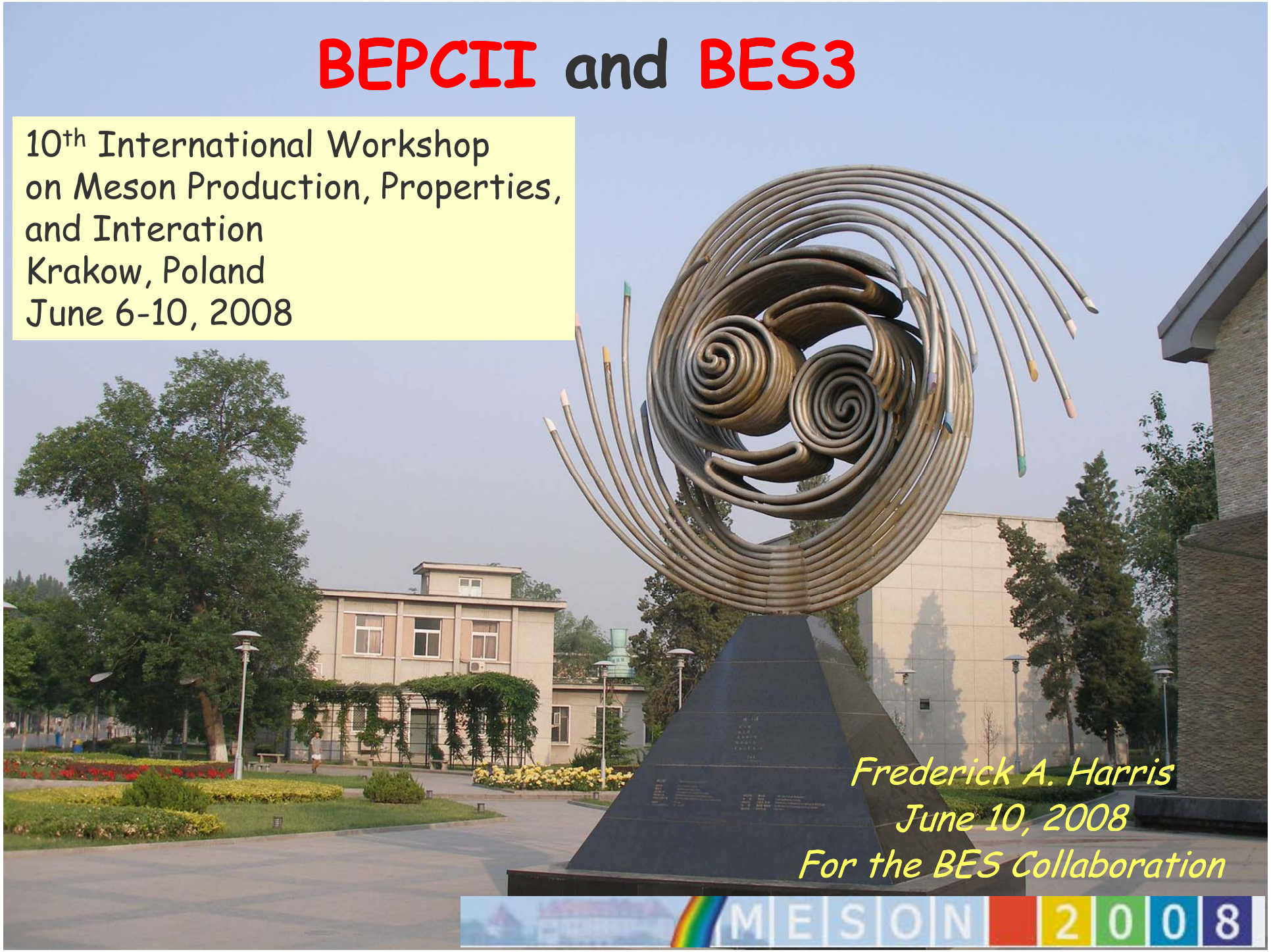
BEPCII and BES3

10th International Workshop
on Meson Production, Properties,
and Interation
Krakow, Poland
June 6-10, 2008



Frederick A. Harris
June 10, 2008
For the BES Collaboration

MESON 2008

OUTLINE

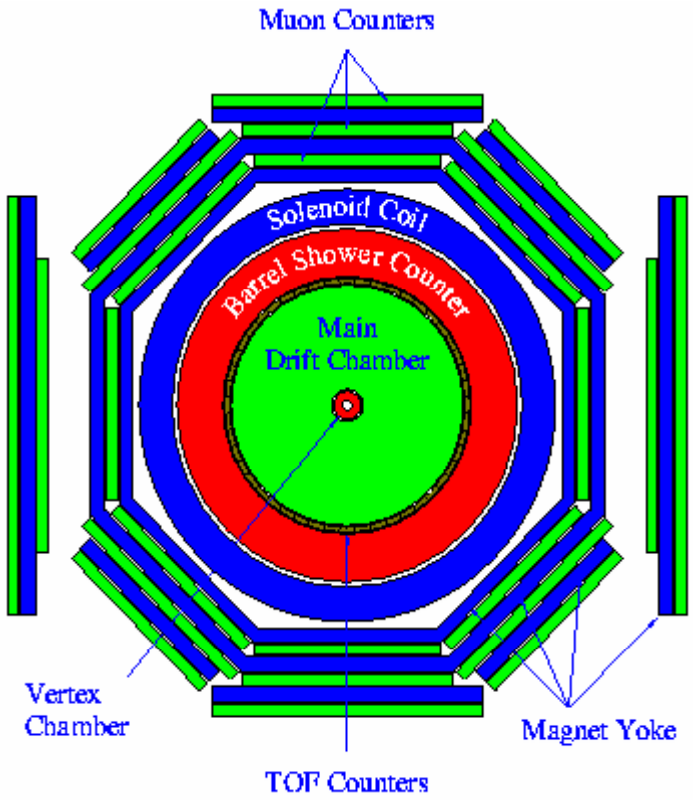
- Introduction
- BEPCII
- BES3 and status
- BES3 physics
- TOF monitoring system
- Summary

Introduction - BES2

CM Energy ranges from 2 to 5 GeV

Luminosity at $J/\psi \sim 5 \times 10^{30}\ cm^{-2}\ s^{-1}$

BES2



A unique e^+e^- machine in the τ-charm energy region from 1989 – until CLEOc (2003).

The future of BEPC

- Decision to build BEPC in the early 1980s was a great success:
  - Rich physics results: (See talk by Xiaoyan Shen)
    - A total of ~120 papers in PRL, PRD, PLB, etc.
    - A total of ~300 entries in the Particle Data Book.
    - Several highlights well known to the community.
  - Established foundation of particle physics and its related technology in China.
  - Started the era of synchrotron radiation studies in China.
  - Technology transfer.
- In the 1990s, there was discussion of the future. The conclusion was to continue tau-charm physics with a major upgrade of the accelerator and detector (BEPCII/BES3).
- The physics window is precision charm physics and the search for new physics.
  - High statistics: high luminosity machine + high quality detector.
  - Small systematic error: high quality detector.

We are unique

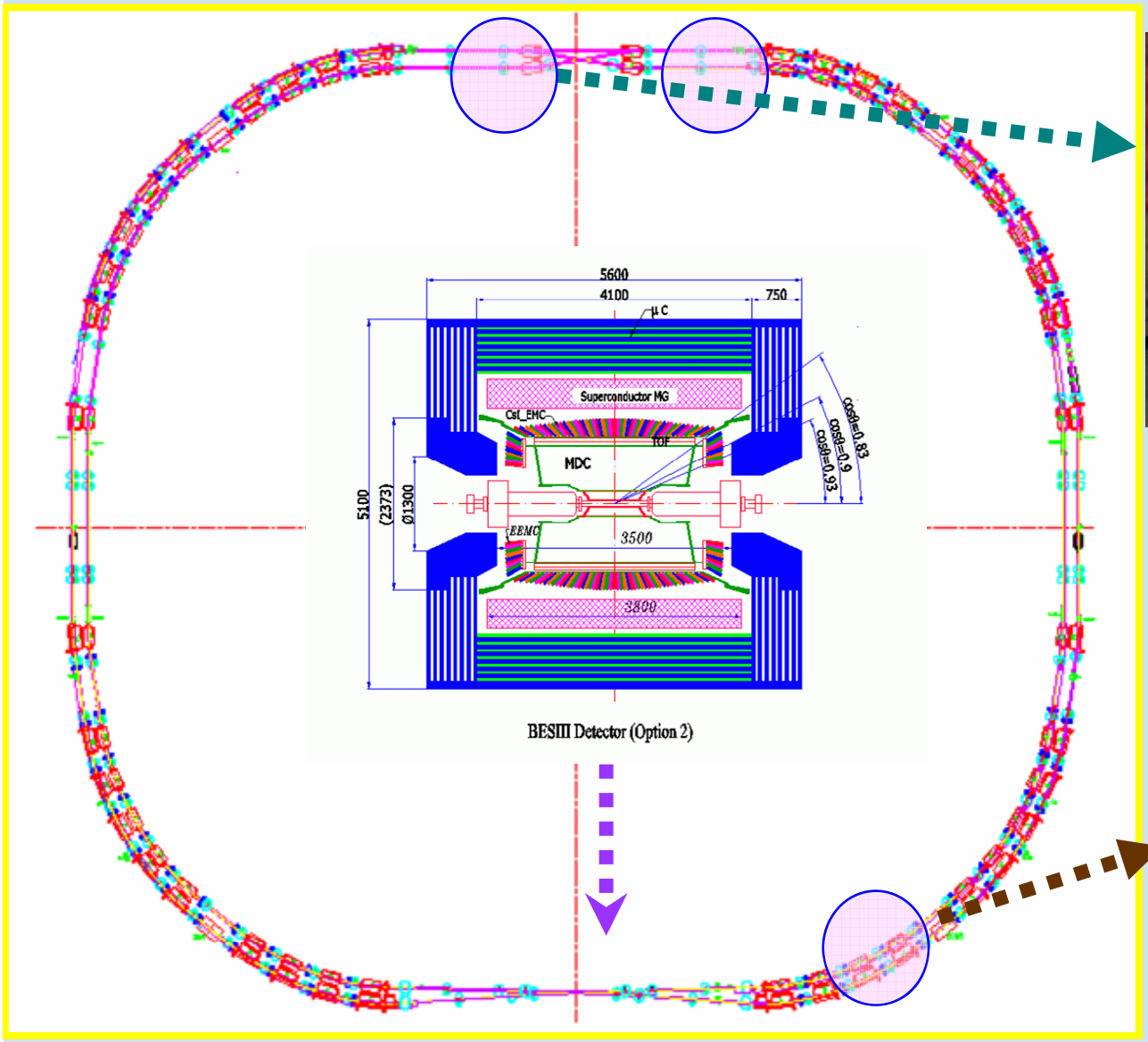
CLEOc stopped in March 2008.

Tau charm physics with BEPCII/BES3:

- In transition region between pQCD and non-pQCD.
- Can provide calibrations and tests of lattice QCD.
- Rich spectra of light hadrons for quark model tests and searches for new hadrons.
- Rich gluonic matter production for tests of QCD.
- Near threshold production for tau and charm. Can provide very high precision measurements of standard model parameters and tests of quantum correlations.


中华人民共和国万岁
世界人民大团结万岁
BEPCII

BEPCII: a high luminosity double-ring collider



SC RF

Beam magnets

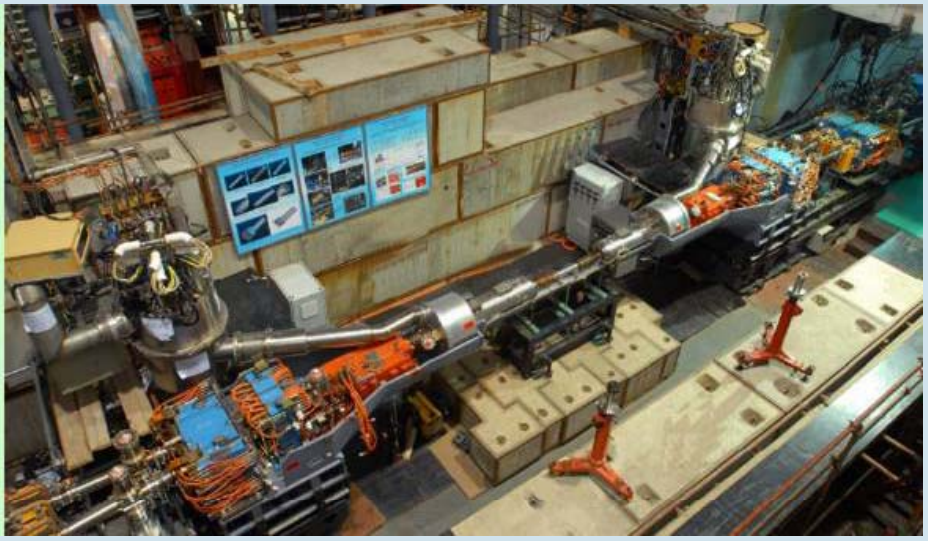
BEPCII Design

Energy range	**1 – 2.1 GeV**
Optimum energy	**1.89 GeV**
Luminosity	**1×10^{33} $cm^{-2}s^{-1}$ @ 1.89 GeV**
Injection	**Full energy injection: 1.55 – 1.89 GeV** **Positron injection rate > 50 mA/min**
No. of bunches	**93**
Current	**0.91 A**
Bunch length	**1.5 cm**
Synchrotron mode	**250 mA @ 2.5 GeV**

Use many bunches and SC mini-beta.

BEPCII Status

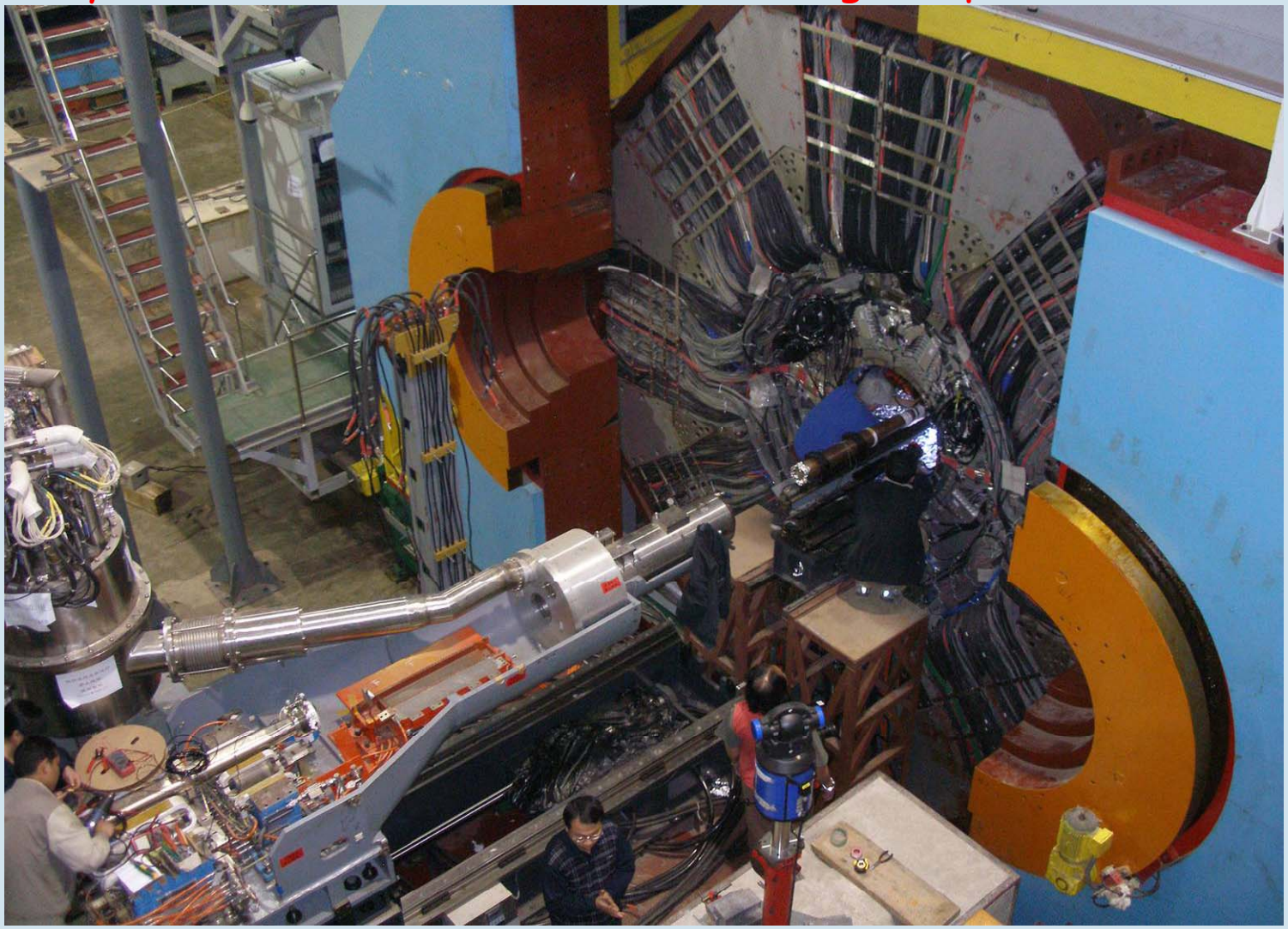
- Nov. 2006 – start commissioning; beam stored in storage ring.
- Mar. 2007 – e e collisions with normal magnets.
- June 2007 - SR radiation for users at 2.5 GeV/c; 200 mA, τ = 5.5 hr.
- Aug. 2007 – beam current reached 0.5 A.
- Nov. 2007 - $e^+ e^-$ with SC quads; collisions with 400 ma and 99 bunches.



