Aging phenomenon in BESIII drift chamber

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On behalf of the working group

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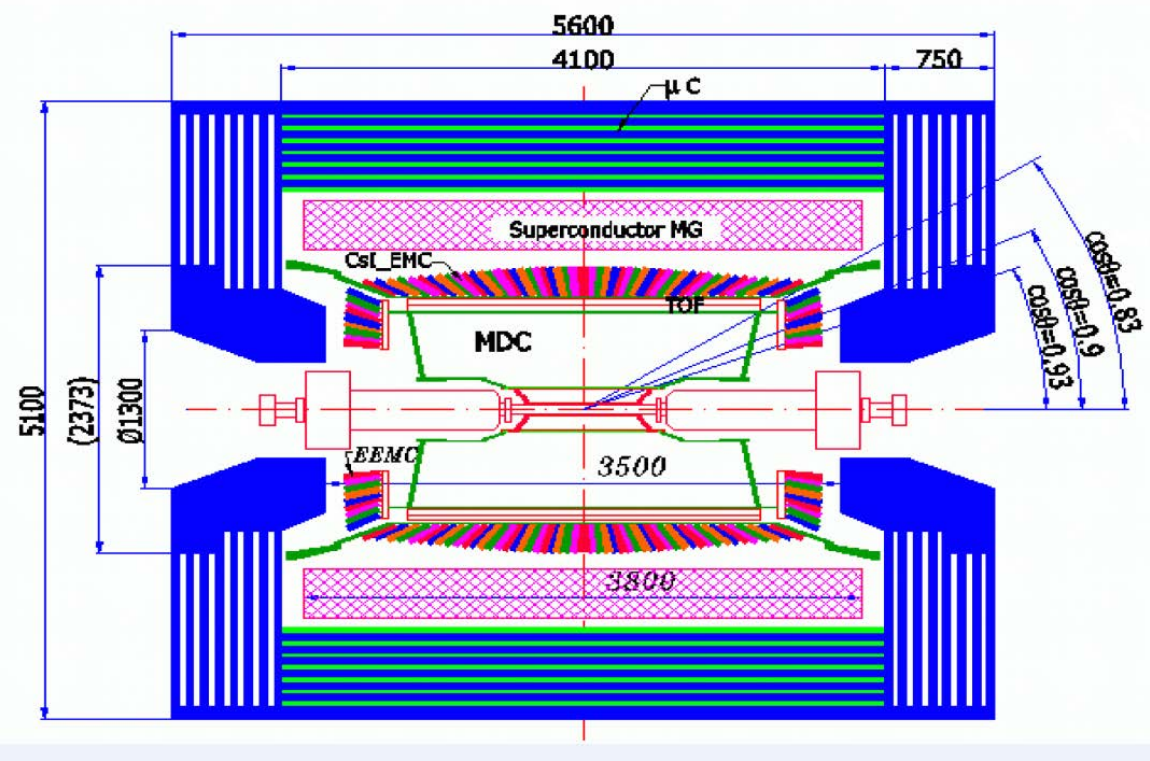
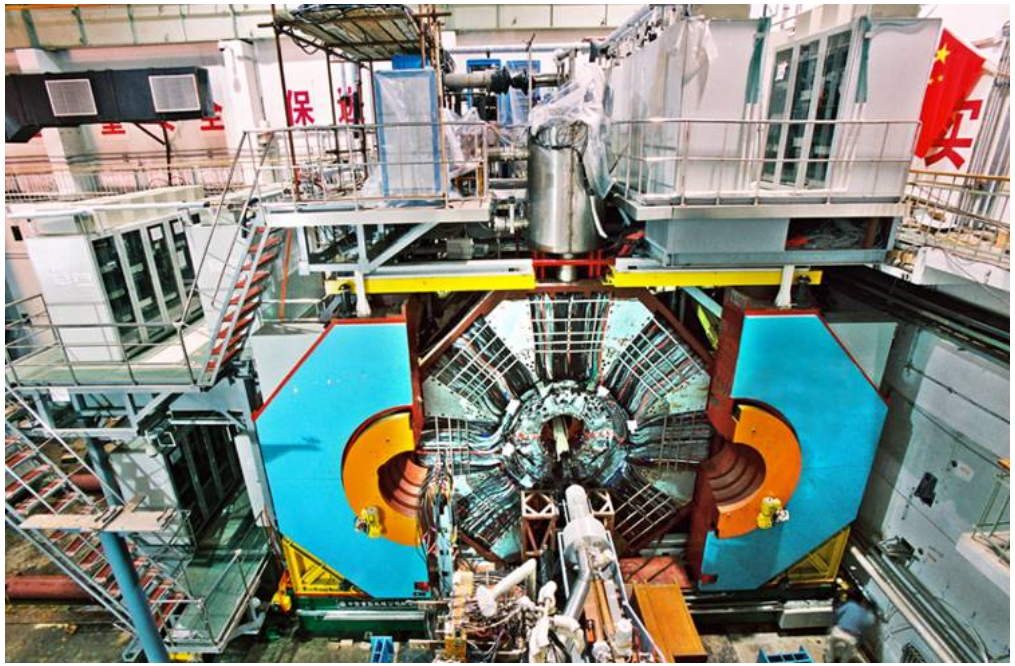
Outline

- Introduction of BESIII and BESIII drift chamber (MDC)
- Aging phenomenon in BESIII drift chamber
  - Cathode aging
  - Anode aging
- Preparation for MDC inner chamber upgrade
- Summary

The BESIII experiment

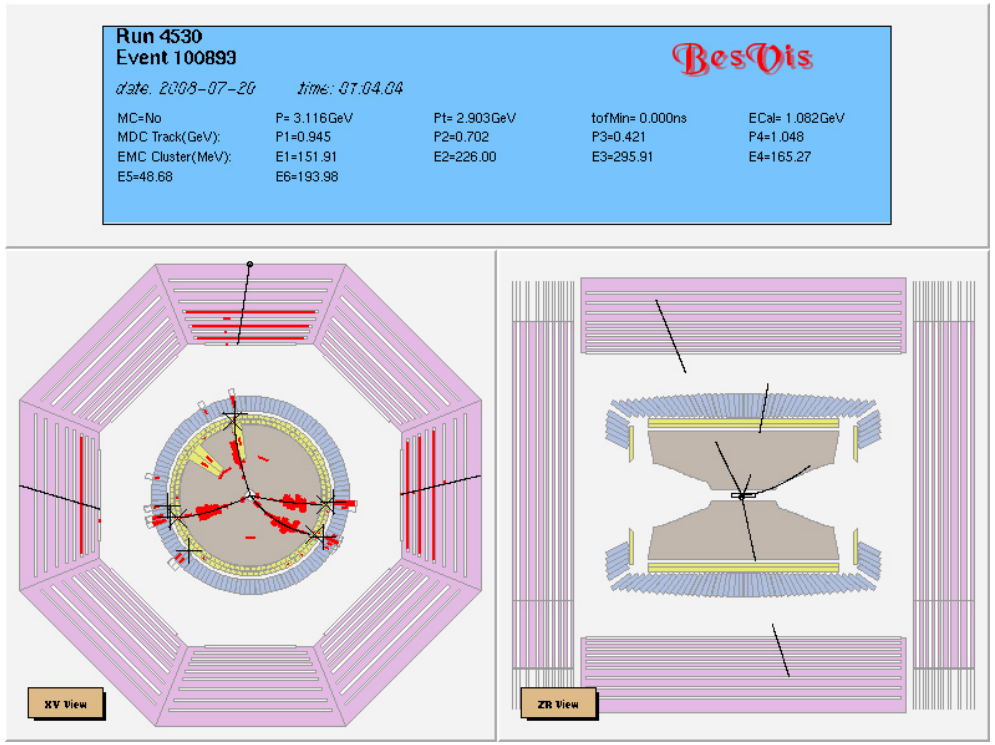
- Beijing Spectrometer(BESIII) is a general purpose detector at Beijing Electron-positron Collider (BEPCII), $E_{cm} \approx$ 2-5 GeV, $L_{peak} \approx 10^{33}/cm^2/s$
- Versatile researches in τ-charm physics
- BESIII collaboration has >500 members from 84 institutes in 17 countries and regions

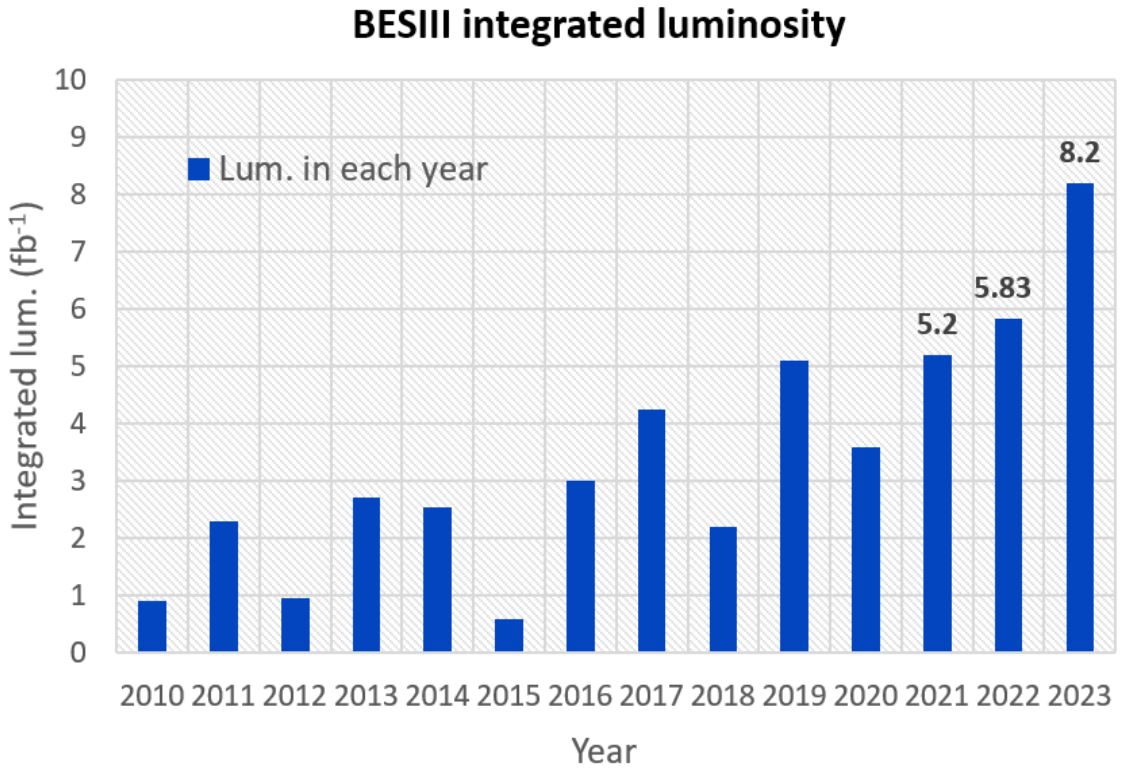




The BESIII experiment

- Started commissioning run in July, 2008
- Started data collection in 2009
- More than 15 years operation
- BEPC will be upgraded next year, and BESIII will continue to operate until 2030

