超級陶粲裝置

Super Tau-Charm Facility

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CHiP Cross-Strait Workshop on Advanced Detectors and Technologies

國立中央大學物理學系, 中央研究院物理研究所

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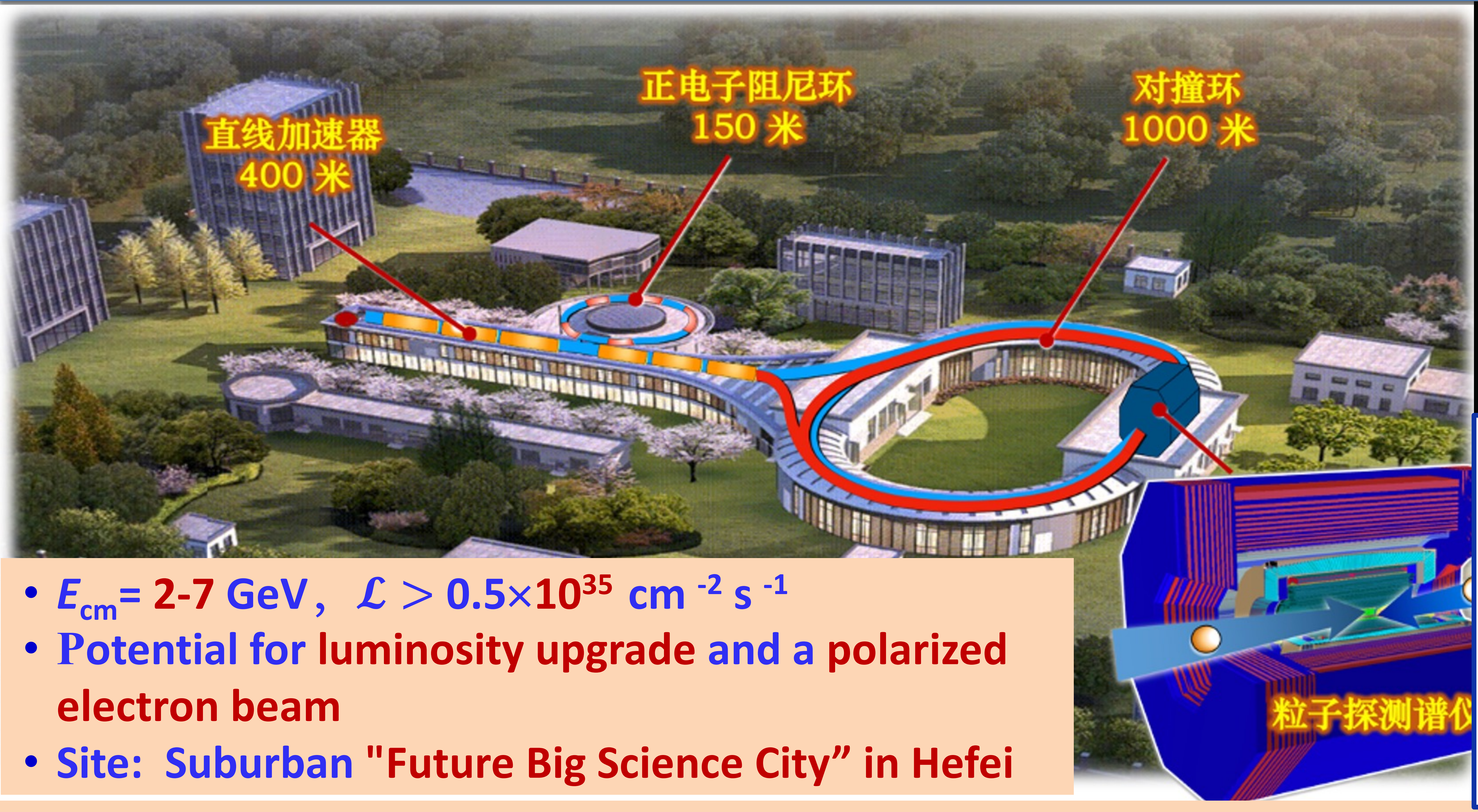
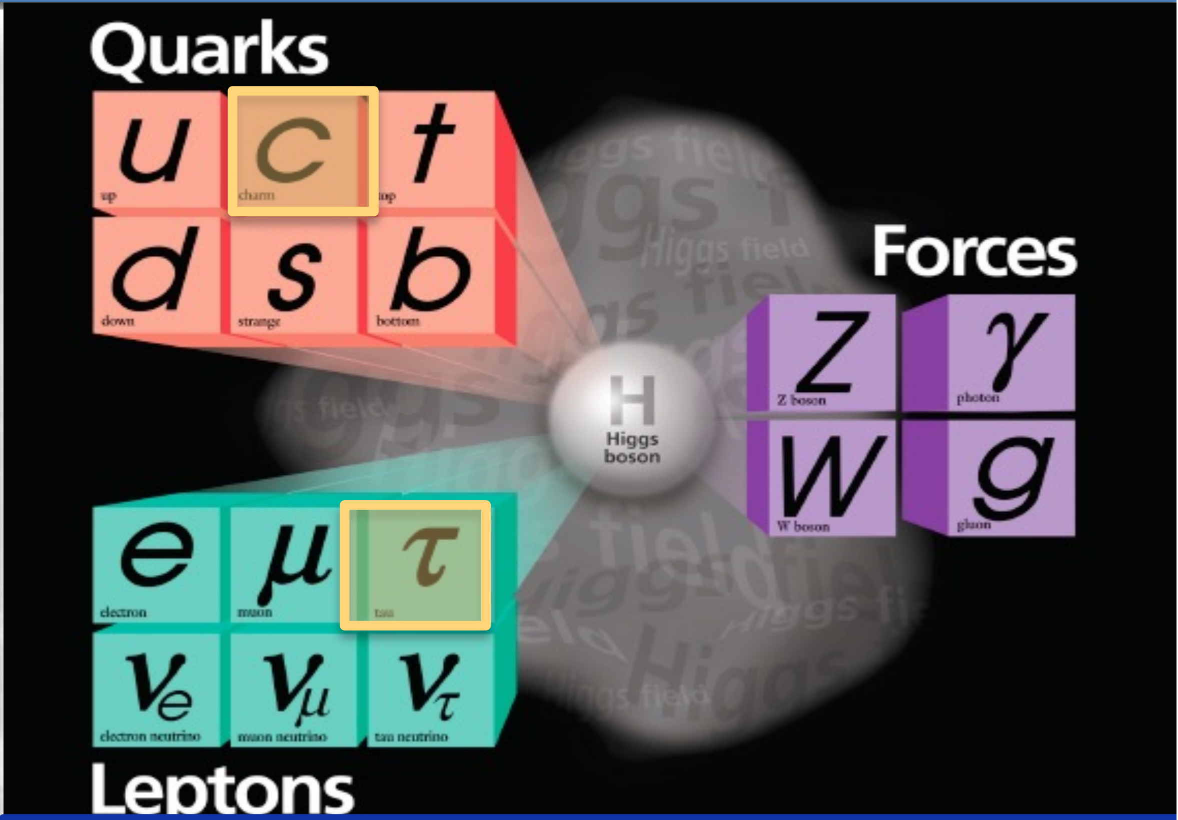
Super Tau Charm Facility (STCF)





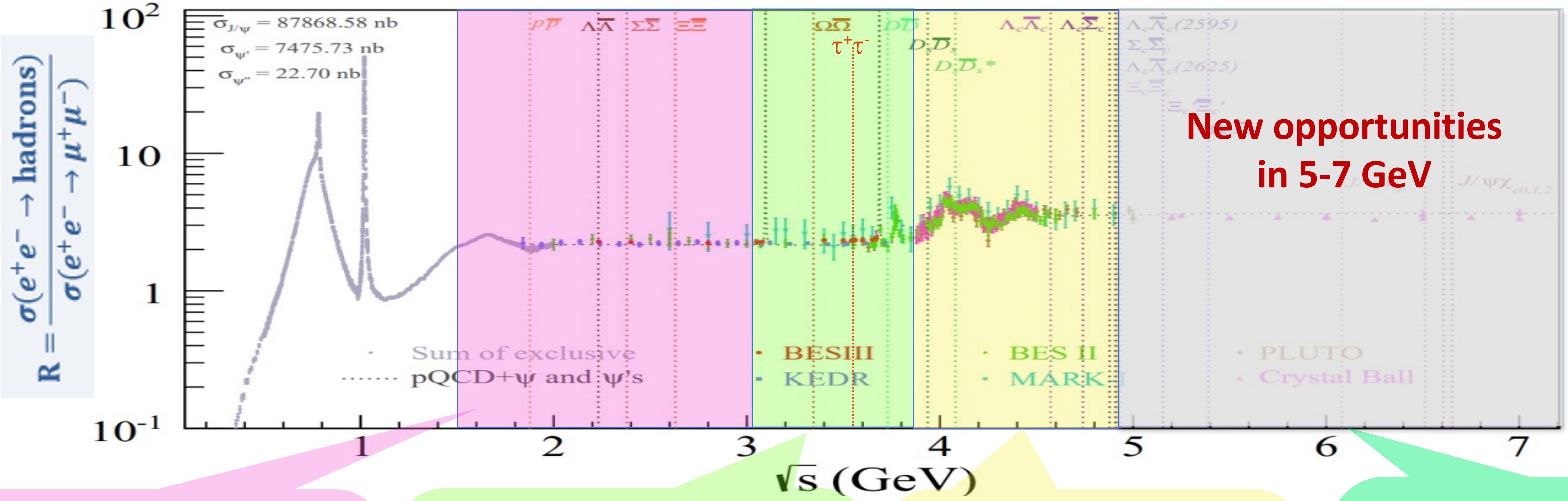
- E_{cm}= 2-7 GeV， $\mathcal{L} > 0.5\times10^{35}$ cm $^{-2}$ s $^{-1}$
- Potential for luminosity upgrade and a polarized electron beam
- Site: Suburban "Future Big Science City" in Hefei

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

2-7 GeV: Unique Features, Broad Physics Spectrum

- **Transition region** between perturbative and non-perturbative QCD
- **Rich** resonant structures, **large production cross-sections** for charmonium states
- **Pair production** of hadrons and tau leptons **at threshold**
- Copious production of **exotic hadrons** (multi-quark, gluonic and hybrid states)



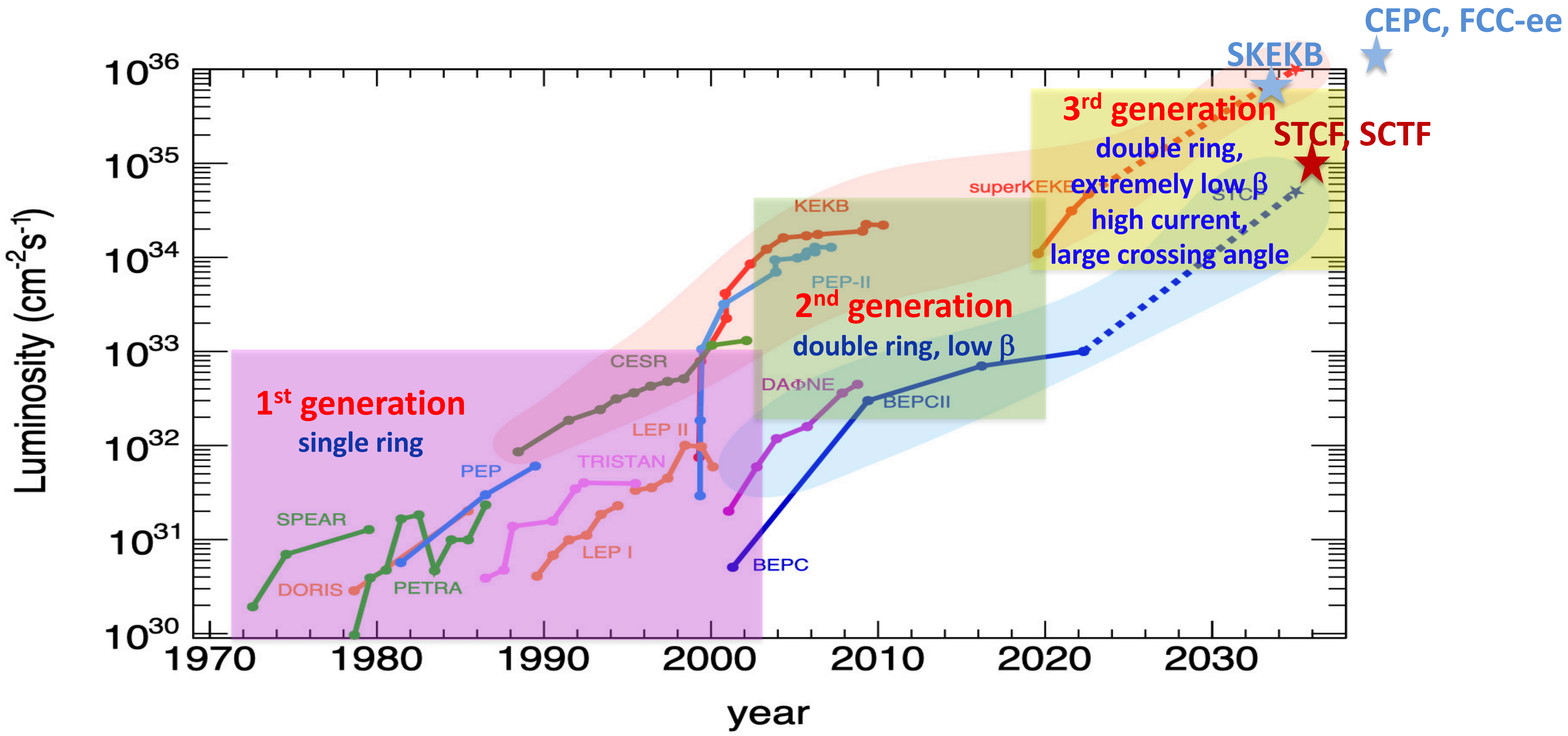
- Nucleon/Hadron form factors
- Y(2175) resonance
- Mutltiquark states with s quark
- MLLA/LPHD and QCD sum rule predictions

- Light hadron spectroscopy
- Gluonic and exotic
- LFV and CPV
- Rare and forbidden decays
- Physics with τ lepton

- XYZ particles
- Physics with D mesons
- f_D and f_{D_s}
- D_0-$\overline{D}_0$ mixing
- Charm baryons

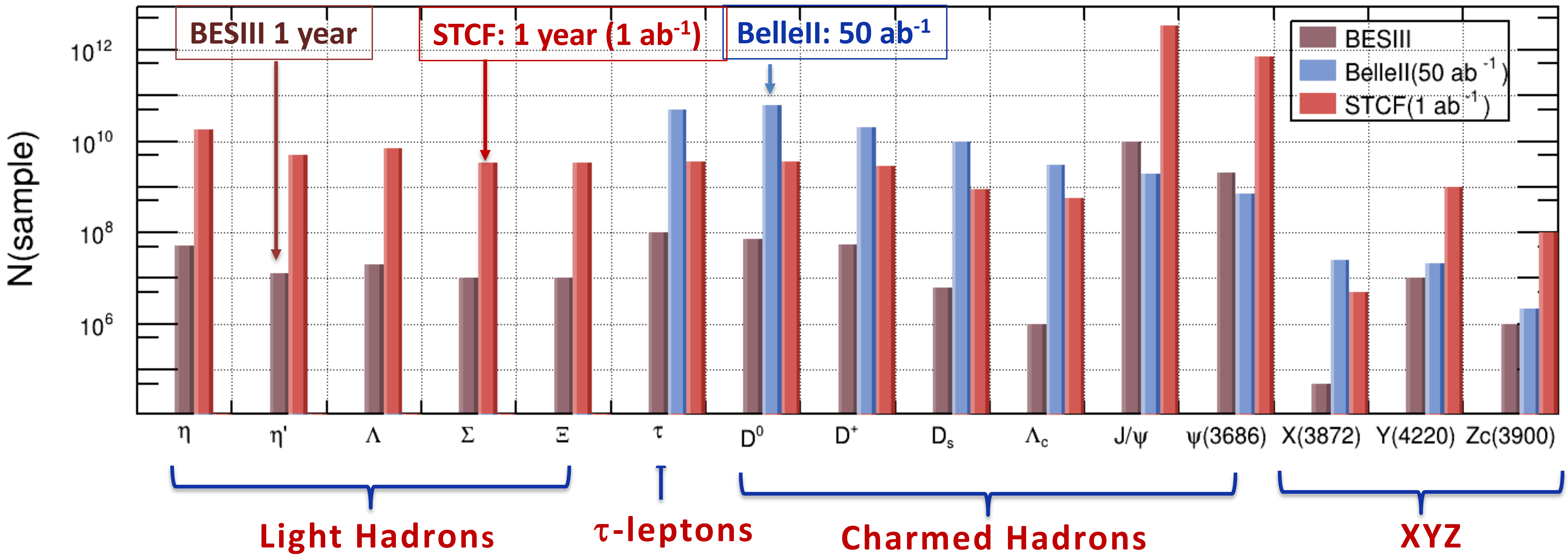
- New XYZ particle
- Hidden-charm pentaquark
- Di-charmonium state
- Charm baryons
- Hadron fragmentation

STCF in Context



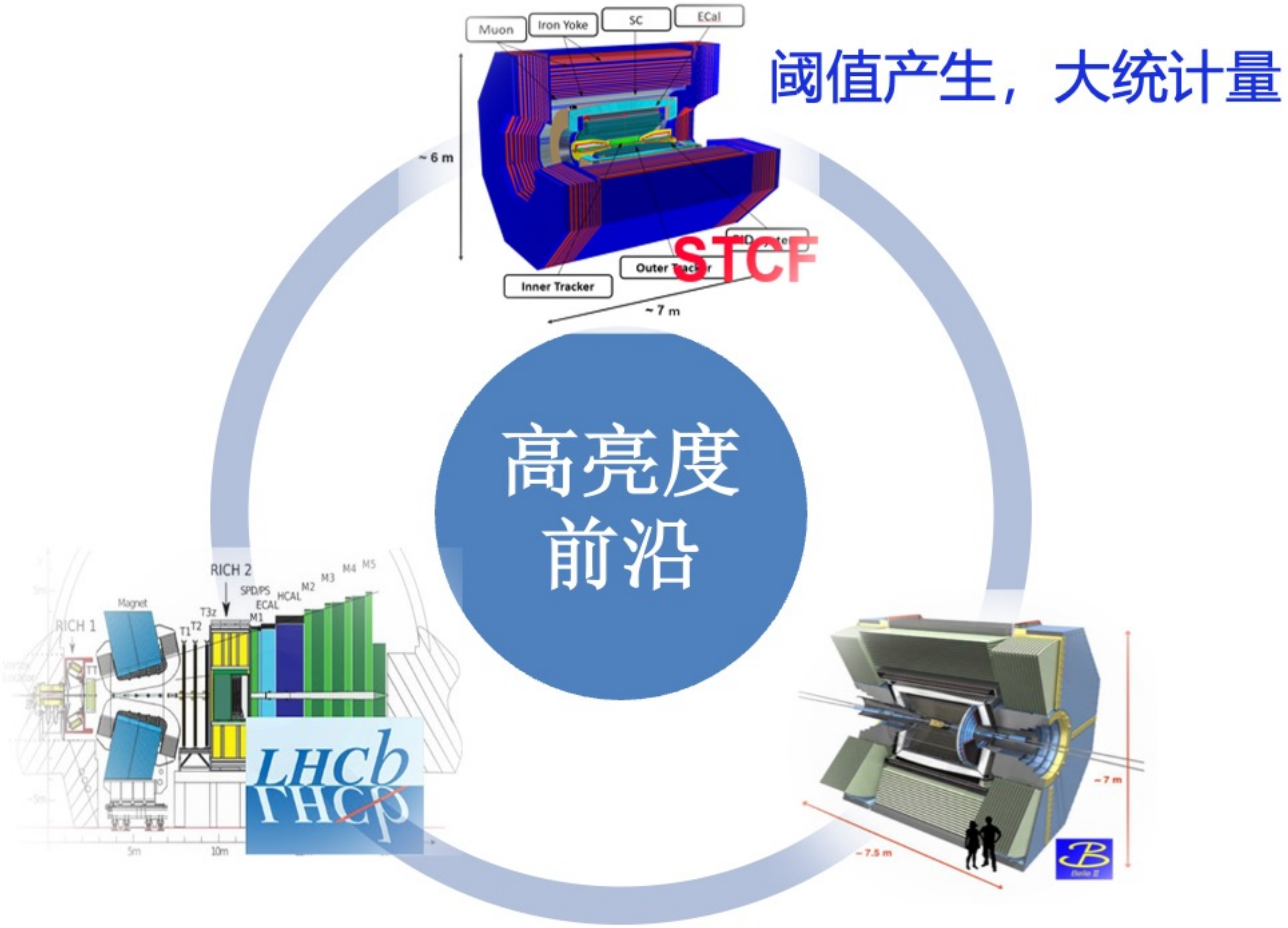
STCF: A 3rd generation e^+e^- machine with super-high luminosity in τ-c region

A Super Factory of Various Particles



- Not only a τ-charm factory, but also a factory of XYZ, hyperons and light hadrons

Physics at STCF

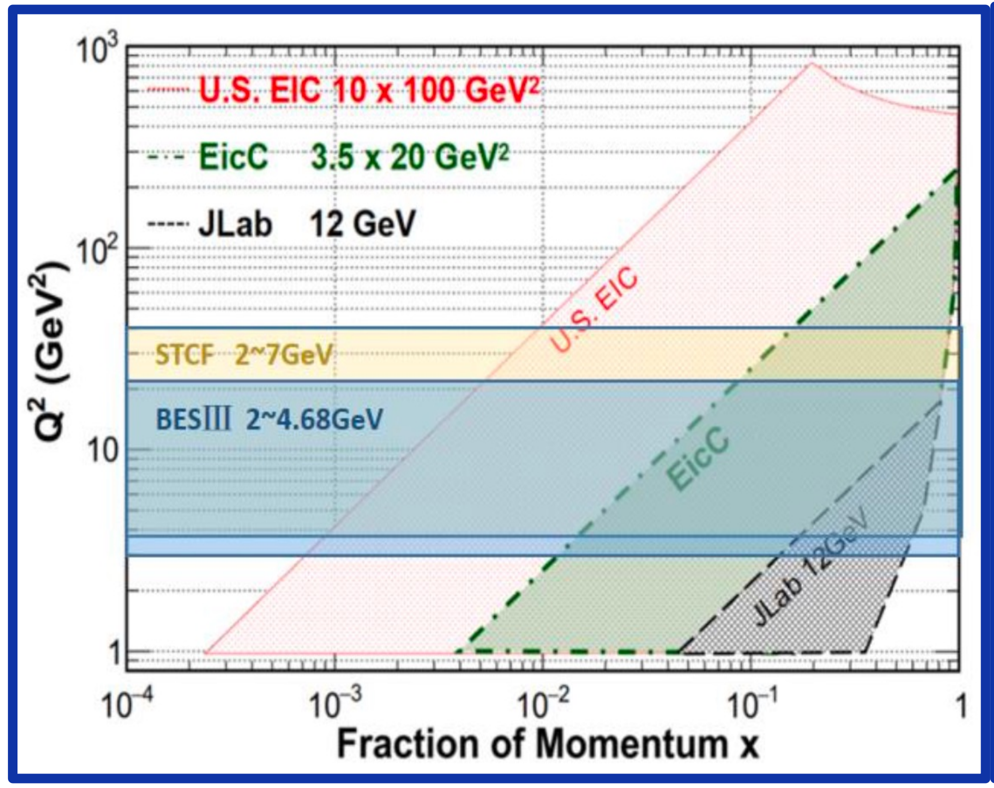


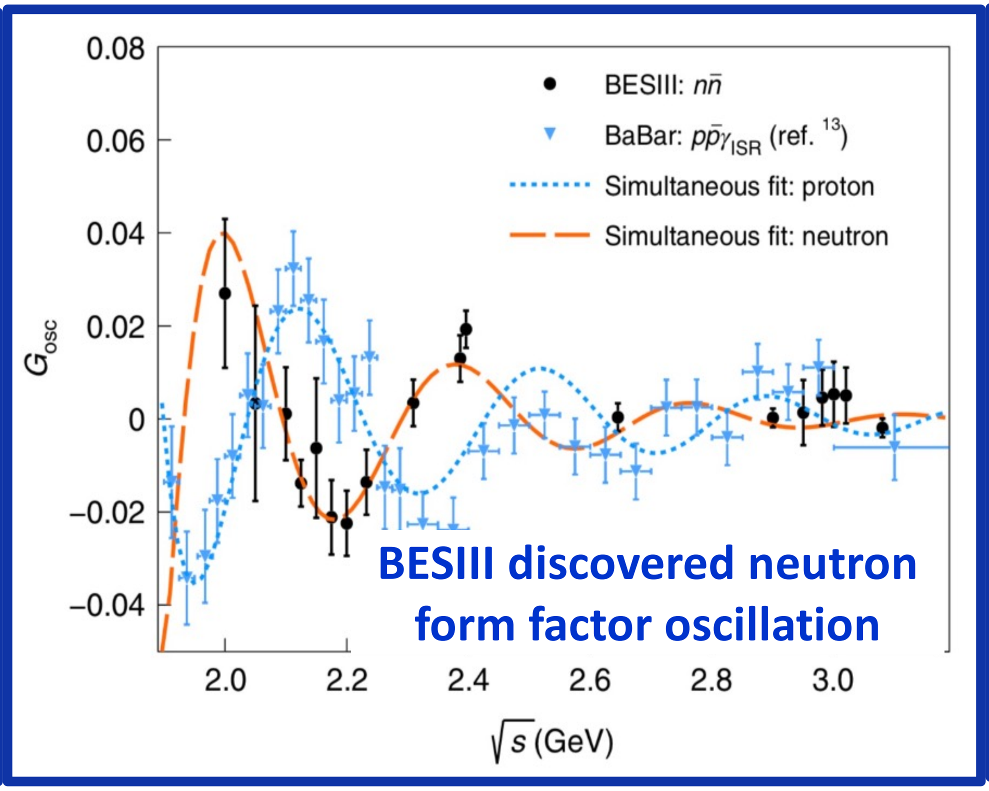
- **Leading role**
- In competition with Belle II/LHCb
- **In synergy with BelleII/LHCb/Eic/EicC**

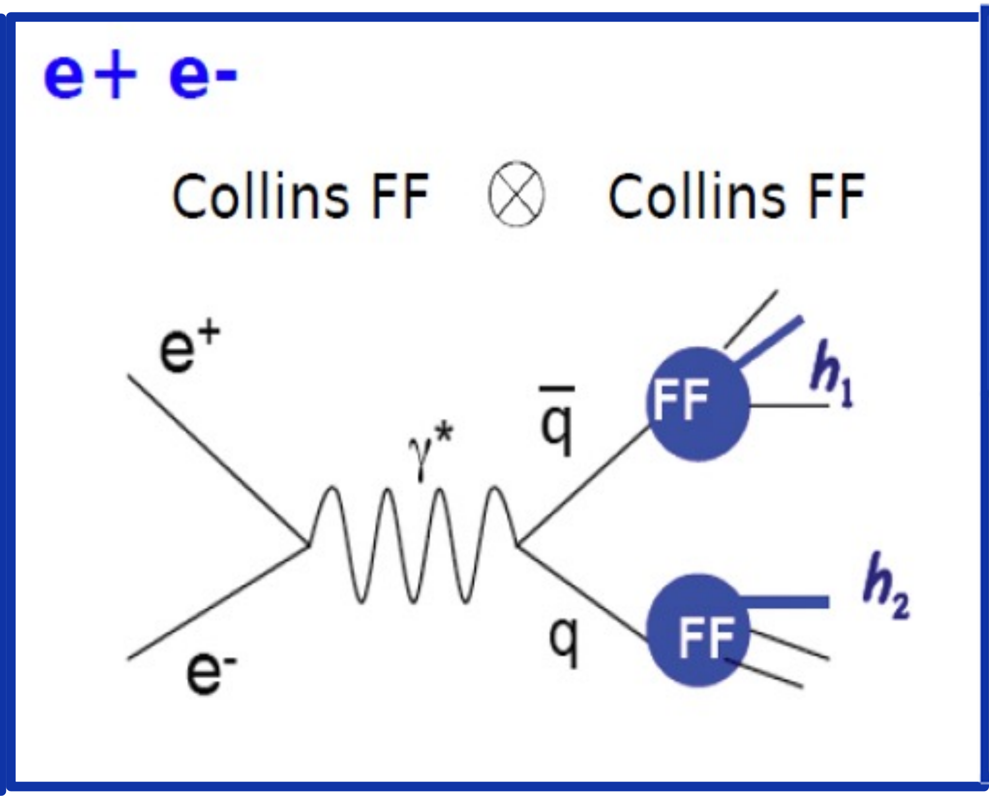
Physics at STCF

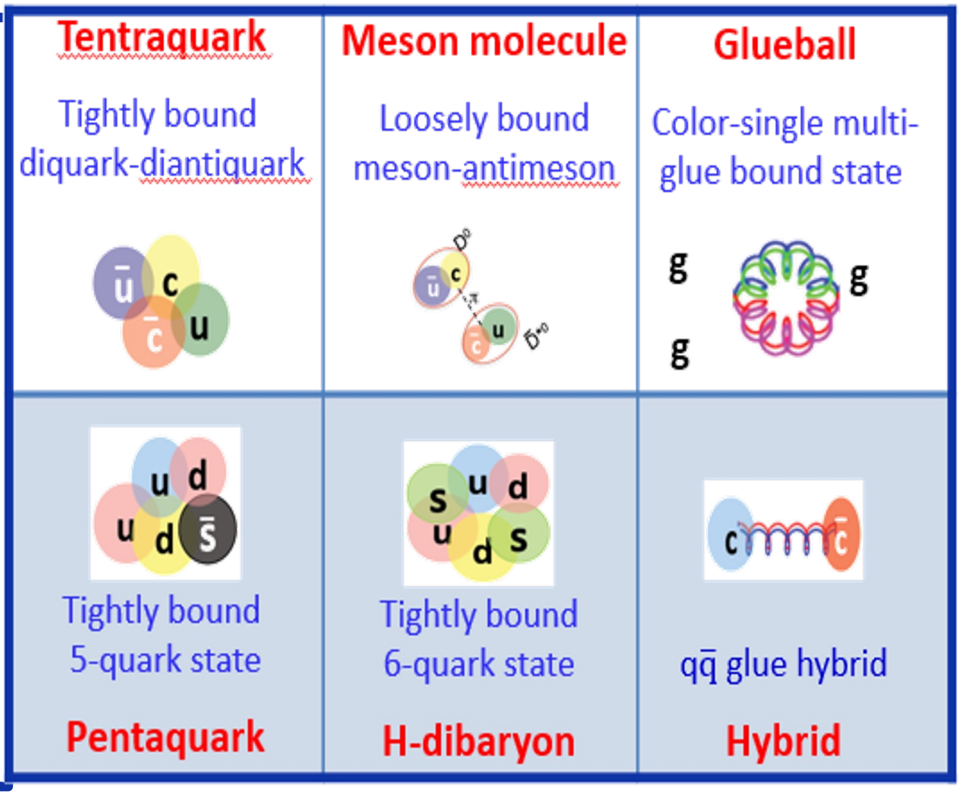
- **QCD and hadronic physics**
  - **XYZ Properties:** e+e-→Y→γX,ηX,ϕX; e+e-→Y→πZc, KZcs
  - **Hadron Spectroscopy:** Excited ccbar and their transition, Charmed hadron spectroscopy, Light hadron spectroscopy
  - **R value:** e+e-→inclusive; τ mass: e+e-→τ+τ-
  - **Nucleon Form Factors:** e+e-→BBbar from threshold
  - **Pentaquarks:** e+e-→J/ψppbar, Λc Dbar pbar, Σc Dbar pbar
    Di-charmonium: e+e-→J/ψηc, J/ψhc
  - **Muon g-2:** e+e-→π+ π-, π+ π- π0, 4π, K+ K-, γγ→π0, η(′),π+ π-
  - **Fragmentation functions:** e+e-→(π,K,p,Λ,D)+X, e+e-→(ππ,KK,πK)+X
- **Flavor Physics and CP Violation**
  - **CKM matrix (Vcd, Vcs):** D_(s)+→l+ν, D→P l+ ν
  - **Charm hadron decay:** Λc+, Σc, Ξc, Ωc decay
  - **CPV in Hyperons:** J/ψ→ΛΛbar, ΣΣbar, Ξ- Ξ+bar, Ξ0 Ξ0bar
  - **D0-D0bar mixing:** ψ(3770)→(D0 D0bar)(CP=-), ψ(4140)→π0 (D0 D0bar)(CP=-) or γ(D0 D0bar)(CP=+)
  - **CPV in τ:** τ→Ks πν, EDM of τ, τ→π/K π0 ν for polarized e- beam
  - **CPV in Charm:** D0→K+K-/π+π-, Λc→pK-π+π0/Λπ+π+π-/pKs π+π
  - **γ/ϕ3 measurement:** D0→K(s/L) π+ π-, K(s/L) K+ K-,K3π, 4π
  - **γ polarization:** D0→K1 e+ ν_e
- **Forbidden/Rare decay and New Particle**
  - **LNV, BNV:** D(s)+→l+ l+ X-, J/ψ→Λc e-, B→Bbar…
  - **Symmetry violation:** η(′)→llπ0, η′→ηll…
  - **FLV decays:** τ→γl, lll,l P1 P2 , J/ψ→ll′, D0→ll′ (l′≠l)…
  - **FCNC:** D→γV, D0→l+ l-, e+e-→D∗ , Σ+→pl+ l-…
  - **Dark photon:** e+e-→γA′(→l+ l-), J/ψ→e+e-A′…
    Millicharged: e+e-→χχ̄γ…

Hadron Production, Structure, Spectroscopy









Hadron Production

- A key approach to understand hadron production mechanism and the interaction
- Covering range (0.7-7 GeV), important input for hadron exp.

Nuclear EM FFs

- Fundamental obs., reflects the inner structure of nucleon
- Complementarity to the e-N elastic scattering experiments in similar q2 region

Fragmentation Func.

- understanding QCD dynamics, hadron structure and production mechanism.
- Comparing with e-p data to verify the universality of fragmentation.

Hadron Spectroscopy

- Natural platform to understand the color confinement of strong interaction,
- Unique and peerless advantages in light hadron, charmonium, XYZ..

