Status of the Super Tau-Charm Facility

超级陶粲装置
Super Tau-Charm Facility

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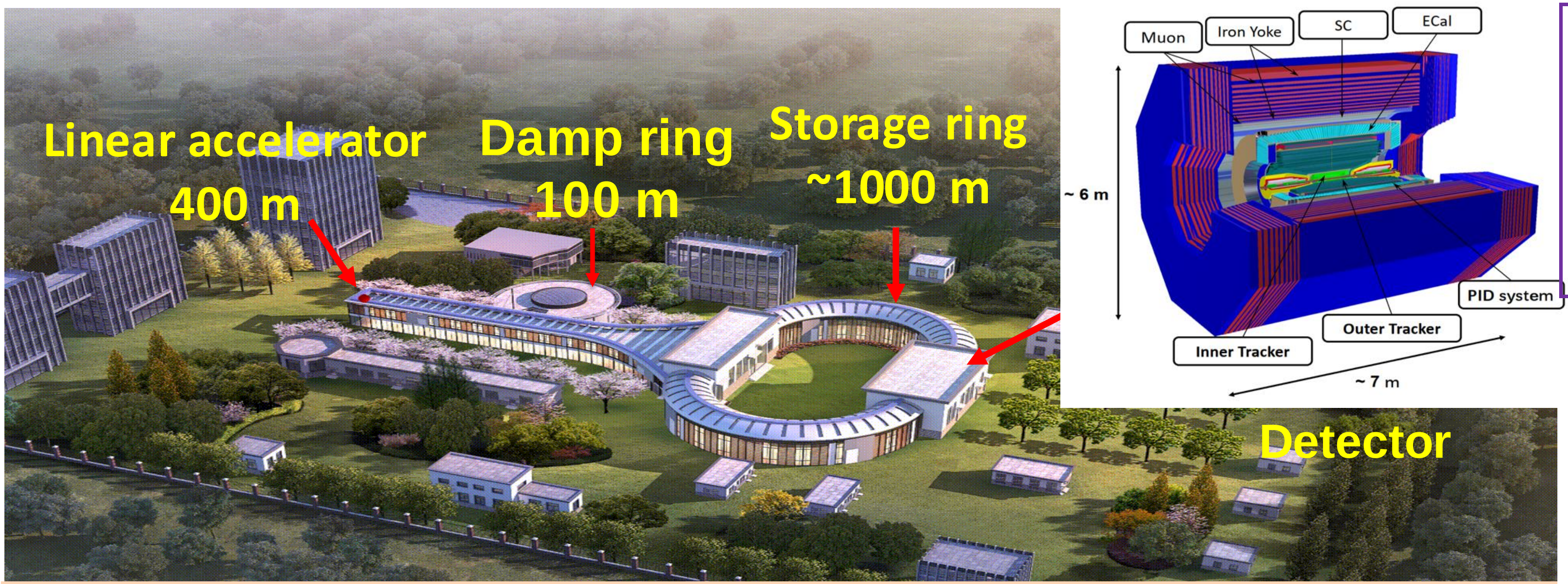
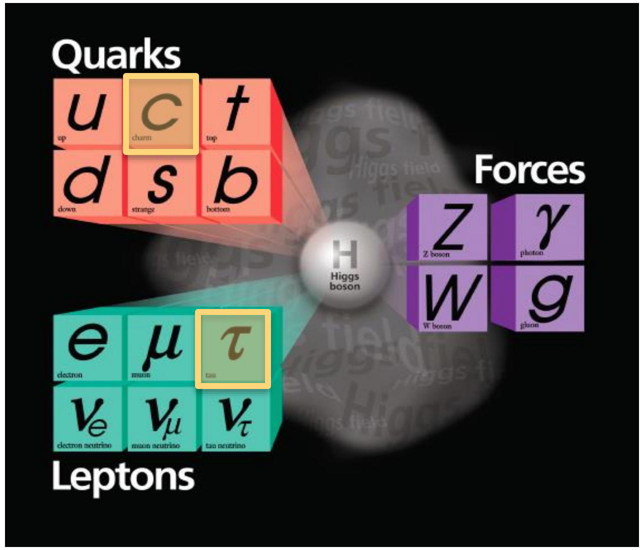
Super Tau Charm Facility (STCF)



A next-generation high-luminosity e^+e^- collider operating in the $\tau - charm$ energy region

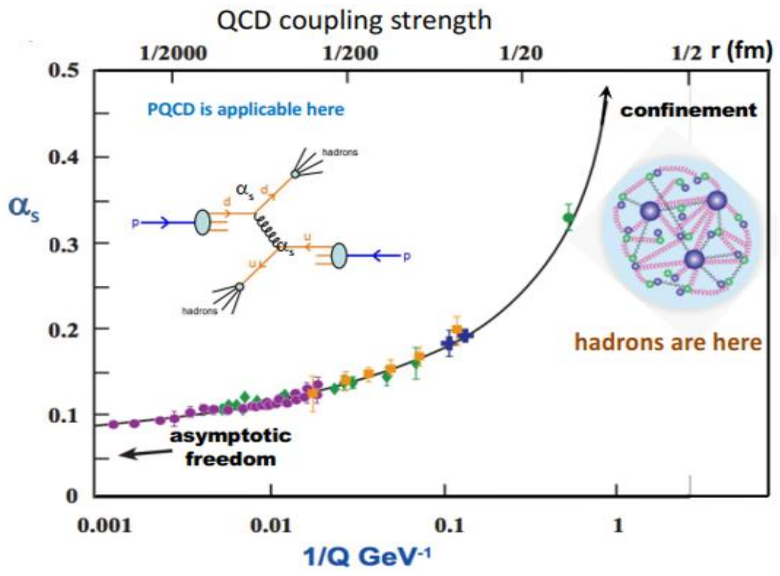


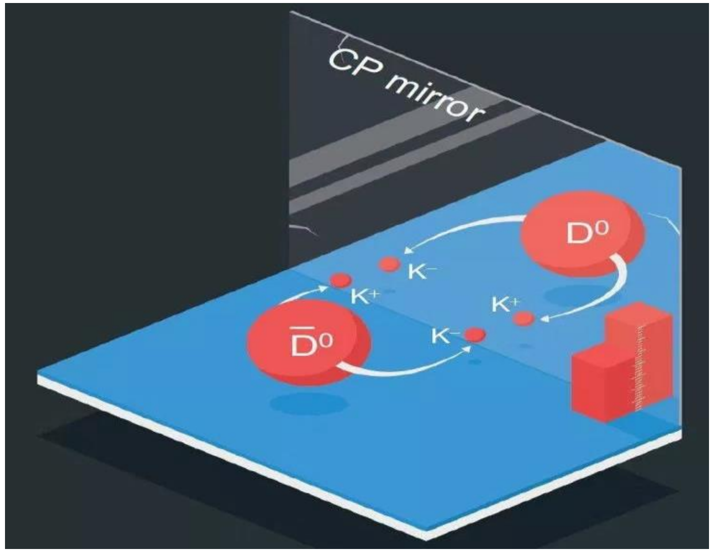
- Energy range: E_{cm} = 2-7 GeV
- Peak luminosity >0.5×10^{35} cm^{-2} s^{-1} at 4 GeV
- Potential for an upgrade to increase lumi. and realize polarized beam

- 1 ab^{-1} data expected per year
- Generate an unprecedentedly large number of τ leptons, particles made of c quarks
- Important playground for study of QCD, exotic hadrons, flavor and search for new physics

Challenges of the SM

- The SM of particle physics is a well-tested theoretical framework
- However, there is a number of unresolved in particle physics:
  - Confinement: formation of colorless bound states —— “hadrons”
  - Matter-antimatter asymmetry of the Universe, dark matter, numbers of flavors, etc.





Masses

Parameter	Value	Method
m_u	1.9 MeV	Lattice
m_d	4.4 MeV	Lattice
m_s	87 MeV	Lattice
m_c	1.3 MeV	Collider
m_b	4.24 MeV	Collider
m_t	173 GeV	Collider
m_e	511 keV	Non-collider
m_μ	106 MeV	Non-collider
m_τ	1.78 GeV	Collider
m_Z	91.2 GeV	Collider
m_H	125 GeV	Collider

Couplings

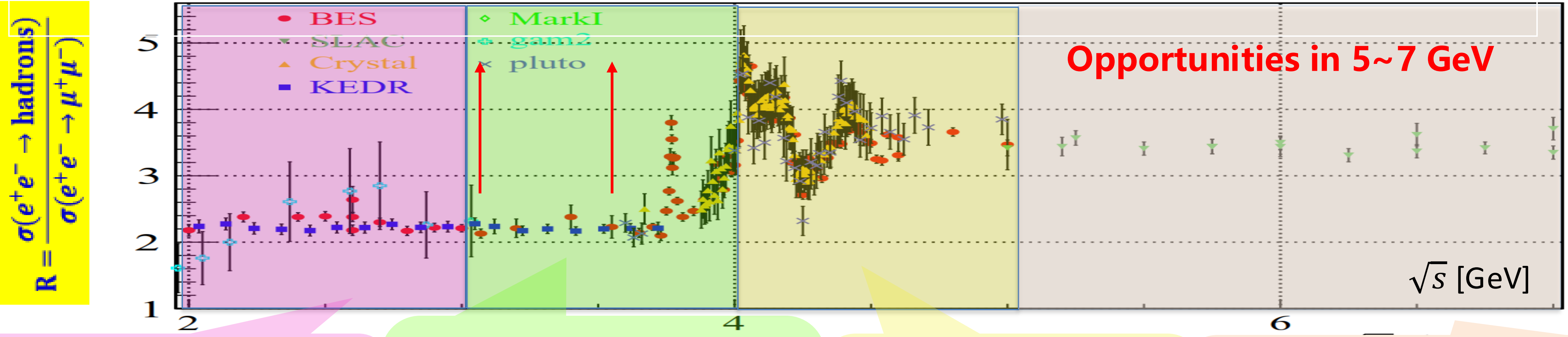
Parameter	Value	Method
α	0.0073	non-collider + collider
G_F	1.17×10^{-5}	Non-collider
α_s	0.12	Lattice + collider

Flavour and CP violation

Parameter	Value	Method
θ_{12} (CKM)	13.1°	Collider
θ_{23} (CKM)	2.4°	Collider
θ_{13} (CKM)	0.2°	Collider
δ (CKM-CPV)	0.995	Collider
θ (strong CP)	~0	Non-collider

Rich Physics in the Tau-Charm Energy Region

- The tau-charm energy region covers a unique transition region between perturbative and non-perturbative QCD, with unique and rich physics programs
  - ❖ 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)



- Hadron form factors
- $Y(2175)$ resonance
- Mutltiquark states with s-quark
- R value / g-2 related

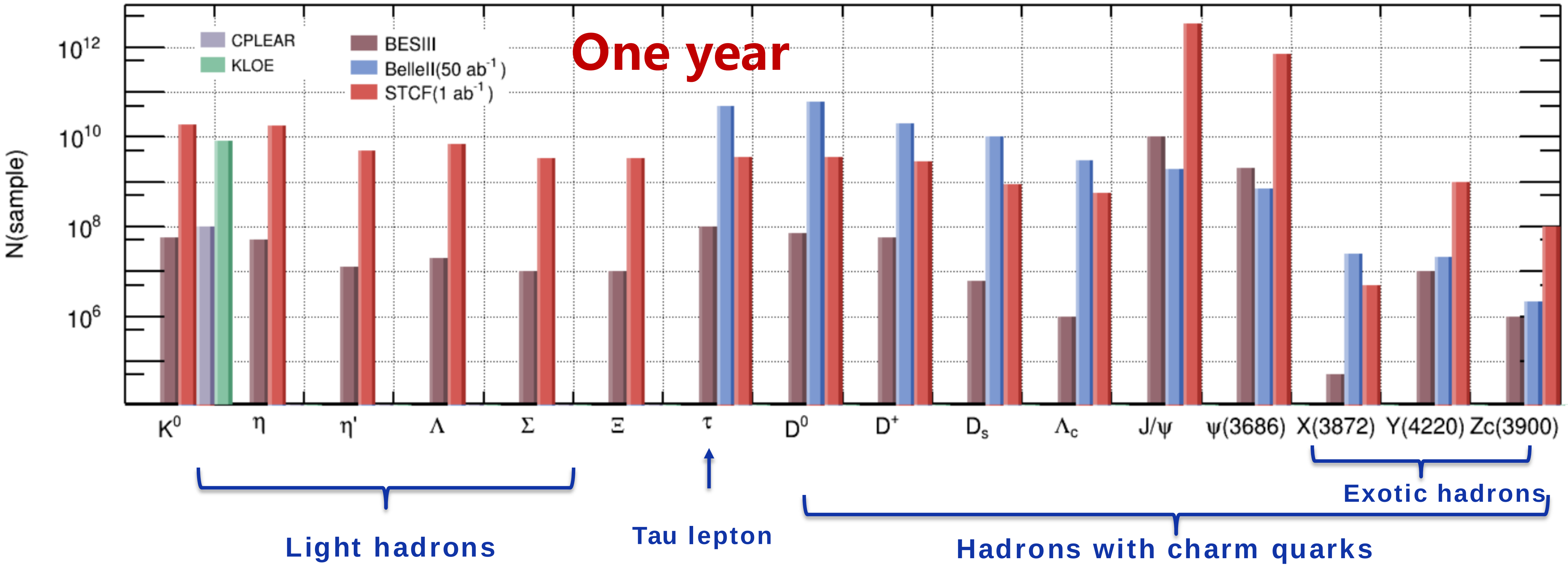
- Light hadron spectroscopy
- Gluonic and exotic states
- Processes of LFV and CPV
- Rare and forbidden decays
- Physics with τ lepton

- XYZ particles
- Physics with D mesons
- f_D and f_{D_s}
- $D^0 - \bar{D}^0$ mixing
- Charm baryons

