南開大學
Nankai University

BESIII

Status and plan for BEPCII and BESIII

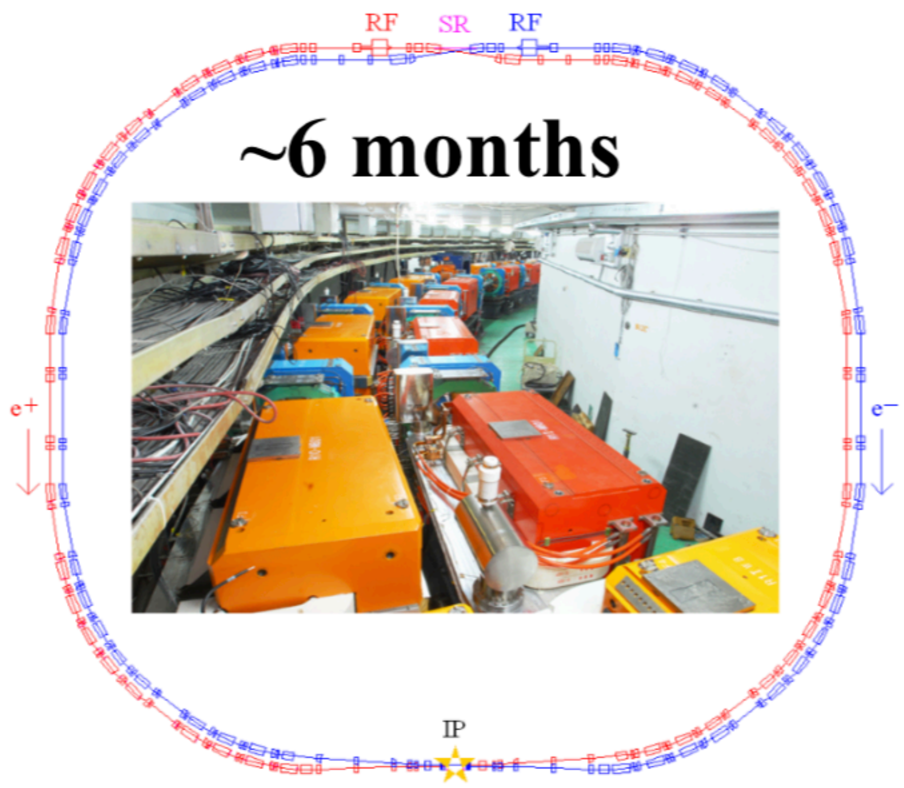
Minggang Zhao

School of Physics, Nankai University, Tianjin, China

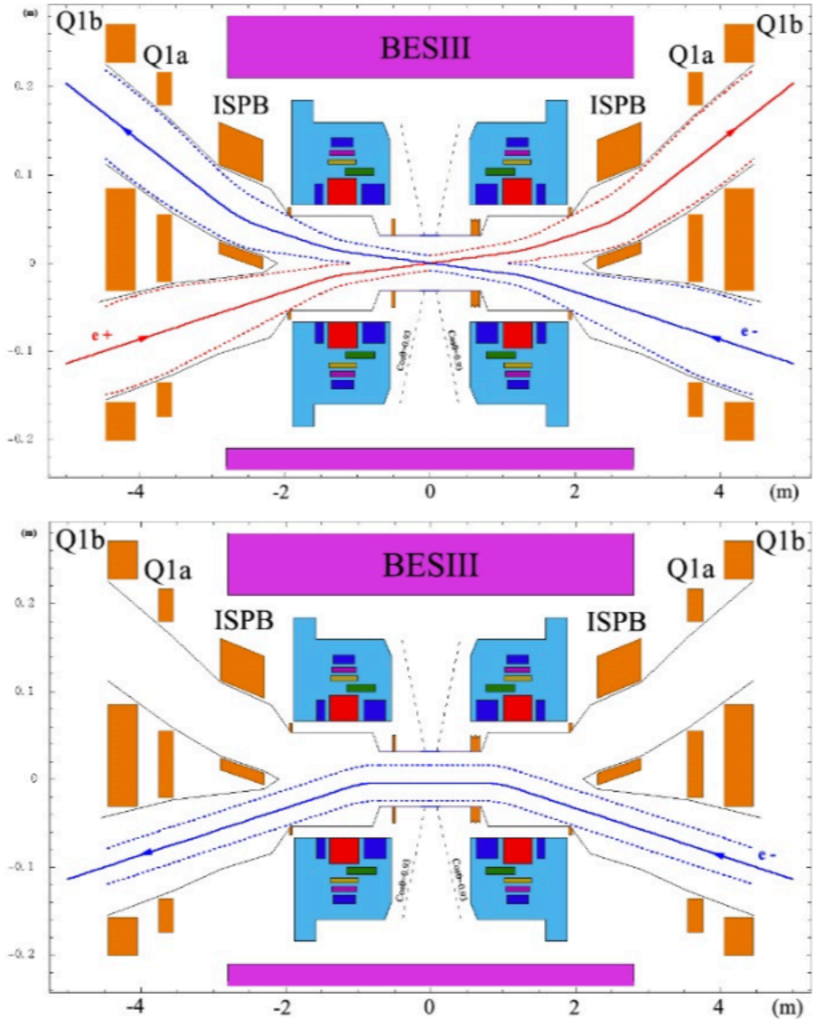
Tau and QCD physics at present and future electron-positron colliders
2019.12.16-18，BINP，Novosibirsk

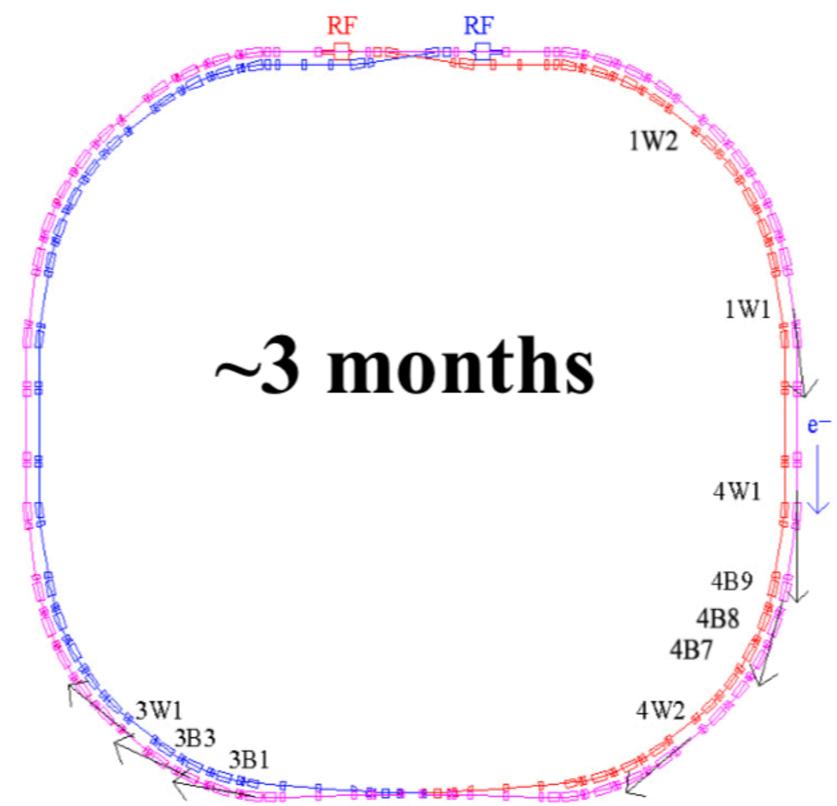
Overview of the Facility

BEPCII



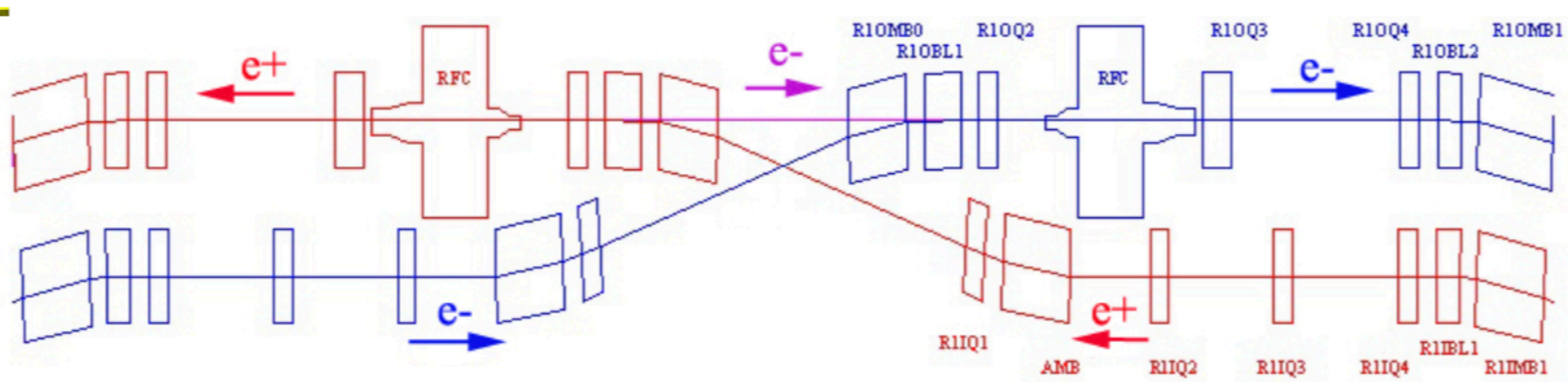
Collider



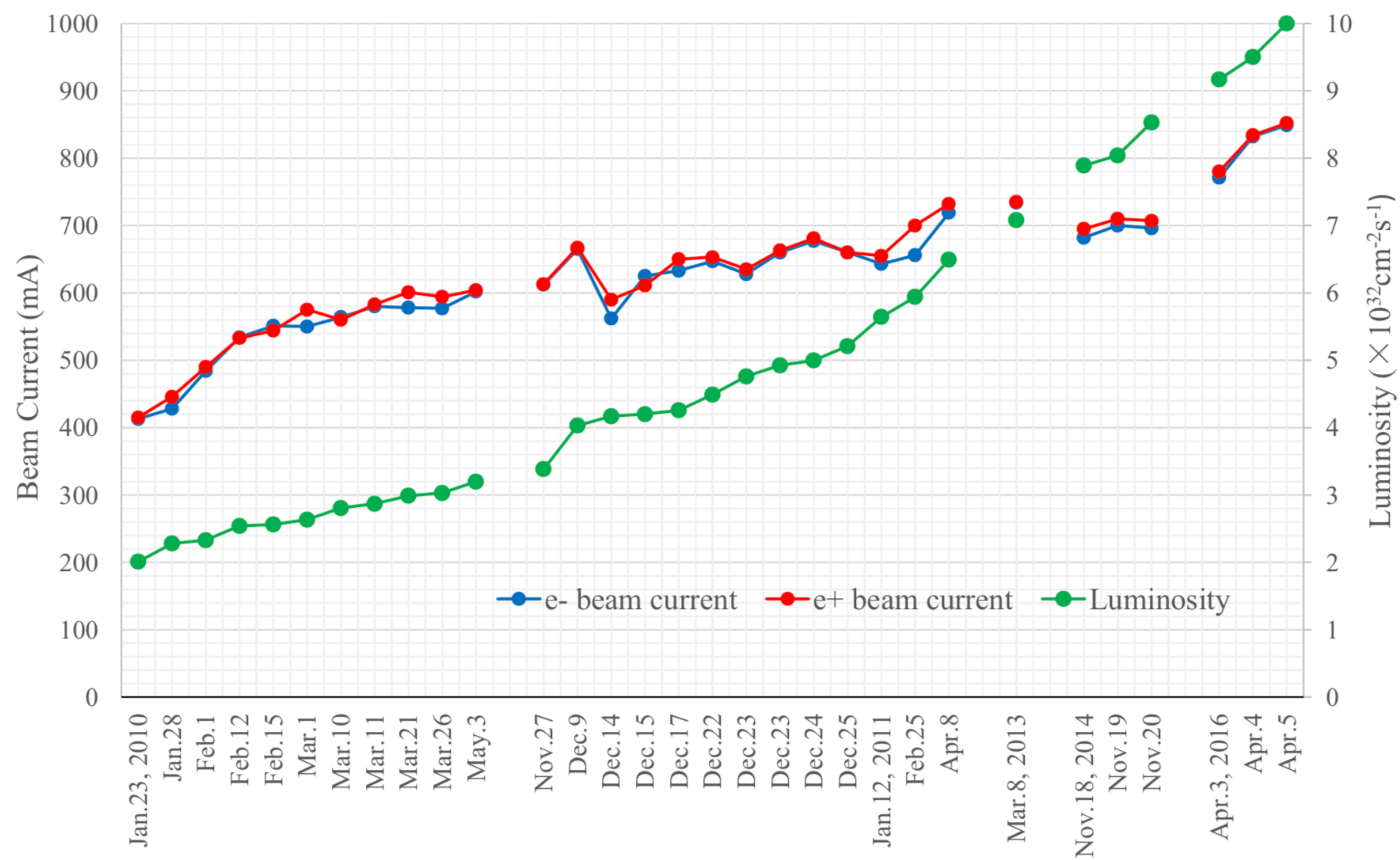


SR Facility

January 2004	Construction started
Mar.28, 2008	Installation of detector started
Jun. 22, 2008	BEPCII Commissioning started
May 13, 2009	Luminosity reached $3.3\times10^{32}cm^{-2}s^{-1}$
Apr. 5, 2016	Luminosity reached $1.0\times10^{33}cm^{-2}s^{-1}$



Designed Luminosity



Operation Schedule

- ✓ 2008.06.22–2008.12.18 Luminosity commissioning & Detector tuning
- ✓ 2008.12.18–2009.01.20 Synchrotron radiation operation for users
- ✓ 2009.01.20–2009.01.31 Installation of movable masks, remove profiles
- ✓ 2009.02.01–2009.03.02 Luminosity commissioning @1.89 GeV
- ✓ 2009.03.02–2009.04.14 High energy physics,100M $\psi(2S)$events @1.84 GeV
- ✓ 2009.04.14–2009.05.19 Luminosity commissioning, $L=3.3\times10^{32}\ cm^{-2}s^{-1}$
- ✓ 2009.05.19–2009.06.01 High energy physics,@1. 825 GeV
- ✓ 2009.06.01–2009.07.31 High energy physics, 200M J/ψ events@ 1.55 GeV
- ✓ 2009.12.18–2011.04.28 High energy physics @ 1.89 GeV
- ✓ 2011.04.28–now High energy physics @ 1.0 ~ 2.3 GeV

Operation Schedule @2019-2020

From	To	Task	Duration
2019.07.26	2019.10.23	Summer shutdown	90 days
2019.10.24	2019.11.06	Machine recovery	14 days
2019.11.07	**2019.12.12**	**SR operation**	**36 days**
2019.12.13	2019.12.17	Switch to collision operation	5 days
2019.12.18	**2020.06.21**	**Data taking @ Y(4660) & Λ_c**	**187 days**
2020.06.22	2020.06.24	Switch to SR operation	3 days
2020.06.25	2020.07.23	SR operation	29 days
2020.07.24	2020.09.21	Summer shutdown	60 days
2020.09.22	2020.10.05	Machine recovery	14 days
2020.10.06	2020.11.09	SR operation	35 days
2020.11.10	2020.11.14	Switch to collision operation	5 days

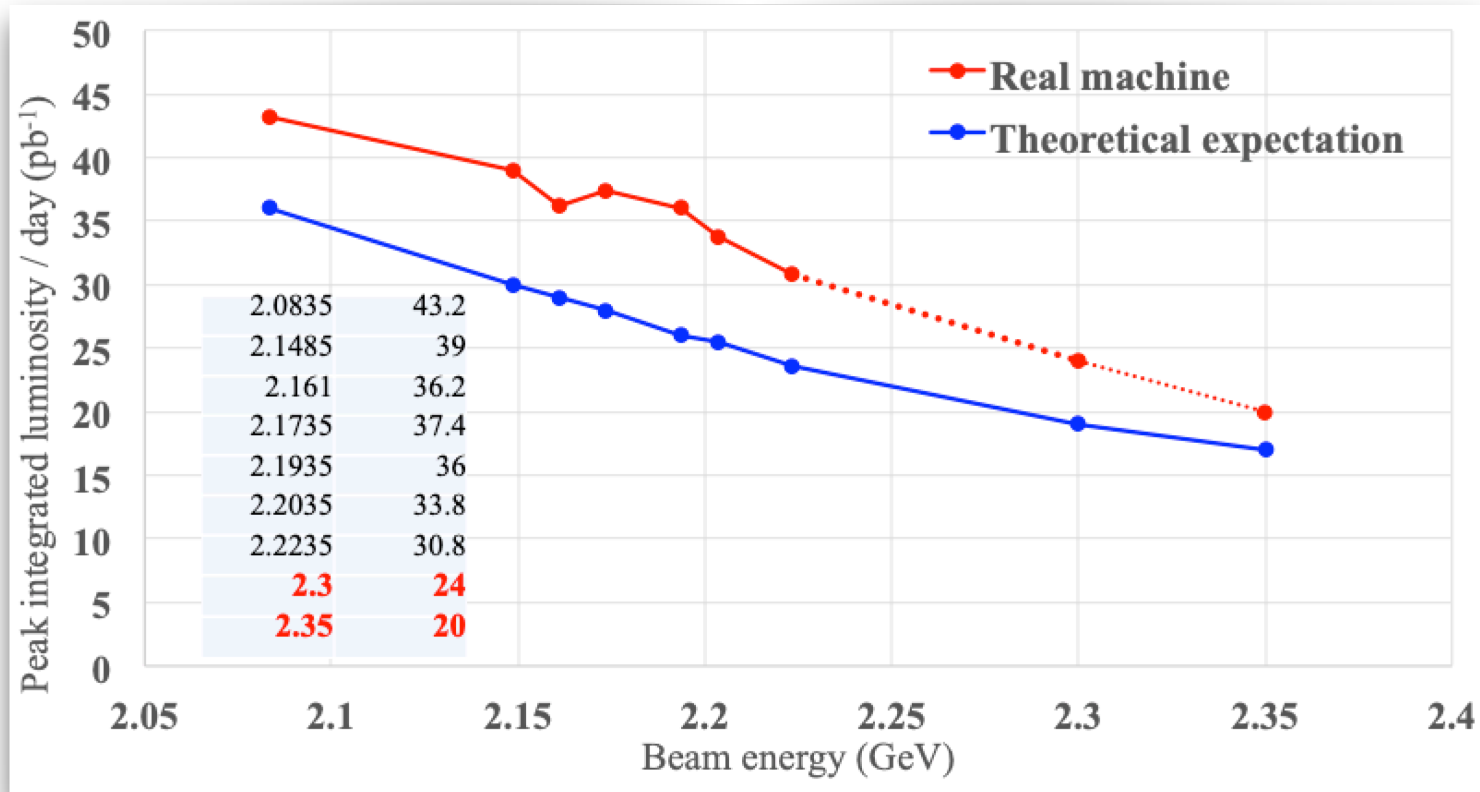
Superconducting 3W1
Beam energy upgrade
Top-up upgrade

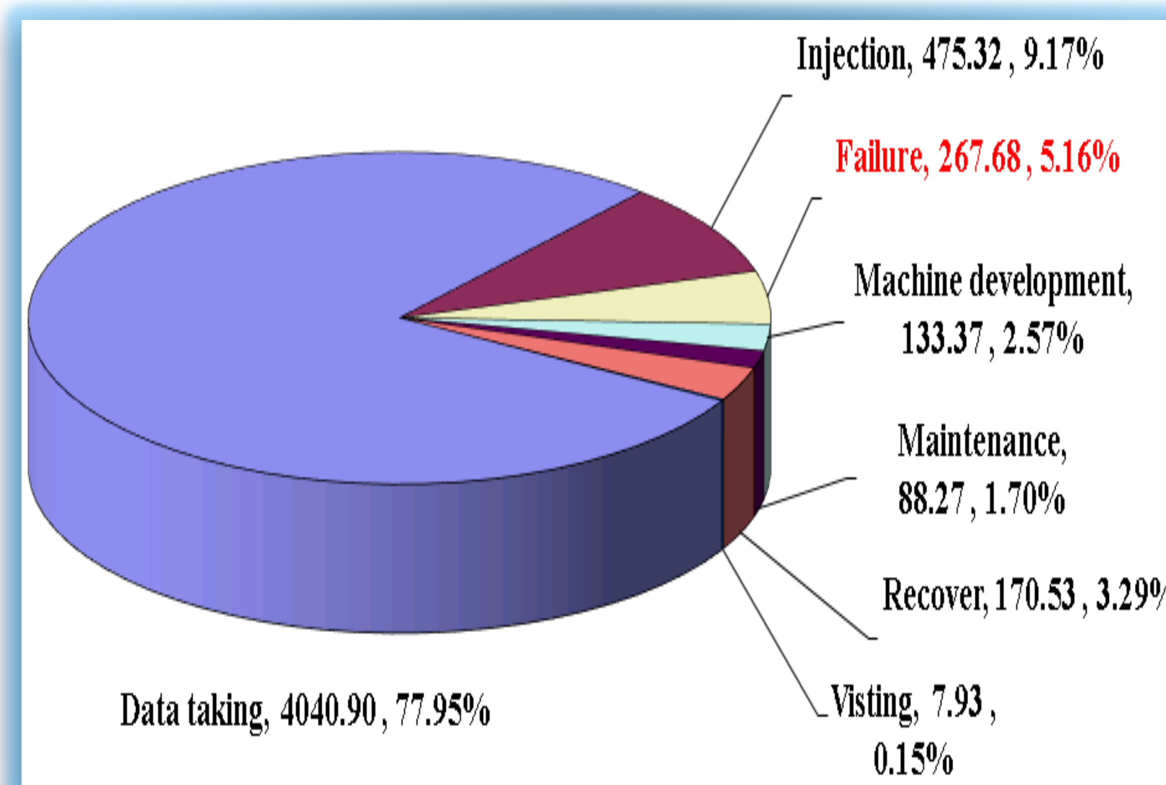
3.5~4.0 fb^{-1}

500 pb^{-1} per point at Ecm= 4.62, 4.64, 4.66, 4.68 and 4.70 GeV
1.0~1.5 fb^{-1} at the maximum cross section of Λ_c

- The BESIII detector finished accumulating a sample of 10 billion J/psi on Feb. 2019.
- XYZ data samples of 3.5~4.0 fb-1 will be taken in 187 days.

Machine Statistics @2018-2019





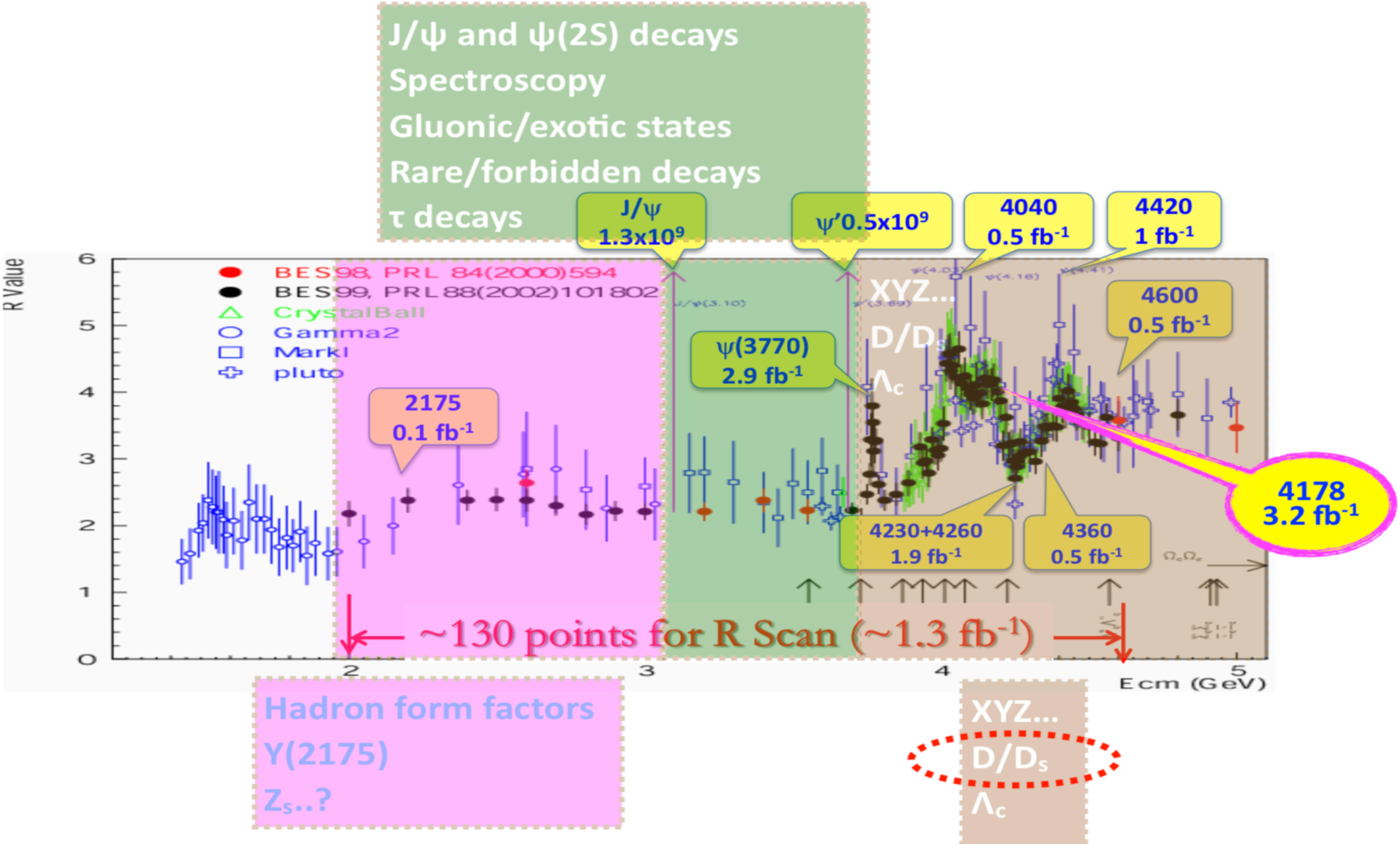
- If BEPCII still keep the same lucky (No serious failure), same high beam power, same high beam performance, and with top-up operation ,

$$\frac{24+20}{2} \times 80\% \times 80\% \times (1+20\%) * 187 = 3160 / pb$$

Average peak integrated Lum. | Average day integrated Lum. | Data taking time | Gain from Topup operation | Operation days

- Expect “miracles” from BEPCII team!

Physics Data



Physics Data

- **2009:** 106 M $\psi(2S)$, 225 M J/ψ
- **2010:** 900 pb^{-1} $\psi(3770)$
- **2011:** 1800 $pb^{-1}\psi(3770)$; 470 pb^{-1}@4.01 GeV
- **2012:** 0.4 billion $\psi(2S)$; 1 billion J/ψ; 100pb^{-1}@R value
- **2013:** 2.0 fb^{-1} Y(4260), 0.5 fb^{-1} Y(4360); 200pb^{-1} @R value
- **2014:** 780pb^{-1}@R value; 500pb^{-1}@4.6GeV; 1.0fb^{-1}@Y(4420); 250pb^{-1}@E_b=2.0~2.3GeV
- **2015:** 100pb^{-1}@E_b=1.08GeV; 500pb^{-1}@R value (1.0~1.6GeV)
- **2016:** 3.0 fb^{-1}@E_b=2.09 GeV
- **2017:** 3.6 fb^{-1}@E_b=2.1~2.2 GeV; 0.2 fb^{-1}@E_b=1.94 GeV; 0.42 fb^{-1}@E_b=1.76 GeV
- **2018:** 1.65 fb^{-1}@E_b=1.55 GeV; 0.5 fb^{-1}@E_b=1.84 GeV
- **2019:** 1.3 fb^{-1}@E_b=1.55 GeV; 3.84 fb^{-1}@E_b=2.06~2.23 GeV

Future Data of the Experiment

Table 7.1: List of data samples collected by BESIII/BEPCII up to 2018, and the proposed samples for the remainder of the physics program.