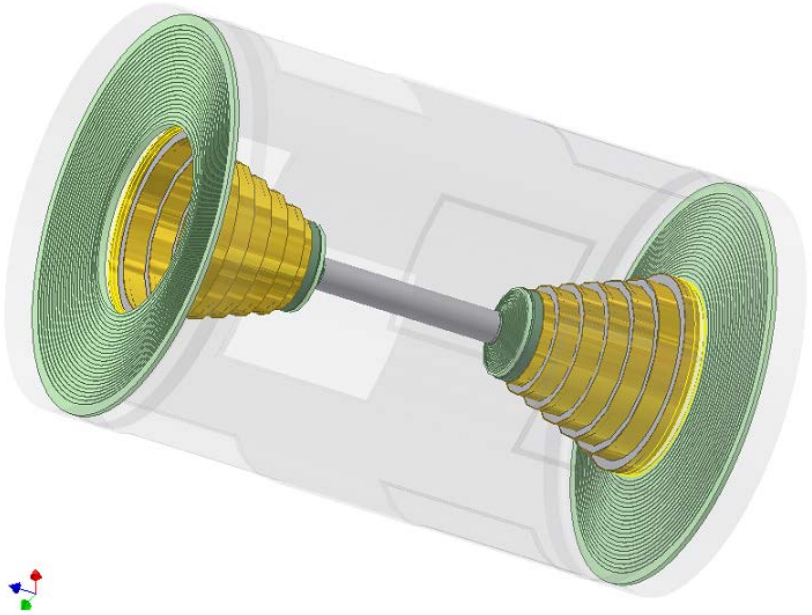


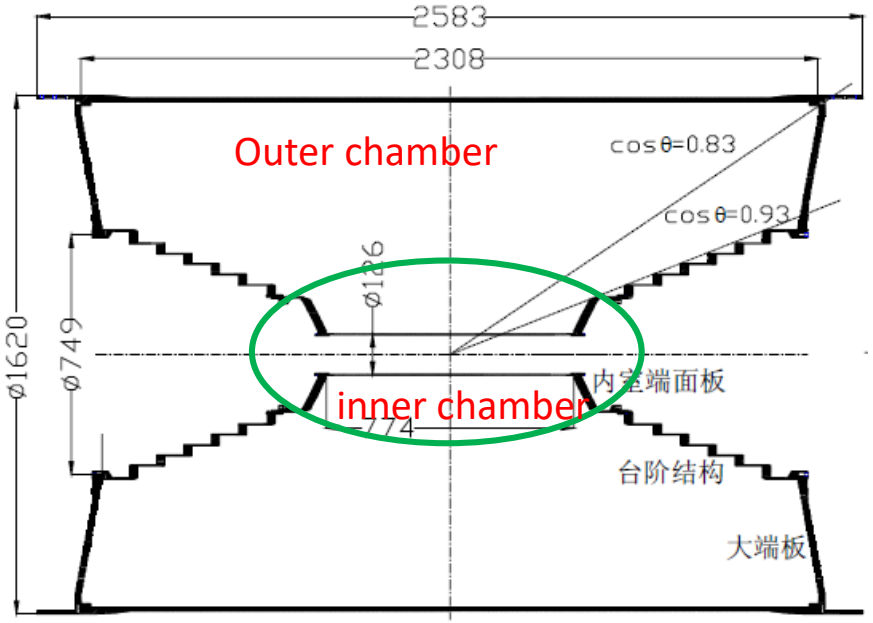


- Total integrated lum. : 47.4 fb^{-1}

BESIII drifter chamber (MDC)

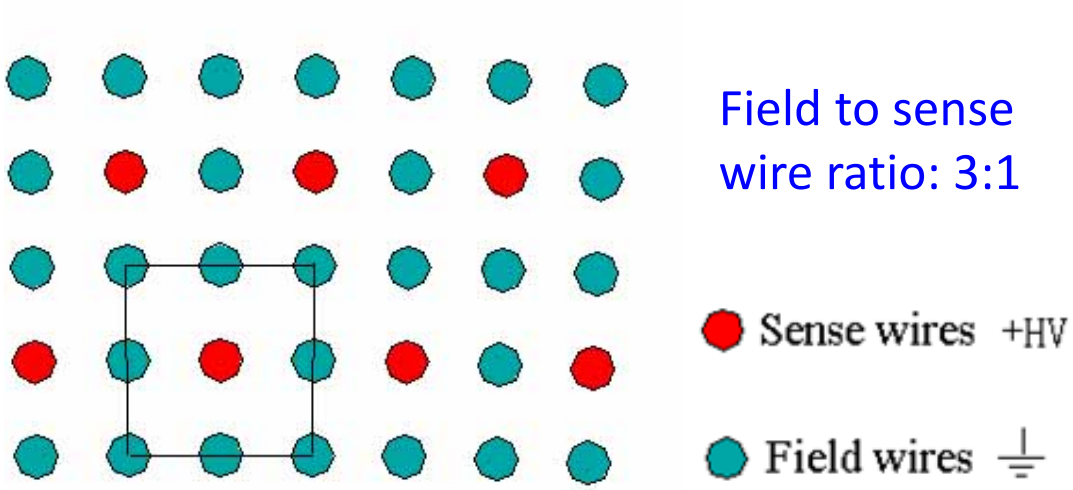
- Main tracking detector for the charged particles
  Position, momentum and dE/dx measurements
- Consists of inner chamber and outer chamber
- 43 layers in total
  8 layers (Inner chamber)+35 layers(Outer chamber)
  19 axial layers, 24 stereo layers, 6796 cells in total





- Radius extension : 63 mm → 810 mm
- Length: 2308 mm
- Inner cylinder: 1.2mm carbon fiber
- Outer cylinder: 11.5 mm CF with 8 windows
- End plates: 18 mm Al (6 stepped and inner end plates : 25 mm Al)

Small cell design



- cell size：
  inner chamber: 12mm×12mm
  outer chamber: 16.2mm×16.2mm

- Sense wires: ϕ25μm W (Au)
- field wires: ϕ110μm Al (Au)
- 28680 wires in total

Attractive features of small cells

- Small drift distance → fast trigger
- Can reduce electron diffusion → improve spatial resolution
- Can put more layers in limited space → improve $\sigma_{dE/dx}$
- Reduce accumulated charge of the cells → slow down aging

He based gas mixture

- **Gas**
  - He based gas mixture , He : C_3H_8 = 60% : 40%
  - low material budget to reduce multiple scattering
  - X_0: 500 m, v_e=3.8 cm/μs
- **High Voltage**
  - About 2200 V, same for the cells in same layer, little difference between each layer
  - Set HV of the first four layers to 98%, 98.5%, 99%, and 99.5% of the nominal value, respectively, due to high beam induced background
  - Gas gain：~ 2×10^4 @2200V

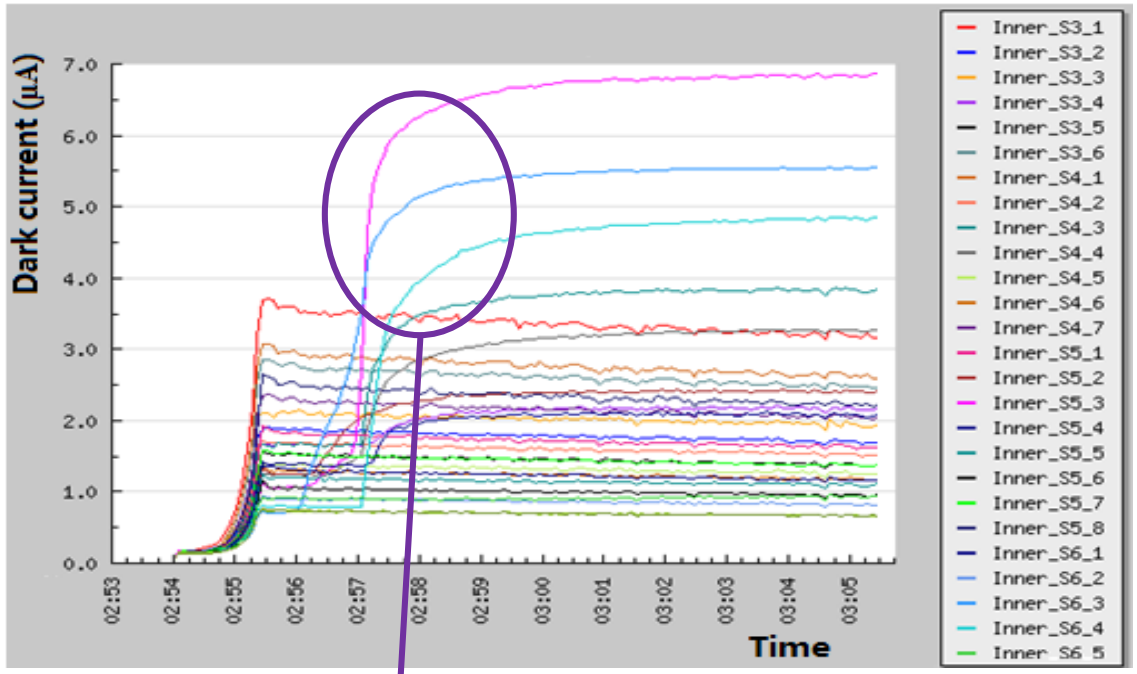
Performance of MDC

Parameters	Design Performance	Achieved Performance
$\sigma_{r\phi}$	$130\ \mu m$	$\sigma_{r\phi} = 115\ \mu m$
$\Delta p/p$	$0.5\%@1GeV$ (B=1T)	$0.47\%@1GeV$ (B=1T)
$\sigma_{dE/dx}$	6%	5.2%