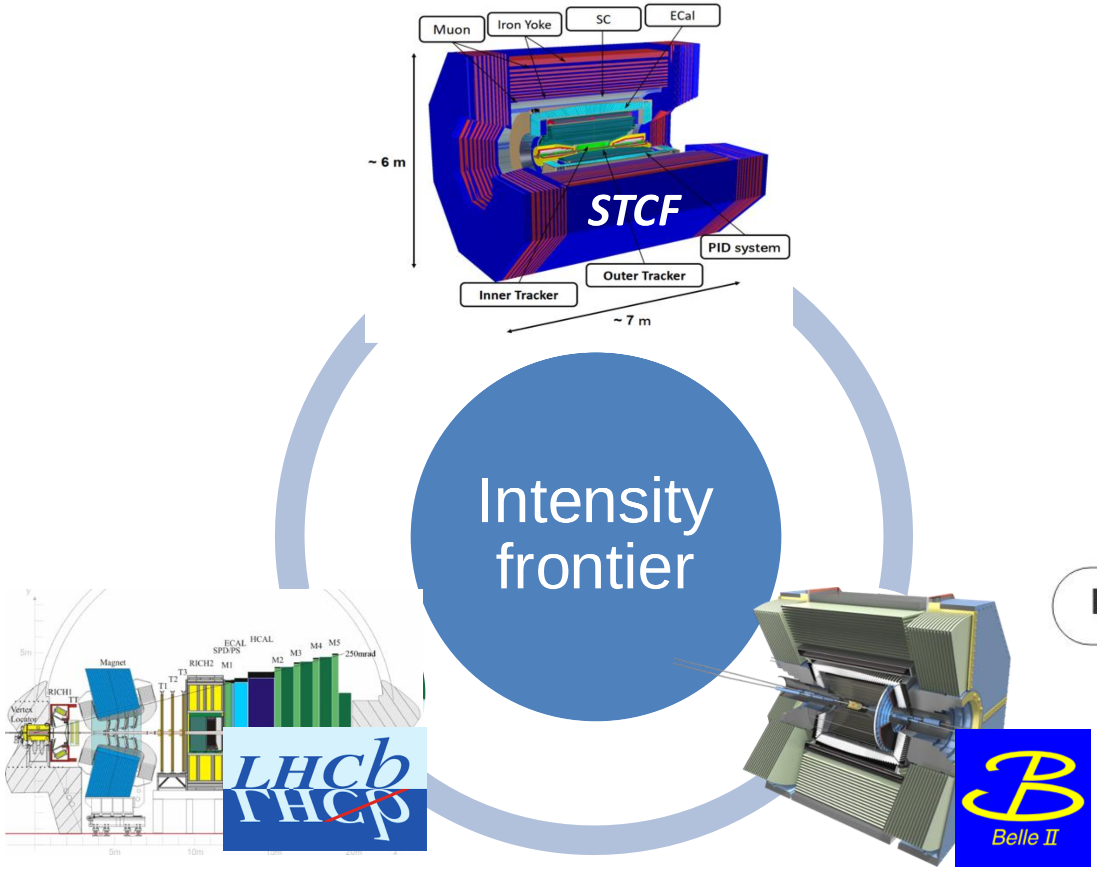
- Complete XYZ family
- Hidden-charm pentaquarks
- Search for $c\bar{c}c\bar{c}$ states
- More charmed baryons
- Hadron fragmentation

A Super Factory of Various Particles

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



Physics at STCF

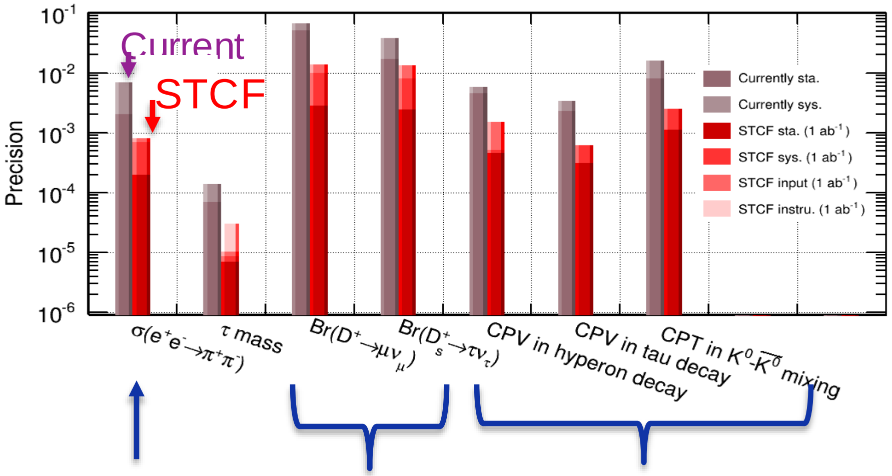


- **Physics at STCF**
  - **QCD and hadronic physics**
    - **XYZ Properties:** e+e-→Y→γX,ηX,ϕX; e+e-→Y→πZc, KZcs
    - **Hadron Spectroscopy:** Excited ccbar and their transition, Charmed hadron spectroscopy, Light hadron spectroscopy
    - **R value:** e+e-→inclusive; τ mass: e+e-→τ+τ-
    - **Nucleon 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+v, D→P l+ v
    - **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 πv, EDM of τ, τ→π/K π0 v 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+ v_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…

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

Precisions and Sensitivities at STCF

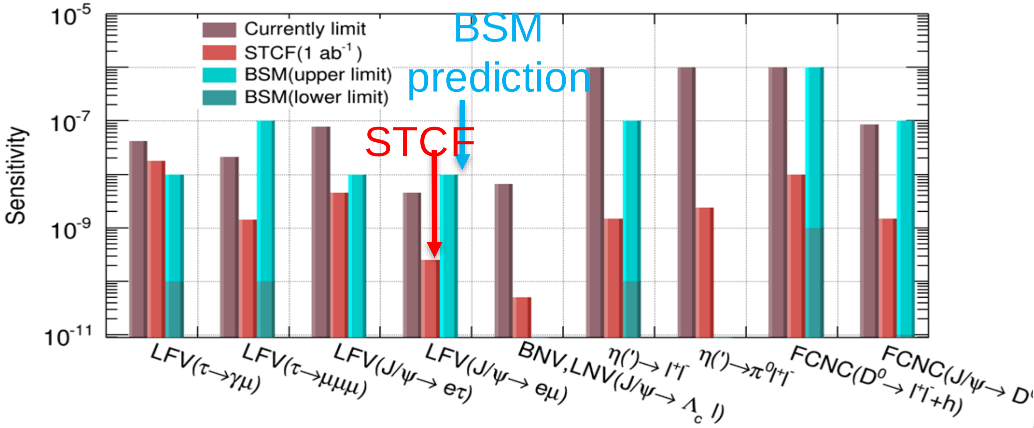
- STCF can improve the current precisions of many important measurements, and sensitivities of many new physics searches by 1-2 orders of magnitude
- Some have exceeded theoretical expectations → Great potential to discover new physics!



R value
Muon g-2

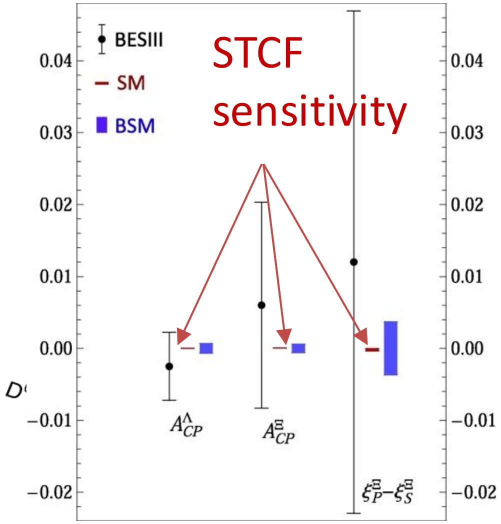
lepton
universality

CPV, CPTV



LFV, BNV, FCNC

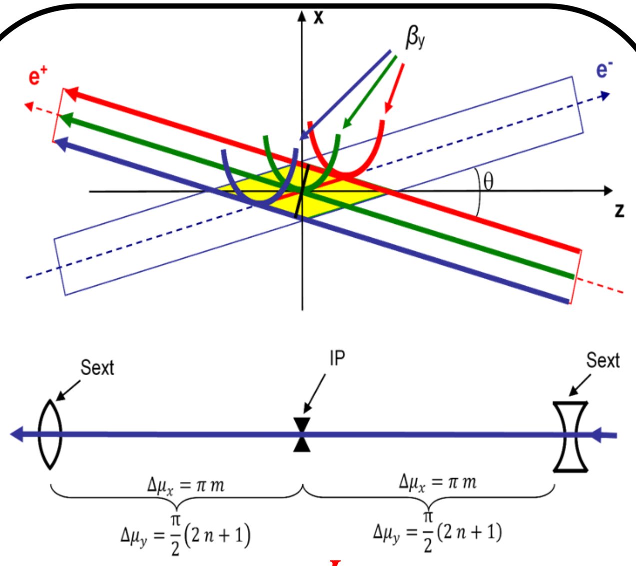
X.G. He et al. Sci.Bull. 67 (2022)



Direct observation of CPV in hyperons

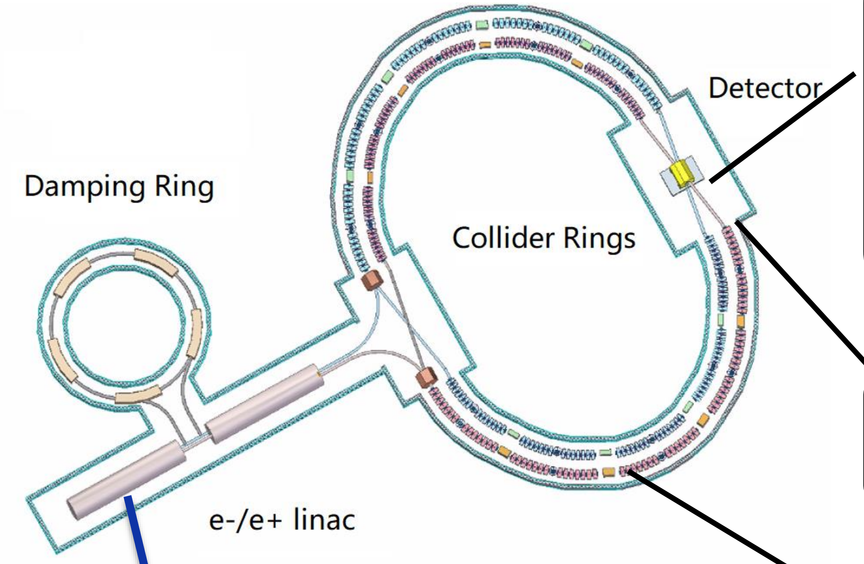
Challenges of STCF Accelerator

- 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



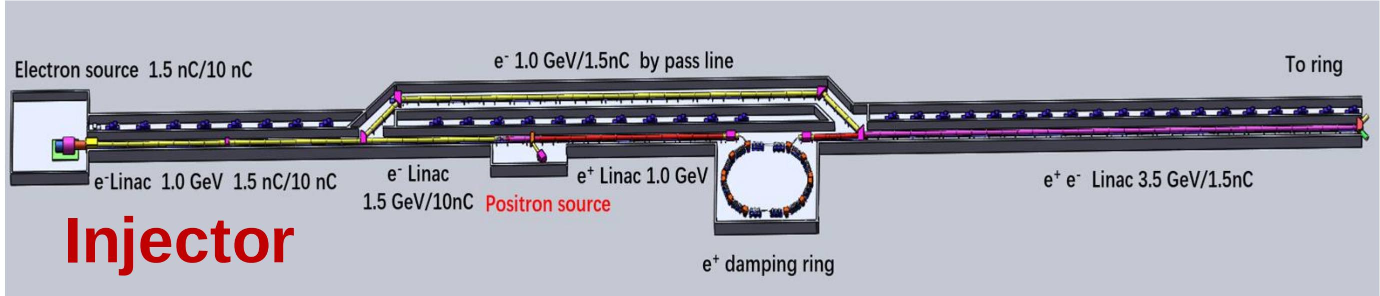
Collider Ring and Interaction Region Physics Design
IP beam size (Y) nm scale, Crab-Waist, nonlinear compensation extremely difficult

IR Technologies
SC magnets, MDI

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

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

STCF Accelerator Pre-Conceptual Design



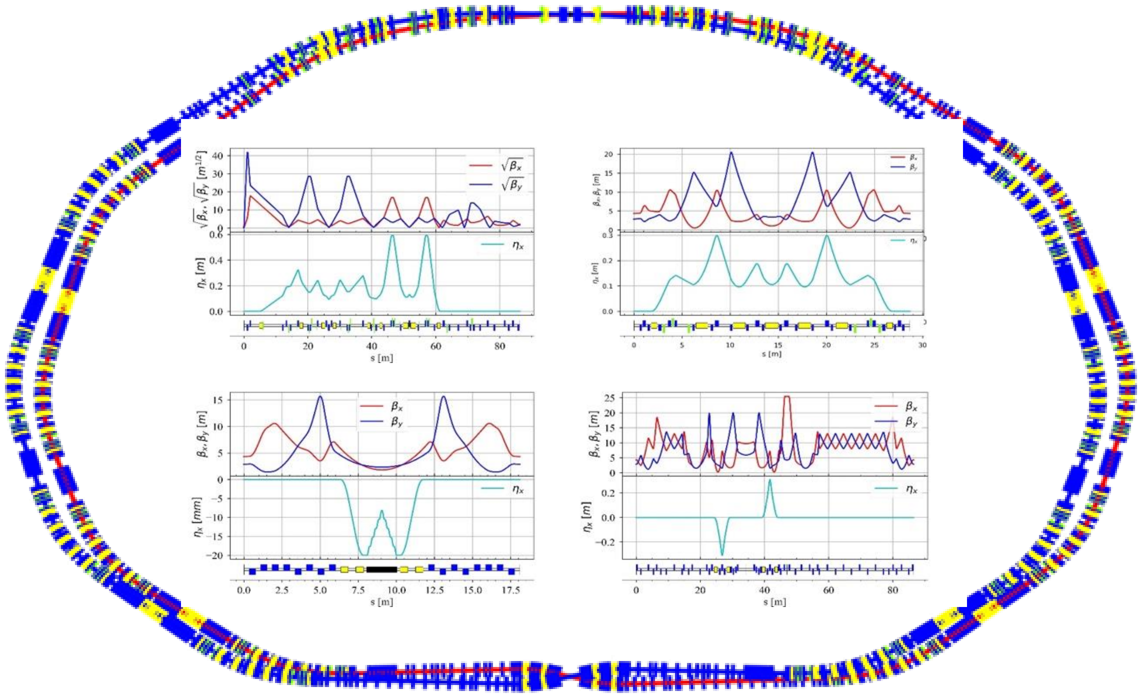
Injector:

- Variable energy: 1-3.5 GeV
- High beam quality (emittance, energy spread)
- Two different CR injection: off-axis and swap-out
- Damping ring or accumulator ring for positrons @1 GeV
- Total length: ~400 m (+100 m beam transp.)

