STCF 探测谱仪研究进展

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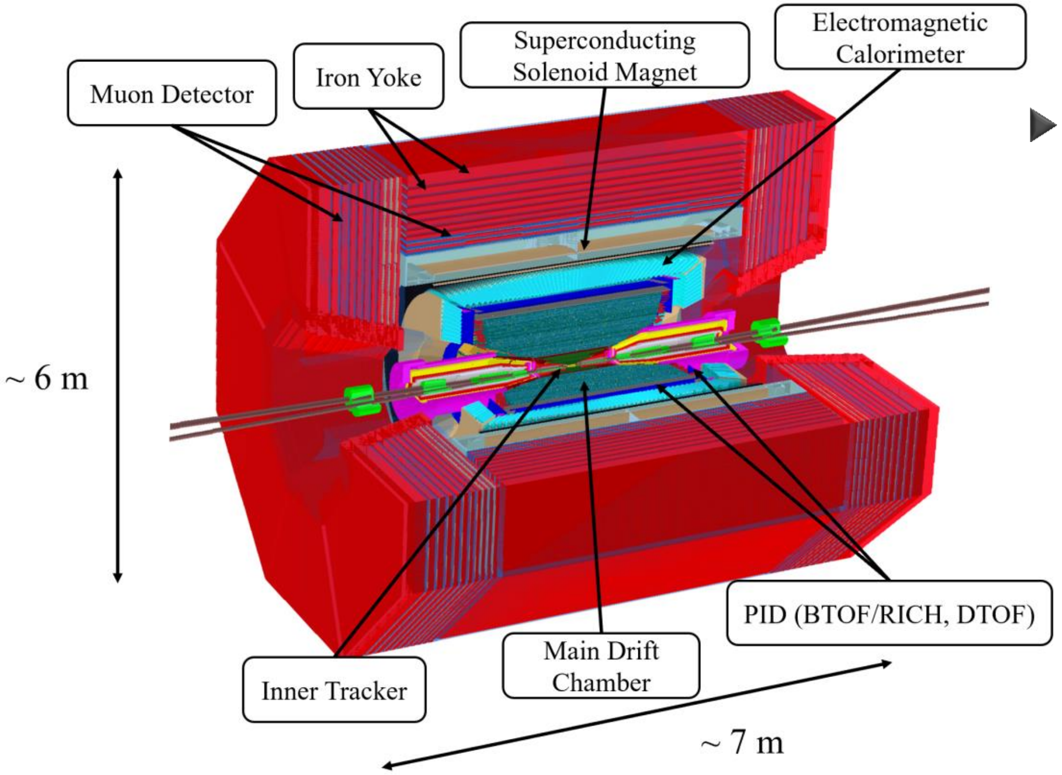
(On behalf of the STCF Detector Working Group)

University of Chinese Academy of Sciences

超级陶粲装置研讨会, 湖南, 2025

June 3, 2025

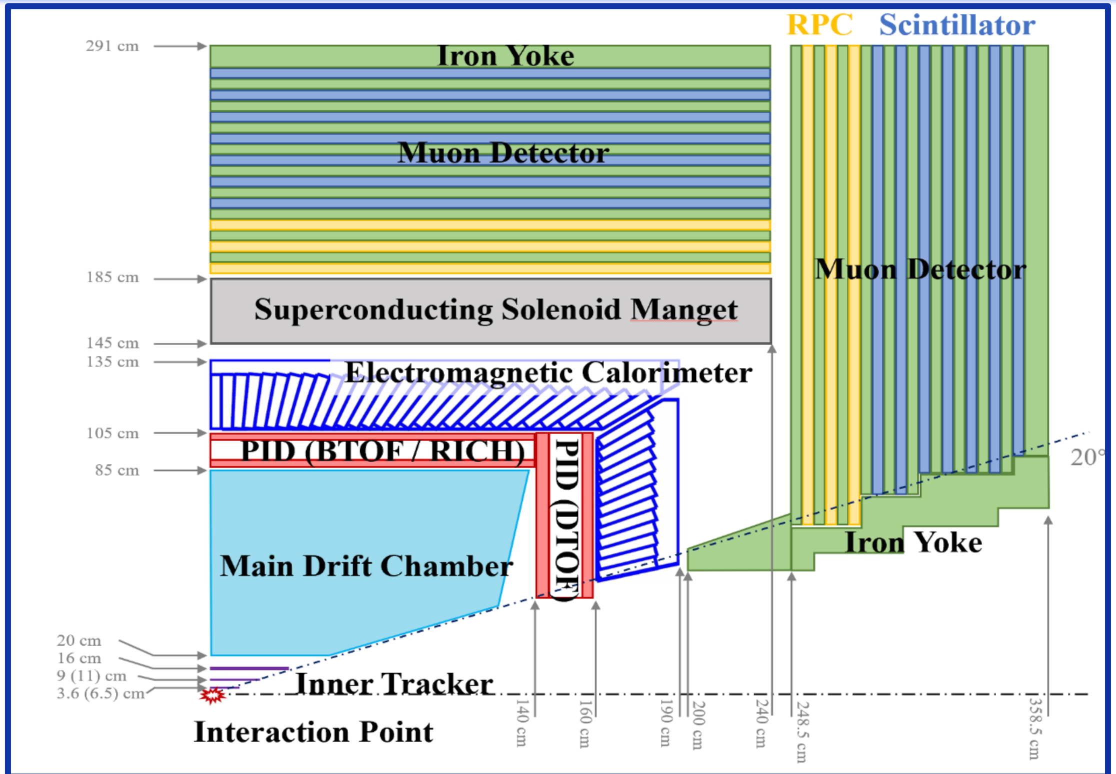
Physics Requirements for STCF Detector



- **Highly efficient and precise reconstruction of exclusive final states produced in 2-7 GeV e^+e^- collisions**
  - Precise measurement of low-p (~>1GeV/c) particles → low mass tracking and PID detectors
  - Excellent PID：π/K and μ/π separation up to 2 GeV and beyond

Process	Physics Interest	Optimized Subdetector	Requirements
$\tau \to K_s \pi \nu_\tau$, $J/\psi \to \Lambda\bar{\Lambda}$, $D_{(s)}$ tag	CPV in the τ sector, CPV in the hyperon sector, Charm physics	ITK+MDC	acceptance: 93% of 4π; trk. effi.: $> 99\%$ at $p_T > 0.3$ GeV/c; $> 90\%$ at $p_T = 0.1$ GeV/c $\sigma_p/p = 0.5\%$, $\sigma_{\gamma\phi} = 130\ \mu$m at 1 GeV/c
$e^+e^- \to KK + X$, $D_{(s)}$ decays	Fragmentation function, CKM matrix, LQCD etc.	PID	π/K and K/π misidentification rate $< 2\%$ PID efficiency of hadrons $> 97\%$ at $p < 2$ GeV/c
$\tau \to \mu\mu\mu$, $\tau \to \gamma\mu$, $D_s \to \mu\nu$	cLFV decay of τ, CKM matrix, LQCD etc.	PID+MUD	μ/π suppression power over 30 at $p < 2$ GeV/c, μ efficiency over 95% at $p = 1$ GeV/c
$\tau \to \gamma\mu$, $\psi(3686) \to \gamma\eta(2S)$	cLFV decay of τ, Charmonium transition	EMC	$\sigma_E/E \approx 2.5\%$ at $E = 1$ GeV $\sigma_{\text{pos}} \approx 5$ mm at $E = 1$ GeV
$e^+e^- \to n\bar{n}$, $D_0 \to K_L\pi^+\pi^-$	Nucleon structure Unity of CKM triangle	EMC+MUD	$\sigma_T = \frac{300}{\sqrt{p^3(\text{GeV}^3)}}$ ps

Detector Design and Key Technologies



Major Performance Requirements

Acceptance: 94%×4π

Momentum res.: σ_p/p ~ 0.5% @ 1 GeV

Energy res. : σ_E/E ~ 2.5% @ 1 GeV

Hadron ID: π/K ~4σ @ 2 GeV

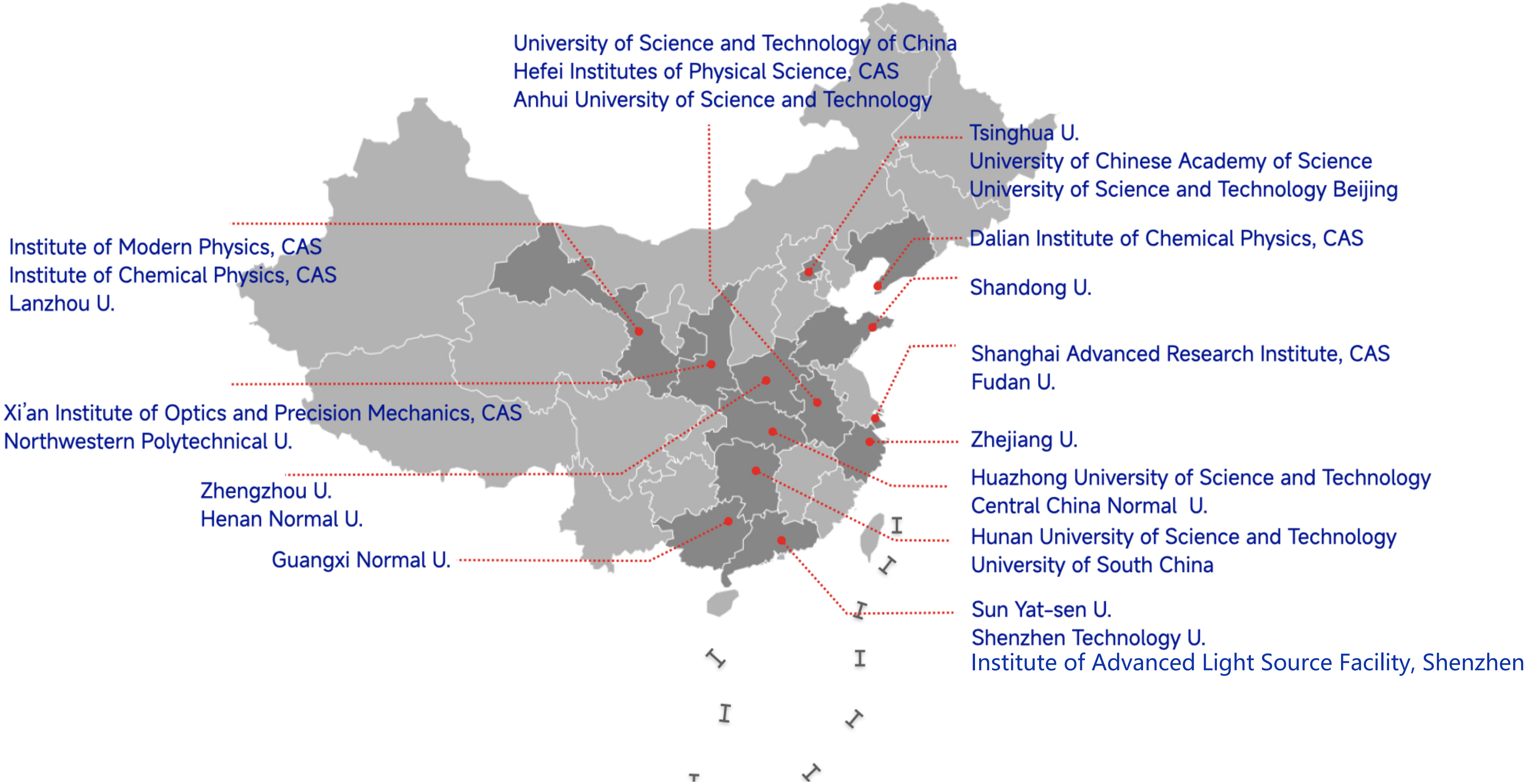
Muon ID: eff. >95%, mis-rate <3% @1 GeV

- Inner Tracker
  - MPGD: cylindrical uRGroove, σ_x ~100 μm
  - Silicon: low-mass MAPS, <0.3%X_0/layer
- Central Tracker (σ_p/p~0.5% @ 1GeV)
  - Drift chamber with super-small cells, σ_x <130 μm
- PID System (π/K ~4σ @ 2GeV)
  - Endcap: DIRC-like TOF - DTOF (σ_t~30 ps)
  - Barrel: RICH (<4mrad) or DTOF (σ_t~30 ps)
- EMC
  - pCsI + APD: (σ_E/E~2.5%, σ_x~5 mm, σ_t~300 ps @ 1GeV)
- Solenoid ： 1 T
- Muon Detector (eff. >95%, mis-rate <3% @1GeV)
  - inner layers : glass RPC， > 300 Hz/cm^2
  - outer layers : scintillator strip + SiPM, ~ 2.4 m
- Trigger, DAQ, Clock and Data Transmission

Beam background at the inner most layer

~1 Mrad/y, ~1×10^{11} 1MeV n-eq/cm^2/y, ~1 MHz/cm^2

Expanding Detector R&D Team



25 universities/institutes: ~240 faculty/staff members and ~300 graduates

Detector R&D Breakdown and Organization

	System name	Code	Leaders	Participating Institutes
1	Inner Tracker - MPGD	ITKW	Y. Zhou, Y. Qian	USTC, IMP
2	Inner Tracker - MAPS	ITKM	L. Xu, J. Qin	USTC, SDU, CCNU, NPU
3	Main Drift Chamber	MDCH	L. Duan, Z. Cao	IMP, USTC, SZTU
4	Barrel PID Detector	PIDB	Q. Liu, J. Li	UCAS, USTC
5	Endcap PID Detector	PIDE	M. Shao, Y. Wang, P. Chen	USTC, XIOPM
6	EM Calorimeter	ECAL	Y. Zhang, Z. Shen	USTC
7	Muon Detector	MUON	K. Liu, Y. Liu, Y. Sun, F. Li	LZU, ZZU, SDU, USTC
8	Clock and Data Trans.	CLDT	J. Wang, D. Guo	USTC, CNNU, HUST
9	Trigger System	TRIG	Z. Fang, C. Feng	USTC, HUST, SDU
10	DAQ system	DACQ	J. Yang, K. Chen	USTC, CNNU
11	Forward System	FWDR	H. Chen, M. Liu	ZJU, GXU, USTC, LNU, NJU, DZU
12	Detector Magnet	DSSM	X. Zhang, C. He, Z. Zhu	SIEMENS SZ, IASF SZ, USTC
13	Mechanical System	MECH	G. Shen, S. Fei, L. Kang	AUST, IHEP
14	Detector Control System	DCSS	D. Hu, M. Li	USTC, IMP

Working Groups Meetings and Topical Workshops

❖ **Weekly or bi-weekly meetings for sub-working groups and detector group plenary meetings on a monthly basis. Mini-workshops on dedicated R&D topics.**

January 2024
- Jan 23 Detector Division Technical Discussion Meeting

November 2023
- Nov 30 Detector Division Technical Discussion Meeting

October 2023
- Oct 27 Detector Division Progress Review Meeting

September 2023
- Sep 27 Detector Division Technical Discussion Meeting
- Sep 08 Detector Division Progress Review Meeting

MAPS-ITK Working Group	85 events
MPGD-ITK & MDC Working Group	31 events
PID Working Group	39 events
EMC Working Group	32 events
MUD Working Group	35 events
Trigger & DAQ Working Group	37 events
Clock and Data Transmission Working Group	7 events
Detector Control System Working Group	1 event
Mechanical Working Group	13 events
Forward Region Working Group	19 events
Magnet Working Group	3 events
General Meetings	21 events

2:00 PM → 2:10 PM **Introduction** 10m
Speakers: Jianbei Liu (University of Science and Technology of China), Qian Liu (University of Chinese Academy of Sciences), Yi Qian (Institute of Modern Physics, Chinese Academy of Sciences), Lei Zhao (University of Science and Technology of China), Dongdong Hu (University of Science and Technology of China)
进度和质量...

2:10 PM → 2:30 PM **MAPS Inner Tracker (ITKM)** 20m
Speakers: Jiajun Qin (University of Science and Technology of China), Lailin Xu (University of Science and Technology of China)
STCF_MAP...

2:30 PM → 2:50 PM **uRWELL Inner Tracker (ITKW)** 20m
Speakers: Yi Qian (Institute of Modern Physics, Chinese Academy of Sciences), Yi Zhou (University of Science and Technology of China)
STCF分总...

2:50 PM → 3:10 PM **Main Drift Chamber (MDCH)** 20m
Speakers: Limin Duan (Institute of Modern Physics, Chinese Academy of Sciences), Zhe Cao (University of Science and Technology of China)
MDC9月总... MDC读出...

3:10 PM → 3:30 PM **Barrel Particle Identification Detector (PIDB)** 20m
Speakers: Lei Zhao (University of Science and Technology of China), Qian Liu (University of Chinese Academy of Sciences)
20230907 ...

3:30 PM → 3:50 PM **Endcap Particle Identification Detector (PIDE)** 20m
Speakers: Ming Shao (University of Science and Technology of China), Yonggang Wang (Univeristy of Science and Technology of China)
STCF谱仪...

3:50 PM → 4:10 PM **Electromagnetic Calorimeter (ECAL)** 20m
Speakers: Yunlong Zhang (University of Science and Technology of China), Zhongtao Shen (University of Science and Technology of China)
STCF EMC ...

4:10 PM

4:30 PM

2:40 PM → 3:10 PM **MAPS Inner Tracker ASIC**
Speakers: Jiajun Qin (University of Science and Technology of China), Lailin Xu (University of Science and Technology of China)
STCF ASIC讨论会...

3:10 PM → 3:50 PM **uRWELL Inner Tracker & PIDB ASIC**
Speaker: jiaming li (University of Science and Technology of China)
STCF RICH μRWELL...

3:50 PM → 4:20 PM **Endcap Particle Identification Detector ASIC**
Speakers: Yonggang Wang (Univeristy of Science and Technology of China), 然 王
2023-09-27_DTOFA...

4:20 PM → 4:50 PM **Muon Detector ASIC**
Speaker: Feng Li (University of Science and Technology of China)
MUD ASIC进展2023...

4:50 PM → 5:20 PM **Data Transmission ASIC**
Speakers: Jinhong Wang (University of Science and Technology of China), 迪 郭 (华中师范大学)
时钟与高速数据传...

高亮度实验MAPS研发讨论会
Saturday, 1 April 2023 from **08:00** to **20:00** (Asia/Shanghai)
at **物质科研楼 (A608)**
中国科大东校区

STCF HLT 计算存储专题研讨会
Thursday Nov 21, 2024, 2:00 PM → 11:05 PM Asia/Shanghai
物质科研楼三楼会议室 (中国科学技术大学)

https://cern.zoom
ZOOM ID: 675 48
Password: 32552

STCF探测谱仪机械设计研讨会
Monday Aug 19, 2024, 9:00 AM → 6:05 PM Asia/Shanghai
物质科研楼三楼会议室 (中国科学技术大学)

Description 本次会议将针对STCF实验谱仪机械结构的设计研发问题进行深入讨论，议题包括：谱仪整体的支撑移动系统设计、各探测器系统的内部与谱仪层级机械连接装配设计、电子学芯片散热设计等。
腾讯会议：456-104-342
https://meeting.tencent.com/dm/3arobCI1DURC

BINP - CAS Super Tau Charm Facility collaboration
星期五 2025年2月28日 上午9:00 → 下午6:00 Asia/Novosibirsk

上午9:10 → 上午9:30 **The current status of STCF in**
报告人: YangHeng Zheng
STCF-Overview-Zheng-BINP.pdf

上午9:30 → 上午9:50 **The progress of STCF accelera**
报告人: Jingyu Tang
02 BINP visit-STCF Accelerator-T

R&D Status Overview

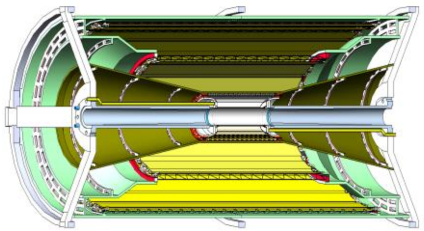
- A complete R&D program covering every aspect of the STCF detector is in place and being vigorously implemented. Many systems are on track to achieve the primary R&D goals by the end of this year or early next year. Some systems have reached the large-scale prototype level.

