超级陶粲装置
Super Tau-Charm Facility

STCF Detector Design and R&D

Jianbei Liu

On behalf of the STCF detector group

University of Science and Technology of China
State Key Laboratory of Particle Detection and Electronics

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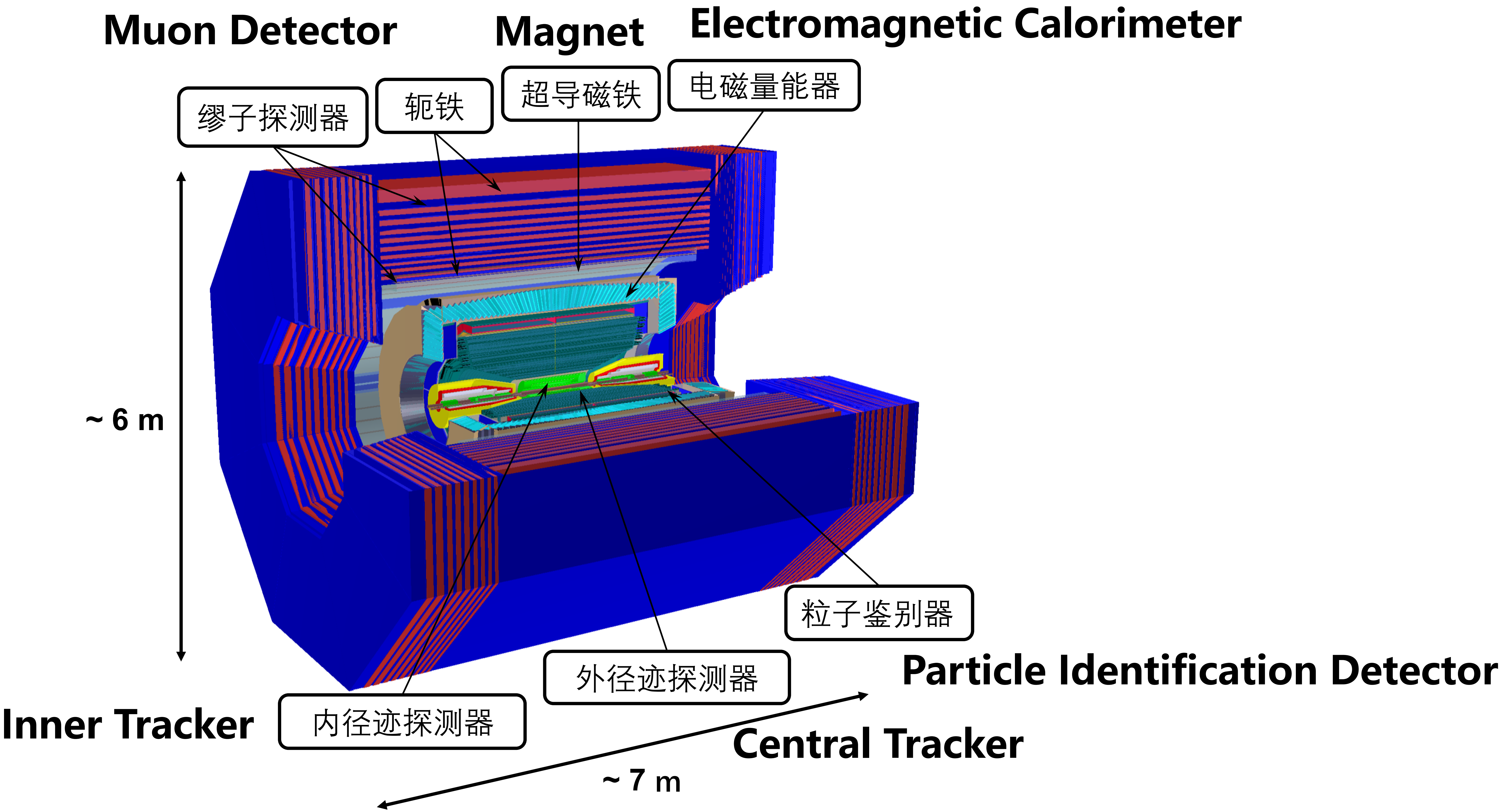
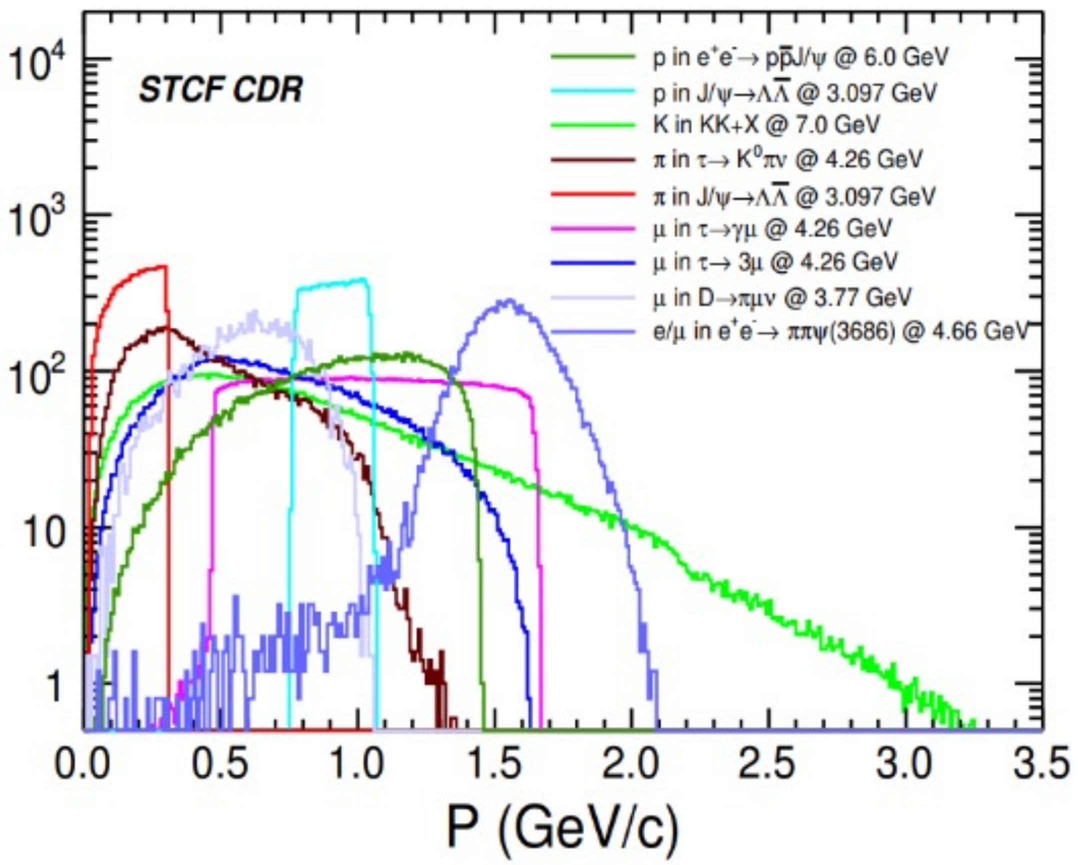
STCF Detector Layout

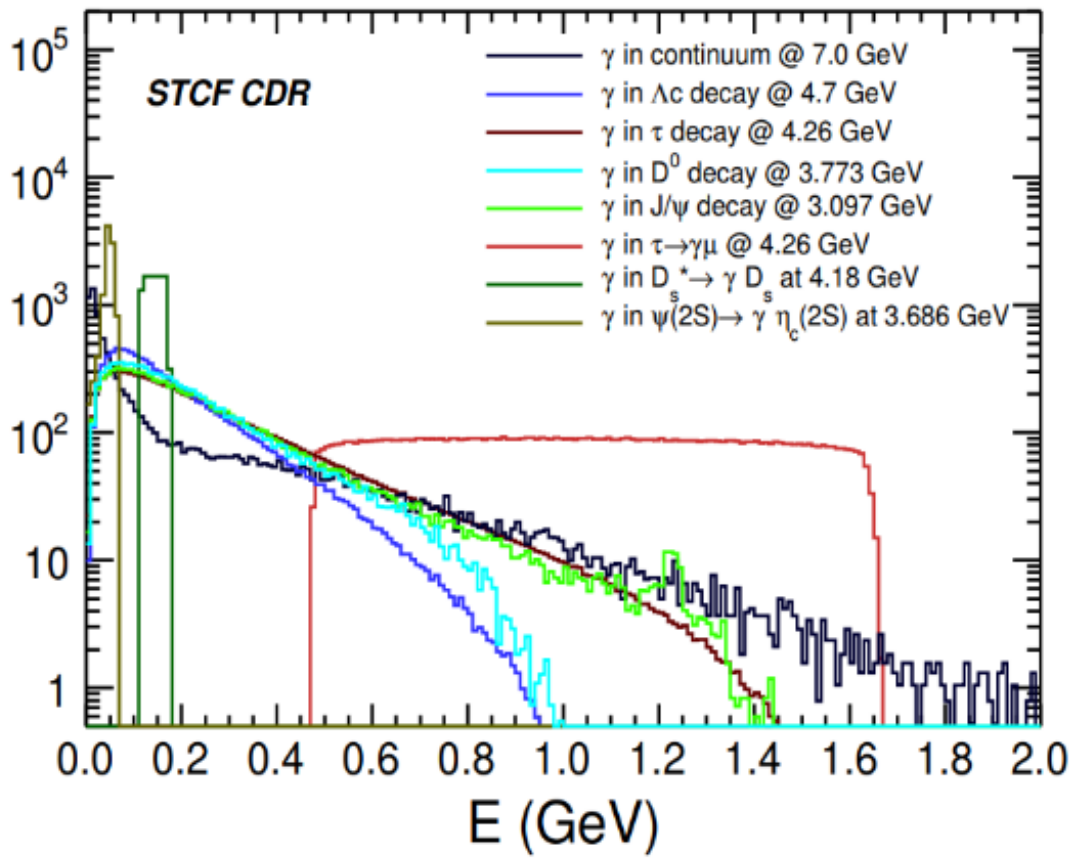


Physics Requirements

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

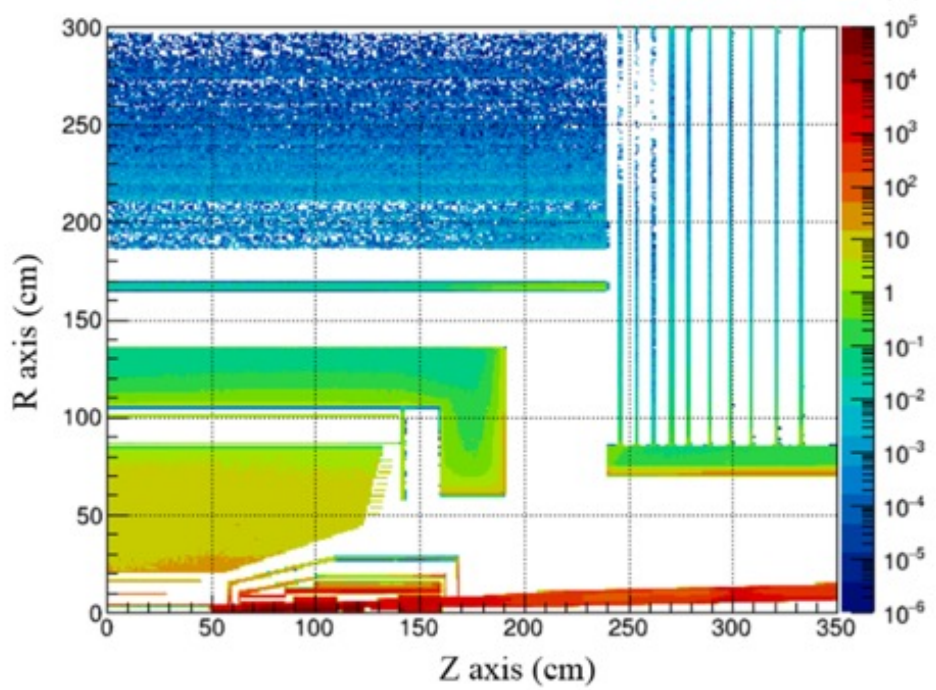
Process	Physics Interest	Optimized Subdetector	Requirements
$\tau \to K_s \pi \nu_\tau$, $J/\psi \to \Lambda\bar{\Lambda}$, $D_{(s)}$ tag	CPV in the τ sector, CPV in the hyperon sector, Charm physics	ITK+MDC	acceptance: 93% of 4π; trk. effi.: $> 99\%$ at $p_T > 0.3$ GeV/c; $> 90\%$ at $p_T = 0.1$ GeV/c $\sigma_p/p = 0.5\%$, $\sigma_{\gamma\phi} = 130\ \mu$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 $\sigma_{\rm pos} \approx 5$ 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	$\sigma_T = \frac{300}{\sqrt{p^3(\mathrm{GeV}^3)}}$ ps



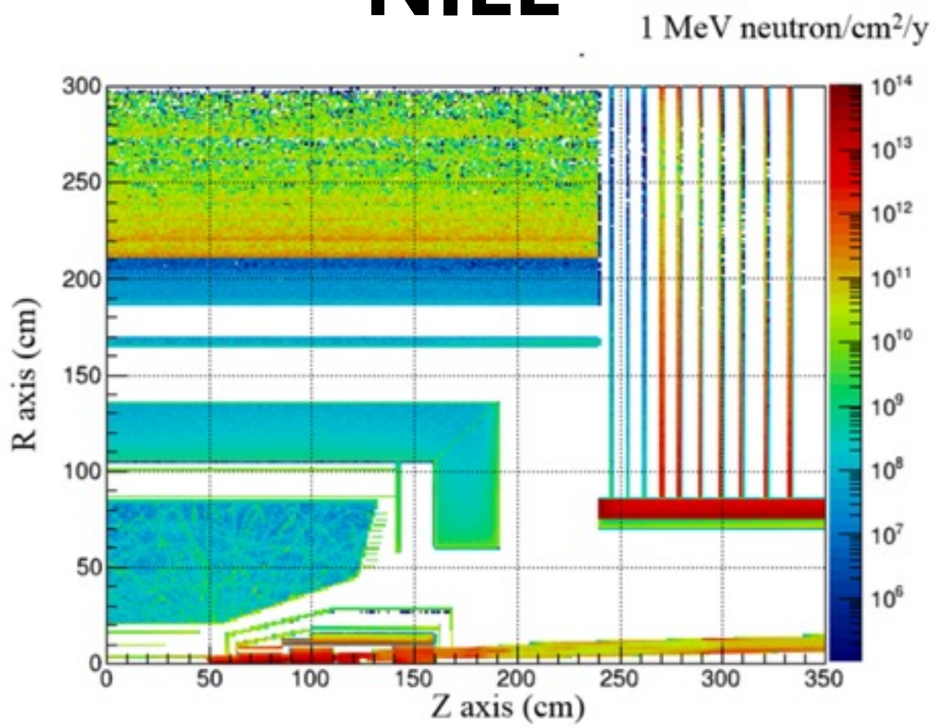


Beam-induced Backgrounds

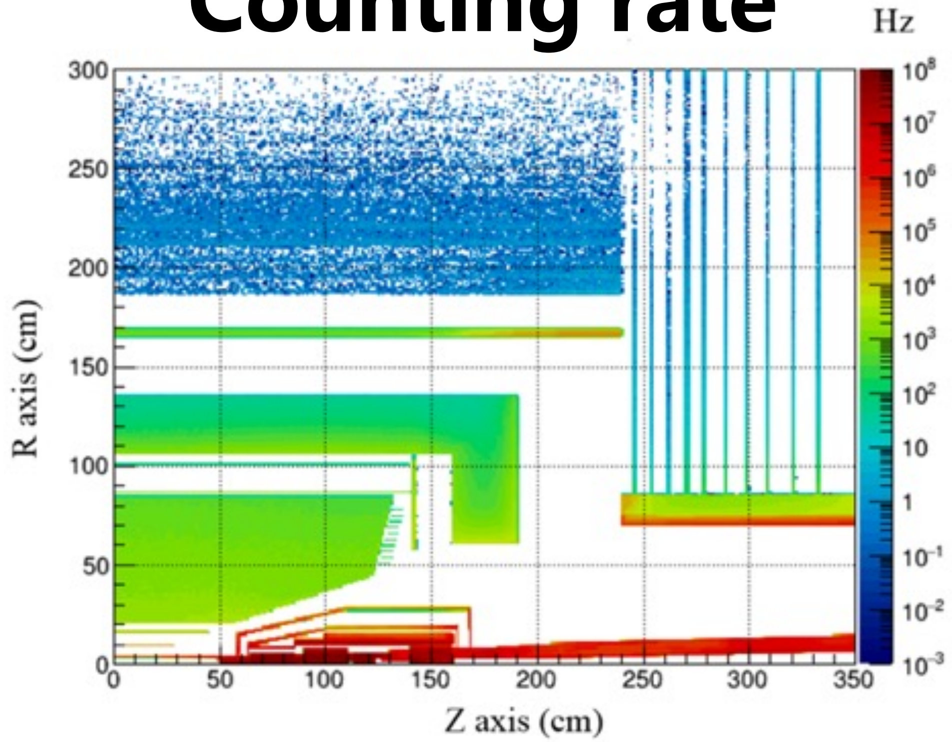
TID

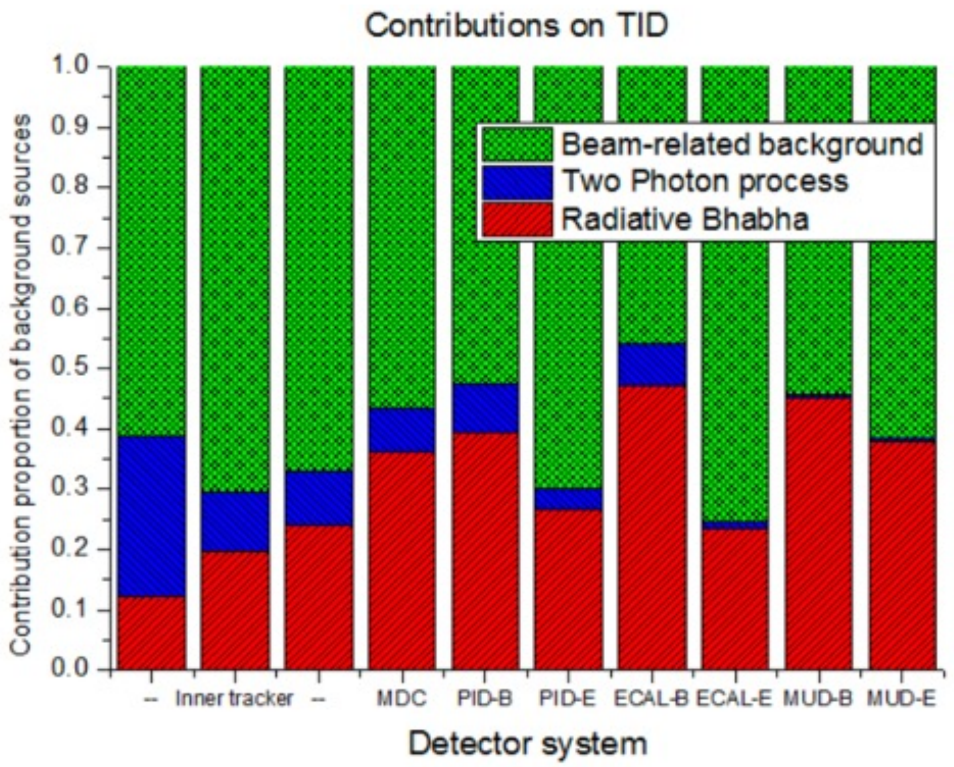


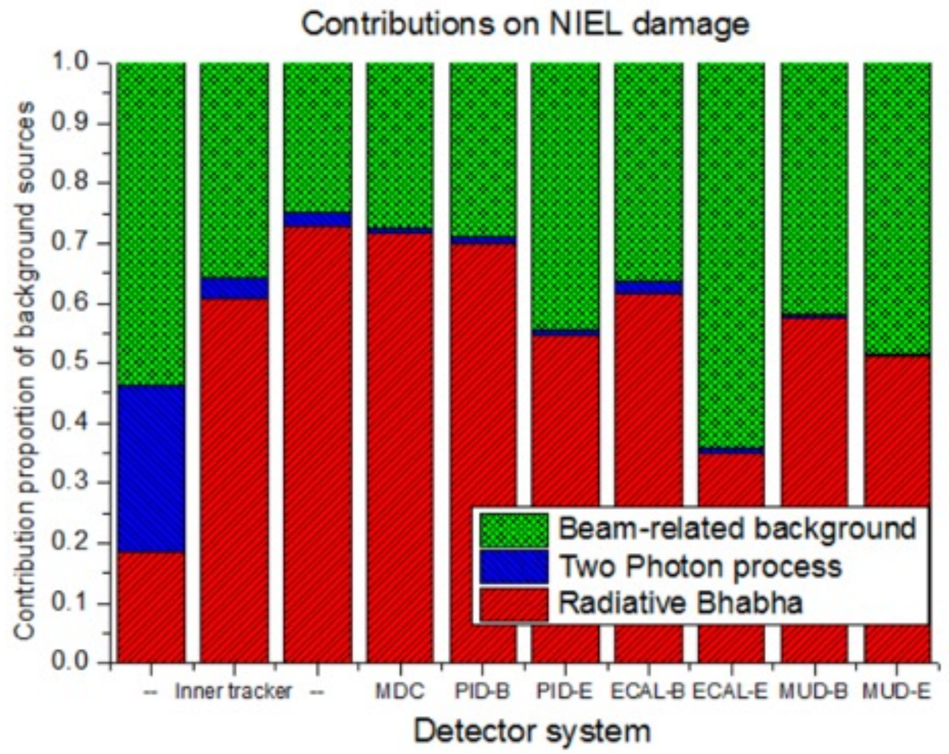
NIEL

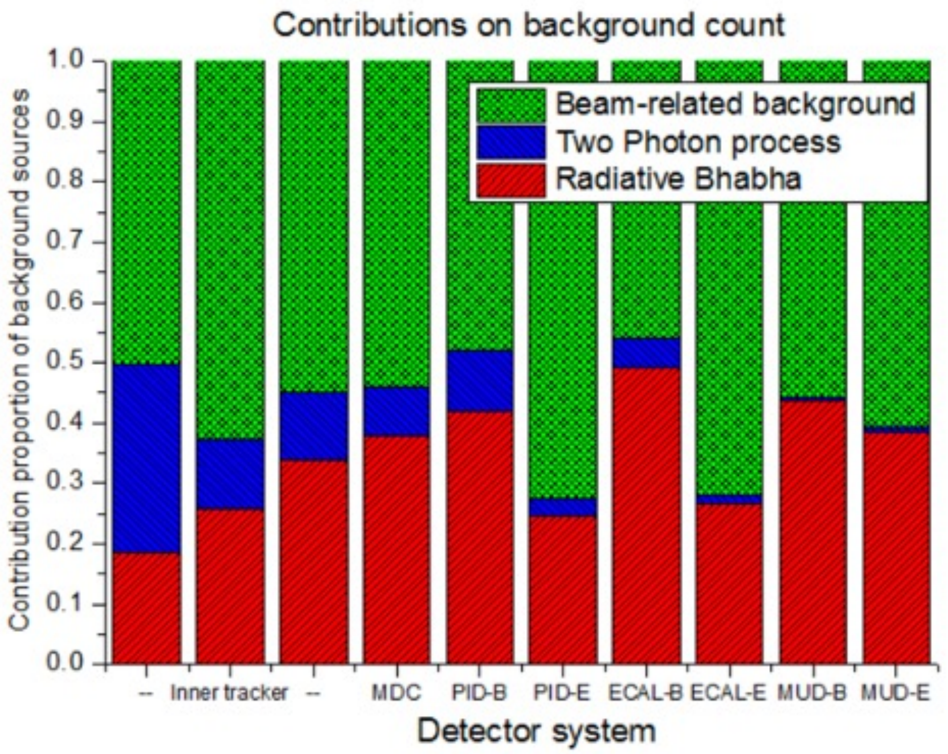


Counting rate





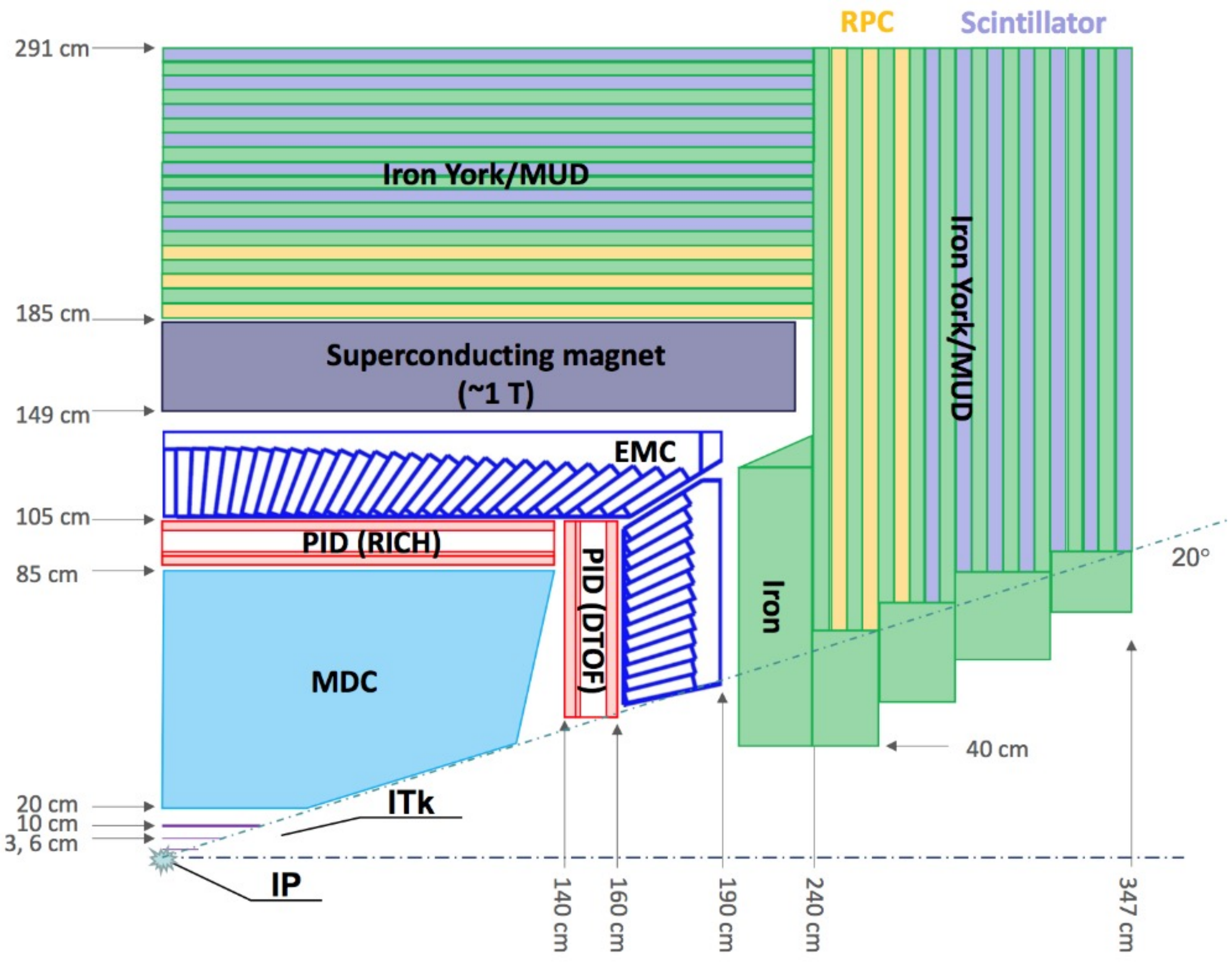




Inner most detector layer: ~3.5 kGy/y, ~2×10^{11} 1MeV n-eq/cm^2/y, ~1 MHz/cm^2

The major challenge is to maintain or even enhance the state of the art performance of τ-**c** detectors in much harsher experimental conditions.

STCF Detector Conceptual Design



Solid Angle Coverage : 94%•4π (θ~20⁰)

- ❖ **Inner tracker** (**ITK**, two options)
  - MPGD: cylindrical MPGD
  - Silicon: CMOS MAPS
- ❖ **Central tracker (MDC)**
  - Main drift chamber
- ❖ **PID**
  - Barrel: **RICH** with CsI-MPGD
  - Endcaps: DIRC-like TOF (**DTOF**)
- ❖ **EMC**
  - pure CsI + APD
- ❖ **Muon detector (MUD)**
  - RPC + scintillator strips
- ❖ **Magnet**
  - Super-conducting solenoid, 1 T

STCF Physics & Detector CDR

82 institutions, 453 authors

arXiv:2303.15790

FRONTIERS OF PHYSICS

REPORT
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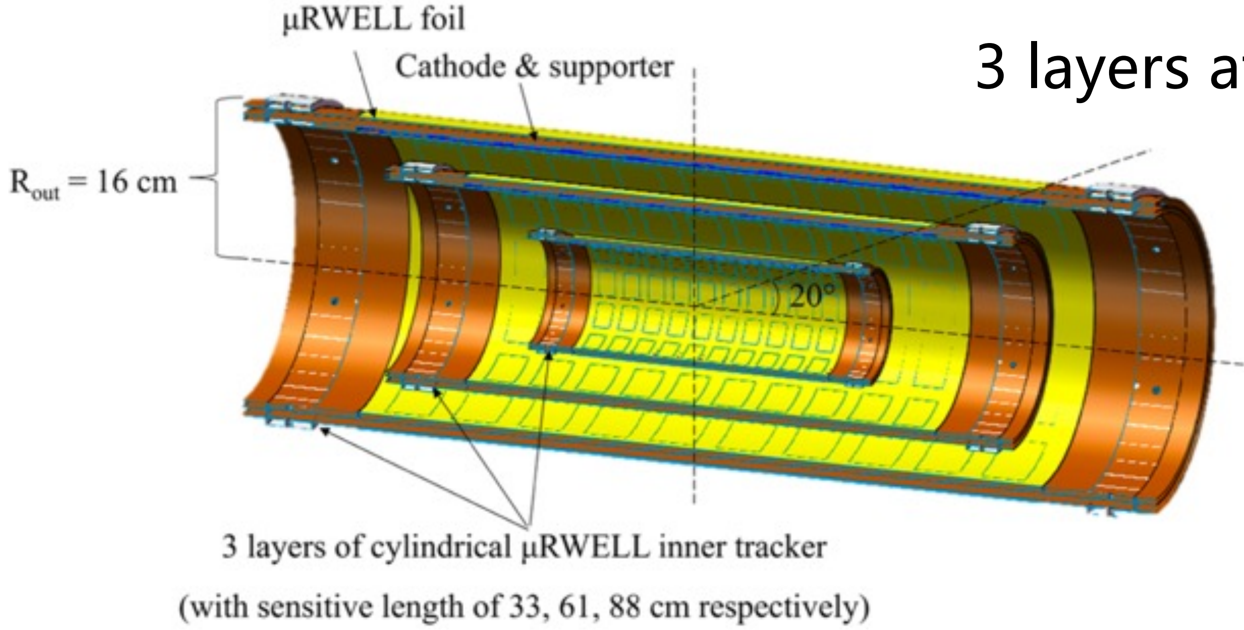
STCF conceptual design report (Volume 1): Physics & detector

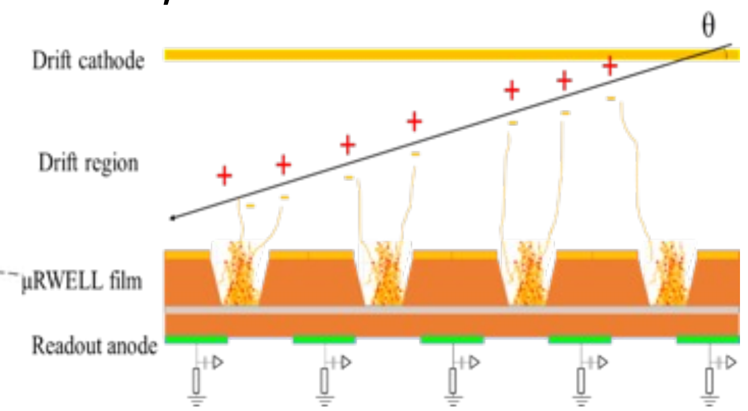
M. Achasov[3], X. C. Ai[82], R. Aliberti[38], Q. An[63,72], X. Z. Bai[63,72], Y. Bai[62], O. Bakina[39], A. Barnyakov[3,50], V. Blinov[3,50,51], V. Bobrovnikov[3,51], D. Bodrov[23,60], A. Bogomyagkov[3], A. Bondar[3], I. Boyko[39], Z. H. Bu[73], F. M. Cai[20], H. Cai[77], J. J. Cao[20], Q. H. Cao[54], X. Cao[33], Z. Cao[63,72], Q. Chang[20], K. T. Chao[54], D. Y. Chen[62], H. Chen[81], H. X. Chen[62], J. F. Chen[58], K. Chen[6], L. L. Chen[20], P. Chen[78], S. L. Chen[6], S. M. Chen[66], S. Chen[69], S. P. Chen[69], W. Chen[64], X. Chen[74], X. F. Chen[58], X. R. Chen[33], Y. Chen[32], Y. Q. Chen[36], H. Y. Cheng[34], J. Cheng[48], S. Cheng[28], T. G. Cheng[2], J. P. Dai[80], L. Y. Dai[28], X. C. Dai[54], D. Dedovich[39], A. Denig[19,38], I. Denisenko[39], J. M. Dias[4], D. Z. Ding[58], L. Y. Dong[32], W. H. Dong[63,72], V. Druzhinin[3], D. S. Du[63,72], Y. J. Du[77], Z. G. Du[41], L. M. Duan[33], D. Epifanov[3], Y. L. Fan[77], S. S. Fang[32], Z. J. Fang[63,72], G. Fedotovich[3], C. Q. Feng[63,72], X. Feng[54], Y. T. Feng[63,72], J. L. Fu[69], J. Gao[59], P. S. Ge[73], C. Q. Geng[15], L. S. Geng[2], A. Gilman[71], L. Gong[43], T. Gong[21], B. Gou[33], W. Gradl[38], J. L. Gu[63,72], A. Guevara[4], L. C. Gui[26], A. Q. Guo[33], F. K. Guo[4,69,2], J. C. Guo[63,72], J. Guo[59], Y. P. Guo[11], Z. H. Guo[16], A. Guskov[39], K. L. Han[69], L. Han[63,72], M. Han[63,72], X. Q. Hao[20], J. B. He[69], S. Q. He[63,72], X. G. He[59], Y. L. He[20], Z. B. He[33], Z. X. Heng[20], B. L. Hou[63,72], T. J. Hou[74], Y. R. Hou[69], C. Y. Hu[74], H. M. Hu[32], K. Hu[57], R. J. Hu[33], X. H. Hu[9], Y. C. Hu[49], J. Hua[61], G. S. Huang[63,72], J. S. Huang[47], M. Huang[69], Q. Y. Huang[69], W. Q. Huang[69], X. T. Huang[57], X. J. Huang[33], Y. B. Huang[14], Y. S. Huang[64], N. Hüsken[38], V. Ivanov[3], Q. P. Ji[20], J. J. Jia[77], S. Jia[62], Z. K. Jia[63,72], H. B. Jiang[77], J. Jiang[57], S. Z. Jiang[14], J. B. Jiao[57], Z. Jiao[24], H. J. Jing[69], X. L. Kang[8], X. S. Kang[43], B. C. Ke[82], M. Kenzie[5], A. Khoukaz[76], I. Koop[3,50,51], E. Kravchenko[3,51], A. Kuzmin[3], Y. Lei[60], E. Levichev[3], C. H. Li[42], C. Li[55], D. Y. Li[33], F. Li[63,72], G. Li[55], G. Li[15], H. B. Li[32,69], H. Li[63,72], H. N. Li[61], H. J. Li[20], H. L. Li[27], J. M. Li[63,72], J. Li[32], L. Li[56], L. Li[59], L. Y. Li[63,72], N. Li[64], P. R. Li[41], R. H. Li[30], S. Li[59], T. Li[57], W. J. Li[20], X. Li[33], X. H. Li[74], X. Q. Li[6], X. H. Li[63,72], Y. Li[79], Y. Y. Li[72], Z. J. Li[33], H. Liang[63,72], J. H. Liang[61], Y. T. Liang[33], G. R. Liao[13], L. Z. Liao[25], Y. Liao[61], C. X. Lin[69], D. X. Lin[33], X. S. Lin[63,72], B. J. Liu[32], C. W. Liu[15], D. Liu[63,72], F. Liu[6], G. M. Liu[61], H. B. Liu[14], J. Liu[54], J. J. Liu[74], J. B. Liu[63,72], K. Liu[41], K. Y. Liu[43], K. Liu[59], L. Liu[63,72], Q. Liu[69], S. B. Liu[63,72], T. Liu[11], X. Liu[41], Y. W. Liu[63,72], Y. Liu[82], Y. L. Liu[63,72], Z. Q. Liu[57], Z. Y. Liu[41], Z. W. Liu[45], I. Logashenko[3], Y. Long[63,72], C. G. Lu[33], J. X. Lu[2], N. Lu[63,72], Q. F. Lü[26], Y. Lu[7], Y. Lu[69], Z. Lu[62], P. Lukin[3], F. J. Luo[74], T. Luo[11], X. F. Luo[6], H. J. Lyu[24], X. R. Lyu[69], J. P. Ma[35], P. Ma[33], Y. Ma[15], Y. M. Ma[33], F. Maas[19,38], S. Malde[71], D. Matvienko[3], Z. X. Meng[70], R. Mitchell[29], A. Nefediev[40], Y. Nefedov[39], S. L. Olsen[22,53], Q. Ouyang[32,63], P. Pakhlov[23], G. Pakhlova[23,52], X. Pan[60], Y. Pan[62], E. Passemar[29,65,67], Y. P. Pei[63,72], H. P. Peng[63,72], L. Peng[27], X. Y. Peng[8], X. J. Peng[41], K. Peters[12], S. Pivovarov[3], E. Pyata[3], B. B. Qi[63,72], Y. Q. Qi[63,72], W. B. Qian[69], Y. Qian[33], C. F. Qiao[69], J. J. Qin[74], J. J. Qin[63,72], L. Q. Qin[13], X. S. Qin[57], T. L. Qiu[33], J. Rademacker[68], C. F. Redmer[38], H. Y. Sang[63,72], M. Saur[54], W. Shan[26], X. Y. Shan[63,72], L. L. Shang[20], M. Shao[63,72], L. Shekhtman[3], C. P. Shen[11], J. M. Shen[28], Z. T. Shen[63,72], H. C. Shi[63,72], X. D. Shi[63,72], B. Shwartz[3], A. Sokolov[3], J. J. Song[20], W. M. Song[36], Y. Song[63,72], Y. X. Song[10], A. Sukharev[3,51], J. F. Sun[20], L. Sun[77], X. M. Sun[6], Y. J. Sun[63,72], Z. P. Sun[33], J. Tang[64], S. S. Tang[63,72], Z. B. Tang[63,72], C. H. Tian[63,72], J. S. Tian[78], Y. Tian[33], Y. Tikhonov[3], K. Todyshev[3,51], T. Uglov[52], V. Vorobyev[3], B. D. Wan[15], B. L. Wang[69], B. Wang[63,72], D. Y. Wang[54], G. Y. Wang[21], G. L. Wang[17], H. L. Wang[61], J. Wang[49], J. H. Wang[63,72], J. C. Wang[63,72], M. L. Wang[32], R. Wang[63,72], R. Wang[33], S. B. Wang[59], W. Wang[59], W. P. Wang[63,72], X. C. Wang[20], X. D. Wang[74], X. L. Wang[63,72], X. L. Wang[20], X. P. Wang[2], X. F. Wang[41],

