超级陶粲装置
Super Tau-Charm Facility

STCF Detector Design and R&D

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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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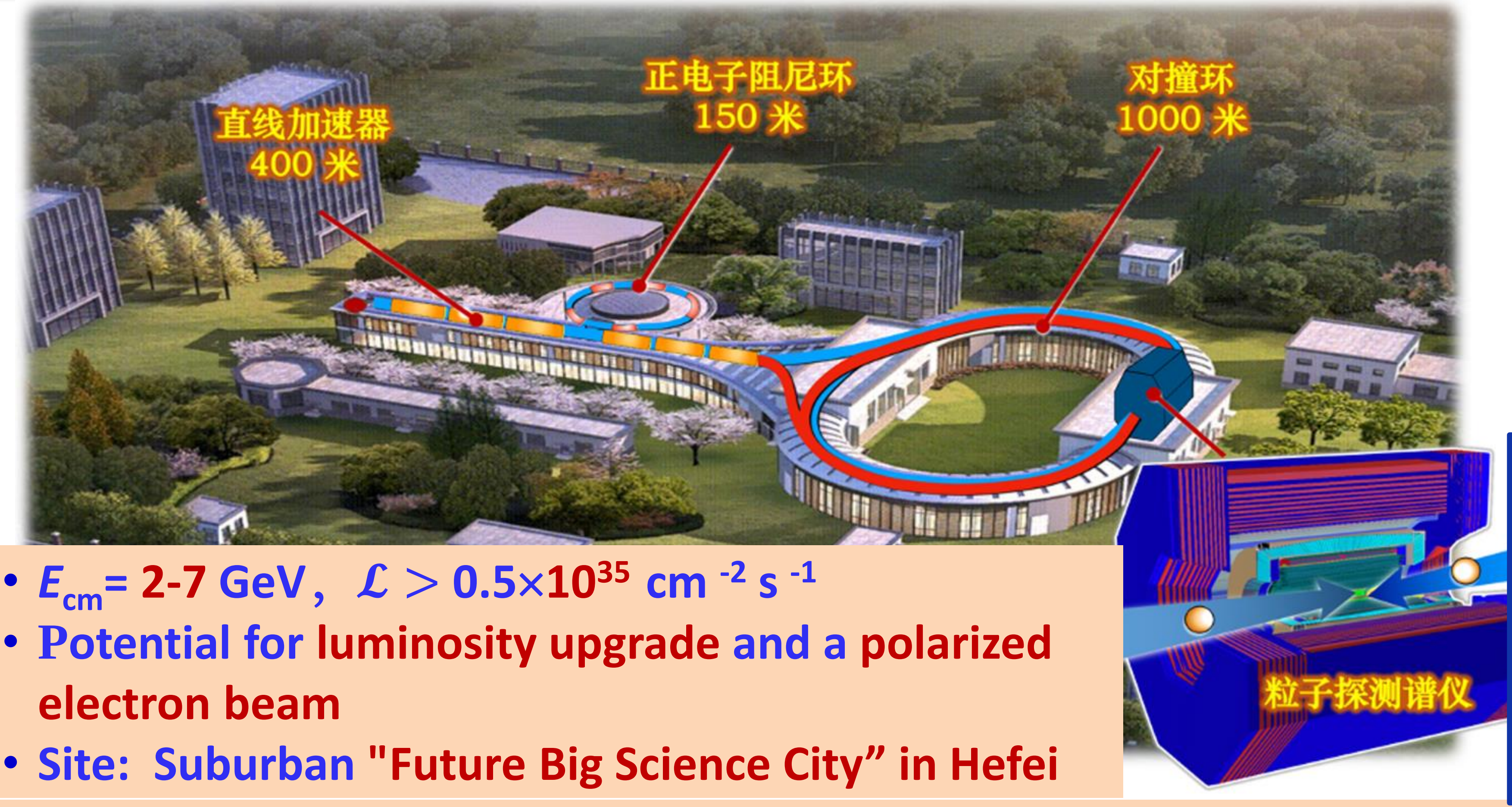
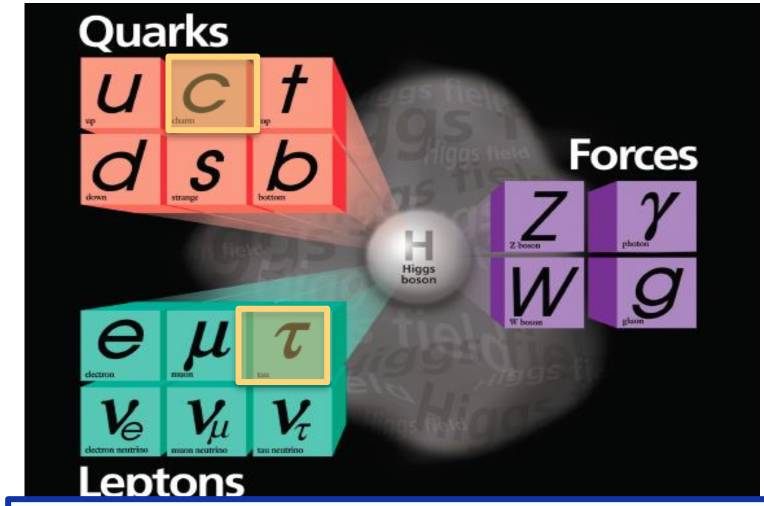
Super Tau Charm Facility (STCF)





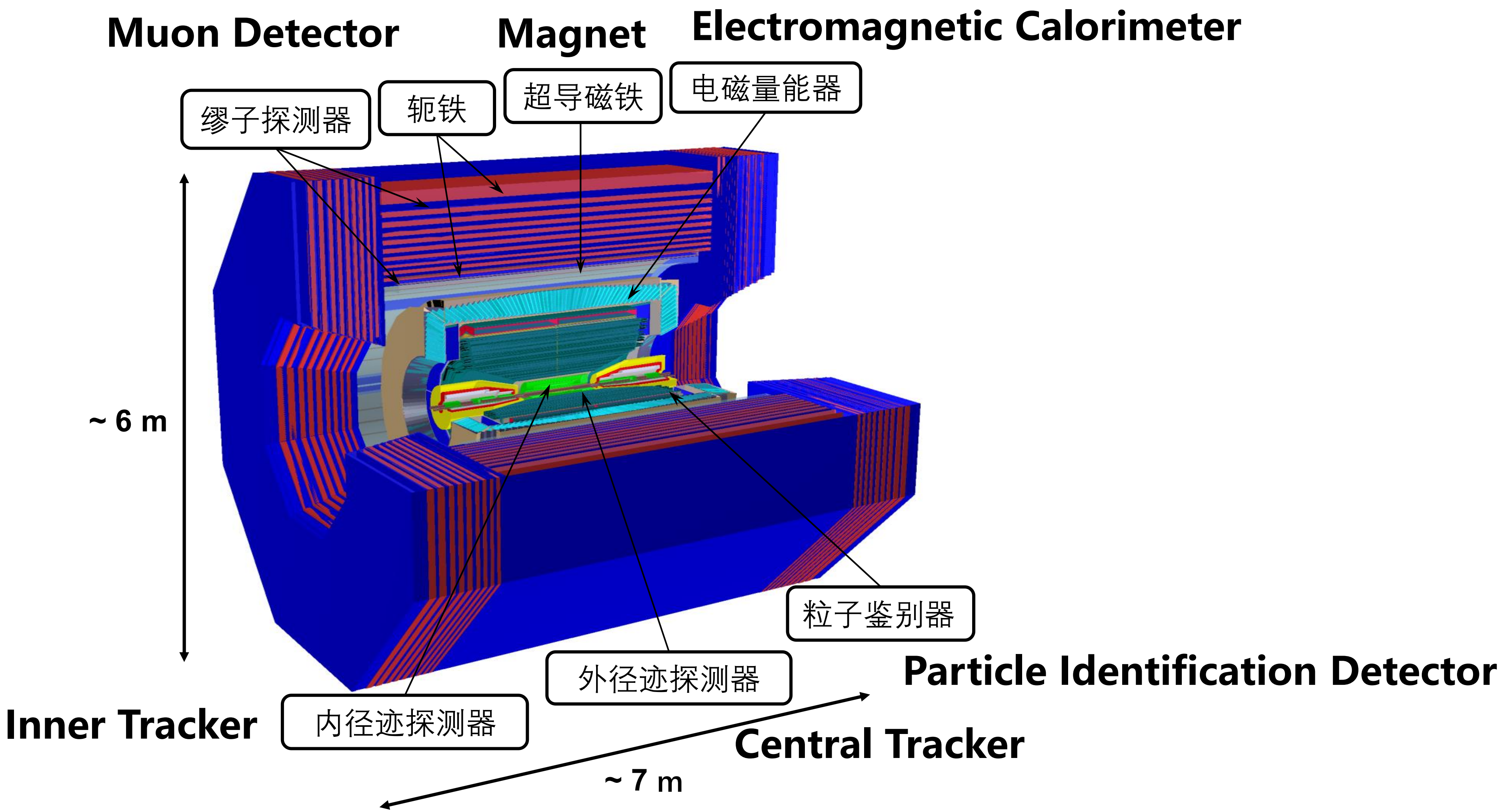
- E_{cm}= 2-7 GeV , $\mathcal{L} > 0.5\times10^{35}$ cm $^{-2}$ s $^{-1}$
- Potential for luminosity upgrade and a polarized electron beam
- Site: Suburban "Future Big Science City" in Hefei

STCF can produce an enormous amount of "clean" tau leptons and charm hadrons, allowing a full exploration of the unique and great physics potential in the tau-charm energy region: QCD, exotic hadrons, flavor physics and CPV, new physics…

- 14th five-year plan (2021-2025): Design studies and R&D on key technologies, ~0.4 B CNY
- 15th five-year plan (2026-2030): Construction to start during this period, ~6 years, ~4.5 B CNY
- Operating for 15 years to be followed by major upgrades

For more information about the STCF project, please see https://indico.cern.ch/event/1291157/contributions/5890162/

STCF Detector Layout



Muon Detector

缪子探测器

轭铁

Magnet

超导磁铁

Electromagnetic Calorimeter

电磁量能器

~ 6 m

粒子鉴别器

Particle Identification Detector

外径迹探测器

Central Tracker

内径迹探测器

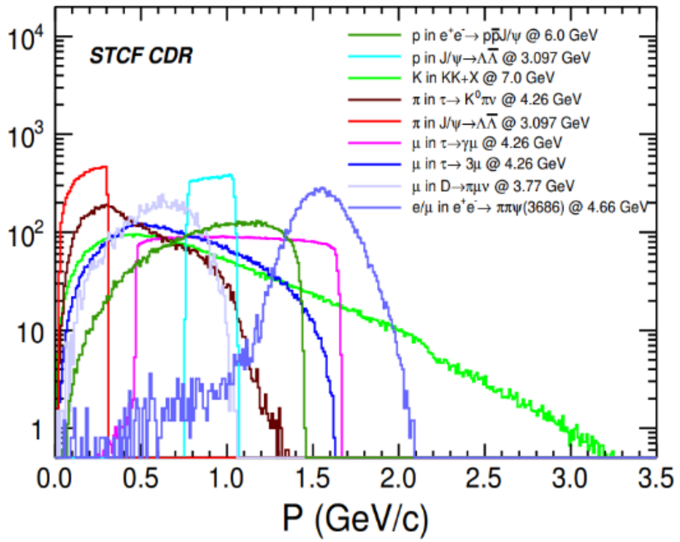
Inner Tracker

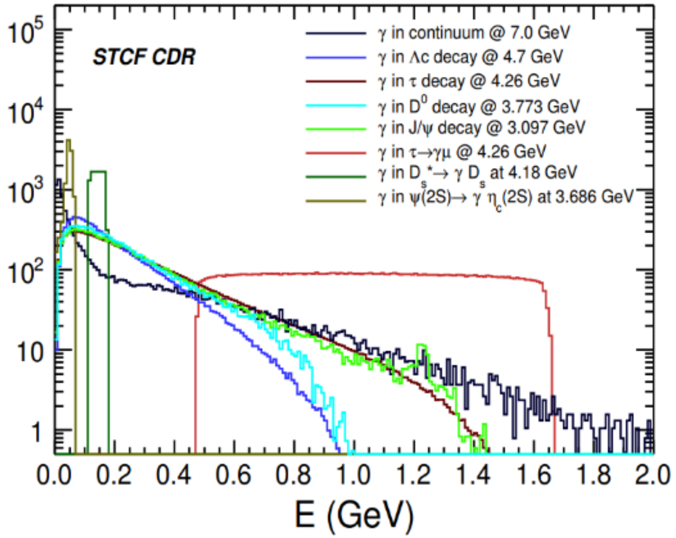
~ 7 m

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

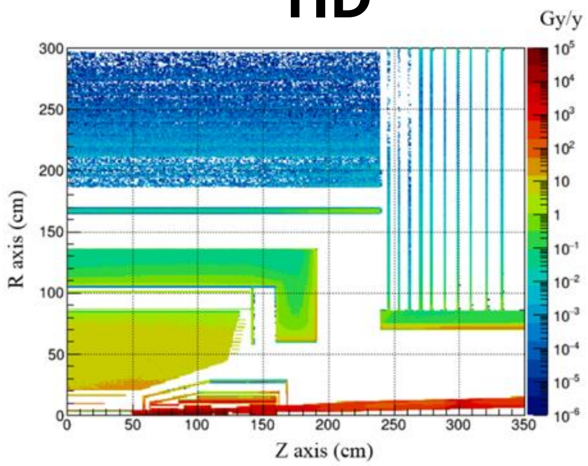
Process	Physics Interest	Optimized Subdetector	Requirements
$\tau \to K_s\pi\nu_\tau$, $J/\psi \to \Lambda\bar{\Lambda}$, $D_{(s)}$ tag	CPV in the τ sector, CPV in the hyperon sector, Charm physics	ITK+MDC	acceptance: 93% of 4π; trk. effi.: $> 99\%$ at $p_T > 0.3$ GeV/c; $> 90\%$ at $p_T = 0.1$ GeV/c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

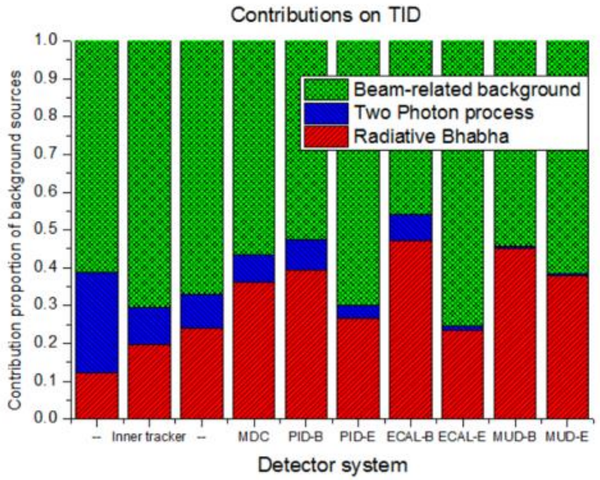




Beam-induced Backgrounds

TID





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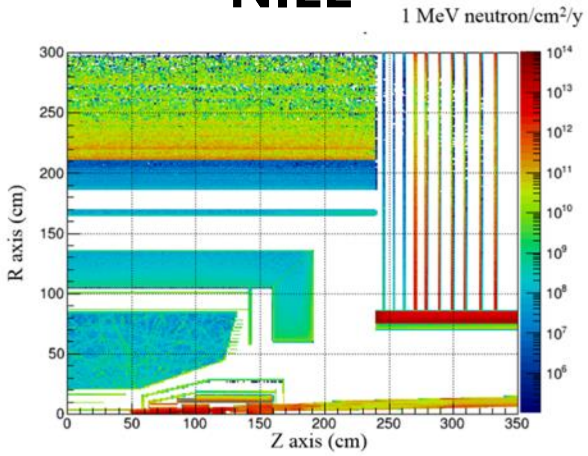
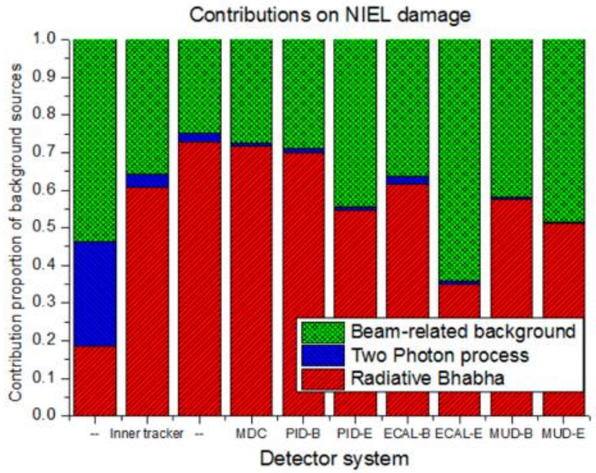
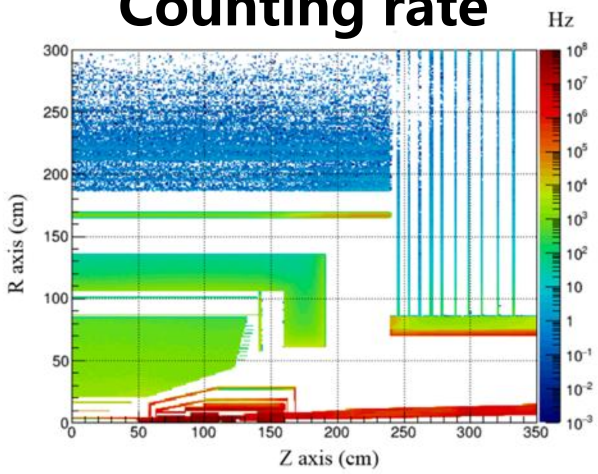
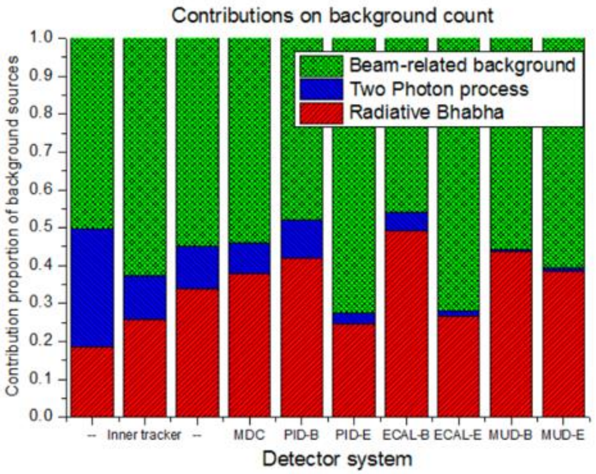