CP/CPT Symmetry Tests

Billions of hyperon pairs from J/ψ decays, clean topology, background free

Transversely polarized, spin correlation

Sensitivity: $A_{CP} \sim 10^{-4}$, $\xi \sim 0.05^{\circ}$

CP in hyperon decay

Peak cross section in $\sqrt{s}$ =4-5 GeV, $\sigma_{\tau\tau} \approx$ 3.5 nb, 10 ab^{-1} data in total

Sensitivity of τ decay with 1ab^{-1} @ 4.26 GeV ~9.7×10^{-4}

CP in tau decay/production

CP in charm mixing

Billions $D^0/\bar{D}^0$, threshold production, quantum coherence with $(D^0\bar{D}^0)_{CP=-}$ or $(D^0\bar{D}^0)_{CP=+}$

Sensitivity: $x \sim 0.035\%$, y~0.023%, $r_{CP} \sim 0.017$, $\alpha_{CP} \sim 1.3^{\circ}$

CPT in kaon mixing

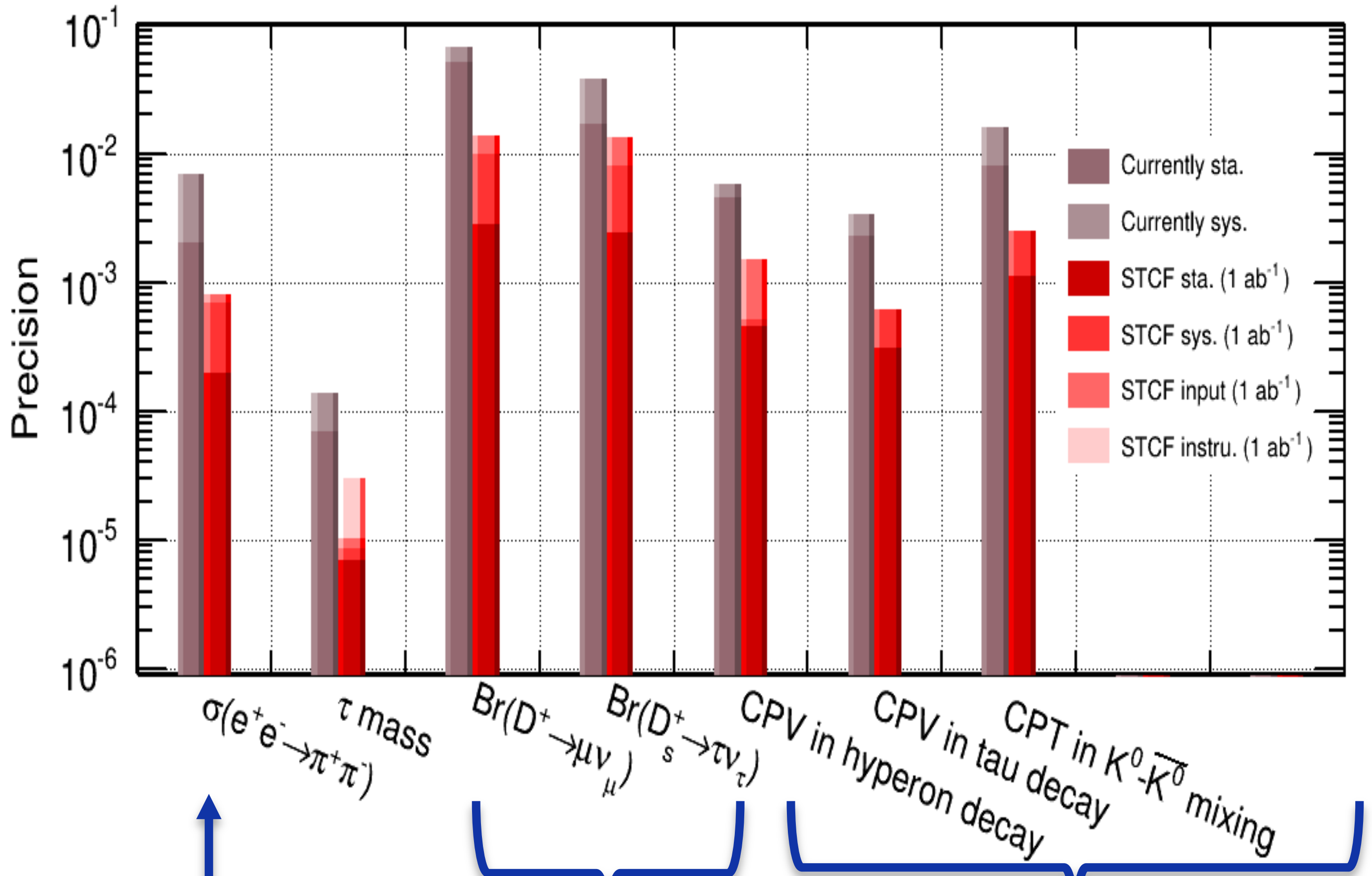
CP tagging and flavor tagging of $K^0/\bar{K}^0$ available from J/ψ decay

CP variables determined with time-dependent decay rate

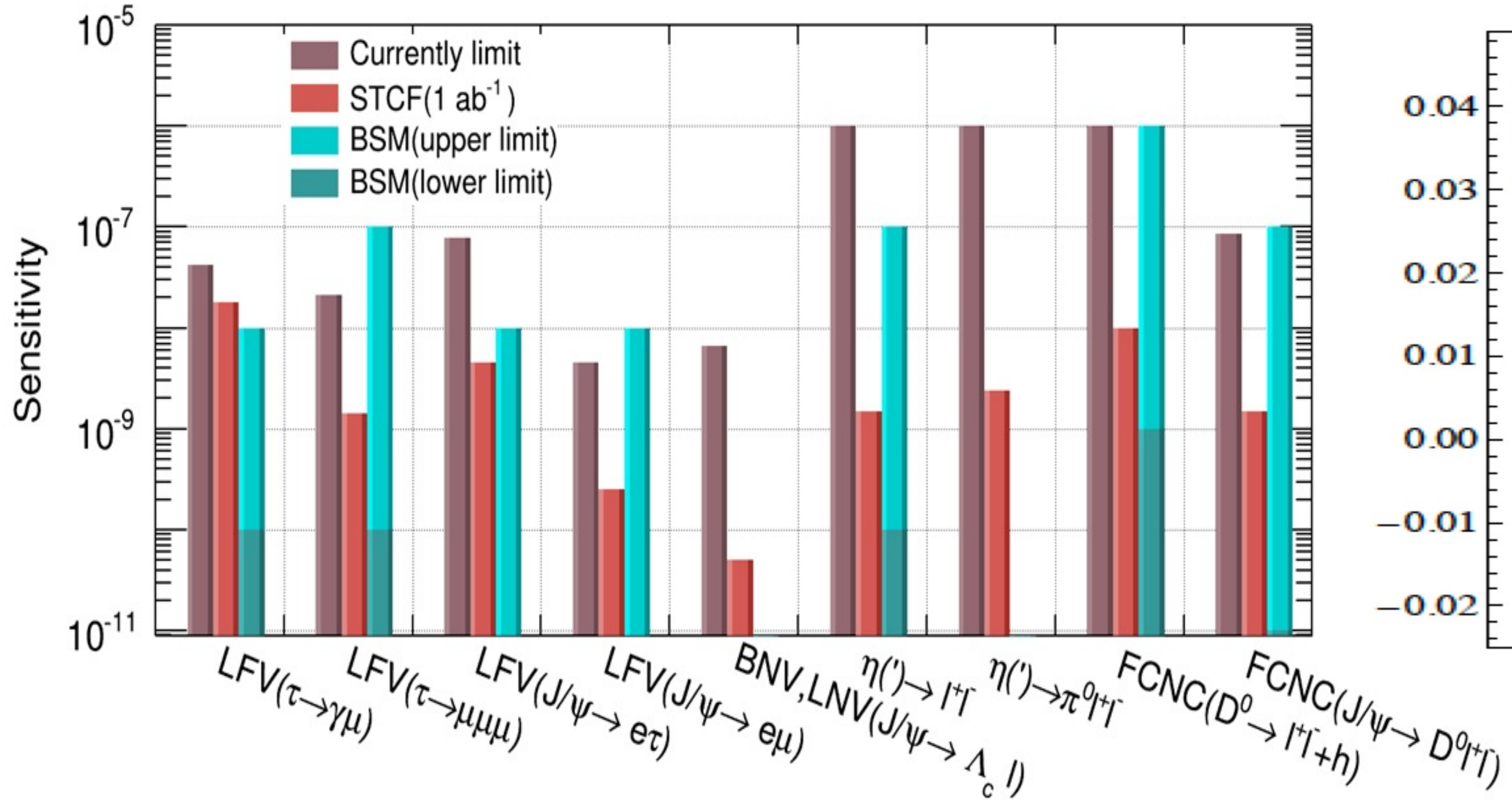
CPT Sensitivity: $\eta_{\pm} \sim 10^{-3}$, $\Delta\phi_{\pm} \sim 0.05^{\circ}$

Precisions and Sensitivities at STCF

- **STCF is expected to improve the current precisions of many important measurements by ~1 order of magnitude and sensitivities to various rare or forbidden decays by ~2 orders of magnitude.**

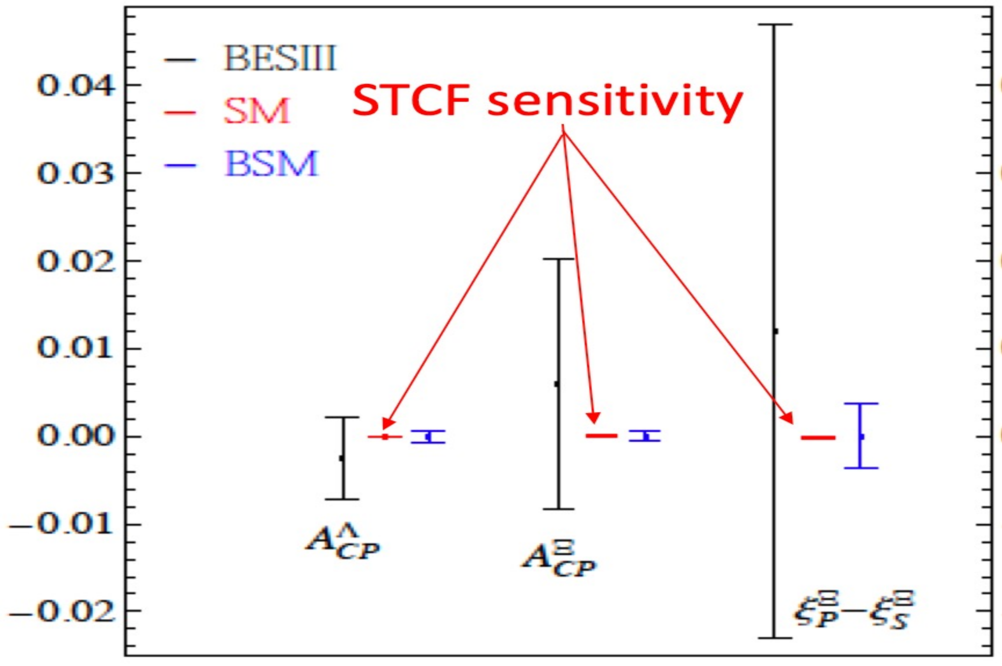


R value g-2 | **lepton universality** | **CPV, CPTV**



LFV, BNV, FCNC to probe BSM

X.G. He et al. Sci.Bull. 67 (2022)

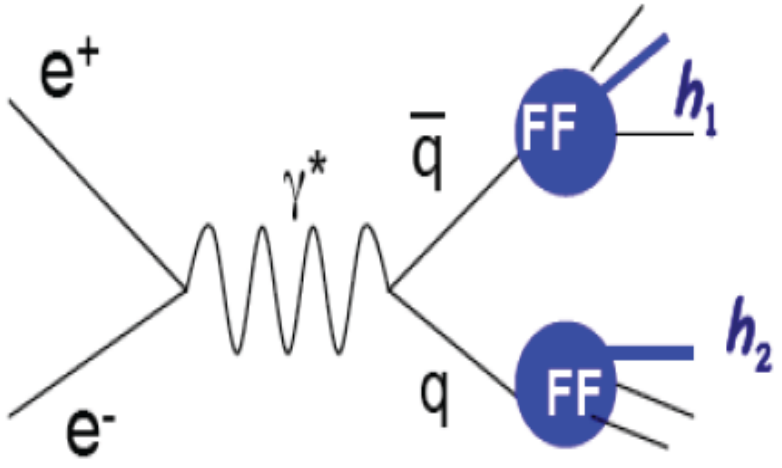


Direct observation of CPV in hyperons

Collins Fragmentation Function

e+ e-

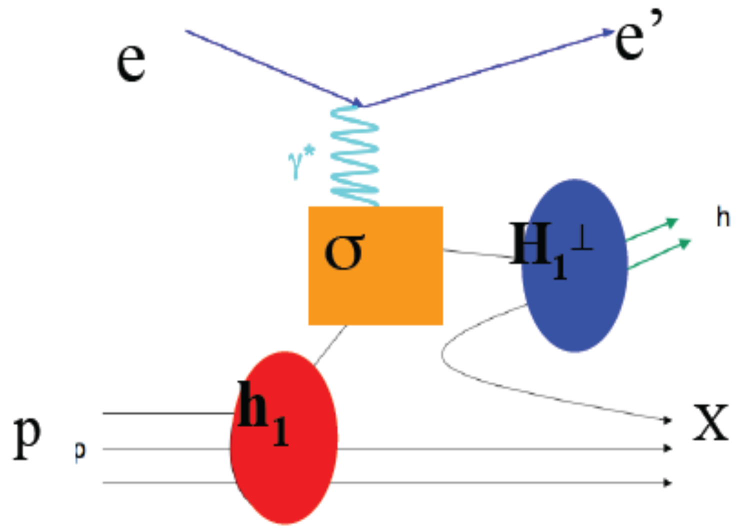
Collins FF ⊗ Collins FF

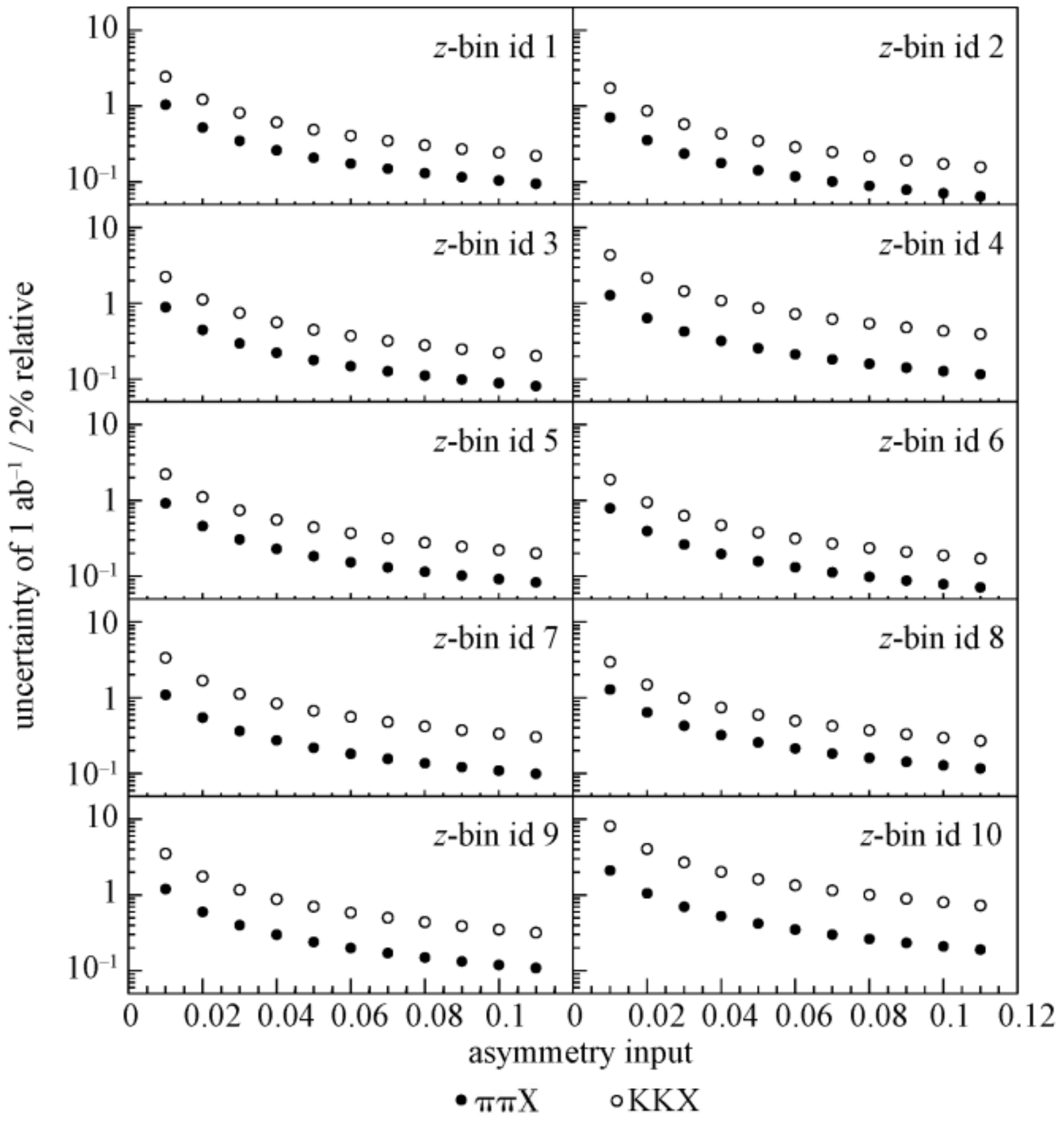


Crucial input to TMD extraction in SIDIS

SIDIS

Transversity ⊗ Collins FF



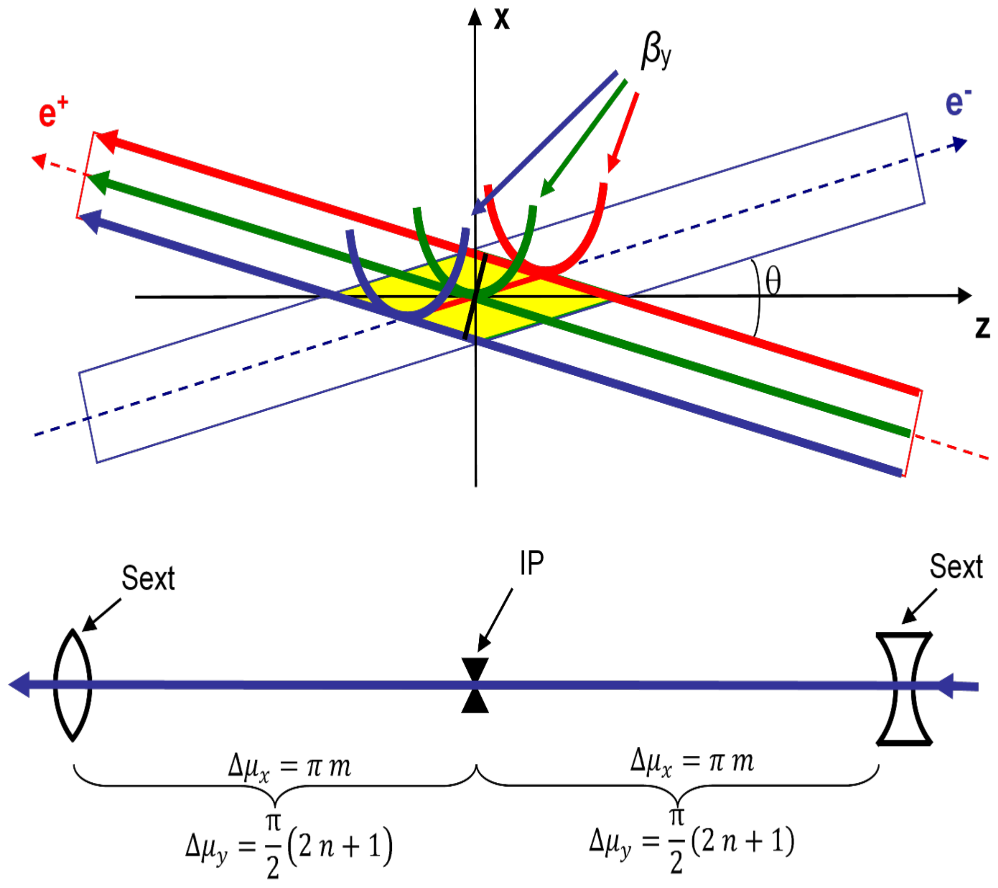


The statistical uncertainty on asymmetry A^{UL} with $1ab^{-1}$ at 7 GeV:
(1.4~4.2)$\times 10^{-4}$ for $\pi\pi X$
(3.5~20)$\times 10^{-3}$ for KKX

STCF will provide precise Collins FF input for TMD extraction at EIC/EicC (*Journal of UCAS 38 (2021) 433*).

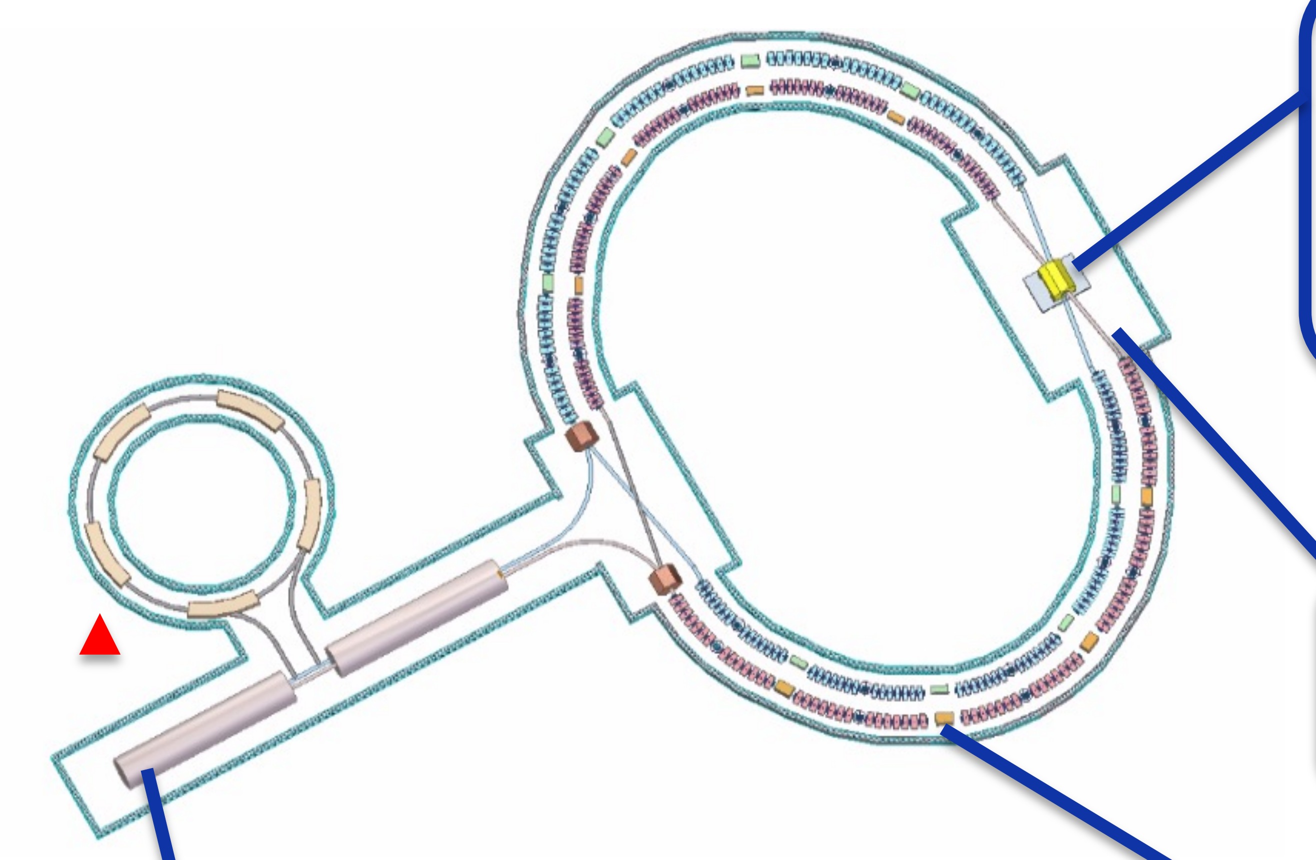
Challenges of STCF Accelerator

- **Ultra-high luminosity in the tau charm energy region, high-quality beam, stable operation**
- **Characterized by extremely small bunch size, high beam current, strong nonlinearity and collective effects**



$$L = \frac{\gamma n_b I_b}{2 e r_e \beta_y^*} \xi_y H$$

Large Piwinski angle + Crab Waist



Collider Ring and IR Physics Design
IP beam size (Y) nm scale, Crab-Waist, nonlinear compensation extremely difficult

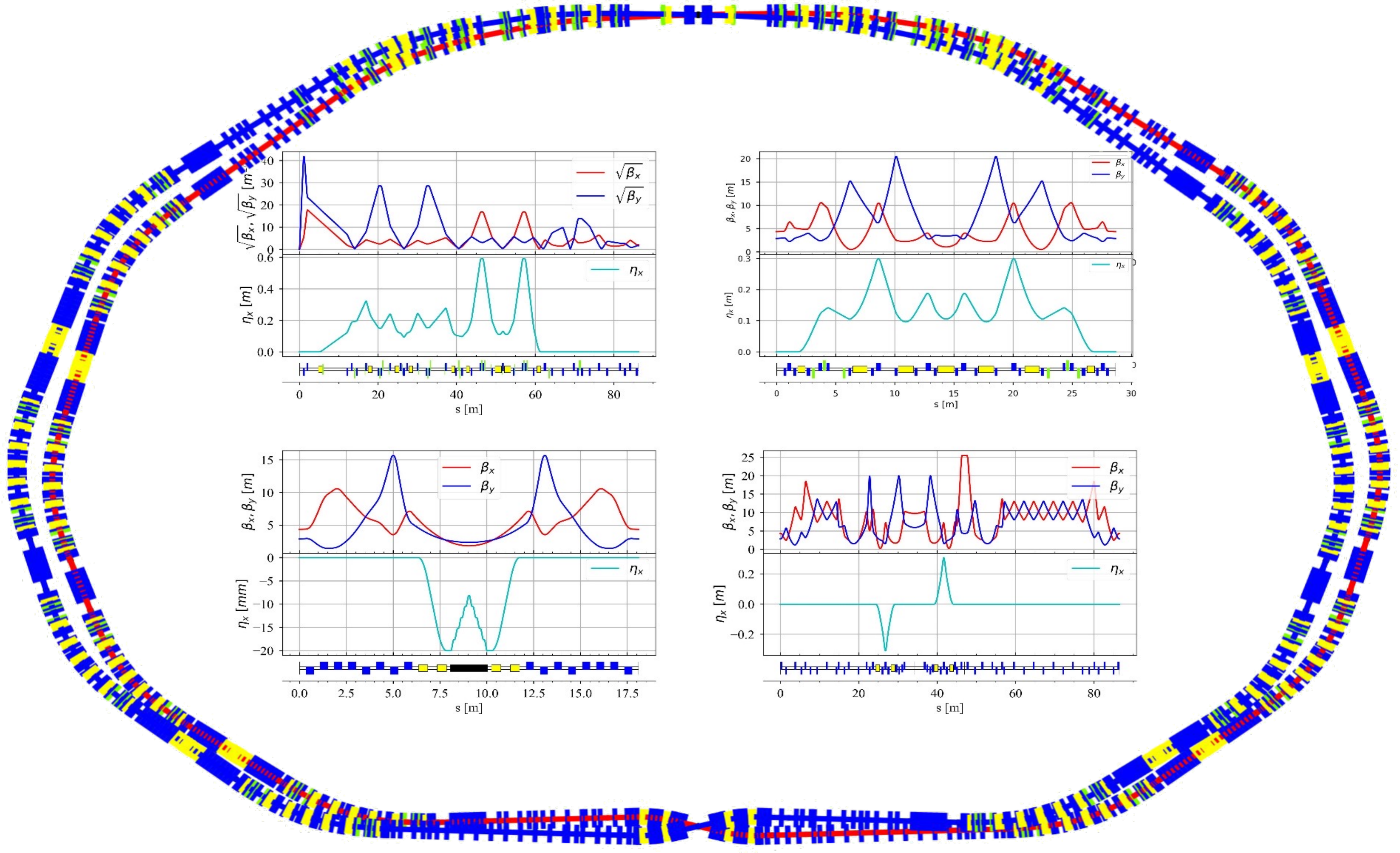
IR Technologies
SC magnets, MDI

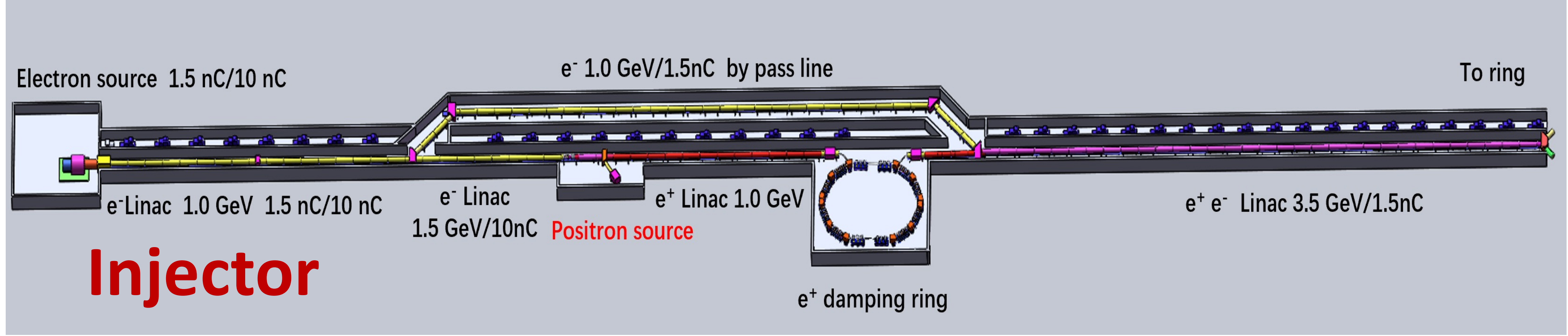
Injection into CR (small DA)
high I_b and low ε e+/e- sources

Other key technologies
Ring RF, beam instrumentation and control, beam injection…

STCF Accelerator Pre-Conceptual Design

Collider ring lattice



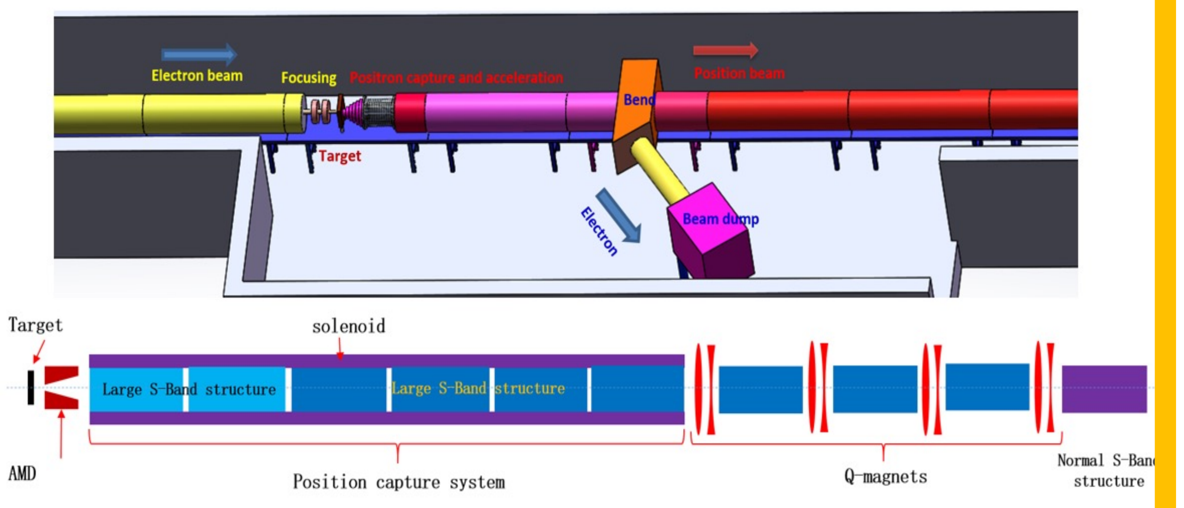


Parameters	Units	STCF
Optimal beam energy, E	GeV	2
Circumference, C	m	616.76
Crossing angle, 2θ	mrad	60
Revolution period, T_0	µs	2.057
Horizontal emittance, ε_x	nm	5.77
Vertical emittance, ε_y	pm	28.85
Beta function at IP, β_x/β_y	mm	40/0.6
Beam size at IP, σ_x/σ_y	µm	15.19 /0.132
Betatron tune, ν_x/ν_y		31.552/24.572
Momentum compaction factor, α_p	10^{-4}	9.71
Energy spread, σ_ε	10^{-4}	8.26
Beam current, I	A	2
Number of bunches, n_b		512
Single-bunch charge	nC	8.04
Energy loss per turn, U_0	keV	286
SR power per beam, P_{SR}	MW	0.572
Transvers damping time, $\tau_{x/y}$	ms	28.59
RF frequency, f_{RF}	MHz	499.7
RF voltage, V_{RF}	MV	1.2
Bunch length, σ_z	mm	8.2
Piwinski angle, ϕ_{Piw}	rad	16.19
Ver. beam-beam parameter, ξ_y		0.107
Luminosity, L	$cm^{-2}s^{-1}$	1.37E+35

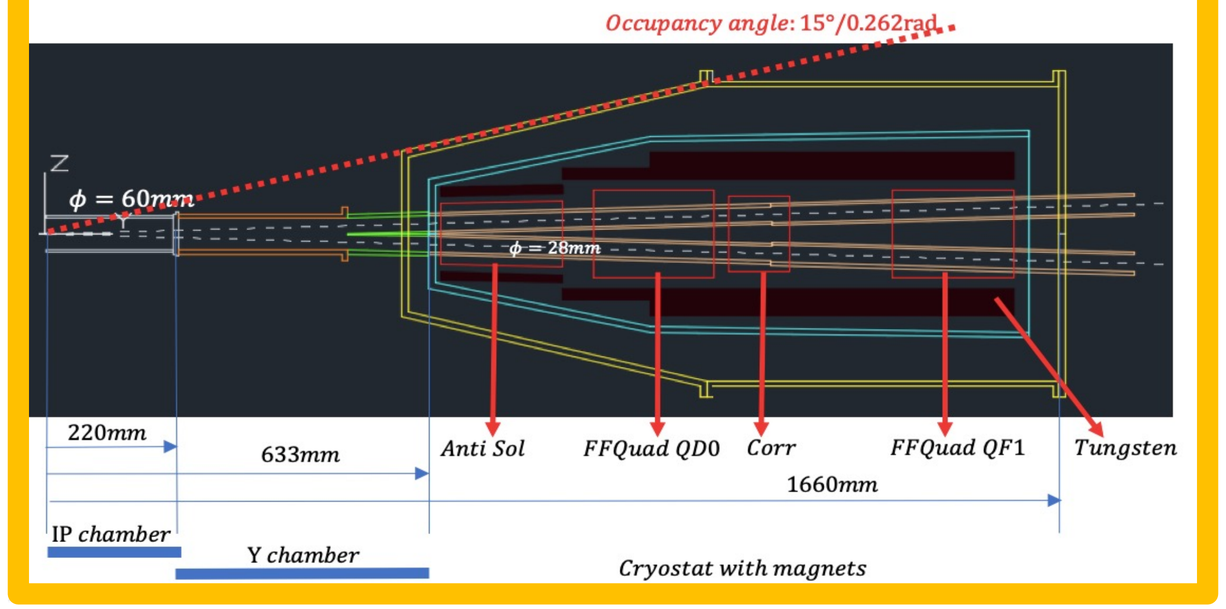
Working on a design with a larger collider ring (800-1000 m)

