BESIII Detector and upgrade

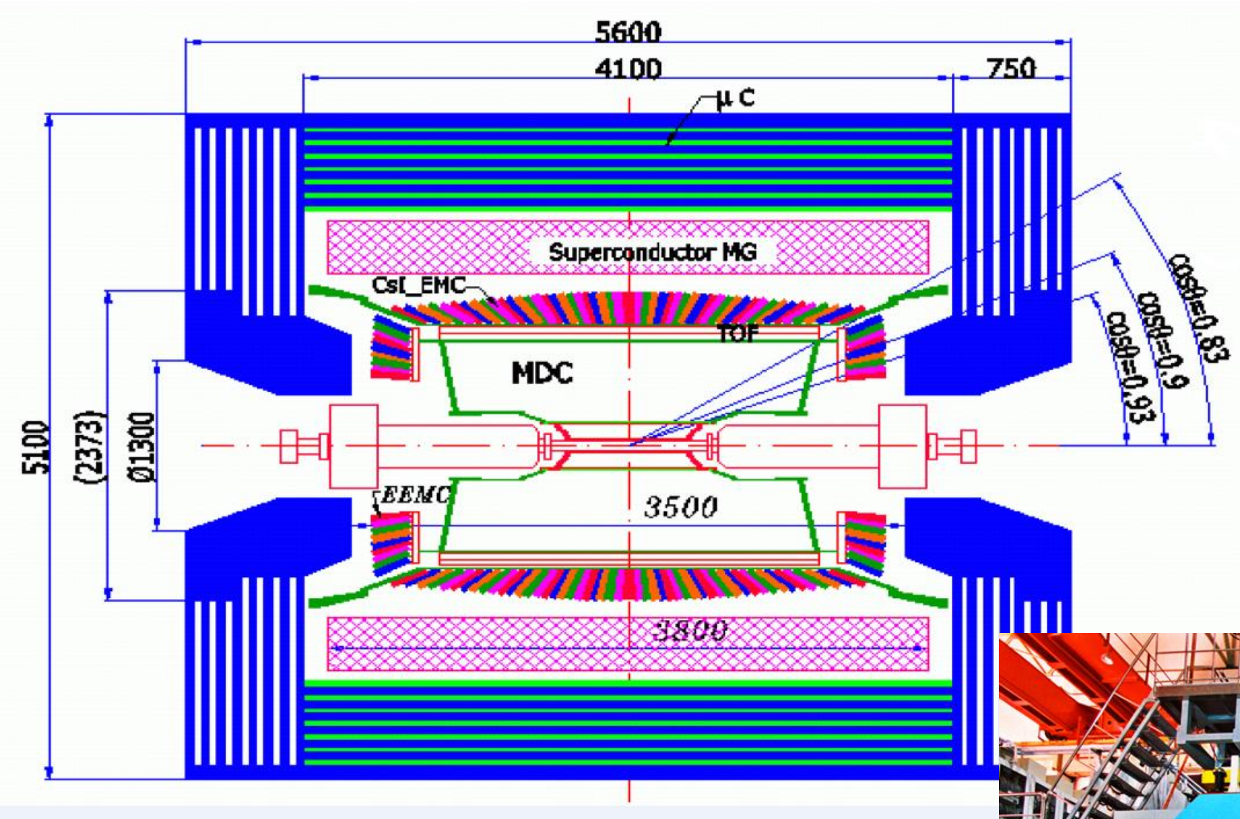
Mingyi Dong
On behalf of the working group

Symposium on 30 years of BES physics, Beijing, 2019.9.6

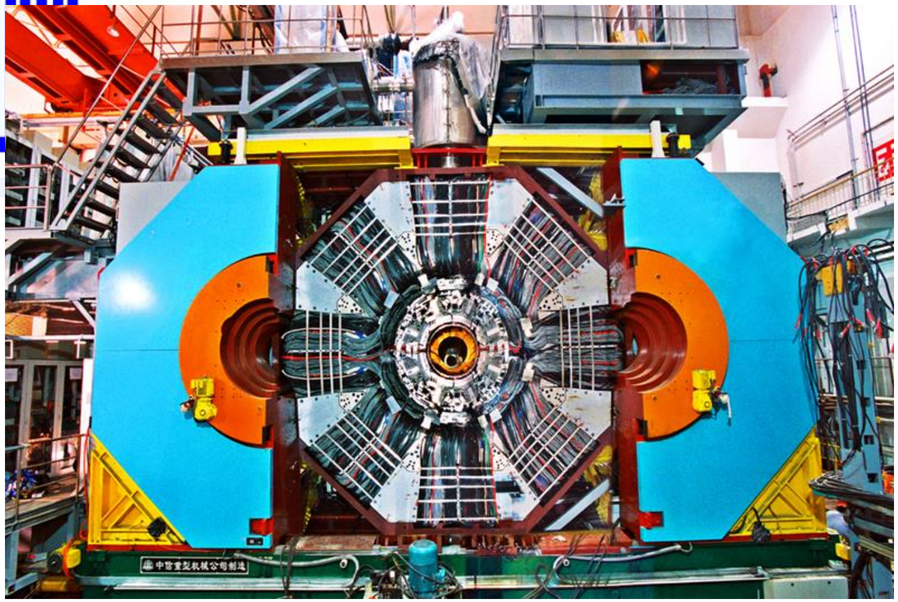
Outline

- The BESIII detector
- Upgrade of the detector
  - New inner drift chamber and CGEM-IT
  - MRPC-based ETOF
  - New valve box of Superconducting Magnet

The BESIII detector



- General purpose detector at BEPCII, $E_{cm} \approx$ 2-4.6 GeV, $L_{peak} \approx 10^{33}/cm^2/s$
- Versatile researches in τ-charm physics

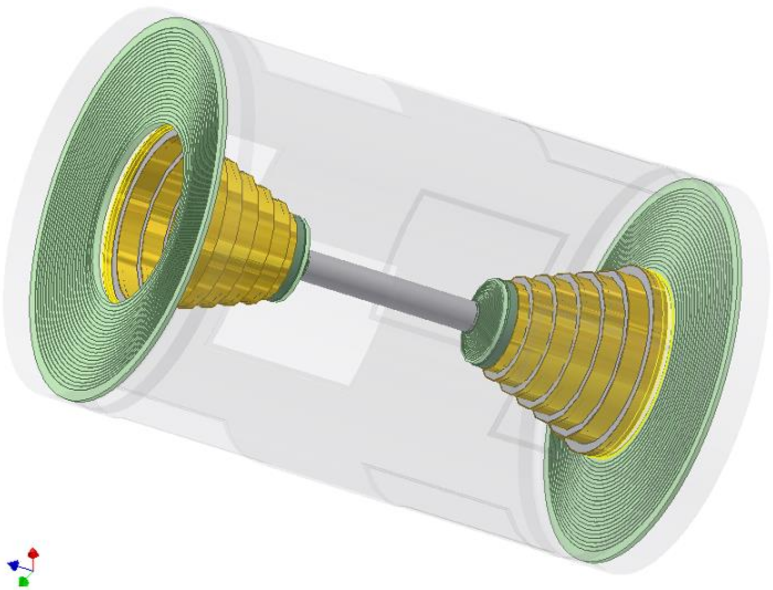


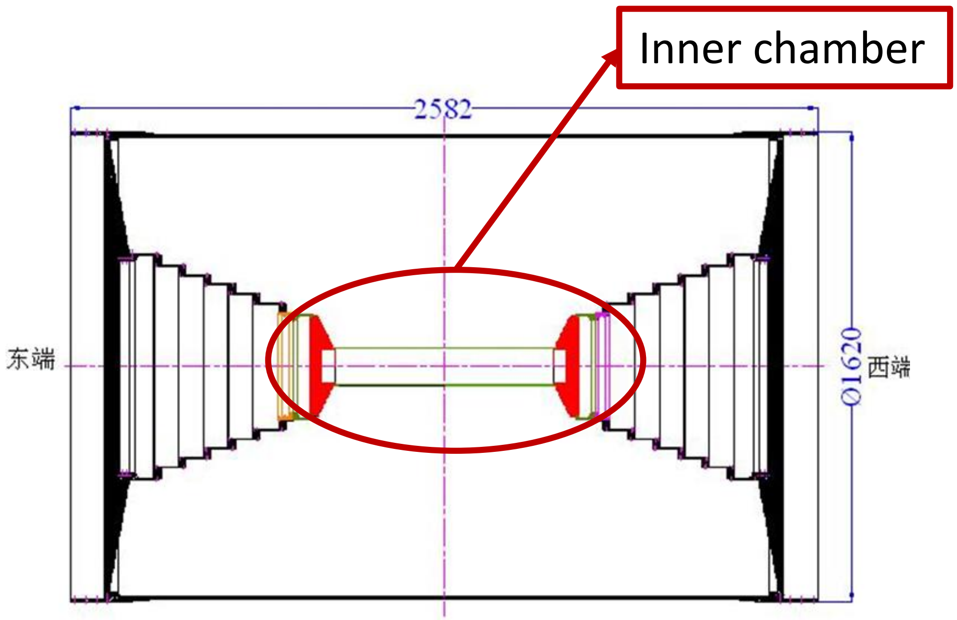
- MDC, TOF , EMC, MUC
- SSM: Solenoid Superconducting Magnet
- Trigger system
- DAQ system
- Slow control system

MDC

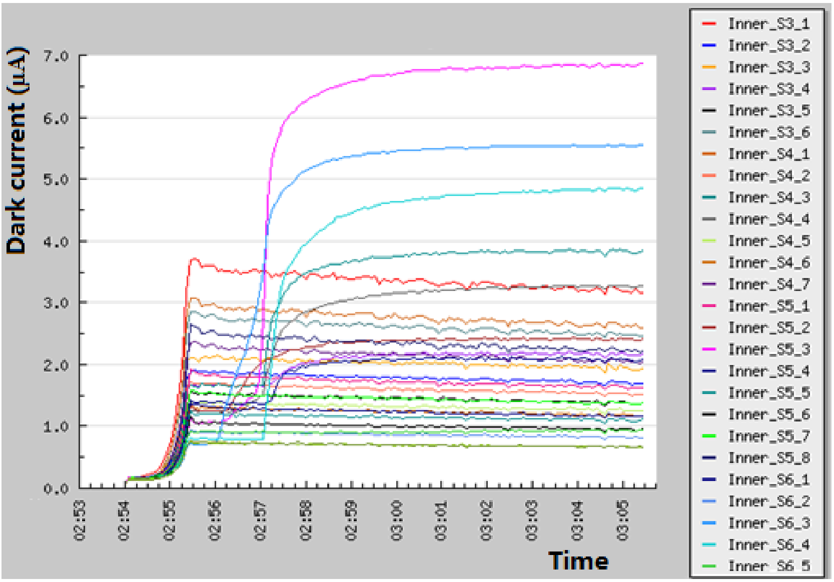
- Wire drift chamber, Inner chamber (8 layers)+ outer chamber (35 layers)
- He-based operating gas: He/C_3H_8=60/40
- Small cell, cell size: 12mm×12mm for inner chamber

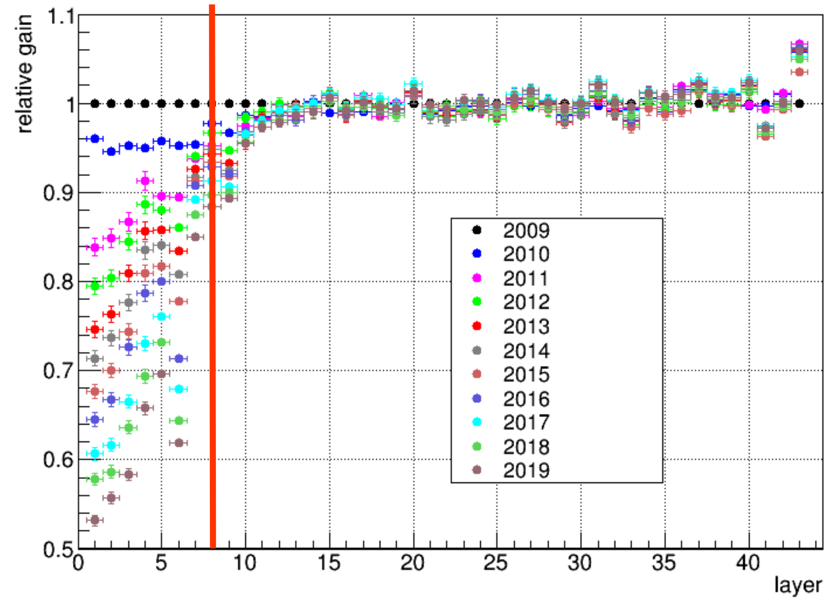
  16.2 mm×16.2mm for outer chamber
- 484 + 6312, 6796 cells in total