IP – Nov. 2007

BEPCII Status

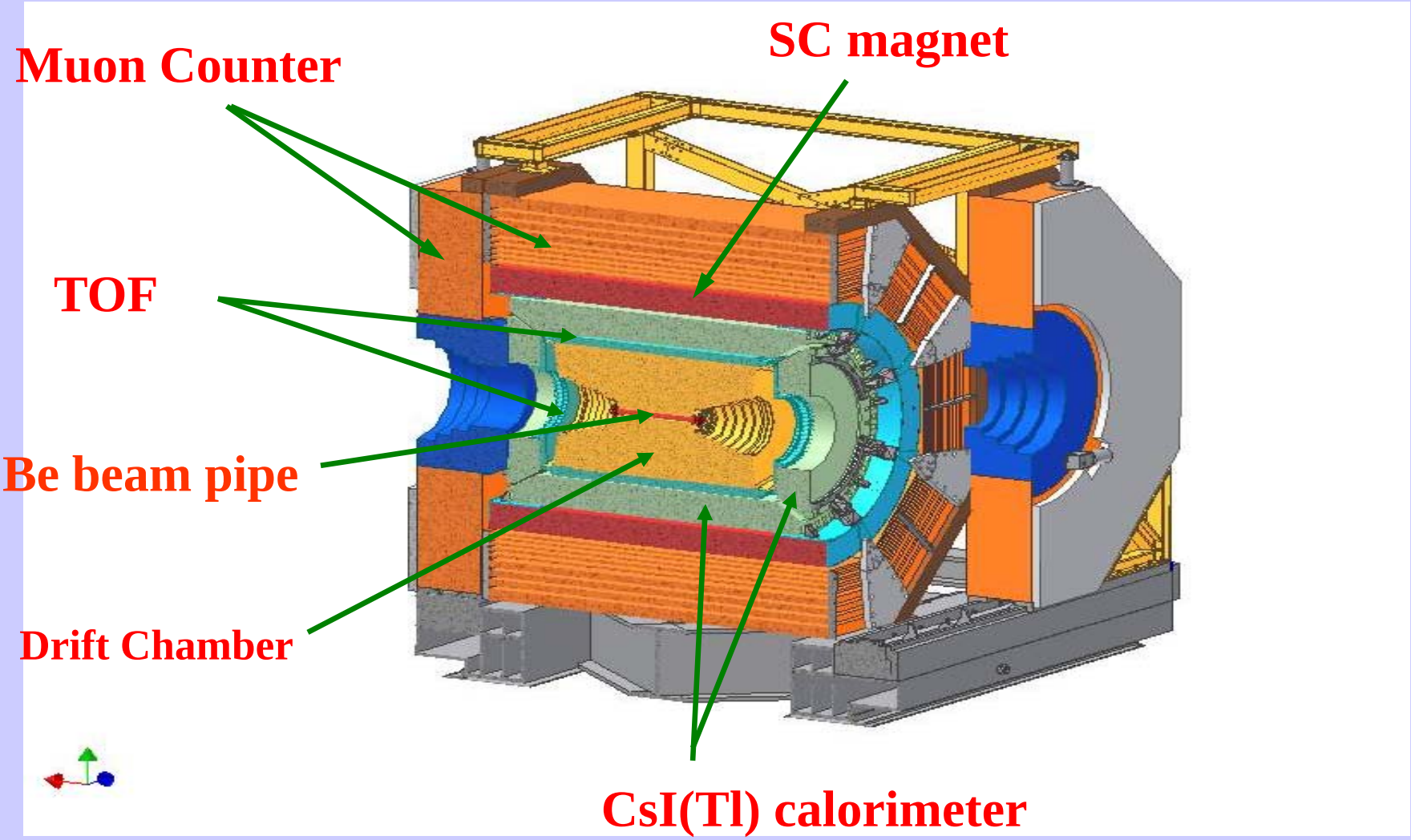
- May 15, 2008: detector at IP; installing SC quads and beam pipe.



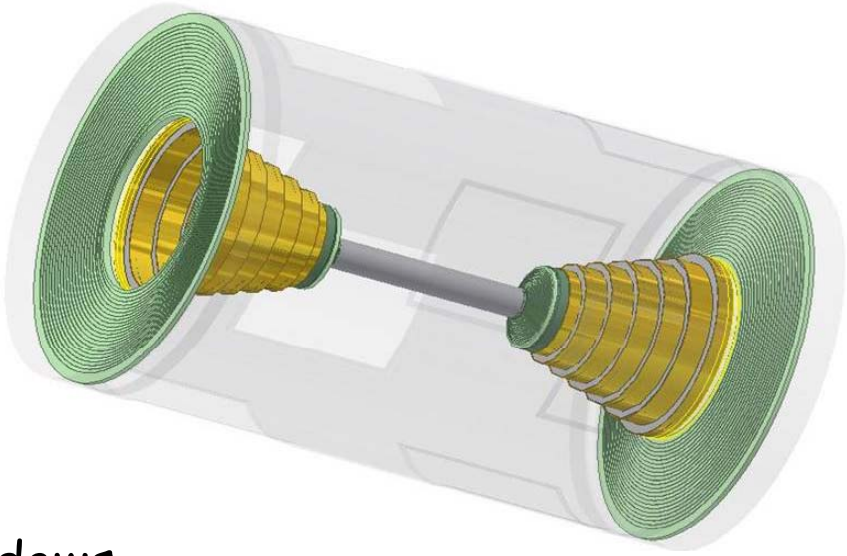
- June: expect collisions.


BES3

BES3 Detector



MDC



Parameters

R inner: 63mm ; R outer: 810mm

Length (out.): 2582 mm

Inner cylinder: 1.2 mm Carbon fiber

Outer cylinder: 11.5 mm CF with 8 windows

Sense wire : 25 micron gold-plated tungsten (plus 3% Rhenium) --- 6796

Layers (Sense wire): 43 (19 axial, 24 stereo)

Field wire: 110 micron gold-plated Aluminum --- 21884

Gas: He + C3H8 (60/40)

Cell: inner chamber --- 6 mm

outer chamber --- 8.1 mm

Polar angle: |cos θ| < 0.83 (all layers)

< 0.93 (20 layers)

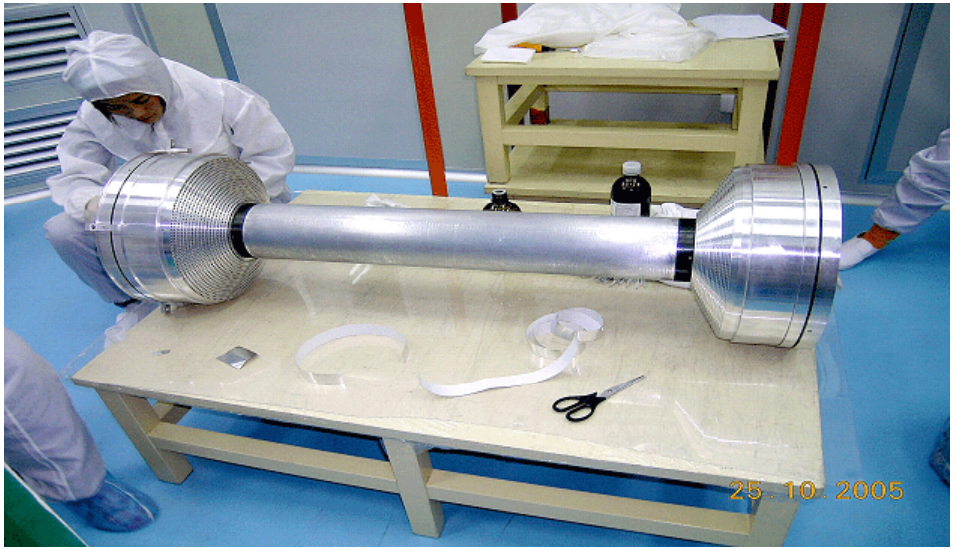
Expected performance

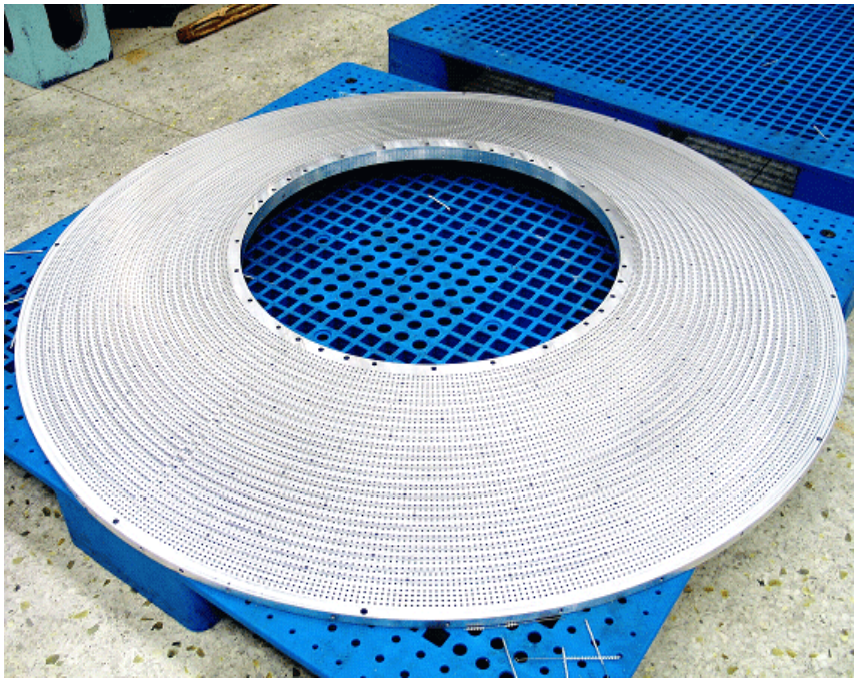
$$\sigma_x \sim 130 \ \mu m$$

$$\frac{\sigma_P}{P} \sim 0.5\% \ @1\text{GeV/C}$$

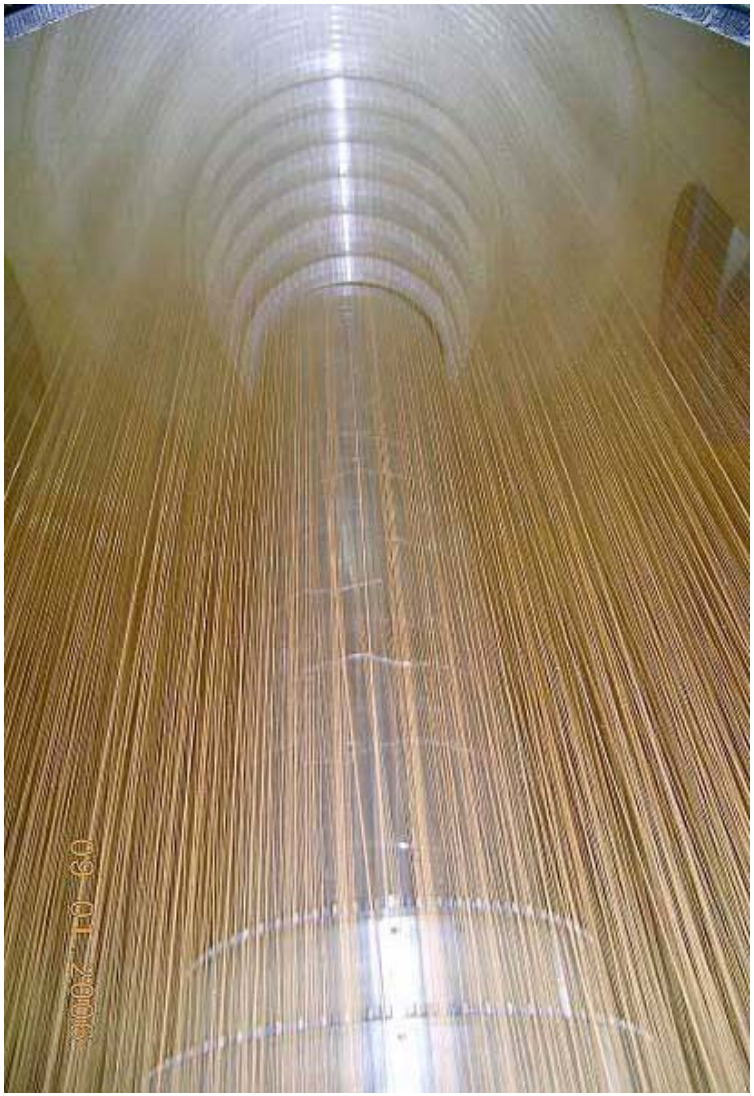
$$\frac{\sigma_{\frac{dE}{dx}}}{\frac{dE}{dx}} \sim 6\%$$

MDC construction

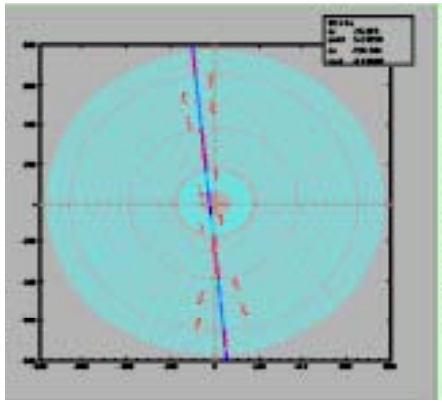


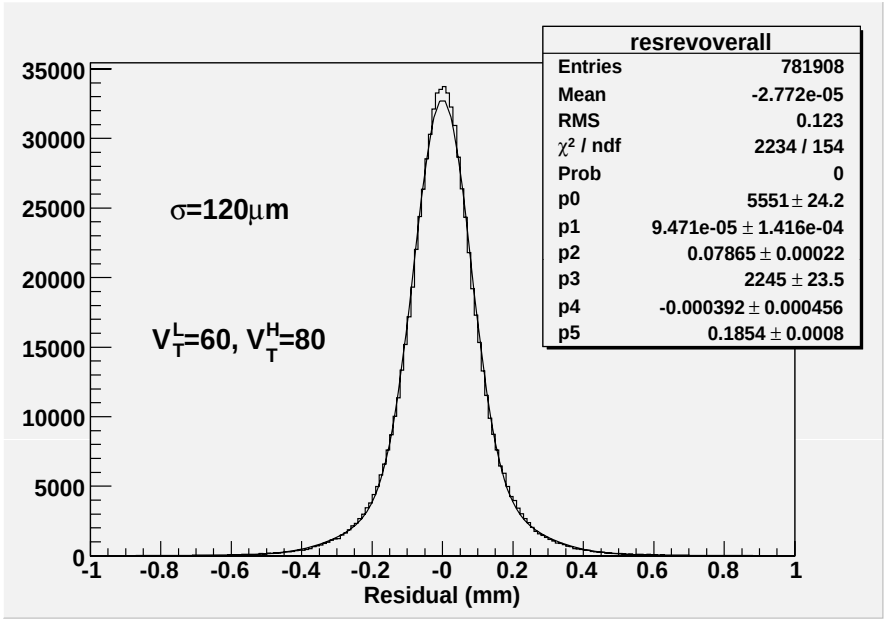


MDC wiring



Cosmic ray test of completed MDC



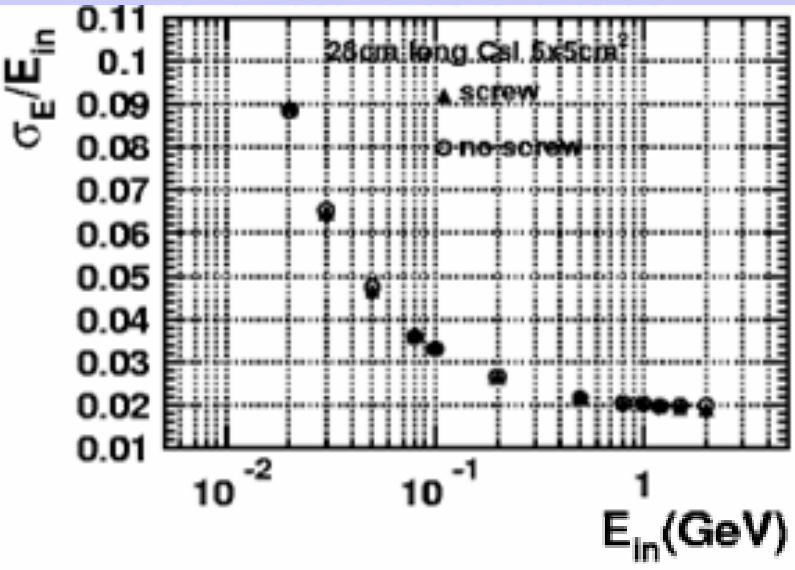


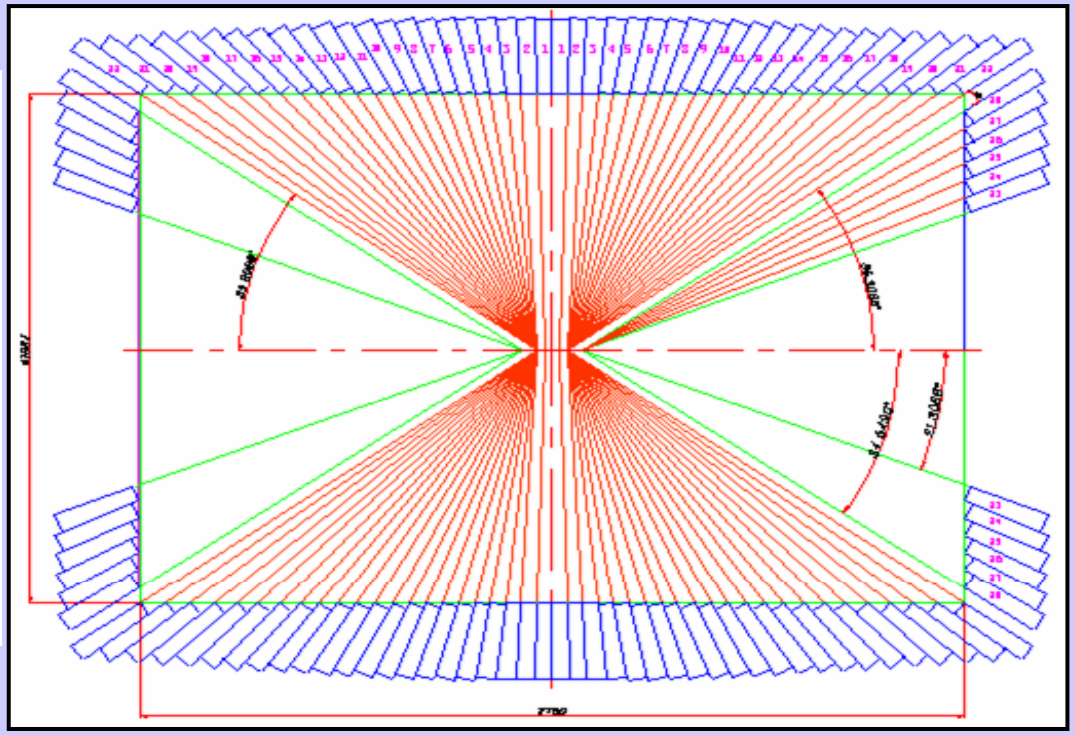
resolution 120 μm

CsI(Tl) crystal calorimeter

- Design goals:
  - Energy: 2.5% @ 1GeV
  - Energy range: 20 MeV- 2 GeV
  - Spatial: 0.6cm @ 1GeV