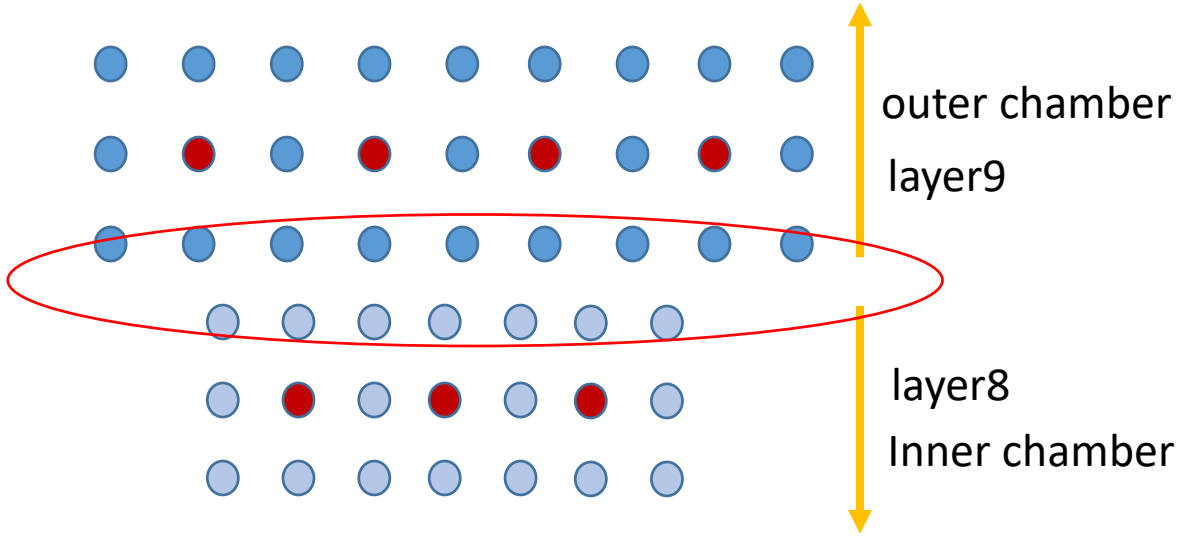
Aging phenomenon in MDC

- Cathode aging (Discharge):
  - Malter effect was encountered by the inner chamber in 2012
- Anode aging (Gas gain reduction):
  - The gains of the cells decrease with the increase of the cell accumulated charges year by year

Cathode aging in MDC



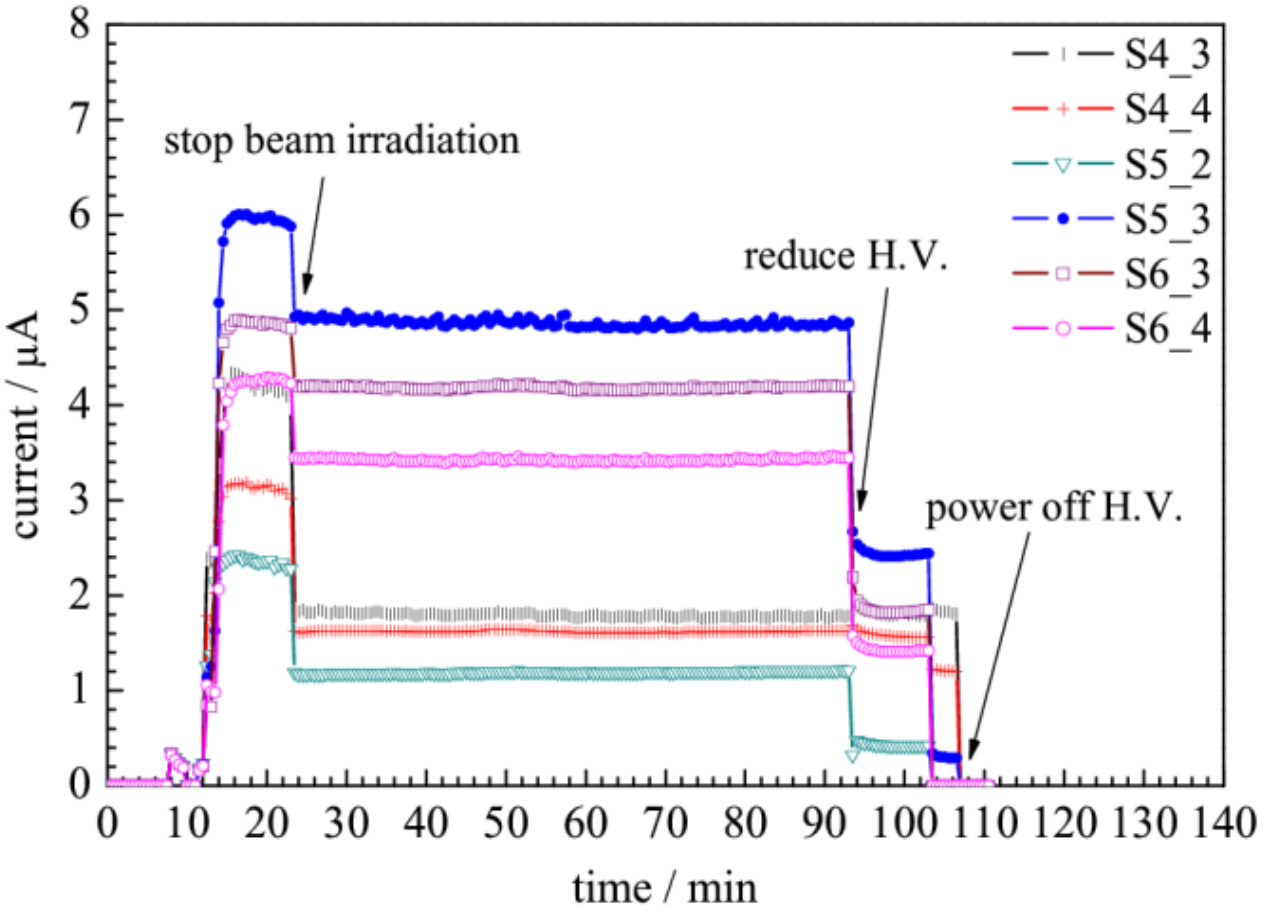
Malter discharge in Jan. 2012



Layers 8 and 9 have independent field wire layers

- Sharp increase in currents in parts of cells in inner chamber
- First found in L7-3, L8-3, rapidly spread to adjacent cells , but did not to cells in outer chamber
- A self-sustaining discharge, non-local because of high infectivity

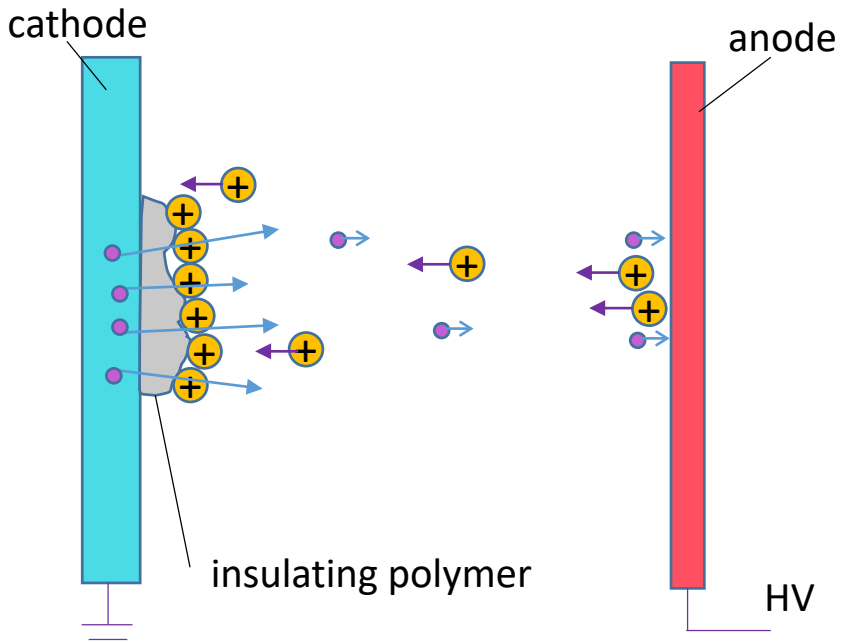
Cathode aging in MDC

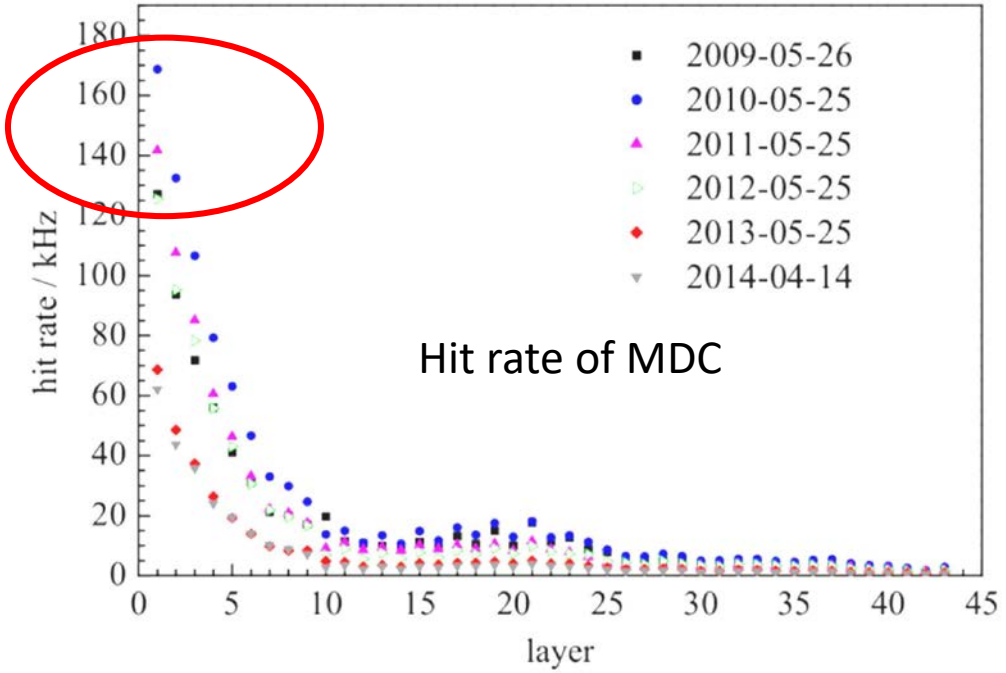


- Test with beam irradiation
  - Discharge occurred at very beginning
  - Did not disappear even after stopping beam
  - Still existed after reducing high voltage
  - Disappeared after powering off HV
- Confirmed to be Malter discharge

Malter effect

- Related to gas impurities, surface defects or contamination of wires
- Triggered by high radiation intensity and high gas gain