Tracking System : ITK + MDC

ITK Gaseous option : MPGD

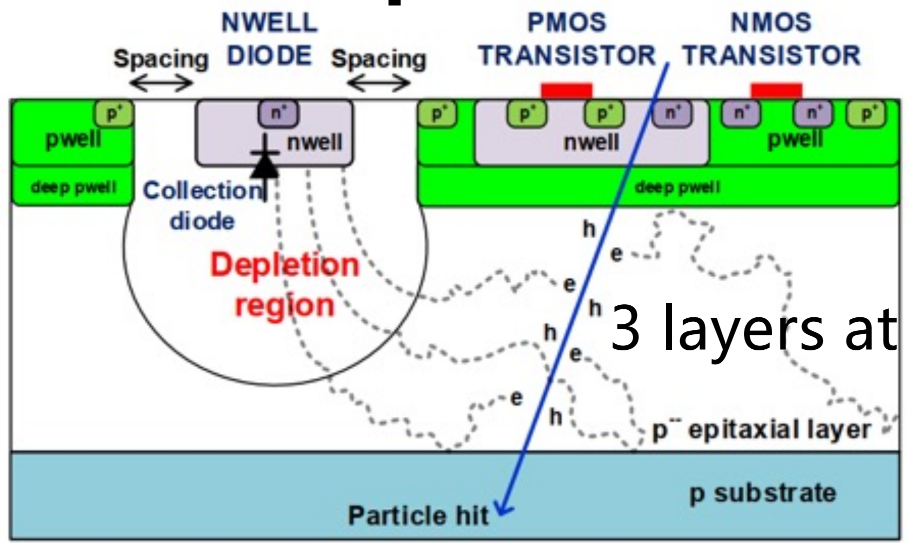
3 layers at 6cm, 11cm and 16 cm





Material budget ~ 0.3%X_0/layer

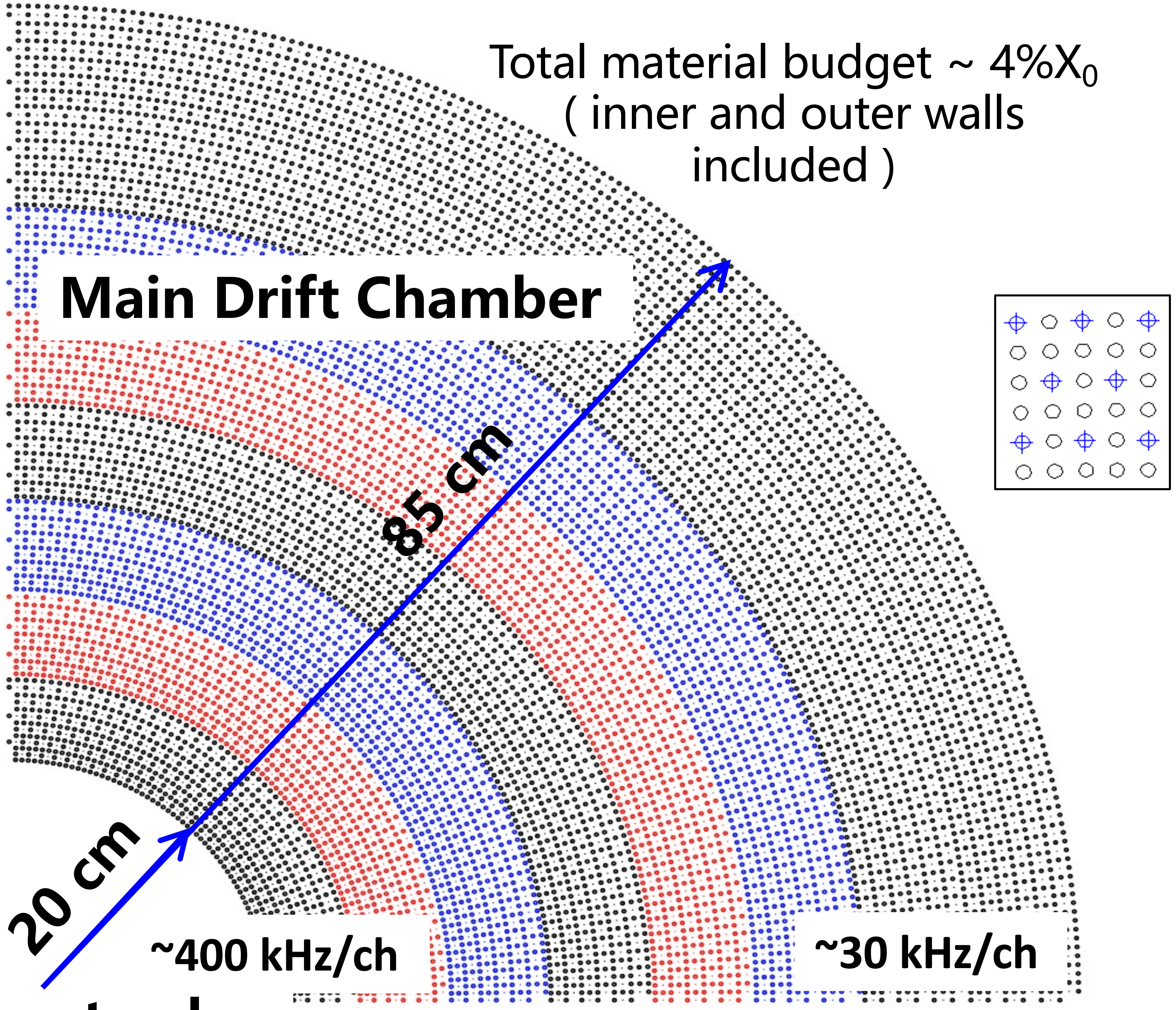
ITK Silicon option: CMOS MAPS



单片有源像素探测器

3 layers at 3.6cm, 9.8cm and 16 cm

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



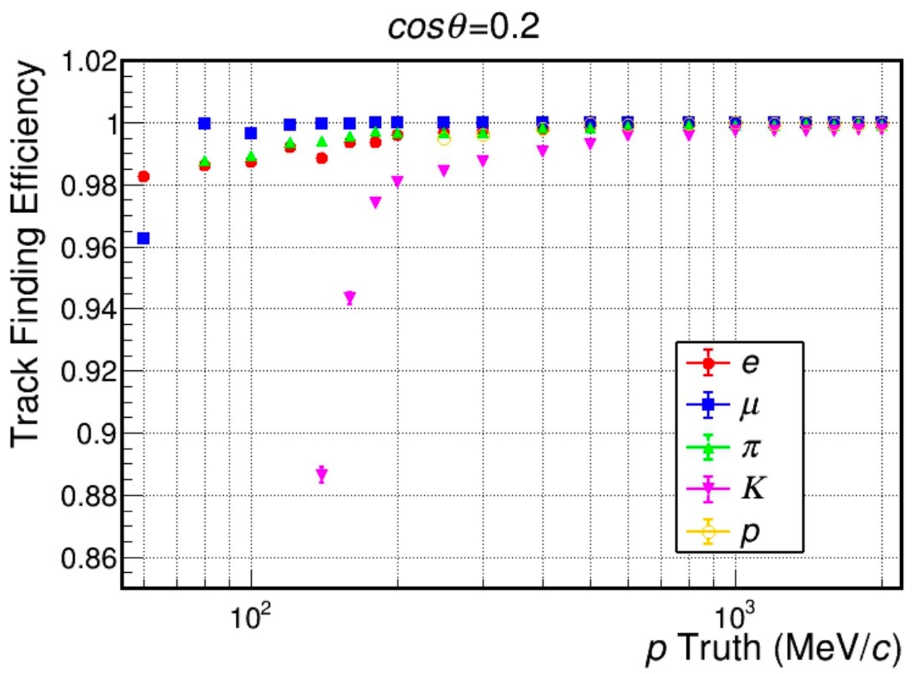
Inner tracker

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

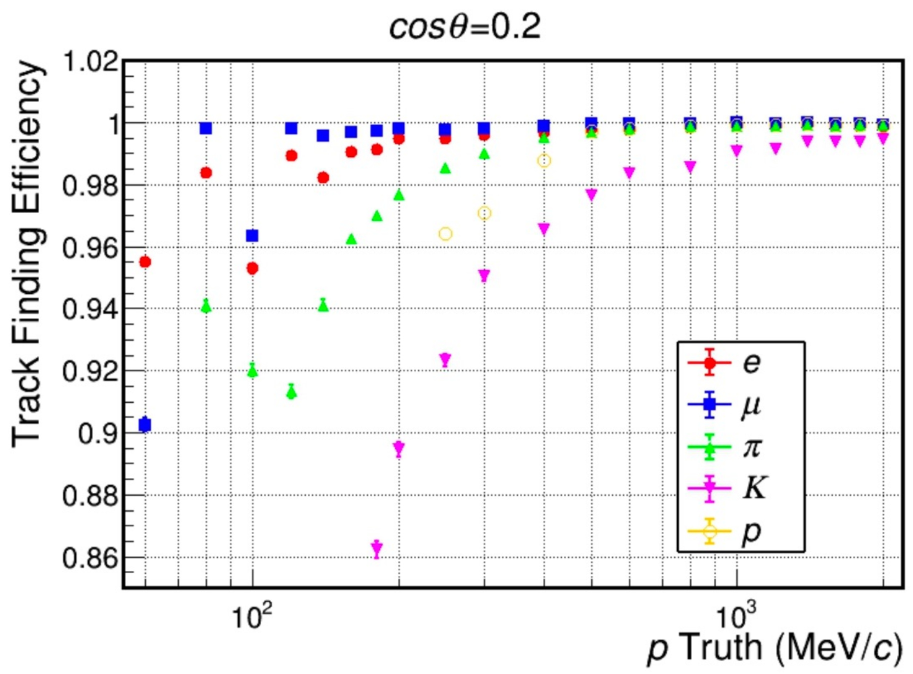
Tracking Performance with Full Simulation

Tracking performance for single particles

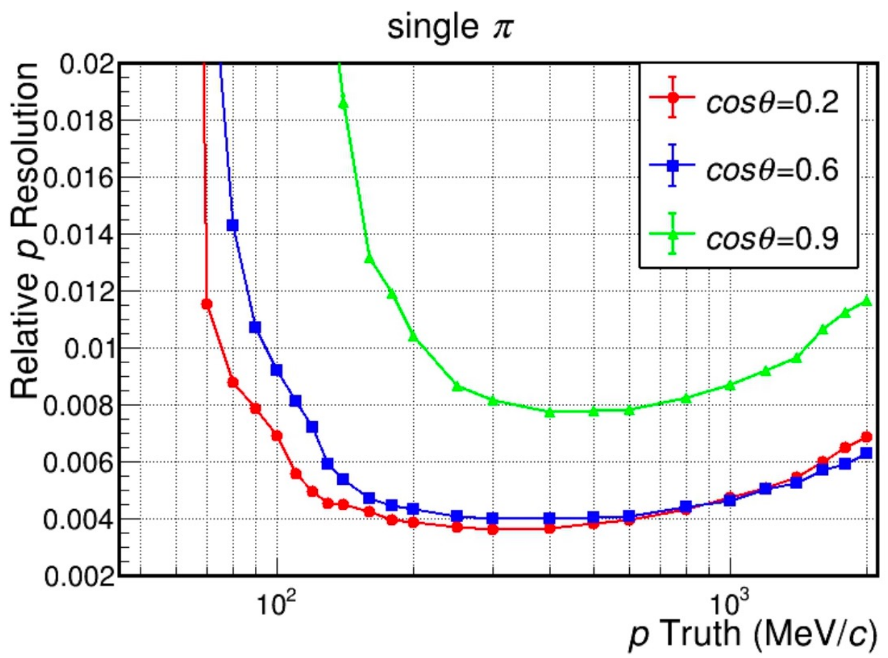
Tracking efficiency without background



Tracking efficiency with background



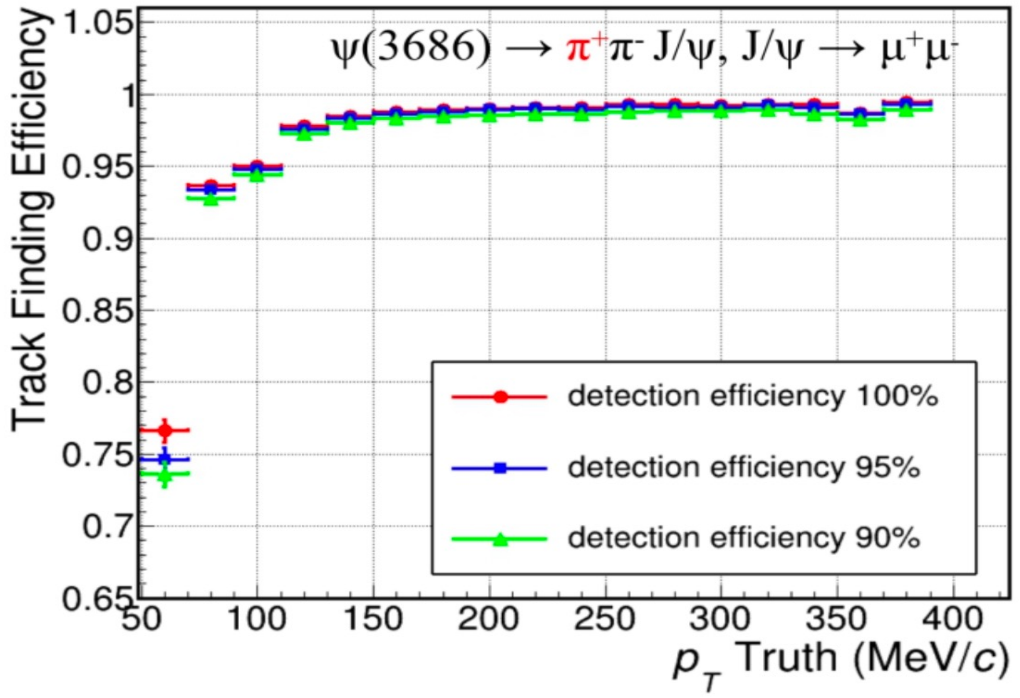
Momentum Resolution



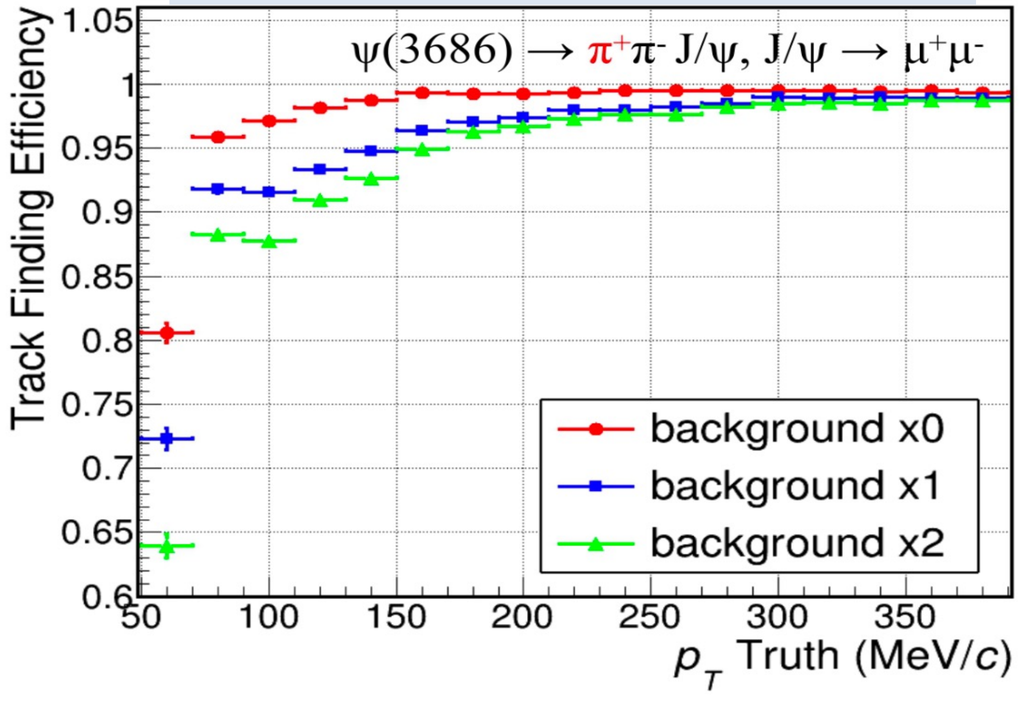
- **High tracking efficiency achieved even in presence of beam background**
- **Momentum resolution meets the physics requirement and is much less impacted by beam background compared to tracking efficiency.**

Tracking performance in physics events

Tracking efficiency with different hit efficiencies



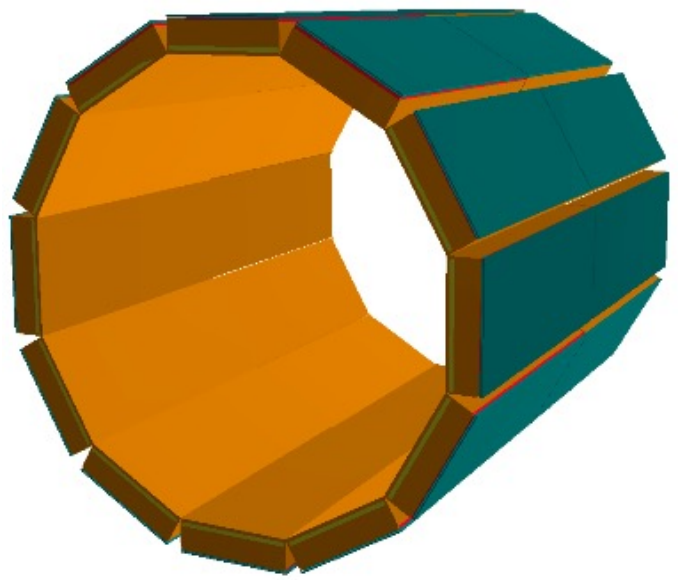
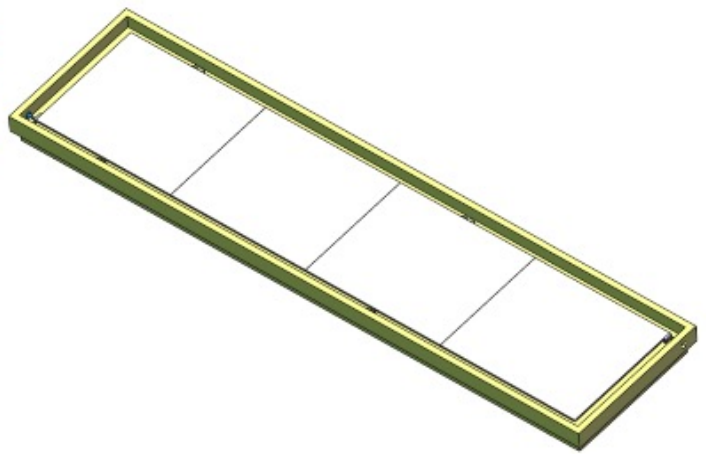
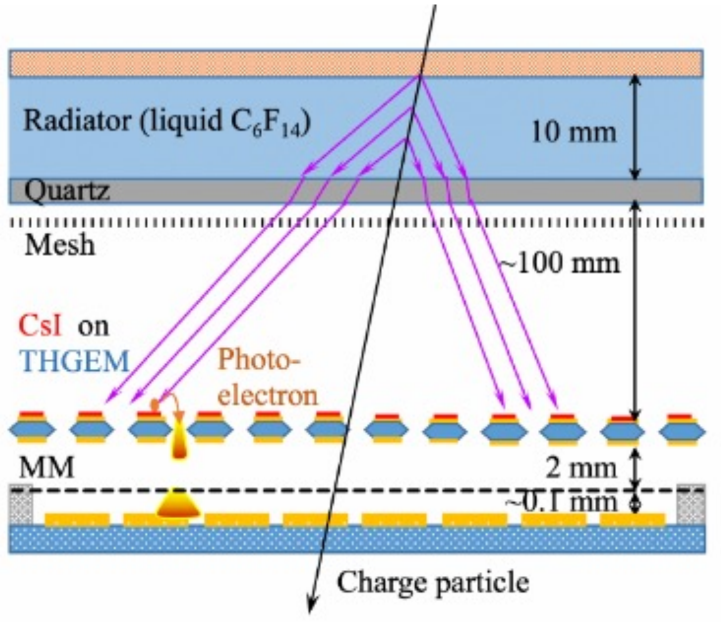
Tracking efficiency with different levels of background



- **The lower tracking efficiency in physics events is due to the kinematic distribution of the particle concerned in the events. For example, the pion+ in the events gets much more forward when its momentum goes down.**
- **The tracking efficiency is robust against beam background and low hit efficiency degradation.**

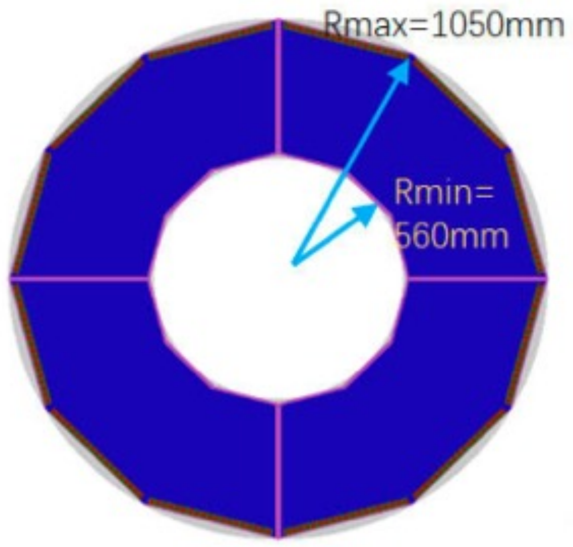
PID, EMC, MUD

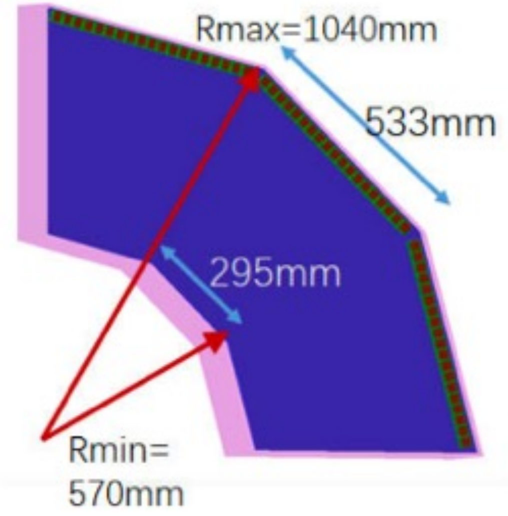
- **Barrel PID: A RICH detector using MPGD (THGEM with CsI + MM) for photon detection**

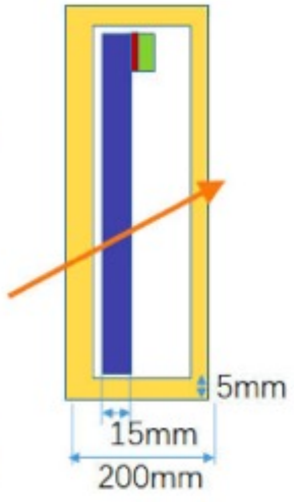




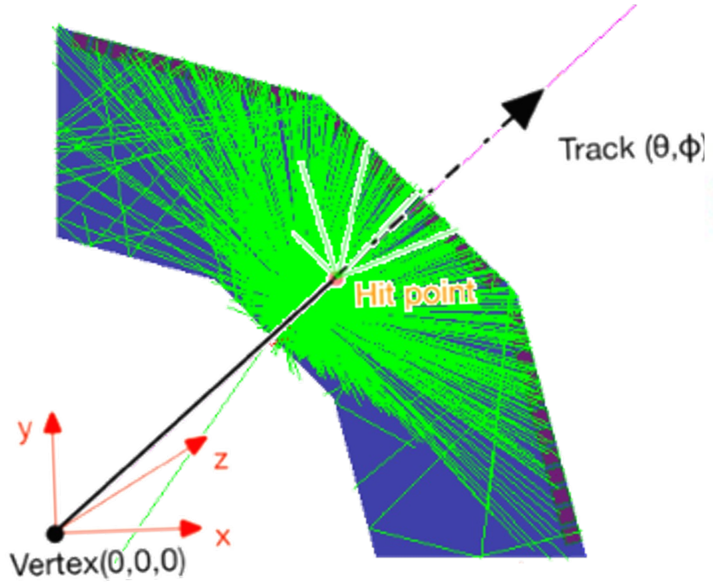
Material budget < $0.3X_0$

- **Endcap PID: A DIRC-like high-resolution TOF detector (DTOF ~ 30ps), quartz plate + MCP-maPMT**

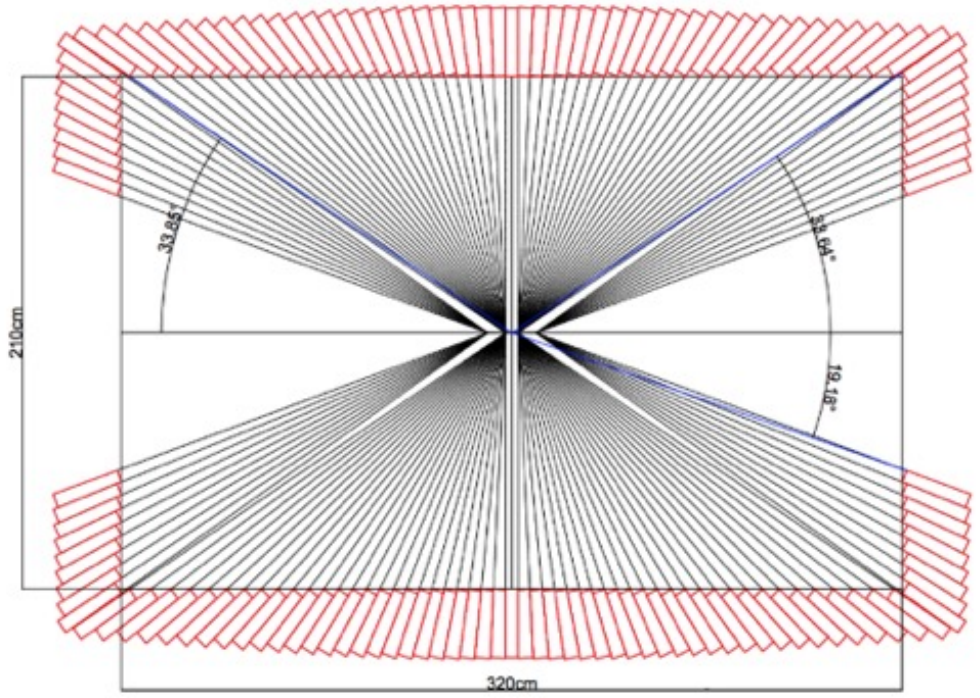






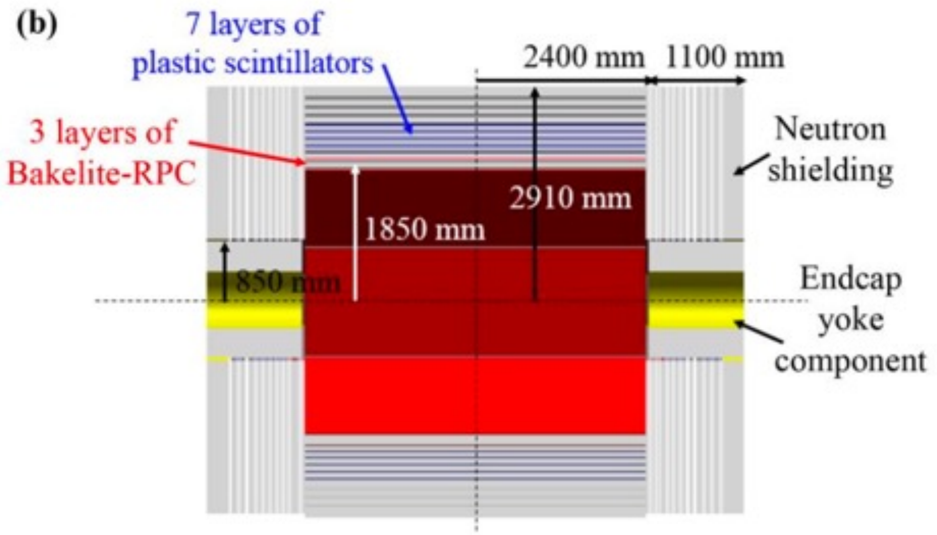


- **EMC: A pure-CsI crystal calorimeter to tackle a high level of background (~1MHz/ch)**



- **Crystal size 28cm (15X0) $5\times5cm^2$**
- **~ 8670 crystals**
- **4 large area APDs ($1\times1cm^2$) to enhance light yield**

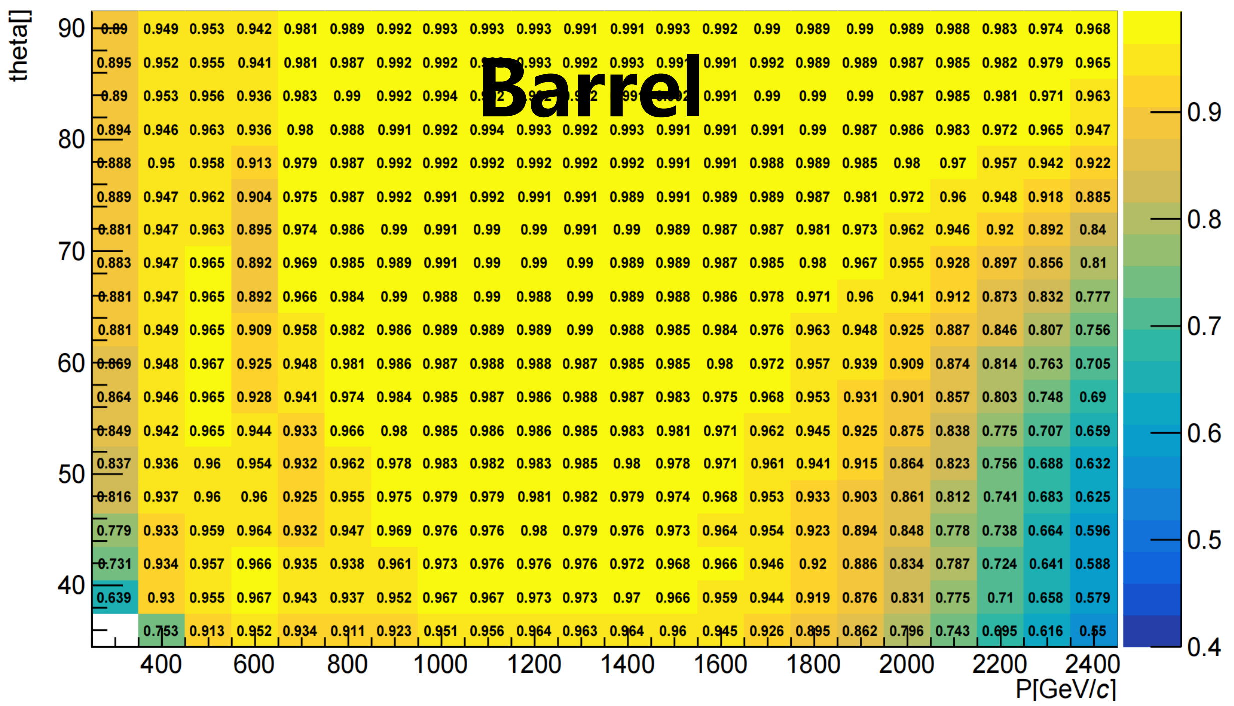
- **MUD: A RPC-scintillator hybrid detector to optimize muon and neutral hadron ID**

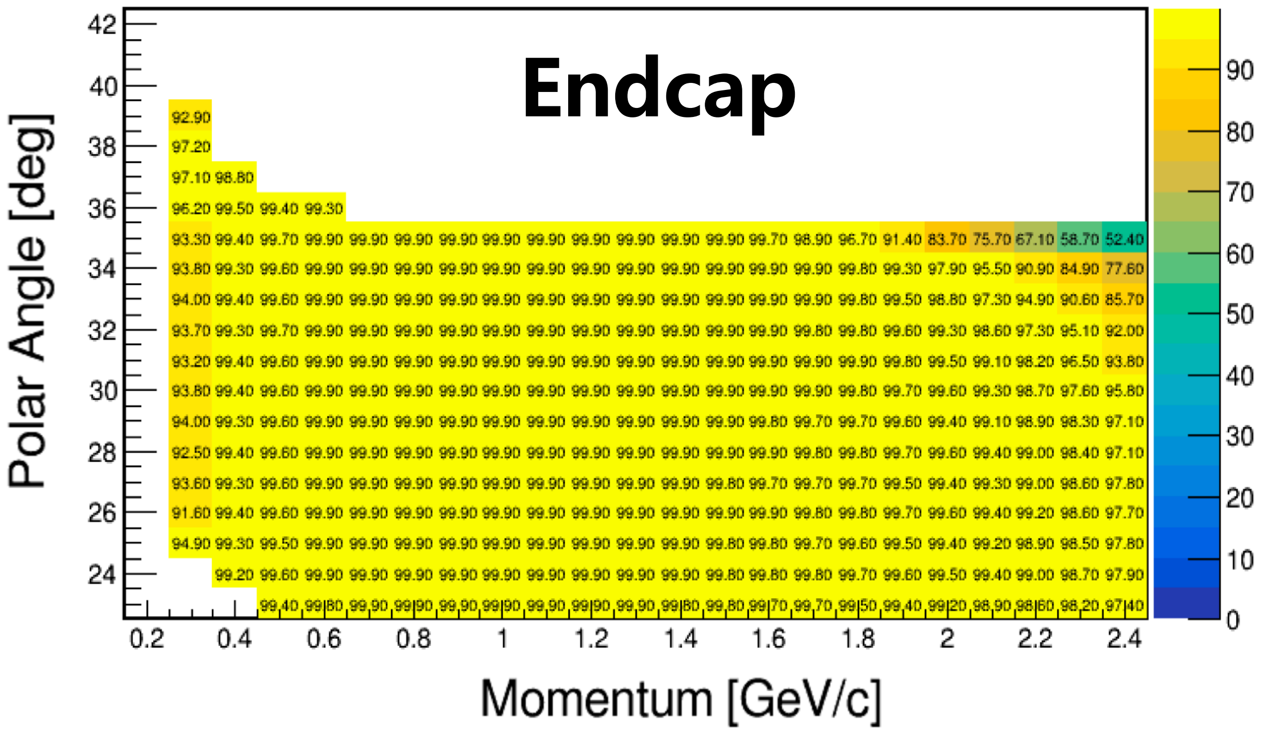


Parameter	Baseline design
R_{in} [cm]	185
R_{out} [cm]	291
R_e [cm]	85
L_{Barrel} [cm]	480
T_{Endcap} [cm]	107
Segmentation in ϕ	8
Number of detector layers	10
Iron yoke thickness [cm] (λ=16.77 cm)	4/4/4.5/4.5/6/6/6/8/8 cm Total: 51 cm, 3.04λ
Solid angle	$79.2\%\times4\pi$ in barrel $14.8\%\times4\pi$ in endcap $94\%\times4\pi$ in total
Total area [m^2]	Barrel ~717 Endcap ~520 Total ~1237

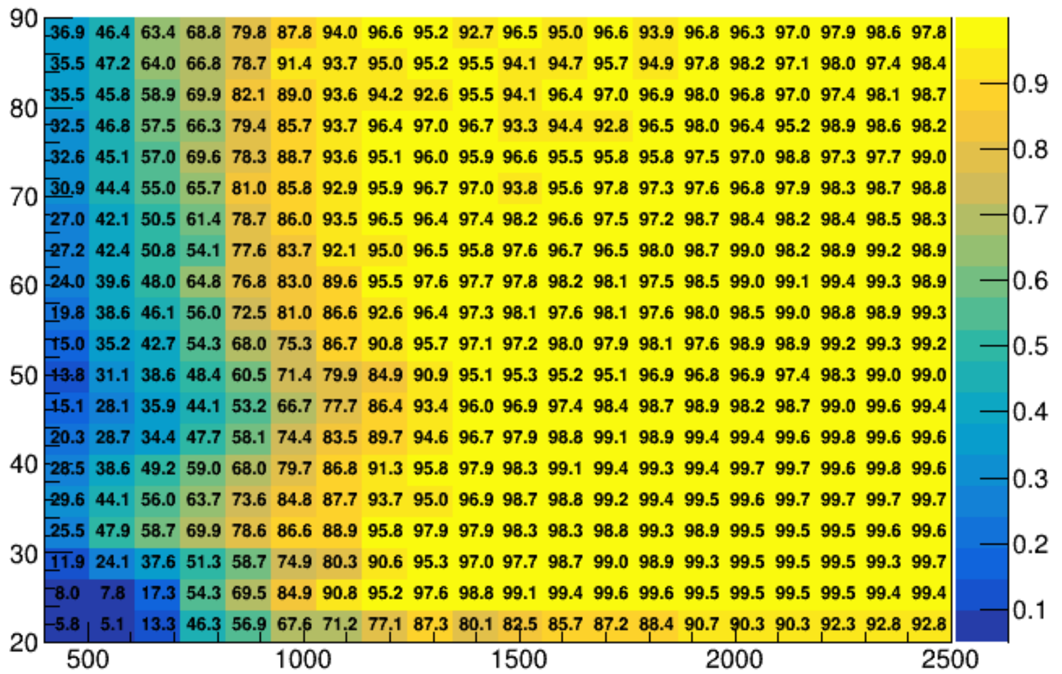
Performance with Full Simulation (and beam background)

PID: Pion ID eff. >97% @ mis-ID (K->pi)=2%



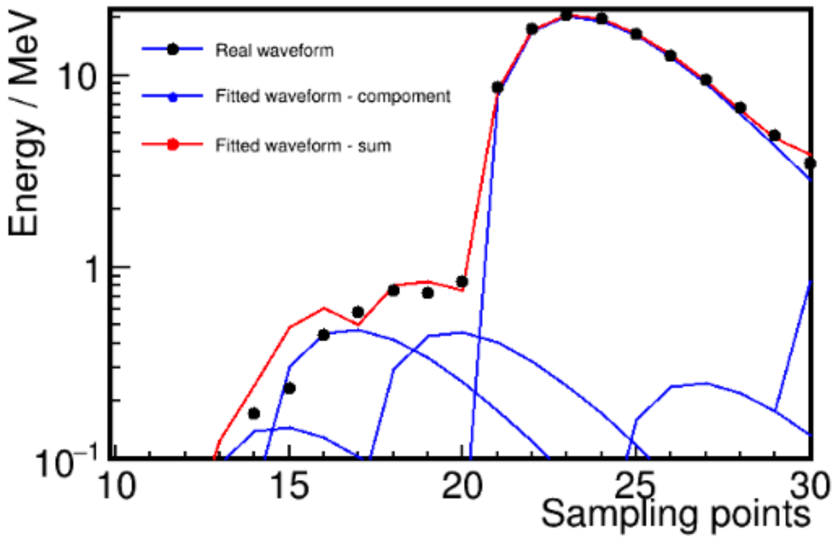


Muon ID eff. @ pi suppression=30

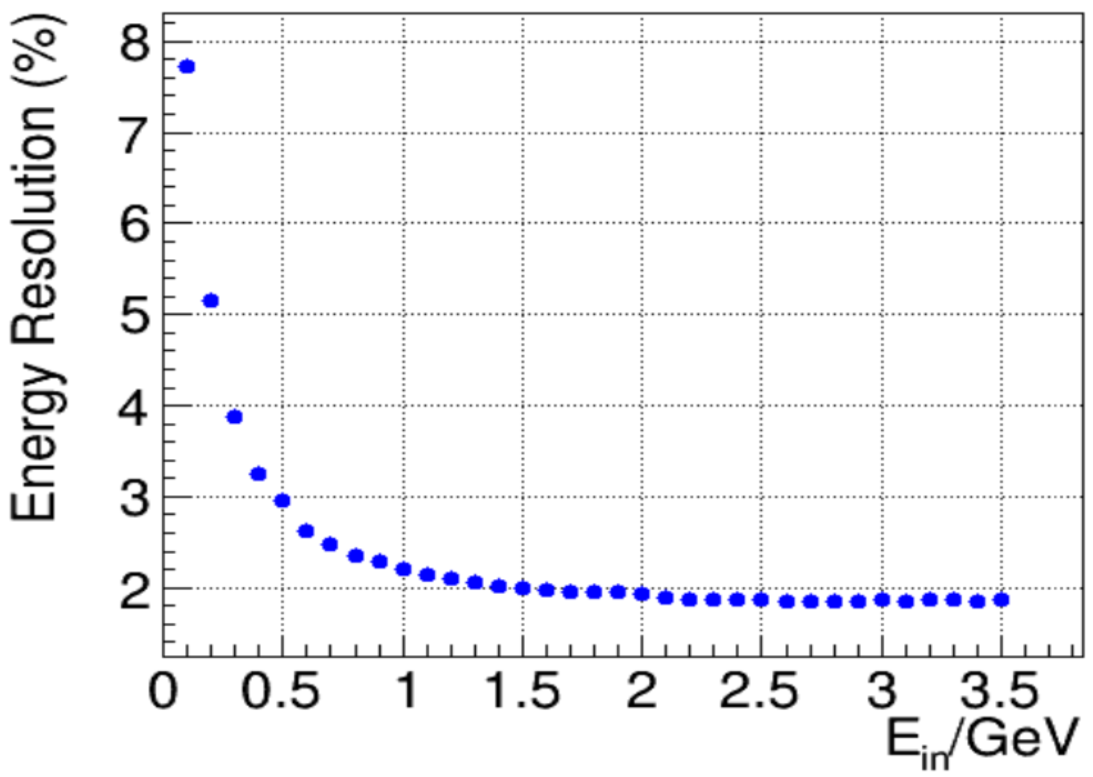


eff. ~> 90% when p ~>1GeV/c

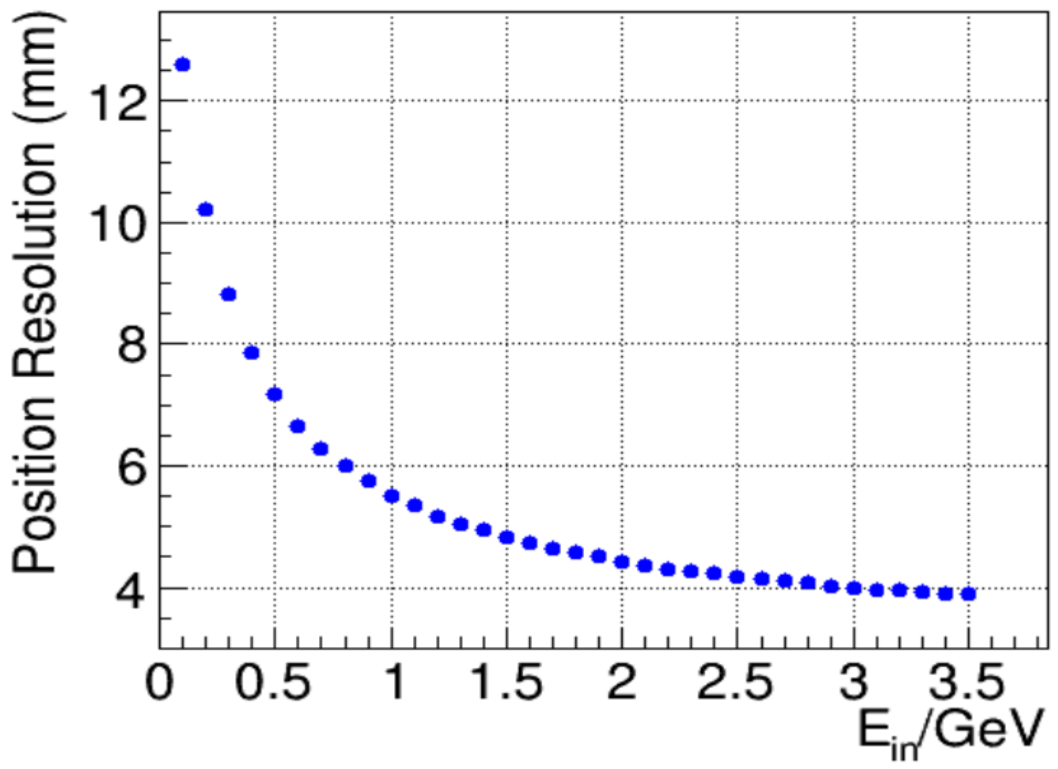
EMC pileup removal with waveform fitting