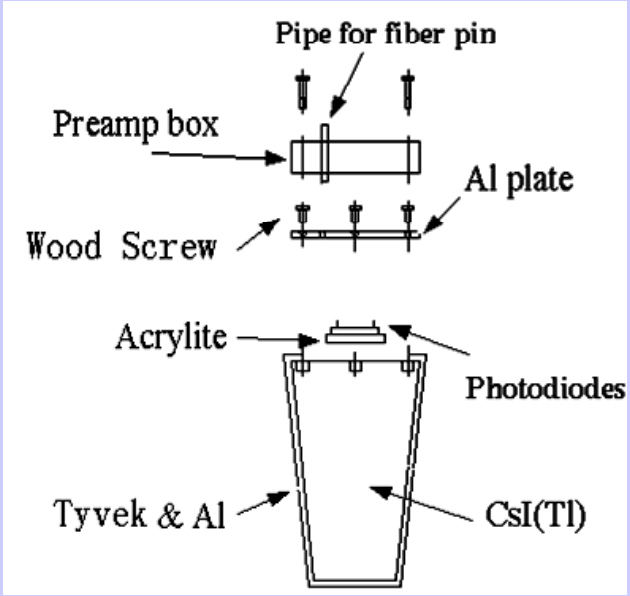
- Crystals:
  - L = 28 cm (15 X_0)
  - A = (5.2 x 5.2 – 6.4 x 6.4) cm^2
  - Barrel: 5280 w: 21564 kg
  - Endcaps: 960 w: 4051 kg
  - Total: 6240 w: 25.6 T

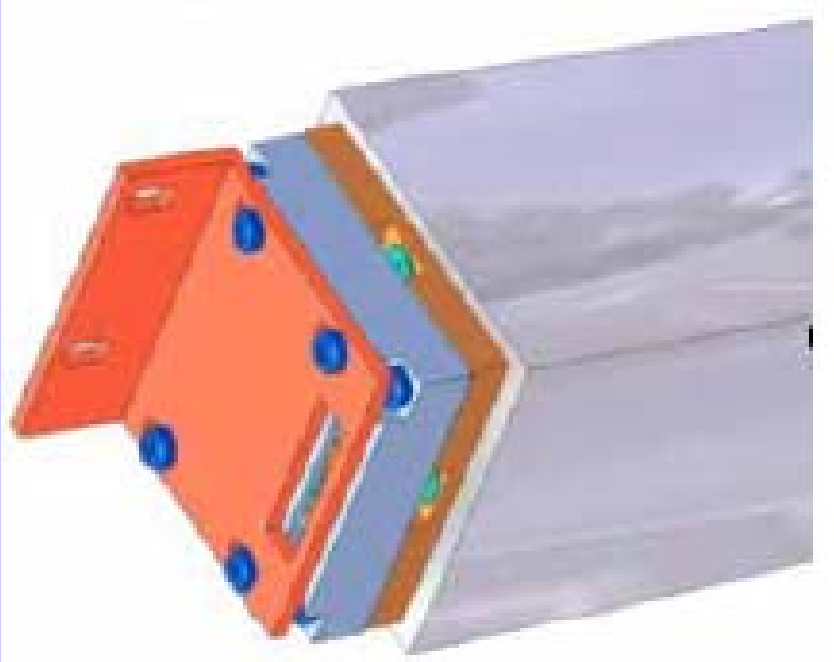


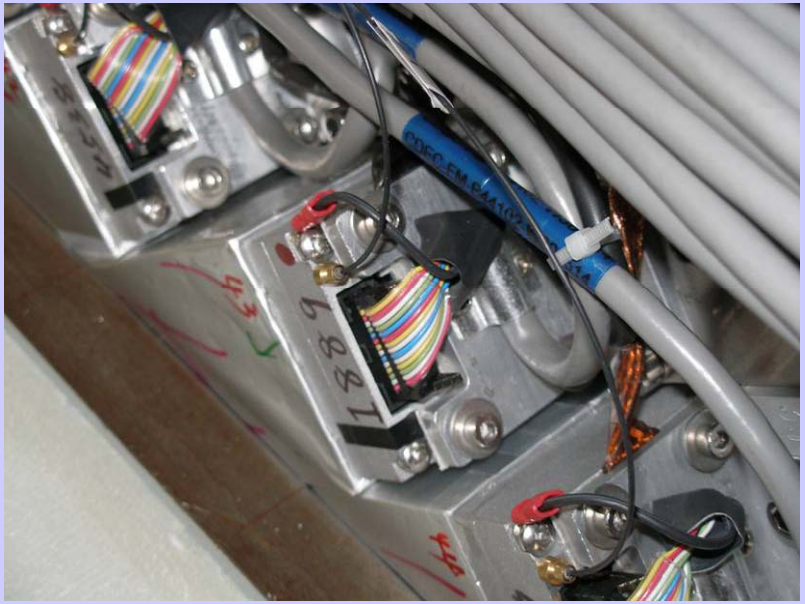


CsI(Tl) crystal calorimeter

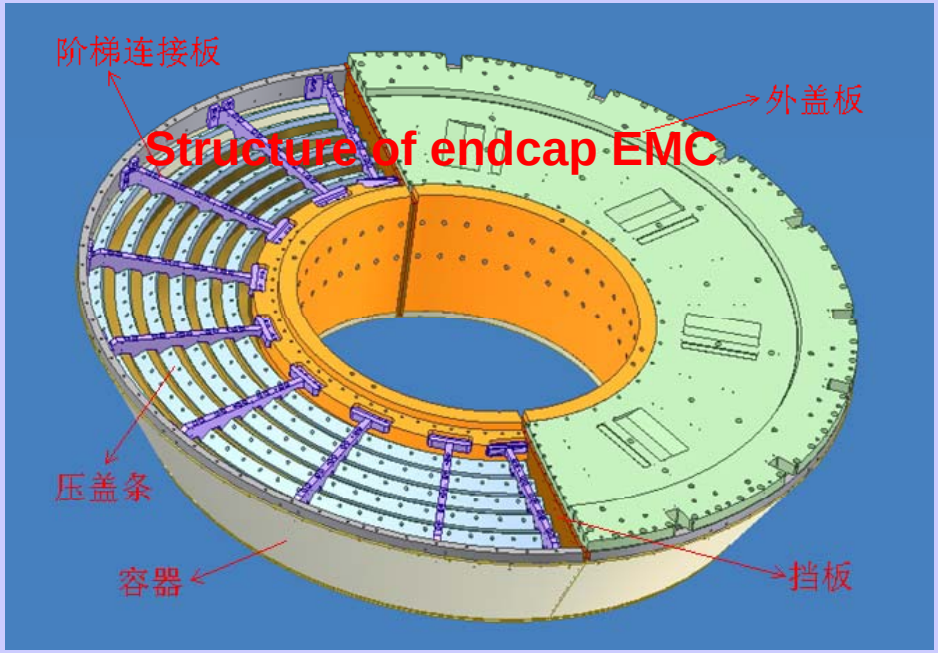
- Readout:
  - 2 PDs + 2 preamps + 1 amp
  - PD: Hamamatsu S2744-08
  - 12480 PDs total (1 cm x 2 cm)
  - Preamp noise: < 220 keV

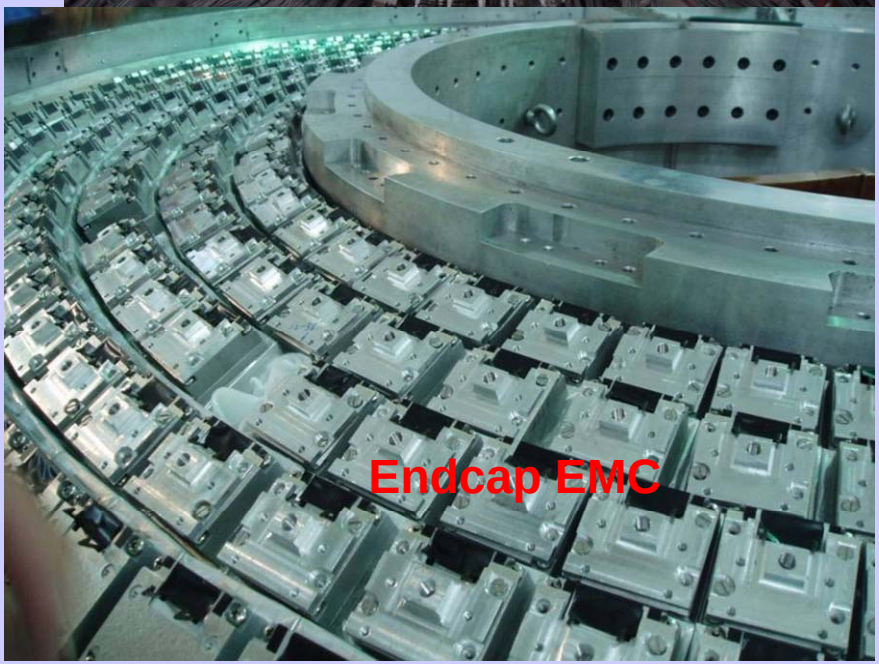






Structure of EMC



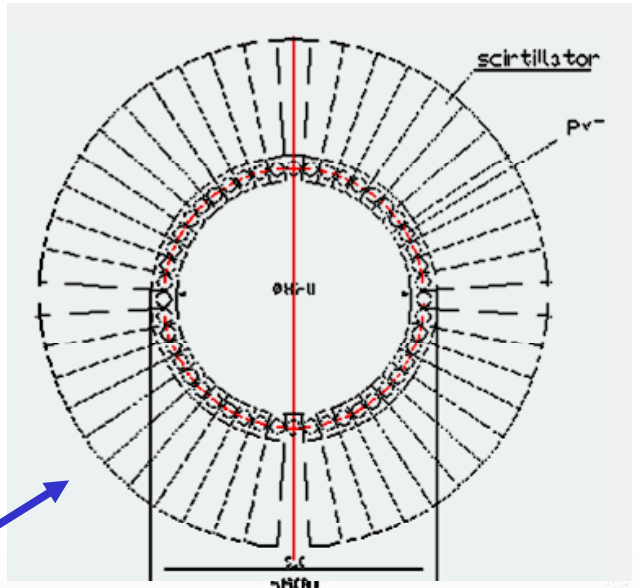


TOF

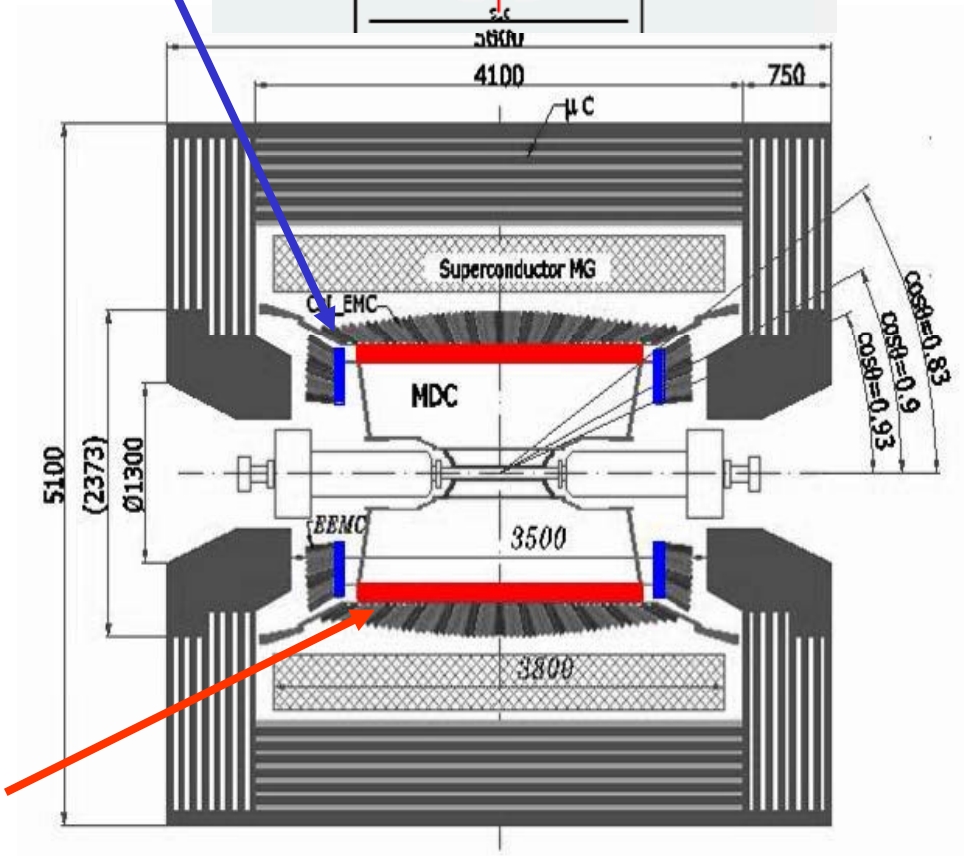
Crucial for particle ID and for fast trigger.

- Barrel
  - 50mm x 60mm x 2320 mm (inner layer).
  - BC408
  - 2 layers – 88 in each
  - Radius from 810 to 930 mm.
- Endcap
  - 48 fan shaped pieces – each end.
  - BC404
- PMT: Hamamatsu R5942 fine mesh
  - 2 on each barrel scintillator
  - 1 on each endcap counter
- Resolution
  - Barrel: σ_T = 100 ps
  - Endcap: σ_T = 110 ps

TOF – IHEP
TOF electronics - USTC

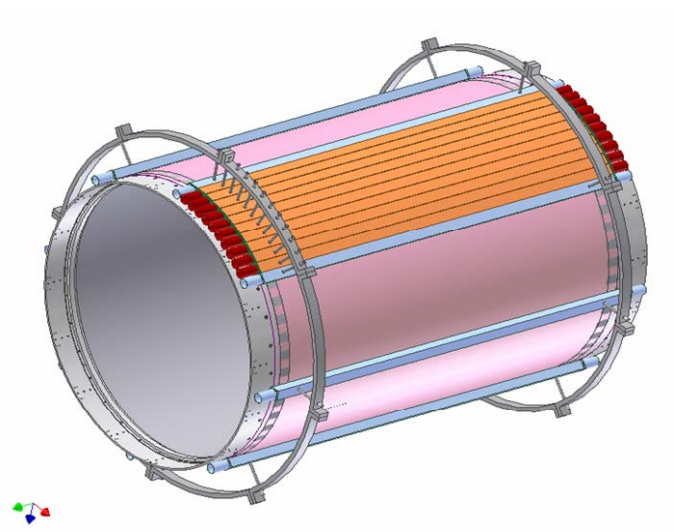


Endcap

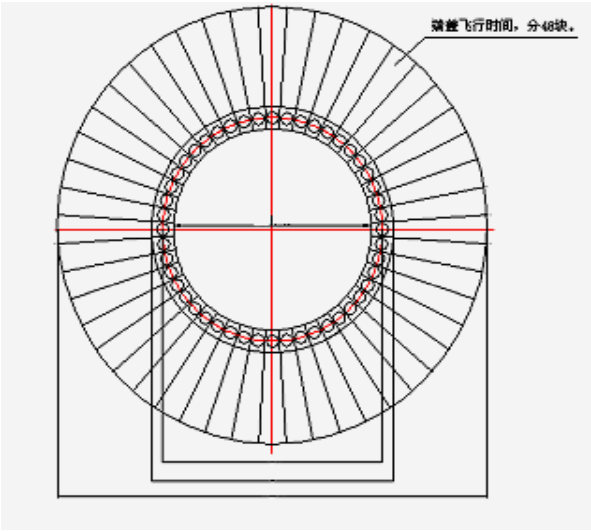


Barrel

Structure of TOF



Structure of Barrel TOF



Structure of Endcap TOF

Superconducting Magnet

Coil: single layer solenoid

Cooling mode: two phase helium force flow

Superconductor: Al stabilized NbTi/Cu

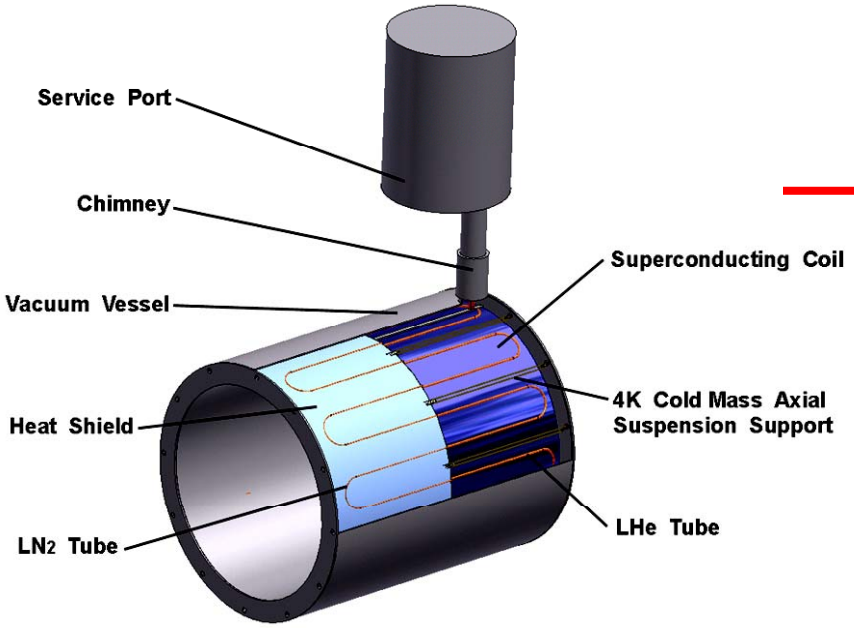
Winding: inner winding

Cold mass support: tension rod

Thermal shield: LN_2 shield, MLI

Flux return: barrel/end yoke, pole tip

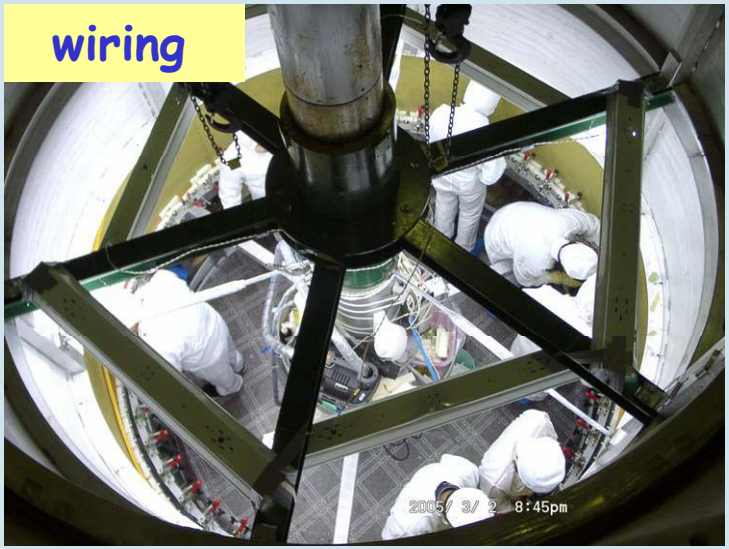
First of its kind built in China.