Counting rate

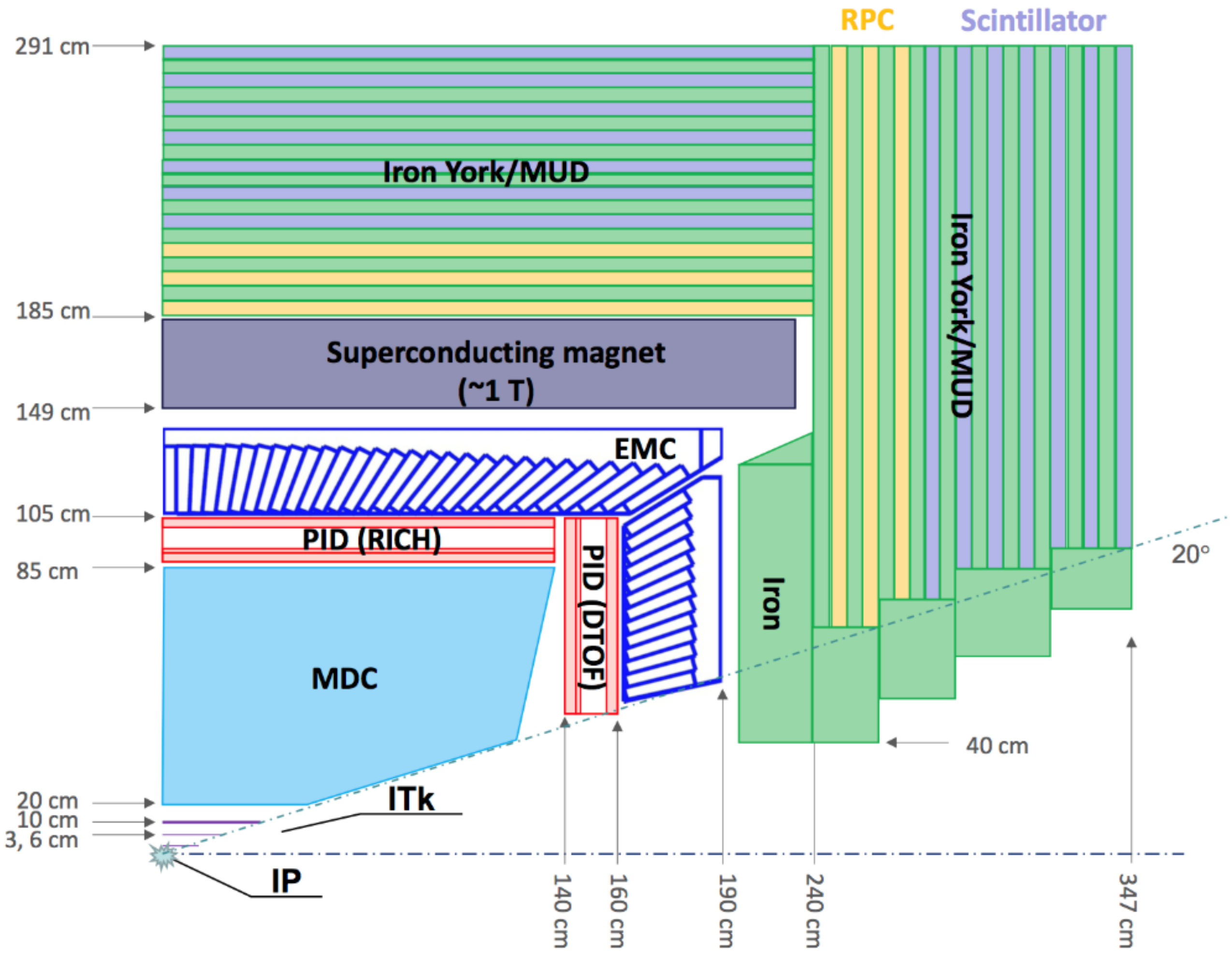




Inner most detector layer: ~3.5 kGy/y, ~2×10^{11} 1MeV n-eq/cm^2/y, ~1 MHz/cm^2

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~20^0)

- ❖ **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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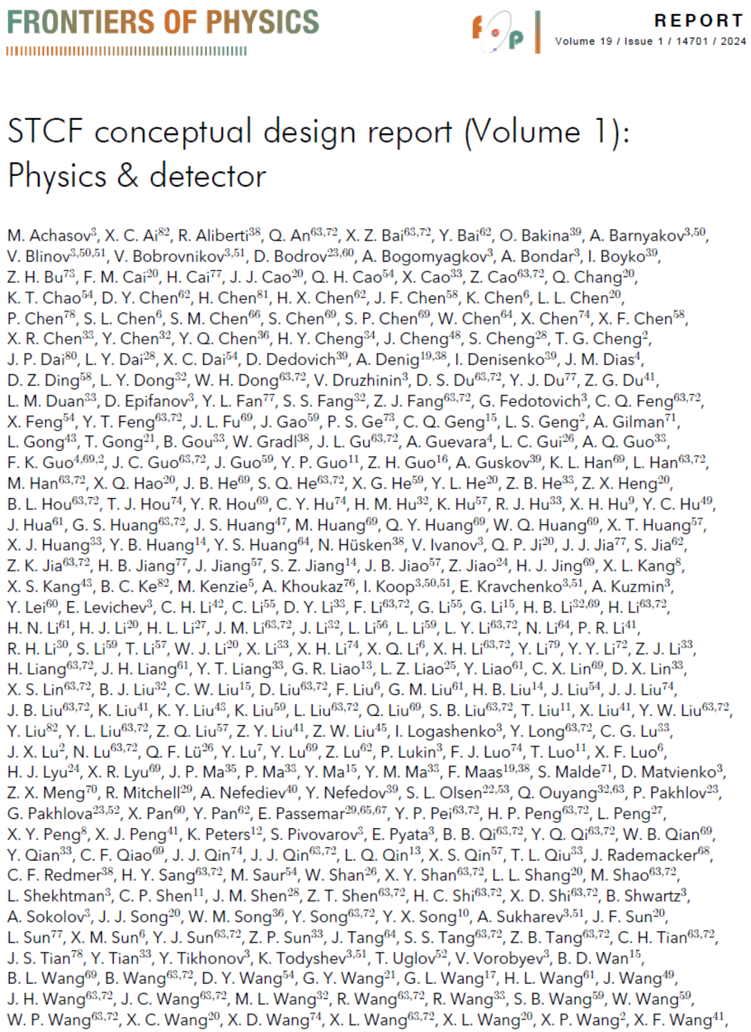
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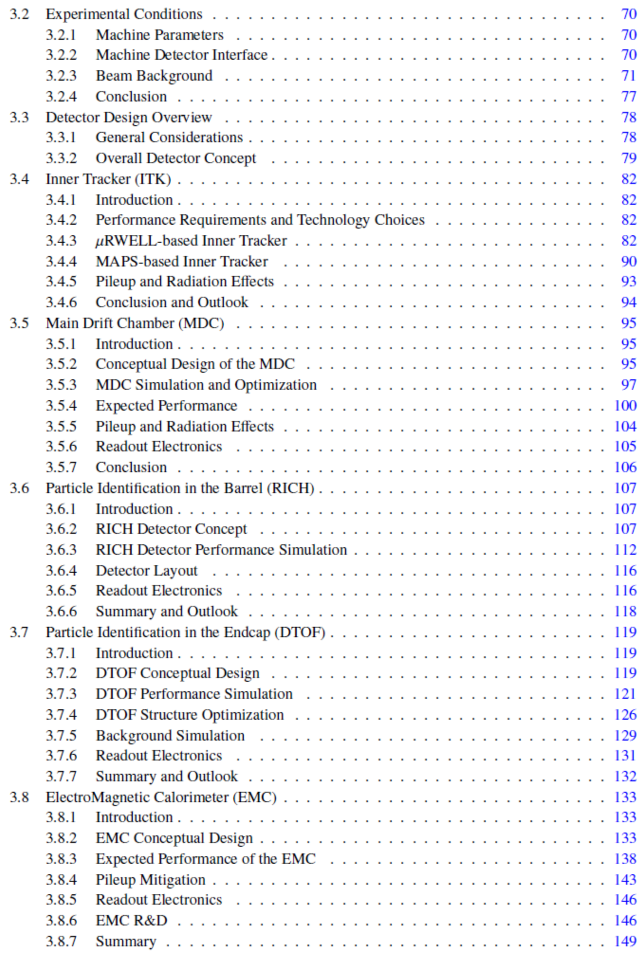
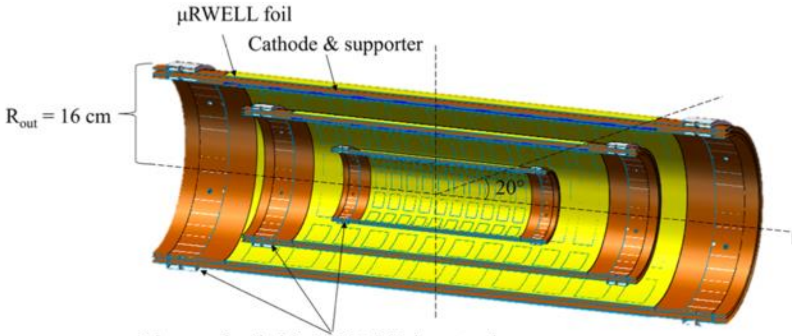
STCF conceptual design report (Volume 1): Physics & detector

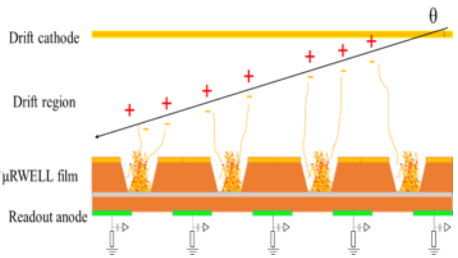
M. Achasov[3], X. C. Ai[82], R. Aliberti[38], Q. An[63,72], X. Z. Bai[63,72], Y. Bai[62], O. Bakina[39], A. Barnyakov[3,50], V. Blinov[3,50,51], V. Bobrovnikov[3,51], D. Bodrov[23,60], A. Bogomyagkov[3], A. Bondar[3], I. Boyko[39], Z. H. Bu[73], F. M. Cai[20], H. Cai[77], J. J. Cao[20], Q. H. Cao[54], 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

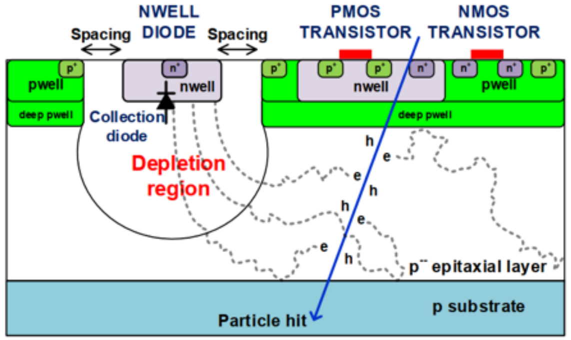




3 layers of cylindrical μRWELL inner tracker
(with sensitive length of 33, 61, 88 cm respectively)

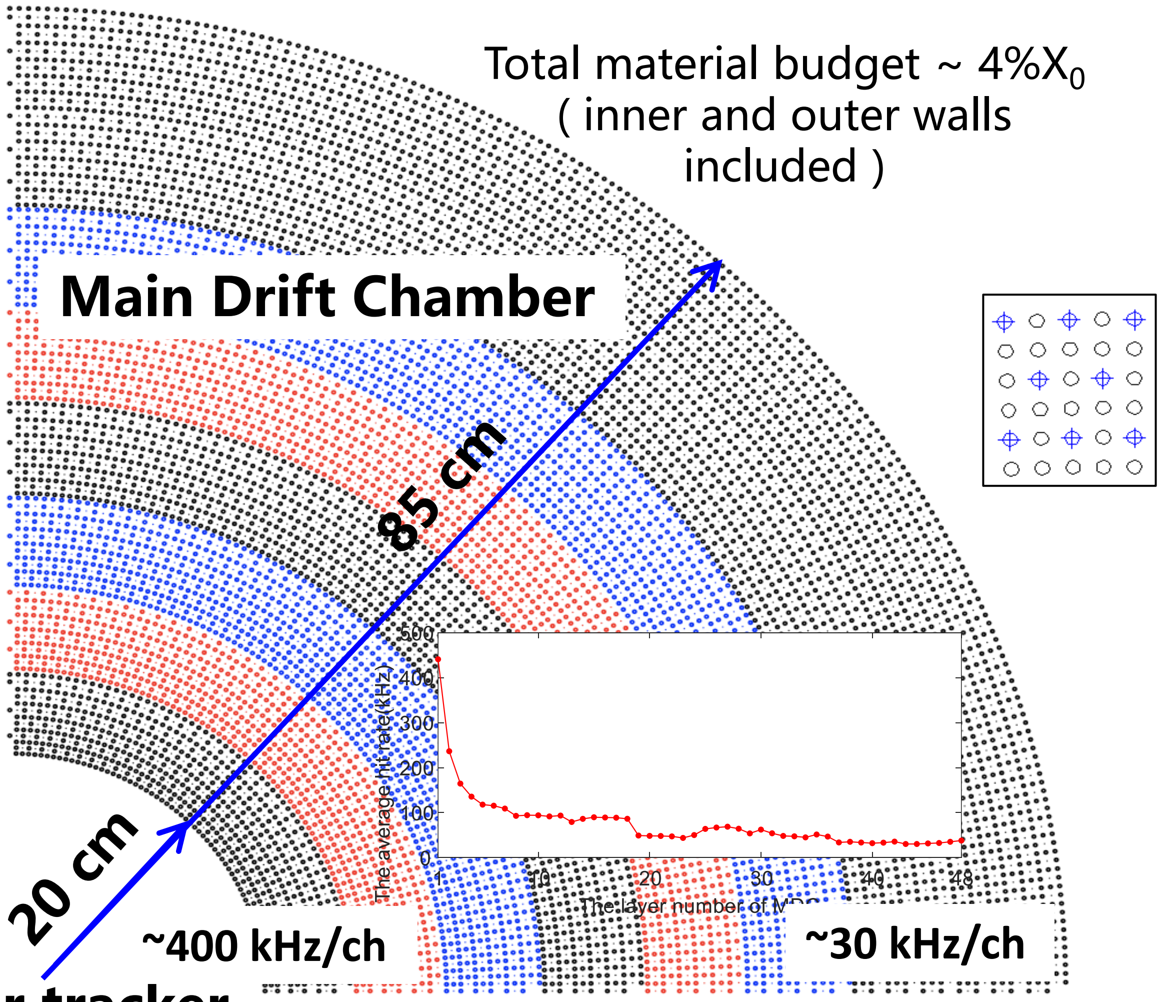
Material budget ~ 0.3%X_0/layer

ITK Silicon option: CMOS MAPS



单片有源像素探测器

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

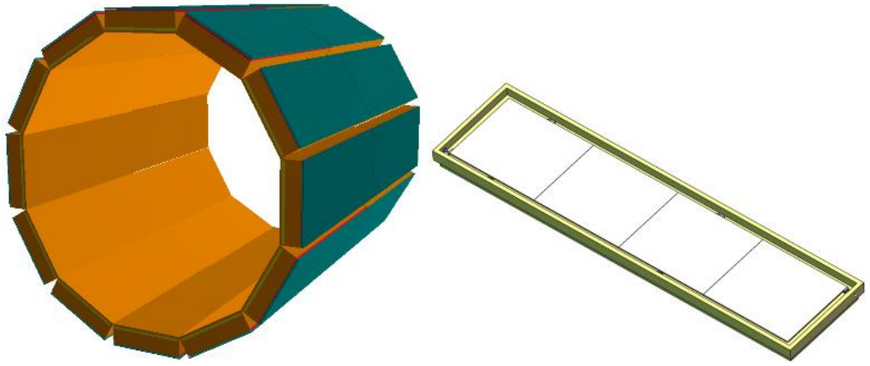


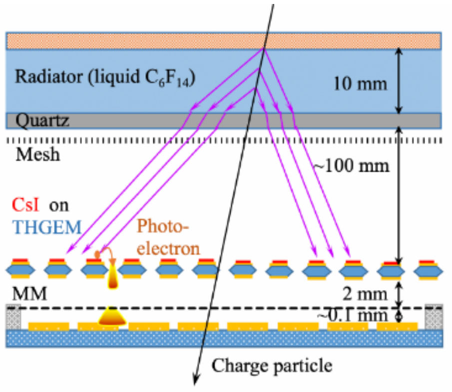
Inner tracker

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

PID, EMC, MUD

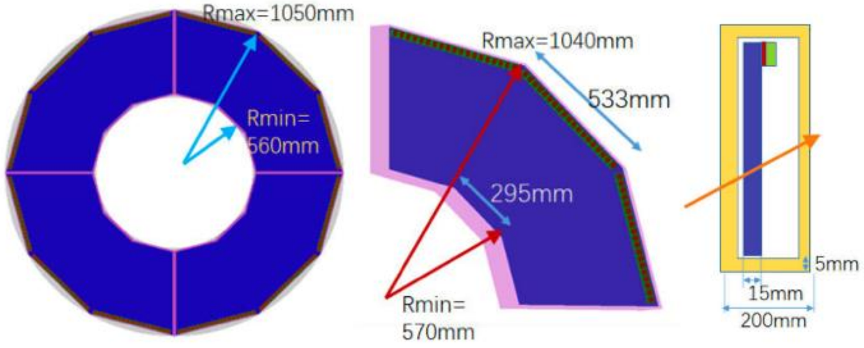
- **Barrel PID: A RICH detector using MPGD (THGEM with CsI + MM) for photon detection**

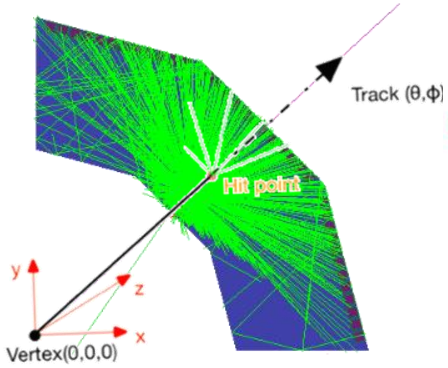




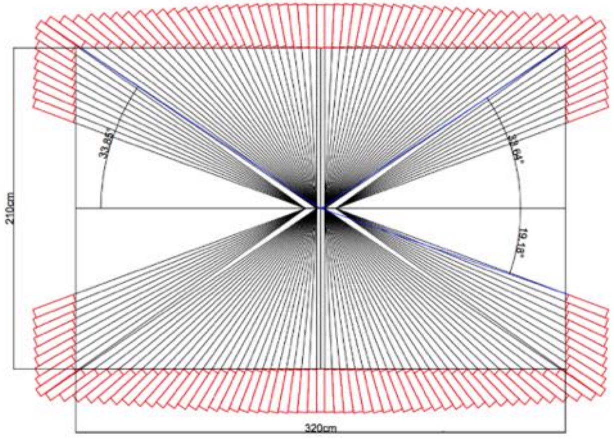
Material budget < $0.3X_0$

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



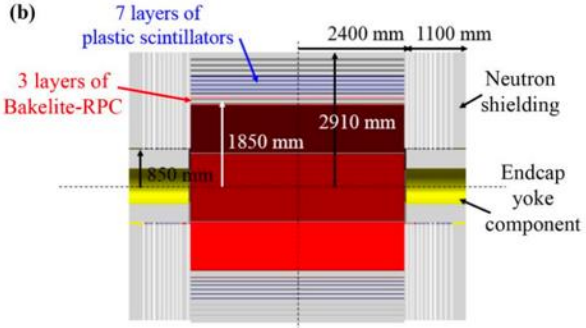


- **EMC: A pure-CsI crystal calorimeter to tackle a high level of background (~1MHz/ch)**