Energy	Physics Highlight	Current data	Expected final data
1.8 - 2.0 GeV	R values cross-sections	N/A	Scan: 3 energy points
2.0 - 3.1 GeV	R values cross-sections	Scan: 20 energy points	No requirement
J/ψ peak	Light hadron & Glueball Charmonium decays	5.0 billion	10.0 billion
$\psi(3686)$ peak	Light hadron & Glueball Charmonium decays	0.5 billion	3.0 billion
$\psi(3770)$ peak	$D^0/D^\pm$ decays Form-factor/CKM decay constant	2.9 fb^{-1}	20.0 fb^{-1}
3.8 - 4.6 GeV	R value XYZ/Open charm	Scan: 105 energy points	No requirement
4.180 GeV	D_s decay XYZ/Open charm	3.1 fb^{-1}	6.0 fb^{-1}
4.0 - 4.6 GeV	XYZ/Open charm Higher charmonia cross-sections	Scan: 12.0 fb^{-1}	Scan: 30.0 fb^{-1} 10 MeV step/0.5 fb^{-1}/point 30 energy points
4.60 GeV	Λ_c/XYZ	0.56 fb^{-1}	1.0 fb^{-1}
4.64 GeV	Λ_c/XYZ	N/A	5.0 fb^{-1}
4.65 GeV	Λ_c/XYZ	N/A	0.2 fb^{-1}
4.70 GeV	Λ_c/XYZ	N/A	0.65 fb^{-1}
4.80 GeV	Λ_c/XYZ	N/A	1.0 fb^{-1}
4.90 GeV	Λ_c/XYZ	N/A	1.3 fb^{-1}
$\Sigma_c^+\Lambda_c^-$ 4.74 GeV	Charm baryons	N/A	1.0 fb^{-1}
$\Sigma_c\Sigma_c$ 4.91 GeV	Charm baryons	N/A	1.0 fb^{-1}
$\Xi_c\Xi_c$ 4.95 GeV	Charm baryons	N/A	1.0 fb^{-1}

Luminosity upgrade in the near future

Luminosity	Present BEPCII	*2.0	*2.5	*3.0
β^*_y	1.5 cm	1.5cm	1.2cm	1.05cm
Bunch currnt	7mA	9mA	9mA	9mA
Bunch number	80	120	120	120
SR power	125kW	250kW	250kW	250kW
Beam-beam	0.036	0.04	0.04	0.04
RF voltage	1.6 MV	2.2 MV	> 3.4 MV	> 4.0 MV
ν_s	0.028	0.033	0.041	0.044
HOM power	7.7 kW	19.1 kW	29.7 kW	38.8 kW
RF cavity		1 new RFC/ring	2 RFC/ring	2 new RFC/ring
Coupling	1	1	*0.8	*0.7
Dynamic	1	1	*0.8	*0.7
Beam lifetime	2 hr	1 hr	0.64 hr	0.5 hr
Cost		¥100M	¥130M	¥150M
RISK		*	**	***

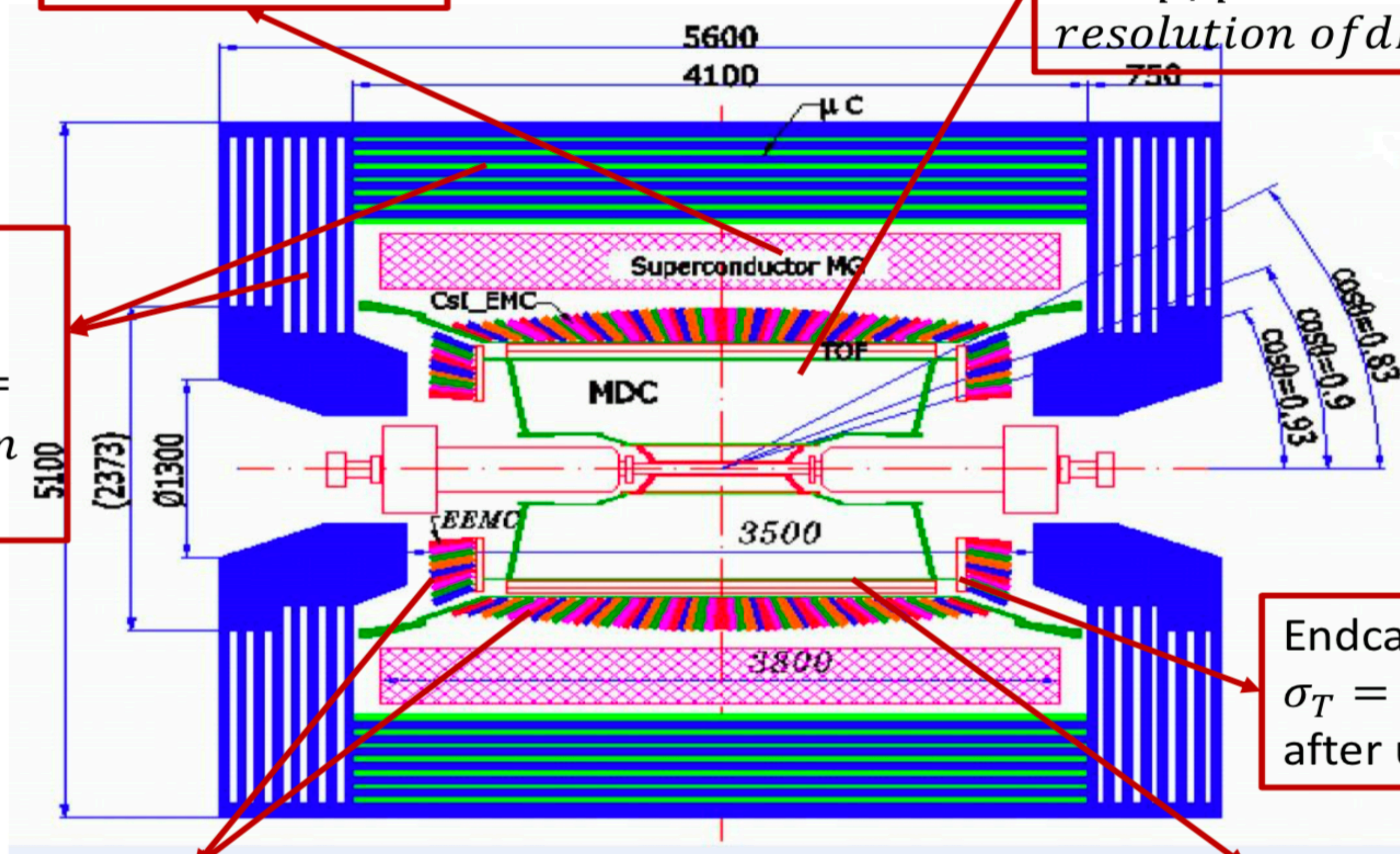
Dedicated for the beam energy above 2.1GeV. 3~4 years after the project is approved.

BESIII

SC Magnet: 1T

MDC: $\sigma_{r\phi} = 115\mu m$
$\Delta p/p = 0.47\%@1GeV$
$resolution\ of dE/dx\ = 5.2\%$

Barrel and endcap Muon counter: $\sigma_{r\phi} = 14mm \sim 15mm$
$\sigma_z \sim 17mm$



Endcap TOF:
$\sigma_T = 54ps \sim 60ps$
after upgrade

Barrel and endcap EMCAL
$\Delta E/E = 2.5\%\ @1GeV\ , \sigma = 6\ mm/\sqrt{E}$

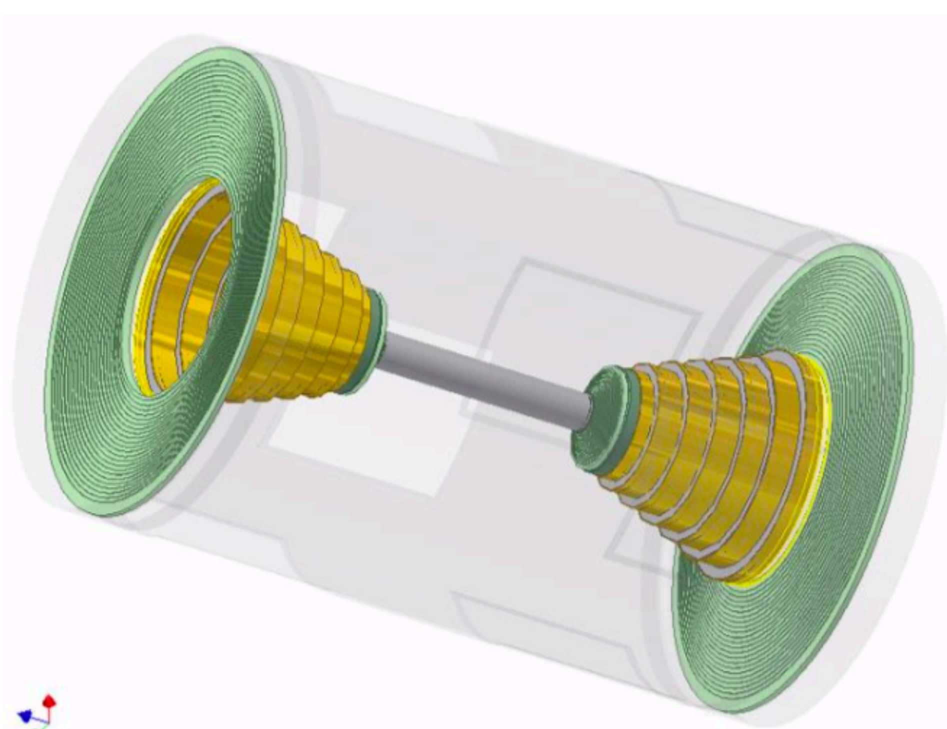
Barrel TOF:
$\sigma_T = 67 \sim 70\ ps$

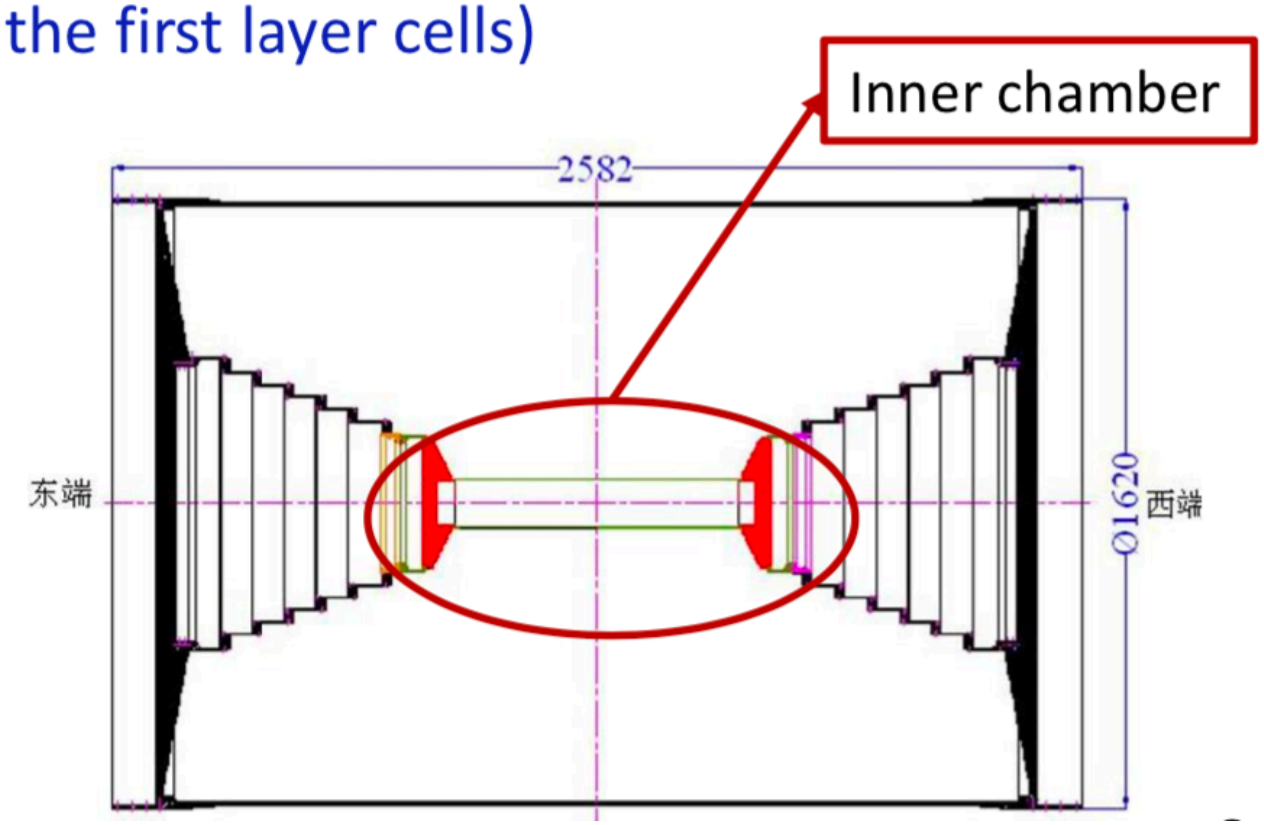
- General purpose detector at BEPCII, $E_{cm} \approx$ 2-4.6 GeV, $L_{peak} \approx 10^{33}/cm^2/s$
- Versatile researches in τ-charm physics

MDC

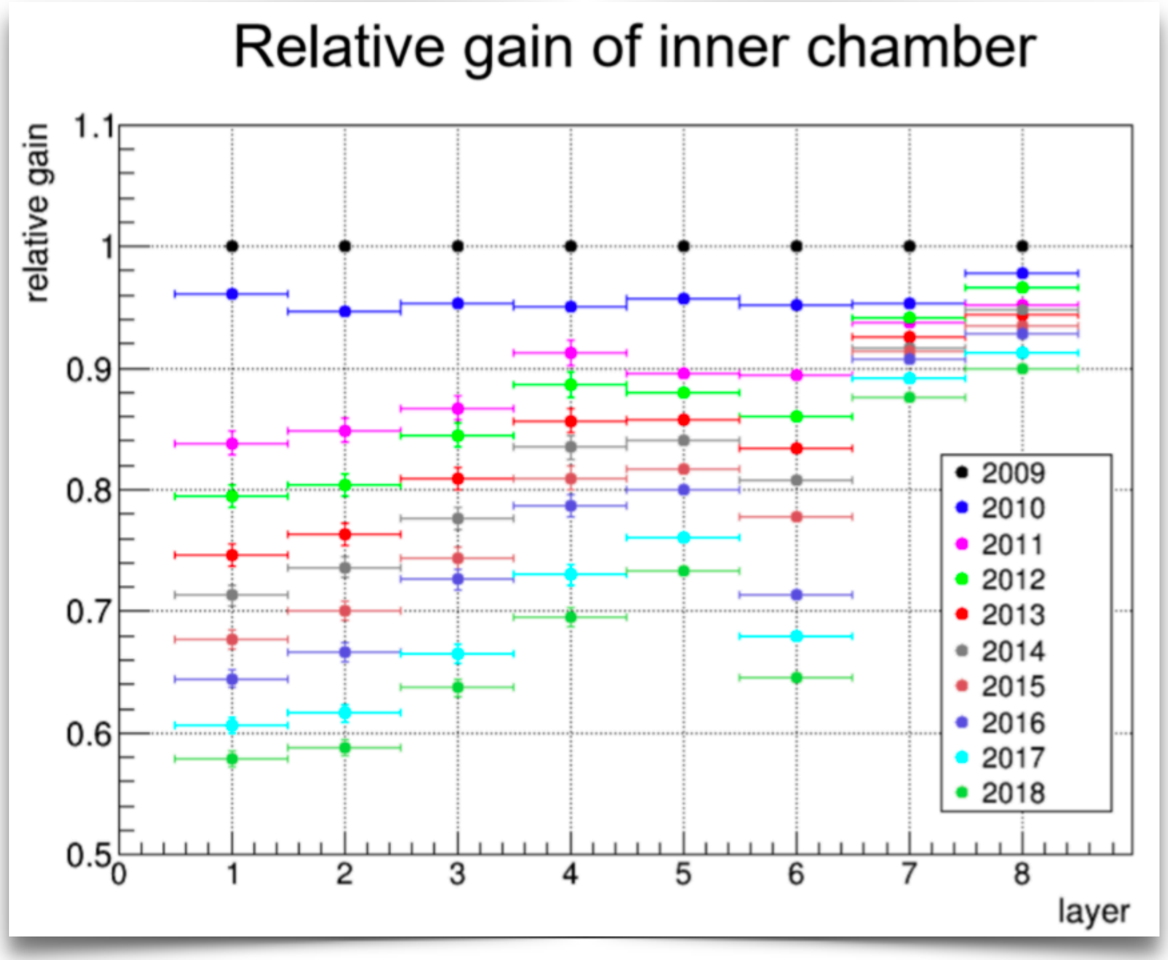
- Main tracking detector for the charged particles: position, momentum and dE/dx measurements
- Inner chamber (8 layers)+ outer chamber (35 layers)
- Operating gas: He/C_3H_8=60/40
- Cell size: 12mm×12mm for inner chamber; 16.2 mm×16.2mm for outer chamber
- Aging problems of the MDC
  - Cathode aging: Malter discharge (cured in 2012)
  - Anode aging: the gains of the cells decrease with the increase of the cell accumulated charges every year

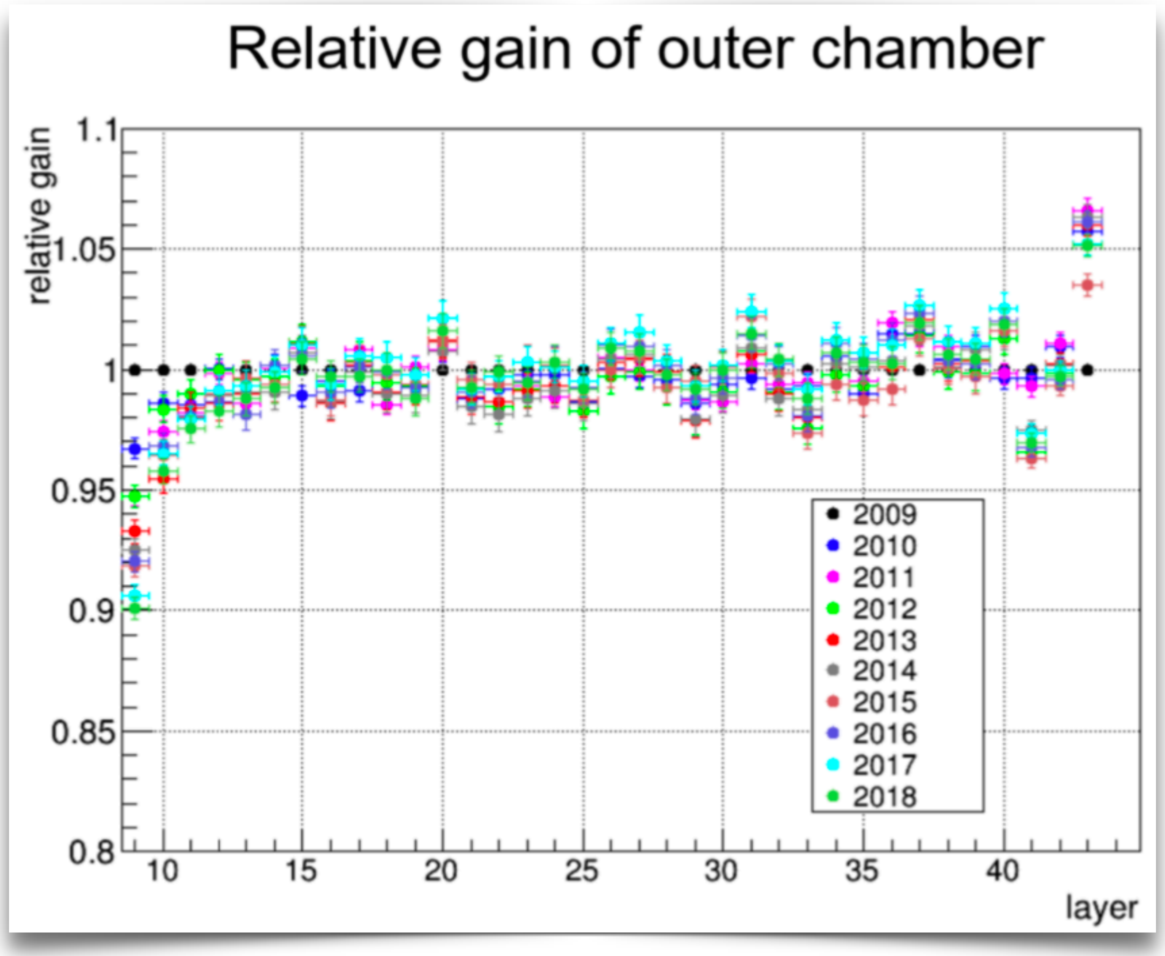
  gain dropped dramatically (42% for the first layer cells)





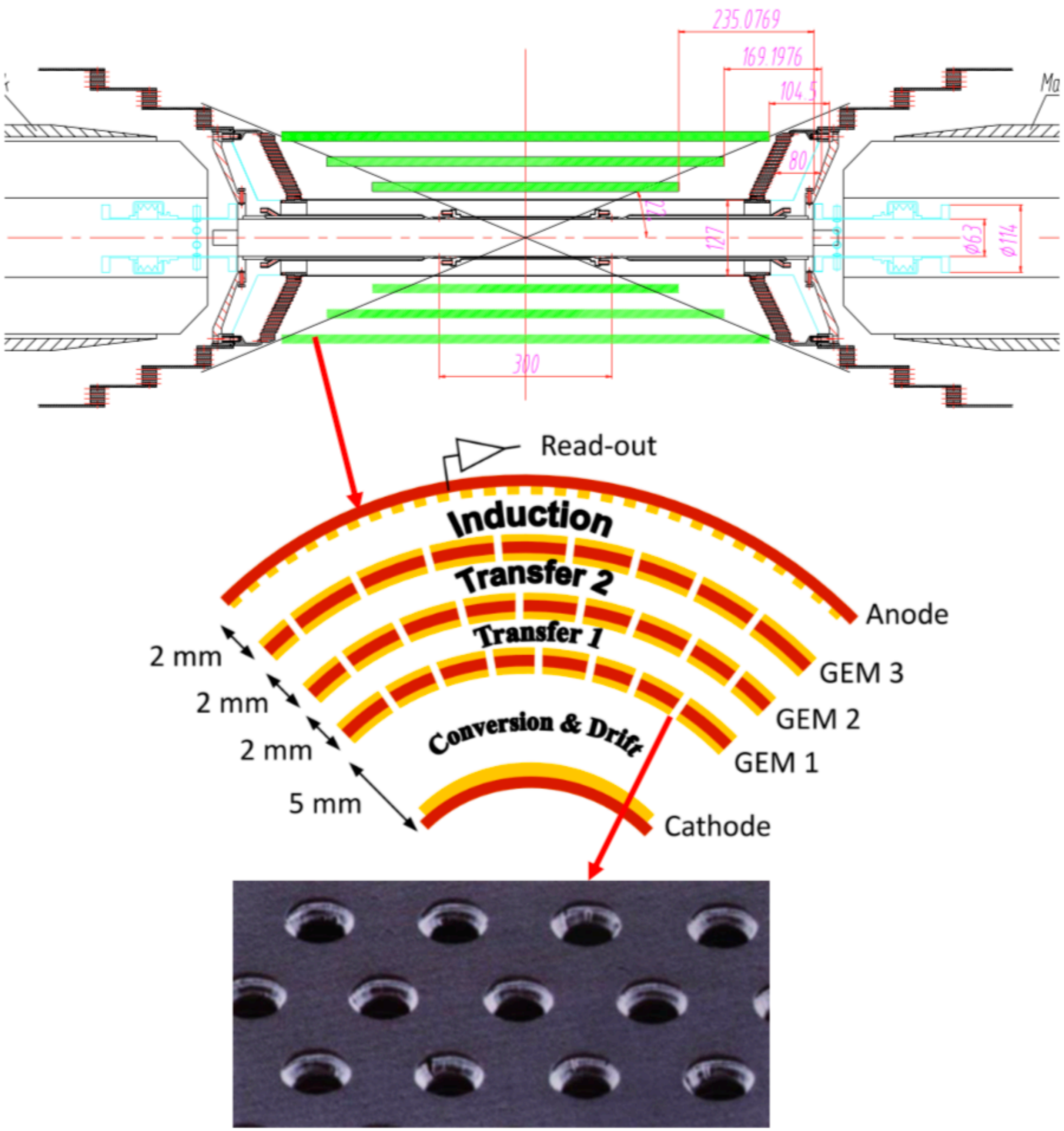
Gain Decrease of the Cells / Years





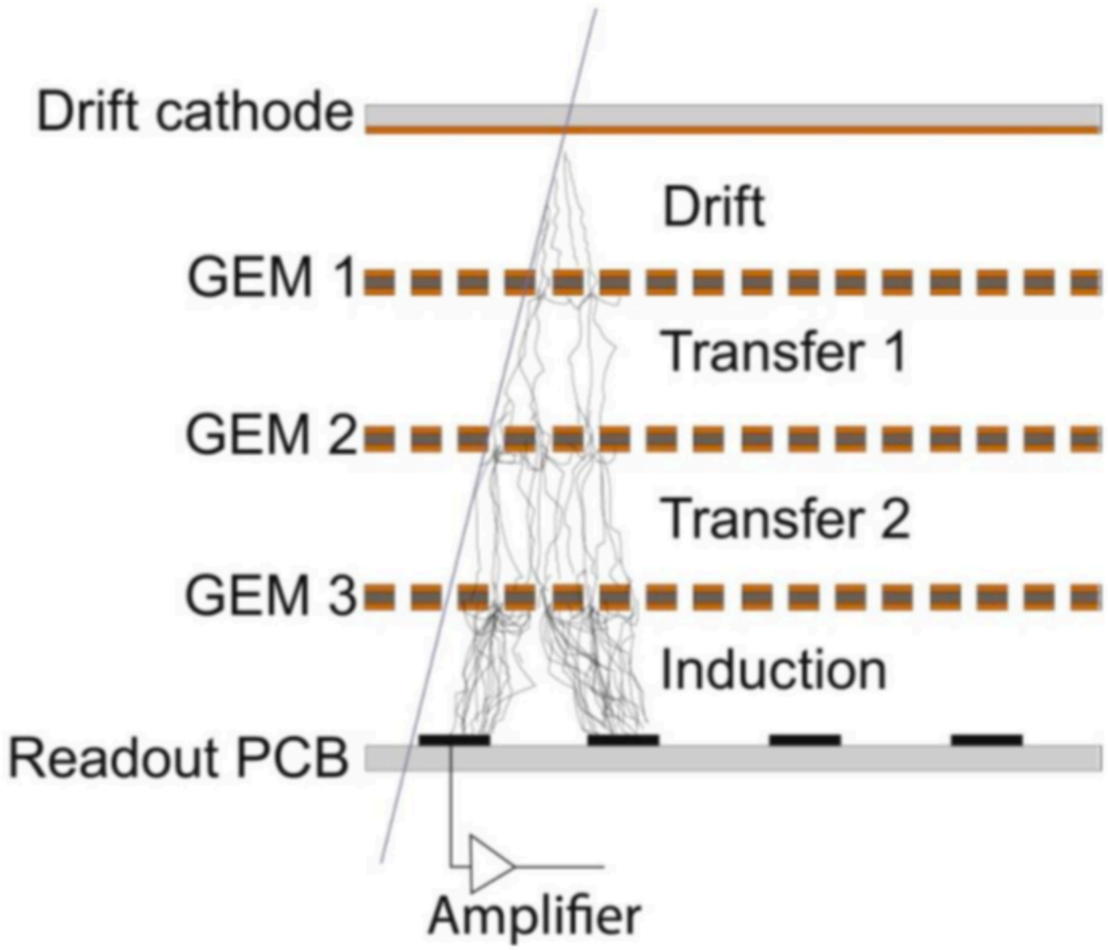
- The Q peak changes of the cells in each year are got from Bhabha events, which give the gain decrease
- The gains of the first 10 layers experience an obvious decrease, reaching a maximum decrease of about 42% for the first layer cells.
- The other layer cells of the outer chamber have almost no change