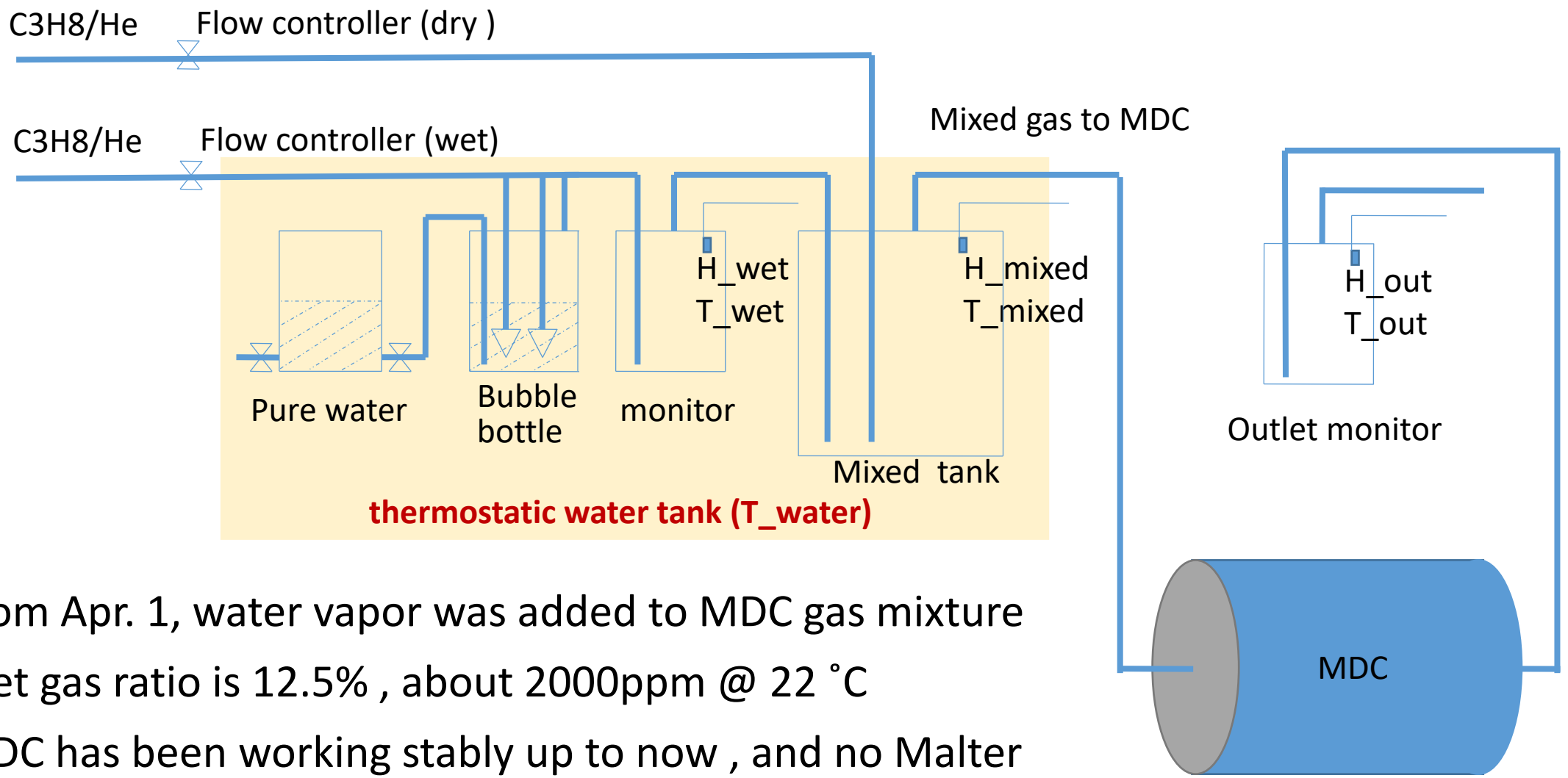


- Insulating polymer deposited on field wires prevents the neutralization of ions, resulting in field strength increase
- Electrons are extracted from the field wire and generate avalanches at the sense wires
- More ions enhance the surface electric field of the shell
- Forms a self-sustaining discharge

CO_2 additive to MDC gas

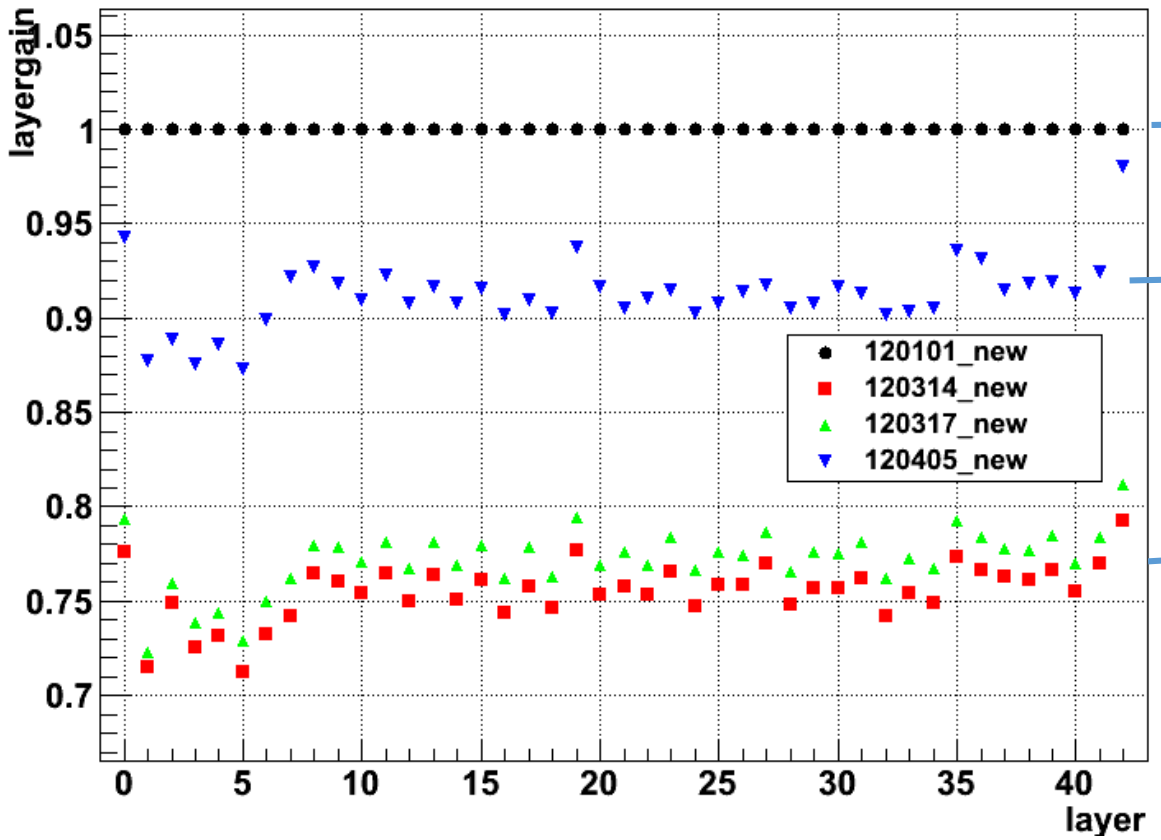
- Added 5% CO_2 to MDC operation gas
- Conducted CO_2 training for about a week with radiation intensity and high voltage increased step by step
- Then MDC worked stably with 5% CO_2 for about one month (From Feb. 27^{th} to March. 30^{th})
  - Malter discharge occurred one time (March. 5^{th})
  - The gas gain decreased about 23%

H_2O additive to MDC gas



- From Apr. 1, water vapor was added to MDC gas mixture
- Wet gas ratio is 12.5% , about 2000ppm @ 22 ˚C
- MDC has been working stably up to now , and no Malter discharge has been observed

Impact of gas additive on gas gain



original

with 2000ppm water vapor

with 5% CO_2

- The gain decreases about 23% with 5% CO_2 additive to the gas
- The gain decreases about 9% with 2000ppm water vapor additive to the gas