- Inner tracker – MPGD : a cylindrical MPGD prototype, readout ASIC prototype with full function
- Inner tracker – MAPS : MAPS designed with different CMOS processes, chips with TJ180 returned
- Main Drift Chamber : a full-length drift chamber prototype with super-small cells under construction
- Barrel PID : a 32×32cm^2 RICH prototype, 3 iterations in readout ASIC design already.
- Endcap PID : a full-size DTOF prototype, readout ASIC prototypes
- EM Calorimeter : a 5×5 pCsI calorimeter prototype, pileup real-time removal algorithm and implementation
- Muon Detector : large-size glass RPC and scintillator units, readout ASIC prototypes
- Clock and Data Transmission : key ASIC modules for clock management and high-speed link
- Trigger : L1 and HLT trigger algorithms, firmware programing and hardware development
- DAQ : architecture design, software and hardware development almost finished
- Detector Magnet : conceptual design optimized, moved to technical design
- Detector Mechanical Design : engineering design for each sub-system, designs for detector assembly and installation
- MDI and Forward detectors : luminosity detectors ad zero-degree detectors, beam background
- Detector Control System : system design and technical demonstrators
- Combined beam test : first such a test performed of EMC + DTOF + DAQ at CERN PS

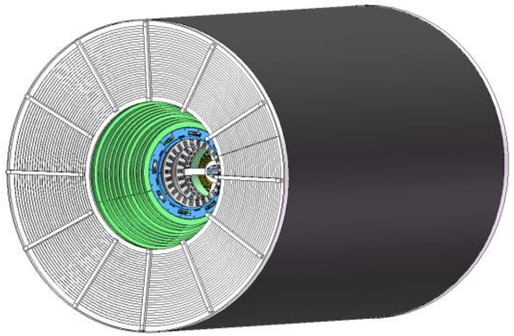
Detector Mechanical Design

- Detector conceptual design has been transferred into engineering drawings
- Engineering design available for each sub-detector or system
- Design studies on detector assembly and installation

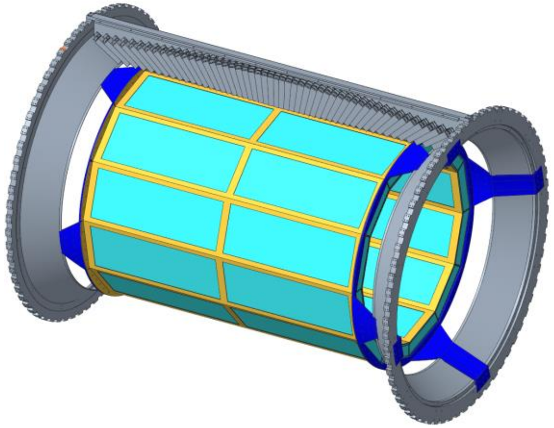
ITK-MAPS



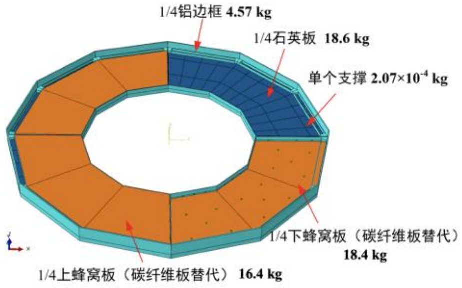
MDC



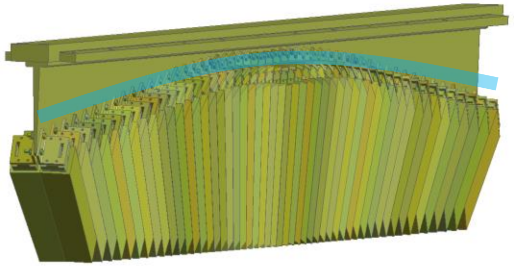
RICH

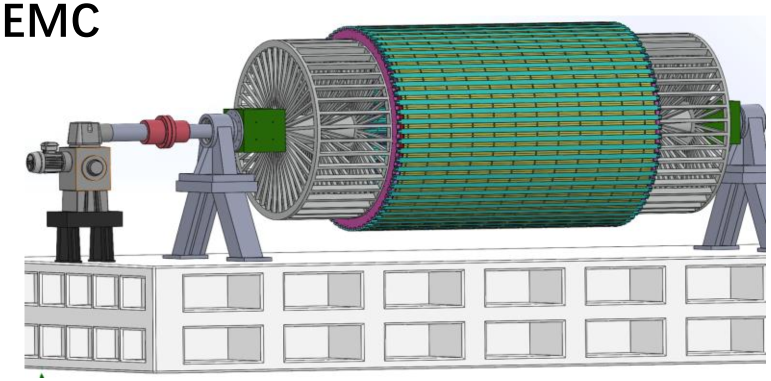


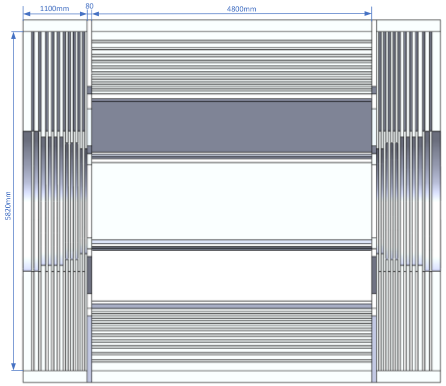
DTOF



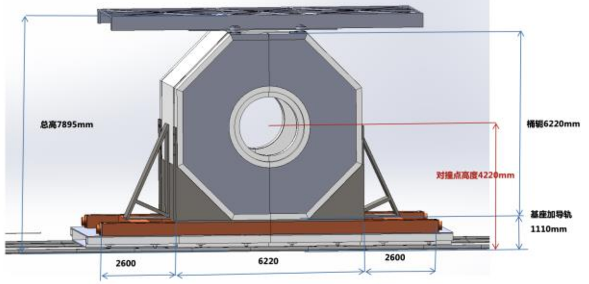
EMC



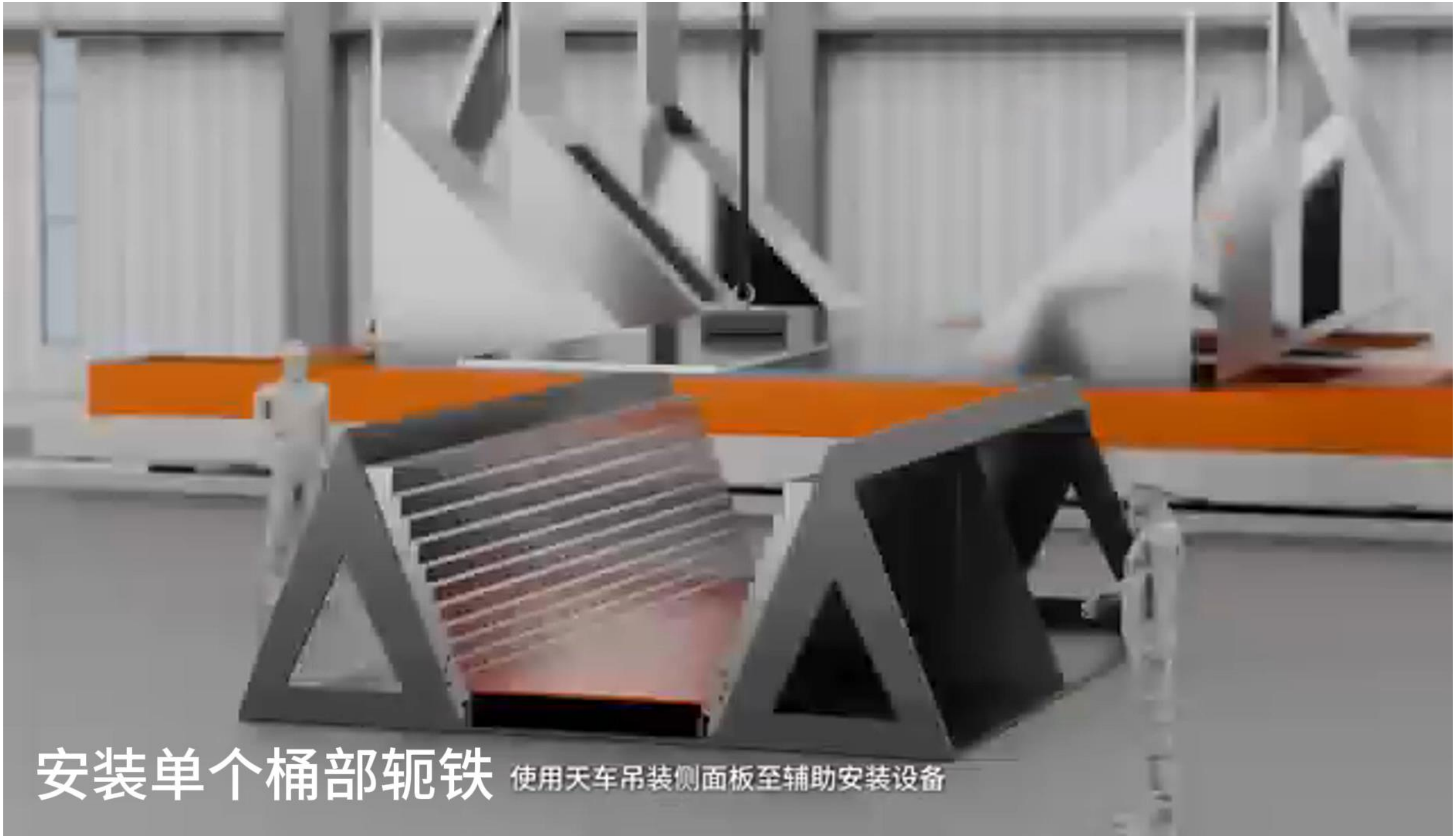




Iron Yoke



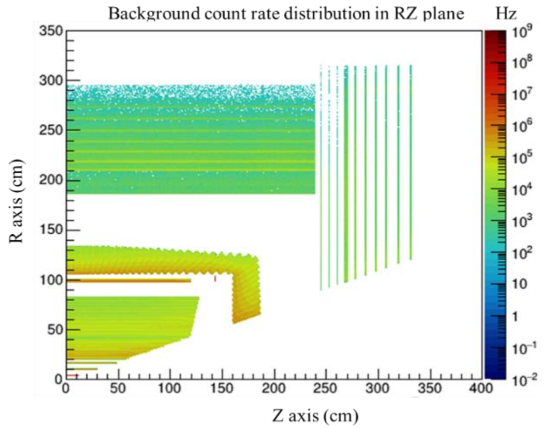
Installation



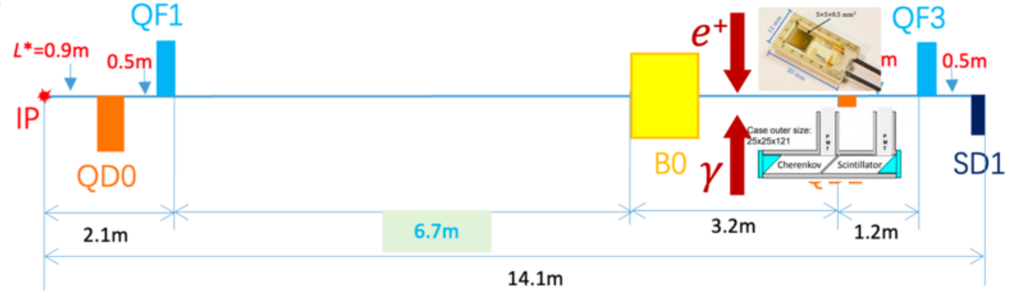
Beam Background and Forward Detectors

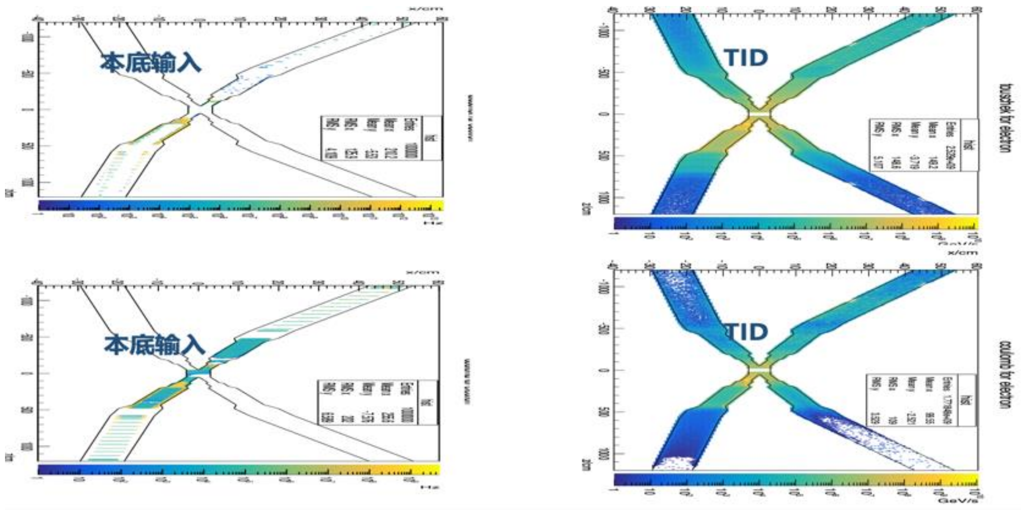
- ❖ **Keeping up with accelerator design evolution for beam background estimation. Working closely with MDI people to optimize the detector geometry and radiation shielding design in MDI region.**
- ❖ **Simulation studies on luminosity detectors (radiative Bhabha) and zero-degree detectors (ISR, two-photon process). Preliminary determination of the sites of these detectors at STCF from these studies.**

Detector	TID value ($Gy \cdot y^{-1}$)	NIEL damage (1 MeV neutron$\cdot cm^{-2} \cdot y^{-1}$)	Total count rate (Hz)	Average count rate (Hz/channel)	Highest count rate (Hz/channel)
ITKW-1	260	1.7×10^{10}	1.1×10^{9}	5.6×10^{5}	7.2×10^{5}
ITKW-2	25	8.3×10^{9}	3.8×10^{8}	1.1×10^{5}	1.4×10^{5}
ITKW-3	9.0	9.5×10^{9}	2.4×10^{8}	4.7×10^{4}	7.3×10^{4}
ITKM-1	4700	3.4×10^{10}	2.0×10^{8}	1.8×10^{1}	2.0×10^{1}
ITKM-2	47	7.9×10^{9}	3.7×10^{7}	0.52	0.57
ITKM-3	18	1.1×10^{10}	3.3×10^{7}	0.18	0.22
MDC	0.17	3.6×10^{13}	3.3×10^{8}	2.9×10^{4}	1.8×10^{5}
PID-Barrel (RICH)	0.90	1.1×10^{10}	2.0×10^{8}	3.0×10^{2}	1.0×10^{4}
PID-Endcap (DTOF)	1.0	1.6×10^{10}	2.9×10^{8}	4.5×10^{4}	6.8×10^{4}
ECAL-Barrel	0.36	1.6×10^{10}	6.7×10^{8}	1.2×10^{5}	1.5×10^{5}
ECAL-Endcap	0.69	1.7×10^{10}	3.5×10^{8}	1.9×10^{5}	5.8×10^{5}
MUD-Barrel-RPC	0.013	1.8×10^{9}	1.0×10^{7}	8.1×10^{2}	3.7×10^{3}
MUD-Barrel-Scintillator	0.0036	4.6×10^{10}	6.1×10^{7}	4.4×10^{3}	2.2×10^{4}
MUD-Endcap-RPC	0.0037	2.8×10^{8}	1.9×10^{6}	3.0×10^{2}	3.5×10^{3}
MUD-Endcap-Scintillator	0.0023	1.1×10^{10}	7.1×10^{6}	6.1×10^{2}	1.2×10^{4}



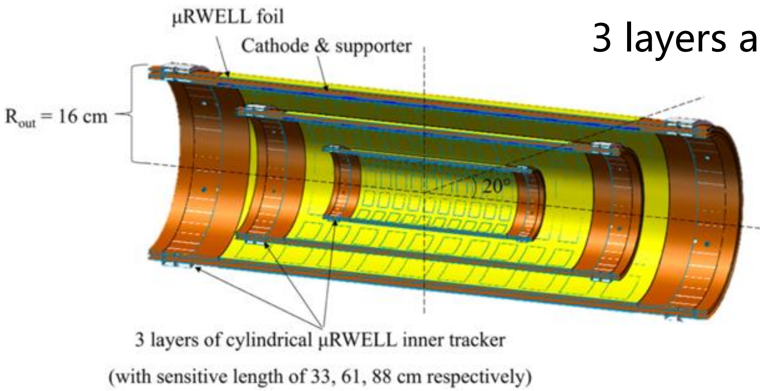
Electronic system	TID value ($Gy \cdot y^{-1}$)	NIEL damage (1 MeV neutron$\cdot cm^{-2} \cdot y^{-1}$)	Average SEEs (Hz/cm^2)	Highest SEEs (Hz/cm^2)
ITKW-1	34	5.4×10^{9}	180	280
ITKW-2	11	6.3×10^{9}	240	380
ITKW-3	5.7	1.0×10^{10}	390	850
ITKM-1	1200	4.5×10^{10}	220	310
ITKM-2	28	7.3×10^{9}	320	660
ITKM-3	11	1.0×10^{10}	410	980
MDC	1.3	6.7×10^{9}	180	1230
PID-Barrel (RICH)	1.7	7.8×10^{9}	350	450
PID-Endcap (DTOF)	1.1	1.5×10^{9}	420	500
ECAL-Barrel	0.034	8.5×10^{8}	36	100
ECAL-Endcap	0.1	1.5×10^{9}	82	490
MUD	0.2	1.8×10^{9}	16	80



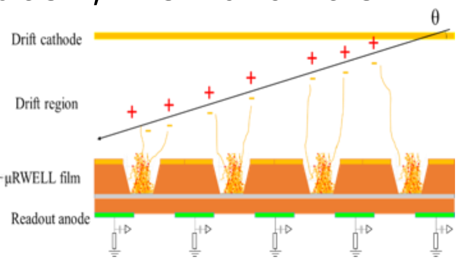


Tracking System : ITK + MDC

ITK Gaseous option : MPGD

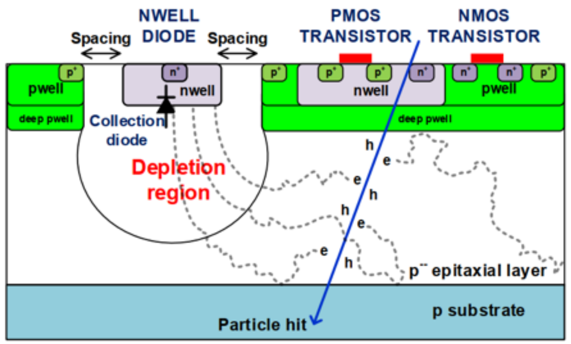


3 layers at 6cm, 11cm and 16 cm



Material budget ~ 0.3%X_0/layer

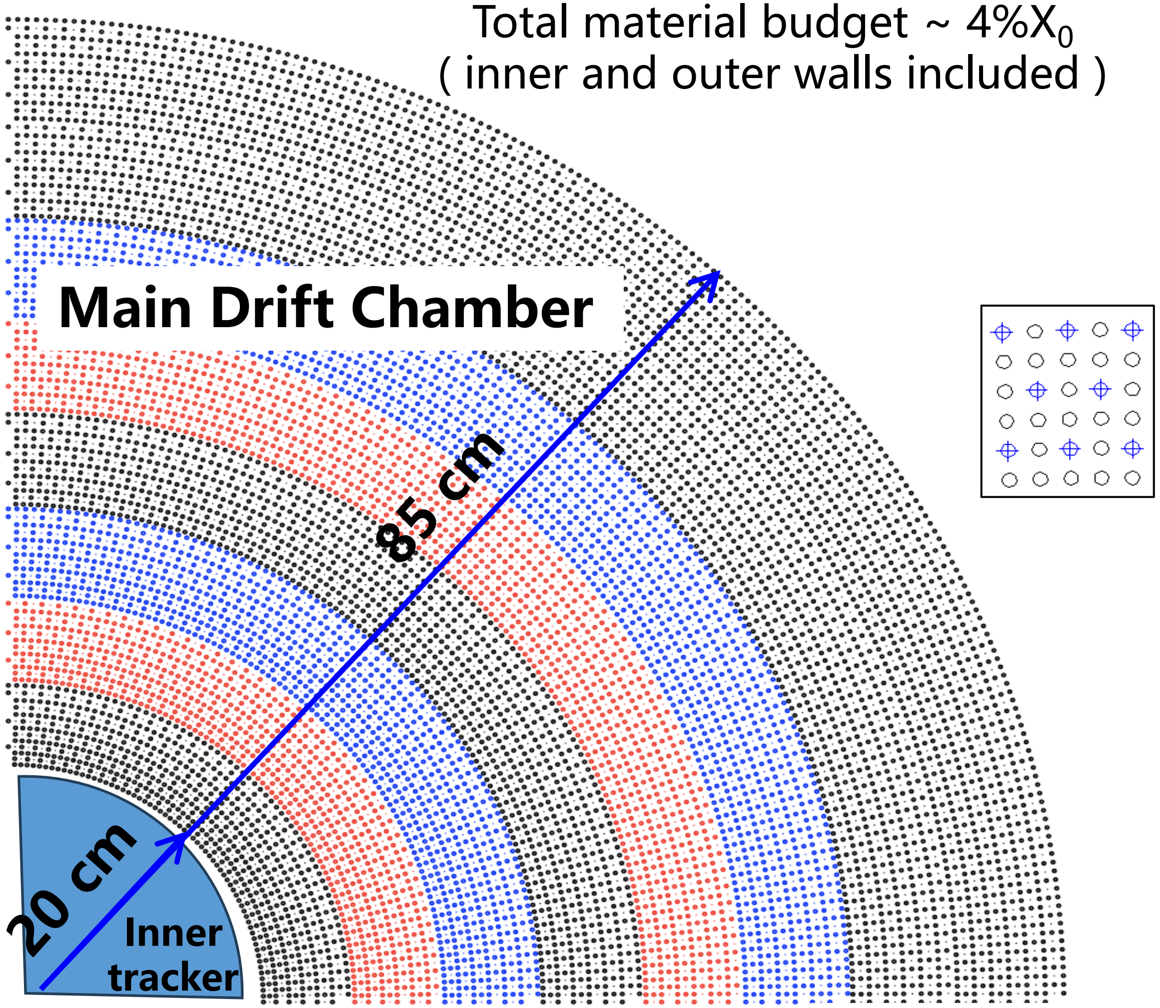
ITK Silicon option: CMOS MAPS



3 layers at

3.6cm, 9.8cm and 16 cm

Total material budget ~ 4%X_0
(inner and outer walls included)