STCF Accelerator Technology R&D

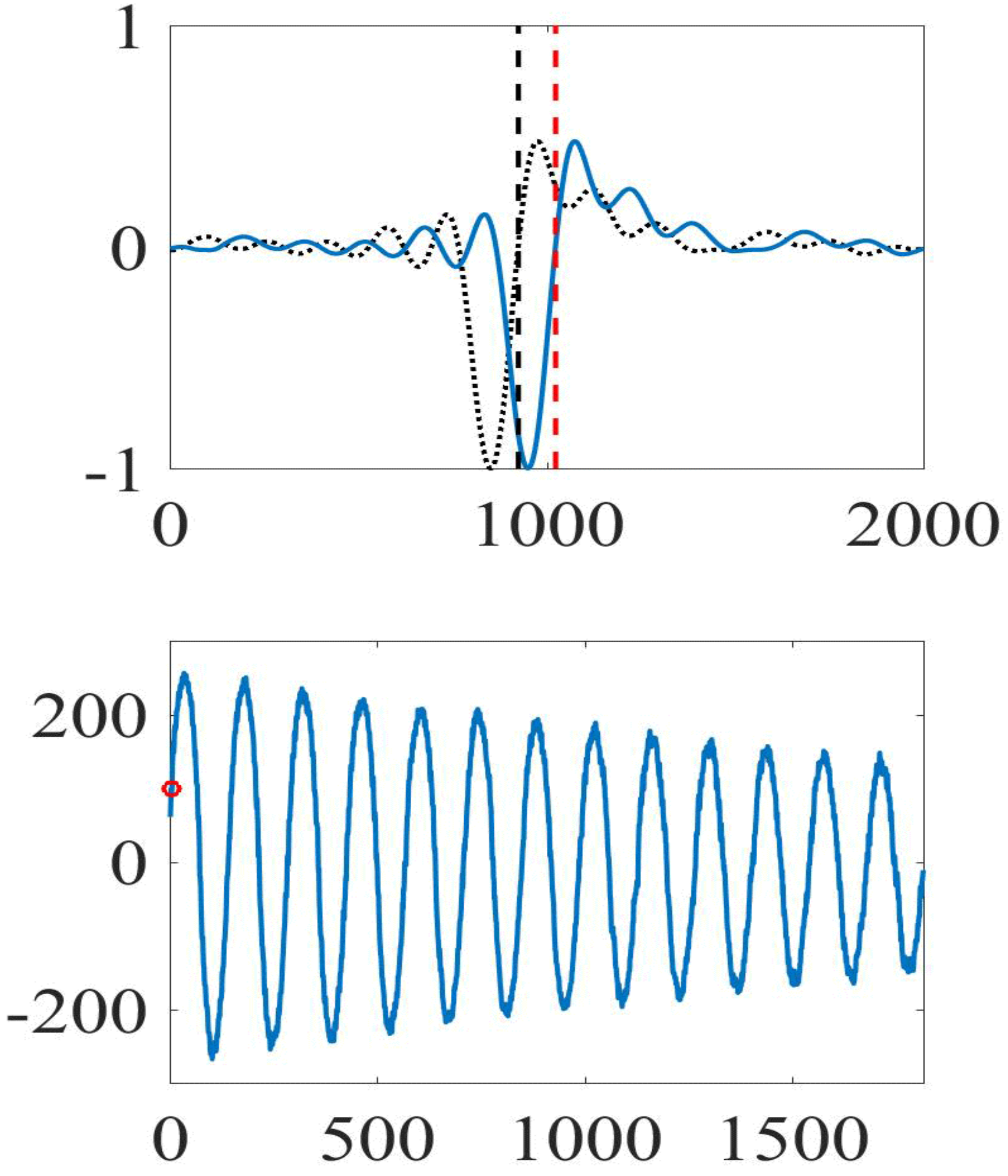
Positron Source



MDI

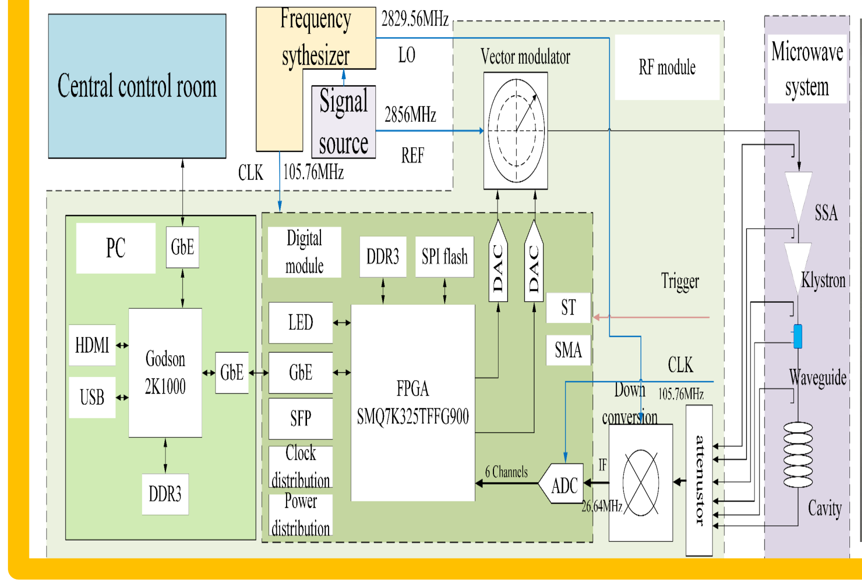


Bunch-by-Bunch 3D position measurement

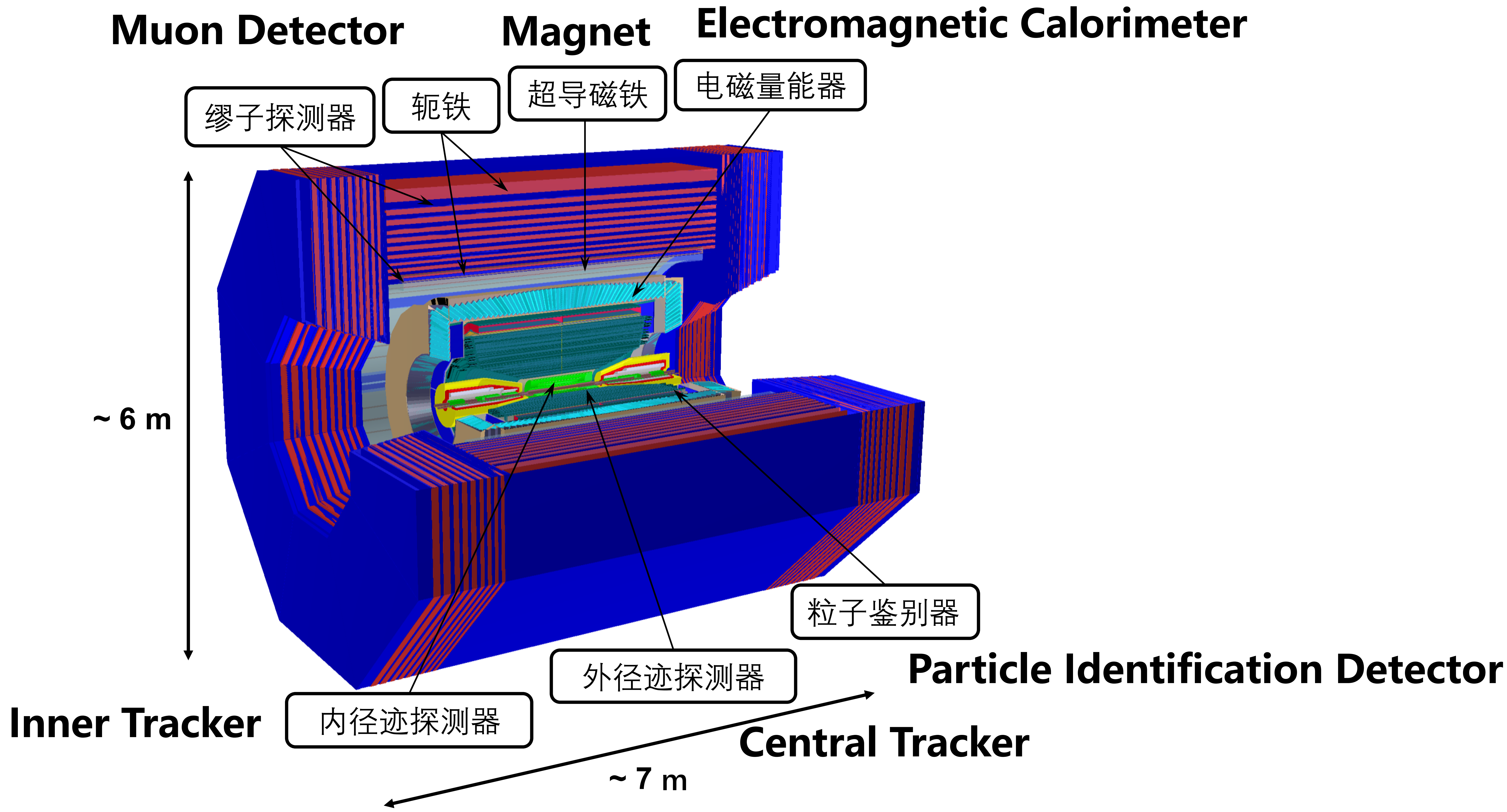


Photocathode e-gun

Low level RF system



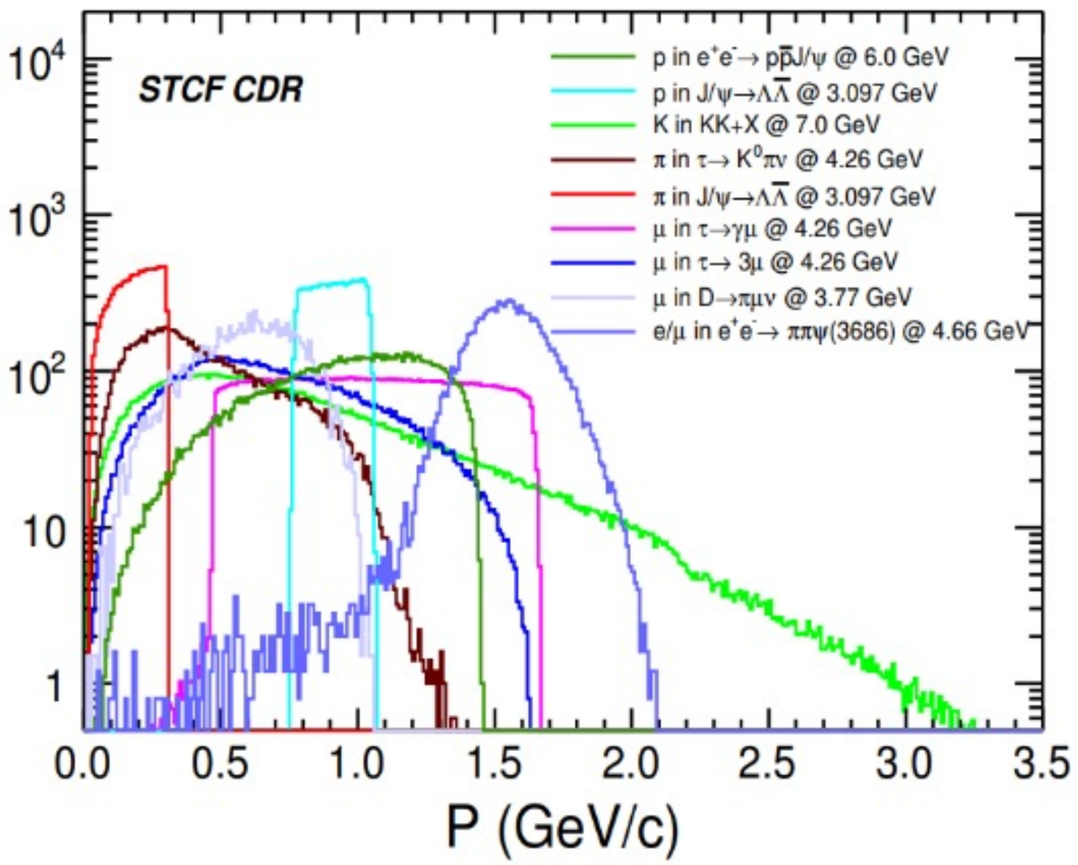
STCF Detector Layout

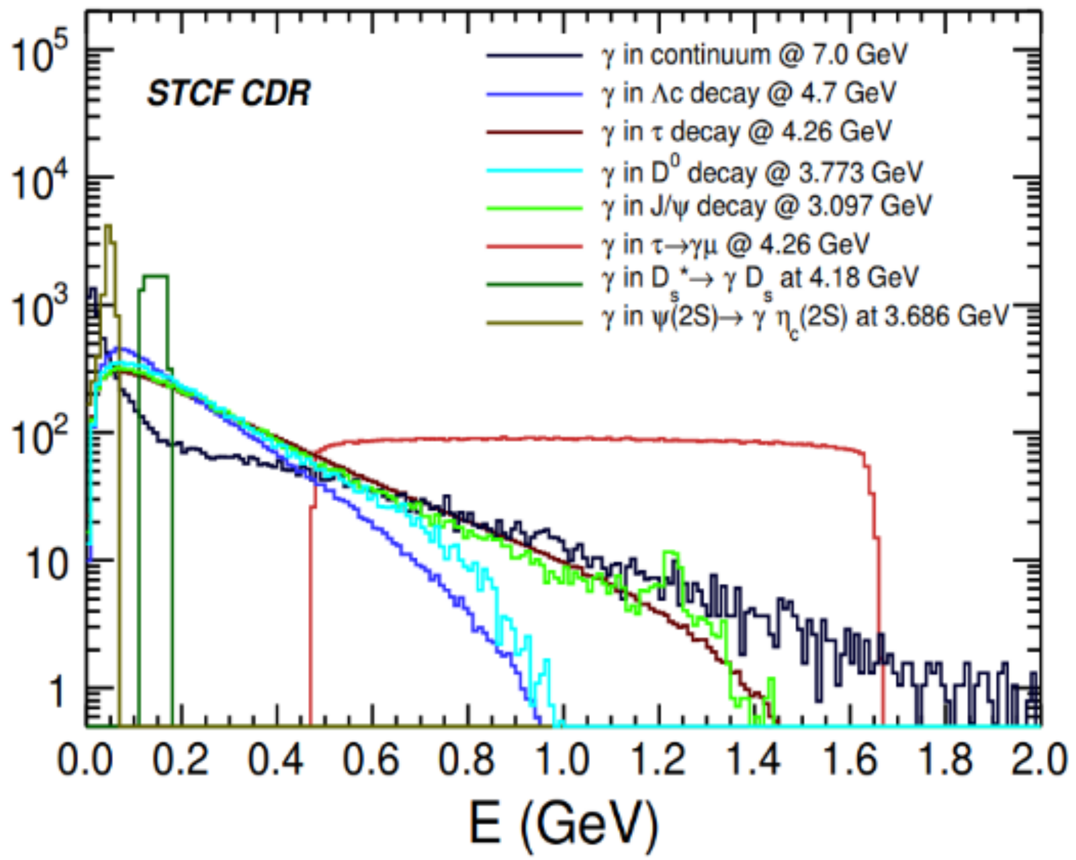


Detector Requirements from Physics

- **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

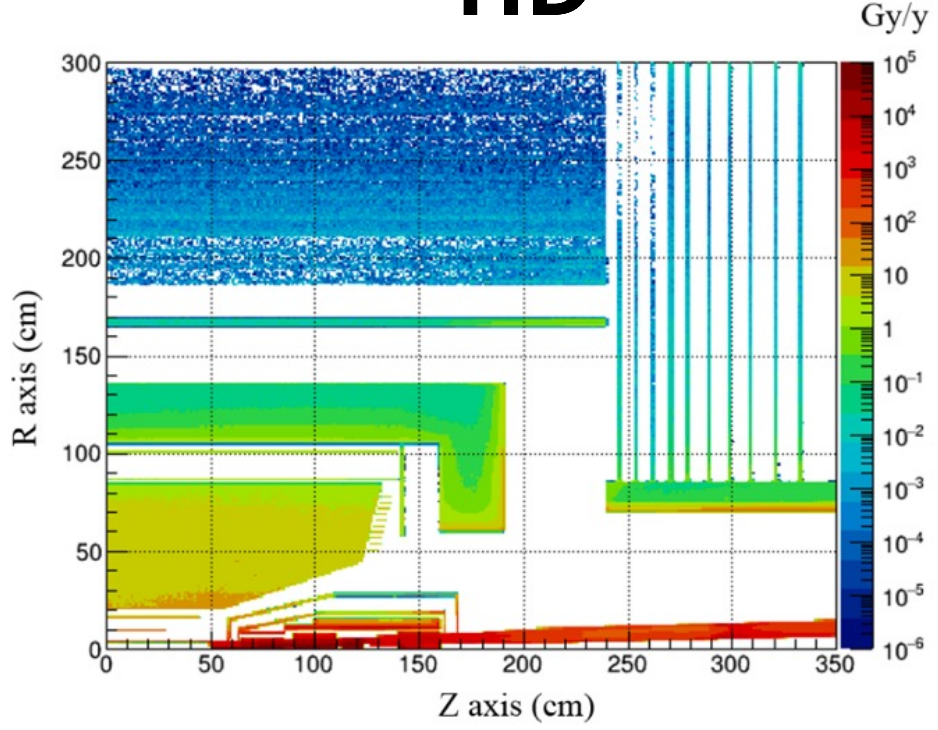
Process	Physics Interest	Optimized Subdetector	Requirements
$\tau \to K_s \pi \nu_\tau$, $J/\psi \to \Lambda\bar{\Lambda}$, $D_{(s)}$ tag	CPV in the τ sector, CPV in the hyperon sector, Charm physics	ITK+MDC	acceptance: 93% of 4π; trk. effi.: $> 99\%$ at $p_T > 0.3$ GeV/c; $> 90\%$ at $p_T = 0.1$ GeV/c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



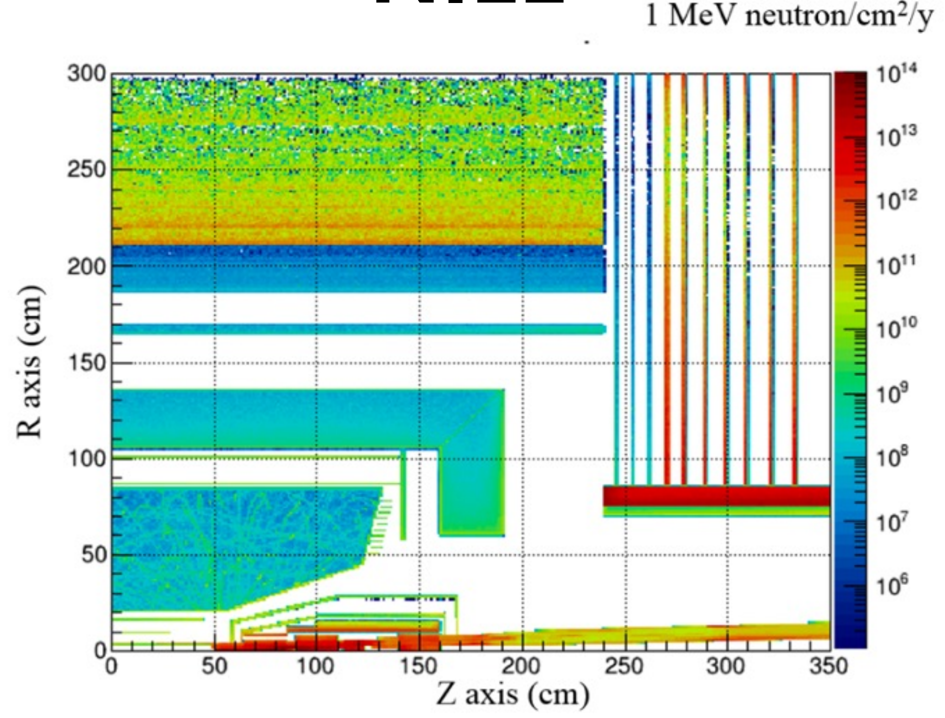


Beam-induced Backgrounds

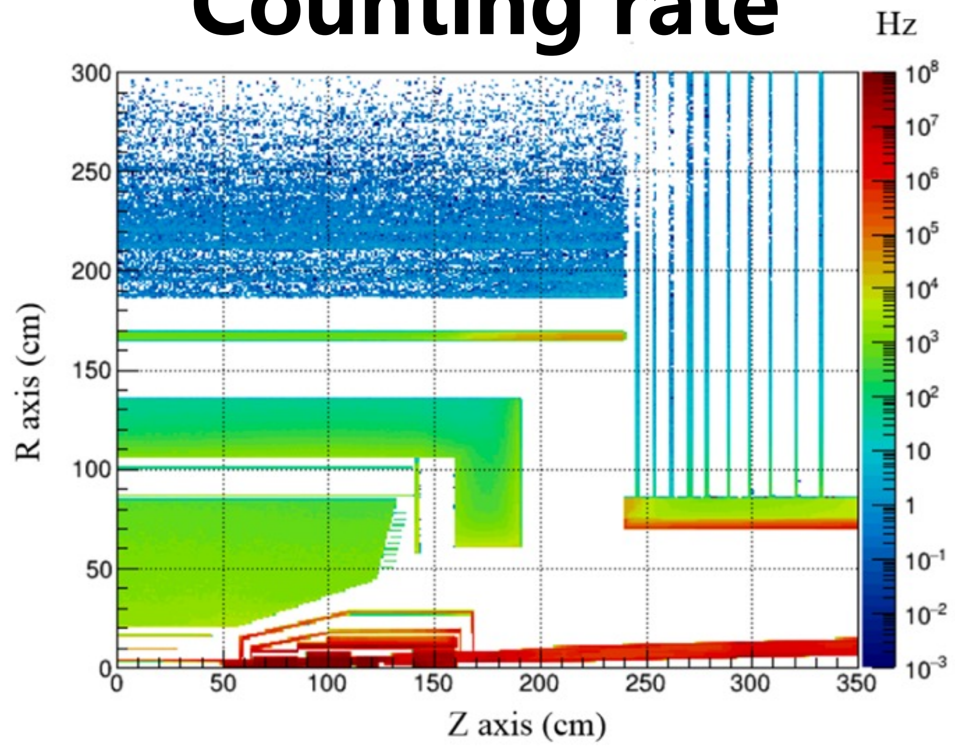
TID

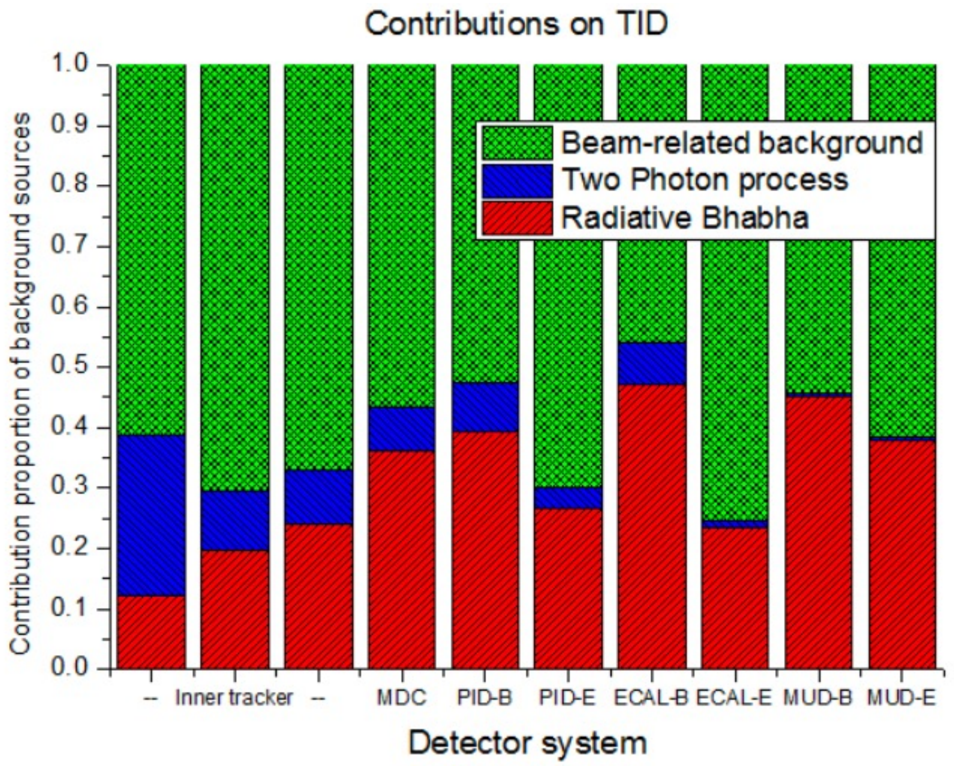


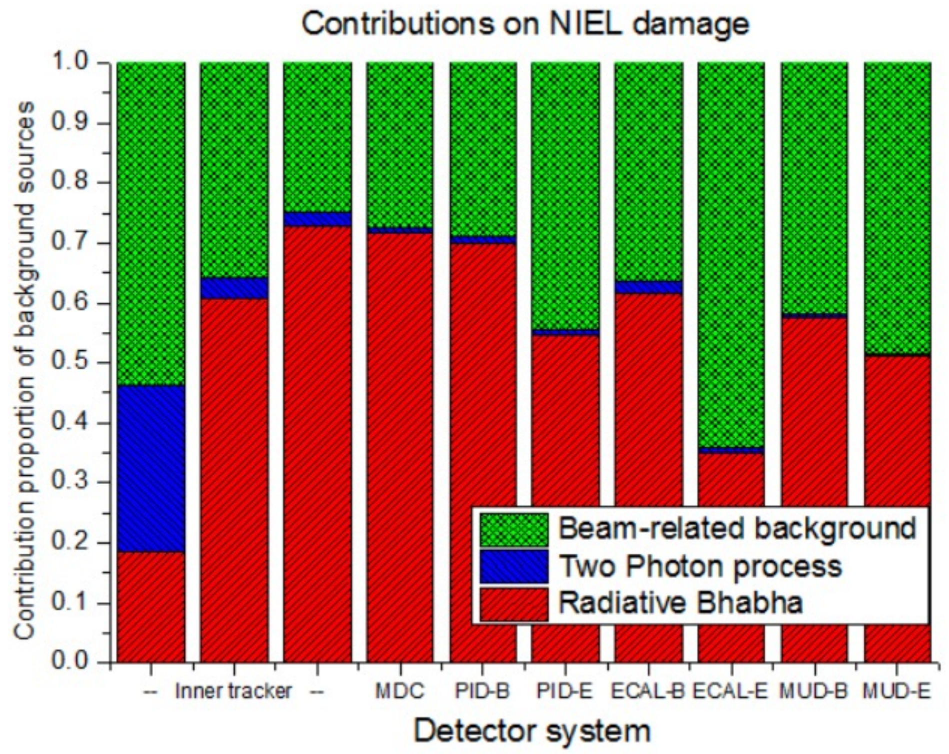
NIEL

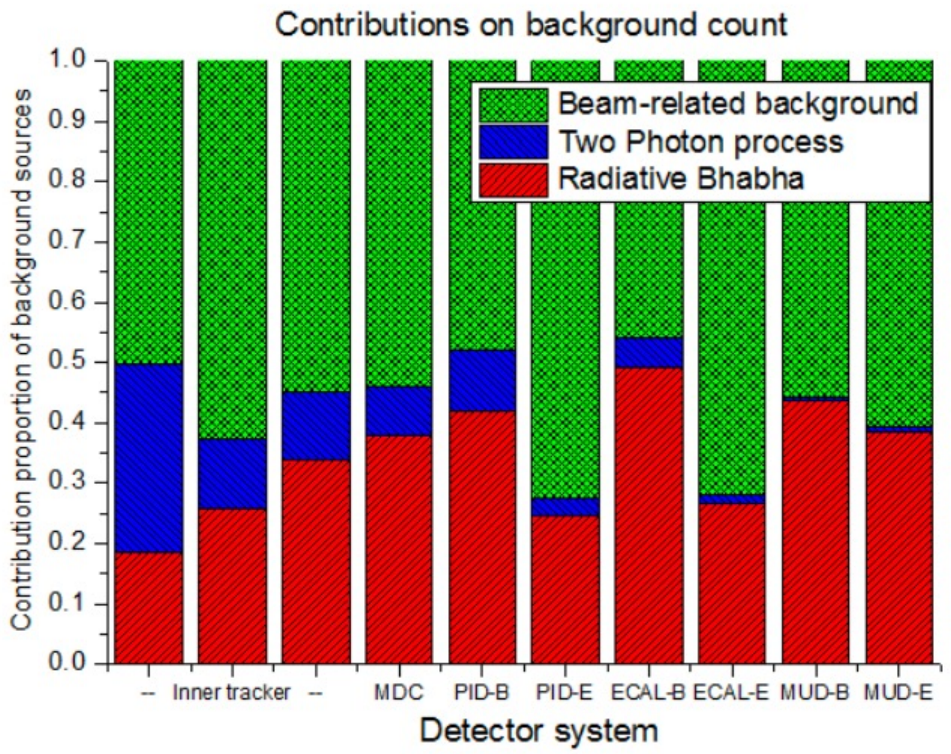


Counting rate





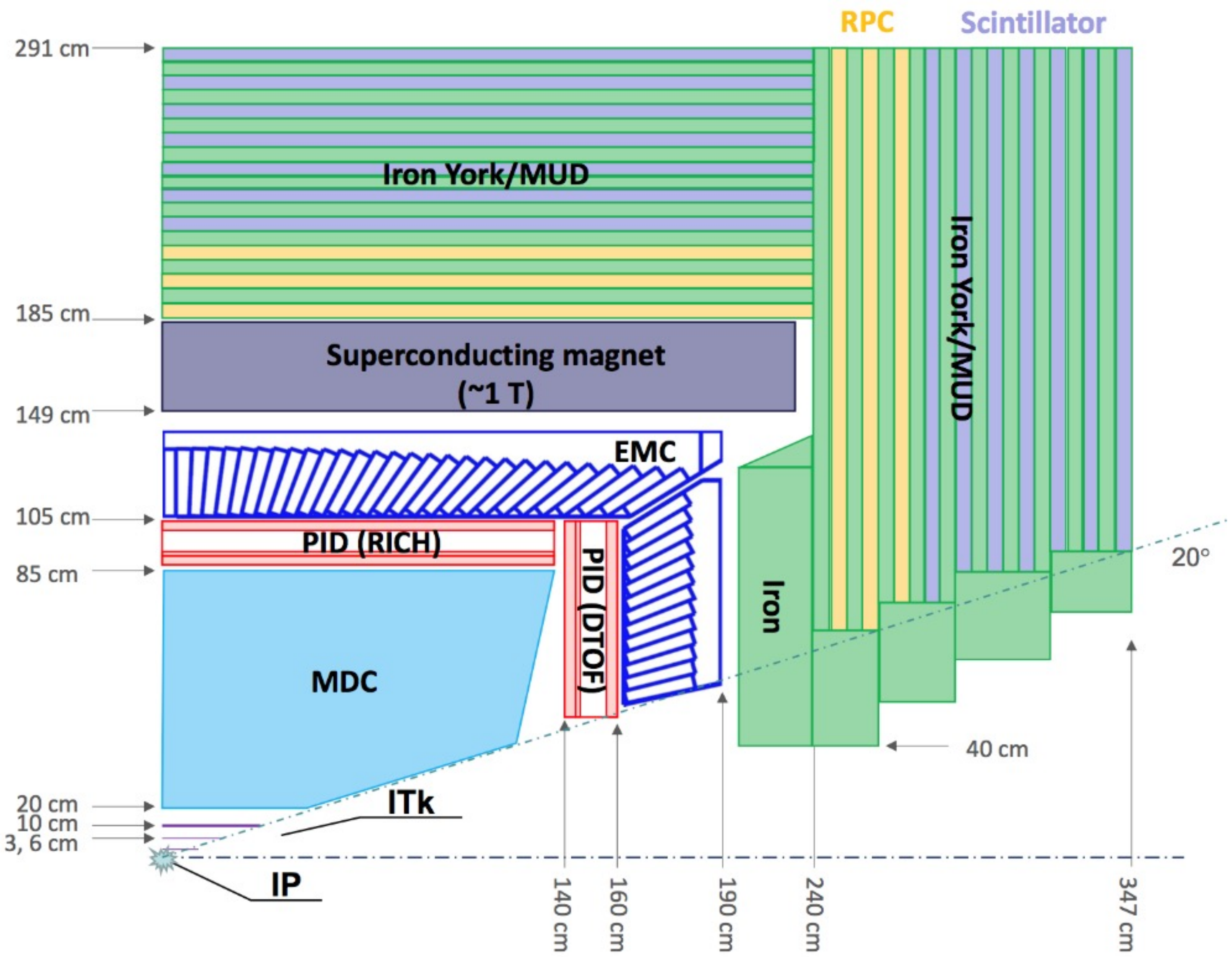




Inner most detector layer: ~3.5 kGy/y, ~2×10^{11} 1MeV n-eq/cm^2/y, ~1 MHz/cm^2

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

STCF Physics & Detector CDR

82 institutions, 453 authors

arXiv:2303.15790

FRONTIERS OF PHYSICS

REPORT
Volume 19 / Issue 1 / 14701 / 2024

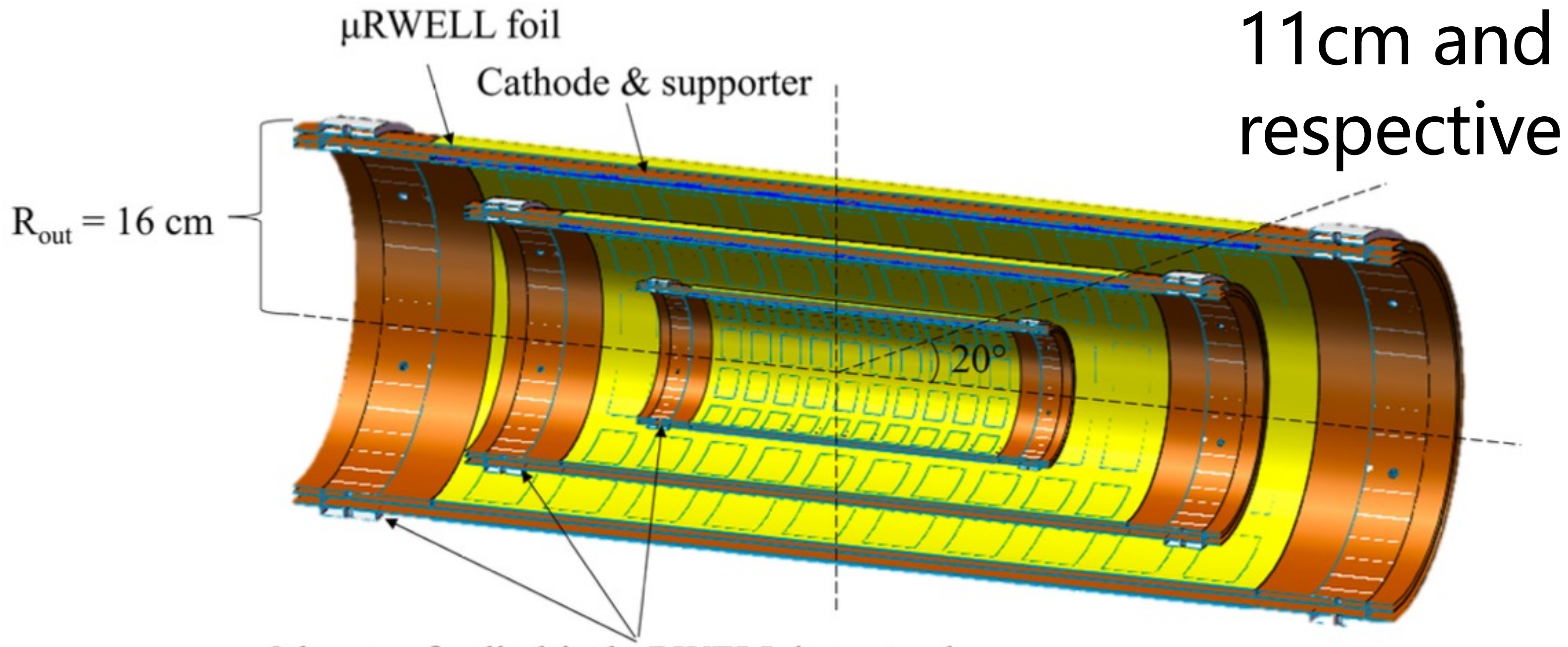
STCF conceptual design report (Volume 1): Physics & detector

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 : inner tracker + main drift chamber

Gaseous option: MPGD

3 layers at 6cm, 11cm and 16 cm, respectively.

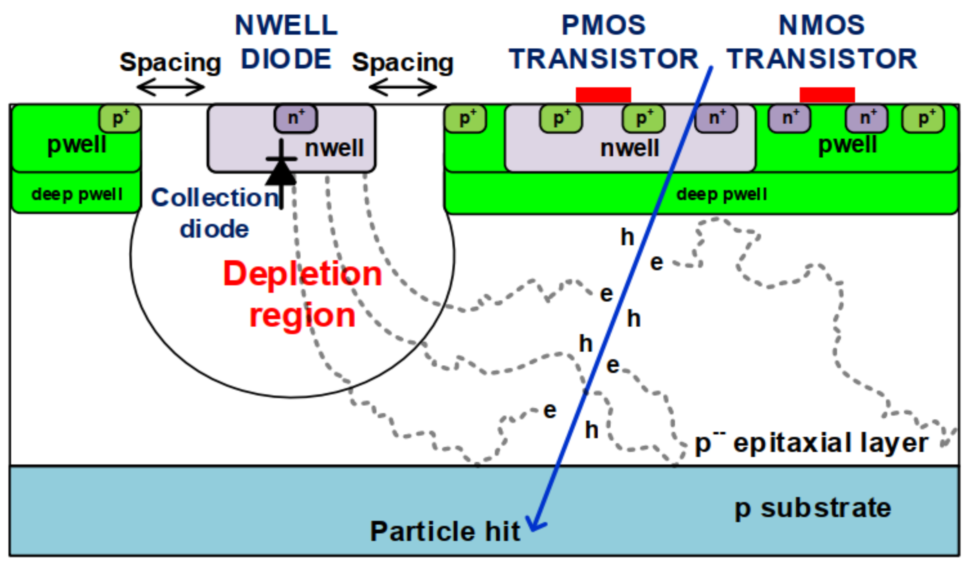


3 layers of cylindrical µRWELL inner tracker

(with sensitive length of 33, 61, 88 cm respectively)

Material budget <0.3%X_0/layer

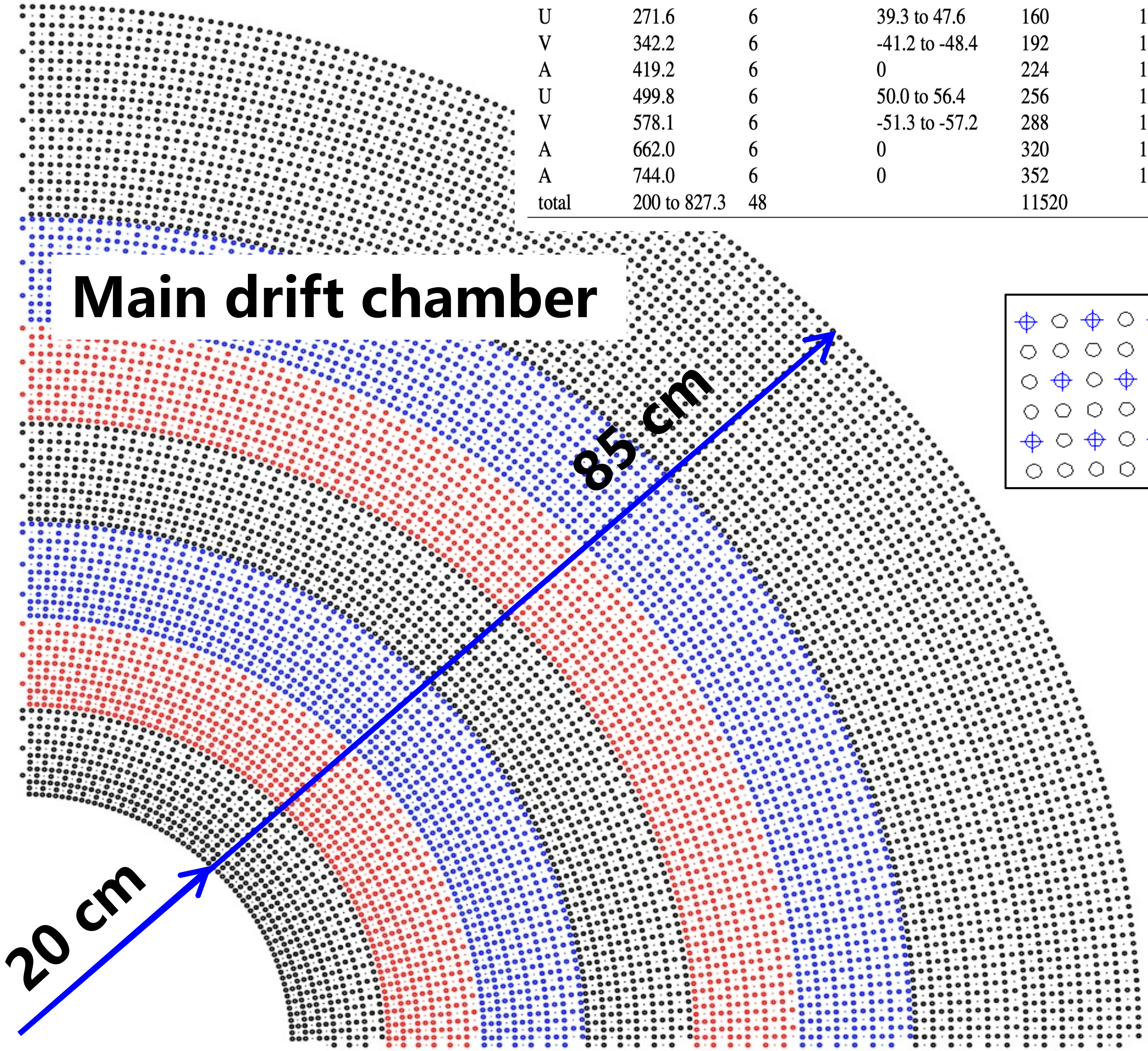
Silicon option: CMOS MAPS



单片有源像素探测器

3 layers at 3.6cm, 9.8cm and 16 cm, respectively.