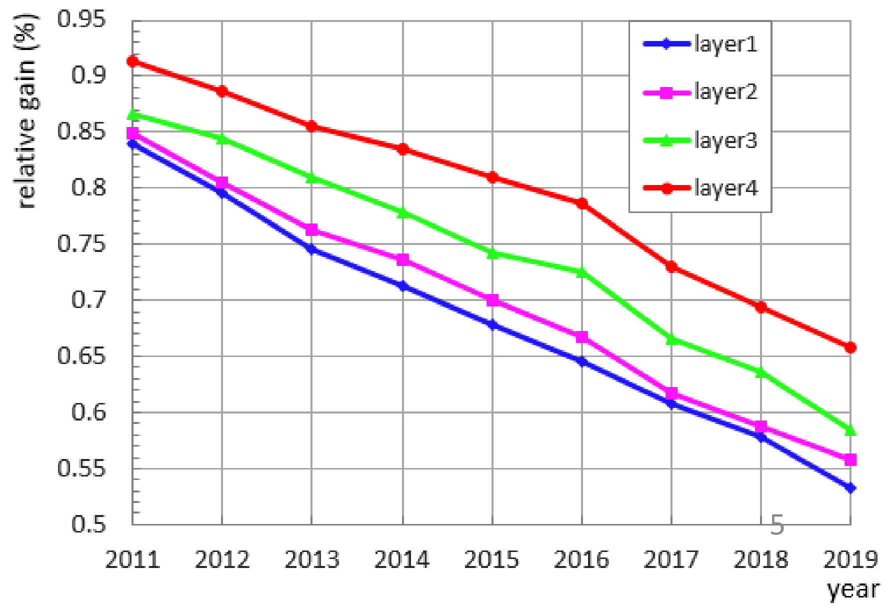
MDC aging



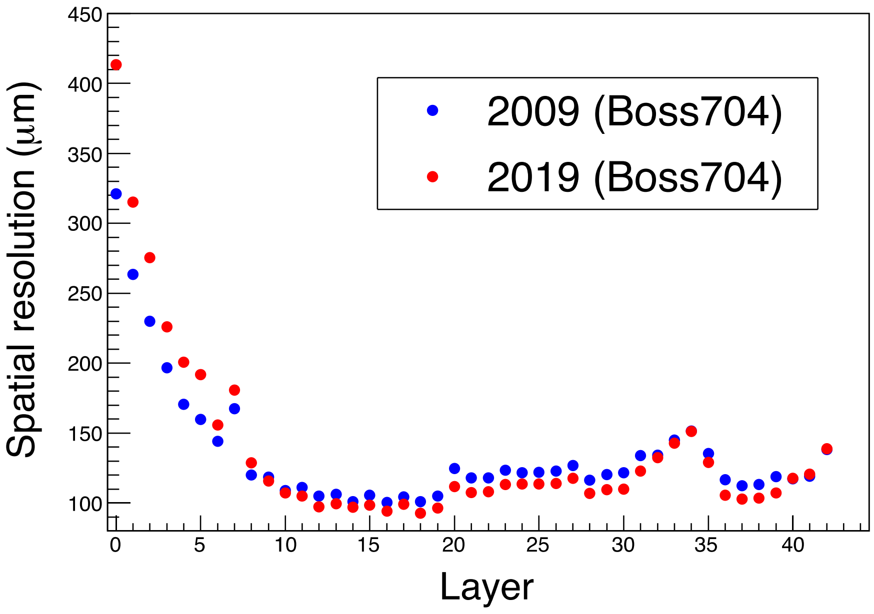


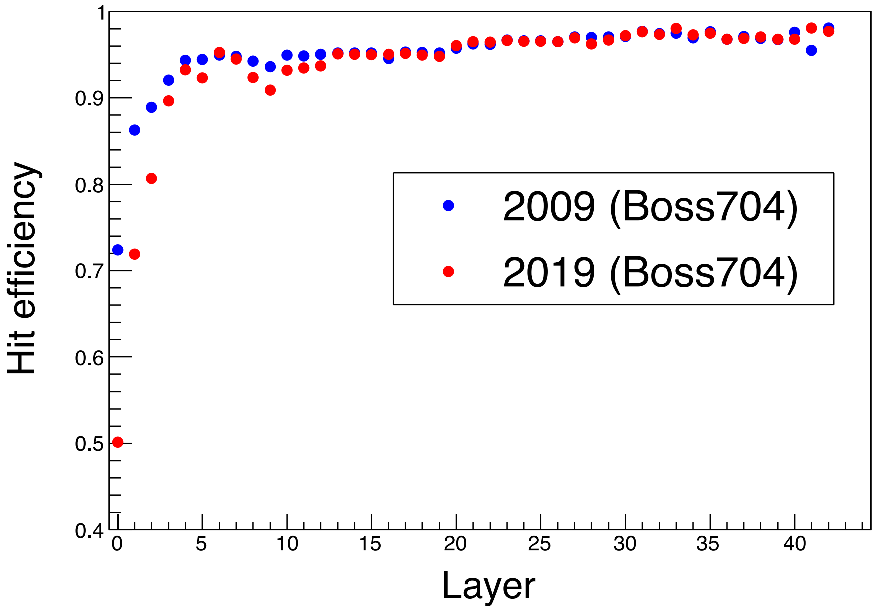
- Cathode aging: Malter discharge in 2012, cured with 0.2% water vapor @ 21 ℃
- Anode aging : The gains of the inner chamber decreases obviously, 46% for layer1
- The gains decrease about 3%-4% For the first two layers
- The total accumulated charges are 190mC/cm for the first layer cells

Aging speed of layer1~4



MDC Performance

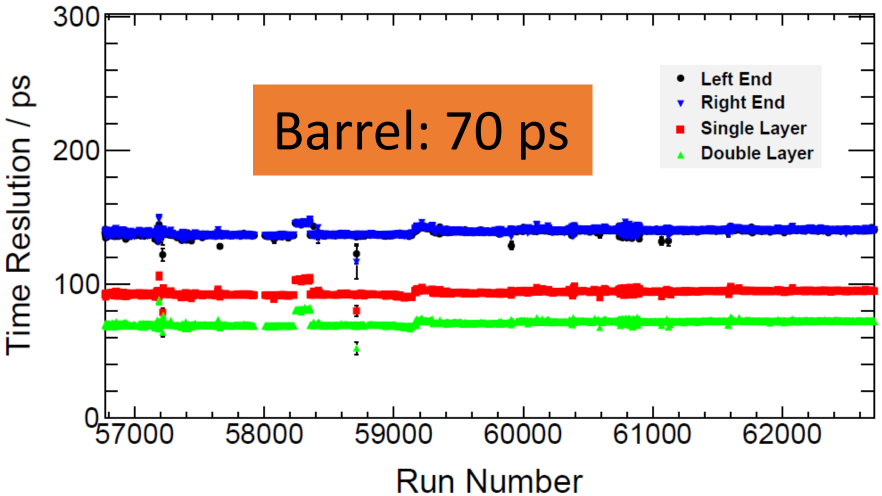




- Aging has caused performance degradation of the inner chamber layers
- For the outer chamber, performance has almost no change if the change of HV is taken into account
- Layer9-40: the reference HV was increased from 2150V to 2200V in 2012
- Layer1-8 (inner chamber), and layer 41-43: HV was not changed

TOF

- Barrel + 2 endcaps
- Barrel: BC408 scintillator, 2 layers, 176 modules, readout from two ends
- Endcap: BC404 Scintillator, 48 modules for each endcap
- Hamamatsu R5924 PMT

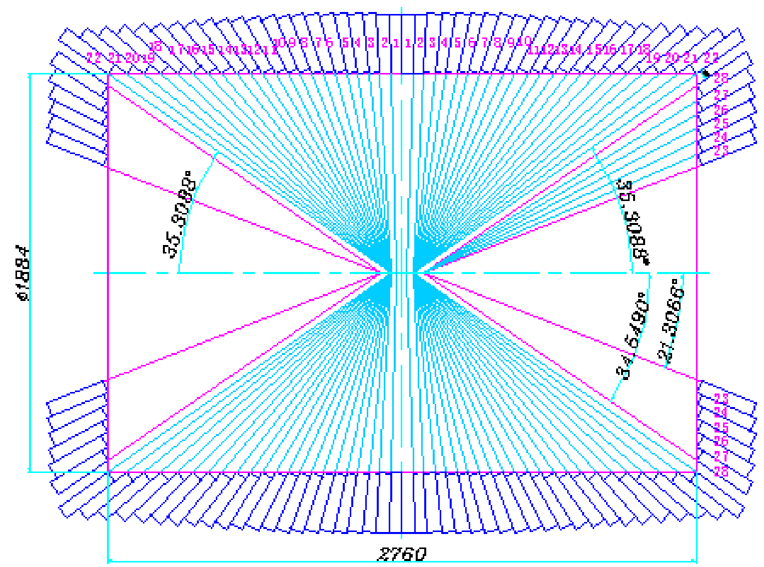


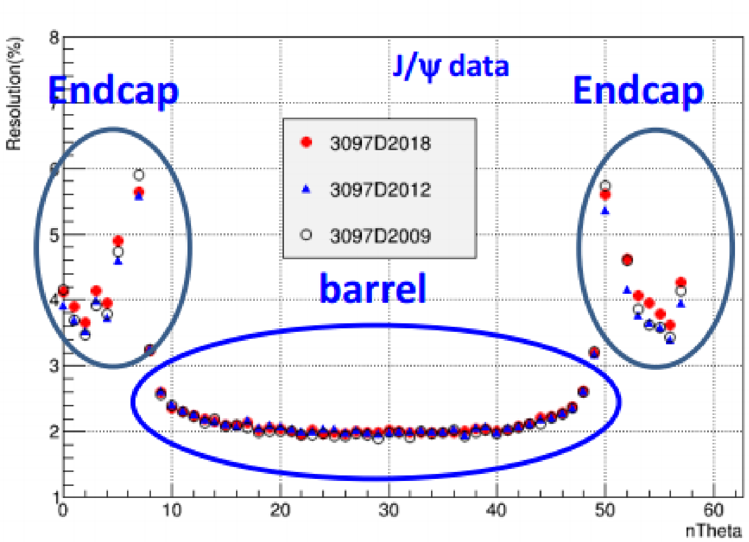
Year	Resolution ps	Efficiency %	Status
2009	67	~97	HV of PMTs is same
2010	70	~96	
2011	70	~94	
2012	67	~97	HV adjusted in 2012
2013	68	~96	
2014	70	~94	
2015	67	~92	
2016	72	~94	HV adjusted in 2016
2017	72	~93	
2018	70	~92	
2019	70	~92	

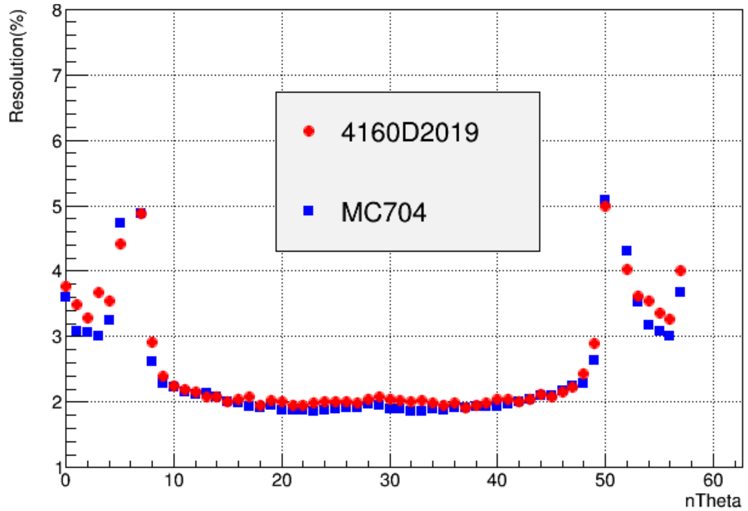
- BTOF has a good and stable time resolution
- Aging effect cause efficiency lost. HV was raised twice to improve the efficiency

EMC

- Barrel + 2 endcaps
- CsI(Tl) crystal
- Hamamatsu S2744-08 PD
- 5280 + 960, 6240 modules in total
- Crystals suspended without supporting wall