New Inner: CGEM



- Layout: three layers
- Low Material budget: ≤1.5% of X_0 For all layers
- Momentum resolution: σ_{Pt}/P_t = ~0.5%@1GeV
- High Rate capability: ~10^4 Hz/cm^2
- Coverage: 93%
- Spatial resolution: $\sigma_{r\varphi}$: 130 -150μ m, σ_z<1mm
- 1 T magnetic filed
- Operation duration: at least 5 years
- Active area
  - – L1 length 532mm
  - – L2 length:690mm
  - – L3 length:847mm
- Inner radius:78mm
- Outer radius:178mm

Why CGEM

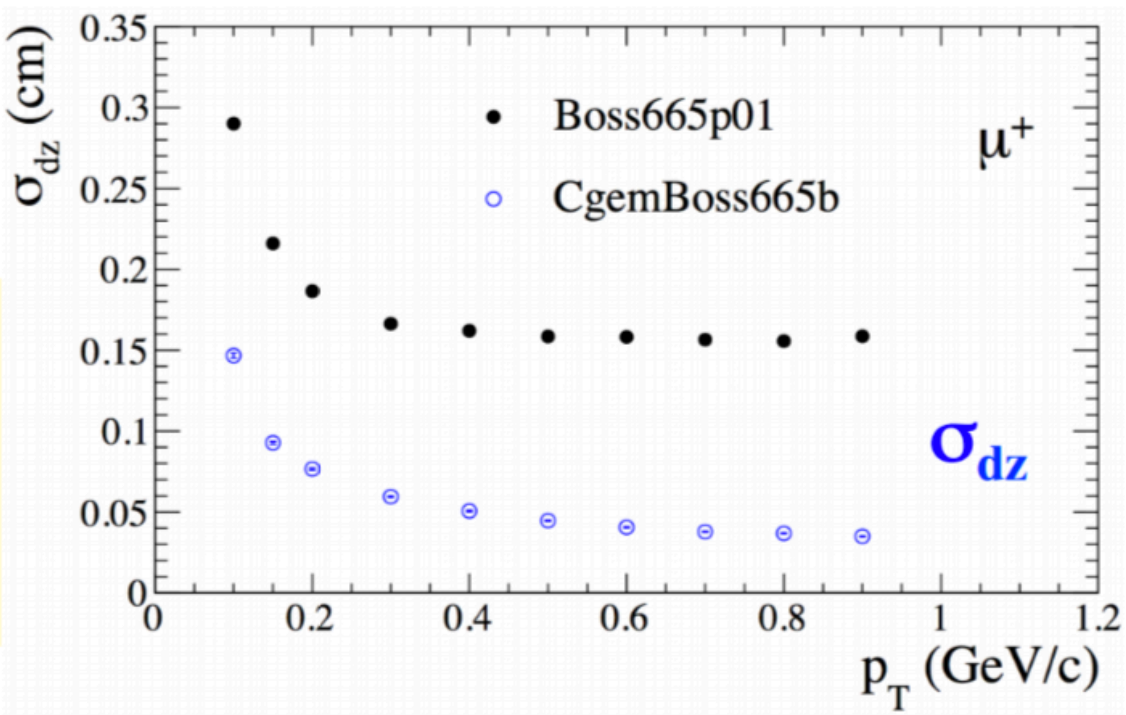


- High particle rates
- Less sensitive to the aging
- Significantly improvement of σ_z
- Less background expected
  - The volume for primary ionization is 6-7 time smaller
- Improvements from Micro-TPC reconstruction [Springer Proc.Phys. 213 (2018) 116-119]

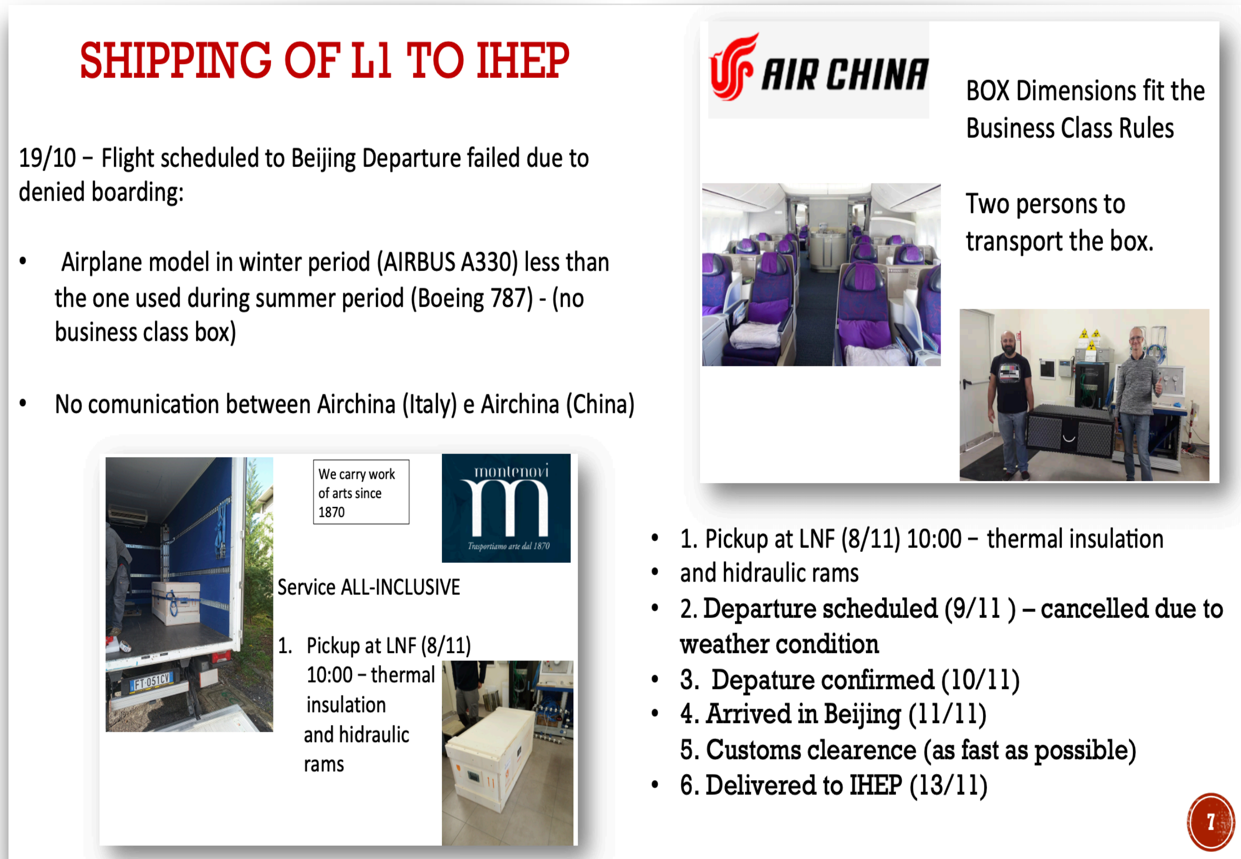
CGEM- inner tracker, new technology

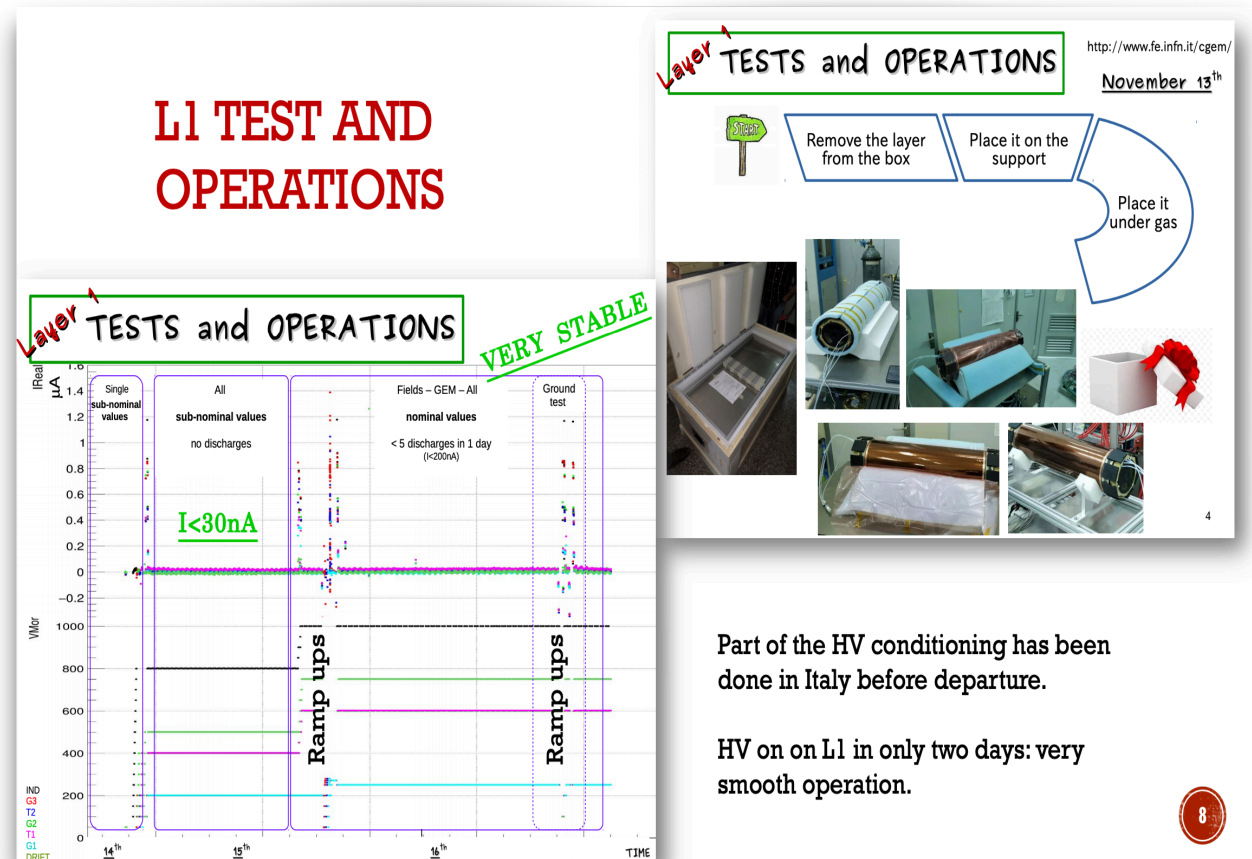
In BESIII, first used

- lower material budget: 0.4% X_0
- Analog readout, charge +time

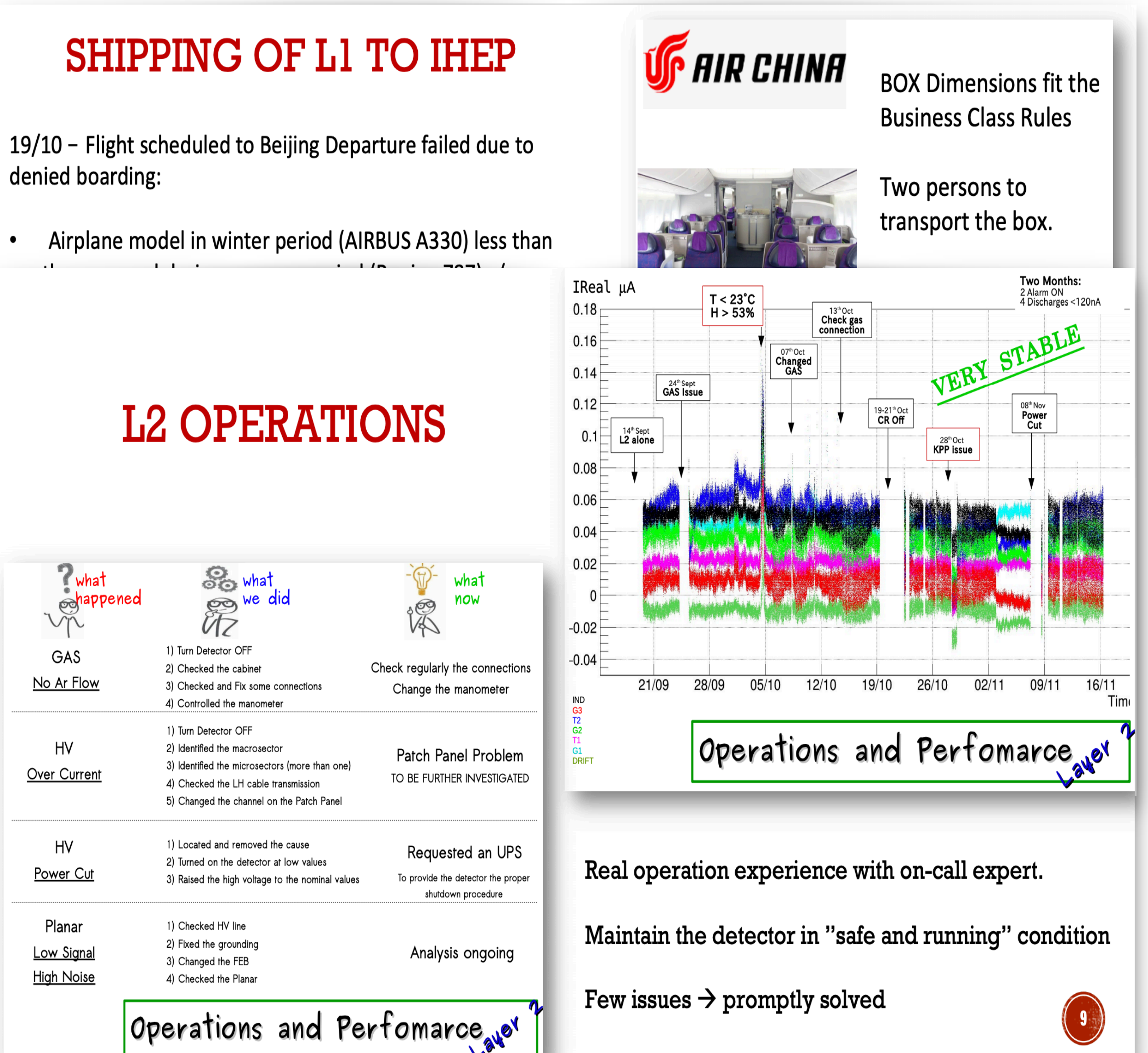


CGEM Status


SHIPPING OF L1 TO IHEP
19/10 – Flight scheduled to Beijing Departure failed due to denied boarding:
• Airplane model in winter period (AIRBUS A330) less than the one used during summer period (Boeing 787) - (no business class box)
• No comunication between Airchina (Italy) e Airchina (China)
AIR CHINA
BOX Dimensions fit the Business Class Rules
Two persons to transport the box.
We carry work of arts since 1870
montenovi
Service ALL-INCLUSIVE
1. Pickup at LNF (8/11) 10:00 – thermal insulation and hidraulic rams
• 1. Pickup at LNF (8/11) 10:00 – thermal insulation
• and hidraulic rams
• 2. Departure scheduled (9/11) – cancelled due to weather condition
• 3. Depature confirmed (10/11)
• 4. Arrived in Beijing (11/11)
5. Customs clearence (as fast as possible)
• 6. Delivered to IHEP (13/11)
7


L1 TEST AND OPERATIONS
Layer 1 TESTS and OPERATIONS
VERY STABLE
Single sub-nominal values
All sub-nominal values
no discharges
Fields – GEM – All nominal values
< 5 discharges in 1 day (I<200nA)
Ground test
I<30nA
Ramp ups
Ramp ups
http://www.fe.infn.it/cgem/
November 13th
Remove the layer from the box
Place it on the support
Place it under gas
Part of the HV conditioning has been done in Italy before departure.
HV on on L1 in only two days: very smooth operation.
8

CGEM Status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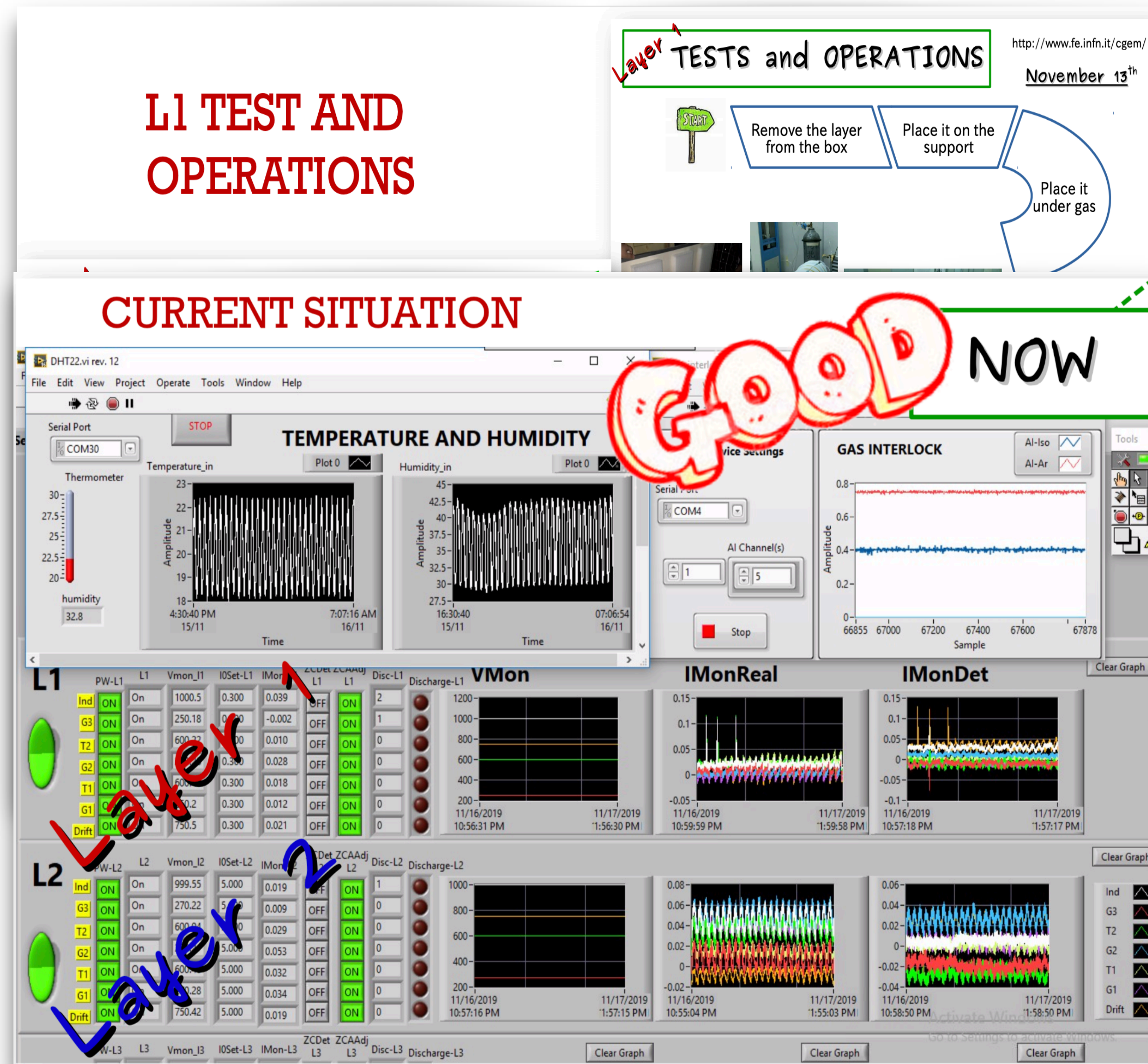
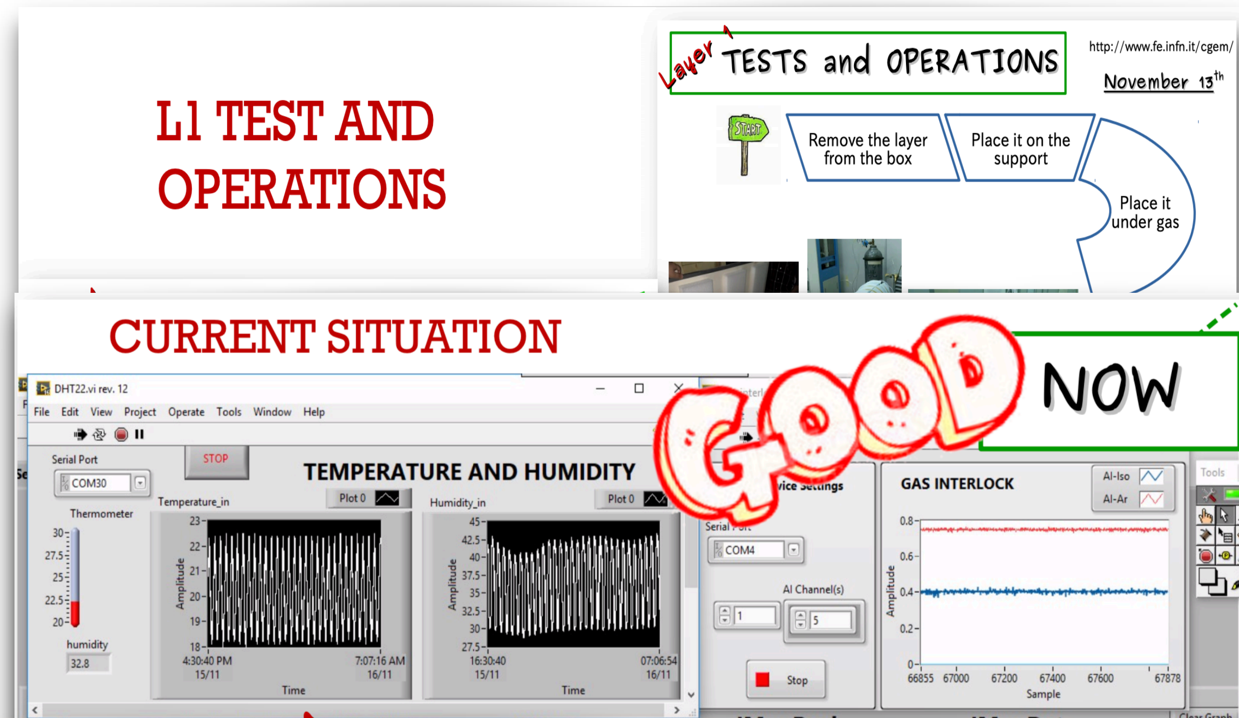
19/10 – Flight scheduled to Beijing Departure failed due to denied boarding:
• Airplane model in winter period (AIRBUS A330) less than
AIR CHINA
BOX Dimensions fit the Business Class Rules
Two persons to transport the box.
L2 OPERATIONS
what happened
what we did
what now
GAS
No Ar Flow
1) Turn Detector OFF
2) Checked the cabinet
3) Checked and Fix some connections
4) Controlled the manometer
Check regularly the connections
Change the manometer
HV
Over Current
1) Turn Detector OFF
2) Identified the macrosector
3) Identified the microsectors (more than one)
4) Checked the LH cable transmission
5) Changed the channel on the Patch Panel
Patch Panel Problem
TO BE FURTHER INVESTIGATED
HV
Power Cut
1) Located and removed the cause
2) Turned on the detector at low values
3) Raised the high voltage to the nominal values
Requested an UPS
To provide the detector of the proper shutdown procedure
Planar
Low Signal
High Noise
1) Checked HV line
2) Fixed the grounding
3) Changed the FEB
4) Checked the Planar
Analysis ongoing
Operations and Perfomarce Layer 2
IReal µA
T < 23°C
H > 53%
VERY STABLE
Two Months:
2 Alarm ON
4 Discharges <120nA
14° Sept L2 alone
24° Sept GAS Issue
07° Oct Changed GAS
13° Oct Check gas connection
19-21° Oct CR Off
28° Oct KPP Issue
08° Nov Power Cut
21/09
28/09
05/10
12/10
19/10
26/10
02/11
09/11
16/11
Time
Operations and Perfomarce Layer 2
Real operation experience with on-call expert.
Maintain the detector in "safe and running" condition
Few issues → promptly solved


L1 TEST AND OPERATIONS
Layer 1 TESTS and OPERATIONS
http://www.fe.infn.it/cgem/
November 13th
Remove the layer from the box
Place it on the support
Place it under gas
CURRENT SITUATION
GOOD NOW
TEMPERATURE AND HUMIDITY
GAS INTERLOCK
L1
L2
VMon
IMonReal
IMonDet
Layer 1
Layer 2

CGEM Status

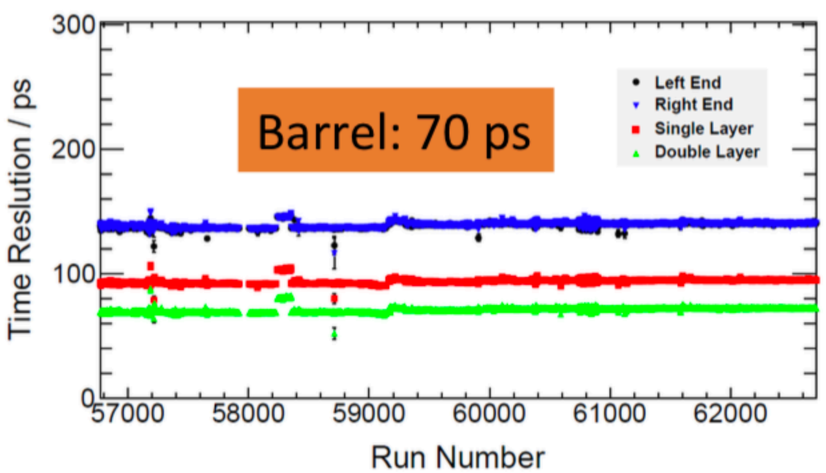


SUMMARY

- Detector
  - L1 arrived at IHEP → smoothly at nominal values
  - L2 smooth operations at IHEP
  - L3 under construction (ready by mid January)
- Detector-electronics integration and system readout → improvements on stability, monitoring and reliability of the system
- As usual the software part will be covered by Liangliang (see his talk in the next session)
- For more details, see slides from the last workshop at https://indico.ihep.ac.cn/event/10925/

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

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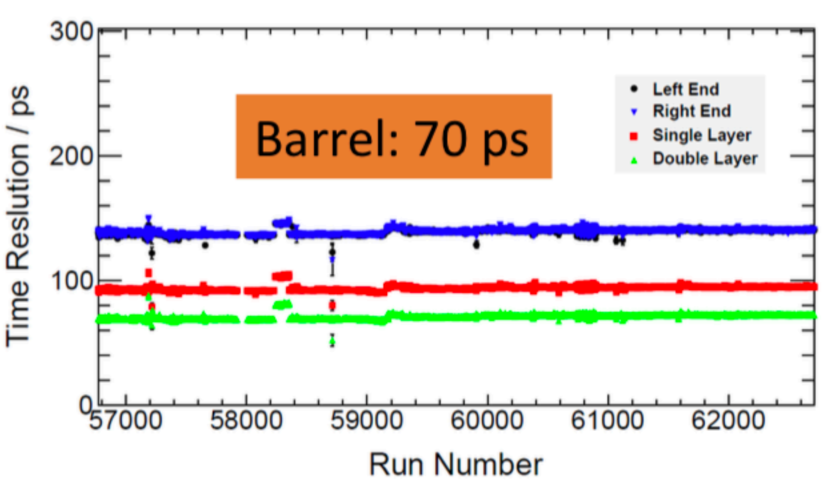
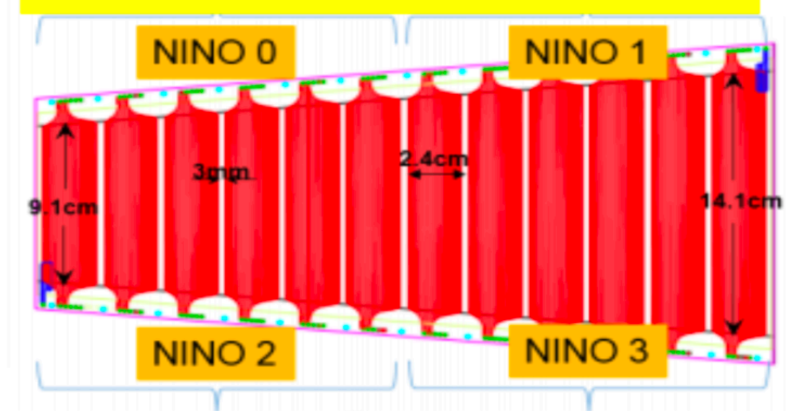