Cryostat	
Inner radius	1.375m
Outer radius	1.7m
Length	3.91m
Coil	
Mean radius	1.482m
Length	3.52m
Cable dimension	3.7mm*20mm
Electrical parameters	
Central field	1.0T
Nominal current	3650A
Inductance	2H
Stored energy	10MJ
Cold mass	3.6ton
Total Weight	15ton
Radiation thickness	$2X_0$

BESIII SC Magnet Progress

wiring

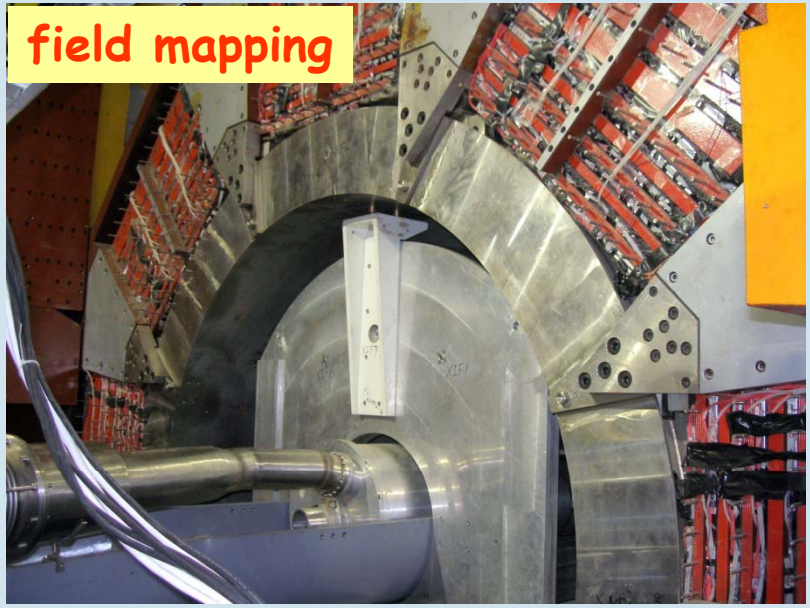


Thermal insulation

assembly

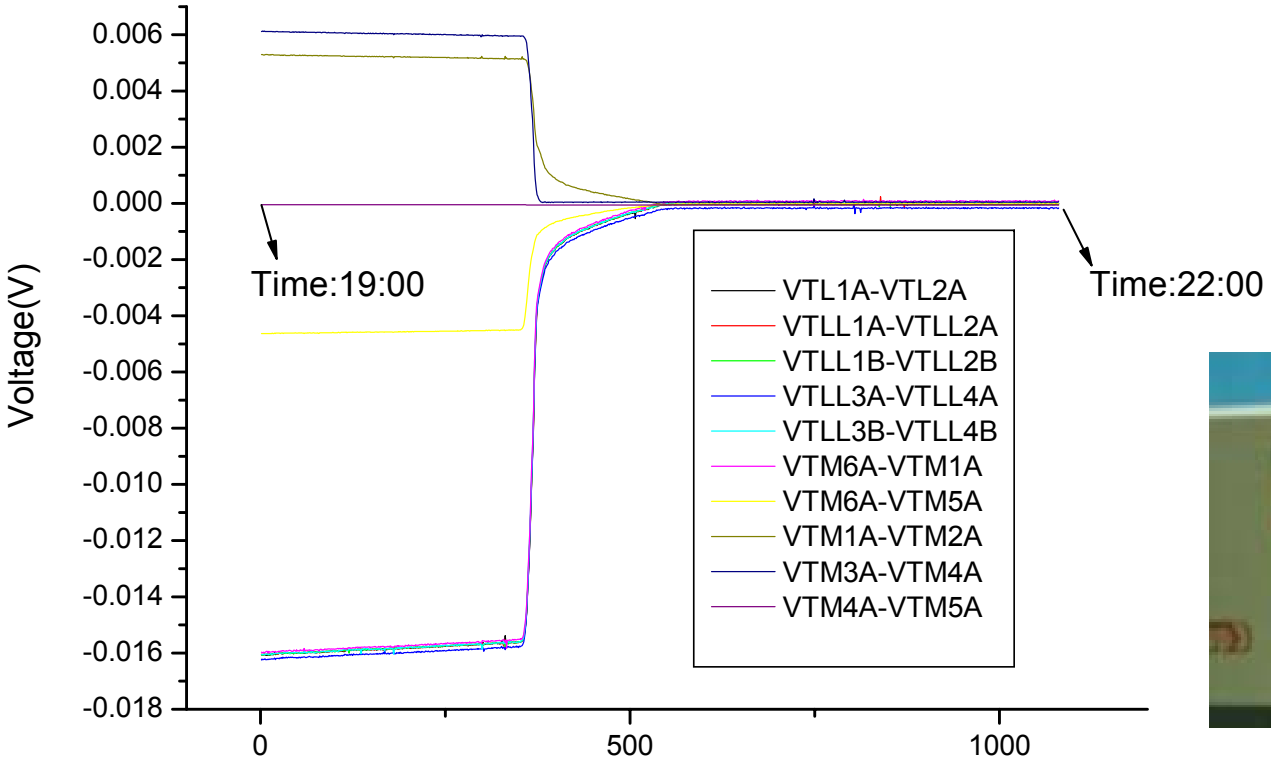
installation

field mapping



BESIII SC Magnet Progress

Sept. 19, 2006

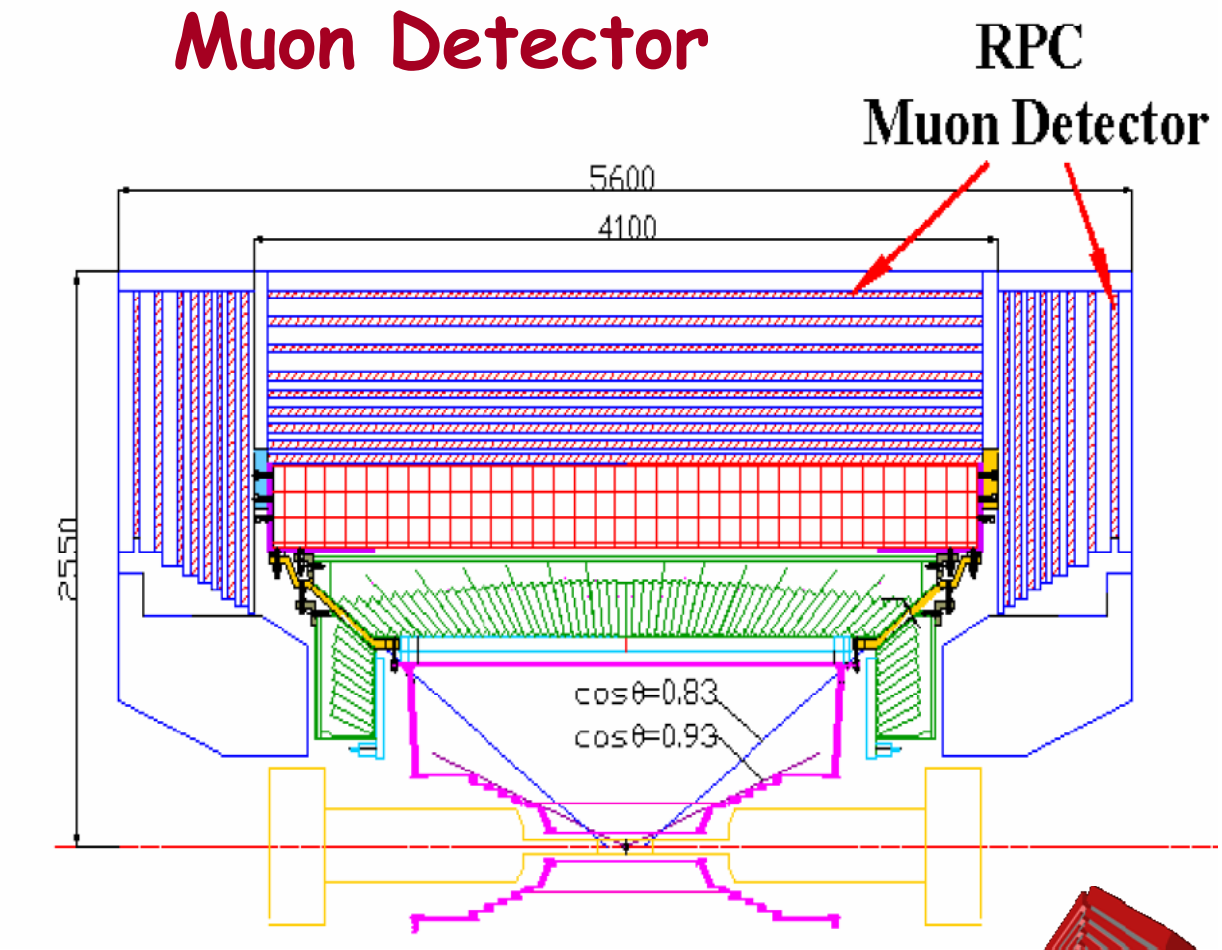


Voltage curve shows that the magnet is in super-conducting state.

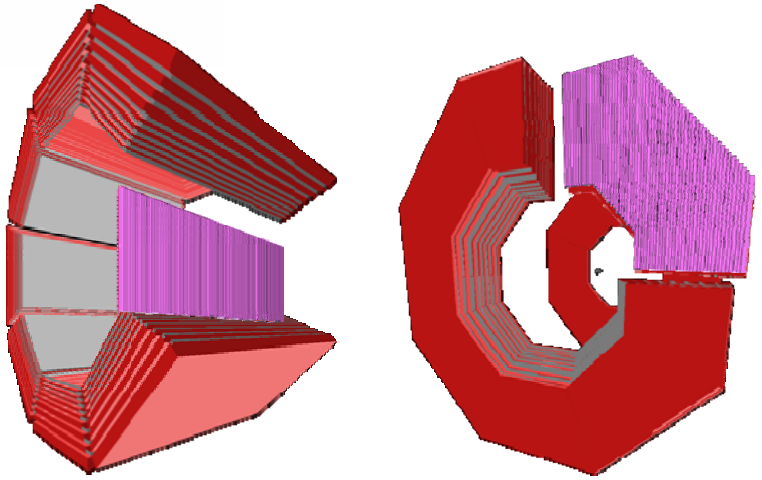
Magnetic field 10029.8 Gauss.

Field mapping of magnet completed.

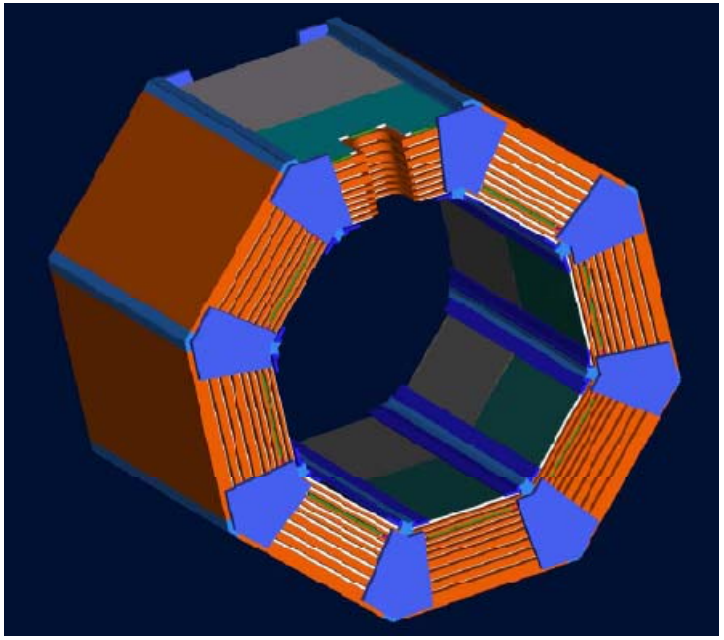
Muon Detector



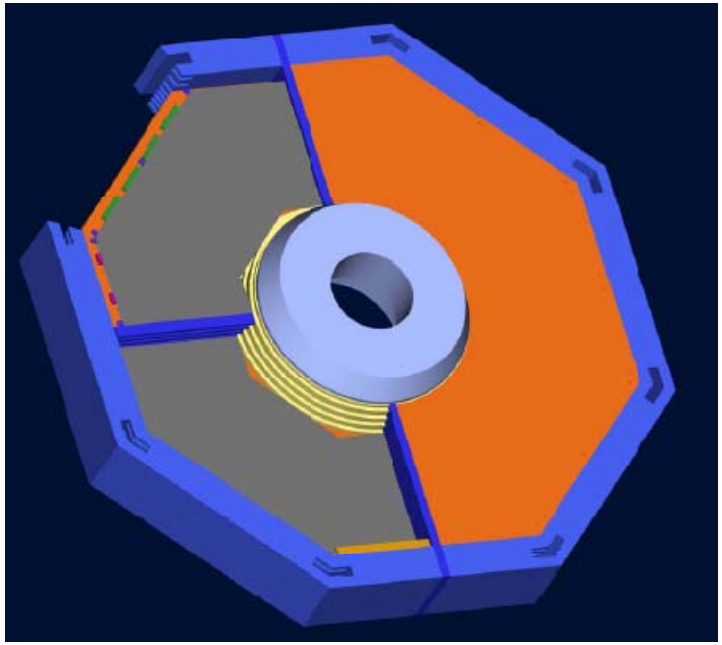
- Barrel + EndCap;
- RPCs as μ detector;
  Barrel: 9 layers – 72 modules
  EndCap: 8 layers – 64 modules



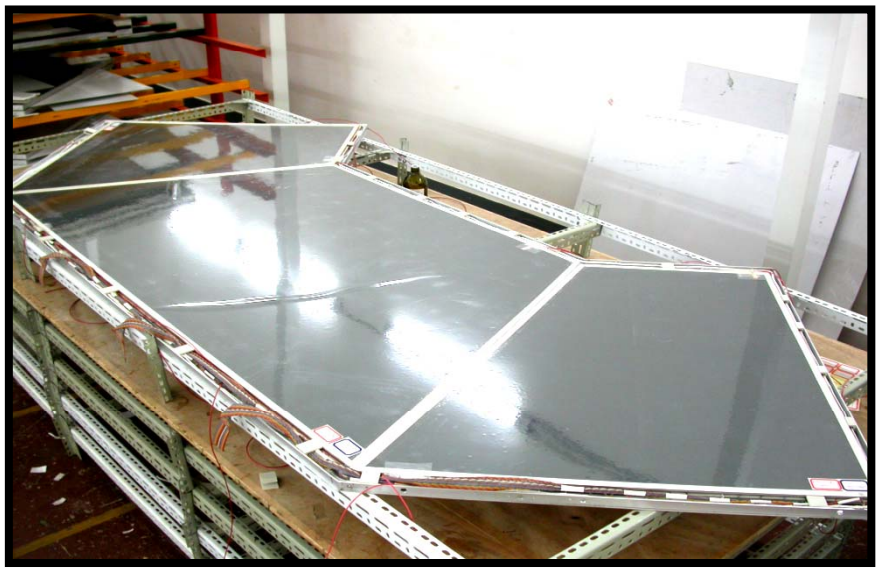
Muon Detector



Barrel

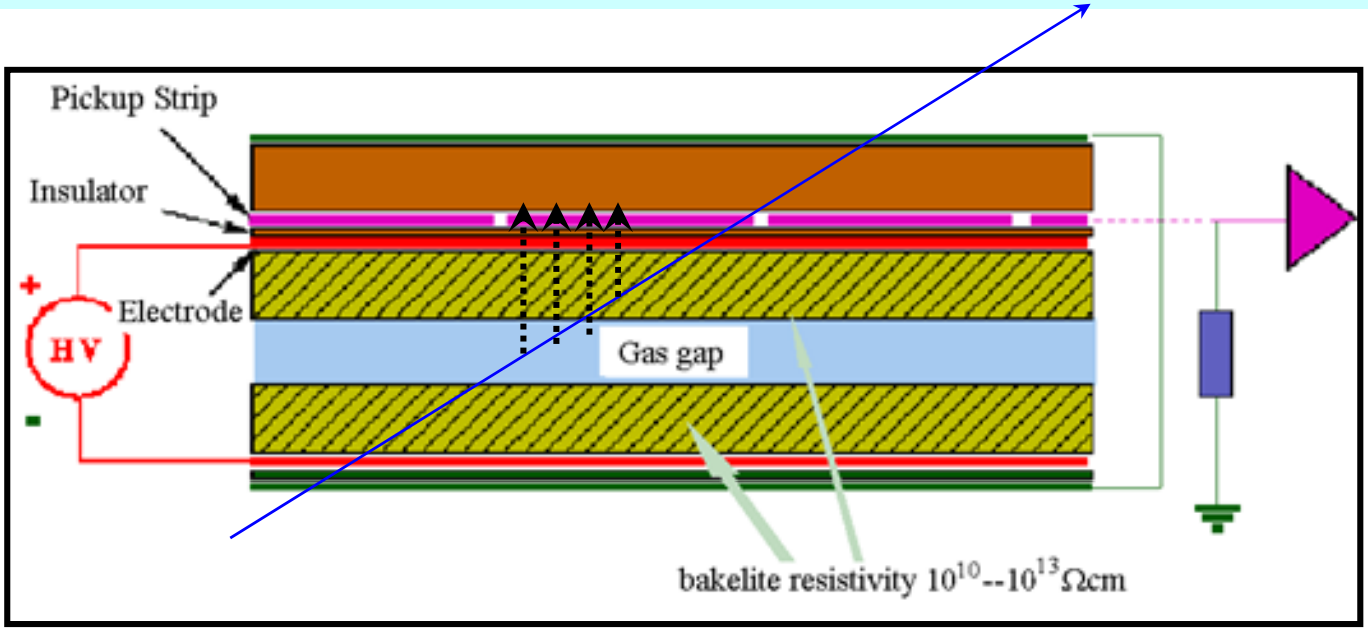


Endcap



RPCs

- Electrodes made from a special type of phenolic paper laminate on bakelite.
- Have good surface quality（~200nm).
- Extensive testing and long term reliability testing done.
- Have high efficiency, low counting rate and dark current, and good long-term stability .
- One dimension read-out strips (4 cm wide) - 10,000 channels.
- Gas: Ar:$C_2H_2F_4$:Isobutane = 50:42:8
- HV voltage: 8000V;
- One module contains two RPC layers and one readout layer.

