CEPC TDR像素型时间投影室TPC探测器束流测试合作讨论会

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Yue Chang, Xin She, Jian Zhang, Hanyu Mao, Jianchun Wang

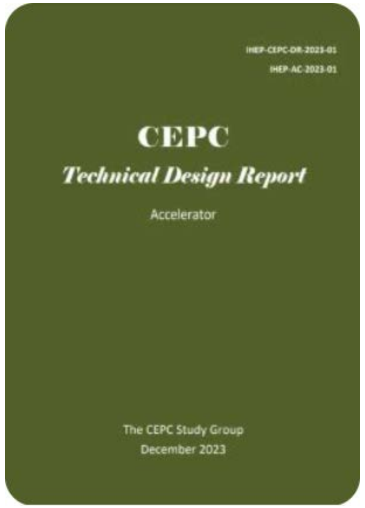
April 24, 2024

主要内容

- 束流测试需求与目标
- 束流测试内容
- 束流测试准备讨论
- 国际合作小结

束流测试需求与目标：Physics requirements of the track detector

- CEPC operation stages: **10-years Higgs → 2-years Z pole → 1-year W**
- CEPC phy./det. TDR (**preparation**)
  - Physics and detector concept designed under the principle.
  - **Requirements may be with regard to runs of Higgs and Z-pole separately**.
    - Mandatory requirements MUST be met.
    - Detector should primarily meet Higgs and run at Z also.



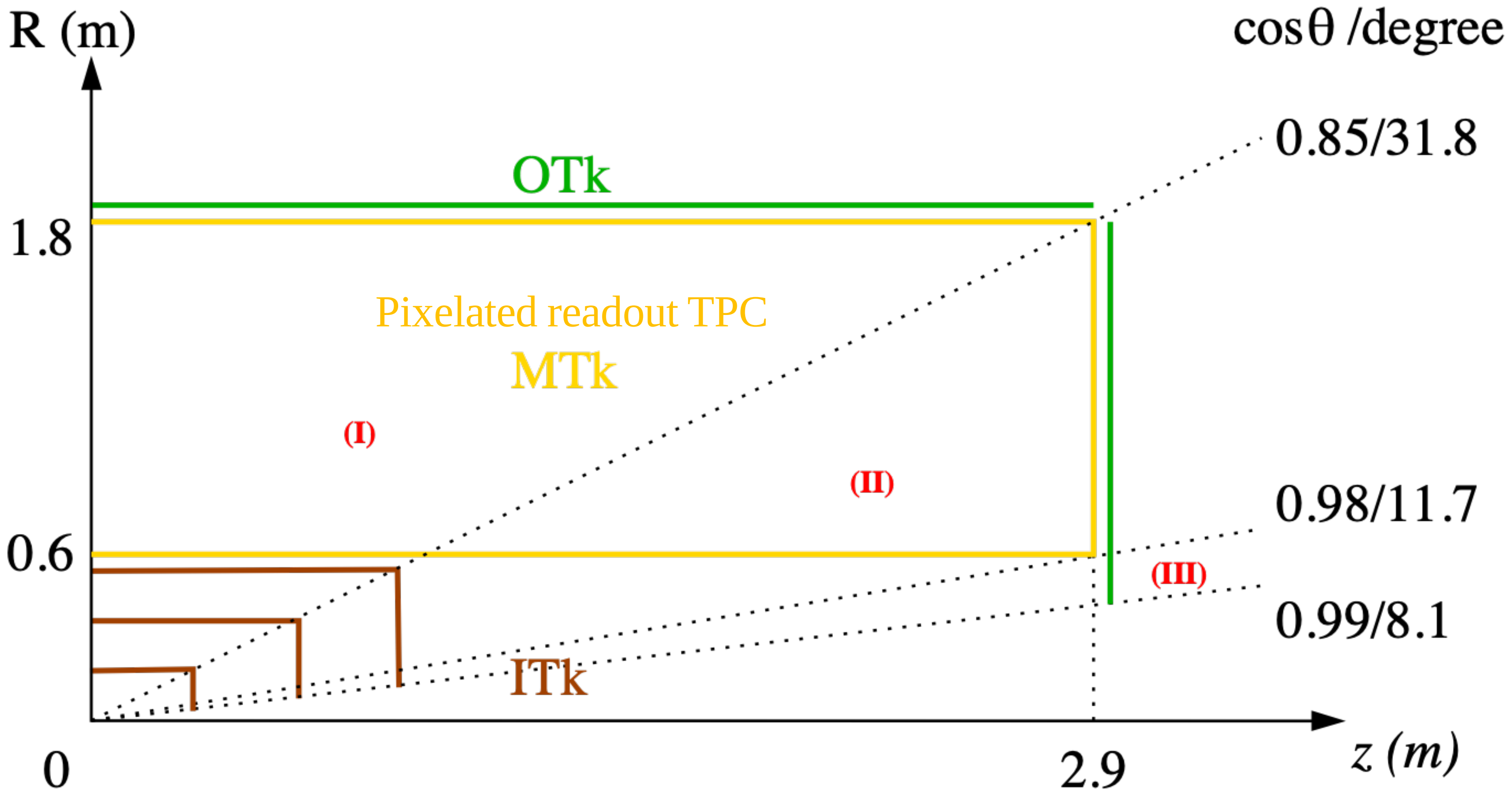
> Chapter 3 of this report outlines that the CEPC is planned to be in operation for 8 months annually, totaling 6,000 hours. This operational schedule is used to calculate the cumulative absorbed doses for magnet coil insulations, as illustrated in Figure 4.2.4.16, considering a 10-year Higgs operation, 2-year Z operation, and 1-year W operation. Figure 4.2.4.17 displays the absorbed doses when an additional 5-year $t\bar{t}$ operation is included. These plots also include the upper limit for absorbed dose in epoxy resin, which is measured at 2×10^7 Gy [11].

CEPC- TDR p116

arXiv:2312.14363

束流测试需求与目标： Track detector system in CEPC Phy.&Det. TDR

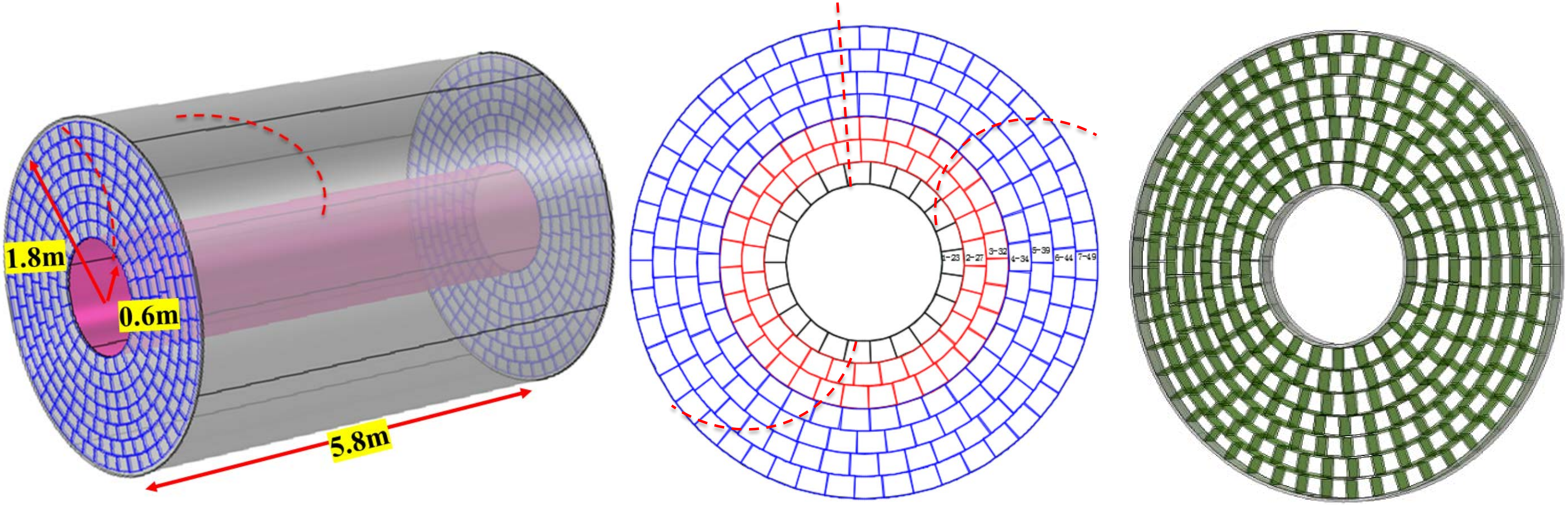
- The track detector system's geometry finalized.
  - All of physics simulation used the updated geometries for CEPC TDR document
  - Pixelated readout TPC as the **main track (MTK)** from radius of 0.6m to 1.8m



Geometry of the track detector system in CEPC TDR

束流测试需求与目标：Easy-to-install modular design of TPC for TDR

- High granularity readout TPC can operate at Higgs run in **3.0T** and Tera-Z run in **2.0T**
- Easy-to-install modular design: optimized modules in the endcap
  - Coverage of the sensitivity readout area increased **to 96%**

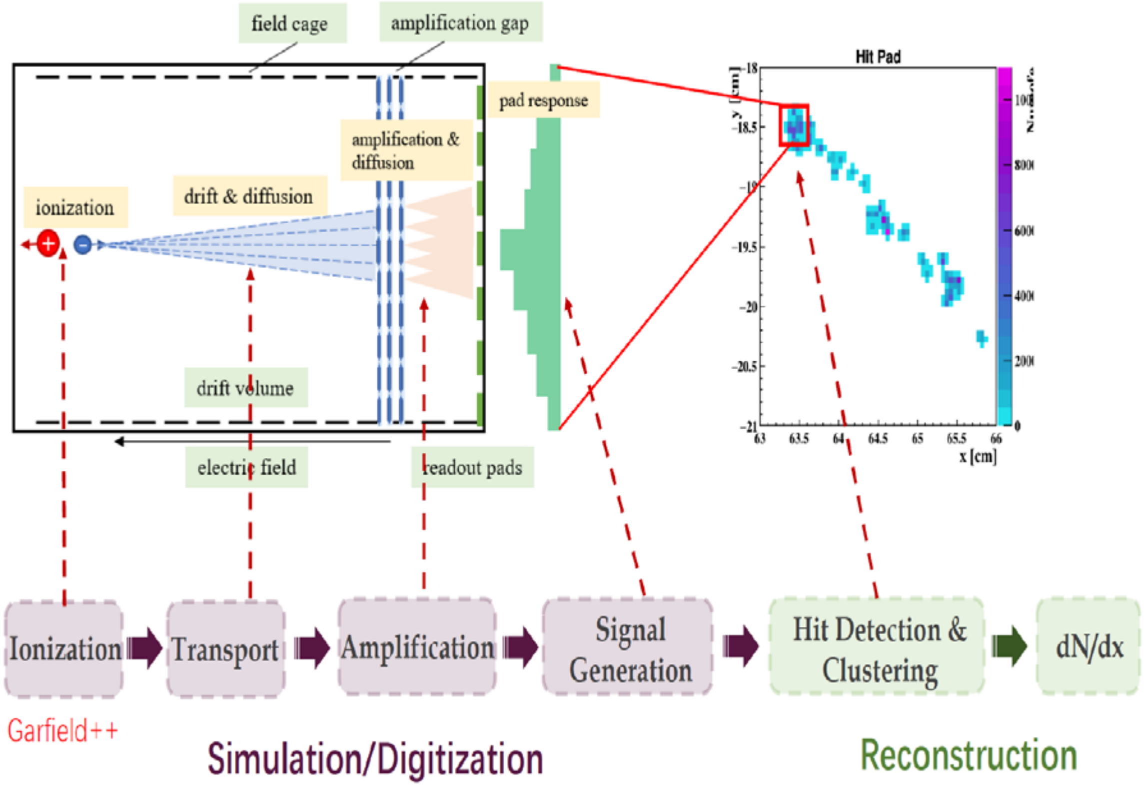


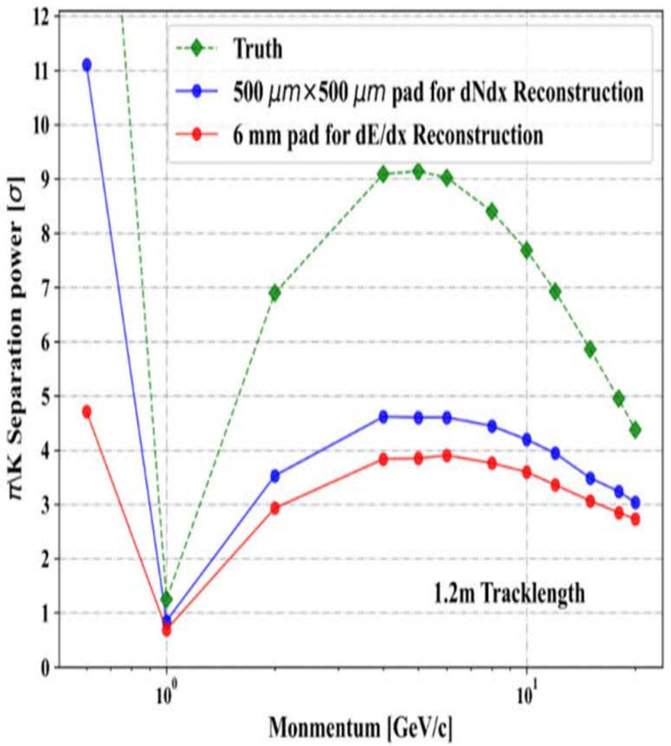
Optimization of Geometry of TPC detector and the Endplate