- BTOF has a good and stable time resol
- Aging effect cause efficiency lost. HV v

- New ETOF was installed into BESIII successfully in summer 2015
  - MRPC detector
  - Two layers at each end cap
  - Two 72 modules
- Work stably during the past three years

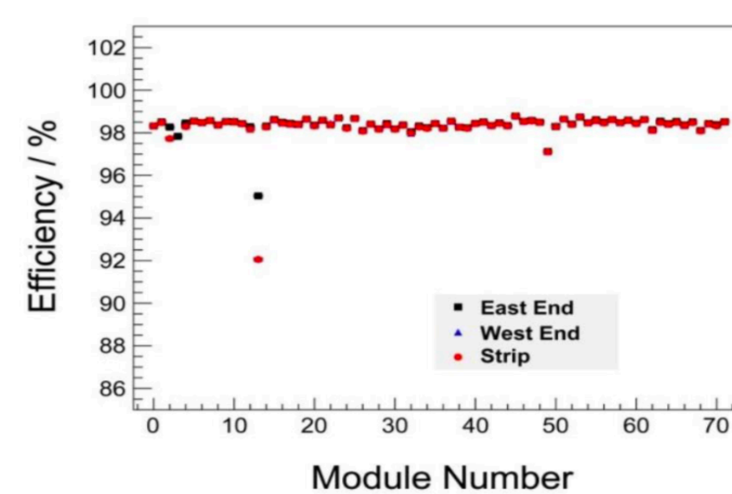
For one module: 4 NINO chips, 12 strips with two end readout



Detector performance

Year	Resolution(ps)	Efficiency
2016	60	~98%
2017	58	~98%
2018	54	~98%

The resolution change is related to energy point, bunch length etc.



stable

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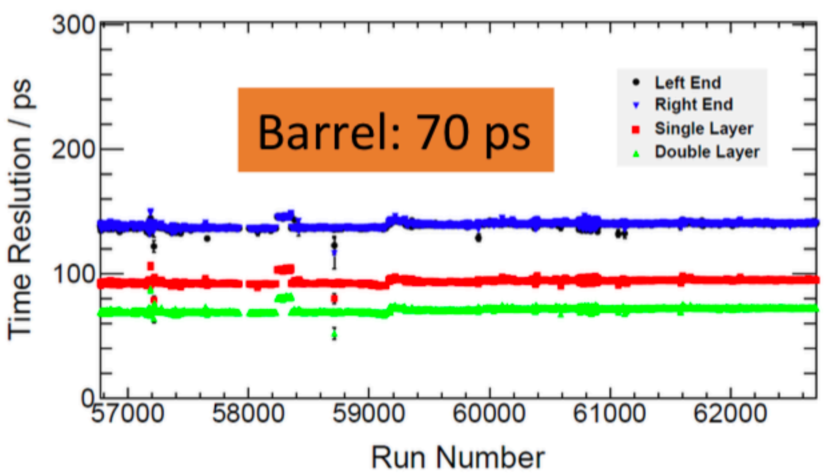

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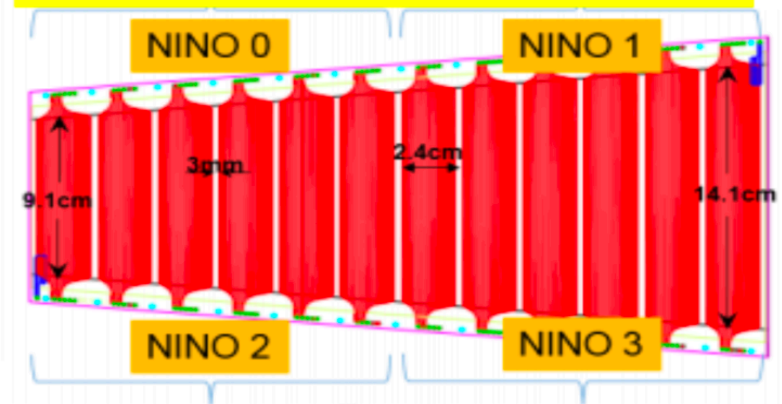

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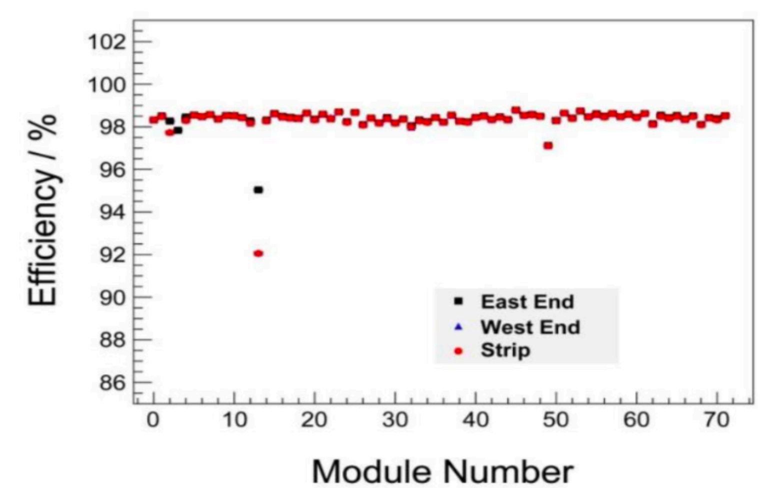
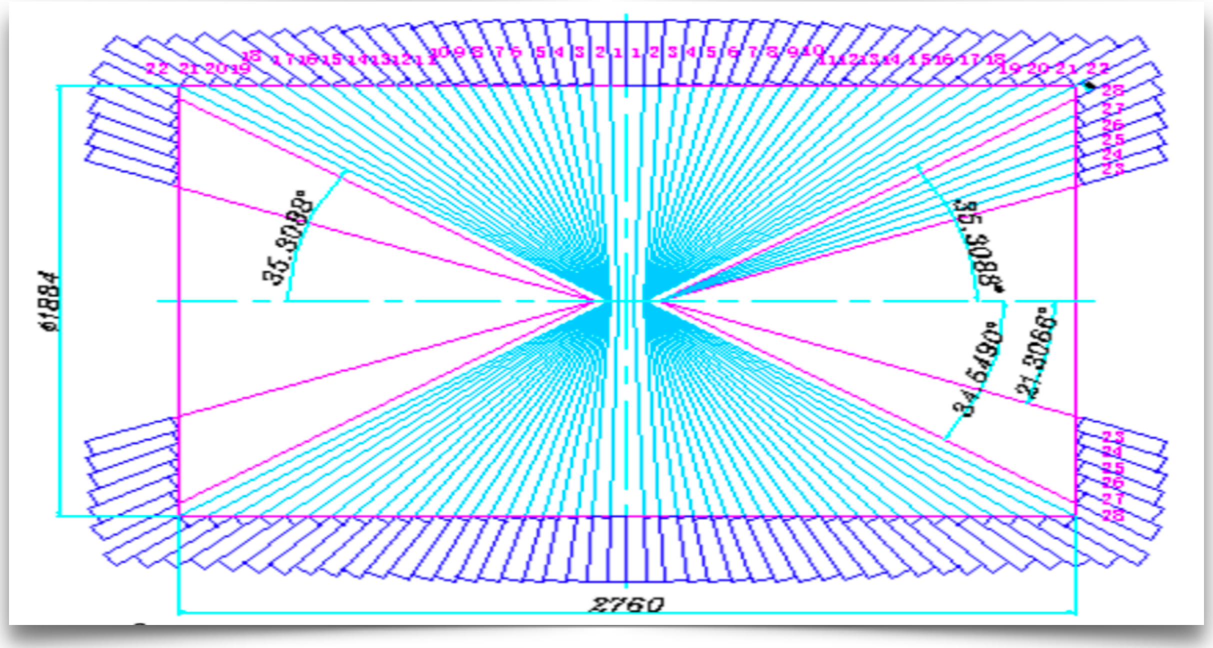
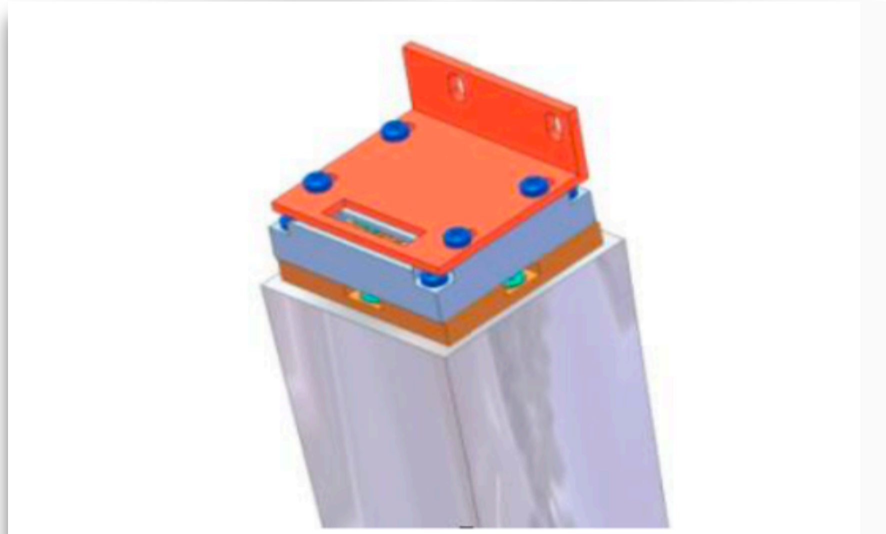
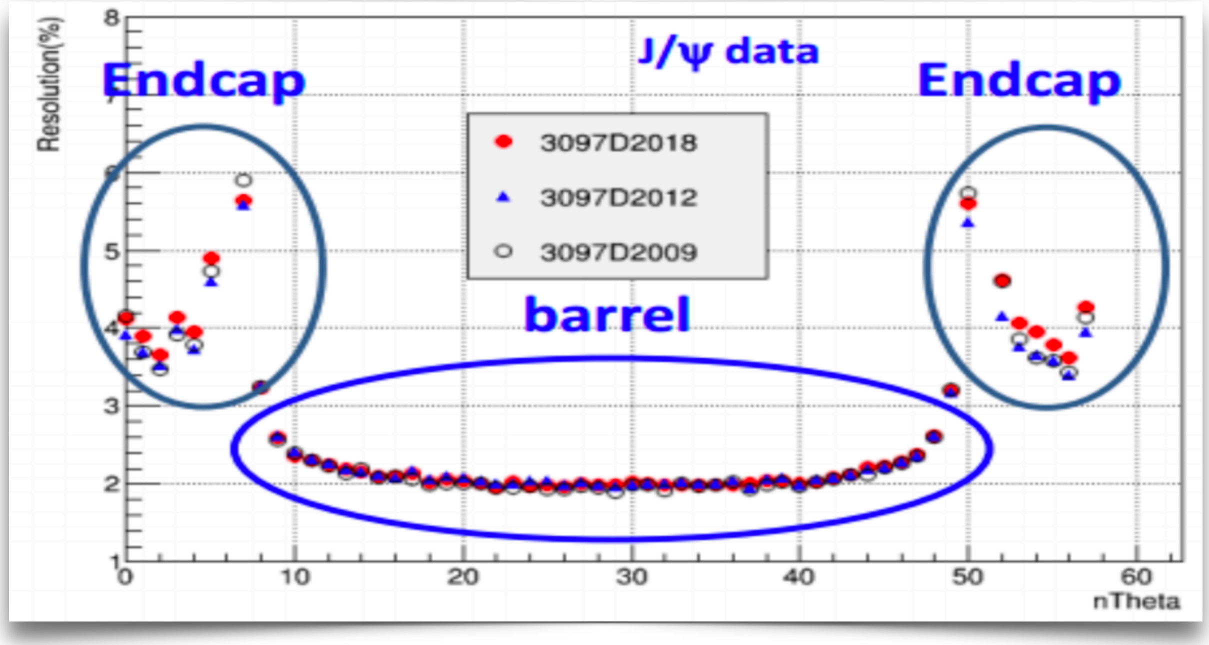


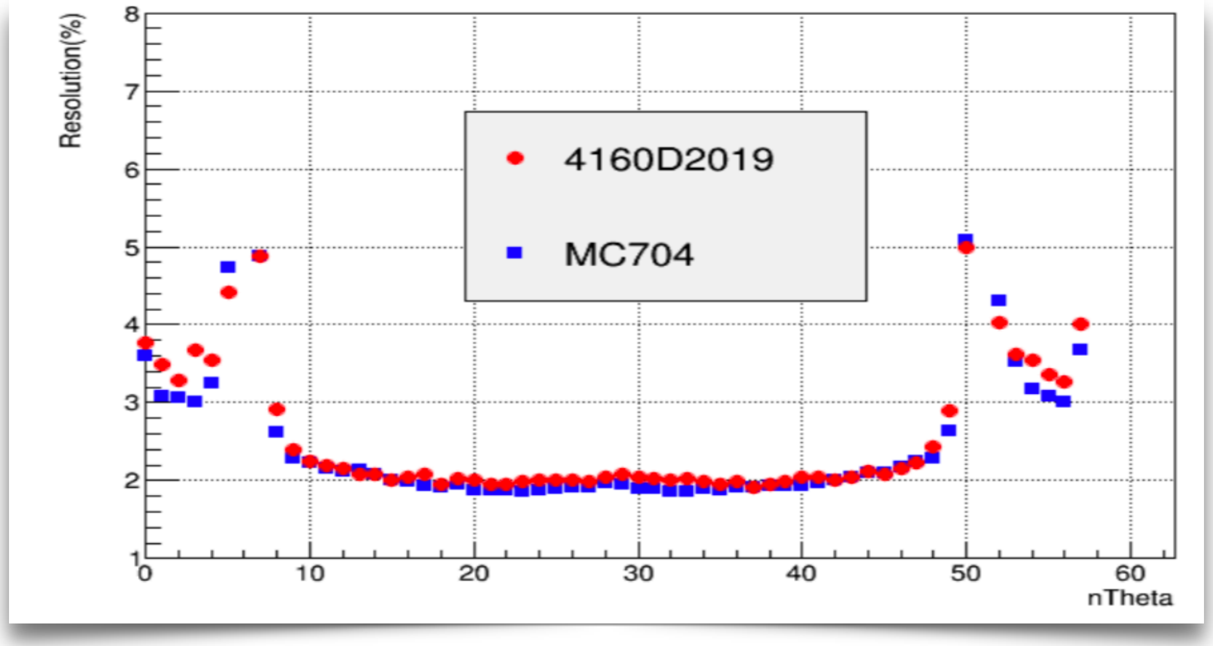
EMC





suspended without supporting wall

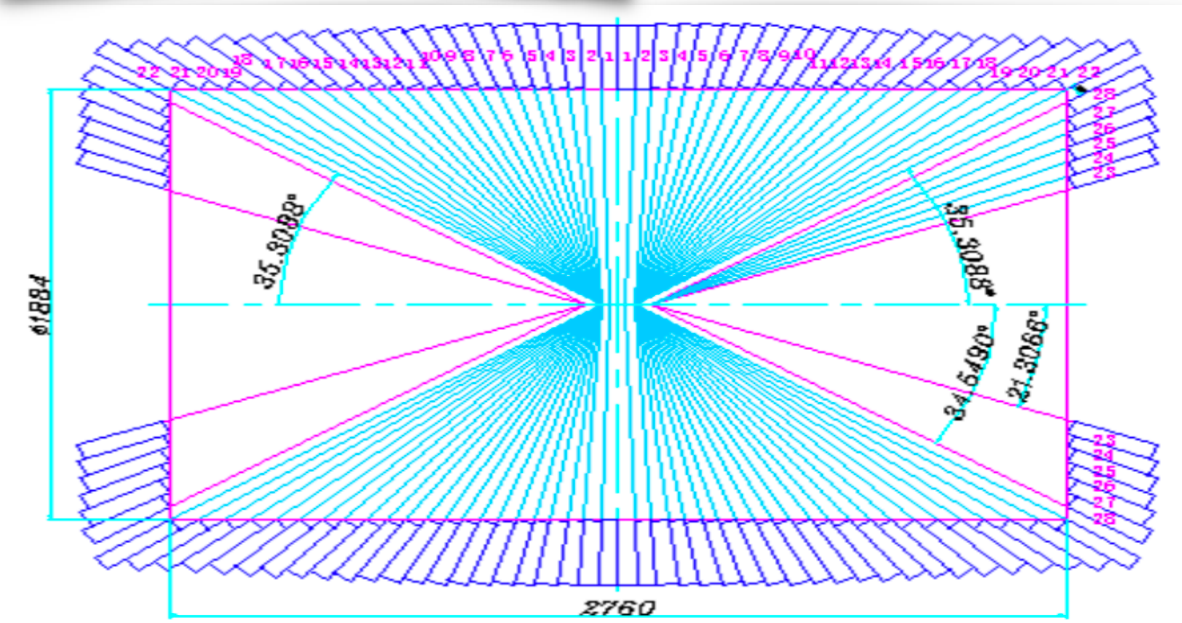


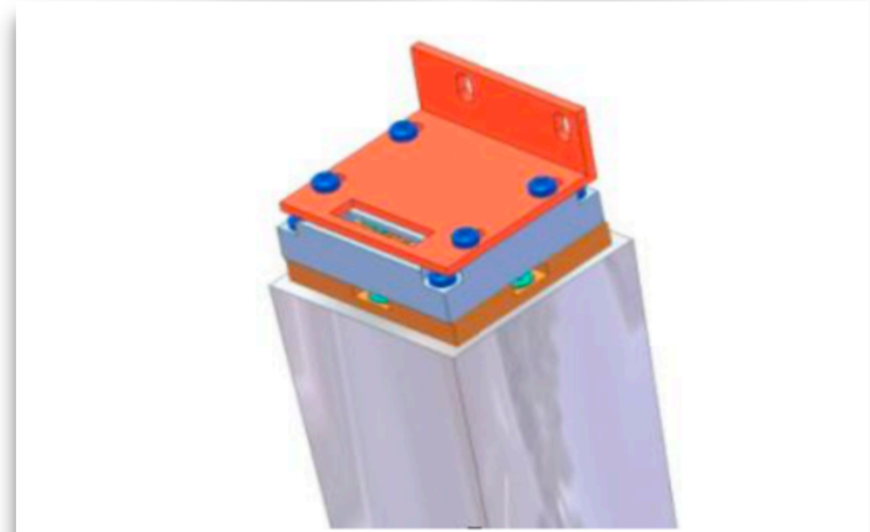


- Barrel + 2 Endcaps [5280+960 modules in total]
- CsI (Tl) Crystal + Hamamatsu S2744-08 Photodiode
- The performance of EMC is stable during the past 11 years.
- The energy resolution of most modules did not change obviously.
- All of the 6240 CsI(Tl) crystal modules worked well. No dead channel was found

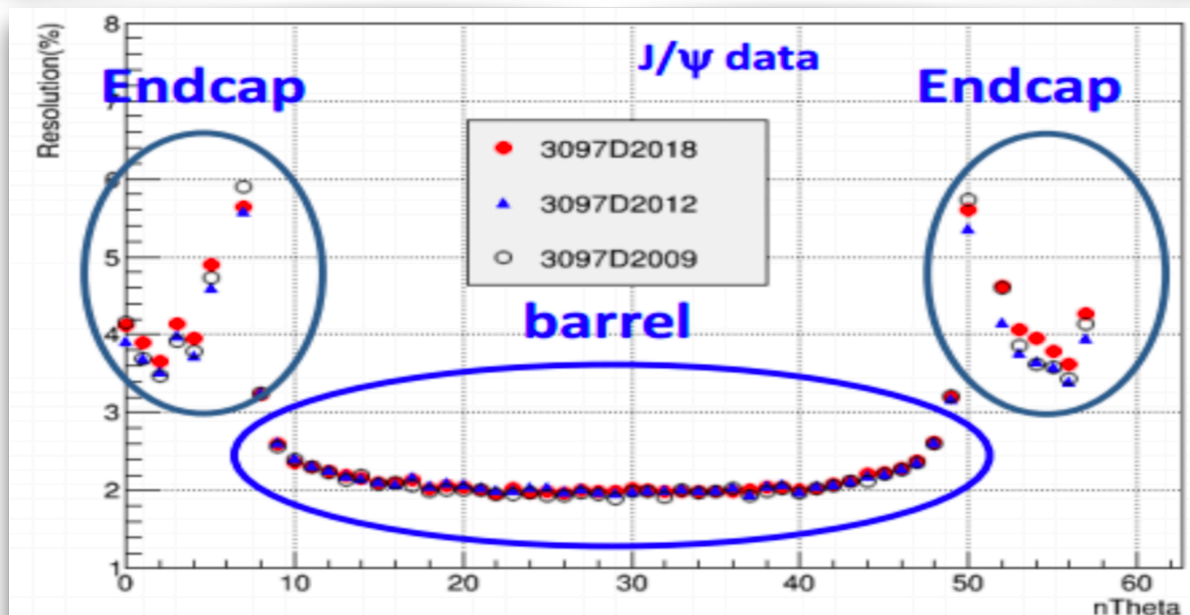
stable

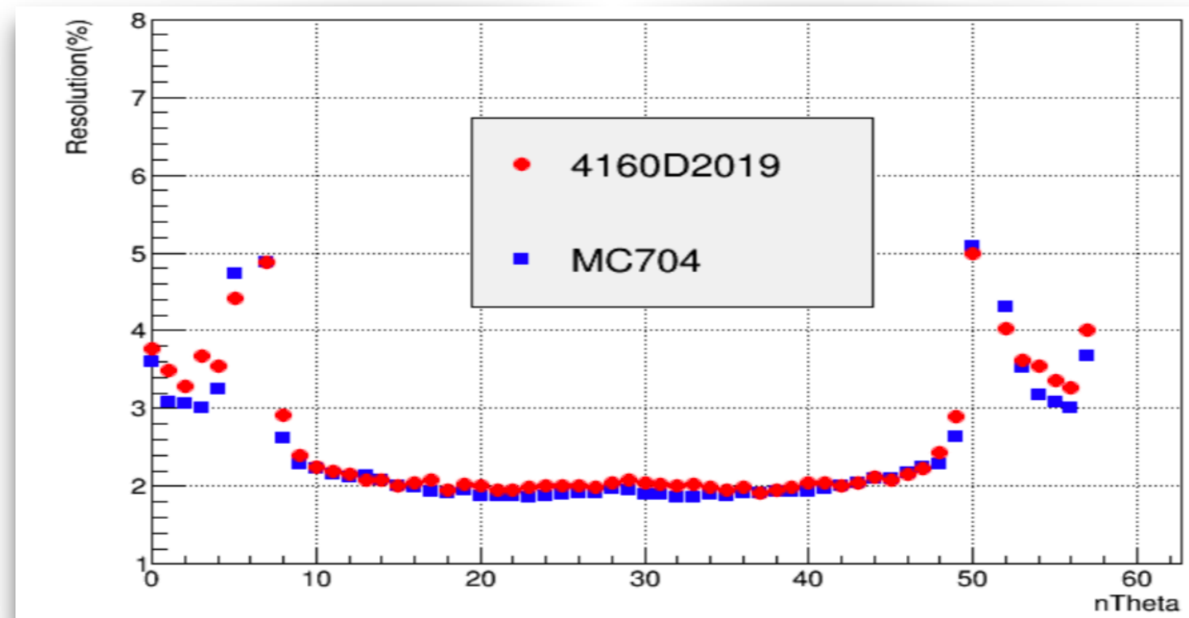
EMC





suspended without supporting wall





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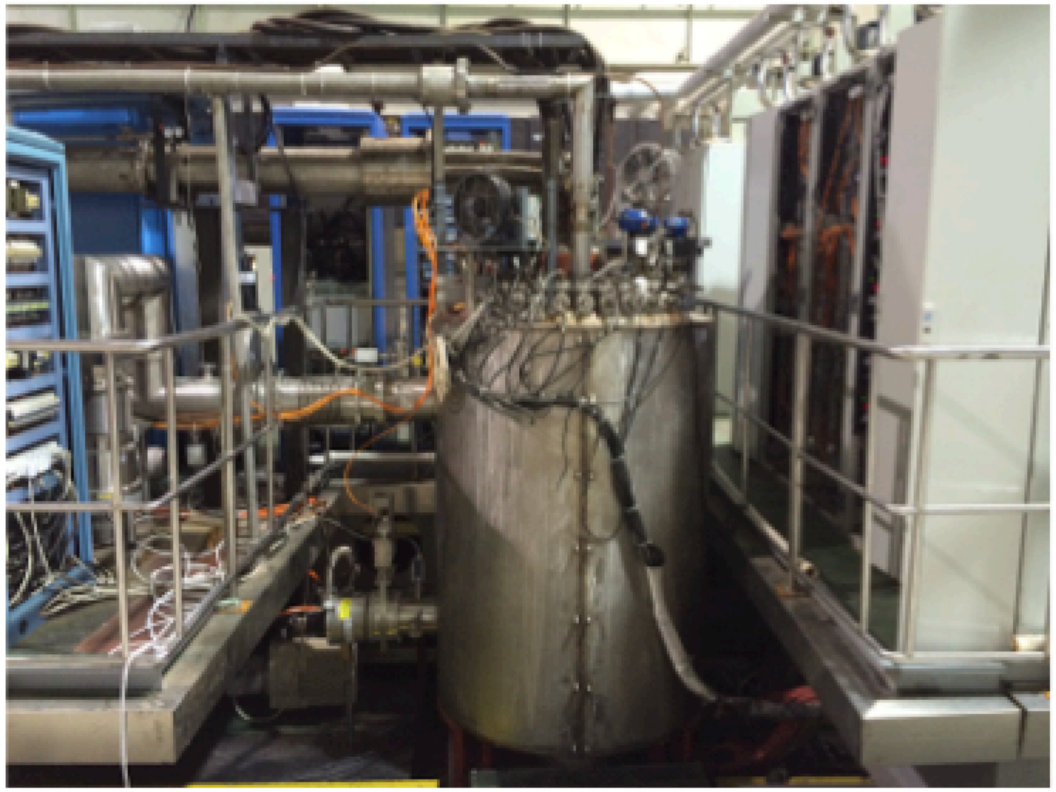
SC Magnetic

SSM: Providing background magnetic field for detector (the largest single superconducting magnet in China@2008)
Operating: 7 months/year since 2008

Central magnetic field	1 Tesla
Operating current	3369A
Field uniformity	5%
Coil diameter	2980mm

- Operating Status
- Past 10 years, total 37 quenches:
  - 19 cryogenic system failure
  - 5 electricity power failure
  - 6 caused by SCQ magnet quench
  - 2 quench detector failure
  - 1 vacuum failure
  - 1 operation error
  - 3 unknown (during ramping up/ down)
- 2018-2019 Run:
  - NO quench this run
  - Excited on 12th Nov. 2018
  - Discharged on 20th June. 2019

The valve box is the transitional connecting of the superconducting coil and room temperature equipment, including electrical, low temperature pipeline, vacuum, quench protection, and monitoring system.



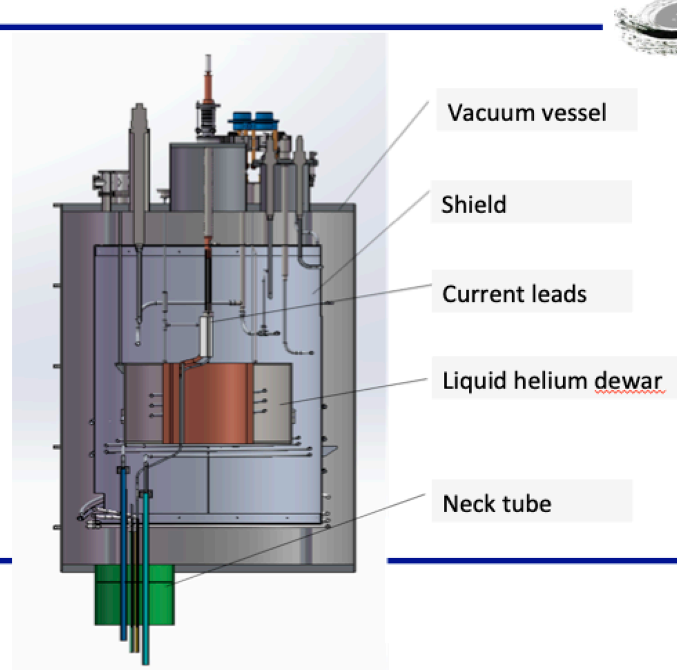
More than 10 years stable running of BESIII detector magnet.
Aging problems become more obvious, and there are potential risks of long period operating.