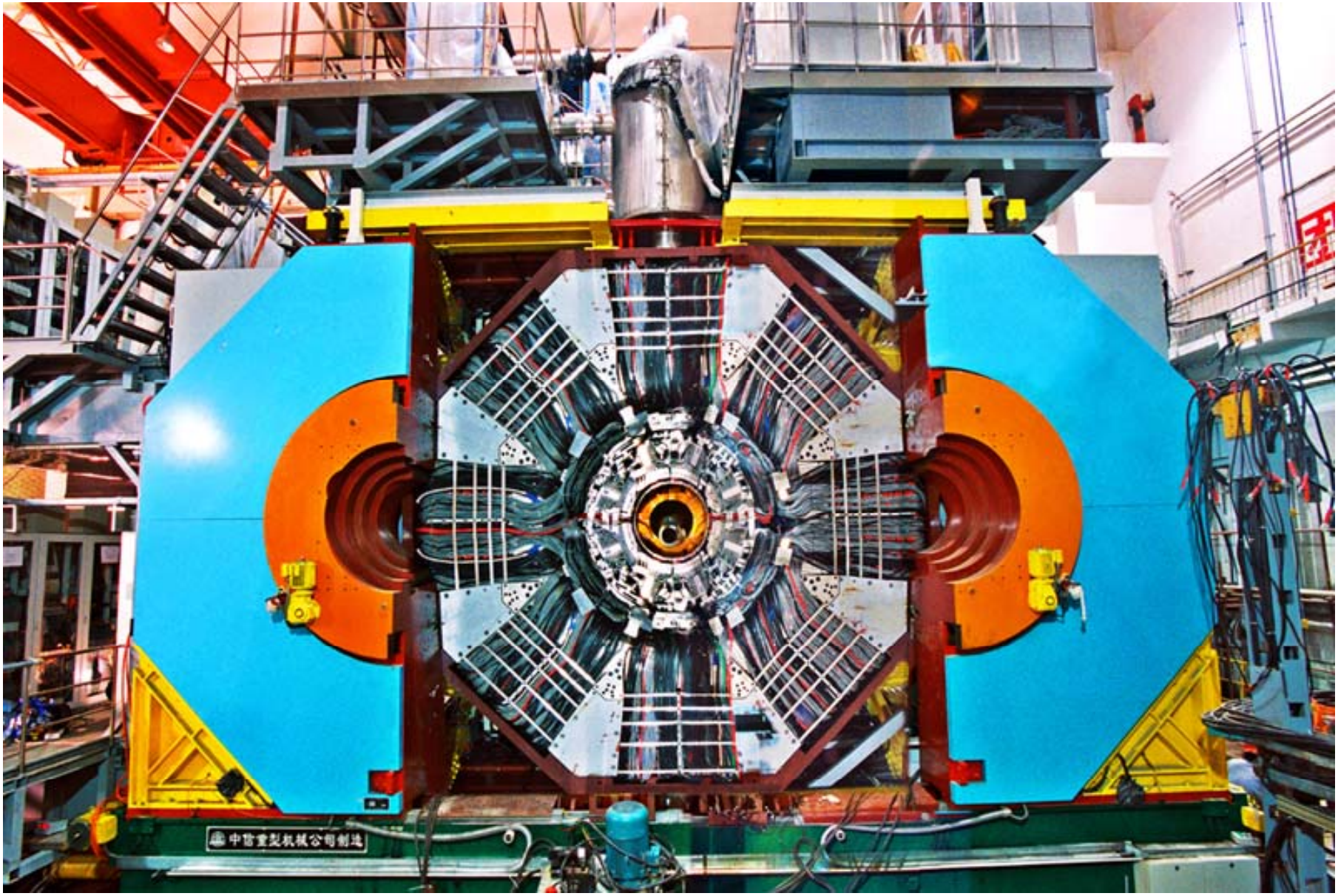


Installation

Barrel EMC

MDC/TOF

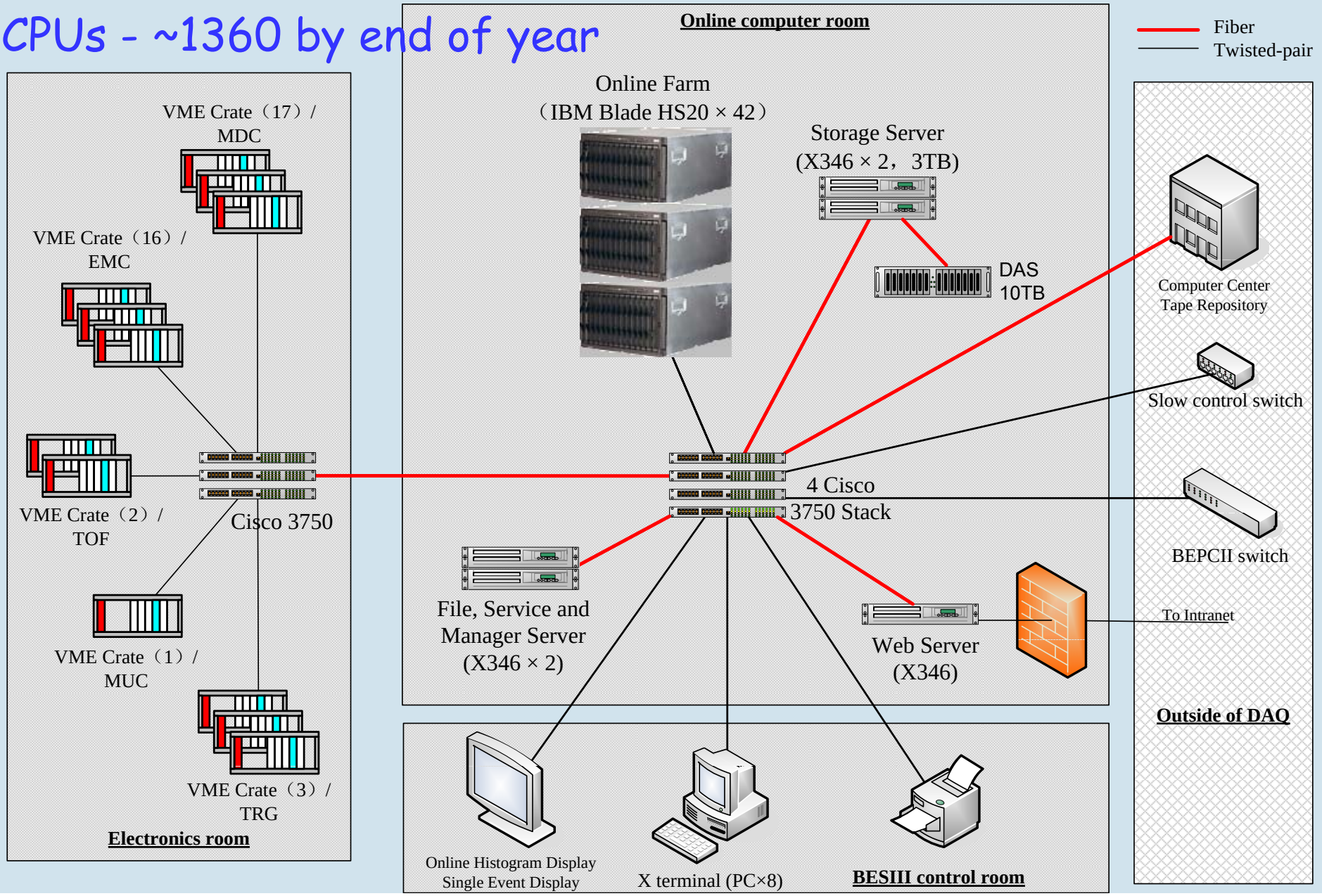
Installation complete



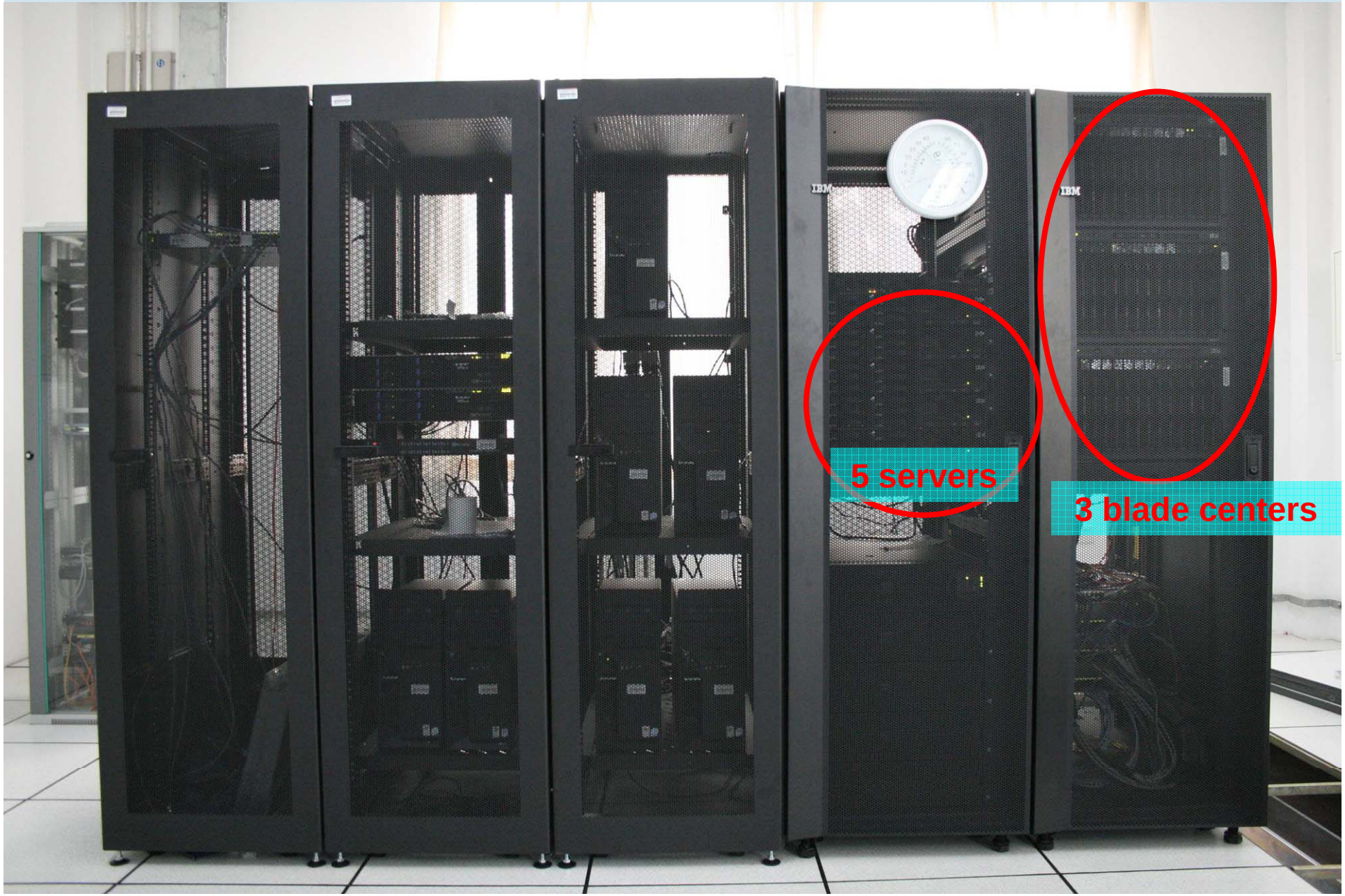
Installation complete

event rate - 3kHz
data rate - 50 MB/s
CPUs - ~1360 by end of year

DAQ



Online computer room

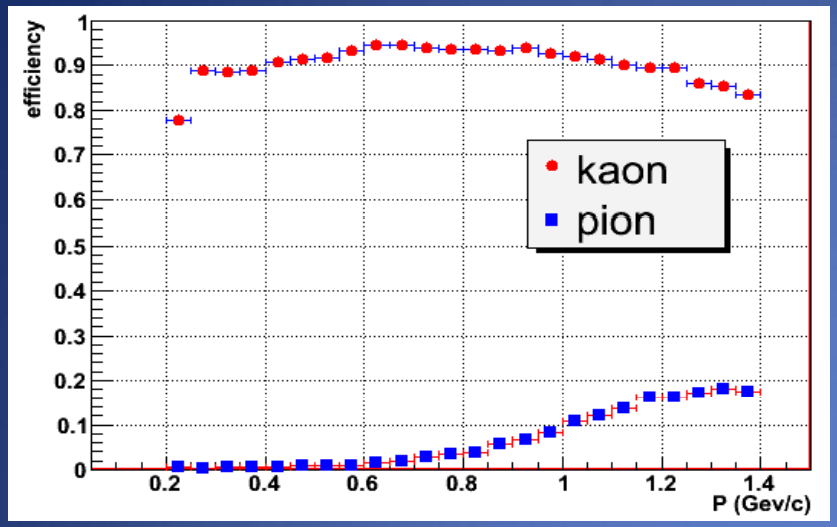


Particle ID Summary

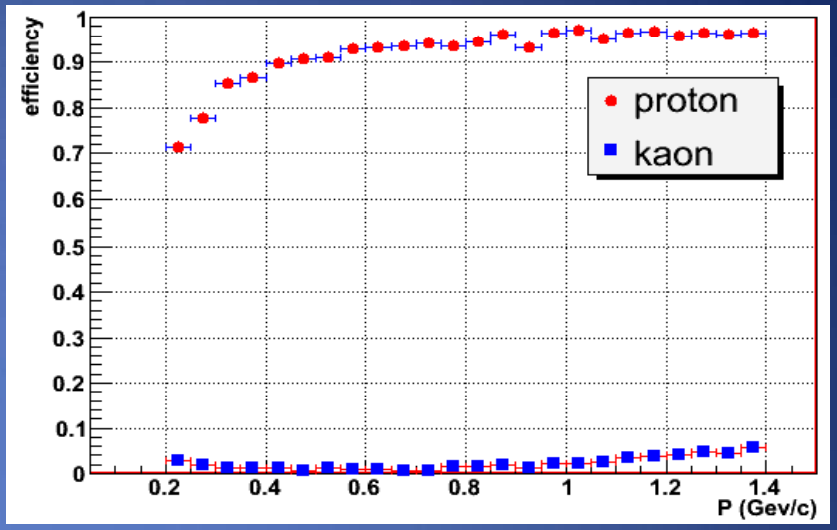
- TOF
  - Two layer barrel time-of flight,time resolution < 90ps
  - 1 layer endcap TOF, time resolution ~ 110ps
- dE/dx
  - Resolution ~ (6-7)%, **3σ K/π** separation up to 600MeV/c
- EMC
  - CsI crystal
  - Energy deposition, "shape" of shower
- MUC
  - cut off momentum, as low as 500MeV
  - μ-ID efficiency > 90%, π punch-through < 5% @ 1GeV

Provide good e/μ/π/K/p separation in large solid angle coverage of BES3 detector

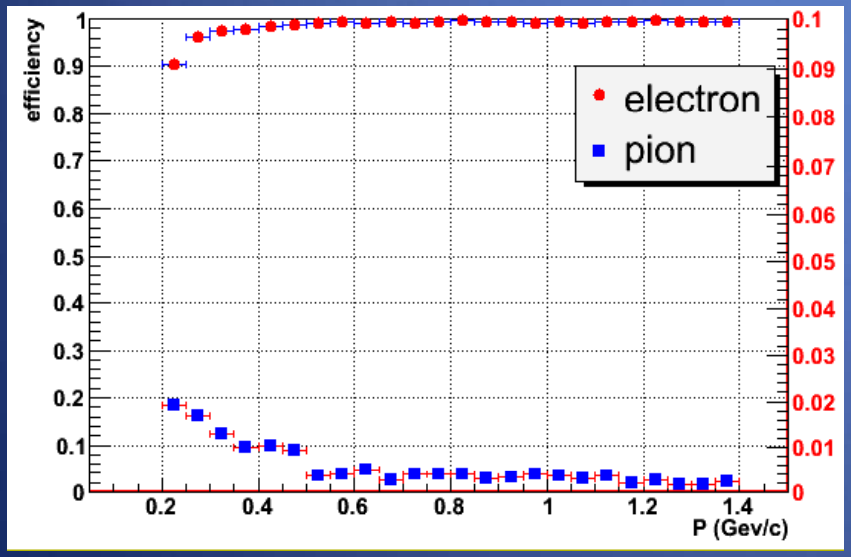
Particle ID



K/pi separation



Proton/Kaon separation



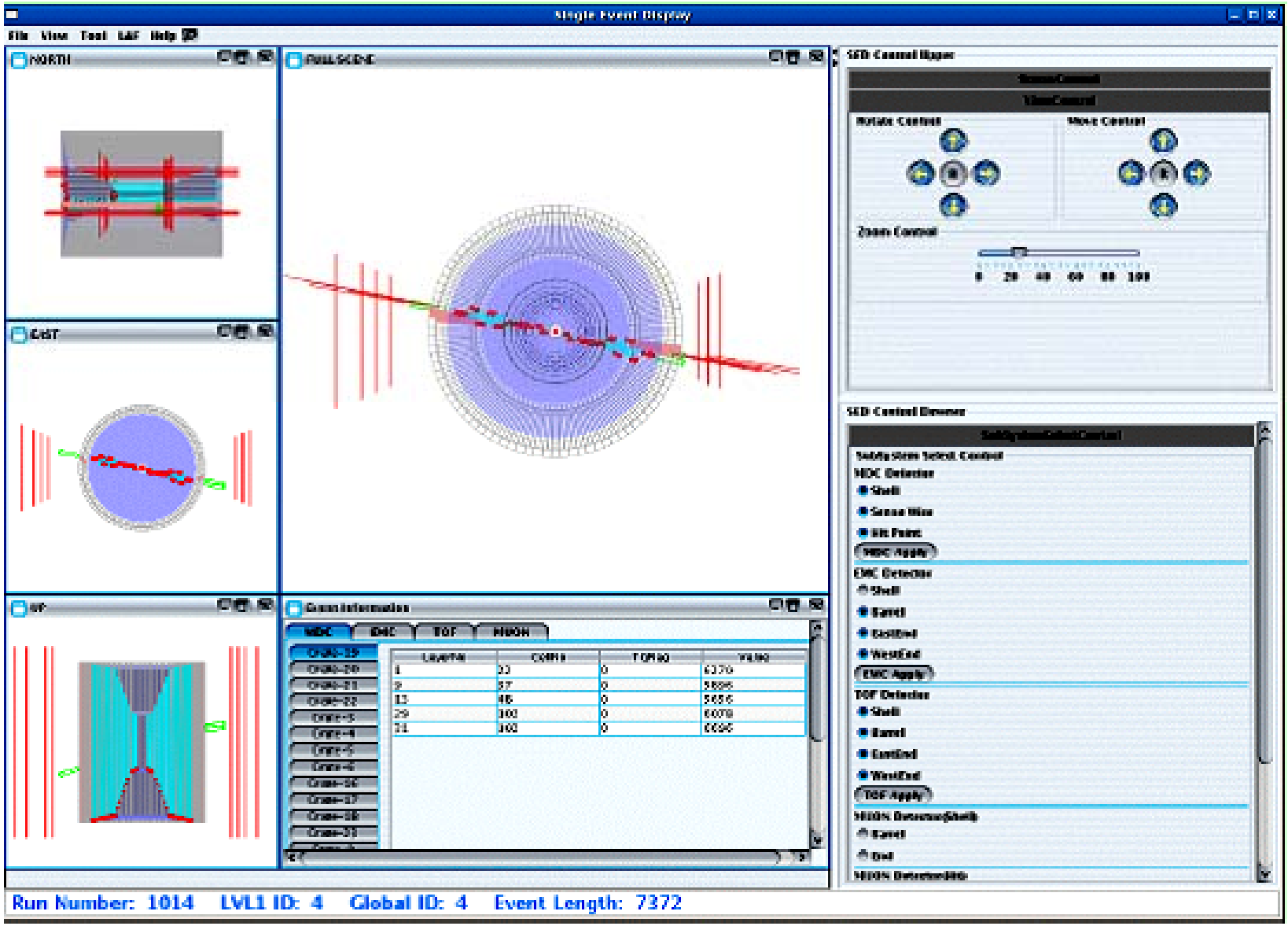
E/pi separation

- K/π likelihood combines TOF and dE/dx information.
- For K /π separation, efficiency > 90% and contamination rate < 10% @ 1GeV/c.
- e likelihood combines TOF, dE/dx and EMC information.
- Excellent electron-ID is expected in full momentum range.