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

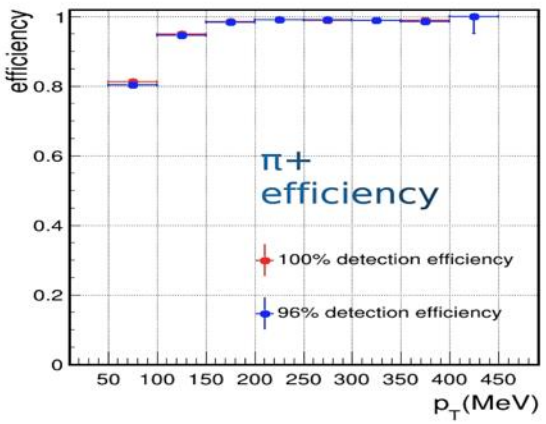
- **MUD: A RPC-scintillator hybrid detector to optimize muon and neutral hadron ID**



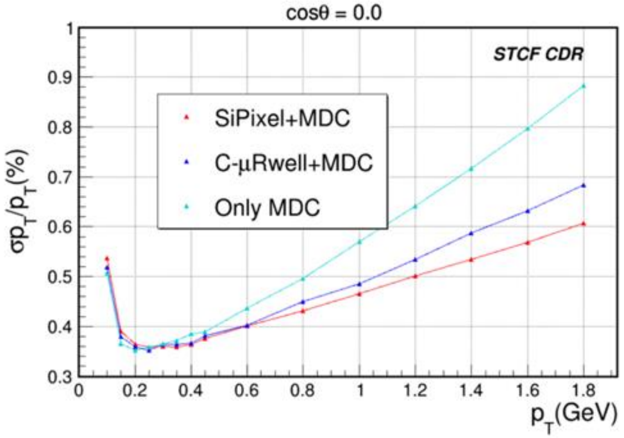
Parameter	Baseline design
R_{in} [cm]	185
R_{out} [cm]	291
R_e [cm]	85
L_{Barrel} [cm]	480
T_{Endcap} [cm]	107
Segmentation in ϕ	8
Number of detector layers	10
Iron yoke thickness [cm] (λ=16.77 cm)	4/4/4.5/4.5/6/6/6/8/8 cm Total: 51 cm, 3.04λ
Solid angle	79.2%×4π in barrel 14.8%×4π in endcap 94%×4π in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

Expected Performance

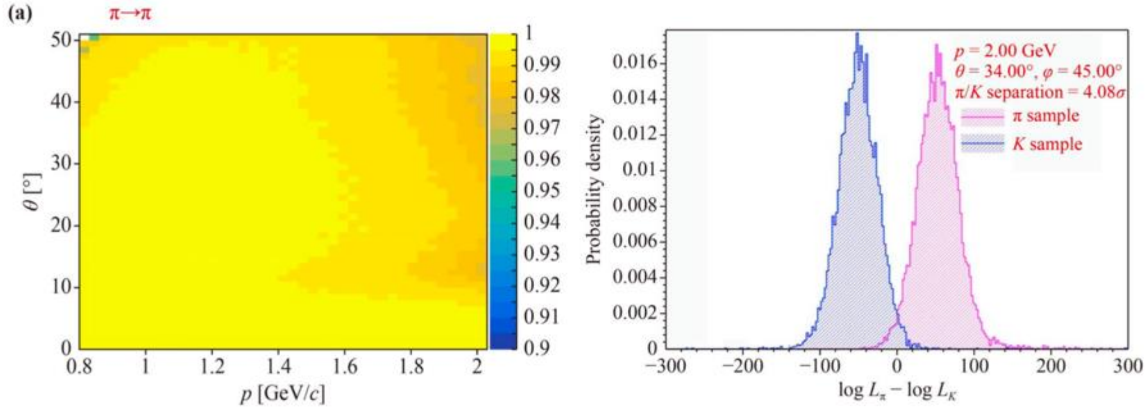
Tracking efficiency



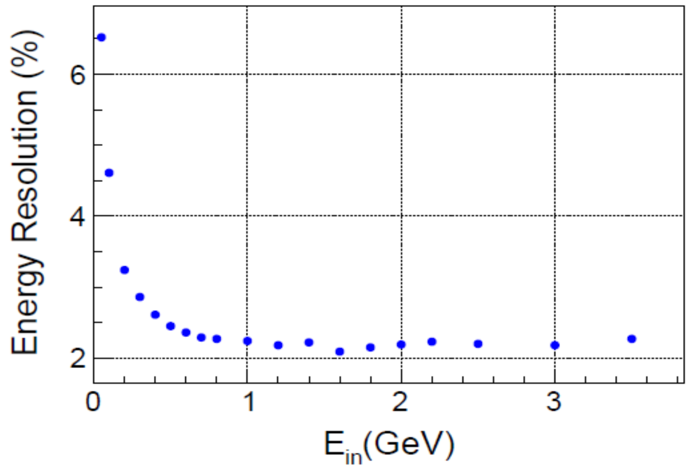
Momentum resolution



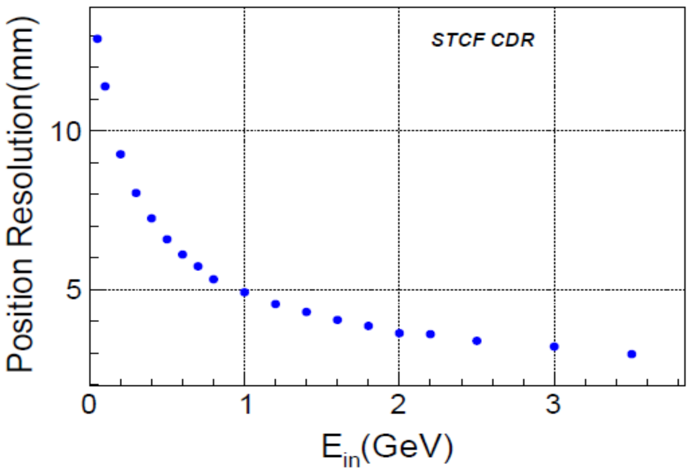
Pion/K separation capability



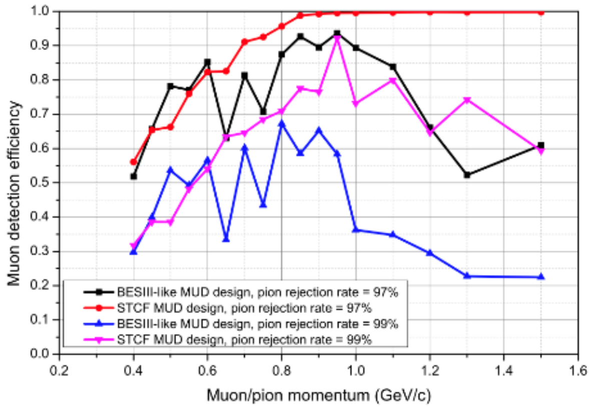
Photon energy resolution



Photon position resolution



Muon identification efficiency



STCF R&D Project Kick-Off and Review Meetings

Kick-off Meeting, Aug. 2023, USTC

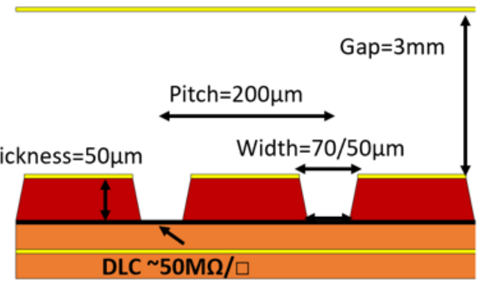
More than 30 academicians of CAS, as well as government officials of Anhui province and Hefei city, along with representatives from various domestic research institutions, totaling 170 attendees.

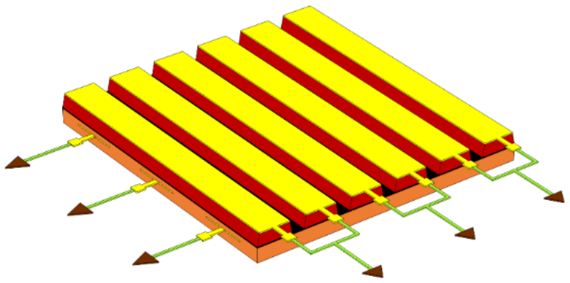
R&D Project Review, Dec. 2023, USTC

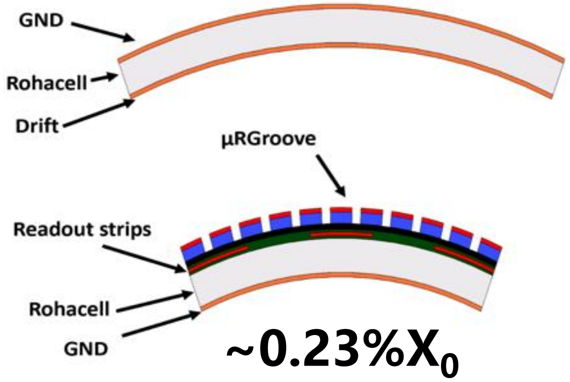
Organized by Development and Reform Commissions of Anhui province and Hefei city. The R&D project was approved for a budget of 364 M CNY and is jointly funded by Anhui, Hefei and USTC.

ITK-MPGD: µRGroove

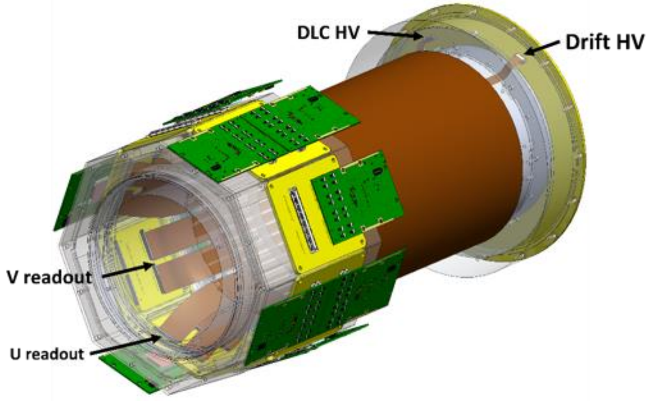
- **µRGroove : A single-stage MPGD involving no stretching or tensioning, 2D strip readout without charge sharing (large S/N), high rate with fast grounding, easy to make a cylinder, low mass, low production cost**



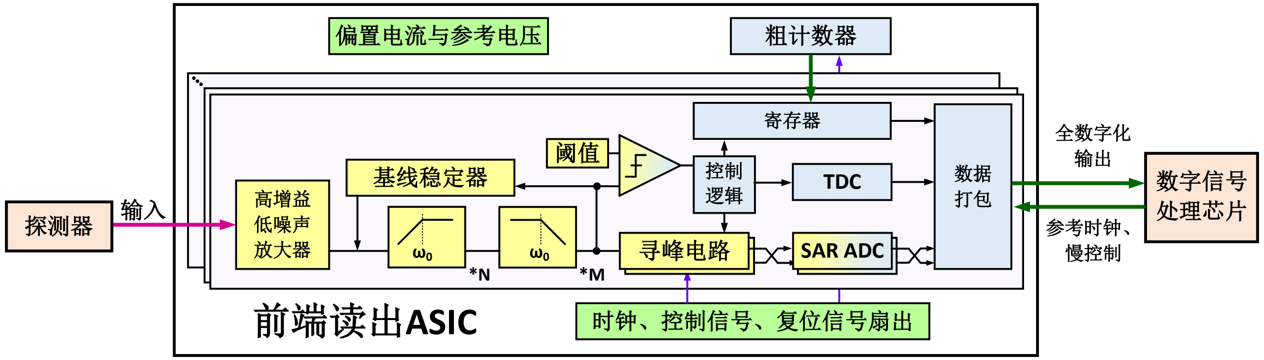




$\sim 0.23\%X_0$



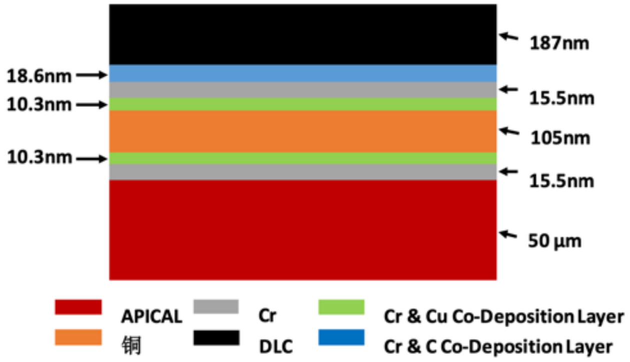
- **High-rate readout ASIC for MPGD (averaged hit rate of 400 kHz/ch)**



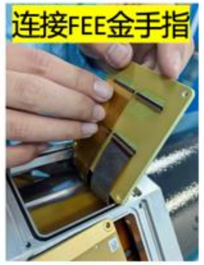
ASIC Specs	Demands
Charge Range	40 fC
Charge precision	～ 1 fC RMS
Time precision	< 10 ns RMS
Max. event rate	4 MHz

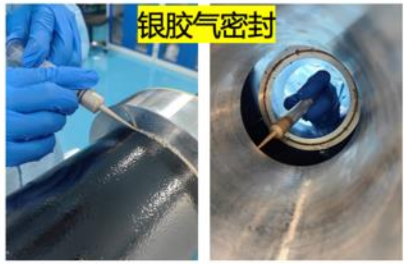
ITK-MPGD R&D

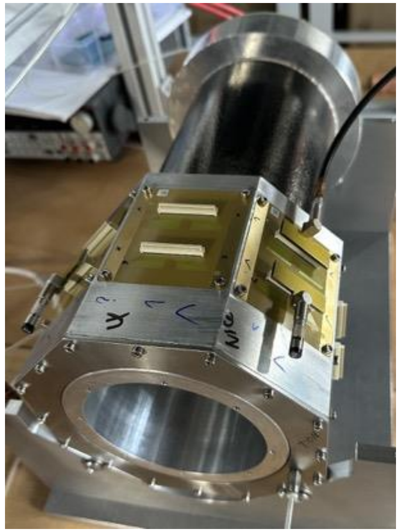
Development of low mass electrodes



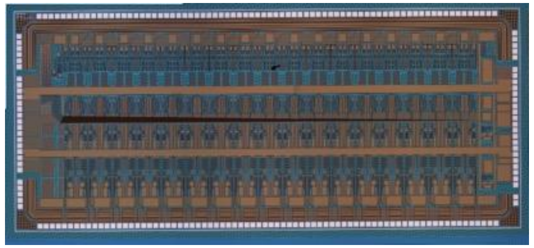
Fabricating cylindrical structure

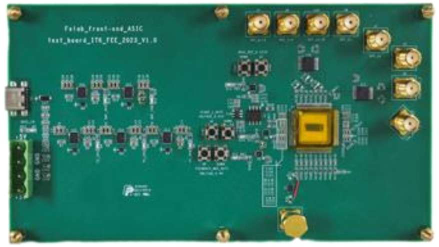


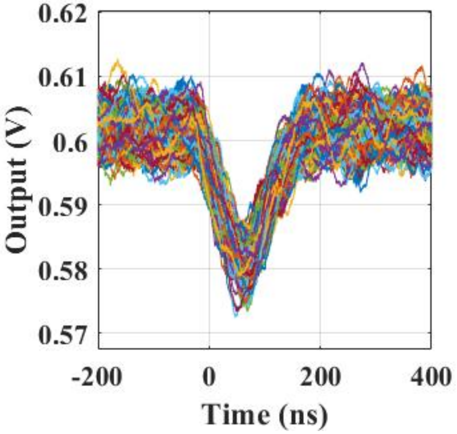


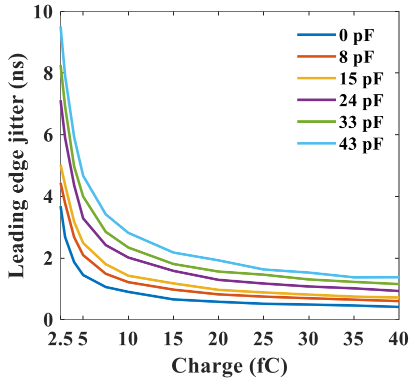


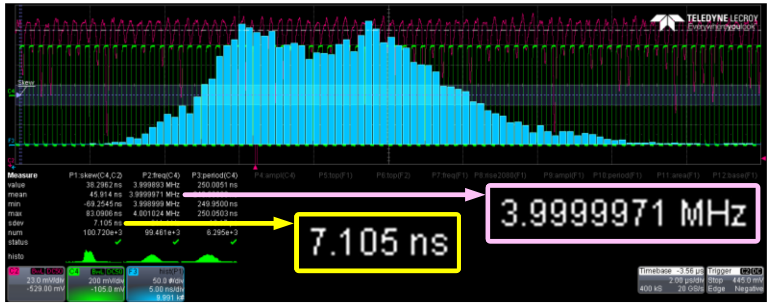
ASIC design and development









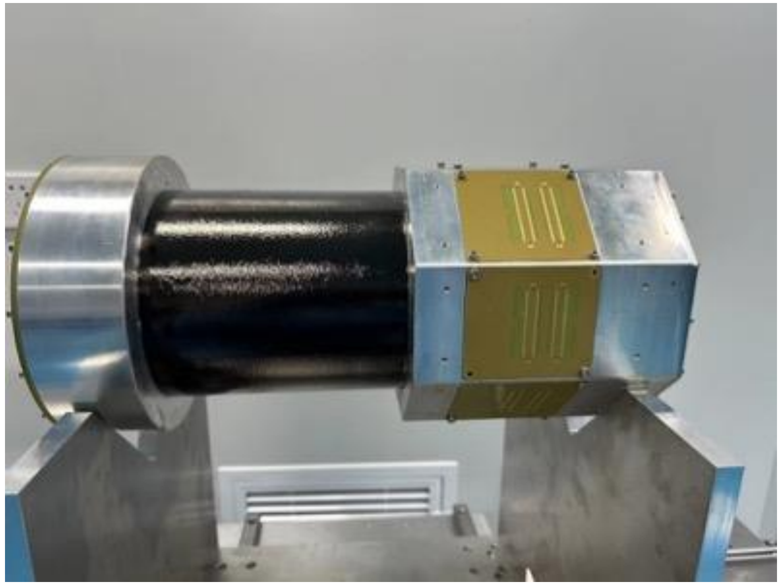


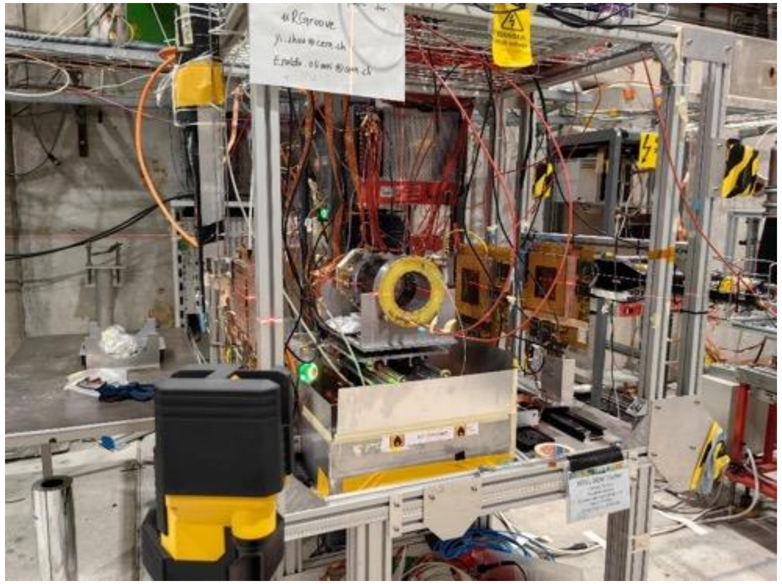
```
Measure   P1:skew(C4,C2)  P2:freq(C4)    P3:period(C4)
value     38.2962 ns      3.999893 MHz   250.0051 ns
mean      45.914 ns       3.9999971 MHz
min       -69.2545 ns     3.998999 MHz   249.9500 ns
max       83.0906 ns      4.001024 MHz   250.0503 ns
sdev      7.105 ns
num       100.720e+3      99.461e+3      6.295e+3
status    ✓               ✓              ✓
histo
```