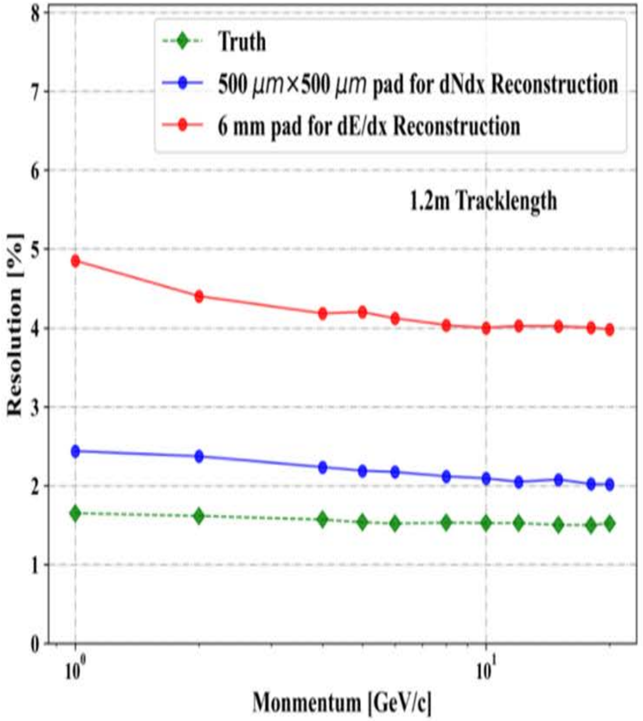
束流测试目标：Improved dE/dx+dN/dx √

- Full simulation framework of pixelated TPC developed using Garfied++ and Geant4 at IHEP
- Investigating the π/κ separation power using reconstructed clusters, **a 3σ separation at 20GeV** with 50cm drift length can be achieved
- dN/dx has significant potential for **improving PID resolution**

$$Sp = \frac{|\mu_A - \mu_B|}{\frac{\sigma_A + \sigma_B}{2}}$$





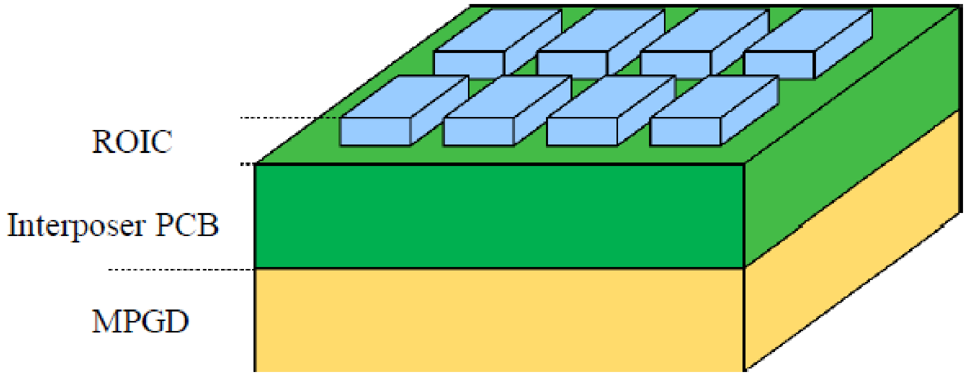


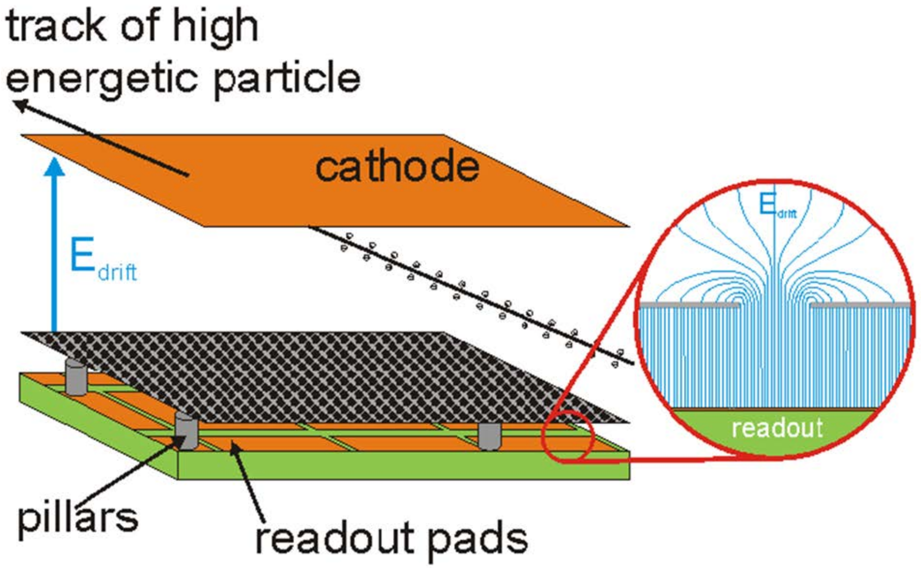
Simulation of TPC detector under 3T/2T and T2K mixture gas

Cite#5 DOI: 10.22323/1.449.0553
Cite#6 EPS-HEP 2023 talk by Yue Chang

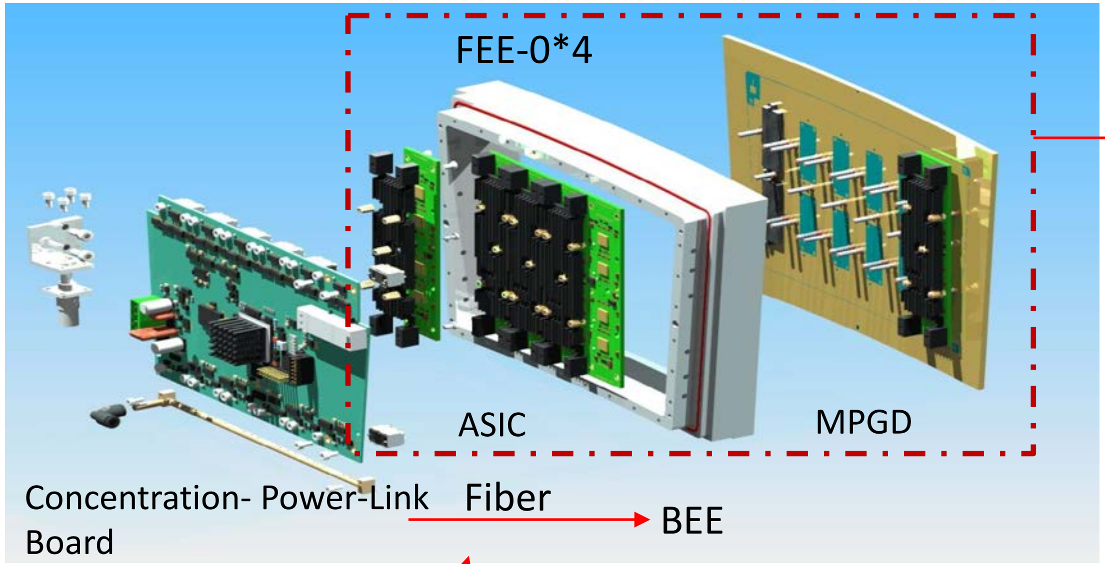
束流测试目标： Pixelated readout TPC technology for CEPC TDR

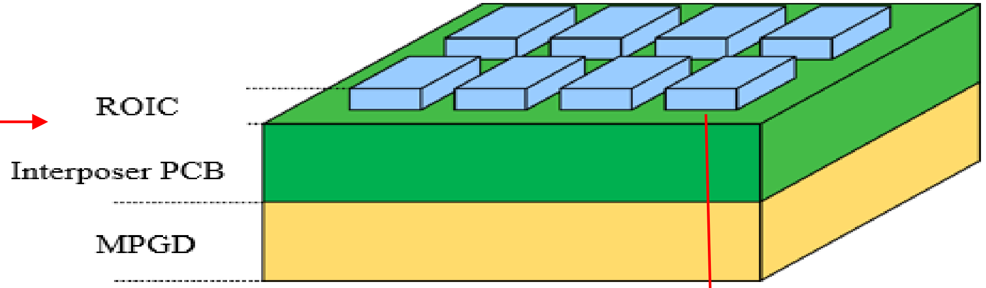
- A pixelated readout TPC is **a good option to provide realistic physics requirements** of Higgs Physical and Tera-Z Physics also (2E36) at CEPC.
    - Pixelated readout→ better resolution → low gain → less distortion
- **束流测试目标实现**
    - **Large prototype TPC的同等尺寸模块与测量条件实验**
    - **实现30mm-50mm 5GeV电子束径迹测量**
    - **在1.0T磁场下完成实验测量**
    - **实现PID的研究，为TDR提供实验依据**
    - **冷却系统？**





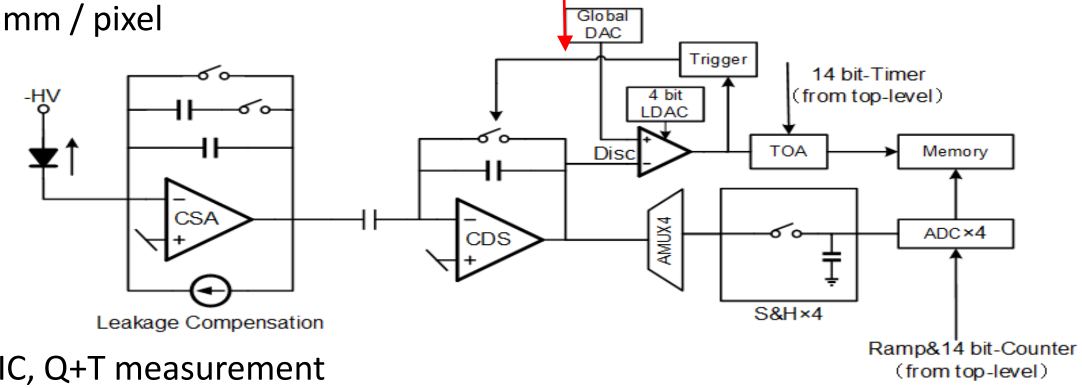
束流测试内容： Readout scheme of Pixelated readout CEPC TPC





