<sup>o</sup>, F. Vazquez Valencia<sup>o</sup>,  
40 S. Carpiinteyro Bernardino<sup>o</sup>,  
41 J. Eysermans<sup>v</sup>, I. Pedraza<sup>v</sup>,

## 文章在Muon合作组内审核通过（邮件）

Dear all,

All my editorial comments have been suitably dealt with and I approve going to the next step, whatever that is, and if it is really required for me to say so.

• **Richard Breedon** [breedon@physics.ucdavis.edu]  
Hi Pengcheng,  
To: Pengcheng Cao  
Cc: Jesus Puerta Pelayo; Sijin Qian; Roumyana Mileva Hadjiiska; Borislav Pavlov

Dear all,

All my editorial comments have been suitably dealt with and I approve going to the next step, whatever that is, and if it is really required for me to say so.

Regards, Richard

## 文章在CMS出版委员会内审核通过（邮件）

Dear Jesus, PubComm has no objections if the relevant conveners agree with the author list (and content, of course).  
Best wishes, Claudia

• **Claudia Wulz**

To: Jesus Puerta Pelayo  
Cc: Carlos Laurence; Boaz Klimk; Borislav Pavlov; richard breedon; Pengcheng Cao; Roumyana Mileva Hadjiiska; Sijin Qian

• You replied on 18/07/2020 13:50.

Dear Jesus,  
PubComm has no objections if the relevant conveners agree with the author list (and content, of course).  
Best wishes, Claudia

文章首页



# 小结与后续计划



- iRPC后端触发电子学板小批量生产进展顺利。触发电子学板指标满足验收指标。
- 2020年1-3月在CERN完成了**二维读出探测器**的联调测试，取得巨大成功。
- 实验结果显示高能所iRPC后端系统基本功能正确，数据读出可靠。证明高能所设计的方案基本可行。文章正在发表中。
- RPC合作组对触发组的工作做了认可。
- iRPC后端系统，期待与法国iRPC **双端读出FEE**联调。
- 依据联调结果决定最终量产计划与明年安装时间