Parameters	Value		Unit
E-gun type	Photo /Thermal	Thermal /Thermal	
Injection e- bunch charge	1.5	8.5	nC
Injection e+ bunch charge	1.5	8.5	
Injection energy	1.0-3.5	1.0-3.5	GeV
Optimal energy	2.0	2.0	GeV
MW frequency	2998.2	2998.2	MHz
Injection emittance (Geo, rms)	≤6	≤30	nm-rad
Injection energy spread (rms)	≤0.1	≤0.3	%
Injection bunch length (rms)	<7		mm
Injection frequency e-	30	30	Hz
Injection frequency e+	30	30	Hz
e+ DR injection emittance	≤1400	-	nm-rad
e+ DR extraction emittance	≤11	-	nm-rad
e+ DR RF frequency	499.7	-	MHz
e+ DR bunch numbers	5	-	
e+ AR injection charge	-	2.5	nC
e+ AR injection frequency	-	120	Hz
e+ AR injection emittance	-	≤1400	nm-rad
e+ AR extraction emittance	-	≤30	nm-rad

STCF Accelerator Pre-Conceptual Design

Collider ring lattice



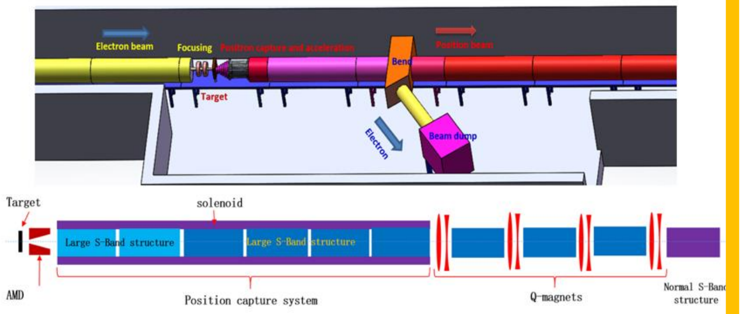
Collider rings:

- Injection energy: 1-3.5 GeV
- Optimal energy: 2 GeV
- Two injection schemes: off-axis, swap-out

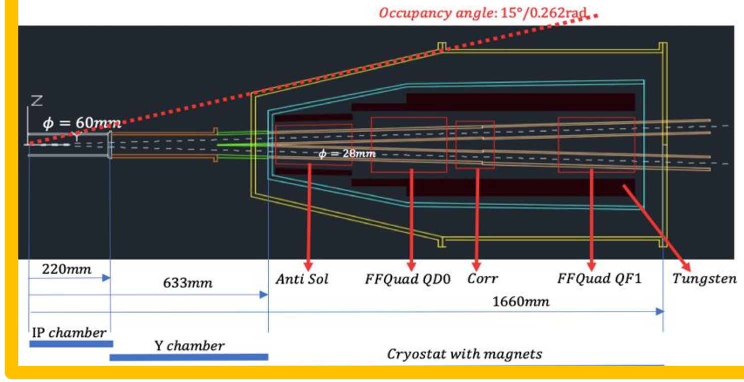
Parameters	Units	STCF
Optimal beam energy, E	GeV	2
Circumference, C	m	871.76
Crossing angle, 2θ	mrad	60
Revolution period, T	μs	2.908
Horizontal emittance, $\varepsilon_x/\varepsilon_y$	nm	6.857/0.034
Coupling, k		0.50%
Beta functions at IP, β_x/β_y	mm	40/0.6
Beam size at IP,σ_x/σ_y	μm	16.56/0.143
Betatron tune, ν_x /ν_y		32.55/29.57
Momentum compaction factor, α_p	10^{-4}	12.322
Energy spread, σ_e	10^{-4}	8.986
Beam current, I	A	2
Number of bunches, n_b		726
Particles per bunch, N_b	10^{10}	5.00
Single-bunch charge	nC	8.01
Energy loss per turn, U_0	keV	406.8
Damping time, τ_x/ τ_y/ τ_z	ms	28.4/28.6/14.4
RF frequency, f_{RF}	MHz	499.333
Harmonic number, h		1452
RF voltage, V_{RF}	MV	1.8
Synchrotron tune, ν_z		0.0158
Bunch length, σ_z	mm	9.72
RF bucket height, δ_{RF}	%	1.47
Piwinski angle, ϕ_{pwi}	rad	17.61
Beam-beam parameter, ξ_x/ξ_y		0.0027/0.082
Hour-glass factor, F_h		0.87
Luminosity, L	$cm^{-2}s^{-1}$	1.0×10^{35}

STCF Accelerator Technology R&D

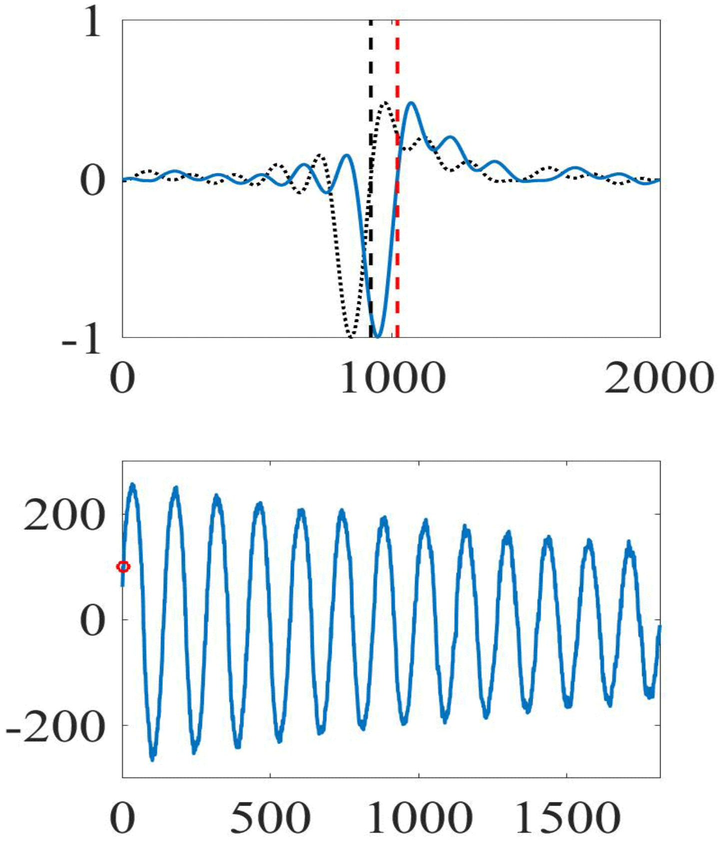
Positron Source



MDI

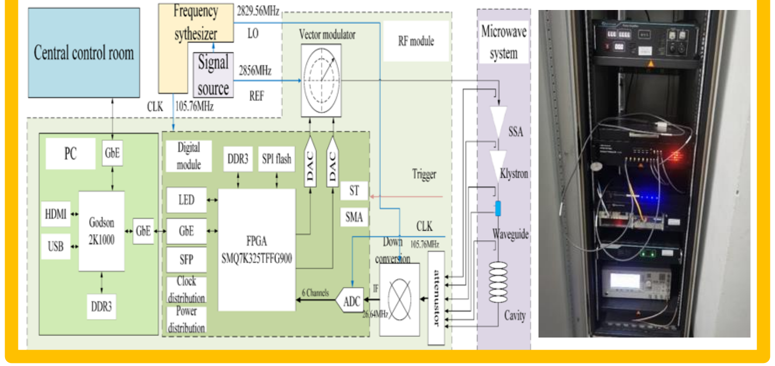


Bunch-by-Bunch 3D position measurement

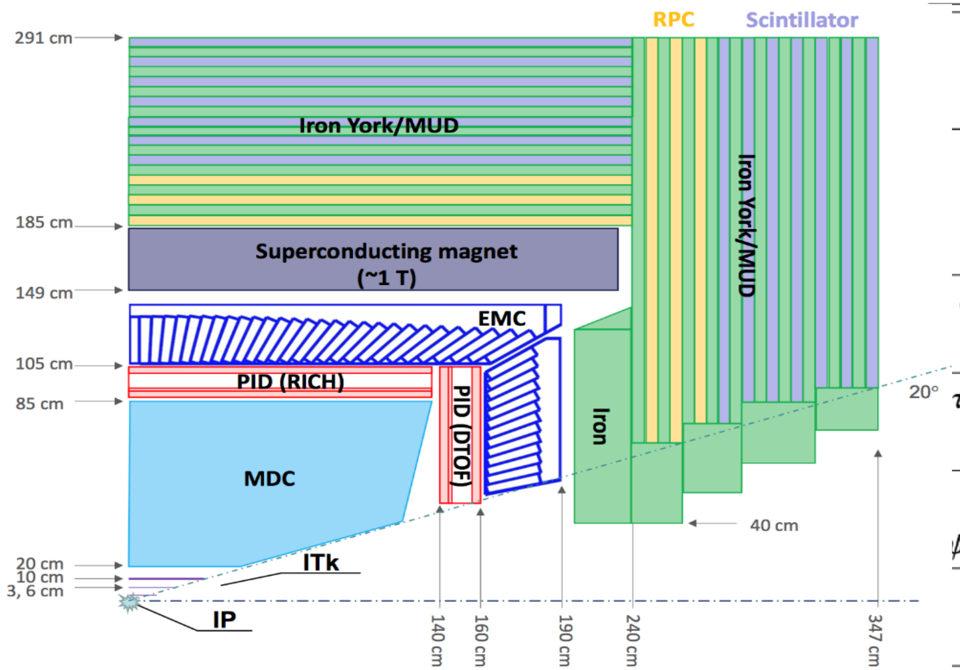


Photocathode e-gun

Low level RF system



Spectrometer Layout and Expected Performance



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

Solid angle coverage: 93%·4π

(polar angle: 20°~160°)

Inner tracker(ITK)
- <0.3%X_0/layer
- σ_{xy}<100μm

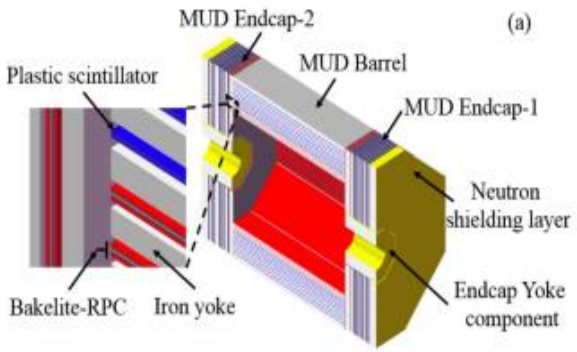
Main drift chamber(MDC)
- σ_{xy} < 130μm
- σ_p/p~ 0.5% @ 1GeV
- dE/dx ~ 6%

Electromagnetic calorimeter(EMC)
- E range : 0.025~3.5 GeV
- σ_E @ 1GeV
  - Barrel 2.5%; Endcap 4.0%
- Pos. res. : 5 mm