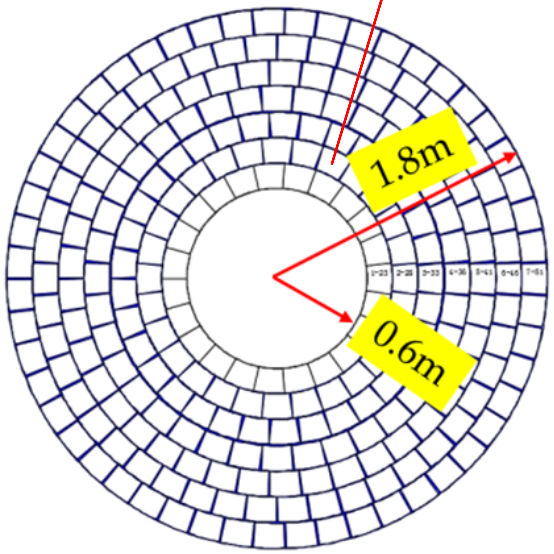
An integrated board with ASIC & MPGD, N(now 4) for a module

0.5mm*0.5mm / pixel



128 chn ASIC, Q+T measurement

142.8k pixel/module → 1115 chip/module→ 279 chip/FEE-0



~248 Module/Endplate

Power:

Limit: <10 kW/endplate ~ 39.7 W/module ~10 W/FEE-0

35mW/ASIC ~ 280uW/chn

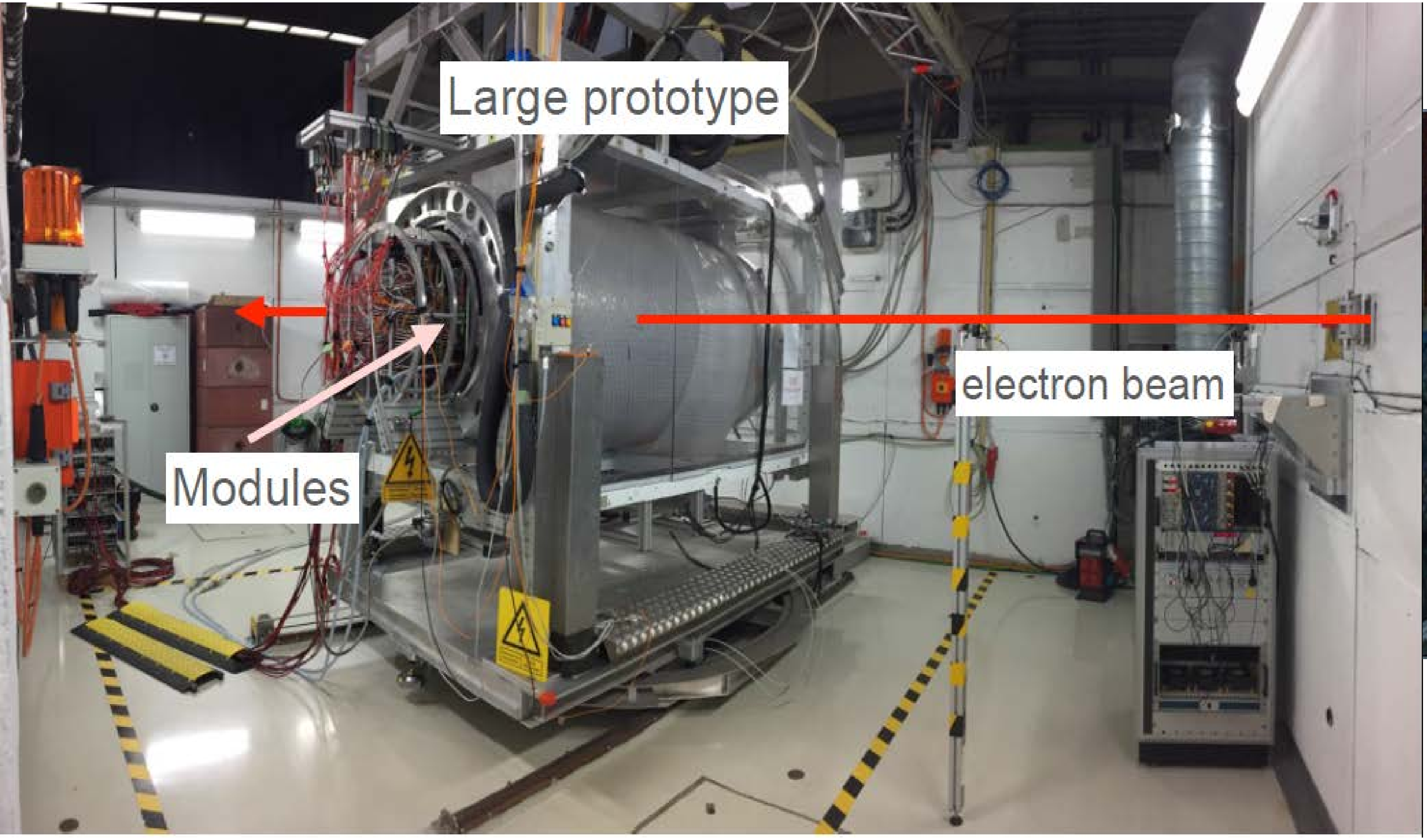
Data rate:

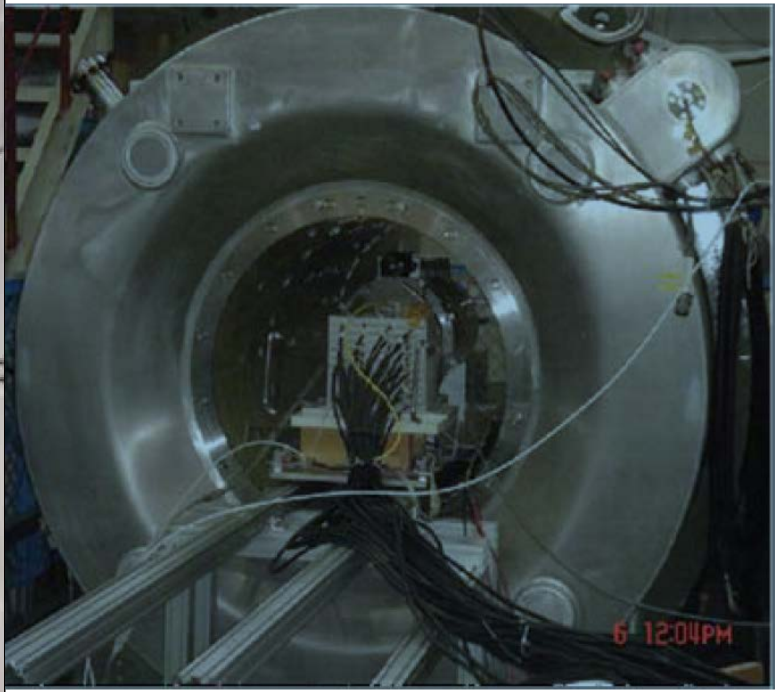
12,000 hit/particle, 32b/hit, @ 40M BX Tera-Z pole

1 Module: **0.05Gbps (Maximum, Inner radius of TPC)**

束流测试内容

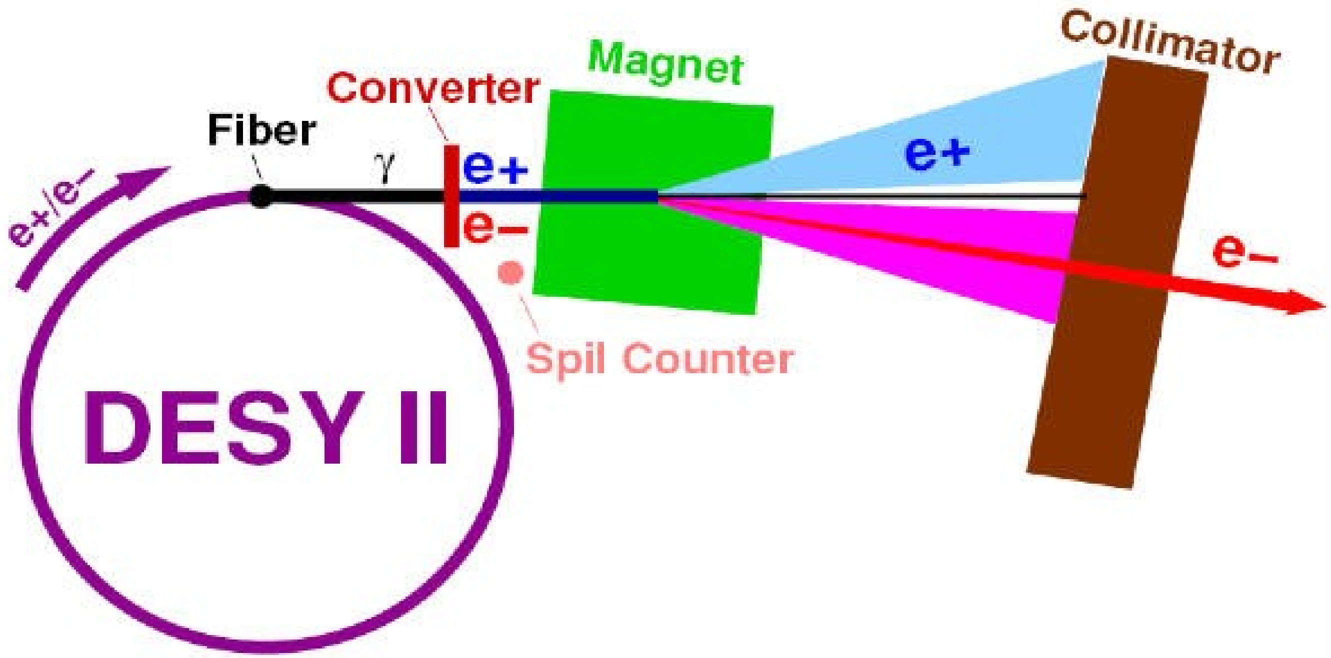
- 测试场所：德国汉堡DESY T-21测试束流站
- 束流情况：5GeV可调， 电子束，触发率`1-2kHz以内。