~400 kHz/ch

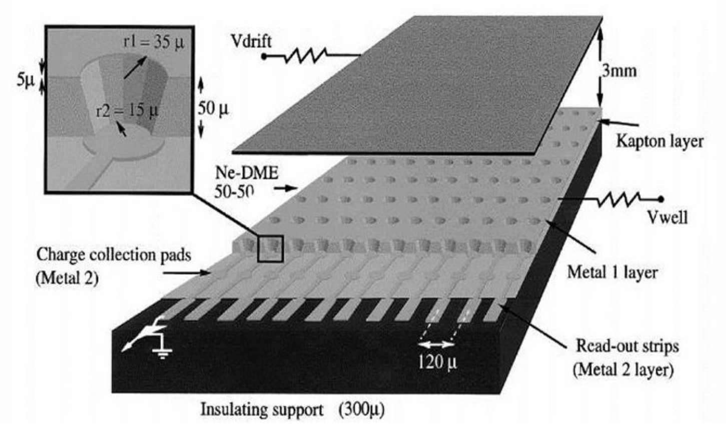
~30 kHz/ch

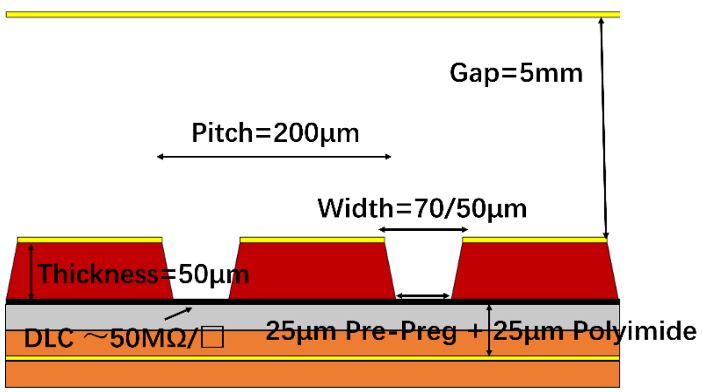
Inner-outer separate designs to accommodate different levels of radiation background

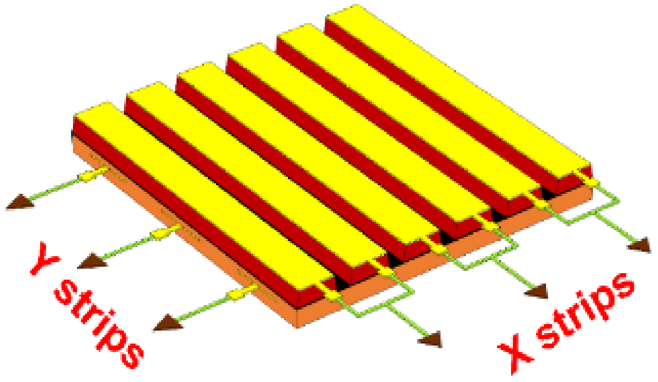
MPGD ITK : µRGroove

特点：低物质量、成本低、抗辐照
挑战：低物质量基材√、圆筒结构√、µTPC…

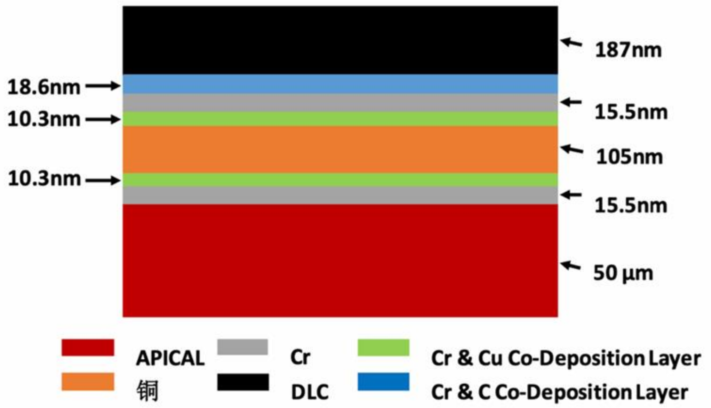
WELL detector

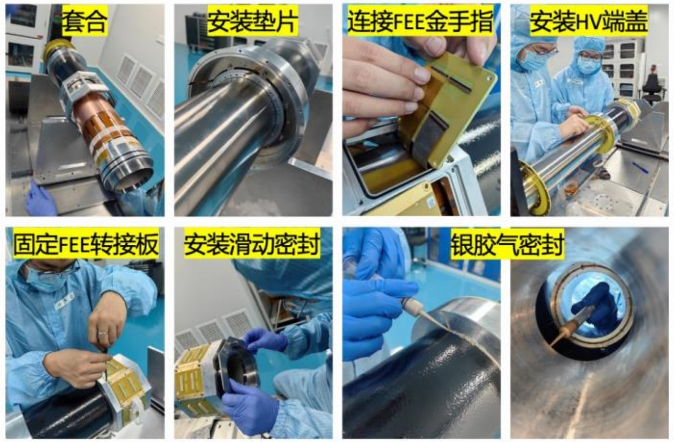


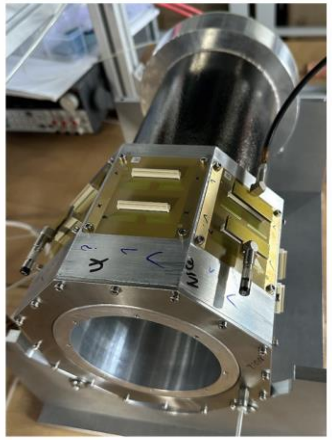




µRGroove provides larger signals and easier production compared to µRWELL.



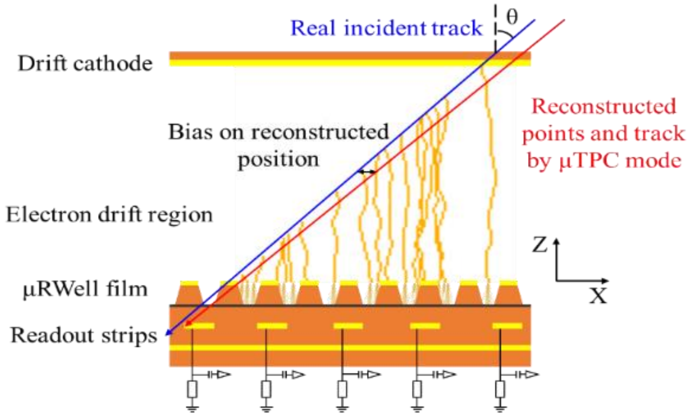


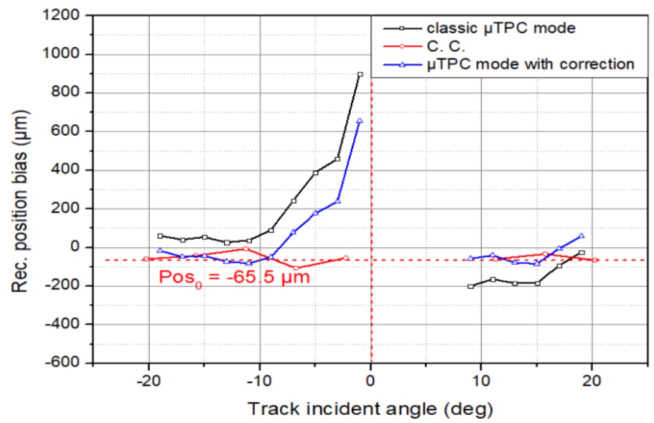


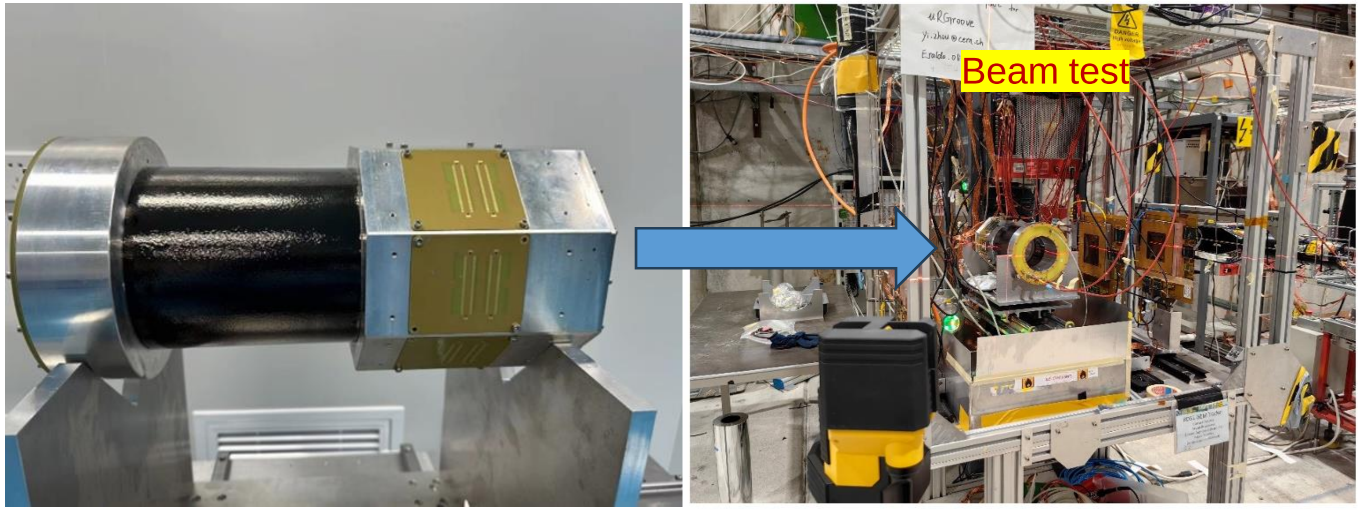
Fabriacating the low-mass c-µRGroove prototype: material budget ~ 0.23%X0/layer

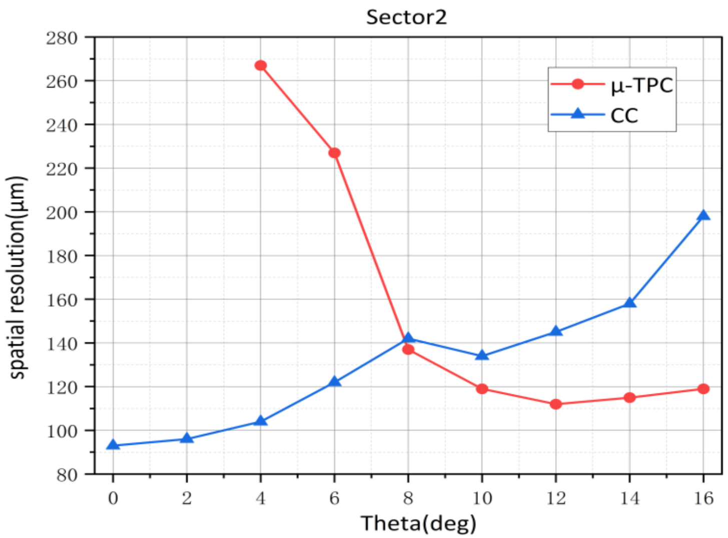
MPGD ITK : μTPC mode

- ❖ **Position reconstruction with μTPC is the key to maintaining good position resolution in magnet field or for inclined tracks. The μTPC method was thoroughly studied for systematic bias and its correction.**





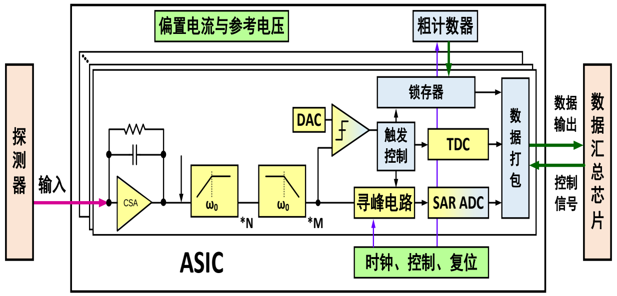


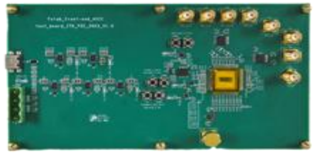


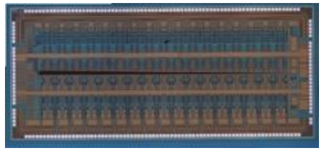
Beam test @ CERN, Position resolution better than 100μm for vertical tracks and ~120μm for inclined tracks

MPGD ITK : Electronics (ASIC / APV25)

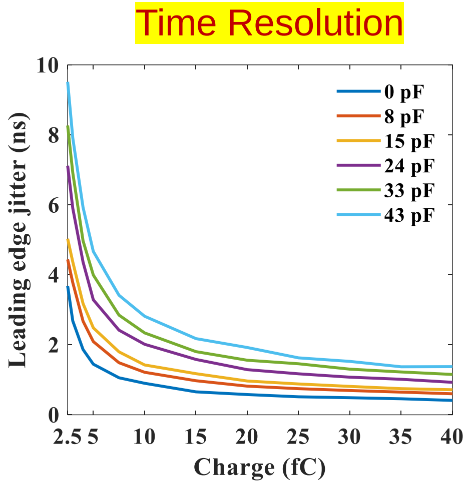
- **ASIC is required for readout. Very challenging performance requirements (event rate much higher than VMM). Designed and produced a 32-channel prototype ASIC chip with full function.**

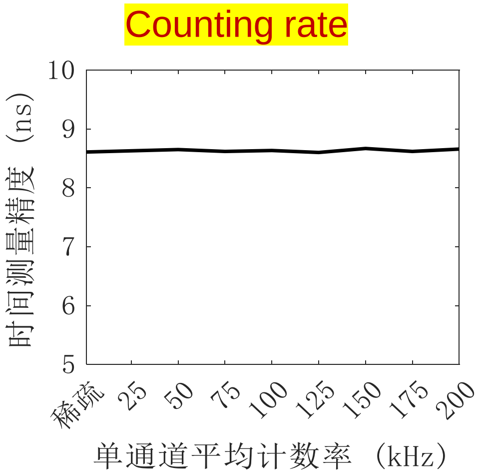




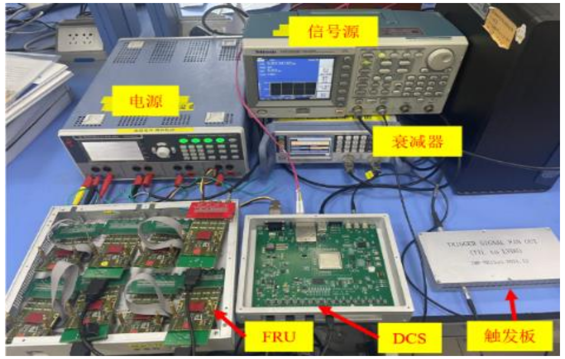


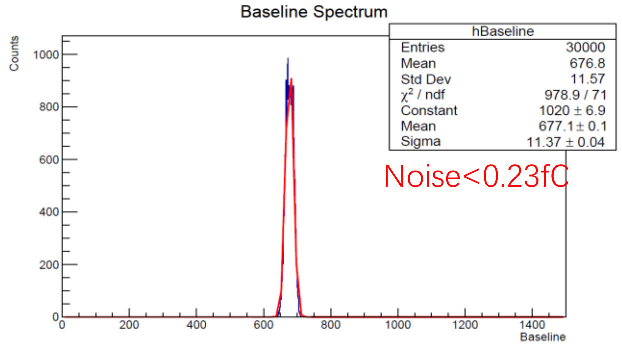
ASIC Specs	Demands
Charge Range	40 fC
Charge precision	~ 1 fC RMS
Time precision	< 10 ns RMS
Max. event rate	4 MHz





- **Designed and built a 1024-channel readout system based on APV25 for the purpose of testing and characterizing detector prototypes.**



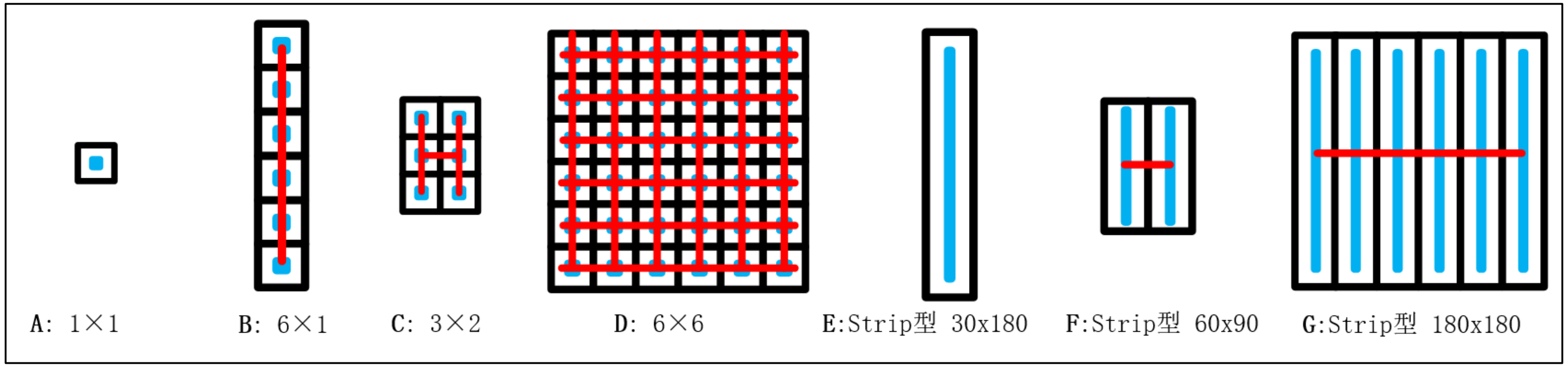


MAPS ITK : MAPS Designs

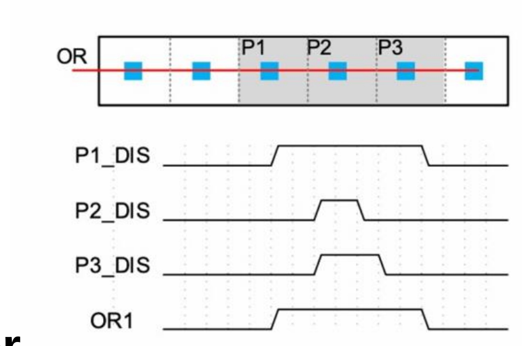
特点：抗辐照强、位置分辨率高
挑战： MAPS工艺、低功耗、定时等

Use larger pixel size to reduce the power consumption density

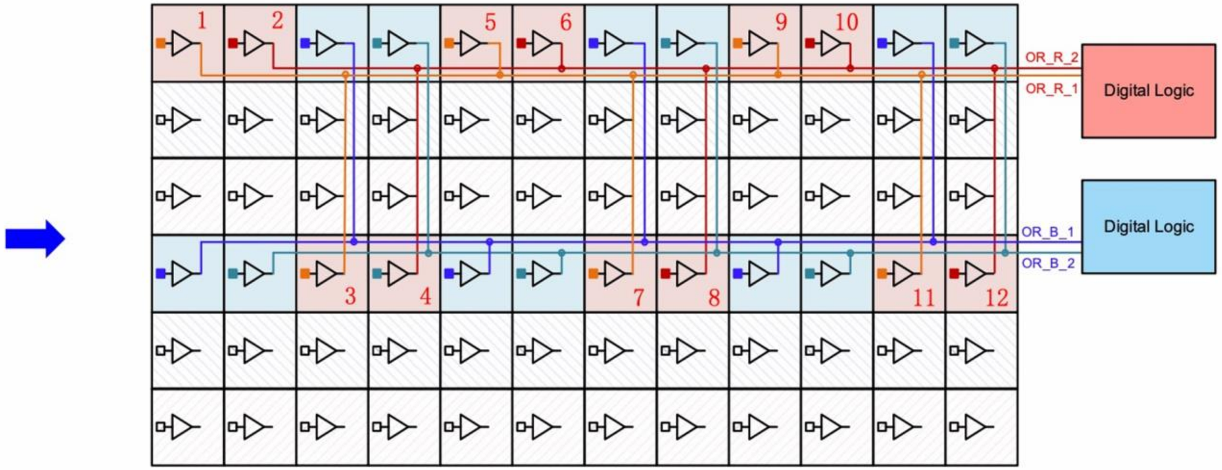
Aiming for a low-power chip design (required for a low-mass system) with timing and charge measurement capability



Combining non-adjacent pixels and designing a super-pixel design that can provide both high position and high time resolutions for low power consumption.