EMC energy resolution

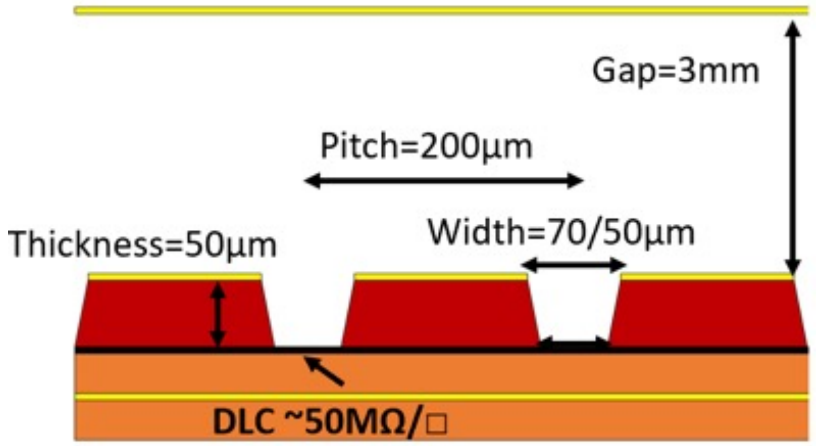


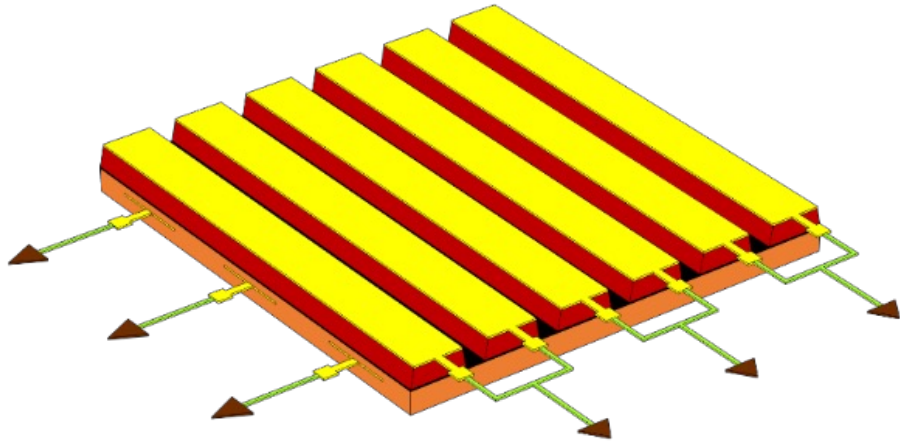
EMC position resolution

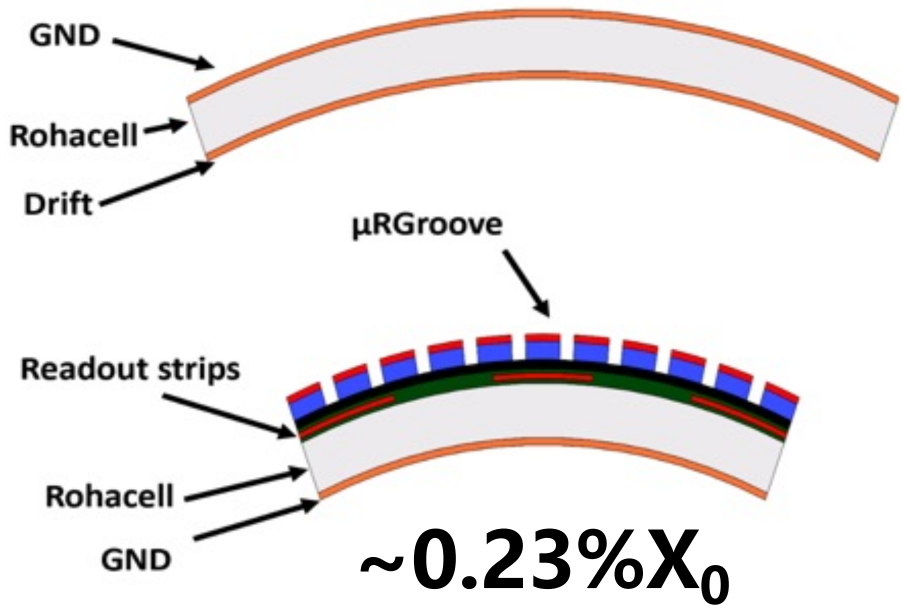


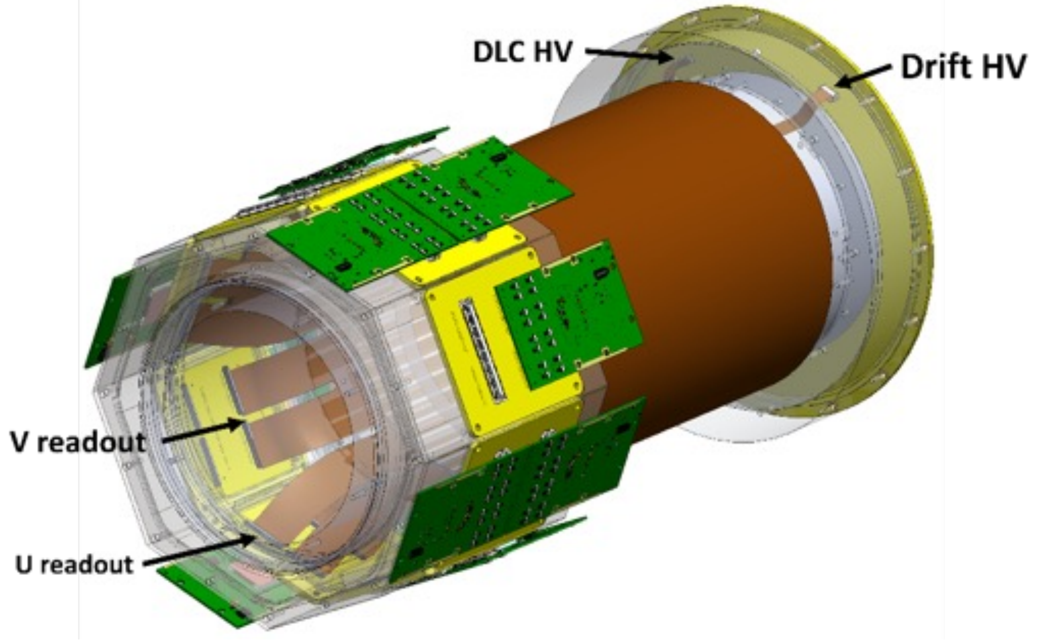
ITK-MPGD: μRGroove

- **μRGroove : A single-stage MPGD involving no stretching or tensioning, 2D strip readout without charge sharing (large S/N), high rate with fast grounding, easy to make a cylinder, low mass, low production cost**

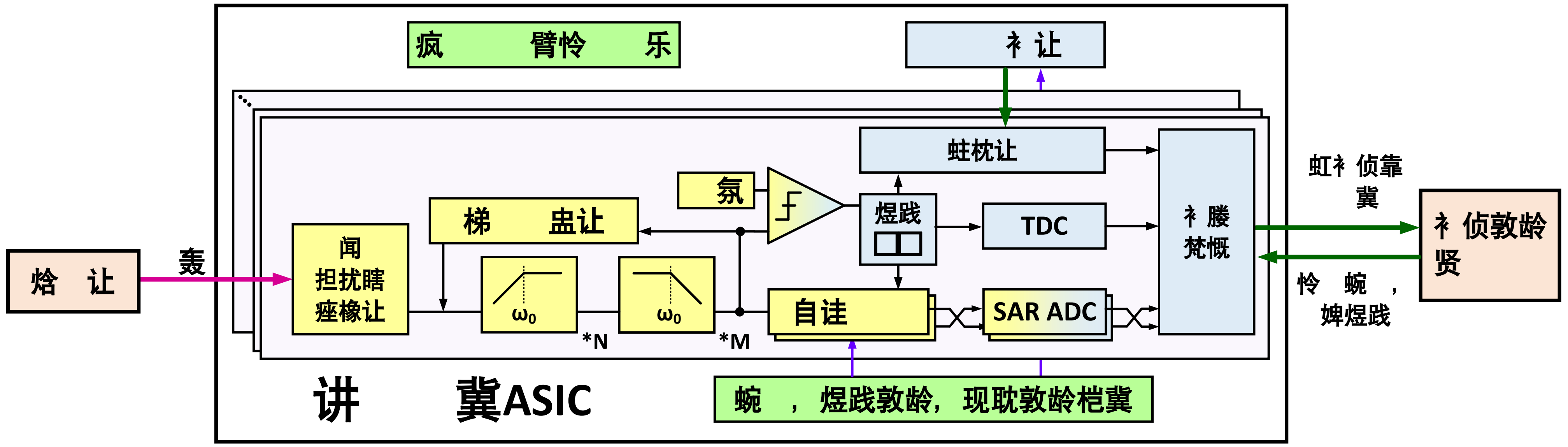








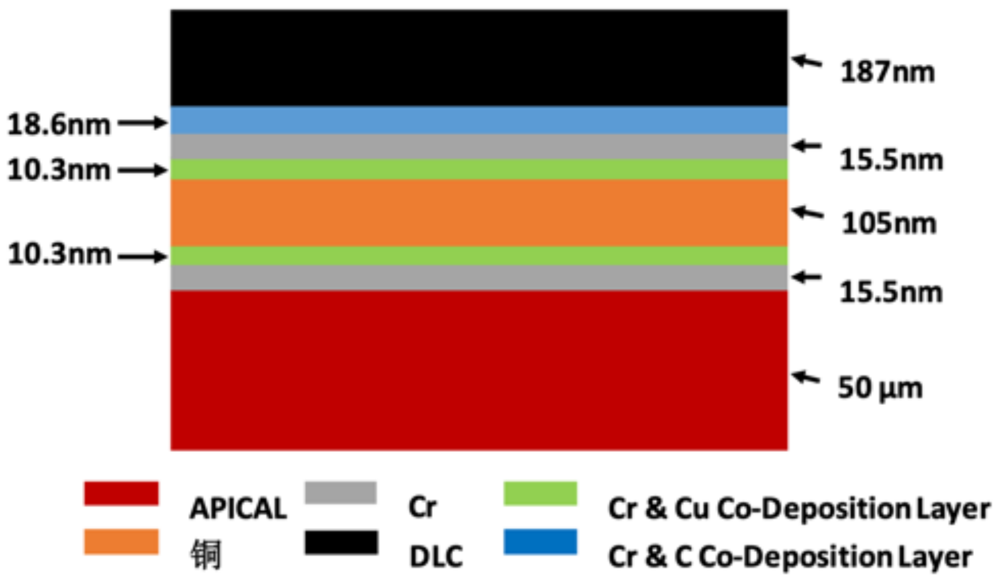
- **High-rate readout ASIC for MPGD (averaged hit rate of 400 kHz/ch)**



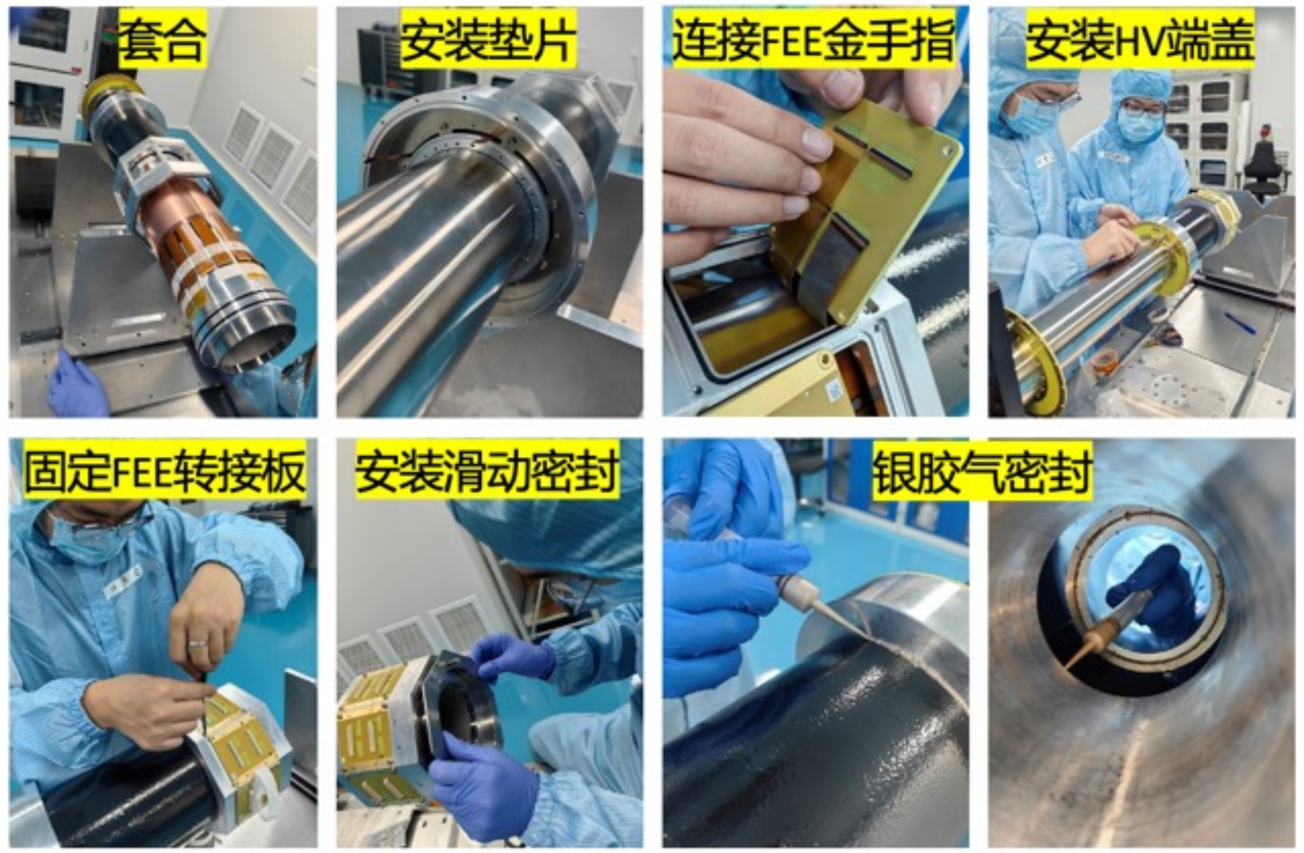
ASIC Specs	Demands
Charge Range	40 fC
Charge precision	～ 1 fC RMS
Time precision	< 10 ns RMS
Max. event rate	4 MHz

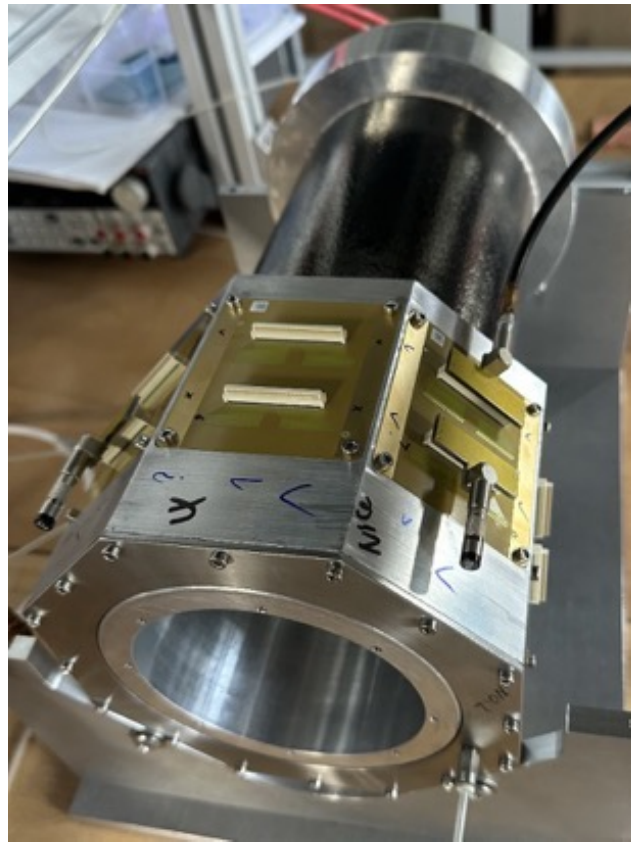
ITK-MPGD R&D

Development of low mass electrodes

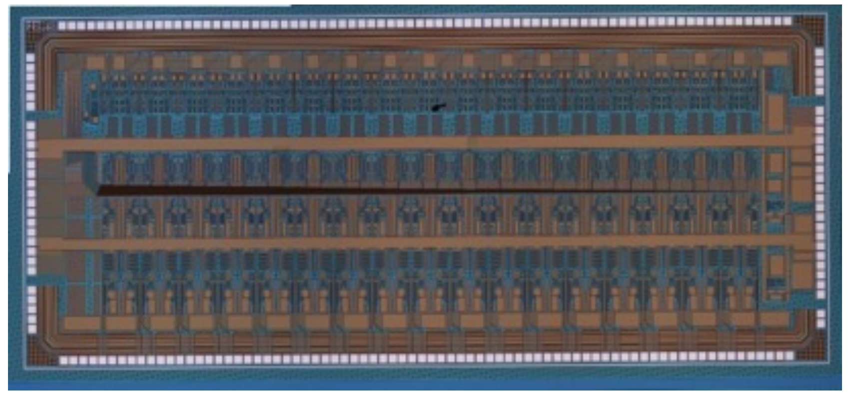


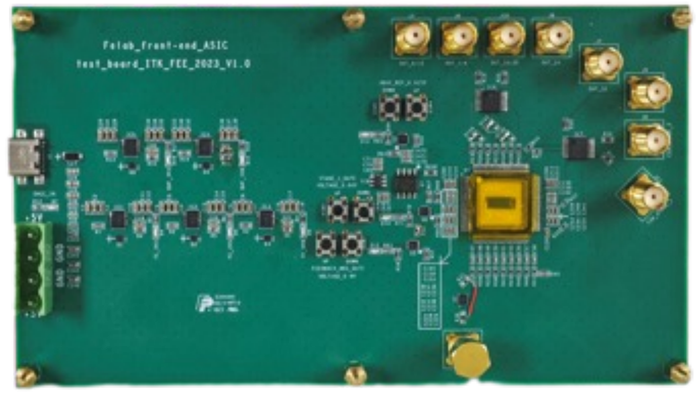
Fabricating cylindrical structure

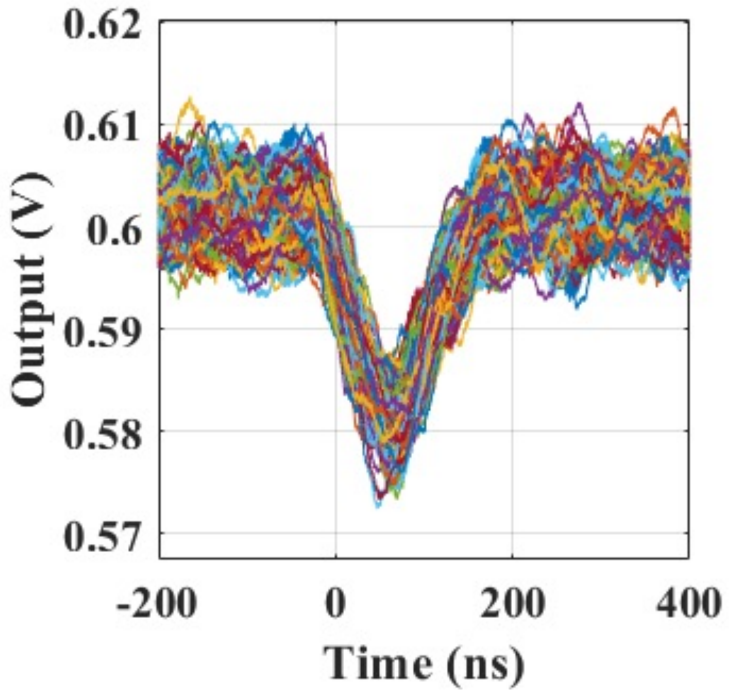


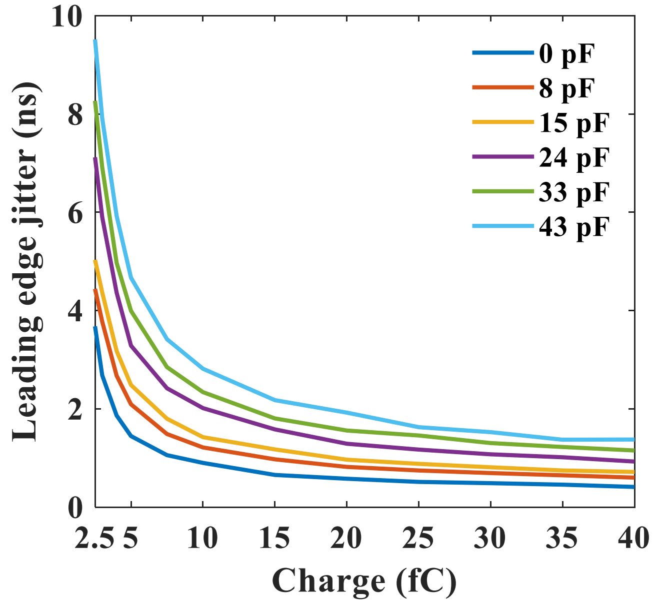


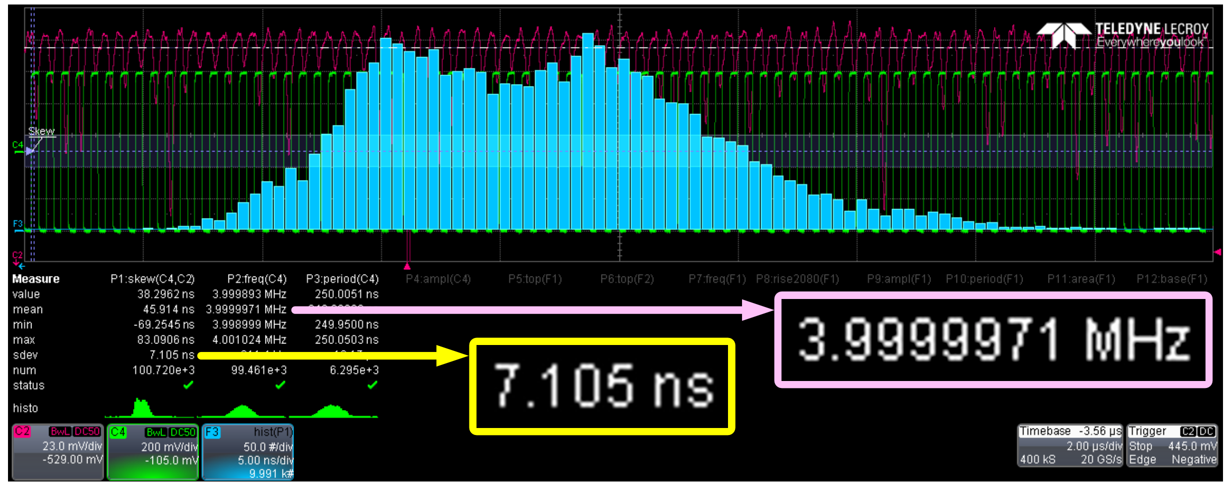
ASIC design and development







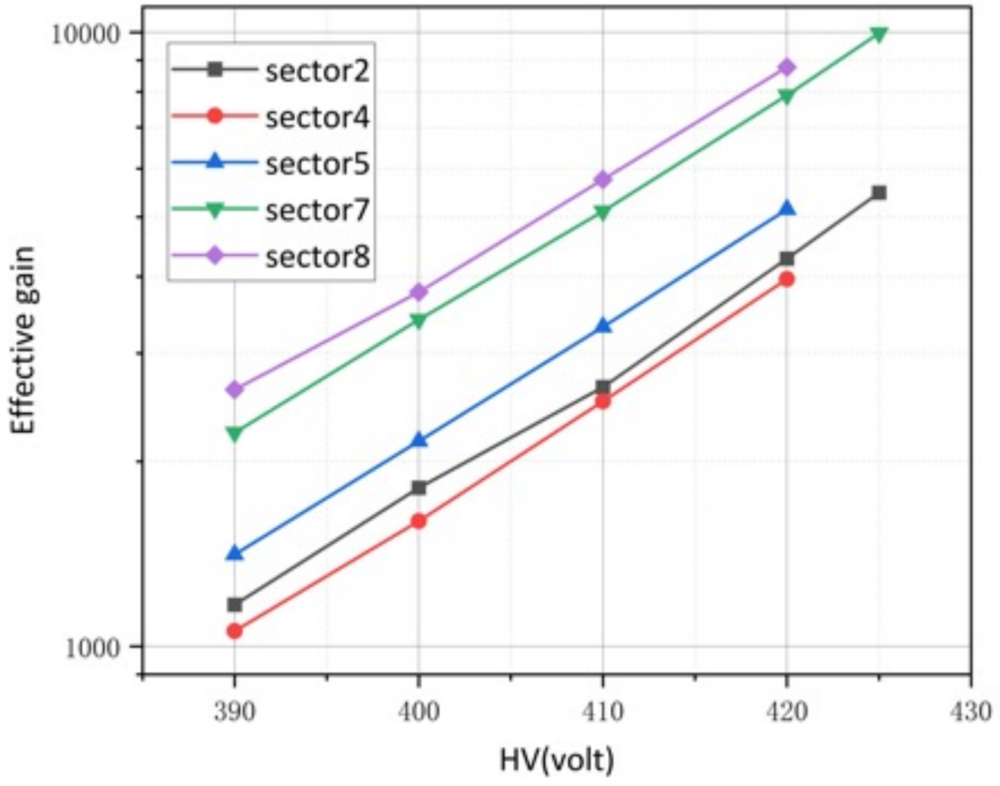


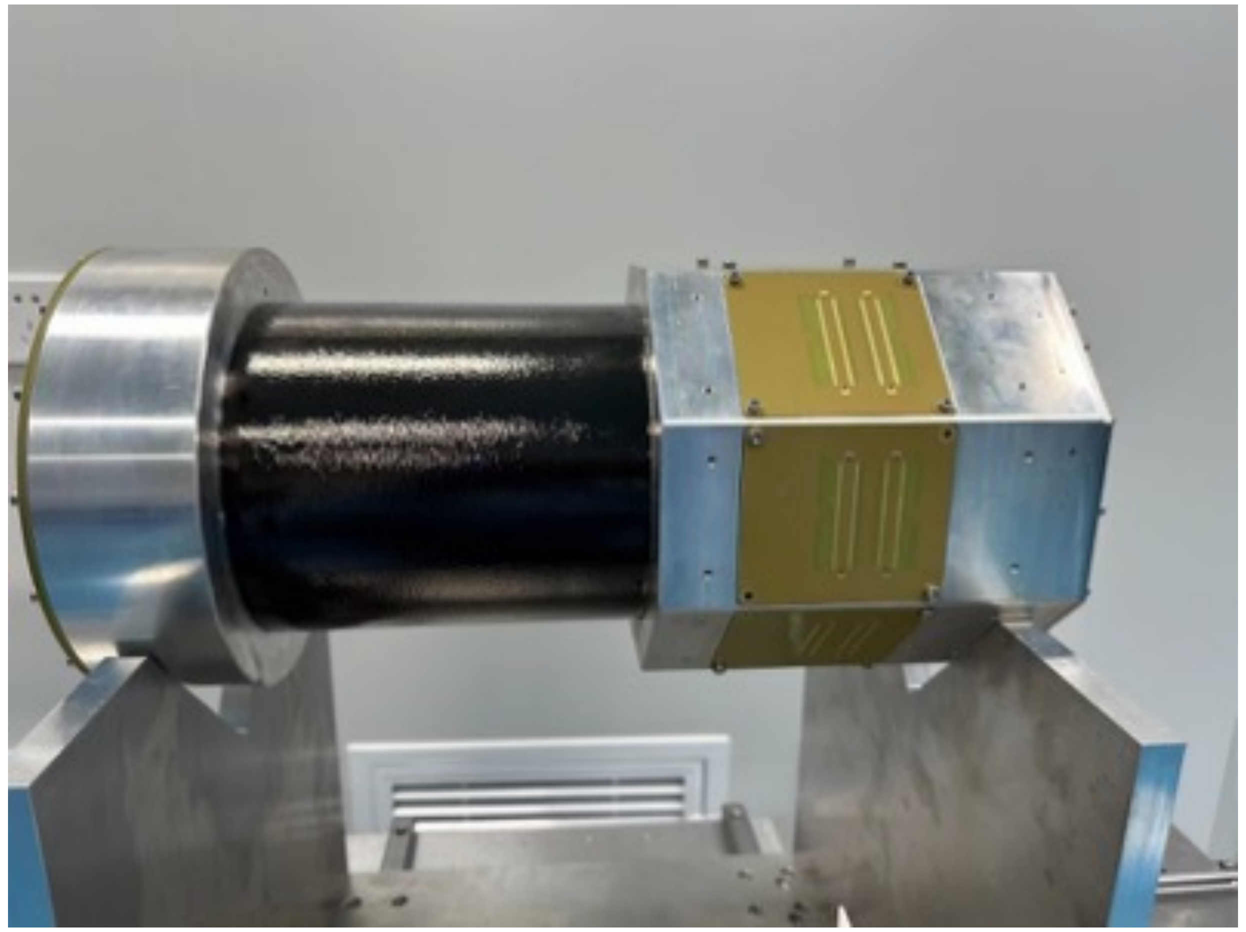


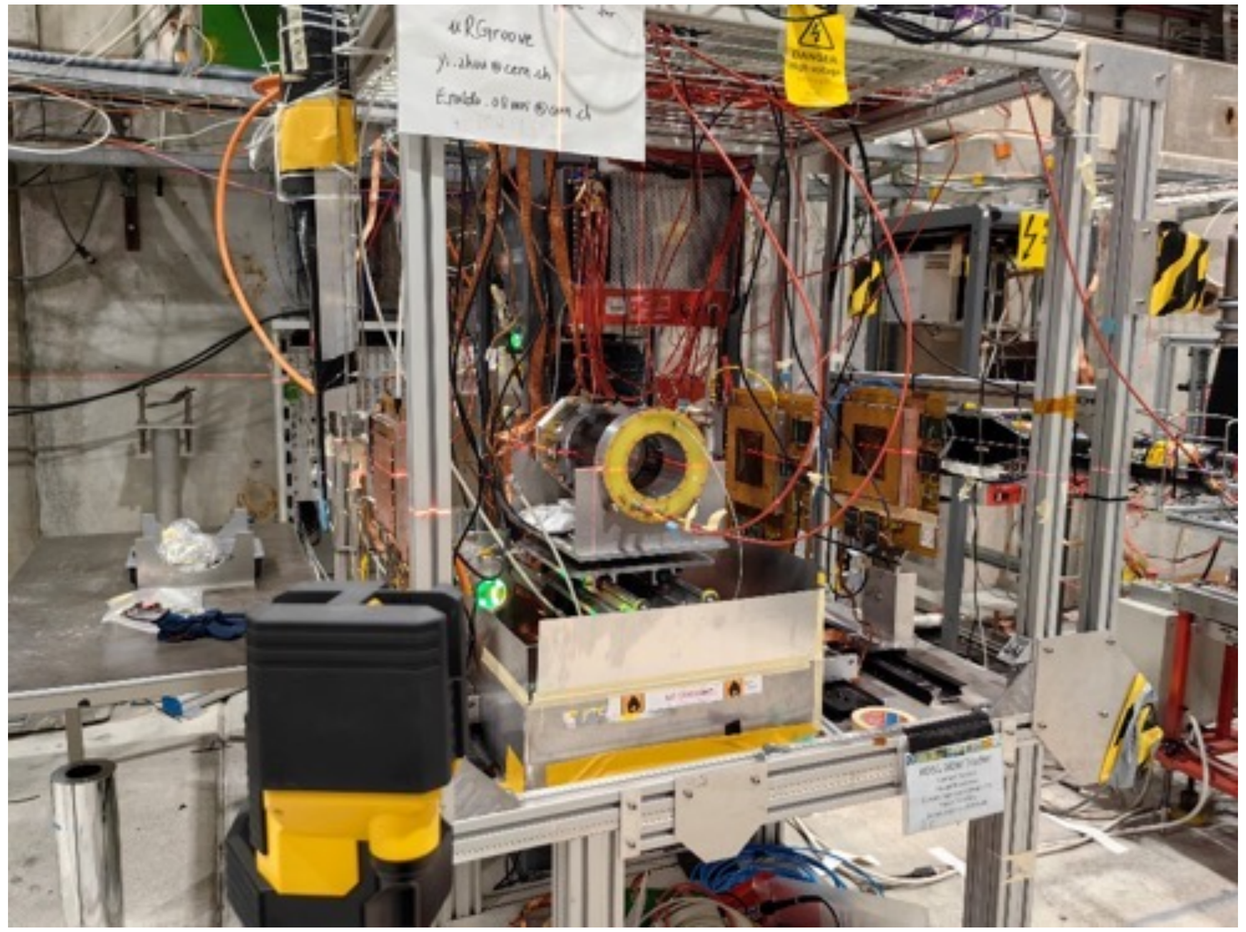
Tested the ASIC chip by feeding simulated detector output pulses to the chip at 4MHz with 35pF

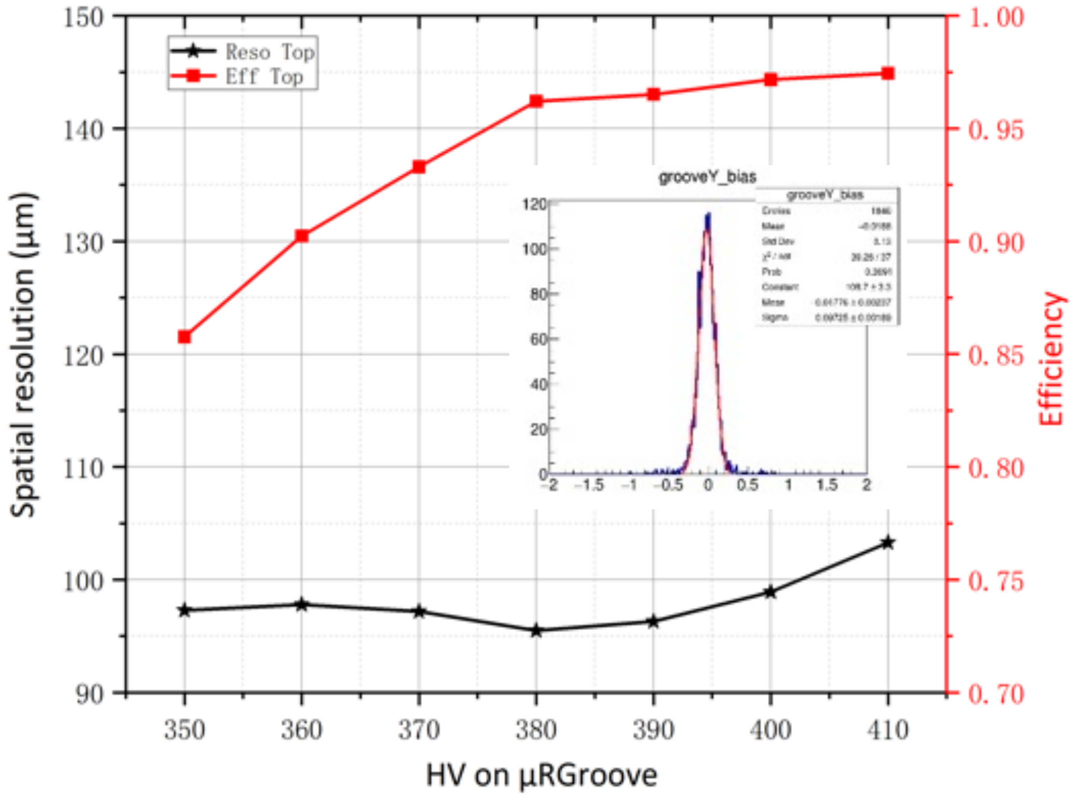
Inner Layer Prototype

- Built a cylindrical μRGroove prototype for the ITK inner most layer
- Tested the prototype with ^{55}Fe source in lab and SPS muon beam at CERN
- Effective gain~5000-10000 for most sectors
- Spatial resolution<100 um and efficiency > 95%
- The detector design and fabrication will be optimized in many aspects based on the prototyping experience



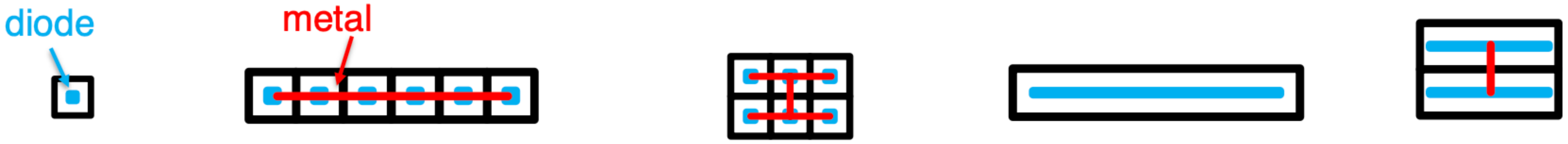






ITK-MAPS

- **Aiming for a low-power MAPS chip design (required for a low-mass system) with timing and charge measurement capability: position, time and charge (TOT)**
- **Low mass outweighs position resolution: exploring large pixel size to reduce power density**



A: pixel 30μm×30μm

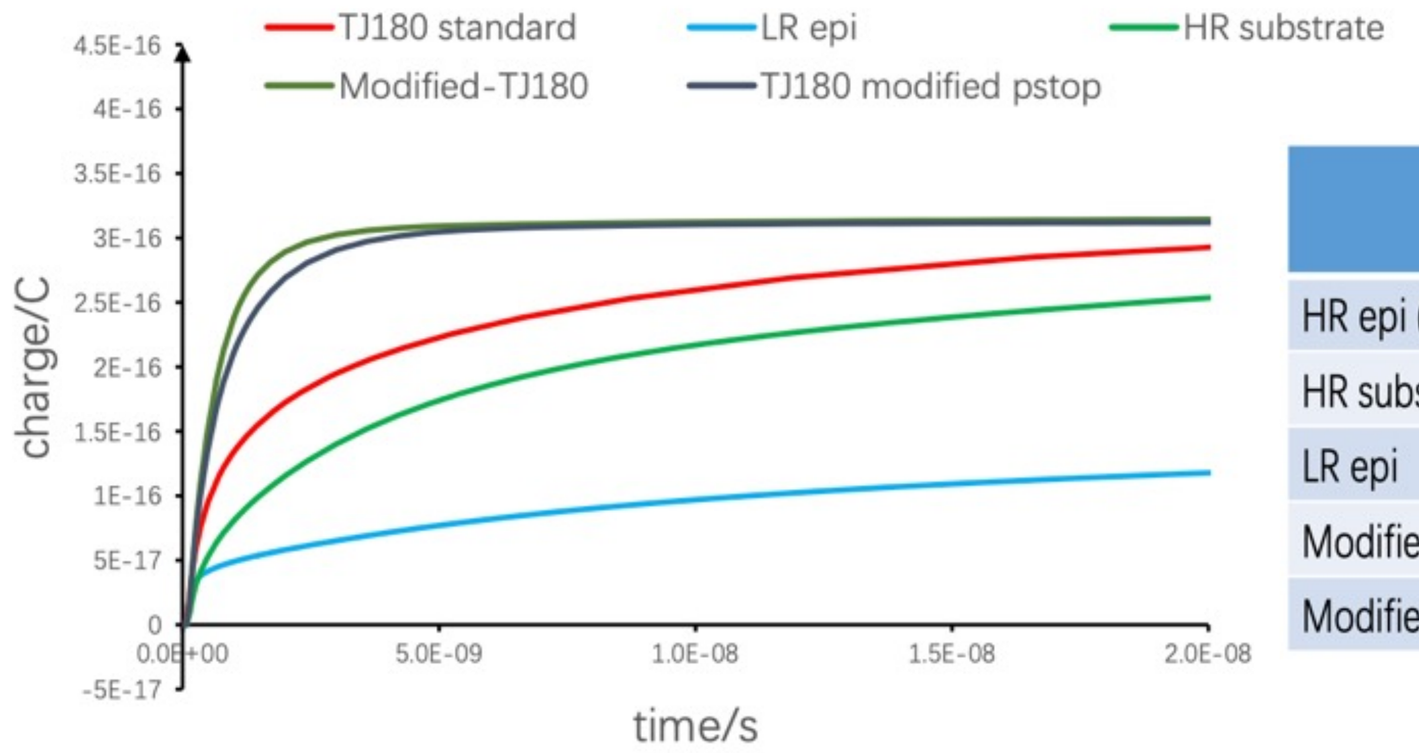
B: Pixel-based 180μm×30μm

C: Pixel-based 90μm×60μm

D: Strip-based 180μm×30μm

E: Strip-based 90μm×60μm

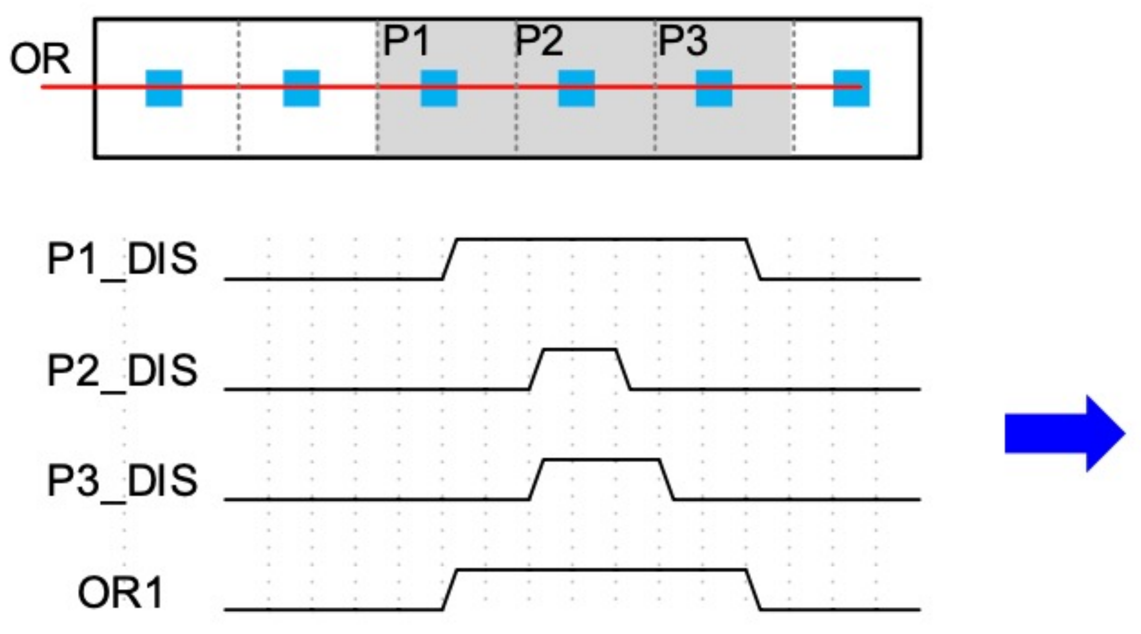
- **CMOS techniques being explored:**
  - **TowerJazz 180nm (HR epi),**
  - **NexChip FCIS/BCIS 90nm (LR epi)**
  - **GSMC 130nm (HR substrate)**