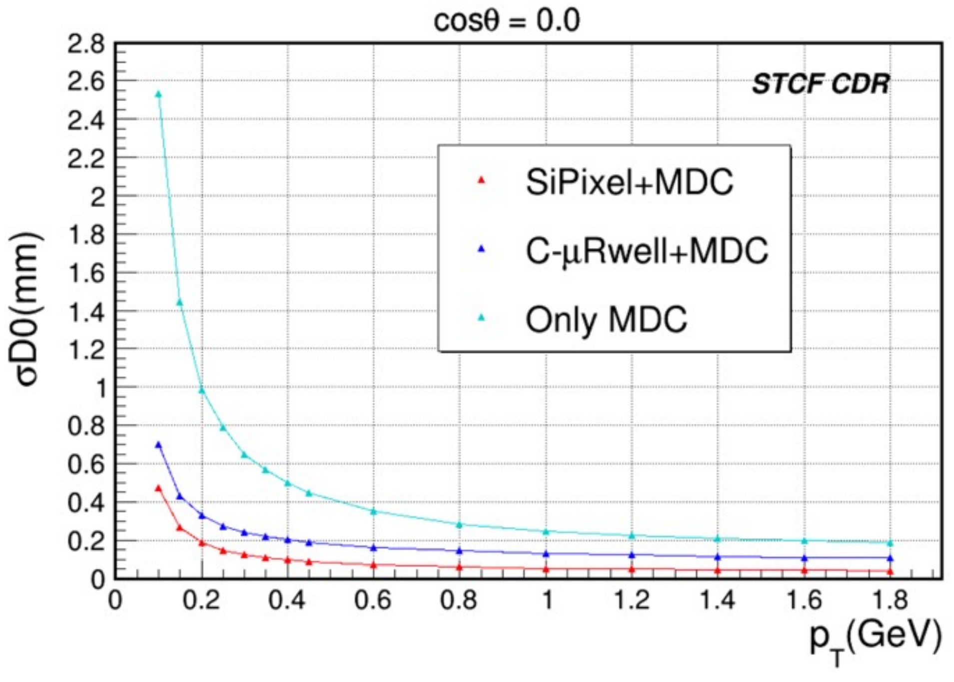
Superlayer	Radius (mm)	Num. of Layers	Inclination (mrad)	Num. of Cells	Cell size (mm)
A	200.0	6	0	128	9.8 to 12.5
U	271.6	6	39.3 to 47.6	160	10.7 to 12.9
V	342.2	6	-41.2 to -48.4	192	11.2 to 13.2
A	419.2	6	0	224	11.7 to 13.5
U	499.8	6	50.0 to 56.4	256	12.3 to 13.8
V	578.1	6	-51.3 to -57.2	288	12.6 to 14.0
A	662.0	6	0	320	13.0 to 14.3
A	744.0	6	0	352	13.3 to 14.5
total	200 to 827.3	48		11520	



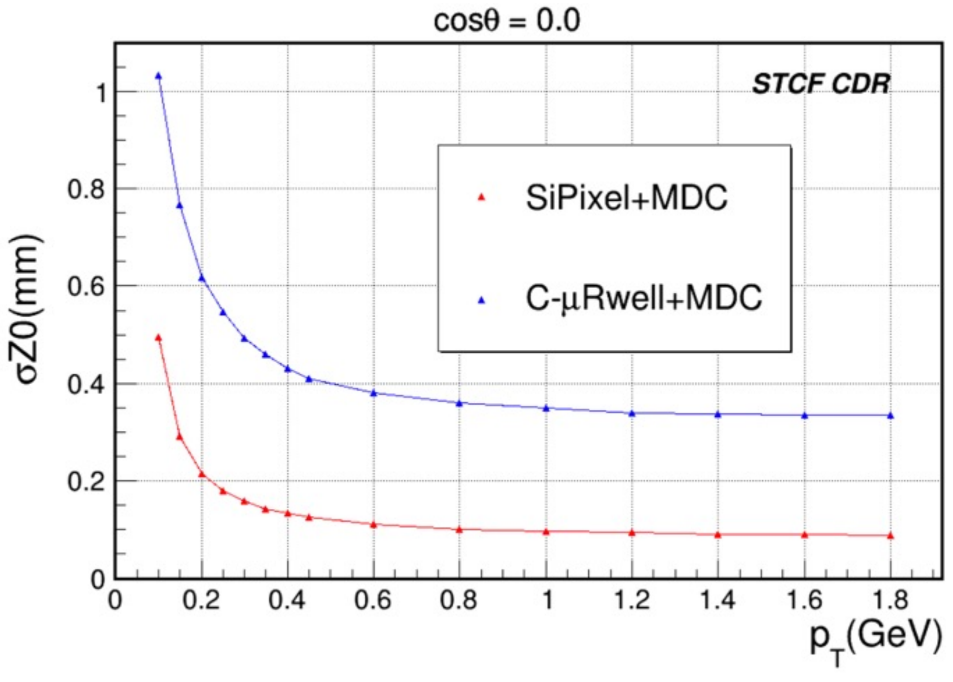
Inner tracker

Total material budget ~ 4%X_0 (walls included)

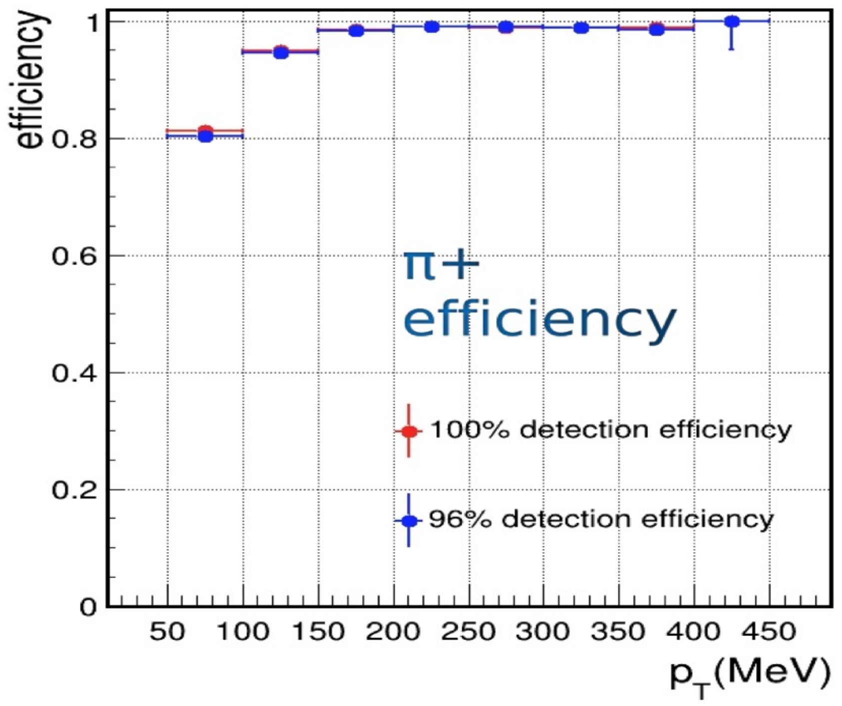
Combined Tracking Performance

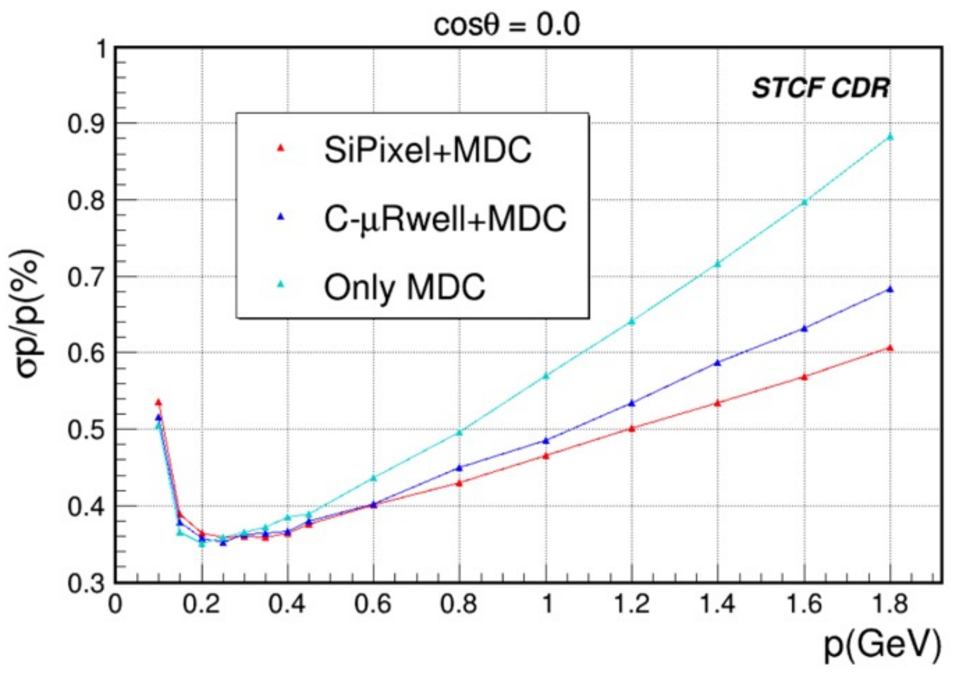


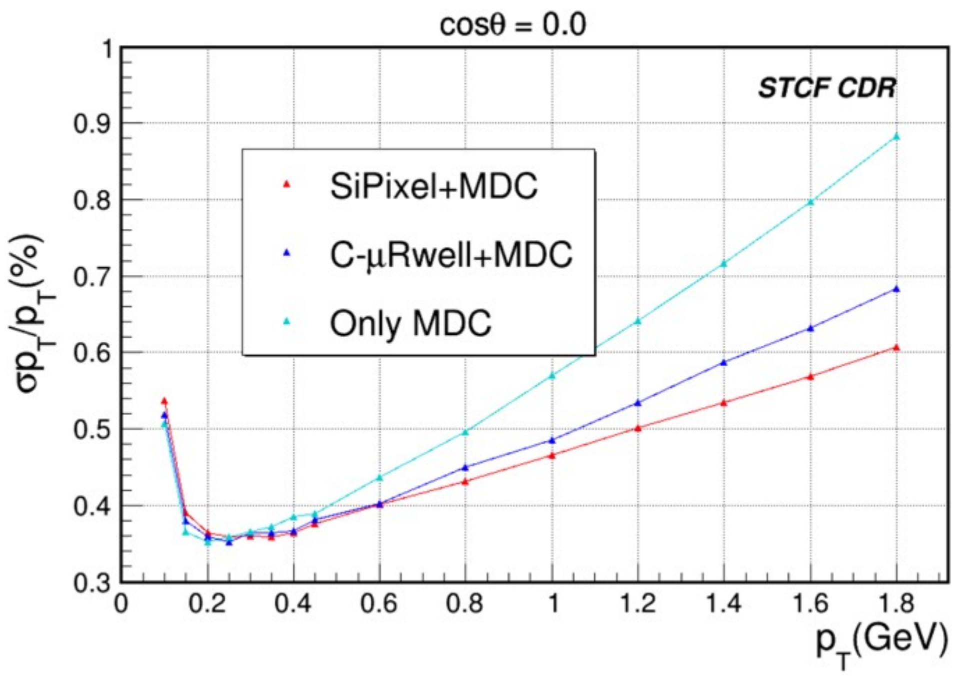
(a)

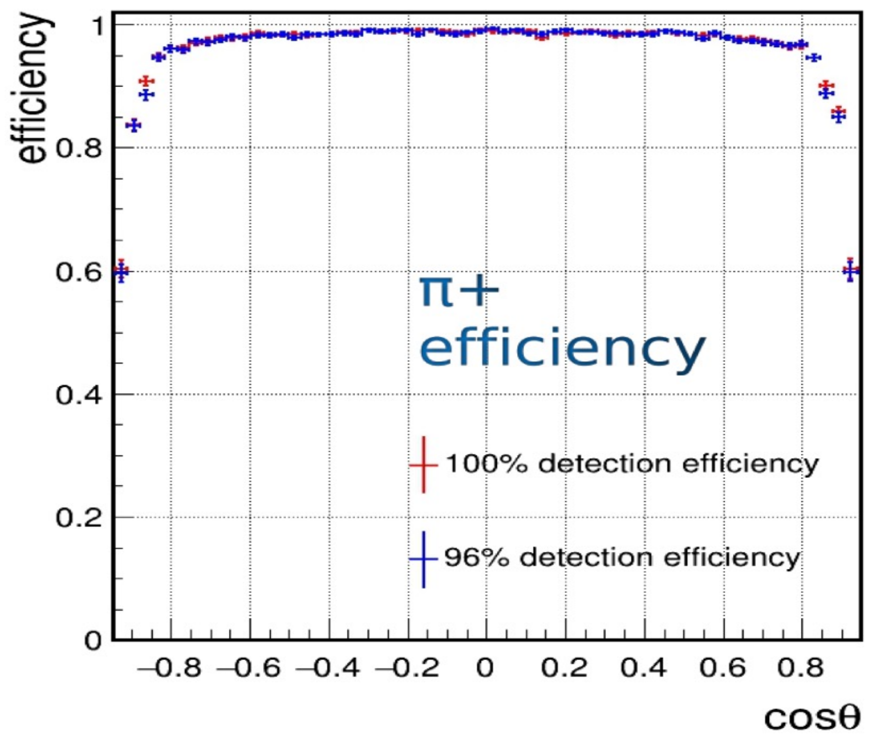


(b)





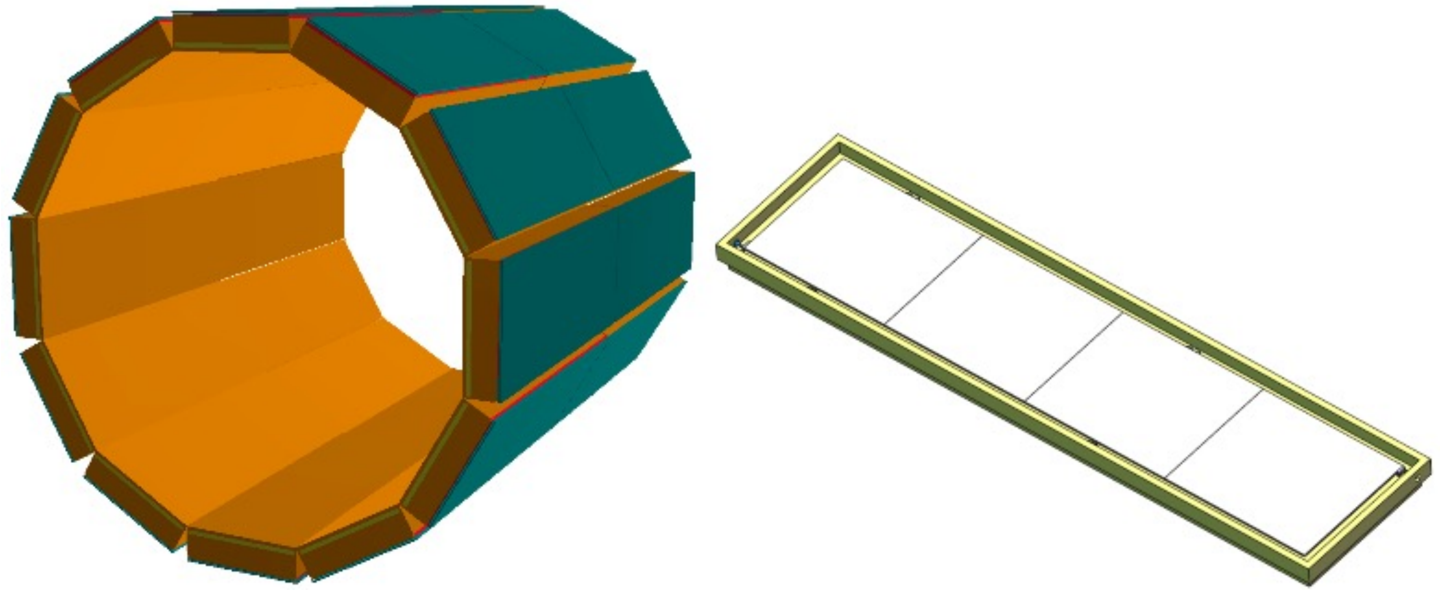


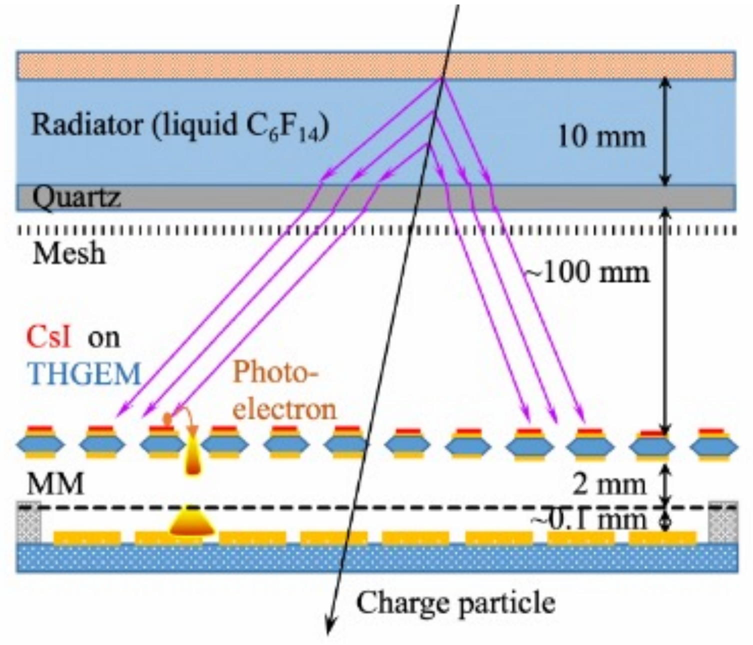


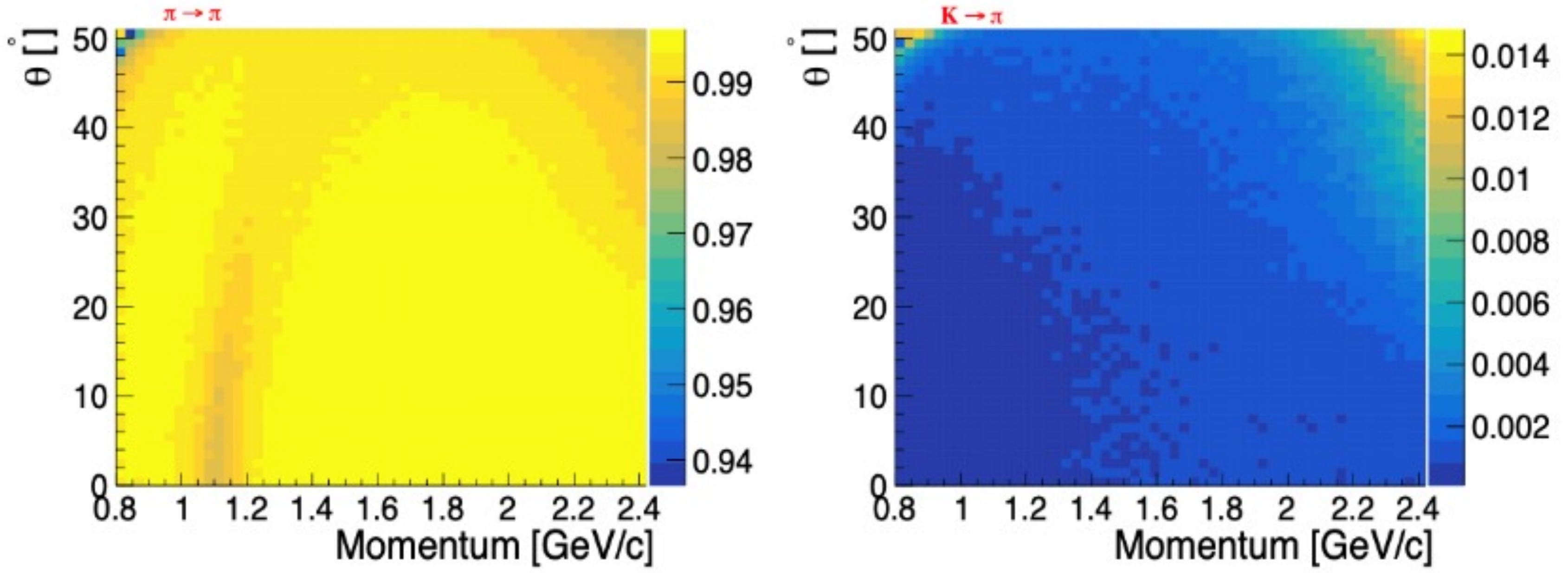
Ongoing layout optimization of the tracking system, particularly targeting low momentum tracking performance.

Particle Identification

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



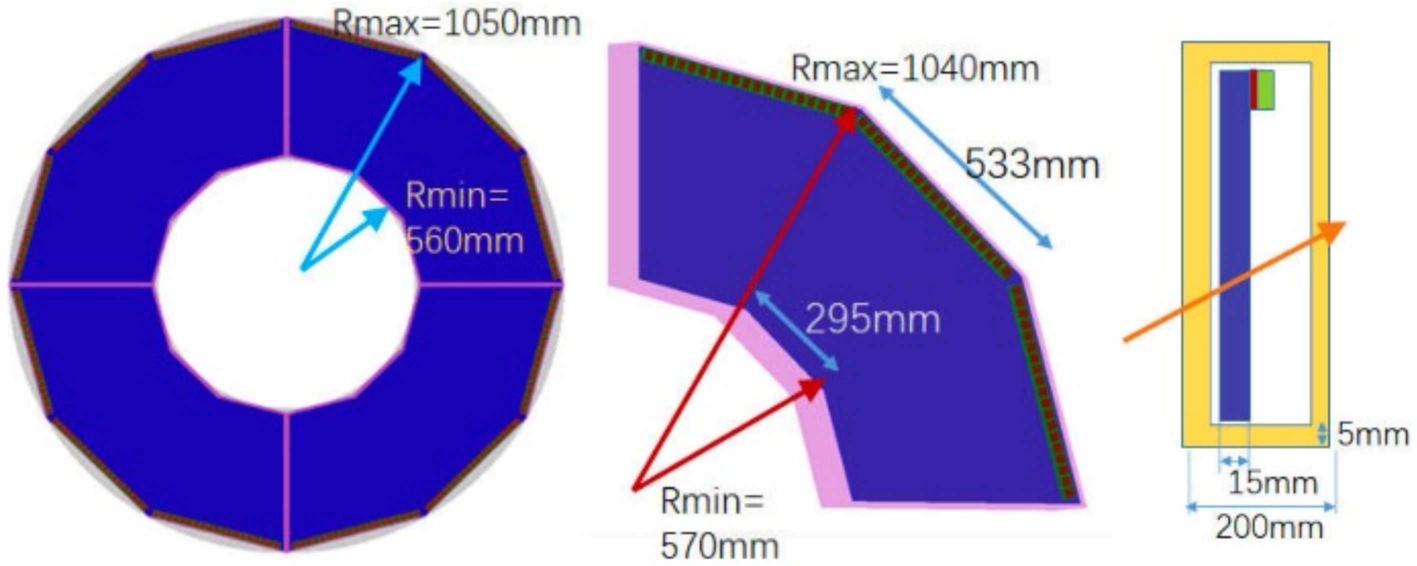


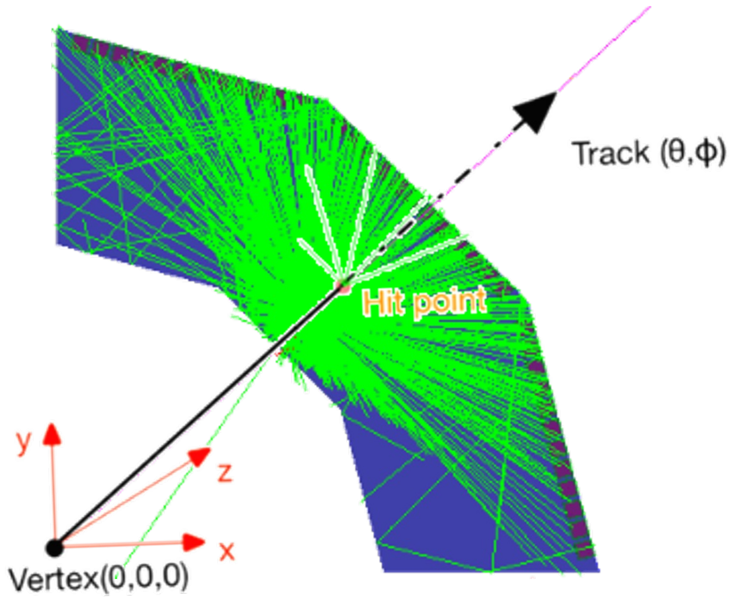


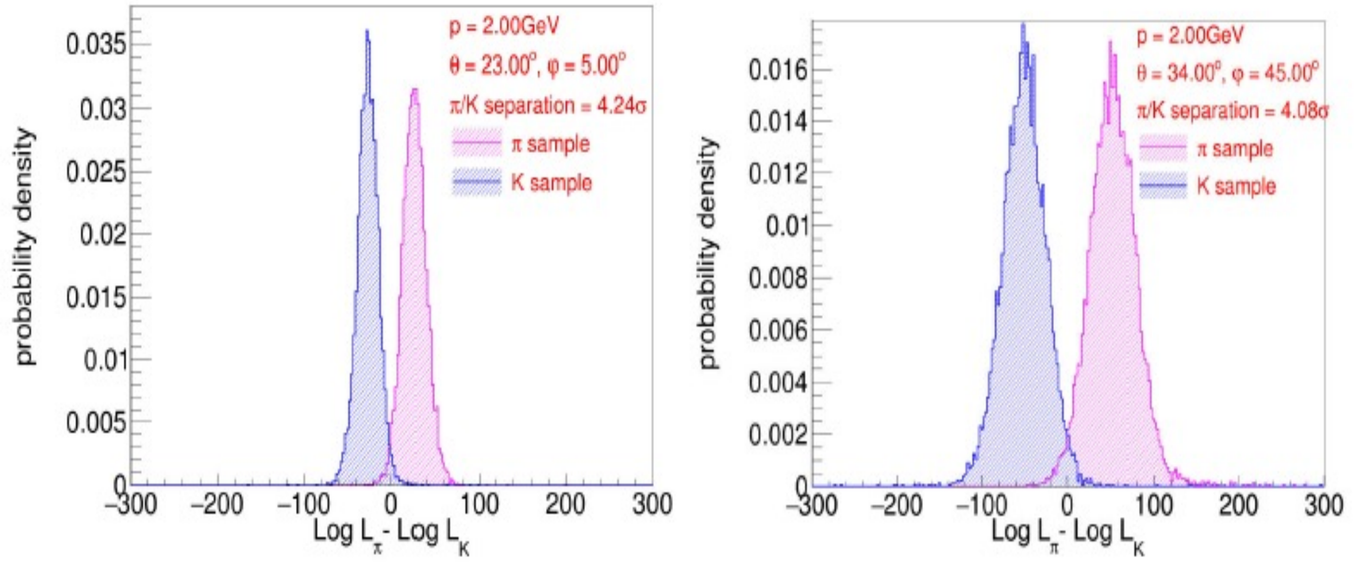
Material budget < 0.3X_0

- **Endcaps : A DIRC-like high-resolution TOF detector (DTOF)**

$K/\pi > 4\,\sigma$ @2.0GeV/c

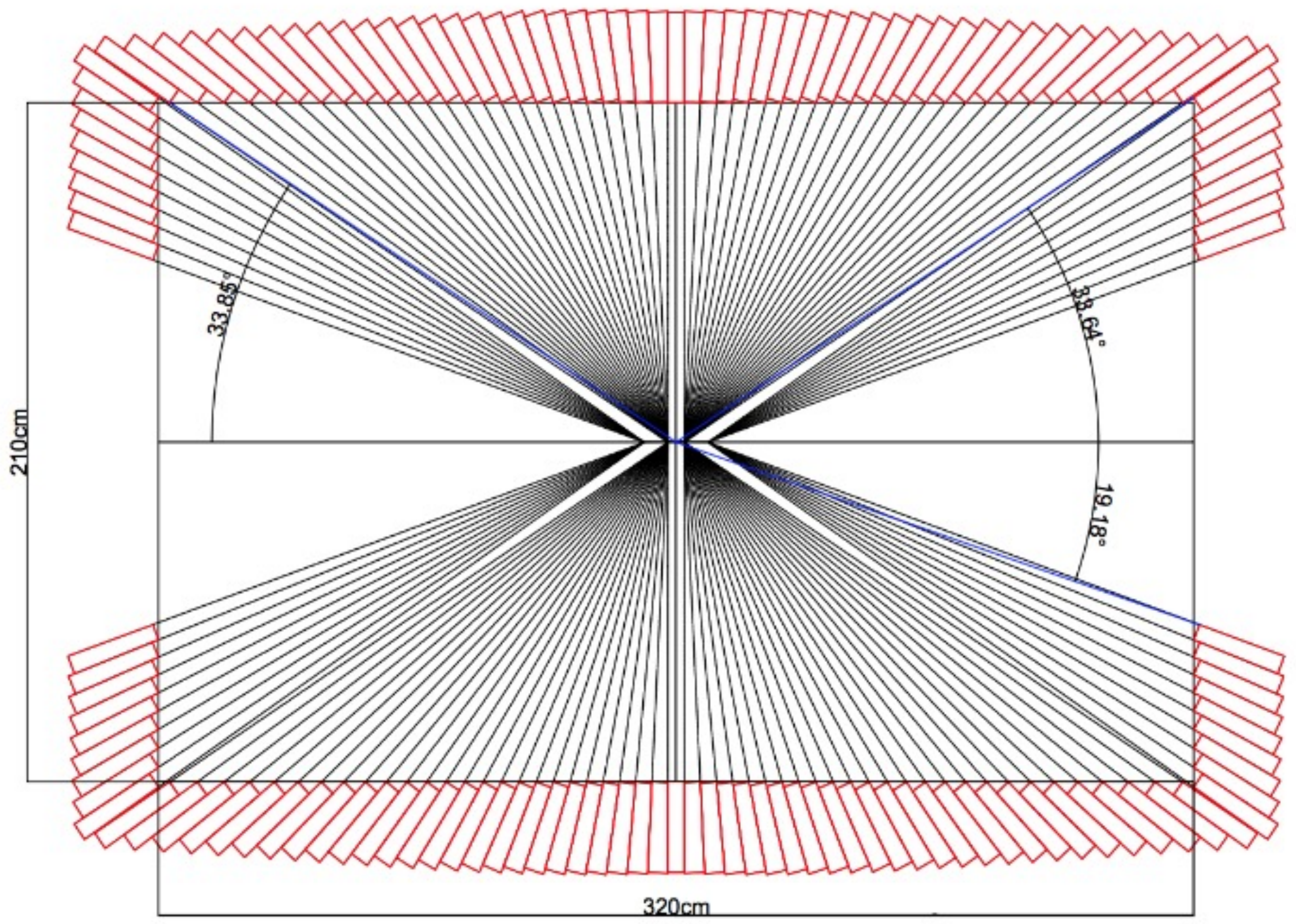


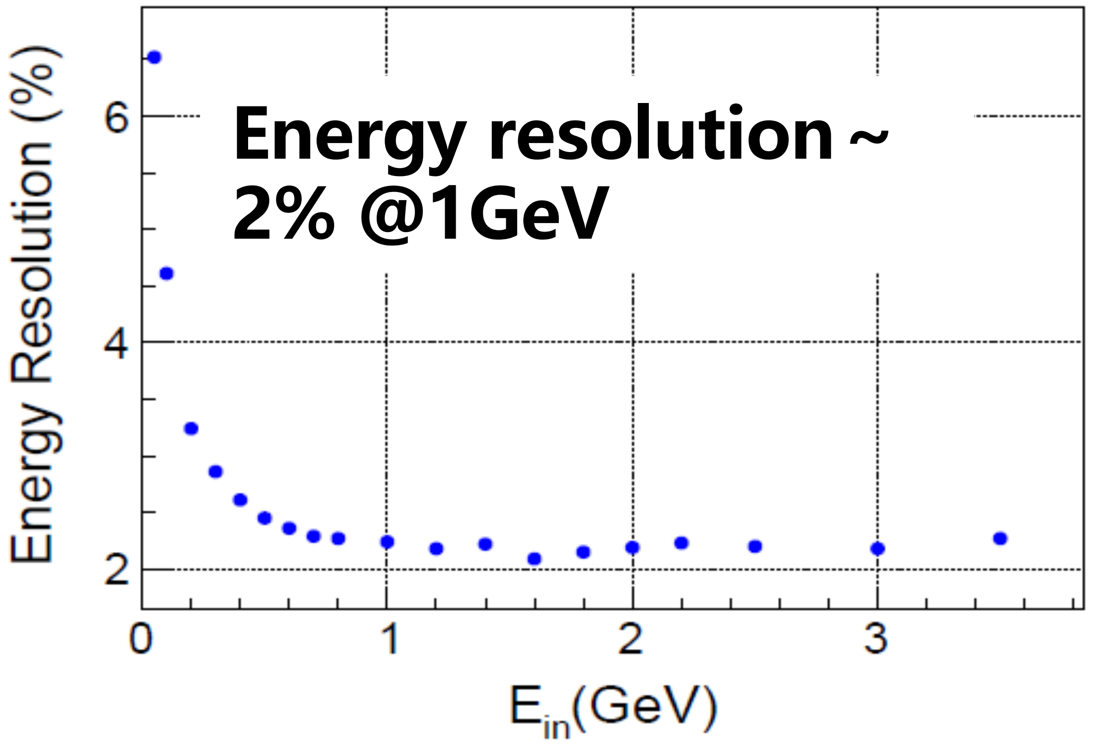


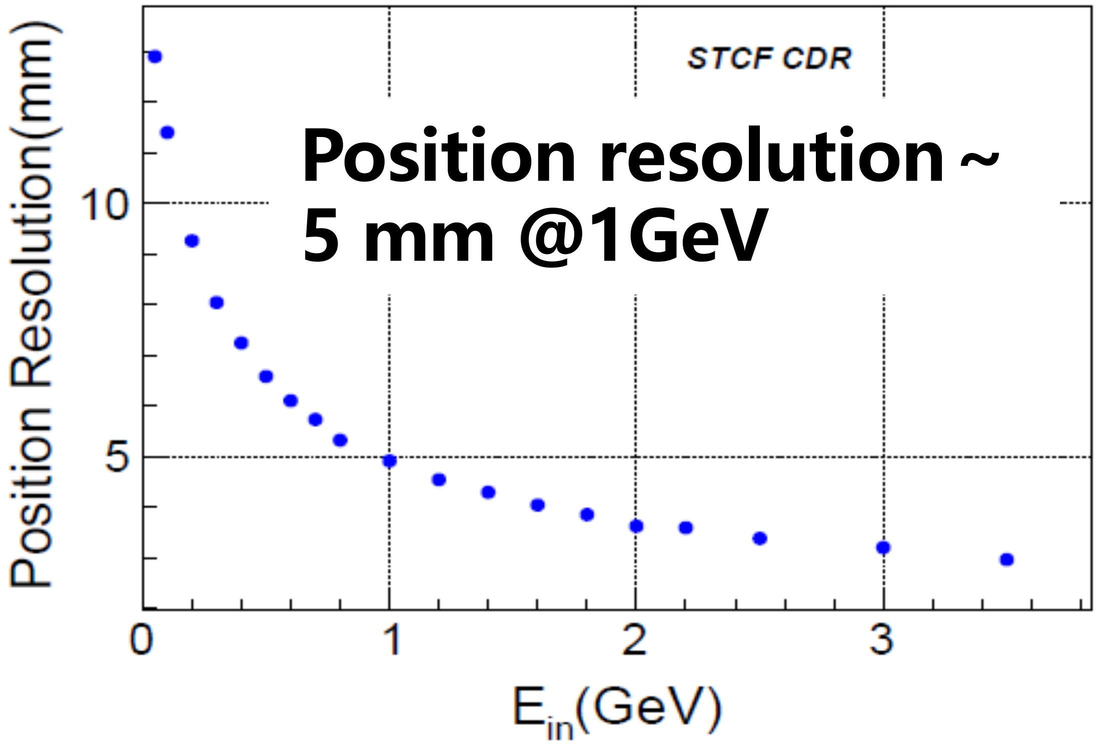


Electromagnetic Calorimeter

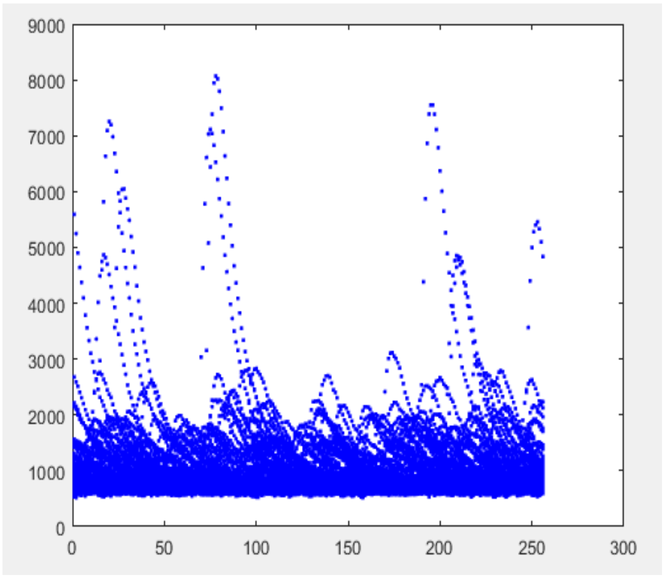
- **A crystal calorimeter using pure CsI to tackle the high background rate (> 1 MHz/crystal)**
  - crystal size: 28cm (15X_0), 5×5cm^2
  - 6732 crystals in barrel, 1938 crystals in endcaps
  - defocused layout
  - 4 large area APDs (1×1cm^2) to enhance light yield

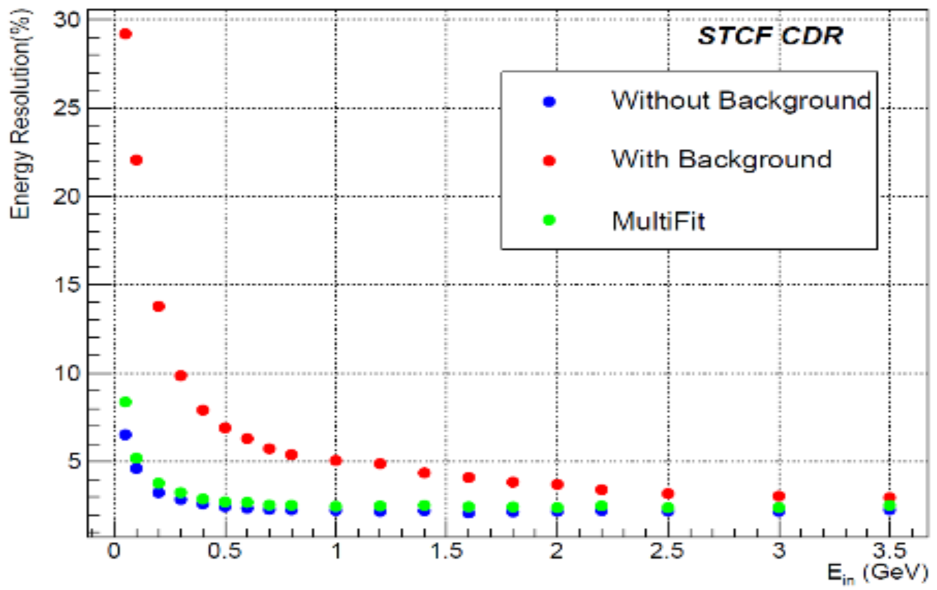






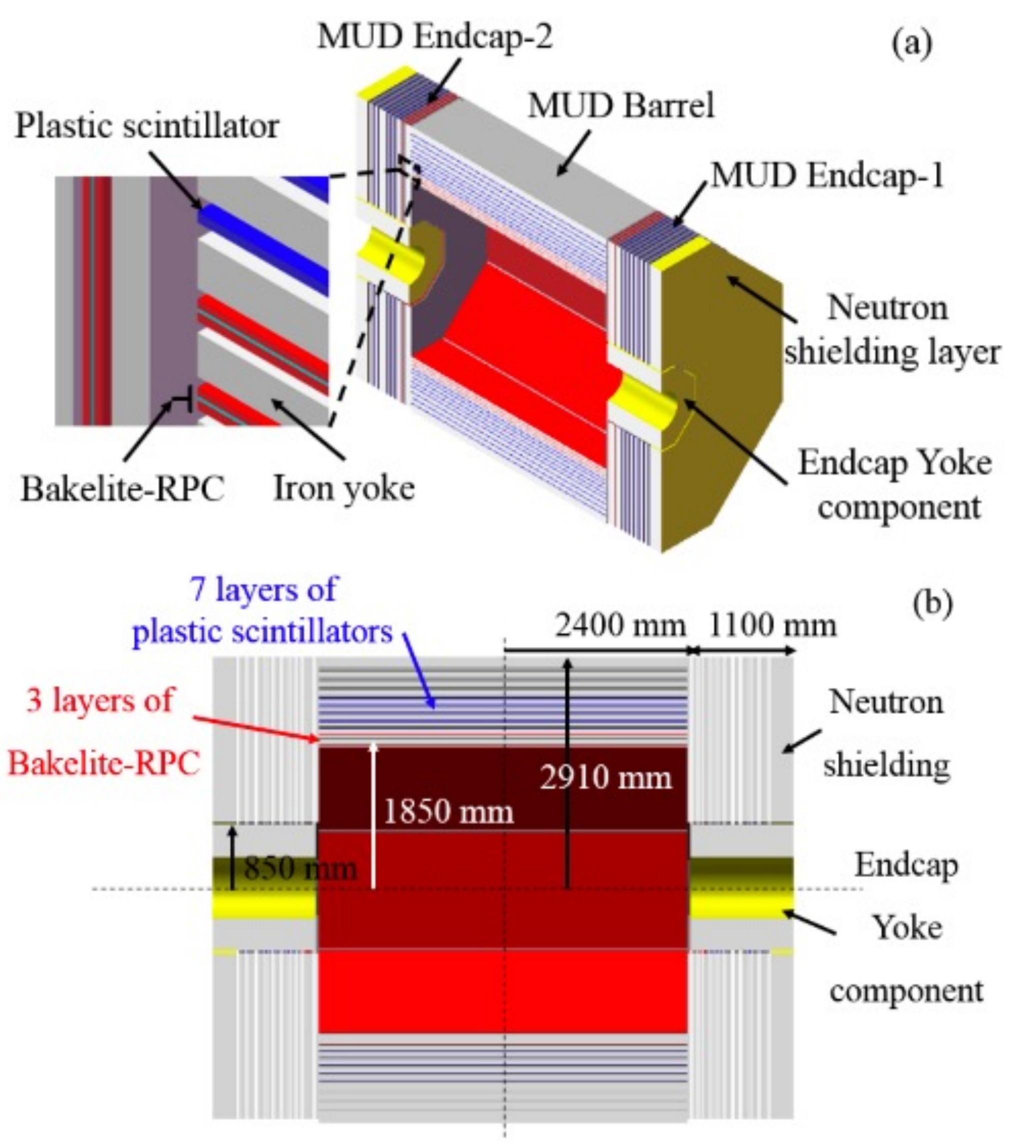
Simulation assuming a light yield of 100pe/MeV