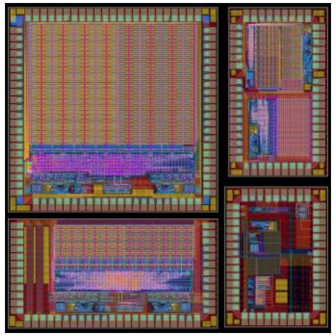
Combining adjacent pixels
→ ToT loss



MAPS ITK : MAPS Fabricating

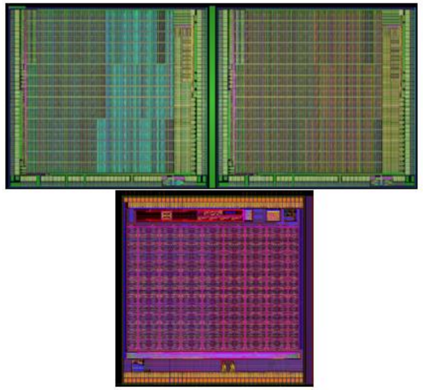
- **Various CMOS processes being explored**
  - **Mature technology: TowerJazz 180nm (HR epi)**

TowerJazz 180nm
Chips received,
testing underway

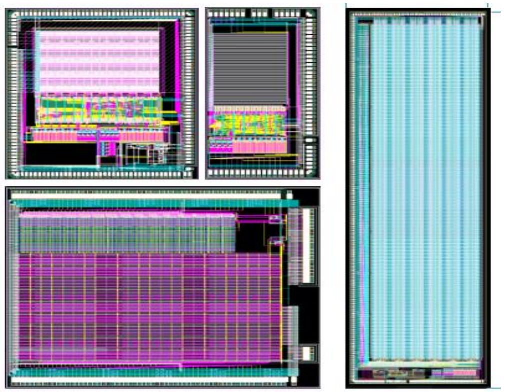


  - **Domestic foundries: NexChip BCIS 90nm (LR epi) , GSMC 130nm (HR substrate), IRAY 180nm (HR epi)**

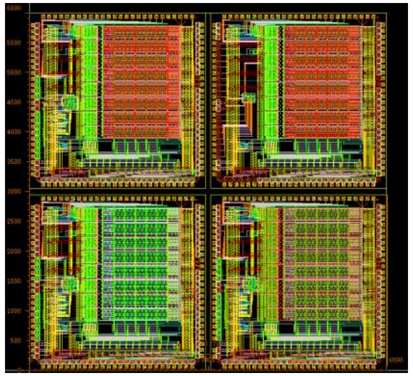
NexChip BCIS 90nm
Submitted in Jan. 2025



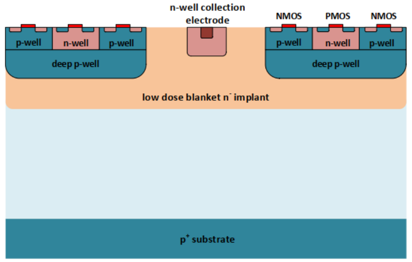
GSMC 130nm
Chips to be received



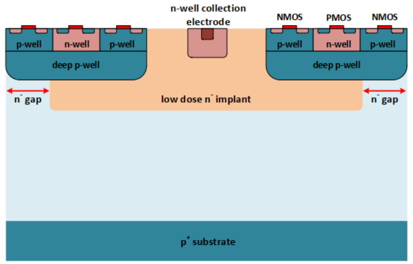
IRAY 180nm
Supporting quadruple-well with possibility of
N-blanket implant and N-gap. In the submission process



N-blanket implant

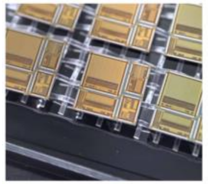


N-gap

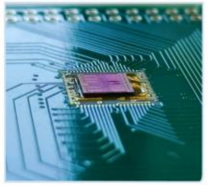


MAPS ITK : MAPS Testing

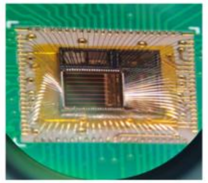
❖ **Characterized the TJ chips for threshold, noise, fake hit rate and capacitance. Tested the chips with laser and radioactive sources (Fe55 and Sr90) for detection efficiency, charge collection efficiency and time resolution.**



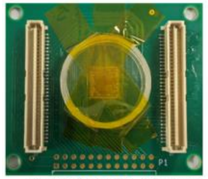
TJ芯片



同尺寸芯片试粘接在绝缘胶上

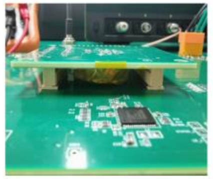


未划片直接打线



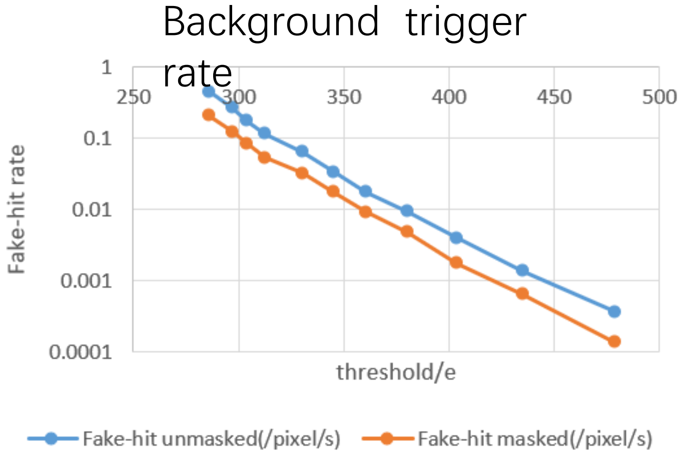
子板背面(芯片+保护壳)

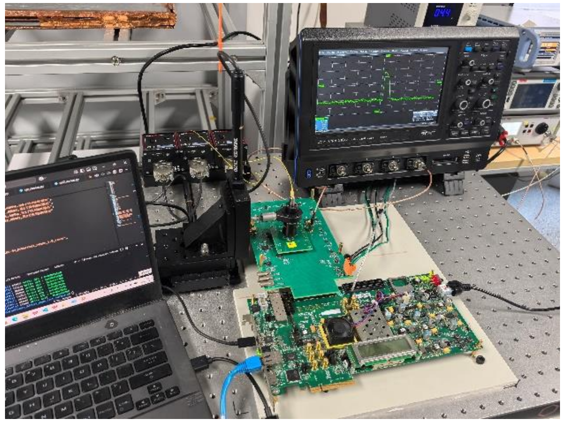
子板正面(绝缘胶挖洞)

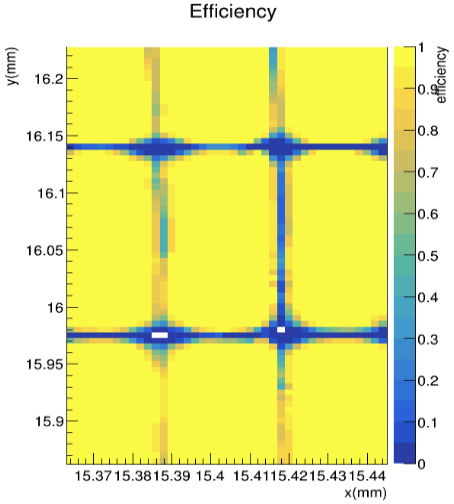


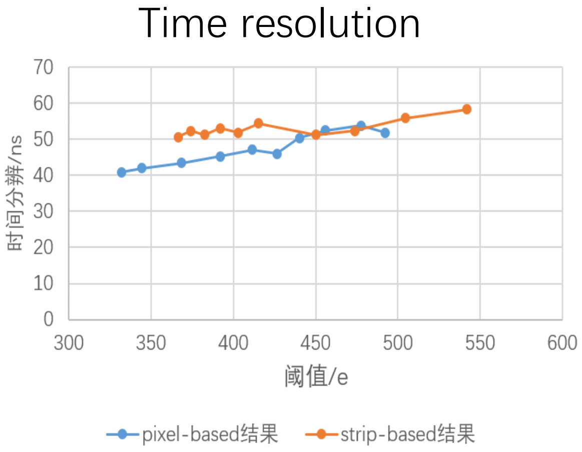
子板安装在测试转接板上

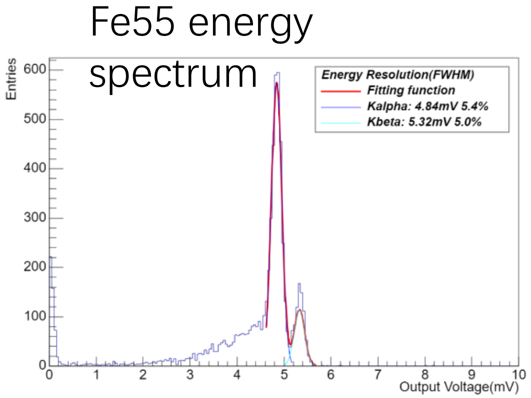
偏压/V	Threshold/e	FPN/e	TN/e	A_{OUT}/mV	基线RMS/mV
-2	268.2	7.15	16.1	523	7.8
-3	234.7	2.75	15.3	477	9.2
-4	212.2	0.82	15.4	417	7.06
-5	178.1	5.32	11.3	348	5.92
-6	182.1	7.11	12.1	292	5.88





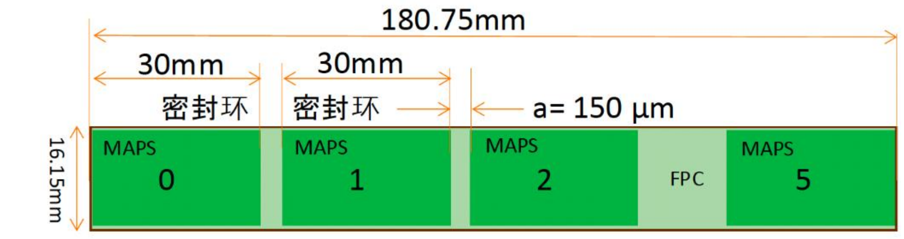


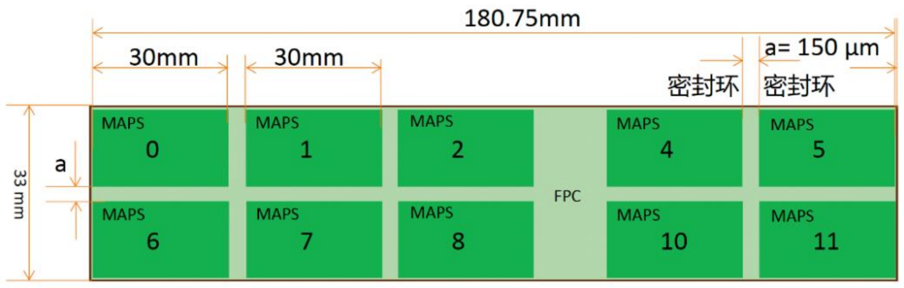




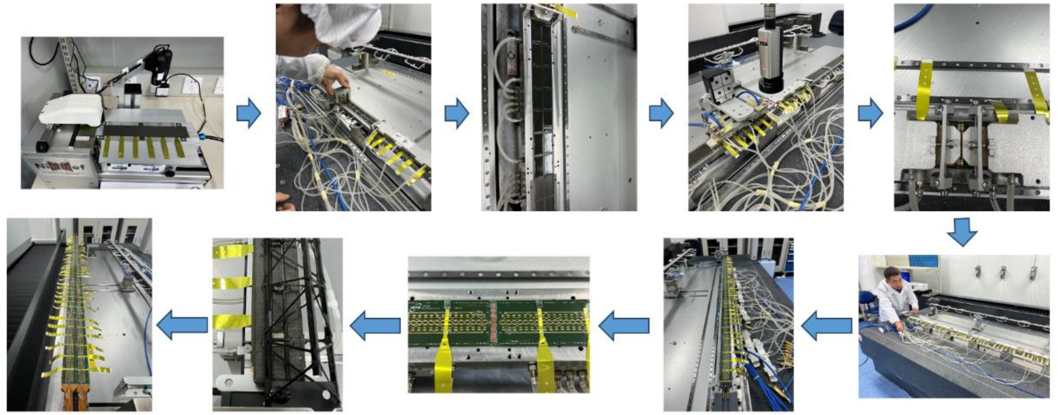
MAPS ITK : Stave Design

❖ **Launched detector module (stave) mechanical design effort**

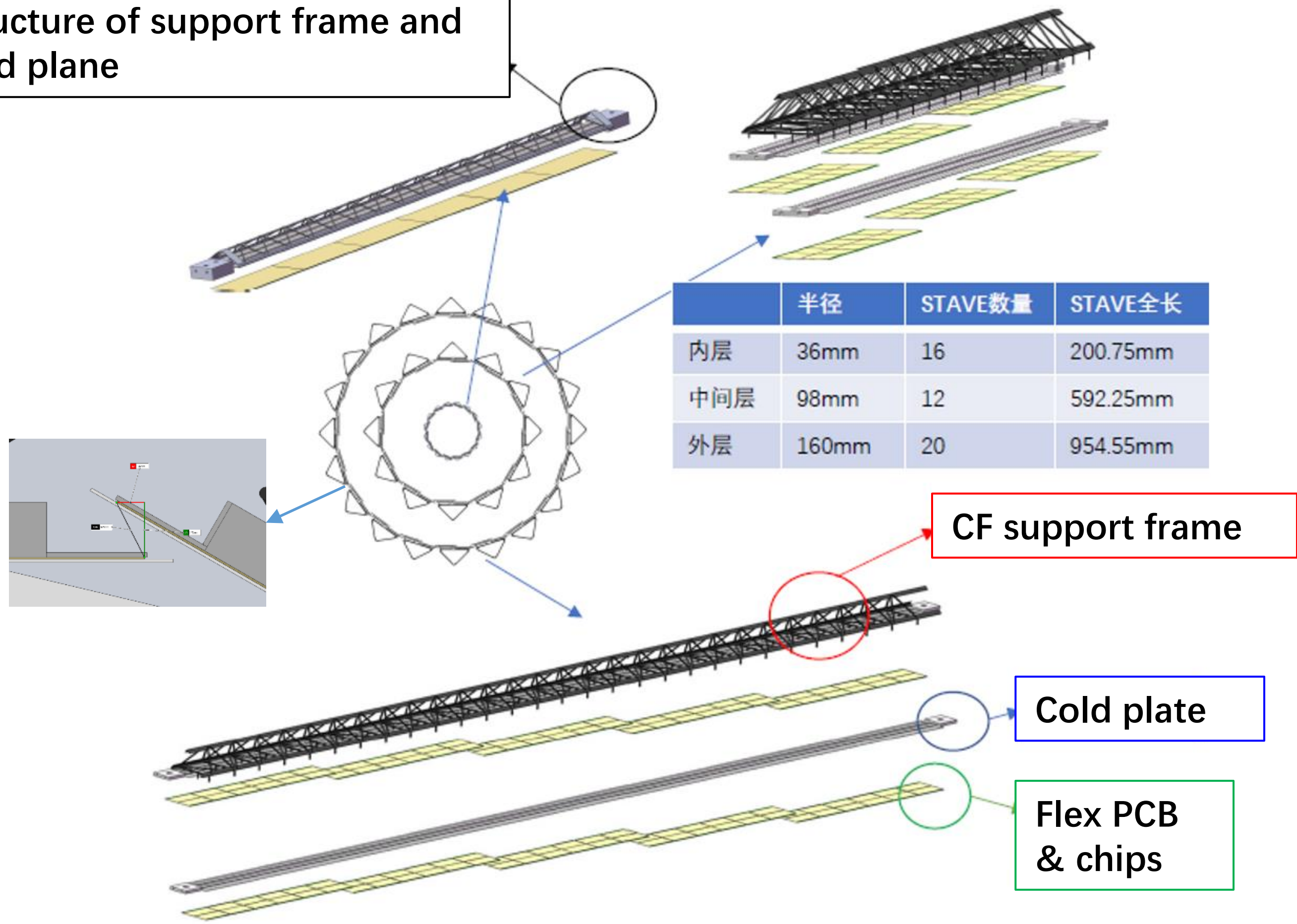




Stave assembly and integration infrastructure and experience



The inner most layer: integrated structure of support frame and cold plane

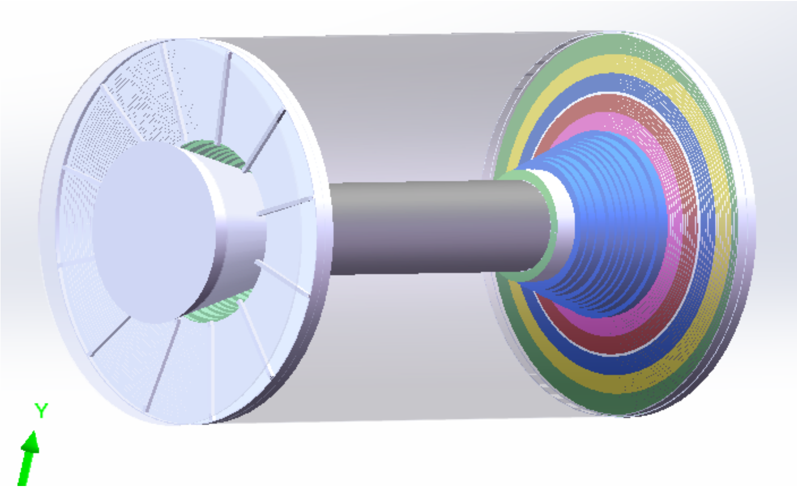


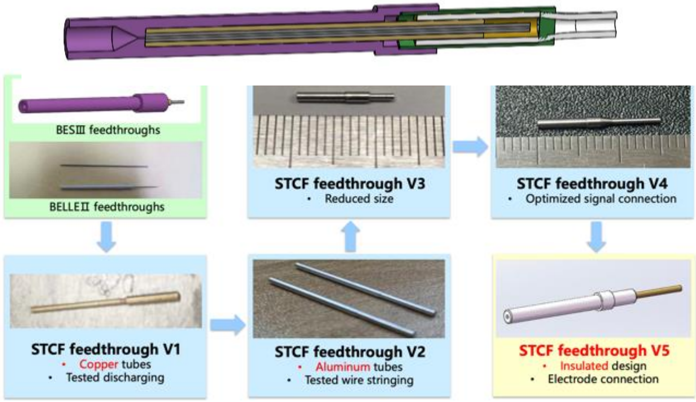
	半径	STAVE数量	STAVE全长
内层	36mm	16	200.75mm
中间层	98mm	12	592.25mm
外层	160mm	20	954.55mm

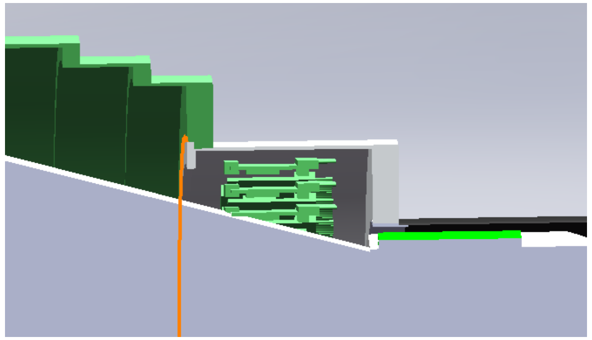
Main Drift Chamber : Detector

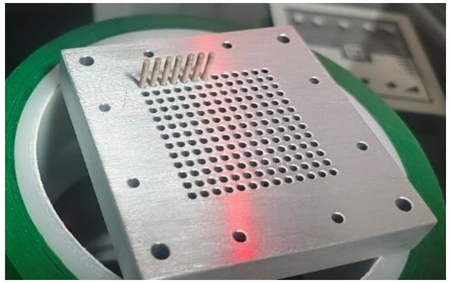
挑战：低物质量、高计数率、小单元等

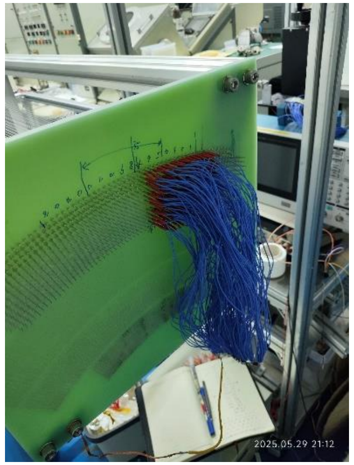
- ❖ Endplate structure optimized to simplify the assembly process
- ❖ Intensive ongoing R&D effort on feedthrough for super-small cells (~5 mm)
- ❖ A full-length super-small cell drift chamber prototype is under construction.