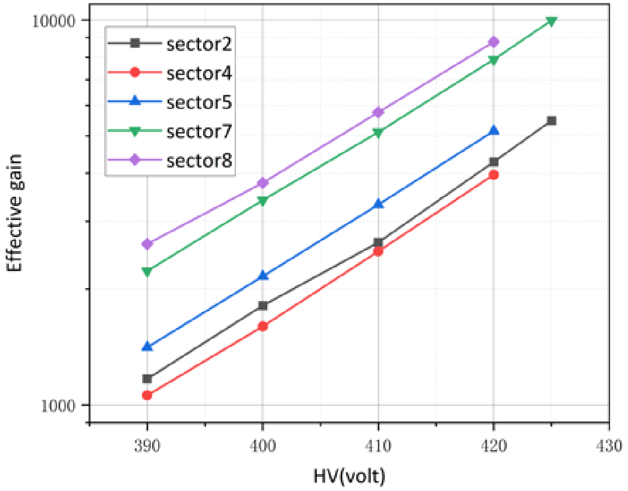
Tested the ASIC chip by feeding simulated detector output pulses to the chip at 4MHz with 35pF

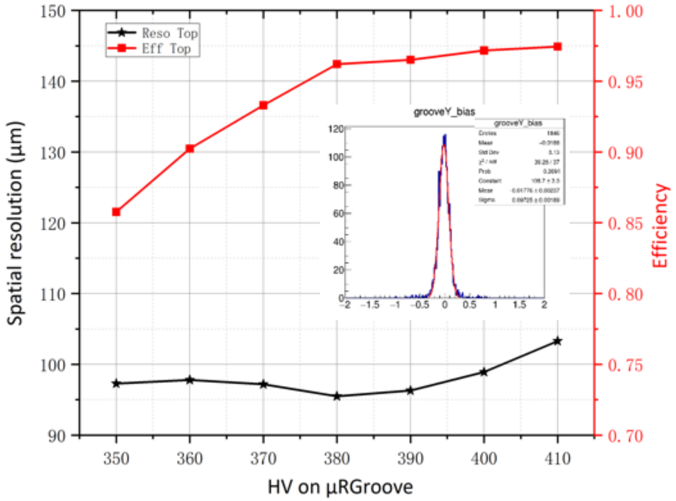
Inner Layer Prototype

- **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**



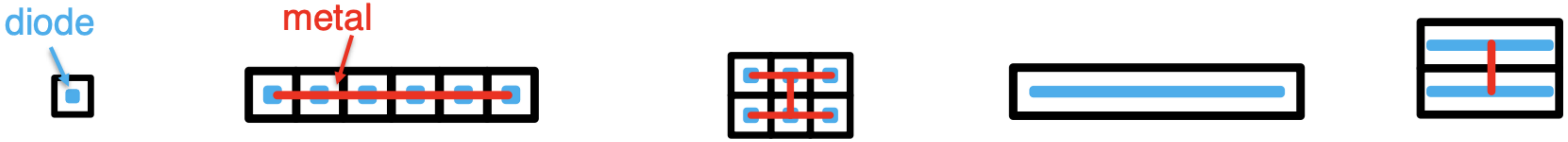






ITK-MAPS

- **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

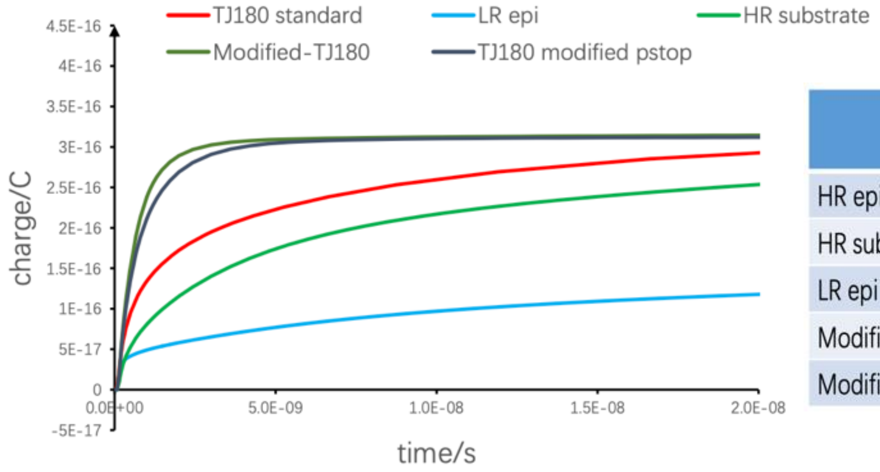
B: Pixel-based 180μm×30μm

C: Pixel-based 90μm×60μm

D: Strip-based 180μm×30μm

E: Strip-based 90μm×60μm

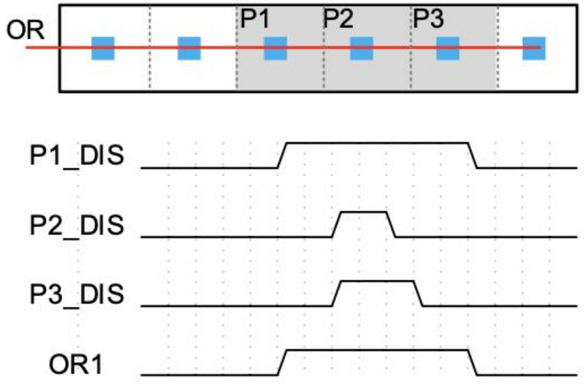
- **CMOS techniques being explored:**
  - **TowerJazz 180nm (HR epi),**
  - **NexChip FCIS/BCIS 90nm (LR epi)**
  - **GSMC 130nm (HR substrate)**



	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

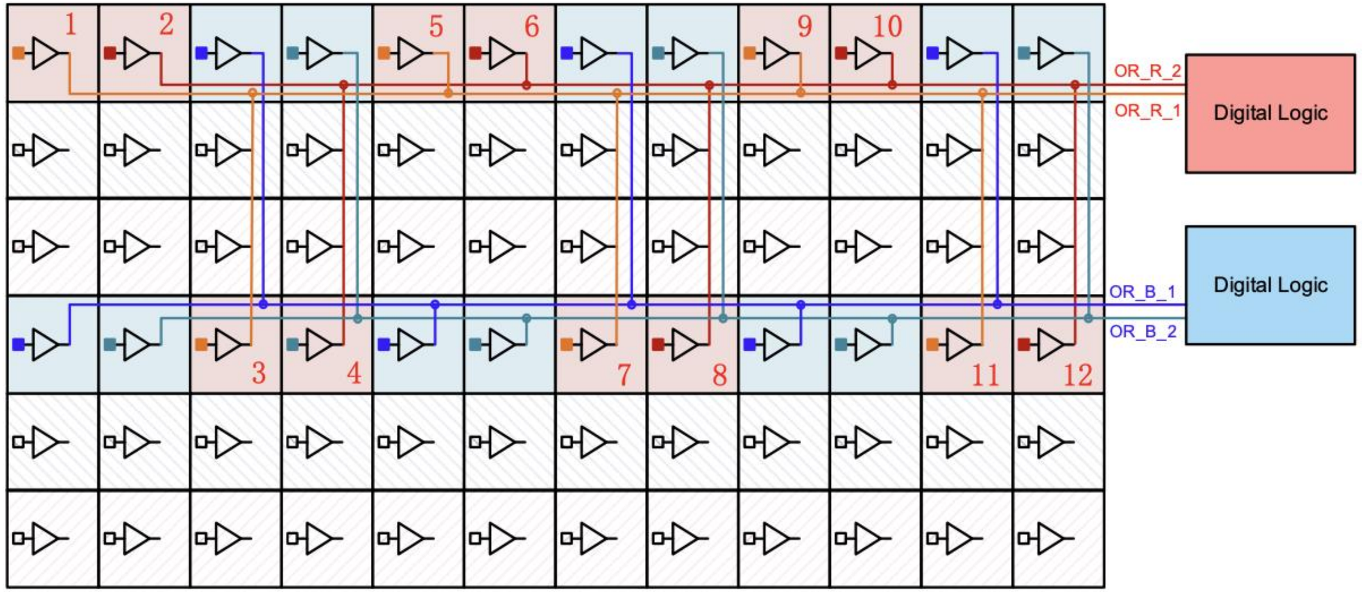
- ❖ Combining non-adjacent pixels: avoid ToT loss
- ❖ Super pixel with 6×12 pixel array
  - – 6 sets of digital readout logic
  - – When cluster size < 3X4, no ToT loss occurs



Combining adjacent pixels

→ ToT loss

Additional 3-bit for group address

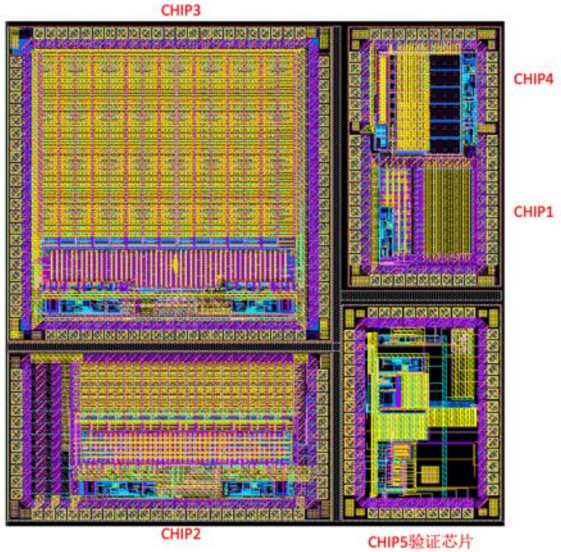


- **Providing both high position and high time resolutions for low power consumption**

ITK MAPS Designs

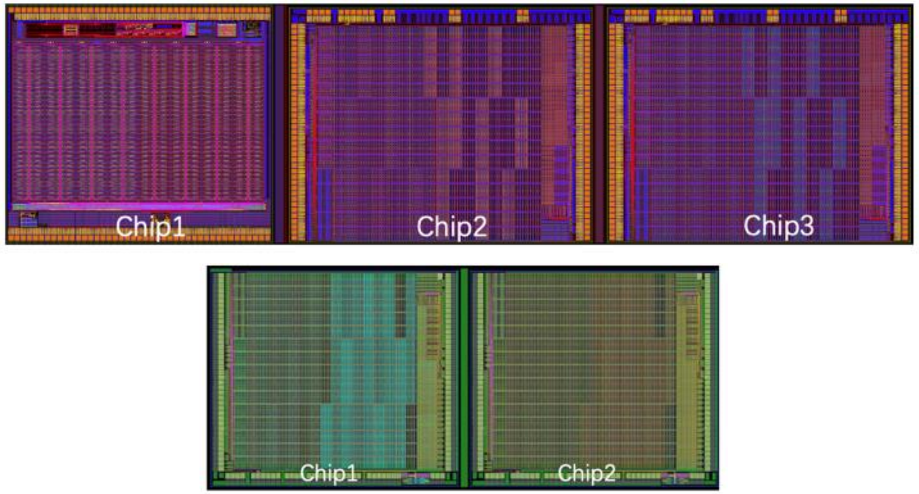
TowerJazz 180nm

Taped out in March 2024



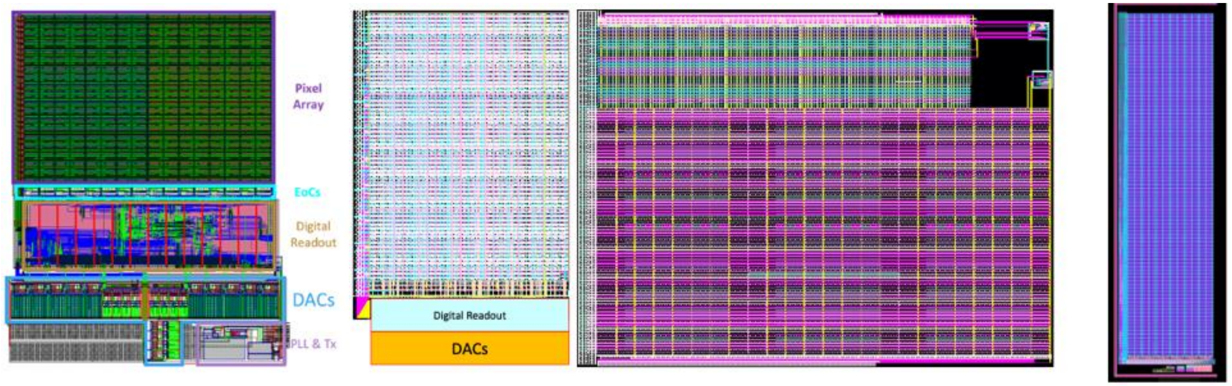
NexChip FCIS/BCIS 90nm

Taped out in May 2024



GSMC 130nm

to be taped out in July 2024



Simulated performance

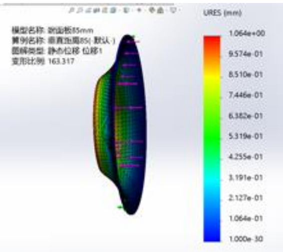
	TJ-MAPS	GSMC-MAPS
Current	**800 nA/pix**	**120*6 nA/pix**
Supply Voltage	1.8 V	1.2 V
Threshold	309.0 e^-	153.8 e^-
ENC	11.4 e^-	5.1 e^-
Mismatch	5.7 e^-	5.8 e^-
t_r @400 e^-	**200 ns**	**81 ns**

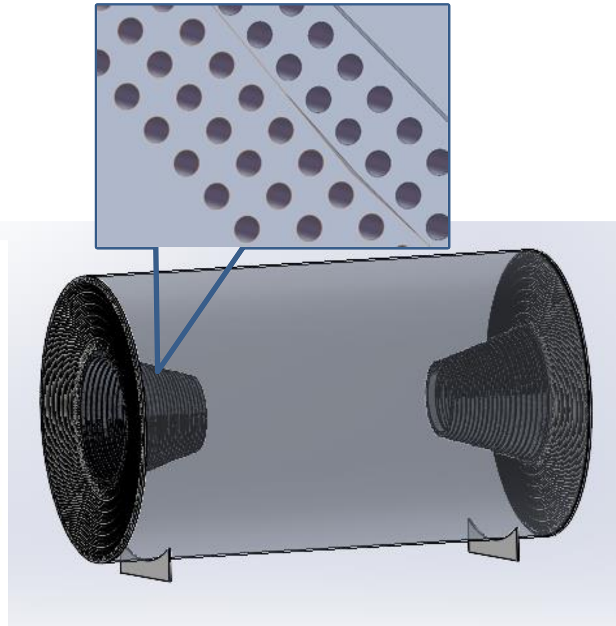
Items	Power consumption	Notes
Analog in pixel matrix	~26 mW/cm^2	Strip-based
	~15 mW/cm^2	Pixel-based
Timestamp clock distribution	12.2 mW/cm^2	
Dynamic power consumption of the pixel matrix	2.4 mW/cm^2	with a data rate of 8.7 MHz/cm^2
Periphery	23.5 mW	32MHz event rate
PLL, serializer, LVDS	39 mW	x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

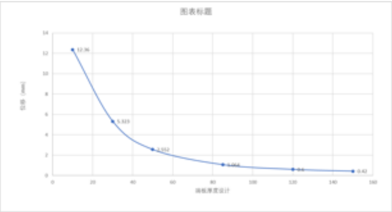
- Strip-based：55.7 mW/cm2
- Pixel-based：46.2 mW/cm2

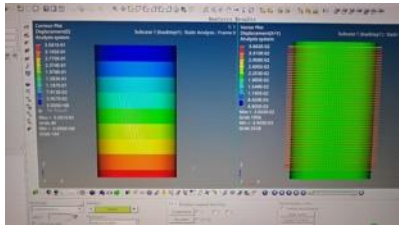
Main Drift Chamber

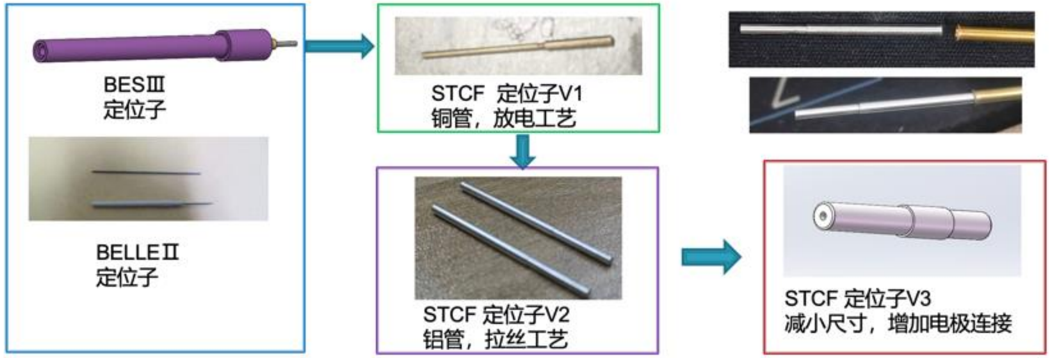
- **Preliminary mechanical design and structural analysis**
- **Big challenges from super-small cells (5mm*5mm, distance between wires ~2.5mm)**
- **Ongoing R&D on feedthroughs, wires and chamber stringing**