SC Magnetic

Design of new valve box ---Requirements

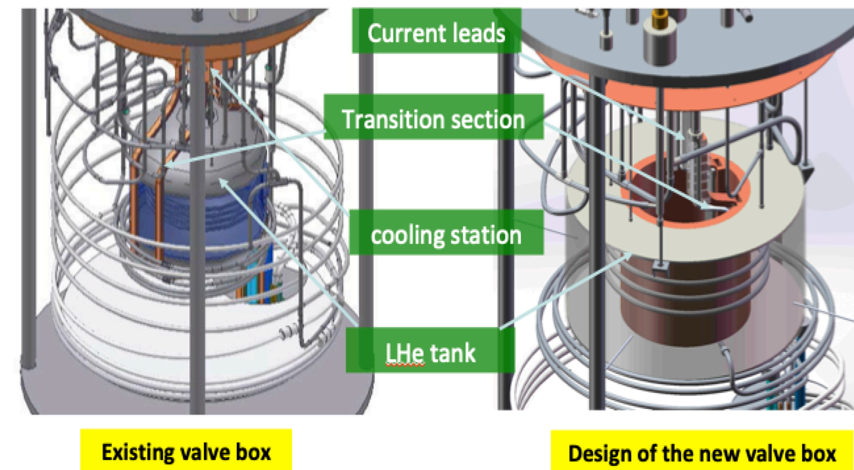
Requirements:

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

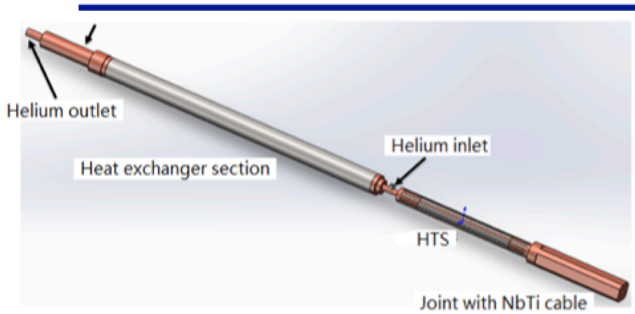


Design of new valve box --- Technical improvements

- HTS 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

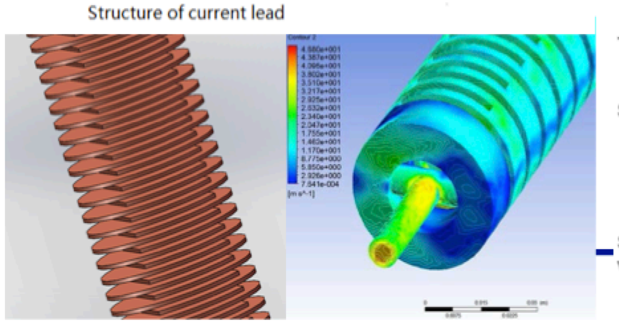


New current leads

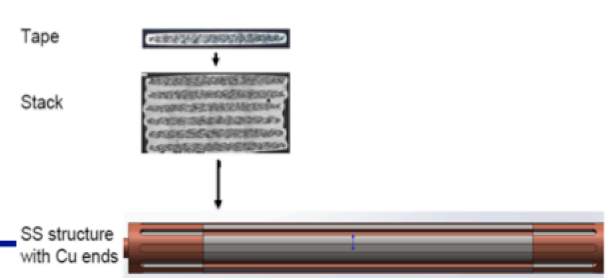


Structure of current lead

- Operating current: 4000A
- Structure: binary current leads
- Heat exchange section: OFHC Fin Heat Exchanger (50K-300K) ,cooled by helium gas
- HTS Component: YBCO Soldered Stacked Conductor (4K-50K)
- LTS Component: Conduction Cooling



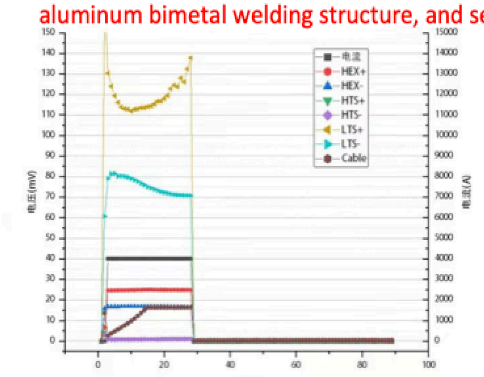
Simulation for Fin HEX Component



HTS stack structure

Offline test results

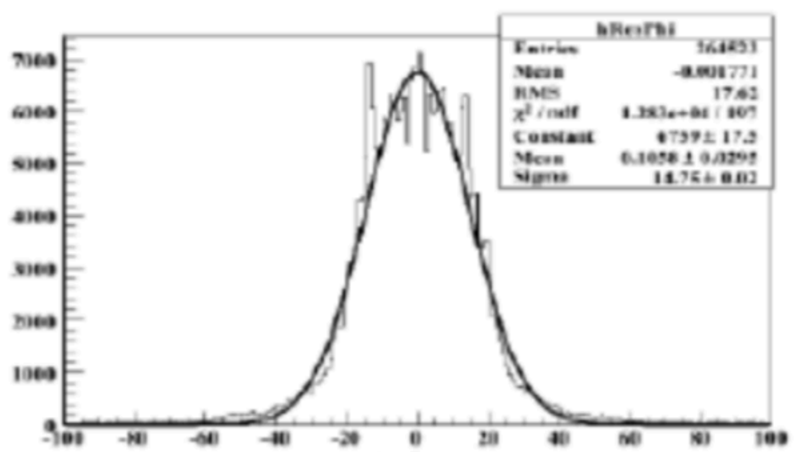
- Vacuum Dewar is temporarily sealed with silica gel, and the vacuum value amount to~ 10-4Pa. No leakage of low temperature pipeline, include the insulators.
- Operating current 4000A, the voltage of heat exchanger are 25mV and 18mV,the voltage of HTS is 1.2mV and 0.9mV. Binary current leads perform well.
- The joint resistance between the lower end of current lead and superconducting cable is too large to keep the cable temperature lower than 6K. Change the joint to copper aluminum bimetal welding structure, and second test is in preparation.

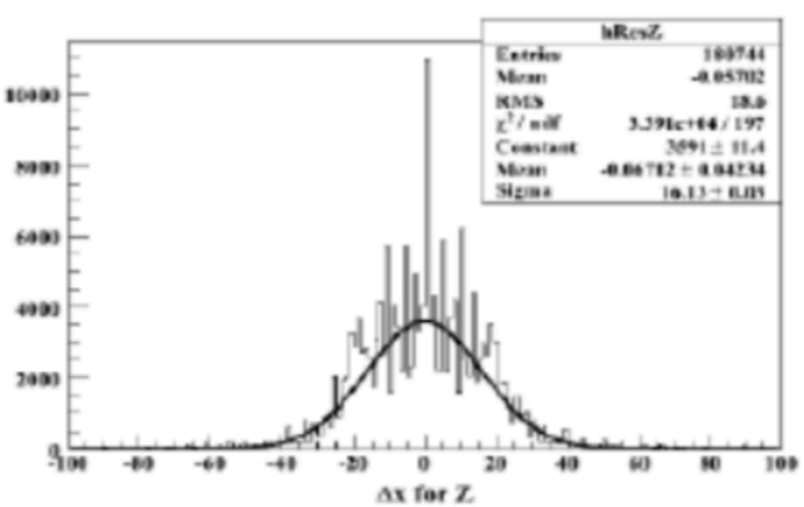


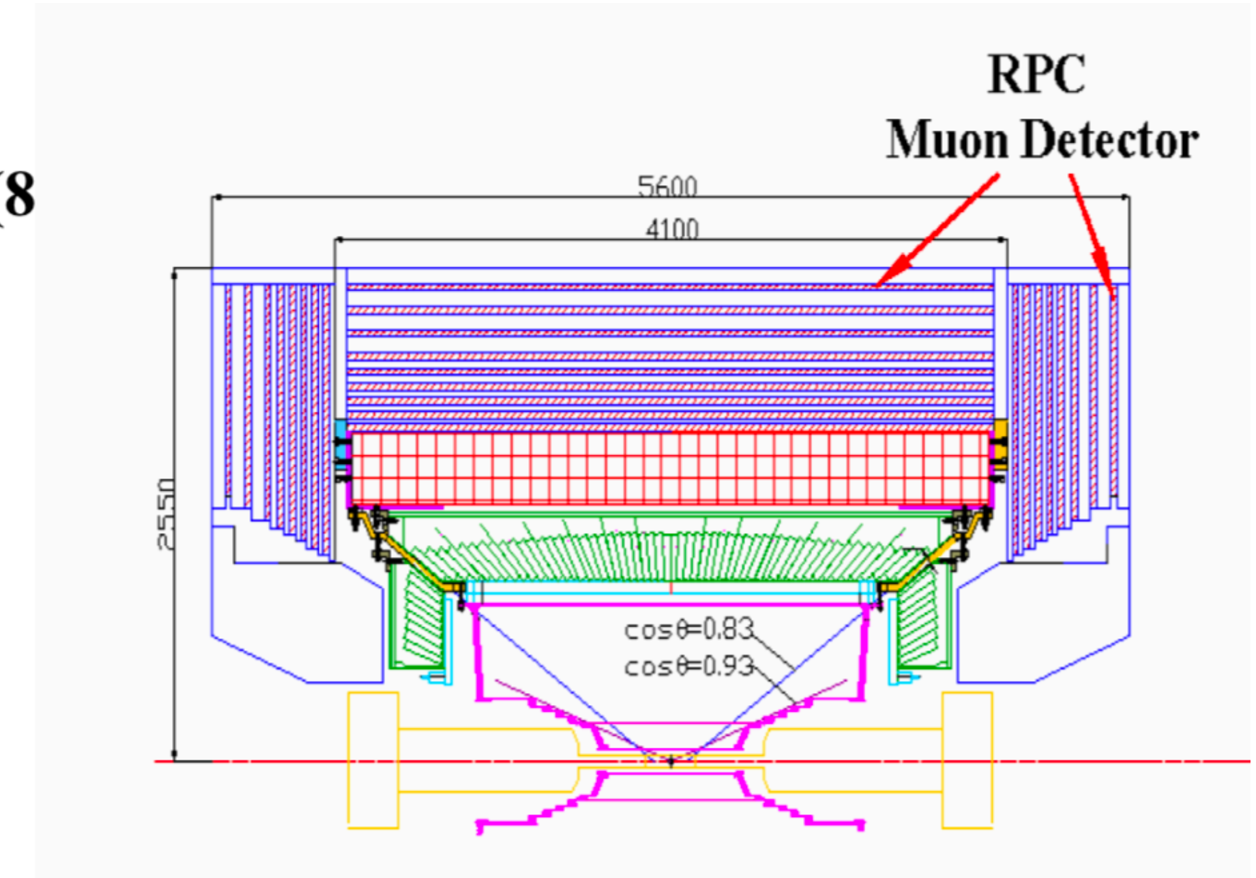
New valve box was developed, and offline test was carried out in Oct. 2019, vacuum and current leads perform well.

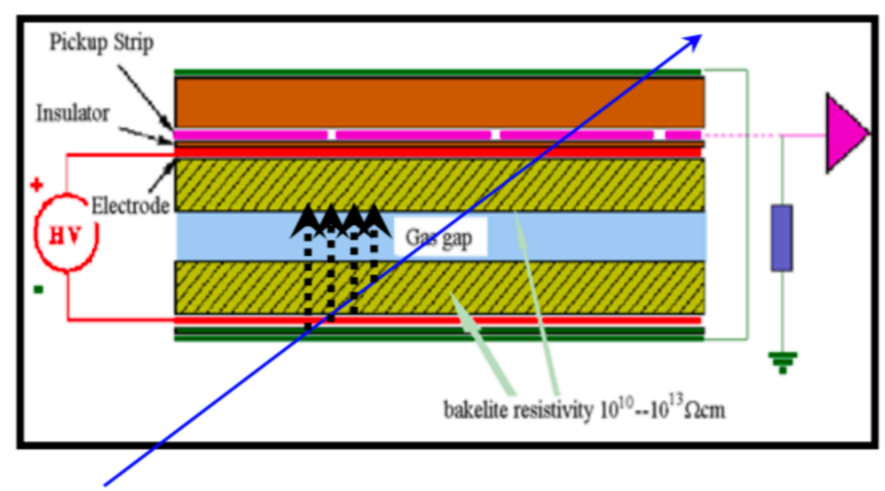
MUC

- **Barrel (9layers)+ two end cap (8 layers)**
- **2000 m² RPC**
- **4cm read out strips,**
- **~9000 channels**
- $\sigma_{r\phi} = 14mm\text{~}15mm, \quad \sigma_z\text{~}17mm$









Electronics system worked well in 2018.

Muon Counter worked stable in 2018.

stable

MUC

- **Barrel (9layers)+ two end cap (8 layers)**
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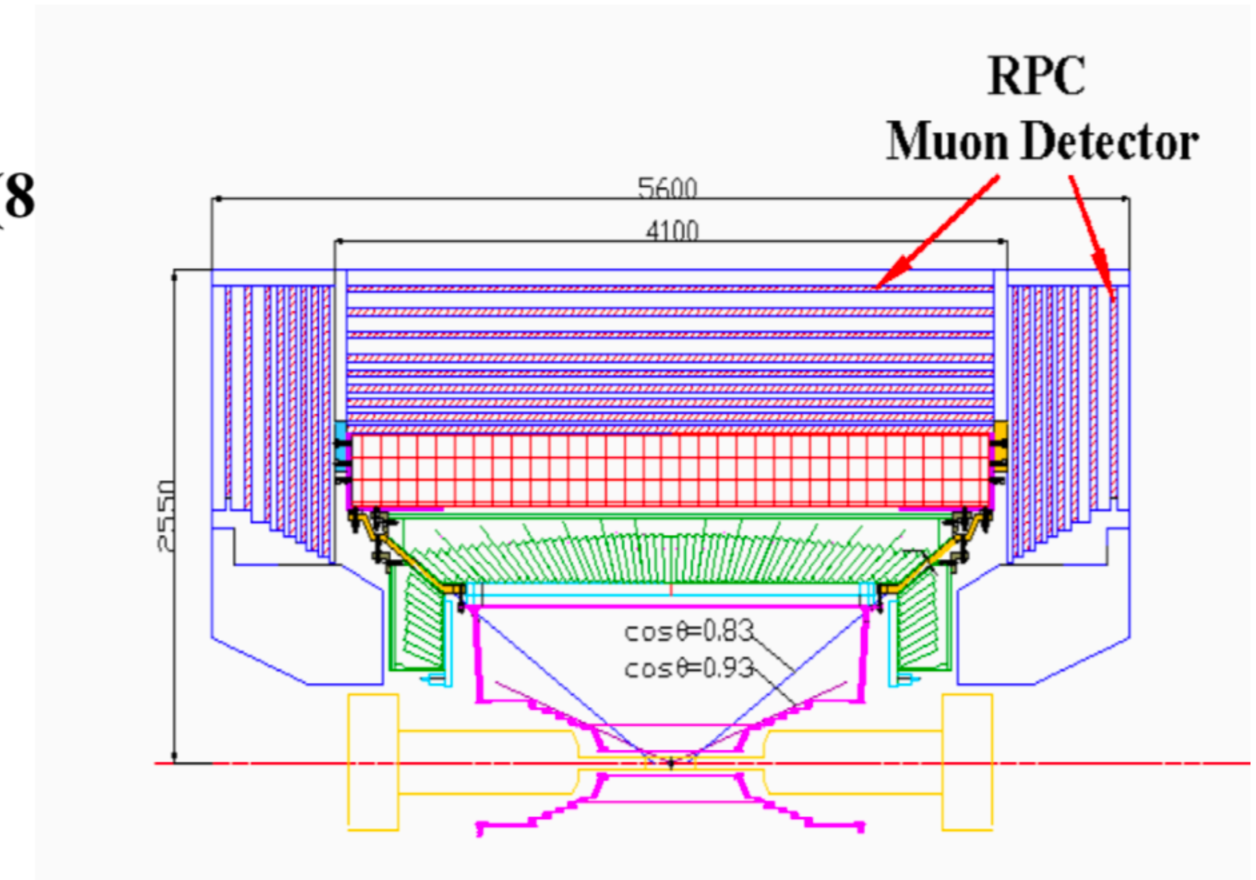
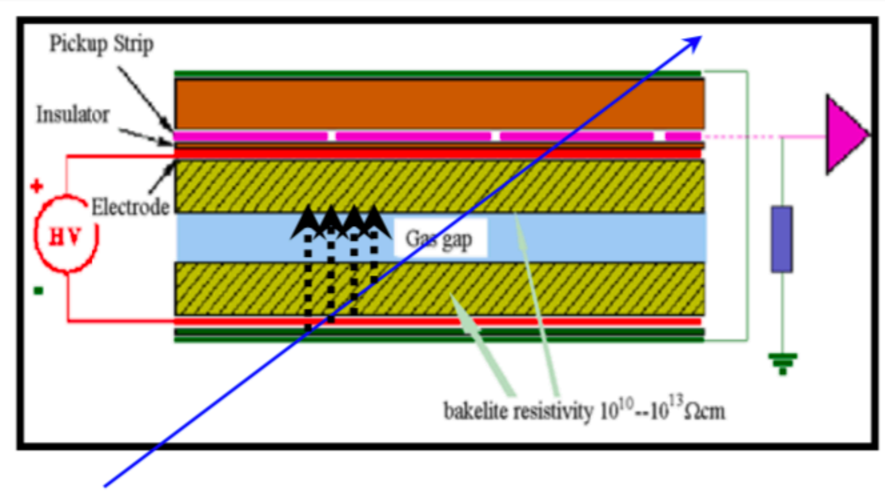
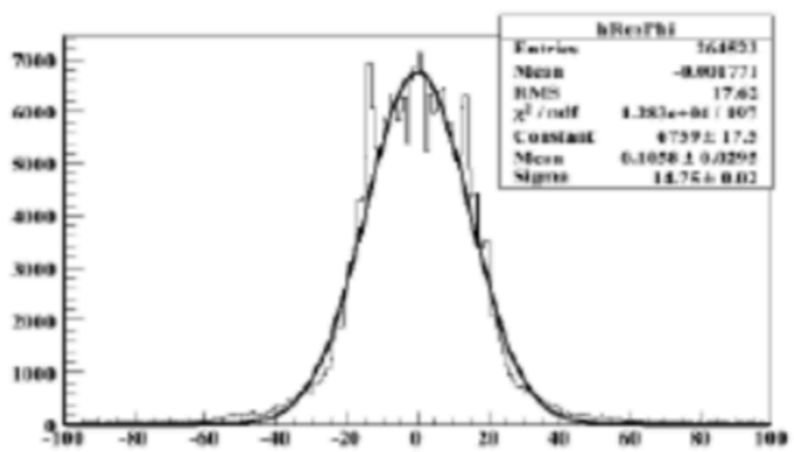
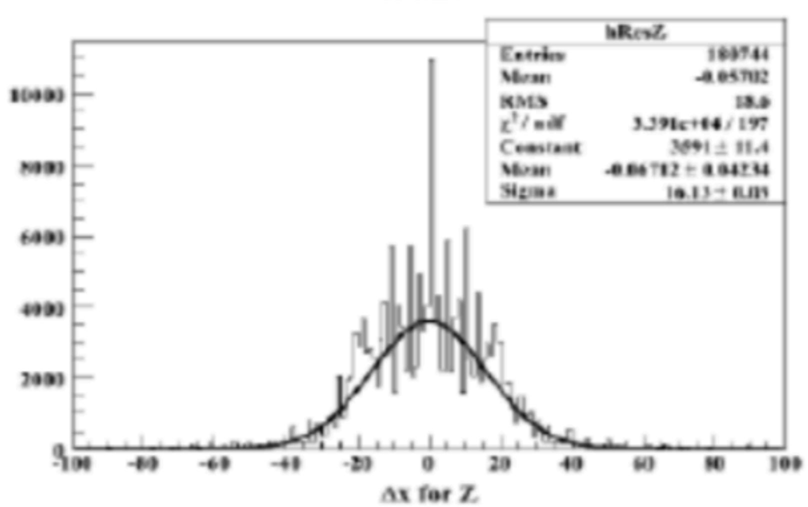








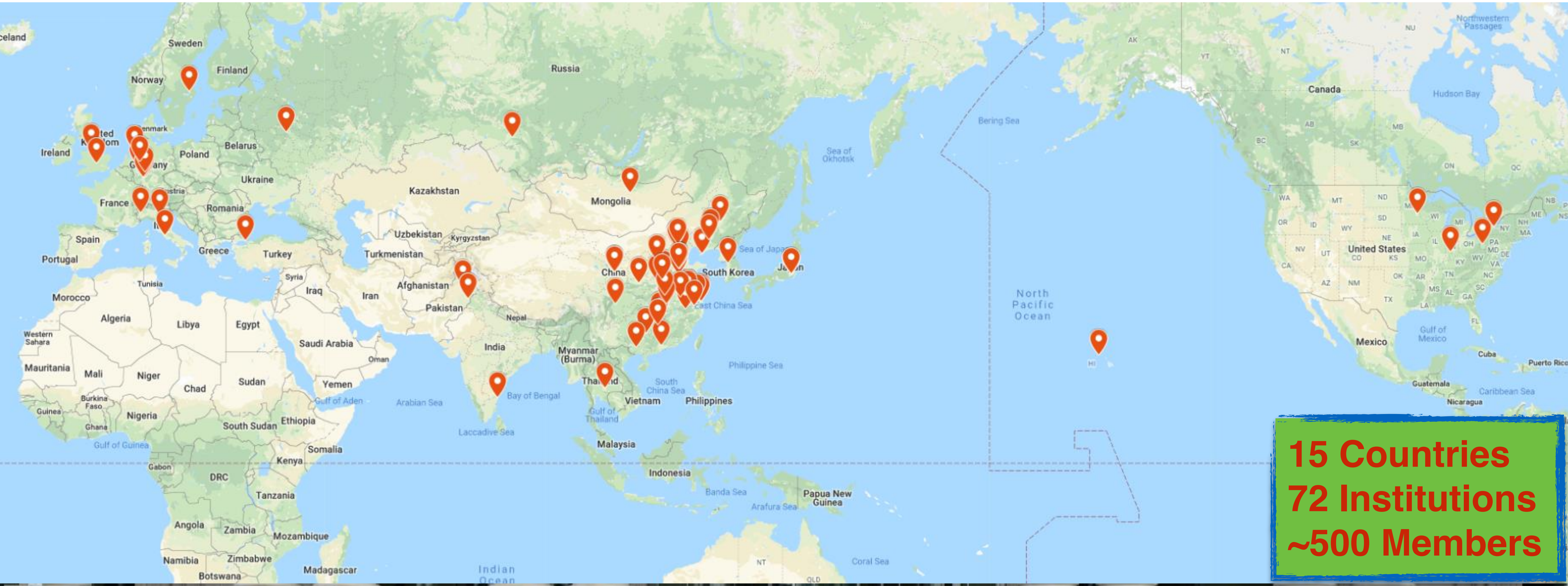
Electronics system worked well in 2018.

Muon Counter worked stable in 2018.

BESIII Performance

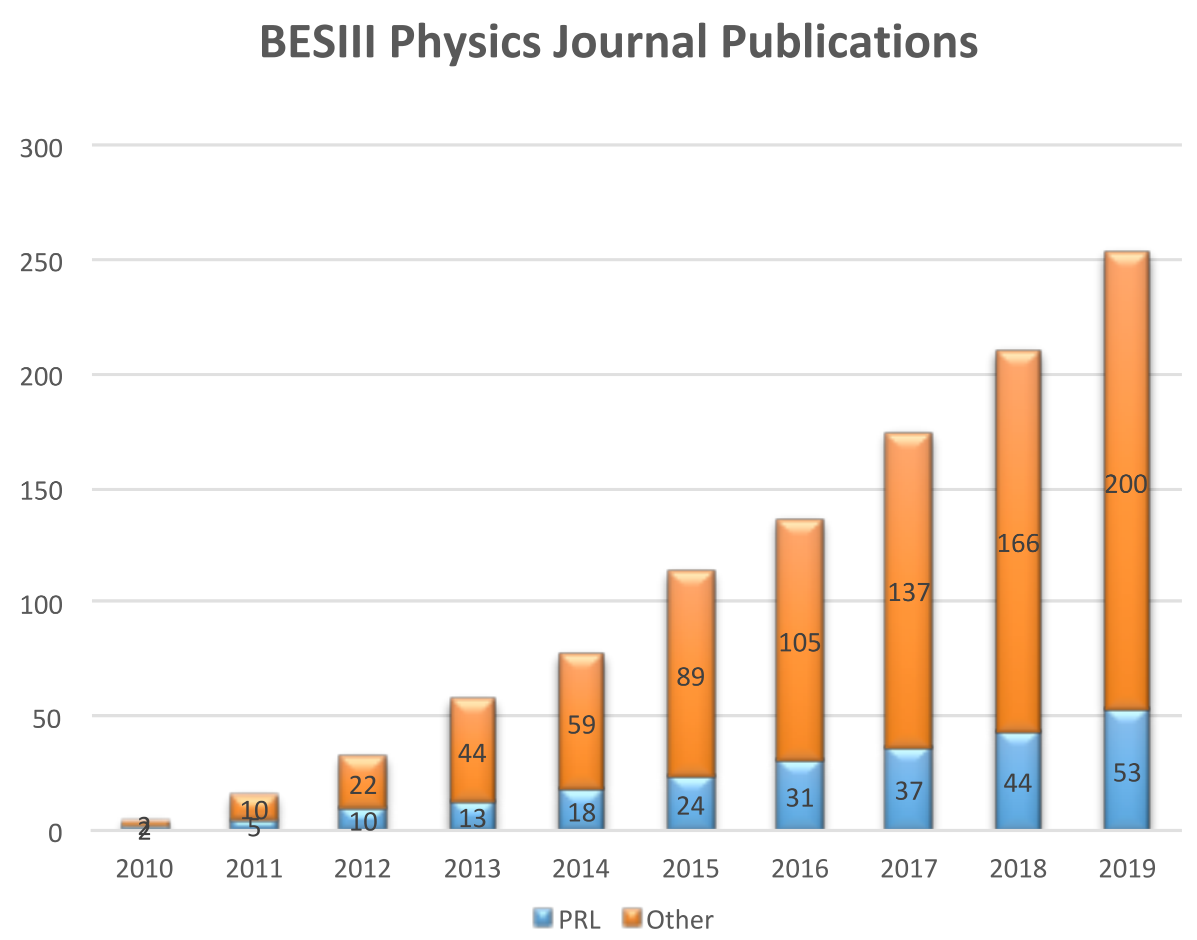
Sub detector		Design Performance	Achieved Performance
MDC		$\sigma_{r\phi} = 130\mu m$ $\Delta p/p = 0.5\%@1GeV$ (B=1T) $\sigma_{dE/dx} = 6\%$	$\sigma_{r\phi} = 115\mu m$ $\Delta p/p = 0.47\%@1GeV$ (B=1T) $\sigma_{dE/dx} = 5.2\%$
TOF	Barrel	$\sigma_T = 80\sim90\ ps$	$\sigma_T = 67\sim70\ ps$
	Endcap	$\sigma_T = 110\sim120ps$ (before upgrade) $80ps\sim100ps$ (after upgrade)	$\sigma_T = 138ps$ (before upgrade) $60ps\sim70ps$ (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		$\sigma_{r\phi} = 14mm\sim17mm$ $\sigma_z\sim17mm$	$\sigma_{r\phi} = 14mm\sim15mm$ $\sigma_z\sim17mm$