	Collected charge (e)	Collection time(ns)
HR epi (TJ180nm)	**2039.81**	**20.56**
HR substrate	**2477.65**	**89.72**
LR epi	**1089.64**	**74.57**
Modified-TJ180nm	1969.85	1.81
Modified-TJ180nm pstop	1952.04	2.47

Super Pixel Design

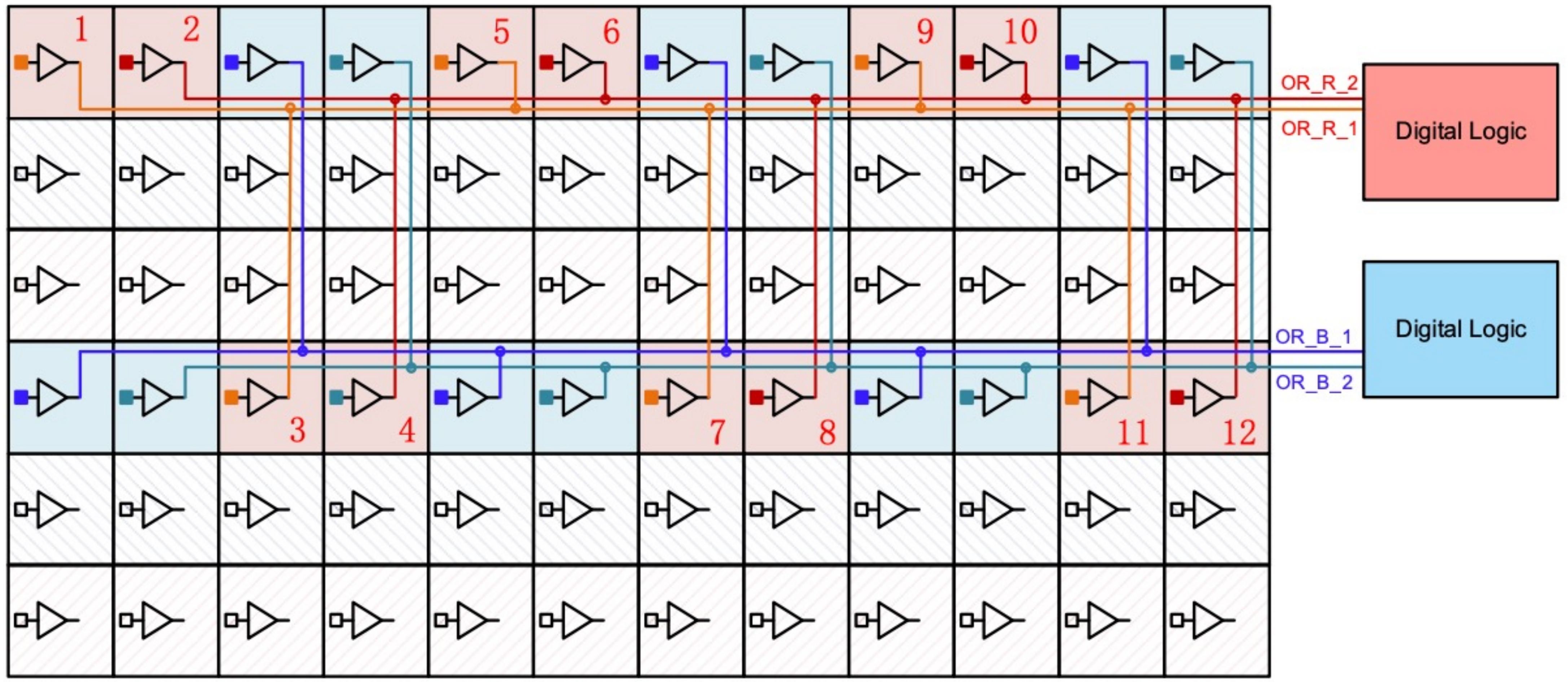
- ❖ Combining non-adjacent pixels: avoid ToT loss
- ❖ Super pixel with 6×12 pixel array
  - – 6 sets of digital readout logic
  - – When cluster size < 3X4, no ToT loss occurs



Combining adjacent pixels

→ ToT loss

Additional 3-bit for group address

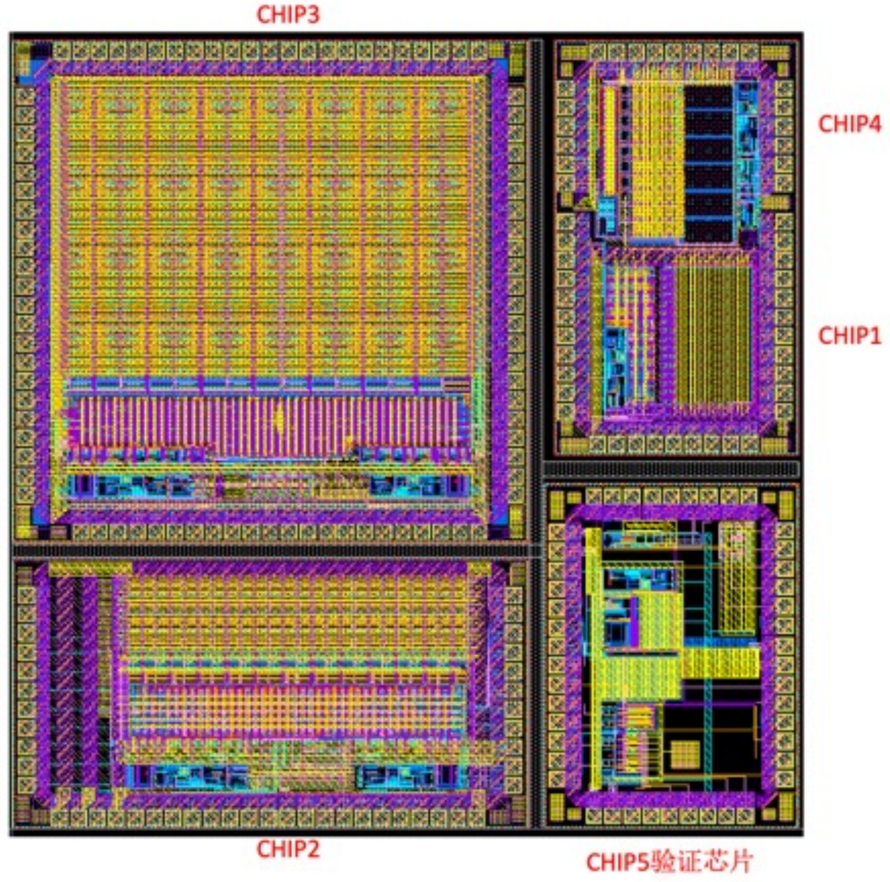


- **Providing both high position and high time resolutions for low power consumption**

ITK MAPS Designs

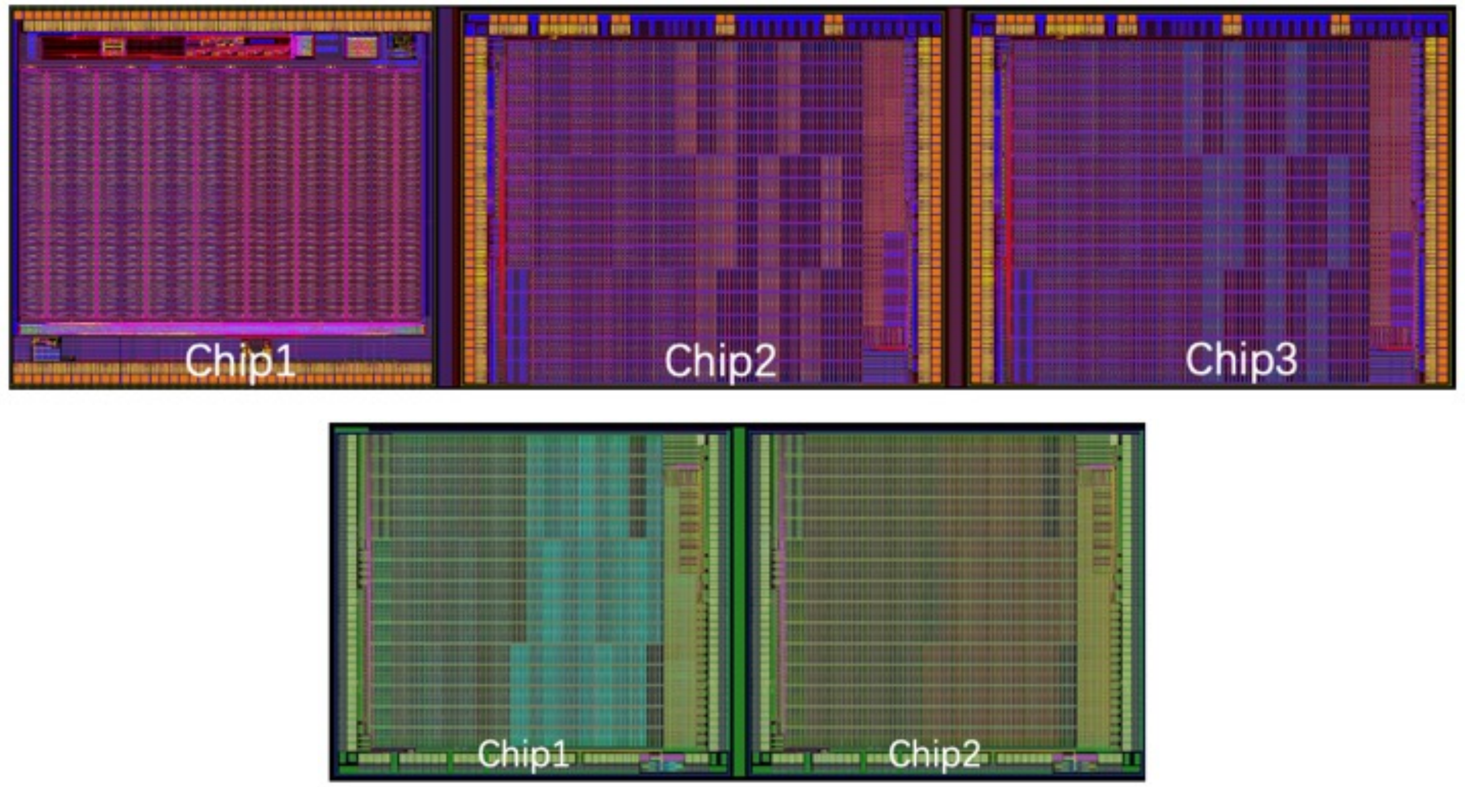
TowerJazz 180nm

Taped out in March 2024



NexChip BCIS 90nm (Hefei, China)

To be taped out in Dec. 2024



GSMC 130nm (Shanghai, China) Taped out in Sep. 2024

Simulated performance

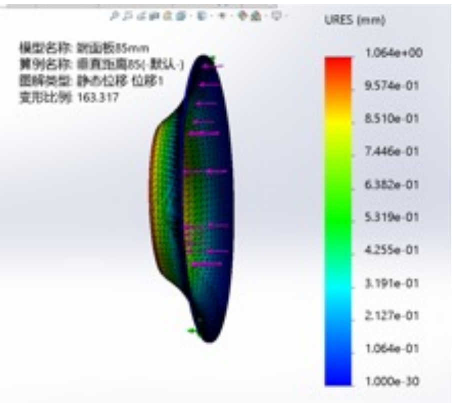
	TJ-MAPS	GSMC-MAPS
Current	**800 nA/pix**	**120*6 nA/pix**
Supply Voltage	1.8 V	1.2 V
Threshold	309.0 e^-	153.8 e^-
ENC	11.4 e^-	5.1 e^-
Mismatch	5.7 e^-	5.8 e^-
t_r @400 e^-	**200 ns**	**81 ns**

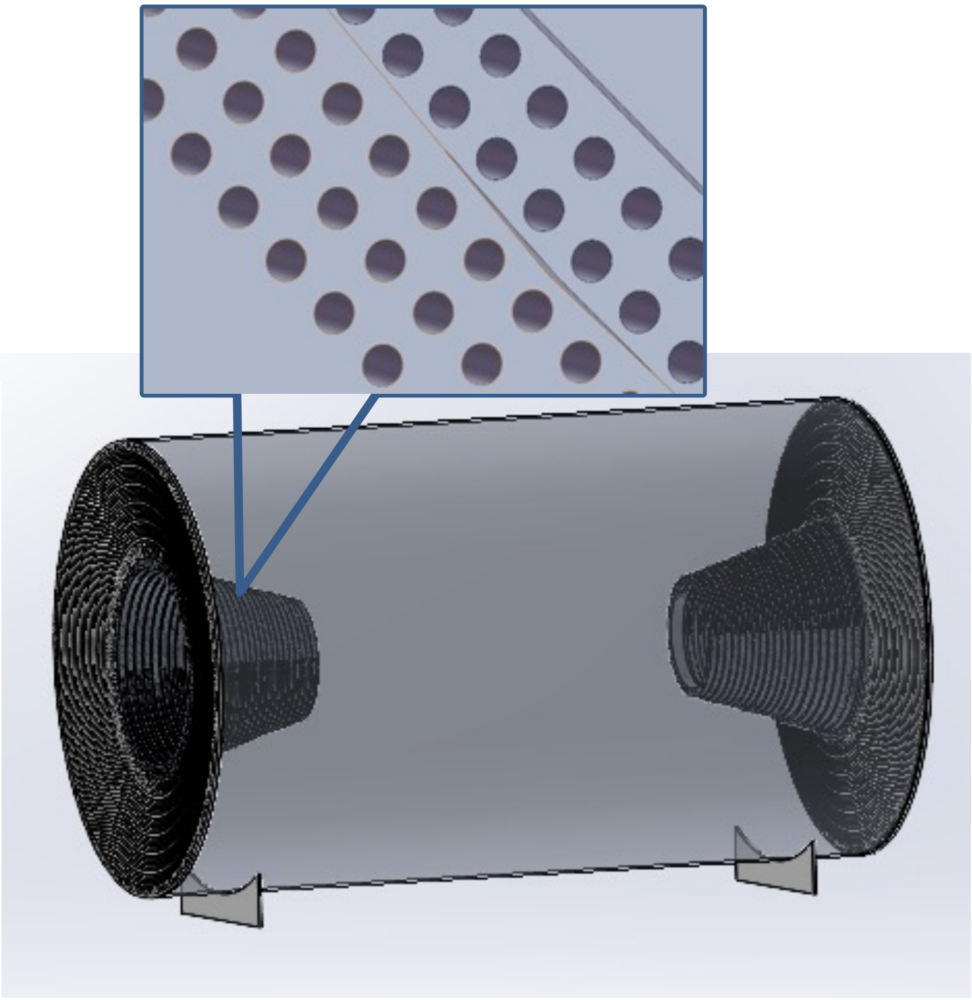
Items	Power consumption	Notes
Analog in pixel matrix	~26 mW/cm²	Strip-based
	~15 mW/cm²	Pixel-based
Timestamp clock distribution	12.2 mW/cm²	
Dynamic power consumption of the pixel matrix	2.4 mW/cm²	with a data rate of 8.7 MHz/cm²
Periphery	23.5 mW	32MHz event rate
PLL, serializer, LVDS	39 mW	x 2 data/clock output
Analog configuration	20 mW	
Total	222.6 mW	Strip-based
	184.6 mW	Pixel-based

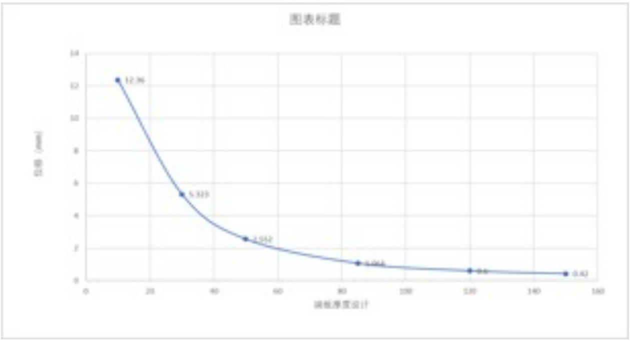
- Strip-based：55.7 mW/cm2
- Pixel-based：46.2 mW/cm2

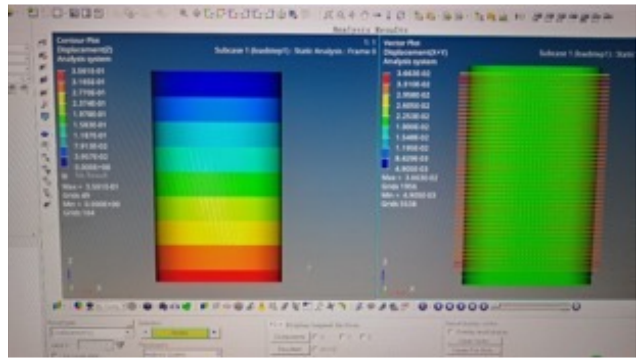
Main Drift Chamber

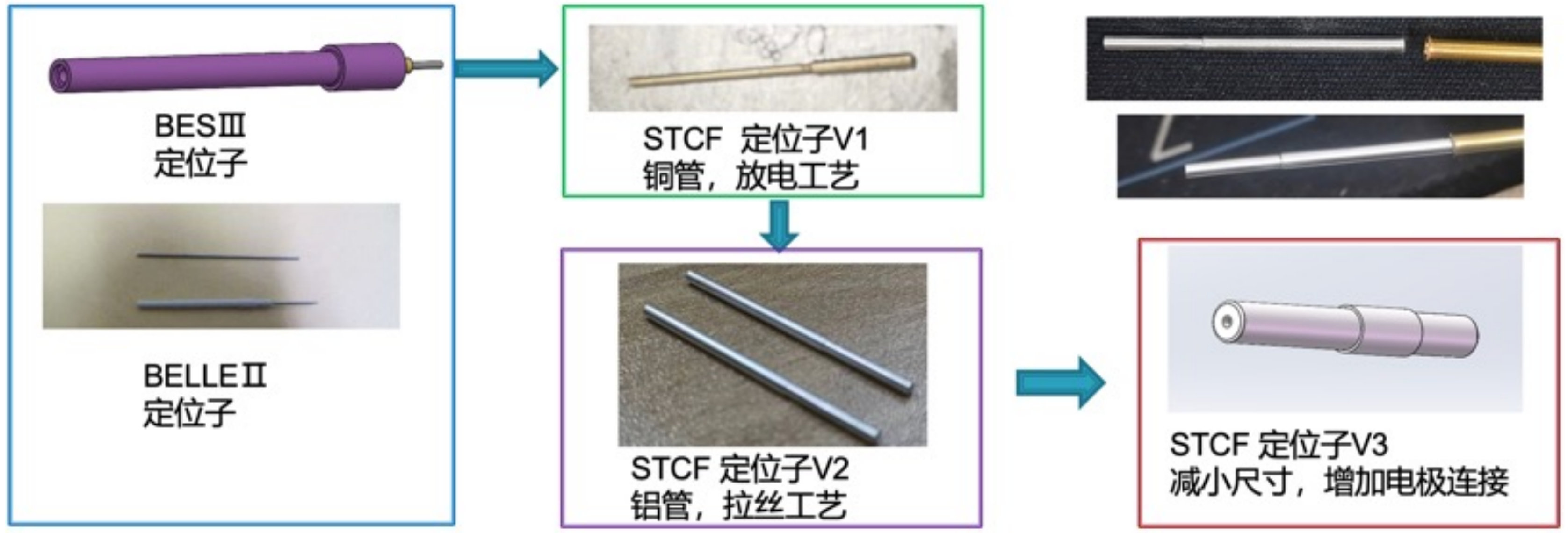
- Preliminary mechanical design and structural analysis
- Big challenges from super-small cells (5mm*5mm, distance between wires ~2.5mm)
- Ongoing R&D on feedthroughs, wires and chamber stringing

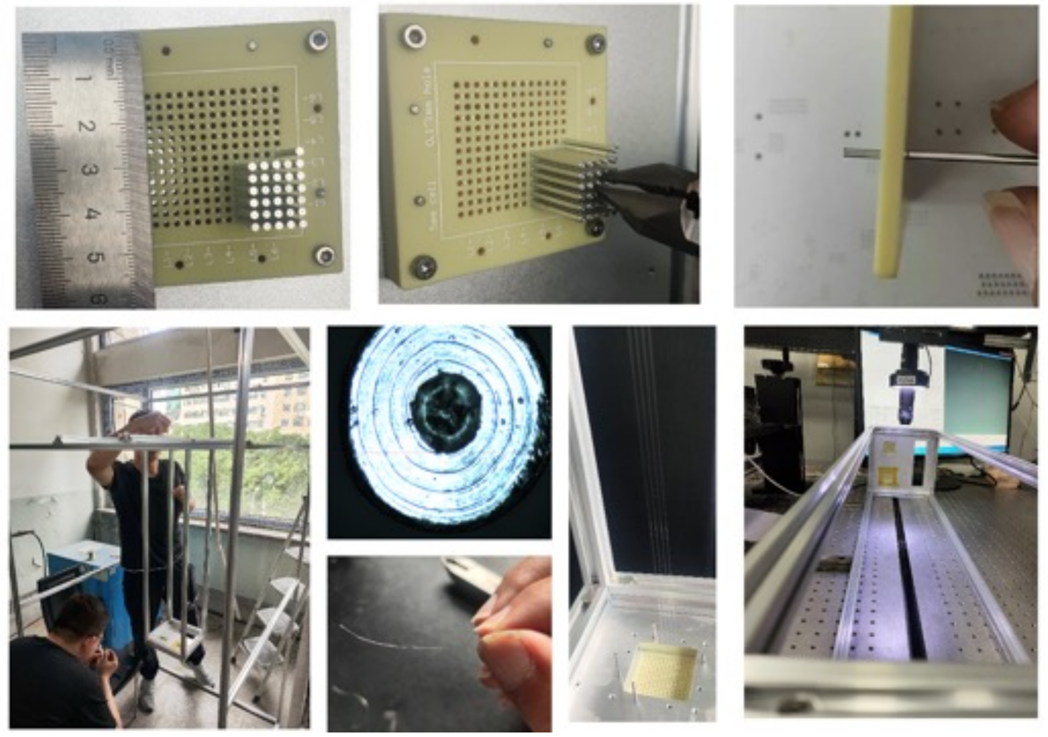






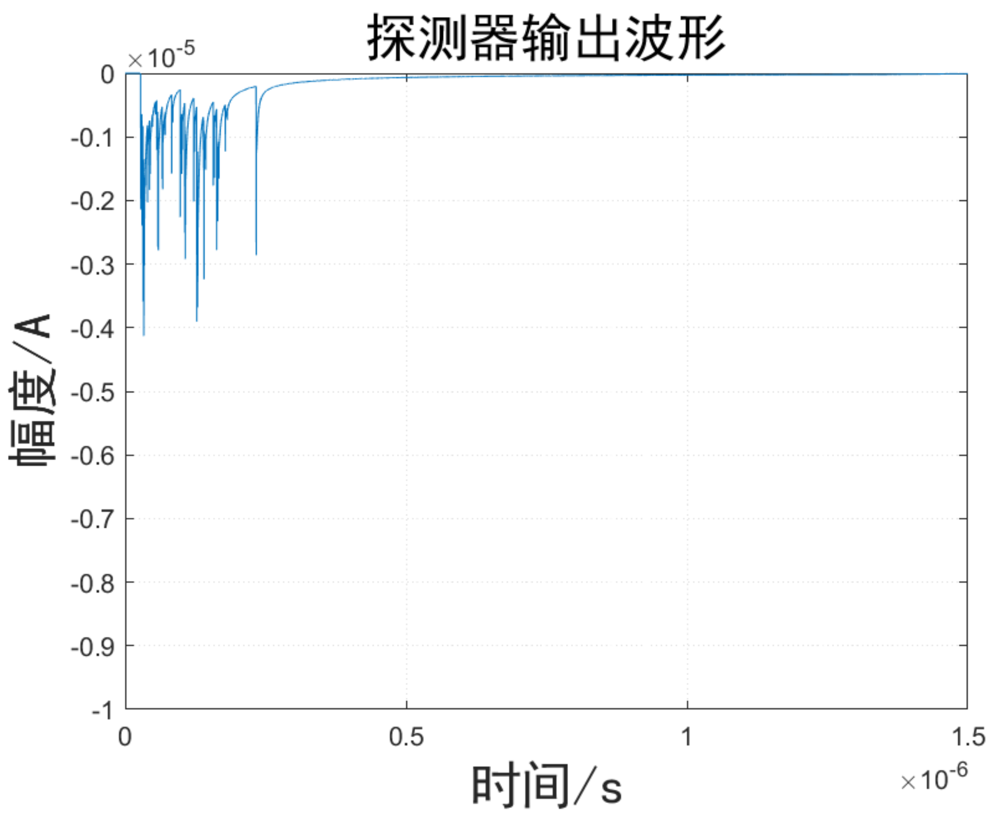




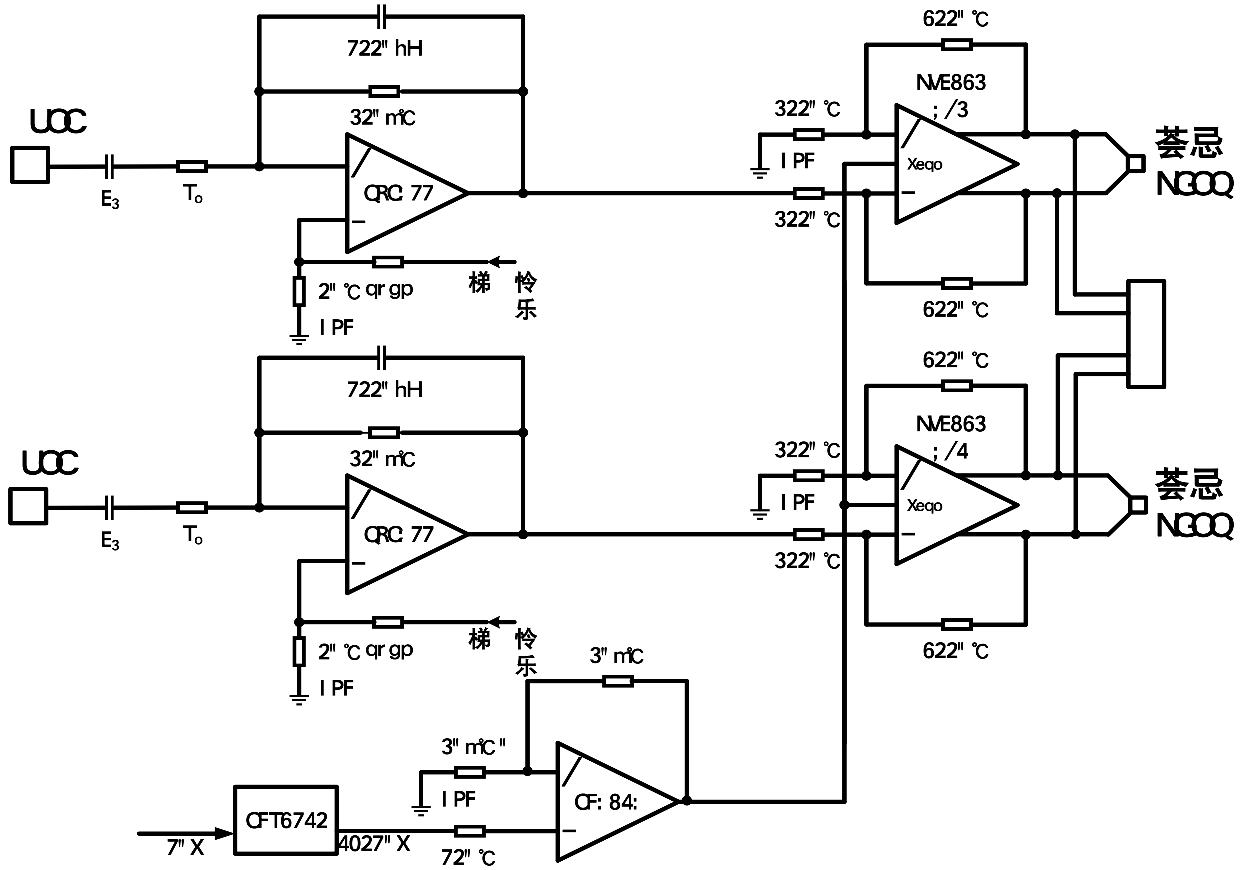


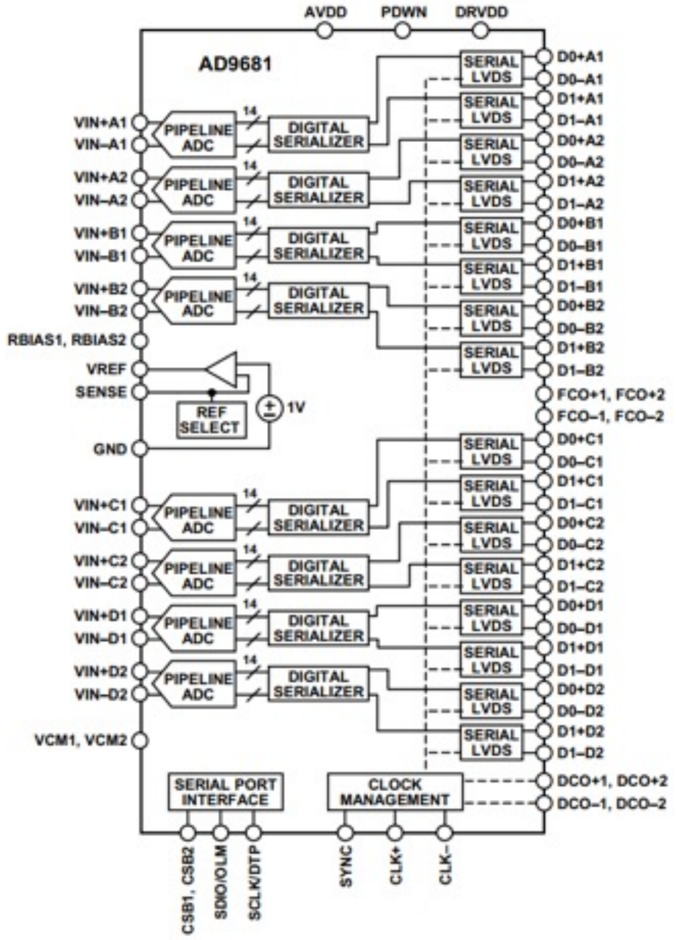
MDC Readout Electronics

- **Challenge: irregular pulse signals overlapping at high rates**
- **Attempt to separate overlapping pulses with waveform digitizing readout. A lot of effort on separation algorithm development and readout optimization.**
- **Developed readout circuit with discrete components (TIA + shaper + ADC). ASIC design also underway.**