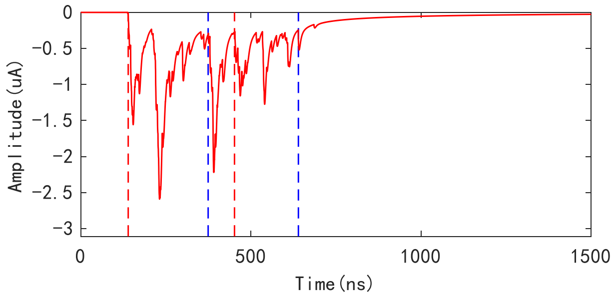


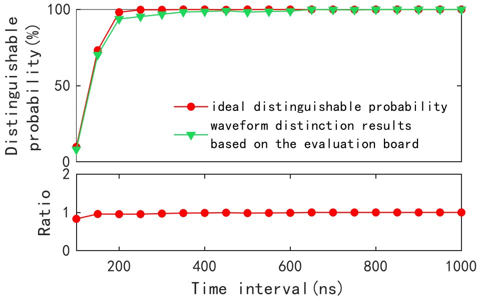


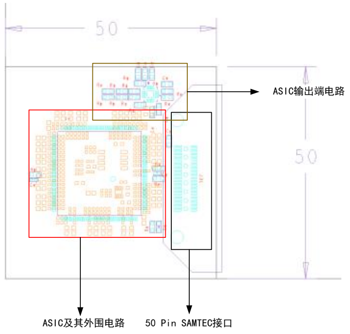


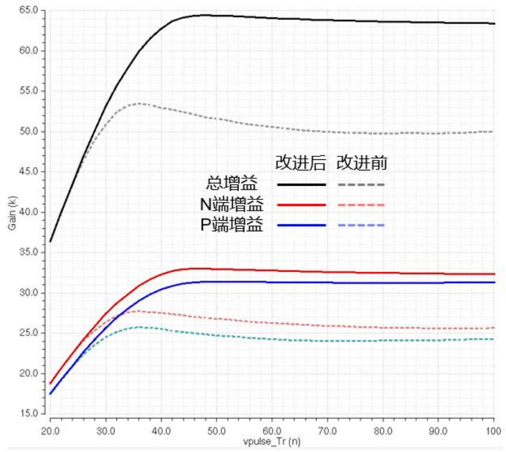
Main Drift Chamber : Electronics

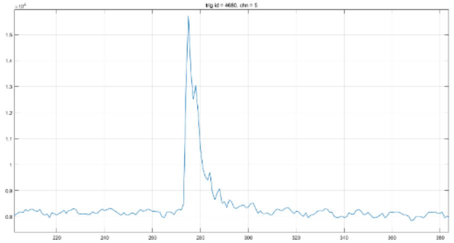
- A major challenge in MDC electronics: discriminating overlapping signal pulses (as a result of high counting rate) that are irregular in shape.
- Waveform digitizing electronics is used to allow online waveform discriminating algorithms that run on PFGA. Developed the electronics with discrete components (TIA + shaper + ADC) and tested with detector prototypes.
- ASIC design is underway. First version of the analogue part has been taped out. The chip prototype has been produced and is being tested.

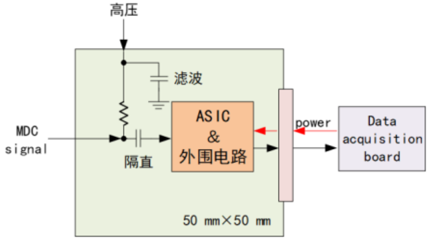








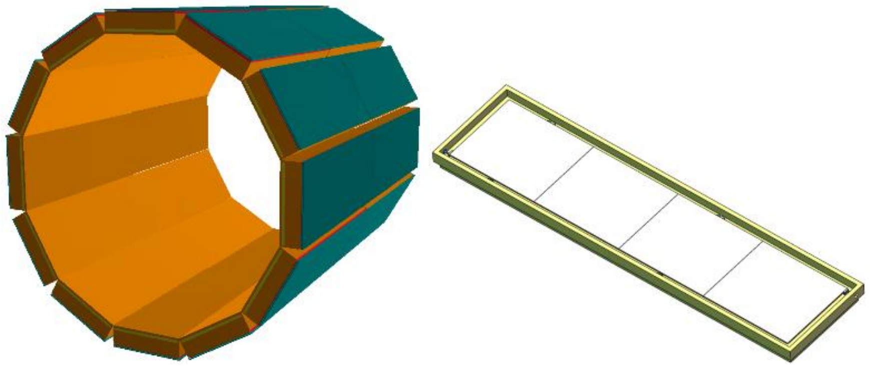




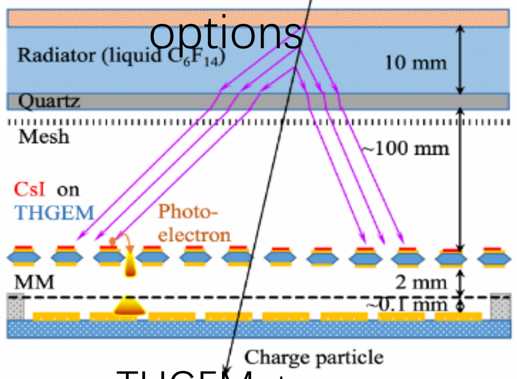
PID System

- PID system: thickness < 20cm, material budget < $0.3X_0$, π/K ~4σ @ 2GeV

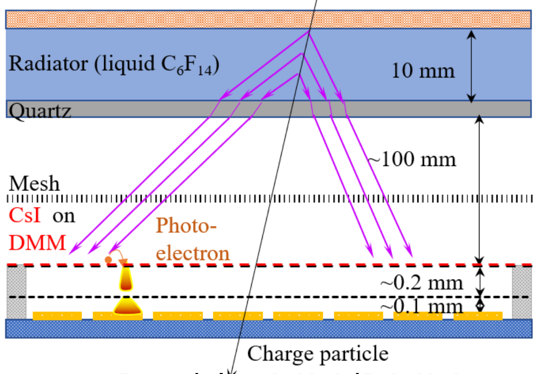
❖ Barrel PID: A RICH detector using MPGD with CsI for photon detection, σ_θ ~ 4 mrad



Two MPGD-based photo detector options

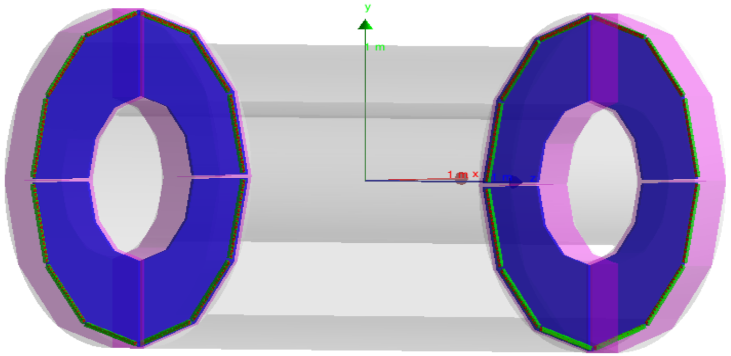


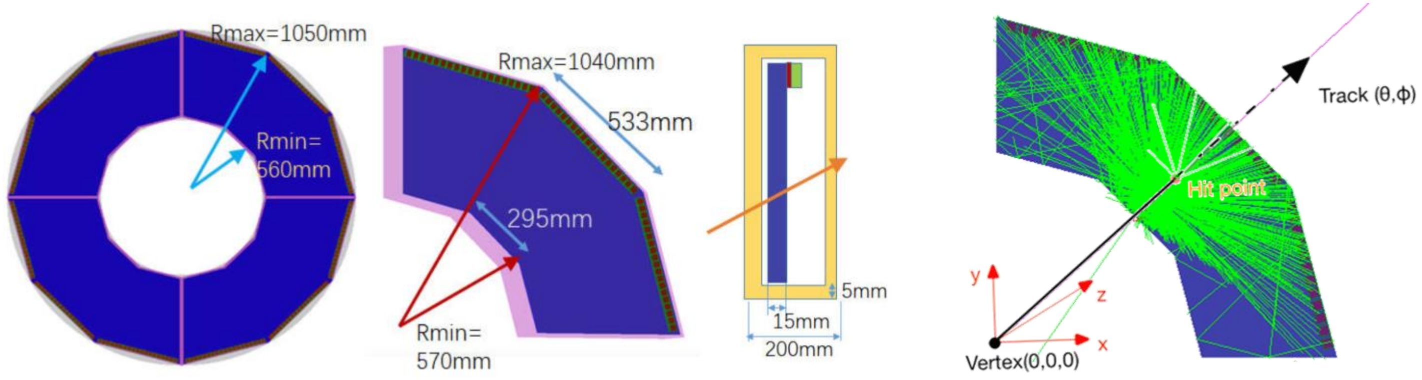
THGEM + MM



Double-MM/DMM

- Endcap PID: A DIRC-like TOF detector, DTOF, quartz plate + MCP-maPMT , σ_t ~ 30ps

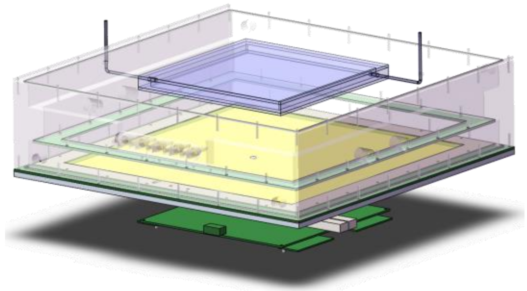


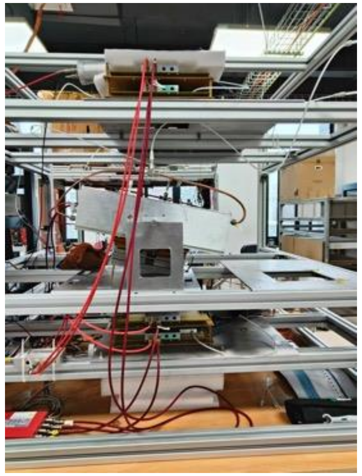


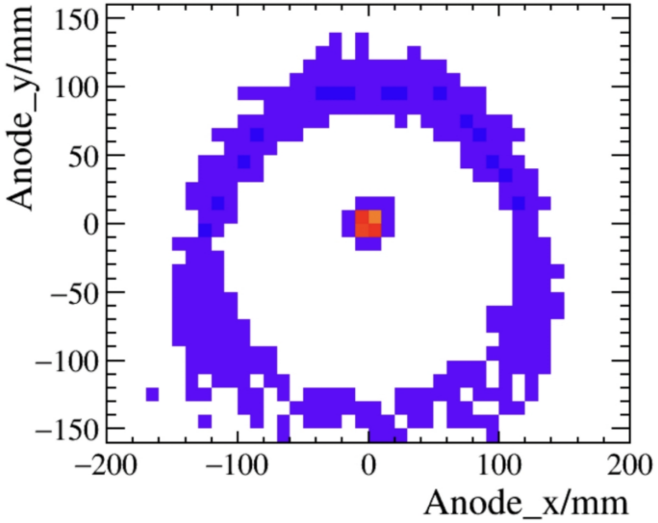
PID Barrel : RICH

特点：大面积单光电子探测
挑战：大面积气体探测器、紫外单光电子探测、读出电子学等

Cosmic-ray test of a 32×32 cm^2 RICH prototype with THGEM + MM

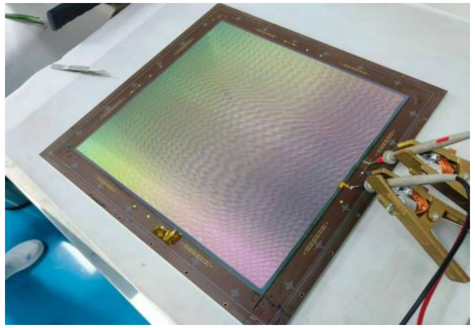






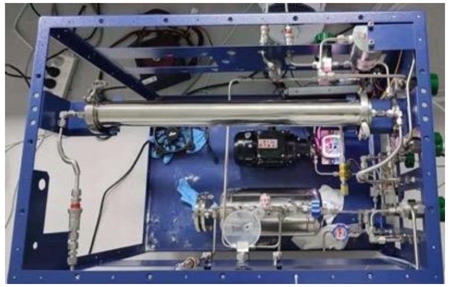
Moved to DMM option : DMM-RICH

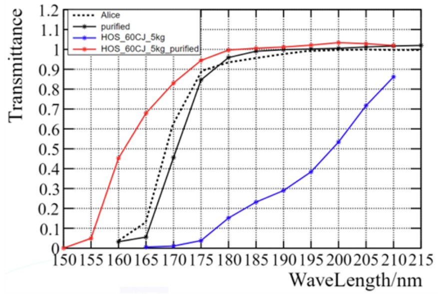
- Compact structure
- High gain & good time resolution
- High electron collection efficiency & low ion backflow



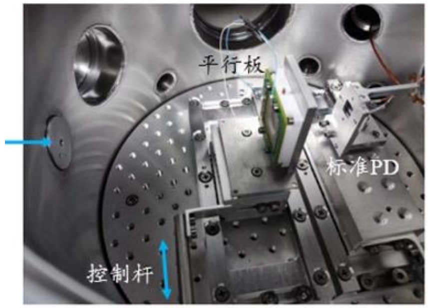
Ongoing test of a DMM-RICH prototype

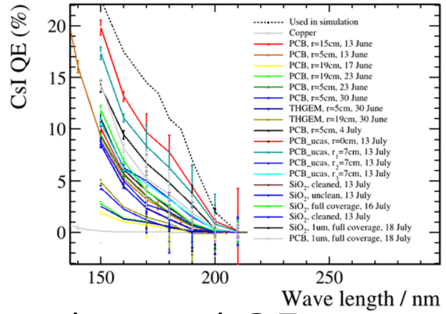
Ongoing efforts to bring up the photoelectron yield





Enhancing radiator transparency by purifying C_6F_{14}



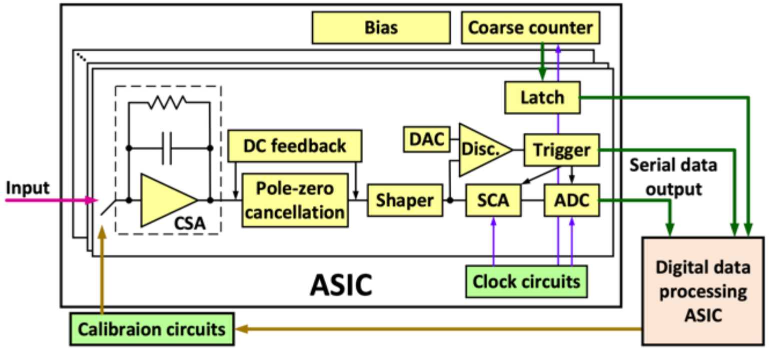


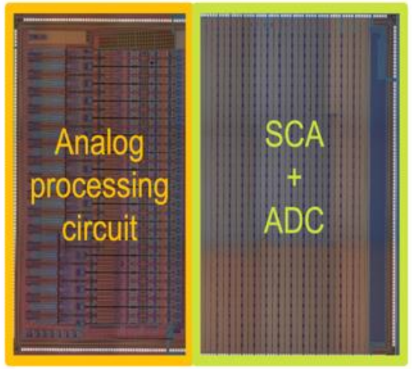
Improving QE: CsI coating and QE measurement

RICH Readout ASIC

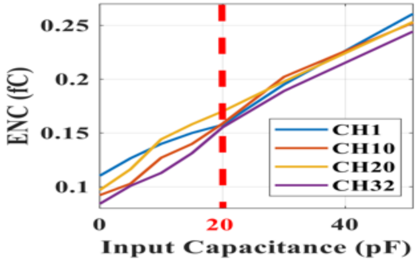
- A large number of readout channels in high density: ~500 k, 5×5 mm^2 granularity , requiring ASIC

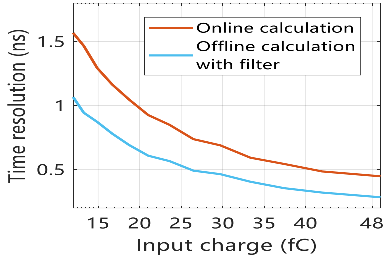
Design specs: σ_t < 1ns @20fC&20pF, event rate ~ 30 kHz, 32-64 channels

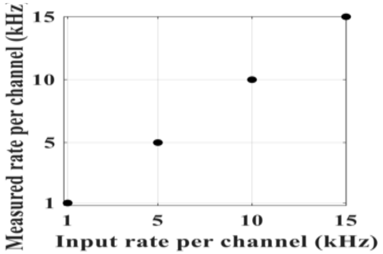




Test results





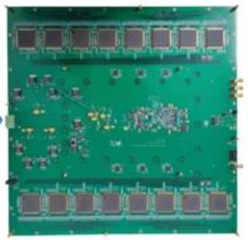


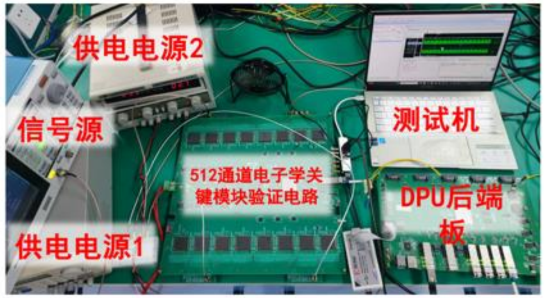
RICH ASIC design evolution

First version

Second version

32 channels/chip

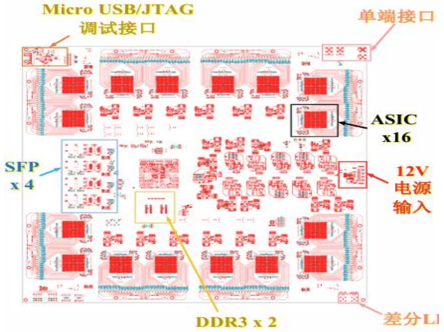




512-channel readout board using the 32-ch ASIC

Third version

64 channels/chip



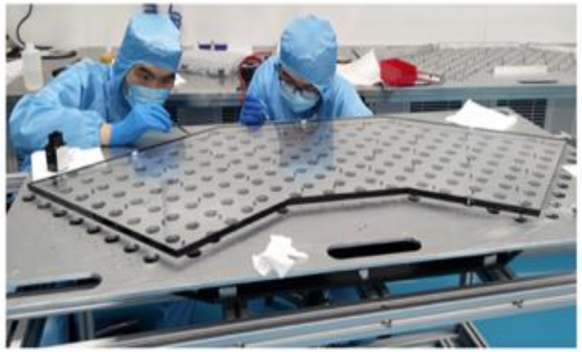
1024-channel readout board being developed

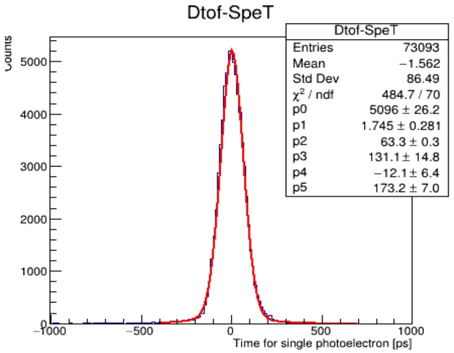
PID Endcap: DTOF

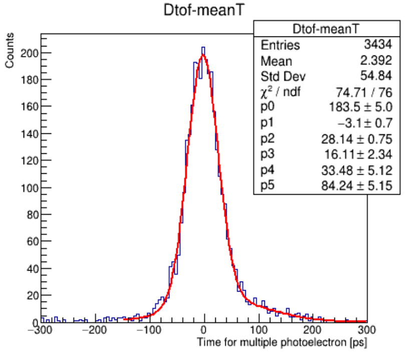
特点：高精度时间探测
挑战：大面积石英辐射体加工、多阳极光电倍增管等

- A full-size DTOF prototype (a quadrant of STCF DTOF at one endcap) was built and tested with cosmic-rays to demonstrate the DTOF concept and technology on the full scale.