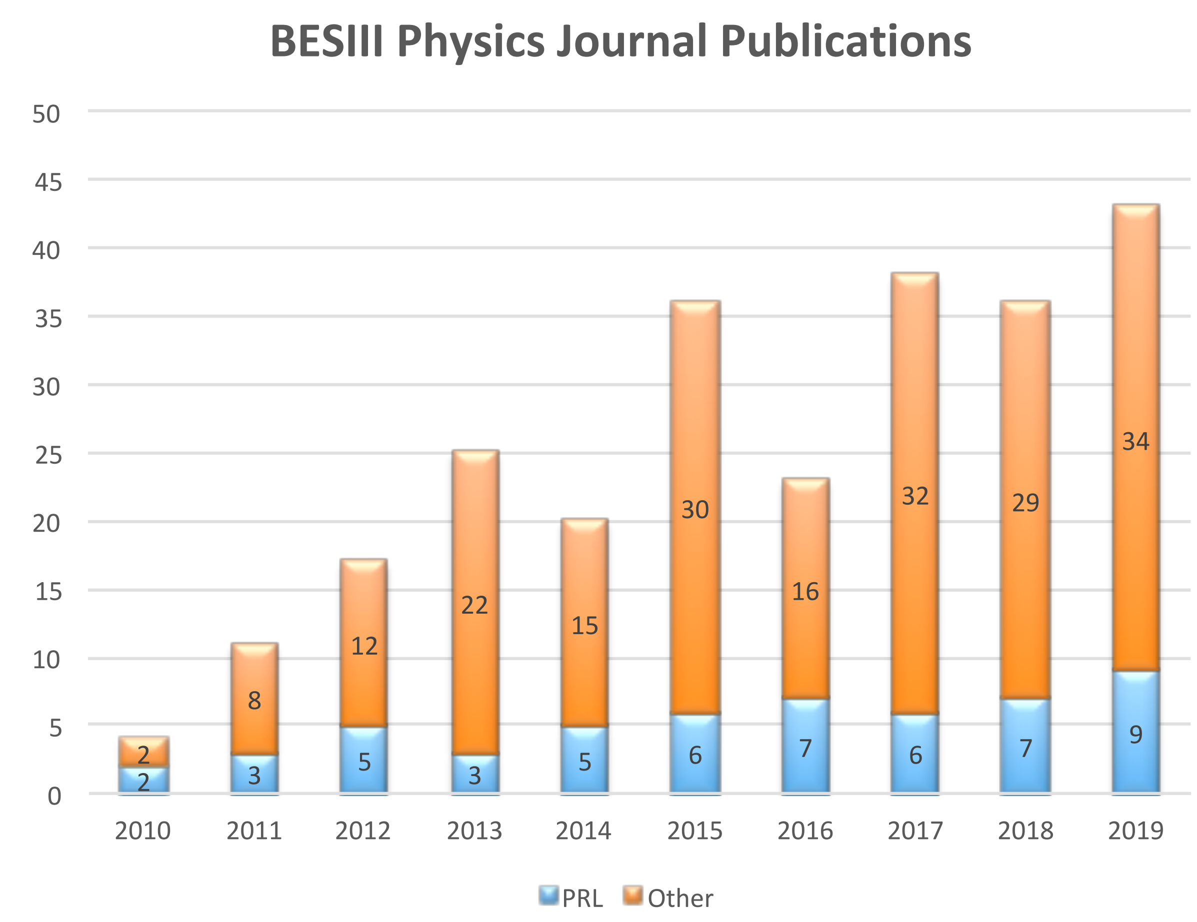
BESIII Collaboration



15 Countries
72 Institutions
~500 Members

BESIII Publications





+ ~100 talks/yr at international conferences

+ (till 2019.11.22)

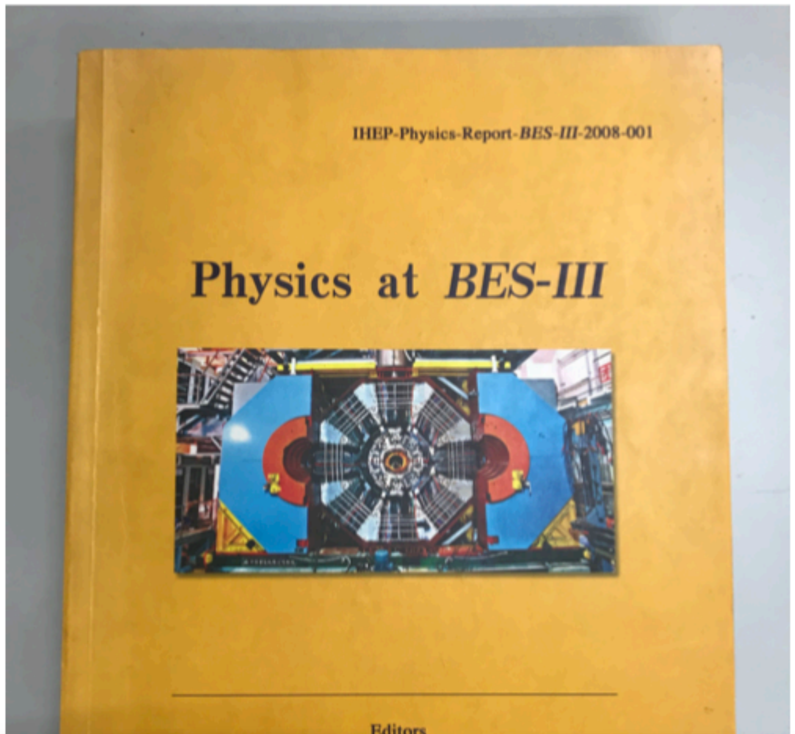
Achievements

Highlights:

- Precision tau mass from BESIII
- Charmonium and *XYZ* spectroscopy： Zc(3900), X(3872) …
- Light hadron & searches of exotics: X(1835), X(ppbar)…
- Precision charm physics: decay constant, form factors, |Vcs|, |Vcd|
- Access to amplitudes of quantum-correlated D^0 decays: relative strong phases
- Charmed baryon production at threshold: Λ_c production and decay
- Probe EM structures of baryons: G_E, G_M of proton, neutron and hyperons
- Hyperon-anti-hyperon pairs from J/ψ and ψ' decays: asymmetry parameters, *CP Violation*, and polarizations of hyperons

Still a Rich Program

2008



2019

White Paper on the Future Physics Programme of BESIII

The BESIII collaboration[¶]

and

L. Calibbi[c], J. Charles[a], H. Y. Cheng[d], S. I. Eidelman[b,g], S. Descotes-Genon[f], F.-K. Guo[c,i], A. A. Petrov[j], J. L. Rosner[h], Z.-Q. Zhang[e]

[a] Aix-Marseille Univ, Université de Toulon, CNRS, CPT, Marseille, France
[b] Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, 630090, Russia
[c] Institute of Theoretical Physics, Beijing 100190, People's Republic of China
[d] Institute of Physics, Academia Sinica, Taiwan 115, Republic of China
[e] Laboratoire de l'Accélérateur Linéaire, IN2P3-CNRS et Université Paris-Sud 11, F-91898, Orsay Cedex, France
[f] Laboratoire de Physique Théorique, UMR 8627, CNRS, Univ. Paris-Sud, Université Paris-Saclay, 91405 Orsay Cedex, France
[g] Novosibirsk State University, Novosibirsk, 630090, Russia
[h] University of Chicago, 5620 S. Ellis Avenue, Chicago, IL 60637, USA

arXiv.org > hep-ex > arXiv:0809.1869

High Energy Physics – Experiment

Physics at BES-III

D. M. Asner, T. Barnes, J. M. Bian, I. I. Bigi, N. Brambilla, I. R. Boyko, V. Bytev, K. T. Chao, J. Charles, H. X. Chen, J. C. Chen, Y. Chen, Y. Q. Chen, H. Y. Cheng, D. Dedovich, S. Descotes-Genon, C. D. Fu, X. Garcia i Tormo, Y.-N. Gao, K. L. He, Z. G. He, J. F. Hu, H. M. Hu, B. Huang, Y. Jia, H.-Y. Jin, S. Jin, Y. P. Kuang, H. Lacker, H. B. Li, J. L. Li, W. D. Li, X. Y. Li, B. J. Liu, H. H. Liu, J. Liu, H. L. Ma, J. P. Ma, Y. J. Mao, X. H. Mo, S. L. Olsen, A. Pich, A. Pineda, R. G. Ping, C. F. Qiao, G. Qin, H. Qin, J. M. Roney, G. Rong, L. Roos, X. Y. Shen, J. Soto, A. Stahl, S. S. Sun, S. T'Jampens, A. Vairo, P. Wang, Y. F. Wang, Y. K. Wang, N. Wu, Y. L. Wu, Z. Z. Xing, G. F. Xu, M. Xu, M. Yang, M. Z. Yang, Y. D. Yang, C. Z. Yuan, D. H. Zhang, D. Y. Zhang, J. Y. Zhang, Z. X. Zhang, X. M. Zhang, X. Y. Zhang, Y. J. Zhang, Q. Zhao, A. Zhemchugov, H. Q. Zheng, Y. H. Zheng, M. Zhong, S.-L. Zhu, Y. S. Zhu, V. Zhuravlov, B. S. Zou, J. H. Zou

(Submitted on 10 Sep 2008)

This physics book provides detailed discussions on important topics in τ-charm physics that will be explored during the next few years at \bes3 . Both theoretical and experimental issues are covered, including extensive reviews of recent theoretical developments and experimental techniques. Among the subjects covered are: innovations in Partial Wave Analysis (PWA), theoretical and experimental techniques for Dalitz-plot analyses, analysis tools to extract absolute branching fractions and measurements of decay constants, form factors, and CP-violation and \DzDzb-oscillation parameters. Programs of QCD studies and near-threshold tau-lepton physics measurements are also discussed.

Comments: Edited by Kuang-Ta Chao and Yi-Fang Wang
Subjects: **High Energy Physics – Experiment (hep-ex)**; High Energy Physics – Lattice (hep-lat); High Energy Physics – Phenomenology (hep-ph)
Journal reference: International Journal of Modern Physics A Volume: 24, Issue: 1 supp (2009)
Report number: IHEP-Physics-Report-BES-III-2008-001
Cite as: arXiv:0809.1869 [hep-ex]

arXiv.org > hep-ex > arXiv:1912.05983

High Energy Physics – Experiment

White Paper on the Future Physics Programme of BESIII

M. Ablikim, M. N. Achasov, P. Adlarson, S. Ahmed, M. Albrecht, M. Alekseev, A. Amoroso, F. F. An, Q. An, Y. Bai, O. Bakina, R. Baldini Ferroli, Y. Ban, K. Begzsuren, J. V. Bennett, N. Berger, M. Bertani, D. Bettoni, F. Bianchi, J Biernat, J. Bloms, I. Boyko, R. A. Briere, L. Calibbi, H. Cai, X. Cai, A. Calcaterra, G. F. Cao, N. Cao, S. A. Cetin, J. Chai, J. F. Chang, W. L. Chang, J. Charles, G. Chelkov, Chen, G. Chen, H. S. Chen, J. C. Chen, M. L. Chen, S. J. Chen, Y. B. Chen, H. Y. Cheng, W. Cheng, G. Cibinetto, F. Cossio, X. F. Cui, H. L. Dai, J. P. Dai, X. C. Dai, A. Dbeyssi, D. Dedovich, Z. Y. Deng, A. Denig, I. Denysenko, M. Destefanis, S. I. Eidelman, S. Descotes-Genon, F. De Mori, Y. Ding, C. Dong, J. Dong, L. Y. Dong, M. Y. Dong, Z. L. Dou, S. X. Du, J. Z. Fan, J. Fang, S. S. Fang, Y. Fang, R. Farinelli, L. Fava, F. Feldbauer, G. Felici, C. Q. Feng, M. Fritsch, C. D. Fu, Y. Fu, Q. Gao, X. L. Gao, Y. Gao, Y. Gao, Y. G. Gao, Z. Gao, B. Garillon, I. Garzia, E. M. Gersabeck, A. Gilman, K. Goetzen, L. Gong, W. X. Gong, W. Gradl, M. Greco, L. M. Gu, M. H. Gu, Y. T. Gu, A. Q. Guo, F. K. Guo, L. B. Guo, R. P. Guo et al. (388 additional authors not shown)

(Submitted on 12 Dec 2019)

There has recently been a dramatic renewal of interest in the subjects of hadron spectroscopy and charm physics. This renaissance has been driven in part by the discovery of a plethora of charmonium-like [Math Processing Error] states at BESIII and [Math Processing Error] factories, and the observation of an intriguing proton-antiproton threshold enhancement and the possibly related [Math Processing Error] meson state at BESIII, as well as the threshold measurements of charm mesons and charm baryons.
We present a detailed survey of the important topics in tau-charm physics and hadron physics that can be further explored at BESIII over the remaining lifetime of BEPCII operation. This survey will help in the optimization of the data-taking plan over the coming years, and provides physics motivation for the possible upgrade of BEPCII to higher luminosity.

Comments: 210 pages; To be submitted to Chin. Phys. C
Subjects: **High Energy Physics – Experiment (hep-ex)**; High Energy Physics – Phenomenology (hep-ph)
Cite as: arXiv:1912.05983 [hep-ex]

Prospects @White Paper

Prospects @White Paper

Prospects @White Paper

Prospects @White Paper

Prospects @White Paper

Competition and Complementary

- **Super-KEKB/Belle-II (50 ab^{-1} ccbar cross-secion = 1.0 nb@Y(4S))**

  arXiv: 1808.10567 (Belle-II physics book)

- **LHCb and its upgrades (50 fb^{-1} → 10^{11} reconstructed charm mesons)**

  arXiv:1808.08865 (LHCb upgrade-II)

- **proton-antiproton collisions (PANDA…)**

- **e-p/gamma-p collisions (Glue-X…)**

- **SHiP experiment at CERN: (10^{18} D mesons, 10^{16} τ, 10^{20} γ)**

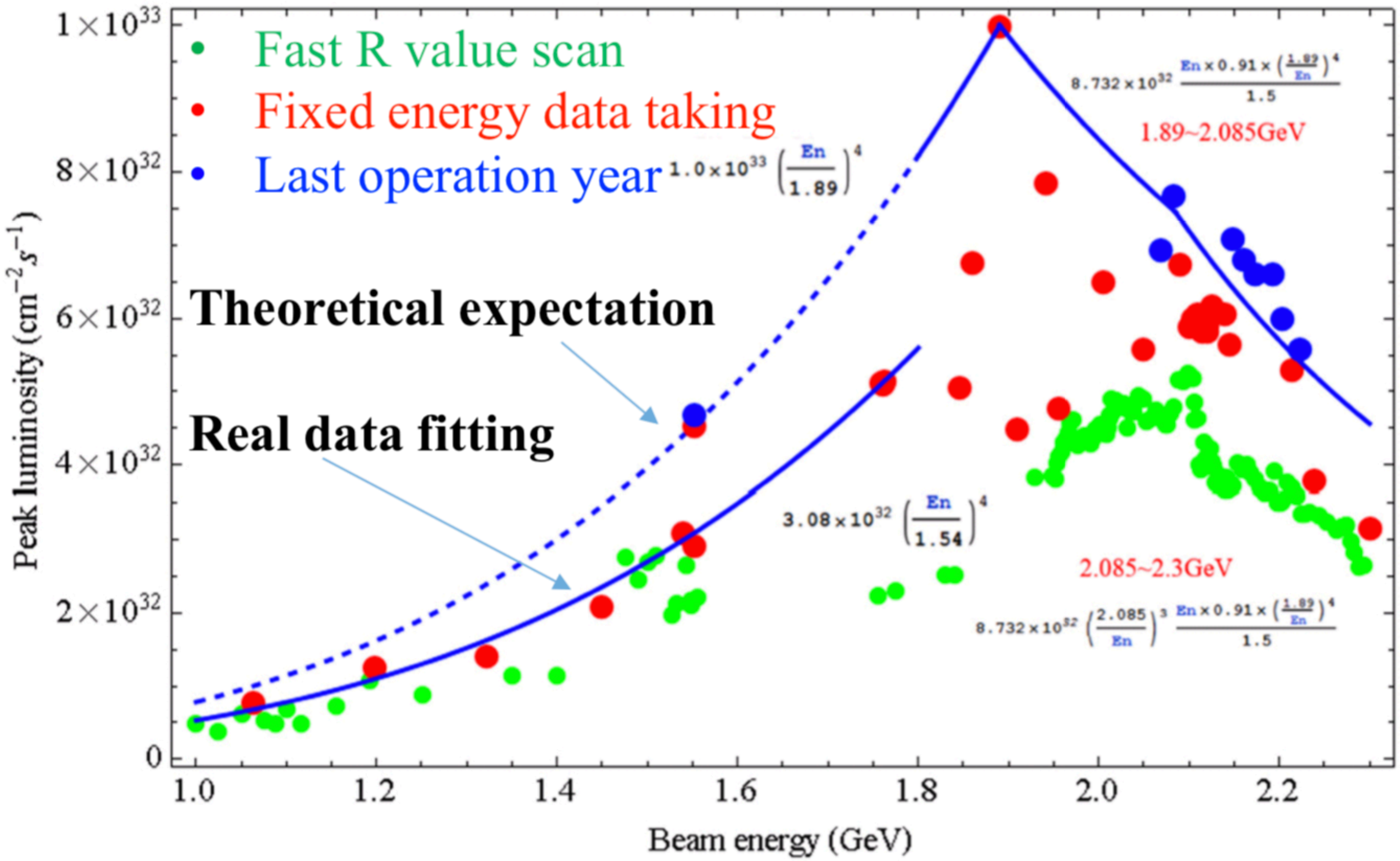
  arXiv:1504.04855 ; arXiv:1807.02746

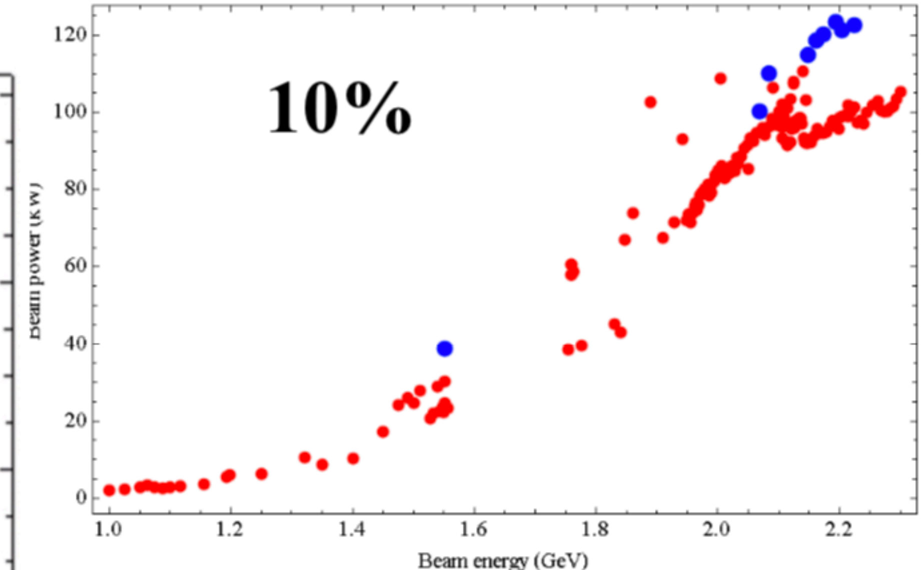
Summary

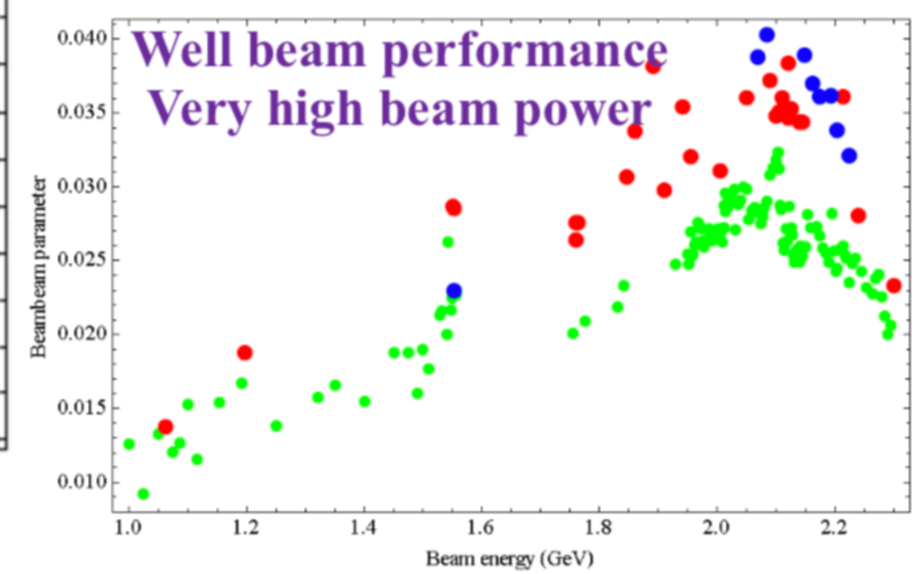
1. BEPCII and BESIII have been running successfully for more than 10 years
2. BESIII is uniquely well suited for a variety of study of pair productions at thresholds; Unique access to strong phase and CPV in hyperons;
3. BESIII has a rich program for another 12 years' running with current BEPCII luminosity performance.
4. BEPCII luminosity upgrade may shorten the running time and benefit BESIII physics program a lot.

Thanks for your attention!

Performance of BEPCII @2019





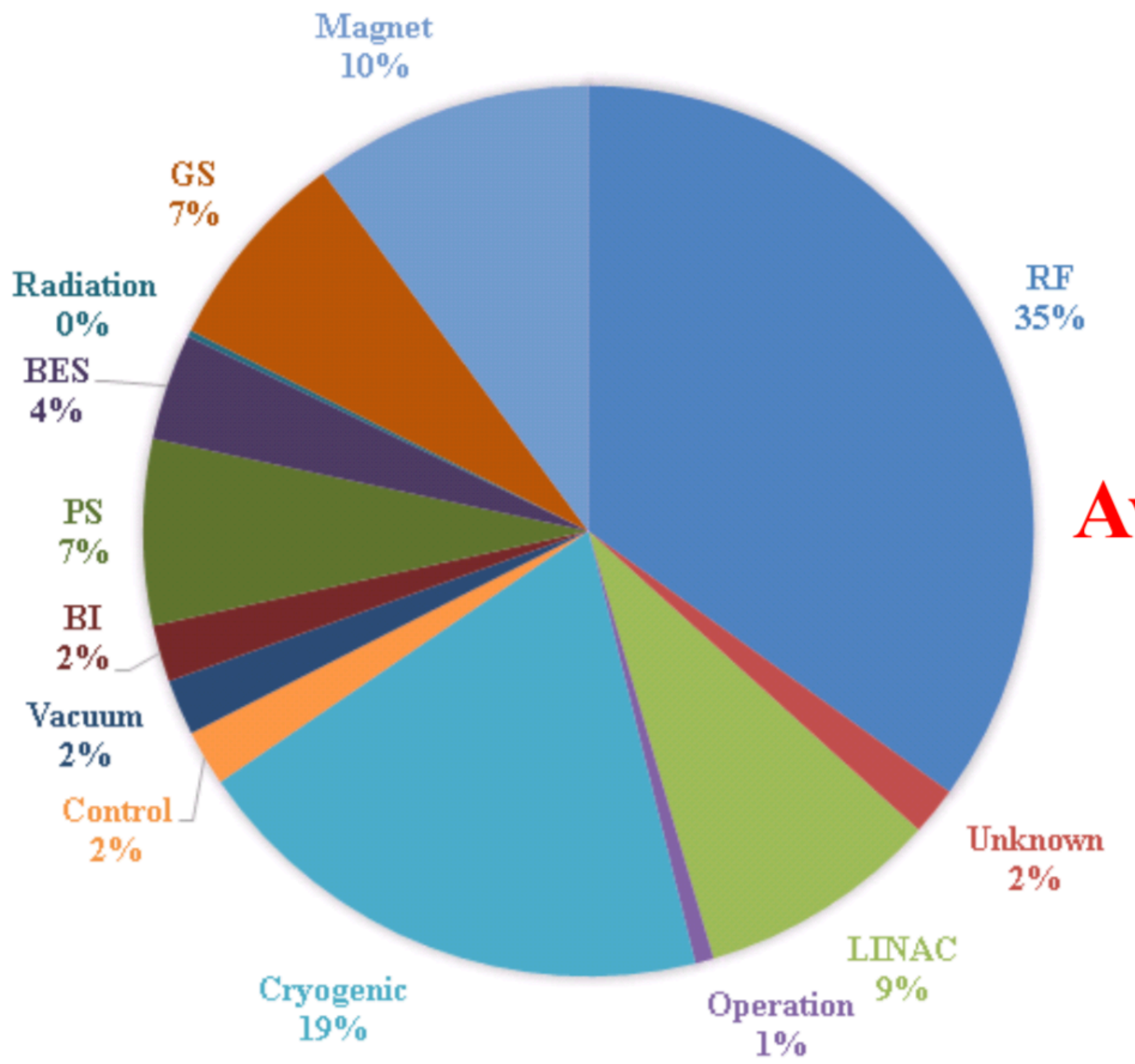


For the high energy region the beam current had to be decreased due to the limitation of RF power. The bunch length and emittance could not be well controlled. **For the low energy region** the multi-bunch instability was very serious due to longer damping time. The injection efficiency was also affected by the longer damping time.