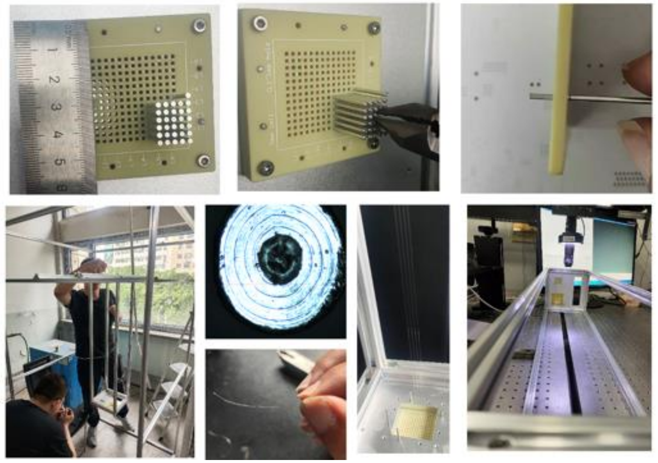
BESIII
定位子

BELLE II
定位子

STCF 定位子V1
铜管，放电工艺

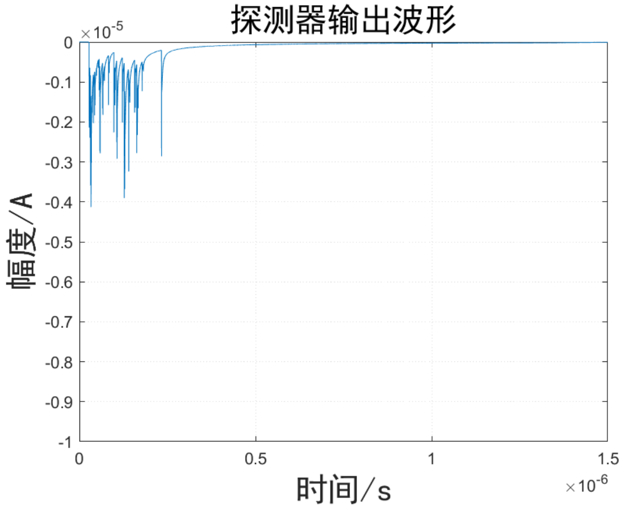
STCF 定位子V2
铝管，拉丝工艺

STCF 定位子V3
减小尺寸，增加电极连接

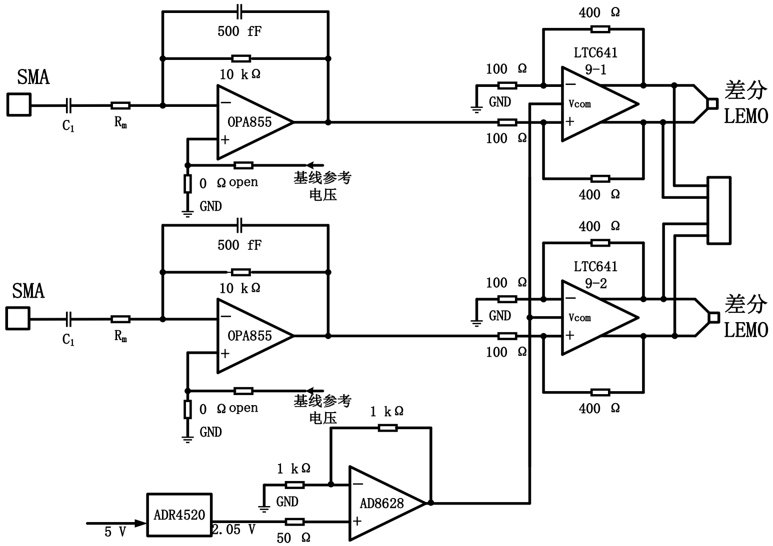


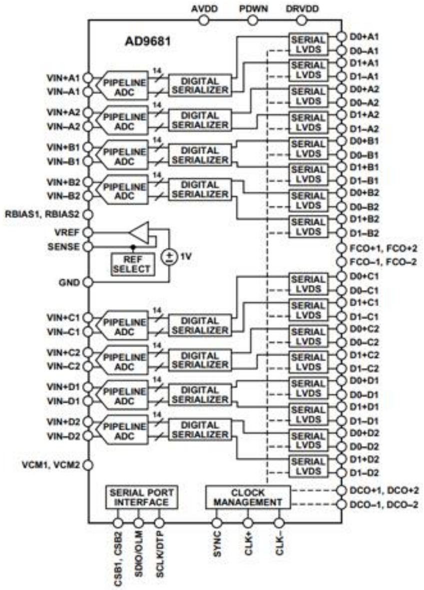
MDC Readout Electronics

- **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

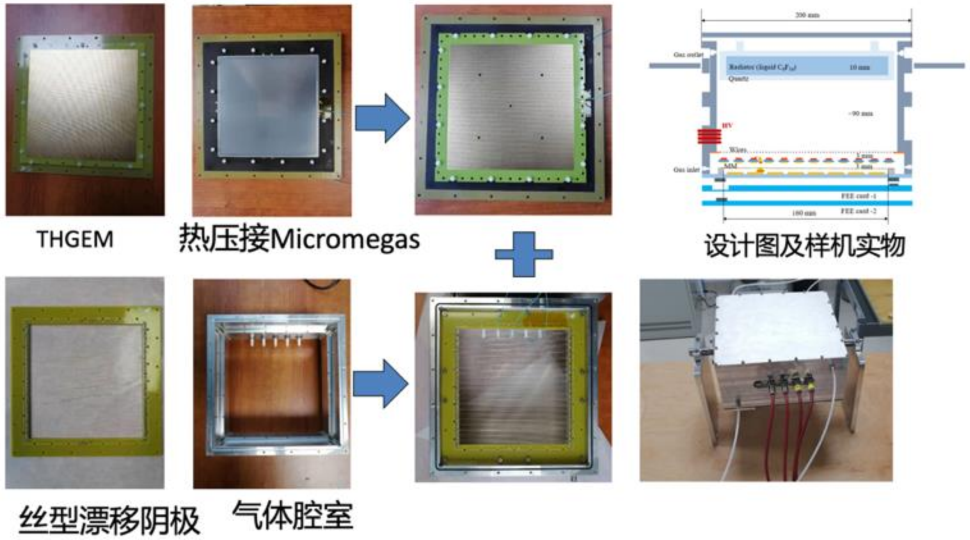




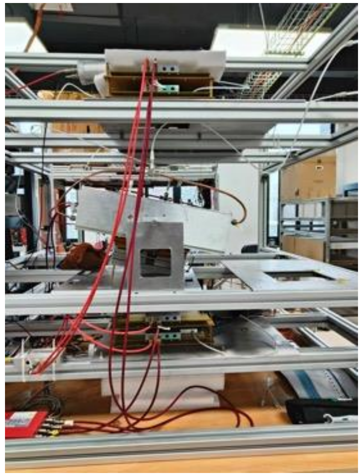
Readout board (16 chs) being tested

PID Barrel: RICH Detector R&D

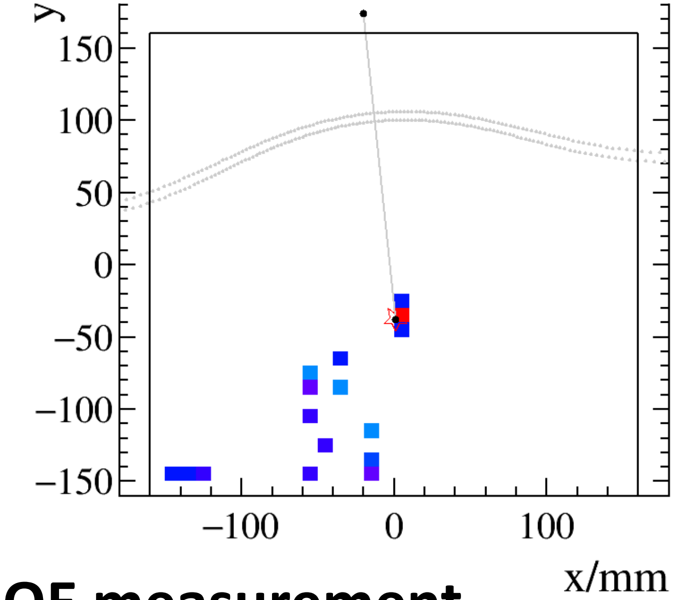
Fabrication of 30cm*30cm RICH prototype



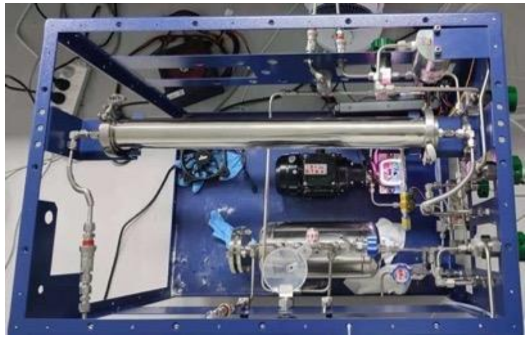
Cosmic-ray tes

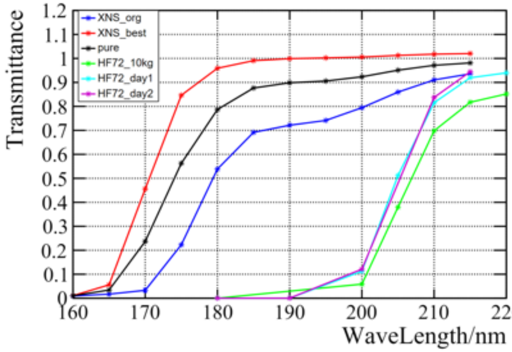


Very weak light observed
Investigation ongoing

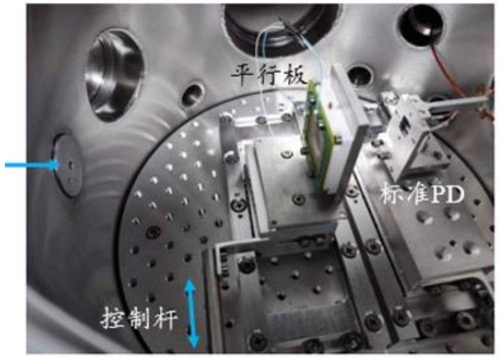


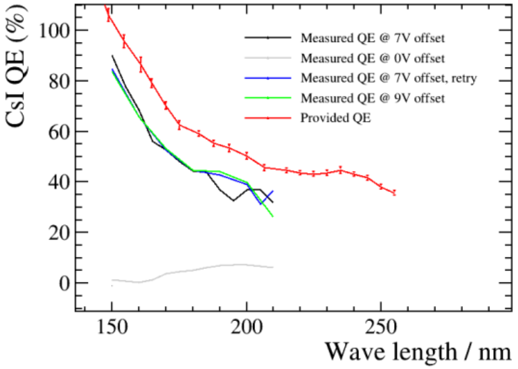
Radiator purifying





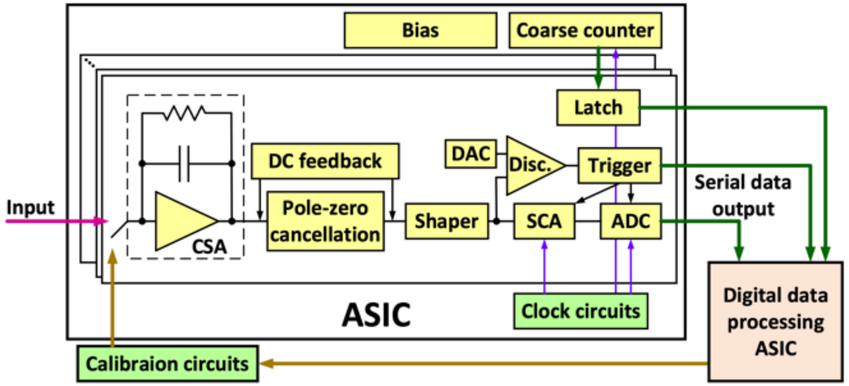
CsI coating and QE measurement

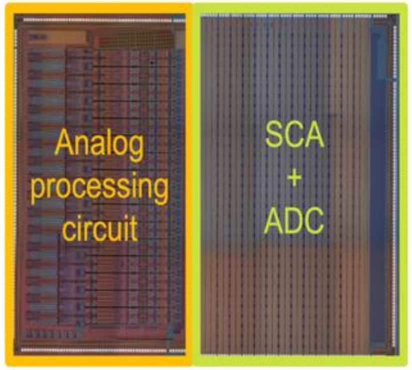




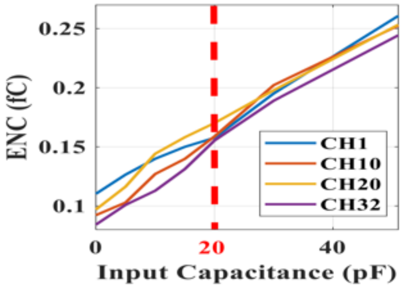
RICH Readout ASIC

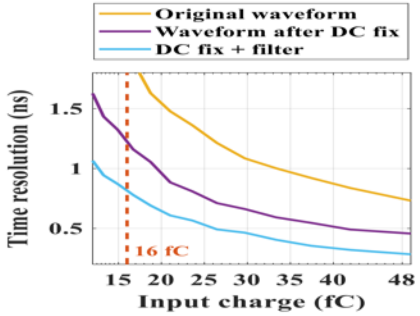
Design specs: $\sigma_t < 1\text{ns}$ @20fC&20pF, event rate ~ 100 kHz, 32 channels

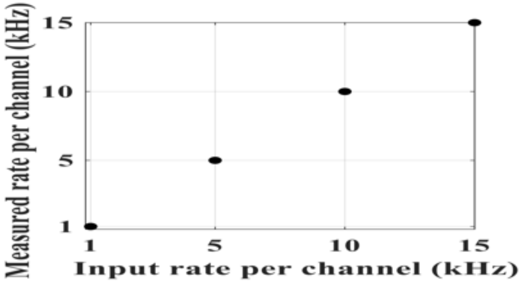




Test results

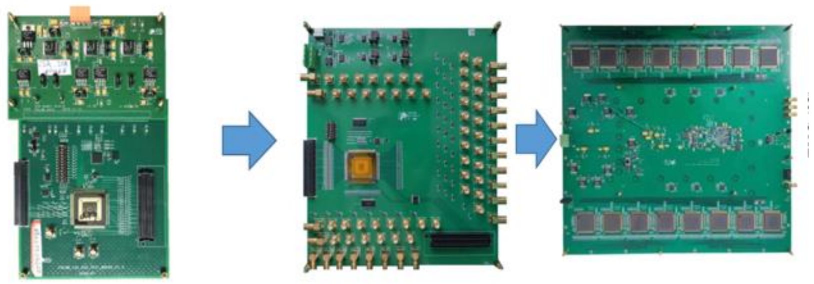


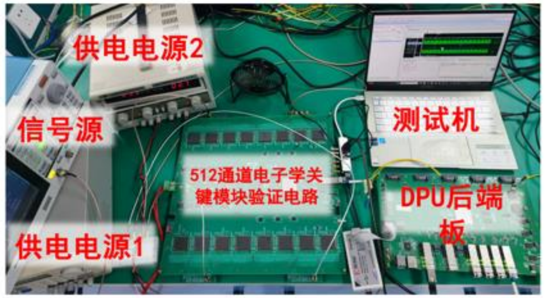




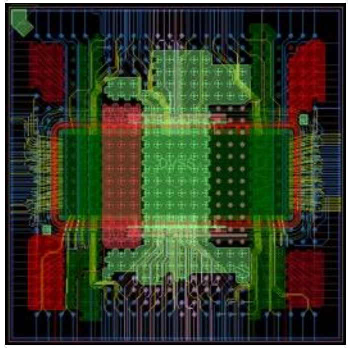
Design iterations

First version Second version



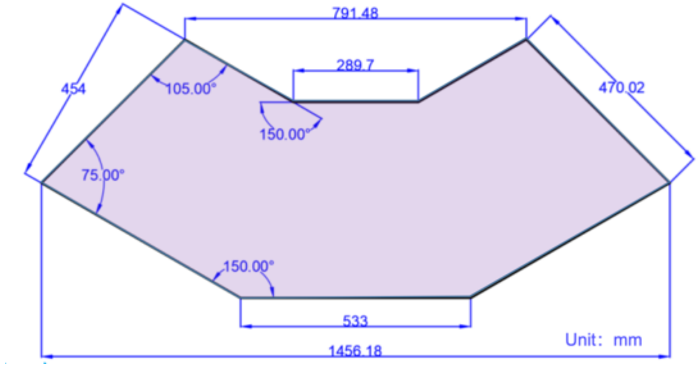


512-channel readout board using the self-developed ASIC



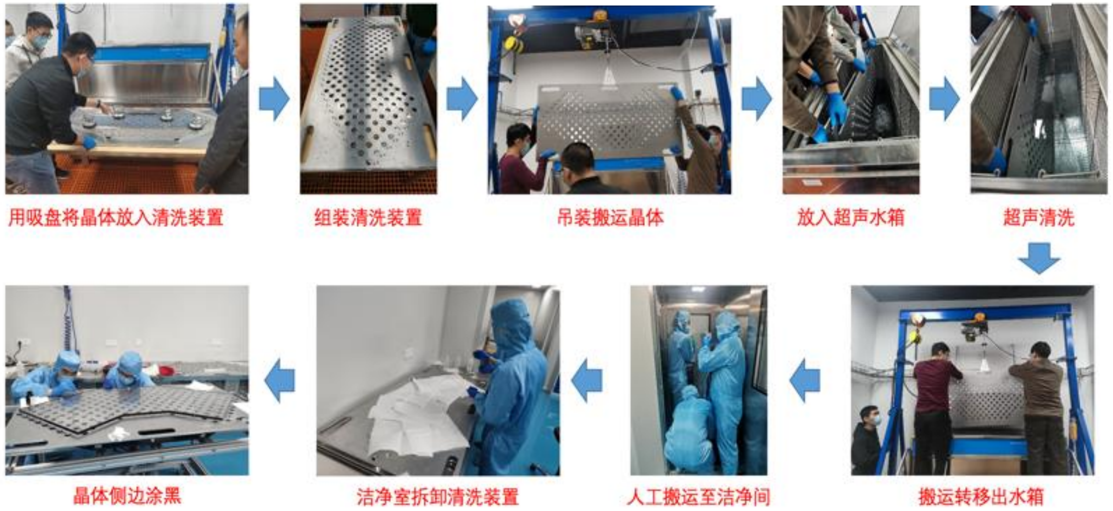
Design with 64 channels is underway

PID Endcap: A full-sized DTOF prototype

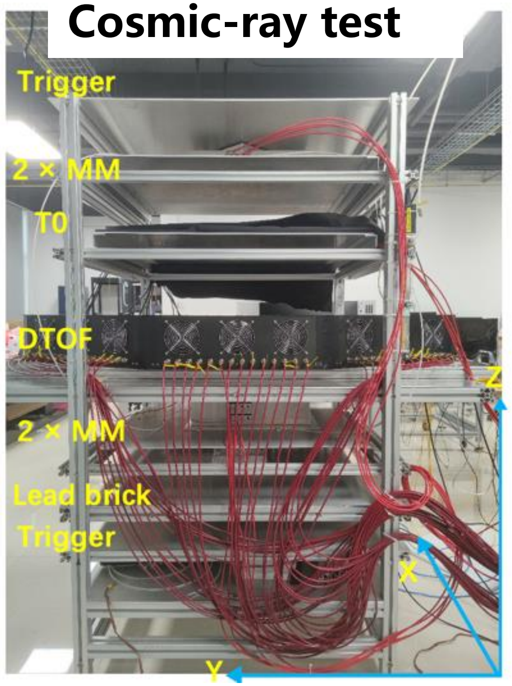


石英清洗和安装

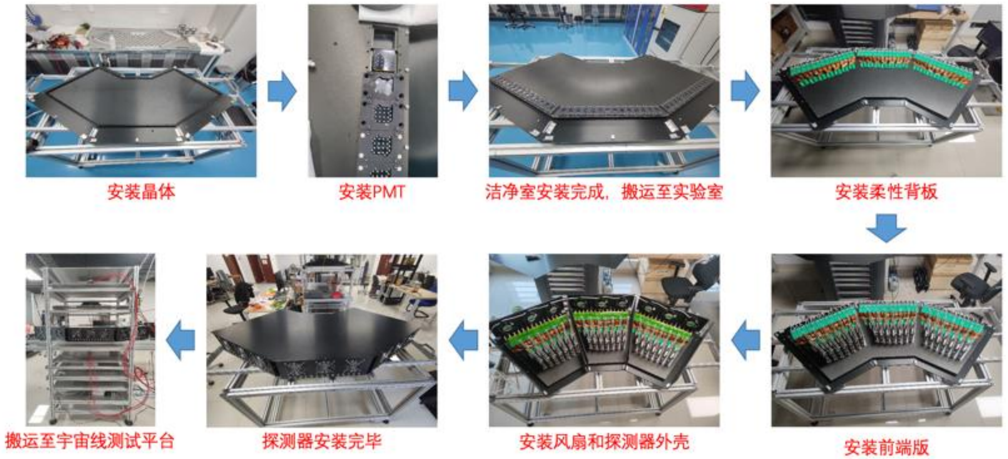
Quartz radiator cleaning and mounting

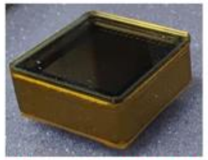


Cosmic-ray test



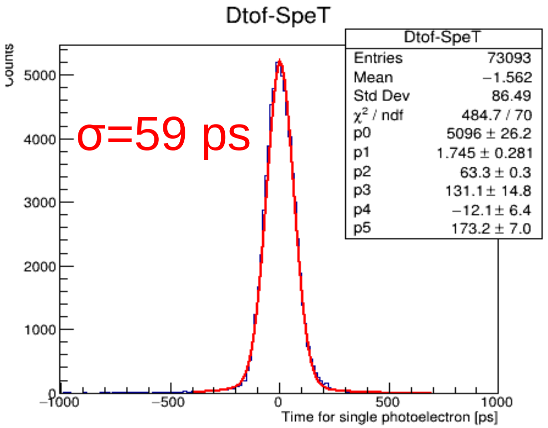
Detector assembling





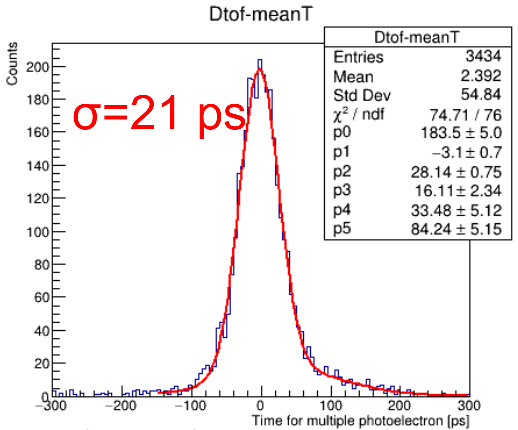
Hamamatsu R10754

- 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)