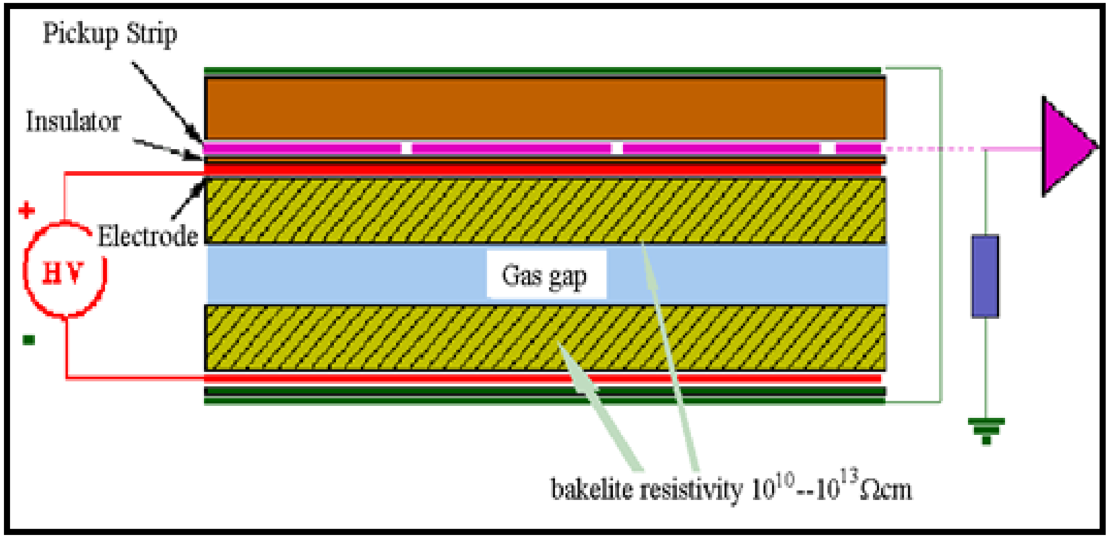


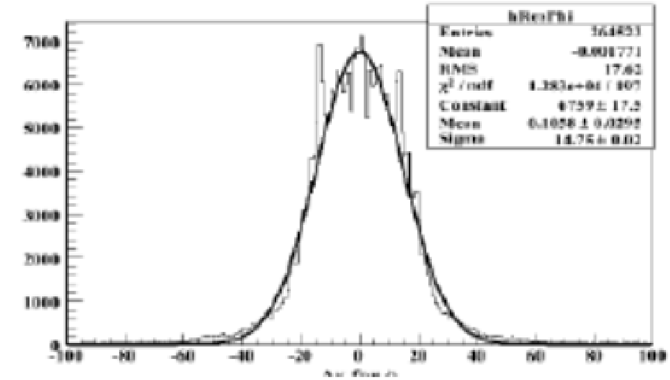


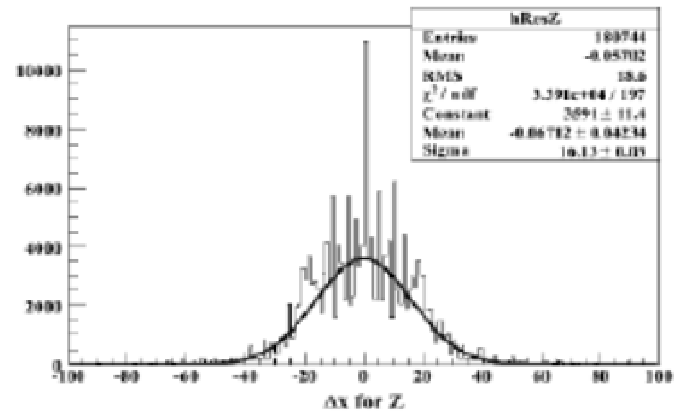


- The energy resolutions with J/Psi data in 2009, 2012 &2018 are similar
- The agreement of the energy resolutions of MC and data are very good

MUC





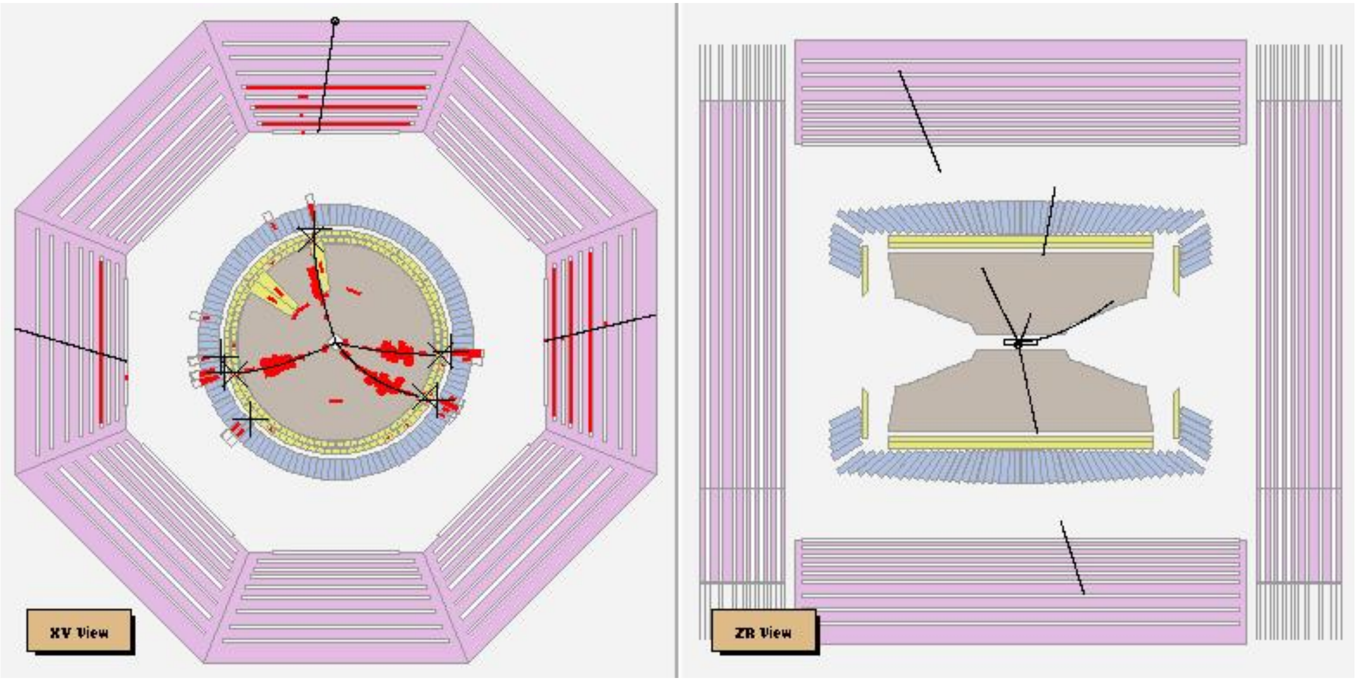


- RPC
- Barrel (9layers)+ two endcaps (8 layers)
- 2000 m^2 RPC
- 4cm read out strips
- ~9000 channels
- $\sigma_{r\phi} = 14mm\sim15mm, \quad \sigma_z\sim17mm$

BESIII performance

Sub detector		Design Performance	Achieved Performance
MDC		$\sigma_{r\phi} = 130\mu m$ $\Delta p/p = 0.5\%@1GeV$ (B=1T) $\sigma_{dE/dx} = 6\%$	$\sigma_{r\phi} = 115\mu m$ $\Delta p/p = 0.47\%@1GeV$ (B=1T) $\sigma_{dE/dx} = 5.2\%$
TOF	Barrel	$\sigma_T = 80{\sim}90\ ps$	$\sigma_T = 67{\sim}70\ ps$
	Endcap	$\sigma_T = 110{\sim}120ps$ (before upgrade) $80ps{\sim}100ps$ (after upgrade)	$\sigma_T = 138ps$ (before upgrade) $60ps{\sim}70ps$ (after upgrade)
EMC		$\Delta E/E = 2.5\%\ @1GeV$ $\sigma = 6\ mm/\sqrt{E}$	$\Delta E/E = 2.5\%\ @1GeV$ $\sigma = 6\ mm/\sqrt{E}$
MUC		$\sigma_{r\phi} = 14mm{\sim}17mm$ $\sigma_z{\sim}17mm$	$\sigma_{r\phi} = 14mm{\sim}15mm$ $\sigma_z{\sim}17mm$

BESIII operation and data taking



July 20, 2008: First e^+e^- collision event in BESIII

- In general, BESIII detector worked well in the past 10 years (2018.7.20-)
- No dead channel in EMC and BTOF, 23 dead channels in MDC, a few of dead channels in MUC. They do not affect the physics analysis
- The sub-detectors have no big aging problems except the inner chamber
- High quality data was taken with high efficiency

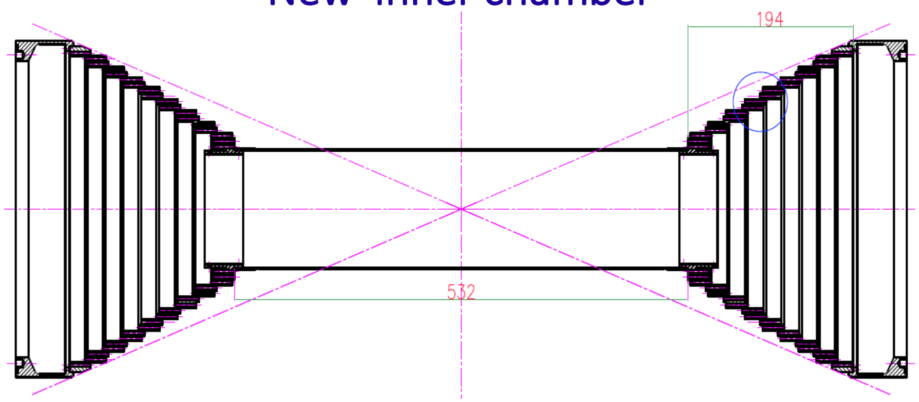
Upgrade of the inner chamber

Two options

- New inner drift chamber
- Cylindrical GEM inner tracker (CGEM)