Performance of BEPCII @2019

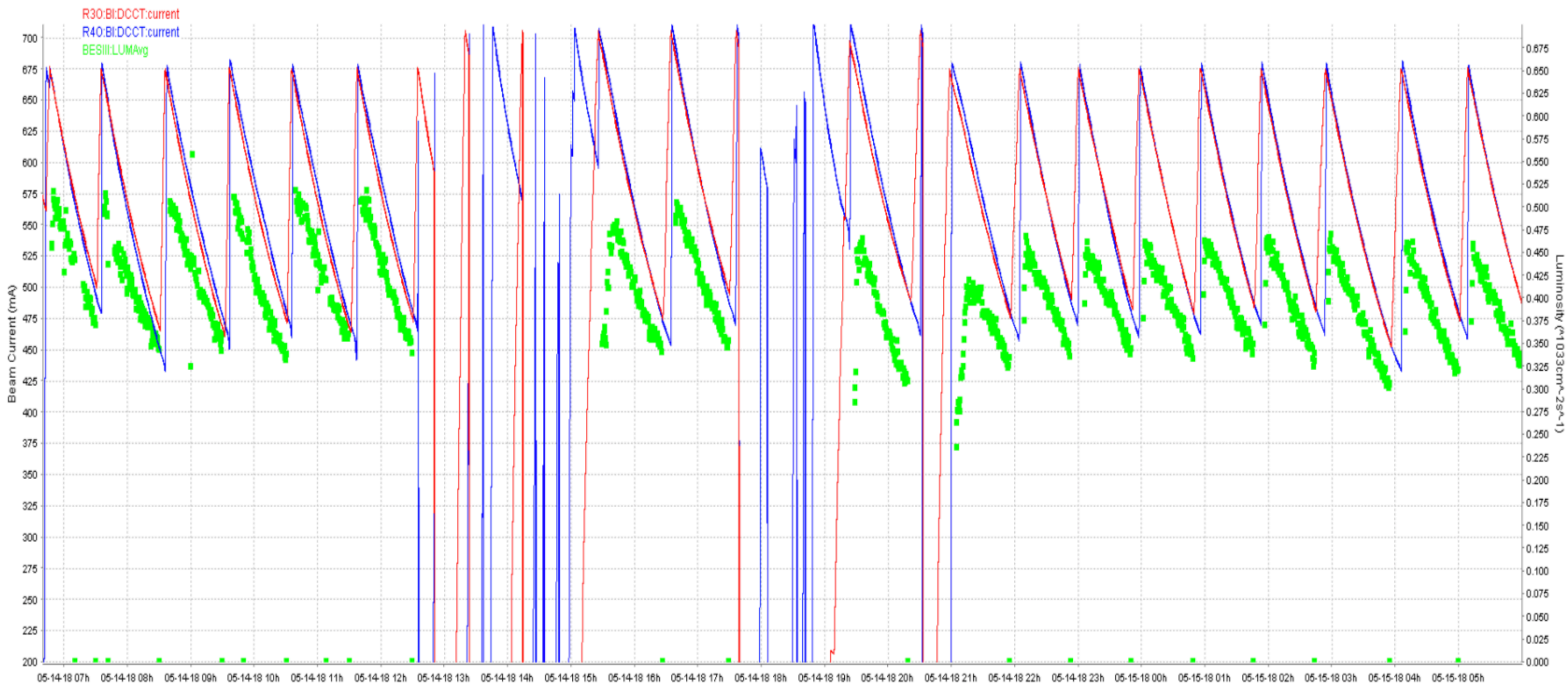
Aging problem become serious

- RF system
- Power supply
- Cryogenic system
- Control system
- Feedback system
- BPM system
- Kickers
- BES
- ……



Average failure rate 12%

Performance of BEPCII @2019

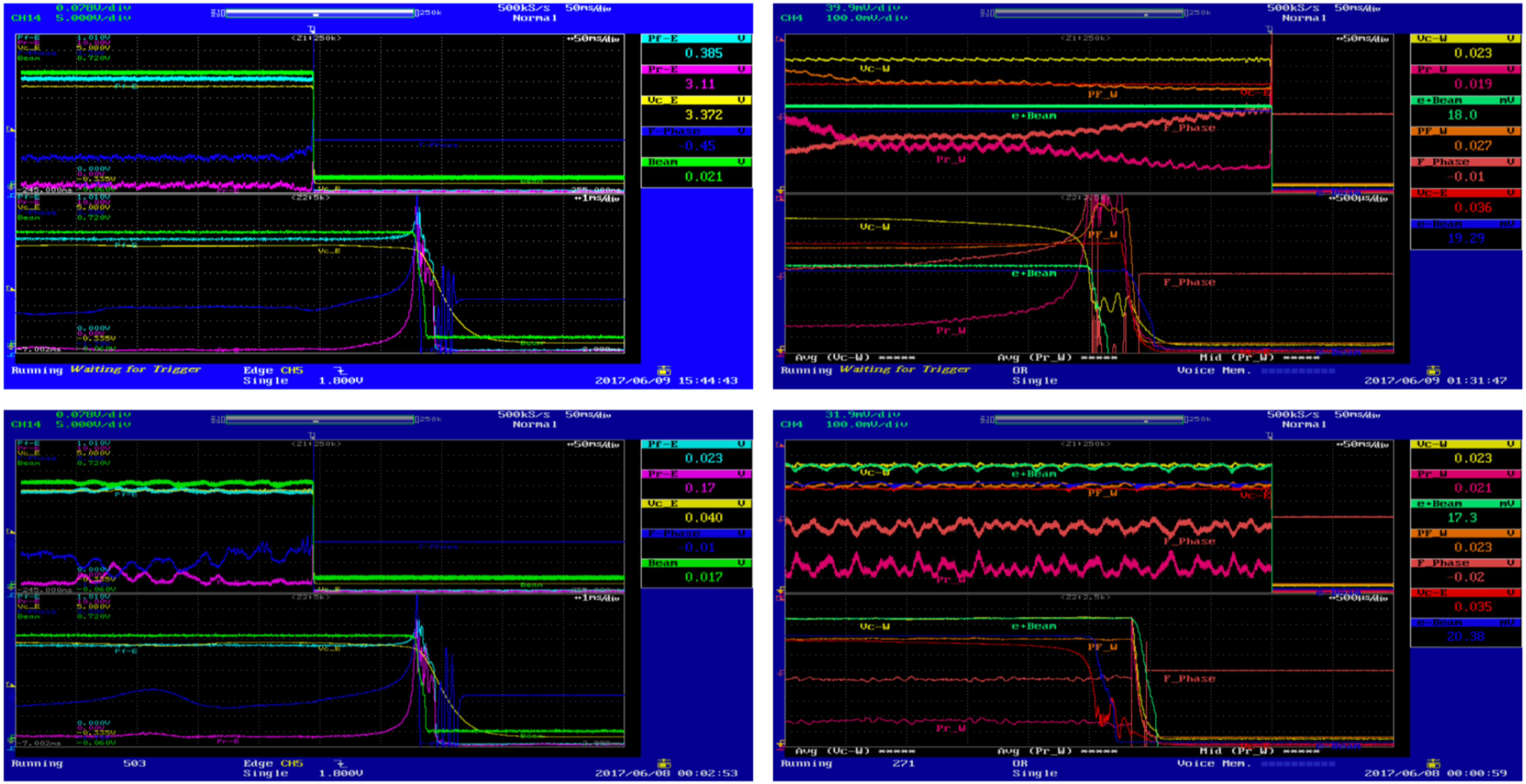


IF beam current > 700mA, beam loss !

IF beam current < 700mA, very stable

Performance of BEPCII @2019

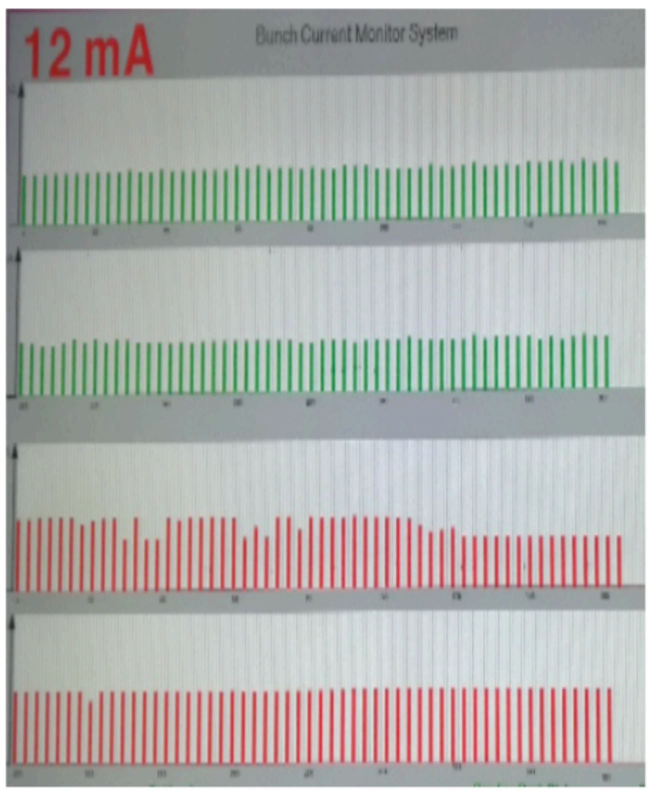
The performance reduction of RF cavities

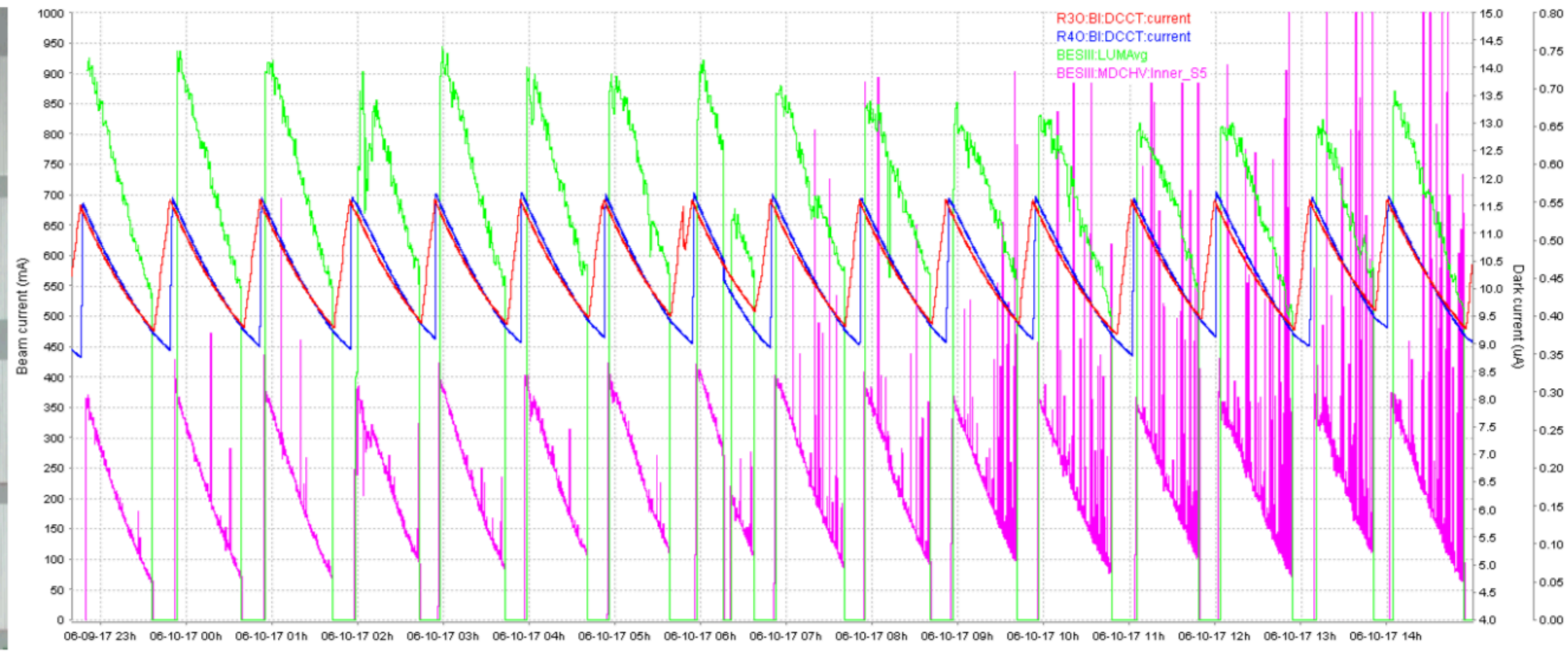


Failure of low level system in both e+ and e- RF cavities. Frequently and no solution

Performance of BEPCII @2019

The performance reduction of feedback system



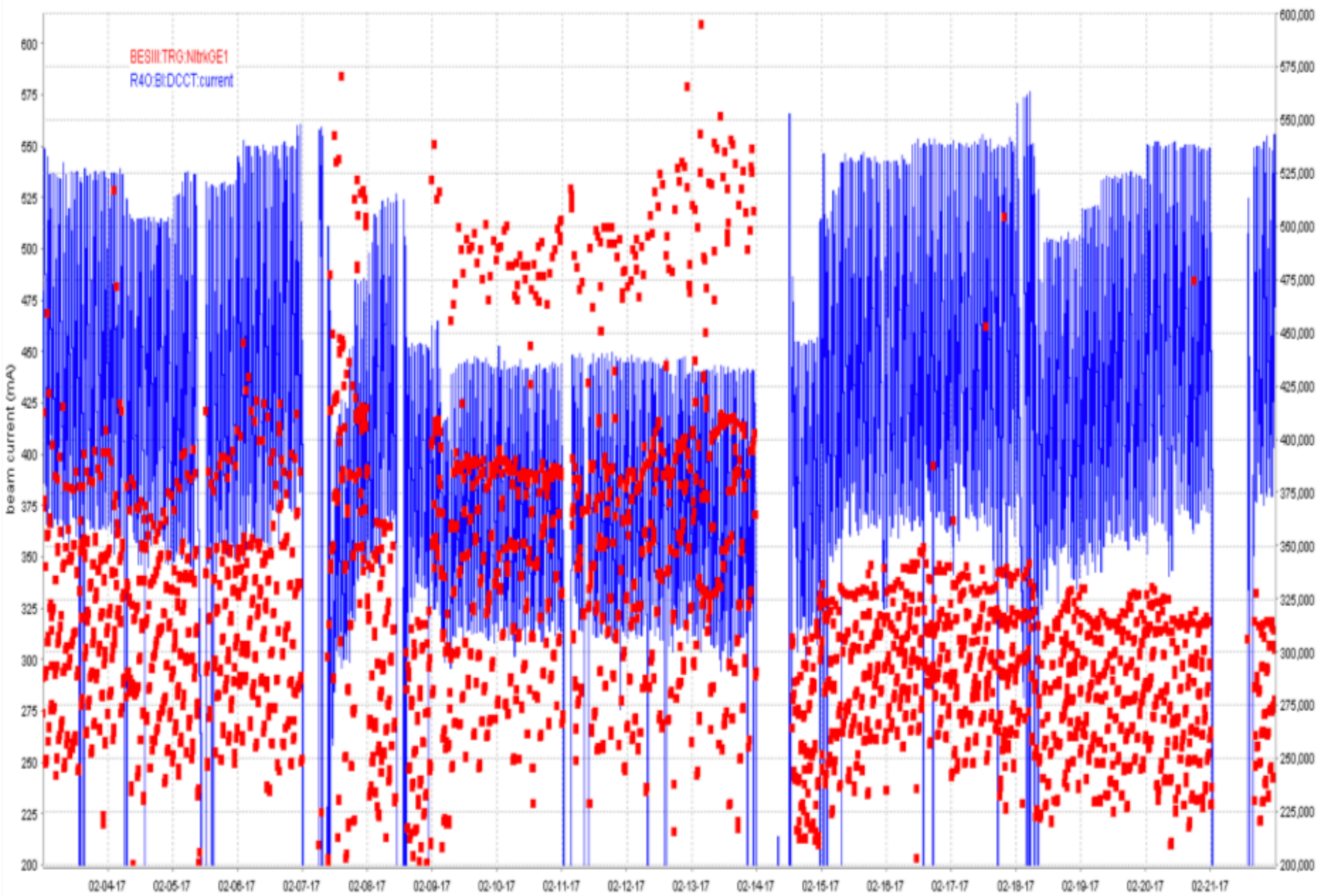


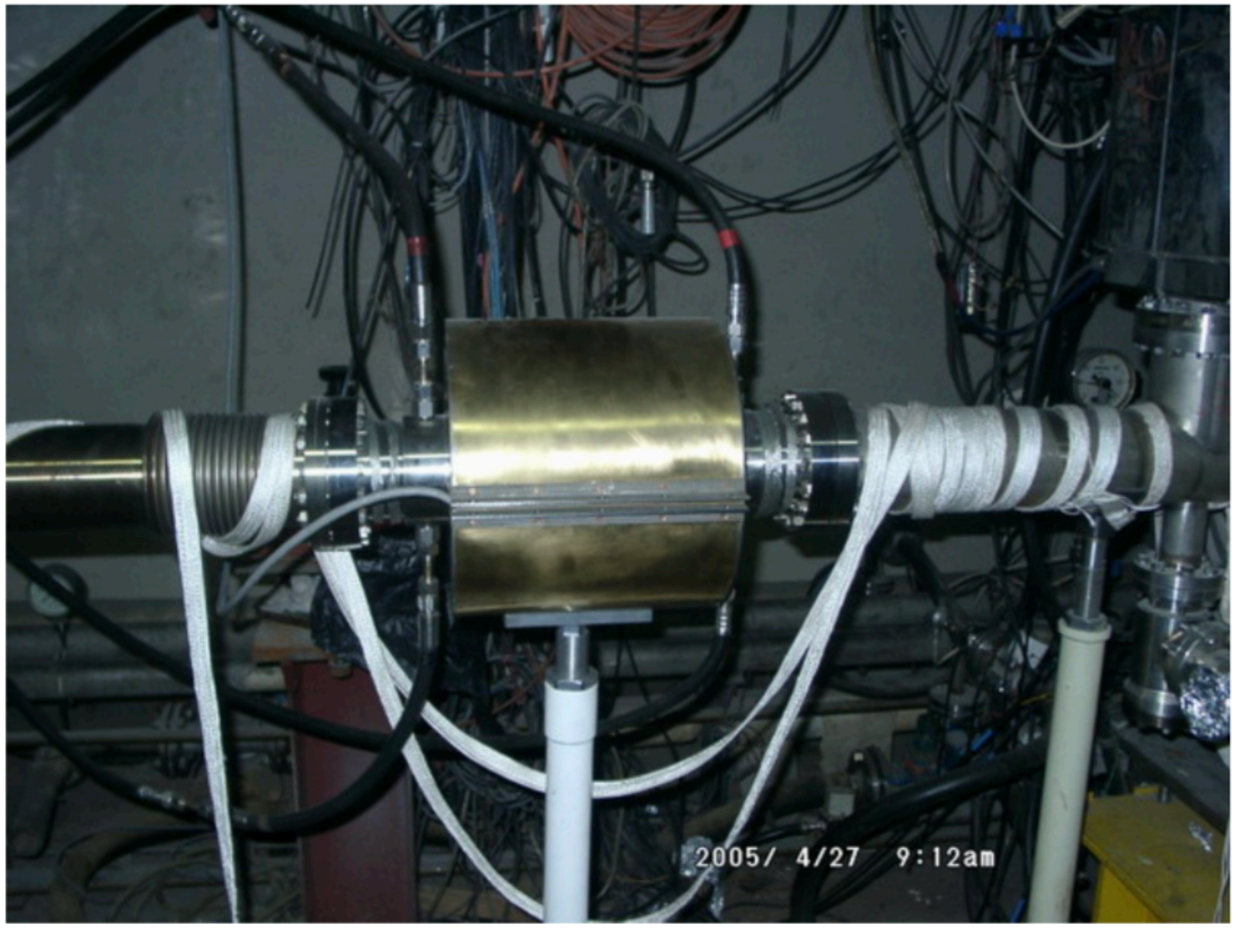
Injection difficulty for high beam current, luminosity reduction, high dark current

Frequently and optimized the system manually every shift.

The restriction of e+ and e- DCCT noise

- Limitation of luminosity
- The noise depends on filling pattern, bunch current and beam current.
- Can be controlled within acceptable level.

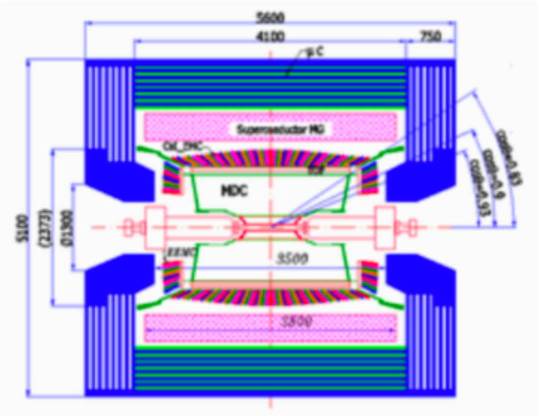




BESIII Accumulates 10 Billion J/ψ Events

- The 10 billion J/ψ-event sample accumulated at BESIII is the world's largest data sample produced directly from electron-positron annihilations.
- The 10 billion J/ψ-event data sample makes the measurements of exotic hadrons in much improved precision and the searches for new processes in much improved sensitivity possible.
- During the data acquisition, the peak luminosity of BEPCII reached 4.7×10^{32} cm^{-2}s^{-1}, which is about 100 times higher than that of BEPC.
- With the unique advantage of an unprecedented high-statistics J/ψ sample, BESIII will continue to play a leading role in research for new forms of hadronic matter in the high-precision frontier.

Highlights

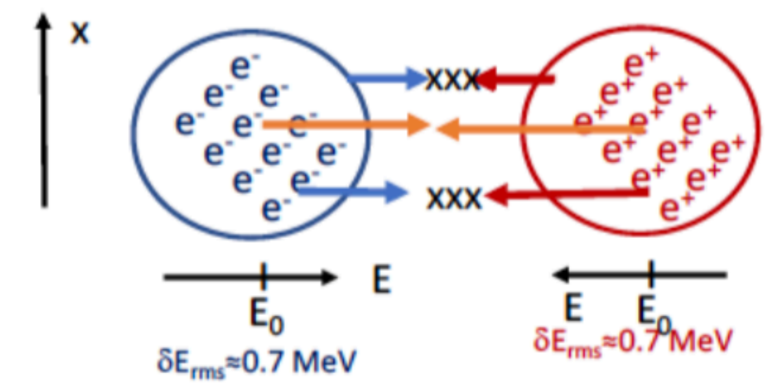


BESIII Accumulates 10 Billion J/ψ Events

The BESIII detector finished accumulating a sample of 10 billion J/ψ events together with a continuum data sample on Feb. 11. The 10 billion J/ψ-event sample accumulated at BESIII is the world's...

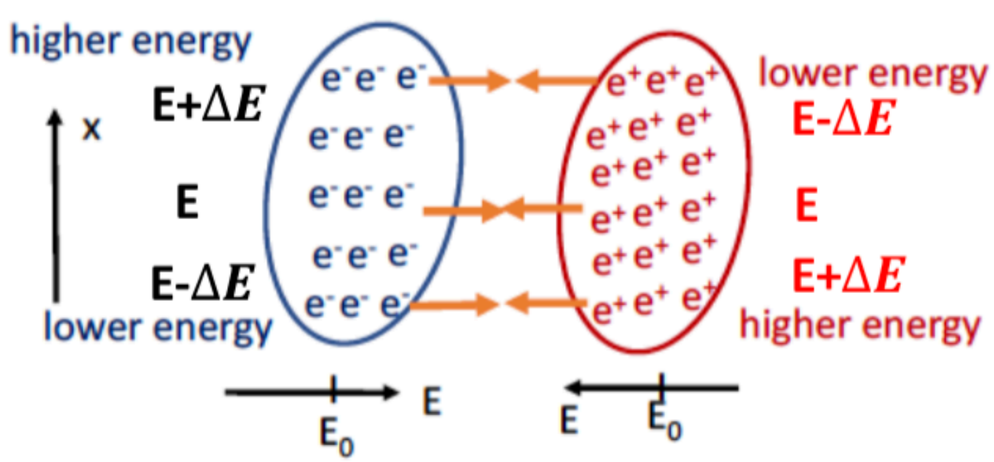
For J/ψ

Monochromatic collision: factor of 10 from reduction of e^+e^- CM spread



only e^+e^- pairs with E_{cm}=3096 ± 0.14 MeV
can produce a J/ψ, ~1/30th of the total

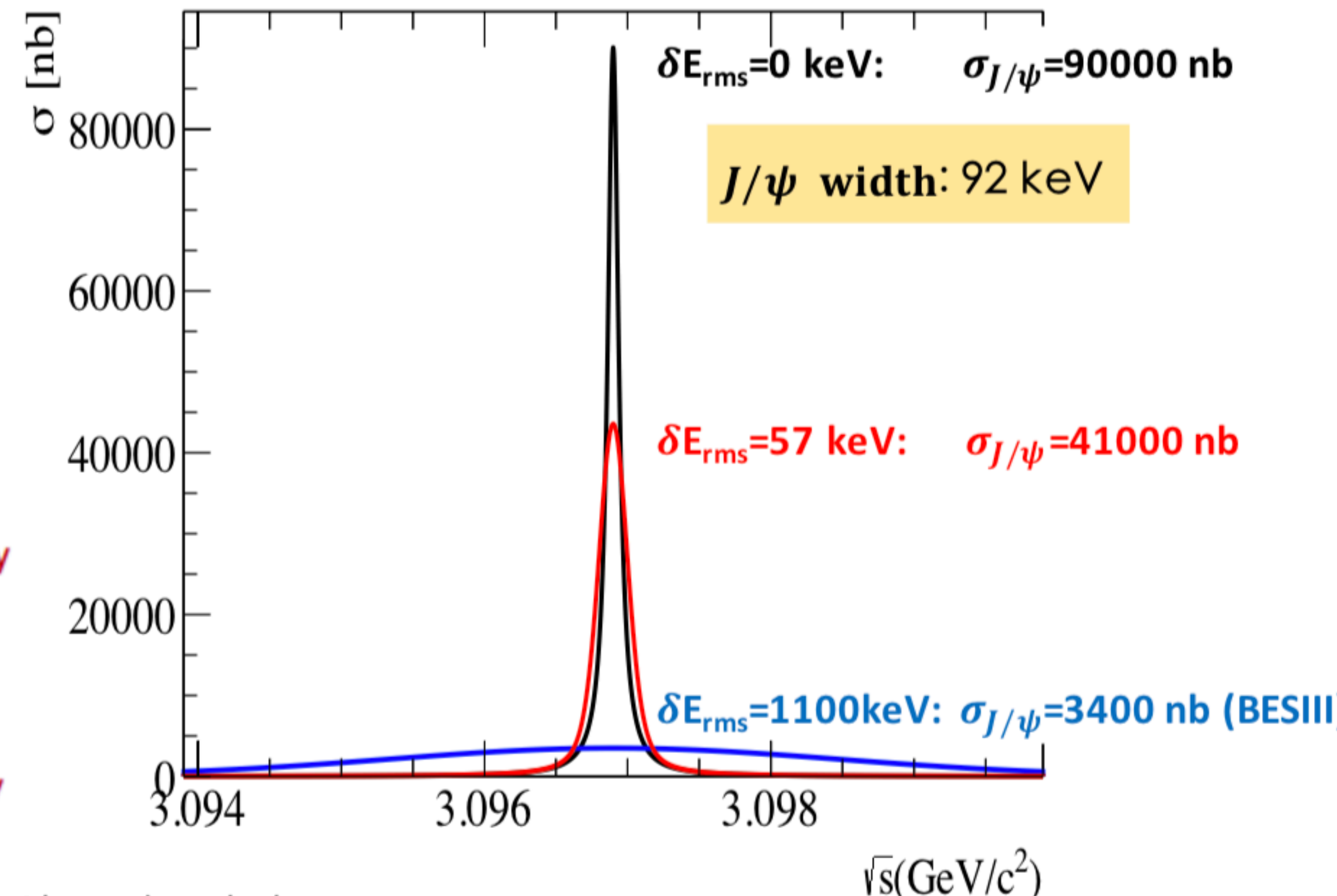
introduce dispersion



more e^+e^- pairs with E_{cm}=3096 ± 0.14 MeV

J/ψ production cross-section

Xiaoshuai Qin



Alexander Zholents
CERN SL/92-27/AP

BESIII may get trillion J/*ψ* per year!
A dream （Steve Olsen)?