Dtof-SpeT	
Entries	73093
Mean	−1.562
Std Dev	86.49
χ^2 / ndf	484.7 / 70
p0	5096 ± 26.2
p1	1.745 ± 0.281
p2	63.3 ± 0.3
p3	131.1 ± 14.8
p4	−12.1 ± 6.4
p5	173.2 ± 7.0

single photon time resolution



Dtof-meanT	
Entries	3434
Mean	2.392
Std Dev	54.84
χ^2 / ndf	74.71 / 76
p0	183.5 ± 5.0
p1	−3.1 ± 0.7
p2	28.14 ± 0.75
p3	16.11 ± 2.34
p4	33.48 ± 5.12
p5	84.24 ± 5.15

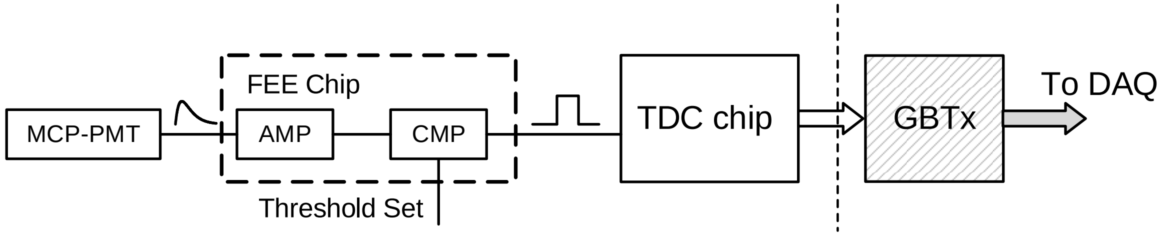
Single track time resolution

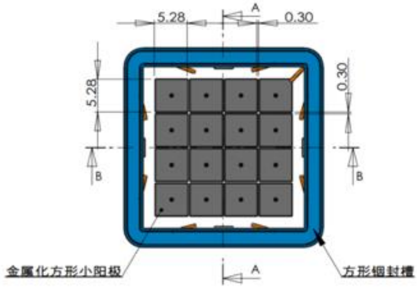
See https://indico.cern.ch/event/1291157/contributions/5888464/ for details

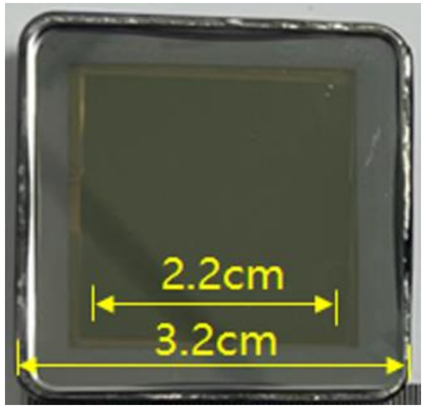
DTOF R&D on MCP-maPMT and Readout ASICs

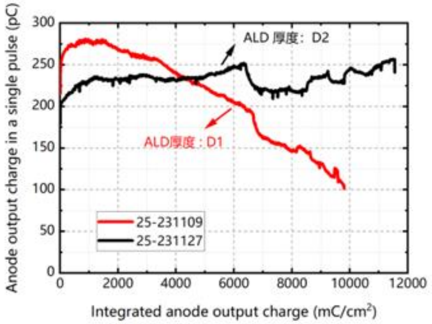
- **MCP-maPMT: a critical component of the DTOF technology**
- **Designed and produced 1-inch MCP-maPMT with 16 annodes, TTS < 40 ps**
- **Intensive R&D on techniques (ALD and electron scrubbing) to produce long-life MCP-PMT (target >10 C/cm²)**

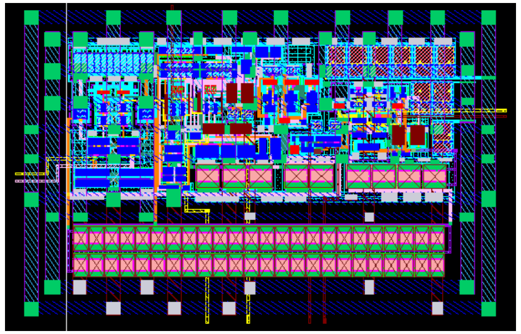
- **Two ASICs designed for MCP-maPMT readout.**
  - **FET (to be taped out in July) ~ 15 ps**
  - **TDC (taped out) ~ 15 ps**

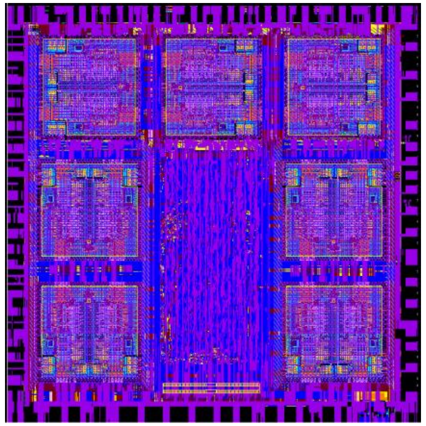






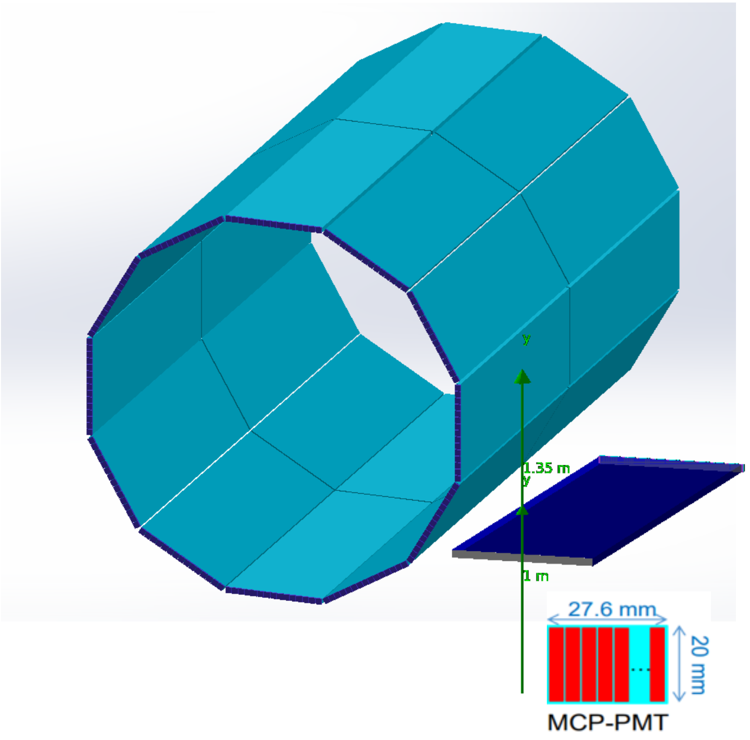


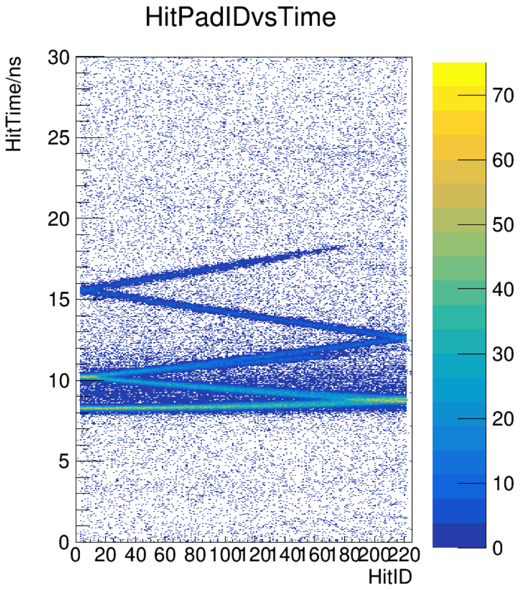


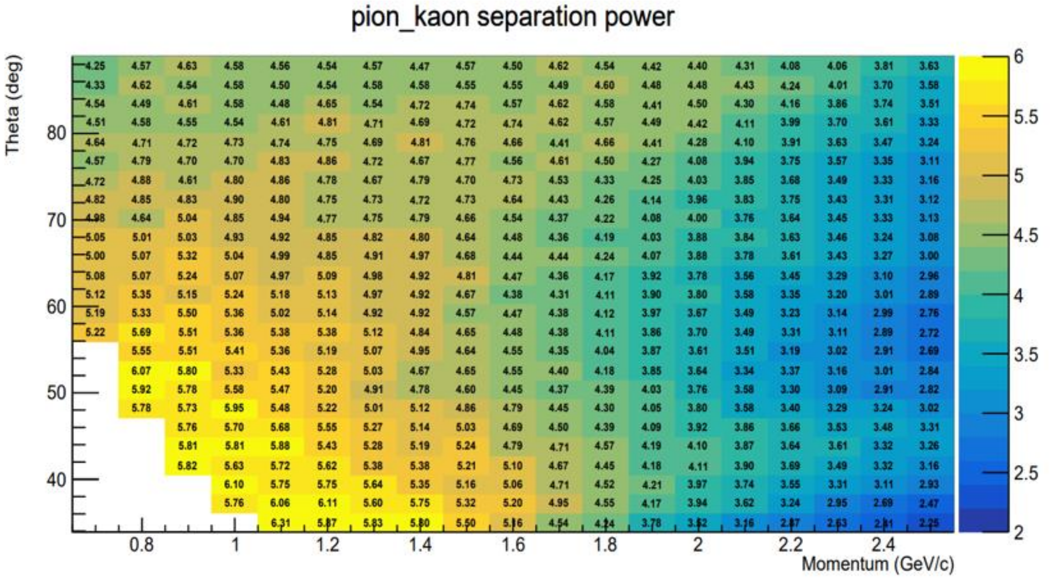


Application of DTOF in Barrel

- 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



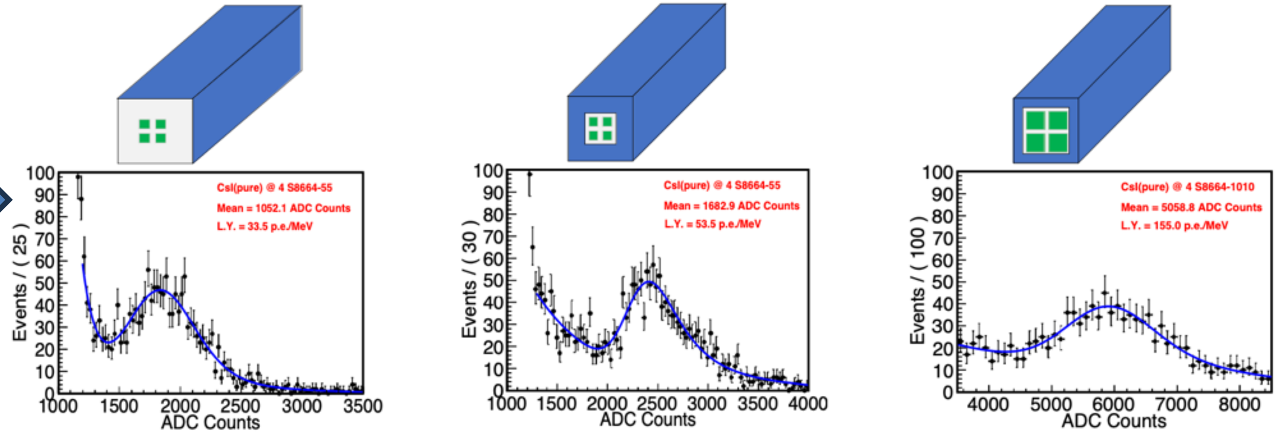


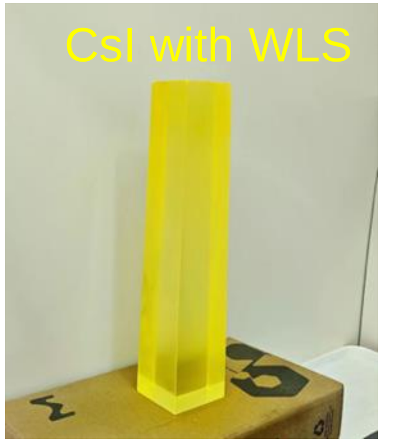


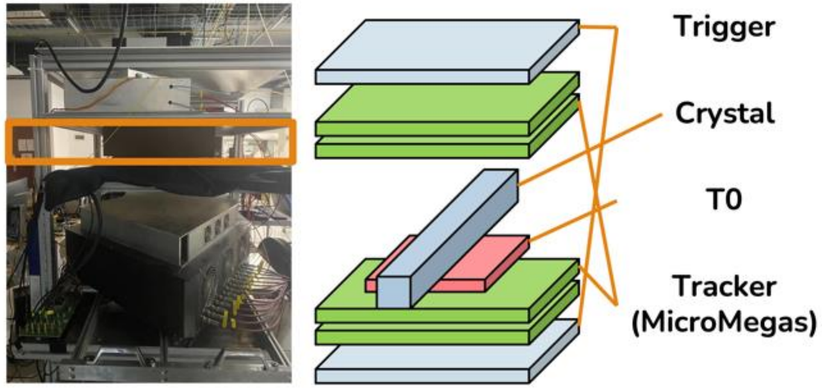
pCsI EMC : Light yield and timing studies

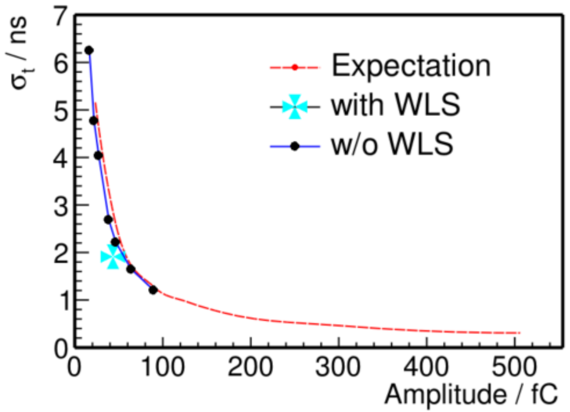
A major R&D task : enhancing light yield

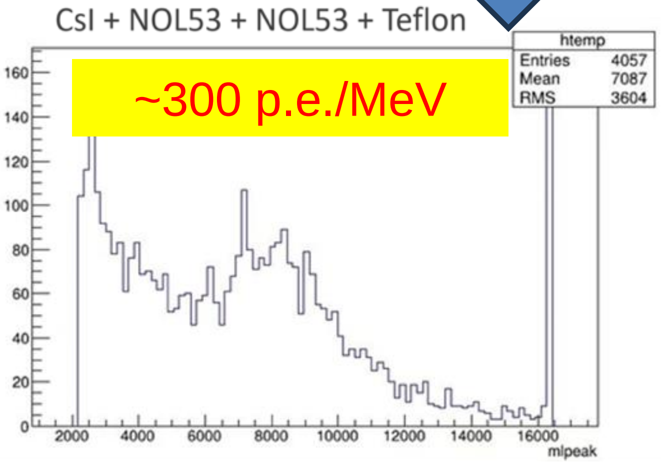
reflector: 225um thick Teflon









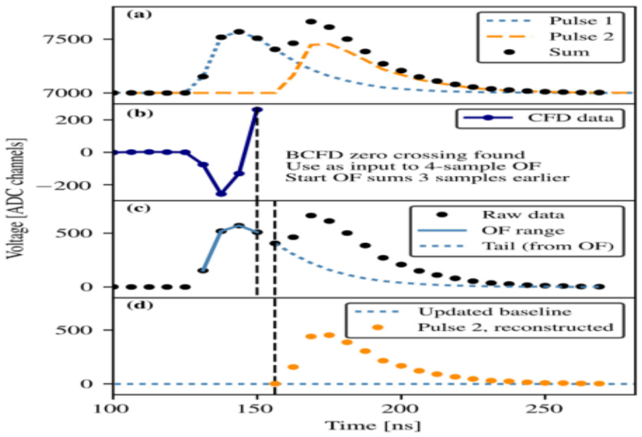


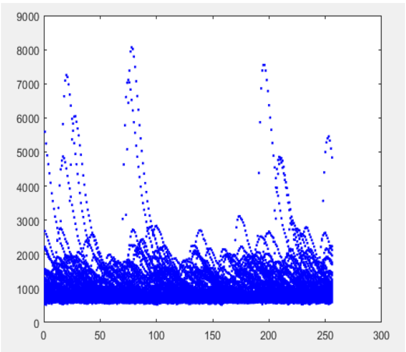
σ_t : 2.0 ns @ 0.03 GeV， 0.8 ns @ 0.1 GeV

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

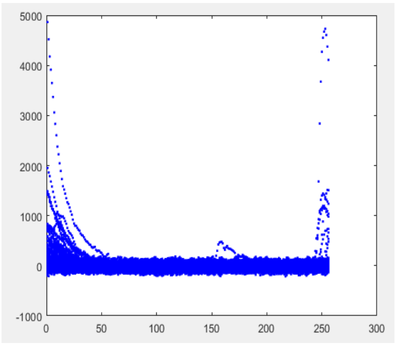
pCsI EMC : Pileup mitigation and electronics