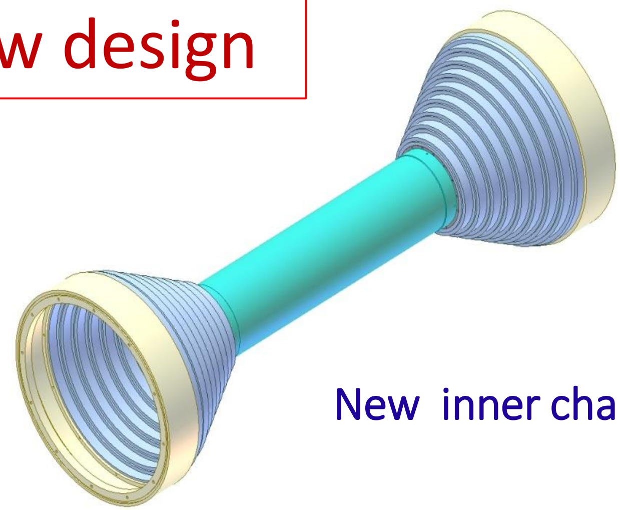
New inner drift chamber

New inner chamber

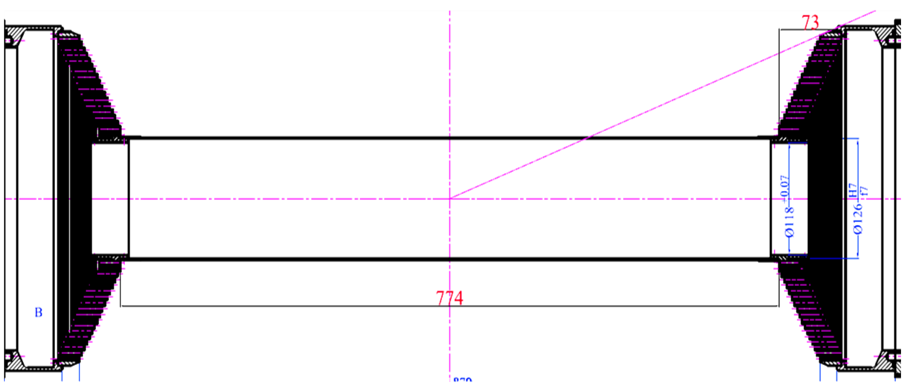


8 layers, 484 cells

New design



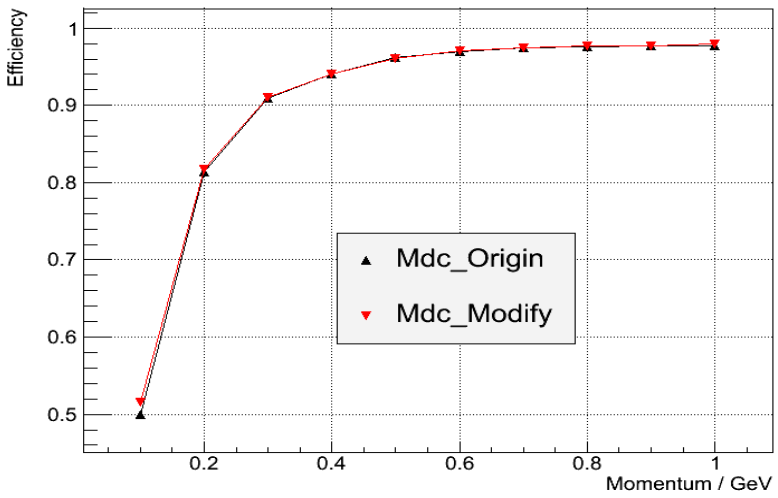
New inner chamber

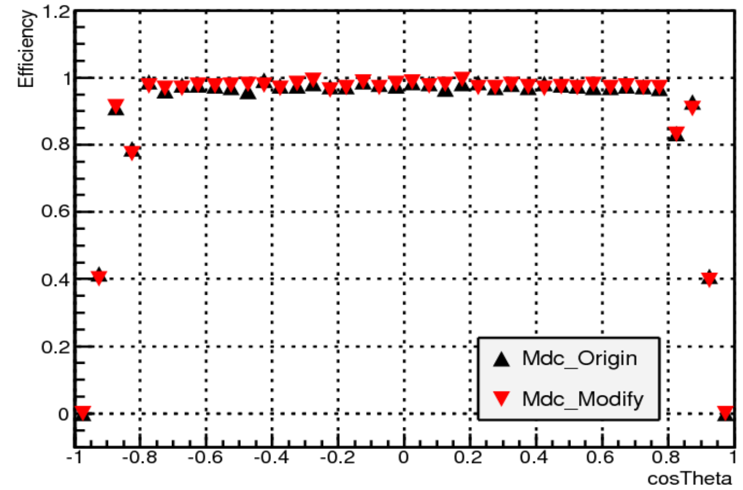


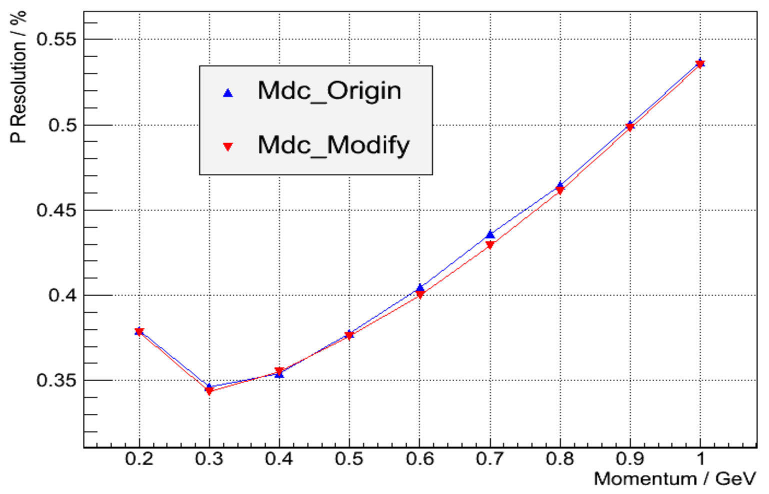
Old inner chamber

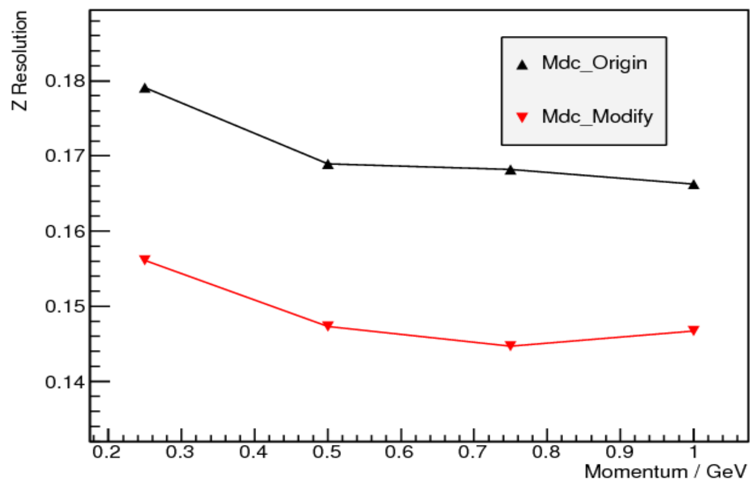
- An improved new inner drift chamber with multi-stepped end-plates
- Shorten wire length exceeding the effective sold angle
- Reduce the background counting hits (currents) of a cell, decrease the risk of wire broken

Performance combined with outer chamber



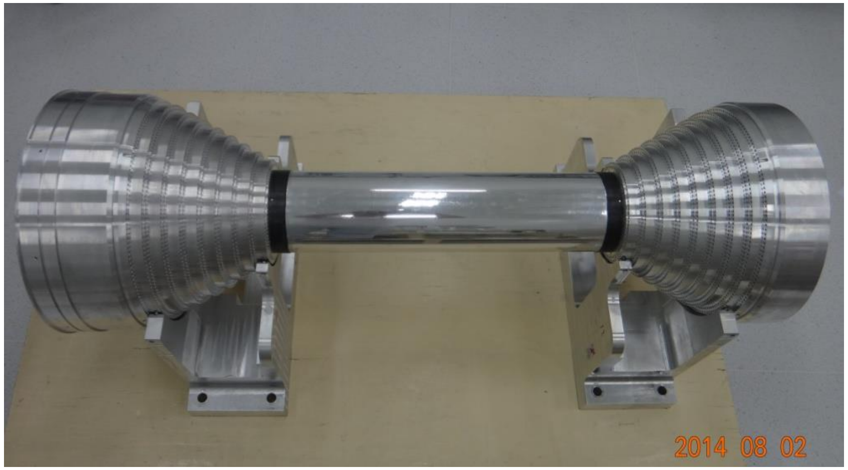


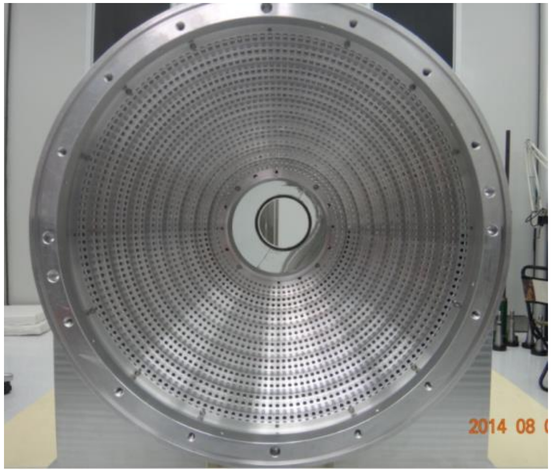
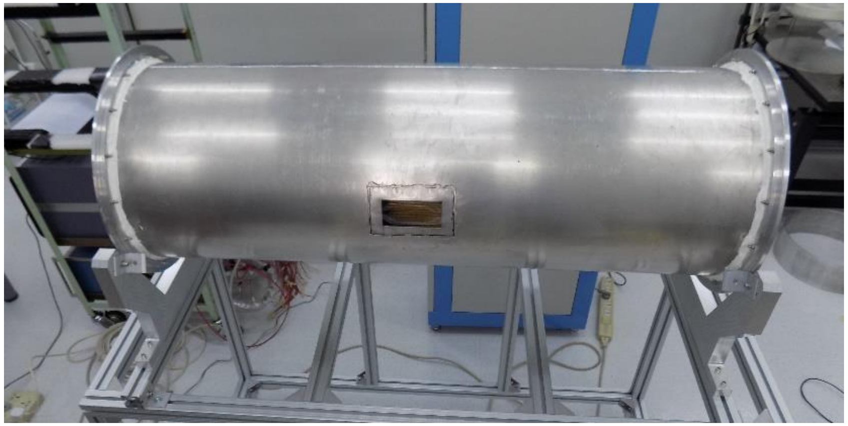
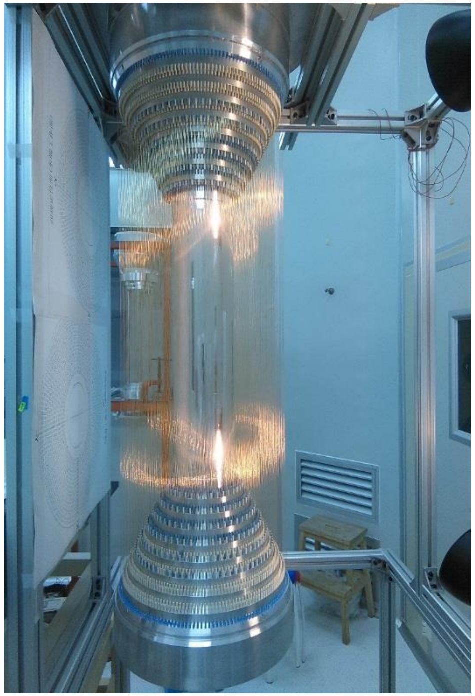




- Tracking efficiency and momentum resolution are similar to the old chamber
- Spatial resolution in z improved a little bit since a larger stereo angle than old one

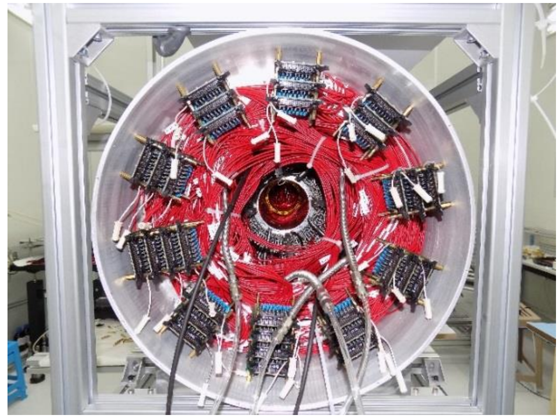
Construction

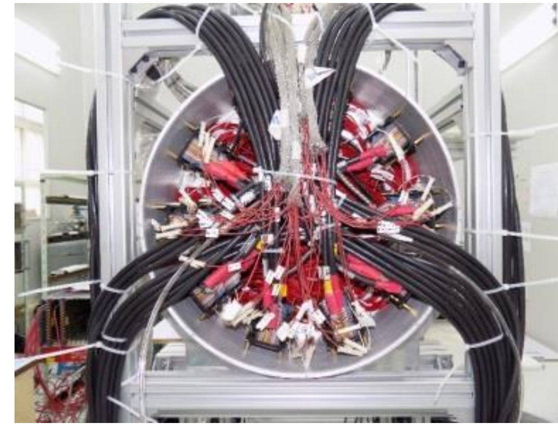


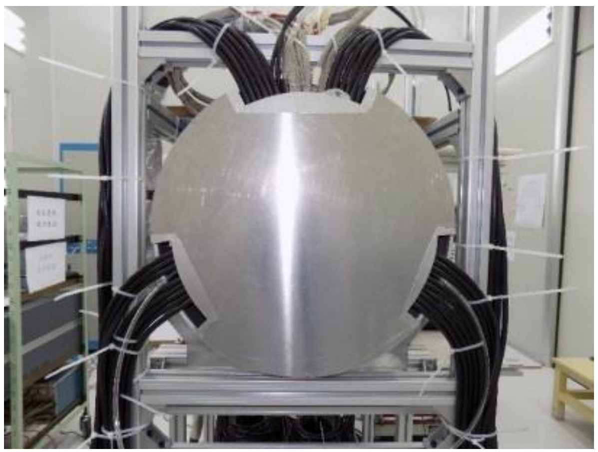




- Mechanical structures assembly, Wiring,
  - Wire tension: ±10% of design value, I: 5nA/cell @ 2200V
- Outer cylinder assembly and sealing
  - leakage rate < 0.1% / h @ 5 times operating gas pressure

Cosmic-ray test

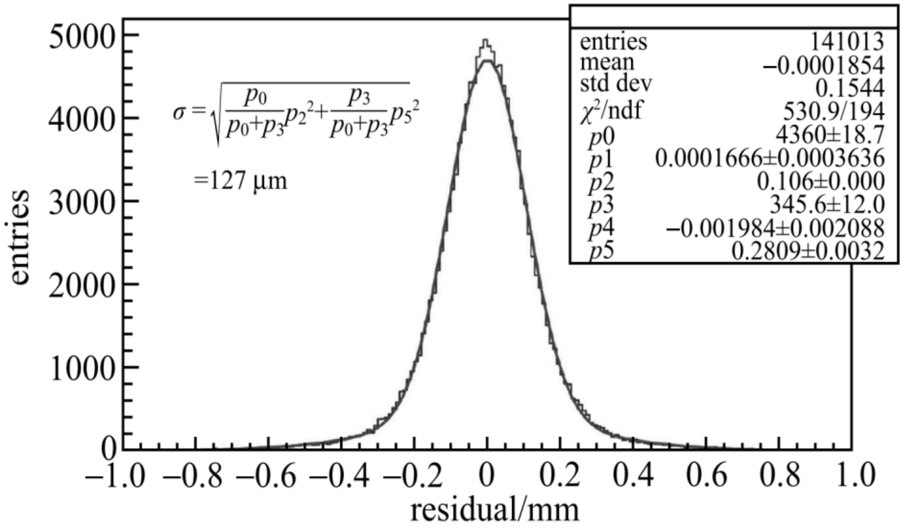




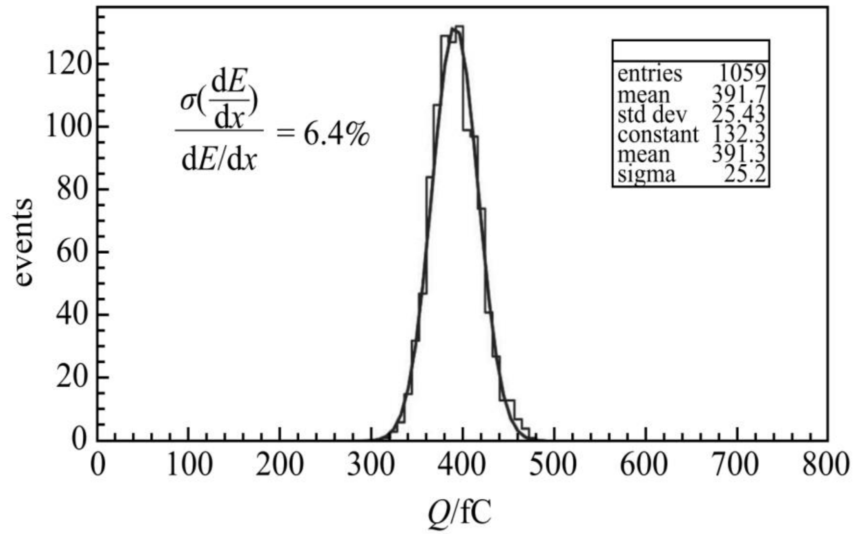


- Field wire grounding
- Preamplifiers mounting, cabling
- Long term cosmic-ray test