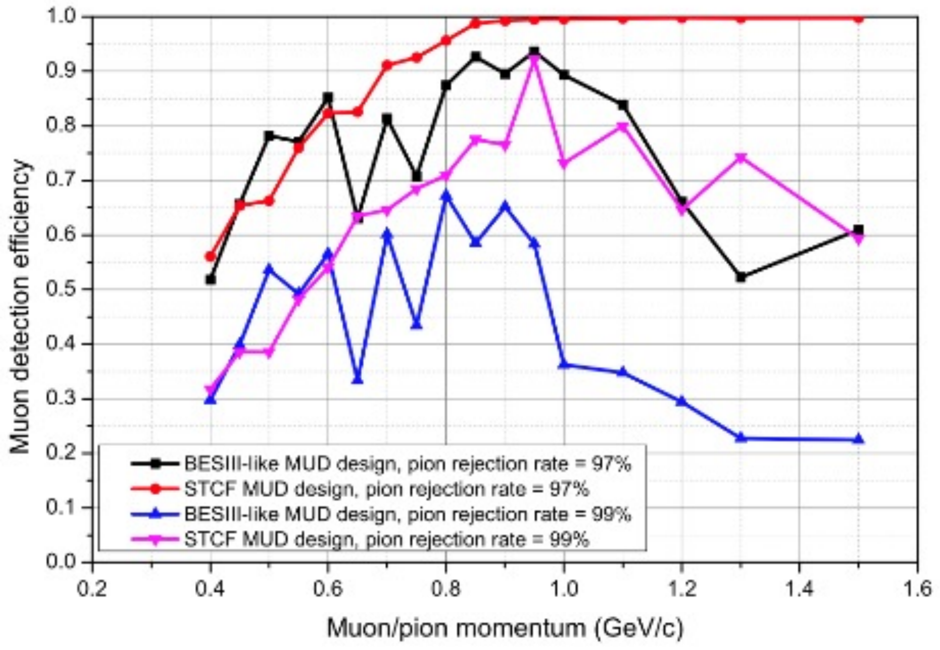
Pileup removal with waveform fitting

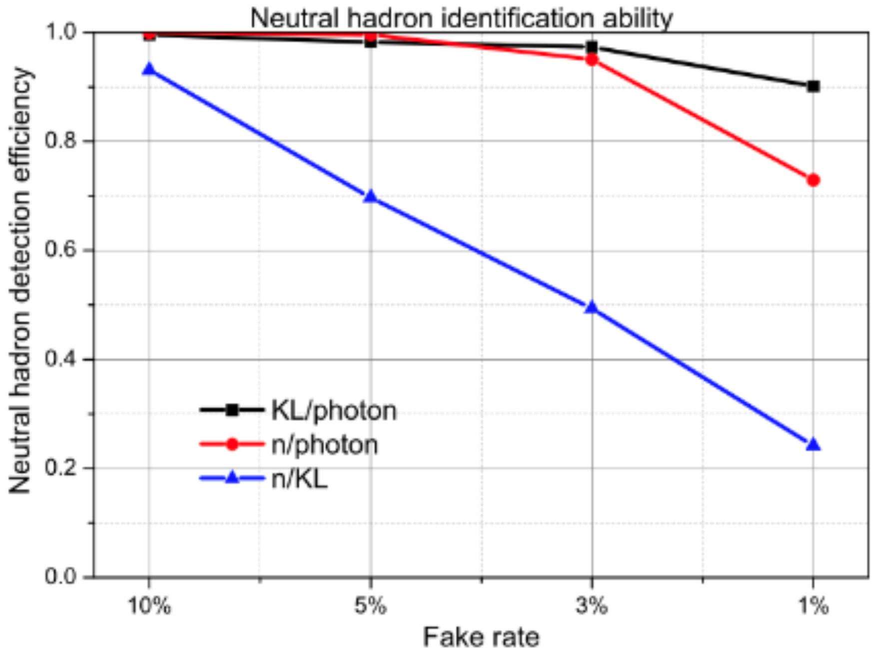
Muon Detector



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

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

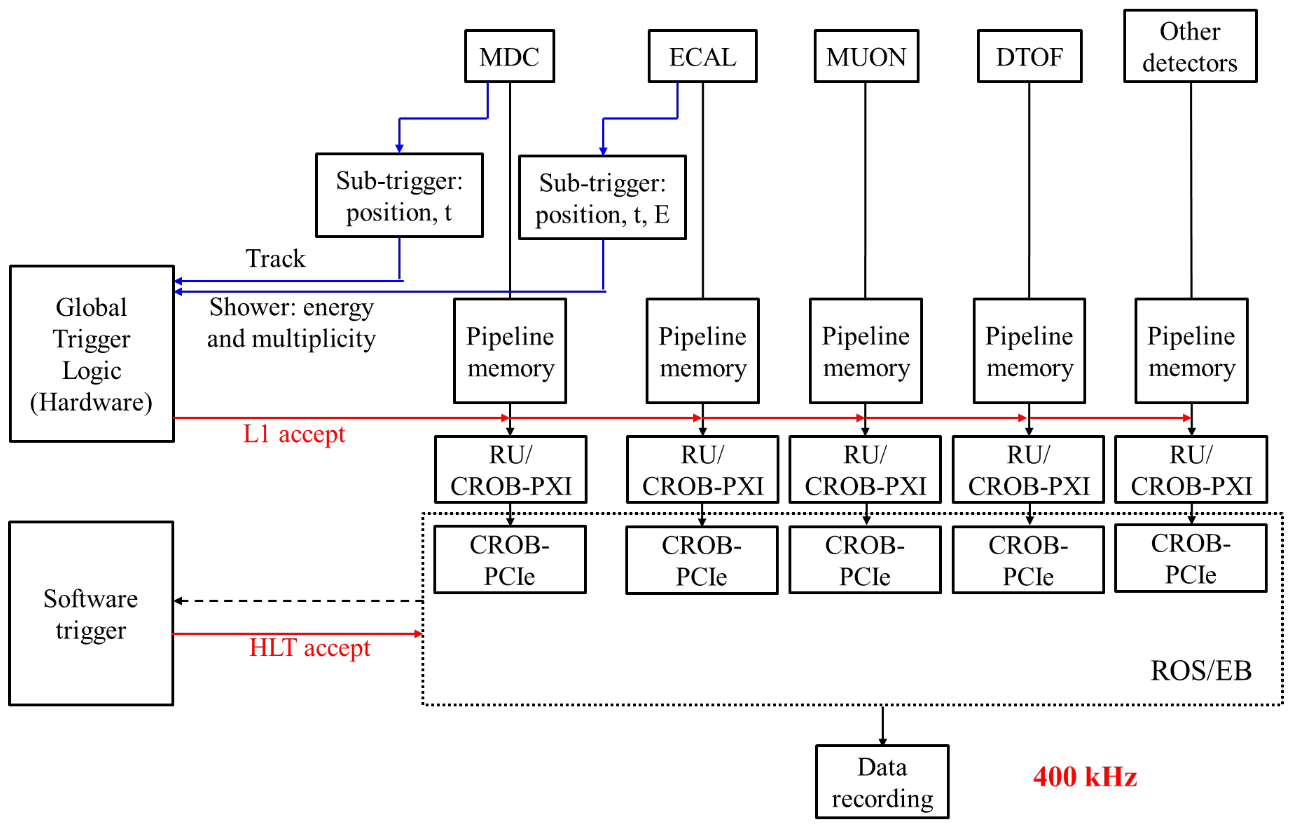


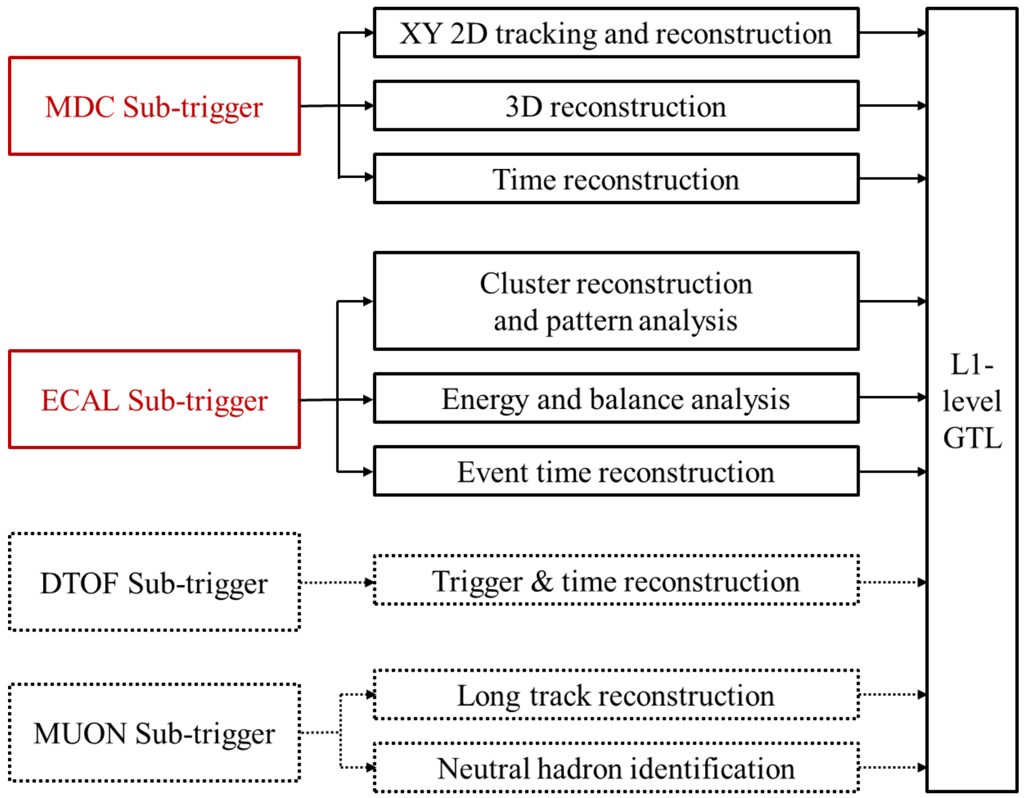


Using BDT combining the muon detector and EMC

Trigger and DAQ

Physics event rate ~ 400 kHz

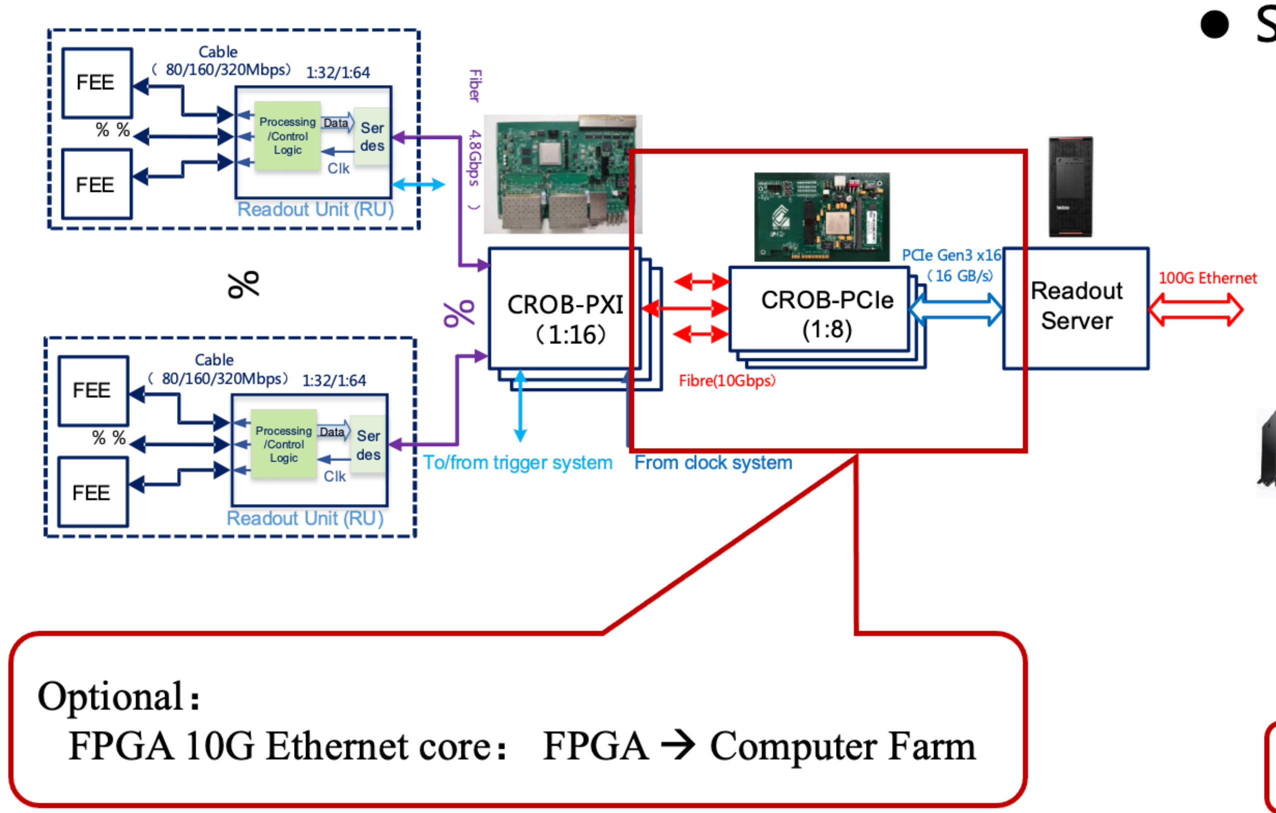




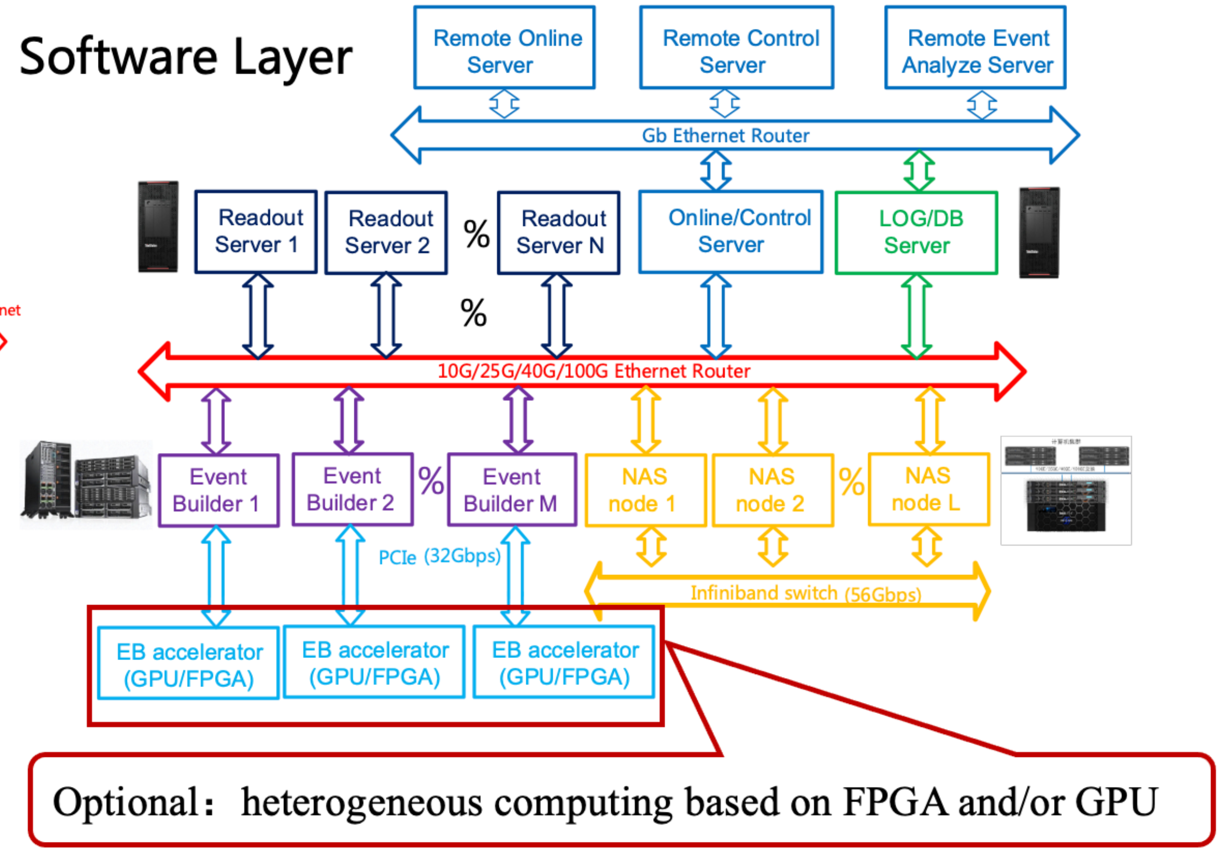
Component	Num. of channels	Readout time window	Event size (B)	Total (B/s)
ITK (Silicon)	50M	500 ns	14300	5.72G
ITK (μRWELL)	10552	500 ns	17232	6.89G
MDC	11520	1 μs	20400	8.16G
PID (RICH)	518400	500 ns	15600	6.24G
PID (DTOF)	6912	500 ns	7380	2.95G
EMC	8670	500 ns	15000	6.00G
MUD	41280	500 ns	262	105M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



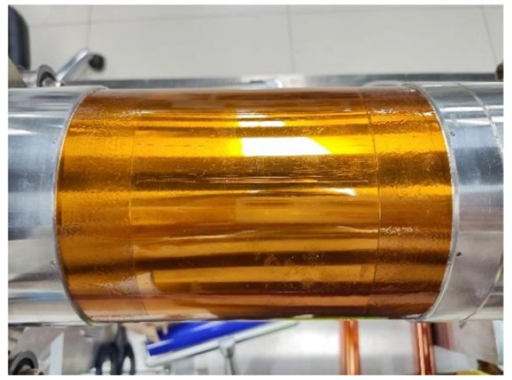
- Software Layer



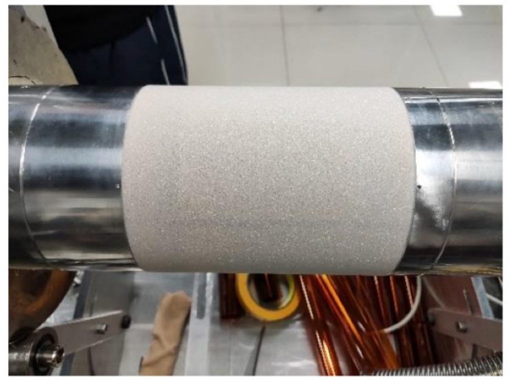
MPGD Inner Tracker R&D

Cylindrical MPGD (uRWELL, uRGroove) and beam test

1、封装kapton层

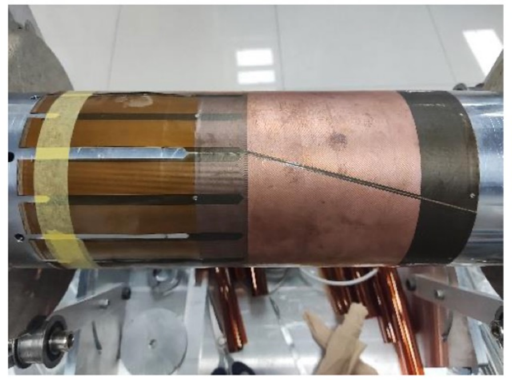


2、PMI泡沫层

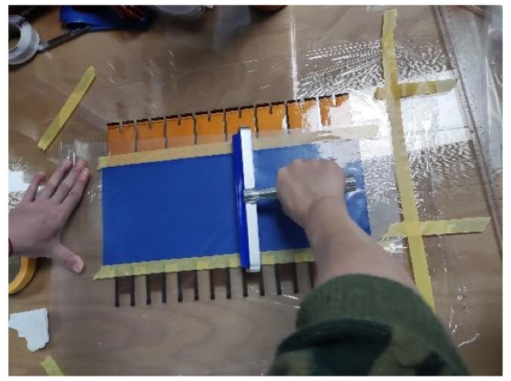


3、V向读出条上胶

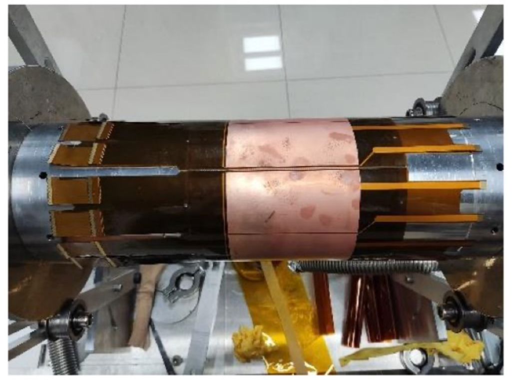
4、V向读出条粘接

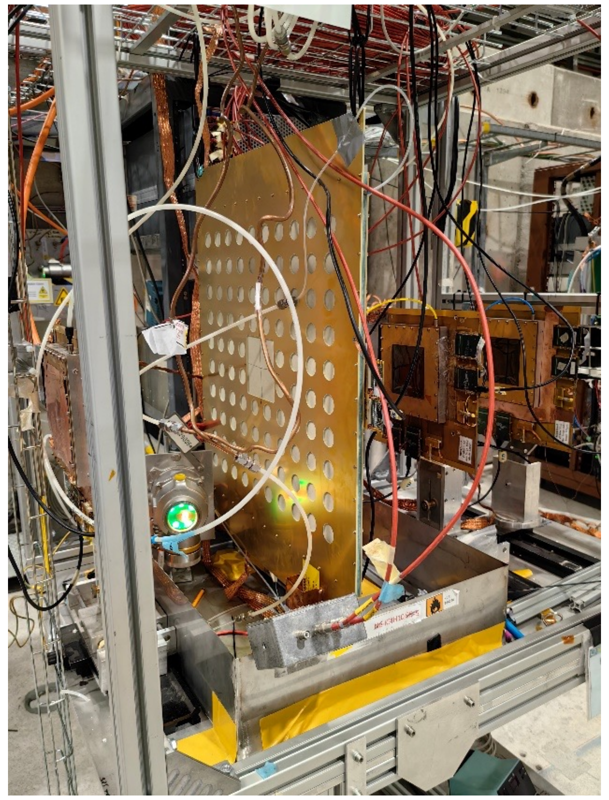


5、X向读出条上胶

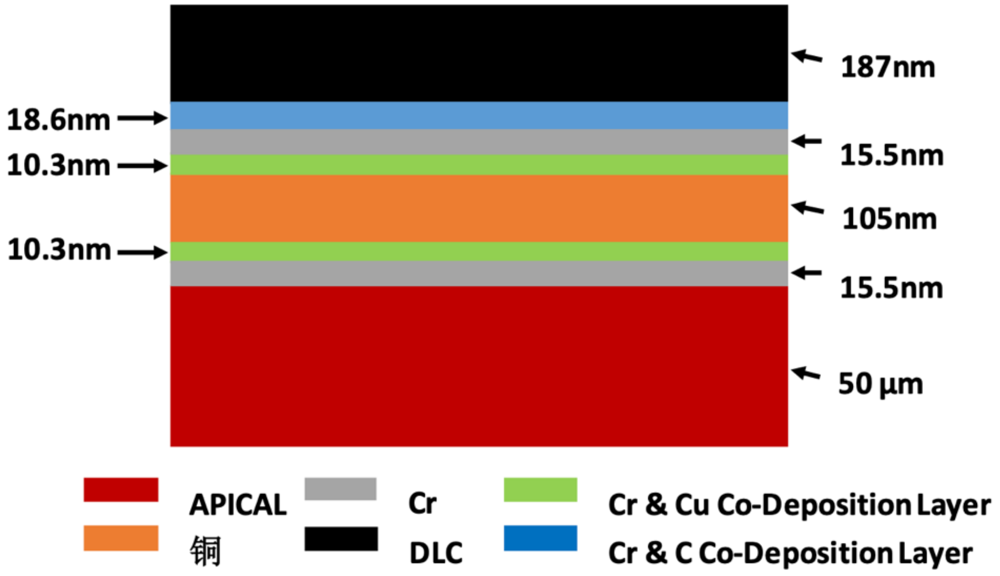


5、X向读出条粘接

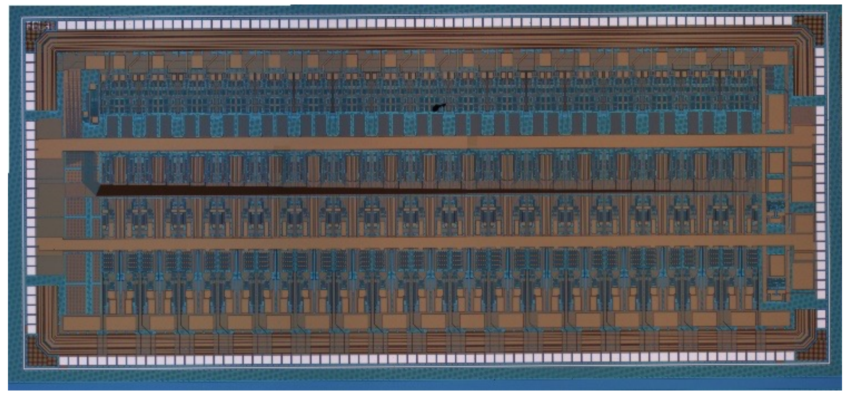


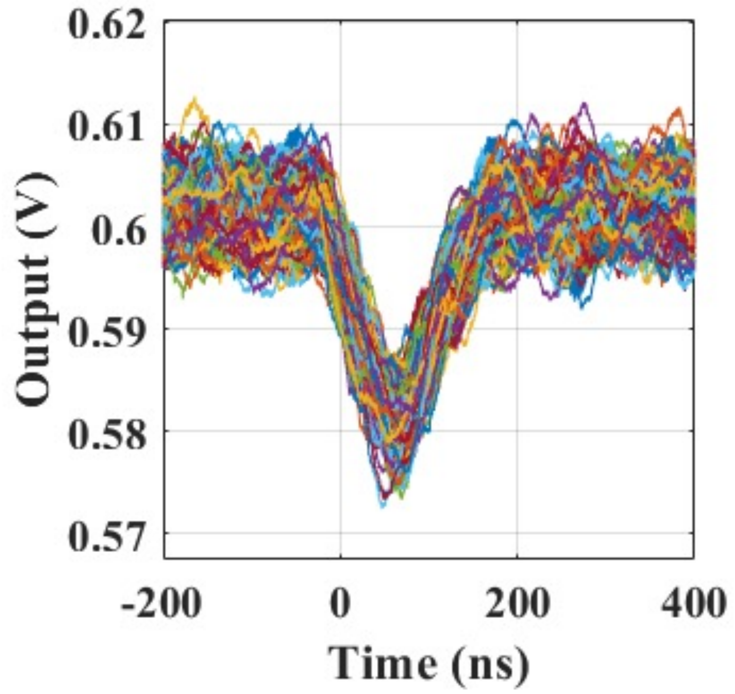


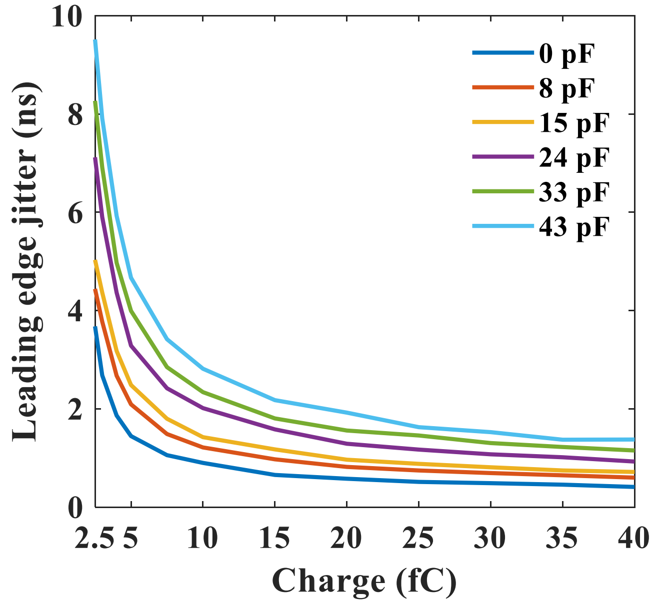
Development of low mass cathode and anode electrodes

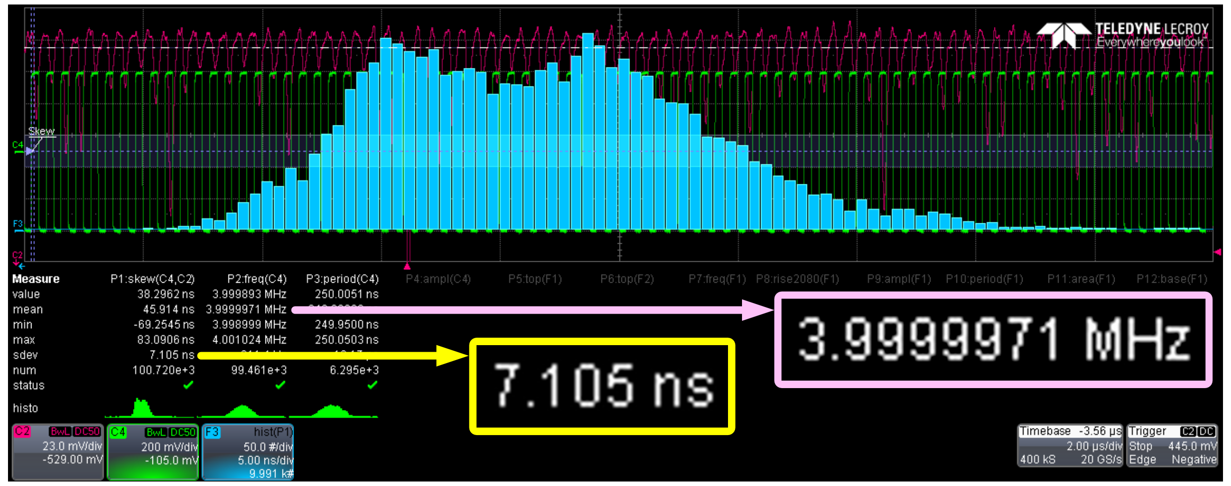


ASIC: σ_t <10 ns@5fC&20pF, counting rate > 4 MHz





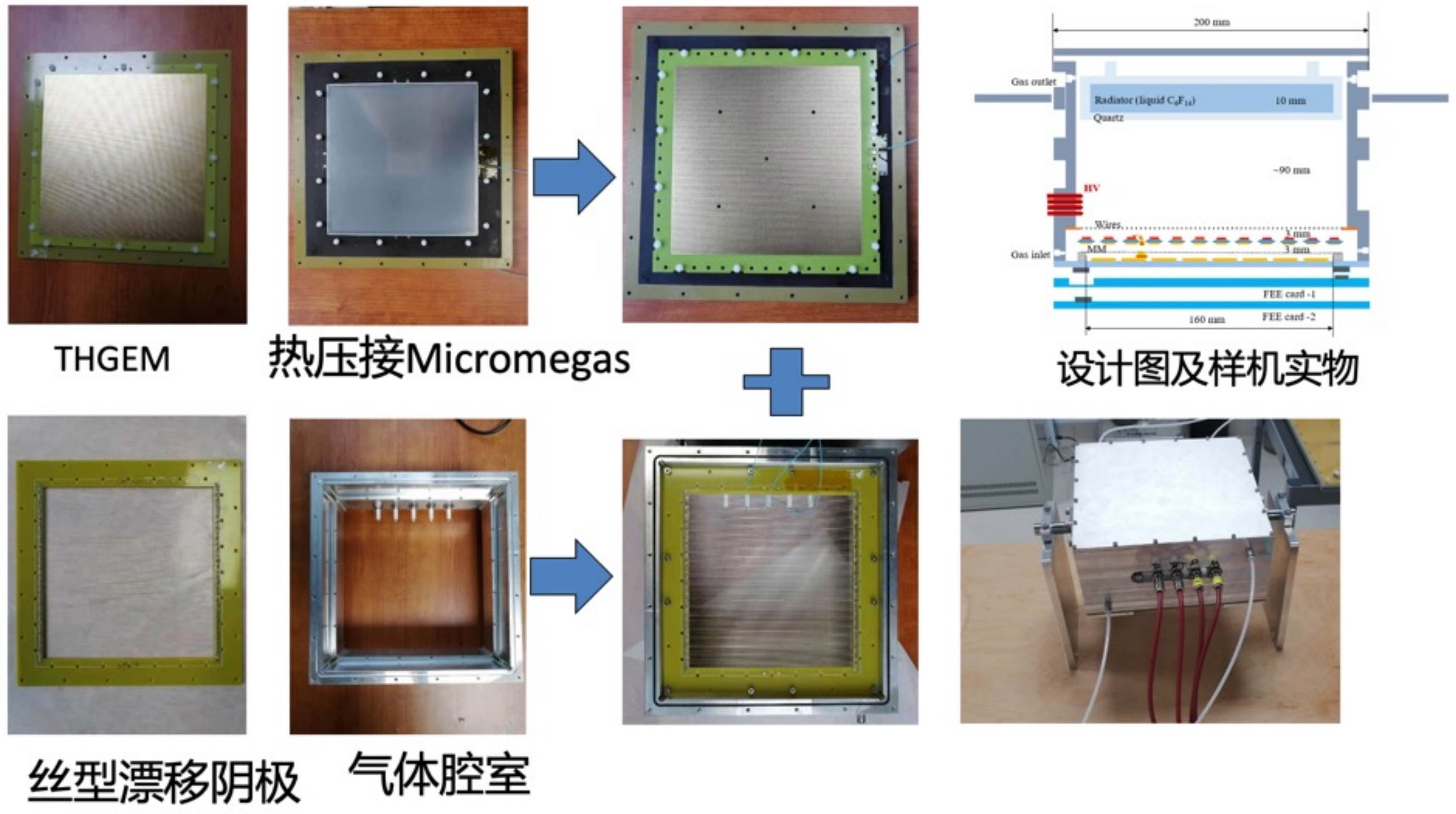


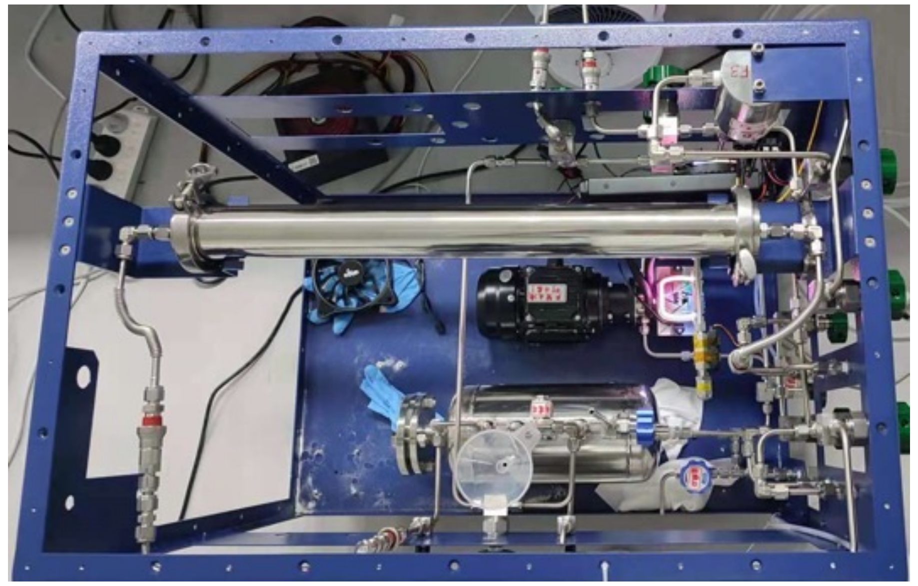


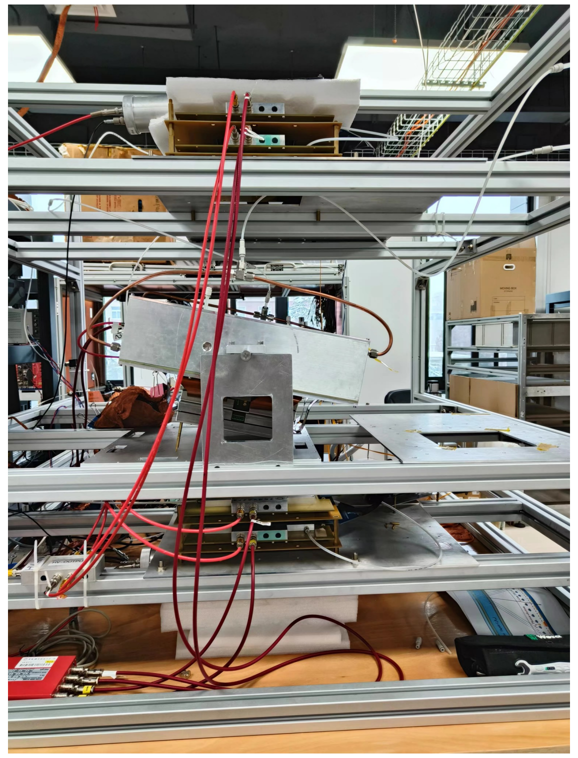
基于探测器模拟的输出波形进行时间精度测试@计数率4 MHz@输入电容35 pF

RICH R&D

30cm*30cm RICH prototype

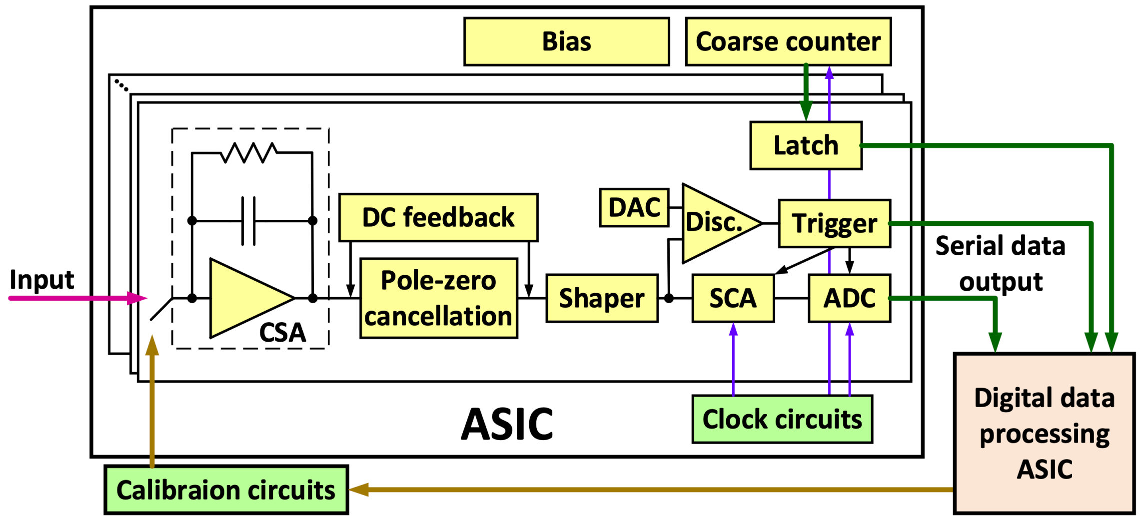


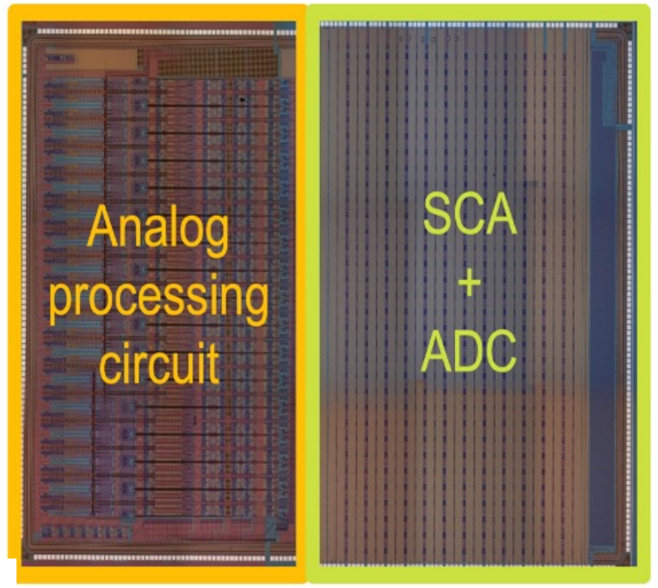




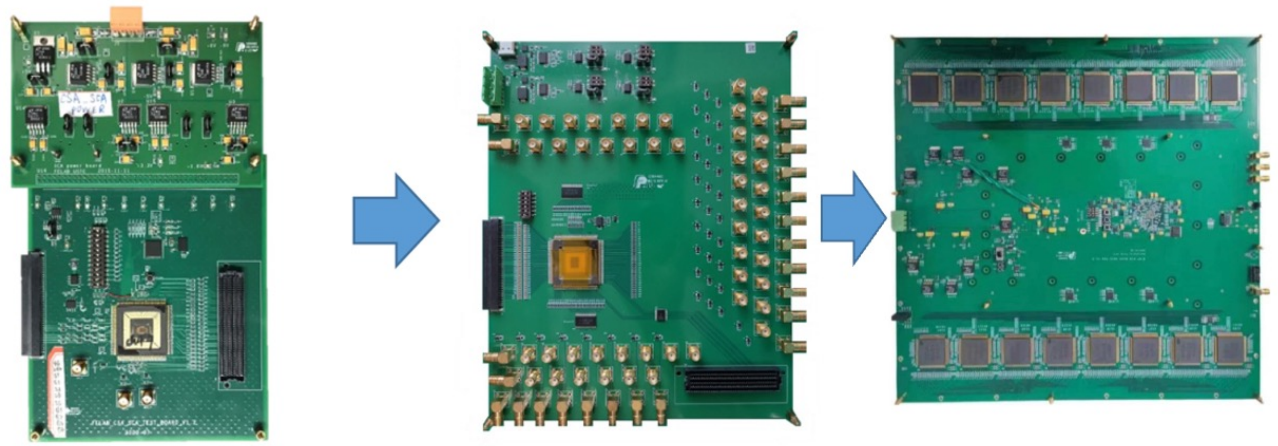
RICH readout ASIC

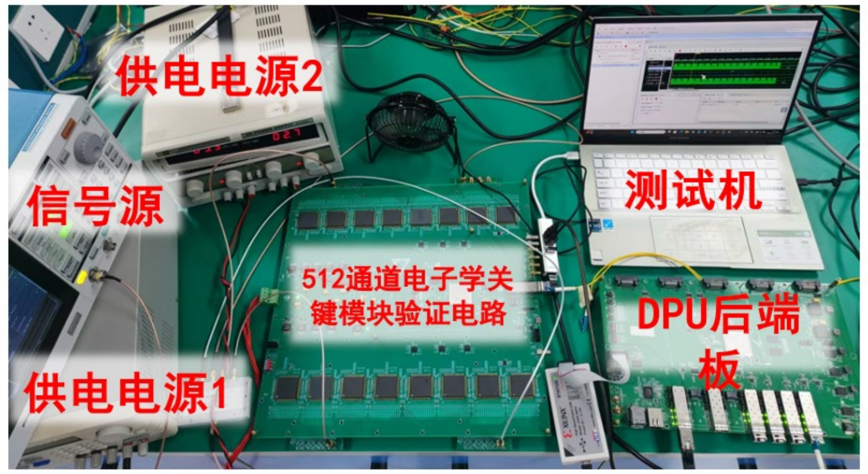
σ_t <1 ns@20fC&20pF
counting rate > 100 kHz