σ_{spe}=59 ps， σ_{track}=21 ps

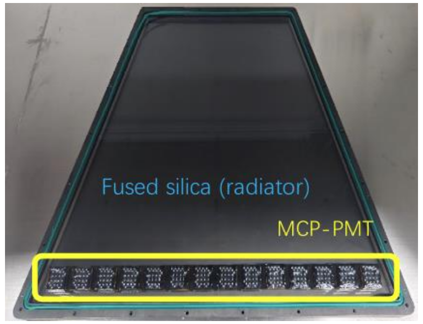


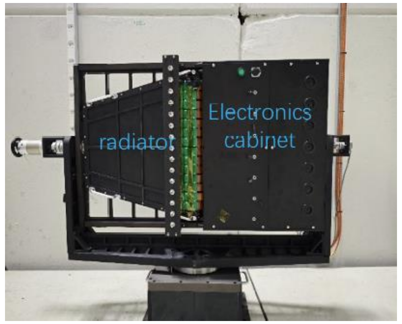


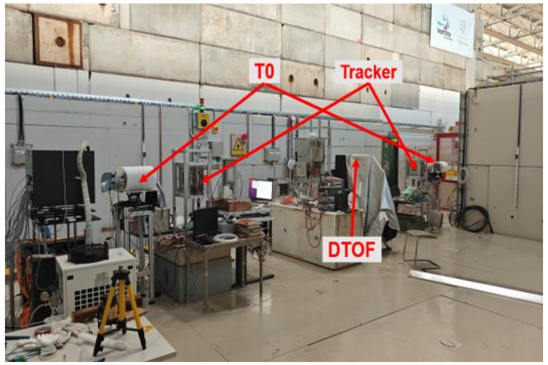


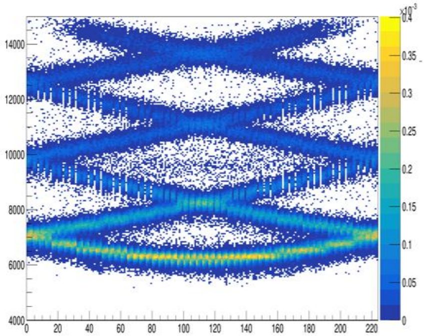
- A smaller DTOF prototype a third the size of the quadrant was built and tested with particle beams at CERN to demonstrate the PID capability of the DTOF detector

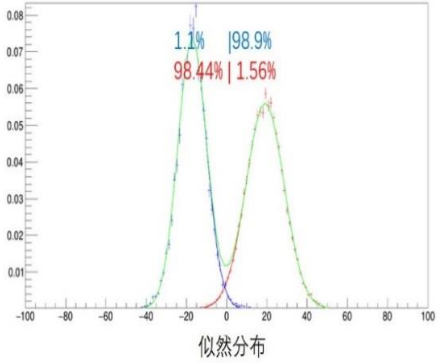
π/K separation >4σ @





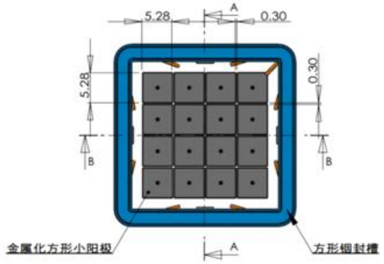


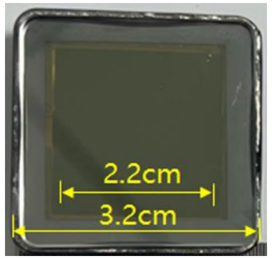




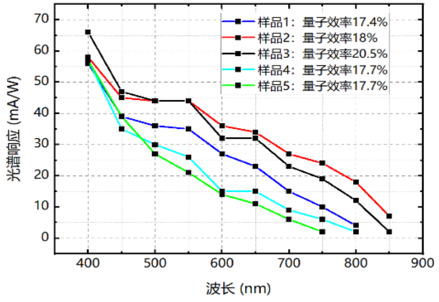
MCP-maPMT and Readout ASICs

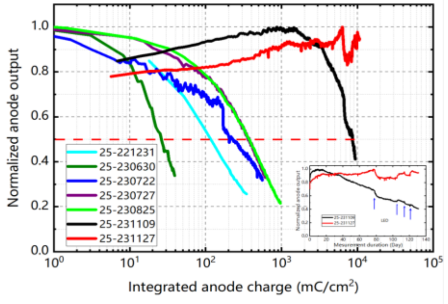
- MCP-maPMT: a critical component of the DTOF technology
- Intensive R&D on techniques (ALD and electron scrubbing) to produce long-life MCP-PMT (target Q > 10 C/cm^2).
- Designed and produced 1-inch MCP-maPMT prototypes with 16 annodes each.
- Carried out various tests of the MCP-maPMT prototypes
  - TTS<40 ps, QE>20%, G>10^6,
  - Aging : <10% gain drop when Q>11C/cm^2



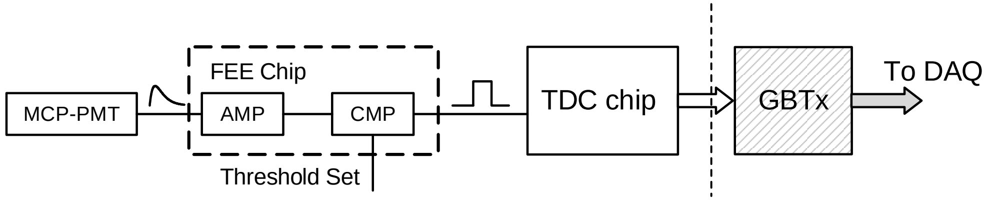


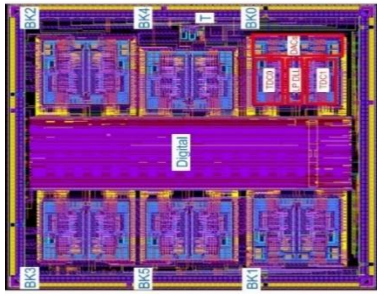
MCP-PMT编号	25-240507	25-240521	25-240605	25-240620
MCP类型	ALD-MCP，ALD镀膜厚度：D2			
MCP厂家	厂家1	厂家1	厂家2	厂家2
MCP电子清刷剂量	0.75 uA·h/cm²	0.87 uA·h/cm²	0.75 uA·h/cm²	0.87 uA·h/cm²

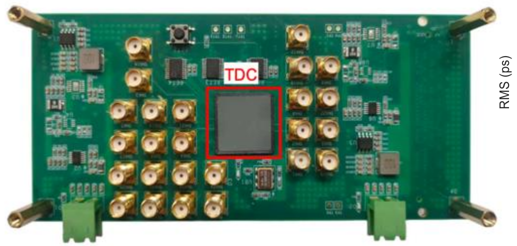


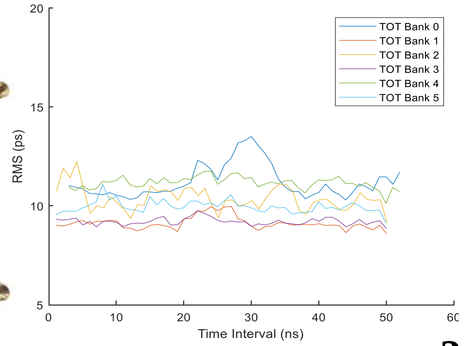


- Two ASICs designed for MCP-maPMT readout. Prototype chips produced and tested
  - FET: target ~ 15 ps, measured ~15 ps
  - TDC: target ~ 15 ps , measured ~10 ps



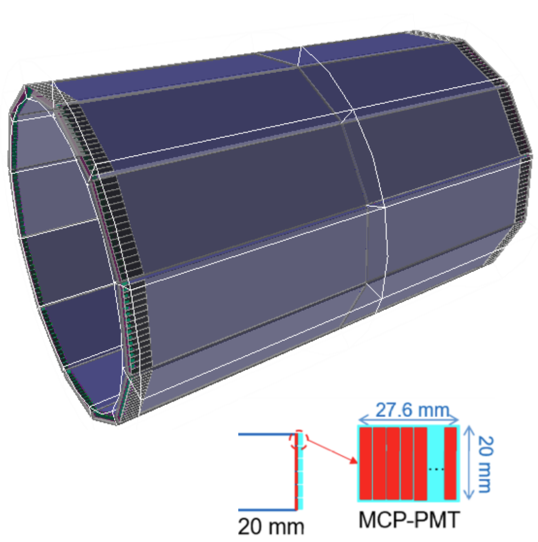


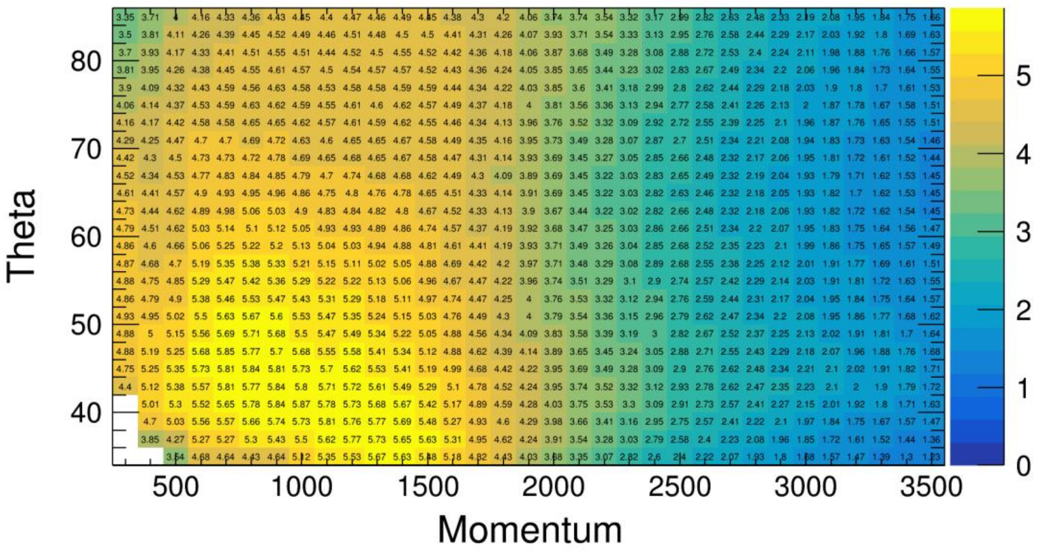


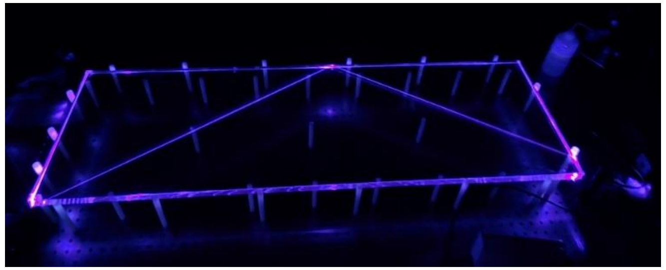


BTOF : DTOF in Barrel

- **Design of a barrel PID detector based on the DTOF technology is available (BTOF)**
  - 12 sectors with 2 modules placed longitudinally in each sector, 24 quartz plates in total
  - Quartz plate parameters : R = 875mm H = 20mm L = 1350mm D = 450mm
  - Inner side of a quartz plate is coated with light absorbing layer while the outer side is equipped with 15 SiPMs for readout
- **Performance with full simulation mostly meets PID requirements. Ongoing effort to optimize the design by scanning a variety of key parameters**
- **A full-length BTOF prototype is under construction and will undergo a beam test**



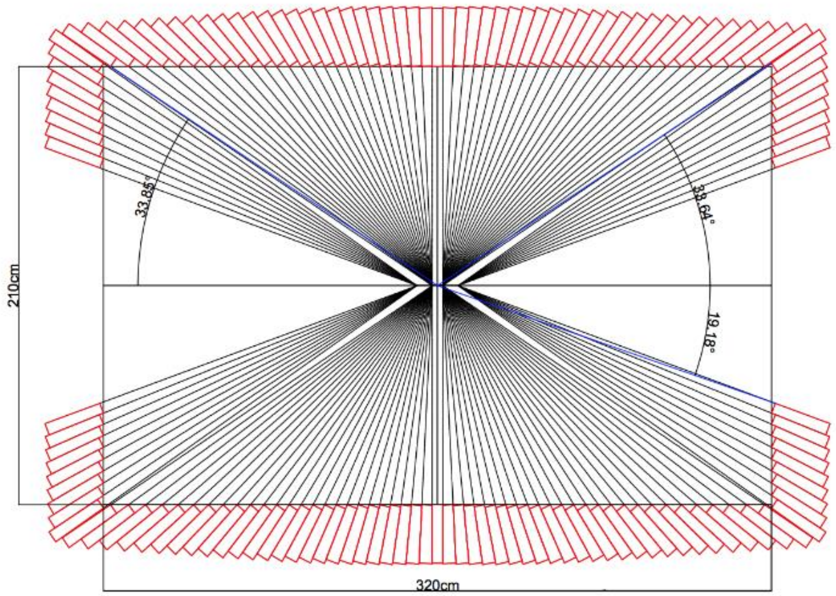




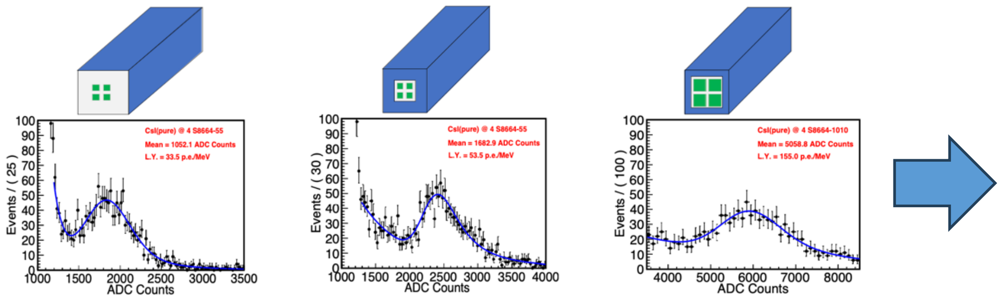
Electro-Magnetic Calorimeter

特点：快时间响应，高能量分辨
挑战： CsI光产额，事例堆积及时间提取等

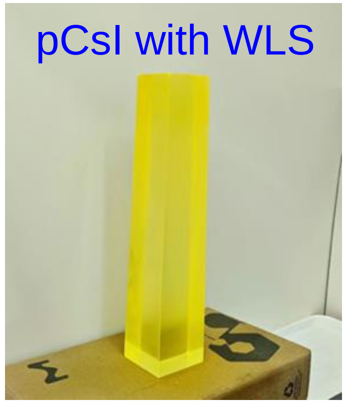
- **A crystal calorimeter using pCsI (short decay time of 30ns) to tackle the high background rate (~1 MHz/crystal)**
  - Crystal size: 28cm ($15X_0$), 5×5cm^2
  - Defocused layout: 6732 crystals in barrel, 1938 crystals in endcaps
  - 4 large area APDs to address low light yield: 4×(1×1cm^2)



A very low light yield of 3.6% for pCsI → a major R&D task : enhance the light yield of a pCsI unit

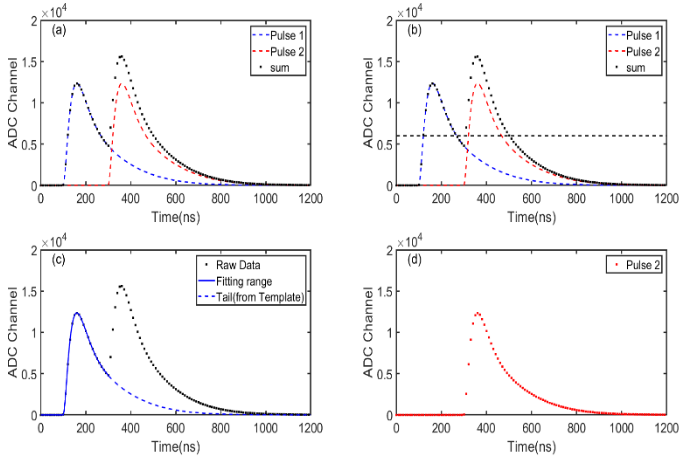


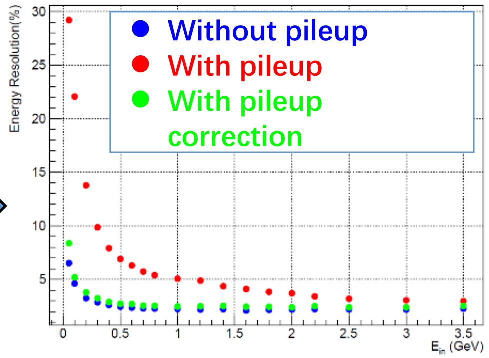
Light yield : 50 p.e./MeV → 300 p.e./MeV



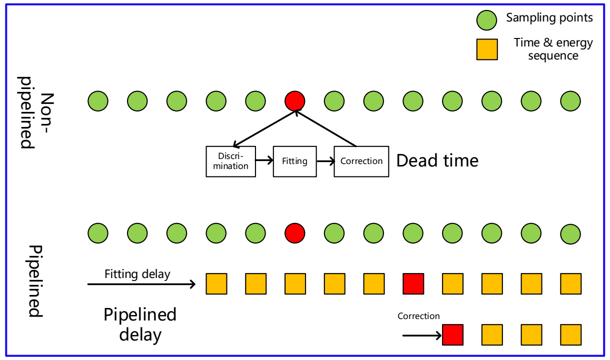
EMC : Pileup Mitigation and Electronics

- Significant pileup in EMC in the presence of beam background (~1 MHz/ch). A dead-time free pileup correction algorithm involving waveform fitting based on pipelined optimal filtering has been developed and implemented in FPGA

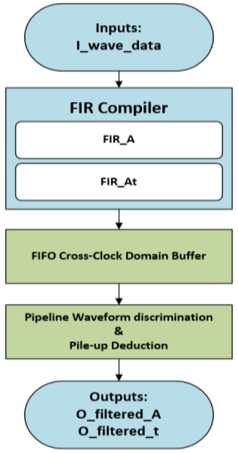




Very effective in mitigating the pileup effect

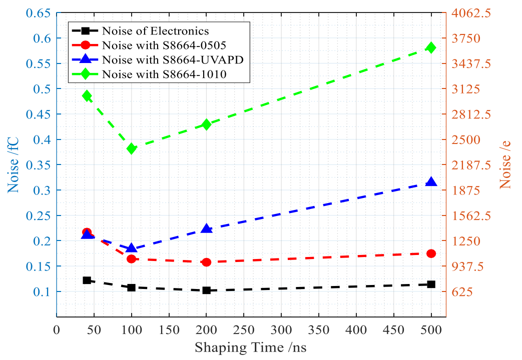


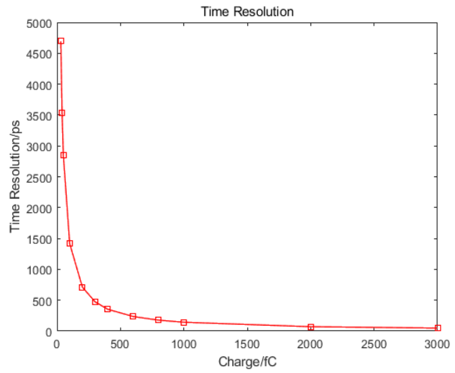
Pipelined correction algorithm



FPGA implementation

- Development of waveform digitization electronics (CSA + shaper + ADC)