Performance of the new inner chamber

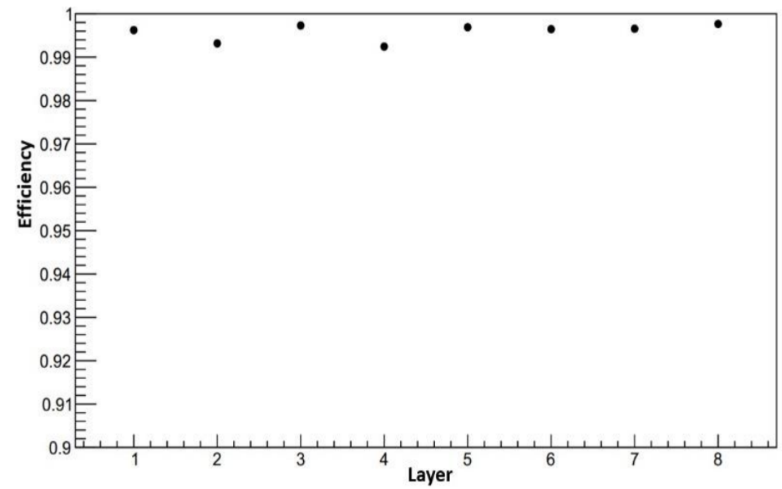


Spatial resolution: 127µm (HV = 2200V)



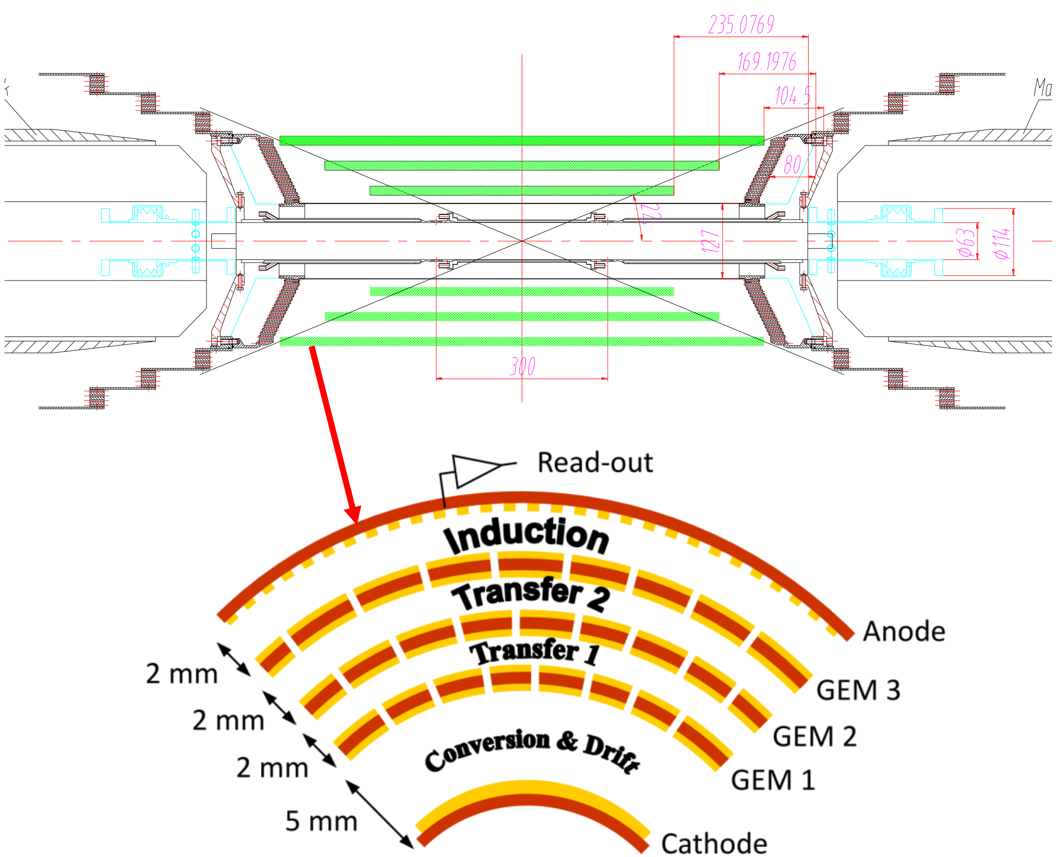
dE/dx resolution: 6.4% (HV = 2200V)

- The performance meets the requirements of BESIII
- The new inner chamber is ready and can be used in the case of unexpected failure of the old chamber



Efficiency: > 99% (HV = 2200V)

Cylindrical GEM inner tracker (CGEM)



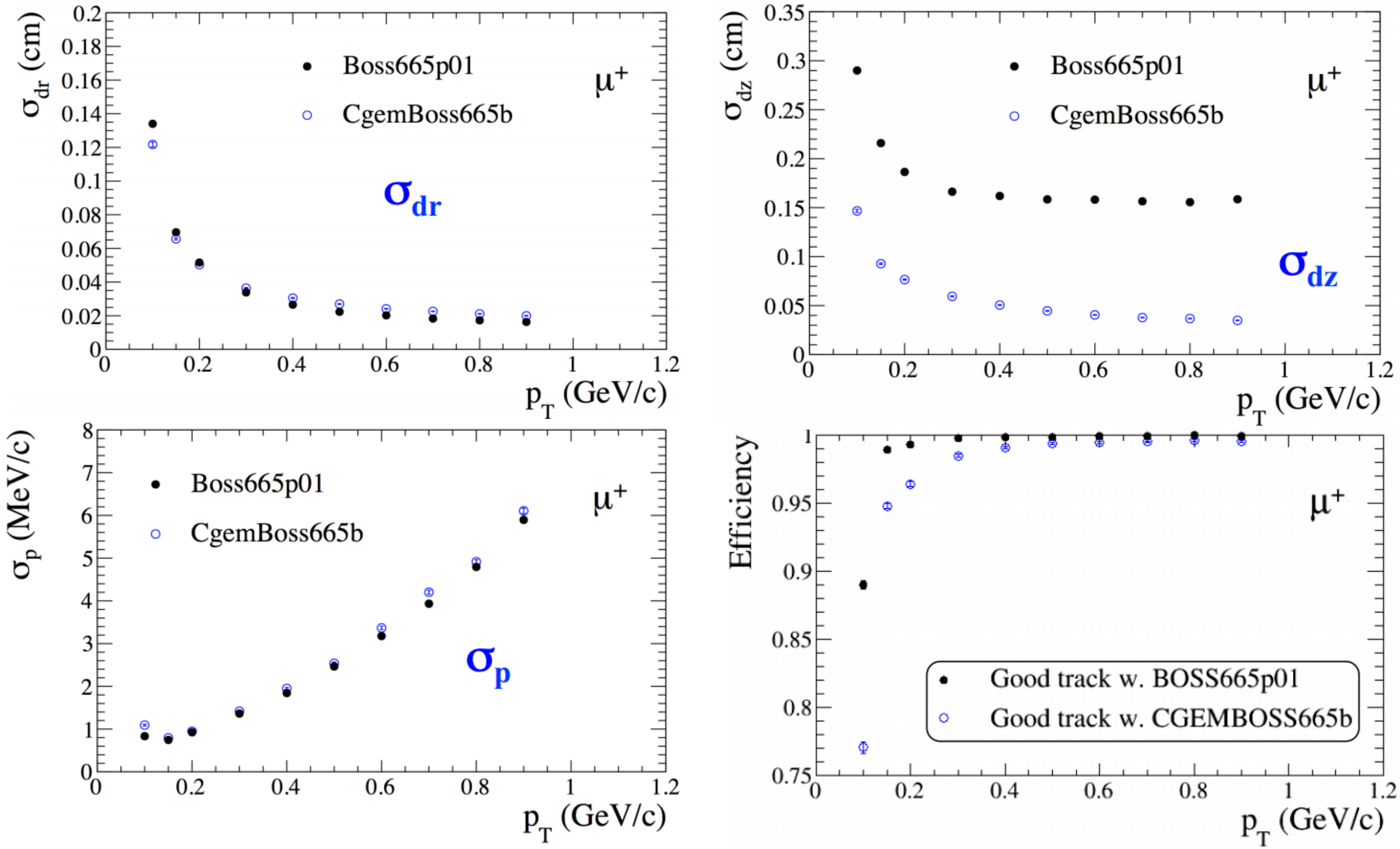
CGEM- inner tracker , new technology
In BESIII, first used

- lower material budget: 0.5% X_0/layer
- Analogy readout, charge +time

- High particle rates
- Less sensitive to the aging
- Significantly improvement of σ_z
- Less background expected
  - The volume for primary ionization is 6-7 time smaller
- Improvements from Micro-TPC reconstruction

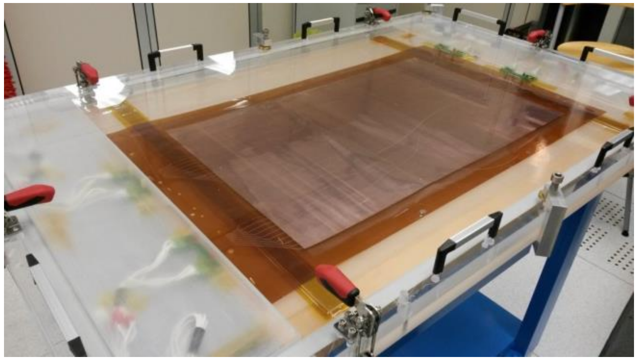
- Layout: three layers
- Coverage: 93%
- Inner radius:78mm
- Outer radius:178mm

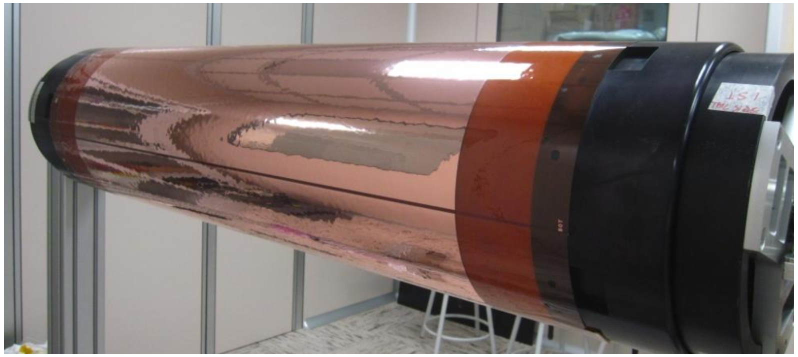
Performance of the CGEM

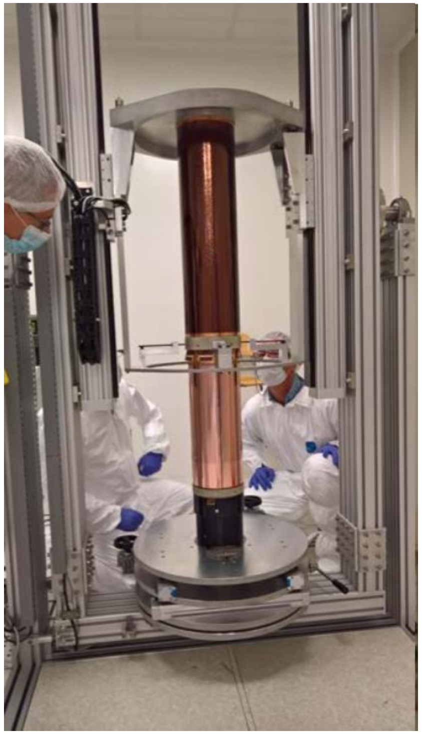


- Spatial resolution in $r\phi$ & momentum resolution is comparable to inner drifter chamber
- Spatial resolution in z is significantly improved with CGEM
- The efficiency for tracks with low transverse momenta will be improved with Hough Transform