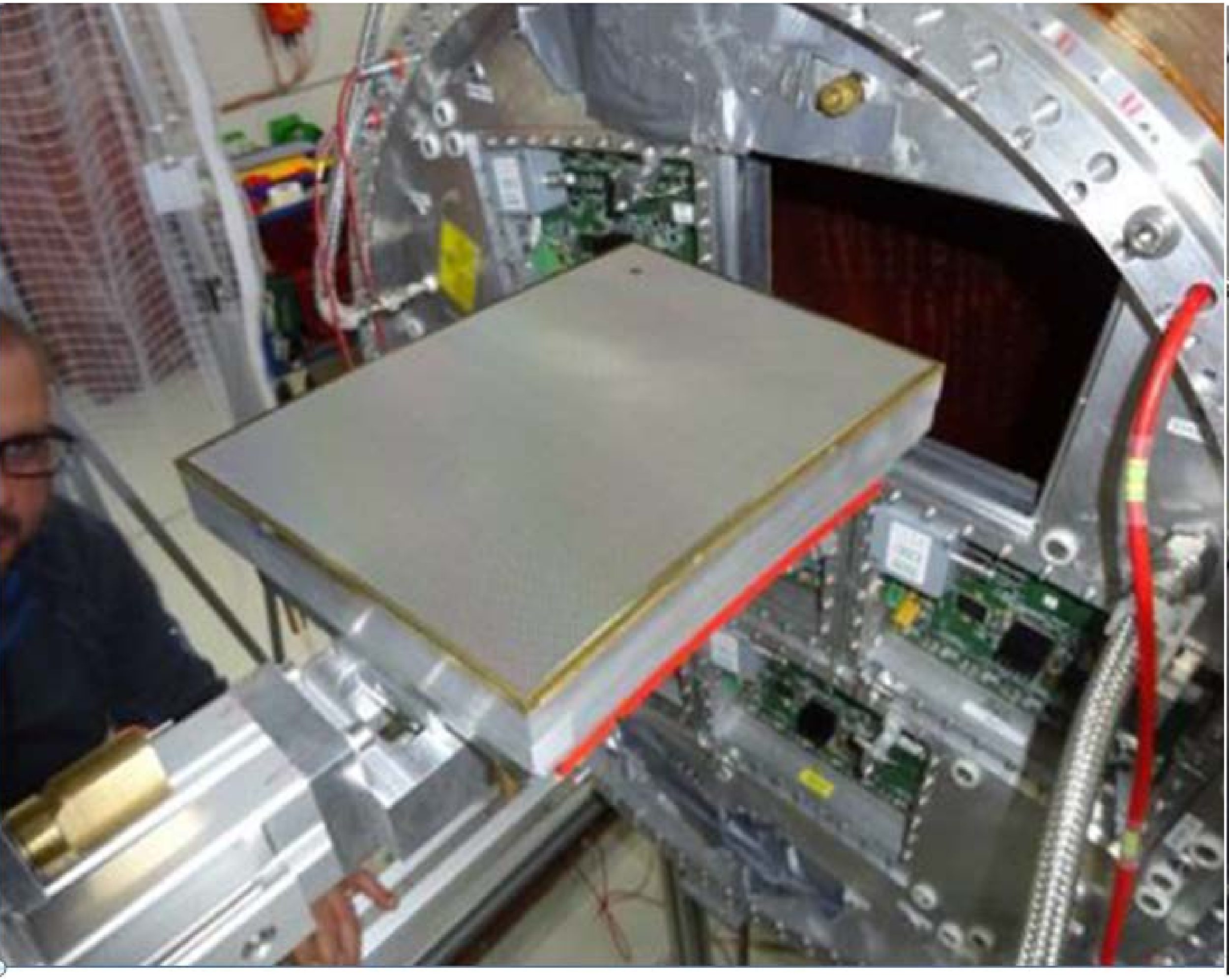


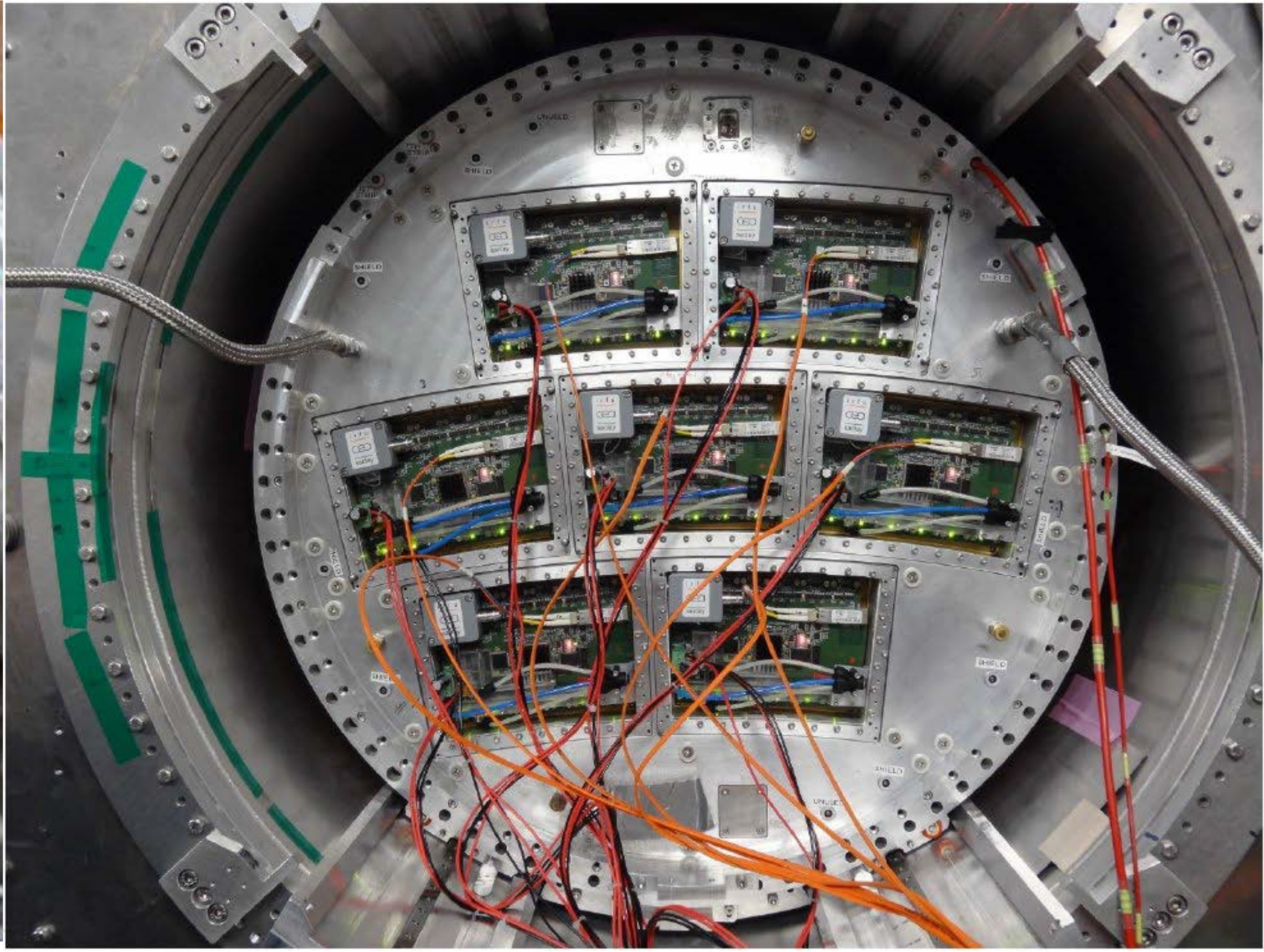
束流测试内容

- 束流情况
  - Initial beam :6.3GeV
  - Initial beam: 6.31E9
  - Test Beam: 5.0GeV

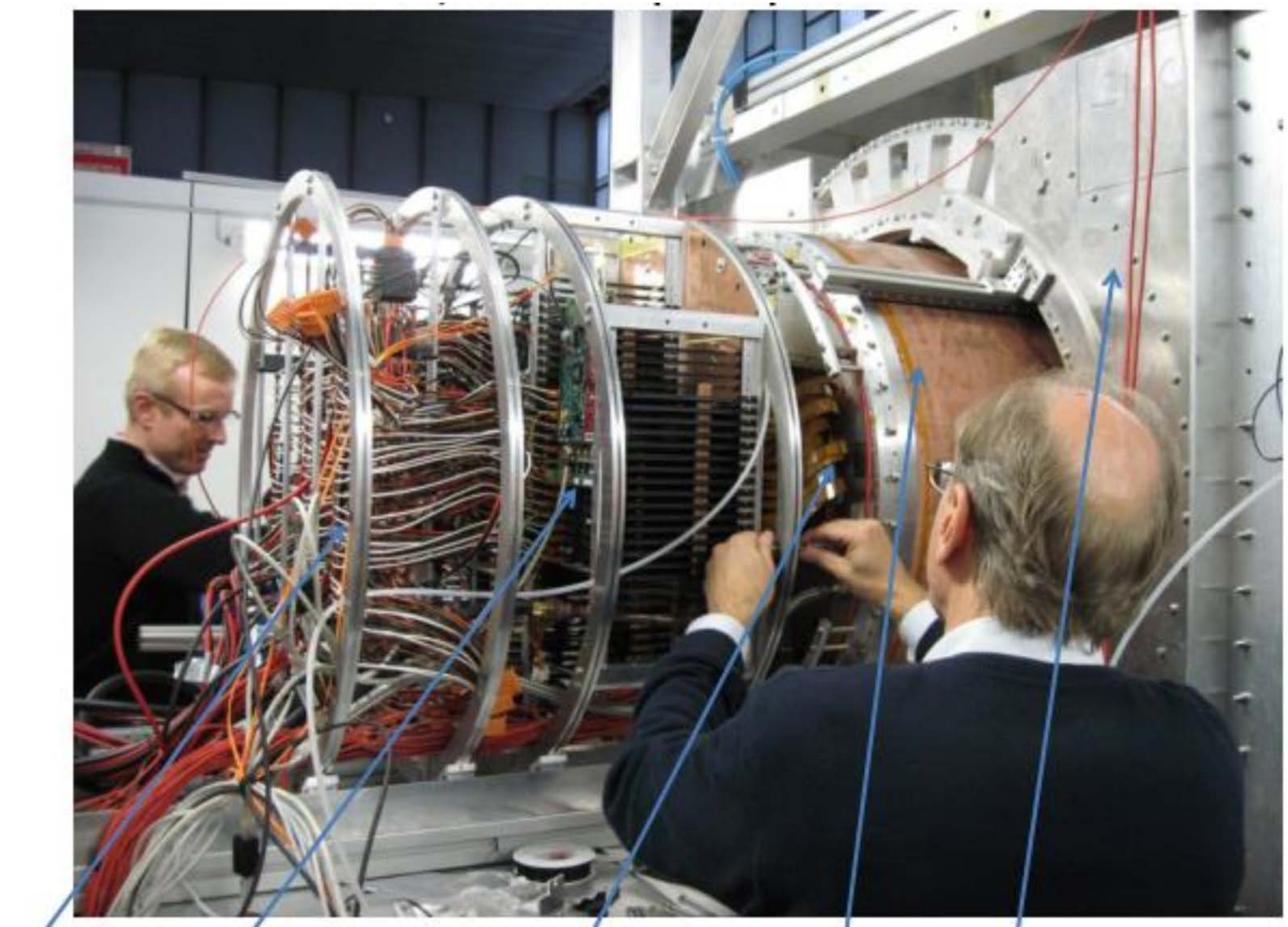


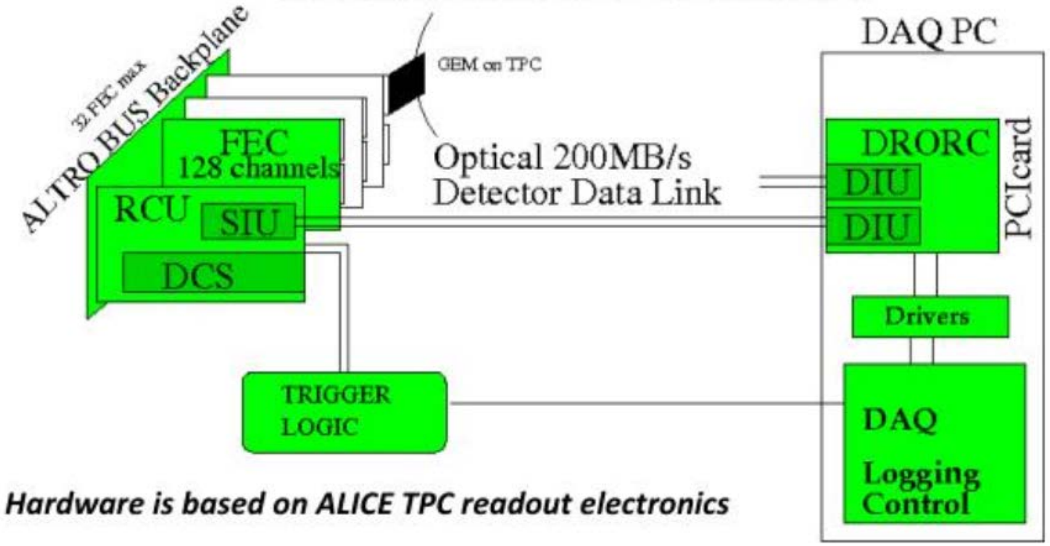
束流测试内容 – TPC module



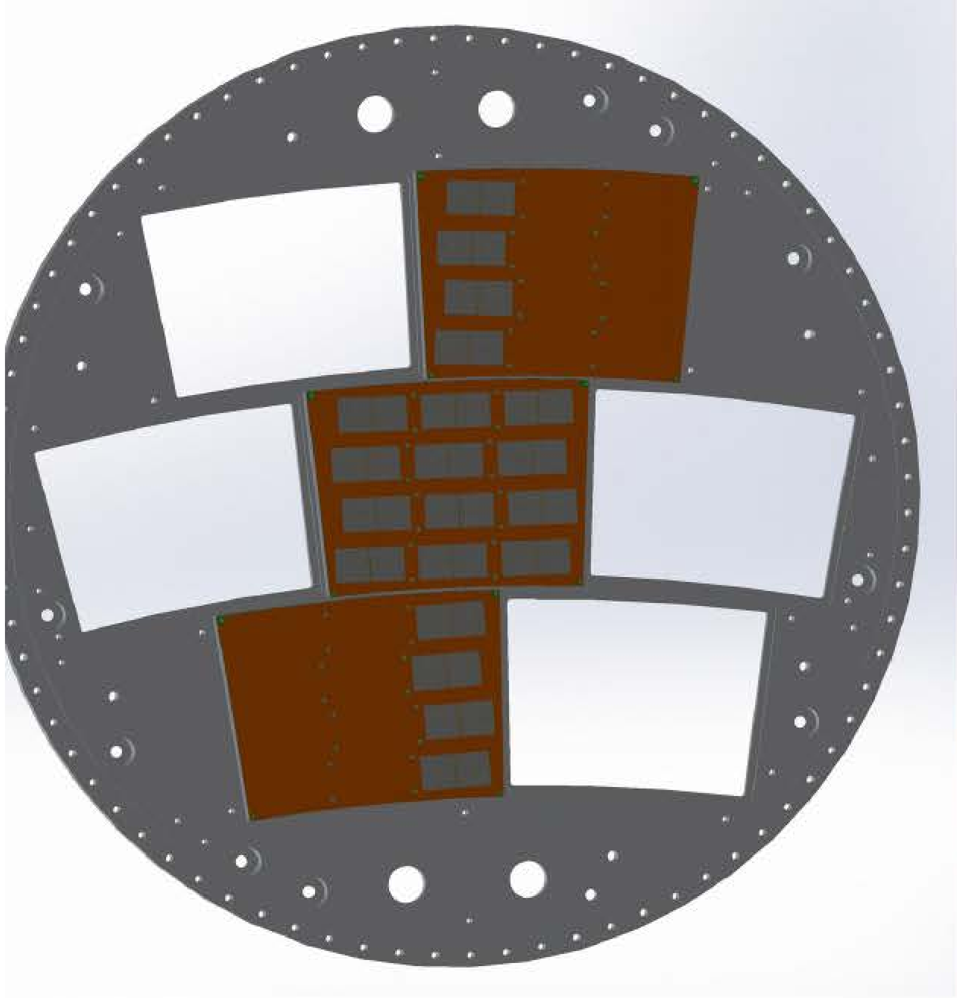