Commissioning

Trigger, DAQ, and Detector (MDC, EMC, TOF, Muon) were commissioned in spring of this year with cosmic rays.

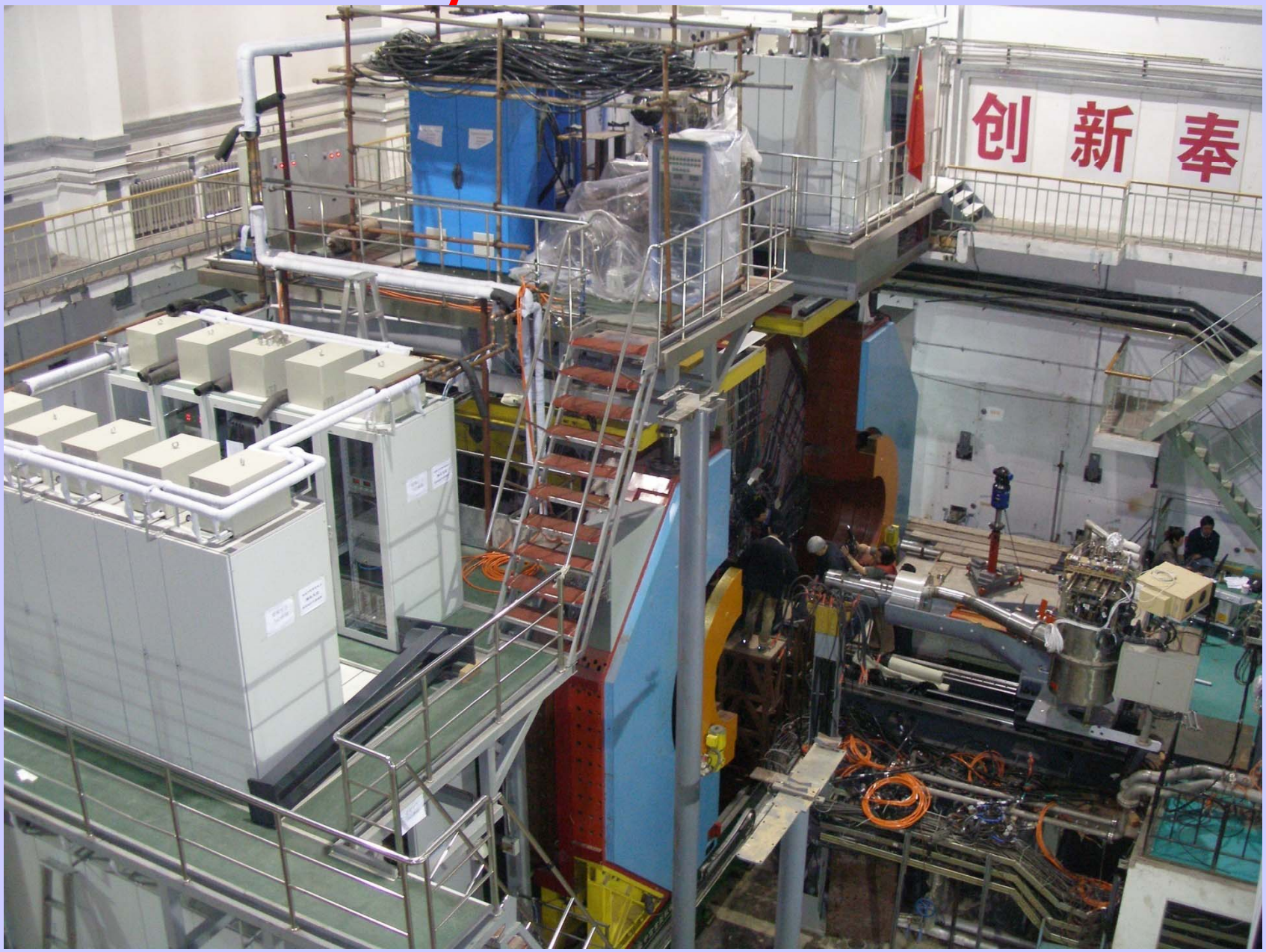
Commissioning – Cosmic Ray Event



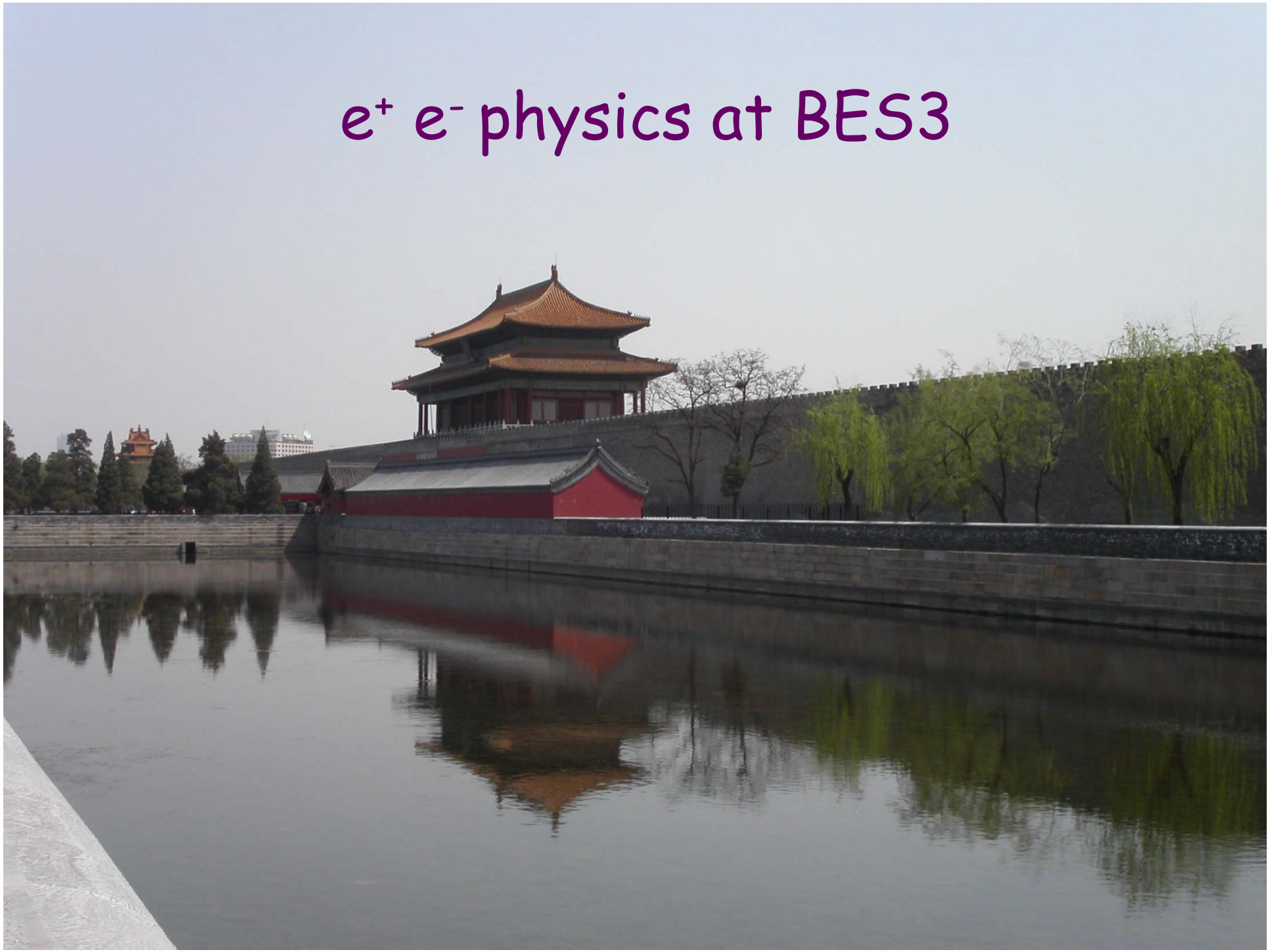
Recent History

- 2/2003 Official approval of BEPCII/BES3 project.
- 7/2004 BES2 detector shutdown.
- 5/2005 Magnet yoke and muon chamber installation.
- 6/2006 Super conducting magnet cool down.
- 6/2007 Magnetic field mapping.
- 8/2007 EMC installation.
- 10/2007 MDC/TOF installation.
- 1/2008 Cosmic ray run.
- 6/2008 BES3 detector at IR.
- 6/2008 Joint tuning of detector and machine.

May 2008 – At IR

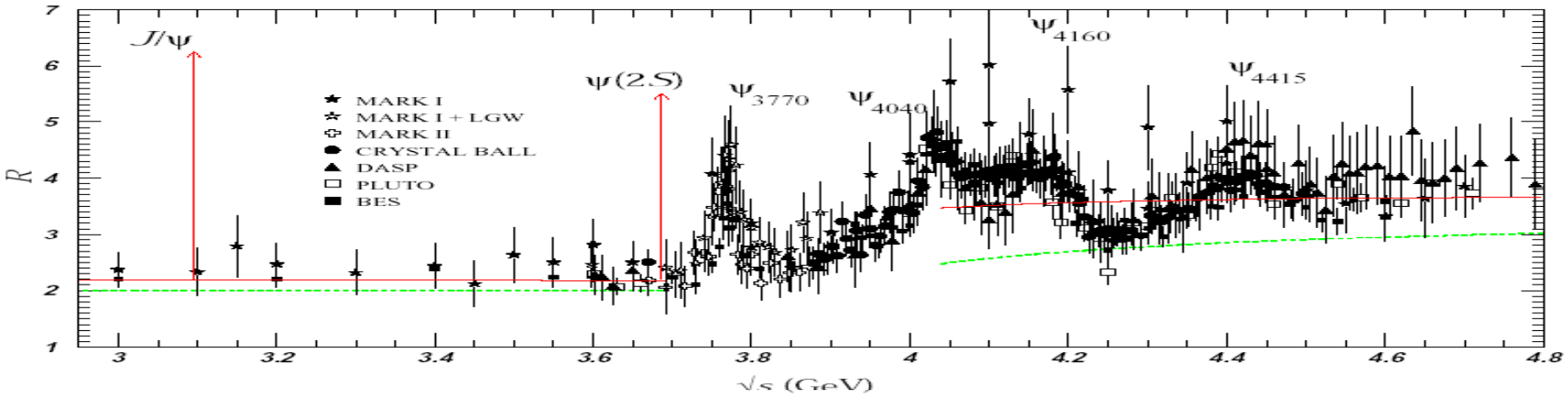


$e^+ e^-$ physics at BES3



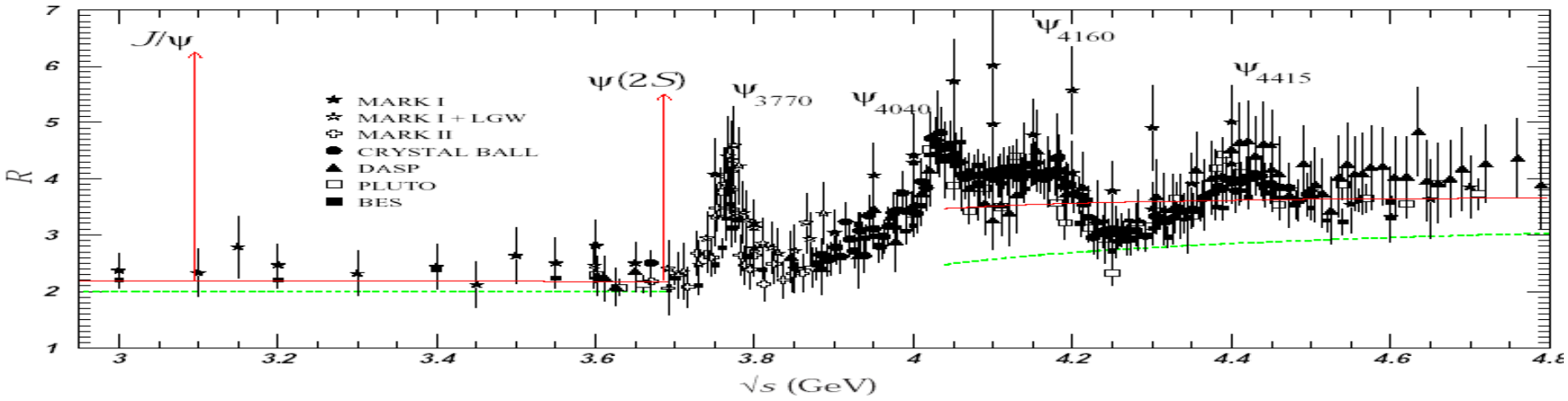
Physics Topics at BES3

- Open charm factory :
  - Absolute BR measurements of D and Ds decays
  - Rare D decay
  - D^0 - D^0bar mixing
  - CP violation, strong phase.
  - f_{D+}, f_{Ds} form factors in semi-leptonic D decays
  - precise measurement (1.6% stat.) of CKM (Vcd, Vcs)
  - light meson spectroscopy in D^0 and D^+ Dalitz plot analyses.



Physics Topics at BESIII

- Light hadron spectroscopy.
- Charmonium: J/ψ, $\psi(2S)$, $\eta_C(1S)$, $\chi_{C\{0,1,2\}}$, $\eta_C(2S)$, $h_C(^1P_1)$, $\psi(1D)$, etc.
- New Charmonium states above open charm threshold.
- Exotics : hybrids, glueballs, and other exotics in J/ψ and $\psi(2S)$ radiative decays.
- Baryons and excited baryons in J/ψ and $\psi(2S)$ hadronic decays.
- Mesons and mixing of quark and gluon in J/ψ and $\psi(2S)$ decays.
- Electromagnetic form factors and QCD cross section (R values).
- tau mass and tau physics near the threshold.
- Search for new physics.



Very rich and interesting energy region.

Production

Average Lum: $\mathcal{L}$ = 0.5 × Peak Lum.; One year data taking time: T = 10^7s

$$N_{event}/year = \sigma_{exp} \times \mathcal{L} \times T$$

Resonance	Mass(GeV) CMS	Peak Lum. ($10^{33}cm^{-2}s^{-1}$)	Physics Cross Section (nb)	Nevents/yr
J/ψ	3.097	0.6	3400	10×10^9
τ	3.670	1.0	2.4	12×10^6
ψ(2S)	3.686	1.0	640	3.2×10^9
D^0D^0bar	3.770	1.0	3.6	18×10^6
D^+D^-	3.770	1.0	2.8	14×10^6
DsDs	4.030	0.6	0.32	1.0×10^6
DsDs	4.140	0.6	0.67	2.0×10^6

Huge J/ψ and ψ(2S) samples at BES3

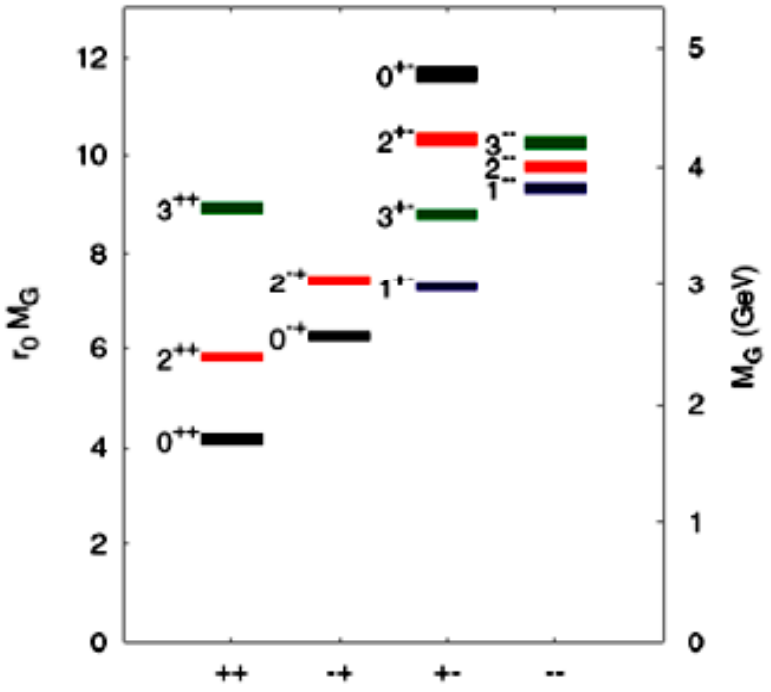
A review (Yellow Book): tau-charm physics at BES3 done soon.