Particle identification(PID)
- π/K (K/p) 3~4σ sepa. up to 2 GeV/c

Muon detector(MUD)
- 0.4 ~ 2.0 GeV
- π suppression > 30

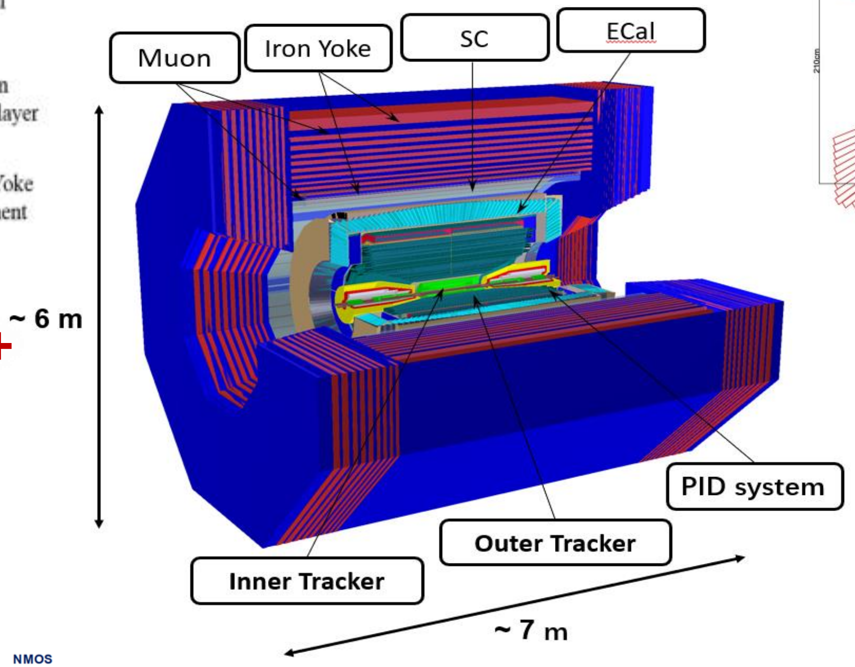
STCF Detector Conceptual Design

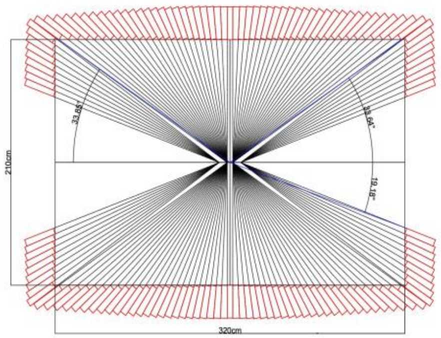


Muon Detector

Resistive Plate Chamber+

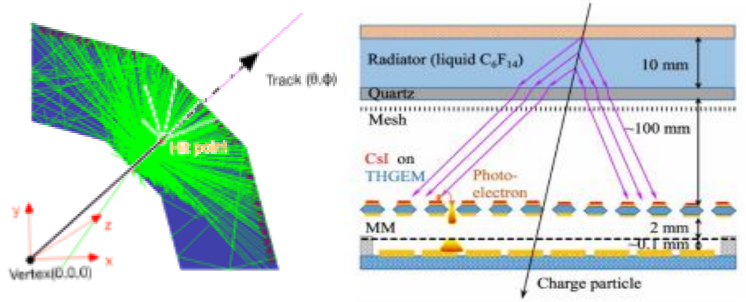
Plastic scintillator





Electromagnetic Calorimeter

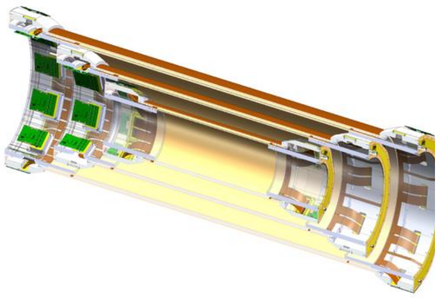
pCsI +APD

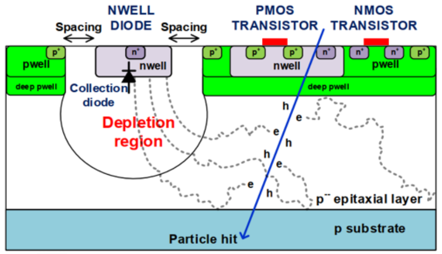


Particle Identification System

Barrel： RICH-like

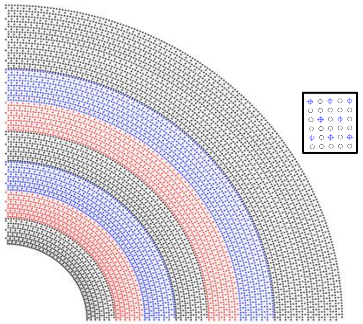
Endcap： DIRC-like





Inner tracker

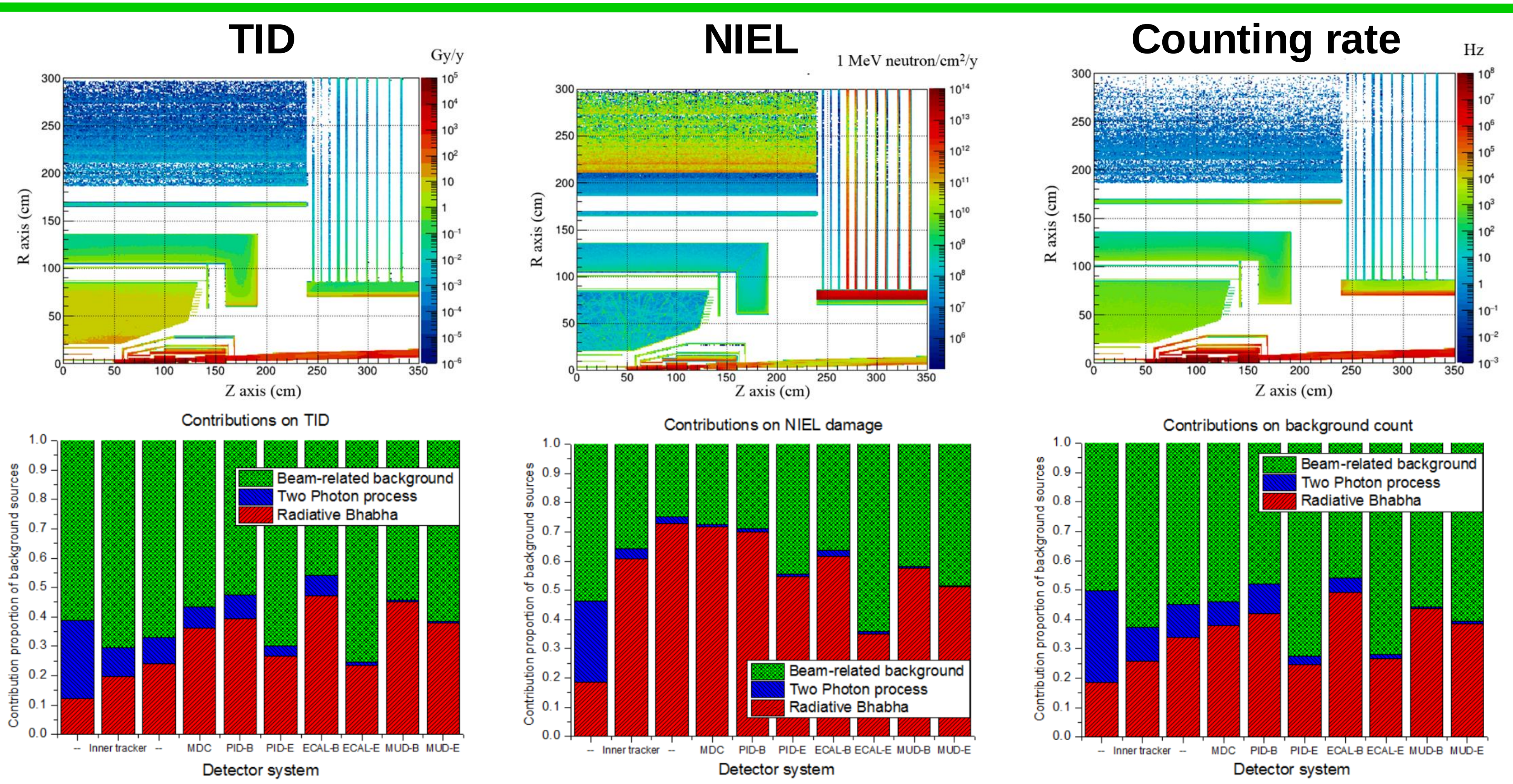
μRWELL Detector/CMOS MAPS



Central Tracker

Low material-budget Main Drift Chamber

Beam-induced Backgrounds



Simulated radiation in the inner most detector layer

~3.5 kGy/y, ~2×10^{11} 1MeV $N_{eq}/cm^2/y$, ~1 MHz/cm^2

STCF Physics & Detector CDR

82 institutions, 453 authors

arXiv:2303.15790

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FRONTIERS OF PHYSICS

REPORT
Volume 19 / Issue 1 / 14701 / 2024

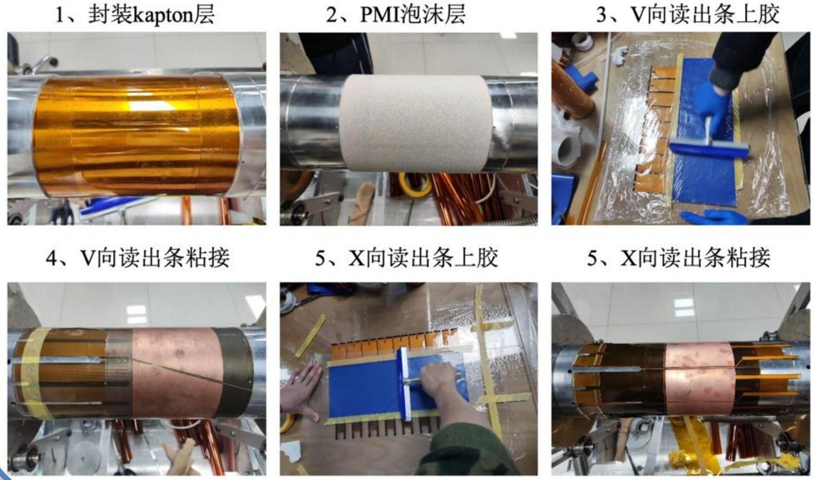
STCF conceptual design report (Volume 1): Physics & detector

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],

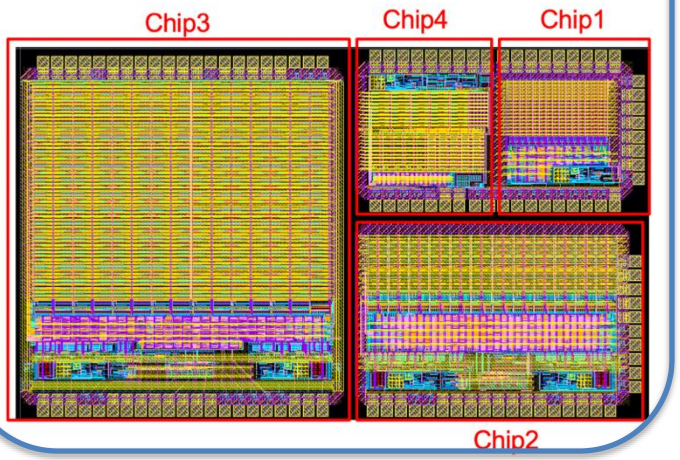
Detector R&D Highlights

- R&D ongoing for all sub-detector systems
- ECAL, RICH, DTOF and DAQ test beam finished in August at CERN

Cylindrical MPGD(uRWELL, uRGroove)

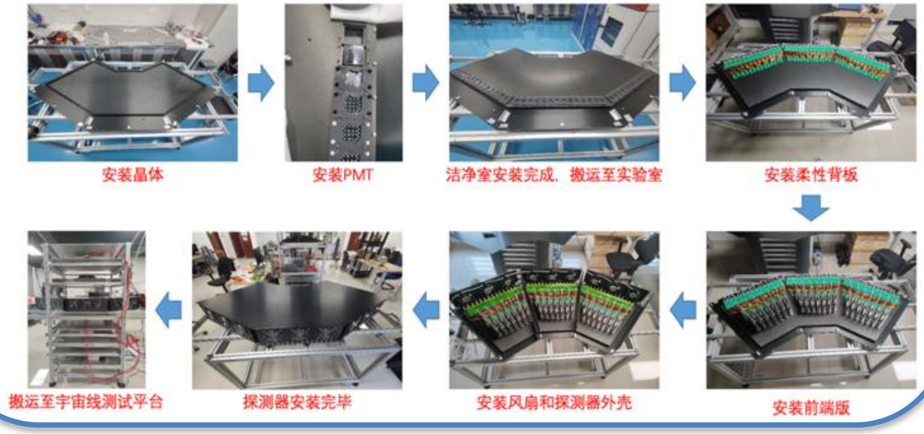


MAPS chip designs

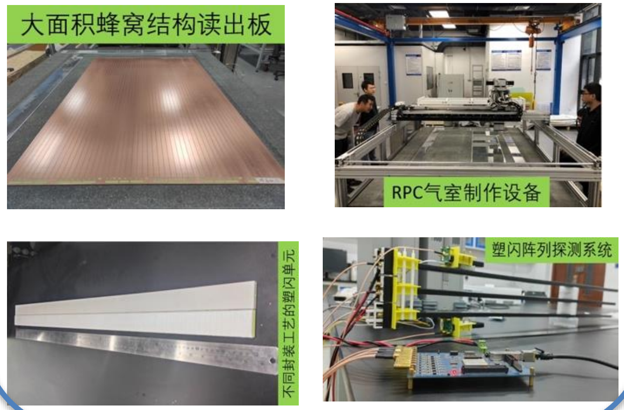


pCsI Ecal protopyte

Full-sized DTOF prototype

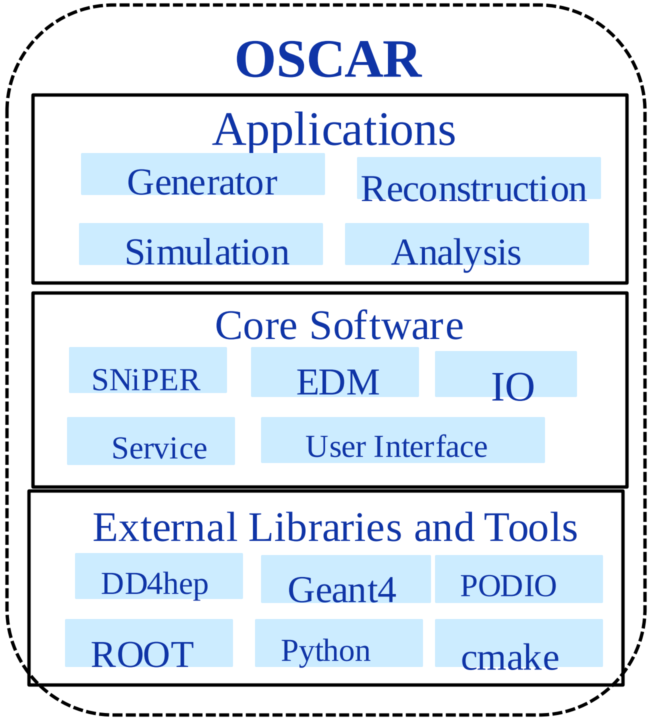


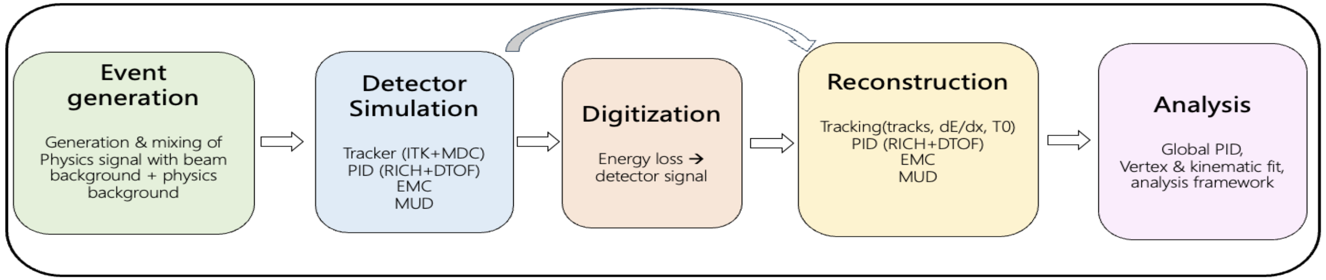
Large sized RPC and scintillator strips

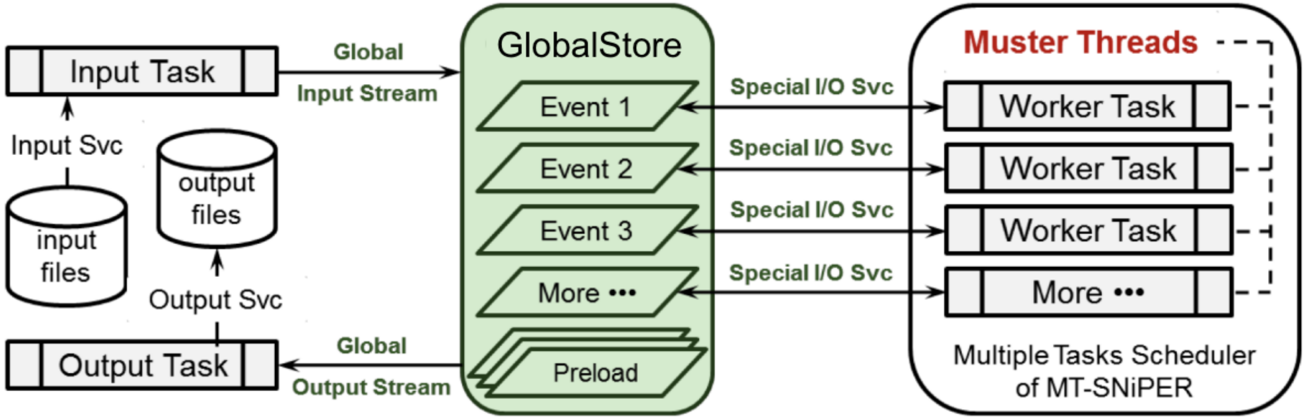


Offline Software

- Offline Software System of Super Tau-Charm Facility (OSCAR)
  - External Interface + Framework + Offline
- SNiPER framework provides common functionalities for whole data processing
- Full chain including Generator, Simulation, Calibration, Reconstruction and Analysis