束流测试内容 – Pad readout实验

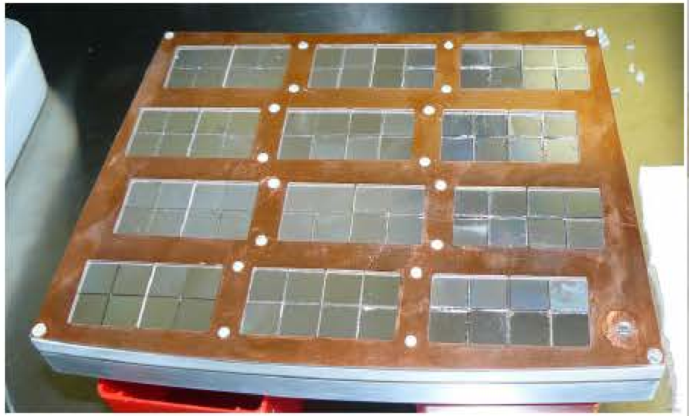


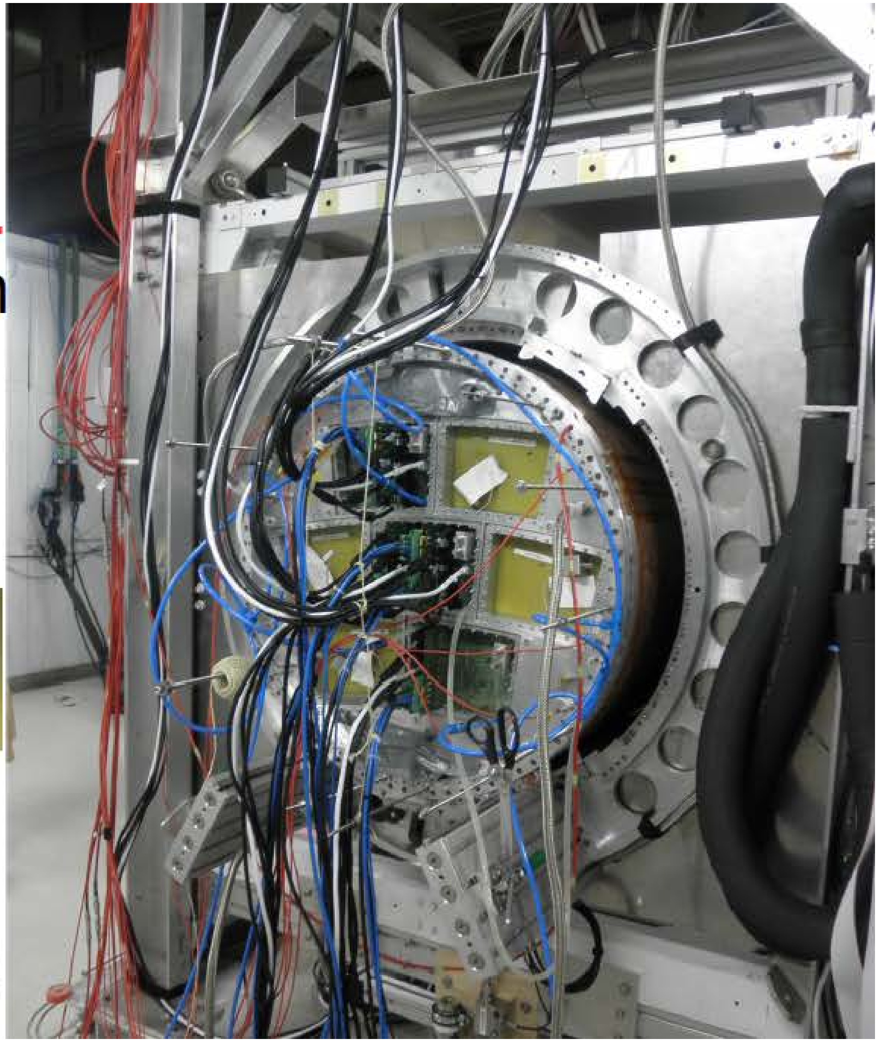


Hardware is based on ALICE TPC readout electronics

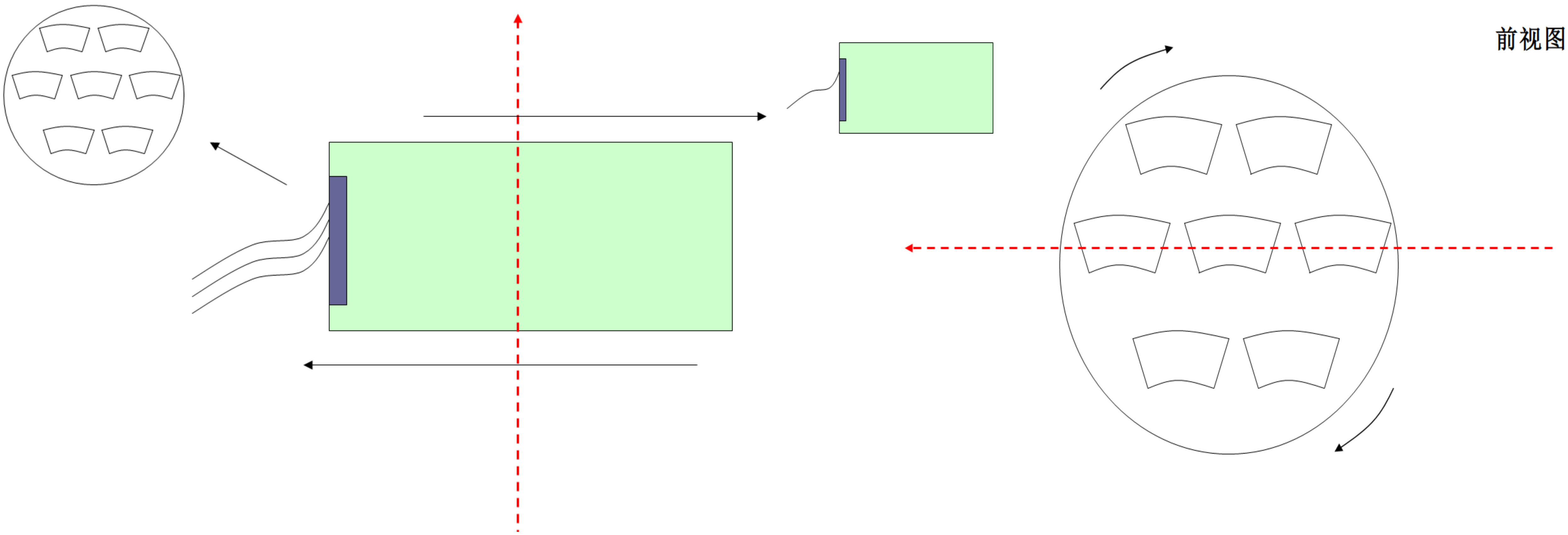


The test beam was a huge success: A pixel TPC is realistic. During the test beam we collected ~10^6 frames at a rate of 4.3-5.1 Hz.