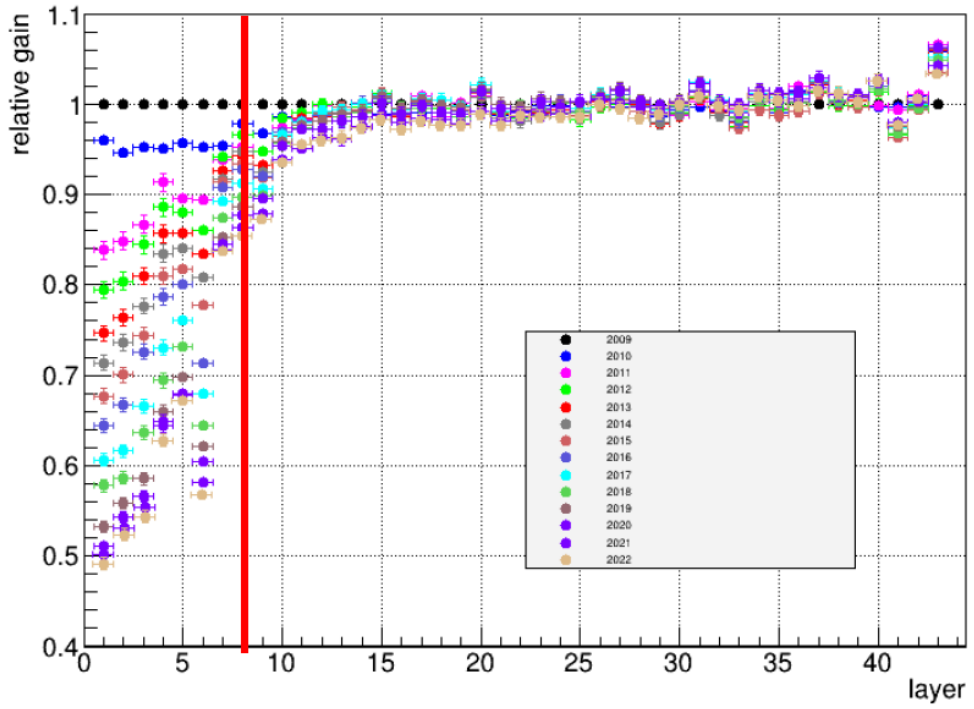
Anode aging in MDC

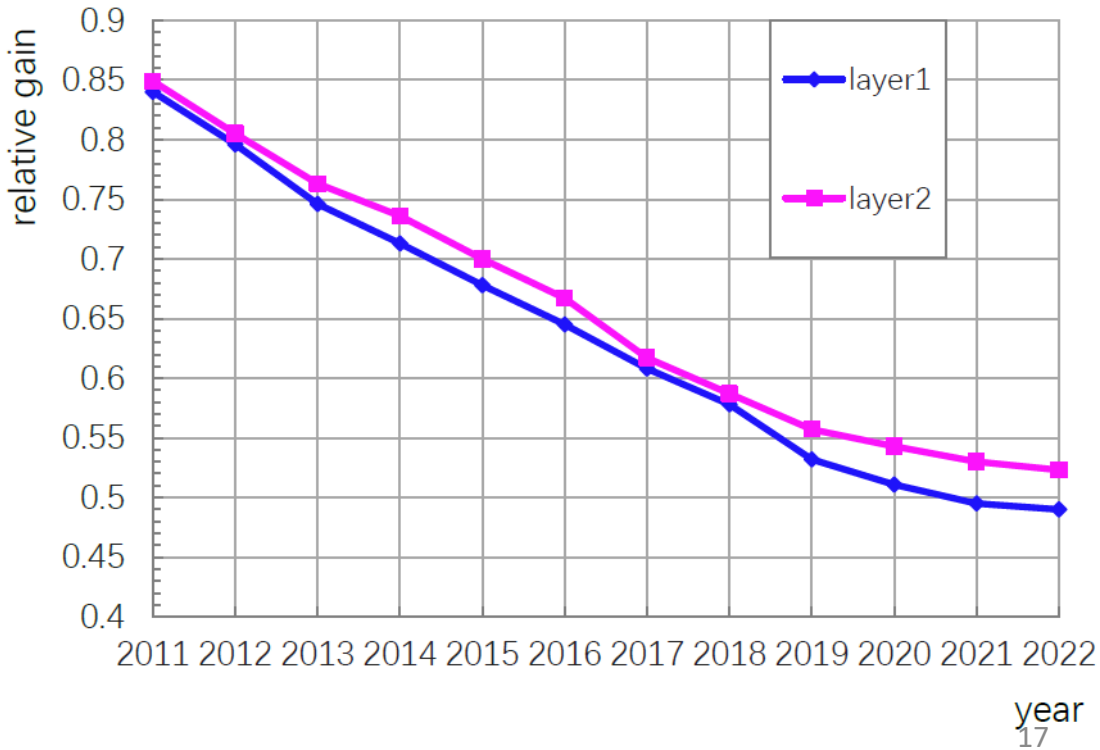
- Deposits on the anodes cause a gain loss due to the increase in effective diameter of the sense wires
- Related to accumulated charges of the sense wires and other correlated parameters

- Obtain the gas gain reduction with Bhabha events
- Integrate dark currents of the sense wires to get the accumulated charges

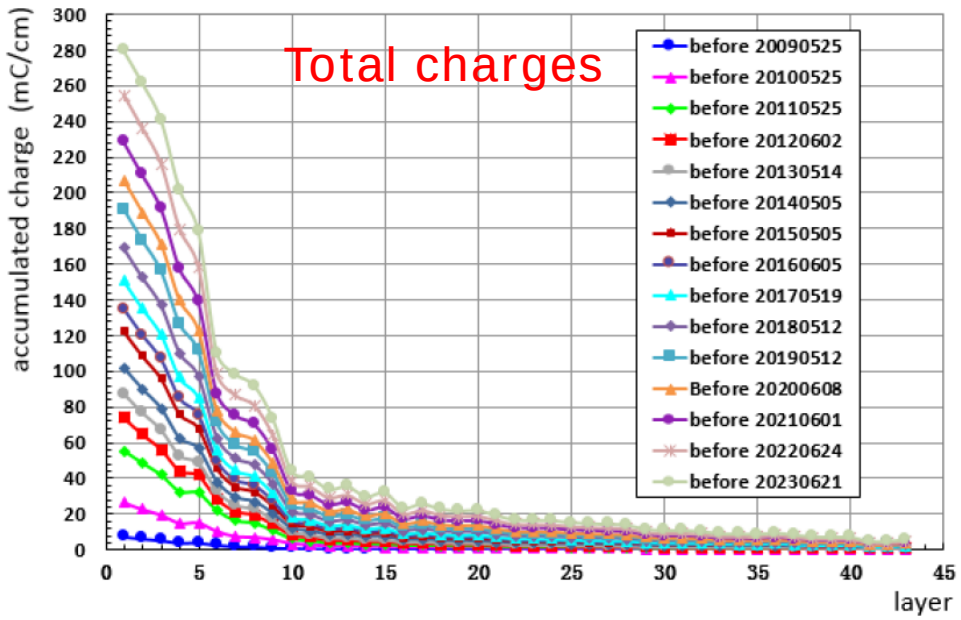
Gain decrease

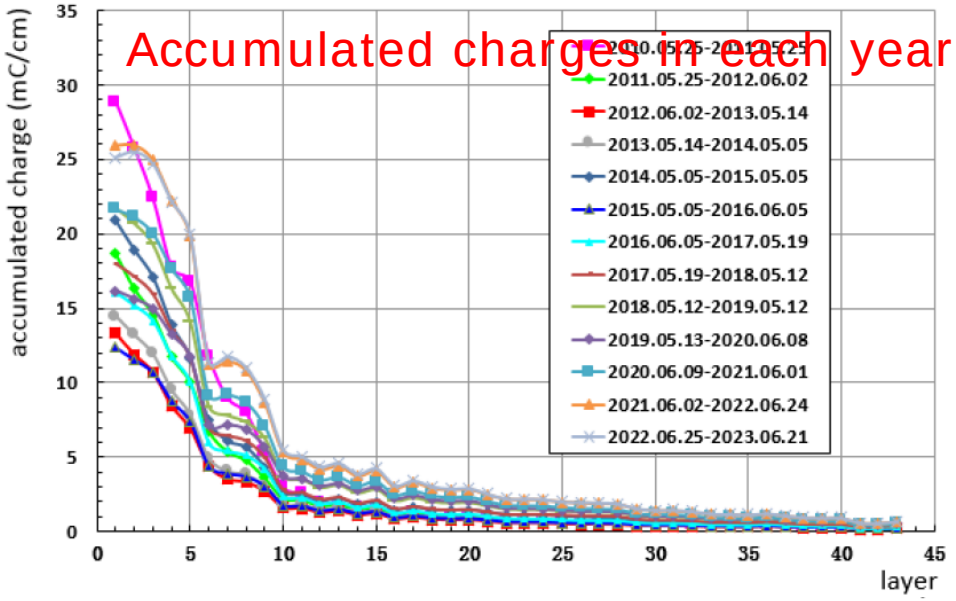
- Gains of inner chamber dropped, about 50% for the first layer cells
- No significant change in gain for outer layers
- Gain decreased by about 3% /year for layer1 and layer2, but slowed down in last three years

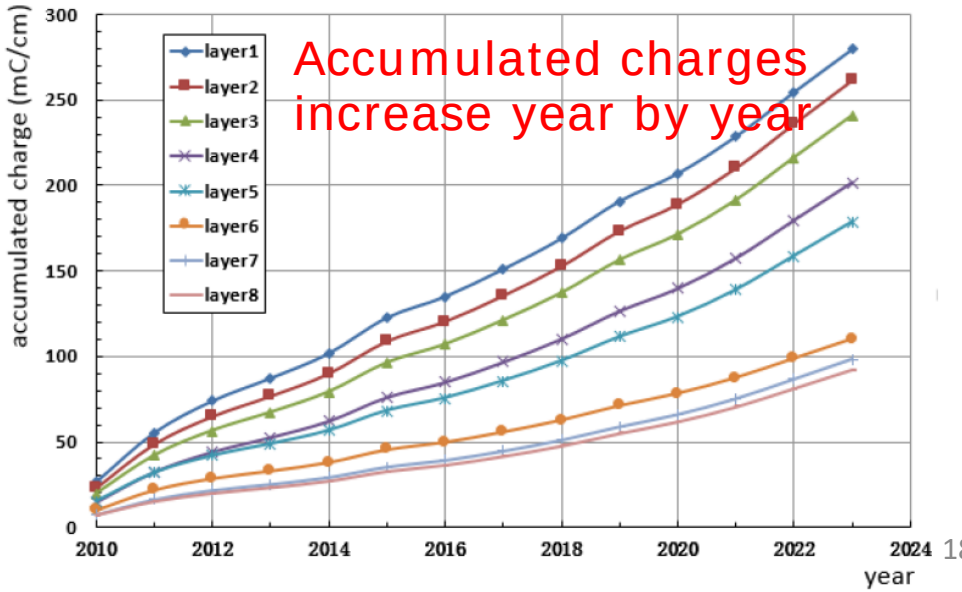




Accumulated charges







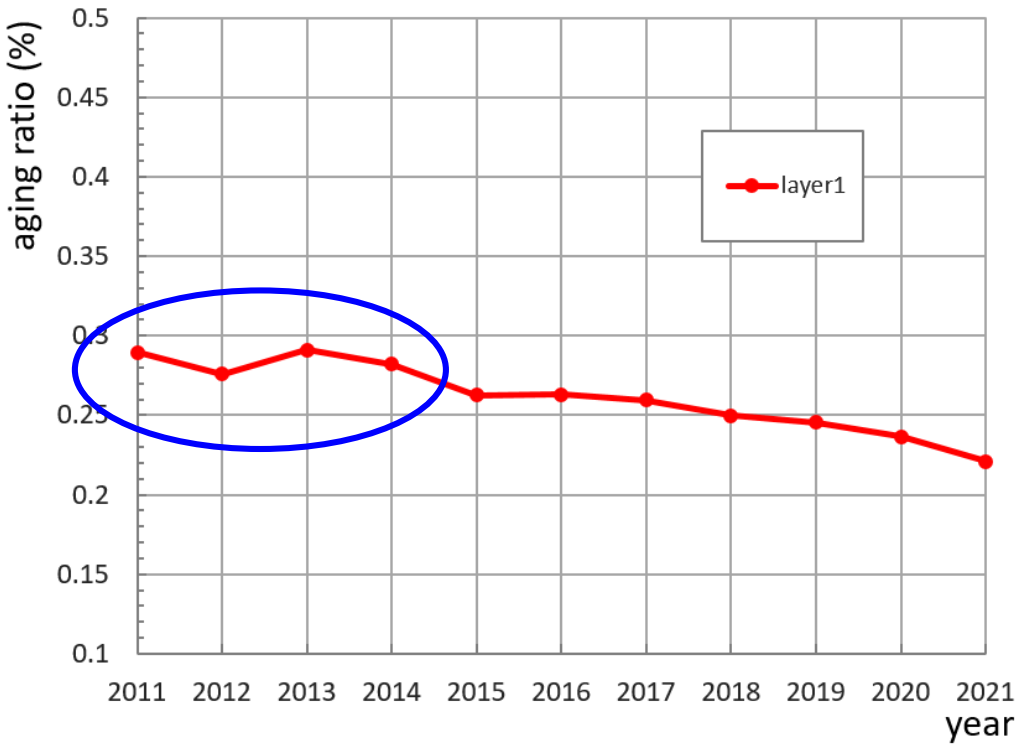
- Integrate currents of each cell to get accumulated charges
- Total charges are about 280mC/cm for the first layer
- Total charges decrease rapidly for the cells far away from the IP