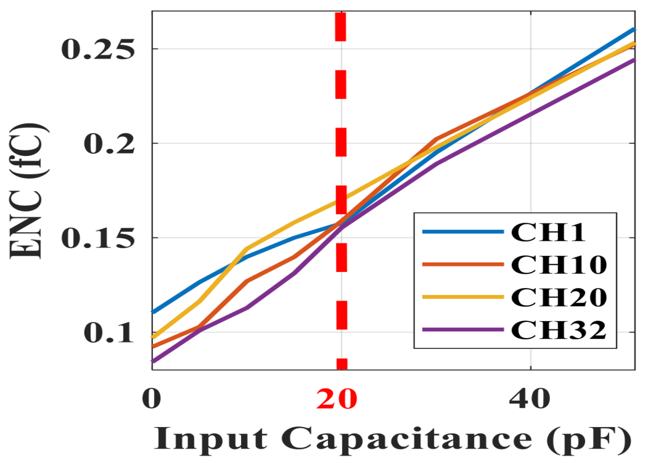


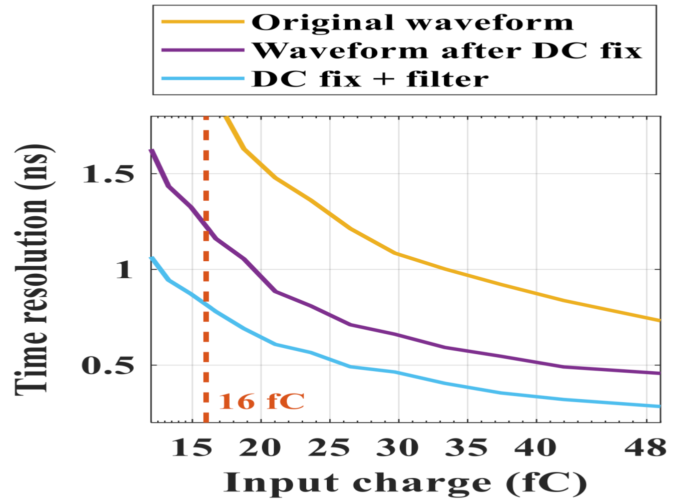


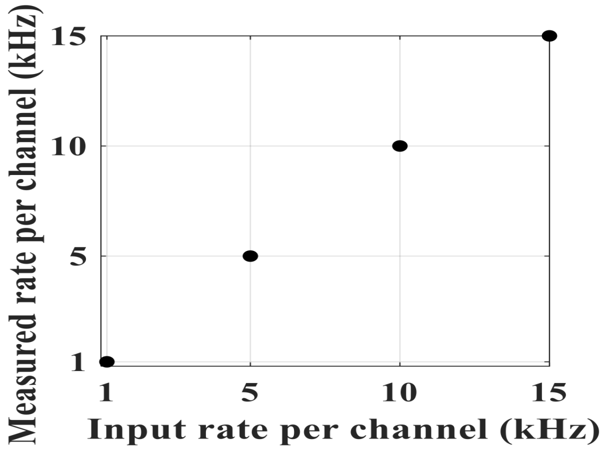
First version Second version



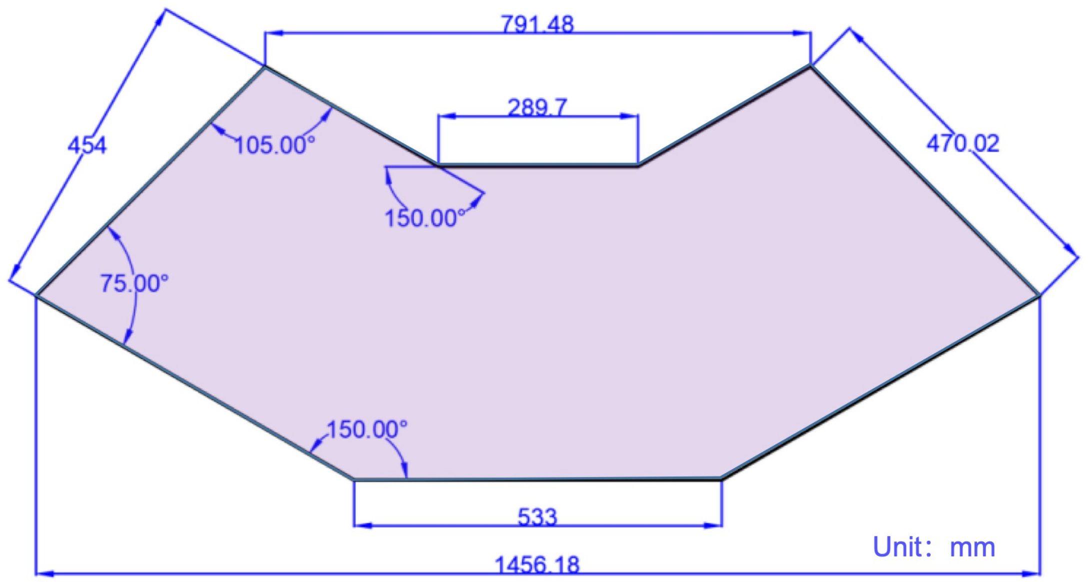






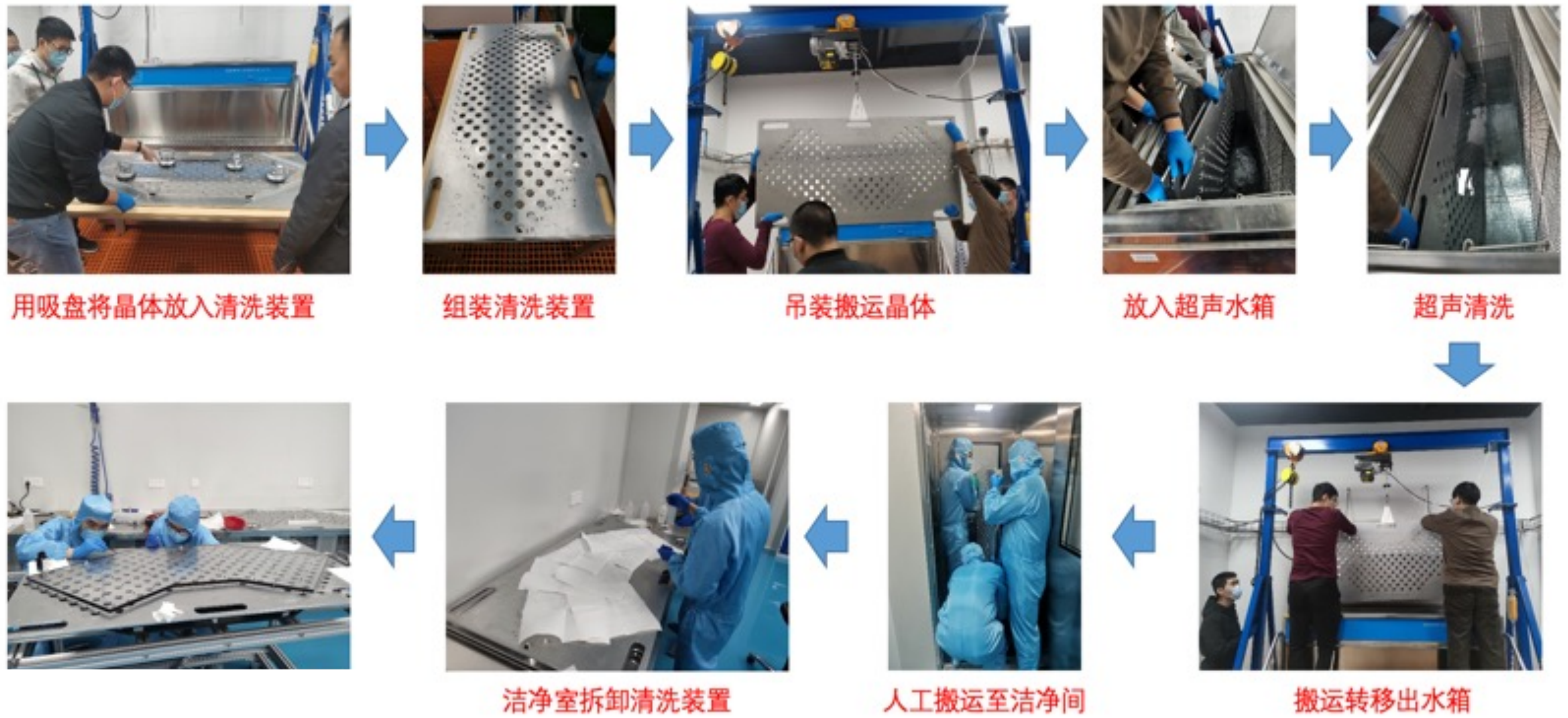


A full-size DTOF prototype

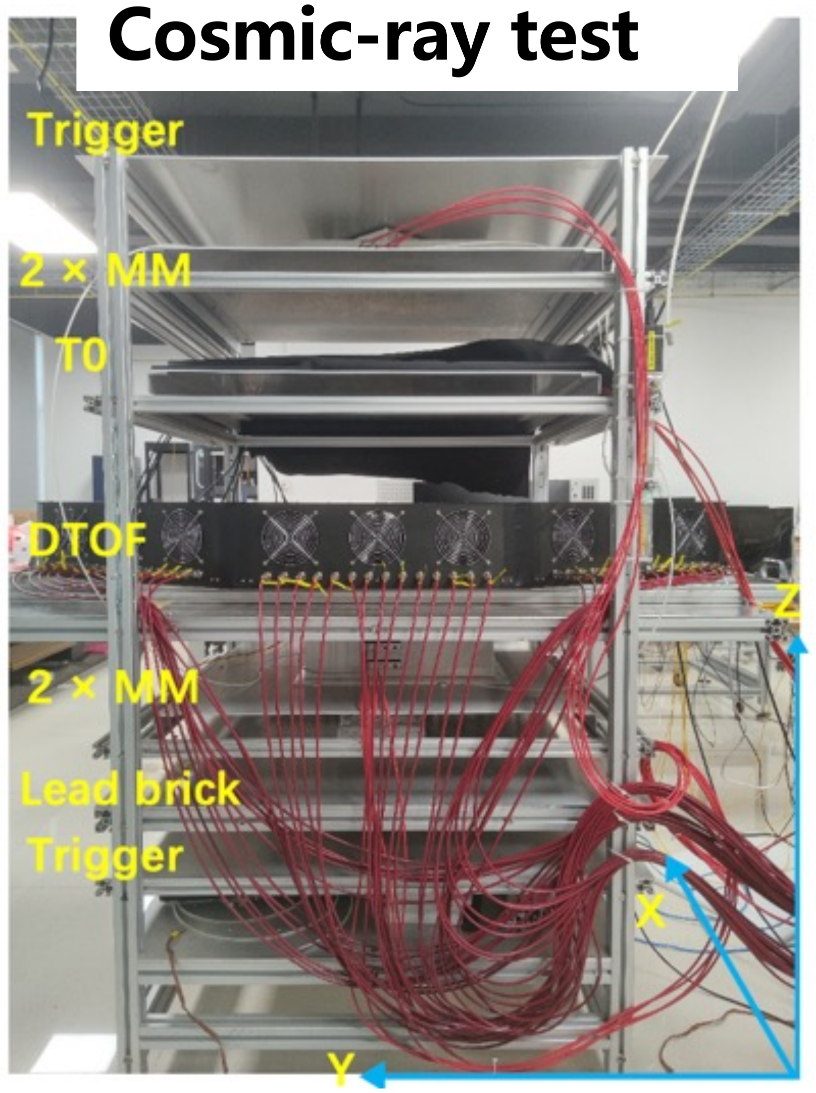


石英清洗和安装

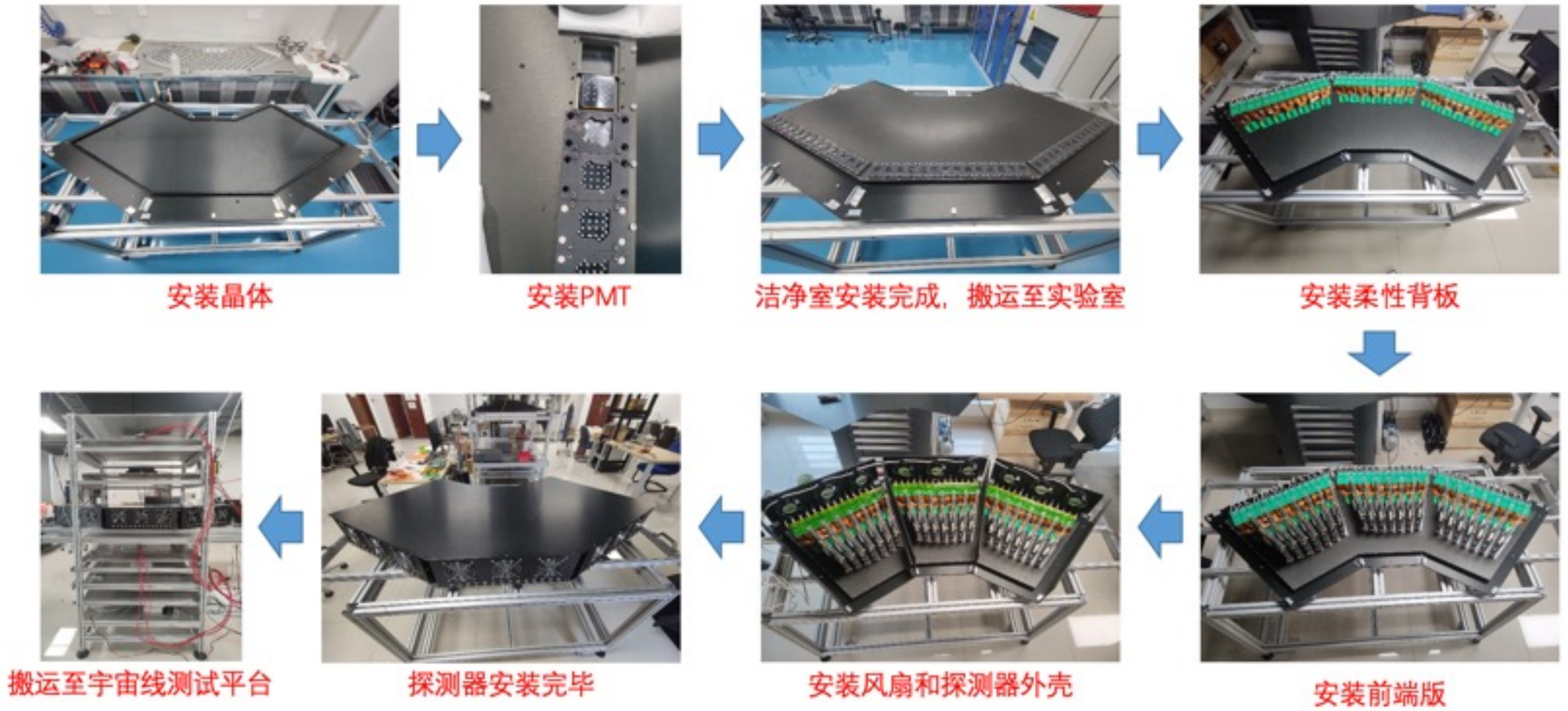
Quartz radiator cleaning and mounting

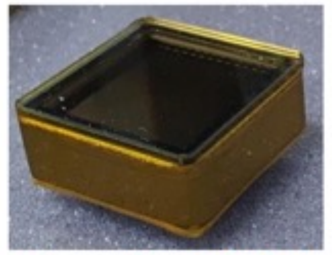


Cosmic-ray test



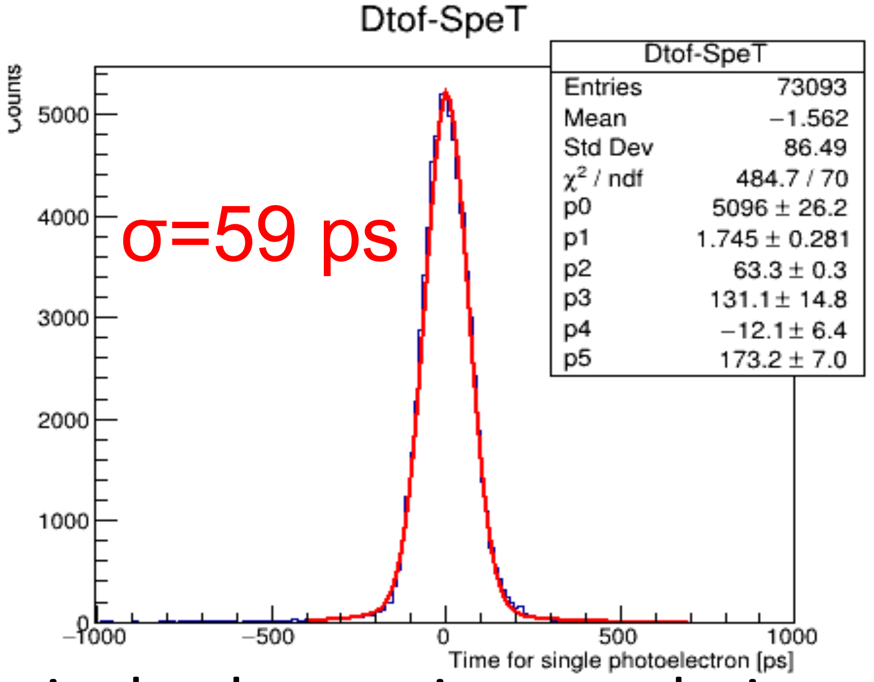
Detector assembling



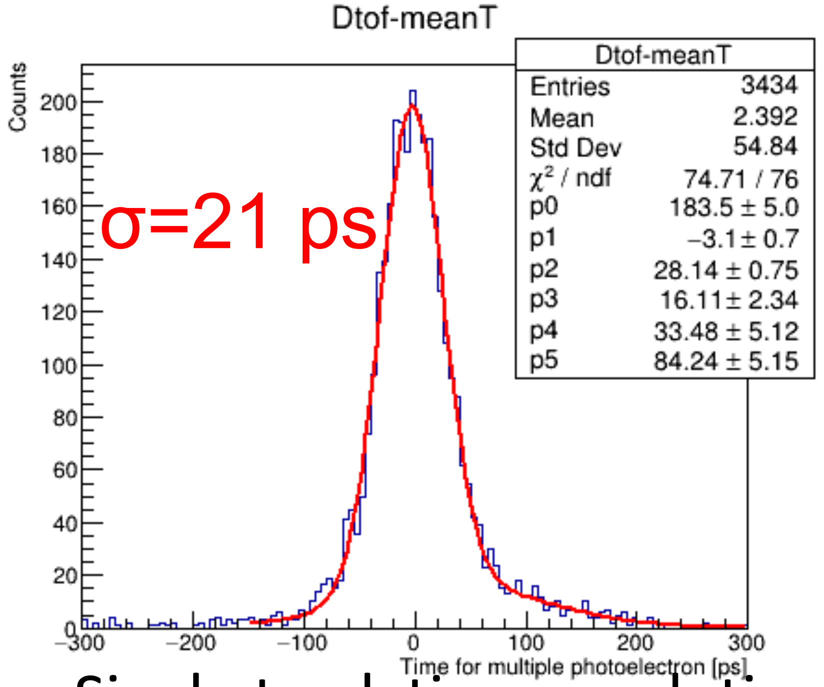


Hamamatsu R10754

- 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

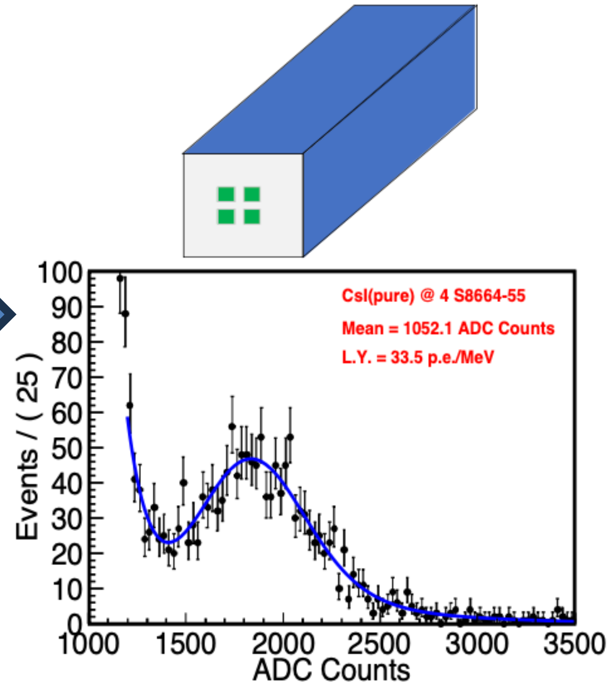


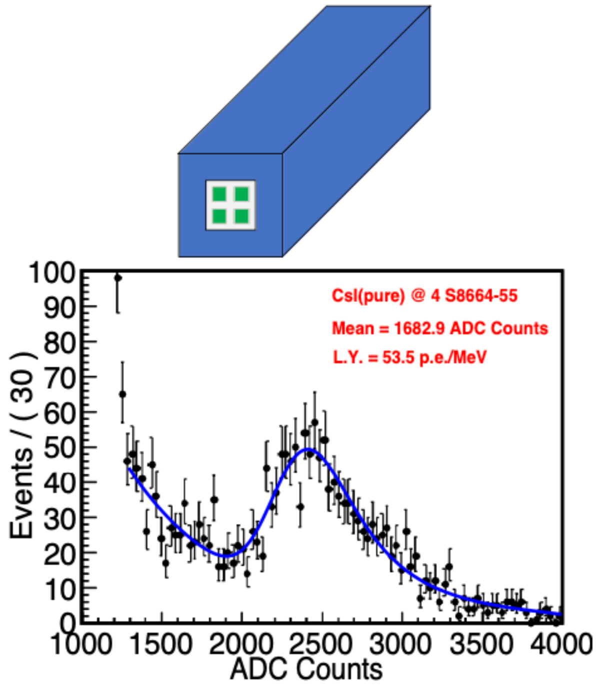
Single track time resolution

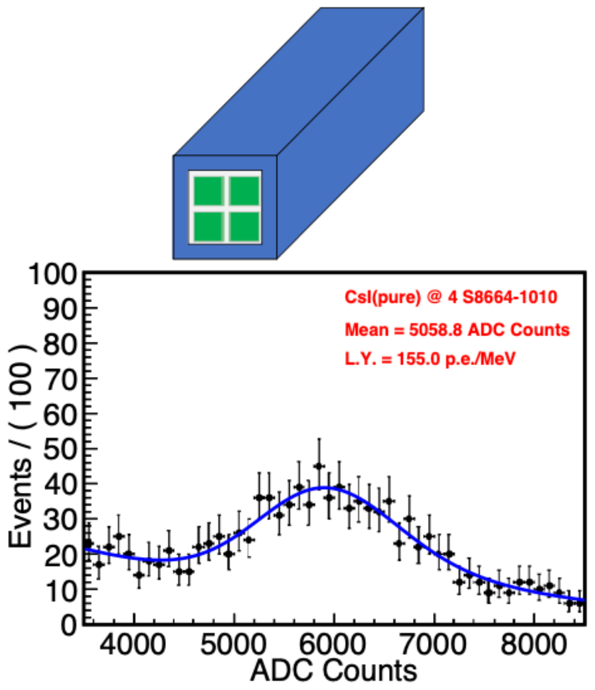
pCsI ECAL R&D: Light yield and timing studies

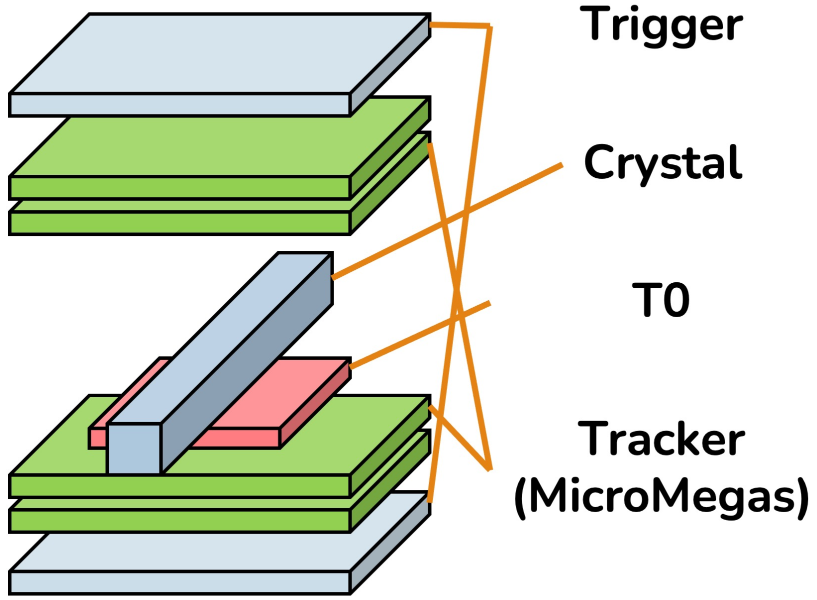
A major R&D task : enhancing light yield

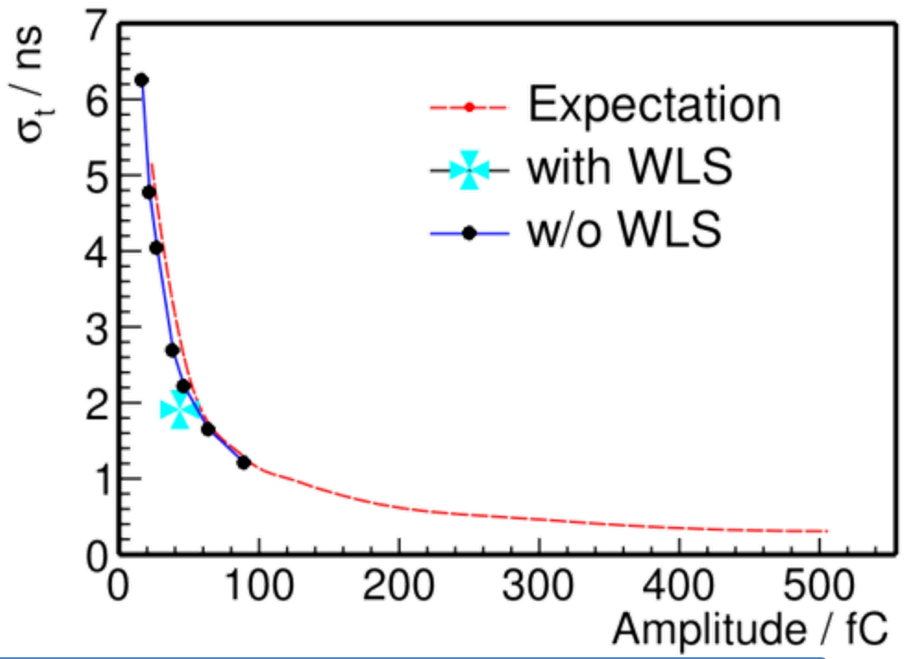
reflector：225um thick Teflon

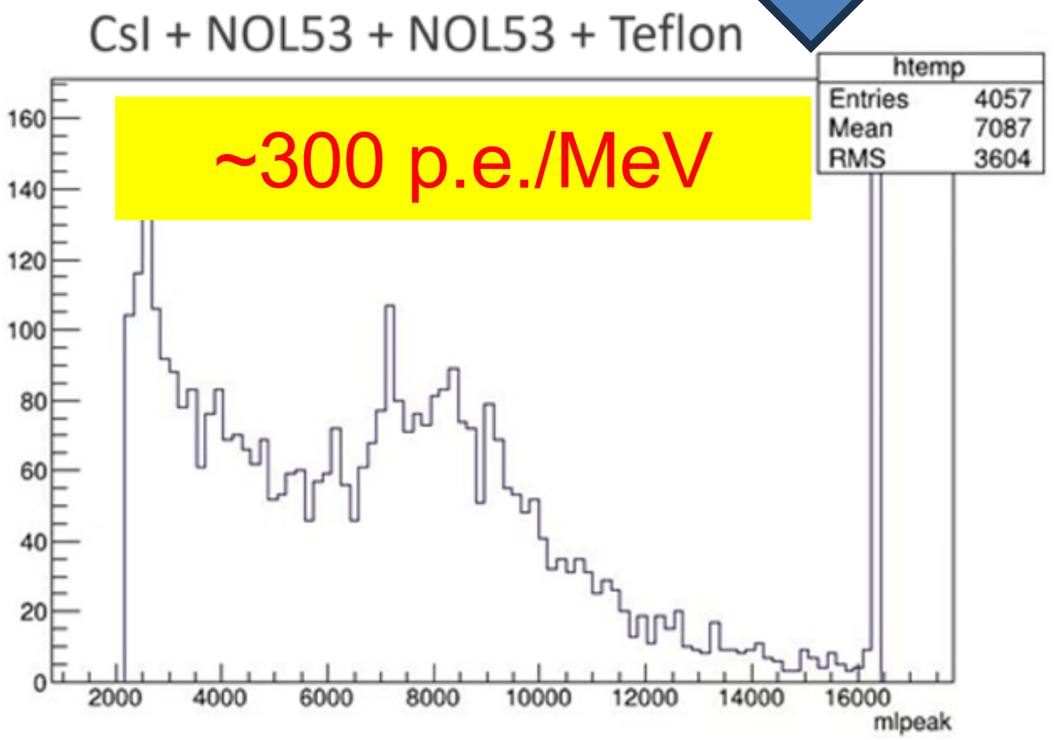










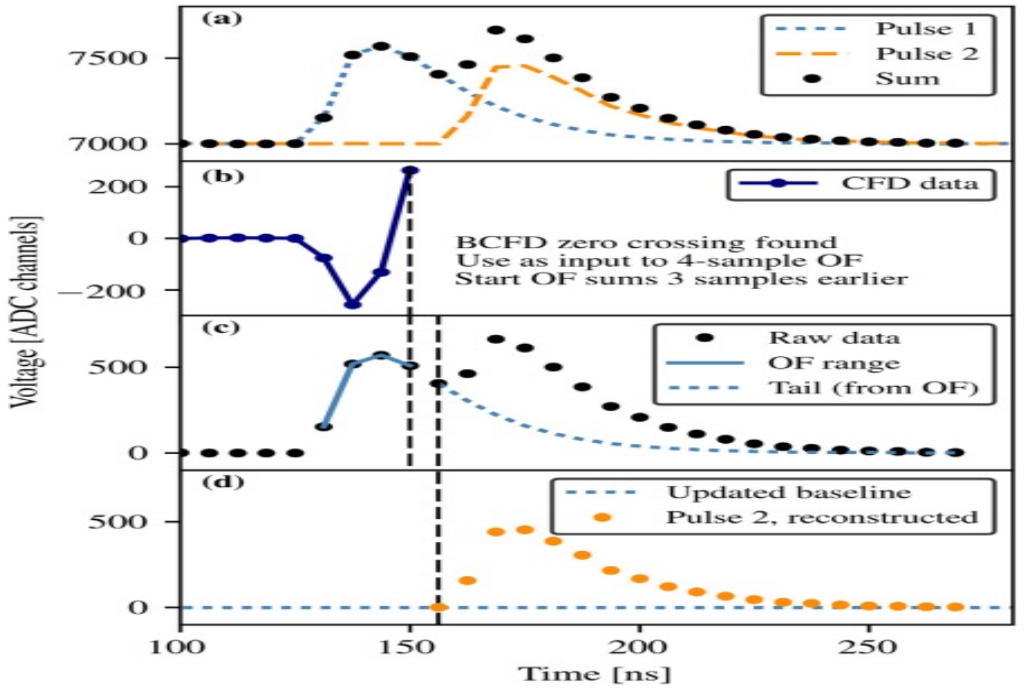


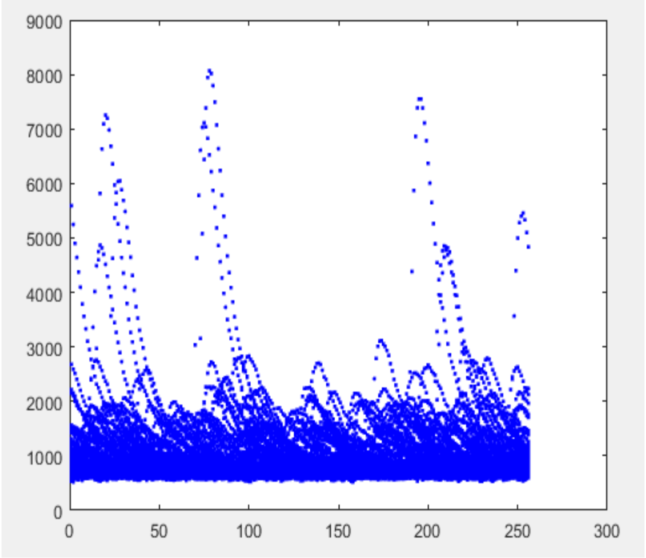
σ_t： 2.0 ns @ 0.03 GeV， 0.8 ns @ 0.1 GeV

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

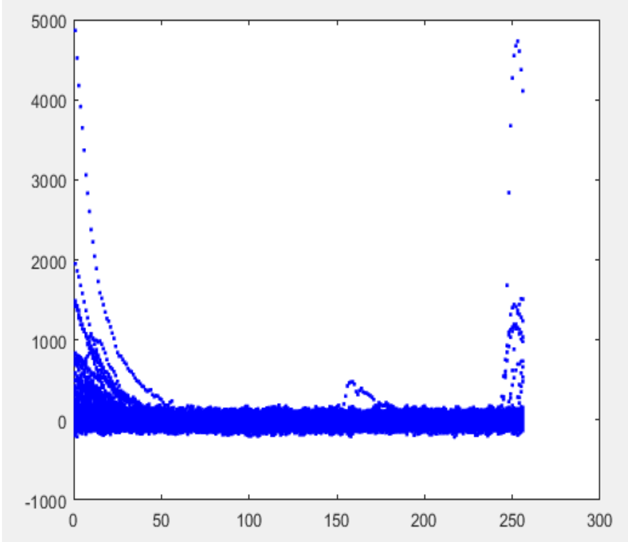
pCsI ECAL R&D: Pileup mitigation and electronics