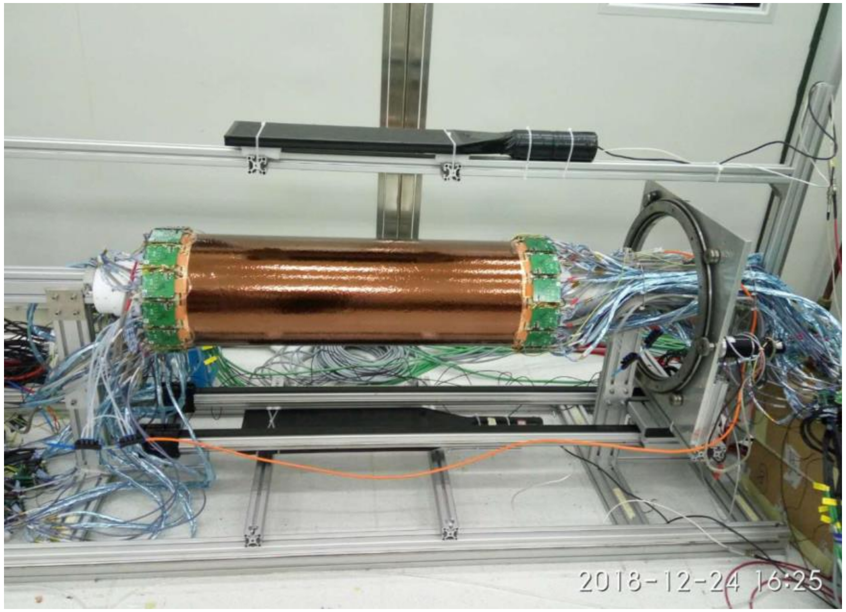
Construction

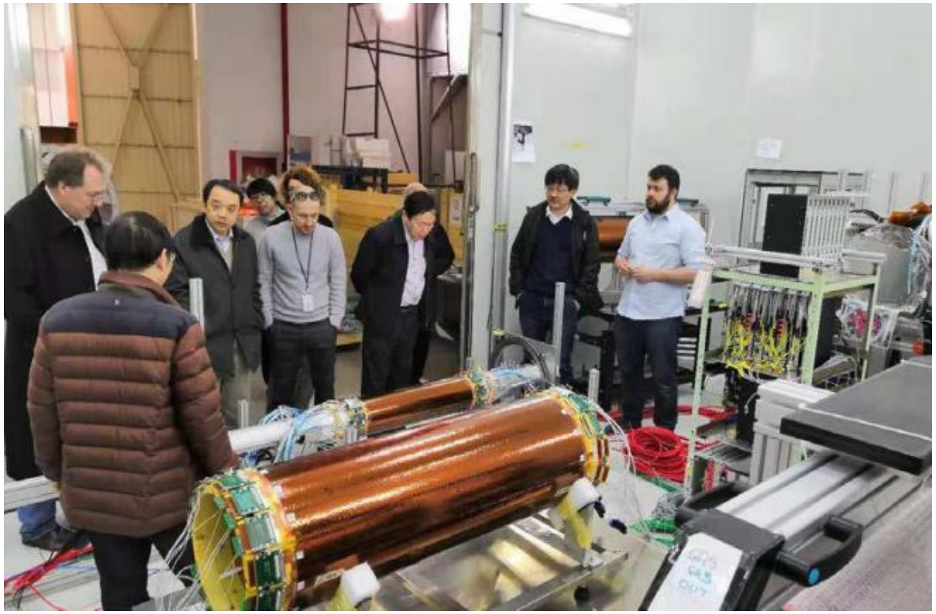






Cosmic ray test

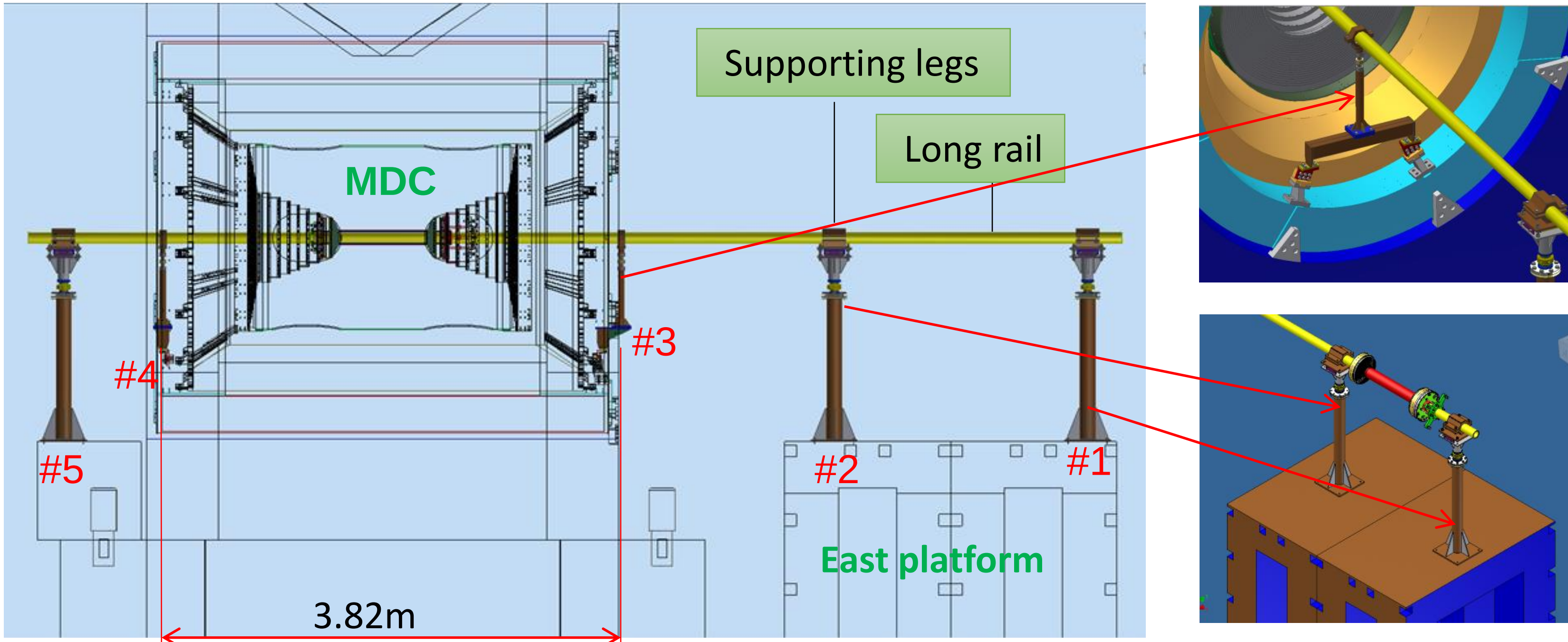


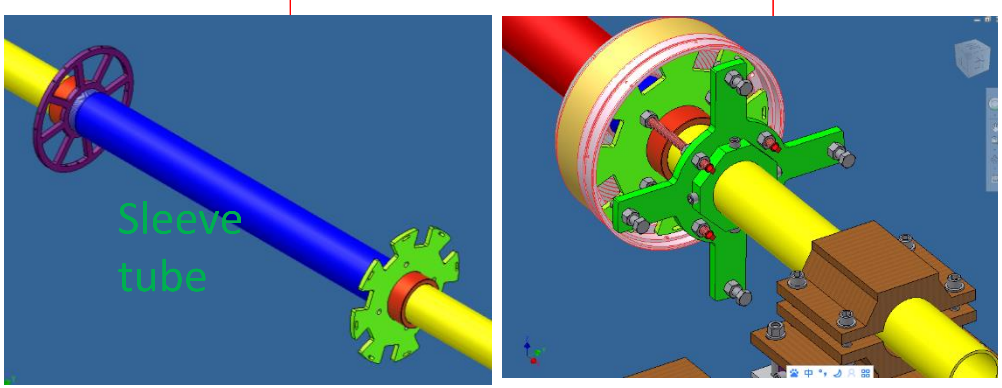


- The CGEM detectors were shipped to IHEP in Nov. 2018
- Detector check, electronics test, preparation and setup for cosmic-ray test
- Layer1 and layer2 assembled together and tested by cosmic rays
- New layer 1 and layer3 are under construction
- Installation will be carried out in summer 2020 if everything is ready

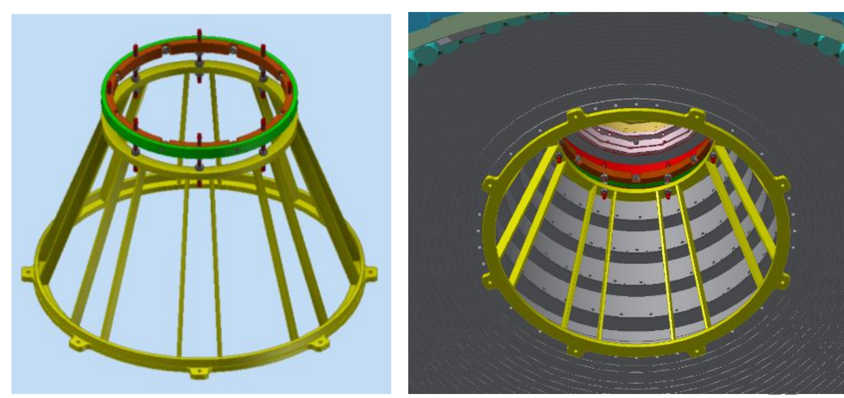
Extraction tooling for inner MDC

Long rail and 5 supporting legs. Sliding inner MDC on the rail for extraction



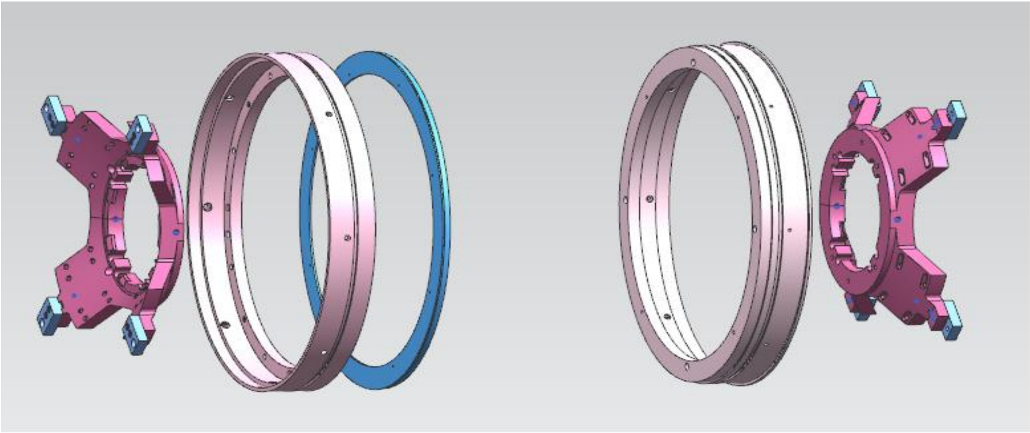


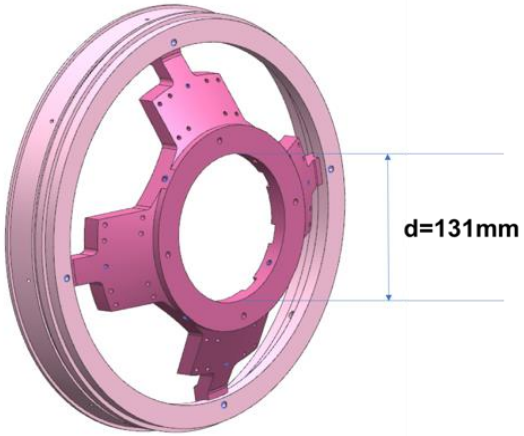
Outer MDC protection

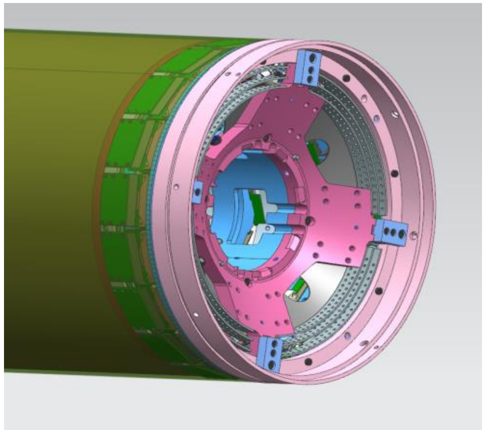


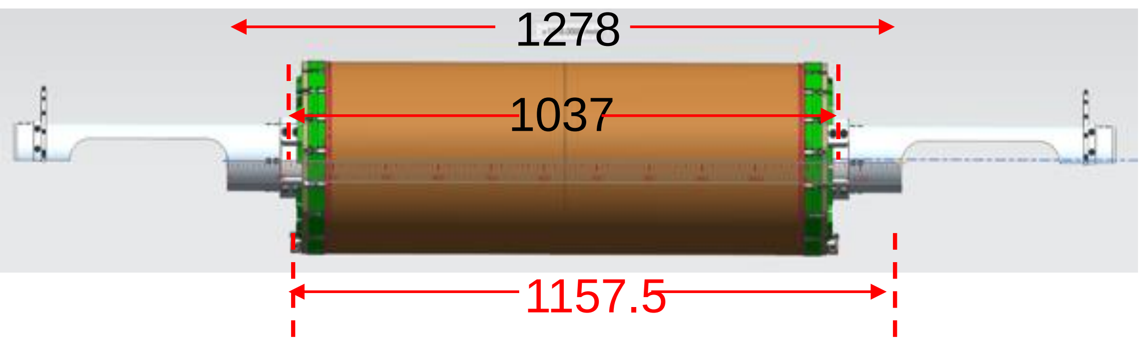
Inner MDC protection

Interfaces of CGEM and MDC









- Supporting flange to fix the CGEM to the MDC
- Installation of the CGEM will share the same support tooling for inner MDC extraction