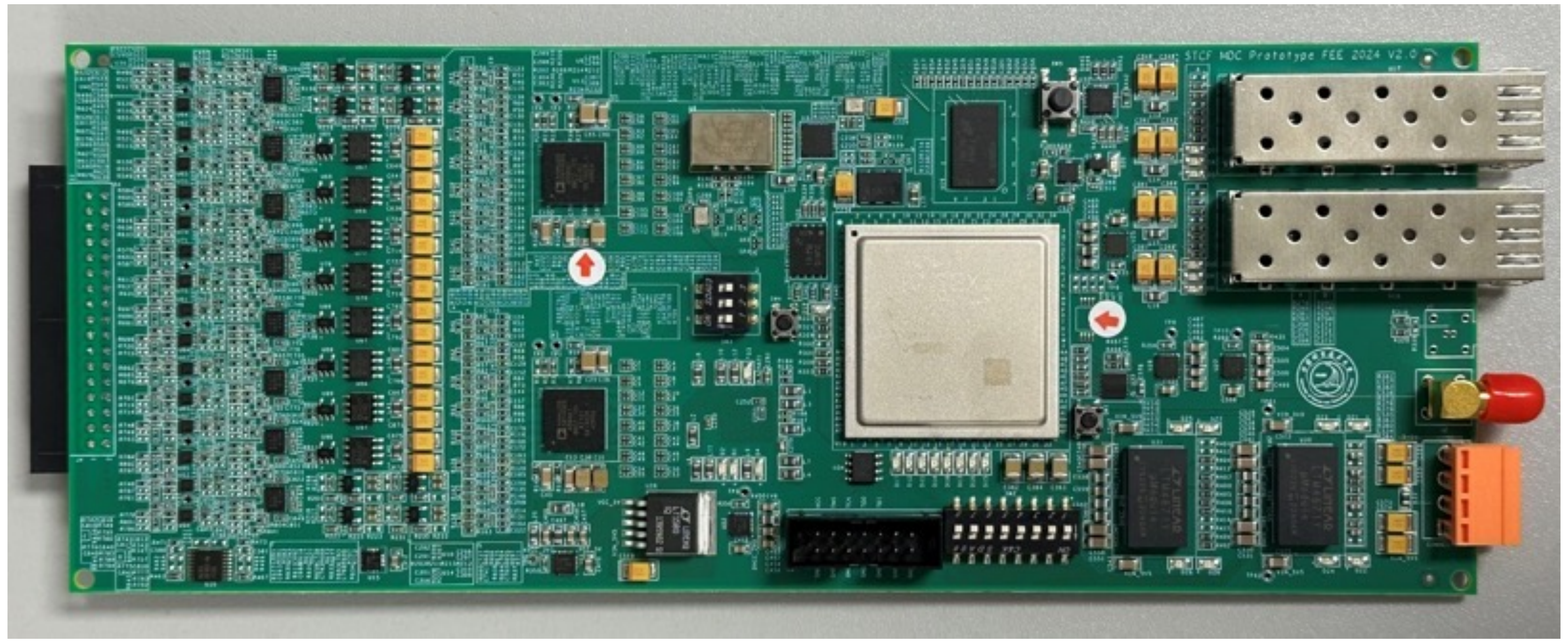


Optimized ADC specs: 14 bit, sampling rate 125 MSPS, bandwidth 650 MHz



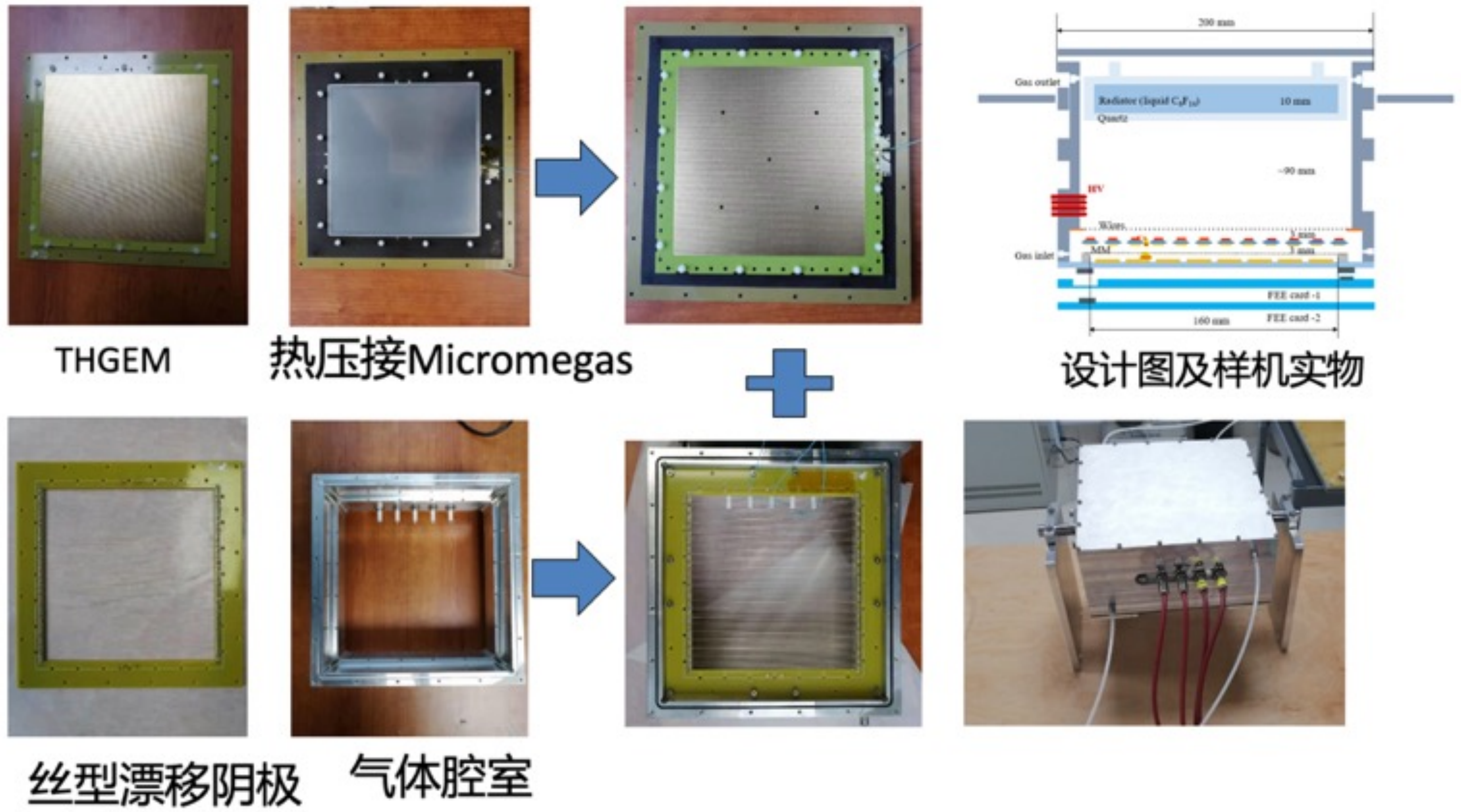


Readout board (16 chs) being tested

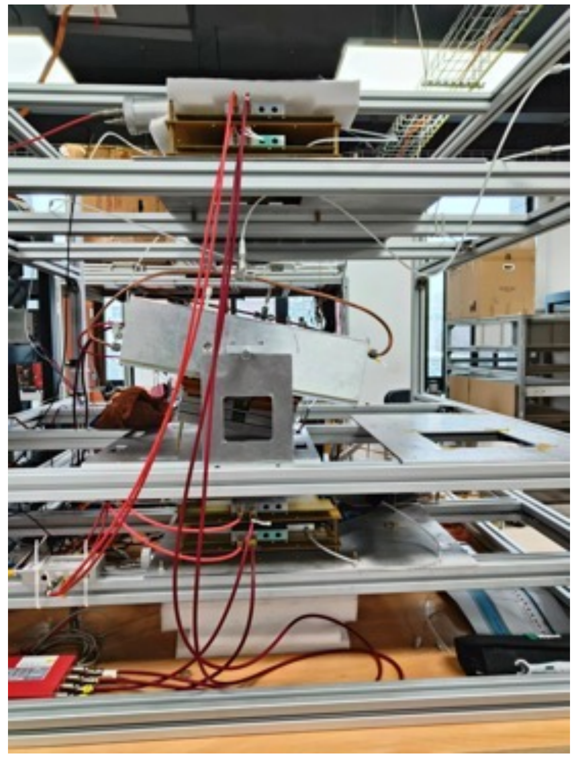


PID Barrel: RICH Detector R&D

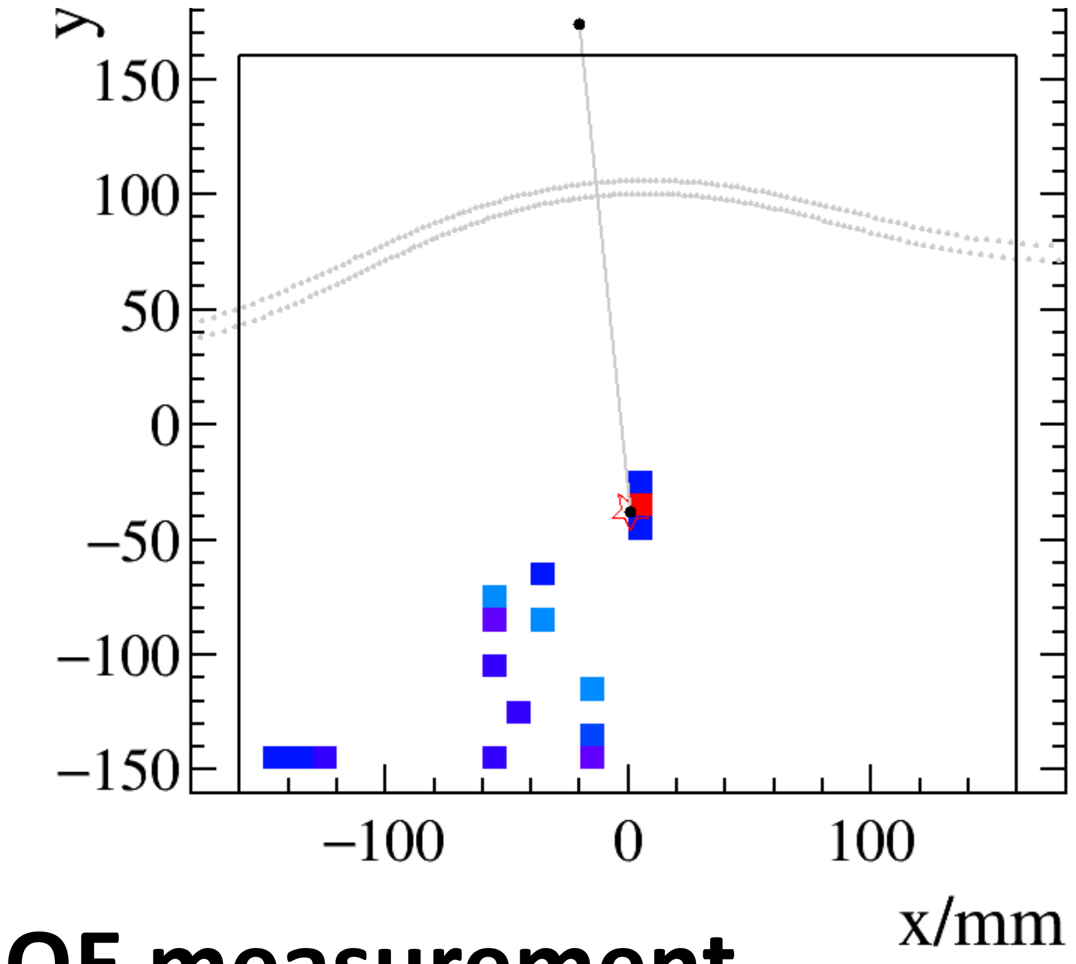
Fabrication of 30cm*30cm RICH prototype



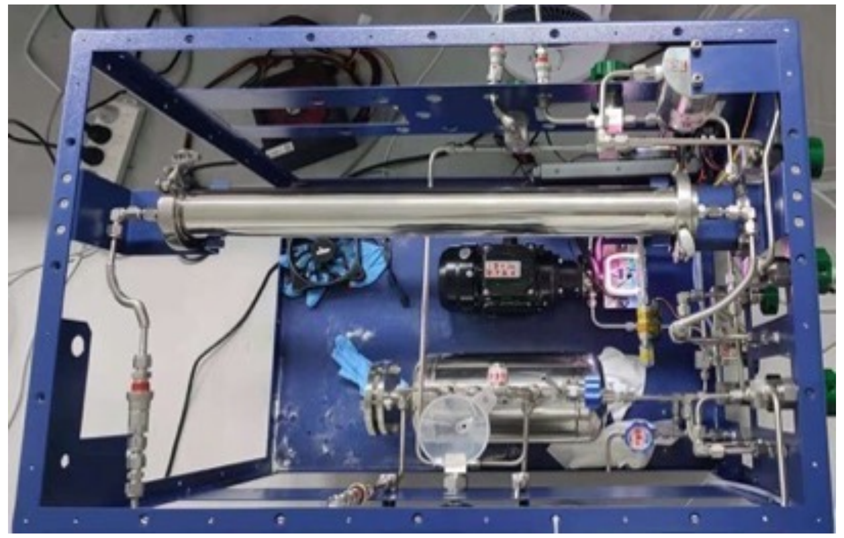
Cosmic-ray tes

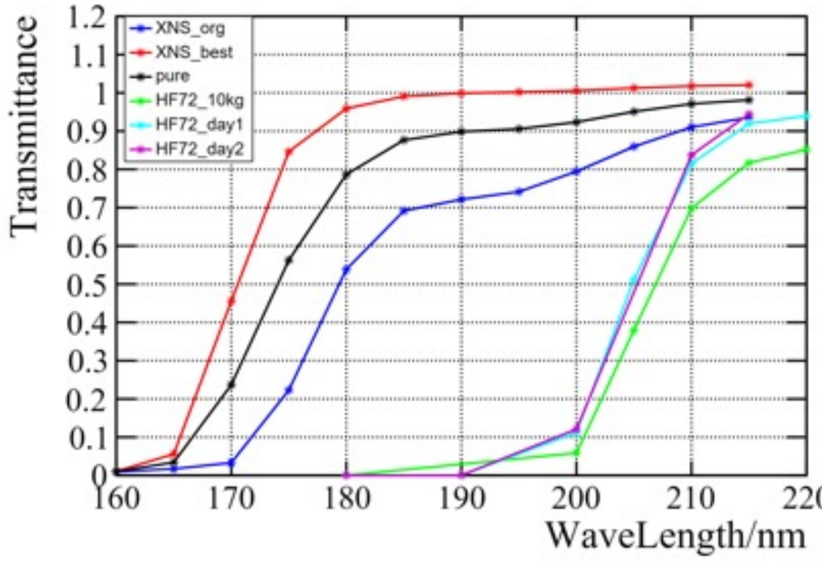


Very weak light observed
Investigation ongoing

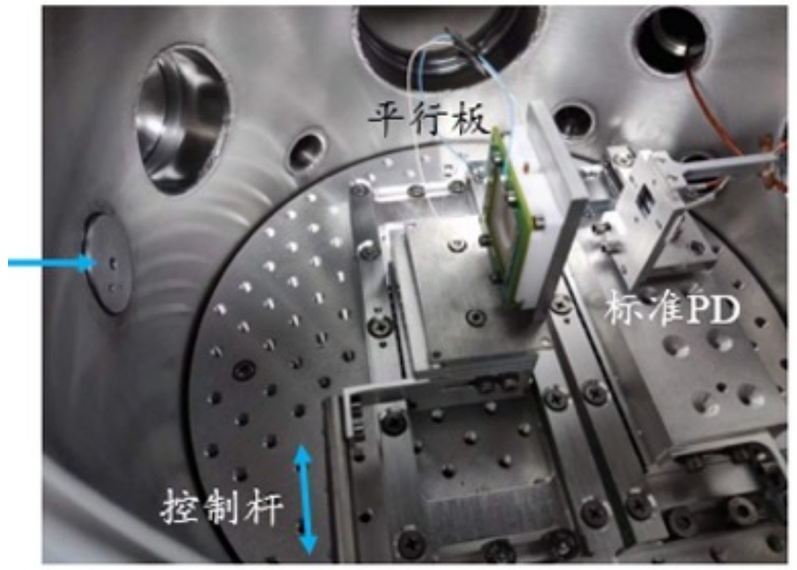


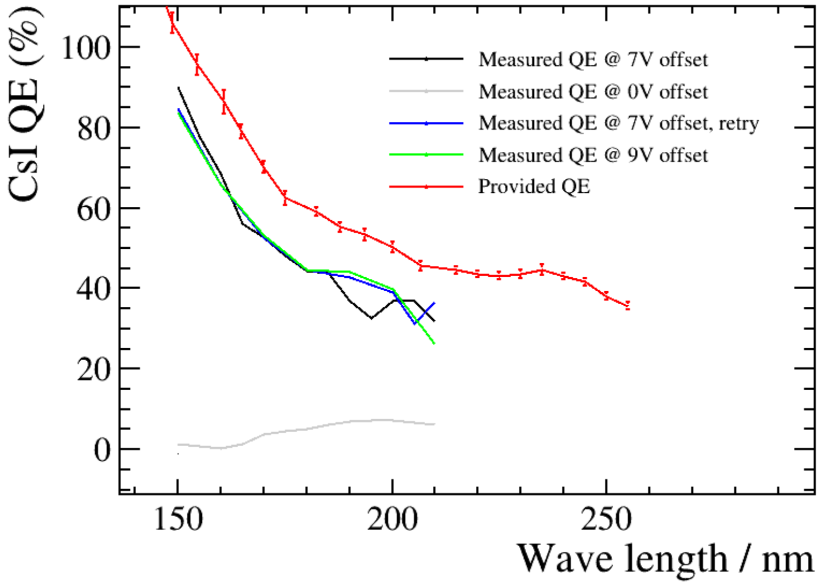
Radiator purifying





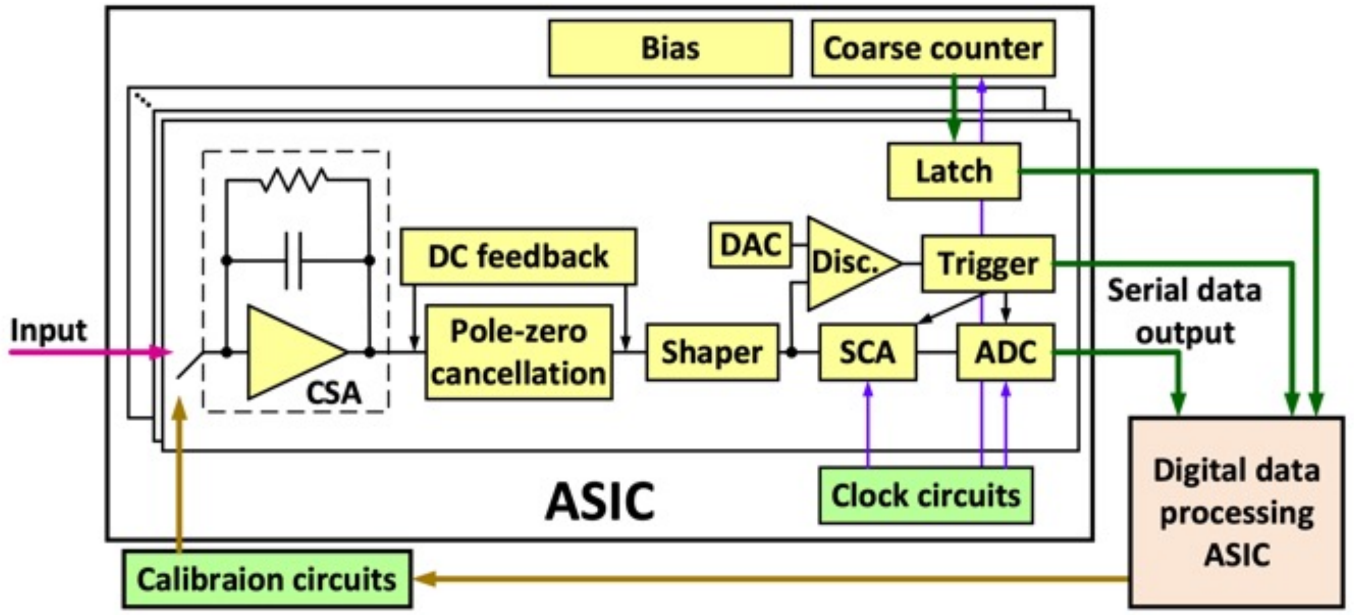
CsI coating and QE measurement

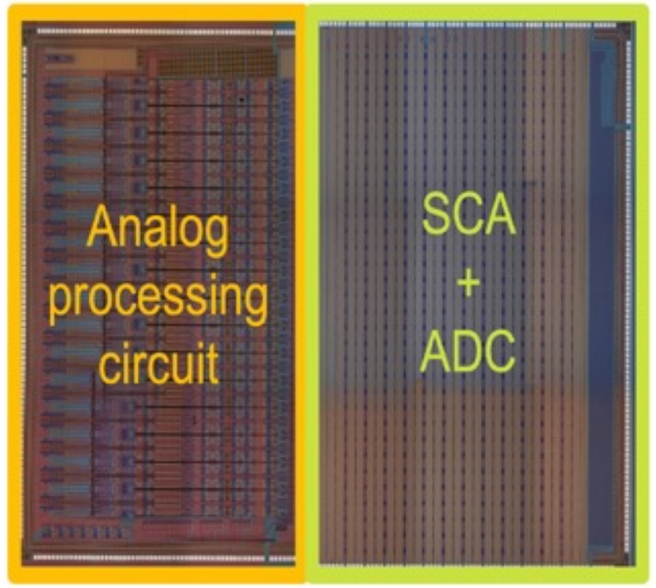




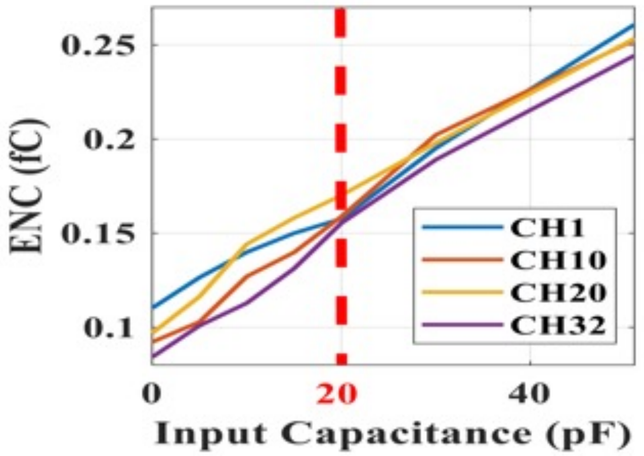
RICH Readout ASIC

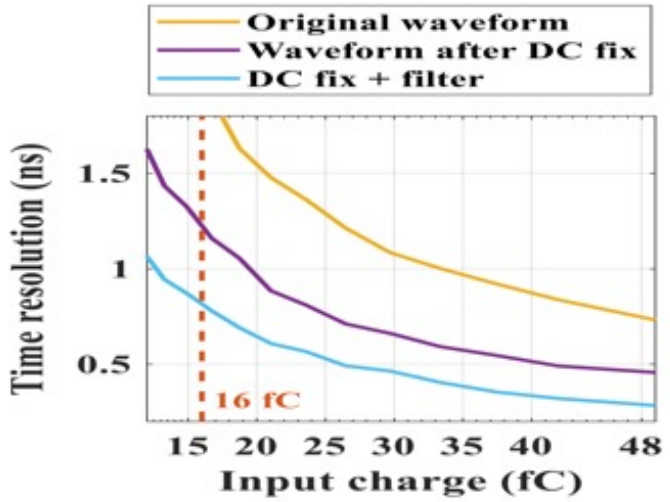
Design specs: $\sigma_t < 1$ns @20fC&20pF, event rate ~ 100 kHz, 32 channels

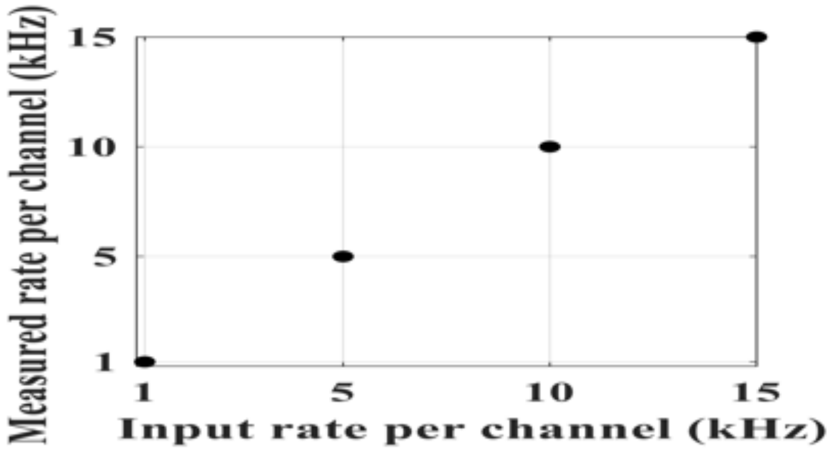




Test results

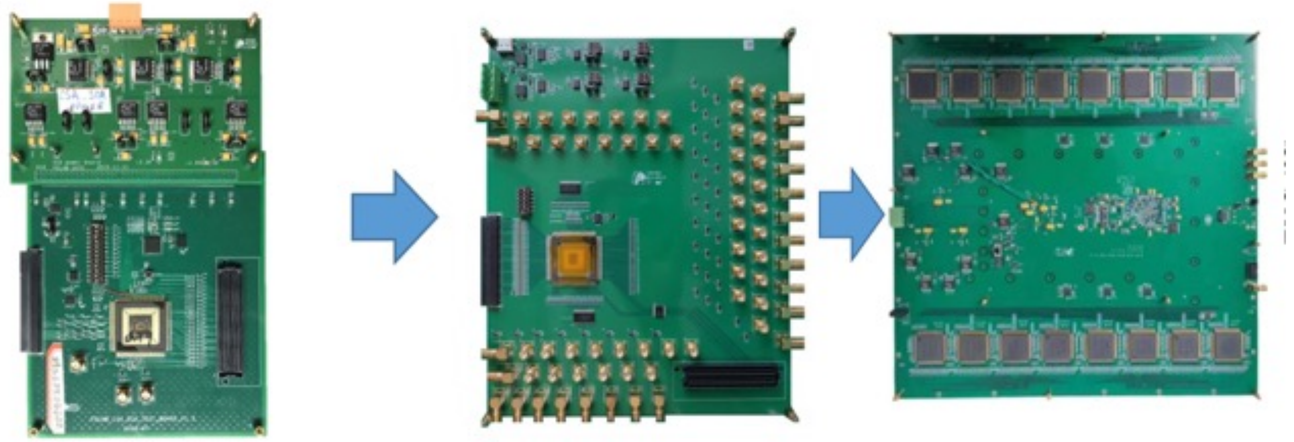


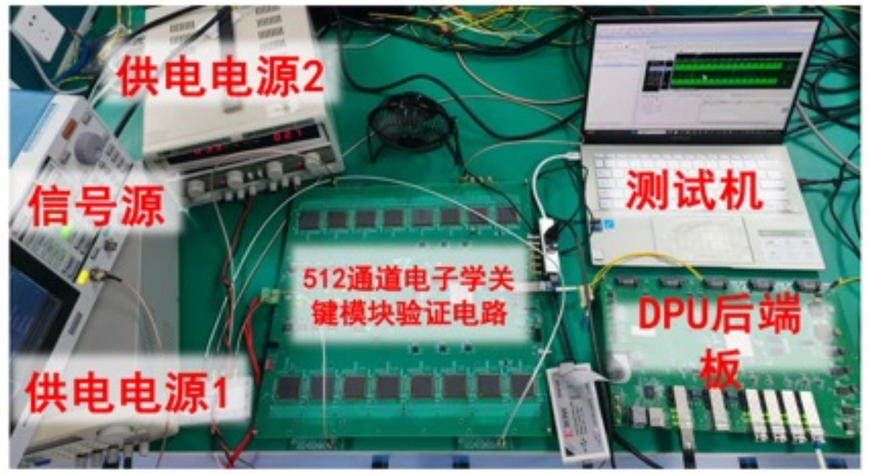




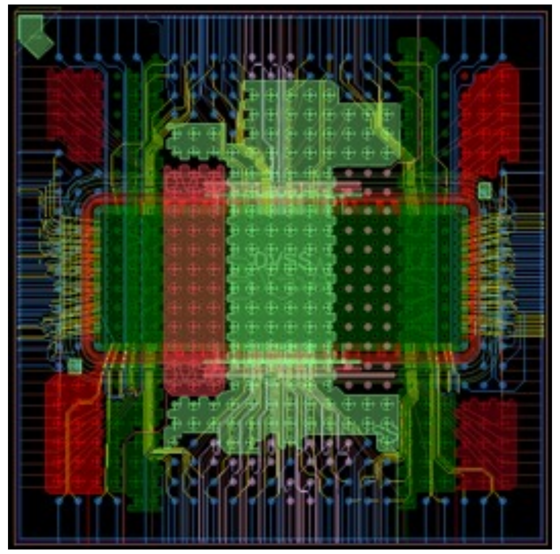
Design iterations

First version Second version



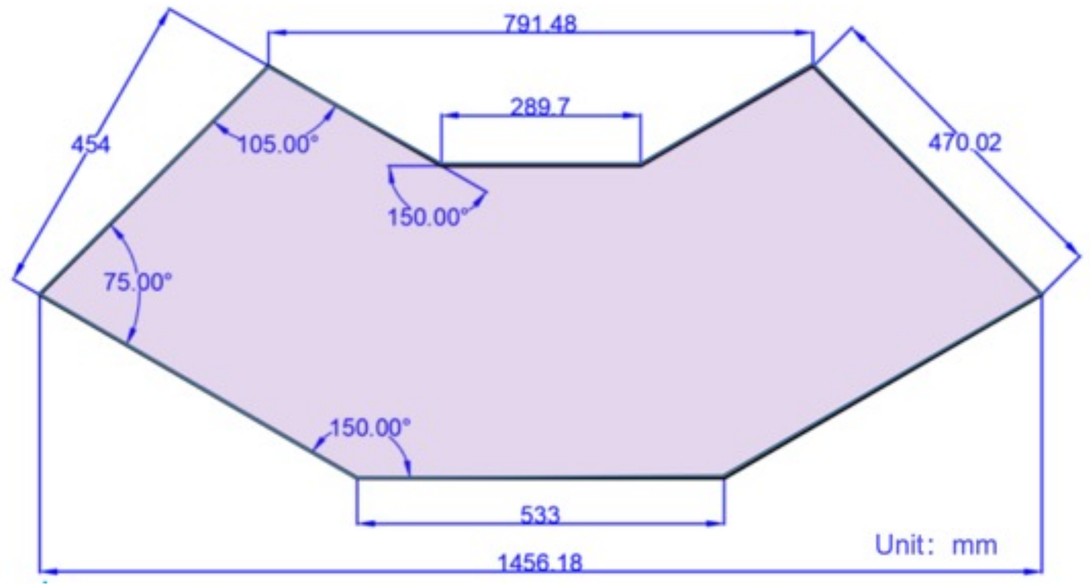


512-channel readout board using the self-developed ASIC



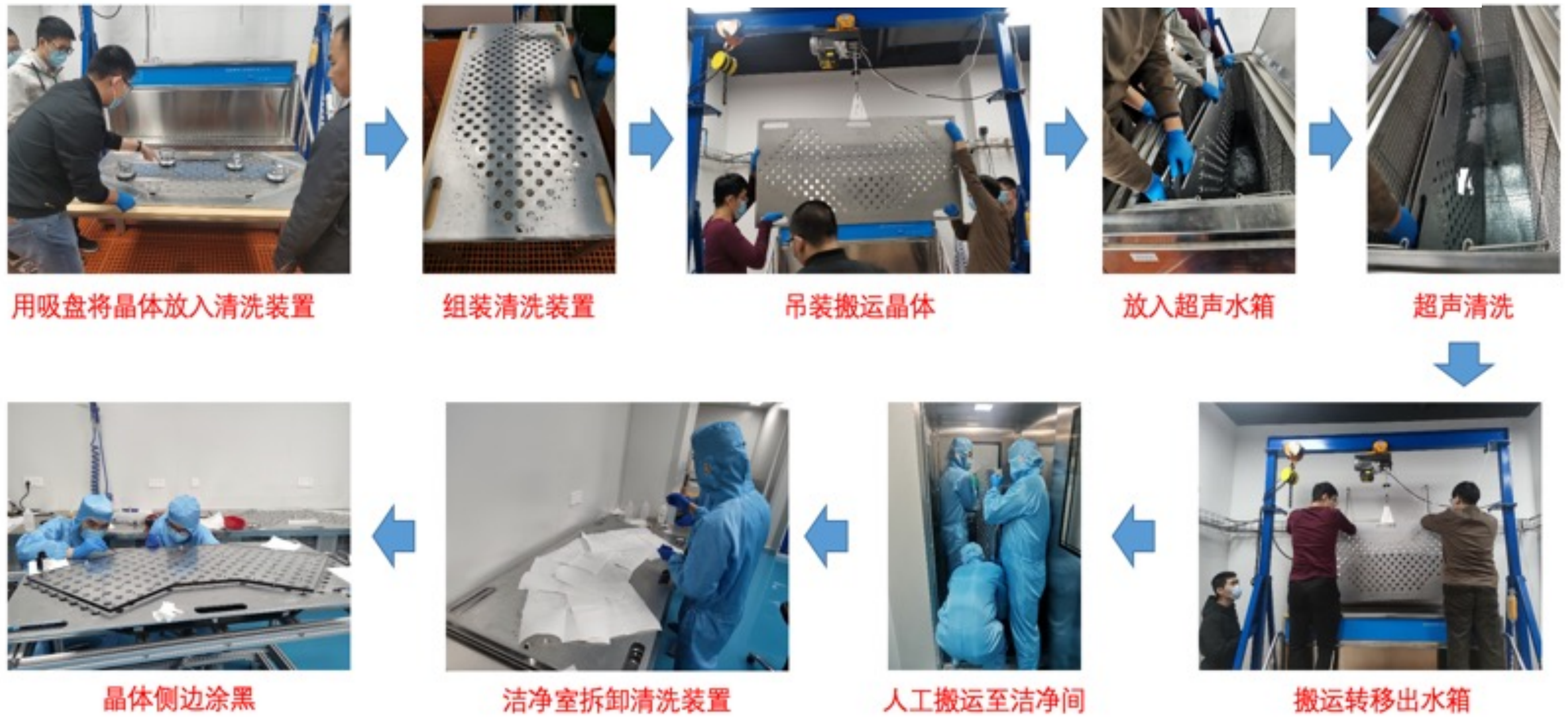
Design with 64 channels is underway

PID Endcap: A full-sized DTOF prototype

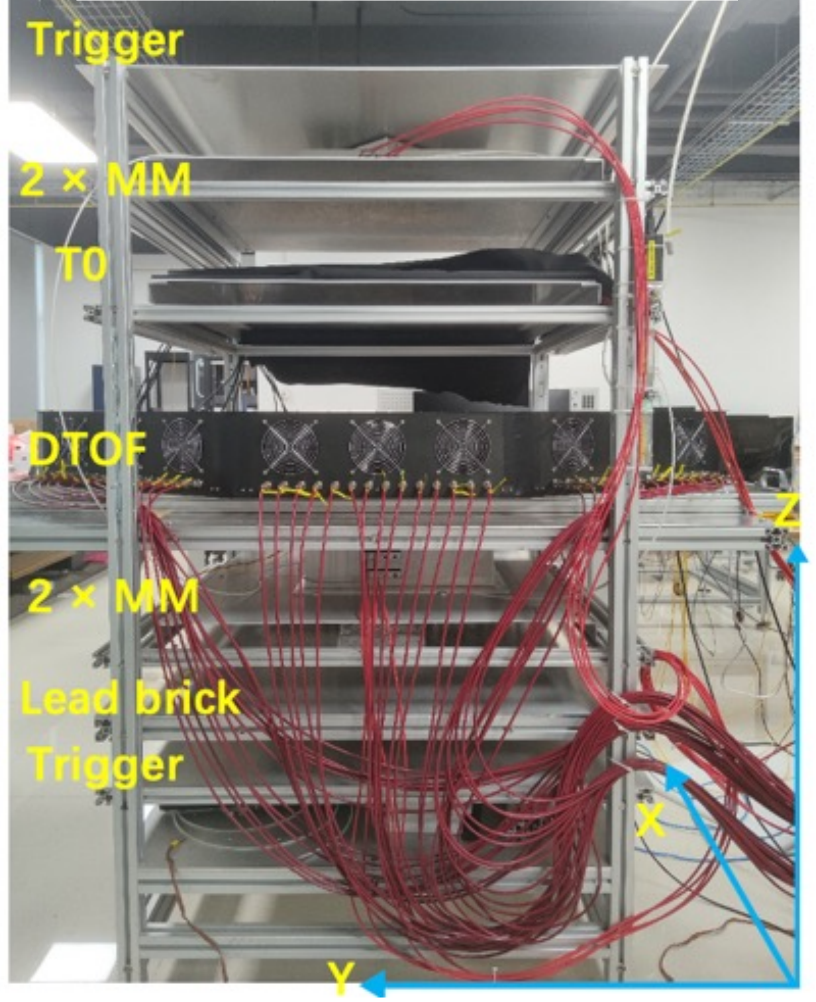


石英清洗和安装

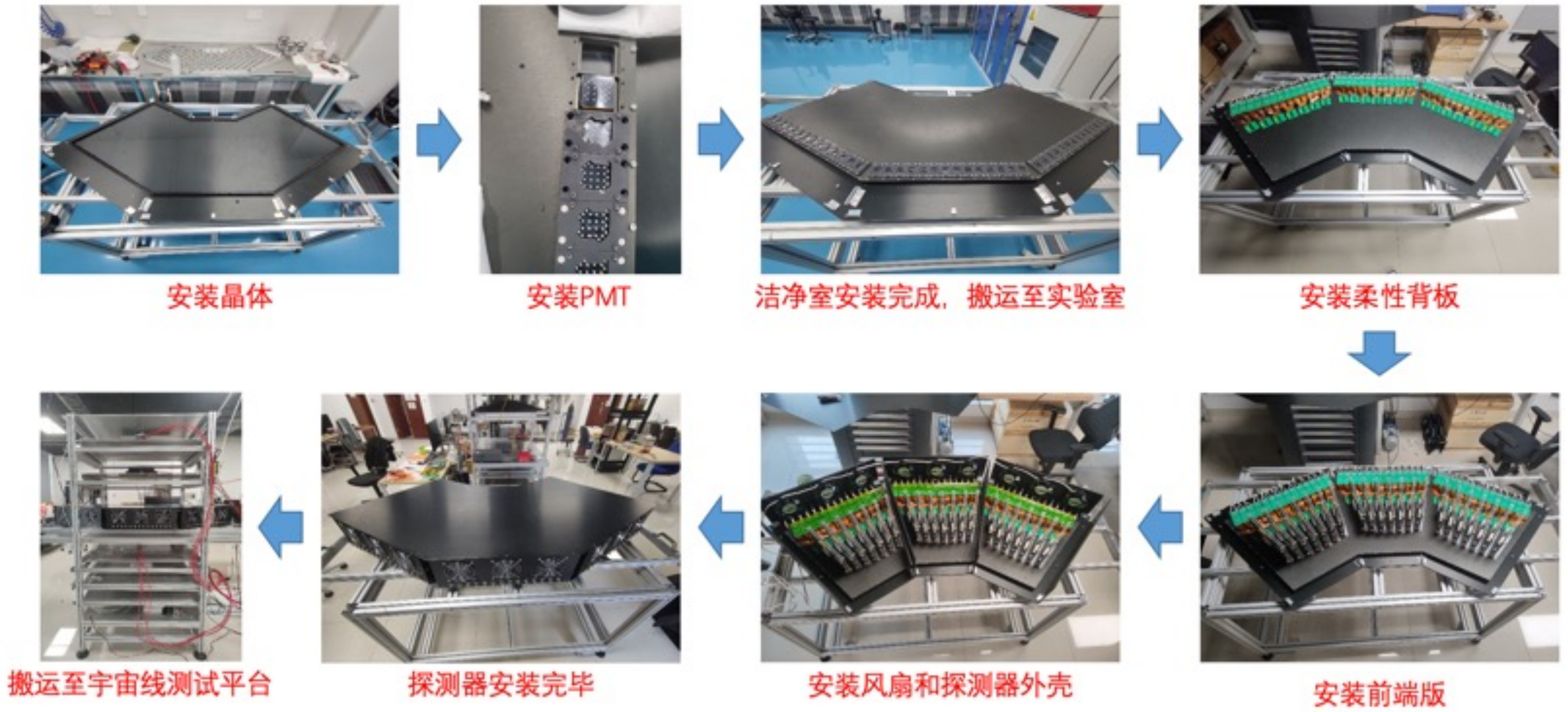
Quartz radiator cleaning and mounting

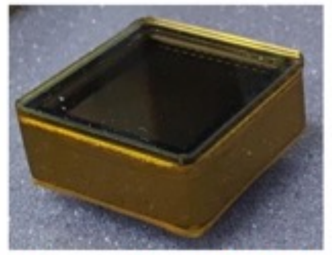


Cosmic-ray test



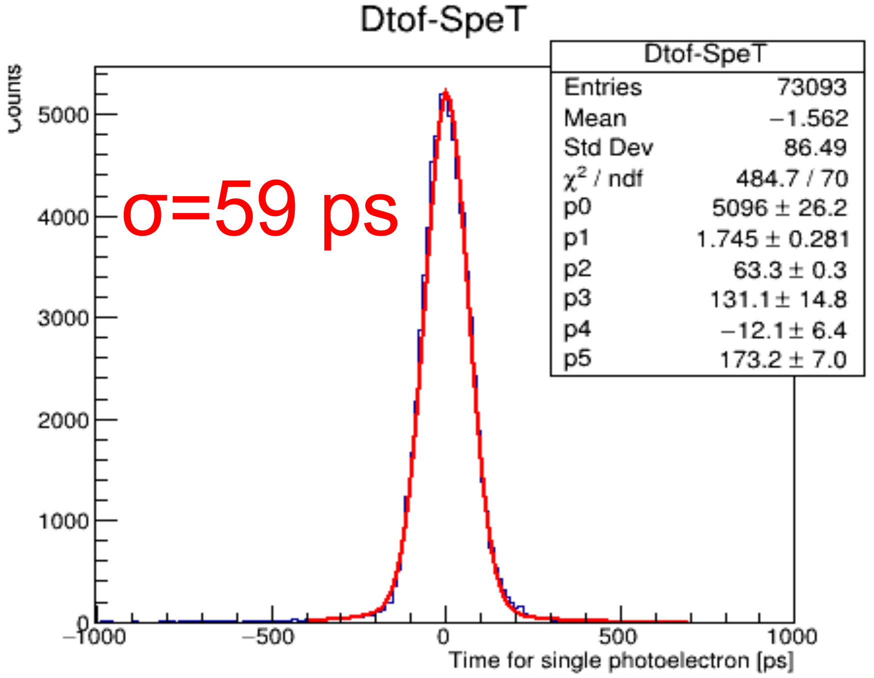
Detector assembling



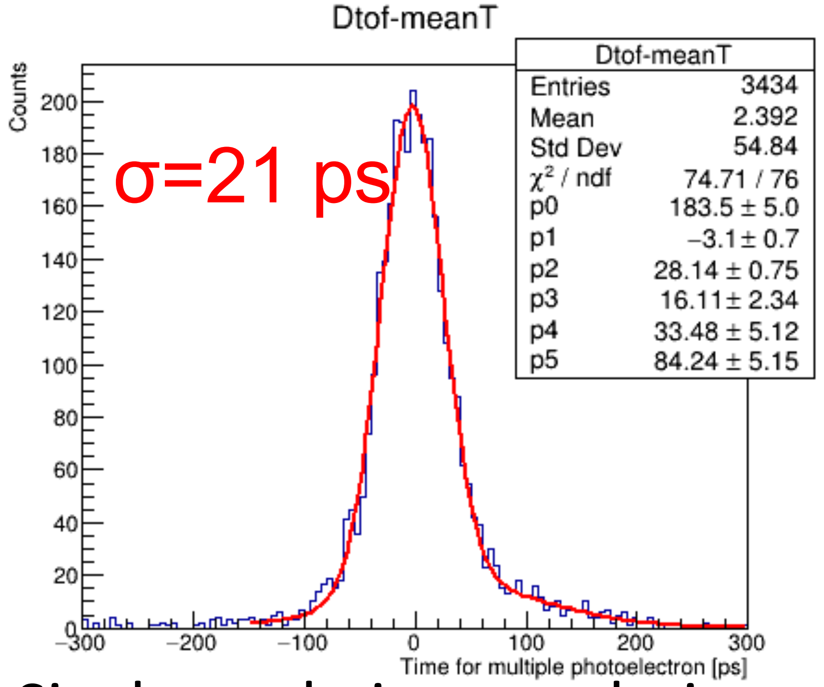


Hamamatsu R10754

- 灵敏面积：23×23 mm^2
- 像素分布：4×4 阵列
- 像素大小：5.5×5.5 mm^2
- 光谱响应范围：200-850 nm
- 量子效率：25%@λ=400 nm
- 单光子灵敏
- 高增益：>10^6
- 增益非均匀性：14% (σ/μ)
- 时间性能：~27 ps



single photon time resolution

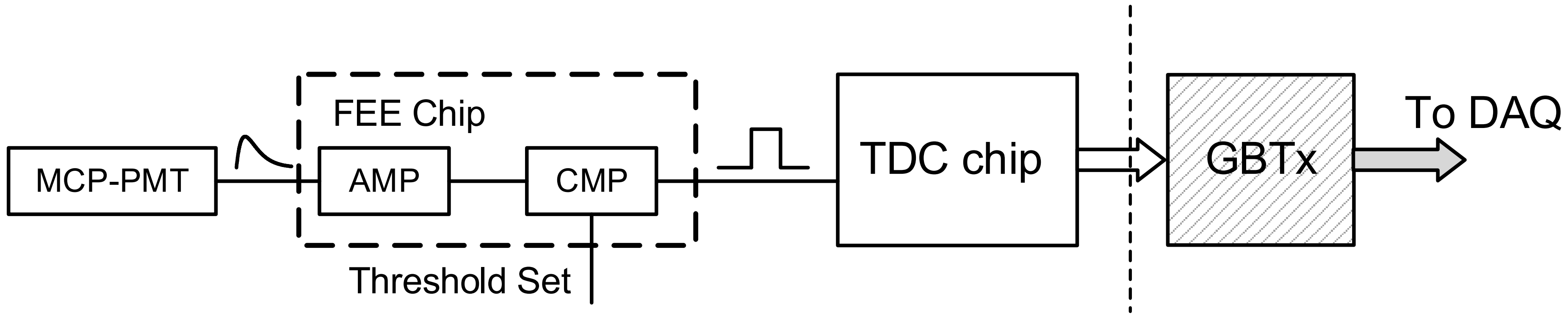


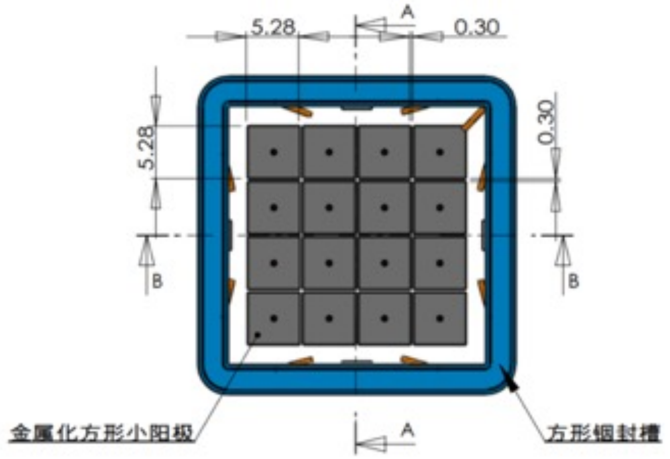
Single track time resolution

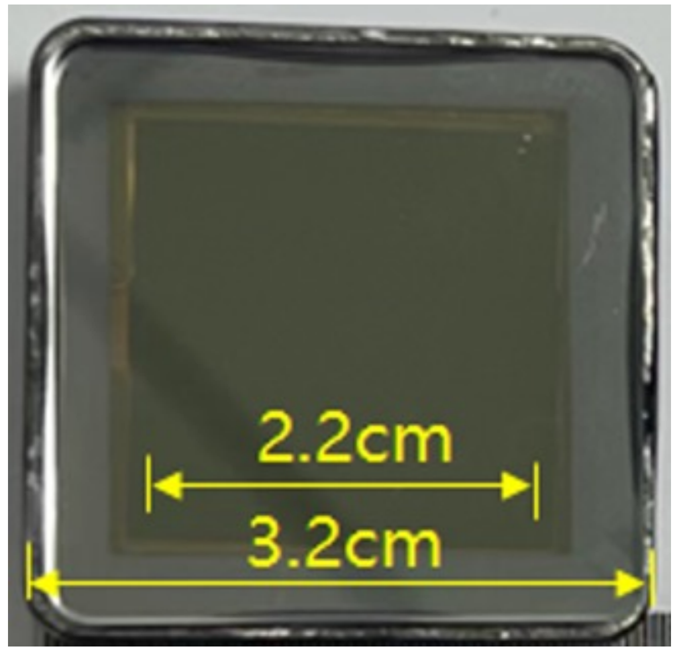
DTOF R&D on MCP-maPMT and Readout ASICs

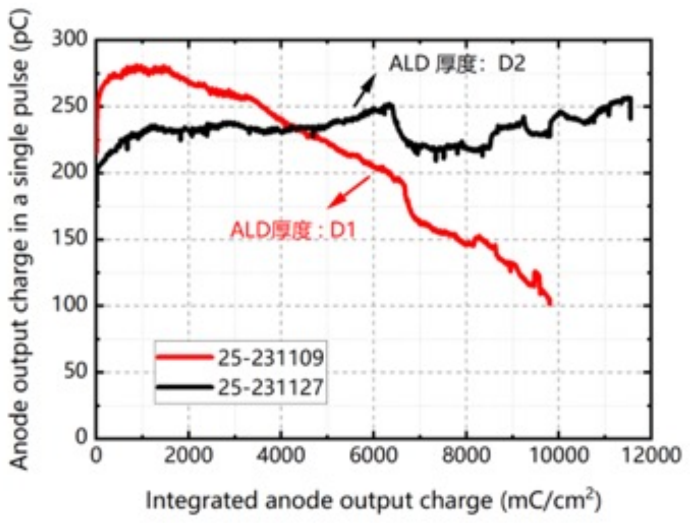
- **MCP-maPMT: a critical component of the DTOF technology**
- **Designed and produced 1-inch MCP-maPMT with 16 annodes, TTS < 40 ps**
- **Intensive R&D on techniques (ALD and electron scrubbing) to produce long-life MCP-PMT (target >10 C/cm²)**

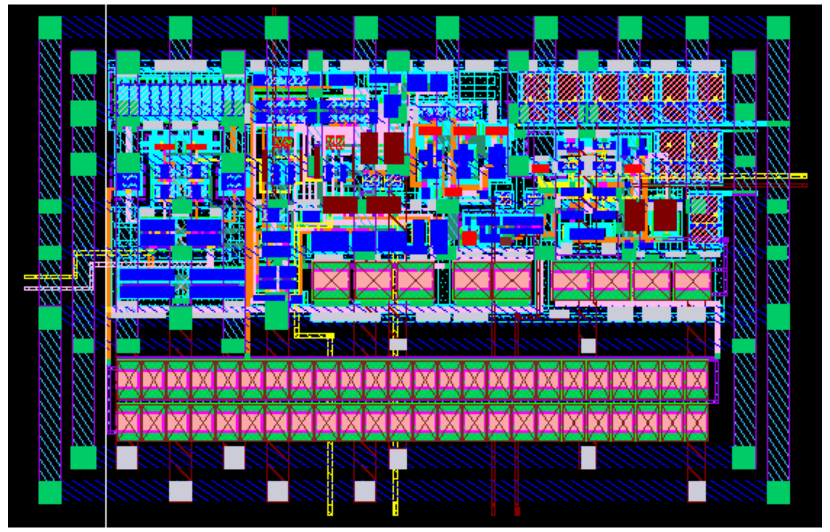
- **Two ASICs designed for MCP-maPMT readout.**
  - **FET (taped out) , target ~ 15 ps**
  - **TDC (taped out), target ~ 15 ps**