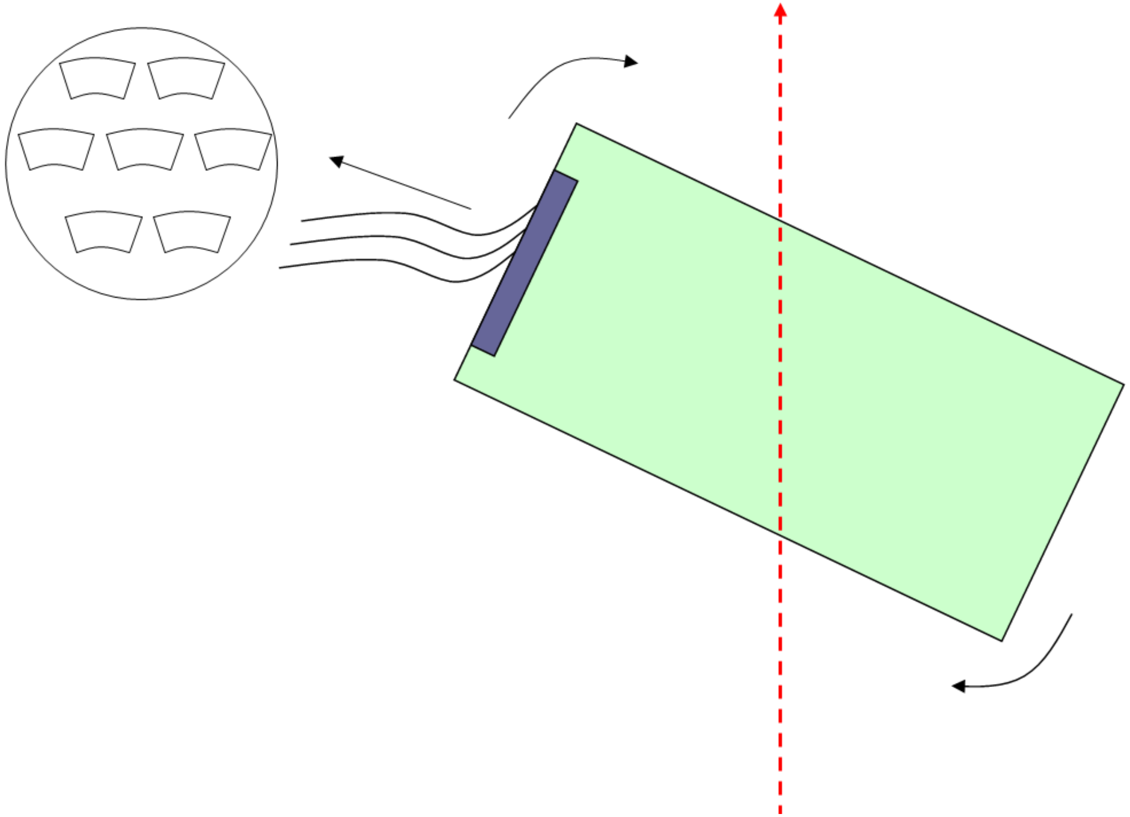


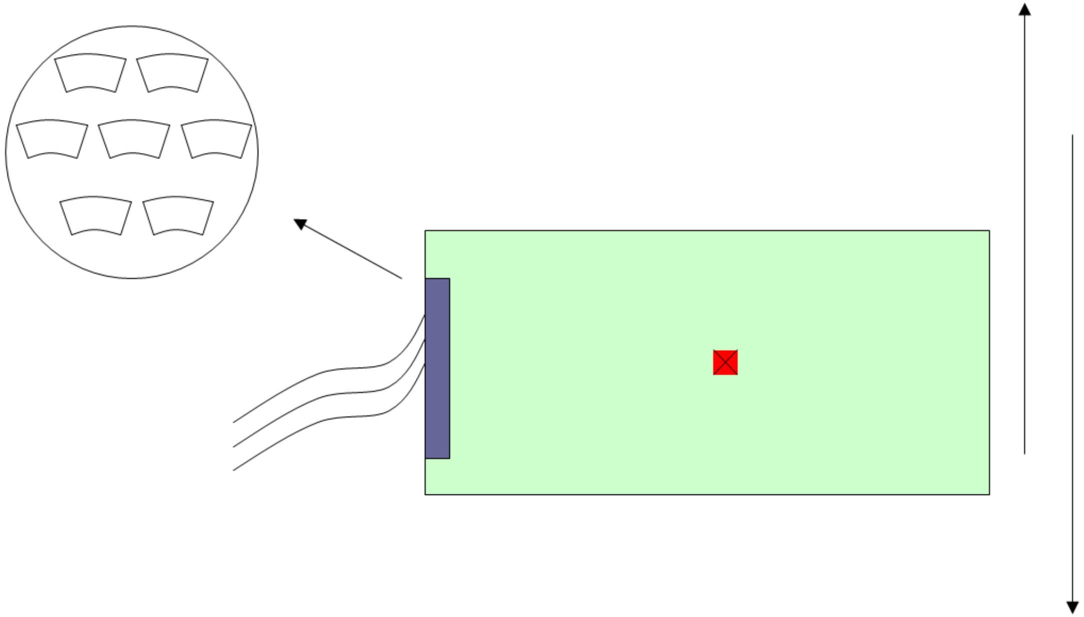


束流测试内容 – 移动测试与调整



束流测试内容 – 移动测试与调整

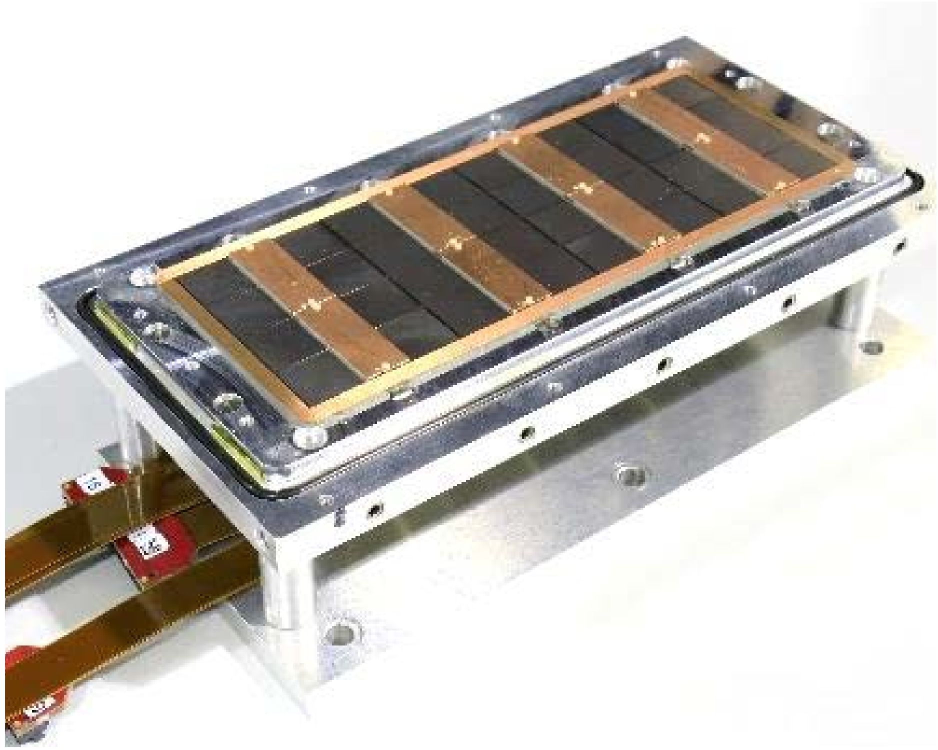


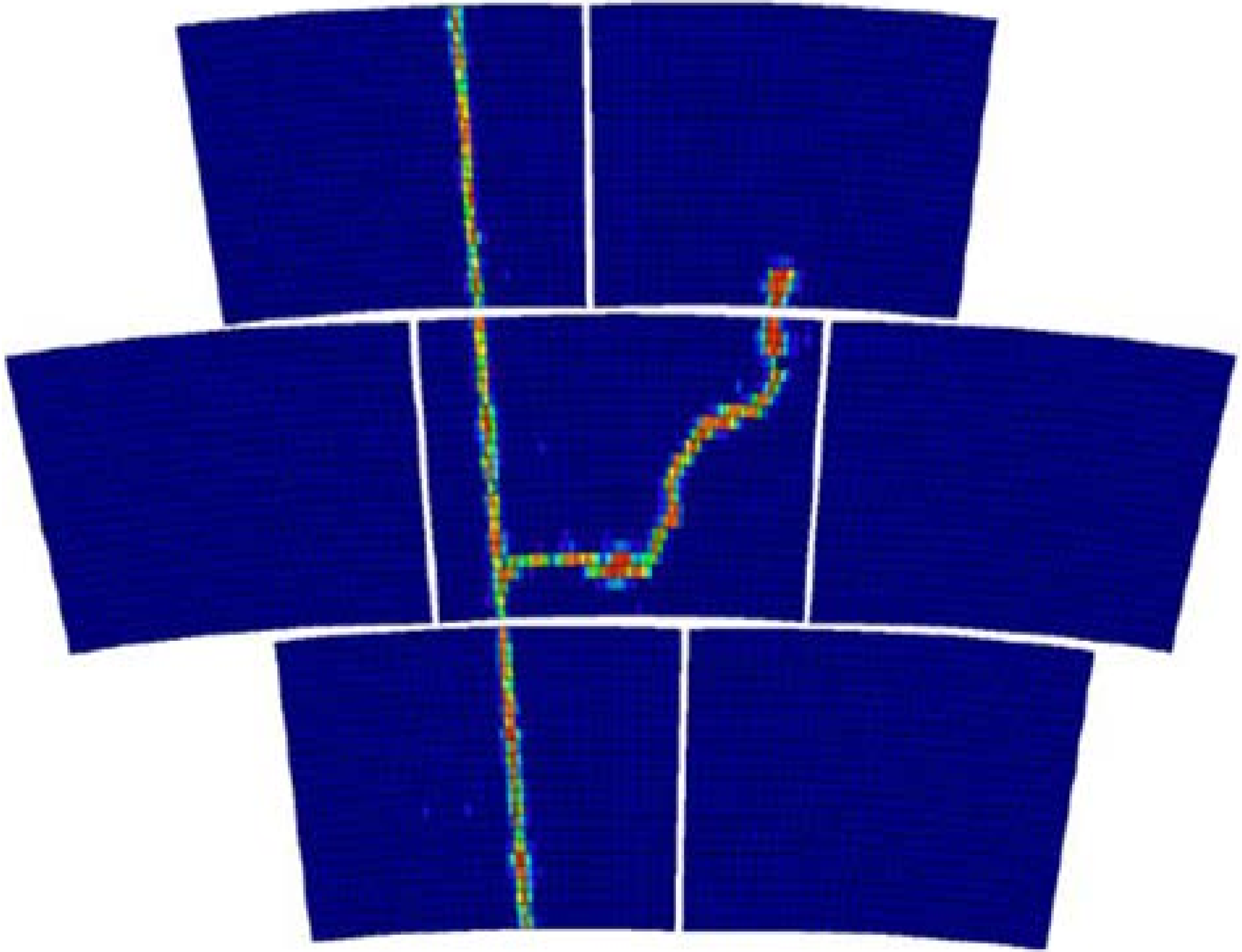


侧视图

束流测试内容 – 移动测试与调整

- 单电子beam宽度（event），与3mm以内（5000增益的时候）
- 长度上可以进行优化到需求的径迹长度
- PID分析需要进行数据拼接（外推）



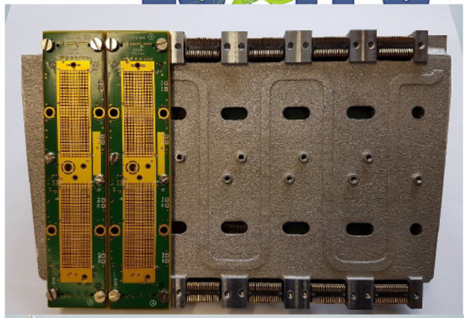


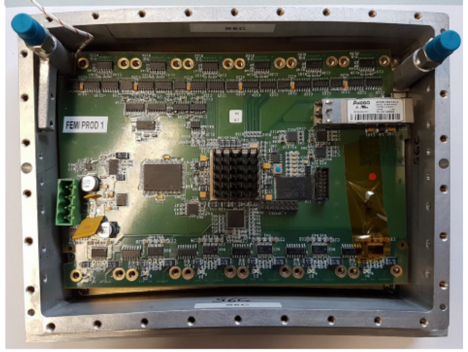
束流测试内容 – 移动测试与调整

- 冷却的确认？ （第一次beamtest）

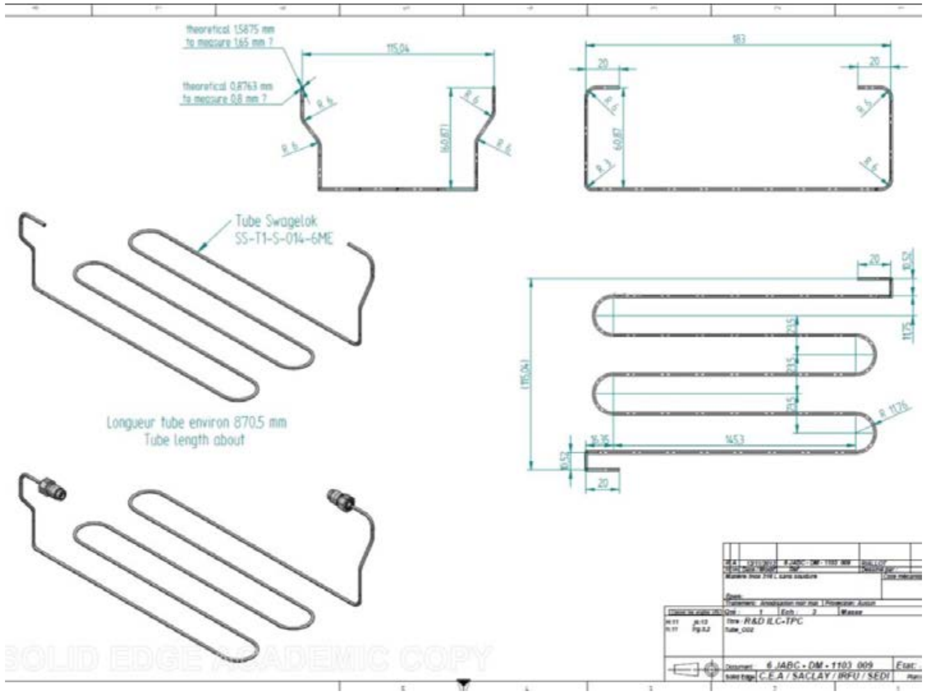
Cooling

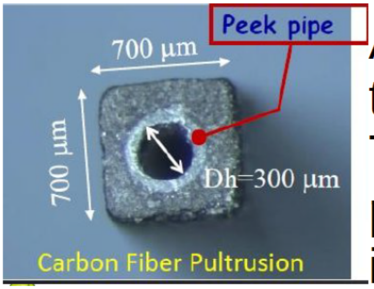
Despite the power pulsing, the readout electronics will require a cooling system. 2-phase CO2-cooling is a very interesting candidate. A fully integrated AFTER-based solution has been tested on 7 Micromegas modules during a test beam.