Aging ratio

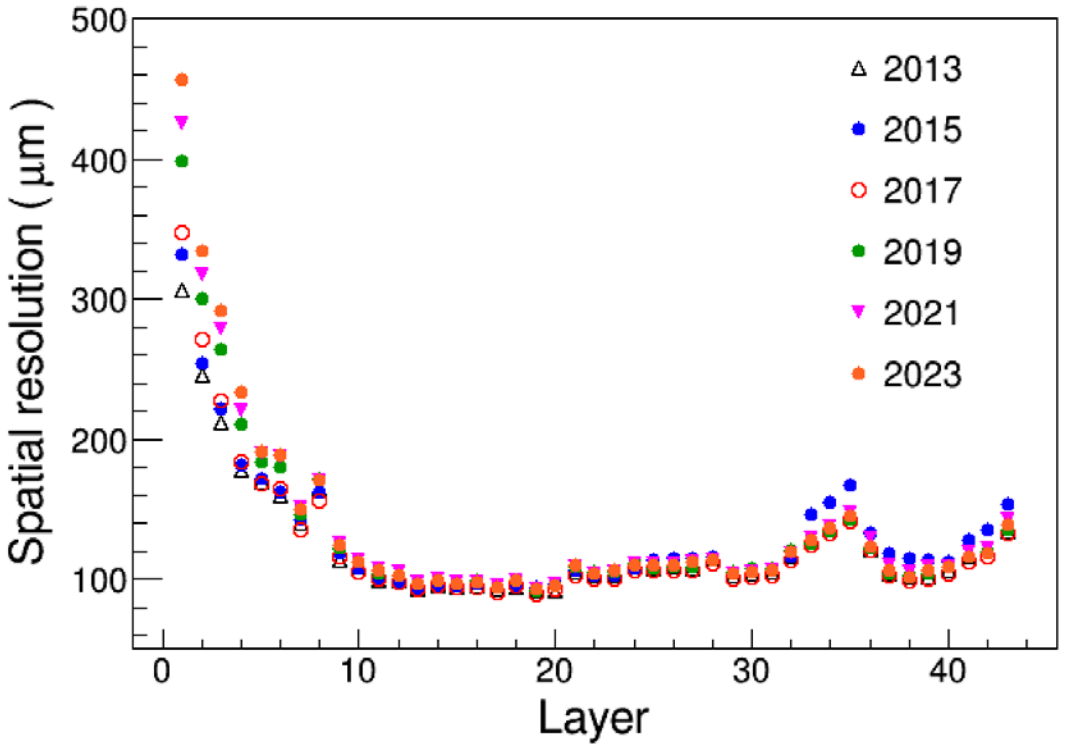
- Generally, the change of the gain is related to accumulated charges
- Based on the decrease in gain and the accumulated charges, aging ratio can be estimated
  - Before 2014, aging ratio is roughly consistent to the results of prototype aging tests (~ 0.3% for inner cell)
  - Confirmed that aging ratio is not a constant. Depend on correlated parameters, such as gas gain, radiation intensity…

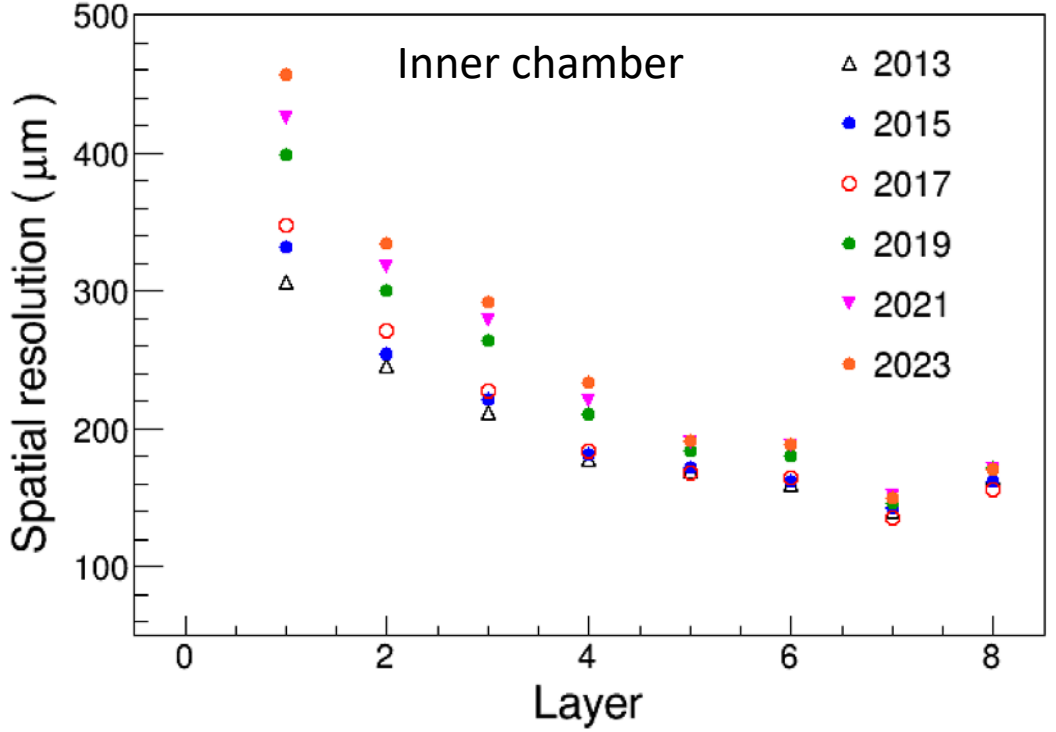
- Aging ratio: $R = -\frac{1}{Q} \cdot \frac{\Delta G}{G}\% \Big/ (mC/cm)$