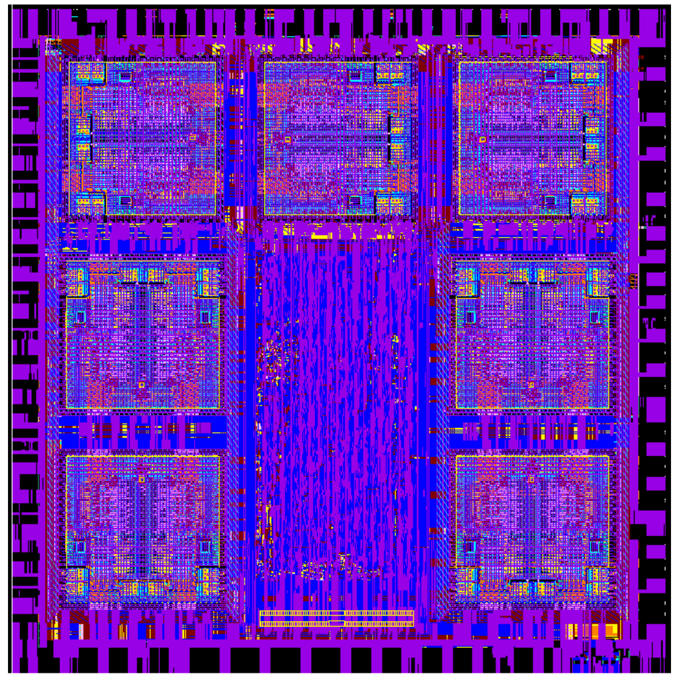






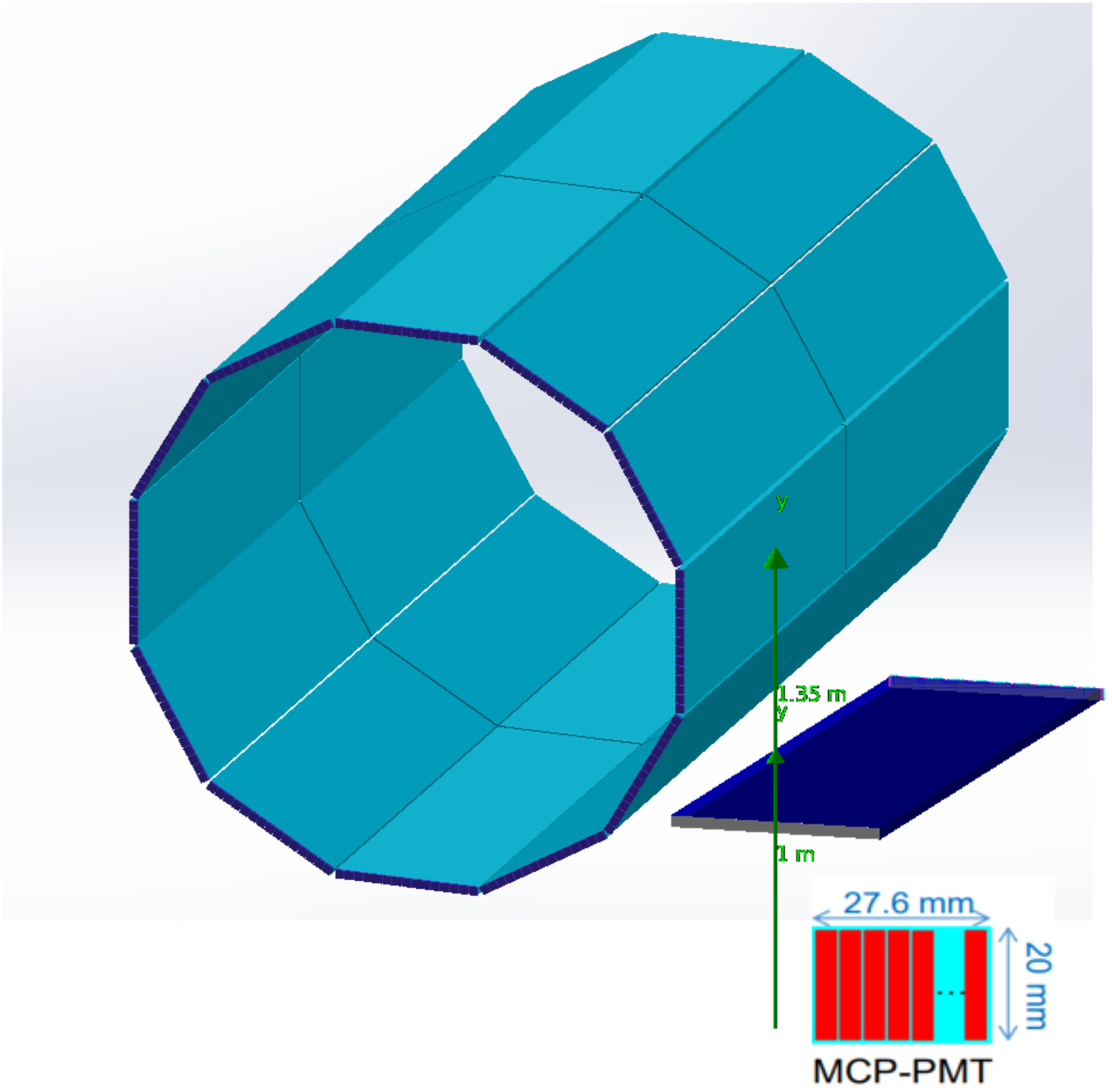


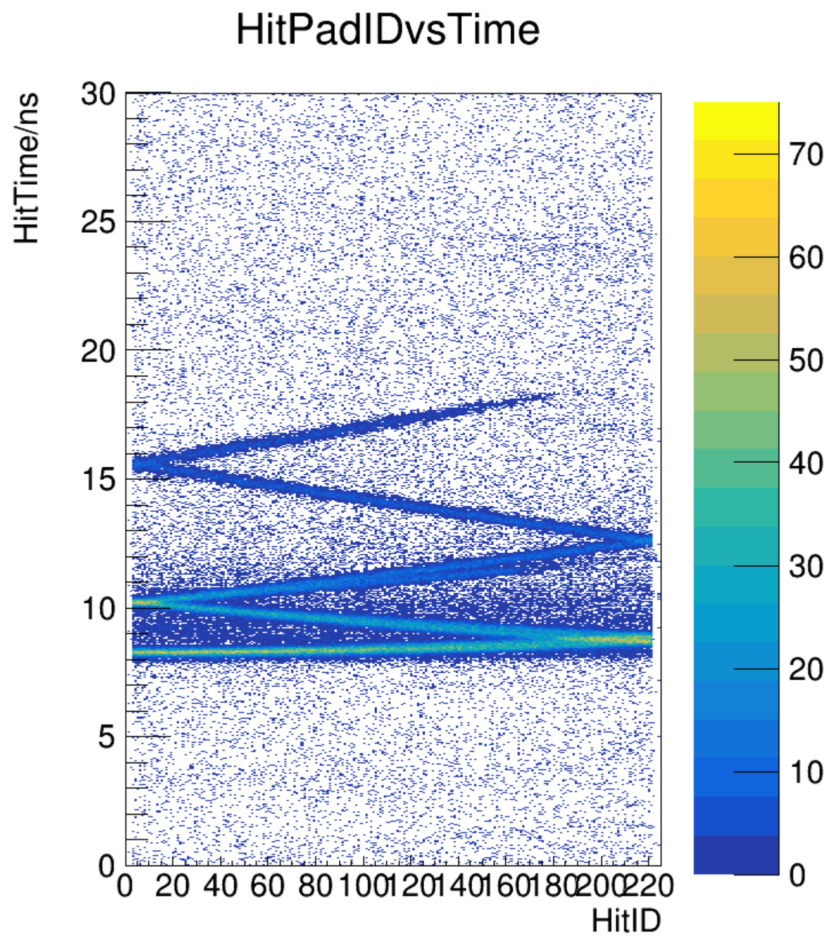


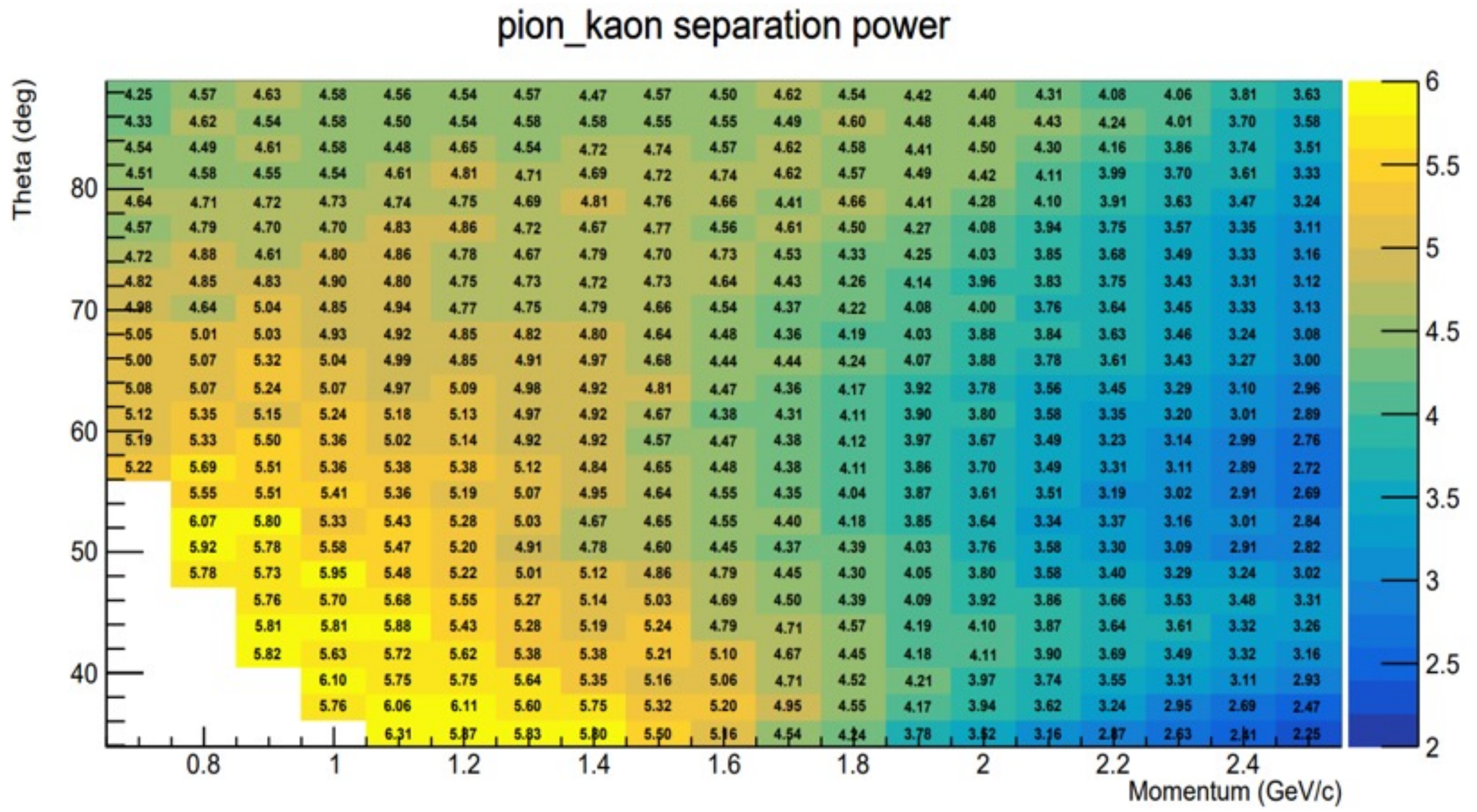


Application of DTOF in Barrel

- Conceptual design of barrel PID based on the DTOF technology
- Design optimization by scanning a variety of key design parameters
- Performance with full simulation mostly meet PID requirements
- More studies and work are planned



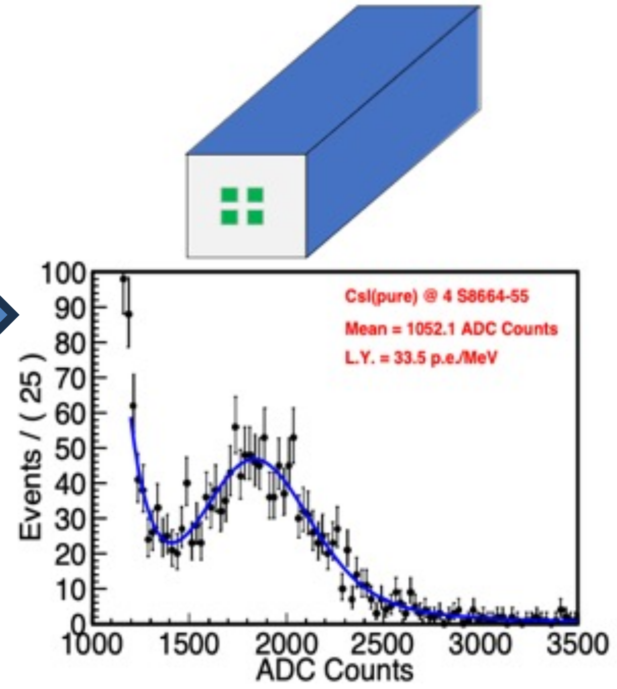


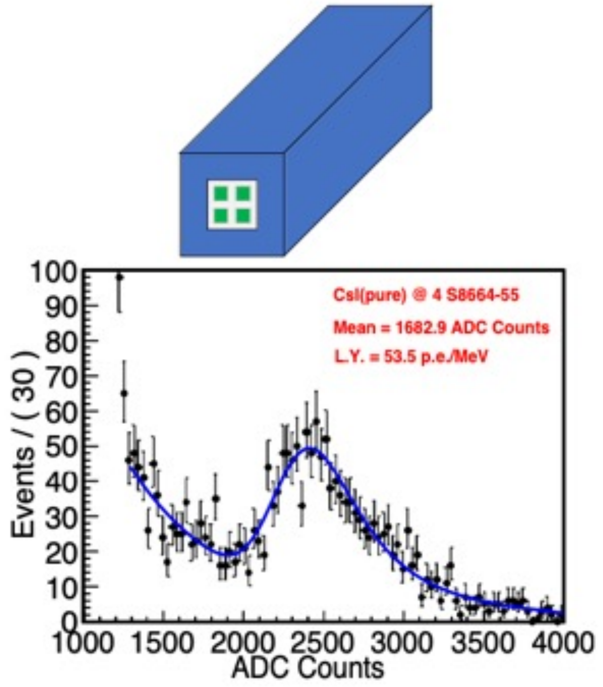


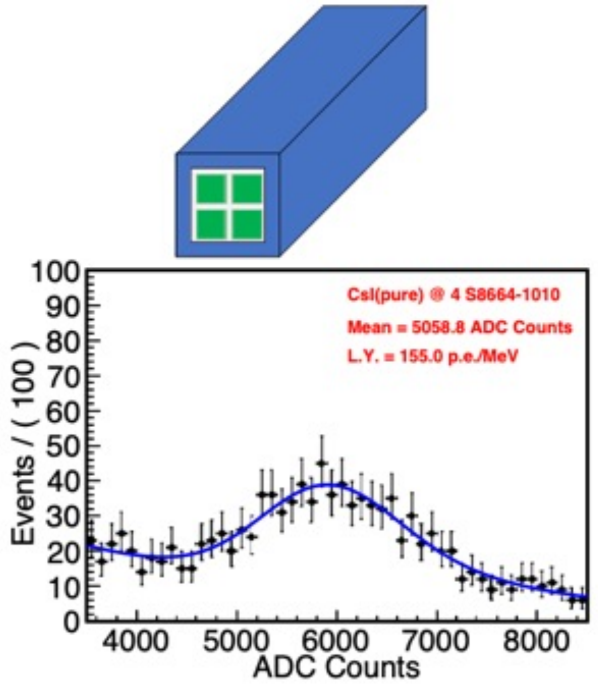
pCsI EMC : Light yield and timing studies

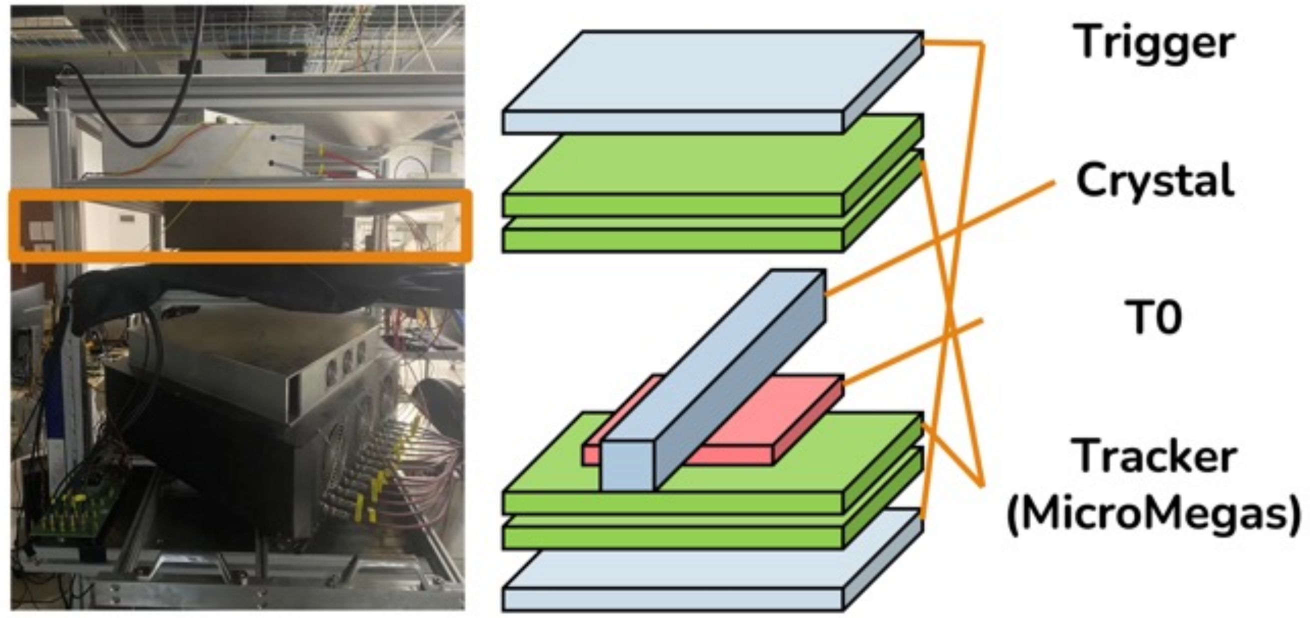
A major R&D task : enhancing light yield

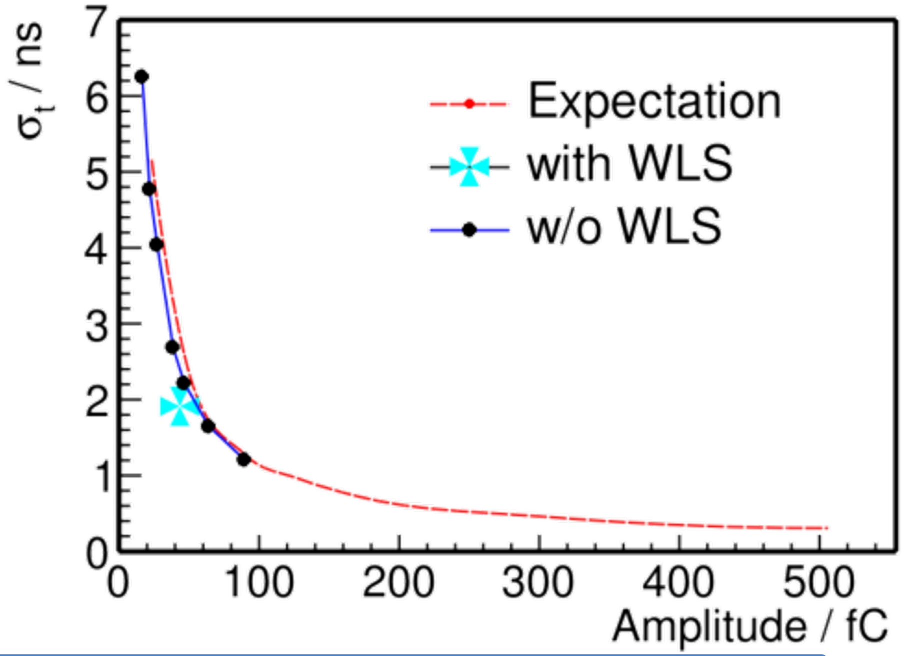
reflector：225um thick Teflon

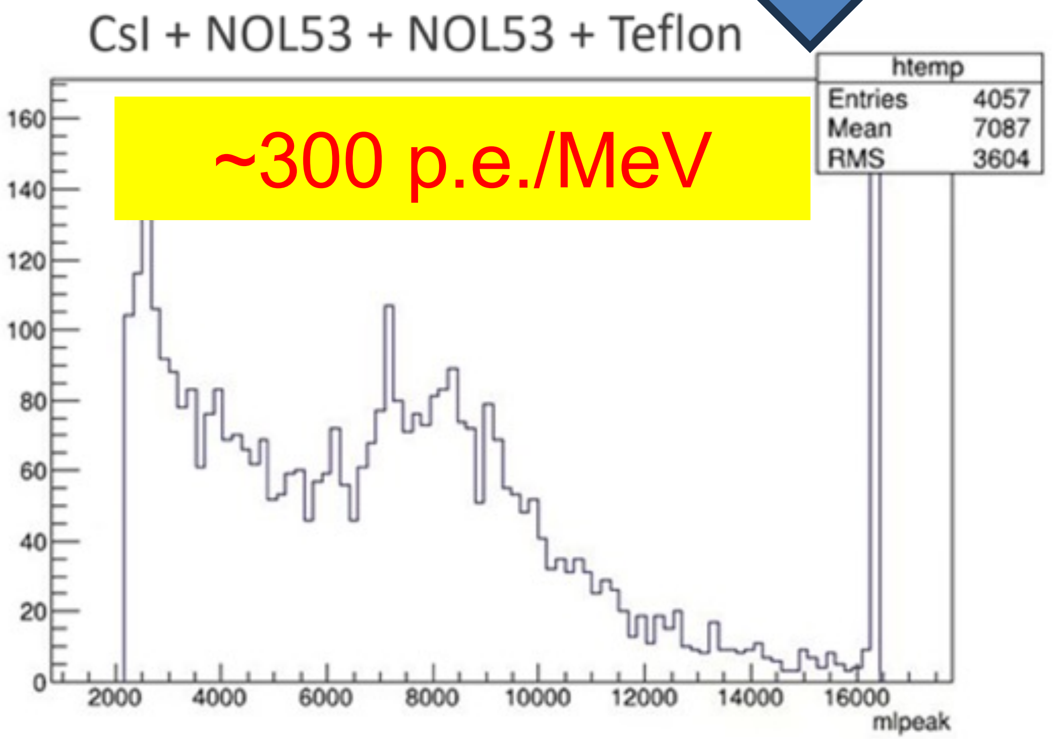










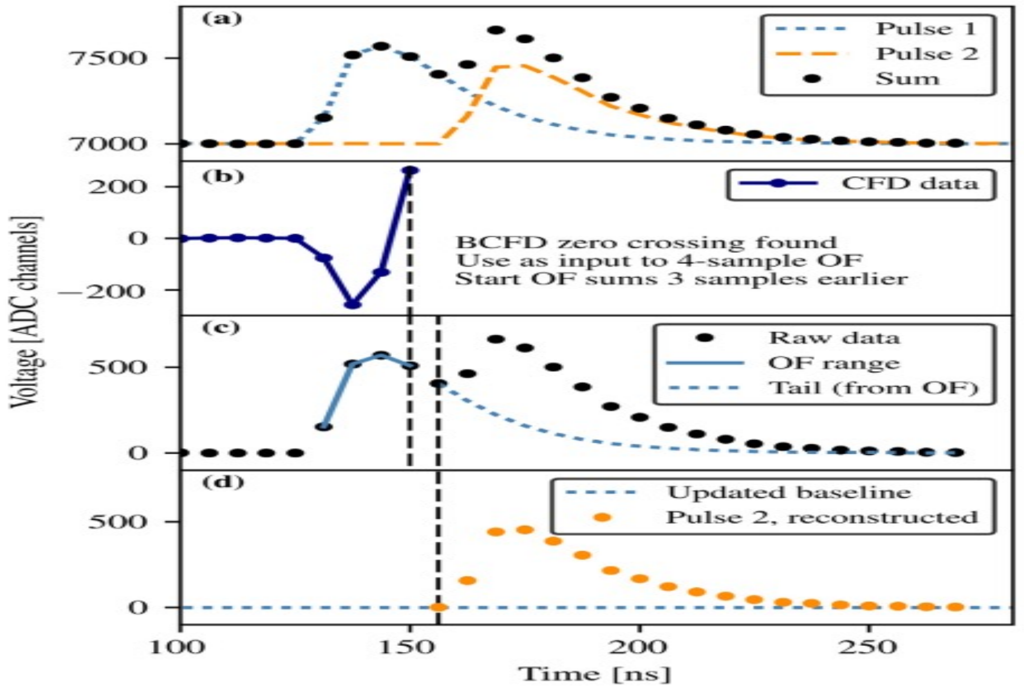


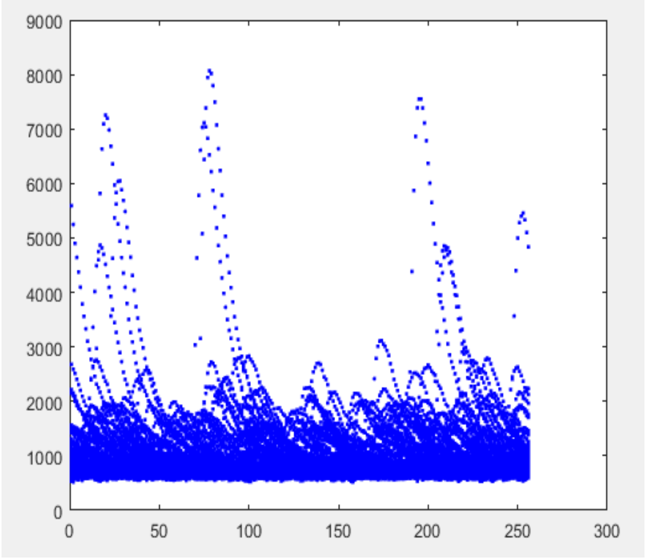
σ_t : 2.0 ns @ 0.03 GeV， 0.8 ns @ 0.1 GeV

Light yield reached up to 300 p.e./MeV

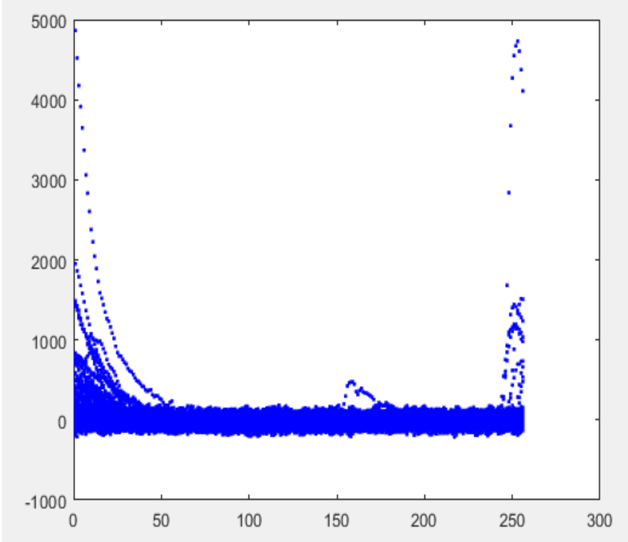
pCsI EMC : Pileup mitigation and electronics

■ **Waveform fitting to remove pileup noise (~1 MHz/ch) and extract signals**

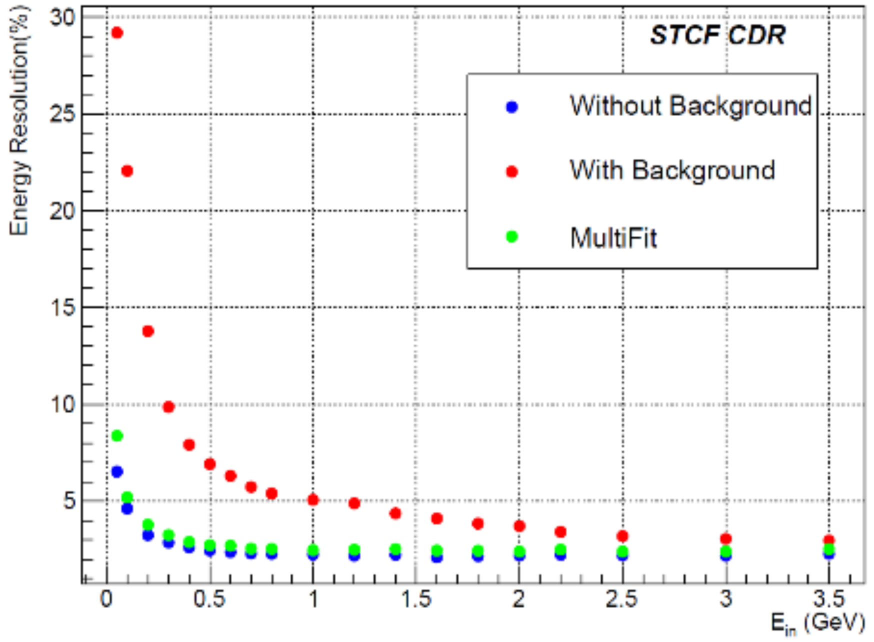




Before

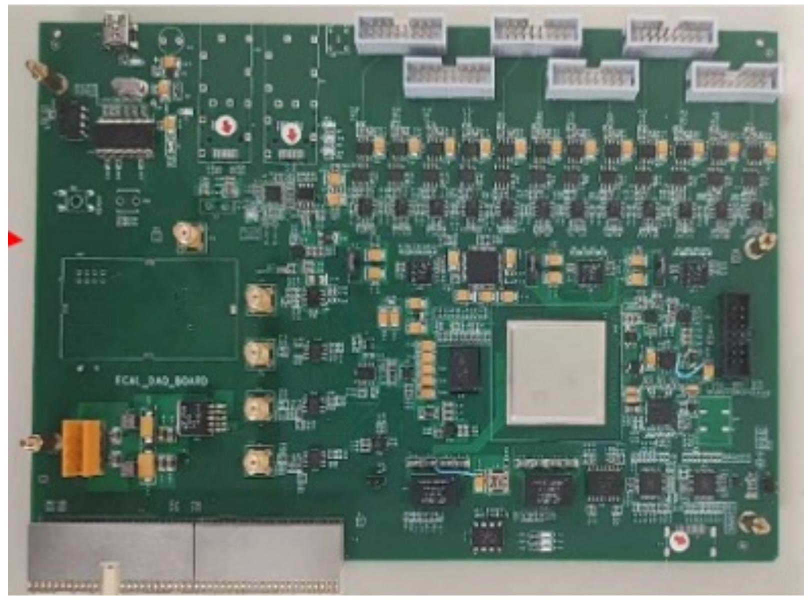


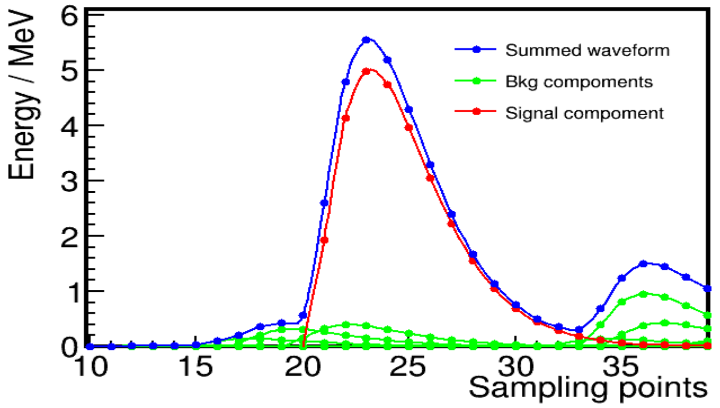
After

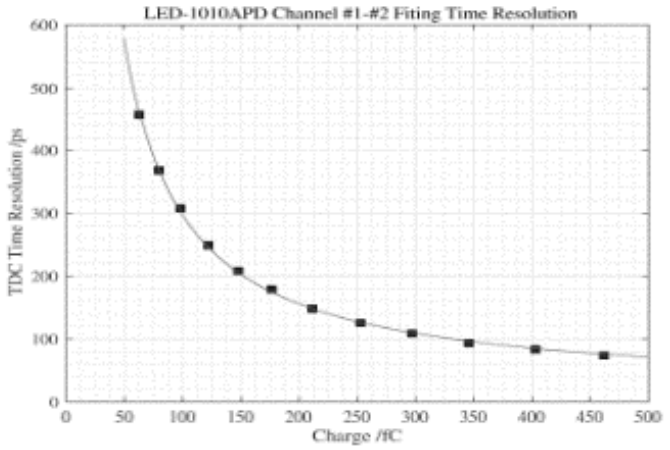


Very effective in mitigating the pileup effect

■ **Development of waveform digitization electronics (CSA + shaper + ADC)**





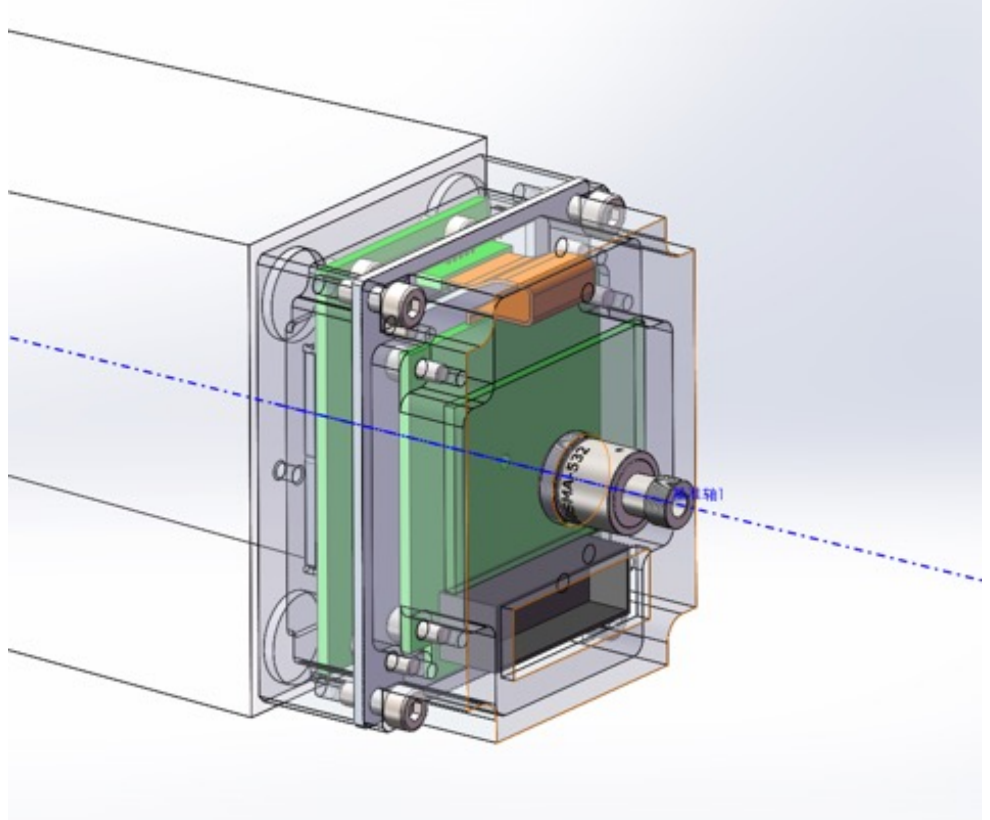


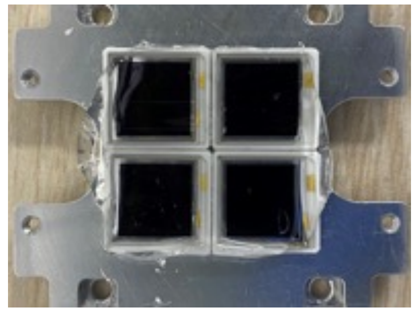
Dynamic range:
3 MeV ~ 3 GeV

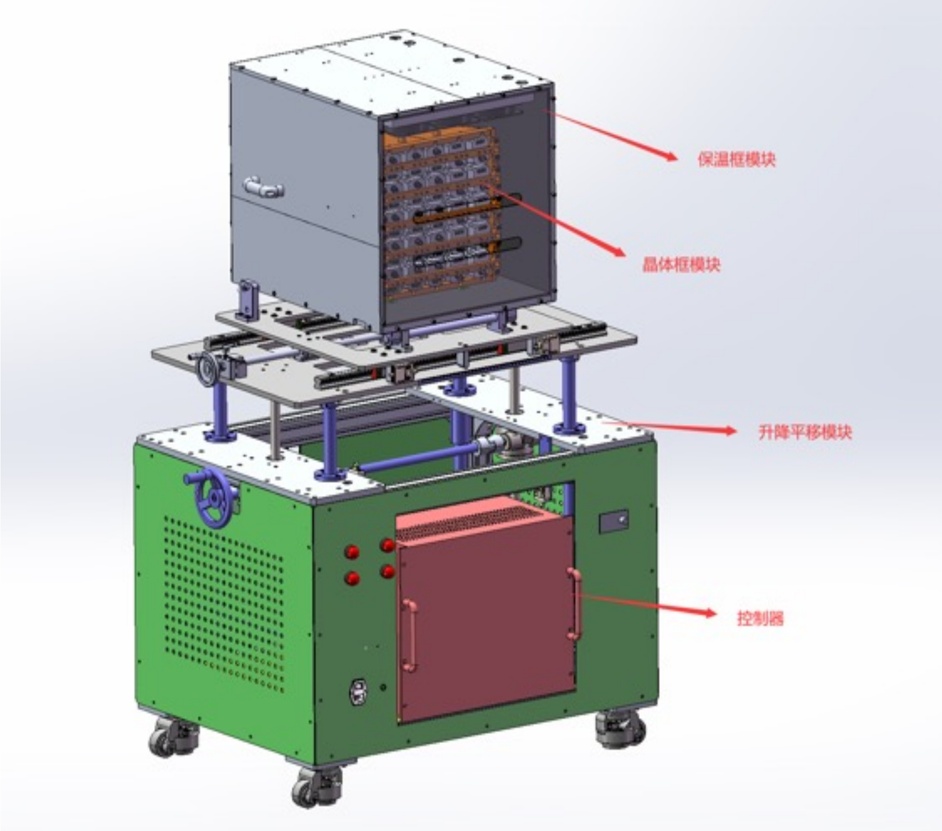
ENE: ~ 0.4 MeV

Time resolution :
< 150 ps@1GeV

5×5 pCsI EMC Prototype

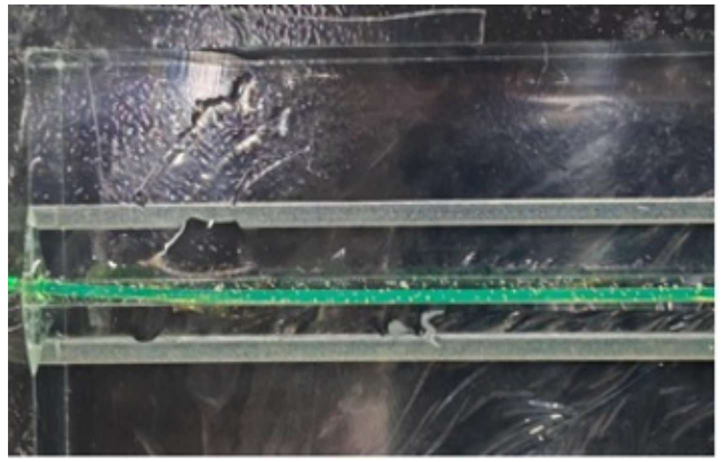


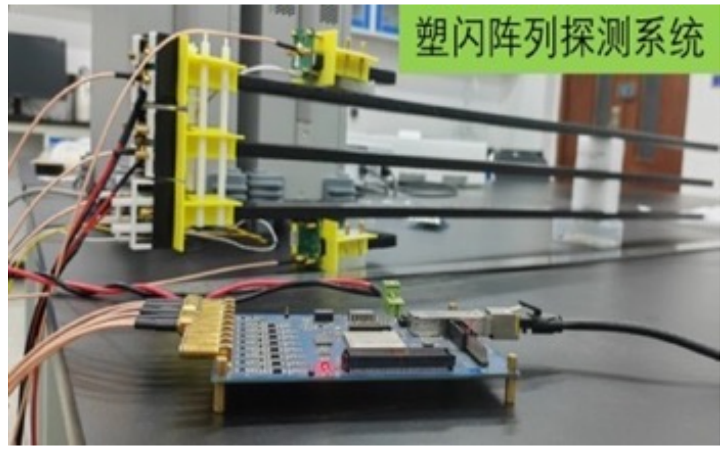


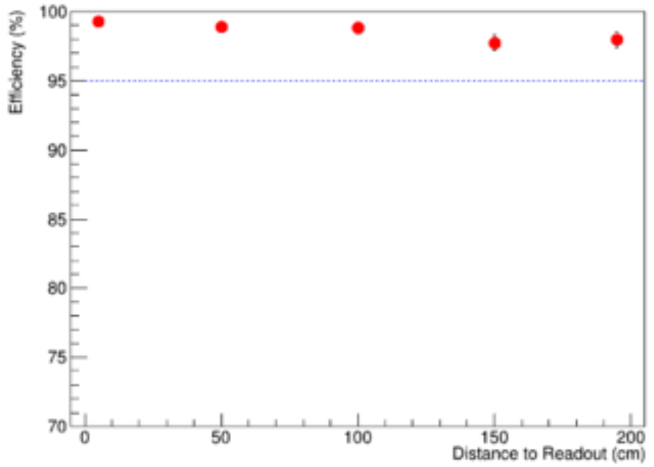


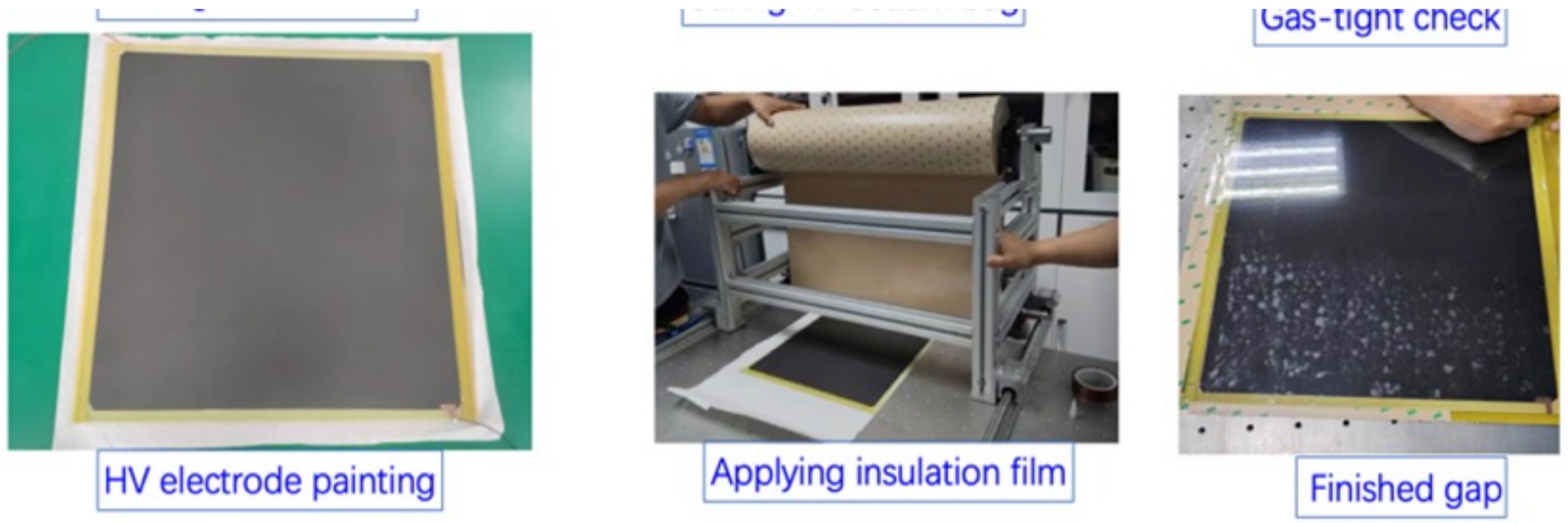
MUD R&D

- **Fabrication and performance studies of large-sized scintillator strips and glass RPC**