■ **Waveform fitting to remove pileup noise and extract signals**

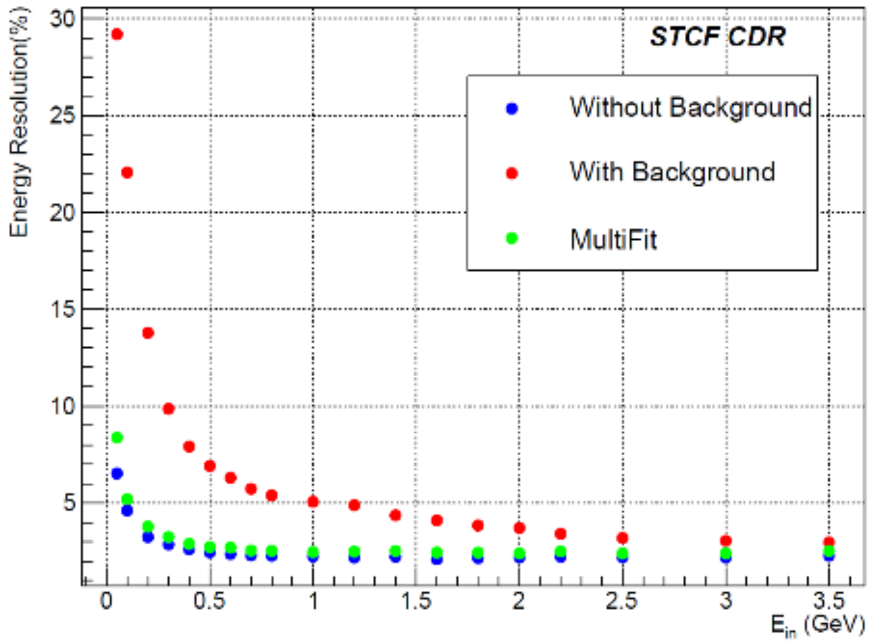




Before

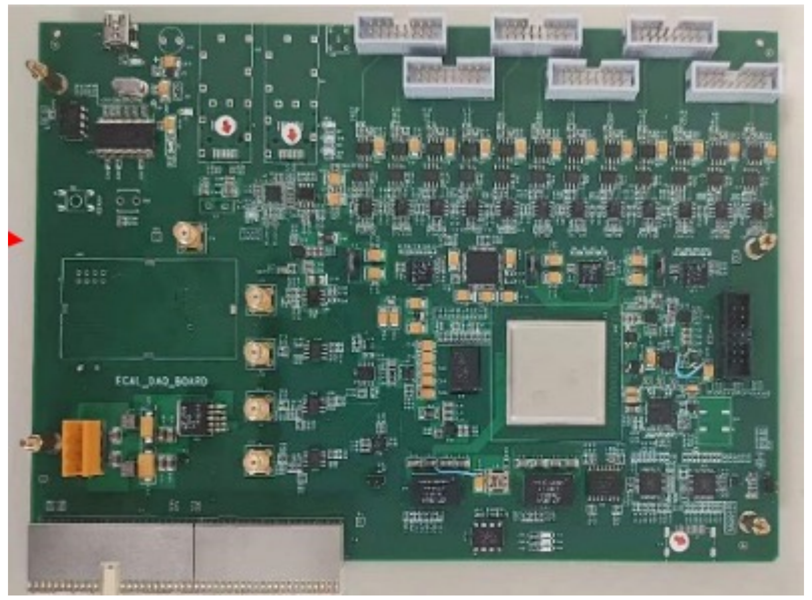


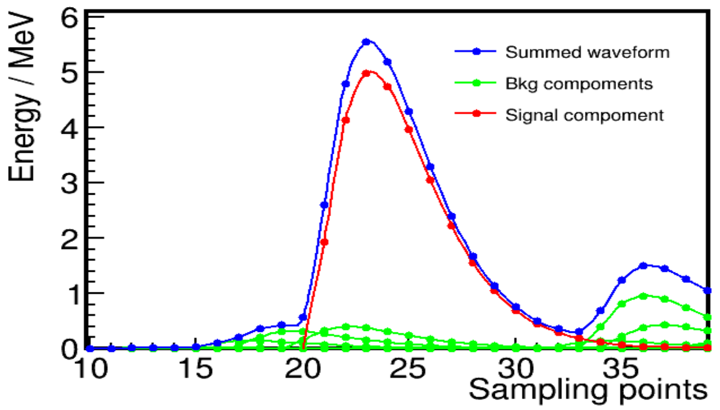
After

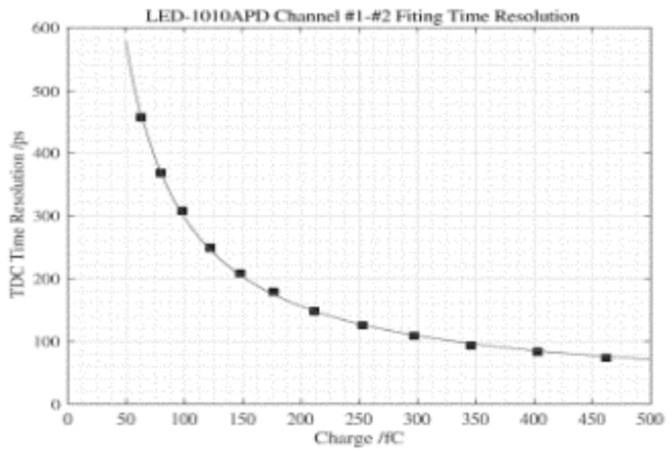


Very effective in mitigating the pileup effect

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





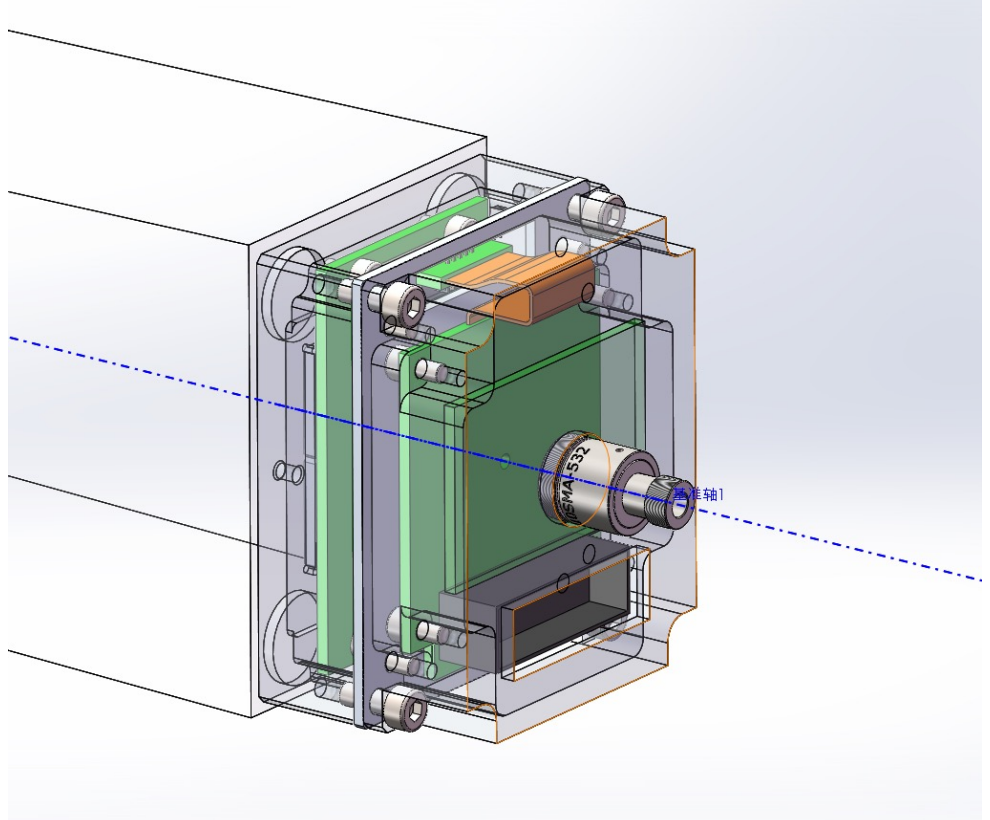


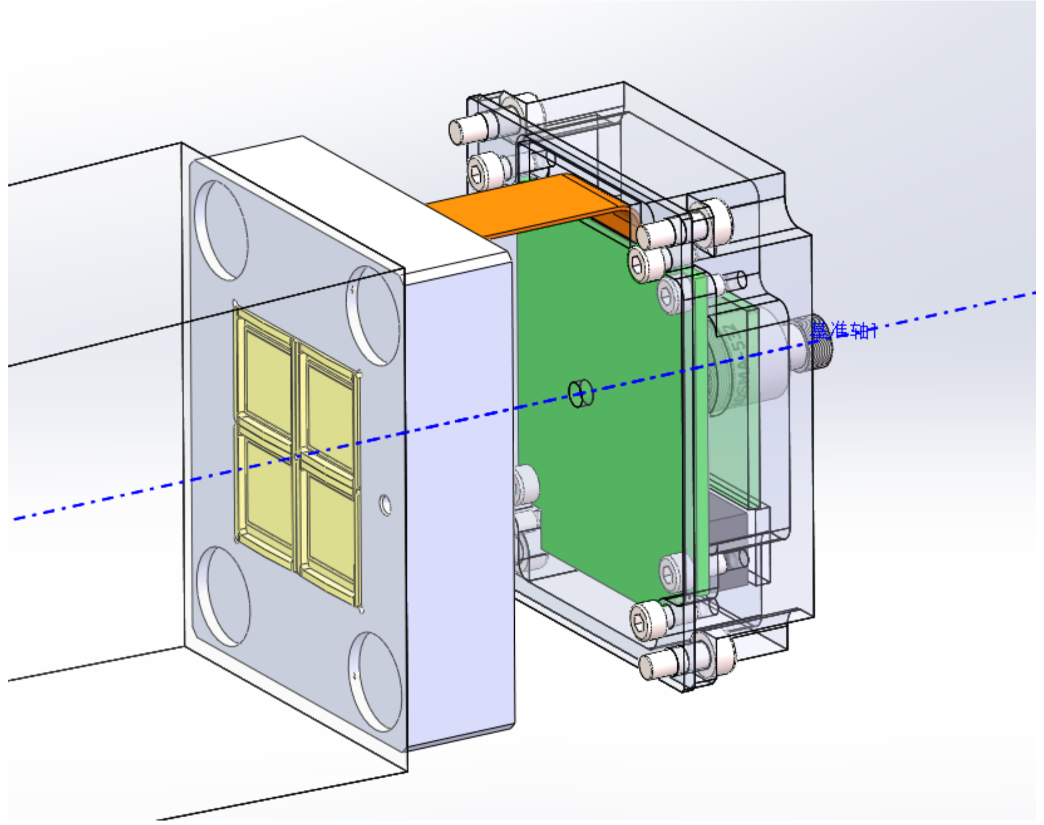
Dynamic range：
3 MeV ~ 3 GeV

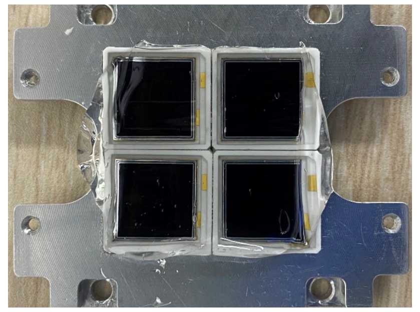
ENE： ~ 0.4 MeV

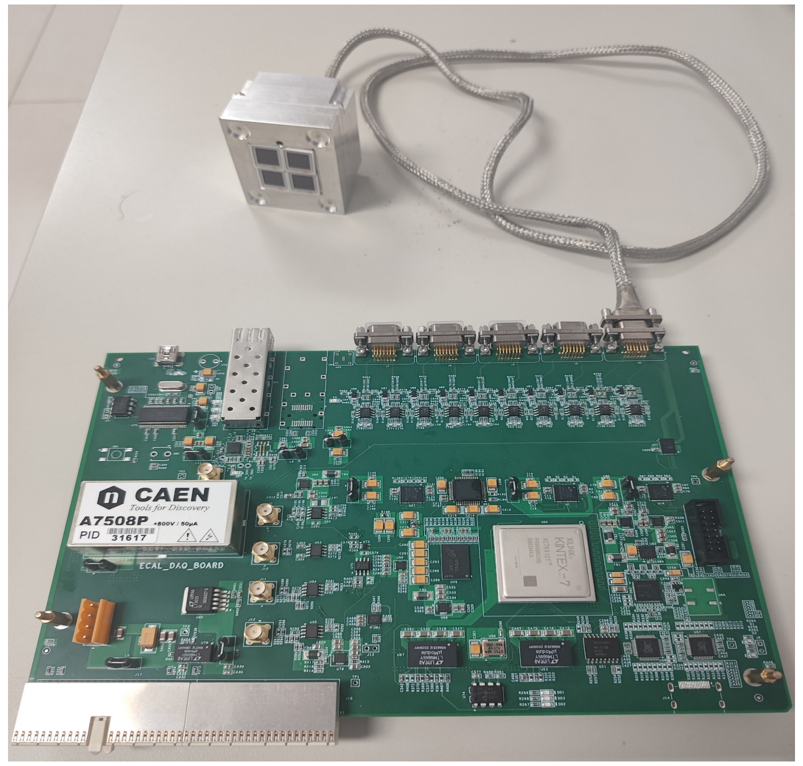
Time resolution :
< 150 ps@1GeV

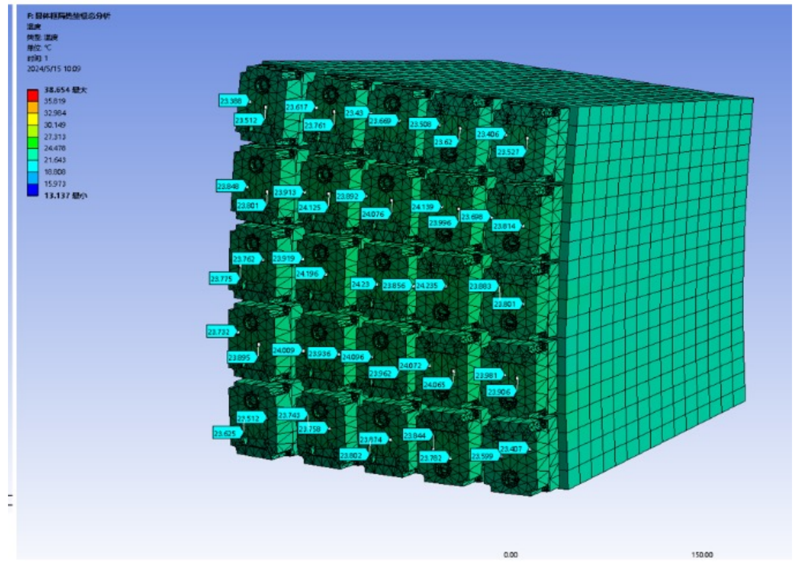
5×5 pCsI ECAL Prototype

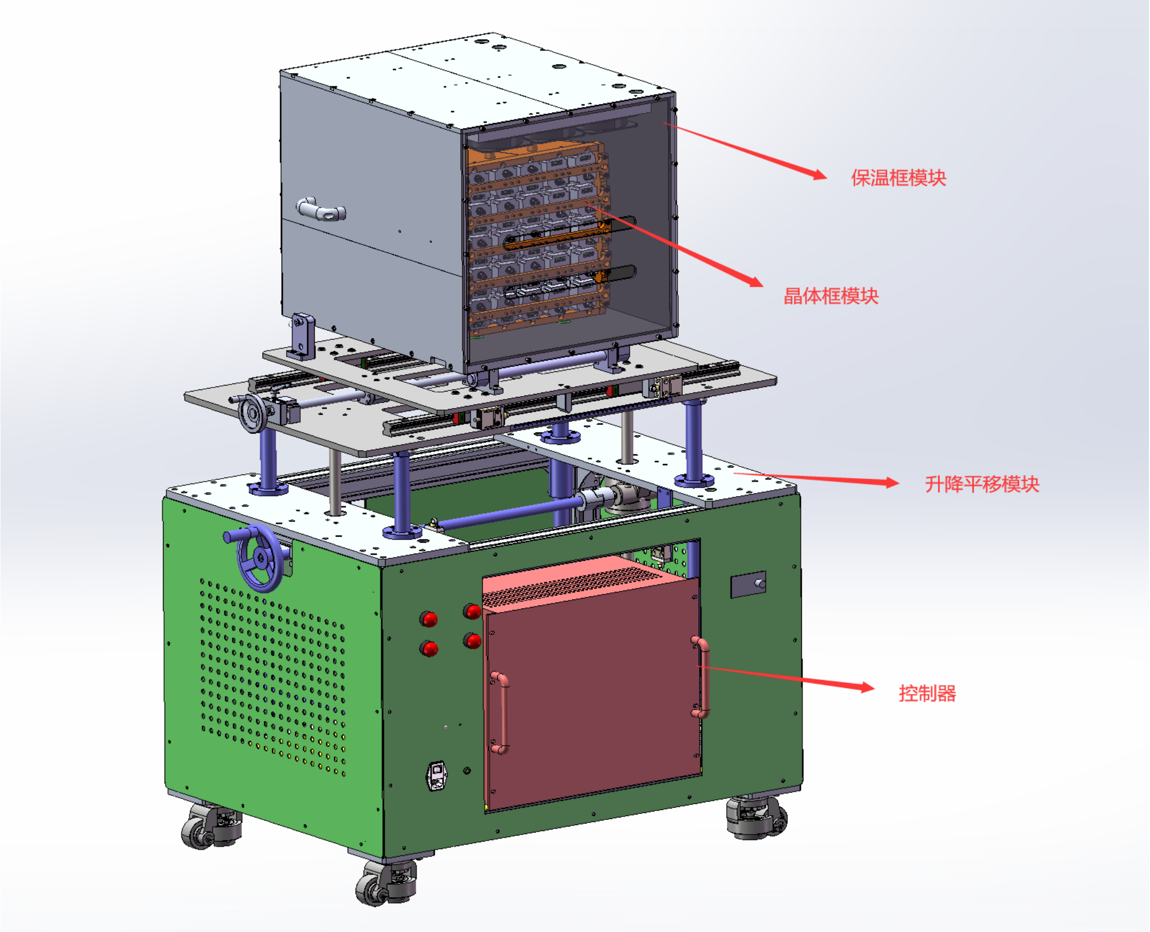






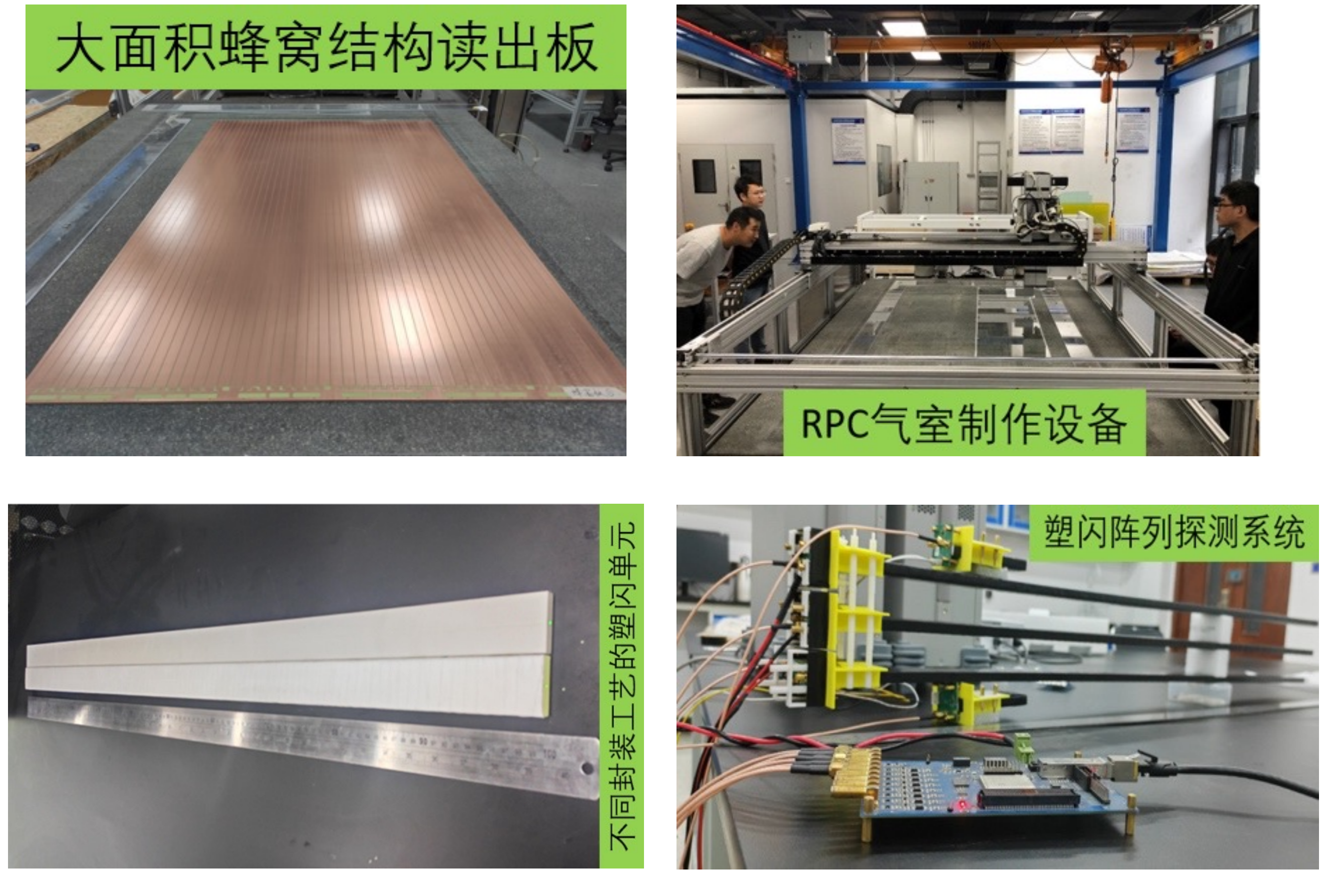






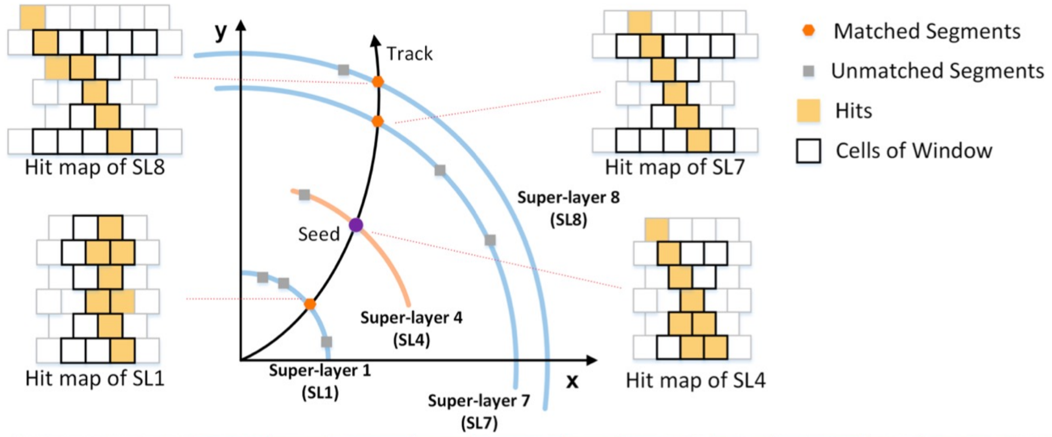
More Detector R&D

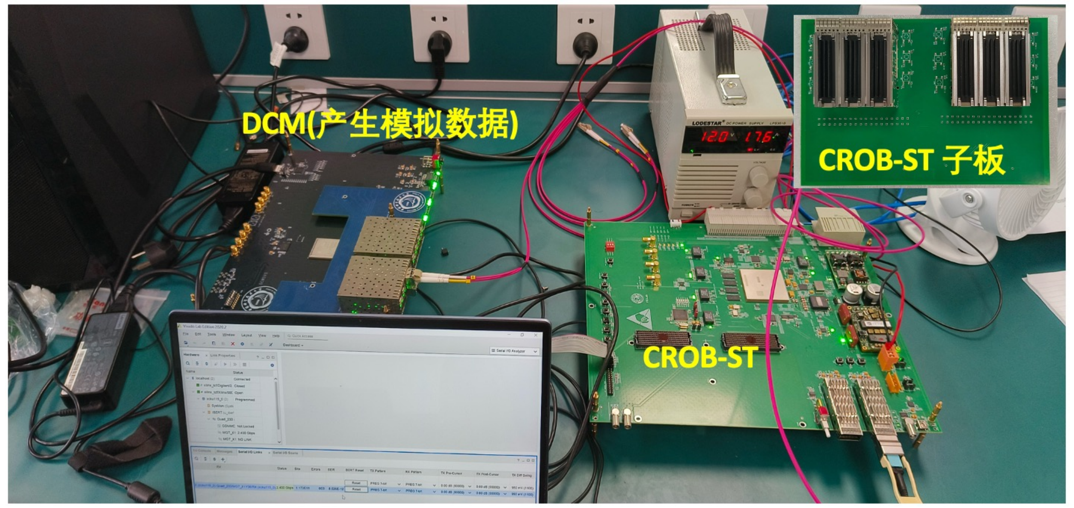
Large sized RPC and scintillator strips



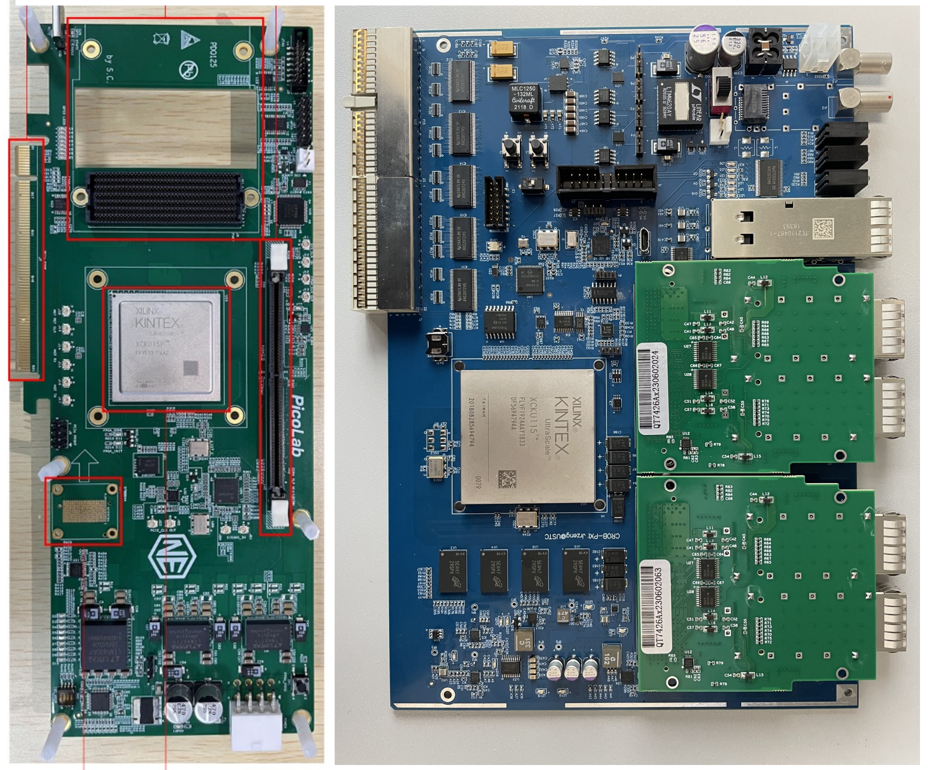
Muon Electronics

Trigger algorithm, logic and electronics

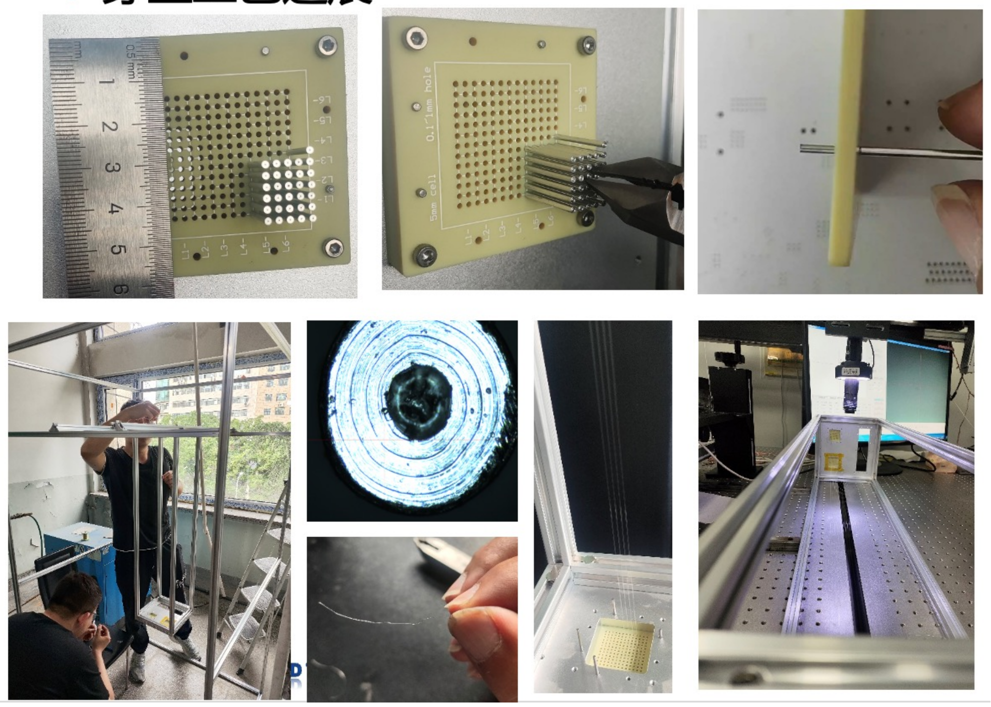




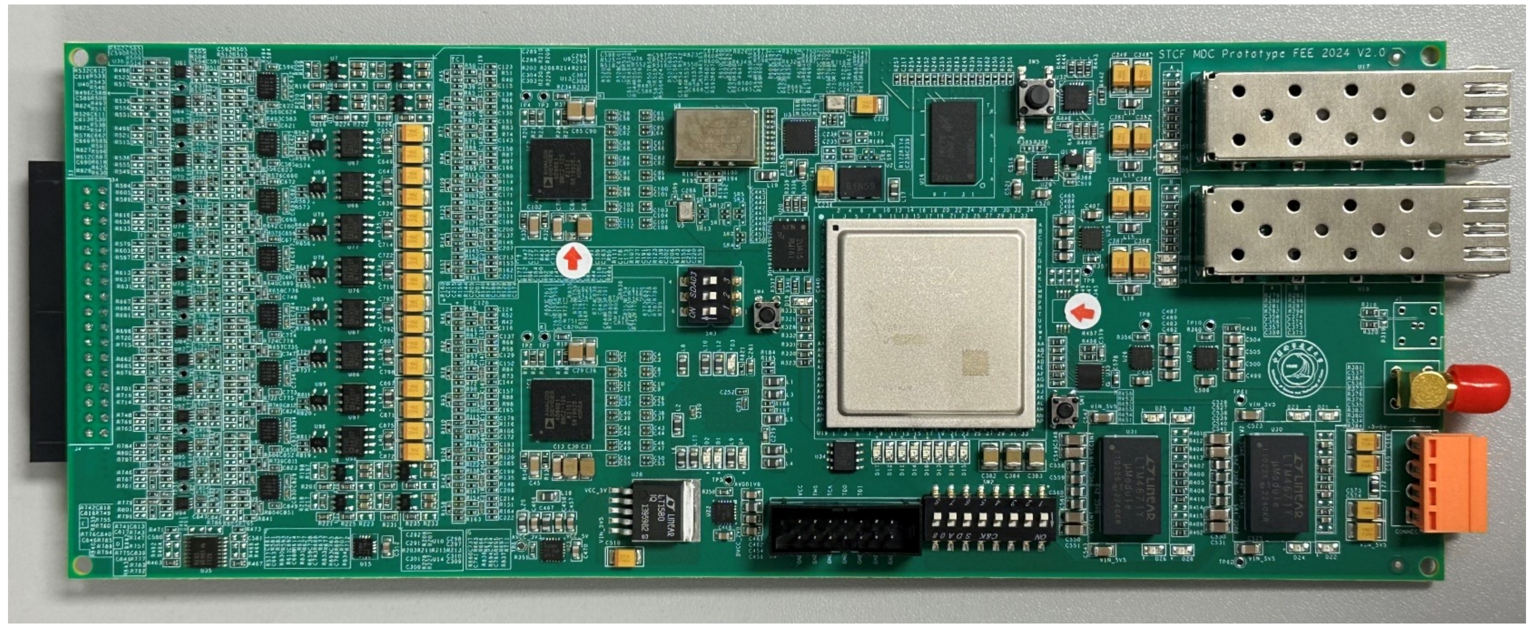
DAQ PXI and PCIe boards



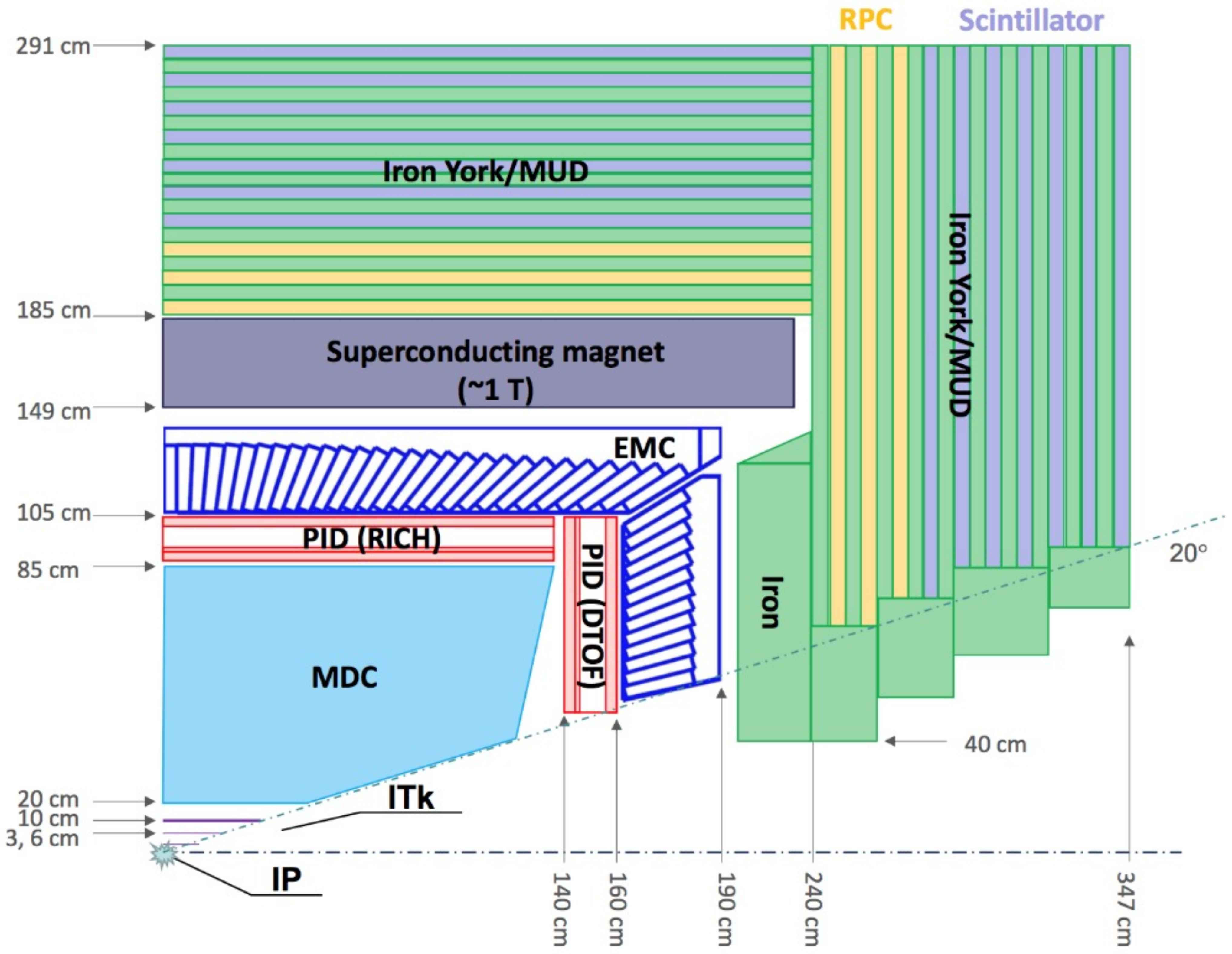
穿丝工艺进展



Drift chamber: stringing and electronics



STCF Detector Summary

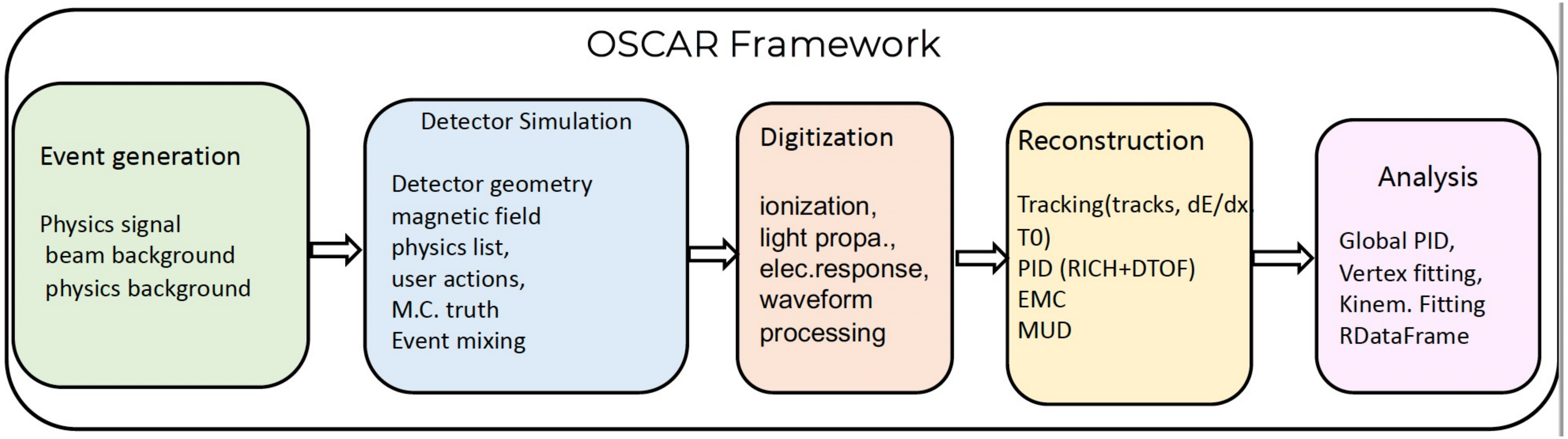


Solid Angle Coverage : 94%•4π (θ~20⁰)