$$\frac{\Delta G}{G}\% = -RQ$$



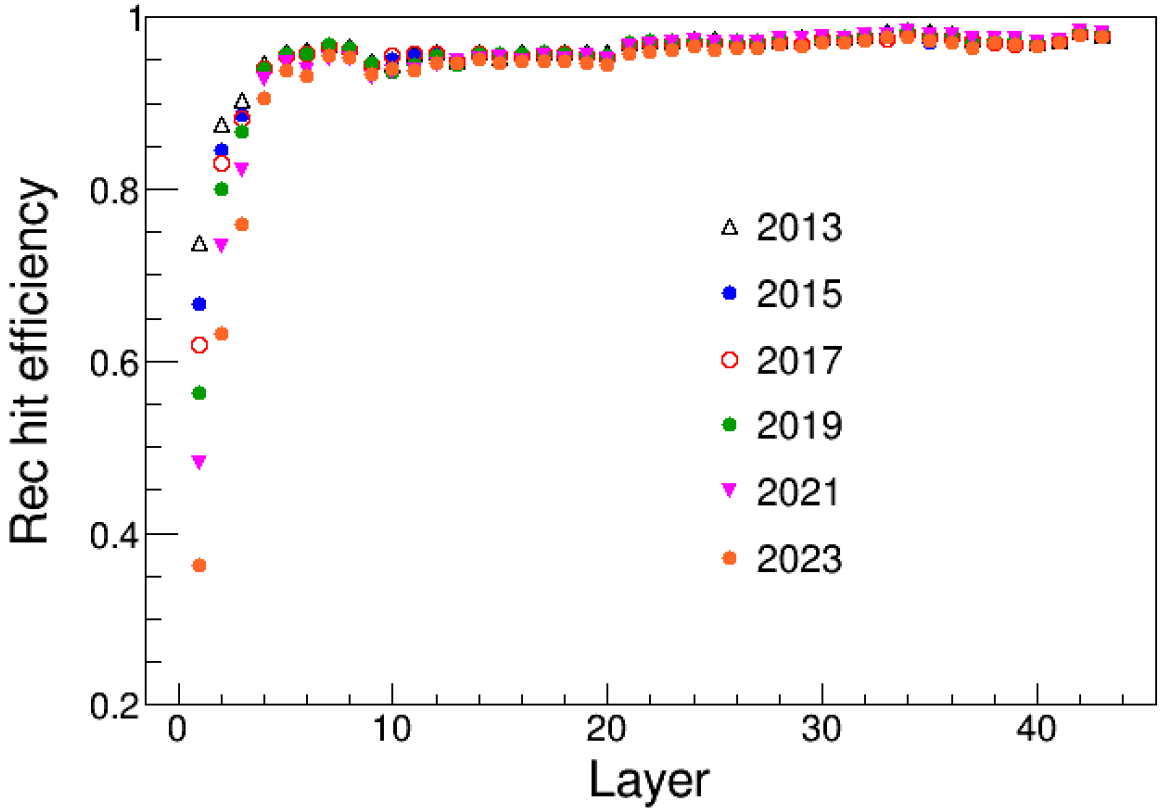
MDC spatial resolution

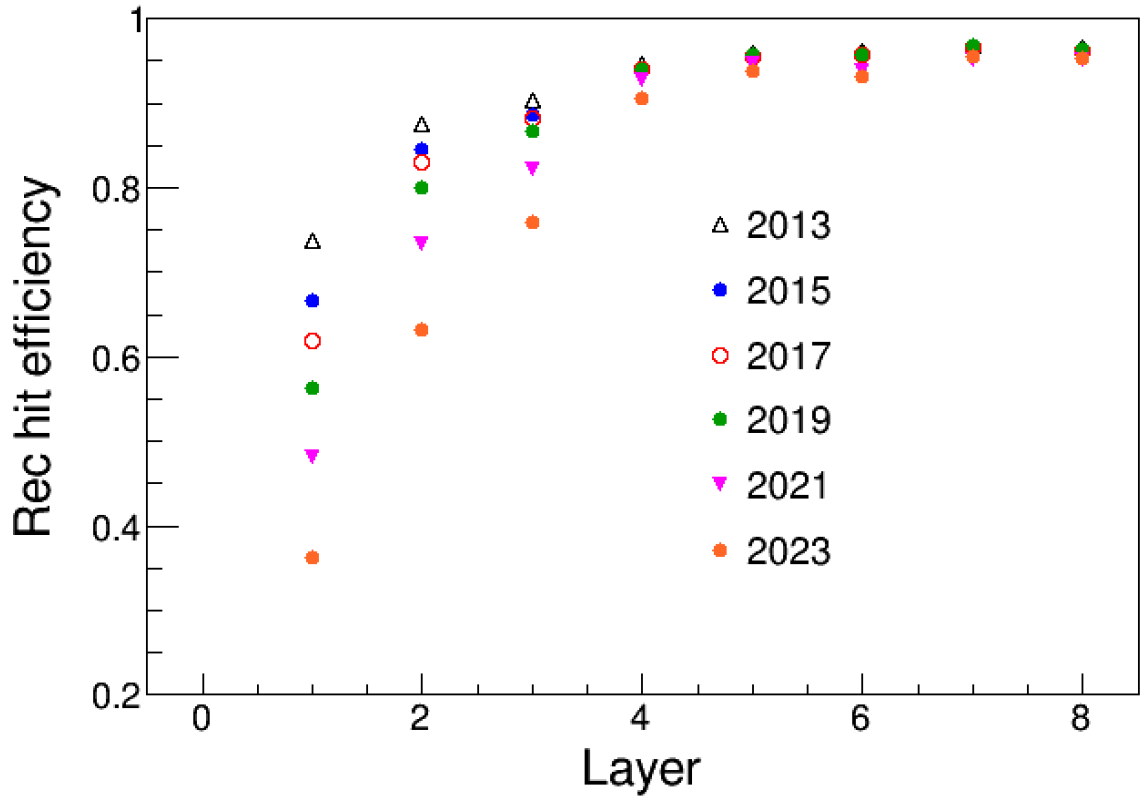




- The resolution of the inner chamber has significantly decreased
  - Decrease in gain caused by aging
  - Low voltage setting leads to low gain for the first four layers
- Almost no changes for the outer chamber

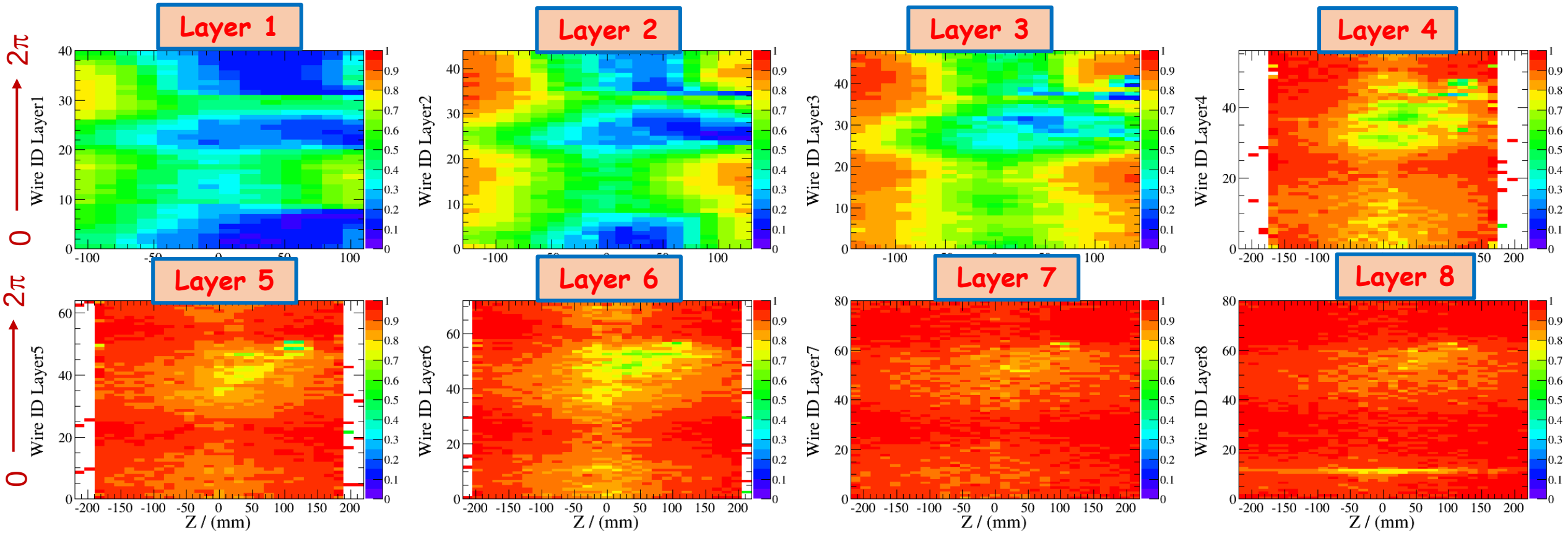
Reconstruction hit efficiency





- No significant decrease for most layers
- Hit efficiency of the first three layers decreased year by year

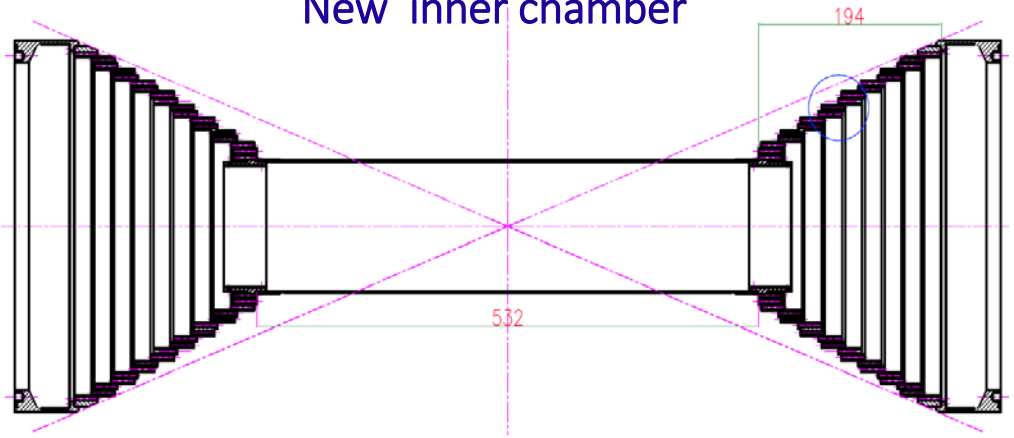
Rec hit efficiency



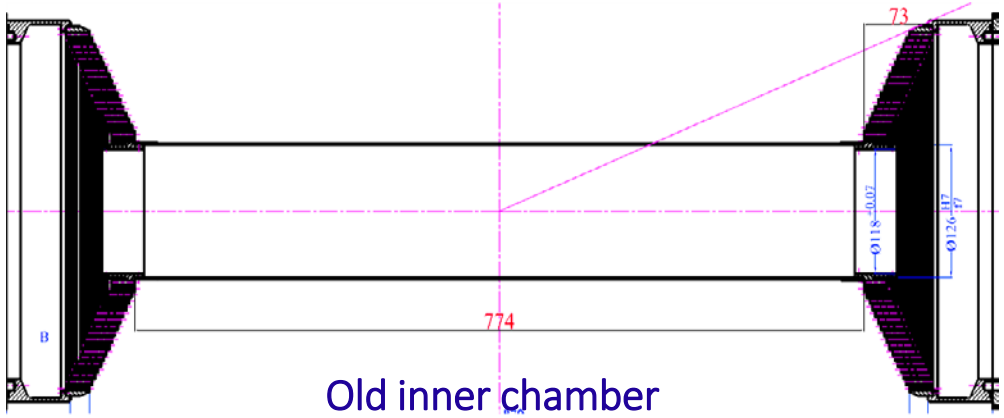
- The efficiency of the first three layers are nonuniform
- Some region is quite low (~*20%*) , Signals are lower than threshold