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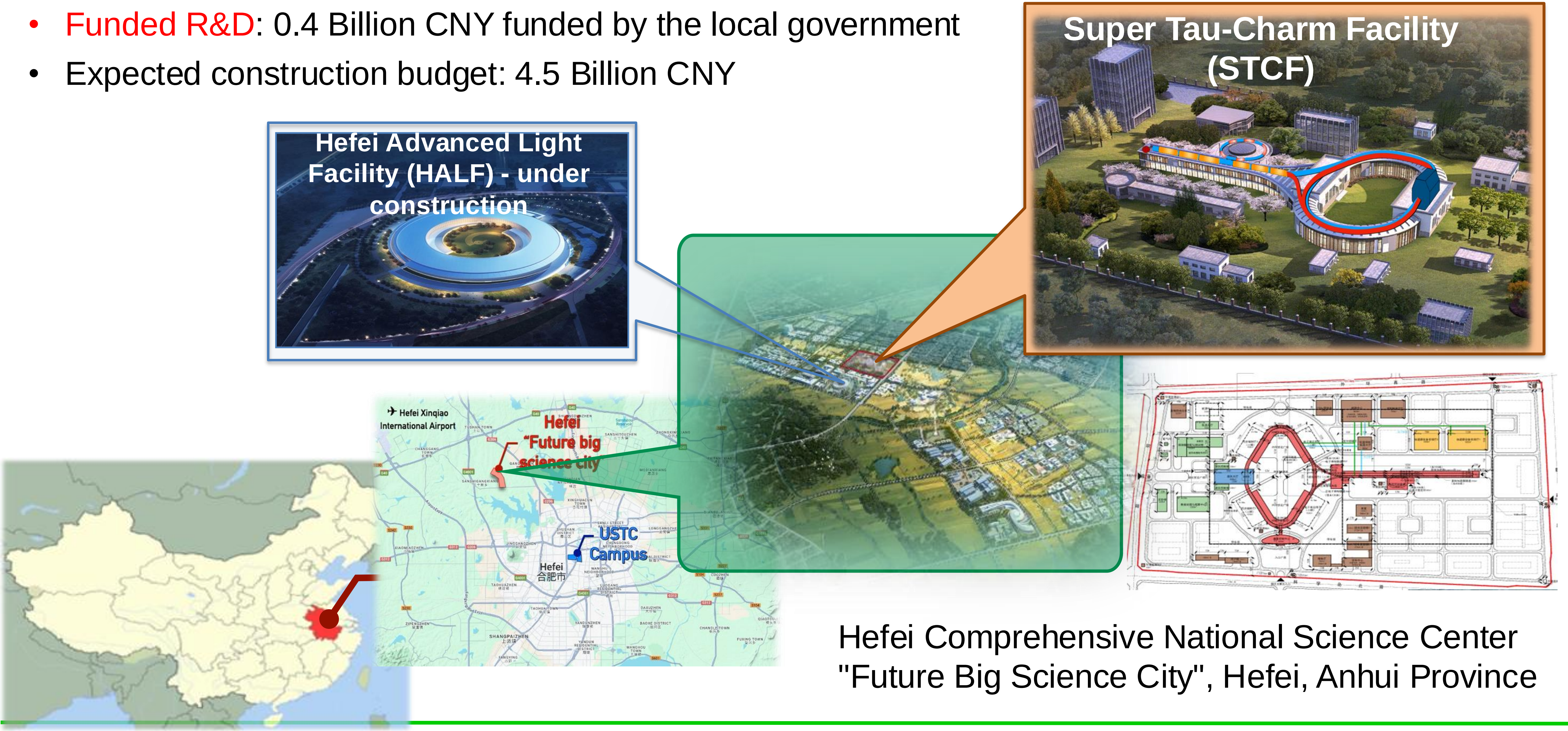
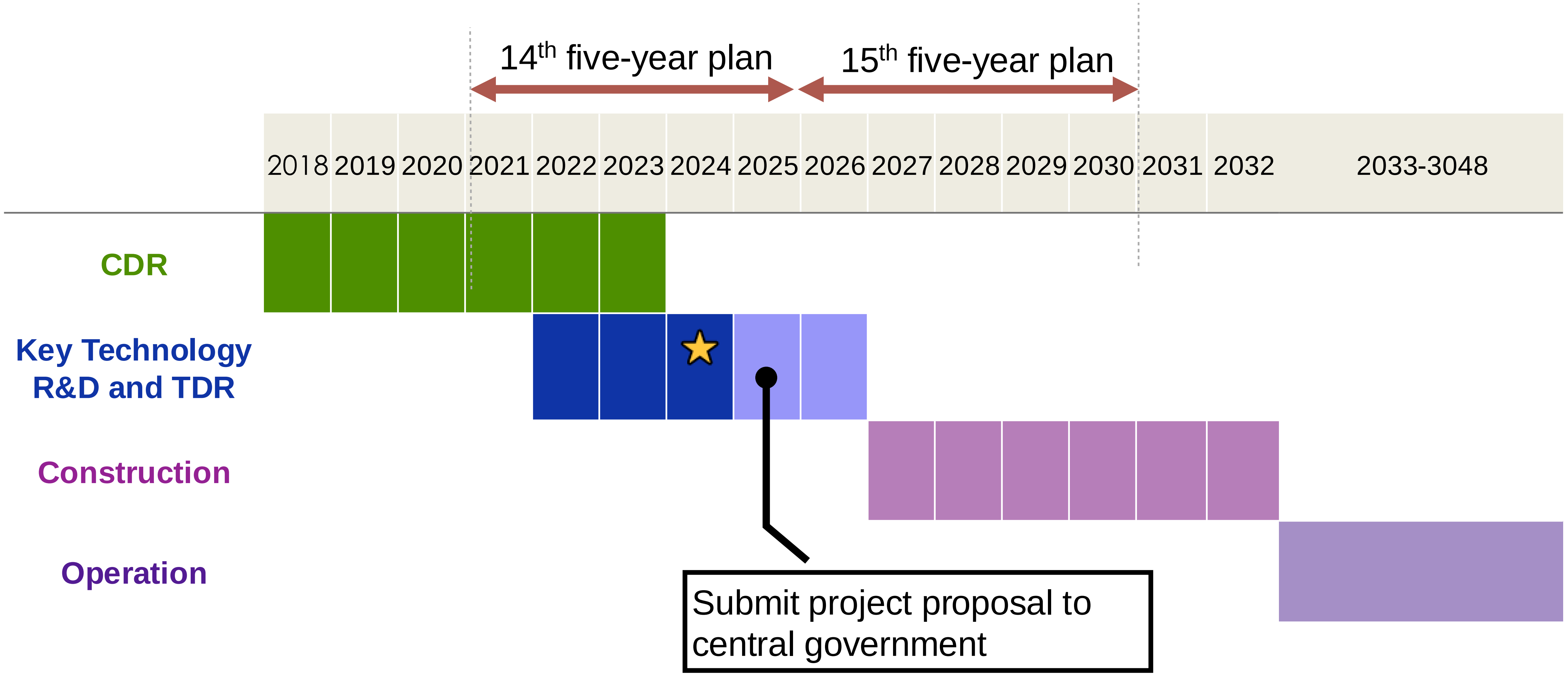
Site Selection: Hefei

- Funded R&D: 0.4 Billion CNY funded by the local government
- Expected construction budget: 4.5 Billion CNY



Hefei Comprehensive National Science Center
"Future Big Science City", Hefei, Anhui Province

Tentative Project Schedule



Summary

- As a key player in HEP precision frontier, STCF holds great potential for discoveries and breakthroughs in studies of QCD, CPV, and new physics search
- Intensive conceptual design studies in the past few years have resulted in Physics and Detector CDR
  - Accelerator CDR to come soon
- The STCF faces challenges in key technologies of accelerator, detector, electronics etc, the R&D project is ongoing with strong support from local governments and USTC
  - A full 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 international collaboration and explore synergies with other projects

FTCF2024-Guangzhou

The 6th International Workshop on Future Tau-Charm Facilities (**FTCF2024-Guangzhou**) will be hosted by Sun Yat-sen University (SYSU) in Guangzhou, China, **Nov. 17-21, 2024**.

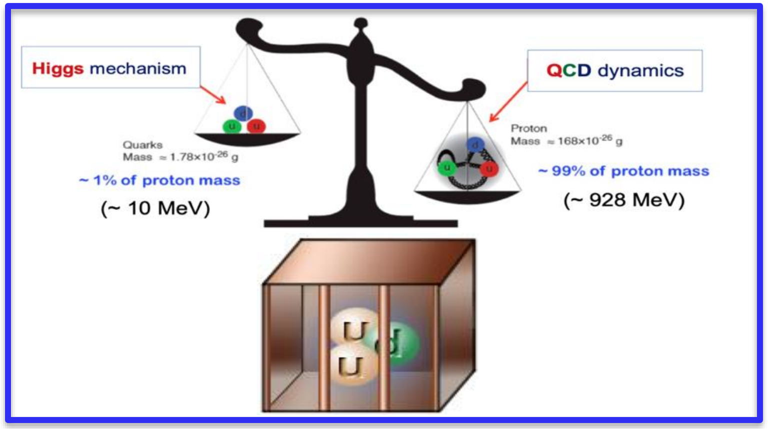
https://indico.pnp.ustc.edu.cn/event/1948/

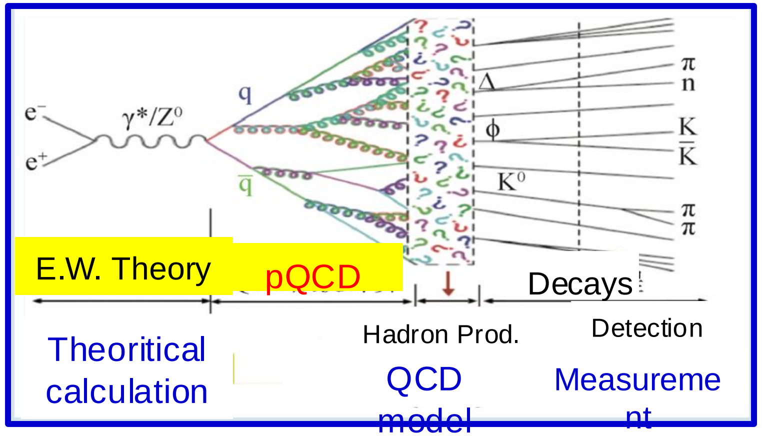
Backup

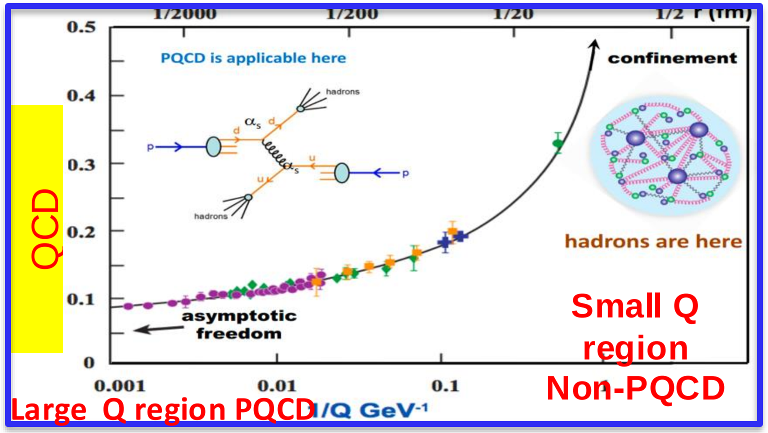
Key Questions To The Strong Interaction

The key questions to the strong interaction

- What is the origin of observable mass (mass of hadrons)?
- How are hadrons formed, and what is the hadron structure?
- What is the essence of asymptotic freedom and color confinement?







The primary task of particle physics: develop understanding of the laws of nature at a more fundamental level.

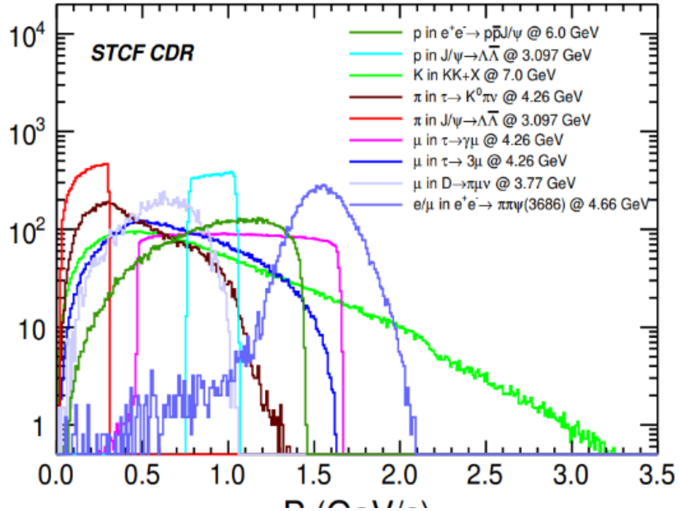
→ Requires a coordinated multi-dimensional program: precise theoretical predictions for observation, experimental measurements with state-of-the-art sensitivities and well-controlled systematic errors.

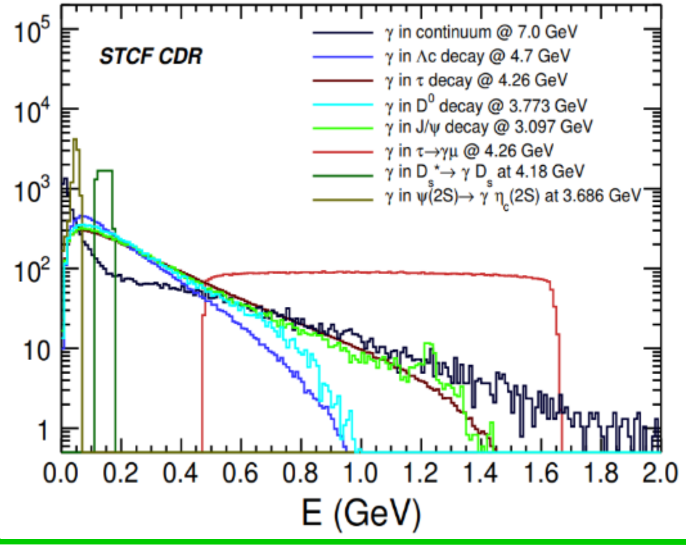
→ STCF can play unique role to this primary task!