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

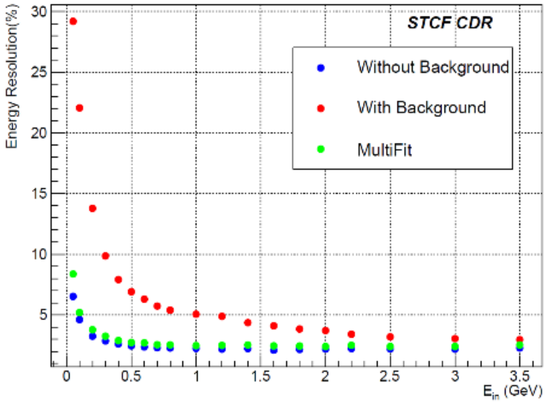




Before

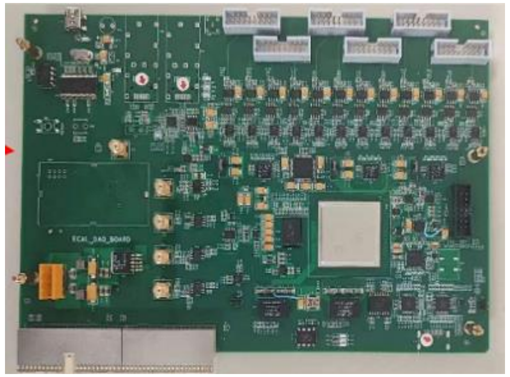


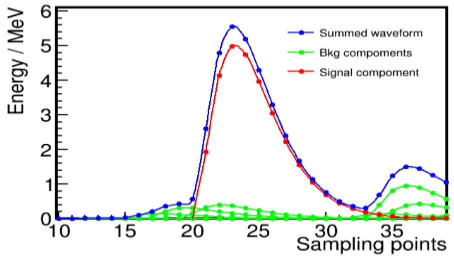
After

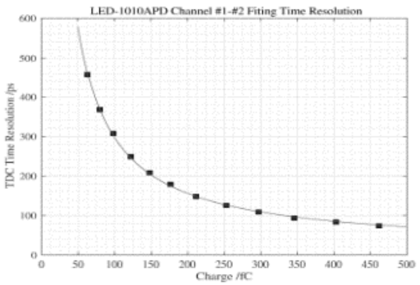


Very effective in mitigating the pileup effect

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





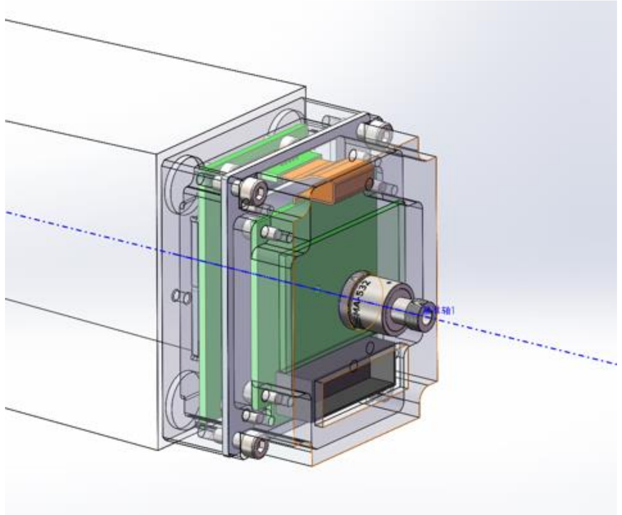
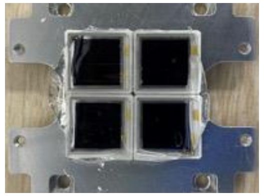


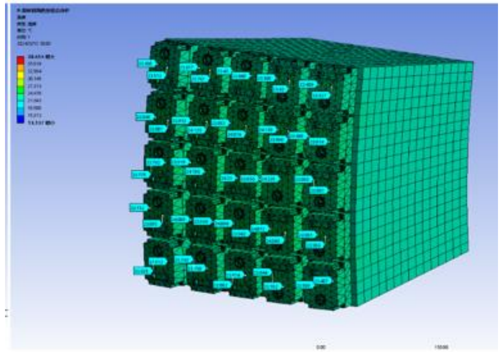
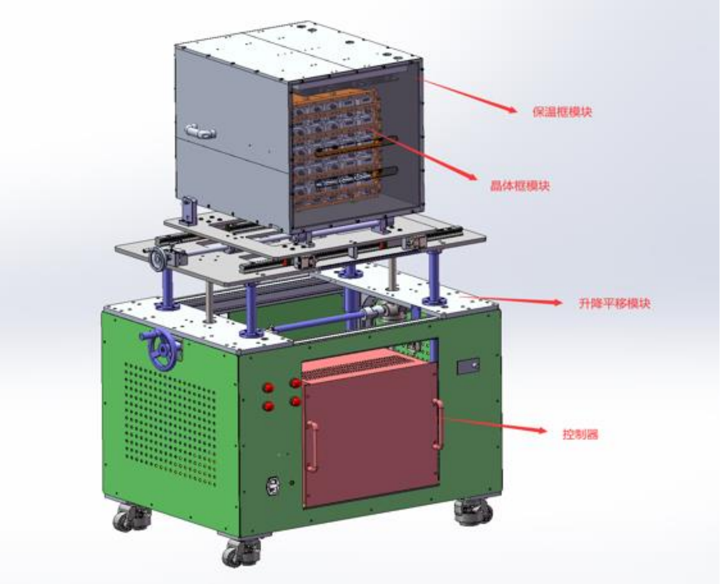
Dynamic range：
3 MeV ~ 3 GeV

ENE： ~ 0.4 MeV

Time resolution :
< 150 ps@1GeV

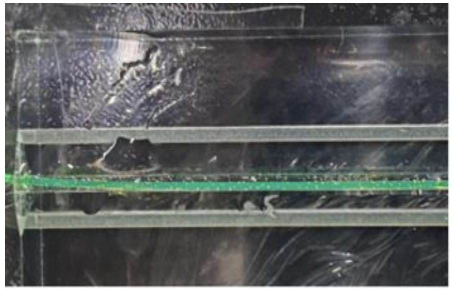
5×5 pCsI EMC Prototype

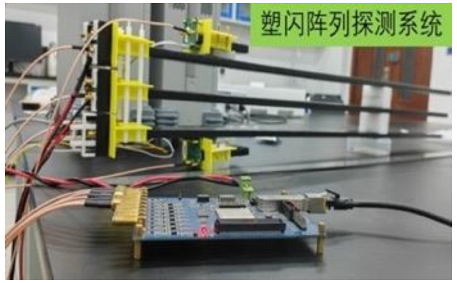




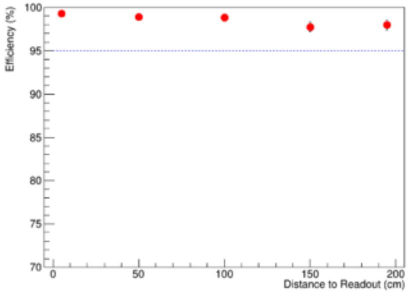




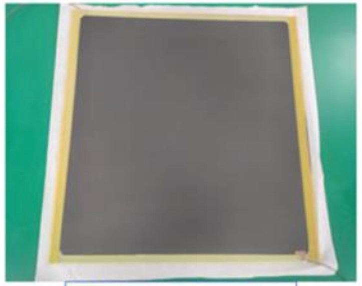
MUD R&D

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



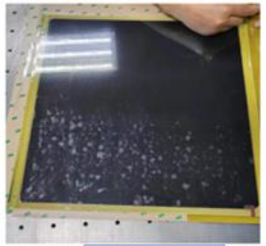

塑闪阵列探测系统



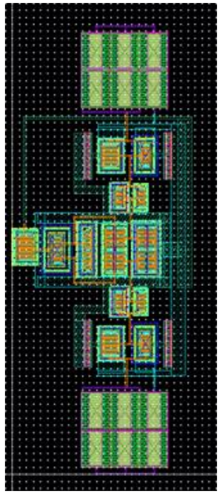

HV electrode painting

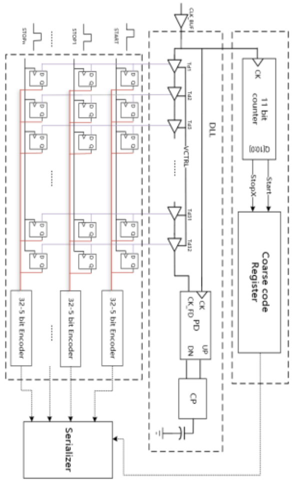

Applying insulation film

Gas-tight check


Finished gap

- **Design of readout ASICs (FEE +TDC) is underway. Readout electronics with discrete components has been developed for detector testing and characterization**





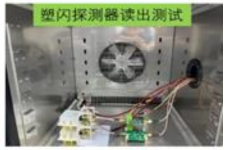

8通道探测器读出电子学板


RPC探测器读出测试


RPC信号前放板

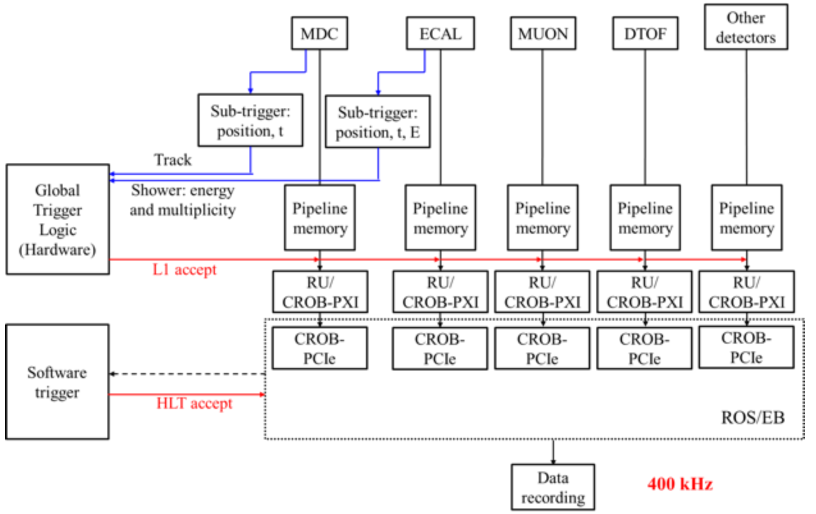

SenSL SiPM信号适配板


SiPM信号前放板


塑闪探测器读出测试

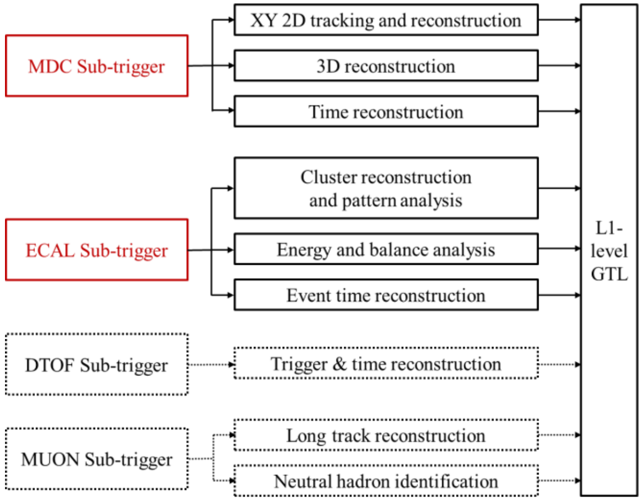
Trigger and DAQ

Physics event rate ~ 400 kHz

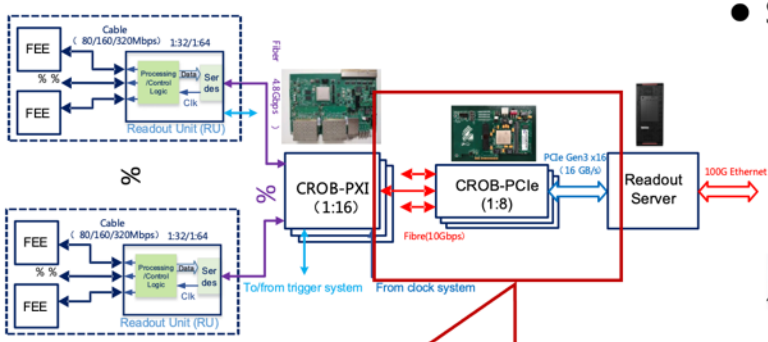


Component	Num. of channels	Readout time window	Event size (B)	Total (B/s)
ITK (Silicon)	50M	500 ns	14300	5.72G
ITK (μRWELL)	10552	500 ns	17232	6.89G
MDC	11520	1 μs	20400	8.16G
PID (RICH)	518400	500 ns	15600	6.24G
PID (DTOF)	6912	500 ns	7380	2.95G
EMC	8670	500 ns	15000	6.00G
MUD	41280	500 ns	262	105M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

Raw data rate > 200 GB/s , triggered data rate ~ 30 GB/s

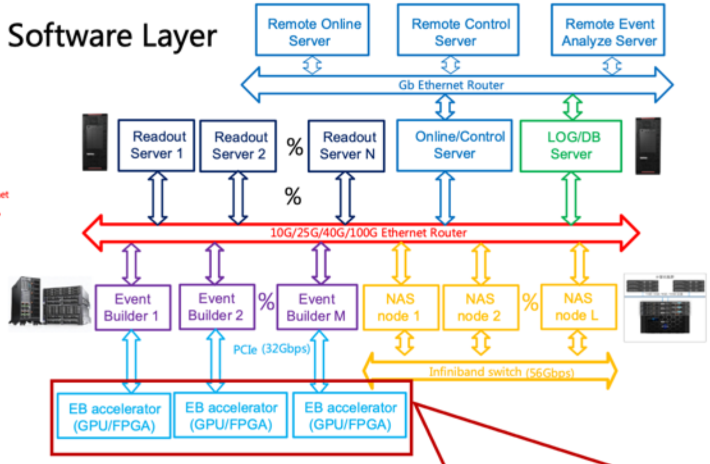


- FPGA Layer



Optional：
FPGA 10G Ethernet core： FPGA → Computer Farm

- Software Layer

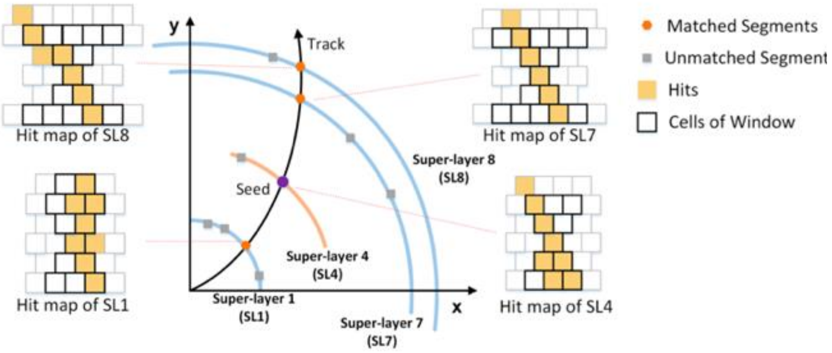


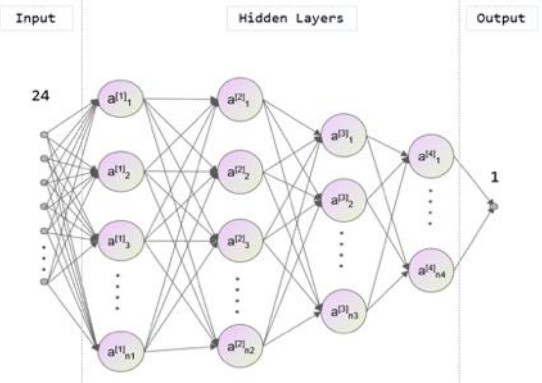
Optional： heterogeneous computing based on FPGA and/or GPU

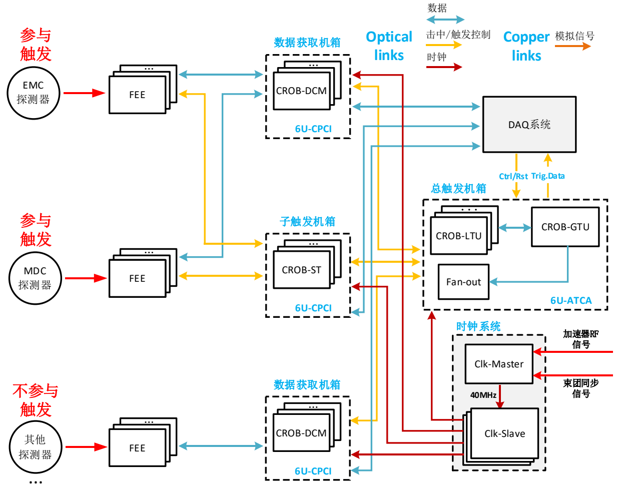
Trigger Algorithms and hardware Development

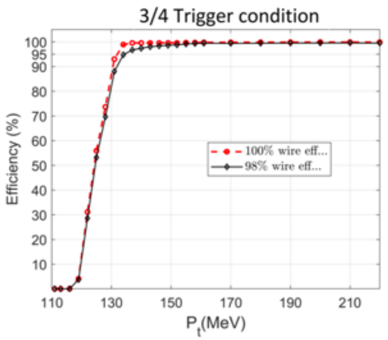
- **MDC 2D and 3D tracking algorithms, EMC clustering algorithms, global trigger algorithms.**
- **PFGA programming to realize the algorithms**

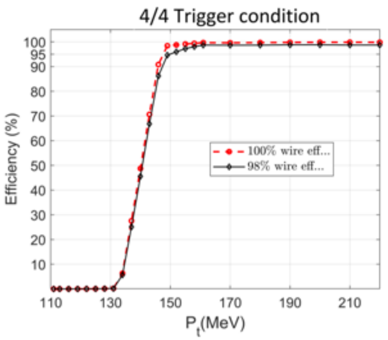
- **Design of trigger electronics and development of core hardware components**