Hadron spectroscopy - light scalars:

- Lattice QCD predicts the lightest 0^{++} scalar glueball mass ~ 1.6 GeV.
- Radiative ψ decay is the ideal glueball hunting ground!

$$\Gamma(\Psi_{\bar{Q}Q} \to \gamma X)_{\text{inclusive}} \approx \Gamma(\Psi_{\bar{Q}Q} \to \gamma(gg))$$

color singlet



Spectrum from quenched LQCD

Y. Chen *et al.*
PRD73:014516,2006
(updates Morningstar & Peardon, '99)

0^{++} : 1710 ± 50 ± 80

Also:
1611 ± 30 ± 160 Michael '98
1550 ± 50 ± ? Bali et al. '93

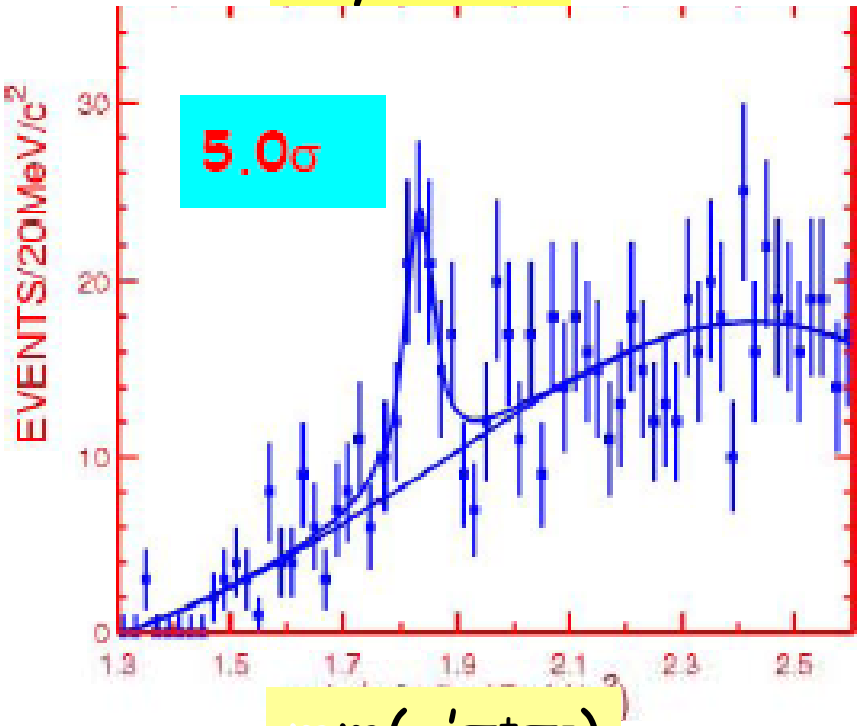
M. Chanowitz – Charm06

X(1835)

Study of X(1835) at BES3 using $J/\Psi \to \gamma\eta'\pi^+\pi^-$, $\eta' \to \eta\pi^+\pi^-$

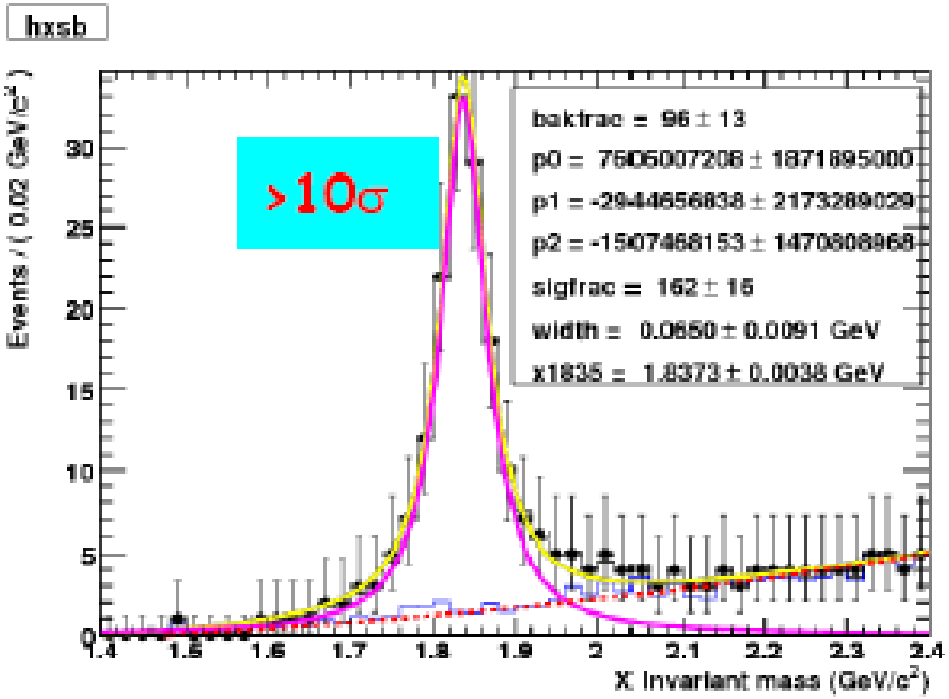
using 58 M events

At BES2
2 years



m(η′π⁺π⁻)

At BES3
2.5 days

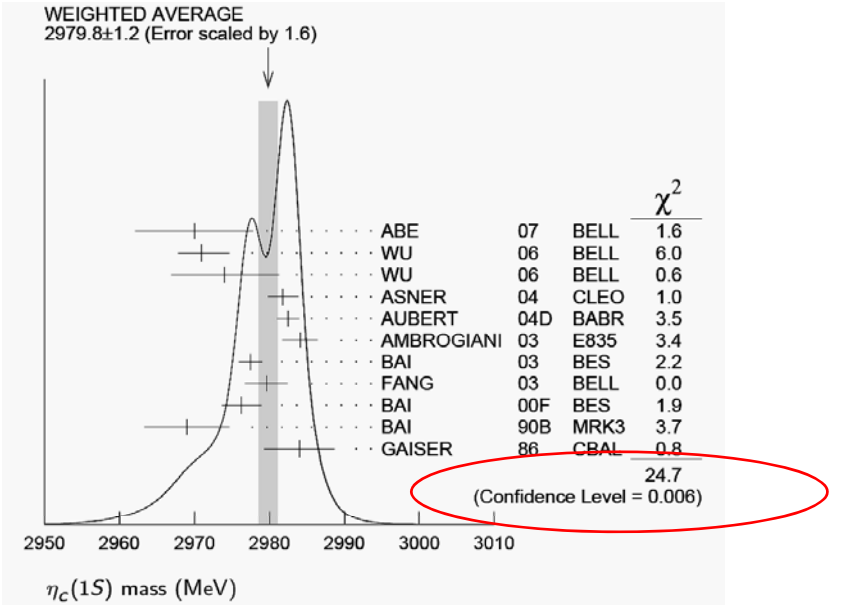


m(η′π⁺π⁻)

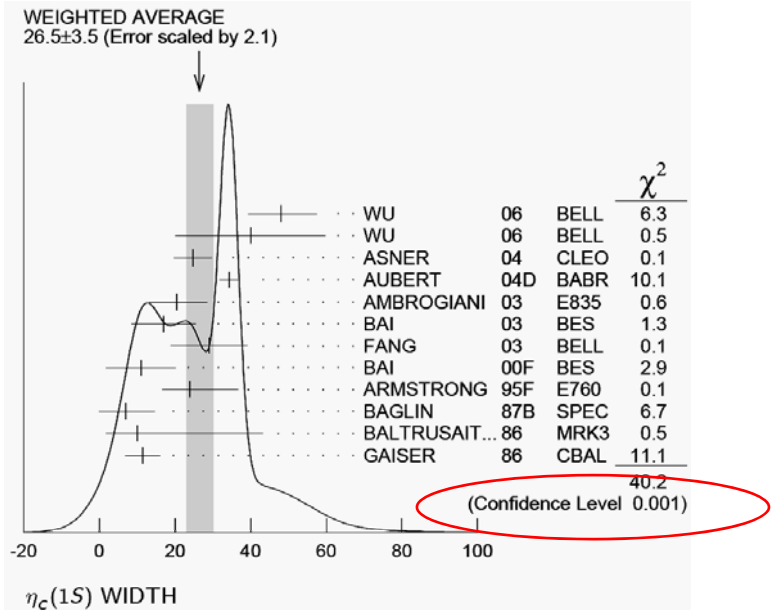
Charmonium spectroscopy

Precise measurement of η_c mass provides information on the hyperfine (spin-spin) splitting of η_c and J/Ψ.

M(η_c) current status



Status of $\Gamma_{tot}(\eta_c)$ even worse!



W.-M. Yao *et al.* (Particle Data Group), J. Phys. G **33**, 1 (2006)

Br(J/Ψ→$\gamma\eta_c$) is off too!

γ energy

$$\Gamma(J/\psi \to \gamma\eta_c) = 4\alpha e_Q^2 k^3 \left| \int \psi_f \psi_i d^3r \right|^2 / 3m_Q^2 = 2.85 keV$$

η_c

Predicts: Br = $\frac{\Gamma_{\gamma J/\psi}}{\Gamma_{tot}}$ = 3.1%

PDG: 1.27 ± 0.36%

CLEO: 1.98 ± 0.09 ± 0.30%

arXiv:0805.0252

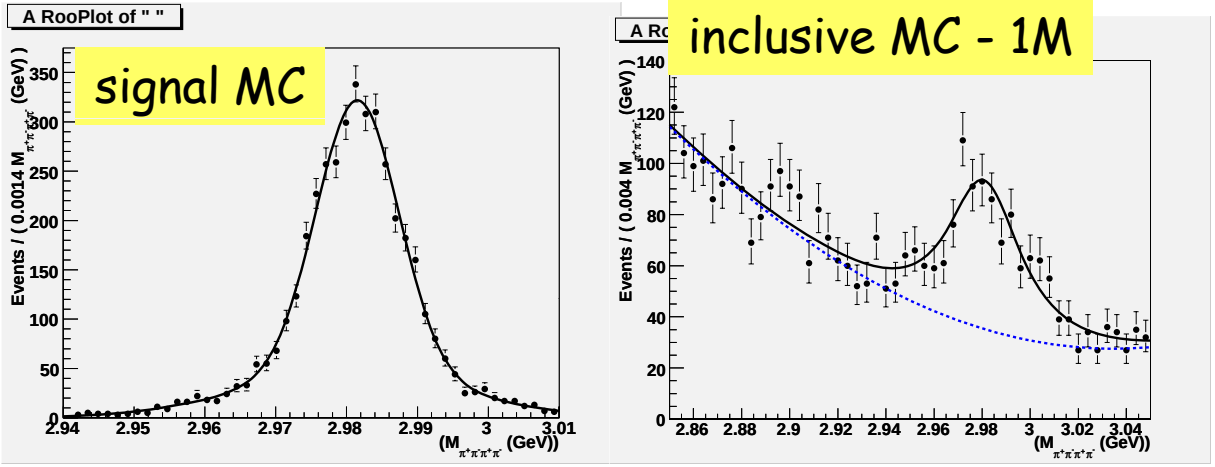
At BES3, measure the inclusive properties of the η_c with > 10x improved precision:

$\delta M_{\eta c}$: ± 1.2 MeV → ≈± 0.1 MeV

$\delta \Gamma_{tot}$: ± 3.5 MeV →≈± 0.5 MeV

$\delta Br(J/\psi \to \gamma \eta_c)$: ± 0.36% → ≈± 0.05%

$$J/\psi \to \gamma\eta_c, \eta_c \to \pi^+\pi^-\pi^+\pi^-$$



$m = 2.9808 \pm 0.0015\ \text{GeV}$

$\Gamma = 0.0256 \pm 0.0058\ \text{GeV}$

Precision CKM measurements

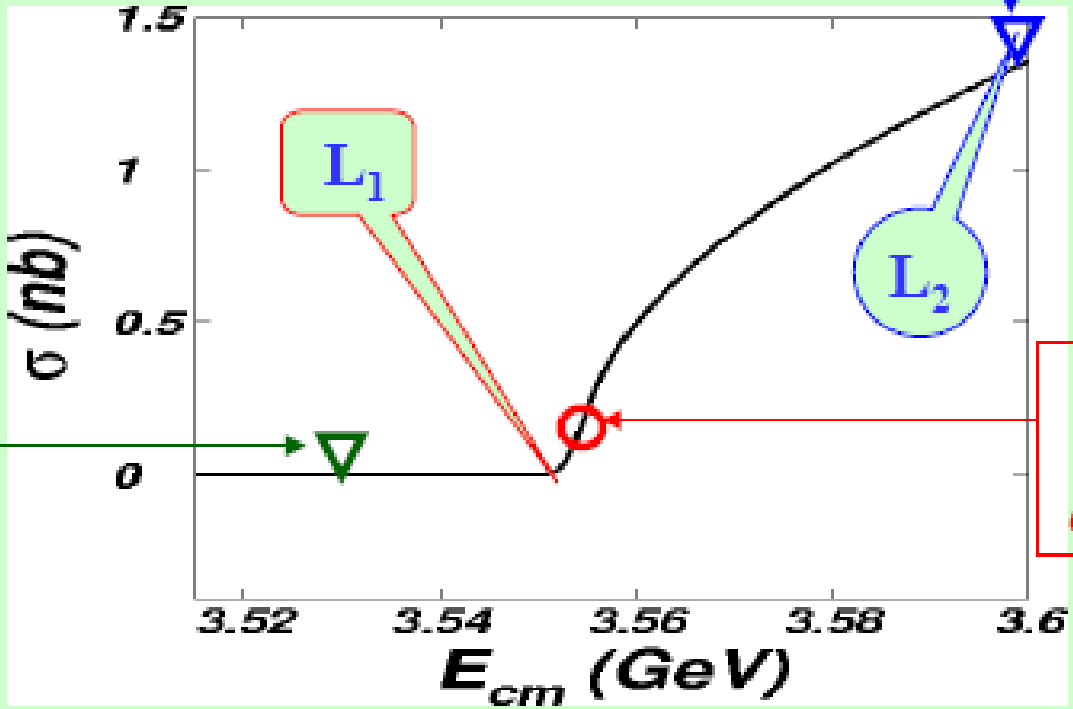
Determined from charmed meson leptonic and semi-leptonic branching ratios:

	Current	BES3
V_{cd}	5%	< 1%
V_{cs}	10%	< 1%

Tau mass measurement

Data taking strategy

Event Selection & Eff. determination



L_1:L_2=3:1

BG. study

Optimal Point to determine m_τ

Using Compton scattering technique to measure the beam energy

Current:

$m_\tau = 1776.96 \,^{+0.18}_{-0.21}\,^{+0.25}_{-0.17}$ MeV

BESIII expected:

Δm_τ = 0.05 +- 0.09 MeV

BESIII Collaboration

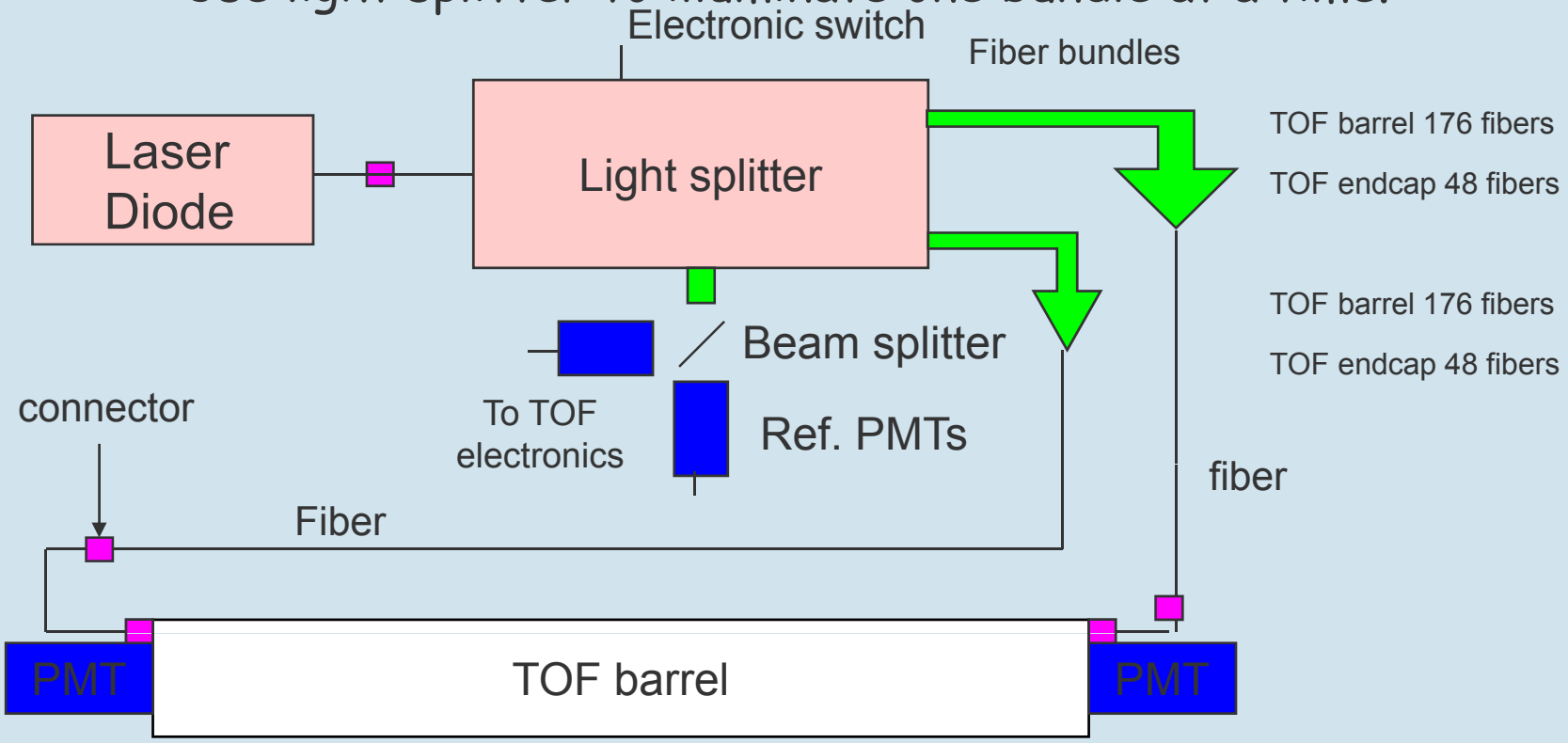
Institute of High Energy Physics
University of Science and Technology
Peking University
Tsinghua University
Shangdong University
Nankai University
University of Zhejiang
University of Zhengzhou
Nanjing Normal University
Nanjing University
Shanxi University
Sichuan University
Henan Normal University
Huazhong Normal University
Wuhan University
Zhengzhou University
Zhongshan University
Liaoning University
Hunan University
Guangshi University
Guangshi Normal University
Hongkong University
Chinese University of Hongkong