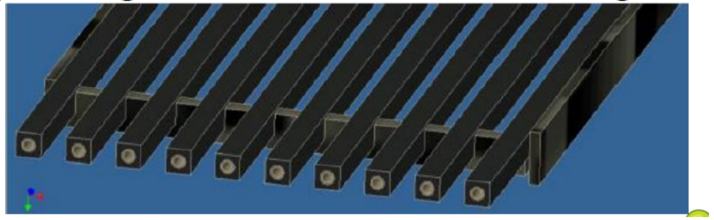


To optimize the cooling performance and the material budget, 3D-printing is an attractive possibility for producing the complex structures required. A prototype for a full module is available now at CEA, Saclay. It will be increased to 4 modules until 2021.



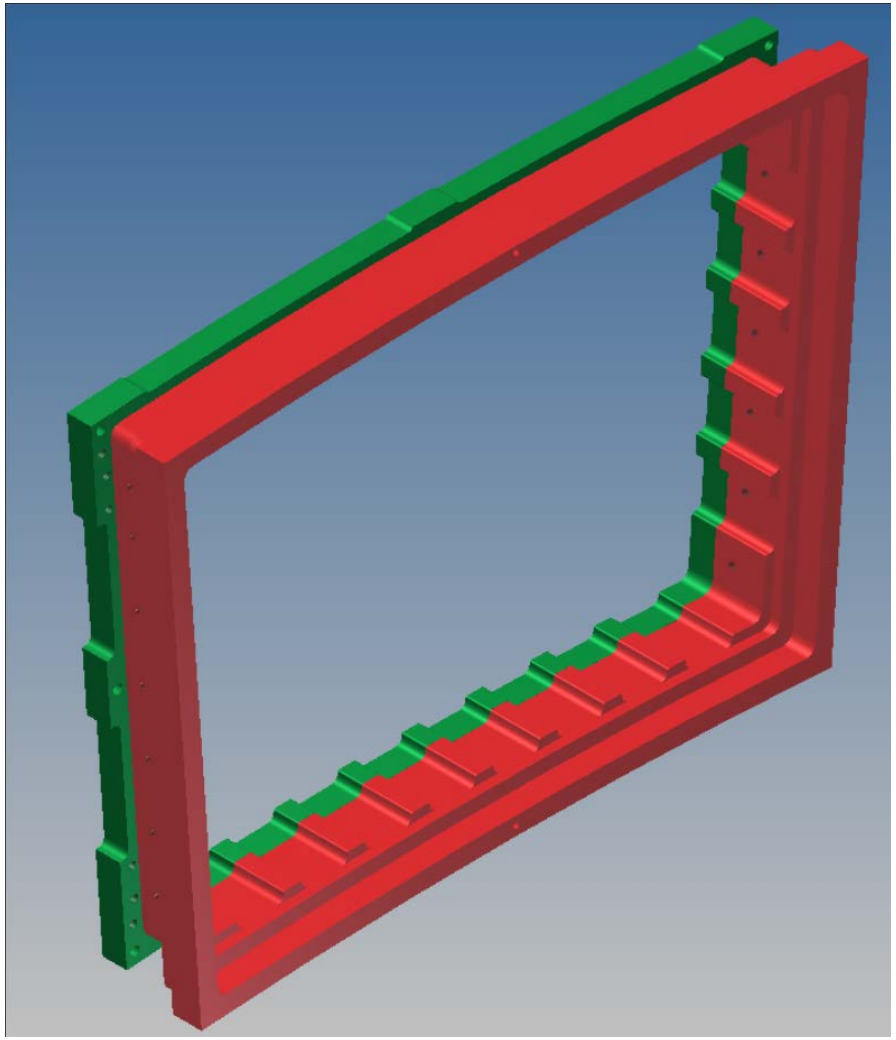


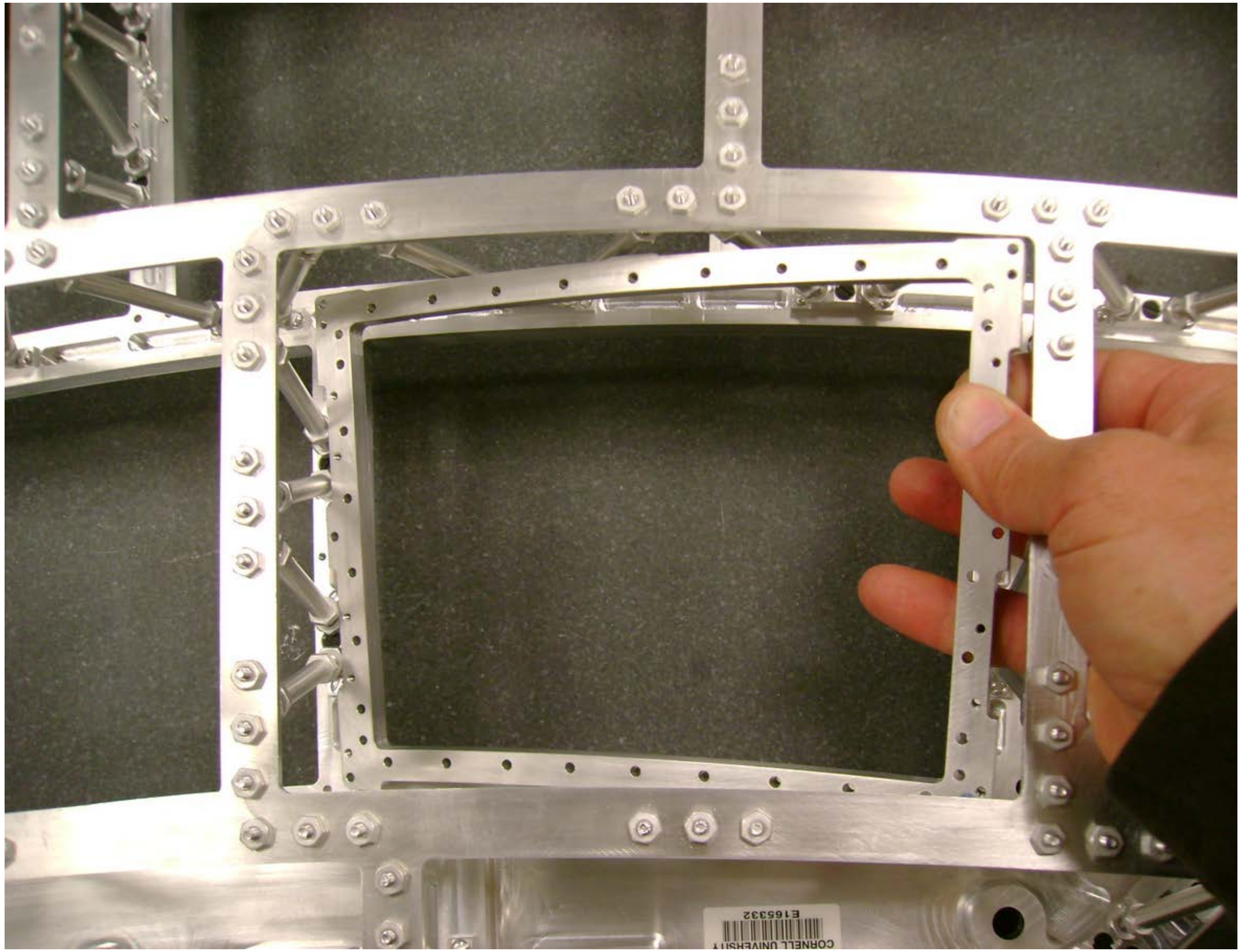
Alternatively, Lund is exploring micro channel cooling together with Pisa. These consists of pipes with Ø 300 µm in carbon fiber tubes.