Spectrometer Design Requirements and Challenges

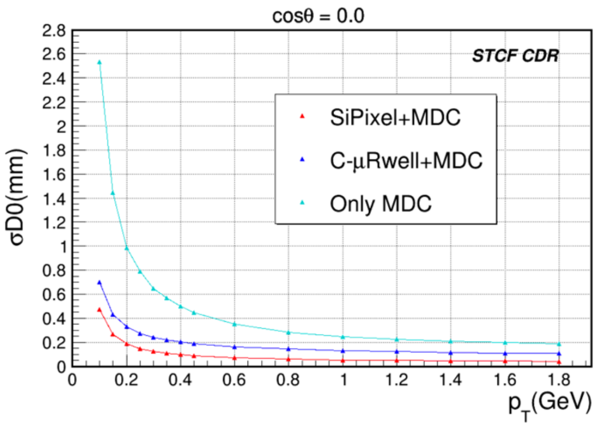
- Highly efficient and precise reconstruction of exclusive final states produced in 2-7 GeV e+e- collisions
  - Precise measurement of low-p particles (<1GeV/c) → low mass
  - Excellent PID : π/K and μ/π separation up to 2 GeV

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

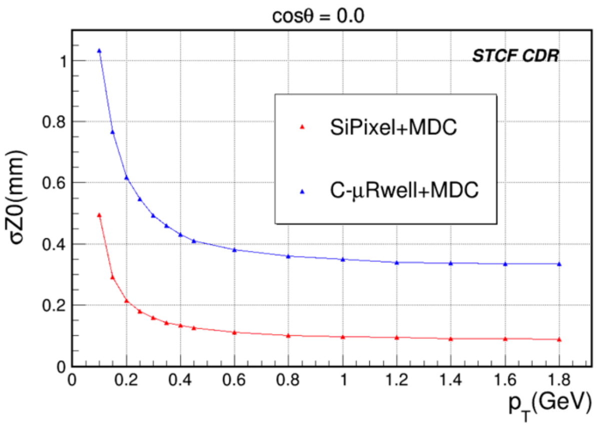




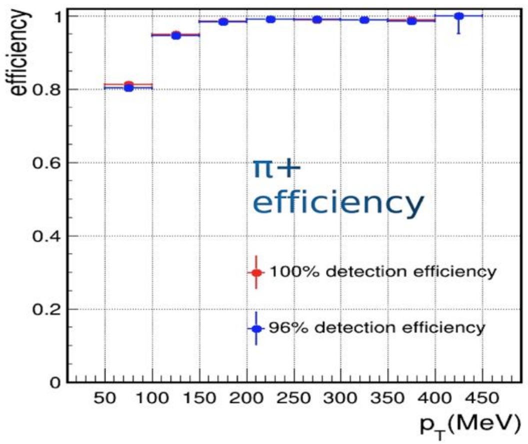
Combined Tracking Performance

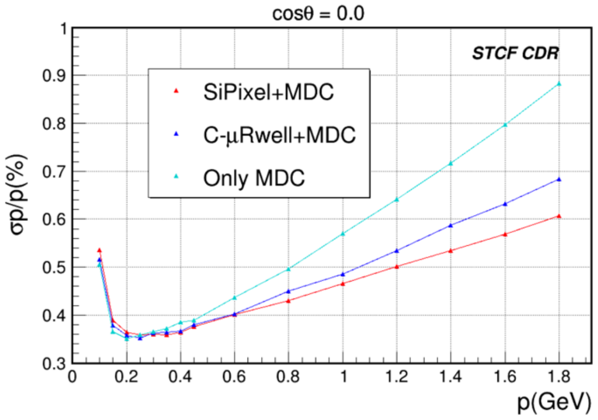


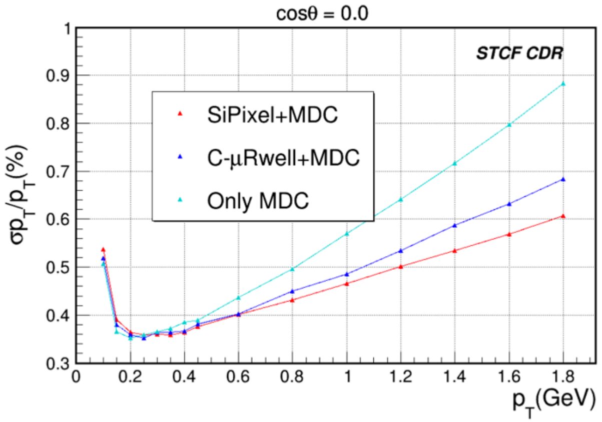
(a)

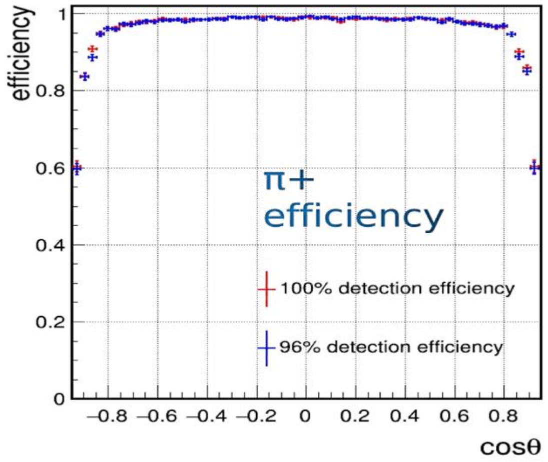


(b)



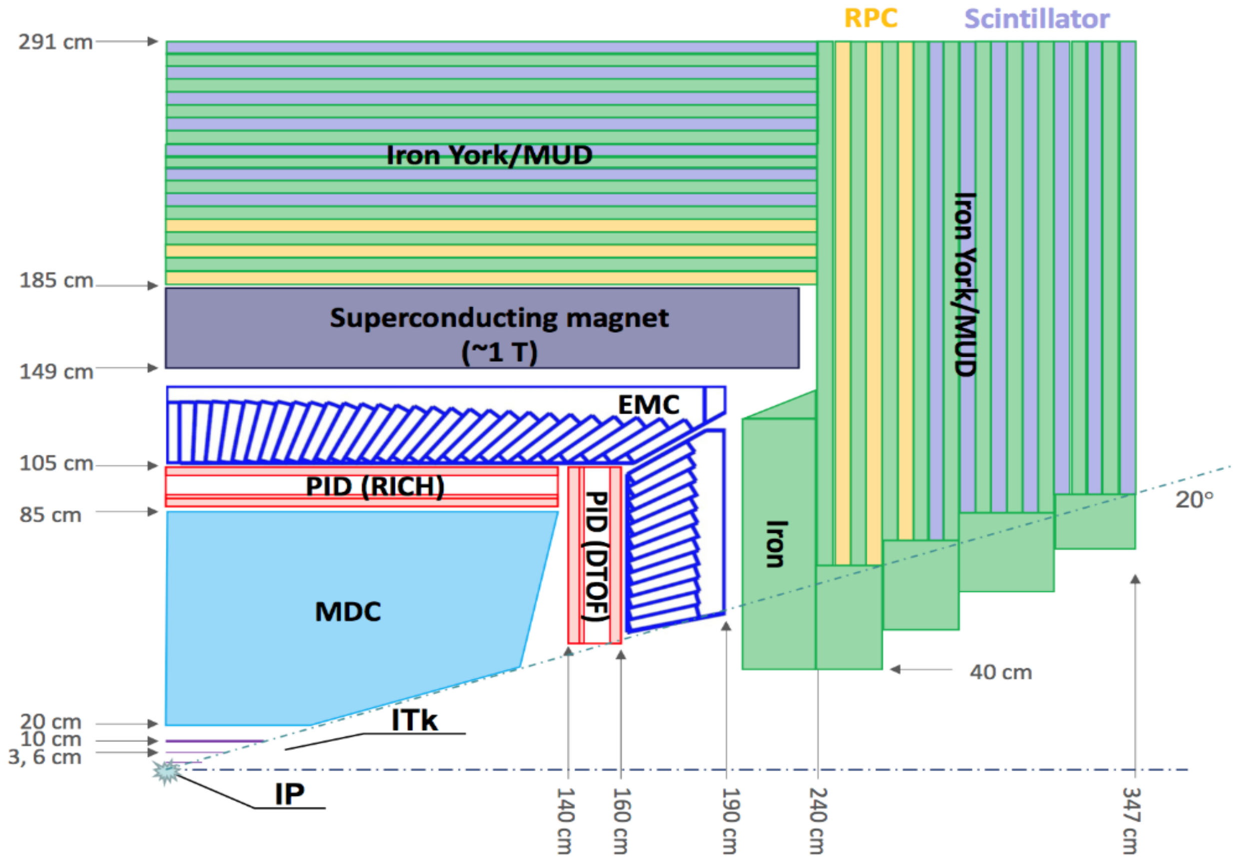






Ongoing layout optimization of the tracking system, particularly targeting low momentum tracking performance.

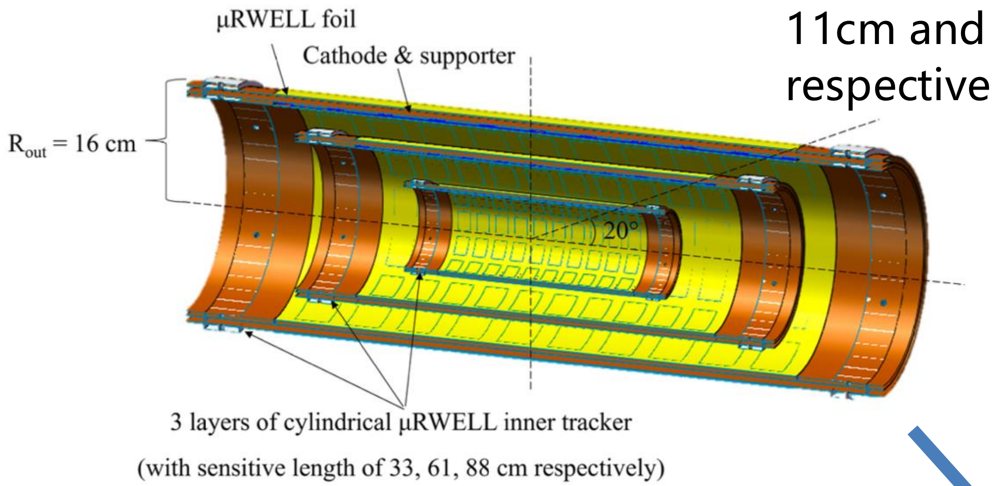
STCF Detector Conceptual Design



- **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

Tracking System : inner tracker + main drift chamber

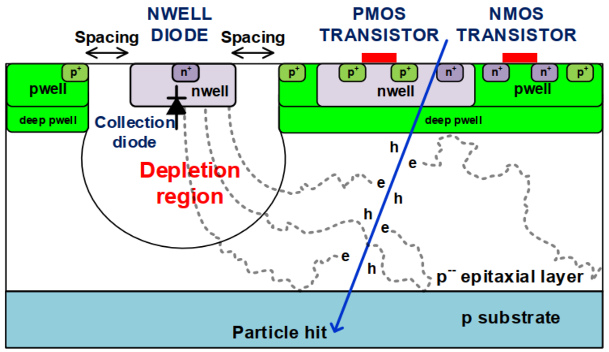
Gaseous option: MPGD



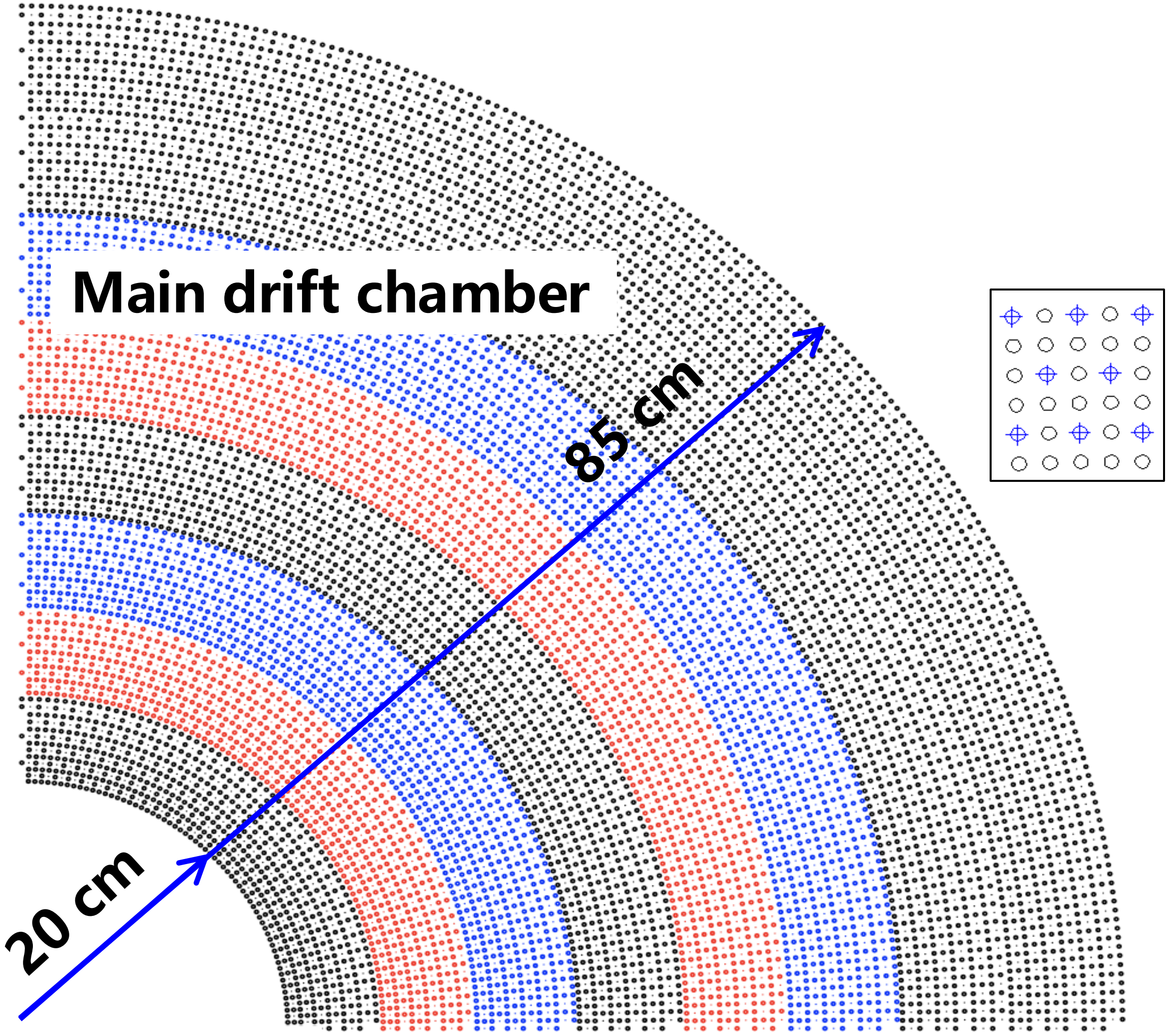
3 layers at 6cm, 11cm and 16 cm, respectively.