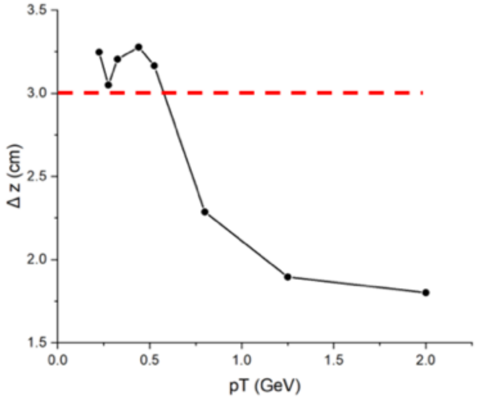


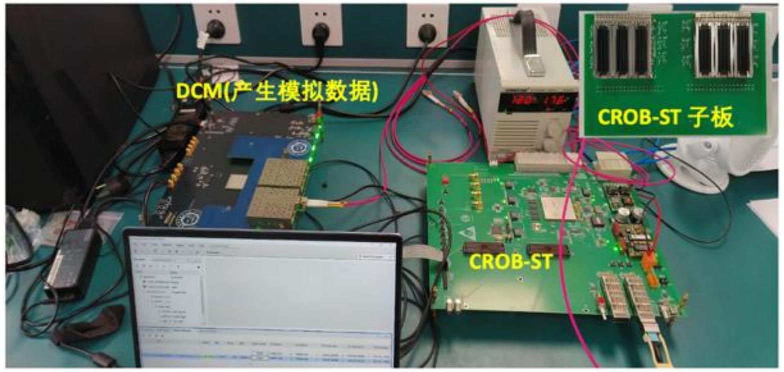






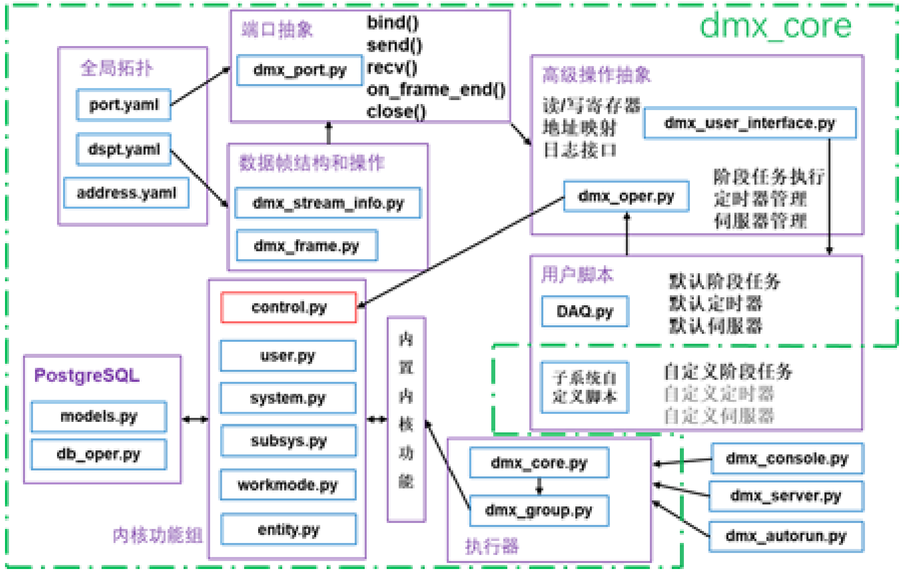




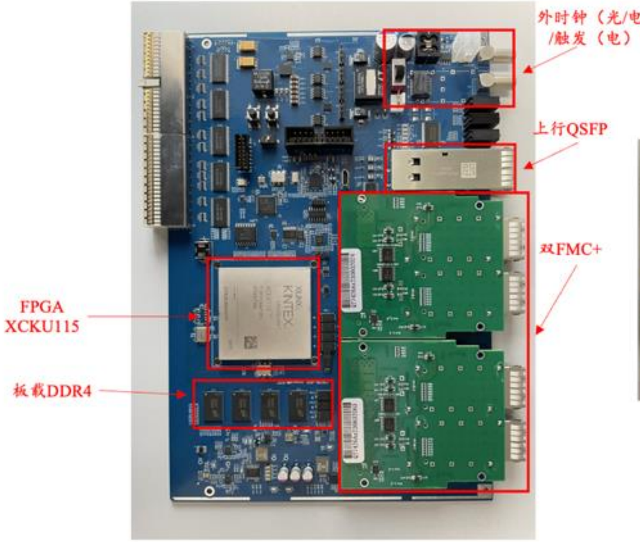


DAQ Software Design and Hardware Development

- **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**

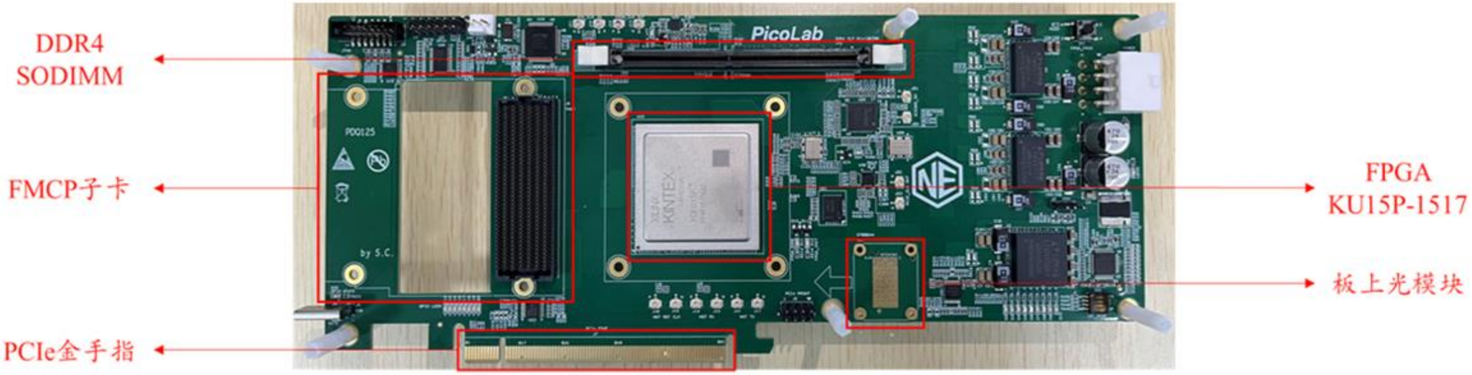


CROB-PXI board



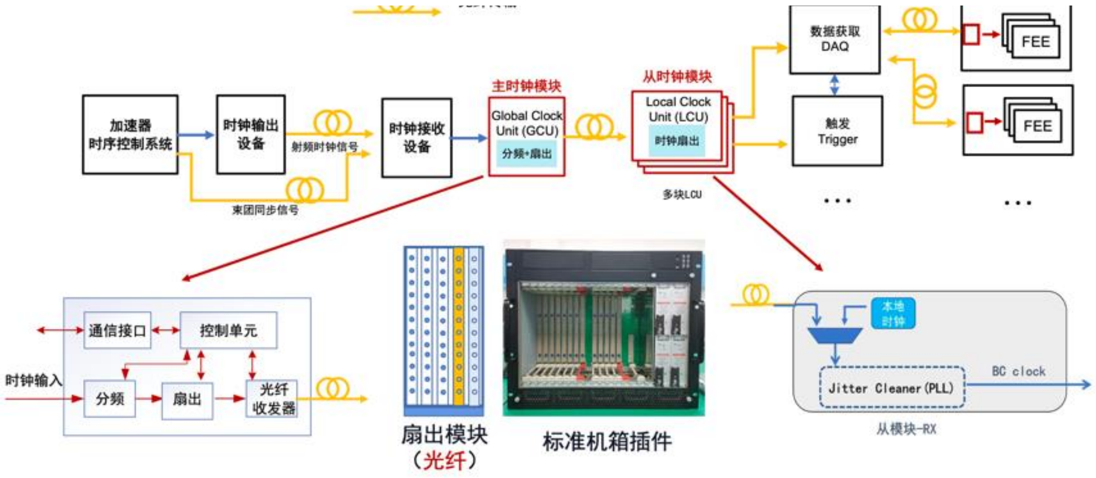
FMCP optical interface board

CROB-PCIe board



Clock and Data Transmission

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



扇出模块（光纤）

标准机箱插件

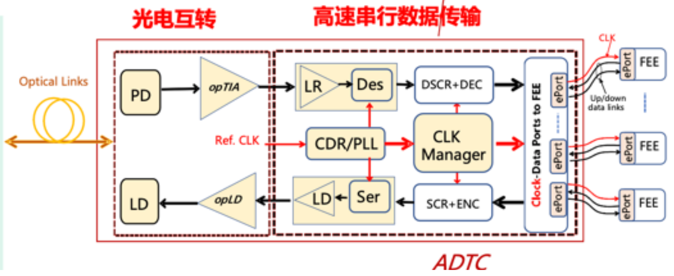
- **High-speed data transmission : ~ 5Gpbs**

关键技术分为以下**4个部分**
→ **时钟模块**
- 时钟恢复（CDR）、时钟锁相环（PLL）、高精度时钟管理（分频、移相、去噪等）

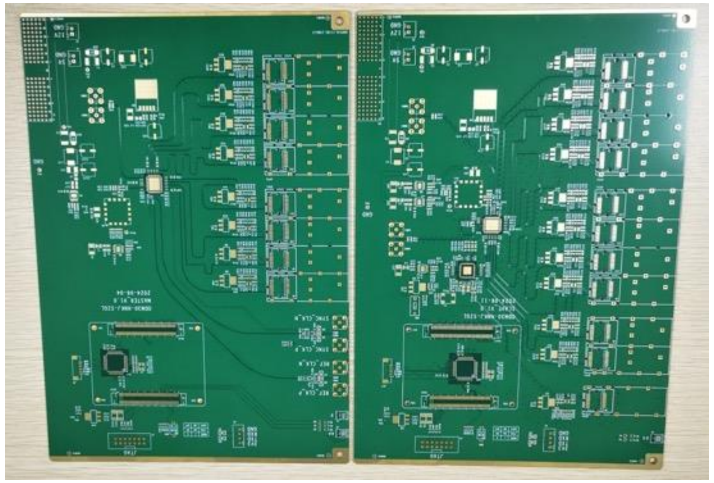
→ **高速数据发送模块**
- 数据编码调制（SCR+ENC）、串并转换（SER）、光驱动及输出（opLD+LD）

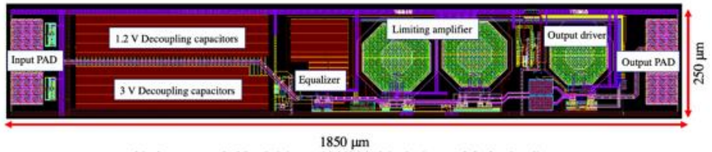
→ **高速数据接收模块**
- 光接收（PD+opTIA）,串并转换（DES）、译码解调（DSCR+DEC）

→ **数据处理单元**（如控制译码、ePort接口等）

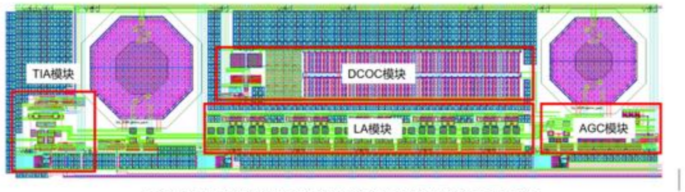


ADTC, an analogue of GBTx

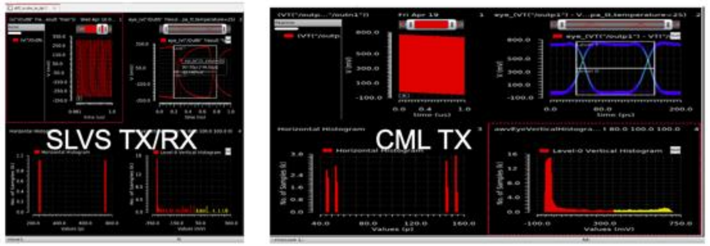




激光器驱动芯片单通道模拟核心版图基本完成



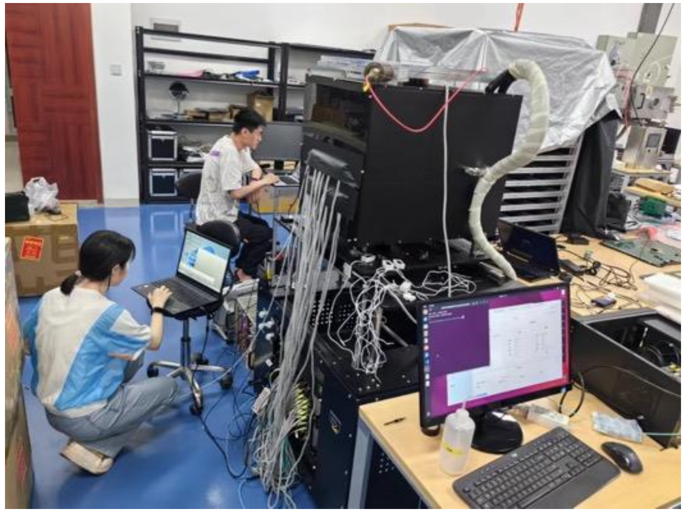
TIA跨导接收芯片单通道模拟核心基本完成

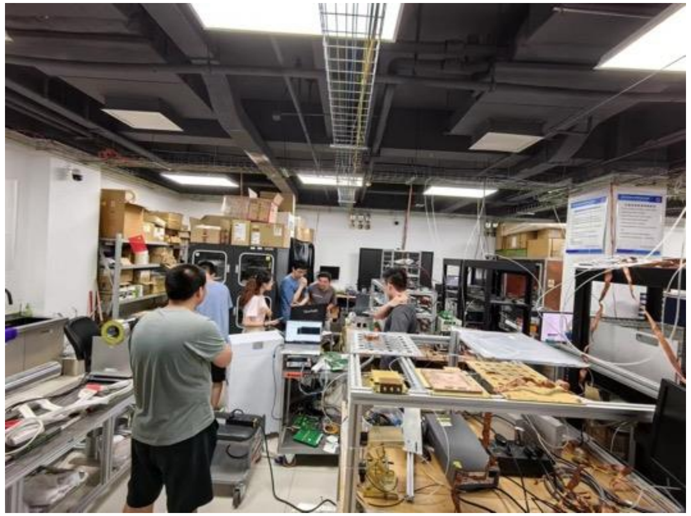


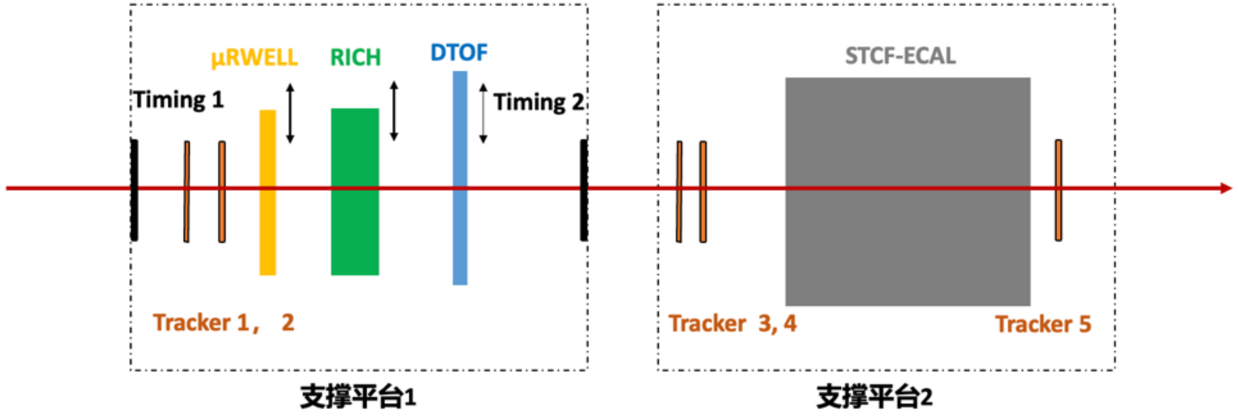
Clock management block

Test Beam Campaign

DTOF and EMC prototypes are combined in a single TDAQ system for test beams
The past two months were a frenzy of preparing and tunning the combined system, and packaging everything.



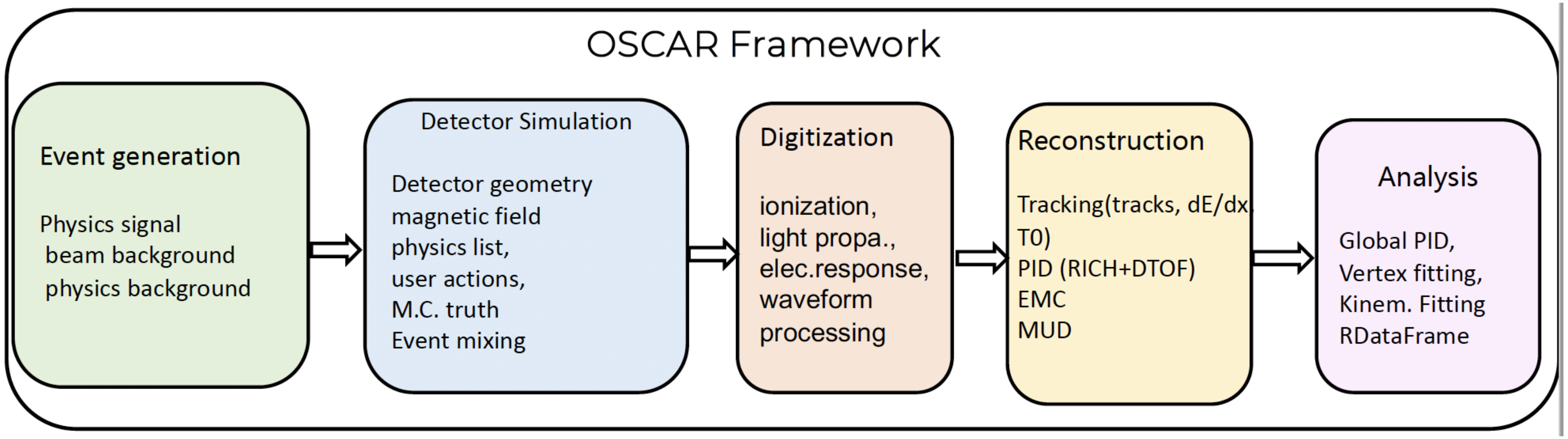




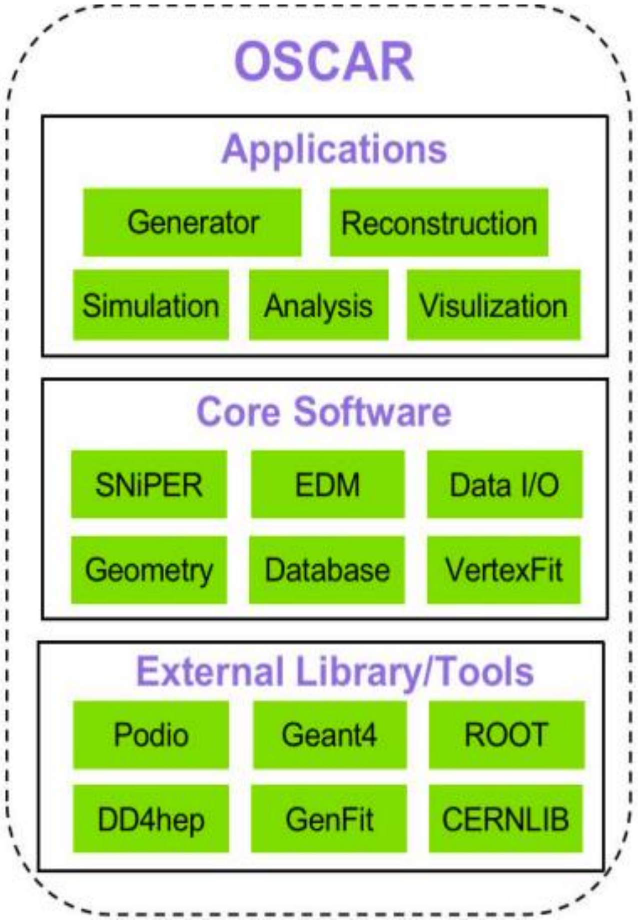
Starting from July 31
Lasting for 2 weeks
CERN PS T9 beam line

Offline Software of Super Tau-Charm Facility （OSCAR）

- OSCAR is based on light-weight and flexible **SNiPER** framework and adopted some state-of-the-art software and computing techniques
  - **Podio** for Event Data Model
  - **DD4hep** for detector description
  - **TBB** for multi-threading
  - **ONNX** for machine learning
- Established the **Full Chain** of the STCF offline data processing



Architecture of OSCAR: three layers



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.
- It is crucial to expand collaboration and explore synergies with other projects.

Thank you !