New inner drift chamber

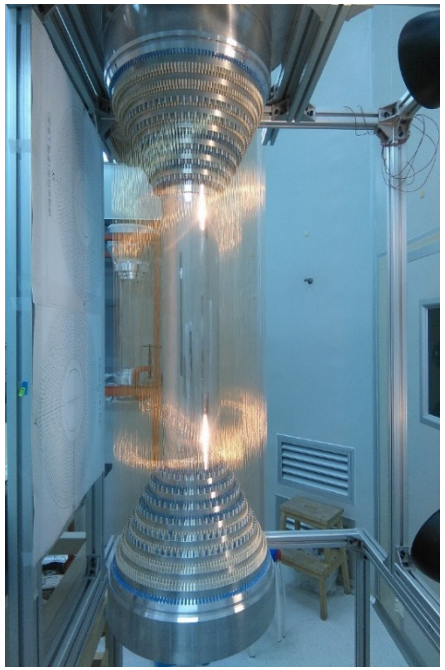
New inner chamber



8 layers, 484 cells



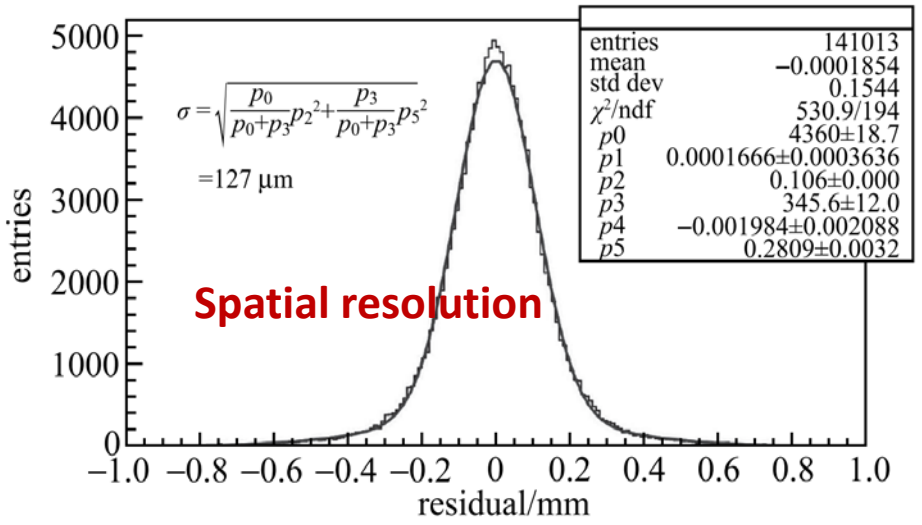
Old inner chamber

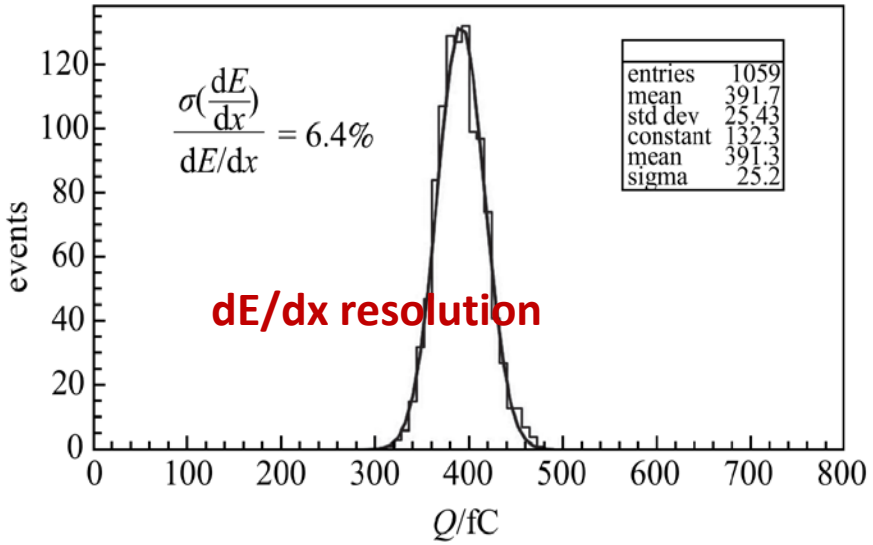


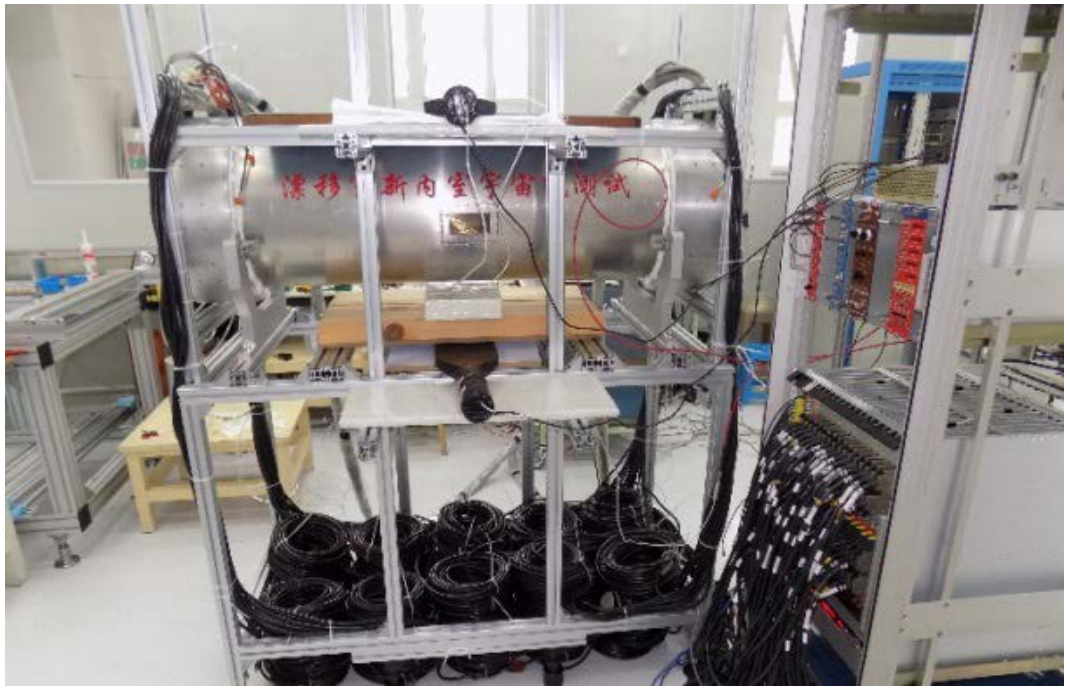
New inner chamber

- An improved new inner drift chamber with multi-stepped end-plates
- Shorten the wire length beyond the effective sold angle
- Reduce the background counting hits (currents) of a cell
- Improve resolution in z direction

New inner drift chamber







- The new inner chamber has been ready
- Cosmic-ray tests show the performance meets the requirements of BESIII

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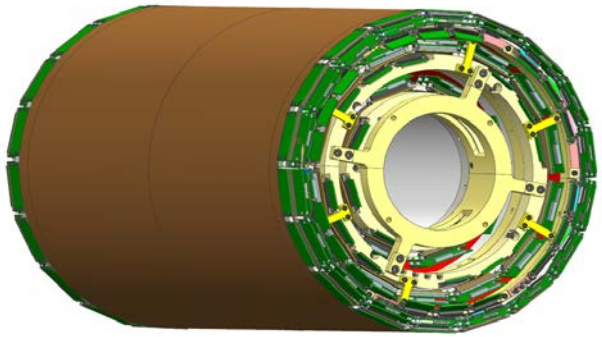
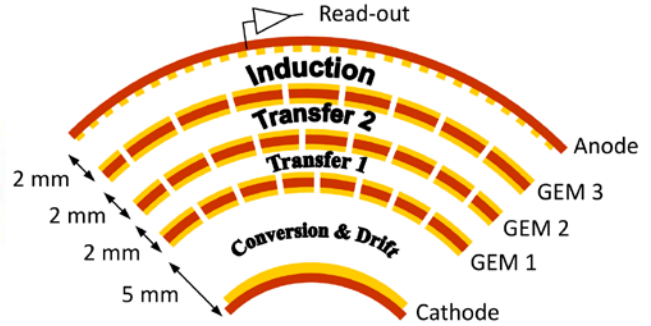
Cylindrical GEM inner tracker (CGEM)

- Built a 3-layer cylindrical GEM inner tracker for inner drift chamber upgrade (INFN and IHEP)
- High counting rate (>10^4 Hz/cm^2),
- Strong anti-aging ability
- Significantly improve z-direction resolution (~1.5 mm →~0.5 mm)

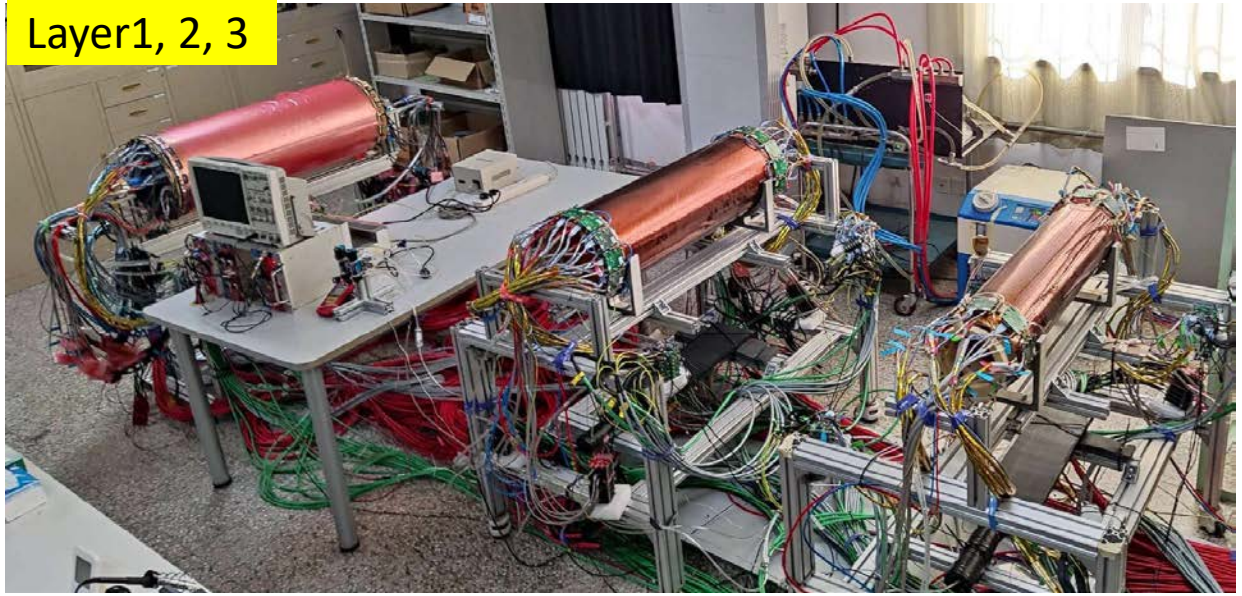


CGEM-IT

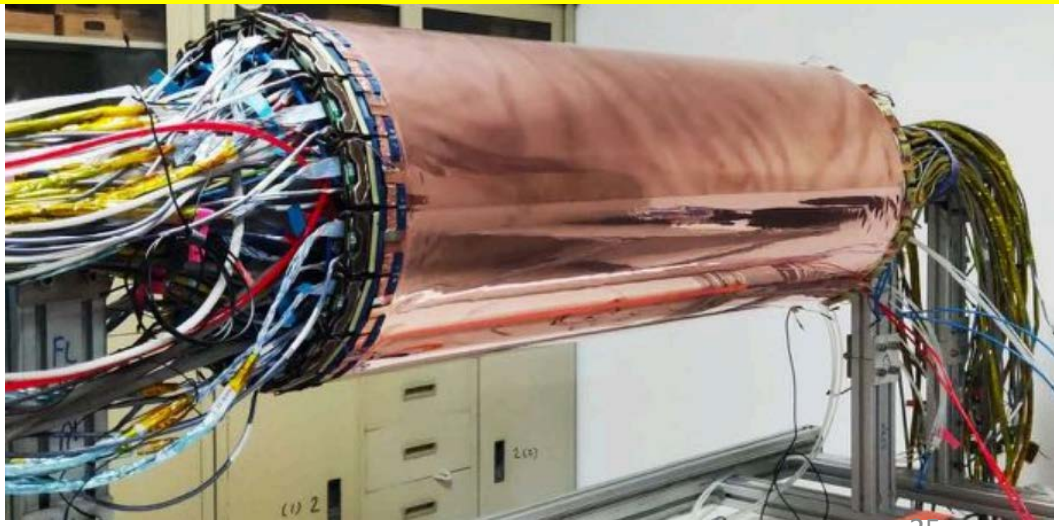


NIMA 824, (2016)515-517

Layer1, 2, 3



Assembled three layers together for cosmic-ray tests



Summary

- BESIII drift chamber has operated more than 15 years, suffering aging problems
- Malter discharge was encountered by the inner chamber in 2012, and was cured by 0.2% water vapor additive to MDC operating gas
- The gains of the inner chamber decreased significantly due to aging, resulting in a degradation of spatial resolution and hit reconstruction efficiency, especially for the first three layers
- A new inner drift chamber and a CGEM inner tracker have been constructed for the upgrade of the inner chamber

Thanks for your attention