Material budget <0.3%X_0/layer

Silicon option: CMOS MAPS



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



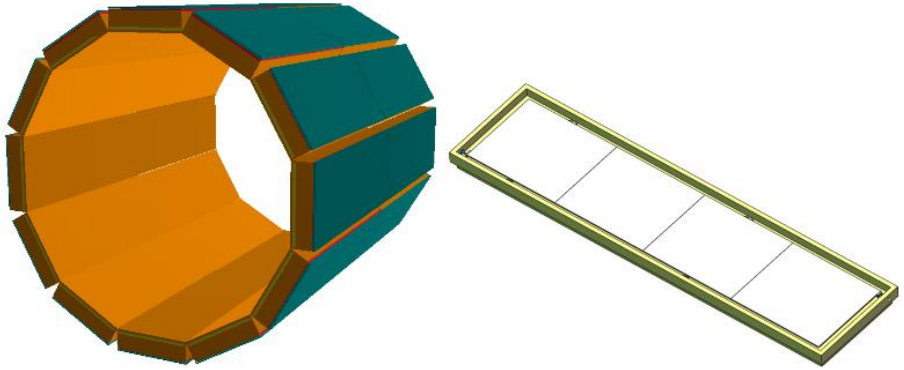
Inner tracker

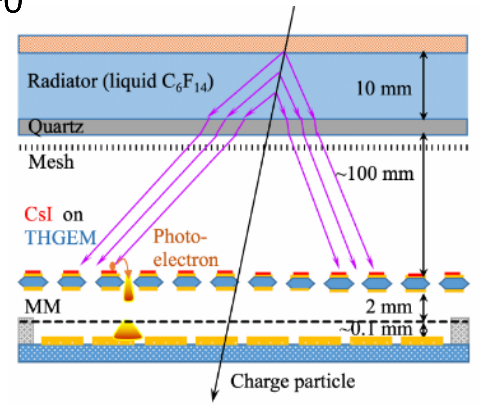
Total material budget ~ 4%X_0 (walls included)

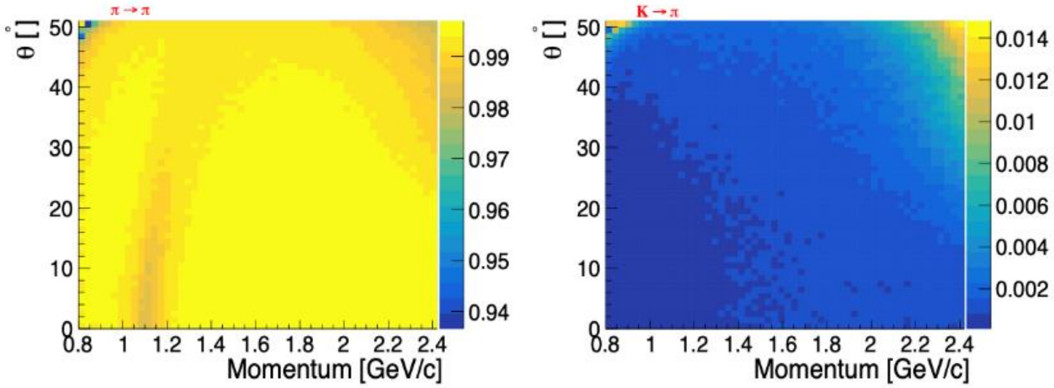
Particle Identification

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

Material budget < $0.3X_0$

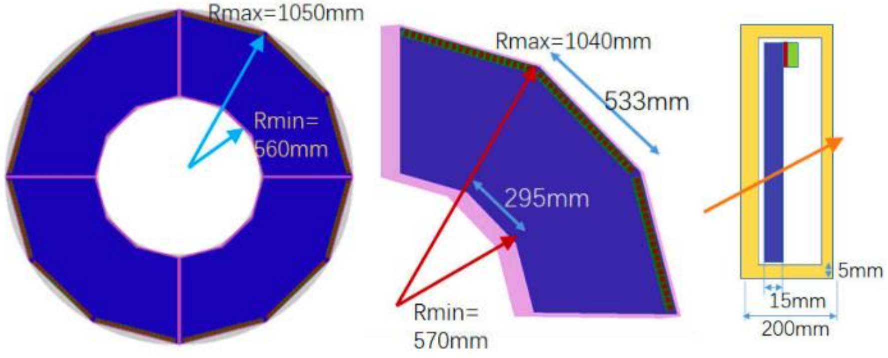


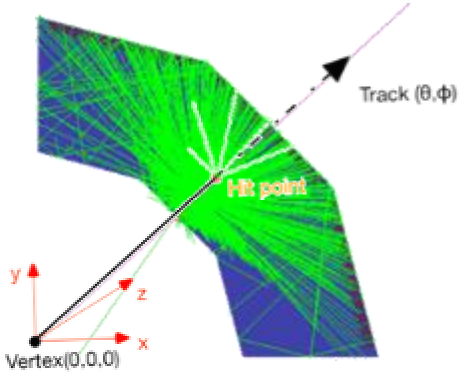


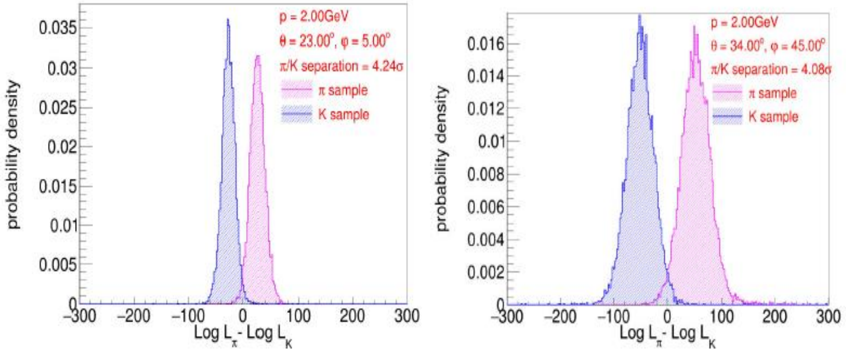


- Endcaps : A DIRC-like high-resolution TOF detector (DTOF)

K/π > 4 σ @2.0GeV

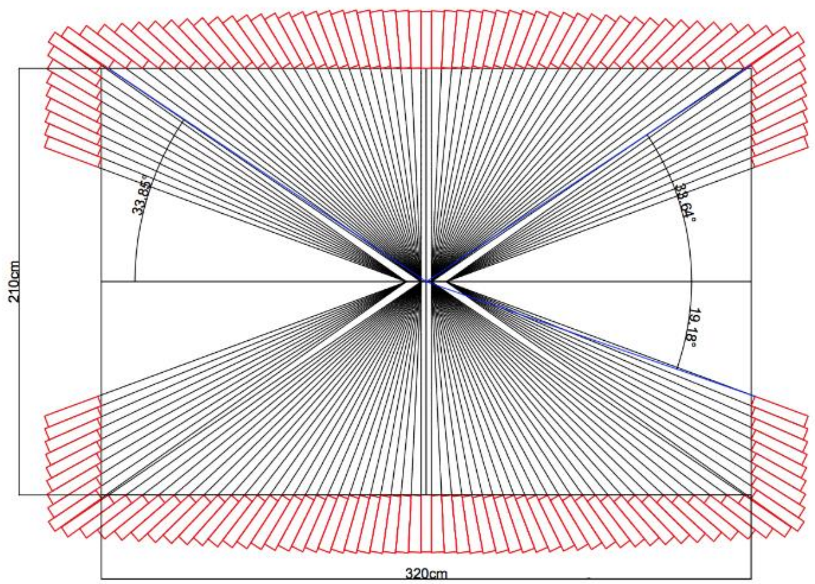


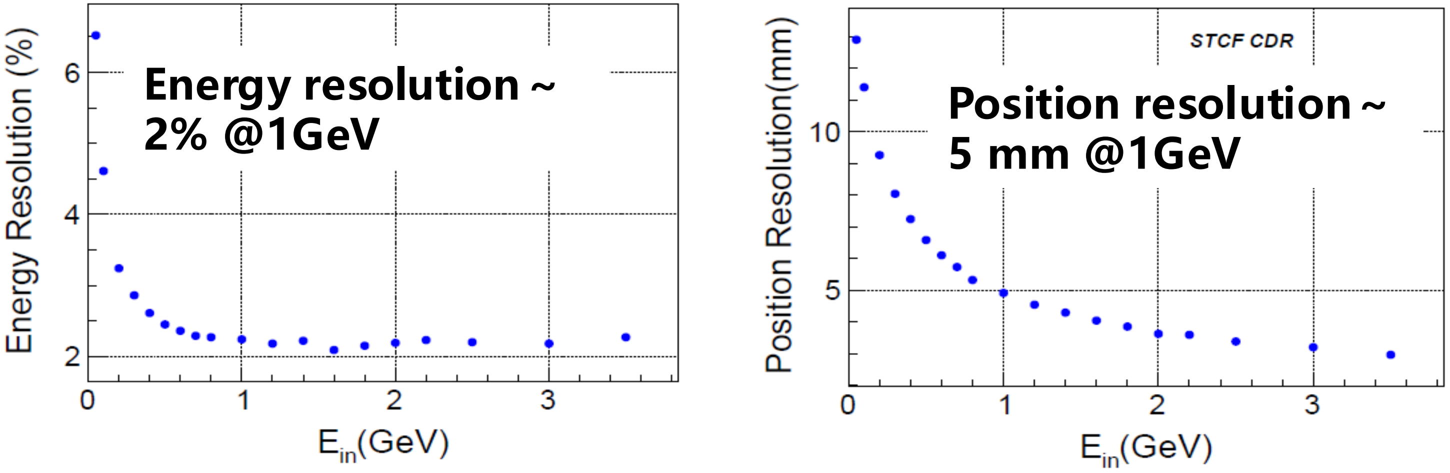




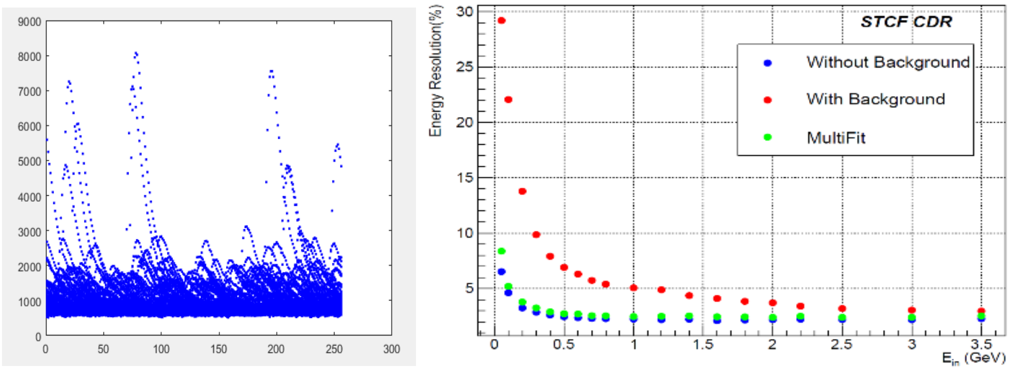
Electromagnetic Calorimeter

- A crystal calorimeter using pure CsI to tackle the high background rate (> 1 MHz/crystal)
  - crystal size: 28cm ($15X_0$), $5\times5cm^2$
  - 6732 crystals in barrel, 1938 crystals in endcaps
  - defocused layout
  - 4 large area APDs ($1\times1cm^2$) to enhance light yield



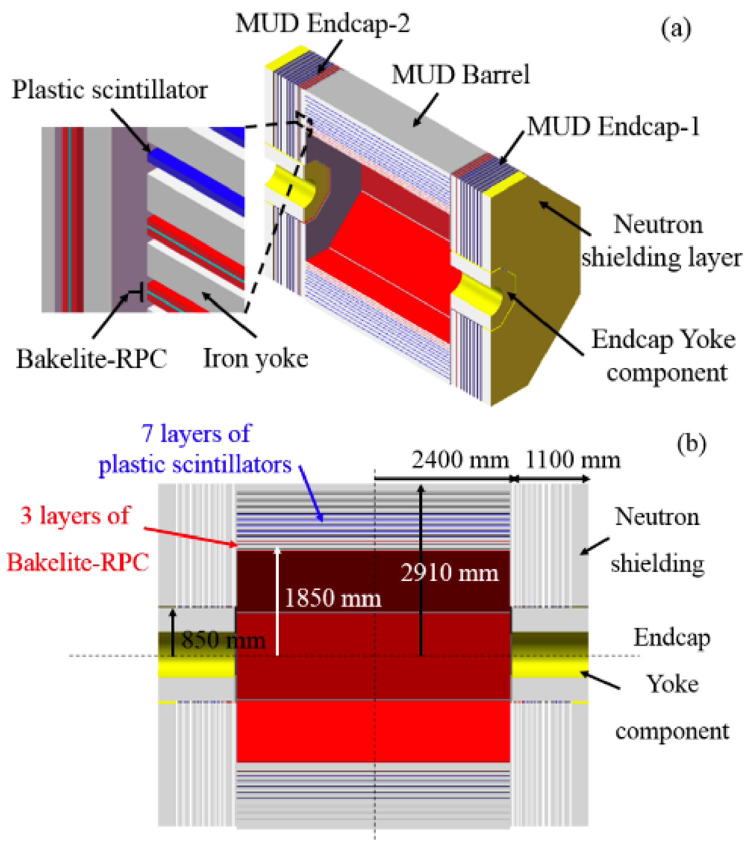


Simulation assuming a light yield of 100pe/MeV

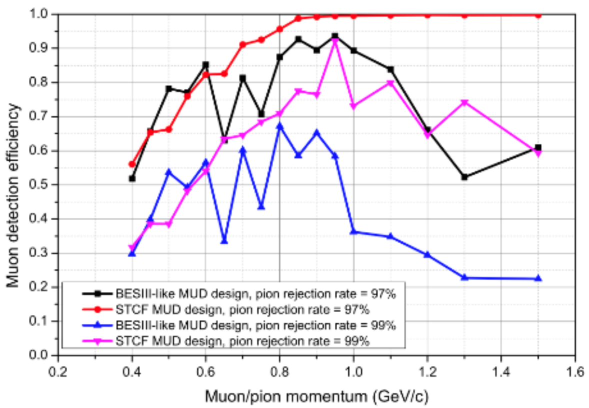


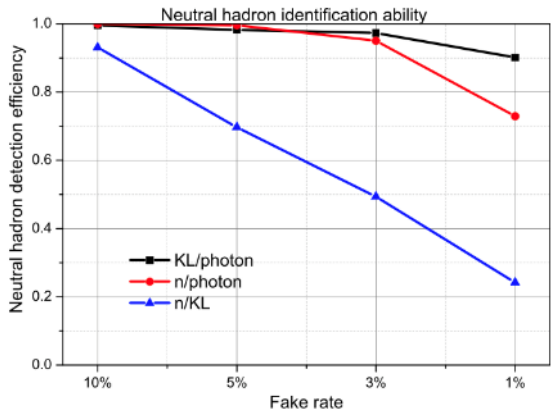
Pileup removal with waveform fitting

Muon Detector



- 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

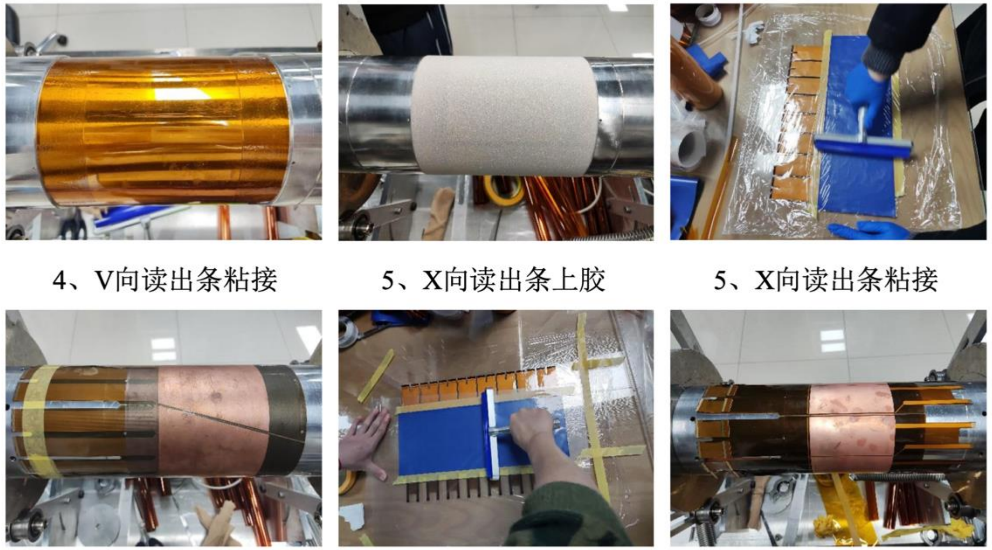




Using BDT combining the muon detector and EMC

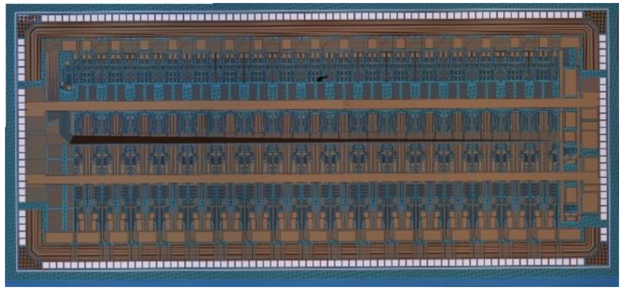
Detector R&D Highlights

Cylindrical MPGD (uRWELL, uRGroove)