30

Conventional Scheme

Increase luminosity by β_y^* and current

$$L(\mathrm{cm^{-2}s^{-1}}) = 2.17\times10^{34}(1+R)\xi_y \frac{E(\mathrm{GeV})k_b I_b(\mathrm{A})}{\beta_y^*(\mathrm{cm})}$$

Vertical β @IP , Limited by hourglass effect

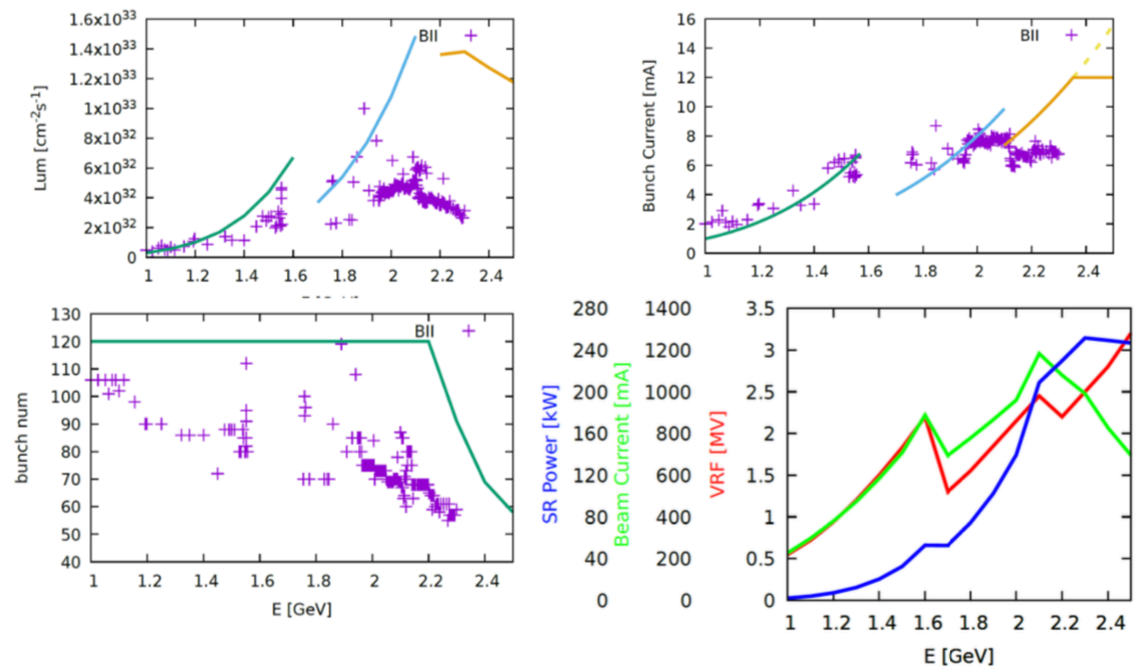
Beam current, Limited by multi-bunch instability and power

- 125kW -> 250kW , @2.2GeV
  - Beam Current : 1100mA. BEPCII ~ 600mA。 (Feedback+RF)
  - Bunch Number : 120. BEPCII ~ 80。 (Feedback+RF)
  - Bunch Current : 9mA. BEPCII ~ 7mA。 (Feedback+RF)
  - Beam-Beam : 0.04。 BEPCII ~ 0.036。 (RF , hourglass effect)

Luminosity = 13E32 $\mathrm{cm^{-2}\,s^{-1}}$

BEPCII ~ 6.5E32

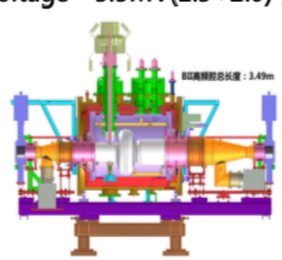
Conventional Scheme: Upgrade Scenario (baseline)



RF System

- Case 1 : ¥50 M , 2.5-3 Yr
  - Keep present cavities
  - One more new cavity/ring

- Voltage ~3.5MV(1.5+2.0) , Power ~ 400kW

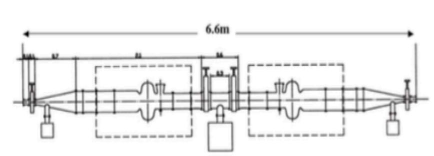


Space may be limited, Solution has been obtained

Low risk for RF technology

- Case 2 : ¥26 M , 2.5 Yr
  - One new cavity/ring

- Voltage ~2.5MV , Power ~ 250kW



High risk for RF technology

Feedback system

¥ 6 M

BEPCII Record: 910mA , 119 bunches

(700mA, 80 Bunches in daily operation)

In order to increase the safe margin(more stable)

- Transverse
  - Bandwidth: 125 MHz -> 250 MHz
  - Amplifier Power: 75 W -> 250 W
- Longitudinal
  - New cavity-like kicker with shunt impedance: 160 -> 400 Ohm
  - Amplifier Power: 100 W -> 200 W

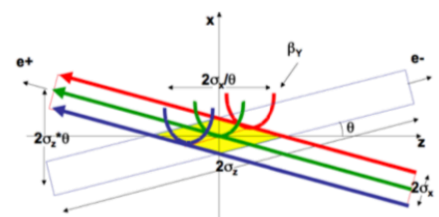
LEPTON Beam Currents Achieved so far

	beam current I [A]	bunch population N_b [10^{11}]	rms bunch length [mm]	bunch spacing [ns]	comment
PEP-II	2.1 (e^-), 3.2 (e^+)	0.5, 0.9	12	4.2	closed
superKEKB	2.62 (e^-), 3.6 (e^+)	0.7, 0.5	7	6	commissioning
DAFNE	2.4 (e^-), 1.4 (e^+)	0.4, 0.3	16	2.7	
BEPC-II	0.8	0.4	<15?	8	

Crab-Waist Scheme

Increase luminosity by crab-waist scheme

1. Large Piwinski Angle, squeeze ϵ_x and β_x, enlarge crossing angle
2. Lower $\beta_y \sim \sigma_x/\theta$
3. Crab-waist sextupole, increase ξ_y



$$L(\mathrm{cm^{-2}s^{-1}}) = 2.17\times10^{34}(1+R)\xi_y \frac{E(\mathrm{GeV})k_b I_b(\mathrm{A})}{\beta_y^*(\mathrm{cm})}$$

Beam-beam parameter, physical limit

vertical β @IP, Limited by hourglass effect

Beam current, Limited by multi-bunch instability and power

Crab-Waist: Parameter Design

Ref: A. Bogomyagkov, E. Levichev, Tau'16

$$\varphi = \frac{\sigma_z}{\sigma_x^*}\tan\left(\frac{\theta}{2}\right)$$

$$\xi_y \propto \frac{N\beta_y^*}{\sigma_x^*\sigma_y^*\sqrt{1+\varphi^2}}$$

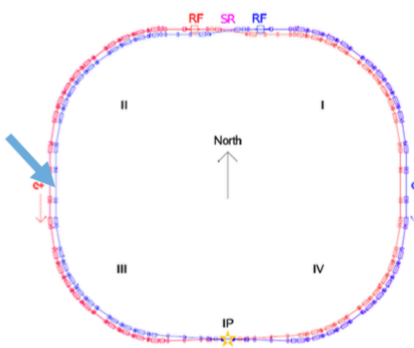
$$L \propto \frac{N\xi_y}{\beta_y^*}$$

- Based on present optics
- Based on achieved beam-beam performance
- Contribution from Damping Wiggler is considered
- ξ_y is increased by a factor of 2 (crab-waist)

(Comment by K. Ohmi, 1.5 gain at DAFNE!!!)

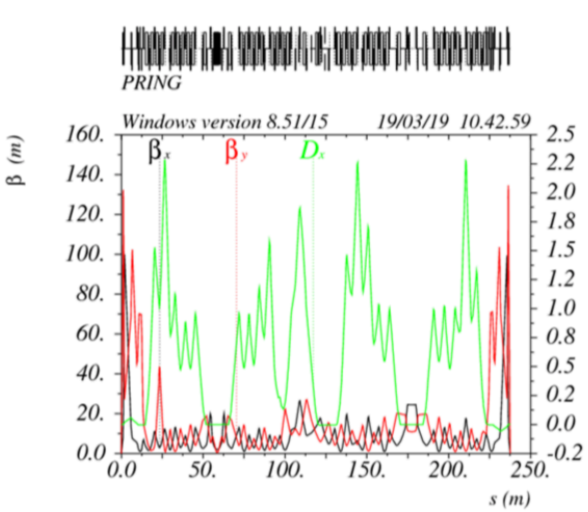
- Inside ring of injection region ~4m。
- *Super-Conducting Wiggler*
- Squeeze emittance by damping wiggler

@2.25GeV,
Luminosity=57 e32, Emittance x [nm] = 50
β_x/β_y [mm] = 140/7.6, Piwinski Angle = 3
ξ_y = 0.096 (assumed gain factor of 2)
Beam Current = 100*9mA, SR Power = 580 kW

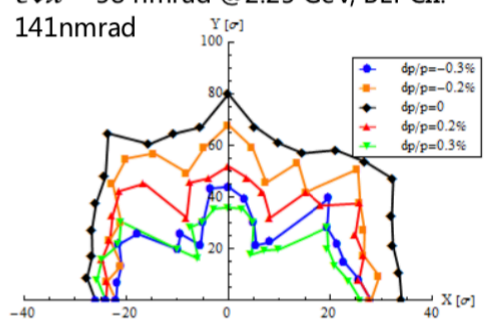


Crab-Waist: Lattice Design

- **Keep the present detector， NO solution**
- A whole new interaction region design is presented (new survey, new, more and stronger super-conducting quadrupoles,)
- Super-conducting wiggler (6T)



Qx/Qy = 8.5/7.5 (BEPCII: 7.5/5.5)
β_x/β_y = 0.12/0.009 m
ϵ_x = 58 nmrad @2.25 GeV, BEPCII: 141nmrad

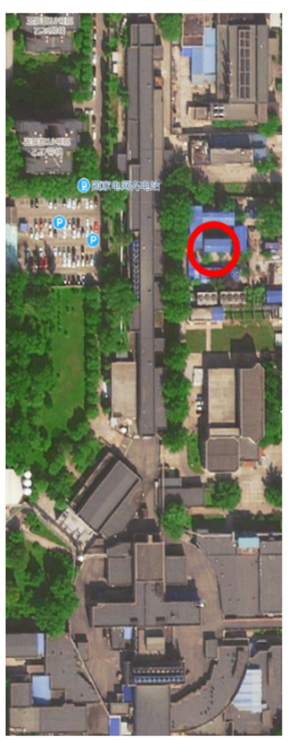


Some sextupoles' strength is two times the present design

Crab-Waist: Challenges

- Super-conducting wiggler (6T)
- Super-conducting quadrupoles
  (The strength is 2 times of BEPCII)
- Local high power SR
  (1.5 times of the whole ring radiation is focused at one point)
- Damping ring is a must for injection

The 'possible' crab-waist machine is "BEPCIII"!!!

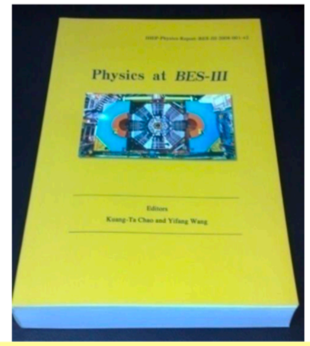


Comparison

	Conventional	Crab-Waist (BEPC3)
Peak Luminosity	*2-3	*10
Beam Current	9*120 mA	9*100 mA
Cost	~￥130 M	?
Time(Design + Fabrication)	2-3 Yr	? Detector, Superconducting Wiggler, Superconducting Quads, Booster
Assemble + Recovery	0.5-1 Yr.	?
Physical Risk	~0	Proof Facility (crab-waist)
Technical Risk	>0	>> 0

Still a Rich Program

- Light hadron spectroscopy
  - Full spectra: conventional/exotic hadrons QCD
  - How quarks/gluons form a hadron? non-pQCD
- Charm physics
  - CKM matrix elements ➔ SM and beyond
  - $D\bar{D}$ mixing and CPV ➔ SM and beyond
- Charmonium physics
  - Spectroscopy and transitions ➔ pQCD & non-pQCD
  - New states above open charm thresholds ➔ exotic hadrons?
  - pQCD: "ρπ puzzle" ➔ a probe to non-pQCD or pQCD?
- τ physics, R values and QCD
  - Precision measurement of the tau mass and R values
- Search for rare and forbidden decay modes



hep-ex/0809.1869
IJMPA V24, No 1 (2009) supp.

Physics program ➔ white paper

- Since 2017, BESIII started to discuss
  - The lifetime of BESIII experiment
  - Important physics topics with BESIII data
  - Competition from other experiments
  - Necessity of BEPCII upgrading
- A working group was formed
  - Convened by Prof. Haibo Li
  - Main contributors
    - BESIII physics group conveners
    - Invited authors, theorists+experimentalists

Physics program ➔ white paper

- First version ready: Feb. 14, 2017
- Edited by international experts
- Collaboration Wide Review: Nov. 11, 2018
- BESIII EB review: Dec. 2018-Feb. 2019
- More edits ……
- Latest version (v15): Aug. 15, 2019
- International Review: Sept. 2-4, 2019

arXiv.org > hep-ex > arXiv:1912.05983

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High Energy Physics – Experiment

White Paper on the Future Physics Programme of BESIII

M. Ablikim, M. N. Achasov, P. Adlarson, S. Ahmed, M. Albrecht, M. Alekseev, A. Amoroso, F. F. An, Q. An, Y. Bai, O. Bakina, R. Baldini Ferroli, Y. Ban, K. Begzsuren, J. V. Bennett, N. Berger, M. Bertani, D. Bettoni, F. Bianchi, J Biernat, J. Bloms, I. Boyko, R. A. Briere, L. Calibbi, H. Cai, X. Cai, A. Calcaterra, G. F. Cao, N. Cao, S. A. Cetin, J. Chai, J. F. Chang, W. L. Chang, J. Charles, G. Chelkov, Chen, G. Chen, H. S. Chen, J. C. Chen, M. L. Chen, S. J. Chen, Y. B. Chen, H. Y. Cheng, W. Cheng, G. Cibinetto, F. Cossio, X. F. Cui, H. L. Dai, J. P. Dai, X. C. Dai, A. Dbeyssi, D. Dedovich, Z. Y. Deng, A. Denig, I. Denysenko, M. Destefanis, S. I. Eidelman, S. Descotes-Genon, F. De Mori, Y. Ding, C. Dong, J. Dong, L. Y. Dong, M. Y. Dong, Z. L. Dou, S. X. Du, J. Z. Fan, J. Fang, S. S. Fang, Y. Fang, R. Farinelli, L. Fava, F. Feldbauer, G. Felici, C. Q. Feng, M. Fritsch, C. D. Fu, Y. Fu, Q. Gao, X. L. Gao, Y. Gao, Y. Gao, Y. G. Gao, Z. Gao, B. Garillon, I. Garzia, E. M. Gersabeck, A. Gilman, K. Goetzen, L. Gong, W. X. Gong, W. Gradl, M. Greco, L. M. Gu, M. H. Gu, Y. T. Gu, A. Q. Guo, F. K. Guo, L. B. Guo, R. P. Guo et al. (388 additional authors not shown)

(Submitted on 12 Dec 2019)

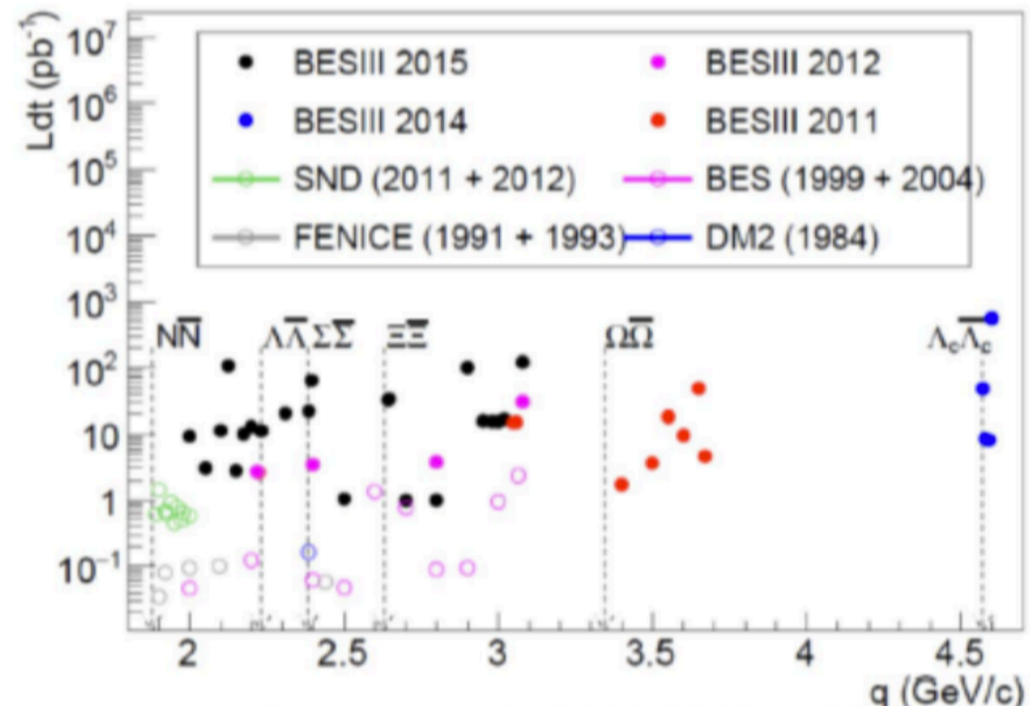
There has recently been a dramatic renewal of interest in the subjects of hadron spectroscopy and charm physics. This renaissance has been driven in part by the discovery of a plethora of charmonium-like *[Math Processing Error]* states at BESIII and *[Math Processing Error]* factories, and the observation of an intriguing proton-antiproton threshold enhancement and the possibly related *[Math Processing Error]* meson state at BESIII, as well as the threshold measurements of charm mesons and charm baryons.
We present a detailed survey of the important topics in tau-charm physics and hadron physics that can be further explored at BESIII over the remaining lifetime of BEPCII operation. This survey will help in the optimization of the data-taking plan over the coming years, and provides physics motivation for the possible upgrade of BEPCII to higher luminosity.

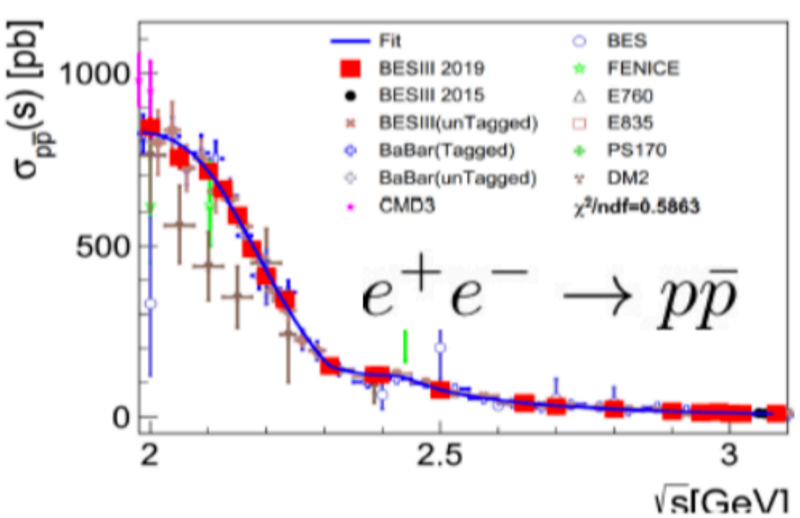
Comments: 210 pages; To be submitted to Chin. Phys. C
Subjects: **High Energy Physics - Experiment (hep-ex)**; High Energy Physics - Phenomenology (hep-ph)
Cite as: arXiv:1912.05983 [hep-ex]

Competition

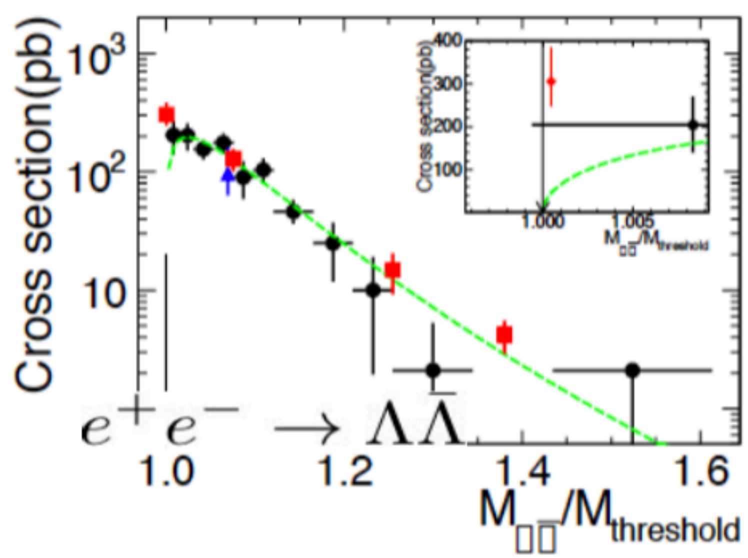
Advantage: unique data near to the thresholds

- **D/Ds/Λ_c hadrons near thresholds:**
  precision branching fractions, unique access to the relative phase, test of SM
- Hyperon and charmed baryon Spin polarization in QC
- Form-factors in the time-like production
- CP violation with quantum-correlated pair productions of hyperons and charmed baryon

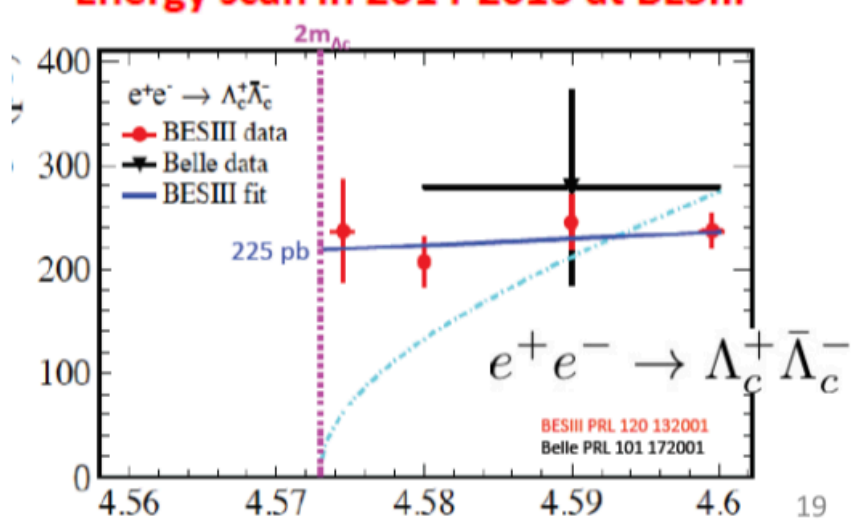




Best precision on σ: 3% (systematic dominant)



Energy scan in 2014-2015 at BESIII



Competition

High precision charm physics @thresholds: D/Ds

Observables	Exp. measure	BESIII	Belle-II	LHCb
$B(D^+ \to l\nu)$	$f_D\|V_{cd}\|$	1.1%	1.4%	N/A
$B(D_S^+ \to l\nu)$	$f_{Ds}\|V_{cs}\|$	1.0%	1.0%	N/A
$\frac{B(D^+ \to l\nu)}{B(D_S^+ \to l\nu)}$	$\frac{f_D\|V_{cd}\|}{f_{Ds}\|V_{cs}\|}$	1.0%	1.4%	N/A
$d\Gamma(D \to \pi l\nu)/dq^2$	$f_{D\to\pi}(0)\|V_{cd}\|$	0.6%	1.0%	N/A
$d\Gamma(D \to Kl\nu)/dq^2$	$f_{D\to K}(0)\|V_{cs}\|$	0.5%	0.9%	N/A
$d\Gamma(D_S \to Kl\nu)/dq^2$	$f_{Ds\to K}(0)\|V_{cd}\|$	1.3%	N/A	N/A
$d\Gamma(D_S \to \phi l\nu)dq^2$	$f_{Ds\to\phi}(0)\|V_{cs}\|$	1.0%	N/A	N/A

Belle: 2.5%

BESIII: 20fb^{-1} @ 3770 MeV, 6fb^{-1} @ 4180 MeV, arXiv: 0809.1869 (BESIII physics book)

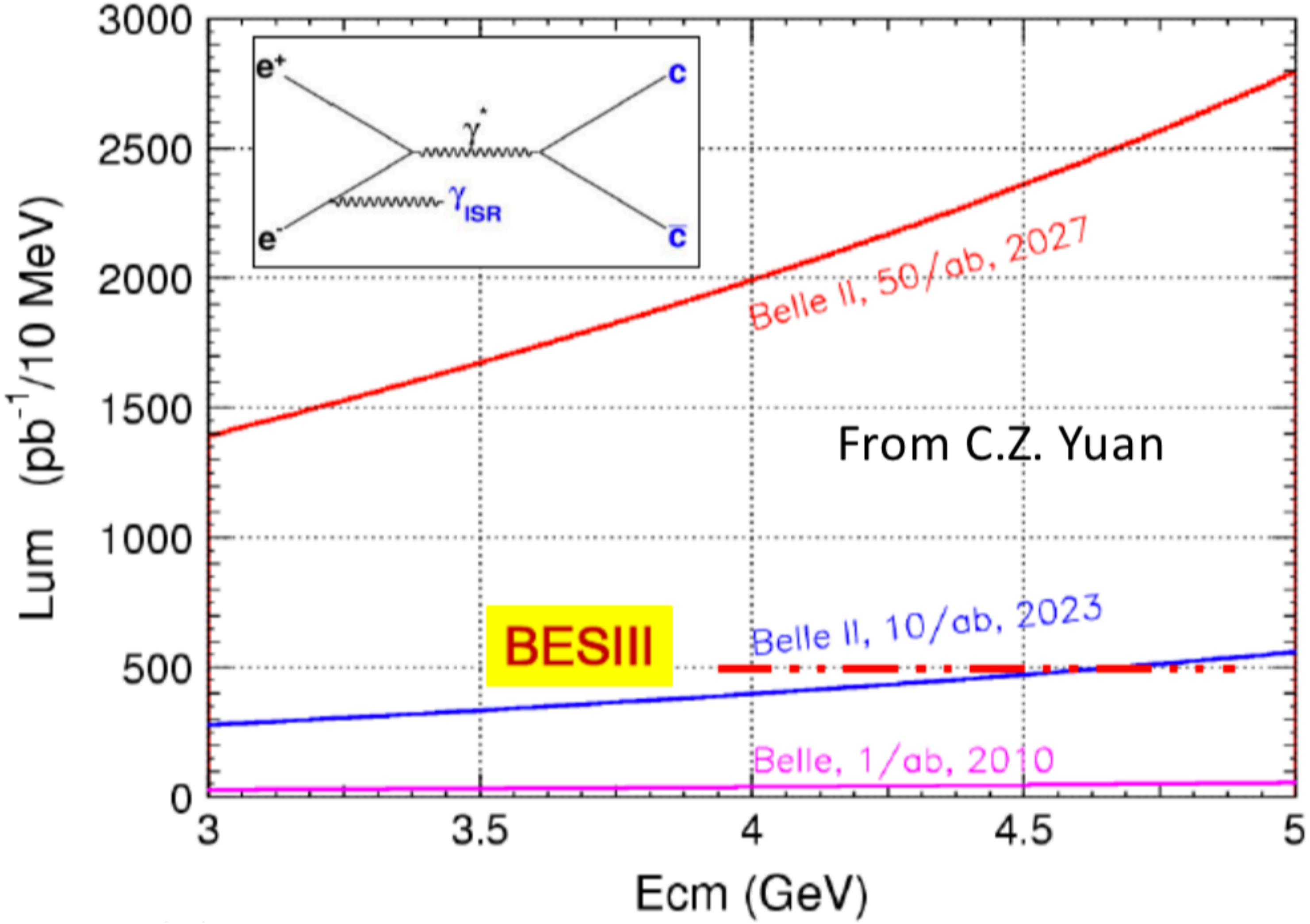
Belle-II: 50 ab^{-1} @ Y(4S) arXiv: 1808.10567 (Belle-II physics book)

LHCb: : arXiv:1808.08865 **for upgrade-II**

Competition

Belle II vs. BESIII

ISR produces events at all CM energies BESIII can reach



BelleII schedule:

2022: 20/ab :

2025: 50/ab:

At 4.26 GeV for $\pi^+\pi^- J/\psi$

ε_{BESIII} = 46%

ε_{Belle} = 10%

BESIII: high efficiency for open-charm

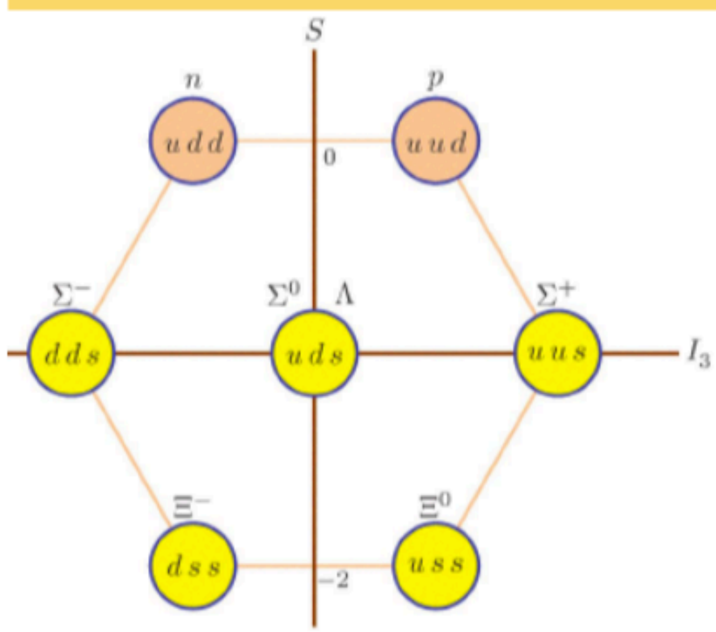
BelleII: very low efficiency for open charm

Competition

CPV in hyperon decays and New physics

CPV in SM is small :			# events	Experiments
B meson :	O(1)	discovered (2001)	10^3	B factory
K meson :	$O(10^{-3})$	discovered (1964)	10^6	Fix targets
D meson :	$O(10^{-4})$	discovered (2019)	10^8	LHCb
Hyperon :	$O(10^{-4})$	10^{-2}	$O(10^8)$	Fix targets
				→ BESIII ?

Flavor-SU(3) Octet of spin ½



Flavor-SU(3) Decuplet of spin 3/2