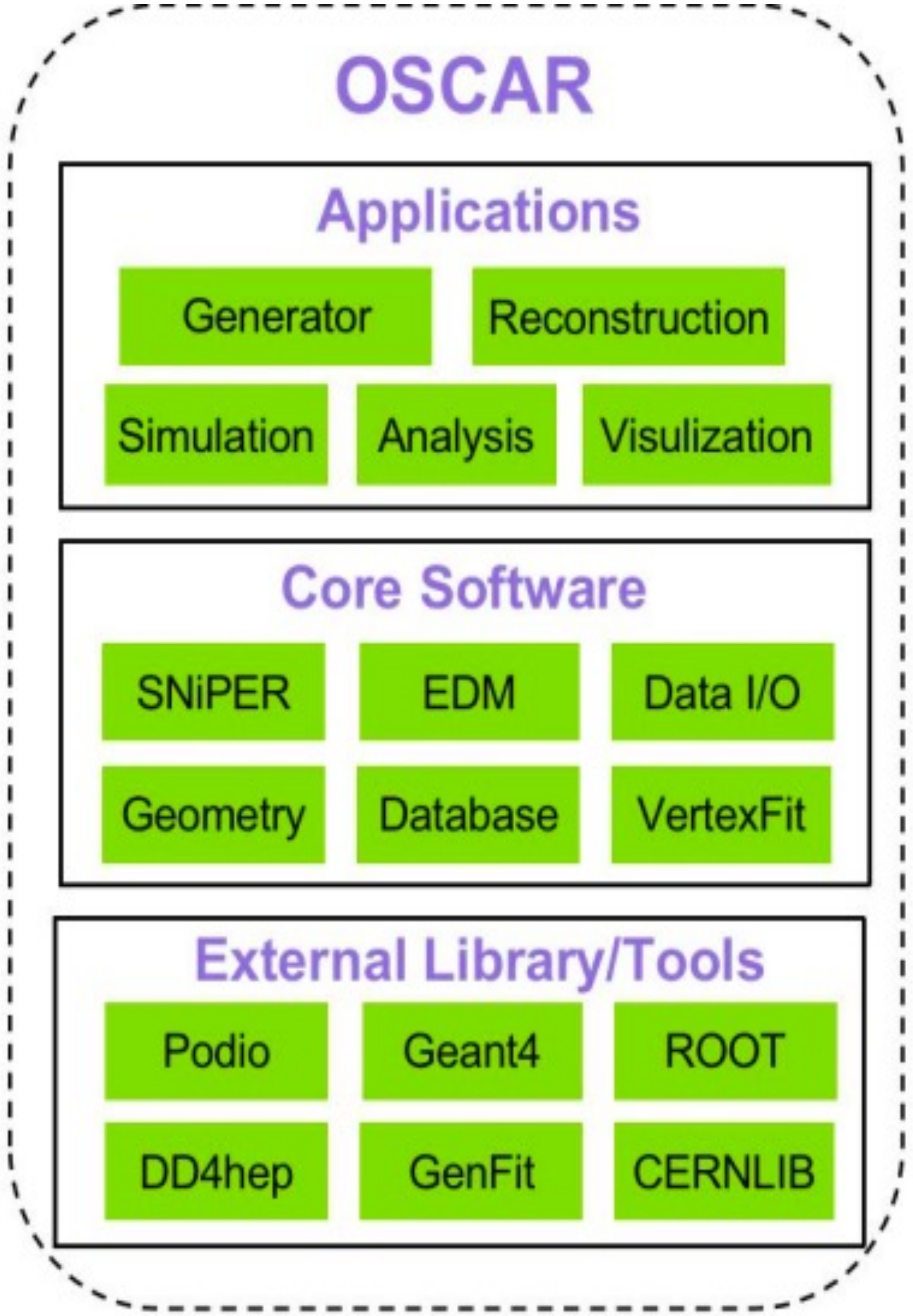
ITK • <~ 0.3%X_0 / layer • σ_{xy}<~ 100 μm	Cylindrical MPGD CMOS MAPS
MDC • σ_{xy}< 130 μm • σ_p/p ~ 0.5% @ 1 GeV • dE/dx~6%	Cylindrical Drift chamber
PID • π/K (and K/p) 3-4σ separation up to 2GeV/c	RICH with MPGD DIRC-like TOF
EMC Energy range: 0.025-3.5GeV σ_E (%) @ 1 GeV Barrel: 2 .5 Endcap: 4 Pos. Res. : 5 mm	pCsI + APD
MUD • 0.4 - 2 GeV • π suppression >30	RPC + scintillator

Offline Software of Super Tau-Charm Facility （OSCAR）

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

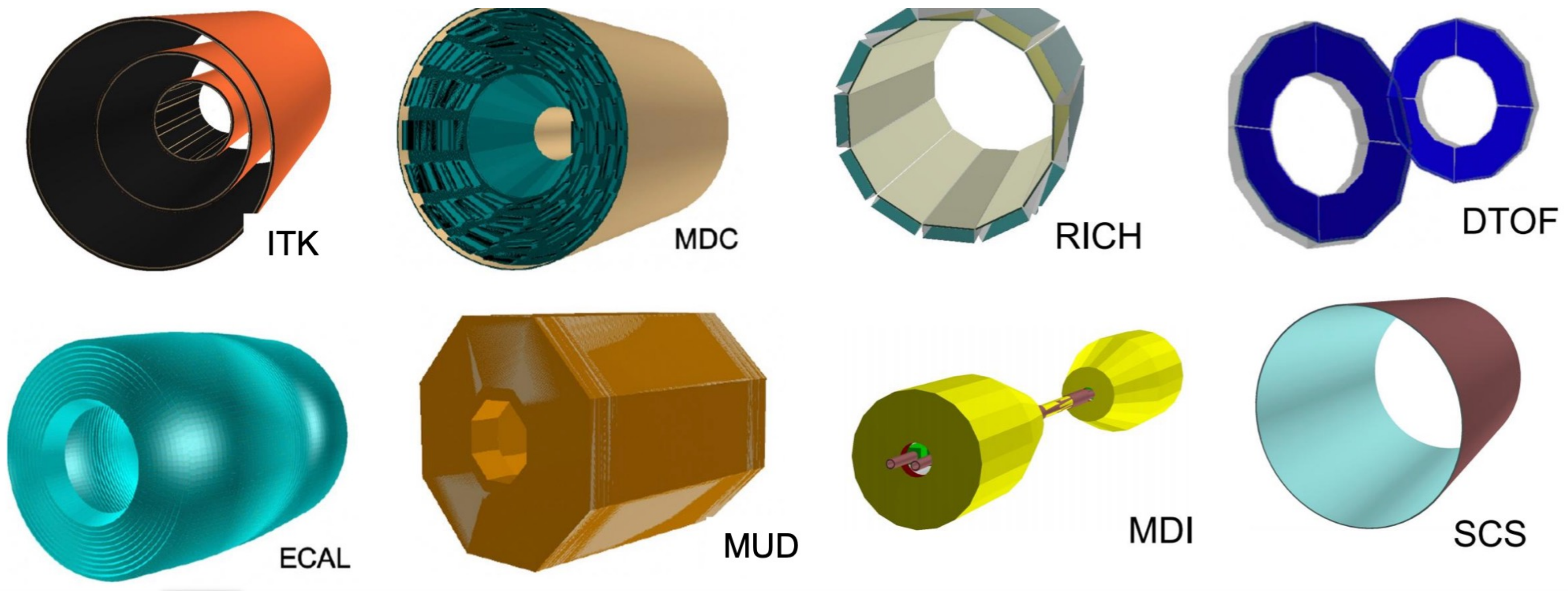


Architecture of OSCAR: three layers



Detector Description and Geometry Management

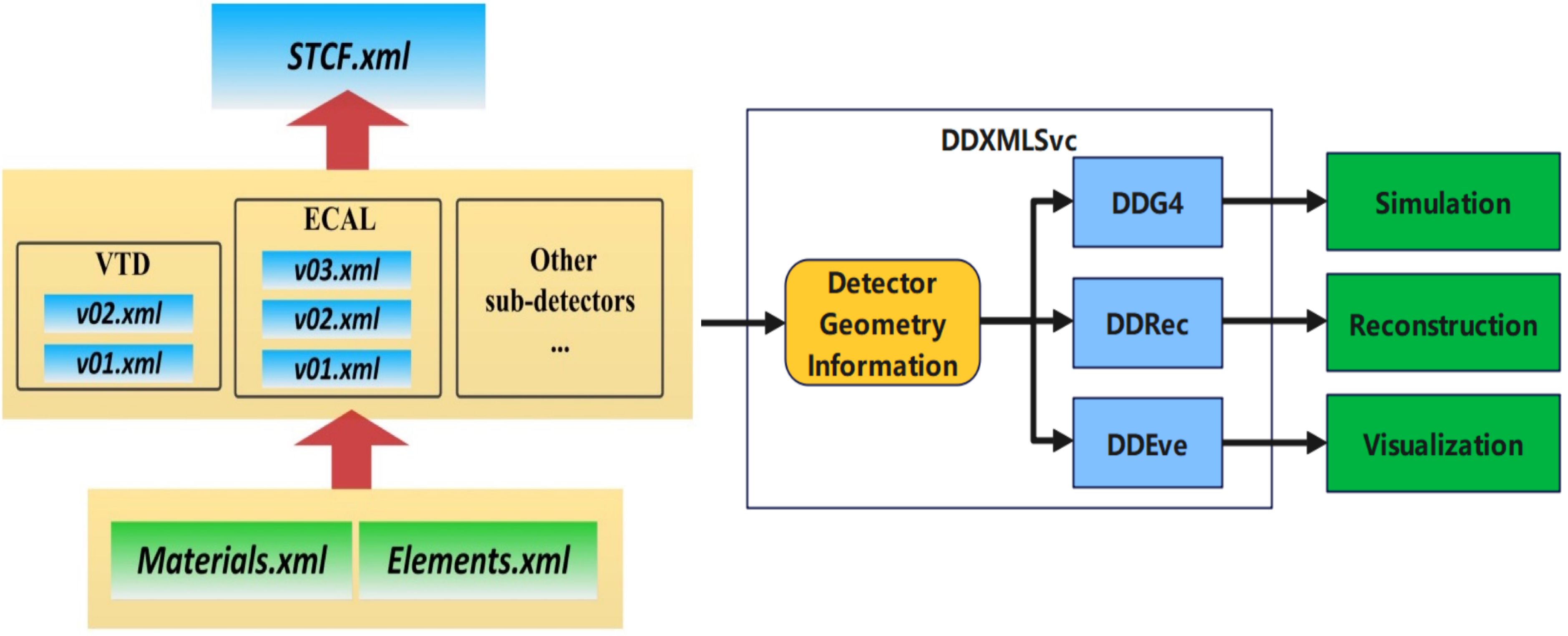
❖ The full Detector is described with DD4hep



Sub-detectors defined with DD4hep

- **Each sub-detector is implemented with a single compact file**
- **The version number is used for different design options**

- **Very convenient to optimize detector geometry according to detector experts**
- **Ensure consistent detector information between different applications**

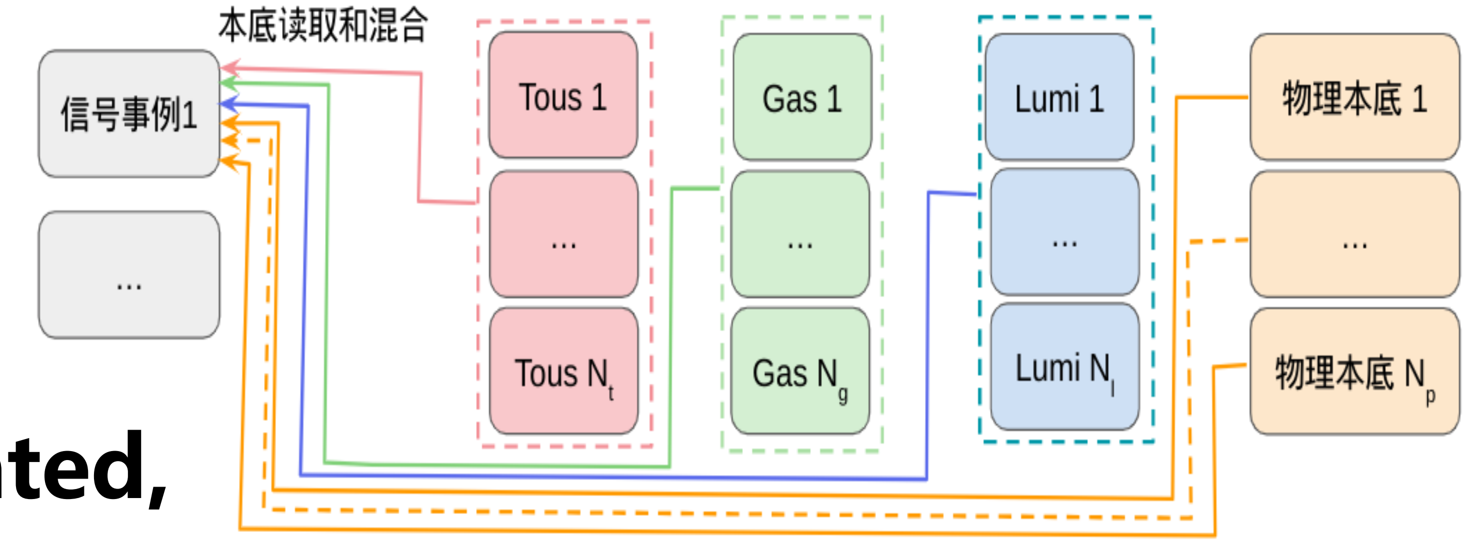


Geometry Management System

Event mixing and Digitization

❖ **Event mixing algorithms** is developed with flexible configuration

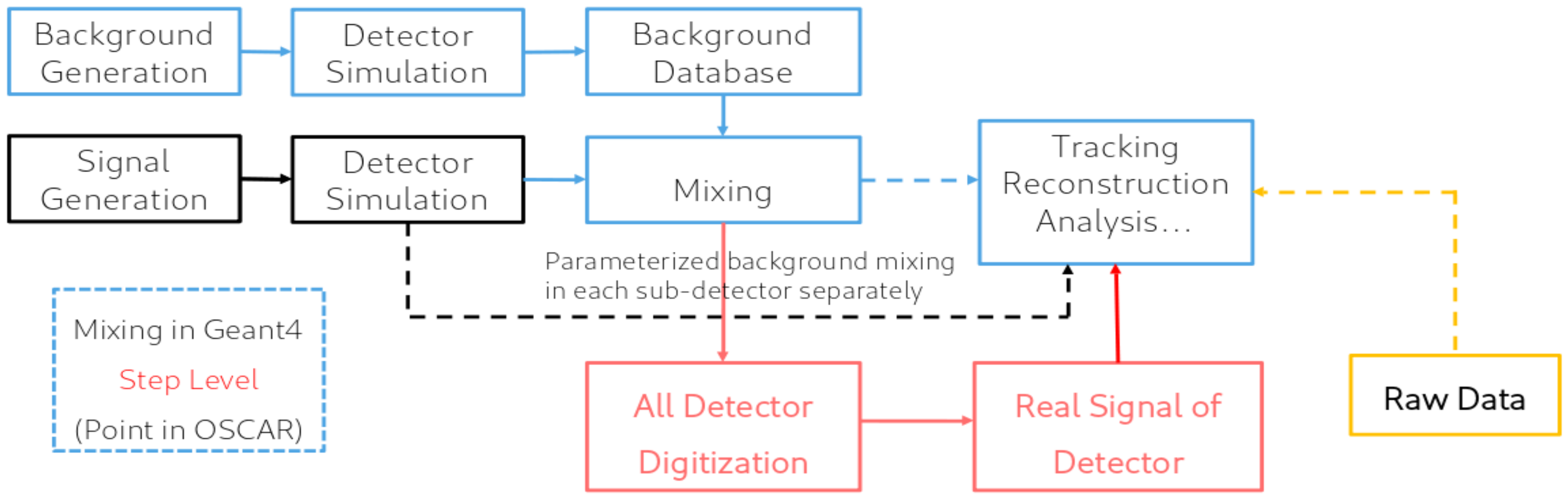
- **Signal,** e.g. $e^+e^- \to \pi^+\pi^- J/\psi(\to \mu^+\mu^-/e^+e^-)$
- **Backgrounds**: Touschek, beam-gas, luminosity-related,
- **Physics background**: $e^+e^- \to anything$ at 4.26 GeV



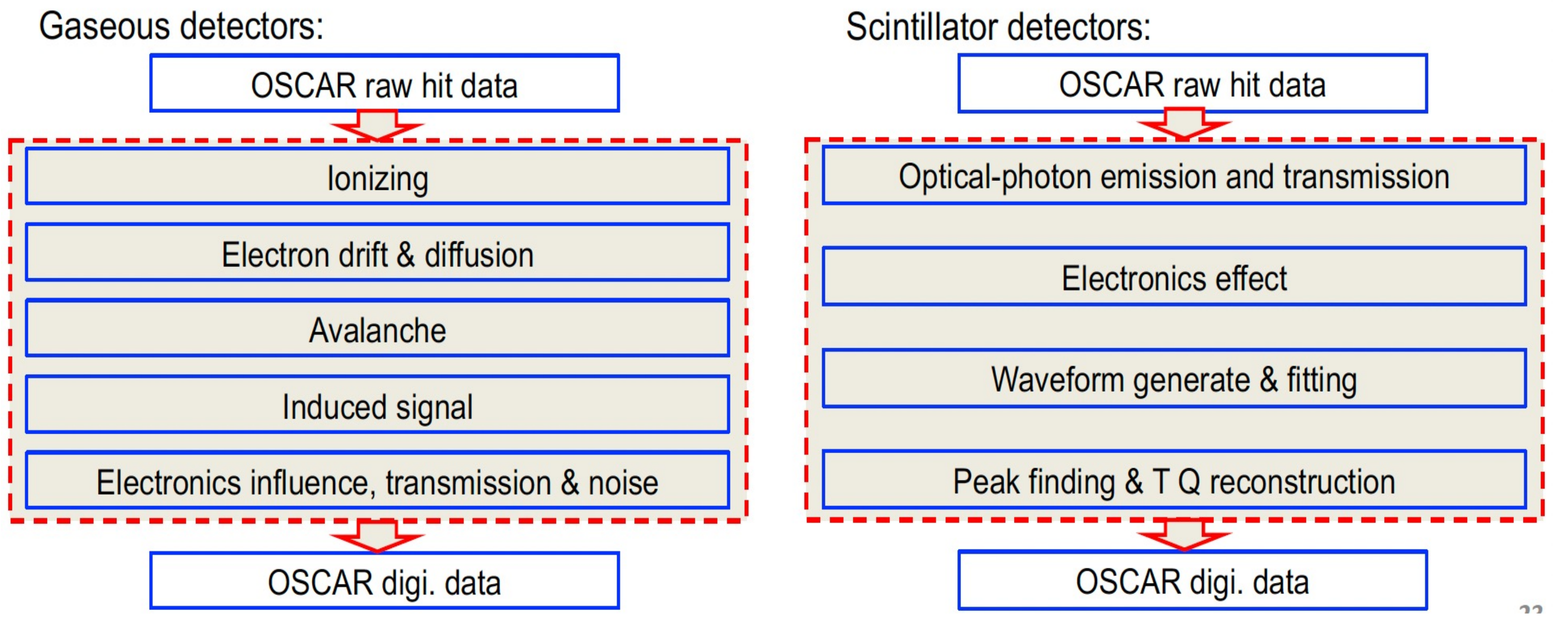
Mixing of physics signal with backgrounds

❖ **Developed a unified digitization framework for all sub-detectors**

- **Each sub-detector implemented its digitization algorithms**
- **The digitization information is used as inputs to tune reconstruction algorithms**



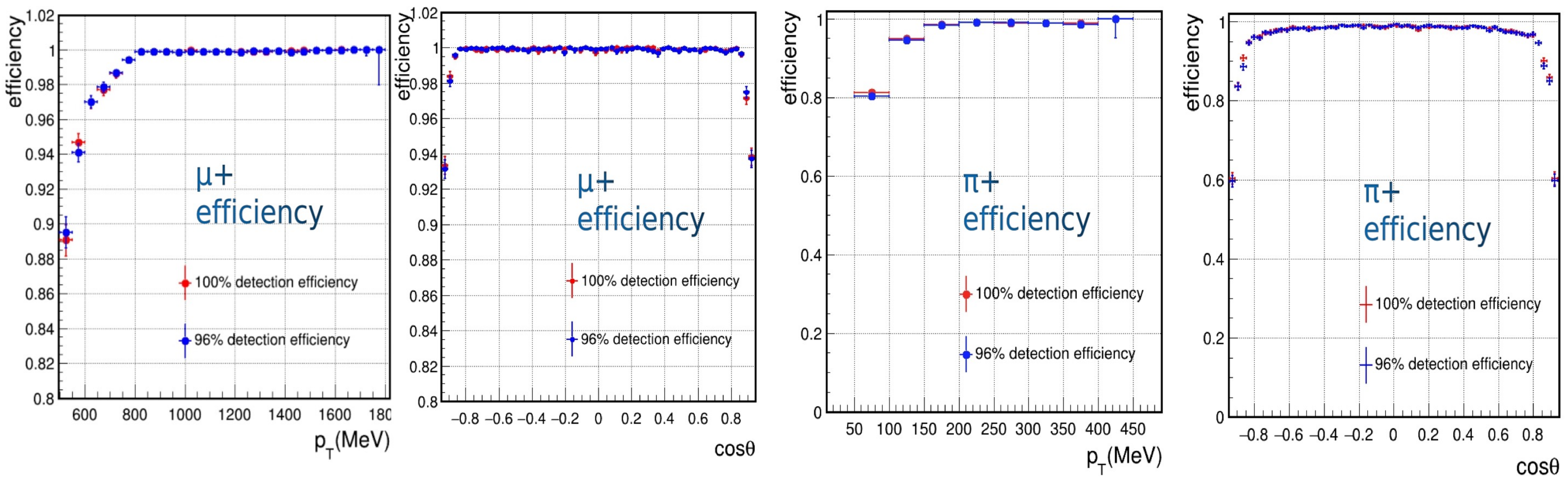
Strategies of event mixing and digitization



Digitization for Gaseous detector and Scintillator Detector

Reconstruction

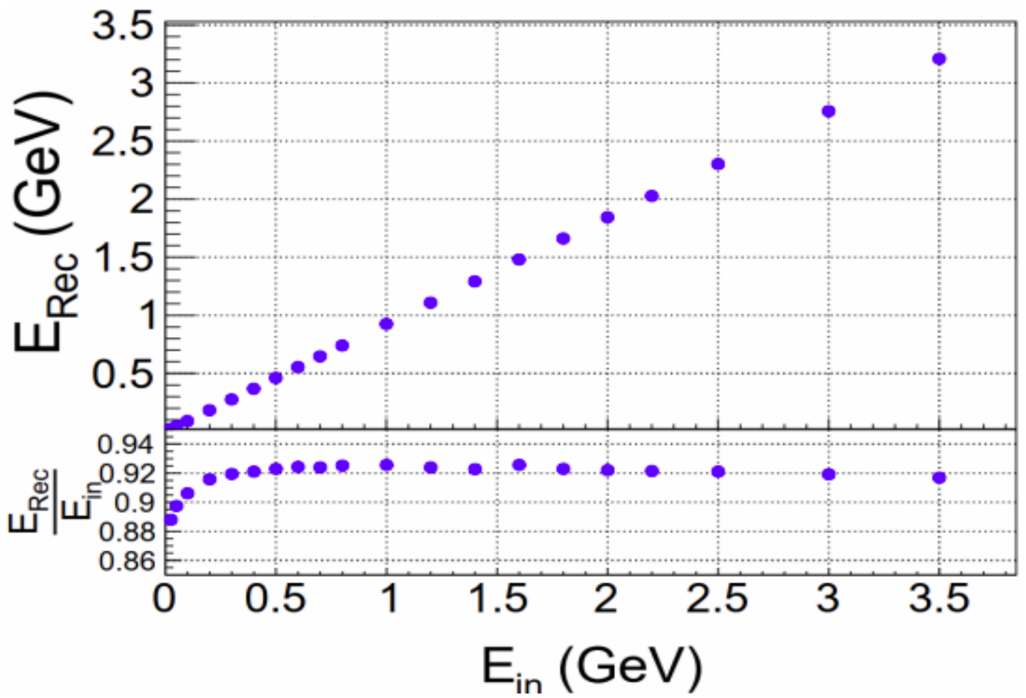
❖ Track reconstruction with global Hough transform



Performance of **Hough Transform**

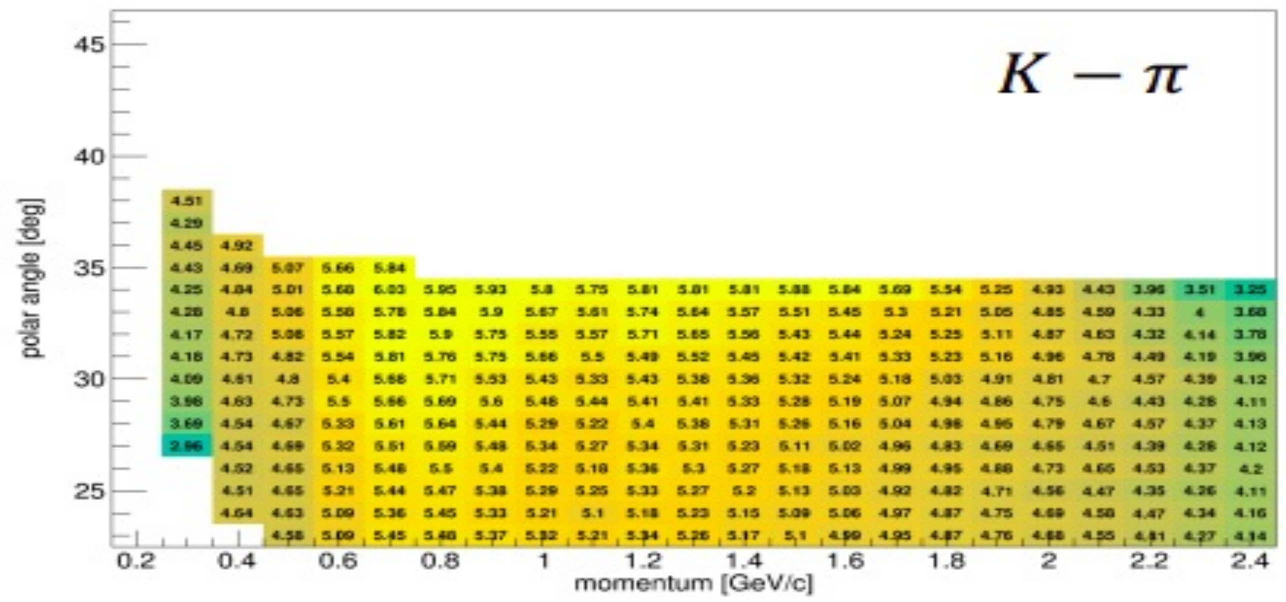
- **>99%** **for muon with P_T > 800 MeV**
- **> 82%** **for pion with P_T in [50, 100] MeV**

❖ Photon reconstruction



Good energy linearity **between 25 MeV–3.5 GeV**

❖ DTOF PID with **imaging method**

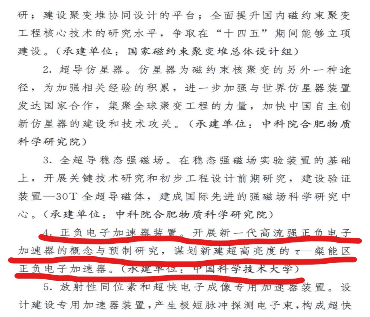


- K/π 4.7σ separation up to 2.0 GeV/c

STCF Project Development

Super Charm-tau Factory

Proposed at "Workshop for acc. based high energy physics development strategy"

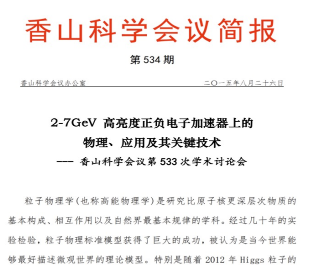


Hefei Comprehensive National Science and Technology center,
STCF listed as a big science facility to be promoted

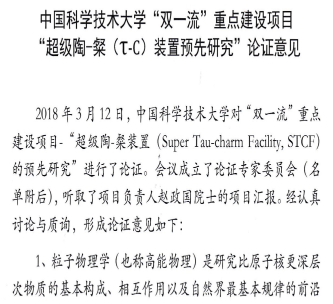
Conceptual Design report
Publish the CDR for the physics and Detector, formulate the preliminary CDR for accelerator

- **Chinese Academy of Sciences**, 2021-2026, International Partnership program, 5.0 M RMB
- **Ministry of Science and Technology**, 2022-2027, National Key R&D Program of China, 17.5 M RMB
- **National Natural Science Foundation** of China, 2024-2027, Group of Key Projects, 14.0 M RMB

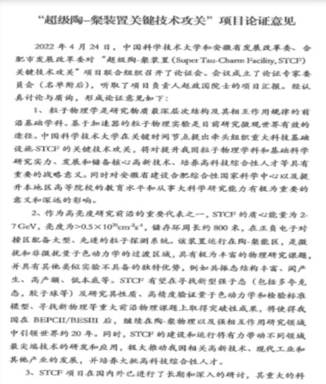
2011 — 2015 — 2017 — 2018 — 2021 — 2022.4



Fragrant Hills Science Forum
Demonstrated its importance and necessity, Urging to lauch fesibility study and R&D

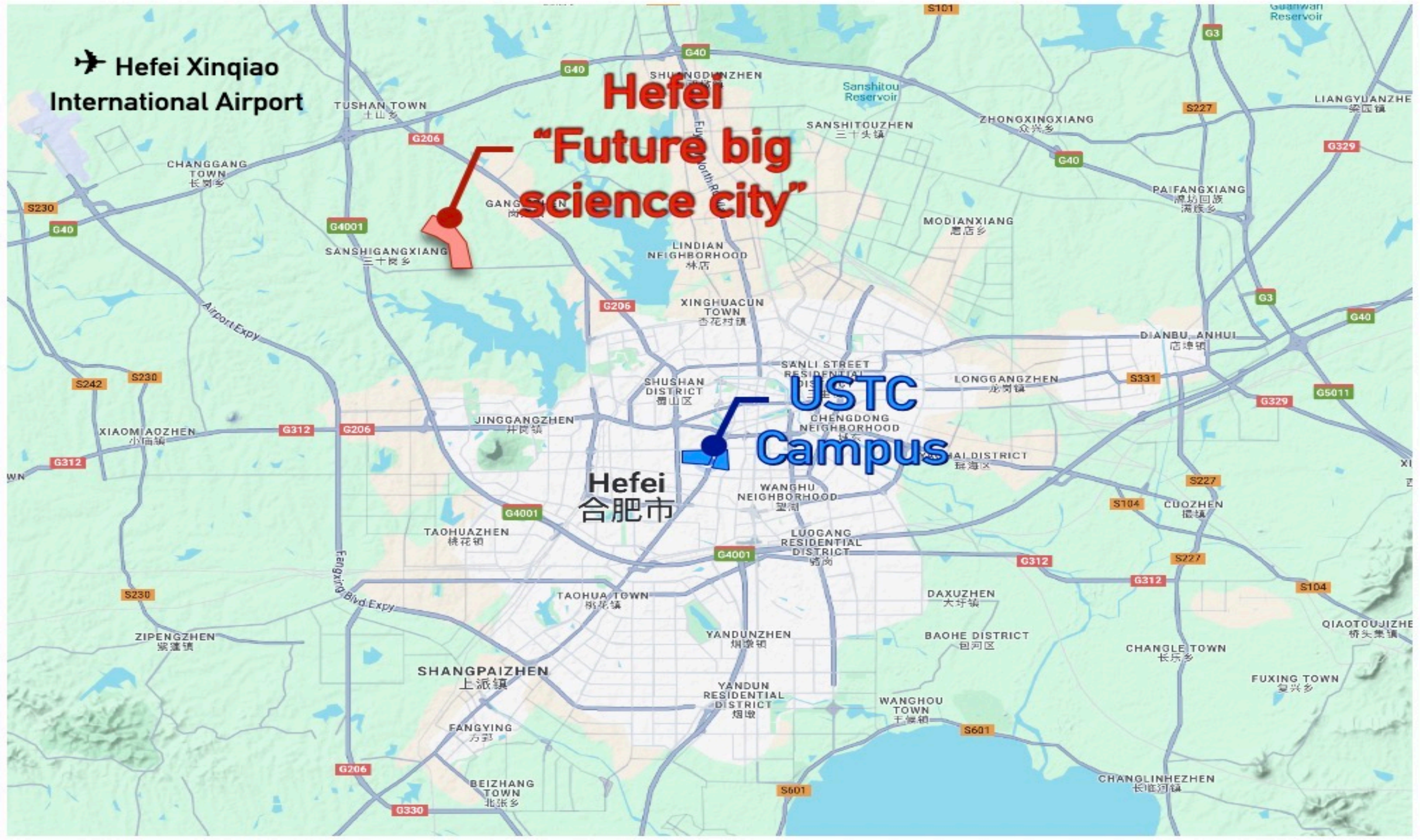


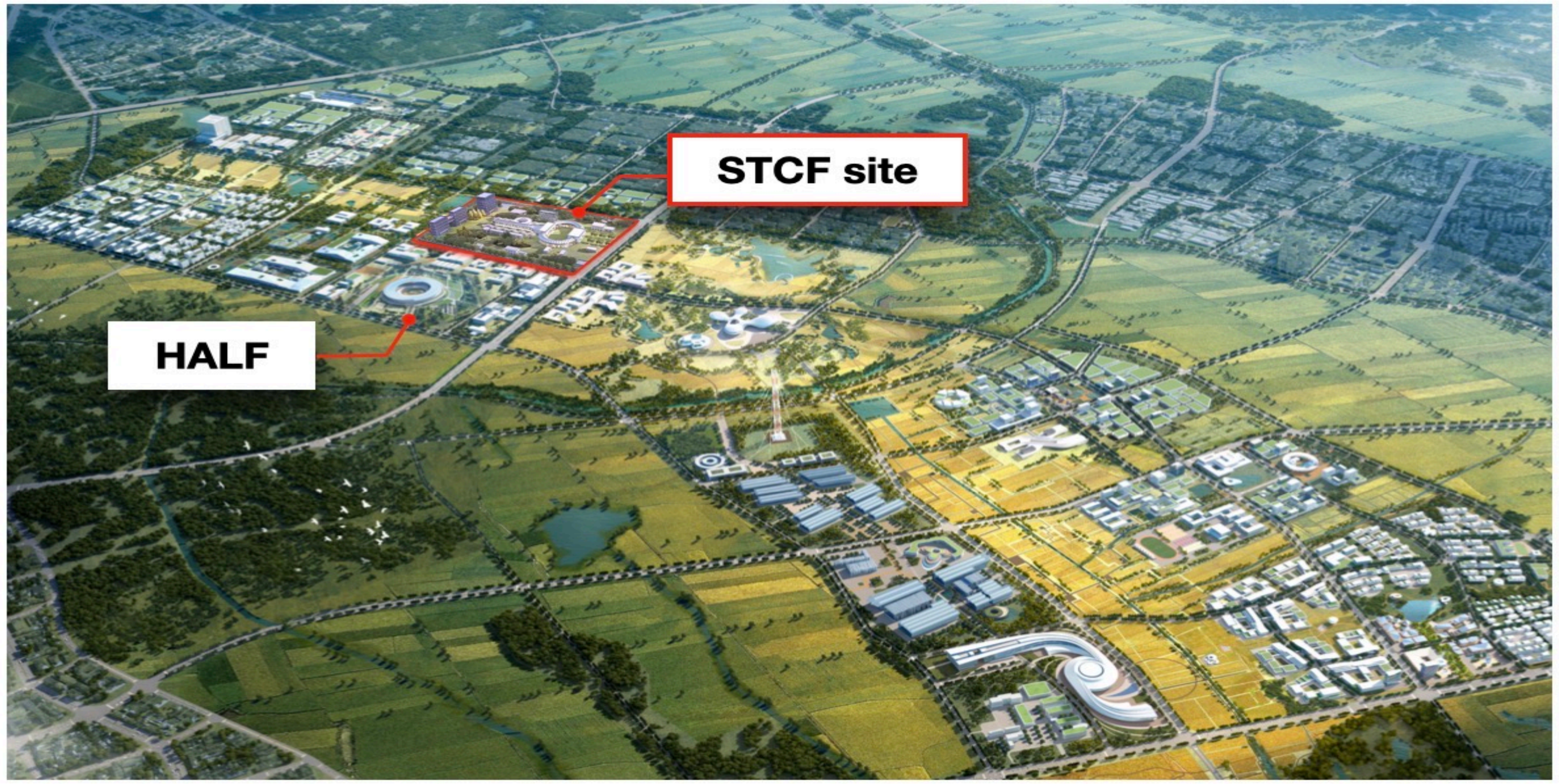
USTC "double first-class" key project
Launch the conceptual design study and feasibility study



Governments of Anhui Province and Hefei City
Launch the STCF Key Technology R&D project

Site Selection – Future Big Science City





- A very attractive Science City under construction in Hefei
  - Home to big facilities for science and technology, with total area of land of 17155 acres
  - Plus 11815 acres of ecological green space and modern agricultural land
- STCF would form a unique international research center for accelerator based high energy physics
- The geological exploration, civil engineering design, and other preparation are in progress

STCF Conferences and Workshops

International

	Place	Content
2015.01	Hefei, China	First
2018.03	Beijing, China	Second
2018.05	Novosibirsk, Russia	Third
2018.12	Paris, France	Fourth
2019.08	Moscow, Russia	Fifth
2020.11	Online, China	Sixth
2021.11	Online, Russia	Seventh
2024.01	Hefei, China	Eighth

Domestic

	Place	Content
2018.10	Hengyang (USC)	STCF
2019.03	Beijing (UCAS)	STCF: Physics
2019.07	Hefei (USTC)	STCF: Accelerator
2019.08	Hefei (USTC)	STCF: Phys. &simulations
2019.11	Beijing (UCAS)	STCF: CDR
2020.08	Hefei (USTC)	STCF: From CDR to TDR
2022.12	Guangzhou(SYU)	STCF: R&D kick-off
2023.07	Zhengzhou(ZZU)	STCF: collaboration

2018年2-7吉电子伏高亮度正负电子对撞机国际研讨会(HIEPA2018)

2018 STCF International Conference

2022超级陶粲装置研究进展研讨会

International Advisory Committee Meeting

国际顾问委员会(IAC)：共22位加速器、粒子物理专家

主　席：Guy Wilkinson (Oxford)

副主席：Frank Zimmermann (CERN)

- **14位成员线下，8位线上**
- **听取项目组织、物理目标、关键技术、未来规划等汇报、实验室实地考察并做专题讨论**

Kick-Off Meeting and R&D Project Review Meeting

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 ~400 M RMB and is jointly funded by Anhui, Hefei and USTC.

Project Schedule in the ideal scenario

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032-2047
Conceptual design CDR															
Key Technology R&D TDR															
Construction															
Operation															15 years

Summary

- As a key player in HEP precision frontier, STCF holds great potential for discoveries and breakthroughs in studies of strong interaction, CPV, and new physics searches.
- STCF builds upon China's great success and well-established unique international position in tau-charm physics, constituting a viable medium-term HEP project in China.
- Intensive conceptual design studies in the past few years have resulted in physics and detector CDR. Accelerator CDR to come soon.
- The STCF project has moved on to the technology R&D stage with committed and strong support from local governments and USTC. A full STCF R&D program has been established and is going full steam ahead.
- Aiming to submit a proposal to the national government for starting STCF construction in the 15th five-year plan period (2026-2030).
- It is crucial to expand collaboration and explore synergies with other projects.

Thank you !