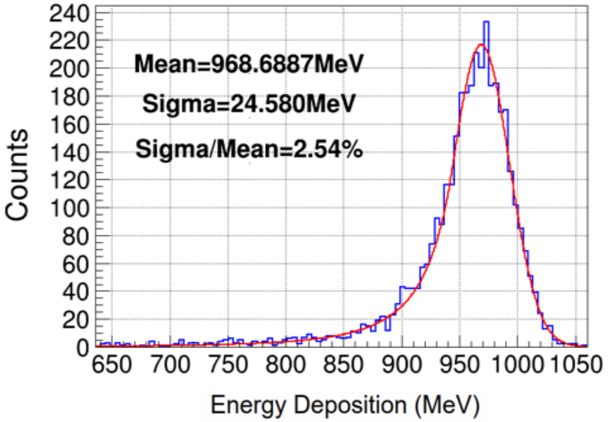
Dynamic range
3 MeV ~ 3 GeV
ENE : ~ 0.5 MeV
Time resolution
< 150 ps@1GeV

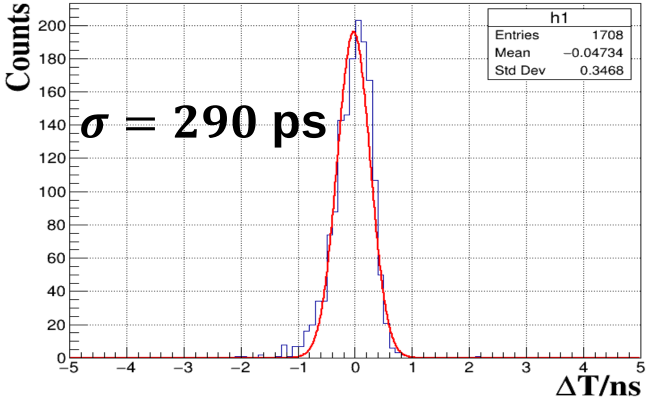
5×5 pCsI EMC Prototype

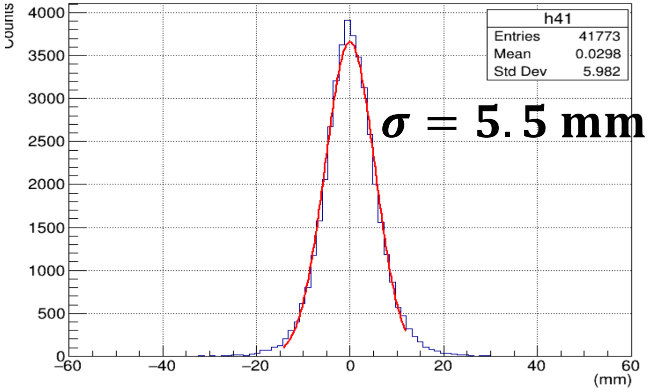
EMC prototype in the making

Beam test at CERN PS

Performance from the beam test with 1 GeV/c electrons



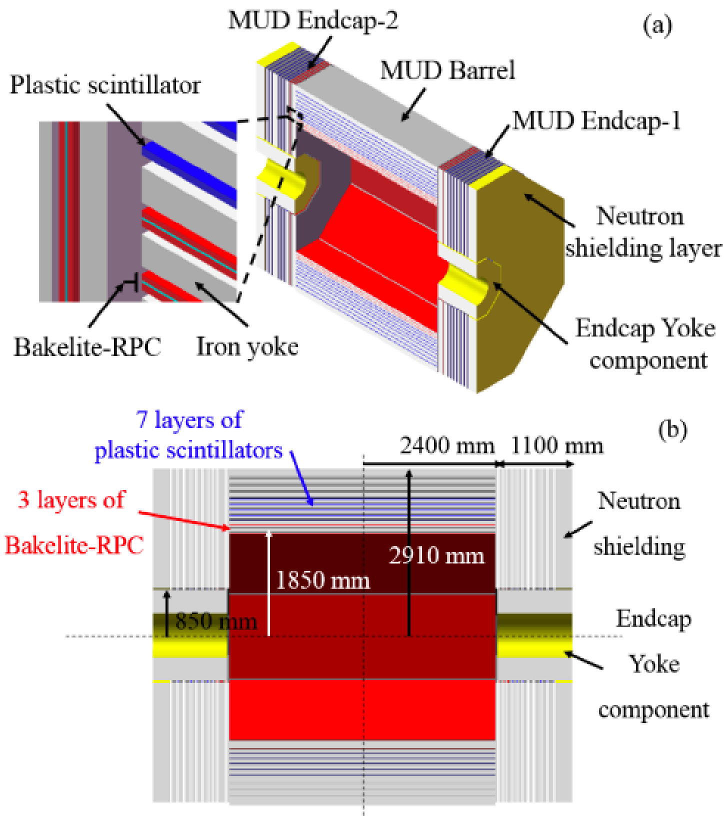




Muon Detector

特点：提供muon和中性强子鉴别
挑战：两种类型探测器的研发及优化

- A hybrid design with RPC and scintillator strips for optimal overall muon and neutral hadron identification performance
  - RPC for inner 3 layers : not sensitive to background
  - Scintillator for outer 7 layers: sensitive to hadrons

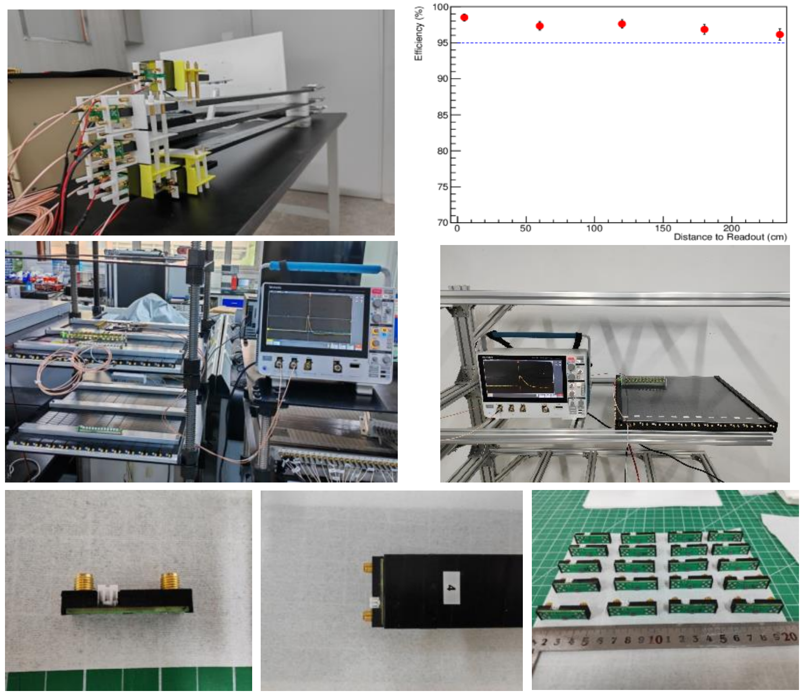


Parameter	Baseline design
R_{in} [cm]	185
R_{out} [cm]	291
R_e [cm]	85
L_{Barrel} [cm]	480
T_{Endcap} [cm]	107
Segmentation in ϕ	8
Number of detector layers	10
Iron yoke thickness [cm]	4/4/4.5/4.5/6/6/6/8/8 cm
(λ=16.77 cm)	Total: 51 cm, 3.04λ
Solid angle	79.2%×4π in barrel
	14.8%×4π in endcap
	94%×4π in total
Total area [m^2]	Barrel ~717
	Endcap ~520
	Total ~1237

MUD R&D

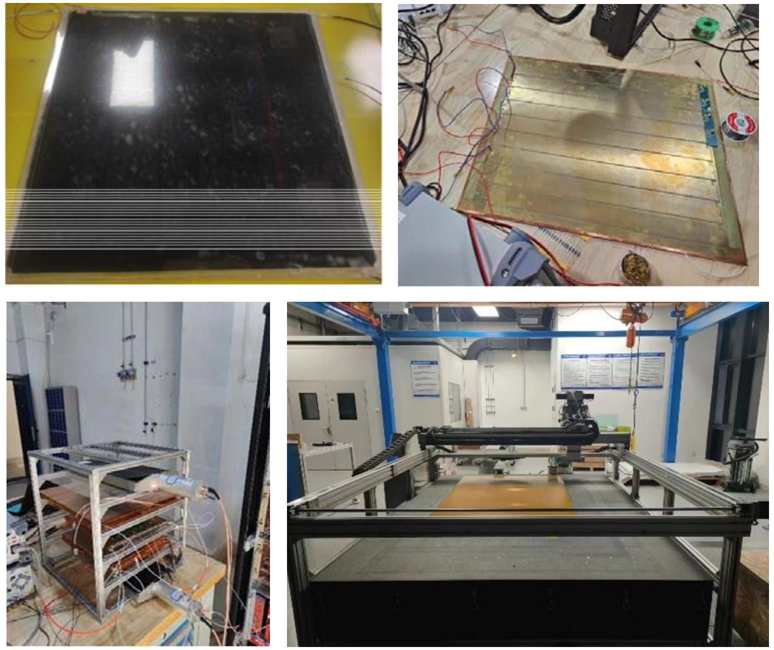
Scintillator strip + WLS + SiPM

- Design and fabrication of the scintillator unit： reflector, fiber groove, optical coupling, surface processing.
- Fabricated 2.4 long scintillator units (efficiency>95%) and a 50×50 cm² scintillator strip array



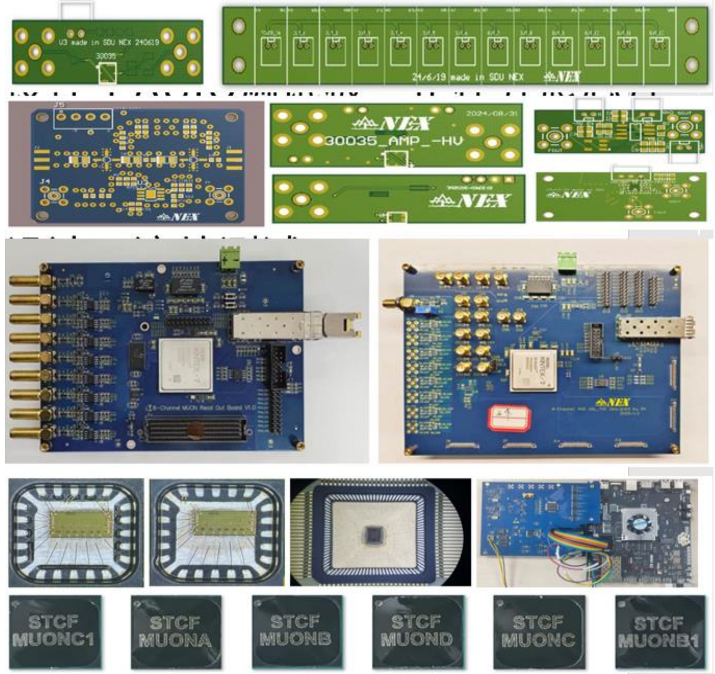
Glass RPC

- Developed glass RPC fabrication techniques and built a 40×40 cm² glass prototype.
- Focusing on low-resistivity glass RPC for high count rate capabilities. Built some small prototypes.



Readout Electronics

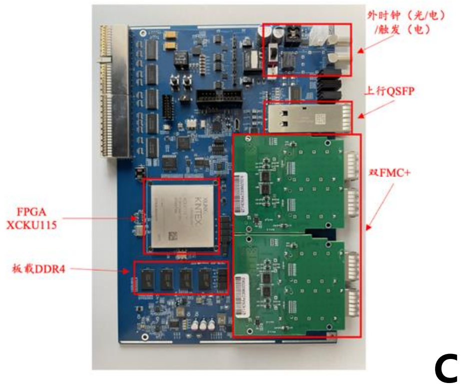
- Developed front-end amplifiers and readout boards. Tested with detector prototypes.
- Designed front-end ASICs for different input capacitance and gains. Prototype chips being tested



DAQ Design and Software&Hardware Development

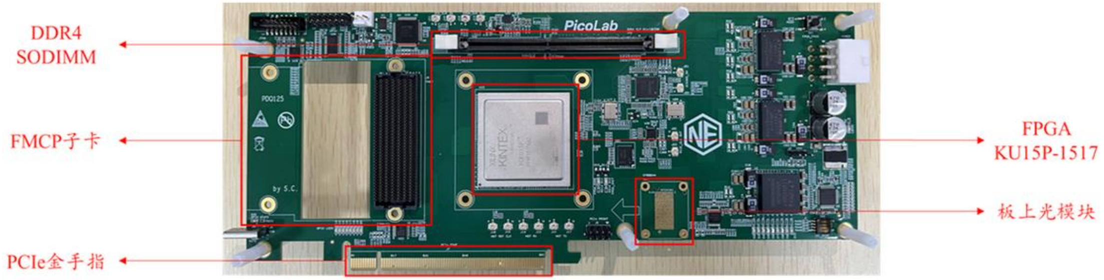
- ❖System architecture based on Data-Matrix: flow processing, hetero-computing, standard interfaces and protocols, global pipeline
- ❖Software and firmware development
- ❖Development of core electronics boards: CROB-PXI, CROB-PCIe, FMCP optical interface board
- ❖System testing and performance evaluation using simulation data

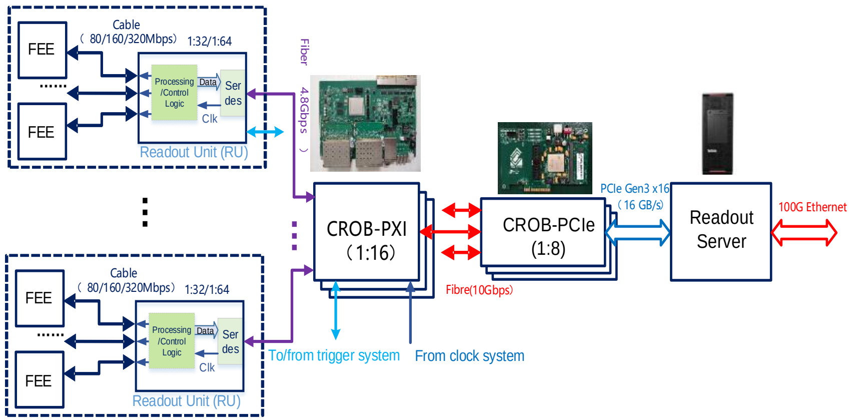
CROB-PXI board

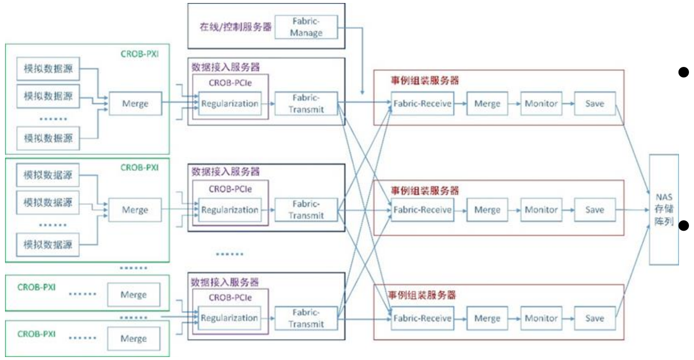


FMCP optical interface board

CROB-PCIe board





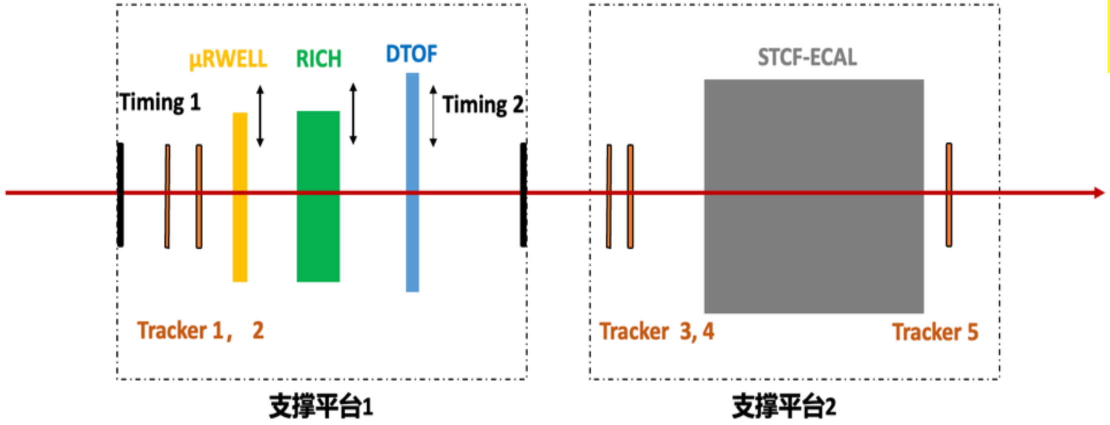


Test of event building

- 12 rack servers
  - 9 servers: readout+ 4 event builders
  - 3 servers: 4 event builders
- 33 simulated data sources
  - 17 big-frame sources: 20~32kB/frame
  - 16 small-frame source: 135 Byte/frame

DAQ Combined with DTOF & EMC @ CERN beam-test

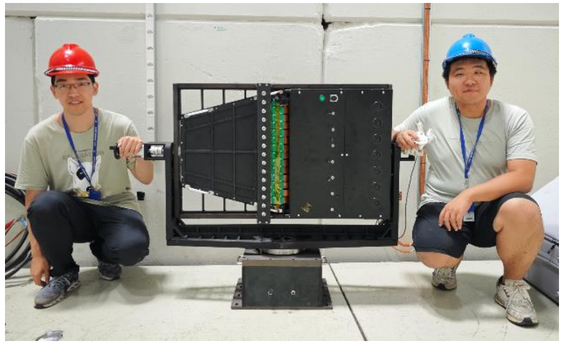
A test beam campaign for a combined system (DTOF, EMC, DAQ)

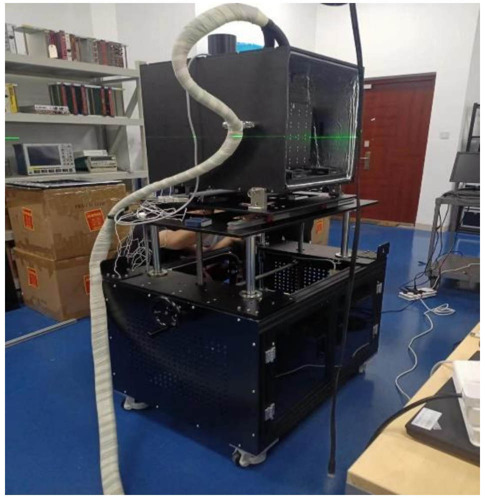


CERN PS T9 beam line (2024 July 31 – August 14)