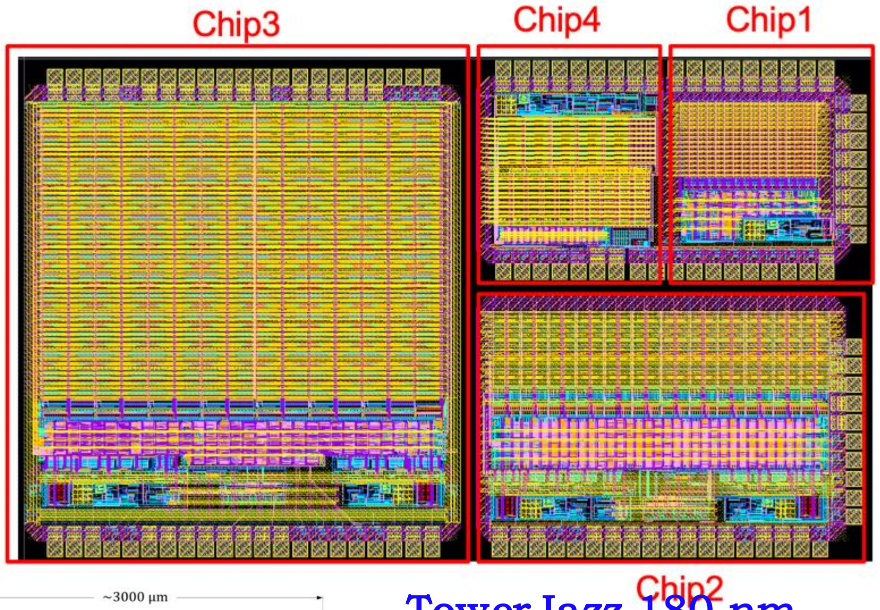


Ultra-low mass DLC resistive electrode

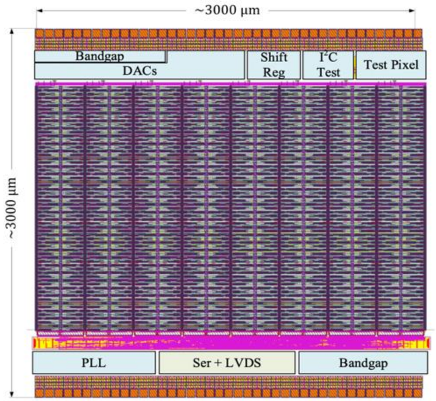
ASIC: σ_t <10 ns@5fC&20pF counting rate > 4 MHz



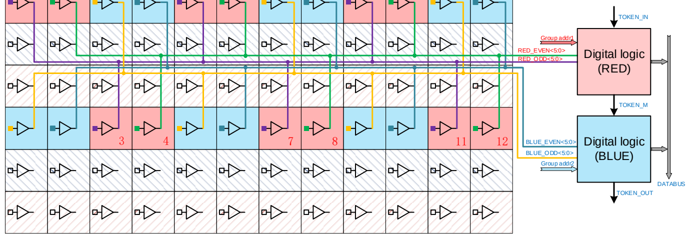
MAPS: aiming for a low-power chip design with timing capability



TowerJazz 180 nm

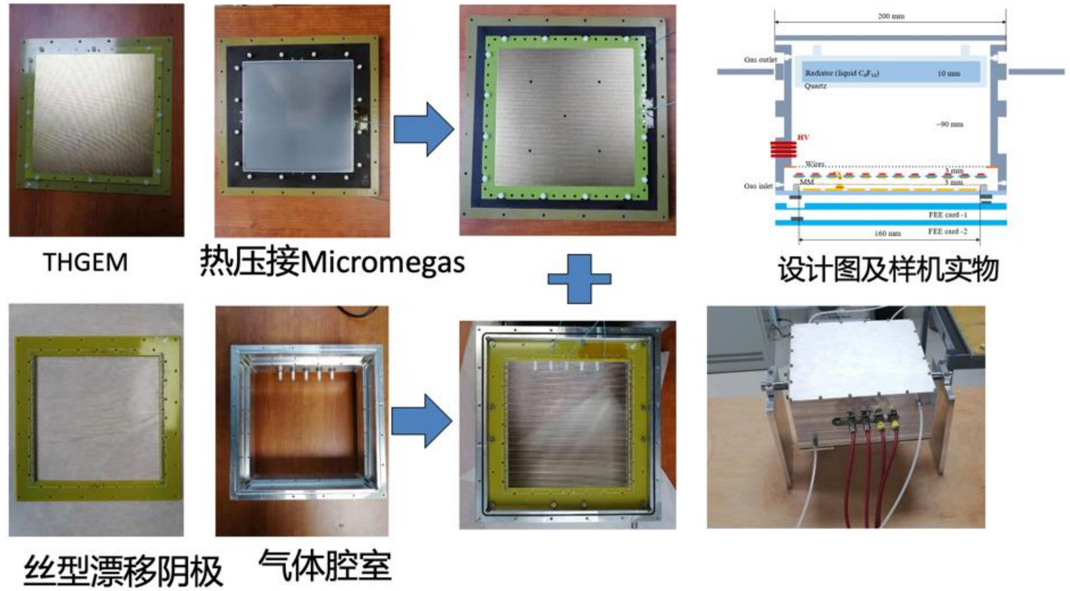


FCIS 90 nm



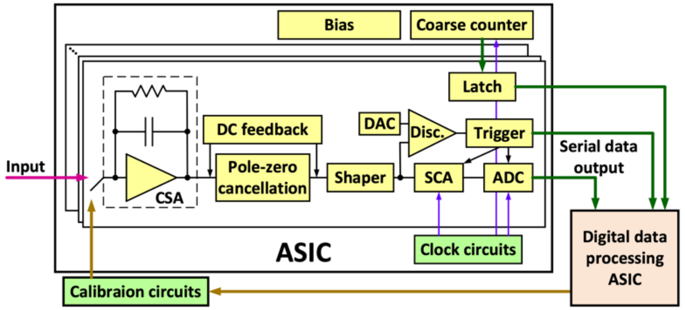
GSMC 130nm

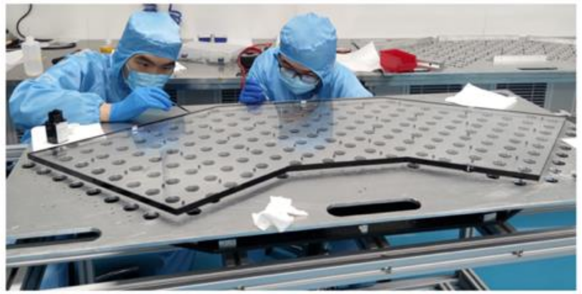
Detector R&D Highlights



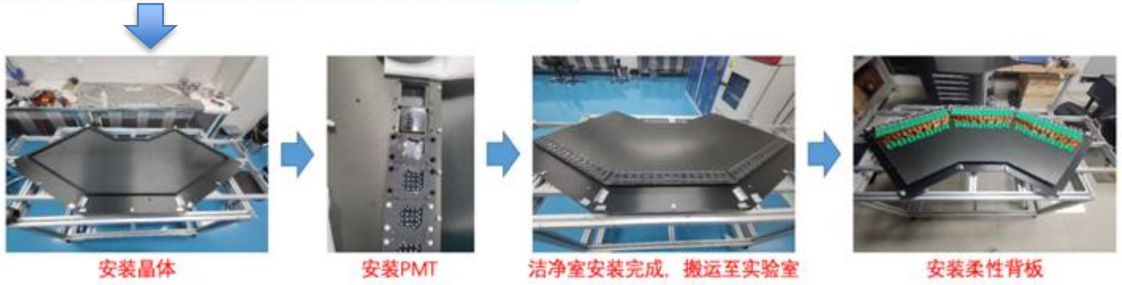
RICH readout ASIC

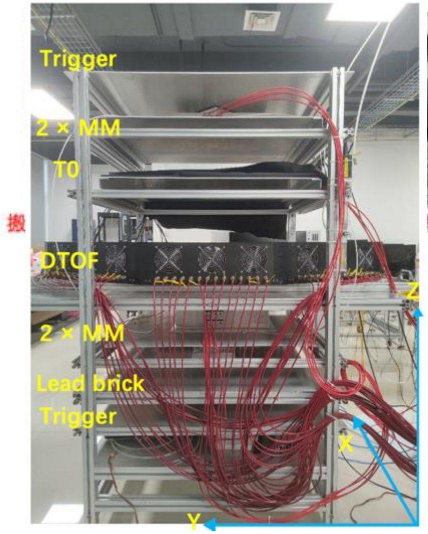
σ_t <1 ns@20fC&20pF
counting rate > 100 kHz





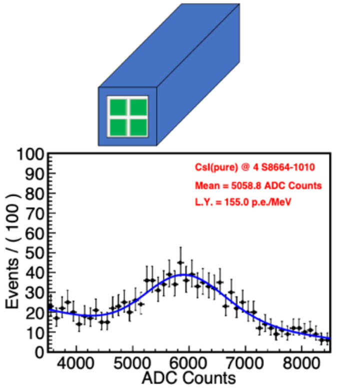
Full-sized DTOF prototype: a complete endcap sector!





Detector R&D Highlights

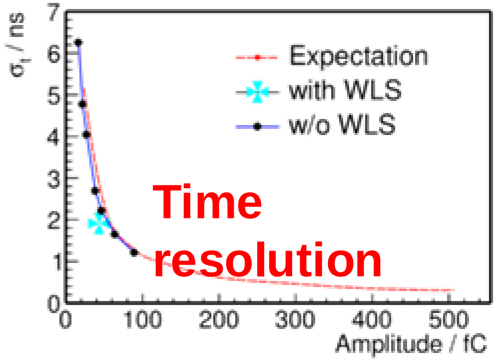
pCsI ECAL: Light yield reached up to 300 p.e./l



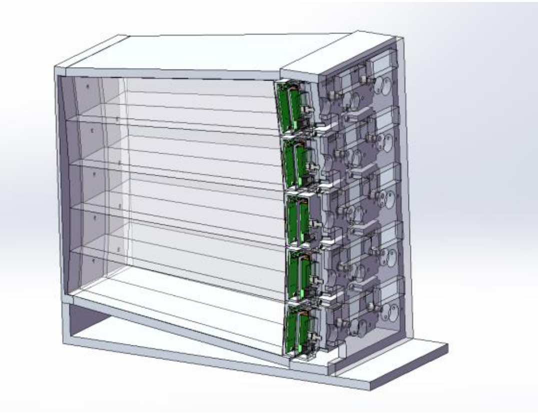
pCsI sprayed with WLS

Readout electronics

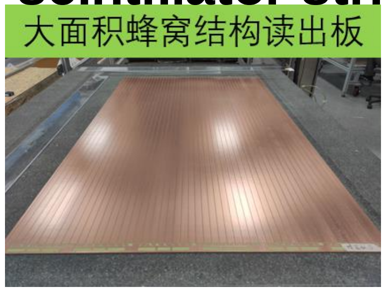
2.0 ns @ 0.03 GeV
0.8 ns @ 0.1 GeV

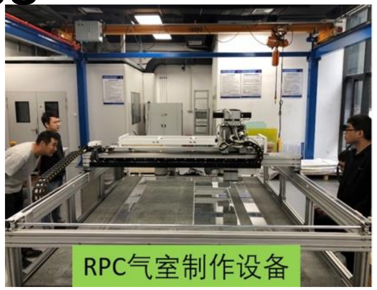


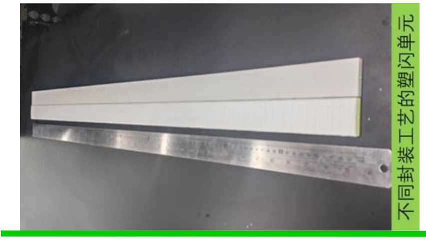
5*5 prototype

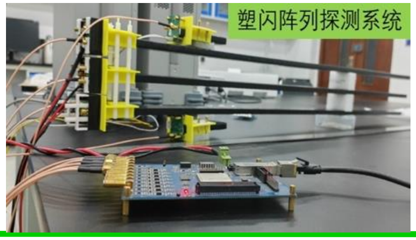


Large sized RPC and scintillator strips

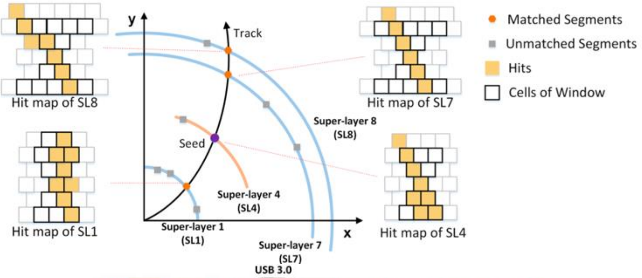


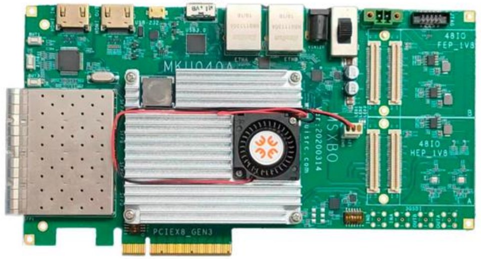




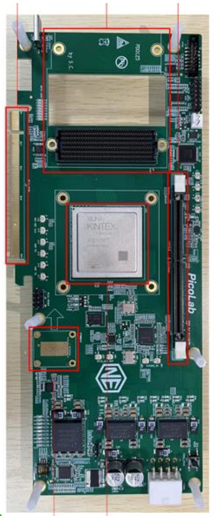


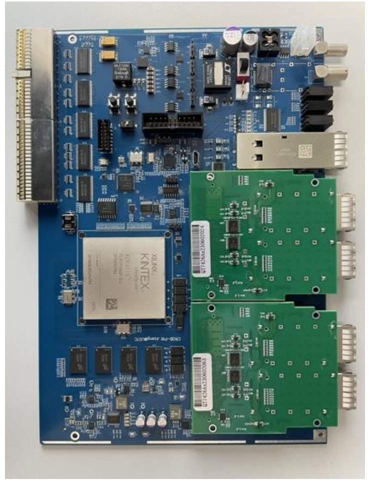
MDC Trigger algorithm and logic





DAQ PXI and PCIe boards





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.

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 STCF International Conference

2022超级陶粲装置研究进展研讨会