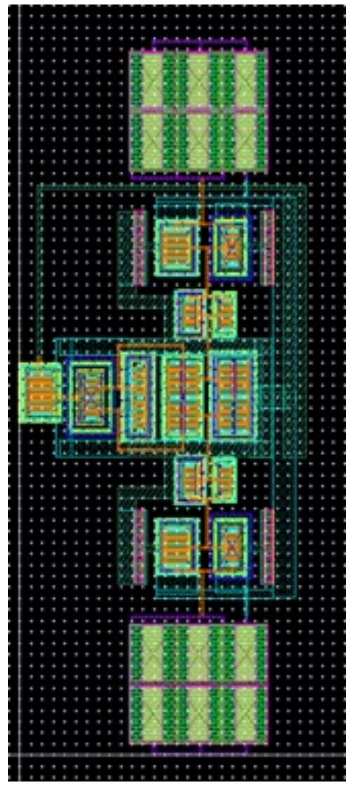


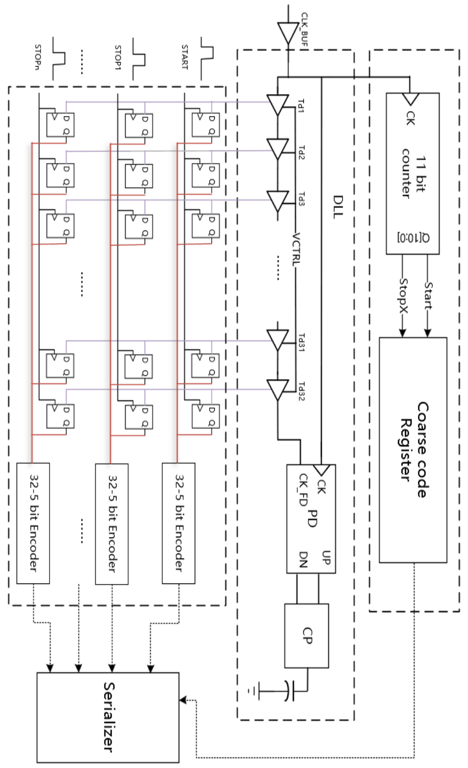


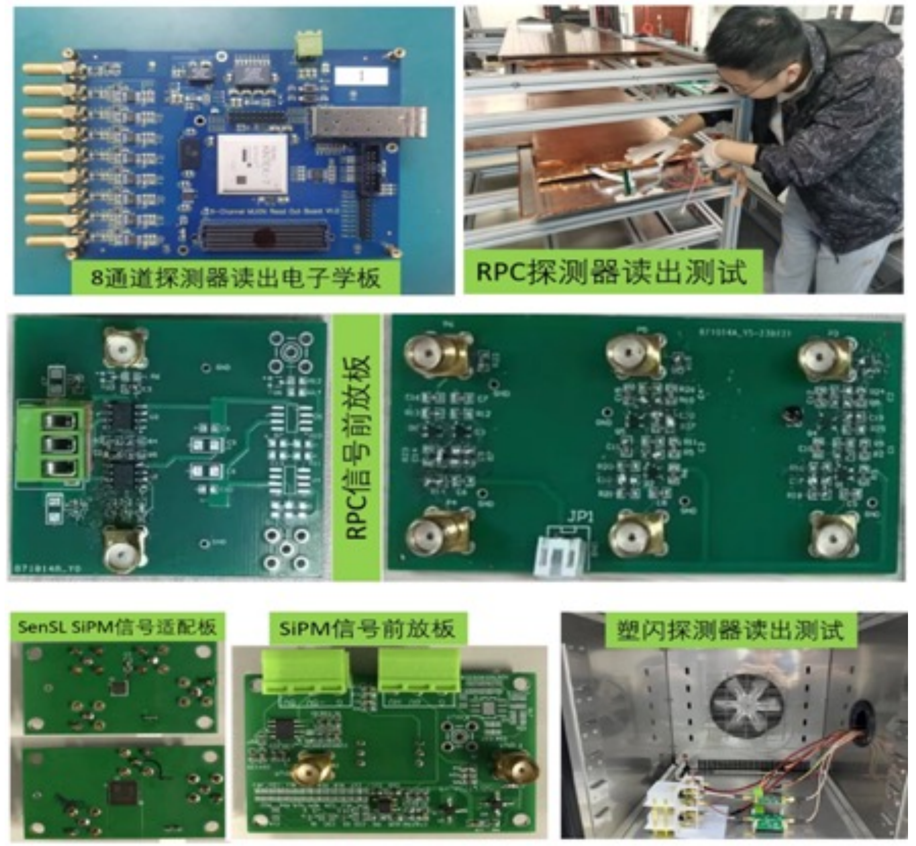




- **Design of readout ASICs (FEE +TDC) is underway. First version of the EFF chip already available. Readout electronics with discrete components has been developed for detector testing and characterization**

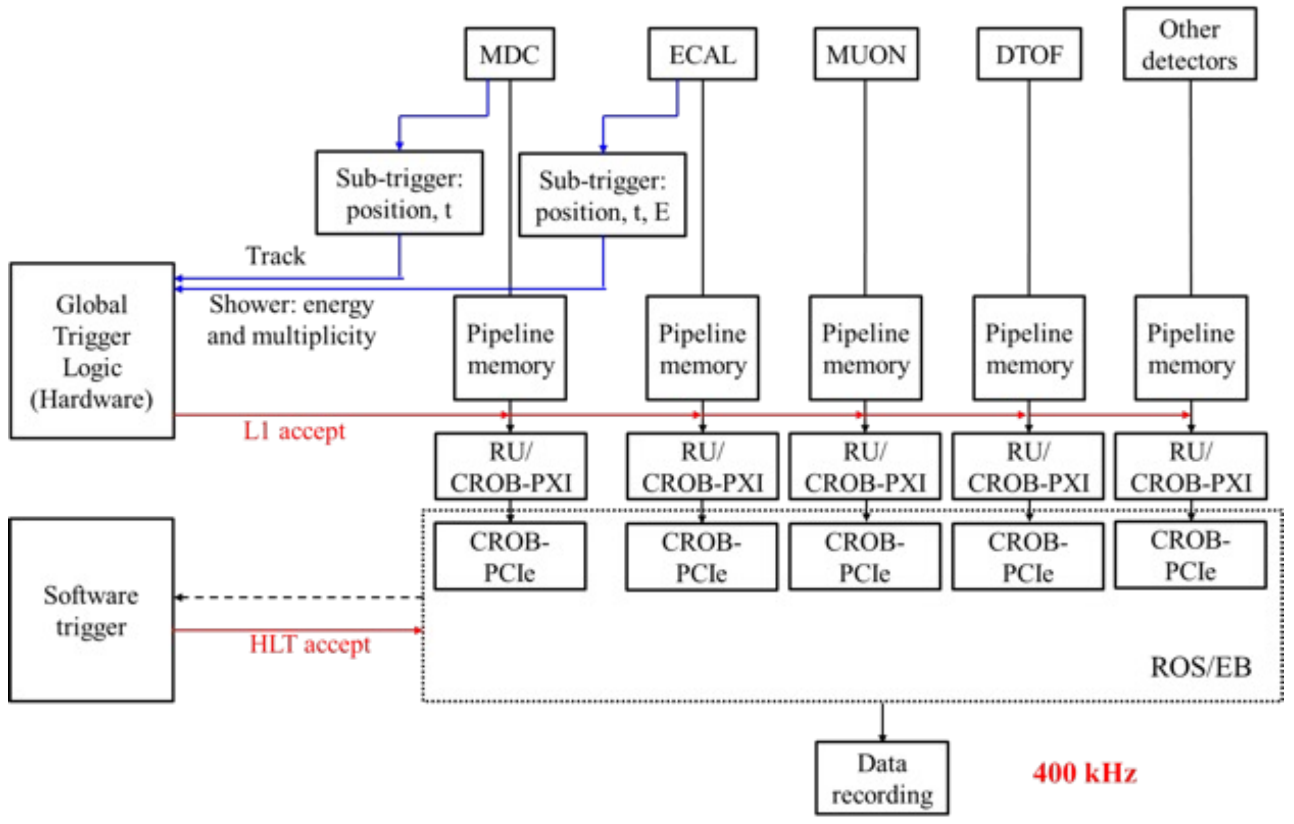


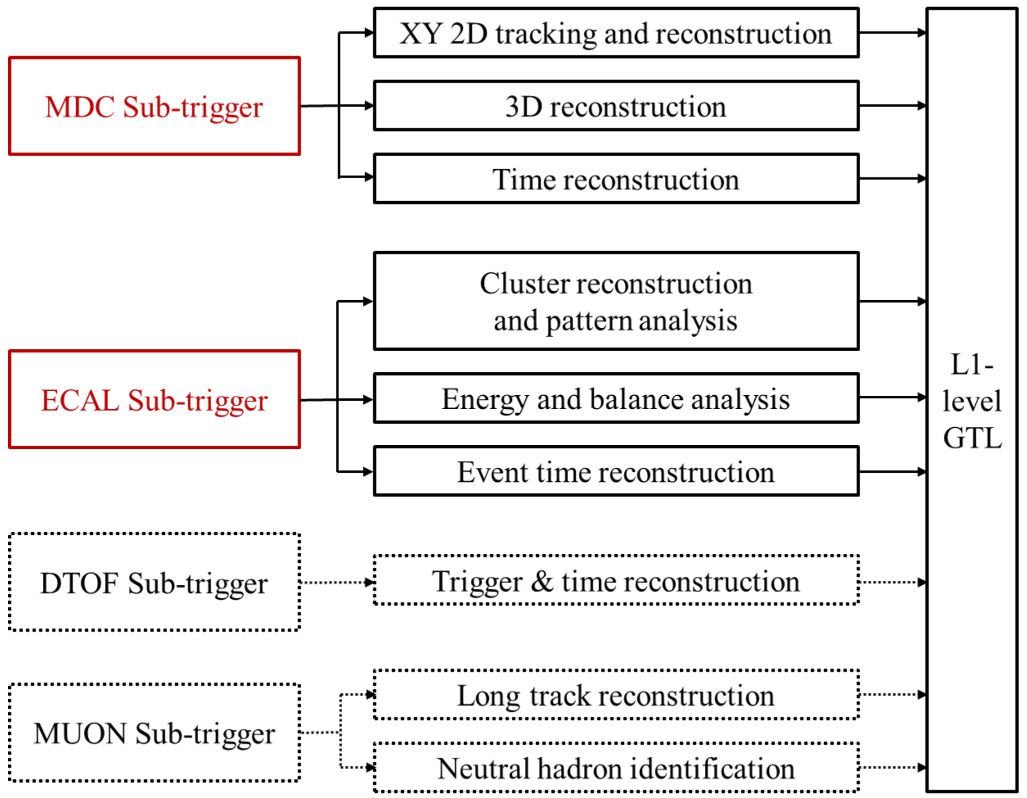




Trigger and DAQ

Physics event rate ~ 400 kHz

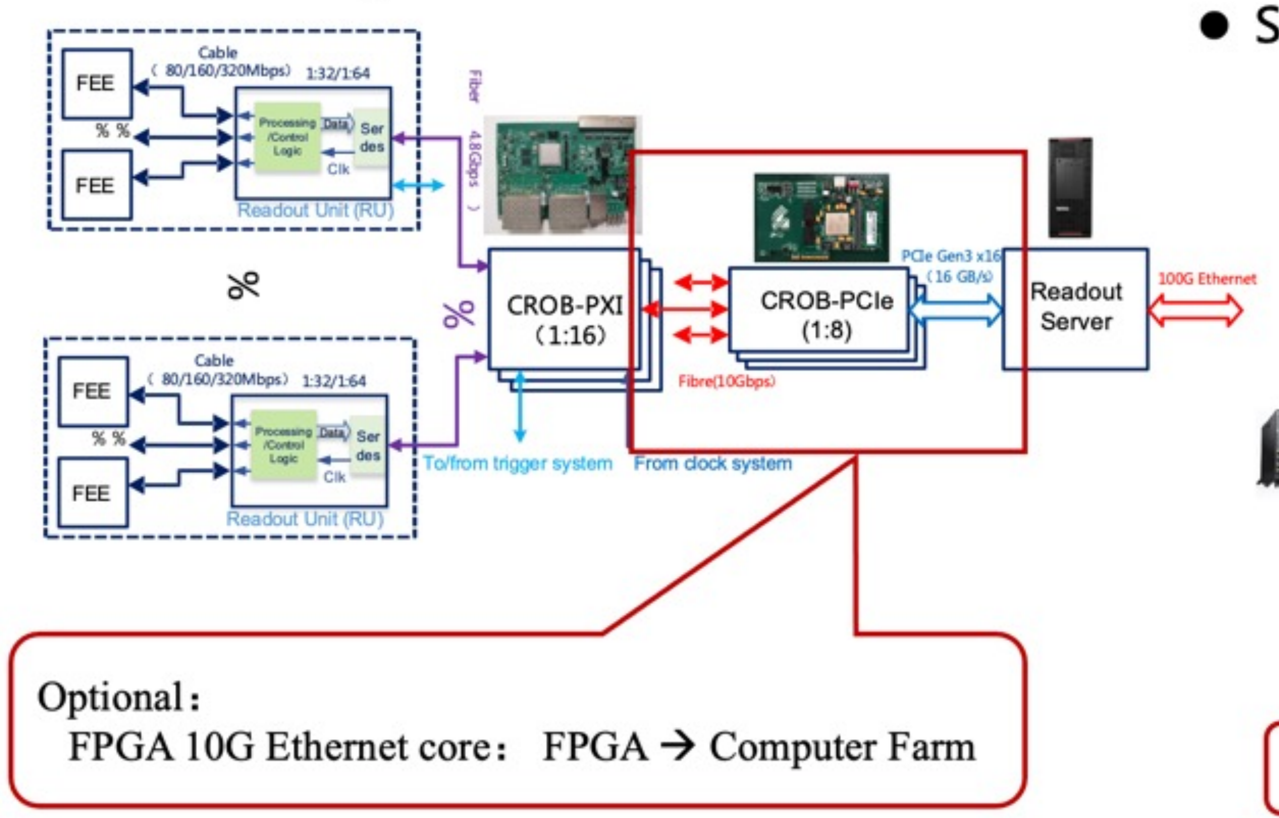




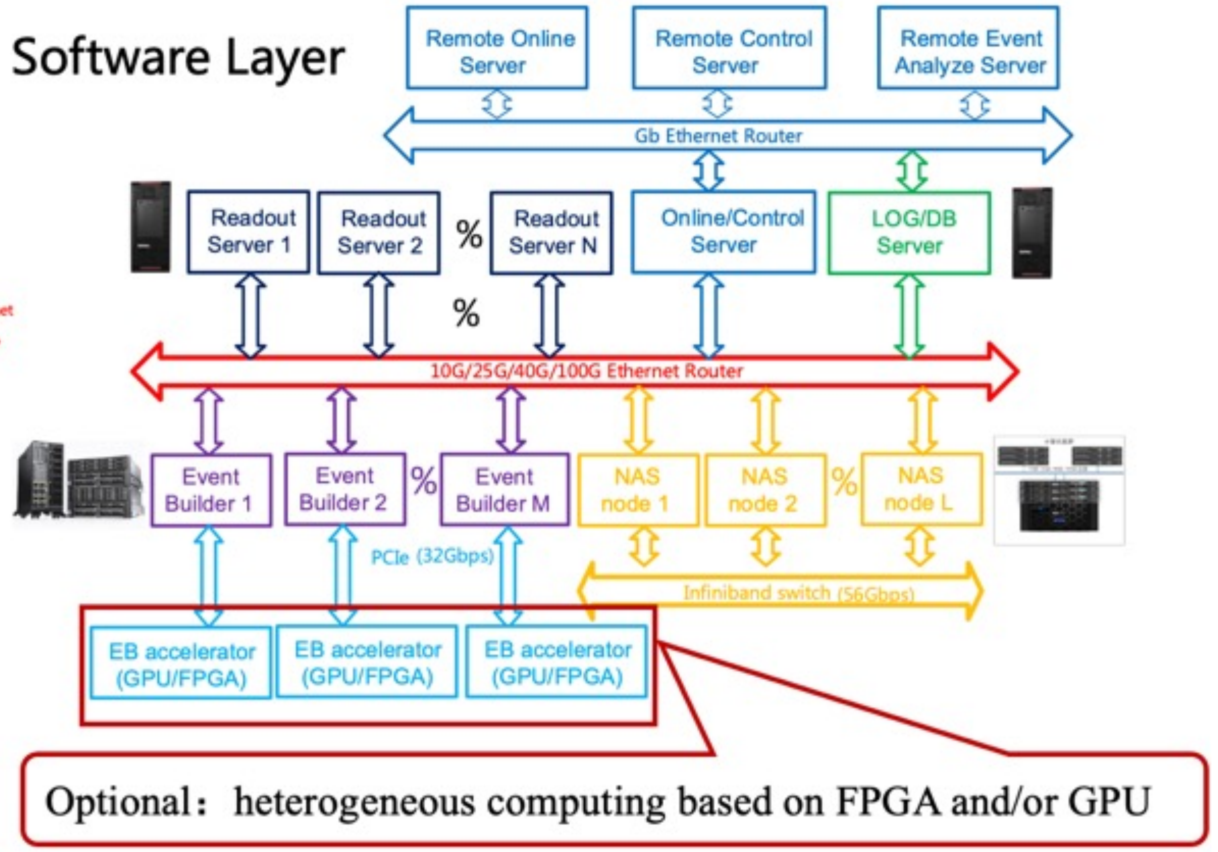
Component	Num. of channels	Readout time window	Event size (B)	Total (B/s)
ITK (Silicon)	50M	500 ns	14300	5.72G
ITK (μRWELL)	10552	500 ns	17232	6.89G
MDC	11520	1 μs	20400	8.16G
PID (RICH)	518400	500 ns	15600	6.24G
PID (DTOF)	6912	500 ns	7380	2.95G
EMC	8670	500 ns	15000	6.00G
MUD	41280	500 ns	262	105M
Total(Silicon)	50.6M	–	72.9k	29.2G
Total(μRWELL)	594k	–	75.9k	30.4G

Raw data rate ~ 200 GB/s , after L1 trigger~ 30 GB/s (latest estimates: ~30 GB/s, ~ 10 GB/s) , HLT is required, anyway.

- FPGA Layer

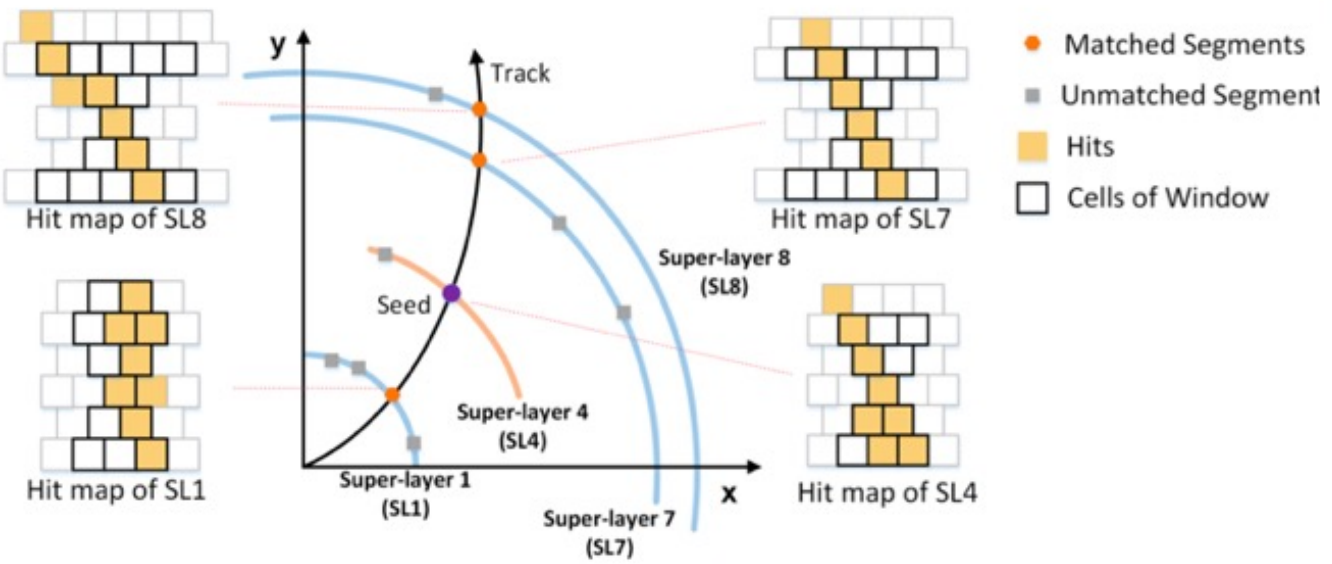


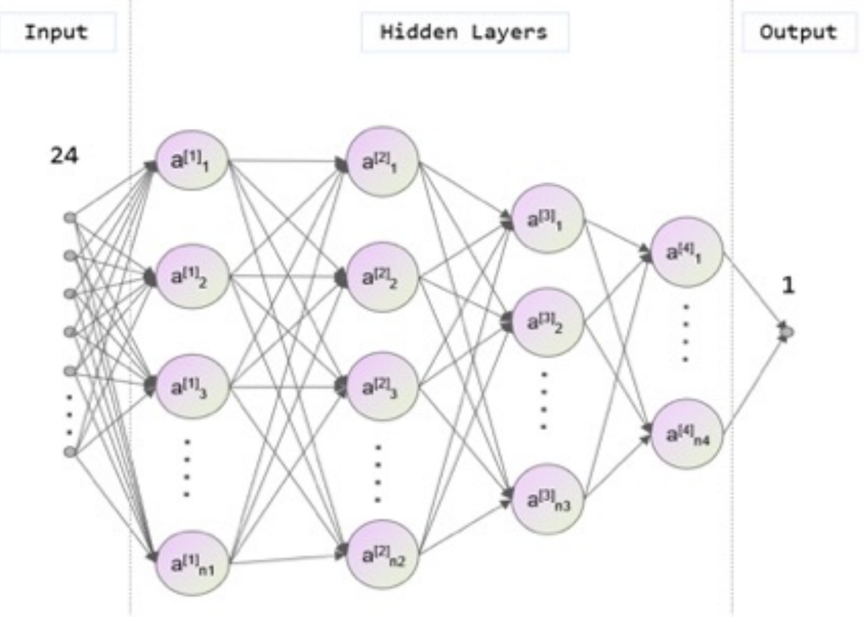
- Software Layer

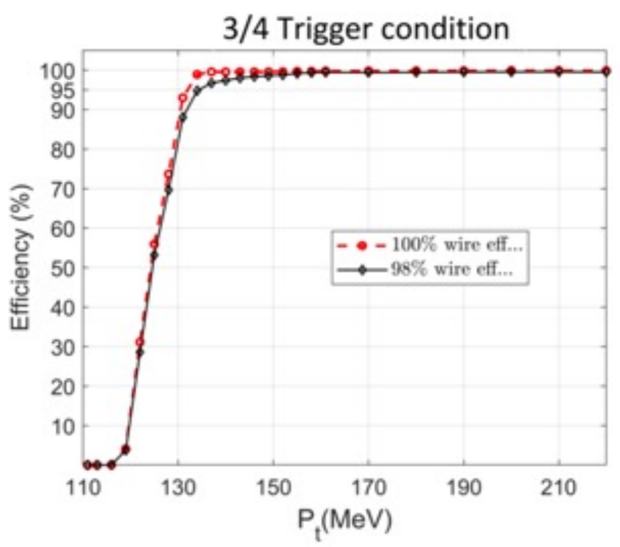


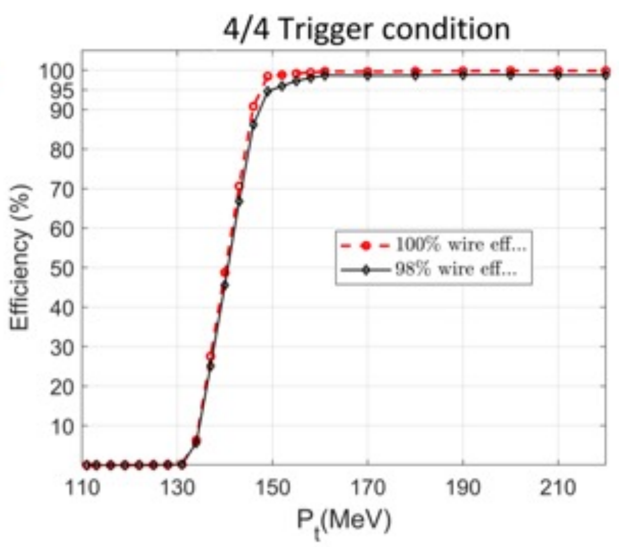
Trigger Algorithms and hardware Development

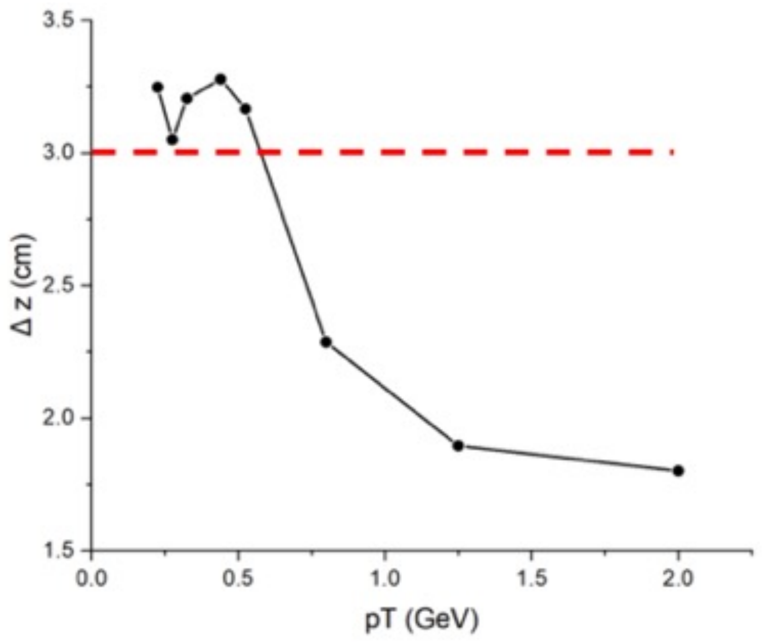
- **MDC 2D and 3D tracking algorithms, EMC clustering algorithms, global trigger algorithms.**
- **PFGA programming to realize the algorithms**



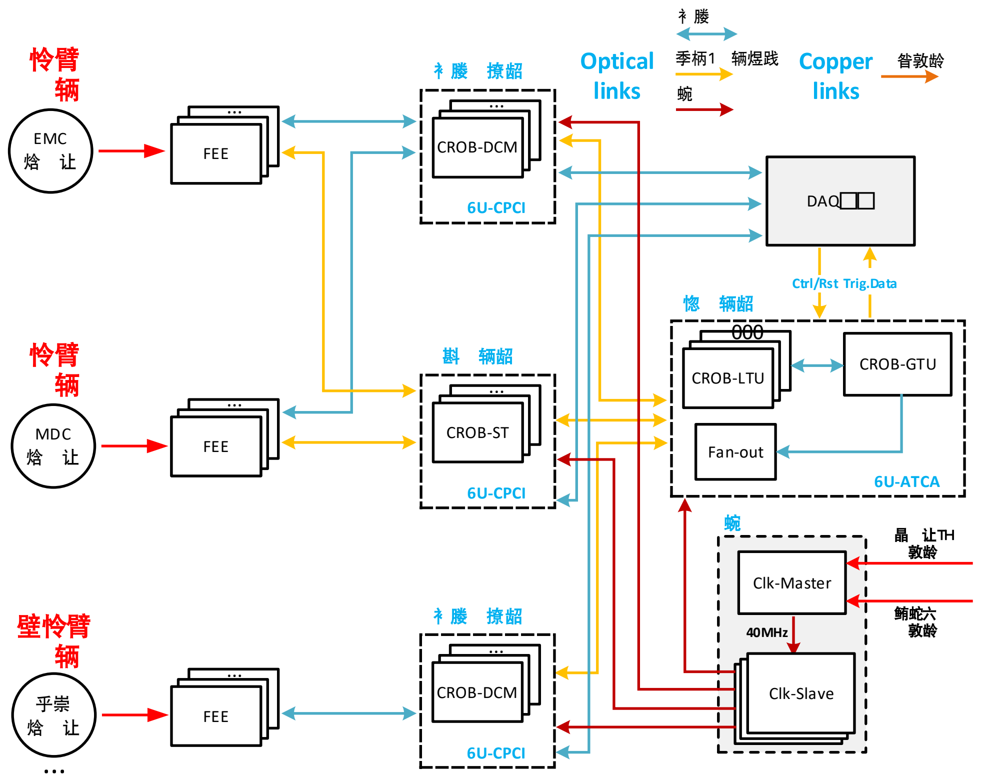


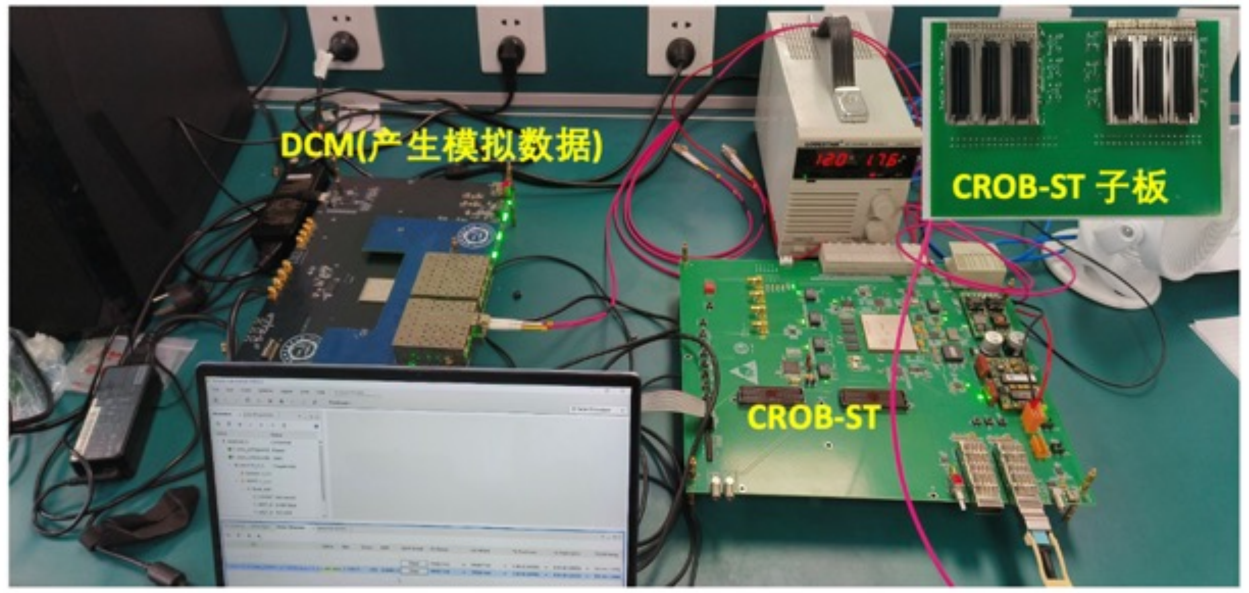






- **Design of trigger electronics and development of core hardware components**



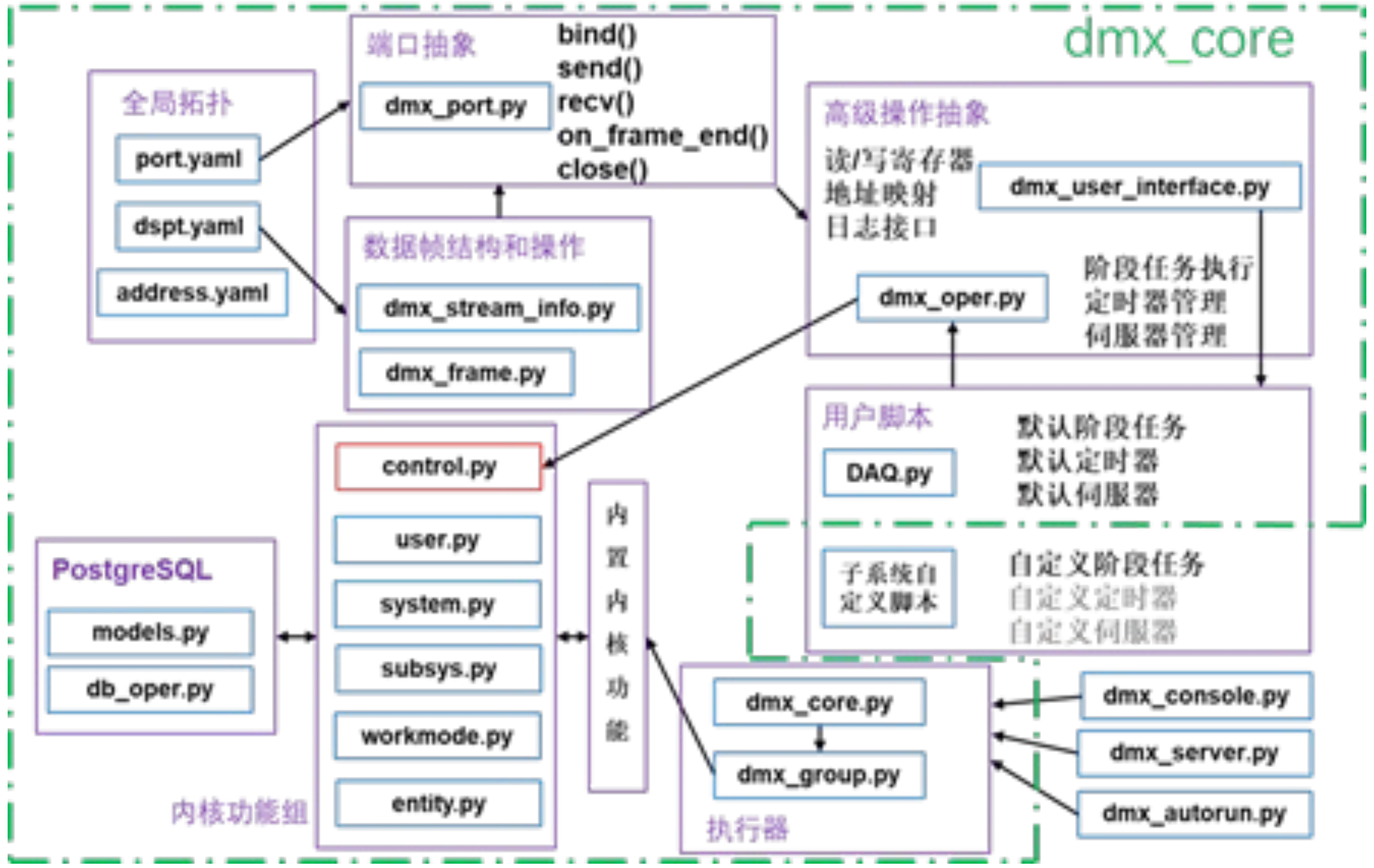


Global Trigger Study

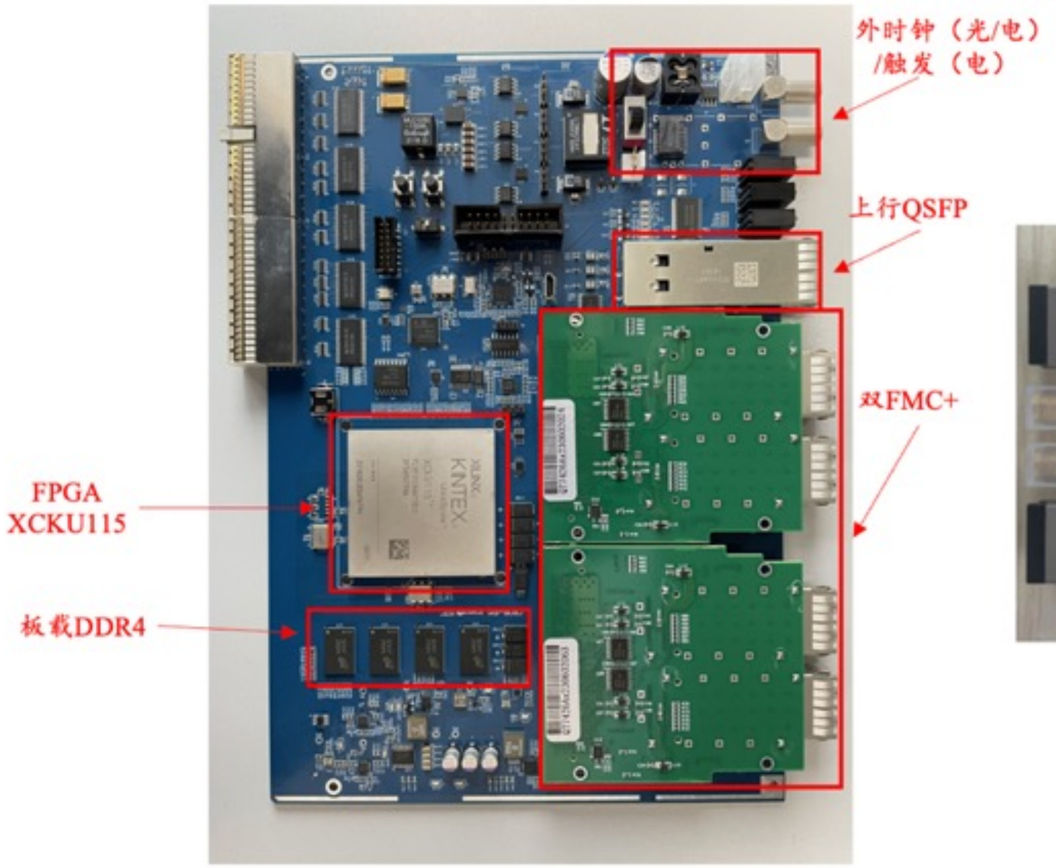
Trigger channel	Physics signal	Energy point	No. of tracks should(is) matched	No. of matched tracks in Endcap	No. of matched tracks in Barrel	Signal trigger rate	Background trigger rate(kHz)	Signal trigger rate
Charged Channels	e^+e^- -> $\pi^+\pi^-$Jpsi; Jpsi -> e^+e^-	4.26GeV	3550 (2811)	448 (93)	3102 (2718)	949/952 (≥3)	21.3	99.7%
	e^+e^- -> $\pi^+\pi^-$Jpsi; Jpsi -> $\mu^+\mu^-$	4.26GeV	3518 (2765)	452 (122)	3066 (2643)	944/948 (≥3)		99.6%
	e^+e^- -> $\tau^+ \tau^-$	4.26GeV	1717 (1448)	186 (54)	1531 (1394)	867/879 (≥2)		98.6%
	e^+e^- -> $\pi^+\pi^-$Jpsi; Jpsi -> $\Lambda \bar{\Lambda}$	3.097GeV	2550 (1917)	220 (67)	2330 (1850)	905/918 (≥3)		98.6%
	e^+e^- -> $\pi^+\pi^-$Jpsi; Jpsi -> $\Xi \bar{\Xi}$	3.097GeV	2713 (2067)	198 (66)	2515 (2031)	912/922 (≥5)		98.9%
	e^+e^- -> K^+K^-Jpsi; Jpsi -> l^+l^-	4.682GeV	3515 (2641)	365 (90)	3150 (2551)	954/964 (≥3)		99.0%
	e^+e^- -> $D_0 \overline{D_0}$	3.773GeV	3387 (2644)	312 (73)	3075 (2571)	954/954 (≥3)		100%
	e^+e^- -> $D^+ D^-$	3.773GeV	4031 (2707)	274 (64)	2640 (2643)	979/983 (≥3)		99.6%
	e^+e^- -> $D_s^+ D_s^-$	4.04GeV	4770 (3312)	462 (98)	4308 (3214)	933/936 (≥5)		99.7%
Neutral Channels	J/psi-> gam invisable	3.097GeV	-	-	-	542/546 (≥1&&gam_momentum>=1)	67.0	99.7%
	e+e- -> n nbar	3.097GeV	-	-	-	538/564 (≥2&&Nbar≥1&&EDep≥0.4)		95.4%
	e+e- -> gam n nbar	3.097GeV	-	-	-	611/613 (≥2&&Nbar≥1&&EDep ≥1)		99.7%
	e+e- -> gam n nbar(ISR)	3.713GeV	-	-	-	550/555 (≥2&&Nbar≥1&&EDep≥0.7)		99. 1%