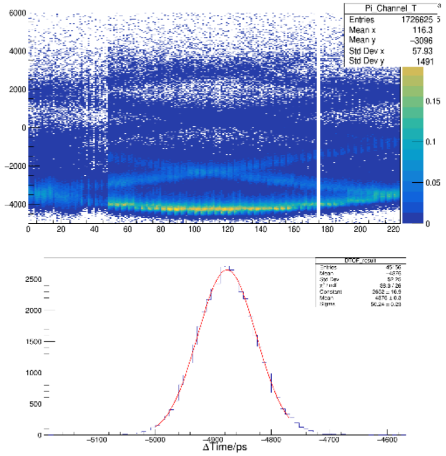
EMC Prototype

DTOF Prototype

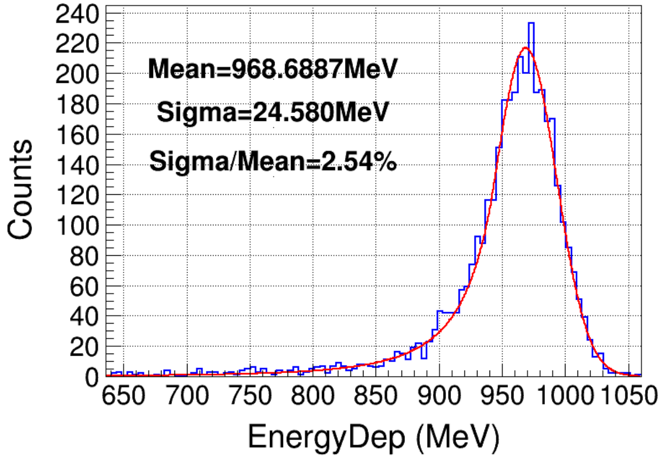




DTOF: σ_t~25 ps

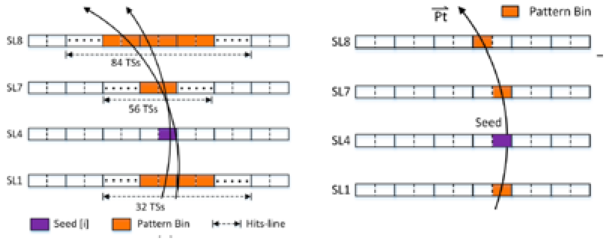


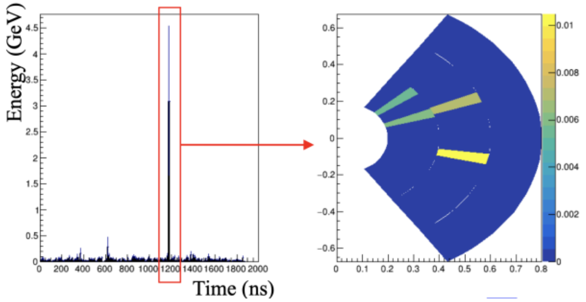
EMC: σ_E/E ~2.5%

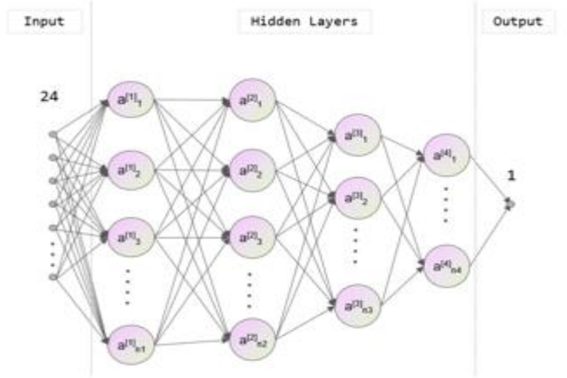


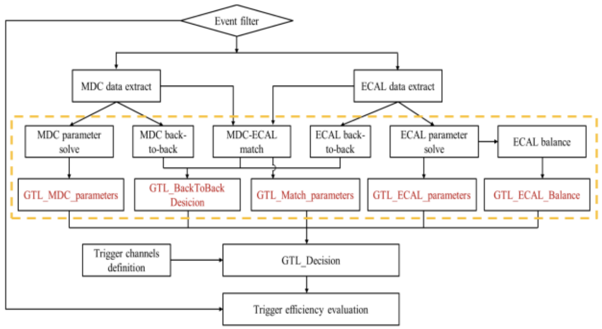
Trigger : Algorithms Studies and Development

- STCF trigger scheme ： L1 (MDC, ECAL and global trigger) + HLT
- L1-MDC trigger algorithms: 2D track reconstruction (track finding and parameters (pt, θ, φ, t) estimation) using pattern matching , 2D short-track reconstruction incorporating stereo layers using NN, Z impact parameter estimation using NN
- L1-ECAL trigger algorithms : overlapping events resolving, cluster reconstruction and splitting (E, θ, φ, t)
- L1 global trigger : track and cluster matching, event T0 estimation, trigger menus for charged and neutral channels
- HLT : currently focusing on MDC HLT aiming to remove noise hits and reduce event size







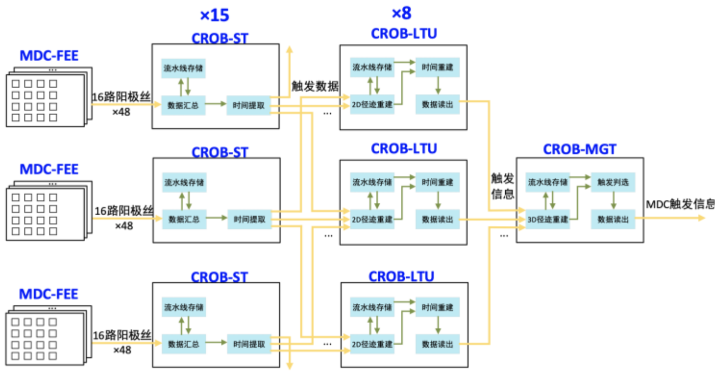


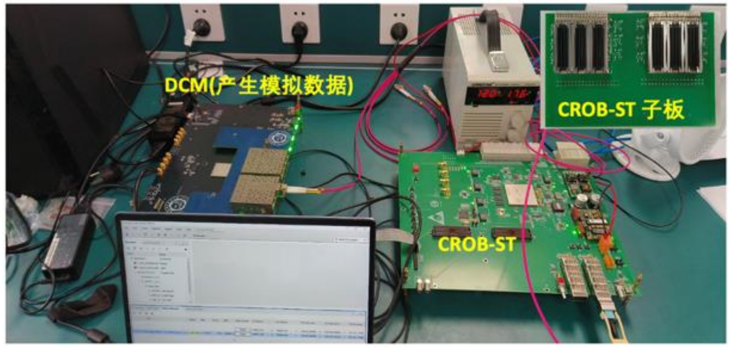
Background trigger rate < 50 kHz

Trigger channel	Physics signal	Energy point	Background trigger rate(kHz)	Signal trigger rate
	e^+e^- -> $\pi^+\pi^-$Jpsi; Jpsi -> e^+e^-	4.26GeV		99.7%
	e^+e^- -> $\pi^+\pi^-$Jpsi; Jpsi -> $\mu^+\mu^-$	4.26GeV		99.8%
	e^+e^- -> τ^+ τ^-	4.26GeV		98.2%
	e^+e^- -> $\pi^+\pi^-$Jpsi; Jpsi -> $\Lambda\,\bar{\Lambda}$	3.097GeV		99.0%
带电道	e^+e^- -> $\pi^+\pi^-$Jpsi; Jpsi -> $\Xi\,\bar{\Xi}$	3.097GeV	43.3	99.1%
	e^+e^- -> K^+K^-Jpsi; Jpsi -> l^+l^-	4.682GeV		100%
	e^+e^- -> $D_0\,\overline{D_0}$	3.773GeV		100%
	e^+e^- -> D^+ D^-	3.773GeV		100%
	e^+e^- -> D_s^+ D_s^-	4.04GeV		100%
	Jpsi -> inclusive	3.097GeV	46.6	97.7%
	J/psi-> gam invisable	3.097GeV		99.7%
	e+e- -> n nbar	3.097GeV		97.6%
中性道			39.4	
	e+e- -> gam n nbar	3.097GeV		99.7%
	e+e- -> gam n nbar(ISR)	3.713GeV		93.1%
亮度监测道	RBB	4.26GeV		98.4%

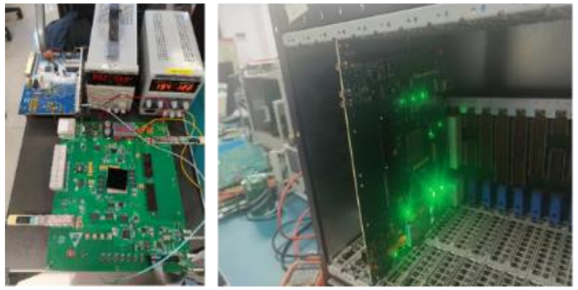
Trigger : Hardware Development

- Design of trigger hardware architecture. Development of various core trigger hardware components (CROB-ST, CROB-LTU, CROB-MGT/EGT, CTM, FMC …) . FPGA implementation of L1 trigger algorithms.
- A prototype L1 trigger system has been designed and is being built to demonstrate the trigger system design and its performance. An event simulator has been developed to generate pseudo data for the prototype trigger system.
- The prototype system will participate in the upcoming combined beam test.

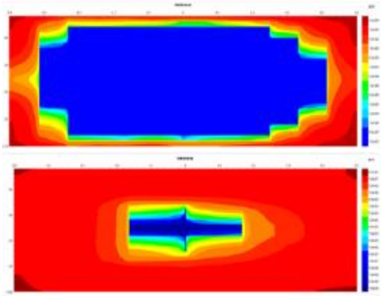




CROB-LTU板卡调试及机箱测试



FMC 不同带宽眼图（上：5Gbps；下：10Gbps）



数据产生板机箱测试

CTM板PCB图

Data Rates Estimation

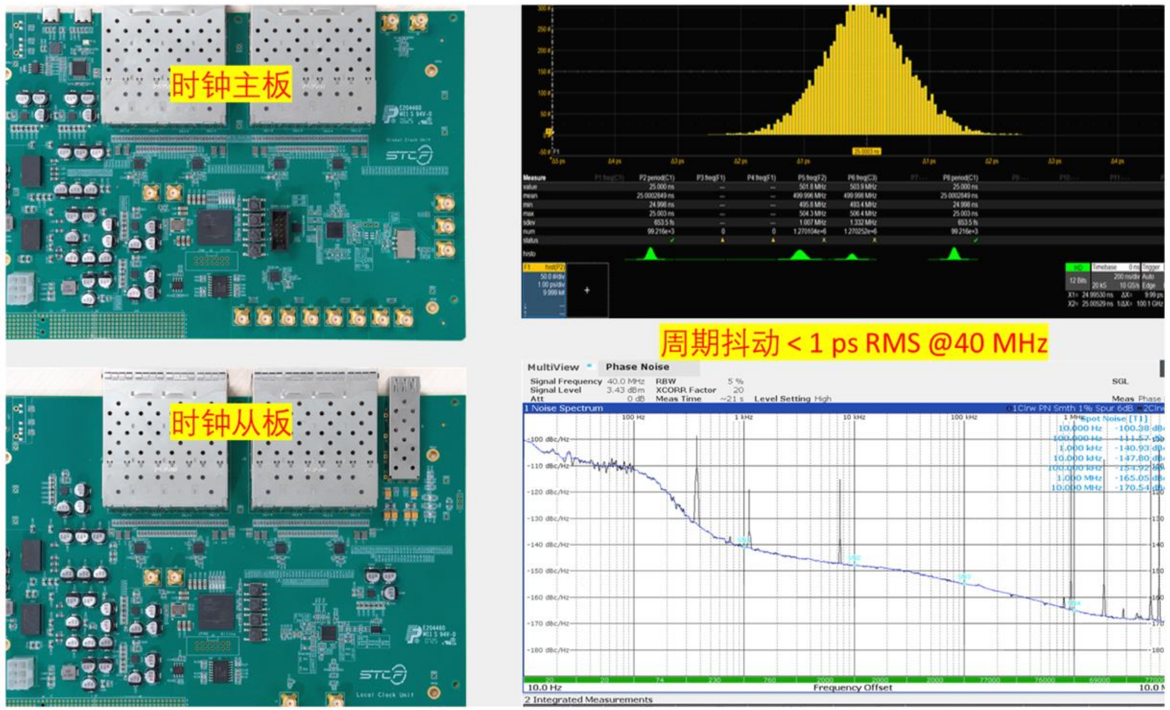
- Peak trigger rate : 400 kHz (physics @J/psi) + 50 kHz (background) = 450 kHz
- Raw event size : 18 kB/event (based on the updated beam background estimation)
- HLT data compression ratio was estimated based on preliminary HLT studies or experience from other experiments (e.g. BELLE2) .
- Final data rate to disk : 4 GB/s assuming HLT is in place.

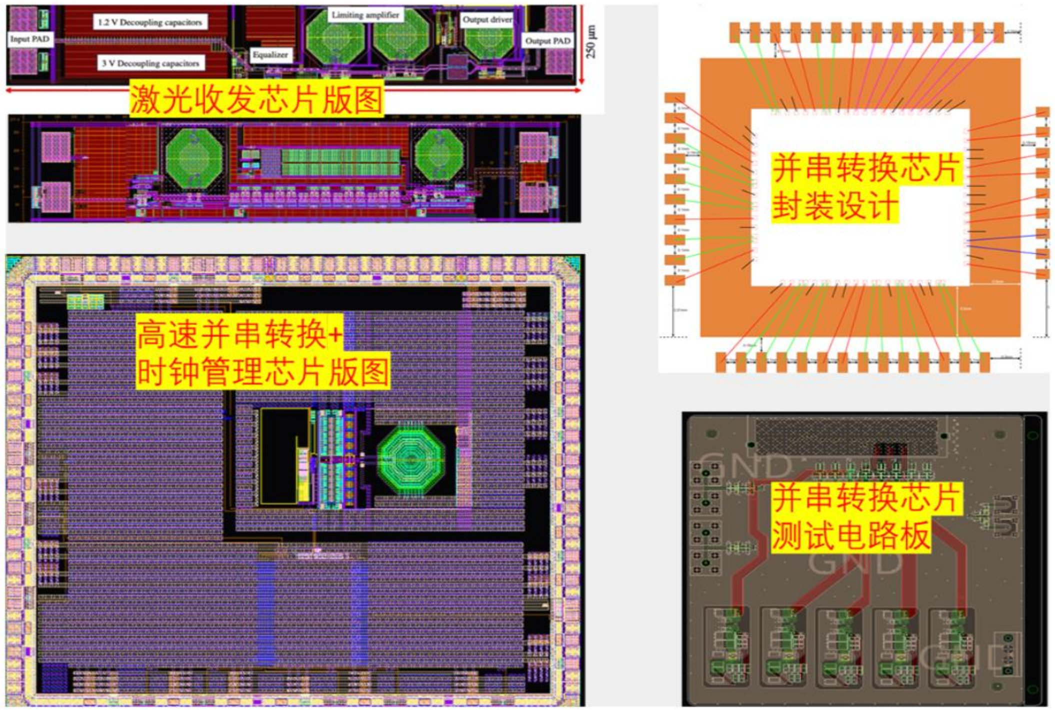
Sub-detector	Raw data (GB/s)	L1 data rate (GB/s)	HLT data compression ratio	HLT data rate (GB/s)
ITK-MAPS	2.57	0.96	0.25	0.24
MDC (SSC)	4.34	1.40	0.45	0.63
BTOF	4.31	1.18	0.95	1.12
DTOF	2.78	0.72	0.95	0.68
ECAL	7.37	1.4	0.7	0.98
MUON	1.48	0.48	0.8	0.38
TOTAL	22.85	6.14		4.03

Redundant information e.g. data package head and tail is excluded from the estimation of L1 and HLT data rates

Clock and Data Transmission

- Clock distribution system providing precise and stable clock signals with jitter < 5ps RMS
- High-speed serial data transmission：a GBTx-like ASIC, ADTC, uplink ~5Gbps



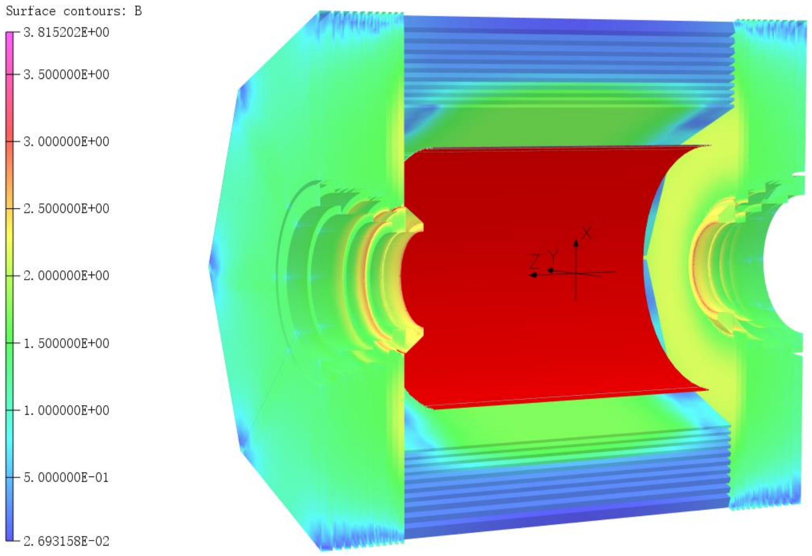


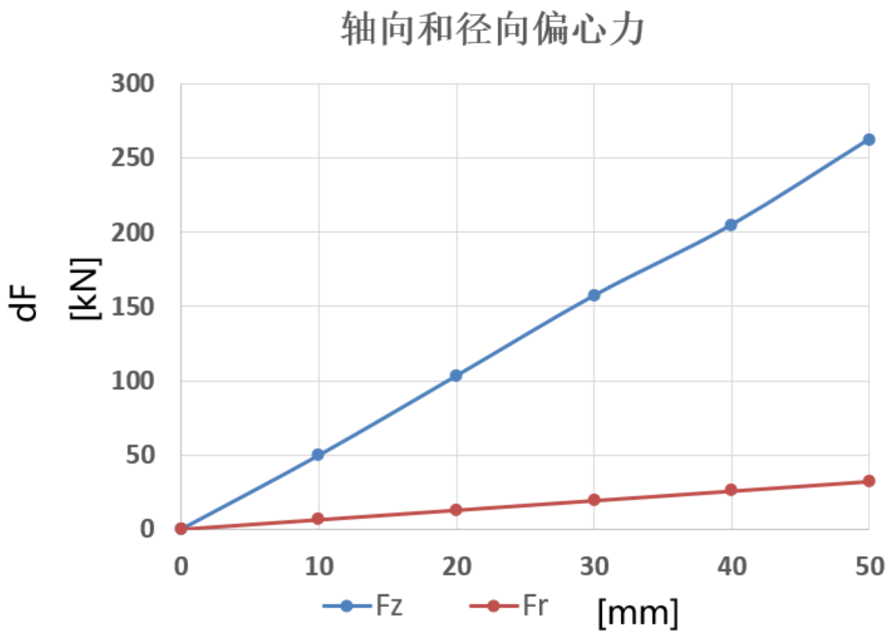
- Completed the design and test of clock distribution modules in a “master-slave” architecture
- Clock jitter tested ~1ps RMS
- Ready to join the upcoming combined beam test

- Designed SerDes and clock managing modules in ADTC, and optical modules. Taped out the designs and received chips.
- Chips being packaged

Super-conducting Solenoid Magnet

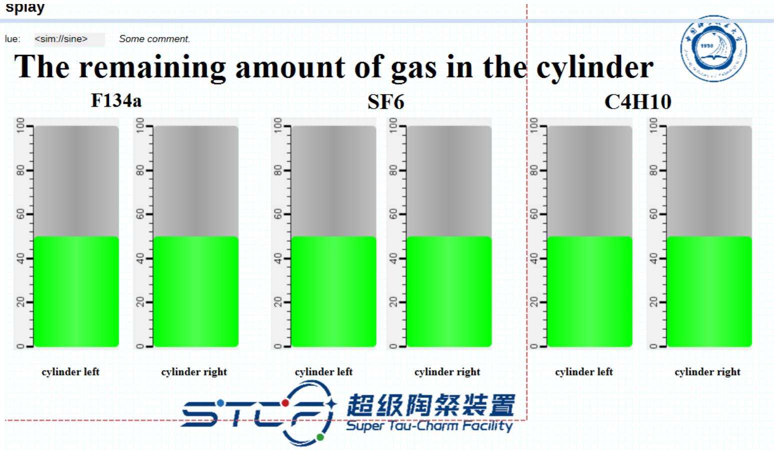
- Optimized the physics design of the magnet by performing FEA of magnet field and unbalanced forces.
- Studied impact of non-uniformity of the magnetic field on tracking performance and solutions to improve magnetic field homogeneity.
- Designing the magnet support structure using carbon fiber. Investigating heat leakage issue.
- Studying cryogenic forced circulation and thermosiphon schemes with FEA.

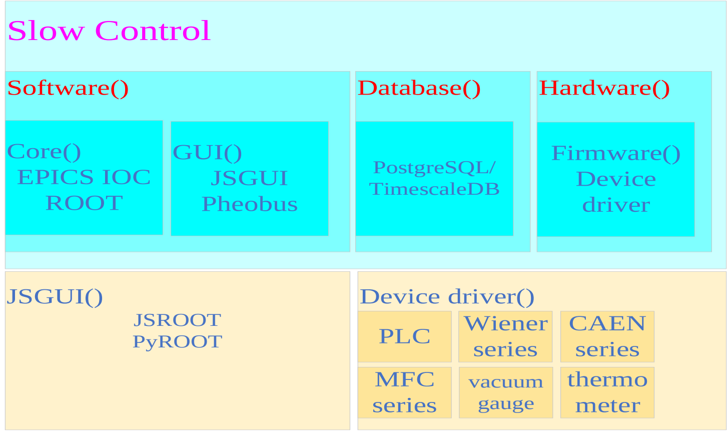




Detector Control System

- Finished conceptual design of the STCF detector control system.
- Designed and developed a control software framework.
- Developed a gas supplying and monitoring system in the framework as a technology demonstrator





Summary

- Intense R&D activities are underway on the baseline detector concept targeting key technologies of all sub detectors. Significant progress has been made and several R&D projects have reached milestones.
- 14 systems have been established and is going full steam ahead.
- Building on the completion of the Conceptual Design Report (CDR) in previous years, we have now shifted our focus to preparing the Technical Design Report (TDR).
- Expanding our collaboration network is more critical than ever. We warmly welcome more institutions to join the STCF project!