University of Hawaii
University of Washington
University of Tokyo
Joint Institute of Nuclear Research, Dubna
Budker Institute of Nuclear Physics, Novosibirsk
GSI
University of Bochum
University of Giessen
University of Minnesota
University of Rochester
University of Florida
Carnegie Mellon University

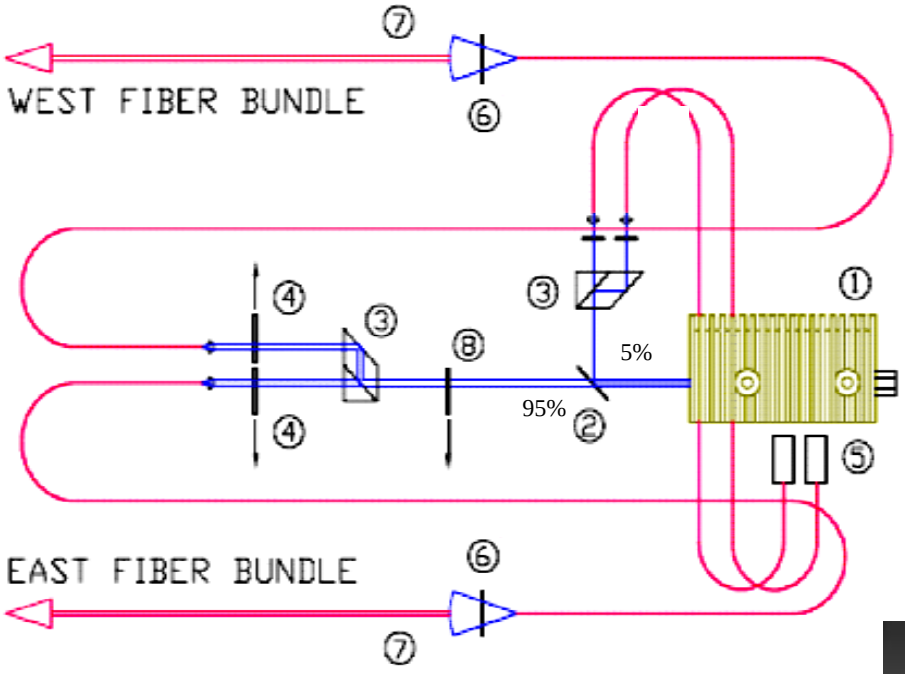

BESIII TOF Monitoring
System
- built at UH

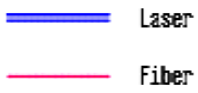
BESIII TOF Monitoring System

- Monitor the amplitude and time performance of each channel including PMTs and electronics.
- Concept:
  - Use fiber cable bundles (2 cables) to distribute light to barrel and endcap TOF counters.
  - Use light splitter to illuminate one bundle at a time.

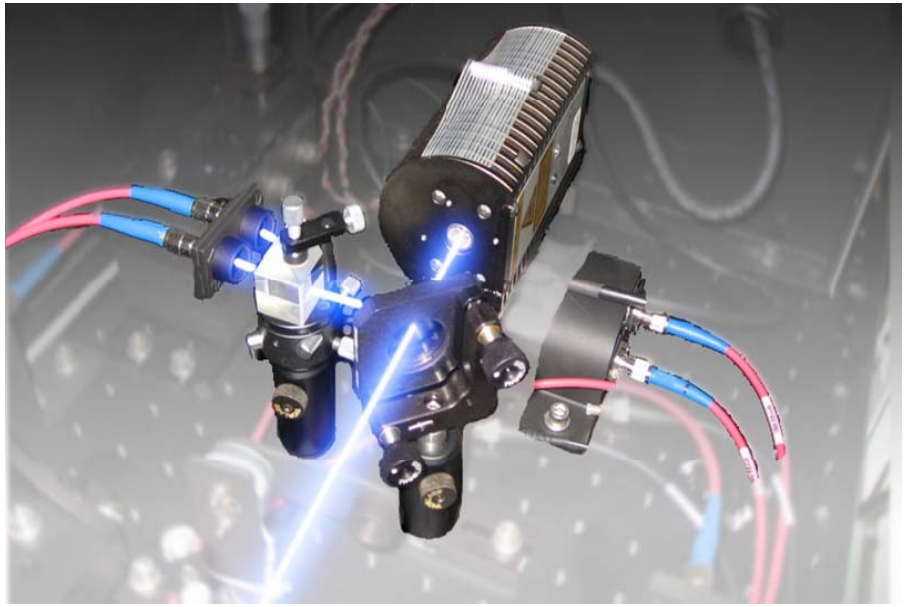


TOF Monitor System

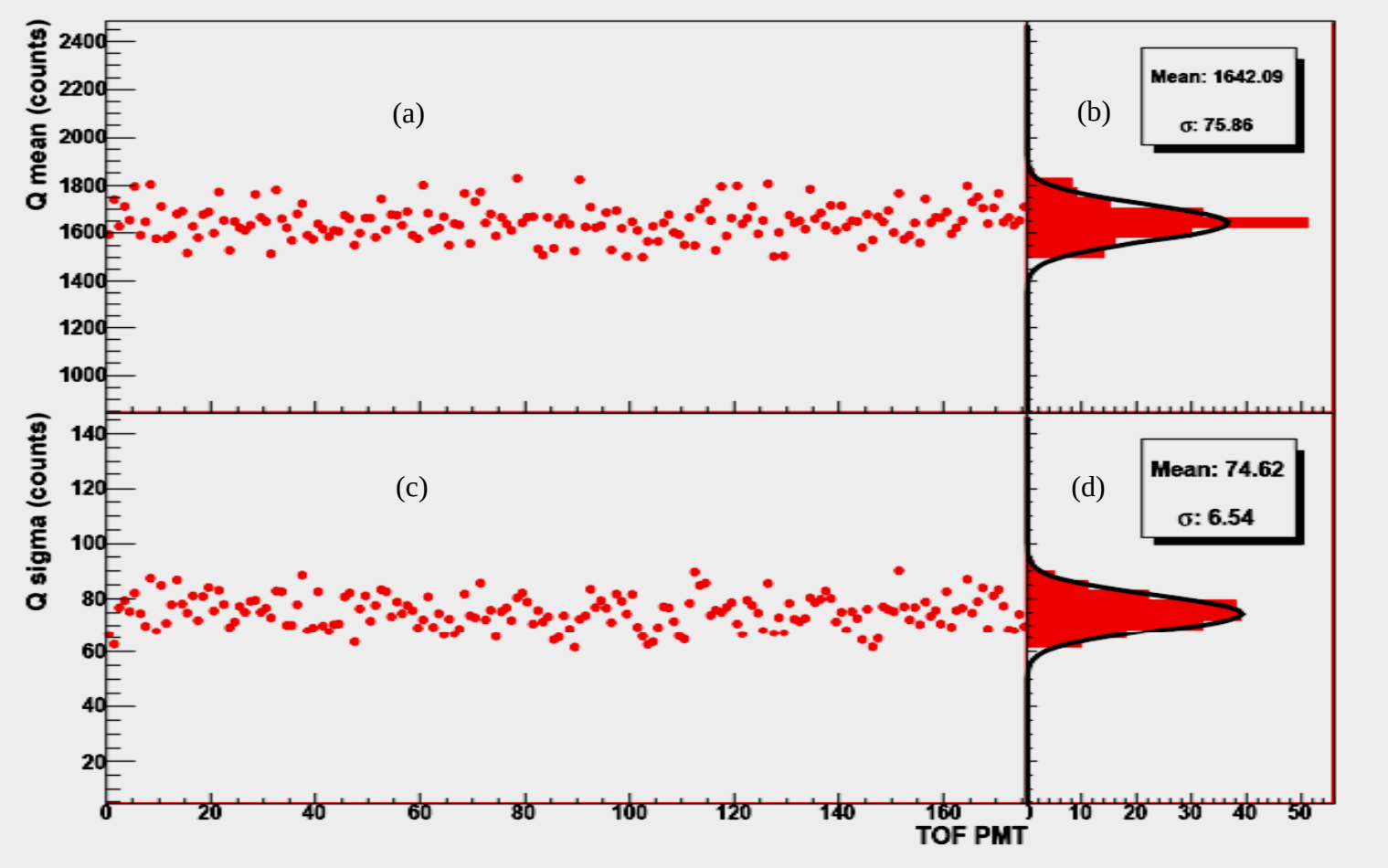




1. Laser diode
2. Beam splitter (5%-95%)
3. Prismatic beam splitters (50-50)
4. Shutters
5. Reference PMTs
6. Diffusers
7. Fiber bundles

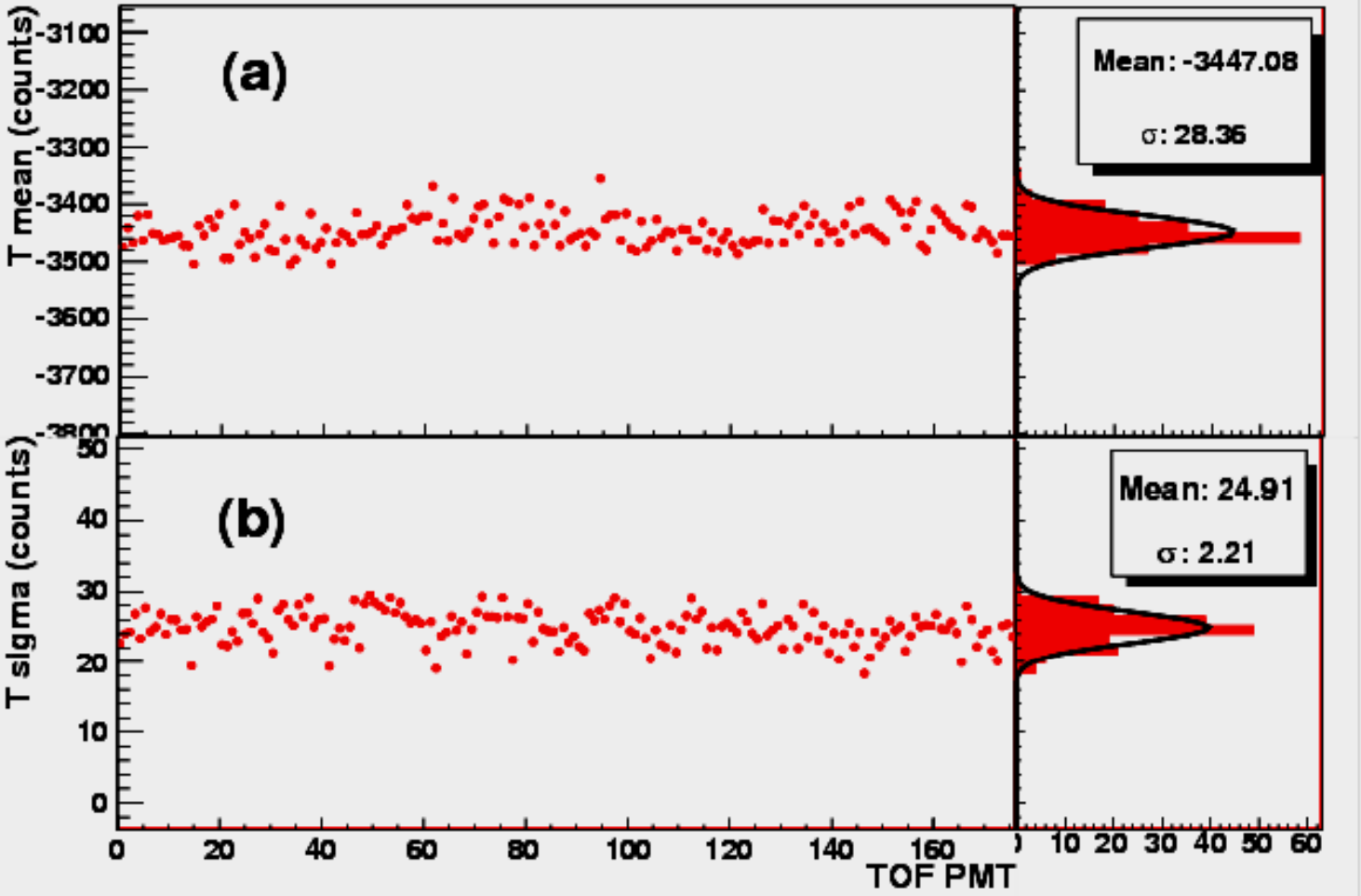


TOF Monitoring



West Barrel TOF's Qm and Qsigma vs. PMT number.

TOF Monitoring

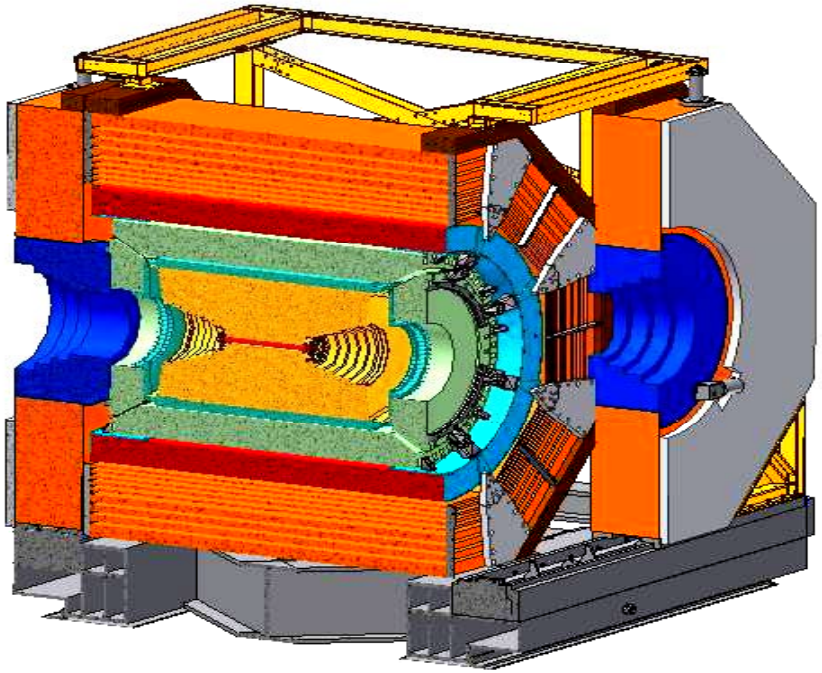


West Barrel TOF's Tmean and Tsigma vs. PMT number.

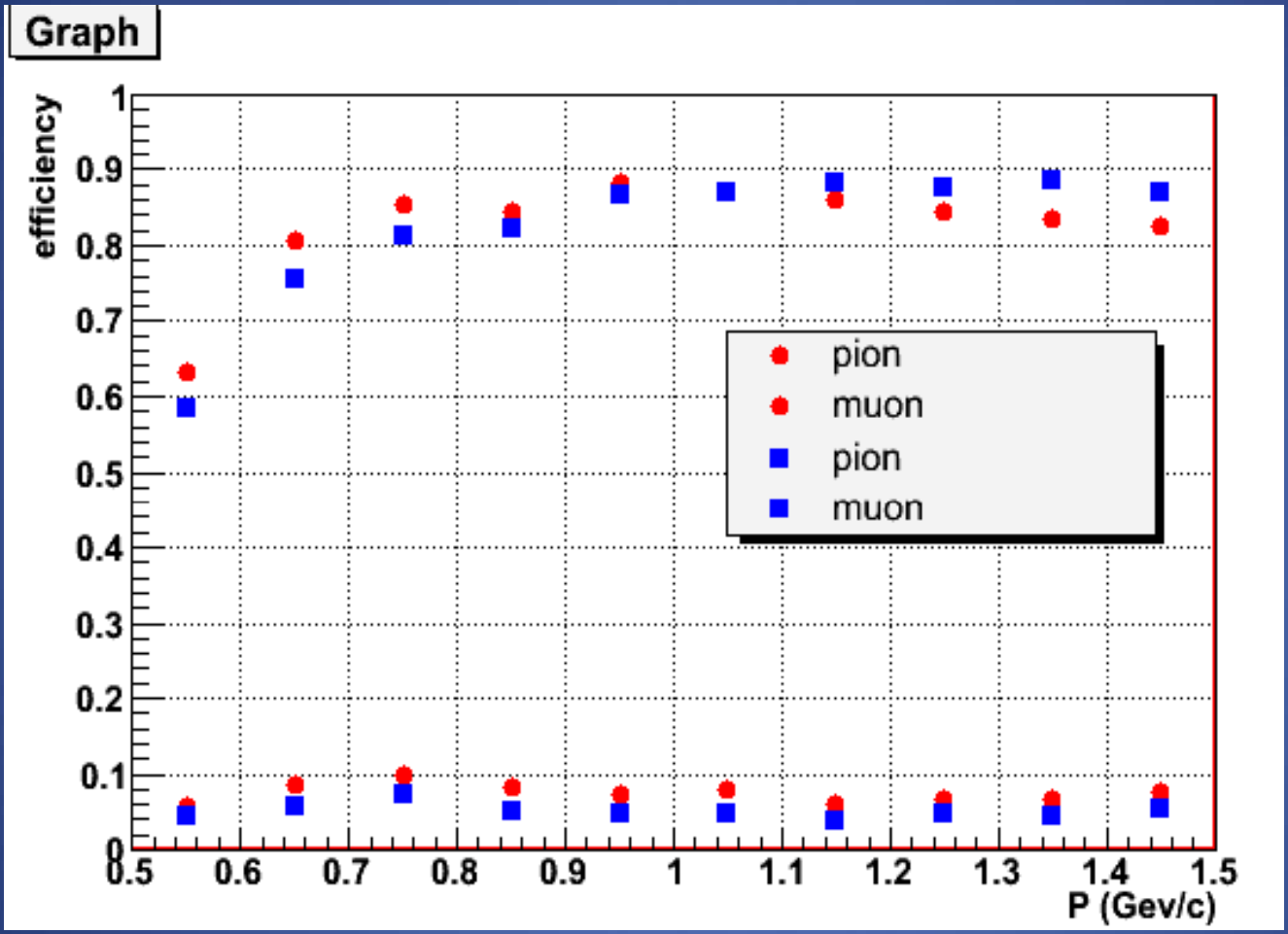
Accepted by NIM, **arXiv:0804.4260** [physics.ins-det]

Summary

- BEPCII/BESIII complete.
- Commissioning of detector/machine soon.
- Rich physics program after CLEO-c. Complementary to B-factories.
- Many results for Meson 2010!



Particle ID



μ/pi separation

Red: two parameters

Blue:four parameters