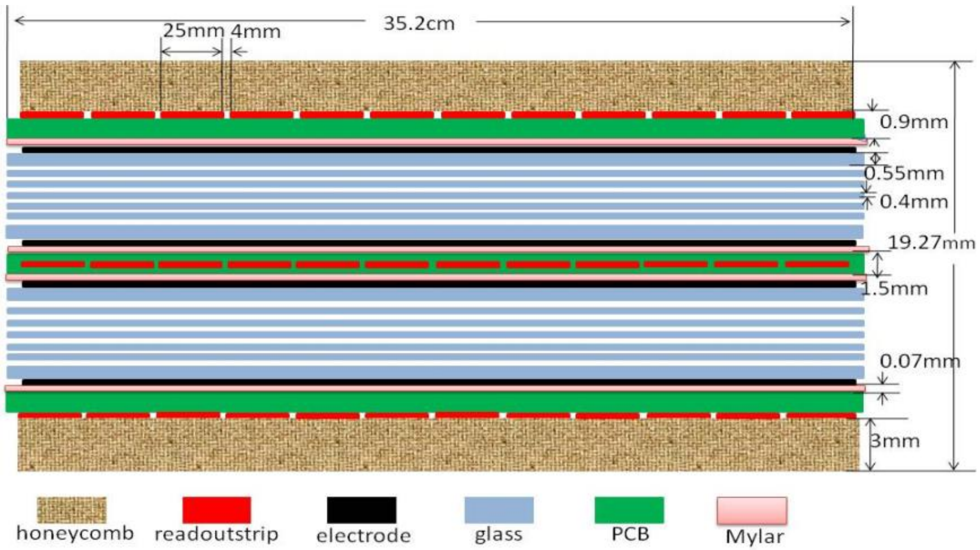
Upgrade of ETOF

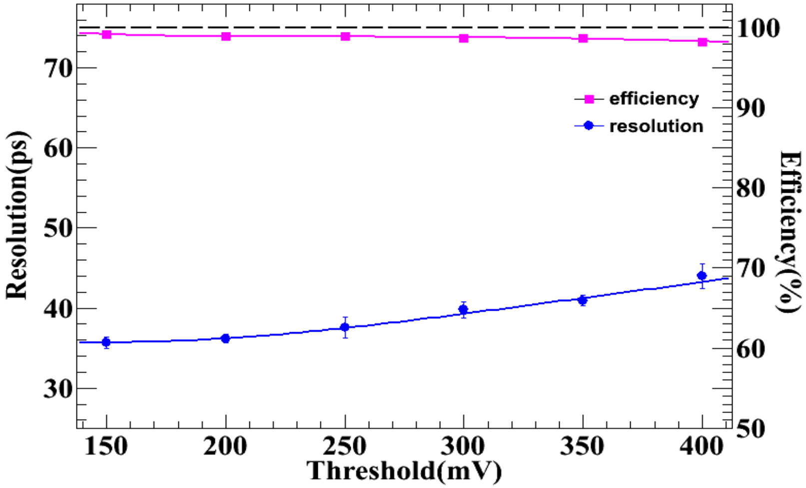
The time resolution of old ETOF : 138ps

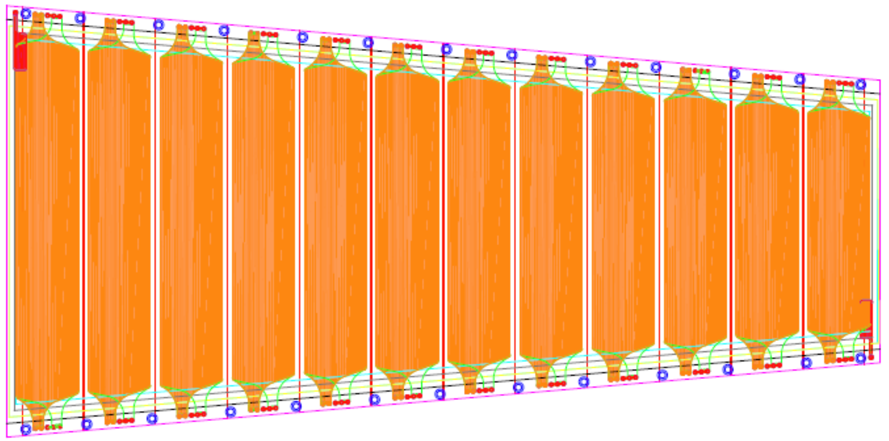
- Multiple scattering due to the big material budget －＞ increase the uncertainty of the length of the tracks
- Few layers of MDC can be used in the track reconstruction with small angle －＞ uncertainty of the hit position in z direction，~90ps/cm
- Multi-hit: 75%
- Noise problem of the ETOF

Key points of upgrade

- MRPC-based detector
- Small strips and readout from two ends of the module to get rid of the impact of the hit position
- Front end electronics: Nino chips, 14ps accuracy
- Read out electronics: HPTDC, 10~20ps accuracy
- R&D, testbeam result: 40-50ps for π (600meV-1.2GeV)

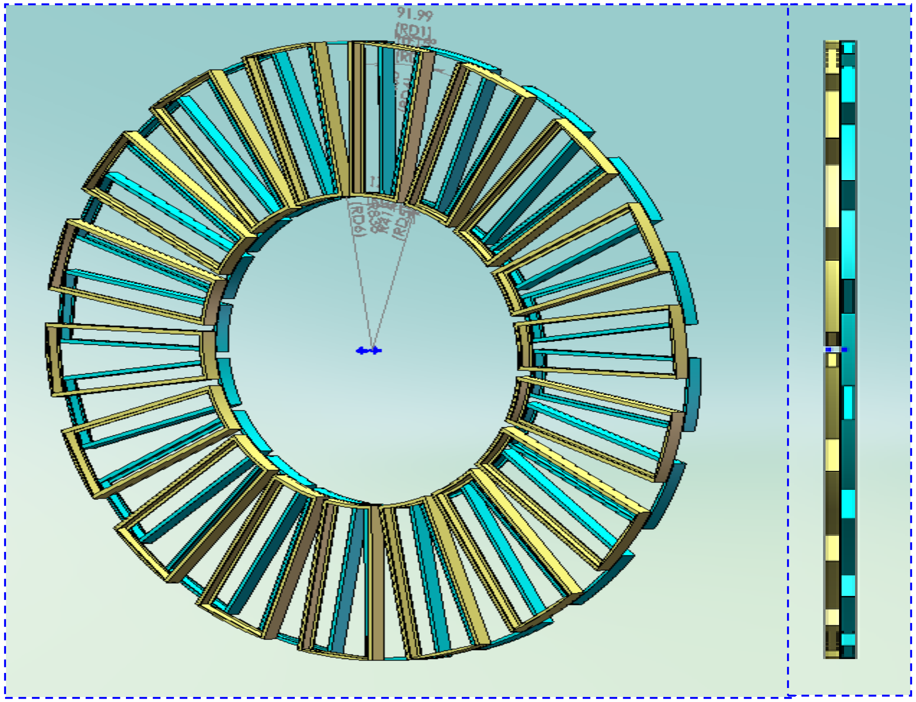


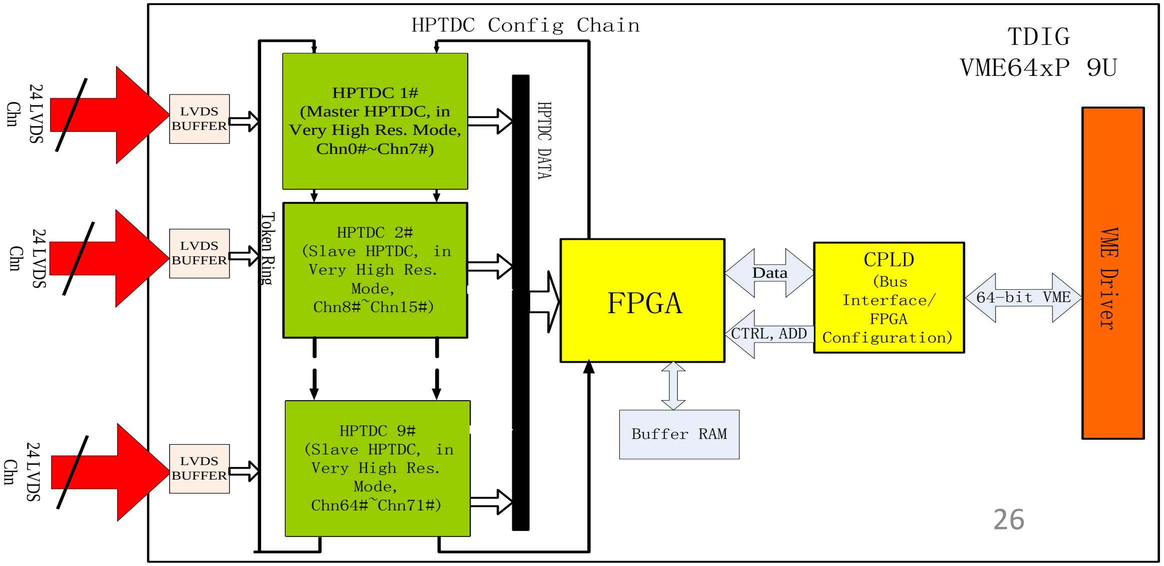




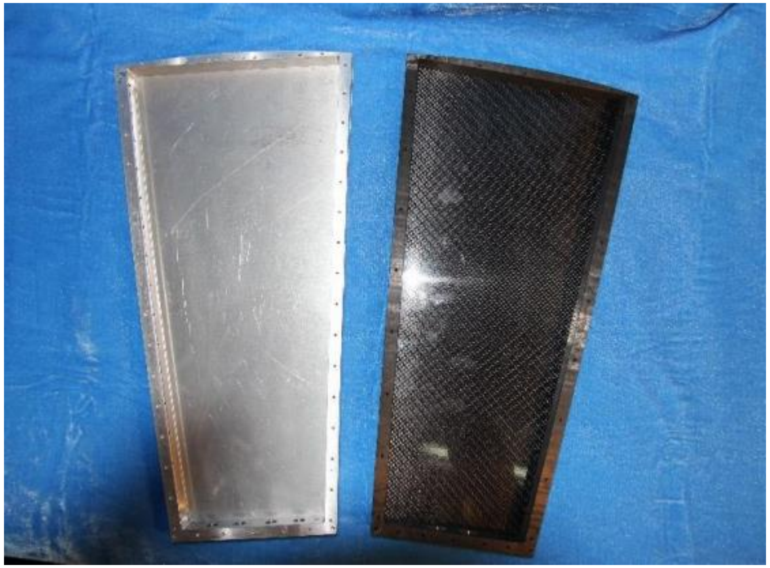
Detector layout

- Detector
  - Two layers in each endcap, the thickness of one layer is less than 25mm
  - 36 modules for each endcap, and 72 modules in total
  - 12 strips in each modules， read out from two ends
- Electronics
  - 1728 channels in total
  - Front end: 72 boards
  - Readout board: 24 TDIG modules