DAQ Software Design and Hardware Development

- **Software and firmware architecture based on Data-Matrix: flow processing, hetero-computing, standard interfaces and protocols, global pipeline**
- **Development of core electronics boards: CROB-PXI, CROB-PCIe, FMCP optical interface board**

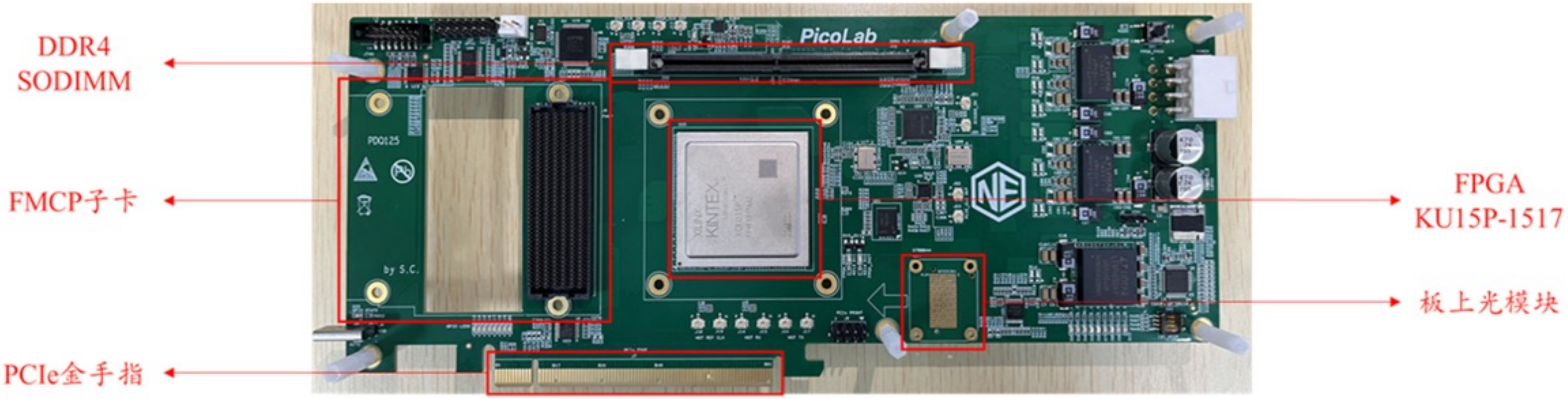


CROB-PXI board



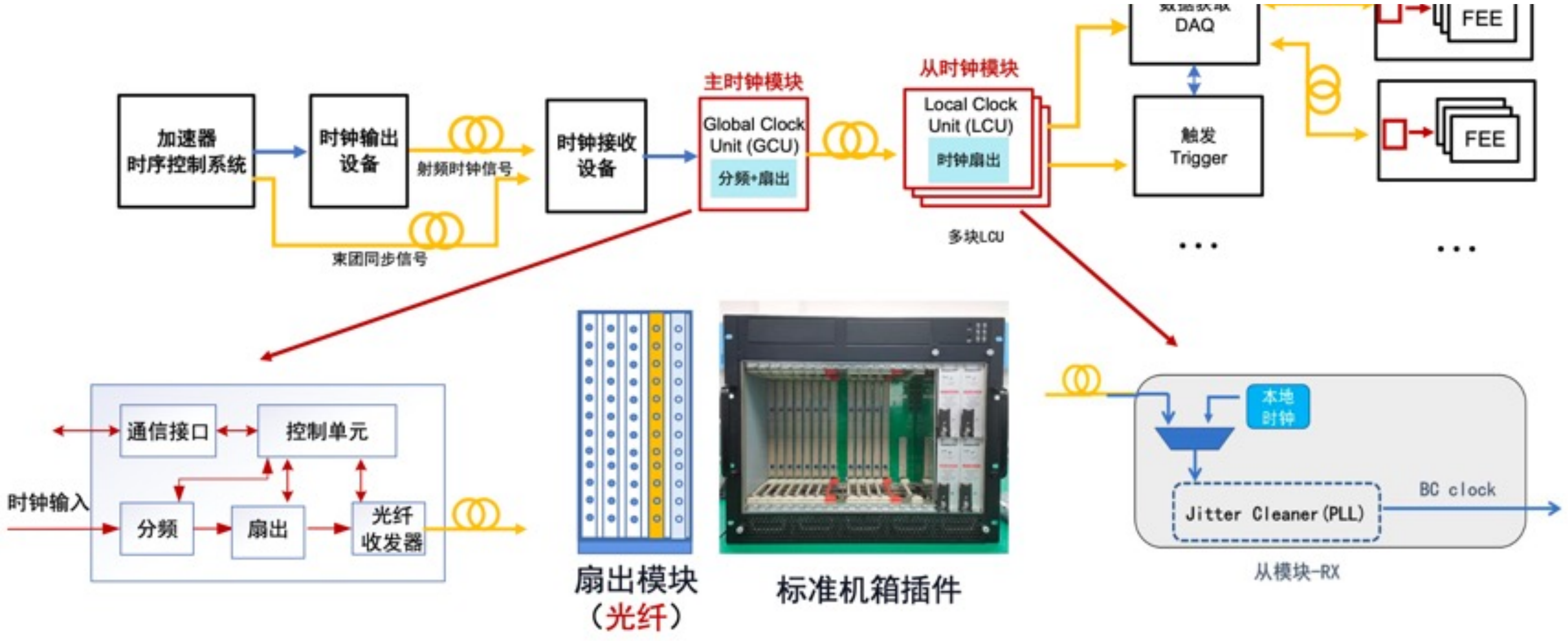
FMCP optical interface board

CROB-PCIe board

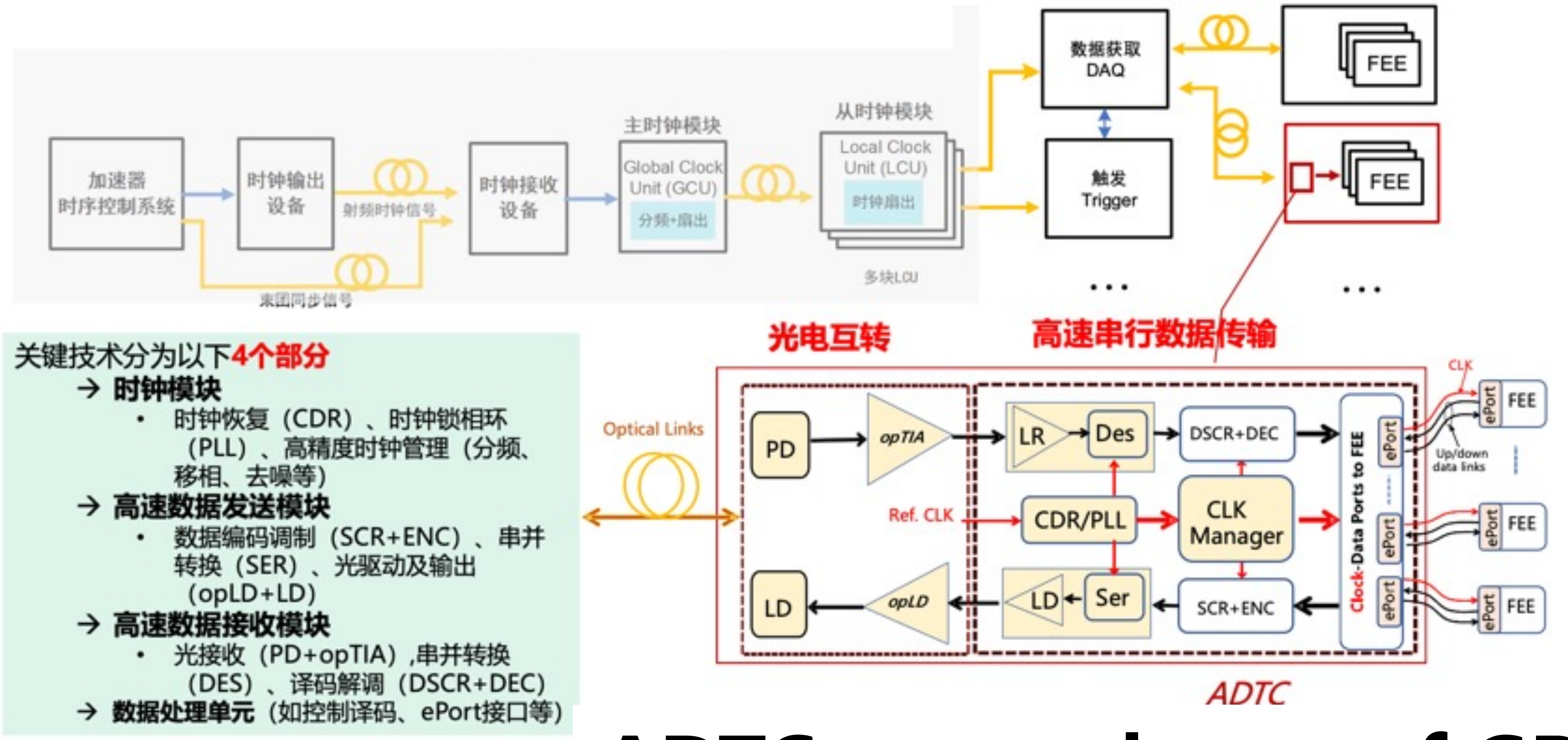


Clock and Data Transmission

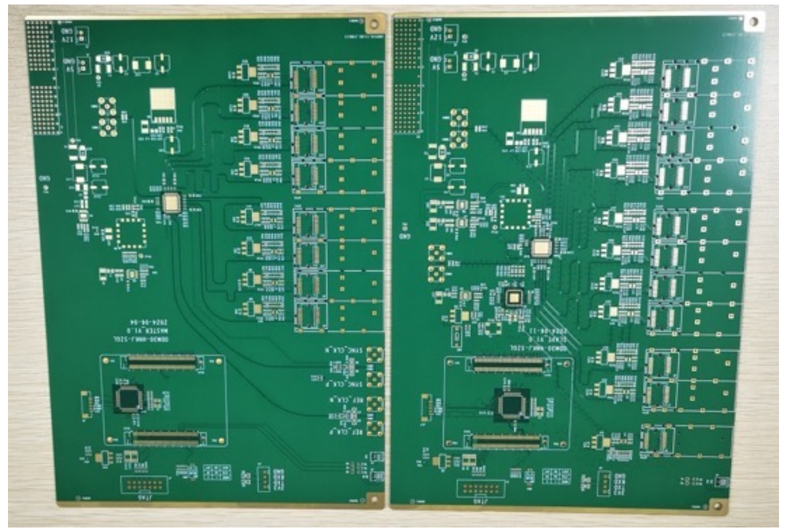
- **Master-slave clock distribution scheme : ~ 5ps**

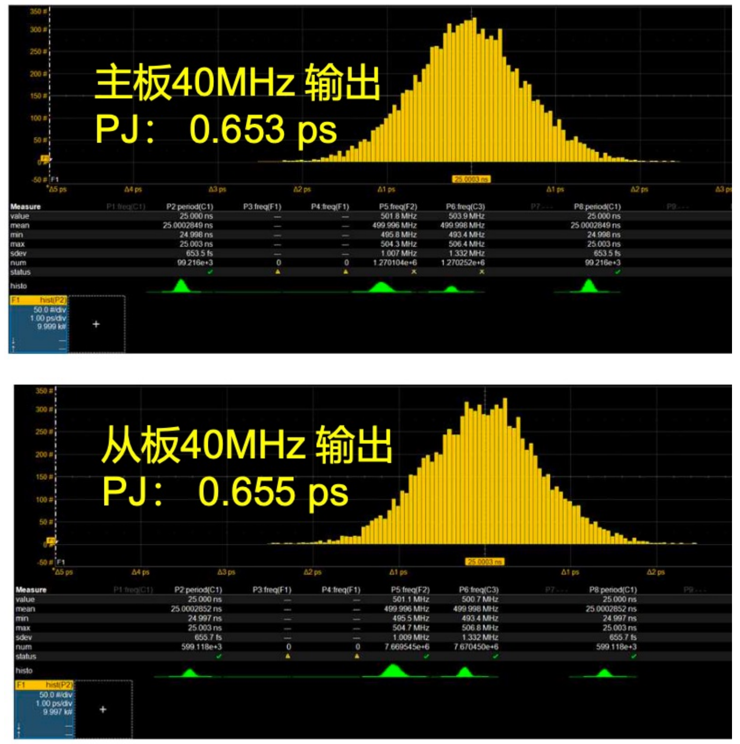


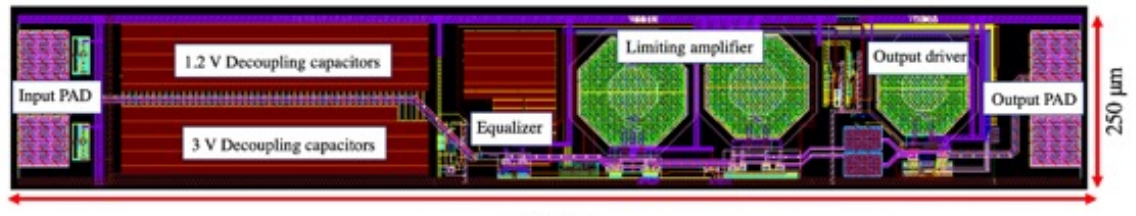
- **High-speed data transmission : ~ 5Gpbs**



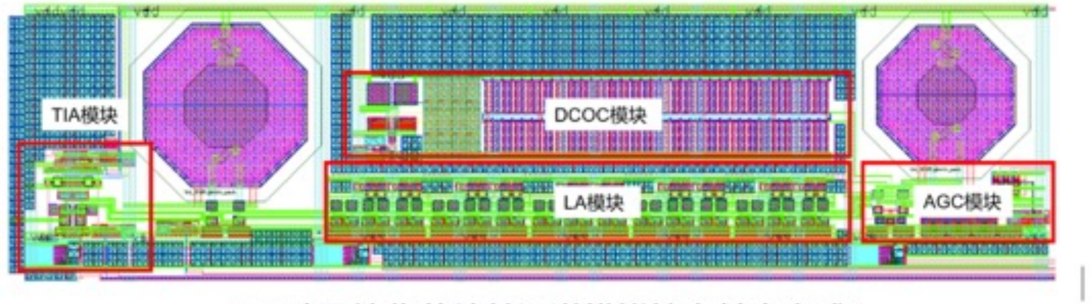
ADTC, an analogue of GBTx



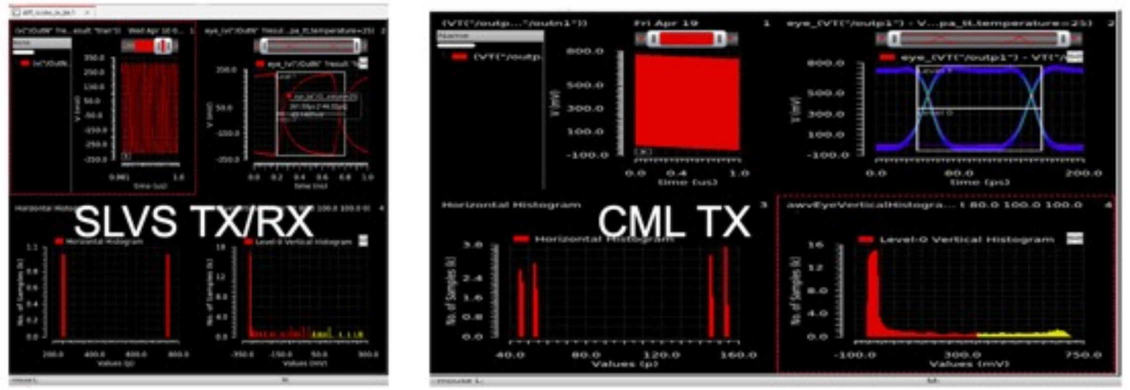




激光器驱动芯片单通道模拟核心版图基本完成



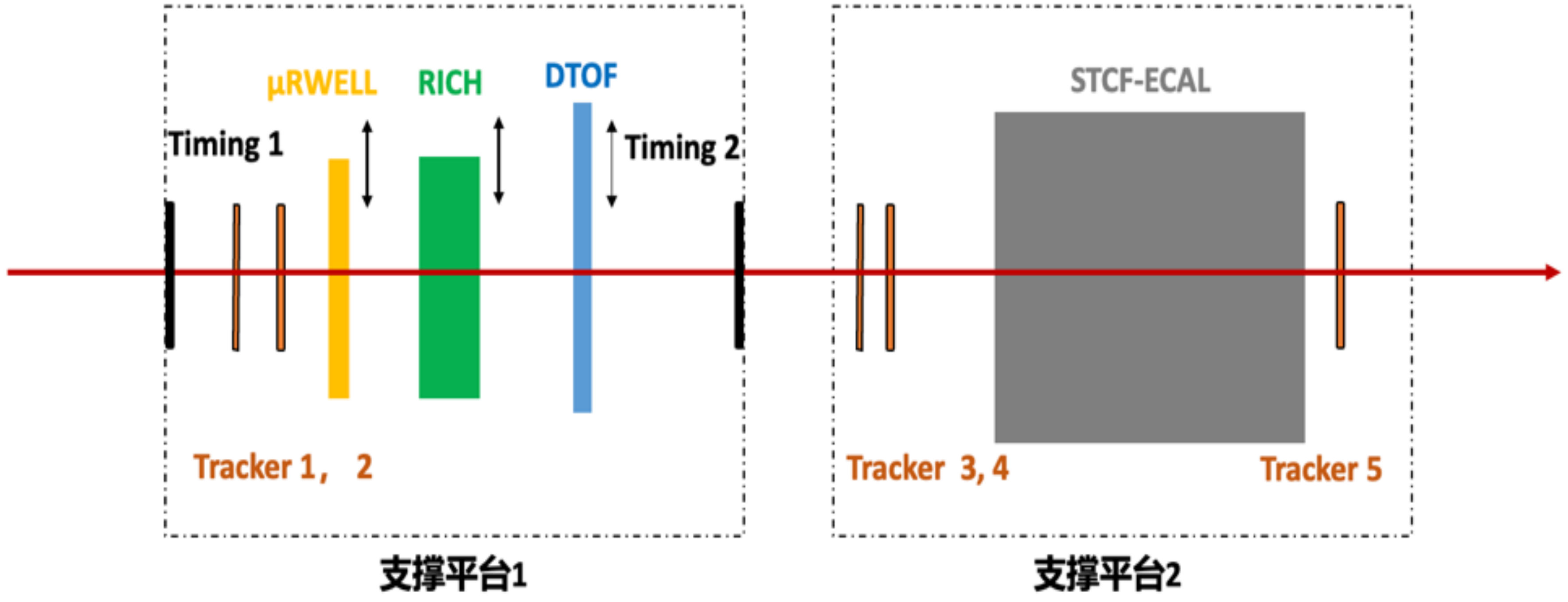
TIA跨导接收芯片单通道模拟核心基本完成



Clock management block and SerDes block taped out

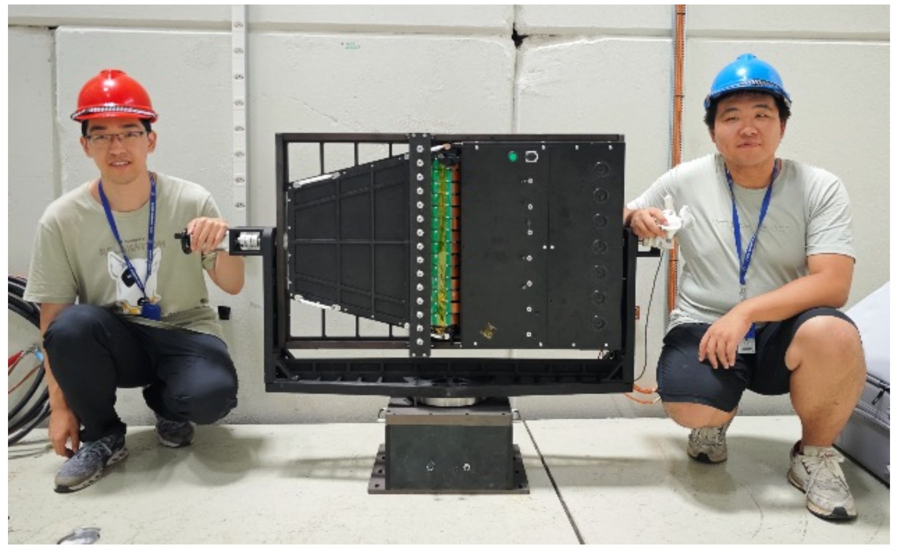
Combined Beam Test

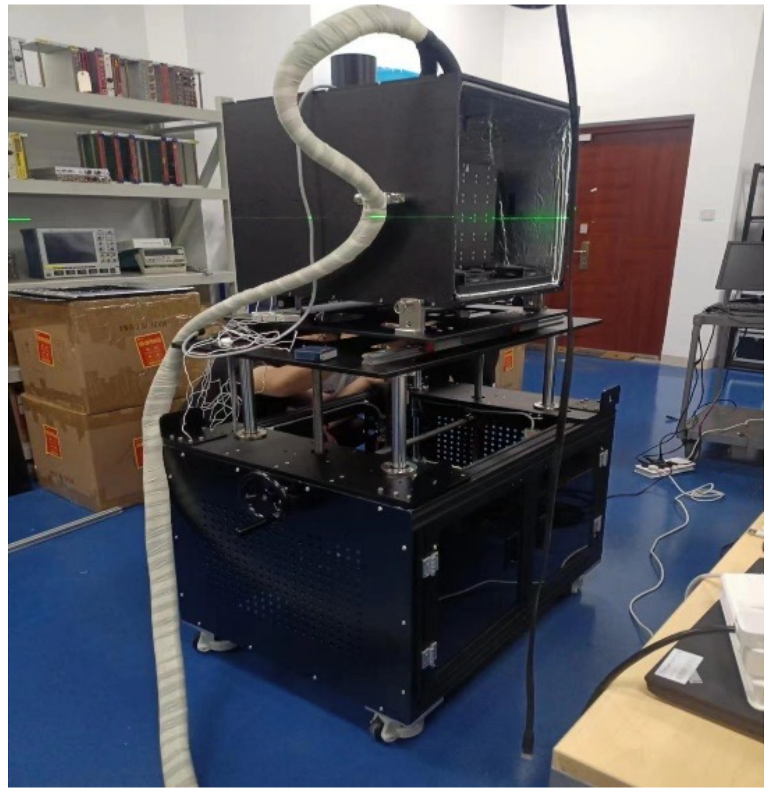
A test beam campaign for a combined system (DTOF, EMC, DAQ)



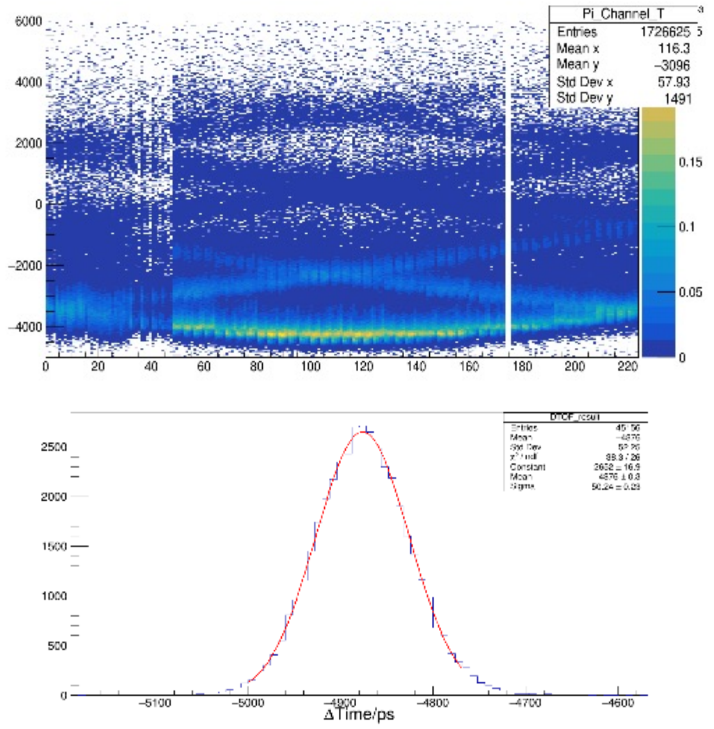
EMC Prototype

DTOF Prototype

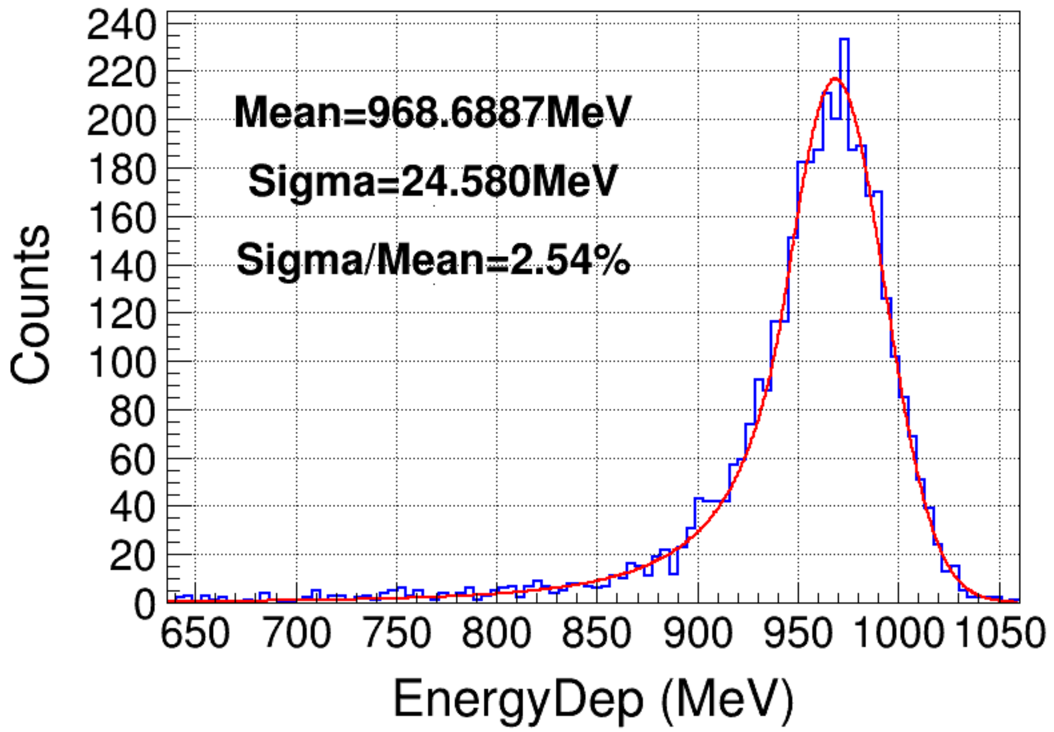




DTOF: σ_t~25 ps

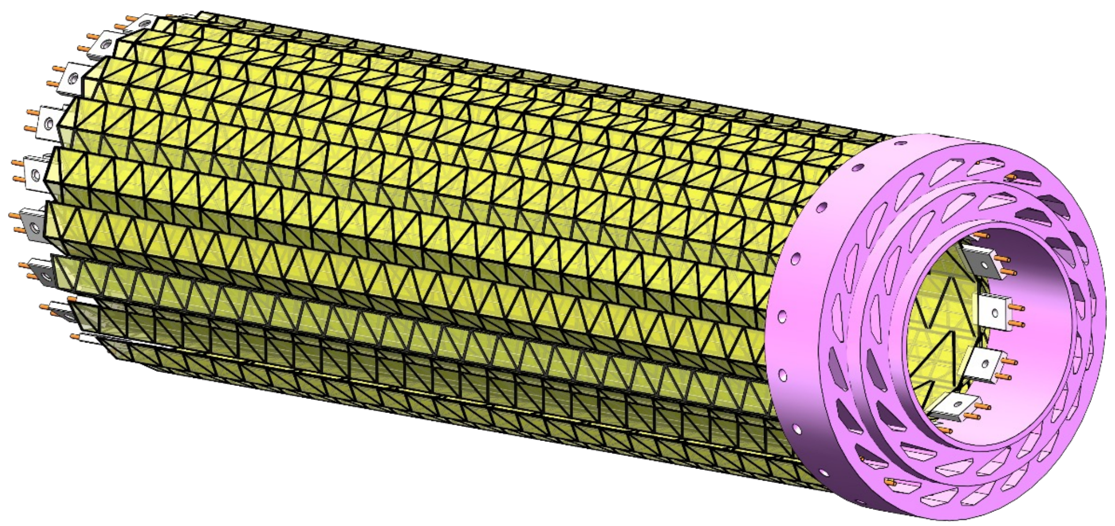


EMC: σ_E/E ~2.5%

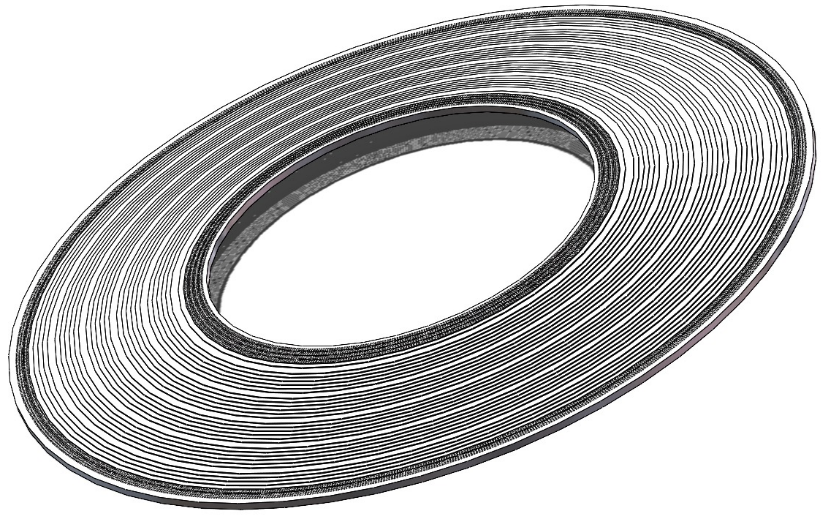


Detector Mechanical Design

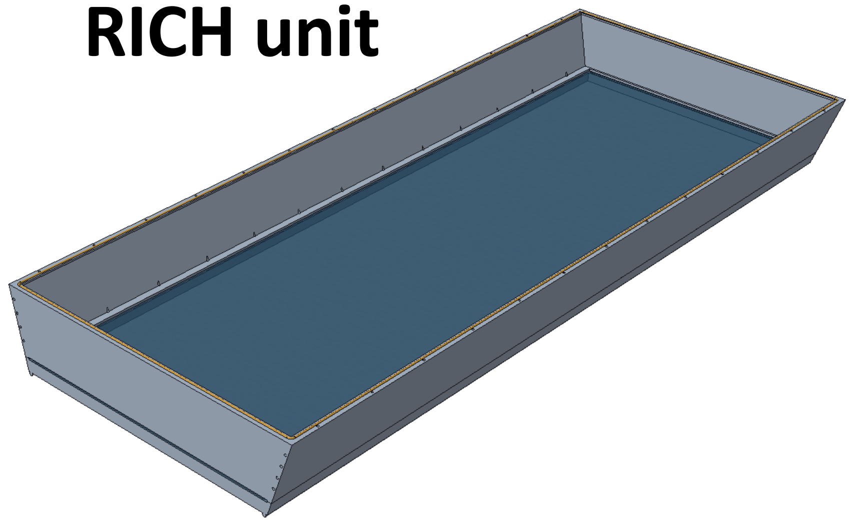
ITK-MAPS



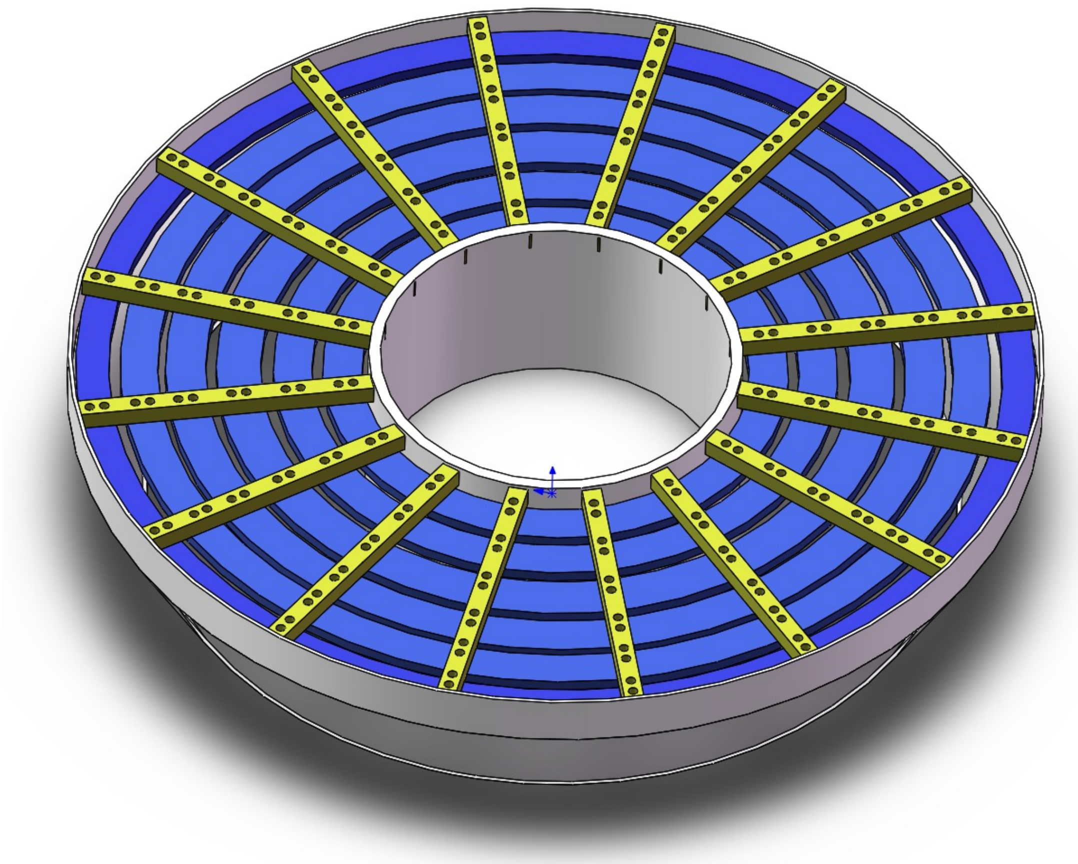
MDC end-plate



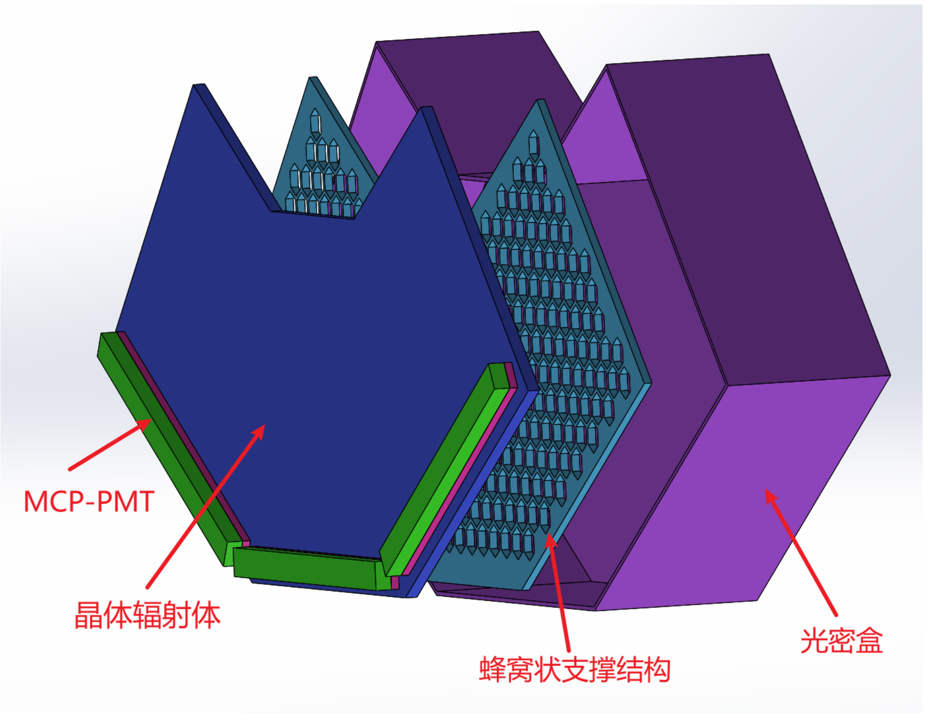
RICH unit



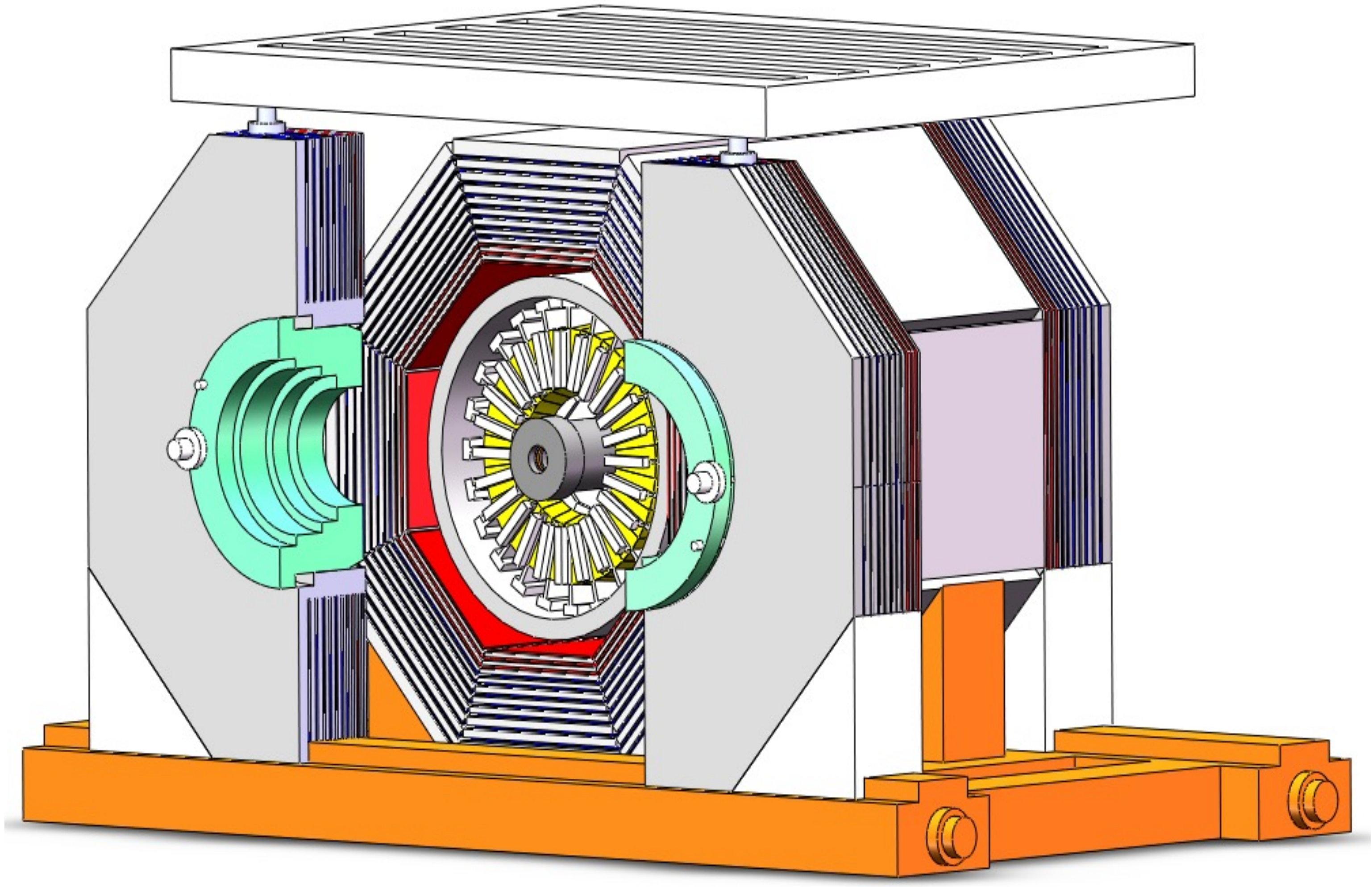
ECAL Endcap



DTOF sector



General structure



Summary

- **STCF detector conceptual design studies in the past few years have culminated with the publication of the physics and detector CDR.**
- **The STCF project has moved on to the technology R&D stage with strong support from local governments and USTC. A full STCF R&D program has been established and is rapidly moving forward.**
- **Intense R&D activities are underway on the baseline detector concept targeting key technologies of all sub-detectors. Significant progress has been made and some systems have reached milestones.**
- **Some sub-systems not covered in this talk: detector magnet, detector control system, luminosity monitors …**
- **A lot of synergy with other projects to explore**

Please join us if you are interested

Still a lot of room to contribute and play an important role

Thank you !