束流测试内容 – 模块安装结构件

- 通用模块结构

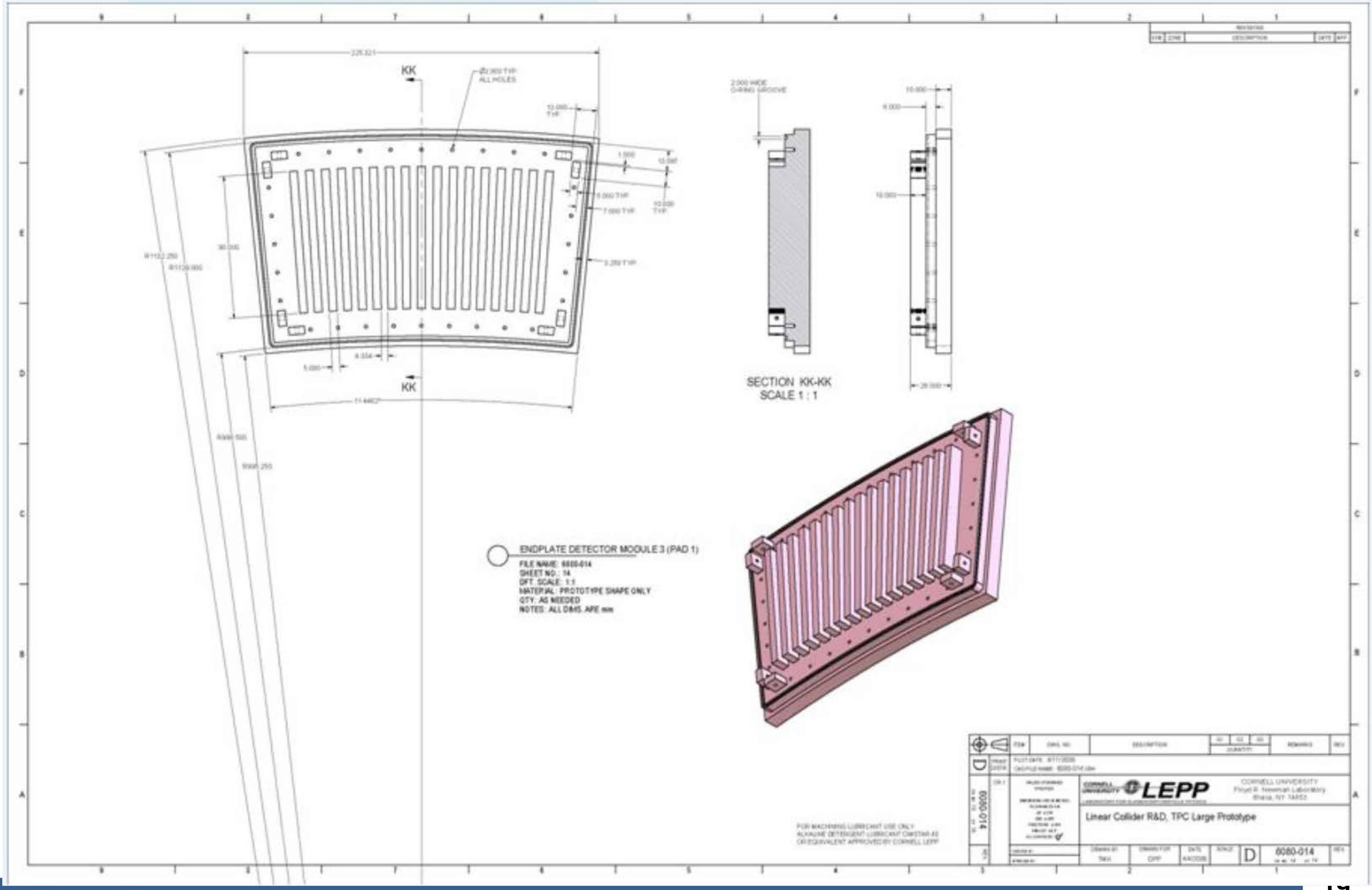




束流测试内容 – 模块安装结构件

- 设计及加工
  - 1月以内

Module



束流测试内容 – 时间安排

DESY 2 Test Beam Schedule 2024 – Status from 22/APR/2024

DESY 2 Test Beam Coordinators: Ralf Diener, Norbert Meyners, Marcel Stanitzki

Startdate	Week	TB21	T	TB22	T	TB241	T	TB24	T
01.01.2024	1	Shutdown		Shutdown		Shutdown		Shutdown	
08.01.2024	2	Shutdown		Shutdown		Shutdown		Shutdown	
15.01.2024	3	Shutdown		Shutdown		Shutdown		Shutdown	
22.01.2024	4	Shutdown		Shutdown		Shutdown		Shutdown	
29.01.2024	5	Startup		Startup		Startup		Startup	
05.02.2024	6	CMS Outer Tracker	X	dSiPM	X			CMS-HGCAL	X
12.02.2024	7	CMS Outer Tracker	X	Mu3e	X			AidaInnova-WP6	X
19.02.2024	8	CMS ETL ETROC	X	Mu3e	X			AidaInnova-WP6	X
26.02.2024	9	CMS ETL ETROC	X	TelePix	X			ATLAS HGTD	
04.03.2024	10	ITk Pixel Dortmund	X	ATLAS-ITk-Strips	X			ATLAS HGTD	
11.03.2024	11	CMS Inner Tracker	X	LHCb-MightyPix	X			CMS ETL	X
18.03.2024	12	CMS Inner Tracker	X	LHCb-MightyPix	X			SHiP-SHADOWS-ECAL	X
25.03.2024	13	Maintenance		Maintenance		Maintenance		Maintenance	
01.04.2024	14	Maintenance				Maintenance		Maintenance	
08.04.2024	15	DESY Heidelberg TB School	X	Tangerine	X			DESY Heidelberg TB School	
15.04.2024	16	Schwartz-Reisman School		Tangerine	X			ALICE-ITS3	
22.04.2024	17	MDI-2		RD50-MPW4	X			CalVision	X
29.04.2024	18	CMS ETL ETROC	X	CMOS Strips Detectors	X			Telescope-Dev	X
06.05.2024	19	CMS ETL ETROC	X	CMOS Strips Detectors	X			IPHC-CE65_v2	
13.05.2024	20	Maintenance		Maintenance		Maintenance		Maintenance	
20.05.2024	21	MDI-2		dSiPM	X			CMS HGCAL	
27.05.2024	22	ATORCH		Tangerine	X			LHCb-ECAL	X
03.06.2024	23	CMS ETL ETROC	X	Tangerine	X			LHCb-ECAL	X
10.06.2024	24	CMS ETL ETROC	X	Telescope-Dev					
17.06.2024	25	CMS ETL ETROC	X	DCRSD	X			CMS ETL	X
24.06.2024	26	CMS Inner Tracker	X	ATLAS-ITk-Strips	X				
01.07.2024	27	Maintenance		Maintenance		Maintenance		Maintenance	
08.07.2024	28	MONOPIX2	X					CMS-HGCAL	X
15.07.2024	29	Belle-II CMOS	X					MIMOSIS	
22.07.2024	30								
29.07.2024	31	BL4S preparation		TelePix	X			EIC AC-LGAD	
05.08.2024	32	Shutdown		Shutdown		Shutdown		Shutdown	
12.08.2024	33	Shutdown		Shutdown		Shutdown		Shutdown	
19.08.2024	34	Shutdown		Shutdown		Shutdown		Shutdown	
26.08.2024	35								
02.09.2024	36								
09.09.2024	37								
16.09.2024	38								
23.09.2024	39								
30.09.2024	40								
07.10.2024	41	Maintenance		Maintenance		Maintenance		Maintenance	
14.10.2024	42								
21.10.2024	43								
28.10.2024	44								
04.11.2024	45								
11.11.2024	46	Maintenance		Maintenance		Maintenance		Maintenance	
18.11.2024	47								
25.11.2024	48								
02.12.2024	49								
09.12.2024	50								
16.12.2024	51								
23.12.2024	52	Shutdown		Shutdown		Shutdown		Shutdown	

束流测试准备讨论

- 探测器模块设计及加工，人员分工
  - 负责人：祁辉荣
    - 机械设计：张建
    - 软件模拟：常悦
    - 调试分析：佘信、毛涵钰
    - LCTPC国际合作
    - DESY束流合作（DRD1架构内）

时间节点：2024年8月下旬
其他事宜？

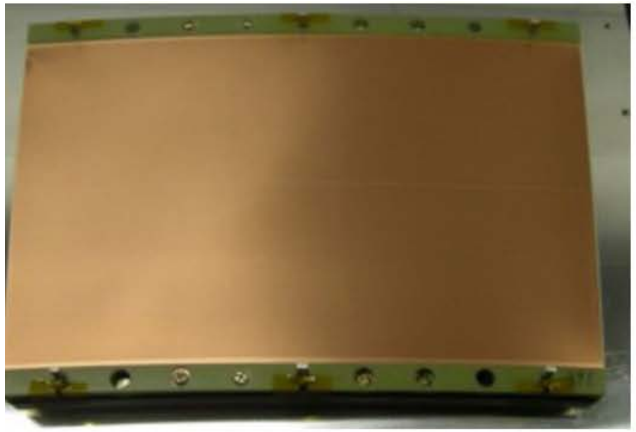
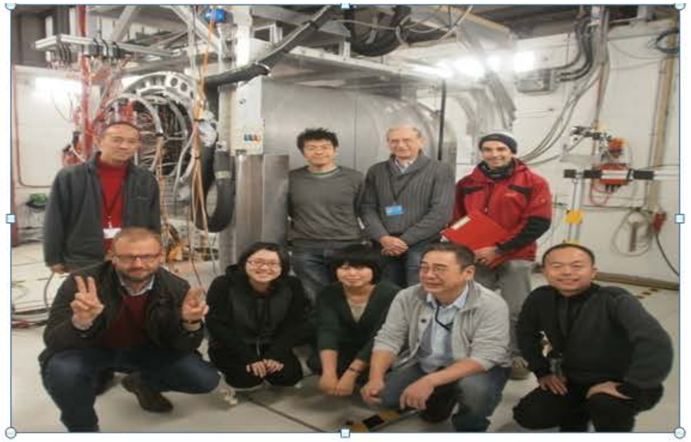
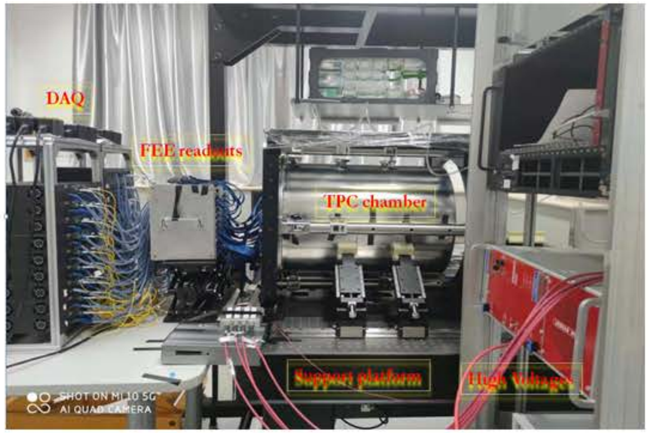
- FEE电子学设计及加工，人员分工
  - 负责人：邓智
    - 接口配合：祁辉荣、张建

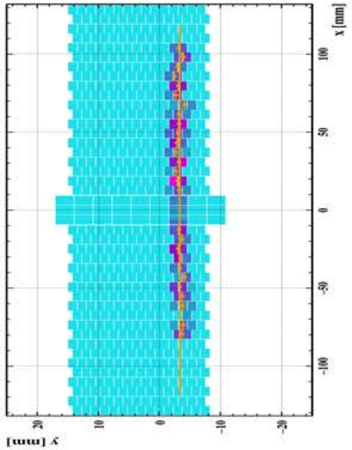
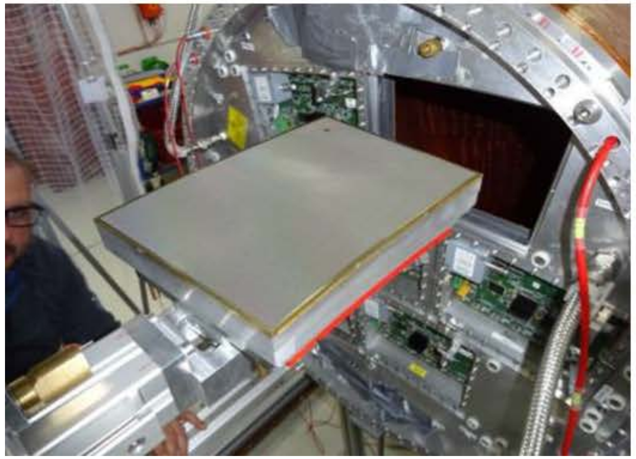
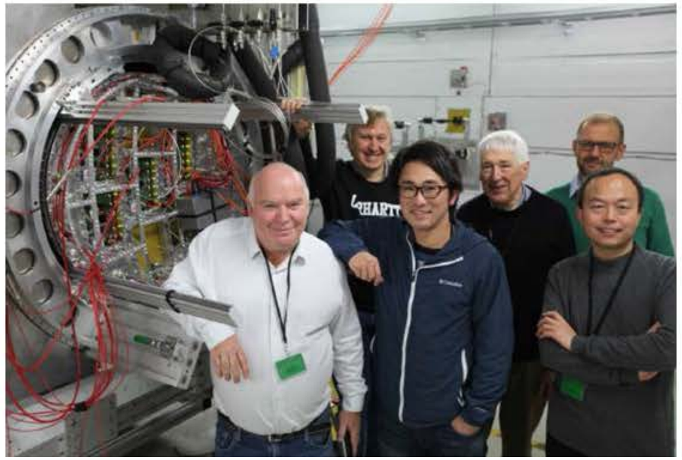
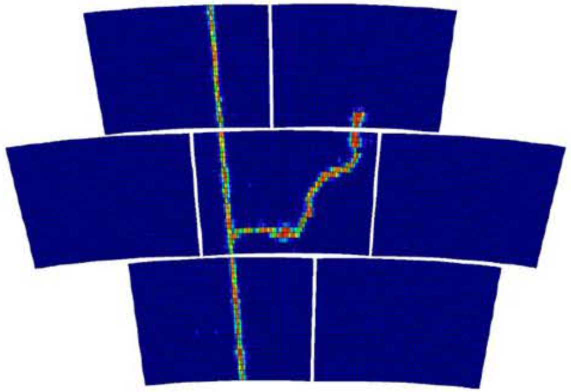
- DAQ数据读出设计及加工，人员分工
  - 负责人：邓智 祁辉荣
    - 设计调试：？

Activity international collaboration - TPC technology R&D

- Activity collaboration: Pixelated readout and Pad readout from IHEP and LCTPC collaboration
  - Large Prototype setup have been built to compare different detector readouts for Tera-Z
  - PCMAG: B < 1.0T, bore Ø: 85cm, Spatial resolution of $\sigma_{r\phi} \leq 100$ μm
  - Collaboration implement improvements in **a pixelated readout TPC for CEPC TDR**

ArXiv. (2023)2006.08562
NIM A (2022) 167241
ArXiv (2022)2006.085
JINST 16 (2021) P10023
JINST 5 (2010) P10011
NIM A608 (2009) 390-396


项目相关基金支撑

- 中国科学院高能物理研究所所长科学家工作室基金
- CEPC重点合作研究基金
- 科技部重大专项研究基金
- 国家基金委重点专项研究群基金

Many thanks!