Module assembly and test

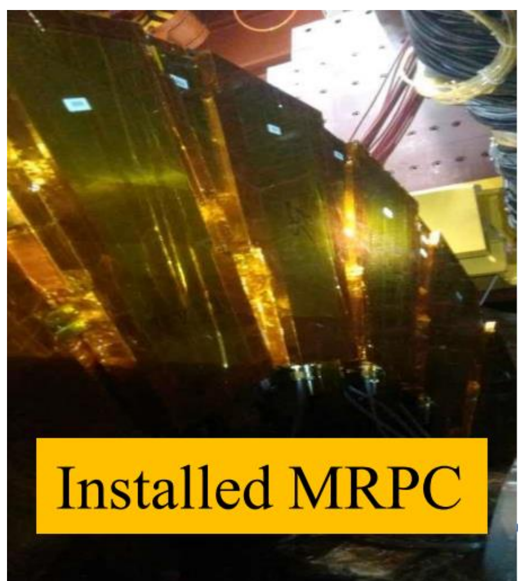


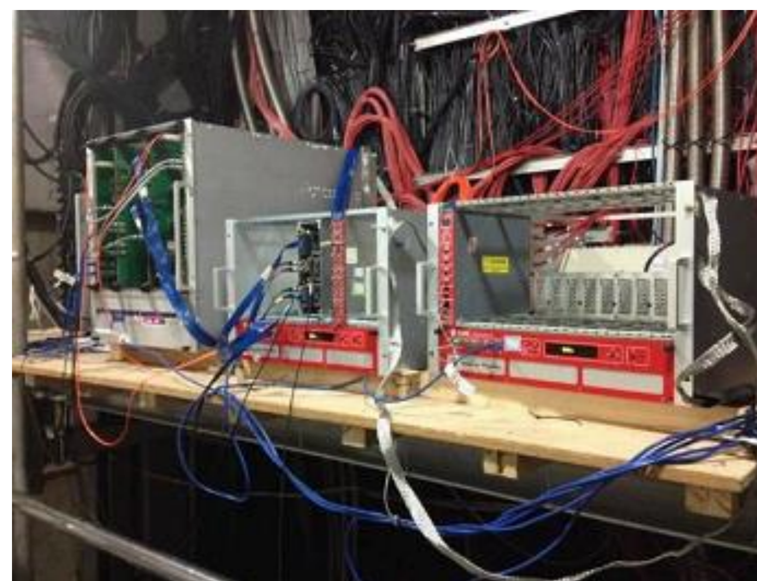
Installation

The installation of ETOF was finished in Summer 2015

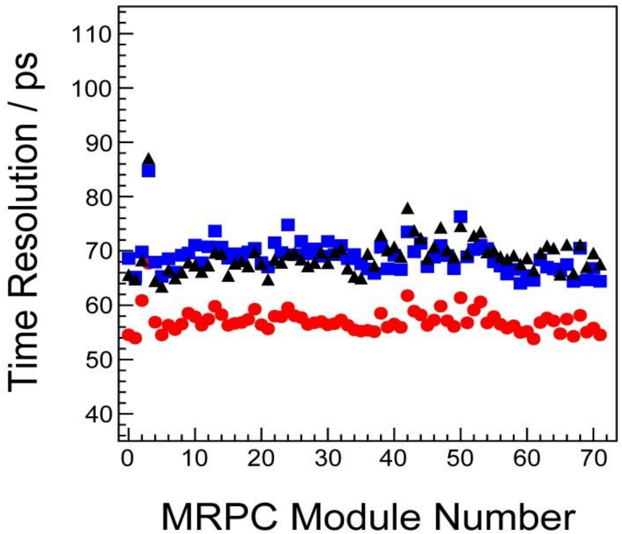


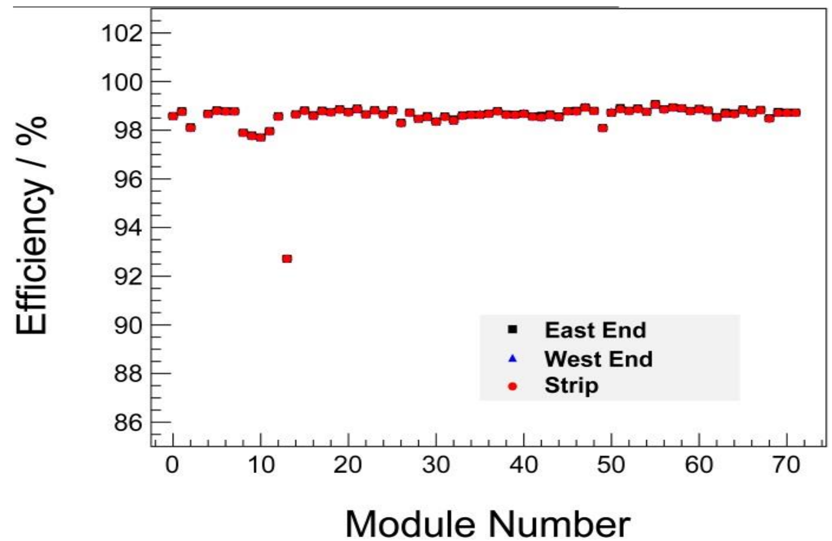


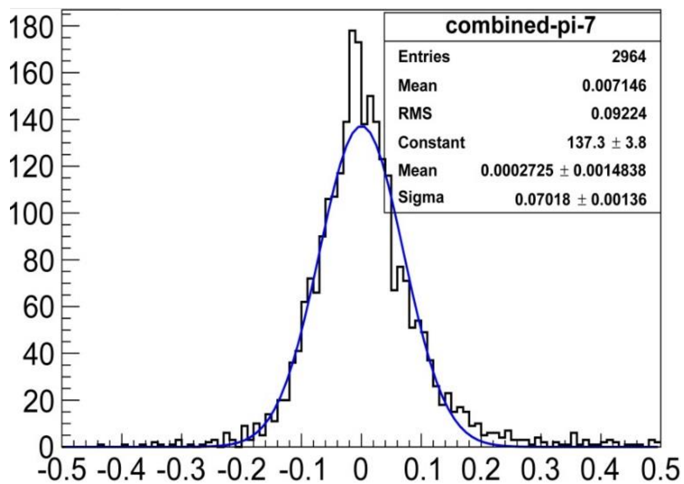



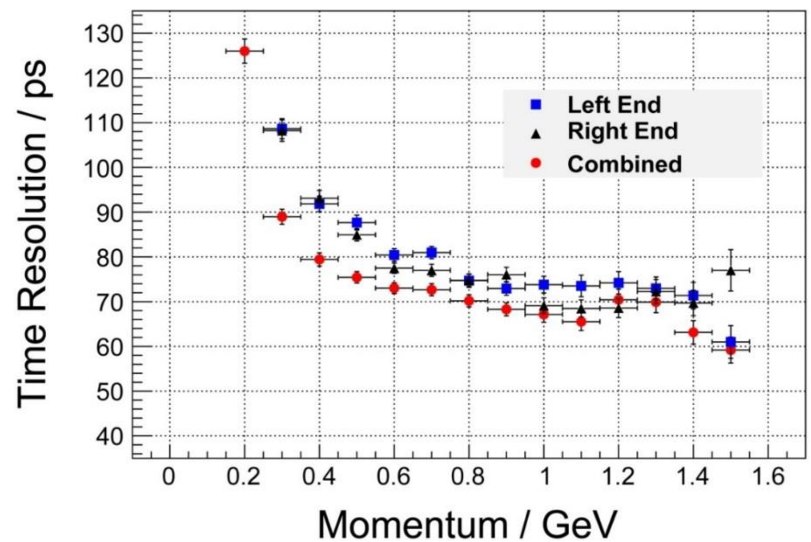


Performance of ETOF









- Time resolution: ~60ps for e, ~70ps for pions

Upgrade of BESIII SSM Valve Box

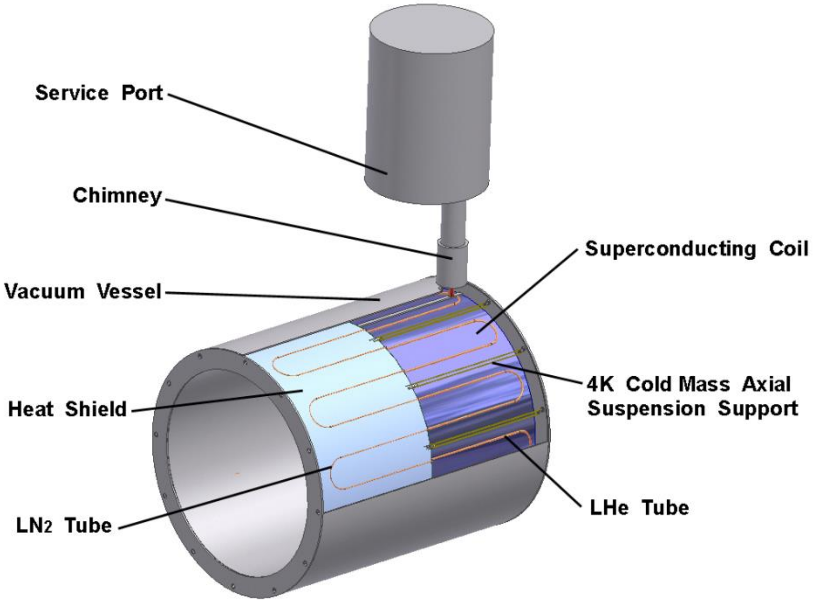
Solenoid Superconducting Magnet (SSM):

- Providing magnetic field for detector
- Currently largest single superconducting magnet in China

Key parameters	Value
Central magnetic field	1 T
Operation current	3369 A
Field uniformity	5%
Coil diameter	2980mm
Coil length	3532mm

Aging problems:

- Vacuum is not stable (LHe leakage):
  - Increased from 2.2×10^{-2} Pa, and reached a maximum of 3.8×10^{-2}Pa in 2016
- Transition Section in Valve Box
  - Temperature keeps rising slowly (End of Current Lead & Beginning of Superconducting Cable)



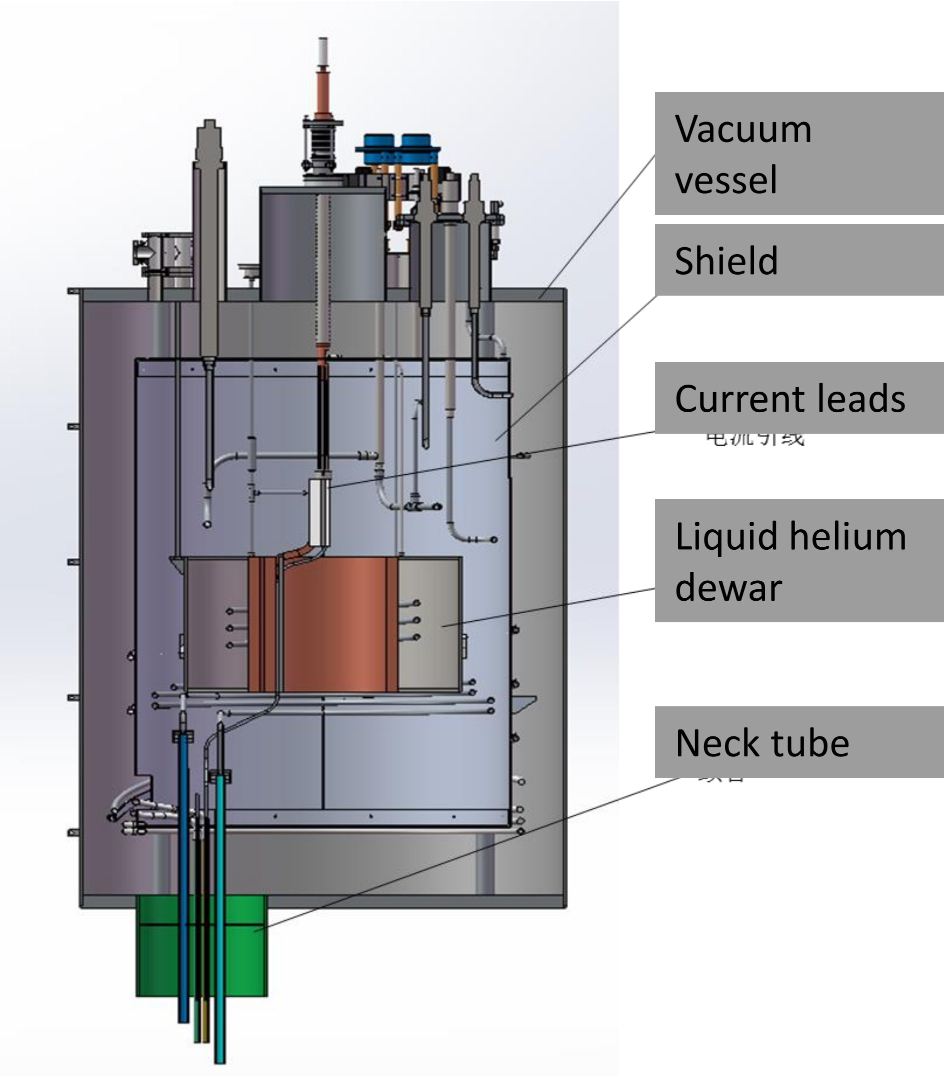
Design of new valve box

Requirements：

- keep the overall dimensions of the valve box
- keep the position and mode of the joint with the cryogenic system
- Keep position of the joints with power bus
- Overall heat leakage can not be increased

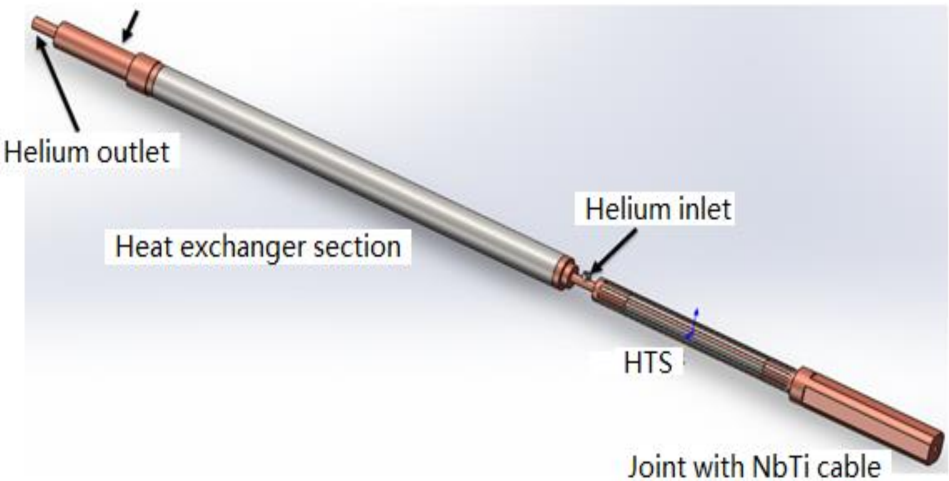
Technical improvements

- HTS (High temperature superconducting) current leads instead of gas-cooled current lead
- Optimize the cryogenic pipeline, reduce number of the bimetal joints, to improve the vacuum
- Optimization of cooling structure of the transition section



Overall Sketch of New ValveBox

New current leads



Structure of current lead

Gas-cooled current leads

- Operating current: 3400A
- Structure: binary current leads
- Heat exchange section selects fin structure, cooled by 50K helium gas
- HTS section: nine HTS stacks with stainless base

Progress and plan

- Study on YBCO conductor, and current lead LN2 test have been done
- The new valve box construction and test will be finished at the end of this year
- The new valve box is as a backup, and will be ready to replace the of the old one if needed.

Summary

- BESIII detector worked well in the past ten years, and took high quality data with high efficiency
- To improve the performance of ETOF, it was upgraded successfully with time resolution increasing from 138ps to 70ps
- To solve the aging problems, the upgrades of the inner chamber and new valve box of the SSM are being implemented
- To keep the BESIII working with high performance in the next ten yeas, we should take good care of the detector and fix the problem in time.
- We should also study the aging of the detector and evaluate its impact on the physics analysis carefully to reduce the risk of the unexpected or uncontrollable case

Thanks for your attention !